DISCUS, a quoit, or circular plate of stone or metal, 10 or 12 inches in diameter, which was used by the ancient Greeks and Romans for throwing to a distance as a gymnastic exercise. Sometimes a kind of quoit of a spherical form was used for the same purpose; and through a hole in its centre a thong was passed, to assist the player in throwing it. Statius, in *Theb.*, vi. 646–721, fully explains the manner in which the discus was used. In the British Museum there is a copy of a famous statue by Myron of a discobolus in the act of throwing the discus.

DISINFECTANTS are agents or substances employed to prevent the spread of contagious or infectious disease. Recent investigations all tend to demonstrate that the efficiency of any disinfectant is due to its power of destroying, or of rendering inert, specific poisons or disease germs which possess in themselves an independent existence; and which, when introduced into the animal system, under favourable conditions, increase and multiply, thus producing the phenomena of special diseases. Therefore, antiseptic substances generally, which check or stop putrefactive decay in organic compounds, by preventing the growth of those minute organisms which produce putrefaction, are, on that account, disinfectants. So also the deodorizers, which act by oxidizing or otherwise changing the chemical constitution of volatile substances disseminated in the air, or which prevent noxious exhalations from organic substances, are in virtue of these properties effective disinfectants in certain diseases. A knowledge of the value of disinfectants, and the use of some of the most valuable agents, can be traced to very remote times; and much of the Levitical law of cleansing, as well as the origin of numerous heathen ceremonial practices, are clearly based on a perception of the value of disinfection. The means of disinfection, and the substances employed, are very numerous, as are the classes and conditions of disease and contagion they are designed to meet. Nature, in the oxidizing influence of freely circulating atmospheric air, in the purifying effect of water, and in the powerful deodorizing properties of common earth, has provided the most potent ever-present and acting disinfecting media. Of the artificial disinfectants employed or available three classes may be recognized:—1st, volatile or vaporizable substances, which attack impurities in the air; 2d, chemical agents for acting on the diseased body or on the infectious discharges therefrom; and 3d, the physical agencies of heat and cold. In some of these cases the destruction of the contagium is effected by the formation of new chemical compounds by oxidation, deoxidation, or other reaction, and in others the conditions favourable to life are removed or life is destroyed by high temperature. Of the first class—aerial disinfectants—those most employed are the gaseous sulphurous anhydride, the fumes of nitrous acid and other acid substances, including vaporized carbolic acid, with chlorine gas and the vapours of bromine and iodine. The use of sulphurous anhydride, obtained by burning sulphur, is of great antiquity, and it still is unequalled as a disinfectant of air on account both of its convenience and general efficacy. Camphor and some volatile oils have also been employed as air disinfectants, but their virtues lie chiefly in masking, not destroying, noxious effluvia. In the 2d class—non-gaseous disinfecting compounds—all the numerous antiseptic substances may be reckoned; but the substances principally employed in practice are oxidizing agents, as potassic manganates and permanganates (Condy's fluid), and solutions of the so-called chlorides of lime, soda, and potash, with the chlorides of aluminium and zinc, soluble sulphates and sulphites, solutions of sulphurous acid, and the tar products—carbolic, cresylic, and salicylic acids. Dr J. Dougall of Glasgow found the following substances the most powerful in destroying minute forms of life:—sulphate of copper, chloride of aluminium, chromic acid and bichromate of potassium, bichloride of mercury, benzoic acid, bromal hydrate, chloral hydrate, hydrocyanic acid, alum, hydrochlorate of strychnia, ferrous sulphate, arsenious acid, and picric acid. Of the physical agents heat and cold, the latter, though a powerful natural disinfectant, is not practically available by artificial means; heat is a power chiefly relied on for purifying and disinfecting clothes, bedding, and textile substances generally. Different degrees of temperature are required for the destruction of the virus of various diseases; but as clothing, &c., can be exposed to a heat of about 250° Fahr. without injury, provision is made for submitting articles to nearly that temperature. For the thorough disinfection of a sick-room the employment of all three classes of disinfectants, for purifying the air, for destroying the virus at its point of origin, and for cleansing clothing, &c., may be required.

DISLOCATION. This term is applied in surgery to the displacement from each other of the cartilaginous or articular surfaces of the bones entering into the formation of a joint. In a normal joint these surfaces are in contact and held together by ligaments and muscles; in a dislocated joint they are separated more or less completely—in the great majority of cases by external violence; in some instances, however, by powerful muscular exertion. The ease with which a joint is dislocated varies with the form and structure of the joint and with the position in which the joint is when the force is applied. The relative frequency of fracture and dislocation depends on the strength of the bones above and below the joint relatively to the strength of the joint. These points may be illustrated by examples from the joints of the arm and leg, because, with perhaps the exception of the joint between the lower jaw and the skull, it is in these situations that dislocation is most frequently observed. The strength of the different joints in the body is dependent on either ligament, muscle, or the shape of the bones. In the hip, for instance, all three sources of strength are present; therefore, considering the great leverage of the long thigh bone, the hip is rarely dislocated. The shoulder, in order to allow of extensive movement, has no osseous or ligamentous strength; its strength is muscular, therefore it is frequently dislocated, because the muscular strength varies in power, the muscles may be relaxed, the person is unprepared, and dislocation occurs; if, on the other hand, the muscles are tense, and the patient is prepared for the strain, then the result will be either a sprain of the joint or a fracture of one of the adjoining bones. The wrist and ankle are rarely dislocated; in the wrist the radius gives way, in the ankle the fibula, these bones being relatively weaker than the respective joints. The wrist owes its strength to ligament, the ankle to the shape of the bones. The elbow is osseously strong, but this strength necessarily varies with the position of the arm. The symptoms of a dislocation are distortion and limited movement, with absence of the grating sensation felt in fracture when the extremities of a broken bone are rubbed together. The treatment consists in reducing the dislocation. The sooner this is done the better—the longer the delay the more difficult it becomes to remedy the displacement. After a variable period, depending on the nature of the joint and the age of the person, it may be impossible to replace the bones. The result will be a more or less useless joint. The administration of chloroform, by relaxing the muscles, greatly assists the operation of reduction. The length of time that a joint has to be kept quiet after it has been restored to its normal shape depends on its form; if osseously strong, then early movement is allowable, as in the elbow joint; if osseously weak, then early movement is unjustifiable. More especially is this the case when, associated with osseous weakness, the strength of the joint is ligamentous, as in the sterno-clavicular and superior radio-ulnar articulations. In such joints the bones must be kept in accurate position and at rest for a lengthened period; if movement is allowed soon after the accident the bone will again slip out of its place.

