SOME PROPERTIES OF NUCLEAR RADIATION

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INSTRUCTOR RESOURCES

a *MicroLAB* Experiment

Learning Objectives

After completing this experiment, you should be able to . . .

- define the term "standard deviation" and use it to determine the "standard error" on a set of measurements.
- use the "square root" of a series of collected counts of a radioactive sample to bracket experimental data points to show their uncertainty.
- differentiate between beta and gamma radiation, and estimate the range of beta radiation in common materials.
- define the term "half life," and determine the half life of an electron-storage device and a radioactive isotope by examination of experimental data.

Procedure Overview

- Review the operation of a Geiger-Mueller tube and the common types of radiation.
- Examine the statistics of radioactive decay, both for background counts and a radioactive source.
- Measure the half life of an electron storage device and plot the natural logarithm to determine a linear relationship.
- Measure the half life of a radioactive substance and plot the natural logarithm to determine a linear relationship.
- Learn how to add error bars on an EXCEL graph. (Only if EXCEL is being used to graph the experimental data.)

Name ______________________________ Section _______ Date ____________________

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Report Sheet

Answer the following questions:

1. For both the background and the radioactive sample, how many of your samples fall outside (greater than, or less than) this range? Does your data fall within the normal range? Explain.

2. From your data, how many data points fall outside the 95 percent range? Does your data fall within the normal range? Explain.

3. How many cards are required to apparently eliminate the beta radiation?

4. What is the approximate half-thickness of index cards for the beta radiation?

5. Make a table consisting of each of your data points in one column, and the square root of the collected count in the second column to include in your report.

6. At what count level does the standard deviation get as large as the background counts?

7. Is "half life" a quantity that always remains the same, regardless of when you begin your measurement?

Name ______________________________ Section _______ Date ____________________

SOME PROPERTIES OF NUCLEAR RADIATION

Report Sheet

8. Does this graph look like the electron half-life experiment graph? Explain.

9. What is the **estimated** half-life for your radioactive isotope from these calculations?

10. What is the decay constant for your radioactive isotope?

11. What is the half-life of your radioactive isotope when calculated using the decay constant? How does this value compare with the value on the lower graph? Discuss any differences.

12. Based on your half-life, and a review of the half-lives listed in Table 1, report what isotope is being separated from the Th-232 sample by your instructor.

13. Calculate the initial instantaneous activity for your radioactive sample.

SOME PROPERTIES OF NUCLEAR RADIATION

Tips and Traps

1. You will need a Geiger-Mueller counter tube with either a 1/4 inch phone jack (for the model 402 ***MicroLAB*** unit) or two banana plugs, preferably **red** and **black**, (for the model FS-522 or ML-507 ***MicroLAB*** units) If you already have GM tubes, they can be modified as above, or, GM tubes can be purchased from ***MicroLAB***, Inc, at **www.microlabinfo.com**, or P.O. Box7358, Bozeman, MT 59771-7358.
2. Care must be exercised in the use of the radioactive sample. The preferable source is a commercially obtained disc on which is a protected coating covering an active sample on the order of 20,000 to 30,000 cpm. This gives good statistics.
3. If a commercial source is not available, a useable source can be constructed using a 1 cm planchet with a small sample of a uranium or thorium salt. Because uranium is colored, it is preferable. The planchet is then covered with two layers of Saran wrap and sealed tight around the sides and bottom with tape. These must be examined after each use to insure that they have not broken open and that radioactive material is not scattered around the lab. **The students should be cautioned to handle them with care**.
4. The electron storage device can be purchased from ***MicroLAB***, Inc., address above, as the Simulated Half-life Model 215. (This has two systems that produce a short and a longer half -life, and is switched to have one, the other or both.), or, one can be constructed using a two prong banana plug(with set screws) which has a small black ridge on one terminal, marking it as the **negative** terminal. The capacitor and resistor are soldered together, the **negative** lead of the capacitor is then attached to the **negative** prong, and the **positive** lead of the capacitor is attached to the opposite prong. **Students should be cautioned to attach the voltage leads with the proper polarity!**
5. **Separation Process for Thallium-208, 3.1 minute half life**

Reagents:

Thorium nitrate "cow":

5 g thorium nitrate dissolved in 10 ml 2 M nitric acid.

