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## OSTWALD'S GENERAL CHEMISTRY.

*Lehrbuch der Allgemeinen Chemie.* Von Dr. Wilhelm Ostwald. Band I. 1891, Band II. Theil I. 1893. Zweite Auflage. (Leipzig : Wilhelm Englemann.)

THE conception of molecule is essential in explaining the phenomena of both chemistry and physics. Porosity and compressibility point to the conclusion that matter does not entirely fill space, to account for the dispersion of light requires that matter should have a grained structure; these and countless other physical facts find an explanation in the conception of molecule. Moreover, from various observations, more especially on the properties of gases and the phenomena of surface tension, the size of molecules can be approximately calculated, and in terms of the idea of molecule deduced in ways such as these physical properties are explained.

The chemist, on the other hand, has arrived at the need of the conception of molecule from totally different considerations. In the early days of his science, when the laws of combining proportions and of chemical equivalents were taking definite shape, the revival of the conception of atom was of immediate service in furthering the progress of chemistry. It was not long in becoming apparent, however, that the conception of atom alone was insufficient to meet the facts.

The relative numbers of atoms entering into the composition of compounds was a matter of doubt until Avogadro's hypothesis was accepted, and until it was granted that definite groups of atoms—chemical molecules— were concerned in chemical processes.

The chemist has thus built up his conception of molecule in accordance with chemical facts; he regards it as a structure composed of parts, and in order to explain the existence of isomers, he has to assume definite relative arrangements of the atoms within a molecule.

From the fact that the two conceptions of molecule have been derived independently of one another, it has come about that physical properties are discussed more or less apart from the chemical nature of the substances examined, and for this reason within recent times there has arisen a fascinating field of inquiry on the borderland of chemistry and physics. For it has been urged, "Is it not possible to trace the cause of physical phenomena beyond the physical molecule?" If, as the chemist has shown, the molecule is a structure composed of parts, is it not possible that these parts of molecules are the units to be dealt with? In short, "Is not the ultimate cause of physical as well as of chemical phenomena to be ascribed to the chemical atoms and their mutual relationships?"

Already this question has been answered in several ways, and in none more striking than by those investigations which are concerned with the physical constants of substances and their chemical nature. Here it has been shown that the magnitudes of many physical constants are conditioned by the nature, number, and arrangement of the atoms which compose molecules and that frequently definite changes in chemical nature bring about definite quantitative changes in the magnitude of physical constants.

Books dealing with such investigations as these are but few, indeed the first volume of the book before us is practically the only one which gives a comprehensive view of what has been done in this direction. If we exclude those parts which are purely physical and which are concerned with familiarising the reader with the physical properties to be treated, the volume may in the main be taken as linking on the chemical to the physical conception of molecule, in so far as to show that the magnitudes of physical constants are functions of molecular weight and molecular structure.

The general arrangement of the contents of this volume is pretty much as it was in the previous edition, although very few pages remain as they were, and the introduction of recent investigations has increased the size of the volume by about one-third. The atomic hypothesis and the laws upon which it is based are first treated, then follows a useful summary of the various atomic weight estimations, from which are deduced the probable values of those fundamental constants, values which are already finding their way into current literature. The numerical relations existing between the atomic weights of the elements constitute the concluding portion of this the first of the six books into which vol. i. is divided. Succeeding books deal respectively with the physical properties of gases, liquids, solutions, and solids, and with the relations existing between the physical properties and the chemical nature of the substances.

Solutions are, in this edition, for the first time treated in a separate book, which with certain additions has been translated into English by Mr. Pattison Muir, and has already been noticed in these columns (NATURE, vol. xlv. p. 193). Electric conductivity and electrolysis now find a place in vol. ii. under electro-chemistry. The sixth and last book of vol. i. deals with chemical systematics—the criteria by which atomic weights are chosen, the periodic law and the relations between the physical constants of the elements and their atomic weights, and the molecular theory and the structure of chemical compounds in which the doctrines of valency, isomerism, &c., are discussed.

The peculiar interest which attaches to connections between the physical constants of substances and their chemical nature lies in the fact that an idea is thereby obtained of the constitution of the substances as they actually exist. Structure as deduced from purely chemical methods is founded upon reaction. The compound has to be decomposed before its constitution can be determined, and occasionally such methods lead to ambiguous results. Examples are steadily multiplying of compounds which in one reaction appear to correspond with one formula, while in another reaction a different formula better represents their chemical behaviour. Already measurements of physical constants have been applied to some such cases and have served to indicate that the structure of a pure substance may be conditioned by its temperature. At high temperatures, for example, acetyl acetone would appear to exist in the ketonic condition, $CH_3CO.CH_2.CO.CH_3$, while as temperature falls it would seem as if a gradual transition to the alcoholic conditions,

$CH_3.C(OH):CH.CO.CH_3$ and $CH_3.C(OH):C.C(OH)CH_3$, took place.

