Nuclear Chemistry Unit: The Manhattan Project

Essential Question:

How have discoveries in science over the past 300 years led to the development of nuclear energy and nuclear bombs?

Subtopics/Content Outline:	*Classroom Activities*
KEY: * *Indicates that this content is discussed in book "Trinity: A Graphic History of the First Atomic Bomb"* # *Indicates that this content is addressed in the movie "Day One"* N *Indicates content well suited to be introduced through primary source archived newspaper articles* *"Suggested discussion questions to prompt discussions about the Nature of Science"*	**KEY:** ***Formative Assessment*** ***Instructional Video*** ***Activity*** ***Problem Sets***
I. **Atomic Structure: *3-5 periods*** ➢ John Dalton ○ First scientific atomic theory. ➢ J.J. Thomson ○ Cathode Ray Tube experiment and the discovery of electrons. ○ Chocolate Chip Cookie model. ➢ Earnest Rutherford *"How did Rutherford's discovery change our understanding of atoms?"* *"Can J.J. Thomson's plum pudding model still be considered a scientific theory?"* ○ Gold Foil Experiment. ○ Discovery of the nucleus. ➢ Isotopes ○ Understanding what distinguishes two isotopes.	***Video 1 – Early Atomic Theory*** ***Inquiry Activity: Rutherford Gold Foil Experiment*** **www.phet.colorado.edu/en/simulation/Rutherford-scattering** ***Students illustrated & annotated a timeline chronicling the development of modern atomic theory.*** ***Video 2 – Isotopes*** ***Practice counting number of protons, neutrons, and electrons in different isotopes of an element.***
II. **Radioactivity and Nuclear Decay: *3-5 periods*** ➢ Marie & Pierre Curie and the Discovery of Radiation *N *"Marie Curie originally wasn't considered for a Nobel Prize, even though she worked with her husband to discover radioactivity. Her husband insisted she be included, and eventually she won the Nobel Prize with her husband and one other scientist. Do you think women in science today still face discrimination?"* ○ Types of radiation ○ Spontaneous decay and radioactive isotopes ➢ Isotopes and Decay ○ Predicting decay of different isotopes ➢ Writing Nuclear Decay Reactions ○ α radiation ○ β radiation ○ γ radiation	***Text Reading & Class Discussion – Marie Curie and the Science of Radioactivity*** **www.aip.org/history/curie/contents.htm** **http://nyti.ms/1virUDq** ***Video 3 – Introduction to Radiation & Types of Decay*** ***Introduce and begin reading graphic novel: Pages 2-15, Radiation & Fission***

	Video 4 – Alpha Decay ***Writing alpha decay nuclear reactions*** ***Video 5 – Beta Decay*** ***Writing beta decay nuclear reactions*** ***QUIZ – Radiation and Nuclear Decay***
III. The Birth of Nuclear Science: *4-6 periods* ➢ Fission *# *"Leo Szilard was made fun of for thinking that a nuclear chain reaction could be possible. Why? Do you think scientists today are ever teased for their ideas?"* *"Who decides what knowledge and ideas are scientific?"* ○ Early nuclear scientists: Otto Hahn & Fritz Strassmann, Lise Meitner, Leo Szilard ➢ Chain Reactions *# ○ Modelling how a chain reaction perpetuates, and the conditions it needs to do so. ➢ Uranium Enrichment * ○ Revisit isotopes and decay ➢ Nuclear Reactor *# *"In the film, Enrico Fermi and the other scientists celebrate when their reactor successfully records a chain reaction. Why is this a big deal? Why does Leo Szilard appear concerned? Should scientists be responsible for thinking about the potential long-term impact of their discoveries?"* ○ Puzzle: How to control a chain reaction ○ Enrico Fermi and Chicago Pile-1	***Graphic novel: Pages 16-37: Groves, Oppenheimer, Szilard, and Los Alamos*** ***Content-based and historical reading comprehension questions which students work through in class, in groups.*** ***Video 6 – Fission & Nuclear Chain Reactions*** ***Activity - Modelling nuclear reactions with diagrams and functions.*** ***Begin Film – Day One*** ***Graphic novel: Pages 38-57, Chain Reaction & Enrichment*** ***Content-based and historical reading comprehension questions which students work through in class, in groups.*** ***Conceptual Mini-Test: Nuclear Fission, Chain Reactions, and Enrichment.***
IV. Building and Dropping the bombs: *# ***5-7 periods*** ➢ The Manhattan Project *"Why did Oppenheimer and General Groves decide to send all the scientists to work together in Los Alamos? Do you think scientists today ever get concerned about secrecy and spies?"* ○ Los Alamos – Secret City ➢ Bomb design *# ○ Uranium & Plutonium ➢ Trinity test *# ○ Observable impacts ➢ The decision to drop the bomb *# *"What influence did the scientists from Los Alamos have in the decision to drop the bomb? Do you believe scientists should be involved in politics?"* *"Do you believe it was an ethical decision to drop the bomb?"* ○ Conflict: Oppenheimer, Truman, and Leslie Groves ➢ Nuclear fallout and radiation poisoning * ○ Long-term impacts ➢ Reactions *# N *"How have Oppenheimer and Einstein's opinions about the decision to build a bomb changed? What caused them to change?"*	***Text Analysis: Einstein's Letter to President Roosevelt*** ***Continue Film – Day One*** ***Video 7: Bomb Design*** ***Graphic novel: Pages 58-79, Bomb Design and Trinity*** ***Content-based and historical reading comprehension questions which students work through in class, in groups.*** ***Graphic novel: Pages 80-95, Deciding to Use the Bomb*** ***Content-based and historical reading comprehension questions which students work through in class, in groups.*** ***Graphic novel: Pages 96-110, Hiroshima*** ***Graphic novel: Pages 111-129, Nagasaki*** ***Finish Film– Day One***

