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Description of the Model

The purpose of this model is to simulate the decay of radioactive nuclei to the stable isotope Lead-206. First and foremost, the model is designed to illustrate the concept of a half-life, which is the amount of time it takes for half a given quality of nuclei to decay to the next nuclei. In addition it also demonstrates that different radioisotopes have different half-lives than one another, and that the mass is conserved in nuclear reactions but not necessarily the number of protons, neutrons, or nuclei.

In order to use the model, an amount of a particular element present in the world is selected from zero to 5000 nuclei. The user then clicks the [Setup] button so that the world reflects the desired quantities of starting nuclei. Finally the user clicks either the [Go], [Go Once], [Go 5], or [Go 50] buttons to begin the simulation. [Go] runs until all nuclei have stabilized, [Go Once] runs one tick or a single 24-hour day, [Go 5] runs five days, and [Go 50] runs fifty days. The model provides a count for the starting and final nuclei, protons, and neutrons, along with a display of the total mass. The total mass is also shown in a line plot. Finally the graph on the far right shows the quantity of each isotope present along with the number of alpha particles formed.

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Content Standards

Key Idea 2: Deductive and inductive reasoning are used to reach mathematical conclusions.

M2.1 Use deductive reasoning to construct and evaluate conjectures and arguments, recognizing that patterns and relationships in mathematics assist them in arriving at these conjectures and arguments.

- interpret a graph constructed from experimentally obtained data
- identify relationships § direct § inverse
- apply data showing trends to predict information

Key Idea 1: The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing, creative process.

S1.1 Elaborate on basic scientific and personal explanations of natural phenomena, and develop extended visual models and mathematical formulations to represent thinking.

- use theories and/or models to represent and explain observations use theories and/or principles to make predictions about natural phenomena
- develop models to explain observations S1.2 Hone ideas through reasoning, library research, and discussion with others, including experts.
- locate data from published sources to support/defend/explain patterns observed in natural phenomena

Key Idea 3: The observations made while testing proposed explanations, when analyzed using conventional and invented methods, provide new insights into phenomena.

S3.1 Use various means of representing and organizing observations (e.g., diagrams, tables, charts, graphs, equations, and matrices) and insightfully interpret the organized data.

- organize observations in a data table, analyze the data for trends or patterns, and interpret the trends or patterns, using scientific concepts

Key Idea 2: Models are simplified representations of objects, structures, or systems used in analysis, explanation, interpretation, or design.

2.2 Collect information about the behavior of a system and use modeling tools to represent the operation of the system.

- show how information about a system is used to create a model, e.g., kinetic molecular theory (KMT)

Explain the benefits and risks of radioactivity.

Major Understandings: 4.4a Each radioactive isotope has a specific mode and rate of decay (half-life).

Students can compare energy relationships within an atom's nucleus to those outside the nucleus.

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5.3f Among other things, mass-energy and charge are conserved at all levels (from sub-nuclear to cosmic).

5.3g The Standard Model of Particle Physics has evolved from previous attempts to explain the nature of the atom and states that:

- atomic particles are composed of sub-nuclear particles

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Lesson Plan

Time	Teacher	Students
0:00-1:00	Welcome students to the lesson Give students learning target	Students take their seats
1:00-5:00	Worksheet is handed out to the students Elements of the worksheet are explained Show model of decay on overhead/smartboard Brief explanation of how to use the model is given	Students take the worksheet Students listen to worksheet explanations Students observe model Students ask questions and listen to instruction
5:00-20:00	Facilitates classroom Asks questions Guides student thinking	Students follow worksheet: • Run default setup • manipulate model on their own • Decay Po-210 to Pb-206
20:00-30:00	Ask students "What did sort of things did you notice?" Show video https://www.youtube.com/watch?v=KWAsz59F8gA (2:00-6:18) Talk about content in video, how it relates to model Explain Half-Life calculation	Students describe their observations Watch video Listen to explanation
30:00-40:00	Handout second worksheet Facilitates classroom Asks questions Guides student thinking	Students take the worksheet Students follow worksheet: • Decay Po-210 to Pb-206 • Decay Bi-210 to Pb-206 • Answer questions
40:00-45:00	Break	Break
45:00-60:00	Facilitates classroom Asks questions Guides student thinking	Students follow worksheet: • Run default setup • manipulate model on their own • Decay Po-210 to Pb-206 • Decay Bi-210 to Pb-206 • Answer questions
60:00-70:00	Have students provide data Discuss data	Students give data Discuss data
70:00-85:00	Nuclear equations and decay type	Students identify from a chain whether the decay is alpha or beta and write the balanced reaction associated with the change
Homework	Turn in chain chart next class along with completed reactions	Students complete homework assignment

