

4.4 Nuclear equations and half-lives

Name: _____ Class: _____ Date: _____

Total: 22 marks

KEY WORDS Half-life

Objective

Write balanced nuclear equations for single alpha and beta decay, and find half-lives from data or graphs. Original questions for spec statements 4.4.2.2–4.4.2.3.

1 Key knowledge and worked examples

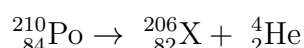
Balance **both rows**: mass number A on top, atomic number Z below.

Decay	Effect on nucleus	Particle written
alpha	$A - 4, Z - 2$	${}^4_2\text{He}$
beta	A same, $Z + 1$	${}^0_{-1}\text{e}$
gamma	neither changes	γ only



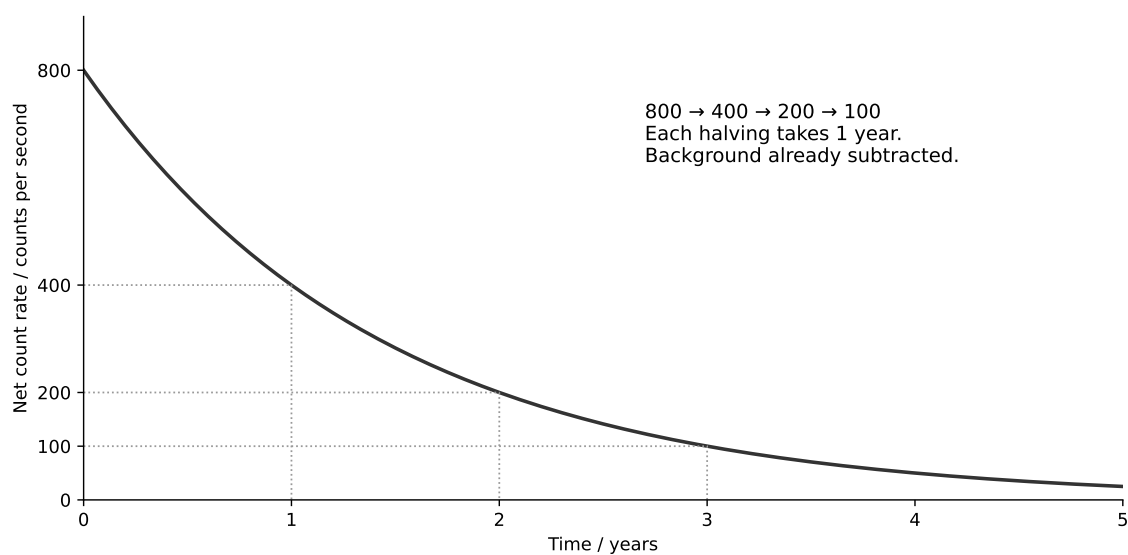
Worked example. Polonium-210 decays by alpha emission.

- Alpha removes 4 and 2: $A : 210 - 4 = 206$; $Z : 84 - 2 = 82$.



- Check: $206 + 4 = 210$ ✓ and $82 + 2 = 84$ ✓. Naming the daughter is not required.

Half-life: the time for the number of nuclei – or the count rate / activity – to **halve**.



Read the time for one halving, several times if possible, and average.

- Two rates and a time: count the halvings, then $t_{1/2} = t/n$.
- (HT) After n half-lives the fraction remaining is $1/2^n$ – the net decline expressed as a ratio.

2 Practice

2.1 Radon-222 ($Z = 86$) decays by alpha emission. Write the balanced equation. [2]

2.2 Strontium-90 ($Z = 38$) decays by beta emission. Write the balanced equation. [2]

2.3 A background-corrected count rate falls from 6400 counts/s to 800 counts/s in 24 hours. Calculate the half-life. [2]

3 Exam-style questions

3.1 Krypton-89 ($^{89}_{36}\text{Kr}$) decays by beta emission.

(a) Write the nuclear equation, using X for the daughter. [3]

(b) State the effect of this decay on the mass number and the atomic number. [2]

3.2 The activity of a sample falls from 1200 Bq to 150 Bq in 15 hours.

(a) Determine the half-life. Show the sequence of halvings. [3]

(b) (HT) Calculate the activity after a further 2 half-lives. [2]

3.3 A rock contains a radioactive isotope with a half-life of 2 hours. At 9:00 am its activity is known to be 5120 Bq.

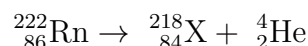
(a) Predict the activity at 5:00 pm the same day. [3]

(b) Explain why the activity can only be predicted for the whole sample, not for a single nucleus. [2]

(c) State one assumption used in the prediction. [1]

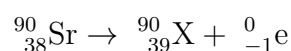
Solutions

2.1 $A : 222 - 4 = 218$; $Z : 86 - 2 = 84$.



(row balance B1, correct values B1)

2.2 A stays 90; $Z : 38 + 1 = 39$.

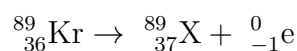


2.3 Halvings: $6400 \rightarrow 3200 \rightarrow 1600 \rightarrow 800$: three halvings.

$$t_{1/2} = 24/3 = \mathbf{8} \text{ hours}$$

(counting halvings C1, answer A1)

3.1 (a)



(mass unchanged C1, $Z + 1$ C1, balanced rows A1) (b) Mass number unchanged; atomic number increases by 1.

3.2 (a) Halvings: $1200 \rightarrow 600 \rightarrow 300 \rightarrow 150$: three halvings in 15 h (C1).

$$t_{1/2} = 15/3 = \mathbf{5} \text{ hours}$$

(C1, A1) (b) Two more halvings: $150 \rightarrow 75 \rightarrow \mathbf{37.5}$ Bq (each halving C1, answer A1).

3.3 (a) Time $9:00$ to $5:00 = 8$ hours $= 4$ half-lives (C1).

$$A = A_0 \left(\frac{1}{2}\right)^n = 5120 \text{ Bq} \times \left(\frac{1}{2}\right)^4 = \mathbf{320} \text{ Bq}$$

(halving chain C1, answer A1) (b) Decay is a random process: it cannot be predicted for any individual nucleus – only the statistical behaviour of large numbers. (c) The sample is unchanged: none of the radioactive material has been lost.