DISMAL SWAMP, the name given to two extensive stretches of morass on the eastern seaboard of North America. The larger of the two, distinguished as the Great Dismal, lies in the peninsula between the James River on the north and Albemarle Sound on the south, and thus belongs partly to Virginia and partly to North Carolina. Its length from north to south is about 40 miles and its breadth about 25. The greater part of the area is covered with a thick stratum of spongy vegetable soil, without any mixture of earthy particles, which at once supports and is augmented by a luxuriant growth of aquatic plants, brushwood, and timber. The prevailing trees are cypress, juniper, and white cedar, and on the higher ridges oak and beech. By a curious arrangement, minutely described by Sir Charles Lyell in his *Travels in North America*, the surface of the swamp is actually higher, in some parts by as much as 12 feet, than that of the surrounding country; so that, except on the western side, where it receives a few small streams, the waters flow outwards. The centre is occupied by Drummond's Lake, an oval basin about 6 miles long and 3 wide, with perpendicular banks and an extreme depth of 15 feet; the water is clear and abounds with fish. The swamp has long furnished large supplies of timber, much of which has been obtained by excavation from the peaty soil in which it was preserved. The transit is facilitated by means of canals, of which the two most important are the Dismal Swamp Canal, uniting the western branch of Elizabeth river with the Pasquotank, and the Chesapeake and Albemarle Canal, connecting the eastern branch of Elizabeth river with Currituck Sound. The former is flanked by a stage road, which terminates in the south at Elizabeth City, and in the north at Norfolk. Two lines of railway pass through the outskirts of the Virginian portion of the swamp.

The Little Dismal is of much less importance. It lies in North Carolina, in the peninsula between Albemarle Sound and Pamlico Sound; and in the days when slavery was still legal, it was a noted harbour of runaway negroes.

DISPENSATION is a term used by the canonists to signify an act of jurisdiction by which the rigour of the general law is relaxed in a particular case. Regarded from this point of view a dispensation is considered by the canonists not to be an exception to, but a complement of, the law, and it is granted with discretion in cases where the law would otherwise work injustice. "Fuit dispensatio inventa, ut esset pars distributivæ justitiæ." The exercise of this jurisdiction in the earlier days of the Christian church was vested in respect of minor matters in the bishops, and in more important matters in the provincial councils; but by degrees this latter jurisdiction came to be exercised by the patriarchs exclusively, and ultimately, in the case of the Western Church, by the Pope alone, who, at the time of the Reformation of the Anglican Church, had acquired for the Holy See supreme authority in all the more important matters of dispensation. It was one object of the Parliament of England, by the statute "concerning Peter Pence and Dispensations" (25 Henry VIII. c. 21), to divest the Pope of the exercise of any powers of dispensation within the realm of England, by forbidding the king and his subjects to sue to the Pope or to the Holy See for any dispensation. The Parliament further vested the power of granting dispensations, such as had been hitherto obtained from the see of Rome, in the archiepiscopal see of Canterbury—subject, however, to the limitation that they should be only granted for such causes as were not contrary or repugnant to Holy Scripture or to the laws of the realm, and for this purpose the archbishop of Canterbury was empowered to constitute a sufficient commissary, and a clerk who should write and register all such dispensations. The representative of the clerk so appointed by the archbishop is the registrar of the office of faculties, over which the master of the faculties presides, as the archbishop's commissary. The matters for which dispensations were accustomed to be granted from the office of faculties, in the reign of Henry VIII., have almost all become obsolete, or have been withdrawn from the cognizance of the master of the faculties; and the special authority of his court in the present day consists in the grant of special licences for marriages, which are valid in both the provinces of Canterbury and of York, and the right of granting which has been preserved to the archbishop of Canterbury in all subsequent marriage Acts. These special licences are simply dispensations for the solemnization of marriage at other times and in other places than those to which marriage is restricted by the Anglican canons or by the statute law of the realm.

D'ISRAELI, Isaac (1766–1848), was born at Enfield in May 1766. He belonged to a Jewish family which, having been driven by the Inquisition from Spain, towards the end of the 15th century, settled as merchants at Venice, and assumed the name which has become famous. In 1748 his father, then only about eighteen years of age, removed to England, where, before passing the prime of life, he amassed a competent fortune, and retired from business. Both he and his wife gradually dropped connection with their co-religionists, with whom their son never appears to have associated himself.

The strongly marked characteristics which determined D'Israeli's career were displayed to a singular degree even in his boyhood. He spent his time over books, and in long day-dreams, and evinced the strongest distaste for business and all the more bustling pursuits of life. These idiosyncracies met with no sympathy from either of his parents, whose ambitious plans for his future career they threatened to disappoint. At length, when he was about fourteen, in the hope of changing the bent of his mind, his father sent him to school at Amsterdam, where he remained four or five years. Here in the principal's library, and under the principal's influence, he studied Bayle and Voltaire, and became an ardent disciple of Rousseau. Here also he wrote a long poem against commerce, which he produced as an exposition of his opinions when, on his return to England, his father divulged his intention of placing him in a commercial house at Bordeaux. Against such a destiny his mind strongly revolted; and, in this extremity, it was natural that he should eagerly seek the sympathy and counsel of a literary friend. He carried his poem, with a letter earnestly appealing for advice and assistance, to Samuel Johnson; but when, full of eager hope, he called again a week after to receive an answer, the packet was returned unopened—the grand old censor was on his death-bed. He also addressed a letter to Dr Vicesimus Knox, in a tone of the loftiest sentiment, displaying all his literary aspirations, his earnestness and simplicity of heart, and his utter lack of all the qualities of "that despicable thing" (as he called him) "a mere man of the world," and begging to be received into the scholar's family, that he might enjoy the benefit of his learning and experience. How this application was answered we do not know. The evident firmness of his resolve, however, was not without effect. His parents gave up their purpose for a time. He was sent to travel in France, and allowed to occupy himself as he wished; and he had the happiness of spending some months in Paris, in the society of literary men, and devoted to the literary pursuits in which he delighted.

