Elements of practical pharmacy / by Robert John Kane.

Contributors

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ELEMENTS

OF

PRACTICAL PHARMACY.

By ROBERT JOHN KANE,
PROFESSOR OF CHEMISTRY TO APOTHECARIES' HALL;
MEMBER OF THE MEDICO-CHIRURGICAL SOCIETY OF DUBLIN;
CORRESPONDING MEMBER OF THE SOCIETY OF PHARMACY
OF PARIS, AND OF THE SOCIETY OF MEDICAL CHEMISTRY
OF THE SAME CITY.

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TO

A. CHEVALLIER,

PROFESSOR OF CHEMISTRY,
ADJUNCT MEMBER
OF THE ROYAL ACADEMY OF MEDICINE OF PARIS,
AND OF THE
ROYAL ACADEMY OF SCIENCES OF BOURDEAUX,
MEMBER OF MANY LEARNED SOCIETIES,
FOREIGN AND DOMESTIC,
ETC. ETC. ETC.

THESE ELEMENTS
OF A SCIENCE
WHICH OWES SO MUCH OF ITS ADVANCEMENT
TO HIS EXERTIONS,
ARE DEDICATED,
AS A TRIBUTE OF RESPECT FOR HIS TALENTS, AND OF
GRATITUDE FOR HIS KINDNESS,
BY

THE AUTHOR.

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PREFACE.

THE succeeding pages are intended to convey to the student a knowledge of the principles upon which the more important pharmaceutic operations are founded, and thus fill up that space which exists between the mere detail of the processes in a Pharmacopœia and the theoretic explanations of their nature given in a systematic book. It is not pretended that all the information necessary for an apothecary is herein given, nor even the greater part; formed as Pharmacy is of an aggregate of sciences, such a work would demand the united labours of many hands, and a long period of time for its completion; but, having remarked a number of circumstances concerning which a pharmaceutic student is expected to be well-informed, and which are not sufficiently detailed in any of the works generally in the hands of that class of readers *in this country*, it occurred to me that some observations on those subjects, connecting theory with practice, might be of use in showing to the youth of our profession that Pharmacy, although falsely designated a trade, is a branch of knowledge ranking among the first of the medical sciences, and rivalling in utility the noblest investigations that ever employed the talents of a Broussais or a Davy; that a real Apothecary (if our profession in this country was so regulated as to allow of the generation of such a being) ought to be a zealous lover of Science, and an original contributor to its improvement; ought to be such as the fostering encouragement of enlightened France has rendered Robiquet, Serullas, Vauquelin, Pelletier, and that host of brilliant names which illuminate the pages of the *Fastes de la Pharmacie Française*, and diffuse round the projectors and supporters of such liberal institutions a glory never to be obscured.

It did not enter into the plan of the present work to give a transcript of, or a commentary on any Pharmacopœia; this object had been already attained by many writers[*] whose books are sufficiently full and explicit, as far as regards the obtaining the officinal preparations; therefore, in selecting from among the pharmacopœial processes some as illustrations of the different pharmaceutic operations, those given were chosen either because of the occurrence of some interesting phenomena in their formation, or for the sake of comparing the processes of the different Pharmacopœias with each other, and with those used in the arts for preparing the same substances.

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[*] Drs. Barker and Montgomery, Observations on the Dublin Pharmacopœia.

Spillan, Translation of ditto.

Brande on the London Pharmacopœia.

Philips on the London Pharmacopœia.

Henry, junior, Translation of the Codex Medicamentarius Parisiensis.

Thompson's London Dispensatory. Part III.

Duncan's Edinburgh Dispensatory. Part III.

INTRODUCTION.

An Apothecary is one who collects and prepares those substances which from their peculiar action on the living system are used as medicinal agents. The general principles upon which the collection and preparation of those substances should be made form the Science of Pharmacy, and the practice of the operations founded on the particular applications of those principles, constitutes the Art of the Apothecary.

A certain number of active substances are presented to us by nature ready formed, others require to be generated by art. Thus the obtaining of drugs consists in two operations, the collection of those which naturally exist, and the preparation of those which are not thus produced. A great number of substances which do not exist in nature in sufficiently large quantities for the demand, are not prepared by the apothecary, but by certain branches of manufacture distinct in themselves, and thus constitute a part of the *Materia Medica,* which consists of those bodies which the apothecary obtains ready formed for him, either by nature or by art. The processes by which the artificial compounds are formed are prescribed for the apothecary by rule, in order that the medicines may be of uniform composition and strength, no matter where obtained. These rules differ in different places, and the collection of them in a book forms what is termed a *Pharmacopœia.*

The proper operations of Pharmacy (of the Pharmacopœias) are therefore those of preparation; before entering into which, the mode of collecting and of preserving the various indigenous objects of *Materia Medica,* upon which we have afterwards to operate, require to be described.

PRELIMINARY OPERATIONS.

Of the Collection of Drugs.

The collection of mineral substances requires no remark; once the localities where they exist are known, they only require to be obtained and kept free from foreign matter; their purity is easily known by their external appearance, or by their physical and chemical properties, and not being subject to decomposition, they may be preserved unaltered for any length of time.

Collection of Plants.

The number of vegetables used in Pharmacy, and their great importance in medicine, render necessary more minute directions with regard to the collection of those of them that are indigenous.

Vegetables should be collected fresh every year, and those of the last year's obtaining rejected; for by keeping they lose their medicinal powers, and would only serve, if used, to render the strength of a preparation made from them doubtful and uncertain.

Many circumstances have considerable influence ont he activity of a plant, as, its age, the wetness or dryness of the time in which it was collected, the kind of soil in which it grew, and whether it existed in a wild or in a cultivated state. The proper time of collection differs also according to the part of the plant required for use, and also often according to the properties which it is required to possess.

Plants should never be collected for medicinal use during their first growth; their peculiar principles have not been at that time developed; their vessels are filled with an inert mucilage, and they differ widely in physiological properties and in chemical composition from the same plant at a more mature age; thus the young borage contains much sulphate of lime, which salt in the full-grown plant disappears, and is replaced by nitre; the negroes eat without injury the young shoots of the apocynum, and the Tuscans those of the clematis; and in

Sweden the young leaves of the aconitum are eaten with relish as a salad.

The influence of soil on the properties of vegetables is remarkable, although our knowledge of it is as yet ill defined. The umbelliferæ, growing in a dry soil, are aromatic; those of the same tribe which love a damp situation, are eminently narcotic. The cruciferæ thrive only in a moist, the greater number of the labiatæ in a dry soil. Other plants prefer a soil containing much decomposed animal matter, as borage and urtica, and we find their juices to contain nitre. Bulbous plants thrive best in a dry situation, and fibrous roots in a soil porous, and easily permeable by their absorbing fibrillæ.

In the absence of accurate knowledge of the changes induced in vegetables by cultivation in different kinds of soil, the rule should be constantly observed of collecting each plant where it naturally grows, as there its active virtues are uniformly found most developed.

The influence of cultivation on the constitution of vegetables also deserves remark. In some cases it diminishes their activity, in a few it augments it; by cultivation the sarcocarp, naturally dry in some of the drupaceæ and pomaceæ is filled with sugar; and the bitter juice of the chicoraceæ, of celery, &c. is converted into one sweetly mucilaginous: the flavour of the aromatic labiatæ and umbelliferæ is, however, much enhanced by proper cultivation.

We shall now consider, *seriatim,* the rules to be observed in the collection of each particular portion of a plant designed for medicinal use.

Collection of Roots.

The London Pharmacopœia orders all roots to be dug up before the stalks or leaves shoot forth. The Dublin or Edinburgh Colleges do not give any directions for the collection of particular parts of plants.

Roots of annual and biennial plants should be collected in the autumn; for if taken before this time their juices are merely those formed for their own nutrition, the active constituents of the plant not having been before that time fully elaborated.

Roots of perennial plants should, on the contrary, be collected in spring, for if left longer they become too ligneous and dry; generally speaking, roots should always be obtained whole, flexible, and juicy, and from plants as young as is consistent with their perfect maturity.*

Collection of Stems.

Stems are either herbaceous or ligneous; the former are to be collected after the formation of the

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* Carbonell (Elementa Pharmaciæ, page 176) states that the roots of annual roots should be taken just as the plant flowers; of biennial, at the commencement of their second year, or in the middle of winter; and of perennial, at the time when the leaves of the plant are full. This is an error; at these periods the roots of the first class have not lived long enough, and those of the two latter have been exhausted by age.

leaves, and before that of the flowers. The latter should be procured in winter, for two reasons: 1st, the quantity of fluids in the root being then very small, desiccation is more easily performed; and 2dly, from the researches of Mr. Knight it appears, that the wood and alburnum are more dense in winter, and furnish to water a greater quantity of extracts.

It has been proposed to bark the trees, in order to render the wood more energetic. That this may be effected is the case, for the juices not being able to descend by the bark, throw themselves on the wood, and augment the quantity of active ingredients existing in it: wood thus barked is much more readily worm-eaten, but for medicinal use this is unimportant, as it is upon the inactive constituents of the plant that insects feed.

Collection of Barks.

Barks (Ph. L.) ought to be collected at that season when they can be most easily separated from the wood. According to the codex, shrubs should be barked in autumn, and trees towards the commencement of the spring.

Barks should be procured either before the flowers are produced, or after the work of generation is perfected; during that process all the powers of the plant are employed in elaborating the organs necessary to that function, and it is only before its commencement, or after its being finished, that the other parts of the plant are suitably supplied with juice. Barks should be obtained from trees neither too young nor too old; when barks have arrived at a certain growth, they become unfit for medicinal use; they split, grow hard, and the quantity of soluble matter in them becomes diminished.

Collection of Leaves.

Leaves (Ph. L.) are to be gathered after the flowers are blown, and before the seeds are ripe. The Codex prescribes their collection before the expansion of the flower.

The leaves are to be obtained at that period when they are in their greatest vigour, that is, before the plant begins to concentrate its energies round the parts of the flower and fruit; for, from the instant that the flower is fully formed, the leaves begin to decline, and their change of colour gives evidence of the alteration of their composition and energies. On the contrary, if taken before they are fully developed, they are mucilaginous and inactive, the principles on which their medicinal power depends being formed only as the leaf approaches to maturity.

One important remark with regard to the collection of the leaves of the biennial narcotic plants has been made by Mr. Houlton. He found that they do not possess medicinal activity until their second year, and that a great part of the leaves of hyosciamus collected for sale are of the first year's growth, mucilaginous and inert. These being mixed in unknown quantities with the active leaves, and sometimes even being alone used, must make the power of an extract or tincture prepared from them very variable indeed.*

Collection of Flowers.

Flowers (Ph. L.) are to be gathered recently blown; the Codex orders them to be collected before they have entirely expanded.

The time during which the flower is in its prime is very short, and it is better to anticipate the period a little than let it pass. When the corolla has perfectly opened, the colour and odour of the petals become less vivid; the ovary has been fecundated, and the petals which served as a protecting envelope, deteriorate, atrophy, and fall. The directions of the Codex are therefore the safer to pursue.

The mode of inflorescence, the size of the petals, the adherence of the corolla to the calix, &c. modify, in some instances, the method of collection. If the flowers are small, and the inflorescence a racemus or thyrsus, they are collected with the common flower stalk, and are then called the flowering summits of the plants. In the synantheræ the aggregated flowers are collected with the common calix, as chamomile; in the dianthus caryophillus, and the Provence rose, the petals are collected without the calix, and the unguis or hook is rejected from the extremity of each petal, because it is the colouring matter which is principally required.

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* Journal of the Royal Institution, vol. i. page 196.

Collection of Fruits.

In a pharmaceutic point of view fruits may be divided into two classes, the fleshy and the dry; within the pericarp of the former there exists a considerable quantity of some cellular tissue, containing the juices of the fruit; in the latter, the cellular tissue is in small quantity dense and dry.

If fruits are to be used fresh, they should not be collected until perfectly ripe; but if they are to be preserved, they should be taken from the plant before maturation is finished. In some fruits, as the orange, it is the epidermoid envelope (*zesta*) alone which is used; and this should be separated as soon as the fruit is obtained by means of an ivory or silver knife.

Seeds are to be collected as soon as they are ripe, and before they begin to fall from the plant; they should be kept in their own seed vessels (Ph. L.). The means of distinguishing when the different kinds of seeds are ripe require notice.

The *farinaceous* seeds, as wheat, barley, &c. are mature when they are heavy, and separate easily from the scaly coverings which invest them.

The *emulsive* seeds, as the almond, &c. when the pericarp is full, and the fruit does not become milky by pressure.

The *aromatic* seeds, as caraway, coriander, &c. when the axes which support them in the umbelliferæ, become dry and brittle; the umbels nearer to the bottom of the stem are earlier matured than those placed higher on the stalk.

In general, all those seeds which are contained in a dry pericarp may be considered ripe, when on shaking the seed vessel, the seeds are heard rattling within; this effect depends on the decaying and breaking of the podosperm, and when this takes place, the nutrition of the fruit has been finished, and it is prepared for the fulfilment of the duties for which it was first formed.

The seeds of the fleshy fruits are mature when the fleshy pericarp itself is ripe; and the seeds of dehiscent fruits are fit for collection when the valves of the pericarp begin to gape.

The apothecary in this country does not collect any animal substances.

The following table shows the vegetable substances of the British *Materia Medica* to be collected in each month of the year:

January and February.

No vegetables, with the exception of a few cryptogamic plants, collected in these months.

March.

Flowers of tussilago farfara.
Leaves of do.
Flowers of viola odorata.

April.

Flowers of viola odorata.
Leaves of asarum europeum.
Leaves of narcissus pseudo-narcissus.
———— lamium album.

May.

Tops of artemisia absinthium.
———— juniperus communis.
Herb of cochlearia officinalis.
Leaves of conium maculatum.
———— prunus lauro-cerasus.
Petals of the rosa gallica,
———— rosa centifolia,
(in a fine season.)

June.

Tops of artemisia absinthium.
——— spartium scoparium.
Leaves of althea officinalis.
——— arnica montana.
——— asarum europeum.
——— atropa belladonna.
——— cnicus benedictus.
——— digitalis purpurea.
——— euphorbia lathyris.
——— hyosciamus niger.
——— lactuca virosa.
——— leontodon taraxacum
——— marrubium vulgare.
Flower of the anthemis nobilis.
——— citrus aurantium, and in July.
——— sambucus niger.
Petals of the papaver rheas.
——— rosa centifolia.
——— rosa gallica.
Seeds of colchicum autumnale.

July.

Tops of artemisia absinthium.
——— rosmarinus officinalis.
Herb of origanum marjorana.
——— melissa officinalis.
——— mentha piperita.
——— ——— viridis.
——— ——— pulegium.
——— lythrum salicaria.
Leaves of erythrea centaureum.
——— nicotiana tabacum.
——— ranunculus acris.
——— ruta graveolens.
Leaves of rumex acetosa.
——— juniperus sabina.
——— salvia officinalis.
——— scrophularia nodosa.
——— rhus toxicodendron.
Flowers of borago officinalis.
——— arnica montana.
——— lavandula spica.
Bulbs of colchicum autumnale.

August.

Bulbs of colchicum autumnale.
Stems of solanum dulcamara.
Herb of datura stramonium.
Flowers of punica granatum.
Strobiles of the humulus lupulus.
Fruit of the momordica elaterium.
——— of the morus nigra.
Capsules of the papaver somniferum.
Seeds of the carum carui.
——— coriandrum sativum.
——— anethum graveolens.
——— fœniculum.

September.

Fruit of the rosa canina.
——— rhamnus catharticus.
——— sambucus niger.
——— punica granatum.
Seeds of ditto.
——— datura stramonium.
Roots of angelica archangelica.
——— aspidium filix mas.

Roots of arnica montana.
——— althea officinalis.
——— calamus aromaticus.
——— cochlearia aromatica.
——— glycyrrhiza glabra.
——— helleborus niger.
——— iris florentina.
——— leontodon taraxacum.
——— orchis mascula.
——— polygonum bistorta.
——— rumex aquatica.
——— tormentilla erecta.
——— valeriana officinalis.
——— veratrum album.

Barks of daphne mezereon.
——— gnidium.
——— quercus robur.
——— ulmus campestris.
Fruit of the vitis vinifera.
Seeds of the pyrus cydonia.
——— ricinus communis.
Roots of the inula helenium.
——— arctium lappa.
——— bryonia alba.
——— rheum palmatum.
——— undulatum.
——— rubia tinctorum.
Stamens of the crocus sativus.

October.

Berries of juniperis communis.
Bark of æsculus hippocastanum.

November and December.

Boletus igniarius.
Cetaria Islandica.
Rocella tinctoria.

2d. *Of the Desiccation of Plants.*

In order to preserve vegetables from decomposition, it is necessary to deprive them of the water which they contain. The quantity of this constituent varies very much; some parts of vegetables, as the pulpy fruits, bulbs, and some leaves contain very much; others, as some roots, barks, and stems, but very little. The mode of desiccation must differ, therefore, according to the nature of the vegetable matter on which we operate.

Plants may be dried by being loosely hung up in the open air, or by being exposed to the moderate heat of a stove in an air-chamber;[*] *cæteris paribus,* the more expeditiously the process is performed the better, and the odour and colour of the vegetable should remain perfectly uninjured, if the desiccation has been properly executed.

Desiccation of roots. The mode to be followed in drying roots differs according to their nature; if they are fibrous and hard, the adherent dirt is to be removed by washing, and the fibrillæ and the neck of the root cut off. The body of the root is to be then cut into slices, and thus divided to be exposed to the sun, or to the moderate heat of a stove, and new surfaces to be frequently exposed to facilitate the desiccation.

Roots should be carefully washed previous to desiccation; by this means some mucilage, which would otherwise tend to grow musty, is gotten rid of, and the root obtained much whiter: the aromatic roots should not be scraped in cleaning, as it is in their epiderms that the odorous principle generally resides.

It is not always the same part of the root which it is desirable to preserve: In some, as arctium lappa, &c. it is the bark of the root which is to be reserved, and the meditullium is to be rejected: this is done by splitting up the root and cutting the inert portion out; in others, as althea officinalis, the bark is to be removed, and the meditullium retained; to effect this, the outer coverings of the root are scraped off

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[*] The Parisian apothecaries generally dry their plants on the tops of bakers' ovens.

until the portion wanted for medicinal use alone is left.

In the desiccation of the *Fleshy Roots* more caution is to be observed; having been washed and cut into thin slices they are to be strung on cords, and dried partially by a current of air, or by the sun; when once moderately dry, the desiccation may be finished by the heat of a stove: but if they had been at once submitted to that temperature, they contain so much water that fermentation might readily be excited.

The only bulbous roots dried by the apothecaries are the squill and colchium. To prepare the squill, the proper root situate at the base of the bulb is to be cut off together with its attached fibrillæ: the external thin reddish scales are then to be taken off and rejected; the central white portion, which afterwards furnishes the stem, is also to be cast away, it being merely mucilaginous and nutritive. The incisions should not be made with an iron knife, but with one of ivory or silver, as the tannin of the bulb would be blackened by the use of an instrument of the former metal. The middle scales, which are paler, thick and juicy, are to be taken off, cut into transverse slices, exposed first to the air for some hours, and then removed to a stove heated to about 100°, and dried gradually.

The meadow saffron, if intended for keeping, should be dried immediately on being obtained; it should be cut into small pieces, and desiccated rapidly at a temperature of 130°; it is tenacious of life, and if its moisture be not quickly and perfectly removed it germinates, its veratrine disappears, and when its stock of nutritive material has been exhausted, it shrinks, dies, and is decomposed.

Some roots are directed to be preserved fresh, by imbedding them in sand; if in this situation they throw out shoots, their medicinal activity becomes very much diminished.

The desiccation of stems, barks, and woods, requires no remark: those that are indigenous, (and which alone are to be dried by the apothecary,) do not contain any principle very readily dissipated, and therefore they may be dried rapidly in a stove.

The desiccation of leaves must be conducted so as to preserve their original colour unaltered, as that is the surest indication of their possessing their active properties unchanged; to effect this they must be protected from the direct solar rays, and the heat used in their desiccation must be cautiously applied.

"Put the leaves or fresh flowers of the herbs, while in blossom, into paper bags, and expose them to a low heat for an hour, (90° to 100° Fahrenheit;) then strew them lightly upon a sieve, and dry them as quickly as possible, taking care that their colour be not spoiled by too great a heat: but if the herbs are to be used in the form of a powder, they must be immediately powdered, and the powder preserved in well closed opaque phials. Herbs and flowers, from which they are to be obtained, should be dried as soon as collected."—*Dublin Pharmacopœia.*

Mr. Battley of London, the well-known excellence of whose vegetable preparations renders his directions valuable, gives the following mode of drying the narcotic plants without injury to their activity:* "The leaves being in a high state of preservation, and entirely freed from the stalks, and, as much as possible, from external moisture, must be laid in thin layers in baskets of willow stripped of its bark in a drying-room, from which light is to be excluded. They should be then exposed to the temperature of not less than 130° or 140° Fahrenheit, for three or four hours, or until they begin to shrivel. They are then to be turned in the same temperature, and the heat kept up for six or eight hours longer, when the operation is generally finished, which is known by the leaves crumbling without much difficulty in the hand. If the process has been in all its parts properly managed, the result will be, that the leaves retain a beautiful green colour, and also, in a high degree, the medical properties of the plant to which they belong."

It is extremely difficult to dry flowers so as to preserve at the same time their colour and odour. Those, indeed, the petals of which contain much water, and at the same time an odorous principle, as most of the cruciferæ are incapable of proper desiccation. Other flowers, however, as those of the sambucus, rosa, anthemis, genista, &c., whose parenchyme is dense, and not loosely cellular, may be dried with facility in the same manner as that directed for the desiccation of leaves.

The desiccation of seeds needs no remark.

Every apothecary who makes his own vegetable preparations should have an apartment solely for

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* London Medical Repository, vol. xiv. page 429.

the drying of herbs: it should be open to the south, but the windows shaded, so as to exclude the direct rays of the sun and the rain; the apertures should not be too numerous, because, although a current of air is necessary to remove the vapour arising from the vegetable whilst drying, too rapid a current would prevent the temperature of the room being kept at the proper height. Round and across the room should be disposed rails on which the wicker baskets containing the plants may be disposed, so as to allow the free passage of the air through every part of them; and it should be of a height above the ground sufficient to protect it from the entry of dust or dirt.

The following tables give the quantities of dried product obtained from 1000 parts of material by Henry and Guibourt.*

ROOTS.

Arctium lappa	301	Inula Helenium	187
Aspidium filix mas	500	Rumex patientia	333
Bryonia alba	125	Valeriana Sylvestris	316

BARKS.

Æsculus Hippocastanum	380	Ulmus campestris	375
Quercus robur	410	Twigs of solanum dulcamara	308
Salix alba	450		
Sambucus niger	292		

LEAVES.

Aconitum napellus	185	Artemisia absinthium	260
Althea officinalis	130	Atropa belladonna	140

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* Abridged from the *Pharmacopée Raisonée.*

Borago officinalis	115	Menyanthes trifoliata	140
Conium maculatum	185	Rhus rhadicans	280
Datura stramonium	110	Ruta graveolens	225
Digitalis purpŭrea	180	Solanum nigrum	150
Hyosciamus niger	135	Tanacetum vulgare	196
Hyssopus officinalis	230	Tops of mentha piperita	215

FLOWERS.

Anthemis nobilis	338	Verbascum thapsus	175
Borago officinalis	96	Petals of dianthus caryophyllus	235
Citrus aurantuisse	250		
Lavendula vera	510	——— papaver rheas	84
Malva Sylvestris	111	——— rosa pallida	180
Sambucus ebulus	250	——— ——— rubra	330
Spartium scopiarum	170	——— viola tricolor hortensis	147
Tussilago farfara	192		

The preservation of vegetables, when once dried, requires some attention: those which originally contained but little water may be kept uninjured for a length of time; others become deteriorated, and require renewal very frequently.

The means by which dry vegetables become unfit for pharmaceutic use is by the destructive effects of insects, or by the supervention of fermentation. The roots and woods which contain much starch, are particularly exposed to the first. The leaves, fruits and flowers, which originally possessed a loose, watery, cellular tissue, with some saccharine principle, are those which are most likely of injury from the latter cause.

The roots and barks which are mucilaginous or merely bitter, as althea, columbo, become inert and useless when attacked by insects, and should be rejected but where a root is resinous, its virtues are not rendered less, but rather relatively greater by the inert material being removed by the animal, which leaves the active principles untouched; this is the case with jalap and some few other roots.

There are two modes of preventing vegetable matters from absorbing moisture, and thus preserving them unaltered; the first, of keeping them in vessels, as jars, &c., which may be covered air-tight; the second is to compress them to such a degree as, in a great measure, to destroy the flaccidity and porosity of their tissue, and thus render them incapable of absorbing moisture; thus they are artificially rendered as capable of preservation, as those plants with closed and densed parenchymes are naturally. In this way the strobiles of the humulus are prepared for commerce, and the petals of the violet, red rose, &c. are kept much more perfectly in this manner. When immersed in water, they absorb it, and recover, in a few moments, their original fulness and form.

ELEMENTS

OF

PRACTICAL PHARMACY.

PART I.

OF MECHANICAL OPERATIONS.

CHAPTER I.

Of those Operations by which the Weight and Bulk of Bodies are ascertained.

There is no operation which requires to be more frequently performed, nor any in the performance of which a greater degree of accuracy is necessary, than that by which we estimate the quantities of the substances which we employ, whether our intention be to ascertain the economic value of a process, or to determine for a purpose purely scientific, the composition of a body by estimating the proportions of its constituents; a great degree of accuracy is also requisite to be obtained in these operations, for an error of even trivial amount in the weighing of a body might give origin to consequences fatal equally to the character of the operator, and to the proper medicinal effects of the substances prepared by him.

An apothecary who would wish to acquire a certain degree of accuracy in his operations, should have more than one balance, at least two, or perhaps three would be found the most convenient number; of these the largest might be capable of weighing from four to seven pounds, and should turn sensibly with the addition of a scruple, when loaded with its greatest weight.—The second capable of weighing from half an ounce to about two pounds, and sensible to two grains with its greatest weight, should vibrate with the addition of a tenth of a grain when loaded with two ounces in each scale. Those are the balances which should be used in making officinal preparations, for which purpose they would be quite sufficiently accurate.

In analytical examinations, where it is required to determine with extreme accuracy the weights of small quantities of matter, a still more delicate balance should be employed; such a balance need not be made to support any great weight, because its sensibility would be by that means diminished, and in analyses no more than 500 grains of a substance need be operated on or weighed at once; if therefore an analytic balance be capable of supporting 500 grains in each dish, and of vibrating, when thus loaded with a proportionally small additional weight, about the $\frac{1}{10000}$ of the whole weight, it may be considered as sufficiently sensible and strong for all the purposes of analysis.

Balances should never be left exposed to the action of the air in a laboratory, for when in full work, the air of that apartment although occasionally renewed, is always contaminated with a quantity of gases, as nitrous acid, chlorine, &c. which would destroy the delicacy of any metallic instrument, in a very short space of time. They and many other pieces of apparatus, equally liable to injury, should be preserved in an apartment near the laboratory, where the substances to be weighed may easily be brought.

The importance of the balance is a sufficient excuse for entering at some length into a description of the principles upon which it acts, and the qualities to be required in a good instrument.

The balance may be described as consisting of an inflexible lever or rod, called the *beam,* furnished with three axes, one the fulcrum or centre of motion, situated in the middle, upon which the beam turns; and the other two near the extremities, and at equal distances from the middle. These last are called the *points of support,* and from them are suspended the *pans* or *scales.*

The points of support, and the fulcrum, are in the same right line; and the centre of gravity of the whole should be a little below the fulcrum when the position of the beam is horizontal.

The arms of the balance being equal, it follows that if equal weights be put into the scales, no effect will be produced on the position of the balance, and the beam will remain horizontal.

If a small addition be made to the weight in one of the scales, the horizontality of the beam will be disturbed, and after oscillating for some time it will on attaining a state of rest, form an angle with the horizon, the extent of which is a measure of the sensibility of the balance.*

Balances in general are preferable when fixed on supports, and so they are at present generally constructed, the support being fitted to a base containing a drawer for weights, &c. Such a frame is absolutely necessary for the larger balances; for it is impossible to support any considerable weight in the air for any time without the arm trembling, in a degree which, although trifling, may yet be the cause of inaccuracy in the results; but for the smaller balances it is not so necessary, though very useful, and thus balances for philosophical purposes are most generally made.

With regard to the goodness of balances, there are several circumstances which it would be well to attend to before purchasing.

One of the most important is, that the knife-edges should be perfectly hard, for if they be not so, no matter how accurate the instrument may be at first, after a little time it becomes worse than useless. This point is easily ascertained by passing the point of a good penknife across the piece which goes through one of the end boxes, and if it makes the slightest mark, even when lightly pressed on, the part is too soft. Having satisfied yourself as to this, you may proceed to examine the accuracy of

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* Cabinet Cyclopædia, vol. v.—Kater on the Balance.

the instrument, and if the results be satisfactory, the balance may be depended on.

1st. The beam, when freed from the dishes, should lie perfectly horizontally between its extreme points; and when the dishes are again added, the horizontality of the beam should not be in the least degree disturbed.

2ndly. When the relative situation of the arms of the balance are changed, its horizontality should remain unaltered, nor should it be at all affected when the dishes are interchanged.

As to the delicacy of the balance, this is to be determined by ascertaining the smallest weight which will make the point of the needle describe a certain segment of a circle.*

With regard to the operation of weighing, few rules will suffice. The accuracy of the instrument should be carefully ascertained before each operation, and care should be taken that no current of air passes through the place in which the operation is performed: on this account, substances should never be weighed when hot, because, by producing an ascending current of heated air from the upper

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* Dr. Ure mentions one benefit which arises from having the balance attached to a support, which is, that if you cause a slight vibration of the balance, by drawing a fine file lightly across the support, its delicacy will be very much increased: thus a balance which under ordinary circumstances required one-tenth of a grain to affect, was by this means rendered sensible to the one-thirtieth.

surface of the dish, they appear to be much lighter than they really are.*

A balance should never be used for a weight greater than that which it is fully competent to support; for when overloaded, it is very apt to *sett*, as it is termed; that is, after oscillating for some time, one side descends suddenly, and remains permanently depressed. Hence one of the greatest benefits of having a series of balances, is, that you are enabled to preserve them from this fault, and nothing ruins the delicacy of an instrument more than a repetition of this circumstance. Balances which have the centre of gravity much below the fulcrum, are more liable to this failing than others.

When using a delicate balance, only a very small weight should be added without resting the pans on a support; even when the weight is very small, it will be better to do so than to attempt to equalize the pans, the apparatus being suspended in the air.

Small weights should never be added with the fingers; if they do not derive any dirt from that source, they at least do moisture, which would be a serious cause of inaccuracy: when a number of small weights are to be employed, they are much better handled by means of a small forceps: for adding small quantities of powders or such substances, nothing is better than a little spatula made of cut letter paper, or a slip of thin platina foil.

It is self-evident that in case of weighing mat-

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* To obviate this latter cause of inaccuracy, philosophical balances are generally enclosed in glass cases, the front of which opens to allow of the introduction of the substance and of the necessary weights.

ters which would act on the dishes, some substances capable of resisting such action should be interposed; for fluids, for instance, a small wedgwood capsule, or what is more convenient, a bit of tube closed at one end; and for solids nothing is better than a piece of thin platina foil, which may be folded into the shape of a cup by being turned up at the edges, and folded carefully at the corners.

The weighing of fluids requires a little notice, in consequence of the necessity of supporting in the dish the vessels in which they are contained. If the quantity of fluid be large, a capsule or bottle answers very well, and requires no support. The best way of supporting a matrass or flask, or a long tube, is to tie them to the suspending hook of the dish by a thread passing round the neck, and allowing them to rest on the dish, and to incline a little to one side: for short tubes, which are most convenient for weighing small quantities of fluids, the best support is to stick them in a cork perforated by means of a rat-tail file.

When it is necessary to add or to remove very small quantities of a fluid, in order to render the weight exact, the best means are, if the fluid be not corrosive, to introduce a portion of it into a tube with a capillary termination, the other end being closed by the finger: then, by gradually raising the finger, the fluid runs out in drops, the number and size of which may be governed by the will of the operator. If the fluid be corrosive, a glass rod dipped in it will convey a portion fully equal to four or five drops. This mode may be practised with non-corrosive liquids also, but is much less convenient than that first mentioned.

With regard to the weights used, they vary according to the purpose for which the substance is weighed. In common pharmaceutical operations the apothecaries' troy weight is employed; but in chemistry generally the grain is the standard.

For philosophical purposes a decimal system of weights is by far the most useful, and the modern French, or metrical scale, is entirely formed on this principle. The most convenient set of laboratory weights is the following, recommended by Dr. Ure, and which does away with the necessity of calculations, which is no trifle, viz. $100^{gr.}$ $900^{gr.}$ $800^{gr.}$ $700^{gr.}$ $600^{gr.}$ $500^{gr.}$ $400^{gr.}$ $300^{gr.}$ $200^{gr.}$ $100^{gr.}$ $90^{gr.}$ $80^{gr.}$ $70^{gr.}$ $60^{gr.}$ $50^{gr.}$ $40^{gr.}$ $30^{gr.}$ $20^{gr.}$ $10^{gr.}$ $9^{gr.}$ $8^{gr.}$ $7^{gr.}$ $6^{gr.}$ $5^{gr.}$ $4^{gr.}$ $3^{gr.}$ $2^{gr.}$ $1^{gr.}$ $\frac{9}{10}$gr. $\frac{8}{10}$gr. $\frac{7}{10}$gr. $\frac{6}{10}$gr. $\frac{5}{10}$gr. $\frac{4}{10}$gr. $\frac{3}{10}$gr. $\frac{2}{10}$gr. $\frac{1}{10}$gr. $\frac{9}{100}$gr. $\frac{8}{100}$gr. $\frac{7}{100}$gr. $\frac{6}{100}$gr. $\frac{5}{100}$gr. $\frac{4}{100}$gr. $\frac{3}{100}$gr. $\frac{2}{100}$gr. $\frac{1}{100}$gr. With these you will always have in the scale the same number of weights as there are figures in the number expressing the weight in grains.

Weights are generally made of brass; the smaller weights, the fractions of a grain particularly, should be made of platina; and indeed, every weight under 100 grains should be of that metal. The most convenient form is that where the weights being made of wire, and being rectilineal figures, have as many sides as there are 10 grains for those between 10 and 100 grains, and as there are grains for those between 1 and 10. Those weights which are below one grain are best made by weighing out a grain of very fine platina wire, and then dividing it into the requisite number of parts.

In works on Pharmacy, particulary the foreign ones, frequent allusion is made to the foreign weights. In order to facilitate study, I submit the following tables of the systems of weights of Germany and France, compared with the apothecaries' weight and with the English grain.

ENGLISH APOTHECARIES' WEIGHT.

℔.	℥	ʒ	℈	Grains.
1 =	12 =	96 =	288 =	5760
	1 =	8 =	24 =	480
		1 =	3 =	60
			1 =	24
				1

MODERN FRENCH WEIGHTS REDUCED TO ENGLISH GRAINS.

1 Kilogramme	=	1000	grammes	=	15444.	grains.
1 Hectogramme	=	100	—	=	1544.4	
1 Decagramme	=	10	—	=	154.44	
1 Gramme	=	1	—	=	15.444	
1 Decigramme	=	0.1	—	=	1.5444	
1 Centigramme	=	0.01	—	=	.15444	
1 Milligramme	=	0.001	—	=	.015444	

MODERN FRENCH WEIGHTS REDUCED TO APOTHECARIES' TROY WEIGHT.

	℔	℥	ʒ	℈	Grains.
1 Kilogramme =	2	8	1	1	4.0
1 Hectogramme =		3	1	2	4.40
1 Decagramme =			2	1	14.44
1 Gramme =					15.444

The lower weights are in the preceding table.

NEW FRENCH WEIGHTS REDUCED TO THE OLD FRENCH.

	Livres.	Onces.	Gros.	Grains.
1 Kilogramme =	2	0	5	35.15
1 Hectogramme =		3	2	11
1 Decagramme =			2	44
1 Gramme =				19
1 Decigramme =				1.9
1 Centigramme =				.19

OLD FRENCH WEIGHTS REDUCED TO APOTHECARIES' WEIGHT.

		℔.	℥.	ʒ.	℈.	Grs.
1 Livre	= 16 Onces =	1	4	0	2	2.07
1 Once	= 8 Gros =		1	0	0	2.62
1 Gros.	= 3 Scruples =			1	0	0.35
1 Scruple	= 24 Grains =				1	0.12
1 Grain =	=					0.83

GRAMMES, DECAGRAMMES, AND HECTOGRAMMES, REDUCED TO ENGLISH WEIGHTS.

Grammes.	Troy Grains.	Deca-Grammes.	Troy		Hecto-Grammes.	Troy Ounces.
			Drms.	Grs.		
1 =	15.444	1 =	2	34.44	1 =	3.2175
2 =	30.888	2 =	5	8.88	2 =	6.4350
3 =	46.332	3 =	7	43.32	3 =	9.6525
4 =	61.776	4 =	10	17.76	4 =	12.8700
5 =	77.220	5 =	12	52.20	5 =	16.0875
6 =	92.664	6 =	15	26.64	6 =	19.3050
7 =	108.108	7 =	18	1.08	7 =	22.5295
8 =	123.552	8 =	20	35.52	8 =	25.7400
9 =	138.996	9 =	23	9.96	9 =	28.9575

Of the German weights, those most used in pharmaceutical works are the Cologne marc, and its subdivisions, and the Nuremberg apothecaries' weight; of these the following are the scales.

DIVISION OF THE COLOGNE MARC REDUCED TO ENGLISH GRAINS.

	Grains Troy.
1 As or Esche =	0.83
8½- = 1 Heller =	7.05
17— = 1 Pfenning	14.11
68— = 4— = 1 Quintlein or Dram =	56.44
272— = 16— = 4= 1 Loth =	225.76
544— = 32— = 8= 2= 1 Unzen =	451.52
4352— = 256— = 64=16= 8=1 Marc =	3612.20
6526— = 384— = 96=24=12=1 Pfund =	548.130
8704— = 512— =128=32=16=1 Marc Pfund =	7224.40

NUREMBERG POUND REDUCED TO ENGLISH GRAINS.

lb.	oz.	Drachms.	Scruples.	Grains.	Troy Grains.
1 =	12 =	96 =	288 =	5760 =	5388
	1 =	8 =	24 =	480 =	460.5
		1 =	3 =	60 =	57.5
			1 =	20 =	19.2
				1 =	0.96

Hence the divisions of the Nuremberg scale being the same as ours, and the ratio being as 74 to 71, the weights can be reduced one to the other by a simple proportion.

Bodies are weighed under two points of view, first, with regard to the number of certain standard weights required to counterpoise them, or with regard to their absolute gravity; and secondly, with respect to the difference between the absolute gravities of the same bulk of various bodies, or with respect to their relative gravities, or, as it is more commonly termed, their specific gravities.

If we could obtain portions of different substances exactly equal in bulk, their specific gravities would be the same as their absolute weights, one of them being taken as a standard; but as this is evidently impossible, many modes are recommended of estimating the specific gravities of substances without regard to the difference of bulk; these means vary according as the substance is a solid, a liquid, or a gas; the different processes for examining the specific gravities of these three classes of bodies we shall now describe.

If we plunge a solid into any fluid, it displaces a quantity of that fluid, equal to its own bulk, and so if the vessel containing the fluid be graduated, we at once know the bulk of the solid. If the specific gravity of the solid be exactly equal to that of the fluid, it remains in whatsoever part of it it may be placed, but if it be greater, the equilibrium of pressure is disturbed and the solid sinks, the pressure from above preponderating; but if the specific gravity of the solid be less than that of the fluid, it floats, because then the pressure from below is most powerful.

But if a solid heavier than a fluid be plunged to a certain depth in that fluid, and the superincumbent pressure be removed, the solid floats at that depth, because the pressure from below increasing in proportion to the depth, at last counterbalances the superior specific gravity of the solid, and the latter remains suspended in the fluid at that point,* as if they were of equal specific gravities; and if a solid relatively lighter than a fluid be placed at the bottom of a vessel, and cut so smoothly as to prevent any of the fluid getting in between it and the bottom, it will remain fixed at the bottom, because the weight of the fluid presses it down, and there is no pressure from below to counterbalance that from above.

Hence it is, that if a solid heavier than water be

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* The depth in the fluid, is the depth of the solid multiplied by the number of times the solid is specifically heavier than the fluid.

weighed, first in air and then in water, it appears to lose a portion of its weight equal to the weight of its volume of water, because it is pressed upwards by a force equal to that weight, and thus is the specific gravity of a solid taken by means of the hydrostatic balance; for example, if we weigh in air a piece of iron, and find the weight to be 100 grains, and then in water by means of the above-mentioned balance, we find that it weighs only 87 grains; then it is evident that the weight of a volume of water, equal to the volume of the piece of iron is 13 grains, so that the specific gravity of iron is to the specific gravity of water as 100 to 13, or as 7.7 to 1. The simple formula being to divide the weight in air by the difference between the weight in air and the weight in water.*

For weighing a body in water, very simple directions are sufficient; attach the solid to the hook of the hydrostatic balance, by a very fine silk thread, or a fine hair, or still better a platina wire, and immerse it in a goblet or a jar of water, taking great care to keep it as nearly equidistant as possible from the sides and bottom of the glass, and from the surface of the water; having thus weighed it, the simple calculation remains to be made, and the operation is finished. (Plate I. Figure 1.)

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* There is yet an inaccuracy in this formula, for the weight of a body in air is less than its actual weight by the weight of a volume of air equal to its own, and this loss requires a very exact operation to be compensated for, but it may well be neglected in ordinary cases. A cubic inch of water weighs less in air than in a vacuum, by rather more than ¼ of a grain.

A very neat application of the hydrometer (an instrument to be hereafter described) was made by Mr. Nicholson, to supply the place of the hydrostatic balance in weighing solids in water. This instrument (Plate I. Figure 2,) consists of a cylindrical ball, made in general of tinned iron, through which passes a wire, forming a stem at either end. To the top of the upper stem is fixed a cup, and to the bottom of the other stem is hung another cup. This instrument is so constructed as to sink in water up to a certain mark on the upper stem, when a certain weight (say 200 grains) is placed on the upper cup; now if a body when placed in this cup requires an additional weight of 50 grains to sink the instrument to the mark on the stem, it is evident that the difference of 150 grains is the weight of the body in air.

Then to find the specific gravity, the body is placed in the lower cup, and the instrument being immersed in water, is sunk to the mark on the stem, by weights placed in the upper cup, let there be 75 grains, then it is evident the substance weighs in water 125 grains, and then you calculate from these data as in the former case. This instrument is easily used, and can be applied to taking the specific gravity of powders, though for this it is not very accurate; its greatest disadvantage is that it is very liable to upset, though this may be prevented by a little attention, or by attaching a small weight to the lower stem.

If the substance to be weighed be lighter than water, the best method (if it be not chemically acted on by that fluid,) is to immerse it in company with a quantity of a heavy substance to sink it. Having ascertained the weight in air of the lighter substance, and the weight in water of the heavier, we are to suspend them in the fluid, tied together, but not so closely as to retain any bubbles of air between them. When we weigh them thus disposed, we will find that the weight in water of both together is less than the weight of the heavier body alone in that fluid, because it is pressed upwards by the buoyancy of the other. Now subtract the weight in water of the united substances, from the weight in water of the heavier substance, and add the remainder to the weight in air of the lighter body. Then divide the weight in air of the lighter body by the sum thus got, and the quotient will be the specific gravity desired.*

If the substance under consideration be chemically acted on by the water, as gum, potassium, &c., the substance may be either coated with wax, (which method is likely to lead into error,) or may be weighed in a fluid which does not act on it, as for instance, gum might be weighed in alcohol, or

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* As an example may render this formula plainer, I select the following from Doctor Paris's Excellent Medical Chemistry: "A piece of elm wood, varnished to prevent the absorption of fluid, was found to weigh in air 920 grains; a piece of lead was found to weigh in water 911.7 grains; the elm and lead together weighed in water 331.7, which subtracted from 911.7, gave 580 grains; then 580 being added to 920, made 1500; and finally, 920 being divided by 1500, gave 0.6133, the specific gravity of elm wood.

potassium in naphtha, then the formula is as follows: as the specific gravity of water is to the specific gravity of the fluid used, so is the specific gravity found to the real specific gravity. For instance, if we wish to take the specific gravity of potassium, we use naphtha, and we find that the apparent specific gravity of the metal is 1.2; then we say as 1,000 (the specific gravity of water) is to 0.708, (the specific gravity of naphtha,) so is the apparent specific gravity of potassium, 1.2 to the real 0.8496.

Charles has imagined a means of applying the hydrometer of Nicholson to the weighing of bodies of a less specific gravity than water; it is sufficient to apply in place of the lower cup, a little funnel penetrated by numerous small holes, under which we place the body. It is evident, that in this case it becomes necessary to add more weight than in general is placed on the upper cup, and that the specific gravity of the substance is a fraction, water being unity.

An instrument which is extremely elegant and accurate, and which serves equally well for estimating the specific gravity of substances which are soluble in or acted on by water, and for powders and porous bodies, is the following described by professor Leslie.

This instrument consists of a glass tube, *a. e.* (Plate I. Figure 3,) about three feet long, and open at both ends; the wide part *a. b.* is about four-tenths of an inch in diameter; the smaller part *b. e.* is about two-tenths.

The two parts communicate by an extremely fine slit at *b.* which allows air to pass, but retains sand or powder. The mouth at *a.* is ground smooth, and can be so shut as to be air tight by a small glass plate *f:* the substance, whose specific gravity we wish to find, (sand for instance), is put into the wide part *a. b.* which may 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 until the metal rises within the gorge *b:* the lid is now 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 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 above its level in the open vessel. It is evident that the air inside the tube is subjected to a pressure of exactly half our atmosphere; it dilates and fills exactly twice the space it originally occupied, since then the air is dilated to twice its volume; the cavity *a. b.* contains exactly half what it did before, and the cavity *b. c.* containing the other half, the quantity of air in these two parts are equal, or the quantity of air in *b. e.* is equal to the quantity mixed with the sand in *a. b.*, and occupies the same volume which the whole did before its dilatation. Let the sand be now taken out, and let the experiment be repeated, the part *a. b.* being now filled with air alone. It is plain that the quantity of air being greater, it will, when dilated to twice its bulk by a pressure of fifteen inches, occupy a greater space, and the mercury will rise only to *d.* for instance: but the rarified air in the narrow part always occupies the volume which the whole did under ordinary pressure, and this space is in one case *b. c.* and in the other *b. d.*, therefore the volume of the difference *c. d.* is the volume of the solid matter in the sand used. Now by marking the number of grains of water held by the narrow tube *b. e.* on a scale attached to it, we find at once the weight of a volume of water equal to the volume of sand, and having the weight of the latter, we find at once its specific gravity.*

The use of this extremely accurate instrument is much easier than would be thought from the length of the description; the only circumstance necessary to be observed is, that in using substances which absorb gases, as charcoal, &c., it is requisite to powder them finely, in order to destroy the cause of that property, their porosity.

There are two ways of ascertaining the specific gravity of fluids, viz., either by weighing a certain bulk of them in the balance, or by the use of certain instruments termed Hydrometers or Areometers, which by their sinking or floating indicate the specific gravity of the liquid in which they are immersed, by showing the relative volumes of the same weight, or the relative weights of the same volume of the different liquids: each of these processes we shall now describe.

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* In the 23rd volume of the Annales de Chimie, Say gives a memoir accompanied with a plate of an instrument for taking specific gravities, which he called a Stereometer; as the principle of this instrument is identical with, and the description the same as that of the instrument invented by the Edinburgh Professor, it is not necessary to notice it further here.

The first is generally performed by means of the specific gravity-bottle, for which purpose any common bottle would do, all that is necessary, being to know accurately the weights of the quantity of water, and of any other fluid required to fill it. But to save the trouble of calculation, and to insure accuracy, bottles are made expressly for this use. These bottles in general hold 250, 500, or 1000 grains of distilled water, when filled exactly to a diamond cut mark on the neck, (which for greater delicacy is made long and narrow), and being filled up to this mark with any other fluid, the weight of the fluid gives at once the specific gravity or its proportional.

The stoppers of these bottles are variously formed, sometimes they are solid, at other times they are perforated by a very fine hole in the centre, (a bit of delicate thermometer tube is often used for this kind of stopper,) and in other bottles the stopper is solid, but a fine line is cut on the side of it with a diamond, which answers the same purpose as if it was perforated. Dr. Ure prefers this last kind of stopper, as allowing the bottle to be more accurately filled, the surplus quantity finding exit by the small hole; and another benefit which he thinks results from their use is, that, the operator can distinguish any slight change of temperature in the contents of the bottle by the rise or fall of the column of liquid in the little tube in or at the side of the stopper.

This is certainly an advantage, but I think with Faraday, that its disadvantages more than counterbalance it. He says: " It not only affords 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 the fluid pass; it actually accelerates the evaporation, for the fluid (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 minute bubbles by the central 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 might evaporate, no more would be able to rise, because air could not enter to supply its place, and the bulk would remain comparatively unchanged."*

From the hydrostatic principle, by which we find the specific gravity of solids, is deduced a mode of determining that of fluids also; for if we take a glass or crystal ball of known weight, and weigh it first in water, and afterwards in any other liquid, the loss of weight in each gives you the weight of the same volume of water, and of the other liquid, and by a simple proportion, the specific gravity of the other liquid. The balls for this purpose are generally attached to a fine platina wire, and suspended from the hook of the hydrostatic balance, as in the case of a solid.

On the same general principle depends the use of those instruments termed hydrometers. The most simple form of the hydrometer is that of a number

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* Chemical Manipulations, p. 55.

of hollow glass beads of different weights, but the proportions of which are known, and the beads marked accordingly. They are successively dropped into the fluid, to be examined, until one of them is found, which neither comes up to the surface nor sinks to the bottom, but remains at rest in whatever part of the liquid it is placed: it is evident that the liquid is of the same specific gravity with this bead, and then you ascertain what that specific gravity is by reference to the number of the bead.

The common hydrometer consists essentially of a hollow ball containing air, from either extremity of which arises a stem; that from the upper surface of the ball is about 6 inches long, and is intended for the reception of the scale, and that from the lower surface is shorter, and to it is attached a weight sufficient to sink the ball and part of the stem to a certain point in distilled water. This point is taken at zero, or 0, and indicates the specific gravity of water. The specific gravity of any other fluid is judged according as the instrument sinks more or less when immersed in it.

Hydrometers are made either of glass of copper, or of brass. Those of the former material, which are those made use of by manufacturers in estimating the strength of saline solutions, of acids, &c. have the stem hollow, and the scale of paper enclosed in it, and the weight, consists of a second ball, containing a certain quantity of mercury. Of these, the best are those of Twaddle of Glasgow, which are in sets of six, and each degree on which corresponds to 0.005 of specific gravity, so that the specific gravity of a liquid is found with Twaddle's hydrometer, by multiplying the number of degrees by 5, and adding 1000. Those next in accuracy to Twaddle's are made by Zanetti of Manchester; his set consists also of six, which commencing at the specific gravity of water, as 100 proceeds up to 185, and the specific gravity is got without calculation, by adding a cypher to the number of degrees.

The hydrometers made of copper or brass are those which in these countries are used for estimating the specific gravities of spirituous liquids, as for instance those of Dicas, Clarke, and Sykes; the latter, which is the instrument now ordered by government to be used by the revenue, has nine shifting weights applicable upon the upper part of the stem, as in the figure, (Plate I. Figure 4,) and is used with a set of tables and a sliding rule, which is sold with it for computing compensation at different temperatures. The scale is divided into ten principal divisions, each of which is subdivided into five parts and by separate application of the weights in succession, completes the range of strengths from pure alcohol to water, each weight being equivalent to ten principal divisions. As the tables or rule are always sold with the instrument, we need not occupy ourselves about them here; but the subjoined table from Dallas,* shewing the relation between the specific gravities of spirits and the degrees of Dicas and Sykes' hydrometers, and the proportion of alcohol at .825, which they are estimated to contain at 60° Fahrenheit may be found of use.

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* Tables of the Comparative Value of Spirits, by James Dallas, 1818.

Sp. Gr.	Parts of Alcohol in1000.	Over Proof. D. or S.	Sp. Gr.	Parts of Alcohol in 1000	Over Proof. D. or S.	Sp. Gr.	Parts of Alcohol in 1000	Under Proof. D. or S.
825	1000	63	884	729	28	938	456	17
826	993	62	886	719	27	940	444	19
828	984	61	888	709	25	942	432	21
830	975	60	890	699	24	944	421	23
832	966	59	892	689	22	946	411	24
834	957	58	894	680	20	948	397	26
836	949	57	896	671	19	950	382	28
838	940	56	898	662	17	952	370	31
840	932	55	900	649	15	954	358	34
842	924	54	902	641	14	956	346	36
844	916	53	904	631	12	958	333	39
846	908	52	906	621	11	960	315	42
848	898	50	908	612	10	962	300	45
850	888	49	910	602	8	964	285	48
852	878	48	912	591	7	966	270	51
854	868	47	914	581	5	968	253	54
856	857	46	916	571	3	970	236	57
858	849	45	918	562	1	972	218	60
860	840	44	920	550	Proof.	974	200	64
862	833	43			Spirits under Proof.	978	175	72
864	823	42				980	150	75
866	813	40				982	135	77
868	807	39	922	540	2	984	120	80
870	798	38	924	531	4	986	105	82
872	787	37	926	521	6	988	90	85
874	776	36	928	510	7	990	75	89
876	768	34	930	500	9	992	60	92
878	757	32	932	489	11	994	45	95
880	746	30	934	479	13	996	30	96
882	738	29	936	468	15	998	15	98
						1000	distilled	Water.

The degrees of these instruments are calculated from a spirit, termed *Proof,* the specific gravity of which varies very much, but is fixed by the Dublin Pharmacopœia at 0.919, at the temperature of 61 Fahrenheit, and which contains about 49 per cent. of real alcohol, and the spirit is said to be, for instance, 20 above proof, when 100 gallons of it would require the addition of 20 gallons of water to bring it down to proof; and it is said to be 20 below proof when 100 gallons of it contain 20 gallons of water more than it should, to be at proof.

By the French, the areometers of Beaumé are almost universally used for determining specific gravities, but as the instruments are never used in these countries, we may omit the minute description, the principle being the same as in the other hydrometers of the same class: however, as there is constant reference made by the French writers on pharmacy to the degrees of this scale, the following table of the relations between these degrees and the specific gravities, compiled from those published in Nicholson's quarto journal, vol. i. page 39, in the Codex Medicamentarius; and from Maroseau's Paper on the areometer and alcoholmeter,* may be found of use.†

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* Journal de Pharmacie.—Août. 1830.

† Latterly the areometer of Cartier has been much used in Paris for determining specific gravities, principally in commerce; the scale is not as minute as that of Beaumé's, and where the degrees are mentioned, those of Beaumé's are given also, wherefore it is needless to give it here. For the description of the instrument and the tables, see Payen and Chevallier Traité des Reactifs, vol. i. p. 15, and Bussy, Traité des Falsifications des drogues simples et composées.

Ascending Scale of Beaumé, for Specific Gravities above 1000,—*Temperature* 54.5 *Fahrenheit.*

Beaumé.	Specific Gravity.	Difference	Beaumé.	Specific Gravity.	Difference
1	1.008		39	1.371	13
2	1.015	7	40	1.384	13
3	1.022	7	41	1.397	13
4	1.029	7	42	1.410	13
5	1.036	7	43	1·424	14
6	1.043	7	44	1.438	14
7	1.051	8	45	1.453	15
8	1.059	8	46	1.468	15
9	1.067	8	47	1.483	15
10	1,075	8	48	1.498	15
11	1.083	8	49	1.514	16
12	1.091	8	50	1.530	16
13	1.099	8	51	1.546	16
14	1.107	8	52	1.563	17
15	1.116	9	53	1.580	17
16	1.125	9	54	1.598	18
17	1.134	9	55	1.616	18
18	1.143	9	56	1.634	18
19	1.152	9	57	1.653	19
20	1.161	9	58	1.672	19
21	1.170	10	59	1.691	19
22	1.180	10	60	1.711	20
23	1.190	10	61	1.732	21
24	1.200	10	62	1.753	21
25	1.210	10	63	1.775	22
26	1.220	10	64	1.797	22
27	1.230	10	65	1.819	22
28	1.241	11	66	1.842	23
29	1.252	11	67	1.866	24
30	1.263	11	68	1.891	25
31	1.274	11	69	1.916	25
32	1.285	11	70	1.942	26
33	1.296	11	71	1.968	26
34	1.308	12	72	1.995	27
35	1,320	12	73	2.023	28
36	1.332	12	74	2.052	29
37	1.345	13	75	2.081	29
38	1.358	13			

Descending Scale for Specific Gravities less than water, Temperature 54.5 Fahrenheit.

