7.1 Radioactivity and half-life

Name: _____ Class: _____ Date: _____ **Total: 23 marks**

Objective

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

You must be able to:

- describe alpha, beta and gamma radiation and their penetration
- complete nuclear equations
- use half-life to find activity and time
- explain the uses and dangers of radioactive sources

1 Key knowledge and worked examples

Radioactivity

radiation	what it is	stopped by	ionising
alpha α	2 protons + 2 neutrons, ${}^{4}_{2}\mathrm{He}$	a sheet of paper, a few cm of air	strongly
beta β^-	a fast electron, ${}^{0}_{-1}\mathrm{e}$	a few mm of aluminium	moderately
gamma γ	an electromagnetic wave	many cm of lead (only reduced)	weakly

- **Isotopes** have the same number of protons but different numbers of neutrons. ${}^{A}_{Z}\mathrm{X}$: A is the nucleon number, Z the proton number.
- **Half-life** is the time for the activity (or number of undecayed nuclei) to halve.

Worked example 1: alpha decay. Radium-226 (${}^{226}_{88}\mathrm{Ra}$) gives off an alpha particle. Find the new nucleus.

1. Known: $A = 226$; $Z = 88$; alpha $= {}^{4}_{2}\mathrm{He}$.
2. Rule: top and bottom numbers balance.
3. Numbers: $226 - 4 = 222$; $88 - 2 = 86$.

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4. Result: $^{222}_{86}\mathbf{Rn}$ (radon).

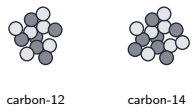
Worked example 2: half-life. A source has activity 800 Bq and half-life 3 hours. Find its activity after 9 hours.

1. Known: 800 Bq; half-life 3 h; 9 h.
2. Rule: $9 \div 3 = 3$ half-lives; halve three times.
3. Numbers: $800 \to 400 \to 200 \to 100$.
4. Result: 100 **Bq**.

Answer shapes: in beta decay a neutron turns into a proton, so Z goes up by 1 and A stays the same.

2 Practice

2.1 Carbon-12 and carbon-14 are isotopes. State what is the same and what is different in their nuclei. [2]



2.2 Give **two** sources of background radiation. [2]



2.3 Complete the equation for the beta decay of carbon-14: $^{14}_{6}\mathrm{C} \to {}^{?}_{?}\mathrm{N} + {}^{0}_{-1}\mathrm{e}$. [2]



3 Exam-style questions

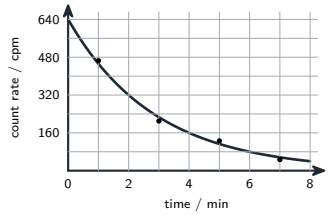
3.1 A source is placed in front of a Geiger–Müller tube. Paper does not reduce the count rate, but 5 mm of aluminium reduces it to background level. Which radiation does the source give out? Explain. [3]



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3.2 A student measures the count rate from a radioactive source every minute. The background count is 20 counts per minute. The graph shows the corrected count rate.

(a) Use the graph to find the half-life of the source. [2]



(b) The measured count rate at the start was 660 counts per minute. Find the corrected count rate after 3 half-lives. [3]

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(c) Explain why the count rate must be corrected for background radiation, and why the readings scatter about the line. [3]

(d) A hospital uses a gamma source to kill cancer cells and a tracer to study a patient's kidneys. Explain which radiation and half-life is best for a tracer, and how staff keep their dose low. [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

- same number of protons (6)
- different numbers of neutrons (6 and 8)

2.2

- two of: rocks (radon gas), cosmic rays, food and drink, medical X-rays, nuclear power and weapons tests

2.3

- top number 14
- bottom number 7

3.1

- beta
- not alpha, because paper would stop alpha and the count would fall
- not gamma, because gamma passes through 5 mm of aluminium

3.2

(a) a correct reading of the time for the count rate to halve, e.g. $640 \to 320$; half-life = **2** minutes

(b) corrected start $= 660 - 20 = 640$; $640 \to 320 \to 160 \to 80$; **80** counts per minute

(c) background radiation is always present and adds to the count; subtracting it leaves the count from the source alone; decay is random, so the readings scatter

(d) points to include:

- the tracer must be a gamma emitter (K)
- gamma passes out of the body and can be detected outside (An)
- alpha and beta would be absorbed inside the body and ionise cells (An)
- the half-life should be a few hours: long enough to do the test, short enough to decay soon after (App)
- staff keep a distance, use tongs, and limit their time near the source (K)
- they stand behind lead screens and wear a dosimeter badge to check their dose (App)

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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