A-LEVEL PHYSICS • EXERCISE SHEET

23.2 Radioactive decay

Name: _____ Class: _____ Date: _____ **Total: 19 marks**

Objective

Build the skills to answer exam questions on **radioactive decay**.

You must be able to:

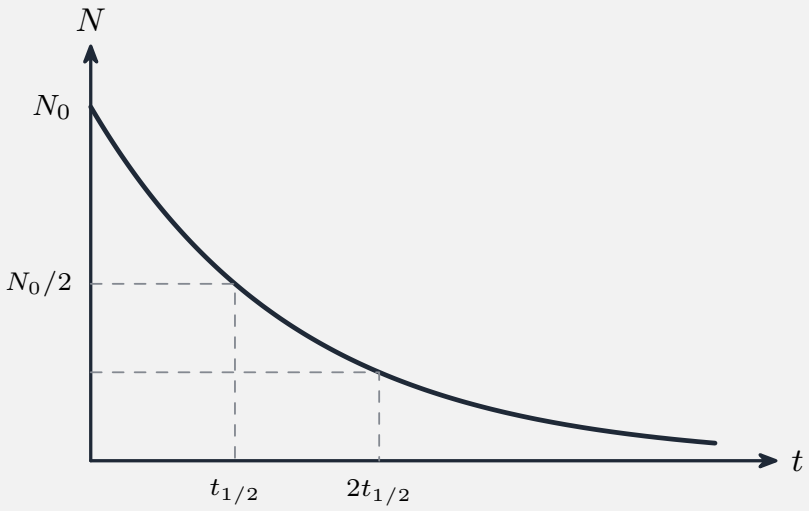
- describe decay as **spontaneous** and **random**
- use **activity** $A = \lambda N$ and $\lambda = 0.693/t_{1/2}$
- use the exponential decay $x = x_0 e^{-\lambda t}$ and **half-life**

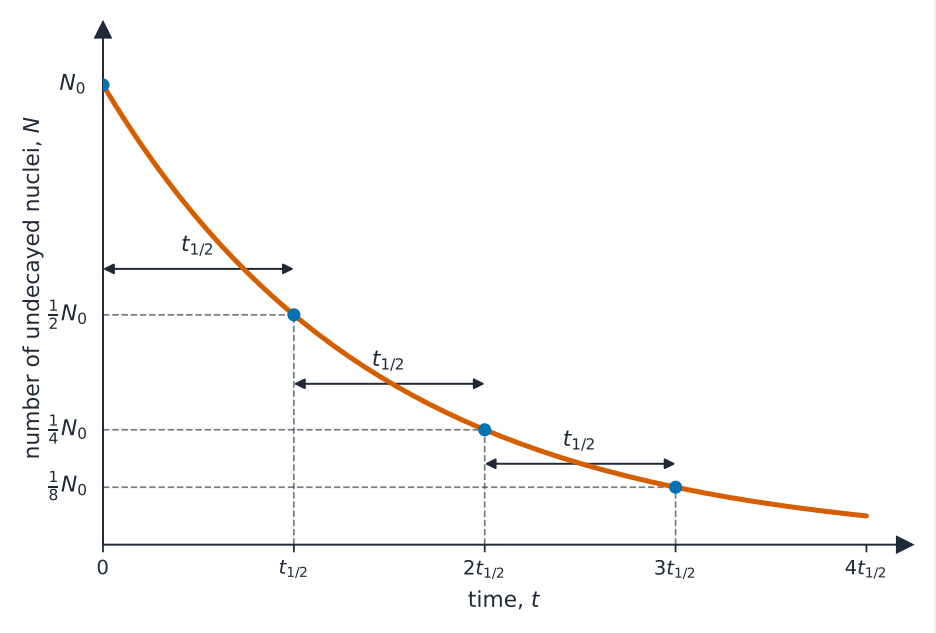
1 Worked examples

Study these first. Each one shows the method for a question type used later —follow the steps and you can do the Practice and Exam-style questions yourself.