In the beginning of 1788 he returned home, being then a few months past his majority, to lay the first stone of his literary fame by an attack on Peter Pindar, under the form of a poem in the manner of Pope *On the Abuse of Satire.* Published, as it was, at a most appropriate moment, it at once attained popularity. Its authorship became the great subject of debate in literary circles, and it was attributed by some to Hayley, upon whom it was actually revenged, with characteristic savageness, by its victim. It is greatly to Wolcott's credit that, sensitive though he was to attacks upon himself, he at once, on learning his mistake, sought the acquaintance of his young opponent, towards whom he seems to have borne no malice, and whose friend he remained to the end of his life. But of all the fortunate issues of this success not the least fortunate was that it brought D'Israeli what he had so long earnestly desired—the friendship of a refined man of letters. Through it he made the acquaintance of Henry James Pye, who helped to persuade his father that it would be a mistake to force him into a business career, and who introduced him into literary circles. Henceforth his life was passed in the way he best liked—in quiet and almost uninterrupted study. His health was for the most part sufficiently robust, though he was for some years the victim of a nervous depression and weakness, which came upon him when he was about twenty-eight years of age, and which doubtless was chiefly caused by his sedentary habits. He was able to maintain his strenuous and extraordinary devotion to study till he reached the advanced age of seventy-two, when, though still in the enjoyment of unimpaired health, and in the very midst of what would have been his greatest undertaking, he was forced, by paralysis of the optic nerve, to give up work almost entirely. He lived ten years longer, and his death, which took place at his seat at Bradenham House on the 19th January 1848, was due not to old age but to an epidemic which carried him off after a few hours' illness.

Isaac D'Israeli is most celebrated as the author of the *Curiosities of Literature*, by far the best and most popular of all the many works of the kind which have appeared in England. It is a miscellany of literary and historical anecdotes, of original critical remarks, and of interesting and curious information of all kinds, animated by genuine literary feeling, taste, and enthusiasm. The first volume was published anonymously in 1791; and it immediately attained the popularity it deserved. Two years later it was followed by a second volume; it was not, however, till the lapse of twenty-four years that the third made its appearance. Three other volumes were subsequently added, and in the later editions the first two volumes were much improved. With the *Curiosities of Literature* may be appropriately classed D'Israeli's *Miscellanies, or Literary Recreations* (1796), the *Calamities of Authors* (1812), and the *Quarrels of Authors* (1814). Towards the close of his life D'Israeli formed the project of embodying his wide knowledge of English literature in a continuous history; loss of sight, however, prevented him from publishing more than three volumes, which appeared in 1841 under the title of the *Amenities of Literature.* But of all his literary works the most interesting and delightful is his *Essay on the Literary Character* (1795), which, like most of his writings, abounds in illustrative ancedotes. His contribution to the famous "Pope controversy"—in which Bowles and Hazlitt so vigorously attacked, and Byron and Campbell so vigorously asserted, the poetical merit and personal worth of the great poet of the 18th century,—a defence of Pope contained in a criticism of Spence's *Anecdotes* contributed to the *Quarterly Review* (July 1820)—is of interest, both as indicating the nature of his critical views, and as founded upon elaborate study of the life and era of the poet. He also published a slight sketch of Jewish history, and especially of the growth of the Talmud, entitled the *Genius of Judaism*, as well as a few poems in imitation of Pope, and several novels.

He was, besides, the author of two historical works—a brief defence of the literary merit and personal and political character of James I. (1816), and a work of considerable research and magnitude entitled a *Commentary on the Life and Reign of King Charles I.* (1828–31). The latter work was recognized by the University of Oxford, which conferred upon the author the honorary degree of D.C.L. As an historian D'Israeli is distinguished by two characteristics. In the first place, he had small interest in politics, and no sympathy with the passionate fervour, or adequate appreciation of the importance, of political struggles. And, secondly, with a laborious zeal then less common than now among historians, he sought to bring to light fresh historical material by patient search for letters, diaries, and other manuscripts of value which had escaped the notice of previous students. Indeed, the honour has been claimed for him of being one of the founders of the modern school of historical research, whose patient labours have thrown so much light upon important events and characters.

Of the amiable personal character and the placid life of Isaac D'Israeli a charming picture is to be found in the brief memoir prefixed to the *Curiosities of Literature*, by his son the earl of Beaconsfield, from which the following may be quoted:—Isaac D'Israeli "was a complete literary character, a man who really passed his life in his library. . . . . He disliked business, and he never required relaxation; he was absorbed in his pursuits. In London his only amusement was to ramble among booksellers; if he entered a club, it was only to go into the library. In the country he scarcely ever left his room but to saunter in abstraction upon a terrace, muse over a chapter, or coin a sentence. . . . . He had by nature a singular volatility which never deserted him. His feelings, though always amiable, were not painfully deep, and amid joy or sorrow, the philosophic vein was ever evident. He more resembled Goldsmith than any man I can compare him to; in his conversation, his apparent confusion of ideas ending with some felicitous phrase of genius, his *naïveté*, his simplicity not untouched with a dash of sarcasm affecting innocence—one was often reminded of the gifted and interesting friend of Burke and Johnson. There was, however, one trait in which my father did not resemble Goldsmith; he had no vanity. Indeed one of his few infirmities was rather a deficiency in self-esteem."

DISTILLATION, a generic term for a class of chemical operations which all agree in this, that the substance operated upon is heated in a close vessel ("retort," "still") and thereby wholly or partially converted into vapour, which vapour is then condensed, by the application of cold, in another apparatus (the "condenser") connected with the vessel, and allowed to collect in a third portion of the apparatus, called a "receiver." In most cases the substance is a liquid, or assumes the liquid form previous to emitting vapours, and the product obtained (the "distillate") is also in greater proportion liquid. The comparatively few and special cases of distillation, wherein solids are converted into vapours which condense directly from the gaseous into the solid form, are designated "sublimations." Thus we speak of the "distillation" of water or of spirits, while we speak of the "sublimation" of sal-ammoniac. Distillations may be divided into two classes—viz., 1st, those which are *not*, and 2d, those which *are*, accompanied by chemical changes. The word "distillation," in a narrower sense, is generally understood to apply to the first class only. The

second might be called "destructive distillations," if it were not customary to reserve this term for the particular case in which the substance operated on consists of vegetable or animal matter which is being decomposed by the application of heat alone, *i.e.*, without the aid of re-agents.

