

Half-life and radioactive-decay graphs

Name: _____ Class: _____ Date: _____

Start here

0-5 minutes

Today: Read half-life graphs, correct detector rates and apply your assigned tier route.

You need: Pen, a different-coloured pen, ruler and calculator. All graphs and reading are supplied.

Teacher-assigned route (tick one): Foundation [] Higher []. If unsure, ask your teacher before the tier pages. Everyone completes pages 1-6 and 9; complete page 7 OR page 8, never both.

Work from memory. Write in this booklet and show working.

1. A sample's expected corrected count rate is 96 counts/s. What is it after one half-life?

2. Measured count rate is 62 counts/s and the supplied background is 12 counts/s. Calculate the corrected source count rate.

3. A pupil says every individual nucleus must decay exactly one half-life after the start. Is that correct? Give a reason.

Stop for check 1. Wait for your teacher before moving on.

Try again A

Only if your teacher asks. Use the first 2 reading minutes, then continue on page 2.

Help: Use the rules on page 2. Corrected = measured - background. Halve only the sample contribution. Random individual events can still give a predictable large-sample trend.

(a) Halve a corrected rate of 84 counts/s once. (b) Measured rate is 77 counts/s and background is 7 counts/s. Find corrected rate. (c) Does half-life give an exact decay time for one nucleus? Explain.

When your teacher says, turn to page 2.

Read the meaning and the method

5-15 minutes

Half-life is an elapsed time for the expected number of undecayed nuclei, activity or corrected source count rate to halve. It is not the time for every nucleus to decay, and a nucleus does not split in half. Individual decay times are random; a large sample has a predictable statistical halving trend.

Quantity	Meaning and unit
Activity	Decays per second in the source; becquerels, Bq.
Measured count rate	Detector events per unit time, including background; e.g. counts/s or counts/min.
Corrected source count rate	Measured rate minus supplied background rate, using the same unit.
Half-life	Time between two levels where the corrected source value halves. Read both times and subtract.

A detector need not count every decay. Do not label its rate in Bq without calibration. Keep the detector arrangement fixed when comparing rates. Short measured counts may fluctuate about the large-sample trend.

Worked models from the revision notes

A source has activity 640 Bq and half-life 3 h. Find activity after 9 h. In a separate detector test, measured rate is 90 counts/min and background is 12 counts/min. Find corrected source count rate.

$9 / 3 = 3$ half-lives: $640 \rightarrow 320 \rightarrow 160 \rightarrow 80$ Bq. In the separate detector test, corrected count rate = $90 - 12 = 78$ counts/min. Activity uses Bq; detector count rate uses counts per unit time. Do not automatically equate them.

Measured or corrected?

If a graph is already corrected, do not subtract background again. If it includes background, subtract the supplied background from every rate before halving. For a measured target after a half-life: subtract background $\rightarrow$ halve the source contribution $\rightarrow$ add the unchanged background.

Count halvings, then use elapsed time

For a known half-life, count intervals in the elapsed time and halve once per interval. To find half-life from a total time, count the halvings between corrected values, then divide the total time by that count. Check minutes versus hours.

Shared reading and models adapted from PhysicsUK Half-Life and Radioactive Decay, sections 1-3. Higher ratios are supplied separately on page 8. Online reading is optional. Optional online reading.

Turn to page 3 for question 4.

Check background correction, then practise

15-20 minutes; start practice at 20 minutes

4. A detector measures 110 counts/s including a constant background of 10 counts/s. After one half-life, what measured rate is expected? Choose a letter and show the source correction, halving and final measured rate.

- A. 55 counts/s
- B. 50 counts/s
- C. 60 counts/s
- D. 100 counts/s

Initial corrected rate = _____ counts/s

After halving = _____ counts/s

Expected measured rate = _____ counts/s; letter: _____

Stop for check 2. Wait for your teacher before moving on.

Try again B

Only if your teacher asks. Complete this instead of questions 5-6, then continue with questions 7-12.

