

Radiation and Half lives

Mark Scheme



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1. Radiation is the emission of particles or waves from an unstable nucleus, while half-life measures how long it takes for the overall rate of this radiation to drop by fifty percent.

For each of the following questions **circle** the letter of the correct answer.

- a) Which statement below about α -particles and β -particles is correct?

D – is the only correct answer.	1 mark
	Total: 1 mark

- b) A hospital safely stores a sealed drum of contaminated medical equipment containing the isotope bismuth-210.

Twenty days after it was stored, the quantity of bismuth-210 present has dropped to 6.25% of its original level. What is the half-life of bismuth-210?

C – is the only correct answer.	1 mark
	Total: 1 mark

- c) Which of the following statements correctly describes a beta particle?

C – is the only correct answer.	1 mark
	Total: 1 mark

- d) A scientist is testing an unknown radioactive source. She finds that the radiation emitted passes easily through a piece of paper, but is completely absorbed by a sheet of aluminium.

Which type of radiation is the source emitting?

B – is the only correct answer.	1 mark
	Total: 1 mark

(Total for Question 1 is 4 marks)

2. Radioactive decay may include the emission of:

α -radiation

β -radiation

γ -radiation

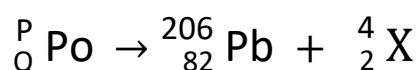
a) From the list, state the type of radiation which is an electromagnetic wave.

Award 1 mark for each correct reactant.	1 mark
	Total: 1 mark

b) From the list, state the type of radiation that consists of fast-moving electrons.

Award 1 mark for each correct reactant.	1 mark
	Total: 1 mark

c) The nuclear equation shows the decay of an isotope of polonium.



i. Identify X.

Helium / He / Alpha particle / α	1 mark
	Total: 1 mark

ii. Determine the values of P and Q.

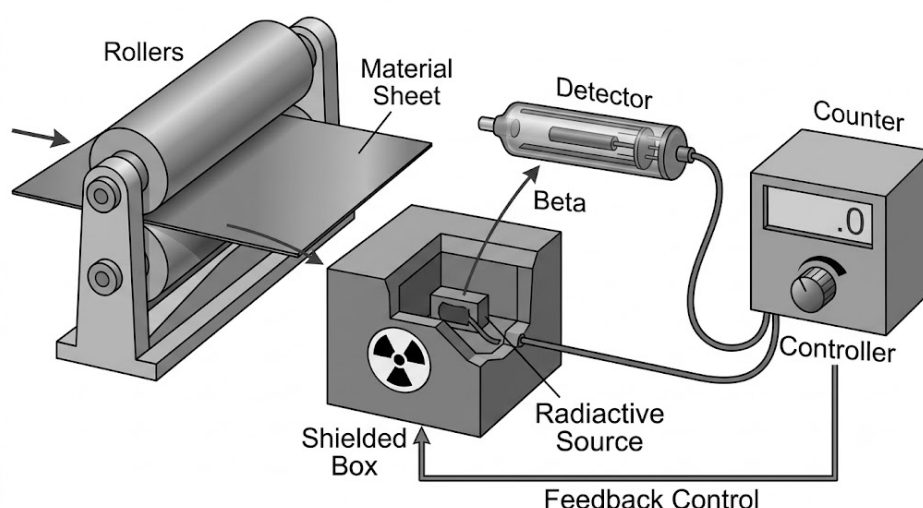
P = 210	1 mark
Q = 84	1 mark
	Total: 2 marks

d) In a factory, rollers press aluminium metal to make thin foil sheets.

An automatic system for controlling the thickness of the foil uses a radioactive source.

The automatic system changes the gap between the top and bottom roller.

The figure below shows the rollers.



The factory uses a β -radiation source.

- i. Explain why an α -radiation source would **not** be suitable for this system.

An explanation to include:	
Alpha radiation would be completely absorbed / stopped by the foil / stopped by the air.	1 mark
Accept: "It cannot penetrate the foil" or "The count rate would just be zero."	
	Total: 1 mark

- ii. Explain why a γ -radiation source would **not** be suitable for this system.

Gamma radiation is highly penetrating / would pass straight through.	1 mark
Accept: "The count rate wouldn't change when the thickness changes" or "It is not absorbed by aluminium."	
	Total: 1 mark

- e) During the manufacturing process, the aluminium foil passing the radiation detector becomes too thick.

- i. Describe how this fault affects the reading on the counter.

The reading / count rate decreases.	1 mark
Accept: "It goes down" or "less radiation reaches the detector."	
	Total: 1 mark

- ii. Suggest how the automated system corrects this fault. State what happens to the rollers.

