Answers

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Atomic structure and the periodic table

Atoms, elements and compounds

1 **a** Atom – The smallest part of an element that can exist; Element – A substance made of only one type of atom; Compound – A substance that contains two or more elements chemically combined; Mixture – A substance that contains two or more elements not chemically combined.

b Br_2; Ar **c** B **d** 9 **e** 3

2 **a** Any two from fluorine, chlorine, bromine, iodine or astatine (must be the name, not the symbol).

b Any two from Li, Na, K, Rb, Cs or Fr (not H as not in group 1 of the periodic table).

Mixtures and compounds

1 Element: hydrogen, oxygen; Compound: sodium hydroxide, water; Mixture: air, salty water.

2 Heat the solution; Allow water to evaporate/leave to form crystals.

3 **a** Condenser

b Water boils and turns into a gas/vapour; The vapour is then cooled in the condenser and turns back into water; The salt remains in the flask as it has a higher melting/boiling point than water.

4 Any four from: Crush rock salt; Add rock salt to water; Heat/stir until NaCl dissolves; Filter to remove sand; Heat remaining solution; Leave to crystallise/allow water to evaporate.

Scientific models of the atom

1 Before the discovery of the electron, atoms were thought to be tiny spheres that could not be divided.

2 Ball/sphere of positive charge; electrons embedded in the sphere.

3 **a** Positive

b Most of the atom is empty space.

c Only part of the atom has a positive charge.

d Mass of the atom is concentrated in the middle/nucleus; this positive charge is found in the middle of the atom/nucleus.

e Neutrons

Atomic structure, isotopes and relative atomic mass

1

Sub-atomic particle	Relative charge	Relative mass
Proton	+1	**1**
Electron	**–1**	Very small
Neutron	**0**	**1**

2 There are equal numbers of protons and electrons/6 protons and electrons; The positive and negative charges cancel each other out.

3 **a** 74 protons and 74 electrons; 110 neutrons.

b Gold (not Au)

4 atomic; mass; protons; neutrons; 6; 6; 7

5 Both isotopes have 35 protons; and 35 electrons; Br-79 has 44 neutrons and Br-81 has 46 neutrons or Br-81 has 2 more neutrons than Br-79.

6 The other isotope makes up 25%;

$(35 \times 75) + (Cl \times 25)/100 = 35.5$;

Cl = 37. (Final answer of 37 gains all 3 marks)

The development of the periodic table and the noble gases

1 **a** 4 **b** 4

c Same number of electrons/5 electrons in outer shell.

d Same number of electron shells.

2 **a** Periods

b For missing/undiscovered elements.

c By increasing atomic/proton number.

d Because they are unreactive.

3 **a** Increase down the group.

b Any number between –185 and –109.

Electronic structure

1 **a** Nucleus

b Protons; and neutrons (1 mark each).

c Aluminium or Al. **d** 14

2 **a** C **b** A **c** B, E

d B, F **e** D **f** A

Metals and non-metals

1 Malleable – Can be hammered into shape; Ductile – Can be drawn into wires; Sonorous – Makes a ringing sound when hit.

2 **a** Na **d** Ar **g** Ca

b Au **e** B **h** N

c Si **f** Br

3 **a** Non-metal **b** 2

c Good electrical conductor; shiny.

Group 1 – the alkali metals

1 They all have 1 electron in their outer shell.

2 Potassium

3 Francium

4 Na

5 Any three from: Fizzing/bubbling/effervescence, not gas given off; Lithium floats; Lithium moves on the surface; Lithium dissolves/gets smaller/disappears.

6 Any two from: Potassium melts/forms a ball; Potassium catches fire; Lilac/purple; Reaction is faster/more vigorous.

Group 7 – the halogens

1 F **2** Fluorine

3 Br_2 **4** Chlorine

5 **a** Lithium and chlorine, as chlorine is more reactive.

b Lithium + chlorine → lithium chloride

c $2Li + I_2 \rightarrow 2LiI$ (correct; balanced)

6 **a**

	Chlorine	Bromine	Iodine
Potassium chloride	x	No reaction	**No reaction**
Potassium bromide	Orange solution formed	x	No reaction
Potassium iodide	**Brown solution formed**	**Brown solution formed**	x

b Chlorine + potassium bromide → bromine + potassium chloride

c Add iodine to potassium astatide (or any astatide salt); Brown colour of iodine disappears/solution turns darker.

$I_2 + 2At^- \rightarrow 2I^- + At_2$

The transition metals

1 Silver; mercury; tungsten.

2 **a** Any from: shiny; unreactive; hard; strong.

b Any three from: High melting points; High density; Unreactive [if not given in (a)]; Hard [if not given in (a)]; Strong [if not given in (a)].

3 **a** Sodium chloride **b** White

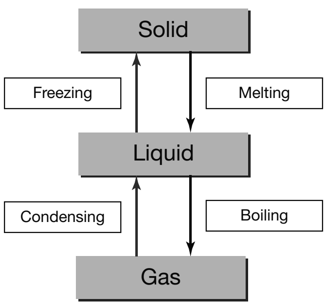
c $2Na + Cl_2 \rightarrow 2NaCl$ (correct; balanced)

4 Less, as iron is less reactive.

Bonding, structure and the properties of matter

Bonding and structure

1



2 **a** 0°C **b** 100°C

3 **a** Gas **b** Solid
c Liquid

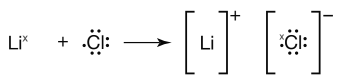
4 **a** Oxygen **b** Nitrogen
c Oxygen **d** Oxygen

Ions and ionic bonding

1 Magnesium is a metal which is found in group **2** of the periodic table. This means it has **2** electrons in its outer shell. When it reacts, it loses **2** electrons and forms an ion with a **2**$^{+}$ charge. Fluorine is a non-metal which is found in group **7** of the periodic table. When it reacts, it **gains** 1 electron to form an ion with a **1**$^{-}$ charge. When magnesium reacts with fluorine, it forms magnesium fluoride which has the formula **MgF_2**.

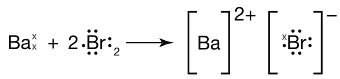
2 Potassium chloride, KCl; Magnesium oxide, MgO; Magnesium chloride, $MgCl_2$; Aluminium fluoride, AlF_3.

3 **a** Formula = LiCl



(correct ion; correct formula)

b Formula = $BaBr_2$



(correct ion; correct formula)

The structure and properties of ionic compounds

1 High melting points; Conduct electricity when molten or in solution; Made of ions.

2 **a** B **b** A **c** C

3 Ionic bonds are formed when **metals** react with **non-metals**. Atoms either lose or gain **electrons** to become positive or negative particles called ions. The ions are held together in a giant ionic **lattice** by strong **electrostatic** forces of attraction acting in all **directions**.

4 Level 1 (marks 1–2)

KI is ionic/made of ions/consists of a giant ionic lattice.

KI will have a high melting point *or* will conduct electricity when molten or in solution.

Level 2 (marks 3–4)

KI will have a high melting point because the ions are strongly attracted together/lots of energy is needed to break the strong ionic bonds *or*

KI will conduct electricity when molten or in solution/dissolved because the ions are free to move.

Level 3 (marks 5–6)

KI will have a high melting point because the ions are strongly attracted together/lots of energy is needed to break the strong ionic bonds *and*

KI will conduct electricity when molten or in solution/dissolved because the ions are free to move *and*

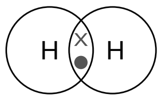
KI will not conduct electricity when solid as the ions do not move/are in fixed positions.