But physical methods can be applied to the study of the phenomena of chemical change as well as to those of chemical structure. Change of any kind taking place in material substances is to be sought in the nature of the energy associated with those substances, and chemical change has therefore to be sought in the nature of chemical energy. Of the nature of chemical energy, however, we know but little. Although it is the source of most of the energy turned to practical account in the arts and manufactures, and indeed, directly or indirectly, of all vital energy, it cannot be directly measured, and its nature is, as yet, but a matter for speculation.

Part 1 of vol. ii. of the "Lehrbuch" is concerned with making clear the present position of knowledge on this subject of chemical energy. To begin with, energy in general is discussed, the various forms under which it is known to us, and the units in which they are measured. Particular attention is directed to the factors which enter into the expressions denoting several of the types of energy, and more especially to the intensity factor. In the case of heat, for example, the intensity factor is temperature, and temperature, of course, determines whether heat energy shall be transferred from one body to another. A heat change between two bodies is conditioned by their temperature, and if the factors entering into the expression for chemical energy could be ascertained, the cause of chemical change might be traced in a similar way.

But although chemical energy cannot be directly measured, it can be transformed into other kinds of energy, and in turn other kinds of energy may pass into chemical energy. The amounts of these other kinds of energy which are thus involved in chemical processes are often capable of accurate measurement, and from such measurements alone can an insight into the nature of chemical energy be at present obtained. With such measurements the rest of the part is concerned.

During chemical change, chemical energy passes most readily and most completely into heat, and hence thermochemistry is first dealt with. A general historical discussion of the subject is succeeded by chapters on the non-metals, salt formation in aqueous solutions, the metals, and organic compounds. The concluding chapters deal with the "energetics" of heat, wherein is to be found the material which can be grouped around the second law of thermodynamics and the nature of heat energy in general, and with "chemical energetics" which treats of such attempts as have been made to arrive at the nature of chemical energy and its relations to heat energy. Where possible, connections between the chemical nature of substances and the heat energy to which they give rise during chemical change are pointed out, and the general application of thermal results to problems in chemical structure is kept well to the front.

The subject of electro-chemistry, which has been entirely recast, now occupies some 500 pages, as compared with little more than 100 in the first edition. It consists of a historical introduction, and of chapters on electrical energetics, Faraday's law, the migration of the ions, the conductivity of electrolytes, the constitution of electrolytes and the properties of ions, electromotive force, the differences of potential in cells, and on electrolysis and polarisation. In this section the author has collected and generalised the mass of communications which have recently been brought into existence by the fruitful hypothesis of electrolytic dissociation, and has connected them up with previous knowledge on the electrical properties of solutions. In conjunction with other portions of the "Lehrbuch" on the stoichiometry of solutions, this section gives the only full and systematic account of the new theory of solutions which is available to the general reader.

The third and last book of this part takes up the subject of photo-chemistry. The nature of radiant energy, which plays so important a part in the economy of nature and its relations to chemical energy, are first discussed. Then follow chapters on actinometry, the law of photochemical action, and on special photo-chemistry, which deals with the assimilation of carbon by plants, and the action of light on various chemical substances.

Enough has been stated to show that the work is unique. There is no other book which even attempts to cover the same ground. No chemical library can be regarded as complete without a copy of Ostwald's "Lehrbuch." It contains an enormous amount of information, both theoretical and practical, which is simply indispensable to the chemist and to the physicist. It is, indeed, difficult to overestimate the value of such a work.

But at the same time, mainly for the reason that it touches upon so many subjects, its usefulness in certain directions may to some extent be interfered with. One cannot fail to notice that the character of the work frequently savours more of a dictionary than a handbook. In the chapters on solutions and electro-chemistry there is, perhaps, not much room for this objection, for there the author has a definite purpose in view—the elucidation of the "new theory"—and writes around it, moulding his information and shaping the issues in a way that leaves little to be desired, if his standpoint be granted. Contrasted with the treatment of these sections we have, on the other hand, that of the book generally. Here are set out short abstracts, in many cases but fragmentary, of the more important researches on the subject under discussion, but little attention being paid however to generalising the results or smoothing down the discrepancies, or indeed the contradictions which occasionally arise. For example, under the subject of the molecular volumes of liquids Kopp's work comes first, and his method of obtaining atomic volumes is given, the values of carbon and hydrogen being derived by the comparison of aromatic and fatty compounds. In due course Horstmann's conclusion that the ring-grouping of atoms exerts a marked effect on molecular volume finds a place, and the author passes on to other researches. But if Horstmann's conclusion is justified the whole superstructure of Kopp's calculated atomic volumes is subject to modification, as the effect of ring-grouping is ignored in the derivation of his atomic constants. Again, here as elsewhere, the author gives Schröder's work the prominence which has been more or less denied it in the past. Schröder's method, however, involves different atomic constants to those of Kopp, and it is left almost entirely to the reader to assess the relative worth of the two systems. On one page of this chapter, too, Schiff's rule relating to

the boiling points and molecular volumes of isomers is given, while two pages later are set out the results of Städel, which lead to the opposite conclusion, a conclusion which is much more generally true than that of Schiff, as the reader may verify by referring to the tables of physical constants given towards the end of the chapter.

The author may purposely have left matters in this condition, his idea being merely to indicate the gist of what has been done on the different questions. Indeed the present condition of subjects like molecular volume is so unsatisfactory as to prevent any very definite conclusions being stated. Nevertheless, if such abstracts as are given had on various occasions been supplemented by a statement of opinion as to the nett upshot of the whole discussion, there is little question that the average student would have found the mastering of several portions of the "Lehrbuch" a task of less difficulty than at present it is.

On p. 387, lines 2, etc., a volume-change due to oxygen is attributed to hydrogen: typographical errors are somewhat numerous, as could hardly be otherwise in a work of this kind.

To complete the second edition of the "Lehrbuch," Part 2 of the second volume, which treats of chemical affinity, has still to be published. Its appearance will serve to complete a work which goes further than any other to show how chemistry and physics must be united in the endeavour to arrive at the real nature of material phenomena.

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## CLARK ON THE STEAM ENGINE.

*The Steam Engine: a Treatise on Steam Engines and Boilers.* By Daniel Kinnear Clark, M.Inst.C.E. (London, Glasgow, Edinburgh and New York: Blackie and Sons, Limited, 1892.)

THE author of this book holds the first place among those who many years ago made the locomotive an object of scientific study. His famous work on railway machinery is still of prime importance, holding as it does an honoured place in many drawing offices. The present work consists of two ponderous volumes of some 800 pages each, and claims to be a comprehensive, accurate, and clearly written text-book, fully abreast of all the recent developments in the principle, performance, and construction of the steam engine. This no doubt is a very large claim to make for any work, but when one remembers who the author is, one is bound to admit that no one is more capable of carrying out so important a scheme.

Besides the author's many researches in locomotive engineering particularly, we notice that the numerous published records of investigation and practice have been made use of. This is certainly as it should be, and having been judiciously done adds greatly to the value of the work as a book for reference.

The work is divided into four main sections:—(1) The principles and performance of steam boilers; (2) the principles and performance of steam engines; (3) the construction of steam boilers; (4) the construction of steam engines. These main sections are again subdivided into many chapters.

The vast amount of information to be gathered from these pages may be imagined when it is noted that the first section alone takes up some 373 pages. Most of this space is absorbed by descriptions of experiments with special types of boilers, mechanical and other means of stoking, the prevention of smoke and the relative efficiency of various kinds of coal. Besides this the properties of steam are discussed, and the question of the economical combustion of fuel is very thoroughly gone into. The second section is an excellent treatise on the general behaviour of steam in the cylinder, and here we find evidence of the great experience of the author in this subject, particularly in the handling of the indicator diagram and the many lessons to be learnt from it when properly understood. The third section deals with the construction of steam boilers and concludes the first volume. Here we find a collection of reports and original matter of a valuable description embracing the whole subject. It is a pity that the classical researches of the late Mr. P. W. Willans find no place in the volume, because he, of all engineers, studied the thermodynamics of steam thoroughly, and his contributions to science on this subject are invaluable. It may be noted that his central valve high-speed engines find no place in the work. This also is to be regretted, because this type of engine is rapidly coming to the front, both as an economical machine and a trustworthy motor particularly for electric lighting by direct driving, the Glasgow Corporation Electric Lighting Station being among the latest to be fitted with these engines.

The first volume may be roughly said to contain most of the theoretical part of the subject, and the second volume the description of many types of stationary, marine, and locomotive engines. This volume begins with a very complete description of the various valve gears in use and the distribution of steam by ordinary and other slide valves, also the construction and modes of working of the many governors in use. Further on stationary engines for general purposes are described and very fully illustrated. We miss from these excellent examples the many types of high-speed engines used for driving dynamos, centrifugal pumps, fans, &c. Many of these have reached a high state of efficiency and might have been included with advantage.

Chapter lx. deals with British and foreign types of locomotives. We are not surprised to find that the many chapters on the locomotive are by far the best in the whole work. The author may be said to have grown up with the locomotive and to have made it his own particular study; to this day the plucky man who rode on the buffer beams of the old Edinburgh and Glasgow four-wheeled engines taking indicator diagrams is often quoted on that line, now part of the North British system.

The paper read by the late Mr. William Stroudley on the construction of locomotive engines, &c., before the Institution of Civil Engineers contains probably the most recent and trustworthy information at present available on this subject. The author has done well in making the quotations he does from this source. Of the British locomotives illustrated all are of most recent design. The table of types of American engines made by the Baldwin locomotive works is interesting, and the illustrations are good; but what is the use of giving the