Chapter 10. Thermal properties of matter

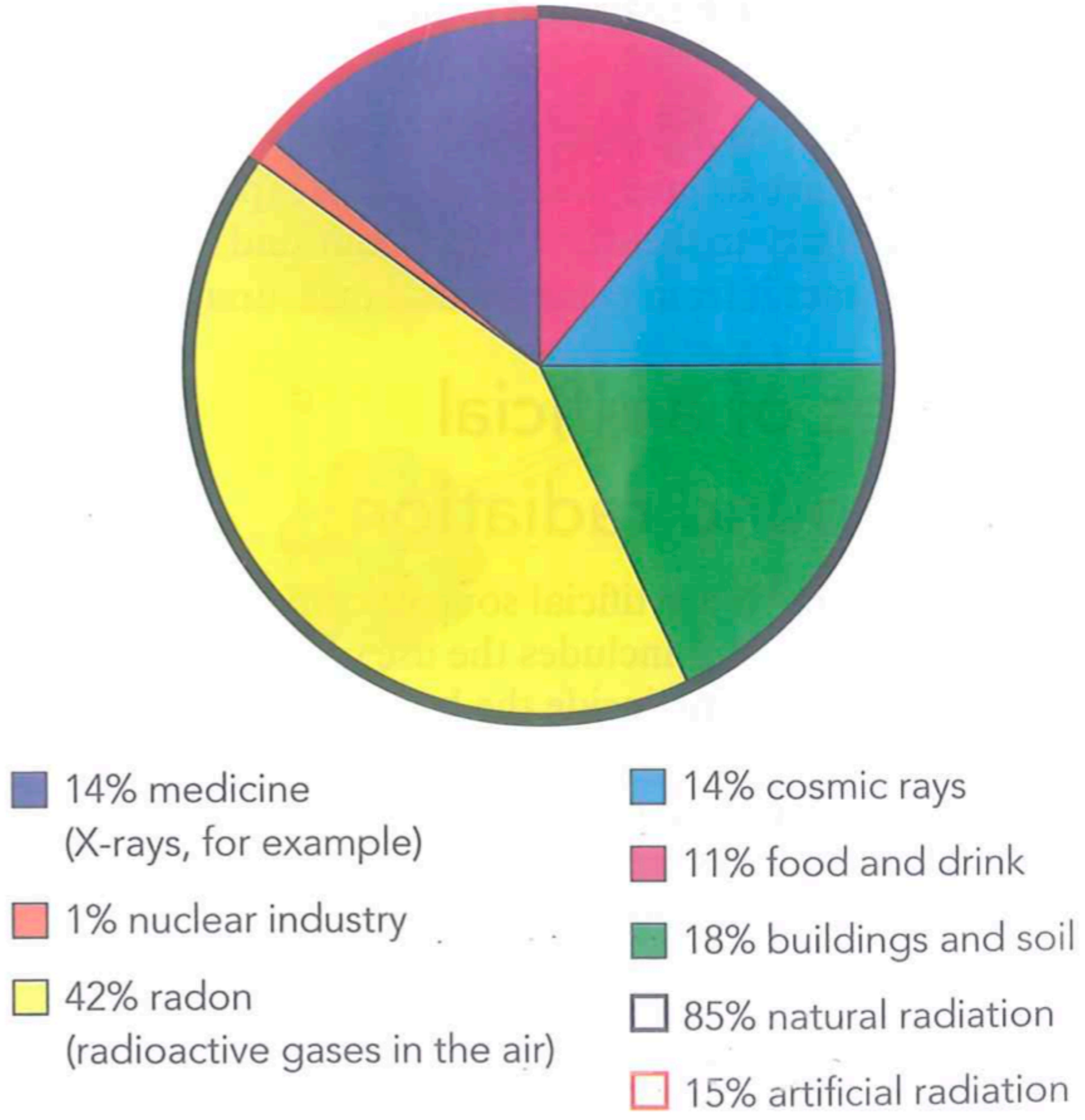
G2 | Ji Yutong | 04/2024

New Words

Radioactivity microbe

Radioactivity

Radioactivity all around us



Background radiation:
weak radiation that can be detected from external source is called background radiation

Natural:

A. Radon gas(in the air)
B. Rocks and buildings
C. Food and drink
D. Cosmic rays

Background radiation

Measurement of radiation: Geiger counter

Unit: counts/s or counts/min

The nuclear radiation enters the tube andionizes the gas inside, which leads to a high-voltage spark across the gas and a pulse of current in the circuit.

A ratemeter is connected to the GM tube to read the counts per second.

it matters how close the tube is to the radiation source

Figure 23.4: Using a Geiger counter to monitor radiation levels in crops.

