Addressing Energy Needs with Radioactive Decay

RESET AN AEOP EFFORT aeop

6 - 9 weeks

Authors

Monique Somma

Christine Girtain

Angela McCulley

SUBJECT/GRADE LEVEL

Subject Area: Chemistry

Grade Level: High School

Materials

- Materials
  - Engage - Modeling_Burning fossil fuels for energy
  - 12-16 500 mL beakers (glass) or mason jars, 2 for each group of 3-4 students.
  - 12-16 Tea candles, 2 for each group
  - 2 Long matches/group or Flint striker
  - 1 Digital or triple beam scale per group
  - Explore
  - Socratic Seminar Guide & Rubric
  - Physical/Chemical/Nuclear change modeling activity - teacher
  - Physical/Chemical/Nuclear change modeling activity - student
  - Penny decay lab sample
  - 6-8 penny rolls_1 Roll of pennies per group
  - 6-8 solo cups or plastic beakers 1 per group
  - Alt Penny decay lab
  - Decay Simulations
    - Phet simulation https://phet.colorado.edu/en/simulations/nuclear-fission
    - Edumedia simulation https://www.edumedia-sciences.com/en/media/588-nuclear-fusion
    - Javalab simulation https://javalab.org/en/nuclear_chain_reaction_en/
    - Visualize it https://visualize-it.github.io/nuclear_fusion/simulation.html
  - Explain
  - Green Energy Socratic Seminar
  - Elaborate

- Nuclear Energy Research Project Guide
- Scaffolded option (for students needing accommodation)
- Evaluate
- Research Project Rubric
- Guide to APA citation
- APA Citation Machine

- Extras
  - Eunice Newton Foote
  - Crash Course Nuclear Chemistry Part 1
  - Crash Course Nuclear Chemistry Part 2
  - Nuclear Chemistry Background Information Resources and Activities
  - Nuclear Fission and Fusion Background
  - Betavoltaic Batteries
  - Tantalum
  - Isotopes of interest

STANDARDS

Next Generation Science Standards

- HS-EST1-3 Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.
- HS-PS1-7. Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction.
- 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.
- HS-ESS3-2: Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.
- HS-PS4-4. Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.
- HS-PS4-5. Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.*

Mathematics Standards | Common Core State Standards

- CCSS.MATH.CONTENT.HSS.MD.A.1 (+) Define a random variable for a quantity of interest by assigning a numerical value to each event in a sample space; graph the corresponding probability distribution using the same graphical displays as for data distributions.
- CCSS.MATH.CONTENT.HSS.CP.B.9 (+) Use permutations and combinations to compute

probabilities of compound events and solve problems.

English Language Arts Standards | Common Core State

- CCSS.ELA-LITERACY.W.9-10.2Write informative/explanatory texts to examine and convey complex ideas, concepts, and information clearly and accurately through the effective selection, organization, and analysis of content.
- CCSS.ELA-LITERACY.W.9-10.7Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
- CCSS.ELA-LITERACY.W.9-10.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.

LESSON OBJECTIVE(S)

Students will investigate how different radioisotopes can be used as a source of alternative energy.

CAREER CONNECTION(S)

Mentor Background:

"Dr. James (Jeff) Carroll leads a research team for the US Army Research Laboratory (ARL) in Maryland. Before joining ARL, he was a Professor in the Department of Physics and Astronomy at Youngstown State University (YSU), a public masters-comprehensive institution in NE Ohio. Youngstown, Ohio, is in the "rust belt" area. Many of the students attending YSU were the first in their families to attend college, so it was exciting to help those students grow in confidence in their abilities and succeed in their education. Jeff has over 35 years of experience in experimental nuclear physics and has published nearly 140 peer-reviewed journal articles on discoveries in that field, including in Nature. He's participated in research at many laboratories and has given nearly 100 plenary or invited presentations worldwide. Jeff's interest in physics started in the 1960s with the Apollo space program, the invention of the first laser, the movie "2001: A Space Odyssey", and the prime-time TV show "Jonny Quest" (Jeff wanted to be the bearded scientist dad "Dr. Quest" instead of the precocious kid). He loves tennis and has been rated as high as a 5.0 on the US Tennis Association rating system (and finds lots of physics in tennis)."

STEM Careers:

- Nuclear physics: Nuclear structure, Types of elements
- Data scientists
- Theorists (statisticians/scientists)
- Computer engineering
- Computer science deals with coding and programming
- Electrical Engineering Technician (Certificate or 2-year degree).
- Heavy Equipment Operator
- Mechanics

ENGAGEMENT

Brief Description: To engage students in the topic of nuclear energy sources, we will first start with energy sources that students are familiar with, burning fossil fuels.

Procedures: (1 - 50 minute class period)

Ask students, where do we get our energy from? Have students get into small groups and allow them to answer the question with a drawing and imagine how carbon is stored in fuels and enters the atmosphere. After students create an image of how carbon gets into the atmosphere, have students share and explain their drawings with another group. Briefly review the carbon cycle or watch a video about the climate change and energy.

Next, students will move into the lab, Engage - Modeling Burning fossil fuels for energy; students will use a candle and a mason jar or beaker to model the formation of Carbon dioxide and how it creates a less-than-desirable impact in a closed system. They will also investigate the law of conservation of mass.

Share the instructions with students digitally or hardcopy. Review the procedure steps with students highlighting the details of how to set up the experiment and conduct it safely.

