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Nobel Prize in Chemistry 1960

Willard Frank Libby

The Nobel Prize in Chemistry 1960 was awarded to Willard F. Libby *"for his method to use carbon-14 for age determination in archaeology, geology, geophysics, and other branches of science"*.

RESEARCH INFORMATION:

The Royal Swedish Academy of Sciences this year has decided to award with the Nobel Prize for Chemistry a scientific feat which is less a direct improvement of our material living standards, but more a means of widening and deepening our knowledge in different scientific fields. Professor Willard Libby has been selected to be the prize-winner for his method of age determination of materials of biological origin by use of carbon-14 as a measurer of time. His method has obtained widespread use and has become indispensable in archaeology, geology, geophysics and other sciences. Fortunately, it is so simple - which is probably not always the case with chemical research distinguished with the Nobel Prize - that everyone should be able to understand the conditions and principles for its execution.

Carbon-14 is a kind of carbon, an isotope of carbon with an atomic weight of 14, which is found in the carbon dioxide of the air. It is formed high up in the atmosphere by

cosmic radiation coming from outer space. How that occurs, we can ignore. The newly formed carbon-14 has high energy at the moment of its formation, so that it rapidly oxidizes to carbon dioxide, which spreads out and distributes itself evenly in the atmosphere.

The ratio of carbon-14 in the carbon dioxide of the atmosphere is very low. In about one million million of these carbon atoms, there is only one which has an atomic weight of 14. But nevertheless, this ratio can be determined, for carbon-14 is a radioactive isotope and manifests itself by its radiation. It is converted into nitrogen by the emission of an electron which can be detected by a sensitive apparatus. The disintegration is such a slow procedure, however, that 5,600 years are required to convert half of these atoms into nitrogen. After another 5,600 years, there is still one quarter left, and after an equally long period of time one eighth, etc. Carbon-14 is thus said to have a half-life of 5,600 years.

If it is assumed that the intensity of the cosmic radiation has been constant during the last few tens of thousands of years, then the average lifetime of carbon-14 - which is approximately 8,000 years - should be sufficiently long to allow for the formation of a stationary state in the concentration of this isotope not only with reference to the atmosphere, but also to the hydrosphere and biosphere as well. Active and non-active carbon dioxide are dissolved in a contant ratio in the water of the seas and lakes where they are converted into carbonate and bicarbonate, and they are assimilated by trees and plants, and finally also by the animals, which ultimately live on plants. The ratio between active and non-active carbon in all living organisms is the same as that in the air.

When an organism dies, the exchange of carbon with its surroundings ceases and the carbon atoms are inexchangeably held fast in the big molecules of the biological substances. Because the activity of the carbon atoms decreases at a known rate, it should be possible, by measuring the remaining activity, to determine the time elapsed since death, if this occurred during the period between approximatively 500 and 30,000 years ago.

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This hypothesis was published by Libby in 1947, and with his great experimental skill it did not take him long to prove the validity of the theory. Recently dead biological substances, such as wood and plant materials, seal oil and others, showed an activity which could the calculated from the knowledge of the production of carbon-14 in the atmosphere, and its rate of decomposition. Fossil material, such as petroleum, was completely inactive; it comes from organisms which lived millions of years ago.

These first control experiments were preceded by a complicated enrichment procedure, but thanks to Libby's experience in working with lowactivity substances, he succeeded in refining the activity measurements so that the preliminary concentration procedures became unnecessary. If this had not been possible, his method of age-determination would not have turned out to be the important tool for the advancement of science it has now become.

This refined method was then tested by Libby and co-workers on, among other things, charcoal and wood found in Egyptian graves. The oldest, about 5,000 years old, were from the time of Vizier Hemaka; the youngest, about 2,000 years old, were from the Ptolemaic period, and others were from the time between these two periods. For all of these graves, the Egyptologists had been able to determine the time when they were built. Libby also checked his method by determining the age of heartwood from the trunks of redwood trees *(Sequoia sempervirens)*, and of Douglas firs *(Tsuga douglasii)*, which were several thousand years old and whose exact age could be determined by counting the annual rings. The results he thus obtained from these control experiments left no doubts about the reliability of the method.

It was then used to solve problems met with by archaeologists and geologists. Important results were obtained in rapid succession. Egyptologists received important support in their efforts to create a chronology dating back to about two thousand years earlier than the first royal dynasty, which started around 3,400 B.C. It was proved that the last great glacial period in the northern parts of Europe and North America was simultaneous, and still had a considerable extension about 11,000 years ago. Traces of the

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first human habitations in these regions were dated to about 10,000 years ago. In the southern part of France, on the other hand, beyond the advance of the ice, remnants were found of charcoal from the campfires of human cave-dwellers, remnants which proved to be 15,000 years old. Similar findings were made in Iraq, showing that people lived there 25,000 years ago. This is just to mention a few of the age determinations which throw light on the prehistory of mankind.

It is true that archaeologists and geologists have had methods at their disposal by which they could date their material within the periods of time mentioned here. In Sweden, pollen analysis, and Gerard De Geer's counting of clay layers are well known. The carbon-14 method is a complement to those methods, enabling more accurate determinations to be made.

The carbon-14 method has also been applied in oceanography, for example, for the dating of relatively recent sea sediments. It has made possible more and more accurate determinations of the rate of turnover of the oceanic deep water, and therefore plays an important role nowadays in connection with one of the central problems of physical oceanography, i.e. water circulation in the sea.

Libby's dating method soon attracted attention from the scientific world, and it was not long before carbon-14 laboratories were set up in many countries. Today, some forty institutions carry on investigations in this field, nearly half of them in America. Also here, in Sweden, we have such institutions, and their investigations have given results of great value. All age determinations - nowadays several thousand every year - are published in a general review, and thus made rapidly available throughout the world. The literature in this field has grown from year to year, and at present covers an impressive area.

One of the scientists who suggested Libby as a candidate for the Nobel Prize has characterized his work in the following way: "Seldom has a single discovery in chemistry had such an impact on the thinking in so many fields of human endeavour. Seldom has a single discovery generated such wide public interest".

Professor Libby. The idea you had 13 years ago of trying to determine the age of biological materials by measuring their carbon-14 activity was a brilliant impulse. Thanks to your great experimental skill, acquired during many years devoted to the study of weakly radioactive substances, you have succeeded in developing a method that is indispensible for research work in many fields and in many institutes throughout the world. Archaeologists, geologists, geophysicists, and other scientists are greatly indebted to you for the valuable support you have given them in their work. The Swedish Academy of Sciences desires to join those who offer you grateful thanks for what you have done for the benefit of so many sciences, and has decided to award you this year's Nobel Prize for Chemistry. May I congratulate you on behalf of the Academy, and ask you to receive the prize from the hands of His Majesty the King.

For more details please visit:

http://www.nobelprize.org/nobel_prizes/chemistry/laureates/1960/press.html