Geiger-Muller Detector:

Operational Directions
And
Experiments for Students

This document is designed to assist teachers in explaining some basic concepts about radiation. This has been prepared by The American Nuclear Society Chapter at The Ohio State University. If there are any questions please visit the following web site:

http://rclsgi.eng.ohio-state.edu/nuclear/

There are links that will provide a more in-depth explanation than those provided within this document. This document provides a detailed description of how to use your Geiger-Muller (GM) Detector and three experiments that can be used to help your students better understand radiation and its effects.

How to Operate your GM Detector

Below are operation instructions for your Geiger-Muller (GM) detector.

1. It is important to remember that when the detector will not be used for a long period of time (i.e. >1 week) you should remove the batteries and place them in a cool dry storage area.

2. Unlatch the GM detector from its battery storage area and insert the batteries.

3. Reattach the GM detector to the battery storage area and move the selector switch from **OFF** to the **X1** position.

4. Once in this position the meter can be read in either **MR/HR** (milliREM/hour) or **C/M** (count/minute).

5. Since you are the X1 scale whatever the dial is indicating is the actual reading. This range is from 0 – 0.5 mr/hr or 0 – 300 c/m.

6. Once the selector switch is place on the **X10** or **X100** then the reading must be multiplied by 10 or 100 respectively. Thus the reading for the X10 is 0 – 5 mr/hr or 0 – 3,000 c/m, and the X100 will read 0 – 50 mr/hr and 0 – 30,000 c/m.

7. You will notice that the initial background reading on the X1 scale is fluctuating slightly. This is due to the fluctuation in natural background that is experienced throughout the earth.

8. The long cylindrical tube is your GM tube. This is the piece of the equipment that actually converts the radiation particle into an electronic pulse for the meter to read.

9. You will notice 3 slots on your GM tube. You can rotate the metal shaft of the tube to allow for metal shielding to be removed from these 3 slots. This will allow you to measure gamma rays, beta particles, and alpha particles. While the metal shielding if covering these 3 slots you will only be able to measure gamma rays. It is important to note that when you are not measuring beta or alpha particles you should keep the 3 slots covered with the metal shielding to prevent damage to your GM tube.

10. You will also notice that on the side of the battery holder there is an “Operational Source Check.” This source check is a beta emitter. To ensure proper operation of your GM detector, you should place your GM tube with the 3 slots pointing toward the black dot. Remember the 3 slots should have the metal shielding removed. You should place this up

against the black dot at _-inch or less, and you should get a reading of >1.5 mr/hr or >1,000 counts. (This will be read on the X10 scale.)

11. If you detector is reading lower than 1.5 mr/hr then this is an indication that there is a major problem with you GM detector and it should not be used.

12. After checking your GM tube you are ready to operate your GM detector for class.

13. Please ensure that your students handle it with care as the wire that connects the GM tube to the meter can be disconnected. While this is a rugged piece of equipment, it can be damaged if students use it improperly.

14. While conducting experiments it should be noted that small particles such as salts can enter the GM tube area while the 3 slots are open and can result in an erroneously high reading throughout the rest of your experiments. Thus it is important to keep the GM tube from actually touching the radioactive source or sources while reading. Readings conducted at a distance of _ -inch or greater will be sufficient for your experiments.

15. Once you have completed your experiments please ensure that the 3 slots are covered with the metal and that the switch is in the OFF position.

16. Remember to prevent corrosion of the battery connections step one must be observed.

Experiment 1
Existence of Radiation

1. Objective

Become familiar with different sources of radiation around us, and measure the level of radiation emitted from them.

2. Experiment apparatus and materials

- GM (Geiger-Muller) tube detector.
- 1950's to 1960's orange Fiestaware (cup, finger bowl, saucer, dinner plate) each piece will cost about $20.00 and can be found in antique shops.
- Radium alarm clock or watch will each cost between $10.00 and $50.00 and can also be found in antique shops.
- Common house hold smoke detector.
- Salt substitute can be found in grocery stores. (potassium iodide – KI)
- Vaseline Glass $10.00 and up can be found in antique shops

3. Background

Radiation is everywhere. It's in our food, in the air, the water and the soil. It's even in our bodies. It comes from naturally-occurring atoms that are unstable because they have extra energy in their nuclei. Eventually, these unstable atoms "decay", releasing the extra energy from their nuclei, and become stable. The energy released is radiation. Our bodies absorb a small amount of this radiation every day.

