FEATURE ARTICLE

75 YEARS OF EXPLOSION OF THE ATOMIC BOMB

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THE EXCITING STORY OF THE UNEARTHING OF THE MYSTERY OF NUCLEAR ENERGY THAT LED TO THE ATOMIC BOMBING OF JAPAN.

THE year 2020 marks the 75th year of the explosion of the nuclear bomb on Hiroshima and Nagasaki on 6 August 1945, resulting in innumerable death and sufferings of innocent people. Six years earlier, two scientists who had no connection whatsoever with this bombing accidentally unearthed the mystery of nuclear energy in Berlin at the radiochemistry laboratory of Kaiser Wilhelm Institute.

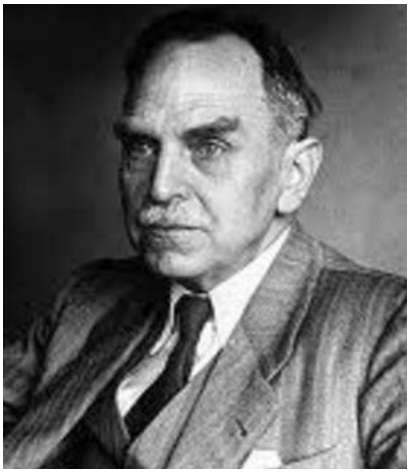
Otto Hahn and Lisa Meitner opened the nuclear genie. This was in 1939 when the carnage of Hitler's Nazi Government was at its peak and Meitner, being a Jew, had to escape to Sweden. The historic paper of nuclear fission, authored by Otto Hahn and Fridge Strassmann, was published in the 1940 January edition of *Naturwiseanschaften,* unfortunately with the omission of Lise Meitner's name as coauthor.

Three months after the explosion of the atomic bomb, to be precise 15 November 1945, Sweden's Nobel committee announced the 1944 Nobel Prize in Chemistry for Otto Hahn for his discovery of nuclear fission in heavy elements. Unaware of his whereabouts to send a formal invitation, the committee publicized the news in the print media. British officers at the Farm Hall informed the news to Otto Hahn where he was under house arrest with nine other German scientists. Even though the scientists joined in greeting Hahn, he was not elated by the news – in fact, he was depressed by the bombing in Japan that put the onus for the loss of so many lives on his discovery.

The story of Hahn and Meitner who had sown the seeds of the atomic bomb is full of stimulating events. Their efforts in the discovery, the ethnic-gender discrimination and the roller coaster ride in thirty years of association culminating in the Nobel committee ignoring the contribution of Meitner for the discovery – makes for exciting anecdotes.

Otto Hahn

Born in Frankfurt in 1870, Hahn got his doctorate in organic chemistry from the University of Marburg in the summer of 1904. In the winter of the same year, he received an invitation from the British Nobel laureate and the discoverer of noble gases William Ramsay with a condition to learn English. He was assigned an arduous task of isolating from 250 kg of a radioactive barium mineral from Ceylon (now Sri Lanka), the element radium discovered by Marie Curie. Hahn not only succeeded in isolating radium, he also discovered a new radioactive isotope in the mineral which he named radiothorium.



Otto Hahn 1879-1968

Supremely happy with Hahn's work in a short time, Ramsay recommended him for an appointment as a radiation chemist at the laboratory of Nobel laureate Emil Fischer in Berlin. Wanting to get more experience in this field, Hahn joined another Nobel laureate Rutherford's team at Montreal

where he continued his research on radioactivity and contributed to the construction of the radioactive series of thorium.

After his return to Berlin in 1907, Hahn introduced novel radiochemical techniques for isolation of radioisotopes at Kaiser Wilhelm Institute of Chemistry. Later, invited lectures on radiochemical techniques delivered by Hahn at different places were published with the title *Applied Radiochemistry* by Cornell University. This became an approved text for the course curriculum of Universities in USA, UK, Europe and the Soviet Union.

Lise Meitner

Born in 1878 in Vienna to relatively wealthy cultured Jewish Austrian-Swedish parents, Lise Meitner, famously called German Mary Curie by Einstein, was especially interested in pursuing mathematics and science. Pursuing physics, Meitner completed her doctoral research in 1905, becoming the first female from the University of Vienna and second in the world to earn a doctorate in physics; the first being Isabella Stone of the USA in 1897.

Participation at Nobel laureate Max Planck's course at the University of Vienna in 1907 encouraged Meitner to pursue her research on quantum physics under Planck at the Berlin University. Planck directed Meitner to meet Hahn at the Kaiser Wilhelm Institute of Chemistry since he was looking for an associate. Meitner

Lise Meitner with Einstein and other scientists

Lise Meitner in the lab with Otto Hahn

met Hahn who helped her to set up a laboratory – beginning a long academic association of over three decades.

