

Radiation in medicine uses risks and half life

AQA GCSE Separate Physics 8463 only | Foundation and Higher | Paper 1

Worked answers | 28 parts | 53 marks including 4 Higher-only marks

Specification points covered

4.4.3.1: background radiation and dose; 4.4.3.2: hazards and different half-lives
4.4.3.3: medical uses and evaluating benefits and risks
4.4.2.1: selected radiation properties, activity and count rate
4.4.2.3: half-life and randomness; 4.4.2.4: contamination, irradiation and precautions

A hospital training team reviews a tracer-imaging service and a separate gamma-radiotherapy service. You will select sources, interpret monitoring data and explain decisions to new staff. All sources, patients and numerical data are fictional teaching examples, not clinical advice.

Original PhysicsUK practice, not an official AQA resource or clinical guidance. Core 26 parts / 49 marks; Higher-only 6(d)–6(e) add 4 marks. Section 6(a)–6(c) is a six-mark-style scaffold with separate point marking, not an AQA levels rubric. Timing is estimated and untrials.

1 Reading the training brief

The team records background exposure as well as exposure from hospital work. A source's activity is its rate of nuclear decay, not the dose received by one person.

1(a) Give one natural source and one man-made source that could contribute to the background radiation recorded by the team. **[2 marks]**

Answer / mark points: Natural: radioactive rocks/radon or cosmic rays. [1] Man-made: fallout from a nuclear accident or weapons testing, or medical X-rays. [1] Do not confuse an external source with the unit of dose.

1(b) The record for source R states a half-life of 2 hours. Explain what that means for a large sample's activity. **[1 mark]**

Answer / mark points: Its activity falls to half its initial value in 2 hours. [1] This does not mean that all nuclei decay, or that each nucleus lives for exactly 2 hours.

1(c) A staff dose record is 0.0008 Sv. Convert this dose to millisieverts so it can be compared with the other records. **[1 mark]**

Answer / mark points: Dose = $0.0008 \times 1000 = 0.80$ mSv. [1]



2 Choosing a tracer source

All four materials are chemically suitable and remain in the organ during this simplified test. Preparation, transport and imaging take 4 hours. Preliminary checks show R and S remain detectable throughout, but Q does not. Choose a useful signal without unnecessarily prolonged exposure afterwards.

Table 1

Source	Radiation emitted	Half-life
P	Alpha only	6 hours
Q	Gamma only	30 seconds
R	Gamma only	2 hours
S	Gamma only	60 days

2(a) Select P, Q, R or S for the 4-hour tracer investigation. Explain the choice using both radiation type and half-life. **[3 marks]**

Answer / mark points: R. [1] Its gamma radiation can pass out of the body to an external detector. [1] Its 2-hour half-life is long enough to leave a useful signal during the stated test but short enough to reduce activity afterwards, unlike S's 60 days. [1] The choice is within the supplied model, not a clinical recommendation.

2(b) Explain two physical reasons why P is unsuitable for this externally detected internal-organ tracer investigation. **[2 marks]**

Answer / mark points: Alpha radiation has a short range/low penetration and is absorbed inside the body, so it will not provide the required external signal. [1] It is strongly ionising near the internal source and can damage nearby cells. [1] Do not say that all internal uses of alpha radiation are impossible.

2(c) Q emits gamma radiation. Explain why its half-life still makes it unsuitable for the stated preparation, transport and imaging schedule. **[2 marks]**

Answer / mark points: Its 30-second half-life is very short compared with the 4-hour schedule, so its activity falls greatly before/during use. [1] The remaining detector signal would be inadequate for the intended investigation. [1] No repeated-halving calculation is needed.

2(d) Compared with R, why is S's long half-life a disadvantage if the tracer material remains in the patient after this short investigation? **[2 marks]**

Answer / mark points: S remains radioactive for much longer. [1] This prolongs irradiation/exposure after the useful test, producing unnecessary continuing dose in the stated circumstances. [1] A long half-life alone is not a universal ranking of risk.

2(e) For a separate sealed external gamma-radiotherapy source that is used repeatedly over many months, which would need less frequent replacement, R or S? Explain. **[2 marks]**

Answer / mark points: S. [1] Its activity decreases more slowly, so it remains useful for longer without replacement. [1] The source remains outside the patient; a long useful life can be beneficial for this different task.



3 Locating the radioactive material

Figure 1 shows two separate procedures. A uses an external sealed gamma source to treat a target. B uses a gamma-emitting tracer deliberately placed inside the body and detected outside. Arrows show radiation paths, not radioactive material moving.

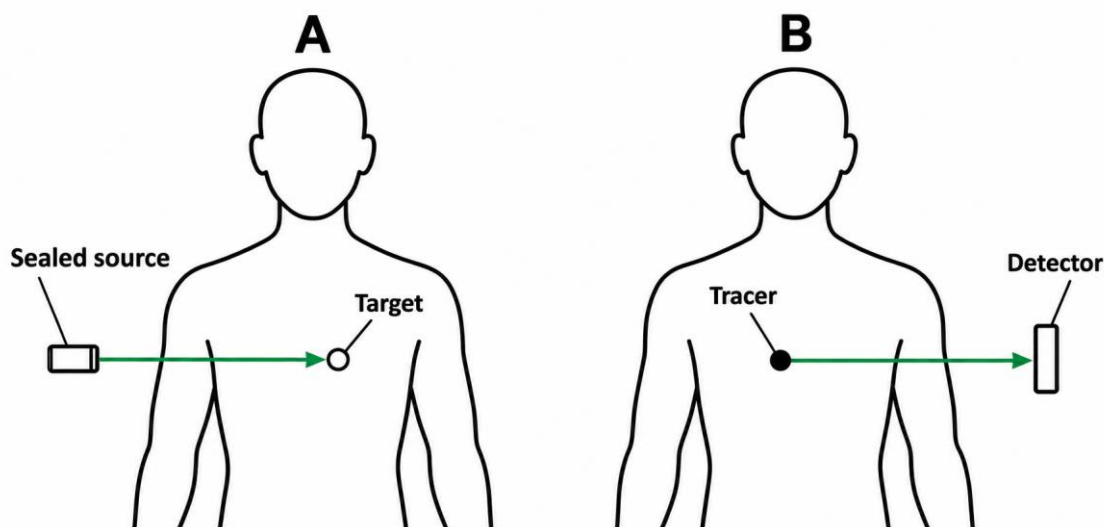


Figure 1

3(a) In A, the sealed source is removed after exposure. State whether irradiation alone makes the patient radioactive, and explain. **[2 marks]**

Answer / mark points: No. [1] The patient has been exposed to radiation, but radioactive atoms have not been transferred from the sealed source into the patient. [1] Do not confuse radiation with radioactive material.

3(b) In B, the detector is switched off and removed. Explain why nuclear radiation may still be emitted from the patient. **[2 marks]**

Answer / mark points: Radioactive tracer atoms remain inside the body. [1] Their unstable nuclei continue to decay independently of whether the detector is operating. [1] The detector detects radiation; it does not make the source decay.

3(c) During preparation, tracer liquid accidentally spills onto a worker's sleeve. Name this event and explain how its hazard differs from irradiation alone. **[2 marks]**

Answer / mark points: Radioactive contamination. [1] Unwanted radioactive atoms are now on the sleeve and continue emitting radiation until removed or decayed; irradiation alone does not leave radioactive material there. [1] Intentional tracer administration in B is distinct from this unwanted spill.

3(d) State one precaution that reduces the chance of tracer liquid contaminating staff, and one different precaution that reduces irradiation from a sealed source. **[2 marks]**

Answer / mark points: Contamination: suitable gloves/protective clothing and careful contained handling, linked to avoiding radioactive material on the body/clothes. [1] Irradiation: suitable shielding, increased distance or shorter exposure time. [1] Gloves are not adequate shielding against gamma rays.

3(e) In A, why must the treatment beam be aimed carefully even though the aim is to destroy unwanted tissue? **[2 marks]**

Answer / mark points: Ionising radiation can damage/kill healthy cells as well as unwanted cells. [1] Careful targeting concentrates the treatment on unwanted tissue while reducing exposure of surrounding healthy tissue. [1] Do not claim that only cancer cells absorb radiation.



4 Checking the activity before use

Table 2 gives measured mean activities of a sealed calibration sample of R. No material is lost or added. These are activities, not patient doses. Use the table directly for the core questions.

Table 2

Time after preparation / h	0	2	4	6	8
Mean activity / kBq	640	320	160	80	40

4(a) Determine R's half-life from Table 2. Identify two values that support it. **[1 mark]**

Answer / mark points: 2 hours: for example, 640 kBq falls to 320 kBq from 0 to 2 h, or 160 falls to 80 kBq from 4 to 6 h. [1 for correct half-life supported by a valid pair]

4(b) Convert the recorded activity of 640 kBq at preparation to becquerels. **[1 mark]**

Answer / mark points: $640 \times 1000 = 640\,000$ Bq, or 6.4×10^5 Bq. [1]

4(c) A trainee says that the 2-hour half-life lets them predict which individual nucleus will decay next. Explain why this is wrong. **[2 marks]**

Answer / mark points: Decay is random, so the decay time of a particular nucleus cannot be predicted. [1] Half-life describes the statistical change in a large sample's activity/number of undecayed nuclei, not an individual nucleus's lifetime. [1]

4(d) This calibration test needs at least 150 kBq at its start. Use Table 2 to decide whether starting 4 hours after preparation is acceptable, and whether a delay to 6 hours is acceptable. **[2 marks]**

Answer / mark points: At 4 h, activity is 160 kBq, so it meets the 150 kBq minimum. [1] At 6 h, activity is 80 kBq, so it fails. [1] These are table readings, not an inferred dose or a clinical threshold.

4(e) A detector records 546 counts in 60 s with a test sample present. Background alone gives 66 counts in the same 60 s. Calculate the sample's background-corrected count rate. **[2 marks]**

Answer / mark points: Source counts = $546 - 66 = 480$ in 60 s. [1]
Corrected count rate = $480 / 60 = 8.0$ counts s^{-1} . [1] This detector count rate is not automatically the source's activity in Bq.



5 Interpreting dose and risk

Table 3 is a fictional staff-monitoring dataset. Each listed daily occupational dose is repeated on 200 working days. These are not exposure limits or claims about typical real hospital doses.

Table 3

Staff role	Occupational dose per working day / mSv	Working days
Office worker	0.0020	200
Imaging worker	0.0060	200

5(a) Calculate the annual occupational dose for each staff role in Table 3. **[2 marks]**

Answer / mark points: Office worker: $0.0020 \times 200 = 0.40$ mSv. [1]
Imaging worker: $0.0060 \times 200 = 1.20$ mSv. [1] These are occupational contributions only.

5(b) The imaging worker also receives 0.0018 Sv from background sources over that year. Calculate the combined dose in mSv. **[2 marks]**

Answer / mark points: Background = $0.0018 \times 1000 = 1.8$ mSv. [1]
Combined = $1.20 + 1.8 = 3.0$ mSv. [1] Allow consistent follow-through from 5(a); do not add Sv directly to mSv.

5(c) A trainee claims that the larger dose proves that every imaging worker will develop cancer. Explain why that conclusion is not justified. **[2 marks]**

Answer / mark points: Ionising radiation can increase the risk/probability of cell damage or mutations/cancer. [1] An increased risk does not mean that every exposed individual will develop cancer; the supplied doses are not individual outcome predictions. [1] Do not replace certainty with a claim of zero risk.

5(d) Two staff have identical jobs, but one hospital is at a much higher altitude. Explain why the natural-background contribution to their doses could differ. **[2 marks]**

Answer / mark points: Cosmic radiation is a natural background source. [1] At higher altitude there is less atmosphere above to absorb it, so exposure to cosmic radiation can be greater. [1] Do not attribute every dose difference to the job.

5(e) The team studies possible health effects of exposure. Explain why its methods and findings should be published for other scientists to review. **[2 marks]**

Answer / mark points: Other scientists can check the methods, analysis and whether the evidence supports the conclusions. [1] This can identify errors, bias or alternative explanations and allow further testing, improving confidence in the findings. [1] Peer review does not guarantee that a conclusion is true.



6 Explaining a balanced decision

A visitor claims that all medical nuclear radiation should be banned. Parts (a)–(c) build a six-mark-style response in three separately marked steps. Use benefits, hazards and practical precautions.

6(a) Explain one benefit of internal tracer imaging and why a gamma-emitting source can provide that benefit. **[2 marks]**

Answer / mark points: It can reveal the location/function of an internal organ or the movement/distribution of a substance without opening the body. [1] Gamma radiation can escape from the body to an external detector, which records the tracer distribution. [1]

6(b) Explain one benefit of radiotherapy and one relevant hazard that must be considered alongside it. **[2 marks]**

Answer / mark points: Ionising radiation can control/destroy unwanted tissue, such as a tumour. [1] It may also damage healthy tissue or increase later cancer/mutation risk. [1] Weigh the benefit and hazard rather than saying that a useful treatment has no risk.

6(c) Give a balanced response to the proposed ban. Explain how one specific precaution can reduce risk while allowing a justified medical use. **[2 marks]**

Answer / mark points: A blanket ban ignores potentially important diagnostic/treatment benefits; trained professionals must compare the expected benefit with the risks for the particular use. [1] One linked precaution, for example careful targeting to reduce healthy-tissue dose, suitable shielding for staff, or selecting an adequate but short tracer half-life to reduce unnecessary continuing exposure. [1] No dose is declared automatically safe.

6(d) HIGHER TIER ONLY. A sealed R sample is left for three half-lives. Calculate the fraction of its initial activity remaining and the fraction by which its activity has declined. **[2 marks]**

Answer / mark points: Remaining fraction = $1/2 \times 1/2 \times 1/2 = 1/8$. [1]
Net decline = $1 - 1/8 = 7/8$. [1] Initial : remaining activity is 8 : 1. Do not confuse the remaining fraction with the decline.

6(e) HIGHER TIER ONLY. A sealed R calibration sample is prepared at 08:00. Its half-life is 2 hours. It must have at least 7.5×10^4 Bq at 14:00. Calculate the minimum activity needed at 08:00. No material is removed. **[2 marks]**

Answer / mark points: Elapsed time = 6 h = 3 half-lives, so preparation activity must be eight times the required arrival activity. [1]
Minimum = $8 \times 7.5 \times 10^4 = 6.0 \times 10^5$ Bq (600 000 Bq). [1] This is a sealed calibration sample, not a prescription for a patient.

Review and improve

Require property-to-use and evidence-to-conclusion links. Irradiation alone does not make a patient radioactive. Deliberate tracer administration is not an accidental spill. Half-life is not a complete hazard ranking; compare activity, exposure and source location too.

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