4. Discussion

The above list of experimental materials is but an example of what can be found emitting radiation within our everyday environment and households. The Fiestaware listed above was originally coated with a small amount of natural uranium to provide the orange color. The half-life of naturally occurring Uranium which is mostly comprised of U-238 (~99.3%)***** is 4.47 billion years. Uranium decays by emitting an alpha particle. Half-life is discussed in better detail in the M&M experiment that has been provided to you. The Radium that is on old glow in the dark alarm clocks or watches has a half-life of 1599 years (Ra-226) and emits an alpha particle. Many smoke detectors have small source of Americium that has a half-life of 432.7 years (Am-241) and also emits an alpha particle. The salt substitute, potassium iodine (KI), is also naturally radioactive due to the small amount of Potassium-40 (0.0117%) which has a half-life of 1.27 billion years (K-40) and emits a beta particle. Vaseline glass was popular from the 1830's until the 1940's, contains natural Uranium, and has the same half-life and emits the same particle as Fiestaware. An interesting side note to Vaseline glass is that if you place it in a dark space and put it under a black light, it will glow.

5. Experimental procedure

- Using the detector, measure the background radiation.
- Using the detector, measure the radiation level of each object.
- Take each measurement, including background, 3 times and find the average.

* Many elements have more than one isotope. U-238 is an isotope of Uranium. 99.3% of all naturally occurring Uranium is U-238

6. Questions and Answers

1. Can you think of other sources of radiation around us?

    - Cosmic radiation that reaches the earth's surface from outer space and is a major source of natural background radiation.

    - Bricks within your house have naturally occurring radioactive elements within them.

    - Bananas contain a high amount of potassium.

    - Carbon-14 which is naturally occurring is within all living organisms.

    - Radon gas which seeps into your basement is from the natural decay of Uranium. (Uranium occurs naturally in soil around the world.)

2. Are all of the counts recorded when you put the GM tube near the source necessarily for that source?

    - No, some counts could be due to background and some could be from other sources if the sources are nearby.

3. How do you calculate the true number of counts due to each radiation source you measured?

    - Subtract background.

Experiment 2
Inverse Square Law

1. Objective

To explore the relationship between the distance from a radioactive source and the intensity of radiation

2. Experiment apparatus and materials

GM (Geiger-Muller) tube detector
"Operational Source Check" (beta source)
12-inch ruler

3. Background

For an isotopic gamma or beta source, the following relations are valid:

$$\frac{I_1}{I_x} = \frac{R_x^2}{R_1^2} \tag{1}$$

$$I_x = I_1 \frac{R_1^2}{R_x^2} \tag{2}$$

Where I_1 is the gamma/beta intensity at a distance R_1, and I_x is the corresponding intensity at a distance R_x. So the strength of the radiation source will be decreasing very fast as the distance increases.

4. Experimental procedure

a. Place the 12" ruler next to the side of the "Operational Check Source."

b. Place the GM tube as close as possible to the "Operational Check Source" with the 3 slots opened and pointing at the source.

c. Once the reading has stabilized then pull the GM tube back to the _-inch mark of the ruler and wait a few seconds for the reading to stabilize.

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d. Record this reading and repeat part b. and part c. two more times.

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e. Place the GM tube as close as possible to the “Operational Check Source” with the 3 slots opened and pointing at the source.

f. Once the reading has stabilized then pull the GM tube back to the 1-inch mark of the ruler and wait a few seconds for the reading to stabilize.

g. Record this reading and repeat part e. and part f. two more times.

h. Place the GM tube as close as possible to the “Operational Check Source” with the 3 slots opened and pointing at the source.

i. Once the reading has stabilized then pull the GM tube back to the 2-inch mark of the ruler and wait a few seconds for the reading to stabilize.

j. Record this reading and repeat part h. and part i. two more times.

k. You may repeat this process, moving the GM tube farther away from the source each time, until you reach background levels that were recorded in Experiment 1.

l. Plot the count vs. distance curve.

Note: If you convert inches to centimeters, students will have a larger range on the x-axis and will see the shape more clearly. Just a reminder that if you were to square any thing less than one, such as .99, you will get a smaller number and not a larger number.

5. Data and Processing

Level	Distance from the detector R (cm)	Average Counts per Minute
1		
2		
3		
4		
5		

6. Questions and Answers

1. What conclusion can you draw about the relationship between the intensity of radiation and the distance to the source?

   - The intensity of a radiation source is inversely proportional to the square of the distance from the source.

2. Why do the calculated and measured counts differ and what could you do to make them more similar?

   - The sensitivity of the GM tube cannot allow for the most accurate measurement. In order to correct for this you can either obtain a more sensitive type of GM counter or apply statistical analysis and thus provide a range for your counts that would be acceptable.