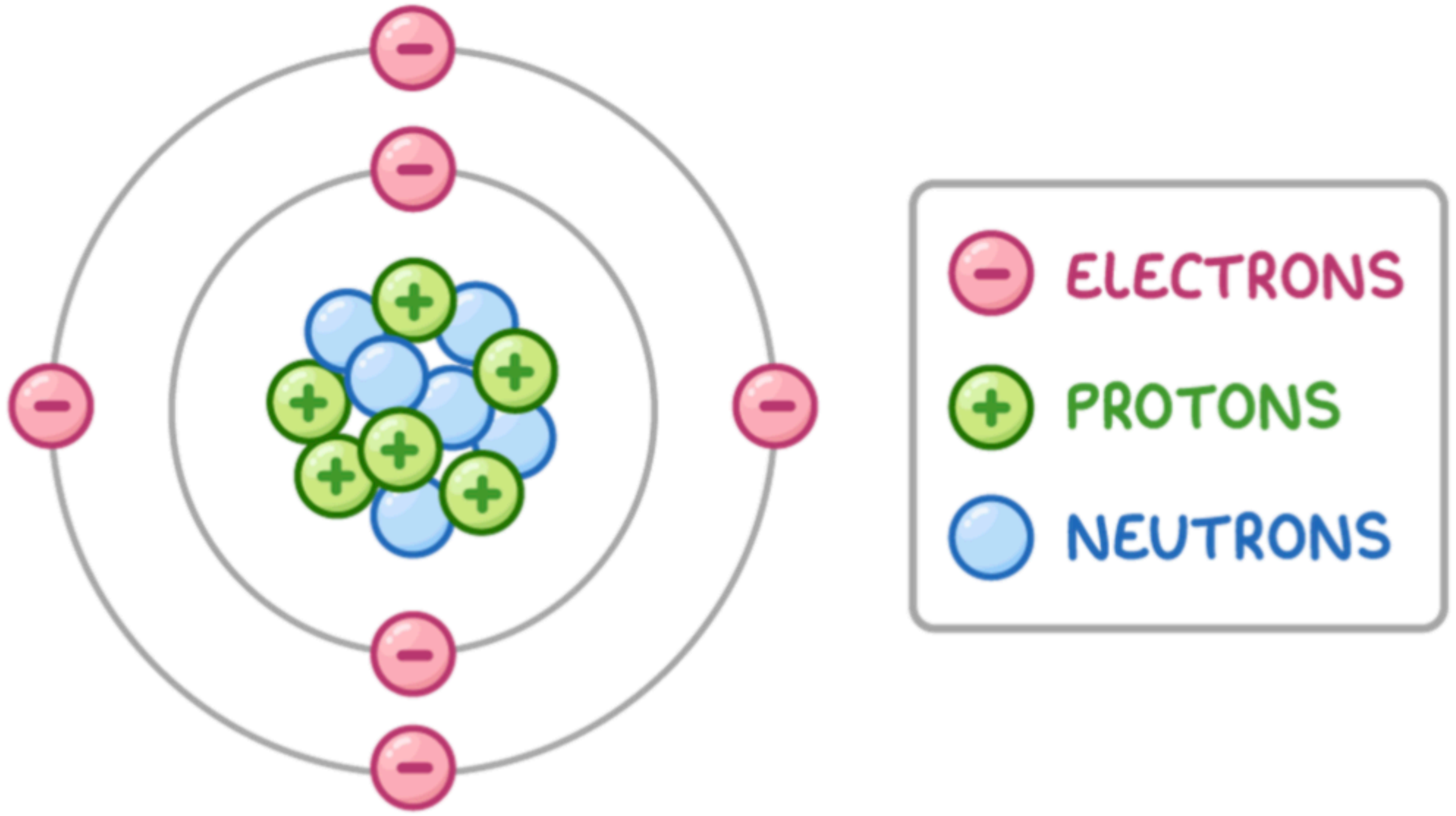
Radioactive Decay

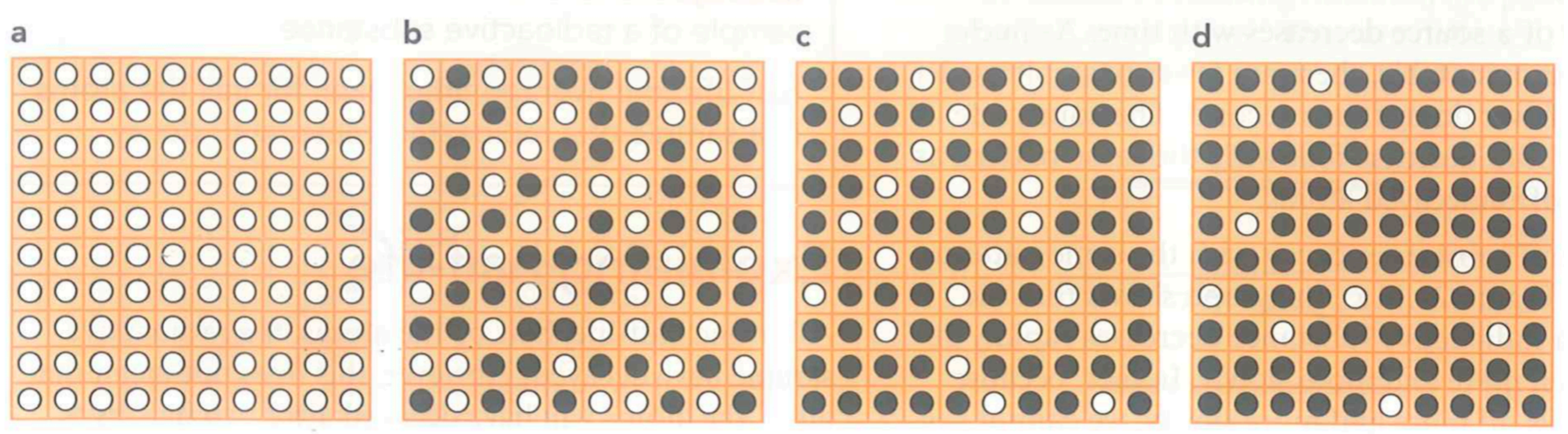
Radioactive decay：

An unstable nucleus will emit particles/radiation that carry energy away from the nucleus **randomly** and **spontaneously** to become more stable.

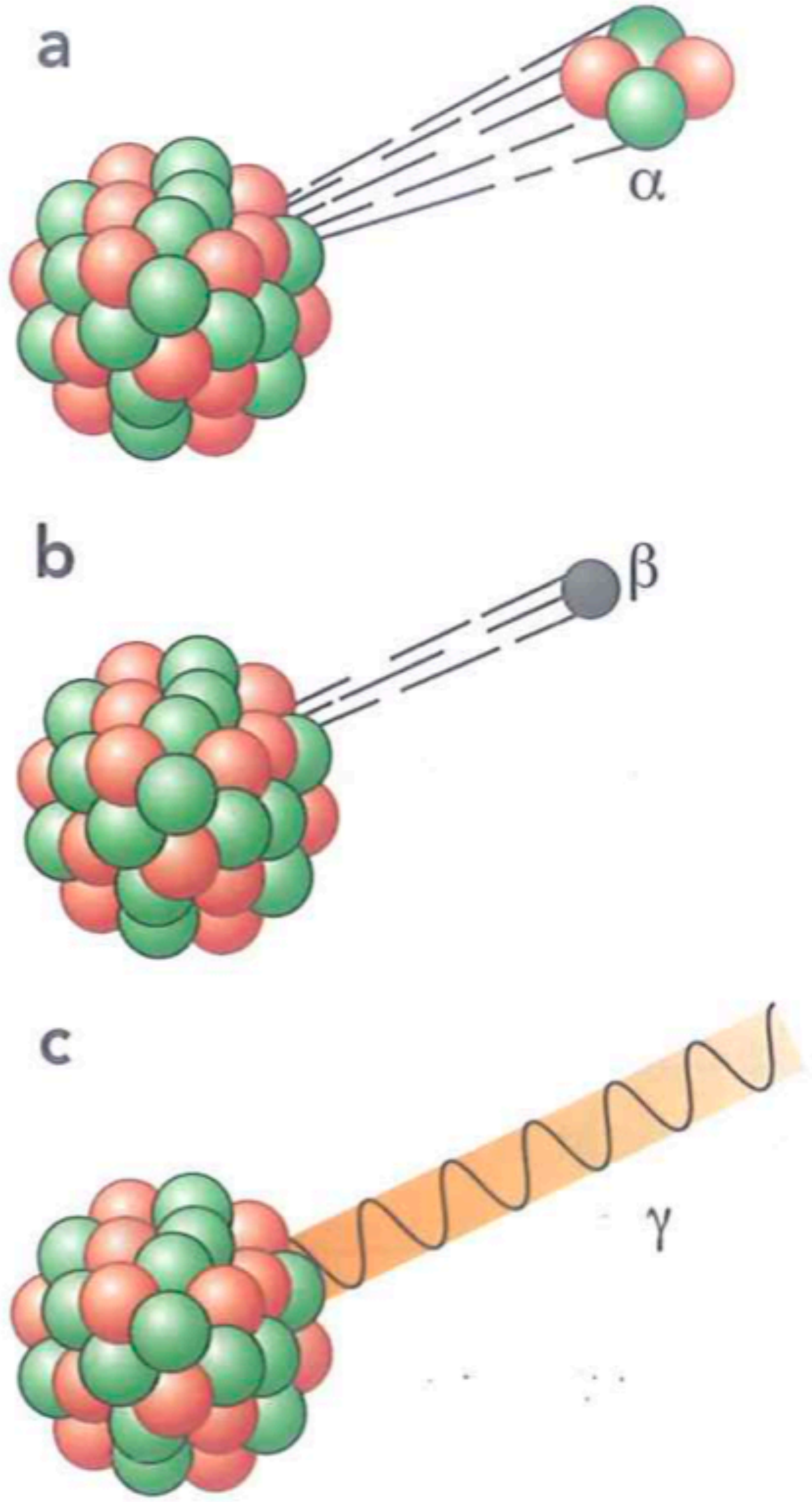
Random: cannot predict which unstable nucleus will decay or when it will decay

Spontaneous: the rate of decay of a given sample cannot be affected in any way, e.g. T



