Al-Mustaqbal University
College of Health and Medical Techniques
Radiological Techniques Department

أساسيات الوقاية من الاشعاع

الجزء العملي

Radiation Protection

Practical course

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Radiation Protection Experiment

instructions to students:

When providing instructions for an experiment, it's important to be clear and thorough to ensure the experiment is conducted safely and effectively. Here's a step-by-step guide on how to do this:

1- Title of the Experiment: Begin by providing the title of the experiment to give students a clear idea of what they will be working on.

2- Objective: State the main objective of the experiment. What do you want the students to learn or discover from conducting this experiment? Make sure the objective is clear and concise.

3- Materials and Equipment: List all the materials and equipment that will be needed for the experiment. Include specific quantities, sizes, and any special requirements. Ensure that students have access to everything they need before they start.

4- Procedure: Outline the step-by-step procedure for conducting the experiment. Be explicit and detailed in your instructions. Include any measurements, time intervals, or specific techniques that students need to follow. Use bullet points or numbered lists to make the instructions easy to follow.

5- Data Collection: Explain how data should be collected during the experiment. Include information about what data to record, how often to record it, and in what format (e.g., tables, graphs). If there are any calculations or data analysis involved, provide guidance on how to perform them.

6- Expected Results: Briefly describe what the students can expect to observe or measure during the experiment. This helps set expectations and allows them to compare their results to the expected outcomes.

7- Conclusion: Explain what should be done after the experiment is completed. This may include summarizing the results, drawing conclusions, and discussing the implications of the findings.

Teach students how to graph:

Before you can create a graph, you need data. Make sure your data is well-organized in a table or spreadsheet. The data should consist of at least two sets of related values, such as time and temperature, distance and time, or concentration and absorbance.

You have completed an experiment and have data that requires analyzing.

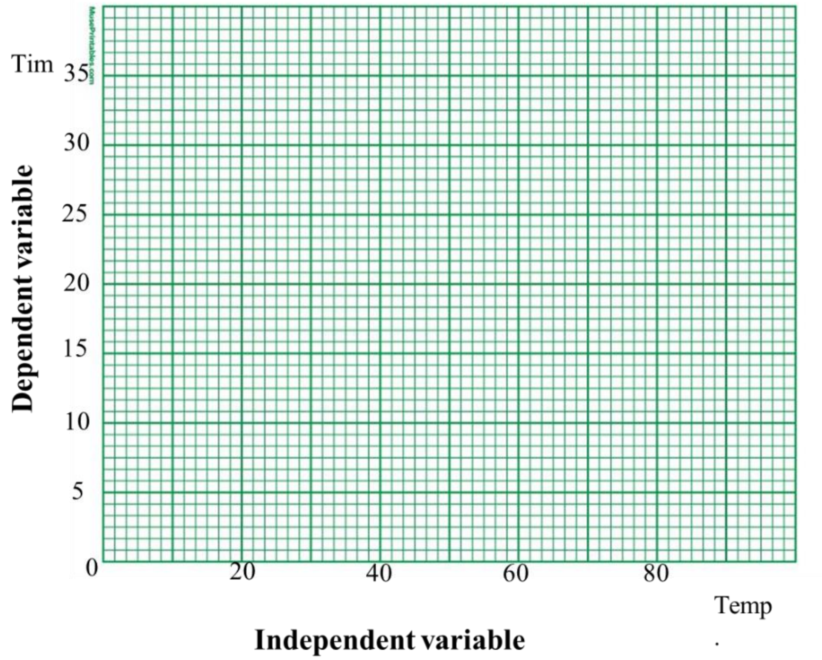
- At the very least, you need to visualize the relationship of the variables measured.
  - What relationship exists, linear non-linear, proportional, inverse, random , etc.
- At the most, it ist possible to obtain a mathematical relationship.
  - If the data is linear, it will fit the relation $y=mx+b$

y → is the variable that appears on the y-axis.

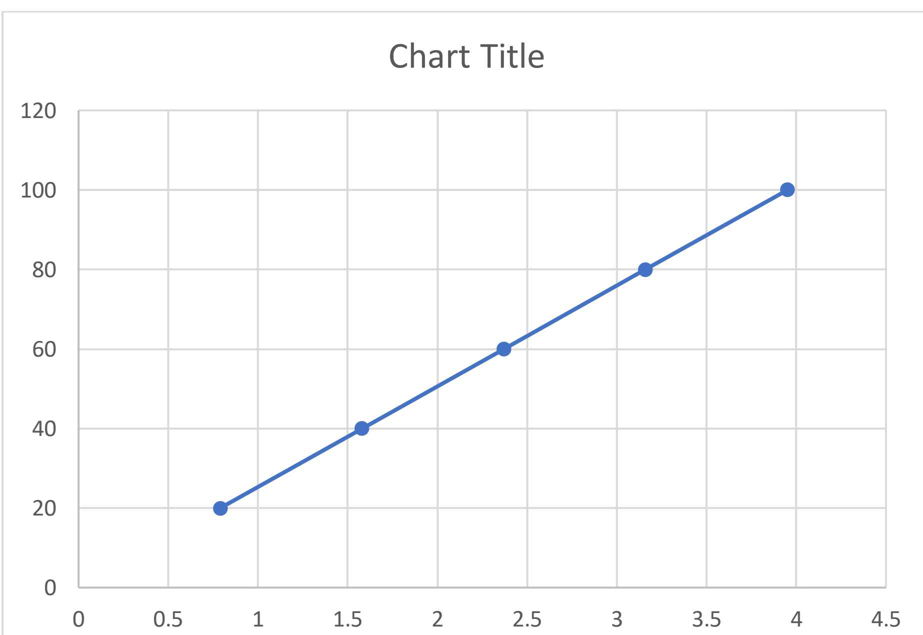
x→ is the variable that appears on the x-axis.

m→ is slope, which is a measure of the relative changes of both variables.
b→ is the y-intercept
$m = \frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1}$, and $b = y - mx$

Time(min)n)	**Temp(°c)**
0	80
1	75
8	70
13	60
20	60
26	55
33	45



L(cm)	T^2 (s^2)
20	0.79
40	1.58
60	2.37
80	3.16
100	3.95



Geiger-Muller Detector:

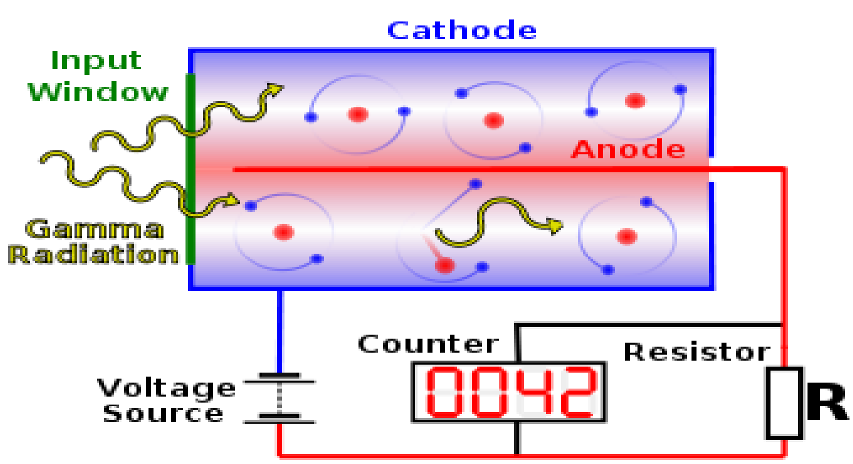
How a Giger-Muller Detector Works:

Gas-Filled Chamber: The G-M detector consists of a sealed tube filled with a low-pressure gas, typically argon, xenon, or a mixture of gases. The gas serves as the medium through which ionization occurs.

High Voltage: A high voltage (several hundred volts to a few thousand volts) is applied between the anode and the cathode. This voltage creates an electric field within the gas-filled chamber.

Ionization by Radiation: When ionizing radiation (e.g., alpha, beta, or gamma radiation) enters the chamber, it can interact with gas atoms or molecules, causing ionization. For example, if a beta particle or gamma photon collides with a gas atom, it can ionize the atom by stripping off an electron.

Amplification: The ionization events created by the radiation are relatively weak, but due to the strong electric field, the resulting free electrons are accelerated towards the anode, and positively charged ions move toward the cathode. As these charged particles move, they can create additional ionization events in the gas, causing a cascade of electron-ion pairs.



Mica is a mineral that forms in layers called *sheets*. These sheets can be split apart into very thin layers, so thin that even an alpha particle can pass through it (remember that alpha particles can be stopped by something as thin as your skin or a sheet of paper). The mica window prevents the argon inside the tube from escaping and also stops air from getting into the tube.

5- Signal Generation: The movement of these ionization electrons and ions towards the anode and cathode generates a current or electrical pulse. This pulse is proportional to the energy of the incoming radiation.

6- Detection and Counting: The electrical pulse generated by the G-M detector is then detected, amplified, and counted by external electronics. The number of pulses is used to determine the intensity or dose of ionizing radiation.

Characteristics of a Geiger Muller:

High Sensitivity: G-M counters are highly sensitive to ionizing radiation, making them capable of detecting even very low levels of radiation. This makes them suitable for a wide range of applications, from laboratory research to environmental monitoring and radiological safety.

Wide Energy Range: G-M counters are effective in detecting a broad range of ionizing radiation, including alpha particles, beta particles, and gamma rays. The energy response of a G-M counter is relatively uniform over this wide energy range.

Output Signal: When ionization events occur, they generate electrical pulses. The number of pulses and their magnitude is proportional to the intensity of the radiation, allowing for the measurement of radiation dose or activity.

Counts Per Unit Time: G-M counters provide measurements in counts per unit time, which is useful for quantifying the radiation intensity or dose rate. The count rate can be used to estimate the level of radiation exposure in a given environment.

Simple Operation: G-M counters are relatively easy to use, and they provide real-time measurements. They are commonly used by radiation protection personnel, first responders, and individuals working with radiation sources.

Dose and Dose Rate Measurements: G-M counters can provide information about both instantaneous dose rates and accumulated doses of radiation, making them valuable tools in radiation protection and safety procedures.

Experiment 1

Characteristics of Geiger Muller Counter

Objective:

1- Plotting the characteristic curve of the GM counter.

2- Determination of:

a. Starting voltage V_s of the GM counter.

b. Threshold voltage $V_{th.}$ (or V_1) of the GM counter.

c. Plateau length of the GM counter.

d. Operating voltage V_0 of the GM counter.

3- Calculation of the percentage gradient of the GM detector.

Theory:

The relation between the counting rate and the voltage applied to the

counter is called the Characteristic curve and from which we deduce the following

characteristics:

- Starting voltage (V_s) : It is the minimum voltage applied the

detector in order for it to operate.

- Plateau length (or operating plateau region): The range voltage

corresponding to the flat part of the characteristic curve.

Plateau length = $V_2 – V_1$.

- Operating voltage (or working voltage) (V_0) : It is the voltage

corresponding to the midpoint of the plateau region.

Operating voltage (or working voltage) (V_0) : It is the voltage

corresponding to the midpoint of the plateau region.

$$V_0 = \frac{V_1 + V_2}{2}$$

Percentage gradient: It is the percentage change in counting rate per volt.

$$Percentage\ gradient = \frac{N_2 - N_1}{N_0(V_2 - V_1)} \times 100\%$$

Sl. No.	EHT(Volts)	Counts in 30 sec N	Background Counts 30-sec N_b	Corrected Counts N_c= (N-N_b) 30 sec
1	343	0	29	29
2	373	6003	31	5972
3	403	6379	33	6346
4	433	6446	35	6411
5	463	6577	38	6539
6	493	6636	41	6595
7	523	6843	44	6799
8	553	7082	46	7036
9	583	7183	49	7134
10	613	7352	50	7302
11	643	7585	55	7530
12	673	13200	59	13141

Estimate from the tabulated readings:

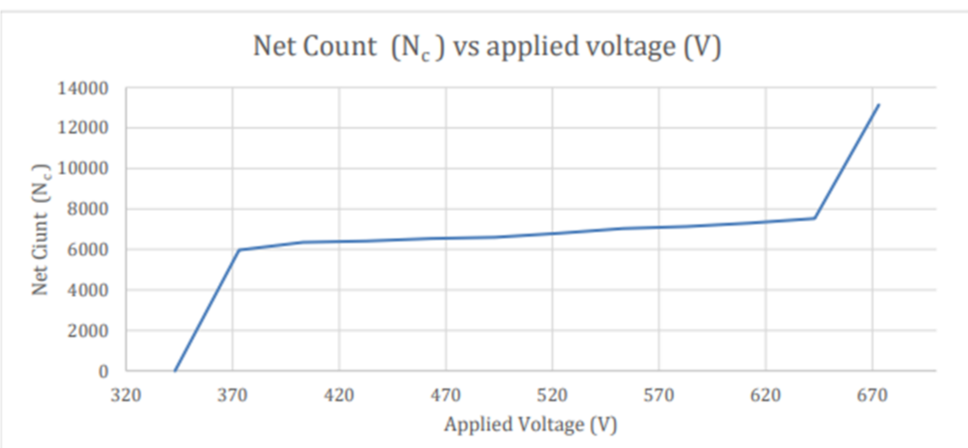
$V_1 = Starting\ voltage\ of\ the\ plateau = 403\ V$

$V_2 = Upper\ threshold\ voltage\ of\ the\ plateau = 613\ V$

$Plateau\ Length = V_2 - V_1 = 210\ V$

$Operating\ Voltage = V_0 = V_1 + \frac{V_2 - V_1}{2} = 508\ V$

$Slope\ Percentage = \frac{N_2 - N_1}{N_1} X \frac{100}{V_2 - V_1} = \frac{7302 - 6302}{6302} X \frac{100}{613 - 403} = 7.2\ \%$



