HALF-LIFE OF BARIUM-137M

Introduction:

One of the characteristics often used to describe radioisotopes is half-life. Half-life is the time required for half of a radioisotope to disintegrate. This value is a constant and is not affected by changes such as temperature or pressure. Half-lives of radioisotopes can vary from fractions of a second to millions of years. In order to determine the half-life of a sample, the actual number of radioactive atoms need not be known. The activity of a sample measured by a G-M tube and scaler is proportional to the number of radioactive atoms in that sample. When the measured activity of a sample reaches a value equal to one half the original activity, half of that sample has undergone radioactive decay. The period of time required for this process is the half-life of the sample.

In this experiment, the half-life of Ba-137m will be determined. A half-life value can be determined in several different ways. These values can be found by estimation of the data, graphically, and mathematically. By comparing the results with the accepted value, the percent error in each method can be calculated.

The source of the Ba-137m is a mini generator or "cow." The Ba-137m is formed by the disintegration of Cs-137. The “m” in Ba-137m means that the nucleus of the newly formed Barium atom is in an excited state. The excited nucleus emits energy and becomes stable.

$$\text{Cs-137} \rightarrow \text{Ba-137m} + {}_{-1}e^{0}$$
$$\text{Ba-137m} \rightarrow \text{Ba-137} + {}_{0}\gamma^{0}$$

The mini generator contains an ion-exchange resin that releases Ba^{++} ions but retains Cs^{+} ions when a solution is passed through the column. This process is sometimes called "milking the cow."

Purpose:

The purpose of this experiment is to determine the half-life of Ba-137m by several methods and to determine the percent error for each determination.

Equipment:

G-M tube and scaler	eluting solution
Cs - Ba mini generator	graph paper (linear and/or semi-log)
planchet	stop watch

Safety:

- Wear gloves and an apron when handling an open source. Special care must be taken not to spill the solution. Leave the planchet in the sample holder when finished. The instructor will dispose of the sample at the end of the lab.

Procedure:

1. Plug in the scaler and allow it to warm up for a few minutes. Set the high voltage to 750.

2. With no sample in the sample holder, take a one-minute background count. Record the value in the data table. Repeat for a second one-minute background count.

3. Obtain a sample containing Ba-137m in a planchet and place it on the highest shelf possible in the sample holder. Set the timer to the manual setting.

4. Beginning on the minute take 10 second readings every 30 seconds for ten minutes. This sounds more complicated than it is. The scaler will be on for ten seconds, then it will be off for twenty seconds. Use this time to record data and reset the scaler. Begin the next reading when the second hand reaches thirty, and continue to read on the minute and half-minute for 10 minutes.

5. Have the instructor remove the sample holder with the planchet. Be sure no radio-active sources are near the scaler.

6. When all samples have been collected, take another one minute background reading and record the information on the data table.

7. Convert the readings for ten seconds to counts per minute by multiplying by six. Subtract background for those values that are less than 1000 cpm. These values constitute your corrected cpm.

8. Plot the corrected cpm on linear and/or semi-log graph paper. The corrected cpm should be plotted on the y-axis and the time on the x-axis. Use the “plot-at” for the time values. These are the time values for the midpoint of each counting interval.

Data Table:

Background count ___________ ___________ ___________

Measure at	Counts 10 s	Counts per min	Corrected cpm	Plot at (s)
0:00 - 0:10				5
0:30 - 0:40				35
1:00 - 1:10				65
1:30 -1:40				95
2:00 - 2:10				125
2:30 - 2:40				155
3:00 - 3:10				185
3:30 - 3:40				215
4:00 - 4:10				245
4:30 - 4:40				275
5:00 - 5:10				305
5:30 - 5:40				335
6:00 - 6:10				365
6:30 - 6:40				395
7:00 - 7:10				425
7:30 - 7:40				455
8:00 - 8:10				485
8:30 - 8:40				515
9:00 - 9:10				545
9:30 - 9:40				575
10:00 - 10:10				605

Calculations:

