STEFANIE HOROVITZ, ELLEN GLEDITSCH, ADA HITCHINS, AND THE DISCOVERY OF ISOTOPES

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In the scientific discovery process, one tends to focus on the "Great Name" and ignore the co-researcher who made the actual discovery or contributed significantly to the discovery. The first detection of pulsars was a classic example. The observation was made by a graduate student, Jocelyn Burnell, but it was her supervisor, Anthony Hewish, who received the Nobel Prize for the discovery (1). In the first decades of the 20th century, this lack of attribution to the lab-bench researcher has had a significant effect of hiding the contributions of women scientists, for few were able to break through the "glass ceiling" and attain recognition as prime researchers.

Atomic science was one area where women scientists played active though subordinate roles (2) (with the exceptions of Marie Curie and Lise Meitner). For example, Ernest Rutherford's first research assistant was a woman—Harriet Brooks. We have reported elsewhere on her career, including the discovery of the recoil of the radioactive atom (3). In this paper, the focus will be on the contributions of three women to the early work on isotopes: Stefanie Horovitz, Ellen Gleditsch, and Ada Hitchins. But first, it is necessary to review the groundwork that made the discovery of the existence of isotopes possible.

Background

Present-day scientists tend to forget that, for the early history of chemistry, atomic weight was of supreme importance. For example, the value of the atomic weights of elements was the prime focus of the Karlsruhe Congress of 1860 (4). Thus chemists were inculcated with the view that the foundations of chemistry depended upon the unique value of the atomic weight of each element—and on the immutability of the elements themselves.

The first crack in the façade of traditional chemistry came with the discovery of radioactive transformations (5). The various species in the decay sequences were identified by names linked to that of the parent. For example, thorium decayed to mesothorium I, to mesothorium II, to radiothorium, to thorium X, and so on. At the time, each of these species was believed to be a new and unique element. It was McCoy and Ross in 1907 who provided the next piece in the puzzle with the statement that (6):

> Our experiments strongly indicate that radiothorium is entirely inseparable from thorium by chemical processes.

Examples of chemically nonseparable pairs (and groups) of radioactive elements began to accumulate very rapidly. Rather than use the cumbersome phrase 'radio elements chemically nonseparable,' Soddy suggested that the term 'isotope' be introduced (7).

It was the Fajans-Soddy Group Displacement Law that provided the next step in the puzzle (8). In radioactive decay, loss of an α-particle resulted in a two-step shift to the left in the periodic table with an accompanying atomic weight loss of four units, while loss of a β-particle resulted in a one-step shift to the right with a negligible change in atomic weight. Starting with the atomic masses of uranium and thorium, Soddy calculated the expected atomic weights of the lead produced from their respective radioactive decay as very different from the 207.2 of 'normal' lead (9). To chemists, finding samples of lead that had 'abnormal' atomic weight would be a confirmation of the existence of isotopes and proof of the group displacement law. In particular, lead from the decay of uranium-238 was predicted to have an atomic weight of about 206 while that from the decay of thorium-232 was expected to have an

Ellen Gleditsch, graduation photo, 1902. (T. Kronnen and A. C. Pappas)

atomic weight of about 208. It is the contributions of three women scientists to the discovery of lead with 'abnormal' atomic weights that will be the focus of this study (10).

To accomplish this task, researchers needed lead-containing samples from uranium or thorium ores. In addition, for the results to be accepted among the scientific community, the researchers themselves had to have credibility in the field of the determination of atomic weights to high precision. Although Soddy and his collaborator, Henry Hyman, and Maurice Curie, nephew of Marie Curie, both reported atomic weights of radioactive-origin lead that were significantly different from that of normal lead (11), neither of these reports was sufficiently reliable in the eyes of analytical chemists. As Badash has commented (12):

> Fajans soon realized that the task [of precise atomic weight determination] required such accuracy that only the results of recognized experts would be widely accepted. Soddy persisted in his efforts, only to have his results viewed sceptically in some quarters.

The world's leading expert on the measurement of atomic weights was Theodore William Richards of Harvard (13), but almost as high in estimation were his two former students, Gregory Paul Baxter, also of Harvard, and Otto Hönigschmid at the Radium Institut in Vienna (14).

