Unit 24 · Radioactivity and Nuclear Reactions

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 33

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Spot the error

ANSWER U · 3

She found the fraction **left**, not the fraction decayed. After 3 half-lives 1/8 is left, so the fraction decayed is $1 - 1/8 = \mathbf{7/8}$.

MARKING SCHEME

- ✓ The error: 1/8 is the fraction left.
- ✓ 3 half-lives leave 1/8.
- ✓ 7/8 has decayed.

2 Read the data

ANSWER HA · 4

(The readings are made up, for a half-life of 5.0 min.)

i. The 20 a minute is background radiation (rocks, cosmic rays), counted with or without the source.

ii. Take off 20: **400, 230, 132, 76, 44, 25** a minute.

iii. They halve every **5 min** or so: 400 falls to about 200 between 4 and 8 min, and 230 at 4 min to about 115 by 9 min; plotted, the curve gives 5 min.

iv. About **20 a minute**, the background.

MARKING SCHEME

- ✓ The background is counted anyway, so it is taken off.
- ✓ Corrected rates 400, 230, 132, 76, 44, 25.
- ✓ Half-life 5 min.
- ✓ After a long time, 20 a minute.

3 Predict, then explain

MARKING SCHEME U · 3

- ✓ Alpha: stopped by paper.
- ✓ Little beta: aluminium stops hardly more than paper.
- ✓ Gamma: some still gets through 5 cm of lead.

4 Show that

MARKING SCHEME A · 3

- ✓ $\lambda t = \ln 10$.
- ✓ $t = (2.303/0.693)\,T½ = 3.32\,T½$.
- ✓ 17.6 years for cobalt-60.

5 A real setting

ANSWER A · 3

$t = \dfrac{T_{1/2}}{0.693} \ln \dfrac{1}{0.70} = \dfrac{5.3}{0.693} \times 0.357 = \mathbf{2.7\ years}$. As it weakens, each treatment must be given for a **longer time**, since the dose is the activity multiplied by the time.

MARKING SCHEME

- ✓ $t = (T_{1/2}/0.693)\ln(1/0.7)$.
- ✓ About 2.7 years.
- ✓ Longer exposure times as it weakens.

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6 Which explanation fits?

MARKING SCHEME U · 2

- ✓ Kamal.
- ✓ Decay is random, so counts scatter about the average.

7 Correct the misconceptions

ANSWER U · 3

1. After two half-lives **a quarter** is still left; a sample never quite all decays in a fixed time.
2. A beta particle is an electron made **in the nucleus**, as a neutron turns into a proton.
3. A gamma ray changes **neither** the mass number nor the atomic number; it only carries away energy. (An alpha particle takes 4 from the mass number.)

MARKING SCHEME

- ✓ A quarter is left after two half-lives.
- ✓ The beta particle comes from the nucleus (n $\rightarrow$ p + e).
- ✓ Gamma changes neither A nor Z.

8 Work backwards

ANSWER A · 3

1/8 is left, so 24 hours is 3 half-lives: $T_{1/2}$ = **8.0 hours**. $\lambda = 0.693 \div 8.0$ = **0.087 per hour**. $\tau = 1/\lambda$ = **11.5 hours**.

MARKING SCHEME

- ✓ 1/8 left: three half-lives, 8.0 hours.
- ✓ $\lambda = 0.087$ per hour.
- ✓ $\tau = 11.5$ hours.

9 Compare

ANSWER HA · 4

i. $A = \lambda N$; λ_A is 3 times λ_B and N_A twice N_B, so A is **6 times** as active at first.

ii. Equal when $\lambda_A N_A e^{-\lambda_A t} = \lambda_B N_B e^{-\lambda_B t}$: $e^{(\lambda_A - \lambda_B)t} = 6$, with $\lambda_A - \lambda_B = 0.347 - 0.116 = 0.231$ per hour, so $t = \dfrac{\ln 6}{0.231}$ = **7.8 hours**.

MARKING SCHEME

- ✓ A = λN.
- ✓ A is 6 times as active at first.
- ✓ $e^{(\lambda_A - \lambda_B)t} = 6$.
- ✓ t = 7.8 hours.

10 Design it

MARKING SCHEME A · 3

- ✓ Technetium-99m.
- ✓ Gamma only, so it leaves the body; a short half-life.
- ✓ Reasons against the others (alpha harmful inside, beta stays in, years too long).

11 Make your own

ANSWER HA · 2

For example: “After 24 days only 1/16 of a radioactive sample is left. Find its half-life.” $1/16 = (1/2)^4$, so 24 days is 4 half-lives and the half-life is 6 days. Any numbers that give 6 days are right.

MARKING SCHEME

- ✓ A sensible problem.
- ✓ Solved correctly to 6 days.

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See it at Science Playground

Exhibits and plants at the center, Bhaktapur, that go with this unit. Book a class visit at science-playground.com/booking.

- **Tree Ring Cross-Section** (exhibit): Each ring is one year's wood, made from carbon in that year's air: rings counted in very old wood are how radiocarbon ages are corrected.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	11	12	10	**33**