SCIENCE

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THE VAN'T HOFF CELEBRATION.

A QUARTER of a century has passed since Van't Hoff obtained the degree of Doctor of Philosophy. This event was celebrated on December 22, 1899, in Rotterdam, by his students and a number of guests, including some of the leading men of science. An extra volume of the *Zeitschrift für physikalische Chemie*, containing investigations by those who, at some time, had worked with Van't Hoff, was published and presented to him on this occasion.

What does this mean; why has such an unusual tribute been paid to this comparatively young man?

There is nothing more inspiring to workers in the field of science, than the lives and works of those who are the leaders of modern science. Let us turn to the biographical sketch of Van't Hoff, by Ostwald, which serves as a preface to the 'Jubelband.'

Van't Hoff is the son of a Dutch physician, and was born in Rotterdam, August 30, 1852. He received his early training at a high school in his native city, and at seventeen entered the Polytechnic Institute in Delft. He then studied at Leiden, with Kekulé at Bonn, and with Würtz in Paris. He made the doctor's degree at the University of Utrecht, on the 22d of December, 1874. In 1876 he became docent at the veterinary school in Utrecht, and in 1877 was called to the University in Amsterdam. In 1894 he left Amsterdam to accept a chair of Physical Chemistry at the University of Berlin, which had been founded especially for him.

Van't Hoff's contributions to science fall into three classes ; or we may say, in brief, he has done three things. His earliest work of importance had to do with the spatial arrangement of the atoms in the molecule. In the same year in which he obtained the degree of Doctor of Philosophy, he published a small pamphlet of eleven pages, which is the beginning of all stereochemistry. In the following year it was enlarged to forty-four pages, and published in French under the title, "La chimie dans l'espace." It was translated into German two years later, with an enthusiastic preface by Wislicenus.

The attitude of Kolbe, who utilized his position to belittle not only the work but also its author, is familiar to every one. Indeed, so familiar, that Kolbe's reputation for liberality is not materially increased by the criticism which he offered of this work.

Van't Hoff attempted, in this work, to formulate a rational theory of the arrangement of the atoms in the molecules of certain substances. Let us consider the very simple compound of carbon and hydrogen, CH_4. All the properties of this substance show that it is a symmetrical compound, every hydrogen atom bearing exactly the same relation to the molecule. By what possible geometrical configuration in three dimensions can this be expressed? Evidently by the regular tetrahedron, and by this alone. If we represent the carbon atom as being placed at the center of a regular tetrahedron, and the four hydrogen atoms at the four corners, or in the four solid angles of the tetrahedron, we have a perfectly symmetrical configuration. This was pointed out by Van't Hoff, and has come to be known as the 'theory of the tetrahedral carbon atom.'

One application of this theory will serve to show how it has been of service in advancing our knowledge of organic substance. A comparatively large number of compounds were known, which, in the liquid state or in solution, would rotate the plane of polarization when a beam of polarized light was passed through them. In some cases the rotation was to the right, in other cases to the left. Further, it was very probable that for every substance which rotates the plane of polarization in one direction, there is a substance of the same composition rotating the plane in the opposite direction. How could these facts be interpreted in terms of the theory of the tetrahedral carbon atom?

Van't Hoff pointed out that every one of these so-called optically active substances contains a carbon atom in combination with *four different atoms or groups*. It is only when the four atoms or groups at the solid angles of the tetrahedron are all different, that two configurations are possible. If any two of the atoms or groups are the same, it is impossible to construct two tetrahedra which shall differ from one another. But if the four atoms or groups are all different, two tetrahedra can be constructed which bear the relation to each other of an object and its image in a mirror. These two configurations represent the two substances which have the same composition, but are optically active in opposite senses. When this theory of 'the asymmetric carbon atom' is applied to all of the facts known concerning optically active substances, we find that out of the seven hundred optically active compounds, there is only *one* which may be an exception to it. But this substance is so complex that its constitution is far from settled.

