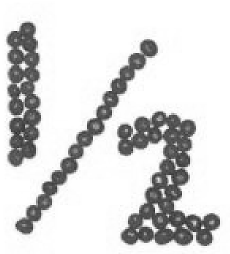


Red Hot Half-Life

Modeling Nuclear Decay

NATIONAL MATH + SCIENCE INITIATIVE

MATERIALS

beans, navy

calculator, graphing

cinnamon candies

2 cups, 9-oz clear plastic

paper towels

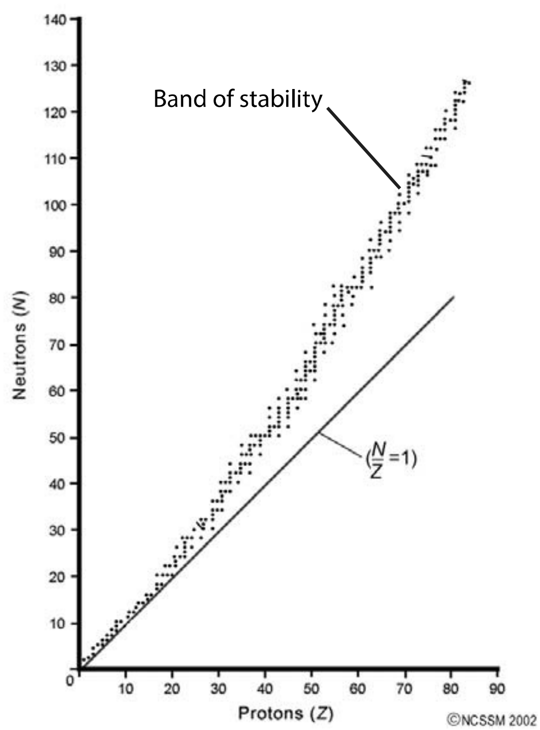
plate, paper

Every element on the periodic table has one or more radioactive isotopes. Recall that **isotopes** are atoms of the same element that differ in the number of neutrons their nucleus contains. Depending on the ratio of neutrons to protons, these isotopes may be stable or radioactive.

Charts have been produced that identify the *band of stability* (Figure 1). Isotopes falling within the band are stable whereas those outside the band are radioactive. Notice that as the elements get heavier, the neutron to proton ratio drifts greater than 1:1. For those isotopes whose neutron to proton ratio lands them outside the band of stability, the nucleus will undergo radioactive decay until a stable atom is formed.

The amount of time it takes for a sample to decay is specific to the type of atom that is decaying. The amount of time it takes for one half of a radioactive sample to decay is called its **half-life**. Half-lives can range from fractions of a second to millions of years.

Figure 1. Band of stability



PURPOSE

In this activity, you will model radioactive decay with cinnamon candies. The analysis of data and the determination of half-life will be done by graphical means.

PROCEDURE

1. Count the candies in your cup. Record this number in the data table on your student answer page. This is the value for 0.0 seconds.
2. Put the candies in the cup and then pour them out onto the paper plate. Remove the candies that landed in the starred section. These candies will be considered "decayed."

   Replace the decayed candies with the same number of navy beans so that the total number of particles remains constant. Count the remaining candies and record this number in your data table. Each trial is to be counted as 10 seconds.
3. Continue this procedure until you have 10 trials or until you have fewer than 5 cinnamon candies left, whichever comes first. Record each trial in the data table.

DATA AND OBSERVATIONS

Table 1. Radioactive Decay

Time (s)	Number of Candies	
	Decayed	Remaining
0		
10		
20		
30		
40		
50		
60		
70		
80		
90		
100		

ANALYSIS

1. Enter the "time" in L1 and the candies remaining in L2. Be sure that your Stat Plot is set up correctly to display a scatter plot of L1 and L2 data. Describe the shape of the graph.

2. Look at graphs from at least two other groups. What is the same about the graphs? What is different about the graphs?

3. Press [STAT] [▸] to Calc. Arrow down to 0:ExpReg. Press [ENTER] to paste the function; be sure that Xlist is L1 and Ylist is L2.

   Arrow down to store RegEQ, then:

   - Press [VARS] to get the variables menu
   - Press [▸] to YVARS
   - Press [ENTER] to select 1:Function
   - Press [ENTER] to select Y1
   - Press [ENTER] to execute the command sequence
   - Press [ENTER] one last time to calculate

   Look at the graph by going to [ZOOM] [9]. Write the equation for the line in the space provided.

Because this is not a linear equation, it will not be in the form of y = mx + b.

ANALYSIS (CONTINUED)

The intersection value will be shown at the bottom of your calculator screen.

4. *Half-life* is defined as the amount of time it takes for one half of a sample to decay. Open [Y=] and arrow down to Y2. Enter the original number of candies, then [÷] [2]. This corresponds to the time it takes for one half of the original sample to decay.

   Go back to [ZOOM] [9]. Next:

   - Press [2nd] [TRACE] [▼] to 5:Intersection
   - Press [ENTER] to confirm the first line
   - Press [ENTER] to confirm the second line
   - Press [ENTER] to guess and get the intersection of these two lines

   What is the half-life of this system?

5. Take the number of candies that you had at the half-life point. Divide that number by 2. Open [Y=] and arrow down to Y2. Clear the current number and enter the new number. Repeat the procedure that you did in Question 4 to determine the intersection of the two lines. Is the new time close to two times the half-life (two half-lives)?

ANALYSIS (CONTINUED)

6. Refer back to Question 3. The equation is not linear but instead is in the form of $y = ab^x$. This is an *exponential function*. In science, we like to have equations in the form of $y = mx + b$. Manipulating the equation, we can do this using what is called a *linear transform*.

   In this case, we would take the natural log (ln) of both sides of the equation. Do this with the equation that you have found in Question 3. Your teacher will assist you if necessary. Write the equation in the space provided.

7. What variables will be used from the equation in Question 6 to obtain a linear graph?

8. Go back to the statistical function, [STAT] [ENTER], to Edit. You want to transform the data in L2. Arrow up so the cursor is sitting on the L2 icon. Press [LN] [2nd] [2] [ENTER]. Go to [ZOOM] [9] to look at the graph. Is it linear?

ANALYSIS (CONTINUED)

9. Go to [Y=] and clear it. Go to [STAT] [▶] to Calc. Arrow down to 4:LinReg, then:
   - Press [ENTER] to select
   - Press [VARS] to get to the variables menu
   - Press [▶] to YVARS
   - Press [ENTER] to select 1:Function
   - Press [ENTER] to select Y1
   - Press [ENTER] to execute the command sequence

   Look at the graph by going to [ZOOM] [9]. Write the equation for the line in the space provided.

Hint: Do not forget to put parentheses ( ) around the 2.

10. For this type of equation, the absolute value of the slope of the line is equal to a constant that we will refer to as *k*. The half-life is found using Equation 1:

$$t_{1/2} = \frac{\ln(2)}{k} \qquad \text{(Eq. 1)}$$

    Divide ln(2) by the absolute value of your slope. Is it close to the half-life that you found in Question 4?