

Topic 1: Atomic structure and the periodic table

AQA 8462 ■ 4.1.1–4.1.3 ■ Higher Tier equations labelled ■ Transition metals:
Chemistry only

From particles to predictions

Count

Atomic number $\rightarrow$ protons.

Mass number $-$ protons $\rightarrow$ neutrons.

Explain

Evidence $\rightarrow$ model.

Electron arrangement $\rightarrow$ group trend.

An element can contain molecules

Representation	Meaning
O_2	Two atoms of one element
H_2O	A compound; $\text{H}:\text{O} = 2:1$
$3\text{H}_2\text{O}$	Six H atoms and three O atoms

Balance without changing formulae

- 1 **Oxygen** 3O_2 and $2\text{Al}_2\text{O}_3$ each contain six O atoms.
- 2 **Aluminium** $2\text{Al}_2\text{O}_3$ contains four Al atoms.
- 3 **Check** $4\text{Al} + 3\text{O}_2 \rightarrow 2\text{Al}_2\text{O}_3$: Al $4 \rightarrow 4$; O $6 \rightarrow 6$.

Choose the separation before heating

Filter: Sand stays in residue.



Concentrate: Evaporate some water.



Cool: Salt forms crystals.



Collect: Filter and dry crystals.

Different mixtures need different methods

Fractional distillation

Different boiling points.

Collect the condensed fraction.

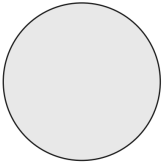
Chromatography

Different movement through phases.

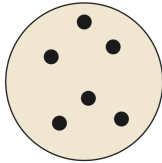
Keep the starting spots above solvent.

Read the atomic-model evidence

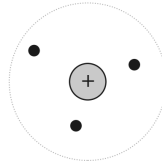
Early model
Indivisible sphere



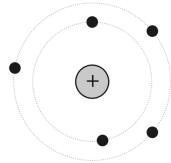
Plum pudding
Positive background
Embedded electrons



Nuclear model
Tiny positive nucleus
contains most mass



Bohr energy levels
Specific energy levels
Later: protons/neutrons



Rare large deflections support a tiny positive nucleus.

What would disprove plum pudding?

- 1 **Volume** Most alpha particles pass through: most atomic volume is empty space.
- 2 **Nucleus** Rare large deflections: positive charge is concentrated in a tiny region.
- 3 **Replace** The spread-out positive charge of plum pudding cannot explain this evidence.

Particle counts: attempt before reveal

Your turn

Atomic number $Z = 12$; mass number $A = 26$; ion charge $2+$. Which p, n, e counts describe this ion?

- A. 12, 14, 10
- B. 12, 26, 10
- C. 14, 12, 12
- D. 12, 14, 14

Count the nucleus, then the charge

1 **Protons** $p = Z = 12$.

2 **Neutrons** $n = A - Z = 26 - 12 = 14$.

3 **Electrons** $e = Z - 2 = 12 - 2 = 10$.

Decision

Ion formation changes electrons; isotopes differ in neutron number.

An isotope average is weighted

- 1 **Model** $A_r = \sum(\text{mass} \times \text{percentage})/100$.
- 2 **Calculate** $A_r = (35 \times 75 + 37 \times 25)/100 = 35.5$.
- 3 **Check** $35 < 35.5 < 37$; mean closer to 35.

Scale is part of the model

Size

$$0.1 \text{ nm} = 1 \times 10^{-10} \text{ m}.$$

Nuclear radius $<$ atomic radius / 10000.

Mass

Almost all mass is nuclear.

Electrons occupy shells around the tiny nucleus.

Electron arrangements locate elements

Element	Shells	Position
Na	2,8,1	Period 3; Group 1
Cl	2,8,7	Period 3; Group 7
He	2	Period 1; Group 0

Why leave a gap in a table?

Early constraint

Atomic weights and observed properties.