Complete the lab together as a class and discuss student observations. Help them infer what occurred during the lab and what it implies about energy and Earth's inhabitants through class discussion.

If completing this activity virtually, try a Jamboard for students to share their thoughts and ideas visually about the cause of carbon emissions and their effects on the atmosphere.

EXPLORATION

Brief Description: To further investigate energy needs and potential sources, students will investigate radioactive decay as an alternative energy source for societal needs.

Procedures: (1 - 50 minute class period)

What is nuclear chemistry? What is radioactive decay? Students view a short clip about radioactive decay, nuclear chemistry part 1, and nuclear chemistry part 2.

For the exploration portion of the activity, students will model radioactive decay with a Penny decay lab or Alt Penny decay lab. Students will read scientific data and discuss options and facts surrounding nuclear energy through Socratic Seminar.

Have students get into groups of 3-4 and conduct the investigation of radioactive decay. Before students begin, review the instructions for the lab and what should be done. Students will conduct the lab activity modeling decay and then discuss the results.

What did they find? How well do they understand the concept of decay? How might the energy from radioactive decay be utilized as an energy source? Sample Socratic Seminar Questions and Reflection.

EXPLANATION

Brief Description: Students will conduct meaningful research from reliable sources about nuclear energy sources, including fission, fusion, or radioactive decay, to complete a research project.

Procedures: [2 weeks (4 - 50 minute class periods)]
Students will learn about effective research methods and reliable sources. Students will select a baseline nuclear energy source, fission or fusion, and an isotope of interest as an alternative nuclear energy source and why it is useful. Students will take notes and write citations in MLA (APA) format. How to conduct meaningful research guide from the Library of Congress. This site can be used in lectures or assigned to students to read independently.

ELABORATION

Brief Description: Students will write a research paper about the pros and cons of alternative energy sources to reduce carbon emissions.

Procedures: [2 weeks (4 - 50 minute class periods)]
Students will complete a research project looking at energy sources that do not rely on fossil fuels. Students will evaluate the reliability of Solar, wind, hydroelectric, geothermal, biomass & nuclear energy sources, including fission, fusion, and radioactive decay. Student research will demonstrate their understanding of each process and its benefits to society and the environment.

Nuclear Energy Project Guidelines.

Teacher - Review the assignment parameters, criteria, and research constraints and facilitate student research and paper writing organization

Students - Utilize information gatherer
Scaffolded option

EVALUATION

Brief Description: Rubric and self-reflection with a hit, miss, or wish.
Research Project Rubric

Procedures:
Students will reflect on what they have completed and their performance on the task. Additionally, students will be evaluated on the feasibility of their solutions and the logic of their writing. Finally, as a class, we will critique the project with an activity called hit, miss, and wish. Hits are things that worked well, Misses are things that did not work well or were exceptionally challenging, and a wish is how to improve it next time.

REFERENCES

- Provide links to resources that you used in the creation of this unit.
- P Kapalo *et al* 2022 *IOP Conf. Ser.: Mater. Sci. Eng.* 1252 012011. DOI 10.1088/1757-899X/1252/1/012011
- Helmenstine, A.M., (2023). What Happens to Candle Wax When a Candle Burns. ThoughtCo, thoughtco.com/where-does-candle-wax-go-607886
- Turk, Lindsay, Activity: Physical, Chemical and Nuclear Changes. American Association of Chemistry Teachers, https://scalacs.org/?page_id=12 activity-physicalchemicalnuclearchanges.docx
- Nuclear Energy Half-Life of a Penny Activity, https://www.stocktonusd.net/cms/lib/CA01902791/Centricity/Domain/3232/chemistry-half_life_of_a_penny_activity_2.1.18.pdf
- Nuclear Fission. Phet.colorado.edu, https://phet.colorado.edu/en/simulations/nuclear-fission
- Nuclear fusion. Edumedia, https://www.edumedia-sciences.com/en/media/588-nuclear-fusion
- Nuclear Chain Reaction. Javalab.org, https://javalab.org/en/nuclear_chain_reaction_en/
- Nuclear Fusion. Github, https://visualize-it.github.io/nuclear_fusion/simulation.html
- Eunice Newton Footes 204th birthday. Google.com, https://www.google.com/doodles/eunice-newton-footes-204th-birthday
- Gonzales, E. (November 19, 2013). Nuclear Chemistry: Crash Course Chemistry #38 #38,https://www.youtube.com/watch?v=KWAsz59F8gA
- Gonzales, E. (November 19, 2013). Nuclear Chemistry Part 2 - Fusion and Fission: Crash Course Chemistry #39 https://www.youtube.com/watch?v=FU6y1XIADdg
- Hill, R. (2022). Popping corn or nuclear decay. Royal Society of Chemistry. All Nuclear chemistry and radioactivity articles, https://edu.rsc.org/nuclear-chemistry-and-radioactivity/115037.subject?page=1
- Diffen. Nuclear Fission and Fusion, https://www.diffen.com/difference/Nuclear_Fission_vs_Nuclear_Fusion
- City Labs. (2022). Radioisotopes and How They Work, https://citylabs.net/radioactive-isotopes/
- Conover, Emily. (OCTOBER 3, 2016). Rarest nucleus reluctant to decay. Science News, https://www.sciencenews.org/article/rarest-nucleus-reluctant-decay
- Bodenhausen, H. (December 7, 2022). What is Climate Change?: Crash Course Climate & Energy #1, https://www.youtube.com/watch?v=9PFhrpyWV-w