Topic 4.4 Atomic structure Revision Booklet

ANSWERS AQA GCSE Physics 8463 · Foundation & Higher



Name _____ Class _____ Target grade _____

4.4
Atomic structure

Work through a topic, then come back to it on the dates in your planner. Little and often beats one long cram.

Revise like a scientist

This booklet uses six revision techniques that research shows work best. Every activity is labelled with the technique it uses and the grade it targets.

Retrieval practice

Pulling ideas out of your memory makes them stick far better than re-reading. Brain dumps, quizzes and cover-and-recall tasks.

Spaced practice

Revisit each topic after 2 days, 1 week and 3 weeks. Forgetting a little, then remembering again, strengthens memory.

Interleaving

Mixed-topic questions train you to spot which idea a question needs, just like the real exam.

Dual coding

Words plus diagrams: graphs, ray diagrams and labelled apparatus give your memory two routes in.

Elaboration

Asking 'why?' and 'how?' and linking ideas together turns facts into understanding.

Worked examples

I do → We do → You do: study a full solution, finish a half-done one, then do one alone.

KEY

Grade pathways

GRADE 4

Secure the basics: recall definitions and units, pick the right equation from the equation sheet, and do one-step calculations.

GRADE 5

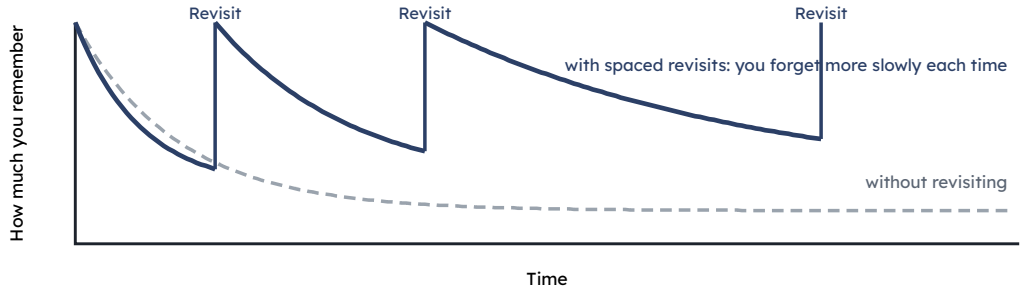
Rearrange equations, convert units, describe practicals and explain in two linked steps.

GRADE 7+

Multi-step calculations, evaluate methods and data, and write logical 6-mark answers.

SPACED PRACTICE DUAL CODING

Why spacing works



SPACED PRACTICE

My spaced revision planner

Write the date you'll do each session. Tick it off when it's done.

Topic	First go	+2 days	+1 week	+3 weeks	Before the mock
4.4 Atomic structure					
Final review					

What's inside

Topic 4 · Atomic structure (4.4)

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Final review

Final review: mixed questions	16

ROUTINE

The routine for every page

1. Try it cold. Answer from memory first, without notes. Struggling a bit is good: it's what makes learning stick.

2. Check and correct. Mark it with the answer booklet in a different colour pen. Fix every mistake.

3. Come back later. Redo anything you got wrong on your next spaced session.

ONLINE

Use it with mrsullyphysics.com

Flashcards for retrieval practice: cards you get wrong come back until you get them right.

Quizzes and Aim higher for extra Grade 5+ and 7+ questions with mark schemes.

Animations to see the physics move (dual coding).

Extra practice

Retrieval · answers in the answer booklet

1 Grade 5 Uranium-238 (92 protons) decays by alpha emission. Give the mass number and atomic number of the new nucleus. [2]

Mass number = 234

Atomic number = 90

2 Grade 7+ Explain why it is important for scientists to publish their research on the effects of radiation and for it to be peer reviewed. [3]

Other scientists can check the methods and results

Errors or bias can be found

So the findings are more likely to be valid and can be trusted (and repeated)

3 Grade 5 Explain the difference between radioactive contamination and irradiation. [2]

Contamination: the unwanted presence of materials containing radioactive atoms on other

materials

Irradiation: exposing an object to nuclear radiation; it does not become radioactive

Brain dump and checklist

RETRIEVAL PRACTICE · GRADE 4 · GRADE 5 · GRADE 7

Brain dump

Set a timer for 5 minutes. Write or draw everything you remember about atomic structure. No notes! Afterwards, add anything you missed in a different colour.

