Transformation
T-STEM 2013
New Directions | New Pathways | New Outcomes

Half-Life Activity

Overview

Radioactive decay is of great interest to scientists, engineers, archeologists, politicians, and many others. Uranium has been used in weapons and for generating power. Carbon-14 has been used to determine the age of bone and tools of ancient animals and people. One way to measure the radioactivity of an element is by way of its half-life, the time it takes for only half of the initial mass to remain.

In this activity, students will learn how to calculate the initial or final mass when the initial or final mass, the half-life and the elapsed time are provided. The Half-Life virtual instrument, VI, will be used in performing and checking calculations as well as building a conceptual understanding of the concept of half-life.

Objectives

Students will be able to:

- Provide a definition of half-life
- Calculate the initial or final mass when the initial or final mass, the half-life, and the elapsed time are provided

Standards (TEKS)

Chemistry 9B

Activity

When the amount of a substance is decreasing over time, the **half-life** of the substance is the amount of time it takes for only half of the original mass to remain. For example, the half-life of uranium-238 is about 4.5 billion years. That is, if you hid 10 grams of uranium-238 in a box 4.5 billion years ago, there will only be 5 grams of the substance left today. In the case of uranium-238, the loss would not be due to theft, rats, or the soundness of your box. The substance underwent **radioactive decay**.

1) Open and run the Half-Life virtual instrument, VI.

The Half-Life VI has controls for setting the initial mass and half-life of a substance. In the graph of remaining mass over time, there is a red vertical line on the graph called a cursor.

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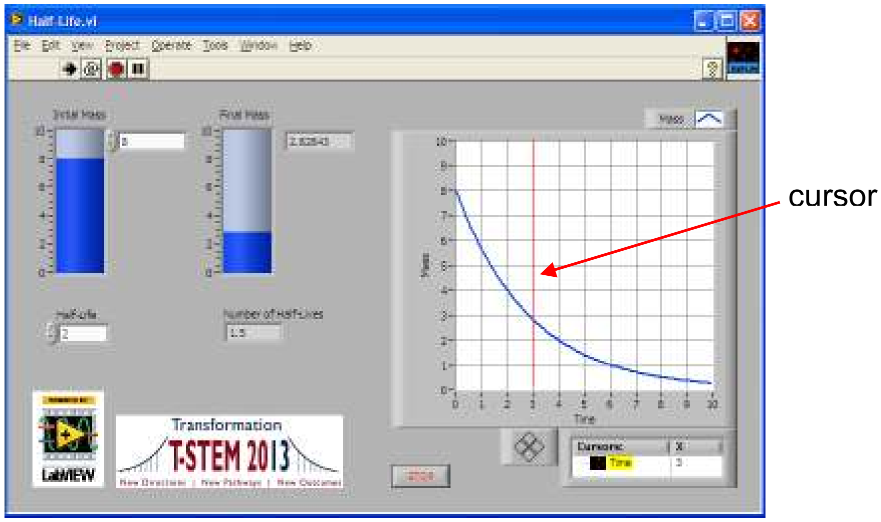
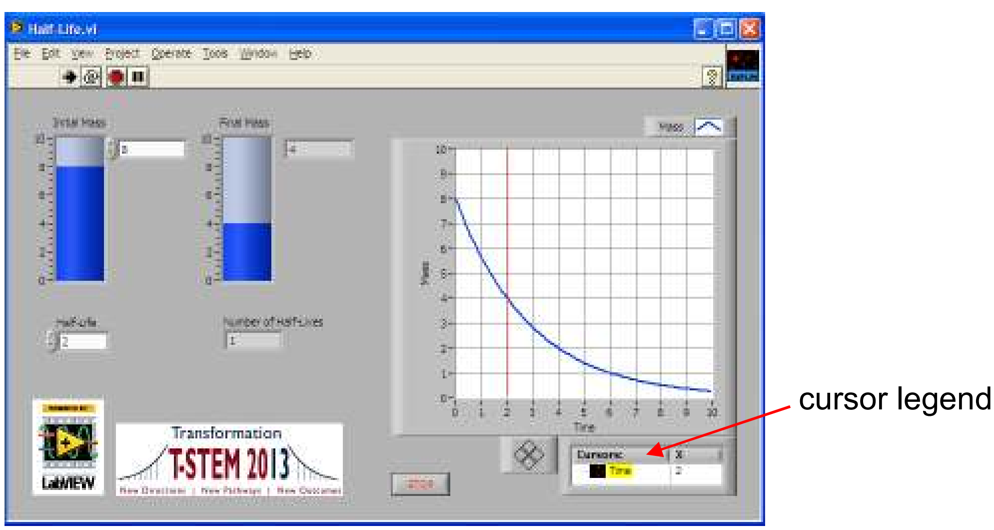


The position of the cursor controls the elapsed time used to calculate the number of elapsed half-lives and the final mass. You can click and drag on the vertical line of the cursor to control the elapsed time.

