

Lab 7

Alpha Decay - PhET Lab

Objectives

To better understand half-life, to draw a radioactive decay graph, and to determine the half-life time ($t_{1/2}$) for Polonium - 211 (^{211}Po)

Introduction

Unstable atomic nuclei may decay into less energetic nuclei by emission of alpha, beta, and gamma radiation. These forms of radiation are now known to consist of ^4He nuclei (α -particle), electron, and high energy photons, respectively. The type of decay a nucleus may undergo depends on how it is unstable. Many materials may emit more than one form of radiation. This is especially true when the parent radioactive nuclei produce daughter nuclei that are also radioactive. The parent nucleus is the original nucleus before decay and the daughter nucleus is the resulting nucleus after decay.

Nuclei with atomic numbers (number of protons, or Z) greater than 83 may all undergo alpha decay (however, the rate of decay may be so slow for some that it seems to be forever). In alpha decay, a helium nucleus consisting of two protons and two neutrons is emitted from the parent nucleus. This reduces the atomic number of the original nuclei by two and its atomic mass (number of both protons and neutrons in the nucleus, or A) by four. We may express such a nuclear decay by the nuclear reaction equation:



For example,



In example 7.2, the total atomic number of Thorium decreases by 2 after alpha decay resulting in the daughter nucleus of Radium and the total mass number decreases by 4. In a nuclear decay equation, the sums of the mass and atomic numbers will be the equal on each side of the arrow. Figure 7.1 shows the decay series of Uranium - 238 (^{238}U) to Lead - 206 (^{206}Pb).

The alpha particles are the most ionizing radiation emitted by natural sources (with the extremely rare exception of the spontaneous fission of uranium) and are stopped by as little as a sheet of paper or a few centimeters of air (2-8cm) depending on their initial velocity. Alpha particles that are emitted from a single type of source are monoenergetic, that is, they are all emitted with the same kinetic energy. Depending on the source, this energy ranges from 3-8MeV corresponding to velocities of $(1.4 - 2) \times 10^7$ m/s! Alpha particles play an important role in nuclear physics.

Half-life is the time it takes for half of the nuclei of a given sample to decay. In other words, after one half-life has expired only one-half of the original amount of radioactive nuclei remains undecayed. After 2 half-lives only one-quarter ($\frac{1}{2}$ of $\frac{1}{2}$) of the original amount remains un-decayed. We can use this property to perform radioactive dating.

The expression that governs radioactive decay is,

$$N = N_0 e^{-\lambda t} \quad (7.3)$$

Where N_0 is the initial number of parent nuclei at $t=0$, and N is the number of parent nuclei any time t , and λ is the decay constant, or the probability per unit time that any one nucleus will decay. The half-life time then is,

$$t_{1/2} = \frac{0.693}{\lambda} \quad (7.4)$$

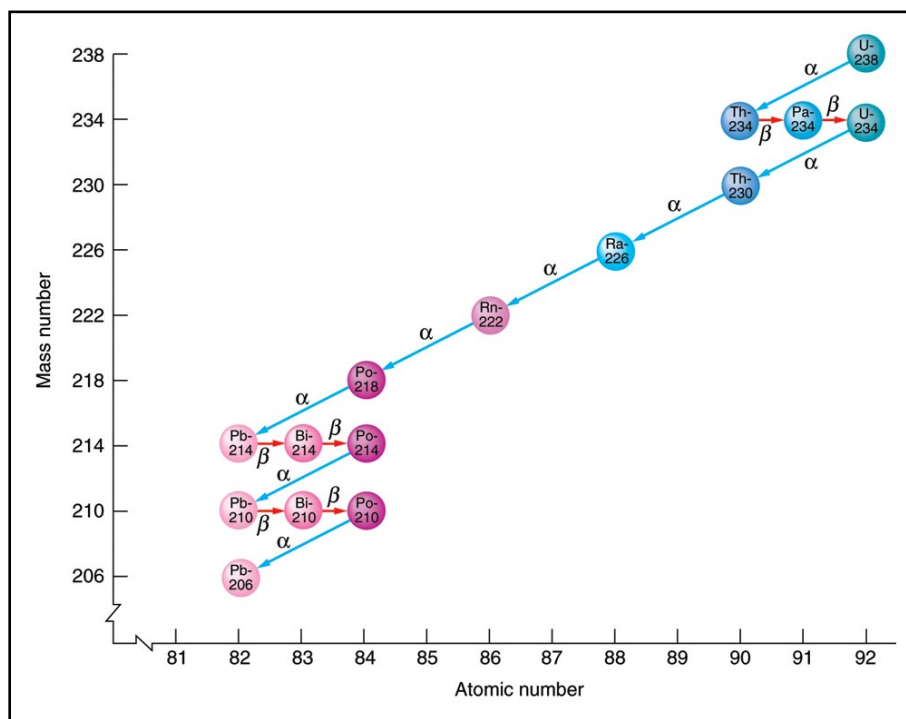


Figure 7.1. Decay series of Uranium - 238 (^{238}U) to Lead - 206 (^{206}Pb).

