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WORKSHEETS
ATTEMPT | CHECK | CORRECT | IMPROVE

Radioactivity

Radiation detection and absorption

35–40 minutes independent work + 15–20 minutes review

OCR A H556 | A-level physics | Module 6 | 38 marks

Specification points covered

6.4.3(a): spontaneous and random nuclear decay.

6.4.3(b)(i–ii): nature, penetration and ionising ability of alpha, beta and gamma radiation; identifying radiation experimentally.

6.4.3(c): balanced alpha, beta-minus and beta-plus nuclear decay equations. Gamma energy changes are covered under 6.4.3(b)(i).

Use count rate in s^{-1}. Activity is the number of nuclear decays per second, in Bq. All tabulated readings are illustrative mean values; background is included unless stated otherwise.

Use a calculator and your OCR A data booklet. Show working, units and directions where relevant.

1 What the detector can tell us

A factory makes thin sterile-filter films. Its laboratory identifies calibration sources before choosing a non-contact thickness gauge.

The filter laboratory must use measurements of many decays, rather than predict the fate of an individual nucleus.

Use the apparatus in Figure 1 for the following tests.

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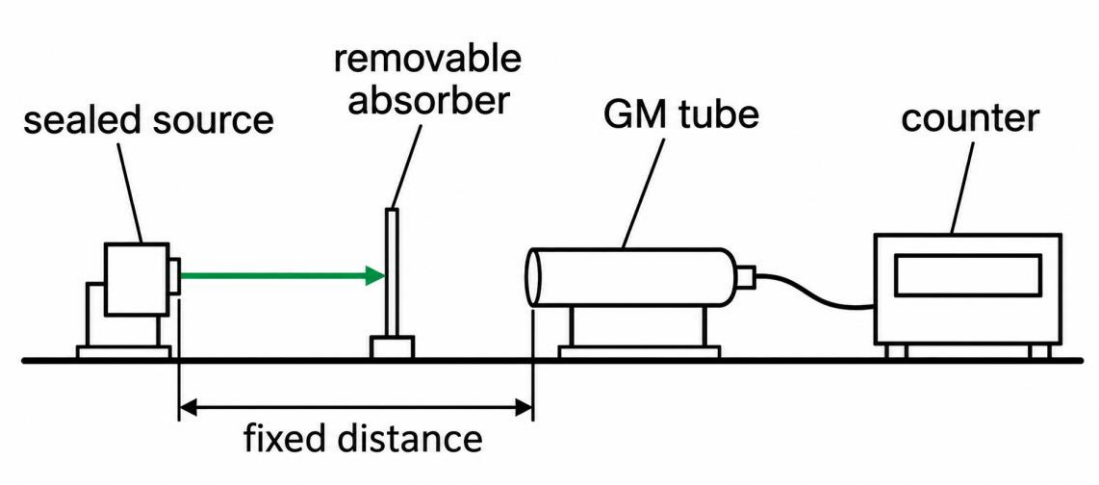


Figure 1 Source–absorber–detector arrangement

1(a) A technician says a particular unstable nucleus will decay exactly 20 s after the counter starts. Explain why this prediction is not possible. **[1 mark]**

1(b) Explain what spontaneous means in this context. Would cooling the source normally switch off its nuclear decay? **[1 mark]**

2 Correct the readings before using them

2(a) With the source removed, the counter records 1440 counts in 240 s. Calculate the background count rate. **[1 mark]**

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2(b) With a source in place, the counter records 13 260 counts in 60.0 s. Calculate the count rate due to the source alone. **[2 marks]**

2(c) The source activity is independently known to be 1.50 kBq. Calculate the fraction of decays recorded as counts in this arrangement. Assume at most one count is recorded per decay. **[2 marks]**

2(d) When testing absorbers, why must the source–detector distance and the measurement time be controlled, or the time allowed for explicitly in processing? **[2 marks]**

3 Identify three unknown sources

For this test the background rate is 6 s^{-1}. Absorbers are tested separately in the same holder, not stacked. Small differences near the original rate are within measurement variation.

Table 1 Gross mean count rates

Source	No absorber / s^{-1}	Paper / s^{-1}	3 mm Al / s^{-1}	Thick lead / s^{-1}
A	226	224	6	6
B	526	524	516	140
C	106	6	6	6

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3(a) Use Table 1 to identify the main radiation from A and justify the identification using both the paper and aluminium readings. **[2 marks]**

3(b) Identify the main radiation from B and C. Explain why the lead reading for B does not mean that lead emits the detected radiation. **[2 marks]**

3(c) Which of alpha, beta and gamma produces the greatest ionisation per unit path length in air, and which generally has the greatest penetration? Explain why these are different properties. **[2 marks]**

3(d) For the film gauge, a source must transmit through the film but give a useful change of count rate when thickness changes. Choose a suitable type of radiation and explain why the other two are less suitable for this thin film. **[2 marks]**

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4 Use the gauge to make a production decision

Table 2 Calibration at fixed geometry

Thickness / μm	50	100	150	200
Net rate / s^{-1}	800	650	500	350

4(a) A film produces 10 120 counts in 20.0 s. The background remains 6.00 s^{-1}. Use Table 2 to estimate the thickness. **[2 marks]**

4(b) The acceptable net count-rate band is 500–700 s^{-1}, including its boundaries. A later net reading is 350 s^{-1}. State whether the film is acceptable and whether the roller gap should be increased or decreased. A smaller roller gap produces a thinner film. **[2 marks]**

4(c) In a separate low-background test, 2500 counts are recorded. For this question use count uncertainty √N and ignore background uncertainty. Calculate the percentage count uncertainty. What measurement duration would approximately halve it if the original duration was 20 s and the mean rate stayed the same? **[2 marks]**

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4(d) A one-second reading fluctuates below the band once. Explain why the controller should not immediately conclude that the film has become too thick. **[1 mark]**

5 Describe the nuclear changes

5(a) A radium-226 nucleus (Z = 88) emits an alpha particle and forms radon. Write the balanced nuclear equation, including mass and proton numbers. **[2 marks]**

5(b) An excited technetium-99 nucleus (Z = 43) emits only gamma radiation. State what happens to A, Z and the energy of the nucleus. **[2 marks]**

5(c) Carbon-14 (Z = 6) emits beta-minus radiation. Write the full nuclear equation and name both emitted leptons. **[2 marks]**

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5(d) Fluorine-18 (Z = 9) undergoes beta-plus decay to oxygen. Write the complete nuclear equation and name both emitted leptons. **[2 marks]**

6 Write a defensible identification method

6(a) The laboratory receives a fourth sealed source. Write a method to determine whether its detectable emission is predominantly alpha, beta or gamma. Link the measurements, controls, background correction and absorber evidence. Include one way to improve confidence in the conclusion. Source handling is performed only under the laboratory's authorised procedures. **[6 marks]**

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