Help: Use page 2: subtract background, halve the sample contribution, then add the same background for a measured target.

A detector measures 150 counts/s including constant background 10 counts/s. Calculate the expected measured rate after one half-life. Show all three steps.

Definitions and a separate test

Independent tests follow. Curves show expected large-sample rates.

5. Define the half-life of a radioactive isotope.

6. A technician follows one unstable nucleus. Explain why its exact decay time cannot be predicted.

Continue with questions 7-12 and Figure 1 on page 4.

Read the corrected decay curve

20-30 minutes

7. A separate test sample has corrected count rate 640 counts/s and half-life 4.0 min. Calculate its expected corrected rate after 8.0 min.

Number of half-lives and halving steps:

Expected corrected rate = _____ counts/s

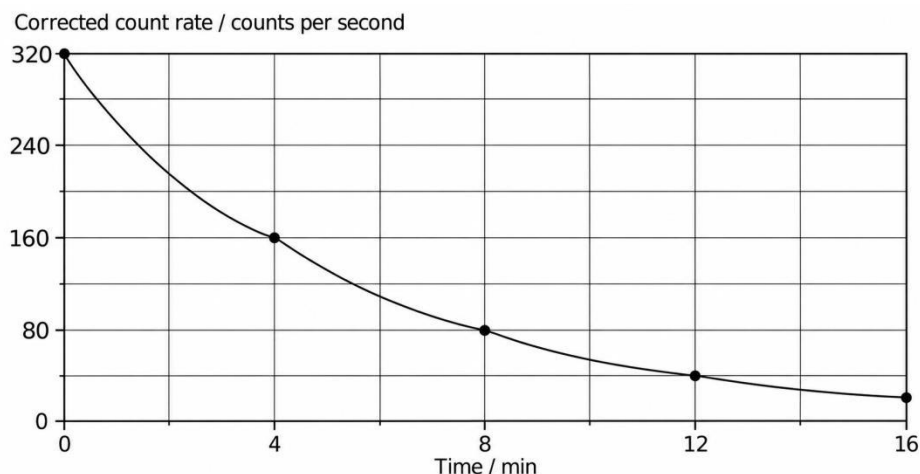


Figure 1: Sample A; background has ALREADY been subtracted. Time axis: minutes.

8. Use Figure 1 to read the corrected count rate at 4.0 min.

9. Use the decrease from 320 to 160 counts/s in Figure 1 to determine the half-life of Sample A.

Times and elapsed interval:

10. Use the decrease from 80 to 40 counts/s in Figure 1 to determine the half-life again.

Times and elapsed interval:

11. Calculate the elapsed time for Sample A to decrease from 80 to 20 counts/s. Show the number of half-lives.

Halving steps and number of half-lives:

Elapsed time = _____ min

12. A separate sample decreases from corrected rate 120 counts/s to 15 counts/s in 18 min. Determine its half-life. Show the number of halvings.

Halving steps and number of half-lives:

Half-life - working and unit:

At about 30 minutes, turn to page 5 for the independent check.

Pause, then read a different detector graph

30-33 minutes; then continue practice

13. In a fresh test the supplied background is 10 counts/s. Measured rates are 110 counts/s at 0 min, 60 counts/s at 3 min and 35 counts/s at 6 min. Find the corrected rates at all three times, then determine half-life. Show the time interval.

Corrected rates at 0, 3 and 6 min:

Halving time interval(s):

Half-life = min

Stop for check 3. Wait for your teacher before moving on.

Try again C

Only if your teacher asks. Complete this instead of questions 14-15, then continue with questions 16-18.

Help: Subtract 14 from each measured rate. Identify two corrected values where one is half the other, then subtract the corresponding times.

In another test, background is 14 counts/s. Measured rates are 94 counts/s at 0 min, 54 counts/s at 4 min and 34 counts/s at 8 min. Find all three corrected rates and determine half-life.

For questions 14-18, Sample B is different from Figure 1. Background with B removed is 20 counts/s; treat it as constant.

