

Half life and decay graphs

AQA GCSE Physics 8463 and Combined Science Trilogy 8464 | Paper 1 | Tier routes below

Worked solutions and teaching prompts | 44 marks per route | Optional Separate section +4

Specification points covered

8463 4.4.2.1 and 4.4.2.3 / 8464 6.4.2.1 and 6.4.2.3: random decay, count rate and half-life

8463 4.4.2.3 / 8464 6.4.2.3: decline ratios after several half-lives are Higher only

Optional Separate Physics only: 8463 4.4.3.2, hazards associated with different half-lives

An industrial laboratory tracks independent radioactive test samples to decide when their count rates are low enough for its next measurements. Curves and tables show expected large-sample rates; short measured counts can fluctuate.

Questions 1-4 plus 5 or 6: 27 parts, 44 marks. Optional Separate 7 adds 4 marks. Background correction is supplied data handling; detected count rate is not automatically activity in Bq. Allow equivalent methods and follow-through. Original PhysicsUK resource, not an official AQA mark scheme.

1 Checking the meaning of half life

1(a) Define the half-life of a radioactive isotope. **[1 mark]**

Answer / mark points: The time taken for the number of undecayed nuclei of the isotope in a sample to halve. [1] Also accept the time for the activity or background-corrected count rate from the sample to fall to half its initial value.

Teacher prompt: Name the quantity. Radioactivity halves alone is too vague; a nucleus does not split in half.

1(b) A technician follows one unstable nucleus. Explain why its exact decay time cannot be predicted. **[1 mark]**

Answer / mark points: Radioactive decay is random, so the time at which this individual nucleus decays cannot be predicted. [1]

2 Halving and reading a decay curve

For (a)-(b), use the stated data. Figure 1, used in (c)-(g), shows Sample A after the background count rate has already been subtracted.

2(a) One test sample has a corrected count rate of 640 counts/s and a half-life of 4.0 min. Calculate its expected corrected rate after 8.0 min. **[1 mark]**

Answer / mark points: 8.0 min is two half-lives: $640 \rightarrow 320 \rightarrow 160$ counts/s. Expected corrected rate = 160 counts/s. [1]

2(b) Another sample initially gives 90 counts/s after correction. Its half-life is 5.0 min. Calculate its expected corrected rate after 15 min. **[1 mark]**

Answer / mark points: 15 min is three half-lives: $90 \rightarrow 45 \rightarrow 22.5 \rightarrow 11.25$ counts/s. [1]

Teacher prompt: An average count rate can be fractional even though an individual detected count is a whole event.

Continue your physics journey

Videos, practice and support for your next step

www.physicsuk.co.uk



2 Halving and reading a decay curve continued

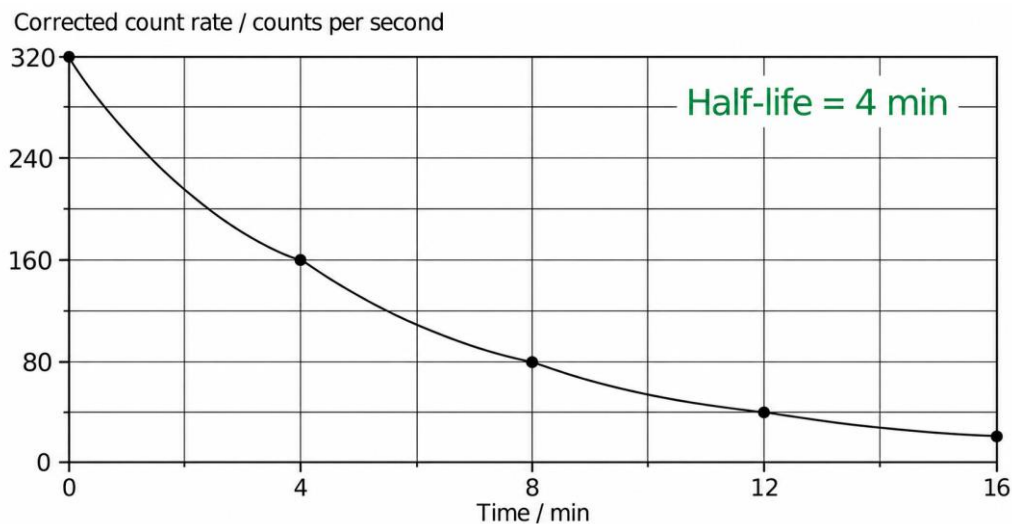


Figure 1

2(c) Use Figure 1 to read the corrected count rate at 4.0 min. **[1 mark]**

Answer / mark points: 160 counts/s. [1] Accept about 155-165 counts/s from the printed graph.

