Physics 197 Lab 13:   Half Life Using Cs-Ba Source

Equipment:

Item	Part #	Qty per Team	# of Teams	Total Qty Needed	Storage Location	Qty Set Out	Qty Put Back
Barium 137 Isogenerator Kit		Shared	8	4			
Computer with Logger Pro		1	8	8			
LabQuest Mini		1	8	8			
Digital Radiation Monitor	Vernier	1	8	8			
USB Cable – LabQuest Mini to Comp.		1	8	8			
Radiation Monitor Cable		1	8	8			
Metal Container for Barium solution		1	8	8			
Lab Stand and Spacer for Rad Monitor		1	8	8			
Small Plastic Container -spill protector		1	8	8			
αβγ radiation sources for initial setup		1	8	8			

Layouts:

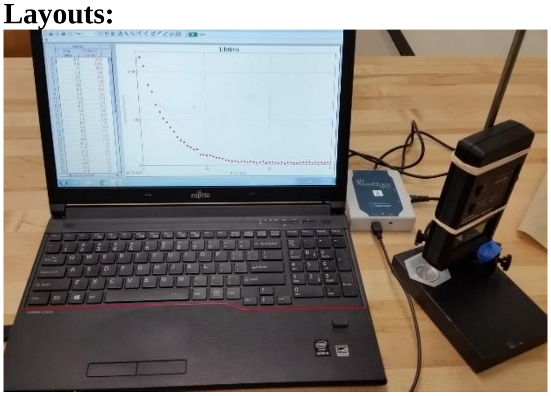


Figure 1, Experimental Set-up

Figure 2, Radiation Monitor ~3 cm above Ba source

Figure 3, Ba-137 Isogenerator kit and Eluting solution.

Summary

In this lab, students will investigate radioactive decay lifetime. The students are provided with a short-lived isotope of Barium (Ba-137) which decays on a time scale such that its lifetime can easily be measured in a lab period. The Ba-137 is a decay product of Cs-137 (a much longer lasting isotope). The Barium is separated chemically from the Cesium, and provided to the students when their apparatus is all set to record radiation counts as a function of time. The amount of barium solution provided, along with the geometry of the apparatus, results in an initial count rate on the order of 1000 counts per 30 second interval. This decays rapidly, such that at the end of 30 minutes only background counts remain. The decay curve (see figure 1) is fit to a decaying exponential, and the lifetime of the Ba-137 is calculated.

The write-up for this lab follows Vernier's Nuclear Radiation Computer Experiments 3, Lifetime Measurement

PreLab:

1. Consider a candy jar, initially filled with 1000 candies. You walk past it once each hour. Since you don't want anyone to notice that you're taking candy, each time you take 10% of the candies remaining in the jar. Sketch a graph of the number of candies for ten hours.

2. How would the graph change if instead of removing 10% of the candies, you removed 20%? Sketch your new graph.

Experiment A: Radiation Decay Lifetime

The *activity* (in decays per second) of some radioactive samples varies in time in a particularly simple way. If the activity (R) in decays per second of a sample is proportional to the amount of radioactive material ($R \alpha N$, where N is the number of radioactive nuclei), then the activity must decrease in time exponentially:

$$R(t) = R_0 e^{-\lambda t}$$

In this equation λ is the *decay constant*, commonly measured in s^{-1} or min^{-1}. R_0 is the activity at $t = 0$. The SI unit of activity is the becquerel (Bq), defined as one decay per second.
You will use a source called an isogenerator to produce a sample of radioactive barium. The isogenerator contains cesium-137, which decays to barium-137. The newly made barium nucleus is initially in a long-lived excited state, which eventually decays by emitting a gamma photon. The barium nucleus is then stable, and does not emit further radiation. Using a chemical separation process, the isogenerator allows one to remove a sample of barium from the cesium-barium mixture. Some of the barium removed will still be in the excited state and will subsequently decay. It is the activity and lifetime of the excited barium you will measure. While the decay constant λ is a measure of how rapidly a sample of radioactive nuclei will decay, the *half-life* of a radioactive species is also used to indicate the rate at which a sample will decay. A half-life is the time it takes for half of a sample to decay. That is equivalent to the time it takes for the activity to drop by one-half. Note that the half-life (often written as $t_{1/2}$) is not the same as the decay constant λ, but they can be determined from one another.

PROCEDURE

1. Prepare a shallow cup to receive the barium solution. The cup sides should be no more than 1 cm high. Mount the radiation monitor above the cup as shown in figure 2.

2. Connect the radiation monitor to the Digital 1 interface on the LabQuest Mini and connect the LabQuest Mini to the computer. Turn on the monitor.

3. Prepare the computer for data collection by opening the file "03 Lifetime" from the *Nuclear Radiation w Computers* folder of Logger *Pro*. One graph is displayed: count rate *vs*. time. The vertical axis is scaled from 0 to 1200 counts/interval. The horizontal axis is time scaled from 0 to 30 minutes.

3.5. Test that all electronics and software are functioning properly and ready to go by recording radiation counts from one of the β or γ disc sources (used in the previous lab) for at least two minutes.

