Course Companion

Pearson Edexcel · International GCSE · Chemistry

Every topic handout in one volume

全部专题讲义合集

exercises.lol

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Principles of chemistry

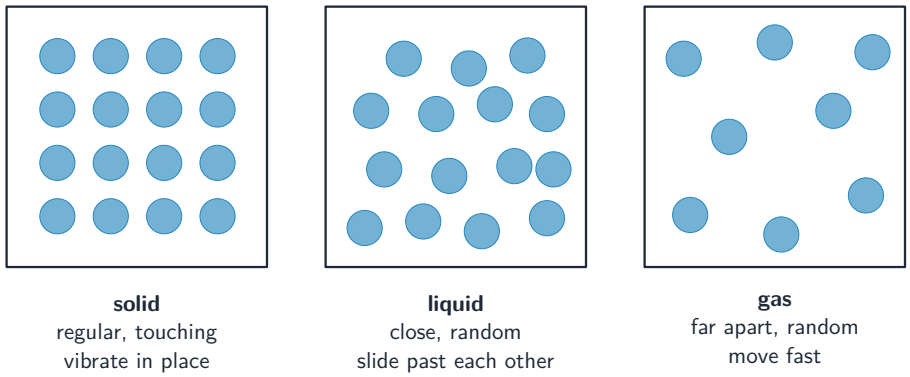
Pearson Edexcel · International GCSE · Chemistry

The language of chemistry

Everything in this course is written in one language: particles, formulae and equations. Section 1 teaches it – how particles arrange themselves in solids, liquids and gases; how atoms are built and lined up in the Periodic Table; how to turn a sentence about a reaction into a balanced equation and a mass calculation; and how the three kinds of bonding give every substance its properties.

Edexcel International GCSE Chemistry 4CH1, Section 1 (statements 1.1–1.60C) is the largest section and the foundation for the other three. C-suffixed statements are the separate-science (Chemistry-only) extension.

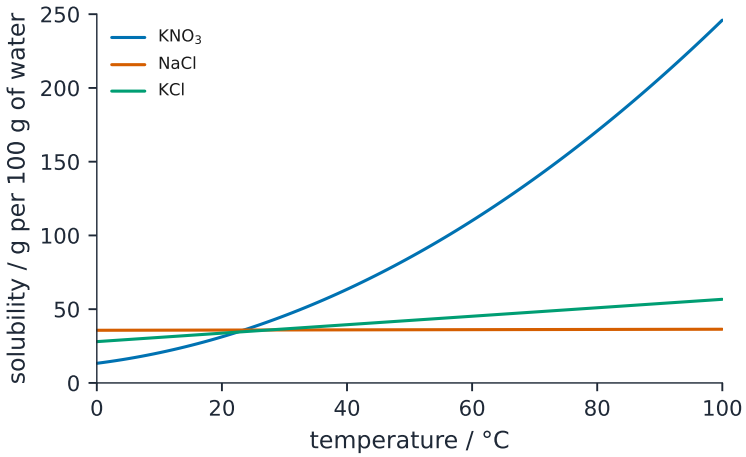
States of matter and solutions



Particle arrangements in the three states: fixed rows in solids, touching but disordered in liquids, far apart and fast in gases.

Solid: particles vibrate about fixed positions in a regular pattern. **Liquid**: particles touch but move past each other at random. **Gas**: particles far apart, fast, random. Interconversions: **melting** 熔化 / **freezing** 凝固, **boiling** 沸腾 / **condensation** 凝结, **evaporation** 蒸发 (surface only, below boiling), **sublimation** 升华 (solid → gas directly). Energy is absorbed to separate particles and released as they bond again.

A **solvent** 溶剂 dissolves the **solute** 溶质 to make a **solution** 溶液; a **saturated solution** 饱和溶液 holds all the solute it can at that temperature. (C) **Solubility** is the mass dissolved per 100 g of solvent at a stated temperature, read from a **solubility curve** 溶解度曲线 – points on the line are saturated; below it, unsaturated.

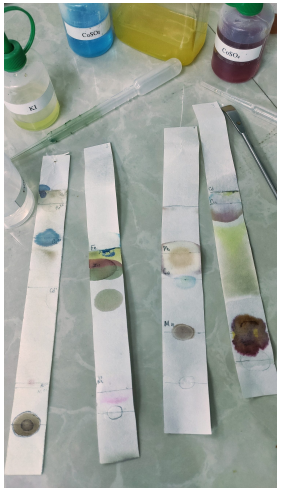


Solubility curves rise with temperature for most solids; read the saturated mass at a stated temperature.

Dilution of coloured solutions and gas diffusion (bromine spreading through air) both show particles moving from where they are many to where they are few.

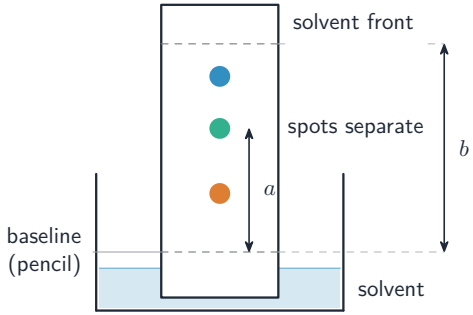
Elements, compounds, mixtures and separation

An **element** 元素 contains one type of atom; a **compound** 化合物 holds different atoms chemically joined; a **mixture** 混合物 is not chemically joined. A **pure substance** has a sharp melting/boiling point; mixtures melt and boil over a range – the test for purity.



Paper chromatography: a mixture of dyes separates into spots that rise different distances up the paper

Separation techniques, matched to the job: **filtration** 过滤 (insoluble solid from liquid); **crystallisation** 结晶 (evaporate a solution to leave crystals); **simple distillation** 蒸馏 (liquid from dissolved solid – evaporate then condense); **fractional distillation** 分馏 (liquids with close boiling points, using a fractionating column); **paper chromatography** 纸层析 (solutes that dissolve differently in a solvent).

