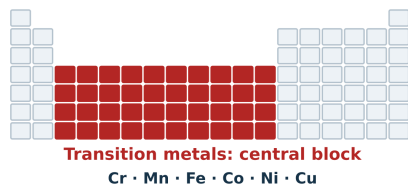


C1 Transition metals

AQA Separate Chemistry 8462 | Paper 1 extras | Foundation + Higher

1 Find the central block



The transition metals lie in the **central block** of the periodic table.

Recognise: **Cr, Mn, Fe, Co, Ni and Cu** (chromium, manganese, iron, cobalt, nickel and copper).

2 Physical properties

Group 1

Lower melting points
Lower densities
Softer and weaker
More reactive

Transition metals

Higher melting points
Higher densities
Harder and stronger
Less reactive

General comparisons between these groups

Compared with Group 1 metals, these transition metals generally have **higher melting points and densities** and are **harder and stronger**. Both groups conduct heat and electricity.

3 Reactivity

Reaction with cold water

Sodium

Vigorous reaction
with hydrogen gas

Iron

No vigorous reaction
in cold water

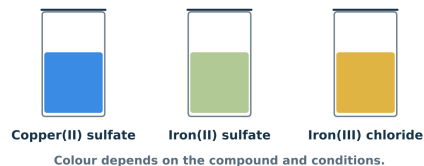
Less reactive does not mean unable to react.

Transition metals are generally **less reactive** with oxygen, water and halogens than Group 1 metals.

Example: iron does not react vigorously with cold water like sodium does.
Less reactive $\neq$ unable to react.

4 Coloured compounds

Examples of coloured solutions



Many transition metals form coloured compounds.

Copper(II) sulfate solution: **blue**.

Iron(II) solutions are often pale green.

Colour depends on the particular compound and conditions.

5 Different ion charges



Iron(II): 2+



Iron(III): 3+

Same element, different ion charges

A transition metal can form ions with different charges.

Fe^{2+} = iron(II)

Fe^{3+} = iron(III)

The Roman numeral indicates the positive charge. Group 1 forms +1 ions.

6 Catalysts

Iron
Making
ammonia

Nickel
Hydrogenating
oils

MnO_2
Decomposing
 H_2O_2

Faster reactions · Catalyst not used up overall

A catalyst makes a reaction **faster** and is **not used up overall**.

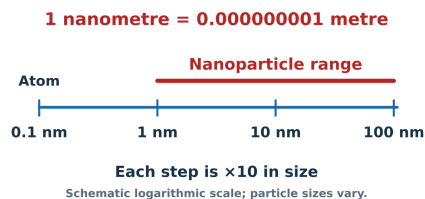
Examples: iron in ammonia production; nickel in hydrogenating oils; manganese dioxide in hydrogen peroxide decomposition.

AQA section 4.1.3.

C2 Nanoparticles

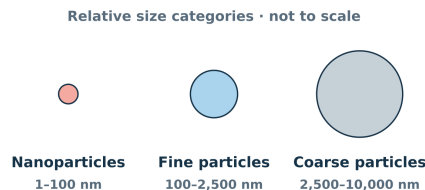
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1 The nanoscale



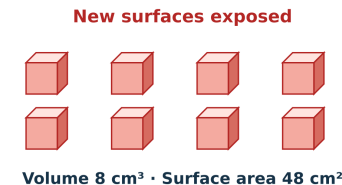
Nanoparticles: **1–100 nm**.
1 nm = 10^{-9} m (one billionth of a metre).
They contain many atoms. They are larger than individual atoms.
 $50 \text{ nm} = 5 \times 10^{-8} \text{ m}$.

2 Particle size categories



Fine particles: 100–2,500 nm.
Coarse particles (dust): about 2,500–10,000 nm.
Nano < fine < coarse.
Compare dimensions in the same units; each factor of 10 is an order of magnitude.

3 Surface area to volume



Splitting a solid exposes more surface. Its **total volume stays the same**.
Smaller particles have a **larger SA:V**.
A larger proportion of atoms is at the surface, which can change properties compared with the bulk material.

4 Cube calculations



Side = a: **SA = $6a^2$; V = a^3** .
2 cm cube: SA = 24 cm^2 ; V = 8 cm^3 ; SA:V = **3:1**.
1 cm cube: SA:V = **6:1**.
Divide side length by 10 → multiply SA:V by 10.

5 Applications

Medicine / electronics Tiny structures	Sun creams / cosmetics Useful optical properties
Deodorants Some antimicrobial uses	Catalysts Large exposed surface

Applications include medicine, electronics, cosmetics, sun creams, deodorants and catalysts.
High SA:V can make small amounts effective.
Use the properties and evidence supplied for an unfamiliar application.

