

Radiation Detection and Engineering of Radiation Detectors

Nuclear Radiation Detectors:

All the nuclear measurements require specialized devices to detect and record the different types of nuclear radiation.

Radiation Detectors:

A special devices used to detect and record the different types of nuclear radiation.

Uses of Radiation Detectors:

- 1 - Specify the types of radiation.
- 2 - Estimate amount of radiation.
- 3 - Determine the energy of radiation.

The type of detectors depend on:

1. Type of particles or radiations which require to detect (heavy charged particles, electrons, x-ray and Gamma rays)
2. Energy of radiation.
3. Intensity of radiation.

The principle of detectors

- The principle of radiation detection on many detectors depends on **ionization phenomena or excitation of radiation** to the atoms and molecules of the material when the radiations pass through it.
- **Other types of detectors depend** on its work on the some chemical changes in its material, and by measuring these changes the amount of radiation can be measured.

The gas detectors:

- ❖ **The principle of gas detectors** depend on collect the electrical charged (electrons and ions) resulted from **ionization of atom or gas molecules** when the ionized radiation pass through it.
- ❖ By measuring the resulted electrical charge or current, the detection of radiation through gases can detected. **The gas detectors** can be classify into three types:
 1. Ionization chamber.
 2. Proportional counter
 3. Geiger- Muller counter

Introduction to Geiger Counters

- **A Geiger counter (Geiger-Muller tube)** is a device used for the detect and measurement of all types of radiation: **alpha, beta and gamma radiation.**
- The Geiger – Müller counter takes advantage of the fact that radioactive decay produces high-energy particles that can ionize the matter through which they pass.

The apparatus of Geiger Counters :

- ❖ The apparatus consists of three parts: **the tube, power supply and the counter** (scaler or ratemeter).
- ❖ The Geiger-Mueller tube is usually cylindrical, with a wire (positive electrode) down the center.
- ❖ The end of the tube is sealed by a **mica 'window'** thin enough to allow **alpha** particles to pass into the tube as well as **beta and gamma** radiation.
- ❖ The tube consists of a pair of electrodes (anode and cathode) surrounded by a gas.
- ❖ The electrodes have a high voltage across them.
- ❖ **The gas used is usually Helium, Argon or Neon.**
- ❖ A high voltage is established across the cylinder and the wire as shown in the figure below.
- ❖ For a brief moment, the gas conducts and a pulse of current flows in the circuit.

- ❖ The circuit includes either a scaler or a ratemeter. A scaler counts the pulses and shows the total on a display.
- ❖ A ratemeter indicates the number of pulses or counts per second.

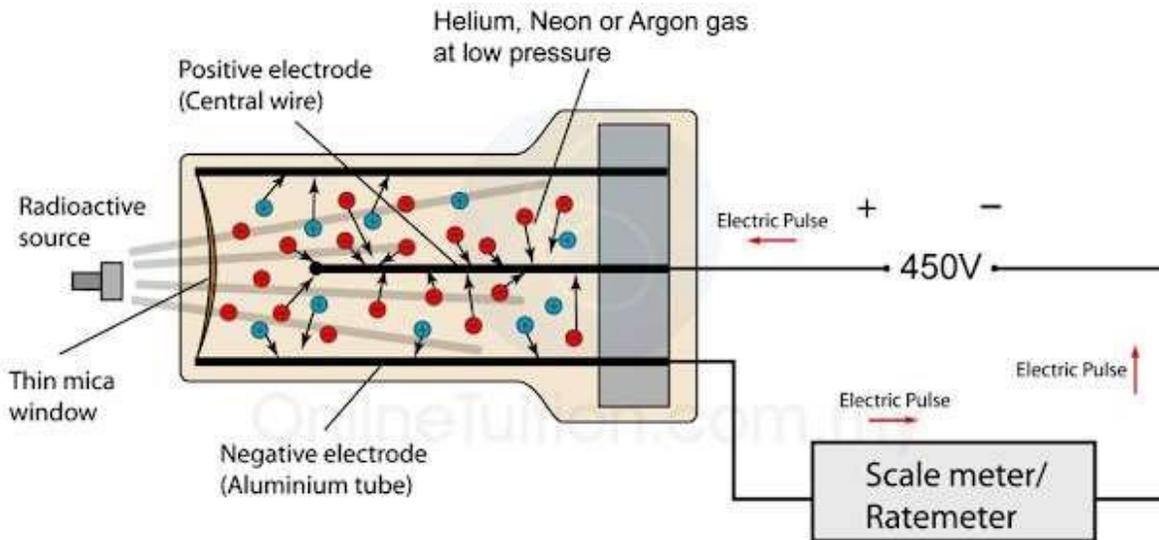


Figure 1. Aschematic representation of a Geiger-Muller counter.

