Radioactivity

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Purpose of Experiment

1. Determine the distance dependence of radiation intensity.
2. Evaluate the shielding power of a number of materials for beta and gamma radiation.

Background Information--- Radiation in General

Certain nuclei are unstable and change spontaneously. In some cases the change is very rapid and in other cases the change may take millions of years. Changes in the nuclei are generally accompanied by the emission of nuclear material in the form of high energy particles. This emission is called radioactivity.

In a very limited way nuclear reactions are like chemical reactions. For example, the mathematics of the decay processes are the same as many chemical reactions (i.e., first-order). The most important difference is that the energy of nuclear reactions are significantly greater than even the most energetic chemical reactions. Energies on the order of millions of electron volts are not uncommon for nuclear reactions while chemical reactions typically have energies of less than two electron volts.

Distance Dependence

In this laboratory we will determine how the intensity of radiation from a source changes with distance from the source. Such information is important when establishing safety criteria for handling radioactive materials.

To begin, it is best to think of the source as a tiny sphere, say the size of a pin head. The radiation will be emitted by the source equally in all directions. The sensitive area of the detector is a circular disk with a diameter of 0.5 inches. Obviously if the detector is close to the source it will intercept a large number of the emitted particles but if we move it away from the source it will intercept fewer particles.

The question of interest is the mathematical relationship between distance and the radiation intensity. We will measure the intensity of the radiation from a source at several different distances and then attempt to find a simple mathematical relationship that relates the two. Since the intensity decreases with increasing distance, we'll plot intensity versus $1/R$ or $1/R^2$. The point of graphing the data way is to find a straight-line relationship. If, for example, we find that a plot of intensity versus $1/R$ yields a straight line then we can say that intensity is proportional to $1/R$ or intensity = k $(1/R)$ where k is the proportionality constant.

From a practical standpoint such a simple relationship is adequate for making decisions about safe handling of radioactive materials.

Shielding of Beta and Gamma Emissions

The most common nuclear emissions are beta particles and gamma rays. Beta particles are high-energy electrons and gamma rays are high-energy forms of electromagnetic radiation. Visible light is a form of electromagnetic radiation but with significantly less energy than gamma rays. Gamma rays are more similar to X-rays, another form of high-energy electromagnetic radiation.

These emissions interact with matter very differently. In this exercise we will examine the shielding necessary for gamma rays and beta particles.

Gamma emissions may have energies that vary from thousands to millions of electron volts. The extent of damage they cause is generally directly related to their energies. Thus, when the hazards of a particular radiation source are evaluated, information must be available concerning the type of emission and the energy of the emission.

This leads to questions about which materials can be used for radiation shielding. In other words, what materials can be used to block radioactive emissions and how much is needed?

^{60}Co emits 1.17 and 1.33 MeV gamma rays and 2.82 MeV beta particles.
^{90}Sr produces only 0.54 MeV beta particles.

Safety Note

Radiation exposures are measured in rems (see your text for a good definition and examples). The sources we will be using are very small and give doses of approximately 0.001 millirem (^{90}Sr) and 0.1 millirem (^{60}Co). Even if you sat on these sources for the entire lab you'd get less than 2% of the dose from the natural radioactive atoms in your body. Never-the-less as a practice of good lab techniques you should try to minimize close contact of the sources with your body.

PROCEDURE

Use of the detector

In the following experiments we will be using a Geiger counter specifically designed for this lab. The instrument is simple to use. It has no on/off switch and only a momentary contact count switch on the top. An LED indicates when the instrument is in the count mode. This instrument will count the number of radioactive emissions reaching the probe for one minute after the count switch is depressed. The count time cannot be interrupted. If you inadvertently start the count before you are ready, do not press the count switch again. Simply wait until the count sequence is finished and try again. Radioactive decay is a random process and the count will vary from minute to minute. You should, therefore, measure the counts two or three times for each measurement of this lab.

Distance Dependence of Radiation Intensity

Place a ruler against the counter under the probe port. Place the ^{60}Co gamma or ^{90}Sr source on edge 1 cm (as measured from the center of the disk) from the probe port and measure the counts/minute. Move the source 2 cm's away and record the counts/minute. Repeat at 1 cm intervals until the source is 10 cm away from the probe. Record measurements at 15 and 20 cm's. Plot the number of counts/minute versus 1/R, and then $1/R^2$, on the graph papers provided.

Evaluation of Shielding Materials for Beta and Gamma Radiation

Using the same set-up, place the gamma source 1.5 cm from the detector and measure the activity (twice). Carefully place 3 mm of lead between the counter and the source. To make the measurement meaningful it is imperative that the source and counter not be moved when the lead is placed between them. Record the counts/minute. Repeat the measurement.

Repeat this procedure but replace the lead with aluminum, then cardboard, then glass.

Repeat all of the above using the beta source.

Name ______________________________________ Section _____________

Data Sheet (Page 1 of 2)

A. Distance Dependence (^{90}Sr or ^{60}Co)

Dis(cm)	1/D	$1/D^2$	Counts/minute	Counts/minute	Average Counts/minute
1	1	1	___________	___________	___________
2	.5	.25	___________	___________	___________
3	.33	.11	___________	___________	___________
4	.25	.062	___________	___________	___________
5	.20	.040	___________	___________	___________
6	.17	.028	___________	___________	___________
7	.14	.020	___________	___________	___________
8	.12	.016	___________	___________	___________
9	.11	.012	___________	___________	___________
10	.10	.010	___________	___________	___________
15	.07	.004	___________	___________	___________
20	.05	.002	___________	___________	___________

B. Shielding Evaluation

Shielder	Gamma Rays Cnts/min	Gamma Rays Cnts/min	Gamma Rays Ave Cnts/min	Beta Particles Cnts/min	Beta Particles Cnts/min	Beta Particles Ave Cnts/min
Lead						
None	________	________	________	________	________	________
One	________	________	________	________	________	________
Two	________	________	________	________	________	________
Aluminum						
None	________	________	________	________	________	________
One	________	________	________	________	________	________
Two	________	________	________	________	________	________
Cardboard						
None	________	________	________	________	________	________
One	________	________	________	________	________	________
Two	________	________	________	________	________	________
Glass						
None	________	________	________	________	________	________
One	________	________	________	________	________	________
Two	________	________	________	________	________	________

Conclusions

1. Describe what your measurements tell you about the relation between the intensity of a radioactive source and distance from the source.

2. What is your conclusion about shielding necessary for gamma radiation?

3. What is your conclusion about shielding necessary for beta radiation?

Name ______________________________________ Section _____________

Pre-Laboratory Assignment

1. What is the make-up of gamma radiation?

2. What is the make-up of beta radiation?

3. Write a balanced nuclear equation for the beta decay of ^{60}Co.

4. What is happening in the nucleus to cause the emission of gamma activity?

5. What is happening in the nucleus that accounts for the emission of a beta particle?