Beaumé.	Specific Gravity.	Beaumé.	Specific Gravity.	Beaumé	Specific Gravity.
10	1.000	27	0.885	44	0.794
11	0.992	28	0.879		
12	0.985	29	0.872	50	0.782
13	0.977	30	0.867	60	0.742
14	0.970	31	0.862	66	0.715
15	0.963	32	0.856		
16	0.956	33	0.851		
17	0.949	34	0.845	In the three last, taken from the Codex, the temperature is not mentioned.	
18	0.942	35	0.840		
19	0.935	36	0.835		
20	0.929	37	0.830		
21	0.922	38	0.825		
22	0 916	39	0.819		
23	0.909	40	0.814		
24	0.903	41	0.809		
25	0.897	42	0.804		
26	0.891	43	0.799		

A hydrometer of great delicacy, and peculiarly useful for measuring the specific gravities of different waters, and thereby ascertaining their purity, consists of a ball of glass three inches in diameter, with another joining it and opening into it, of one inch diameter, *B c* (Plate I. Figure 5.) and a brass neck, *d*, into which is screwed a wire, *a o*, about 10 inches long and $\frac{1}{40}$th of an inch in diameter, divided into inches and tenths of an inch: the whole weight of this instrument is 4000 grains when loaded with shot in the lower ball.

It is found that when plunged into water in a jar, a grain laid upon the top *a*, makes it sink one inch: therefore a tenth of a grain makes it sink a tenth of an inch. Now if it will stand in one kind of water a tenth of an inch lower than in another, it shows that a bulk of one kind of water equal to the bulk of the instrument weighs one-tenth of a grain less than an equal bulk of another kind of water, so that a difference in specific gravity of one part in forty thousand is thus detected. This weight of 4000 grains is convenient for comparing water, but the quantity of shot in the lower ball may be varied so as to make it lighter or heavier, and so adapt it to measure the specific gravities of lighter or heavier liquids. It will always be an accurate and very delicate measure for liquids of nearly the same weight; its delicacy is so great that an impurity too slight to be detected by any ordinary test, or by the taste, will be discovered by this instrument.*

In June, 1829, MM. Chevallier and Bussy made a report to the Society of Pharmacy, on an instrument for ascertaining the specific gravity of essential oils: this instrument was invented by Violet and Gulnot in order to detect the adulteration of the higher priced oils by means of the cheaper oils: it is only a modification of Beaume's areometer, but more elegant, therefore it need not be

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* Library of Useful Knowledge.—Hydrostatics.

more particularly dwelt upon; but in the table of specific gravities those of the essential oils will be given as determined by means of it, the table of which was published in the Bulletin des Travaux de la Societé de Pharmacie for July same year.

Another modification of the common hydrometer is that class of instruments termed per centage hydrometers, and designed to show the quantity of a substance contained in one hundred parts of a certain fluid. These are generally named from the substance the quantities of which they are intended to estimate, as, Lactometers, Saccharometers, Alkalimeters, and it is evident that their graduations being dependant on the strength of the fluid taken as zero, or as unity, their use is very much restricted. The most useful instrument of this class is Gay Lussac's Alcoholmeter, which indicates the quantity of real alcohol contained in any spirits. The scale consists of 100 degrees, each degree indicating the quantity of alcohol contained in 100 parts of the spirits; as, for instance, a spirit marking 50 on the alcoholmeter contains 50 per cent. of real alcohol and 50 of water: for more minute comparison the degrees are reduced to specific gravities in the following table, which taken from Maroseau's excellent Paper, before quoted, is given here not so much for sake of the instrument, which is very little used in this country, as for being an extremely accurate table of the quantities of real alcohol (sp. gr. 795) contained in a spirit of any given specific gravity.

Specific Gravities, as given by Gay Lussac's Centesimal Alcoholmeter, Temperature 15° cent. = 59° Fahrenheit.

Degrees.	Specific Gravity.	Degrees.	Specific Gravity.	Degrees.	Specific Gravity.	Degrees.	Specific Gravity.
0	1.000	25	.971	51	.934	76	.876
1	.999	26	.970	52	.932	77	.874
2	.997	27	.969	53	.930	78	.871
3	.996	28	.968	54	.928	79	.868
4	.994	29	.967	55	.926	80	.865
5	.993	30	.966	56	.924	81	.863
6	.992	31	.965	57	.922	82	.860
7	.991	32	.964	58	.920	83	.857
8	.989	33	.963	59	.918	84	.854
9	.988	34	.962	60	.915	85	.851
10	.987	35	.960	61	.913	86	.848
11	.986	36	.959	62	.911	87	.845
12	.984	37	.957	63	.909	88	.842
13	.983	38	.956	64	.906	89	.838
14	.982	39	.954	65	.904	90	.835
15	.981	40	.953	66	.902	91	.832
16	.980	41	.951	67	.899	92	.829
17	.979	42	.949	68	.896	93	.826
18	.978	43	.948	69	.893	94	.822
19	.977	44	.946	70	.891	95	.818
20	.976	45	.945	71	.888	96	.814
21	.975	47	.941	72	.886	97	.810
22	.974	48	.940	73	.884	98	.805
23	.973	49	.938	74	.881	99	.800
24	.972	50	.936	75	.879	100	.795

As these instruments, the use of which we have described, are never made by the apothecary, we need not enter into the minutiæ of their mode of graduation referring those who wish more particularly to investigate the subject, to Mr. Moore's of this city, very valuable Paper on the graduation of the common hydrometer,* to that of Montigny on areometers,† San Martini, on the areometer,‡ to a very good Paper on the hydrometer by Dr. Blagden,‡ and to Meissner's work on areometry.§

There are, however, a few circumstances which it may be necessary to notice, because if unobserved (and they might easily pass unnoticed) they might lead the operator into considerable error. When using the instrument, (hydrometer or areometer,) let it sink gradually until it remains at rest, and then depress it about an inch lower. The pressure being then removed it will rise, but not to so high a level as it was at before, for there exists a force of repulsion between the fluid and the instrument, which tends to prevent it sinking in the fluid, but which almost entirely ceases to act when all the instrument in contact with the fluid is thoroughly wetted. This force acts much more powerfully in the more adhesive fluids, as in oil, sulphuric acid, &c., than in those which are less so, as in water, though even in the latter it is sufficiently powerful to elevate the stem 1, or 1½ degrees more than it ought.

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* Dublin Philosophical Journal, vol. i. page 384.

† Memoires de l'Academiè, Paris, (1768,) page 435.

‡ Memor. Italian Society, vii. 79.—Philosophical Transactions, (1790,) page 342.

§ Die Areometrie in ihren Anwendung auf chemie und technik.—1816.

Any circumstance which increases the energy of this force, of course makes the liability to error much greater, and therefore the stem of the instrument should be kept dry and free from dirt, particularly from any oily or unctuous substance.

In taking the specific gravities of solids or of fluids, water is generally assumed as unity, or else as 1000 at a certain temperature, which it is very important to state, because the specific gravities of all bodies diminish by an increase of temperature, the body dilating, and consequently the same absolute weight occupying a greater volume.* This temperature is generally taken in this country as 60° Fahrenheit, and also often by the continentalists, although they more generally estimate specific gravities at the temperature of 0° Réaumeur or Centigrade equal to 32° of Fahrenheit, because bodies are much more conveniently kept at this temperature for a certain length of time by means of melting ice.†

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* To this there are some exceptions, as, for instance, water which begins to expand when cooled below 41.5° Fahrenheit.

† Tables have been constructed of the differences in the specific gravities of fluids according to the differences in temperature, but as different bodies expand differently by the same increase of temperature, no general formula can be given. Water being always assumed as a standard, is the substance the ratio of whose expansion it is most interesting to know, with regard to the differences of specific gravities by different additions of heat; and Nicholson found that the fifth decimal in the specific gravity of this fluid changes for every 3 degrees of Fahrenheit, a formula which agrees nearly perfectly with the result of the researches of Hällestrom and Deluc.

In the commencement of this subject we intentionally omitted giving any directions for the weighing of gases when speaking of the mode of weighing other substances, considering that it would better be treated of in connexion with the means of estimating their specific gravities, the mode of conducting both which operations is now to be described.

The principle of weighing a gas is exceedingly simple. We weigh an exhausted globe, then we introduce into it the volume of gas, the weight of which we wish to ascertain, and then we weigh it again: the increase of weight gives the weight of the quantity of gas submitted to experiment. But this process is very far from being so facile in practice, for the accuracy requisite in counterbalancing; the care of drying the gas; the calculations necessary; and the extreme nicety required in the manipulation, render this one of the most delicate operations in chemistry.

The apparatus generally used for this purpose is a light glass globe or flask (Plate I. Figure 6) fitted with a good stop-cock and cap, which by means of a connector screws on the stop-cock of a pneumatic jar accurately graduated to cubic inches and the hundredths of a cubic inch, and containing the gas. Having exhausted the globe, let the stop-cocks be cautiously opened, and allow the gas to enter very gradually, lest any drops of the fluid over which it stands should be thrown into the globe, whether that fluid be water or mercury; indeed, if it be the former, it would be well to place a bit of bibulous paper in the connector which would effectually detain any small particles of water which might be carried by the current of gas into the exhausted vessel: the gas having entered thus slowly, the stop-cocks are to be closed as soon as we have admitted the required volume, which is known by the rise of the fluid in the graduated jar, and then having weighed the flask, and subtracting its weight when exhausted, we find the weight of the volume of gas contained in it.*

During this operation the temperature should be kept as equable as possible, and the globe, if it be at all heated by handling, should be allowed to cool down to the temperature of the surrounding air before separating it from the bell-glass, and the stop-cocks remaining open: the pressure within and without the jar should be carefully equalized by bringing the fluid within and without to the same level. The height of the mercury in the barometer, and the temperature of the room having been observed, the globe is to be separated from the jar, the stop-cocks having been first accurately closed, and the weight of the gas contained in it estimated.

In estimating the specific gravity of gases, the temperature is generally assumed as 60° Fahrenheit, and the barometric pressure as 30 inches; when ascertaining the specific gravity of the gas at any other temperature, or under any other pressure, it

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* The globe need not be entirely exhausted; for all that is necessary is, to introduce a certain volume of the gas into the globe, and ascertain the consequent increase of weight, which does not include the necessity of perfect exhaustion.

is necessary to reduce the volume of gas used to the volume which it would have at these standards: the mode of doing this we shall now expose.

By Gay Lussac's and Dalton's law for the dilatation of gases, it is proved that,—

1st. The dilatation of air is uniform from 32° to 212° on Fahrenheit's scale.

2ndly, That it is for each degree the $\frac{1}{480}$th part of the volume at 32°.

3rdly. That all gases dilate uniformly as air, and that for all the coefficient of dilatation remains the same; this is always for each of them the $\frac{1}{480}$th part of the volume at 32°.

The rule for correction to be applied to a certain volume of gas, is, therefore, to add the number of degrees between 32° and the observed temperature to 480, and to divide the observed volume by this sum, which gives the expansion or contraction for each degree at the observed temperature; then we must multiply this quotient by the number of degrees between the observed and the mean temperature, and we get the whole change of volume, which we subtract, if the observed temperature is above the mean, or add if it be below it.

For instance, if we have 100 cubic inches of a gas at 65°, and we wish to determine what would be its volume at 60°, we add 33 (the difference between 32 and 65) to 480, and we divide the observed volume 100 by the sum thus obtained, 513, and we then obtain the quotient, .194932 of a cubic inch as the expansion for one degree, then having multiplied this quotient by 5, (the number of degrees between 65° and 60°,) we get .974660 as the whole expansion between 60° and 65°, which then subtracted from 100 cubic inches (the volume at 65°) gives 99.025340 as the volume of the gas at 60°, and under the same pressure.

Before stating the formula for correction for pressure, it may be useful to describe and to explain the use of that instrument by which the pressure of the atmosphere is measured, as it naturally comes under the head of the weight of gases, and as an acquaintance with it may be necessary in order to fully comprehend the subject.

The atmosphere is a mass of elastic fluid about 42 miles in height from the surface of the earth, and the weight of which is equal to a pressure of about 15 pounds upon every square inch; therefore, if this pressure be removed from the surface of a fluid for a space equal to a square inch, the pressure remaining undiminished on the remaining surface; in consequence of the property which fluids possess of transmitting pressure equally in every direction, the surface of the fluid which is free from the pressure of the air is forced upwards by a force equal to about 15 pounds, and rises until the pressure is equalized by the weight of the column of fluid becoming equal to the pressure exercised on it by the atmosphere; this height is obviously in an inverse ratio with the specific gravity of the fluid, the column being higher as the liquid is less dense; for instance, the height of the column of water averages 35.5 feet, and that of the column of mercury 30 inches; and as the height of the column is always in proportion to the weight of the atmosphere, the slightest change in the latter will be immediately indicated by an alteration in the height of the column of mercury in the instrument, which for this cause is called a Barometer.

The ordinary barometer consists of a tube (Plate I. Figure 7.) more than 32 inches long, which being filled with mercury is inverted in a cup containing the same metal: very generally the end of the tube being bent and blown out, is made to serve as a basin to receive the surplus quantity of mercury: to the last three or four inches of this tube a scale is attached, divided into inches, and their tenths and hundredths, calculated from the height of the mercury in the cistern, and as this height varies inversely with the height of the mercury in the tube itself, and is thereby liable to be a cause of error in the graduation, the cup or cistern is generally made so large that a considerable variation in the level of the mercury in the tube will not create any very sensible difference in the level of the metal in the cistern.*

The pressure is taken as a mean, when the mercury in the barometer stands at 30 inches, and for reducing the volume of a gas at any other pressure to the volume at that, a very simple formula is sufficient; for as by Mariott's law the volume

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* For some excellent observations on the barometer, its modifications and applications, see Pouillet, Elemens de Physique et de Meteorologie; the Paper on Pneumatics in the Library of Useful Knowledge, and Dr. Jacob's Paper on a Portable Barometer, Dublin Philosophical Journal, vol. i.

of a gas is inversely as the pressure, it is only necessary to compare the observed height with the mean pressure, and increase or diminish the volume in a simple proportional; as, for instance, if the volume of a gas be 100 cubic inches at the pressure of 30.7 inches, what will be the volume at 30 inches, (the mean pressure,) then

as 30 : 30.7 : : 100 : 102.333

When a gas has been standing over water, it contains a quantity of aqueous vapour in a state of intimate mixture with it, and therefore, in weighing the gas, we must estimate what quantity of its volume and weight depends on the pressure of the aqueous vapour, and subtract it before we can ascertain the true volume and weight of the gas which we wish to examine.

There are two ways of doing this; first, by drying the gas perfectly, and then we weigh a pure body in place of a mixture of the gas with water; secondly, having fully saturated it with the vapour of the fluid, we calculate the increase of volume and of weight dependant on the quantity of vapour which the gas contains. The latter way is the most convenient; and as the quantity of vapour varies with the temperature, but is equal in each gas for the same temperature, tables can be constructed of the quantity of vapour which gases contain at different temperatures, and the following contains a range which will be found sufficiently extensive for all practical purposes, the atmospheric pressure being taken as at 30 inches:

40°	,00933	61°	,01923
41	,00973	62	,01980
42	,01013	63	,02050
43	,01053	64	,02120
44	,01093	65	,02190
45	,01133	66	,02260
46	,01173	67	,02330
47	,01213	68	,02406
48	,01253	69	,02483
49	,01293	70	,02566
50	,01333	71	,02653
51	,01380	72	,02740
52	,01426	73	,02830
53	,01480	74	,02923
54	,01533	75	,03020
55	,01586	76	,03120
56	,01640	77	,03220
57	,01693	78	,03323
58	,01753	79	,03423
59	,01810	80	,03533
60	,01866		

With respect to the mode of drying gases, it is very simple, all that is necessary being to pass the gas frequently backwards and forwards through a tube containing fragments of a substance, which has a power of absorbing water with considerable energy.

The desiccating substance varies with the nature of the gas which is to be dried. Chloride of calcium answers very well for the greater number of gases, but is unfit for drying ammonia, or the acid gases. Caustic potash answers very well for ammonia, but not for the acid gases; besides, the caustic potash of the shops always contains some deutoxide of potassium, which, when it comes in contact with water is decomposed, being resolved into protoxide (potassa) and gaseous oxygen, which mixing with the gas under examination, is liable to become a cause of error. Faraday[*] uses strong sulphuric acid as a desiccator for all the gases except ammonia, by filling a curved tube with bits of broken rock crystal, introducing a little acid, and then inclining the tube so as to moisten all the pieces according as by the draining of the acid they become dry.

The desiccation of a gas is tedious, and it is difficult to know when it is entirely finished unless by a hygrometrical experiment, which it is inconvenient to make; therefore, except under some particular circumstances, it is better to have the gas perfectly saturated with water, which is easily done by leaving the globe containing it in connexion with a bell glass over water, and allowing the stop-cocks to remain open for some hours; then knowing its temperature, we subtract from its volume, the volume of vapour which it contains, as given in the table, and thus we get the volume of dry gas at that temperature; then if the temperature be not the mean, we reduce the resulting volume of dry gas to the volume which it would occupy at the mean temperature. Next correct the weight by subtracting from the observed weight the weight of the aqueous vapour[†] which the gas contained, and thus we obtain the real

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[*] Faraday's Chemical Manipulations, p. 384.

[†] A cubic inch of permanent aqueous vapour at the mean temperature and pressure weighs 0.1929.

weight and volume of the pure gas at the mean temperature, and if the barometric pressure be not the mean, it is to be reduced to it by the formula just given; as, for instance, if a gas standing over water at 50° and 29.4 barometric pressure be weighed, and 220 cubic inches having entered the globe, caused an increase of weight of 101.69 grains. By the table it is found that at the temperature of 50° the quantity of aqueous vapour in gas standing over water is ,0133, which in the 220 cubic inches amounts 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 will be found equal to 219.929 cubic inches, from which if 2.942 (the volume of aqueous vapour present) be subtracted, it will leave 216.987 cubic inches on the volume of dry gas at the mean temperature and pressure; 2.942 inches of aqueous vapour weigh 0,5675 of a grain, for $2.942 \times 0{,}1929 = 0{,}5675$, this subtracted from 101.69 grains, (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, dry and at mean temperature and pressure, will weigh 46.603 grains.*

Having thus minutely described the mode of weighing gases, and the corrections necessary in that operation, the directions for estimating their specific gravities become very simple; for this class of bodies, instead of water, air is taken as the standard, and

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* For this numerical illustration I am indebted to Faraday's excellent work, "Chemical Manipulation."

reckoned as 1000, and knowing the weight of a certain volume of dry air, we compare the weight of the same volume of the dried gas to it as 1000, and thus we get the relative weight of the same volume of the gas, *i. e.* its *specific gravity ;* as for instance, if we have 100 cubic inches of hydrogen gas, weighing 2.118 grains; now 100 cubic inches of atmospheric air weigh 30.5 grains, and therefore

As 30.5 : 2.118 : : 1000 : 0.0694

the specific gravity of hydrogen.

Where the volume of gas does not equal 100 cubic inches, it is as well to calculate what would be the weight of 100 cubic inches (which is done by a simple proportional) and then proceed as before.

The following table contains the specific gravities of most of the substances in the Materia Medica, as well as of many other bodies, whose properties are of interest to the pharmaceutical student.

A Table of Specific Gravities of Bodies, Water being 1,000.

Acorn, (dry)	0.755	Baras	1.044
Acid, Acetic	1.062	Barley	1.279
—— Arsenic	3.391	Baryta	4.000
—— Arsenious	3.728	—— (Sulphate of)	
—— Benzoic	0.667	from	4.000
—— Boracic, (crystals)	1.479	to	4.865
—— Citric	1.034	—— (Carbonate of)	
—— Muriatic, (pure,)	1.200	from	4.100
—— —— Dub. Phar.	1.160	to	4.600
—— —— Edin. Phar.	1.170	Bdellium	1.371
—— Nitric, (real.)	1.583	Bassora, (Gum)	1.434
—— —— Dub. Phar.	1.490	Benzoin	1.092
—— —— Edin. Phar.	1.520	Blood, (Human)	1.053
—— —— Lon. Phar.	1.500	—— Crassamentum of,	1.245
—— Phosphoric, solid	2.800	—— Serum of,	1,030
—— Prussic, (pure)	0.700	Borax	1,714
—— —— of Scheele	0.900	Brazil Wood, (red)	1.031
—— —— Dub. Phar.	0.998	Butter	0.942
—— Sulphuric, (pure)	1.847	Calomel	7.176
—— — Real, (Bussy)	2.1250	Camphor	0.988
Acajou	1.445	Campeachy Wood	0.913
Alcohol	0.797	Caoutchouc	0.933
—— (highly rectified)	0.809	Caragna	1.124
—— (of commerce)	0.835	Catechu	1.398
Aloes, Socotorine	1.379	Chalk from	2.252
—— Hepatic	1.358	to	2.657
Alouchi, (Drymis Win-		Cinnabar, (Native)	6.982
teri)	1.060	Coals, from	1.020
Alum	1.714	to	1.300
Amber	1.078	Copaiva, (Balsam of)	0.886
Ambergris	0.800	Copal	1.045
Ammonia, Water of,		Charcoal, from	0.280
(pure)	0.875	to	0.440
—— Water of, (D. P.)	0.950	Copper, Carbonate of,	
—— Carbonate of	1.496	(Malachite)	3.600
—— Muriate of	1.520	Copper, Acetate, (Ver-	
Ammoniacum	1.207	degris)	1.780
Anime	1.028	Copper, Sulphate	2.230
Arcanson	1.085	Coral	2.690
Arnotto	0.595	Corrosive Sublimate	5.140
Assafœtida	1.327	Crab's Eyes	1.890
Asphaltum, from	1.450	Diamond	2.521
to	2.060	Dolomite from	2.540

to	2.830
Dragon's Blood, (Resin)	1.204
Elemi	1.018
Ether, Acetic	0.866
—— Muriatic	0.729
—— Nitric	0.908
—— Sulphuric, (pure)	0.632
—— —— Dub. Ph.	0.795
Euphorbium	1.124
Extract of Liquorice	1.722
—— Areca	1.457
Emerald, from	2.600
to	2.770
Fat of Beef	0.923
—— Hogs	0.936
—— Mutton	0.923
—— Veal	0.934
Feldspar	2.500
Flint, Black	2.582
Frankincense	1.173
Galbanum	1.212
Galipot	1.081
Gamboge	1.222
Garnet, (common) from	3.576
to	3.700
—— (precious) from	4.000
to	4 230
Guiac, (Resin)	1.228
—— (Wood)	1.333
Gum Arabic	1.452
—— Cherry Tree	1.481
—— Tragacanth	1.316
—— Lac	1.139
Glass, Crown	2.520
—— Flint, from	2.760
to	3.000
—— Green	2.642
Granite, from	2.613
to	2.956
Gypsum, compact	2.025
—— crystallized	2.735
Gas*	
Honey	1.450
Hornblende, from	3.250
to	3.830
Hog's Lard, from	0.942
to	0.956
Jet	1.300
Jalap, (Resin)	1.218
Indigo	1.009
Iodine	4.948
Ironstone, (Lancashire)	3.573
Isinglass	1.111
Ivory	1.825
Labdanum	1.186
Lead, Sulphuret of, (Galena)	7.000
Lignum Vitæ	1.327
Lime	2.300
Limestone, compact, from	2.386
to	3.000
Magnesia, (pure)	2.300
—— Native Hydrate	2.330
—— Carbonate of from	2.220
to	2.612
—— Sulphate of	1.664
Marble, Carrara	2.716
—— Parian	2.560
Mastic	1.074
Metals, Antimony	6.702
—— Arsenic	5.763
—— Bismuth	9.880
—— Cadmium	8.600
—— Chromium	5.900
—— Cobalt	8.600
—— Copper	8.900
—— Gold	19.25
—— Iron	7.788
—— Lead	11.350
—— Manganese	8.000
—— Mercury, solid	
—— at —39° Fah.	15.61
—— —— at +60°	13.58
—— —— at +212°	13.37
—— Molybdenum	8.600

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* For specific gravity of gases, see Table, page 54.

Metals, Nickel - -	8.666	Olibanum - - -	1.173
——— Platinum -	21.47	Opium - - - -	1.336
——— Potassium at		Opoponax - - -	1.622
59° Fah. -	0.865	Orpiment, from	3.048
——— Silver - -	10.470	to	3.500
——— Sodium at 59°		Oyster shells - -	2.092
Faht. - -	0.792	Pearl, Oriental - -	2.600
——— Tin - - -	7.290	Peruvian Bark - -	0.784
——— Tungsten -	17.40	Phosphorus - - -	1.770
——— Zinc, from	6.900	Pitch - - - - -	1.150
to	7.210	Plumbago, from	1.987
Milk - - - - -	1.032	to	2.400
Monbaris Gum - -	1.420	Porphyry - - -	2.500
Mutton Suet - - -	0.923	Potassa - - - -	1.708
Myrrh - - - -	1.360	——— Arsenite -	2.640
Naptha, from	0.700	——— Carbonate of	2.340
to	0.847	——— Bicarbonate	2.085
Nitre, (see Nitrate of		——— Chlorate -	1.990
Potash) - -		——— Chromate -	2.600
Obsidian - - - -	2.370	——— Feroprussiate	1.830
Oils, essential.		——— Muriate - -	1.980
—— Amber - - -	0.868	——— Nitrate - -	2.073
—— Annise-seed -	0.986	——— Sulphate -	2.670
—— Bergamotte -	0.945	——— Tartrate - -	1.556
—— Carraway-seed	0.974	——— Bitartrate -	1.950
—— Cinnamon -	1.050	——— Tartrate of, and	
—— Citron - - -	0.927	——— Antimony -	2.246
—— Cloves - - -	1.036	Proof Spirit, Dub. Ph.	0.919
—— Fennel - -	0.929	Pumice Stone - -	0.752
—— Lavender - -	0.868	Quartz from	2.624
—— Mint, common	0.898	to	3.750
—— Peppermint -	0.955	Realgar, from	3.225
—— Sassafras - -	1.180	to	3.338
—— Turpentine -	0.870	Rosin, common - -	1.072
—— Wormwood -	0.907	Rock Crystal, from	2.581
Oils, expressed.		to	2.888
—— Sweet Almonds	0.932	Sagapenum - - -	1.200
—— Filbert - -	0.916	Sanders Wood, red -	1.128
—— Hempseed -	0.926	Sandarac - - - -	1.092
—— Linseed - -	0.940	Sarcocol - - - -	1.265
—— Olives - -	0.915	Sassafras Wood - -	0.482
—— Poppy-seed -	0.939	Scammony, Smyrna -	1.274
—— Rapeseed - -	0.913	——— Aleppo -	1.235
—— Ricinum - -	0.916	Schorl, from	2.922
—— Walnut - -	0.930	to	3.452
—— Whale - - -	0.923	Slate - - - - -	2.110

Spar, Fluor, from	3.094	Soda, tartrate	1·744
to	3.791	—— Potash, tartrate	1.680
—— Calcareous, from	2.620	Sugar	1.606
to	2.837	Sugar of Lead	2.345
—— Calcareous, dou-		Sulphur, native	2.033
ble refracting	2.724	—— fused	1.990
Spermaceti	0.943	Tacamahaca	1.046
Staclactite	2.510	Tallow	0.941
Steatite	2.490	Turpentine	0.991
Strontian	1.647	Vinegar from	1.013
—— Sulphate, from	3.583	to	1.080
to	3.958	—— Distilled	1.005
——Carbonate, from	3.658	Water, Sea	1.028
to	3.675	Wax, white	0.968
Storax	1.109	—— yellow	0.964
Soda	1.336	Whey, (Cow's)	1.019
—— Acetate	2.101	Wine, Spirits of, D. P.	0.840
—— Arsenite	1.76	—— Bourdeaux	0.993
—— Borate	1.351	—— Burgundy	1.991
—— Biborate	1.714	—— Malaga	1.022
—— Carbonate	1.417	—— Port	0.997
—— Nitrate	2.000	Zircon, from	4.385
—— Phosphate	1.519	to	4.700
—— Sulphate	1.44	Zinc, Sulphate of,	1.912

Of the measures of capacity which are used in pharmacy, the gallon is in this country taken as the standard, and by it and its subdivisions the quantities of liquids used in pharmaceutical processes are estimated. However, in very many cases where operations not purely officinal are concerned, an other integer, the cubic inch, is selected in consequence of its more equable subdivision and its more convenient application; therefore we shall consider first those measures which are graduated according to the national standard, and afterwards those which are arranged according to the philosophical one.

The measures arising from the subdivision of the gallon are, the pint, the ounce, the drachm, the scruple, and the grain. The pint measures found in commerce are generally cylindrical or conical, and are sold ready graduated, but sometimes very incorrectly, therefore they should always be verified before being allowed to pass into use. The next measures generally contain two ounces, and are conical, so that the same measure serves to estimate from half a drachm upwards; the capacity of the vessel diminishing as the quantity of the liquid, so that the small volume may be as accurately determined as the large.

The grain measures are generally cylindrical, and of about two-tenths of an inch bore, so that they can be very easily graduated to parts of a grain if care be employed; but the graduation of this measure in particular, should not be left to a glass-cutter, for in the valuation of volumes of such fluids as are dispensed in fluid grains, a slight error might produce serious consequences; indeed it were much to be wished that the apothecaries would purchase all their measures plain, and then graduate them themselves.

The number of measures which the apothecary should have, is in a great degree at his own disposal, but separate measures for a pint, a half pint, and four ounces, would be found extremely useful; the common two ounce measure answers very well for quantities as low as half an ounce, but he ought to have tubular measures graduated for drachms, and the grain and minim measures should at least be so narrow as to allow of the volume of four grains being decimally divided.

When very accurate measurement of a moderately large quantity of fluid is desirable, the best form of the vessel is to have a nearly globular body with a long and narrow neck; let a certain quantity of fluid, say a pint, fill all the body and part of the neck, and having marked on the neck with a file a tangent to the surface of the fluid, the slightest change in volume of the whole bulk will become very evident on the narrow column of fluid in the neck; for this reason the necks of specific gravity bottles are generally thus formed.*

The fluid drachm is now divided by the Dublin Pharmacopœia into 57 grains, and by that of London into 60 minims, each minim equalling, therefore, 0.95 grains. Before these divisions were adopted, the drachm was divided into 60 drops, and this mode of measurement being yet in frequent use, it is of importance to ascertain accurately the quantity of a fluid corresponding to a certain number of drops; and this quantity has been found to differ materially not only in different liquids, but in the same liquid when dropped from vessels of different sizes or shapes, and even a difference of inclination of the fluid in the vessel produces a great change in the size of the drop.

The general inaccuracy of this mode of measurement was known long since, but Shuttleworth first subjected the matter to experiment, and constructed

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* On this principle are constructed the elegant instruments of Dr. Apjohn, for analysing expired air, vide Dublin Hospital Reports, vol. v. page 528; and of Dr. Ure, for analysing the Carbonates, vide Dictionary of Chemistry, edit. 3d, article, "Ammonia, Carbonate of."

the following table showing the number of grains and of drops in a measured drachm of several fluids.

Substances.	Grains.	Drops.
Distilled Water - -	60	60
Solution of Arsenic -	60¾	60
White Wine - - -	58¾	94
Ipecacuanha Wine -	59¾	84
Antimonial Wine -	59¾	84
Rectified Spirits - -	51½	151½
Proof Spirit - - -	54¼	140
Laudanum - - -	55½	134
Tincture of Foxglove	58	144

The weight of a certain number of drops of several fluids has been determined very accurately by the Editors of the French Pharmacopœia; the process which they employed, and the table of the results, are as follows:

"We have employed the following process for valuing the liquids which are prescribed by drops, and particularly those which are rather volatile, as alcohol, ether, &c., in order to prevent the evaporation from leading into error.

"Having filled with these liquids a small narrow-necked bottle with a flat lip turned outwards, and having carefully weighed the bottle and the liquid, we have counted a certain number of drops flowing slowly from the inclined orifice, and we have then weighed the residue; then having divided the loss into as many parts as we had counted drops, we got the weight of each drop, and thus we have succeeded in arranging the following table, showing the weight of 20 drops of each substance.

As to the weight of drops, as it depends on their volume, it must be deduced less from the density of the liquid itself, than from its viscosity or the cohesion of its molecules."*

Of the following liquids, twenty drops weigh—

	French Grs.	Grms.
Sulphuric Ether, sp. gr. 0.715	7	0.35
Alcoholized S. Ether, or Hoffman's liquor	9	0.45
Purest Alcohol, sp. gr. 0.847		
Compound Alcoholate of Melissa		
Alcohol saturated with Potassa	10	0.50
Animal Oil of Dippell		
Alcoholic Tincture of Benzoin		
———————— Castor		
Oil of Olives	11	0.55
Oil of Almonds		
Densest Acetic Acid, sp. gr. 1075	12	0.60
Common Acetic Acid, (distilled vinegar,)	13	0.65
Volatile Oil of Mint		
Volatile Oil of Petrolium or Naptha	14	0.70
Alcoholized Sulphuric Acid		
Simple distilled Water		
Liquid Laudanum of Sydenham	15	0.75
Volatile Oil of Cloves	16	0.80
Solution of Caustic Soda, sp. gr. 1321	18	0.90
Saturated Solution of Sulphate of Magnesia		
Laudanum of Abbé Rousseau	22	1.10
Hydrocyanic Acid, sp. gr. 900	23	1.15

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* Pharmacopée Francaise, traduite avec de notes, par Ratier et Henry fils, 1827, p. 166.

	French Grs.	Grms.
Sulphuric Acid, sp. gr. 1847 Water containing one-eighth of Gum Arabic	24	1.20
Simple Syrup, sp. gr. 1321	30	1.50

In the number of his Journal for June, 1830, Mr. Donovan makes some very excellent observations on the impropriety of measuring fluids by drops, of which, as the experiments differ rather in their design from those above-mentioned, we shall give a short resumé. "He filled an exceedingly accurate drachm measure, made of narrow glass tube, with a certain number of drops of various fluids, and found that with the same fluid a multitude of circumstances influence the number of drops required to fill it, as, the temperature, the density, the steadiness of the hand that dropped the liquid, the size of the lip of the phial from which the drops fall, the quickness or slowness with which the drops follow one another, the volume of the liquid contained in the phial, and many other circumstances: from his researches he concludes, that no fixed law can be established as regulating these results; that of some liquids 30 drops are equal to a drachm, of others, very nearly five times that number; that, for instance, the number of drops in a drachm of tincture of opium varies from 100 to 142; and finally, that dropping, as a mode of admeasurement, should be altogether relinquished."*

The cubic inch measure is generally applied to estimate the volumes of liquids for philosophical

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* Annals of Pharmacy, Dublin, edited by M. Donovan.

purposes, and the volumes of gases are almost universally ascertained by this graduation, therefore some minute directions as to the peculiarities of this scale may not be unimportant.

In order to graduate a vessel by cubic inches and their subdivisions, you first take a scratching diamond, or what is equally good, a small three square file, and mark a line on the vessel from top to bottom; this is easily done by laying it (whether it be a bottle or a tube) on its side against the edge of a rule, and drawing the diamond down it, where it rests against the rule; then counterpoise the vessel, and if it be large, weigh into it successive portions of water, by which the cubic inches and their larger subdivisions are to be measured out, marking carefully the level of the fluid after each addition, by a transverse line cutting the longitudinal one at right angles. If the vessels be small, as for instance a tube, it will be found much more convenient to graduate it by weighing portions of mercury into it, than by using water, because a small weight of this latter fluid being equal to a cubic inch, its minute divisions are very liable to inaccuracy in the weighing, but for the larger parts of the cubic inch, as the fourth or halves, it is much more suitable than mercury, the great weight of the latter fluid being a considerable inconvenience.*

When weighing mercury for graduation, it is ra-

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* Temperature being 62° Fahrenheit, and Barometric pressure being 30 inches; a cubic inch of water weighs 252.458 grains, and a cubic inch of mercury 3425.0 grains.

ther difficult to arrive at perfect equalization of the balance, because, owing to the cohesion of the metal, you may either remove or add too much. The best means of adding extremely small portions of this fluid is to use the small tube which is figured by Faraday,* about half an inch in diameter and four inches long, cut level at one end, and drawn off laterally to a capillary opening at the other. (Fig. 8, Plate 1st.) If this tube be full of mercury, it will not flow out at the capillary extremity as long as it remains in the position in the figure, but if the other end be raised, the metal will flow out either in a minute stream, or in a succession of drops, (according to the degree of inclination,) the number and size of which may be further graduated by applying the finger to the upper extremity. Thus can be added the most minute quantity of mercury, and the weighing of each portion accurately is thus much facilitated.

In the table of specific gravities those of gases were omitted, because they are better given in the following table along with the weight of 100 cubic inches of each gas.

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* Chemical Manipulation.

Names.	Sp. Gr. air = 1.00.	Weight in Grains of 100 cubic inches.
Hydrogen	0.0694	2.1180
Subcarburetted Hydrogen	0.5555	17.000
Ammonia	0.5902	18.000
Steam of Water	0.4810	14.680
Phosphuretted Hydrogen	0.9020	27.470
Carbonic Oxide	0.9722	29.650
Carburetted Hydrogen	0.9722	29.650
Nitrogen	0.9722	29.650
Hydrocyanic Acid Vapour	0.9374	28.590
Atmospheric Air	1.0000	30.509
Deutoxide of Nitrogen	1.0416	31.770
Oxygen	1.1111	33.888
Vapour of Sulphur	1.1111	33.888
Sulphuretted Hydrogen	1.1805	36.006
Hydrochloric Acid	1.2840	39.183
Carbonic Acid	1.5277	46.596
Protoxide of Azote	1.5277	46.596
Cyanogen	1.8055	55.070
Sulphurous Acid	2.2222	67.770
Deutoxide of Chlorine	2.3610	72.000
Protoxide of Chlorine	2.4400	74.420
Chlorine	2.5000	76.250
Sulphuric Ether Vapour	2,5860	78.870
Nitrous Acid	2.6380	80.480
Hydriodic Acid	4.3400	132.37
Oil of Turpentine Vapour	5.0130	152.90
Iodine Vapour	8.6110	262.635

Measures, particularly the larger ones, should be graduated on two sides at least, for when the scale is applied to one side only, the level of the fluid may be accurately at a certain mark on that side, yet the vessel not being based equably, or not being held steadily, the surface of the liquid at another side may be either lower or higher than at that to which the scale is applied, and consequently the apparent quantity may be either greater or less than the real; but if the vessel be graduated at two or at three sides, by making the surface of the liquid correspond to the same points on each scale, all possibility of error is removed.

With regard to the operation itself of measuring, very few directions are necessary; the best mode of ascertaining the volume of a solid is to drop it into a graduated glass vessel containing a fluid, in which it is not soluble, and the volume of fluid which is displaced gives at once the volume of the solid; for fluids no remark is necessary, and all the minutiæ of the measurement of gases have been detailed in speaking of the mode of ascertaining their specific gravities.

The following comparative Tables of Measures may be found useful for reference; the French measures of length are given, in order to render more intelligible to the student, descriptions of apparatus in which these measures are frequently alluded to.

French Measures of Length reduced to English.

		English Inches.		Miles.	Fur.	Yds.	Feet	Inchs.
Millimetre	=	.03937						
Centimetre	=	.39371						
Decimetre	=	3.93710						
Metre	=	39.37100	=	0	0	1	0	3.7
Decametre	=	393.71000	=	0	0	10	2	9.7
Hecatometre	=	3937.10000	=	0	0	109	1	1
Kilometre	=	39371.0000	=	0	4	213	1	10.2
Myriametre	=	393710.0000	=	6	1	156	0	6

Measures of Capacity reduced to English.

		Cubic Inches.			
Millilitre	=	.061028	=	16.3 Mims. or 15.6 grs.	Apothecary's Measure.
Centilitre	=	.610280	=	2.705 fl. drachms.	
Decilitre	=	6·102800	=	3.381 fl. ounces.	
Litre	=	61.028000	=	2.113 pints.	
Decalitre	=	610.280000	=	2.642 gallons.	
Hecatolitre	=	6102.8000	=	22.01 gallons	Imperial Measure.
Kilolitre	=	61028.000	=	27.51 bushels	
Myrialitre	=	610280.000	=	34.39 quarters	

Litre.		Eng. Cubic inch.		Im. Pints.		Wine Pts.		Oz. Troy of Water.
1	=	61.028	=	1.7608	=	2.1135	=	31.104
2	=	122.056	=	3.5216	=	4.2270	=	62.208
3	=	183.084	=	5.2822	=	6.3405	=	96.312
4	=	244.112	=	7.0430	=	8.4541	=	128.416
5	=	305.140	=	8.8038	=	10.5676	=	160.520
6	=	366.168	=	10.5646	=	12.6811	=	192.624
7	=	427.196	=	12.3253	=	14.7947	=	224.728
8	=	488.224	=	14.0861	=	16.9082	=	256.832
9	=	549.252	=	15.8469	=	19.0217	=	288.936

CHAP. II.

Operations by which Bodies are mechanically divided.

THE operation termed pulverization, by which we reduce substances of a grosser bulk to finer particles, is always purely mechanical: the mere act of pulverization never separating the elementary constituents of a body, but merely diminishing its aggregation.

The substances to be submitted to this operation are numerous, and of very different natures, and therefore they require very different manipulations in order to reduce them to powder. Some, as ores and other mineral substances, the black oxide of manganese used in the preparation of chlorine, for instance, many barks and roots, as cinchona, jalap, &c., when large quantities are operated on at once, are ground in mills of a peculiar construction; other bodies, which are not required to be so finely divided, are reduced to coarse powder by means of the rasp, as, for instance, the wood guiacum, and some metals; and others, which are only wanted in moderately small pieces, are cut or slit with the knife, as is the case with sarsaparilla, sassafras, &c. These latter modes of mechanically dividing bodies, grinding, rasping, cutting, do not require any particular notice; we will therefore pass to the most important of these operations, *pulverization* and its varieties.

The most practical division of pulverization is, into pulverization, as performed by means of the mortar, and pulverization as performed by means of other instruments than the mortar. The first of these genera will admit of three species, viz.

Pulverization by Contusion,
———— by Trituration,
Mediate Pulverization;

and the second of four, viz.

Pulverization by Friction,
Porphyrization,
Levigation,
Granulation.

We shall first consider generally the instrument by which the operations of the first genus are performed, and then the operations themselves.

Mortars are of different sizes and materials, according to the use for which they are designed; for rough purposes, as for the pulverization of hard bodies which require a considerable force to break them, as muriate of ammonia, large metallic mortars must be used. These instruments were usually made of brass, but now they are generally formed of cast iron, which renders them both much cheaper and better, as brass is a metal which should on no account be used in the construction of vessels assigned to pharmaceutical purposes. There should be at least two or three of these metallic mortars of different sizes; and there are now made in London, small ones of an exceedingly hard steel, which answer as well for powdering rare or hard substances, gems for instance, as those of agate or jaspar, and are much less easily frangible.

These mortars are only for powdering substances which are hard, and would require a degree of force sufficient to endanger an instrument of more brittle materials, but for bodies which do not require hard blows, or which would act on a metallic vessel, those of wedgewood-ware are more generally used.

These mortars are now made very bad; Faraday laments most pathetically the degeneracy of modern mortars, and thus describes the qualities which a good one should possess: "A good mortar should scarcely allow of being scratched by the edge of a piece of flint or quartz, and absolutely resist steel, not by any glaze on its surface, but on an accidental fracture, as well as on other parts; it should not be stained by having a strong acid solution of sulphate of copper, or of 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 a fine powder, the sand should acquire no appreciable increase of weight; it should be sufficiently thick at bottom to resist the blows to which it will at times be subject, as well as to give it weight and steadiness; and it should not be of brittle materials, and apt to shiver; though if unavoidable, that fault is more easily borne with than any other of those mentioned."*

This is certainly the *beau ideal* of a mortar, and I would congratulate any person happy enough to find an instrument possessing all these qualifications. The mortars I have generally met with were certainly not too fragile, but so far from resisting the friction of sea sand or quartz, an ounce of common green glass, when powdered, in them was sensibly increased in weight; and having at one time precipitated a quantity of prussian blue in one of those so called wedgewood-ware mortars, the precipitate incorporated itself so with the substance of the vessel, that I could not by any means cleanse it, though it discoloured every thing that was afterwards powdered in it.

The pestles to these mortars are generally made

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* Chemical Manipulation, p. 149.

of two pieces, the bottom being of stoneware and the handle of wood; this is a very bad way, the handle is fitted into the bottom with soft cement, which loosens if by any means the pestle becomes heated, and it is very inconvenient to be perpetually fastening it in; besides there is always some space between the wooden and the other part of the pestle into which dirt introduces itself, and occasionally falling out whilst the mortar is in use, dirties and renders impure the contents, a matter which might be productive of serious consequences.

For expediting the process of pulverization, it is useful that the surfaces of both pestle and mortar should be slightly rough; when the instrument is long in use this roughness is naturally produced, but if it be wished to produce it quickly, a little flint or emery rubbed to powder in it will do it sufficiently.

Glass mortars have not any superiority over those of wedgewood-ware, to entitle them to a preference, there are very few substances which act on the latter, which do not act equally on the former; those of glass are much too soft for pulverizing many bodies, and are too brittle for general pharmaceutical use.

When the substance to be operated on is light and easily dispersable, or when it may produce any bad effect by coming in contact with the operator, it is prudent to cover the mortar with such a material as may prevent the powder from rising out of it; one way is to have a wooden cover fitted to the mortar and perforated to admit the pestle, but otherwise tight enough to prevent the finer particles from flying off; another is to tie closely round the mouth of the mortar and round the stalk of the pestle, a large piece of leather so pliable as to admit the free motion of the latter. A very pretty combination of the two modes has been invented by M. Gay, (Plate I. Fig. 9.) It is fitted to a mortar of iron with rather a broader flange than in general, and from which, at opposite sides, arise two long screws; the cover is of wood with an iron rim, having two ears which are perforated to allow of the passage of the screws attached to the mortar, to which the cover when on is tightly secured by nuts. The hole in the centre of this cover is pretty large, and to its rim is attached a piece of leather like a sleeve, the upper end of which is applied to the lower part of the handle of the pestle.*

Having thus shortly described the instrument by which the operations of the first genus are performed, we shall now rapidly notice these different operations.

1st Species.—*Pulverization by Contusion.*

"Contusion consists in putting the body which is to be reduced to powder, into a mortar, and striking it strongly with the pestle, in order to separate its parts; this mode is used for all those dense materials whose molecules adhere very strongly together and are not susceptible of being softened by heat."†

To this description of contusion little need be

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* Foy, Manuel de Pharmacie, page 522.

† Soubeiran, Manuel de Pharmacie, page 81.

added; it differs from trituration both in its end and in its manipulation.

The design of contusion is either to break large masses of hard bodies into smaller, and thus prepare them for the triturating action of the pestle, or to reduce substances, whether vegetable or mineral, to a coarse powder, which is better adapted to be acted on by solvents, than if either the fragments were larger or the powder finer; in the former case, the surface exposed to the action of the menstruum being too small, and in the latter, the powder (especially if it be vegetable) collecting into masses, and producing nearly the same result.

Contusion differs from the other varieties of pulverization in its manipulation. In it the pestle is carried down with force on the substance to be broken, without any rotatory motion; the degree of force differs according to the degree of brittleness of the body; if glass, or any equally brittle substance be employed, there should be scarcely any impetus given to the blôw, the pestle being allowed to drop almost merely by its own weight; in the case of the generality of earthy minerals, and some ores, weight and force must be added to the blow by an action of the hand, and when we operate on tough fibrous bodies, as muriate of ammonia, and some vegetable substances, the force of the blow must be increased by the strength of the arm, and continued even for some time after the descent of the pestle is stopped.

2d Species.—*Pulverization by Trituration.*

When it is the object not merely to reduce bodies to coarse particles, but to obtain them in the state of a very fine, or as it is commonly termed, an *impalpable* powder, we operate in a different manner from that before described, and this operation is termed trituration.

The bodies which are subjected to trituration require to have been previously reduced to a coarse powder by contusion, then having placed a moderate quantity of it in a mortar, we move the pestle in a rotatory manner, describing larger or smaller circles round the centre of the bottom of the mortar, and at the same time pressing strongly and equally upon it; a little well observed practice will better enable the operator to arrange the powder so as to act upon it with most effect, and to bring the coarse particles where they will be most exposed to the direct action of the pestle, than the most minute and detailed description; but the quantity of material used at once should be small, for when too large a quantity is employed, the coarser particles imbedding themselves in the fine powder, escape the action of the triturating surfaces.

All bodies which are pulverizable may be subjected to this operation; most of the fine powders used in medicine and pharmacy are thus procured, the peculiar nature of each substance demanding precautions which may better be adverted to when speaking of pulverization in general.

3d Species.—*Mediate Pulverization.*

There are many substances which, when submitted by themselves to the action of the pestle, cannot be reduced to powder, on account of some peculiarity inherent to the substance itself, therefore when the powder of such bodies is required, it is necessary to add some substance which may at the same time counteract this peculiarity, and not interfere with the action of the body if it be a medicine, nor alter its relations with other substances if it be required for chemical purposes.

In order therefore to fulfil these two indications, we must examine, seriatim, the most important of those bodies, and thus ascertain what are the substances the addition of which is best calculated to render them pulverizable.

There are some bodies (principally vegetables) which are so dry, so tenacious, and so membranous, as agaric, colocynth, &c., that by themselves they never could be reduced to powder; these bodies are best obtained in a fine powder as follows: take colocynth as an example—take one part of gum tragacanth and make with it mucilage in the usual way, then take eight parts of the pulp of colocynth and beat it up with the mucilage until they form an homogeneous paste; this is then to be dried, and can easily be reduced by mere trituration to a fine powder.

Some bodies resist pulverization from their elasticity, as for instance, camphor, which is rendered easily friable by the addition of a few drops of alcohol.

Many organic products form, when rubbed in the mortar, a kind of paste, and cannot be pulverized ; in some of these cases it is sufficient to operate at a low temperature, and the end will be attained, but in others it will be necessary to add some substance capable of diminishing this property : in the French Pharmacopœia, the pulp of the fruit of the *Epidendron Vanilla* is ordered to be powdered by being mixed with four times its weight of sugar, the powder thus obtained being capable of being sifted ; in cases where it is only wanted to prepare the substance for the action of some solvent, glass or clear sea sand being pulverized with it will answer very well, and not being acted on by the fluid, the substance is dissolved away pure from it, thus can resinous substances be prepared for solution in alcohol at any temperature.

There are many metals which on account of their ductility cannot be immediately pulverized, as gold, copper, &c, ; the best mode of powdering these substances is to take the metal in very thin laminæ, (in leaf, as it is termed) and having mixed it with honey or sugar to rub them up together until the metallic appearance nearly disappears, then to pour boiling water on the mass, which dissolving the honey, leaves the metal reduced to a very fine powder.*

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* In the same manner that the pulverization of gold leaf is facilitated by the addition of sugar, so is also the pulverization (minute mechanical division) of mercury facilitated by the addition of such substances as manna, chalk, sugar, lard, &c., for I

A very happy illustration of mediate pulverization, though not performed by the mortar, is the method of obtaining calomel in an impalpable powder, by condensing its vapour in a vessel filled with the vapour of water, which condenses at the same time. This method was originally proposed by Jewell, and has been much improved by Henry, junior, who uses the following apparatus. (Plate II. Fig. 1.) 1st. An earthenware retort luted, with the neck wide and short, is placed in a reverberatory furnace, and contains the calomel: 2d a glass retort placed over a chauffer, and containing water: 3d, a balloon receiver with three tubulures, one lateral, very large and very short, which receives the neck of the earthenware retort; the second lateral, placed opposite the first, and which gives passage to the

cannot help requiring better proof than has been as yet brought forward of the existence of oxide of mercury in these preparations; the weight of evidence is certainly against it.

That there does not exist any protoxide of mercury in blue pill or in the powder of mercury with chalk, or with magnesia, I have repeatedly satisfied myself by experiment, and Guibourt has disproved its presence in the best mercurial ointment prepared by trituration: however high authority ranks on the other side—Dr. Montgomery (" Remarks upon the Pharmacopœia") says, when speaking of mercurial pill, "that this change (the conversion into black oxide) does take place to a certain extent, appears most probable," &c.—" for mercury in its metallic state is without action on the living system."—Certainly a person may swallow a quantity of the metal without fatal results being produced, but in what state does the mercury exist in those vapours which produce such dreadful affections in gilders and others?—certainly not as an oxide.

neck of the glass retort; the third tubulure, of a large diameter is situated inferiorly, and it is destined to conduct into a bottle which receives it, the calomel and the water which condenses in the receiver. It is well, in order to prevent the calomel from condensing in the neck of the retort, to introduce some fuel into the dome of the furnace so as to keep the upper part of the retort always very warm.

We now come to consider the species of pulverization performed by means of other instruments than the mortar.

1st Species.—*Of Pulverization by Friction.*

This is a mode of pulverization but little practised; in fact all the bodies generally reduced to powder in this way are capable of pulverization by trituration. It is applied to substances such as cerussa, magnesia, chalk, &c., which are very soft and friable, and which when placed on a sieve, instead of passing through the pores, fill up and obstruct them. In order to obtain these substances in an equally fine powder, we take a lump of one of them, magnesia for instance, and we rub it on a wire sieve over a sheet of paper, the friable substance is thus pushed through the sieve by the friction of the mass behind, and a powder is obtained which does not contain any little unequal particles with which it would always be mixed if it were obtained by trituration.

2d Species.—*Of Porphyrization.*

This operation is so termed from the material of which the apparatus used is most generally made; in it the substances are submitted to the triturating action of two surfaces, one a perfect plane, and the other a concave segment of a very large sphere, the latter surface is the base of a cone, termed the muller, which is applied with a kind of rotatory motion to the other, the *plane* surface of a large *slab* of the same materials.

The same general rule mentioned for trituration, applies also to this operation, viz. that the substances should be previously reduced to a coarse powder.

3d Species.—*Of Levigation.*

There are some substances which are naturally presented to us in a state of very fine powder, but mixed with other bodies less minutely divided, which therefore it is only necessary to separate in order to have the substance we want pure.* This is performed by levigation, and the whole description of the process is contained in the following directions for preparing chalk.

"In an earthen-ware mortar, with the addition of a little water, let it be triturated to powder, and

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* In the abstract this operation is one of separation and not of division, and therefore might more properly be spoken of in the next chapter than in this, but as most authors have classed it with pulverization, we were unwilling to deviate from their example. It will be again mentioned as a mode of mechanical separation.

by stirring it let this be mixed with a sufficiently large quantity of water, then after a short delay for the purpose of letting the coarse parts to subside, pour off the liquor; this operation is to be frequently repeated; the very subtile powder which has fallen down in the effused liquor is to be collected and dried on a bibulous stone, or on paper."*

This mode it is evident is only applicable to bodies which are not acted on by water, and which are mechanically mixed with substances in a coarser state of division, as chalk, which contains particles of silica and of alumina, (the latter earth however is not gotten rid of by those means); and many metallic substances, as sulphuret of antimony, &c.

4th Species.—*Of Granulation.*

This mode of mechanical division need merely be adverted to; it is applied in pharmacy only to the division of some metals, as for instance, tin or zinc may be reduced to powder, by being melted and shook until cold, in a box lined with chalk; in this way phosphorus is divided by being agitated and melted in water, or better in alcohol; and manufacturers of mordants divide tin so as to expose a great surface of the metal to the action of the acid, by, as they term it, *feathering, i. e.* the metal, when poured in small drops very hot from some height into a vessel of water, spreads out, in solidifying, into beautiful arborizations of an extreme tenuity.

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* Dublin Pharmacopœia. Translated by Drs. Barker and Montgomery.

Of mechanical Division in General.

Having thus described each of the varieties of mechanical division, we shall now consider the operation generally, with reference to its uses, and to the peculiarities of the different substances which are subjected to it.

