REVIEWS OF BOOKS.

The Scientific Papers of J. Willard Gibbs, Ph.D., LL.D. In two volumes. Vol. I., pp. 434 + xxviii. Price 24s. Vol. II., pp. 284 + viii. Price 18s. (Longmans, Green & Co., 1906.)

At last, after many years of waiting, the English-speaking public can read the papers of Professor Gibbs in the language in which they were written. For this happy consummation we all owe a deep debt of gratitude to the editors, Professor Henry Andrew Bumstead and Dr. Ralph Gibbs van Name, and to the publishers, Messrs. Longmans, Green & Co.

Vol. I., which contains all the thermodynamical papers of Gibbs, is the one which is of most immediate interest to physical chemists and electrochemists. It contains, as frontispiece, the fine portrait of Gibbs which appeared in the *Zeitschrift für Physikal. Chemie,* and also a very interesting biographical sketch. Gibbs was born in 1839, and was therefore between thirty-seven and thirty-eight years of age when, in 1876 and 1878, the two parts of his famous paper, "On the Equilibrium of Heterogeneous Substances," appeared in the Transactions of the Connecticut Academy. It is interesting to learn that in 1868 Gibbs came under the influence of Kirchhoff and Helmholtz at Heidelberg. Doubtless the teaching of these two great men had a powerful effect in directing the current of Gibbs' thought towards thermodynamical subjects.

The first 54 pages of Vol. I. contain the papers dealing with the graphical representation in two and three dimensions of the thermodynamical properties of substances. To most of us these papers are not by any means so well known as they ought to be. This applies with special force to the paper dealing with the volume-entropy-energy surface. It appears, indeed, very probable that a thorough study of this thermodynamic model is necessary to a proper comprehension of the extremely generalised and abstract reasoning contained in the classical paper on heterogeneous equilibrium.

Concerning this latter paper, little requires to be said at the present day. It is universally recognised as having laid in an imperishable form the foundations of that branch of chemical science which deals with the equilibrium, co-existence, and stability of chemical systems, whether homogeneous or heterogeneous. It introduced the concept of a "phase," and established the conditions for the co-existence of different phases—*i.e.*, the now celebrated "phase-law." Not only is a very large portion of modern physical chemistry built on the foundations here laid by Gibbs, but also many important branches of applied physical chemistry, such as the study of alloys, owe their very existence as sciences to the work of Gibbs. Already geology and mineralogy are advancing in the same direction, as witness the work of Van 't Hoff on the oceanic salt-deposits of Stassfurth, and that of Vogt, Doelter, and the Washington Geophysical Laboratory on the formation of minerals and rocks. And many important industries, such as those dealing with soap, cements, pottery and glazes, enamels, glass, artificial stone, sand-lime bricks, &c., will probably in the near future derive immense benefit from a study of the equilibrium of phases.

The paper on heterogeneous equilibrium extends from page 54 to page 349, and deals in its later portions with the equilibrium of substances in cases where capillary and electric actions are not excluded. Here are dealt with many questions which still await adequate experimental development. Of these, perhaps, adsorption is the one which has so far attracted the most investigation, but there are many others which have scarcely been touched. It would not be surprising if a study of this portion of Gibbs' work were found to throw light on some of the obscure questions connected with colloids, though it must not be forgotten that most of Gibbs' work applies to radii of curvature which are large in comparison with the sensible range of molecular forces.

Vol. I. concludes with a paper on homogeneous equilibrium, in which the vapour-densities of dissociating gases such as N_2O_4, PCl_5, formic and acetic acids are dealt with, with some letters to Professor Lodge and to *Nature*, treating of electrochemical thermodynamics and osmotic pressure, and finally with some unpublished fragments, which formed portions of a supplement to the paper on heterogeneous equilibrium in preparation by the author at the time of his death. It is greatly to be regretted that the author did not live to complete this supplement, for in most cases we are bequeathed only suggestive titles. One title in particular, "On the Fundamental Equations of Molecules with Latent Differences," leads one to believe that Gibbs might have laid the foundation for a thermodynamical treatment of what we at present regard as the composition and structure of molecules. As it is, however, the two fragments which have come down to us are of great value, since they show how to apply Gibbs' generalised equations to the phenomena of dilute solutions, and thus connect up the theory of solutions as we owe it to Van't Hoff and Arrhenius with Gibbs' general system.

