

THE GERMAN ROYAL NAVAL OBSERVATORY.—The twenty-fifth annual volume (1902) of the publications of this observatory, entitled "Aus dem Archiv der Deutschen Seewarte," contains descriptive papers on "The Regulation of Marine Compasses," "A New Free-horizon Astronomical Base Line," "The Definitive Determination of the Path of the Comet Swift (1899.1)," and "The Results of Sextant Tests made at the Observatory."

In addition to the introduction, Dr. Neumayer, the director, contributes an article on "A New Method of Forecasting the Meteorological Conditions of the North Atlantic Ocean," and a novel chart, indicating all the meteorological conditions obtaining in the North Atlantic area during March, 1902, accompanies the volume.

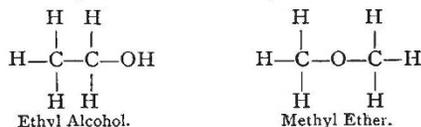
RECENT ADVANCES IN STEREOCHEMISTRY.¹

IN the year 1803, just a century ago, John Dalton delivered a series of scientific lectures in the Royal Institution during the course of which he doubtless laid before his audience a theory which he had recently devised for the purpose of connecting together the vast number of isolated chemical facts known at the commencement of the nineteenth century. This theory, of which the centenary is being celebrated during the present month by the Manchester Literary and Philosophical Society, is known as the atomic theory, and was destined to form the foundation upon which the whole superstructure of modern chemistry has been built. For our present purpose Dalton's theory may be briefly stated in the form of the following two principles:—(1) Every element is made up of homogeneous atoms of which the mass is constant; (2) chemical compounds are formed by the union of atoms of the various elements in simple numerical proportions. In accordance with Dalton's hypothesis, chemical substances may be mentally pictured by imagining the atoms as small spheres which have the power of aggregating themselves together under suitable conditions to form complexes or "molecules"; thus, taking two similar spheres representing hydrogen atoms, in conjunction with a sphere of a different kind, representative of an atom of oxygen, a chemical representation can be given of the compound water, the molecule of which is composed of two atoms of hydrogen and one of oxygen. The original atomic theory offers no explanation of the observed fact that the atoms combine together in different proportions; this deficiency was remedied by the doctrine of valency enunciated by the late Sir Edward Frankland in 1852. Frankland supposed that the atoms of certain elements, such as hydrogen and chlorine, are unable to combine with more than one atom of any other element; these elements are termed monovalent. Other atoms, such as those of barium and zinc, can become directly attached to at most two other atoms; these are the divalent elements. Tri-, tetra-, penta-, hexa-, hepta- and octa-valent elements can be similarly distinguished, the valency of hydrogen being taken as unity, in order to measure and define the saturation-capacity or the atom-fixing power of the atoms of the other elements. It will be clear that for rough diagrammatic purposes we may provide the spheres representing the atoms with as many wooden pegs as the element itself exhibits units of valency; compound molecules can then be represented by fitting the atoms together by means of the pegs representing the number of valency-units possessed by the various constituent atoms. By so doing a great advance is made upon the atomic theory of Dalton's time, and a mental picture is obtained of the way in which the atoms are connected together within the molecule itself.

During the early part of the nineteenth century it became evident, principally from the work of Liebig and Wöhler in Germany, and of Faraday at the Royal Institution, that substances exist which possess totally different properties, but nevertheless have the same molecular composition; as this became slowly realised, the atomic theory was naturally called upon to furnish some adequate explanation. In view of the proven identity of molecular composition, the required explanation could only be sought for in differences

¹ A discourse delivered at the Royal Institution on May 1 by Prof. William J. Pope, F.R.S.

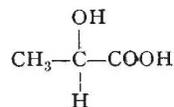
in the atomic arrangement within the molecules of the several substances. That such differences can be successfully illustrated by the aid of the atomic models will be seen on considering some specific case. Ordinary ethyl alcohol and methyl ether differ greatly from each other—the first is a liquid, whilst the second is a gas at ordinary temperatures—but possess the same molecular composition, the molecule in each case consisting of two atoms of carbon, six of hydrogen and one of oxygen. These two substances have to be represented on the assumption that hydrogen is monovalent, carbon tetravalent, and oxygen divalent. By joining wooden spheres together in the order shown in the figures—in which the valencies of the component atoms are carefully respected—diagrammatic representations are obtained which illustrate to the chemist the differences existing between ethyl alcohol and methyl ether.



Substances related to each other in this way are said to be isomeric; they have the same molecular composition, but different molecular constitutions. The step in advance which is involved in thus writing molecular constitutions or in constructing molecular models was taken by Kekulé in 1858.

Two great stages in the development of chemical theory have now been indicated. First, that contributed by Dalton, who regarded constancy of molecular composition as characteristic of a chemical substance; secondly, that further stage, attained as a result of the labours of Liebig, Wöhler, Faraday, Frankland and Kekulé, which involved the introduction of the idea that the chemical individuality of a substance is dependent upon its molecular constitution as well as upon its molecular composition. A third great development in the atomic theory had yet to take place.