The uses of mechanical division are of two kinds; first, of facilitating chemical action, and secondly, of rendering more convenient the administration, and often increasing the medicinal energy of a substance; of the first use it is needless to adduce any examples, as almost every process in the pharmacopœia affords instances of it; the second is not of less frequent occurrence; in the application of solid irritating substances, as cantharides or tartar emetic, to the skin, the degree of effect produced depends on the degree of mechanical division of the substance used, and in certain cases of intermittent fever, where the internal administration of the remedy is contra-indicated by the presence of permanent gastric irritation; sulphate of quinine being applied in the state of division in which it is generally met with, to a blistered surface, often fails in producing any effect, because being in coarse particles, it irritates the denuded skin so as to prevent its own absorption, whilst if this substance be reduced to a very fine powder by means of trituration with a little starch or loaf sugar, its application does not give rise to the slightest irritation, but it is absorbed and speedily produces its usual therapeutical effects.

It is self-evident that before a substance be powdered, it should be carefully dried : with respect to inorganic bodies which are acted on but by few of the common physical agents, little care is required, but in preparing vegetables for pulverization, those directions given, when speaking of the drying of plants, should be strictly adhered to.

Many bodies before being submitted to pulverization require some previous preparation ; thus, most fibrous roots must be cut transversely into thin slices in order to divide the fibres, that the powders may not be mixed with those unpulverized. The crab's stones of the Edinburgh Pharmacopœia require to be well washed in order to remove a mucous substance which coats them, and which appears to have been secreted by the membrane which originally invested them ; all silicious, and many other minerals, as sulphate of baryta, may be pulverized much more easily after having been made red hot and then suddenly plunged in cold water, the sudden cooling producing innumerable fissures in the stone, which thus becomes much more friable.

It is sometimes (particularly in warm weather) very difficult to obtain substances containing resin, as aloes, scammony, ammoniac, &c., in very fine powder, the particles adhering both to each other, and to the mortar, and thus preventing their more minute division. There are two ways of remedying this, first by using only a small quantity of materials at a time, and by operating in cold weather, and secondly, by rubbing the bottom of the mortar and the pestle with a little oil ; this last answers perfectly, but is objectionable, because after a short time the oil mixed with the resinous substance becoming rancid, communicates to it a very disagreeable odour.

The weight of the powder obtained is never equal to the weight of the dry substance used, for, 1st, a quantity of the finest powder is always driven away by the manipulation; and 2nd, a quantity of inert woody fibre always remains after powdering vegetables; the loss from the former cause is in proportion to the skill with which the process has been conducted, that from the latter varies according to the nature of the substance used. The following table, abridged from that given by MM. Henry and Guibourt,* contains the quantity of powder got from 1000 parts of each article.

Aloës	960	Hemlock leaves	800
Angustura, true	825	Henbane leaves	530
Antimony, sulphuret	950	Ipecacuanha	750
Arsenic, white oxide	950	Jalap root	940
Belladonna leaves	785	Nux vomica	850
Calamus aromaticus	840	Opium	930
Castor	900	Rhubarb	920
Catechu	900	Rhatany	850
Cantharides	850	Snake root	800
Cinchona, yellow	900	Squill bulb	820
——— pale	875	Simarouba bark	900
——— red	380	Savine	800
Cinnamon	890	Senna leaves	720
Colocynth	500	Sabadilla fruit	900
Colombo	900	Scammony	915
Digitalis leaves	790	Tin	825
Gentian root	850	Tragacanth	940
Gum arabic	925	Valerian	860

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* Pharmacopée Raisoneé. Paris, 1828.

When the substance to be powdered is composed of parts, heterogeneous, and of different degrees of friability, we can often obtain a powder superior in medicinal power to the original substance, by separating the active from the inert portion. If the active principle be with difficulty pulverizable, as is the case in the barks of the cinchona lancifolia and cascarilla, the first products of pulverization, which consist almost entirely of woody and fibrous parts, should be rejected, whilst, if the active portion be the most easily reduced to powder, the latter products are to be separated from it; thus are circumstanced all the fibrous roots and the fibrous parts of the leaves and stems of plants; the residuum which they leave being totally inert, is to be rejected. Ginger is a good instance of this class, and hippo also, but this latter should be subjected to a peculiar process; it should be bruised in a mortar, and the dark cortical layer removed and pulverized alone, the white ligneous meditullium being totally useless.

No matter how carefully substances are pulverized, there exists, always mixed with the fine powder, a quantity of coarse material, which it is necessary to separate from it. The mode of effecting this, a species of mechanical separation, shall be hereafter described.

CHAP. III.

Of those Operations by which Bodies are mechanically separated.

The operations by which bodies are mechanically separated from each other, may be divided into three classes: the first, containing those by which solids are separated from solids; the second, those by which solids are separated from fluids, and the third, those by which different fluids are separated from each other.

Belonging to the first class there are two processes; one, in which the finer parts of a solid, unacted on by water, are separated from the coarser, by washing with that fluid. This is termed *elutriation*, and has been already noticed as a mode of mechanical division. The second is that by which the finer particles are separated by means of a sieve, through the interstices of which they pass, leaving the coarser parts behind.

Sieves are made of various materials, as silk, wire, linen, or woollen cloth, hair, &c. The common sieve consists merely of a frame, round the margin of which the sifting material is attached. In pharmacy, however, in order to prevent loss of product, and to avoid the inconvenient effects of irritating substances upon the operator, compound sieves are used.

The compound sieve consists of a common sieve, to which is fitted a lid covered with leather, and a receiver, the bottom of which also is generally made of leather: the lower edge of the body of the sieve fits into the receiver, and the upper edge into the lid, so tight as to prevent the escape of the finer particles of the substance operated on.

In sifting, the sieve is generally subjected to a gentle rotatory motion; sometimes the side of it is struck slightly against a hard body; but this last action forces through its pores particles much larger than would otherwise pass.

In some processes in the arts, the sifting material is formed into a cylinder, in which is contained the substance to be sifted; the cylinder is then made to revolve rapidly on its axis, and the finer powder escapes through the pores of the sieve.

There are various modes of separating fluid from solid bodies.

When the solid is specifically heavier than the fluid, advantage is taken of that circumstance to separate them. This is done, by allowing the mixture to remain at rest for some time, when the powder falls to the bottom, and the fluid may be poured off, or *decanted*, as it is termed.

This process is named by writers *deposition*, when it is performed for the sake of the solid, and *defæcation*, when our object is the purification of the fluid; it is obvious, that the greater the difference between the specific gravities of the two bodies, the shorter is the space of time required for *deposition*, and the more perfect is the process. Thus sulphate of baryta, or chloride of silver, will subside in much less time than is required for the separation of magnesia or its carbonate from a liquid, and where there is but little difference between the relative gravities of the fluid and of the solid body, the process is scarcely, if at all, admissible.

The shape of the vessel also in which the operation is conducted, influences very powerfully its success. The common jars, which are generally narrower at their bottom than at their top, are not proper for it, as they do not admit of the fluid being poured off without disturbing the residue.

This inconvenience may be in a great degree obviated by using Phillips's precipitating jars, which are conical, and thus allow almost all the fluid to be decanted with very little agitation of the solid body.

In many instances, instead of decanting the fluid, other means of removing it are resorted to; if it be in small quantity, it may be conveniently removed by means of the common sucking tube, or pipette (an instrument so familiar to every one that a description of it is unnecessary;) if the quantity be larger, the siphon is generally employed for that purpose.

This instrument consists of a curved tube, of which one leg is longer than the other, the tube being filled with a liquid, the shorter leg is placed in the fluid which is to be drawn off. The liquid immediately commences to flow up the shorter leg, and down the longer, until the fluid in the receiver attains the same level with that into which the shorter leg is immersed.

To comprehend the principle upon which the siphon acts, let us suppose the water at the point B, (Fig. 2. Plate II.,) acted upon by two pressures, one towards C, and the other towards D. It will move in the one direction or in the other, according as the one or the other pressure prevails. The atmospheric pressure acting on the surface D, supports the column in the siphon between the surface and the point B, and it presses the water at B towards C, with a pressure equal to the amount by which the atmospheric pressure exceeds the weight of the column D B, which it sustains in the siphon. The atmospheric pressure also acts on the mouth C of the siphon, and is resisted by the weight of the column C B; it exerts a pressure on the water at B, amounting to the excess of the atmospheric pressure above the weight of the column C B. Thus it appears that the water at B is urged towards C by a force equal to that pressure by which the atmospheric pressure exceeds the weight of the water in B D, and this is resisted by a force equal to that by which the same atmospheric pressure exceeds the weight of the water in C B. Now since the atmospheric pressure exceeds the weight of the water in D B by a greater quantity than it exceeds the weight of the water in B C, it follows that B will be urged towards C with a greater force than it is urged toward D, and therefore that it will move towards C. It is evident, that the excess of the force which urges it towards C above the force which urges it towards D, will be equal to the weight of the column of water C, which is contained in the longer leg of the siphon below the level of the water in the cistern D.

If the leg of the siphon terminate at D′, the forces which would act on the water at B would be equal, for the one would be the atmospheric pressure diminished by the weight of the water in B D, and the other would be the atmospheric pressure diminished by the weight of the water in B D′, but the weight of the water in B D and B D′, being equal, the forces which act upon the water at B will also be equal, therefore no water will flow from the siphon.

If the leg of the siphon terminate above D′ as at E, then the pressure on the water at B, the siphon being supposed to be filled, will be greater in the direction at B D than in the direction at B C, and therefore the water will flow back again into the cistern, and the siphon will be useless.*

In practice the compound is much more easily used than the simple siphon. This consists of a common siphon, near the extremity of the longer leg of which a tube is adapted, that, mounting along it, terminates in an open mouth, by means of which we exhaust the air from the siphon by suction. The opening of this tube into the longer leg must be below the level of the fluid to be drawn off, to insure which object it is generally placed below the level of the shorter leg.

When the fluid is contained in a vessel with a narrow opening, the siphon of Bunter may be used with advantage to remove it. This is a common siphon, on the longer leg of which, near the top, is blown a ball. To use it, we fill the longer leg and the ball with a fluid, and we immerse the shorter leg

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* Cabinet Cyclopedia, vol. 17, Hydrostatics and Pneumatics, by Dr. Lardner, page 328.

in the vessel. The fluid descending from the ball, and the longer leg, by its own weight, carries up after it the liquid in contact with the shorter leg, and the current is maintained, although the ball may be partially empty.

Very often the solid particles differ too little in specific gravity from the fluid to admit of their separation by *deposition.* In this case we have recourse to filtration, and the apparatus which we use is termed a filter.

A filter should be of a material totally unacted upon by the fluid to be passed through it, and the diameter of its pores should be directly as the viscosity of the fluid.

Many substances may be used as filters; woollen or linen cloths, paper, glass or sand and charcoal.

Flannel filters are more usually employed to depurate sirups and expressed juices of vegetables. They are generally made of a square piece of flannel, fixed at its angles to a wooden frame. Generally the first portions of liquid which pass are turbid, and require to be poured back; but as the fibres swell by imbibing the fluid, the diameter of the pores diminishes, and the fluid passes nearly clear.

Linen filters are of a closer texture than those of flannel, and are applicable to the filtration of many substances, as basic salts, which would act upon a woollen filter. In the arts, linen filters serve to collect precipitates, which in the smaller laboratory are separated by paper. They are generally fixed upon a frame in the same manner as those of flannel. The material most employed, however, by the experimental pharmaceutist is paper, the kind of which varies with the design of the operation.

Where the object is to separate a fluid from a material insoluble in it, the quantity of which does not require to be determined, the common filtering paper is the most applicable ; but from its thickness it retains so much of the powder that its use must be given up when we have to ascertain the quantity of the latter. In this case I have found the common tissue paper to form the most useful filter, as its pores are so fine that it does not allow any of the solid material to penetrate its texture (except in some very few instances) and its surface is so smooth, that when dry it allows all the powder to be removed with the smallest possible loss. There are however two things which require notice; from its delicacy it requires to be incased in another filter of stronger materials, and from the fineness of its pores the process is necessarily prolonged.

Paper filters are of two sorts, the plain and the folded. The first is made simply by folding the paper twice in opposite directions, so as to bring the four corners together, and then opening one corner from the other three, so as to produce a conical cavity. This filter is very easily formed, but has two disadvantages. Its surface being smooth adheres in every place to the funnel, and one side being three times as thick as the other renders the strength of the filter very unequal.

Many contrivances have been made to obviate the obstruction to the passage of the fluid caused by the close contact of the sides of the simple filter with the funnel, such as interposing glass rods or straws between them, so as to give a passage to the air, and by using ribbed funnels. This end is however attained much more readily, and at the same time the strength of the filter rendered equal, by using the folded in place of the simple filter.

To make the folded filter, the paper is first doubled, and then again folded into halves; these into quarters, and these again into eighths. The folds being all upon the same side, each eighth is now to be folded into sixteenths, in the opposite direction, but the folds all radiating from the centre to the circumference; the doubled piece then resembles a child's fan; and when opened, and the projecting corners cut off, it will be found, that the paper is equally divided into parts, forming alternate external, and internal angles, except in two opposite places, where two external angles meet. The paper here should be folded down, so as to form internal angles, and being opened sufficiently, and the bottom brought into proper shape, is to be dropped into the funnel.

In making this filter, the folds should not be continued entirely to the apex, because, by the repeated folding, that place would be perhaps broken, or at least considerably weakened. In a well made filter the bottom is rounded and smooth, and the folds commencing about $\frac{3}{4}$ of an inch above it proceed regularly and acutely to the edge. The paper between the folds should not be wrinkled nor softened by handling in the making.

The advantage of these filters is, that they allow the fluid to percolate through every part of the paper, and consequently filter much more rapidly than a plain filter of an equal size; but where we want to collect the solid matter, they are inapplicable, as the powder is spread unequally over a large surface, whence it can with difficulty be collected. In the plain filter we have it contained in a much smaller space, and can remove it with much less loss.

When we fear lest the filter should give way, under the weight of the material in it, it is proper to place a smaller filter under the bottom of the larger one, and the vessel into which the fluid filters should be of such a size, that in case the filter should burst, none of its contents would be lost by the accident.

A very convenient mode of filtration is that proposed by Hauÿ in his letter to Berzelius.*

Plate II. fig. 3. represents two glass vessels, of which the superior, A, inverted in the funnel, contains the liquor to be filtered, whilst the second, B, receives what percolates through the filter. In the funnel the level remains nearly at the line, *m, n;* the air enters into the bottle A, according as the level in descending leaves its orifice open.

Nothing is more easy than to dispose the apparatus as the figure indicates. Place the filter in the funnel, and attach it by a few drops of water; stop the mouth of the vessel A, containing the liquor to be filtered, by a cork attached to a bit of wire; invert it in the filter, and then withdraw the cork; the fluid gushes out until it attains its level, and thence the filtration proceeds with regularity.

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* Annales de Chimie, Mars, 1831.

In the same way any sized apparatus can be used. To filter large quantities of a fluid, two large sized bottles are placed one above the other, (Plate II. Fig. 4.) a tube of about ¼ inch in diameter is tightly passed through a cork, after which the vessel A is filled; the operation goes on then as in the former instance. When the process is long continued, it becomes necessary to fit a cover to the filter; for this purpose, a simple piece of tin plate, which slides up and down on the tube C, may be employed. The edges of the cover are a little turned down, to make it fit closer to the rim of the funnel D.

The advantage of this apparatus is, that a powder dispersed through a large quantity of fluid can be collected upon a small filter with very little loss; the process goes on of itself, and does not require any attention; the whole apparatus can be placed in a stove, and thus saturated solutions can be filtered while hot, without any danger of crystallization.

Concentrated acids are generally filtered through powdered glass or quartzose sand. A fragment of glass is first dropped into the tube of the funnel, and over it several smaller pieces; we cover them with successive layers of the same material, more and more finely divided, until the upper surface is composed of a nearly impalpable powder. The filter thus prepared is then washed with diluted muriatic acid to remove all adherent particles of earthy matter, and then the last traces of the acid are washed away by distilled water.

On the filter thus prepared we pour the acid; it deposits in the interstices of the sand or glass all the matters which disturbed its transparency, and flows out transparent from the tube of the funnel.

Filters of powdered charcoal are very frequently employed; the action of this separating agent is, however, not merely mechanical; it appears to exert a certain chemical agency in combining with certain colouring and odorous principles, and separating them from the fluid which was contaminated by their presence.

Most charcoals acquire this property by being heated in close vessels, but by no means all in the same degree. That brilliant form of charcoal obtained from substances which fuse before charring, does not at all possess it, no matter how finely pulverized it may be, and common wood charcoal acts but with very feeble energy.

The most active of all charcoals is that which we obtain by carbonizing an animal matter, as dried blood, hair hoofs, &c., with carbonate of potash, which prevents its fusion, and gives the greatest possible degree of mechanical division to the resulting charcoal. The carbonate of potash is washed away from the mass by water, and the charcoal dried for use.

Another form of carbon of great power is ivory black, obtained by charring bones: here the phosphate of lime effects the minute division of the charcoal, as the carbonate of potash did in a former instance. The carbon is here, however, diluted with a quantity of inert saline matter, which cannot be removed by water, and if we use muriatic acid, the decolorizing power of the product is considerably impaired.

It has not been as yet perfectly made out what colouring matters are and what are not destroyed by animal charcoal. As far as is at present known, it appears to act merely upon compounds of organic origin, such as the colouring matters of cochineal, litmus, logwood and indigo dissolved in sulphuric acid, the colouring matter of red wine, of unrefined sugar, the fœtid effluvia of putrefying matter, and many volatile and empyreumatic oils, as that which exists in spirit obtained from grain.

To separate these bodies from the fluid which held them in solution, the liquor is mixed with the animal charcoal, and left in contact with it for some time. The whole being then thrown upon a filter, the fluid passes colourless; sometimes it is necessary to boil the charcoal with the fluid. Charcoal loses this property of decolorizing by use; it becomes saturated with the colouring matter, and will not then combine with any more. Simple ignition does not then restore this property, but if it be mixed with a chemical agent capable of preventing the fusion of the combined colouring matter, it then becomes energetic as before.

This process is extensively used in France for refining the sugar obtained from the root of the red beet. It was not however admissible in pharmaceutic operations (the sirup acquiring a slightly disagreeable taste from the solution of the salts contained in the charcoal) until Dumont, by the invention of his filter* brought the process to perfection, and enabled us to obtain from raw sugar sirups of an admirable limpidity and purity of taste.

He first prepares the charcoal by granulating it like gunpowder, and carefully separating it from the dust. The size of the grains varies according to the density of the sirup to be decoloured ; the greater the specific gravity of the fluid the larger are the grains of charcoal.

The filter is in the form of an inverted truncated pyramid of wood lined inside by tinned copper ; at the bottom is a cock for the discharge of the filtered sirup, and a little above it, an opening communicating with a tube applied to the exterior of the vessel, and serving for the evacuation of the air contained in the apparatus. The filter is furnished with two diaphragms of different sizes, made of tinned copper. When we wish to use the apparatus, we place the smaller diaphragm, sustained on four feet, at the bottom of the filter, above the cock, and the opening of the air tube ; on this we lay a coarse cloth, on which is placed the charcoal, previously moistened with the sixth of its weight of water ; we flatten the surface of the charcoal by means of another cloth and of the second diaphragm, and we pour the sirup into the empty part of the filter. By this disposition the charcoal does not be disturbed by the affusion of the sirup, which percolates slowly, but equally, through every part of the filter. In passing through the layers of charcoal the sirup displaces the water with which the for-

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* Journal de Pharmacie, October, 1829.

mer had been moistened, and forces it to flow out through the cock : this is put aside until it is replaced by the sirup, which then flows in a continued stream, which may be kept up by fresh additions.

If the charcoal was not previously moistened, the sirup would not be equally imbibed : it would pass more readily through one part of the mass than another, and the filtration would not proceed regularly. The water also removes the soluble impurities of the charcoal, as is found by its disagreeable taste, on passing out of the filter.

In the experiments of the reporters on this instrument, a solution of dark beet sugar was filtered, and the product having been divided into three parts, the first was perfectly colourless, the second was as clear as a solution of common loaf sugar, and the third was a little coloured. The whole having been mixed, was as clear as a solution of the best clayed sugar, was free from any disagreeable taste, and was fit for all domestic and pharmaceutical purposes.

Many fluids would be injured by exposure to the air whilst filtering, as for example, solutions of potash, baryta or lime ; others being easily volatile, a quantity would be lost by evaporation if the operation was performed in open vessels, as tinctures, water of ammonia, &c. ; for the filtration of such products, Mr. Donovan invented a very simple and useful apparatus : we place the fluid to be filtered in the upper vessel, A, (Plate II. Fig. 5.,) the beak of which is stopped by a morsel of linen cloth, loosely rolled; the beak of A is introduced into the neck of the lower vessel D, into which it fits by grinding; we then fit on the tube C, and the filtration proceeds without the access of any more air than that contained in the two vessels and the connecting tube. If we wish to filter an acid we replace the linen cloth by a sand or glass filter as before described.*

M. Riouffe has considerably improved this apparatus.† The tube, G, (Plate II. Fig. 5.) is for supplying the liquor to be filtered without dismounting the apparatus, and the opening, E, allows of the exit of the corresponding volume of air. The cock, K, admits of the discharge of the filtered liquor, and being situated a few lines above the bottom of the vessel, does not disturb those deposits which, in many instances, form after filtration.

Very often, when the quantity of fluid bears but a small proportion tō the solid matter, we are obliged to use mechanical force to effect their separation; the operation is then termed *expression.*

Expression is most generally performed for sake of the fluid product, as in the preparation of the expressed juices of plants; occasionally it is used to force the water from spongy precipitates, and in the preparation of elaterium, to separate the active solid material from the inert juice.

The instruments by means of which expression is performed are of different kinds, according to the degree of force required to be exerted: in some in-

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* Dublin Philosophical Journal, vol. i. p. 75.

† Journal de Pharmacie, 1826, page 12.

stances, as in the expression of the juice from grapes, lemons, &c., the pressure of the hand is sufficient: in others, as in the obtention of the expressed juices of herbs, as of conium, belladonna, &c., the material is subjected to the gradually augmented pressure of a screw press, the plates of which are generally of wood, occasionally of iron: a still greater degree of force is given by the use of Ruthven's excentric wheel press, or by the hydrostatic press invented by Bramah: a detailed description of these instruments is not necessary.

An instrument founded upon the same principle as the hydrostatic press (*viz.* that fluids press equally in all directions, and that the amount of pressure is equal to the perpendicular height of the column of fluid multiplied into the area of its base) has been proposed by Count Real for the more perfect extraction of those principles of vegetables which are soluble in water. He terms it a filter-press. It consists of a tin box, in which is contained the vegetable matter, either cut into small pieces, or in coarse powder: from the top of the box ascends a perpendicular tube to the height of 50 or 60 feet, the communication of which with the box may be cut off by means of a stop-cock. The bottom of the box is pierced with a number of very minute holes, and under it is placed a vessel to receive the liquid. The perpendicular tube is filled with water, which pressing upon the vegetable matter with all its weight, penetrates it every where, and goes out through the perforated bottom highly charged with all the soluble principles. This instrument has been rendered more convenient by substituting for the column of water, one of mercury, which pressing upon the water intended as a solvent, gives the same amount of pressure with a much less height of tube.[*]

A similar mode of forcible expression is that of Romershausen,[†] who, instead of making artificial pressure above the vegetable substance, economizes the atmospheric pressure by forming a vacuum below it.

Authorities differ as to the practical value of these instruments; Virey[‡] bears testimony to the great excellence of extracts prepared by the evaporation of the juices thus expressed; while the learned Duncan[§] considers, that "in practice both these modes of forcible expression have disappointed the expectations of their authors."

The juices obtained from vegetables by means of expression are of two kinds, the *watery* and the *oily*.

With regard to the preparation of the watery juices of plants, as the quantity of juice varies very much, being abundant in some, it exists in but small quantity in others, in some embarrassed by the coexistence of mucilage, in others, impacted in the network of a dense cellular tissue; it is evident that the rules for the expression of watery juices must differ according to their composition and quantity.

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[*] Virey, Traité de Pharmacie, vol. 1. page 117.

[†] Buchner Repertorium für die Pharmacie, Band. xiii 375.

[‡] Traité de Pharmacie, vol. i. 117.

[§] Supplement to Dispensatory, p. 151.

In general, 1st, If the plants are very succulent it is sufficient to cleanse and cut them in small pieces, to beat them in a mortar, and then submit them to the press.

2d, If the plants are but slightly succulent, or if they are mucilaginous, they might be beaten up with a little water; in the first instance the water serves to wash the vegetable fibre, and to dissolve the juice which it retains; in the second, it dilutes the mucilage and facilitates the exit of the juice.

3d, Some juices are improved by being kept for some time before expression; others, as those of oranges and lemons, should be allowed to ferment after having been expressed; the last named fruits should be peeled before being expressed, to prevent the admixture of their acrid essential oil with the acid juice.

The composition of vegetable watery juices is very complex. Besides the principles on which the activity of the plant immediately depends, they not only contain salts, vegetable acids, gum and chlorophile, but also sugar, albumen, and other matters which tend to promote fermentation. On this account they are never used just as they are obtained; they are purified, sometimes by deposition, sometimes by filtration, and occasionally by clarification, a process to be hereafter described.

The oily juices of plants, or *the expressed oils,* as they are more properly termed, form a numerous and important class of vegetable products: closely allied, in some respects, to the volatile or essential oils, they in many circumstances differ widely from them: their principal characters may be given as follows:

1*st, Source.* All contained in the cotelydons of the seed, except the olive oil, which is contained in the fleshy pericarp or drupe.

2nd, Physical characters. Specific gravity less than that of water. Taste mild, generally sweetish. Odour nearly null.

3rd, Chemical characters. Insoluble in water and in alcohol, except the oil of the ricinus communis. Decomposed by contact with certain bases or saponafiable.*

4th, Composition. Stearine and Elain.

5th, Medicinal characters. Very feeble.

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* When we heat a fat or a fixed oil with a solution of a base, as potash, soda, or oxide of lead; both constituents of the oily matter, together with a quantity of the water of solution, are decomposed, and four new compounds generated, to wit, margaric, oleic and stearic acids, which unite with the base, and form salts soluble in water, (the aggregate of which constitutes soap,) and a fourth, glycerine, which is soluble in water, of a very sweet taste, and cannot be obtained solid.

The acids may be obtained from soap if we abstract the base by means of a stronger acid, (Chevreul uses the phosphoric or tartaric,) when being insoluble in water they are precipitated, and may afterwards be separated from each other. That the four bodies are formed by the action of the base, and that water is necessary to their formation, is proved by the fact that the sum of the weights of the three acids and of the glycerine, is much greater than the weight of the oily material employed.

Some non-volatile oily substances, however, are not saponafiable. When wax is acted upon by an alkali, and the compound decomposed by an acid, the wax reappears unchanged. The

Though expression is the mode by which these oils are all obtained, yet as the preliminary operations differ in each case, it may be worth noticing the method of obtaining some of the more important.

Castor Oil. There are two modes of preparing this oil; 1st, by decoction, 2nd, by expression.

To prepare it according to the first method, the seeds are first roasted gently; they are then beaten in a mortar with water into a paste, more water is then added, and the mixture is boiled, being kept carefully stirred until all the oil comes to the surface, when it is strained off through flannel.

The oil thus prepared is perfectly mild, and destitute of acrimony, of a very slight odour and a fine pale colour; being separated from all the mucilage of the seeds, it does not grow rancid so soon as the oil prepared by expression.

To express the oil from the seeds, these last are spread out on a table, and struck lightly with a small wooden mallet so as to break the coloured envelope (testa) without injuring the cotelydons; they are then carefully deprived of their integument, and enclosed in a strong cloth folded like a letter, and placed between the plates of a screw press. The impure oil thus obtained is filtered through paper; it passes clear, colourless, and of a very mild taste. It how-

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oily matter which exists in the blood, and in many pathological products, that which forms the basis of the nervous tissue (Cerebrine of Vauquelin, phosphuretted fats of Denis and of Fourcroy) acts in a similar manner.

ever still retains a little mucilage, which renders it more liable to rancidity, and the process of filtering it through paper is exceedingly slow.*

The drastic oil of the croton tiglium is prepared, according to Dr. Nimmo, by digesting the bruised seeds for a certain length of time, and then throwing the whole upon a filter, which should be closely covered during the process. The residuum should be washed with a little ether to remove the last portions of the oil which may then be recovered by spontaneous evaporation.

In the olive the oil is contained not in the cotelydons but in the parenchyme of the drupe, whence it is obtained in the following manner: In Provence and Italy, the fruit is gathered when at its utmost maturity, in November, when it begins to redden; being first put under the mill as soon as gathered, taking care that the mill stones are set at such a distance that they do not crush the nut of the olive. The pulp covering the nut or stone, and containing the oil in its cells, being thus prepared, is put into bags made of rushes and moderately pressed, and thus is obtained a considerable quantity of a greenish semi-transparent oil, which from its superior excellence is termed virgin oil; the marc remaining

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* The whole seeds are very irritating and drastic, while the expressed oil is mildly laxative. The reason is this: the irritating principle resides in the coloured envelope (testa) of the seed, and is volatile. In the first process it is all driven off by the previous roasting and the subsequent boiling; and in the mode, by expression, the seeds are deprived of their envelope previous to being subjected to the action of the press.

after the first pressure, is broken to pieces, moistened with water, and returned to the press, upon which there flows out a mixture of oil and water which spontaneously separates by rest; this oil, although inferior to the former, is of good quality and fit for the table. The marc being again broken into pieces, soaked in water, and fermented in large cisterns, is again submitted to the press, by which is obtained a third oil, that is valuable to manufacturers. In Spain, the olives instead of being gathered, are beaten down, so that the ripe and unripe ones are mixed; to these are added such as have fallen of themselves, and are therefore more or less decayed. All these are thrown together in a heap, and soon ferment. The olives in this state are ground and pressed, and thus is produced, with little trouble, a large quantity of an oil of a rank and disagreeable flavour.*

The following table contains the average quantity of oil obtained from one pound of the fresh vegetable substance:†

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* Stephenson and Churchill, Medical Botany, vol. i.

† Abridged from that given by Chevallier, Dictionaire des Drogues.

Names.	Part of Plant.	Mode of Obtention.	Quantity of Oil.	Authors.
Amygdalus Communis,	Seeds,	Cold expression,	℥vii ʒiv	Recluz.
Cocos Nucifera,	Do.	Do.	℥iv	Guibourt.
Croton Tiglium,	Do.	By Analysis,	℥viii ʒvi	Nimmo.
Euphorbia Lathyris,	Fruits,	Do.	℥vii gr. 23	Chevallier.
Fagus Sylvestris,	Seeds,	Do.	℥vi ʒiv	Recluz.
Linum Usitatissimum,	Do.	Do.	℥iii ʒi	Ebermeyer.
Olea Europea,	Fruit not Fermented,	Do.	℥iii ʒii	Recluz.
Do.	Do. Fermented	Ebullition,	℥iv gr. 35	Do.
Papaver Somniferum,	Seeds,	Cold expression,	℥iv	Do.
Ricinus Communis,	Entire Seeds,	Do.	ʒv ʒvi	Do.
Do.	Seeds without envelope,	Hot expression,	℥viii	Do.
Do.	Entire Seeds,	Do.	℥vii	Do.

NOTE.—The importance of the expressed oils in many pharmaceutical preparations demands some remark on the mode of ascertaining their degree of purity. The only ones liable to adulteration are those of the ricinus and of the olive.

Formerly the castor oil of commerce was much adulterated by admixture with other fixed oils, but since the discovery by Planche that castor oil is perfectly soluble in alcohol, the facility of detection has done away with the abuse.

The olive oil of commerce is frequently sophisticated with the cheaper expressed oils, as those of the poppy (papaver somniferum) and the rape, (brassica rapa.) There are three modes of detecting these adulterations.

1st. Pure olive oil freezes totally at the temperature of melting ice. If poppy oil be present even in small proportion, the solidification is not perfect, and when it amounts to one-third of the volume, no part of the oil freezes at that temperature.

2nd. A better mode is that proposed by Pontet, an apothecary at Marseilles. It is founded on the property possessed by olive oil, of solidifying completely when mixed with certain proportions of the acid nitrate of mercury, while the other expressed oils do not present a similar phenomenon. The nitrate is made by acting in the cold upon six parts of mercury by 7½ parts of nitric acid, sp. gr. 1,355.

To try the oil, twelve parts are mixed with one of the mercurial solution, and agitated for some time; after twenty-four hours the whole is completely solidified if the oil be pure. The presence of one-tenth of poppy oil is sufficient to prevent its acquiring a consistence greater than that of thin paste, and a greater quantity of adulteration has a still more powerful effect.

3rd. An instrument has been invented by M. Rousseau, for estimating the adulteration of olive oil, which is said by the French writers on Pharmacy to be of great sensibility; but it requires a nicety of manipulation in its use not generally possessed.

Its action depends on the property which olive oil possesses of conducting electricity but very imperfectly, whilst the other oils transmit it with great facility. It is termed a *Diagometer.*

The apparatus is composed of a cake of gumlac, A B, Plate II. Fig. 6. supported on a foot. In the centre of this cake is placed vertically a very fine metallic stem C, which supports a very slender needle, D E, weakly magnetized, and bearing at one extremity a small vertical disc. On the edge of the resinous cake is placed a metallic support, F, which communicates with the central stem by a metallic conductor lying horizontally, and from which arises another metallic stem, carrying at its summit, and on a level with the magnetic needle, another disc also vertical, and in the plane of the horizontal conductor. This entire apparatus is covered by a dry glass bell, on which is described on a level with the magnetic needle, a horizontal semi-circle divided into degrees.

To use this instrument we turn the resinous cake until (the needle being *in equilibrio*, and in the plane of the magnetic meridian) the disc E, which it bears at one of its extremities, comes nearly into contact with the disc H; the bell glass is then turned round until zero on the horizontal scale corresponds to the end D of the needle.

The instrument being thus arranged, a metallic cup, containing the oil to be examined, is placed on the support F; on the other hand we take a dry pile, I, which may or may not be permanently attached to the instrument, and we make a communication by means of a metallic wire between one of the poles of the pile and the surface of the oil in the cup. If the oil employed be any other than that of the olive, the electricity will pass from the oil to the cup, and thence to the needle, and consequently to the two discs, which being similarly electrified, and so exerting an action mutually repulsive, the moveable disc will retire to some distance from that which is fixed; this distance, which may be measured by the arc of the circle passed through, will depend on the force of the pile and the conducting power of the oil, and the phenomenon of repulsion will be produced at the instant that we apply the wire of the pile to the oil. If we employ pure olive oil for this experiment, no motion will be perceived in the needle, (unless the pile be very powerful, or the contact too long continued,) but when a drop of poppy oil is added, the magnetic needle deviates immediately in a perceptible degree, when the quantity of adulteration does not amount to one hundreth part of the oil.

Clarification is a mode of mechanical separation, in which, by the use of certain processes, those substances, which disturb the transparency and impair the purity of certain fluids, are rendered more easily separable by subsequent filtration or defæcation.

Liquids are clarified by means which vary according to their composition and the nature of their impurities. In some instances, as in that of honey, where the viscidity of the liquid is the only obstacle to its purification by simple filtration, a slight elevation of the temperature by means of a water bath, is sufficient to separate its particles to such a degree as to allow the heavier impurities to subside to the bottom, and those of a less specific gravity, as the wax, etc. to ascend to the surface of the melted honey, whence they can be easily removed.

The great clarifying agent, however, is the substance termed albumen, which is soluble in cold water, but becomes solid on the heat being raised to about 160° Fahrenheit, and after that is insoluble in water, whether hot or cold: this phenomenon is termed coagulation.*

Very often (as in the expressed vegetable juices) the liquid contains naturally a sufficient quantity of

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* From the general use of albumen in clarifying fluids, Henry junior, and other writers on pharmacy, substitute the term coagulation for clarification, in describing this process.

albumen to effect its own coagulation on applying heat. The coagulum in forming envelopes the impurities dispersed through the filter, and forms with them a mass from which the depurated juice is readily separated by filtration. When, however, albumen does not exist ready formed in the fluids, it must be added by the operator. In this case, animal albumen is used, derived either from the serum of the blood, or the white of eggs, the former being generally used in the extensive processes of the arts, the latter in the more delicate operations of pharmacy.

In some circumstances, particularly where the liquid contains a substance which would be injured by the application of heat, the albumen is coagulated, and the clarification effected by the addition of a small quantity of alcohol, or of an acid, as vinegar or cream of tartar. When these substances are employed, great caution should be used as to the quantity, as an excess of either would injure the properties of the product.

A mode of clarification frequently employed by the continental pharmaceutists is by fermentation. This process does not simply separate the impurities from the liquid mechanically, as the former method, but it restores the limpidity of the fluid, by decomposing and destroying them; so the vegetable juices subjected to this mode of clarification, acquire by the process physical and chemical properties, quite different from those which they before possessed, and probably their medicinal virtues are also affected in some degree. Thus, by the British

Pharmacopœias, the juice used in the preparation of the sirup of buckthorn is merely allowed to deposit its insoluble dregs, and is strained ; it is then of a dark greenish colour, which the sirup made from it retains while fresh. By the French, the expressed juice is left to clarify itself by fermentation, by means of which, along with the alcohol, a quantity of acetic acid is generated, which acting upon the colouring material of the juice (before green from the predominance of alcalinity) changes it to a fine crimson colour: the active ingredients of the juice no doubt also undergo some simultaneous and important changes.

Fluids can be separated from *fluids* only when there exists between them no disposition to combination, and when they are of different specific gravities, so that on being allowed to rest, the heavier of the two will sink to the bottom of the vessel, and the lighter remain upon the surface; they may then be easily separated.

There are many modes of effecting this process. The first, which is termed despumation or skimming, consists in removing the supernatant fluid with a ladle or spoon, or by a small syphon, taking care to close the mouth of the longer leg before the lower liquid ascends into the shorter.

A second mode is by using an instrument termed a separatory, by means of which the heavier liquid is allowed to flow out through the lower aperture, until the inferior surface of the stratum of lighter fluid approximates closely to it. The aperture is then stopped, or the current is arrested by closing the opening through which the air entered into the top of the vessel.

A third mode is by imbibing a filter with the heavier of the two fluids, and then pouring the viscid mass into it; it affords easy passage to that with which its pores are already filled, but remain impervious to the other.

CHAP. IV.

Of those Operations by which Bodies are mechanically mixed.

The operations by which bodies are mechanically mingled present but little interest in a scientific point of view, although as a means of diffusing equally through each other the ingredients of compound medicine, their accurate and perfect performance is of considerable importance alike to the apothecary and to the physician.

Dry powders are frequently mixed together, to form compound powders; this is effected by first triturating them together in a mortar, and then passing the mixed mass through a fine sieve.

Dry powders are often mechanically mixed with soft substances, as in making pill-masses, by beating and kneading, and in making ointments and plasters, when the powder is generally added to the fatty ingredients liquified by heat, the whole is then stirred with a spatula until the mass becomes solid. Soft substances are generally mixed by being beaten, or if they be fatty or resinous, by being melted together.

Dry substances are generally mixed with, or, as it is more commonly termed, diffused through fluids, by triturating the solid in fine powder, with the fluid gradually added; thus are formed the emulsions or mixtures of camphor, chalk, ammoniacum, &c.

Fluids which do not combine chemically, are often mixed by agitation for extemporaneous formulæ, as castor oil, or oil of turpentine, with a tincture, or with water.

PART II.

CHEMICAL OPERATIONS.

INTRODUCTION.

Of Heat considered as an Agent in Pharmaceutic Operations.

We could not enter into the examination of the chemical processes of pharmacy without first noticing that agent, by the operation of which the greater number of them are performed; considering its general properties, and describing those of its effects which are taken advantage of in our art; we mean not, however, to enter into the subject of the nature of heat, nor even to dwell upon its properties at any length, those belong to the domain of physical chemistry; we shall consider only the methods of estimating the temperature of bodies, the sources from whence we can obtain a supply of heat, and the manner of employing and managing it in practice.

SECTION I.

Of the Modes of estimating the Temperature of Bodies.

The temperature of a body is generally estimated by the dilatation which is produced in another body placed in contact with it; occasionally some other indications are made use of which shall be hereafter noticed.

The nature of the substance, the dilatation of which is used as an index of temperature, varies; sometimes it is a solid, at others a fluid, or a gas. The expansibility of the first class of bodies being but small, they cannot so well be used to indicate as minute changes of temperature as a liquid or a gaseous substance, which dilates much more for an equal elevation of temperature; while for measuring high degrees of heat, fluids do not answer, they being either volatilized or decomposed. There are therefore required two distinct sets of instruments, one for estimating the lower, the other for measuring the higher temperatures; the former are called *Thermometers*, and the latter *Pyrometers*.

Thermometers are of three kinds, according as the substance of which they are formed is a fluid, a gas, or a solid. Thus we have the mercurial and alcoholic, the air and the metallic thermometers; the mode of construction of each differs, and each has its own peculiar advantages.

The form of the mercurial thermometer is well known; it is made by taking a small glass tube, as nearly as possible cylindrical; if it is not so, and nearly all thermometer tubes are sections of a very long cone, it can be divided into lengths of exactly equal capacities, by introducing a small quantity of mercury and marking the lengths of the tube which it successively occupies; the whole tube having been thus divided into equal portions, the mercury is to be expelled, and the bulb blown at one extremity by means of the blow-pipe. The bulb and tube is to be next filled with recently distilled pure mercury; this is to be done by attaching to the end of the tube a small funnel containing mercury; the bulb is then to be warmed, the included air expanding, a portion of it is driven out, and when the remainder on cooling regains its original volume, a portion of mercury enters into the bulb to supply its place. The bulb being thus partly filled with mercury, the instrument is again submitted to a strong heat, and the mercury is made to boil; when all the air and vapour of water has been expelled by the vapour of the mercury, we allow the bulb to cool, and more mercury entering, entirely fills the bulb and tube.

If the quantity of mercury which has entered be too great, a portion of it must be expelled by heat. It is evident that for the highest temperature which the instrument is intended to indicate, the column of mercury should not rise entirely to the summit of the tube, and at the lowest should not descend quite to the bulb.

The tube should next be sealed at the extremity; for this purpose the bulb is heated until the mercury occupies the entire tube, and the flames of the blow-pipe directed on the capillary extremity, closes it in an instant.

The next step is to mark on the stem the points which correspond to the temperatures of freezing and of boiling water. The determination of the first requires no remark, with the second more precaution is necessary; thus distilled water should be employed, and in a metallic vessel, and the atmospheric pressure should be carefully ascertained.*

Having thus obtained these two fixed points, the instrument is to be finished by applying to it the scale. There are three scales at present in use in Europe, that of Rèaumur, which takes the freezing point at 0, and divides the interval between it and the boiling, into 80 degrees; that of Celsius, where the freezing point is likewise 0, and the boiling 100, whence it is called by the French, the centigrade thermometer, and that of Fahrenheit, (the one used in this country,) on which the zero is the cold procured by mixing snow and salt, the freezing point is at 32°, and the space between that and the boiling point is divided into 180°, whence the boiling point is marked 212. The graduation is continued above the boiling point in the same way, and for temperatures below 0, the scale recommences proceeding downwards. Those temperatures above the zero are either expressed simply as 50°, or have prefixed to them the plus sign, as + 50°, those below the zero are always expressed by prefixing to the number the minus sign, as — 30°.

Three different scales being in very general use amongst scientific men, it is necessary to be able to

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* Any impurities which the water may contain elevates its boiling points. Gay Lussac found that in glass and earthenware vessels the boiling point was also raised, and the temperature at which water boils varies with the pressure; on which fact is founded Mr. Wollaston's admirable thermometer for measuring the height of mountains, by observing the point at which ebullition takes place.

reduce the degrees on one to the corresponding points upon another scale; this is very simply effected; in most books comparative tables of the different scales are given, but as the formulæ are easy, they alone will be sufficient here.

The interval between the freezing and boiling points of water on Fahrenheit is 180°, on the Centigrade 100, and on Reaumur 80, therefore a degree of Fahrenheit is to a degree of the centigrade as 180 to 100, or as 9 to 5, and to a degree of Rèaumur as 180 to 80, or as 9 to 4; so 9 degrees of Fahrenheit is equal to 5 of centigrade, or 4 of Rèaumur; therefore when we wish to convert the centigrade degrees into those of Fahrenheit, we have to multiply the number of the former by 9, divide by 5, and add 32, and to reduce Fahrenheit to centigrade, the converse will give the result. When the degrees of Rèaumur are to be reduced to those of Fahrenheit, we have to multiply by 9, divide by 4, and add 32, and subtracting 32 from a given degree on Fahrenheit, multiplying the remainder by 4, and dividing by 9 will give the corresponding number on Rèaumur's scale.

The formulæ may be thus shortly expressed:

$$1. \quad F = \frac{9\,C}{5} + 32$$

$$2. \quad C = \frac{(F-32)\times 5}{9}$$

$$3. \quad F = \frac{9\,R}{4} + 32$$

$$4. \quad R = \frac{(F-32)\times 4}{9}$$

These formulæ apply to all degrees above the freezing point of water, but when negative centigrade degrees are to be converted into the corresponding ones on Fahrenheit's scale, multiply the degrees of centigrade by 9, divide by 5, and the difference between the quotient and 32 is the required degree of Fahrenheit; or when negative degrees of Fahrenheit are to be reduced to centigrade, add 32 to the given degrees of Fahrenheit, then multiply by 5 and divide by 9. By substituting 4 for 5, the same formulæ will apply to Fahrenheit and Reaumur; all which may be thus expressed:

$$1.\quad -F=\frac{9\,C}{5}\backsim 32$$

$$2.\quad -C=\frac{(F+32)\times 5}{9}$$

$$3.\quad -F=\frac{9\,R}{4}\backsim 32$$

$$4.\quad -R=\frac{(F+32)\times 4}{9}$$

For general purposes, mercurial thermometers are the most useful, because the interval between the freezing and boiling points of that fluid metal is greater than that of any other liquid; consequently a mercurial thermometer has the greatest range. Secondly, (what is a consequence of the length of its interval,) its ratio of dilatation for successive increments of temperature is more uniform than that of any other fluid, and as counteracted by the increasing expansion of the glass approaches nearly to exact equality.

Where it is required to estimate very low temperatures, the mercurial thermometer cannot be made use of, in consequence of that metal solidifying at — 39° F. In such instruments, alcohol, coloured by litmus or cochineal must be employed, but as the ratio of dilatation of alcohol is much less equable than that of mercury, these instruments are not so accurate, and this fluid boiling at a low temperature, their range is necessarily small.

With regard to the mode of using thermometers, very little need be said. The smaller the instrument is, *cæteris paribus*, the greater is its delicacy, because, as the heated body loses a portion of its own heat in raising the temperature of the thermometer, if the latter be too large relatively to the volume of the heated body, the observed temperature may be much below that of the substance before the experiment. It is evident, that if we examine a very cold substance, we might fall exactly into the opposite error, the thermometer imparting to it a quantity of heat capable of influencing our results. If the heated body be a fluid, the thermometer should be stirred up and down through it, in order that the temperature of the entire mass might be equal, and the instrument should never be suddenly plunged into a very hot or a very cold medium, as a sudden change of temperature might occasion the fracture of the glass.*

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* When a thermometer is suddenly plunged into a heated fluid, we observe a depression of the mercury in the stem, apparently indicating a degree of cold: This effect, however, is only momentary; the mercury soon begins to rise, until it indi-

A circumstance which influences the indications of a thermometer is the quantity of mercury subjected to the operation of the heat; for instance, the same instrument, plunged into a heated bath, will indicate a higher temperature if the entire stem be sunk, than if the bulb alone be immersed in the water; this arises from, in the former case, the dilatation of the mercury in the tube being added to that of the bulb, which alone expands in the latter instance; the larger the bore of the tube, the greater the liability of the instrument to this fallacy.

Air thermometers are composed of a very long capillary tube, open at one extremity, and terminated at the other by a bulb. The bulb and tube is filled with dry air, a small cylinder of mercury is introduced into the tube, and the instrument is then graduated as a mercurial or alcoholic thermometer. The air in the bulb indicates the slightest increase of temperature by its expansion depressing the cylinder of mercury in the tube, and any degree of cold is rendered evident by the corresponding ascent of the mercury consequent on the diminution of volume of the air in the bulb.

These instruments are advantageous in experiments of research, from their great delicacy, and from the ratio of dilatation of gases being exactly equal at all temperatures, but they cannot supply the place of

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cates the proper temperature. This appearance depends upon the expansion of the glass preceding for an instant the expansion of the mercury: it receiving the first impression of the heat, the capacity of the bulb increases, and consequently the column of mercury in the stem is for an instant depressed.

the mercurial or alcoholic thermometer. Their indications are affected by every variation of atmospheric pressure, and by every change in the position of the instrument; they are also very liable to accident.

Metallic thermometers have not as yet come into general use, that of Breguet alone requires to be noticed. It consists (Plate II. Fig. 7,) of a helix A, formed of three metals of unequal expansibility : the exterior plate of this delicate helix is of silver, the interior of platina, and between them is one of gold. Two only are necessary to the perfect action of the instrument, but from the difference of expansibility between silver and platina, they would be liable to separate by sudden changes of temperature, and a thin plate of gold which is of intermediate expansibility, is interposed ; the whole form a single flat plate or wire about one-hundredth of an inch in thickness. The upper extremity of the helix is fixed to the brass support B, which by its form insulates the helix and permits its coiling and uncoiling freely. To its lower extremity is attached a gold needle E, kept horizontal by a small counterpoise. This needle moves round a graduated circle representing degrees of the centigrade scale. When the ambient air is heated, the expansion of the metals carries round the needle in the direction of the coils of the helix, and a diminution of temperature moves it in the opposite direction by relaxing the coils. Experiment has proved that equal increments of temperature move the needle over equal spaces of the scale, so that it is comparable with other thermometers.

There has not as yet been invented an instrument capable of registering high degrees of heat with any degree of accuracy. The pyrometer of Wedgewood was once considered to attain this end, but can no longer be relied on, as the pieces of clay cannot be had sufficiently homogeneous, and besides, Hall has proved that a low degree of heat long continued produced as great a contraction in the pyrometric pieces as a much more intense heat applied only for a short time. However, as the temperature at which many important effects of heat are produced, are given in books, according to the scale of this instrument, a knowledge of its construction may be required. Wedgewood employed as pyrometric pieces, cylinders of fine porcelain clay slightly flattened on one side, and baked by exposure to a dull red heat; it was found by experiment, that the pieces of clay contracted more and more in an uniform ratio to the degree of heat communicated to them, and permanently retained this contraction, so that by applying them to a scale when cold, an indication of the degree of heat was obtained.

The scale employed by Wedgewood consisted of two brass rods $\frac{1}{4}$ inch square and two feet in length fixed on a brass plate convergingly, so that they were distant at one end 0.5, and at the other 0.3 inch; with this degree of convergence, the whole groove is divided into inches and tenths, making 240 degrees in the whole scale, and the higher the temperature to which the pyrometric piece has been exposed, the further will it slide up the scale.

Wedgewood attempted to reduce the degrees of this scale to those of Fahrenheit, and from the expansion of silver, he considered each degree on his instrument as equal to 130° of Fahrenheit's scale, and that his zero corresponded to 1077 of the common scale. The results obtained by Guyton de Morveau, however, differed widely from these, and probably were not much nearer the truth.

The only pyrometers on the results of which any reliance can be placed, are those of Guyton de Morveau and Daniell; the basis of that of De Morveau is a small yet solid plate of highly baked porcelain, (Plate I. Fig. 8.) in which is a groove capable of containing a flat bar of platina, C, 1.75 inch in length, 0.2 inch broad, and about 0.1 inch in thickness. One end of this bar rests against the bottom of the groove, the other presses against the short arm of a bended lever, the long arm of which moving on a pivot, becomes the index of the instrument. The short arm of the lever is just one-twentieth of the length of the long arm, which in the original instrument was just 1.8 inch; consequently the space moved over by the longer arm will be twenty times as great as the motion caused in the short arm by the expansion of the bar.

A finely graduated arc of a circle, of which the index is a radius, is fixed on the porcelain, and each degree of this arc is subdivided into ten parts by a vernier on the extremity of the index itself, and thus the instrument is capable of indicating an expansion of $\frac{1}{5730}$th part of the radius: all these parts are of platina.*

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* Library of Useful Knowledge. Thermometer and Pyrometer, page 30.

By means of this pyrometer Guyton de Morveau corrected the indications given by Wedgewood's instrument, but fell himself into some inaccuracies, particularly with regard to the temperature of a red heat in day-light, which he placed at 517°. Fahrenheit, instead of 1077.5° ; this is too low, for mercury and oil may be raised to that temperature, without becoming luminous even in the dark. The general accuracy of his results is proved however by their coincidence with those obtained by Daniell with a different instrument.*

This instrument may be used to estimate the temperature of most furnaces. It is generally placed in a crucible, to defend it from the slags and ashes, but possesses the inconvenience, as Daniell's does also, of rendering the examination of the situation of the inside, while in the furnace, necessary ; that which is not requisite with Wedgewood's pyrometrical pieces, the contraction of which, when once produced, is permanent.

Plate III. Fig. 1. represents Daniell's pyrometer, the tube, *a. b. c.* is made of black lead earthen-ware, and the shoulder in its centre is moulded in its construction. The extremity *a.* is closed, and the extremity *c.* open : *d.* is a ferule of brass, into which the end of the black lead tube is accurately fitted, and to which the scale *e. f. g. h.* is attached. In the inside of the tube, *a. b. c.* lying upon it, and extending to *b.* is a bar of platinum, 10.2 inches long, and 0.14 of an inch in diameter. It is immoveably fixed

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* Quarterly Journal of Science, vol. xi. page 309.

at *a.* by a nut and screw of the same metal on the outside, and a pin or shoulder on the inside; it is likewise confined to its place at *b.* by a small perforated plate of platinum, through which it passes. From its end *b.* proceeds a fine platinum wire, of about $\frac{1}{100}$ of an inch diameter, which coming out of the tube at *d.* passes two or three times round the axis of the wheel *i.* fixed at the back of the scale, *e. f. g. h.* and represented at Fig. 2. Plate III. It is then bent back, and attached to the extremity of a slight spring, which is stretched on the outside of the brass ferule, and fixed by a pin at *n.* The wire is thus kept extended by the action of the spring. The axis of the wheel *i.* is 0.062 in diameter, and the wheel itself is toothed, and plays into the the teeth of another smaller wheel *k.* This smaller wheel is $\frac{1}{3}$ the diameter of the larger, and carries on its circumference $\frac{1}{3}$ the number of teeth. To its axis, which passes through the centre of the scale, *e. f. g. h.* is attached the index *l.* Now the theory of this combination is, that any alteration of the relative lengths of the metal wire, and of the earthen tube, will cause the wheel *i.* to move by the action of the spring *m. n.* which motion will be multiplied three times by the wheel *k.* and measured by the index *l.* The scale is divided into 360°. Instead of passing the fine platinum wire round the axis of the wheel, it has been found better in practice to attach a short silk string to its extremity and pass that round and fit it to the spring.

If the extremity of the instrument *a. b.* be now gently heated, the index will be seen to move forward with a gradual and very equal motion, and by a careful cooling will return as gradually to the point from whence it started. The accession of heat causes the metal bar and wire to expand more than the earthen tube; the consequence is, that the action of the spring always keeping the wire tight, draws the wheel round. In cooling, the metal again contracts, and restores the spring to its former degree of tension.

The zero of this instrument is made to correspond with 56° of Fahrenheit, and each degree to be equal to 7° on that scale. The results of Daniell's experiments on the temperature at which ignition commences, and on the fusing points of many metals, nearly agree with those of Guyton de Morveau, but differ widely from those announced by Wedgewood. This pyrometer is undoubtedly the most elegant and most accurate instrument which we possess for measuring high temperatures, but unfortunately, as it must be carefully kept from the contact of fuel or of metals, its application is very limited.

The most useful advice which can be given on the mode of estimating high temperatures is that of Faraday.* "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 which 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

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* Manipulation, page 145.

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."

SECTION II.

Of the Mode of applying and regulating Heat in Pharmaceutic Operations.

The methods employed to elevate the temperature of bodies, vary according to the heat to which the body is to be raised. Considered without reference to any operation in particular, we may describe them under three heads, viz.

1st. Where the substance to be heated is directly in contact with the fuel.—All furnaces.

2d. Where there is a medium interposed between the substance to be heated and the fire.—Water bath, sand bath, air closet, &c.

3d. Where the heat is obtained by the condensation of a vapourous body.—The steam bath.

The instruments in which the combustion of fuel is directly applied as a heating agent, are termed furnaces. They are of various kinds; the more important are

The air furnace, used in crucible operations.

The blast furnace, used in the same operations on a smaller scale.

And the reverberatory furnace, used in distillations which require a high heat.

