SN
EDUCATOR GUIDE

November 25, 2017

Mosses Tell Story of Retreating Ice

Activity Guide for Students: Exploring half-life

Purpose: To understand the meaning and implications of radioactivity, exponential decay and half-life.

Procedural overview: Students can use simulate exponential radioactive decay and half-life with pennies and also with a food coloring/bleach chemical reaction. They can also calculate exponential decay and exponential growth processes.

Before beginning the activity, create your own data table for the entire activity, dividing it up by parts. You will need to read through the entire procedure for this part to determine what observations you are trying to collect. If you are working in a pair, individually read through the procedure and decide all key information before collaborating with your partner on a data table.

Part 1: Heads or Tails, a Penny Model

1. Put 16 pennies heads-up on a table. You will help the pennies undergo “radioactive exponential decay” to tails-up, with a half-life of 1 minute. Write down how many pennies are heads-up.

2. Start a timer. At around 1 minute, flip each of the 16 pennies in the air and let them randomly land heads-up or tails-up. Write down how many pennies are heads-up.

3. At around 2 minutes, take only the pennies that are still heads-up, flip each of them in the air and let them randomly land heads-up or tails-up. Write down how many pennies are heads-up.

4. At around 3 minutes, take only the pennies that are still heads-up, flip each of them in the air and let them randomly land heads-up or tails-up. Write down how many pennies are heads-up.

5. At around 4 minutes, take only the pennies that are still heads-up, flip each of them in the air and let them randomly land heads-up or tails-up. Write down how many pennies are heads-up.

6. At around 5 minutes, take only the pennies that are still heads-up, flip each of them in the air and let them randomly land heads-up or tails-up. Write down how many pennies are heads-up.

7. Repeat until all pennies are tails-up.

8. Graph the number of heads-up pennies versus time in minutes. How does the graph compare with what you would ideally expect?

9. Instead of exponential decay, you could demonstrate exponential growth with pennies. Let's say one student in the class is a robber, who initially has one penny from their own group. In every round, the robber will steal until he or she doubles the number of pennies by taking pennies as necessary. How many rounds would it take for the robber to steal all the pennies from their own group? How many rounds does it take for the robber to steal all of the pennies from the class?

Part 2: Blues Fade Away, A Chemical Model

1. A chemical reaction can also demonstrate exponential decay. The chemical reaction of blue food coloring and sodium hypochlorite (the main ingredient in bleach) is a first-order reaction. Ever wonder how bleach works? You'll see it for yourself during this reaction. Use the following procedure to get set up.

- Obtain five identical clean and dry test tubes.
- Label test tubes 1 through 5.
- Fill test tubes 1 through 4 about two-thirds of the way with water (make sure the volume of water is the same for every test tube). Ideally, measure the water in the first test tube with a graduated cylinder, and then use that measurement to pour water into the other four test tubes.
- Add two drops of blue food coloring to test tubes 1, 2 and 3.
- Use a clean pipette to add two drops of bleach to test tube 4. Test tube 4 is a control to show a tube with no blue food coloring.
- Let the tubes sit until each has a uniform color, or cover them tightly and gently swirl them until a uniform color is reached.
- Add two additional drops of water to test tubes 1 and 2 and gently swirl. Test tube 2 is a control to show a tube with the maximum concentration of blue food coloring (or the initial concentration of blue food coloring at time=0 seconds)
- Pour exactly half of the solution in test tube 1 into test tube 5. Add water to test tube 5 until the total volume of solution matches the total volume of solution in test tube 4. Test tube 5 is a control test tube to show the color of the solution after half of the original blue food coloring has reacted.

- Set test tube 1 aside. Take a cell phone photo or otherwise note the color difference between your control test tubes 5, 2 and 4. Test tube 3 will be your experimental test tube.

2. Start a timer and start video recording the tubes as soon as you add drops of bleach to test tube 3. Add a few drops of bleach to test tube 3, and record how many drops you added.

3. Record how long it takes for test tube 3 to become the color of test tube 5. This is the time that it takes for half of the original concentration of blue food coloring to react, analogous to the half-life of a radioactive elemental sample.

4. Keep video recording. At twice the time of the half-life, what do you notice about the color of test tube 3?

5. Keep video recording. How long does it take for test tube 3 to become essentially the same color as test tube 4? How many half-lives is this?

6. Remove test tube 3 and repeat the experiment at least two more times with a new, clean tube each time. Increase or decrease the number of drops of bleach for each trial. Record your results as before.

7. Graph your results for the half-life versus the number of drops of bleach you have added. What is the trend in your results?

Part 3: Decaying Radioactively, Date the Carbon-14

1. You can use equations to calculate exponential decays. If t is the time since exponential decay began, $t_{1/2}$ is the half-life, k is the exponential rate constant, N_o is the initial number of carbon-14 atoms (or

concentration), and N_t is the number of carbon-14 atoms remaining at time t (or concentration), the exponential decay may be written as:

$$\ln(N_t) = -kt + \ln(N_o)$$

$$t_{1/2} = \ln(2)/k$$

The half-life of carbon-14 is 5,730 years. What is the exponential rate constant for the decay of carbon-14? Don't forget to include units.

2. At time t = 0, 1.00×10^{-12} percent by mass of the carbon in a newly deceased organism (plant or animal) is carbon-14. How much of the total carbon is carbon-14 after 1,000 years?

3. How much of the carbon is carbon-14 after 10,000 years?

4. How much of the carbon is carbon-14 after 100,000 years?

5. Congratulations! You have just found a priceless ancient human artifact carved from mammoth bone. Analysis shows that 2.30×10^{-14} of its carbon is carbon-14. How old is the artifact?

6. Indiana Jones has just discovered King Tut's underwear, which is made of natural materials. Analysis shows that 6.67×10^{-13} percent by mass of its carbon is carbon-14. How old is the underwear?

7. What have you learned about exponential decay?