6 Benefits and possible risks

Possible benefits Effective in small amounts Useful size / properties Application-specific	Questions to investigate Effects on cells? Exposure and dose? Environmental effects?
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Use evidence for the particular material.

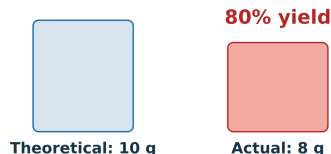
Weigh benefits against possible effects on cells and the environment. Consider material, particle size, dose and exposure.
Further testing may be needed. Avoid claiming all nanoparticles are safe or all are harmful.
AQA section 4.2.4.

C3 Yield and atom economy

AQA Separate Chemistry 8462 | Paper 1 extras | Foundation + Higher

1 Actual and theoretical yield

Product collected from the same reaction



Actual yield: product obtained.

Theoretical yield: maximum possible amount.

The theoretical amount is supplied in introductory questions. Calculating it from reactant mass and an equation is Higher Tier.

2 Percentage yield

Percentage yield

$$\frac{6 \text{ g collected}}{8 \text{ g possible}} \times 100 = 75\%$$

Yield (%) = actual mass ÷ theoretical mass × 100.

Use the same mass units.

6 g collected / 8 g possible:

$$6 \div 8 \times 100 = 75\%.$$

Do not turn the fraction upside down.

3 Why yield can be lower

Separation

Product lost in transfer or on equipment

Reversible

Some product changes back to reactants

Side reactions

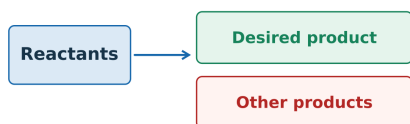
Reactants make unwanted products

Product may be lost during transfer or separation. A reversible reaction may not finish. Side reactions may make unwanted products.

An apparent yield above 100% can indicate wet/impure product or measurement error.

4 Atom economy

Track all the reactant atoms



High atom economy → less unwanted material

Atom economy (%) = desired product formula-mass total ÷ reactant formula-mass total × 100.

Use the balanced equation and include all coefficients (large numbers before formulae).

5 A worked example

Desired product: calcium oxide



$$\text{Atom economy} = 56 \div 100 \times 100 = 56\%$$



CaO is wanted. M_r values: 100, 56, 44.

Atom economy = $56/100 \times 100 = 56\%$.

CO₂ is the by-product here.

A one-product reaction has 100% atom economy.

6 Do not mix the measures

Percentage yield

How much possible product did we actually collect?

Atom economy

How much reactant mass becomes the desired product?

Yield: how much possible product was collected?

Atom economy: how much reactant mass goes into desired product?

High atom economy reduces waste but does not guarantee high yield.

AQA section 4.3.3.

C4 Titration required practical

AQA Separate Chemistry 8462 | Paper 1 extras | Foundation + Higher

1 Purpose and equipment

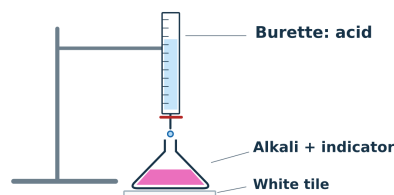


Find volumes of a strong acid and strong alkali that react exactly.

A: pipette + filler measures a fixed alkali volume into a conical flask.

B: burette delivers a variable acid volume. Wear eye protection.

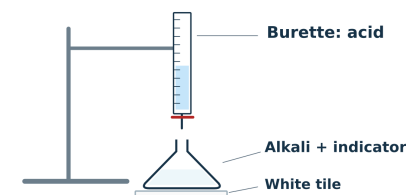
2 Prepare accurately



Rinse pipette with alkali; measure alkali into the flask. Add a few drops of a suitable indicator.

Rinse burette with acid, fill it and its tip, then remove the funnel. Record the initial reading.

3 Find the end-point



Place flask on a **white tile**; swirl while adding acid. Add **drop by drop** near the end. Stop at the first permanent colour change. With phenolphthalein, acid added to alkali changes pink → colourless.

4 Read and subtract

Initial reading	Final reading
1.20 cm ³	24.60 cm ³

$$\text{Titre} = 24.60 - 1.20 = 23.40 \text{ cm}^3$$

Read the bottom of the meniscus at **eye level**. The burette scale increases downwards.

Titre = final – initial reading.

$$24.60 - 1.20 = 23.40 \text{ cm}^3$$

Record appropriate precision.