The materials employed in the construction of furnaces should fulfil two conditions, viz., of conducting heat badly, and of being capable of resisting high degrees of temperature; all stones, baked earth, and many other substances, possess the property required by the first, but there are few substances which perfectly fulfil the second condition; among the materials which may be employed in building, some silicious sandstones alone possess the required degree of infusibility, as well as some varieties of bricks, called refractory or fire bricks; all the other substances vitrifying by exposure to a very intense heat, owing to their containing lime, and certain metallic oxides.

However, it is only the internal surface of the furnaces which demands this refractory material, the remainder of the mass may be built of common bricks and mortar. The refractory bricks lining the furnace should not be cemented with mortar, but with a clay containing no lime. To insure their close union, furnaces are often lined with unbaked bricks, which thus cohere perfectly, and are afterwards baked thoroughly in their places; but until this is effected, the heating of the furnace should be very gradual, as the mass is extremely liable to crack and break down in drying.

Furnaces should always be bound by strong bands of iron, otherwise they would be very soon rent asunder by the unequal effects of the heat.

The furnaces generally used for fusion are the air, the reverberatory, and the blast furnaces. Plate III. Fig. 3. exhibits the wind or air furnace; A is the ash hole, B an opening for the air, C the fire-place, containing a covered crucible standing upon a support of baked earth, which rests upon the grate; D is the passage into the chimney, and E is an earthen or stone cover, to be taken off when it becomes necessary to add a supply of fuel.

The air furnace is capable of giving a very intense heat when well built, and supplied with proper fuel. The combustion is most intense when carried on in a furnace of the same diameter with the flue, the length of this latter being about thirty times its diameter. The hottest place is considered to be about two inches above the grate, to which height the the crucible may be elevated on a stand. The fuel should be good coke, or a mixture of two parts of coke and one of coal; for the latter, when used alone, not only clogs up the interstices of the grate, and thus prevents the free access of air, but also forms a slag, which often flows into the crucible, and destroys it together with its contents.

The blast furnace is where the combustion is kept up by a continual stream of air supplied by means of a double bellows, as in the common smith's forge; it gives the most intense heat which can be obtained in a furnace, but we can operate upon only moderately small quantities of matter.

(Plate III. Fig. 4.) " 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 bottom 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 application. A small blue pot of seven inches and an 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-blowers' pots, to which enough of water had been added to moisten the powder, which was pressed down with 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 7½ inches from the grate to the bottom, and the latter 7½ inches from the grate to the top. Finally, a horizontal hole, conical in form, and 1½ 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 air chamber beneath. When vapour ceased to be formed, the furnace was considered to be ready for use.

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 a 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 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

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[*] Faraday, Manipulation, p. 96.

of the operation. 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."

The reverberatory furnace is represented in Plate III. Fig. 5. Fire-place, *a. a.* an ash-hole, *b. b. c. d.* doors of ash-hole and fire-place, *e. e.* body of the furnace, fitting on the fire-place, *f. f.* dome, terminated by a chimney, and serving to *reverberate* the heat back upon the retort, *h. h.*, which is placed, as in the figure, in the body of the furnace.

We thus see that the reverberatory furnace consists of three parts; a lower, containing the fire-place and ash-pit, a middle piece, termed the body, and the superior or dome, the proper reverberating portion; at the junction of the body with the dome, there are cut notches, which allow of the passage of the necks of retorts or of tubes, and which, when not in use, are closed by stoppers of baked clay, which fit accurately.

The air and the blast furnaces are generally used for fusion; the former for operations on large quantities, the latter more commonly for experiments of scientific research.

The reverberatory furnace is used for a different class of operations from those performed in the air or blast furnaces. Incapable of raising so intense a heat, it is not usually used for fusion, but is generally applied to distillations which require a red heat, and to operations conducted in iron or earthen tubes, which are conveniently passed through it. A different modification of the reverberatory furnace is used in roasting ores, &c.; the substance to be roasted is stratified on a horizontal floor, over which the flame and heated air from the fire-place, reflected by the dome above, plays; when speaking of the operation of *torrefaction,* the different processes conducted in this kind of furnace will be explained.

The retorts used in reverberatory furnaces are of glass, earthen-ware, or iron. Those of glass are always coated, the manner of doing which will be mentioned, when speaking of lutes. Those of earthen-ware are of two kinds; the one fine, which is scarcely permeable to air, but very liable to crack; the others are made of a coarser material; they stand the fire much better, but are very porous. This may be in a great degree obviated by coating them with a mixture of two parts powdered glass, and one borax, made into a cream with water, which, when heated, effectually glazes them. They can scarcely ever be used a second time, except for the same kind of operation, and require to be heated and cooled very gradually.

Iron retorts are seldom used: they are useful in distilling mercury, and in many chemical operations.

The same remarks apply to tubes as to retorts; they are made of the same materials, are subject to the same accidents, and require the same precautions in their use.

The media through which heat is indirectly applied to bodies are termed baths; the nature of the medium varies with the temperature to which the body is to be subjected, being sometimes air, as in the air-closet and stove; water, in the water-bath; mercury, or fusible alloys, as in the various metallic baths, and sand in the sand-bath.

Air is generally used as a heating medium where the temperature required is not equal to that of boiling water. Thus, in the desiccation of plants, in the drying of many precipitates, to obtain very slow, and consequently regular crystallizations, or to allow of the filtration of a fluid, which is liable to crystallize on cooling; for these purposes, the pieces of apparatus in which the operations are carried on are placed in a chamber or stove, through which a current of heated air is made to circulate.

An air-chamber may be very conveniently put up in many parts of a laboratory, at the side of a furnace, or near a flue. It should not be close, but should allow of the formation of a current, so that the air contained in it might be frequently renewed. A very convenient situation for one is in the body of the table furnace, to be hereafter described, where, by a simple arrangement, the current of air can be readily heated.

A very excellent air-chamber has been constructed by Mr. Cooper. It consists of an enclosed space, 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.

The lamp-stove of D'Arcet is very convenient for the desiccation of vegetable substances. It consists (Plate IV. Fig. 1.) of a rectangular case of deal, A. A., the front of which, B. B. B. B. opens at will, and serves as a door. R. R. are apertures, which may be closed by corks, as we wish to augment or diminish the heat of the stove. E. E. E. E. E. E. are brackets fixed on the side of the case. Fig. 2. is a metal heater,* composed of a plate A. B., circular, and slightly concave inferiorly: 2d. of two concentric tubes, one external, D. D., of 3.20 inches in diameter, and of 5.5 inches in height, attached to the plate A. B. by three iron supports, *e. e. e.* The other internal, G. G., of 2 inches in diameter, and united to the external by small cross bars, F. F. F. F. In Fig. 1., the heater is seen in its place, and receiving in the tube G. G. the glass of a lighted argand lamp. Fig. 3. is a cover or stopper, pierced by two

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* In the original, *champignon* (mushroom) from its figure; its office is to diffuse the heated air equally every where.

holes, *b.* C.; this stopper fits at the extremity of the tube D. Fig. 2. The opening, C. is for the passage of the glass of the lamp, and the hole, *b.* allows of the motion of the rack, M. according as it is necessary to raise or depress the wick; the use of this stopper is to intercept the current of cold air which is established between the tubes of the heater, and to augment thus the temperature of the air in the stove.

This stove is set upright in a corner of the laboratory, and the matters to be dried are placed on gratings of wire sustained on the brackets, E. E., &c. The greatest heat afforded, is when the cover is on the tubes, and the openings R. R. closed; it then is about 150° at the upper part of the case, but in the lower part it rises above 212°.

In very many operations, it is necessary to keep the temperature of the substances we operate upon at a certain height; in many instances of solution, particularly of organic matters, as gelatine sugar, &c., and in cases where a peculiar action takes place at a certain temperature, which is not effected, if the heat be either too high or too low; in making ointments and plasters, and in the evaporation of extracts and inspissated juices, where it is necessary to guard against the too great elevation of the heat. In these cases, a medium is used, the temperature of which remains at a certain level, and we vary the nature of the medium, according to the degree of heat required.

The water-bath is that which gives the most moderate elevation of temperature; for operating on quantities of matter, they are generally constructed with, and attached to the vessels which contain the substance to be heated, as in Plate IV. Fig. 4., where A. is the vessel containing the body under operation, under and attached to which is another, B. containing water, through which the heat generated by the fire is conveyed to the substance in A.

For more minute operations, however, water baths are generally of extemporaneous construction; a tin saucepan of a depth suitable to the vessel to be heated, makes an excellent one. The immersed vessel should not touch the bottom of the bath, for a quantity of heat would then be communicated to it by direct conduction, which would raise the temperature much higher than was the intention of the operator. If the vessel be a flask, some hay or tow should be placed at the bottom of the bath, and the flask placed on it; a board perforated with holes to admit the necks of the flasks, should be placed across the top of the tin vessel, and if there be more than one flask in the bath, a little hay placed between them will prevent any inconvenience arising from the violence of ebullition.

It is necessary to take care that the water in the bath be not too much diminished in quantity by evaporation; as not only would it occasion the derangement of the apparatus, but also might prevent the temperature being raised to the required degree, the quantity of heat carried off by the steam formed, neutralizing the supply given by the source of heat.

The highest temperature which can be thus gained by means of boiling water, is about 210°. Where it is desirable to obtain a higher degree of heat in this form of apparatus, we must substitute certain solutions of salts for the simple water; the temperatures at which these solutions boil vary with the nature of the salt and the quantity of it held in solution.

Griffith has determined the boiling points of saturated solutions of the following salts:

of Bitartrate 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[*]

Thus by using alum, common salt, or nitre, (the cheapest of the salts,) we can have any temperature intermediate between 212° and 238°, for by making a solution not quite saturated, we can obtain a heat a certain number of degrees below the boiling point of the saturated solutions.

Mercurial baths, and baths of fusible metal are often used in certain experiments of chemical research, but are not of important application in pharmacy; where the heat required is higher than that given by boiling saline solutions, the sand bath or the furnace is invariably employed.

The sand bath is merely a vessel of iron, copper, or earthenware, containing sand, in which the vessel

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[*] Quarterly Journal of Science, xviii. 90.

to be heated is imbedded; the size and shape of the bath of course depends entirely on the shape and nature of the vessel which it is intended to contain.

Where it is required to apply heat to a number of vessels to effect solution or evaporation, the baths are generally large and shallow, forming the upper plate of a furnace, the flue of which passes immediately under them; for distillation, sand is placed in an iron pot deep enough to contain the lower part of the retort, which is imbedded to a depth proportional to the heat intended to be used. This form of bath is also very useful in the operation of sublimation.

A very useful piece of apparatus which contains both forms of sand bath, is the table furnace, represented in Plate IV. Fig. 5 and 6. In it at the front is an iron pot, in which may be performed most operations of distillation and sublimation; the rest of the upper part is occupied by a large flat sand bath of 2½ or 3 inches in depth, on which liquids may be readily evaporated, and smaller vessels of any kind heated. Under the flue is situated an air chamber, already referred to, which is closed tight by the doors, as seen in the figure.

For general operations this is the most useful of all furnaces, and no laboratory, whether of manufacture or of research, should be destitute of it.

By means of the sand bath any degree of heat below redness may be obtained; the exact amount depends upon the strength of the fire, the distance of the vessel from the fire-place, and the depth to which it is immersed in the hot sand. If a vessel be too much heated, its temperature is readily diminished by raising it out of the sand, and letting it merely lie upon the surface, or by removing it to a part of the bath farther from the fire; and if it be required to increase the heat, it is easily effected by placing the vessel in a hotter part of the bath, or by heaping the sand round it; the sand, however, should never be raised higher than the level of the fluid in the vessel, as it would render it extremely liable to break. The temperature of a flask is often very conveniently increased, by confining round it a coating of heated air by means of a conical jacket, for which purpose an old tin funnel, with the tube broken off, answers very well, or it may be made, on occasion, of strong paper, or of pasteboard.

One of the most important modes which we possess of applying heat is by the condensation of steam. In this the vapour is made to communicate to the colder bodies, with which it is brought into contact, that enormous quantity of heat which it absorbed and rendered latent in passing from the liquid to the gaseous form. This method embraces many advantages; 1st, we have all our vessels free from the dirt of fuel and smoke; as even the furnace used in supplying the necessary steam may be situate in a remote apartment. 2d. We can regulate the heat to any degree we wish by proportioning suitably the quantity of steam admitted, and the pressure under which it exists; and finally, we can cut off the source of heat in an instant, by turning a stop-cock, and can again allow the calorifying agent to play upon our vessels with the same facility and rapidity.

The general mode of heating by steam is as follows: the vapour generated at a certain pressure in a boiler, is conducted by tubes into the space between two vessels, one of which contains the substance to be heated. The hot steam coming into contact with this cold body is condensed, communicates to it a portion of its heat, and collects as water in the inferior vessel from which it is from time to time removed.

The great use of steam, as a heating agent, is in the preparation of vegetable extracts, the evaporation of which cannot be sufficiently expedited in any other way without endangering the value of the product; in the distillation of the medicated waters and spirits, and of the essential oils. The most approved form of apparatus are those of Henry, junior, and Pelletier; the former of whom uses the steam at the common pressure, the latter under a pressure moderately increased.

The apparatus employed by Henry at the central pharmacy of the hospitals of Paris, consists of a covered boiler in which the water is heated; the steam is conducted from it to the evaporating pans, by means of metallic tubes; each of these vessels is of the form of a common copper basin, to which is soldered a capsule of tin, broad and shallow, into which the liquor to be evaporated is put. The steam circulates between these capsules, envelopes them, and yielding its caloric of vaporization to them, passes in part to the state of water which flows out by a cock at the bottom of each vessel. The last pan is terminated by a tube plunging into a vessel of cold water, which opposes a slight resistance to the escape of the uncondensed vapour. The liquor is distributed among three or four capsules; in proportion as its volume diminishes by concentration it is collected into one, and is stirred towards the end in order to promote the evaporation. The advantages of this apparatus are, that it evaporates the liquids rapidly without subjecting them to a strong heat, without endangering the burning of the extracts, and by using it, a large quantity of distilled water sufficiently pure for most purposes is economically obtained. The steam being subjected merely to the common pressure of the atmosphere, the temperature of the liquids holding in solution the vegetable matter is constantly lower than that of boiling water; for if there are four evaporating vessels, one after the other, the first which is nearest to the boiler will be at about 198° Fahrenheit, and the fourth or last at 135°. In the instrument contrived by Pelletier, the temperature can be raised much higher, as the pressure may be increased to a certain height according to the weight which presses upon the safety valve. The steam circulates round the capsules containing the liquid to be evaporated, preserving the pressure under which it was generated, so that its calorifying effects are infinitely more powerful than those of an apparatus under common pressure. Finally, after having been put in contact with the double bottom of each capsule, the vapour escapes from the last by raising up a valve, the power of which is less than that of the safety valve of the boiler.

Dr. Ure has described a vapour bath for small operations which is extremely convenient, and indeed indispensable, in an experimental laboratory: "A square tin box, about 18 inches long, 12 broad, and 6 deep, has its bottom hollowed a little by the hammer towards its centre, in which a round hole is cut of five or six inches diameter. This tube is made to fit tightly into the mouth of a common tea-kettle which has a folding handle. The top of the box has a number of circular holes cut into it, of different diameters, into which evaporating capsules of platina, glass, or porcelain are placed. When the kettle, filled with water, and with its nozzle corked, is set upon a stove, the vapour playing on the bottoms of the capsules, heats them to any required temperature, and being itself immediately continually condensed, 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 is corked up and placed with its filter directly into the proper sized opening. For drying red cabbage, violet petals, &c. a tin tray is provided, which fits close on the top of the box, within the rim which goes about it; the round orifices are left open when the tray is applied."*

An apparatus of this kind, which I had made, differs in some degree from the above description:

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* Chemical Dictionary, page 292.

the boiler has no spout, and the steam-chamber has no fixed top. The openings being cut in a tray, which, like the one for drying vegetables, fits on the top, the junctions are secured by the edges of the trays dropping into a rim which surrounds the top of the steam chamber, and contains a little water.

The heating power of steam is also extensively applied to drying substances in the arts, as cotton and linen cloths, and in pharmacy precipitates and vegetable preparations, as leaves, petals, &c. The mode of applying the vapour is exactly the same as in the evaporating vessels, but the trays are flat, in order that the contained substance may be equally stratified. Many forms of apparatus have been devised for this mode of desiccation, but none of such interest as to claim particular attention.

Another mode of applying steam to heat liquids, and still used extensively in the arts, is to conduct the steam by a pipe directly into the fluid to be heated, where it is immediately condensed; this method is used for effecting solution on the large scale, but is not applicable to the other operations.

Another mode of obtaining a supply of heat is by the combustion of certain gaseous, fluid, or easily fusible substances in lamps. These instruments are very economical, and of easy use, but they are inapplicable to operations on a large scale, as they are only capable of heating small quantities of matter.

The most important lamps are those of alcohol, oil, and gas. The spirit lamp is that which affords the highest heat, and is the most convenient, from its not throwing off any smoke. It need not be described, as the common form is universally known. The most useful modifications of the spirit lamp are those of Cooper, for the ignition of certain lengths of tubing, as in organic analysis,[*] and that of Mitterslich with the circular wick, which produces a heat capable of igniting a small platinum crucible with its contents, and of performing all other operations of minute analysis.[†] These instruments being used in philosophical chemistry, and not in proper pharmacy, the reference to where the figures and descriptions may be found, is sufficient here.

It is not so, however, with a form of spirit lamp, which I believe few apothecaries' apprentices were destitute of, although to Mr. Philips is due the merit of publishing a description of it.[‡] Take a little tin tube, about one inch long, and three-eighths of an inch in diameter; if the edges are well hammered there is no necessity for soldering: perforate a cork previously fitted to a phial, and put the tube in the cork. Now place a cotton wick in the tube and a perfect spirit lamp is constructed, taking care that the cork do not fit too tight to allow of the air getting into the phial to supply the place of the spirit ascending by the wick.

The spirit used in these lamps need not be very strong. A spirit, sp. gr. .84 or .85 is sufficiently so. A much cheaper ingredient, proposed by Faraday, as a substitute for spirits, is the volatile fluid obtained along with the acetic acid, by the destructive

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[*] Quarterly Journal of Science, xvii. 232.

[†] Rose's Analytical Chemistry, translated by Griffin, p. 49.

[‡] Annals of Philosophy, vii. 36. new series.

distillation of wood, called pyroxilic spirit, or pyroligneous ether: it is easily inflammable, and burns with a bluish white flame, and but very little smoke. It does not produce as high a temperature as the flame of alcohol.

Oil is universally used as a combustible in argand lamps, which have circular wicks, and a double current of air. They are made with copper chimneys, and are extremely useful, giving a steady and pretty high temperature for any length of time, and, if the wick be properly attended to, not throwing off any smoke with good oil. For producing a greater heat oil lamps are made with double concentric wicks, but these are inconvenient, both wicks being commonly attached to the same rack, and the inner one burning much quicker than the outer, the combustion goes on very irregularly, and much smoke is produced. However, by having the wicks attached to separate racks, and by using care, these lamps may be used very advantageously.

The combustion of gas as a mode of producing heat has not as yet been extensively used, but as it probably will in some time, it requires some mention of the mode of employing it. The inconvenience in burning gas is the large quantity of smoke which it (particularly oil gas,) throws off; and secondly, the small space into which the heat is concentrated from a common burner, which renders it difficult to heat large vessels by means of it. The best mode of obtaining a smokeless flame from gas, is by mixing it with air previous to combustion, in the mode described by Faraday.* Plate IV. Fig. 8. represents the section of a 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, and the aperture at the top should be about one-fifth of an inch in diameter. 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 burned. More or less air may be allowed to mix with the gas, by raising or lowering the cone. The upper aperture is large, so that the gas and air may readily 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 otherwise pass downwards, and sometimes cause combustion beneath, or an unpleasant smell."

To render the flame from gas more diffused, and so apply it to heating large vessels, Duncan† proposes to burn it on wire gauze burners; but this proposition has not as yet been applied to practice.

APPENDIX.

There are some circumstances connected with the management of heat, which if mentioned under the different operations in

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* Manipulation, page 108.

† Edinburgh Dispensatory, 1831, p. 47.

the course of which they occur, would lead to too frequent repetition, and consequently are best considered here; they are the methods of enabling apparatus to sustain a high temperature, and rendering them impervious to those substances which are generated or contained within them by *coating*, *luting*, or *cementing*.

Tubes, retorts, &c. are coated when they are to be subjected to a temperature capable of fusing them if exposed to it without defence. Where the heat is very intense, as in the preparation of potassium, pure Stourbridge clay alone must be used as the coating. In this state it contracts so much when heated that it is very apt to fall off from the vessel, and if any other material be mixed with it to diminish its contractility, the lute becomes too easily fusible.

But when a bright red or a yellow is the highest heat to which the vessel is to be exposed, then we may use a mixture of Stourbridge clay with very finely powdered sand, and the addition of some fibrous material, as cut tow or horse dung, renders the coating less contractile and more adhesive, by giving a direction to the fissures, connecting together the different parts of the lute, and by substituting for several large cracks, a great number of very minute fissures which do not so much disturb the adherence between the vessel and its coating.

The clay is to be made into a thin paste, and as much of the fine sand added as does not deprive the mass of its proper tenacity; the tow or horse dung finely chopped is then added, and the whole beaten up until it is perfectly ductile and uniform; it is then to be flattened out into a cake of a size corresponding to that of the vessel to be coated, and of the requisite thickness. The vessel is then to be laid upon it, and the coating applied gradually and equally, taking care that no air be left interposed between it and the vessel. The piece of apparatus thus prepared is left to dry in the sun, or in some convenient place of a moderate warmth, and the small cracks which are formed during the desiccation are filled up by a fresh portion of lute.

Another intention of coating vessels is that of rendering them impervious to atmospheric air and to the vapours generated inside. This is effected by coating them externally with a substance which fuses when heated, and combines in some measure with the substance of the vessel, so as to form on its outer surface a coating of glaze perfectly air tight. The best mode of effecting this is that used by Willis with the retorts for distilling phosphorus; an ounce of borax is to 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 in a day or two, and the retorts are then fit for use; any cracks which may occur during an operation are easily closed by a little of the linseed oil and lime.

The lutes used for closing the joints of the apparatus are very various: the principal are the following:

Plaster of Paris is used as a lute, by being made into a thin paste with water, and immediately applied; it sets very soon, and becomes solid, expanding considerably during solidification, so that if incautiously introduced between thin pieces of glass apparatus, it frequently breaks them. This lute is of extensive applicability; it sustains a nearly red heat without alteration, and is acted on but by few substances; it is not however perfectly impervious, but may be rendered so by being rubbed with a little wax and oil.

A very excellent lute is obtained by making slaked lime into a thin paste with white of egg, the serum of blood, or with a solution of glue in water. This lute hardens very rapidly, is very impervious, and will bear a heat approaching to ignition without injury. It is useful also, that if a leak occurs with this lute, a fresh portion applied adheres at once, and closes it readily and perfectly.

Linseed meal, well beaten up with water, until it is of a proper consistence, forms a very useful lute, where the temperature of the vessels does not exceed 600°, and no acid or corrosive vapours are generated. When such is the case, we must have recourse to what is termed *fat* lute. This is made by forming into a paste some dried clay, finely powdered, sifted through a silken sieve, and moistened with water, and then by beating this paste well in a mortar with boiled linseed oil. This lute easily takes and retains the form given to it; it is generally rolled into cylinders of a convenient size. These are to be applied, by flattening them to the joinings of the vessels, which ought to be perfectly dry, because the least moisture would prevent the lute from adhering. When the joinings are well closed with this fat lute, the whole is to be covered with slips of linen spread with lute of lime and whites of eggs. These slips are to be fastened with thread. The second lute is necessary to keep on the first, because the fat lute remains soft, and does not become solid enough to stick on alone.

Besides the above, many extemporaneous lutes present themselves to the operator under different circumstances. Thus, slips of moistened bladder adhere very firmly when dry, and form an excellent mode of union. Paste or mucilage, spread on slips of linen, may also be occasionally employed, and in minute operations, the use of corks, and of caoutchouc connectors, has almost entirely done away with the application of any lute.

It may be useful to give here the mode of preparing two substances of very extensive use: 1st., hard cement, for fastening caps and such brass apparatus, on tubes, bell-glasses, retorts, &c., which is made by melting together five parts of resin, and one of yellow wax, and as soon as the mixture has ceased frothing, stirring in one part of red ochre, previously well dried. The whole is to be carefully stirred until it is so thick that the earthy matter cannot separate. 2nd. Soft cement, for rendering joints air tight in many operations at common temperatures, is made by melting together one part of yellow wax with half its weight of turpentine, and a little Venetian red to give it colour. Concerning the mode of applying these cements, no remark need be made.

PART II.

CHEMICAL OPERATIONS.

THERE exists at present a difference of opinion concerning the ultimate nature of a certain class of operations, some referring them to the agency of chemical affinity, others to the influence of mere physical forces.

These operations are Liquefaction and Solidification, which embrace among their sub-species a great number of the most important processes in Pharmacy. The supporters of the physical nature of these operations are, on the Continent, numerous and celebrated, but in this country that opinion has been embraced but by very few; their mode of reasoning is however worthy of some notice, they say—

The grand characteristic of chemical action is a mutual change of chemical properties in the substances between which it is exerted; where therefore we can perceive no trace of such alteration, where the product differs from the materials merely in those characters which are universally allowed to depend upon the physical disposition of the ultimate molecules of bodies, and not in any way to result from the exertion of chemical affinity, we are justified in inferring that those operations in which the physical characters alone of bodies are thus altered, are not dependent upon the agency of this last mentioned power, and can be satisfactorily explained upon simple physical principles.

Substances which have undergone these processes therefore have not suffered any change in their chemical relations; their composition remains the same, the nature of their actions upon other bodies remains unaltered, although the intensity of their actions is occasionally augmented, and sometimes on the contrary much diminished; their physical properties alone are different from what they before possessed, and of these the change in the form of aggregation, as it is the most constant, the most prominent, and the most tangible, so is it that by which they can best be characterized. We shall therefore commence the chemical operations with those of de-aggregation, and re-aggregation, without however entering into or taking any part in the theories which are used to account for them.

Class 1st.—*Operations of De-aggregation.*

The operations of De-aggregation are those in which the state of aggregation of the body is diminished, *i. e.* it is converted from a solid to a fluid, or from a fluid to a vaporous form. To the former of those processes is applied the term Liquefaction, and to the latter Vaporization.

Genus 1st.—*Liquefaction.*

The process of liquefaction may be accomplished in either of two ways, *immediately,* as when by simply increasing its temperature we cause a piece of wax or of lead to assume the liquid form; this is familiarly termed fusion; or *mediately*, as when by means of another body already fluid, we remove the particles of a solid body to a distance beyond the sphere of mutual attraction. In this case the process is commonly termed Solution, and the fluid used is called the medium of solution or the solvent ;each of these processes deserves particular consideration.

Species 1st.—*Immediate Liquefaction, or Fusion.*

Fusion is always produced by an increase of temperature; the precise amount of this increase differs for almost every substance, but the fact is universally true, and no other known cause can produce the same change of state; ice may be broken and reduced to powder, it may be submitted to all the mechanic powers and to the action of all the natural agents, without ceasing to be a solid body, unless the action of heat is superadded to effect its change into water: wax may be softened by pressure in the hands; lead may be melted by repeated blows upon an anvil; but in both cases it is the heat communicated to the body which produces its liquefaction.

The fact of the dilatation of bodies by heat being universal, it is interesting to know whether the phenomenon of fusion is equally general. But when we examine the action of heat on solid bodies we find great difference to exist; there are some which cannot be subjected to even a moderately low temperature without being fused, such as ice, phosphorus, wax, &c.; there are others as tin, lead, or copper, which demand for their liquefaction much higher temperatures, whilst many bodies, as platina, iron, &c. require the greatest heat we are able to produce. There are even numerous bodies which cannot be deprived by any known heat of their solid form; these are said to be *infusible,* but as our means of producing intense heat become more perfect, the number of these substances gradually diminishes.

Organic substances are in general composed of carbon and gaseous elements, whence it results that those bodies, when heated, are decomposed before they enter into fusion. Many inorganic substances are similarly circumstanced; thus marble, when exposed to heat, parts with its carbonic acid at a temperature below that at which it fuses, and the residual lime is infusible; but Hall ingeniously proved that if we prevent the escape of the volatile ingredients, the compound body is easily fused.*

When bodies pass from the solid to the liquid state, they present two singular phenomena; the first, that they remain solid until they have arrived at a certain temperature, which differing for each substance, is constantly fixed for the same substance, and it is only on reaching this temperature that

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* He enclosed chalk in a gun barrel, with the touch-hole plugged, the open end was then welded firmly to prevent the escape of the carbonic acid. The whole apparatus was exposed to a yellow heat in an air furnace, and having been opened when cold, the inside of the tube was found lined with a beautiful grey marble of a crystalline texture.

fusion commences; the second, that once fusion has commenced the temperature remains the same until the last particle of solid matter has been liquefied, no matter what quantity of caloric may be supplied to it.*

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* The heat thus employed in producing the liquefaction of the body is termed the caloric of fluidity; or from its not being indicated by the thermometer, it is termed latent heat. On the theory of the material nature of caloric, fluids are said to be *composed* of the solid and this quantity of heat chemically united. But the fact can be satisfactorily explained on the other principle. The effect of heat is to expand the solid, i. e. to separate its molecules from one another, and when they are so far separated that the force of cohesion is rendered null, the body becomes fluid. As long as there is any remaining solid particles the supply of heat is used in disaggregating them, and consequently does not increase the sensible heat of the mass, but when the whole is rendered fluid, further additions of heat produce the usual effects upon the thermometer.

The quantity of heat thus rendered latent varies for almost every substance. The amount has been ascertained by experiment in a few instances given in the following table:

Table of Latent Heats of Fluids.

	Caloric of fluidity.
Water	140°
Sulphur	143.68
Spermaceti	145
Lead	162
Bees' wax	175
Zinc	493
Tin	500
Bismuth	550

The following Table gives the fusing points of some of the more important bodies which at common temperatures exist under the solid form:

Bodies.	Fahren.	Bodies.	Fahren.	Bodies.	Fahr.
Lard . .	97°	Ambergris .	145°	Camphor	303°
Phosphorus	99	Potassium .	150	Tin . .	442
Stearine .	112	Bleached wax	155	Bismuth	476
Spermaceti	112	Sodium . .	200	Lead .	612
Tallow . .	127	Iodine . .	210	Zinc .	700
Bees' wax	142	Sulphur . .	218	Antimony	809

Bodies.	Wedgewood's Pyrometer.	Fahrenheit by Wedgewood.	Fahrenheit by Daniell.
Brass . .	21	3807	1869
Copper .	27	4587	2548
Silver . .	28	4717	1830
Gold . .	32	5237	2590
Cobalt . .	130	17977	3479
Nickel . .	150	20577	****
Iron . .	158	21637	****
Platinum .	170	23177	****

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[*] It is worth observing, that in general the bodies which are most easily fused are those which dilate most by a certain increase of temperature, as is seen in the following table of the lengths which a bar of metal takes on being heated to 212° whose length at 32° is 1.000000:

Tin	1,00284000.	Copper . .	1,00191000.
Lead . . .	1,00284000.	Gold . . .	1,00150000.
Zinc . . .	1,00294200.	Iron . . .	1,00118203.
Brass . . .	1,00216000.	Platinum . .	1,00085655.

The dilatability is here directly as the fusibility very nearly;

The vessels in which bodies to be fused are contained, are termed *crucibles.* They are made of different materials according to the nature of the substance to be heated in them, and to the degree of heat to which they are to be subjected. There are earthen crucibles, others of porcelain and Wedgewood ware, black lead, of iron, of silver, and of platina.

The earthen-ware crucibles are of two kinds, the English and Hessian. The English are soft and easily broken, of a conical or sometimes triangular form, and fitted with covers of the same material. When heated beyond bright redness, they begin to soften, and frequently occasion the loss of their contents by melting. Their fusibility is very much increased by fluxes, whence they are unfit for many operations of reduction.

The Hessian crucibles are far superior to the English in power of resisting intense heat, and the action of fluxes. They are triangular, but have no cover, which is a serious inconvenience. They are of a darker colour than the English, much harder, and their fracture sharper and less granular.

The best mode of supplying the want of covers to the Hessian crucibles is to insert a smaller one inside that containing the material, and to fill up the interval between the two by a lute of Stourbridge

this is what we should expect from theory, both effects depending upon the same cause, (separation of the particles of the solid to a greater distance from one another,) but the law is not universal. Bismuth presents a remarkable exception, its dilatability being between that of gold and iron, viz. 1,00139200, whilst it is one of the most fusible of the metals.

clay. Faraday prefers making a cake of Stourbridge clay, about one-fourth of an inch thick, putting it on the top of the crucible, and pressing it down into it with a common English cover; the excess of the cake is then cut round the edge; the cover luted on the crucible, and the whole well dried before being used.

The crucibles of Wedgewood ware and of porcelain are made of a close white composition, which is with difficulty acted upon by most fluxes; they are well formed, very smooth, and their covers in general fit with accuracy; they bear a very strong heat, but are extremely liable to crack, if heated or cooled incautiously.

Black lead crucibles are formed of a mixture of plumbago and clay. They bear a high temperature. They are not liable to crack, and they resist the action of fluxes better than any other kind of crucible, whence they are best fitted for reducing metals. When highly heated in a strong current of air, however, they are occasionally burned.

Silver crucibles are useful for many purposes, as for the analyses of minerals by fusion with the caustic or carbonated alcalies, and the fusion of the caustic potash, and of the lunar caustic of the Pharmacopœia is to be performed in a vessel of this material. The metal must be perfectly pure, and when heated should be cautiously handled, as for some time before it reaches the fusing point, silver becomes so brittle, that if the crucible at that temperature was lifted by one edge with a forceps, the piece would very probably break out. The fusing point of silver being at a yellow heat, it is evident that a crucible of this material cannot support intense heats.

Platina crucibles are extremely useful; from their price they are generally made thin; hence they must be cautiously handled, and the substance in them should be loosened as much as possible by pressure and by solution, and not by means of any hard instrument. They are always fitted with covers, and should never be used for the ignition of metals or of their compounds, which are capable of being reduced by heat, as in such case alloys will be formed and the crucible lost.

The fusion of many bodies is very much assisted by the addition of substances, which are for that reason termed *fluxes*. Cream of tartar, nitre, or sulphate of potash and borax, are frequently employed; but the most valuable of these compounds, particularly in experiments of the reduction of metals from their ores, are the white and the black fluxes.

Species 2nd. *Mediate Liquefaction or Solution.*

Solution is an operation, the object of which is to break down the force of aggregation which unites the integrant particles of a body, by means of a liquid, which interposes itself between them, and separates without decomposing them.*

The most universal solvent is water. Many other fluids also act as media of solution, as alco-

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* Chevallier, Manuel du Pharmacien, vol. i. page 185.

hol, ether, oil, &c. The acids are sometimes said to be powerful solvents, but they never act as such without effecting some change in the solid body; thus phosphate of lime is dissolved by muriatic acid, but the resulting fluid is not a solution of phosphate of lime in muriatic acid, but a solution of bi-phosphate of lime, and of muriate of lime in water, with an excess of muriatic acid: therefore acids cannot be considered as media of solution, and of the other liquids water is the most powerful.*

By the writers of this country, the phenomena of solution are accounted for, by supposing that there exists a certain chemical affinity between the solid and the fluid, to the exertion of which is opposed the cohesive force of the particles of the solid: where the power of cohesion is superior to the force of affinity, the solid remains insoluble; where the affinity is more powerful, it is soluble in the fluid; and according to the greater or less predominance of this force of affinity is the solid body more or less easily dissolved. This affinity diminishes as the

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* Many writers on pharmacy distinguish between solution and dissolution, making the former a mechanical and the latter properly a chemical process. Solution (they say) acts upon the integrant, dissolution upon the constituent molecules of bodies: after solution, the chemical properties of the solid are retained; after dissolution, they are found to have disappeared, and are lost. Sugar disappearing in water is an example of solution; zinc disappearing in dilute sulphuric acid an example of dissolution; on this principle, water and alcohol would be called *solvents*, acids would be termed *dissolvents* of solid bodies.

fluid (water for example) dissolves more of the solid, until at last it is so far weakened as to be unable to overcome the force of cohesion of the solid, the rest of which remains undissolved, and the water is said to be saturated.

Heat is said to increase this affinity between the salt and the water, therefore most salts are more soluble in boiling than in cold water; and if we take a solution saturated at any given temperature, and cool it, a quantity of the salt will re-assume the solid form, the force of aggregation overcoming the chemical affinity.

When a solvent cannot dissolve any more of a solid body at a given temperature, it is said to be saturated. However, although saturated with one substance, it may yet be able to dissolve another; thus, when we saturate boiling water with nitre, it cannot dissolve any more of that salt, but is still capable of dissolving a quantity of sulphate of soda. It often happens in this case that the fluid acquires, in consequence of the operation of certain affinities, the faculty of dissolving a new quantity of either of those salts with which it had been saturated before the mixture. Thus water fully saturated with nitre, and in which common salt had been dissolved, becomes capable of holding in solution a fresh quantity of nitre; in this case an interchange takes place between the acids and the bases, and we have in place of two, four salts in solution, so that the entire phenomenon is but an illusion. In fact, chloride of potassium does not become more soluble in water, when we add chloride of sodium, nor is the solubility of nitrate of potassa increased by the addition of nitrate of soda.*

NOTE.—The mechanical theory of solution deserves, from the number and character of its supporters, a more particular notice here, that it may be compared with the chemical explanation, as advanced above.

According to this view, the water insinuating itself between the particles of the solid, separates them from one another; when this takes place to a certain extent, the force of cohesion is destroyed, and the salt loses its solid form; the whole mass is now a liquid, through every part of which the particles of the salt are diffused, unacted upon and unchanged. Let us represent that distance between the particles of salt at which cohesive attraction begins, or ceases to be exerted by A., when we diffuse a certain quantity of a salt through water, the distance between its particles is much increased, it becomes equal to A^2; then take this solution, and add water to it; it is evident we can augment still more the distance between the particles of salt, until we may represent it by A^4. If now we add fresh quantities of salt to this dilute solution, it is plain, that as we do so we diminish the distance of each particle from those which surround it, and consequently the value of this distance descends from A^4 through A^3 and A^2 to A; but this is the distance at which cohesive attraction commences to be exerted between the particles of the salt, and therefore if we add more, its particles cannot be separated from one another. The interstices between the particles of the fluid being already occupied, it cannot be dissolved, and the fluid is said to be saturated with the salt.

Now take a solution thus saturated, and apply heat; in obedience to the general law of expansion, its volume augments, the distance between its particles increases, and it becomes A^2, and therefore is capable of conferring the liquid form upon a fresh

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* Berzelius, Traité de Chimie, vol. i. page 462.

quantity of salt. On the other hand, take as before, the saturated solution, and contract its volume by refrigeration ; the distance between the particles of the salt is diminished, it becomes less than A, the attraction of cohesion is immediately exerted, and a quantity of saline matter becoming solid separates itself from the liquid, until the distance between the particles of the residual salt is restored to its equilibrium A.

The solution of a solid in a liquid is favoured by many circumstances, of which the following are the most important:

1st. Quantity of solvent. Solution of a certain quantity of a salt takes place much more rapidly when there is present a considerable excess of the solvent, than when only a sufficient quantity for holding the salt in solution ; because as we before saw that the power of dissolving diminishes as the quantity of matter dissolved increases, the smaller proportion the solid bears to the fluid the more quickly the process of solution will go on.

2d. Division. The more the solid body be comminuted, the greater surface does it expose to the action of the solvent. If, however, it be in very fine powder, it has a tendency to form a mass with a portion of the fluid, which is with difficulty penetrated by the supernatant liquid, unless continually agitated.

3d. Agitation. The stratum of fluid immediately in contact with the solid becomes saturated, it therefore cannot dissolve any more : its specific gravity is increased, and therefore it remains at the bottom and prevents any fresh liquor from coming in contact with the solid, unless we use agitation, which by dispersing the fluid already saturated through the entire mass, prevents any one portion becoming saturated before another, and thus favours the rapidity of the process.

4th. Heat favours solution, for generally speaking, salts are more soluble in hot than in cold fluids; the reason of this has been already mentioned when explaining the theory of this process.

This law of the solubility increasing with the temperature is by no means universal; many bodies, as muriate of soda, the alkali lithia, and others, are as soluble in cold as in boiling water, and some substances are even dissolved in less quantity by water at a high than at a low temperature. Thus the solubility of sulphate of soda increases to 90° and then decreases progressively to its boiling point. For,[*]

100 parts of Water dissolve of Sulphate of Soda,

Dry	5.02	10.12	28.11	50.65	46.82	42.05
Cryst.	12.17	28.38	99.48	322.12	262.35	
Temp.	32°	52°	76°	90°	122°	218°

Another salt, muriate of baryta, has been found by Brandes to present a still more curious anomaly, it increasing in solubility from 13° Fahrenheit to

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[*] Gay Lussac, Annales de Chimie, xi. 296.

122°, from whence it diminishes to 145°, and again increases until it reaches its boiling point. Thus :[*]

100 parts of Water dissolve of Muriate of Baryta,

Salt.	39.6	42.2	43.7	51	65	48	63	65	72
Temp.	61°	68°	72.5	100	122	145	167	190	212

An equally curious anomaly was found by Marx to exist in the case of nitrate of soda, which is nearly three times as soluble in water at 21°, as in water at 50°. Thus :[†]

100 parts of Water dissolve of Nitrate of Soda,

Salt	63.1	80	22.7	55	218.5
Temp.	21°	32°	50°	60°	246°

Among the organic principles these exceptions are more rare; albumen soluble in cold water but solidifying when heated to 160° cannot be considered as one, because it certainly undergoes some other changes. Duncan has however found one instance ; mudarine the peculiar principle, discovered by him in the bark of the root of the *Calotropis Mudarii,* is completely soluble in cold water ; but

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[*] Brandes, as quoted by Duncan, Dispensatory, 172.

[†] Berzelius, Traite de Chimie, vol. iii. p. 460.

latinizes, when the solution is heated to 85° or 90°, and again redissolves as the solution cools.*

5th. Pressure may also be mentioned as a means of promoting solution; it is probable that it acts merely by raising the boiling point of the fluid, and thus allowing a greater heat to be applied. In this way the gelatinous principles are extracted from bones by water heated in a digestor, which could not be dissolved out by water boiling at 212° under the common pressure.

An important phenomenon which almost always accompanies solution, is the production of cold. The reason of this is very evident; every substance owes its liquid form to the presence of heat, and when it liquefies it renders latent a quantity of caloric which it abstracts from the surrounding bodies, and of course reduces their temperature proportionally. This diminution of sensible heat is seldom in common cases very considerable, but where a large quantity of solid matter is liquefied, as where both solvent and solvend having been previously solid, become fluid on being mixed, a considerable depression of temperature is produced. On this principle is founded the mode of making freezing mixtures, combinations of solids with fluids, or with solids, which in passing to a liquid form produce a degree of cold capable of being applied to useful purposes. These mixtures are of considerable use in pharmaceutic and chemical processes; but the formulæ for making them, and the degrees of cold which they

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* Edinburgh Philosophical Transactions, 1830.

produce, being given in all the common books, need not be here repeated.*

Solution may be considered under two heads; 1st, where we operate upon a homogeneous solid entirely soluble in the medium, and 2d, where we act upon an aggregate of solid bodies, of which some are and others are not soluble in the fluid used, and we are thus enabled to effect their separation. We shall now consider the principal instances of each mode of solution.

SECTION I.

Solutions of an homogeneous Solid.

The principal solutions of homogeneous bodies in water used in pharmacy are

1st, Solutions of Acids, Bases and Salts.
2d, ———— Certain vegetable principles, as sugar, gum, starch, camphor, &c.
3d, ———— Certain animal principles, as albumen, gelatine, &c.

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* There are some salts which, when dissolved, produce heat in place of cold; they are those which as dry carbonate of soda, dry muriate of lime, &c. have the property of combining with, and rendering solid, a considerable quantity of water, the solidification of which producing more heat than the subsequent lique-

1st, *Of the Solubility in Water of the Acids, Bases, and Salts.*[*]

Solubility of Acids in 100 parts of Water.

Acids.	Temp. 60°	212°	Authors.
Arsenious	1.66	8.13	Bucholz.
Arsenic	16.6	50.	+
Benzoic	0.25	50.	Lichtenstein.
Boracic	3.33	33.6	Berzelius.
Citric	133.	200.	Vauquelin.
Gallic	4.16	33.3	Berzelius.
Oxalic	11.5	+	Do.
of Commerce	23.78	any quantity.	Kane.
	50.	100.	+
Phosphoric	20.	any quantity.	+
Succinic	4.	33.	Berzelius.
Tartaric	125.	200.	Gay Lussac.
Uric	0.01	+	Prout.

faction of the hydrated salt produces cold, the temperature of the fluid is slightly elevated: these therefore are only apparent exceptions. Salts containing much water of crystallization are those which produce most cold on solution, and are the most useful for making freezing mixtures.

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[*] These tables have been compiled generally from original authorities; in some instances, where there existed great contrariety between the experiments of others, I have given the results obtained by myself: where a number is not well determined, its place is filled by the mark +, and that mark met with in the column of authorities, indicates that the corresponding numbers have been taken from sources where the name of the author was not given.

Solubility of Bases in 100 parts of Water.

Bases.	Temp. 60°	212°	Authors.
Potassa, (Real) -	41.	56.5	Duncan.
——— Hydrated -	all proportions.		Berzelius & Thenard.
Soda, Hydrated -	very soluble.		+
Lithia, Hydrated -	very sparingly soluble.		Berzelius.
Baryta, Crystallized	57.	all proportions.	+
Strontia, Do. -	1.92	50.	Berzelius.
Lime, Anhydrous -	0.128	0.078	Dalton.
Magnesia - -	00.194	0.00277	Fyfe.

Solubility of Salts in 100 parts of Water.

Salts.	Temperature 60°.	212°.	Authors.
Alum, Potash - - - -	14.79	133.	Thompson.
——— Soda - - - -	110.	+	Gay Lussac.
Ammonia, Sesqui-carbonate	30.	100.	Ure.
——— Bi-carbonate -	12.5	decomposed	Gay Lussac.
——— Muriate - - -	33.	100.	Do.
——— Nitrate - - -	73.	173.	Do.
——— Phosphate - -	15.	25.	+
——— Sulphate - -	50.	100.	+
Antimony, Tartrate of, and Potash - -	6.6	33.	Duncan.
Baryta, Acetate - - -	88.	96.	Ure.
——— Muriate - - -	43.5	77.9	Gay Lussac.
——— Nitrate - - -	9.	35.	Do.
Copper, Sulphate - - -	25.	50.	Do.
Iron, Proto-sulphate - -	50.	133.	Do.
——— Tartrate of, and Potash	14.84	18.	Kane.

Salts.	Temperature 60°.	212°.	Authors.
Lead, Acetate - - - - -	27.	29.	Berzelius.
—— Muriate - - - - -	3.	5.	Gay Lussac.
—— Nitrate - - - - -	61.	79.	Kane.
Magnesia, Carbonate - -	0.04	0.0111	Duncan.
——— Sulphate - -	103.7	644.4	Gay Lussac.
Mercury, Proto-acetate -	0.178	+	Kane.
——— Bi-chloride - -	7.	35.	Gay Lussac.
——— Sub-persulphate	0.05	0.16	+
Potassa, Acetate - - -	100.	any quantity.	+
——— Bin-arseniate - -	43.18	149.35	Kane.
——— Carbonate - -	100.	any quantity.	+
——— Bi-carbonate - -	25.	decomposed.	Gay Lussac.
——— Bi-chromate - -	11.5	110.8	Kane.
——— Hydriodate - -	140.	+	Gay Lussac.
——— Muriate - - -	32.5	59.3	Do.
——— Nitrate - - -	26.6	246.15	Do.
——— Sulphate - - -	11.	26,3	Do.
——— Bi-sulphate - -	50.	100.	+
——— Oxalate - - -	33.	+	Gay Lussac.
——— Bin-oxalate - -	+	10.	Do.
——— Tartrate - - -	25.	all proportions.	Berzelius.
——— Bi-tartrate - -	1.05	6.6	Do.
——— Boro-tartrate - -	133.	400.	Do.
Silver, Nitrate - - - - -	100.	+	Gay Lussac.
Soda, Acetate - - - - -	33.	+	Do.
—— Carbonate - - - -	50.	100.	Berzelius.
—— Bi-carbonate - - - -	7.7	decomposed.	Do.
—— Borate - - - - -	16.5	50.	Gay Lussac.
—— Phosphate - - - -	31.94	263.2	Kane.
—— Sulphate - - - -	37.	125	Gay Lussac.
—— Bi-sulphate - - - -	50.	73.	Berzelius.
—— Nitrate - - - - -	55.	218.	Marx.
—— Tartrate - - - - -	20.	all proportions.	Berzelius.

Salts.	Temperature 60°.	212°.	Authors.
Soda, Bi-tartrate - - -	12.5	50. 5	Do.
—— Tartrate and Potash	40.	+	Do.
Strontian, Muriate - -	140.	all proportions.	Gay Lussac.
——— Nitrate, anhydrous	83.14	113.63.	Kane.
Zinc, Sulphate - - - - -	40.	+	Gay Lussac.

2d. *Aqueous Solutions of homogeneous vegetable Principles.*

OF SIRUPS.

Sirups are of two kinds, simple or compound.

Simple sirup is prepared by dissolving twenty-nine ounces of refined sugar in one pint of water, by digestion with a medium heat, (from 100° to 200°.)

The compound sirups are made by dissolving sugar in solutions of various substances, obtained in many instances by infusion, as in sirup of roses, of violets, and oranges; in others by decoction, as in sirup of sarsaparilla, of marsh mallow, &c.; and in some by direct expression, as in sirup of lemons and of buckthorn.

The principal circumstances to be attended to in the preparation of sirups, are 1st, the kind of sugar, 2nd, the management of the heat, 3d, the degree of concentration of strength to which the sirup is to be brought, and lastly their preservation when made.

The sugar used in the preparation of sirups should be perfectly pure; the Pharmacopœias therefore direct that refined sugar should be employed. Under peculiar management, however, the better varieties of raw sugar can be made to yield sirups no way inferior in colour or taste.

From the mode of its clarification the sugar of commerce generally contains a small quantity of lime. In preparing the sirup of lemons with such sugar we have found a portion of insoluble citrate of lime, which is not of importance; the presence of this impurity is however to be guarded against in the preparation of sirup of violets, as the fine blue colour of the petals would be materially injured by it.

The best mode of making sirups from non-refined sugar is that of Dumoriez.

He places 40 pounds of common sugar in a tinned copper vessel, and pours on it 22 pounds of cold water, leaves the water in that state to dissolve the sugar, with occasional agitation, until the next day, and then adds to the solution ivory black, which had been freed from the phosphate of lime by muriatic acid. He leaves it to digest for a day, and then throws the whole upon four paper filters.

The sirup thus obtained is colourless, perfectly limpid, and of the specific gravity of 1.263.

The heat used in the solution of the sugar should be moderate, and applied either by means of a water, or of a steam bath; the operation should be executed as quickly as possible, for sugar, when subjected to a prolonged, although moderate heat, becomes altered and uncrystallizable. When, therefore, it is necessary to evaporate the sirup this should be done rapidly, as the use of a moderately high heat is much less detrimental, the length of the operation being thereby considerably diminished.

Sirups when well prepared should be limpid,* of a certain viscidity of consistence, and capable of being preserved without entering into fermentation or crystallizing. These last properties depend on the proper proportioning of the sugar, an excess of it being generally deposited in a crystalline form, and where it is deficient, the sirup runs into fermentation.

There are various modes of ascertaining whether this mean has been attained; the principal are the density of the sirup and the point at which it boils. The specific gravity of well prepared simple sirup is, when boiling, 1.261, and when cold (60°) 1.321. According to Thompson, when cold it ought to be 1.385. The boiling point of sirup, of the specific gravity whilst boiling of 1.261 is 221° Fahrenheit. The thermometer and the hydrometer are therefore the most certain means of ascertaining when the preparation of a sirup is finished.

There are, however, other signs which, although very certain, require some degree of experience to be used without danger; they are derived from the degree of viscosity which the sirup has acquired, as evinced by the time which the parts of a drop di-

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* Except sirup of tolu, which is opaque from the suspended resin.

vided by a spoon take to reunite, and by the length of thread which a drop will produce before detaching itself from the extremity of the string; where the small quantity of the sirup, on cooling, presents a crystalline pellicle, the evaporation has been carried too far. Where, however, the sugar is mixed with an acid, or where the process has been too much prolonged, the sugar loses its power of crystallizing, and no matter how far concentrated, the solution does not present a pellicle when cooled.

When sirups are kept they occasionally undergo various alterations, the nature of which depends on the quantity of sugar used, on the nature of the solvent, and on the degree of care with which the preparation has been made.

The acid sirups, as sirup of lemons, if too concentrated undergo a very peculiar change. A short time after having been prepared they deposit at the bottom of the bottle a quantity of solid matter, and sometimes solidify entirely. By a moderate heat their fluidity may be restored to them, but after some time they again lose it. This deposit is a peculiar combination of the acid and the sugar; it is not crystalline but granulated like cauliflowers.*

When the sugar bears too small a proportion to the liquid, the sirup is often spoiled by fermentation. But even when it is in proper quantity, this change often comes on, if the solution contains much amylaceous or extractive vegetable matter; for these principles themselves undergoing a certain

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* Chevallier, Manuel du Pharmacien, 1831, vol. i. p. 257.

degree of decomposition act as a yeast, and excite the fermentation of the sugar.

When the sirup is too concentrated, it gradually deposits a quantity of the sugar in a solid form. In this case also, the liquor often enters into fermentation, for the crystals formed by the excess of sugar take away in time a quantity of that which is necessary for the preservation of the sirup, and the equilibrium being thus broken, decomposition sets in. What passes here is precisely similar to that which takes place in saline solutions saturated while hot; the crystals which occupy the bottom of the vessels go on increasing in volume, whilst those which were originally attached to the sides finally disappear; so that in sirups, as in saline solutions, the density of the inferior is greater than that of the superior layers of the fluid. The superior strata finally become sufficiently diluted to allow fermentation to commence.

The means of preserving sirups are therefore the methods of guarding against those alterations to which they are subject. They should always be kept in a cool situation (55° F. Phar. Lond.) and, except in immediate use, should be protected from the agency of air, by being preserved in bottles carefully closed. The subject will be more minutely entered into at the article, *Fermentation.*

The mucilages of starch and gum do not require any particular notice.

3rd. *Solutions in Alcohol of Homogeneous Solids.*

The inorganic substances soluble in alcohol are not so numerous as those soluble in water, in which fluid they are, with very few exceptions, also capable of being dissolved. The saline substances soluble in alcohol are in general deliquescent, and those insoluble or sparingly soluble in water are not soluble in alcohol. The efflorescent salts are similarly circumstanced.

The solubility in alcohol of the various acids, bases, salts, &c. is not so accurately known as that of the same substances in water. Tables have been constructed by Macquer, Wenzel, Thenard, and others, of the quantities of different substances dissolved by alcohol of various specific gravities, but the discordance of their results prevents us from placing any firm reliance upon the numbers given.

Gmelin * gives the best resumé of the substances soluble in alcohol. It dissolves,

1st. The arsenious, chromic, boracic, arsenic, and molybdic, among the mineral acids.

2d. Most of the vegetable acids : particularly the benzoic, boletic, suberic, kinic, malic, meconic, gallic, succinic, &c. The citric, and tartaric acids in but small proportion.

3rd. Potassa, and soda are abundantly soluble ; lithia, baryta, strontia, and lime, but sparingly.

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* Handbuch der Theoretischen Chemie : 2ten Band, 1sten abtheilung. p. 297, et seq.

4th. Most of the bases of organic origin, as quinine, morphine, emetine, &c.

5th. The sulphurets, chlorurets, iodurets, and cyanurets of potassium, and sodium. The chloruret, and sulphuret of lithium; the chlorurets of strontium and calcium; of zinc, of antimony, of iron, and of gold; the deuto-chlorurets of mercury, and of platina,* and the ioduret of tin.

6th. The hydrothionates (hydrosulphurets) of potash and of soda, of baryta, strontia, lime, and magnesia.

7th. The nitrates of soda and of lithia; of lime, magnesia, cerium, glucina and zirconia; of cobalt, of zinc, iron, nickel, and of silver. The sulphates of lithia, of uranium, and of platina; the per-sulphate of iron; the chlorates of soda, strontian, lime, and of magnesia.

