Half-Life of Ba-137m

Equipment Spectech isotope generator kit, Geiger tube with power supply and counter, sample tray, meter stick, 2 trays, stop watch

Reading Write-up for Absorption of Radiation experiment (this experiment uses same geiger tube and power supply-counter), your textbook (look under half-life in the index)

Safety Considerations

This experiment uses weak radioactive sources that, if used prudently, are not dangerous. Nevertheless, use care when handling these materials, avoid spilling the solutions, and use the gloves provided.

1 Purpose

Atomic nuclei have excited states that decay with the emission of radiation such as photons or particles. An important characteristic of these radioactive nuclei is the time it takes for half of them to decay. This is called the half-life, or $T_{1/2}$. In this experiment you will measure the half-life of ${}_{56}Ba^{137m}$, where the "m" means that the Ba is in a metastable state and decays to the ground state with the emission of a higher energy photon (gamma ray).

2 Theory

If there are, at the time t, a number $N(t)$ of identical radioactive nuclei, it is not possible to say when anyone of them will decay. The probability per unit time that one of them will decay is given by the decay constant λ. The change in N in the time dt given by $dN = -\lambda N dt$. This integrates to give

$$N(t) = N_0 e^{-\lambda t}, \tag{1}$$

where N_0 is the number of radioactive nuclei at time $t = 0$. The decay is exponential with respect to time. To find $T_{1/2}$ in terms of λ, let $t = T_{1/2}$ and $N/N_0 = 1/2$. The result is

$$T_{1/2} = \frac{\ln 2}{\lambda} = \frac{0.693}{\lambda}. \tag{2}$$

3 The Radioactive Source

The source is a cylinder that has two openings on the top and bottom that are capped with removable plugs. Inside the source is a small quantity (10 μCi) of ${}_{55}Cs^{137}$ which is radioactive and has a half-life of 30.1 y. Please see Fig. 1. This isotope of cesium is a β^- emitter and 94.6% of the time decays to a metastable state of barium, ${}_{56}Ba^{137m}$. This isotope of barium decays to the ground state by emitting a 0.662 MeV gamma ray photon. The half-life of ${}_{56}Ba^{137m}$ is 2.55 min and is the half-life that is the subject of this lab. The cesium is bound on an ion exchange medium and hopefully stays in the source. In the source, the amount of radioactive cesium stays essentially constant due to its long half-life. The concentration of

radioactive barium will reach an equilibrium amount in 4-5 barium half-lives. When needed for the experiment, the barium is flushed out of the source by an "eluting" solution. Elute is a verb that means to remove an adsorbate from an absorbent by means of a solvent. The eluting solution is not supposed to remove any cesium. In less than an hour, the equilibrium concentration of barium is again established in the source and the source can be used again.

4 Strength of the Source

There are two radioactive items associated with this lab. The first is the cylinder that contains the radioactive cesium. This will be referred to as "the source.". The second is the solution that contains the radioactive barium. This will be referred to as the "barium solution."

Review the sections of the write-up for the Absorption of Radiation experiment that deal with the operation of the Geiger tube and power supply-counter. Turn on the power supply. Place the Geiger tube on its side at one end of the bench, with the open side (the side of the stand that has the slots for the sample trays) toward the bench top. Place the source as close to the window end of the tube as possible and find a suitable plateau voltage for the Geiger tube. Count for 0.1 min, record the counts, and then move the source 5 cm away from the tube window. Again count for 0.1 min. Repeat this procedure, building up a table of 0.1 min counts versus distance of source from Geiger tube.

1. How far away does the source have to be before its presence makes no difference? When measuring the strength of the barium solution, keep the source a sufficient distance from the Geiger tube so that the source does not contribute to the counts.
2. How does the strength of the source fall off with distance? Discuss.

Turn the Geiger tube to the normal upright position

Important

Before proceeding, read and digest the rest of this write-up so that you can do the procedures expeditiously. The barium half-life is short, and you do not want to take too much time between drawing the barium solution and counting decays. On the other hand, you should not move so quickly that you risk spilling the barium solution.

5 Preparing The Barium Solution

From the isotope generator kit, locate the syringe, tubing, eluting solution, and planchet (small metal cup). Also have on hand two dishes and the sample tray that fits into the slots in the Geiger tube holder. Put on a pair of the disposable gloves provided. Place the planchet into the sample tray and place the tray into one of the dishes provided. (The purpose of the dishes is to contain any spills.) Remove the two caps from the source and put the source in a dish. Put the tubing onto the end of the syringe and push the syringe plunger all the way in. Stick the free end of the tubing into the eluting solution and draw about 2 ml of eluting solution into the syringe by pulling back on the plunger. While one end of the tubing is still in the eluting solution bottle, remove the tubing from the end of

the syringe and let the solution in the tubing run back into the bottle. Place the tubing in a dish. Attach the syringe to the top of the source. There is an arrow on the source that indicates the direction of flow of the solution through the source. Hold the bottom of the source over the planchet and carefully deposit 7 drops of solution into the planchet by pushing on the syringe plunger. Remove the syringe from the source and empty it into the eluting solution bottle. Put the empty syringe into a dish. Put the caps on the source and put the source in a dish. Insert the sample tray with the planchet into the top pair of slots of the Geiger tube holder. Record the time of day. (We will ask you to measure the strength of the source at the end of the lab and the time since the source was prepared.)