Software Requirements

Windows	Macintosh	Linux
Microsoft Windows XP/Vista/7/8.1/10 Latest version of Java	OS X 10.9.5 or later Latest version of Java	Latest version of Java

UPDATED JAVA. Be sure to have Java with Web Launcher. PhET Simulation “Alpha Decay”.

Run <http://phet.colorado.edu/en/simulation/alpha-decay>

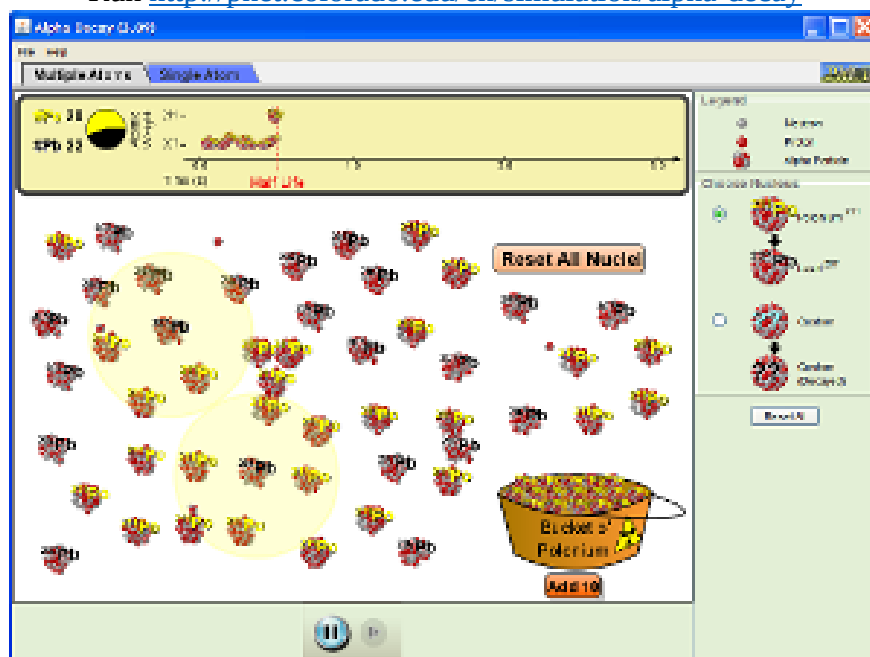


Figure 7.2. Screen shot of ‘Alpha Decay’ from PhET Interactive Simulations.

For students not running Java use the following link:

<https://phet.colorado.edu/sims/cheerpi/nuclear-physics/latest/nuclear-physics.html?simulation=alpha-decay>

Procedure

PART 1

1. Choose “Multiple Atoms” option (Tab on top of page).
2. Click to “Custom” from the column on the right of the screen.
3. Adjust the half life to any value you choose that is between 0.5-1 second by clicking and dragging the double-sided green arrow. Estimate and record this value.
4. Add all atoms to the screen from the bucket by clicking the ‘Add 10’ icon below the bucket at the bottom of the page.
5. By clicking the play/pause button (center/bottom of page) start and stop the decay reaction every half second. Use the timer at the top of the page. Find how many parent nuclei (undecayed nuclei) remain at each time (upper left corner of page).
6. Repeat your measurement 4 more times, record your data below and calculate averages.

Half-life value you chose: _____seconds

Time (s)	0	0.5	1.0	1.5	2.0	2.5	3.0
Number of parent nuclei (N)	99						
	99						
	99						
	99						
	99						
Average	99						

- Draw number of parent nuclei vs. time on a graph. Compare your graph with the graph found on PAGE 625 (CH 33.5) of your textbook. Point out any similarities and differences.

PART 2

- On the right side on the screen, choose “Polonium - 211 to Lead - 207”.
- Add 20 nuclei of ^{211}Po (N_0) from the basket (i.e. click twice on ‘Add 10’).
- When the time t reaches 1 second, Record number of ^{211}Po (N at $t=1.0$ second). Do this 3 times. Find the average value. Record this as N .
- By using formula 7.3, where $t = 1$, $N_0 = 20$ and N is your average calculated from step 10, calculate the decay constant λ .
- Using formula 7.4 and λ calculated in step 11, calculate $t_{1/2}$ for ^{211}Po .

Questions

- Tabulate your results.
- Plot number of parent nuclei remaining vs. time.
- Compare your graph with the graph found on PAGE 625 (Chapter 33.5) of your textbook. Point out any similarities and differences that you see.
- What is the shape of your graph? Did you expect that it should be a straight line?
- Should the graph pass through the origin? Explain.
- By using formula 7.3, calculate the decay constant λ for ^{211}Po .
- Using formula 7.4, calculate the half-life ($t_{1/2}$) for ^{211}Po .
- Write a brief error analysis for PART 2 of the experiment. What are your main sources of error? What might you do differently next time to increase the accuracy of the measured half-life of ^{211}Po ?

Thanks to: **PhET Interactive Simulations**
University of Colorado
<http://phet.colorado.edu>.