Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Student Exploration:** **Half-life**

**Vocabulary:** daughter atom, decay, Geiger counter, half-life, isotope, neutron, radiation, radioactive, radiometric dating

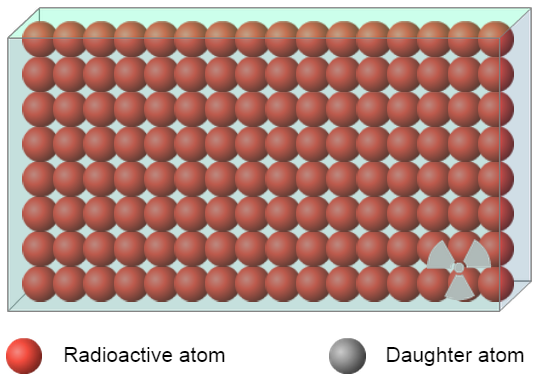
**Prior Knowledge Questions** (Do these BEFORE using the Gizmo.)

1. Have you ever made microwave popcorn? If so, what do you hear while the popcorn is in the microwave? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. If you turn the microwave on for two minutes, is the rate of popping always the same, or does it change? Explain. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Gizmo Warm-up**

Like an unpopped kernel in the microwave, a **radioactive** atom can change at any time. Radioactive atoms change by emitting **radiation** in the form of tiny particles and/or energy. This process, called **decay**, causes the radioactive atom to change into a stable **daughter atom**.

PlayThe *Half-life* Gizmo™ allows you to observe and measure the decay of a radioactive substance. Be sure the sound is turned on and click **Play** ( ).

1. What do you see and hear? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Note: The clicking sound you hear comes from a **Geiger counter**, an instrument that detects the particles and energy emitted by decaying radioactive atoms.

1. What remains at the end of the decay process? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. Is the rate of decay fastest at the beginning, middle, or end of the process? \_\_\_\_\_\_\_\_\_\_\_\_\_

|  |  |  |
| --- | --- | --- |
| **Activity A:**  **Decay curves** | Get the Gizmo ready:   * Click **Reset** (Replay). Be sure that **User chooses half-life** and **Random decay** are selected. * Check that the **Half-life** is 20 seconds and the **Number of atoms** is 128. | 369SE2 |

**Question: How do we measure the rate of radioactive decay?**

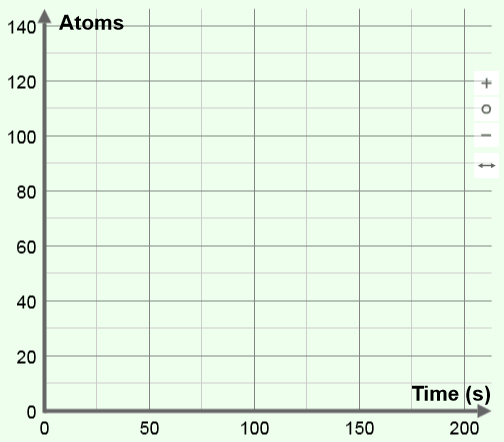
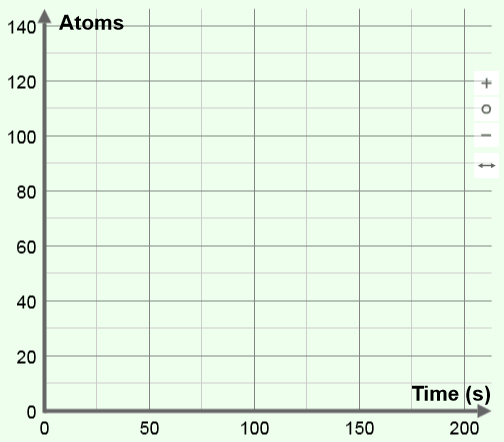
1. Observe: Select the BAR CHART on the right side of the Gizmo and click **Play**.
   * 1. What happens to the numbers of radioactive and daughter atoms as the simulation proceeds? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

* + 1. Do the numbers of radioactive and daughter atoms change at the same rate throughout the simulation? Explain. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Experiment: Click **Reset**, and select the GRAPH tab. Run a simulation with the **Half-life** set to 5 seconds and another simulation with the **Half-life** set to 35 seconds. Sketch each resulting decay curve graph in the spaces below.

**Half-life = 5 seconds Half-life = 35 seconds**

1. Interpret: How does the **Half-life** setting affect how quickly the simulated substance decays?

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**(Activity A continued on next page)Activity A (continued from previous page)**

1. Collect data: Click **Reset**. Change the **Half-life** to 10 seconds and click **Play**. Select the TABLE tab and record the number of radioactive atoms at each given time below.

