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

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Radiation Protection Course

Lecturer

Prof. Dr. Amer A. AlQra'wi

Chapter Seven

Radiation Detection and Measurement

Introduction:
Radiation detection and measurement involve the identification and quantification of ionizing radiation for various purposes, such as safety, environmental protection, and scientific research. This field uses specialized detectors and instruments to monitor and assess radiation levels, ensuring safety and facilitating various applications, including nuclear power, medicine, and environmental monitoring. Radiation detectors of a wide variety are used for detecting, measuring, characterizing, and classifying radiation emissions.

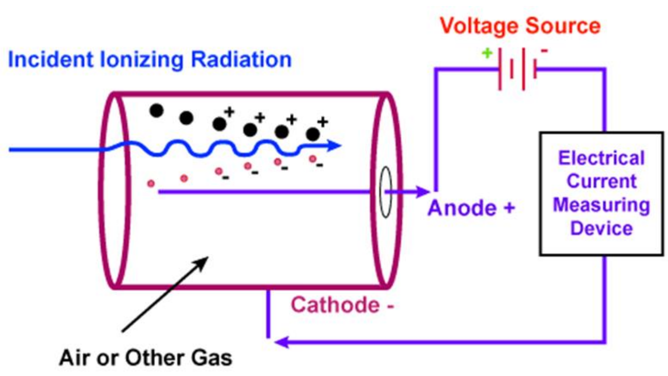
Ionization gases detectors (Gas-Filled Detectors): often referred to as gas-filled detectors, are a class of radiation detectors that use a gas-filled chamber to detect and measure ionizing radiation. These detectors operate on the principle that when ionizing radiation passes through the gas in the chamber, it can ionize the gas atoms or molecules, creating positively and negatively charged ions. This ionization process is then used to detect and measure the radiation. . These detectors are commonly used in various applications, including nuclear physics experiments, medical radiation therapy, industrial radiation monitoring, and more. Common types of gas-filled detectors include:

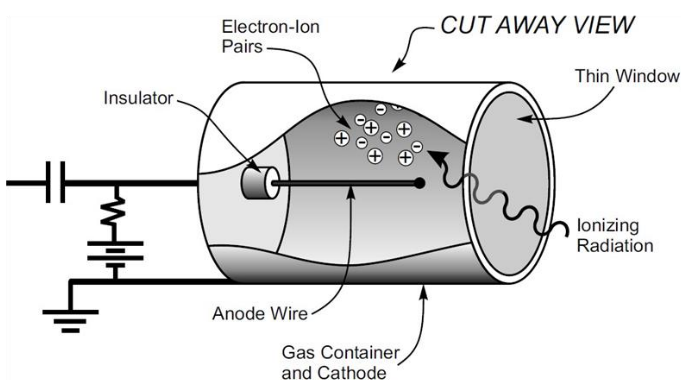
1- Geiger-Mueller detector:

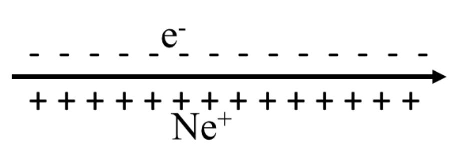
Principle of GM:

Ionization of Gas: The fundamental principle of a GM tube detector is the ionization of gas by ionizing radiation. When ionizing radiation, such as alpha particles, beta particles, or gamma rays, passes through the gas-filled tube, it can ionize the gas molecules by knocking out electrons.

Gas-Filled Tube: The GM tube contains a gas, typically an inert gas like argon or xenon and Neon , at low pressure. The gas serves as the medium through which ionization occurs. If the gas is neon (the most common gas in a GM detector), the positive member of each ion pair is a neon ion (Ne+) while the negative member of the pair is a freed electron (e-). In the absence of an electric field, the ion pairs created in the gas of the detector simply recombine.







