

Radioactive decay and nuclear radiation

4.4.2.1 · Atomic structure · revision notes

Why some nuclei are unstable, what alpha, beta, gamma and neutron radiation are, and how alpha, beta and gamma compare in penetration, range in air and ionising power.

Expect recall, 'compare' questions, and 'explain which radiation is best for a use' questions.

Key facts

- Activity = decays per second, unit becquerel (Bq)
- Count rate = decays recorded per second by a detector
- Alpha α = 2 protons + 2 neutrons (helium nucleus), charge +2
- Beta β = high-speed electron from the nucleus (neutron $\rightarrow$ proton), charge -1
- Gamma γ = electromagnetic radiation from the nucleus, no mass, no charge
- Absorbed by: α paper; β a few mm aluminium; γ reduced by thick lead or concrete
- Range in air: α a few cm; β about 1 m; γ very far
- Ionising power: $\alpha > \beta > \gamma$

Notes

Radioactive decay

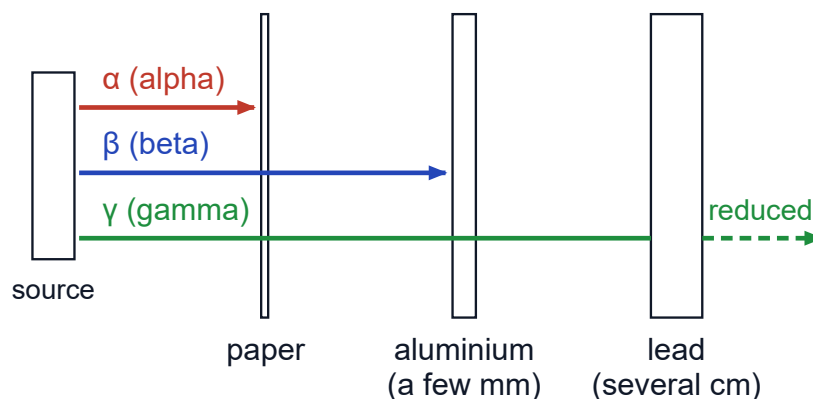
- Some atomic nuclei are **unstable**. The nucleus gives out radiation as it changes to become more stable. This is **radioactive decay**.
- Decay is **random**: you cannot predict which nucleus will decay next, or when.
- Activity** is the rate at which a source of unstable nuclei decays. It is measured in **becquerels (Bq)**: 1 Bq = 1 decay per second.
- Count rate** is the number of decays recorded each second by a detector, such as a **Geiger–Müller tube**.

Types of nuclear radiation

- Alpha particle (α)**: two protons and two neutrons, the same as a helium nucleus. Relative charge +2.
- Beta particle (β)**: a high-speed electron ejected from the nucleus when a neutron turns into a proton. Relative charge -1 .
- Gamma ray (γ)**: electromagnetic radiation from the nucleus. No mass and no charge.
- Neutron (n)**: some nuclei emit a neutron. It has no charge.

Comparing alpha, beta and gamma

- Penetration: alpha is stopped by a sheet of paper or the outer layer of skin; beta by a few millimetres of aluminium; gamma is only reduced by several centimetres of lead or thick concrete.

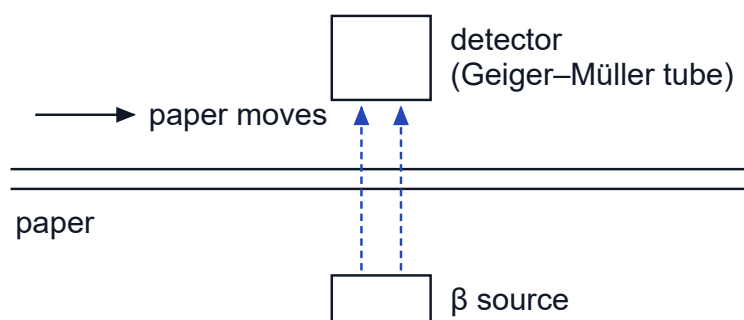


What stops each type of radiation.

- Range in air: alpha travels a few centimetres; beta about a metre; gamma a very long way.
- Ionising power: alpha is strongly ionising, beta is less ionising, gamma is weakly ionising.

Choosing a source for a use

- Smoke alarms use alpha: it strongly ionises the air inside the alarm, so a small current flows. Smoke absorbs the alpha particles, so the current falls and the alarm sounds. Alpha's short range keeps it inside the alarm.
- Thickness gauges for paper use beta: some passes through, and the amount changes when the thickness changes. Alpha would all be absorbed; gamma would nearly all pass through whatever the thickness.



Thickness gauge: if the paper gets thicker, more beta is absorbed and the count rate falls.

- Sterilising medical equipment uses gamma: it passes through the packaging and kills microorganisms.

How to answer each type of question

Identify a radiation from absorption data

2 marks

Grade 5

1. See which material stops the radiation (count rate falls to background).
2. Match it: paper → alpha; a few mm of aluminium → beta; only thick lead reduces it → gamma.
3. Quote the evidence from the question as your reason.

Example. A radioactive source emits one type of radiation. A sheet of paper placed in front of the source does not change the count rate. A 3 mm sheet of aluminium reduces the count rate to the background level.

Which type of radiation does the source emit? Give a reason for your answer.

Model answer. Beta (1). It passes through paper but is absorbed by 3 mm of aluminium (1).

Describe what each radiation is

1 to 3 marks

Grade 5

1. Alpha: say what particles it is made of.
2. Beta: say it is an electron AND that it comes from the nucleus.
3. Gamma: say it is electromagnetic radiation from the nucleus.

Example. (a) Describe the structure of an alpha particle. (1 mark)

(b) Describe how a beta particle is produced. (2 marks)

Model answer. (a) Two protons and two neutrons (1)

(b) A neutron in the nucleus changes into a proton (1) and a high-speed electron is ejected from the nucleus (1).

Don't lose marks

- ✗ Saying beta particles are electrons from outside the nucleus. They are created in the nucleus.
- ✗ Saying gamma is 'stopped' by lead. Thick lead greatly reduces it, but some still gets through.
- ✗ Confusing activity (decays per second in the source) with count rate (what the detector records).
- ✗ Saying gamma rays have mass or charge. They are electromagnetic waves.
- ✗ In 'best source' questions, only explaining why the chosen one works, and not why the others do not.

More tips

Memory tricks

- **PAL:** Paper stops alpha, Aluminium stops beta, Lead reduces gamma.
- Ionising power and range go opposite ways: the most ionising (alpha) travels the least far.
- Alpha is heavy with a +2 charge, so it ionises everything it passes and is stopped quickly.
- Beta is an electron, but it is made in the NUCLEUS, not taken from the electron shells.

Exam technique

- Use comparatives in 'compare' questions, e.g. 'alpha is more ionising than beta'.
- Quote data from the question, such as the thickness of material or count rates, in your answer.
- Give activity in Bq and name the detector (Geiger–Müller tube) if asked how radiation is measured.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3

Name the types of nuclear radiation

Alpha particles (α), beta particles (β), gamma rays (γ) and neutrons (n).

Grade 4

Define radioactive decay and activity

Unstable nuclei give out radiation to become more stable; activity is decays per second, in becquerels (Bq).

Grade 4

State what absorbs each radiation

Alpha: paper; beta: a few mm of aluminium; gamma: reduced by thick lead or concrete.

Grade 5

Describe what each radiation is

Alpha: 2 protons and 2 neutrons; beta: a fast electron from the nucleus; gamma: electromagnetic radiation.

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