MEASUREMENT OF RADIOACTIVITY

In order to measure the radiations of alpha, beta and gamma particles, many techniques involving detection and counting of individual particles or photos have been available. The gas ionization devices include:

1. Pulse ionization chamber
2. Proportional counters
3. Geiger-Muller counters
4. Scintillation counter
5. Solid state detectors

These methods are especially employed for counting gamma radiations. The method selected for the measurement of radioactivity depends upon the extent of energy dissipation and penetrability of radiation.

1. **Ionization Chambers:** These are available in various shapes and sizes. An ionization chamber consists of chambers filled with gas and fitted with two electrodes kept at different electrical potentials (50 to 100 volts for each centimeter of distance between the two electrodes) and a measuring device to indicate the flow of electric current. Radiation brings about ionization of gas molecules or ions which cause emission of electrons which in turn revels the changes in electric current.

2. **Proportional Counters:** These are modified ionization chambers in which an applied potential of primary electrons causes production of more free electrons which get carried to the anode. As for each primary electron liberated, much more additional electrons get liberated; the current pulse through electric circuit is amplified. The voltage range over which the gas amplification (ionization) occur is called the proportional region and the counters working in the region are called proportional counters.

3. **Geiger-Muller Counter:** These are the most popular radiation detectors. They do not need the use of a high-gain amplifier and they can detect alpha, beta and gamma radiations.

   A G-M Counter is having the ionization gas and is also having a quenching vapor whose functions have been:

   1. To prevent the spurious pulses that may get produced due to the positive ions reaching the cathode
   2. To absorb the photons emitted by excited atoms and molecules returning to their ground state

   Both bromine and chlorine are used as quenching agents.
   Ethyl alcohol and ethyl formate are used as organic quenching agents

Construction: A G-M Counter possesses a cylindrical cathode, which is usually 1-2 cm in diameter, along the centre of which is a wire anode. The space is filled with a special gas mixture which gets readily ionized together with a small proportion of quenching vapor.

The design and construction have been found to depend on the purpose for which they are required.

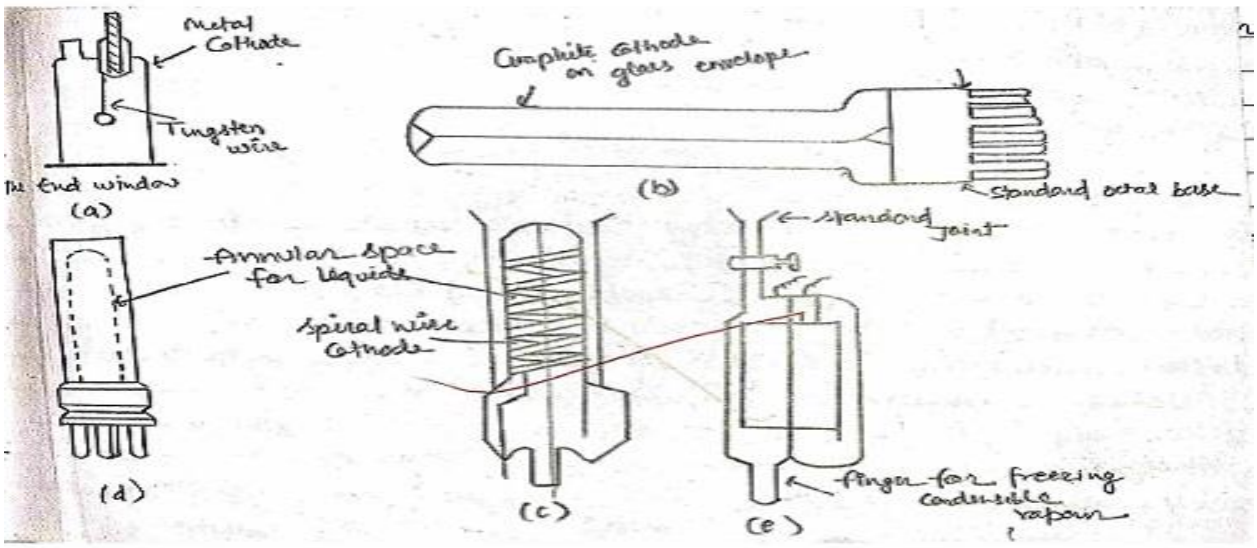
1. **For counting the radioactive solid source:** The end window type G-M counter has been the most popular [diagram (a)]. The window has been made of an aluminum alloy (7 mg cm^{-2}) , mica or may be a thin glass bubble (about 15 mg cm^{-2}).

