7.1 Atomic structure and radiation

Name: _____ Class: _____ Date: _____ **Total: 27 marks**

KEY WORDS isotope • half-life

Objective

Build the skills to answer exam questions on **atoms and radioactivity** : the nuclear model, isotopes, alpha, beta and gamma radiation, nuclear equations, background radiation, half-life, and contamination and irradiation.

You must be able to:

- describe the nuclear model of the atom and the alpha-scattering evidence for it
- compare alpha, beta and gamma radiation and balance nuclear equations
- find half-life from data or a graph and use it in calculations
- explain background radiation, contamination and irradiation, and how people are protected

1 Key knowledge and worked examples

■ Atoms and radioactivity

idea	equation or rule
the atom	a tiny, dense, positive nucleus (protons and neutrons) with electrons around it; ${}^{A}_{Z}\mathrm{X}$: A = protons + neutrons, Z = protons
isotopes	the same number of protons, a different number of neutrons
radiation	alpha (${}^{4}_{2}\alpha$): stopped by paper, strongly ionising; beta (${}^{0}_{-1}\beta$): stopped by a few mm of aluminium; gamma: reduced by thick lead, weakly ionising
equations	alpha decay: A falls by 4, Z falls by 2; beta decay: A stays, Z rises by 1; the top and bottom numbers balance
half-life	the time for the number of nuclei (or the count rate) to halve; after n half-lives, $\frac{1}{2^n}$ is left
background	radiation all around us (rocks, cosmic rays, medical uses); subtract it from readings

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Worked example 1: a nuclear equation. Polonium-210 ($^{210}_{84}$Po) decays by alpha emission to lead (Pb). Write the equation.

1. Known: an alpha particle is $^{4}_{2}\alpha$.
2. Rule: top numbers and bottom numbers balance.
3. Numbers: $210 - 4 = 206$; $84 - 2 = 82$.
4. Result: $^{210}_{84}\mathbf{Po} \rightarrow {}^{206}_{82}\mathbf{Pb} + {}^{4}_{2}\alpha$.

Worked example 2: half-life. A sample has an activity of 640 Bq. Its half-life is 3 days. Find the activity after 12 days.

1. Known: 12 days = 4 half-lives.
2. Rule: halve once for each half-life.
3. Numbers: $640 \rightarrow 320 \rightarrow 160 \rightarrow 80 \rightarrow 40$.
4. Result: 40 **Bq**.

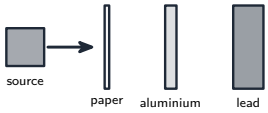
Answer shapes: count the half-lives first; take away background before you find a half-life.

2 Practice

2.1 How many protons and how many neutrons are in the nucleus shown? [2]

$^{14}_{6}$C

2.2 Radiation from a source is aimed at three absorbers. Which radiation is stopped by the paper? Which radiation can pass through the aluminium? [2]



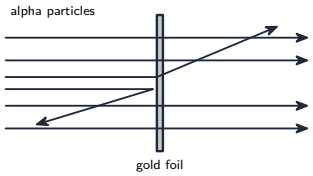
2.3 The count rate from a source falls from 800 counts/min to 200 counts/min in 10 hours. Calculate the half-life. [2]



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3 Exam-style questions

3.1 Alpha particles are fired at a thin gold foil. The diagram shows what happens to them. Explain what each result tells us about the atom. [3]



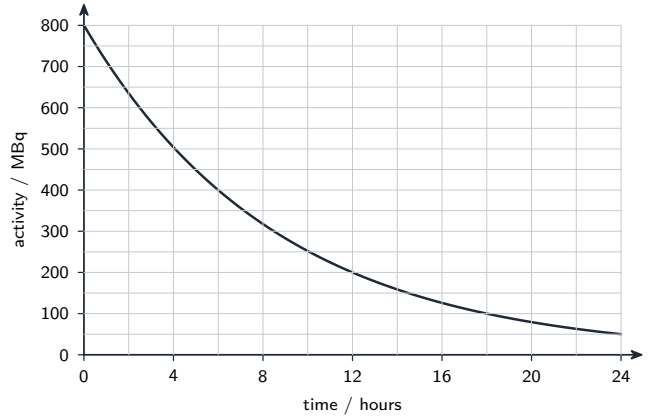
3.2 Complete the two nuclear equations. Name the type of decay in each. [3]

(1) $^{226}_{88}\text{Ra} \rightarrow \square + {}^{4}_{2}\alpha$

(2) $^{14}_{6}\text{C} \rightarrow {}^{14}_{7}\text{N} + \square$

3.3 Technetium-99m is used to look at organs inside the body. A patient is given an injection of it. It gives out gamma radiation. The graph shows how the activity of the injection changes.

(a) Use the graph to find the half-life of technetium-99m. Show your working on the graph. [3]



(b) Calculate the activity after 24 hours. [3]

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(c) Explain why a gamma source with a half-life of a few hours is chosen to use inside the body. [3]

(d) Explain the difference between contamination and irradiation. Describe how the nurse who gives the injection is protected. [6]

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Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

2.1

- **6** protons; $14 - 6 = \mathbf{8}$ neutrons

2.2

- **alpha** is stopped by the paper; **gamma** passes through the aluminium

2.3

- $800 \to 400 \to 200$ is 2 half-lives; half-life $= 10 \div 2 = \mathbf{5}$ hours

3.1

- most go straight through: the atom is mostly empty space
- a few are deflected: the nucleus is positive and repels the alpha particles
- very few bounce back: the mass is in a very small nucleus

3.2

- (1) ${}^{222}_{86}\mathrm{Rn}$
- (2) ${}^{0}_{-1}\beta$ (or ${}^{0}_{-1}\mathrm{e}$)
- (1) alpha decay; (2) beta decay

3.3

(a) read the time when the activity is 400 MBq; and when it is 200 MBq; half-life = **6** hours

(b) $24 \div 6 = 4$ half-lives; $800 \to 400 \to 200 \to 100 \to 50$; **50** MBq

(c) gamma passes out of the body, so it can be detected outside; gamma is weakly ionising, so it does less damage to cells; the activity falls quickly, so the patient is not exposed for long, but there is enough time for the scan

(d) points to include:

- contamination: radioactive atoms get onto or into something (skin, clothes, food)
- irradiation: being exposed to radiation from a source outside the body
- contamination lasts until the material is removed or decays; irradiation stops when you move away
- the nurse wears gloves to avoid contamination and handles the syringe quickly
- keeps a distance (tongs), uses a lead shield, and wears a badge to measure the dose

Levels: **5–6** a full, logical answer with correct physics and correct terms; **3–4** several correct points, partly linked; **1–2** one or two relevant points.

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