Covalent bonds and simple molecules

1 NH_3; Water.

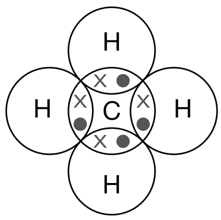
2 **a** and **b**

Hydrogen



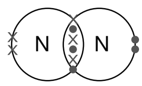
Formula: H_2

Methane



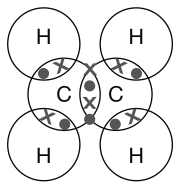
Formula: CH_4

3 **a**



b Covalent bond – triple bond

4 **a**



(each single bond; correct double bond)

b Covalent bonds – 4 × single and 1 × double

Diamond, graphite and graphene

1 **a** A **b** C

2 **a** Strong covalent bonds; large amounts of energy needed to overcome/break covalent bonds.

b Each carbon is bonded to 4 other carbon atoms; covalent bonds are very strong.

c Both have delocalised electrons; both conduct electricity.

3 **a** Does not have delocalised electrons. (do not allow free/mobile ions).

b High melting/boiling points hard. (due to no delocalised electrons).

Fullerenes and polymers

1 **a** D **b** C
c A **d** B

2 **a** Hollow/spherical

b Large surface area

3 **a** Covalent

b
- Polyethene is a bigger molecule so has larger intermolecular forces;
- More energy needed to overcome these intermolecular forces;
- Increases the melting point;
- Allow reverse argument.

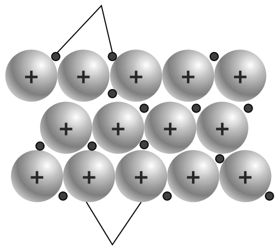
Giant metallic structures and alloys

1 Metals are **giant** structures. The atoms are arranged in **layers**.

The outer shell electrons become detached from the rest of the atom and are said to be **delocalised**. This means they are free to move throughout the whole metal.

Metallic bonding is strong because of the **electrostatic** attraction between the positive metal ions and the electrons.

2 **free electrons** from outer shells of metal atoms



metal ions

Giant structure; Positive metal ions drawn and labelled; Delocalised electrons drawn and labelled; Electrons can carry charge throughout the metal.

3 **a** Strong electrostatic attraction between positive metal ions and delocalised electrons; Lots of energy needed to overcome the strong attraction.

b Carbon/different sized atoms distort the regular lattice; Layers cannot slide over each other.

Nanoparticles

1 1–100 nm

2 **a** 8.6×10^{-8} m

b 1.46×10^{-8} m

c 1.58×10^{-7} m

d 8.2×10^{-9} m

e c– because the value is > 100 nm (both points needed)

3 **a**
- Surface area = $5^2 \times 6$ = 150 nm^2; [units not needed]
- Volume = 5^3 = 125 nm^3;
- SA:volume ratio = 150/125 = 1.2.

b As length of the side increases, ratio increases; by a factor of 10.

Quantitative chemistry

Conservation of mass and balancing equations

1 a Magnesium + oxygen → magnesium oxide
  b Reactants: Magnesium, oxygen; Products: Magnesium oxide.
  c 20 g

2 a Nitrogen + hydrogen → ammonia
  b

	Reactants	Products
N	2	1
H	2	3

  c $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

3 $Fe_2O_3 + 2CO \rightarrow 2Fe + 2CO_2$

Relative formula masses

1 The relative atomic mass (symbol = A_r) of an element is the weighted average mass of its naturally occurring isotopes;

You calculate the relative formula mass (symbol = M_r) of a compound by adding up all the relative atomic masses of all the atoms present in the formula of the compound;

The elements hydrogen, oxygen, nitrogen, chlorine, bromine, iodine and fluorine exist as diatomic molecules- in equations their relative formula masses are twice their relative atomic masses;

The law of mass conservation means that in a chemical reaction the sum of the relative formula masses of the reactants is equal to the sum of the relative formula mass of the products.

2 Carbon – 12; Oxygen – 16; Chlorine 35.5; Iron – 55.8

3 a NaOH – 40; H_2SO_4 – 98; Na_2SO_4 – 142; H_2O – 18
  b 10 g/98 = 0.010 → 0.010 × 18 = 1.84 g
  c 5 g/142 = 0.35 → 0.035 × 40 × 2 = 3.7 g
  d So they know how much product will be made OR to avoid waste.

The mole and reactive masses

H 1 a 0.1 moles b 0.1 moles
  c 0.003 (or 3.125×10^{-3}) moles
  d 0.5 moles

H 2 a 36.5 g b 60 g
  c 31.8 g d 171 g

H 3 a

Substance	A_r or M_r	Mass/g	Moles
sodium	23.0	2.30	0.1
sulfur	**32**	0.32	0.01
CH_4	**16**	1.60	**0.1**

  b 1.37 moles

H 4 a 152 b 38 g
  c 19 g d 7.5×10^{22}

H 5 a 14 g
  b 1 136 364 (or 1.13664×10^6) g

H 6 a 0.003 moles
  b 2.9 × 10 – 2 moles
  c 2.3×10^{23}

Limiting reactants

H 1 a Hydrochloric acid
  b Magnesium

H 2 How many moles of water can be produced by 1 mole of H_2? 1

How many moles of water can be produced by 1 mole of O_2? 2

Which is the limiting reactant? H_2

How much H_2O is produced in the reaction? 1

Which reactant is in excess? O_2

How many moles of O_2 is used in the reaction? 1

H 3 a $4Cu + O_2 \rightarrow 2Cu_2O$
  b Cu → 1.26 moles; O_2 → 1.56 moles
  c Copper; because in the equation, the ratio of moles is Cu:O_2 4:1, however in the experiment there was only 1.26:1.56 moles.

H 4 a $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$
  b 2.84 g
  c The limiting reactant is oxygen; because in the balanced equation the ratio is 1:5 (0.3:1.5), but the engine only has 0.3:0.1; they could make the engine more efficient by increasing the amount of oxygen.

Concentrations in solutions

H 1 a 1 b 2

H 2 a Test 1 – 250 g/dm³
  Test 2 – 400 g/dm³
  Test 3 – 571 g/dm³
  b Test 1 – 0.09 moles
  Test 2 – 0.17 moles
  Test 3 – 0.34 moles

H 3 a 143
  b 0.01 moles/143 g/mol = 1.43 g = 1.43 g/dm³
  c 3 575 000 g; 3.575×10^6 g

Moles in solution

H 1 a 0.25 moles b 10 mol/dm^{-3}

H 2 0.05 mol/dm^{-3}

H 3 1 260 mol/dm^{-3}

Moles and gas volumes

H 1 At the same temperature and pressure equal **volumes** of different gases contain the same number of molecules.

This means that under the same conditions, equal volumes of gases have the same number of **moles** present.

At room temperature (20°C) and **atmospheric pressure,** together known as **room temperature and pressure (RTP)**,1 mole of any gas occupies a volume of 24 dm³.

H 2 144 dm³

H 3 a 83.3 moles b 0.083 moles
  c 3.66 g

Percentage yield and atom economy

1 a $\frac{\text{Relative formula mass of desired product}}{\text{Sum of relative formula masses of reactants}} \times 100$
  b They would understand how much of the desired product is made from the reactants and how much is wasted; it can inform decisions about the sustainability of different methods/percentage yield gives no information about the quantity of wasted atoms.
  c 1 $\frac{48}{128} \times 100 = 38\%$
   2 $\frac{48}{80} \times 100 = 60\%$
  d It would increase the atom economy of method (2) to 100%; making method (2) even more favourable.

2 a $CaCO_3$ = 100; CaO = 56
  b 56%
  c 7g
  d $\frac{6.5}{7} \times 100 = 92.9\%$

Chemical changes

Metal oxides and the reactivity series

1 a Magnesium + oxygen → magnesium oxide
  b $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$ (correct; balanced)
  c Oxygen is gained/electrons are lost.

2 a Aluminium + lead chloride → aluminium chloride + lead
  b Silver + copper oxide → no reaction
  c Calcium + zinc nitrate → calcium nitrate + zinc
  d Iron chloride + copper → no reaction

3 a 1-Sodium, 2-X, 3-Magnesium, 4-Copper.
  b Copper

Extraction of metals and reduction

1 Carbon is less reactive than magnesium.

2 It's unreactive/doesn't easily form compounds.

3 a Copper oxide + carbon → carbon oxide/dioxide + copper (reactants; products)
  b Carbon

4 a Reduction/redox

b $2Fe_2O_3$(s) + 3C(s) → 4Fe(l) + $3CO_2$(g) (reactants; products)

c Iron is a liquid.

d Carbon is more reactive than iron.

e Any metal above iron in the reactivity series; Too expensive/metals above carbon extracted by electrolysis so require more energy.