2(d) Read the corrected count rate at 12 min. **[1 mark]**

Answer / mark points: 40 counts/s. [1] Accept about 37-43 counts/s.

2(e) Use the decrease from 320 to 160 counts/s in Figure 1 to determine the half-life of Sample A. **[1 mark]**

Answer / mark points: The rate halves between 0 and 4.0 min, so half-life = $4.0 - 0 = 4.0$ min. [1]

Teacher prompt: Half-life is an elapsed time between two halving levels, not a count rate.

2(f) Now use the decrease from 80 to 40 counts/s to determine the half-life again. **[1 mark]**

Answer / mark points: The corresponding times are 8.0 and 12 min: half-life = $12 - 8.0 = 4.0$ min. [1]

2(g) Calculate the elapsed time for Sample A to decrease from 80 to 20 counts/s. Show the number of half-lives. **[2 marks]**

Answer / mark points: $80 \rightarrow 40 \rightarrow 20$ counts/s is two half-lives. [1]
Elapsed time = $2 \times 4.0 = 8.0$ min. [1] Equivalently, the graph times are 8 and 16 min.



2 Halving and reading a decay curve continued

2(h) A separate sample decreases from a corrected rate of 120 counts/s to 15 counts/s in 18 min. Determine its half-life. Show the number of halvings. [2 marks]

Answer / mark points: $120 \rightarrow 60 \rightarrow 30 \rightarrow 15$ is three half-lives. [1]

Half-life = $18 / 3 = 6.0$ min. [1]

3 A detector reading includes background

Figure 2 is a different sample, B. With this sample removed, the measured rate is 20 counts/s. Treat this supplied background rate as constant. Subtract it from every measured rate to find the corrected rate from Sample B.

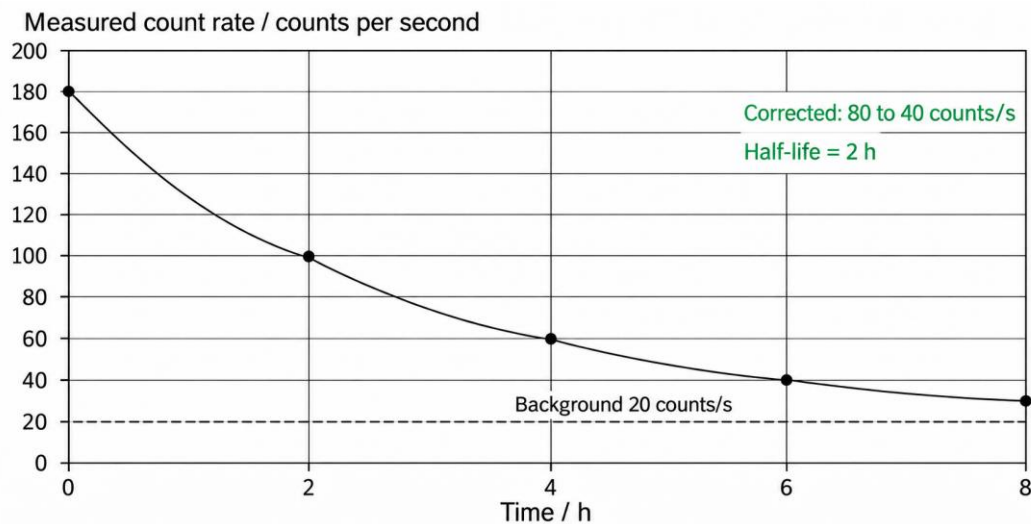


Figure 2

3(a) Use Figure 2 to read the measured count rate at 2.0 h. [1 mark]

Answer / mark points: 100 counts/s. [1] Accept about 96-104 counts/s.

3(b) Calculate the corrected count rate from Sample B at 2.0 h. [1 mark]

Answer / mark points: Corrected rate = $100 - 20 = 80$ counts/s. [1]



3 A detector reading includes background continued

3(c) Calculate the corrected rates at 4.0 h and at 6.0 h using Figure 2. **[2 marks]**

Answer / mark points: At 4.0 h: $60 - 20 = 40$ counts/s. [1]
At 6.0 h: $40 - 20 = 20$ counts/s. [1] Allow sensible graph-reading tolerance.

