LESSON 5.2.2

Absorption, Ionising Radiation and Safety

Ionising radiation can remove electrons from atoms. The way it transfers energy determines its ionising effect, penetration and the protection required.

α ALPHA

Helium nucleus: 2 protons + 2 neutrons; charge +2e, mass about 4u.

Dense ionisation along a short track. Typical range in air: a few centimetres. Paper or the outer skin layer stops typical alpha particles.

β BETA

Fast electron (beta-minus) or positron (beta-plus); charge -e or +e.

Less dense ionisation and greater penetration than typical alpha radiation. Often travels metres in air; a few millimetres of aluminium or suitable plastic can stop many beta particles.

γ GAMMA

High-energy electromagnetic photon; zero charge and zero rest mass.

Ionises indirectly through secondary charged particles. Highly penetrating: lead or concrete reduces intensity. There is no sharp maximum range or single thickness that stops every photon.

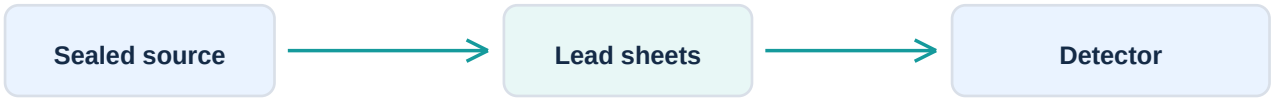
These are typical comparisons, not fixed ranges: particle energy and absorber material matter. Weak penetration does not imply low danger if a source enters the body.

Ionising power and penetrating power are different properties.

1 Core Practical 15: gamma absorption

Investigate how lead thickness changes the detected count rate, keeping source strength, alignment and source-detector distance constant.

FIXED GEOMETRY; CHANGE ONLY ABSORBER THICKNESS



Schematic beam path; not an apparatus construction plan.

A. Measure background.

With the source safely stored away, count for a suitable time and calculate the background rate.

B. Collect comparable readings.

Measure total lead thickness. Record counts over equal intervals for several thicknesses; repeat readings.

C. Correct and plot.

Subtract background from each count rate. Plot corrected rate against thickness, or use a log plot.

$$R = R_0 e^{-\mu x} \qquad x_{1/2} = \frac{\ln 2}{\mu}$$

R is the net count rate; its subscript 0 means no absorber. x is thickness and μ has units of inverse length, not inverse time. A narrow beam of one photon energy is the simplest exponential model; scattering can affect real readings.

WORKED EXAMPLE: BACKGROUND = 20 COUNTS PER MINUTE

Measured rates: 660 without lead; 180 after 24.0 mm of lead.

$$\text{Fraction transmitted} = \frac{180 - 20}{660 - 20} = \frac{1}{4}$$

Two half-thicknesses give 24.0 mm, so the half-thickness is 12.0 mm.

A half-thickness is a distance through an absorber. A half-life is a time for source activity to fall. Lead attenuates the beam; it does not change the source half-life.

2 Control exposure and contamination

Ionisation can damage cells and DNA. Risk depends on the radiation type, energy, absorbed dose, exposure duration and whether radioactive material enters the body.

IRRADIATION

Radiation reaches an object from an external source. Removing or shielding that source reduces the exposure. Ordinary alpha, beta or gamma irradiation does not itself deposit radioactive material.

CONTAMINATION

Radioactive material is on or inside an object or person. It can continue emitting radiation until it is removed or decays. Prevent inhalation, ingestion and entry through wounds.

1. TIME

Prepare the task before exposing the source. Keep exposure time as short as reasonably achievable.

2. DISTANCE

Use the approved handling tool and maximise distance. Never hold a source directly or point it towards people.

3. SHIELDING

Use shielding chosen for the radiation. Dense material attenuates gamma rays; suitable plastic is often used for beta shielding to limit bremsstrahlung.

Alpha radiation is strongly ionising but poorly penetrating: an alpha-emitter inside the body can be much more hazardous than the same source outside intact skin. Gamma radiation can reach internal tissue from outside.

SCHOOL PRACTICALS REQUIRE TRAINED SUPERVISION

Use only approved, intact sealed sources under the local risk assessment. Never open a source. Return it to designated secure storage after use. Follow local handling procedures; do not use this summary as permission to handle radioactive material.

Sources: Pearson IAL Physics p. 34 (137, 138, 140); Practical Guide, CP15.

US EPA: Radiation Basics; Protecting Yourself from Radiation.

Course lesson numbering. Next: nuclear fission, fusion and energy release.