6. Nuclear Physics

In this 5E segment, students will use models to explain radioactive decay, fission, and fusion. Students will use simulations to investigate radioactive decay and half-life.	
Student Science Performance	
Physics **Topic: Nuclear Physics**	**Title:** Nuclear Physics
Performance Expectation for GSE: **SP6. Obtain, evaluate, and communicate information about nuclear changes of matter and related technological applications.** a. Develop and use models to explain, compare, and contrast nuclear processes including radioactive decay, fission, and fusion. b. Construct an argument to compare and contrast mechanisms and characteristics of radioactive decay. (*Clarification statement:* Include alpha, beta, and gamma decays and their effects.) c. Develop and use mathematical models and representations to calculate the amount of substance present after a given amount of time based on its half-life and relate this to the law of conservation of mass and energy.	
Performance Expectations for Instruction: 1. Students will be able to differentiate between radioactive decay, nuclear fusion, and nuclear fission. 2. Students will be able to classify chemical equations as representing alpha, beta, or gamma decay. 3. Students will be able to account for a loss of mass as energy and explain this process. Additional notes on student supports	
Materials Pennies Shoebox Chart Paper Graph Paper Computer with Internet Access	
Students will continuously obtain, evaluate, and communicate information. This is not a linear process. Students will communicate through writing and discussions to allow for formative assessment. This benefits the teacher, student, and whole group to guide instruction to clarify misconceptions or extend content.	
Engaging Learners	**Phenomenon** Areas around a nuclear accident remain unsafe for humans.
	Obtaining Students obtain information about the Chernobyl disaster, or others, in attempt to answer the guiding question: *If Chernobyl happened in 1986, how are some areas still not safe for humans?* *Teacher Notes: a video or photographs should be shown to illustrate the nuclear disaster.*
	Evaluating Evaluate student claims based on evidence and reasons given for areas still be in high in radioactive emissions.

	Communicating Students share initial claims through group or class discussion and writing.
Exploring ***Exploring Phenomena***	*Obtaining* To further the discussion, conduct the following demonstration of decay and half-life: Penny Decay Demo This demonstration shows how decay is exponential and is a good visual of half-life and the randomness of decay. 1. Start by giving a penny to each student in class. Each student with his or her penny represents a radioactive isotope. Have one student at the board to graph the results of the demo. 2. With all students standing, tell them to flip their coins. If the student gets tails= they sit down; this represents an isotope decaying into something more stable. If they get heads= they do not decay and remain standing. 3. Have the students come up with the best way to graph the data, possibly with # of students on the y axis and flip # on the x axis. 4. Have the remaining students flip again, with the same heads or tails result. 5. Continue until only a few students remain. Consider repeating to see if the data is similar again.
	Communicating Discussion: Each flip represents a half-life; after a couple of runs through the demo, students should see how the amounts are somewhat predictable (as far as # of students remaining). The graph should show an exponential curve.
	Evaluating Pose the following questions to students (individual or in groups): 1. Can you predict what round of coin flips/half-lives you will sit down in? Explain. 2. How closely can you predict how many students will remain standing after 2 flips/half-lives? 3. Do the same number of students sit down after each flip/half-life? Why or why not? 4. If this was a large class of 40 students, how many flips/half-lives would it take to only have a few standing? 5. If your class had twice the number of students, about how many students would have "decayed" (sat down) by the third flip/half-life?