8th. The acetates of potash, lime, baryta, ammonia, and zinc. The per-acetate of iron.

9th. It also dissolves some of the simple substances, as iodine, abundantly; selenium, phosphorus, and sulphur in smaller proportion, and absorbs many of the simple gases in nearly the same quantity as water.†

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* The double chloruret of potassium and platinum is totally insoluble in alcohol; and hence, in order to give the platinum test all its delicacy, the suspected base is to be converted into a chloruret, and dissolved in alcohol, a solution of chloruret of platinum in alcohol is then to be added, and a precipitate is produced, if the solution contains even a very small proportion of potash.

† In general the weaker the alcohol is, the more salt it is

There exist many officinal solutions of salts in alcohol; as of the per-acetate of iron, the acetate of zinc, the per-muriate (one and half chloride) of iron; and a solution of iodine containing about 7.7 per cent. of that substance. This preparation does not require any particular remark.

There are few homogeneous solutions of organic principles in alcohol, made by the pharmaceutist. Solutions of some vegetable bases, as strychnine and morphia are kept for medicinal use; a solution of camphor, and solutions of the volatile oils, which are termed essences.

The power of the other substances, used as solvents, is not of great pharmaceutic interest. The most important is ether; it dissolves most of the inorganic substances soluble in alcohol, but in smaller proportion than that fluid. These solutions are readily decomposed; the ether yielding hydrogen, sometimes to the oxygen of the acid, in which case the oxide of the metal is precipitated, and sometimes to the oxygen of the oxide, when the metal is revived; these effects are much favoured by the influence of light.* Ether dissolves most of the organic principles soluble in alcohol, and some, as resins and fats, in greater proportion.

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capable of dissolving, in consequence of the combined water also acting upon the solid body; there are some salts, however, more soluble in strong than in weak alcohol, as muriate of magnesia, of which Kirwan found 100 parts of alcohol, sp. gr. 848. to dissolve 23.75; of .834, 36.25; and of .817,50 parts. The same takes place, though more limitedly, with acetate of lime.

* Gmelin's Handbuch, &c. Band. ii. ab. 1st, 311, et seq.

SECTION II.

Solutions of an heterogeneous Solid.

THE operations by which solutions of heterogeneous substances are effected are various, and receive different names, according to the temperature at which the fluid is used. The principal are,

Maceration, performed at from	60° to 90° Fahr.
Digestion	90° to 100° do.
Infusion, the temperature descends from	212° do.
Decoction .... is retained at	212° do.

1st. *Maceration* is an operation, in which, by the action of a fluid at common temperatures, continued for a certain length of time (from twelve hours to seven or eight days) a solution of the principles of an organic substance soluble in that fluid is obtained.

Maceration is used, 1st, where it is designed to dissolve only some of the principles of the heterogeneous substance, and to obtain a preparation free from other substances, which would dissolve if a higher temperature was employed, and would impair its efficacy, or render it less elegant as a medicinal agent. 2nd. Where either the solid or the fluid would be injured or dissipated by exposure to heat. Thus the medicated vinegars and wines must be prepared by maceration, and in infusions which contain aromatic substances; these last should not be added until the fluid has cooled down nearly to the temperature of the atmosphere.

Maceration is sometimes employed as a preparatory step to other operations. If we wish to extract the medicinal principles of certain dense roots, or hard woods, it is very useful, previous to boiling them, to let them macerate for some time. By this mode the water gradually penetrates through the substance; softens it, and render its cells and vessels easily permeable to the boiling water, so that the solution of its active constituents becomes much more perfect and more easily effected. In maceration, and the other solutions of vegetable substances, soft water should be employed, those prepared with hard water being of much inferior value.

Provided it be not acted upon by either of the materials, the nature of the vessel in which maceration is performed is of no consequence. It should however be covered, to prevent evaporation.

The menstrua used in maceration are various:

Water, as in different cold infusions.
Alcohol, as in different tinctures.
Wine, as in medicated wines.
Vinegar, as in medicated vinegars.

The preparation of cold infusions requires little additional remark; the time should not exceed from twelve to twenty-four hours, as solutions thus prepared are very liable to decomposition.

The solutions obtained by macerating vegetable or animal substances in alcohol are termed *tinc-*

tures; they are *simple* when but one, *compound* when many substances are used in their preparation.

The strength of the alcohol employed varies according to the nature of the substance to be dissolved; if it be mostly resinous, rectified spirit, sp. gr. .840, is directed to be used; if it contain also matters soluble in water, and insoluble in very strong spirit, as gum, &c. which yet it is desirable to hold in solution, proof spirit, sp. gr. 919. is used as the solvent.

The period of maceration varies from seven to fourteen days; during the process the vessels should be kept carefully closed, to prevent loss by evaporation.

When the spirit has remained upon the solid matter for the directed period, it should be immediately decanted; it is often customary, in place of doing this, to leave the tincture standing upon the dregs until it is used; the evil consequences of this method are well remarked on by Mr. Brande, who relates a circumstance that may serve to impress its incorrectness upon the operator:

" A person suffering under hydrothorax, who had been in the habit of taking forty drops of tincture of digitalis every night, went from home without his medicine, and was obliged to send to an apothecary in the country for an ounce of the tincture, of which he took the accustomed dose: its effects were much more violent than usual; and he died, exhausted by repeated faintings, in the morning. Very particular inquiries were made respect-the quality of the tincture, when it appeared that the leaves had been shaken out of the bottom of the vessel in nearly a dry state, since an ounce of the tincture was with much difficulty squeezed out of them. Here therefore the strength of the tincture was not only increased by long standing, but probably very greatly augmented by evaporation, and there is little doubt that the patient died of the overdose, and not of the disease."*

There are some tinctures made with ether as the menstruum; the Codex Medicamentarius contains many of these formulæ; the Edinburgh and London Pharmacopœias one. The Dublin Pharmacopœia possesses no etherial tincture.

There are some tinctures made with an alcohol containing ammonia (spirit of ammonia.) These are called *ammoniated* or *volatile* tinctures.

It was originally considered that the solvent powers of the alcohol were enhanced by its combination with the alkali, but the contrary has been since proved to be the fact.

Medicated wines are solutions in wine of the soluble principles of certain vegetables. The wine directed to be employed is the Spanish white wine (sherry,) because it is rich in alcohol, and contains but little colouring matter liable to decomposition.

The dissolving power of wine on vegetables is easily understood by considering its composition. All wines are formed in variable proportions of water, alcohol, a little acetic acid, bi-tartrate of

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* Manual of Pharmacy, page 81.

potash, and other salts of potash and lime, of mucilage, colouring matters and tannin. Of all these bodies the water and the alcohol are the sole agents of solution; the first dissolving the extractive matter and the salts, the second the resinous and aromatic principles. The bi-tartrate of potash was of use when formerly the wines of iron and of antimony were prepared by digesting the wine on the metal, a potash-tartrate being formed in both instances, but these preparations are now very justly abandoned for more certain and uniform modes.

The other principles of wines are injurious to it as an excipient. The mucilage, &c. disposing it to fermentation, especially when a new quantity of these substances is dissolved during medication, and the colouring matters and tannin frequently injuring the preparation, by combining with, or decomposing the active principles of the vegetables dissolved.

On this account the use of wine as a solvent is beginning to be laid aside, and mixtures in different proportions of alcohol and water are substituted as a solvent for it. This change is a considerable improvement, and abolishes the almost only remnant (at least in these countries) of the ridiculous ancient polypharmacy.

Vinegar used as a solvent forms what are termed the *medicated vinegars:* they are also gradually disappearing from our Pharmacopœias, according as our means of simplifying pharmaceutic preparations increase with the progress of science.

The only superiority which vinegar possesses over water as an excipient, is where the activity of the medicinal substance depends on the existence of an alkaloid, which forming with the acetic acid a salt readily soluble, it may be more perfectly extracted by means of this acid fluid than by mere water.

The vegetable matter which even distilled vinegar contains renders it liable to decomposition; this may be avoided by using the pure acid suitably diluted. Solutions of the acetates of the vegetable alkalies in water, or in a dilute alcohol, may be however substituted for these preparations with all their good effects and without their disadvantages.

2d. *Digestion*—The action of the solvent is promoted by a gentle heat, otherwise the process is the same as maceration; it is used in obtaining the same products, and they are in many cases employed indifferently; it consequently does not require any particular remark.

3d. *Infusion,* (hot infusion, Duncan,) is an operation which consists in raising the temperature of a liquid to its boiling point, and then pouring it on the body (in coarse division), the soluble parts of which we wish to extract; they are left in contact for some time, generally until the liquid is quite cold, and during the refrigeration are frequently agitated.

In infusion, the high temperature of the liquid augments very much its solvent power, and thus we dissolve substances which would not be extracted by simple maceration. This energetic action lasts but for a short time, as the temperature of the fluid progressively decreasing, finally sinks to that of the surrounding objects; hence infusion is applicable best to such matters as are easily permeable, as leaves, flowers: those, the properties of which would be impaired by ebullition, as cloves, orange peel, and some barks; but it is not so fitted for extracting the virtues of dense roots or woods, from its action being of so short duration; except in cases, as colombo, where we wish to avoid the solution of a principle which would be taken up by decoction, and would injure the preparation.

The vessels in which infusions are made are generally stone, or earthen-ware. As it is an object in the preparation to retain the heat as long as possible, polished metallic vessels, provided they be not acted upon by the infusion, would be the most applicable, as they, from their very inferior radiating power, would allow of the escape of less heat than almost any other material.

These preparations are only made for extemporaneous use; they very soon run into decomposition, and consequently cannot be prepared in any quantities for keeping.

4th. In *Decoction* the substance to be acted upon is subjected to the solvent action of a liquid at its boiling point, generally for a few minutes only; occasionally where the substance is with difficulty extracted, the ebullition is continued for a much longer period. The menstruum in all the officinal decoctions is water.

By decoction we are enabled to dissolve all the principles of a vegetable soluble in water, and even many substances, not properly speaking soluble in that fluid, are by this process diffused through it, and held in suspension by means of other principles of more easy solubility. Thus the acrid oil of liquorice, insoluble in water, is contained plentifully in the officinal decoction ; we can use a decoction of rattle-snake root (*polygala senega*) with great effect as a therapeutic agent, although its active principle, (senegine) is totally insoluble in water, and guïacum yields to decoction a quantity of its peculiar resin. On the other hand there are many substances which would be injured or dissipated by decoction. The aromatic substances would lose their oils by being subjected to this process ; rhubarb and senna lose their purgative properties by decoction ; the bitter principle of the liverwort (*cetraria islandica*) is destroyed ; and sugar, by too long exposure to a boiling temperature, loses its power of crystallizing.

Generally, it is necessary to employ decoction where we have to act upon bodies of great density and with difficulty permeable : and where it is required to obtain in solution principles not soluble in the liquid, *per se,* and which can only be dissolved by means of other substances and the action of a certain degree of heat.

On the other hand there are many cases where its use should be prohibited ; when the vegetable principles are easily alterable, by heat or by exposure to the air ; where there exist in the solid used, substances, which it is not desirable to obtain in the solution, and which would be dissolved by ebullition, as starch ; and where the substance contains a volatile ingredient.

In many instances, the decoction, on cooling, deposits a portion of the material which it had dissolved by the aid of heat; this is particularly the case with the astringents; this matter is however not totally inert, and ought not to be separated from the fluid; the decoction should be strained while hot, before the deposition begins to take place.

The water used in this, as in all the other solutions of vegetable substances, should be soft; the solid cut into small bits, or broken into coarse powder; the vessels may be metallic, but should be rather deep to prevent as much as possible the influence of the air upon the product.

Like infusions, decoctions are only made for extemporaneous use; they are easily decomposed, and containing a number of vegetable principles in solution, as tannin, colouring matters, that indefinite substance *extractive matter*, &c. are precipitated by a number of the metallic salts; the incompatibility of substances in prescription is however the province of the Pharmacologist, and does not belong to Pharmacy.

Genus 2d.—*Of Vaporization.*

The transformation of liquids into elastic fluids, is termed *vaporization.* This change is by *ebullition,* when the vapours are formed throughout the mass of the fluid; by *evaporation* when they are produced only at the surface.

When we heat a fluid to its boiling point in a glass vessel, and observe the phenomena, we see that bubbles of vapour are formed on the heated parietes of the vessel, which ascend through the fluid, and break on arriving at the surface; at first small, they increase in size as they ascend, and are less pressed upon, and are generated in greater quantity where the strongest heat is applied to the vessel. In order that these bubbles could be formed and ascend in the midst of the fluid which presses them upon all sides, it is evidently necessary that the vapour of which they are composed should have a degree of tension equal to the surrounding pressure, and it is the degree of heat necessary to give that tension, which determines the boiling points of different liquids, and of the same liquids under different pressures.

When the liquid has arrived at the point of ebullition, its temperature remains constant until the entire mass has been vaporized; consequently the whole of the heat applied has been employed in forming the vapour with which it remains combined and latent; this is called the caloric of vaporization, and is analogous to the similar disappearance of sensible heat that accompanies fusion. The quantity of heat thus rendered latent varies for different substances; in water it is greater than in most other fluids, and equals about 967° Fahr.*

Such a quantity of heat being absorbed during

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* The sensible and latent heats of steam make a constant quantity: if the boiling point be raised, the latent heat of the steam produced at that temperature is proportionally diminished; this is the reason why high pressure steam will not scald; I know not if other vapours follow the same rule.

vaporization, it is manifest that unless the heat be supplied in sufficient quantity from a certain source, the temperature of the mass of fluid and of the surrounding bodies from which it it is derived will be considerably depressed; this is the reason of the great cold produced by evaporation.

If we pour a little ether into the hollow of the hand, we immediately feel a degree of cold; and if the evaporation be promoted by rapidly removing the vapour as it is formed, water may be readily frozen in this manner.

By using liquids, volatile at very low temperatures, intense cold may be produced. Thus Bussy, from the vaporization of liquid sulphurous acid, was enabled to condense, by simple reduction of temperature, all those gases which Faraday liquefied by pressure. The congelation of mercury, by surrounding the bulb of a thermometer with cotton, moistened with sulphuret of carbon, and placed in an exhausted receiver, is a very striking and simple experiment.

Different substances demand different degrees of heat to make them enter into ebullition; the boiling points of some of the more important are here given:—

Ether -	- sp. gr.	0.7365 at 48°		Gay Lussac	100°
Carburet of sulphur	—			Do.	113
Alcohol, -	sp. gr.	0.813	——	Ure.	173.5
Nitric acid,	——	1.500	——	Dalton,	210
Do.	——	1.450	——	Do.	240
Do.	——	1.400	——	Do.	247
Do.	——	1.300	——	Do.	236
Do.	——	1.160	——	Do.	220

Muriatic acid, sp. gr.	1.127	at 48°	Dalton,	222°
Do ——	1.094	——	Do.	232
Do. ——	1.047	——	Do.	222
Water,				212
Rectified petroleum,			Ure,	306
Oil of turpentine,			Do.	316
Sulphuric acid,——	1.30	——	Dalton,	240
Do. ——	1.52	——	Do.	290
Do. ——	1.73	——	Do.	391
Do. ——	1.810	——	Do.	843
Do. ——	1.842	——	Do.	545
Do. ——	1.848	——	Ure,	600
Do. ——	1.850	——	Dalton,	620
Phosphorus				554
Sulphur				570
Mercury, (Dulong 662°.)				656

The boiling point of a fluid is not perfectly fixed; it may be depressed or raised by a number of circumstances, the principal of which are the amount of the super-incumbent pressure, the cohesion of the fluid, the nature of the containing vessel, and the depth of the fluid.

Pressure. The ebullition of liquids commencing when the elastic force of their vapours* is equal to the atmospheric pressure, it is evident that the boiling point must follow the variations of the barometer; these are in general so small that it is only where, as in Wollaston's thermometer, the degrees are extremely large, we are able to observe them.

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* The elastic force or *tension* of a vapour is estimated by the height of a column of mercury which it is able to sustain; at the boiling point this height is equal to that which the atmosphere sustains in the barometer, or about thirty inches.

But where we diminish the pressure considerably, as by forming a vacuum more or less perfect over the surface of the heated fluid, we there observe a great depression of the boiling point; thus, water merely milk-warm, will boil violently in an exhausted receiver, and ether may be converted into vapour at the temperature of — 40° Fahrenheit. Professor Robinson found that fluids generally boil *in vacuo* 140 degrees lower than in the open air.*

On the contrary, when we submit to the action of heat, a liquid contained in a closed vessel, the vapour which is generated increases the elastic force of the internal atmosphere which presses upon it, and continually retards the ebullition up to a certain limit for each fluid, beyond which the entire of the mass is converted into vapours of great density, which occupy the entire volume of the vessel.†

On this principle is formed the common digester of Papin, in which the vapour being confined by

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* The important applications of this principle to distillation and evaporation will be described under those heads: the general fact only is mentioned here.

† This fact, which was proved by Cagniard de la Tour, deserves notice. He found that ether was converted into vapour in a closed vessel at the temperature of 300° Fah. and occupied a space only twice its original volume; this vapour exercised a pressure of seventy atmospheres. Alcohol and water presented the same phenomenon; the exact temperature at which it took place could not be observed, but alcohol, on vaporizing in a space three times its own volume, produced a pressure equal to 119 atmospheres; that of water was still greater. Annales de Chimie, xxi. 178.

a valve, the water is subjected to a pressure of many atmospheres, its boiling point considerably raised, and its solvent power very much augmented. Water can in these vessels be raised to 250° or 300°, and Muschenbrock states that he thus melted tin ; they are not used in pharmaceutic operations, but principally for extracting the animal matter from bones.

The cohesion of the liquid may, according to Gay-Lussac, have an influence in modifying the principle, that the liquid boils when the tension of the vapour is equal to the atmospheric pressure. In fact, the small bubbles cannot form without separating the particles which surround them, and therefore they have to overcome, as well the cohesion of the liquid, as the atmospheric pressure, and so the liquid does not enter into ebullition until the force of its vapour is greater than the pressure by a quantity equal to the force of the cohesion of the liquid ; but the bubbles once formed, the effect of cohesion is diminished, and the vapour suddenly expands ; on this account ebullition is retarded, and when commenced, proceeds irregularly and in bursts.*

The nature of the vessel influences also the point of ebullition ; Gay Lussac remarked that water boiled more readily in a metallic than in a glass vessel, and he attributes the cause to a certain action, similar to cohesion, taking place between the smooth surface of the glass and the vessel. The metal, no matter how polished, is not perfectly smooth, it

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* Annales de Chimie, Mars, 1818. and Pouillet Elemens de Physique, tome 1re. p. 353.

affords a number of minute points on which the vapour is more easily generated, and thus enables the liquor to boil at a lower temperature. The fluid may be made to boil at as low a temperature in a glass vessel, if a metallic wire, a few filings, or in fact any pointed body, as glass or saw dust, be immersed in it ;* this addition remedies at the same time another inconvenience ; it prevents the formation of those sudden bursts of vapour that sometimes take place and renders the vaporization regular and quiet. This will be again adverted to when speaking of the distillation of sulphuric acid.

Where the mass of fluid is very deep, in addition to the pressure which is exerted on the surface, the inferior strata support also the pressure of the super-incumbent strata : thus if in a boiler the water was thirty-two feet in depth, the bottom layers are pressed upon by two atmospheres, and therefore no vapour can form until the temperature rises to 249°8; the superior layers, however, do not exceed the usual temperature of boiling water, and so the heat gradually diminishes as we ascend; this takes place even in small vessels for a short time before ebullition commences; the layers at the bottom become sufficiently heated to boil, small bubbles are formed,

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* An experiment which may serve to impress this fact upon the memory, and is very easily performed, is to boil a little water in a flask, remove it from the fire, and when it has cooled one or two degrees, to throw into it a few iron filings ; ebullition immediately recommences for a short time, the vapour being formed at the edges and angles of the filings: perfectly spherical bodies have been found by Thenard not to produce the same effect.

which ascending, pass into colder strata, and are there condensed suddenly with a kind of noise, termed *simmering*.

Vaporization is the basis of some of the most important operations in pharmacy; we may consider the processes in which it occurs under two heads; 1st, those in which it is performed for sake of the volatilized product; and 2ndly, where the solid body which had been dissolved by the liquid is regained by the evaporation of the latter.

There are two circumstances connected with vaporization, which are important in their consequences: 1st, that although vaporization (of water, for instance,) takes place at all temperatures, yet that each substance has a point at which its vaporizability ceases, and below that temperature it is perfectly fixed: this has been fully proved by Faraday to be the case,* and we have many bodies which, at common temperatures, are quite fixed, although, on raising the heat a little, they generate vapour, as sulphuric acid, which boils at 600°, and mercury, which gives off vapours at all temperatures above 30°, while below 20° none are produced, so that at temperatures below that degree, the space above the mercury in the barometer is a real and perfect vacuum, and the only one we can form.

It is universally known that many bodies which require a much higher heat to make them boil, distil over very rapidly at 212° in company with the va-

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[*] Philosophical Transactions, 1826, and Journal of the Royal Institution, vol. i. p. 70.

pour of water; this is the method of rectifying the essential oils which, on the condensation of the mixed vapours, are obtained unaltered and free from empyreuma.

Many other bodies which require under ordinary circumstances a much greater heat to effect their volatilization, when their aqueous solutions are distilled, rise, although in small quantity, along with the watery vapour. A solution of ten grains of bi-chloride of mercury in eight ounces of water having been distilled to one half, the distilled portion of the fluid contained evident traces of the salt; arsenious acid was found to act in a similar manner, and some other substances, though not so remarkably.*

This fact is of importance, particularly in medico-legal analyses. It teaches that suspected liquors should be concentrated, not by evaporation, as is at present done, but by distillation; and in certain cases, the distilled fluid being freed from all colouring organic matter may be of advantage in the preliminary use of re-agents.

Species, 1st. *Of Vaporization for sake of the volatile Body.*

This class of operations may be conveniently divided, according as the product is a liquid or a solid body; *i. e.* into *distillation* and *sublimation.*

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* These experiments were made long since, but from other occupations were not followed up, or published. Since they were

Variety 1st. *Of Distillation.*

The object of distillation is to separate a volatile liquid from other matters which are either fixed, or volatile, but requiring for their volatilization a different temperature.

Distillation consists of two distinct processes; 1st, the production of the vapour, and 2nd, its condensation.

The circumstances to be considered in the production of the vapour are, 1st, the mode of applying heat; and 2d, the vessels in which the vapour is generated. The different modes of applying heat have been already generally described; the applications of particular modes to certain peculiar processes will be hereafter adverted to.

The instruments used in distillation are the retort and the still; one or other is used according to the nature and quantity of the substance to be operated on.

Retorts are made of various materials, as glass, earthen-ware or porcelain, lead, iron or platina: the form of the instrument requires no remark. They are sometimes tubulated, at others plain. The tubulated are more convenient for facility of charging without soiling the neck: where fluids are to be in-

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performed, Faraday has remarked the volatility of corrosive sublimate at common temperatures, and Saladin, (Journal de Chimie Medicale, 1830, page 553,) the volatility of arsenious acid, &c. in vapour of water.

troduced into a plain retort, a bent funnel sufficiently long for the extremity of it to reach the body of the retort is to be used for that purpose, by inclining the neck of the retort downwards, and elevating the extremity of the funnel, it may be then withdrawn without any of the fluid coming into contact with the neck. Solids in powder may be introduced in the same manner; or if the neck be clean and dry, the use of the funnel may be dispensed with, as none of the solid body can adhere to it.

These retorts are sometimes immersed in a sand or a water-bath; sometimes heated by means of a lamp, and occasionally are raised to a full red heat in certain processes, by being placed in a crucible or a reverberatory furnace. For these last purposes they are always coated previous to use.

The common still does not require any illustration: it consists of two parts: the boiler, which is that to which the heat is applied, is generally of a cylindrical shape, and may be either exposed to the naked fire, or immersed in a water-bath, according to the temperature to be employed. The second part is the head or capital, generally of a globular form, the top of which tapers to a pipe, and being curved laterally, communicates with the extremity of the serpentine or worm, which is a very long tube immersed in cold water, in passing through which the vaporized substance is condensed.

The vessels in which condensation is effected are termed refrigeratories, condensers, or receivers. The common refrigeratory used with the common still is the worm above described. The rapidity of condensation depends upon two things, by attending to which much more perfect refrigerating instruments than that, have been proposed and used; the first is the constant supply of cold water, and the second, the exposing as large a surface as possible of the vapour to its action.

The condensation taking place almost entirely in the first coils of the worm, and the heated water being specifically lighter than the colder fluid; the water in the top of the worm tub becomes very hot before the temperature of the lower portion is much raised. It is the object therefore to remove this heated stratum, which is effected by inserting the exit pipe of the water near the top of the tub, while the tube bringing the cold water from the reservoir is conducted down, and opens at the bottom of the refrigeratory. Edelcrantz proposed shutting up the top of the refrigeratory, and making it part of a syphon, and thus keeping up a constant current of water through it without the necessity of a reservoir above the worm tub.* There are however many objections to the use of this mode in practice.

Many modifications of the common worm have been used with success. The baron Gedda used a refrigerating apparatus, composed of two truncated cones, with the same axis, but of different diameters; the interval separating them being of some inches above, and but of a few lines below. This interval is closed below by a diaphragm of copper soldered,

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* Peclet, Traité de la Chaleur, vol. ii. page 229.

above by a diaphragm luted only in order to allow of being removed, and the interior cleansed. The lower part is inclined, and furnished with a tube and stopcock for the exit of the condensed fluid; and at the upper part is another tube which receives the tubular end of the capital of the still. This apparatus is easily cleansed, and possesses great condensing power; it has perfectly succeeded in practice.*

Peclet † found the apparatus, Plate V. Fig. 1. to be of great power under a small volume. It consists of a series of circular boxes slightly inclined, and communicating by means of tubes of a small diameter; very nearly the same disposition had been made use of with success, and a description of the instrument published by Mr. B. O'Reilly, an apothecary of this city, without any knowledge of Peclet's previous invention.‡

The condensers used with retorts are generally globular vessels, sometimes plain, at others furnished with a quill dipping into a bottle or flask, which assists in the refrigeration, and receives the portion of fluid condensed in the neck of the retort, and in the globe. The cooling of these receivers is effected by covering the neck of the retort and the globe with bibulous paper kept moist by water, which evaporating, keeps their temperature low; the flask or bottle is generally immersed in water, retained at or below 40°, by means of a few bits of ice. The

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* Peclet, Traité de la Chaleur, vol. ii. page 230.

† Opus Citatum, vol. ii. page 230.

‡ Dublin Philosophical Journal, vol. ii. page 521.

minutiæ of this mode of condensing, as described by Faraday, is well worthy of the attention of the operative student, Plate V. Fig. 2. represents the retort, receiver and flask, fitted for refrigeration; their joints closed by corks, and secured by means of bladder or linseed lute: "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 above the junction of the retort, with the receiver as at A.; it should be moderately tight round the glass, and should be carefully separated from the bladder or cork beyond, 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; 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 are of such inclination that the fluid condensed will run down the neck into the receiver, and not return again to the body of the retort.

"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, and also shall descend upon the paper a little way from its upper extremity. 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 then descend and be caught in a basin placed underneath, 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."*

When during a distillation some gaseous matter is generated, which is to be collected, the condenser is fitted with a tubulure, to which is adapted a tube to conduct the elastic fluid to its proper receptacle; the suitable apparatus for such products will be hereafter described.

It has been already shown, that fluids are converted into vapour at very low temperatures, when the atmospheric pressure is removed. This fact was applied to practice by Watt for economic purposes, but he found that there was no saving of fuel in the process, because, as the latent and sensible heats make a constant quantity, the caloric supplied must always be the same, the quantity of heat absorbed being greater, as the temperature of ebullition is depressed; however, in pharmacy the mode of distil-

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* Chemical Manipulation, page 213.

ling *in vacuo* is yet of importance, for by this process, products, containing an easily alterable substance, as the distilled oils and waters, may be obtained of a much superior flavour to those distilled under the common pressure.

The only instrument for this purpose which requires to be described is the still of Tritton, for which a patent has been taken out: the still is of the common form, but instead of being placed immediately over a fire, it is immersed in a vessel containing hot water. The pipe from the capital bends down and terminates in a cylinder or barrel of metal plunging into a cistern of cold liquid. From the bottom of this barrel a pipe proceeds to another of somewhat larger dimensions, which is surrounded with cold water, and furnished at the top with an exhausting syringe.

The pipe from the bottom of the still for emptying it, and that from the bottom of each barrel, are provided with stop-cocks; hence, on exhausting the air, the liquid will distil over rapidly when the bottom of the alembic is surrounded with boiling water.

Duncan has ingeniously applied the barometric valve to effect the exhaustion of the still and receivers, without a syringe or pump; he connects with the condenser a tube thirty inches long, the lower end of which dips into a shallow dish containing a sufficient quantity of mercury to fill it. The boiler is then heated until the whole air be expelled through the tube, and vapour begins to escape; and upon condensing the vapour in the condenser, the mercury rises in the tube, effectually precluding the pressure of the atmosphere, and the distillation may be completed at a greatly reduced temperature.*

Although not yet applied to any particular pharmaceutic process, the complex distillatory apparatuses or *appareils d'analyse des vapeurs*, as they are termed by the French, demand mention from their importance; they are used generally in the distillation of brandy, and are capable of giving at a single distillation a spirit of any strength up to nearly pure alcohol.

The problem to be resolved is, a mixture of water and alcohol, boiling and producing a continued current of vapours of water and alcohol, being given, to separate the watery from the alcoholic vapour partially or totally. A simple mode of effecting this was contrived by Mr. Coffey of Dublin: from the first and second rounds of the worm two pipes proceeded, which opened into the boiler of the still; the effect was, that as the most watery portions of the alcohol were condensed in these two hottest rounds, they were conducted away by the two pipes which opened into them, and discharged into the boiler for re-distillation, while the stronger alcohol was condensed lower down and separately collected.†

All the instruments for separating mixed vapours are founded upon one or more of the following principles:

1st. When a mixture of vapours of water and alcohol passes into a refrigeratory, the first vapours which condense are more aqueous, and the last

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* Edinburgh Dispensatory, 1830, p. 66.

† Domestic Economy. By M. Donovan, vol. i. p. 235.

the most alcoholic. If the refrigeratory is insufficient to condense the whole of the vapours, those which escape will be more alcoholic as their temperature is less elevated.

2nd. A mixture of water and alcohol boils at a heat so much lower, and the vapour generated is more alcoholic, as the mixture contained less water and more alcohol.

3d. When the vapour of pure water meets an alcoholic liquor at a lower temperature, the vapour of water is mostly condensed, and the heat resulting from the condensation forms alcoholic vapours.*

The most important of these apparatuses are that of Adams, which is founded on the second of the above principles; and the still of Derosnes, which is based upon the first and third, and which has attained such perfection as almost to defy the possibility of improvement. The details of these instruments would, from their complexity, be too long for insertion here, as the instruments themselves have not as yet been made use of in this country.†

The distillatory pharmaceutic operations may be divided into two classes, those of *purification* and those of *extraction*; the former containing the distillation of water and vinegar, of sulphuric and other acids; the second, of the essential oils, of alcohol, the medicated waters, spirits, &c.

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[*] Peclet. Traité de la Chaleur, vol. ii. p. 246.

[†] A complex distillatory apparatus, somewhat similar in principle to that of Derosnes, has been devised, and a patent obtained for the invention, by Mr. Æneas Coffey of this city: vide London Journal of the Arts and Sciences, September, 1831, p. 328.

1st.—*Distillation of Water.*

Steam is now so universally used as a heating agent, that from its condensation, a constant supply of distilled water may be obtained in large towns, and particularly if there be steam evaporating, or other apparatus in the apothecary's own laboratory. The water thus obtained may not, however, be so strictly pure as is required for some purposes, and it must then be distilled as directed by the Pharmacopœias.

The impurities of the water are numerous salts which remain behind with the water left in the still; the carbonic acid, however, comes over with the first portions of the water and deteriorates them, they are consequently directed to be rejected: this is very un-economical; a little lime added to the water before distillation removes the carbonic acid, and the water may then be collected perfectly pure from the commencement of the process.

2nd.—*Distillation of Sulphuric Acid.*

The distillation of sulphuric acid is a process which demands considerable care in the operator to insure its safe performance; the latent heat of the acid being very small, once it has reached its boiling point the vapour is generated very rapidly, and in bursts, similar to slight explosions; this, as has been mentioned before, is attributed by Gay-Lussac to the attraction between the fluid and the smooth glass preventing the disengagement of the vapour until a considerable quantity be generated, which is then dispersed with explosive violence.

The operation should be performed in a retort capable of holding at least four times the quantity of acid used; it should be heated over a chaufer in order that the heat may be as diffused and as equal as possible, and the junctions of the retort and adaptor with the receiver, which should be of a large size, should be left unluted. The pharmacopœia orders the first twelfth which distils over to be rejected as too watery, and the process to be then continued till the residuum becomes dry.

The bursts of vapour which occur in this process are rendered much less violent by passing into the retort some slips of platina foil, or cut wire, or angular fragments of glass. It is not well understood how these act; Dr. Barker thinks their action to be merely mechanical, and to arise from the bubbles of vapour being broken by the platina at the instant of their formation;* this view is not satisfactory; the sudden formation of such masses of vapour arises from the small latent heat of the acid; if, therefore, the latent heat be augmented, the ebullition will be rendered more quiet and regular, and I think it probable that it is thus the platina clippings act, diminishing the sensible heat of the boiling acid, and increasing the quantity of heat absorbed, as filings or chips of wood produce the same effect on water, the sensible and latent heats of each fluid making a constant quantity.

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* Barker on the Pharmacopœia of Dublin, p. 67.

The impurities of sulphuric acid are the sulphates of lead and potash, with some sulphurous and muriatic acids; the former remain fixed in the retort, the latter escape at the commencement of the ebullition, and are rejected, together with the watery portions of the product.

3rd—*Preparation of the Essential Oils.*

The *volatile* or *essential oils* form a most important class of vegetable products; before entering into the details of the method of obtaining them, it is proper to present a view of their most prominent characters:

1st. *Source.* Disseminated through different parts of vegetables, roots, barks, wood, leaves, calices, petals, fruits and seeds: when they exist in the seeds they always occupy the external integument, and never the cotelydons; they are generally contained in peculiar glands or utriculæ.

2nd. *Physical Characters.* Specific gravity generally less than that of water, in some, as those of cinnamon and cloves, greater; odour strong and peculiar; taste acrid and burning; but slightly viscid.

3rd. *Chemical Characters.* Entirely soluble in ether, alcohol, and the fixed oils; sufficiently soluble in water to impart to it their odour; easily volatilized, insaponafiable; when exposed to the air rapidly absorb oxygen, become thick, and appear to be converted into a resinous matter.*

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* This explains the circumstance related by Chevallier, of several persons having been asphyxiated from descending into a

4th. *Composition.* Principally carbon and hydrogen, with small quantities of oxygen and sometimes nitrogen. Those which contain only carbon and hydrogen, are the oils of turpentine, of citron, bergamotte, and otto of roses ; by cold a solid matter is deposited by many of these oils, which does not appear necessary to their composition ; in some it is camphor, in others, napthaline or benzoic acid.

5th. *Medicinal Characters.* Powerfully stimulant and irritating.

The vegetable substances from which the oil is to be obtained are to be macerated in water, and when well soaked, are to be put into a still, with as much water as will cover them ; heat is to be applied by means of steam, and the oils condensed in a receiver containing some water.

One of the most important points to be attended to in the preparation of volatile oil, is the avoidance of any empyreuma. To effect this object many plans have been proposed ; that of Webster, strongly recommended by the Codex, is to submit the vegetable matter to the action of the vapour only, in place of the boiling water. A proper quantity of water is placed in the bottom of the still, and the herbs or flowers are laid lightly in a basket, of such size as to enter the still and rest against its side just above the water. The capital being then put on, and the distillation proceeded with, the vapour of the water passing through the vegetable matters, ex-

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cellar where casks of oil of turpentine had been preserved for some time.

tracts the oil and carries it over with it to the receiver, where both are condensed.

Others have proposed to effect the distillation *in vacuo,* at so low a temperature as to render burning impossible; the form of apparatus has been already described, and Duncan states* that the most elegant oils he had ever seen were prepared by Mr. Barry, in this manner.

The rules to be observed in the distillation of the volatile oils, are thus given by Chevallier:

1st. To operate upon large quantities in order to obtain more product and of a better quality.

2d. To conduct the distillation rapidly.

3d. To divide the substances minutely, in order to facilitate the exit of the oil which they contain.

4th. To employ only water enough to prevent the plant from burning.

5th. For exotic substances whose oil is heavier than water; to saturate the water in the still with common salt, which raises the boiling point and enables the aqueous vapour to carry over more of the vapours of the oil.

6th. To employ water which had been already distilled from off the same substances, and had thus become saturated with the oil.

7th. To use for the oils of a specific gravity below 1, a Florentine receiver.†

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* Dispensatory, p. 672.

† The Florentine receiver is a vessel formed like a decanter, (Plate V. Fig. 3.) growing narrow towards the neck; from the bottom a pipe arises along the side of the receiver, but does not go so high as the neck. By this construction the lighter oil

8th. For the oils naturally fluid, to cool the fluid in the refrigeratory frequently, but to retain it at 80° or 90° for those oils which easily become solid, as those of roses, anise, &c.*

The volatile oils of orange, lemon, and some others, are occasionally obtained by expression; this mode requires no particular remark.

The following table gives the average quantities of oil obtained from 31½lbs. of material.†

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collects in the neck, and the heavier water goes out by the opening of the pipe, in proportion as the distillation proceeds.

* Manuel du Pharmacien, vol. i. p. 159.

† Chevallier and Richard, Dictionnaire des Drogues.

NAME OF PLANT.	*Part employed.*	*Quantity.*	*Colour.*	*Authors.*
Anethum Fœniculum	Dry fruit,	℥ii ʒvi	Slight citron,	Beaumé.
——— Graveolens	Fresh seeds,	℥xii	Colourless,	Niemann.
Anthemis Nobilis	Fresh flowers,	℥i ʒivss	Sapphire,	Cartheuser,
Carum Carui	Fresh seeds,	1lb. ℥ii ʒvi	Pale yellow,	Do.
Caryophillum Aromaticum,	Dry fruit.	4lb. ℥viii	Colourless,	Tromsdorff.
Do.	Do.	3lb. ℥vi ʒii	Do.	Vauquelin.
Citrus Aurantia	Fresh flowers,	ʒvi	Do.	Beaumé.
——— Medica	Rind.	℥v ʒvi	Greenish yellow,	Recluz.
Juniperus Communis	Entire dry fruit,	℥iiss	Amber,	Beaumé.
——— Sabina	Fresh leaves,	℥iv ʒvi	Limpid,	Do.
Laurus Cinnamomum	Dry bark,	℥vi ʒii	Golden yellow,	Cartheuser.
——— Sassafras	Dry wood,	℥v ʒiv	Amber,	Beaumé.
Lavandula Vera	Dry spikes,	1lb. ℥iv	Yellowish,	Cartheuser.
Mentha Piperita	Fresh plant,	℥iii ʒii	Colourless,	Recluz.
——— Pulegium	Do.	℥i ʒiii	Citrine,	Do.
——— Sativa	Do.	ʒvi		Brande.
Myrtus Pimenta	Dry fruit,	℥i ʒivss	Colourless,	Cartheuser.
Origanum Marjorana	Fresh plant,	℥iss	Amber,	Beaumé.
Pimpinella Anisum	Fresh seeds,	℥ix ʒvii	Yellowish,	Do.
Rosmarina Officinalis	Entire fresh plant,	℥ii	Amber,	Lewis.
Ruta Graveolens	Do.	℥i ʒii	Greenish,	Cartheuser.

When kept, essential oils undergo certain changes; they become dark-coloured, loose their agreeable odour, and grow thick and clammy; it is then necessary to re-distil them, by which the undecomposed oil is obtained again separate and pure. The essential oil is put into a retort with some water, and heat applied, the vapours rise together and are condensed; if the oil were heated without the water, the high temperature necessary to make it boil would injure it still further.

Volatile oils may be sophisticated in four ways; 1st, by a fixed oil, 2d, by alcohol, 3d, by oil of turpentine, and 4th, by an essential oil of inferior quality; the first adulteration is readily detected by imbibing a little paper with some of the oil; if a fixed oil be present the stain is not entirely dissipated by heat. If alcohol be present in quantity it may be discovered by the milkiness imparted to water by agitation with the oil, or a small proportion may be detected by means of potassium, as proposed by M. Beral; this metal is not acted upon by a pure essential oil, but if it contain even a twelfth or twenty-fifth of alcohol, the potassium is rapidly acted upon, and disappears*. If the suspected oil contains turpentine it is manifested by the odour of that oil being rendered evident on rubbing a little of the oil between the hands, or by burning a paper imbibed with it; but the adulteration most difficult of detection is where an essential oil of inferior value is used; the only means we possess of ascertaining the existence

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* Bussy, Traité des Sophistications des Drogues, p. 238.

of this kind of sophistication is, by taking the specific gravity of the oil as proposed by Guenot and Violet,* together with observing the inferiority of the oil which we suspect.

4th. *Of the Medicated or Distilled Waters.*

A medicated water is merely distilled water, holding in solution a certain quantity of the volatile and aromatic principles of a plant: there are two modes of obtaining this class of preparations; 1st., by distilling the water directly off the vegetables; or 2ndly, by using the oil already separated from the plants, and distilling it over with the water.

The rules for the preparation of the distilled waters are, with but little variation, those before given for the obtaining of the essential oils. In all cases where the fresh plants can be obtained they are to be preferred, and should be mechanically divided, to allow of their more perfect penetration by the water, of which a sufficient quantity should be put into the still, to allow, after the required product has been obtained, of enough remaining behind to prevent any trace of empyreuma.

The water should be brought rapidly to ebullition, and the distillation conducted as quickly as possible, taking care to avoid any danger of the still boiling over, as the slightest trace of the decoction of the plant passing into the worm would totally destroy the distilled product.†

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* Vide p. 28-29.

† There is some dissension as to the possibility of rendering

The distilled waters should be free from all saline impurities, and should possess in an eminent degree the odorous and medicinal virtues of the plant from which they are prepared. When first prepared they in general have a slightly empyreumatic odour, depending on the re-action which takes place among the vegetable principles, even at a low temperature;* this disappears after some time; or, as Chevallier remarks, the water may be deprived of it almost immediately by exposure to a cold of about 32°.

The distilled waters, after some time, become unfit for use; the vegetable matter in solution passing into decomposition, and a disagreeable smell replacing the peculiar aroma of the plant. To obviate this, a small portion of rectified spirit is generally added to the water (half an ounce to each pound, Ph. D.) before it is put up for keeping. Chereau recommends its addition to the materials before distillation. A better mode of procedure is to re-distil the water, as soon as it

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distilled waters more energetic, and saturating them more fully with the active principles of the vegetable by frequent re-distillation of the same water, or *cohobation*, as it is termed. It is ordered by the codex for the plants of a weak smell, and followed by the French school, on the authority of Deyeux. Duncan doubts the propriety of the process, and thinks it rather injurious than otherwise: it is not ordered by any of the British colleges.

* Chevallier found that acetate of ammonia was formed, and existed in the product, during the distillation of the medicated waters, even though the heat was managed with extreme care.

commences to change; it recovers its pristine odour perfectly, and is afterwards less subject to alteration.

When the distillation is finished, there is generally a small quantity of oil in excess, which floating through the water injures its limpidity, and renders it rather acrid and disagreeable. This is easily removed by filtration, taking care first to moisten the pores of the filter with a little pure distilled water.

5th. *Of the Distillation of Alcohol.*

According to the quantity of water which it may contain, and its purity, alcohol assumes in commerce the names of raw spirit, rectified spirit and alcohol: the preparation of the last alone is in the hands of the chemist; the first being obtained by the distiller from the fermented grain; the second by the rectifier.

The un-rectified spirit, besides being diluted with much water, contains always a quantity of an oil, semi-solid at common temperatures, and volatile; of a flavour differing according to the source from which the spirit was obtained, and developed, most probably, simultaneously with the sugar during fermentation, to which origin we must also refer a trace of acetic acid, which the commercial spirit often contains.

The object of rectification is therefore two-fold: 1st, to deprive the alcohol of that oily contamination which it possesses, and to remove from it any empyreumatic odour which it might have contracted by having been distilled from a wash not sufficiently well cleared; and 2dly, to obtain it more concentrated, by separating it from the quantity of water by which it was diluted.

By a single distillation carefully and slowly conducted, both these ends are pretty well obtained; the spirit of commerce yielding about three-fourths of its weight of a rectified spirit of .840 nearly free from the oily impregnation.

Many modes have been invented for separating alcohol from this impurity: where the quantity of oil is large, the old method of Kunkel of precipitating it by the addition of water, and then re-distilling, is very useful, although it does not effect it perfectly. One of the most powerful modes is by means of animal charcoal, as before alluded to. In France they effect the separation of alcohol from oil, intentionally mixed with it, by filtering it in a close vessel through slaked lime;[*] and Cadet de Vaux found the peculiar flavour of the different kinds of spirit to be effectually removed by a re-distillation with milk.[†]

The celebrated Œrsted of Copenhagen has found the peculiar flavour of grain and potatoe spirit to be totally removable by the action of chloride of lime; he mixes the spirit with a concentrated solution of the chloride, lets the mixture settle, decants and proceeds to distillation: the only nicety in this

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[*] Béaumé, Elemens de Pharmacie, p. 457.

[†] Dublin Philosophical Journal, vol. i. p. 280.

process is not to add an excess of the chloride: according to his experiments made in conjunction with Zeize, one ounce of the chloride is enough for the purification of about 20 pints of spirit. Chevallier has substituted for the chloride of lime, a solution of chlorine in water with complete success; he adds the chlorine water gradually, tasting the spirit after each addition; and when the peculiar flavour is no longer sensible, submits it to re-distillation.*

A very good method of obtaining by simple distillation a spirit almost free from the oil, is used by my friend Mr. Scanlan. The pipe of the capital of the still divides into two tubes, each connected with a distinct refrigeratory; at their junction is a stop-cock so situated, that by turning it the communication between the still and either of the refrigeratories may be opened or cut off, and the vapour produced directed to the one or the other worm, at the pleasure of the operator. The oil is much less volatile than the alcohol, and does not begin to rise until the liquor in the still becomes considerably reduced in strength. By allowing the alcoholic vapours produced before this point to enter into one vessel, and then, the stop-cock having been turned, receiving the impure spirit subsequently distilled in a separate condenser, he obtains an alcohol as nearly as possible free from its usual impurities.

It still remains, however, to remove the water, and thus obtain what is termed absolute alcohol. This is done generally by distilling the rectified spi-

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* Manuel du Pharmacien, vol. i. p. 169.

rit from off substances (as pearl-ash, salt of tartar, dry chloride of calcium, lime, &c.) having a powerful affinity for the water which they retain, and allow the pure alcohol alone to be vaporized by the heat. The strongest alcohol thus obtained is of the specific gravity 0.796 ; it however still contains some water, which, most probably, as is the case with liquid nitric acid, oxalic acid, &c. is essential to its existence.

The alcohol thus obtained very often contains small quantities of the substances from off which it had been distilled ; thus, muriate of lime, muriate of soda, lime, sulphate of soda, &c. have been found in alcohol distilled over them ; spirit distilled from off carbonate of potash, or of soda, possessed alkaline properties ; while, if calcined alum be used, the alcohol reddens litmus paper.*

Soemmering † asserted, that if we put alcohol of a moderate strength into an ox's bladder, coated with isinglass, and suspend it over a sand-bath, in a few days the alcohol will lose one-fourth of its volume, and be found quite free from water : that this opinion is fallacious ; in fact, that the contrary is the case, has been fully proved by Duncan ‡ and by Donovan,§ in whose experiments the alcohol submitted to trial had increased in specific gravity.

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* Dubue, Annales de Chimie, vol. 86. p. 314.

† Giornale di Fisica, vol. vii. p. 239.

‡ Supplement to Dispensatory, page 11.

§ Cabinet Cyclopædia. Domestic Economy, page 262.

Mr. Graham has published a very elegant mode of concentrating alcohol, by placing it under the receiver of an air-pump, along with a substance capable of absorbing aqueous vapour rapidly, and exhausting; in a few days, the vapour of the water being absorbed as fast as generated, it is all removed, while the alcohol remains unaffected, its evaporation having been prevented by the persistence of its own vapour.* This mode of Graham's differs only in the evaporation being accelerated by being performed *in vacuo* from the method of rectification in the cold, proposed long since by Pajot des Charmes,† by exposing spirit in a flat-bottomed dish to the action of an extensive surface of dry chloride of calcium contained in a separate vessel, and both included in a larger vessel; by this method he got alcohol of 0.800.

6th. *Of the distilled Spirits.*

The pharmaceutic preparations, termed *spirits*, are solutions in alcohol of certain aromatic and volatile vegetable principles, obtained by distillation; they are colourless, of an odour less pronounced than that of the distilled water of the same plant, but becoming more developed if the spirit be diluted. Their preparation requires but little additional remark; the most necessary are, that the spirit used should be totally destitute of its oily impregnation,

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* Edinburgh Philosophical Transactions, 1828.

† Annales de Chimie et de Physique, Juillet, 1825.

and of any empyreumatic odour, either of which would injure the flavour of the distilled product. The vegetable matters should be macerated for some time in the spirit before being submitted to distillation; the heat should be cautiously managed, and applied either by a water-bath or by steam, and the water in the refrigeratory should be as frequently renewed as possible.

7th.—*Distillation of Vinegar.*

In order to free the vinegar of commerce from the large quantity of vegetable matter which it holds in solution, and from other impurities, as sulphuric and some vegetable acids, alcohol, &c. it is submitted to distillation. The first portions which come over are rejected from their containing the alcohol, which existed in the vinegar, some acetic ether, and but very little of the acetic acid; the succeeding portions are then collected for use, until the liquor in the retort becomes thickish and very dark coloured, when the distillation must be arrested, as the product then obtained would probably be empyreumatic; dividing the quantity operated on into ten portions, the first is to be rejected, the succeeding seven preserved, and two left as residue; these, however, are still strongly acid, and may be used advantageously for many purposes. Glass vessels should be used in this process, and the heat is best applied by means of a sand bath.

8th.—*Distillation of Mercury.*

The mercury of commerce is always sophisticated by admixture with lead, bismuth, tin, and sometimes zinc. To obtain it free from these impurities it is submitted to distillation, and two-thirds of the quantity employed are brought over and collected; the process needs but little comment; the retort used should be of iron or of earthen-ware, and should be inserted in a reverberatory furnace; the receiver, which should be large, scarcely requires artificial refrigeration, and the process is to be conducted slowly in order to avoid the violent ebullition of the metal, which might cause the fracture of earthen-ware or porcelain vessels; or else the projection of a portion of the contents into the neck of the retort. Sometimes iron filings or lime are mixed with the mercury to be distilled, although without any good reason: the mercury used in the preparations of the codex is reduced from cinnabar, and consequently quite pure.

Of Destructive Distillation.

This is a process not legitimately coming under disaggregation, as the products are formed by the exertion of new affinities, and did not pre-exist in the substances submitted to the operation; as, however, they are obtained by distillation, we shall notice the mode of operating briefly, in two processes, in which it is used in British pharmacy; 1st, the destructive distillation of wood, and 2d, the destructive distillation of amber.

1st.—*Of the Distillation of Wood.*

In the preparation of pyro-ligneous acid, the harder woods, as oak, elm, beech, &c. are exposed to a red heat in iron cylinders placed two in each furnace; the pipes issuing from all communicate together, and terminate in a large wooden vessel acting as receiver. By being thus exposed to heat, the wood is decomposed; a considerable quantity of acetic acid is generated, with a proportion of tar, which condenses along with it, and remains partly dissolved and partly floating on its surface, and a quantity of pyro-acetic spirit is at the same time formed and condensed. Along with these liquid products, a large quantity of gaseous matter burning with a very pale bluish flame, and amounting, according to Dr. Ure, to nearly one-half of the weight of the wood, is produced, and charcoal of about one-fifth the weight of the material used remains behind in the retort; the heat is kept up for each charge for 12 or 14 hours, and the charcoal extracted, and a new charge introduced as soon as the apparatus has become quite cold.

The mixture of impure acetic acid and tar is allowed to settle, when the greater quantity of the tar sinks to the bottom, and some of a less specific gravity floats on the top; intermediate between these strata, the impure acid still containing some tar, &c. rests, and is removed by a pump, which, descending nearly to the surface of the lower stratum of tar, is worked until the middle liquor being all taken away the lower surface of the light, and the upper of the heavy tar, come nearly into contact. It is then neutralized by slaked lime, during which process more tar separates, and the impure acetate thus obtained is evaporated to dryness and gently heated, which destroys still more of the empyreumatic impurities. The acetate is then re-dissolved in water, and mixed with a solution of sulphate of soda; a considerable quantity of sulphate of lime is deposited, and an acetate of soda remains in solution; this is evaporated to a pellicle, and on cooling solidifies into a mass of irregular crystals, which, if not pure enough, are fused, re-dissolved, and crystallized.

When the acetate of soda has been thus obtained, totally free from tar or oily matter, it is decomposed by the necessary quantity of sulphuric acid and the pure concentrated acetic acid distilled over. The acid thus procured is chemically pure, but is not so pleasant for domestic use, as not possessing the fine aromatic flavour of wine vinegar.*

2d. *Distillation of Amber.*

The products obtained in the distillation of amber are an oil, (the volatile oil of amber,) and succinic acid; the former is produced by the decomposition of the material, the latter naturally pre-existed in the amber, and is merely separated in consequence of its volatility.

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* By some manufacturers, the acetate of lime is at once decomposed by sulphuric acid, which renders the process more economical, but the acid obtained is not so free from empyreumatic impregnation as that obtained by the process described in the text.

The amber is to be broken finely and washed, then mixed with its own weight of sand, and heated in a retort to a dull redness. If we operate with a naked fire, the retort should be earthenware or glass coated; but the coating is not necessary if the retort be placed in a sand bath; in the arts where large quantities are operated upon at once, iron retorts are generally made use of. To the neck of the retort is attached a long adaptor, which fits into a receiver tubulated and furnished with a tube passing into a bottle containing water; heat is applied at first gently, the amber softens and melts, but is prevented by the sand from forming a solid mass; it froths a little, but soon after settles down, at which period the operation is finished.

The products are first, a yellowish acid water, principally acetic acid, then a yellow very fluid oil, with a quantity of carburetted hydrogen, carbonic acid, and carbonic oxide, for the passage of which the receiver is fitted with the tube; at this time the acid begins to sublime, and is deposited on the neck of the retort and on the receiver, in brownish crystals; a quantity passes over also dissolved in the water and in the oil. Towards the end of the process the oil becomes thick and blackish, and of a very disagreeable odour; the mixed acid and oil are then separated by filtration, and each afterwards purified for use.

The oil is purified by rectification with water, when it becomes paler and less fœtid; the acid may be purified either by re-sublimation or by neutralization with carbonate of potash, then decomposing the succinate of potash by acetate of lead, and separating the succinic acid from the succinate of lead by the superior affinity of sulphuric acid; in either of these modes there is a loss of acid, but they are the only ones by which the product is obtained in a state of perfect purity.

Variety 2d. *Of Sublimation.*

Where the volatilized matter on condensing assumes the solid form, the process is called sublimation. The vessels in which it is performed vary; being sometimes retorts with wide necks, occasionally matrasses, the mouths of which are loosely stopped to prevent loss, while the sublimed substance condenses in their upper part; an instrument, termed an alembic, is frequently employed, when, at the same time, a portion of liquid is produced; it consists of a body resembling a matrass with a large mouth, on which fits a head or capital of a conical figure, and having round its lower part a depression, from the bottom of which issues a pipe passing into a recipient. The solid matters remain attached to the inside of the head, while the liquids collecting in the depression run off by the pipe into the vessel placed to receive them. The alembic is represented adapted for such an operation in Fig. 3. Plate V. A crucible placed on top of, and luted on another containing the materials to be acted on by heat, forms often a simple and very useful apparatus for sublimation.

Substances thus obtained are generally met with in masses of a shape representing, in some degree, the form of the vessel into which they had been sublimed, in hemispherical or conoidal cakes; they are smooth and shining on the outer surface, from having been in contact with the polished internal surface of the subliming vessel, and on their internal surface present an approach to crystallization more or less perfect, according as the process had been conducted with greater or less rapidity. It is considered in commerce an advantage for the sublimed masses to possess a degree of translucidity which is given to them by, towards the end of the operation, increasing the heat so as to allow the material condensed in the capital to undergo a commencement of fusion; this is particularly done with the cakes of sal ammoniac, camphor, the two chlorides of mercury, and arsenious acid; in the latter substance it is probable that some other change than mere fusion is effected, as Guibourt has found the opaque and semi-transparent varieties of sublimed arsenious acid to differ considerably in their relative solubility in water.

