Center for History of Physics

Lesson Plan
Lise Meitner: Her Life in Modern Physics

By: Hannah Pell, Research Assistant
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Images courtesy of the AIP Emilio Segré Visual Archives

"Life need not be easy; what is important is that it not be empty. And this wish I have been granted." – Lise Meitner

Grade Level(s): 11-12, College **Subject(s): History, Physics, Chemistry**

In-Class Time: 45-60 Minutes **Prep Time: 15-25 minutes**

Materials

- Audio/Visual Equipment
- Printed Copies of Readings from Supplemental Materials

Objective

Students will learn about the incredible life and accomplishments of Lise Meitner, one of the most important physicists during the 20th century, by reading about her critical role in the discovery of nuclear fission and contributions to the early science of atomic and nuclear physics. Additionally, students are introduced to *nuclear fission*, and read about and discuss different ways that the First and Second World Wars affected physics research in Europe.

Introduction

Early Life in Vienna

Lise Meitner was born on November 7, 1938 in Vienna, Austria, as the third of eight children. Although of Jewish descent, she was baptized and raised in a Protestant household. She attended the University of Vienna and pursued physics "because of a burning desire to understand the working of nature, a desire that appears to go back to her childhood."[1] She also studied mathematics and philosophy, later remarking: "No doubt, like many other young students, I began by attending too many lectures."[2] According to her nephew, Otto Frisch: "from her university days she remembered occasional rudeness on the part of the students (a female student was regarded as a freak) but also much encouragement from her teachers. In particular she often spoke of the contagiously enthusiastic lectures of Ludwig Boltzmann; it was probably he who gave her the vision of physics as a battle for ultimate truth, a vision she never lost."[3] She earned her Doctorate in Physics in 1905—becoming the second woman in Vienna to do so.

1907 – 1934: Research in Berlin

Meitner was invited to Berlin for a post-doctoral position by Max Planck in 1907. After her arrival, she eventually met Otto Hahn, a chemist who was looking for a physicist to partner with to study the emerging science of *radioactive decay*, the process by which a nucleus is turned into another by emission of an alpha or beta particle. Meitner agreed to join him at the Chemical Institute, recalling that "Hahn was of the same age as myself and very informal in manner, and I had the feeling that I would have no hesitation in asking him all I needed to know."[4] Despite the rule of Emil Fischer's, the director of the Chemical Institute, against women conducting research in the laboratory, she was permitted to carry out radiation experiments from a "damp, converted carpentry shop in the basement, accessible by a separate entrance."[5] In 1909, this ban was lifted, and Meitner was able to pursue her work in the chemical laboratories. During her time in Berlin, she became close friends with a myriad of physicists, including Albert Einstein, Erwin Schrödinger, Otto Hahn, Max Born, and Niels Bohr.[6]

With the outbreak of the First World War in 1914, Meitner and Hahn were called to support the war efforts. Meitner volunteered as an X-ray nurse at an Austrian army hospital. Their research was significantly interrupted, as Hahn and Meitner both had to travel between Berlin and their posts during their war service. By the end of the war, they had discovered *protactinium* and were ready to publish their results in 1918. In the years after, Hahn and Meitner remained equals scientifically and professionally, each heading their own section of the Chemistry Institute: Hahn for radioactivity, Meitner for physics.[7] Over time, however, it proved more difficult to collaborate across their newly established institutional disciplinary divide; they did no research together after 1920.

1934-1938: The "Transuranium" Years

However, in 1934 Meitner convinced Hahn to "join the race against Enrico Fermi, Ernest Rutherford, and Irene Joliot-Curie to track down new heavy elements."[8] These new elements were *transuranium*: unstable elements with atomic numbers greater than 92 (atomic number of uranium) which decay radioactively into other elements. Over these four years, Meitner led the investigation into these elements, an investigation which, ultimately, culminated in the experimental discovery of nuclear fission several months after she was forced to flee Berlin.[9] Hahn and his assistant Strassmann published these results in *Naturwissenschaften* on January 6, 1939 under their names only—excluding Meitner.[10]