This is but one application of the theory of the tetrahedral carbon atom. This theory has thrown entirely new light on the meaning of isomerism in organic chemistry. By means of it many cases of isomerism have been satisfactorily explained, whose meaning was entirely shrouded in darkness before the theory was proposed. By means of this theory large numbers of isomeric substances have been predicted, and many of these have already been discovered.

The theory of the space relations in carbon compounds has led directly to a theory of the stereochemistry of compounds containing nitrogen, and some extremely interesting and important work has been done in the last ten years upon this problem. Under the guidance of these new conceptions entirely new classes of compounds have been brought to light, and cases of isomerism discovered whose existence could never have been suspected, had not the theory of the tetrahedral carbon atom been proposed.

If we look over the field of organic chemistry in a broad way, it is not too much to say that the most important advances which have been made in organic chemistry in the last quarter of a century, have centered closely around this theory of the tetrahedral carbon atom. If we think only of the applications of the theory which have been made by Wislicenus, Hantzsch, and Emil Fischer, we shall see that it has contributed more to the advancement of our knowledge in this field, than any suggestion since Kekulé proposed the benzene hypothesis which bears his name.

In 1878 Van't Hoff published a book which is but little known, and which has had but little direct influence—'Ansichten über die organische Chemie.' But this book is closely connected with his second great contribution to chemistry.

He attempted to develop a side of organic chemistry which had hitherto received but very little attention. What would be the effect of different masses of one substance when allowed to act on a given mass of another substance? This quantitative side of organic chemistry had been either entirely neglected, or dealt with only as affecting the yield which would result from the reaction. Van't Hoff applied the law of Guldberg and Waage to organic reactions, and pointed out the importance of the study of the dynamics of reactions. He studied the velocity with which given reactions would take place, and the conditions under which equilibria in chemical processes were established. His first results were published in his 'Études de Dynamique Chimique' in 1884.

The work is not simply experimental. Indeed its theoretical side is of the very highest importance, since it was shown here that we can apply thermodynamics to chemical processes. The whole science of chemical dynamics and statics has acquired an entirely new meaning in the light of this work, which has contributed more to place organic chemistry on a quantitative basis, than any investigation which has ever been published. This work was greatly enlarged and published in 1896, under the title 'Studien zur chemischen Dynamik,' by Van't Hoff and Cohen.

The second epoch-making work of Van't Hoff is much less widely known than the first. This is due in part to the comparative complexity of the processes dealt with, and in part to the rigorous mathematical treatment which he applied to them. But I believe that time will show that the *Chemical Dynamics* of Van't Hoff is vastly more important than his *Stereo-chemistry* in placing chemistry upon that exact mathematical basis, toward which all branches of natural science tend, as our knowledge of the phenomena becomes deeper and deeper.

The third great work of Van't Hoff still remains to be considered. I refer to the relation which he showed to exist between the pressure of gases and the osmotic pressure of solutions. The genesis of this idea has been furnished us by Van't Hoff himself, in the lecture which he was invited to deliver before the German Chemical Society in 1894. As we have seen, he was early occupied with the study of the position of atoms in space. From this he was led to study the velocity of reactions and the conditions of equilibrium in chemical processes. But the problem of affinity was closely connected with that of equilibrium. As an example of affinity he studied the attraction of salts for their water of crystallization. He found this to be very small and adds: "I had the impression that even the weakest chemical forces are very large. * * * The question arose whether it is not possible, in simpler cases, to measure the attraction for water more directly; and for this purpose the aqueous solution is the simplest conceivable—much simpler than the compound containing water of crystallization. Coming from the laboratory with this question in mind, I meet my colleague De Vries, and his wife. He was just at that time carrying out osmotic investigations, and he told me about Pfeffer's determinations."