The general object of simple distillation is the separation of substances of different degrees of volatility. The apparatus used varies very much according to the nature of the substance operated on and of the product extracted, and according to the scale on which the operation is carried out. Of the various contrivances used in chemical laboratories, the simplest is a glass retort, the descending neck of which is inserted into, and goes to near the bottom of, a slanting globular flask. The retort serves for the reception of the substance to be distilled, and is heated by means of charcoal or gas fire; the vapours pass into the flask, which is kept cool by a continuous current of cold water running over it, or, in the case of more volatile substances, by being immersed in ice or some freezing mixture. This somewhat primitive arrangement works satisfactorily only when the vapours are easily condensible, and when the product is meant to be collected as a whole. In the majority of cases, however, the distillate has to be "fractionated," *i.e.*, collected in a number of separate, consecutive portions; and it is then desirable that the apparatus should be so constructed as to enable one at any moment to examine the distillate as it is coming over. For this purpose it is necessary to condense the vapours on their way to, and not within, the receiver, so that the latter can, at any time, be removed and replaced by another. The condenser most generally used in chemical laboratories is that known as *Liebig's condenser.* It consists of a straight glass or metal tube, 1 to 3 feet long and ½ to 1 inch wide, fitted co-axially, by means of corks or india-rubber tubes, into a wider tube (made of glass or iron) which communicates at the lower end with a water tap, and at the upper with a sink, so that a stream of cold water can be made to run *against* the current of the vapour. The condenser tube is fixed in a slanting position, and the vapours made to enter at the upper end. The dimensions of the condenser and rate of water-flow depend on the speed at which the vapour is driven over, and on the temperature of that vapour, and, last not least, on the *latent heat of the vapour* and *specific heat of the distillate.* To show the importance of the last-named point, let us compare the quantities of heat to be withdrawn from 1 ℔ of steam and 1 ℔ of bromine vapour respectively, to reduce them to liquids at 0° C. We have in the case of water and bromine—

	Water.	Bromine.
For the temperature of the vapour....	100°	63°
For the latent heat.......	536°	45°·6
For the specific heat of the liquids......	1°	0°·106
For the total heats of the vapours......	636°	52°·3

The withdrawal of 52·3 units of heat from 1 ℔ of bromine vapour reduces it to liquid bromine at 0° C. By the withdrawal of $\left(\frac{100}{63} \times 52{\cdot}3 =\right)$ 83 units from the steam, as an easy calculation shows, only 0·16 ℔ of liquid water, of even 100°, could be produced—hence *more* than 0·84 ℔ of steam remains uncondensed (at a temperature of about 96° C., assuming the steam to remain saturated, and to have the temperature of the condensed water). But obviously a condenser under all circumstances is the more efficacious the greater its surface and the thinner its body. It is also obvious, *cæteris paribus*, that the most suitable material for a condenser tube is that which conducts heat best. Hence a metal tube will generally condense more rapidly than one of glass, and for metal tubes copper is better than tin, and silver better than either. In chemical laboratories glass is the only material which is quite generally applicable. In chemical works, on the other hand, glass, on account of its fragility, is rarely used; condensers there, wherever possible, are made of metal, usually fashioned into spirals ("worms") and set in tub-shaped refrigerators. Where acids have to be condensed, stoneware worms are generally employed. In the distillation of acetic acid platinum worms, notwithstanding their high price, have been found to work best, and in the long run to be cheapest.

The theory and successful execution of the process assume their greatest simplicity when the substances to be separated differ so greatly in their volatility that, without appreciable error, one can be assumed to be non-volatile at the boiling point of the other. A good illustration of this special case is afforded by the customary process used for the purification of water. A natural sweet water may in general be assumed to consist of three parts—1st, water proper, which always forms something like 98 per cent. or more of the whole; 2d, non-volatile salts; 3d, gases. To obtain pure water from such material, we need only boil it in a distillation apparatus, so as to raise from it dry steam, which steam when condensed yields water contaminated only with the gases. To expel these all that is necessary is to again boil it for a short time; the gases go off with the first portions of steam, so that the residue, when allowed to cool in absence of air, constitutes pure water. To pass to a less simple case, let us assume that the substance to be distilled is a solution of ether in water, and the object is the separation of these two bodies. Ether boils at 35° C., water at 100° C. The elastic force of saturated steam at 35° is 42 mm., $= \frac{42}{760} = \frac{1}{18}$th of an atmosphere. Assuming now the mixture to be distilled from a flask, what will go on? Neglecting for the sake of simplicity the small tension of the steam at 35°, we should expect that at first the ether would simply boil away, so to speak, from a bath of warm water at 35° C.; that the vapour would be pure ether, and maintain that composition until all the ether had boiled off; then there would be a break—the temperature of the liquid would gradually rise to 100°, and the water then distil over in its turn. And so it is approximately, but not exactly. Our theory obviously neglects some important points. Water at 35° has a tension of $\frac{1}{18}$th atmosphere, ether of one atmosphere; hence the two saturated vapours together should press with a force of $1\frac{1}{18}$th atmosphere—in other words, the mixture should commence to boil at less than 35°. This however (as in the majority of analogous cases), is not confirmed by experiment. The mixture commences to boil at a little above 35°, and the boiling point rises *steadily* as the proportion of ether in the liquid decreases. Now, *a priori*, we should presume that at every given moment the volumes of ether and water in the vapour should be, approximately at least, proportional to the respective vapour tensions at the temperature at which the mixture happens to boil. Thus, for instance, assuming at the first that the liquid boils at 40° C., when the two tensions are equal to 910 and 55 mm. respectively, the vapour will contain $\frac{910}{910+55} = 0{\cdot}94$ of its volume of ether vapour, and 0·06 of its volume of steam, supposing both substances to have the same chances of forming saturated vapour, which, of course, holds only so long as they both are present in appreciable quantities. We easily see that, as the distillation progresses, the ether vapour must get more and more largely charged with vapour of water, until at last what goes off is *steam*, contaminated with less and less of ether vapour. A thermometer placed near the entrance end of the condenser will, of course, record lower than one plunged into the boiling liquid, because the vapour in rising undergoes partial condensation, and the thermometer being bedewed with the condensed vapour will approximately indicate the boiling point of that dew, *i.e.*, of that which is just going over. The composition of the vapour as above given must not be confounded with the composition by *weight* of the distillate. To obtain the latter we must multiply each of the two volumes by the density of the respective vapour, or, what comes to the same thing, by its molecular weight as expressed by the chemical formula. In our case the vapour volume ratio

$$\frac{\text{water}}{\text{ether}} = \frac{55}{910}$$

corresponds to the weight ratio

$$\frac{55 \times H_2O}{901 \times C_4H_{10}O} = \frac{55 \times 18}{910 \times 74} = \frac{1}{68} \text{ nearly.}$$

This consideration strips of its apparently anomalous character what we observe when vegetable substances containing essential oils are distilled with water, when we find that these oils, although boiling far above 100° C., go over with the first fractions of the water. Take the case of lemon oil, which boils at about 174° C. The molecular weight of the oil is $136 = C_{10}H_{16}$; its vapour tension at 100° is 70 mm. Hence what goes over at first when lemon peel is distilled with water should contain oil and water in the proportion—

$$\overbrace{\underset{\substack{\text{Mol.}\\ \text{wt.}}}{136} \times \underset{\substack{\text{Vap.}\\ \text{tension.}}}{70}}^{\text{Oil of Lemons.}} : \overbrace{\underset{\substack{\text{Mol.}\\ \text{wt.}}}{18} \times \underset{\substack{\text{Vap.}\\ \text{tension.}}}{760}}^{\text{Water.}} = 12 : 17 \text{ (nearly).}$$

The oil, although the less volatile substance of the two, being present in small quantity, but finely diffused, is soon completely driven over. No doubt the latent heats of vaporization of the two constituents have something to do with the composition of the vapour formed, as the chance of every particle of the mixture to be vaporized is obviously the greater the less its latent heat of vaporization.

After what has been said it will be clear that in the distillation of a mixture of two substances of approximately equal molecular weight and latent heats of vaporization, supposing neither to predominate overwhelmingly over the other, the one with the lower boiling point will predominate in the early, and the other will gradually accumulate in the later, fractions of the distillate. And similarly with mixtures of three or more bodies. The further the respective boiling points are removed from one another the more complete a separation can be effected; but in no case is the separation perfect. It is, however, easily seen that the analytic effect of a distillation can be increased by causing the vapour, before it reaches the condenser, to undergo *partial* condensation, when naturally the less volatile parts chiefly will run back. This artifice is largely employed by chemists, technical as well as scientific. The simplest mode is to let the vapour ascend through a long, vertical tube before it reaches the condenser, and to distil so slowly that a sufficiently large fraction of the vapour originally formed fails to survive the ascent through the cooling influence of the atmosphere. A more effective method is to let the condensed vapour accumulate in a series of small receptacles inserted between flask and condenser, constructed so that the vapour cannot pass through the receptacles without bubbling through their liquid contents, and so that the liquid in the receptacles cannot rise above a certain level, the excess flowing back into the next lower receptacle or into the still. But the most effective method is to let the vapour ascend through a slanting condenser kept by means of a bath at a certain temperature, which is controlled so that while the liquid in the flask boils rapidly, the distillation only just progresses and no more.

The general principles thus stated regarding fractional distillation are liable to not a few exceptions, of which the following may be cited as examples. A solution of one part of hydrochloric acid gas in four parts of water boils (constant) at 110° C.—*i.e.*, 10° above the boiling point of water, although the acid constituent is an almost permanent gas. This, however, is easily explained; there can be no doubt that such an acid is a mixture of real hydrates, *i.e.*, does not contain either free water or free hydrochloric acid. A similar explanation applies to the case of aqueous oil of vitriol, which boils the further above 100° the stronger it is, although the vapour may be, and in the case of acids containing less than 84 per cent. of real acid really is, pure steam. The following cases, however, can scarcely be disposed of by the assumption of the interference of chemical action. Propyl alcohol boils at 97° C., water at 100°; and yet a mixture of the two, as Pierre and Puchot found, when distilled always commences to boil at 88°·5 with formation of a distillate of the approximate composition $C_3H_8O + 2{\cdot}78H_2O$; and this particular aqueous alcohol boils without apparent decomposition at 88° 3. Some time later Dittmar and Steuart made a precisely analogous observation with regard to aqueous allyl alcohol. A strong temptation exists to explain these anomalies by the assumption of definite hydrates in the aqueous alcohols, and this hypothesis would serve in the meantime were it not for the curious fact, discovered by the two French chemists named, that amyl alcohol and water (two liquids which *do not mix*), when distilled simultaneously out of the same retort, go over at a constant temperature less than 100°, and with formation of a distillate which, although it is not even a mixture, has a constant composition. The most natural explanation of these phenomena is to assume them to be owing, not to chemical action, but rather to an exceptional absence of chemical affinity between the two components of the mixture, which for once gives the physical forces fair play.

DRY (DESTRUCTIVE) DISTILLATION.—Of the great number of chemical operations falling under this head, we can notice only those which are carried out industrially for the manufacture of useful products. Of such the most important are those in which wood, coal, shale, and bones form the materials operated upon. But as these processes form so many important industries, which have all special articles devoted to them, we must confine ourselves here to summing up shortly the features common to all.

In all cases the "retorts" consist of iron or fire-clay semi-cylinders placed horizontally in a furnace and connected by iron pipes with refrigerators, and through these with gas-holders. Within these retorts the materials are brought up, more or less gradually, to a red heat, which is maintained until the formation of vapours practically ceases. Each of the materials named is a complex mixture of different chemical species. Wood consists mainly of cellulose and other carbo-hydrates, *i.e.*, bodies composed of carbon and the elements of water; in coal and shale the combustible part consists of compounds of carbon and hydrogen, or carbon, hydrogen, and oxygen, richer in carbon than the components of wood; bones consist of about half of incombustible and infusible phosphate of lime (bone earth) and half of organic matter, of which the greater part is gelatine (compounds of carbon, nitrogen, hydrogen, and oxygen), and the lesser is fat (compounds of carbon, hydrogen, and oxygen). The chemical decomposition in each case is highly complex. An infinite variety of products is invariably formed, which, however, always readily divide into three:—1st, a non-volatile residue, consisting of mineral matter and elementary carbon ("wood charcoal," "coke," &c.) which, in the case of animal matter, contains chemically combined nitrogen; 2d, a part condensible at ordinary temperatures which always readily separates into two distinct layers, viz.:—(*a*) an aqueous portion ("tar-water"), and (*b*) a semifluid, viscid,

oily, or resinous portion ("tar"); and 3d, a gaseous portion.