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[1] Frisch, "Lise Meitner, 1878-1968," 405.
[2] Meitner, "Looking Back," 2.
[3] Frisch, "Lise Meitner," 405-406.
[4] Meitner, "Looking Back," 5.
[5] Swaby, *Headstrong*, 126.
[6] "Not only were they brilliant scientists—five of them later received the Nobel Prize—they were also exceptionally nice people to know. Each was ready to help the other, each welcomed the other's success. You can understand what it meant to me to be received in such a friendly manner into this circle." Meitner, "Looking Back," 5.
[7] Sime, "Lise Meitner and the Discovery of Nuclear Fission," 81.
[8] Swaby, *Headstrong*, 127-128.
[9] Sime, "Lise Meitner's escape," 262.
[10] Sime, "A Nobel Tale," 26.

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1938: Meitner's Escape from Germany

When Hitler rose to power, Meitner was still temporarily shielded from deportation by her Austrian citizenship. At the time, in 1933, many in Germany did not recognize the severity of the threat by the Nazis, and she did not want to emigrate because "she was afraid of being an outsider again, unwelcome in a foreign land, of losing her institute, work, colleagues, and friends."[11] As the war progressed, Otto Hahn got word that Lise was in trouble ("The Jewess endangers the institute."[12]) and dismissed her. Physicists outside Germany understood the escalating severity of the situation; Bohr invited her to lecture in Copenhagen at any time, all expenses paid. However, Meitner did not want to leave Berlin without the security of a full-time position, and so she stayed, continued her research, and waited.

She learned in April that the Austrian Ministry of Education had become aware of her case and began to worry. ("Promises are not kept, possibilities are narrowing," she noted in her diary).[13] She decided to leave for Copenhagen, so she could be close to Niels Bohr and her nephew Otto Frisch who was working at Bohr's institute. She visited the Danish consulate the next day to prepare to leave Germany but learned that her travel visa had been revoked. She was trapped, and the window of opportunity to legally emigrate was closing.

> "For the first time in months, Lise was free to think beyond the moment of escape. Relief turned to shock. Completely uprooted, she had been torn from her work, friends, income, language . . . Stateless and without a passport, she did not know where she would live or how she would travel." - Ruth Lewin Sime, *Lise Meitner: A Life in Physics*

Several more weeks passed. In July, Carl Bosch (German chemist and engineer) learned that a policy prohibiting scientists from leaving Germany would be strictly enforced; it was clear that Meitner needed to leave immediately. Together with the help of Dirk Coster (a Dutch physicist) and Peter Debye (a Dutch American physicist and physical chemist), and several frantic telegraph messages, Meitner was successfully smuggled to safety in the Netherlands. After 31 years in Berlin, Meitner "left Germany forever—with 10 marks in [her] purse."[14] In August of that year, she accepted a full-time position in Stockholm, where she remained until her retirement.

Nuclear Fission: Physics, Chemistry, or both?

While based in Stockholm, Meitner continued her correspondence with Hahn. Following Hahn and Strassmann's initial publication on the *experimental* discovery of nuclear fission, Meitner and Frisch gave the first *theoretical* interpretation of the process, which was published in *Nature* on February 11, 1939.[15] These two publications on the discovery of nuclear fission deeply divided the discovery between Hahn and Strassmann and Meitner and Frisch, chemistry and physics, experiment and theory, Germans and emigres. The science of radioactivity was, in fact, highly interdisciplinary, and these divisions were an unfortunate consequences of Meitner's forced emigration and German anti-Jewish policies.[16]

Meitner's Exclusion from the 1944 Nobel Prize for Nuclear Fission

The 1944 Nobel Prize in Chemistry was awarded to Otto Hahn "for his discovery of the fission of heavy nuclei."[17] It is thought that Strassmann was excluded from the prize because he was Hahn's assistant at the time. However, as noted in the article "A Nobel Tale of Postwar Injustice," the authors write:

[11] Sime, "Lise Meitner's escape," 262.
[12] Ibid., 262.
[13] Ibid., 262.
[14] Ibid., 266.
[15] Sime, "A Nobel Tale," 26.
[16] Ibid., 26-27.
[17] "The Nobel Prize in Chemistry 1944."