Whilst the theoretical views which culminated in Kekulé's constitutional formulæ were at first found sufficient to explain numerous observed cases of isomerism, instances soon began to accumulate of substances which exist in so many isomeric forms that the Kekulé method of representation is incapable of accounting for them all. At an early date Pasteur showed clearly that substances exist which have the same molecular composition and the same molecular constitution, but which nevertheless differ in important respects. A crisis was ultimately reached when, in 1870, Wislicenus demonstrated the existence of three isomeric lactic acids, all having the molecular composition $\text{C}_3\text{H}_6\text{O}_3$, and the molecular constitution



and contended that he had amply proved the insufficiency of Kekulé's method of writing constitutional formulæ.

The step needed to rid the atomic theory of these apparent anomalies was indicated by van 't Hoff and Le Bel in 1874; they pointed out that the weakness of the Kekulé method lies in the tacit assumption that the molecule is spread out upon a plane surface, and that by throwing this assumption aside and taking a rational view of the way in which the molecule is extended in space, all difficulties immediately vanish. The considerations put forward by van 't Hoff and Le Bel form the basis of the subject now known as stereochemistry, the branch of science which deals with the manner in which the atoms are distributed within the molecule in three-dimensional space; they deal, in the first place, with the arrangement of the constituent atoms in the simple organic compound, methane, the molecule of which has the composition CH_4 , or consists of one carbon atom and four hydrogen atoms. The Kekulé constitutional formula pictures the component atoms of the methane molecule as if joined together in one plane (Fig. 1), whilst according to the new view, the four hydrogen atoms are imagined situated at the four apices of a regular tetra-

hedron of which the carbon atom occupies the centre (Fig. 2). This is conveniently illustrated with the aid of a few cardboard models.

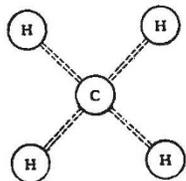


FIG. 1.

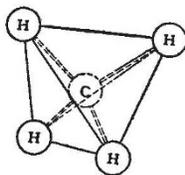


FIG. 2.

Consider now the result of replacing three of the four hydrogen atoms present in the methane molecule by three different groups of atoms, the three groups CH_3 , OH , and CO_2H for example. One of the most striking results which has accrued from the chemical investigation of the past century has been the demonstration of the remarkable rigidity with which the atoms are held together in the molecule; it might therefore be anticipated that by actually making all the isomerides having the constitution indicated above, some means would be afforded of judging whether the van 't Hoff-Le Bel or the Kekulé view forms the closest approximation to truth. Kekulé's constitutional formulæ indicate the existence of two isomeric compounds of the following types:—



whilst on the van 't Hoff-Le Bel view, two isomerides of the nature illustrated by Figs. 3 and 4 are indicated; although in each case two isomerides would be obtainable, the examination of the two kinds of figure reveals very essential differences. The solid-figure isomerides differ only in that the one is the image in a mirror of the other—they are related in the same kind of way as a right and a left hand glove. The differences observable between two molecules thus related should consequently not be differences of an ordinary chemical nature, but differences involving merely a kind of chemical, physical and mechanical right- and left-handedness. The two Kekulé constitutional formulæ, on the other hand, would indicate—if they indicate anything—that the substances to which they refer differ in the more gross way in which ordinary chemical isomerides differ in chemical, physical and mechanical respect. That carbon atom which was present in the original methane molecule is, in these new compounds, now attached to four different atomic groups, and such a carbon atom is termed an "asymmetric" carbon atom. It is in the case of substances containing an asymmetric carbon atom that a lack of agreement is observed between the facts and the kind of isomerism indicated by the Kekulé

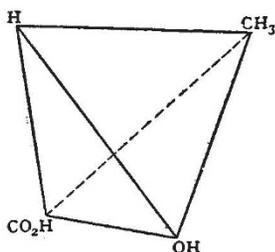


FIG. 3.

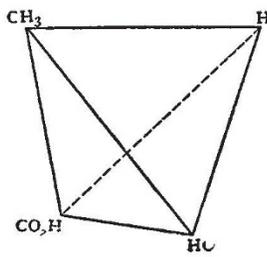
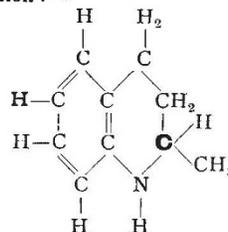


FIG. 4.

formulæ, and in these cases, also, the species of isomerism indicated by the solid models exhibited is found to correspond closely with the facts.

To illustrate this we may refer to a somewhat complicated substance, termed tetrahydroquinoline, which has the following constitution:—



and the molecule of which contains an asymmetric carbon atom, that, namely, which is printed in heavy type. Three

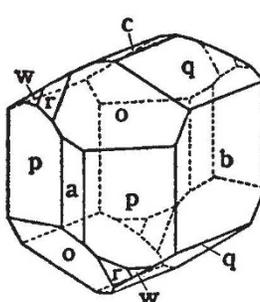


FIG. 5.