1. One method to estimate a value for half-life is to examine the data. From the data table, select two values (corrected cpm). One value should be twice as large as the other. Take the difference between these values. This is an approximate half-life. Calculate percent error for this determination.

   count rate_1 = __________

   count rate_2 = __________

   time difference = half life = __________

   percent error = __________

2. A second method of determining half-life is to use a graph of the data. From the graph, choose two count rates of which one is twice as large as the other. List these count rates and the time difference between these points. The time difference is the half life. Calculate the percent error for determining half-life by this method.

   count rate_1 = __________

   count rate_2 = __________

   time difference = half life = __________

   percent error = __________

3. The last method to find half-life is a mathematical method. Find the cpm for 65 and 575 seconds from your graph. The best-fit line is a better representation of the data than the individual data points. Use the formula below to calculate the half-life and then calculate the percent error for this determination. Show work.

   t_1 = 65 seconds   count rate_1 = ____________

   t_2 = 575 seconds   count rate_2 = ____________

$$t_{1/2} = \frac{-(\ln 2)(t_2 - t_1)}{\ln (CR_2 / CR_1)}$$

Questions:

1. Why does a researcher often take a background reading before and after an experiment where an open source has been used?

2. What would happen if the half-life data were plotted at the end of the counting interval instead of at the middle, as was suggested in this experiment?

3. What would happen to the value for your half-life if corrections for background were not made?

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TEACHER NOTES

Standards Met:

3.4.12.A – Apply concepts about the structure and properties of matter.

- Classify and describe, in equation form, types of chemical and nuclear reactions.
- Explain how radioactive isotopes that are subject to decay can be used to estimate the age of materials.
- Apply the conservation of energy concept to fields as diverse as mechanics, nuclear particles and studies of the origin of the universe.
- Apply the predictability of nuclear decay to estimate the age of materials that contain radioactive isotopes.

3.7.10.B – Apply appropriate instruments and apparatus to examine a variety of objects and processes.

- Describe and use appropriate instruments to gather and analyze data.

3.1.10.B – Describe concepts of models as a way to predict and understand science and technology.

- Apply mathematical models to science and technology.

3.1.12.E – Evaluate change in nature, physical systems and man made systems.

- Evaluate fundamental science and technology concepts and their development over time.

3.7.12.A – Apply advanced tools, materials and techniques to answer complex questions.

- Demonstrate the safe use of complex tools and machines within their specifications.
- Evaluate and use technological resources to solve complex multistep problems.

Lab Time: 45 minutes

Answers to Questions:

1. Why does a researcher often take a background reading before and after an experiment where an open source has been used?

   A background reading is often taken at the beginning and end of a lab to determine if the operator of the scaler has contaminated the scaler with a radioactive material. If the set-up is clean at the end of an experiment the background should be the same as at the beginning.

2. What would happen if the half-life data were plotted at the end of the counting interval instead of at the middle, as was suggested in this experiment?

   The value for the half-life would not change. The line would be shifted slightly to the right, but the slope and therefore the half-life would remain the same.

3. What would happen to the value for the half-life if corrections for background were not made?

   The end of the graph would be higher. This would reduce the slope and give longer values for the half-life.

Considerations:

The Ba/Cs mini generator used in this experiment poses little risk. Due to the short half-life of the isotope generated, the activity should drop to background within an hour. If this does not occur, some of the Cs-137 may be leaking through. Under normal circumstances the used solution can be washed down the drain.

The half-life of Barium-137m is approximately 153 seconds. Different references will give slightly different half-life values.

Instruct the students in how to find half-life from a graph. If students are careful, percent errors of less than 5-10% are not uncommon.

Half-Life Computer Simulation

To prepare students for a half-life experiment, a program called *Decay* available from Seraphim Software may be useful. This program may be obtained free or at the cost of a disk through the Spectroscopy Society of Pittsburgh.

The program simulates nuclear decay on the screen and then prints out a set of data for the students. Each group of students receives a different set of data. The students may then plot the data and obtain half-life values. No time units are provided. The students may make up their own units as well as name the "isotope" being studied.

Last updated 11-02.