AQA · GCSE · PHYSICS • EXERCISE SHEET

4.6 Background radiation and uses of radiation

Name: _____ Class: _____ Date: _____ **Total: 23 marks**

KEY WORDS background radiation

Objective

List background radiation sources, subtract it from measurements, and explain how half-life governs both hazard and choice of medical source. Physics only. Original questions for spec statements 4.4.3.1–4.4.3.3.

1 Key knowledge and worked examples

Background radiation is present all the time:

- **natural**: rocks (radon gas), cosmic rays from space, food and the body;
- **man-made**: fallout from weapons testing, nuclear accidents and medical uses.

Dose depends on **occupation and location** (aircrew get more cosmic; some industries more exposure). Dose unit: sievert (Sv); 1000 mSv = 1 Sv (recall not required).

Every measurement needs the background subtracted:

$$\text{net count-rate} = \text{measured count-rate} - \text{background count-rate}$$

Worked example. A detector reads 65 counts/s with the source present and 25 counts/s with it removed.

- Net count rate: $65 - 25 = 40$ counts/s. Use corrected rates for half-life work and keep the detector geometry unchanged. This does not establish that the source activity is 40 Bq.

Half-life and hazard:

Half-life	Hazard/use profile
very long (thousands of years)	waste stays active for millennia – storage problem
short	activity falls quickly; must allow time for the investigation
long	changes slowly over use; useful for smoke alarms

For equal numbers of unstable nuclei, a shorter half-life means greater activity. Hazard also depends on source amount, emission type and exposure.

Medical uses:

- **Exploration**: gamma tracer injected; organs show on a scan; half-life allows time for the scan, then reduces activity and further dose.
- **Destruction**: radiotherapy kills unwanted (cancer) tissue with focused gamma/beta.

Risk evaluation: compare the dose and the consequence of the procedure with the risk of doing nothing – use the numbers given.

2 Practice

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

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]

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]

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]

Solutions

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

2.2 $88 - 48 = \mathbf{40}$ counts/s.

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

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.

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 $= 1/2^4 = \mathbf{1/16}$.

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.