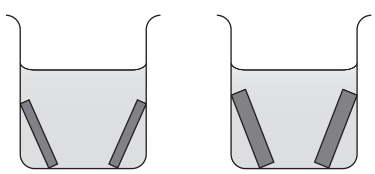
Collins CSEC® Chemistry Workbook answers

A1 States of matter

1. a) i) Ammonium chloride **(1)**
   ii) Diffusion
   Diffusion is the movement of particles from an area of higher concentration to an area of lower concentration until the particles are evenly distributed. **(2)**
   iii) The ammonia solution gave off ammonia gas and the hydrochloric acid gave off hydrogen chloride gas. The particles of the two gases diffused along the tube, collided and reacted to form ammonium chloride. **(3)**

   b) i)
   
   (1)
   ii) The distilled water had a higher water content than the cytoplasm inside the paw paw cells and the cell membranes were differentially permeable. The water molecules were able to move through the membranes into the cells causing the cells to swell and the strips to increase in volume. **(3)**
   iii) Osmosis **(1)**

   c) Sodium chloride draws water out of the cells of the fish and any micro-organisms by osmosis. Water is, therefore, not available for chemical reactions in the cells, some of which cause decay, and micro-organisms can't grow. **(2)**

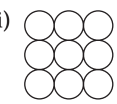
2. a)

Property	**Solid**	**Liquid**	**Gas**
Volume		definite	variable; the volume is the same as the entire container
Arrangement of particles	packed closely together, usually in a regular way		randomly arranged with large spaces between
Energy of particles	have very small amounts of kinetic energy	have medium amounts of kinetic energy	

(6)

   b) i) The particles have large spaces between them, so they can be easily pushed closer together. **(1)**
   ii) The particles are packed tightly together with very little empty space between. **(1)**
   iii) The particles move around rapidly and have weak forces of attraction between them, so they spread out to fill any available space in the container. **(2)**

   c) i) **A:** Melting **B:** Boiling or evaporation
   C: Freezing **D:** Condensation **(4)**
   ii) Iodine or carbon dioxide or ammonium chloride or naphthalene **(1)**

   d) i) Liquid **(1)**
   ii) 56 °C **(1)**
   iii)
   
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A2 Mixtures and separations

1. a) i)

	Pure substance	**Mixture**
Composition		variable
Properties	fixed and constant	variable; the components retain their individual properties

(3)

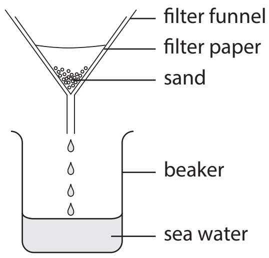
   ii) An element is a pure substance that cannot be broken down into any simpler substances by any ordinary chemical or physical means. A compound is a pure substance that contains two or more different types of element that are bonded together chemically in fixed proportions and in such a way that their properties have changed. **(2)**

   b) i) The particles in a suspension are larger than those in a colloid. **(1)**
   ii) The particles in a suspension settle if left undisturbed, whereas the particles in a colloid never settle. **(1)**
   iii) Light does not pass through a suspension, whereas most colloids scatter light. **(1)**

   c) i) A solution is a homogeneous mixture consisting of two or more components, one of which is usually a liquid. **(1)**
   ii) Solubility is the mass of solute that will saturate 100 g of solvent at a given temperature. **(1)**

   d) i) 17 g per 100 g water **(1)**
   ii) 45 °C **(1)**
   iii) At 76 °C, 54 g of **Z** saturate 100 g water
   At 10 °C, 12.5 g of **Z** saturate 100 g water
   ∴ mass of **Z** crystallising out of a saturated solution containing 100 g water = 54 – 12.5 g
   = **41.5 g** **(3)**
   iv) At 62 °C, 39 g of **Z** saturate 100 g water
   ∴ at 62 °C, 45 g of **Z** saturate $\frac{100}{39} \times 45$ g water
   = **115.4 g of water** **(2)**
   v) At 55 °C, 33 g of **Z** saturate 100 g water
   ∴ at 55 °C, $\frac{33}{100} \times 350$ g of **Z** saturate 350 g water =
   115.5 g of Z **(2)**

2. a) i)