> "Meitner's exclusion, however, points to other flaws in the decision process, and to four factors in particular: the difficulty of evaluating an interdisciplinary discovery, a lack of expertise in theoretical physics, Sweden's scientific and political isolation during the war, and a general failure of the evaluation committees to appreciate the extent to which German persecution of Jews skewed the published scientific record."[18]

Hahn maintained his stance that the discovery of nuclear fission relied solely on chemical experiments that were done after Meitner had left Berlin. "She and physics, he maintained, had nothing to do with his success, except perhaps to delay it."[19] Hahn never once mentioned Meitner, her initiative for the uranium project, her leadership of the Berlin team, or their collaboration even after she had settled in Sweden. Years later, she wrote to him: "The chance that I might become your Nobel colleague is finally settled. If you are interested, I could tell you something about it."[20] It is not known if Hahn responded.

Awards, Honors, and Later Life

Meitner was awarded many other accolades for her invaluable contributions to nuclear physics: the Woman of the Year Award (1946) presented by the National Press Club, the Max Planck Medal (1949) from the German Physical Society, the Enrico Fermi Prize (1966), among many others. She was elected a member of both the Royal Swedish Academy of Sciences and Austrian Academy of Sciences and received several honorary doctorates.

The Second World War fractured the international physics community in many irreconcilable ways, and Meitner understood the weighted moral responsibilities of nuclear research. She wrote, "what still gives me ground for anxiety, of course, is what mankind will make of this newly won knowledge, which could come to be used for destruction on a tremendous scale."[21] It was through these factious and unstable years in the history of physics that Meitner emerged as a leader in the new era of modern physics, and the field remains indebted to her contributions today.

Instructions/Activities

Engage: 5-10 minutes

Introduce the class by playing the "Lise Meitner" podcast episode from *Encyclopedia Womannica* (September 25, 2019). Ask students to take notes about major life events, physicists she collaborated with, and details about their historical context in early 20th-century Europe.

What is the teacher doing?	What are the students doing?
Play the podcast episode over a sound system in the classroom, asking students to take note of major life events, physicists with whom Lise worked, and other details about historical context. Fill in additional details from the provided biography above.	Students should be taking notes about major events in Lise Meitner's life, physicists who she collaborated with, as well as other details about historical context.

[18] Sime, "A Nobel Tale of Postwar Injustice," 26.
[19] Sime, "Lise Meitner and the Discovery of Nuclear Fission," 80.
[20] Sime, "A Nobel Tale," 31.
[21] Meitner,"Looking Back," 7.

The teacher can also project the **Powerpoint** included in Supplemental Materials that includes photographs of her as well as the places in which she studied.	

Explore: 10-15 minutes

Depending on class size and available resources, fill this time with an activity introducing or demonstrating **nuclear fission**. Our teaching guide, "Women and the Manhattan Project," includes a useful introduction to explaining the process. Several options are provided below:	
What is the teacher doing? Leading an introduction to or demonstration of the nuclear fission process. (1) "Lesson 3: Nuclear Fission." 2011 Science Outreach Catalyst Kit, American Institute of Physics. (Included in Supplemental Materials) (2) "Educational Activities" from the Center for Nuclear Science and Technology Information. (3) YouTube Video: "What Really Happened the First Time We Split a Heavy Atom in Half."	**What are the students doing?** Participate in the activity or demonstration introducing nuclear fission. With a nearby classmate, explain the physical process of nuclear fission, and why this discovery was so important.

Explain: 15 minutes

Students will read "Lise Meitner and the Discovery of Nuclear Fission." (skip article section titled "Untangling Decay Chains").	
What is the teacher doing? Divide the class into groups and pass out printed copies of the article "Lise Meitner and the Discovery of Nuclear Fission." Instruct the students to take note about details regarding the historical context surrounding the discovery of nuclear fission. Why was Meitner not included in the original publication? What were potential reasons she was excluded from the Nobel prize? In what ways did the Second World War effect the international physics network?	**What are the students doing?** Students will read "Lise Meitner and the Discovery of Nuclear Fission" (skipping the section titled "Untangling Decay Chains"). Students will highlight and make note of details regarding the historical context of the nuclear fission discovery, paying special attention to the questions provided in the box on the left.