2) To get familiar with this VI and the idea of half-life, set the **Initial Mass** to 8 and **Half-Life** to 2.
3) Click and drag the vertical red line of the cursor to the right.
    a) Notice the time increases.
    b) What happens with the **Number of Half-Lives** as time increases?
    c) What happens to **Final Mass** as time increases?

A particular value of time can be set using the cursor legend below the graph. Simply double-click on the number displayed and set it to the desired amount of time.



4) Use the cursor to set the time to 2.
    a) What is the **Number of Half-Lives**?
    b) How much mass remains?
5) Now, set the time to 4.
    a) What is the **Number of Half-Lives**?
    b) How much mass remains?

With a half-life of 2, let's say thousand years, then after 4 thousand years, the initial mass has been cut in half twice. That is, the amount of mass is divided by two or multiplied by ½ each time a half-life elapses.

6) If you start with 8 g of a substance with a half-life of 2, how long would it take to be left with 1 g of the substance? Check your answer with the VI.
7) If you start with 20 g of a substance with a half-life of 4.5 billion years, how long would it take to be left with 5 g of the substance? Use the VI to figure this out.
    a) Set the **Initial Mass** to 20 and the **Half-Life** to 4.5.
    b) Click and drag on the cursor and watch the amount of **Final Mass**.
    c) Make note of the time when the **Final Mass** is about 5. Remember time is in billions of years in this problem.
8) Make sure your answer in the last problem makes sense.
    a) How much time did you say it would take to leave 5 g remaining?
    b) How many half-lives would have elapsed? (Hint: To find the number of half-lives, just divide the elapsed time by the half-life. This is how the VI calculates it.)
    c) How many times would you have to cut the initial amount of substance, the 20 g, in half to be left with 5 g?
    d) Do your answers to (b) and (c) match? Explain.

The **number of half-lives** is the number of times the mass will be cut in half. It is also the elapsed time divided by the half-life. That is,

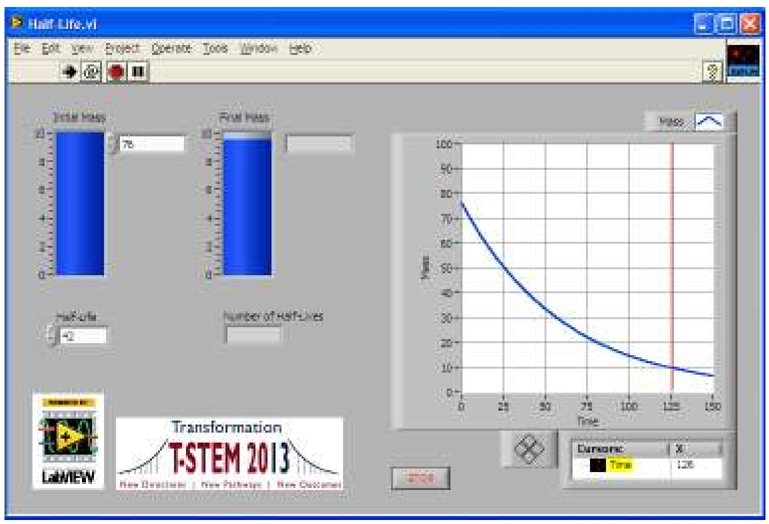
$$\text{number of half-lives} = \frac{\text{elapsed time}}{\text{Half}-\text{Life}}.$$

If a substance has a half-life of 20 seconds and 60 seconds elapse, then 60/20 = 3 half-lives have elapsed.