Why we use inert gas in Gas filled detector:

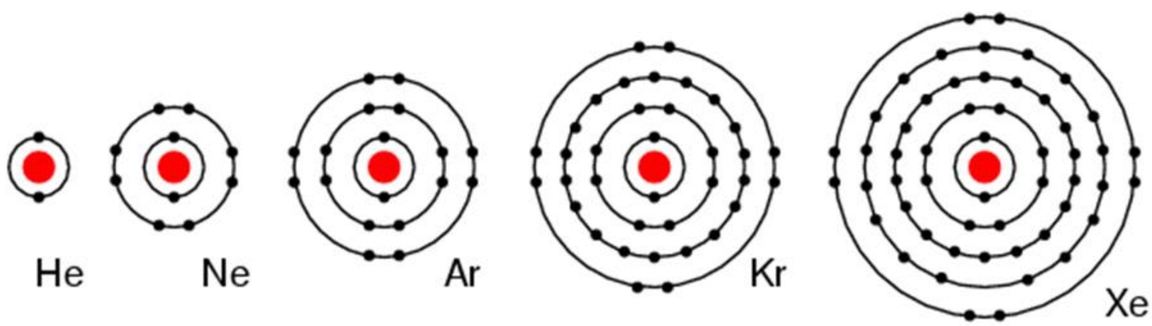
Stability: Inert gases are highly stable and do not easily react with other elements or compounds. This stability ensures that the gas inside the

GM tube remains unchanged over time, which is important for the reliable and consistent operation of the detector.

Why the ionization Gas filled detector work under low pressure: Lowering the pressure inside the tube reduces the chances of gas molecules colliding with each other, allowing ionizing radiation to travel through the gas more effectively and produce more ionization events. This makes the detector more sensitive to low levels of radiation. Operating at low pressure allows them to detect and count these events accurately and efficiently.

why we add ethyl alcohol to Geiger muller detector:

the tube needs to return to its ready state quickly in order to detect subsequent radiation events. Ethyl alcohol can help extinguish the discharge (avalanche) of electrons that follows ionization, allowing the tube to recover more rapidly.



High Voltage: A high voltage is applied across the electrodes of the GM tube, creating an electric field within the tube. This high voltage helps to accelerate the charged particles produced during ionization. However, if the ionization occurs between two oppositely charged electrodes, and if the electric field is sufficiently strong, the positive and negative members of the ion pairs will separate and be collected at the electrodes.

Anode: the positively charged electrode

Cathode: the negatively charged electrode

Gas Amplification: When ionization occurs, it creates electron-ion pairs. The electric field within the tube causes these electrons to move towards the positively charged anode while the positive ions move towards the negatively charged cathode. As these electrons gain kinetic energy, they can collide with other gas molecules, creating additional electron-ion pairs. This process, known as gas amplification, results in a cascade of ionization events, creating a detectable electrical pulse.

Electrical Pulse: Each ionization event produces a small electrical pulse that can be detected by the GM tube's electronics.

Radiation Dose Measurement: The rate of electrical pulses produced in the GM tube is proportional to the intensity of ionizing radiation. By counting the number of pulses over a given time period, the GM tube can be used to estimate the radiation dose or intensity.

Geiger-Muller counting equation" and is given as follows:

$$N = (Q / W)$$

Where:

N = Number of ion pairs produced

Q = Total electrical charge collected at the detector's electrodes

W = Work done to create an ion pair in the gas

N (Number of Ion Pairs Produced): This represents the number of ion pairs (electron-ion pairs) generated in the gas within the GM tube due to the passage of ionizing radiation. Each ion pair is typically produced when a single ionizing event occurs.

Q (Total Electrical Charge Collected): Q represents the total electrical charge collected at the electrodes of the GM detector. As ion pairs are created, the electrons move towards the positively charged anode and the positive ions move towards the negatively charged cathode. The electrical charge generated by this movement is collected and measured as an electrical pulse.

W (Work Done to Create an Ion Pair): W is the amount of energy required to create a single ion pair in the gas. It is a material-specific constant and is typically expressed in electron volts (eV). The value of W depends on the type of gas and the pressure within the GM tube.

Example:

Suppose you have a GM detector filled with argon gas at a pressure of 760 mm Hg (standard atmospheric pressure), and it is exposed to a source of alpha particles. You want to calculate the number of ion pairs produced by the GM detector during a 10-second exposure to the alpha radiation. we'll assume that the work done to create an ion pair in argon gas (W) is approximately 26 eV, and GM detector generates an electrical pulse of 2,000 pico Coulombs (pC) during the 10-second exposure.

