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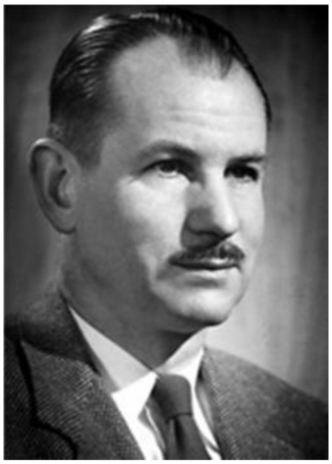
Nobel Prize in Chemistry 1951



Edwin Mattison McMillan

Glenn Theodore Seaborg

The Nobel Prize in Chemistry 1951 was awarded jointly to Edwin Mattison McMillan and Glenn Theodore Seaborg *"for their discoveries in the chemistry of the transuranium elements"*

RESEARCH INFORMATION:

In his famous treatise on air and fire, published in 1777, Scheele writes that in some quarters at that time it was regarded as futile to make any more research into what elements bodies might consist of. "A depressing prospect" he adds, "for those whose greatest pleasure it is to study the composition of substances found in nature." Scheele's own experience and the subsequent developments up to our day have shown that, at the end of the 18th century, there certainly still was enough to do for those who wanted to discover new elements. At least as many elements as were then known still remained to be discovered.

In 1794, Scheele's friend from his days in Uppsala, the Åbo professor Johan Gadolin published in the proceedings of the Academy of Sciences a report on a "Study of a black heavy kind of stone from Ytterby Stone Quarry at Roslagen". In this mineral - later called gadolinite, after him - he had found a hitherto unknown earth, the so-called yttria. Nine years later Berzelius, in a mineral from Riddarhyttan in Västmanland (the so-called "Bastnäs tungsten") discovered another earth, ceria.

These two discoveries together provided the starting-point for studies of the so-called rare-earth elements which went on throughout the 19th century. Already Gadolin had reckoned with the possibility that the yttria isolated by him was not a simple substance and it proved indeed later to consist of several oxides. Berzelius' ceria turned also out to be a mixture. The separation of the different components in these compound earths has been no easy task, since they are chemically very similar to one another. Little by little, however, it has been possible to divide them up completely, and within this group alone as many as 14 different elements have been isolated. Swedish chemists, chief among them being Mosander and Cleve, have made very valuable contributions in this domain of chemistry. Of the rare-earth metals many - yttrium, terbium, erbium, ytterbium, scandium, thulium, holmium - have been given names that show their origin in various Swedish localities.

Besides this group of closely connected rare-earth metals many other elements were discovered in the course of the 19th century. A comprehensive survey of all the known elements was provided in 1869 by the establishment of the Periodic System. At that time Mendeleev and Lothar Meyer independently discovered that there were clear evidences of periodicity in the chemical character of the elements when they were arranged in the order of increasing atomic weights. From this regularity Mendeleev was able to conclude that certain gaps remained still to be filled, and he could even predict all the most important properties of these still undiscovered elements and their compounds. His predictions have been fully confirmed by later discoveries.

During the years around 1920, Niels Bohr's investigations on the structure of atoms threw new light on the Periodic System. It was now possible, among other things, to explain the chemical similarity between the rare-earth elements. The positive charge in the nucleus of the atom and the number of electrons surrounding it rises by one unit for every step upwards in the element series. This additional electron usually forms part of the outermost shell of the atom, and since the chemical characteristics depend on the structure of the atom in just this part, the successive members in the series of elements can for the most part be clearly distinguished from one another in respect to their chemical properties. But within the group of the rare earths it is not the outermost electronic shell that is developed, nor the shell beneath it, but the one that underlies that.

The result is that, through the whole series of these elements, the exterior parts of the atomic structure remain virtually unchanged. Together they come to form what might be called a group of quasi-isotopes. Since they are like lanthanum, the first element in the series, they have been given the comprehensive name of lanthanides.

If, said Bohr, there existed an extension of the series of elements beyond the heaviest of them all, Nr. 92, uranium, then this would form a new series of very closely associated elements. They would all resemble uranium and, by analogy with the lanthanides, would form a series of uranides.