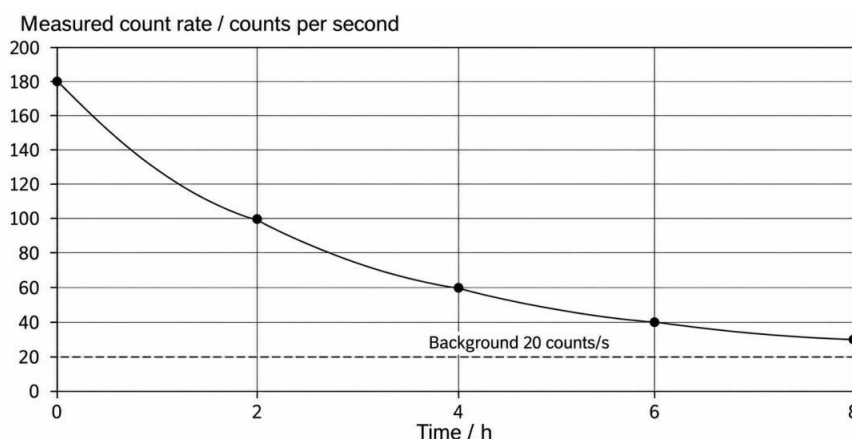


Figure 2: different Sample B; measured rate INCLUDES constant background 20 counts/s. Time axis: hours.

14. Use Figure 2 to read the measured count rate at 2.0 h.

15. Calculate the corrected count rate from Sample B at 2.0 h.

Working and corrected rate:

Continue with the repeated Figure 2 on page 6.

Correct both readings before finding half-life

33-41 minutes

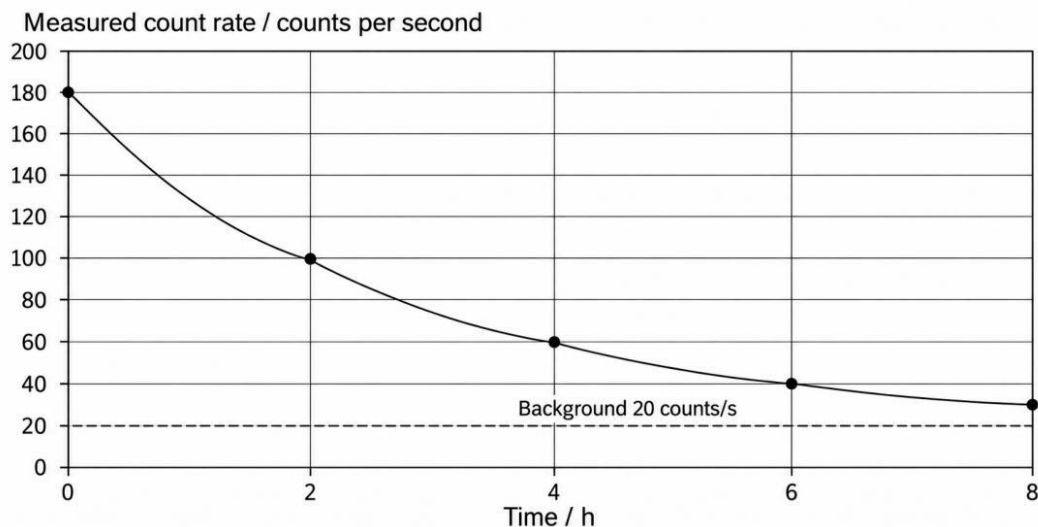


Figure 2: different Sample B; measured rate INCLUDES constant background 20 counts/s. Time axis: hours.

16. Calculate the corrected rates at 4.0 h and 6.0 h using Figure 2.

At 4.0 h - working and corrected rate:

At 6.0 h - working and corrected rate:

17. Use the corrected rates at 2.0 h and 4.0 h to determine Sample B's half-life. Give it in hours and minutes.

Corrected halving levels and time interval:

Half-life = h = min

18. A trainee halves the initial measured rate of 180 counts/s and looks for 90 counts/s to find half-life. Explain why the correct measured target is 100 counts/s.

