Geiger-Muller Plateau

Goal:
Using a Geiger-Mueller (G-M) tube to count the radioactive beta-decays of various radioactive substances, as we apply an operating voltage through it.

Apparatus:
o Geiger-Mueller tube
o Equipment to which the GM-tube is connected
o tube stand and sample holder
o stopwatch
o radioactive source to be obtained from the instructor

Introduction:
A Geiger-Muller (G-M) tube is comprised of a cylindrical container filled with an inert gas. Inside, a wire runs along the cylinder's axis, and a high voltage is applied between the wire and the cylinder. When a high-energy particle or radiation enters the G-M tube through its designated "window," it collides with and ionizes an atom within the tube. Due to the high voltage between the wire and the cylinder, the ionized atom's two parts accelerate towards their respective collectors and subsequently collide with and ionize other atoms. This chain reaction of ionization generates a detectable electrical pulse in the detector.

Not all G-M tubes operate at the same voltage, owing to variations in their construction. If a radioactive sample is positioned such that radiation enters the tube and the voltage applied to the tube is gradually increased from zero, the atoms within the tube will not ionize until the voltage reaches a specific initial potential. As the voltage surpasses this point, there is a rapid rise in the count rate. Eventually, the rate of increase slows down at a voltage referred to as the "threshold." Beyond this threshold, further increases in bias voltage result in only minimal gains in the counting rate. This particular range is called the "plateau." Operators typically select an operating voltage within this plateau for their measurements.

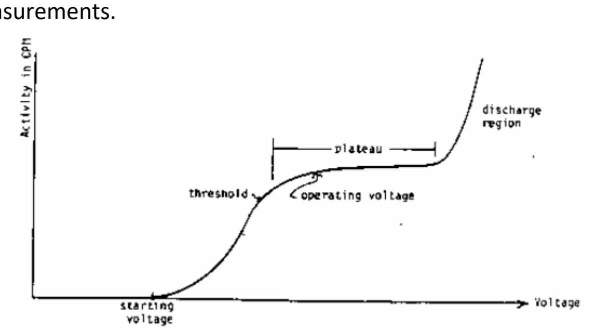


Figure 1. The activity of a radioactive sample as detected by a G-M tube at various operating voltages.

Procedure:
In the initial phase of our experiment, we aim to determine the optimal operating voltage for the G-M tube. Once we've swiftly identified the starting voltage, we'll incrementally increase the voltage by 25 volts, to preserve the life of GM tube. During each voltage increment, we'll count the number of radioactive disintegrations detected over a one-minute period. These data will be graphed in real-time to ensure that we do not exceed a safe maximum voltage for the tube.

Here's a step-by-step breakdown of the procedure:
a) Turn the voltage knobs on the scalar to their lowest values (completely counterclockwise). Turn on the power switch and allow the instrument to warm up.

b) Place the encapsulated source on the planchette and slide the planchette into the second set of slots below the G-M tube.

c) Ask your instructor to help you find the start voltage. Then, reset the counter by pressing the reset button, and set the timing interval to half a minute. Press the count button. The scalar automatically will stop after counting the number of radioactive disintegrations in one half-minute.