5 Repeat and find a mean

Choose concordant accurate titres

Rough	Run 1	Run 2	Run 3
24.10 cm ³	23.40 cm ³	23.45 cm ³	23.40 cm ³

$$\text{Mean of runs 1-3} = 23.42 \text{ cm}^3$$

Do a rough run, then accurate repeats. Select **concordant** titres (commonly within 0.10 cm³; use the stated criterion).

Exclude the rough result. Calculate the mean of agreeing accurate titres.

6 Explain the choices

White tile: see colour change.

Dropwise: avoid overshooting.

Swirl: mix the solutions.

Eye level: reduce parallax.

Remove funnel: avoid extra drops entering the burette after the initial reading.

Distilled-water rinse of flask walls:

washes splashes into the mixture without adding acid or alkali.

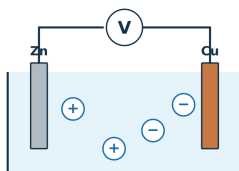
Concentration calculations: Higher Tier.

Required practical 2; section 4.4.2.5.

C5 Chemical cells and fuel cells

AQA Separate Chemistry 8462 | Paper 1 extras | Foundation + Higher

1 A simple chemical cell



Electrolyte: mobile ions

Two different metal electrodes contact an **electrolyte** containing mobile ions. Chemical reactions produce a potential difference and can power a circuit.

Voltage depends on electrodes and electrolyte.

2 Batteries

Cells connected in series



Same direction: $1.5 + 1.5 = 3.0 \text{ V}$

A battery contains two or more cells connected in **series**.

In the same direction their voltages add: $1.5 \text{ V} + 1.5 \text{ V} = \mathbf{3.0 \text{ V}}$.

Use data to compare cell materials and practical uses.

3 Rechargeable cells

Using the cell
Chemical reactions produce an electrical transfer

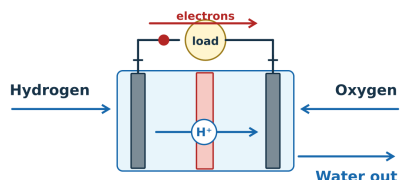
Recharging
External current reverses the chemical reactions

Non-rechargeable cells stop when a reactant is used up. Standard alkaline cells are non-rechargeable.

An external current **reverses reactions** in a rechargeable cell.

Compare cost, life and disposal.

4 Hydrogen fuel cells



Hydrogen ions cross; electrons take the circuit.

Supply **hydrogen and oxygen/air** continuously. The reactions produce a potential difference. The fuel cell keeps operating while reactants are supplied. Hydrogen is oxidised; electrical energy is transferred.

5 The product is water

Hydrogen + oxygen → water



Electrical energy transfer

No carbon dioxide at the point of use



Water is the product. There is no CO_2 from this reaction at the point of use.

This does not prove the whole system has no environmental impact.

6 Evaluate the whole system

Fuel cell
External fuel supply
Refuelling infrastructure
Hydrogen storage

Rechargeable battery
Stored reactants
Recharging time
Limited cycle life

Compare the full system using the data given.

Compare fuel-cell and battery systems using range, cost, lifetime, efficiency and refuelling/recharging data.

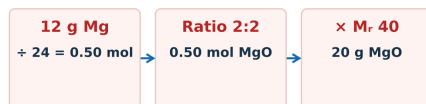
Hydrogen storage is difficult; it is flammable. Production needs energy and may cause emissions.

AQA section 4.5.2.

Higher Tier Quantitative extras

AQA Separate Chemistry 8462 | Paper 1 extras | Higher Tier only

1 Theoretical yield



Excess oxygen · Theoretical yield = 20 g

$2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$; excess oxygen.
 $12 \text{ g Mg} \div 24 = \mathbf{0.50 \text{ mol Mg}}$.
Ratio 2:2 gives 0.50 mol MgO.
 $M_r(\text{MgO}) = 40 \rightarrow \mathbf{20 \text{ g maximum}}$.
16 g actual $\rightarrow \mathbf{80\% \text{ yield}}$.

2 Choose a reaction route

Route A

Atom economy 90%
Yield 40%
Unwanted by-product

Route B

Atom economy 75%
Yield 95%
By-product can be sold

Compare all relevant evidence before choosing.

Compare **atom economy, yield, rate, equilibrium position and useful by-products**. Use supplied data; costs and energy may matter.
A route with a saleable by-product or higher yield may be preferable despite lower atom economy.

