Background

Isotopes are atoms with the same atomic number (the number of protons), but different mass numbers (the number of protons and neutrons). Some isotopes have unstable nuclei and emit particles of electromagnetic radiation, transforming the nuclei into more stable ones. This emission is called radiation and the isotope is said to have undergone radioactive decay. The most common types of radioactive decay are alpha, beta, and gamma radiation.

Alpha particles are high energy helium nuclei that consist of two protons and two neutrons. They are represented by the symbol ${}^{4}_{2}\mathrm{He}$ or ${}^{4}_{2}\alpha$ in a nuclear equation. When a nucleus undergoes alpha decay, emitting an alpha particle, the mass number will decrease by 4 and the atomic number will decrease by 2. This is shown in the following equation.

$${}^{238}_{92}\mathrm{U} \longrightarrow {}^{4}_{2}\mathrm{He} + {}^{234}_{90}\mathrm{Th}$$

Nuclear equations are balanced by making sure the sum of the mass numbers and the sum of the atomic numbers are equal on both sides of the equation.

Beta particles are high energy electrons and are represented by the symbol ${}^{0}_{-1}e$ or ${}^{0}_{-1}\beta$ in a nuclear equation. These electrons have negligible mass, represented by the 0, and a negative charge, represented by the –1 in the symbol. Carbon-14 undergoes beta decay as shown in the following equation.

$${}^{14}_{6}\mathrm{C} \longrightarrow {}^{0}_{-1}\mathrm{e} + {}^{17}_{7}\mathrm{N}$$

Gamma rays are very high energy electromagnetic radiation and are represented with the symbol γ or ${}^{0}_{0}\gamma$ in nuclear equations. Gamma decay occurs when an atom in an excited state decays to its ground state. Gamma rays are pure energy and do not affect the mass number or atomic number as shown in the following equation.

$${}^{235}_{92}\mathrm{U} * \longrightarrow {}^{0}_{0}\gamma + {}^{235}_{92}\mathrm{U}$$

Radiation can be very damaging to cells and is of particular interest in medicine, where it can be used for benefit. Although radiation can be used for positive outcomes, caution must be exercised when exposure will occur. Precautions include shielding the body from the radiation, increasing the distance from the source of radiation, and limiting the amount of time exposed to the radiation. You've probably experienced one of these if you've had x-rays taken. You were required to wear a lead apron during the x-rays to limit the exposure on other areas of your body. Increasing the

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distance from a radiation source also limits exposure. Doubling the distance will decrease the exposure by one-fourth. Figure 1 illustrates different ways exposure to radiation can be limited.

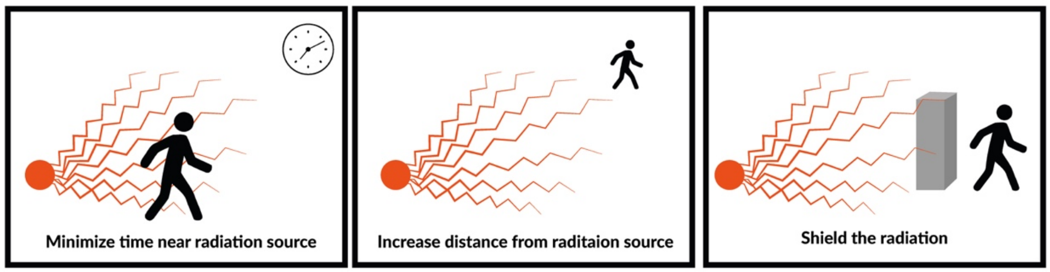

Figure 1 Effects of Time, Distance, and Shielding on Radiation Exposure

Radiation can be detected using a Geiger-Müeller tube, or Geiger counter, similar to the one in Figure 2. This device works by producing ion pairs when radiation passes through the gas inside the tube. These ion pairs emit bursts of current that are converted to flashes of light and clicking sounds. Your instructor will demonstrate how to use this device. Then, you will use it to detect background radiation, radiation from various sources, and finally to see how shielding, distance, and time affect the amount of radiation detected.