3(d) Use the corrected rates at 2.0 h and 4.0 h to determine the half-life of Sample B. Give the half-life in hours and in minutes. **[2 marks]**

Answer / mark points: Corrected rate halves from 80 to 40 counts/s between 2.0 and 4.0 h, so half-life = 2.0 h. [1]
 $2.0 \times 60 = 120$ min. [1]

3(e) A trainee halves the initial measured rate of 180 counts/s and looks for 90 counts/s to find the half-life. Explain why the correct measured target is 100 counts/s. **[2 marks]**

Answer / mark points: The initial corrected rate is $180 - 20 = 160$ counts/s, which halves to 80 counts/s. [1] The background does not halve with the sample; adding its unchanged 20 counts/s gives a measured target of 100 counts/s. [1]

3(f) Predict the measured rate for Sample B at 10 h, including the unchanged background. Show your working. **[2 marks]**

Answer / mark points: 10 h is five half-lives. Corrected rate: $160 \rightarrow 80 \rightarrow 40 \rightarrow 20 \rightarrow 10 \rightarrow 5$ counts/s. [1]
Measured rate = $5 + 20 = 25$ counts/s. [1]

3(g) After many half-lives, should the expected measured curve approach zero or 20 counts/s? Explain your answer. **[2 marks]**

Answer / mark points: It approaches 20 counts/s. [1] The contribution from Sample B becomes very small, but the unchanged background still gives about 20 counts/s. [1]

Teacher prompt: Do not describe the background line as the remaining count rate from Sample B itself.



4 Checking a third sample and the measurements

Table 1 gives expected corrected rates for Sample C. Two entries are missing. Background has already been removed.

Table 1

Time / min	0	3.0	6.0	9.0	12
Expected corrected rate / counts per second	192	96		24	

4(a) Complete the two missing corrected count rates in Table 1. Use the pattern of successive halvings. **[2 marks]**

Answer / mark points: At 6.0 min: $96 / 2 = 48$ counts/s. [1]

At 12 min: $24 / 2 = 12$ counts/s. [1]

4(b) Determine the half-life of Sample C from Table 1. **[1 mark]**

Answer / mark points: 3.0 min. [1] Each successive halving occupies a 3.0 min interval.

4(c) Compare Samples A and C. Which takes less time for its corrected rate to halve? Justify your choice with both half-lives. **[2 marks]**

Answer / mark points: Sample C takes less time. [1] Its half-life is 3.0 min, compared with 4.0 min for Sample A. [1]

Teacher prompt: A smaller graph height alone does not establish a shorter half-life; compare halving intervals.

4(d) Near 6.0 min, three consecutive 1.0 s readings give 45, 53 and 46 counts after background correction. Calculate their overall count rate. Explain why the individual counts differ. **[2 marks]**

Answer / mark points: Total corrected count = $45 + 53 + 46 = 144$ in 3.0 s, so rate = $144 / 3.0 = 48$ counts/s. [1] Individual decay events occur randomly, so equal short intervals can contain different numbers of detected events. [1]

Teacher prompt: These nearby intervals are short compared with the 3 min half-life; their expected rates are approximately equal.

4(e) Describe how a technician could use a detector and a clock to obtain corrected count-rate data and determine a half-life. Include the background measurement and how the detector position is controlled. **[4 marks]**

Answer / mark points: Measure background counts with the sample removed over a known interval; divide by the interval to obtain its count rate. [1]

With the sample present, keep detector distance and orientation fixed; record counts in known, consistent short intervals and convert to rates. [1]

Repeat at regular recorded elapsed times across several halvings, subtract the background rate and plot corrected rate against time with a smooth best-fit curve. [1]

Choose a corrected rate and half that rate; read both corresponding times and subtract to find the half-life, checking other pairs if possible. [1]

Teacher prompt: Use a fixed interval long enough to reduce random scatter but short relative to the half-life. This is an interpretation task, not a required-practical claim.

4(f) Measured points scatter slightly about the expected decay trend. Should a student join consecutive points with straight lines or draw a smooth best-fit curve? Explain. **[2 marks]**

Answer / mark points: Draw a smooth decreasing best-fit curve. [1] Random fluctuations cause scatter; a smooth curve represents the underlying large-sample trend rather than treating every fluctuation as a change in the decay behaviour. [1]

Continue your physics journey

Videos, practice and support for your next step

www.physicsuk.co.uk



5 Foundation practice and decisions

Foundation route: complete this instead of Question 6. A new sample, D, initially gives a corrected rate of 320 counts/s and has a half-life of 3.0 min.