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Name:_____   Date:_____

Directions: Today you will be working with a simulation on the program NetLogo. First launch the program, go to File then click Open, and click the file Radioactive Decay.nlogo. Your screen should look like this:
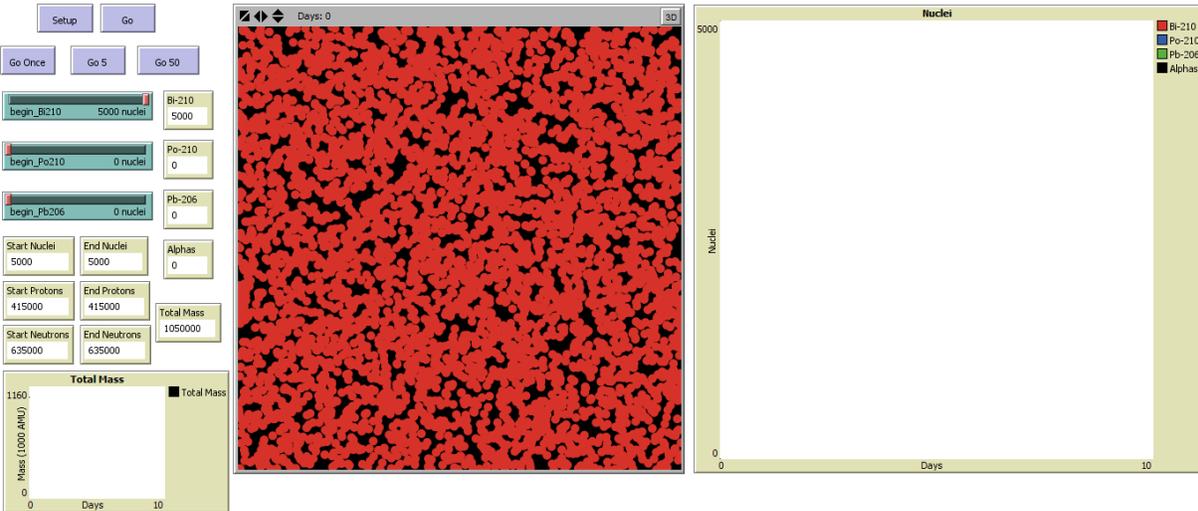
1. To begin, first click [Setup] then click [Go]

2. What do you notice about the total mass?

    _____

3. What do you notice about the three curves on the graph on the right?

_____

_____

_____

4. What do you notice is changing within the world?

_____

_____

_____

Try changing the starting nuclei and see what happens

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Name:_____   Date:_____

Directions: Open up the Radioactive Decay.nlogo file. Click the slider called [begin_Bi210] and slide that down to zero. Then slide [begin_Po210] slider to 5000. Click [Setup], your world should contain only green circles, if this is not the case check each of your sliders to make sure all sliders besides [begin_Po210] are at zero. Then click [Go]

1. Is mass conserved in this reaction? How do you know?

_____

_____

2. What is happening to the number of nuclei? What is happening to the number of alpha

    particles? What do you notice about the number of alpha particles relative to the

    number of Lead Particles?

_____

_____

_____

3. What kind of decay is this?_____

4. Click [Setup], make sure your simulation is not running. Now use the [Go Once], [Go 5]

    and [Go 50] buttons until your total number of Polonium is about half of what you

    started with. How many days have gone by? What is this time period called?

_____

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5. Now allow the same number of days to pass by again, how many Polonium nuclei do

    you have relative to what you started with? The same number of days a third time?

    _____

    _____

    _____

6. Now move the [begin_Po210] slider to zero and the [begin_Bi210] slider to 5000. Click

    [Setup] then click [Go]. How many days did it take for the complete decay to

    occur?_____

7. Explain why the decay chain stops at Lead-206

    _____

    _____

8. Click [Setup], make sure your simulation is not running. Now use the [Go Once], [Go 5]

    and [Go 50] buttons until your total number of Bismuth is about half of what you started

    with. How many days have gone by? What is this time period called?

    _____

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9. Click [Setup], make sure your simulation is not running, and now use the [Go Once]

   button. Why are Lead-206 and alpha particles already forming?

_____

_____

_____

_____

Class Data:

Groups	Half Life Po-210	Half Life Bi-210	# of Days to Complete the Decay
1			
2			
3			
4			
5			
6			
Average			