Nuclear physics

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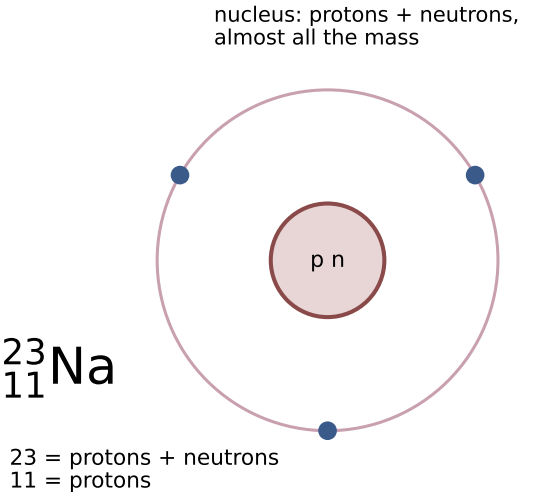
The nucleus is a millionth of the atom yet holds nearly all its mass – and unstable nuclei pour out energy as radiation, fission fragments, or the fusion that lights the stars. OxfordAQA's seventh topic covers the nuclear model, the three radiations, half-life, contamination versus irradiation, reactors and (P) fusion.

OxfordAQA International GCSE Physics 9203, topic 3.7 (Version 5.1). Statements marked (P) are Paper-2-only.

Atomic structure

An atom is about $\mathbf{10^{-10}}$ **m** across: a tiny positive nucleus (protons and neutrons, nearly all the mass) with electrons around it – Rutherford's **alpha-scattering** evidence for the concentrated nucleus. Proton mass 1 charge +1; neutron mass 1 charge 0; electron charge −1, negligible mass. A neutral atom has equal protons and electrons; atoms lose or gain electrons to become **ions**.

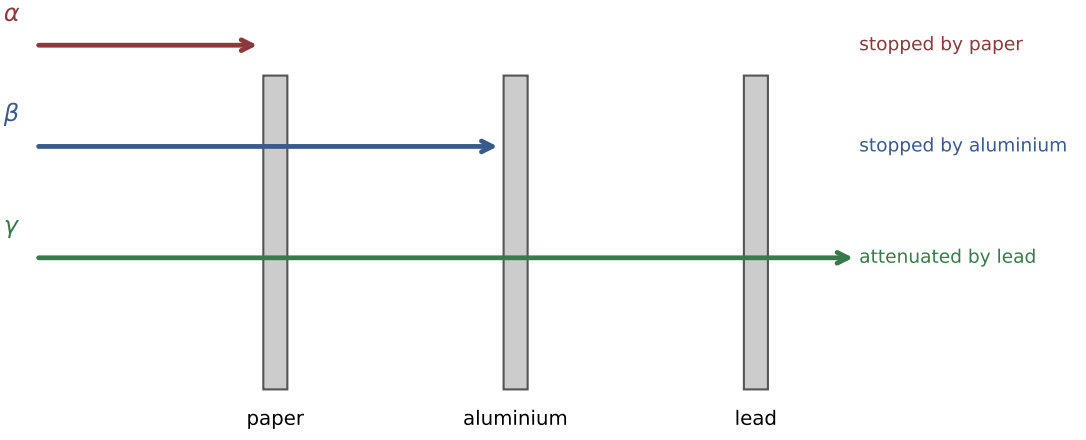


$^{A}_{Z}X$: A = mass number (protons + neutrons), Z = proton number; isotopes share Z and differ in neutrons.

Ionising radiation from the nucleus

Unstable nuclei decay **randomly**, unaffected by chemistry or physics, emitting:

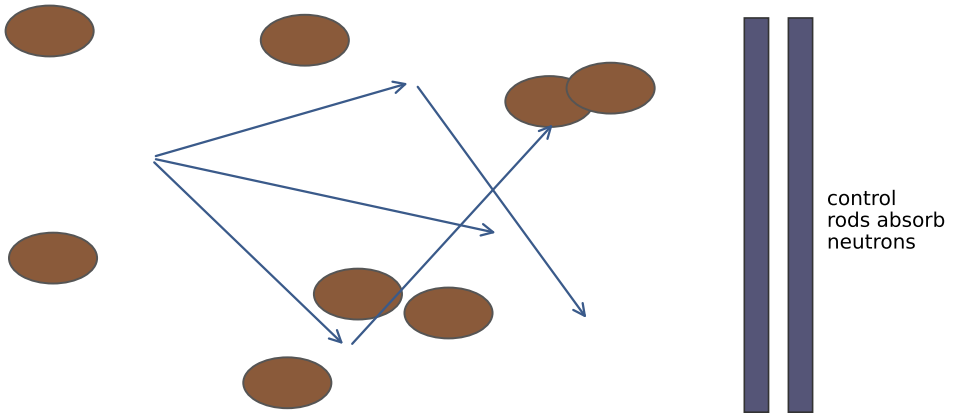
Radiation	Nature	Ionising	Range in air
alpha	2p + 2n (helium nucleus)	strongest	a few cm
beta-minus	fast electron (neutron → proton)	medium	tens of cm
gamma	electromagnetic wave	weakest	metres



Nuclear equations conserve mass number and charge: ${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$ (alpha); ${}^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$ (beta). **Background radiation** comes from rocks, space, food and medical devices. (P) The **half-life** is the time for half the nuclei (or half the count rate) to decay – most unstable nuclei have short half-lives; the least unstable last millennia. **Contamination** (radioactive atoms on you) is a lasting hazard; **irradiation** exposes without making you radioactive. Dangers: mutations, cell and tissue damage.

Nuclear fission and (P) fusion

Fission splits a large unstable nucleus: **U-235** or **Pu-239** absorbs a neutron, splits into two smaller nuclei with 2–3 neutrons and far more energy than any chemical reaction. Neutrons striking further nuclei give a **chain reaction**; in a reactor **control rods** absorb neutrons to hold one fission per neutron.



one fission: U-235 + n → 2 nuclei + 2-3 n + energy

Radioactive waste stays dangerous for times set by its half-life – a managed-disposal cost of nuclear power. (P) **Fusion** joins two light nuclei into a heavier one, converting mass to energy: it powers the stars, but positive nuclei repel, so it needs **extreme temperature and pressure**.

Check yourself

1. Give the relative masses and charges of the proton, neutron and electron.
2. In $^{19}_{9}F$, how many protons and neutrons?
3. What did alpha scattering reveal about the atom?
4. Name the three radiations and their natures.
5. Which radiation is stopped by paper, and which penetrates aluminium?
6. Balance the alpha decay of $^{226}_{88}Ra$.
7. (P) Define half-life.
8. (P) Explain the difference between contamination and irradiation.
9. What do control rods do in a reactor?
10. (P) Why does fusion need extreme temperatures?

Answers: 1 proton 1/+1; neutron 1/0; electron negligible/−1; 2 9 protons, 10 neutrons; 3 mass and positive charge concentrate in a tiny nucleus – most alphas pass, a few bounce; 4 alpha – helium nucleus; beta – fast electron; gamma – EM wave; 5 alpha; gamma (needs thick lead); 6 $^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$; 7 (P) the time for half the nuclei (or the count rate) to halve; 8 (P) contamination – radioactive material on you, a hazard until removed; irradiation – exposure to radiation, ending when the source leaves; 9 absorb neutrons, holding the chain to one fission per neutron – steady; 10 (P) positive nuclei repel; they must collide at enormous speed to fuse.