Ammonium phosphate solution:

100 ml distilled water.

0.75 g ammonium phosphate, monobasic, and mix well

ammonium molybdate solution:

300 ml distilled water,

30 g of ammonium molybdate, and mix well

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Absorbent: Materials for 100 runs.

Ammonium molybdophosphate

To 700 ml distilled water, add the following,

50.0 g ammonium nitrate and 100 ml concentrated nitric acid.

Add the 100 ml of Ammonium phosphate solution from above.

Add the 300 ml of Ammonium molybdate solution from above.

Heat in a water bath at about 80 degrees °C for about 20 minutes

The yellow precipitate that forms is ammonium molybdophosphate.

SOME PROPERTIES OF NUCLEAR RADIATION

Tips and Traps

To run the experiment:

Prepare a small (1 cm) filter paper and Buchner funnel. Wet the filter paper and start a slight vacuum.

Shake up the ammonium molybdophosphate suspension and pour 10 ml of the suspension into the funnel. Rinse with distilled water.

Pour the 10 ml of thorium nitrate solution onto the ammonium molybdophosphate absorbent.

Rinse with 10 ml of 2 M nitric acid by pouring over the entire surface of the precipitate to remove essentially all radioactive isotopes except the Tl-208.

Wearing gloves and carefully using tweezers, remove the filter paper, place it in a 1 cm planchet, wrap the planchet in one layer of saran wrap and tape it underneath.

Immediately place the planchet under the Geiger tube and count for 30 second intervals for ten minutes.

Disposal:

The filtrate contains the radioactive Th-232. After about 30 minutes it can be poured over another sample of ammonium molybdophosphate precipitate on a filter paper and milked again for another thallium sample.

Only the Tl-208 adheres to the precipitate, so if you collect the rinse filtrate in a separate filter flask, the original filtrate will contain nearly all of the thorium nitrate solution and it can be used again and again by simply pouring it over another precipitate sample and rinsing with 10 ml of 2 M nitric acid in the same manner, collecting each rinse in the same filter flask.

After the experiment, all of the Th-232 solutions can be combined, evaporated down to 10 ml again, and used another time. This way, you don't have a disposal problem for the Th-232.

Be sure to rinse those containers that have been in contact with the Th-232 several times, testing the last rinsing for traces of radioactivity. Combine all of the rinses in one container, evaporate to dryness, and dispose congruently with proper techniques for radioactive thorium.

Tl-208 decays into stable Pb-208, so the precipitate and filter paper will not be radioactive after about 30 minutes and may be disposed of properly along with any remaining ammonium molybdophosphate suspension at the end of the experiment.

6. Sample Radiation Counting Program, data taken at a given time interval.

purpose: Use for timed data collection for any sensor, but especially a Geiger Mueller counter.

Suggested name: ***Radiation.exp***

Sensors: **Time**: X axis, Col. A, DD on top, units = sec; **GM Tube**: Y1 axis, Col B, DD in middle, units = counts.

Special Program:

Repeat every 30 seconds (Starts repeat loop of 30 second counts of ionizing radiation through the counter.)

Read Sensors (Records the total elapsed time and counts for that loop.)

Restart the counter (Resets and restarts the timer to collect the next 30 second count.)

Until Loop Count is 20 (Ends experiment after 20 counts of 30 seconds each.)

Comment: The program will accumulate all counts received by the counter each 30 second interval and record the total time to that loop number and the counts for that loop. .

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Answer to the Report Sheet questions

1. For both the background and the radioactive sample, how many of your samples fall outside (greater than, or less than) this range? Does your data fall within the normal range? Explain.

   Student's answers will vary here, but should be about six to seven values.

2. From your data, how many data points fall outside the 95 percent range? Does your data fall within the normal range? Explain.