3. Why are the calculated and measured counts different?

   - The GM tube is not designed to give extremely accurate measurements. It is a rugged detector designed to help scientists determine whether a source of radiation is nearby. Counts per minute or mr/hr determined using a GM detector are approximate.

   - Radioactive decay is a random event somewhat like tossing a coin and getting either heads or tails. You know you should get heads 50% of the time when you toss the coin, but you have to toss it many, many times before you are likely to get that percentage of heads. Taking radiation measurement for a short time is not likely to give you an accurate reading.

4. How do you make the measured results more similar the calculated results?

   - Get a more accurate type of detector.

   - Count for a longer time.

Experiment 3
Penetrating Power

1. Objectives

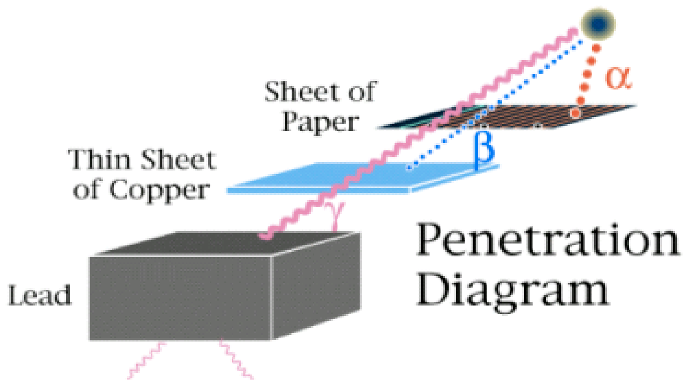
a. To discover the effect of shielding on the intensity of radiation.
b. To study the differences among the effect of shielding on alpha, beta and gamma rays.

2. Experiment apparatus and materials

GM (Geiger-Muller) tube detector
Gamma source (iodine)
Beta source
Alpha source
Shielding materials (paper, Lead sheet, Lead Block, Plastic sheet)

Note: It is not normally possible to buy a gamma source of sufficient energy to actually conduct this experiment. You may purchase Iodine Tincture (2%) at your local drugstore or grocery store. This will provide an on contact reading with your GM tube slightly above your background levels, but will not actually provide enough counts to conduct this experiment. Also you should never use bare lead this experiment as it is dangerous for children to come into direct contact with it. If you do obtain a gamma source of sufficient energy and you do obtain some lead then please make sure you cover the lead with some heavy duty tape or other material so that your children will not come into direct contact with the lead.

3. Background



There are 3 types of ionizing radiation: alpha, beta and gamma rays. There is great difference in their penetration ability. An alpha particle has a very short range, and it can be stopped even by a sheet of paper. A beta particle has greater penetrating ability. A sheet of metal or a thick sheet of plastic is required to stop a beta. A gamma ray has the strongest penetrating ability and can sometimes go through a block of lead.

4. Experimental procedure

1) Alpha Ray

a. Place the alpha source close to the face of the GM detector with the three slots open and pointing towards the source. The intensity of radiation can be known from the frequency of the sound or the reading of the meter.

b. Put a sheet of paper between the source and detector; pay attention to the change in the frequency of the sound and also in the reading.

2) Beta Ray

a. Place the beta source close to the face of the GM detector with the three slots open and pointing towards the source. Notice the frequency of the sound and the reading.

b. Put a sheet of paper between the source and detector. Pay attention to the change in the frequency of the sound and the reading.

c. Remove the paper and put a plastic board between the source and detector. Pay attention to the change in the frequency of the sound and the reading.

3) Gamma Ray

a. Place the gamma source close to the face of the GM detector. The three slots are not required to be open for this part of the experiment. Notice the frequency of the sound and the reading.

b. Put a sheet of paper between the source and detector; pay attention to the change in the frequency of the sound and the reading.

c. Remove the paper and put a plastic board or lead board between the source and detector. Pay attention to the change in the frequency of the sound and the reading.

d. Remove the board and put a lead block between the source and detector. Pay attention to the change in the frequency of the sound and the reading.

5. Questions and Answers

1. You had 3 radioactive sources one emitting alphas, one emitting betas, and one emitting gamma rays all emitting the same dose rate. You had to hold one in your hand, place one in your pants pocket, and place one in a lead box which one would go where and why?

    - You'll hold the alpha source in your hand since your dead layer of skin will protect you.

    - You'll place the beta source in your pants pocket since your clothing will provide sufficient shielding.

    - You'll place the gamma ray source in the lead box since lead can provide sufficient shield from gamma rays.