NUCLEAR RADIATION AND SHIELDING

LAB NR 8.CALC

From *Nuclear Radiation with Computers and Calculators,* Vernier Software & Technology, 2001

INTRODUCTION

Nuclear radiation can be broadly classified into three categories. These three categories are labeled with the first three letters of the Greek alphabet: ά (alpha), β (beta) and γ (gamma). Alpha radiation consists of a stream of fast-moving helium nuclei (two protons and two neutrons). As such, an alpha particle is relatively heavy and carries two positive electrical charges. Beta radiation consists of fast-moving electrons or positron (an antimatter electron). A beta particle is much lighter than an alpha, and carries one unit of charge. Gamma radiation consists of photons, which are without mass and carry no charge. X-rays are also photons, but carry less energy than gammas.

Some materials absorb beta rays. You can measure this absorption by fixing a beta source and a radiation monitor so their positions do not change, and then inserting layers of cardboard between them.

When an absorber is in the path of beta rays, it will allow a certain fraction, f, to pass through. The fraction, f, depends on the density and thickness of the absorber, but will be a constant for identical absorbers and fixed beta ray energy. If the number of counts detected in a count interval is N_0 when no absorber is in place, then the counts, N, with the absorber is $N = f N_0$. In the Development of a Model section, you will develop a more general expression for additional layers of cardboard absorbers, and then test it against real data

You will then investigate the absorbency of other materials and determine if any material will absorb gamma radiation.

In this experiment, you will use small sources of beta radiation and gamma radiation. Beta rays are high-energy electrons. Gamma radiation is not a particle, but a bundle of energy called a photon. *Follow all local procedures for handling radioactive materials.*

SAFETY

- Always wear goggles and an apron in the lab.
- Follow all local procedures for handling radioactive materials.

PURPOSE

The purpose of this experiment is to create a model for the absorption of radiation by matter, to test it experimentally , and to determine if any material will absorb gamma radiation.

MATERIALS

Computer
Vernier Computer Interface
Logger Pro
Vernier Radiation Monitor
Strontium-90 beta source
Co-60 gamma source
Po-210 alpha source
Metric ruler
Ten, 10 cm x 10 cm identical cardboard squares
Variety of shielding materials

PREMLIMINARY QUESTIONS

1. Most nuclear radiation carries energy in the range of a few million electron volts, or MeV (1 MeV= 10^6 eV = 1.6 x 10^{-13} J), regardless of its type (alpha, beta, or gamma). This means that particles that are more massive generally travel more slowly than light particles. Make a preliminary guess as to which radiation type will in general interact most strongly with matter, and therefore would be most strongly absorbed as it passes through matter. Consider electrical charge, mass and speed. Explain your reasons.

2. Which radiation type do you predict would interact, in general, least strongly with matter, and so be less absorbed than others? Why?

3. Which radiation type do you predict would have an intermediate level of interaction with matter? Why?

4. You will be using paper and aluminum sheet metal as absorbers for the radiation. Which material has the greatest areal density (that is, a density per unit area, which could be measured in g/cm^2), and so would present more matter to the passing radiation? Which material would have less?

5. In your radiation monitor sensitive to all three types of radiation? How can you tell? Devise a test and carry it out. If your radiation monitor does not detect one form of radiation, then you will be able to compare the absorption of the remaining two types.

DEVELOP MENT OF A MODEL

1. Place your Sr-90 source on a table. Turn on the radiation monitor to the audio mode, so that it beeps when radiation is detected.
2. Hold the monitor near the source. Where is the most sensitive place on the detector?

3. Attach the source disc to a support using adhesive tape so that the source held at the source held at the same height as the Geiger tube in the radiation monitor. Do not cover the source with tape.

4. Place the source so it is about eight centimeters from the most sensitive place on the monitor, so that there is room to place all ten layers of cardboard between the source and the monitor. **Note:** It is essential that neither the source nor the monitor move during data collection.

5. Based on your observations, sketch a qualitative graph of the beep rate *vs*. numbers of layers of shielding.

6. In the introduction we used the expression, $N = f N_0,$ to describe the transmission of beta rays by one layer of cardboard. Assuming this model, how many counts would be detected if you added a second layer of cardboard, identical to the first, which also transmitted a fraction, *f*? (For example, if the first layer transmitted 90% of the radiation, then the second would transmit 90% of that transmitted by the first. The overall transmission would then be 0.90 x 0.90 = 0.81 = 81% of the no-shielding number of counts.)