The "tar-water" is the one, of all the four products, of which the qualitative composition most directly depends on the nature of the material distilled. In the case of wood it has an acid reaction, from the presence in it of acetic acid, which is associated (amongst many other things) with acetone and methyl alcohol. In the case of coal it is alkaline, from ammonia, present as carbonate, sulphide, sulphocyanide, and in other forms. Alcohols and oxygenated acids are absent.

The "tar" is a complex mixture of carbon compounds, all combustible, but, although all directly derived from a vapour, not by any means all of them *volatile*. (Regarding the components, see TAR.) The quantity and quality of the tar naturally depend on the kind of material used, but perhaps yet more on the mode in which the distillation is conducted. Thus, for instance, a coal tar produced at low temperature contains a considerable percentage of paraffins. If, on the other hand, the distillation is conducted at a high temperature, the paraffins are almost absent, while the proportion of benzols considerably increases. A similar remark applies to the gaseous portion, as will readily be understood when we say that *all* volatile tar constituents, when passed through red hot tubes, are decomposed with formation of hydrogen and gaseous hydrocarbons, which latter again, when submitted to the same operation, are all liable to undergo dissociation into simpler compounds and association into more complex.

DISTILLATION OF WATER.—The continual interchange and circulation of water, between oceans and other great reservoirs of water on the one hand and dry land on the other, may be regarded as a process of distillation. Rain is thus a form of distilled water; and when it falls through a pure atmosphere it is found to possess the softness and freedom from dissolved salts characteristic of water artificially distilled. Rain water, however, absorbs a considerable proportion of air and some carbonic acid from the air, and also frequently contains ammonia, salts, and free acids.

Water of that purity which can be secured only by distillation is of indispensable value in many operations both of scientific and industrial chemistry. The apparatus and process for distilling ordinary water are very simple. The body of the still is made of copper, with a head and worm, or condensing apparatus, either of copper or tin. The first portion of the distillate brings over the gases dissolved in the water, ammonia, and other volatile impurities, and is consequently rejected, and scarcely two-fifths of the entire quantity of water can be with safety used as pure distilled water.

Among the innumerable schemes which have been proposed for the production of a potable fresh water from the salt water of the ocean, two or three dependent on simultaneous distillation and aeration have been found, in practice, to produce most satisfactory results. Of course the simple distillation of sea water, and the production thereby of a certain proportion of chemically fresh water, is a very simple problem; but it is found that water which is merely evaporated and recondensed has a very disagreeable empyreumatic odour, and a most repulsive flat taste, and it is only after long exposure to pure atmospheric air, with continued agitation, or repeated pouring from one vessel to another, that it becomes sufficiently aerated to lose its unpleasant taste and smell and become drinkable. The water, moreover, till it is saturated with gases, readily absorbs noxious vapours to which it may be exposed. For the successful preparation of potable water from sea water, therefore, the following conditions are essential:—1st, aeration of the distilled product so that it may be immediately available for drinking purposes; 2d, economy of coal to obtain the maximum of water with the minimum expenditure of fuel, and 3d, simplicity of working parts, to secure the apparatus from breaking down, and enable unskilled attendants to work it with safety. Among the forms of apparatus which have most fully satisfied these conditions are the inventions of Dr Normandy and of Chaplin of Glasgow. While these have met with most acceptance in the United Kingdom, the apparatus of Rocher of Nantes, and that patented by Gallé and Mazeline of Havre, have been highly appreciated by French maritime authorities.

Normandy's apparatus, while leaving nothing to be desired in point of economy of fuel and quality of water produced, is very complex in its structure, consisting of very numerous working parts, with elaborate arrangements of pipes, cocks, and other fittings. It is consequently expensive, and requires for its working the careful attention of an experienced workman. It consists of three essential parts, in addition to any convenient form of boiler from which steam under a certain amount of pressure may be obtained. These parts are called respectively the evaporator, the condenser, and the refrigerator. These are all closed cylindrical vessels, permeated internally with sheaves of pipes, through which pipes the steam generated percolates, condenses, and is aerated as explained below. The refrigerator is a horizontal vessel above which the condenser and the evaporator are placed in a vertical position. When the apparatus is in operation the refrigerator and condenser are filled with sea water, and a constant current is maintained which enters by the refrigerator, passes upwards through the condenser, and is discharged by an overflow pipe at a level a little above the top of the condenser. The evaporator is filled only to about two-thirds of its height with water from the condenser, and the admission and regulation of its contents are governed by a stop-cock on the pipe communicating between the two vessels. The vessels being so prepared, superheated steam is admitted by a pipe leading from the boiler into the top of the evaporator, and, passing through the sheaf of pipes immersed in water, is there condensed. The condensed water passes direct from the evaporator into the pipes of the refrigerator, in which it is cooled to the temperature of the surrounding sea water. Here then is produced pure distilled but non-aerated water; and the means by which it is aerated and rendered fit for immediate use may be now traced. The superheated steam in permeating the pipes in the evaporator heats and vaporizes a portion of the water around them. The steam so generated passes into the sheaf of pipes in the condenser, in which, as already explained, a current of water is constantly rising and passing away by the overflow pipe. The condensation of the steam within the pipes, again, communicates a high temperature to the upper stratum of water in the condenser. As water at a temperature of 54°·5 C. parts with its dissolved air and carbonic acid gas, a stream of water is continually rising to the upper part of the condenser at a temperature more than sufficient to liberate these gases, and by means of a pipe these pass over into the upper part of the evaporator, and there mingle with and supersaturate the steam generated in that vessel. Instead, therefore, of it being simply steam which passes from the evaporator to the tubes of the condenser, it is a mixture of steam and gases, the latter being in sufficient quantity not only to supersaturate the steam with which they are mixed, but also fully to aerate the condensed steam which passed direct from the evaporator into the refrigerator. The super-aerated condensed steam passes from the pipes in the condenser into those in the refrigerator, where it meets the non-aerated water from the evaporator pipes, the course of which has already been traced. Here the two products mingle, cool down to the temperature of the sea, and passing outwards through a filter, may be drawn off as pure aerated water of excellent quality. In Dr Normandy's apparatus the combustion of 1 ℔ of coal yields from 14 to 20 ℔ of potable water. The apparatus is extensively adopted in the British navy, the Cunard line, and many other important emigrant and mercantile lines.