2. **To count high range beta particles (about 0.5 MeV) and for gamma counting:** thin glass walled counters are used. These have been normally of about 1cm in diameter, having a glass wall of 20-40 mg cm^{-2} thickness; the actual thickness depends on the length of the counter. The tube has been coated o the inside with graphite to form the cathode. [Shown in diagram (b)].

3. **To count the radioactive liquids:** It is having the capacity of 10 cm^3 in annular space [Shown in diagram (c)]. In such a counter, 10 cm^3 of 3% solution of a uranium salt gives nearly 10,000 counts per minute.

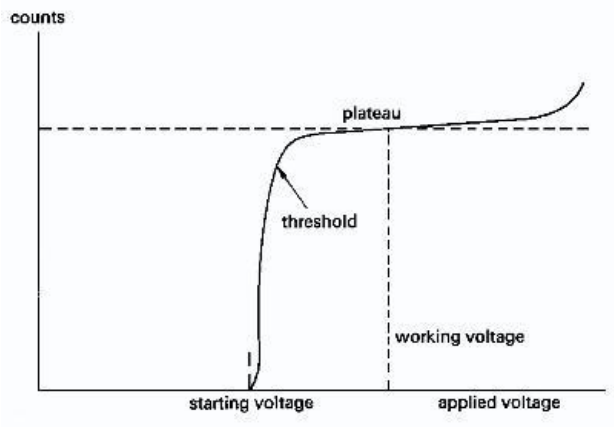
   The type shown in [diagram (d)] is having a capacity of approx. 5 cm^3 and gets converted by a plug and a socket. Other types of G-M counters are known which are containing a thin walled tube or spiral tube through which radioactive liquids can be drawn.

4. **To count the radioactive gases:** [Shown in diagram (e)]. In this counter radioactive gas is introduced together with the counting gas. For the more efficient gamma counting-counters having lead or copper cathode have been used.



Operation of Geiger-Muller Counter: A G-M probe unit is regarded as an electrical switch, in which each pulse may make the current to pass to scaler to counting unit for recording the number of pulses.

- To operate the G-M Counters, a source of high-voltage, together with a low-gain amplifier and sealing unit for registering of the pulses are needed.
- To reduce the background counting rate, the G-M Counter has been mounted with a lead shield.
- It is having two shelves to hold a source in one or more positions and for holding absorbers between the counter and the source.
- When the voltage on the counter gets raised, no registration of pulses will be observed until a certain voltage gets reached (starting voltage).
- The counting rate increases rapidly to the threshold and at 150-200 volts or more, the counting rate becomes constant.
- At the same time, the size of individual pulses gets increased with the voltage, so that at higher voltages there has been a tendency for spurious discharges to get initiated. It has been one of the causes for the slope of plateau.
- The voltage selected for the operating point is generally 100 volts above the threshold voltage.