In 1912, the Hahn-Meitner team moved to the newly constructed Kaiser Wilhelm Institute where Meitner worked without salary, receiving her first remuneration in 1915 when she was appointed as Professor at the Berlin University. Planck developed high admiration for Meitner and invited her at his parties for distinguished foreign scientists and delegates where Meitner established contact with scientists of repute – Einstein, Heisenberg, Niels Bohr, James Frank, von Baeyer and Gustav Hertz.

The First World War was just coming to an end.

Hahn-Meitner-Strausman & Fermi

Hahn and Meitner discovered hitherto unknown phenomena in radioactivity and a number of new radioisotopes. And the Kaiser Wilhelm Institute for Chemistry got recognition as a reputed centre of radiochemistry. During 1920-1930 their names were recommended

several times for the Nobel honour in Chemistry and Physics.

Fridge Strassman, a bright young chemist, joined the team in 1932. The team of Hahn-Meitner-Strassman, popularly known as the Berlin team, continued the work of revealing the obscurities of radionuclides.

In 1932, the Nobel Prize-winning discovery of the neutron by James Chadwick was also creating waves in nuclear physics. Between 1932 and 1936 the mercurial Italian physicist Enrico Fermi bombarded several elements with neutron as projectile and published about the formation of artificial radioisotopes. One of Fermi's papers astonished the scientific world on the report regarding the unexpected formation of new elements beyond uranium (transuranium elements) when bombarded by slow neutrons. Fermi reported two elements beyond uranium and even named them.

The Berlin team geared up to disentangle the conundrum of the formation of transuranium elements during the slow neutron bombardment of uranium. Induced radioactivity with slow neutrons resulting in multiple radioisotopic activity was known by Fermi's experiments. The Berlin group soon realised that unscrambling this puzzle would be an arduous task when they observed a plethora of induced radioactive isotopes in the mixture after bombardment. In those times, separation and identification of hundreds of radioisotopes with the available instruments based on their half-lives and radiation tracks required extraordinary radiochemical skills. Hahn had vast experience in radiochemical separations and thorough knowledge in co-precipitation carrier characteristics of radium, thorium and other elements near uranium. To say that Hahn was the only chemist who could take up this challenge at that point of time may not be an unjust statement.

Meitner's association of thirty years with Hahn and her extensive knowledge in radiation physics was a big resource to the team. Resuming the work on the separation of different isotopes in the mixture, Hahn and Strassman focused on radium isotopes. Several repeats of the experiments puzzled them with an unexpected result that contravened the earlier result. Hahn shared this with Meitner. Little did they know that solving this puzzle would make them epoch makers in the history of science.

At this prime moment in her career, Meitner was blissfully unaware of the twist of fate in her life to follow.

Meitner Goes into Exile

In 1933, the Nazi Government revoked the assignment of Meitner as Professor at the Berlin University. For the next five years, Hahn accommodated her in the Kaiser Wilhelm Institute Radiation laboratory. In 1938, Germany captured Austria, her homeland, and Meitner lost the validity of her passport. News came in of genocide committed by the army on Jews in Austria. Not able to protect a Jew any more at his Institute, Hahn and other friends secretly planned for her escape from Germany. Her Swedish cousin Otto Frisch requested his friend, Dutch Physicist Dirk Coster to facilitate Meitner's escape from Berlin to cross over at the Dutch border.

The date and time of Meitner's escape were top-secret. On the fateful day of July 1938, not to raise any doubt, Meitner worked as usual in the laboratory and spent her evening at Hahn's home. Hahn gave her a diamond ring inherited from his mother to bribe at the border security if demanded. Coster, a frequent traveller between Germany and the Netherlands, escorted her to the border. Assuming Meitner to be his wife, the border security raised no questions.

After three months of her escape from Berlin, in November 1938, Nazis looted houses and business offices of Jewish descent in Berlin and killed Jews indiscriminately. Meitner had just escaped from Germany at the right time.

Hahn's Research Continues

Hahn and Strassman continued their work on resolving the puzzle of radium in the complex mixture of uranium bombarded with slow neutrons. Adopting scrupulous analytical radiochemical techniques, used several times in their previous work, they found that the radium under investigation was not radium but indeed a barium radioisotope. Hahn shared the findings with Meitner. Uranium breaking into barium, a phenomenon beyond a chemist's comprehension, required an explanation from the physicist Meitner to back up.

In December 1938, Hahn and Strassman reported their findings to *Naturwiseanschaften* omitting the name of Meitner as coauthor. The paper merely mentioned the possibility of the presence of elements of intermediate-mass numbers in the neutron bombarded uranium. Perhaps, for want of a clear explanation, Hahn hesitated to reveal the presence of barium though there was a clear proof of its presence.

Hahn wrote to Meitner on 19 December 1938: '…the isotope what we have noticed is not that of radium but we have to decide that it is indeed barium. The theory we know prohibits such a bursting of uranium to barium. …Perhaps you have an explanation for this.'

