RADIOACTIVITY DETECTION & MEASUREMENT

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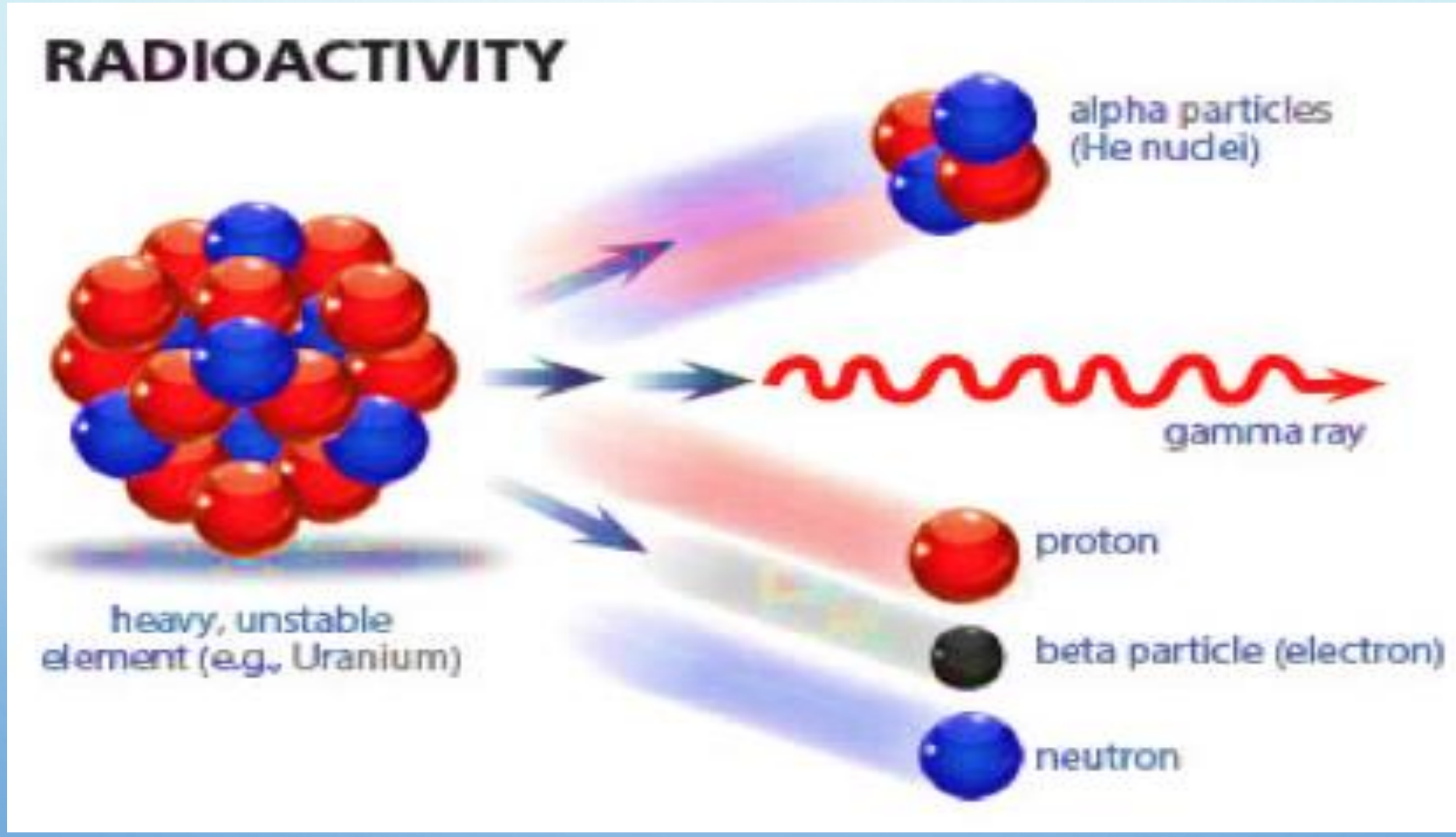
INTRODUCTION

- Radioactive isotopes occur naturally or can be generated artificially.
- They emit ionising radiation in the form of electromagnetic waves or energetic particles.
- Exposure to ionising radiation above permissible limits can result in serious biological damage.

- A radioactive nucleus is unstable it can become stable by ejecting particles and electromagnetic waves.
- If an atom loses an orbiting electron it becomes a positive ion as it will have more positive charges than negative charges.
- The electron that was removed becomes a negative ion.


