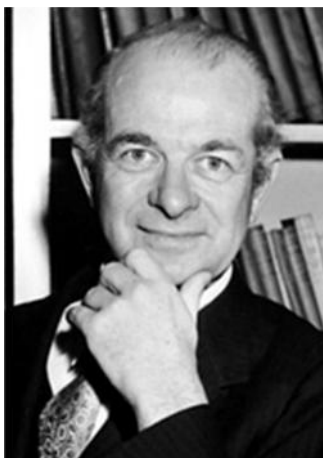


Nobel Prize in Chemistry 1954



Linus Carl Pauling

The Nobel Prize in Chemistry 1954 was awarded to Linus Pauling "*for his research into the nature of the chemical bond and its application to the elucidation of the structure of complex substances*".

RESEARCH INFORMATION:

When, in the early nineteenth century, Dalton had produced experimental proofs that matter consists of atoms it was not long before an explanation was sought of the forces that bind the atoms together. Berzelius was of the opinion that this chemical bond was caused by electrostatic attraction between the atoms; according to this belief, a bond was established between two atoms if one of the atoms was positively, and the other negatively charged. In 1819 when Berzelius presented his theory he could apply it almost exclusively to inorganic substances; only few organic substances were known as pure compounds, and the study of these was difficult due to their complicated and often insufficiently known composition. Berzelius, however, contrived to explain, with the help of the new theory, the bond conditions for a great number of inorganic substances, and could in this way contribute in a high degree to a greater clarity in this field.

Even in inorganic chemistry, however, certain difficulties arose. How should one explain, for instance, how two hydrogen atoms unite to become a hydrogen molecule? In order to obtain attraction between atoms, one of the atoms must be positive and the other negative; but why should two atoms of the same kind possess charges with opposite sign? And when the knowledge of organic compounds increased, new difficulties arose. Berzelius, for example, found it necessary to assume that the hydrogen atom was always positive and the chlorine atom always negative. Now it was also found that in organic molecules a hydrogen atom could often be exchanged for a chlorine atom, which should be impossible if one was positive and the other negative. With increased knowledge, problems that could not be explained by Berzelius' theory became more and more numerous, and the theory became discredited.

After the atomic theory had been accepted, it soon became apparent that another important object in the field of chemistry must be to determine not only the nature of the chemical bond but also how the atoms are arranged geometrically when they unite to form larger groups, such as molecules. Permit me to quote from a book, remarkable in its day, *Die Chemie der Jetztzeit* written in 1869 by the Swedish chemist Blomstrand:

"It is the important task of the chemist to imitate faithfully in his own way the elaborate constructions which we call chemical compounds, and in the erection of which the atoms have served as building stones, to determine as to number and relative position the points of attack at which one or the other of the atoms attaches itself to the other, in short, to determine the distribution in space of the atoms."

Blomstrand makes it the aim, therefore, to find the geometrical construction of substances, or what is nowadays called their structure.

At the end of the last century it became obvious that one had to consider several different kinds of chemical bond. Thus, the difficulties of the Berzelius theory were also explained. Berzelius' interpretation was in principle correct as regards a very important type of bond, but he had made the mistake of applying it also to bonds of a different type. After Bohr had introduced his atomic theory one could moreover with its help give a fairly

satisfactory explanation of the Berzelius bond. As this bond occurs between electrically charged atoms, so-called ions, this bond type has often been called the ionic bond. The most typical ionic bonds unite the atoms in the crystals of simple salts.

The bond which above all others had prevented a general application of the Berzelius theory is now commonly known as the covalent bond. It occurs commonly when atoms unite to form a molecule and was once characterized by the famous American chemist Gilbert Newton Lewis as "*the* chemical bond". The bond between the two hydrogen atoms in a hydrogen molecule, which, as was said before, could not be explained by Berzelius' theory, is covalent.

For a long time it was difficult to explain the nature of the covalent bond. Lewis, however, succeeded in 1916 in showing that it is brought about by electrons - generally two - which are shared in common by two neighbouring atoms, thereby uniting them. Eleven years later Heitler and London were able to give a quantum-mechanical explanation of the phenomenon. An exact mathematical treatment of the covalent bond, however, was possible only in the simple case where only one electron unites the two atoms, and when these do not contain additional electrons outside the atomic nuclei. Even for the hydrogen molecule, which contains two electrons, the treatment cannot be absolutely exact, and in still more complicated cases the mathematical difficulties increase rapidly. It has, therefore, been necessary to use approximate methods, and the results depend to a large extent on the choice of suitable methods and the manner of their application.

Linus Pauling has actively contributed towards the development of these methods, and he has applied them with extreme skill. The results have been such as to be easily usable by chemists. Pauling has also eagerly sought to apply his views to a number of structures which have been experimentally determined during the last decades, both in his own laboratory in Pasadena and elsewhere. It is hardly necessary to mention that we have nowadays great possibilities of reaching Blomstrand's objective of determining the distribution of atoms in space. This is principally done by methods of X-ray crystallography involving an examination of how a crystal influences X-rays in certain respects, and then

out of the effect seeking to determine how the atoms are placed in the crystal. Pauling's methods have been very successful and have led to observations which have further advanced the theoretical treatment.

But if the structure of a substance is too complicated it may become impossible to make a more direct determination of the structure with X-rays. In such cases it may be possible, from a knowledge of bond types, atomic distances and bond directions, to predict the structure and then examine whether the prediction is supported by the experiments. Pauling has tried this method in his studies of the structure of proteins with which he has been occupied during recent years. To make a direct determination of the structure of a protein by X-ray methods is out of the question for the present, owing to the enormous number of atoms in the molecule. A molecule of the coloured blood constituent hemoglobin, which is a protein, contains for example more than 8,000 atoms.

In the late nineteen thirties Pauling and his colleagues had already begun to determine with X-rays the structure of amino acids and dipeptides, that is to say, compounds of relatively simple structure containing what may be called fragments of proteins. From this were obtained valuable information - about atomic distances and bond directions. These values were supplemented by the determination of the probable limits of variation for distances and directions.

On this basis Pauling deduced some possible structures of the fundamental units in proteins, and the problem was then to examine whether these could explain the X-ray data obtained. It has thus become apparent that one of these structures, the so-called alpha-helix, probably exists in several proteins.

How far Pauling is right in detail still remains to be proved, but he has surely found an important principle in the structure of proteins. His method is sure to prove most productive in continued studies.

It is hardly necessary to question the practical use of the knowledge of the nature of chemical bonds and of the structure of substances. It is obvious that the properties of a substance must largely depend on the strength with which its atoms are united and the

nature of the resulting structure. This I does not only apply to the physical properties of the substance, for instance hardness and melting point, but also to its chemical properties, that is to say how it participates in chemical reactions. If we know how certain atoms or groups of atoms are placed in a molecule we can often predict how the molecule should react under given conditions. And as every reaction results in the breaking of some bonds and the formation of others the result will largely depend on the relative strength of the different bonds.

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