Some elements were still undiscovered.

Testable prediction

Leave a gap; predict properties.

Compare a newly found element with the prediction.

Compare the group trends

Group 0

Not readily reactive

Full outer shell
Boiling point rises ↓

Group 1

Reactivity rises ↓

One outer electron
Lost more easily ↓

Group 7

Reactivity falls ↓

Seven outer electrons
Gain less easily ↓

Down a group, the outer occupied shell is farther from the nucleus.

Reactivity trends depend on whether electrons are lost or gained.

Three groups, three explanations

- 1 **Group 1** Downwards: the outer electron is lost more easily; reactivity rises.
- 2 **Group 7** Downwards: an incoming electron is attracted less; reactivity falls.
- 3 **Group 0** Stable outer shell; stronger attractions downwards raise boiling points.

Alkali-metal reactions conserve atoms

- 1 Water** $2Na + 2H_2O \rightarrow 2NaOH + H_2$.
- 2 Chlorine** $2Na + Cl_2 \rightarrow 2NaCl$.
- 3 Explain** One outer electron is lost to form Na^+ ; use school-approved demonstrations.

Unfamiliar displacement: predict first

Your turn

Compare $\text{Cl}_2 + \text{KBr(aq)}$ and $\text{I}_2 + \text{KBr(aq)}$. Which halogen displaces bromine?

- ☐ A. Both displace bromine
- ☐ B. Only chlorine displaces bromine
- ☐ C. Only iodine displaces bromine
- ☐ D. Neither displaces bromine

Displacement follows the reactivity order

- 1 **Rank** Reactivity: chlorine > bromine > iodine.
- 2 **Equation** $Cl_2 + 2KBr \rightarrow 2KCl + Br_2$.
- 3 **Counterexample** $I_2 + KBr$: no displacement under these aqueous conditions.

Transition metals: separate Chemistry

Group 1 examples

Soft; lower densities and melting points.

Reactive; usually +1 compounds.

Transition examples

Generally harder and stronger.

Variable ion charges; coloured compounds; catalysts.

Higher Tier: cancel spectators, conserve charge

- 1 **Full** $\text{AgNO}_3(\text{aq}) + \text{NaCl}(\text{aq}) \rightarrow \text{AgCl}(\text{s}) + \text{NaNO}_3(\text{aq})$.
- 2 **Net ionic** $\text{Ag}^+(\text{aq}) + \text{Cl}^-(\text{aq}) \rightarrow \text{AgCl}(\text{s})$.
- 3 **Half equation** $\text{Mg} \rightarrow \text{Mg}^{2+} + 2\text{e}^-$; charge $0 = +2 - 2$.

Names, symbols and whole-particle counts

- 1 Co is cobalt; CO is carbon monoxide.
- 2 MgCl_2 : magnesium chloride; Na_2O : sodium oxide.
- 3 $3\text{H}_2\text{O}$ contains 6 H atoms and 3 O atoms.

Attempt: recover two products from a new mixture

- 1 Insoluble powder in two miscible liquids: boiling points 65 °C and 100 °C.
- 2 Collect the powder dry; then separate the liquids.
- 3 Explain why a filter cannot collect the lower-boiling liquid alone.

Reveal: filtration before fractional distillation

- 1 Filter, wash suitably and dry the powder.
- 2 Fractionally distil the filtrate; collect the lower-boiling fraction first.
- 3 Both liquid components pass through filter paper.

Attempt: radius is not diameter

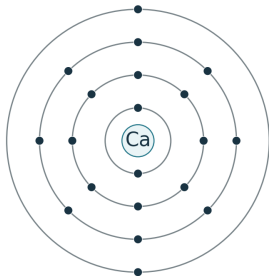
- 1 Atom radius: 1×10^{-10} m. Line length: 1×10^{-3} m.
- 2 Estimate the number of touching atoms along the line.
- 3 Then enlarge the atomic radius to 1 m: bound the nucleus radius.