RADIOACTIVITY
alpha particles
(He nuclei)
gamma ray
proton
beta particle (electron)
neutron
heavy, unstable
element (e.g., Uranium)

TYPES OF EMISSIONS

The electromagnetic wave/particles emitted by the radioactive isotopes are-

- alpha
- beta
- gamma

Properties of α, β and γ rays

The three types of radiation

Use this table to find information about and to compare α, β and γ radiation

	Alpha (α)	Beta (β)	Gamma (γ)
Nature	It's a nucleus of helium $^{4}_{2}He$. Two protons and two neutrons	It's an electron e^{-}	It's an electromagnetic wave
Charge	+2	-1	0
Mass	Relatively large	Very small	No mass
Speed	Slow	Fast	Speed of light
Ionizing effect	Strong	Weak	Very weak
Most dangerous	When source is inside the body	When source is outside the body	When source is outside the body

Units of Radioactivity:

- Counts per second [c.p.s]: The *recorded* rate of decay
- Disintegrations per second [d.p.s]: The *actual* rate of decay
- Curie [Ci]: The number of d.p.s. equivalent to 1g of radium (3.7×10^{10} d.p.s)
- Becquerel [Bq] = 1 d.p.s

➢ $1\ Ci = 3.7 \times 10^{10}\ Bq$

- Rad [rad]: The dose that gives an energy absorption of 0.01 Jkg^{-1} [100 $ergg^{-1}$]
- Gray [Gy]: The dose that gives an energy absorption of 1J kg–1.

➢ 1 Gy= 100 rad

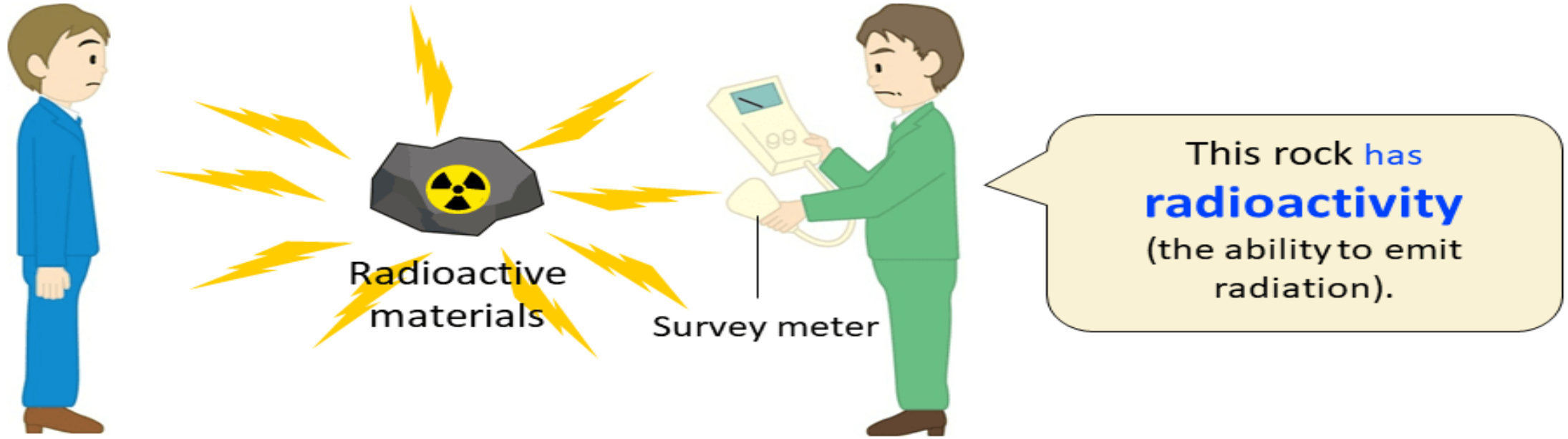
- Rem [rem]: The amount of radiation that gives a dose in humans equivalent to 1 rad of X-rays
- Sievert [Sv]: The amount of radiation that gives a dose in humans equivalent to 1 Gy of X-rays

➢ 1 Sv= 100 rem

- Roentgen [R]: The amount of radiation that produces 1.61×10^{15} ion pairs kg^{-1}
- 1 Electron volt [eV] = 1.6×10^{-19} J

Radiation and Radioactivity

Units of Radiation and Radioactivity



Becquerel (Bq)
Unit for intensity of radiation: one nucleus decays (disintegrates) per second = 1 becquerel

Sievert (Sv)
Unit of radiation exposure dose which a person receives: associated with radiation effects

RADIATION DETECTORS

- The interactions of alpha, beta, and gamma radiations with matter produce positively charged ions and electrons.
- **Radiation detectors** are devices that measure this ionization and produce an observable output.

WHY TO DETECT RADIATION?

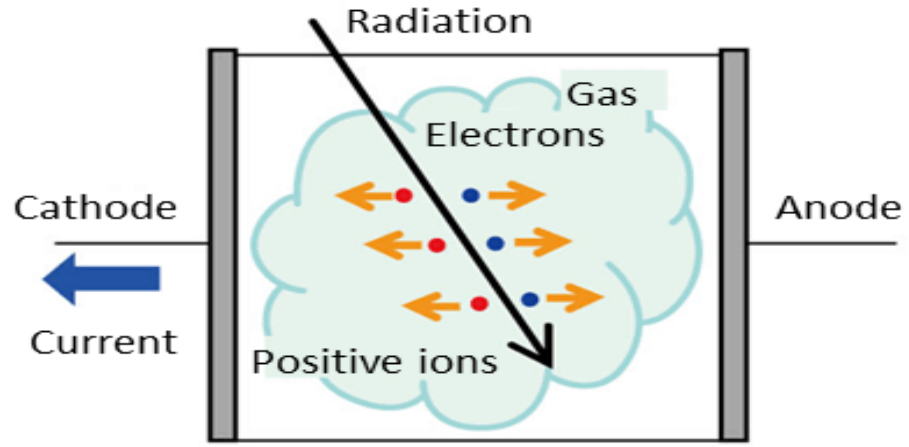
- Research application
- Environmental safety
- Power regulation in nuclear reactors
- Personal protection of occupational workers
- Estimation of radiation dose in treatment of patients
- Calibration of radioactive isotopes etc.

