Physics 197 Lab 12: Radiation alpha, beta, gamma

Equipment:

Item	Part #	Qty per Team	# of Teams	Total Qty Needed	Storage Location	Qty Set Out	Qty Put Back
Set of 3 Radiation sources α,β,γ		1	8	8			
Computer with Logger Pro		1	8	8			
LabQuest Mini		1	8	8			
Digital Radiation Monitor	Vernier	1	8	8			
USB Cable – LabQuest Mini to Comp.		1	8	8			
Radiation Monitor Cable		1	8	8			
Aluminum Foil 16 layer Attenuators	Students can make	4	8	32			
Wooden blocks to support sources		1	8	8			
Blue tape		share	8	share			
Ruler		1	8	8			
Box of radiation attenuators		share	8	1			

Layouts:

Figure 1, Radiation Sources and blockers

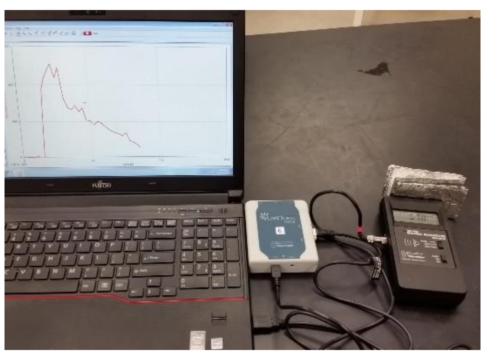


Figure 2, Attenuation of Sr-90 source with different Al thicknesses

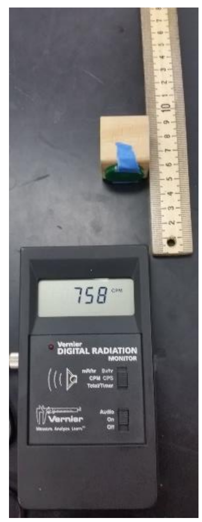


Figure 3, Counts vs. distance

Figure 4, Co-60 count statistics

Summary:

In this lab, students will investigate α, β and γ radiation from three different radioactive sources. (The sources are designed for student laboratory use and are safe to handle). First, students will do qualitative experiments to see the stopping power of different materials for the different forms of radiation (see figure 1). Then they will make quantitative measurements of the attenuation as a function of aluminum foil thickness for a Sr-90 source (figure 2). Then they will use the Sr-90 source to study the fall-off in radiation with distance (figure 3). Finally, using the Co-60 source placed right next to the detector (figure 4) students will look at radiation statistics, and how the shape of a count histogram depends on the average number of counts in an interval.

The write-up for this lab follows Vernier's Nuclear Radiation Computer Experiments 1 (α, β, γ), Experiment 2 (Distance and Radiation) and Experiment 4 (Counting Statistics).

PreLab:
For today's lab you will have three radiation sources available. These are Polonium 210, Strontium 90 and Cobalt 60. What type of radiation do these three sources emit, and what are the half-lives of the three sources (you may have to do a search for the half-life information).

For Experiment C you will be changing the distance between a radiation source and a detector. How do you expect the count rate to change as a function of distance?

For Experiment D you will be investigating count statistics. For the situation in which there are a large number of radiation counts in a sample, and you take many samples in which the count varies in a regular statistical pattern, what do you expect the width of the histogram to be compared to the number of counts at the center of the distribution?

Experiment A: Stopping power of various materials for α, β, and γ radiation.

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.

Most nuclear radiation carries energy in the range of a few million electron volts, or MeV (1 MeV = 106 eV = 1.6 x 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. Which radiation type do you predict would interact, in general, least strongly with matter, and so be less absorbed than others? Why?

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

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/cm2), and so would present more matter to the passing radiation? Which material would have less?

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 the Digital 1 input of the Labquest Mini, and connect the Labquest Mini to the computer. Under the start menu find Logger Pro in the Vernier Software Folder. It should open with the Radiation monitoring template. You can get a rough sense of the count rate by having the radiation monitor in Geiger mode, in which case it makes clicking sounds. (File under Nuclear Radiation with Vernier called 01 Alpha Beta Gamma).

2. Place one of the three sources near the metal screen of the radiation monitor by taping it to a wooden block. When using an absorber, place the absorber between the source and the screen. Use approximately the same position for the sources each time, with and without an absorber. The sources are usually mounted in small plastic

discs, with the most radiation emitted from the underside of the disc. To observe radiation from the polonium source it needs to be close to the detector because of attenuation by the air.

Begin with no source, to determine the background count rate. Move all sources away from the monitor. Click to begin collecting data. While it may appear as if data collection did not start, Logger *Pro* is collecting data. Wait 50 s for the number of counts to appear in the meter. Record the number of counts for no source, no shielding.

3. Using no absorber, place the beta source near the appropriate region of your radiation monitor, with the underside of the disc facing the monitor. Click to begin collecting data. Wait for Logger *Pro* to complete data collection. Record the number of counts for the beta source, no shielding.
4. Place a single sheet of paper between the beta source and the monitor, and measure the counts as before. Take care to keep the source in the same position with respect to the radiation monitor. Record the count rate.
5. In a similar manner, record the counts for the following used as absorbers for each of the three sources:
a. a single sheet of paper
b. a single sheet of aluminum

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?