	Formative Assessment of Student Learning
Explaining Finalizing Model	*Obtaining* Students will research the mechanisms of radioactive decay in order to construct arguments to compare and contrast alpha, beta, and gamma decay. Arguments should include the effects of the different types as well.
	Evaluating Evaluate student arguments for the mechanisms and characteristics of each type of decay.
	Communicating Students will communicate findings with a group/class discussion or poster-sharing session.
Elaborating Applying Model to Solve a Problems	**Phenomenon** Radioactive elements decay in a predictable manner.
	Obtaining 1. Students will create a graphic organizer that provides sample problems and equations of fission, fusion, alpha decay, beta decay, gamma decay, and half-life. 2. Students will also identify the relationship between each of these phenomena
	Evaluating 1. Students will complete the comprehensive investigation using PhET Simulations. (Attribution: PhET Interactive Simulations, University of Colorado Boulder; https://phet.colorado.edu) ● Alpha Decay ● Beta Decay ● Nuclear Fission 2. Students will use the following handout: Nuclear Physics Investigation 3. Students complete the Uranium decay series.
	Communicating Students will develop models and use these models to write an argument using the Claim-Evidence-Reasoning format.
Evaluation	***Assessment of Student Learning***
	Students are assessed throughout this segment with class discussions, group work, lab sheets, and student writing.
SEP, CCC, DCI	**Science Essentials**
Science and Engineering Practices	● Developing and Using Models ● Using Mathematics and Computational Thinking ● Engaging in Argument from Evidence
Crosscutting Concepts	● Energy and Matter ● Stability and Change ● Scale, Proportion, and Quantity
Disciplinary Core Ideas	From *A Framework for K-12 Science Education*: ● PS2C: Nuclear Processes ● PS2B: Types of Interactions ● PS4B: Electromagnetic Radiation

Additional Supports for struggling learners:

The following supports are suggestions for this lesson and are not the only options to support students in the classroom. These supports target students that struggle with science material, this lesson or a previous lesson. These are generalized supports and do not take the place of IEP accommodations as required by each student's Individualized Education Program.

General supports for the following categories:

Reading:

1. Provide reading support by reading aloud or doing partner reads
2. Have the teacher model what they are thinking when reading the text
3. Annotate the text with students so that they may refer to it as they work through the lab

Writing:

1. The teacher can provide a sentence starter for the students.
2. The teacher can give students an audience to write to (i.e. Write a letter to your sibling explaining this topic).
3. The teacher can provide constructive feedback during the writing process to help students understand the expectations.

Math:

1. Provide calculators as needed.
2. Provide graph paper as needed.

Supports for this specific lesson if needed:

Performance expectations for instruction:

1. The teacher should provide information to students in various formats to reach as many students as possible.
2. The students should be given adequate time to complete each part of the lesson.
3. The students should be allowed to express their knowledge in various formats.
4. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material.

Engage:

1. The teacher should consider providing students with an organizer to record their research.
2. The teacher should also consider providing students with sources to use in their research.
3. The teacher should, also, consider using video, articles, text-to-speech and audio to assist students in accessing the material.
4. The teacher should have clear and consistent guidelines for discussions to help students feel more comfortable and be more likely to participate.
5. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material. These formats could include diagramming, drawing, writing or verbally explaining.
6. Students may need additional time to complete their assignment.
7. The teacher should consider providing students with multiple ways to share their work. These formats could include using technology, gallery walks or presentations.

Exploring:

1. The teacher should be prepared to repeat directions as needed.
2. The teacher needs to explicitly state the connections between the penny demo and decay.
3. The teacher should discuss and show what an exponential curve looks like and what it means.
4. The teacher should provide students with an opportunity to answer individually prior to discussing.
5. The teacher should have clear and consistent guidelines for class discussions. these guidelines should help students feel more comfortable and be more likely to participate.

Explaining:

1. The teacher should consider providing students with sources to use in their research.
2. The teacher should consider providing students with an organizer to record their research.
3. The teacher should be prepared to remind students of the definition of a scientific argument.
4. The teacher should consider providing students with a rubric to self-evaluate their scientific argument. This should increase student ownership of their argument.
5. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material. These formats could include diagramming, drawing, writing or verbally explaining.
6. Students may need additional time to complete their assignment.
7. The teacher should consider providing students with multiple ways to share their work. These formats could include using technology, gallery walks or presentations.

Elaborating:

1. The teacher should be sure to provide multiple ways for the students to communicate their knowledge of the material. These formats could include diagramming, drawing, writing or verbally explaining.
2. Students may need additional time to complete their assignments.
3. The teacher should consider providing students with a graphic organizer to assist students in organizing the material.
4. Students may need sentence starters to assist students in writing their scientific argument.
5. The teacher should consider providing students with a CER template.

