Unit 12 · Radioactivity

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 50

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

Her equation doesn't balance: 130 + 0 = 130, not 131, and 52 + (−1) = 51, not 53. In beta decay a neutron turns into a proton (which stays) and an electron (which leaves), so the atomic number goes **up** by 1 and the mass number stays the same:
$^{131}_{53}\mathrm{I} \longrightarrow {}^{131}_{54}\mathrm{Xe} + {}^{0}_{-1}\mathrm{e}$. Check: 131 = 131 + 0; 53 = 54 − 1.

MARKING SCHEME

- ✓ Her equation doesn't balance (or: the electron comes from a neutron turning into a proton, so Z goes up).
- ✓ Z goes up by 1 and A stays the same.
- ✓ The right daughter: xenon-131, Z = 54, A = 131.

2 Is the chain possible?

ANSWER A · 4

i. **Manisha's.** Only alpha particles change the mass number, by 4 each, so the fall in A must divide by 4. 238 − 205 = 33 does not.

ii. Rakesh: 232 − 208 = 24, so **6 alpha**. Z falls to 90 − 12 = 78, and must rise to 82: **4 beta**.

Rohan: 214 − 206 = 8, so **2 alpha**. Z falls to 83 − 4 = 79, and must rise to 82: **3 beta**.

MARKING SCHEME

- ✓ Manisha's chain: the fall in A must divide by 4, and 33 does not.
- ✓ Rakesh's: 6 alpha.
- ✓ Rakesh's: 4 beta.
- ✓ Rohan's: 2 alpha and 3 beta.

3 What does the source give out?

ANSWER HA · 5

i. 500, 280, 40, 10.

ii. **All three.** Paper cuts the count (500 to 280), so there is **alpha**. Aluminium cuts it further (280 to 40), so there is **beta**. Some still gets through aluminium and even lead (10 above background), so there is **gamma**.

iii. Alpha: 500 − 280 = **220**. Beta: 280 − 40 = **240**. Gamma: **about 40** before any lead.

iv. Lead only reduces gamma rays. Each extra layer cuts what reaches it by the same fraction, so no thickness stops every last gamma ray; enough lead only makes them too few to matter. The tube would also still count the background of 20 a minute.

MARKING SCHEME

- ✓ The net counts 500, 280, 40 and 10.
- ✓ All three radiations, each with its evidence.
- ✓ About 220 alpha and 240 beta.
- ✓ About 40 gamma.
- ✓ Lead only reduces gamma rays, and never to exactly zero.

4 Choose the source

ANSWER

i. **P**: alpha ionizes the air strongly, is stopped by the air and the case, and with its long life it keeps working.

ii. **Q**: a thin sheet absorbs part of a beta beam, and 30 years means the count hardly drifts from month to month.

iii. **R**: gamma rays get out of the body to the camera, and very little is left in the body after a day.

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iv. **S**: only gamma gets through thick metal, and it lasts for years; R would be gone in days. **A · 4**

MARKING SCHEME

- ✓ P, for strong ionizing and short range.
- ✓ Q, since a thin sheet absorbs part of a beta beam, with a long life.
- ✓ R, since gamma leaves the body and a short life leaves little behind.
- ✓ S, since gamma passes through thick metal and it lasts.

5 Time, distance and lead

ANSWER **A · 4**

i. $90 \div 3^2 =$ **10 µSv per hour**.
ii. 20 mSv = 20,000 µSv. $20{,}000 \div 10 =$ **2,000 hours**.
iii. 2.4 cm is two layers of 1.2 cm: $10 \times ½ \times ½ =$ **2.5 µSv per hour**.
iv. 1 mSv = 1,000 µSv. $1{,}000 \div 2.5 =$ **400 hours**.

MARKING SCHEME

- ✓ 10 µSv per hour at 3 m.
- ✓ 2,000 hours a year.
- ✓ 2.5 µSv per hour behind two layers of lead.
- ✓ 400 hours.

6 Estimate it

ANSWER **A · 3**

$100 \div 6.6 \approx 15$ halvings. $2^{15} = 32{,}768$, so about **1/30,000** gets through.
A thousandth is about 10 halvings ($2^{10} = 1{,}024$): 10×1.2 cm = **12 cm of lead**.

MARKING SCHEME

- ✓ About 15 halvings.
- ✓ About 1/30,000 gets through.
- ✓ About 10 halvings, so 12 cm of lead.

7 The nucleus recoils

ANSWER **HA · 3**

Total momentum before = 0, so the radon gets momentum equal and opposite to the alpha particle's: $222 \times v = 4 \times 1.5 \times 10^7$, so $v = 6 \times 10^7 \div 222 =$ **2.7×10^5 m/s**.
It moves **opposite to the alpha particle**, like a gun's recoil, and more slowly because it is much heavier.