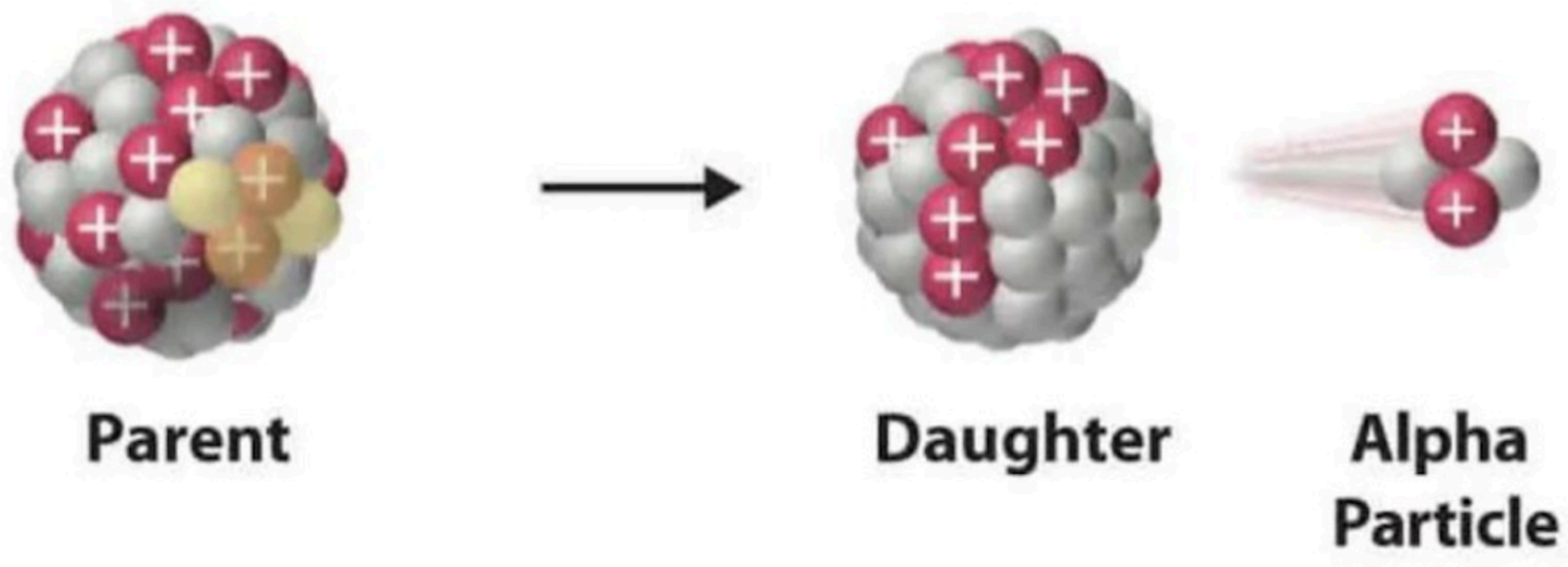


Three types of radiation:



Alpha Decay

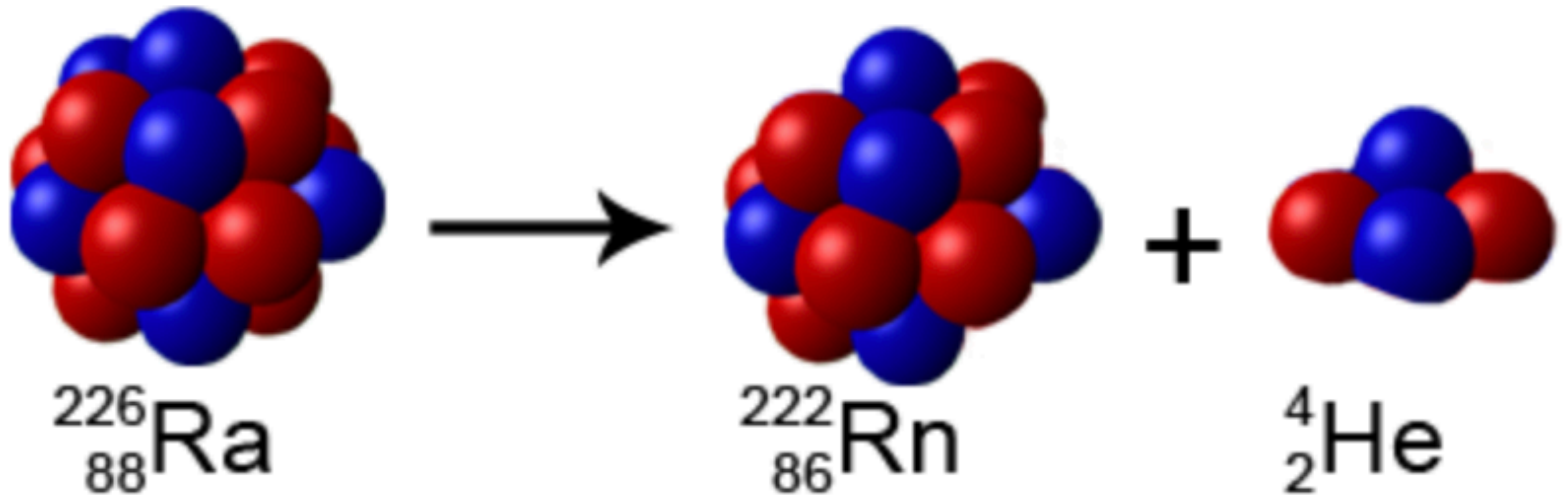
Alpha Decay: emits alpha particle(helium nucleus/ 2p + 2n)



Nucleon number, proton number, charge are conserved.

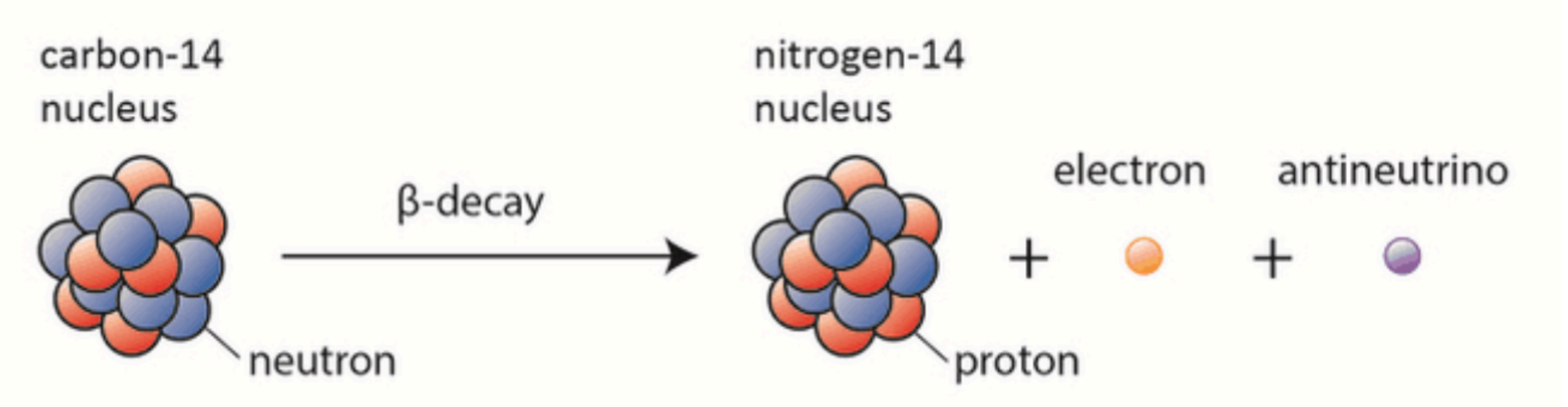
$$^{A}_{Z}X \rightarrow \, ^{A-4}_{Z-2}Y + \, ^{4}_{2}He$$

- A $\boxed{\text{new element}}$ is formed, with an atomic number 2 less than before, mass number is 4 less than before.