Vol. II. deals with varied topics, including papers on the fundamental formulæ of dynamics, vector analysis, multiple algebra, applications of vector analysis to astronomical problems concerning orbits, the electromagnetic theory of light, together with some miscellaneous papers, obituary notices, reviews, and letters to *Nature* about quaternions and vector-analysis. The chief things in the volume are the paper on vector-analysis and those on various questions—*e.g.*, double refraction and dispersion—connected with the electromagnetic theory of light. The latter are characterised by the same rigour, desire for generality, and avoidance of unnecessary hypothesis which are such marked features of Gibbs' thermodynamical work. In fact, Gibbs here applies the electromagnetic theory without making any special appeal to hypotheses concerning the connection or relation between ether and matter. It is only assumed that matter possesses a structure which is fine-grained with respect to a wave-length of light, but not infinitely fine-grained, and that the oscillating electric fluxes are disturbed by this grained structure.

In the paper on vector analysis, which was written for Gibbs' students, and first privately printed in 1881 and 1884, the author breaks away from the somewhat artificial restrictions of Hamilton's quaternionic system, and develops a system of vector algebra more closely allied to the work of Grassmann and more suitable for application to the problems of mathematical physics. In this, as in all his other work, the independence and originality of mind possessed by Gibbs are strikingly seen.

At the present time, when the placid tide of the development of science is continually being disturbed by the surge of new discoveries, there is a danger that the generalised thermodynamic method of Gibbs may fall somewhat into discredit. It must not be forgotten, however, that Gibbs' thermodynamical work was, after all, the magnificent generalisation and summing up by a master-mind of the great discoveries and laws of the first three-quarters of the nineteenth century. The end of the nineteenth and the beginning of the twentieth century have been characterised, just as was the corresponding period one hundred years earlier, by an enormous effervescence of experimental discovery. Scientific theory has now to deal with many new elements, and with a finer analysis of the grainedness of matter. But when this outburst of pioneer discovery ceases for a while, as usually has happened in the past, it is to be hoped there will arise some twentieth century Gibbs, who will collate the old elements with the new, and once again present science with a generalised survey and summing-up, in which all unnecessary hypotheses are sternly suppressed.

There are many phenomena not dealt with by the fundamental laws on which Gibbs built—*e.g.*, those involving the velocity, rather than the direction, of change of chemical systems. And there may, indeed, exist phenomena in which these inductive generalisations do not hold, as pointed out long ago by Clerk Maxwell. But there exists, and always will exist, an enormous field of phenomena of which it may well be doubted if the human mind will ever discover a more suitable or more profound description than that given in Gibbs' immortal work. The whole of chemistry as ordinarily understood falls within this splendid domain, although as yet many of the problems studied by chemists, such as those relating to valency, structure, and configuration, have not appeared to derive any aid from thermodynamical considerations.

May this not perhaps be due in part to the want of a suitable algebra? The concept of chemical structure or configuration is a multiple concept, involving the potentiality of many relationships, to which crude expression is ordinarily given by a sort of geometrical model. Perhaps we might better express the concept in question as the eliminant of a system of simultaneous equations in which the unknowns represent reacting quantities and the coefficients molar relationships?

Should it ever become possible to discover such a manifold or multiple algebra, then undoubtedly the way would lie open for a fresh extension of Gibbs' methods and results.

It may seem to many that these are pious wishes foredoomed to non-fulfilment, and that it is rather to the development of the electron-theory that we must look for progress. It may not be amiss to point out that herein lies no antagonism. Gibbs himself, the most strenuous seeker after generalised mathematical expression that perhaps the world has ever known, was a firm believer in the kinetic molecular theory, and strove most successfully to find in this theory a basis for the fundamental laws of thermodynamics. The advance of science consists, in fact, in an ever finer specification of the specific, combined with an ever-broadening generalisation of the general. As Larmor has well expressed it, thermodynamics supplies us with the frame, but it does not paint the details of the picture. Yet it is well for the artist to know the framework in which his picture must be set, or he may find his landscape rudely short of much that he considered to be its most picturesque elements.