Evaluating:

1. The teacher should consider giving students multiple formats to communicate their knowledge. This could be drawing, writing or designing a presentation.
2. Students may need additional time to complete their assignments.

Nuclear Processes

<u>Goal:</u> To better understand natural/artificial transmutation and nuclear fission.

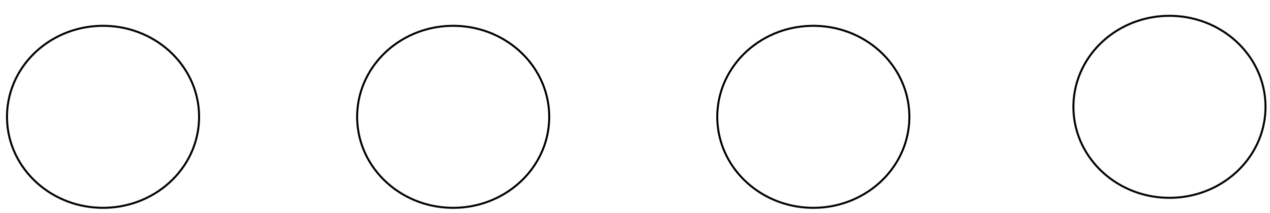
Part A: Alpha Decay

Start by opening the PhET model "Alpha Decay". Make sure that you first start by clicking on the single atom tab. (Attribution: PhET Interactive Simulations, University of Colorado Boulder; https://phet.colorado.edu)

1. Observe the decay of Po-211. Write a nuclear equation for the decay of Polonium-211.

2. What has to happen within the nucleus in order for an atom of Polonium-211 to decay?

The half-life of Po-211 is approximately 500 ms (half a second). **Without using the PhET model**, sketch a pie graph indicating the number of **undecayed Po-211 atoms** for a reaction starting with 100 total atoms.



t= 0.5s t=1.0s t=1.5s t=2s

Now, simulate the decay of 100 Po-211 atoms by adding 100 atoms from the “Bucket o’ Polonium”. Sketch what the pie graph looks like at the times shown.

t= 0.5s   t=1.0s   t=1.5s   t=2s

3. Compare your prediction to the results that you observed. How can you explain any discrepancies?

4. Is it reasonable to assume that if you start with 10 atoms of Polonium, that 0.5s later only 5 will remain undecayed? What if you start with 500 atoms? Explain.

Part B: Beta Decay

Open the "Beta Decay" PhET model. Make sure that you click on the "Single Atom" tab. (Attribution: PhET Interactive Simulations, University of Colorado Boulder; https://phet.colorado.edu)

5. Observe the beta decay in the PhET model. Write a nuclear equation for the process.

6. When an atom undergoes beta decay, where does the beta particle come from? What other particle is produced in this process?

Part C: Nuclear Fission

Open the "Nuclear Fission" PhET model. Make sure that you click on the "Fission: One Nucleus" tab. (Attribution: PhET Interactive Simulations, University of Colorado Boulder; https://phet.colorado.edu)

7. Briefly describe the process by which Uranium-235 can be made unstable. Write a nuclear equation for the process.

8. Suppose that you have 100 atoms of Uranium-235 and you fire a neutron into a single atom. Sketch a qualitative graph of Fissioned U-235 Atoms vs. Time.

Using the “Chain Reaction” tab within the model, validate your prediction from question 7.