Dose Measurement and Calculation

Principles of Radiation Measurement

Measurements are carried out utilizing the interaction between radiation and substances.

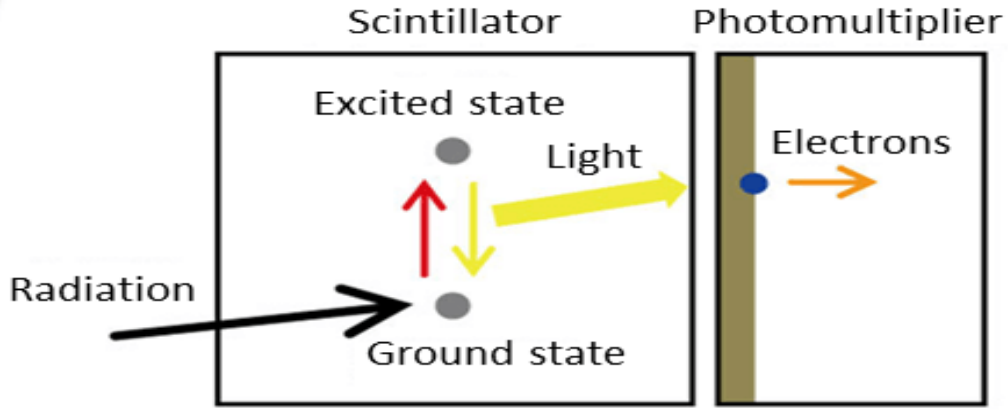
Ionization (with gas atoms)



- Detectors are filled with gases such as inert gases or air.
- When radiation passes through gas, molecules are ionized, creating positive ions and electrons.
- Positive ions and electrons are drawn toward the electrodes and are converted into electric signals for measurement.

GM counter survey meters, ionization chambers, etc.

Excitation



- When radiation passes through a scintillator, molecules are excited, but they return to their original state (ground state).
- Light emitted in the process is amplified and converted into a current for measurement.

NaI (TI) scintillation survey meter, etc.

METHODS OF DETECTION

- (1) Methods based upon gas ionization
- (2) Methods based upon excitation
- (3) Methods based upon exposure of photographic emulsions.