The pharmaceutic products obtained by sublimation are numerous and important, but however require little remark, considered merely with regard to this process; the phenomena of their preparation, their properties, &c. will be explained when speaking of their formation; sublimation being used merely to separate them from other substances formed at the same time, or from impurities, but not being a process essential to their preparation.

Species 2d. *Of Vaporization for sake of the non-volatile Body.*

In the operations before considered, the valuable substance was that which was capable of volatilization, and was thus separated from the inert or useless matter which remained behind; the succeeding processes are conducted exactly with the reverse intent; a solution of certain substances is given, and it is wished to obtain them free from the fluid agent of solution; to effect this heat is applied, the liquid is volatilized and allowed to escape uncondensed; and we obtain the non-volatile matters which were the object of the operation in a solid form.

Vaporization, when the volatile body is not again condensed, is called *evaporation;* it requires consideration under two points of view: first, the principles on which the operation is founded, and the phenomena which accompany it; and secondly, the mode of obtaining the pharmaceutic products (generally heterogeneous) of this process: these products are the *extracts* and *inspissated juices.*

1st. *Of Evaporation.*

The rapidity of evaporation depends upon two circumstances, the temperature and the pressure; at common temperatures most fluids and some solids are gradually converted into vapour: this is termed *spontaneous evaporation;* and they disappear the more rapidly as their boiling point is lower; thus ether evaporates quicker than water, and water than mercury, and if we reduce the temperature of mercury below 20° Fahr. we put an end to its vaporization altogether.

Fluids evaporate much more rapidly *in vacuo;* because, as their boiling point is considerably reduced by a removal of the atmospheric pressure, they have as great a tendency to evaporate at common temperatures *in vacuo* as if they had been heated in the open air, until their temperature approached as near to their boiling point. Thus water, at about 85° boils *in vacuo;* at 50°, therefore, it would have as great a tendency to evaporate as it would were it heated to about 170°, under the common pressure of the atmosphere. The mode of evaporation may thus be conveniently considered under two heads, according as it is performed *in vacuo* or not.

Most fluids, and many solids also, as camphor, corrosive sublimate, chloride of antimony, ice, &c. throw off considerable quantities of vapour at common temperatures; this *spontaneous* evaporation was formerly explained, by saying that the air having an affinity for these substances, dissolved them, and kept them in solution by a sort of chemical affinity: This view agreed very well with many phenomena; (as the chemical view of solution in general agrees with many phenomena;) thus the solvent power of the air was augmented by heat and diminished by cold; and the evaporation of the fluid was increased in rapidity by a current of air, the quantity of the solvent being then so much greater, &c. But this view, otherwise so plausible, was soon overturned by De Luc, who discovered that the presence of the air was absolutely an obstacle to evaporation, and that that process went on with infinitely greater energy *in vacuo,* where no air at all was present.

All fluids have, within certain limits of temperature, a tendency to convert themselves into vapour; and the vapour, when once formed, diffuses itself through the air as one gas does through another, according to the law of Dalton. At a certain temperature the particles of the air are at a certain distance from each other, and are capable of allowing a certain number of particles of water to penetrate between them; when these spaces are filled up, the air is saturated with water at that temperature; if the heat be increased, it becomes capable of holding more; if its temperature be diminished, it deposits some of the vapour by which it had already been penetrated. As the quantity of superincumbent vapour increases, the pressure upon the remaining fluid augments, and at last reaches a point where evaporation at that temperature ceases. A current of air promotes evaporation, therefore, not by presenting new quantities of a solvent to the water, but by removing the particles of vapour as they are formed, and thus preventing any considerable augmentation of pressure.

Evaporation taking place only at the surface of a fluid, the extent of surface presented influences in a great degree the quantity of vapour formed.

Spontaneous evaporation is used in the chemical arts for many purposes, as the obtaining of sea salt from sea water, &c. In pharmacy it is not usually employed, although Laugier and Chevallier state that many distilled waters, as that of tobacco, for example, which yield no solid substance when evaporated by heat, leave behind, when given up to spontaneous evaporation, a peculiar greenish extractive matter, probably possessing active properties.

Evaporation in the open air is generally expedited by applying heat; the mode of effecting this purpose varies with the nature of the substance upon which we operate. In evaporating solutions of salts, or other substances not destructible by heat, the process may be accomplished either with a naked fire or on the sand-bath, taking care not to produce such violent ebullition as would endanger the ejection of any of the liquid from the vessel. A few circumstances only require notice in such a case; in evaporating concentrated saline solutions, on reaching a certain point the salt begins to be deposited on the sides of the vessel; if the salt be anhydrous, its particles gradually form a cake, between which and the inside of the evaporating basin steam is formed, which being for a time confined, at last forces its way out with a force sufficient to cause the dispersion of a great quantity of the material, and often the breaking of the vessel. This is easily avoided by frequently stirring the mass, and thus preventing the adherence of the deposited salt to the bottom of the basin. When there is any danger of dust or smoke falling into the basin, it should be covered, and the cover should be always formed convex inferiorly, so that any drops which may be thrown up against it by the ebullition may run down again into the liquid, and not to the outside of the vessel, as they would do was the cover convex at its upper surface.

When the substance to be obtained by evaporation is of organic origin, it is necessary to avoid the application of so high a heat, and to be extremely cautious in its management. When the solution is dilute, the process may be commenced on the sand-bath, taking care not to immerse the vessel too deep in it, and to place under the basin a slip of card or a wood shaving, by the occasional inspectión of which it can be coarsely known whether the heat applied be sufficient to endanger the decomposition of the vegetable matter. Once the liquid begins to thicken it should be immediately removed from the sand-bath, and the evaporation effected either through the medium of vapour or of water; indeed, where great care is required, the process should be terminated by the gentle heat of a stove, or of the water-bath at a reduced temperature.

The method of applying steam as a heating agent has been already adverted to; an apparatus not described there is that of M. Bernard Derosne: it consists, 1st, of a boiler, the cover of which is surmounted by a tube to conduct the steam; 2d, of two dishes or shallow trays of tinned copper, furnished with double bottoms, and covered externally with wood; 3d, of a reservoir with a cock; this vessel is to contain the liquor to be evaporated. The second basin is fitted with a stop-cock, by means of which the condensed vapour is allowed to escape.

His mode of operation is as follows: If we act upon a juice the albumen and chloropylle is to be separated by means of heat, and the liquor then strained through a woollen cloth. It is then to be placed in the reservoir, and heat applied to the water in the boiler; when the temperature of the trays is sufficiently elevated, the cock of the reservoir is opened, and the depurated juice allowed to run through the divisions made on the upper surface of the trays, and finally to flow into a receiver placed at the extremity; it is then removed from this receiver and placed in the reservoir, whence it again flows over the heated surface of the trays. The evaporation is thus continued until the volume of the liquor is reduced to one half. The process is then stopped, and the liquor allowed to rest till next day, when it is again strained, and the evaporation continued as before until the liquor becomes too thick to flow freely through the divisions of the trays: The cover of the boiler is then to be removed, a water-bath placed on it, and the evaporation finished by it in the usual manner.

This apparatus appears to have succeeded very well in practice. Henry and Hernandez, who reported on it, state, that it possesses the advantages of, 1st, very rapid evaporation; 2d, the employment of a heat incapable of sensibly injuring the products; 3d, of requiring but very little watching; 4th, and of affording an economical mode of, at the same time, obtaining a good supply of distilled water.*

From the large quantity of heat rendered latent by the conversion of a liquid into a vapour, evaporation is very extensively used as a means of effecting refrigeration. In warm climates the excessive heat of the air of the houses is reduced by the evaporation of water sprinkled on the floors; and the liquors used as drink being placed in porous vessels, are cooled by the evaporation of that portion of fluid which permeates to the external surface. Most products of distillation are condensed by the evaporation of water from the surface of the adaptor or receiver, as before described, and the same principle (the evaporation being expedited by the removal of the atmospheric pressure,) has been applied by Leslie to the obtaining ice even in the warmest countries of our globe.†

Vegetable extracts are now very generally prepared for the apothecary, according to Mr. Barry's mode, in which the evaporation going on *in vacuo*, the possibility of the heat necessary being capable of injuring any of the constituents of the plant is

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* Chevallier et Idt. Manuel du Pharmacien, vol. i. p. 116.

† He places a capsule of water under the receiver of an air pump along with a vessel containing strong sulphuric acid or any other substance which absorbs water rapidly: on exhaustion, the water evaporates rapidly, but the vapour being absorbed as it is formed, the vacuum is kept perfect, and after some time the evaporation of the one portion of the water depresses the temperature of the rest so low as to freeze it.

done away with: he has taken out a patent for the apparatus, but not for the process, so that any person may prepare extracts in this way, provided they use a different form of apparatus.

His mode of proceeding is as follows: The evaporating pan or still is a hemispherical dish of cast iron, polished on its inner surface, and furnished with a nearly flat air-tight lid. From the centre of this a pipe rises, and bending like the neck of a retort, it forms a declining tube, which terminates in a copper sphere, of a capacity four times greater than that of the still. There is a stop-cock on that pipe midway between the still and the globe, and another at the under side of the latter.

The juice or other solution of the vegetable matters is introduced into the polished iron still, through a large opening, which is then closed, made air-tight, and covered with water. The stop-cock which leads to the sphere is also shut. In order to produce the vacuum, steam from a separate apparatus is made to rush by a pipe through the sphere till it has expelled all the air, for which five minutes are commonly sufficient. This is known to be effected by the steam issuing uncondensed. At that instant the copper sphere is closed, the steam shut up, and cold water admitted on its external surface. The vacuum thus produced in the copper sphere, which contains four-fifths of the air of the whole apparatus, is now partially transferred to the still, by opening the intermediate stop-cock. Thus four-fifths of the air in the still rush into the sphere, and the stop-cock being shut again, a second exhaustion is effected by steam in the same manner as the first was, after which a momentary communication is again allowed between the iron still and the receiver; by this means four-fifths of the air remaining after the former exhaustion are expelled. These exhaustions, five or six times repeated, are usually found sufficient to raise the mercurial column to the height of 28 inches. The water-bath, in which the iron still is immersed, is now to be heated until the fluid that is to be inspissated begins to boil, which is known by inspection through a glass window, fitted air-tight in the apparatus, and the temperature at which the boiling point is kept up is determined by the thermometer. Ebullition is continued until the fluid is inspissated to the proper degree, which also is judged of by its appearance through the glass window. The temperature of the boiling point is usually about 100, but it might be brought down to nearly 90°.

The other parts of the apparatus in which the vapour formed during the evaporation is again condensed, will be easily understood. Plate V. Fig. 4. represents one of the evaporating vessels, with its cistern B. and refrigerating plates. The cistern is kept cool after the manner of a distiller's worm tub. The evaporating vessel is furnished with several appendages, such as the charging measure, *c.*, and discharging pipe, *d.* which is moved perpendicularly by its lever. Man hole, *g.* and chamber, *f.* for catching any fluid that may chance to boil over: it is surrounded at the lower part with a steam or water-bath, *e.* for boiling its contents. A pipe, *m.* passing from the chamber, *f.* gives origin to several refrigerating plates, which have their lower extremities terminating in another pipe, *n.* The transverse section in Fig. 4. represents these plates upright and parallel with each other in the cold water cistern. They occupy very little room, and may be multiplied to an indefinite number, to furnish a proportional quantity of cooling surface; on entering these the vapour is instantly condensed, and dropping into the lower pipe, is conducted to a *cylindrical* receiver, shown in the *transverse* section, *h.* It is of sufficient capacity to collect all the fluid condensed during the process.

The great advantages of this process over those in ordinary use, are easily perceived on comparing the extracts obtained by means of each. The most cautious use of the steam or water-bath cannot preserve the peculiar odour and colour of the narcotic plants in the manner in which the extracts prepared according to Barry's method possess them.

2d. *Of the Preparation of Extracts.*

In pharmacy the name of *extract* is given to the product obtained from a vegetable or animal substance by solution in an appropriate medium, and reduced by evaporation to dryness, or to a pilular consistence.

The composition of extracts is very complex; it in some degree varies according to the nature of the liquid used in their preparation, but owing to the reaction of the vegetable principles upon each other, many substances, not of themselves soluble in the fluid, exist in the extract, being held in solution or diffusion by means of other substances which co-exist with them. Formerly the basis of the extract was supposed to be a principle possessed of peculiar properties, to which was applied the term *extractive*, but since the great progress which organic analysis has made within these last years, the substances of which vegetables are composed have become better known, and extractive matter as an organic principle is not now allowed to have any real existence. The proximate components of vegetable extracts are, generally speaking, gum, sugar of different kinds, resin, and some other substances approaching in their nature to it, various colouring matters, tannin, usually accompanied by gallic acid, fixed oily matters, starch, vegetable albumen, the various alcaloids, the vegetable acids, and various salts.

The classification of extracts has been, since the origin of our science, an object of interest to apothecaries. The old division by Rouelle into *gummy*, *saponaceous*, *gum-resinous* and *resinous* extracts is still occasionally employed ; Braconnot classed them into *azotated* extracts, which might or might not contain bitter principle, into *hydro-azotated*, and into *oxygenated* extracts destitute or not of bitter principle. The most modern and most elaborate classification is that of Recluz, as follows : 1st, *alcaloid* extracts, which owe their properties to a vegetable base, as quinine or morphia ; 2d, the *resinous* extracts, as of guiacum and jalap; 3d, the *bitter* extracts, of which class there are three orders; 1st, the *bitter extracts properly so called*, which are tonic, as of gentian; 2d, the *cathartic bitter extracts*, as of colocynth, and 3d, the *astringent bitter extracts* which generally contain tannin, as extract of catechu. The 4th class are the *saccharine* extracts, as of liquorice; the 5th the *animal* extracts which do not exist in British pharmacy, and 6th, the *polydiote* extracts,[*] which is merely a temporary class to contain those extracts of the nature of which we know little, until their composition be better ascertained, when they can be removed either to one of the preceding divisions, or a new class better defined be established.

These classifications are, however, of a nature too refined and too complex for immediate application to practice; the division which we shall follow is simply according to the nature of the solvent used in their preparation, into 1st, aqueous, and 2nd, alcoholic extracts.

In the preparation of extracts, the object is to obtain first a solution of the active principles of the vegetable, as unaltered and as free from inert matter as possible; and secondly, to evaporate this solution to a certain degree of dryness so as to preserve uninjured the chemical and medicinal powers of the plant.

The state of the vegetable at the time at which it is used, and its age, influence the goodness of the extract obtained from it, and therefore require notice;

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[*] *πολυ*, many, *ιδιοτης*, peculiar property.

it is by no means indifferent whether the plant employed be dry or fresh, for desiccation produces in the component principles of plants several important changes, many of the more volatile parts fly off, the vegetable albumen becomes insoluble in water, the gum or mucilage is also modified in some way, and it is therefore preferable to prepare the extracts of mucilaginous vegetables from the dry plants, as they are thus obtained less viscid and better capable of being kept; for the same reason the plants should not be collected until they had gained their full vigour of vegetation, for during their youth, the inert mucilaginous matters are very abundant, while the more active principles have not been as yet sufficiently formed.

The nature of the medium is always decided by the composition of the vegetable; if the active principles are all soluble in water, that fluid is used as the vehicle of extraction; if on the contrary the medicinal energy depends on a substance insoluble in water, as resin, &c., alcohol of a certain strength is employed; and if it be desired from any circumstance that all the principles soluble in either medium should be reunited in the extract, the vegetable matter is first submitted to the action of the one and then to the action of the other liquid, and the solutions thus obtained are afterwards mixed and inspissated together.

A very important proposition to be decided is, by what temperature should the action of the solvent upon the solid body be assisted. This must vary according to the composition of the vegetable substance; but in the British Pharmacopœias, decoction is ordered for all the aqueous extracts, a mode which is injurious to most, and totally destructive to the virtues of some of the narcotic plants. In many cases there is also another objection to the use of decoction, for the quantity of product obtained is often less than that procured by infusion; and where it is apparently equal or superior, its quality is generally deteriorated; for instance, rhubarb root gives an equal weight of extract whether decoction or infusion is employed, but in that obtained by the former process a considerable quantity of the active principles of the root is destroyed, and its place filled up with a mass of inert starch which does not exist in the preparation made by infusion. As a general rule, therefore, in the preparation of the watery extracts, infusion or maceration is the process which should be used, except under certain peculiar circumstances, which will be hereafter detailed, where decoction is absolutely required.

When the active matters soluble in water are naturally mixed with starch, it is necessary to use maceration in order to insure their separation; the use of boiling water in such case would not only add a quantity of inert matter to the extract, but in many instances where there exists at the same time tannin, the starch combines with it, and forms a compound soluble in boiling water, but precipitating as the liquor cools; this compound is inert, and so the starch removes from the extract a considerable portion of one of its most active ingredients.* Extracts containing starch are also more pasty in their consistence, and do not preserve sufficiently well.

An important circumstance in which the use of cold water is necessary, is where there exist in the vegetable, substances which it is not desirable to extract, but which would be dissolved by ebullition, and give properties to the product different from those which it is desired to possess. Thus the sweet principle (glycyrrhizine) of the liquorice is obtained distinct from its acrid oil; and the watery extract of opium contains the hypnotic principle, freed in a great degree from the resin and narcotine. The preparation known under the name of the extract of cinchona of Leroy, or the essential salt of bark, is obtained on the same principle, by acting upon bark by cold water. The kinate of lime, the gum, the soluble red colouring matter, and the yellow colouring matter, are dissolved with but very little of the insoluble active red colouring matter, or of the salts of the alcaloids; consequently this preparation, although occasionally used, is but very feebly febrifuge.

But it sometimes happens, that the substance to which the vegetable owes its medicinal powers is insoluble in water by itself, and cannot exist in a watery extract, except it be kept in solution by

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* This precipitate constitutes what was formerly termed *oxidized extractive*, it being supposed that the extractive matter by long boiling absorbed oxygen, and became insoluble in water. The same phenomenon is observed in making decoction of cinchona.

the play of affinities among the other substances co-existent with it. In this case the use of *decoction* cannot be dispensed with, it requires even protracted boiling to obtain a solution of such principles, and an extract from a vegetable of this class, prepared by infusion, would be destitute of the slightest power. This remark applies particularly to the preparation of the extract of cinchona prepared by decoction, which is immensely superior to that before noticed obtained by maceration.

The preparation of alcoholic extracts does not require much separate remark; in composition they are generally more resinous than those obtained by means of water, and their inspissation is somewhat differently conducted; at first the solution is distilled, in order to save as much as possible of the alcohol, and the remaining liquor evaporated cautiously in a water bath to dryness.

With regard to the mode of evaporating extracts, every requisite information has been already given when speaking of the management of heat and of evaporation; but few more remarks are necessary; the vegetables used should be in the best possible preservation if dry, or should be newly gathered if intended to be used fresh. The quantity of fluid used should be as small as may be consistent with the perfect extraction of the active matter, (eight times the weight of the vegetable matter Ph. Dub.) and the evaporation conducted as rapidly as possible. The water employed should be distilled or rain water, to avoid increasing the quantity of the extract by salts foreign to its nature, and to evaporate to a consistence, so that the mass shall not adhere to the hand, or moisten bibulous paper, if intended for making pills, or else until it breaks easily and with a sharp fracture, if it be designed for pulverization.

The following table contains the quantities of product obtained from 100lb. of material at Apothecaries' Hall, in Ireland :

NAME OF PLANT.	*Part used.*	*Quantity per cent.*	*Solvent and mode of Solution.*	*Observations.*
Aconitum Napellus	Fresh leaves,	5	From the juice.	
Aloes Hepatica	Inspissated juice,	54	Decoction in water,	
Anthemis Nobilis	Dry flowers,	48†	Do.	
Artemisia Absinthium . . .	Dry plant,	35	Do.	
Atropa Belladonna	Fresh leaves,	4	From the juice,	At first soft, but dries from the crystallization of its salts.
Cinchona Lancifolia	Dry bark,	25	Decoction,	Hard, and generally remains so, but occasionally softens.
Cucumis Colocynthis . . .	Fruit dry and free from epidermis and seeds,	65	Do.	If soft at first, generally grows dry and friable
Conium Maculatum	Fresh leaves,	6	From the juice,	At first soft, then gets dry and full of crystals of chloride of sodium.
Convolvulus Jalapa	Dry root,	22.5	Maceration in alcohol sp. gr. 0.840 and decoction in water,	Grows very soft, contains much crystallized nitrate of potash.
Datura Stramonium	Seeds,	12	Decoction.	
Gentiana Lutea	Dry root,	56	Do.	
Glycyrrhiza Glabra	Root,	28†	Do.	
Hematoxylon Campechianum,	Rasped wood,	20†	Do.	Grows very hard.
Humulus Lupulus	Dry strobiles,	40	Do.	
Hyosciamus Niger	Fresh leaves,	4.6	From the juice,	At first soft, then dries and contains crystals of nitre and chloride of sodium.
Leontodon Taraxacum . . .	Root,	6	Decoction.	
Papaver Somniferum . . .	Opium,	61	Infusion.	
Do.	Capsules without seeds,	35	Decoction.	
Rheum Palmatum	Dry root,	47	Infusion in very dilute spirit.	
Ruta Graveoleus	Fresh leaves,	9.7	Decoction.	
Sambucus Niger	Ripe berries,	16.5‡	From the juice.	
Smilax Sarsaparilla	Dry root,	13	Decoction,	Permanently firm, contains crystals of common salt.
Do.	Do.	210 Fluid, sp.gr. 1.045	Do.	
Spartium Scoparium	Fresh tops,	9.5	Do.	
Strychos Nux Vomica . . .	Dry seeds,	9	Digestion in spirit of 0.919.	

The quantities marked thus † were obtained at the Apothecaries' Hall, London, by Professor Brande.

‡ Result obtained by Beaume.

A kind of extract which deserves to be considered separately from those hitherto described under that name, are the inspissated juices of the Dublin Pharmacopœia, obtained by expressing the juice from the leaves of the narcotic plants, and from the ripe berries of the common elder, and evaporating to a proper consistence, as in the preparation of the other extracts.

These inspissated juices differ very much in activity according as they are prepared from the juice, depurated or not, or as it is termed by the French Pharmaceutists, according as they are made with or without *chlorophylle*. The fresh juices of plants, as has been already mentioned, contain, besides their active ingredients, a considerable quantity of vegetable albumen, and of chlorophylle, or the green colouring matter of their leaves; both these matters are inert, and therefore an extract prepared from a juice freed from them must be much more powerful than one from that which is diluted with them: these principles are both easily separated from the juice, the albumen being coagulated by heat, and removing along with it the chlorophylle, which is insoluble in water by itself.

The inspissated juices of the British Pharmacopœias are prepared according to the original method of Baron Störk, who first introduced the use of these narcotic preparations: the fresh juice without defœcation is evaporated to a proper consistence, with due precaution in the application and management of the heat.

The plan of the codex differs from this; the juice, strained to remove any amylaceous fecula is boiled for some time, until the albumen and chlorophylle are separated; it is then again strained through a woollen cloth, the coagulated matter laid aside, and the evaporation continued until the clarified juice becomes of the consistence of honey: the moist mass of chlorophylle and coagulated albumen is then added, and carefully incorporated with the inspissated juice, the evaporation of which is then carefully finished.* This mode has also been made use of by Mr. Battly of London, who published a detailed description of the process, which it is not necessary to transcribe.†

In the table of extracts, the quantities of inspissated juices obtained have been inserted under their different heads.

Extracts seldom preserve the consistence at which they are prepared; some soften, others, on the contrary, grow hard. Those which contain deliquescent salts attract moisture from the air, become soft, and are apt to mould. The greater number, however, grow dry and hard on keeping, from the evaporation of the water, and also from the crystallization of certain salts in the interior, which abstract from them the water necessary to their preserving a proper consistence.

Extracts should be preserved in glazed earthenware pots, protected as much as possible from the action of the air. The evaporation of the water may

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* Pharmacopée Francaise, par Henry, fils et Ratier, p. 310.

† London Medical Repository, vol. iv. p. 198.

be in a great degree prevented by slightly oiling the upper surface of the extract, a practice which cannot be productive of any inconvenience. Where the extract has deliquesced, it should be again brought to a proper consistence in a water or steam-bath, and if it has become too hard, it can be softened with a little water, heated by the same medium.

Class 2nd. *Operations of Re-aggregation.*

The operations of re-aggregation are those in which the state of aggregation of the body is increased, *i. e.* it is converted from a gaseous to a fluid, or from a fluid to a solid form. To the former of these processes is applied the term *condensation,* and to the latter *solidification.*

Genus 1st. *Of Condensation.*

The elastic fluids which are by condensation converted into liquids are of two kinds: the permanently elastic fluids or *gases,* and those which assume the liquid form by a slight reduction of temperature, and are termed *vapours;* the condensation of these last has been already described when speaking of distillation; we have here to occupy ourselves with the mode of effecting the condensation of the gases properly so called, and the phenomena which accompany the process. This condensation may be performed either *immediately* or *mediately.*

Species 1st. *Of immediate Condensation of Gases.*

The analogy which exists between the properties of vapours and of gases justifies us in considering the latter merely as the vapour of certain liquids whose boiling point is so low, that at common temperatures they never exist under that form. This conjecture, first thrown out by Amontons, was verified by the actual condensation of several of the gases effected by Faraday.

It has been already mentioned that there are two methods of diminishing the elastic force of the vapour of a body, and thus of effecting its condensation; 1st, by pressure, 2d, by cold: By using the former, Faraday, and by the application of the second, Bussy succeeded in obtaining under the liquid form many of the bodies usually gaseous.

Faraday generated the gas in a thick tube, strongly sealed, and capable of resisting a pressure of very many atmospheres; Bussy having obtained liquid sulphurous acid by passing the gas through tubes immersed in freezing mixtures, applied the cold produced by its evaporation to the condensation of the more permanent gases. Those which were thus re-aggregated were all compound except chlorine; the chemical books give all the necessary details of the processes and pressures; the operation not being of use in pharmacy does not require to be more minutely described here.

Species 2d. *Of the Mediate Condensation of Gases.*

The *absorption of gases* by liquids, or the *mediate condensation of gases,* depends upon the operation of two forces, 1st, the chemical affinity which is exerted between the gas and the liquid, and 2nd, the tendency in the gas to permeate the liquid and insinuate itself between its particles, as takes place with the molecules of a solid in solution. Occasionally this last force alone comes into action, and there the volume of gas condensed is very small, as in the case of oxygen, hydrogen, and such other gases as have no affinity for water ; but where the gas is capable of combining chemically with the fluid, as muriatic acid, ammonia, &c. The volume of gas absorbed is very large, and the evolution of a considerable quantity of heat accompanies its condensation.

The quantity of different gases absorbed by 100 volumes of water, is given in the following table:

Names.	Volumes.	Authors.
Ammonia	78000.	Thompson.
Muriatic Acid . . .	48000.	Davy.
Sulphurous Acid . .	4378.	Saussure.
Sulphuretted Hydrogen	253.	Do.
Carbonic Acid . .	100.	Dalton.
Olefiant Gas . . .	15.3	Do.
Oxygen	3.7	Do.
Carbonic Oxide . .	1.56	Do.
Hydrogen . . .	1.56	Do.
Nitrogen	1.56	Do.

The lighter a liquid is, the greater is its power of absorbing gases, provided no peculiar affinity interferes to influence the result; thus alcohol absorbs more of a given gas than oil of turpentine, oil of turpentine than water, and pure water more than a solution of any substance in that liquid: the probable reason of this is, that in fluids the distances between their ultimate molecules is some way inversely as their specific gravities, and therefore the lighter a liquid is the more room there is for the particles of the gas to insinuate themselves into its interior. The inferior absorbing power of solutions of salts may be readily accounted for, seeing that the interstices between the aqueous molecules are already filled up by the atoms of the solid body.

The viscid liquids absorb as much gas as those which are more fluid, but the process occupies a longer time from the difficult penetrability of the adhesive liquid.

Those forces which augment the tension of the gas diminish its condensibility by water, and *vice versa*: a fluid already saturated with a gas, parts with the whole of it when heated to ebullition; and if a portion of water, impregnated with a gas, be placed *in vacuo*, the elastic fluid escapes with an appearance of ebullition; on the other hand, if the pressure be increased, the capability of the gas to be condensed augments likewise, and on this principle are founded all the instruments devised for super-saturating water with carbonic acid, &c.*

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* Water absorbs always its own volume of carbonic acid:

If water, saturated with a gas, be exposed to the action of another gas, which is capable of combining with the first, more of the second gas will be absorbed than under any other circumstances; but if the second gas does not enter into combination, then a portion of the first will be expelled, and its place supplied by a corresponding volume of the second. The same takes place when water is agitated with a mixture of gases; some of each is absorbed, and the quantity of each depends on their relative condensibility in water; thus, if the mixture be of two gases of equal solubility, one half the volume, which would have been absorbed of either if it were presented to it alone, will be absorbed of each; and if one gas be twice as soluble as the other, two-thirds of the absorbed mixture will be composed of the gas most easily absorbed by water.

Common water always contains some air, which contains more oxygen and carbonic acid than that of the atmosphere, and from which it may be in a great degree freed by boiling.

Of the Methods used in impregnating Water with Gases.

Numerous forms of apparatus have been invented for expediting the condensation of gases in

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now, if we, by a force of two atmospheres, compress 100 cubic inches into 50, these 50 will be still absorbed by 50 of water; and if by 4 atmospheres we reduce them to 25, an equal volume of water will still absorb them; thus the absorption is directly as the pressure.

water, and from the importance of many preparations thus obtained, they present considerable interest.

The Woulfe's apparatus, and some of its modifications, however, alone claim our attention, as the making of soda-water, for which various large instruments have been invented, does not, at least in this country, belong to the apothecary.

The original apparatus, as used by Woulfe, is designed in Plate V. Fig. 5. Before proceeding to the description of its office, some principles require to be explained.

1st. All gases, as well as vapours, are endowed with a certain tension or elastic force, by virtue of which they press against the parietes of the vessels which contain them.

2d. The tension of a gas is proportional to its quantity; it augments with the temperature and diminishes by cooling.

3d. The atmospheric pressure is constantly exerted to the amount of about 15lb. on every square inch; and,

4th. All liquids, elastic and inelastic, transmit this pressure equally in all directions.

Now if a gas be generated in A. it will pass successively from the retort into the first bottle; from that into the second, and so to the third; at the commencement of the operation the fluid is at a level in all the tubes, but it soon ceases to be so; why, it is necessary to explain. A certain quantity of gas being disengaged in A. augments the tension of the air contained therein, and consequently an increased pressure is exercised on the sides of the vessel which resist it, and on the liquids in the tubes S. and *e.* which yield to the pressure, so that the liquid is elevated to a certain height in the upper arm of the first and lowered in a corresponding degree in the second, until the force of the air in A. becomes sufficiently powerful to depress the whole of the fluid from the tube *e.* then the gas traverses the liquid in the bottle B. dissolves in it if it is soluble, if not it rises to the surface, and augments the tension of the air contained in B. Here phenomena similar to those which have been already explained take place, viz. augmentation of tension in B. elevation of the liquid in the safety tube S′. and a corresponding depression in the longer leg of *i.*

When the gas has reached C. it acts exactly in the same manner, that is, it forces the fluid to ascend in S″. and to descend in *o*: but in the last bottle the liquid does not rise in the tube S‴. because this bottle being open the gas which arrives there, mingling with the atmosphere, its effect becomes inappreciable, and the increase of pressure upon the surface of the water in the bottle D. is counterbalanced by the equally increased pressure on the surface of the fluid in S‴. So this tube is useless, and is merely figured to facilitate explanation.

When the gas which is disengaged in A. begins to reach the bottle D. if we examine the level of the liquid in the different safety tubes, we shall see that it is equal to it in the tube S‴. higher than it in S″. still more elevated in S′. and that the elevation in S. is equal to the sum of the columns in S′. and S″. Why does this take place?

The level in the tube S‴. is the same as that of the water, because the atmosphere presses equally upon both surfaces; the liquid is raised to a certain height in S″. because the pressure of the gas in C. is superior to that of the atmosphere upon the liquid in S″. for it was equal to it before the operation began, and has been augmented by the tension of all the gas which has reached that bottle, and to whose exit the column of water in the tube *o*. is opposed.

The liquid is more elevated in S′. than in S″. the reason is, that the tension of the gas in B. is augmented by the resistance which the liquid in C. opposes to its issue, a resistance which is increased by all the effect of the augmentation of tension of the gas in C; in fact to escape from C. the gas had only to overcome the weight of the column of water in the tube *o*. along with that of the atmosphere, while to escape from B. its tension must be sufficiently great to equal the weight of the column of water in *i*. increased by all the pressure of the gas in C. which, as we have seen, was greater than that of the atmosphere.

Finally, the elevation in the tube S. is equal to the sum of the elevations in the tubes S′. and S″. because to escape from A. the gas must overcome the sum of the pressures exercised in B. C. and D.

The tube S. serves to introduce into the first vessel the requisite materials, but it has another not less important office in common with the straight tubes, viz. that of preventing the mixing of the products of the operation, whence they are called tubes of safety. If these tubes did not exist, when the tension of the internal atmosphere of the retort would be diminished by cooling, the pressure of the gas in the first bottle would be greater than that in the retort, and weighing upon the liquid in B. would force it into A; consequently the pressure in B. would become less, and would not be able to counterbalance that in C.; the liquid in C. would pass into B. by the tube *i.* and finally the fluid in D. would be pressed into the bottle C. by the weight of the external air. But when the tubes of safety exist, as the tension in A. diminishes, the air presses more and more on the liquid in S. forces it into the shorter leg, and finally into the apparatus, until the equilibrium is restored: the same effect is produced in the other bottles by the straight tubes, but they should dip very little into the liquid: otherwise the fluid might be thrown into the preceding bottles, before its level would be so much depressed as to allow of a communication through the safety tube with the external air. The tube S. is generally made with a ball blown on the short leg, so that when the interior pressure is diminished the whole of the fluid is forced into the ball, and the external air ascending through it alone, passes into the retort, which is thus freed from the danger and inconvenience of the sudden influx of a quantity of cold water. Tubes of a similar form are sometimes attached to the conductors, and serve as safety tubes; they are called Welther's safety tubes.

Various modifications of this apparatus have been proposed by North, Hamilton, &c., to describe all which would be an endless task: the principle upon which the instrument is contrived being what it is wished to impress upon the student, as the pieces themselves of apparatus are every day in his hand.

It now remains to notice the peculiarities of the preparation of some of the solutions of gases in water.

1st. *Muriatic Acid.*

Muriatic acid is obtained by decomposing sea-salt by sulphuric acid; forming a bisulphate of soda, which remains as residuum, and hydrochloric acid gas, which, condensed in water, forms liquid muriatic acid. In the laboratory this is performed in glass vessels; but from the waste of retorts in consequence of the difficult extraction of the residual salt, it is more economical to purify the acid of commerce for chemical purposes.

The acid of commerce is obtained by heating the materials in iron pots lined with a coating of closely joined fire tiles; the gas is condensed in stone-ware vessels like two necked bottles, the connecting tubes descending very nearly to the surface of the water, but not to any depth in it, (even in the preparation of the pure acid the tubes should merely touch the surface of the water,) because the water, as it becomes saturated, descends, and the lighter unimpregnated fluid rises to supply its place: the acid thus obtained is impure, containing some sulphuric acid, generally driven over towards the end of the process, and some iron: from both these it may be freed by re-distillation; and the fixture of the sulphuric acid may be secured by the addition of a little litharge; a small quantity of water should be put into the receiver to condense the portions of the gaseous acid which come over first.

2d. *Of Water of Ammonia.*

Prepared by decomposing muriate of ammonia by lime; according to the generally received doctrines a case of simple elective affinity, aided by the tendency of the ammonia to assume the elastic form. The process needs no peculiar comment; the decomposition is effected in an iron or earthen vessel; the heat, at first very gentle, is gradually increased; and in the condensing bottles the connecting tubes should dip entirely to the bottom of the fluid, because the water of ammonia, being so much lighter than the unimpregnated water, gains the surface, and we must keep the gas in contact with the unsaturated liquor; exactly the same end being gained in the preparation of muriatic acid by the opposite disposition.*

The other solutions of gases in water do not require any observation. Chlorine water, water saturated with carbonic acid, &c. have not in their preparation any particularities which demand comment. Prussic acid, which is, properly speaking, a solution of a gas in water, like muriatic acid, is prepared simply by distillation, and will be hereafter noticed.

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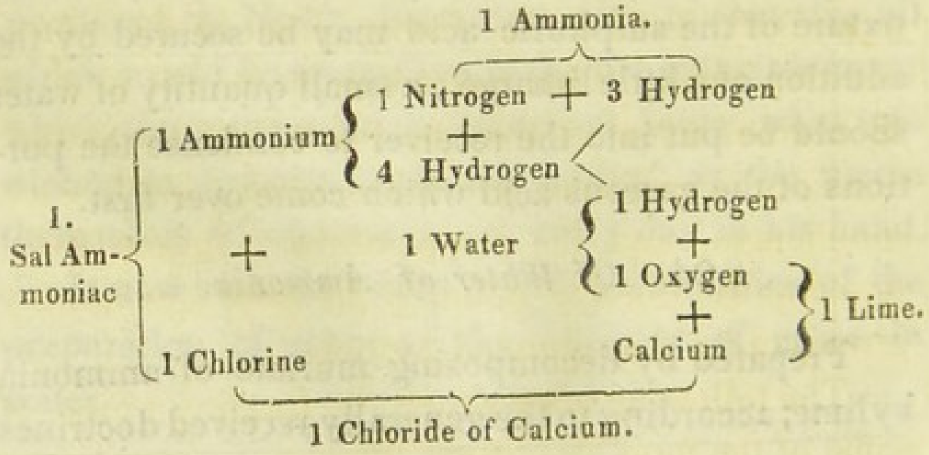
* According to Berzelius' supposition of sal-ammoniac being a chloride of the metal ammonium, the decomposition will be illustrated thus:



Genus 2d.—*Of Solidification.*

Solidification may be considered as being of two kinds, first, where the fluid becomes entirely solidified, as when a fused mass of lead becomes solid; and 2dly, when certain portions of matter only lose their fluid form, and assume certain more or less regular figures, as when a saturated hot solution of sulphate of soda is allowed to cool. The first of these divisions may be termed *congelation,* and the second, *crystallization;* although convenient for practice, they have not in reality any distinct line of separation.

Species 1st.—*Of Congelation.*

When a body passes from the fluid to the solid form, two phenomena, corresponding to those which we observed to accompany the fusion of bodies, always take place; 1st, the solidification takes place at a fixed temperature, which is the same at its melting point; and 2dly, the latent heat which it absorbed during its liquefaction becomes again disengaged, and sensible to the thermometer.

The solidifying point of a fluid is not however so perfectly fixed as the fusing point of the corresponding solid. Thus water may be cooled to 20 or 25 degrees below its freezing point, but the instant that from agitation or any other cause, solidification commences, and the temperature is immediately raised to the freezing point by the caloric of fluidity given out by the solidified portion.

The following table shows the freezing points of some of the more important fluids:

Substances.		Fahrenheit.
Sulphuric Ether	—	46°
Liquid Ammonia	—	46
Nitric Acid, sp. gr. 1.424	—	45.5
Sulphuric Acid, sp. gr. 1.6415	—	45
Mercury	—	39
Brandy	—	7
Sulphuric Acid, sp. gr. 1.8376	+	1
Oil of Turpentine		14
Blood		25
Vinegar		28
Milk		30
Water		32
Olive Oil		36
Sulphuric Acid, sp. gr. 1.780		46
Oil of Anise		50
Concentrated Acetic Acid		50

The mode of effecting congelation demands little remark. The application of freezing mixtures to produce the requisite reduction of temperature requires no comment, and the cold produced by the rapid evaporation of ether, of sulphuret of carbon, or of sulphurous acid *in vacuo,* has been already noticed as a powerful means of refrigeration.

Species 2d.—*Of Crystallization.*

When during the gradual transition from the fluid to the solid form, the particles of a body assume certain regular forms, these forms are termed *crystals,* and the phenomena of their production *crystallization.*

Crystallization requires to be considered under two heads, 1st, the mechanical structure of crystallized bodies, and the theory of their production; and 2dly, the methods by which the crystallization of substances are promoted or retarded.

The crystalline forms assumed by bodies are of two kinds, 1st, *Primitive* or *derivative,* which are constant for the same substances; and 2dly, *Secondary* or *derived,* many of which may be born by substances of the same composition.

The primitive form always exists in the secondary, enveloped by it, and may be discovered and extracted, either by cleavage, according to Haüy's mode, or by the slow solvent action of water, as recommended by Daniell.*

The secondary forms are immensely numerous; the primitive were given by Haüy as six, *viz.* the parallelopipedon, the octohedron, the tetrahedron, the regular hexahedral prism, the dodecahedron with rhombous planes all equal and similar, and the dodecahedron with triangular planes, composed of two straight pyramids, joined base to base; by Mr. Brooke as fifteen. By successive layers of molecules of the body stratified in different ways on planes of the primitive forms, all the secondary figures have their origin. These primitive forms are themselves not simple; they can be reduced to other forms, three in number, *viz.* the tetrahedron, the triangular

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* Quarterly Journal of Science, vol. i. p. 24.

prism, and the parallelopipedon; which Haüy assumed in his theory to be the shapes of the ultimate particles of matter.

This theory of Haüy, although very extensively applicable, yet is inconsistent with many well determined facts. There are many figures which could not be formed from his molecules, without leaving empty spaces; according to his theory, some crystals should have cleavages different from those which they really possess, and for the formation of others, the particles should attract each other by their edges and not by their planes, which is impossible. The other hypothesis by which the structure of crystalline bodies may be explained is the spherical theory of Wollaston.*

On the supposition of the ultimate particles of bodies possessing the figures of spheres, most of the forms of crystals may be explained, and substituting for the perfect spheres, oblate or oblong speroids, most of the other figures may be easily constructed; this hypothesis, first advanced by Wollaston, has lately been ably elucidated,† and supported by additional reasoning by Professor Daniell.

Crystals are described by the form which they possess, and by the values of the angles uniting their plane surfaces: the values of the angles are estimated by the number of degrees which they include, (the circle containing 360°); the instrument used for these measurements is termed a *goniometer*.

It is not absolutely necessary that bodies should

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* Philosophical Transactions, 1813.

† Journal of the Royal Institution, August, 1831.

possess the fluid form, to pass from an amorphous to a crystalline state; barley sugar, copper wire, and many others, are familiar instances, and Mitterslich has discovered that many crystals change their form, by the operation of peculiar agents;* thus the prismatic sulphate of nickel changes into a number of octoëdrons with square bases, and the same occurs with the seleniate of zinc if these crystals be heated for an instant on a sheet of paper; if transparent prismatic crystals of sulphate of magnesia, or of zinc, be boiled in alcohol for a few minutes, they become opaque, and break into a number of small crystals of a totally different figure. Even many crystals which do not lose their form, alter the measure of their angles when heated from expanding unequally: these phenomena have been ably brought forward by Daniell, in support of the spheroidal hypothesis, by which they may be beautifully explained; but the details of such abstruse matter would be foreign to a work of an elementary nature.

A circumstance important to the chemist equally in a theoretic and practical point of view, is the law of isomorphism, discovered by Mitterslich of Berlin. He found that certain substances when similarly combined with the same body, always affect the same crystalline form: thus the arseniates and the phosphates of the same bases, and containing the same quantity of acid and of water, crystallize in the same shape: the sulphates and the seleniates; the salts of iron and of alumina: the salts of lead, strontia and baryta,

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* Annales de Chimie et de Physique, vol. xxxvii. page 205.

follow the same law; and the salts of lime, magnesia, protoxides of iron and of manganese, of cobalt, nikel, zinc, and of deutoxide of copper, combined in the same manner with the same acid, possess similar crystalline forms; hence bodies are classified into groups which are termed *isomorphous,* as is seen in the arrangement used above.

An important consequence of this law is, that isomorphous bodies may be substituted for each other, in combinations, and yet the crystalline form of the compound remain unaltered; thus, by uniting persulphate of iron to sulphate of potash, we obtain by crystallization an alum exactly similar in taste, colour, and figure, to the common sulphate of alumina and potash; and another curious fact is, that salts composed of a base united to ismorphous acids, or of an acid joined with ismorphous bases, generally contain exactly the same quantity of water of crystallization. The law of ismorphism has been attempted to be explained in two ways, 1st, by supposing that the same number of atoms arranged in the same mechanical manner, always assume the same figure, whatsoever may be their chemical nature; or 2d, by assuming that there exist certain simple bodies which are ismorphous, and that the principle of isomorphism would equally pervade their corresponding compounds with the other bodies. Thus that sulphur and selenium are isomorphous; therefore the compounds with the same quantity (3 atoms) of oxygen, the selenic and sulphuric acids, would be ismorphous, and that compounds with 3 atoms of oxygen and one atom of potash, would also possess the same figure. In the present state of science, it perhaps may be safest to at once confess our ignorance of the cause.

In a practical point of view, crystallization is a most important process; it is useful in obtaining substances free from impurities, for which purpose no other way is so successful; it confers upon a body a defined state, in which its quantity can be readily determined; and the figure of its crystals affords us a means of recognizing a substance with considerable accuracy.

For practical purposes substances are always converted into liquids previous to crystallization: this is effected in either of three ways; 1st, by fusion, 2d, by solution, and 3d, by volatilization.

1st. Crystallization by fusion; fusion is made use of where the substance to be crystallized is insoluble in water, as in the case of the metals, of sulphur, &c. In this case the sulphur, for instance, is fused in an earthen-ware pot, and allowed to cool gradually, until a solid crust has formed on its upper surface. This is to be perforated in two places diametrically opposite, and the remaining fluid portion run out through the lower, while the air enters through the upper orifice: when the solid mass has cooled, the interior is found lined with numerous crystals; prisms in the case of sulphur, cubes with bismuth, &c. The slower the refrigeration of the mass has been conducted, the more perfectly formed these crystals will be.[1] For pharmaceutical purposes this mode of crystallization is seldom had recourse to.

2d. Crystallization by solution is the mode generally adopted for that purpose; it may be effected in either of two ways, 1st, by the cooling of a solution saturated at a higher temperature, or 2d, by the evaporation of a solution saturated at common temperatures : the former is the better and the more generally applicable ; the latter, however, must be used with some substances which are not much more soluble in hot than in cold water.

A saturated solution of a salt in boiling water may be obtained either by heating the water with an excess of the salt, or by evaporating a more dilute solution to the requisite degree ; the point of concentration at which the solution will crystallize on cooling, is easily known by letting fall a drop of the liquor on a cold plate of glass, when if strong enough, the formation of minute crystals will be immediately perceived : it is sometime ordered to evaporate a saline solution to a *pellicle,* that is until a scum of solidified salt forms on the surface whence the evaporation takes place; but when the concentration is pushed so far the crystallization is always crowded and confused, and the crystals ill-formed and small.

Crystallization is much promoted by agitation, but the crystals then produced are small : some years since there existed abundantly in the market a fictitious Epsom salt, prepared by agitating while crystallizing, a strong solution of sulphate of soda, the crystals formed were very small, and presented, at first sight, an appearence somewhat similar to that of commercial Epsom salt ; light promotes crystallization ; and the same effect is produced by negative electricity, while the positive counteracts it.* Ber-

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* Ure, Quarterly Journal of Science, vol. iv. page 106.

zelius thinks this effect is produced by the acid evolved at the positive pole forming a more soluble, while the base, eliminated at the negative, forms a less soluble salt, which therefore becomes solid first.[*] Crystallization is often very much promoted by dropping into the solution a fragment of some solid body, or a bit of a crystal of the same substance, which serves as a nucleus round which the particles of the salt collect and unite: in this way the sugar candy is crystallized on threads, and verdigris on pieces of wood, &c.

The vessels in which crystallization by cooling is to be performed should be of glass or earthen-ware, and about the depth of half their diameter: they should be covered to protect them from the dust, and to prevent evaporation, and the cooling should be as quiet and slow as possible, because the size and regularity of the crystals are directly as the slowness of their formation. An excellent mode of getting large crystals is that recommended by Faraday, of placing the solution on the sand bath when the fire is going out, heaping the sand around it and leaving it undisturbed until morning; the cooling proceeds very slowly, the evaporation is slightly kept up, and a fine crop of large crystals generally obtained.[†]

Where the crystallization is to be effected by evaporation, a solution saturated at common temperatures is to be taken and set aside; the containing vessels should be shallow and wide, so as to expose a considerable surface of the fluid, and they should

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[*] Traité de Chimie, vol. i. page 465.

[†] Manipulation, page, 252.

be left in a place with draught sufficient to remove the vapour as it is formed; where there is any danger of dirt, the basin should be covered with a fine cloth or paper, but this, by impeding the evaporation, renders the length of the process much greater.

By the method of Le Blanc very large crystals may be obtained: a few crystals are left in a solution of the substance; as it evaporates spontaneously they increase in size, and the increase is rendered equal by frequently turning the crystals from one side to another in the solution.

The nature of the liquor from which a salt is crystallized, influences sometimes the conformation of the solid; thus, from a solution of urea, common salt crystallizes in octohedrons, and alum in cubes; and the crystals of nitre which form from the solution of that salt in lime water, are exceedingly well formed and large. Crystals collect generally at the bottom or on the sides of the containing vessel; some salts however crystallize on the edges of the dishes, totally out of the fluid and under the form of granular excrescences. The bi-sulphate of potash, the carbonate of soda, sulphate of zinc, sal ammoniac, and the red prussiate of potash, particularly affect this mode of crystallizing: many others also do so, but none to such a degree. The reason of this extraordinary saline vegetation is, that the water evaporating on the sides of the vessel deposits there minute particles of salt; between these and the vessel the fluid ascends by capillary action, and evaporating in the same way produces new deposits, each advancing higher from the surface of the fluid, until the rim of the vessel is crowned with a curious arborescent mass of salt.

Most crystals, in forming from their solution in water, combine with and render solid a certain quantity of water, which is thence termed *water of crystallization*. Many salts, as sulphate of potash, chloride of sodium, nitre, &c. do not combine with any water, but in those that do, the combination takes place in definite proportions, and *the oxygen of the water is a multiple or submultiple by a whole number of the oxygen of the base* contained in the salt.

The same salt is capable of crystallizing sometimes with, and sometimes without water, according to the temperature at which the process is conducted, and the figure of the crystals differ accordingly. Thus sulphate of soda crystallizes at 90° Fah. in an *anhydrous state*; nitrate of strontia is nearly similarly circumstanced, and at the temperature of 14° Fah., common salt combines with a considerable quantity of water of crystallization.

Berzelius* considers the term *water of crystallization* incorrect, for many substances not crystalline combine with water and form *hydrates*, as the hydrate of lime, the hydrate of the deutoxide of copper, &c. he proposes to substitute for it, the phrase *water chemically combined*, which is not liable to the same objections.

Many salts which do not contain water of crystallization, yet in solidifying, enclose between their particles small drops of the mother liquor: when

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* Traité de Chimie, vol. i. p. 470.

such a salt is heated, the enclosed water is vaporized, and the vapour, by its tension, bursts asunder the crystal to escape : this phenomenon is termed *decrepitation,* and is well exemplified in the case of common salt.

Salts which contain much water of crystallization, and which are very soluble in hot water, when heated, melt, and are dissolved by their own chemically combined water ; this is termed the *aqueous fusion* of a salt : on continuing the heat the water is vaporized and the dry salt remains, which, on an increase of the heat, undergoes the proper or *igneous fusion.*

Some salts, when exposed to the air, lose by degrees the water of crystallization which they contained, and are said to *effloresce ;* some, as phosphate of soda, part with only a portion of the water, and preserve their form ; others, as sulphate of soda, lose the whole and fall into a fine powder ; if water be added to these thus effloresced salts, they gradually re-unite with it and form a hard transparent semi-crystalline mass.

Other salts which have a great affinity for water, when exposed to the air attract its moisture, and fall into a viscid liquor, this is termed *deliquescence ;* the salts which are not altered by exposure to the air are called *permanent ;* this state depends so much upon the dryness or dampness of the air, that some bodies, as oxalic acid, effloresce in a dry, but deliquesce in a moist atmosphere.

Although crystallization is very useful as a means of separating substances from one another, yet there are many bodies, as was proved by Beudant, which have a remarkable tendency to crystallize together; at all times two or three crystallizations are required before a salt can be obtained perfectly free from the substances which contaminate the mother water; after having been obtained, the crystals should be washed with a small quantity of distilled water or alcohol, and put up in vessels capable of excluding the air if the substance crystallized be either efflorescent or the contrary.

Species 3d.—*Of Precipitation.*

Where a body assumes the solid form very suddenly, its particles have not time to arrange themselves in regular geometrical forms, and the solid appears as a powder, impalpable, if it be totally insoluble in water, or more or less gritty, if the body from partial solubility makes any approaches to crystallization. This phenomenon is termed *Precipitation.*

Precipitation is effected in either of two ways; 1st, by mixing a solution in water of a certain substance with another fluid which combines with the water, and the body suddenly passing from the fluid to the solid form is precipitated. Thus nitre or the ammoniuret of copper is obtained in very minute crystals by mixing their aqueous solution with alcohol; 2d, by generating from the admixture of solutions of two bodies, a third which is insoluble in the medium of solution, and which is consequently precipitated as soon as formed: thus, oxalate of lime is precipitated when we add lime water to a solution of oxalic acid, and sulphate of baryta is deposited when we mix together solutions of sulphate of soda and muriate of baryta.

The vessels used in precipitation are very simple; test tubes, deep earthen-ware crocks, &c. are usually employed; for collecting precipitates Philips' jars, before adverted to, are the most advantageous.

The products obtained by precipitation are, many salts as carbonate and phosphate of lime, carbonate of magnesia, &c. metallic oxides, as those of zinc, mercury, &c. and some other preparations, the details of which are fully entered into by the different commentators on the Pharmacopœias.

Class 3d. *Operations of Decomposition.*

Decomposition takes place when the constituents of a compound body are separated, one remaining combined with the substance, by the superior affinity of which the decomposition was effected; and the other being disengaged is obtained isolated as the product of the operation.

These operations may be divided into two genera, according as the product is an acid or a base; thus nitre decomposed by sulphuric acid, cyanuret of mercury by muriatic acid, are instances of the first kind; carbonate of potash by lime; muriate of ammonia by the same earth, are instances of decomposition of the second kind.

Decomposition being always produced by the exertion of chemical affinity, a few words concerning the circumstances which modify this force, and the laws which govern its action, are necessary before entering into the particular instances of this operation.

Affinity differs from cohesion in not being exerted at sensible distances, nor between bodies of the same nature.

Affinity acts upon bodies with different degrees of energy, varying as well with the proportion of the same body as with the nature of the bodies themselves.

Affinity is said to be *Simple,* when bodies unite merely from their natural attraction, as phosphorus and oxygen; *Compound,* where more than one new body is generated; and *Disposing,* where bodies unite not merely in consequence of the affinity they possess for each other, but of the affinity which the compound they are about to form has for another substance present, with which it immediately combines, as when the decomposition of water by zinc or iron is promoted by the presence of dilute sulphuric acid.*

The attractions which tend to preserve the original arrangement of particles are termed the *quiescent,* and those which tend to destroy the original and form new arrangements, are termed the *divellent* attractions. It is plain that no new arrangement can be produced, no *Decomposition* effected, unless the divellent be more powerful than the quiescent attractions.

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* The supposition of the existence of disposing affinity is a mere hypothesis.

When bodies having an affinity for each other unite, the combination always takes place in definite proportions; this is the principle upon which is superstructed the *atomic theory.*

When a body A. unites in many proportions with a body B., as in the proportions of A.+B, A.+2 B, &c., it generally occurs, that in A.+2 B, the first B. is much more powerfully retained than the second, and so the second B. may be removed from A. by a force which is not able to separate the first. However it sometimes, although not often, happens, that A. retains 2 B. more powerfully than it does B., so that it may be easy to decompose A.+B, but more difficult to produce the same effect on A.+2 B. Thus protoxide of mercury is reduced by exposure to light or by friction in the hands, whilst the deutoxide requires a full red heat for its decomposition; the protoxide of tin is also very readily reduced, whilst the deutoxide is with much more difficulty.