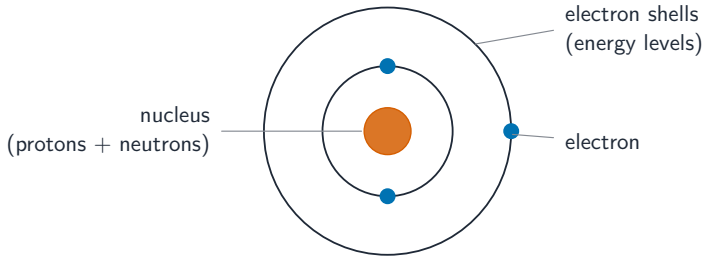


$$R_f = \frac{a}{b} = \frac{\text{spot}}{\text{solvent}}$$

A chromatogram: the solvent front and spot distances give Rf values that identify each component.

Rf = distance moved by the spot ÷ distance moved by the solvent. The same substance always has the same Rf in the same solvent – comparing with known values identifies the components of the mixture.

Atoms and the Periodic Table



The nuclear atom: protons and neutrons in the nucleus, electrons in shells.

Particle	Relative mass	Relative charge
proton	1	+1
neutron	1	0
electron	1/1835 (≈0)	−1

Atomic number 质子数 = protons; **mass number** 质量数 = protons + neutrons. **Isotopes** 同位素 have the same protons but different neutrons. **Relative atomic mass** (A_r) is the weighted mean over the isotopes.

Worked check. Chlorine: 75 % Cl-35, 25 % Cl-37 → $A_r = (75\times35+25\times37)/100 = 35.5$.

The Periodic Table lists elements by atomic number into **groups** 族 (columns, same outer electrons) and **periods** 周期 (rows). The first 20 electronic configurations follow 2,8,8,2 shells (e.g. sodium 2.8.1). Metals sit left/centre: their oxides are basic and they conduct; non-metal oxides are acidic. Group members behave alike because they have the same number of outer electrons; Group 0 noble gases have full outer shells and do not readily react.

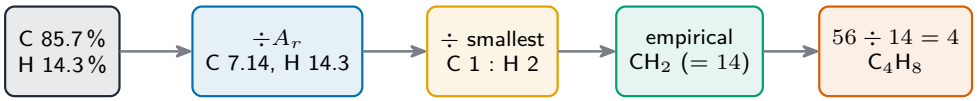
Formulae, equations and calculations

Balance equations with **state symbols** 状态符号: (s), (l), (g), (aq). M_r sums the A_r values. The **mole** 摩尔 is the amount of substance: $n = m/M_r$ (mass in grams).

Worked check (reacting masses). What mass of magnesium oxide forms from 6.0 g of magnesium? $2Mg + O_2 \rightarrow 2MgO$: $n(Mg) = 6.0/24 = 0.25$ mol → $n(MgO) = 0.25$ mol → mass $= 0.25 \times 40 = 10$ g.

Percentage yield 产率 = actual ÷ theoretical × 100 %. **Empirical formula** 实验式 is the simplest whole-number ratio (divide each mass by its A_r, scale to integers); the **molecular formula** is the true count (M_r ÷ empirical mass gives the multiplier).

Worked check. A hydrocarbon is 85.7 % C, 14.3 % H: C 85.7/12 = 7.14, H 14.3/1 = 14.3 → ratio 1:2 → empirical CH_2. With $M_r = 56$: 56/14 = 4 → molecular C_4H_8.



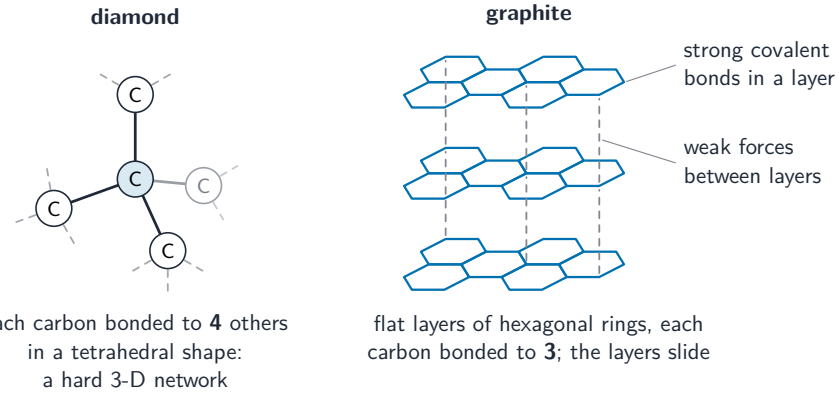
Divide by Ar, divide by the smallest, then scale by Mr.

(C) **Solutions**: $n = c \times V$ with c in mol/dm^3 and V in dm^3 (cm^3 ÷ 1000). **Gases**: molar volume 24 dm^3 at rtp, so $n = V/24$. (C-practical) A metal oxide's formula comes from combustion (weigh magnesium, burn, weigh the oxide) or reduction (weigh copper(II) oxide, reduce with hydrogen, weigh the copper).

Bonding

Ionic bonding 离子键: metals lose electrons to non-metals; the charged ions attract electrostatically in a **giant lattice** – dot-and-cross diagrams show the transfer (Groups 1–3 with 5–7). High melting points (strong attractions); conduct only when **molten or dissolved** (ions free to move). Learn the charges: Groups 1/2/3 → 1+/2+/3+; Groups 5/6/7 → 3−/2−/1−; Ag^+, Cu^{2+}, Fe^{2+}, Fe^{3+}, Pb^{2+}, Zn^{2+}; OH^-, NH_4^+, CO_3^{2-}, NO_3^-, SO_4^{2-}. Formulae balance the charges: calcium nitrate $Ca(NO_3)_2$, ammonium sulfate $(NH_4)_2SO_4$.