- Einstein and Oppenheimer
- Truman
- Eisenhower – Atoms for Peace

V. **Nuclear Energy:** ***3-5 periods***

- Nuclear power plants [N]

  "What contributes to the tension over whether or not we should further pursue nuclear power in the United States?"
  - Design and function
  - Nuclear waste disposal
  - Fuel: mining and enrichment
- Three Mile Island, Chernobyl, and Fukushima Daiichi [N]

  "Are the potential benefits of nuclear power worth the risks?"

Text Analysis: Atoms for Peace Speech

Graphic novel: Pages 130-151, Political Aftermath

Video 8: Nuclear Energy

Pro/Con analysis of nuclear energy as alternative fuel.

Quiz: Mechanisms of nuclear power, synthesis of main arguments for/against.

Students will be able to:

- ✓ Explain how a series of scientific discoveries has led to our current understanding of the structure of the atom.
- ✓ Explain the concept of radiation, and describe the different types of radiation that exist.
- ✓ Distinguish between alpha, beta, and gamma radiation, and predict the daughter of a nuclear decay reaction.
- ✓ Describe how two isotopes of the same element differ, and know how to read a graph to predict if and how an isotope will decay.
- ✓ Outline the historical context and key scientific discoveries that lead to the creation of the first atomic bomb.
- ✓ Explain how the structure of a nuclear reactor permits for a controlled fission reaction.
- ✓ Distinguish between the nuclear fission reactions created in an atomic bomb and in a nuclear power plant.
- ✓ Cite key arguments for and against the use of nuclear energy.
- ✓ Discuss the way that science impacts society, and vice versa.

Assessments

Formative

- *Entrance and Exit Tickets*
- *Reading logs - Trinity*
- *Quizzes*
- *Day One Movie Reflection*
- *Newspaper Analysis*
  - Marie Curie
  - Hiroshima
  - Three Mile Island
  - Chernobyl
  - Fukushima Daiichi

Summative

Unit Exam

Standard content exam on relevant chemistry concepts. Includes a mix of multiple choice and constructed response questions.

Analytic paper

1. *What three discoveries in science were most important in leading mankind to discover nuclear energy and nuclear bombs? Explain each discovery and why you think it was a significant event leading to our discovery of nuclear energy and nuclear bombs."*
2. *If you could give out a post-mortem Nobel Prize in Chemistry for the most significant contribution to modern science, to whom would you give the prize? How has this person's discovery changed the course of mankind? (For the purposes of this essay, limit yourself to one of the discoveries we discussed in this course).*
3. *Should scientists get involved in politics?*
4. *Who is responsible for the development of the atomic bomb?*
5. *Should the United States invest in building its nuclear power infrastructure?*
6. *What should the United States be doing, if anything, to compensate the families impacted by fallout from by nuclear testing?*

Extensions:

For more advanced students, consider the following extension:

- Have students read *The Girls of Atomic City: The Untold Story of the Women who Helped Win World War II*, by Denise Kiernan, and reflect on the role of women in science over the course of the 20th century.

