

AQA A level Radioactivity and half life

35–40 minutes independent practice + 15–20 minutes review | 46 marks

Specification points covered

• 3.8.1.2 α , β and γ radiation: absorption, thickness gauges, background correction and γ inverse-square law. Required practical 12: investigate the inverse-square law for γ radiation.

• 3.8.1.3 Radioactive decay: random decay, constant probability, $A = \lambda N$, $N = N_0 e^{-\lambda t}$, $A = A_0 e^{-\lambda t}$, $T = \ln 2/\lambda$, decay curves and log graphs. A-level-only content.

Scenario Monitoring precision aluminium foil

A factory rolls thin aluminium foil for specialist packaging. A sealed source and detector check its thickness without touching it. The laboratory investigates source lifetime and verifies a separate γ detector setup. Show working and units. Use mean decay models and correct for background. Laboratory nuclides C and D differ from production source B. Any source handling is carried out only under an authorised teacher's approved procedure.

Selecting and identifying radiation

1. State what is meant by the random nature of radioactive decay. [1 mark]

2. Define the half-life of a radioactive nuclide in terms of its undecayed nuclei. [1 mark]

3. A manufacturer needs a transmission gauge for thin aluminium foil: some radiation must pass through the foil, but the detected rate must change appreciably when its thickness changes. Choose α , β or γ radiation and explain why the other two types are less suitable. [2 marks]

Table 1 Mean raw readings at fixed geometry

Absorber	None	Paper	5 mm aluminium	25 mm lead
Count rate / s^{-1}	310	310	10	10

4. Table 1 tests a spare source that emits only one of α , β or γ radiation. Its background count rate is $10 s^{-1}$. Identify the radiation and justify your answer using both the paper and aluminium results. [2 marks]

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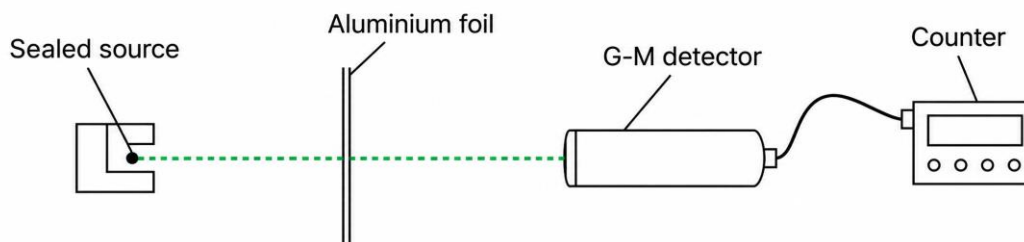
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Keeping the foil at the correct thickness

5. Figure 1 shows the foil gauge. With standard foil in place, the detector records 14 400 counts in 60.0 s. With the source removed, it records 2400 counts in 240 s. Calculate the count rate due to the source through the foil. [2 marks]



6. For unchanged source activity and geometry, a batch gives a lower net count rate than the standard foil. Explain whether the foil is thicker or thinner, and whether the gap between the rollers must be increased or decreased to restore the standard thickness. [2 marks]

7. Two consecutive 60.0 s readings for the same foil are 14 400 and 14 240 counts. Explain why this difference alone does not establish a change in thickness. Suggest how to obtain stronger evidence. [2 marks]

8. For this foil and geometry, the detector counts a fraction 2.00×10^{-4} of the source decays. Using your net count rate from Question 5, determine the source activity and explain why the raw detector count rate cannot be used as its activity. [2 marks]

9. The production source B initially has activity 1.60 MBq and half-life 8.00 years. Calculate its activity after 4.00 years. Assume only the parent nuclide contributes to the measured signal. [1 mark]

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Source lifetime and the remaining nuclei

10. Source B must be replaced when its activity reaches 1.00 MBq. Calculate the time after installation at which this occurs. Show how you deal with a time that is not a whole number of half-lives. [2 marks]

11. Using $1 \text{ year} = 3.16 \times 10^7 \text{ s}$, determine the decay constant of source B in s^{-1} . [2 marks]

12. Determine the initial number of undecayed parent nuclei in source B. State the initial rate of change of this number, including its sign. [2 marks]

13. Explain why warming source B cannot restore its activity. [1 mark]

14. Two sealed candidate sources contain the same number of undecayed parent nuclei. One has half-life 8.00 years and the other 4.00 years. Determine the ratio of their activities, $A(4\text{-year})/A(8\text{-year})$, and explain why their activities differ. [2 marks]

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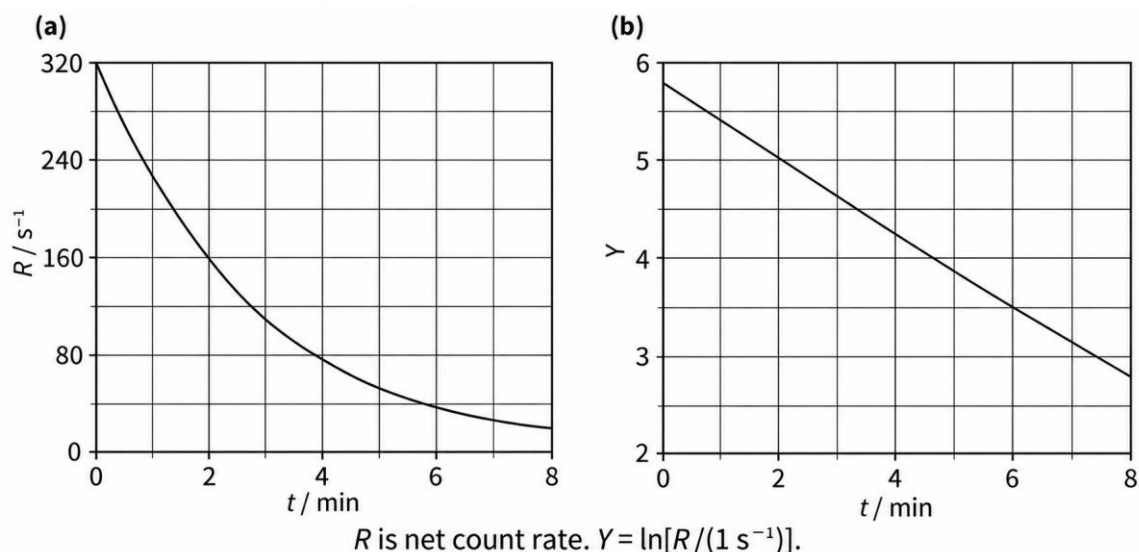
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Decay curves and logarithmic graphs

15. The laboratory studies two short-lived nuclides, C and D, distinct from source B. Figure 2(a) is the net count-rate curve for C; Figure 2(b) is a log graph for D. Both use constant detector efficiency. Use graph (a) to estimate the half-life of C over two successive halving intervals. Show the readings you use. [2 marks]



16. Determine λ for sample C in min^{-1} , then predict its net count rate at $t = 5.00$ min. Use an exponential calculation rather than linear interpolation between readings. [2 marks]

17. Graph (b) plots $Y = \ln[R/(1 \text{ s}^{-1})]$ against t in minutes for nuclide D. Use two widely separated points on its straight best-fit line to determine its gradient. Hence determine λ for D and state which nuclide, C or D, has the shorter half-life. [2 marks]

18. The experiment is repeated using an otherwise identical detector with half the original, constant efficiency. Explain whether the half-life obtained from the log-graph gradient changes. [2 marks]

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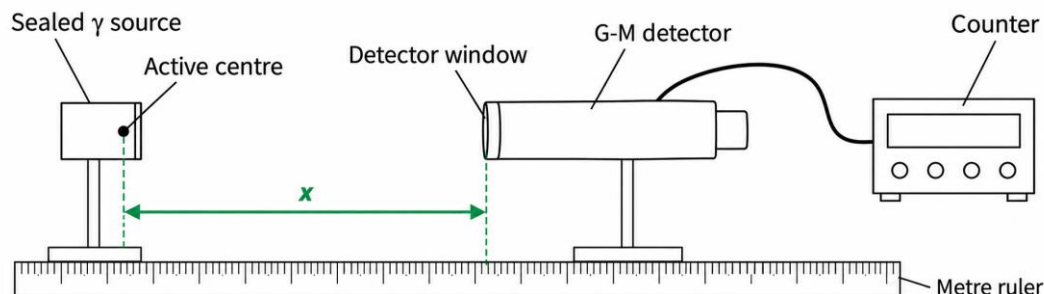
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Required practical 12 Testing the inverse-square law

19. Required practical 12. Figure 3 shows a sealed γ source and detector, operated by an authorised teacher. Write a method to test $R = k/x^2$. Use the headings measurement and background correction; distance and control of conditions; analysis and risk reduction. Explain how the results would support an inverse-square relationship. Treat the source as approximately point-like, and keep the detector within its reliable count-rate range. [6 marks]



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Testing the model with detector data

Table 2 Mean γ detector readings

Distance x / m	0.100	0.150	0.200	0.300
Raw count rate / s^{-1}	925	425	250	125

20. Table 2 gives mean raw count rates from the γ investigation. The background count rate is 25.0 s^{-1} . Correct all four readings and use suitable calculations to judge whether they are consistent with an inverse-square relationship. [2 marks]

21. For the Table 2 setup, predict the raw count rate at $x = 0.500 \text{ m}$, assuming the inverse-square model remains valid. Include background in your final answer. [2 marks]

22. A student plots raw count rate vertically against $1/x^2$ horizontally. State the expected graph shape and vertical intercept. Explain how the intercept would differ if net count rate were plotted instead. [2 marks]

23. Another student measures distance from the front of the source holder, 20 mm in front of the active source, rather than from the active source to the detector window. At their recorded distance of 0.100 m, calculate the actual source-to-window distance. Explain why this offset produces a larger percentage distance error at short separations. [2 marks]

Review and improve

Distinguish activity, raw count rate and net count rate; check the time units of λ .

Use precise language: net count rate decreases exponentially, λ stays constant, and the log-graph gradient is negative.

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