A History of Chemistry. By F. P. Armitage, M.A. Pp. xx. + 266. (London, 1907, Longmans, Green & Co. Price 6s.)

Historical chemistry, like historical science of any kind, is always an interesting subject, and very often the advanced student learns much more by studying the manner in which a science was built up and often pulled down again, than by an examination of the already finished structure. But who, in these days of advance in all branches of science, can or dare say that the structure of any one science—least of all chemistry—is finished?

Mr. Armitage has endeavoured to show us how chemistry was gradually built up and became a science. There is, as a rule, very little scope for literary style when dealing with scientific subjects, although perhaps an historical survey, especially at the earlier periods, lends itself more to fine phrases than the description of scientific results. We are sorry to have to say that Mr. Armitage, in his striving at effect and literary style, has in many cases made his sentences so involved that we wonder what in the name of science he means. Does "a moment's thought on the nature of chemical facts convince us that their recognition was coeval with the dawn of human intelligence, even during that stage of transition which separated him from brute creation? . . ." This is the very first sentence; but because man found it unwise to eat deadly nightshade, surely this fact can hardly be called the dawn of the nature of chemical facts within him.

The book shows careful study on the part of the author, and the arrangement is good, but, as already stated, although the student may find the style interesting to read, the involved way in which the sentences are strung together will prevent him from grasping and remembering the salient facts.

The first chapter deals with the earliest times. With Chapter II. we are introduced to the work of Lavoisier and the establishment of quantitative method. The establishment of a quantitative basis was much more the dawn of chemistry, to our mind, than the discovery by pre-historic man that some things were good and some bad. The book then leads through the work of Dalton and Davy, Berzelius, and the fortunes of the Atomic Theory, the development of organic chemistry, and finally the development of stereo-chemistry, and the work of Pasteur, Wislicenus, Van't Hoff, and others. Owing to its diffuse style, the reader will have to study this book with especial care or else he will carry little away with him; but by careful study he will learn a great deal, for the book is really quite interesting.

Hermann von Helmholtz. By LEO KOENIGSBERGER. Translated by Frances A. Welby. With a Preface by Lord Kelvin. (Oxford, 1906: The Clarendon Press. Royal 8vo. Pp. 440. Price 16s. net.)

This excellent translation of Koenigsberger's fine Life of Helmholtz is a worthy English monument to one of the grandest figures in the scientific history of the past century. For we have in this Life, not merely a mechanical record of biographical incidents which, interesting as they are, are yet such as might have befallen a thousand other German professors, but a vivid and living account of the life-work of a man of science, who, equally great as a biologist, physicist, or mathematician, made unique and lasting contributions to each and all of these varied branches of human knowledge, leaving the impress of his work on the science of our day as few before him were able to do. His smaller contributions to chemical physics and electrochemistry alone would have sufficed to give most men a respectable reputation; and when we consider that they were crowned by the immortal Faraday Lecture of 1881, in which the atomic theory of electricity, now, as Lord Kelvin remarks in his Preface, accepted by all, was put forward for the first time, and when we consider, too, that this work forms but an insignificant proportion of the sum total of his researches and discoveries, we may then form some idea of the inspiring value, to young and old alike, of the study of a life like Helmholtz's.

A very good reproduction of Lenbach's majestic portrait of Helmholtz, painted in 1876, forms the frontispiece to the volume, which also contains an interesting Daguerreotype taken in 1848, when Helmholtz was 27 years of age, and a pastel, also by Lenbach, sketched in 1894. It is interesting to note that on his mother's side Helmholtz was descended from William Penn; and not the least gratifying portions of the Life are those which deal with the always cordial and often deeply friendly relations existing between him and his English *confrères.*