

Nobel Centennial Essays

A Century of Chemical Dynamics Traced through the Nobel Prizes

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1943: George de Hevesy

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Nobel Prize in Chemistry 1943 George de Hevesy (1885–1966)

for his work on the use of isotopes as tracers in the study of chemical processes

The Nobel presentation for Wilhelm Ostwald in 1909 contained a statement that reflected a characteristic optimism of the end of the first decade of the 20th century. It said: “The rate of a reaction is a measurable parameter and hence all parameters affecting it are measurable as well. Catalysis, which formerly appeared to be a hidden secret, has thus become what is known as a kinetic problem and accessible to exact scientific study. Ostwald’s discovery has been



George de Hevesy

Photo: Aaron Hilde collection

profusely exploited. Besides Ostwald himself a large number of eminent workers have recently taken up his field of study and the work is advancing with increasing enthusiasm. The results have been truly admirable” (1). With that 1909 statement as background, it is rather surprising then that the next Nobel Prize for work related to chemical dynamics was not awarded until 34 years later, with the 1943 Nobel Prize to George de Hevesy for developing isotope tracer techniques (2). In fairness to the Nobel committee responsible for the 1909 statement, the years between 1909 and 1943 were marked by two world wars during which Nobel Prizes were not awarded. During World War II, Nobel Prize awards resumed in 1943 for chemistry, physics, and medicine, but not until 1944 for peace and literature.^W In the field of chemistry between 1910 and the last pre-WW II Nobel Prize in 1939, Nobel Prizes went primarily for organic synthesis, for laying the foundations of modern biochemistry, or for isolating and characterizing new elements and isotopes (3).

George de Hevesy developed his own interest in isotopes while working in Ernest Rutherford’s lab in Manchester, England between 1910 and 1913, and with Frederic Paneth at the Vienna Institute of Radium Research from 1913 to 1915 where de Hevesy and Paneth carried out the first radioactive tracer research (3). Rutherford had already received the Nobel Prize in 1908 for his “investigations into the disintegration of the elements and the chemistry of radioactive substances” (4). Prior to going to work with Rutherford in 1910,

de Hevesy studied at Budapest University in his native Hungary and at Berlin Technical University. After receiving his doctorate from the University of Freiburg im Breisgau in 1908, de Hevesy worked for two years as an assistant at the Institute of Physical Chemistry, Technical University of Switzerland and briefly with Fritz Haber, who was then working on the catalytic synthesis of ammonia by what later came to be known as the Haber process, and for which Haber received the Nobel Prize in 1918 (5). After serving in the Austro-Hungarian army during World War I, de Hevesy went to Copenhagen in 1919 to join the Institute for Theoretical Physics headed by Niels Bohr. Bohr received the Nobel Prize in physics in 1922 for his well-known theory of atomic structure (6). Bohr and de Hevesy had worked simultaneously in Rutherford’s lab in Manchester a decade earlier. It was, of course, Rutherford’s famous alpha-particle scattering experiments, performed in 1909 (7), that led to the original nuclear model of the atom and ultimately to the Bohr model. That chronology is included in most introductory texts describing the development of modern models of atomic structure.

The early isotope work in Rutherford’s lab that led eventually to de Hevesy’s Nobel Prize was, ironically, a failed experiment. Rutherford was interested in studying the properties of what was then known as radium-D in radioactive lead, and he was frustrated by his inability to separate the radium-D from the bulk of the lead (8). This is described in de Hevesy’s own words in an account published in this *Journal* in 1963: “One day...Rutherford...suggested that if I were worth my salt, I should separate radium-D from all that nuisance of lead. Being a young man, I was an optimist and fully convinced that I would succeed; but even though I worked very hard for a year, trying a large number of separations, I failed entirely. To make the best of this depressing situation, I decided to make use of the inseparability of radium-D from lead. By adding pure radium-D of known activity to 1 mg of lead nitrate, the lead present in that compound could be labeled, and its path followed through chemical reactions with the aid of radioactive measurements” (9). Similarly, de Hevesy failed in all attempts to isolate inactive radium-G, the last of the decay products of radium. We now know that radium-D and radium-G are actually ^{210}Pb ($t_{1/2}$ 21 years) and ^{206}Pb (24.1% natural abundance), respectively (10).

Although the chemical nature of radioisotopes is well understood today, de Hevesy’s discovery was remarkable at the time. After recognizing that the difficulty of separating radioisotopes from “ordinary” atoms of the same element meant that they were chemically identical, he went on to pioneer the use of radioisotopes as tracers, a technique that continues today in investigations of chemical reactions as well

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as in physiological studies. In fact, de Hevesy himself appears to have been more interested in the uses of tracers in physiological studies than in mechanistic chemical investigations. For example, he was among the first to employ ^{32}P -labelled sodium phosphate injected into animals and humans to study the rate of incorporation of phosphorus from the blood stream into various tissues, organs, bones, and tooth enamel. He performed similar experiments with radio-labeled sodium, potassium, lead, bismuth, and thallium in plants and animals. He also employed stable nuclides—for example, using deuterium-enriched water provided by Harold Urey,¹ de Hevesy found that fish and amphibians swimming in that water take up deuterium and come to equilibrium with their environment with respect to deuterium in about four hours, and that humans who drink D_2O excrete deuterium in their urine in about 26 minutes (2, 9).

de Hevesy's contribution to the study of chemical dynamics using isotopic tracers is unquestionably an important one. Although much of his own work was devoted to biological and physiological processes, de Hevesy also conducted some direct investigation of chemical dynamic processes himself. For example, he used ^{210}Pb as a marker to determine the solubility of lead chromate and lead sulfate in various solvents and under various conditions. He precipitated "thorium-D" (^{212}Pb , $t_{1/2}$ 10.64 hours) (10) onto the surface of lead and studied the diffusion of the labeled lead atoms in the solid by monitoring the decrease in radioactivity as the radio-labeled lead isotope diffused into the bulk material. By this technique he also was able to determine the crystal lattice dissociation energy of lead, finding it to be comparable to the heat of vaporization of lead. de Hevesy is credited with developing the neutron activation analysis technique, one of the most powerful non-destructive methods for the elemental analysis of solid samples. Of all his accomplishments, de Hevesy was most proud of his discovery of the element hafnium in 1923 while working with Niels Bohr—in part because of the difficulty of separating hafnium from zirconium, where hafnium occurs naturally at 1% to 5% abundance, but also because of the importance of hafnium in organizing the periodic table (8, 9). Thus it can be seen that in addition to chemical dynamics, de Hevesy made direct contributions to many branches of science through his research with isotopes.

Modern chemists studying chemical reaction mechanisms are less reliant on isotope tracer techniques than were their counterparts half a century ago. This is a result of safety and regulatory issues and new instrumental techniques. Nevertheless, isotope tracer experiments continue to be prominently featured as examples in the teaching of reaction mechanisms in the classroom, if not in the laboratory. In addition, de Hevesy's contributions to our understanding of

isotopes as chemical species is critical to modern NMR and to mass spectroscopy, both of which are now among the most powerful methods for determining chemical structures and for studying reaction dynamics.

Notes

1. Harold Urey was the chemistry Nobel Laureate in 1934 for his discovery of deuterium.

Supplemental Material

A list of all recipients of the Nobel Prize in Chemistry, their affiliations, and work for which the award was made is available in this issue of *JCE Online*.

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