By experiments which were carried out during the years 1936-1938, Otto Hahn and Lise Meitner believed they could confirm Fermi's statement that the transuranium elements are formed by irradiating the heaviest elements with neutrons. But these synthetic elements were not like uranium, but appeared to be homologues of elements so dissimilar to one another as rhenium, the platinum metals, and gold. Hahn and Strassmann made, however, late in 1938, the epoch-making discovery that is was not really a question of transuranium elements at all here. The heavy atoms were found to split up into substances belonging to the middle of the elemental series and this brought the whole problem into a new stage.

The first transuranium element of which there was definite proof was produced by McMillan and Abelson in May 1940 at the University of California, by irradiating uranium with neutrons with the aid of the cyclotron built by Lawrence. It was obtained as a disintegration product of a beta-radiating uranium isotope, which has a half-life of 23 minutes. Hahn and Meitner had also discovered this body, but their preparation was too weak for its daughter-product to be demonstrated. The Americans were able to investigate this thoroughly, and showed that it forms an isotope of element 93, that is to say, a transuranium element. They called it *neptunium* after the planet Neptune, whose orbit lies next outwards after Uranus in the solar system. By irradiating uranium with rapid neutrons or with heavy-hydrogen nuclei, deuterons, other neptunium isotopes were soon produced in Berkeley.

In 1940 McMillan and Seaborg and their fellow-workers had already reported that when neptunium disintegrates it gives rise to an element 94. By analogy with the way in which names had been found for neptunium and uranium, this second transuranium element was called *plutonium*, after the planet Pluto, which has its orbit next outside that of Neptune. The first isotope of this element, which has a half-period of 24,000 years and thus is relatively stable, is what is called an atomic fuel. This plutonium isotope reacts with slow neutrons in the same way as the uranium isotope ^{235}U, that is to say, when it is split it develops great energy and gives off neutrons. In this way it came to play an important part in the atomic-bomb project during the war, and methods were developed for its production on a large scale.

After these problems, conditioned by the war, had been solved, Seaborg, as leader of a comprehensive group of able colleagues, completed the studies of the transuranium elements. In doing this, he has written one of the most brilliant pages in the history of the discovery of chemical elements.

Not less than four more transuranium elements have been produced. The chemical characteristics of all these new elements have been established by developing a refined ultra-microchemical experimental technique. Bohr's prophesy that in the transuranium elements we are dealing with a group of substances of the same sort as the rare-earth metals, has thus been confirmed. However, this new series of closely associated elements does not begin with uranium 92, but with actinium 89. Thus, corresponding to the lanthanides, there are the actinides, and a certain agreement can be found member for member between these two series. Seaborg therefore proposed for the new transuranium elements 95 and 96 the names *americium* and *curium*, in analogy with their corresponding rare earths europium and gadolinium (after Europe and Gadolin respectively). The two transuranium elements most recently discovered, berkelium and californium, correspond to terbium and dysprosium in the lanthanides.

By irradiating different sorts of heavy atoms with neutrons, protons, deuterons, helium nuclei, or, most recently, carbon nuclei, a great number of isotopes have been produced from the six transuranium elements. The study of these isotopes' formation and properties has yielded a wealth of scientific material.

A great many, originally isolated, observations on the radioactive transmutation series were made during the work on the great plutonium project. Thanks above all to Seaborg's activities it has been possible to bring these observations together into a comprehensive wholeness. In this way there was discovered an entirely new radioactive series which, from its most long-lived member, is now called the neptunium family.

The mass numbers of the three radioactive families which were previously known have the form 4n (thorium series), 4n + 2 (uranium series) and 4n + 3 (actinium series). Here the neptunium series fills a gap with mass numbers of the form 4n + 1.

During his studies on the reaction of slow neutrons with thorium, Seaborg and his colleagues made a discovery which opened important technical prospects. They obtained a uranium isotope ^{233}U, which gives off alpha-rays and has a half-period of 120,000 years. This isotope, like ^{235}U, can be used as an atomic fuel. Thorium, which is more plentiful in nature than uranium, will therefore probably play a role as a basic material in the production of atomic energy.

The Swedish Academy of Sciences is of the opinion that these discoveries in the realm of the chemistry of the transuranium elements, of which I have here tried to give a brief account, are of such importance that McMillan and Seaborg have together earned the 1951 Nobel Prize for Chemistry.

For more details please visit:

http://www.nobelprize.org/nobel_prizes/chemistry/laureates/1951/press.html