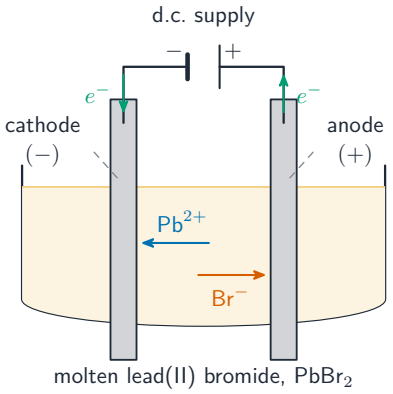
Covalent bonding 共价键: shared pairs of electrons (dot-and-cross for H_2, O_2, N_2, halogens, HCl, H_2O, NH_3, CO_2 and small organics). **Simple molecular** substances have weak intermolecular forces – low melting points, rising with M_r; they do not conduct (no ions, no free electrons). **Giant covalent**: diamond (each C bonded to 4 – very hard, non-conductor), graphite (3 bonds + one free electron per C, layers with weak forces – soft, conducts, slippery), C_{60} fullerene (simple molecular cage).



Diamond bonds every carbon to four others; graphite bonds three and keeps one electron free between weak layers.

(C) **Metallic**: a lattice of positive ions in a sea of delocalised electrons – electrostatic attraction; the free electrons conduct electricity, and layers slide (malleable).

Electrolysis (C)



Electrolysis of molten lead(II) bromide: lead at the cathode, bromine at the anode.

Electrolysis 电解 uses electricity to split **molten or dissolved ionic compounds**: the **cathode** 阴极 (negative) attracts **cations** 阳离子; the **anode** 阳极 (positive) attracts **anions** 阴离子. Molten $PbBr_2$ gives Pb at the cathode ($Pb^{2+} + 2e^- \rightarrow Pb$) and Br_2 at the anode ($2Br^- \rightarrow Br_2 + 2e^-$). In aqueous solution, **hydrogen forms at the cathode if the metal is more reactive than hydrogen**; at the anode, halide ions give the halogen, otherwise oxygen ($4OH^- \rightarrow O_2 + 2H_2O + 4e^-$). Loss of electrons is **oxidation** 氧化, gain is **reduction** 还原.

Check yourself

1. Describe the particle arrangement and movement in a liquid.
2. Define saturated solution, and state the units of solubility.
3. Which technique separates two miscible liquids with close boiling points?
4. An isotope has 17 protons and 20 neutrons. Give its mass number and the numbers of each particle.
5. Calculate A_r of an element with 80 % of mass 20 and 20 % of mass 22.
6. Balance with state symbols: magnesium + oxygen → magnesium oxide.
7. 8.4 g of the oxide of calcium forms from 6.0 g of calcium. Show the empirical formula of the oxide.
8. Write the formula of ammonium carbonate.
9. Explain why graphite conducts but diamond does not.
10. (C) What forms at each electrode in the electrolysis of molten potassium chloride?

Answers: 1 particles touch but are disordered, moving randomly past each other; 2 a solution containing the maximum mass of dissolved solute at that temperature; g per 100 g of solvent; 3 fractional distillation; 4 mass number 37; 17 protons, 20 neutrons, 17 electrons; 5 $(80 \times 20 + 20 \times 22)/100 = 20.4$; 6 $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$; 7 Ca $6.0/40 = 0.15$ mol; O mass $8.4 - 6.0 = 2.4$ g $\rightarrow 2.4/16 = 0.15$ mol; ratio 1:1 → empirical formula CaO; 8 $(NH_4)_2CO_3$; 9 graphite uses three bonds per carbon, leaving one delocalised electron per carbon free to move between layers – diamond uses all four in fixed bonds; 10 (C) potassium at the cathode ($K^+ + e^- \rightarrow K$) and chlorine at the anode ($2Cl^- \rightarrow Cl_2 + 2e^-$).

Inorganic chemistry

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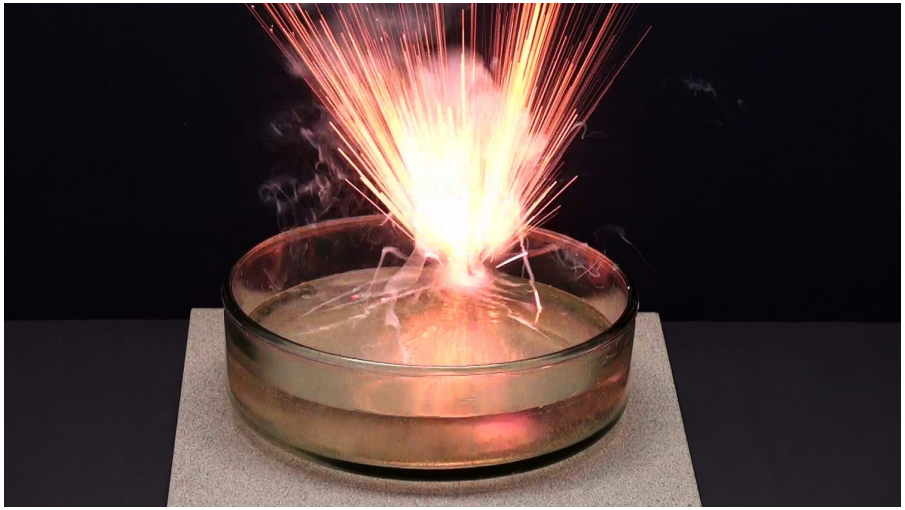
The reactive world of inorganic chemistry

Drop lithium in water and it fizzes gently; drop potassium and it ignites. This section follows the patterns behind those observations – the families of the Periodic Table, the air we breathe, the ladder of reactivity that decides how every metal is extracted and why iron rusts – and then the huge practical centre of the course: acids, alkalis, salt preparation and the identification tests.

Edexcel International GCSE Chemistry 4CH1, Section 2 (statements 2.1–2.50) supplies most of the recall and practical questions on both papers. C-suffixed statements are Chemistry-only.

Group 1 and Group 7

Group 1 (Li, Na, K) react with water to make the hydroxide and hydrogen – fizzing, floating, melting (Na), lilac flame (K). The reactions get **faster and more vigorous down the group**: a family with a trend. (C) Reactivity rises because the outer electron is further from the nucleus and lost more easily.