Beta decay(minus)

A neutron in decaying **nucleus** turns into a proton, emitting an electron(beta particle) (and an antineutrino).



A new element is formed, with an atomic number 1 more than before. The mass number is unchanged.

$$^{14}_{6}C \rightarrow \, ^{14}_{7}N + \, ^{0}_{-1}e + \text{energy}$$

$$^{1}_{0}n \rightarrow \, ^{1}_{1}p + \, ^{0}_{-1}e$$

Gamma radiation

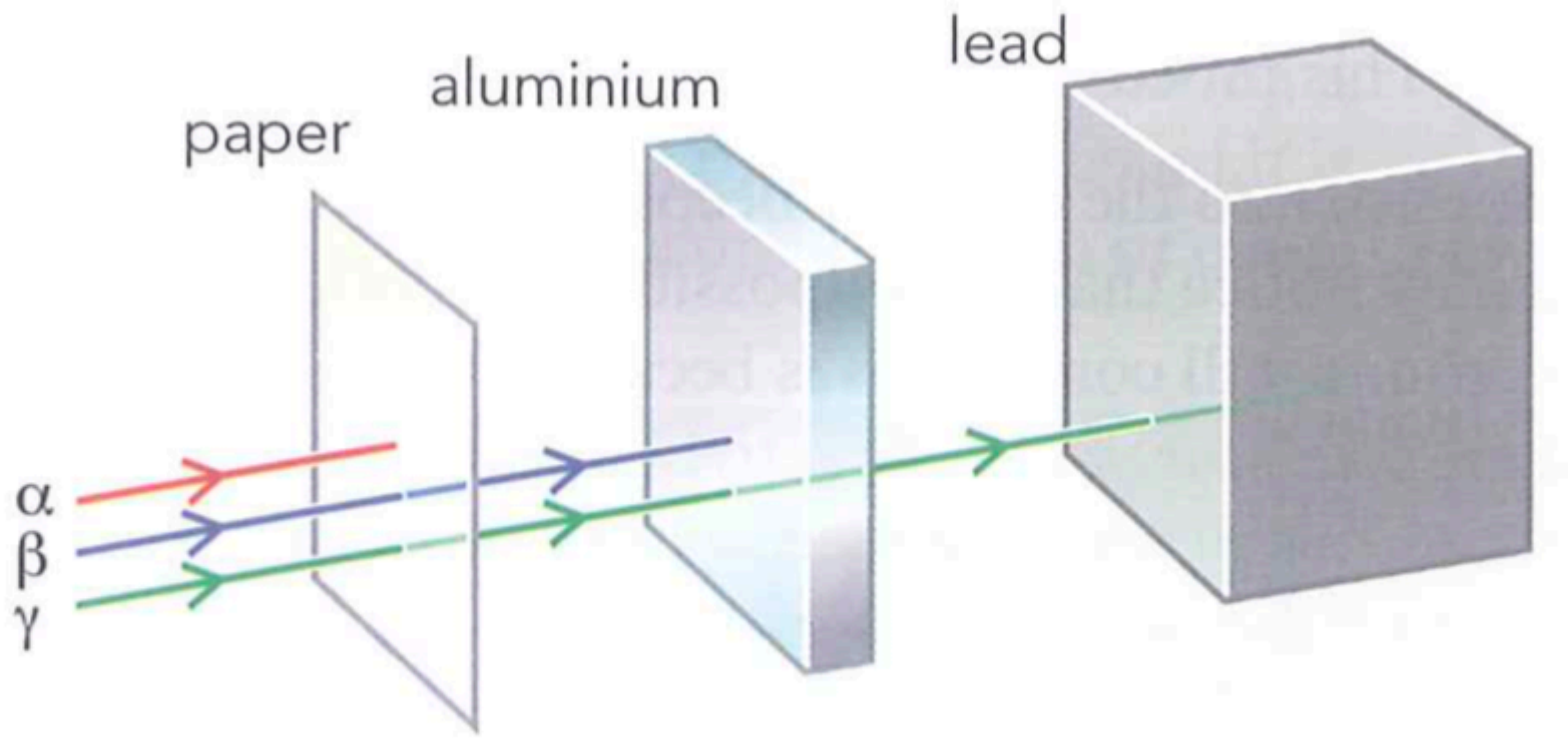
- release energy in the form of EM wave(gamma ray);
- no mass, no charge;
- along with alpha/beta decay.

Comparing three radiations.

Name	Symbol	Made of	Mass	Speed/m/s
alpha	α	2 protons + 2 neutrons	approx. (mass of proton) × 4	$\sim 3 \times 10^7$
beta	β	an electron	approx. (mass of proton) ÷ 1840	$\sim 2.9 \times 10^8$
gamma	γ	electromagnetic radiation	0	3×10^8

	Ionization:	Penetration:
highest:	Alpha (slowest, largest charge)	Gamma
lowest:	Gamma (fastest, no charge)	Alpha

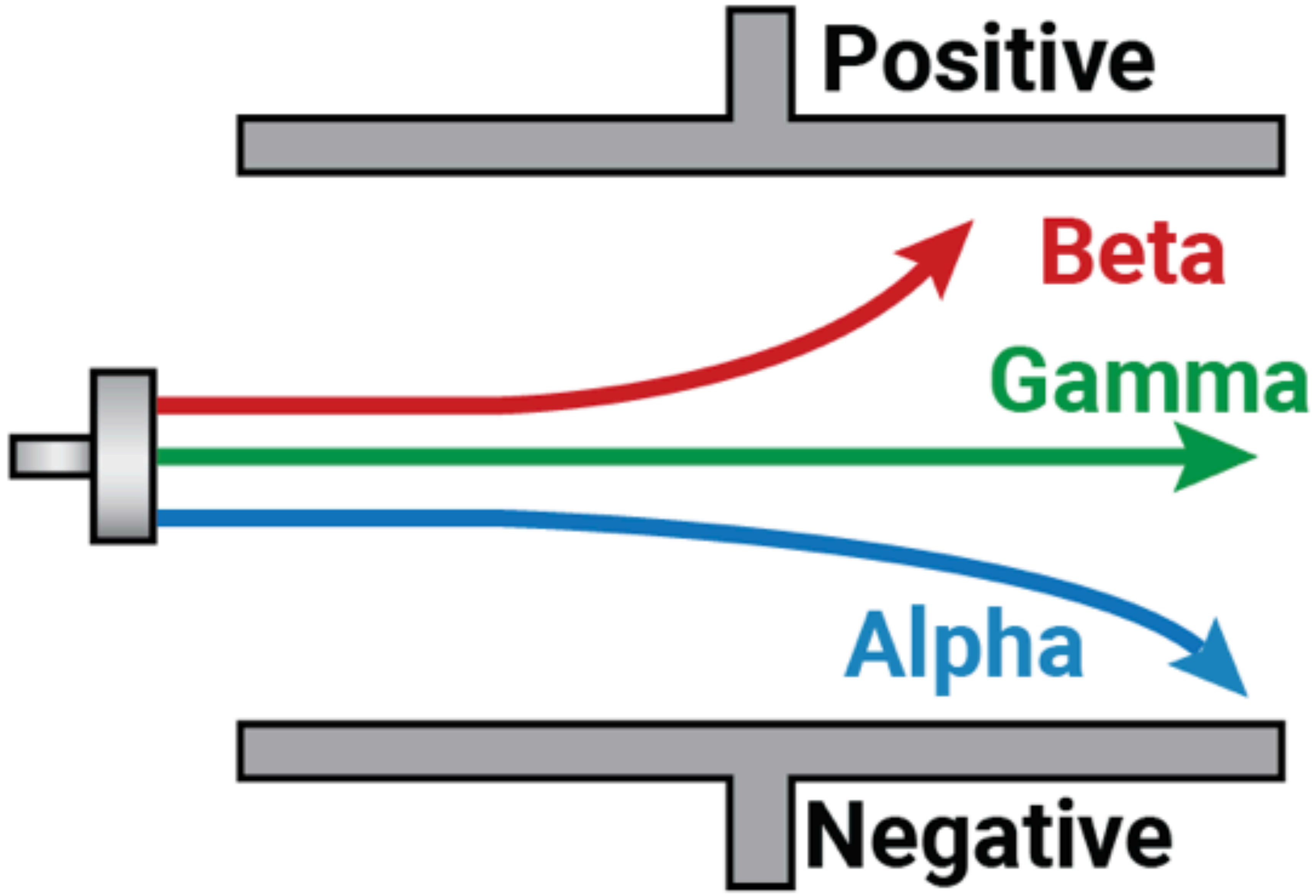
Comparing three radiations.

