

Exercise walk-through

4.6

Uses of nuclear radiation; choosing half-lives (4.4.3.2–4.4.3.3)

AQA · GCSE · Physics

Classify background sources and dose factors

Natural sources	Man-made contributions
Radon from rocks; cosmic rays; food and the body.	Medical uses; fallout from weapons testing or nuclear accidents.

Use the evidence

Location (rock type, altitude) and occupation affect dose. Dose is measured in sieverts: $1000 \text{ mSv} = 1 \text{ Sv}$.

Your turn: subtract background first

Your turn

Teacher-written detector task: background is 48 counts/s. With a sample the reading is 88 counts/s initially and 68 counts/s after 12 hours. Geometry is unchanged.

- A. Find both net count rates.
- B. Use the corrected values to determine the half-life.
- C. Can these readings alone establish the source activity in Bq?

Use corrected rates and keep the unit honest

- 1 Subtract** $R_{\text{net}} = R_{\text{measured}} - R_{\text{background}}$: initially $88 - 48 = 40$ counts/s; later $68 - 48 = 20$ counts/s.
- 2 Halving** The net rate halves once in 12 hours, so the half-life is 12 hours.
- 3 Limit** The net count rate is detector counts per second. Source activity in Bq would require further information about detection efficiency.

Compare half-lives with the amount stated

Your turn

AQA June 2025 Q07.5 [2 marks]: a sample contains equal numbers of Po-209 and Po-210 atoms. Their half-lives are 125 years and 138 days respectively.

- A. Which isotope has the lower activity?
- B. Explain using its half-life and the equal numbers of atoms.
- C. Extra teacher check: could you rank activities if the isotope amounts were unknown?

Explain the activity comparison without overclaiming

- 1 **Compare** Po-209 has the longer half-life and therefore the lower activity for equal numbers of unstable atoms.
- 2 **Condition** Different amounts could change the ranking of source activities.
- 3 **Hazard** Dose also depends on radiation type and exposure pathway; activity alone is not a complete hazard comparison.

Your turn: choose a tracer for a one-hour scan

Your turn

Teacher-written comparison: assume each tracer is in the target organ when a one-hour scan begins. All emit gamma. Half-lives are A: 10 seconds, B: 6 hours, C: 10 years.

- A. Which half-life best balances investigation time and later dose?
- B. Why must the gamma reach a detector outside the body?
- C. Explain how a radiotherapy use differs from this tracer use.

Match the source to the purpose

- 1 **Time** B remains useful during the one-hour scan and decays much sooner than C. A loses its activity too quickly for the stated procedure.
- 2 **Detection** Gamma can escape the body to an external detector. Its path provides information about the organ.
- 3 **Treatment** Radiotherapy aims to damage unwanted tissue. A tracer aims to provide diagnostic information while limiting dose.
- 4 **Evaluation** Compare the expected benefit with dose and possible harm using any data supplied.

Exercises 2.1·2.3

2.1 Give two natural and two man-made sources of background radiation. [4]

2.2 A detector reads 48 counts/s background and 88 counts/s with a sample. State the net count rate due to the sample. [1]

2.3 Give one reason a medical tracer should have a half-life of hours, not years. [1]

3 Exam-style questions

Exercises 2.1·2.3

2.1 Give two natural and two man-made sources of background radiation. [4]

2.1 Natural: radon from rocks; cosmic rays (also food/the body). Man-made: fallout from weapons testing; nuclear accidents.

2.2 A detector reads 48 counts/s background and 88 counts/s with a sample. State the net count rate due to the sample. [1]

2.2 $88 - 48 = 40$ counts/s.

2.3 Give one reason a medical tracer should have a half-life of hours, not years. [1]

3 Exam-style questions

2.3 The patient's dose ends soon after the scan – activity falls quickly.

Exercise 3.1

3.1 The table shows average annual background doses.

Source	Dose in mSv
radon gas	1.3
medical	0.4
cosmic rays	0.3
food and drink	0.3

- (a) State which source is the largest and whether it is natural or man-made. [2]
- (b) A pilot's cosmic-ray dose is 3 times the ground-level value. Calculate the pilot's cosmic-ray dose. [1]
- (c) Explain why background dose varies with location. [2]

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3.1 (a) Radon gas; natural. (b) $3 \times 0.3 = \mathbf{0.9}$ mSv. (c) Radiation levels differ by place: radon depends on local rock; cosmic rays increase with altitude.

Exercise 3.2

3.2 Technetium-99m has a half-life of 6 hours and emits gamma.

- (a) Explain why a short half-life makes it suitable as a medical tracer. [2]
- (b) Explain why gamma is the right emission for tracking it through the body. [2]
- (c) After 24 hours, what fraction of the original activity remains? [2]

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3.2 (a) The activity falls rapidly after the scan, reducing further dose after the investigation (provided the activity lasts long enough for the scan). (b) Gamma is the most penetrating, so it leaves the body and reaches the external detector. (c) 24 hours = 4 half-lives; fraction = $1/2^4 = 1/16$.

Exercise 3.3

3.3 A hospital stores two waste sources: A (half-life 12 hours, beta) and B (half-life 24 000 years, alpha).

- (a) Explain which source needs secure long-term storage and why. [2]
- (b) Explain why the half-lives alone do not determine which source gives the larger dose during the first hour after use. [2]
- (c) Justify the choice of storage precautions for source B. [2]

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3.3 (a) Source B: with a 24 000-year half-life it remains active for millennia, so it needs secure long-term storage. (b) The initial numbers of unstable nuclei or measured activities are not supplied; dose also depends on radiation type, shielding, distance, time and whether material enters the body (one relevant factor, B1). Half-life alone is insufficient. (c) Store in sealed, shielded containers (alpha is stopped by modest shielding – but containment must prevent ingestion); label, keep away from people, and monitor for leakage over the long term.