Potassium reacts violently with water, giving off hydrogen that burns with a lilac flame

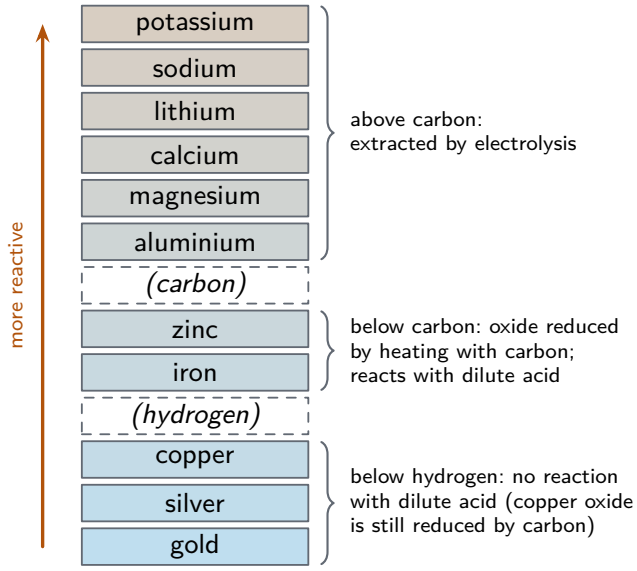
Group 7 (Cl_2 pale green gas, Br_2 orange-brown liquid, I_2 grey-black solid) darken down the group. A **more reactive halogen displaces** a less reactive one's salt: chlorine displaces bromine from potassium bromide (solution turns orange). (C) Reactivity falls down the group – the outer shell is further away, so gaining an electron is harder.

Air and gases

Dry air: about **78 % nitrogen, 21 % oxygen, 0.93 % argon, 0.04 % carbon dioxide** (the four most abundant). The oxygen percentage can be measured by using it up – iron rusting in damp air over water, or phosphorus burning, so the water rises about one-fifth of the way. Elements burn in oxygen: magnesium gives a bright white flame and white MgO; hydrogen burns with a pop to steam; sulfur gives a blue flame and choking SO_2. Copper(II) carbonate decomposes on heating: $CuCO_3 \rightarrow CuO + CO_2$ (limewater turns milky). CO_2 is a **greenhouse gas** 温室气体 whose rising level contributes to climate change.

The reactivity series and metals

Order to learn: **potassium, sodium, lithium, calcium, magnesium, aluminium, (carbon), zinc, iron, (hydrogen), copper, silver, gold**. Metals above hydrogen – everything down to iron – react with dilute HCl/H_2SO_4 giving hydrogen; the more reactive, the faster the fizz. A metal displaces any **less reactive** metal from its salt solution or oxide.



The reactivity series ladder with carbon and hydrogen between the metals.

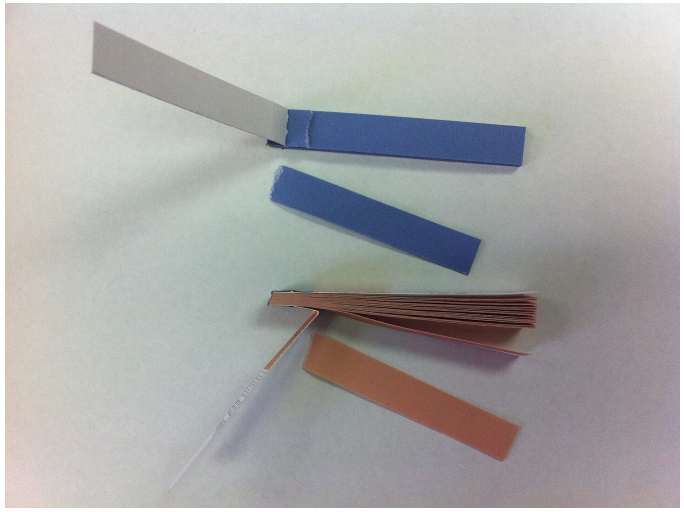
Rusting 生锈 needs **oxygen and water**; prevented by barrier methods (paint, oil, plastic), **galvanising** 镀锌 (zinc coat) and **sacrificial protection** 牺牲保护 (a more reactive metal such as zinc or magnesium corrodes instead). **Oxidation** 氧化 is loss of

electrons or gain of oxygen; **reduction** 还原 the reverse; a **redox** reaction has both; the oxidising agent 氧化剂 is reduced, the reducing agent 还原剂 is oxidised.

(C) **Extraction** matches reactivity: unreactive metals (gold, silver) occur native; those below carbon (iron) are **reduced by carbon** in a blast furnace; those above (aluminium) need **electrolysis** of molten ore. Aluminium (low density, resists corrosion), copper (conducts), iron and steels (strong; stainless resists rust) are chosen for their properties. **Alloys** 合金 mix a metal with other elements and are **harder** because the different-sized atoms disturb the layers' sliding.

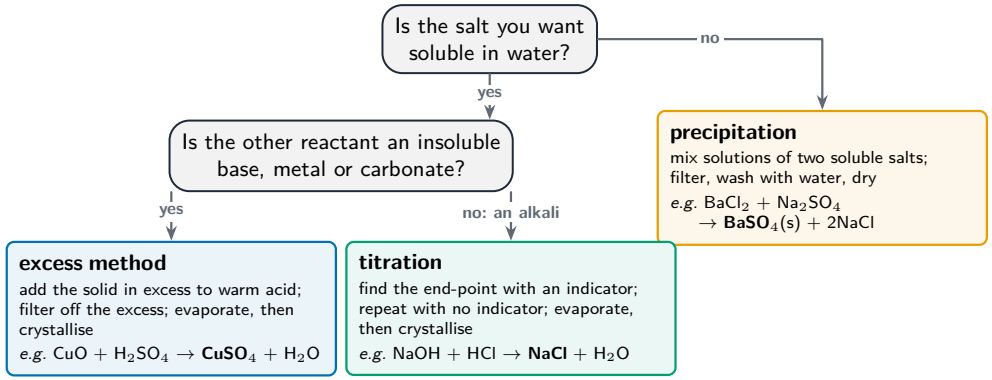
Acids, alkalis and salts

Acids provide $\mathbf{H^+(aq)}$; alkalis provide $\mathbf{OH^-(aq)}$. Indicators: **litmus** (red in acid, blue in alkali), **phenolphthalein** (colourless → pink), **methyl orange** (red → yellow). The **pH scale** pH 值 0–14 classifies solutions (0–3 strongly acidic … 11–14 strongly alkaline); universal indicator measures approximate pH. Neutralisation: acid + alkali → salt + water. (C) Acids are **proton donors**, bases **proton acceptors**; alkalis are soluble bases. (C) Titration 滴定: fixed volume of alkali with indicator in a flask, acid from a burette dropwise to the colour change, repeat for concordant results.