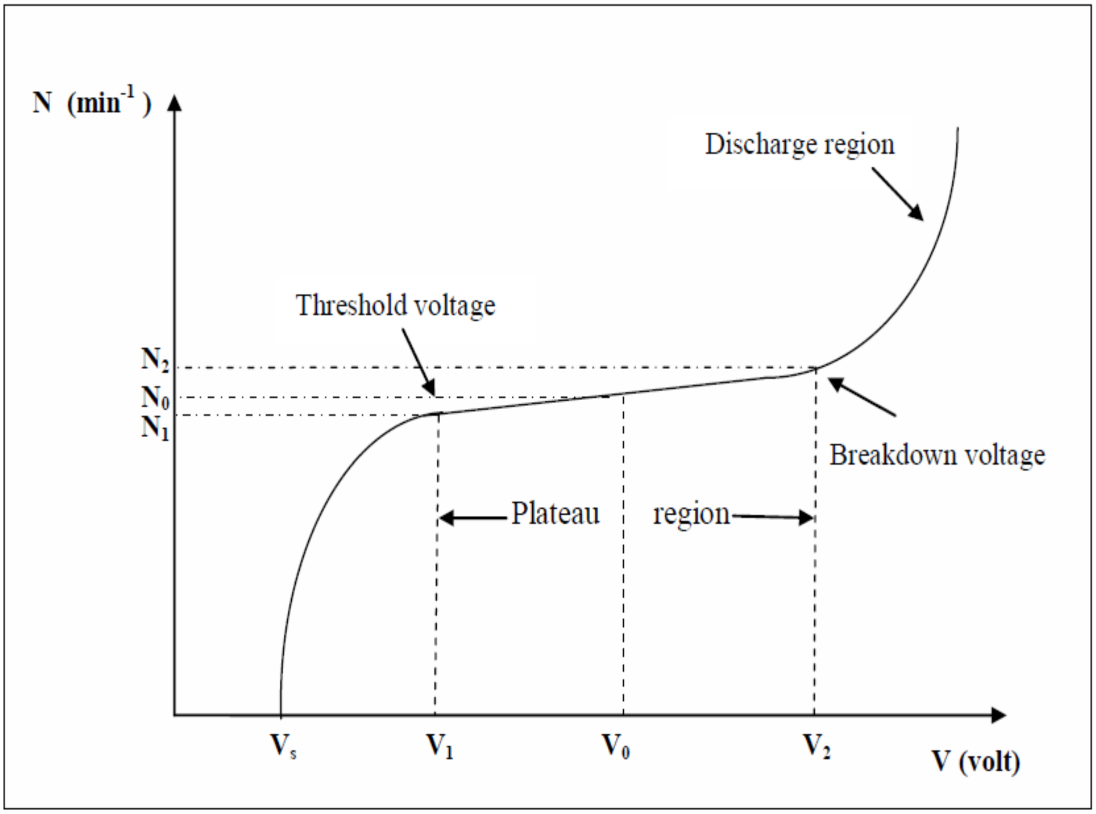


Fig.1

Apparatus:

Source of radiation. Geiger detector. HV power supply.

Procedure:

1. Connect the plugs of the electric mains.
2. Set the timer to 60 s and the HV to 280 Volt.

3. Record the count rate per one minute for the back ground ($N_{B.G}$).
4. Put the source in front of the Gieger tube on the second shelf from top .
5. Set the high voltage to 220 V and start counting. Increase the applied voltage in steps of 20 V until the detector begins to operate, this is the starting voltage (V_s).
6. Increase the applied voltage and record the count rate per one minute (N_1) for each voltage. Take two readings for each voltage andtake their average.
7. Plot the counting rate (N) versus the applied voltage (V) deduce the threshold voltage, the plateau length, the operating voltage and the percentage gradient of the detector.

Geiger Counter Experiment 2

Measuring Background Radiation

Sources of Background Radiation

Everyone on the Earth is exposed to background radiation. Therefore, it is important to establish the sources of our background radiation. The three primary sources are; radiation from space (cosmic rays) and terrestrial (Earth) and internal (for our own body). Cosmic radiation from deep space and some released from our Sun during solar flares account for 8% of natural radiation exposure. Terrestrial radiation from rocks and soil accounts for 8% of natural radiation exposure. Added to the terrestrial radiation is radon. Radon, which is an invisible heavier than air gas emitted by uranium and thorium, accounts for about 65% of natural radiation exposure. Finally internal radiation, our bodies also contain radioactive materials, like potassium-40, which account for approximately 11% of natural radiation exposure.

Why Measure Background Radiation?

In order to make accurate measurements for some experiments you may need to subtract the background radiation from your measurements in order to obtain meaningful results.

For example, if you are measuring material that is emitting low levels of radioactivity you would need to subtract the background radiation to determine the radioactivity level of the material.

Taking Background Radiation Measurements

We use the Geiger counter to take background radiation measurements. Position the Geiger counter or the Geiger counter's sensor in an area that is free from external radioactive sources. Take a minimum of 10 measurements. In the example shown below, 20 measurements were recorded then added together for a total. Divide the total by the number of samples, in this case 20. This will be your average background radiation. In addition, note the highest and lowest numbers you obtain in your sample. This will be you Max and Min.

