Radioactive Decay

Simulation and Determination of Half-life

HIU SCI1365
Week 5 Lab (Part 2)

Introduction

The ability to find absolute dates for rocks, artifacts, and the Earth itself is based on the decay of radioactive elements.

When an unstable element (the parent) decays it typically transforms into a lighter element (called a daughter) and releases some energy and a small particle like a proton, neutron, electron, or alpha-particle, or multiples of these. There is no certainty that the daughter will be a stable element and it may decay as well in what is referred to as a decay chain.

The unique property that allows us to use the radioactive decay as a clock is called the half-life. For a large number of atoms of a radioactive element the half-life is the amount of time it will take, on average, for half of the atoms to decay. It is a random process – as you are about to demonstrate – so probability plays a big part. It is also an effect which is seen in large populations, so if you set a single unstable atom on your desk and waited, it might decay in one minute, it might decay a million years from now, or it just might decay at about the length of the half-life. There is no way to know in advance.

Some of the element isotopes which are important for geologic dating include Carbon-14 (^{14}C) with a half-life of 5730 years, Uranium-238 (^{238}U) with a half-life of 4.5 billion years (about the age of the Earth), and Rubidium-87 (^{87}Rb) with a half-life of 48.8 billion years.

Presently there are numerous methods that use these, and other radioactive elements, as well as their daughter products to determine the ages of rocks, or the age of their last heating episode as heating can "reset" some of these features and decay chains.

Materials

- 50 pennies (or similar 2-sided objects)
- A container large enough to conveniently shake up the pennies (such as a coffee can or plastic pitcher)
- Paper or spreadsheet to record your results
- 2 sheets of graph paper or spreadsheet to graph your results

Your Data Table will have four columns—Trial number, elapsed time, number of parents, the cumulative number of daughters. (Parents plus daughters will always add up to 50) Being a simulation, we will say that the elapsed time will be 2 seconds between trials, so that number will simply be two times the number of the trial.

Procedure (If using another suitable object other than pennies, substitute that in the instructions below and include in your report what objects you used.)

1. Record the 50 pennies as parents under time trial 0 in the Data Table.
2. Put the pennies in the container, shake the contents for several seconds, and pour the pennies from the container onto a large flat surface. Without flipping any of the pennies over arrange them into a single layer.
3. Count the number of parent pennies with heads showing, and the number of daughter pennies with tails showing. Record these values under Trial 1 (Tme 2 seconds) in the Data Table.
4. Set the daughters aside, but put the parent pennies from the trial back into the container. Shake as before and pour them back onto the surface for another trial.
5. Again, count and record both the heads parent pennies and the tails daughter pennies. For the parents, record only the number of pennies counted. For the daughters, you should record the number counted, then add that number to the previous count so that a running cumulative total of daughters is recorded. (Remember, parents plus daughters will always equal 50).
6. Repeat this process until no parent pennies are remaining.

For the data analysis, we will stipulate that the time between each trial is 2 seconds. So for the time axis of the graphs, the time intervals plotted with be 0, 2, 4... seconds.

Questions:

1. Graph the results of your experiment. Plot the number of parent atoms (pennies) remaining after each trial on the y-axis. Plot the time on the x-axis.
2. Construct another graph. Plot the number of daughter atoms (pennies) after each observation on the y-axis. Plot the time of the observation on the x-axis.
3. What is the mathematical form of the two lines? How do the two lines differ?
4. Determine the half-life ($t_{½}$) of this hypothetical element from your graph. Be sure to check the first few half-lives, not just the first.
5. Using the half-life you just determined, and the equation $t_{½}=0.693/\lambda$, calculate λ the decay constant

Scan or create a PDF of your answers, data table, calculations, and graphs and submit on Canvas