Stefanie Horovitz

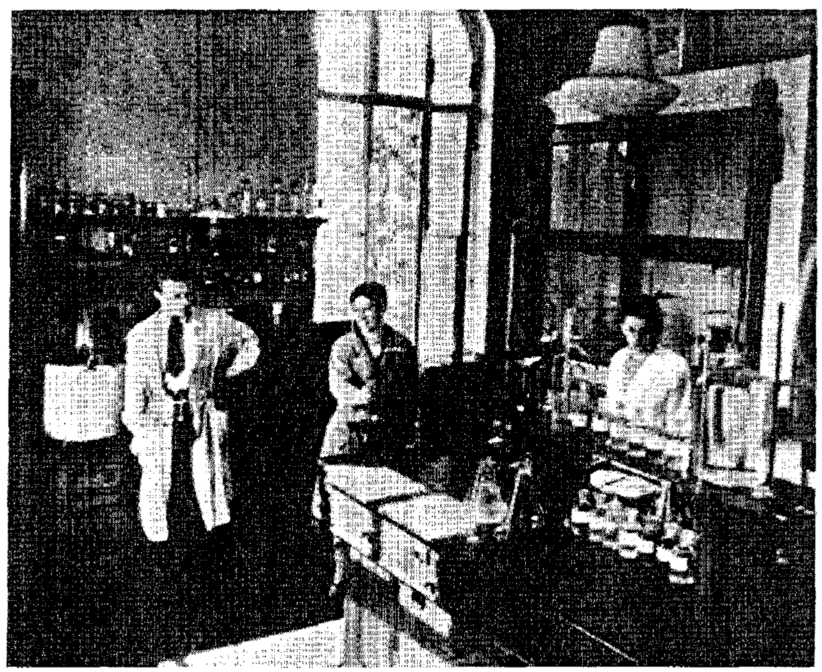
Hönigschmid had the talent and also the opportunity, for the major source of radioactive ores at the time was the mine at St. Joachimstal in Austria (15). Much of his work was accomplished with his research student, Stefanie Horovitz. Horovitz was born in Warsaw on April 17, 1887, her family moving to Vienna about 1890 (16). She graduated from the University of Vienna in 1914 with a doctorate in organic chemistry, although she seems to have started as a research worker at the Radium Institute of Vienna with Hönigschmid in late 1913. Hönigschmid was actually affiliated with the Technical University of Prague from 1911 to 1918, but he maintained research facilities in Vienna.

Horovitz's initial task was the time-consuming separation of lead from the residues of the radioactive ores after the radium had been extracted. This was followed by the demanding gravimetric procedures to the nearest hundred thousandth of a gram. The first report by Hönigschmid and Horovitz provided a value of 206.736 for the atomic weight of lead from the St. Joachimstal mine, compared to 207.190 for 'normal' lead (17). Such a significant difference from a respected analytical laboratory was the first definitive evidence that atomic weights were not necessarily invariant. As a result of its importance, this paper by Hönigschmid and Horovitz was chosen by Henry Leicester as one of the crucial publications in chemistry in the first half of the twentieth century (18). The two researchers were dedicated to their work, as is apparent in a letter from Hönigschmid to Lise Meitner (19):

> ... Miss Horovitz and I worked like coolies. On this beautiful Sunday we are still sitting in the laboratory at 6 o'clock.

Subsequently, Hönigschmid and Horovitz analyzed new samples from St. Joachimstal as well as samples from two other mines: pitchblende from German East Africa; and bröggerite from Norway. These results were even more convincing, giving values as low as 206.046 (20). A difference of over one mass unit could not be explained by experimental error. There clearly were significant differences in the atomic weight of lead, depending upon source.

Hönigschmid and Horovitz made a second contribution to the isotope story. Boltwood had claimed the discovery of another radioactive element, ionium (21). Most chemists accepted the existence of this element, it even being assigned a symbol, Io. However, it was the atomic weight and spectroscopic analyses performed by Hönigschmid and Horovitz that showed ionium to be no more than an isotope of thorium, making thorium only the second element for which isotopic behavior had been proven at that time (22). These were the last publications of Horovitz. Many years later, Horovitz's fate was discussed in an exchange of letters between Kasimir Fajans and Elizabeth Róna (23). In the last of the correspondence, Fajans commented (24):



Gleditsch, with her assistants Ernst Føyn (left) and Ruth Bakken (right), in the Chemistry Laboratory, Oslo, ca 1930 (T. Kronnen and A. C. Pappas)

> You probably have not received any information from Vienna about the fate of Dr. Stephanie Horovitz. I learned about it from a mutual relative at Warzawa. Stephanie moved there after World War I and after her parents had died in Vienna to join her married sister. She was not active in chemistry and both were liquidated by the Nazis in 1940.

Ellen Gleditsch

Concurrently the master himself, T. W. Richards, had launched an investigation into what he called a subject of (25):

> ... peculiar and extraordinary interest, because it involves a readjustment and enlargement of many rather firmly fixed ideas concerning the chemical elements and their mutual relations, as well as the nature of atoms.

His first report described lead samples with abnormally low atomic weights, the lowest value of 206.40 coming from a sample of uraninite from North Carolina (26). This particular lead sample was noted in the data table as being provided by Gleditsch. This was Dr. Ellen Gleditsch, who at the time was working with Bertram Boltwood at Yale. In the paper, Richards stated that this "most valuable" of the samples had been supplied by Gleditsch as lead chloride; thus Gleditsch played an active role in the discovery process by performing the extraction of a pure lead salt from the uranium ore. In a subsequent paper (27) Richards reported atomic weights of 206.12 and 206.08 for lead from uranium ore samples obtained from Norway. He added that these two samples "of especial value and significance (27)" were both obtained from Ellen Gleditsch, who had returned, by then, to her native country of Norway. These values were so close to that predicted by Soddy for pure lead produced at the end of the uranium decay series that the group displacement law could no longer be in doubt.