Reveal: five million atoms; a nucleus smaller than 0.1 mm

- 1 Diameter = 2×10^{-10} m.
- 2 Count = $(1 \times 10^{-3}) / (2 \times 10^{-10}) = 5 \times 10^6$.
- 3 Enlarged nucleus radius $< 1/10000$ m = 0.1 mm.

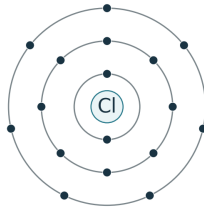
Complete diagrams must count every electron

Calcium: 20 electrons



2,8,8,2

Chlorine: 17 electrons



2,8,7

Neutral atoms • dots are electrons • shell sizes are schematic, not to scale

Calcium: 2,8,8,2. Chlorine: 2,8,7.

Attempt: identify an element from its arrangement

- 1 A neutral first-twenty atom has arrangement 2,8,8,2.
- 2 Give its proton number, period and group.
- 3 Explain the charge of its usual ion.

Reveal: calcium, Period 4, Group 2

- 1 Total electrons/protons = 20.
- 2 Four occupied shells; two outer electrons.
- 3 Losing two electrons forms Ca^{2+} ; the nucleus is unchanged.

When atomic mass reverses the modern order

- 1 X: proton number 18, relative atomic mass 40.0.
- 2 Y: proton number 19, relative atomic mass 39.1.
- 3 Modern order X then Y; mass-only order would reverse them.

Metals and non-metals: patterns with exceptions

- 1 Metals typically conduct and can be shaped; solid non-metals are often brittle.
- 2 Metals lose electrons to form positive ions.
- 3 Non-metals may gain or share electrons; graphite conducts.

Group 1: three reactants, different products

- 1 $4Li + O_2 \rightarrow 2Li_2O$ uses the supplied oxide formula.
- 2 $2Na + Cl_2 \rightarrow 2NaCl$.
- 3 $2K + 2H_2O \rightarrow 2KOH + H_2$.

Halogen element and halide compound are different

- 1 Cl_2 , Br_2 and I_2 are diatomic elemental molecules.
- 2 NaCl has Na^+ and Cl^- ions; HCl has covalent molecules.
- 3 Down Group 7: molecular mass and melting/boiling points rise.

Attempt: classify a supplied unfamiliar metal

- 1 P: density 0.8 g/cm^3 , melting point $80 \text{ }^\circ\text{C}$, fast water reaction.
- 2 Q: density 8.0 g/cm^3 , melting point $1400 \text{ }^\circ\text{C}$, no cold-water reaction.
- 3 Choose the better transition-metal candidate; give three reasons.

Reveal: Q fits the typical comparison

- 1 Higher density; higher melting point; lower water reactivity.
- 2 These support Q over P as the transition-metal candidate.
- 3 No evidence here establishes compound colour or catalytic activity.

Different iron charges give different salt formulas

- 1 $Fe^{2+} + SO_4^{2-}$ gives $FeSO_4$.
- 2 Two Fe^{3+} ions balance three SO_4^{2-} ions: $Fe_2(SO_4)_3$.
- 3 Charge totals: $+2/-2$ or $+6/-6$; both compounds are neutral.

Final transfer: support a claim with evidence

Your turn

A sample dissolves in water; filtration leaves no residue. Does this prove it is an element, and how can the dissolved solid be recovered?

- A. Element; filter again
- B. Compound; simple distillation proves it
- C. Identity not established; crystallise dissolved solid
- D. Mixture impossible; heat strongly to dryness

Check yourself

- 1 **Reject overclaim** Solubility and passage through a filter do not establish element identity.
- 2 **Recover** Concentrate $\rightarrow$ cool $\rightarrow$ filter crystals $\rightarrow$ dry.
- 3 **Classify** Determine elemental composition and whether different elements are chemically combined.