Lise Meitner (Nuclear Physicist and Fission Pioneer) November 7,1878 – October 27, 1968



Lise Meitner is known as the person who discovered fission and the woman who split the atom! Both descriptions are correct since she was the one who figured out what was happening with an experiment done by her collaborators Otto Hahn and Fritz Strassman and she coined the word "fission". Her collaborator of 31 years, Otto Hahn, received the 1944 Nobel Prize in Chemistry for this discovery. But everyone in the scientific community knew that it was Lise Meitner who solved the mystery of the transuranic experiment done by her collaborators, Otto and Fritz. She should have been included in the Nobel Prize, but that didn't happen for two reasons: first, she was a woman and second, she was a Jew. And Otto Hahn refused to acknowledge Lise Meitner's contribution to his Nobel Prize. Albert Einstein called her the Marie Curie of Germany!

**Her science journey** began when Elise Meitner was born in Vienna, Austria in 1878. She was one of 8 children born to Phillip and Hedwig Meitner. Phillip was an Austrian lawyer and chess master. In the birth register of Vienna's Jewish community, her birth was listed as November 17, 1878, but on all other documents it was listed as November 7, 1878. Lise Meitner considered November 7 as her birthday so we will also use that. That would make her birthday the same day as Marie Curie's! In this way she has been connected to Marie Curie since birth. Elise Meitner would change her name from Elise to Lise in her adult years.

Lise's aptitude for science and math was evident since she was a child. She slept with a math book under her pillow. She had many questions about the things around her. For example, she studied the colors in a drop of oil on a puddle. She looked at the reflections in the puddle and asked how the film formed on top of the puddle. Her parents, especially her father, encouraged and supported her natural curiosities. Here again we see how a supportive parent, especially the father, can nurture the intellect of a child. Most parents want to have the best education for their child whether male or female. Lise's father wanted the best education for both his sons and daughters. Three of Lise's sisters also received their doctorate degrees.

Lise wanted to go to high school but there were no high schools for girls. Her parents encouraged her to study on her own. In 1897, when she was nineteen, women in Vienna were finally allowed to go to universities. But the universities required Lise and her sister Gisela (who wanted to become a doctor) to pass the high school exit exam called Matura, even though they did not actually go to high school. So, Lise and Gisela started studying for the exit exam. Gisela passed the Matura first and was admitted to medical school. Then Lise passed the exit exam with a lot of help and tutoring from Dr. Arthur Szarvassy, a young physicist who just finished his doctorate at the University of Vienna. She was one of four girls who passed the exam out of fourteen who took it. Three girls who passed were tutored by Dr. Szarvassy and the other girl was the daughter of a famous theoretical physicist Ludwig Boltzmann. Dr. Boltzmann was also the physics professor at the University of Vienna. Lise was really interested in physics but worried about the practical application of physics. She thought medical school might be better. Her father eventually convinced her that she should study physics because that's the subject that's she's really interested in. The father knew his daughter well!

In 1901 she became the first female student of physics at the University of Vienna. In 1906 she became the second woman to get a PhD, and first in a PhD in Physics at the University of Vienna. She graduated with the honor of summa cum laude. After she received her doctorate there were still no jobs available for her as a woman. Her professor Ludwig Boltzmann died on September 5, 1906, and was replaced by his assistant Stefan Meyer. Meyer was interested in the new field of radioactivity. Lise worked for Stefan Meyer in the evening while teaching at a girls' school in the daytime. Meyer was investigating the radiation emitted by the new elements discovered by Pierre and Marie Curie: polonium, radium, and actinium. Thus, the research interest of Lise shifted to radioactivity. In Vienna, her future seemed to lie in teaching, but she soon realized that she may have more opportunities in Berlin. So, she asked her parents if she could go to Berlin for a few terms. As usual, her parents were very supportive and agreed.

# Berlin



Lise arrived in Berlin in September 1907. Her professor Ludwig Boltzmann had talked about Berlin; and also, she knew Max Planck was there. She had met Max before in Vienna. She asked Max Planck if she could attend his lectures at the Friedrich-Wilhelm-Universität, now called Humboldt University of Berlin. The lectures, however, were not enough to occupy her day, so she looked for something else to do. She asked Dr.

Heinrich Rubens for ideas. Dr. Rubens was the head of the experimental physics institute at the University of Berlin. He offered her a place in his laboratory as an unpaid assistant. While she

was considering his offer, Dr. Rubens added that Dr. Otto Hahn was interested in collaborating with Lise. Dr. Hahn heard of Lise's work in radioactivity and read her one published article. Dr. Hahn was the same age as Lise but he had already made a name for himself in the field of radioactivity. He got a degree in chemistry from the University of Malburg. He worked with Dr. William Ramsay (credited with discovering argon) in London who introduced him to the field of radioactivity. Hahn discovered a new radioactive substance, radiothorium and soon decided he would be a radiochemist. He went to Montreal and worked with Ernest Rutherford. Then he returned to Germany and worked as a chemist at the institute of Emil Fischer, the famous organic chemist in Berlin. At that time no one was working on radioactivity research in Berlin.

#### **Collaboration with Otto Hahn**



The collaboration of Lise Meitner and Otto Hahn would last for 31 years. It was one of the most successful collaborations in science. They were the best of friends and treat each other with mutual respect. Their first collaboration at the University of Berlin was an investigation of all the beta-emitting radioactive sources at their disposal. They deemed this investigation necessary because most of the earlier experiments done by other scientists were performed at different experimental conditions, so the results were hard to interpret. Most understood that beta particles were high-energy electrons but everything else about them was quite unclear including their emission energy and the way they were absorbed in various materials. In April 1908 they submitted their results to *Physikalische Zeitschrift*, a German scientific journal of physics published from 1899 to 1945. The title of the paper was "On the Absorption of the Beta Rays of Several Radioelements." Next, they studied the active deposit of actinium which is known to contain one beta emitter, actinium A, and its daughter actinium B which was thought to emit both alpha and beta particles. They found out that actinium B was only an alpha emitter. They

discovered a short-lived radioactive element actinium C. In ten months working together, Lise and Otto accomplished much more than if they had each worked alone.

When Lise went back to Vienna in the summer of 1908, she changed her religion and was baptized in a Lutheran church.

Lise and Otto continued their close collaboration studying radioactivity, combining their knowledge of chemistry in Otto's part and physics in Lise's part. Otto ran the experiments and Lise interpreted the results and wrote the articles. They discovered new elements and expanded the world's understanding of radioactivity. Their work got a lot of attention so that when the new Kaiser Wilhelm Institute (KWI) was built, the chemistry and physics departments were separated and each of them got a modern laboratory.

During World War I, Otto was drafted and served in the infantry. Lise volunteered as a nurse in the X-ray unit in the Austrian army. She was posted in the Russian front. Otto Hahn used his expertise in chemistry to supervise the use of chemical weapons in Galicia using both chlorine and phosgene gas on enemy soldiers. When Lise heard of what Otto was doing in the military, she was horrified that science was being used for killing rather than pure knowledge. She asked to be discharged from the military service. She went back to work at the KWI and continued collaboration with Otto through letters. They were looking for the origin of the element actinium and discovered a new element Protactinium. This element decays or turns into actinium. Lise did the experiments, discussed the results with Otto, wrote the findings and published them. She did all the work, but she always included Otto's name as true collaborators do. Otto got the credit for discovering Protactinium and was given the Emil Fischer award by the Association of German Chemists. Lise got a copy of the medal. This is the first injustice Lise would experience while collaborating with Otto Hahn.