(3)

ii) Simple distillation **(1)**

iii) Leibig condenser
It provides a cold surface on which the steam can condense. **(2)**

b) i) Fractional distillation **(1)**

ii) Ethanol and water are separated based on their different **boiling points**. **(1)**

c) i) A separating funnel **(1)**

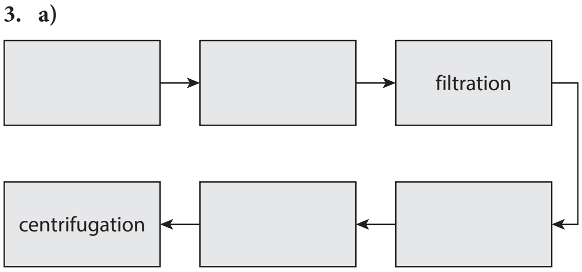
ii) They are immiscible.
They have different densities. **(2)**

d) i) Chromatography **(1)**

ii) Sam's pen **(1)**

iii) The solubility of the dye in the solvent used.
How strongly the dye was attracted to the paper used. **(2)**

3. a)



(2)

b) Calcium hydroxide **(1)**

c) The cane juice is heated in a series of evaporators at successively reduced pressures and it boils at successively lower temperatures. This causes the water to evaporate and the juice becomes concentrated, forming a thick syrup. **(2)**

A3 Atomic structure

1. a) i) An atom is the smallest component of an element that can exist and still have the same chemical properties as the element. **(1)**

ii) Mass number is the total number of protons and neutrons in the nucleus of one atom of an element. **(1)**

iii) Atomic number is the number of protons in the nucleus of one atom of an element. **(1)**

iv) Relative atomic mass is the average mass of one atom of an element compared to one-twelfth the mass of an atom of carbon-12. **(1)**

b)

Particle	Relative mass	Relative charge	Location in the atom
		+1	in the nucleus
	$\frac{1}{1840}$		spinning around the nucleus
neutron	1		in the nucleus

(7)

c) **A:** Mass number
B: Atomic number
X: Atomic symbol **(3)**

d)

Nuclear notation	$^{31}_{15}$P	$^{65}_{30}$Zn	$^{207}_{82}$Pb	$^{108}_{47}$Ag
Name of element	phosphorus	zinc	lead	silver
Number of protons	15	30	82	47
Number of neutrons	16	35	125	61
Number of electrons	15	30	82	47

(4)

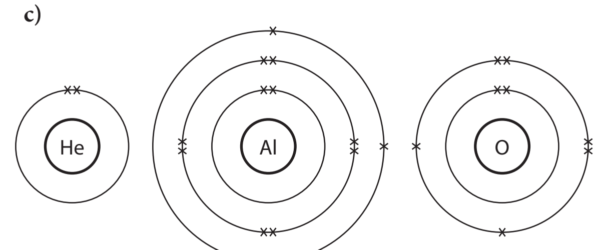
2. a)

Element	Potassium	Nitrogen	Chlorine
Atomic symbol	K	N	Cl
Mass number		14	35
Atomic number	19	7	17
Number of protons	19	7	
Number of electrons		7	17
Number of neutrons	20		
Electronic configuration	2,8,8,1		2,8,7

(5)

b) $^{40}_{18}$Ar: 2,8,8
$^{12}_{6}$C: 2,4
$^{7}_{3}$Li: 2,1
$^{32}_{16}$S: 2,8,6 **(4)**

c)



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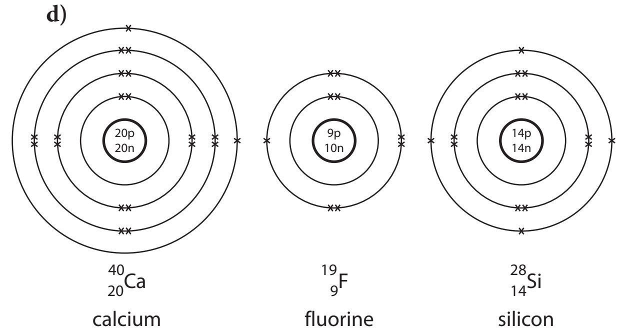
d)



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3. a) i) Isotopy is the occurrence of atoms of the same element which have the same number of protons and electrons but different numbers of neutrons. **(1)**

ii) ${}^{23}_{11}$Y 11 protons, 12 neutrons, 11 electrons
${}^{25}_{11}$Y 11 protons, 14 neutrons, 11 electrons **(2)**

iii) Average mass number = $\left[\frac{85}{100} \times 23\right] + \left[\frac{15}{100} \times 25\right]$
= **23.3** **(1)**

iv) They both contain the same number and arrangement of electrons. **(1)**

v) They would have slightly different masses because ${}^{25}_{11}$Y has two more neutrons than ${}^{23}_{11}$Y, therefore ${}^{25}_{11}$Y would be slightly heavier than ${}^{23}_{11}$Y. **(1)**

b) i) An isotope with an unstable nucleus that splits spontaneously to become more stable. As it splits, it ejects one or more small particles and radiation. **(1)**

ii) A controlled beam of gamma radiation from the cobalt-60 is directed at the tumour containing the cancerous cells and it destroys the cells. **(2)**

iii) *Any three of the following:*
To date plant and animal remains. Isotope: carbon-14
Tracers for use in medical treatment or biological research. Suitable isotope for use in medical treatment: iodine-131. Suitable isotope for use in biological research: carbon-14
To power the batteries used in heart pacemakers. Suitable isotope: plutonium-238
To generate electricity in nuclear power stations. Suitable isotope: uranium-235 or plutonium-239 **(3)**

A4 Periodic table and periodicity

1. a) i) Döbereiner found that if certain groups of three elements that possessed similar properties were arranged in increasing relative atomic mass, the relative atomic mass of the middle element was close to the average of the other two elements. Mendeleev created the first version of the periodic table. He arranged elements in increasing relative atomic mass, placed elements with similar properties together in vertical columns and left gaps when it seemed that elements had not yet been discovered. **(4)**

ii) Elements are arranged in order of increasing atomic number and in relation to the electron structure of their atoms and according to their chemical properties. **(2)**

b) i) For elements in Groups I to VII, the group number is the same as the number of valence electrons. **(1)**

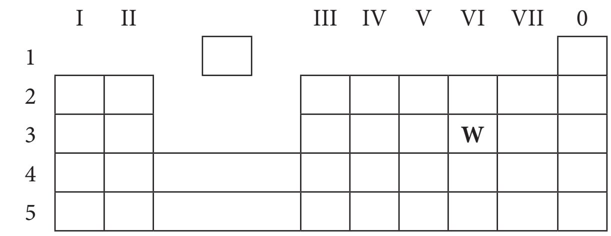
ii) The period number is the same as the number of occupied electron shells. **(1)**

iii) Potassium is in Group I, period 4. **(2)**

iv) 2,8,5 **(1)**

2. a) i) Mg and A, or *any two of* D, Br and E. **(1)**

ii) **(1)**



iii) Electronic configuration: 2,8,4
Name: Silicon **(2)**

b) i) Element **A**
The atomic radius of A is greater than that of magnesium because it has one more electron shell. As a result, the attraction of the positive nucleus on the valence electrons is weaker in A and it ionises more easily than magnesium. **(3)**

ii) $Mg(s) + 2H_2O(l) \longrightarrow Mg(OH)_2(aq) + H_2(g)$ **(2)**

iii) A reacts with oxygen and dilute hydrochloric acid. **(2)**

c) i) Halogens **(1)**

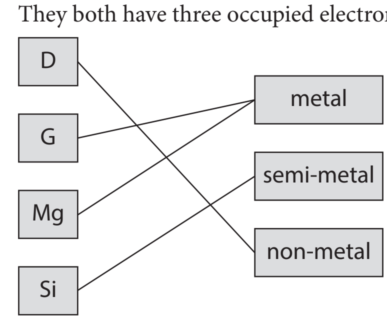
ii) Gaseous state. **(1)**

iii) Bromine
The atomic radius of bromine is less than E because it has one fewer electron shells. As a result, the attraction of the positive nucleus on the valence electron to be taken from another reactant is greater in bromine than in E, therefore it takes this electron more easily than E. **(3)**

iv) Chlorine has a greater strength of oxidising power than bromine, and therefore displaces bromine from the potassium bromide. The bromine produced is orange-brown and it dissolves in the solution. **(3)**
$2KBr(aq) + Cl_2(g) \longrightarrow 2KCl(aq) + Br_2(aq)$

d) i) They both have three occupied electron shells. **(1)**

ii)



