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

Worked example 1: a nuclear equation. Polonium-210 (${}^{210}_{84}\mathrm{Po}$) 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**.

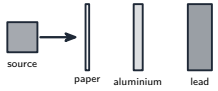
Answer shapes: count the half-lives first; take away background before you find a half-life.

2 Practice

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

${}^{14}_{6}\mathrm{C}$

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]

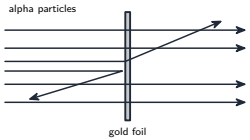


2.3 The count rate from a source falls from 800 counts/min to 200 counts/min in 10 hours. Calculate the half-life. [2]



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]



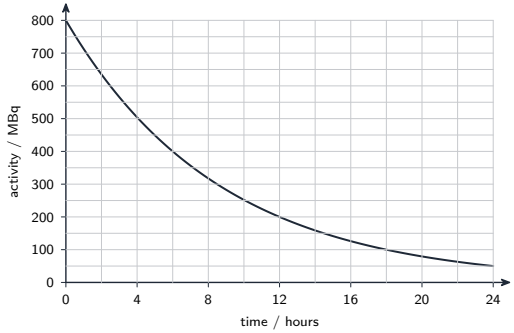
3.2 Complete the two nuclear equations. Name the type of decay in each. [3]

(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]

(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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