# Hitler and the Nazi

After World War I, Lise and Otto continued their collaboration. Meanwhile Adolf Hitler and the Nazis were making life difficult for Jews in Germany. One by one, the Jewish scientists in Germany went abroad. Everyone asked Lise to go abroad. Lise was not bothered because she thought they would not bother her since she had an Austrian passport. But when Germany invaded Austria, she lost her citizenship and her Austrian passport. There were also lots of talk about the treatment of Jews in concentration camps. She started communicating with scientists in other countries who could help her secure a job abroad. She wanted to go to Copenhagen and work with Niels Bohr. A community of scientists were looking for ways to get her out of Berlin. Lots of them suggested using a forged passport. That scared her! Finally, a solution was reached. Niels Bohr talked to his friend Mannie Siegbahn, and Siegbahn gave Lise a position in his new research institute in Stockholm. Dick Coster, a Dutch physicist went to Berlin to help Lise travel by train to the Netherlands. A friend later commented on how Dick Coster would forever be known for discovering the element Hafnium and for the abduction of Lise Meitner from the

Nazis! Lise went to the Netherlands first and then visited Niels Bohr in Denmark before finally moving to Sweden.

#### **Discovery of Fission**

Even when she was in Stockholm, Lise couldn't feel secure. She was worried about her siblings who were still living in Vienna. She heard that her brother-in-law Justinian was arrested and sent to the Dachau Concentration Camp. She wrote Otto Hahn for advice in helping her brother-inlaw. Otto did not want Lise to leave Berlin. But Lise being a Jew was bringing him down also. He was worried that his association with her, a non-Aryan, would keep him from getting promotions and grants. Still, they continued their collaboration by writing letters to each other. Otto got a new collaborator in his laboratory, another chemist named Fritz Strassman. Even though Lise was not doing any meaningful laboratory experiments in Stockholm, Otto had been collaborating with her through letters. One of the experiments done by Otto and Fritz was the bombardment of uranium with neutrons. Earlier experiments done by Enrico Fermi showed that new elements heavier than uranium were formed when the uranium was hit with a neutron, but barium was such a light element! They were baffled by the results and thought they made a mistake. Lise thought about it. It was still on her mind when her nephew Otto Robert Frisch, a physicist working for Niels Bohr in Copenhagen, visited her in Stockholm. They went skiing in Kungälv, on the west coast of Sweden. She told him about the barium results and then while she was explaining the experiment to her nephew, she realized that the nucleus probably split into two. Otto Frisch became excited at this idea. He took off his skis and thought about it more carefully.

Lise started writing on paper. It looked like uranium split into two elements Barium and Krypton. The protons of Barium (56) and Krypton (36) did add up to 92 but the weight did not add up. The mass of uranium is 238, barium is 139 and krypton 89. Barium and Krypton only added to 228. They were missing 10 units of mass. Where would that energy come from? Lise suggested that they look at the nucleus like a liquid drop, following a model that have been proposed earlier by the Russian physicist George Gamow and then further promoted by Niels Bohr. Otto Frisch drew diagrams showing how after being hit with a neutron, the uranium nucleus might, like a water drop, become elongated, then start to pinch in the middle and finally split into two drops. After the split, the two drops would be driven apart by their mutual electric repulsion at high energy, about 200 MeV. So the answer to where would that energy come from is from the loss of mass! Mass in another form was energy. So as the nucleus divided, the lost mass would be transformed to energy. Using the formula of Einstein for relativity, E=mc<sup>2</sup> one fifth of proton mass equaled 200 million electron volts. Barium plus krypton plus the energy released equaled the atomic weight of the original uranium nucleus. Otto's experiment showed that the atom was being split. Otto Robert Frisch called a biologist friend and asked what they call when a single cell splits into two. The answer was "fission". And that's how Lise and her nephew came up with the word "fission" for the splitting of the atom. Lise explained to Otto and Fritz what happened, and they both got excited also. In January 1939, Otto Hahn wrote the results of his and Fritz

experiments and published them. In February 1939, Lise and her nephew Otto Frisch wrote and published the physical explanation for the observations in *Nature* and called the process "nuclear fission". The title of their article was "Disintegration of Uranium by Neutrons: A New Type of Nuclear Reaction".

