Radioactivity and particles

Pearson Edexcel · International GCSE · Physics

The nucleus at work

Some nuclei are unstable: they throw out radiation at random, decay by half-lives, and – in reactors and stars – release energy by splitting or joining. This section covers atomic notation, the three ionising radiations with their penetrating powers, half-life calculations, the fission chain reaction, and why fusion lights the stars but not our power stations.

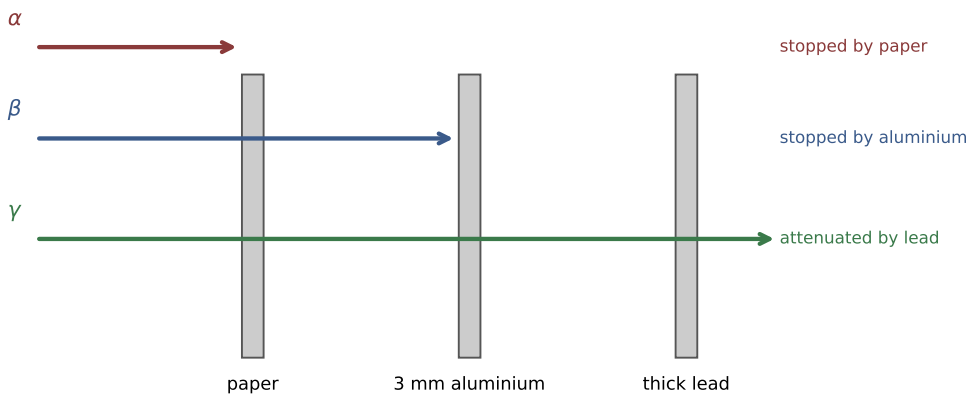
Edexcel International GCSE Physics 4PH1, Section 7 (statements 7.1–7.26). Units: becquerel (Bq), with time in s, min or h.

Radioactivity

An atom holds protons and neutrons in a nucleus; notation ${}^{A}_{Z}X$ gives **mass (nucleon) number** A and **atomic (proton) number** Z. **Isotopes** share Z but differ in neutrons.

Unstable nuclei emit – randomly – **alpha** α (helium nucleus, ${}^{4}_{2}\mathrm{He}$), **beta-minus** β^- (an electron, created as a neutron turns proton) and **gamma** γ (high-energy electromagnetic wave, no particles). Balancing: both **mass number and charge are conserved**.

Worked check. Carbon-14: ${}^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$ – A stays 14; charge $6 = 7 + (-1)$ ✓. Radon: ${}^{222}_{86}Rn \rightarrow {}^{218}_{84}Po + {}^{4}_{2}He$.

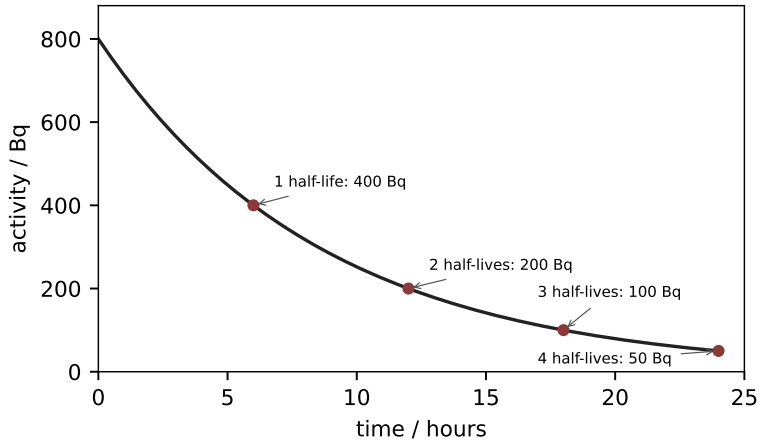


Alpha stopped by paper, beta by a few mm of aluminium, gamma attenuated by thick lead.

Radiation	Nature	Ionising	Range in air
alpha	2p + 2n	strongest	a few cm
beta	fast electron	medium	tens of cm
gamma	EM wave	weakest	metres

Detection: photographic film (badge) or a **Geiger–Müller tube**. **Background radiation** comes from rocks and cosmic rays (space), food, medical uses and fallout.

Activity (in becquerels; 1 Bq = 1 decay/s) falls steadily: the **half-life** is the time for half the undecayed nuclei to decay. **Worked check.** 800 Bq with half-life 6 h: after 24 h (4 half-lives) activity $= 800/2^4 = 50$ Bq.