Prompts if you get stuck: protons, neutrons, electrons? · isotopes? · plum pudding? · alpha scattering? · alpha, beta, gamma? · nuclear equations? · half-life? · contamination? · fission and fusion?

METACOGNITION

How confident am I?

Rate each statement now (before) by shading R, A or G. Rate again at the end of the topic (after).

I can...	Before			After		
	R	A	G	R	A	G
Describe the structure of the atom and its size (about 1×10^{-10} m)	○	○	○	○	○	○
Explain how electrons change energy levels by absorbing or emitting EM radiation	○	○	○	○	○	○
Use mass number and atomic number; define isotopes	○	○	○	○	○	○
Describe how the model of the atom changed: plum pudding, alpha scattering, Bohr, Chadwick	○	○	○	○	○	○
Describe alpha, beta and gamma: what they are, how penetrating and how ionising	○	○	○	○	○	○
Write balanced nuclear equations for alpha and beta decay	○	○	○	○	○	○
Define half-life and find it from a graph	○	○	○	○	○	○
Calculate the net decline as a ratio after a number of half-lives (Higher)	○	○	○	○	○	○
Explain the difference between contamination and irradiation	○	○	○	○	○	○
Describe uses and dangers of nuclear radiation (Physics only)	○	○	○	○	○	○
Describe nuclear fission and fusion and chain reactions (Physics only)	○	○	○	○	○	○

Extra practice

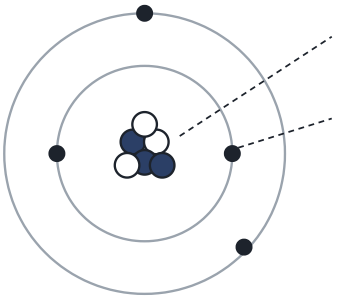
Retrieval · answers in the answer booklet

1 True or false? Radioactive decay is random. Explain. [2]

True. You can't predict which nucleus will decay next.

DUAL CODING | GRADE 4 | GRADE 5 | GRADE 7

THE ATOM · ALPHA SCATTERING

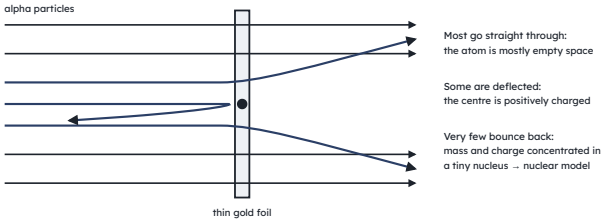


Nucleus: protons (+) and neutrons (0)
tiny: radius less than 1/10 000 of the atom

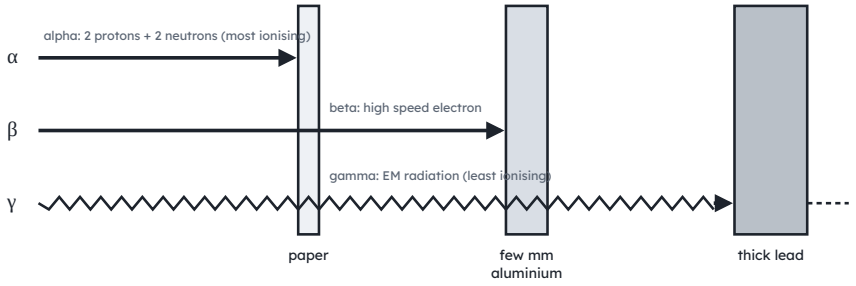
Electrons (–) in energy levels (shells)
absorb EM radiation → move to a higher level
lose an outer electron → positive ion