At about 41 minutes, use ONE assigned tier page

Foundation: turn to page 7 for questions 19-20. Higher: skip page 7 and turn to page 8 for questions 21-22. Both routes then go directly to page 9. Do not complete both tier pages.

Follow your teacher-assigned tier route now.

Foundation route - this page replaces page 8

41-45 minutes - Foundation only

Complete this page only if your teacher assigned Foundation. Higher pupils skip to page 8. This is a new Sample D: corrected rate initially 320 counts/s; half-life 3.0 min. Background is already removed.

19. Foundation: Sample D initially gives corrected rate 320 counts/s and has half-life 3.0 min. Calculate its expected corrected rate after 6.0 min.

Number of half-lives:

Halving steps:

Expected corrected rate = counts/s

20. Foundation: the next measurement of Sample D can start when its expected corrected rate is at most 20 counts/s. Find the earliest time after the start. Show the number of half-lives.

Keep the quantity and unit precise

For your answers, name the corrected count rate and the elapsed time. Count halving intervals rather than the number of values written in a chain.

Skip page 8. At 45 minutes turn directly to page 9 for review.

Higher route - this page replaces page 7

41-45 minutes - Higher only

Complete this page only if your teacher assigned Higher. Foundation pupils skip this page. These questions use Sample D: corrected rate initially 320 counts/s; half-life 3.0 min. Background is already removed.

A ratio must name the requested quantities in order. Remaining : initial compares what is left with the starting value. Decrease : initial compares initial minus remaining with the starting value. This reading is adapted from revision-note section 5.

Higher worked model - name the numerator

Higher only: a different sample's corrected rate falls from 400 to 100 counts/s. Find remaining : initial and decrease : initial.

Remaining : initial = $100 : 400 = 1 : 4$. Decrease = $400 - 100 = 300$ counts/s; decrease : initial = $300 : 400 = 3 : 4$. Name the numerator before simplifying.

21. Higher only: Sample D initially gives corrected rate 320 counts/s and has half-life 3.0 min. After three half-lives, give the ratio of expected corrected rate to initial rate, in that order.

Three halving steps:

Remaining : initial =

22. Higher only: after those three half-lives, give the ratio of the decrease in corrected rate to the initial rate. Show how you find the decrease.

Decrease - working and unit:

Decrease : initial =

Check the order of both ratios. They describe different quantities; neither denominator is the number of minutes.

At 45 minutes turn directly to page 9 for review. Do not complete page 7.

Review, then show what you can do

45-55 minutes review; 55-60 minutes independent exit

23. Correct your assigned practice in a different colour. Explain one correction using a quantity, background subtraction or elapsed time. If all answers were correct, explain why halving a measured rate that includes background gives the wrong target.

Independent exit - only when your teacher says

Everyone completes question 24. Cover earlier pages and previous answers.

24. A new sample has measured rate 170 counts/s initially and 50 counts/s after 4.0 min. Supplied background is constant at 10 counts/s. (a) Find both corrected rates. (b) Use the number of halvings to determine half-life. (c) Can the resulting half-life predict the exact decay time of one nucleus? Explain.

(a) Initial corrected rate - working and unit:

Later corrected rate - working and unit:

(b) Halving steps and half-life - working and unit:

(c) Individual nucleus - decision and reason:

Stop for check 4. Wait for your teacher before moving on.

Hand in the whole named booklet. Leave the unassigned tier page blank; include your working and corrections.

Try again D - next lesson

Leave this today. Your usual teacher may ask you to do it next lesson.

Help: Next lesson revisit page 2: correct both rates, count the halvings, then divide total elapsed time by that count. Cover the reading before the fresh attempt.

Next lesson: measured rate is 202 counts/s initially and 58 counts/s after 12 min. Constant background is 10 counts/s. Find the corrected rates and half-life. Explain whether this predicts an individual nucleus's exact decay time.

Hand your complete booklet to your teacher.