BASIC RADIATION DETECTOR SYSTEM

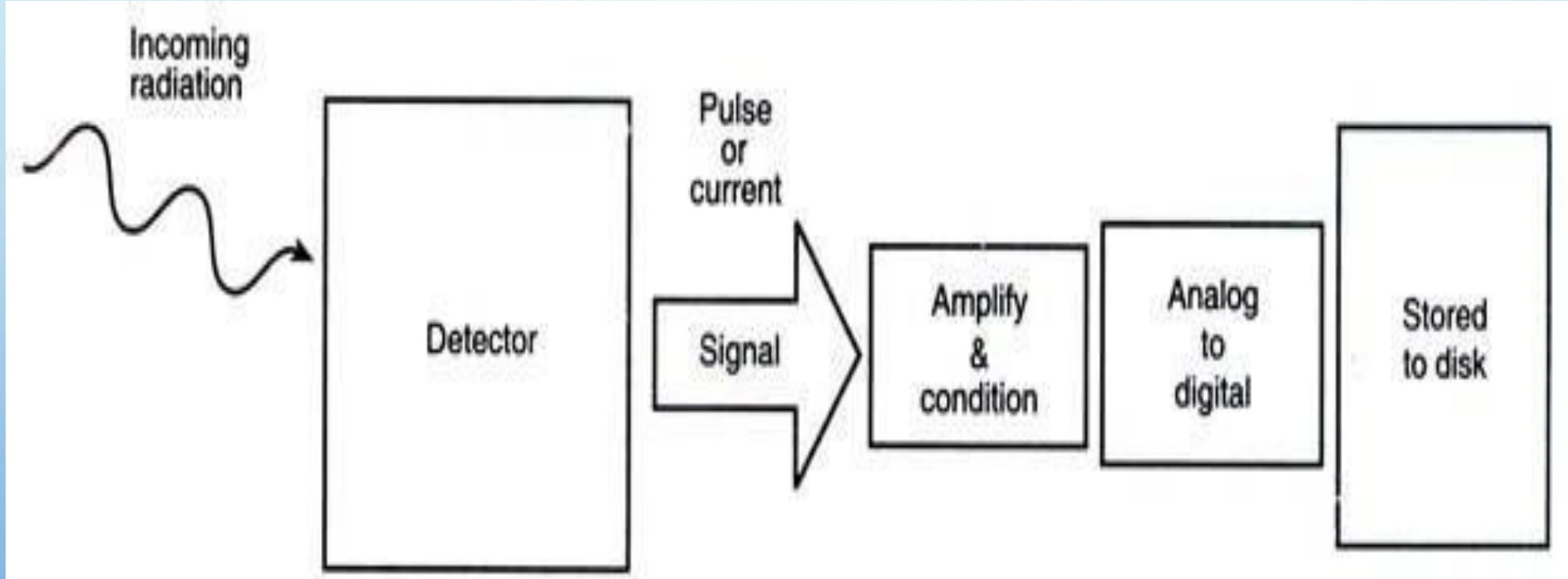


Fig. 13.8: Scheme of basic detector system

1. METHODS BASED UPON GAS IONIZATION:

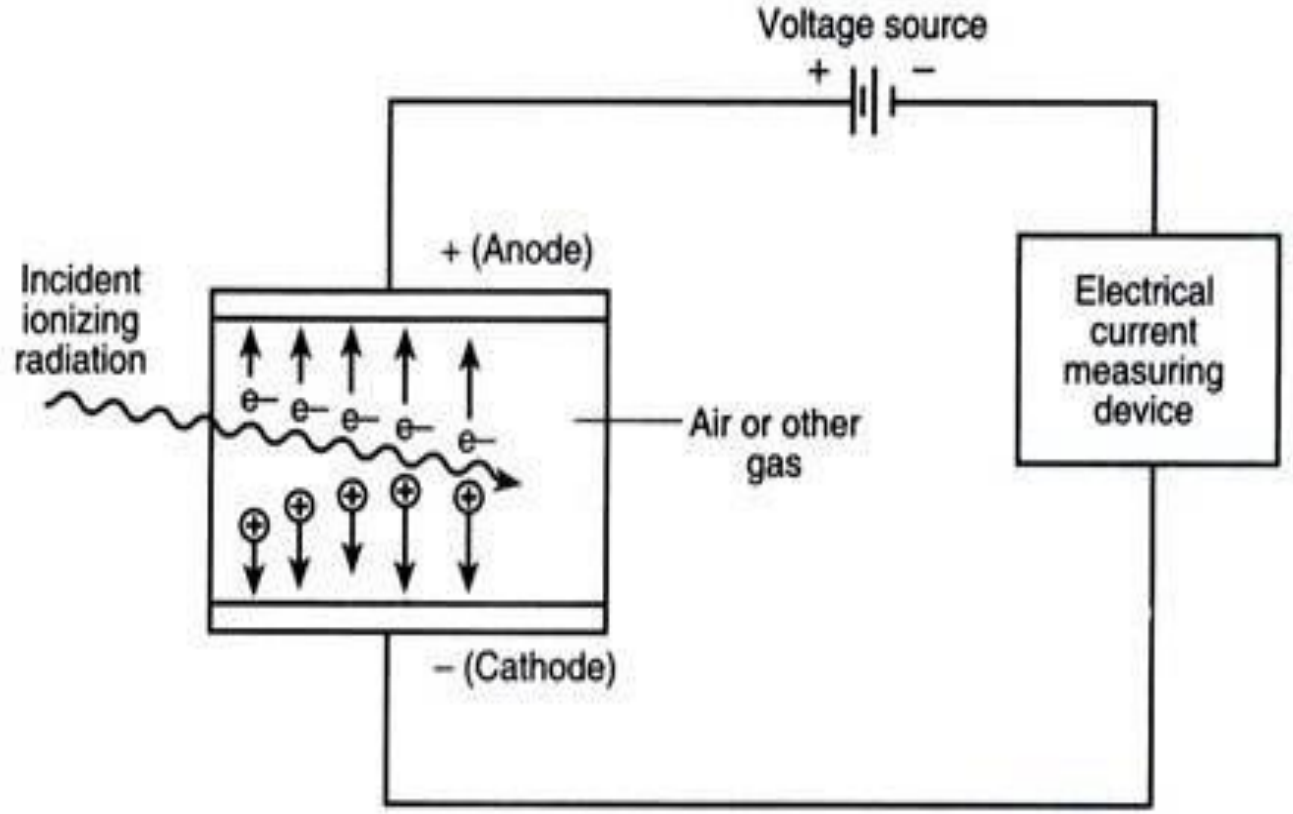


Fig. 13.9: Basic principles of gas filled detectors. The electrical charge liberated by ionising electrodes is collected by positive and negative electrodes

The effect of voltage upon ionization

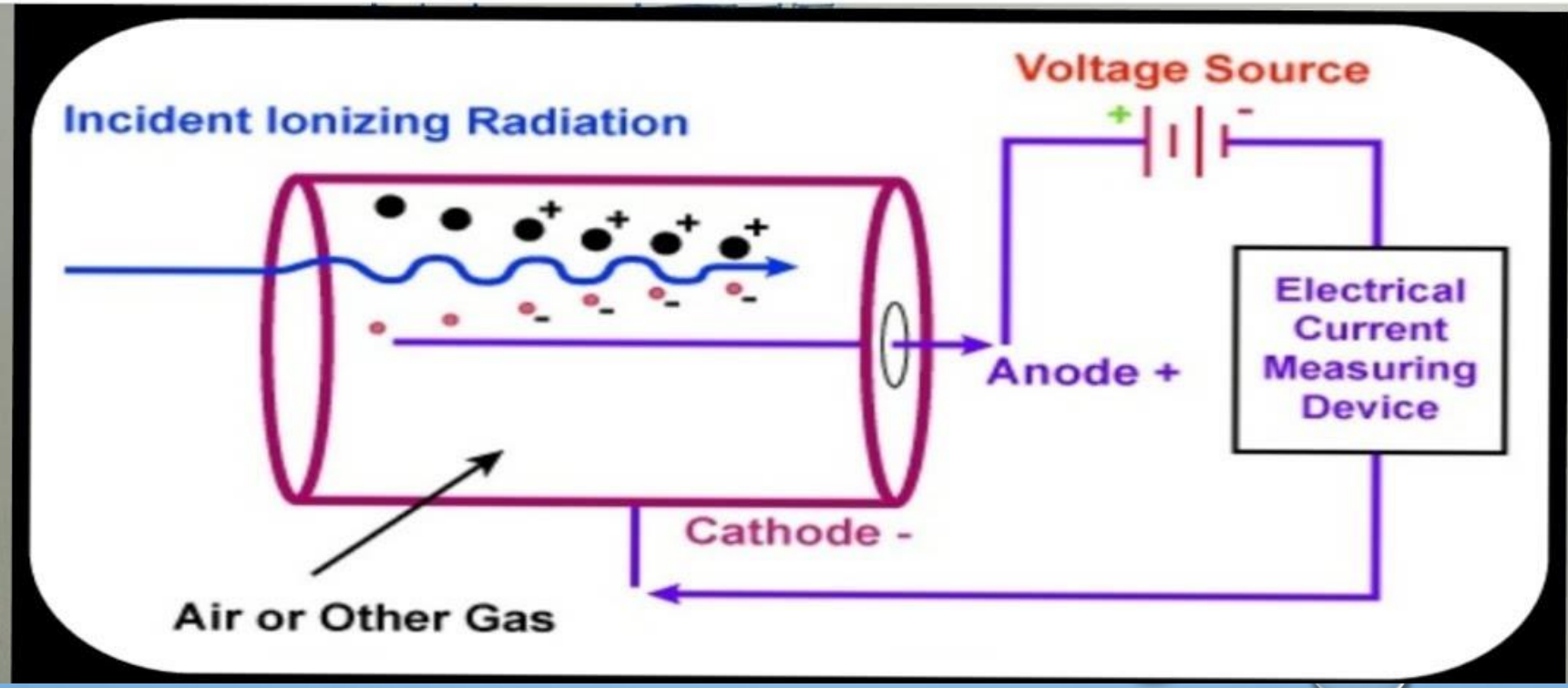
- As a charged particle passes through a gas, its electrostatic field dislodges orbital electrons from atoms sufficiently close to its path and causes ionization .The ability to induce ionization decreases in the order
- $\alpha > \beta > \gamma$(10 000: 100: 1)
- Accordingly, α- and β-particles may be detected by gas ionization methods, but these methods are poor for detecting γ. if ionization occurs between a pair of electrodes enclosed in a suitable chamber, a pulse (current) flows, the magnitude of which is related to the applied potential and the number of radiation particles entering the chamber .

GEIGER-MULLER COUNTER

- It is made of a glass or metal tube containing a mixture of gases, an inert gas like helium or argon and an organic vapour or a gas eg. isopropanol or isobutene or cooking gas (which is a mixture of hydrocarbons).
- It has a thin window, usually made of mica at one end to enclose the gas. depending upon the thickness of the window and the energy of radiation of the radio-isotopes a fraction of the particles emitted enter the counting tube and ionize the gas mixture inside.

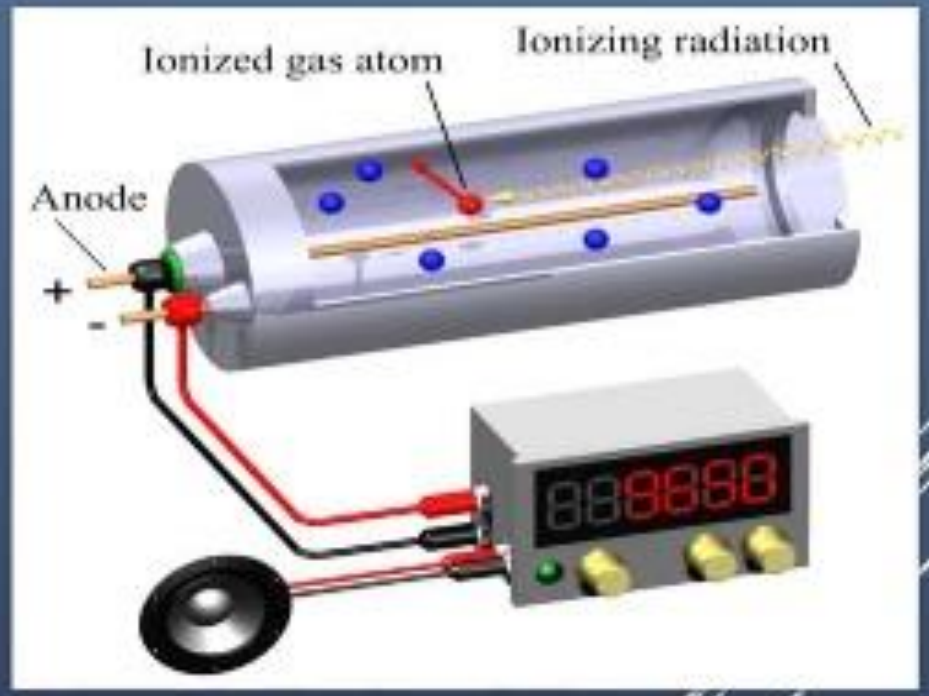
MEASUREMENT OF RADIOACTIVITY

GEIGER MULLER (GM) COUNTER



PRINCIPLE OF OPERATION

- A Geiger counter consists of a ***Geiger-Müller tube***, the sensing element which detects the radiation, and the processing electronics, which displays the result.
- The Geiger-Müller tube is filled with an inert gas such as helium, neon, or argon at low pressure, to which a high voltage is applied.



- The tube briefly conducts electrical charge when a particle or photon of incident radiation makes the gas conductive by ionization.
- The ionization is considerably amplified within the tube by the ***Townsend Discharge Effect*** to produce an easily measured detection pulse, which is fed to the processing and display electronics.

- The small current generated is magnified at high voltage, and measured with a scaler calibrated to record disintegrations per unit time.
- The counts recorded include counts due to ionization of the gas mixture by cosmic rays passing through the tube, any radioactivity present in the surrounding area, etc.
- This is known as the background. these background counts have to be substracted from the counts given by the sample.

2.METHOD BASED ON EXCITATION

Types of scintillation:

There are **2 types** of scintillation:-
Scintillation can be counted by the two different techniques as follows:-

a) Solid Scintillation (External) counting:-

- In the case, the sample is placed close to a floor crystal (crystallized silver activated zinc sulphides) for alpha-emitter; sodium iodide for gamma-emitter; anthracene or stilbene for beta-emitters, which in turn is placed adjacent to a photomultiplier. This photo multiplier is connected to a high voltage supply and a scalar.

