Lise Meitner (1878–1968)

A Physicist Who Never Lost Her Humanity

"Science makes people reach selflessly for truth and objectivity; it teaches people to accept reality, with wonder and admiration, not to mention the deep awe and joy that the natural order of things brings to the true scientist."

– Lise Meitner

Lise Meitner, was born on November 7, 1878 in Vienna, Austria into a Jewish family. Right from the beginning, she was interested in mathematics and physics. She completed her public school education by the age of 14. Further education was not a possibility, since in Austria, women were not permitted in the universities till ~1900. In 1901, she passed the qualifier examination required to enter university by studying at home. The intellectually stimulating family atmosphere and supportive parents, enabled her to pursue a career in science.

She joined the University of Vienna in October 1901, where she discovered her preference for physics over mathematics. Her first physics teacher was Franz Exner, who had set up the radioactivity research in Vienna. She also had an opportunity to learn from another famous physicist – Ludwig Boltzmann. She was greatly influenced by his enthusiasm and vision of physics. After completing the course work in 1905, she started doing doctoral research. In February 1906, she was awarded the doctoral degree for her dissertation 'Conduction of heat in inhomogeneous solids'. She was the second woman to get a doctorate in Austria. As job opportunities for women were limited, she took up a teaching job in a girls' school. She used to teach in the daytime and do research in the evening. She carried out experiments to study β, α absorption in various metal foils, making entry into the then nascent field of radioactivity. She designed a special experimental set up to generate a collimated α beam from a radioactive source for scattering studies, to investigate structure of the atom. This work gave her the confidence of independent research, and she went to the University of Berlin in 1907 with her parent's permission and financial support. The choice of Berlin was perhaps influenced by Boltzmann's high regard of the place and presence of another great physicist – Max Planck, whom she had met earlier. This turned out to be a major turning point in her career.

The atmosphere in Berlin was exciting for science but not friendly towards women. She obtained permission to attend Max Planck's lectures, which was an exception. She started working in the Chemistry Institute with Otto Hahn, a collaboration which flourished and lasted for three decades. The Chemistry Institute was off limits for women, so she was given a small carpenters room in the basement to set up a laboratory. It had a separate entrance, and she was not permitted to go to any other part of the Institute. Few years later, she was given appointment as an 'unpaid guest' in the newly founded Kaiser Wilhem Institute (KWI) of Chemistry[1], where her collaborator Hahn was offered a job as a scientific associate. She translated scientific articles from English to German to supplement the allowance she received from her parents.

In 1912, she got her first paid position when Max Planck appointed her as an assistant. She became the first woman assistant in Prussia to grade student's papers. A year later, she was made a scientific associate at a much lesser salary than other colleagues. As a result, the official 'Hahn–Meitner lab' was set up, where she (a physicist) and Hahn (a chemist) paved the way for interdisciplinary research in radioactivity. Her regular appointment resulted in additional laboratory space, and they could separate chemistry and physics experiments. This helped in minimizing both the cross-contamination and the background in measurements, and consequently improved the data quality (as compared to the basement lab). She set up training procedures for handling radioactive elements in order to study weak radioactivity. She also worked as a X-ray technician nurse in the Military Hospital for some time during the first World War. In 1917, she was appointed as the head of physics section, and in 1919 she became the first German woman professor. In 1922, she qualified for university teaching and in 1926, went on to become the first woman university professor in Germany.

Major Scientific Achievements

Around 1910–20, very little was known about nucleus. Neutron was yet to be discovered. Meitner carried out detailed investigations of α, β spectroscopy and their connections to nuclear masses and binding energies. She was keen to adopt new experimental techniques. She had built a beta-ray spectrometer and a cloud chamber. The cloud chamber detector permitted measurements of tracks of charged particles (α, β), and from the curvature of track, accurate information of momentum/energy was derived. She introduced the radioactive recoil method for physical separation of elements. It was observed that during a nuclear decay emitting α/β radiation, the daughter nucleus also recoiled in order to conserve momentum. She deduced that if the source is thin enough, then recoiling daughter nuclei can come out and be collected. This physical separation method was found to be pure and effective for small fractions and was extensively used. She performed several experiments to study energy loss of alpha particles while traversing the matter, in order to study Bohr's formula and understand atomic structure.

In 1919, she and Hahn discovered the element protactinium (Z=91). She showed that γ radiation was emitted after the α/β decays, and from the energy measurements concluded that this

[1]Present Max Planck Institute of Chemistry.

was analogous to atomic spectra. She was the first to observe radiationless transitions, where the energy is transferred to an electron in the atomic shell, ejecting it from the atom (instead of a photon). This was later independently discovered by Auger and is known as 'Auger effect'. From early study of isobars[2] and isotopes[3], she concluded that protons formed even numbered complexes, which many years later was understood in terms of effect of pairing. She estimated the age of the Earth to be $\sim 10^{10}$ years, from distribution of lead isotopes in minerals. In 1933, she observed positron tracks in the cloud chamber showing $e^+ - e^-$ appearing in pairs, which was the first identification of positrons from a non-cosmic source. She was a complete scientist– both a theorist and an experimentalist.