Litmus paper: blue turns red in acid, red turns blue in alkali

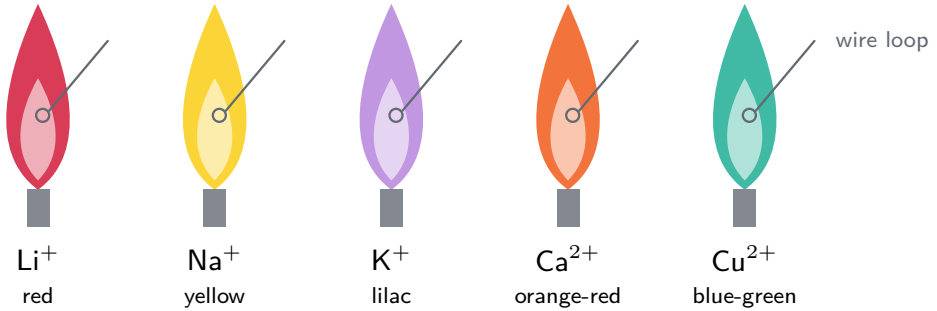
Solubility rules: sodium, potassium and ammonium salts – soluble; all nitrates – soluble; chlorides – soluble except AgCl and $PbCl_2$; sulfates – soluble except $BaSO_4$, $CaSO_4$ and $PbSO_4$; carbonates – insoluble except Na^+, K^+, NH_4^+; hydroxides – insoluble except Na^+, K^+ ($Ca(OH)_2$ slightly).



Choosing a salt preparation: solubility of the salt first, then whether the other reactant is insoluble or an alkali.

Acid + metal / base / carbonate gives a salt: e.g. $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$; $CuO + 2HNO_3 \rightarrow Cu(NO_3)_2 + H_2O$. **Soluble salt from an insoluble reactant** (CuO + warm dilute H_2SO_4): add excess base, filter, evaporate, crystallise. (C) From acid + alkali: titrate, then evaporate. (C) **Insoluble salt**: mix two solutions so a **precipitate** 沉淀 forms ($Pb(NO_3)_2 + Na_2SO_4 \rightarrow PbSO_4\downarrow + 2NaNO_3$), filter, wash, dry.

Chemical tests



Flame-test colours for five cations.

Gases: hydrogen – a lit splint pops; oxygen – relights a glowing splint; carbon dioxide – turns limewater milky; ammonia – turns damp red litmus blue; chlorine – bleaches damp litmus paper white. **Cations**: **flame tests** 焰色试验 (Li^+ red, Na^+ yellow, K^+ lilac, Ca^{2+} orange-red, Cu^{2+} blue-green); NH_4^+ warms with NaOH(aq) giving ammonia; $Cu^{2+}/Fe^{2+}/Fe^{3+}$ give blue/green/rust-brown precipitates with NaOH(aq). **Anions**: $Cl^-/Br^-/I^-$ give white/cream/yellow precipitates with acidified silver ni-

trate; SO_4^{2-} gives a white precipitate with acidified barium chloride; CO_3^{2-} fizzes with dilute HCl giving CO_2. **Water**: turns anhydrous copper(II) sulfate white → blue; a pure water sample boils sharply at 100 °C.

Check yourself

1. Describe the trend in reactivity down Group 1 and give the (C) electron reason.
2. What is seen when chlorine water is added to potassium bromide, and why?
3. Name the four most abundant gases in dry air with approximate percentages.
4. State the two conditions needed for iron to rust, and two prevention methods.
5. Define oxidation and reduction in terms of electrons.
6. (C) Why is aluminium extracted by electrolysis but iron by carbon reduction?
7. Which chlorides are insoluble, and which sulfates?
8. Write the equation for copper(II) oxide reacting with sulfuric acid.
9. Describe the flame-test colours for sodium, potassium and copper.
10. Describe the test for sulfate ions and the positive result.

Answers: 1 reactivity increases down the group (B1); (C) the outer electron is in a shell further from the nucleus, so it is lost more easily; 2 the solution turns orange – chlorine displaces bromine because chlorine is the more reactive halogen; 3 nitrogen ≈78 %, oxygen ≈21 %, argon ≈0.93 %, carbon dioxide ≈0.04 %; 4 oxygen and water; barrier methods (paint/grease/plastic) and galvanising or sacrificial zinc; 5 oxidation is loss of electrons, reduction is gain; 6 (C) aluminium lies above carbon in the reactivity series, so carbon cannot reduce its oxide – electrolysis of molten alumina is needed; iron lies below carbon, so carbon displaces it from its oxide; 7 AgCl and $PbCl_2$; $BaSO_4$, $CaSO_4$ and $PbSO_4$; 8 $CuO(s) + H_2SO_4(aq) \rightarrow CuSO_4(aq) + H_2O(l)$; 9 sodium yellow, potassium lilac, copper blue-green; 10 acidify with dilute hydrochloric acid, add barium chloride solution – a white precipitate of $BaSO_4$ confirms sulfate.

Physical chemistry

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Energy, speed and balance

Three questions decide whether a reaction is useful: does it heat or cool, how fast is it, and does it finish? Physical chemistry answers them – calorimetry and Q = mcΔT, collision theory with its four levers, and the dynamic equilibrium a reversible reaction reaches in a closed vessel.