9) Compute the number of half-lives:
    a) Elapsed time = 1500 years and half-life = 250 years
    b) Half-life = 2.45 thousand years and elapsed time = 49,000 years
    c) Elapsed time = 12 billion years and half-life = 18 million years

It is important to make sure your units agree. (Check your work in part (c) of the last problem.) The VI does not have fixed units. This allows it to be used for any appropriate units. It also means it is up to you to make sure your units agree. Make sure your time units match. That is, your half-life and your elapsed time units should be the same. This is also true of the initial and final mass. If one is in kilograms, so is the other.

10) There are 76 g of a substance with a half-life of 42 million years, after 126 million years,
    a) How many half-lives have elapsed?
    b) How much of the substance remains?
    c) Now, use the VI to answer these.
        i. Set the **Initial Amount** to 76 and the **Half-Life** to 42.
        ii. Change the limits on the graph.
            1. Double-click the 10 on the Mass scale and change it to 100.
            2. Double-click the 10 on the Time scale and change it to 150.
        iii. Use the cursor to set the time to 126.



    d) Do your answers match the answers on the VI?

11) If there are 100 kg of a substance initially, without using the VI, how much of it will remain
    a) After 1 half-life?
    b) After 2 half-lives?
    c) After 4 half-lives?
    d) Did you need to know the half-life of the substance is to answer these? Explain.
    e) How did you find the answers in parts (a), (b), and (c)?

By now, you probably have a sense that calculating the final mass is a matter of dividing the initial mass by two over and over again. You might think of it as multiplying by ½ repeatedly. If four half-lives have elapsed, you are multiplying the initial mass by ½ four times to find the final mass.

Repeated multiplication calls for exponents. That is,

$$\text{initial mass}\left(\frac{1}{2}\right)^{4} = \text{final mass}.$$

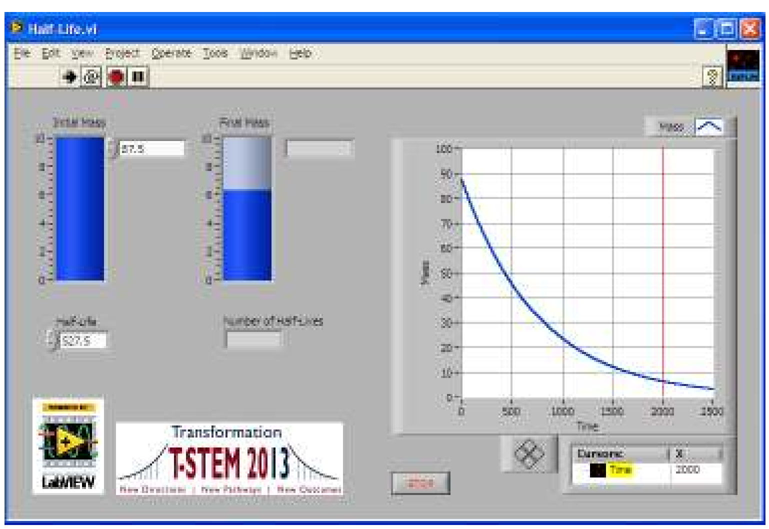
The “4” is the number of half-lives. Let’s generalize this into a formula:

$$\text{initial mass}\left(\frac{1}{2}\right)^{(\text{number of half-lives})} = \text{final mass}.$$

Example:
There are 23.7 g of a substance with a half-life of 50 seconds. Five minutes, or 300 seconds, have elapsed. How many grams of the substance remain?

a. First, calculate the number of half-lives $= \frac{300}{50} = 6$
b. Then, use the formula: $\text{final mass} = 23.7\left(\frac{1}{2}\right)^{6} = .37$ g.

12) There are 17 mg of a substance with a half-life of 4.5 billion years, after 14 billion years,
   a) How many half-lives have elapsed?
   b) How much of the substance remains?
13) There are 87.5 kg of a substance with a half-life of 527.5 years, after 2000 years,
   a) How many half-lives have elapsed?
   b) How much of the substance remains?



It is also possible to find the initial mass, if you are given the final mass, the half-life, and the elapsed time.

14) Find the initial mass of a substance with a half-life of 13.7 thousand years, if 12.5 kg remain after 230 thousand years.
15) A substance with a half-life of 3 thousand years has been found. Find the mass of the substance 13 thousand years ago, if the amount of the substance found is
    a) 25 g
    b) 3 kg
    c) 126.5 g
16) Stop the VI. You are done.