Elaborate: 10-15 minutes

Students will work in their groups to write their own history of the discovery of nuclear fission, including details about Lise Meitner's life, her collaborators, where the research was being done, controversy about the Nobel prize and broader political and international events of that time and place.

What is the teacher doing?	What are the students doing?
Instruct the students to work together and write their own version of the story. They can choose to write a skit, make a timeline, act out a mock interview with Lise Meitner, use a map—whatever tools they can utilize to best tell their story.	Students are working in groups to write their own historical account of the nuclear fission discovery, using information from the article.

Evaluate: 5-10 minutes

Student groups share their stories with the rest of the class. If time remains, discuss aspects of the story that all the groups shared. Ask students why they chose to include certain details and leave others out, and why considering the historical context is important for telling the story of a scientific discovery.

Required/Recommended Reading and Resources

On the Nuclear Fission Discovery:

- Meitner, L., & Frisch, O. (1939). Disintegration of Uranium by Neutrons: A New Type of Nuclear Reaction. *Nature*, *no. 3615*, 239–240.
- Sime, R. L. (1998). Lise Meitner and the Discovery of Nuclear Fission. *Scientific American*, *278*(1), 80–85.

Biographical Resources:

- Frisch, O. R. (1970). Lise Meitner. 1878-1968. *Bibliographical Memoirs of Fellows of the Royal Society*, *16*, 405–420.
- Meitner, L. (1960). The status of women in the professions. *Physics Today*, *13*(8), 16–21. https://physicstoday.scitation.org/doi/10.1063/1.3057062
- Meitner, L. (1964). Looking Back. *Bulletin of the Atomic Scientists*, *20*, 2–7.
- Sime, R. L. (1990). Lise Meitner's escape from Germany. *American Journal of Physics*, *58*, 262–267. https://doi.org/10.1119/1.16196
- Swaby, R. (2015). *Headstrong: 52 Women Who Changed Science—And the World*. New York, New York: Broadway Books.

On the Nobel Controversy:

- Crawford, E., Sime, R. L., & Walker, M. (1997). A Nobel Tale of Postwar Injustice. *Physics Today*, *50*(9), 26–32. https://doi.org/10.1063/1.881933

Extensions

Related AIP Teacher's Guides on Women and Minorities in the Physical Sciences:

- "The Nobel Prize in Physics: Four Historical Case Studies"

Common Core Standards

For more information on Common Core Standards, visit http://www.corestandards.org/.

Speaking & Listening	
CCSS.ELA-LITERACY.SL.11-12.1	Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 11-12 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.
CCSS.ELA-LITERACY.SL.11-12.2	Integrate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data.
CCSS.ELA-LITERACY.SL.11-12.4	Present information, findings, and supporting evidence, conveying a clear and distinct perspective, such that listeners can follow the line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and a range of formal and informal tasks.
History/Social Studies	
CCSS.ELA-LITERACY.RH.11-12.1	Cite specific textual evidence to support analysis of primary and secondary sources, connecting insights gained from specific details to an understanding of the text as a whole.
CCSS.ELA-LITERACY.RH.11-12.2	Determine the central ideas or information of a primary or secondary source; provide an accurate summary that makes clear the relationships among the key details and ideas.
CCSS.ELA-LITERACY.RH.11-12.7	Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., visually, quantitatively, as well as in words) in order to address a question or solve a problem.
CCSS.ELA-LITERACY.RH.11-12.9	Integrate information from diverse sources, both primary and secondary, into a coherent understanding of an idea or event, noting discrepancies among sources.
Science & Technical Subjects	
CCSS.ELA-LITERACY.RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
CCSS.ELA-LITERACY.RST.11-12.2	Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
CCSS.ELA-LITERACY.RST.11-12.4	Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 11-12 texts and topics*.

Next Generation Science Standards

For more information on the Next Generation Science Standards, visit http://www.nextgenscience.org/.

Dimension One: Practices	1. Asking questions (for science) and defining problems (for engineering)

	6. Constructing explanations (for science) and designing solutions (for engineering) 8. Obtaining, evaluating, and communicating information
Dimension Two: Crosscutting Concepts	2. Cause and effect 3. Scale, proportion, and quantity 5. Energy and matter
Dimension Three: Disciplinary Core Ideas	Core Idea PS1: Matter and Its Interactions