Van't Hoff was thus introduced to the work of Pfeffer, in which the latter had measured the osmotic pressure exerted by aqueous solutions of a number of substances, when separated from the pure solvent by a semipermeable membrane, through which the solvent, but not the dissolved substance, could pass. Van't Hoff observed from Pfeffer's results, that the osmotic pressure exerted by any substance at a constant temperature is proportional to the concentration of the solution, and saw in this an analogy to Boyle's law for gas-pressure. The gas-pressure of a gas is proportional to the concentration of the gas. Having found this one relation between osmotic pressure and gas-pressure, he tested other laws of gas-pressure by the osmotic pressure of solutions, and found that the law of Gay Lussac for the temperature coefficient of gas-pressure, applies also to the temperature coefficient of osmotic pressure. These two laws of gas-pressure might apply to the osmotic pressure of solutions, and still the absolute value of the two pressures be very different.

The fundamental question still remains: Is there any close relation between the actual pressure exerted by a gas, and the osmotic pressure exerted by a solution containing the same number of dissolved particles in a given space as there are gas particles; temperature, of course, being the same in the two cases? Van't Hoff discovered this remarkable fact; that the gas-pressure exerted by a gas particle is *exactly equal* to the osmotic pressure exerted by a dissolved particle, concentration and temperature being the same in the two cases; space playing a rôle with gases, which is analogous to that of the solvent with solutions. In a word, Avogadro's law for gases applies directly to the osmotic pressure of solutions. The three fundamental laws of gas-pressure thus apply directly to the osmotic pressure of solutions.

This relation is, in itself, of course very interesting. But why is it referred to as of epoch-making importance? Partly because of the new light which it throws on the whole problem of solution. We can apply thermodynamics freely to gases, and since the laws of gases apply to solutions, we can use thermodynamics in dealing with solutions in the same sense as in dealing with gases. And partly because it is the forerunner of the most important theory which has been proposed in chemistry or in physical chemistry for the last half-century.

We have stated that the laws of gas-pressure apply to the osmotic pressure of solutions, and this is true for solutions of certain classes of substances. It holds for all of those substances which, when in solution, do not conduct the current and therefore do not undergo decomposition. These substances are called non-electrolytes. But this relation does not hold for any substance which, when dissolved in water, conducts the current; and this class, called the electrolytes, includes all the acids, all the bases and all the salts. The exceptions to Van't Hoff's generalization are quite as numerous as the cases which conform to it; and the former are even more interesting than the latter.

To account for these exceptions it was assumed that in aqueous solutions of acids, bases and salts, the molecules are more or less broken down or dissociated into ions; the amount of the dissociation increasing with the dilution of the solution. An ion is an atom, or group of atoms, charged either positively or negatively. This suggestion, which has been placed upon its present quantitative bases by Arrhenius, is the direct outcome of the analogy between the laws of gas-pressure and of osmotic pressure, pointed out by Van't Hoff. The theory of electrolytic dissociation thus originated.

The importance of the discovery of the applicability of the gas laws to osmotic pressure can now be seen, when we consider that this relation, together with its direct consequence, the theory of electrolytic dissociation, are the two corner-stones of modern physical chemistry. Indeed, the physical chemistry of to-day has grown up almost entirely around these two conceptions. It is from these two generalizations, directly, that Nernst has calculated the electromotive force of primary cells, and has furnished us with the first satisfactory theory of the action of such cells. Still further, he has gone into the cell itself and analyzed its action, calculating the amount of potential which exists at the several sources of potential, and has shown that molecules as such have nothing to do with the action of the primary element; only the ions into which the molecules dissociate coming into play.

These generalizations have, on the other hand, entirely revolutionized our conception of chemical activity. We now know that a large majority of the chemical reactions with which we have to deal, take place entirely between ions; atoms and molecules as such, playing no rôle whatsoever in the reaction. Indeed, we have already reached a stage where it is safe to say that very few chemical reactions are other than ionic; and very recent work makes it more than probable that atoms and molecules are entirely incapable of entering into any chemical reaction. The chemistry of atoms and molecules is thus rapidly giving place to the chemistry of ions. But space will not allow further applications of these all-important generalizations.