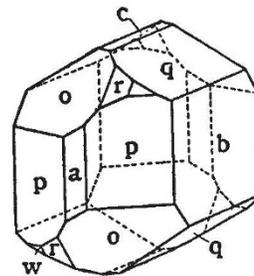


FIG. 6.

different isomeric forms of this substance exist, and are quite indistinguishable by any of the ordinary methods of chemical or physical identification; one of these is a loose kind of compound of the other two, and may therefore be disregarded for the moment. The remaining two have the same melting point, the same boiling point, and correspond exactly in all ordinary properties; they yield, however, series of derivatives which differ in the same sort of way that a right-hand and a left-hand glove differ. Here, for instance, is a diagram showing the shapes of the crystals

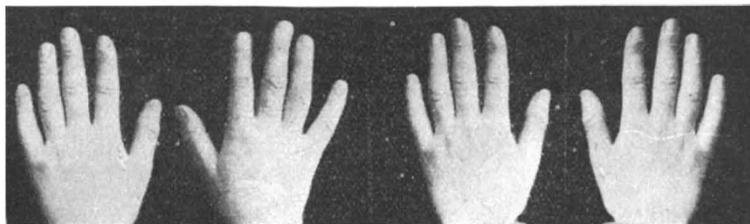


FIG. 7.

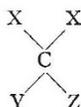
FIG. 8.

of the salts which these two substances form with hydrochloric acid (Figs. 5 and 6); the crystals obtained from the one base are the mirror-images of those prepared from the other. Any figure which possesses handedness of the kind exhibited by these two crystal figures is termed "enantiomorphous," and two figures which are related to each other as these figures are related are said to be "enantiomorphously related." A hand is thus enantiomorphous, and a right and a left hand are enantiomorphously related, the one being the mirror-image of the other. Here, for example, is a photograph showing a right hand and a left hand side by side (Fig. 7); the pair of hands is exactly reproduced in the next photograph (Fig. 8), which shows a right hand side by side with the photograph of its reflection in a mirror. Just the same enantiomorphous relationship as that existing between the right and the left hand, exists between the molecular pictures of the two lactic acids discovered by Wislicenus, and shown in Figs. 3 and 4.

Reference may now be made to the existence of other differences of an enantiomorphous character between substances which possess enantiomorphously related structures. Early in the last century the French physicists Arago and Biot showed that a number of substances have the power of deflecting the plane of polarisation of a plane-polarised

beam of light thrown through their solutions. Such substances are said to be optically active, and since the deflection of the plane of polarisation may be either towards the right or towards the left, the exhibition of optical activity constitutes an enantiomorphous property; optically active substances are conveniently classified as dextro- and lævoro-rotatory. Van 't Hoff and Le Bel declared that the molecules of all naturally occurring substances which exhibit optical activity when in the fluid state contain asymmetric carbon atoms. All substances the molecules of which contain an asymmetric carbon atom must possess enantiomorphous molecular configurations—similar to those assigned to the two lactic acids—because they exhibit properties of an enantiomorphous character. A very beautiful experiment which the late Sir George Gabriel Stokes devised may be so modified as to serve for the demonstration of optical activity. Stokes's experiment consists in passing a plane polarised beam of light through a tall cylinder containing water which has been rendered very slightly turbid by the addition of a little alcoholic solution of resin; a spectrum is then seen spread out in the column of liquid, and spread out in a way which is not enantiomorphous, the water possessing no optical activity. The modification of Stokes's experiment consists in replacing the non-enantiomorphous water by some enantiomorphous liquid—conveniently by a 70 per cent. aqueous solution of the dextrorotatory cane-sugar, or by a 50 per cent. solution of the lævoro-rotatory fruit-sugar; on making this change it is seen that instead of the spectrum lying in the cylinder vertically, and therefore non-enantiomorphously, it winds spirally or corkscrew-wise round and round the column of the enantiomorphous liquid. The two spirals or helices are clearly enantiomorphous, and the two liquids of opposite optical activity give rise in this experiment to oppositely wound spirals—to spirals which are related to each other like the right- and left-handed corkscrews shown in the lantern slide. The opposite sign of the rotatory power exhibited by the cane-sugar and fruit-sugar solutions is more clearly shown by turning the polarising prism in its mount, when the two spirals turn in opposite directions.

Although cases of optical activity are very frequently met with among chemical substances of animal or vegetable origin, it must be noted that no purely laboratory product or substance prepared without the use of enantiomorphous operations or materials is, in the ordinary way, optically active. The reason of this needs but little seeking, if the solid tetrahedron models are once more consulted. Starting with a non-enantiomorphous substance is equivalent to starting with a methane derivative of the constitution



and replacing one of the two X groups by a fourth group Q so as to obtain a compound containing an asymmetric carbon atom. Obviously, unless some power of selection of an enantiomorphous nature is exercised in replacing X by Q, the doctrine of chance will ensure the one X group being replaced the same number of times as the other in an enormous number of tiny molecules. Thus there will result just the same amount of the right-handed optically active substance as of its left-handed isomeride. When an optically active substance is prepared in the laboratory, it is therefore obtained as a mixture of two enantiomorphously related isomerides; such a mixture is said to be compensated, because the right-handedness of the one component is just counterbalanced by the left-handedness of the isomeric constituent. These compensated substances are represented by the third lactic acid and by the third tetrahydroquin-aldine previously referred to, but not further discussed.

