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WORKSHEETS
ATTEMPT | CHECK | CORRECT | IMPROVE

Investigating radioactive decay

Graphs, half-life measurements, modelling and dating

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

OCR A H556 | A-level physics | Module 6 | 45 marks

Specification points covered

6.4.3(e)(ii): experimental determination of half-life, for example using protactinium.

6.4.3(f)(ii): simulation of radioactive decay using dice.

6.4.3(g): graphical methods and spreadsheet modelling of $\Delta N/\Delta t = -\lambda N$.

6.4.3(h): radioactive dating, including carbon-14. Supporting ideas: 6.4.3(a), (d), (e)(i), (f)(i).

Use ln 2 = 0.693. For carbon-14, $t_{1/2}$ = 5730 years. In this sheet R means background-corrected count rate. The prepared short-lived sample gives a signal dominated by one decaying component.

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

1 Separate signal from background

A conservation laboratory checks a short-lived-source counter before dating carbon from a harbour timber. All numerical readings are illustrative data.

Figure 1 is a planning diagram, not instructions for preparing a radioactive source. In a protactinium half-life investigation, preparation and handling follow the authorised laboratory procedure.

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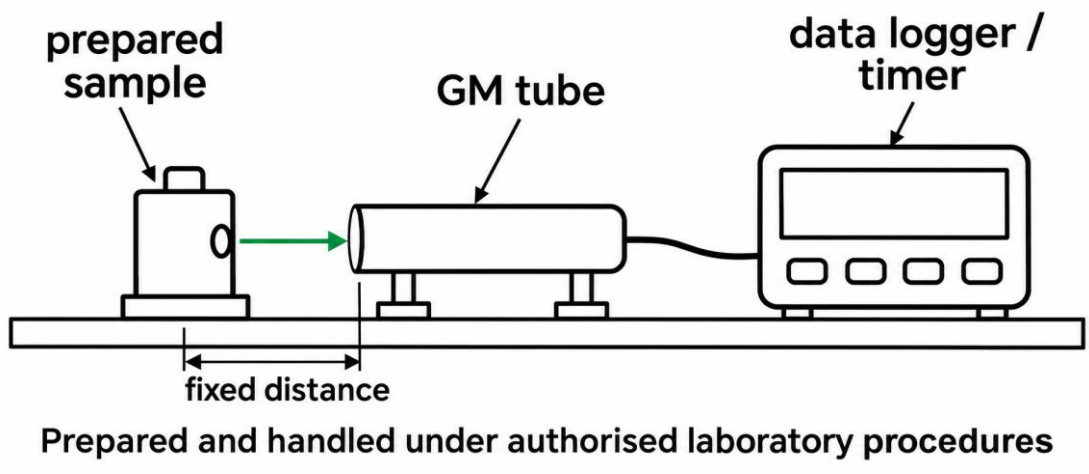


Figure 1 Fixed-geometry counting arrangement

1(a) A sample is prepared by an authorised technician. Before measuring it, the counter records 6000 background counts in 300 s. Calculate the background rate. **[1 mark]**

1(b) Explain why the prepared sample and the GM tube should remain in fixed positions throughout a decay run. **[1 mark]**

1(c) An assistant wants to take only one reading at the start and one near the background level. Give one reason for collecting several intermediate readings instead. **[1 mark]**

2 Extract a half-life from the data

Table 1 Rounded mean rates for a short-lived component

Time / s	0	35	70	105	140	175	210
Gross rate / s^{-1}	340	246	180	133	100	77	60

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2(a) Copy Table 1 into the working space and add a row of net count rates R by subtracting the background rate of 20 s^{-1}. **[1 mark]**

2(b) Use two different intervals in Table 1 to estimate the half-life. State the pairs of net rates used. **[2 marks]**

2(c) Someone halves the initial gross rate, 340 s^{-1}, and looks for 170 s^{-1}. Explain why this gives the wrong half-life and state the gross rate that actually corresponds to half the initial source signal. **[2 marks]**

2(d) The mean gross rate eventually approaches 20 s^{-1}. Explain why that does not mean that the activity approaches 20 Bq. **[1 mark]**

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3 Linearise the decay

3(a) For t = 0, 70, 140 and 210 s, calculate $y = \ln[R/(1\ s^{-1})]$ to three decimal places. Explain why the quantity inside the logarithm is dimensionless. **[2 marks]**

3(b) Draw a graph of y against t using the four points from 3(a). Choose labelled linear scales that use the space well, then draw a straight best-fit line. The vertical scale need not start at zero. **[3 marks]**

3(c) Use a large triangle on your line to determine λ and hence the half-life. Show the sign of the gradient and its units. **[3 marks]**

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3(d) A second run detects exactly half the fraction of source emissions, but that fraction is constant throughout the run. Predict how the logarithmic graph's gradient and intercept change. **[2 marks]**

4 Test two models before trusting them

4(a) A dice model starts with 600 dice. On each throw, remove every die showing a six and throw only those remaining. Calculate the expected numbers remaining after one throw and after four throws. **[2 marks]**

4(b) Find the model half-life in throws using $600(5/6)^n = 300$. Explain one limitation of the dice model. **[3 marks]**

4(c) A spreadsheet instead uses $N_{next} = N_{now} - \lambda N_{now}\Delta t$ with $\lambda = 0.0100\ s^{-1}$, $N_0 = 600$ and $\Delta t = 5.00$ s. Calculate the next two values of N. **[2 marks]**

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4(d) For the same spreadsheet λ, a student chooses $\Delta t = 150$ s and obtains a negative population. Explain the failure and one way to improve the calculation. **[2 marks]**

4(e) The spreadsheet models $\Delta N/\Delta t = -\lambda N$. On an N-against-t graph, find the initial tangent gradient for $N = 600$ and $\lambda = 0.0100\ s^{-1}$. Explain how its magnitude changes as N decreases. **[2 marks]**

5 Date the harbour timber

5(a) Equal masses of carbon from living reference material and the timber give net rates 50.0 and 20.0 s^{-1} in the same geometry and detector. Calculate the surviving carbon-14 fraction in the timber and state why equal carbon masses matter. **[2 marks]**

5(b) Calculate the timber's age using the carbon-14 half-life of 5730 years. **[3 marks]**

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5(c) State two assumptions needed for this simple dating estimate, beyond the measured half-life being correct. **[2 marks]**

5(d) Modern conservation adhesive adds carbon with a larger carbon-14 fraction than the timber. Predict the effect on an uncorrected age estimate and explain using the measured ratio. **[2 marks]**

6 Bring the practical together

6(a) Write a method to determine the half-life of a short-lived component such as protactinium using Figure 1. The sample is prepared and handled under an authorised laboratory procedure. Explain the measurements, processing and checks needed for a defensible value. Include how you would use either repeated halvings or a logarithmic graph. **[6 marks]**

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