Experiment #7: Radioactive Decay of Barium

Introduction

There is no simple way to influence the random decays of radioactive nuclei. Heating or cooling, changing the pressure, etc., all have no effect. The rate at which the nuclei decay is determined by the nuclear structure. If we know the number of nuclei present and the rate of decay, we can predict how many nuclei will remain at some future time (at least within some statistical uncertainty).

The number of radioactive decays per second (the ***activity*** of the sample of nuclei) may be plotted as a function of time. As the number of remaining nuclei decrease, so will the activity. The equation relating the activity to time is given by equation 7.1

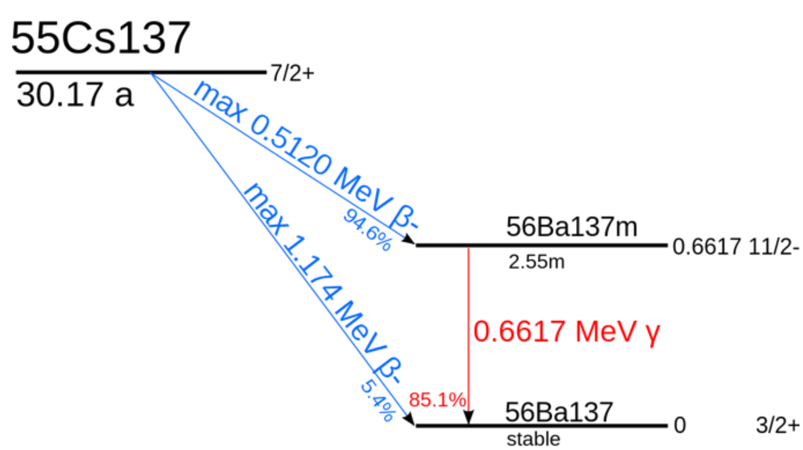
$$A = A_0 e^{-\lambda t} \quad (7.1),$$

where A is the activity after a time t, and A_0 is the initial activity of the sample. The experiment today is designed to investigate the time dependence of the activity and to determine the half-life of the sample of barium.

The half-life of a radioactive sample is the time it takes for one-half of the activity of (or number of, or mass of) the radioactive sample to decrease by 50%. We determine the half-life from equation 7.1 by substituting $\frac{A_0}{2}$ for the activity. This produces

$$t_{1/2} = \frac{\ln 2}{\lambda} \quad (7.2).$$

The barium sample you have comes from washing a solution of $0.04\, M\, HCl$ and $0.9\%\, NaCl$ through a cesium filter and eluting the barium onto a holder. The cesium remains in the filter and decays into barium (with a half-life of 30.7 years for the cesium) and the short-lived barium is washed out and collected. The decay is shown in the following diagram. The cesium beta decays into a metastable state of barium and this metastable state of barium decays by emitting a $0.662 MeV$ gamma ray. This gamma ray is what you'll be detecting in the experiment.



http://en.wikipedia.org/wiki/File:Cs-137-decay.svg

Experiment #7: Radioactive Decay of Barium Pre-Laboratory Questions

Read laboratory experiment #7 on the radioactive decay of barium, then answer the following questions in complete sentences. Be sure to print out and hand in any data and graphs you made along with the answers to these questions. The pre-laboratory exercise is due at the beginning of the laboratory period and late submissions will not be accepted.

1. Suppose that measurements were taken on the activity of a sample of radioactive material as a function of time and the data for the experiment are given in Table PLE7.1. Plot the data of the activity (on the y-axis) as a function of time (on the x-axis). Fit the data with equation 7.1 and extract the decay constant.

   Equation of the fit to the data: $A =$

   Decay constant: $\lambda =$

2. From the decay constant, calculate the half-life of the radioactive sample. Show the calculation and record the value below.

   Half-life: $t_{1/2} =$

$A\left(\frac{counts}{s}\right)$	$t\ (s)$
225.00	0
211.20	20
198.24	40
186.08	60
174.67	80
163.96	100
153.90	120
144.46	140
135.60	160
127.28	180
119.47	200
112.14	220
105.27	240
98.81	260
92.75	280
87.06	300
81.72	320
76.71	340
72.00	360
67.58	380
63.44	400
59.55	420
55.90	440
52.47	460
49.25	480
46.23	500
43.39	520
40.73	540
38.23	560
35.89	580
33.69	600

Table PLE7.1: Activity A of a sample of radioactive material as a function of time t.

Experimental Procedure:

Once again, we will be using a data acquisition program Pasco Capstone to collect the data. Open Capstone from the desktop and click hardware setup from the left-hand side of the screen. On the data collection box that appears on the screen click the small digital input circle labeled 1 and from the drop-down menu choose Geiger counter. If you get a yellow triangle after choosing Geiger counter, consult your instructor. If you get no error messages, close the hardware setup box by clicking hardware setup again.

From the choices on the screen, select sensor data and this should give you a graph of counts/sample (on the y-axis) and time (on the x-axis). If you don't see this screen consult your instructor. You are now ready to collect data.

When you are ready, you will receive a drop of radioactive barium dispensed on a piece of an index card. Place the sample on the index card under the Geiger counter as close to the Geiger counter as possible without putting the counter into the liquid. Click record and wait about 30 minutes for the data to collect. While the data are collecting, move as far away as you can from the radioactive sample and other groups around you are collecting data. The data will appear very random at first and you should see the number of counts per second (the activity) decrease with time. After about 30 minutes you should have a reasonably smooth curve. Click stop on the data collection and fit the data with a natural exponential function according to equation 7.1.

Data Analysis & Post-Laboratory Exercises

Based on your data collected, graphs generated, and equations of fits to the data, answer the following questions. Be sure to print out and hand in your data and graphs along with the answers to these questions.

1. From your plot of the data on the activity of the sample of barium versus time, what is the equation of the fit to the data for activity of barium as a function of time? Do the data obey equation 7.1? Explain.

2. What is the proportionality constant from the curve fit to the data represent? From the proportionality constant, what was the initial source activity A_0 of your sample?

3. What is the decay constant λ for the decay of ${}^{137}_{56}Ba^*$? How is this determined from the fit to the data? Explain.

4. What is the experimental value for the half-life $t_{1/2}$ of ${}^{137}_{56}Ba^*$ according to equation 7.2? Look up, and cite, a source for the accepted value for the half-life of ${}^{137}_{56}Ba^*$ and calculate a percent difference.

5. What are some sources of uncertainty in the experiment. Is there any way to influence the rate at which the ${}^{137}_{56}Ba^*$ decays?