$Q = 2{,}000 \text{ pC} = 2{,}000 \times 10^{(-12)} \text{ C} = 2 \times 10^{(-9)} \text{ C}$

$N = (2 \times 10^{(-9)} \text{ C}) / (26 \text{ eV})$

Now, we need to convert the energy from electron volts (eV) to joules (J), as 1 eV is approximately $1.602 \times 10^{(-19)}$ J:

$W = 26 \text{ eV} \times 1.602 \times 10^{(-19)} \text{ J/eV} \approx 4.1632 \times 10^{(-18)} \text{ J}$

Now, we can calculate N:

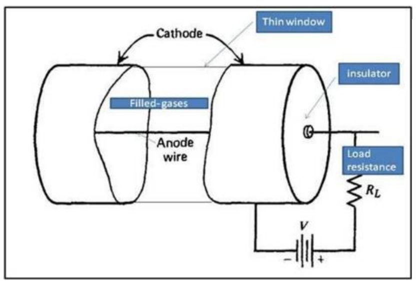
$N = (2 \times 10^{(-9)}\ C) / (4.1632 \times 10^{(-18)}\ J)$

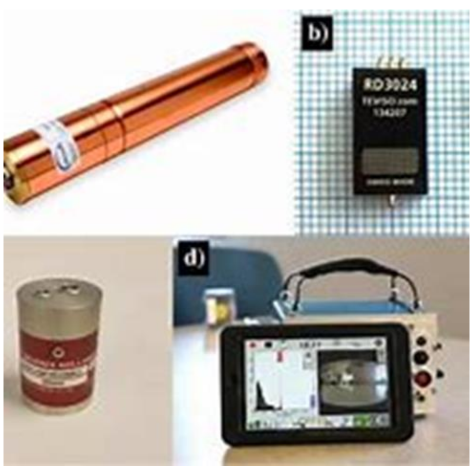
$N \approx 4.80 \times 10^{8}$ ion pairs

So, during the 10-second exposure to alpha radiation, the GM detector produced approximately 4.80 x 108 ion pairs in the argon gas. This information can be used to estimate the intensity or dose of ionizing radiation and is important for radiation safety and monitoring applications.

Proportional Counter:

Ion Chamber:





Characteristic	GM Tube	Proportional Counter	Ion Chamber
Ionization Process	High amplification of individual ionization events, resulting in a large electrical pulse for each event.	Moderate amplification of ionization events, producing a proportional electrical pulse for each event.	Low amplification, with the ionization events producing a small, nearly linear electrical pulse.
Sensitivity	Very sensitive to ionizing radiation, capable of detecting low levels of radiation.	Sensitive to ionizing radiation, but less sensitive than GM tubes.	Less sensitive compared to GM tubes and proportional counters, primarily used for high radiation fields.
Energy Discrimination	Limited energy discrimination, mainly detects the presence of ionizing radiation without distinguishing between types or energies.	Provides some energy discrimination, allowing for the differentiation of certain types of ionizing radiation.	Better energy discrimination, making it suitable for measuring the energy and type of radiation.
Application	Used for general radiation detection, contamination monitoring, and detecting radioactive materials.	Used in nuclear physics experiments, radiation spectroscopy, and environmental monitoring.	Commonly used in radiation therapy, radiation dosimetry, and high-precision radiation measurements.

Operating Voltage	Operates at a lower voltage (typically a few hundred volts 300-1500V).	Operates at higher voltages (800-2000volts).	Operates at even higher voltages (100-500 volts).
Gas Filling	Typically filled with a low-pressure inert gas (e.g., argon, neon) and a quenching gas (e.g., halogen).	Filled with a specific gas mixture to achieve proportional response (e.g., argon and methane).	Filled with a high-pressure gas (e.g., air) or a low-pressure gas for greater energy resolution.
Radiation Types Detected	Detects alpha, beta, and gamma radiation.	Detects alpha, beta, and gamma radiation with some discrimination capability.	Detects alpha, beta, gamma, and X-ray radiation with better discrimination.
Size and Portability	Compact and portable, suitable for handheld devices.	Larger and less portable due to higher operating voltages and more complex construction.	Bulkier and less portable due to high-pressure gas and additional components.