(2)

iii) *Any three of the following:*
Magnesium is a solid at room temperature, whereas D is a gas.
Magnesium has high melting and boiling points, whereas D has low melting and boiling points.
Magnesium conducts electricity and heat, whereas D does not conduct electricity or heat.
Magnesium has a high density, whereas D has a low density. **(3)**

iv) Element G
The atomic radius of G is greater than that of magnesium because it has one fewer protons, therefore the attraction between the positive nucleus and the valence electron is weaker in G. As a result G ionises more easily than magnesium. **(3)**

v) $Mg(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$ **(2)**

A5 Structure and bonding

1. a) i) To gain a full outer electron shell and become stable. **(1)**

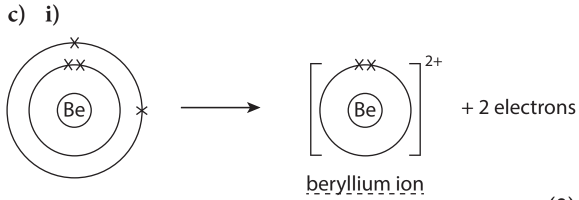
ii) Ionic bonding: metal atoms lose their valence electrons and non-metal atoms gain these electrons to fill their valence electron shells.
Covalent bonding: atoms of non-metals share their valence electrons. **(2)**

b)

Name of compound	Formula of compound	Type of bonding in the compound
ethane	C_2H_6	covalent
sodium oxide	Na_2O	ionic
magnesium nitride	Mg_3N_2	ionic
sulfur dioxide	SO_2	covalent
calcium chloride	$CaCl_2$	ionic
trifluoromethane	CHF_3	covalent

(3)

c) i)



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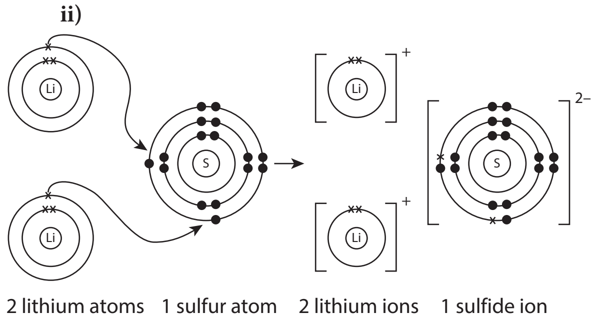
ii)



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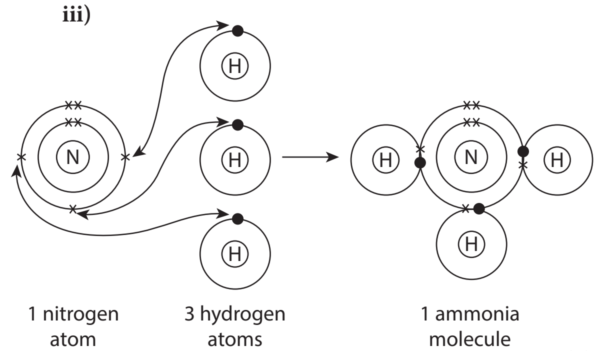
iii)



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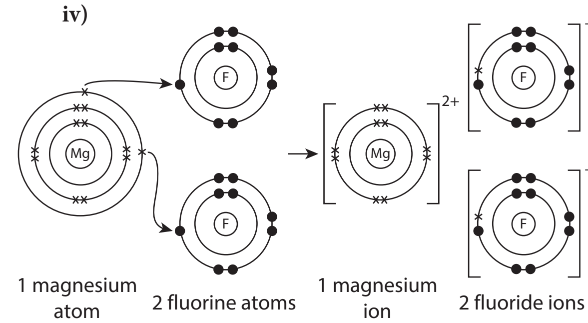
iv)



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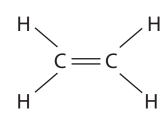
d) i) C_2H_4 **(1)**

ii) 4 single bonds **(1)**

iii) 1 double bond **(1)**

iv)



(1)

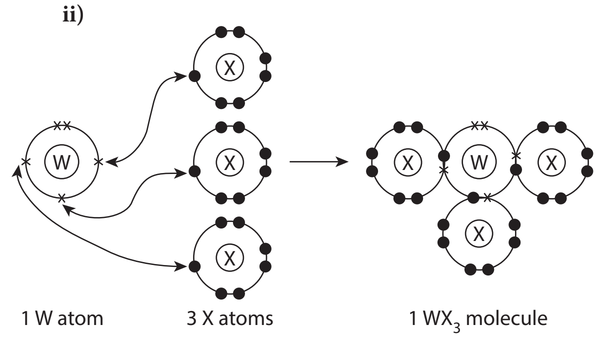
2. a)