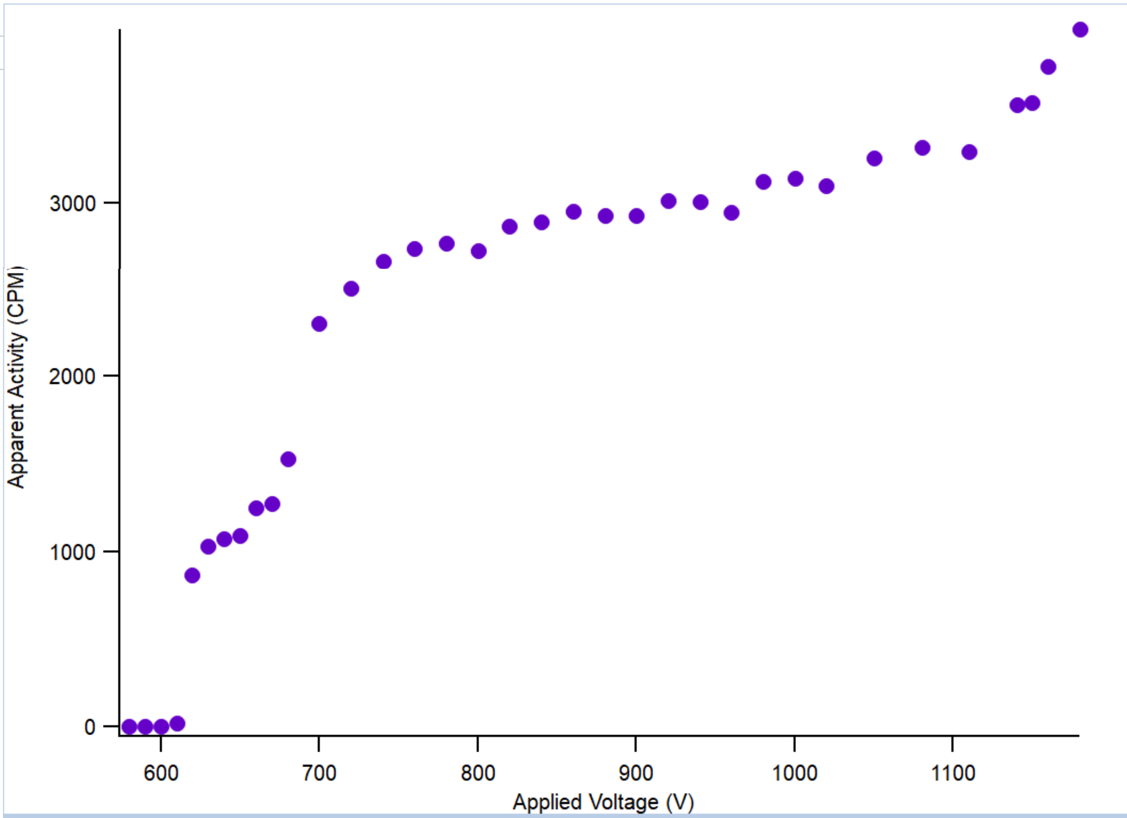
d) Repeat step (c) at 25 volt intervals. While the data is being collected, plot the data on a voltage versus activity graph. The activity is in counts per minute (CPM). Do not exceed a voltage value that is 10% above the average plateau value. Continuous discharge can take place and will drastically shorten the life of the G-M tube.

e) From the graph in (d), choose an operating voltage for the G-M tube. The voltage should be a value that is approximately 25% from the threshold along the plateau. Report this operating voltage clearly in your lab notebook: you will need it for all subsequent experiments that use this detector.

f) Remove the radioactive source and place it at least one meter from the G-M tube in order to minimize its effect on the subsequent measurements.

Data:

Point	Applied Voltage (V)	Apparent Activity (CPM)
0	580	0
1	590	0
2	600	0
3	610	19
4	620	862
5	630	1028
6	640	1069
7	650	1090
8	660	1245
9	670	1269
10	680	1525
11	700	2301
12	720	2497
13	740	2664
14	760	2735
15	780	2769
16	800	2723
17	820	2866
18	840	2889
19	860	2951
20	880	2927
21	900	2926
22	920	3008
23	940	3005
24	960	2943
25	980	3120
26	1000	3135
27	1020	3096
28	1050	3253
29	1080	3315
30	1110	3287
31	1140	3558
32	1150	3566
33	1160	3774
34	1180	3988



We can see in the graph and the table, that the CPM remain zero from 580V - 600V, which indicates that the start voltage has not been reached. However, at 610V the CPM increases to 19 (this is out start voltage) and continues increasing rapidly till 1180V. By observing the graph, we can observe a plateau like region begin and the CPM starts to stabilize around 800.

Analysis:

The data depicting voltage in relation to the CPM offers valuable insights into how the Geiger-Mueller detector functions. Examining the graph, we notice that there are no recorded counts until we reach 610V. This observation suggests that this specific voltage is the threshold required to initiate the counts. Below this starting voltage, the electric field strength is insufficient to trigger ionization.

Once we surpass this initial voltage, we witness a rapid uptick in counts, as the field strength approaches the level needed for full amplification of each radiation interaction. The plateau phase extends from 620V to 1000V, within which further adjustments in voltage have minimal impact (more stable) on the multiplication gain. This range represents the optimal operational zone.

Beyond the 1000V mark, we observe counts starting to rise once more, indicating spontaneous discharge and the onset of instability, which could potentially lead to damage. The plateau teaches us that a minimum field strength between 620V and 700V is necessary to fully register each radiation event, and higher voltages don't yield such rapid gains.

Conclusion:

The CPM vs Voltage graph shows us how we can count the radioactive decays of various radioactive substances, as we apply an operating voltage through it. We also learned how by using appropriate voltages and incrementing them in small amount can help us operate a Geiger-Mueller (G-M) tube for detecting radiation safely.