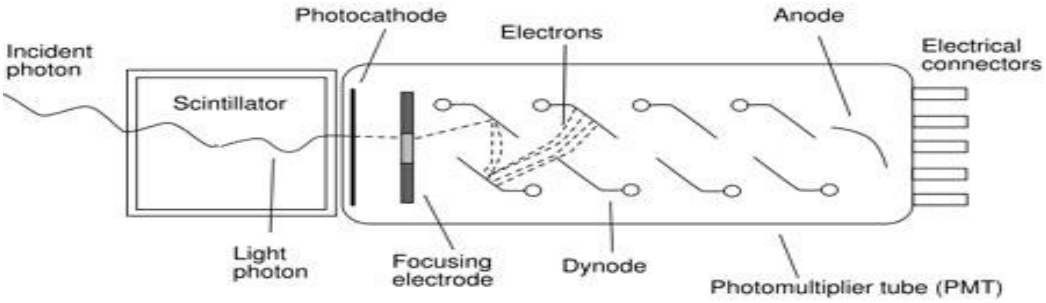


4. <u>Scintillation Counters:</u> When radiation is incident on certain substances such as phosphor, . a flash of light is given out. It thus becomes possible to measure alpha, beta and gamma radiations by scintillation detectors provided the detectors has been suitably modified for the type of radiation to be measured.

This method is mainly useful for counting of gamma emitters. In earlier devices, counting of scintillations was done visually. This method is tedious, slow and not sensitive.

- The development of photomultiplier tube, consisting of photoelectric cells directly linked to electron multipliers.

- Fluorescent materials or phosphor have been used
- Introduction of thallium - activated sodium iodide is used in scintillation techniques for gamma counting and energy determination.



- The scintillation counter consists of a cell, a photomultiplier tube which is coupled with phosphor or fluorescent material to convert scintillations into electric pulses in amplifier and a scaler.
- For gamma radiations (as they have high penetrating power), the phosphor used has been a crystal of sodium iodide which gets activated with about 1% of thallium for increasing the degree of fluorescence.
- The gamma radiations passing through a small window enter the crystals (NaI(Ti)) where it gives rise to a small flash of light.
- This is brought to the photomultiplier tube which in turn detects flash amplifies and converts it into an electric impulse,
- This impulse is recorded by means of a scaler.

The scintillation counters are used for detecting and measurement of tritium ^{3}H and ^{14}C.

1. **Inorganic scintillators:** Alkali halides are the most commonly used compounds.
   - NaI(TI) is the most widely used scintillators for gamma counting due to its availability in desired shape and size and high detection efficiency.
   - Other scintillators like: CsI (TI), CsI (Na), Lil (Eu), BaF_2, bismuth germinate are used.
2. **Organic scintillators:** Anthracene having high scintillation efficiency and stilbene having low scintillation efficiency are most widely used scintillators.
   - Liquid scintillators find wide applications where large volume detectors are required. They are also used for simple alpha and beta counting with 100% efficiency.
3. **Plastic scintillators:** They show fast timing response, are very useful in nuclear spectroscopy.

5. Autoradiography: It is more useful in detecting and determining gamma radiations in physiological studies of plants and animals.

- Administering of a radioactive substance, say an animal, and after sufficient time lapse of localization, the tissue is remove, embedded in paraffin, cut into thin section by microtome and the section is kept in contact with photographic emulsion in a dark room.
- The radioactive atoms (present in the cut section) are emitting particles which darken the photographic emulsion.
- After sufficient time exposure, the emulsion has been developed and fixed.

6. Solid state detectors: These detectors have:

- High resolution
- Compactness
- Easy interpretation of output signal

1. **Semi conductor detectors**: In this type of detectors, the band gap is very small of the order of 2 to 3 eV and therefore, large numbers of electron hole pairs are formed for incident radiation quantum.
   - **Eg**: lithium drifted Ge, silicon detectors, Ge (Li), Si (Li) and high purity Ge detectors (HPGe) are most widely used in X-ray and gamma counting.
   - Surface barrier silicon detector is most commonly used for alpha spectroscopy and fission fragment kinetic energy spectra.

2. **Photographic emulsions (Autoradiography):** An Ordinary photographic film consists of an emulsion of silver halide grains suspended in a gelatin matrix and supported with a glass or cellulose acetate film. Ionizing radiations sensitizes the silver halide grains which remain intact for indefinite period until they are developed.
   Eg: Radiographic films and nuclear emulsions.
   These are most useful in detecting and determining gamma radiations in physiological studies of plants and animals.

3. **Cerenkov detectors:** These are based on the light which are emitted by fast charged particles passing through an optically transparent medium with refractive index more than one.