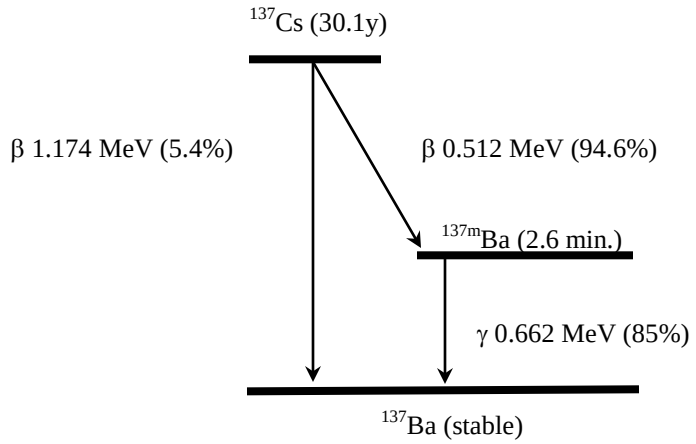
THE LAW OF RADIOACTIVE DECAY

Object: This experiment will show the exponential behavior of radioactive decay.

Apparatus: Geiger-Müller tube, Support Stand, Cs/Ba-137m Isotope Generator, 9 Planchets.

Discussion: The parent isotope Cs-137 with a half-life of 30.1 years beta decays (94.6%) to the metastable state of Ba-137m. This further decays by gamma emission (662 keV) with a half-life of 2.6 min. to the stable Ba-137 element. A diagram of this decay process is show below.



The nuclear decay process described above can be detected by observing the 2.6 minute half-life associated with the decay of Ba-137m. The Cs/Ba-137m generator can produce small quantities of the short lived Ba-137m isotope. The Ba-137m sample is produced by gently forcing an eluting solution (0.9% NaCl) through an exchange medium containing the parent Cs-137 isotope. During elution, the Ba-137m is selectively "milked" from the generator leaving behind the Cs-137 parent. Regeneration of the Ba-137m occurs as the Cs-137 continues to decay, re-establishing equilibrium in less than 1 hour. Each generator contains 10uCi. of Cs-137 which represents one Exempt Quantity making if free from specific State and Federal licensing. Approximately 30 minutes after elution, the residual activity of the Ba-137m solution has decayed to less than 1/1000 of its original activity making it safe for normal disposal.

A Geiger-Müller tube can detect the gamma ray emission associated with the decay of the Ba-137m nuclei and the computer will record the number of events per minute. The instructor will provide a few drops of a HCL-NaCl solution containing the eluted Ba-137m.

Radioactive decay is described by the equation,

$$N(t) = N_o e^{-\lambda t} \qquad (1)$$

Where, N (t) is the number of radioactive nuclei remaining at time t, N_0 is the initial number at t = 0 and λ is the decay constant. The activity, A, or number of disintegrations per unit time, is related to the number of decaying nuclei N by $A = \lambda N$. The mean life, τ, is equal to the inverse of the decay constant and is related to the half-life, $T_{1/2}$, by the equation

$$T_{1/2} = \tau \ln (2) = 0.693\tau = 0.693/\lambda$$

In this experiment you will measure $T_{1/2}$ and compare your experimental value with the known half-life of 2.6 minutes.

Experimental Procedure

I. **Measuring Background**

1) Plug in the Geiger-Müller (GM) Tube. Plug the GM tube connecting jack into the Signal Interface digital channel one.

2) Open the file “bckgrdc.sws”.

3) With no sample present, simultaneously press the "alt" and the "R" keys to begin recording data. After 10 minutes, the average of nine 1-minute background counts will be displayed. Record this value.

II. **Measuring Radioactive Decay**

1) Use the file “bckgrdc.sws”.

2) The instructor will place 1-2 drops of the Ba-137m solution in the planchet. Carefully place the planchet under the Geiger-Müller Tube. Position the GM tube approximately 1 inch above the planchet. (Instructors see the eluting procedure section on page 119.)

3) Simultaneously press the "alt" and the "R" keys to begin recording data. After 10 minutes you will see a data table with nine 1-minute GM tube count rate samples.

III. **Analysis**

1) For each of the nine 1-minute counts, subtract the background rate measured in part I.

2) Plot the natural logarithm of the counts on the y axis and the time (in minutes) on the x axis.

3) Place vertical error bars on the data points. For random radiation events such as these the ± error is approximately given by the square root of the counts.

Starting with equation (1)

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

Taking the logarithm of both sides;

$$1n(N) = 1n(N_0) + (-\lambda t)$$
$$(Y = b + mX)$$

Thus, the graph represents equation (1) and the slope of the graph is equal to the decay constant λ.

4) Draw a “best-fit” line through the data points and obtain λ from a pair of arbitrarily selected points taken near opposite ends of the best-fit line.

5) The slope of this line is the time constant for Ba-137m. Compare it with the accepted value of 2.6 minutes. What is your percent error?

Eluting Procedure: Only the instructor should operate the generator. Care should be exercised to avoid spills and contaminating work surfaces. If a spill does occur, the Ba-137m isotope will decay to practically zero activity within 15 minutes presenting no waste disposal issue.

1) Place the planchet on the sample tray being be used.

2) Attach the plastic tube on the syringe and draw the eluting solution into the syringe.

3) Remove the tubing from the syringe and the stoppers from the generator column.

4) Insert the syringe firmly into the hole on the top of the generator and while holding the generator vertically, **gently** force approximately two drops of solution through the generator onto the planchet.

5) After use, remove the syringe from the column and replace the stoppers.

Be careful to give each planchet only 1-2 drops of eluting solution. The generator can only create ~ 20 drops of Ba-137m per hour.

Data Table for Radioactivity

Time (minutes)	A	A- Average count	Ln(A-Ave. Count)
1			
2			
3			
4			
5			
6			
7			
8			
9			