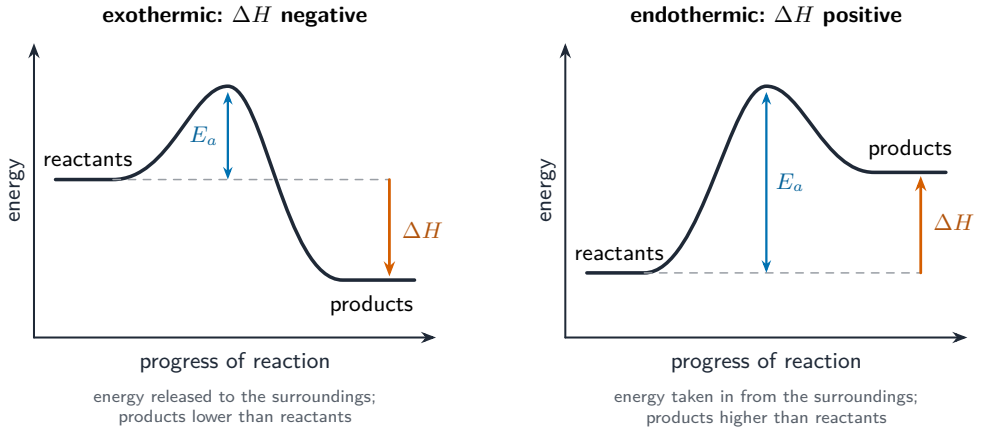
Edexcel International GCSE Chemistry 4CH1, Section 3 (statements 3.1–3.22C) is short but calculation-heavy. C-suffixed statements are Chemistry-only.

Energetics

Exothermic 放热 reactions give out heat (combustion, neutralisation, most displacements) – the mixture warms, ΔH is negative. **Endothermic** 吸热 reactions take heat in (thermal decomposition, some dissolving) – the mixture cools. Simple **calorimetry** 量热: measure the temperature change of a known mass (polystyrene cup for solutions; spirit burner under a water beaker for combustion).

$$Q = mc\Delta T$$

Worked check. 50 g of water rises 24 °C in a spirit-burner trial: $Q = 50 \times 4.2 \times 24 = 5040$ J. If 0.010 mol of fuel burned: $\Delta H = -5040/0.010 = -504\,000\ \text{J mol}^{-1} = -504\ \text{kJ mol}^{-1}$.



Energy profiles for exothermic and endothermic reactions with activation energy marked.

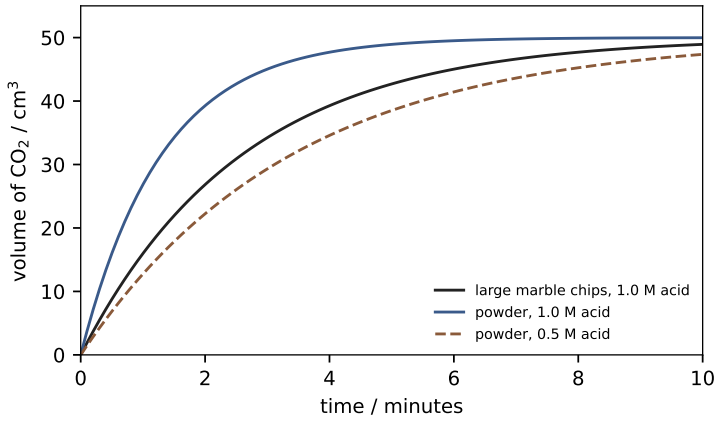
(C) **Bond breaking is endothermic; bond making is exothermic.** ΔH = bonds broken − bonds formed. **Worked check.** $H_2 + Cl_2 \rightarrow 2HCl$: broken 436 + 242 = 678; formed 2 × 431 = 862; $\Delta H = 678 - 862 =$ **−184 kJ/mol** (exothermic).

Rates of reaction

Experiments follow a reaction that is visible: gas volume (marble + acid), mass loss on a balance, or disappearing cross (sodium thiosulfate + acid). Four levers: **surface area** of a solid, **concentration** (or gas pressure), **temperature**, and a **catalyst** 催化剂.



The honeycomb inside a catalytic converter gives the catalyst a huge surface area, so the reactions are fast

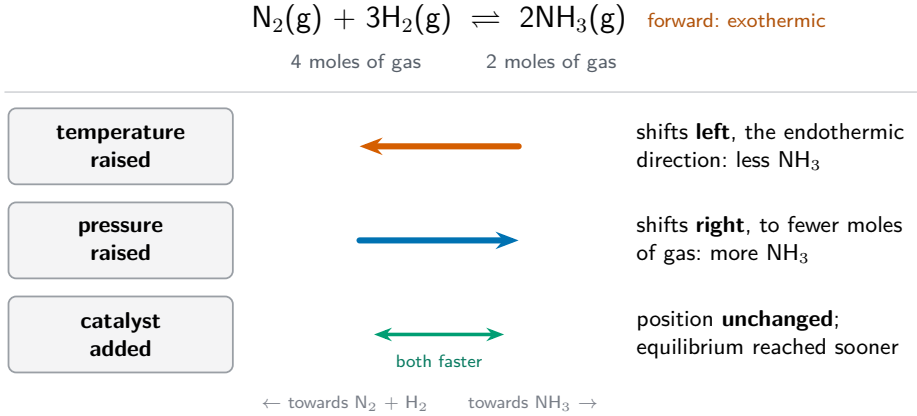


Rate curves: powder beats chips; more dilute acid slows it.

Collision theory 碰撞理论 explains them all: reactions need collisions with at least the **activation energy** 活化能. Powder gives more exposed surface → more collisions per second; higher concentration or pressure packs particles closer → more frequent collisions; higher temperature makes particles faster → collisions both more frequent and more energetic – of these three, the only lever that raises the *fraction* of collisions with at least the activation energy. A catalyst provides an **alternative pathway with lower activation energy** – more collisions succeed – and is chemically unchanged at the end; it does not change the amount of product, only how fast it appears.

