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REVIEW ARTICLE

ALFRED WERNER, PATHFINDER OF MODERN INORGANIC STEREO CHEMISTRY

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Abstract

"The Inorganic Kekule" Alfred Werner was born on December 12, 1866, at Mülhausen in Alsace. In 1913, he received the Nobel Prize for Chemistry. Werner's name will always be coupled with the theory of coordination theory which he established and also with his work on the spatial orientation of atoms in the inorganic molecule, the work he did, when he was only 24. In the present day coordination theory can be seen in accomplishment all over molecular compounds, organometallics, biomolecules, inorganic solids, minerals, catalysts and so on.

1. Introduction

Few words on Alfred Werner

1913 was an memorable year for each and every Indian; Rabindranath Tagore became the first Indian to be given the Nobel Prize for creating "insightful, speaking new and elegant poetry" and also in the year of 1913, Alfred Werner became the first Swiss chemist to win it for throwing new insight on the association of atoms in inorganic molecules(1).
Alfred Werner, son of factory foreman J.A. Werner and his wife Jeanne, *née* Tesche, was born on December 12, 1866, at Mülhausen in Alsace, where he went to school. He attended the École Libre des Frères (1872–78), followed by the École Professionelle, a technical school where he studied chemistry (1878–85). In 1886 he enrolled in the Eidgenössisches Polytechnikum (now the Eidgenössische Technische Hochschule [ETH], or Swiss Federal Institute of Technology) in Zürich, from which he was awarded a technical chemical degree (1889).Werner acknowledged a doctorate formally from the University of Zürich in 1890. In 1889 he was selected assistant in professor Lunge's laboratory at the Zurich Technical High School and he then engaged himself to assist with Professor Hantzsch in research. In 1890 he took his degree in the University of Zurich with a thesis on the spatial arrangements of the atoms in molecules containing nitrogen (2).Until 1891 he did more work on this subject area and visited Paris, where he worked under the guidance of Professor Berthelot at the Collège de France. In 1892 he returned to Zurich as a lecturer in the Technical High School, and in 1895, at the age of twenty-nine he became the professor of Chemistry in the university, giving the lectures on organic chemistry. In 1902, he took over the lectures on inorganic chemistry (3).
In 1894, Werner married Emma Giesker of Zurich, a member of a German family. They had one son, Alfred, and one daughter, Charlotte.

As a lecturer he was a convincing speaker with a contribution for clear explanations of tricky problems. Precious for others were his books *Neuere Anschauungen auf dem Gebiete der anorganischen Chemie* (New ideas in inorganic chemistry) and *Lehrbuch der Stereochemie* (Textbook of stereochemistry), both published in 1904.Werner was corresponding member of the Royal Society of Sciences (Königliche Gesellschaft der Wissenschaften) at Göttingen and of the Physico-Medical Society (Physikalisch-medizinische Sozietät) of Erlangen. He was awarded an honorary doctorate by the University of Geneva, and was an Honorary Member of the Society of Physics and Natural History in the same town, of the Physical Association of Frankfurt/Main, of the German Bunsengesellschaft, of the Société Vaudoise des Sciences Naturelles at Lausanne, and of the Chemical Society of London. He was also a permanent member of the Imperial Society of Friends of Natural History, Anthropology and Ethnography of Moscow. France conferred upon him the Leblanc Medal of its Societe Chimique and the distinction of Officier de l'Instruction Publique (4)

Werner was an open minded man, whose recreations were billiards, chess and the Swiss card game.

In 1913, the year in which he received the Nobel Prize for Chemistry, he was previously suffering from arteriosclerosis and by 1915 this had compelled him to give up his general lectures on chemistry and in 1919 he had to give up his Professorship. On November 15, 1919, he died at the early age of 53.

2. Near the beginning of his research work by Alfred Werner

Werner's first publication, a foundation stone of stereochemistry, based on his doctoral dissertation and written with his research supervisor, Arthur Hantzsch applied Joseph-Achille Le Bel and Jacobus Henricus Van't Hoff's perception of the tetrahedral carbon atom (1874) to the nitrogen atom. It explained several cases of *cis-trans* isomerism among trivalent nitrogen compounds such as the oximes, led to the breakthrough of new isomers, and positioned the stereochemistry of nitrogen on a trustworthy theoretical establishment. In 1892 Werner became an unsalaried lecturer at the Polytechnikum upon getting of his original research paper required in order to teach at a university. In this work, which elicited little notice because it was published (1891) in an local journal, he projected replacing August Kekule's firmly directed valence bonds in organic compounds with a more flexible approach of viewing affinity as a variously separable force acting equally in all directions from the atom's centre.

Werner's name will always be coupled with the theory of coordination which he established and also with his work on the spatial orientations of atoms in the inorganic molecule. In this work he gave the idea that, in the many compounds of nitrogen, the three valence bonds of the nitrogen atom are directed towards the three corners of a tetrahedron, the fourth corner of this being occupied by the nitrogen atom. In 1891 he had published a paper on the theory of affinity and valence, in which he substituted for Kekulé's idea of constant valence, the idea that affinity actually is an attractive force exerted from the centre of the atom which acts uniformly towards the entire parts of the Surface of the atom (5).