Atomic number		Type of bonding in the compound
Element 1	Element 2	
17	8	Covalent
13	16	Ionic
20	7	Ionic
15	9	Covalent

(4)

b) i) Covalent **(1)**

ii)



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c)

Entity	Formula	Entity	Formula
potassium ion	K^+	water molecule	H_2O
sulfate ion	SO_4^{2-}	sulfur trioxide molecule	SO_3
hydrogen carbonate ion	HCO_3^-	carbon monoxide molecule	CO
magnesium ion	Mg^{2+}	calcium hydrogensulfate	$Ca(HSO_4)_2$
nitrate ion	NO_3^-	sodium nitride	Na_3N
iron(III) ion	Fe^{3+}	ammonium phosphate	$(NH_4)_3PO_4$
fluoride ion	F^-	copper(II) nitrite	$Cu(NO_2)_2$
carbon disulfide molecule	CS_2	silver sulfide	Ag_2S
chlorine molecule	Cl_2	aluminium carbonate	$Al_2(CO_3)_3$
nitrogen dioxide molecule	NO_2	zinc hydroxide	$Zn(OH)_2$

(5)

3. a) The copper atoms are packed together in rows and the valence electrons from each atom become delocalised. This forms positive copper cations and a sea of mobile electrons. The strong electrostatic forces of attraction between the delocalised electrons and the cations, called the metallic bond, hold the copper lattice together. **(3)**

b) i) The delocalised electrons from each copper atom are free to move and carry electricity. **(1)**

ii) The copper atoms are all the same size and can roll over each other into new positions without breaking the metallic bond when the copper is drawn out. **(1)**

iii) The strong electrostatic forces of attraction between the cations and delocalised electrons require fairly large amounts of heat energy to break. **(1)**

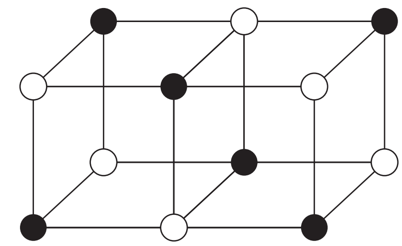
4. a)

Property	Ionic solid	Simple molecular solid
Structure	composed of ions held together by strong ionic bonds	composed of molecules held together by weak intermolecular forces
Melting point	high	low
Solubility	most are soluble in water and insoluble in organic solvents	most are insoluble in water and soluble in organic solvents
Electrical conductivity	do not conduct electricity when solid; do conduct electricity when molten or dissolved in water	do not conduct electricity in any state

(8)

b) When sodium chloride is solid, the ions are held together by strong ionic bonds and are not free to move. When it is molten or dissolved in water, the ionic bonds have broken and the ions are free to move and carry electricity. **(2)**

c)



(2)

d) i) Allotropy is the existence of different structural forms of the same element in the same physical state. **(1)**

ii) Their chemical properties are the same because they are both made of the same element, carbon. Their physical properties are different because the atoms are bonded differently in each of them. **(2)**

iii) Diamond has a high melting point: The strong covalent bonds between the carbon atoms throughout the structure of diamond need large amounts of heat energy to break. **(2)**

Graphite conducts electricity: One of the four valence electrons from each carbon atom is delocalised and free to move and carry electricity. **(2)**

Diamond is used in the tips of cutting tools: Diamond is extremely hard because of the strong covalent bonds between the carbon atoms throughout its structure. **(2)**

Graphite is used as a solid lubricant: Weak forces of attraction exist between the layers of carbon atoms, which allow the layers to slide easily over each other. **(2)**