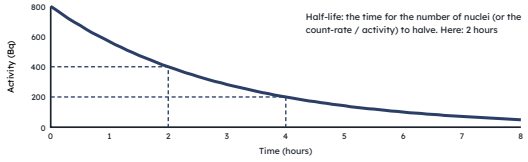
Atom radius about 1×10^{-10} m
neutral: number of protons = number of electrons

proton neutron electron



PENETRATION · HALF-LIFE





NUCLEAR RADIATION

Alpha (α): two neutrons and two protons (a helium nucleus). Most ionising; stopped by paper or a few cm of air.
Beta (β): a high speed electron ejected from the nucleus as a neutron turns into a proton. Stopped by a few mm of aluminium.
Gamma (γ): electromagnetic radiation from the nucleus. Least ionising; reduced by thick lead or concrete.

NUCLEAR EQUATIONS

Alpha: $^{219}_{86}Rn \rightarrow {}^{215}_{84}Po + {}^{4}_{2}He$
Beta: $^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}e$
Gamma: no change to mass or charge. Mass and atomic numbers balance on both sides.

TURN OVER

Key words, misconceptions, required practicals and Grade 7+ links are on the next page.

Knowledge organiser: key words, misconceptions, practicals

ELABORATION GRADE 4 GRADE 5 GRADE 7

KEY WORDS: LEARN THESE WORD FOR WORD (SAME AS SIDE 2 OF YOUR KNOWLEDGE ORGANISER)

Isotopes: atoms of the same element with the same number of protons but different numbers of neutrons.
Atomic number: the number of protons. Mass number: protons + neutrons.
Activity: the rate at which a source of unstable nuclei decays, in becquerel (Bq).
Count-rate: the number of decays recorded each second by a detector (e.g. Geiger-Muller tube).
Half-life: the time for the number of nuclei of the isotope in a sample to halve, or for the count-rate (or activity) to fall to half its initial level.
Contamination: the unwanted presence of materials containing radioactive atoms on other materials.
Irradiation: exposing an object to nuclear radiation; the object does not become radioactive.
Nuclear fission (PO): the splitting of a large and unstable nucleus into two smaller nuclei, roughly equal in size.
Nuclear fusion (PO): the joining of two light nuclei to form a heavier nucleus.

MISCONCEPTIONS: SPOT THE MISTAKE

× Common mistake	✓ What's actually true
× Irradiated food becomes radioactive.	✓ Irradiation doesn't make things radioactive; contamination is the problem.
× Gamma is the most dangerous everywhere.	✓ Inside the body, alpha is most dangerous because it's most ionising.
× Half-life is half the time a sample lasts.	✓ It's the time for the activity (or number of nuclei) to halve.

AIM FOR GRADE 7+

- Balance nuclear equations: mass and atomic numbers must add up on both sides.
- Choose a medical isotope: type of radiation and half-life, with reasons.
- Explain how the model of the atom changed with new evidence.

Extra practice

Retrieval · answers in the answer booklet

1 Grade 5 Radium-226 (atomic number 88) decays by emitting an alpha particle. State the mass number and atomic number of the new nucleus. [3]

An alpha particle is 2 protons + 2 neutrons

Mass number: 226 − 4 = 222

Atomic number: 88 − 2 = 86 (radon)

2 Grade 7+ A source has an activity of 3200 Bq and a half-life of 6 hours. Calculate its activity after 1 day, and the net decline as a ratio. [4]

1 day = 24 hours = 4 half-lives

3200 → 1600 → 800 → 400 → 200 Bq

Decline = 3200 − 200 = 3000 Bq

Net decline = 3000 ÷ 3200 = 15/16

3 Fill the gap: Activity is measured in _____. [1]

becquerels. 1 Bq = 1 decay per second.

RETRIEVAL PRACTICE GRADE 4 GRADE 5

Order it: the decay of an unstable nucleus

Put the statements in order to describe radioactive decay.

emits alpha, beta or gamma radiation · becomes more stable · the nucleus is unstable · a different element may be formed · decay happens at random

The nucleus is unstable → decay happens at random → it emits alpha, beta or gamma radiation

→ a different element may be formed (alpha, beta) → the nucleus becomes more stable

RETRIEVAL PRACTICE GRADE 4 GRADE 5

Fill the gaps

Use the AQA key words. No word bank: that's the point.

1. The number of protons in an atom is its atomic **number**.
2. An alpha particle is made of two protons and two **neutrons**.
3. Electrons can move to a higher energy level by **absorbing** electromagnetic radiation.
4. The activity of a source is measured in **becquerels** (Bq).
5. A chain reaction in a reactor is controlled by **control rods** that absorb neutrons. (Physics only)

ELABORATION GRADE 5

Odd one out

Circle the odd one out in each row and explain why.

1. Rutherford · Bohr · Chadwick · Newton

Newton: the others developed the model of the atom.

2. alpha · beta · gamma · X-ray

X-ray: it is not emitted from the nucleus.

3. ionising · penetrating · half-life · insulating

Insulating: the others describe radioactivity.

Extra practice

Retrieval · answers in the answer booklet

1 Grade 5 Carbon-14 has an atomic number of 6. State the number of protons and neutrons in its nucleus. [2]

6 protons

14 – 6 = 8 neutrons

2 Which radiation is the most penetrating? [1]

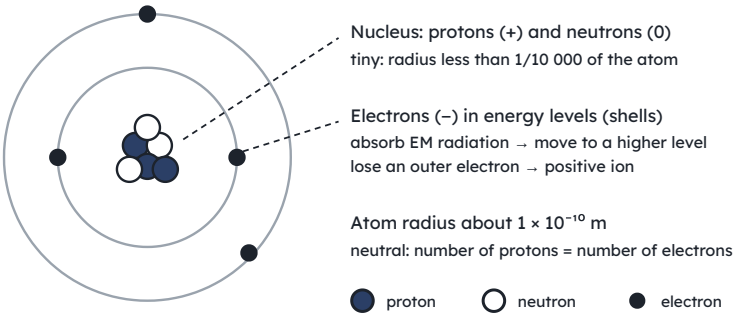
A Gamma **B** Alpha **C** Beta **D** They're all the same

A: Gamma. Gamma is only reduced by thick lead or concrete.

DUAL CODING GRADE 4 GRADE 5

Isotopes of carbon

Carbon-12 and carbon-14 are isotopes.



a Carbon has atomic number 6. How many protons and neutrons does carbon-14 have? [2]

6 protons

8 neutrons

b What is the same and what is different about the two isotopes? [2]

Same number of protons (and electrons);

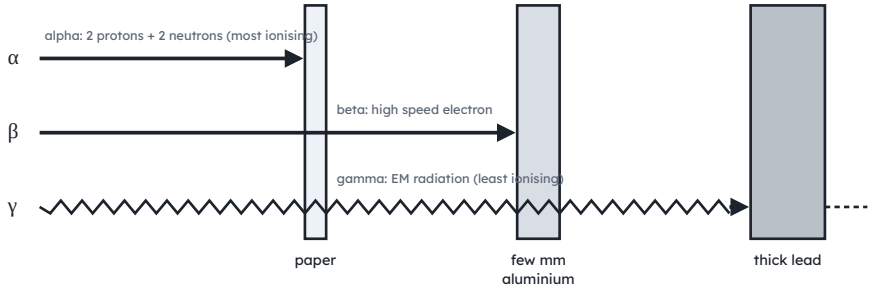
different numbers of neutrons (different mass numbers).

c Carbon-14 decays by beta emission. What element does it become? [1]

Nitrogen-14 (atomic number goes up by 1).