Chaplin's apparatus, which was invented and patented later, has also, since 1865, been sanctioned for use on emigrant, troop, and passenger vessels. The apparatus possesses the great merit of simplicity and compactness, in consequence of which it is comparatively cheap and not liable to derangement. In addition to a boiler for generating steam from sea water the apparatus consists of an aerator, a condenser, and a filter. The condenser is a cylinder, usually of cast iron with an internal worm pipe of copper, which is found to be the only really suitable metal for this use. The steam to be condensed is admitted to this worm or coil through the aerator. This part of the apparatus—the aerator—is really the essential feature in the invention, and consists simply of a series of holes perforated around the steam inlet pipe at the point where it enters the condenser. The steam passing down in a powerful jet draws with it through these holes a proportion of atmospheric air sufficient to properly aerate the water for drinking purposes. The steam and air thoroughly commingled are together condensed as they pass through the coils of the worm,—cold sea water passing in to the condenser at its lowest end, and rising upwards and flowing away at the top. After passing through the filter placed directly under the condenser, the aerated water is delivered or stored ready for use, clear, bright, colourless, palatable, and devoid of odour, at a temperature of about 15° C. The cold sea water for condensing may be forced into the condenser by a special steam pump attached to the apparatus—a plan usually followed on sailing vessels—or any other convenient pumping arrangement may be resorted to. The steam for condensation is, in steamers, frequently supplied from the engine boilers; but generally it is preferable to employ a special small upright boiler, or to use the boilers attached to steam winches. Chaplin's apparatus has been adopted by many important British and Continental shipping companies, among others by the Peninsular and Oriental, the Inman, the North German Lloyd, and the Hamburg American Companies.

DISTILLATION OF SPIRITS.—Notwithstanding the enormous scale on which this industry is now prosecuted, it is only in modern and comparatively recent times that it has attained to the important position which it now occupies. The art of separating alcoholic spirit from fermented liquors appears, however, to have been known in the far East from the most remote antiquity. It is supposed to have been first known to, and practised by, the Chinese, whence a knowledge of the art gradually travelled westward. A rude kind of still, which is yet employed, has been used for obtaining ardent spirits in Ceylon from time immemorial. The name alcohol indicates that a knowledge of the method of preparing that substance probably came to Western Europe, like much more chemical knowledge, through the Arabs. Albucasis, who lived in the 12th century, is spoken of as the first Western philosopher who taught the art of distillation as applied to the preparation of spirits; and in the 13th century Raymond Lully was not only well acquainted with the process, but also knew the method of concentrating it into what he denominated *aqua ardens* by means of potassic carbonate. At the time when Henry II.—in the 12th century—invaded and conquered Ireland, the inhabitants were in the habit of making and using an alcoholic liquor—usquebagh (*uisge-béâtha*, water of life), a term since abbreviated into whisky, which consequently is synonymous with the classical *aqua vitæ*. It is further a noticeable fact that Captain Cook found, among the inhabitants of the Pacific Islands discovered by him, a knowledge of the art of distilling spirit from alcoholic infusions.

The preparation of ardent spirit involves two separate series of operations:—1st, the making of an alcoholic solution by means of vinous fermentation; and 2d, the concentration of the alcoholic solution so obtained by the process of distillation and rectification.

All substances in nature which contain sugar in any of its forms are susceptible of undergoing vinous fermentation, and may therefore be used as sources of alcohol. Further, all starchy substances and ligneous tissue, seeing that by various chemical processes starch and cellulose may be converted into grape sugar, may also be used for the preparation of alcohol. It is thus obvious that the variety of organic substances, especially of the vegetable kingdom, from which alcohol may be elaborated is almost endless; and in practice it is found that the sources employed are very numerous. Commercially, distilled alcoholic liquors are manufactured of varying strength, or proportion of alcohol to water, according as the spirit is intended to be used for drinking purposes or for employment in the arts. The standard by which excise duty on alcoholic liquor is charged in Great Britain is proof spirit, in which the alcohol and water are in almost equal proportions by weight, there being in 100 parts 49·24 of absolute alcohol, and 50·76 of water. Distilled spirits are said to be "over proof" when the proportion of alcohol is greater, and "under proof" when there is more water present than is indicated by "proof." Thus a spirit 11 over proof (o.p.) is a compound which requires the addition of 11 volumes of water to every hundred to reduce it to proof strength; and similarly 10 under proof (u.p.) indicates a liquor from every 100 gallons of which 10 gallons of water must be withdrawn to bring it to proof strength. Spirit for drinking is seldom sold at more than 11 over proof, from which it varies downward to 25 and more under proof. Rum, however, is manufactured and imported as highly concentrated as from 10 to 43 over proof. Spirit of wine as used in the arts must be at least 43 over proof, and generally it is sold at from 54 to 64 over proof.

The alcoholic liquors enumerated below are those most commonly distilled for drinking or medicinal purposes. Brandy, when genuine, is a spirit chiefly distilled in France from wine. Rum is made from molasses or treacle, and is distilled in the West Indies, and generally in all countries where the sugar cane is cultivated. From fermented infusions of grain, malted and unmalted, and chiefly from barley, whisky is distilled, and that spirit when "silent" or flavourless is the basis of flavoured spirits, such as gin and factitious or British brandy. Arrack is an Oriental spirit distilled from "toddy," or the fermented juice of certain palm trees, and also from rice, which grain is the source of saké, the national spirit of the Japanese. Potato brandy is very extensively prepared from the fecula of potatoes in Germany and Russia, and is a spirit much used for fortifying wines, and for making factitious wine, as well as in the arts. Beet root, carrots, Jerusalem artichokes, and several other saccharine roots are also used for the distillation of spirit on a commercial scale. The only example of a spirit drawn from animal sources is the koumiss of the Tartars, which is distilled from the fermented milk of mares.