The principle operation of Geiger Counters (مهم جدا)

- ❖ When ionizing radiation such as an alpha, beta or gamma particle enters the tube, it can ionize some of the gas molecules in the tube.
- ❖ From these ionized atoms, an electron is knocked out of the atom, and the remaining atom is positively charged.
- ❖ The high voltage in the tube produces an electric field inside the tube.
- ❖ The electrons that were knocked out of the atom are attracted to the positive electrode, and the positively charged ions are attracted to the negative electrode.
- ❖ This produces a pulse of current in the wires connecting the electrodes, and this pulse is counted.

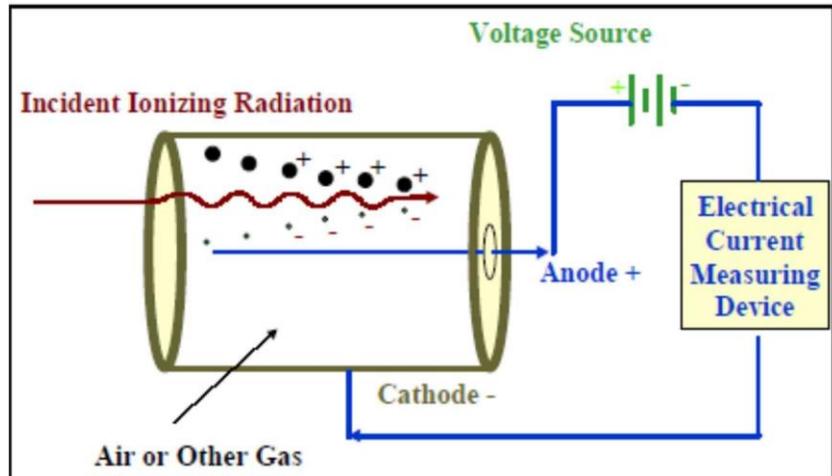


Figure 2. A schematic representation of a Geiger-Muller counter

- ❖ After the pulse is counted, the charged ions become neutralized, and the Geiger counter is ready to record another pulse.
- ❖ In order for the Geiger counter tube to restore itself quickly to its original state after radiation has entered, a gas is added to the tube.

How much the voltage across the electrodes

For proper use of the Geiger counter, **one must have the appropriate voltage across the electrodes:**

- If the voltage is too low, the electric field in the tube is too weak to cause a current pulse.
- If the voltage is too high, the tube will undergo continuous discharge, and the tube can be damaged.
- Usually the manufacture recommends the correct voltage to use for the tube.
- Larger tubes require larger voltages to produce the necessary electric fields inside the tube.

Geiger counter curve (count versus the applied voltage)

- For low voltages, no counts are recorded. This is because the electric field is too weak for even one pulse to be recorded.
- As the voltage is increased, eventually one obtains a counting rate. The voltage at which the G-M tube just begins to count is called the **starting potential**. The counting rate quickly rises as the voltage is increased.
- The rise in potential is so fast, that the graph looks like a "step" potential. After the quick rise, the counting rate levels off. This range of voltages is termed the "**plateau**" region.
- Eventually, the voltage becomes too high and we have continuous discharge. The **threshold voltage** is the voltage where the plateau region begins.
- **Proper operation** is when the voltage is in the plateau region of the curve.
- **For best operation**, the voltage should be selected fairly close to the threshold voltage, and within the first 1/4 of the way into the plateau region.
- **In the plateau region** the graph of counting rate versus voltage is in general not completely flat. The plateau is not a perfect plateau.
- In fact, **the slope of the curve in the plateau region** is a measure of the **quality of the G-M tube**.
- An excellent tube could have **the plateau slope as low as 3 percent** per 100 volts.