ELABORATION GRADE 5 GRADE 7

Choosing a source



a A factory checks the thickness of paper by measuring radiation passing through it. Which type should it use? Explain. [3]

Beta,

because alpha would be stopped completely by the paper,

and gamma would pass through almost unaffected by small thickness changes.

b Why should the source have a long half-life? [1]

So the count-rate doesn't fall noticeably over time (no need to replace it often).

Picture it (continued)

RETRIEVAL PRACTICE GRADE 4 GRADE 5

Energy levels

a Describe what happens when an electron moves to a lower energy level. [2]

The electron moves closer to the nucleus

and the atom emits electromagnetic radiation.

b What happens if an atom loses an outer electron? [2]

It becomes a positive ion

(it has more protons than electrons).

c Why is an atom neutral overall? [1]

It has the same number of electrons as protons.

Extra practice

Retrieval · answers in the answer booklet

1 Grade 7+ Polonium-210 (84 protons) decays by alpha emission to an isotope of lead. Give the mass number and atomic number of the lead nucleus, and explain how you worked them out. [3]

Mass number = 210 – 4 = 206

Atomic number = 84 – 2 = 82

An alpha particle contains 2 protons and 2 neutrons, and the equation must balance

2 Grade 7+ Radon is a radioactive gas that emits alpha particles. Explain why breathing it in is a hazard, and one way the risk is reduced. [3]

Inside the body alpha is absorbed by nearby cells

Alpha is highly ionising, so it can damage cells/DNA and cause cancer

Ventilate homes / seal floors / use radon sumps to reduce the dose

3 Grade 7+ A radioactive sample decays for 4 half-lives. Calculate the fraction of the original nuclei left, and the net decline as a ratio. [3]

After each half-life the number halves

$(\frac{1}{2})^4$ = 1/16 remain (6.25%)

Net decline = 15/16 of the original, ratio of decline to initial = 15 : 16

4 Grade 5 Explain why an alpha source is safer than a gamma source outside the body, but more dangerous inside it. [3]

Outside: alpha is stopped by skin or a few cm of air, so it can't reach living cells

Gamma is very penetrating, so it passes into the body

Inside: alpha is highly ionising, so it badly damages nearby cells

WORKED EXAMPLES GRADE 4 GRADE 5

Mass number and atomic number

I do (worked example)

Give the number of protons, neutrons and electrons in $^{23}_{11}Na$.

1. Protons = atomic number = 11
2. Neutrons = 23 − 11 = 12
3. Electrons = 11 (neutral atom)

We do (finish it)

$^{35}_{17}Cl$

1. Protons = ___ **17**
2. Neutrons = ___ **18**
3. Electrons = ___ **17**

You do

$^{238}_{92}U$

92 protons

146 neutrons

92 electrons

WORKED EXAMPLES GRADE 5 GRADE 7

Half-life from activity

I do (worked example)

A source falls from 960 Bq to 120 Bq in 15 days. Half-life?

1. 960 → 480 → 240 → 120
2. That's 3 half-lives
3. 15 ÷ 3
4. **Half-life = 5 days**

We do (finish it)

2000 Bq, half-life 8 hours. Activity after 1 day?

1. 24 ÷ 8 = ___ half-lives **3**
2. 2000 → 1000 → ___ → ___ **500 → 250**
3. ___ Bq **250**

You do

How long for 64 g of an isotope (half-life 2 years) to reduce to 4 g?

64 → 32 → 16 → 8 → 4

4 half-lives

8 years

WORKED EXAMPLES GRADE 7

Nuclear equations (Grade 7+)

1 Radium-226 (atomic number 88) decays by alpha emission to radon (Rn). Then radon-222 decays by alpha emission to polonium (Po). Write both nuclear equations. [4]

$^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$

$^{222}_{86}Rn \rightarrow {}^{218}_{84}Po + {}^{4}_{2}He$

Extra practice

Retrieval · answers in the answer booklet

1 Grade 5 Describe what happens when an atom absorbs electromagnetic radiation, and how a positive ion can form. [2]

Electrons can move to a higher energy level (further from the nucleus)