Key Resources:

- *Fetter-Vorm, J. (2012). Trinity : a graphic history of the first atomic bomb (1st ed. ed.). New York: Hill*

and Wang. Film: *Day One*, Acorn Media, 1989
- *Day One* [Motion picture on DVD]. (1989). Acorn Media.
- New York Times digital archives

Supplemental Resources for Students and Teachers:
- Ottaviani, J. (2001). *Fallout : J. Robert Oppenheimer, Leo Szilard, and the political science of the atomic bomb*. Ann Arbor, MI: G.T. Labs.
- Nakazawa, K. (2004). *Barefoot Gen : a cartoon story of Hiroshima*. San Francisco, Calif.: Last Gasp of San Francisco.
- The Chemical Heritage Foundation: *http://www.chemheritage.org/*
- Sheinkin, S. (2012). *Bomb : the race to build and steal the world's most dangerous weapon*. New York: Roaring Brook Press.
- *Simon, S. L., et al. (2006). "Fallout from Nuclear Weapons Tests and Cancer Risks: Exposures 50 years ago still have health implications today that will continue into the future."* American Scientist ***94****(1): 48-57.*
- Aczel, A. D. (2009). *Uranium wars : the scientific rivalry that created the nuclear age* (1st ed. ed.). New York, NY: Palgrave Macmillan.
- Kiernan, D. (2013). *The girls of Atomic City : the untold story of the women who helped win World War II* (1st Touchstone hardcover ed. ed.). New York, NY: Simon & Schuster.

Next Generation Science Standards

Performance Expectation:
HS – PS1 – 8
Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

Science and Engineering Practices:
Developing and Using Models
Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
Engaging in Argument from Evidence
Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.

Disciplinary Core Ideas:
PS1.A: Structure and Properties of Matter
- Each atom has a charged substructure consisting of a nucleus, which is made of protons and neutrons, surrounded by electrons.
- The periodic table orders elements horizontally by the number of protons in the atom's nucleus and places those with similar chemical properties in columns. The repeating patterns of this table reflect patterns of outer electron states.

PS1.C: Nuclear Processes
- Nuclear processes, including fusion, fission, and radioactive decays of unstable nuclei, involve release or absorption of energy. The total number of neutrons plus protons does not change in any nuclear process.

Cross-Cutting Concept:
"Energy and Matter"
**In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.*

Understandings about the Nature of Science:
- Most scientific knowledge is quite durable but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence.
- Scientists often use hypotheses to develop and test theories and explanations.
- Scientific knowledge is a result of human endeavor, imagination, and creativity.
- Science and engineering are influenced by society and society is influenced by science and engineering.
- Science and technology may raise ethical issues for which science, by itself, does not provide answers and solutions.

Common Core State Standards

English Language Arts Standards – Literacy in Science & Technical Subjects:

Literacy.RST.9-10.2

- Determine the central ideas or conclusions or a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.

Literacy.RST.9-10.4

- Determine the key 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 9-10 texts and topics.

Literacy.RST.9-10.9

- Compare and contrast findings presented in a text to those from other sources (including their own experiments), noting when the findings support or contradict previous explanations or accounts.

English Language Arts Standards - Writing:

Literacy.W.9-10.1

- Write arguments to support claims in an analysis or substantive topics or texts, using valid reasoning and relevant and sufficient evidence.

Literacy.W.9-10.4

- Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

Literacy.W.9-10.9

- Draw evidence from literary or informational texts to support analysis, reflection, and research.

English Language Arts Standards – Reading Informational Text:

Literacy.RI.9-10.6

- Determine an author's point of view or purpose in a text and analyze how an author uses rhetoric to advance that point of view or purpose.

Literacy.RI.9-10.9

- Analyze seminal U.S. documents of historical and literary significance, including how they address related themes and concepts.

Mathematics Standards – Linear, Quadratic, and Exponential Models:

Math.Content.HSF.LE.A1

- Distinguish between situations that can be modeled with linear functions and with exponential functions.

Math.Content.HSF.LE.A2

- Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs.