DETECTION AND MEASUREMENT OF RADIOACTIVITY

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Methods based upon gas ionisation

- If a charged particle passes through a gas, its electrostatic field dislodges orbital electrons from atoms sufficiently close to its path and causes ionisation (Fig. 14.2).
- The ability to induce ionisation decreases in the order

$$\alpha > \beta > \gamma \ (10\,000 : 100 : 1)$$

- If ionisation occurs between a pair of electrodes enclosed in a suitable chamber a pulse (current) flows.
- Ionisation counters are sometimes called proportional counters ('proportional' because small voltage changes can affect the count rate).
- The **Geiger–Mu¨ ller counter** has a cylindrical-shaped gas chamber and it operates at a high voltage.
- This makes the instrument less dependent on a stable voltage, so the counter is cheaper and lighter.

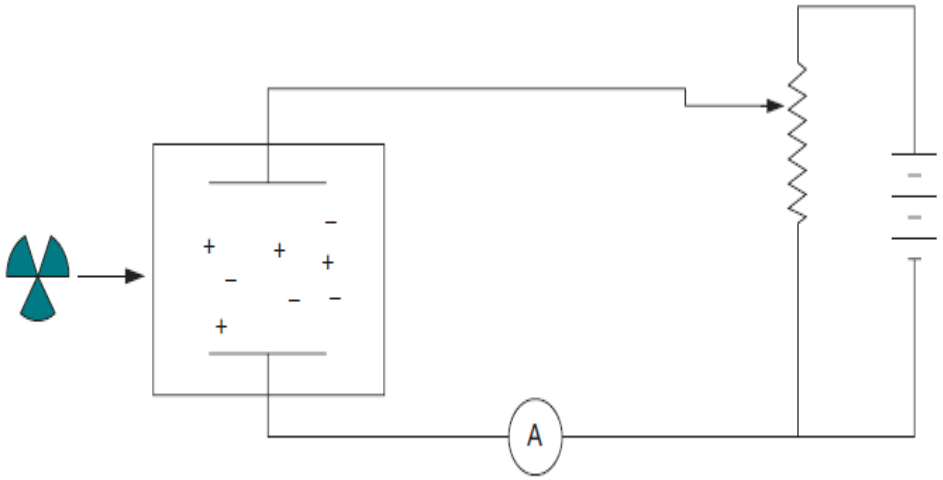


Fig. 14.2 Detection based on ionisation.

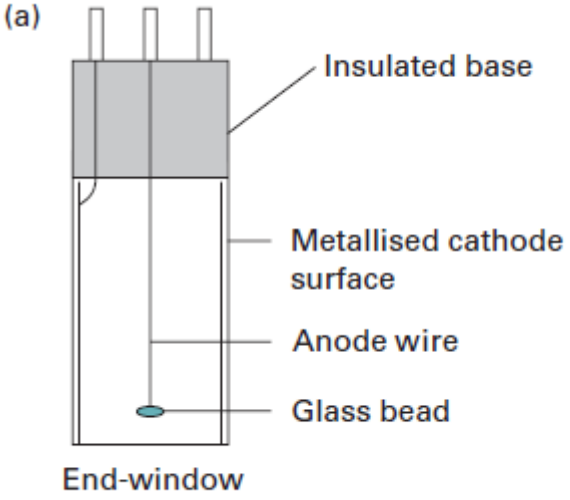
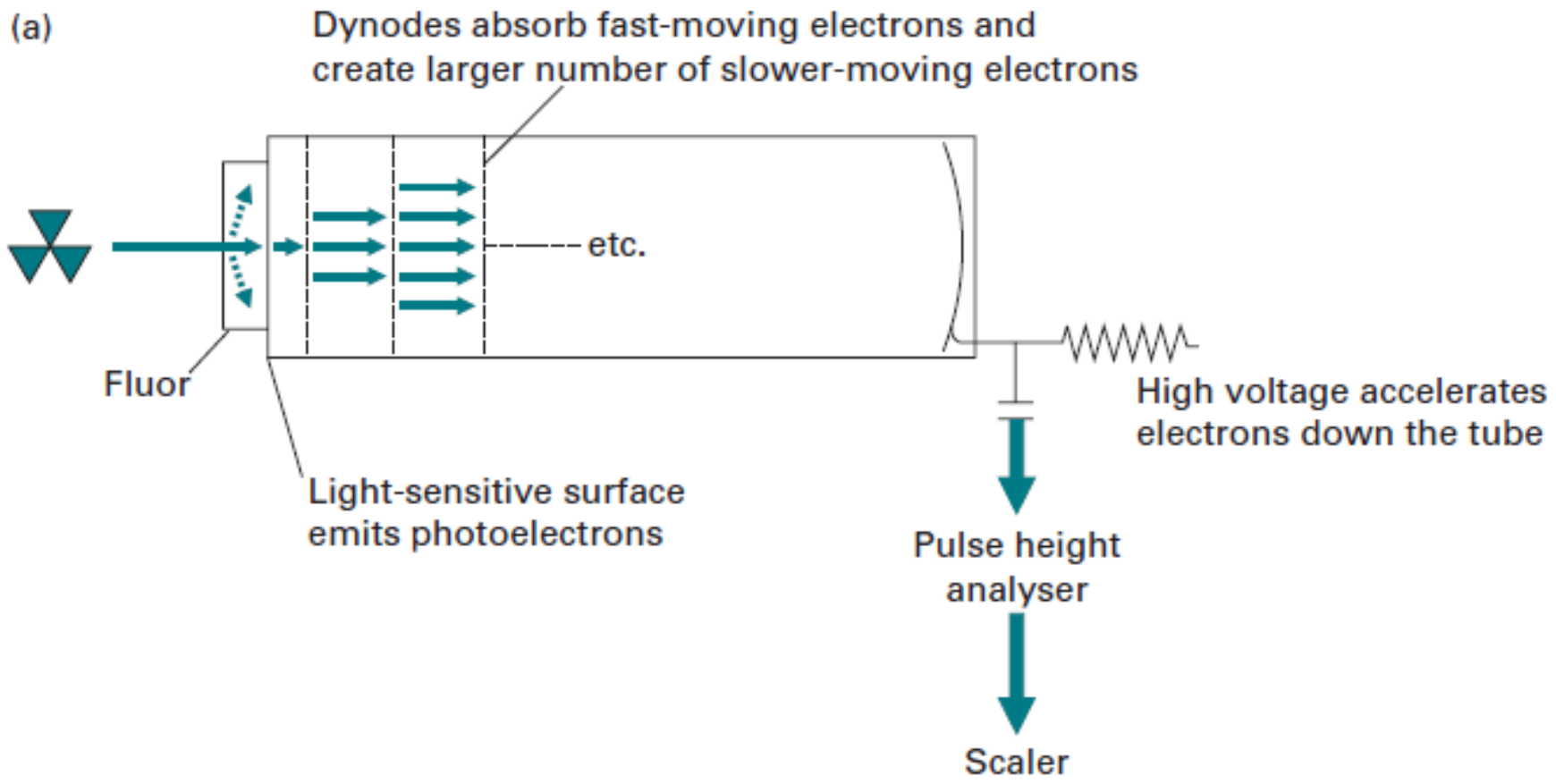