When two bodies, A. and B., tend with different affinities to combine with another body C., and that the quantity of C. is insufficient completely to saturate both A. and B., the body C. is divided between A. and B. in the compound proportion of their original affinities, and of their quantities. This rule is however very often modified by circumstances.*

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* For a most elaborate investigation of the laws of affinity, see Berzelius, " Observations generales sur les Phenomenes de l'Affinité Chimique," in vol. iv. of his Traité de Chimie, from whence the following remarks have been principally extracted.

When a combination A. B. is put into contact with another C. D.; that A. can combine with D. and B. with C., and that A. and D. have more powerful affinities, these two combinations change their constituents, so that the stronger bodies A. and D. unite to produce A. D. and the weaker C. and B. combine to form C. B. If, on the contrary, A. and B. are the more powerfully disposed to unite, no change takes place.*

If one of the bodies generated be insoluble, and so can be removed from the sphere of action as it is formed, the decomposition may be perfect, and none of either A. B. or C. D. may remain in solution; but if the resulting compounds be soluble, the exchange of elements is not entirely complete, and we obtain a mixture of A. B., A. D., C. D., and B. C.; this is probably the way in which many mineral waters are composed, although by analysis we extract the elements rather differently arranged and in fewer combinations.

These laws of affinity are so modified by circumstances that the chemist often obtains a result quite contrary to that indicated by the rule. These modifying forces, are, temperature, the greater or less volatility of the bodies, their different degrees of solubility, and their disposition to enter into peculiar states of combination.

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* This is what is termed double decomposition: an operation which, as the products obtained are always saline, will be treated of among the operations of *Halogenesis.* The theoretic rationale of its phenonomena, however, should not be separated from the general view of the laws of chemical affinity.

1st. *Modifications by Temperature.* The influence of temperature upon affinity is very great; a peculiar compound being often generated at a certain temperature, which is capable of being again decomposed by an increase of heat. Thus, carbonic acid gas being passed through a solution of carbonate of potash at common temperatures, the bicarbonate of the alkali is formed; but if the solution be heated to ebullition, this salt is decomposed, and one atom only of carbonic acid left in combination. Mercury, at one temperature, abstracts oxygen from the air; the oxide is reduced at a heat not much higher. At the temperature of boiling water silver reduces the per-sulphate of iron to the proto-sulphate, and is dissolved; but as the solution cools, the proto-sulphate precipitates the silver in the metallic state, and is again converted into the per-sulphate.

2d. *Modifications arising from the volatility of Bodies:* When two bodies, A. and B. have a tendency to combine with a third body, C., and that the body A. (the more powerful) is in possession of the body C.; B. may yet expel A. if the latter be volatile, so that it may be vaporized, or may escape under the form of gas. For at the moment that B. begins to act in proportion to its quantity and affinity, a portion of A. disengaged is driven off, and so does not oppose the tendency which B. has to combine with new proportions of C.; if the body A. is not volatile at common temperatures, the decomposition does not commence until the heat has been raised to the point at which A. is converted into vapour. Thus the nitrates are decomposed by boracic acid at the temperature at which nitric acid is volatilized; potassium decomposes oxide of iron at common temperatures, but iron decomposes potassa when the heat is very intense.

When we mix two compound bodies, A. B. and C. D. and that they are exposed to a temperature sufficient to volatilize a combination of A. with D. the two bodies are decomposed at that temperature; and although the affinity of A. for B. should be the more powerful, yet A. D. is volatilized, and C. B. remains behind. Thus, at common temperatures, borate of ammonia and muriate of soda do not act upon one another, yet if the temperature be raised, muriate of ammonia sublimes, while borate of soda remains fixed. If, on the contrary, the four bodies A. B. C. D. form all one compound at common temperatures, but that B. forms with C. a compound volatile at a more elevated temperature, A. B. C. D. is converted at this degree of heat into B. C., which sublimes, and into A. D., which remains fixed. Thus the double salts of ammonia, when heated, are decomposed; the ammonia sublimes with one proportional of the acid, while the other base remains combined with the rest.

3d. *Modifications arising from the degrees of solubility of Bodies.* When two bodies, A. and B., have an affinity for a third body, and each on its own part tends to unite with it, but that either one or the other of these bodies form with C. a compound insoluble in water, this compound separates when the aqueous solutions of these bodies are mixed. If A. has more affinity for C. than B. has, yet if B. C. be insoluble, a greater quantity of it will be precipitated, notwithstanding the exertion of the original affinity, than would be formed if B. C. remained dissolved; because that the portion precipitated is subtracted from the action of the substances in solution, and the affinity of A. for its solvent diminishes its affinity for C: the more insoluble B. C. is, the greater quantity of it will be formed. Thus tartaric acid precipitates a solution of nitrate of lime, although the affinity of nitric acid for lime is greater than that of tartaric acid; but if the affinity of A. for C. be much greater than that of B. for C., B. C. will not be found, although it may be insoluble; thus, although tartaric acid acts as above, carbonic acid does not decompose nitrate of lime, notwithstanding the insolubility of the calcareous carbonate.

If we mix aqueous solutions of two compound bodies, A. B. and C. D. among which A. has most affinity for B. while A. may form an insoluble compound with D; a precipitate of A. D. is instantly obtained, and C. B. remains in solution. If A. D. in place of being insoluble is only less soluble than C. B., A. B., and C. D., and that the solution be evaporated, A. D. crystallizes; or if A. D. has a tendency to effloresce, and that the solution be abandoned to itself, A. D. gradually separates itself by efflorescence from the other substances. For example, when we mix a solution of sulphate of soda with one of acetate of lead, sulphate of lead is precipitated, although the affinity of sulphuric acid for soda is the strongest. When solutions of sulphate of magnesia and of common salt, are mixed, and the liquor evaporated, during the evaporation crystals of chloride of sodium are deposited, because that salt is at that temperature the least soluble constituent; but if we expose the mixture to a cold of 37° F. we obtain crystals of sulphate of soda, because at that temperature this is the substance least easily dissolved, and when a mixture of a large quantity of carbonate of lime with a little chloride of sodium is left exposed to the air, it after some time becomes covered with an efflorescence of carbonate of soda.

A tendency to form peculiar combinations also makes substances deviate considerably from the general laws of affinity; thus, when we mix chloride of gold with ammonia, at first the chlorine divides itself between the gold and the ammonia; but when more ammonia is added, this last divides itself between the chlorine and the gold, and we have on the one hand sal ammoniac, and on the other fulminating gold formed: also, phosphate of lime cannot be decomposed by even the strongest bases, but the weakest acid takes from it a portion of the lime, in consequence of the tendency of the phosphoric acid to form a bi-salt. The formation of double salts also influences, in a great degree, the power of the different bases of precipitating each other from their saline combinations.

A still greater degree of complexity is given to the phenomena of affinity, by the fact, that several of these modifying causes, and probably many others of whose existence we as yet know nothing, concur in producing their several effects.

1st.—*Of the Preparation of the Acids by the Decomposition of their Salts.*

1st.—*Of Acetic Acid.*

In the Pharmacopœial process, the acetate of potash is decomposed by sulphuric acid, and the liberated acetic acid separated by distillation; this is the most elegant and direct mode of obtaining the acid, but is not economical; all the necessary precautions are fully detailed by the commentators on the Pharmacopœia.

There are many other methods of obtaining acetic acid, among which two particularly deserve remark, 1st, by the distillation of crystallized binacetate of copper; this salt in powder is to be put into a coated retort connected with a receiver, kept cool, not by moistened cloths, but by a continual stream of water; the heat is gradually to be raised to dull redness; the water of crystallization of the salt first rises, it then commences to be decomposed, and a mixture of aqueous acid and of pyro-acetic spirit is obtained in the receiver; some crystals of acetate of copper rise into the neck of the retort, and a mixture of protoxide, and of metallic copper, with carbon, remains behind. A considerable quantity of acid is lost in this process, for the water of the salt is driven off before the acid begins to come over, and as it (the acid) cannot exist in a totally uncombined state, one portion is decomposed to give water of constitution* to the rest, and is resolved into

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* Many acids cannot exist except in combination; and when

water and pyro-acetic spirit; notwithstanding, from the cheapness of the acetate of copper, this is one of the most economic modes of obtaining real acetic acid: the product is generally green from the passage of some acetate of copper into the receiver, from which impurity it may be separated by re-distillation. This method is adopted by the codex.

2nd.—By mixing acetate of lead and sulphate of iron, and submitting them to distillation, we obtain very economically a strong acetic acid; (the sulphate of iron having been previously deprived of its water of crystallization,) a portion of the acid is however decomposed, and the product contains much sulphurous acid, arising from the action of the carbon of the acetic acid upon the sulphuric acid; from this impurity the acid may be freed by digestion on some per- (puce-coloured) oxide of lead, as long as the portions added are turned white; (the sulphurous acid being converted into sulphuric acid which forms sulphate of protoxide of lead); the acetic acid is then to be decanted and re-distilled. This is the process of the Edinburgh Pharmacopœia.

2nd.—*Of Benzoic Acid.*

The preparation of benzoic acid requires no observation. Cluzel remarked that by adding a small quantity of sulphuric acid, the quantity of benzoic acid obtained by sublimation was much in-

separated from a base, unless they have water to unite to in definite proportions, are immediately decomposed: the water thus necessary to the isolated existence of the acid, is termed *water of constitution*, and those acids are actually *hydrates*.

creased. It deserves mention, that an extensive adulteration of benzoic acid with amianthus, in Germany, has been discovered by Dr. Scheneman.* The pure acid should be totally soluble in alcohol.

2nd.—*Of Nitric Acid.*

In the decomposition of nitrate of potassa by sulphuric acid, there are some circumstances necessary to be remarked in order to understand the phenomena of the process. When we heat together nitre and oil of vitriol in the quantities of two proportionals of each, the whole of the nitre is decomposed and a sulphate of potash formed, but of the nitric acid evolved, only one half is obtained in a liquid form, the other half being decomposed, and resolved into nitrous acid and oxygen, for nitric acid cannot exist except in combination with either water or a base. The aqueous acid is composed of 1 atom nitric acid + 2 atoms water, and therefore in operating upon the above proportions there are two atoms of nitric acid liberated from the nitre, of which one unites with the two atoms of water which the oil of vitriol contained, while the other having nothing to combine with, is decomposed and lost.

Hence the necessity of using two atoms of sulphuric acid to one of nitre, to insure the condensation of the whole of the product, and not to form a bi-sulphate of potash, as some books inculcate, for one atom of sulphuric acid can decompose an atom

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* Repertorium für die Pharmacie von Buchner. Band. 15. s. 445.

of nitre, but the bi-sulphate formed is much more readily extracted than the neutral salt.

Even using two atoms, a small quantity of the nitric acid is decomposed, particularly at the commencement and termination of the process, periods when the water comes over in smaller quantity.

The nitric acid of commerce contains generally iron derived from the vessels in which it is prepared by the manufacturer, chlorine arising from the impurity of the unrefined nitre, which always contains common salt, and sulphuric acid, which rises when towards the close of the process the heat is raised to fuse the remaining bi-sulphate of potash or sal-enixum, to fit it for its uses in the arts; from these impurities, it may be separated by re-distillation from a little litharge.

3rd.—*Of Prussic Acid.*

The method pursued by Scheele is adopted as modified by Robiquet, by the Dublin Pharmacopœia, for the preparation of hydrocyanic acid; it does not require comment, the cyanuret of mercury is decomposed by hydrochloric acid; and the hydrocyanic acid disengaged, is obtained diluted with water, to the sp. gr. 0,998, containing 1. 6 per cent. of real acid.

There are some other modes of obtaining this acid, of which two deserve notice: 1st, that proposed by Gea-Pessina, an apothecary of Milan;* eighteen parts of ferro-prussiate of potash, reduced to fine powder, are to be introduced into a retort, adapted to a receiver, with a bent tube passing into a bottle contain-

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* Giornale di Fisica, Agosto, 1822.

ing some water; nine parts of strong sulphuric acid, diluted with twelve parts of water, are then to be poured on the salt, the tubulure of the retort carefully closed, and the whole left to digest for twelve hours, refrigerating the receiver by means of iced water; after the expiration of twelve hours, a very moderate and diffused heat is to be applied to the retort, and kept up until the quantity of vapour condensed diminishes very much, and a bluish matter begins to froth up in the retort, the fire is to be immediately withdrawn, and the apparatus cooled; the acid thus obtained is pure, and of sp. gr. 898 or 900.

The second is that modification of Vauquelin's by which the apothecaries of Paris generally prepare their acid; one part of pure cyanuret of mercury is to be dissolved in eight parts of water and a current of sulphuretted hydrogen passed through, until the liquor smells strongly of the latter; this acid is then separated by agitating the mixture with some carbonate of lead, and filtering; the prussic acid thus obtained is pure, and of sp. gr. 0,900.

Prussic acid is easily decomposed by light; its preservation may be assisted by adding to it a little alcohol; the only impurity which it is liable to contain is muriatic acid, which may be detected by the acid giving with nitrate of silver a precipitate insoluble in nitric acid concentrated and boiling.

Of the other acids prepared by decomposition, the muriatic acid has been before noticed; the citric and tartaric acids do not need any particular remark.

2d. *Of the Preparation of the Bases by Decomposition.*

1st.—*Caustic Potash.*

An aqueous solution of potash is obtained by decomposing the impure carbonate of potash obtained from the commercial potashes, by an equal weight of lime, and 7½ parts of water: the solution thus prepared is impure, containing all the soluble impurities of the materials, as sulphates and muriates of potash, lime, silica, &c. The caustic potash obtained by evaporating this solution to dryness and fusing in silver vessels the potash obtained, is not more pure, but is sufficiently so for its principal use as an escharotic.

A very pure potash may be obtained by a mode proposed by Mr. Donovan.* He uses the crystallized bicarbonate of potash, which is free from those impurities, and decomposes it by means of its own weight of lime: an impurity mentioned by Mr. Donovan as existing in the potash as commonly prepared, is caustic soda, from which also it is by his process obtained free.

The mode of obtaining pure potash for chemical purposes, is, separating it from its saline impurities by solution in strong alcohol, rapid evaporation and fusion; for merely medicinal use however this process is too expensive, and is unnecessary.

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* Dublin Philosophical Journal, vol. i. page 48.

2d.—*Protoxide of Mercury.*

When the solution of potash is agitated with calomel, the oxygen of the potash is transferred to the mercury, chloride of potassium remains in solution, while the black protoxide of mercury is deposited. This preparation, as commonly made, consists, according to Mr. Donovan, of a mixture of metallic mercury and peroxide of mercury, along with the protoxide; but a pure oxide may be obtained by using very finely levigated calomel and a great excess of potash. The protoxide of mercury, even when procured at first pure, does not remain so; mere exposure to light, or to a very moderate heat, is sufficient to convert it into metallic mercury and peroxide, this extreme facility of decomposition may explain the difficulty of obtaining by the usual method a pure protoxide.

A black oxide of mercury, much used on the Continent, is termed *Hannehmann's soluble mercury;* it is prepared by precipitating a very pure pronitrate of mercury by ammonia, and leaving a slight excess of the nitrate, to avoid the formation of a double subnitrate of mercury and ammonia. The precipitate is to be dried in the cold, and out of the contact of light. The details of Guibourt's (the best) mode of obtaining it are given in the Codex, Henry junior's translation.*

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* Pharmacopée Francaise, p. 360.

3d.—*Oxide of Zinc.*

The London College, in order to obviate the occasional admixture of unburned zinc with the oxide prepared by direct *oxidizement,* decomposes the sulphate of zinc by means of the water of ammonia, and thus obtains the oxide by *precipitation ;* the oxide thus procured is not so light or spongy as that gotten by the combustion of the metal; the quantity of water ordered is at least five or six times too small, and any excess of the ammonia causes a loss of product by re-dissolving some of the precipitate.

The only other base obtained by direct decomposition in the British Pharmacopœias is ammonia, the preparation of which has been before adverted to.

Class 4th.—*Operations of Halogenesis.*

The operations of *Halogenesis* are those where, by the union of two substances relatively electro-positive and electro-negative, a substance is generated termed a *salt.*

Formerly a salt was defined a substance formed by the union of an acid with a base; more recent researches have proved that it is necessary to extend the definition, for many salts are composed of substances not possessing the properties of either acids or bases.

Salts may be divided according to the classification of Berzelius into 1st. Haloïd salts, and 2d. Amphide salts.

1st. *Haloïd Salts* are composed directly of a metal and a halogenic substance,* as chloride of sodium, iodide of potassium, fluoride of calcium, or cyanuret of mercury.

2d. *Amphide Salts* are composed of an acid, or a sulphide † united to a base, or a sulphuret, as sulphate of potash, oxalate of lime, sulpho-carbonate of mercury, or sulpho-arseniate of tin. Hence the amphide salts consist of

a. The *oxy-salts,* composed of an acid and a base.

b. The *sulpho-salts,* composed of a sulphide united to a sulphuret.‡

When we add an ox-acid or a hydracid to an alkali, and occasionally examine by litmus and turmeric papers the mixture, there arrives a point at which the compound is without action on these colouring matters. The acid and the alkali are then said to be mutually neutralized, and the compound formed is a *neutral salt.* Salts may also be formed which contain an excess of acid; they are termed *super,* or *acid salts;* others crystallize with an excess of base; these are called *sub,* or *basic salts.*

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* The *Corpora Halogenia* are chlorine, iodine, bromine, fluorine, and Cyanogen.

† The compounds of sulphur with the electro-negative metals, that is, those which form acids by uniting with oxygen, are termed by Berzelius *Sulphides,* and those with the electro-positive metals, or those that form bases by uniting with oxygen, *Sulphurets.*

‡ There exist also probably seleni-salts and telluri-salts, formed in a similar manner with selenium and tellurium, but they are not as yet known.

Occasionally two salts combine, whence there results the class of *double salts,* which may be either,

1st. Two different acids united to the same base, or

2d. Two different bases, united to the same acid.

3d. Two different acids united to two different bases.

The constituents of a salt combine in definite proportions, and these quantities are always multiples or sub-multiples of each other; thus, 1 atom of acid unites to 1, 1½, 2, 3, or 4 atoms of base, and reciprocally 1 atom of base sometimes unites to 1, 1½, 2, 3 or 4 atoms of acid; of these the 1½, 3, or 4 combinations are the most rare; the 1 and 2 the most commonly met with.

A neutral salt has been defined above that in which the properties of neither acid nor base preponderate; this requires a little more remark. A salt, as phosphate of soda, may be neutral, and yet affect vegetable colours: Gay-Lussac* defines a neutral salt that in which the acid and the base are united atom to atom; but the salts of deutoxides are opposed to this definition, they containing two atoms of acid to one of base, and being yet necessarily considered neutral. It is better to consider those salts as neuter in which *the number of atoms of acid is equal to the number of atoms of oxygen in the base.*

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* Histoire des Sels : tome premier, page 15.

The metallic oxides have a tendency to combine and form compounds which possess a considerable similarity to salts; thus the black oxide of iron is composed of the proto- and per-oxides of iron, and the same compound exists in large quantities in nature (iron glance, Elba ore); the brown oxide of chrome is formed by the union of the green oxide and chromic acid, and many combinations of the earths amongst each other are also examples: water also occasionally supplies the place of a base, by uniting with an acid, or of an acid in uniting with a base. Hence the liquid nitric and acetic acids, the hydrates of lime, of copper, &c.

When into the solution of a neutral metallic salt, a metal having a greater affinity for oxygen than that which is dissolved, is introduced, the latter is precipitated in a metallic form, and the former dissolved in its place; the solution remains neutral, the acid and oxygen of the base remain unaffected, the two metals alone changing places, and so much of the new one being dissolved as is capable of combining with the quantity of oxygen which the oxide of the original metallic salt contained.

For pharmaceutic purposes salts are obtained in either of two ways; first, by the direct union of their constituents; secondly, by double decomposition, the theoretic principles of which have been already explained when speaking of the laws and phenomena of affinity.

Genus 1st.—*Of the Haloid Salts.*

These compounds all containing as their electro-negative element, a substance capable of forming an acid by uniting with hydrogen, and as their electro-positive a metal; they may also be considered as composed of the hydracid, united to the base generated by the metal.

1st.—Of the Chlorides.—*(Hydro-chlorates.)*

Proto-Chloride of Mercury.

There are two modes of preparing calomel; 1st, by precipitation; 2d, by sublimation; each, if carefully practised, is capable of giving an unexceptionable product. In the first, a solution of proto-nitrate of mercury is mixed with one of chloride of sodium; the oxygen of the oxide of mercury passes to the sodium, while the chlorine and mercury uniting are precipitated as calomel. In order to render this process perfect, the following directions must be observed: 1st, more mercury must be used than the acid can dissolve; 2nd, the solutions must be acid at the instant that they are mixed, in order to prevent the formation of sub-per-nitrate, and this may be effected either by adding a little dilute nitric acid to the previously prepared solution of nitrate of mercury, or muriatic acid, to the chloride of sodium; and 3d, the solutions must be dilute to prevent the evolution of chlorine, which would convert some of the calomel into corrosive sublimate.

Calomel is also prepared by triturating the per-sulphate of mercury with an additional quantity of the metal, mixing it with chloride of sodium and subliming; or by rubbing corrosive sublimate with more mercury, and subliming in the same manner: some deuto-chloride generally rises also, from which the calomel can be freed by washing with water (not with a solution of sal-ammoniac). When sub-nitrate of mercury exists in the precipitated calomel it is discovered by heating the sample in a tube; nitric oxide is given out, which forms orange fumes with the air in the upper part of the tube.

Deuto-chloride of Mercury.

Corrosive sublimate is formed by decomposing the per-sulphate of mercury by chloride of sodium, and subliming: the deuto-chloride volatilizes and collects in colourless nearly transparent semi-crystalline cakes. The process presents nothing peculiar.

A preparation termed *martial flowers,* prepared by evaporating to dryness mixed solutions of sal-ammoniac and per-chloride of iron, is sometimes used; it is generally considered to be a definite combination, but is not so, being merely a mixture of the two salts.

The making the per-chloride of iron requires no remark.

There are some combinations of chlorine of extensive medicinal use, the preparation of which requires some remark. They are the *chlorides* of the oxides. (*Chlorites.* Berzelius.)

1st.—*Of Chloride of Lime.*

This salt is made in large quantities in the arts for the purposes of bleachers; the chlorine is evolved from a mixture of sea-salt, black oxide of manganese, and sulphuric acid, and passed into large shallow vessels containing the lime spread out in thin layers, by which it is absorbed. This chlorine is then dissolved in water, and the solution, brought to a certain specific gravity according to the use for which it is designed, is termed in commerce, *bleaching liquor*. Its strength is tried conjointly by its specific gravity, and its power of decolorizing sulphate of indigo suitably diluted with water. It occasionally contains a little muriate of lime, and sometimes the solution has a slightly pinkish or violet hue, which renders it useless for bleaching. But the *Eau de Javelle* (solution of the chloride of potash) so much used on the continent, is admired for this colour, and it is always given to it by digesting it on a little oxide of manganese. This pink depends on the presence of a trace of manganesic acid, which is volatile, and passes over along with the chlorine.* From the residuum of this process, most of the Glauber salt of commerce is obtained.

2d.—*Of Chloride of Soda.*

This substance, a solution of which in water is so extensively used as the *Liqueur disinfectante de Labarraque,* may be prepared in either of two ways:

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* Pearseall, Journal of the Royal Institution, vol. ii. p. 49.

the first, proposed by Labarraque, the second by the celebrated manufacturing chemist, Payen.

Labarraque's process is as follows :

	Parts.
Take crystallized subcarbonate of soda	2500
Dissolve it in pure water	10000

This solution having been prepared, introduce into a matrass

Finely powdered common salt	576
Black oxide of manganese	448

To the matrass are adapted two tubes, one double curved, for the introduction of the acid, and the other bent at right angles, and passing into a two-necked bottle containing water to wash the chlorine : from the second neck of the bottle a tube passes into the vessel containing the solution of carbonate of soda. The apparatus being thus disposed, the junctions are luted with linseed meal and starch, and secured outside by strips of linen, covered with white of egg and lime ; when the lutes are dry, introduce into the matrass by the proper tube,

	Parts.
Sulphuric acid, .1.845	448
Diluted with Water	576

Favour the action by a moderate heat, and when no more chlorine is disengaged, dismount the apparatus, and ascertain the strength of the chloride by its decolorizing power.

To prepare it by Payen's mode,

Take	Parts.
Chloride of lime	500
Sub-carbonate of soda	1000
Water	9000

Diffuse the chloride of lime in 6000 parts of the water, and let it settle for three or four hours, then pour off the clear liquor ; throw the remainder on a filter, with another 1000 parts of water, to obtain as much solution of the chloride of lime as possible. Next dissolve by means of heat the sub-carbonate of soda in the remaining 2000 parts of water; let it cool, and mix together the two solutions, agitating them well. The whole of the lime is thrown down as carbonate, and the chlorine combines with the disengaged soda ; the solution is to be filtered rapidly, and kept in bottles carefully secured.

2d.—Of the Iodides.—(*Hydriodates.*)

Iodide of Potassium.

The only iodide formed in the British Pharmacopœias is that of potassium prepared by neutralizing the hydriodic acid previously made, with potash, and evaporating to dryness. The resulting salt is purified by solution in rectified spirit and evaporation to dryness.

There are various much more economical modes of obtaining this salt, for example, 1st, dissolving iodine in solution of hydro-sulphuret of potash ; filtering and evaporating to dryness; 2d, heating iodine with iron filings, decomposing the iodide of iron by carbonate of potash, filtering and evaporating; or 3d, dissolving iodine in water of caustic potash evaporating to dryness, and bringing the mass to a dull red heat. This last process gives a beautifully white salt, but the heat requires to be carefully watched, the iodide being volatile at a temperature not much higher than that required for the decomposition of the iodate of potash.[*]

The iodides of mercury are preparations which from the trials as yet made appear likely to be extensively used; the proto-iodide is formed by decomposing a solution of proto-nitrate of mercury by hydriodate of potash; the deuto-iodide by precipitating a solution of corrosive sublimate by the same salt; the first is of a bright yellow, the second of a fine crimson colour; they should be well washed and dried without exposure to light.

3d.—CYANURETS.—(*Hydro-cyanates.*)

Cyanuret of Mercury.

The cyanuret of mercury is prepared (Ph. D.) by decomposing Prussian blue by deutoxide of mercury, separating the per-oxide of iron by filtration, and crystallizing the cyanuret of mercury. The product obtained by the first crystallization generally contains a little iron, from which it may be freed by re-dissolving in water, boiling the solution with some red oxide of mercury, and crystallizing a second time. A very fine salt is thus obtained, but from the high price of pure Prussian blue, (which the apothecary must himself prepare,) it is not economical.

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[*] It is curious that Dr. William Gregory (Edinburgh Medical and Surgical Journal, October, 1831, page 368) gives this mode of obtaining this salt, as new and peculiar to himself. It has been in use extensively for more than twelve years, and is mentioned in every chemical or pharmaceutical book of any note.

Chevallier and Desleschamps disengage prussic acid according to the process of Gea-Pessina, and condense the vapour in a bottle containing water, through which is diffused a quantity of per-oxide of mercury, which dissolves, and the cyanuret is obtained by crystallization, pure from the beginning. Defosses decomposes a per-sulphate of mercury by the ferro-prussiate of potash, filters the boiling solution, to separate a greenish deposit containing the iron of the ferro-prussic acid, and crystallizes the cyanuret of mercury by refrigeration. The quantity of product is somewhat greater than the weight of the ferro-prussiate of potash used, and still more may be obtained by crystallizing the mother-waters, and separating the mixed sulphate of potash and cyanuret of mercury by boiling alcohol, which may be distilled off, and the cyanuret re-crystallized.

Chevallier* considers the last process as the most economical, from 100 of ferro-prussiate of potash, and 200 of dry per-sulphate of mercury, he obtained 145 of pure well crystallized cyanuret.

Cyanuret of Potassium.

The cyanuret of potassium has been much used in France as a more uniform medicine than prussic acid: the mode of preparing it used by Robiquet, is to calcine, by a strong and long continued heat, the common ferro-prussiate of potash. This salt is first converted into cyanuret of potassium and of iron, and then into cyanuret of potassium and

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* Manuel du Pharmacien, vol. i. page, 538.

quadri-carburet of iron. The mass being dissolved in water, the carburet of iron is separated, and the cyanuret crystallizes from its solution in anhydrous cubes. Tilloy of Dijon * found that a portion of the cyanuret of potassium was by the long calcination converted into carbonate of potash; he therefore dissolves the calcined mass in alcohol, and obtains thus a cyanuret, free from the carbonate which is insoluble in that menstruum.

4th.—SULPHURETS.—(*Hydro-sulphates. Hydro-thionates.*)

Sulphuret of Antimony.

The sulphurets of antimony require some notice as to their composition and preparation. There are three of them: the proto, the deuto, and the trito-sulphurets corresponding in their composition to the oxide of antimony, the antimonious and antimonic acids. The first alone is of pharmaceutic interest; the others are not of use.

The common ore of antimony is the proto-sulphuret; it is very fusible, and is thus freed from the fragments of gangue which adhere to it, and run into conical moulds, whence it is met with in commerce under the form of sugar loaves.

When this substance is boiled with a solution of caustic potash, it is dissolved; some doubt however exists as to the changes which accompany its disappearance: the most reasonable is the following explanation.

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* Journal de Chimie Medicale, December 1830. Page 578.

A portion of both the potash and the sulphuret of antimony is decomposed; the oxygen of the potash passing to the antimony and the sulphur, and the rest of the liberated sulphur uniting to the potassium; we then have in the liquid, oxide of antimony, potash, hypo-sulphurous acid, sulphuret of potassium, and sulphuret of antimony. These principles arrange themselves thus: the hypo-sulphurous acid and the oxide of antimony divide the potash between them, and we have formed hypo-sulphite and hypo-antimonite of potash; and the two metallic sulphurets combining generate a sulpho-salt, in which the sulphuret (sulphide) of antimony acts as the electro-negative element. This disposition is soon broken; as the solution cools, a quantity of the sulphuret of antimony falls down as a deep brown hydrate: *kermes mineral:* and a sulpho-salt, with excess of base, remains in solution.*

The kermes being thus removed, there still exists in the liquor hypo-antimonite and hypo-sulphite of potash, sulphuret of potassium, and sulphuret of antimony; an acid being now added, they are all decomposed. The elements of the sulpho-salt being separated, the sulphuret of antimony precipitates in

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* A quantity of oxide of antimony generally precipitates along with the kermes, owing to which the nature of this preparation was for a long time misunderstood, and considered to contain necessarily oxidated antimony. This is not the case: in Fabroni's method no oxide can possibly be generated, and yet it gives most excellent kermes.†

† He heats sulphuret of antimony and cream of tartar together in a covered crucible, pulverizes the fuzed mass, dissolves it in boiling water, and obtains the kermes on the cooling of the liquor.

combination with water, and the sulphuret of potassium is by the decomposition of water converted into sulphuretted hydrogen and potash, the former escapes with effervescence, the latter unites with the decomposing acid. The potash of the other salts being similarly taken from them, the hypo-sulphurous acid is converted into sulphurous acid, which escapes, and sulphur which is deposited, and the oxide of antimony remains dissolved, or is precipitated according as it forms a soluble or insoluble combination with the acid used.

Thus the visible changes which follow the addition of an acid to the mother liquor of the kermes, are, the escape of sulphuretted hydrogen and sulphurous acid gases, and the precipitation of a mixture of hydrated sulphuret of antimony with hydrated sulphur, the brown of the former and the pale yellow of the latter forming the colour of the *golden sulphuret of antimony*.

The *brown antimoniated sulphur* of the Pharmacopœia, being prepared by decomposing the solution of the sulphuret of antimony in water of caustic potash, by an acid, without allowing the kermes to subside, is nearly intermediate in colour and composition with the two preparations described above.

Those preparations called *hepar antimonii; crocus metallorum; vitrum antimonii*, &c., are combinations of sulphuret of antimony with oxide of that metal, *stibio-thionates* of Buchner.*

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* Buchner* calls the sulphuret of antimony (*Antimonious*

* Repertorium fur die Pharmacie, 1822, p. 169.

The *sulphuret of mercury* is prepared in the manner described by the commentators on the Pharmacopœias. There is no second sulphuret of mercury; the black and the red have exactly the same composition, and the difference of colour arises from the state of aggregation. In Æthiop's mineral the sulphuret is mixed with a great excess of sulphur.

The cleanest, the best, and the most economical mode of making sulphuret of iron, is by fusing eight parts of iron and five of sulphur stratified in a common crucible. The combination takes place at about a reddish yellow heat.

Genus 2d.—*Of the Oxy-salts.*

Species 1st.—OF THE NITRATES.

Nitrate of Silver.

The silver used in the formation of lunar caustic should be pure, which is best obtained by reducing the chloride; the silver of commerce generally contains copper, which when used gives a greenish tinge to the solution, and renders the fused nitrate deliquescent; when the salt is crystallized, howe-

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Sulphide. Berzelius) stibio-thionic acid, and considers kermes to be a stibio-thionate of antimony: as there exists kermes not containing oxide of antimony,† Buchner's view of its composition is untenable; he allows the golden sulphuret to be merely a hydrated sulphuret with excess of sulphur.

† Berzelius, Traite de Chimie, tome ii. page 502.

ver, the nitrate of copper mostly remains in the mother-water. A mode of separating the copper recommended by Gay-Lussac,* is to precipitate a portion of the solution by potash: take the oxide of silver thus obtained, and boil it with the remaining solution; the oxide of silver throws down the oxide of copper, as potash would, and takes its place.

A very gentle heat is sufficient to decompose this nitrate; if the neutral salt be fused, a portion of acid is driven off, and some oxide of silver separates, which discolours the preparation. This is obviated, by adding a little nitric acid just as the mass has fused, or by throwing in a few crystals unwashed, and containing some acid in excess. By this process, first used by Mr. Mc. Kenna, operative chemist at the Apothecaries' Hall of Ireland, a fused nitrate of a dazzling white colour is obtained.†

Sub-nitrate of Bismuth.

The preparation of this salt demands no remark, but in most books its composition is incorrectly stated. By the researches of Menigant,‡ it has been proved, that the solution of bismuth in dilute nitric acid gives a salt, composed of an atom of acid to an atom of base. When this solution is poured into water, there is formed a quadri-nitrate of bismuth (*quadri-nitras bismuticum,*) composed of

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* Histoire des Sels, vol. i. leçon 12. page 8.

† Annals of Pharmacy, Dublin, vol. i. page 388.

‡ Journal de Pharmacie, vol. xiii. page 9.

4 acid + 1 base, which remains in solution, and a tetra-nitrate of bismuth (*nitras quadri-bismuticum,*) composed of 1 acid + 4 base, which falls as the white powder required. This precipitate should be well washed.

Species 2d.—SULPHATES.

Sulphates of Mercury.

By heating sulphuric acid with mercury sulphurous acid gas is given off, and a sulphate of mercury remains as a solid mass of very minute shining crystals. This salt is incorrectly termed a bi-persulphate; in it are the oxygen of the base and the acid, and in the same ratio, and it is therefore a neutral salt.

This salt is decomposed by water: Dr. Barker * considers that it is merely deprived of an atom of acid by the water, and that the *turbith mineral* which remains undissolved, is composed of an atom of acid to one of base; this cannot be the case; the liquor contains mercury; and the yellow sub-sulphate, according to the analyses of Berzelius and of Gay-Lussac, is a tri-basic salt.

3d.—*Carbonates.*

The carbonate of iron is prepared by decomposing sulphate of iron by carbonate of soda; the

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* Remarks on the Dublin Pharmacopœia, Part first, p. 277.

carbonate is precipitated, collected, and dried. The sulphate of iron contains always some per-oxide; and when the solutions are mixed, the proto-carbonate and peroxide are thrown down together; the former alone is of a pale green colour, the latter brownish red; the precipitate at first produced is therefore generally a dirty green: the proto-carbonate is decomposed by exposure to air, and so in drying the precipitate, the carbonic acid flies off, oxygen is absorbed, and the preparation finally obtained is a reddish-brown powder, containing but very little carbonate. If the precipitate be left moist the colour does not be so deep, but rather yellowish brown, and it appears not to be so perfectly decomposed. It is used to form some of the per-salts of iron.

Species 4th.—TARTRATES.

Tartaric acid itself forms but weak combinations with the metallic bases, but it has a singular disposition to form double salts, one of whose bases is generally potash; these combinations of tartaric acid and potash with a second base are much more permanent than simple tartrates, which induced Gay-Lussac to consider the bi-tartrate of potash as acting the part of an acid, and to term these salts *cream-tartrates* of the second base.

Tartrate of Potash and Antimony.

The Dublin formula for preparing tartar emetic is, although not the most economical, the most elegant in use; the powder of algaroth is deprived of all its muriatic acid by repeated washing, and the remaining protoxide is easily dissolved by the bitartrate of potash. The French use for obtaining tartar emetic the glass of antimony, which yields its oxide to the cream of tartar, while the sulphuret remains unacted upon. This is the most economical mode, but not equal to the Dublin in neatness and elegance. According to Serullas,* this and the chloride are the only antimonial preparations that are free from arsenic, which, existing in the ore, is not removed by the processes used in the preparation of the others.

Tartrate of Iron and Potash.

In this process cream of tartar is put in contact with iron, which oxidises itself, partly by the oxygen of the air, and partly by decomposing the water with which the materials are kept moist. The product obtained is an olive green solution, containing probably a mixture of the two oxides of iron; on evaporation, it furnishes a dry salt, slightly deliquescent. This process is tedious; the oxidation of the iron may be much expedited by placing a few clean slips of copper in the vessel, and thus rendering the iron electro-positive, when it is acted upon much more rapidly; as long as an atom of iron exists undissolved no action takes place on the copper.

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* Journal de Pharmacie, vol. vii. p. 425.

Species 5th. Acetates.

Acetate of Potash.

When distilled vinegar is saturated with potash, the small quantity of vegetable matter existing in the acid is acted upon by the alcali, and gives the solution a dark colour; to free the salt from this, it is directed to be fused at the end of the evaporation; the organic matter is destroyed, and the salt being dissolved in water, and the solution filtered, appears on evaporation white and flaky: if the heat be not very cautiously managed in this process, a portion of the acid is decomposed, and the acetate contains carbonate of potash; the salt of commerce frequently browns turmeric paper.

Acetate of Iron.

The Dublin Pharmacopœia possesses three forms of acetate of iron; 1st, mere acetate; 2d, the tincture of the acetate; and 3d, the tincture with alcohol: the first needs no remark.

When acetate of potash and undried sulphate of iron are rubbed together they coalesce into a soft mass, which during desication absorbs oxygen, and becomes of a reddish brown colour; on this is then digested spirit of wine, which dissolves the per-acetate of iron, and the excess of acetate of potash leaving the sulphate of potash unacted upon.

This tincture is very liable to spoil, it deposits peroxide of iron; the alcoholic is the most permanent.

The tincture is a solution of the acetate of potash and iron, in a dilute alcohol; the acetate of potash is gradually decomposed and converted into carbonate, which then re-acts upon the acetate of iron, and throws down the per-oxide, at the same time the alcohol appears to be in some way altered also; the alcoholic tincture is more permanent, 1st, because the quantity of acetate of potash is smaller, there is therefore less excess of it in solution; and 2d, the spirit being stronger, prevents the decomposition from going on so rapidly. It has been found that a more permanent tincture is obtained by drying the sulphate of iron before mixing it with the acetate of potash, and allowing the solution to remain as short a time as possible on the dregs.

Drs. Barker and Montgomery consider this preparation as a solution of a double proto-acetate of iron and potash in alcohol. I do not know how this opinion can be correct; from my own experiments I should rather think that the quantity of acetate of potash does not bear any atomic relation to the quantity of the acetate of iron, but varies according to the excess, being much greater in the tincture with rectified spirit than in that with alcohol: the solution gives no precipitate with the red ferroprussiate, but a copious one of Prussian blue with the yellow ferroprussiate of potash, and therefore cannot contain any protoxide of iron. Dr. Barker seems to consider that the red oxide of iron is insoluble in acetic acid: Berzelius states that the *solution* of peroxide of iron in acetic acid yields, on evaporation, a brown very deliquescent jelly.

Class 5th.—*Operations of Fermentation.*

When animal and vegetable principles, by being deprived of life, become subjected to the general laws of chemical affinity, they react upon each other, and give rise to the formation of certain new products. This process is termed *fermentation*.

There are many kinds of fermentation, according to the nature of the product; thus the *saccharine*, the *alcoholic*, the *acetous*, and the *putrefactive*. In the three former the substance generated is well defined and peculiar, the results of the last kind of fermentation are complex and not well known; formerly that kind of fermentation which takes place during the making of bread, was considered to be distinct, and called the *panary*, but as alcohol is generated during the process, it is now classed as an instance of the second species.

In order that fermentation should commence, there are certain circumstances necessary to be observed.

1st. Water must be present in certain quantity.

2d. The temperature must be moderate; that is, ranging between 60 and 80°.

3d. There must be a yeast or fermenting material, generally gluten, present; and,

4th. There must be a material by whose decomposition the new product is to be formed. This fermentable body is starch for the saccharine, sugar for the alcoholic, and alcohol for the acetous fermentations.

Genus 1st.—*Of the Saccharine Fermentation.*

During the germination of seeds, an action is set up in their tissue, by which the insipid insoluble amylaceous principle is converted into a substance fit for the nourishment of the embryo plant, sugar;

the same change is produced by malting, which might be defined artificial germination, and is essential to the subsequent obtaining of alcohol from the grain. This change is termed the saccharine fermentation.

Starch and sugar have very nearly the same chemical composition, and their difference depends more perhaps upon the mode of arrangement of the molecules of their components than upon a variety in their nature or number; we can thus readily explain their facile conversion one into the other, without any other new products being generated, as instanced in the two examples brought forward above.

This change of starch into sugar can be brought on by the exertion of other influences than merely those of heat and moisture, which alone come into play during germination. If we take 100 parts of potatoe starch, 2 parts of strong sulphuric acid, and 400 of water, and boil all together, we will obtain a quantity of sugar equal to that of the starch; the acid is not altered, and we can obtain it all by adding chalk, which throws it down as sulphate of lime; this sugar resembles that of grapes in not crystallizing, but gives by fermentation an excellent spirit; other strong acids have the same effect; the nitric, however, cannot be employed, for as it developes the sugar, it converts it *pari passu* into oxalic acid.

Other vegetable substances than starch are capable of being converted into sugar, although not of undergoing the regular saccharine fermentation; thus, during the ripening of many fruits a considerable quantity of acid disappears, and its place is supplied by sugar; and if we treat lignin by sulphuric acid we obtain a kind of gum, which by boiling is converted into sugar; in this case, however, it is probable that some oxygen is supplied to the lignin, as much sulphurous acid is driven off during the process.

Genus 2nd.—*Of Alcoholic Fermentation.*

If to a weak solution of sugar and water we add a small quantity of yeast, a considerable action takes place after a short time; carbonic acid gas is copiously disengaged, a whitish flocculent matter floats through the liquor, and when the effervescence has finished, the saccharine taste of the solution will be found to have nearly totally disappeared, and to be superseded by that of spirit. If the liquor be now distilled it will afford a certain quantity of alcohol. This is the *alcoholic fermentation.*

Alcohol, however, is never at once prepared as above described; it is derived from liquors which are obtained by the fermentation of certain vegetable substances, either fruits or seeds, of which the grape and barley may be considered the principal.

Of Vinous Fermentation.

The important constituents of the grape juice are sugar, bi-tartrate of potash, and a kind of yeast: the former principle exists but in small quantity in the unripe juice, but increases as the fruit advances towards maturation; the quantity of the acid principles on the contrary diminishes as the grape ripens; the yeast is held in solution by the cream of tartar, and its presence is the reason that the juice is capable of entering into fermentation without any extraneous assistance. According as the sugar is converted into alcohol, the cream of tartar, being insoluble in that liquor, is deposited on the sides of the containing vessel. The whole of the sugar is seldom converted into alcohol, as when the quantity of this fluid rises to a certain amount it puts an end to the fermentation, as it would to the putrefaction of a piece of muscle immersed in it.*

There is every reason to suppose that sugar is the only substance capable of affording alcohol by fermentation, and that in all cases where a spirit is obtained from bodies not containing sugar, the latter is previously generated by the decomposition of some component of the substance, generally starch; this, as was before mentioned, takes place in obtaining alcohol from the seeds of the grasses, the amylaceous parts of the grain being first saccharified by malting, and then the sugar being converted into alcohol by the proper vinous fermentation. The germination of the grain having been put an end to

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* Mr. Donovan differs from most chemists with regard to the properties of grape sugar; he says, (Domestic Economy, p. 269), " and it differs from common sugar in being much more easily crystallizable." Gay-Lussac (Cours de Chimie, vol. ii.) says, " this sugar can never be brought to crystallize like that of the sugar cane; it forms small grains like sandstone." The other writers say the same as Gay-Lussac. I know not any author that supports Mr. Donovan's opinion.

by exposure to a certain heat, (kiln-drying,) an infusion of the dried malt is made of a certain strength; to this is added a sufficient quantity of yeast, and the temperature being retained between 50° and 70° Fah., fermentation sets in, and the alcohol is gradually formed.

The nature of the substance termed *yeast,* or *ferment,* is not well understood, and differs most probably in different vegetables: in common barm it is a white curdy matter, in gooseberries, &c. a gelatinous sort of fluid, and it is characterized by containing much nitrogen; of all the well characterized vegetable principles, gluten comes nearest to it in properties, and as pure wheat gluten has the power of exciting fermentation, it is probable that it is the real *ferment,* although in some degree modified in different plants: in germination and malting it is the gluten of the grain which determines the conversion of the starch into sugar.

The part which the yeast acts in fermentation is not well understood; it is probable that it merely alters the arrangement of the components of the starch without itself undergoing any change; indeed after the process is over it may be almost entirely recovered in its original form, and capable of again acting the same part with undiminished energy; therefore the only circumstance which requires examination, in a theoretic view, is the gradual disappearance of the sugar, and the evolution of the carbonic acid and alcohol, the united weights of which two latter are equal, according to the experiments of Lavoisier and Thenard, to the sugar which is lost: this view exactly coincides with the relative constitution of the three substances, viz.

Sugar, composed of	Carbonic Acid.
Carbon 3 = 18	Carbon 1 = 6
Oxygen 3 = 24	Oxygen 2 = 16
Hydrogen 3 = 3	
45	22

Alcohol.

Carb. 2 + Hyd. 2 = Carburetted hydrogen 1 = 14
Oxygen 1 + Hyd. 1 = Water 1 = 9
23

Alcohol, 22 + Carbonic Acid, 23 = Sugar, 45.

We thus see that omitting the small quantity of yeast, not quite one per cent., which is lost in the process, one atom, or forty-five parts of sugar, yields by fermentation one atom, or twenty-two parts of carbonic acid, and one atom, or twenty-three parts, of alcohol.

The spirit obtained from grain always contains a kind of concrete oil, which probably existed in the vegetable previous to fermentation; the potatoe spirit yields a liquid oil: the means of separating these impurities during the rectification of spirits have been already spoken of.

3rd.—*Of the Acetous Fermentation.*

If during the vinous fermentation of a liquid the quantity of yeast be too great, and the temperature too high, the decomposition does not stop at the production of alcohol, but it also is acted upon, disappears, a glutinous material is deposited in shreds, and acetic acid is developed; this process is called the *acetous fermentation.* It may also be provoked in alcoholic liquors whose fermentation is over, by adding a quantity of yeast, and subjecting them to the requisite degree of temperature.

The changes which take place during this operation are not so well known as those which accompany the preceding variety of fermentation: a gentle effervescence pervades the fluid, some carbonic acid is given out, and very nearly the same volume of oxygen is absorbed from the atmospheric air if the process be performed in open vessels; but the exclusion of the air does not prevent the development of the acid, so that it is by reaction amongst the principles of the liquor itself that the new products are formed.

In the saccharine fermentation the sugar and starch are so nearly similar that without any forced stretch of imagination we can believe their conversion one into the other; in the alcoholic we have the exact constituents of the sugar divided between the alcohol and the carbonic acid; but in the acetous we have none such facts to rest on, the alcohol disappears; the acetic acid appears, and their quantities are generally in the same ratio, but further than that we know nothing of the process, the small quantity of oxygen absorbed, or of carbonic acid disengaged, being totally inadequate to account for the phenomena.

Mr. Donovan* throws out a conjecture that, as the alcohol is converted into acetic acid and *something else,* may not that glutinous material always present in the vinegar obtained by fermentation, be the second principle, formed by those of the constituents of the alcohol not employed in making acetic acid, as the carbonic acid is formed by the constituents of the sugar not used in the production of the alcohol; facts however are wanted on every part of this subject.†

The whole of the alcohol, however, is not decomposed, the vinegar always contains some, and the wine vinegar also a small quantity of tartaric and malic acids; a small quantity of sulphuric acid generally exists in the vinegar of commerce, and much vegetable matter; from these it is freed by distillation, the mode of effecting which has been before detailed.

4th.—*Of the Putrefactive Fermentation.*

The last link in the chain of decompositions through which organized matter once deprived of vitality must pass, is putrefaction, or the putrefactive fermentation; it is undergone by vegetable, as well as by animal materials, but the products of the decomposition of each class differ, animal substances giving out much ammonia, which is not

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[*] Domestic Economy, p. 125.

[†] The Society of Pharmacy of Paris has offered a prize of 1000 francs for an experimental essay on the acetous fermentation; many have been sent in, but they did not establish any *facts*, and the field of competition remains open to all apothecaries.

yielded by the generality of vegetables, those, however, which contain nitrogen, as the fungi, cruciferæ, &c., act in this respect in a way similar to animals.

Among the organic principles some are much more susceptible of decomposition than others; and this appears to result from their composition; those in which hydrogen predominates, as the inflammable bodies, do not easily putrefy, and those that contain an excess of oxygen, as the acids, may be kept for a length of time: the neutral organic bodies, those in which the proportions of oxygen and of hydrogen balance each other, are those which most readily enter into the putrefactive fermentation, and of those the dense and compact substances have least tendency to decomposition.

The products of putrefaction are very numerous, as water, acetic acid, some oil, ammonia, carbonic acid, hydrogen, light carburetted hydrogen, and probably some other inflammable gases, and there remains behind the great part of the carbon of the substance, probably combined with some of the other elements.

Of the Means of Preventing and Checking Fermentation.

It has been already mentioned, that exposure to either a high or a low temperature, as to the heat of boiling, or to the cold of freezing water, arrests the progress of fermentation; hence one of the best modes of preventing the commencement of this process is by keeping the temperature of the substance reduced, and therefore the London Pharmacopœia directs sirups to be kept at a temperature of 55°.

It is unnecessary to mention instances of the preservative power of snow or ice, which act merely by retaining the temperature at 32°. Persons who had perished in snow storms, or amongst the glaciers, have been found at the end of a long time perfectly unaltered, and the Siberian mammoth found at Tamut had remained dead, but undecomposed, incased in a block of ice, probably since the existence of an antecedent world.

Desiccation is a powerful means of preventing decomposition; it is with this intention that vegetables intended to be preserved for pharmaceutical purposes are previously dried. The whole art of mummy-making resided in the proper desiccation of the body; it is probable that a freezing temperature is aided powerfully in its preservative qualities by the solidification of the watery portions of the organized substance to be preserved.

There are very many substances which prevent putrefaction, principally by combining with the water existing in the body, thus alcohol, sugar, common salt, nitre, &c.; and others, which appear to have a direct influence in preventing the process from setting in, and of arresting it if it has already commenced, as chlorine, acetic acid, charcoal, vegetable mould, &c. Those means, however, not being of pharmaceutical use, are not here of importance.

The only substances used in pharmacy, the fermentation of which is to be dreaded and avoided are sirups and vegetable juices; with regard to sirups, if they are kept cool, and have been properly prepared, there is very little danger of their decomposition; the juices of vegetables should not be kept unused for any time; they should be at once subjected to those processes by which they are to be rendered proper for medicinal use, as when kept they pass very readily into decomposition.

The addition of a little sulphate of potash, or of chlorate of potash, has been recommended as a means of preventing fermentation; these salts being nearly tasteless, may be dissolved in sirups without injury to their flavour. A better mode is that recommended by Chereau,* to add to every 1000 parts of sirup, 32 of sugar of milk, which is not susceptible of fermentation, and perfectly prevents its supervention. In the sirups, sulphurous acid gas possesses considerable power of keeping back fermentation; wines are what is termed *sulphured* by burning sulphur in the casks; and vegetable juices, when they are to be kept, are best preserved by adding to them, before bottling, a little sulphite of lime, which is decomposed by the acid of the juice, and the disengaged sulphurous acid dissolving in the fluid preserves it from decomposition. When the juices are heated, either for inspissation or for making sirups, the sulphurous acid gas is entirely driven off.

The process most generally used on the continent, where vegetable juices are kept for a long time, is that of Appert: The juice is put into strong

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* Duncan's Supplement, 1830, p. 161.

black bottles up to three or four fingers' breadth of their necks, and the bottles are stopped with good corks secured by cross wires; they are then placed in a water bath with hay, and boiled for a quarter of an hour; this drives all the air out of the space above the juice; the bottles are then taken out of the bath, and their mouths covered with a cement of resin and wax, and placed in a cool cellar. The theory of this process is not well understood; if the bottles be opened after some months, the juice is then as capable of undergoing fermentation as when it was first extracted from the fresh plant. Chevallier* considers that by the assistance of the heat all the oxygen of the air in the bottles is absorbed by a part of the ferment, which by this excess of oxygenation loses its fermenting power, while the rest of the ferment not having any oxygen to combine with, cannot undergo any change.

Class 6th.—*Operations of Etherification.*

The name of ether was originally given to an inflammable liquid of a very low specific gravity, obtained by the distillation of a mixture of sulphuric acid and alcohol; other fluids similar to the former in their inflammability and levity, being prepared by the action of other acids as the nitric and acetic, on alcohol, they also are termed ethers, so that the word is now used as a *generic* designation, the spe-

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* Manuel du Pharmacien, vol. i. p. 94.

cies of each genus being determined by the nature of the acid used in their formation.

Ethers may be divided into three classes; the mode of obtaining and the rationale of the formation of each of which require to be considered by themselves: they are,

1st. Those prepared with an ox-acid which does not exist in the produced ether, as the sulphuric and phosphoric.

2d. Those prepared with an ox-acid which does exist in the produced ether, as the nitric and oxalic ethers; and,

3d. Those prepared by means of a hydracid, as the hydro-chloric and hydriodic ethers.

§ 1st.—*Of the Preparation of the First Class of Ethers.*

THIRTY-TWO ounces by weight, of rectified spirit, (specific gravity, 0.840,) with an equal weight of sulphuric acid, (specific gravity, 1.845,) are to be put into a glass retort, the spirit first, and the acid in an unbroken stream upon it; they are to be mixed gradually, and twenty ounces by measure to be distilled with a sudden and sufficiently strong heat, into a receiver kept cold.

If sixteen ounces of rectified spirit be poured upon the acid remaining in the retort, sulphuric ethereal liquor (impure ether) will again come over by distillation.*

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* Dublin Pharmacopœia, by Drs. Barker and Montgomery, p. 363.

The London directions are more minute; the mixture of the acid and spirit is to be made so cautiously that the temperature should not rise higher than 120° Fahrenheit. The retort is to be placed in sand previously heated to 200°, and the distillation is to be continued until a heavier fluid begins to come over, which may be seen forming a stratum under the ether in the receiver.

In the above processes we get by distillation at first a quantity of alcohol, the ether then commences to come over, and continues until the relative quantity of the sulphuric acid gradually increasing, a portion of the alcohol is totally decomposed, olefiant gas is disengaged, and sulphurous acid, which uniting to water forms that heavy fluid under the ether, which indicates, according to the London formula, the termination of the process.

The more slowly the materials are heated the more unaltered alcohol comes over, therefore the Colleges directed the heat to be suddenly raised to the proper height; the temperature mentioned by the London College is too low, a heat of 250° or nearer 300° is required, and even so some undecomposed alcohol is obtained.

Operating on small quantities, glass vessels are employed; but where the ether is manufactured on a large scale, the number of retorts necessary, and their breakage, would render their use uneconomical; in extensive laboratories, the materials are introduced into a leaden still, heated previously by steam applied either to the outer surface of the body, or conducted through the liquid by an extensive coil of leaden tube; the refrigeratory is kept well supplied with very cold water, and ether is thus obtained at far below what it could be sold for if prepared in glass vessels.

When a certain quantity of ether has been taken off, its place is to be supplied by fresh spirit introduced into the still, and thus a fresh quantity of product obtained; this may be repeated more than once, but more and more undecomposed alcohol comes over each time, and finally the activity of the acid becomes exhausted, and it will etherify no more.