Mean (Average)

```
        32
        28
        42
        35
        35
        35
        30
        37
        30
        32
        31
        39
        33
        36
        43
        34
        28
        32
        35
      + 28
      ----
Total  675
```

Total / # of samples = Average (Mean

675 / 20 = 33.75 (rounded up to 34 Cl

Average Background Radiation = 34 (

Min CPM 21
Max CPM 43

Geiger Counter Experiment 3

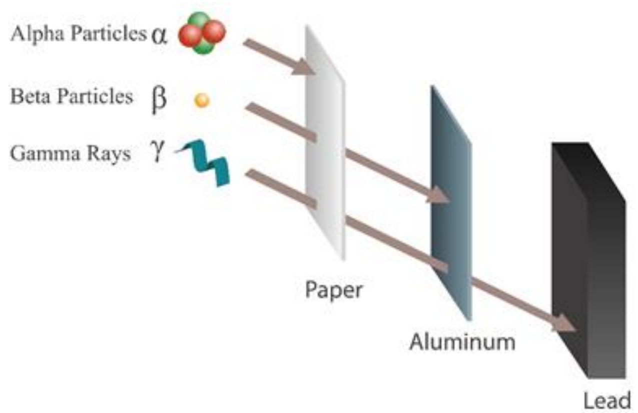
Detecting alpha, beta and gamma radiation

Nuclear radiation is ionizing radiation. Ionizing radiation is radiation that can strip electrons from atoms and molecules. We classify this ionizing radiation into three major categories; gamma rays, beta and alpha particles.

Gamma (and x-rays) are ultrashort electromagnetic radiation. They have great penetrating power and can easily pass through the body and are attenuated by dense materials such as lead.

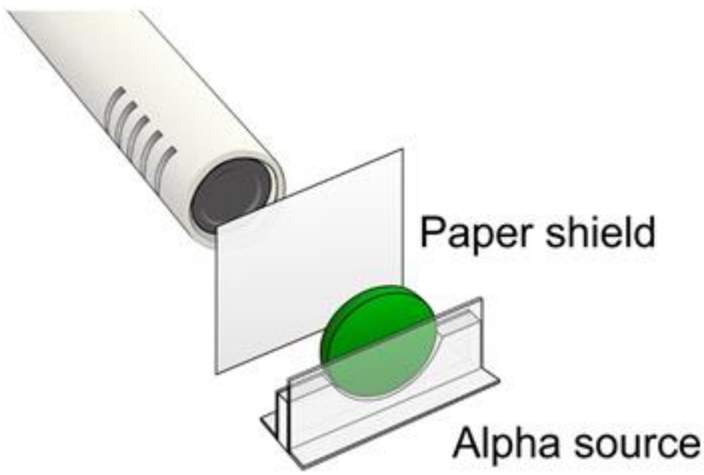
Beta particles are electrons. Beta particles have a net negative charge. They have low penetrating power. Most beta radiation can be blocked by 1/8" (4mm) of aluminum.

Alpha particles are massive particles consisting of two neutrons and two protons. Alpha particles have a net positive charge. They are equivalent to the nucleus of a helium atom. Alpha particles have a low penetration power. A few inches of air or a piece of paper can effective block alpha particles.

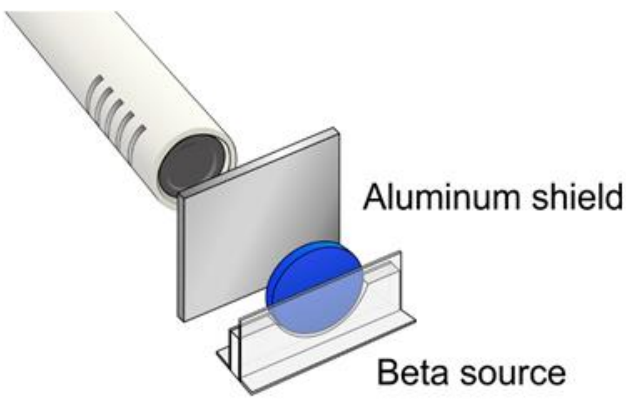


In this experiment, we will examine each type of radiation using a Geiger counter and verify it penetrating power using paper, aluminum and lead shields. License exempt radioactive isotope button sources are available for purchase. You will need an alpha, beta and gamma button sources.