On 21 December, Meitner replied: 'A reaction with slow neutrons that supposedly leads to barium! …At the moment the assumption of such a

thoroughgoing breakup seems very difficult to me, but in nuclear physics, we have experienced so many surprises that one cannot unconditionally say it is impossible.'

This reply makes history in nuclear science.

Encouraged by the backup from Meitner, Hahn adds another passage to his paper.

'…In addition to the transuranium elements reported by Fermi, we have found a clear experimental proof for the presence of barium along with possibility of elements 43 through 46 in the soft neutron bombarded uranium. Perhaps uranium bursts (Ger: urasplatung) into barium.'

Christmas holidays had just begun. Hahn speaks over the phone to the chief editor of *Naturwiseanschaften* to include the passage in his paper. The milestone paper on *urasplatung* appeared on 6 January 1939.

Meitner's Explanation for Urasplatung

Meitner's cousin Otto Frisch, who was a researcher with Bohr on liquid drop model of the nucleus, visited Meitner in the Christmas holidays of 1938. While taking a walk, Meitner shared the findings of Hahn on neutron bombardment of uranium. She tells Frisch, 'If barium is present as Hahn says, then uranium is split, and it should accompany enormous energy. Let us calculate the energy released.'

She takes her notebook, scribbles and exclaims 'it is about 200 MeV'; a figure several orders of magnitude of TNT energy. Her calculation just required the mass defect and Einstein's relation $E=mc^2$. Both parameters were known but getting this energy out was a million-dollar question.

Using Bohr's liquid drop model Meitner and Frisch wrote a paper explaining the mechanism of urasplatung naming it nuclear fission. A simple illustration of absorption of neutron by uranium splitting into two halves releasing large amount of energy is the crux of the paper. The journal *Nature* received it on 16 January 1939.

On the same day, Meitner and Frisch met with Bohr who was rushing to visit Einstein at Princeton. After learning about fission of nucleus, Bohr, the proponent of liquid drop model, exclaimed, 'How foolish we are, why did it not occur to us before!'

Bohr placed the news of splitting the uranium atom before his university fellow scientists at Princeton and Columbia. The news of the possibility of enormous energy release spread like wildfire creating panic.

Meitner and Frisch's paper on nuclear fission appeared on 11 February 1939. Release of a huge amount of energy, of a different kind by splitting nucleus, becomes a distinct possibility.

Hahn and Meitner had opened the gate to the atomic age – from chemical fuel to atomic fuel. The nuclear bomb became the first use of atomic fuel.

Nobel laureate chemist Glenn Seaborg refers to Hahn as the father of nuclear and radiochemistry. It was Hahn's book on Applied Radiochemistry that helped him to separate plutonium so quickly to make the plutonium bomb.

In 1954, Meitner in a radio interview says, "…Hahn and Strassmann were able to do this by exceptionally good chemistry, fantastically good chemistry, which was way ahead of what anyone else was capable of at that time. The Americans learned to do it later. But at that time, Hahn and Strassmann were really the only ones who could do it. And that was because they were such good chemists. Somehow they really succeeded in using chemistry to demonstrate and prove a physical process…"

In the same interview, Strassmann responded: "Professor Meitner stated that the success could be attributed to chemistry. I have to make a slight correction. Chemistry merely isolated the individual substances; it did not precisely identify them. It took Professor Hahn's method to do this. This is where his achievement lies."

Delay in recognising the contribution of Meitner was compensated in an exceptional manner. In 1982, the International Union of Pure and Applied Chemistry (IUPAC) named element 109 as Meitnerium, immortalizing Lise Meitner.

Put through the Wringer

Between 1935 and 1938, the Berlin team published jointly seven papers on uranium bombardment. Why is Meitner's name omitted as a coauthor in the eighth paper which fetches the Nobel prize to Hahn? Is this because of her Jewish descent and Hahn's self-protection? Why does the Sweden committee ignore Meitner's name for the 1944 Nobel honour? Was her significant contribution and multiple nominations for the award overlooked? Another question: Had Hahn missed seeing barium in the mixture, would it have delayed the end of the Second World War? Perhaps.

In 1933, Max Planck and Robert Bosch cautioned Hitler about the exodus of eminent basic science professors of Jewish descent. Hitler remarked with disdain, "Germany is in no need of physicists and chemists for another hundred years." Was Hitler's faith in his military stronger than his faith in German science? Did this lead to the failure of Germany to produce the bomb even though the discovery of fission was made in Berlin?

Hahn and Meitner continue to maintain harmonious understanding even after Hahn received the Nobel honour. Meitner participated in the award ceremony on 16 December 1946. In his Nobel speech, Hahn recognized her contribution and praised her involvement. He gave due credit to Meitner and Frisch for using the term nuclear fission and admitted that they were the first to realise the possibility of enormous energy release.

Hahn shared the prize money with Meitner who gracefully accepted. She contributed it to Albert Einstein's Emergency Committee of Atomic Scientists promoting peaceful uses of atomic energy.

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