The ether obtained by these processes is impure, it contains alcohol, sulphurous acid, acetic acid, and a substance to be hereafter described, termed oil of wine; to free it from these contaminations it is to be rectified; being mixed with potash or its carbonate, and being re-distilled by a low heat, (water bath heated to 120°,) it is thus procured pure, and of a specific gravity, 0,765. (Ph. D.)

From 100 parts of sulphuric acid, and 100 of alcohol at the commencement, and 50 parts more of alcohol added during the process, Professor Brande obtained 58 parts of rectified ether, sp. gr. 0,733. The results of other experiments appear to give rather a higher average.

" After the distillation of sulphuric ether, having lowered the heat, again distil the liquor until a black froth swells up; then instantly remove the retort from the fire. Add water to the liquor remaining in the retort, so that the oily part may float upon the surface. Remove this, and add to it a sufficient quantity of lime water to saturate the acid it contains, and shake them together. Lastly, remove the separated *ethereal oil.*"[*]

This is the *oil of wine* which plays an important part in the modern theories of the generation of ether; it is not used in medicine, it is composed of carbon and of hydrogen in the same relative proportions as olefiant gas, the liquid carburet of hydrogen and otto of roses; these four bodies differing only in their mode of aggregation. It is slightly citrine; volatile, but its boiling point is high; insoluble in water, and very easily dissolved by ether: it may be easily prepared by distilling a mixture of 2 parts of sulphuric acid and one of alcohol; the neutral sulphate of carburetted hydrogen comes over, which by a base is resolved into the bisulphate, (sulpho-vinic acid,) which unites to the base used and the oil of wine which floats on the surface, and may be separated. The lime water acts thus in the pharmacopeial method of obtaining it.[†]

An excellent method of obtaining ether is that followed by Wittstock at Berlin.[‡] 6 parts of alcohol sp. gr. 0.835 are mixed with 11.7 parts of sulphuric acid, and the mixture introduced into a tubulated retort of a large capacity; to the tubulure is

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[*] London Pharmacopœia.

[†] Hennell considered the neutral sulphate of carburetted hydrogen to be the *oil of wine,* and thus produced a good deal of confusion, which the researches of Serullas have removed.

[‡] Journal de Pharmacie, 1831, page 82.

adapted, by means of a perforated cork, a glass tube curved at right angles. The short branch of this tube plunges into the liquor in the retort to about the depth of an inch; to the longest, which should be at least 3 feet in length is added a brass tube 4 or 5 inches long, furnished with a stop-cock; this last tube is fitted by means of a cork to a bottle containing the alcohol, which is to pass into the retort in the course of the distillation. It is well to cut the glass tube at the right angle, and to unite the pieces by a caoutchouc connector, as thus the tube is more easily managed and less liable to accidents. The retort is immersed in a sand bath to the height of its contents, a small Gedda's refrigeratory* adapted to it, (the only lute required is at the junction of the neck of the retort to the tube of the refrigeratory,) and the mixture brought rapidly to ebullition. As the ether distils over, a corresponding quantity of alcohol passes into the retort from the bottle by opening the stop-cock of the brass tube, and the materials in the retort are always kept at the same level, marked on a bit of paper pasted on the outside. The addition of the alcohol may be continued until 52 parts have been introduced.

The ether thus obtained is at first pure, but the latter portions contain the usual foreign matters; from these it is purified by rectification from lime; from 100 parts of alcohol Wittstock obtains by this process 62.5 parts of rectified ether, sp. gr. 0.720.

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* For a description of Gedda's Refrigeratory, see page 189.

Theory of the Formation of Sulphuric Ether.

The first rational account of the formation of sulphuric ether was that proposed by Thenard : it was founded on the relative composition of ether and of alcohol, and had the merit of simplicity and of accounting for all the phenomena which had been at that time observed.

The composition of alcohol has already been stated, as being

1 Olefiant gas = 14
1 Water = 9
—
1 Atom of alcohol 23

Ether is composed of

2 Atoms of olefiant gas = 28
1 Atom of water = 9
—
1 Atom of ether 37

Now he supposed that sulphuric acid, in consequence of its great affinity for water, decomposed two atoms of alcohol, took one atom of water, and left the two atoms of olefiant gas and one atom of water, just in the proportions for forming one atom of ether; the quantity of alcohol gradually diminishing, all the other compounds generated towards the end of the process are easily accounted for; for the decomposition of the alcohol becoming more and more perfect, oil of wine and olefiant gas are formed, and the deposited carbon re-acting on the sulphuric acid gives rise to the evolution of sulphurous acid gas.

But it was observed by many chemists, that the sulphuric acid, when mixed with alcohol, lost its saturating power, and therefore it was concluded that it could not exist in the mixture as sulphuric acid, although it did so in the residue of the distillation; and finally Vogel discovered the sulpho-vinic acid, which rendered a new theory of etherification necessary.

The second theory was constructed on the statements of Vogel and Gay-Lussac, that sulpho-vinic acid was composed of hypo-sulphuric acid and a vegetable matter. It was as follows: The alcohol separated into two parts, one of which, by losing hydrogen and oxygen in the proportions for forming water, was directly converted into ether; the hydrogen, thus separated, took away some oxygen from the sulphuric acid, and converted this latter into hypo-sulphuric acid: the oxygen combining with the other portion of the alcohol constitutes a vegetable matter, which unites to the hypo-sulphuric acid, and forms with it, *sulpho-vinic acid,* which is found in the residue. The sulphurous acid, olefiant gas, sweet oil of wine, water, and carbon, result from the decomposition by the heat of the organic matter and the hypo-sulphuric acid.

This theory rested upon the composition of sulpho-vinic acid, as given by Gay-Lussac; this has been since proved by Hennell * and Serullas †

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* Philosophical Transactions, 1826.

† Bulletin Universal. Section 1re. Fevier, 1830.

to be incorrect; this acid being an acid sulphate of carburetted hydrogen. This theory also is therefore untenable, and it is questionable if the newest is more universally reconcileable to facts.

Before entering into the statement of the hypothesis advanced by Hennell, it is necessary to examine more minutely the action of sulphuric acid on alcohol, and particularly the formation and properties of the *sulpho-vinic acid.*

If we take 440 grains of strong sulphuric acid and precipitate it by means of acetate of lead, we will obtain 1313 grains of dry sulphate of lead: now, if we take 440 grains of sulphuric acid, mix them with 440 of alcohol, let them rest for some hours in action, and then add acetate of lead, we will obtain only 542 grains of dry sulphate of lead; nearly two-thirds of the sulphuric acid having lost its power of precipitating lead.

If we mix, as before, 440 grains of acid with 440 alcohol, and the changes having taken place, distil the mixture, ether comes over, and from the residium we obtain the entire quantity of sulphate of lead, 1313 grains, by adding a solution of the acetate.

Thus we must conclude, that on mixture the sulphuric acid and alcohol combine, so that the distinctive properties of each are lost; and when the combination thus formed is heated, ether distils over, and the sulphuric acid is all regained as a residuum.

The combination formed in the first instance is sulpho-vinic acid, which may be thus procured:

Equal weights of acid and alcohol are mixed as for making ether: the mixture is digested on carbonate of baryta, sulphate and sulpho-vinate of that base are formed, the latter remains in solution; the liquor is poured off the sulphate of baryta, and sulphuric acid being added so as to throw down all the baryta, the sulpho-vinic acid remains in solution; its properties are very similar to that of hypo-sulphurous acid, which accounts for the error of Vogel and of Gay-Lussac; it is decomposed by heat into ether, and sulphuric acid; but by evaporation *in vacuo* it may be obtained very viscid and of sp. gr. 1.319; its salts are sweet, all soluble and most deliquescent, and when exposed to heat, blacken, give out an inflammable gas, and sulphates remain behind.

Its composition is, by Hennell's analysis,

2 atoms sulphuric acid $(40 \times 2) = 80$
2 atoms olefiant gas $(14 \times 2) = 28$

1 atom of sulpho-vinic acid $= 108$*

Faraday observed that sulphuric acid absorbed olefiant gas, and that the same acid was formed.

The liquid which Hennell† terms oil of wine,

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* In place of saying that olefiant gas exists in those substances, we may replace each 2 atoms of it by 1 atom of the liquid tetarto-carbo-hydrogen $(4\,C + 4\,H.)$ Then ether will be 1 tetarto-carbo-hydrogen + 1 water: Sulpho-vinic acid 1 tetarto-carbo-hydrogen + 2 sulphuric acid: and the neutral sulphate (Hennell's oil of wine,) 2 tetarto-carbo-hydrogen + 2 sulphuric acid. This view differs merely in name from the original one, but having been adopted by Thompson (Chemistry of Inorganic Bodies, vol. ii. page 306,) it required notice.

† Philosophical Transactions, 1826. Part 3d.

but which is different from that commonly so called, may be obtained by heating 2½ parts of sulphuric acid and 1 of alcohol, 0.835 a little ether is produced, and then a yellow oily liquor, which is the product required; it is to be washed with a small quantity of water to remove some sulphuric acid, alcohol, ether, and sulphurous acid; the water is to be poured off and the yellow liquor evaporated *in vacuo;* after some time a neutral sulphate of carburetted hydrogen is obtained of a deep green colour: its taste is cooling and bitter, perfectly neutral, slightly soluble in water, very soluble in alcohol or ether, decomposed by much water being resolved into the proper oil of wine (hydro-carbon) and sulpho-vinic acid; or by a base, the oil of wine being separated and a sulpho-vinate formed. Its composition is

2 atoms of sulphuric acid	(40 × 2) = 80
4 atoms of olefiant gas	(14 × 4) = 56
1 atom of neutral sulphate of olefiant gas	136

This substance when heated, is decomposed into sulphuric acid and alcohol.

From these data Hennell considers himself justified in concluding, and his view has been since adopted by Serullas, that in the formation of ether the changes which take place are, when the acid and alcohol are mixed, one portion of each unite and form sulpho-vinic acid, which when the heat is raised is converted into ether and sulphuric acid; and the other portion of alcohol and acid reacting upon each other, give rise to the formation of the other compounds which are generated towards the termination of the process.

To prove that the alcohol does not act directly in the formation of ether, Hennell forms that body without the intervention of alcohol at all; he takes sulpho-vinate of potash and decomposes it by strong sulphuric acid, ether is disengaged, and bi-sulphate of potash remains; the sulphuric acid yielding one atom of water to the two atoms of olefiant gas existing in the sulpho-vinic acid, forms exactly one atom of ether.

If more water than is necessary for the formation of ether be presented to the nascent olefiant gas arising from the decomposition of sulpho-vinic acid, alcohol, and not ether, is formed: Hennell shows this very well by two experiments,—1st, if a sulpho-vinate is decomposed by dilute sulphuric acid, alcohol and not ether distils over; and 2ndly, mix 500 grains of strong sulphuric acid with 500 of alcohol; if this mixture was distilled, we would of course obtain ether; but dilute it with 1000 grains of water and then submit it to distillation, not a particle of ether will be obtained; the original 500 grains of alcohol will pass over into the receiver, and the 500 of acid will remain in the retort.

It is difficult to oppose a series of facts so well connected and affording to each other such mutual support; the main objection to it is, that although the decomposition of sulpho-vinic acid explains the formation of ether of the first class by sulphuric acid, yet the other acids which have a powerful affinity for water, as the phosphoric and arsenic, give rise to the formation of the same substance. This, however, is rather an objection arising from our want of knowledge, and Lassaigne* has already alleged the existence of a phospho-vinic acid, and that it acts a corresponding part in the preparation of phosphoric ether.

§ 2d.—*Of the Preparation of the Second Class of Ethers.*

The ethers of the second class are those formed by the action of nitric acid, or of a vegetable acid on alcohol, and they contain the elements of both acid and alcohol, in some kind of combination. The only one officinal in this country is nitric ether.

The mode of obtaining nitric ether proposed by Thenard, and very generally adopted, is to mix equal parts of alcohol at 0.835 with nitric acid at 1.30; a considerable rise of temperature accompanies the mixture; introducing them into a retort of a capacity double their volume: placing the retort, by means of an iron triangle, over a chauffer, which may be withdrawn at pleasure; and connecting it with five Woulf's bottles, of which the first is empty, and the other four half filled with water saturated with sea-salt; each bottle is immersed in a vessel where it is surrounded by a mixture of ice and salt, and receives the long branch of a tube which connects it with the preceding bottle, in such a manner that this branch reaches its bottom. The chauffer is then placed under the retort until the mixture begins to

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* Annales de Chimie et de Physique, xiii. 294.

boil; the fire is then to be withdrawn, and the retort cooled occasionally to moderate the ebullition which continually tends to increase in violence; when the matter in the retort ceases to boil when left to itself the operation is finished.

The liquid product in the flasks is to be collected and purified by redistillation at a temperature of 100° into a receiver immersed in a freezing mixture: if necessary the addition of a little lime separates any traces of acid which might adhere to it.

In this process a quantity of both acid and alcohol are decomposed; a considerable quantity of gaseous matter is evolved, consisting of carbonic acid, nitrogen, nitrous and nitric oxides, with persistent vapour of ether; the residue contains undecomposed nitric acid, oxalic acid, some acetic acid, and a peculiar carbonaceous matter: the impure ether which is obtained in the bottles consists of a mixture of alcohol, ether, nitric and nitrous acids, with acetic acid and water, from all which it may, as before-mentioned, be purified by rectification.

From 500 of alcohol and 500 of acid, Thenard obtained about 100 of pure ether: Dumas and Boullay have remarked that the smaller the quantities operated on are, the less loss occurs in the process, and the product is less impure; they also consider the apparatus of Thenard as unnecessarily complex, as the receiver and one bottle containing brine, is sufficient to condense all the ether which is formed.

The loss in Thenard's process being occasioned by the violent action of the strong acid and alcohol, various modes of moderating this have been devised: Black interposed a stratum of water between the acid and alcohol, and thus the mixture was effected and the ether formed very slowly.

The Dublin Pharmacopœia disengages the acid from nitre by means of sulphuric acid, and thus it comes into action gradually, and violent ebullition is avoided: the process is also more economical from using the materials for making nitric acid in place of the acid itself.

Mr. Donovan prepares nitric ether with very moderate reaction, by distilling twelve ounces of alcohol with two of nitric acid; collecting the ethereal product, distilling it again with two ounces of acid more, and repeating this operation until eight ounces of acid have been used; he thus gets a pure ether boiling at 80° Fah. immiscible with water, not acid, and powerfully dulcifying alcohol:* he recommends this process as being easy of performance, and giving a sufficient quantity of product in a short time, for nitric ether should not be prepared in large quantities, as it undergoes decomposition.

It is a fact that the formation of nitric ether is much facilitated by the presence of sulphuric acid in the mixture; on this account, Duroziez employs in the process three pounds of alcohol at 0.835, and one and a half pounds of nitric acid, sp. gr. 1.285, and adds to them, when mixed, twelve ounces of sulphuric acid. It was supposed that the latter acted merely by raising the boiling point of the mixture,

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* Annals of Pharmacy, June 1830, p. 394.

and thus enabling the nitric acid and alcohol to act more completely upon each other before the vaporization of any principle took place; but this view has been proved to be incorrect, and Dumas and Boullay[*] have shown that it acts by determining the previous formation of sulphuric ether, a circumstance which Thenard suspected, but did not rigorously ascertain.

Brugnatelli obtains his nitric ether by mixing 32 parts of sugar with 64 of alcohol and 96 of nitric acid; by this process he obtains a quantity of ether equal in weight to the alcohol employed. The use of the sugar will be seen when the theory of the formation of this product has been explained.[†]

Theory of the Formation of Nitric Ether.

When we heat nitric ether with a solution of a base, it is decomposed; alcohol passes over, and a hypo-nitrite of the base remains behind.[‡]

Hence it was inferred by Thenard that the second class of ethers are combinations of alcohol with the acid which was used in their formation.

On this view nitric ether should be composed of 1 vol. vapour of nitrous acid + 1 vol. vapour of alcohol = 1 vol. vapour of ether.

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[*] Annales de Chimie et de Physique, xxxvii. November.

[†] Pharmacopœia, &c. della Republica Italiana. 1802. p. 91.

[‡] This salt was then considered to be a *nitrite*, the hypo-nitrous acid not having been discovered at the time of Thenard's researches.

Or, atomically,

1 of nitrogen = 14
2 — carbon = 12
3 — hydrogen = 3
5 — oxygen = 40
—
1 atom of nitric ether 69

But this is far different from its real composition, for, by the most accurate analysis, it consists of

1 of nitrogen = 14
4 — carbon = 24
5 — hydrogen = 5
4 — oxygen = 32
—
75

Now these elements are arranged so as to form a neutral hypo-nitrite of sulphuric ether, for,

$$\underbrace{\begin{array}{lll} \text{1 of nitrogen} = 14 & \left.\begin{array}{l}\text{4 of carbon}\\ \text{4 — hydrogen}\end{array}\right\} & \text{2 olefiant gas} = 28 \\ \text{3 — oxygen} = 24 & \left.\begin{array}{l}\text{1 — hydrogen}\\ \text{1 — oxygen}\end{array}\right\} & \text{1 of water} = 9 \\ \quad — & & \quad — \\ \left.\begin{array}{l}\text{1 atom of hypo-}\\ \text{nitrous acid}\end{array}\right\} 38 & & \text{1 atom of ether } 37 \end{array}}$$

1 atom of hypo-nitrate of sulphuric ether, or of nitrous ether.

According to this view, advanced by Dumas and Boullay,* in the formation of nitric ether, the alcohol is divided into two portions, one of which is totally decomposed, and yielding its carbon and hydrogen to two atoms of the oxygen of the nitric acid, reduces it to hypo-nitrous acid, and water and car-

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* Annales de Chimie et de Physique, 1828, page 26.

bonic acid is formed; the other portion of alcohol loses some water, is reduced to the state of sulphuric ether, which then combines with the hypo-nitrous acid, and forms nitrous ether. A quantity of both acid and alcohol are totally decomposed, and yield the gaseous products, the evolution of which has been already remarked.

We can now see the use of the addition of sulphuric acid in this operation; it developes the sulphuric ether without any loss of alcohol or acid, and the benefit of Brugnatelli's mode, in which he de-oxidizes the nitric acid by sugar, and thus none of the alcohol being lost, he obtains a product equal to it in weight.

Boullay explains the evolution of alcohol from the ether by a base, by showing that the ether, in being separated, takes a new quantity of water from the solution of the base employed and forms alcohol: he conceived, that if we could decompose one of these ethers by a base without water, we should get ether and not alcohol; for this purpose he passed ammoniacal gas through oxalic ether; but it was not decomposed; it combined directly with the ammonia, and formed a salt, very like sulpho-vinate of the same base; he called it oxalo-vinate of ammonia, or oxalate of ammonia and carburetted hydrogen.

The other ethers of the same class, as the acetic, oxalic, &c., not being of pharmaceutic importance need not be described; their mode of preparation is given in chemical books, and the rationale is identical with that of nitrous ether.

§ 3d.—*Of the Preparation of the third Class of Ethers.*

These are the products formed by the action of the hydracids on alcohol.

Take equal volumes of alcohol, of specific gravity 0.814 and of muriatic acid, of specific gravity, 1.20; if the acid or the alcohol be weak, no ether will be formed, and a mere mixture of acid and of alcohol will distil over. The materials are to be introduced into a glass retort, furnished with a safety tube, and well mixed, and a little siliceous sand introduced to moderate the ebullition. To the retort is connected a tube bent at right angles, and passing to the bottom of a Woulf's bottle, containing water kept at 65°. Fahrenheit; from the other neck of this bottle (which is also provided with a safety tube) passes another tube bent at right angles, and passing to the bottom of a matrass, quite dry, and surrounded with a mixture of ice and salt. On the heat being raised the muriatic ether passes in a gaseous form through the water in the first bottle into the second, where it is condensed. Any alcohol or acid which might distil over is arrested in the water, and the ether is obtained pure in the refrigea rating matrass.

This ether is colourless, neutral, and extremely volatile; at 52° Fahrenheit it becomes gaseous, and therefore does not exist as a fluid at moderate temperatures. It is a neutral hydrochlorate of carburetted hydrogen, its composition being

$$\begin{array}{l}\left.\begin{array}{ll}1 \text{ hydrogen} & 1\\ 1 \text{ chlorine} & 36\end{array}\right\} = 1 \text{ hydrochloric acid} = 37\\ \left.\begin{array}{ll}2 \text{ hydrogen} & 2\\ 2 \text{ carbon} & 12\end{array}\right\} = 1 \text{ carburetted hydrogen } 14\\ \hline \hfill 51\end{array}$$

The theory of its formation is very simple: a part of the muriatic acid takes an atom of water from the alcohol; and the disengaged carburetted hydrogen combines with the rest of the hydro-chloric acid.

The conclusions of Dumas and Boullay, concerning the properties of carburetted hydrogen and its etherial combinations, are of sufficient interest to justify their insertion here.

1st. Carburetted Hydrogen (2 H + 2 C) is a base, equally powerful with ammonia, and were it soluble in water, would act with equal intensity upon the vegetable colours.

2d. Alcohol, and the ethers of the first class, (sulphuric, &c.) are hydrates of carburetted hydrogen, the base being combined with twice as much water in the former as it is in the latter fluid.

3d. The second class of ethers (the nitrous, acetic, &c.) are hydrated salts of carburetted hydrogen; their formula may be expressed (1 acid + 1 water + 1 base) or (1 acid + 1 ether.)

4th. The third class of ethers (the muriatic, &c.) are anhydrous salts of carburetted hydrogen, and their formula may be expressed (1 acid + 1 base.)

5th. Sulpho-vinic acid is an acid hydrated sulphate of carburetted hydrogen: Hennell's oil of wine is a neutral hydrated sulphate of carburetted hydrogen, and the real oil of wine (separated from Hennell's oil by the action of a base) is identical in chemical composition with carburetted hydrogen, (its formula being $2\,H + 2\,C$,) and differs from it merely in its form of aggregation.

Class 7th.—*Operations of Oxidation.*

Oxidation is the combination of a substance with oxygen; it always takes place in definite proportions, and is often accompanied by the evolution of heat and light, or combustion; this phenomenon, however, takes place during the exertion of intense chemical affinity between any two bodies; and is not peculiar or confined to the combining of bodies with oxygen.

Oxidation, may be effected either *immediately* by acting on the substance by pure oxygen, or by atmospheric air, under favourable circumstances, or *mediately*, by acting on the body by compounds containing much oxygen, with which they readily part, yielding it to the more active affinities of the substance to be oxidized. Thus arsenic is acidified by heating in nitric acid; water takes an additional atom of oxygen from the deutoxide of barium; by being heated with deutoxide of copper, the carbon of vegetable matters is converted into carbonic acid, in order to effect their ultimate analysis, and many substances may be oxidized by being heated along with chlorate or nitrate of potash.

There are many important pharmaceutic agents obtained by oxidation; the mode of preparation of some of the most worthy of notice follows.

1st.—*Of Black Oxide of Iron.*

When iron is exposed while intensely heated to the action of atmospheric air, its external surface burns, and is converted into the brittle black oxide; which detaches itself under the form of scales during the working of the iron, and is to be collected and washed: when dry they are to be separated from impurities by the application of a magnet, and fitted for medicinal use by reduction to an impalpable powder.

This is not a pure protoxide; when iron is heated in oxygen both the proper protoxide and the peroxide are generated, which by their union form the black oxide, (*oxidum ferroso-ferricum* of Berzelius.) It is found abundantly native at Fahlun, and elsewhere, and is also generated by the action of heated iron on steam. A method of obtaining a much purer oxide is that of Guibourt: minutely divided iron-wire is put into an earthen vessel with water enough to keep it moist: the material is kept occasionally stirred with a spatula, and water added to keep the mass moist; the iron absorbs oxygen as well from the air as from the water; some ammonia is formed by the nascent hydrogen of the water uniting to the nitrogen of the air; and a fine black powder (the oxide) is formed, which is washed away from the iron, and powdered by levigation.

2d.—*Of Red Oxide of Iron.*

Sulphate of iron is to be dried and then roasted until it ceases to give out sulphuric acid vapours; the mass is then to be well washed to remove any undecomposed red sulphate, and the remaining oxide dried for use.

In this process, the proto-sulphate of iron is decomposed by heat, and resolved into protoxide of iron and sulphuric acid: a portion of this last gives oxygen to the protoxide sufficient to convert it into peroxide, and is itself reduced to the state of sulphurous acid. The fuming sulphurous acid is prepared on the continent in this way, the copperas being decomposed in earthenware retorts. The glacial acid may be obtained by re-distilling this fuming acid into a receiver surrounded with ice and salt; it condenses in white opaque filamentous masses, like amianthus; this is the acid quite free from water, or *anhydrous*, combined with one atom of water, it forms the concentrated acid of our shops.

The oxide varies in its colour according to its degree of aggregation, passing from a fine red, and reddish brown to brown, and when it has been exposed to an intense heat, to nearly black; in this state it is scarcely soluble in acids.

3d.—*Of Peroxide of Mercury, per se.*

Into a flat-bottomed matrass, provided with two necks of a nearly capillary bore, and one much longer than the other, as much perfectly pure mercury is to be introduced as will cover the bottom to the depth of about a quarter of an inch.

The apparatus is to be heated on a sand bath until the mercury approaches its boiling point, and the temperature kept about 600° Far. until the metal is converted into semi-crystalline scales of peroxide.

In this process the air in the apparatus is continually renewed by the two necks of unequal lengths producing a current, and the heat applied being sufficient to vaporize the mercury without making it actually boil, the metal unites with the oxygen of the air, and forms the peroxide which is deposited on the surface of the mercury and on the sides of the vessel in crystalline grains of a ruby colour, and sometimes in well formed crystals, which are either octohedrons, or elongated quadrangular pyramids. This process is excessively tedious: the only attention required is to keep the temperature at the proper height, as if lower the combination would not take place, and if it was more elevated the compound already formed would be decomposed.

4th.—*Oxide of Mercury by Nitric Acid.*

By the decomposition of the per-nitrate of mercury a peroxide is obtained, much more economically than by the other process, and with proper precautions the product may be obtained perfectly free from nitric acid.

Pure mercury is to be dissolved in nitric acid perfectly free from muriatic acid, and the solution evaporated to dryness; the heat is then to be gradually increased until no more nitrous fumes are produced, and some oxygen begins to be disengaged, as shewn by the re-illumination of an extinguished taper held above the mouth of the matrass; the matrass is then to be accurately corked, cooled very slowly, and the oxide removed when cold.

It is sometimes difficult to obtain this oxide of the fine crystalline appearance for which it is admired. Gay-Lussac considers that this depends on the state in which the nitrate of mercury is used; if it be powdered, as directed by the Edinburgh College, the product is in fine powder, dull, and of an orange yellow colour; if the salt was in large crystals, the oxide is of a deep orange; and if it be in small crystalline grains, as it is left by a moderately slow evaporation to dryness, it is brilliant, crystallized, and of a fine orange red. Chevallier * lays great stress on the matrass being allowed to cool very slowly with the orifice closed.

This oxide, as prepared for commerce, often contains some sub-pernitrate, from the heat not having been continued long enough; this impurity may be detected by washing with a little potash water, evaporating to dryness, and mixing the residue with some copper filings and sulphuric acid: if nitric acid existed in the oxide, nitrous acid fumes will be rendered evident by their reddish colour. The oxide may be freed from the last portions of nitric oxide by repeated washings with warm water, as recommended by Brugnatelli.

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* Manuel du Pharmacien, vol. ii. p. 463.

Oxide of Zinc.

Zinc is a metal which has a great affinity for oxygen, and when heated powerfully with access of air, is converted into oxide with the evolution of heat and light. This is the pharmacopœial process.

According to the British commentators, the zinc should be thrown in but in small quantities at a time, lest the inferior portions of the metal should be excluded from the air. Chereau and Robiquet, however, advise the contrary, and say that all the zinc to be oxidized should be at once thrown into a crucible, of which it is sufficient to fill two-thirds. The crucible is to be so covered as to allow the free access of air, and then brought to a full white heat. The zinc vaporizes, and the vapour burns with a bluish white flame, depositing the oxide produced on the sides and cover of the crucible, and on the surface of the fluid metal, under the form of light snowy flocculi.

A quantity of this oxide is always driven off, during the combustion, in light white vapours, which the operator should avoid, as, if respired, they produce considerable irritation.

Deflagration is a mode of oxidizement very often used. It consists in mixing the substance to which the oxygen is to be supplied with a certain quantity of nitre, and heating the mixture; at a dull red heat the nitre gives out oxygen rapidly, and combustion ensues. The compound produced generally combines with the potash of the nitre.

In this way the bin-arseniate of potash is formed by heating arsenious acid with nitre, and various old antimonial preparations were made by deflagrating the sulphuret of antimony with nitre. A quantity of both sulphur and antimony being in those cases oxidized, sulphurous and antimonious acids are generated, and unite to the potash; while the small quantity of protoxide of antimony formed combines, according to Buchner, with the sulphuret, to form a stibio-thionate of that metal. The sulphate of potash with sulphur of the Edinburgh Pharmacopœia is formed also by deflagrating nitre with more sulphur than it can convert into sulphuric acid, the sulphate formed remaining mechanically mixed with the excess of sulphur.

Class 8th.—*Operations of Reduction.*

Reduction is the separation of a metal from whatever bodies it had been previously combined with.

The compounds from which we have in general to obtain the metallic constituent, are, oxides, chlorides, and sulphurets; of these, the reduction of an oxide is the most common and the most important.

Reduction is performed in crucibles, when the metal to be obtained is fixed, but in earthenware or iron retorts, when it is capable of being volatilized;

occasionally in reduction by means of hydrogen gas, earthenware or glass tubes are employed.

The great agent in the reduction of metals from their oxides is carbon; it is used in a variety of ways; the crucible is often lined with a paste made of clay and powdered charcoal, with a cover of the same materials (the *creusets brasqués* of the French); Klaproth often hollowed out of a piece of charcoal into the shape of a small crucible, and stopping it with another lump of charcoal, enclosed the whole in an earthenware crucible to defend it from combustion: and an excellent mode of mixing the oxide perfectly with finely divided charcoal is to make it into a ball with melted wax, and decompose the organic material by heat.

The uses of fluxes have been already adverted to in speaking of *fusion:* it is here necessary to mention one frequently employed in reduction, as serving at once to supply carbon to the oxide, and to promote the fusion of the mass, which is black flux.

Black Flux, is made from a mixture of one part nitre and two parts crude tartar, deflagrated 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 a great excess of carbon, mixed with carbonate of potash, and which assists in reducing metals by abstracting the oxygen; cream of tartar also when decomposed by heat yields a carbonate of potash with excess of carbon, and as it can be intimately mixed with the oxide, in the state of tartar, acts very powerfully: both those fluxes yield a considerable quantity of potassium to the metals reduced by them. The use of the fluxes in reduction is to retain the mass in a certain degree of fluidity, so that the particles of metal, as they are reduced, may fall to the bottom and unite into a button, and may not come into contact with the air by which they might be re-oxidized: for the same purpose, when the crucible is taken from the fire, the bottom is often struck gently once or twice to shake down any metal remaining scattered through the mass.

Metallic oxides are often reduced by means of another metal possessing a more powerful affinity for oxygen than that already oxidized; this may be effected in either of two ways; 1st, by dissolving a salt of the metal to be reduced in water and suspending in the solution a piece of the more energetic metal, when it displaces the first which is gradually deposited on it; the rationale of this has been already explained; 2nd, by heating the metal with the oxide, when the oxygen changes places generally with an evolution of heat and light; thus potassium decomposes oxide of chrome, and the potash formed being washed away with water, the metal, in a state of fine division, remains behind.

A mode frequently employed of reducing oxides is by means of hydrogen; to effect this the oxide is put into a glass tube and heated to dull redness, and hydrogen gas passed over the oxide as long as moisture is deposited on the cold portion of the tube; when no more water is formed the lamp is removed, and the current of hydrogen continued until the tube is cold.* All metals possessing for oxygen an affinity less energetic than that of iron may be reduced by this process, as may also oxide of iron, but iron in its turn takes oxygen away from steam.

Chlorides are generally converted into oxides previous to reduction, and the oxide then decomposed in some of the ways already mentioned ; they may, however, be decomposed by removing the chlorine by means of a more active metal, thus Wöhler obtains aluminum by heating its chlorides with potassium ; or by hydrogen, as by putting chloride of silver into an iron vessel with dilute sulphuric acid, the hydrogen evolved unites with the chlorine, and the silver is separated in delicate arborizations.

There are many modes of reducing metallic sulphurets; 1st, by previous conversion into an oxide ; 2nd, by fusion with another metal; 3rd, by fusion with an oxide, &c. ; 4th, by hydrogen.

A metallic sulphuret is converted into an oxide by deflagration with nitre: sulphate of potash being formed which acts in the reduction as a flux ;—for such operations what is termed *raw flux* is used, the ingredients of black flux are well mixed up with the sulphuret in fine powder, and the whole heated ; the oxide produced is thus obtained intimately mixed with the necessary quantity of charcoal for its decomposition, and of flux to enable the drops of me-

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* The reason of continuing the current of hydrogen until the oxide is cold, is, that if the air was admitted to the metal in a state of such minute division as that in which the product of this operation exists, while hot, it would rapidly re-absorb oxygen, and perhaps take fire.

tal to unite; thus antimony is obtained from the native sulphuret, and other metals in a similar manner.

Sulphurets are decomposed often by being heated with a metal capable of taking the sulphur from that previously in combination with it; the metal and the sulphuret finely divided are mixed and exposed to a high heat; a button of the liberated metal sinks to the bottom, and the newly formed sulphuret floats above; thus antimony may be procured by heating the sulphuret with iron filings, and mercury by heating in an earthen or iron retort iron filings with twice their weight of cinnabar.

Sulphurets may be reduced, as proposed by Berthier, by fusion with an alcali or an alcaline earth: the action of a sulphuret on the base is such that there is formed an alcaline sulphate, and a combination of the metallic sulphuret with the sulphuret of the alcaline metal, which are all fused with the excess of alcali, and a quantity of metal which had given up its sulphur is found reduced; if we then roast these sulphuretted compounds, the sulphur of the metallic sulphuret is converted into sulphuric acid, which saturates the excess of alcali, and then the rest of the metal previously combined is reduced; the process may in some cases be expedited by the addition of a little iron to the fused mass, and has been found very economical in manufacture, using lime as the base.

The application of hydrogen to the reduction of metallic sulphurets is limited; no metal of a higher degree of affinity for oxygen than copper being decomposed by it; where it does succeed the rationale is very simple: the hydrogen forming sulphuretted hydrogen with the sulphur, and the liberated metal remaining behind.

Metals may be reduced in many other ways than those above-mentioned; thus, green sulphate of iron reduces gold; a solution of oxalic acid has the same effect; proto-chloride of tin reduces mercury; sulphurous acid gas reduces gold and silver; vegetable or animal matter reduces gold, silver, and mercury, and the compounds of these metals and of platinum may be almost all reduced by a red heat; light also promotes the reduction of many metals; those methods, however, not being of applicability on a scale of any extent, are rather matters of scientific curiosity.

The mode of obtaining the more important officinal metals in a pure state requires notice.

1st.—*Of the Preparation of Silver.*

The silver of commerce always contains a quantity of copper and generally a trace of gold; to free it from those it is to be dissolved in pure nitric acid, sp. gr. 1.350, the gold remains unacted on as a black powder: to the cold solution, sea salt dissolved in water is to be added as long as any precipitate is produced, and the chloride of silver thrown down, washed until the water runs off tasteless: it is to be then dried without exposure to light.

Take twice its weight of dry carbonate of potash, fuse it in a black lead crucible, and throw by small portions at a time, the chloride into it: each addition is followed by the disengagement of the carbonic acid and oxygen of the carbonate of potash; the potassium unites with the chlorine, and the metallic silver is separated: when the whole is decomposed the heat is raised, and the silver obtained in a button when the crucible cools.

2d.—*Of Antimony.*

Antimony may be obtained from the sulphuret by fusion with raw flux or with iron filings; when prepared in either of these ways it is impure; it contains sulphur, arsenic,* and either potassium or iron; to free it from these, Berzelius recommends the metal to be heated with its own weight of antimonious acid, which yields its oxygen to the impurities, and the whole antimony is obtained perfectly pure.†

3d.—*Of Mercury.*

The mercury of commerce is exceedingly impure, and it is ordered in the Pharmacopœias to be re-distilled, in order to obtain it free from sophistication; for the same purpose, the codex uses for all the mercurial preparations the metal revived from cinnabar, the sulphuret being decomposed by lime or by iron filings.

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* Serullas found arsenic in all the native sulphurets of antimony, and it exists in all pharmacopœial preparations of that metal except tartar-emetic, in the mother liquors of which it remains.—Journal de Pharmacie, tome vi. and vii.

† Traité de Chimie, tome ii. 494.

The impurities of mercury may be bismuth, lead, tin, or zinc; the mode of discovering them belongs rather to pure chemistry, and the process of purification by distillation has been already described. If we pour on impure mercury a weak slightly acid solution of nitrate of mercury, and leave it for some time, the foreign metals will precipitate the mercury from the solution and take its place; and taking care to agitate the mass of mercury frequently, we can thus purify mercury from its adulterations without distillation.

4th.—*Of Zinc.*

The zinc of commerce is obtained by heating the native calamine with charcoal; the heavy vapour of the reduced zinc descends, and is condensed in pots placed under the crucibles; the zinc thus obtained is impure; it contains cadimum, copper, lead, and often bismuth, carbon, and iron; from these it is to be purified by distillation. If this be performed in an earthen retort, the metal condensing in the neck is very liable to obstruct it, and render the frequent use of a curved iron rod necessary to clear it; the metal thus obtained then contains iron; the best apparatus is to have a crucible, through whose bottom passes an earthen tube rising about half-way to the top of the crucible, and descending through the bars of the grate into a vessel of water placed underneath; the zinc is to be put into the crucible, so that when melted it will not rise within 1½ or 2 inches of the open mouth of the tube, and the cover is to be then luted firmly on. On heat being applied, the heavy vapour of the metal passes down the tube, which is sufficiently hot to prevent solidification, and condenses in the water placed below. This is an instance of what the old writers termed distillation *per descensum.*

The copper, lead, tin, and iron wire of commerce are sufficiently pure for pharmaceutic use, and do not require notice.

Class 9th.—*Operations of Calcination.*

In calcination we drive off, by means of heat, the volatile ingredients of a body, and in some instances decompose others more fixed : it requires no other notice than the details of the principal cases in which it is used : they are not numerous.

1st.—*Calcination of Carbonate of Magnesia.*

By calcining carbonate of magnesia we expel some water and the carbonic acid, and we obtain isolated the earth magnesia or oxide of magnesium; the product should be white, very light and pure ; its purity is readily secured by having used a pure sulphate for the preparation of the carbonate, and by continuing the heat until all the carbonic acid is expelled : the cleanliness of the vessels insures its whiteness. Its levity depends a good deal upon the manner in which the operation is conducted; if the heat be too elevated, the product is much more dense ; and in the mode very often pursued of ladling the magnesia in and out of the crucible, the desirable degree of levity is scarcely ever obtained.

The crucible being about two-thirds filled with the carbonate, is to be heated to bright redness; the carbonic acid is driven off in white fumes, arising from a quantity of the magnesia being carried up by the current of gas; the decomposition is accompanied by an appearance of ebullition. The heat should not be raised to whiteness, for the magnesia obtained at that temperature would be much more dense, and those portions next the crucible would undergo a sort of vitrification, rendering them gritty and less easily soluble in acids.

In order to obtain magnesia of as low a specific gravity as possible, Planche recommends the following process:

He substitutes for crucibles the earthenware pots, not glazed, used by house-painters. The superior edge of each pot is carefully ground with sand, and, by means of a well-tempered punch, a large hole is cut in the bottom of each, excepting one. This having been done, the unperforated pot is placed at the bottom, and one perforated on top of it, so that by means of grinding they fit accurately to each other; on this four other pots are placed in order, each being perforated at the bottom. The junctions are then luted carefully with cows' hair, burned clay, and water.

This apparatus is now filled with carbonate of magnesia, in light powder, obtained by friction, and the upper pot is closed by a cover of baked earth, with a small hole for the escape of the water and carbonic acid. In order to render the apparatus more firm, the whole is surrounded by four iron rods secured to each pot, and above and below to each other. The whole is brought to redness in a proper furnace, and the magnesia is obtained as a powder of extreme levity.

The magnesia sold in commerce by the name of Henry's Calcined Magnesia, is very ponderous, and is considered by Duncan as being probably obtained by direct precipitation from the sulphate. Robinet employs a mode which gives a heavy magnesia, somewhat like Henry's, and is very economical. He makes the carbonate into a mass like dough, with water, and presses it strongly between folds of linen; he then places these masses in a crucible, and calcines as usual. Thirty ounces of magnesia may be made by this process in a vessel which would hold only twelve of the dry carbonate. The product, however, does not possess the lightness which is generally desired.

2d.—*Calcination of Alum.*

This process is merely one of desiccation, as if properly performed, the operation is stopped before any of the fixed ingredients of the salt are decomposed. The alum, when heated, undergoes *aqueous fusion,* that is, its solubility in water is so much increased by heat that its own water of crystallization is capable of holding it in solution; as the water is driven off by heat, the salt gradually dries, and when the exsiccation is finished the fire is to be removed.

If the action of the heat be too long continued, the salt itself becomes altered; the sulphate of alumina is decomposed, its sulphuric acid being resolved into sulphurous acid and oxygen gases. If the other constituent of alum be sulphate of potash, it remains behind along with the alumina, but if sulphate of ammonia, it sublimes, and alumina alone remains. The ammonia alum is rarely met with in this country, although commonly in France.

3rd.—*Calcination of Bones.*

To obtain the phosphate of lime used in making phosphate of soda, phosphoric acid, cupells, &c. the animal matter of bones or horns is destroyed by calcination, and the residual earthy salt preserved.

This calcination must be performed with access of air, otherwise the carbonaceous matter would not be burned out, and the bones would remain blackened. The process may be performed in a common fire, stratifying the fuel and the bones broken into moderately small pieces; a quantity of carburetted hydrogen is formed which burns with a bright flame, some other gases are given out, and the remaining carbon is gradually converted into carbonic acid, leaving behind the earthy salts preserving the original form of the bone; these are mostly phosphates of lime and of magnesia, fluate of lime, &c., with some free lime arising from the decomposition of a small quantity of carbonate which existed in the bones.

Lime is obtained by calcining the native carbonate, generally that of secondary formation. When for chemical purposes the apothecary has to prepare pure lime, he may obtain it by calcining the precipitated carbonate, or the native granular carbonate (carrara marble,) taking care to select pieces free from silicious veins.

Class 10th.—*Operations of Carbonization.*

"Carbonization is an operation by means of which we obtain the carbon of an organic substance, dissipating, by means of heat, a part of the elements with which it had been combined."[*]

There is only one process of any importance for obtaining a medicinal agent by carbonization.

Preparation of Burned Sponge.

Pieces of sponge are to be picked as clean as possible from the little stony matters which adhere to them, put into a covered crucible and heated until no more vapours are produced; when all the volatile ingredients have been driven off, and the sponges are black and friable, they are to be powdered, passed through a fine sieve, and preserved in closely stopped bottles, as the powder rapidly attracts moisture from the air. Chereau[†] recommends that the sponge should be merely torrefied, so as to be brown and friable, stating that the powder thus prepared acts more energetically in counteracting hypertrophy. It

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[*] Chevallier, Manuel, vol. i. p. 76.

[†] Duncan, Supplement to Dispensatory, 149.

is not known whether any of the iodine be dissipated during the operation.

. The constituents of burned sponge are, chloride of sodium, iodide of sodium, magnesia arising from the decomposition of the muriate, lime from that of the carbonate, sulphuret of calcium, (the sulphate of lime having been reduced by the carbon), the presence of which is the reason of burned sponge emitting the smell of sulphuretted hydrogen when moistened, and some other unimportant salts.

Class 11th.—*Operations of Torrefaction.*

The properties of vegetable substances are often considerably altered by exposure to heat, and roasting is often performed in order to develope some peculiar power which they did not exhibit so energetically before. Thus the root of the rhubarb, when heated until its external surface is slightly carbonized, becomes astringent in place of purgative, and the torrefied or roasted rhubarb is often prescribed as exerting this physiological action: the aromatic principles of certain organic products are also more highly developed by this process, probably by their requiring a certain degree of heat to volatilize them, and thus the fine flavour of roasted coffee, or of roasted beef, is satisfactorily accounted for.

The roasting of minerals is performed with a view generally of oxidation; in the obtaining of lead from galena, of copper from its sulphuret, &c., the ore broken into pieces is roasted in a reverberatory furnace, the sulphur is converted into sulphurous acid and driven off, and the metal into an oxide, which is afterwards easily reduced.

The arsenious acid of commerce is obtained by the torrefaction of the ores of cobalt, the volatile arsenic is driven off by the heat, combines with the oxygen of the air, and the produced acid is condensed on the long dome of the furnace, from which it is collected and purified by re-sublimation : in the districts where there exist mines of iron pyrites, much sulphuric acid is obtained by roasting the pyrites and using the sulphurous acid produced, in place of directly burning sulphur to generate the acid.

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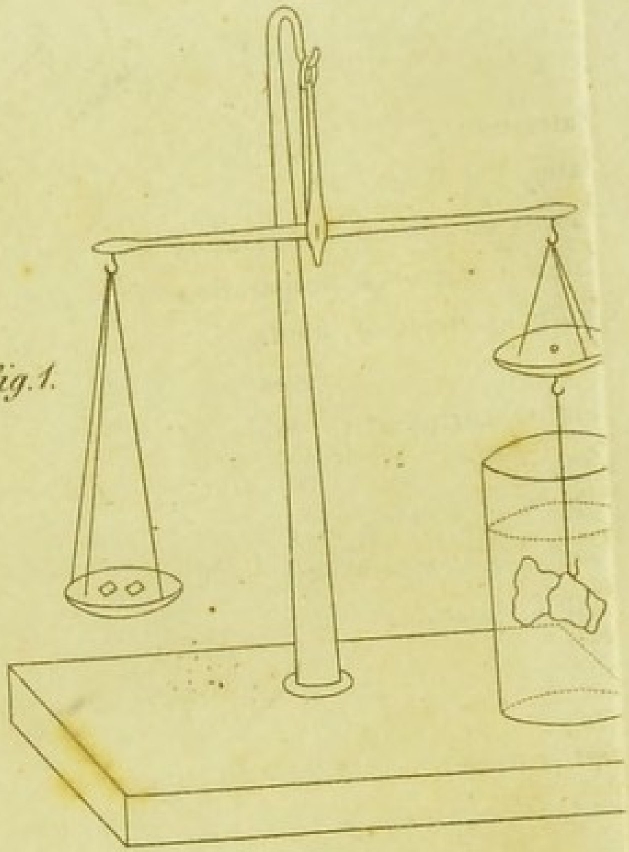

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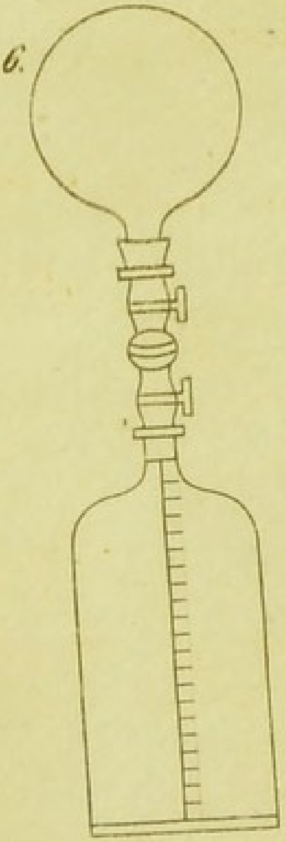

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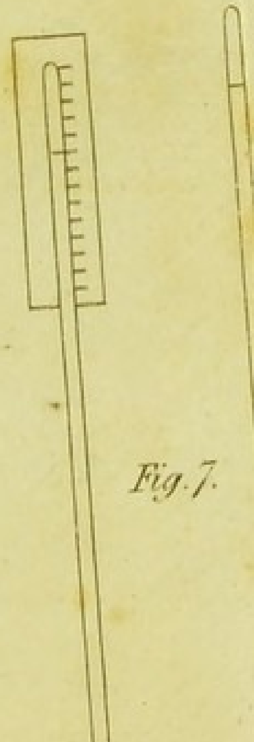

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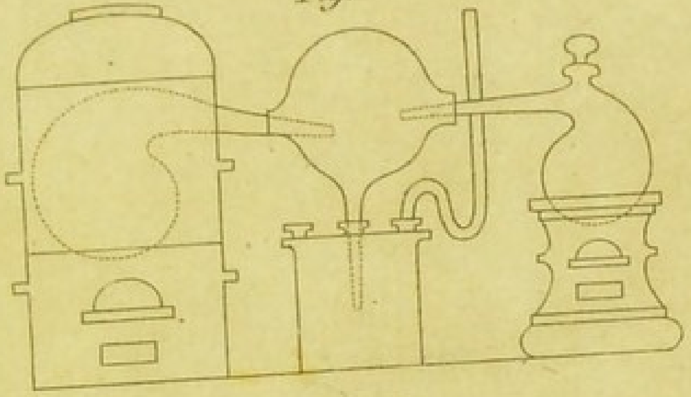

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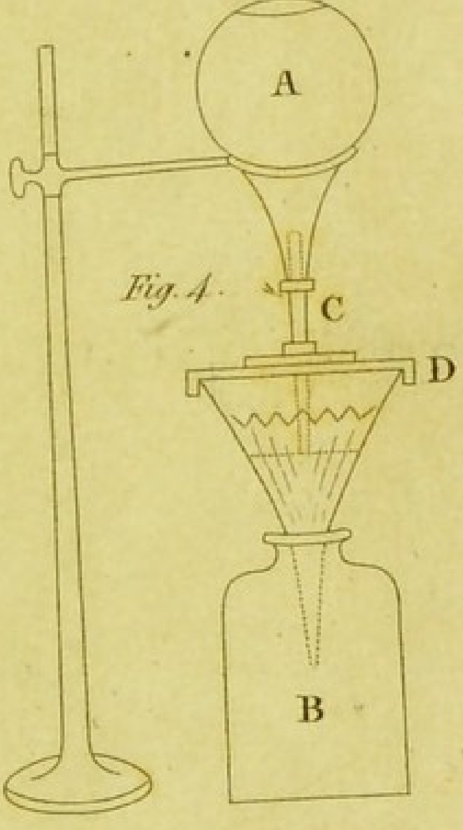

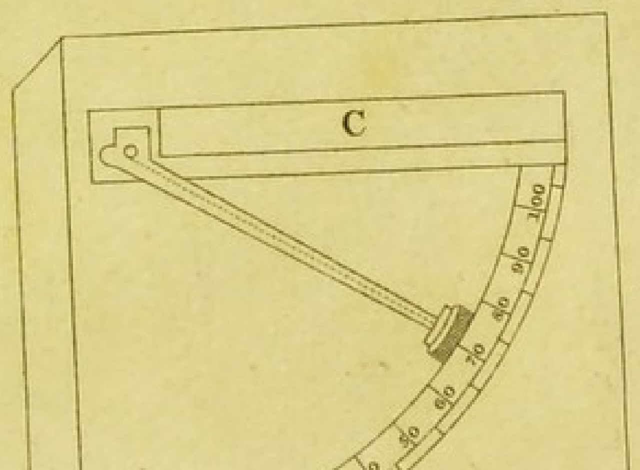

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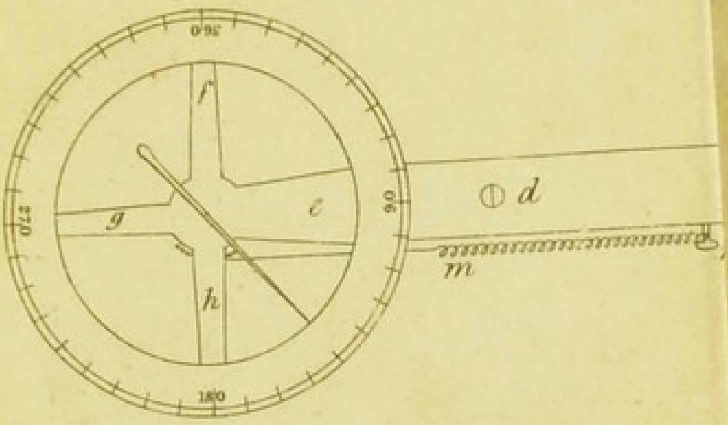

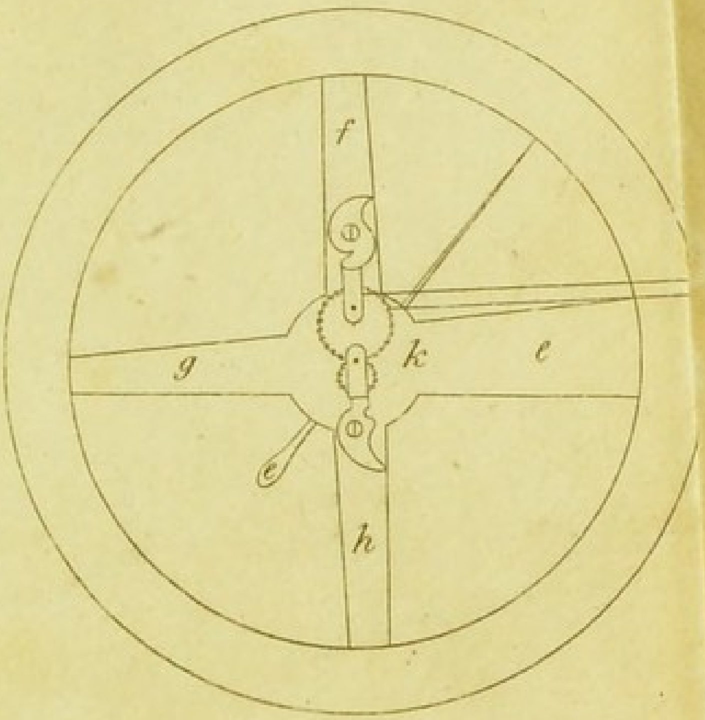

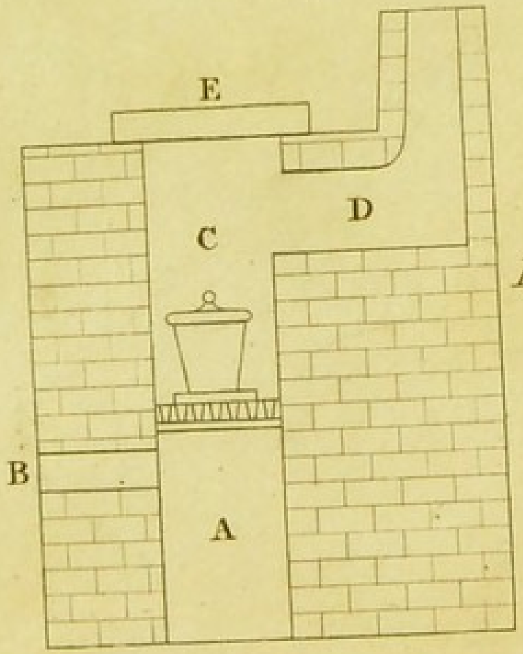

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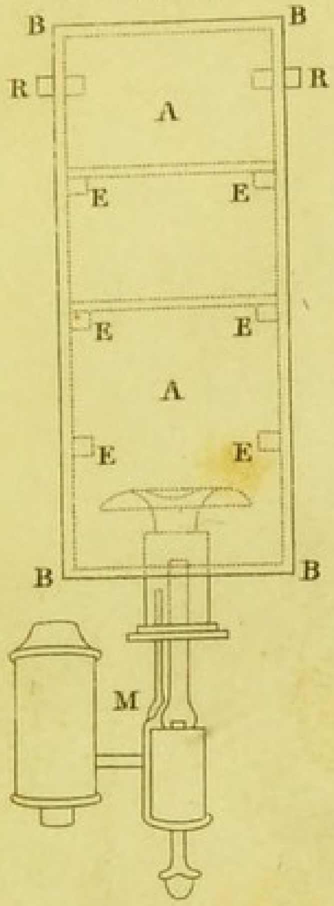

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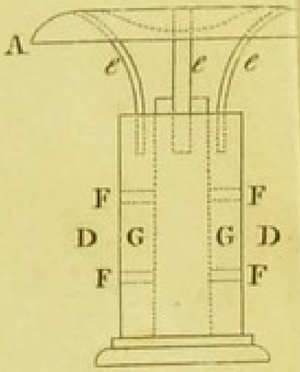

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