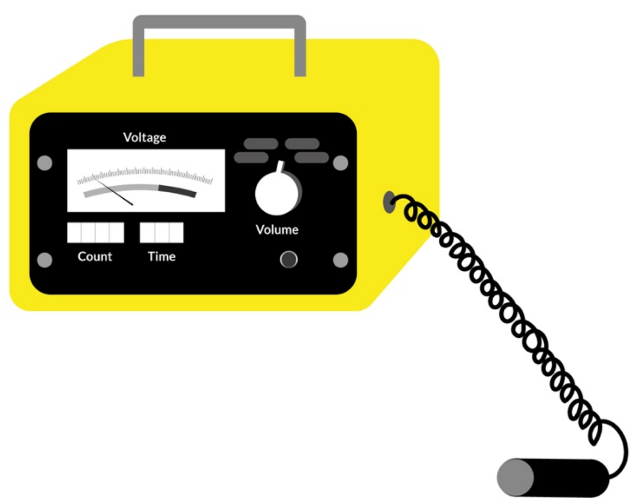

Figure 2 Depiction of Geiger-Müeller Tube

Objectives

- Learn how to use a Geiger-Müeller counter
- Determine how distance, time, and shielding affect radiation exposure
- Complete a nuclear equation

Materials

- Geiger-Müeller counter (detection tube)
- Yardstick
- Radioactive sources of alpha- and beta-radiation
- Shielding materials (wood, plastic, water, etc.)

Check with TA or Instructor for any other supplies you may need.

Procedure

Background Radiation Count

1. Set the counter to the proper voltage for operation and let it warm up for at least 5 minutes. Make sure that no sources of radiation are near the counter.
2. Once the device is warmed up, count the radiation in the room for 1 minute and record.
3. Repeat step 2 for 2 additional times and record.

Radiation from Sources

4. Retrieve one of the radioactive sources available in the lab and make note of it in your notebook.
5. Place the source ~15 cm from the detection tube.
6. Count the radiation for 1 minute and record. Be sure to subtract the background radiation from your measurement.
7. Repeat steps 4 – 6 for a total of five sources of radiation. Make sure all sources are the same distance from the counter.

Effects of Shielding, Time, and Distance on Radiation Count

A – Time

8. Obtain a radiation source and place it the same distance from the counter as in the previous steps.
9. Count the radiation for 1 minute and record. Be sure to subtract the background radiation count.
10. Repeat steps 8 and 9, but count the radiation for 2 minutes and 5 minutes. Record the counts, but this time subtract two times the background count and five times the background count, respectively.

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B – Shielding

11. Obtain a radiation source and place it the same distance from the counter as in the previous steps.
12. Choose a shielding material and place it between the source and the counter. Record the type of shielding material used.
13. Count the radiation for 1 minute and record. Be sure to subtract the background radiation count.
14. Repeat steps 8 – 10 for a total of three different types of shielding materials.

C – Distance

15. Remove the shielding material from between the source and counter.
16. Move the radiation source so it is 10 cm from the counter.
17. Count the radiation for 1 minute and record. Don't forget to subtract the background radiation.
18. Repeat steps 16 and 17 for distances of 30 cm, 60 cm, 90 cm, and 120 cm and record the counts per minute. Be sure to subtract the background radiation from all measurements.

Data Analysis

19. Using the counts per minute measured in part A, calculate the counts per minute at 20 minutes and 60 minutes.
20. Using the counts per minute measured in part C, calculate the ratio of counts per minute at 30 cm and 60 cm. This ratio is equal to the increase in radiation when the distance is halved.
21. Graph the counts per minute versus the distance from the source.
22. Predict the counts per minute at two distances that were not directly measured (25 cm and 50 cm, for example).

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Nuclear Radiation Report Sheet

Name ________________________ Date __________________________

Team ________________________ Section ________________________

Instructor ____________________________________

Background Radiation

Time	**Counts**
First minute	
Second minute	
Third minute	
Total Counts	
Average Counts counts/minute (cpm)	

Radiation from Sources

Item	**Counts per minute (cpm)**	**Background**	**Source cpm**	**Type of radiation**

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Effects of Distance, Time, and Shielding

Time

Time	Counts per minute (cpm)	Background cpm × number of minutes	Source cpm
1 minute			
2 minutes			
5 minutes			
20 minutes (calculated)	N/A	N/A	
60 minutes (calculated)	N/A	N/A	

Shielding

Shielding Type	Counts per minute (cpm)	Background cpm	Source cpm
No shielding			

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Distance

Distance	Counts per minute (cpm)	Background cpm	Source cpm
10 cm			
30 cm			
60 cm			
90 cm			
120 cm			
25 cm	N/A	N/A	
50 cm	N/A	N/A	

Ratio: 30 cm/60 cm = _______________

Include your graph with counts per minute versus the distance from the source.

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