If an atom loses an outer electron it becomes a positive ion

2 Grade 5 Which type of nuclear radiation is (a) the most ionising, (b) the most penetrating, (c) stopped by a sheet of paper? [3]

(a) Alpha

(b) Gamma

(c) Alpha

3 In beta decay, what happens to the mass number? [1]

A Decreases by 4 **B** Increases by 1 **C** Stays the same **D** Decreases by 1

C: Stays the same. A neutron becomes a proton, so the mass number stays the same and the atomic number goes up b

Why? How? Explaining atomic structure

ELABORATION GRADE 4 GRADE 5 GRADE 7

Build an explanation

Answer each question in two steps. Use the starter, then push yourself with the Grade 7+ extension.

1 Explain why scientists accepted the nuclear model of the atom.

Grade 4–5 starter: "The alpha scattering experiment produced results that…"

Most alpha particles passed straight through the gold foil: most of the atom is empty space.

Some were deflected: the nucleus is positively charged.

Grade 7+ extension: "Link evidence to model:…"

A very few bounced back: the mass is concentrated in a tiny nucleus.

The plum pudding model could not explain these results, so it was replaced.

2 Explain why gamma radiation is used to sterilise surgical instruments. (Physics only)

Grade 4–5 starter: "Gamma is very penetrating, so…"

Gamma rays are very penetrating, so they pass through the sealed packaging.

They are ionising, so they kill bacteria and other microorganisms.

Grade 7+ extension: "Link to killing bacteria:…"

The instruments are irradiated, not contaminated,

so they do not become radioactive and are safe to use.

3 Explain why nuclear fusion is harder to achieve on Earth than fission. (Physics only)

Grade 4–5 starter: "Fusion needs two light nuclei to join, but…"

Nuclei are positively charged, so they repel each other.

To fuse, they must be moving extremely fast,

Grade 7+ extension: "Link to temperature and pressure:…"

which needs very high temperatures and pressures,

which are very difficult to create and contain.

ELABORATION GRADE 5

True or false? Justify it.

Saying why is worth more marks than saying true or false.

4 "Radioactive materials stay dangerous for the same length of time." [2]

False: it depends on the half-life;

a short half-life source becomes safe much sooner.

5 "The plum pudding model has electrons orbiting a nucleus." [1]

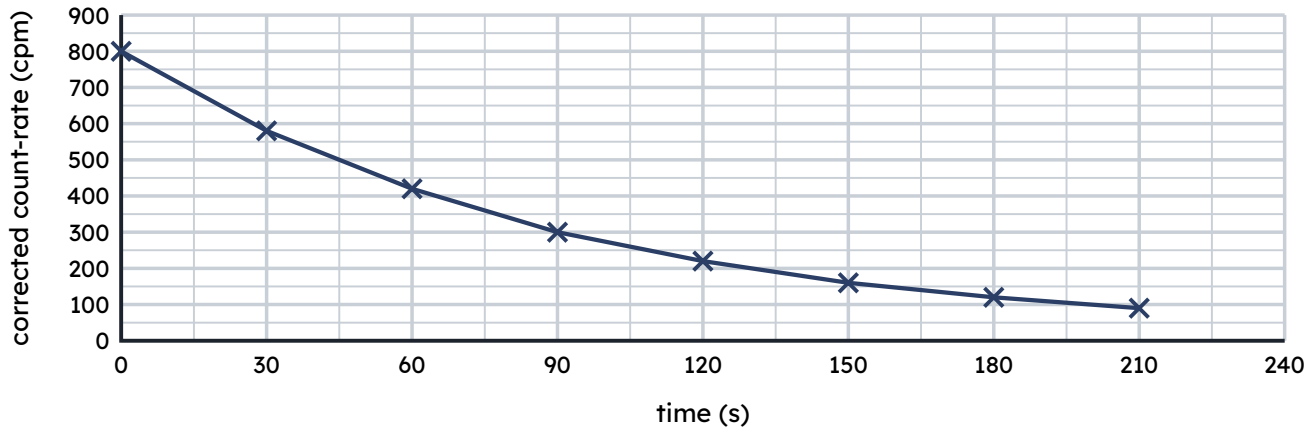
False: it has electrons embedded in a ball of positive charge (no nucleus).