MARKING SCHEME

- ✓ Total momentum is zero before and after: $222\ v = 4 \times 1.5 \times 10^7$.
- ✓ $v \approx 2.7 \times 10^5$ m/s.
- ✓ Opposite to the alpha particle (recoil).

8 Predict, then explain

ANSWER **HA · 3**

Beta and gamma reach the screen; alpha does not. Alpha particles travel only about 3 to 7 cm in air, using up their energy on the ions they make. Beta particles travel up to a few meters, and gamma rays much farther.
To show the alpha particles were there, put the detector within 3 cm of the source: a count that paper cuts down shows them.

MARKING SCHEME

- ✓ Beta and gamma reach the screen; alpha doesn't.
- ✓ Alpha travels only 3 to 7 cm in air, losing its energy making ions.
- ✓ A detector close to the source, with paper as a test.

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9 Which explanation fits the evidence?

ANSWER HA · 3

Radhika's. If each sheet took the same fraction, the second sheet would take as big a share as the first. The first takes 40% of what reaches it (100 to 60), while the seventh and eighth together take almost nothing (25 to 24). So one part is stopped quickly, within the first few sheets, and another hardly notices the sheets.

MARKING SCHEME

- ✓ Radhika's explanation.
- ✓ The fraction removed isn't constant: 40% by the first sheet, about 4% by the last two together.
- ✓ So one kind is stopped quickly and another penetrates.

10 Design a fair test

ANSWER A · 4

i. The number of sheets is changed; the counts in a fixed time are measured.

ii. Any three: the same source; the same distance from source to tube; the same counting time; the same kind and thickness of sheet; the same place for the tube.

iii. Count with the source away and take this from every reading, since the tube always counts background radiation; otherwise it hides the fall at large thicknesses.

iv. Any two: only the teacher handles the source, with tongs; students watch from a distance; time near the source kept short; the source goes back into its locked lead container. Support: each sheet multiplies the net count by about the same fraction.

MARKING SCHEME

- ✓ Changes the number of sheets, measures counts in a fixed time.
- ✓ Any three things kept the same.
- ✓ Takes the background from every reading, because the tube always counts it.
- ✓ Two safety rules, and each sheet multiplying the net count by about the same fraction.

11 What if?

ANSWER A · 3

Alpha particles ionize the air between two plates; the ions carry a small current; smoke particles catch the ions, the current drops, and the alarm sounds.

With gamma: (1) it ionizes least, so very few ions and almost no current for the smoke to change; (2) it passes through the plastic case and through people, so it would no longer be safe on a ceiling.

MARKING SCHEME

- ✓ Alpha ionizes the air, the ions carry a current, smoke catches the ions and the current drops.
- ✓ Gamma ionizes too weakly to make a useful current.
- ✓ Gamma passes through the case, so it is not safe.

12 Correct the misconceptions

ANSWER U · 3

1. A beta particle comes out of the **nucleus**, made when a neutron turns into a proton; it isn't one of the atom's electrons.
2. Heating makes **no difference**: heat doesn't reach the nucleus.
3. Radiation passing through leaves a person **not radioactive**; only radioactive material on or in something (contamination) is dangerous to others.

MARKING SCHEME

- ✓ A beta particle comes from the nucleus, from a neutron turning into a proton.
- ✓ Heat does not change the rate.
- ✓ Radiation passing through doesn't make a person radioactive.

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13 Judge the case

ANSWER A · 3

Any three: keep sources locked away; label every container with the warning sign; keep a written record of every source, so that none gets lost or sold as scrap.
A source can't be switched off: its nuclei go on decaying whether the machine is used or not. Rubbed on skin and carried home, the powder contaminated people.

MARKING SCHEME

- ✓ Any two of locking, labeling and keeping records.
- ✓ A third rule of the same list.
- ✓ A source can't be switched off, and the powder contaminated them.

14 Think

ANSWER HA · 3

$A = 226 - 4 - 4 =$ **218**. $Z = 88 - 2 - 2 + 1 + 1 =$ **86**.
Same Z as radon-222, a different A: it is an **isotope** of radon-222. Z alone decides the element.

MARKING SCHEME

- ✓ $A = 218$.
- ✓ $Z = 86$.
- ✓ An isotope: the same atomic number, a different mass number.

15 Make your own

ANSWER HA · 2

For example: stand at 2 m, $160 \div 4 = 40$ μSv per hour; add 3.6 cm of lead (3 layers), $40 \div 8 =$ **5 μSv per hour**. Any plan works that gives $(\text{distance})^2 \times 2^{\text{(layers)}}$ of at least 32.

MARKING SCHEME

- ✓ A plan using both distance and lead layers.
- ✓ A worked dose rate of 5 μSv per hour or less.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	0	6	25	19	**50**

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