

Half-lives and the random nature of radioactive decay

6.4.2.3 · Physics · revision notes

What half-life means, how it links to the random nature of radioactive decay, and how to find a half-life from a graph or data. Expect graph reading and 2 to 4 mark calculations.

Key facts

- Half-life: time for the number of unstable nuclei in a sample (or its count rate) to halve
- Number of half-lives = time passed $\div$ half-life
- Subtract the background count rate before finding a half-life
- Radioactive decay is random: you cannot predict which nucleus decays or when
- Fraction left after 0, 1, 2, 3, 4 half-lives: 1, $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$

Notes

Random decay

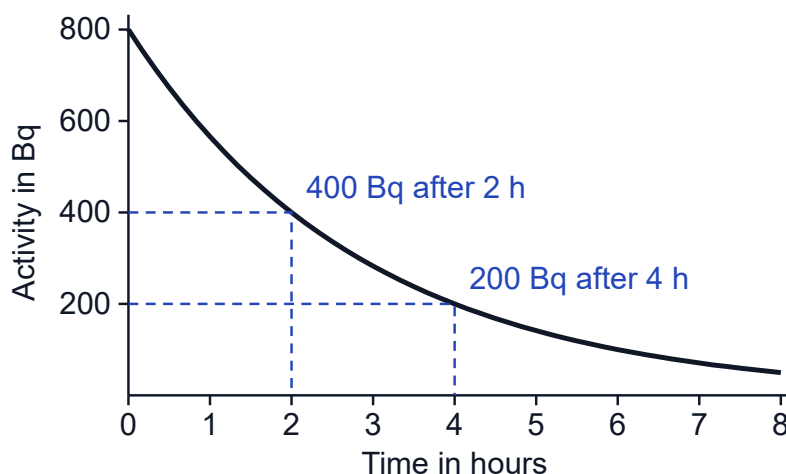
- Radioactive decay is **random**. You cannot predict which nucleus in a sample will decay next, or when a particular nucleus will decay.
- But a sample contains a huge number of nuclei, so the fraction that decays in a given time is predictable. That is why each isotope has its own fixed half-life.

Half-life

- The **half-life** of a radioactive isotope is the time it takes for the number of nuclei of the isotope in a sample to halve.
- It is also the time it takes for the count rate (or activity) from a sample containing the isotope to fall to half its initial level.
- After each half-life the activity halves again, e.g. $800 \text{ Bq} \rightarrow 400 \text{ Bq} \rightarrow 200 \text{ Bq} \rightarrow 100 \text{ Bq}$ after 3 half-lives.
- Number of half-lives = time passed $\div$ half-life.

Finding the half-life from a graph

- Choose a starting value on the curve that is easy to halve, e.g. 600 Bq, and read the time.
- Find where the activity is half that value (300 Bq) and read that time.
- The difference between the two times is the half-life. Repeat from another starting value and take the mean.



The activity halves every 2 hours ($800 \rightarrow 400 \rightarrow 200$ Bq), so the half-life is 2 hours.

- If the readings include background radiation, subtract the background count rate first.

How to answer each type of question

Define half-life and random decay

1 to 2 marks

Grade 5

1. Half-life: 'the time taken for the number of unstable nuclei (or the count rate) to halve'.
2. Random: 'cannot predict which nucleus will decay next, or when'.

Example. (a) Define the half-life of a radioactive isotope. (1 mark)
(b) Radioactive decay is random. Explain what this means. (1 mark)

Model answer. (a) The time taken for the number of unstable nuclei of the isotope in a sample to halve (1)

(b) You cannot predict which nucleus will decay next, or when a particular nucleus will decay (1)

Don't lose marks

- ✗ Thinking that after two half-lives the sample has all gone. A quarter is left.
- ✗ Dividing the time by 2 instead of by the half-life to find the number of half-lives.
- ✗ Forgetting to subtract the background count rate before finding the half-life.
- ✗ Defining half-life as 'half the time it takes for the sample to decay completely'.

More tips

Memory tricks

- Halving table: write time and activity in two columns, and halve down the columns until you reach the value you need.
- Calculator: 0.5^n gives the fraction left, e.g. $0.5^4 = 0.0625 = 1/16$.
- Sense check: 1 half-life leaves a half, 2 leave a quarter, 3 leave an eighth.
- On a graph, draw lines across to the curve and down to the time axis so the examiner can see your readings.

Exam technique

- Show each halving step, e.g. $2400 \rightarrow 1200 \rightarrow 600 \rightarrow 300$, so your method is clear.
- When reading a graph, pick a starting value that is easy to halve and read to the nearest small square.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 4

Define half-life

The time for the number of unstable nuclei in a sample, or its count rate, to halve.

Grade 5

Explain what random decay means

You cannot predict which nucleus will decay or when, but a large sample decays in a predictable way.

Grade 5

Find a half-life from a graph

Read the time for the activity or count rate to fall to half of any starting value.

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