The rollers move closer together.	1 mark
Accept: "The gap between the rollers is decreased" or "they press harder."	
	Total: 1 mark

- f) The radioactive source used in this machine is strontium-90, which has a half-life of 29 years.

Explain why a radioactive source with a very short half-life would be unsuitable for this factory.

An explanation to include:	
The count rate / activity of the source would drop too quickly.	1 mark
The source would need to be replaced constantly / the machine would need constant recalibration.	1 mark
	Total: 2 marks

(Total for Question 2 is 11 marks)

3. Radioactive isotopes are frequently put inside a patient's body to act as medical tracers.

- a) Which type of radiation is most suitable to be used as a medical tracer because it can easily pass out of the body? **Circle** the letter of the correct answer.

C – is the only correct answer.	1 mark
	Total: 1 mark

- b) When a patient is injected with a radioactive tracer, it is important that the radioactive isotope has a short half-life rather than a long half-life.

Explain why a short half-life is necessary.

An explanation to include:	
The activity of the source will drop quickly / it will not stay radioactive for long inside the body.	1 mark
Allow: 1 mark for the idea of the radiation fading quickly.	
This reduces the amount of damage / radiation dose / risk of cancer to the patient's healthy cells.	1 mark
Allow: 1 mark for linking this to reducing harm/damage to the patient.	
	Total: 2 marks

- c) Medical staff who use radioactive materials in their work need to be protected from high levels of exposure.

Describe some precautions that medical staff can take to ensure they reduce their exposure to radioactive materials.

A description to include any three of the following:	
• Stand behind lead/protective screens. • Wear lead-lined aprons / protective clothing. • Keep as far away as possible from the source / use long tongs to handle materials. • Limit the time spent working with/near the radioactive sources. • Wear a radiation monitor / film badge / dosimeter to track exposure. • Store the materials in lead-lined boxes when not in use.	
Do not accept vague answers like "wear goggles/gloves" unless specifically linked to preventing contamination (e.g., stopping radioactive liquid getting on the skin).	
	Total: 3 marks

(Total for Question 3 is 6 marks)

4. There are three main types of nuclear radiation: alpha (α), beta (β), and gamma (γ). Compare the properties of alpha, beta, and gamma radiation.

In your answer, you should include:

- what each type of radiation consists of
- their relative ionising powers
- their relative penetrating powers.

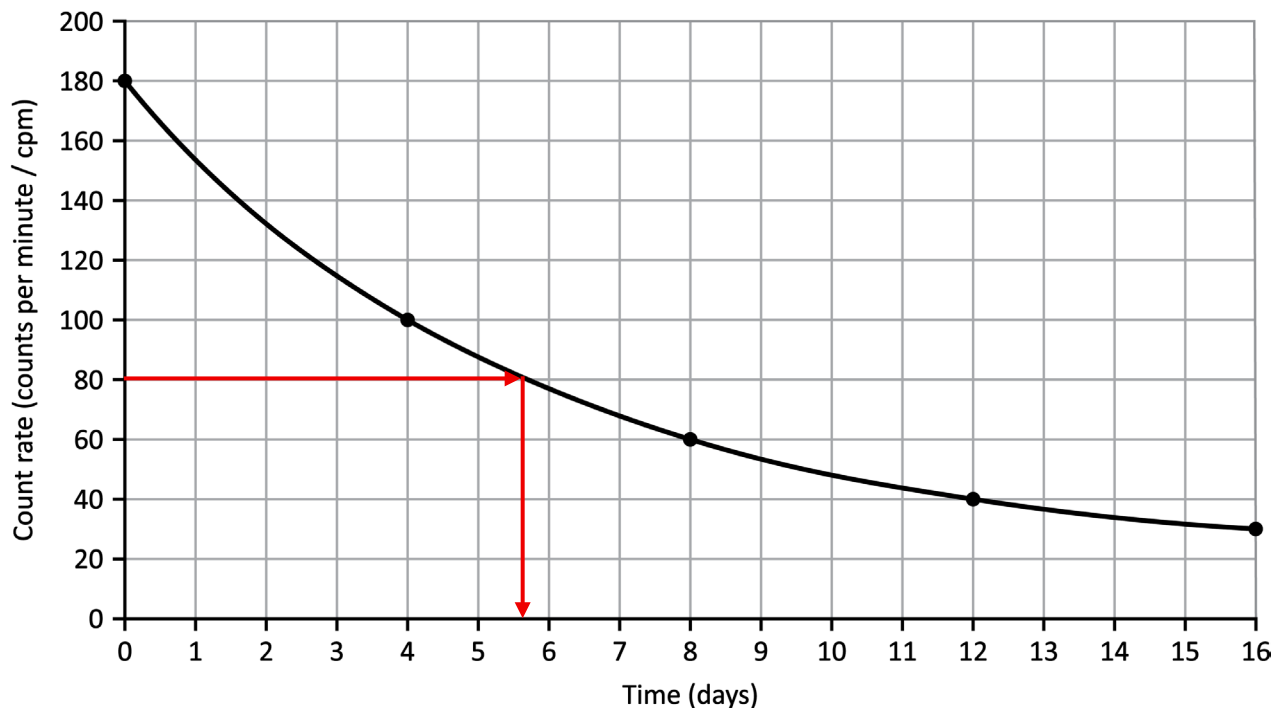
Marking guidance		
Level	Marks	Descriptor
Level 1	1 - 2	Simple, fragmented statements. The student correctly identifies at least one property of one type of radiation (e.g., "alpha is stopped by paper").
Level 2	3 - 4	A mostly correct description. The student describes the properties of at least two types of radiation, or lists several properties but lacks clear comparison. May contain minor inaccuracies or omissions.
Level 3	5 - 6	A detailed, coherent, and logically structured comparison. The student correctly identifies the composition, penetrating power, and ionising power for all three types of radiation.

