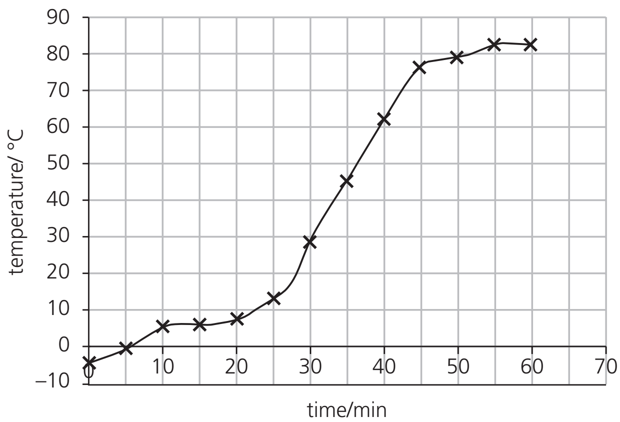
Cambridge IGCSE® Chemistry Practice Book

Answers

1 All about matter

1 (a) **A** condensation, **B** boiling, **C** freezing, **D** melting, **E** sublimation [1 for each]
(b) gas – particles are far apart and move around randomly [1], colliding with each other occasionally [1]
liquid – particles are closer together [1], they move relative to one another [1], colliding more often than in the case of gases [1]
solid – particles are very close together [1] and vibrate about a fixed point [1]
(c) (i) carbon dioxide or iodine [1]
(ii) water [1]

2 (a)



[1 for scale, 1 for axis labels and units, 1 for points plotted correctly, 1 for line]

(b) 5 °C [1]
(c) 82 °C [1]
(d) The particles move around more as they gain kinetic energy. This breaks more of the inter-particle bonds, allowing the particles to move away from each other. [2]

3 In ice, I (the water molecule) am bonded to other water molecules and vibrating in a fixed position [1]. As the temperature rises, there is enough energy for some of the bonds between us to weaken and begin to break during the increase in vibrations [1]. This allows me to move further from my neighbouring molecules and I am able to move past them [1]. As the temperature continues to rise, more of the bonds between us begin to break and I move away from my neighbouring molecules and move much more quickly [1]. At 100 °C I have so little attraction to my neighbouring molecules that I am able to break away [1] and move a long way away from them [1].

4 (a) converting temperatures to 295 K and 299 K [1]
$V = 38 \times 299/295$ [1] = 38.51 cm^3 [1]
(b) converting temperatures to 293 K and 303 K [1]
$V = 75 \times 303/293$ [1] = 77.56 cm^3 [1]
(c) temperatures are 298 K and 350 K [1]
$V = (100 \times 350)/(2 \times 298)$ [1] = 58.72 cm^3 [1]

5 **(a)** **(i)** when a substance changes from a solid to a liquid [1]

(ii) when substances are changed into different substances by chemical reaction [1]

(iii) when a solid changes directly to a gas, or vice versa [1]

(iv) when a gas changes into a liquid [1]

(v) when a liquid changes into a gas [1]

(vi) when a solute disappears into a solvent to form a solution [1]

(b) **(i)** condensation [1]

(ii) melting [1]

(iii) sublimation [1]

(iv) dissolving [1]

6 **(a)** When the plunger is pulled back, the volume increases and the pressure in the syringe drops. To even out the pressure, blood is drawn into the syringe. [2]

(b) As the balloon rises, the pressure outside the balloon decreases relative to that inside the balloon. The gas inside the balloon increases its volume, filling up the balloon more. If the balloon was completely filled at ground level, it would burst well before it reached the required height. [2]

(c) When the de-icer is sprayed from the can, the pressure inside the can decreases a little. Because the volume of the can does not change, the temperature falls; this demonstrates the fact that with a decrease in pressure the temperature falls. [2]

(d) These sea creatures are used to the high pressure of the deep sea. Their bodies are able to withstand the external water pressure. When they are brought to the surface, the pressure inside their bodies is greater than the pressure from the reduced depth of water and than that of the air. Their membranes, bladders and cells burst owing to the large increase in volume they experience. [2]

(e) The hotter temperatures of summer would cause the compounds with low boiling points to vaporise, causing a dangerous build-up of pressure in garage storage tanks and car petrol tanks. More of the fuel would evaporate and the fuel could fail government volatility tests. [2]

7 **(a)** **(i)** Most of the red liquid bromine would be in the lower gas jar with a small amount of red bromine vapour above it [1].

(ii) Bromine vapour would occupy both of the gas jars, with a higher concentration (deeper colour) in the lower jar [1].

(b) As the bromine evaporates the particles move in a random manner, colliding with one another and filling up both of the gas jars [1]. The higher concentration in the lower jar is due to the high density of bromine [1].

(c) diffusion [1]

(d) It would have taken much longer for the diffusion to take place as the bromine molecules would have had less kinetic energy [1] and so would move more slowly [1].

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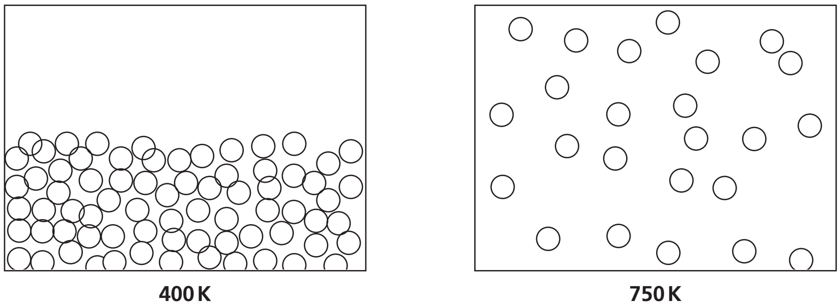


[4]

Stretch and challenge

9 **(a)** ammonia [1]

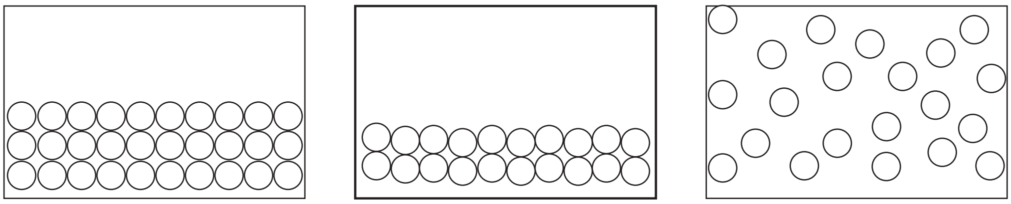
(b) point **B** [1]

Both HCl and NH_3 particles move randomly along the tube, but the ammonia particles are lighter and so will move faster and further along the tube than the HCl particles [1].

(c) randomly [1]

Exam focus

1 (a) (i) solid – cannot be compressed, has a fixed shape, expands on heating [2]
liquid – will flow and take up the shape of the container, can only be compressed a small amount, its volume increases when heated [2]
gas – is easily compressed, will fill the whole volume of its container [2]

(ii)  [3]

solid liquid gas

(b) (i) –39 °C [1]
(ii) oxygen [1]
(iii) phosphorus and iron [1]
(iv) bromine [1]

2 (a) Gas particles from the coffee are moving randomly, from the coffee shop, colliding with other particles in the air until they reach you. They are diffusing. [2]
(b) When the temperature rises, the steel tracks will expand. The gaps allow the tracks to expand without buckling the railway lines. [2]
(c) The particles of tea move randomly and collide with water molecules in the water. They diffuse from the tea bag until eventually all of the water in the cup changes colour as the tea dissolves. [2]
(d) Water vapour inside the house, caused by central heating, hot water and people breathing, condenses onto the glass of the windows, which is colder. [2]
(e) At the bottom of the ocean the bubble has a large amount of pressure all around it due to the depth of water, and has an equal interior pressure caused by methane molecules. As the bubble rises, the external pressure decreases and the relative greater interior pressure of the gas in the bubble causes the volume of the methane bubble to increase. [2]
(f) (i) moving randomly around [1]
(ii) The pollen grains would be moved randomly by water molecules colliding with them. The dust particles would be moved randomly by colliding with molecules and atoms in the air. [2]

2 Elements, compounds and mixtures

1 (a) a substance which cannot be further divided [1] into simpler substances [1] by chemical methods [1]
(b) (i) silver, calcium, lead, mercury, zinc, sodium, magnesium [1 for each]
(ii) carbon, hydrogen, chlorine, oxygen, astatine, bromine, phosphorus [1 for each]
(c) (i) high, good, solids, liquid, malleable, ductile, lustrous [1 for each]
(ii) low, densities, poor, insulators, brittle, gases, dull [1 for each]

2 [1 for each]

Element	Symbol
	Ar
Fluorine	
	Cu
Nickel	
	Si
Potassium	
	He
Tin	
	Kr
Aluminium	

3 **(a)** substances **E** and **I** [1 for each]
(b) substances **G** and **H** [1 for each]
(c) substance **F** [1]
(d) substances **F** and **H** [1 for each]
(e) substance **H** [1]
(f) substance **F** [1]
(g) substance **I** [1]
(h) substances **E**, **G** and **I** [1 for each]
(i) substance **G** [1]
(j) substance **I** [1]

4 **(a)** **(i)** C [1], C is a non-metal [1]
(ii) iron [1], iron is a metal [1]
(iii) Na [1], its symbol is related to the Latin name [1]
(b) **(i)** false [1]
(ii) true [1]
(iii) true [1]
(iv) false [1]
(v) true [1]
(vi) false [1]
(vii) true [1]

5 **(a)** The elements in a compound, e.g. iron sulfide [1], cannot be separated by physical [1] means whilst a mixture of iron filings and sulfur powder can be separated by a magnet [1].
(b) **(i)** carbon monoxide, sulfuric acid, methane, sodium hydroxide, limestone [1 for each]
(ii) stainless steel, lemonade, cement, beer, brass [1 for each]
(c) **(i)** water [1], water is a compound [1]
(ii) chromium [1], chromium is an element [1]
(iii) F_2 [1], F_2 is an element [1]
(d) **(i)**

Example	Type of mixture	Mixture made from
Bread	Foam	Gas in solid
Mayonnaise	Emulsion	Immiscible liquids
Jelly	Gel	Liquid trapped in solid

[1 for each]

(ii) An emulsion is a mixture of immiscible liquids [1] whilst a foam is a substance that is formed by trapping pockets of gas [1] in a liquid or solid [1].

6 **(a)** **(i)** Use safety spectacles [1] to protect eyes [1].
(ii) A new substance is being produced [1].
(iii) zinc sulfide [1]
(iv) zinc + sulfur → zinc sulfide [1]
$Zn(s) + S(s) \rightarrow ZnS(s)$ [1 for reactants, 1 for products]
(v) Zinc and sulfur can be separated by physical means (e.g. using an organic solvent to dissolve the sulfur) [1] whereas the compound zinc sulfide [1] needs chemical means to separate the elements [1].
(vi) three (or more) from – food flavouring, de-icer on roads, in water softening, to make dyes fast, in soap manufacture, in curing of animal hides [3]
(b) **(i)** copper, oxygen [1 for each]
(ii) copper sulfide, copper oxide, sulfur dioxide, carbon dioxide [1 for each]
(iii) copper sulfide + oxygen → copper oxide + sulfur dioxide [1]
$2CuS(s) + 3O_2(g) \rightarrow 2CuO(s) + 2SO_2(g)$ [1 for reactants, 1 for products, 1 for correct balancing]
copper oxide + carbon → copper + carbon dioxide [1]
$2CuO(s) + C(s) \rightarrow 2Cu(s) + CO_2(g)$ [1 for reactants, 1 for products, 1 for correct balancing]

7 **(a)** [1 for each]

Formula of substance	Elements present			Total number of atoms
	Symbol	Name	Number of atoms	
$LiNO_3$	Li	Lithium	1	5
	N	Nitrogen	1	
	O	Oxygen	3	
$CaCO_3$	Ca	Calcium	1	5
	C	Carbon	1	
	O	Oxygen	3	
Mg_3N_2	Mg	Magnesium	3	5
	N	Nitrogen	2	
Ag_2CrO_4	Ag	Silver	2	7
	Cr	Chromium	1	
	O	Oxygen	4	
$AlBr_4Cs$	Al	Aluminium	1	6
	Br	Bromine	4	
	Cs	Caesium	1	
$NH_4CO_2NH_2$	N	Nitrogen	2	11
	H	Hydrogen	6	
	C	Carbon	1	
	O	Oxygen	2	
$NaAuCl_4$	Na	Sodium	1	6
	Au	Gold	1	
	Cl	Chlorine	4	

(b) **(i)** $\underline{2}Pb(s) + O_2(g) \rightarrow \underline{2}PbO(s)$ [2]

(ii) $\underline{2}H_2(g) + O_2(g) \rightarrow \underline{2}H_2O(l)$ [2]

(iii) $C_2H_4(g) + \underline{3}O_2(g) \rightarrow \underline{2}CO_2(g) + \underline{2}H_2O(l)$ [2]

(iv) $\underline{2}Fe(s) + \underline{3}Br_2(l) \rightarrow \underline{2}FeBr_3(s)$ [2]

(v) $CuO(s) + \underline{2}HCl(aq) \rightarrow CuCl_2(aq) + H_2O(l)$ [2]

(vi) $SnO_2(s) + \underline{2}H_2(g) \rightarrow Sn(s) + \underline{2}H_2O(l)$ [2]

(vii) $\underline{3}KOH(aq) + H_3PO_4(aq) \rightarrow K_3PO_4(aq) + \underline{3}H_2O(l)$ [2]

(viii) $ZnO(s) + \underline{2}HCl(aq) \rightarrow ZnCl_2(aq) + H_2O(l)$ [2]

(ix) $\underline{3}CuO(s) + \underline{2}NH_3(g) \rightarrow N_2(g) + \underline{3}Cu(s) + \underline{3}H_2O(l)$ [2]

(x) $\underline{2}Pb(NO_3)_2(s) \rightarrow \underline{2}PbO(s) + \underline{4}NO_2(g) + O_2(g)$ [2]

8 **(a)** **(i)** **1** thermometer, **2** cold water out, **3** cold water in, **4** fractionating column, **5** heat, **6** distillate, **7** mixture of liquids, **8** Liebig condenser [1 for each]

(ii) crude oil [1], the fractions within the mixture have different boiling points [1]
air [1], the gases in the mixture which is air all have different boiling points [1]

(b) **1** chromatography paper, **2** beaker, **3** pencil line, **4** solvent, **5** samples [1 for each]

(c) **(i)** two from – light, low stiffness value (flexible), low cost [2]

(ii) Kevlar [1], strong and stiff [2]

(iii) a material which combines the properties [1] of the substances present in order to get the desired properties [1]

Stretch and challenge

9 **(a)** a reaction which involves the processes of both oxidation [1] and reduction [1]

(b) **(i)** coke (carbon) [1]

(ii) zinc oxide [1]

(iii) zinc oxide [1]

(iv) coke (carbon) [1]

(c) $2ZnO(s) + C(s) \rightarrow 2Zn(s) + CO_2(g)$ [1 for reactants, 1 for products, 1 for correct balancing]

(d) (i) carbon, hydrogen [1 for each]
(ii) lead oxide, tin(IV) oxide [1 for each]
(iii) lead oxide, tin(IV) oxide [1 for each]
(iv) carbon, hydrogen [1 for each]
(v) $2PbO + C \rightarrow 2Pb + CO_2$ [1 for reactants, 1 for products, 1 for correct balancing]
$SnO_2 + 2H_2 \rightarrow Sn + 2H_2O$ [1 for reactants, 1 for products, 1 for correct balancing]

10 (a) (i) an agent that causes colourless [1] substances on a chromatogram to become coloured [1]
(ii) the ratio of the distance travelled by the solute [1] to the distance travelled by the solvent [1] in chromatography
(b) ninhydrin [1]
(c) (i) sample 1 = alanine [1], sample 2 = lysine [1], sample 3 = glycine [1]
(ii) The R_f values of these amino acids are closest to those of the samples [1].

Exam focus

1 (a) (i) $C(s) + O_2(g) \rightarrow CO_2(g)$ [1 for reactants, 1 for products]
(ii) $CO_2(g) + C(s) \rightarrow 2CO(g)$ [1 for reactants, 1 for products, 1 for correct balancing]
(b) carbon [1]
(c) carbon dioxide [1]
(d) $Fe_2O_3(s) + \underline{3}CO(g) \rightarrow \underline{2}Fe(l) + \underline{3}CO_2(g)$ [2]
(e) reducing agent CO [1], oxidising agent Fe_2O_3 [1]
(f) [1 for each]

Formula of substance	Elements present			Total number of atoms
	Name	Symbol	Number of atoms	
Fe_2O_3	Iron	Fe	2	5
	Oxygen	O	3	
CO	Carbon	C	1	2
	Oxygen	O	1	
Fe	Iron	Fe	1	1
CO_2	Carbon	C	1	3
	Oxygen	O	2	

(g) (i) iron [1]
(ii) iron(III) oxide, carbon monoxide, carbon dioxide [1 for each]

2 (a) [1 for each]

Element	Metal or non-metal?	Shiny?	Conductor of electricity?	Melting point
W		Yes		
X				
Y	Metal			
Z			No	

(b) high density [1]
(c) (i) iron or oxygen [1]
(ii) iron(III) oxide [1]
(iii) Particles of iron(III) oxide can get into the eyes [1].
(iv) $4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$ [1 for reactants, 1 for products, 1 for correct balancing]

3 Atomic structure and the periodic table

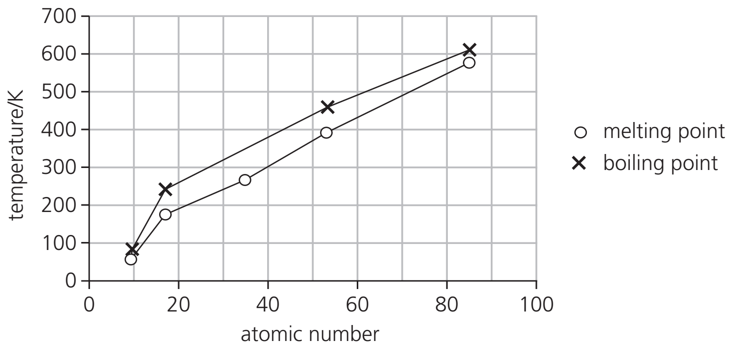
1 (a) (i) 19 electrons, 19 protons, 20 neutrons [1 for each]
(ii) 2,8,8,1 [1]
(iii) Group 1 [1], it has one electron in the outer energy level of the atom [1]
(iv) Y^+ [1]
(b) 7 [1]

(c) (i) potassium bromide [1]
(ii) potassium + bromine → potassium bromide [1]
$2K + Br_2 \rightarrow 2KBr$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(iii) Both chlorine and bromine gain an electron, from the potassium, when they react [1]. Chlorine is more reactive than bromine as it is a smaller atom [1] which attracts the incoming electron more strongly as its nucleus is closer to its outer energy level [1].

2 (a) (i) element **C** 2,8,3 [1], element **D** 2,6 [1]
(ii) 17 [1]
(b) (i) element **A** [1]
(ii) element **B** [1]
(iii) element **E** [1]
(iv) element **C** [1]
(c) (i) element **C** [1]
(ii) element **D** [1]
(iii) element **A** [1]

3 (a) Mn [1]
(b) C [1]
(c) Br [1]
(d) Na [1]
(e) Ne or Kr [1]
(f) P [1]
(g) Na [1]
(h) F [1]

4 (a)



[1 for scale, 1 for axis titles, 2 for melting points plotted and joined, 2 for boiling points plotted and joined]

(b) 350–400 K [1]
(c) The melting points increase with increasing atomic number [1].
(d) F [1] and Cl [1]

5 (a)

Isotope	Number of		
	Electrons	Protons	Neutrons
^{63}Cu	29	29	34
^{65}Cu	29	29	36

[1 for each correct row]

(b) atoms [1] of the same element which have different numbers of neutrons in their nuclei [1]
(c) the average mass of the isotopes of an element [1] compared with one-twelfth the mass of one atom of carbon-12 [1]
(d) A_r of Cu = (63 × 69.1 + 65 × 30.9)/100 [1] = 63.6 [1]

6 (a) aluminium + chlorine → aluminium chloride [1]
$2Al(s) + 3Cl_2(g) \rightarrow 2AlCl_3(s)$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(b) Chlorine is a toxic gas [1].
(c) fluorine [1]
(d) any suitable metal, e.g. sodium, potassium, magnesium or gallium [1]

7 (a) (i) They all react vigorously [1], giving off hydrogen [1] and producing an alkaline solution [1]. This is due to one electron in the outer energy level [1].
(ii) They show a difference in how vigorously they react with water [1]. This is due to different distances between the electron in the outer energy level and the nucleus [1].

(b) (i) Group 2 **[1]**

(ii) 2 **[1]**

(iii) barium **[1]**

Barium is furthest down the group and is the largest atom. It will therefore lose the two electrons from its outer energy level most easily, owing to the weakest attraction from the nucleus **[1]**.

8 Dmitri Mendeleev, atomic mass, group, iodine (I), spaces, atomic number **[1 for each]**

Stretch and challenge

9 (a) The metallic character decreases **[1]**.

(b) 3 **[1]**

(c) (i) 12 **[1]**

(ii) +2 **[1]**

(d) two (or more) from – phosphorus, sulfur, chlorine **[2]**

(e) (i) does not react **[1]**

(ii) Argon already has a full energy level of electrons **[1]** so it has no need to react to gain or lose electrons **[1]**.

(iii) the gas in older style (non-fluorescent) electric light bulbs **[1]**

Exam focus

1 (a) potassium bromide + chlorine → potassium chloride + bromine **[1]**

$2KBr(aq) + Cl_2(g) \rightarrow 2KCl(aq) + Br_2(l)$ **[1 for reactants, 1 for products, 1 for correct balancing]**

(b) Chlorine is a smaller atom than bromine **[1]**. Therefore it attracts the incoming electron from the potassium more strongly as its nucleus is closer to the outer energy level than bromine's **[1]**.

(c) fluorine **[1]**

(d) no **[1]**, bromine is less reactive than fluorine **[1]**

2 (a) (i) Na 2,8,1 **[1]**, K 2,8,8,1 **[1]**

(ii) potassium **[1]**

Both potassium and sodium have one electron in their outer energy level, which is lost when they react with the water **[1]**. In potassium (the bigger atom), the electron in the outer energy level is further from the nucleus and is less tightly held in the atom and so is lost more easily, making it more reactive **[1]**.

(iii) $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**

(b) (i) 7 **[1]**

(ii) gain one electron **[1]**

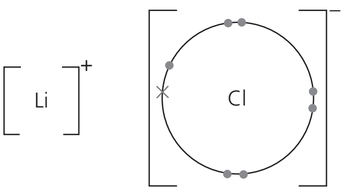
(iii) –1 **[1]**

(iv) fluorine **[1]**

It is the smallest of all the halogen atoms **[1]** and attracts the incoming electron most strongly, as its nucleus is closest to the outer energy level into which the electron is coming **[1]**.

4 Bonding and structure

1 (a)



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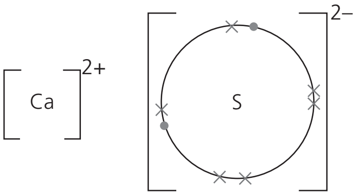
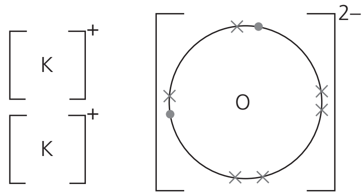
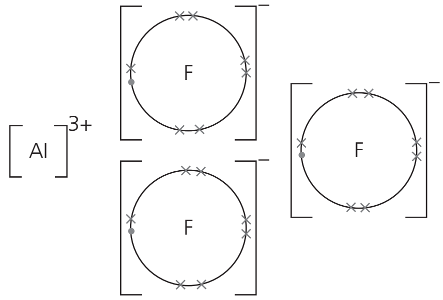


(c)



(d)

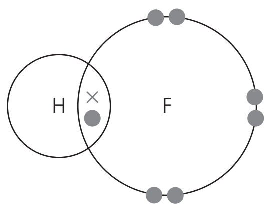


[2 for each metal ion, including charge, 2 for each non-metal ion, including charge]

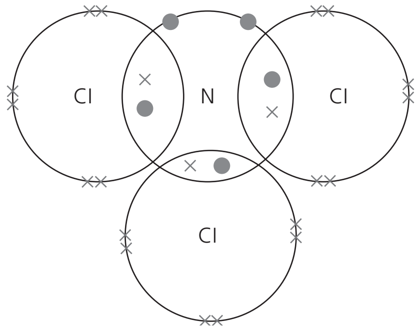
2 **(a)** false **[1]**
(b) true **[1]**
(c) false **[1]**
(d) true **[1]**
(e) true **[1]**
(f) true **[1]**

3 **(a)** **(i)** KCl **[1]**
(ii) CuF_2 **[1]**
(iii) Na_2CO_3 **[1]**
(iv) Ag_3PO_4 **[1]**
(v) PbO **[1]**
(vi) $(NH_4)_2SO_4$ **[1]**
(vii) $Mg_3(PO_4)_2$ **[1]**
(viii) BaS **[1]**
(ix) $Al(OH)_3$ **[1]**
(x) $FeBr_3$ **[1]**
(b) **(i)** 1 K : 1 Cl **[1]**
(ii) 1 Cu : 2 F **[1]**
(iii) 2 Na : 1 C : 3 O **[1]**
(iv) 3 Ag : 1 P : 4 O **[1]**
(v) 1 Pb : 1 O **[1]**
(vi) 2 N : 8 H : 1 S : 4 O **[1]**
(vii) 3 Mg : 2 P : 8 O **[1]**
(viii) 1 Ba : 1 S **[1]**
(ix) 1 Al : 3 O : 3 H **[1]**
(x) 1 Fe : 3 Br **[1]**

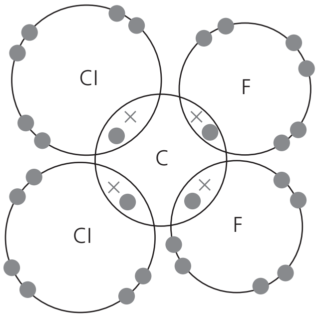
4 **(a)**



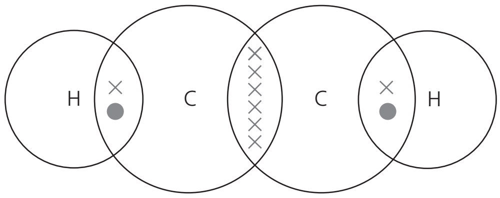
(b)



(c)



(d)



[2 for correct numbers of electrons, 2 for correct sharing in overlap areas]

5 **(a)** true [1]
(b) true [1]
(c) true [1]
(d) true [1]
(e) false [1]
(f) true [1]

6 **(a)** **(i)** sulfur dioxide, ethanol, hexane, ammonia [1 for each]
(ii) copper(II) chloride, barium chloride, aluminium oxide, potassium chloride, lead sulfide, tin(IV) chloride [1 for each]
(v) Covalent substances are usually those with low melting and boiling points [1] and formed between non-metal elements only [1]. Ionic substances are usually those with high melting and boiling points [1] and formed between non-metal and metal elements [1].
(b) **(i)** sulfur dioxide, ammonia [1 for each]
(ii) ethanol, hexane [1 for each]
(c) **(i)** tin(IV) chloride [1]
(ii) This substance contains a metal and a non-metal [1] but has low melting and boiling points [1].

7 **(a)** hydrogen, oxygen, chlorine, fluorine, nitrogen [1 for each]
(b) lithium, gold, magnesium, titanium, tin [1 for each]
(c) ammonia, hydrogen chloride, water, carbon dioxide, sulfur trioxide [1 for each]
(d) sodium chloride, nickel(II) bromide, lead nitrate, copper(II) sulfate, iron(II) oxide [1 for each]

8 **(a)** **A** diamond [1], **B** graphite [1]
(b) different structural forms of the same element [1] that have the same physical state [1]
(c) **(i)** covalent [1]
(ii) macromolecular or giant covalent [1]
(d) **(i)** 4 [1]
(ii) 3 [1]
(e)

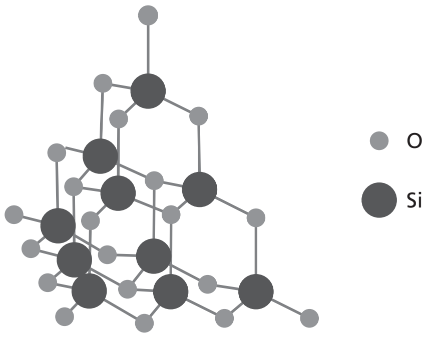
Substance	**Electrical conductivity**	**Melting point**	**Hardness**
A	Poor	High	High
B	Good	High	Low

[1 for each]

(f) buckminsterfullerene [1]

Stretch and challenge

9 **(a)**



(b) covalent [1]

(c) **(i)** The silicon and oxygen atoms form strong covalent bonds [1] throughout the three-dimensional macromolecular structure [1].

(ii) The structure does not contain free electrons [1] or ions [1].

(iii) The silicon and oxygen atoms are arranged in a very regular structure [1] with strong bonds between the atoms [1].

10 **(a)** conductors, energy levels, negative, energy, delocalised, ions, malleable, ductile, high, attractive [1 for each]

(b) Calcium has two delocalised electrons from each metal atom [1]. They have a much stronger force of attraction for the Ca^{2+} ions [1] in the metal structure than in the case of potassium, which has only one delocalised electron per atom [1] and in which the force of attraction for the K^+ ions in the metal structure is lower. Hence the melting point of calcium is higher than that of potassium [1]. (Note that the calcium ions are also arranged in a more economical packing than the potassium ions, again giving a stronger possible force of attraction.)

Exam focus

1 **(a)** Na 2,8,1 [1], Na^+ 2,8 [1]

(b) Cl 2,8,7 [1], Cl^- 2,8,8 [1]

(c) ionic [1]

(d) **(i)** Each Na^+ ion is surrounded by six Cl^- ions [1] and vice versa [1].

(ii) There are strong electrostatic forces between the oppositely charged ions [1]. A lot of energy is therefore needed to separate the ions and melt the substance [1].

(iii) In the solid state the ions are not free to move [1] but in the molten state the ions are free to move to the oppositely charged electrodes [1].

2 **(a)** covalent (single bonds) [1]

(b) electrons [1]

(c) It is a small molecule [1] with weak forces of attraction between the molecules [1].

(d) In the molecule, the carbon atom has eight electrons in its outer energy level [1]. It achieves this by sharing electrons with four hydrogen atoms [1].

(e) **(i)** helium [1]

(ii) neon [1]

(iii) The only energy level in the hydrogen atom is the first, which is full when it contains only two electrons [1].

5 Chemical calculations

1 **(a)** **(i)** 46 [1]

(ii) 88 [1]

(ii) 74 [1]

(iv) 42 [1]

(b) **(i)** 106 [1]

(ii) 74 [1]

(iii) 132 [1]

(iv) 160 [1]

2 **(a)** **(i)** 2 moles [1]
(ii) 0.01 mole [1]
(iii) 0.32 mole [1]
(b) **(i)** 0.5 mole [1]
(ii) 2 moles [1]
(iii) 3 moles [1]

3 **(a)** 200 g [1]
(b) 20 g [1]
(c) 12.75 g [1]
(d) 585 g [1]
(e) 4.5 g [1]
(f) 100 g [1]

4 **(a)** **(i)** 0.6 mole calcium, 0.4 mole nitrogen [1], Ca_3N_2 [1]
(ii) 0.8 mole copper, 0.4 mole oxygen [1], Cu_2O [1]
(iii) 0.22 mole aluminium, 0.66 mole chlorine [1], $AlCl_3$ [1]
(iv) 0.18 mole carbon, 0.36 mole hydrogen, 0.09 mole oxygen [1], C_2H_4O [1]
(b) **(i)** 7.7 moles carbon, 7.7 moles hydrogen [1], CH [1]
(ii) 2.5 moles magnesium, 2.5 moles oxygen [1], MgO [1]
(iii) 1.25 moles iron, 1.875 moles oxygen [1], Fe_2O_3 [1]
(iv) 1.19 moles sodium, 1.2 moles hydrogen, 1.19 moles carbon, 3.57 moles oxygen [1], $NaHCO_3$ [1]
(c) mass of empirical formula = 12 + 2 = 14 [1]
molecular formula C_4H_8 [1]
(d) mass of empirical formula = 24 + 4 + 16 = 44 [1]
molecular formula $C_4H_8O_2$ [1]

5 **(a)** **(i)** 0.125 mole [1]
(ii) 0.05 mole [1]
(iii) 0.1875 mole [1]
(iv) 0.75 mole [1]
(b) **(i)** $1\,mol\,dm^{-3}$ [2]
(ii) $1\,mol\,dm^{-3}$ [2]
(iii) $0.4\,mol\,dm^{-3}$ [2]
(iv) $3\,mol\,dm^{-3}$ [2]
(c) **(i)** 0.025 mole [1], 1 g [1]
(ii) 0.125 mole [1], 10.625 g [1]

6 **(a)** $2HCl + Na_2CO_3 \rightarrow 2NaCl + H_2O + CO_2$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(b) Five (or more) from:
- $25\,cm^3$ of the sodium carbonate solution is placed in a conical flask using a pipette and safety filler.
- three or four drops of phenolphthalein (or methyl orange) indicator are added to the sodium carbonate solution.
- A burette is filled with the hydrochloric acid solution, ensuring that some runs through the valve, and the initial burette reading is taken.
- The acid is added from the burette into the flask, with swirling, until the colour of the indicator just changes.
- The final burette reading is taken and the volume of acid needed to neutralise the sodium carbonate is found.
- The process is repeated to obtain three concordant results (within $0.10\,cm^3$ of each other). [5]

(c) moles of Na_2CO_3 used = $0.1 \times 25/1000 = 2.5 \times 10^{-3}$ mole [1]
moles of HCl = $2 \times 2.5 \times 10^{-3} = 5 \times 10^{-3}$ mole [1]
concentration of HCl = $5 \times 10^{-3} \times 1000/18.95 = 0.26\,mol\,dm^{-3}$ [1]

7 (a) moles of N_2 = 1.4/28 = 0.05 mole [1]
moles of O_2 = 3.2/32 = 0.1 mole [1]
1 mole of N_2 reacts with 2 moles of O_2 in the equation [1]
$N_2(g) + 2O_2(g) \rightarrow N_2O_4(g)$ [1]

(b) (i) $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$ [1 for reactants, 1 for products, 1 for correct balancing]
(ii) moles of Mg used = 0.24/24 [1] = 0.01 mole [1]
(iii) moles of HCl = 2 × 0.01 = 0.02 mole [1]
volume of HCl = 0.02 × 1000/1.0 = 20 cm^3 [1]
(iv) moles of $MgCl_2$ produced = 0.01 mole [1]
mass of $MgCl_2$ = 0.01 × (24 + 35.5 + 35.5) = 0.95 g [1]
(v) moles of H_2 gas produced = 0.01 mole [1]
volume of H_2 gas = 0.01 × 24 = 0.24 dm^3 (240 cm^3) [1]

8 (a) (i) $Fe(s) + 2HCl(aq) \rightarrow FeCl_2(aq) + H_2(g)$ [1 for reactants, 1 for products, 1 for correct balancing]
(ii) moles of Fe used = 5.6/56 = 0.1 mole [1]
(iii) moles of $FeCl_2$ = 0.1 mole [1]
mass of $FeCl_2$ = 0.1 × (56 + 35.5 + 35.5) = 12.7 g [1]
(iv) percentage yield = 9.17 × 100/12.7 [1] = 72.2% [1]

(b) moles of Fe_2O_3 = 100 × 10^6/160 = 625 000 moles [1]
moles of Fe formed = 2 × 625 000 = 1 250 000 moles [1]
mass of Fe expected = 1 250 000 × 56 = 70 000 000 g (70 tonnes) [1]
percentage yield = 7 × 100/70 = 10% [1]

Stretch and challenge

9 moles of NaCl used = 11.7/58.5 = 0.2 mole [1]
moles of HCl produced = 0.2 mole [1]
concentration of HCl formed = 0.2 × 1000/250 [1] = 0.8 mol dm^{-3} [1]

10 (a) $H_2SO_4(aq) + K_2CO_3(aq) \rightarrow K_2SO_4(aq) + H_2O(l) + CO_2(g)$ [1 for reactants, 1 for products, 1 for correct balancing]

(b) (i) moles of K_2CO_3 = 0.05 × 25/1000 [1] = 1.25 × 10^{-3} mole [1]
(ii) moles of H_2SO_4 = 1.25 × 10^{-3} mole [1]

(c) concentration of H_2SO_4 = 1.25 × 10^{-3} × 1000/23.55 [1] = 0.053 mol dm^{-3} [1]

Exam focus

1 (a) (i) moles of CuO used = 8/(64 + 16) = 0.1 mole [1]
moles of H_2 gas needed = 0.1 mole [1]
volume of H_2 gas = 0.1 × 24 = 2.4 dm^3 (2400 cm^3) [1]
(ii) moles of Cu obtained = 0.1 mole [1]
mass of Cu = 0.1 × 64 = 6.4 g [1]
(iii) percentage yield = 5.8 × 100/6.4 = 90.625% [2]

(b) (i) moles of propane = 10/24 = 0.417 mole [1]
moles of O_2 needed = 5 × 0.417 = 2.085 mole [1]
volume of O_2 needed = 2.085 × 24 = 50 dm^3 [1]
(ii) volume of CO_2 = 0.417 × 3 × 24 = 30 dm^3 [1]
volume of H_2O = 0.417 × 4 × 24 = 40 dm^3 [1]
total volume = 30 + 40 = 70 dm^3 [1]

2 (a)

	Rough	1	2	3
Final burette reading/cm^3				
Initial burette reading/cm^3				
Volume of sulfuric acid used/cm^3	21.75	22.25	22.35	22.30

[1]

(b) average volume = (22.25 + 22.35 + 22.30)/3 [1] = 22.30 cm^3 [1]
(c) $2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$ [1 for reactants, 1 for products, 1 for correct balancing]
(d) moles of NaOH = 0.25 × 25/1000 [1] = 6.25 × 10^{-3} mole [1]
(e) moles of H_2SO_4 neutralised = 0.5 × 6.25 × 10^{-3} = 3.125 × 10^{-3} mole [1]
(f) concentration of H_2SO_4 = 3.125 × 10^{-3} × 1000/22.30 [1] = 0.14 mol dm^{-3} [1]

6 Electrolysis and its uses

1 **(a)** **1** anode, **2** cathode, **3** electrolyte, **4** heat [1 for each]
(b) a process in which a chemical decomposition reaction [1] is caused by the passage of an electric current [1]
(c) **(i)** the positive electrode [1]
(ii) the negative electrode [1]
(iii) a substance that will carry an electric current only when it is molten [1] or dissolved in water [1]
(d) where the electric current enters [1] and leaves [1] the electrolytic cell
(e) carbon (graphite) or platinum [1]
(f) The substance needs to be molten so that the ions have separated [1] and are mobile and free to move to the electrodes [1].

2 **(a)** the chemical breakdown of the substance [1], caused in this case by the passage of an electric current [1]
(b) a solution in which water [1] is the solvent [1]
(c) negative ions [1] which are attracted to the anode [1]
(d) positive ions [1] which are attracted to the cathode [1]
(e) a substance that will not react [1] with the electrolyte or with the products at the electrodes [1]
(f) the addition of oxygen to [1] or the loss of electrons from [1] a substance
(g) the removal of oxygen from [1] or the gain of electrons by [1] a substance

3 **(a)** reduction [1], cathode [1]
(b) oxidation [1], anode [1]
(c) oxidation [1], anode [1]
(d) reduction [1], cathode [1]
(e) reduction [1], cathode [1]
(f) oxidation [1], anode [1]

4 **(a)** $Na^+ + \underline{e}^- \rightarrow Na$ [1]
(b) $\underline{2}Br^- \rightarrow \underline{Br_2} + 2e^-$ [2]
(c) $Ca^{2+} + \underline{2e}^- \rightarrow \underline{Ca}$ [2]
(d) $\underline{Cu}^{2+} + \underline{2e}^- \rightarrow Cu$ [2]
(e) $\underline{2}I^- \rightarrow \underline{I}_2 + \underline{2e}^-$ [3]
(f) $\underline{4}OH^- \rightarrow \underline{2}H_2O + \underline{O}_2 + \underline{4}e^-$ [4]

5 **(a)** false [1]
(b) true [1]
(c) true [1]
(d) true [1]
(e) false [1]
(f) true [1]

6 **(a)** substances **T**, **U**, **W** and **Z** [1 for each]
(b) substances **X** and **Y** [1 for each]
(c) substance **U** [1]
(d) substance **X** [1]
(e) substance **V** [1]
(f) dilute acid or dilute alkali [1]
(g) copper(II) oxide [1]

7

Substance	**Material of electrodes**	**Substance formed at the cathode**	**Substance formed at the anode**
		Lead	Chlorine
Dilute sulfuric acid			
	Carbon	Calcium	Bromine
Molten sodium chloride	Carbon		
		Copper	Oxygen

[1 for each]

8 **(a)** This increases the conductivity of the copper(II) sulfate solution [1].
(b) Chlorine and sodium hydroxide will react together [1] and so the products would not be as wanted [1].
(c) The anodes burn away with the oxygen produced at high temperature [1], producing carbon dioxide [1].
(d) The grease would prevent an even covering of the metal [1] onto the item being electroplated [1].

Stretch and challenge

9 **(a)** **(i)** titanium [1]
(ii) steel [1]
(b) **(i)** $\underline{2}H^+(aq) + \underline{2}e^- \rightarrow H_2(g)$ [2]
(ii) $\underline{2}Cl^-(aq) \rightarrow Cl_2 + \underline{2e^-}$ [2]
(iii) hydrogen – making margarine and hydrochloric acid [2]
chlorine – making plastics and solvents [2]
(c) **(i)** 234 g of NaCl = 2× that shown [1]; produces 2× that shown, i.e. 160 g of NaOH [1]
(ii) 234 g of NaCl = 2× that shown [1]; produces 2× that shown, i.e. 142 g of Cl_2 [1]
(iii) 234 g of NaCl = 2× that shown [1]; produces 2× that shown, i.e. 4 g of H_2 [1]
(iv) in soap [1] and paper manufacture [1]

10 **(a)** **(i)** $Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(ii) for galvanising [1] and making brass [1]
(b) **(i)** oxygen [1]
(ii) $4OH^-(aq) \rightarrow 2H_2O(l) + O_2(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(iii) in steel making [1] and for producing very hot flames with ethyne [1]
(c) hydrogen [1]
(d) Because the zinc is continuously removed [1] from the solution, by being deposited at the cathode [1]. Hence the solution needs replacing.

Exam focus

1 **(a)** The temperatures required for chemical reduction are too high [1] and therefore energy costs are too high [1].
(b) The mixture of cryolite and aluminium oxide [1] has a much lower melting point, of about 1000 °C [1].
(c) **(i)** cathode [1]
(ii) $Al^{3+} + \underline{3}e^- \rightarrow Al$ [1]
(d) **(i)** carbon [1]
(ii) $\underline{2}O^{2-} \rightarrow O_2 + \underline{2e^-}$ [2]
(e) **(i)** The carbon anodes react with oxygen at high temperatures [1], producing carbon dioxide [1].
(ii) $C(s) + O_2(g) \rightarrow CO_2(g)$ **[1 for reactants, 1 for products]**
(f) provision of cheap [1] hydroelectric power [1] for the smelting
(g) It is cheaper to recycle the aluminium than to get it from the ore [1]. It is environmentally more sensible – less mining is required and there are fewer cans kicking about! [1]

2 **(a)** **(i)** increases [1]
(ii) Metallic tin is deposited at the cathode [1].
(b) **(i)** +2 [1]
(ii) The electrolyte is tin(II) sulfate [1].
(c) **(i)** no [1]
(ii) It stays the same because the tin taken out of the solution [1] is replaced by tin from the anode [1].
(d) **(i)** $Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(ii) $Sn(s) \rightarrow Sn^{2+}(aq) + 2e^-$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(e) The tin sticks better to the surface of the steel by electroplating [1], so it is less likely to go into solution in the food can [1].
(f) Mild steel is mainly iron, which would corrode when in contact with the food and any solutions in the can [1].

7 Acids, bases and salts

1 **(a)** sodium carbonate + nitric acid → sodium nitrate + water + carbon dioxide [1]
$Na_2CO_3 + 2HNO_3 \rightarrow 2NaNO_3 + H_2O + CO_2$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(b) magnesium + hydrochloric acid → magnesium chloride + hydrogen [1]
$Mg + 2HCl \rightarrow MgCl_2 + H_2$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(c) potassium hydroxide + sulfuric acid → potassium sulfate + water [1]
$2KOH + H_2SO_4 \rightarrow K_2SO_4 + 2H_2O$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(d) copper(II) oxide + nitric acid → copper(II) nitrate + water [1]
$CuO + 2HNO_3 \rightarrow Cu(NO_3)_2 + H_2O$ **[1 for reactants, 1 for products, 1 for correct balancing]**

2

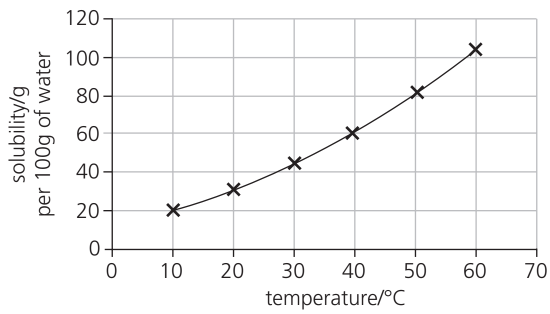
Substances used to make the salt		Salt prepared	Other products
		Calcium chloride	Water
Sodium hydroxide/oxide			
	Nitric acid		
Zinc			
		Lead chloride	
		Barium sulfate	Potassium chloride

[1 for each]

3 **(a)** iron(III) chloride, $FeCl_3$ **[2]**
(b) iron(III) hydroxide, $Fe(OH)_3$ **[2]**
(c) iron(II) chloride, $FeCl_2$ **[2]**
(d) hydrogen, H_2 **[2]**
(e) silver chloride, AgCl **[2]**

4 **(a)** **(i)** Add a small amount of dilute nitric acid followed by a few drops of silver nitrate solution **[1]**. A white precipitate will be formed **[1]**.
(ii) Add a small amount of dilute nitric acid followed by a few drops of silver nitrate solution **[1]**. A cream (off-white) precipitate will be formed **[1]**.
(iii) Add a small amount of dilute nitric acid followed by a few drops of silver nitrate solution **[1]**. A yellow precipitate will be formed **[1]**.
(b) Add some dilute hydrochloric acid **[1]**. Fizzing (effervescence) will be observed, caused by the production of carbon dioxide (which would turn limewater cloudy) **[1]**.
(c) Add a small amount of dilute hydrochloric acid followed by some barium chloride **[1]**. A white precipitate will be formed **[1]**.
(d) **(i)** Add some dilute sodium hydroxide solution **[1]**. A green precipitate will be formed **[1]**.
(ii) Add some dilute sodium hydroxide solution **[1]**. An orange-brown precipitate will be formed **[1]**.

5 **(a)**



[1 for scale, 1 for axis labels and units, 1 for points plotted correctly, 1 for best-fit line]

(b) **(i)** 37 g per 100 g of water **[1]**
(ii) 68 g per 100 g of water **[1]**
(iii) 85 g per 100 g of water **[1]**
(c) **(i)** 34 °C **[1]**
(ii) 47 °C **[1]**
(iii) 56 °C **[1]**
(d) **(i)** At 35 °C, 52 g would dissolve in 100 cm^3 of water **[1]**, so 13 g would dissolve in 25 cm^3 of water **[1]**.
(ii) At 55 °C, 91 g would dissolve in 100 cm^3 of water **[1]**, so 36.4 g would dissolve in 40 cm^3 of water **[1]**.
(e) Solubility at 47 °C is 75 g per 100 cm^3 of water **[1]**, solubility at 23 °C is 35 g per 100 cm^3 of water **[1]**. The mass of potassium nitrate that would crystallise out is 75 – 35 = 40 g **[1]**.

6 **(a)** **(i)** silver nitrate **[1]**, sodium chloride (or other soluble chloride) **[1]**
(ii) barium chloride or nitrate **[1]**, sodium sulfate (or other soluble sulfate) **[1]**
(iii) calcium nitrate or chloride **[1]**, sodium or potassium carbonate **[1]**
(b) Mix together solutions of lead(II) nitrate and sodium or potassium iodide to give a yellow precipitate of lead(II) iodide **[1]**. Filter the mixture obtained **[1]**. Wash with distilled water **[1]**. Dry the yellow solid **[1]**.
$Pb^{2+}(aq) + 2I^-(aq) \rightarrow PbI_2(s)$ **[1 for reactants, 1 for products, 1 for correct balancing, 1 for state symbols]**

7 **(a)** It produces hydrogen ions ($H^+(aq)$) **[1]** when added to water **[1]**.
(b) **(i)** an acid which only partially **[1]** ionises (dissociates) **[1]** when added to water
(ii) an acid which completely **[1]** ionises (dissociates) **[1]** when added to water

(c) **(i)** $HCl(g) \rightarrow H^+(aq) + Cl^-(aq)$ **[1 for symbols, 1 for complete ionisation]**

(ii) $CH_3COOH(l) \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$ **[1 for symbols, 1 for 'reversible' arrows]**

(d) A strong acid is one which completed ionises (dissociates) when added to water [1], whereas a weak acid ionises (dissociates) only partially [1]. A concentrated acid contains a high concentration of acid particles [1], whereas a dilute acid contains a much lower concentration of acid particles and lots of water [1].

8 **(a)** fizzing (effervescence) [1]

(b) The fizzing (effervescence) stops [1].

(c) excess sodium carbonate solid [1]

(d) to allow the crystals to form slowly from a saturated solution [1]

(e) hydrochloric acid + sodium carbonate → sodium chloride [1] + water + carbon dioxide [1]

(f) $2HCl(aq) + Na_2CO_3(s) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**

Stretch and challenge

9
- Label each of the bottles **A** to **E** [1].
- Add dilute nitric acid followed by silver nitrate to samples of each of the solutions in test-tubes [1]. The solution which gives a yellow precipitate will be potassium iodide [1], the one which gives a cream (off-white) precipitate will be sodium bromide [1], and the one which gives a white precipitate will be hydrochloric acid [1].
- Now add the hydrochloric acid to the two remaining solutions. The one which fizzes will be potassium carbonate [1] and the one which does not is the iron(II) sulfate [1]. (An alternative final step would be to distinguish the iron(II) sulfate from the potassium carbonate by its pale green colour.)

Exam focus

1 **(a)** Seven (or more) from:
- $25\,cm^3$ of the dilute sodium hydroxide solution is placed in a conical flask using a pipette and safety filler.
- three or four drops of phenolphthalein indicator are added to the sodium carbonate solution.
- A burette is filled with the dilute sulfuric acid solution, ensuring that some runs through the valve, and the initial burette reading is taken.
- The acid is added from the burette into the flask, with swirling, until the colour of the indicator just changes from pink to colourless.
- The final burette reading is taken and the volume of acid needed to neutralise the sodium hydroxide is found.
- The process is repeated, this time without an indicator but using exactly the same volumes of dilute sodium hydroxide and dilute sulfuric acid as found in the first experiment.
- The neutralised solution from the repeat experiment is poured into an evaporating basin and the solution is heated until half of the volume has evaporated.
- The solution is then left to cool and the crystals will form slowly. [7]

(b) $2NaOH(aq) + H_2SO_4(aq) \rightarrow Na_2SO_4(aq) + 2NaOH(aq)$ **[1 for reactants, 1 for products, 1 for correct balancing]**

2 **(a)** hydrogen, $H^+(aq)$, bases, hydroxide, $OH^-(aq)$, neutralisation **[1 for each]**

(b) $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$ **[1 for reactants, 1 for products, 1 for correct balancing]**

(c) **(i)** $2HCl(aq) + K_2CO_3(s) \rightarrow 2KCl(aq) + H_2O(l) + CO_2(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**

(ii) to ensure that all the hydrochloric acid had been neutralised [1]

(iii) potassium chloride solution [1]

(iv) a saturated solution [1]

8 Inorganic carbon chemistry

1 **(a)** false [1]

(b) false [1]

(c) true [1]

(d) false [1]

(e) true [1]

(f) true [1]

2 **(a)** the starting material [1] from which a more refined substance is produced [1]
(b) manufacture of iron and steel [1], cement [1], lime [1]
(c) advantages – increased employment possibilities for local people [1], improvements in the local economy [1] and infrastructure [1]
disadvantages – atmosphere contaminated by dust and fumes [1], increased traffic around the locality including heavy road vehicles [1], local wildlife habitats destroyed [1]

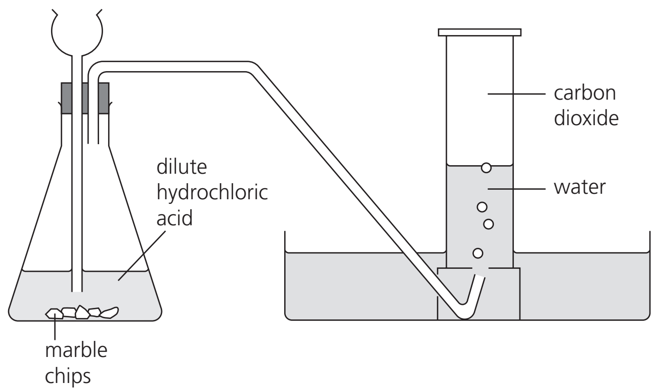
3 **(a)** **(i)** a soluble base [1] which dissolves in water to produce $OH^-(aq)$ [1], forming a solution of pH greater than 7 [1]
(ii) two from – to make bleaching powder, to reduce soil acidity, in glass manufacture [2]
(b) **(i)** A white precipitate [1] of calcium carbonate [1], $CaCO_3$ [1], is produced.
(ii) The white precipitate dissolves [1] and the solution goes clear [1]. Calcium hydrogencarbonate [1], $Ca(HCO_3)_2$ [1], is formed.
(iii) mortar [1]

4 **(a)** Add dilute hydrochloric acid [1] to the substance. It effervesces [1] if a carbonate is present. Carbon dioxide gas is produced [1].
calcium carbonate + hydrochloric acid → calcium chloride + carbon dioxide + water [1]
$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(b) **(i)** Na_2CO_3 [1]
(ii) three from – in the manufacture of soap, detergents, dyes, drugs [3]
(c) **(i)** Generally they are unstable in the solid state [1].
(ii) magnesium hydrogencarbonate, calcium hydrogencarbonates [2]
(iii) It reacts with the excess acid in the stomach [1] and neutralises it [1].

5 **(a)** two from – sulfuric acid, H_2SO_4, aqueous ammonia, $NH_3(aq)$ (or NH_4OH), slaked lime, $Ca(OH)_2$ **[1 for each name, 1 for each formula]**
(b) **(i)** solvent – the substance, e.g. water [1], in which the solute, e.g. sugar, dissolves [1]
solute – the substance, e.g. sugar [1], which dissolves in the solvent, e.g. water [1]
(ii) sodium chloride, sugar, potassium nitrate **[1 for each]**
(iii) More of the solute will dissolve (the solubility increases) [1].
(c) Hard water has a high concentration of substances such as calcium sulfate, calcium hydrogencarbonate and magnesium sulfate [1] dissolved in it. It is hard to lather with soap [1]. Soft water contains only small amounts of any of these substances [1] and is easy to lather with soap [1].

6 **(a)** **(i)** a gas that contributes to the greenhouse effect [1] by absorbing infrared radiation [1] and leading to atmospheric warming
(ii) a general warming [1] across the surface of the Earth caused by the greenhouse effect [1]
(b) climate changes [1], melting of the ice caps [1], flooding caused by rise in sea levels [1]

7 **(a)** carbon monoxide, CO [2]
(b) for making carbonated drinks [1], in fire extinguishers [1]
(c) air [1]
(d) **(i)** covalent [1]
(ii) a bond formed by the sharing of two pairs of electrons [1] between the carbon and oxygen atoms in carbon dioxide [1]

8 **(a)** 

[2 for apparatus, 4 for correct labelling]

(b) A conical flask containing concentrated sulfuric acid [1] is introduced. The carbon dioxide gas is passed through a delivery tube into the concentrated sulfuric acid [1] and the acid absorbs the moisture in the gas [1]. It is then collected by downward delivery into a gas jar [1].

(c) (i) The magnesium burns with a spluttering bright white flame [1]. A white powder [1] is produced and black specks [1] are seen on the side of the glass container.

(ii) $\underline{2}Mg(s) + CO_2(g) \rightarrow \underline{2}MgO(s) + C(s)$ [2]

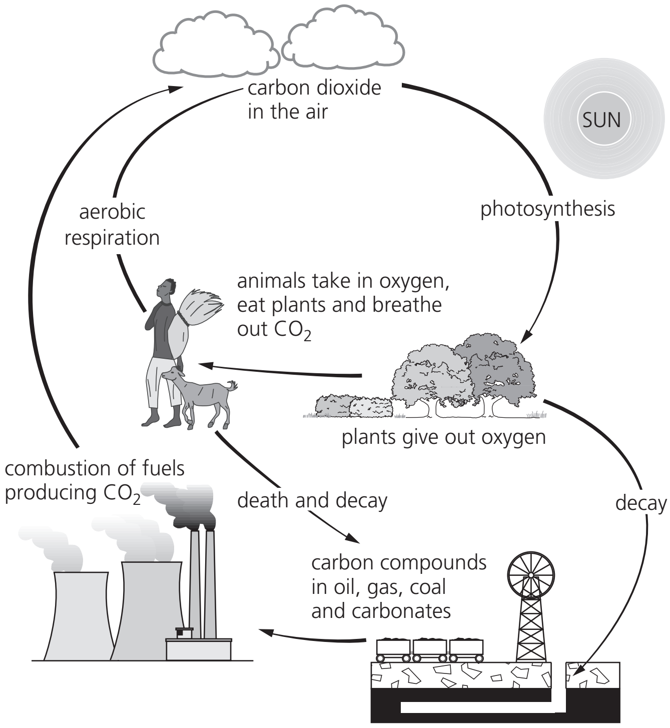
(iii) magnesium + carbon dioxide → magnesium oxide + carbon [1]

(iv) a chemical reaction which involves both oxidation [1] and reduction [1]

(v) reducing agent – magnesium [1], Mg [1]
oxidising agent – carbon dioxide [1], CO_2 [1]

Stretch and challenge

9 (a) [6]



(b) aerobic respiration – the process by which living organisms take in oxygen [1] from the atmosphere to oxidise food [1] to obtain energy [1]

photosynthesis – the chemical process by which green plants synthesise their carbon [1] from atmospheric carbon dioxide [1] using light as the energy source [1] and chlorophyll as the catalyst [1]

combustion – a reaction in which a fossil fuel such as coal, oil or natural gas is burned in oxygen from the air [1] to produce carbon dioxide [1], heat [1] and light [1]

(c) carbon dioxide, CO_2 [2]

(d) two from – water, nitrogen, rock [2]

10 (a) (i) a substance such as coal, oil or natural gas which is formed from the remains of plants and animals [1] over millions of years [1]

(ii) coal or oil [1]

(iii) 32 g of CH_4 = 2× that shown [1]; produces 2× that shown, i.e. 88 g of CO_2 [1]

(iv) 88 g of CO_2 = 2 moles of CO_2 [1]; it occupies $2 \times 24\,dm^3 = 48\,dm^3$ [1]

(b) C_8H_{18} contains eight times as much carbon as found in methane [1].

Exam focus

1 (a) (i) calcium oxide, CaO [2]

(ii) carbon dioxide, CO_2 [2]

(iii) water [1]

(iv) calcium hydroxide, $Ca(OH)_2$ [2]

(b) When marble is heated, it absorbs heat energy [1] to cause its decomposition [1].

(c) chalk [1]

(d) substance **A** – as a drying agent or for making soda glass [1]
substance **B** – for neutralising industrial waste or in water purification [1]

2 **(a)** from the burning coke in the limestone/coke mixture [1]
(b) to provide air for the reaction in part **(a)** [1] and to flush out the exhaust gases [1]
(c) (i) a chemical reaction in which the break-up [1] of a substance is caused by heat [1]
(ii) 40 tonnes [1]
(d) carbon + oxygen → carbon dioxide [1]
$C(s) + O_2(g) \rightarrow CO_2(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(e) methane, CH_4 [2]

9 Metal extraction and chemical reactivity

1 **(a)** $\underline{MgCO_3(s)} + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2O(l) + \underline{CO_2(g)}$ [2]
(b) $2Ca(s) + O_2(g) \rightarrow \underline{2CaO(s)}$ [1]
(c) $Mg(s) + \underline{ZnSO_4(aq)} \rightarrow MgSO_4(aq) + Zn(s)$ [1]
(d) $\underline{2Mg(s)} + \underline{O_2(g)} \rightarrow 2MgO(s)$ [2]
(e) $Zn(s) + 2\underline{HCl}(aq) \rightarrow \underline{ZnCl_2(aq)} + H_2(g)$ [2]

2 **(a) (i)** $Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(ii) The blue colour of the copper(II) sulfate solution would disappear [1]. The silver-grey metal would react to give a pink-brown metal [1].
(iii) The zinc metal displaces the copper from its salt [1] because zinc is more reactive than copper [1].
(b) Tin is less reactive than iron [1] and only corrodes very slightly and very slowly when in contact with food in the can [1].

3 **(a)** $2Li(s) + 2H_2O(l) \rightarrow 2LiOH(aq) + H_2(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(b) $Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(c) $Mg(s) + CuO(s) \rightarrow MgO(s) + Cu(s)$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(d) $Pb(s) + 2AgNO_3(aq) \rightarrow Pb(NO_3)_2(aq) + 2Ag(s)$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(e) $Zn(s) + H_2O(g) \rightarrow ZnO(s) + H_2(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(f) $Mg(s) + 2H_2O(l) \rightarrow Mg(OH)_2(aq) + H_2(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**

4 **(a)** to produce heat required by reacting with oxygen [1], to produce carbon monoxide [1]
(b) after decomposing, to form a slag with the sandy impurities from the haematite [1]
(c) (i) $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(ii) $C(s) + O_2(g) \rightarrow CO_2(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(iii) $C(s) + CO_2(g) \rightarrow 2CO(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(iv) $Fe_2O_3(s) + 3CO(g) \rightarrow 2Fe(s) + 3CO_2(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(v) $CaO(s) + SiO_2(s) \rightarrow CaSiO_3(s)$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(d) reducing agent [1]

5 **(a)** hydrogen [1]
(b) $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(c) magnesium oxide [1]
(d) $Mg(s) + H_2O(g) \rightarrow MgO(s) + H_2(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(e) zinc [1]

6 **(a)** a change in colour of the solution and/or the solid [1]
(b) displacement [1]
(c) **E, F, B, A, D, C** **[3 for all six correct, 2 for four or five correct, 1 for two or three correct]**

7 **(a) (i)** carbon [1]
(ii) It is reacted with oxygen gas, through a water-cooled lance [1] to produce oxides which are lost as gases [1].
(b) alloy [1]
(c) Stainless steel is too expensive [1] and too dense [1].
(d)

Object	**Properties**	**Steel**
Car body	Easily shaped, not brittle	Mild steel
Axe	Tough	Hard steel
Surgical knife	Tough, sharp-edged, non-corrosive	Stainless steel

[1 for each]

8 (a) (i) It is a drying agent [1] and removes the water vapour from the air [1].

(ii) Boiling the water removes any oxygen gas from the water [1] because gases are less soluble in hot water [1].

(iii) Oil is less dense than water and floats on its surface [1]. It prevents oxygen gas from the air above re-dissolving into the water [1].

(b)

Tube	Water	Oxygen
A	✓	✓
B		✓
C	✓	
D	✓	✓

[1 for each correct row]

(c) (i) tubes **B** [1] and **C** [1]

(ii) In tube **B** there is no water and in tube **C** there is no oxygen [1]. Both water and oxygen are needed for iron to rust [1].

(d) (i) tube **D** [1]

(ii) There is a higher concentration of oxygen gas in tube **D** than in tube **A** [1].

Stretch and challenge

9 (a) copper(II) oxide + zinc → copper + zinc oxide [1]
$CuO(s) + Zn(s) \rightarrow Cu(s) + ZnO(s)$ [1 for reactants, 1 for products]

(b) copper [1]

(c) zinc oxide [1]

(d) (i) zinc [1]

(ii) Zinc is gaining oxygen [1].

(iii) The copper is being reduced [1].

10 (a) $Fe_2O_3(s) + 2Al(s) \rightarrow 2Fe(s) + Al_2O_3(s)$ [1 for reactants, 1 for products, 1 for correct balancing]

(b) Aluminium has been oxidised [1], iron has been reduced [1].

(c) (i) moles of aluminium = 108/27 = 4 moles [1]
moles of iron expected = 4 moles [1]
mass of iron expected = 56 × 4 = 224 g [1]

(ii) percentage yield = 180 × 100/224 [1] = 80.4% [1]

Exam focus

1 (a) **A** zinc oxide, ZnO, **B** magnesium oxide, MgO, **C** zinc, Zn, **D** zinc chloride, $ZnCl_2$, **E** hydrogen gas, H_2, **F** magnesium, Mg, **G** oxygen gas, O_2, **H** copper, Cu, **I** magnesium sulfate, $MgSO_4$ [1 for each]

(b) (i) $ZnO(s) + Mg(s) \rightarrow MgO(s) + Zn(s)$ [1 for reactants, 1 for products]

(ii) $Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$ [1 for reactants, 1 for products, 1 for correct balancing]

(c) anode – $2O^{2-} \rightarrow O_2(g) + 4e^-$ [1 for reactants, 1 for products, 1 for correct balancing]
cathode – $Mg^{2+} + 2e^- \rightarrow Mg(s)$ [1 for reactants, 1 for products, 1 for correct balancing]

2 (a) (i) $PbO(s) + Fe(s) \rightarrow FeO(s) + Pb(s)$ [1 for reactants, 1 for products]

(ii) a reaction in which both oxidation [1] and reduction occur [1]

(iii) The iron is being oxidised [1], the lead(II) oxide is being reduced [1].

(b) (i) $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$ [1 for reactants, 1 for products, 1 for correct balancing]

(ii) Magnesium is more reactive than hydrogen [1], whereas copper is less reactive than hydrogen and cannot displace it from HCl [1].

(iii) silver [1]

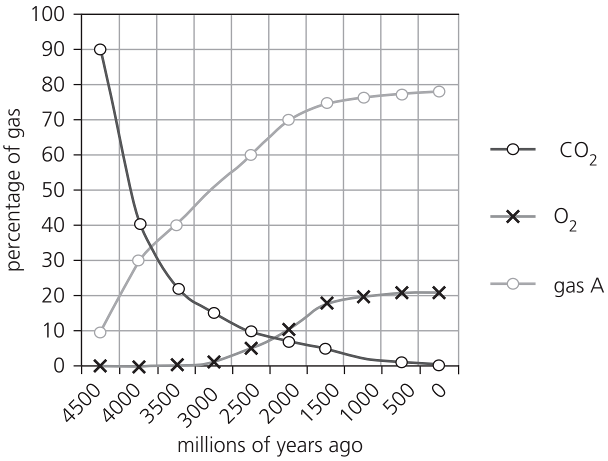
(c) (i) magnesium oxide, MgO [1]

(ii) $ZnO(s) + Mg(s) \rightarrow MgO(s) + Zn(s)$ [1 for reactants, 1 for products]

(iii) nothing – it would remain white in colour [1]

10 Atmosphere and oceans

1 **(a)**



(b) **(i)** nitrogen [1]

(ii) The percentage of gas **A** matches the present amount of nitrogen in the atmosphere, 78% [1]. This is known to be the largest major constituent of the air by a long way [1].

(c) The following labels should be added along the time axis of the graph:

(i) 'bacteria' about 3000 million years ago [1]

(ii) 'land plants' about 400 million years ago [1]

(iii) 'oceans' about 3800 million years ago [1].

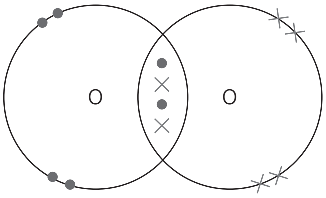
(d) Photosynthesis in the land plants [1] caused the amount of carbon dioxide to fall to its present value [1].

2 **(a)** It contains eight protons and eight electrons [1]. The electronic configuration is 2,6 [1], so there are six electrons in the outer energy level and the element belongs to Group 6 [1]. It is a non-metal [1].

(b) a molecule that contains two atoms [1] of the element bonded together [1]

(c) (double) covalent bond [1]

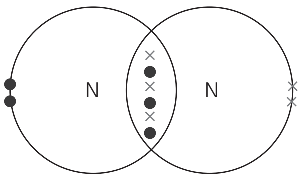
(d) [3]



(e) two from – in hospitals and by mountaineers and climbers to aid breathing, in fuel cells in spacecraft, in welding [2]

3 **(a)** It contains seven electrons and seven protons [1]. The electronic configuration is 2,5 [1], so there are five electrons in the outer energy level and the element belongs to Group 5 [1]. It is a non-metal [1].

(b)



The atoms of nitrogen are held as a diatomic molecule by the sharing of three pairs of electrons, forming a triple covalent bond. [4]

(c) **(i)** the triple covalent bond in nitrogen [1]

(ii) There are three negative electron pairs attracting the positive nuclei in nitrogen [1] compared with two negative electron pairs attracting the positive nuclei in oxygen [1] and this gives rise to a greater bond strength [1].

(d) in food packaging, (as a liquid) for freezing food [2]

4 **(a)** Group 0 **[1]**
(b) **(i)** He 2 **[1]**, Ne 2,8 **[1]**, Ar 2,8,8 **[1]**
(ii) They are unreactive because they have full outer energy levels **[1]**.
(iii) They achieve a full outer energy level **[1]** like that of the nearest inert gas **[1]**.
(c) helium – to provide an inert atmosphere for some chemical processes **[1]**
neon – in the helium–neon gas laser (these substances do not react together) **[1]**
argon – to provide an inert atmosphere in light bulbs with a tungsten filament **[1]**

5 **(a)** total = 32.07 g per dm^3 **[1]**, so 32.07/10 = 3.207 g **[1]** in 100 cm^3
(b) Sea water contains water, collected by rivers, taken from all over the world **[1]**. Hence a greater variety of substances from the land masses, as well as from the land under the oceans, is present in the water found in sea water **[1]**.
(c) **(i)** Br^- **[1]**
(ii) Cl^- **[1]**
(iii) K^+ **[1]**
(iv) Ca^{2+} **[1]**
(d) **(i)** KCl **[1]**
(ii) $CaBr_2$ **[1]**
(e) **(i)** Calcium salts are less soluble than sodium salts **[1]**.
(ii) The value for the concentration of calcium ions in solution is much lower than the value for the concentration of sodium ions in solution. **[2]**
(f) When sodium (2,8,1) or potassium (2,8,8,1) react, they lose the electron from their outer energy level **[1]**. This means that there is now one more proton (positive charge) in the nucleus than the number of electrons (negative charge) **[1]**, and hence a single positive charge on each ion **[1]**.

6 **(a)** Excess fertiliser dissolves **[1]** and runs off fields into streams and rivers during wet weather **[1]**.
(b) ammonium, NH_4^+ **[2]**, nitrate, NO_3^- **[2]**
(c) ammonium nitrate, NH_4NO_3 **[2]**
(d) **(i)** algae and marine plants **[2]**
(ii) As algae and marine plants die and decay, oxygen is removed from the water **[1]**. This leaves insufficient oxygen for fish and other organisms to survive **[1]**.

7 **(a)** Incomplete combustion takes place when there is insufficient oxygen to completely oxidise **[1]** the carbon in the hydrocarbon molecules to carbon dioxide, so that carbon monoxide is produced **[1]**.
(b) $\underline{2}C_8H_{18}(l) + 17O_2(g) \rightarrow \underline{16}CO(g) + \underline{18}H_2O(l)$ **[3]**
(c) **(i)** platinum (mixed with iridium) **[1]**
(ii) $2CO(s) + O_2(g) \rightarrow 2CO_2(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**

8 **(a)** This is a modification of the environment caused by human influence **[1]**. It is caused by gases such as sulfur dioxide, carbon monoxide and nitrogen oxides (pollutants) being released into the atmosphere by a variety of industries **[1]** and by the burning of fossil fuels **[1]**.
(b) **(i)** oil, coal and natural gas **[3]**
(ii) 64 kg **[1]**
(iii) sulfurous acid, H_2SO_3 **[2]**, sulfuric acid, H_2SO_4 **[2]**
(iv) extensive damage to forests **[1]**, increased corrosion of exposed metals **[1]** and damage to buildings and statues made from limestone and marble **[1]**
(v) flue gas desulfurisation units or FGD units **[1]**

Stretch and challenge

9 **(a)** **(i)** 96 dm^3 **[1]**
(ii) $\underline{2}NO(g) + O_2(g) \rightarrow \underline{2}NO_2(g)$ **[2]**
(iii) catalytic converter **[1]**
(b) **(i)** nitric acid, HNO_3 **[2]**
(ii) nitrogen(IV) oxide + water → nitric acid + nitrogen monoxide **[1]**
$3NO_2(g) + H_2O(g) \rightarrow 2HNO_3(aq) + NO(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**

10 (a) by filtration [1]

(b) –80 °C [1]

(c) (i) The gases and vapours would solidify and block the pipes [1], leading to a danger of explosion [1].

(ii) neon and helium [2]

(iii) oxygen and argon [2]

(iv) Their boiling points are very close together [1].

(d) The temperature is slowly raised for the liquid mixture from –200 °C [1] and held at the boiling point of the first liquid element, nitrogen, at –196 °C [1]. When this gas stops coming away from the liquid mixture, the temperature is raised again until the second liquid, argon, has boiled off at –186 °C and this gas is collected [1]. This goes on until all the gases shown in the table have been separated and collected [1].

(e) helium and neon

Exam focus

1 (a) (i) The water is passed through screens [1].

(ii) to filter out floating debris [1]

(b) to kill any remaining bacteria in the water [1]

(c) hydrochloric acid, HCl [2]

(d) to neutralise the acidic solution [1]

(e) fluoride, F^- [2]

(f) (i) Acidify the tap water with dilute nitric acid [1], then add a few drops of aqueous silver nitrate [1]. If chloride ions are present, a white precipitate will be seen [1].

(ii) Chlorine atoms have the electronic configuration $_{17}Cl$ 2,8,7 [1]. During the chemical reaction when chlorine is bubbled into the water, a change takes place and the chlorine atom gains an electron to become a chloride ion [1] with the electronic configuration Cl^- 2,8,8 [1].

2 (a) (i) carbon dioxide, CO_2 [2]

(ii) photosynthesis [1]

(iii) There is much more nitrogen in the air (78%) [1] and much less carbon dioxide (0.04%) [1]. There is no hydrogen in the air [1] and only a trace of carbon monoxide [1].

(b) The temperature in the volcano is 1000 °C, which is much higher than the boiling point of water [1].

(c) As the Earth cooled down and the temperature of the atmosphere dropped below the boiling point of water [1], the water vapour condensed into liquid water [1]. This liquid water slowly produced the oceans we have today [1].

(d) carbonic acid, H_2CO_3 [2], sulfuric acid, H_2SO_4 [2]

11 Rates of reaction

1 (a) At higher temperatures, the particles have more kinetic energy [1]. This causes them to move around more quickly [1] and collide with other particles more frequently [1]. More of the collisions will have sufficient energy to overcome the activation energy for the reaction [1].

(b) surface area [1], concentration [1], use of a catalyst [1], light [1]

(c) (i) the minimum energy required from a collision [1] for a chemical reaction to begin [1]

(ii) a collision which occurs with sufficient energy to overcome the activation energy barrier for a particular reaction so that products are produced (or a reaction occurs) [2]

2 (a) At higher concentrations there are more particles in a given volume of the solution [1] and hence more collisions between the particles [1]. Some of these extra collisions will be successful collisions, thus increasing the rate of the reaction [1].

(b) Powdered zinc has a larger surface area than strips of zinc [1]. The larger surface area allows more collisions to occur between the hydrochloric acid particles and the zinc [1]. Some of these extra collisions will have sufficient energy to overcome the activation energy barrier of the reaction [1].

(c) A catalyst lowers the activation energy of the reaction [1], allowing more of the collisions which occur to be successful collisions [1]. This increases the rate of the reaction [1].

3 (a) in all experiments, moles of Mg used = 2/24 = 0.083 mole
maximum number of moles of H_2SO_4 used = 0.1 × 40/1000 = 0.004 mole [1]
There is a 1 : 1 mole relationship in the balanced equation so magnesium is in excess [1].

(b) [1 for each]

Line	A	B	C	D	E
Experiment	II	III	I	V	IV

(c) The reaction shown by line **B** uses 2 g of powdered magnesium, which has a larger surface area **[1]** than the magnesium ribbon used in the reaction shown by line **C**. Hence more collisions occur, so more successful collisions occur and this gives a faster rate of reaction **[1]**.

(d) The reaction shown by line **D** is carried out at a higher temperature **[1]**. So the particles have more energy and move faster, causing more successful collisions to occur and hence giving rise to a faster rate of reaction **[1]**.

4 (a) $Mg(s) + 2HCl(l) \rightarrow MgCl_2(aq) + H_2(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**

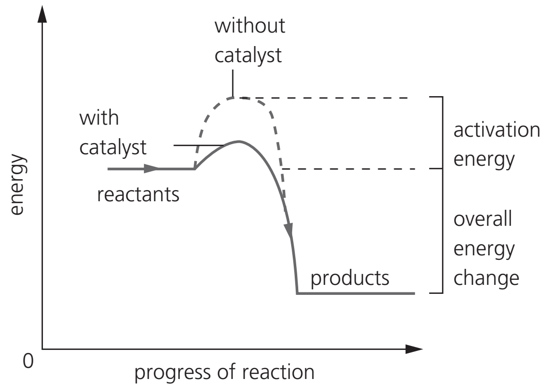
(b) Record the volume of hydrogen gas collected against time **[1]**, using a gas syringe or inverted burette to collect the gas **[1]**.

(c) (i) two from – increasing the temperature, increasing the concentration of the acid, using powdered magnesium **[2]**

(ii) two from – lowering the temperature, decreasing the concentration of the acid, using larger pieces of magnesium **[2]**

5 (a) Being catalysts, they both lower the activation energy of the reaction **[1]**, allowing more of the collisions which occur to be successful collisions **[1]**.

(b)



[3]

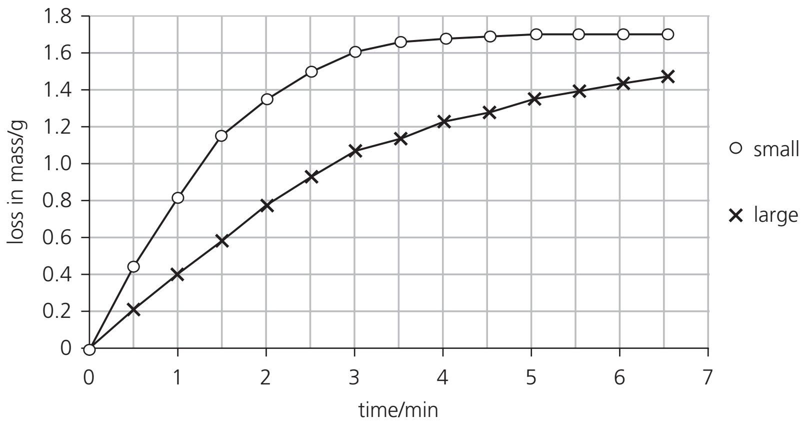
(c) Catalase, being an enzyme, denatures at temperatures over 40 °C **[1]**. Weak attractive forces in the catalase are broken and the shape of the active site changes **[1]**, preventing the hydrogen peroxide molecule from bonding to it **[1]**.

6 (a) $CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**

(b) to prevent the loss of acid spray from the flask **[1]** which would have led to increased values for the loss in mass of the flask and its contents **[1]**

(c) Carbon dioxide gas was being lost from the flask **[1]**.

(d)



[1 for scale, 1 for axis labels, 1 for points plotted correctly, 1 for best-fit lines]

(e) the reaction with the smaller chips **[1]**
The line is steeper at the beginning **[1]**.

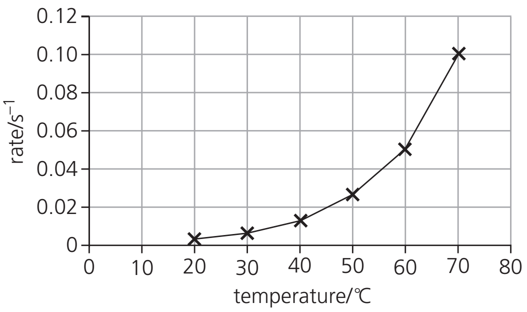
7 (a) $Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**

(b)

Temperature/°C	Rate/s^{-1}
20	
30	0.65×10^{-2}
40	
50	2.70×10^{-2}
60	5.00×10^{-2}
70	10.00×10^{-2}

[2 for all four correct, 1 for two or three correct]

(c)



[1 for scale, 1 for axis labels, 1 for points plotted correctly, 1 for best-fit line]

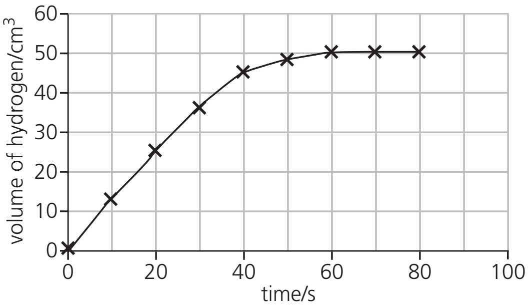
(d) (i) $1.20 \times 10^{-2}\,s^{-1}$ **[1]**

(ii) $6.60 \times 10^{-2}\,s^{-1}$ **[1]**

(e) (i) rate = $0.90 \times 10^{-2}\,s^{-1}$ **[1]**, time = 111 s **[1]**

(ii) rate = $3.50 \times 10^{-2}\,s^{-1}$ **[1]**, time = 29 s **[1]**

8 (a)



[1 for scale, 1 for axis labels, 1 for points plotted correctly, 1 for best-fit line]

(b) (i) at the beginning of the experiment **[1]**

(ii) The slope is steepest at the beginning **[1]**.

(c) $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**

(d) moles of H_2 produced = 50/24 000 = 2.08×10^{-3} mole **[1]**

moles of Na used = $2 \times 2.08 \times 10^{-3} = 4.16 \times 10^{-3}$ mole **[1]**

mass of Na used = $23 \times 4.16 \times 10^{-3}$ = 0.096 g **[1]**

(e) (i) 31 cm^3 **[1]**

(ii) 50 cm^3 **[1]**

(f) lithium **[1]**

Stretch and challenge

9 (a) $2CO(g) + 2NO(g) \rightarrow 2CO_2(g) + N_2(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**

(b) (i) carbon monoxide **[1]**

(ii) nitrogen monoxide **[1]**

(c) platinum (alloyed with small amounts of iridium) **[1]**

(d) (i) $C_8H_{18}(l) + 12\tfrac{1}{2}O_2(g) \rightarrow 8CO_2(g) + 9H_2O(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**

(ii) mass of octane burned = 5000×0.70 = 3500 g **[1]**

moles of octane burned = 3500/114 = 30.7 moles **[1]**

mass of carbon dioxide produced = $30.7 \times 44 \times 8$ = 10 806 g (10.806 kg) **[1]**

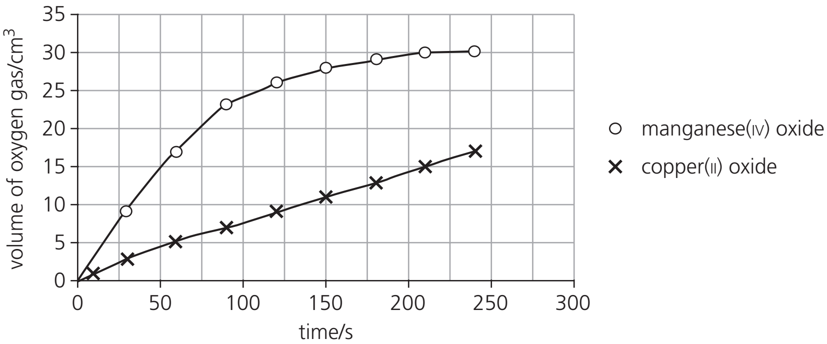
(iii) volume of carbon dioxide produced = $30.7 \times 8 \times 24$ **[1]** = 5894.4 dm^3 **[1]**

(iv) 100 g of CO is 100/28 = 3.57 moles **[1]**; produces 3.57 moles of CO_2 **[1]** = 3.57×44 = 157 g **[1]**

10 (a) a substance which speeds up a chemical reaction **[1]** without itself being chemically changed **[1]**

(b) $2H_2O_2(l) \rightarrow 2H_2O(g) + O_2(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**

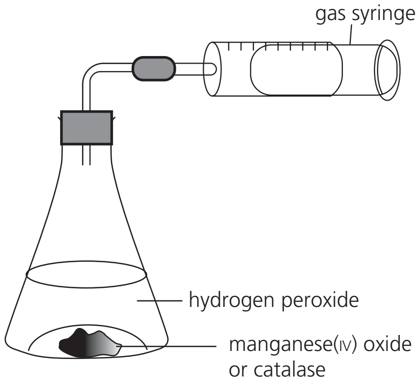
(c)



[1 for scale, 1 for axis labels, 2 for points plotted correctly, 2 for best-fit lines]

(d) manganese(IV) oxide **[1]**, steeper line so faster rate **[1]**

(e) **[4]**



(f) 5 g **[1]**, it is a catalyst so none of it is used up in the reaction **[1]** as catalysts remain chemically unchanged **[1]**

Exam focus

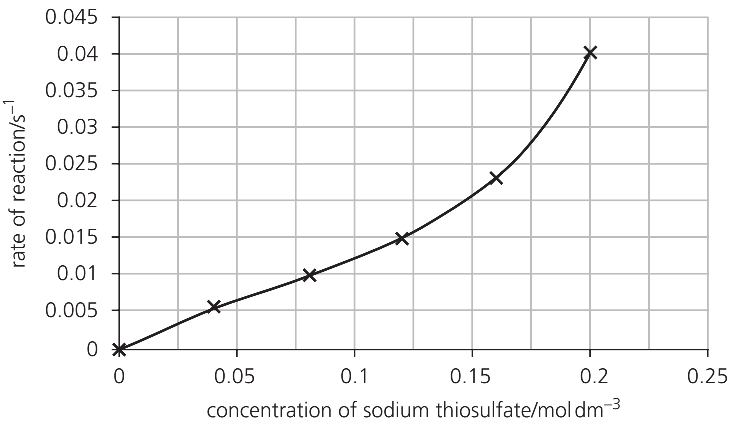
1 **(a)** to ensure a fair test **[1]**, different volumes would lead to different concentrations of hydrochloric acid **[1]**

(b) Solid yellow sulfur is formed in the reaction **[1]** so it becomes impossible to see the cross **[1]**.

(c) **[1 for each]**

Experiment	Rate of reaction/s^{-1}
1	
2	2.3×10^{-2}
3	1.5×10^{-2}
4	1.0×10^{-2}
5	0.6×10^{-2}

(d) **[1 for scale, 1 for axis labels, 1 for points plotted correctly, 1 for best-fit line]**



(e) **(i)** 0.15 mol dm^{-3} **[1]**

(ii) 45 cm^3 **[1]**

(iii) 83 s **[1]**

2 **(a)** reaction **A** **[1]**, steepest line **[1]**

(b) **(i)** reaction **A** **[1]**

(ii) reaction **C** **[1]**

(c) by using powdered zinc or more concentrated acid **[1]**

(d) $Zn(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2(g)$ **[1]**

moles of H_2 produced = 25/24 000 = 1.04×10^{-3} mole **[1]**

volume of H_2SO_4 = $1.04 \times 10^{-3} \times 1000/0.05 = 20.8\ cm^3$ **[1]**

(e) moles of H_2 produced = 50/24 000 = 2.08×10^{-3} mole **[1]**

mass of H_2 produced = $2.08 \times 10^{-3} \times 2 = 4.16 \times 10^{-3}$ g **[1]**

12 The petroleum industry

1 **(a)** ease of importing oil by sea **[1]**

(b) **(i)** The crude oil is heated to about 400 °C **[1]**. This vaporises most of the different substances in the crude oil mixture **[1]**.

(ii) naphtha **[1]**

(iii) surfacing roads **[1]**

(iv) diesel oil **[1]**

(c) **(i)** bitumen **[1]**

(ii) refinery gas **[1]**

(d) gasoline **[1]**

(e) fractionally distilled **[1]**

2 **(a)** fuel oil and bitumen, diesel oil and gasoline **[3]**

(b) **(i)** refinery gas **[1]**

(ii) They are the smallest molecules in crude oil **[1]**.

(c) 53% **[1]**

(d) carry out cracking **[1]** on the bigger molecules with lower demand, i.e. kerosene and fuel oil **[1]**

(e) reduce the price of this fraction to ensure top sales **[1]** and look for further markets for the product **[1]**

3 **(a)** acids and alkalis **[2]**

(b) complete combustion **[1]**

(c) natural gas **[1]**

(d) **(i)** It is an exothermic reaction **[1]**.

(ii) 1 mole

(iii) moles of methane = 64/16 = 4 moles **[1]**

mass of carbon dioxide = 44 × 4 = 176 g **[1]**

(iv) volume of CH_4 = volume of CO_2 **[1]**

Therefore 100 dm^3 of methane would give 100 dm^3 of CO_2 **[1]**.

4 **(a)** the process of breaking large molecules **[1]** into smaller more useful molecules **[1]**

(b) a substance that alters the rate of a chemical reaction **[1]** without itself being chemically changed **[1]**

(c) the chemical breakdown of a substance **[1]** under the influence of heat **[1]**

(d) a family of saturated hydrocarbons **[1]** with the general formula C_nH_{2n+2} **[1]**

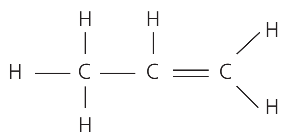
(e) molecules that possess only single **[1]** covalent bonds **[1]**

(f) molecules that contain one or more double **[1]** covalent bonds **[1]**

5 **(a)** alkenes **[1]**

(b) C_3H_6 **[1]**, C_8H_{16} **[1]**, C_6H_{12} **[1]**

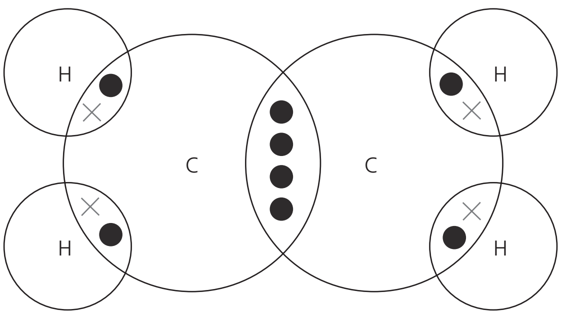
(c)



[2]

6 **(a)** a carbon–carbon double bond **[1]**

(b)



[1 for each overlap area showing the correct sharing of one or two pairs of electrons]

7 **(a)** true **[1]**

(b) false **[1]**

(c) true **[1]**

(d) true **[1]**

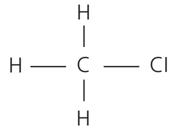
(e) false **[1]**

(f) false **[1]**

8 **(a)** statement **E** [1]
(b) statement **G** [1]
(c) statement **F** [1]
(d) statement **A** [1]
(e) statement **B** [1]
(f) statement **D** [1]
(g) statement **C** [1]

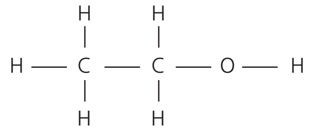
Stretch and challenge

9 **(a)** chloromethane [1]



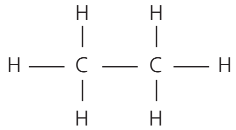
[1]

(b) ethanol [1]



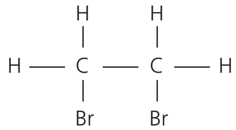
[1]

(c) ethane [1]



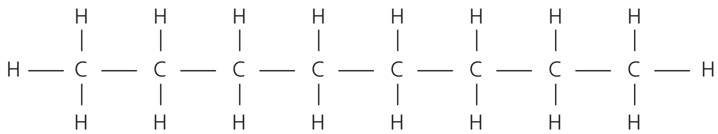
[1]

(d) 1,2-dibromoethane [1]



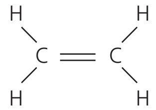
[1]

(e) octane [1]



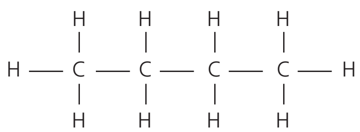
[1]

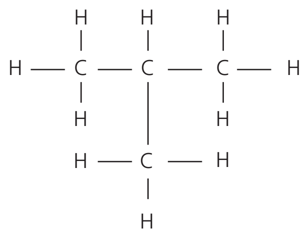
ethene [1]



[1]

10 **(a)** Isomers are compounds which have the same molecular formula [1], but different structural formulae [1], e.g. butane [1] and 2-methylpropane [1].





[2]

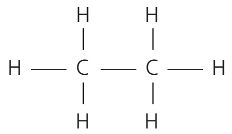
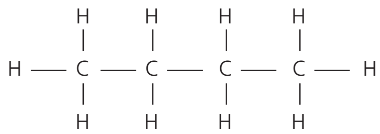
(b) **(i)** The isomer with the side chain will have lower melting and boiling points [1].
(ii) The isomer with the side chain is more compact, so the forces of attraction are less strong [1]. Hence the heat energy required to separate the molecules (to melt or boil the substance) is not so great [1].
(c) For the majority of organic compounds, a vast array of different isomer molecules is possible [1].
(d) Different isomers of carvone are present in the different foods [1] and these different isomers give rise to different tastes [1].

Exam focus

1 **(a)** homologous series – a family of organic compounds which have similar structures **[1]**, name endings **[1]** and chemical properties **[1]**, and which show a trend in their physical properties **[1]**

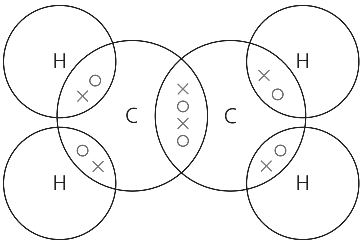
hydrocarbons – molecules that contain hydrogen and carbon atoms only **[1]**

(b) (i)

Alkane	Formula	Structure
Methane	CH_4	
Ethane		
Propane	C_3H_8	
Butane	C_4H_{10}	

[1 for each]

(ii) single **[1]** covalent bonds **[1]**

(iii) 

[4]

(iv) Decane is likely to be a liquid **[1]**.

(v) C_nH_{2n+2} **[1]**

2 **(a)** **A** paraffin-soaked mineral wool, **B** hard-glass boiling tube, **C** water, **D** gaseous alkene **[1 for each]**

(b) as a hot surface **[1]** for the alkane molecules to break up over **[1]**

(c) The substance collected over water is an unsaturated hydrocarbon **[1]** and reacts with the bromine dissolved in the organic solvent **[1]**. The substance produced, 1,2-dibromoethane, is colourless **[1]**.

(d) A star should be drawn by the delivery tube on the diagram, between the bung and the crystallising dish **[1]**.

(e) hydrogen, H_2 **[2]**

(f) **(i)** $C_{12}H_{26} \rightarrow C_4H_8 + \underline{C_8H_{18}}$ **[1]**

(ii) butene, octane **[2]**

13 Energy sources

1 **(a)** a substance which releases energy **[1]** when it is combusted **[1]**

(b) four from – cheap, available in large quantities, safe to store, safe to transport, easy to ignite, produces no pollution, releases large amounts of energy **[4]**

(c) **(i)** one from – petrol, diesel or other liquid fuel from the fractional distillation of crude oil **[1]**

(ii) e.g. coal **[1]**

(iii) e.g. natural gas **[1]**

(d) e.g. methane + oxygen → carbon dioxide + water **[1]**

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**

2 Possible answers are shown in the table below.

Source	Advantages	Disadvantages
Nuclear power	1 Does not produce CO_2 2 Renewable	1 Radioactive waste 2 Radioactive leaks
Wave power	1 Non-polluting 2 Low operation costs	1 Expensive to build infrastructure 2 Can affect ecosystems
Hydroelectric power	1 Can produce electricity quickly 2 Cheap source of energy	1 Expensive to build 2 Could require the flooding of valleys
Wind power	1 Non-polluting 2 Can generate electricity in remote locations	1 Unsightly 2 Can be noisy

[1 for each]

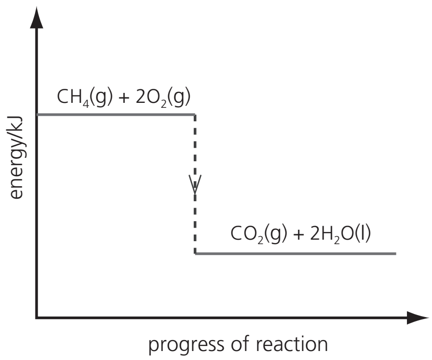
3 (a) (i) $2 \times -728 = -1456\,kJ\,mol^{-1}$ **[1]**

(ii) $0.25 \times -728 = -182\,kJ\,mol^{-1}$ **[1]**

(iii) $(8/16) \times -728 = -364\,kJ\,mol^{-1}$ **[1]**

(iv) $(64/16) \times -728 = -2912\,kJ\,mol^{-1}$ **[1]**

(b)



[1 for axes, 1 for reactants higher than products, 1 for formulae and balancing]

4 (a) $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$

breaking:

2 C—C + 8 C—H + 5 O═O

$2 \times 347 + 8 \times 413 + 5 \times 498$ **[1]** = $6488\,kJ\,mol^{-1}$ **[1]**

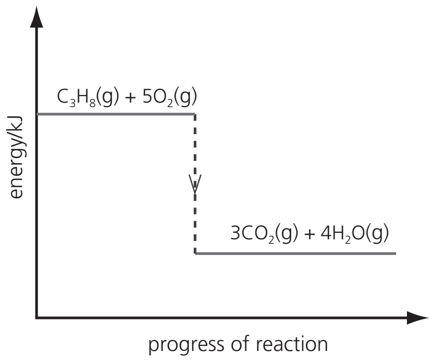
forming:

6 C═O + 8 O—H

$6 \times 805 + 8 \times 464$ **[1]** = $8542\,kJ\,mol^{-1}$ **[1]**

$\Delta H = 6488 - 8542 = -2054\,kJ\,mol^{-1}$ **[1 for value, 1 for '–' sign]**

(b)



[1 for axes, 1 for reactants higher than products, 1 for formulae and balancing]

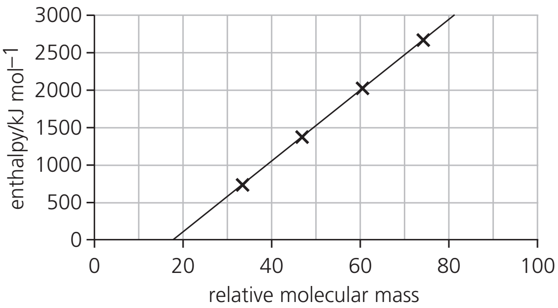
(c) (i) $0.5 \times -2054 = -1027\,kJ\,mol^{-1}$ **[1]**

(ii) $5 \times -2054 = -10\,270\,kJ\,mol^{-1}$ **[1]**

(iii) $(11/44) \times -2054 = -513.5\,kJ\,mol^{-1}$ **[1]**

5 **(a)** $H_2(g) + ½O_2(g) \rightarrow H_2O(l)$
(or $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$) **[1 for reactants, 1 for products, 1 for correct balancing, 1 for state symbols]**
(b) endothermic **[1]**, energy has to be supplied to break chemical bonds **[1]**
(c) breaking:
1 H—H + ½ O═O
1 × 436 + ½ × 498 **[1]** = 685 kJ mol^{-1} **[1]**
forming:
2 O—H
2 × 464 **[1]** = 928 kJ mol^{-1} **[1]**
ΔH = 685 − 928 = −243 kJ mol^{-1} **[1]**
(or double this if second equation given in part **(a)**)

6 **(a)**



[1 for scale, 1 for axis labels, 1 for points plotted correctly, 1 for best-fit line]

(b) **(i)** −3318 kJ mol^{-1} (±100 kJ mol^{-1}) **[1 for value, 1 for '–' sign]**
(ii) The difference between successive alcohols is a $-CH_2-$ group each time and the average enthalpy difference is −648 kJ mol^{-1} **[1]**. Using this, the enthalpy for pentan-1-ol should be around −2670 − 648 = −3318 kJ mol^{-1} **[1]**.
(c) The values get progressively larger **[1]**.

7 **(a)** **(i)** $C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**
(ii) breaking:
1 C—C + 5 C—H + 1 C—O + 1 O—H + 3 O═O
1 × 347 + 5 × 413 + 1 × 358 + 1 × 464 + 3 × 498 **[1]** = 4728 kJ mol^{-1} **[1]**
forming:
4 C═O + 6 O—H
4 × 805 + 6 × 464 **[1]** = 6004 kJ mol^{-1} **[1]**
ΔH = 4728 − 6004 = −1276 kJ mol^{-1} **[1]**
(b) energy density of ethanol = (−1276/46) **[1]** × 1000 = −27 739 kJ kg^{-1} **[1]**
energy density of hydrogen = (−286/2) **[1]** × 1000 = −143 000 kJ kg^{-1} **[1]**
(c) Hydrogen has a much higher energy density than ethanol **[1]**. 1 mole of hydrogen has a mass of 2 g whilst 1 mole of ethanol has a mass of 46 g **[1]** so there are many more moles of hydrogen in 1 kg than there are of ethanol **[1]**.

8 **(a)** −114 kJ mol^{-1} **[1]**
(b) −14.25 kJ mol^{-1} **[1]**
(c) $H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$ **[1]**
Two moles of hydrogen ions are being neutralised **[1]**.
−114 kJ mol^{-1} **[1]**
(d) −114 kJ mol^{-1} **[1]**

Stretch and challenge

9 **(a)** **(i)** $C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g)$ **[1 for reactants, 1 for products]**
(ii) breaking:
1 C═C + 4 C—H + 1 H—H
1 × 612 + 4 × 413 + 1 × 454 **[1]** = 2718 kJ mol^{-1} **[1]**
forming:
1 C—C + 6 C—H
1 × 347 + 6 × 413 **[1]** = 2825 kJ mol^{-1} **[1]**
ΔH = 2718 − 2825 = −107 kJ mol^{-1} **[1]**

(b) (i) $C_2H_4(g) + H_2O(g) \rightarrow C_2H_5OH(g)$ **[1 for reactants, 1 for products]**

(ii) breaking:

1 C═C + 4 C—H + 2 O—H

$1 \times 612 + 4 \times 413 + 2 \times 464$ **[1]** = 3192 kJ mol^{-1} **[1]**

forming:

1 C—C + 5 C—H + 1 C—O + 1 O—H

$1 \times 347 + 5 \times 413 + 1 \times 358 + 1 \times 464$ **[1]** = 3234 kJ mol^{-1} **[1]**

ΔH = 3192 – 3234 = –42 kJ mol^{-1} **[1]**

10 (a) reduction **[1]**, gain of electrons **[1]**

(b) $Mg(s) \rightarrow Mg^{2+}(aq) + 2e^-$ **[1 for reactant, 1 for product, 1 for electrons on right, 1 for state symbols]**

(c) from magnesium to copper **[1]**

(d) ions **[1]**

(e) to allow ions to move through it **[1]**

Exam focus

1 (a) 1.91 g **[1]**

(b) 20.8 °C **[1]**

(c) energy transferred = 500 **[1]** × 4.2 × 20.8 **[1]** = 43 680 J **[1]**

(d) relative molecular mass of butan-1-ol = 74 **[1]**

moles of butan-1-ol burned = 1.91/74 **[1]** = 0.026 mole **[1]**

(e) enthalpy of combustion of butan-1-ol = 43 680/0.026 **[1]**

= 1 680 000 J mol^{-1} (1680 kJ mol^{-1}) **[1 for value, 1 for units]**

2 (a) $H_2NNH_2(g) + O_2(g) \rightarrow N_2(g) + 2H_2O(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**

(b) breaking:

1 N—N + 4 N—H + 1 O═O

$1 \times 158 + 4 \times 390 + 1 \times 498$ **[1]** = 2216 kJ mol^{-1} **[1]**

forming:

1 N≡N + 4 O—H

$1 \times 946 + 4 \times 464$ **[1]** = 2802 kJ mol^{-1} **[1]**

ΔH = 2216 – 2802 = –586 kJ mol^{-1} **[1]**

(c) mass of 1 mole of hydrazine = 32 g **[1]**

energy released = (–586/32) × 240 × 10^3 **[1]** = –4 395 000 kJ **[1]**

14 The (wider) organic manufacturing industry

1 (a) a substance possessing very large molecules consisting of repeated units **[1]** and with a very large relative molecular mass **[1]**

(b) a chemical reaction **[1]** in which small molecules join together to form a polymer **[1]**

(c) a simple molecule, such as ethene **[1]**, which can be polymerised **[1]**

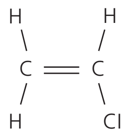
(d) a polymer (such as poly(ethene)) formed by an addition reaction **[1]** between the monomer units **[1]**

(e) a very large molecule **[1]**

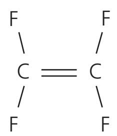
2 (a) (i) polyvinyl chloride or poly(chloroethene) **[1]**

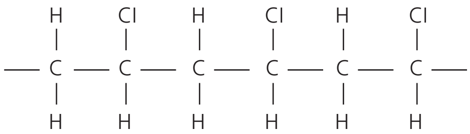
(ii) polytetrafluoroethene **[1]**

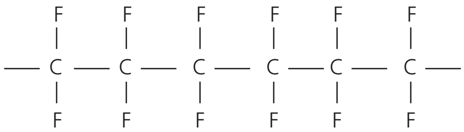
(b) (i) vinyl chloride or chloroethene **[1]**


[1]

(ii) tetrafluoroethene **[1]**


[1]

(c) (i)  [1]

(ii)  [1]

(d) (i) making pipes, electrical insulation [2]

(ii) soles of irons, non-stick lining for frying pans [2]

3 **(a)** true [1]
(b) false [1]
(c) true [1]
(d) true [1]
(e) true [1]
(f) true [1]

4 **(a)** condensation polymerisation [1]
(b) (i) 1,6-diaminohexane [1], hexanedioic acid [1]
(ii) ethane-1,2-diol [1], benzene-1,4-dicarboxylic acid [1]
(c) water, H_2O [2]
(d) (i) amide [1]
(ii) ester [1]
(e) (i) making ropes, woven into fabric [2]
(ii) woven into fabric, plastic bottles [2]
(f) In condensation polymerisation a small molecule (water) is produced during the process [1], whereas addition polymerisation is the addition of monomers without producing another product [1].

5 **(a)** [1 for each]

Alcohol	Formula
	CH_3OH
Ethanol	
	C_3H_7OH
Butanol	

(b) the atom or group of atoms [1] responsible for the characteristic reactions of a compound [1]
(c) There is an increase in the length of the hydrocarbon chain [1] which will give an increase in the attractive forces between the larger molecules compared to the smaller ones [1]. This causes an increase in the amount of heat energy required to put these molecules into the gas phase [1] and hence in the boiling point.
(d) $C_nH_{2n+1}OH$ [1]

6 **(a)** covalent [1]
(b) (i) the part containing the carbon–carbon double bond [1]
(ii) the part containing the –OH group [1]
(c) the part containing the carbon–carbon double bond [1]
(d) the part containing the –OH group [1]

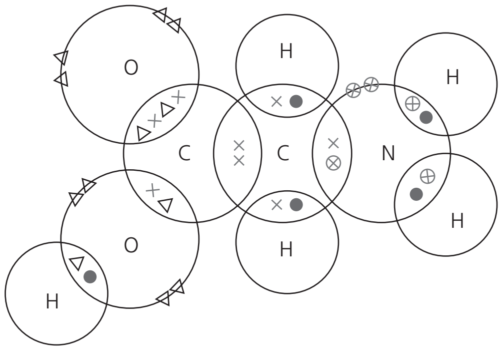
7 **(a)** a chemical reaction involving the reaction of a compound with water [1]
Acid hydrolysis usually involves dilute hydrochloric acid and enzyme hydrolysis involves enzymes [1].
(b) (i) **A** glucose, $C_6H_{12}O_6$, **B** ethanol, C_2H_5OH, **C** ethanoic acid, CH_3COOH [2 for each]
(ii) Add ethanol [1] in the presence of a strong acid catalyst [1]. Gives a sweet smell [1] (of an ester, ethyl ethanoate).
(iii) oxidising agent [1]
(iv) maltose [1]
(v) amylase [1]

8 **(a)** statement **D** [1]
(b) statement **G** [1]
(c) statement **F** [1]
(d) statement **C** [1]
(e) statement **E** [1]
(f) statement **A** [1]
(g) statement **B** [1]

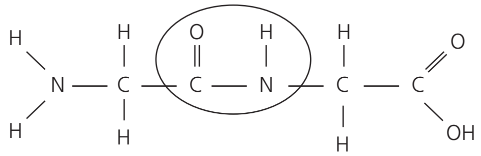
Stretch and challenge

9 **(a)** Using $M_1V_1 = M_2V_2$:
$M_1 = ?$, $V_1 = 25.00\,\text{cm}^3$, $M_2 = 0.10\,\text{mol dm}^{-3}$, $V_2 = 20\,\text{cm}^3$ [1]
$M_1 \times 25.00 = 0.10 \times 20.00$ [1]
$M_1 = 0.08\,\text{mol dm}^{-3}$ [1]
(b) mass of 1 mole of ethanoic acid = 60 g [1]
mass of ethanoic acid in 1 litre ($1\,\text{dm}^3$) bottle = $60 \times 0.08 = 4.8$ g [1]

10 **(a)** 20 [1]
(b) amine, carboxylic acid [2]
(c) [8]

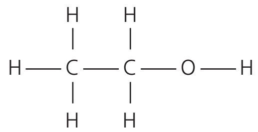


(d) **(i)** condensation polymerisation [1]
(ii) nylon [1]
(iii) a peptide composed of two amino acids [1]
(iv) [1]



■ *Exam focus*

1 **(a)** **(i)** addition polymerisation [1]
(ii) poly(ethene) [1]
(iii) Mix with bromine dissolved in 1,1,1-trichloroethane [1]. If ethene is present, the orange colour will disappear [1].
(b) **(i)** The plastic does not react with substances in the environment [1] and is not decomposed by bacteria, so it will not rot away [1]. The bags will therefore stay unchanged over many, many years [1]. They create a polluted environment and are a danger to animals [1].
(ii) In recycling, new bags are made from the existing plastic [1], saving in the costs of energy and raw materials [1].
(iii) stronger [1] (and more flexible)
(c) **(i)** a substance which cannot be further divided into simpler substances [1] by chemical methods [1]
(ii) hydrocarbon [1]
(iii) exothermic [1]
(iv) Plastics contain substances called plasticisers [1] which are added to enhance the properties of the plastic [1]. When these plasticisers burn, they can give off poisonous gases such as hydrogen cyanide [1].

2 (a)  **[1]**

(b) (i) $C_6H_{12}O_6(aq) \rightarrow \underline{2}C_2H_5OH(l) + \underline{2}CO_2(g)$ **[2]**

(ii) glucose **[1]**

(iii) 180 **[1]**

(c) (i) oxidation **[1]**

(ii) carboxylic acids **[1]**

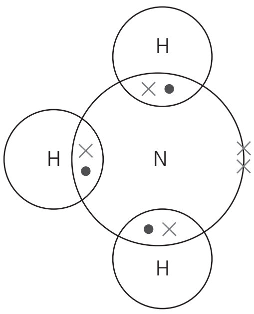
(iii) ethyl ethanoate, $CH_3COOC_2H_5$ **[2]**

(iv) concentrated sulfuric acid **[1]**

(v) a reaction that can go both ways **[1]**

This means that once some of the products have been formed they will undergo a chemical change to re-form the reactants once more **[1]**. The reaction from left to right is known as the forward reaction **[1]** whilst the reaction from right to left is known as the back reaction **[1]**.

15 Nitrogen

1 (a)  **[1]**

(b) $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ **[1 for reactants, 1 for products, 1 for correct balancing, 1 for 'reversible' arrows]**

(c) exothermic **[1]**, the products are at a lower energy than the reactants **[1]**, showing energy is given out when the reaction occurs **[1]**

(d) (i) ΔE_1 **[1]**

(ii) ΔE_3 **[1]**

(iii) ΔE_2 **[1]**

(e) (i) to increase the rate of the reaction **[1]**, so that lower temperatures can be used **[1]**

(ii) larger surface area **[1]**, increases the rate of reaction **[1]**

2 (a) (i) $HNO_3(aq) + KOH(aq) \rightarrow KNO_3(aq) + H_2O(l)$ **[1 for reactants, 1 for products]**

(ii) $2HNO_3(aq) + Na_2CO_3(s) \rightarrow 2NaNO_3(aq) + H_2O(l) + CO_2(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**

(iii) $2HNO_3(aq) + CuO(s) \rightarrow Cu(NO_3)_2(aq) + H_2O(l)$ **[1 for reactants, 1 for products, 1 for correct balancing]**

(b) Add copper(II) carbonate solid to a beaker containing dilute nitric acid **[1]**. Stir the mixture and keep adding copper(II) carbonate until the effervescence **[1]** stops and there is some solid at the bottom of the beaker **[1]**. Filter off the excess solid, allowing the filtrate to run into an evaporating basin **[1]**. Heat the solution until half of it evaporates **[1]**. Allow the remaining solution to cool to allow the copper(II) nitrate crystals to form slowly **[1]**.

3 (a) (i) methane, CH_4 **[2]**

(ii) nitrogen, N_2 **[2]**

(iii) nitrogen monoxide, NO **[2]**

(iv) nitrogen dioxide, NO_2 **[2]**

(b) (i) iron **[1]**

(ii) platinum **[1]**

(c) fractional distillation of liquid air **[1]**

Air is liquefied and the temperature is slowly raised **[1]**. As each gas reaches its boiling point, it is removed and stored **[1]**.

(d) $NH_3(g) + HCl(aq) \rightarrow NH_4Cl(aq)$ **[1 for reactants, 1 for products]**

(e) $HNO_3(aq) + NaOH(aq) \rightarrow NaNO_3(aq) + H_2O(l)$ **[1 for reactants, 1 for products]**

4 **(a)** $HNO_3(aq) + NH_3(g) \rightarrow NH_4NO_3(aq)$ **[1 for reactants, 1 for products]**

(b) **(i)** moles of $HNO_3 = 1 \times 10^6/63 = 15873$ moles **[1]**
moles of NH_3 needed = 15873 moles **[1]**
mass of NH_3 needed = 15873 × 17 = 269841 g (269.841 kg) **[1]**

(ii) moles of NH_3 used = 15873 moles **[1]**
moles of NH_4NO_3 made = 15873 moles **[1]**
mass of NH_4NO_3 made = 15873 × 80 = 1269840 g (1269.84 kg) **[1]**

(c) mass of nitrogen in NH_4NO_3 = 2 × 14 = 28 g **[1]**
percentage of nitrogen = 28 × 100/80 = 35% **[1]**

5 **(a)** ammonium chloride **[1]**

(b) calcium hydroxide **[1]**

(c) $Ca(OH)_2(s) + 2NH_4Cl(s) \rightarrow CaCl_2(s) + 2NH_3(g) + 2H_2O(l)$ **[1 for reactants, 1 for products, 1 for correct balancing]**

(d) calcium oxide **[1]**

(e) blue **[1]**

(f) It is less dense than air **[1]**.

6 **(a)** Five (or more) from:

- 25 cm^3 of the potassium hydroxide solution is placed in a conical flask using a pipette and safety filler.
- three or four drops of phenolphthalein (or methyl orange) indicator are added to the potassium hydroxide solution.
- A burette is filled to the zero mark with the nitric acid solution, ensuring that some runs through the valve, and the initial burette reading is taken.
- The acid is carefully added from the burette into the flask, with swirling, until the colour of the indicator just changes.
- The final burette reading is taken and the volume of acid needed to neutralise the potassium hydroxide is found.
- The process is repeated to obtain three concordant results (within 0.10 cm^3 of each other). **[5]**

(b) $HNO_3(aq) + KOH(aq) \rightarrow KNO_3(aq) + H_2O(l)$ **[1 for reactants, 1 for products]**

(c) moles of HNO_3 used = 0.05 × 21.65/1000 **[1]** = 1.08×10^{-3} mole **[1]**

(d) 1.08×10^{-3} mole **[1]**

(e) concentration of KOH = $1.08 \times 10^{-3} \times 1000/25$ **[1]** = 0.043 mol dm^{-3} **[1]**

7 **(a)** $\underline{6}NO(g) + \underline{4}NH_3(g) \rightarrow \underline{5}N_2(g) + \underline{6}H_2O(g)$ **[4]**

(b) **(i)** moles of NO = 16/30 = 0.533 mole **[1]**
moles of NH_3 = 0.533 × 4/6 = 0.356 mole **[1]**
mass of NH_3 = 0.356 × 17 = 6.052 g **[1]**

(ii) moles of N_2 gas produced = 0.533 × 5/6 = 0.444 mole **[1]**
volume of N_2 gas produced = 0.444 × 24 = 10.656 dm^3 **[1]**

(c) total mass of NO produced on the journey = 20 × 200 = 4000 g **[1]**
mass of ammonia needed = (4000/30) × (5/6) × 17 = 1889 g (1.89 kg) **[1]**

8 **(a)** **(i)** proteins **[1]**

(ii) potassium **[1]**, phosphorus **[1]**

(b) **(i)** one from – pea, bean, clover **[1]**

(ii) by adding fertiliser to the soil **[1]**

(c) **(i)** 16.47% **[1]**

(ii) 28.19% **[1]**

(iii) 46.67% **[1]**

(iv) 21.21% **[1]**

Stretch and challenge

9 **(a)** $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ **[1 for reactants, 1 for products, 1 for correct balancing, 1 for 'reversible' arrows]**

(b) **(i)** high pressures **[1]**
At high pressures the equilibrium moves to the right **[1]**. There are fewer moles of gas on the right hand side of the equation **[1]** so this move reduces the pressure and offsets the change made **[1]**.

(ii) 200 atmospheres **[1]**

(c) **(i)** low temperatures **[1]**
The forward reaction is exothermic **[1]**. Low temperatures favour the exothermic reaction **[1]** as this reaction will release heat energy and offset the change made **[1]**.

(ii) 450 °C [1]

(iii) Although a low temperature would give more ammonia [1], the rate of the reaction would be very slow [1]. An optimum or compromise temperature is used to produce sufficient ammonia at a fast enough rate [1].

(d) platinum [1]

10 (a) (i) calcium [1]

(ii) Chloride ions are present [1].

(iii) $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$ [1 for reactants, 1 for products]

(b) (i) potassium [1]

(ii) sulfate [1]

(iii) $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$ [1 for reactants, 1 for products]

(c) (i) copper [1]

(ii) carbonate [1]

(d) (i) $CaCl_2$ [1]

(ii) K_2SO_4 [1]

(iii) $CuCO_3$ [1]

Exam focus

1 (a) nitrogen from air [1], hydrogen from methane [1]

(b) (i) $2NH_3(g) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(aq)$ [1 for reactants, 1 for products, 1 for correct balancing]

(ii) moles of H_2SO_4 = 49/98 = 0.5 mole [1]

moles of $(NH_4)_2SO_4$ produced = 0.5 mole [1]

relative formula mass of ammonium sulfate = 132 [1]

maximum mass of $(NH_4)_2SO_4 = 0.5 \times 132 = 66$ g [1]

(iii) percentage yield = $40 \times 100/66$ [1] = 60.6% [1]

2 (a) (i) Increasing the pressure increases the yield of ammonia [1] at any temperature [1].

(ii) Decreasing the temperature increases the yield of ammonia [1].

(b) As the pressure is increased, the position of equilibrium will move to the right [1] as this produces fewer moles of gas [1], lowering the pressure of the system [1].

(c) The production of ammonia is an exothermic process (negative sign) [1]. A decrease in temperature would favour the exothermic reaction [1]. As the yield of ammonia increases with decreasing temperature, the forward reaction must be exothermic [1].

(d) 25% [1]

(e) Although more ammonia [1] would be produced at lower temperatures, the rate at which it was produced would be too slow [1].

16 Sulfur

1 (a) 16 [1]

(b) 16 [1]

(c) 6 [1]

(d) Group 6 [1]

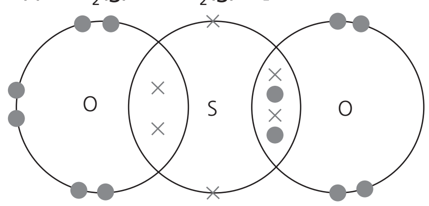
(e) two from – oxygen, selenium, tellurium, polonium [2]

(f) making sulfuric acid, vulcanising rubber [2]

2 (a) sulfur + oxygen → sulfur dioxide [1]

$S(s) + O_2(g) \rightarrow SO_2(g)$ [1 for reactants, 1 for products]

(b) [4]



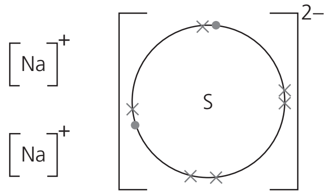
(c) covalent [1]

3 **(a)** **(i)** Carbon dioxide from the air dissolves in rainwater **[1]** to give carbonic acid, H_2CO_3 **[1]**.
(ii) about pH 5.7 **[1]**
(iii) nitric acid, HNO_3 **[2]**
(b) **(i)** between pH 3 and pH 4 **[1]**
(ii) two from – destroys forests, corrodes metal, corrodes structures and statues made from limestone or marble **[2]**

4 **(a)** **A** sodium hydroxide, NaOH, **B** magnesium sulfate, $MgSO_4$, **C** hydrogen, H_2, **D** water, H_2O, **E** copper(II) sulfate, $CuSO_4$ **[2 for each]**
(b) sulfuric acid + sodium hydroxide (**A**) → sodium sulfate + water **[1]**
$H_2SO_4(aq) + NaOH(aq) \rightarrow Na_2SO_4(aq) + H_2O(l)$ **[1 for reactants, 1 for products]**
sulfuric acid + magnesium → magnesium sulfate (**B**) + hydrogen (**C**) **[1]**
$H_2SO_4(aq) + Mg(s) \rightarrow MgSO_4(aq) + H_2(g)$ **[1 for reactants, 1 for products]**
sulfuric acid + copper(II) oxide → copper(II) sulfate (**D**) + water (**E**) **[1]**
$H_2SO_4(aq) + CuO(s) \rightarrow CuSO_4(aq) + H_2O(l)$ **[1 for reactants, 1 for products]**
(c) Put a lighted wooden splint to the mouth of a test-tube containing gas **C** **[1]**. A squeaky pop confirms that it is hydrogen **[1]**.

5 **(a)** a salt that is formed when all the replaceable hydrogen of an acid **[1]** is completely replaced by metal ions or the ammonium ion **[1]**
(b) Acidify a solution of the substance with dilute hydrochloric acid **[1]**, then add a few drops of aqueous barium chloride **[1]**. If a white precipitate appears, a soluble sulfate is present **[1]**.
(c) **(i)** sodium hydrogensulfate, $NaHSO_4$ **[2]**
(ii) a salt that is formed when some of the replaceable hydrogen of an acid **[1]** is replaced by metal ions or the ammonium ion **[1]**

6 **(a)** **[4]**



(b) soluble in water **[1]**, crystalline solid **[1]**, high melting and boiling points **[1]**
(c) **(i)** yes **[1]**
(ii) The ions in Na_2S separate when the substance is molten **[1]** and are free to move to the oppositely charged electrodes **[1]**.

7 **(a)** false **[1]**
(b) true **[1]**
(c) true **[1]**
(d) false **[1]**
(e) true **[1]**
(f) true **[1]**

8 **(a)** statement **E** **[1]**
(b) statement **F** **[1]**
(c) statement **D** **[1]**
(d) statement **G** **[1]**
(e) statement **C** **[1]**
(f) statement **A** **[1]**
(g) statement **B** **[1]**

Stretch and challenge

9 **(a)** Using $M_1V_1 = M_2V_2$:
$M_1 = ?$, $V_1 = 25.00\,cm^3$, $M_2 = 0.10\,mol\,dm^3$, $V_2 = 15\,cm^3$ **[1]**
$M_1 \times 25.00 = 0.10 \times 15.00$ **[1]**
$M_1 = 0.06\,mol\,dm^{-3}$ **[1]**
(b) mass of 1 mole of sulfuric acid = 98 g **[1]**
mass in 1 litre (1 dm^3) of acid rain = 98 × 0.06 **[1]**
mass in 1000 litres (1000 dm^3) of acid rain = 98 × 0.06 × 1000 = 5880 g **[1]**
(c) iron + sulfuric acid → iron(II) sulfate + hydrogen **[1]**
$Fe(s) + H_2SO_4(aq) \rightarrow FeSO_4(aq) + H_2(g)$ **[1 for reactants, 1 for products]**

10 **(a)** $Fe_2O_3(s) + \underline{3}H_2SO_4(aq) \rightarrow Fe_2(SO_4)_3(aq) + \underline{3}H_2O(l)$ [2]

(b) Initially the acid reacts with the rust and cleans the steel [1]. If left in too long, however, the iron in the steel reacts with the acid [1], reducing the thickness of the steel [1].

(c) ammonium sulfate [1]

(d) (i) The acidity of the sulfuric acid solution is destroyed by the addition of the ammonia solution [1]. Destroying the acidity means removing the H^+ ions from the solution [1] by reaction with OH^- ions from the ammonia solution [1].

(ii) M_r for sulfuric acid = 98 [1]
M_r for ammonium sulfate = 132 [1]
196 = 2 × 98; produces 2× that shown [1]
So 196 tonnes of sulfuric acid produces 2 × 132 = 264 tonnes of ammonium sulfate [1].

Exam focus

1 **(a)** speeds up the reaction [1], reduces costs [1] by reducing the temperature needed for a reasonable yield of sulfur trioxide [1]

(b) vanadium(v) oxide, V_2O_5 [2]

(c) sulfur dioxide + oxygen → sulfur trioxide [1]
$2SO_2(g) + 3O_2(g) \rightarrow 2SO_3(g)$ **[1 for reactants, 1 for products, 1 for correct balancing]**

(d) There are some reactants remaining [1], due to a small amount of the products breaking down when produced [1].

(e) (i) oleum [1]

(ii) The reaction of sulfur trioxide with water is highly exothermic [1]. If water was added directly to the sulfur trioxide, the reaction would overheat and run out of control, which is highly dangerous [1].

(f) Water is added to the sulfur trioxide in the form of the 2% water in concentrated sulfuric acid [1].
$H_2S_2O_7(l) + H_2O(l) \rightarrow 2H_2SO_4(l)$ **[1 for reactants, 1 for products, 1 for correct balancing]**

(g) two from – making paints, pigments, plastics [2]

2 **(a)** $CO_3^{2-}(s) + 2H^+(aq) \rightarrow CO_2(g) + H_2O(l)$ **[1 for reactants, 1 for products, 1 for correct balancing]**

(b) oxides of nitrogen [1]

(c) (i) M_r for calcium carbonate = 100 [1]
mass of 1 mole of calcium carbonate = 100 g [1]
So 150 g of calcium carbonate contains 1.5 moles [1].

(ii) M_r for carbon dioxide = 44 [1]
1.5 moles of calcium carbonate will produce 1.5 moles of carbon dioxide [1].
1.5 × 44 = 66 g [1]

(iii) The general industrial activity of humans has increased [1]. This means that more fossil fuels, which contain sulfur, will be burned [1]. Hence more sulfur dioxide is produced and dissolves in rainwater, producing more sulfuric acid [1].

Past exam questions

1 All about matter

1 **(a)** Substance containing only 1 type of atom/substance which cannot be broken down to any other substance by chemical means [1]

(b) B [1]

(c) A + D (both needed) [1]

(d) (i) C [1]

(ii) carbon [1]

(iii) drill bits/for cutting OWTTE [1]

(e) Any 3 of:
conducts heat/conducts electricity/malleable/ductile/sonorous/shiny NOT: silvery/high melting OR boiling points [3]

(f) (i) alloy(s) [1]

(ii) mild steel → car bodies;
stainless steel → chemical plant;
aluminium → aircraft ALLOW car bodies;
copper → electrical wiring [4]

2 Elements, compounds and mixtures

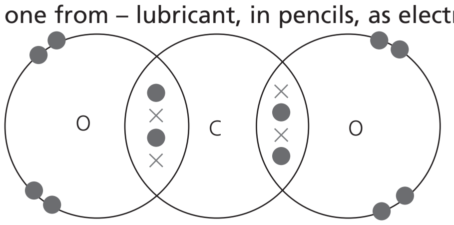
2 **(a)** substance **E** [1]
(b) substances **A**, **C**, **E** [1]
(c) substance **A** [1]
(d) substance **F** [1]
(e) substance **C** [1]
(f) substances **D**, **F** [1]

3 Atomic structure and the periodic table

3 **(a)** **(i)** D [1]
(ii) E [1]
(iii) B or F [1]
(iv) B [1]
(v) A [1]
(b) **(i)** CF_2 or CaI_2 [1]
COND next two marks conditional on correct formula C^{2+} and F^- or Ca^{2+} and I^- [1]
7× and 1o round F/I [1]
NOTE covalent = 0
Ignore electrons around Ca accept arrow notation arrow from electron on calcium atom to iodine
(ii) high melting point or boiling point
conducts when molten or in solution
soluble in water
brittle
correct chemical properties
hard
Any TWO [2]
NOT crystalline solid NOT does not conduct as a solid

4 Bonding and structure

4 **(a)** **(i)** Diamond is a macromolecular structure [1] in which all the carbon atoms are held in position to four other carbon atoms, all by strong bonds [1].
(ii) one from – jewellery, drill bits, cutting tools, engraving tools, cutting edges in scalpels [1]
(iii) Graphite has a layer or sheet structure [1] where the layers can slide over each other easily [1].
(iv) one from – lubricant, in pencils, as electrodes [1]
(b) **(i)**



[1 + 1 for four electrons between carbon and oxygens, 1 for two non-bonding pairs on both oxygens]

(ii) This is because there are four O atoms around each Si atom [1] and there are two Si atoms around each O atom [1].
(iii) two from:
- SiO_2 will have higher melting and boiling points [1]
- SiO_2 will be a solid and CO_2 will be a gas (at r.t.p.) [1]
- when both substances are solids, SiO_2 will be harder [1]
- SiO_2 has higher density than CO_2 [1]
- SiO_2 will be insoluble whilst CO_2 will be soluble [1]

5 Chemical calculations

5 **(a)** 72/24 = 3 and 28/14 = 2 [1]
Mg_3N_2 [1]
accept just formula for [2] even with incorrect or no working
NOT ecf
(b) $Al_4C_3 + 12H_2O = 4Al(OH)_3 + 3CH_4$ [2]
For Al_4C_3 ONLY [1]

(c) (i) silicon is limiting reagent [1]
0.07 moles of Si and 25/160 = 0.156 moles of Br_2 [1]
because 0.14 (2 × 0.07) < 0.156 [1]
If 80 used to find moles of Br_2 the mark 1 and 3 still available
arguments based on masses can be used
(ii) 0.07 [1]
NOT ecf

6 Electrolysis and its uses

6 **(a)** decomposition [1]
(b) The ions must be able to move and this is possible in the molten material [1].
(c) The cryolite lowers the melting point of the electrolyte [1].
(d) **B** [1]
(e) anode – oxygen [1]
cathode – aluminium [1]
(f) The oxygen produced at the anode reacts with the carbon anodes at high temperature [1], producing carbon dioxide [1].
(g) $Al^{3+} + \underline{3}e^- \rightarrow Al$ [1]
(h) one from – used to make aircraft bodies, car bodies, saucepans, electricity cables, food containers, drinks cans, window frames, cooking foil [1]

7 Acids, bases and salts

7 **(a)** pH < 7 [1]
example [1]
pH > 7 [1]
example [1]
NOT amphoteric oxides Be, Al, Zn, Pb, Sn etc
pH = 7 [1]
example H_2O, CO, NO [1]
the two marks are not linked, mark each independently
NOT amphoteric oxides Be, Al, Zn, Pb, Sn etc.
(b) **(i)** shows both basic and acidic properties [1]
(ii) a named strong acid [1]
a named alkali [1]

8 Inorganic carbon chemistry

8 **(a)** **(i)** heating (calcium carbonate in a furnace) [1]
(ii) $CaCO_3 \rightarrow CaO + CO_2$ [1]
(iii) One from: neutralising (acid) soil/neutralising industrial waste [1]
(b) **(i)** Left to right: thermometer; flask; measuring cylinder [3]
(ii) calcium carbonate + hydrochloric acid → calcium chloride + carbon dioxide + water
(1 mark for correct reactants; 1 mark for correct products) [2]
(iii) between 81 and 90s – best answer 86s [1]
(iv) slope of graph steeper and always above other line [1]
graph flattens out at 80 cm3 gas; [1]
(v) (speed) decreased/less/slower [1]
(speed) increased/more/faster [1]

9 Metal extraction and chemical reactivity

9 **(a)** Haematite. [1]
(b) **(i)** Limestone. [1]
(ii) C. [1]
(c) **(i)** $2C + O_2 \rightarrow 2CO$ [1 for O_2, 1 for balancing]
(ii) It is toxic/poisonous to humans. [1]
(d) The iron gets reduced and the carbon gets oxidised. [1]

(e) It is a more reactive metal than iron [1] and carbon is not able to reduce the aluminium oxide. [1]

(f) (i) Electrolysis. [1]

(ii) Drinks cans, baking foil, power cables, alloys [1]

10 Atmosphere and oceans

10 (Part of this question also requires knowledge from Chapter 11.)

(a) (i) one from – argon, krypton, helium, xenon, radon [1]

(ii) water and carbon dioxide [2]

(b) (i) one from – sulfur dioxide, lead compounds, CFCs, methane, particulates, unburnt hydrocarbons, ozone [1]

(ii) by the incomplete combustion [1] of a fossil fuel such as coal, oil etc. [1]

(iii) at high temperatures inside the engine [1]; at these high temperatures nitrogen and oxygen (from the air) react together [1].

(iv) The catalyst in the converter helps the changes of carbon monoxide to carbon dioxide [1] and oxides of nitrogen to nitrogen [1]. [Also the word or symbol equation would suffice:

nitrogen monoxide + carbon monoxide $\rightarrow$ carbon dioxide + nitrogen [2]

$2NO + 2CO \rightarrow CO_2 + N_2$ [2]

Also an explanation using redox, such as: the oxides of nitrogen oxidise carbon monoxide to carbon dioxide [1], whilst they are reduced to nitrogen [1].]

11 Rates of reaction

11 (a) (i) Temperature. [1]

(ii) Mass/particle size of manganese(IV) oxide [1]

(b) (i) Speed increases as the hydrogen peroxide concentration increases. [1]

(ii) The experiment which gave Graph B used twice as many hydrogen peroxide molecules. [1]

(iii) 25s [1]

$37cm^3$ [1]

(c) Worst catalyst → Best Catalyst

magnesium oxide copper(II) oxide manganese(IV) oxide lead(IV) oxide [1]

12 The petroleum industry

12 (a) fractional distillation [1]

(b) two from – refinery gas, naphtha, fuel oil, lubricating oil fractions, residue [2]

(c) one from – for use as a fuel in oil stoves, aircraft and car engines, for making more petrol [1]

(d) structures **A** and **D** [1; both needed]

(e) ethane, unreactive, oxygen, water [4]

(f) saturated – the molecule has only single bonds joining the atoms together [1]

hydrocarbon – a compound containing hydrogen and carbon only [1]

13 Energy sources

13 (a) $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$/$Zn + 2H^+ \rightarrow Zn^{2+} + H_2$ [1 for reactants, 1 for products]

(b) All chemical cells produce electrical energy so they are exothermic. [1]

They are redox reactions because electrons are being lost (by the zinc) [1] and gained (by the hydrogen ions). [1]

(c) Zinc. [1]

It loses its electrons more easily than iron. [1]

(d) 2 of:

Increase the concentration of the sulfuric acid.

Replace the zinc electrode with a more reactive metal.

Replace the iron electrode with a less reactive metal.

14 The (wider) organic manufacturing industry

14 (Part of this question also requires knowledge from Chapters 5, 7, 9 and 12.)

(a) two from – the molecules within a homologous series have the same general formula [1], the same chemical properties [1], the same functional group [1], the physical properties vary in a predictable way [1], the molecules have common methods of preparation [1] and consecutive members differ by CH_2 [1]

(b) (i) $2HCOOH + CaCO_3 \rightarrow Ca(HCOO)_2 + \underline{CO_2} + \underline{H_2O}$ **[2; only 1 if the equation is not balanced]**
(ii) zinc + methanoic acid → <u>zinc methanoate</u> + <u>hydrogen</u> **[1 for each product]**
(iii) The aluminium is protected by an oxide layer **[1]**.

(c) name – butanoic acid **[1]**
molecular formula – $CH_3—CH_2—CH_2—COOH$ or $C_4H_8O_2$ or C_3H_7COOH or C_4H_7OOH **[1]**
empirical formula – C_2H_4O **[1]**

15 Nitrogen

15 (a) potassium, phosphorus, nitrogen **[3]**

(b) two from:
- plants take up nitrogen / phosphorus / potassium to grow healthily
- nitrogen / phosphorus / potassium needs to be replaced as previous crops grown have removed these important elements
- to enable plant growth / greater yield **[2]**

(c) (i) The salt dissolves (or idea of dissolving) in water **[1]**.
(ii) by the titration of an acid with an alkali **[1]**

(d) ammonia **[1]**

(e) (i) calcium oxide or lime **[1; allow calcium hydroxide (slaked lime) / calcium carbonate (limestone)]**
(ii) Plants grow best at a particular pH / to get best yield **[2]**.

(f) (i) 4 **[1]**
(ii) 15 **[1]**

16 Sulfur

16 (Part of this question also requires knowledge from Chapter 5.)

(a) (i) from oil refineries and natural gas (it is an impurity in these fossil fuels) **[1]**
(ii) one from – used for making bleach for wood pulp (making paper), bleaching cloth or straw, used to preserve food and also for sterilising equipment for wine making, used as a fumigant or refrigerant **[1]**
(iii) vanadium(V) oxide (vanadium pentoxide, V_2O_5) **[1]**
(iv) The lower temperature causes the rate to be too slow (and it is not economic) **[1]**.
(v) because the reaction is too violent and a mist is formed **[1]**

(b) (i) Add water to the yellow powder or to the anhydrous $FeSO_4$ **[1]**; it would go green **[1]**.
(ii) a colour change from purple (or pink) **[1]** to colourless **[1]**
(iii) H_2SO_3 reacts with oxygen in air to form H_2SO_4 **[1]**

(c) number of moles of $FeSO_4$ used = 9.12/152 = 0.06 **[1]**
number of moles of Fe_2O_3 formed = 0.03 **[1]**
mass of 1 mole of Fe_2O_3 = 160 g **[1]**
mass of iron(III) oxide formed = 0.03 × 160 = 4.8 g **[1]**
total number of moles of gas formed = 0.03 **[1]**
volume of sulfur trioxide formed = 0.03 × 24 = 0.72 dm^3 **[1]**