Fig. 14.3 (a) The Geiger–Müller (G–M) tube

- In ionisation counters, the ions have to travel to their respective electrodes; other ionising particles entering the tube during this time (the so-called ‘dead time’) are not detected and this reduces the counting efficiency.
- Ionisation counters are used for routine monitoring of the laboratory to check for contamination.
- They are also useful in experimental situations where the presence or absence of radioactivity needs to be known rather than the absolute quantity.
- For example quick screening of radioactive gels prior to autoradiography, checking that a labelled DNA probe is where you think it is (and not down the sink!) or checking chromatographic fractions for labelled components.

Methods based upon excitation

- Radioactive isotopes interact with matter in two ways, ionisation and excitation.
- The latter effect leads an excited atom or compound (known as a fluor) to emit photons of light. The process is known as scintillation.
- When the light is detected by a photomultiplier, it forms the basis of scintillation counting.
- Essentially, a photomultiplier converts the energy of radiation into an electrical signal, and the strength of the electric pulse that results is directly proportional to the energy of the original radioactive event.
- This means that two, or even more, isotopes can be separately detected and measured in the same sample, provided they have sufficiently different emission energy spectra.

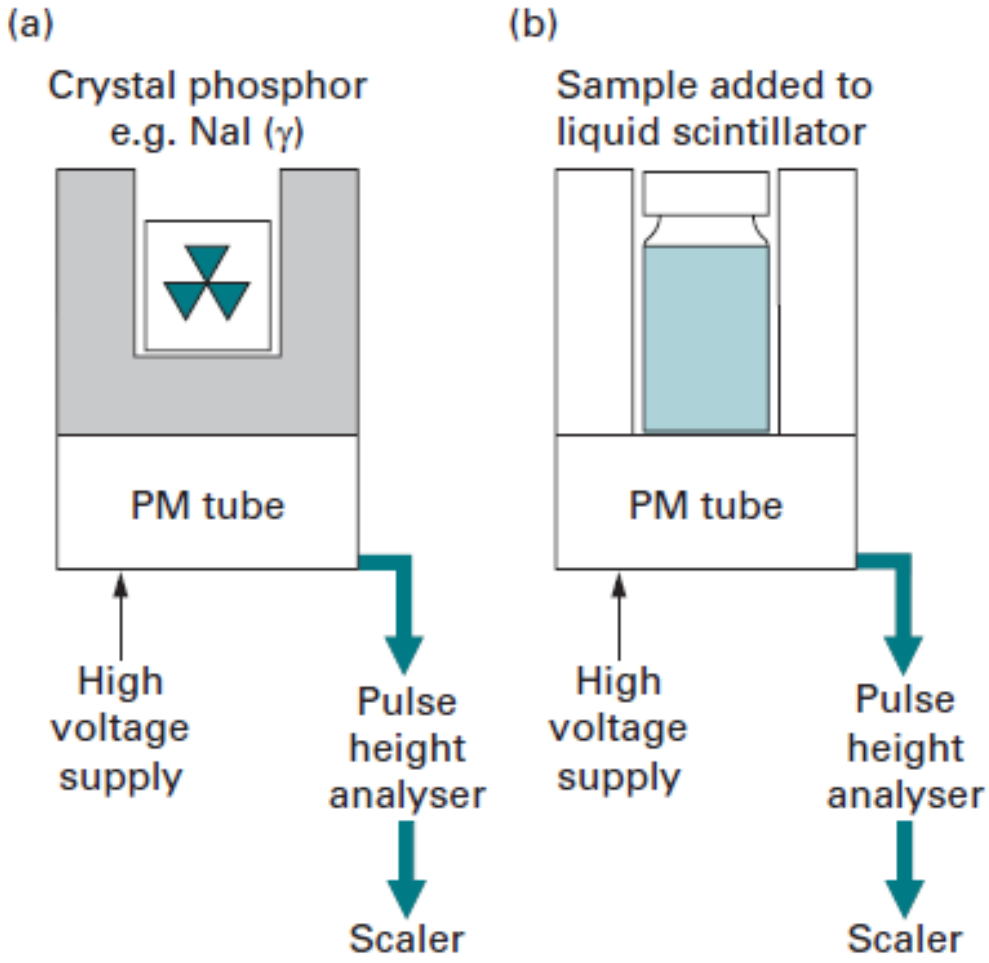


The mode of action of a photomultiplier

Types of scintillation counting

- There are two types of scintillation counting.
  - Solid scintillation counting
  - Liquid scintillation counting
- In **solid scintillation counting** the sample is placed adjacent to a solid fluor (e.g. sodium iodide).
- Solid scintillation counting is particularly useful for γ-emitting isotopes.
- This is because they can penetrate the fluor.
- The counters can be small handheld devices with the fluor attached to the photomultiplier tube, or larger bench-top machines with a well-shaped fluor designed to automatically count many samples.

Diagrammatic illustration of (a) solid and (b) liquid scintillation counting methods



liquid scintillation counting

- In liquid scintillation counting, the sample is mixed with a scintillation fluid containing a solvent and one or more dissolved fluors.
- This method is particularly useful in quantifying weak β^-emitters such as ^{3}H, ^{14}C and ^{35}S, which are frequently used in biological work.