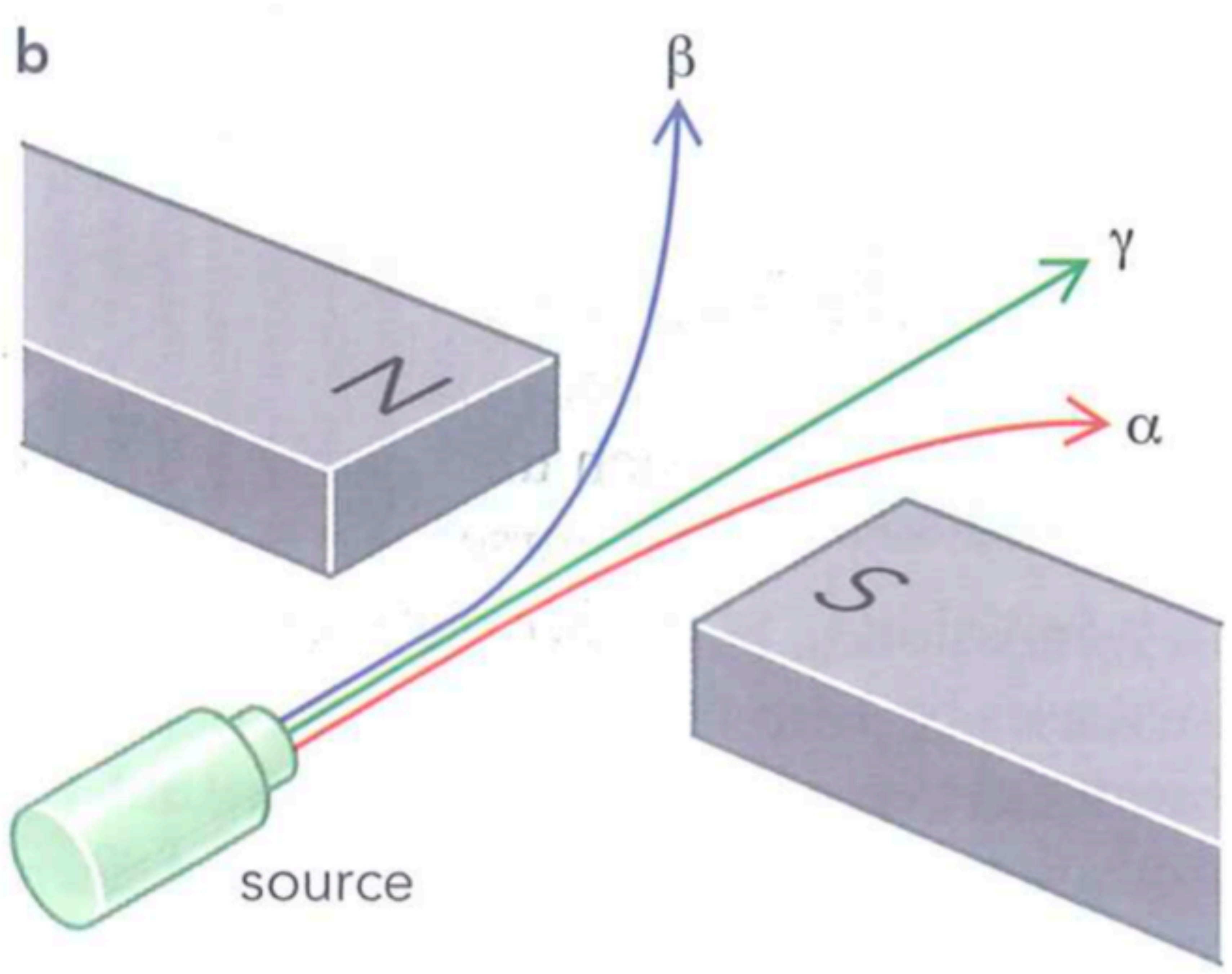


Emission	Composition	Range	Ionizing ability
α	a helium nucleus (2 protons and 2 neutrons)	low penetration, biggest mass and charge, absorbed by a few centimetres of air, skin or thin sheet of paper	very highly ionizing
β	high energy electrons	moderate penetration, most are absorbed by 25 cm of air, a few centimetres of body tissue or a few millimetres of metals such as aluminium	moderately highly ionizing
γ	very high frequency electromagnetic radiation	highly penetrating, most photons are absorbed by a few cm of lead or several metres of concrete few photons will be absorbed by human bodies	poorly ionizing – usually secondary ionization by electrons that the photons can eject from metals

Using Geiger counter at different distance with different blockers to differentiate three radiations.