In addition to these three monumental pieces of work, any one of which would secure permanent fame for its author, Van't Hoff has made a number of important contributions to science. His paper on *Solid Solutions* has called attention to an interesting and important class of phenomena, which had never been in any sense connected with solutions. And the activity which characterized the earlier years of his life still manifests itself to an unusual degree. This is seen in the number and nature of the investigations which are coming from his laboratory in Berlin, and in the volumes which are appearing from his pen.

If we take into account the nature and significance of the entire work of this remarkable man, it seems quite safe to predict that he will be regarded in the future as occupying a place in the same rank with men like Pasteur and Virchow, Helmholtz and Kelvin.

The celebration in Rotterdam in honor of the first twenty-five years during which Van't Hoff has worked for pure science, is a memorable event especially in the history of modern physical chemistry. There were present such men as Ostwald, Roozeboom, Lobry de Bruyn, Spring, Lorenz, Goldschmidt, Du Bois, Bredig, Ikeda, Dawson, De Hemptinne, Holleman, Jorissen, Reicher, Var Laar, Wind, Cohen, Meyerhoffer, and many others; including a large number of his students and friends.

The Burgermeister of Rotterdam made an address of welcome, which was followed by a second address by Ostwald. Telegrams were received from all parts of Europe, and cablegrams from America, Japan and Java; extending congratulations to Van't Hoff. Cohen, who was for a long time Van't Hoff's assistant in Amsterdam, prepared and presented to Van't Hoff a biographical sketch of the life of the latter, while Meyerhoffer presented the 'Jubelband.'

A word in conclusion in reference to this volume. Some two years ago a printed slip was sent to all who had worked with Van't Hoff, inviting them to contribute an original investigation to a volume which would be published and presented to Van't Hoff on the twenty-fifth anniversary of the day on which he received his degree of Doctor of Philosophy. A short time before the volume was published we were notified that it would appear as an extra volume of the *Zeitschrift für physikalische Chemie.*

It has thus appeared as volume 31 of this Journal and is known as the 'Jubelband für J. H. Van't Hoff.' Outside of its personal interest to those who have sent contributions, and of its scientific value, it has a linguistic interest. It contains papers in four languages: German, English, French, and Dutch. The papers are evidently published in the languages in which they were written by the contributors. The volume contains twenty-six papers in all, most of them from Germany and Holland, but there are a few from England and two from America.

Thus was celebrated the first quarter of a century of activity of this most brilliant man. The history of men of science has few such records.

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February 2, 1900.

THE MEETING OF NATURALISTS AT CHICAGO.

IN response to a call issued December 8, 1899, and signed by Professors C. R. Barnes, H. H. Donaldson, S. A. Forbes, W. A. Locy and Jacob Reighard, about thirty naturalists of the Central States met at the Hull Biological Laboratory, on Thursday and Friday, December 28th and 29th. Among those present, in addition to the Chicago naturalists, were Professors Burrill, Kofoid and Smith, of the University of Illinois; J. G. Needham, of Lake Forest; H. V. Neal; of Knox College; Birge, of Wisconsin; Lee, Nachtrieb and Sigerfoos, of Minnesota; H. L. Osborne, of Hamline University; Nutting, of Iowa; Eigenmann, of Indiana and Reighard and Jennings, of Michigan. Professor Donaldson presided at all the meetings and at the dinner.

Thursday morning and Friday morning and afternoon were devoted to the reading of papers. Twenty-five titles were announced; but five of these were omitted through the absence of the naturalists who announced them or through lack of time. Thursday afternoon was devoted to a discussion on 'Methods and Results of Limnological Work.' Professors Birge and Kofoid opened the discussion, in which Professors Reighard, Nachtrieb, Eigenmann, Osborn and Davenport also took part. The papers of Professors Birge and Kofoid follow this report. On Thursday evening a dinner was held at the Quadrangle Club, and was attended by thirty persons. After the dinner the question of organization was considered. Since the American Society of Naturalists simultaneously meeting at New Haven had neither rejected nor adopted the