How do you ask a rock its birthday?

A laboratory experiment from the Little Shop of Physics at Colorado State University

Overview

The decay we are used to encountering on a daily basis is typically along the lines of leaves decaying on the forest floor or food decaying in the office refrigerator. Radioactive decay, on the other hand, refers to the nature of unstable nuclei changing their structure or breaking into smaller pieces. We encounter this phenomenon on a daily basis as well however we hardly notice it due to its microscopic nature. How can this concept be made hands-on and interactive?

Necessary materials:

- pennies, one per student
- an area where students can sit and stand

This activity can be done with any object that has two distinct sides.

A tasty, table-top variation is included at the end of this document.

Theory

There are two important points to keep in mind when studying radioactive decay. First, when a nucleus decays it does not vanish or disappear - it simply changes into a different kind of nuclei. Second, the process of decay is random. We have equations, which we will explore later, that allow us to predict the amount of time it will take for certain amounts of the original sample to decay but we can't pinpoint which nuclei specifically.

If you start with a certain amount of radioactive nuclei, N_0, half of them will have decayed in an interval of time called the *half-life* or $t_{1/2}$. With each passing half-life one half of the remaining nuclei will decay. The amount of nuclei still in their original form after some time t is given by

$$N = N_0 \left(1/2\right)^{t/t_{1/2}}$$

We can see by this relation that after one half-life there are $N = N_0/2$ nuclei remaining, after two half-lives there are $N = N_0/4$ nuclei, after three half-lives there are $N = N_0/8$ nuclei remaining.

There are several other aspects of radioactive decay that are worth mentioning as they are crucial to a formal study of the subject although the focus of this activity is half life.

The decay of a radioactive sample is exponential and can be described by:

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

where τ is the time constant.

The activity, *R*, of a radioactive sample is the number of decays per second. This is a measure of how much radiation is emitted by the sample and is given by:

$$R = N/\tau = 0.693N/t_{1/2}$$

where N is the size of the sample, the number of nuclei. An important point to make about this relation is that the activity is inversely proportional to the half-life. In other words, the shorter the half-life is the greater the activity of the sample. The SI unit of activity is the becquerel (Bq) and is defined to be one activity per second.

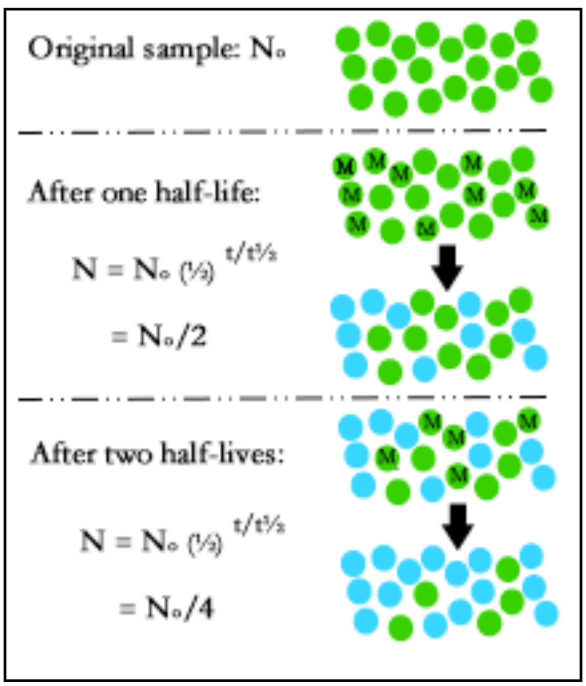
Rather than starting your study of half-lives and radiation with the equations, begin with an exploration of the behavior of the nuclei. These concepts can be hard to grasp but if we look at what the nuclei are doing, use a kinesthetic atomic model, we can more readily understand their behavior.

Doing the Experiment

Explain to your students that they will be participating in an activity that will simulate radioactive decay. They will each play the part of a radioactive atom and whether or not they decay at any given time will be random - it will depend on the outcome of the flip of a coin. Ask students to predict how many cycles it will take for every student in the class to “decay.”

Hand out one penny to each student and have them all stand up at their seats. Take a count of how many “nuclei” you start with. Have all students flip their coin once as a group. Instruct those students whose coin came up heads to sit down. They have decayed into a stable nucleus. Take note of this number. The other students are still radioactive and have the chance to decay again. Have them all flip their coins a second time. Again, those whose coins came up heads must sit. Repeat until all students are sitting, making note of how many sit down at each turn and how many turns this required.

Once all students are sitting ask them to plot the number of students who “decayed” at each turn. Notice that in each turn approximately half of the students standing sat down. We can relate each flip of the coin to be one passing half-life for our “radioactive sample.”



Another way to illustrate the concept of decay and half-life is to use M&Ms and Skittles. Have students sit in small groups. Each group needs about 20 M&Ms, 20 Skittles, and 2 small cups or containers. Instruct the students to shake the M&Ms in one of the containers and roll them out onto the table top. Any M&Ms that landed with the M up have decayed and should be replaced with Skittles (these M&Ms can be placed in a cup off to the side). The students should have 20 pieces of candy on the table top. This sample should now be put into a cup, shaken, and rolled. Again, those M&Ms that land with the M up should be replaced with Skittles. Ask students to continue until their entire sample has decayed from M&Ms to Skittles. This variation enforces the concept that when a nucleus decays it doesn’t disappear - it just transforms into something else. You can extend this activity by having the Skittles represent unstable nuclei as well. When they are rolled with the rest of the sample take note if they land with the S up and if so replace them with another similarly shaped food item - like Cheerios.

Summing Up

This activity is a great way to introduce the concept of half life and decay before a formal study of the subject ensues. After doing this activity students will be more receptive to the concepts described by the equations given above.

For More Information

CMMAP, the Center for Multiscale Modeling of Atmospheric Processes: http://cmmap.colostate.edu
Little Shop of Physics: http://littleshop.physics.colostate.edu