Random and exponential

Decay is **spontaneous** (no trigger) and **random** (the count rate fluctuates). The number of undecayed nuclei falls **exponentially**, halving every **half-life**:





The exponential radioactive decay curve

$$A = \lambda N, \qquad \lambda = \frac{0.693}{t_{1/2}}, \qquad N = N_0 e^{-\lambda t}.$$

- **activity** A —decays per second (becquerel, Bq); **decay constant** λ —probability of decay per second.

The same exponential law applies to the **activity** and the **count rate**: $A = A_0 e^{-\lambda t}$.

■ Finding the time —take logs

For a **whole number** of half-lives, just halve repeatedly (after n half-lives a fraction $(\frac{1}{2})^n$ remains). For **any** time or fraction, take the natural log of $N = N_0 e^{-\lambda t}$:

$$\ln\frac{N}{N_0} = -\lambda t \quad \Longrightarrow \quad t = -\frac{1}{\lambda}\ln\frac{N}{N_0}.$$

Worked example. A source has half-life 8.0 days, so $\lambda = \dfrac{0.693}{8.0} = 0.0866 \text{ day}^{-1}$. The time for its activity to fall to 20% is $t = -\dfrac{1}{0.0866}\ln(0.20) = 18.6$ days.

2 Practice

Now apply the methods above.

2.1 State **two** features of radioactive decay. [2]

2.2 Define **activity** and the **decay constant**. [2]

2.3 Define **half-life**. [1]

2.4 Write the equation linking **activity**, **decay constant** and **number** of nuclei. [1]

3 Exam-style questions

3.1 The **half-life** is the time for: [1]

- **A** all the nuclei to decay
- **B** half the (undecayed) nuclei to decay
- **C** the activity to reach exactly zero
- **D** the decay constant to halve

3.2 A source has a decay constant of 0.040 s^{-1}. Calculate its **half-life**. [2]

3.3 A sample has 2.0×10^{20} undecayed nuclei and a decay constant of 1.5×10^{-9} s^{-1}. Calculate its **activity**. [2]

3.4 A radioactive isotope has a half-life of 6.0 hours. What **fraction** of the original nuclei

remains after 18 hours? [2]

3.5 A radioactive source has a half-life of 8.0 days. Calculate the **time** for its activity to fall to 20% of its initial value. [4]

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **23.2 Radioactive decay** past-paper sheet in the Library, or try these in **Practice mode**:

- 9702/44 N25 —Q8 (radioactive decay, structured)
- 9702/41 J25 —Q9 (activity and decay constant)
- 9702/42 J25 —Q10 (half-life and exponential decay)
- 9702/43 J25 —Q9 (radioactive decay)
- 9702/42 M25 —Q9 (decay constant)

Solutions

2.1 It is **spontaneous** (unaffected by external conditions) and **random** (cannot predict which nucleus decays when).

2.2 **Activity** —the number of decays per unit time; **decay constant** —the probability per unit time that a nucleus decays.

2.3 The time for **half** the undecayed nuclei (or the activity) to decay.

2.4 $A = \lambda N$.

3.1 **B** —half the undecayed nuclei to decay.

3.2 $t_{1/2} = \dfrac{0.693}{\lambda} = \dfrac{0.693}{0.040} = 17$ s.

3.3 $A = \lambda N = (1.5 \times 10^{-9})(2.0 \times 10^{20}) = 3.0 \times 10^{11}$ Bq.

3.4 18 h = 3 half-lives; fraction $= (\frac{1}{2})^3 = \frac{1}{8}$.

3.5 $\lambda = \dfrac{0.693}{t_{1/2}} = \dfrac{0.693}{8.0} = 0.0866$ day^{-1}; $t = -\dfrac{1}{\lambda} \ln \dfrac{A}{A_0} = -\dfrac{1}{0.0866} \ln(0.20) = 18.6$ days.