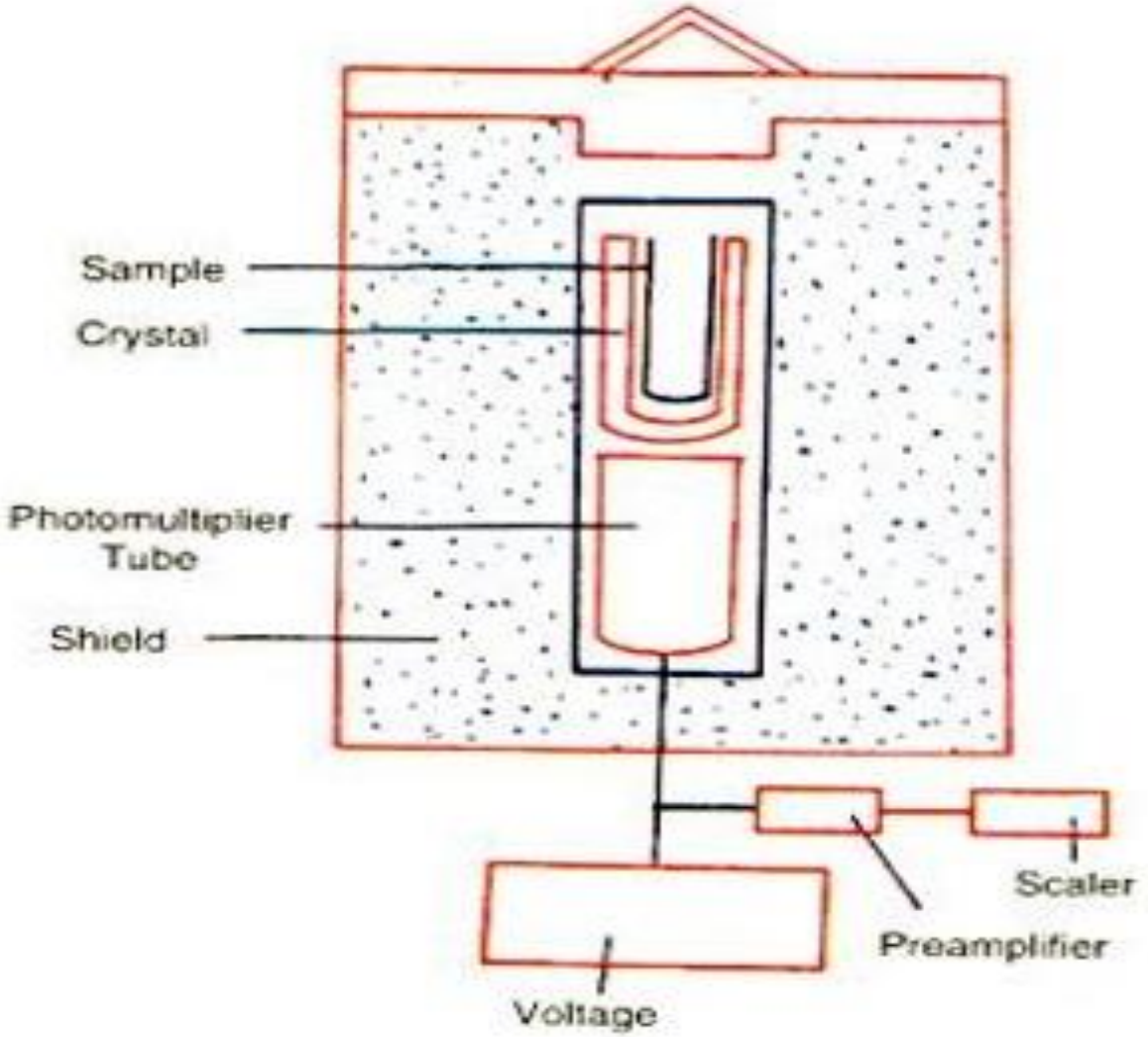
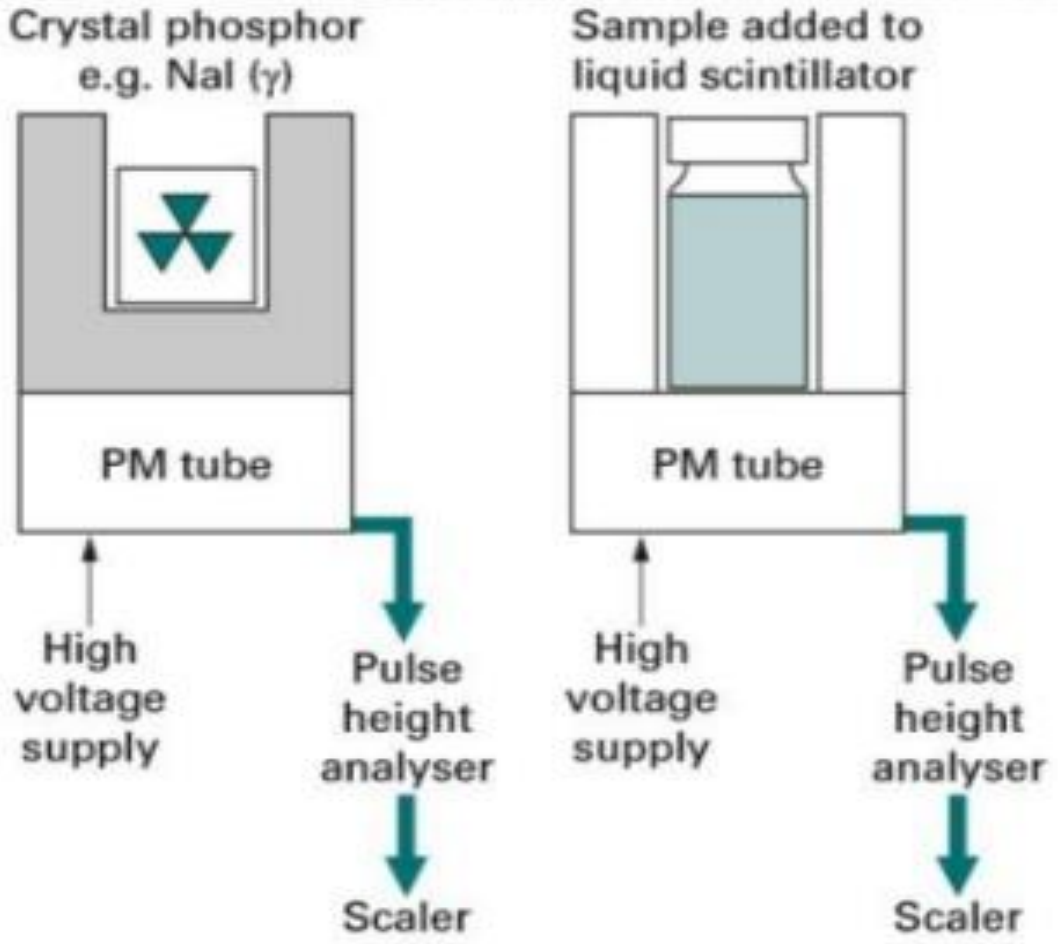


Fig. 35.11 : Scintillation counter for measurement of radiations (diagrammatic.)