The first source we will use is the polonium-210 alpha particle source. The polonium-210 has a half-life of 138 days. After the source has been in storage for a year or so, it will become too weak to perform useful experiments. The alpha particle source will need to face the mica window of the gm tube inside the wand. It will need to be in close proximity to the mica window. I needed to move my source to a distance of only 1.5 cm away from the mica window of the GM tube to get a significant reading above background.

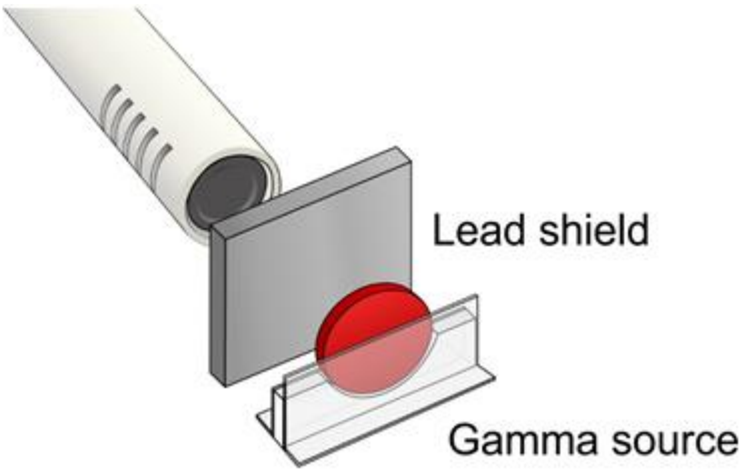


Next use the Sr-90 beta source. I place this source 4 cm from the front of the GM tube.



Take the readings as before and record your average. Next place the paper shield in front of the beta source. Record your results. Next place an aluminum shield of approximately 1/8” (4mm) thickness in-between the source and GM tube. Record your results.

Next use the Co-60 gamma source. I placed this source 3 cm from the front of the GM tube. Take readings as before. Record your results. Next place an aluminum shield of approximately 1/8” (4mm) thickness in-between the source and GM tube. Record your results. Next place a lead shield of approximately 1/8” (4mm) thickness in-between the source and GM tube. Record your results. Next place a lead shield of approximately 1/2” (13mm) thickness in-between the source and GM tube. Record your results.



Record Your Results:

What conclusions can you draw about the penetrating power of radiation

Experiment 4

Dead Time

Objective:

1- Calculate the dead time (T) of the GM detector.

2- Calculate the corrected or actual count rate (N) of the GM detector.

3- Calculate the percentage of the missed particle counts for each source.

Theory: When ionization radiation enters the GM tube through the window and loses its energy by creating electron-ion pairs, the electrons that are produced in the resulting avalanche are accelerated to the anode and collected in a short period of time. The positive ions, however, are more massive and make their way slowly to the cylindrical cathode. If their average transient time is T, the GM tube is busy, so to speak, during T. if another ionizing particle enters the GM tube during T, it will not be counted. This time (T) is called the dead time (or resolving time) of the GM tube. The existence of this dead time causes the count rate we read from the counter to be less than the actual number of particles that interact with the gas and walls of the tube in a particular time interval. To find this the corrected count rate or the actual count rate we define the following variables:

T = the resolving time or dead time of the detector per one count.

t_r = the real time that the detector is operating. This is the actual time that the detector is on. It is our counting time.

t_l = the live time that the detector is operating. This is the time that the detector is able to record counts. tl depends on the dead time of the detector.