- Scintillation fluids are called ‘cocktails’ because there are different formulations, made of a solvent (such as toluene or diisopropylnaphthalene) plus fluors such as 2,5-diphenyloxazole (PPO), 1,4-bis(5-phenyloxazol-2-yl)benzene (nicknamed POPOP, pronounced as it reads: ‘pop op’) or 2-(4’-t-butylphenyl)-5-(4’’-bi-phenyl)-1,3,4-oxydiazole (butyl-PBD).
- Cocktails can be designed for counting organic samples, or may contain detergent to facilitate counting of aqueous samples.

Advantages of scintillation counting

- Scintillation counting is widely used in biological work and it has several advantages over gas ionisation counting:
  - fluorescence is very fast so there is effectively no dead time.
  - counting efficiencies are high (from about 50% for low-energy β^- emitters to 90% for high-energy emitters)
  - the ability to count samples of many types, including liquids, solids, suspensions and gels.
  - the general ease of sample preparation.
  - the ability to count separately different isotopes in the same sample (used in dual-labelling experiments)
  - highly automated (hundreds of samples can be counted automatically and built-in computer facilities carry out many forms of data analysis, such as efficiency correction, graph plotting, radioimmunoassay calculations, etc.).

Disadvantages of scintillation counting

- cost of the instrument and cost per sample (for scintillation fluid, the counting vials and disposal of the organic waste)
- potentially high background counts; this is due to photomultiplier noise but can be compensated for by using more than one tube (noise is random, but counts from a radioactive decay are simultaneous, the coincident counts only are recorded)
- ‘quenching’: this is the name for reduction in counting efficiency caused by coloured compounds that absorb the scintillated light, or chemicals that interfere with the transfer of energy from the radiation to the photomultiplier (correcting for quenching contributes significantly to the cost of scintillation counting)
- chemiluminescence: this is when chemical reactions between components of the samples to be counted and the scintillation cocktail produce scintillations that are unrelated to the radioactivity; modern instruments can detect chemiluminescence and subtract it from the results automatically
- phospholuminescence: this results from pigments in the sample absorbing light and re-emitting it; the solution is to keep the samples in the dark prior to counting.