Liquid scintillation counting

- Standard laboratory method for measuring radiation from beta-emitting nuclides.
- Samples are dissolved or suspended in a "cocktail" containing an aromatic solvent (historically benzene or toluene, and small amounts of other additives known as fluors.
  - Beta particles transfer energy to the solvent molecules, which in turn transfer their energy to the fluors;
  - Excited fluor molecules dissipate the energy by emitting light.
  - Each beta emission (ideally) results in a pulse of light.
  - Scintillation cocktails may contain additives to shift the wavelength of the emitted light to make it more easily detected.
- Samples are placed in small transparent or translucent (often glass) vials that are loaded into an instrument known as a liquid scintillation counter.

Solid and Liquid Scintillation Counters:



- **Solid scintillation:**
  - Useful for γ-emitting isotopes
- **Liquid Scintillation:**
  - For quantifying weak β-emitters
  - Scintillation fluids
    - Solvent (eg. toluene) +
    - Fluors
      - 2,5-diphenyloxazole (PPO)
      - 1,4-bis(5phenyloxazol-2-yl)benzene (POPOP)

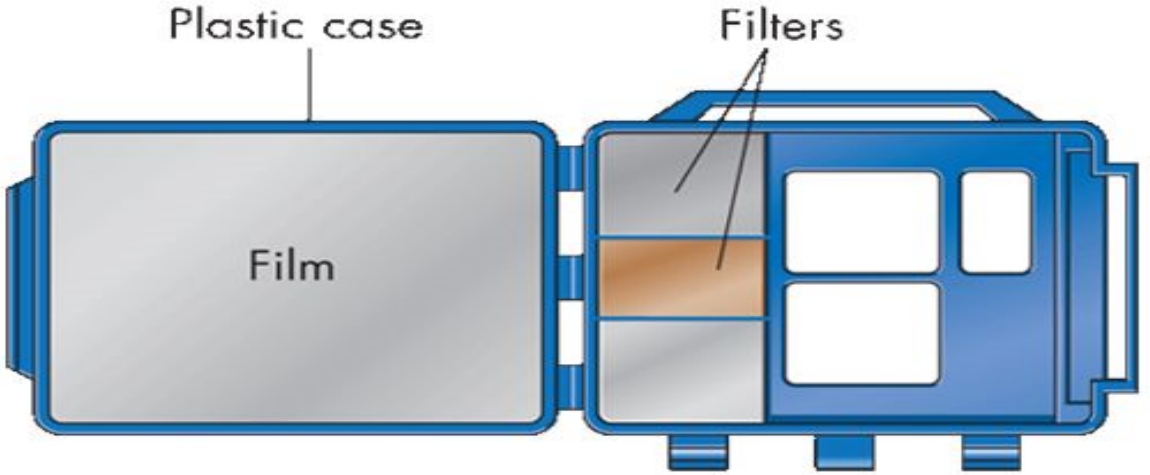
3.PHOTOGRAPHIC EMULSIONS METHODS

- A photographic emulsion consists of a suspension of silver halide grains in an inert gelatin matrix and supported by a backing of plastic film or another material.
- If a charged particle or fast electron passes through the emulsion, interactions with silver halide molecules produce a similar effect as seen with exposure to visible light.
- Some molecules are excited and will remain in this state for an indefinite period of time. after the exposure is completed, this latent record of the accumulated exposure can be made visible through the chemical development process.

Film Badge

This is a diagram of a typical film badge.

- The badge contains layers of photographic film covered with black light-proof paper.



- To reach the film, radiation must pass through a filter, which absorbs some radiation, or a transparent area through which radiation can pass easily.

MEDICAL APPLICATIONS OF RADIOACTIVITY

Table 5.2 Radioisotope in Diagnosis

Radioisotope	Diagnosis used for
Iodine-131	Location and detection of brain tumor, thyroid gland disorder
Sodium-24	Location of blood clot and circulation disorders, pumping action of heart
Iron-59	Diagnosis of anaemia, pregnancy disorder
Cobalt-60	Diagnosis of cancer
Hydrogen-3	Water content of the human body

INDUSTRIAL APPLICATIONS OF RADIOACTIVITY

Radioactive Isotope	Industrial Applications
Americium-241	For uniform thickness when rolling steel and paper, determine location of oil wells
Sodium-24	Oil well studies and to locate leaks in pipe lines
Iridium-192	Test integrity of boilers and aircraft parts
Uranium-235	Nuclear power plant and naval propulsion systems fuel, production of fluorescent glassware and colored wall tiles
Californium-252	Determine moisture content of soil – important for road construction and building industries

REFRENCES

- HTTP://WWW.BIOLOGYDISCUSSION.COM/BIOCHEMISTRY/RADIOISOTOPE-TECHNIQUES/DETECTION-AND-MEASUREMENT-OF-RADIOACTIVITY-3-METHODS/12858
- HTTPS://BYJUS.COM/PHYSICS/SCINTILLATION-COUNTER/

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