5(a) Foundation: calculate the expected corrected rate for Sample D after 6.0 min. **[1 mark]**

Answer / mark points: Two half-lives: $320 \rightarrow 160 \rightarrow 80$ counts/s. Expected corrected rate = 80 counts/s. [1]

5(b) Foundation: the next measurement can start when the expected corrected rate is at most 20 counts/s. Determine the earliest time after the start. Show the number of half-lives. **[2 marks]**

Answer / mark points: $320 \rightarrow 160 \rightarrow 80 \rightarrow 40 \rightarrow 20$ requires four half-lives. [1]
Time = $4 \times 3.0 = 12$ min. [1]

5(c) Foundation: a trainee says the same number of nuclei decays in every 3.0 min interval. Explain why the expected decay curve does not support this claim. **[2 marks]**

Answer / mark points: The expected number of nuclei halves in each 3.0 min interval, so fewer nuclei remain for each later interval. [1] The expected number decaying per interval therefore decreases, rather than staying the same. [1]

5(d) Foundation: one short reading drops below 20 counts/s before 12 min. Explain why this alone does not show that Sample D has a shorter half-life, and suggest what the technician should do. **[2 marks]**

Answer / mark points: A short reading can fluctuate below the expected rate because decay is random. [1] Take repeated or longer timed readings, within an interval short relative to the half-life, and use the trend before changing the estimated half-life. [1]



6 Higher only ratios and decisions

Higher route: complete this instead of Question 5. Use Sample D: initial corrected rate 320 counts/s, half-life 3.0 min. Write ratios in the order requested.

6(a) Higher only: after three half-lives, give the ratio of expected corrected rate to its initial value, in that order. **[1 mark]**

Answer / mark points: After successive halvings the ratio is 1 : 8. [1]

6(b) Higher only: after three half-lives, give the ratio of the decrease in corrected rate to the initial rate. Show how you find the decrease. **[2 marks]**

Answer / mark points: Take the initial rate as 8 equal units: 1 unit remains, so the decrease is $8 - 1 = 7$ units. [1]

Decrease : initial rate = 7 : 8. [1]

Teacher prompt: 1 : 8 is the remaining-to-initial ratio, not the decrease-to-initial ratio.

6(c) Higher only: a second measurement requires the expected corrected rate to be at most 10 counts/s. Find the final-to-initial ratio and determine the earliest time after the start. **[2 marks]**

Answer / mark points: $10 : 320 = 1 : 32$, reached after five halvings ($320 \rightarrow 160 \rightarrow 80 \rightarrow 40 \rightarrow 20 \rightarrow 10$). [1]

Earliest time = $5 \times 3.0 = 15$ min. [1]

6(d) Higher only: a trainee gives a final-to-initial ratio of 1 : 6 after 6.0 min, using the elapsed time as the denominator. Correct the ratio and explain the error. **[2 marks]**

Answer / mark points: The ratio is 1 : 4. [1] 6.0 min is two 3.0 min half-lives, so the rate halves twice; the denominator follows successive halvings, not the numerical time in minutes. [1]

7 Optional Separate Physics only hazards

Separate Physics only, both tiers: Combined pupils omit this question. Two materials initially contain equal numbers of radioactive nuclei. P has a half-life of 2 h; Q has a half-life of 2 years. Their radiation type and energy, shielding and exposure geometry are the same.

7(a) Separate Physics only: for a brief exposure at the start, which material has the greater activity and therefore the greater dose rate under the stated conditions? Explain using half-life. **[2 marks]**

Answer / mark points: P. [1] With equal initial numbers of undecayed nuclei, the shorter half-life means more nuclei decay per second, so the activity and dose rate are greater under the matching conditions. [1]

Teacher prompt: Do not justify with more radiation alone; specify per second. Different initial quantities or exposure conditions would change the comparison.

7(b) Separate Physics only: equal initial numbers of radioactive nuclei of P and Q contaminate separate surfaces. Which contamination is likely to persist as a radioactive hazard for longer? Explain. **[2 marks]**

Answer / mark points: Q. [1] Its much longer half-life means its activity decreases much more slowly, so the contaminating material continues emitting radiation for longer. [1]

Teacher prompt: Longer persistence is not an unconditional claim of greater immediate danger. Half-life alone does not determine every risk.

Review and improve

Name what halves: activity, corrected count rate, or the number of undecayed nuclei. Do not say each nucleus splits in half, all nuclei decay at the half-life, or the same number decays in each interval. Distinguish a predicted large-sample trend from a fluctuating short reading.

Continue your physics journey

Videos, practice and support for your next step

www.physicsuk.co.uk