   Again, student's answers will vary here, but should be about one or two values

3. How many cards are required to apparently eliminate the beta radiation?

Again, student's answers will vary here, depending on the thickness of the cards and the initial distance of the GM tube from the radioactive sample. An average should be taken for the class.

4. What is the approximate half-thickness of index cards for the beta radiation?

   The student's value should be about ½ of the class average determined in question 3.

5. Make a table consisting of each of your data points in one column, and the square root of the collected count in the second column to include in your report.

   This should be intuitive to the instructor.

6. At what count level does the standard deviation get as large as the background counts?

   The correct response here must be judged on the above table for each student.

7. Is "half life" a quantity that always remains the same, regardless of when you begin your measurement?

   A true half-life will remain constant withing the statistical nature of radioactive counting for a given isotope

SOME PROPERTIES OF NUCLEAR RADIATION

Report Sheet

8. Does this graph look like the electron half-life experiment graph? Explain.

The graph of the radioactive sample should be analogous to the electron half-life experiment, except that the initial values will be different, and the time values will be different.

9. What is the **estimated** half-life for your radioactive isotope from these calculations?

The students estimated half-life should be somewhere around 2.5 minutes.

10. What is the decay constant for your radioactive isotope?

The decay constant should be on the order of 0.250 min$^{-1.}$

11. What is the half-life of your radioactive isotope when calculated using the decay constant? How does this value compare with the value on the lower graph? Discuss any differences.

Values may differ here, but should be on the order of 2.60 minutes, the accepted value.

12. Based on your half-life, and a review of the half-lives listed in Table 1, report what isotope is being separated from the Th-232 sample by your instructor.

The isotope being separated is Tl-208, based on the observed half-life of about 3 minutes.

13. Calculate the initial instantaneous activity for your radioactive sample.

This value will vary from class to class, depending on how long it has been since the Tl-208 had been milked, how long it took to begin counting, etc. The value is obtained from the Y intercept of the natural logarithm plot.

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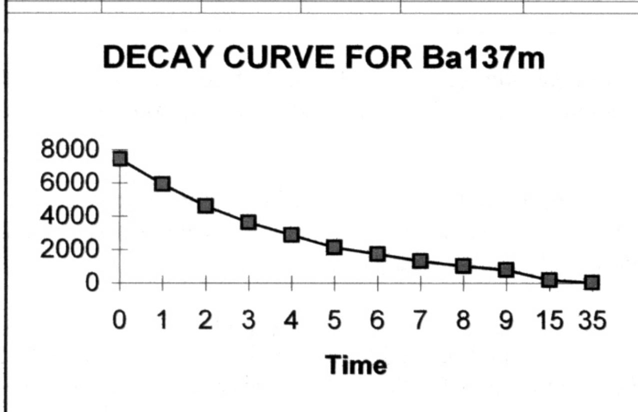
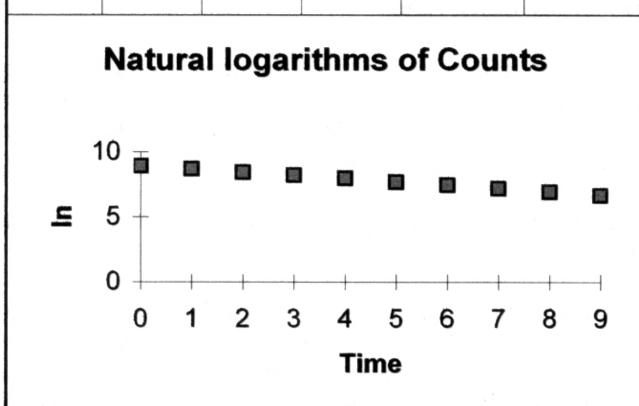
Sample Data

Sample data for the Cs-137 daughter decay, Ba-137* in EXCEL format. Note that the average of the four estimated half-lives is 2.68 minutes, very close to the accepted value of 2.60 minutes