In 1944 the Nobel Prize Committee awarded Otto Hahn the Nobel Prize in Chemistry for discovering fission. No award was given to his collaborators Fritz Strassman and Lise Meitner.



Lise Meitner's fission experiment table as shown in the Deutches museum in Munich, Germany.

# The Atomic Bomb

What Lise Meitner neglected to include in her research on fission was that the bombardment of uranium with neutrons could produce more neutrons which can keep on hitting other atoms, releasing a lot of energy. This phenomenon is called a "chain reaction" and is the essential principle behind the making of an atomic bomb. Many physicists including Albert Einstein realized this and advised President Roosevelt to use this knowledge to stop Hitler and World War II. They tried to recruit Lise to work in the Manhattan Project, but she declined. Still, after the bomb was released in Hiroshima people learned about her discovery of fission and called her the

"Mother of the Atomic Bomb". This was exactly why she had refused to work on the Manhattan Project! Photos of her holding her bag in the train leaving Germany were captioned as *the Lady with the atomic bomb in her purse*! This was not how she wanted to be remembered in history! Her research was not to be used for killing people!

#### **Postwar Life**

In 1946, Lise did an American lecture tour where she was recognized for her accomplishments. While dining with President Harry Truman at a dinner for the Women's Press Club honoring Lise's accomplishments the president told her, "So you're the little lady who got us into all of this!" But Lise never worked on the atomic bomb research itself. After World War II, the KWI was renamed the Max Planck Institute. Otto Hahn and Fritz Strassman helped clear all the German scientists, even those who were Nazi supporters. Otto Hahn offered Lise the position of Head of the Physics Department. It was a great honor especially for a woman! There were no women heads of departments then. But Lise declined, telling Otto that as a Jew and as an Austrian she wouldn't be comfortable in such a position. She remained in Stockholm and worked with Dr. Sigvard Eklund who would later be the director of the International Atomic Energy Agency. She and Eklund built the first experimental reactor in Sweden. In 1949, Lise and Otto Hahn won the Max Planck Medal. For the first time since 1938, she returned to Berlin. She worked until 1954, retiring at age seventy-five years. She retired with a small pension from Sweden. She never received her pension from KWI, as it was frozen when she went to Sweden. Aside from the pension, she lost all her scientific achievements in the revisionist history of Germany. It seemed all her achievements were erased! Most of German literature would mention her only as a "long term co-worker of Otto Hahn". She has published 128 books and articles. She was nominated for the Nobel Prize in Chemistry or Physics 48 times, 29 for physics and 19 for chemistry. But Otto Hahn never acknowledged Lise's role in his Nobel prize. In 1955, to add insult to injury, Lise was awarded the first Otto Hahn Prize for Chemistry and Physics given by the German Chemical Society. Lise's stiff grin in the award photo showed what she really felt about that award. In 1966, the Enrico Fermi Award was given to Lise, Otto Hahn, and Fritz Strassman by the United States Department of Energy.

After Lise retired, she kept working in physics and science. She was particularly interested in the status of women in science and the military use of nuclear energy. In 1960 she moved to Cambridge, England to be closer to her nephew Otto Frisch and his family. Lise died on October 27, 1968 in a nursing home in Cambridge, England at the age of 89. Despite being a cigarette smoker, she outlived most of her contemporary scientists. Enrico Fermi died in 1954, Albert Einstein in 1955, Joliet Curie in 1956 and Niels Bohr in 1962. Lise was buried in the churchyard of the Church of St. James, Bramley, Hampshire in a private ceremony attended by family

members only. On her tombstone are inscribed the words: "A physicist who never lost her humanity".

# HER LEGACY



Lise will forever be known as the woman who split the atom! She and Otto Hahn and Fritz Strassman will be in history as the three collaborators who discovered fission. She will also be known as the "Mother of the Atomic Bomb", on the basis of a common misguided assumption that she worked on the Manhattan Project also. Despite the misleading press reports in Sweden and the misperceptions of President Truman, Lise never worked on

atomic bomb research itself.

She will also be remembered for discovering Element 91 Protactinium.

In 1922, while working with British physicist Charles Drummond Ellis, searching for nuclear beta electrons, Lise observed and published the Auger-Meitner effect, an electron emission process. The French physicist Pierre Victor Auger independently discovered it in 1923 upon analysis of a Wilson cloud chamber experiment. It became the central part of his PhD work. The Auger-Meitner Effect is a physical phenomenon in which the filling of an inner-shell vacancy of an atom is accompanied by the emission of an electron from the same atom. When a core electron is removed, leaving a vacancy, an electron from a higher energy level may fall into the vacancy, resulting in a release of energy.

In 1994, Element 109, Meitnerium was named in honor of Lise. Its discoverer, German physicist Peter Ambruster, named the element for Lise Meitner as a form of restitution for the injustice she had experienced in Germany. Otto Hahn may have had a Nobel Prize but Lise Meitner has an element named after her. The element may be a more lasting memorial!

Lise Meitner and Otto Hahn attended the opening ceremony of the institute named after them, the Hahn-Meitner Institute, in 1959. This is the former Kaiser Wilhelm Institute for Chemistry in West Berlin.



#### HER SCIENCE JOURNEY

1878- Elise Meitner was born in Vienna, Austria

1892- Finished school at Burgerschule in Vienna

1897- The law was changed to allow women to study in the university

1899- Lise and her sister Gisela started studying for the Matura, the Viennese high school exit exam

1901- Enrolled as the first woman to study physics at the University of Vienna

1906- Became the first woman to get a doctorate in physics at the University of Vienna

1907- Lise moved to Berlin and started collaborating with Otto Hahn

1908- Lise converted from Judaism to Protestant, changed her name from Elise to Lise

1914- Beginning of World War I

1915- Worked as volunteer X-ray nurse/technician for the Austrian army near the Russian front

1917- Released from military duty and set up the physics department at KWI

1918- Discovered Protactinium, end of World War I

1919- KWI gave Lise a long term contract and raised her salary

1920- KWI created separate department for physics and chemistry

1921- Visited Niels Bohr in Copenhagen, Adolf Hitler was elected chairman of the National Socialist German Workers' Party (commonly called the Nazi party)

1922- Became one of the first women in Germany named assistant professor with full salary and benefits

1923- Published two papers on the electron emission process which was later called the "Auger-Meitner Effect"

1924- Lise and Otto Hahn were nominated for the Nobel Prize in Chemistry, Lise won the silver medal for the Leibniz Prize by the Berlin Academy of Sciences, the first woman to win that award

Lise became the first scientist to publish experiments using a cloud chamber which she built herself

1925- Won the Ignaz Lieben Award given by the Vienna Academy of Sciences for her work on beta and gamma rays

Lise and Otto Hahn were nominated for the Nobel Prize in Chemistry

1926- Promoted to ausserordentlicher (exceptional) professor at the University of Berlin

1928- Lise and Pauline Ramart-Lucas won the Ellen Richards Prize given by the Association to Aid Women in Science. This is the first time Ellen Richards and Lise Meitner names would be connected. This award is also known as the "Nobel Prize for Women"

1929- Lise and Otto Hahn were nominated for the Nobel Prize in Chemistry

1932- Hitler ran for the presidency of Germany and lost to Paul von Hindenburg

1933- Lise and Otto Hahn were nominated for the Nobel Prize in Chemistry

Published a paper with Max Delbruck on nuclear structure

Hindenburg appointed Hitler as chancellor of a coalition government, ceding power to him.