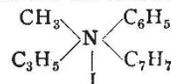
Since one of the great problems with which chemistry is grappling involves the synthetic preparation of naturally occurring optically active substances, it is of the utmost importance that the chemist should be in possession of working methods for resolving these compensated mixtures into their optically active components. All the kinds of methods applicable to such resolutions necessarily involve the introduction of enantiomorphism—either of method or

of material. Three types of methods were introduced by Pasteur, namely, (1) spontaneous resolution by crystallisation; (2) resolution by combination with optically active substances; and (3) resolution by the action of living organisms.

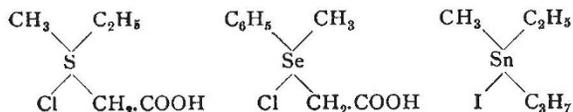
The first method depends upon the fact that on crystallising a compensated substance it sometimes deposits crystals of the dextro- and of the lævo-isomeride side by side, and of such size that they can be mechanically sorted. The enantiomorphous factor determining the separation in this kind of method is obviously the enantiomorphous intelligence which has the power of discriminating between right- and left-handedness. This sort of method is unfortunately but rarely applicable, owing to the fact that two enantiomorphously related substances usually crystallise together in the form of a loose chemical compound.

The second kind of Pasteur method is applicable to the resolution of compensated acids and bases, and depends upon the following considerations. On combining a compensated basic substance, viz. a mixture of *d*-B and *l*-B with an optically active acid—say with *d*-A—a mixture of two salts, namely *d*-B, *d*-A and *l*-B, *d*-A, will be obtained. These salts, however, are not enantiomorphously related, as will be realised on substituting for illustrative purposes a hand for the base and a glove for the acid; the combination *d*-B, *d*-A will then be represented by a right-hand in a right-handed glove, whilst the combination *l*-B, *d*-A will correspond to a left hand in a right-handed glove. The struggles of the left hand with the right-handed glove will not be a factor in determining the behaviour of the appropriately assorted right hand and right-handed glove. So, also, the properties of the substance *d*-B, *d*-A—its solubility, melting point, &c.—will be conditioned by an enantiomorphous relationship of quite a different order from that determining the corresponding properties of the salt *l*-B, *d*-A; the solubilities, being determined by different factors, will naturally also differ, and the two salts will therefore be separable by crystallisation. The first resolution of a compensated base was effected in 1885 by Ladenburg, and consisted in resolving the synthetic alkaloid coniine into its optically active components—one of which proved to be identical with the alkaloid contained in the juice of the hemlock—by crystallising it with dextrotartaric acid. Since this time the methods of resolving compensated bases have been materially improved by the application of optically active acids derived from camphor for use in place of the dextrotartaric acid, and an experiment in illustration can now be shown on the lecture table.

On adding a solution of ammonium dextrobromocamphor-sulphonate to a solution of compensated tetrahydro- β -naphthylamine hydrochloride, a white crystalline precipitate of dextrotetrahydro- β -naphthylamine dextrobromocamphor-sulphonate—the salt *d*-B, *d*-A—is thrown down, whilst the lævotetrahydro- β -naphthylamine remains in solution as its hydrochloride. The resolution in this, and in many other cases, can be very rapidly effected, and by still further applying the optically active sulphonic acids derived from camphor a considerable extension of the original van 't Hoff-Le Bel theory has become possible. These workers traced all cases of optical activity to the presence of an asymmetric carbon atom, and deduced from their work the conclusion that the environment of the carbon atom in methane is a tetrahedral one. It is true that all the optically active substances which have yet been obtained from natural sources owe their optical activity to the presence of an asymmetric carbon atom, but it is important to note that by applying the second Pasteur method to the investigation of synthetic materials, substances owing their optical activity to the presence of asymmetric atoms of elements other than those of carbon can be prepared. Thus, ammonium iodide has the molecular composition NH_4I , and, like methane, contains in its molecule four hydrogen atoms which are replaceable by other atoms or groups of atoms; on replacing these hydrogen atoms by the four groups of atoms or radicles, methyl, allyl, benzyl and phenyl, a substance is obtained which is conveniently named methylallylbenzylphenyl-ammonium iodide, and has the following constitution:—