Discovery of Fission

In 1934, production of new elements by neutron irradiation was pursued by different groups in Europe. Lise Meitner and Otto Hahn initiated investigation of transuranium elements at KWI, by irradiating Uranium (Z=92) with thermal neutrons. Results were puzzling since the products were different than the expected elements near Uranium. She continued work at KWI, despite the changing political situation prior to World War II, as she was reluctant to leave physics section – her life's work. However, when situation got worse in 1938, she had to escape to Sweden *via* Netherlands with the help of friends, and consequently could not participate in the final stages of neutron induced reaction studies on Uranium, in Berlin. She got a position in Stockholm and continued to have correspondence with Hahn to follow up on the experiments they had started together. They even met in Copenhagen in November 1938 to discuss and to plan the next set of measurements, which at that time had to be kept secret. Just before Christmas, Hahn sent her a letter which confirmed that element Ba (Z=56) was produced when Uranium was bombarded by a neutron. This result, namely, a nucleus with nearly half the mass of Uranium can be produced when a neutron hits the Uranium nucleus, was incomprehensible at that time. Lise Meitner and her nephew Otto Robert Frisch (also a nuclear physicist) were spending the Christmas vacation together. Solution to this mystery of nuclear physics came during a long walk in the woods. Nucleus – a highly charged, wobbly, liquid drop breaks into two nearly equal sized drops when disturbed even slightly. Sitting on a tree trunk, she did a quick calculation and estimated that ~200 MeV will be released in the process as these two similarly charged fragments repel each other. In January 1939, Hahn and Strassmann published the observation of Barium (using chemical methods) resulting from neutron bombardment of Uranium. Meitner did not feature in the author list, in spite of her strong involvement in the work leading up to the final result. Meitner and Frisch published a letter in *Nature* in February 1939 (reproduced in this issue, p.323) giving the explanation for this observation and the process

[2]Different atomic number Z and same mass number A.

[3]Same Z and different A.

was referred to as 'fission' – analogous to cell division in biology. This paper, which provided insight into the physics of fission, was not just a very important step for nuclear physics, but the world has not been the same afterwards. Immediately after this, Otto Frisch published his observation of the physical measurement of the energetic, heavy fission fragments. This was also independently and simultaneously verified by many groups. A detailed framework was developed by Bohr and Wheeler in the following year. The fission process is very complex and a complete understanding has remained an open challenge, for both experimentalists and theorists, for more than 75 years. It continues to be an active research area even today.

Struggle and Recognition

Lise Meitner, referred by Einstein as *our Marie Curie*, was a shy person. When she started work in the basement laboratory, she was mostly left out of scientific discussions. This often was the case even during the visits of prominent scientists. During the first World War, Hahn was on military duty and most of the work was done by her. She kept up her correspondence with Hahn and published the work jointly, keeping in mind that foundations of the work was laid by both of them. After the forced emigration, She felt completely uprooted, not just due to lack of home but because she was deprived of her research lab. Moreover, at Siegbahn's laboratory in Stockholm, she experienced difficulty because of Siegbahn's prejudice against women in science. Although she visited Germany in later years, she continued to work in Sweden till her retirement in 1960 and moved to Cambridge in her last years. She shared close friendship with many scientists.

The Nobel Prize awarded to Hahn in 1944 for the discovery of fission, gave rise to lot of discussions and controversies which continued for many years. Discovery of fission and understanding of the underlying science, was a team work involving chemistry and physics, and somehow this point was lost during the award of the Nobel Prize. Unfortunately, for a long time her independent work explaining fission was ignored and her role in collaborative work undervalued. She was always treated as a 'woman sub-ordinate to a man in collaboration', even though she has been described by some group members as the 'intellectual leader of the team'. She did not like to talk about her struggles or about the missed recognition, and avoided public controversy. After the publication of Hahn's autobiography in 1963, she wrote an article emphasizing the role of physics in Uranium studies and her insistence on experiments. Later in 1966, the prestigious Fermi Prize was given to the 'fission team' namely – Lise Meitner, Otto Hahn and Fritz Strassmann, which recognized the discovery of fission as a group effort. Her citation of the Fermi prize read as *for pioneering research in naturally occurring radioactivity and extensive experimental studies leading to nuclear fission*. Release of relevant documents by the Nobel Foundation in 1990s (after 50 years) have further strengthened the view of the scientific community that her exclusion was unjust.

She was given 'Woman of the year' award by the US National Press Club in 1946. She also received many awards and honours after 1947. In 1958, Nuclear Physics Institute in Berlin was named Hahn–Meitner Institute in the honour of Hahn and Meitner. In 1997, the element Z=109 was named 'Meitnerium' in her honour. She is the only woman, besides Marie Curie, to have this honour.

Her journey started in Austria, where opportunities of higher education for women were very limited. Her passion for science was very strong and she pursued the same in spite of enormous socio-political obstacles. She will be remembered as one of the most significant woman scientists of the 20th century – a role model for many generations. Known as the 'mother of nuclear power', she refused to work on the Manhattan project for atomic bomb. She was a strong believer of the use of nuclear energy for peaceful purposes. The inscription on her tombstone by Otto Frisch is a fitting tribute: *Lise Meitner : A Physicist Who Never Lost Her Humanity*.

Suggested Reading

[1] **Sime, Ruth Lewin, *Lise Meitner: A Life in Physics*, University of California Press, Berkeley, California,1996.**

[2] **O R Frisch, *What little I remember*, Cambridge University press, Cambridge 1979.**

[3] **Elisabeth Crawford, Ruth Lewin Sime and Mark Walker, *Physics Today*, Sept. 1997, doi: 10.1063/1.881933.**

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