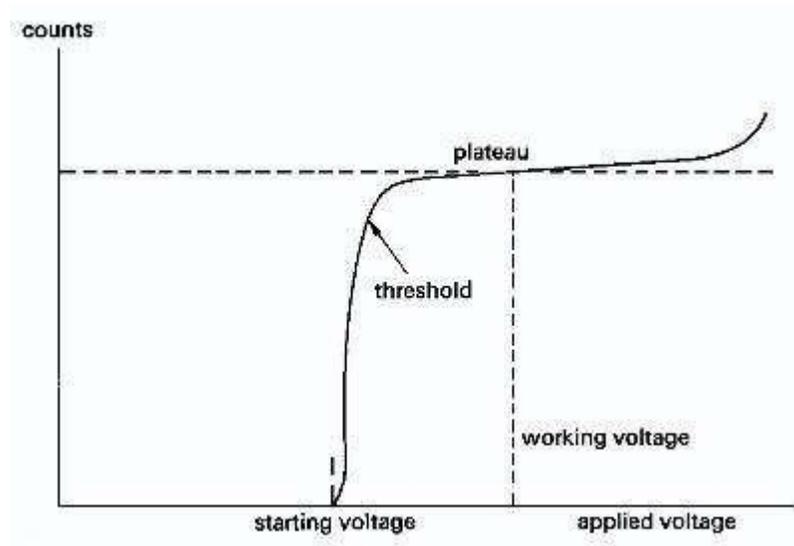
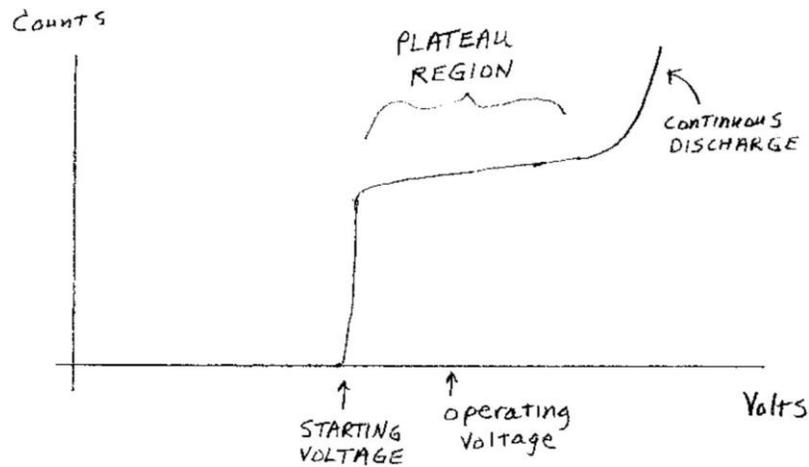


Figure (3): Geiger counter curve (count versus the applied voltage)

Efficiency of the Geiger-counter:

The efficiency of the detector: Is the ratio of the (number of particles of radiation detected) divided by (number of particles of radiation emitted):

$$\varepsilon \equiv \frac{\text{number of particles of radiation detected}}{\text{number of particles of radiation emitted}}$$

This definition for the efficiency of a detector is also used for our other detectors.

Why the efficiency of Geiger counter system is small ?

The reason that the efficiency is small for a G-M tube is that:

- A gas is used to absorb the energy.
- A gas is not very dense, so most of the radiation passes right through the tube.

Why the Geiger Counter is most efficient for beta particles

Although the Geiger counter can detect all three types of radiation, it is most efficient for beta particles and not very efficient for gamma particles.

- If beta particles enter the tube they have the best chance to cause ionization.
- Gamma particles themselves have a very small chance of ionizing the gas in the tube. Gamma particles are detected when they scatter an electron in the metal cylinder around the gas into the tube.
- Unless alpha particles are very energetic, they will be absorbed in the cylinder that encloses the gas and never even make it into the G-M tube.

Some of the disadvantages of using a Geiger Counter are:

- a) They cannot differentiate which type of radiation is being detected.
- b) They cannot be used to determine the exact energy of the detected radiation.
- c) They have a very low efficiency.