August Kekulé, the final of structural organic chemistry, had shown that carbon usually forms four bonds. Then in 1874 two young men, van't Hoff and Le Bel, proposed that these bonds are tetrahedrally inclined in space. Organic chemistry was experiencing great triumph in the latter half of the 19th century. It is in this environment that Werner started his research work.The act of spatial orientation of bonds (stereochemistry) as a special feature of carbon alone did not echo rational to him. Werner was inventing a new model in chemical science.

In 1893 he declared, in a paper on mineral compounds, his theory of variable valence, in which inorganic molecular compounds contain single atoms which act as central nuclei around which are, arranged a definite number of other atoms, radicals or other molecules in a simple, spatial, geometric pattern. The figure which expresses the number of atoms thus grouped round a central nucleus was called by Werner the coordination number, the most important of these coordination numbers being 3, 4, 6 and 8, the number 6 occurring more frequently. A lot of molecular compounds correspond to the number 6 type, and in the greater part of these there is a central atom with coordinated atoms at the corners of an octahedron (6).

For the next 20 years Werner and his collaborators extensively prepared new series of molecular compounds and studied their configurations. Finally, his work in the discovery of optically-active isomers of the complexes studied, the existence of which had been forecast by his hypothesis. More than 40 series of optically-active complexes with octahedral symmetry were isoiated in optically-active forms, with the result that the spatial configuration of the complexes to the coordination number 6 was established as firmly as that of the tetrahedral carbon atom of Van't Hoff and Le Bel. Werner also worked on complexes with other coordination numbers, in particular 4, for which the form can be tetrahedral or a plane square. As Paul Pfeiffer, in his account of Werner's work published in *Great Chemists* (1961, Edited by Eduard Farber, Interscience, New York) comments the coordination theory of Werner extended all through the entire range of systematic inorganic chemistry and into organic chemistry also. For his work on it Werner was awarded the Nobel Prize for Chemistry for 1913 (7).

At the time of its commencement, Werner's theory was mostly without experimental verification and the data that he cited in support of his ideas had been obtained by his primary scientific observation, the Danish chemist Sophus Mads Jørgensen. Jørgensen adhered to the rival Blomstrand-Jørgensen "chain theory," which was ultimately outdated by Werner's theory, the foundation for modern coordination chemistry (8).

Werner discarded Kekule's artificial distinction between "valence compounds," amenable to classical valence theory, and "molecular compounds," those not explicable by this theory. Werner projected a revolutionary approach in which the constitution and configuration of metal-ammines (now called "Werner complexes"), double salts, and metal salt hydrates were logical consequences of a new concept, the coordination number. He separated metal-ammines into two classes—those with coordination number six, for which he postulated an octahedral configuration, and those with coordination number four, for which he proposed a square planar or tetrahedral configuration. He also postulated two types of valence—primary valence, which bonded the anion to the metal atom, and secondary valence, which bonded the ammonia to the metal atom. Werner confirmed the validity of his views by citing numerous reactions, transformations, and cases of isomerism (9).

3. Most important theoretical Work by the Werner

A historically significant molecular compound, also called coordination compound or complex, is yellow colored $CoCl_3.6NH_3$. Werner formulated it as the salt $[Co(NH_3)_6]Cl_3$, where the six NH_3 molecules are coordinated to the central cobalt ion forming the complex cation $[Co(NH_3)_6]^{3+,}$ its ionic charge being balanced by $3Cl^-$. Here the coordination number is 6 and the geometry is octahedral. Coordination in terms of isomerism and other properties. All the chemistry was falling into a melodious pattern and finally in 1911, an asymmetric inorganic complex was resolved into optical isomers suggestive of the ultimate achievement of his belief (10).

4. Conclusion

Significance of Werner Coordination theory at the present day

In the present day coordination theory can be seen in accomplishment all over molecular compounds, organometallics, biomolecules, inorganic solids, minerals, catalysts and so on. This is so because polyhedral arrangement of valence is deep-seated in the electronic structure of atoms as was shown by Linus Pauling and others years later. His thoughts are applicable to almost the entire field of inorganic, organic, analytical, and physical chemistry, as well as biochemistry, geochemistry, and mineralogy.

5. Summary

Dmitri Ivanovich Mendeleev who invented the foundation of elemental order, the periodic table (1869), once said that a true mover of inorganic chemistry has to be "a thinking creative artist". Alfred Werner remains the most distinguished example. He was one of the first to show that stereochemistry is not restricted to organic chemistry but is a general occurrence. His coordination theory has had an effect on inorganic chemistry similar to that exerted on organic chemistry by the ideas of Kekule, Archibald Scott Couper , Le Bel, and van 't Hoff. He is sometimes called "the inorganic Kekule".

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