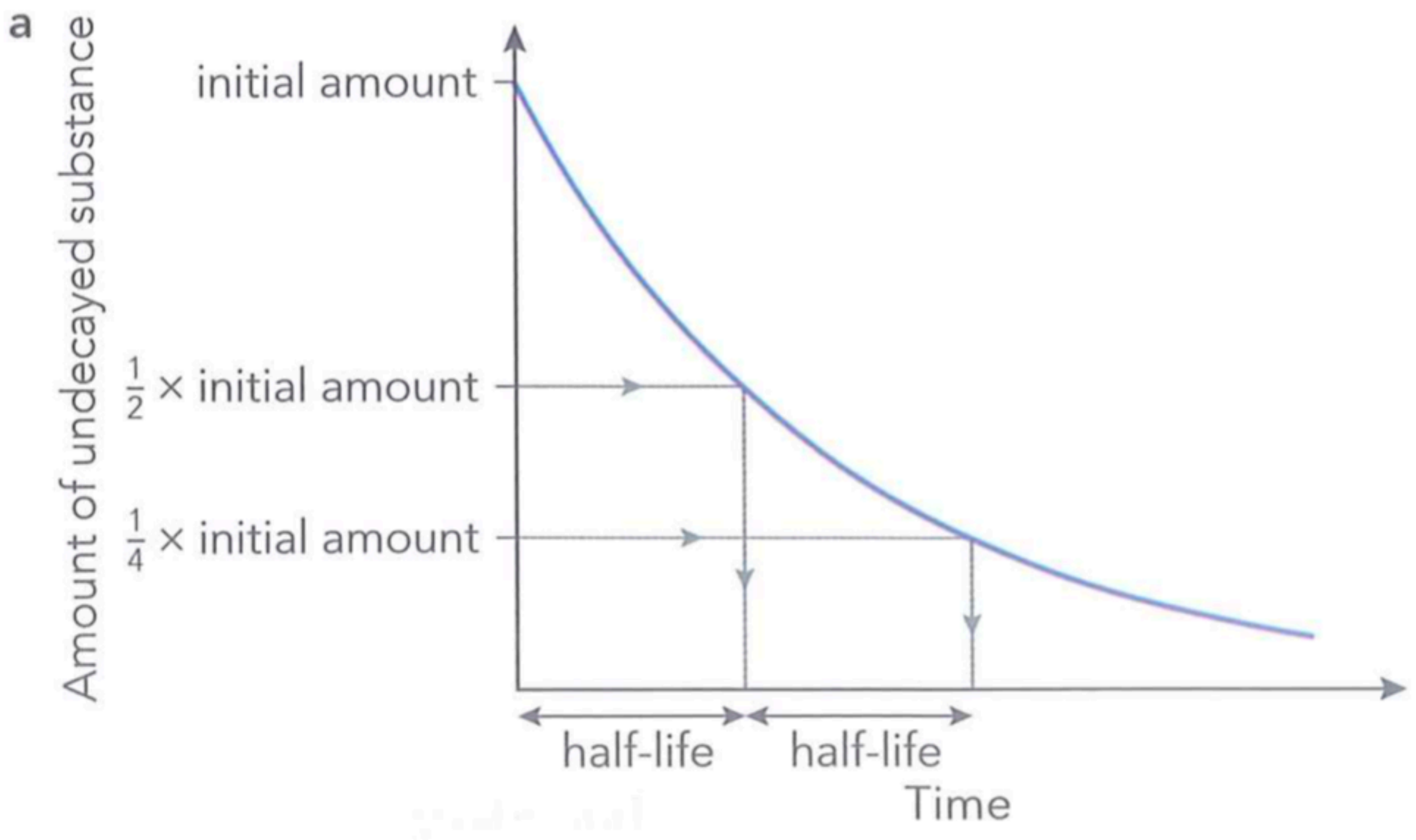
In Electric/Magnetic Field:

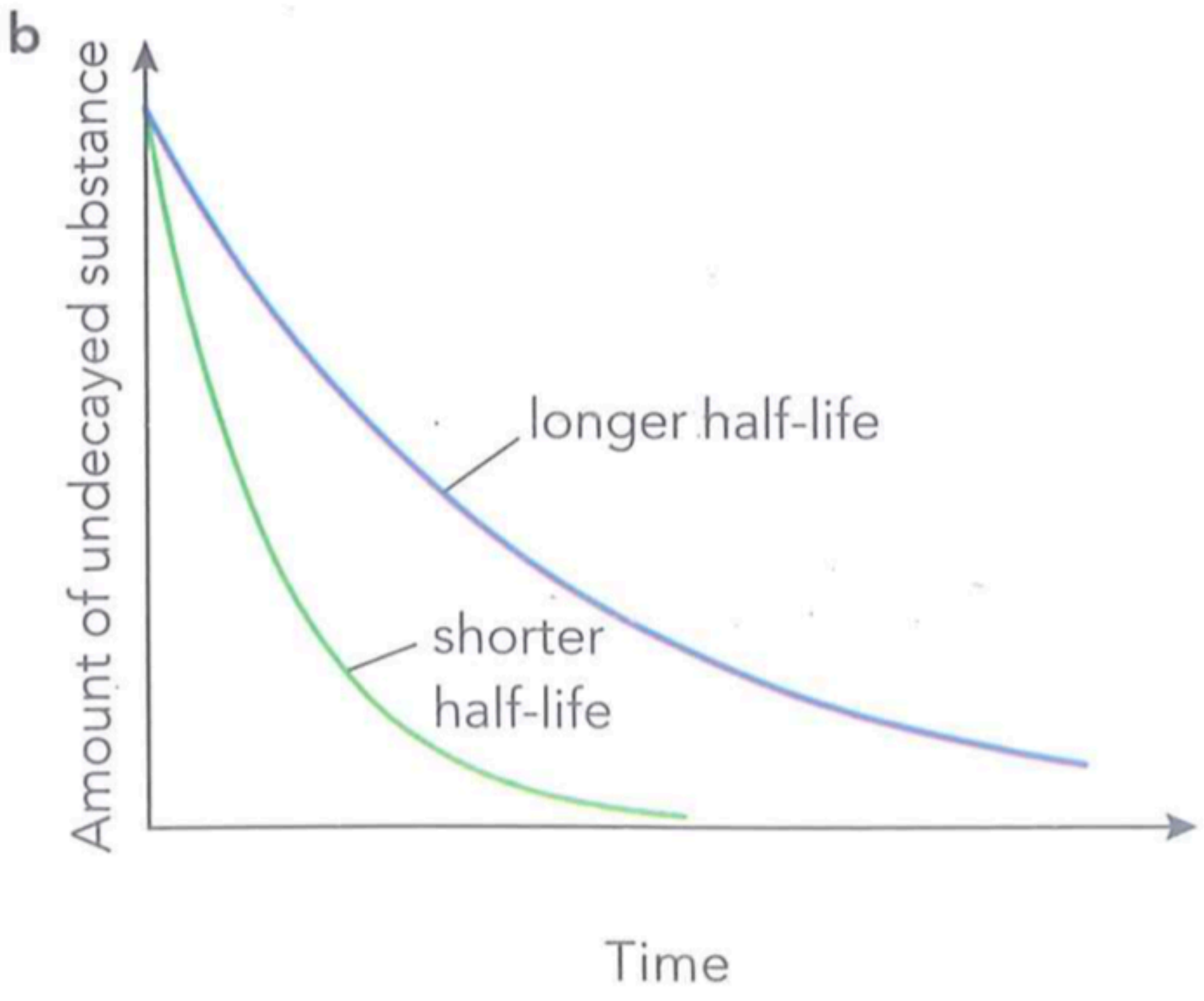




Activity and Half-life

half life: the time taken for half the nuclei to decay, or the time taken for the activity to halve.





Activity and Half-life

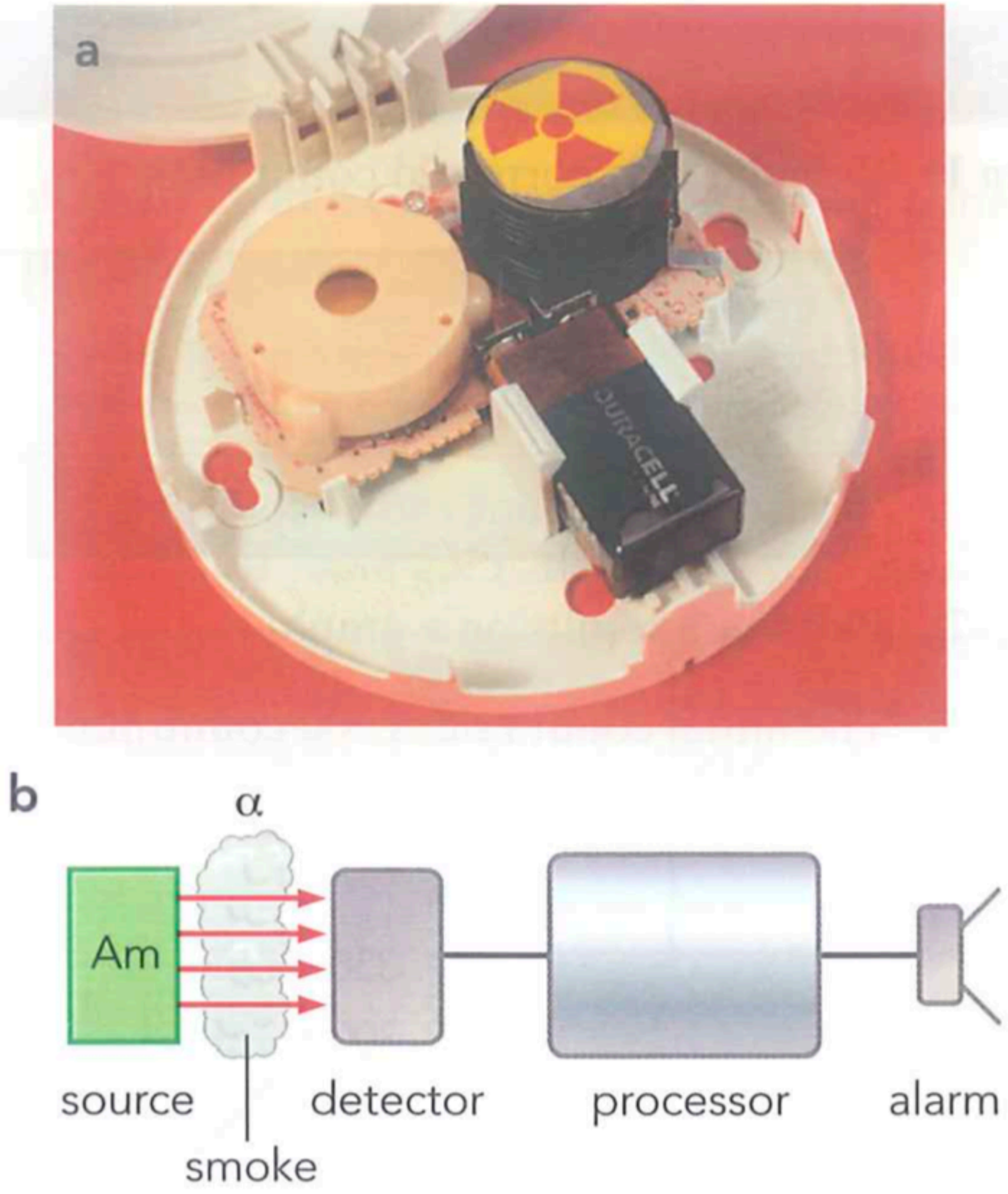
half life: the time taken for half the nuclei to decay, or the time taken for the activity to halve.

Time / min	0	10	20	30	40	50	60
Count rate / count/min	330	230	165	120	92	70	56
Corrected count rate / count/min	300	200	135	90	62	40	26

Corrected count rate = measured count rate - background count rate

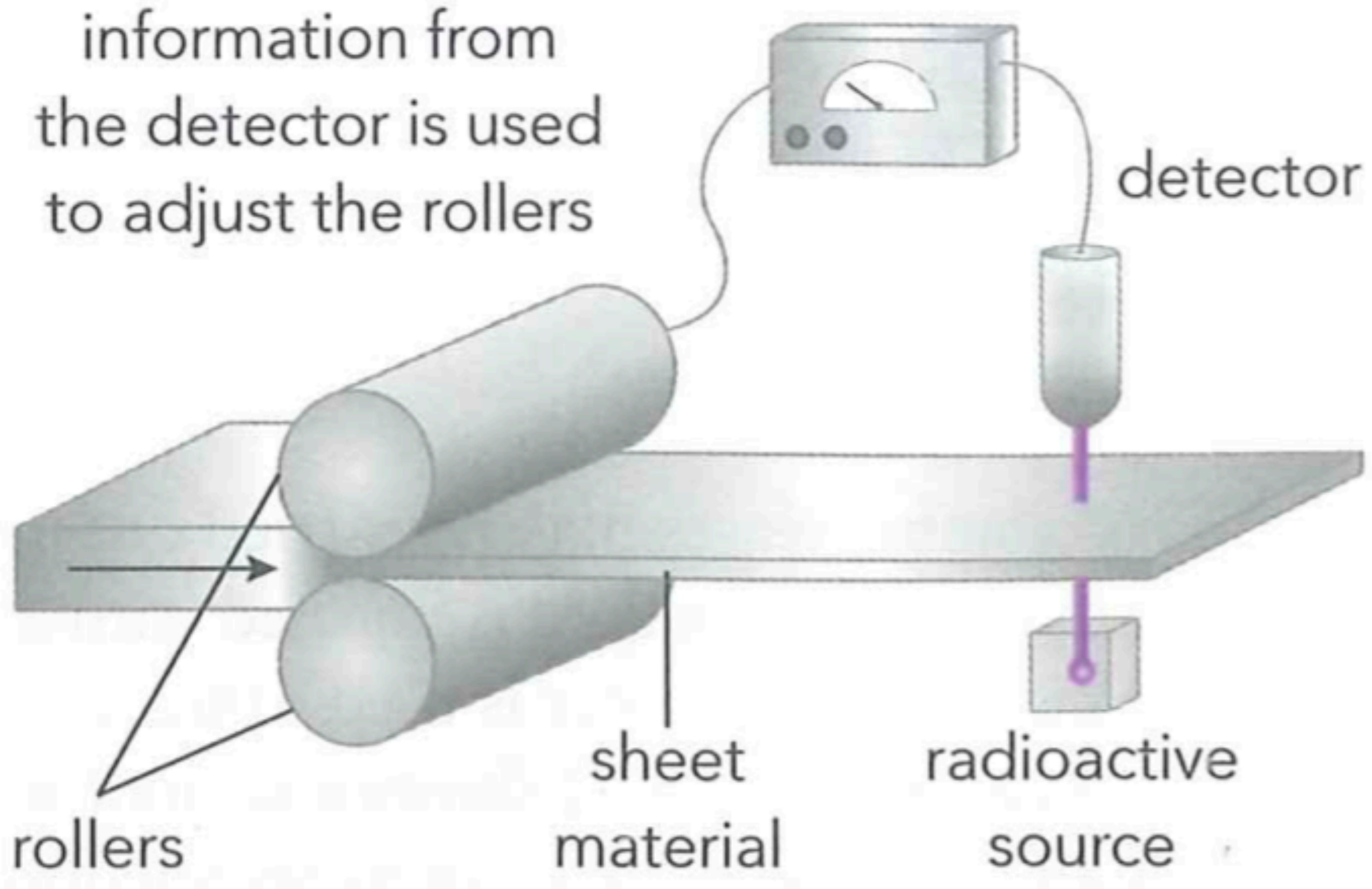
Background radiation has to be **subtracted** before attempting to perform half-life calculations!!!

