α, β, and γ

Nuclear radiation can be broadly classified into three categories. These three categories are labeled with the first three letters of the Greek alphabet: α (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 positrons (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 massless and carry no charge. X-rays are also photons, but carry less energy than gammas.

After being emitted from a decaying nucleus, the alpha, beta or gamma radiation may pass through matter, or it may be absorbed by the matter. You will arrange for the three classes of radiation to pass through nothing but a thin layer of air, a sheet of paper, and an aluminum sheet. Will the different types of radiation be absorbed differently by the air, paper and aluminum? The question can be answered by considering which radiation type will interact more strongly with matter, and then tested by experiment.

In this experiment you will use small sources of alpha, beta, and gamma radiation. *Follow all local procedures for handling radioactive materials*.

OBJECTIVES

- Develop a model for the relative absorption of alpha, beta, and gamma radiation by matter.
- Use a radiation counter to measure the absorption of alpha, beta, and gamma radiation by air, paper, and aluminum.
- Analyze count rate data to test for consistency with your model.

MATERIALS

LabQuest
LabQuest App
Vernier Radiation Monitor
paper sheet
polonium-210 0.1µC alpha source
strontium-90 0.1µC beta source
cobalt-60 1µC gamma source
aluminum sheet, about 2 mm thick

PRELIMINARY QUESTIONS

1. Most nuclear radiation carries energy in the range of a few million electron volts, or MeV (1 MeV = 10^6 eV = 1.6×10^{13} J), regardless of its type (alpha, beta, or gamma). This means that more massive particles 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 measure in mass 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. Is your Radiation Monitor sensitive to all three types of radiation? How can you tell? Devise a test and carry it out.

PROCEDURE

1. Connect the Radiation Monitor to a DIG port of LabQuest. Choose New from the File menu.
2. Set up the data-collection mode.
   a. On the Meter screen, tap Mode.
   b. Change the data-collection mode to Selected Events and select OK.
3. Determine the background count rate.
   a. Move all sources away from the Radiation Monitor.
   b. Start data collection to prepare the system for data collection.
   c. Tap Keep. Counts are taken for 50 seconds.
4. When the first point has been collected, place the beta source near the monitor screen of your Radiation Monitor, with the underside of the disc facing the monitor. **Note**: Place the Radiation Monitor and the source in approximately the same position each time you collect data. When using an absorber in later steps, place the absorber between the source and the monitor screen. Each time you collect data, the distance between the Radiation Monitor and the source should be approximately the same.

5. Test the beta radiation source.
   a. Tap Keep. Counts are taken for 50 seconds.
   b. Place a single sheet of paper between the beta source and the monitor.
   c. Tap Keep.
   d. Place a single sheet of aluminum between the beta source and the monitor.
   e. Tap Keep.
6. Stop data collection.
7. Tap the Table tab to view your data. Record the values in your data table.
8. Tap the Meter tab and repeat Steps 4–7 with the alpha radiation source.
9. Tap the Meter tab and repeat Steps 4–7 with the gamma radiation source. When you have completed the testing and recording your data, store the radiation sources as directed by your instructor.

DATA TABLE

Counts in 50 s interval			
	No shielding	Paper shield	Aluminum shield
No source (background)			
Alpha source			
Beta source			
Gamma source			

ANALYSIS

1. Compare the no-source, or background, count with the no-absorber counts for the sources. Is the background count number a significant fraction of the counts from the sources? Do you need to consider a correction for the background counts?
2. Inspect your data. Does the count rate appear to follow your initial guesses for the relative absorption of the various types of radiation by matter? Be specific, considering which source should be the most penetrating (least interacting), and which absorber is more difficult to penetrate.
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 lap before

making the X-ray. What is the function of the lead apron? Support any assertion you make from your experimental data.

EXTENSIONS

1. If you were presented with a safe, but unknown, radiation source, and assuming that it emitted only one type of radiation, devise a test that would allow you to tentatively identify the type of radiation as primarily alpha, beta, or gamma. Write instructions for another student to follow in performing the test.

2. Your monitor detected some radiation even without a source present. Devise a method to correct for this background radiation. Do the corrected data still agree with your prediction?