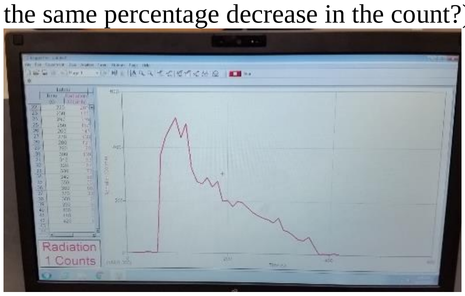
2. Inspect your data. Does the count rate appear to follow your initial guesses for the relative absorption of the various types of radiation by matter? Be specific, considering which source should be the most penetrating (least interacting), and which absorber is more difficult to penetrate.

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.

As an extension, spend about 5 minutes placing different absorbers from the box of "random materials" to see what seems to provide good radiation shielding and what doesn't. Record your observations.

Experiment B: Sr-90 Count rate versus aluminum thickness.

In this part of the lab, you will try to quantify the effect of placing different thicknesses of aluminum foil between the Sr-90 source and the detector. Use Logger-Pro (File: Open: Nuclear Physics: αβγ: Distance a) and it should come up with radiation counts at 10 second intervals over a 600 second window. Start the experiment with the source removed and measure background counts for about 60 seconds. Then put the source 2 cm from the detector and count for another 60 seconds. Then subsequently insert different thicknesses of aluminum foil every 60 seconds and finally end the experiment by removing the source again before the 600 seconds are up. You should end up with a time history of the radiation count as in the figure below, changing with the number of layers of aluminum foil at each time interval. (Make four separate aluminum foil attenuators by folding a piece of aluminum foil into 16 layers. Then use 1, 2, 3 and 4 of these attenuators for your measurement). From your experimental results, would you conclude that the attenuation by the aluminum foil (which reduces the number of counts at the detector) is removing energy from each of the radiation particles, or is scattering radiation particles out of the path to the detector without reducing the energy of those that still get counted? Please explain your reasoning. (Hint, did each attenuator cause the same percentage decrease in the count?)

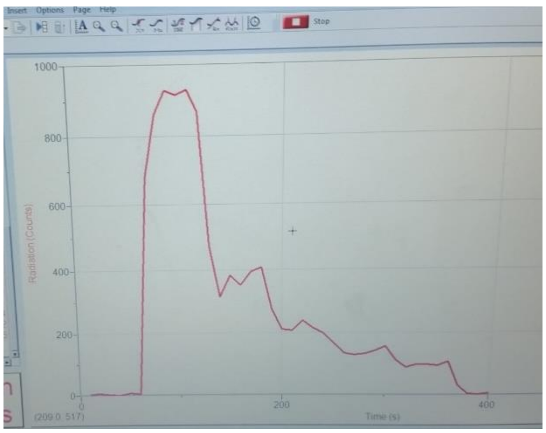


Please print out your plot and put it in your notebook or make a fairly accurate sketch. Label the plateaus in the curve by the number of sheets of aluminum.

Experiment C: Sr-90 Count rate versus distance from source to detector

Set up the source and detector with a ruler as in figure 3. Think carefully about where the you think the detector location is within the radiation monitor. You want to be measuring from the detector itself, not the front of the radiation monitor.

You should set up Logger Pro as before, counting for 600 seconds total, first counting background, then counting with the source at a distance of 1 cm from the detector (have a ruler ready), and subsequently at 2, 3, 4 and 5 cm (finishing up with another background count). Allow sufficient time for each distance so you can get a good average of the counts per 10 second interval. Print out the graph of counts vs. time, labelling the different distances used in the experiment. Plot the number of counts vs. distance (by hand in your notebook with a careful graph), and compare to what you would expect to see. An example Logger Pro output follows:



Experiment D: Count rate statistics using Co-60 source.

In this experiment, you will need to add a histogram plot on top of the regular radiation count vs. time plot. (The histogram shows the number of times different counts are achieved). The plot can be accessed by opening the “04 Statistics” file under Nuclear Radiation with Computers in Logger Pro. For this experiment, use the Co 60 source and place it right up against the detector as in figure 4. The point of this experiment is to investigate the counting statistics of radiation. (You should have noticed in the previous experiments that the number of counts in a given time interval fluctuates).

First make a histogram with 300 seconds worth of samples, at 5 seconds/sample. (Use bins which are 5 counts wide). Print this out, and compare the width to the mean count. Then collect a histogram for 100 seconds with 0.5 seconds/sample. (Use bins which are 2 counts wide). Now what is the width compared to the mean? Is the histogram starting to look like a familiar kind of curve? Finally, make a histogram with 100 seconds of data and 0.02 seconds per sample. (Use bins which are 1 count wide). What is different about the shape of this count distribution? Can you come up with a simple reason for why it has to be different? Please discuss what you learned from this experiment. Example histograms for the three cases are below: