The Geiger-Müller Counter Tube

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1 Introduction and Theory

Radioactive decay is the spontaneous break down of unstable nuclei. This happens due to unbalanced forces within the nuclei, and during radioactive decay, they decompose into nuclei of higher stability via the emission of radiation. There are three main types of radiation: α-particles, β-particles and γ-rays.

α-particles are released by high mass, proton rich unstable nuclei and consist of a fast moving helium nuclei. β-particles are released by neutron rich unstable nuclei and are fast moving electrons. γ-rays are emitted by most radioactive sources, along with α and β radiation and are high frequency electromagnetic waves. α, β and γ radiation are all ionising, and this characteristic is employed by the Geiger-Müller tube in order to detect them.

A Geiger-Müller tube is a piece of apparatus which detects radiation by the ionisation produced in a low pressure gas inside a tube. Radiation, when it enters the gas tube and interacts with particles of the gas, will produce ionised particles. The tube is able to amplify each ionisation event which occurs inside of it by means of the townsend avalanche effect, and can produce an easily measurable current pulse which is passed to the processing electronics. The townsend effect is a gas ionisation process where free electrons, accelerated by a sufficiently strong electric field, give rise to electrical conduction through a gas by avalanche multiplication caused by the ionisation of molecules by ion impact. When the number of free charges drops or the electric field weakens, the phenomenon ceases. Any radiation which enters the tube will result in particle ionisation, and if a voltage is applied across the tube, the townsend effect can kick in and result in the gas becoming electrically conductive.

The Geiger-Müller tube consists of a sealed metallic tube filled with a noble gas mixed with a small amount of alcohol vapour. The gas is held at a pressure below atmospheric and a thin metal wire runs through the centre of the tube. An electric potential of several hundred volts is maintained between the metal wire (anode) and the cylinder (cathode). The current in the external circuit is governed by the conductivity of the gas inside the tube, and as a result by how high a degree of ionisation has occurred within the gas. If no radiation is present, no gas molecules are ionised, and no current flows in the external circuit. If some radiation is present and resultantly ionises some of the gas molecules, some current will flow. The events which take place after the initial ionisation effect depend on the voltage applied across the tube. If the electric field is weak, the newly produced electrons and ions recombine. If the field is strong, the positive ions and electrons are attracted towards their respective electrodes and produce a current pulse in the external circuit.

A characteristic curves for a gas filled detector consists of a plot of number of collected ions/electrons versus Voltage. As the voltage is increased, five regions are revealed:

1. The recombination region: applied voltage is low, and most ionised particles recombine. Current is very small.

2. The ionisation chamber region: separated ions and electrons are forced to drift towards their respective electrodes, and as recombination is delayed or prevented, most reach the electrodes. Current in external circuit depends on the number of ions generated by the radiation.

3. The proportional-counter region: electrons are accelerated to high velocities and by collisions with other particles, produce secondary ions. This results in a multiplication of charge. A large current pulse can be produced in the external circuit. The amplitude of the pulse is proportional to the energy of the ionising particles. As the applied voltage increases, the output current depends more on the applied voltage than on initial number of ionisation events.

4. The Geiger counter region: Ion multiplication escalates due to the townsend effect. The Geiger-Müller tubes operate in this region, and it is often referred to as the Geiger Muller plateau.

5. The Glow discharge region: a further increase in voltage results in further escalation of the avalanche effect and total ionisation of the gas results. A self sustaining discharge can be instigated by a single pulse. Lengthy operation in this region can be harmful to the detector and should be avoided.

All Geiger-Müller tubes are designed to operate in the geiger counter region conditions; when radiation enters the gas, some initial ionisation occurs. When appropriate operating voltage is applied, electrons and ions near the respective electrodes are collected. The remaining electrons and ions aswell as the ion multiplication products follow, and a current pulse is detected in the external circuit, which can be then detected by a counter.

2 Experimental Method

Figure 1: Experimental setup.

The apparatus is set up as shown. The shielded radioactive source is placed in front of the geiger muller tube which is in turn connected to a digital counter. The source is guided to a distance of roughly 1mm from the counter, and the digital counter is turned on. The geiger tube is connected to inket A of the counter, and button A is selected on the counter. The loudspeaker is switched on, the button Rate is selected, the time interval 1 second is pressed and the start button was pressed in order to start taking measurements. The potentiometer A was turned to the left until the acoustic signal disappeared and the display showed zero counts detected. The voltage at which this occurred was noted and named Uo, the threshold voltage. The Voltage was reduced by roughly 100V and the measurement time interval was changed to 10 seconds. The measurement was started using the stop button, and after 10 seconds passed, the count was noted along with the corresponding voltage. The voltage was raised by roughly 40V and the measurement retaken until 640V was reached. The distance between the source and the detector was increased to 10mm, and after to 20mm and the process outlined above was repeated.

3 Results and Analysis

	$d = 1$mm	$d = 10$mm	$d = 20$mm
U (V)	$R\left(\mathrm{s}^{-1}\right)$		
216	0.0	0.0	0.0
256	0.0	0.0	0.0
296	0.0	0.0	0.0
320	34.9	164.0	17.4
324	1027.8	719.5	288.7
328	1498.6	780.4	307.2
336	1578.8	793.9	315.8
376	1783.3	846.7	315.8
416	1793.6	851.8	324.4
456	1805.0	859.1	334.7
496	1762.6	860.9	343.9
536	1775.2	860.0	341.3
576	1779.4	859.4	341.7
616	1752.2	850.4	345.8
640	1768.2	862.7	345.3

The voltage of the counter tube was varied and the counting rate was measured in each case. This was repeated for different distances between the source and the counter tube: 1mm, 10mm and 20mm. From

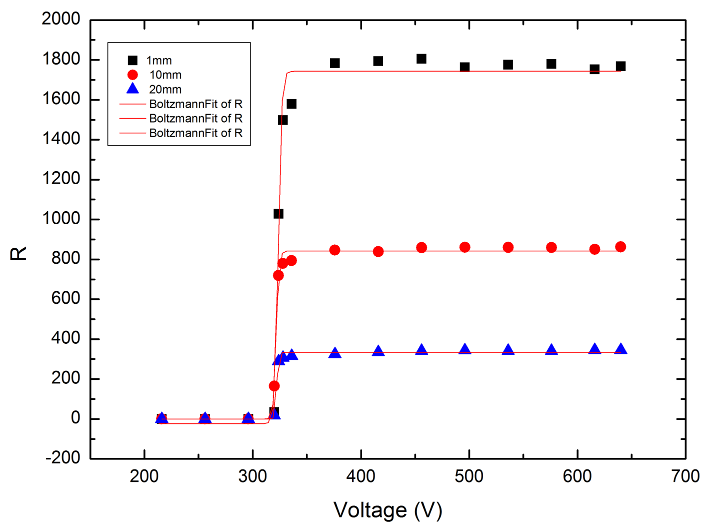

Figure 2: Counting rate R as a function of voltage for the counter tube for various distances from the source.

this graph the position and width of the plateau of the Geiger-Müller tube were determined to be 324 ± 4V and 316 ± 4V, respectively.

4 Discussion and Conclusions

The counting rate was observed to drop as the distance between the source and the counter was increased. The graph of the counting rate as a function of voltage for different distances was successfully obtained. Values of 324 ± 4V and 316 ± 4V were obtained for the position and width of the plateau. The width of the plateau could have been larger, but in this case it was taken to be the distance between the position and the last measurement so as not to break the counter.

In the interest of safety, the distance between the source and the counting tube was measured very approximately, and the accuracy of this experiment could be improved by introducing a safe but accurate method of measuring this distance.