0 s: \_\_\_\_\_ 10 s: \_\_\_\_\_ 20 s: \_\_\_\_\_ 30 s: \_\_\_\_\_ 40 s: \_\_\_\_\_ 50 s: \_\_\_\_\_

1. Analyze: What pattern, if any, do you see in your data? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Revise and repeat: Use your data from #4 above to fill in the first line of the data table below. Then repeat the experiment four more times. Calculate the average number of radioactive atoms for each time.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Trial** | **0 s** | **10 s** | **20 s** | **30 s** | **40 s** | **50 s** |
| 1 |  |  |  |  |  |  |
| 2 |  |  |  |  |  |  |
| 3 |  |  |  |  |  |  |
| 4 |  |  |  |  |  |  |
| 5 |  |  |  |  |  |  |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Averages:** |  |  |  |  |  |  |

1. Analyze: A **half-life** is defined as the amount of time it takes for half of the radioactive particles to decay. For the simulated substance, every 10 seconds represents one half-life.

How does your data demonstrate the definition of a half-life? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Revise and repeat: Click **Reset**. Real radioactive samples will contain billions of radioactive atoms. To model the decay of a large sample, change from **Random decay** to **Theoretical decay** on the SIMULATION pane. Click **Play** and record the numbers of radioactive atoms:

0 s: \_\_\_\_\_ 10 s: \_\_\_\_\_ 20 s: \_\_\_\_\_ 30 s: \_\_\_\_\_ 40 s: \_\_\_\_\_ 50 s: \_\_\_\_\_

How does this data demonstrate the meaning of half-life? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

|  |  |  |
| --- | --- | --- |
| **Activity B:**  **Measuring half-life** | Get the Gizmo ready:   * Click **Reset**. * Select **Isotope A** from the left drop-down menu. * Check that **Theoretical decay** is selected. | 369SE5 |

**Introduction:** Different **isotopes** of the same element have the same number of protons but different numbers of **neutrons** in the nucleus. Some isotopes are radioactive.

**Question: How do we find the half-life of a radioactive isotope?**

1. Observe: Select the GRAPH tab, and click **Play**. Based on the graph, what is your estimate of the half-life of isotope A? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. Measure: Turn on the **Half-life probe**. Use the probe to measure how long it takes for exactly one-half of the original radioactive atoms to decay.

What is the exact half-life of isotope A? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Collect data: In the first row of the table below, write how many seconds represent one half-life, two half-lives, and so forth. On the next row, predict the number of radioactive atoms that will be present at each time. Then use the probe to find the actual values.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Half-life** | 0 | 1 | 2 | 3 | 4 | 5 |
| **Time (seconds)** |  |  |  |  |  |  |
| **Predicted # radioactive atoms** |  |  |  |  |  |  |
| **Actual # radioactive atoms** |  |  |  |  |  |  |

1. Calculate: Calculate the percentage of radioactive atoms that are left after each half-life.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Half-life** | 0 | 1 | 2 | 3 | 4 | 5 |
| **Percentage radioactive atoms** |  |  |  |  |  |  |

1. Apply: Suppose you found a material in which 12.5% of the original radioactive atoms were present. If the half-life is 47 years, how old is the material? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**(Activity B continued on next page)Activity B (continued from previous page)**

1. Apply: Use the Gizmo to find the half-life of **Isotope B**. What is it? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_
2. Practice: Click **Reset**. Select the **Mystery half-life** from the left menu. In this setting, the half-life will be different each time you run the simulation. Run at least three trials. In each trial, measure the half-life using the **Half-life probe** on the graph.

When you have found the half-life, click the camera (snapshot camera) icon. Right-click the image, and click Copy. Then paste the image into a blank document, and label each image with the half-life. Print out this document and turn it in with this sheet.

1. Explore: Use the Gizmo to explore whether the number of atoms present affects the half-life that you measure. Describe your findings below:

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

1. Extend your thinking: The slow decay of radioactive materials can be used to find the age of rocks, fossils, and archaeological artifacts. In a process called **radiometric dating**, scientists measure the proportions of radioactive atoms and daughter atoms in an object to determine its age. Carbon-14 is a useful isotope because it is found in wood, ash, bone, and any other organic materials.

You can use the *Half-life* Gizmo to model the decay of Carbon-14, which has a half-life of approximately 6,000 years (actual value is 5,730 years). In the Gizmo, select **User chooses half-life** and **Theoretical decay**. Set the **Half-life** to 6 seconds (to represent 6,000 years) and the **Number of atoms** to 100.

Use the Gizmo to estimate the age of each of the objects below. For these questions, each second in the Gizmo represents 1,000 years.

|  |  |
| --- | --- |
| **Description** | **Age (years)** |
| Egyptian papyrus with 63% of its original carbon-14 atoms |  |
| Aboriginal charcoal with 22% of its original carbon-14 atoms. |  |
| Mayan headdress with 79% of its original carbon-14 atoms |  |
| Neanderthal skull with 3% of its original carbon-14 atoms |  |