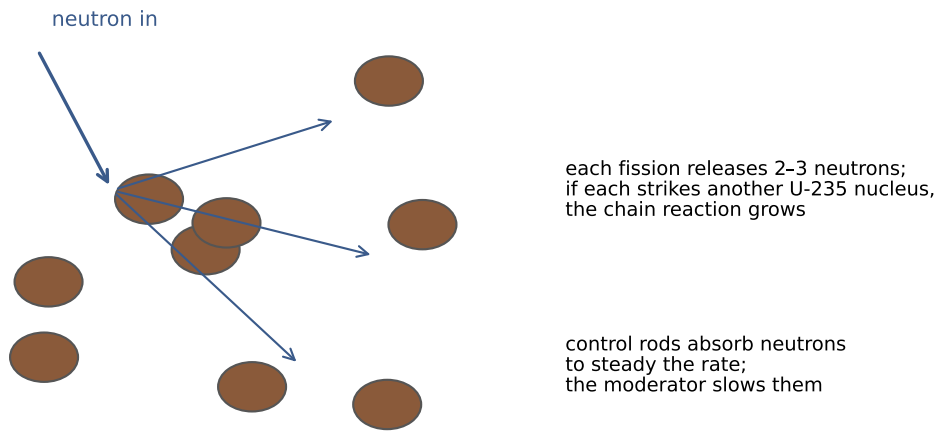


A decay curve halving every half-life, annotated at each halving.

Uses: medical tracers (short half-life, gamma), cancer treatment, sterilising, thickness control (beta through paper). **Contamination** (radioactive material on you – must be removed) differs from **irradiation** (exposure to radiation – stops when the source leaves). Dangers: mutation of DNA, cell and tissue damage; radioactive waste must be stored safely for its long half-lives.

Fission and fusion

Split a big nucleus or join two small ones – both release energy, and each powers a different machine.



Each fission releases neutrons that can strike further U-235 nuclei; control rods and moderator manage it.

Fission : a neutron strikes **U-235**, splitting it into **two radioactive daughter nuclei**, 2–3 neutrons and **kinetic energy** – and if those neutrons strike more U-235, a **chain reaction** runs. The **moderator** slows neutrons so they split nuclei efficiently; **control rods** absorb neutrons to hold the rate steady; **shielding** protects workers. **Fusion** joins small nuclei into a larger one, converting mass to energy – the Sun's source. Fusion needs enormous temperature and pressure because **positively charged protons electrostatically repel** – the nuclei must collide fast enough to overcome that repulsion.

Check yourself

1. In $^{19}_{9}F$, state the numbers of protons, neutrons and electrons in the neutral atom.
2. Name the three ionising radiations and their natures.
3. Write the full equation for alpha decay of $^{226}_{88}Ra$.
4. Which radiation is stopped by paper, and which passes through aluminium?
5. Give two sources of background radiation.
6. Define half-life.
7. A source of 3200 Bq has half-life 8 days. Find its activity after 32 days.
8. State the difference between contamination and irradiation.
9. Name the roles of the moderator, control rods and shielding in a reactor.
10. Why does fusion need such high temperatures?

Answers: 1 9 protons, 10 neutrons, 9 electrons; 2 alpha – helium nucleus (2p+2n); beta-minus – fast electron; gamma – high-energy electromagnetic wave; 3 $^{226}_{88}Ra \rightarrow$ $^{222}_{86}Rn + ^{4}_{2}He$; 4 alpha stopped by paper; gamma passes aluminium (needs thick lead); 5 any two: rocks/building materials, cosmic rays, food/drink, medical, radon gas, nuclear fallout; 6 the time taken for half the undecayed nuclei (or the activity) to decay; 7 32 days = 4 half-lives: 3200 $\rightarrow$ 1600 $\rightarrow$ 800 $\rightarrow$ 400 $\rightarrow$ 200 Bq; 8 contamination – radioactive material stuck to you, hazard remains until removed; irradiation – exposure to radiation from a source, ends when the source is removed; 9 moderator slows neutrons for efficient fission; control rods absorb neutrons to control the rate; shielding absorbs escaping radiation to protect workers; 10 the positively charged protons of two nuclei repel electrostatically, so nuclei must collide at enormous speed – only reached at very high temperature and pressure – to get close enough to fuse.