DUAL CODING | ELABORATION | GRADE 5 | GRADE 7

Data skills: half-life of protactinium

A student records the count-rate from protactinium-234 every 30 s. Background count = 30 counts per minute.

Time (s)	0	30	60	90	120	150	180	210
Measured (cpm)	830	610	450	330	250	190	150	120
Corrected (cpm)	**800**	**580**	**420**	**300**	**220**	**160**	**120**	**90**



a Correct each reading for background radiation and plot the graph. [3]

800, 580, 420, 300, 220, 160, 120, 90; smooth curve.

b Use the graph to find the half-life. Show your method on the graph. [2]

800 → 400 at about 64 s; 400 → 200 at about 130 s

half-life ≈ 65 s

c Why does taking the count over a longer time give a more reliable reading? [2]

Decay is random,

so counting for longer reduces the effect of random variation.

d Explain why the student is not in danger after the experiment ends, even though she was exposed. [2]

She was irradiated, not contaminated;

she doesn't become radioactive, and the source is put away.

Extra practice

Retrieval · answers in the answer booklet

1 Grade 5 Carbon-14 (6 protons) decays by beta emission to nitrogen. State the atomic number and mass number of the nitrogen nucleus. [2]

Atomic number = 7

Mass number = 14

Exam practice

GRADE RADE 4

Secure the basics

1 Name the particle found outside the nucleus. [1]

Electron

2 What is the charge on a beta particle? [1]

−1

3 Which radiation is stopped by a few millimetres of aluminium? [1]

Beta

4 What is background radiation? [1]

Radiation around us all the time from natural and man-made sources.

5 Which is the most ionising: alpha, beta or gamma? [1]

Alpha

GRADE RADE 5

Apply and rearrange

6 An isotope has a half-life of 6 hours. What fraction of it remains after 18 hours? [2]

18 ÷ 6 = 3 half-lives

$\frac{1}{8}$

7 Describe the difference between contamination and irradiation. [2]

Contamination: radioactive atoms get onto or into an object.

Irradiation: exposure to radiation; the object does not become radioactive.

8 Give two ways a worker can reduce their exposure to a radioactive source. [2]

Keep exposure time short / stay as far away as possible / use tongs

Use lead shielding / wear a dosimeter badge

Extra practice

Retrieval · answers in the answer booklet

1 Grade 7+ Explain how the alpha scattering experiment led to the plum pudding model being replaced. [4]

Most alpha particles passed straight through: most of the atom is empty space

Some were deflected: the centre (nucleus) is positively charged

A very few bounced back: mass and charge are concentrated in a tiny nucleus

The plum pudding model couldn't explain these results, so the nuclear model replaced it

2 True or false? Gamma emission changes the mass number of the nucleus. Explain. [2]

False. Gamma is electromagnetic radiation: no change to mass or atomic number.

Exam practice (continued)

GRADE RADE 7+

Stretch

9 Iodine-131 (atomic number 53) decays by beta emission. Write the nuclear equation and explain what happens in the nucleus. [4]

$^{131}_{53}I \rightarrow {}^{131}_{54}Xe + {}^{0}_{-1}e$

A neutron turns into a proton,

and a high speed electron is emitted from the nucleus,

so the atomic number increases by 1 and the mass number stays the same.

10 Compare nuclear fission and nuclear fusion. (Physics only) [6]

Fission: a large and unstable nucleus splits into two smaller nuclei.

Fission is usually started by absorbing a neutron and releases two or three neutrons (chain reaction).

Fusion: two light nuclei join to form a heavier nucleus.

Fusion needs very high temperature and pressure; it powers stars.