Gleditsch was born on December 29, 1879 in Mandal, in southern Norway (28). After obtaining a pharmacological qualification, she became a research assistant at the University of Kristiania (now Oslo), being unable to afford to enroll as a university student. From 1907 to 1912, she worked with Marie Curie in Paris, where she received the qualification of *Licenciée ès Sciences*. In 1913, Gleditsch received a fellowship to work with Bertram Boltwood at Yale (29). Although he was opposed to women researchers, Gleditsch arrived before he had a chance to reject her application. Her work on the half-life of radium (30) so impressed Boltwood that he became a warm friend. While at Yale, she received an invitation from Richards to visit him at Harvard, and it was possibly during the meeting that she agreed to supply the lead samples that proved most crucial. About this time, she was awarded an honorary Doctor of Science degree from Smith College, Northampton, Massachusetts.

Gleditsch was to have a very successful career at the University of Oslo, being hired initially as a docent and, by the time she retired, becoming a professor of chemistry. She spent most of her nonteaching time in Paris. For example, during World War I, Curie pleaded with Gleditsch to return to Paris to supervise the radium extraction facilities. This journey involved a dangerous voyage across the U-boat ridden North Sea; and Ernest Rutherford, a friend of Gleditsch, arranged for a security clearance for her stopover in England on the way. Her teaching demands at Oslo were very heavy, leaving little time for research. She did manage some, however, particularly during her many sojourns in Paris (31). Following Richards' work, she reported on the atomic weight of lead in another mineral sample from Norway, this one giving a value of 206.17 (32). Then she commenced work on a study of the atomic weight of chlorine. Irène Curie had claimed to find a salt sample in which the atomic weight of chlorine was above the normal value (33). Gleditsch and coworker B. Samdahl showed that the value resulted from a contamination with bromide ion (34). Nevertheless, Gleditsch pursued a more thorough study of possible variations in the atomic weight of chlorine, some of the research being performed with her sister, Liv Gleditsch (35). The results showed that, unlike lead, the average atomic weight of chlorine was invariant with the mineral source. Gleditsch maintained an active life, becoming president of the International Federation of University Women, and during World War II, being an active member of the resistance. She died at the age of 89 on June 5, 1968.

Congress on Radioactivity, Oxford, 1952, Gleditsch surrounded by Irène Joliot-Curie (left) and Fritz Paneth and Marguerite Perey (right). (T. Kronnen and A. C. Pappas)

Ada Hitchins

The search for the higher atomic weight value of lead derived from thorium-232 decay was pursued by Hönigschmid (36) and by Soddy. Soddy, in the report of his definitive result of 207.74, noted the contribution of his research student, Ada Hitchins, for the separation and analysis work (37). The sample used by Hönigschmid was provided by Soddy (37); thus both teams probably relied on Hitchins' extractions. Born in Devon, England (38) in 1891, Hitchins graduated with a B.Sc. from the University of Glasgow in 1913. She commenced research with Soddy during her last undergraduate year; and when Soddy moved to the University of Aberdeen in 1915, Hitchins accompanied him, obtaining a position as Carnegie Research Scholar. It was during this period that Hitchins performed the extraction and analytical work on the lead samples from thorium ores. In addition, Hitchins took over the research on protactinium of Soddy's other student, John Cranston, when the latter was drafted for World War I (39).

In 1916 Hitchins herself was drafted to work in the Admiralty Steel Analysis laboratories (40). She rejoined

Soddy in 1921, by which time he had moved to Oxford University. Despite a Nobel Prize in Chemistry, Soddy had great difficulty in attracting graduate students to work with him (41); thus Hitchins played a crucial role in Soddy's research program. Initially appointed as technical assistant, she was promoted to private research assistant in 1922. Soddy noted (42):

> ... she has also charge of my radioactive materials ... and has worked up considerable quantities of radioactive residues and other materials for general use.

Hitchins finally left Soddy's employ in 1927, moving to Kenya with her family. There she worked as Government Assayer and Chemist in the Mining and Geological Department of the Colonial Government until she retired in 1946 and returned to England. At some point, late in life, she married a farmer, John Rees Stephens. She died in Bristol on January 4, 1972.

Commentary

Scientific research in the early decades of the 20th century is commonly regarded as a male preserve, except for that of Marie Curie. Here, three women scientists have been identified who played significant roles in the discovery of the existence of isotopes, one of the most crucial scientific findings of the period. In an era when women scientists were largely confined to support roles (43), it is important to correct the historical record and acknowledge the contributions of Horovitz, Gleditsch, and Hitchins.

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