Hitler blamed communists on the fire that destroyed the Parliament Building

Hindenburg signed the decree giving Hitler vast totalitarian power over the country

The Law for the Restoration of the Professional Civil Service kicked out German Jews as "non-Aryans" from all universities

Lise filled out a questionnaire about her race and admitted that she was a Jew. In late Summer, her position as a professor was taken away. Jews were no longer allowed to work at the university, but she continued to work at KWI

1934- Lise and Otto Hahn were nominated for the Nobel Prize in Chemistry

Lise convinced Otto to start research on transuranic elements

President Hindenburg died. The offices of President and Chancellor were joined into "Fuhrer and chancellor of the Reich". Hitler became the Fuhrer and Chancellor.

1935- Lise and Otto published papers on transuranic elements

The Nuremberg Laws were passed. German Jews were stripped of their citizenships and rights

1936- Lise and Otto Hahn were nominated for the Nobel Prize in Chemistry

1937- Lise and Otto Hahn were nominated for the Nobel Prize in Chemistry and Physics, the first nomination for each in physics

1938- Germany invaded Austria and Austrians became citizens of the Reich. As a Jew, Lise lost her citizenship and her passport

Otto asked Lise to leave the KWI

Lise escaped from Berlin and settled in Stockholm

Otto and Fritz Strassman worked on an experiment that resulted in barium. Lise and her nephew Otto Robert Frisch figured out that fission took place in the experiment.

1939- Lise and Otto published their article on nuclear fission in Nature: "Disintegration of Uranium by Neutrons: A New Type of Nuclear Reaction"

Germany invaded Poland. Britain declared war on Germany.

1941- Lise and Otto Hahn were nominated for the Nobel Prize in Physics and Chemistry

Japan attacked Pearl Harbor and the United States entered the war on the side of the Allies: France, Britain and Russia

Jews in Germany were ordered to wear the yellow star

1942- Lise and Otto Hahn were nominated for the Nobel Prize in Chemistry

1943- Lise and Otto Hahn were nominated for the Nobel Prize in Physics

Lise was invited to work on the Manhattan Project, but she declined.

1944- The Allies liberated Normandy in France, a major factor in ending the war in Europe one year later

1945- The Alsos Mission captured the members of the Uranium Group including Werner Heisenberg and Otto Hahn

Hitler committed suicide in an underground bunker. The Allies occupied Berlin and ended the war in Europe.

The first atomic bomb was successfully tested in the New Mexico desert

The first atomic bomb dropped in Hiroshima and the second one in Nagasaki destroying both cities and essentially ending the war in the Pacific

Lise was honored as the third woman to become a foreign member of the

Royal Swedish Academy of Sciences

Lise and Otto Hahn were nominated for the Nobel Prize in Physics

Otto was given the Nobel Prize in Chemistry for the discovery of nuclear fission

1946- Lise did a lecture tour of America

Lise and Otto Hahn were nominated for the Nobel Prizes in Physics and Chemistry

Vienna awards the Lieber Prize for Science and Art to Lise Meitner

Lise accepted a salaried position in the physics department of the Royal Institute of Technology in Stockholm

1948- Lise and Otto Hahn were nominated for the Nobel Prizes in Chemistry and Physics

1949- Lise and Otto Hahn were awarded the Max Planck Medal by the German Physical Society. Lise returned to Berlin for the first time since 1938

Lise became a delegate to the United Nations International Atomic Energy Agency

Lise became a Swedish citizen

1954- Lise retired at seventy-five years old but continued her lectures and work with graduate students

Lise became the first recipient of the Otto Hahn Prize

1959- Lise attended the opening of the Hahn-Meitner Institute for Nuclear Research in West Berlin

1960- Lise was awarded the Wilhelm Exner Medal by the Austrian Industry Association

Lise moved to Cambridge, England to be closer to her nephew Otto Frisch and his family

1962- Lise received the Dorothea Schlozer Medal from the University of Gottingen

1966- The Enrico Fermi Award was given to Lise, Otto and Fritz Strassman by the US Department of Energy

1968- Lise died on October 27 in England

1994- Element 109 was named Meitnerium in honor of Lise Meitner

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