C = the total number of counts that we record.

n = the measured counting rate, $n = \frac{C}{t_r}$

N = the actual (corrected) count rate. $N = \frac{C}{t_1}$

Note that the ratio *n/N* is equal to

$$\frac{n}{N} = \frac{C/t_r}{C/t_l} = \frac{t_l}{t_r}$$

This means that the fraction of the counts that we record is the ratio of the "live time" to the "real time". This ratio is the fraction of the time that the detector is able to record counts. The key relationship we need is between the real time, live time, and dead time. To a good approximation, the live time is equal to the real time minus C times the dead time T :

$$t_l = t_r - CT$$

This is true since CT is the total time that the detector is unable to record counts during the counting time t_r. We can solve for N in terms of n and T by combining the two equations above. First divide the second equation by t_r:

$$\frac{t_l}{t_r} = 1 - \frac{CT}{t_r} = 1 - nT$$

Then from eq (1) we get: $\frac{n}{N} = 1 - nT$

Solving for N, we obtain the equation:

$$N = \frac{n}{1 - nT} \qquad (2)$$

This is the equation we need to determine the true counting rate from the measured one. Notice that N is always larger than n.

$$N_{12} = N_1 + N_2 \qquad (3)$$

$$\frac{n_{12}}{1 - n_{12}T} = \frac{n_1}{1 - n_1T} + \frac{n_2}{1 - n_2T}$$

An approximate solution to this equations is given by

$$T \approx (n_1 + n_2 - n_{12}) / 2n_1n_2 \qquad (4)$$

The percentage of counts that is missed in each case is:

$$\%\, missed\ counts = \frac{N - n}{N} \times 100$$

Apparatus:

Two Sources of radiation .

Geiger detector.

HV power supply

Procedure:

1. Connect the plugs of the electric mains.
2. Set the timer to 1 min and the voltage to the operating voltage you found in experiment (1).
3. Record the count rate per 1 min for the back ground ($N_{B.G}$).
4. Set the timer to 300 s.
5. Put the 1st source in front of the GM tube and count.
6. Convert the resulting count rate from count/300 s to count/min and record it as count rate (n_1).
7. Put the 2nd source with the 1st source in the same shelf (without changing anything in the existing geometry of the experiment) and count.
8. Repeat step no.6 and record it as count rate (n_{12}).
9. Remove the 1st source and record the count rate for the 2nd source (n_2) following step no.6.
10. Calculate the dead time (T) of GM detector in minutes and micorseconds.
11. Calculate the true counting rate (N) of the actual particles that interacted inside the tube for each source and for both sources together using eq 2.
12. Calculate the percentage of the missed counts for each source and for the combined sources using eq5.
13. Find N_{12} by adding N_1 and N_2 (eq3) and compare with the value you found in step no.10. (Find percentage error). Find n_{12} by adding n_1 and n_2 and compare it to n_{12} that was counted by the counter.
14. Which has less error n_{12} or N_{12} (from step 12) ?

Experiment 5

Efficiency of a G-M tube for β counting Geiger Muller

1. Geiger-Muller tube
2. Beta radiation source (e.g., Strontium-90)
3. Beta shield (to block other radiation)
4. Record the background radiation count rate with no beta source present.
5. Measure Total Radiation with Beta Source:

Calculate Efficiency:

a. Calculate the net count rate due to beta radiation by subtracting the background count rate from the total count rate.

Net Count Rate (beta)=Total Count Rate−Background Count Rate

b. Calculate the efficiency using the formula:

$$Efficiency\% = \left(\frac{Net\ count\ rate\ (beta)}{Total\ counts\ due\ to\ beta\ source}\right) \times 100$$

a. Repeat the entire experiment multiple times to ensure accuracy and consistency.

b. Calculate the average efficiency from your measurements.