The reactions of acids

1 Both neutralise acid; Bases are insoluble/alkalis are soluble bases/alkalis form hydroxide/OH^- ions ins solution.

2 **a** Sodium chloride – sodium hydroxide and hydrochloric acid.

b Potassium nitrate – potassium carbonate and nitric acid.

c Copper sulfate – copper oxide and sulfuric acid.

3 **a** Solid dissolves/colourless solution forms.

b Fizzing occurs with magnesium carbonate.

c Magnesium oxide + hydrochloric acid → magnesium chloride + water

d $MgCO_3$

4 **a** Mg(s) + 2HCl(aq) → $MgCl_2$(aq) + H_2(g)

b Li_2O(s) + H_2SO_4(aq) → Li_2SO_4(aq) + H_2O(l)

c CuO(s) + 2HCl(aq) → $CuCl_2$(aq) + H_2O(l)

5 **a** Ca(s) + $2H^+$(aq) → Ca^{2+}(aq) + H_2(g) (reactants; products; state symbols)

b Ca oxidised; H^+/hydrogen reduced.

The preparation of soluble salts

1 **a** Copper carbonate + sulfuric acid → copper sulfate + water + carbon dioxide

b Any two from: Copper carbonate dissolves; Fizzing/bubbles/effervescence; Blue/green solution forms.

c To ensure all the acid reacts.

d Filtration

e Copper oxide/copper hydroxide.

f Any one from: Salt lost from spitting during evaporation; Solution left in container; Not all the solution crystallises.

2 **a** Ca(s) + $2HNO_3$(aq) → $Ca(NO_3)_2$(aq) + H_2(g) (reactants; products; state symbols)

b % yield = 2.6/3.0 x 100; 86.7%

3 **Possible steps to include:** Reactants (zinc/zinc hydroxide/zinc oxide/zinc carbonate) and hydrochloric acid; Correct equation for chosen reactants; Heat acid; Add base until no more reacts/dissolves so the base is in excess; Filter unreacted base; Heat solution on a steam bath until half the water has evaporated; Leave remaining solution to cool so crystals form.

Equipment list: Bunsen burner; Heatproof mat; Tripod; Gauze; Beaker; Evaporating dish; Funnel; Filter paper; Conical flask; Spatula; Measuring cylinder; Safety glasses.

Oxidation and reduction in terms of electrons

1 **a** Mg(s) + Cu^{2+}(aq) → Mg^{2+}(aq) + Cu(s)

b Mg is oxidised and Cu is reduced.

2 **a** Mg(s) + Zn^{2+}(aq) → Mg^{2+}(aq) + Zn(s); Mg oxidised, Zn reduced.

b 2Na(s) + Zn^{2+}(aq) → $2Na^+$(aq) + Zn(s); Na oxidised, Zn reduced.

c Cu(s) + $2Ag^+$(aq) → Cu^{2+}(aq) + 2Ag(s); Cu oxidised, Zn reduced.

d 3Ca(s) + $2Fe^{3+}$(aq) → $3Ca^{2+}$(aq) + 2Fe(s); Ca oxidised, Fe reduced.

pH scale and neutralisation

1 Strong acid — pH 2 — Red, Weak acid — pH 5 — Yellow, Strong alkali — pH 13 — Purple, Weak alkali - pH 9 — Blue, Neutral — pH 7 — Green.

2 Hydroxide ion

3 H^+

4 pH 1

5 pH 12

6 **a** Potassium hydroxide.

b 2KOH + H_2SO_4 → K_2SO_4 + $2H_2O$

c H^+ + OH^- → H_2O ***or*** $2H^+$ + $2OH^-$ → $2H_2O$

7 OH^- and NH_4^+

Strong and weak acids

1 **a** HNO_3(aq) → H^+(aq) + NO_3^-(aq)

b HCOOH(aq) → H^+(aq) + COO^-(aq)

c H_2SO_4(aq) → $2H^+$ (aq) + SO_4^{2-}(aq) ***or*** H_2SO_4(aq) → H^+ (aq) + HSO_4^-(aq)

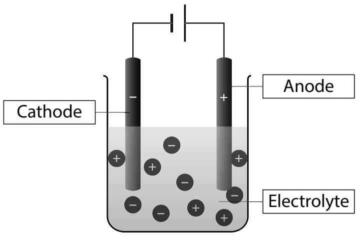
2 Weak acid only partially ionises in solution; Dilute acid has fewer moles of solute dissolved.

3 **a** 1×10^{-3}

b Answer is 100 times greater as if pH decreases by 1, H^+ concentration increases by 10; 0.1 (overrides previous mark); 1×10^{-1}

Electrolysis

1



2 Ions are free to move when molten/aqueous; Ions in fixed positions/ions can't move in solid lattice.

3 **a** Zinc and chlorine.

b Silver and iodine.

c Copper and oxygen.

4 **a** Pb^{2+} + $\mathbf{2e^-}$ → Pb ; $2Br^-$ → Br_2 + $\mathbf{2e^-}$

b Lead/lead ions reduced and bromine/bromide ions oxidised.

The electrolysis of aqueous solutions

1 **a** Copper chloride – copper and chlorine.

b Potassium bromide – hydrogen and bromine.

c Zinc sulfate – zinc and oxygen.

d Sodium carbonate – hydrogen and oxygen.

2 **a** $\mathbf{2}H^+$ + $\mathbf{2e^-}$ → H_2

b Chlorine; $2Cl^-$ → Cl_2 + $2e^-$ (correct; balanced)

3 **a** H^+/hydrogen; Li^+/lithium; OH^-/hydroxide.

b I^-/iodide ions attracted to anode/positive electrode; Lose electron/an electron; Form iodine; $2I^-$ → I_2 + $2e^-$.

c Lithium hydroxide/LiOH.

4 **a** Anode

b $4OH^-$ → O_2 + $2H_2O$ + $4e^-$; OH^- and H_2O (correct; balanced)

The extraction of metals using electrolysis

1 **a** Strong ionic bonds/strong electrostatic attraction between oppositely charged ions; Requires lots of energy to overcome.

b So the ions are free to move.

c Reduce the operating temperature; Saves energy/reduces energy costs.

d Electrons are lost.

e Al^{3+} + $3e^-$ → Al (correct; balanced electrons)

f They react with the oxygen produced; Carbon + oxygen → carbon dioxide/C + O_2 → CO_2

g Electricity wasn't discovered/electricity not needed to extract iron.

Practical investigation into the electrolysis of aqueous solutions

1 **a** Independent – Metal/metal ion in salt; Dependent variable – Product formed at cathode; Control variables – Volume of solution, Concentration of solution, Negative ion in salt, Voltages.

b Only 1 variable is changed.

2 Place a lighted splint into the gas; Positive test – burns with a squeaky pop.

3 **a** $CuCl_2$ – Copper; all others – Hydrogen.

b Solutions containing metals above hydrogen in the reactivity series produce hydrogen on electrolysis; Solutions containing metals below hydrogen in the reactivity series produce the metal on electrolysis.

4 Chlorine; Bleaches blue litmus paper **or** bleaches UI in solution.

Titrations

1 a Titre 1: 14.90 cm^3 ; Titre 2: 15.35 cm^3; Titre 3: 14.80 cm^3 (3 correct 2 marks, 2 correct 1 mark. Must be to 2 decimal places.)

b 14.85 (2 marks as outlier ignored); 15.02 (1 mark if outlier included)

c Until consistent results/two titres within 0.10 cm^3

2

Volume NaOH (cm^3)	Concentration NaOH (mol/dm^3)	Volume HCl (cm^3)	Concentration HCl (mol/dm^3)
25.00	0.1	25.00	0.1
25.00	0.1	50.00	**0.05**
12.50	0.2	**25.00**	0.1
20.00	0.5	10.00	**1.0**

3 **Possible steps to include:** Use of pipette to measure out alkali; Place this solution into a conical flask; Add an indicator; Place conical flask onto a white tile; Fill burette with acid; Carry out rough titration; Add acid to alkali until there is a colour change; Record readings to nearest 0.05cm$^{3;}$ Repeat, slowing down addition of acid when close to rough titration reading; Continue until consistent results obtained/two results within 0.10 cm^3 of each other.

Equipment: Conical flask; Pipette (and filler); Burette; White tile; Indicator.

4 a Moles NaOH = conc × vol = 0.1 × 0.025 = 0.0025; moles HNO_3 = 0.0025; Conc HNO_3 = moles/vol = 0.0025/0.0216 = 0.116 mol/dm^3

b Formula mass HNO_3 = 63; Conc HNO_3 = 63 x 0.116 = 7.29 g/dm^3

5 a $2KOH + H_2SO_4 \rightarrow K_2SO_4 + 2H_2O$

b i Moles KOH = conc x vol = 0.2 x 0.025 = 0.005; moles H_2SO_4 = 0.005 x 2 = 0.0025; Conc H_2SO_4 = moles/vol = 0.0025/0.0145 = 0.172 mol/dm^3

ii Formula mass H_2SO_4 = 98; Conc HNO_3 = 98 × 0.172 = s16.9 g/dm^3

(Allow error carried forward from an incorrect calculation.)

Energy changes

Exothermic and endothermic reactions

1 a Endothermic – surrounding temperatures decrease as heat energy is needed by the reaction.

b Exothermic – surrounding temperatures increase as heat energy is released by the reaction.

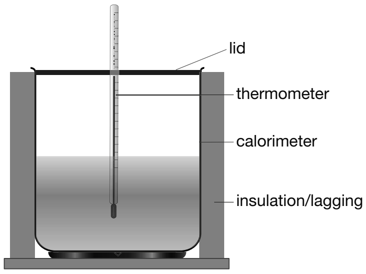
2 a 15.4°C − 23.7°C = −8.3. The reaction is endothermic as the temperature decrease.

b i 37°C − 25°C = +12

ii Exothermic

Practical investigation into the variables that affect temperature changes in chemical reactions

1 a



b To reduce heat loss; to give a more accurate result.

c Two from: The reaction of iron and oxygen is exothermic; The temperature increase is greatest with iron filings; Iron filings are more reactive.

d To make it a fair test; oxygen may be controlling the rate of reaction.

2 **Possible steps to include:** Use an insulated calorimeter; to reduce heat loss; use a thermometer to record temperature; use same equipment throughout; use hydrochloric acid at different concentrations; use same volume of hydrochloric acid; same volume of calcium carbonate; same particle size of calcium carbonate; to ensure a fair test; temperature increase will increase with concentration; because the rate of reaction will increase; record data on a table –

	Concen-tration 1	Concen-tration 2	Concen-tration 3
Initial temperature / °C			
Final temperature / °C			

Reaction profiles

1 A **reaction profile** shows how the energy changes from reactants to products

In a reaction profile for an **exothermic** reaction the products are lower in energy than the reactants because **energy** is released to the surroundings during the reaction.

In a reaction profile for an **endothermic** reaction the **products** are higher in energy than the **reactants** because energy is taken in from the **surroundings** during the reaction.

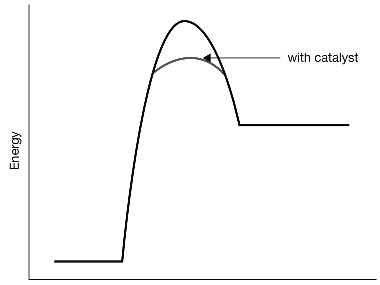
Chemical reactions occur when reacting particles collide with enough energy to react. This energy is called the **activated energy** (Ea).

2 a Products are higher in energy that reactants; the student is incorrect; the reaction is endothermic.

b i A Activation energy.

ii B Energy absorbed from surroundings.

c Catalyst reduces the activation energy:



The energy changes of reactions

H 1 a H–H = 436 kJ

Cl-Cl = 243

Sum (bond breaking): 436+243 = 679 kJ

b 2 × 432 = 864 kJ

c Exothermic

d 679 − 864 = −185

H 2 a 2x (H-Br) ⟶ H-H + Br-Br

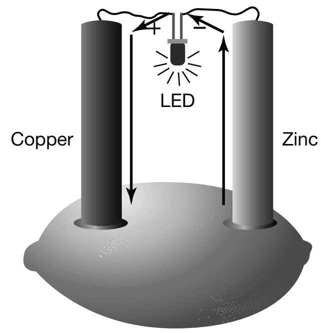
b Reactants = 366 × 2 = -732 kJ (breaking).
Products = 432 + 193 = + 625 (making).
625–732 = –107kJ = Endothermic.

Chemical cells and fuel cells

1 a Zinc

b Lemon juice/citric acid

c



2 9/1.5 = 6 cells

3 a Electrolysis

b

Chemical cells	Fuel Cells
Can be used anywhere.	Hampered by the need for hydrogen containers.
When non-rechargeable batteries run out, they have to be thrown away and sent to recycling centre.	These will continue to work as long as the hydrogen flows.
Re-chargeable batteries can be charged again and again.	The product of the reaction is water.
Some of the metals used are toxic.	The hydrogen is flammable.

H c At the negative electrode of the fuel cell hydrogen reacts with hydroxide ions to produce water and electrons.

$2H_2(g) + 4OH^-(aq) \longrightarrow 4H_2O(l) + 4e^-$

At the positive electrode oxygen gains electrons and reacts with water to produce hydroxide ions.

$O_2(g) + 2H_2O(l) + 4e^- \longrightarrow 4OH^-(aq)$

Rates of reaction and equilibrium

Ways to follow a chemical reaction

1 a Size of marble chips.

b Time

c Volume of carbon dioxide given off (if collected); OR change in mass (if carbon dioxide allowed to escape); OR time for marble chips to disappear (if excess hydrochloric acid).

d Two from: Mass of marble chips; volume of acid; Concentration of acid; Amount of stirring; Temperature.

2 a Production of sulfur, S, which makes the solution opaque.

b Concentration of sodium thiosulfate.

c Two from: Volume of sodium thiosulfate; Volume of acid; Concentration of acid; Amount of stirring; Temperature; Same person doing the timing.

d Could use a light meter and a lamp; to reduce uncertainty about whether the x is visible or not.

3 **Possible steps to include:** Measure a fixed volume of (e.g. 50 cm^3) of hydrochloric acid; using one of the measuring cylinders and pour it into the conical flask; Put a bung in the conical flask with a delivery tube which goes into an upturned measuring cylinder which is full of water and in a water trough; this allows me to measure the amount of hydrogen gas given off; Cut the magnesium into pieces the same size; put one piece into the conical flask; start the timer; record the amount of hydrogen gas at regular intervals on a table; Repeat for different concentrations of hydrochloric acid.

Calculating the rate of reaction

1 Rate of reaction = Amount of product formed/Time taken

2 a The rate of reaction is constant

b The rate of reaction is constant

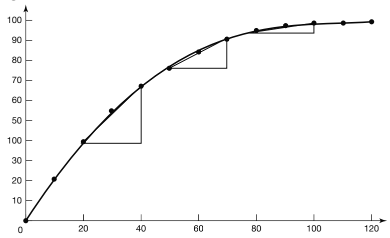
c The rate of reaction decreases with time

d The rate of reaction increases with time

3 a $Mg + 2HCl \rightarrow MgCl_2 + H_2$

b 99/120 = 0.825 cm^3/second

c



d see above.

H e 30s = 1.8 cm^3/s (Allow +/– 0.2)

60s = 0.75 cm^3/s (Allow +/– 0.2)

90s = 0.15 cm^3/s (Allow +/– 0.2)

H f 30s – from graph: 1.8 cm^3/s; 110/24 = 0.75 moles/s

60s – from graph: 0.75 cm^3/s; 168/24 = 0.03125 moles/s

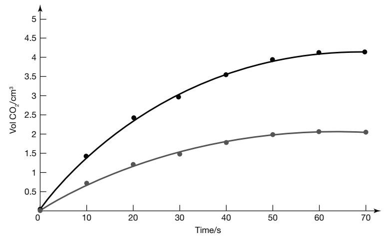
The effect of concentration and on reaction rate and the effect of pressure on the rate of gaseous reactions

1 For a reaction to happen, particles must **collide** with sufficient **energy**. The minimum amount of **energy** that particles must have for a specific reaction is known as the **activation energy**. The rate of a reaction can be increased by increasing the **energy** of collisions and increasing the **frequency** of collisions.

2 There are more particles; The frequency of successful collisions increases.

3 a C b A

4 a



b Rate of reaction starts off fast; slows down as the reaction progresses.

c One (or more) of the reactants has been used up.

d see above (light grey line)

e There are half as many hydrochloric acid particles; reducing the frequency of successful collisions; reducing the rate of reaction.

Rates of reaction – the effect of surface area

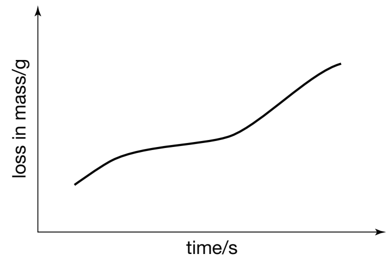
1 a B b B

c More particles exposed to the other reactant; increasing the frequency of collisions.

d Sugar is used to make marshmallows; sugar has a larger surface area; the rate of reaction with oxygen under heat would be much higher.

2 a Cut tablets; grind into powder using a pestle and mortar.

b see graph



c Collect carbon dioxide bubbles in upturned measuring cylinder; allow carbon dioxide to escape and measure mass change.

The effects of changing the temperature and adding a catalyst

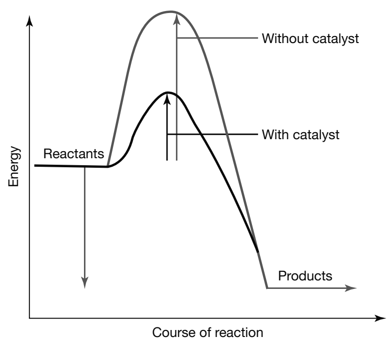
1 a The particles have more energy so they collide more frequently; and with more energy

b 10°C increase ~doubles rate. So at 30°C= 20 s. 40°C = 10 s.

2 a It is a catalyst.

b It provides an alternative route for the reaction; reducing the activation energy.

c



3 a Collect oxygen given off in an upturned measuring cylinder.

b **Possible steps to include:** Put hydrogen peroxide in a test tube; Use the same volume and concentration for both tests; Put a bung at the top of the test tube with a delivery tube to an upturned measuring cylinder; Add a quantity of liver to the hydrogen peroxide; Record the volume of oxygen produced at intervals; Repeat with the same mass of manganese oxide.

An investigation into how changing the concentration affects the rate of reaction

1 a $2HCl(aq) + Na_2S_2O_3(aq) \rightarrow 2NaCl(aq) + SO_2(g) + S(s) + H_2O(l)$

b As the concentration increases, the rate of reaction will increase.

c The hypothesis will be confirmed/ as the concentration increases the rate of reaction will increase; there will be more particles; more frequent collisions.

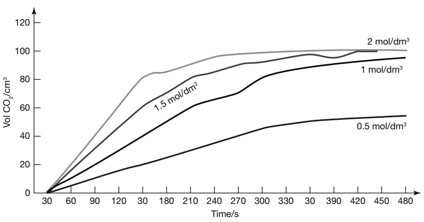
d **Possible steps to include:** Measure out the same volume of different concentrations of sodium thiosulfate /hydrochloric acid into conical flasks; Measure out a volume of hydrochloric acid/sodium thiosulfate; Using the same volume and concentration throughout; To ensure a fair test; Mark a cross on a sheet of white paper; Put conical flask on cross; Mix reactants; Record the time it takes for the cross to disappear; Repeat for other concentrations.

e Temperature would increase the frequency and energy of collisions; increasing the rate of reaction.

f Cross to disappear – easy and convenient/requires no special equipment; but can be subjective (it is down to an individual's opinion).

Lamp and light sensor – more accurate; because it is not dependent on an individual's opinion; requires additional equipment.

2 a



b $0.5 mol/dm^3 = 0.113 cm^3/s$

$1 mol/dm^3 = 0.198 cm^3/s$

$1.5 mol/dm^3 = 0.222 cm^3/s$

$2 mol/dm^3 = 0.256 cm^3/s$

Reversible reactions

1 a $\rightleftharpoons$

b Reversible reactions can go both forwards and backwards in certain conditions.

c A dynamic equilibrium is when the rate of the forward reaction is equal to the rate of the backward reaction; the concentration of the reactants and products remains constant.

2 a A reversible reaction is one which can go both ways. This means that as well as reactants forming products, the products can also react to give the reactants.

b Exothermic; the forward reaction requires heat so is endothermic; the backwards reaction is always the opposite of the forwards reaction.

c The reversible reaction has reached dynamic equilibrium; both reactions are occurring at the same rate; there is no net change in the volume of carbon dioxide.

The effect of changing conditions on equilibrium

H 1 At dynamic equilibrium, the rate of the forward reaction is the same as the backward reaction.

H 2 Temperature; pressure; concentration.

H 3 If a chemical system is at equilibrium and one or more of the three conditions is changed; then the position of equilibrium will shift so as to cancel out the change; and we get either more reactants or more products.

H 4 a The reaction would shift to the left; because the forward reaction is exothermic as it gives out heat; producing more nitrogen and hydrogen gas.

b The forward reaction needs enough energy to overcome the activation energy or the rate of reaction will be too slow.

c It provides an alternative route for the reaction – reducing the activation energy; and increasing the rate of reaction; meaning the reaction can be run at the lowest possible temperature which reduces the backward reaction (a compromise temperature).

d There are fewer moles of gas in the products; increasing pressure therefore increases the forwards reaction.

Organic chemistry

Alkanes

1 a They are molecules that contain ***only*** hydrogen and carbon.

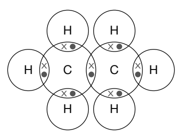
b They only contain C-C single bonds.

c Any two from: They have similar chemical properties; They have the same general formula; Each member differs by CH_2; Same trend in physical properties.

2 a $C_{20}H_{42}$

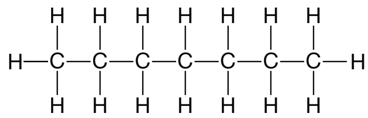
b C_8H_{18}

3



(Correct C-H bonds; Correct C-C bond)

4 a



b C_7H_{16}

5 CH_4

6 Pentane

7 C_4H_{10}

Fractional distillation

1 Any 4 from: Crude oil heated; Crude oil evaporates; Vapour rises up fractionating column; Fractions with lower boiling points rise further up column/Temperature gradient in column (hotter at the bottom, cooler at the top); When vapour cools to boiling point of fractions molecules condense into a liquid; Statement relating to bigger molecules having higher boiling points.

2 a Fuel for aeroplanes

b $C_{12}H_{26}$

c Bigger molecules so greater intermolecular forces; More energy is needed to overcome these forces.

3 a $C_2H_6 + 3½\ O_2 \rightarrow 2CO_2 + 3H_2O$

b $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

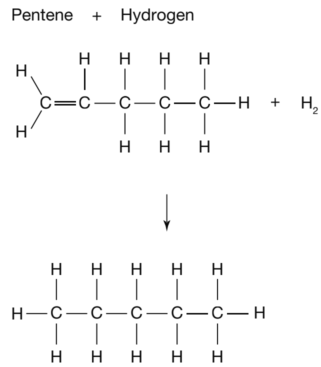
c $C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$

(correct; balanced)

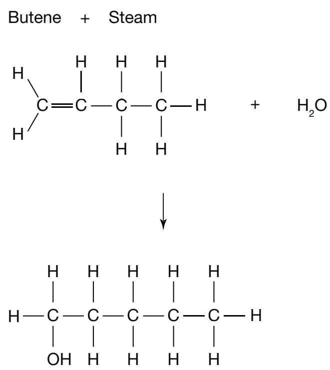
Cracking and alkenes

1 Contain a C=C bond; Molecules made of only carbon and hydrogen.

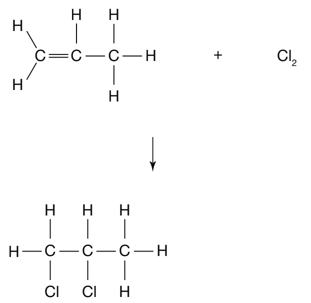
2 a i



ii



iii Propene + Chlorine



b Only one product/no waste products.

3 a $C_8H_{18} \rightarrow C_5H_{12}$ + $\mathbf{C_3H_6}$
 b $C_{18}H_{38} \rightarrow C_3H_6$ + $\mathbf{C_{15}H_{32}}$
 c $\mathbf{C_{13}H_{28}} \rightarrow C_4H_8 + C_9H_{20}$
 d $C_{14}H_{30} \rightarrow C_4H_{10} + C_6H_{12}$ + $\mathbf{C_4H_8}$
 e $C_{14}H_{30} \rightarrow C_8H_{18}$ + $\mathbf{2C_3H_6}$

4 a $C_{10}H_{22}$ **b** Fuel/petrol
 c It's an alkene.
 d Polymers
 e $C_{10}H_{22} \rightarrow C_6H_{14} + C_4H_8$

Alcohols

1 a B **b** D **c** A **d** C **e** B

2 a Methanol + oxygen → carbon dioxide + water; $CH_3OH + 3/2O_2 \rightarrow CO_2 + 2H_2O$
 b Propanol + oxygen → carbon dioxide + water; $CH_3CH_2CH_2OH + 9/2O_2 \rightarrow 3CO_2 + 4H_2O$
 (multiples allowed)

3 a Fizzing; sodium dissolves/disappears.
 b Dissolves/forms a colourless solution/miscible.
 c Acidified potassium dichromate turns green.

Carboxylic acids

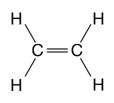
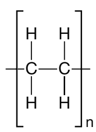
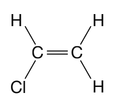
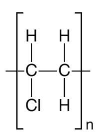
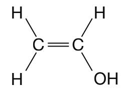
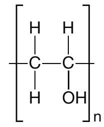
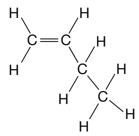
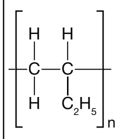
1 a E **b** A **c** C
 d B **e** D **f** C

2 a $C_8H_{16}O_2$
 b $C_3H_6O_2$; Propanoic acid.

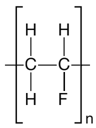
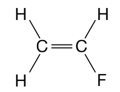
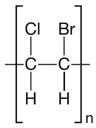
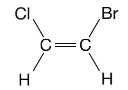
3 HCl is a strong acid; CH_3COOH is a weak acid; HCl fully ionises; CH_3COOH only partially ionises; $HCl \rightarrow H^+ + Cl^-$ or $CH_3COOH \rightleftharpoons CH_3COO^- + H^+$

Addition polymerisation

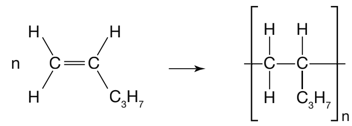
1

Monomer	Repeating unit	Name of polymer
 Ethene		**Polyethene**
 Chloroethene		**Polychloroethene**
 Ethenol		**Polyethenol**
 Butene		**Polybutene**

2

Repeating unit	Monomer
	
	

3 a



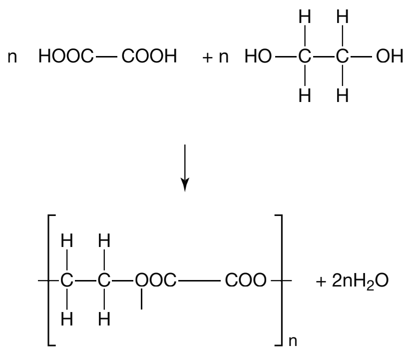
(Correct repeating unit; 'n' on both sides.)

b Polypentene

Condensation polymerisation

H 1 a A and D **b** C
 c Alcohol **d** Carboxylic acid

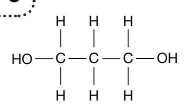
H 2 a

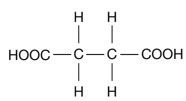


(reactants; repeating unit; all 'n' in correct places)

b Water/waste product is formed.

H 3





Amino acids and DNA

1 Two amino acids can join together by **condensation** polymerisation to form polypeptides and **proteins**. Each amino acid contains two functional groups, a **carboxylic** acid group which has the formula –COOH and an amine group, which has the formula $-NH_2$. The –COOH on one amino acid reacts with the $-NH_2$ group on another amino acid forming a polymer, with the elimination of **water**.

2 a n $H_2NCH(CH_3)COOH \rightarrow (-HNCH(CH_3)COO-)_n + nH_2O$
 (products; reactants)
 b $n\ H_2NCH_2COOH + n\ H_2NCH(CH_3)COOH \rightarrow (-HNCH_2CONHCH(CH_3)COO-)n + 2nH_2O$
 (reactants; 'n'; correct product with peptide link)

3 Nucleotides

4 Sugars

Chemical analysis

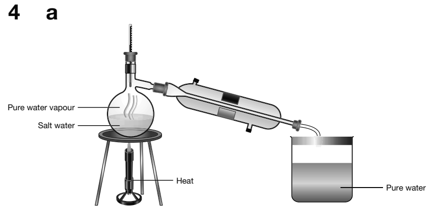
Pure substances and formulations

1 Pure substances are either single elements or single compounds.

2 a Although milk doesn't contain additives; it is a mixture of compounds.
 b You could heat the mixture and using a thermometer; observe a range of boiling points; pure substances have a specific boiling/melting point. (No mark for 'separate the mixture'.)

3 It is not pure – it contains other elements or compounds.

4 a



b The salt water is heated; water boils at 100°C; the water vapour rises up the round-bottomed flask and enters a condenser where it cools and turns into a liquid; the salt is left behind as it boils at a higher temperature.

5 a A formulation is a mixture that is designed to be an improvement on the activate substance on its own – the lubricant stops the paracetamol sticking/makes it easier to swallow.
 b 0.5g + 0.25g + 1.25g = 2g
 0.5g/2g = 0.25 × 100 = 25%

H c i Paracetamol = 151 → 0.5/151
 = 0.003 moles or 3×10^{-3} moles
 ii Starch = 162 → 1.25/162
 = 0.008 moles or 8×10^{-3} moles
 iii Magnesium stearate = 591 → 0.25/591 = 0.0004 moles or 4×10^{-4} moles

 d 0.003 + 0.008 + 0.004 = 0.0114.
 0.003/0.0114 × 100 = 26.3%

Chromatography

1 Chromatography is a technique that can be used to separate mixtures into their components; Chromatography works because different compounds have different levels of attraction for the paper and the solvent.

2 a Water line is above the base line; which will cause the inks to disperse in the water rather than up the paper; The base line is drawn in ink; which may contain colours that could contaminate the chromatogram/which could interfere with the experiment.

b R_f = distance travelled/solvent front = 22/25 = 0.88. C is yellow.

Testing for gases

1 Hydrogen – a lighted splint put into a test tube of the gas – is extinguished with a 'pop';
Oxygen – a glowing splint put into a test tube of the gas – Relights;
Carbon dioxide – bubble the gas through a solution of limewater – produces solid calcium carbonate, turning the limewater cloudy.

2 a The gas turns limewater turns cloudy **Carbon dioxide**

b The gas bleaches litmus paper **Chlorine**

c The gas extinguishes a lighted splint with a pop **Hydrogen**

d The gas relights a glowing splint **Oxygen**

3 a $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ Bubble through limewater – would turn cloudy.

b $Mg + H_2SO_4 \rightarrow MgSO_4 + H_2$ A lighted splint put into the gas – extinguishes with a pop.

c $CO_2 + H_2O \rightarrow C_6H_{12}O_6 + O_2$ A glowing splint put into the gas – will reignite.

d $HCl + MnO_2 \rightarrow MnCl_2 + 2H_2O + Cl_2$ Litmus paper when exposed to the gas – will bleach.

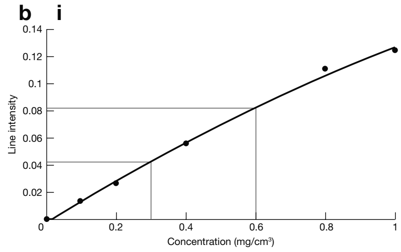
4 Carbon dioxide gas produced so the limewater will turn cloudy; because it is a combustion reaction involving a fuel and oxygen.
Description of different tests for each gas: hydrogen – lit splint in flame/ oxygen – glowing splint will reignite/ chlorine – bleaches litmus paper; these tests will be negative.

Identifying metal ions using flame tests, flame emission spectroscopy and sodium hydroxide

1 Lithium carbonate – Crimson; Sodium chloride – Yellow; Potassium sulfate – Lilac; Calcium nitrate – Orange-red; Copper phosphate – Green.

2 a Lithium; Sodium.

b i



ii 0.3 moles/cm³ (accept within 2 d.p.)

iii Line intensity 0.0.82 (accept within 2 d.p.)

Testing for negative ions (anions) in salts

1

Chloride (Cl^-)
Nitric acid followed by silver nitrate solution
White precipitate (of silver chloride);

Bromide (Br^-)
Nitric acid followed by silver nitrate solution
Cream precipitate (of silver bromide);

Iodide (I^-)
Nitric acid followed by silver nitrate solution
Yellow precipitate (of silver iodide);

Sulfate (SO_4^{2-})
Hydrochloric acid followed by barium chloride solution
White precipitate (of barium sulfate);

Carbonate (CO_3^{2-})
Hydrochloric acid then pass gas formed through limewater
Effervescence and gas turns limewater cloudy/milky.

2 a Carbonate was present; chloride was present from the sodium chloride.

b Hydrochloric acid contains chloride ions; this would give a positive reading to test; regardless of the contents of the salt.

c Silver chloride.

H d $2H^+(aq) + CO_3^{2-}(s) \rightarrow CO_2(g) + H_2O(l)$

Identifying ions in an ionic compound

1 a Flame test – calcium gives red flame, lithium gives crimson; OR add sodium hydroxide, if white precipitate forms it is calcium.

b Nitric acid followed by silver nitrate solution; chloride gives white precipitate, bromide gives cream.

2 Positive ion: Flame test – yellow flame if sodium present; Negative ion: Hydrochloric acid followed by barium chloride solution; White precipitate if sulfate present.

3 A – Potassium carbonate; B – Lithium sulfate; C – Aluminium bromide; D – Iron(III) iodide.

4 Hydrochloric acid + calcium carbonate → calcium chloride + carbon dioxide + water; Flame test – brick red; Nitric acid followed by silver nitrate solution; gives white precipitate.

Chemistry of the atmosphere

The composition and evolution of the Earth's atmosphere

1 a Carbonate rock formation; Fossil fuel formation.

b Condensation/formation of oceans OR used in photosynthesis by plants.

c It reduced; carbon dioxide dissolved in the oceans.

d $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$ (correct; balanced)

2 a $2Cu + O_2 \rightarrow 2CuO$

b 21.5%

c To make sure no other variables were affecting the results; to reduce error.

Global warming

1 a Climate is complex **or** models are simplifications.

b Results of experiments are checked by other scientists.

c Carbon dioxide; methane; water vapour.

d Any four from: Carbon dioxide – burning fossil fuels in our homes/ industry/cars; deforestation;

Methane – cattle farming; rice crops; landfill;

Water – small increases from farming and burning fossil fuels, most is due to natural evaporation; higher global temperatures increases the rate of evaporation.

2 a Temperature increases at the same time as CO_2 increases; There is a big increase in temperatures more recently.

b The graph shows a correlation between CO_2 and temperature; it is known that human activity has increase atmospheric CO_2; it is known that CO_2 is a greenhouse gas; recent temperatures are much higher than in the past.

The carbon footprint and its reduction

1 Alternative energy – Renewable energy sources such as solar cells, wind power and wave power do not rely on the burning of fossil fuels;

Energy conservation – Reducing the amount of energy used by using energy-saving measures such as house insulation, using devices that use less energy, reduces the demand for energy;

Carbon Capture and Storage (CCS) – Removing the carbon dioxide given out by power stations by reacting it with other chemicals. The product of this reaction can then be stored deep under the sea in porous sedimentary rocks;

Carbon taxes – Penalising companies and individuals who use too much energy by increasing their taxes reduces the demand for energy;

Carbon offsetting – Removing carbon dioxide from the air using natural biological processes such as photosynthesis. This is achieved by planting trees and increasing marine algae by adding chemicals to the oceans.;

Using plants as biofuels – Plants take in carbon dioxide as they grow, when they are burned they only release the same amount of carbon dioxide. This makes them carbon neutral.

2 a Any two from: High use of cars/preference for large cars; developed countries use more energy; high level of industrialisation in USA and Qatar; China and India and developing countries.

b It has **reduced** from 10 tonnes per person to 7.1 tonnes per person.

c Increase in population; increase in industry; increased development has resulted in greater energy use.

Atmospheric pollutants

1

Soot	Global dimming and lung damage	Ensure complete combustion of fossil fuels
Carbon monoxide	A toxic gas which binds to haemoglobin in the blood, preventing the transport of oxygen around the body	Ensure complete combustion of fossil fuels
Sulfur dioxide	Dissolves in clouds to cause acid rain and causes respiratory problems	Desulfurisation of petrochemicals before combustion
Oxides of nitrogen	Dissolves in clouds to cause acid rain and causes respiratory problems	Catalytic converters used after combustion

2 a Petrol emits more carbon dioxide/diesel emits less carbon dioxide; diesel emits four times more sulfur dioxide; diesel emits particulate matter, petrol does not; diesel emits slightly more oxides of nitrogen.

b Any two from: Energy and materials are used in construction and transport of vehicles; energy is required to power the vehicles; this energy comes from electricity; which may be produced by burning fossil fuels.

H 3 a Complete combustion = CH4 + 2O2 → CO2 + 2H2O, therefore:

i $CH_4 + 1\frac{1}{2} O_2 \rightarrow CO + 2H_2O$

ii $CH_4 + O_2 \rightarrow C + 2H_2O$

b When 4 moles of coal are burned, 960 moles of carbon dioxide are produced; therefore, 960/4 = 240 moles of carbon dioxide per mole of coal. 240 × 8 = 1920 moles of carbon dioxide.

c Burning coal produces nitric acid (HNO_3) and sulfuric acid (H_2SO_4); causing acid rain which is corrosive/reacts with limestone.

Using resources

Finite and renewable resources, sustainable development

1 The **natural resources** used by chemists to make new materials can be divided into two categories – **finite** and **renewable**. **Finite** resources will run out. Examples are fossil fuels and various metals. **Renewable** resources are ones that can be replaced at the same rate as they are used up. They are derived from plant materials.

Sustainable development meets the needs of present development without depleting natural resources for future generations.

2 Have reactions with high atom economy with as few waste products as possible; Use renewable resources from plant sources; Have as few steps as possible to eliminate waste and increase the yield; Use catalysts to save energy.

3 They reduce the activation energy required for reactions; reducing the use of heat which typically comes from fossil fuels.

4 a Company A = 22/25 × 100 = 88%; Company B = 17.5/19 × 100 = 92%.

b Company B has a higher percentage yield so is more sustainable.

Life cycle assessments (LCAs)

1 A life cycle assessment is an assessment of the environmental impact of the manufacture and use of different materials and products.

2 Resources used, production, use and disposal.

3 a

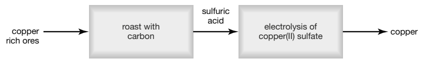
Stage of LCA	Plastic bag	Paper bag
Source of raw materials	**From ethene, which is produced during cracking of petrochemicals**	Come from trees
Production	Simple process involving no chemical change	**Consumes water and produces acidic gases and greenhouse gases**
Use	Reusable	**Damaged by water and more difficult to reuse**
End of life	Decompose slowly but produce less **solid waste**	Decompose quickly but generate more **solid waste**

b Any two from: Paper bags come from a renewable source whereas plastic comes from a finite resource; Plastic bags are reusable but decompose slowly at the end of their life whereas paper bags can't be reused easily but decompose quickly at the end of their life; Paper bags produce more pollution and consume more water.

4 The supermarket has conducted a selective/shortened/abbreviated LCA, ignoring negative points, e.g. slow decomposition/source materials are finite.

Alternative methods of copper extraction

H 1 a



b It is not pure copper.

H 2 Smelting and electrolysis use a lot of energy; Copper-rich ores are scarce.

H 3 a Bioleaching using bacteria; Phytomining using plants; Displacement using iron.

b i Bioleaching: produces pure copper so needs little further processing; but is slow.

ii Phytomining: environmentally friendly; but is slow/requires further processing.

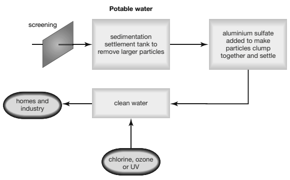
iii Displacement using iron: can use scrap metal; may increase demand for iron.

Making potable water and waste water treatment

1 Water that is safe to drink – harmful chemicals and microbes have been removed.

2 A pure substance is one element or compound; potable water contains other substances like salts and minerals.

3 a

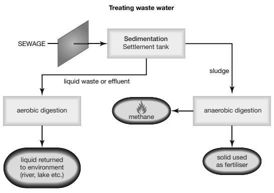


b To sterilise the water.

4 a Reverse osmosis.

b Distillation separates the water from the salt by heating the salt water until the boiling point of water; this requires energy.

5 a



b Removal of harmful chemicals.

Ways of reducing the use of resources

1 a Reduces use of glass bottles; Reduces use of limited raw materials to make other glass products.

b Separation; Reforming; Melting.

2 a It is magnetic.

b Steel is made with iron, carbon and other metals; recycling iron in steel uses the amount of iron needed by extraction from its ore.

c Aluminium extraction uses a lot of energy; which comes from burning fossil fuels – releasing carbon dioxide; recycling aluminium uses less energy.

Rusting

1 Corrosion is the destruction of materials by chemical reactions with substances in the environment.

2 a Test tube 1.

b Rust requires oxygen and water; only test tube 1 is exposed to both oxygen and water; it will rust the most.

c Iron + oxygen + water → hydrated iron(III) oxide

d Test tube 2: No water; Test tube 3: No oxygen; Test tube 4: Paint barrier prevents oxygen or water contacting the iron; Test tube 5: Galvanised with a more reactive metal – stops oxygen or water contacting the iron and, as the metal is more reactive, it will oxidise instead of iron.

e Magnesium or zinc; because it is more reactive; it will react instead of iron.

Alloys as useful materials

1 An alloy is a mixture of metals.

2 a Gold is soft; alloys are harder.

b Gold ions are arranged in layers; Gold ions can slide over each other.

c Copper atoms are a different size to gold atoms; disrupting the layers of gold atoms which makes it more difficult for them to overlap.

3 a Car bodywork needs to be hard but still bendable into shape; more carbon makes it strong.

b Sample A, because it contains more carbon so is hardest.

H c M_r iron = 55.8 – number of moles = 24.80/55.8 = 0.4444 moles.
% = 0.444/0.461 × 100 = 96.1%
M$_r$ carbon = 12 – number of moles = 0.21/12 = 0.0175 moles.
% = 0.0175/0.461 × 100 = 3.9%
(ignore rounding errors)

Ceramics, polymers and composites

1 a

Borosilicate glass	High melting point	Silicon dioxide and boron trioxide
Fibre glass	Strong and light	Strands of glass fibre and plastic resin
Ceramics	Hard, brittle, electrical insulators, waterproof	Metal ions and covalent structures

b Ceramic

c Glass fibres reinforce the material; plastic resin is the supporting matrix.

d A composite.

e Fibre glass is light; and strong.

2 a i LDPE

ii HDPE

iii Thermoplastic

iv Thermosetting plastic

b HDPE and LDPE are both produced from chains of the monomer ethene; HDPE has few branches; meaning intermolecular forces are maximised; LDPE has many branches; therefore HDPE is strong and has a higher melting point.

c Milk bottles are made of thermoplastic so can be melted down to make new products; plastic electrical componenets are made of thermosetting plastic so can't be melted down; thermosetting plastics form strong bonds between strands when they set; thermoplastics have weak intermolecular forces between strands.

The Haber process

1 Ammonia

2 $N_2 + 3H_2 \rightarrow 2NH_3$

3 The reaction is reversible and the forward reaction is exothermic. This means that the backward reaction is endothermic.

4 The conditions used are a temperature of 450°C; a pressure of 200–250 atmospheres; and an iron catalyst.

H 5 As the forward reaction is exothermic, it would be favoured by lowering the temperature; the problem is that a low temperature would make the reaction slow; compromise is arrived 450°C; forward reaction reduces number of moles of gas; increasing pressure favours forward reaction; an iron catalyst is used to speed up the reaction.

H 6 a Few molecules of gas in forward reaction; higher pressure favours fewer molecules of gas.

b Higher temperatures reduce percentage yield of ammonia; but lower temperatures make the reaction too slow.

c i 300 atmospheres and 400°C = 50%

ii 200 atmospheres and 350°C = 54% (accept ± 2 percentage points)

Production and uses of NPK fertilisers

1 Plants need compounds of **Nitrogen (N)**, **Phosphorous (P)** and **Potassium (K)** for the growth and carrying out photosynthesis. **Fertilisers** containing these three elements are called **NPK fertilisers**.

2

Ammonium nitrate, NH_4NO_3	Ammonia from the Haber process is oxidised to form nitric acid which is then reacted with ammonia
Ammonium hydrogen phosphate, $(NH_4)_2HPO_4$	Mined phosphate rock is reacted with nitric acid to form phosphoric acid, H_3PO_4, which is reacted with ammonia.
Potassium chloride, KCl	Obtained by mining

3 Different crops/plants have different nutrient needs; their soil may be lacking in particular nutrients

4

Fertiliser	Acid	Alkali
Ammonium nitrate	**nitric acid**	ammonia
Ammonium phosphate	**phosphoric acid**	ammonia
Ammonium sulfate	**sulfuric acid**	ammonia
Potassium nitrate	**nitric acid**	potassium hydroxide

5 Atomic mass of phosphorous = 31
Molecular mass of ammonium hydrogen phosphate = 132
31/132 x 100 = 23.5%

H 6 Atomic mass of nitrogen (x2) = 28
Molecular mass of ammonium nitrate = 80
28/80 = 35% 0.35x500g = 175 grams
175/28 = 6.25 moles
Or
N_2 and $(NH_4)_2HPO_4$ have 2 atoms of nitrogen; there is a 1:1 ratio; 500/80 = 6.25 moles

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