7. In the Data Table, write a general expression for the number of counts, N, detected for any number, x, of identical layers, each of which transmits a fraction, f, of the incident radiation. Use N_0 as the counts detected when no shielding layers are used. **You have just developed a model for the transmission of radiation through matter. Next, you will test your model against experimental data.**

8. Is your model consistent with your qualitative graph you sketched based on initial observations? (Remember that *f* is a number less than one.)

PROCEDURE

1. Connect the radiation monitor to SONIC/DIG 1 of the LabPro.

2. Prepare the calculator for data collection by pressing *Apps>VST Apps>DATARAD.*

3. With no source within 1 meter of the monitor, record the background radiation. Press *set up>background Correction> 1.Perform Now.* Enter 50 for number of intervals. > Enter.
   - When background Correction is complete press Enter then 7 to remain to main screen.
   - If Mod is not *Events with Entry,* press *1.setup* and select “Events with Entry”.
4. Confirm that the source and monitor are positioned so they will not move, and so that there is enough space between them for ten layers of cardboard.

5. Remove all cardboard from between the source and monitor.

6. Press (2) Start > Enter to begin collecting data. DATARAD will begin counting the number of beta particles that strike the detector during each 50-second count interval.

7. In the entry field that appears, enter **0**, which is the number of layers of cardboard. Complete your entry by pressing enter on the keyboard. Data collection will now pause for you to adjust the apparatus.

8. Insert one layer of cardboard between the source and detector. Be sure that the cardboard completely covers the source's "view" of the Geiger tube in the detector.

9. Press Enter to collect more data, and wait 50 seconds.

10. Enter the number of layers of cardboard.

11. Without moving the source or the monitor, and adding an additional layer of cardboard each time, repeat steps 9 and 10 until you have completed data collection for ten layers.
12. Press STO to end data collection. Go to ANALYSIS section on pg. NR8-6.

13. Try using other absorbers from the set of absorbers provided. Record your findings in the Data Table 2.

14. Try using a gamma source in the activity instead of a beta source. Record your findings in Data Table 2.

15. Place a ruler on lab bench direction in front of the Geiger tube on the radiation monitor. Place an alpha source on the ruler at 1 cm mark and record the counts per second. Move source to 10 and 20 cm position and repeat.

16. Place a thin sheet of paper between the alpha source and the monitor and record the counts per second. Repeat with Beta and Gamma.

DATA SHEET

Name__________________________
Name__________________________
Period_______Class_____________
Date_____________

RADIATION SHIELDING

DATA TABLE 1

Model Equation	
Fitted equation with parameters	

DATA TABLE 2

Material	Thickness	Denisty (mg/cm^2)	Absorbance (counts/interval)	
			Beta	Gamma

ANALYSIS

1. Inspect your graph. Does the count rate appear to follow your model?

2. Fit an appropriate function to your data.
   a. To choose a function, look for one that has the same mathematical form as your model.
   b. To see the functions available, single-click on the graph. Click the *curve-fit button* (Hint: Which fit functions have an x, the horizontal axis variable, in the same special location as in your model equation?)
   c. Select an equation from the equation list, and then click *try fit.* A best-fit curve will be displayed on the graph. In your data follow the selected relationship, the curve should closely match the data.
   d. If the curve does not match well, try a different fit and click *try fit a*gain.
   e. When you are satisfied with the fit, click *ok.*
   f. Print or sketch your graph. Record the fitted equation and parameters in your Data Table.

3. From the evidence presented in your graph, does the transmission of beta radiation through the cardboard match that predicted by your model?

4. From the parameters of your fitted equation, determine the fraction f, of beta rays transmitted, on average by one layer of cardboard. Do not use your raw data to calculate the fraction, but instead use the information from your fitted equation. Hint: Remember that $A^{(Bx)} = (A^B)^X$.
5. Return to step #13 of the Procedure, page. 4.

6. What materials absorb beta radiation?

7. What materials absorb gamma radiation?

8. What materials absorb alpha radiation?

EXTENSIONS

1. Use a longer counting interval so that you collect at least 2000 counts when no absorbing cardboard is in place. Is the agreement with the model and different? Try a much shorter count interval. How is the resulting graph different? Why?

2. Cosmic rays continue to strike the detector regardless of the absorbing cardboard. Does the count rate with the maximum number of cardboard sheets equal the back-ground measure with no source? Correct your data for background radiation. Repeat the analysis.

3. X-rays are photons, just like gamma rays. X-rays carry lower energy, however, and so historically received a different name. If you have had an X-ray film picture of your teeth taken by a dentist, the dentist probably placed a lead-lined apron on your chest and lab before making the X-ray. What is the function of the lead apron? Support any assertion you make from your experimental data.