4. The instructor will prepare the isogenerator for use as directed by the manufacturer. The instructor will extract the barium solution into the prepared cup. Work quickly between the time of solution extraction and the start of data collection in step 6, because the barium begins to decay immediately. Depending on how many times the source has been used recently, the number of drops of liquid may be between 12 and 18 or so.

5. Place the cup under the radiation monitor so that the rate of flashing of the red LED is maximized. Take care not to spill the solution. The count rate should be approximately 1000 counts in the first 30 seconds. (2000 – 2500 counts per minute on the radiation monitor).

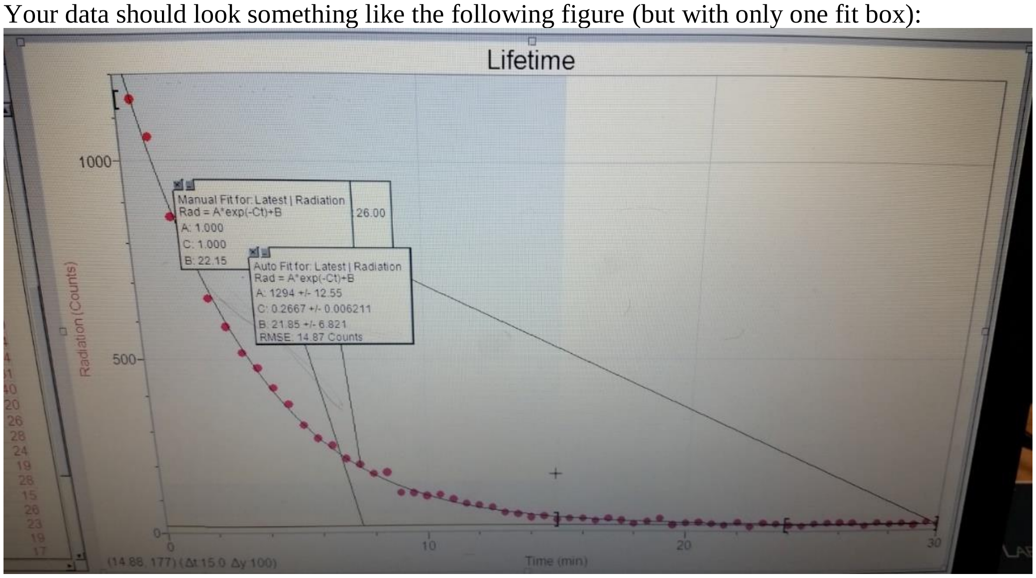
6. Click to begin collecting data. Logger *Pro* will begin counting the number of gamma photons that strike the detector during each 30 second count interval. Data collection will continue for 30 minutes. Do not move the detector or the barium cup during data collection.

7. After data collection is complete, the button will reappear. Set the radiation monitor aside, and dispose of the barium solution and cup as directed by your instructor.

ANALYSIS

1. Inspect your graph. Does the count rate decrease in time? Is the decrease consistent with an activity proportional to the amount of radioactive material remaining?
2. Compare your graph to the graphs you sketched in the Preliminary Questions. How are they different? How are they similar? Why are they similar?
3. The solution you obtained from the isogenerator may contain a small amount of long-lived cesium in addition to the barium. To account for the counts due to any cesium, as well as for counts due to cosmic rays and other background radiation, you can measure the background count rate from your data. By taking data for 30 minutes, the count rate should have gone down to a nearly constant value, aside from normal statistical fluctuations. When you do a fit to your data in Logger Pro (step 4), it should include a constant offset which accounts for this residual background.
4. Fit an exponential function to your data. Click the curve fit button . Select Natural Exponential from the equation list. Notice that the Natural Exponential fit [y=A*exp(–Ct)+B] includes an additive term B. This term will account for the constant background counts due to non-barium sources. A best-fit curve will be displayed on the graph. If your data follow the exponential relationship, the curve should closely match the data. When you are satisfied with the fit, click “OK”
5. Print or sketch your graph.
6. Record the fit parameters A, B, and C in your notebook.
7. From the definition of half-life, determine the relationship between half-life ($t_{1/2}$, measured in minutes) and decay constant (λ, measured in min^{-1}). Hint: After a time of one half-life has elapsed, the activity of a sample is one-half of the original activity.
8. From the fit parameters, determine the decay constant λ and then the half-life $t_{1/2}$.
9. Is your value of $t_{1/2}$ consistent with the accepted value of approximately 2.552 minutes for the half-life of barium-137?
10. What fraction of the initial activity of your barium sample would remain after 25 minutes? Was it a good assumption that the counts near the end of your 30 minute data collection would be due entirely to non-barium sources?

Your data should look something like the following figure (but with only one fit box):



EXTENSION

1. How would a graph of the log of the count rate *vs.* time appear? Using Logger *Pro*, Graphical Analysis, a spreadsheet, or by hand in your notebook, make such a graph. Interpret the slope of the line if the data follow a line. Will correcting for the background count rate affect your graph?