The Nobel Prize in Chemistry 1953

Presentation Speech by Professor A. Fredga, member of the Nobel Committee for Chemistry of the Royal Swedish Academy of Sciences

Your Majesties, Royal Highnesses, Ladies and Gentlemen.

"Even the ancient Greeks..." is a frequent preamble to the survey of a historical event and the hearer sees a vision of frightening profundity. I should like today to begin with Democritus of Abdera who formulated the first atomistic conception of the world and thus created the first atomic concept. However, the meaning of this concept did not become more closely defined until about 1800 by the Englishman Dalton who assumed that each element had its specific type of mutually identical atoms. In the formation of a chemical compound a number of atoms of two or more elements are linked together by chemical bond forces into particles for which the Italian Avogadro introduced the name molecules. In the second half of last century through the work of the German Kekulé and the Dutchman van 't Hoff, knowledge was gained of important principles in the architecture of the molecules. The relative positions of the atoms have been determined to a certain extent; they link one another together to form chains, simple or branched, or to form more complex structures. Both molecules and atoms, however, were purely hypothetical concepts at that time; not until the turn of the century was definite proof of their actual existence forthcoming, and so it became possible to determine their actual size and mass. As expected they were found to be very small. The number of molecules in one litre of water is expressed by a number containing 26 digits.

It was often wondered how many atoms could be combined in one molecule, to what degree this compression of matter could be taken, to use the phrase with which the situation was expressed by a leading research worker of the day. The fact that the atoms in the molecule are held together by chemical bond forces is closely related to the question of the strength of the chemical bond, of which only little was known. On the one hand it was known that the molecules of apparently very stable compounds could readily be split by electrolytic dissociation, on the other hand there was a dawning realization that chemical forces had a profound bearing on the structure of solid crystals. Molecules with one to two hundred atoms had been built in stages and this fact was considered remarkable. There was an eagerness to experiment, to advance further, but it was believed that little more could be achieved in this way.

In the early 1920's Professor Staudinger expressed the view that a molecule could be very large, almost arbitrarily large in fact, that such macromolecules could very easily, sometimes with apparent spontaneity, be formed of 10,000 or 100,000 atoms and that the particles of colloidal solutions were in many cases actual molecules of this type. I shall attempt to reproduce his trend of argument.

In organic chemistry it not infrequently occurs that sparingly soluble or insoluble resinous or pitch-like masses are obtained instead of the product expected; occasionally a change of this type occurs without visible cause. All the indications are that in some way the molecules become joined together. Such products were usually designated high polymer or high molecular substances but for many reasons there was a desire to regard the phenomenon as a physical one. On the other hand numerous cases were known where a small number of molecules, perhaps two or three, united to yield a larger molecule with a ring structure. Professor Staudinger pointed out that the formation of high molecular substances occurs where ring closure is expected in principle but is hindered for geometric reasons or, in other words, in cases where the ends of the atomic chains only meet with difficulty. Here, however, the chain ends must link up with other molecules which in turn capture new molecules and so the chain grows until the process is interrupted by some external circumstance, perhaps because the material is exhausted. The high molecular products were thus alleged to consist of chains formed in this way and since there can scarcely be any doubt that the ring molecules just referred to have been created by means of normal chemical bond forces, such must also be the case with the chains.

This argument, which strikes us nowadays as completely obvious, was very strange in the early 1920's, running partly counter to the spirit of the period, and the next ten years were charged with controversy. It was theoretically very difficult and practically very laborious to find decisive evidence or counter-evidence. For the time being it was impossible to determine the molecular weights of the magnitudes involved here but it was considered that the new theory placed impossible demands on the strength of the chemical bond forces. Concepts and definitions had to be revised, including the chemical compound concept. Categories of compounds had to be recognized in which the molecules are not completely identical. The high molecular compounds consist of chain molecules constructed according to a common pattern and often with a characteristic average length but the length of the individual chains depends upon arbitrary circumstances. The new theory was not universally recognized until the 1930's.

The macromolecular theory had then already been adopted in technology. People learned to use the strong giant molecules for the manufacture of what are nowadays commonly termed plastics. Isolated products of this type had been known previously but now theoretical principles for further work, with almost limitless possibilities for varying the properties of the material according to different requirements were available, and so in the 1930's and 1940's a powerful growth came about in this sector. We are aware that in many respects this development has laid its imprint on the modern material culture; it is indeed stated that we are living in the age of plastics. For pure science too, however, the macromolecular theory has been of the greatest significance.

An impressive number of workers have been active in the macromolecular field during the last decennia. Professor Staudinger has not been involved directly in the technical and industrial development but without his energetic and bold pioneering work this development would scarcely be conceivable.

Professor Staudinger. More than thirty years ago you expressed the view that a chemical molecule can attain an almost arbitrary size and that such macromolecules are of great importance in our world. Your view was based on logical reasoning. You drew attention to the fact that what are termed high polymers are formed when for some reason or another an anticipated ring closure fails to occur. You thus submitted an argument which an organic chemist cannot ignore. Moreover, in extensive and painstaking series of studies you have provided experimental proof.

It is no secret that for a long time many colleagues rejected your views which some of them even regarded as abderitic. This was understandable perhaps. In the world of high polymers almost everything was new and untried. Long standing, established concepts had to be revised or new ones created. The development of the macromolecular science does not present a picture of a peaceful idyll.

As time passed, the conflicts vanished and the controversies were stilled. Unity has been achieved on the major issues and the importance of your pioneering work has become more and more apparent. In recognition of your services to the natural science and the material culture made possible by your discoveries in the field of high molecular compounds, the Royal Swedish Academy of Sciences has resolved to award you the Nobel Prize for this year. I congratulate you on behalf of the Academy and would ask you to receive the Nobel Prize from the hands of His Majesty the King.

From *Nobel Lectures*, Chemistry 1942-1962.