Using Radioisotopes



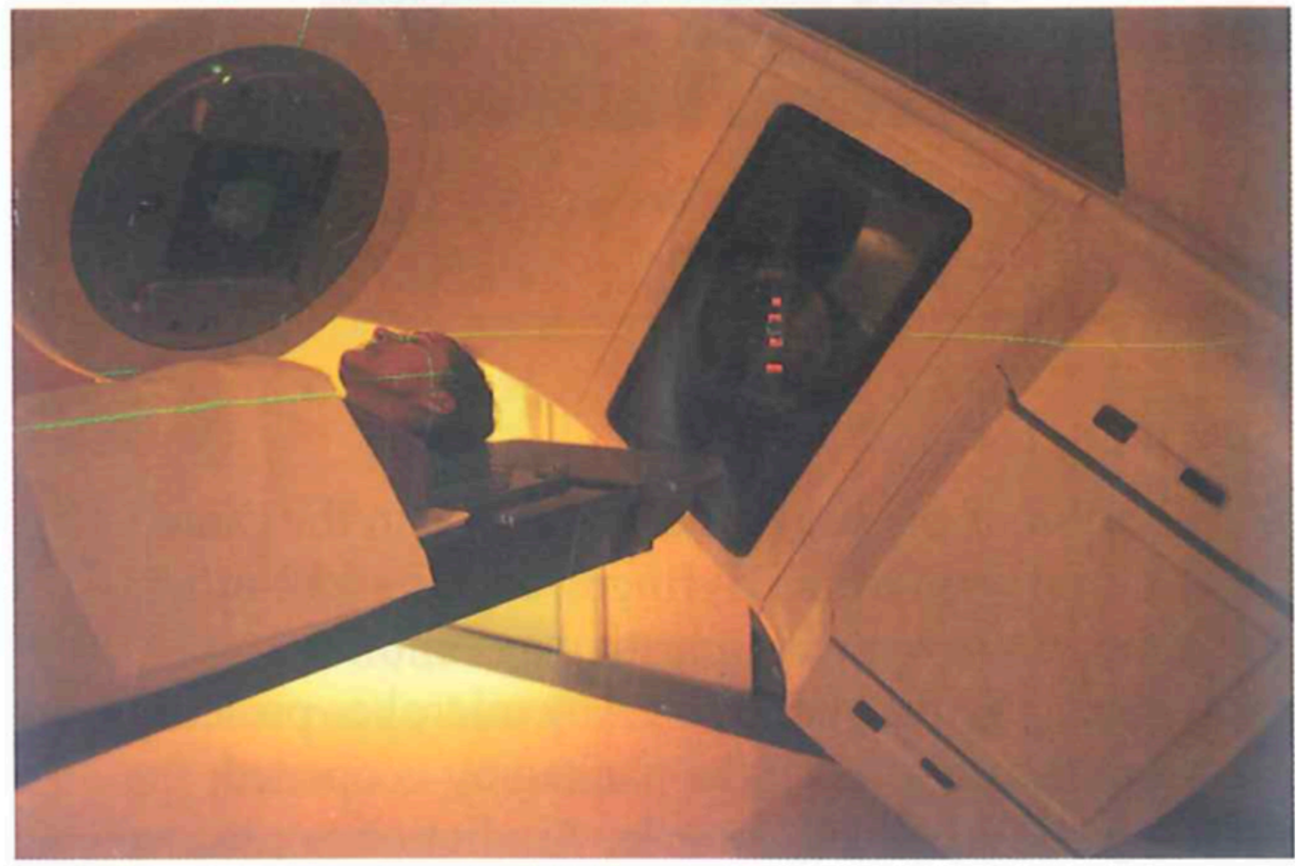
Smoke detectors

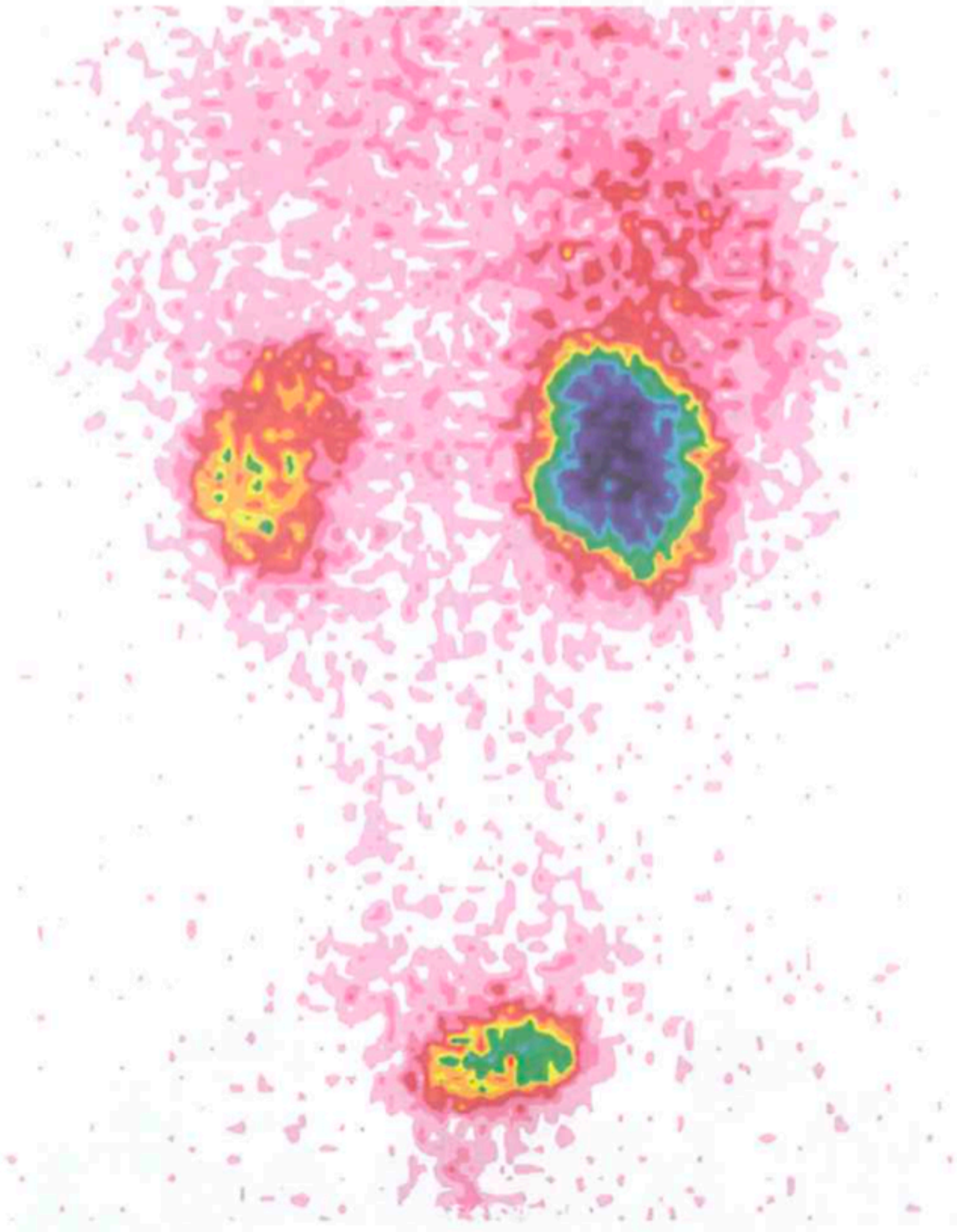
Using Radioisotopes



Thickness monitoring

Using Radioisotopes





Cancer treatment &
Diagnose

Using Radioisotopes

Food irradiation & Sterilization

Safety Measures

Exposure to radiation can destroy living cell membranes by ionisation, causing the cells to die, or damage DNA which causes mutations that could lead to cancer.

Safety measures include:

- Minimising the time of exposure to radiation. For example, radioactive tracers with a short half life should be used.

- Keeping as big a distance from the radioactive source as possible. They should be handled using tongs and held far away from people.

- Using shielding against radiation, such as the concrete shielding around a nuclear reactor. Radioactive sources must also be kept in a lead-lined box.