Reversible reactions and equilibria

A reversible reaction 可逆反应 (⇌) runs both ways: hydrated copper(II) sulfate ⇌ anhydrous salt + water (heat drives it forward, water reverses it); ammonium chloride ⇌ ammonia + hydrogen chloride on heating. (C) In a **sealed container** it reaches **dynamic equilibrium** 动态平衡: forward and reverse rates are equal, and all concentrations stay constant – both reactions still run.



What each change does to the position of equilibrium, worked on N2 + 3H2 ⇌ 2NH3.

(C) **Temperature up** → equilibrium shifts in the **endothermic** direction; **pressure up** → shifts towards the side with **fewer moles of gas**; a **catalyst** speeds both directions equally and leaves the position unchanged.

Check yourself

1. Classify as exo- or endothermic: combustion, thermal decomposition, neutralisation.
2. 100 g of water cools by 8.0 °C in a dissolving experiment. Calculate Q.
3. (C) State the sign of ΔH for bond breaking and bond making.

4. Use bond energies to find ΔH for $2H_2 + O_2 \rightarrow 2H_2O$ (H–H 436, O=O 498, O–H 463 kJ/mol).
5. Why does powdered marble react faster with acid than one large chip?
6. Of surface area, concentration and temperature, which increases the fraction of successful collisions, and why?
7. Define a catalyst.
8. (C) State the two characteristics of dynamic equilibrium.
9. (C) $N_2 + 3H_2 \rightleftharpoons 2NH_3$: what does raising the pressure do, and why?
10. (C) Why does a catalyst not change the position of equilibrium?

Answers: 1 exothermic (combustion), endothermic (thermal decomposition), exothermic (neutralisation); 2 $Q = 100 \times 4.2 \times 8.0 = 3360$ J taken in – the water cools, so the dissolving is endothermic; 3 (C) breaking positive (endothermic), making negative (exothermic); 4 broken: $2(436) + 498 = 1370$; formed: $4(463) = 1852$; $\Delta H = 1370 - 1852 = -482$ kJ/mol (per 2 mol H_2O); 5 powder exposes far more surface, so more acid collisions per second; 6 temperature – faster particles collide more often AND more collisions exceed the activation energy; 7 a substance that increases the rate but is chemically unchanged at the end; 8 (C) forward and reverse rates equal; concentrations of all substances constant; 9 (C) shifts right – 4 moles of gas on the left, 2 on the right, so higher pressure favours the fewer-mole side.

Answers continued: 10 (C) it lowers the activation energy of forward and reverse equally, speeding both without changing their balance.

Organic chemistry

Pearson Edexcel · International GCSE · Chemistry

Carbon's family tree

Crude oil is a mixture of hydrocarbons – compounds of carbon and hydrogen only – built from the smallest molecules in the gas fraction to the tars of bitumen. This section organises them into families, follows crude oil from well to fraction, and then meets each family in turn: the unreactive alkanes, the double-bonded alkenes, and (C) the alcohols, acids, esters and polymers that come after.

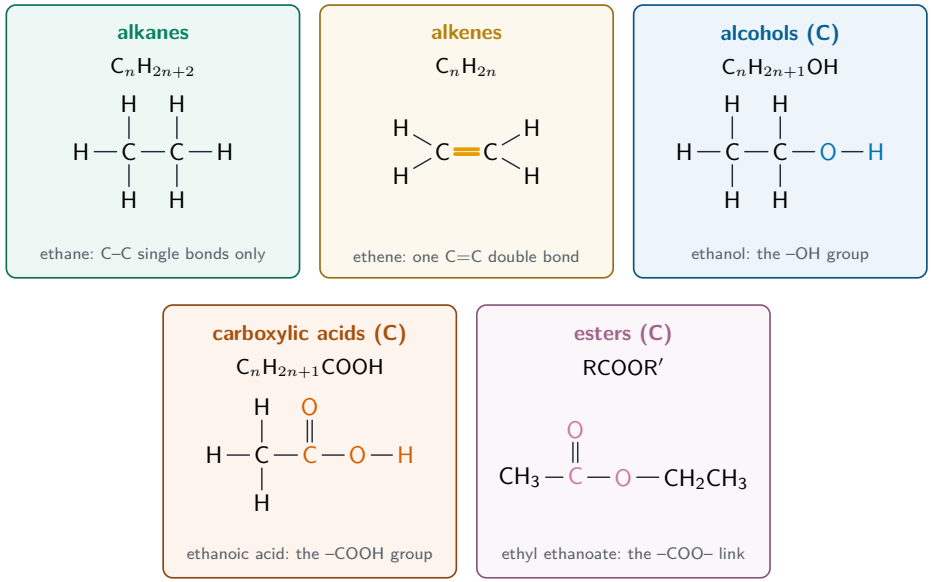
Edexcel International GCSE Chemistry 4CH1, Section 4 (statements 4.1–4.50C) closes the course. C-suffixed statements are Chemistry-only.

Introduction and crude oil

A **hydrocarbon** 烃 holds hydrogen and carbon only. Molecules are drawn as empirical, molecular, general, structural and **displayed formulae** 结构式. A **homologous series** 同系列 shares a general formula and **functional group** 官能团, members differing by CH_2; **isomerism** 同分异构现象 – **isomers** 同分异构体 share a molecular formula with different structures. IUPAC naming runs to six carbons.

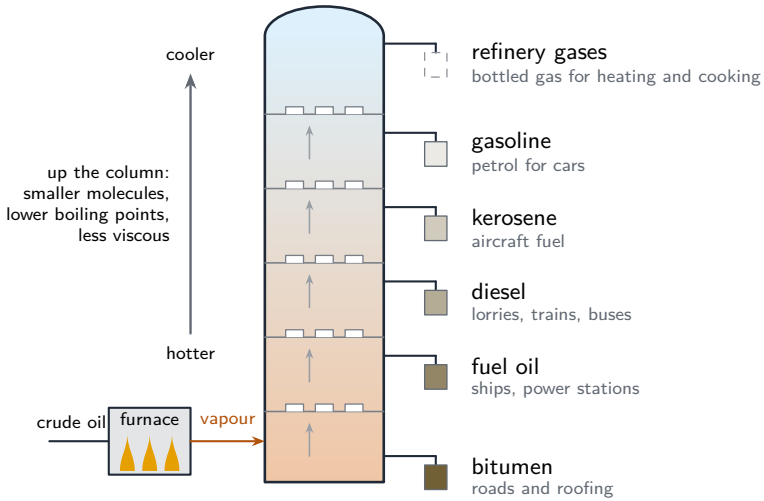


An oil refinery separates crude oil into fractions by fractional distillation



The homologous series of this specification with general formulae and functional groups.