Ba137m gamma decay, all counts for 0.5 min.							
	Bckgrnd	Time	Counts	Cnts - Bgd	ln(Cnt-Bgd)		
	6	0	7434	7426.6	8.912823	t1/2(cnts) =	3713.3
	7	1	5933	5925.6	8.687037		
	9	2	4607	4599.6	8.433725	t1/2(exp.) =	2.90
	12	3	3624	3616.6	8.19329		
	3	4	2863	2855.6	7.957037		
Total	37	5	2138	2130.6	7.664159	t1/2(cnts) =	1808.3
Average	7.4	6	1732	1724.6	7.45275		
		7	1320	1312.6	7.179765	t1/2(exp.) =	2.79
		8	1027	1019.6	6.927166		
		9	784	776.6	6.654925		
		15	193	185.6	5.223594	t1/2(cnts) =	1065.3
		35	32	24.6	3.202746		
				Slope =	0.2511	t1/2(exp.) =	2.84





t1/2(cnts) =	656.3
t1/2(exp.) =	2.20
Experimental values	
t1/2(exp. ave) =	2.69
k = ln(2)/2.69	0.2577
Integrated R. Calc. values	
k=-ln(N/No)/t =	0.2509
t1/2=ln2/k =	2.76
Published values	
k = ln(2)/2.60	0.2666
t1/2(meas) =	2.60
Ln Exp. Values	
Exp k =	0.2511
t1/2(calc.) =	2.76

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Laboratory Preparation (per student station)

Equipment

- radiation counter (GM tube) with a BNC for ***MicroLAB*** model 402.
- sufficient 3X5 file cards to cut into 60 - 2.5" X 3" pieces for each pair of students.
- ring stand and three-pronged clamp to hold the GM tube.
- water bath set at about 80 degrees °C
- 1 cm Buchner funnel with 1 cm filter paper
- Multiple filter flask aspirator set-up such that it is not possible for the radioactive filtrates to be siphoned back into the potable water supply while producing the Tl-208 samples.

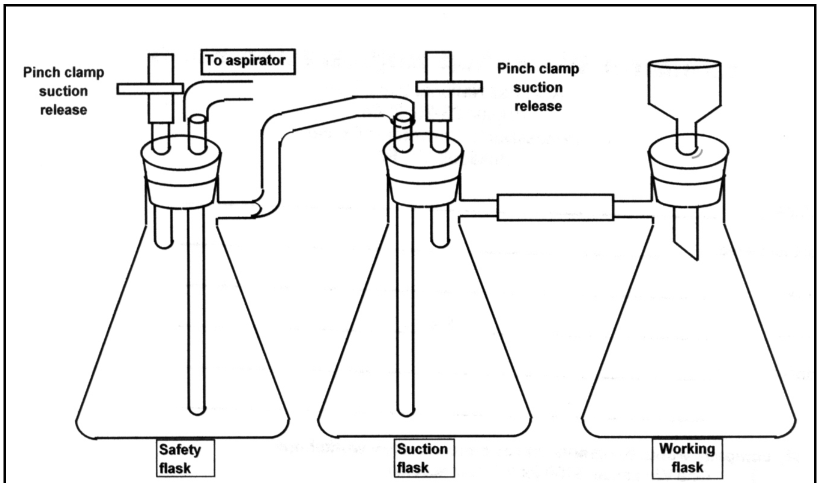

Diagram for setting up the suction flasks so there is no possibility that radioactive liquid can be siphoned back into the potable water supply.

Supplies

- towels

Chemicals

- 1 L of 2 M nitric acid
- 100 ml conc. Nitric acid
- 5 g Thorium nitrate
- 50.0 g ammonium nitrate
- 0.75 g ammonium phosphate, monobasic
- 30 g of ammonium molybdate

Safety and Disposal

- **CAUTION: Students should be cautioned to handle the radioactive source with great care, especially if it is not a commercially produced sample, i.e., a sample that has been made in a 1 cm planchet covered with Saran Wrap.**
- **The Th-232 solution must be properly labeled and stored congruently with handling moderately radioactive materials.**
- after 10 half-lives (about 30 minutes) the Tl-0208 milked solution's radiation level is essentially background and can safely be discarded down the sink.