NUCLEAR SCALERS PURDUE UNIVERSITY INSTRUMENT VAN PROJECT
HALF-LIFE OF A RADIOISOTOPE

(7-23-03)

INTRODUCTION

The half-life of a radioisotope is defined as the amount of time necessary for one-half of the quantity of nuclide to decay, i.e., be converted into another species. The conversions involve either alpha or beta particle release, and the reaction can be followed by measuring the number of particles given off. A nuclear scaler will be used to measure the amount of radiation evolved, and graphical interpretations will allow calculation of the half-life.

PURPOSE

To extend the nuclear chemistry unit to include a simple quantitative study of half-life.

SAFETY CONSIDERATIONS

Wear disposable gloves when handling the isogenerator column and eluted solutions.

At the completion of the experiment, the solutions may be safely flushed down the sink. Gloves and paper towels may be thrown into normal trash containers.

PRE-LAB QUESTIONS

1. Write the nuclear equation for the transformation of Cs-137 to Ba-137m.
2. Write the nuclear equation for the transformation of Ba-137m to Ba-137.
3. What trend in the data obtained from the nuclear scaler do you expect?
4. Using counts per minute obtained at time intervals, explain how to graphically determine the half-life.
5. Knowing that the nuclear reaction follows first-order kinetics, how would you more accurately calculate the half-life. (Hint: apply the integrated rate equation.) *

*AP Level

MATERIALS

Per Group Per Class

Sample planchet 2 isogenerators (Cs-137)
Water bottle ring stands and clamps aste)
Disposable gloves 250 mL beakers
Nuclear scaler distilled water der Eluting Solution
Sample holStopwatch

PROCEDURE

1. The nuclear scalers should be set up (450v) and background radiation measured. Put radioactive sources from the kits in another part of the room!
2. Wearing disposable gloves, the students should collect 7 drops of the eluate in the planchet and immediately place the sample in slot 2 of the Geiger-Mueller tube. Take a one minute count (time = 1 minute), followed by one minute counts every other minute (t = 1, 3, 5, 7.... 19 minutes).
3. The sample planchet may safely be rinsed in the sink with water and dried. Gloves and paper towels may be disposed of in the normal trash cans.

4. The EDTA solution is critical to the success of the experiment.

NOTE: Use only Purdue Instrument Van Project supplied solutions!!

DO NOT use your own EDTA solution!!

Our experience shows this will ruin the column.

ANALYSIS/CONCLUSIONS

1. Discuss the shape of the curve obtained from a plot of activity versus time. Does it make sense?
2. From your curve in Step 1, determine the half-life of the reaction. Show all work and reasoning.
3. Why did you wear gloves in the beginning of the experiment, yet were allowed to dispose of materials in the sink and trash can?
4. What is the daughter nuclide formed in this nuclear reaction? Why was EDTA used as the elutant?
5. Why should the concept of half-life of radioisotopes be understood by all citizens, not just chemistry students?
6. *Using your activity/time data and the integrated rate equation for first-order kinetics, calculate the half-life of the reaction. (Hint: least squares program of graphical analysis program).

TEACHERS' GUIDE
HALF-LIFE OF A RADIOISOTOPE

TYPICAL CLASSROOM USAGE

First-year chemistry
AP chemistry

CURRICULUM INTEGRATION

Radioactivity
Half-life of radioactive elements
Graphing and interpretation of graphs

PREPARATION

1. Only materials supplied by the Van Project are to be used.
2. The generator may be milked many times in quick succession without total depletion of the Ba-137 isotope. After three milkings the sample activity will drop to about 1/5 of the initial milking but still produces a satisfactory sample for half-life measurement.
3. Only the qualified instructor should operate the generator. Care should be exercised to avoid spills and contaminating work surfaces. If a spill does occur, the Ba-137 isotope will decay to practically zero activity within 15 min. presenting no waste disposal issue.

TIME

Prepare Lab: 15-20 minutes
Stopping Point: None
Student Time: 30 to 40 minutes

SAFETY AND DISPOSAL

Solutions may be washed down the drain. Disposable gloves and paper towels may be placed in the normal trash cans.

ASSESSMENT

Check graphs for correctness
Check calculations and results
Check answers to Analysis/Conclusions questions Include lab questions in unit test on Nuclear Chemistry

CURRICULUM CONNECTIONS

Indiana State proficiencies (page 11): 1, 2, 3, 4, 5, 6, 7, 1.

Proficiency #3 expanded: Construct a graph and interpret the information. Determine the half-life of Ba-137m.

PRE-LAB QUESTIONS

1. Cs-136 -> Ba-137m + electron (beta particle)
2. Ba-137m -> Ba-137 + gamma ray)
3. CPM will decrease as time increases
4. On the Y-axis locate any point. Read the counts per minute off the graph. Divide CPM/2 to determine the counts left after one half- life. Locate this point on your graph. Find the amount of time elapsed between the initial reading and the final reading. This is $t_{½}$.
5. The first order rate equation is $\ln A/A_o = -kt$; where A_o is the initial concentration, A is the concentration at time, t and k is the first order rate constant (slope).

ANALYSIS/CONCLUSIONS

1. The counts/minute decrease as time increases. Yes.

2. Reported value for μof Ba-137m is 2.55 minutes.

3. Sample was radioactive at the beginning of the experiment. The half-life was so short that the radioactivity decreased rapidly and approached background radiation by the end of the experiment. Non-radioactive barium should be disposed of in solid waste; however, the amounts of barium in this experiment are so small that the manufacturer of the isogenerator recommends rinsing the planchets in the sink and drying them for re-use.

4. Ba-137m is a meta-stable isotope of Ba. EDTA is ethylenediaminetetraacetic acid and has the ability to bind (chelate) the metal ion and remove it from the Isogenerator column.

Sample Data/Results:

Time (minutes)	cpm (corrected)	ln (cpm)
1	2952	7.99
3	1593	7.37
5	936	6.84
7	598	6.39
9	316	5.76
11	181	5.20
13	101	4.62
15	75	4.32
17	48	3.87
19	15	2.71

$1n\ (A/A_o) = -\ kt$

slope = -0.274/minute
y-intercept = 8.25
rate = 0.995
$t_{½}$= 0.693/k = 0.693/0.274/min. = 2.53 min.

Suggested terms:

Half-life	corrected (cpm)	graph
Ba -137m	activity (cpm)	nuclear scaler
Ba – 137	time	solution of EDTA
Cs 137	beta (β) particle	isogenerator
background (cpm)	gamma (γ) ray	first order rate equation

LAB ADAPTED BY: Mike Grubber and Richard Partezana

REFERENCES

"Procedure for Preparation of Cs-137/Ba-137m Isogenerator Column", (supplied by Oxford Instruments, Inc.)

Herron, Dudley J. Et al., Chemistry, D.C. Heath Publishing Company, Lexington, MA. 1993, p. T318-319.

"Cs/Ba-137m Isotope Generator Operating Instructions", (supplied by Spectrum Techniques