On replacing the iodine atom in this molecule by an optically active group of atoms, viz. by the dextrobromocamphor-sulphonic residue two salts are obtained each of which contains an optically active basic part and an optically active acidic part; these are salts of the kinds *d*-B, *d*-A and *l*-B, *d*-A, and can be separated by crystallisation from a convenient solvent, and, after separation has been effected, each salt may be reconverted into the iodide. These regenerated iodides are found to be optically active in solution, and the conclusion is consequently drawn that optical activity is an attribute of the asymmetric pentavalent nitrogen atom as well as of the asymmetric tetravalent carbon atom. The optical activity of this substituted ammonium compound indicates that its molecule has an enantiomorphous configuration, and is extended in three-dimensional space; the exact nature of this configuration is not yet known, inasmuch as a space arrangement of five groups is concerned, but the environment of the nitrogen atom in ammonium salts is clearly not a simple tetrahedral one. Just as enantiomorphism has been proved to be an attribute of the asymmetric nitrogen atom, we have also demonstrated that asymmetric tetravalent atoms of sulphur, selenium and tin give rise to optical activity; optically active substances having the constitutions shown below have been prepared, and we are thus well on the way towards obtaining a complete stereochemical scheme embracing all the elements:—



It has been mentioned that optically active substances occur as such, rather than in the compensated form, in many animal and vegetable products, and also that when a substance containing an asymmetric carbon atom is prepared synthetically in the laboratory, it is of necessity obtained in the compensated form, or as a mixture in equal proportion of the dextro- and the laevo-isomerides. Taken together, these two facts have a very interesting bearing upon our speculations as to the origin of animal and vegetable life. Optically active substances have been isolated as products of the vital activity of all forms of animal or vegetable life which have been properly examined, but in spite of this they are never obtained directly as laboratory products; some enantiomorphous influence has always to be employed in their synthetic preparation, just as Pasteur applied enantiomorphism, either of method or of material, to the resolution of compensated substances. It was very strenuously argued by Prof. Japp, in his presidential address to the Chemical Section of the British Association in 1898, that no matter how successful we may be in reducing the problems relating to vital processes to mere questions of physics and chemistry, a residuum will always evade explanation by such means; this residuum will involve the discussion of the way in which the first enantiomorphous substance was resolved into its optically active components. This question involves the introduction of an enantiomorphous agency at some period during the evolutionary development of living matter. In attributing difficulty to the solution of this residuary problem, Dr. Japp implies that the enantiomorphous agency, the cooperation of which is essential, must be an intelligent agency. Let us ask ourselves whether the enantiomorphous agency premised is necessarily other than one acting fortuitously. The assumption of a fortuitously enantiomorphous agency is certainly all that need be made to explain the building up of many enantiomorphous systems. The dead universe itself, as we know it, is enantiomorphous, but this fact has never been regarded as a valid argument against the current hypothesis as to the cosmic origin of our planet. Some degree of obscurity is, however, introduced into the discussion of the primitive origin of the optically active substances now produced by animals and plants by the probability that ages of evolution have transformed the primeval optically active substance into multitudes of other and more complex products—have, in fact, accentuated the enantiomorphism to such an extent that physiological chemistry is now almost entirely the chemistry of enantiomorphous substances.

If in any particular case, however, we can show that an optically active substance can be locally accumulated by the aid of some enantiomorphous agency acting purely fortuitously, it will be clear that the formation of the first optically active substance was not necessarily the work of an intelligent enantiomorphous agency. Such a species of separation of an optically active substance from a compensated one can be readily brought about in the laboratory. Pasteur showed that on crystallising the sodium ammonium salt of compensated tartaric acid (racemic acid) at ordinary temperature, large crystals separate, each of which consists of the salt of one or other of the *d*- and *l*-tartaric acids, the separation being brought about by the first of the Pasteur methods. If one of these crystals be selected casually, without the exercise of any selective intelligence, and used as a nucleus for inducing the crystallisation of further large quantities of the original solution, it will cause the separation of salt of its own kind, and ultimately a large quantity of salt of one of the optically active tartaric acids can be accumulated as a result of the introduction of an enantiomorphous agency such as might act fortuitously in a non-living universe. The probability of such a fortuitous agency arising would naturally be far greater in a living universe.

Again, suppose that at its origin life were carried on non-enantiomorphously, and that it involved the consumption and the production only of non-enantiomorphous substances and of compensated mixtures; it may well be foreseen that a stage in development might arise when each individual, in view of the increasing complexity of his vital processes, would have to decide to use only the one enantiomorphous component of his compensated food, and so evade an otherwise necessary duplication of his digestive apparatus. Acting unintelligently or fortuitously, one-half of the individuals would become dextro-beings, whilst the other half would become laevo-individuals; the succeeding generations would thus be of two enantiomorphously related configurations. It is, however, very difficult to believe that the natural selective operations which have been instrumental in conducting living organisms to their present stage of development would allow the perpetuation of this state of affairs for any considerable period; some fortuitous enantiomorphous occurrence would temporarily give the one configuration the advantage over the other, an advantage which would be quickly accentuated and would involve the permanent disappearance of the weaker configuration.