Crude oil separates by **fractional distillation** 分馏: the furnace vaporises the oil, and vapours rise up the column, cooling as they go – small molecules with low boiling points collect at the top, large viscous molecules at the bottom.



Fractional distillation: vapours rise and cool, and each fraction is drawn off at its own level; small molecules at the top, darker, more viscous fractions at the bottom.

Fractions darken and thicken down the column (rising boiling point and viscosity). **Complete combustion** gives CO_2 + H_2O; **incomplete combustion** 不完全燃烧 also gives carbon monoxide – poisonous because it reduces the blood's oxygen-carrying capacity – and soot. In engines, hot air makes nitrogen and oxygen combine into oxides of nitrogen; sulfur impurities burn to SO_2; both gases dissolve in rain making it acidic (acid rain damages leaves, lakes and buildings). **Cracking** 裂解 converts long-chain alkanes to alkenes + shorter alkanes over silica/alumina at 600–700 °C – because the refinery's supply of long fractions outstrips demand while short fractions are wanted.

Alkanes and alkenes

Alkanes 烷烃 (C_nH_{2n+2}) are **saturated** 饱和 – only single C–C bonds. Methane, ethane, propane, butane, pentane. With halogens in **ultraviolet light** they substitute one hydrogen: $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$ (substitution 取代).

Alkenes 烯烃 (C_nH_{2n}) carry **C=C** – **unsaturated** 不饱和. With bromine they add across the double bond to a dibromoalkane (addition 加成): $C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$. **Bromine water** distinguishes them: decolourised (orange → colourless) by an alkene, unchanged by an alkane.

Alcohols, acids and esters (C)

Alcohols 醇 carry **–OH**: methanol, ethanol, propan-1-ol, butan-1-ol. Complete combustion of ethanol produces carbon dioxide and water. Ethanol oxidises to ethanoic acid by microbial oxidation in air or by warming with potassium dichromate(VI) in dilute sulfuric acid. Ethanol is made by **ethene + steam** over a phosphoric acid catalyst (≈300 °C, 60–70 atm) or by **fermentation** 发酵 of glucose with yeast enzymes in the absence of air at ≈30 °C – the optimum for the enzymes, and no oxygen so the yeast produces ethanol not water.

Carboxylic acids 羧酸 carry **–COOH**: methanoic, ethanoic, propanoic, butanoic. Their solutions react with metals (giving H_2) and carbonates (giving CO_2) like other acids; vinegar is dilute ethanoic acid.

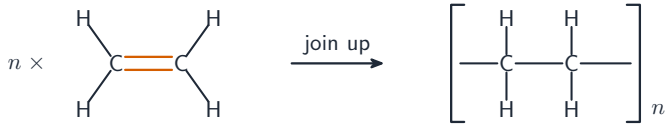
Esters 酯 carry **–COO–**: ethanol + ethanoic acid, with an acid catalyst, give **ethyl ethanoate** 乙酸乙酯 and water (esterification). Given an alcohol and an acid, join the acid's –COOH to the alcohol's –O–. Esters are volatile, sweet-smelling, used as flavourings and perfumes.

Synthetic polymers

Addition polymers 加成聚合物 form when many alkene **monomers** 单体 join, opening their C=C bonds.



Most addition polymers are non-biodegradable, so waste plastic builds up in the environment



From ethene to poly(ethene): open the double bond and draw the repeat unit between brackets with n.

Draw the repeat unit of poly(ethene), poly(propene), poly(chloroethene), PTFE; from a repeat unit, close the two bonds back into a C=C to recover the monomer. Disposal problems: these addition polymers resist many chemical reactions and do not readily biodegrade, and burning can release toxic gases. (C) **Condensation polymerisation**: a dicarboxylic acid + a diol link ester bonds, releasing water – a **polyester** 聚酯; some (biopolyesters) biodegrade.

Check yourself

1. Define hydrocarbon, homologous series and isomerism.
2. Name the six main fractions of crude oil in boiling-point order.
3. Write the products of complete and incomplete combustion of a hydrocarbon.
4. Give two pollutant gases from burning fuels and one source of each.
5. Why is cracking necessary?
6. Write the equation for methane reacting with chlorine in UV light, naming the reaction type.
7. How does bromine water distinguish an alkene from an alkane?
8. (C) Name the two methods of manufacturing ethanol with one condition for each.
9. (C) Which alcohol and acid make ethyl ethanoate, and what else forms?
10. (C) What monomers make a polyester, and what small molecule is released?

Answers: 1 a compound of hydrogen and carbon only; a family with the same general formula and functional group, differing by CH_2; molecules with the same molecular formula but different structures; 2 refinery gases, gasoline, kerosene, diesel, fuel oil, bitumen; 3 complete: carbon dioxide + water; incomplete adds carbon monoxide (and soot); 4 carbon monoxide – incomplete combustion; sulfur dioxide – burning sulfur impurities; oxides of nitrogen – hot engine air; 5 supply of long-chain fractions exceeds demand while short fractions and alkenes are in short supply; 6 $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$ – substitution (photo, UV); 7 the alkene decolourises orange bromine water; the alkane leaves it orange; 8 (C) ethene + steam, phosphoric acid catalyst, ~300 °C, 60–70 atm; fermentation of glucose with yeast, no air, ~30 °C; 9 (C) ethanol + ethanoic acid – water also forms (acid catalyst); 10 (C) a dicarboxylic acid and a diol; water is released at each ester link.