9. Explain how the model validates/invalidates your prediction made in question 7, citing specific observations.

10. Using the “Chain Reaction” tab, determine the criteria and settings needed to create an atomic bomb.

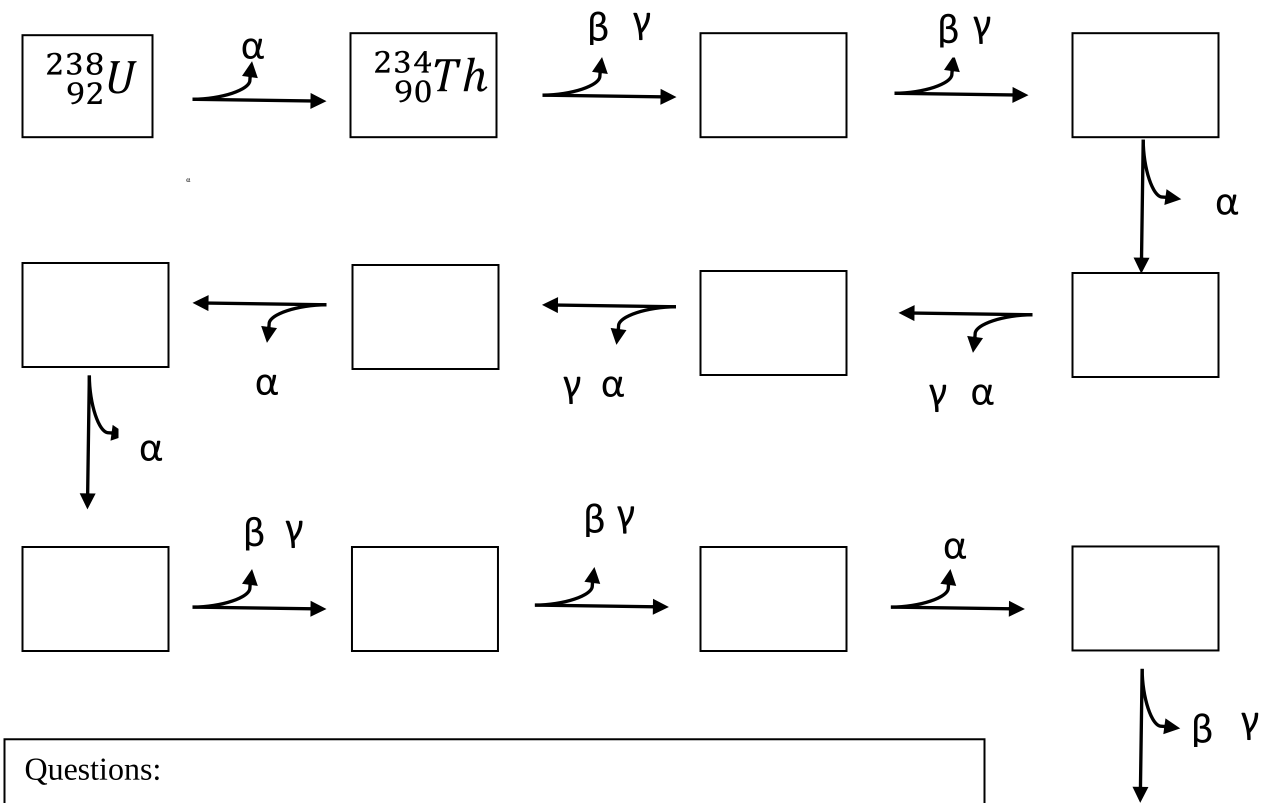
11. Explain why “weapons-grade” Uranium would not likely contain very much Uranium-238.

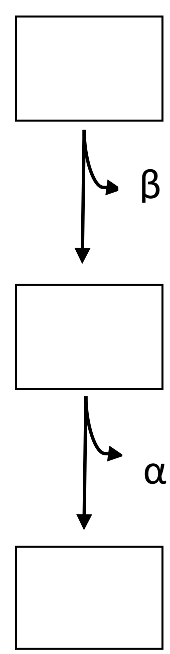
12. Use the “Nuclear Reactor” tab to determine the purpose of control rods within a nuclear fission reactor.

Return to Instructional Segment

Uranium Decay Series

Directions: after each parent nuclide, the type of decay (or particles) are shown. You must determine what the resulting (daughter) isotope/element is and write the symbol (with mass #, atomic #). The first decay after Uranium is done for you.





Questions:

1. What element did the decay series end on? Why? Look up this isotope and determine why it is referred to as "stable".

Using your text or online sources, answer the following (separate sheet):

2. What is the relationship between half-life and stability?
3. What are the characteristics and mechanisms of alpha, beta, and gamma radiation?
4. What is the most common source of radiation in our homes?
5. Is all radiation harmful? Explain.

Return to Instructional Segment