The kind of difficulties involved in the existence, side by side, of dextro- and laevo-individuals such as these may be shown by a simple illustration. There is no reason connected with human enantiomorphism why vehicular traffic should be forced to keep to one side of the road rather than to the other; as, however, the conditions of civilised life have gradually become more complex, economic reasons have arisen causing us to make an enantiomorphous selection, and in this country we arbitrarily force the traffic to keep to the left; other countries also make an arbitrary and sometimes a different selection. Even if, when legislation on this matter first became necessary, the population had been equally and obstinately divided upon the question of the rule of the road, we cannot doubt that by this time the question would have been satisfactorily and finally settled by the extermination of one or other of the enantiomorphously inclined parties without the cooperation of any intelligent enantiomorphous agency.

I mentioned that Pasteur gave a third method for the resolution of compensated substances, a method depending upon the selection exercised by living organisms upon the enantiomorphously related components of the mixture. He found, for instance, on allowing the mould *Penicillium glaucum* to grow in a solution containing compensated tartaric acid, that the mould used the *d*-tartaric acid as a food-stuff, and rejected the laevo-isomeride, which latter could ultimately be separated from the solution. The kind of method thus indicated has been applied with success in a great number of cases, and is, in the end, merely a special application of Pasteur's second method. During recent years a considerable change has taken place in our views upon the action of the lower organisms upon their food-stuffs. It was formerly supposed, for example, that the fermentation of sugar by an ordinary beer yeast is a part

of the vital process of the organism itself—that the sugar taken in as food by the organism is finally thrown out in the form of carbon dioxide and alcohol; it is now clear, however, that the formation of these two products is in no way a vital process. By triturating yeast with powdered quartz, so as to shatter the cell walls, and expressing the pulp thus produced, Buchner has succeeded in obtaining a solution which, when mixed with sugar solution, converts the sugar into carbon dioxide and alcohol. The fermentation is therefore not a vital phenomenon, but is a chemical action induced by some non-living substance contained in the expressed juice of the yeast cells. This substance—zymase—has been isolated in the solid state, and belongs to the class of substances known as unorganised ferments or enzymes. Although many enzymes are known, each active in inducing the occurrence of some particular chemical change or changes, nothing is as yet known as to their molecular constitutions; ages of evolution have given such complexity to these substances that a century or less of chemical investigation has contributed practically nothing towards elucidating their nature.

During the investigation of cases of animal and vegetable vital activity, great numbers of instances of the action of enzymes have been found, the function of the enzyme being to bring about the molecular degradation and, in certain cases, the molecular complication, of more or less complex materials used or produced in the organism. As an example of molecular degradation due primarily to enzymic action, the action of zymase on grape-sugar—*d*-glucose—may be quoted. In aqueous solution, one molecule of grape-sugar becomes directly converted into two molecules of alcohol and two molecules of carbon dioxide, in accordance with the equation



by the enzyme zymase. The enzyme itself suffers no permanent change as a result of exercising the power of causing this chemical reaction to take place, so that a comparatively minute quantity of the enzyme, acting for a more or less prolonged period, is able to convert an unlimited quantity of grape-sugar into alcohol and carbon dioxide. The power which the enzyme possesses of inducing the occurrence of some chemical reaction which otherwise does not take place is not peculiar to enzymes; many substances, which are all classed together as the so-called catalytic agents, are known to exercise the same sort of influence in assisting a chemical reaction to occur. Thus the action of finely divided platinum in causing certain inflammable gases to ignite in air at the ordinary temperature is a catalytic action. The particular function exercised by enzymes in animal or vegetable life consists in bringing about chemical change, quietly and continuously, without necessitating the application of any violent chemical effects such as we are in the habit of using in the laboratory. Although they proceed so quietly, the chemical changes thus effected are, in certain cases, changes which we have not yet succeeded in carrying out without the assistance of an enzyme; in the conversion of sugar into alcohol and carbon dioxide, zymase is performing a reaction which has never yet been brought about by the use of the ordinary laboratory methods.

Without quoting more specific instances, it may be generally stated that most of the cases of enzymic action hitherto investigated are cases in which a large molecular complex is degraded or broken down into substances of lower molecular weight. But it is important to note that the organism is also the seat of processes which result in the building up of very complex molecules from simpler ones, such, for instance, as the formation of starch from carbon dioxide and water. A specific case in which enzymic action leads to the production of a complex substance from simpler ones has been recently worked out by Fischer and Armstrong, who show that the enzyme, lactase, converts the sugar galactose, $C_6H_{12}O_6$, into a new sugar, isolactose, $C_{12}H_{22}O_{11}$, of nearly twice the molecular weight of the former.

All the enzymes with which we are acquainted appear to be enantiomorphous bodies; they are, perhaps, substances to which no definite molecular composition can ever be assigned, inasmuch as they may be systems consisting of a number of different true chemical compounds, the system be-

ing one which becomes endowed with extraordinary chemical activity when placed in a suitable environment. The enantiomorphism of the enzyme has been repeatedly demonstrated during the course of Emil Fischer's remarkable synthetic work on the sugars. Fischer succeeded in preparing fruit-sugar or fructose by purely synthetical methods as a mixture of the dextro- and the lævo-isomerides; in order to isolate the previously unknown *l*-fructose, he applied the third Pasteur method in that he cultivated a yeast in the solution of the compensated fructose. The yeast enzyme—presumably zymase—has arrived at its present stage of development by passing through countless generations, all of which have been fed upon sugars of the dextro-configuration, these being the only ones occurring in Nature. In Fischer's experiment the enzyme therefore readily devoured the *d*-fructose, but refused to touch the *l*-fructose, which had never before been presented to it. The *l*-fructose was, of course, subsequently isolated from the solution. The need for compatibility between the enzyme and the material upon which it has to act is very clearly illustrated by considering the effect of yeast upon a number of optically active and isomeric sugars. In the table (Fig. 9) are given the constitutions of a number of sugars of the composition $C_6H_{12}O_6$, the configurations of the three or four asymmetric carbon atoms present in the molecule being indicated by writing the hydrogen atoms on the right or the left of the figure, as the case may be; the right or left hands indicate which asymmetric carbon atoms are of similar, and which of opposed, configurations.

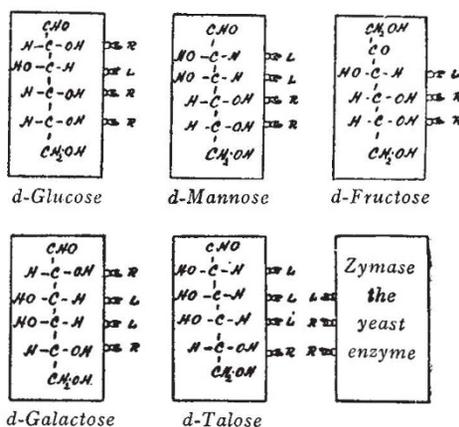


FIG. 9.

The beer yeast ferments *d*-glucose, *d*-mannose and *d*-fructose, each of which contains in the molecule a set of three asymmetric carbon atoms of similar configuration, with about equal readiness; *d*-galactose is, however, only fermented with difficulty—in the set of three asymmetric carbon atoms referred to, it contains one differing in configuration from the corresponding one in the three easily fermentable sugars. *d*-Talose, in which two of the three asymmetric carbon atoms differ in configuration from the corresponding carbon atoms in *d*-fructose, is quite unaffected by the yeast. It is just as if the enzyme were provided with three hands, in the order right, right, left, to enable it to grip the sugar molecule and commence tearing it to pieces; with these three hands it grips the corresponding hands—also of the configuration and order, right, right, left, of the first three sugars. The enzyme can, however, only grip the *d*-galactose molecule by two hands, and so obtains a less firm hold. Owing to the greater incompatibility between the zymase and the *d*-talose, the former obtains too feeble a hold on the latter to enable it to make a successful assault, and the sugar therefore remains unfermented.

The fact that the chemical reactions of animal and vegetable physiology consist, in the main, of the production or destruction of optically active substances through the agency of enantiomorphous enzymes is one of enormous importance. The complex substances concerned, such as starches, albumins and food-stuffs generally, occur in Nature in but

one of the enantiomorphously related configurations; all the albumins are lævo-rotatory, all the starches and sugars are derived from dextro-glucose. Since Fischer's work teaches us that none of the sugars derived from lævo-glucose are fermentable by yeast, it would seem to follow as a legitimate conclusion that, whilst *d*-glucose is a valuable food-stuff, we should be incapable of digesting its enantiomorphously related isomeride, *l*-glucose. Humanity is therefore composed of dextro-men and dextro-women. And just as we ourselves would probably starve if provided with nothing but food enantiomorphously related to that to which we are accustomed, so, if our enantiomorphously related isomerides, the lævo-men, were to come among us now, at a time when we have not yet succeeded in preparing synthetically the more important food-stuffs, we should be unable to provide them with the food necessary to keep them alive.

CHLORINE SMELTING, WITH ELECTROLYSIS.

A PAPER on chlorine smelting with electrolysis was read by Mr. Swinburne at the first meeting of the Faraday Society; as the process described in the paper is of considerable interest, and may one day be of great importance, we give a brief abstract of the paper below.

The process is one for the treatment of complex sulphide ores, such, for example, as the Broken Hill slimes, and is divided into three stages as follows:—(1) the treatment of the ores with hot chlorine, whereby the metals are all obtained as chlorides; (2) the treatment of the mixed chlorides by substitution until finally all the chlorine is combined with zinc; and (3) the electrolysis of the zinc chloride to extract the zinc and recover the chlorine. The first stage of the process is carried out by blowing hot chlorine into the crushed ore in a "transformer"; the essential feature is to avoid the formation of chloride of sulphur.

This involves a careful regulation of temperature and of the rate of feed of the ore; the temperature can be easily regulated by the rate of feed of the ore and chlorine as the reaction evolves a great deal of heat, and the transformer is entirely self-heating. Advantage can be taken of the composition of the ore, as some of the metals have a greater heat of reaction than others; if necessary, a mixture of ores of different compositions can be made so as to give a satisfactory working material. The sulphur is set free and condensed. At the end of a charge the ore feed is stopped, and the excess of sulphides converted to chlorides, after which the fused chlorides are drawn off and dissolved; the gangue having been separated by filtration, the second part of the process begins. This naturally depends on the composition of the ore; lead, silver, and gold are separated with the gangue, and after drying are fused first with lead, which extracts the silver and gold, and then with zinc, which gives lead and zinc chloride, the former practically pure. The filtrate is treated with spongy copper to separate lead and silver, and then with zinc to take out the copper. Iron, manganese, and zinc chlorides are left; the iron is chlorinated up to the ferric state, and precipitated as ferric hydrate by zinc oxide, and further chlorination in presence of the zinc oxide throws down the manganese as peroxide. There is thus left only zinc chloride in solution, and this is evaporated down and fused. To it is added the fused chloride from the lead substitution, and the whole is electrolysed in vats made of iron lined with fire-brick. The heating is internal; the current and the chloride soaking into and solidifying in the fire-brick gives really a vat with zinc chloride walls. Vats taking 3000 amperes have been in use, but these are small, and 10,000 ampere vats are to be tried; the pressure required is less than four volts. The result of the process is pure zinc and chlorine ready for chlorination of fresh ore.

It will be seen that the chief merits of the process are its comprehensiveness, its cyclical nature, and the fact that it turns out pure metals. Obviously it is suited, with only slight modifications, for the treatment of a great variety of ores. The chlorine simply goes round and round; apart from leakage, which, as Mr. Swinburne says, if it would show on the balance sheet would make the works uninhabit-

able, chlorine can only be lost as chloride of sulphur (a source of loss the inventors claim to have overcome), and as oxychlorides formed in the iron separation and in evaporation of the zinc chloride, neither of great importance if care be taken. The works therefore simply take in ore and electrical energy and turn out metals, sulphur, and gangue. Mr. Swinburne enters at some length into the question of cost, but space does not permit of our following him here; we have said enough to indicate the interesting character of the paper, to which those more specially interested may be referred for further details.

M. S.

THE ROYAL INSTITUTE OF PUBLIC HEALTH.

THE annual congress of the Royal Institute of Public Health was held at Liverpool, July 15-21, under the presidency of the Earl of Derby. The sections met in the various departments of the University College, and were thus closely associated and readily accessible. The proceedings were opened by an interesting address from the Earl of Derby, in which he directed attention to the considerable progress in sanitation that had been made by many ancient civilisations. The Harben medals for 1901 and 1902 were then presented to Sir Charles Cameron and Prof. W. R. Smith.

A combined conference of the preventive medicine and municipal hygiene sections discussed the subject of tuberculosis, and Dr. Nathan Raw read a paper upon "The Prevention of Consumption in Large Cities," in which he expressed the opinion that consumption is frequently conveyed to children by milk from tuberculous cows, though patients in the advanced stage are the greater source of danger to the community. He suggested as means for controlling the disease (1) the establishment of a central office where consumptives might seek advice; (2) the erection of a municipal sanatorium which, for Liverpool, should contain 100 beds, and be within the reach of any needy citizen; and (3) the foundation of a hospital for the poor for at least 100 incurable cases. Several other papers dealing with tuberculosis were also contributed; one, by Mr. McLauchlan Young, who summarised the experiments performed by Prof. Hamilton and himself upon the communicability of bovine tuberculosis to man, and expressed the opinion that there could be little doubt that human tubercle can be readily inoculated upon bovines; another, by Drs. Dean and Todd, upon the communicability of human tuberculosis to the pig, in which the six animals experimented upon were all infected with the human bacillus. Thus there is already an accumulation of evidence against the view expressed by Koch at the Tuberculosis Congress of 1901, that bovine tuberculosis is probably not communicable to man.

In the section of bacteriology and comparative pathology, the president, Prof. Boyce, F.R.S., in his opening address directed attention to the connection between abstract research and the good of the community, instancing the value of bacteriological research to practical medicine, to the farmer, to the water engineer, and to the oyster merchant. A paper by Dr. Savage upon "A Uniform Method of Procedure for the Bacterioscopic Examination of Water," evoked an interesting discussion. He considered the subject under four headings:—(1) the methods of collection and transmission of the samples; (2) the data which it is desirable to ascertain; (3) the processes and procedures of the examination; and (4) the significance to be attached to the results obtained. It was ultimately resolved to form a committee to consider whether it might not be possible to systematise the methods, &c., to be used for the bacteriological examination of water.

Another important discussion, upon "the nature and significance of the pseudo-diphtheria bacillus," was opened by Dr. Cobbett, who expressed the opinion that this organism has nothing whatever to do with the true diphtheria bacillus. Prof. Hewlett stated that he was not yet convinced that the two organisms had no connection, and directed attention to several points of similarity between the two. Several medical officers of health held that, whether the two organisms had any connection or no, the pseudo-bacillus sometimes produced a diphtheritic condition. It is im-