3 Concentration in mol/dm³

Concentration = amount ÷ volume

$$c = n \div V$$

$$n = c \times V \quad V = n \div c$$

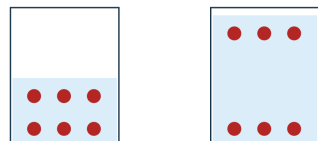
$$c \text{ in mol/dm}^3 \cdot n \text{ in mol} \cdot V \text{ in dm}^3$$

$$\text{Mass of solute} = n \times M_r$$

$c = n/V$; $n = cV$; $V = n/c$.
Use V in dm³: cm³ ÷ 1,000.
200 cm³ of 0.50 mol/dm³:
 $n = 0.50 \times 0.200 = \mathbf{0.100 \text{ mol}}$.
Mass = $n \times M_r$.
g/dm³ = mol/dm³ × M_r .

4 Dilution and concentration

Same solute amount · More total volume

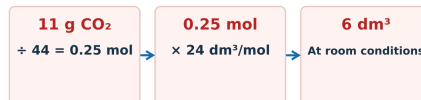


Initial concentration Half the concentration

Same solute and volume: doubling mass doubles concentration.
Same solute amount: doubling solution volume halves concentration.
Concentration measures solute per solution volume, not just the total solute amount.

5 Gas volume from mass

CO₂: $M_r = 44$



At **20°C and 1 atmosphere**, 1 mol gas occupies **24 dm³**.
 $V = n \times 24$; $n = V/24$.
11 g CO₂, $M_r = 44$:
 $n = 11/44 = 0.25 \text{ mol}$.
 $V = 0.25 \times 24 = \mathbf{6 \text{ dm}^3}$.

6 Gas volume ratios



1 : 3 : 2

10 dm³ 30 dm³ 20 dm³

Same temperature and pressure

Assumes complete reaction for the maximum product.

At the same temperature and pressure, gas volumes follow equation coefficients.
 $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$ gives **1:3:2**.
 $10 \text{ dm}^3 \text{ N}_2 + 30 \text{ dm}^3 \text{ H}_2 \rightarrow$ at most $20 \text{ dm}^3 \text{ NH}_3$ for complete reaction.
Sections 4.3.3–4.3.5.

Higher Tier Titrations and fuel cells

AQA Separate Chemistry 8462 | Paper 1 extras | Higher Tier only

1 Plan a titration calculation



Known acid
 0.100×0.0200
 $= 0.00200 \text{ mol}$

Use 1:1 ratio
NaOH amount
 $= 0.00200 \text{ mol}$

Unknown alkali
 $0.00200 \div 0.0250$
 $= 0.0800 \text{ mol/dm}^3$

Convert cm^3 to dm^3 before using c and V.

Known c and V → moles → equation ratio → unknown c.

Convert both volumes to dm^3 .

Divide unknown moles by the original volume of that solution, not the total mixture volume.

2 A 1:1 calculation



25.0 cm^3 alkali reacts with 20.0 cm^3 of 0.100 mol/dm^3 HCl.

HCl moles $= 0.100 \times 0.0200 = \mathbf{0.00200 \text{ mol}}$.

1:1 ratio → NaOH $= 0.00200 \text{ mol}$.

$c(\text{NaOH}) = 0.00200 / 0.0250 = \mathbf{0.0800 \text{ mol/dm}^3}$.

$M_r(\text{NaOH}) = 40$.

Mass concentration $= 0.0800 \times 40 = \mathbf{3.20 \text{ g/dm}^3}$.

3 Check the acid ratio



1 mol acid
Sulfuric acid

2 mol alkali
Sodium hydroxide

$\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$.

1 mol acid needs 2 mol alkali.

0.0020 mol acid needs 0.0040 mol NaOH. In 0.025 dm^3 , this is $0.0040 / 0.025 = \mathbf{0.16 \text{ mol/dm}^3}$.

Do not assume every ratio is 1:1.

4 Acidic fuel-cell equations

Acidic fuel cell

Negative electrode: oxidation



Positive electrode: reduction



Atoms balance · Total charge balances

Negative electrode: hydrogen loses electrons (oxidation).

Positive electrode: oxygen gains electrons (reduction).

Electrons travel through the external circuit.

Both half-equations transfer four electrons.

5 Alkaline fuel-cell equations

Alkaline fuel cell

Hydrogen is oxidised



Oxygen is reduced



Same overall reaction: $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$

An alkaline electrolyte uses OH^- in its half-equations.

Check atoms and total charge on both sides.

Use the species given.

Do not combine one acidic half-equation with one alkaline half-equation.

6 Overall reaction and checks

Hydrogen + oxygen → water



Electrical energy transfer

No carbon dioxide at the point of use

Add matching half-equations. Cancel equal electrons and ions on both sides (and water where appropriate).

Overall: $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$.

Oxidation = electron loss.

Reduction = electron gain.

Sections 4.4.2.5 and 4.5.2.2.