Both release energy (some mass is converted into energy) and gamma radiation.

Fission is used in nuclear power stations; fusion is not yet practical on Earth.

Total: _____ / 21

RETRIEVAL PRACTICE SPACED PRACTICE GRADE 4

Quick-fire retrieval: Atomic structure

Cover everything. Answer in under 3 minutes. Redo it on your next spaced session.

1 Charge of a neutron?

0

2 Mass number?

Protons + neutrons

3 What stops gamma?

Thick lead / concrete (reduces it)

4 Unit of count-rate?

Counts per minute (or per second)

5 Model before nuclear model?

Plum pudding

6 Isotopes differ in?

Number of neutrons

Extra practice

Retrieval · answers in the answer booklet

1 Grade 5 The count-rate from a sample falls from 600 to 150 counts per minute in 8 hours. Calculate the half-life. [3]

600 → 300 → 150

That's 2 half-lives

Half-life = 8 ÷ 2 = 4 hours

Reflect and plan

METACOGNITION

Re-rate yourself

Go back to the checklist at the start of this topic and fill in the 'After' column.

METACOGNITION GRADE 4 GRADE 5 GRADE 7

Exam wrapper: why did I drop marks?

After marking the exam practice, write the question numbers you got wrong in the right row.

Reason I lost marks	Question numbers	What to do next
I didn't know or remember it (knowledge gap)		Flashcards and brain dumps
I knew it but misread the question or command word		Underline command words
Maths slip: units, rearranging, standard form		Redo the "we do / you do" pages
I ran out of time or didn't finish		Timed practice: 1 mark per minute

METACOGNITION

Two things I'm now confident about

METACOGNITION

One thing I still need to work on, and how I'll fix it

e.g. 'Rearranging equations → redo the Grade 7+ questions and use the website's Aim higher section.'

SPACED PRACTICE

Book my next spaced sessions

Write the dates in the planner at the front: +2 days, +1 week, +3 weeks.

Extra practice

Retrieval · answers in the answer booklet

1 True or false? Gamma emission changes the mass number of a nucleus. Explain. [2]

False. Gamma is EM radiation: no change to mass number or atomic number.

Final review

RETRIEVAL PRACTICE | SPACED PRACTICE | GRADE 4 | GRADE 5 | GRADE 7

Final review: test yourself on the whole topic

Do these without your notes, a week after finishing the booklet. Mark them with the answer booklet and add any you got wrong to your 'still to learn' list on the reflect page.

Each question shows its target grade. Aim to get every Grade 4 and 5 question right before moving on to Grade 7+.

Extra practice

Retrieval · answers in the answer booklet

1 Grade 5 An atom of sodium has 11 protons and a mass number of 23. How many neutrons and electrons does it have? [2]

Neutrons = 23 − 11 = 12

Electrons = 11 (same as protons in a neutral atom)

2 Grade 7+ A doctor needs a radioactive tracer to inject into a patient. Explain what type of radiation it should emit and what its half-life should be. [4]

Gamma (or beta) emitter: can pass out of the body to be detected

Not alpha: it would be absorbed in the body and is highly ionising, damaging cells

Short half-life (hours) so the activity falls quickly and the patient's dose is low

But long enough for the scan to be carried out

3 A sample has an activity of 1200 Bq. Its half-life is 3 hours. What is its activity after 9 hours? [2]

9 h = 3 half-lives: 1200 → 600 → 300 → 150 Bq.

4 Which radiation is stopped by a sheet of paper? [1]

A Alpha **B** Beta **C** Gamma **D** Neutrons

A: Alpha. Alpha is big and heavily ionising, so it's stopped by paper or a few cm of air.

5 Fill the gap: Atoms of the same element with different numbers of neutrons are called _____. [1]

isotopes. Same protons, different neutrons.

6 Put the models of the atom in the order they were proposed. [2]

A Plum pudding model
B Nuclear model
C Tiny indivisible spheres
D Bohr's electron shells

C → A → B → D