Indicative content:	
Alpha (α) radiation: • Composition: 2 protons and 2 neutrons / a helium nucleus. • Ionising power: strongly / highly ionising. • Penetrating power: low penetrating power / stopped by paper or a few centimetres of air. Beta (β) radiation: • Composition: a high-speed / fast-moving electron. • Ionising power: moderately ionising. • Penetrating power: moderate penetrating power / stopped by a thin sheet of aluminium or a few metres of air. Gamma (γ) radiation: • Composition: an electromagnetic wave. • Ionising power: weakly / poorly ionising. • Penetrating power: highly penetrating / stopped by thick lead or metres of concrete.	
	Total: 6 marks

(6 marks)

(Total for Question 4 is 6 marks)

5. A student uses a Geiger-Muller tube to measure the count rate of a radioactive isotope over 16 days. The student leaves the radioactive source in the same position on the desk for the entire experiment.



- a) State the background radiation count rate in the laboratory.

20	1 mark
	Total: 1 mark

- b) State one natural source of background radiation.

Radon gas / cosmic rays / rocks (e.g., granite) / food / building materials.	1 mark
	Total: 1 mark

- c) Use the graph to determine the half-life of the radioactive isotope.

You **must** show clearly how you used the graph to obtain your answer.

True initial activity calculation: $180 \text{ (total)} - 20 \text{ (background)} = 160$	1 mark
Halving the true activity: $160 \div 2 = 80$	1 mark
Finding the target reading on graph: $80 \text{ (true)} + 20 \text{ (background)} = 100$	1 mark
Reading the time: Time taken to drop to 100 cpm = 4 days.	1 mark
	Total: 4 marks

- d) Calculate the total count rate the GM tube would detect on day 20.
Show your working.

Determine number of half-lives: $20 \text{ days} \div 4 \text{ days} = 5 \text{ half-lives.}$	1 mark
Calculate true activity remaining: Initial true activity = 160 Halved 5 times ($160 \rightarrow 80 \rightarrow 40 \rightarrow 20 \rightarrow 10 \rightarrow 5$). True activity = 5 cpm.	1 mark
Add back the background radiation: $5 \text{ cpm} + 20 \text{ cpm} = 25 \text{ cpm}$	1 mark
	Total: 3 marks

- e) At the end of the experiment, the student places a 3 mm thick sheet of aluminium between the radioactive source and the GM tube.

The reading on the GM tube immediately drops to exactly 20 cpm.

Use this information to deduce the type of radiation emitted by this isotope.

Explain your reasoning.

Type of radiation: Beta / β radiation	1 mark
An explanation to include two of the following:	
- The count rate dropped to 20 cpm, which is the background radiation level. - This means all the radiation from the source was absorbed/stopped by the aluminium. - Beta is stopped by a few mm of aluminium (whereas gamma would pass straight through it).	2 marks
	Total: 3 marks

(Total for Question 5 is 12 marks)

6. A technician uses a Geiger-Muller (GM) tube to measure the radioactivity of a sample in a laboratory.
- The GM tube gives a reading of 185 counts per minute.
- The average background radiation in her laboratory is 25 counts per minute.



- a) What is the corrected count rate, in counts per minute, for the radioactive sample alone?

B – is the only correct answer.	1 mark
	Total: 1 mark

- b) Name **one** artificial source of background radiation.

Medical X-rays / radiotherapy / nuclear weapons testing / nuclear power stations / nuclear accidents.	1 mark
Do not accept natural sources like rocks, radon gas, cosmic rays, or food.	
	Total: 1 mark

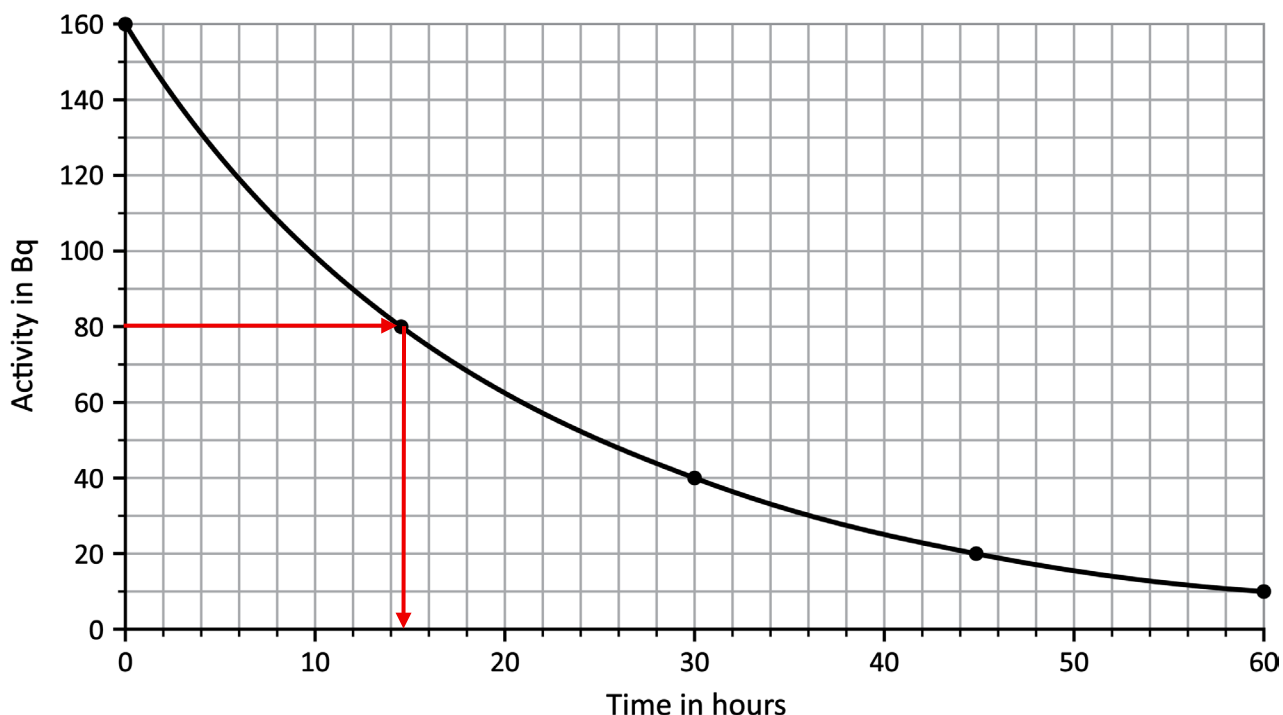
- c) Explain why a commercial airline pilot receives a higher dose of background radiation than a person who works in an office on the ground.

An explanation to include:	
The pilot flies at a high altitude / closer to space.	1 mark
Therefore, there is less atmosphere to absorb cosmic rays / they are exposed to more cosmic radiation.	1 mark
	Total: 1 mark

- d) Name **one** natural source of background radiation.

Radon gas / cosmic rays / rocks (e.g., granite) / food / building materials.	1 mark
	Total: 1 mark

- e) A hospital accidentally spills a small amount of liquid containing the radioactive isotope Sodium-24. The graph shows how the activity of the spilled sample changes over 60 hours.



- i. Use the graph to estimate the half-life of Sodium-24. Show your working clearly.

Identifies initial activity is 160 and halves it to 80.	1 mark
Reads across from 80 Bq to find a half-life of 15 (hours).	1 mark
	Total: 2 marks

- ii. The laboratory is declared safe to enter only when the activity of the spill falls to exactly 40 Bq. Use the graph to find how many hours it took for the laboratory to become safe.

Identifies 40 Bq on the y-axis and traces to the line.	1 mark
Award 1 mark for drawing a line across from 40 Bq to the curve and down to the x-axis.	
30 (hours).	1 mark
Award 1 mark for the correct answer of 30.	
	Total: 2 marks

- iii. When Sodium-24 decays, it emits gamma radiation.

State why gamma radiation is difficult to contain within the laboratory.

It is highly penetrating / has a very long range in air / requires thick lead or concrete to absorb it.	1 mark
Accept: It can pass easily through walls/doors.	
	Total: 1 mark

(Total for Question 6 is 10 marks)