The modifications of stills or of distilling apparatus used in the preparation of alcoholic liquor are exceedingly numerous. and many of the later inventions are of most

complicated structure. The simple and primitive varieties of apparatus yield only a comparatively weak spirit on the first distillation, while the effect of the complex appliances now generally used is to produce, in one operation, a highly concentrated spirit, and that with a great saving of fuel, time, and labour. All varieties of distillatory apparatus resolve themselves under these heads:—1st, stills heated and worked by the direct application of the heat of a fire; 2d, stills worked by the action of steam blown direct into the alcoholic solution from a steam boiler; and 3d, stills heated by steam passing in coiled pipes through the alcoholic solutions to be acted upon.

To the first of these classes—stills heated by direct fire—belong the earliest and simplest forms of distillatory apparatus; and for producing particular classes of alcoholic liquor, stills very simple in their construction are yet employed. The common still is a flat-bottomed, close vessel of copper, with a high head to prevent the fluid within boiling over. To the top of this head a tube is connected, which is carried in a spiral form round the inside of a tub or barrel (the condenser or refrigerator), filled with cold water, and from its twisted form this tube receives the name of the "worm." The tube terminates at the bottom of the barrel, passing through it to the outside, and is conducted into the vessel termed the receiver, a stopcock, or more commonly a vessel termed a "safe," being usually placed on the tube where it leaves the refrigerator. In distilling with an apparatus of this simple construction, it is obvious that at the beginning of the operation, when the wash or liquid to be distilled is rich in alcohol, and its boiling point consequently low, the distillate will pass over at a low temperature and contain a high percentage of alcohol. But as the operation progresses, the boiling point of the mixture in the still rises, the heat has therefore to be forced, and the quantity of watery vapour which passes over with the alcohol is proportionately increased. As the wash or liquid in the still continually weakens, a point is arrived at when the value of the weak distillate produced will not balance the expenditure on fuel for maintaining the heat of distillation.

One of the earliest devices for economizing the heat of distillation consisted in interposing between the still and the refrigerator a wash warmer, or vessel charged with liquid ready for distillation. Through this vessel the pipe conveying the hot vapours to the refrigerator coil passed, and the vapours, partly condensing there, heated up the wash, which was thus prepared to pass into the still at an elevated temperature. The "pot" stills, in which the markedly flavoured Irish whisky is made, are of this construction. In the great establishment of the Banagher Distillery Company, King's co., Ireland, simple stills of a capacity of 20,000 gallons are erected having a rousing apparatus within them to keep the wash in agitation so as to prevent solid particles from settling on the bottom and burning. Beyond a wash warmer, or intermediate charger interposed between the still and the condenser, there is no other appliance attached to the apparatus. The first distillate from the still is termed "low wines," and passes into the "low wines receiver," whence it passes into No. 1 "low wine still" to undergo a second distillation. The product of the second distillation, under the name of "faints or feints," is caught in the "faints receiver," from which it passes to No. 2 low wines still, and from this it is discharged as Irish whisky.

The introduction of another principle into distillatory apparatus is illustrated by Dorn's still, which was introduced into Germany in the early part of the century, and is yet much used in smaller establishments in that country. In that apparatus the vessel, of copper, interposed between the still and the condenser is divided horizontally into two unequal compartments by a diaphragm of copper. The upper and larger portion acts as a wash warmer (German, *Vorwärmer*), and through it the pipe from the still body coils, opening into the lower division. For a time the whole distillate condenses in this division, but as the temperature of the wash in the upper division rises, and the heat of the more watery distillate from the still also increases, the condensed liquor in the lower division in its turn begins to boil, and undergoes a second distillation or rectification, the vapours from it passing onwards to be condensed in the ordinary refrigerator. In many forms of distillatory apparatus two or more such rectifiers are placed between the primary still and the final condenser. The principle of the rectifier is easily understood. Supposing the operation of distilling to commence, the vapours which condense in rectifier No. 1 are much richer in alcohol than the liquid remaining in the still. The boiling point of the condensed liquid is consequently proportionately lower, and the vapour from the still passing into it gradually raises it to the boiling point, so that in its turn rectifier No. 1 distills into rectifier No 2 a liquid of still higher alcoholic richness. The relation of No. 2 to No. 1 is the same as that of No. 1 to the still body, and thus the concentration and redistillation might be carried on to any practicable or desired extent.

Another principle brought into play in complex stills for the separation of stronger from weaker alcoholic solutions consists of dephlegmation, or the submitting of the vapour to a temperature so regulated that a portion of it, and that of course the most watery, is condensed and separated, running back into the still or into a special vessel, whilst the richly alcoholic vapour passes on to the rectifier or condenser. In Dorn's still the wide and lofty head attached acts as a dephlegmator, watery vapours condensing on it, and thence falling back into the body; but in the more recent forms of apparatus—such as those of Pistorius and Siemens—special dephlegmators of an elaborate nature are introduced.

Of the second class of stills—those in which the operation is conducted by the heat of steam generated in a boiler, and forced into the apparatus—the Coffey still may be taken as an example. It is the form most frequently adopted in Great Britain for the manufacture of "silent" spirit, and it is generally recognized as the best and most economical device for preparing a highly concentrated spirit in a single operation. The Coffey still may further be regarded as a type of continuous distilling apparatus, as in it the necessity for withdrawing exhausted solutions and recharging the still with fresh wash is avoided. Beginning, as the Coffey still does, with the steam of pure water. the principle of rectification formerly alluded to is here carried out from the first step. The watery vapour becomes more and more highly charged with alcoholic fumes, till in the end the strongest spirit falls, condensed, into the receiver. In Coffey's apparatus the wash is exposed in a series of shallow chambers, placed one over the other. to the vapour of steam, which rises through the perforated bottoms of each chamber, and carries off the alcoholic vapours into the condenser. This condenser also consists of a series of chambers separated from each other by perforated plates, and is so contrived that the cold wash passing in pipes through these chambers, in its way to feed the other series of chambers, acts as the condenser to the vapour of the alcohol, the wash being gradually heated thereby, as it passes through the successive chambers. The still, therefore, consists essentially of three separate but connected parts. The first is a large square receiver at the base, which receives the spent wash after it has been deprived of its alcohol by passing through the series of evaporating chambers; the second, a large, square, upright