6 Taking Data

Set the counter to count for 0.1 s. Start the stopwatch and counter at the same time. As soon as the counter stops write down the number of counts and reset the counter. Do not stop the stopwatch. When the stopwatch reaches 30 s start the counter again, writing down the counts when the counter stops. Repeat this process, recording the counts every 30 s. Use your judgment for how long to do this, but probably 3.5 to 4.0 min should be sufficient. When finished, leave the planchet with the Ba solution under the Geiger tube.

7 Analysis

Plot your data on one or two cycle semi-log graph paper, with counts on the logarithmic axis and time on the linear axis. Draw what you consider to be the "best" straight line through your data points. Pick two widely spaced convenient points on this line whose coordinates are (N_1, t_1) and $N_2, t_2)$, where $t_2 > t_1$. Calculate the slope of the line which is the decay constant λ from the equation

$$\lambda = \frac{\ln \frac{N_1}{N_2}}{t_2 - t_1}. \tag{3}$$

Use Eq. **??** to calculate the half-life. Compare your result to the published value of $T_{1/2} = 2.55\ min.$

If your calculator will give you a least squares fit for a line, use your calculator and all your data points to give you such a fit. From the slope provided, calculate the half-life and compare to the value you got from the straight line on your graph.

8 Source Check

Measure the strength of the Ba solution by counting for 1 min. Remove the planchet and its tray from beneath the Geiger tube, put them in a dish, and move them to the far side of the bench. Count the background, and note the time. If more than 20 min has passed since the Ba solution was prepared, there should be very little acitvity from the Ba solution. If this is not the case, inform the 2nd floor staff. It means that Cs is getting out of the source. Leave the barium solution on the bench. The staff will dispose of it.

9 Finishing Up

Please leave the bench as you found it. Thank you.

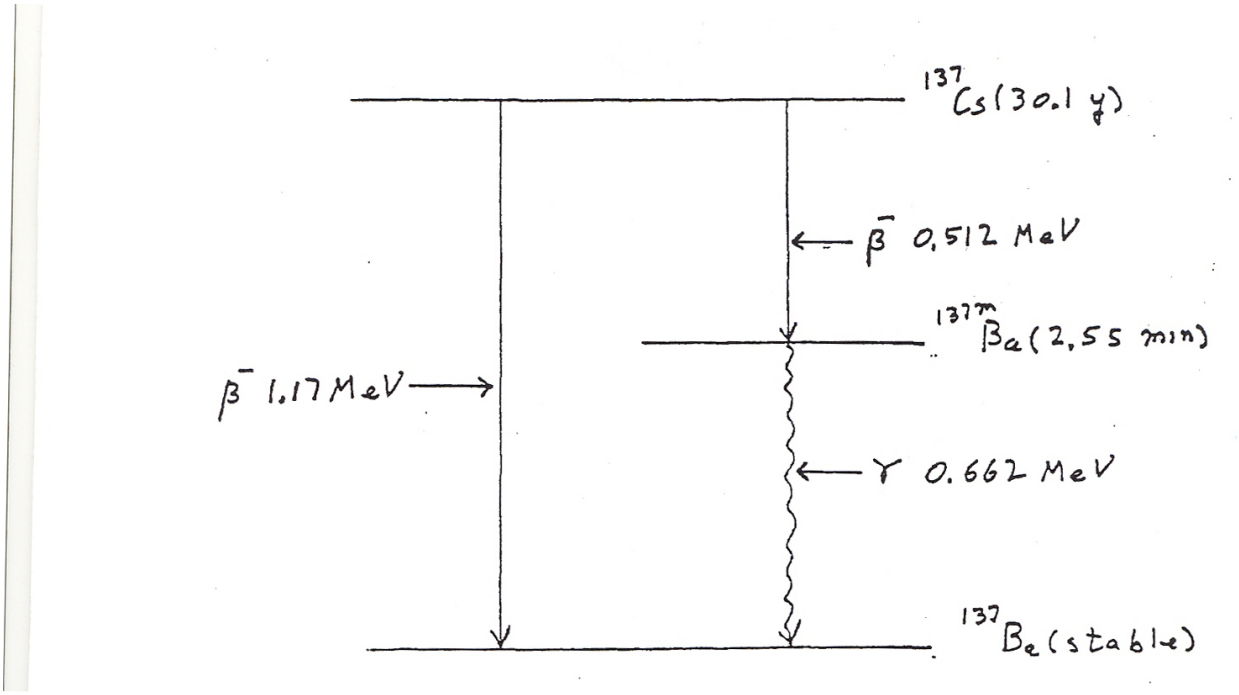

Figure 1: Decay of Cs-137