

Pre-Lab Activity: Dependence of Radioactivity on Time – Half-life Student Sheet

Purpose: To simulate how the amount of radioactive material changes over time.

Background:

Radioactivity is a process where certain types of matter emit radiation, and is one type of phenomena that helped change the nature of science as the twentieth century began (helped lead to fundamental changes in our understanding of chemistry, nuclear physics, biology, archeology and geology). And one of the most important ideas to come from the studies of radioactivity is the concept that it is a *statistical and probabilistic process*. This means that one can apply statistical and probability methods to the study of radioactivity, and one of those statistical measures is the **half-life**. You will begin to gain understanding of half-lives by using some pretty sophisticated equipment.

Equipment: M & M's (pretty sophisticated, huh?!); Skittles also work, depending on your taste

Procedure:

Work your way through the following questions with your M & M's; choose one side of your M & M's to represent a 'living' radioactive atom, and the other side to represent a decayed atom (i.e. one that has 'died') that will be removed from your sample. Dump your 'living' atoms on your table and remove those that have just decayed. Continue this until all have decayed. Feel free to consume the dead atoms.

Below are some possible analysis questions for students to consider and work on:

Questions and Analysis:

1. Make a data table to keep track of how many M & M's decay each time you dump them on the table. Make sure to count the original number of pieces before you begin. After all the pieces have decayed, make a graph of the number of pieces left after each 'half-life' (y-axis) versus the number of the turn you dumped them (x-axis). Use Excel to make the graph and to determine the best fit for the graph. Is the shape of your graph linear, a power law, or exponential, based on what you find with Excel?
2. The half-life for carbon-14 (this is an isotope of normal carbon-12; it just has two extra neutrons that make it radioactive) is about 5700 years. What does half-life mean if you have a sample of 1000 carbon-14 atoms? What does half-life mean if you have a single carbon-14 atom?
3. Make a graph of the number of carbon-14 atoms (suppose you have an initial

sample of 1000 atoms) as a function of time, knowing the half-life is 5700 years. For an initial sample of 1000 carbon-14 atoms, approximately how long would it take to have only 700 carbon-14 atoms remaining from the original sample? How long would it take to have only 100 carbon-14 atoms from the original sample? Make approximations from your graph.

4. Describe the process of how scientists can use carbon-14 as a way of measuring the age of bones. Would you trust carbon-14 dating for objects that may be millions of years old? Why or why not?
5. Name three other phenomena, events, activities, etc., that require statistics to describe them. Also, in your own words, define "probability."
6. Research how geologists determine the age of the first rocks that formed on Earth. How can scientists determine the age of objects that are several *billion* years old?
7. For more mathematically advanced students: Calculate how long we would expect a sample of 1000 carbon-14 atoms to decay down to 700 carbon-14 atoms, as well as how long it would take 1000 carbon-14 atoms to decay to only 100 carbon-14 atoms. Compare your answers to what you approximated from your graph in question 3. To do such a calculation, use the exponential decay law

$$N(t) = N_0 e^{-t/\tau}$$

where N_0 is the initial number of carbon-14 atoms and τ is a characteristic decay time constant for carbon-14 and has a value of

$$\tau = t_{1/2} / \ln 2 = 5700 \text{ yr} / \ln 2$$

More information about all aspects of radioactivity can be found at:

<http://en.wikipedia.org/wiki/Radioactivity>

<http://en.wikipedia.org/wiki/Radiation>

http://en.wikipedia.org/wiki/Nuclear_reaction

<http://hyperphysics.phy-astr.gsu.edu/hbase/nuccon.html#c1>