A6 Mole concept

1. a) i) A mole is the amount of a substance that contains 6.0×10^{23} particles of the substance. **(1)**

ii) Relative mass is the average mass of one atom, molecule or formula unit of a substance compared to one-twelfth the mass of an atom of carbon-12, whereas molar mass is the mass of one mole of a substance. **(2)**

iii) Chlorine (Cl_2): $2 \times 35.5 = \mathbf{71}$
Nitrogen dioxide (NO_2): $14 + (2 \times 16) = \mathbf{46}$
Hydrogen sulfide (H_2S): $(2 \times 1) + 32 = \mathbf{34}$ **(3)**

iv) Aluminium oxide (Al_2O_3): $(2 \times 27) + (3 \times 16) = \mathbf{102}$
Ammonium sulfate ($(NH_4)_2SO_4$): $(2 \times 14) + (2 \times 4 \times 1) + 32 + (4 \times 16) = \mathbf{132}$
Calcium hydrogen carbonate ($Ca(HCO_3)_2$): $40 + (2 \times 1) + (2 \times 12) + (2 \times 3 \times 16) = \mathbf{162}$ **(3)**

v) Magnesium nitrate ($Mg(NO_3)_2$): $24 + (2 \times 14) + (2 \times 3 \times 16)$ g mol^{-1} = **148 g mol^{-1}**
Sucrose ($C_{12}H_{22}O_{11}$): $(12 \times 12) + (22 \times 1) + (11 \times 16)$ g mol^{-1} = **342 g mol^{-1}** **(2)**

b) i) Mass of 1 mol $Zn(OH)_2$ = 65 + (2 × 16) + (2 × 1) g = 99 g
∴ mass of 0.4 mol $Zn(OH)_2$ = 0.4 × 99 g = **39.6 g** **(2)**

ii) Mass of 1 mol K_2CO_3 = (2 × 39) + 12 + (3 × 16) g = 138 g
∴ number of moles K_2CO_3 in 8.28 g = $\frac{8.28}{138}$ mol
= **0.06 mol** **(2)**

iii) Mass of 1 mol CO_2 = 12 + (2 × 16) g = 44 g
∴ number of moles CO_2 in 11 g = $\frac{11}{44}$ mol
= 0.25 mol
1 mol CO_2 contains 6.0×10^{23} CO_2 molecules
∴ 0.25 mol CO_2 contains $0.25 \times 6.0 \times 10^{23}$ CO_2 molecules = **1.5×10^{23} CO_2 molecules** **(3)**

c) Mass of 1 mol $Al_2(CO_3)_3$ = (2 × 27) + (3 × 12) + (3 × 3 × 16) g = 234 g
Mass of oxygen in 1 mol $Al_2(CO_3)_3$ = 9 × 16 g = 144 g
∴ percentage oxygen in Al_2CO_3 = $\frac{144}{234}$ × 100 %
= **61.54 %** **(3)**

2. a) i) Avogadro's Law states that equal volumes of all gases, under the same conditions of temperature and pressure, contain the same number of molecules. **(1)**

ii) At rtp: 24 dm^3 or 24 000 cm^3
At stp: 22.4 dm^3 or 22 400 cm^3 **(2)**

b) i) Volume of 1 mol SO_2 at stp = 22.4 dm^3
∴ number of moles in 3.36 dm^3 SO_2 = $\frac{3.36}{22.4}$ mol
= **0.15 mol** **(1)**

ii) Volume of 1 mol O_2 at rtp = 24.0 dm^3
∴ volume of 0.075 mol O_2 at rtp = 0.075 × 24.0 dm^3 = **1.8 dm^3** **(1)**

iii) Volume of 1 mol NH_3 at stp = 22 400 cm^3
∴ number of moles in 1792 cm^3 NH_3 = $\frac{1792}{22\,400}$ mol
= 0.08 mol
Mass of 1 mol NH_3 = 14 + (3 × 1) g = 17 g
∴ mass of 0.08 mol NH_3 = 0.08 × 17 g = **1.36 g** **(3)**

iv) 1 mol H_2 contains 6.0×10^{23} H_2 molecules
∴ Number of moles in 4.8×10^{22} H_2 molecules
= $\frac{4.8 \times 10^{22}}{6.0 \times 10^{23}}$ mol = 0.08 mol
Volume of 1 mol H_2 at rtp = 24.0 dm^3
∴ volume of 0.08 mol O_2 at rtp = 0.08 × 24.0 dm^3
= **1.92 dm^3** **(2)**

3. a) i) $Ca(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2(g)$ **(2)**

ii) $Zn(HCO_3)_2(aq) + 2HNO_3(aq) \longrightarrow Zn(NO_3)_2(aq) + 2CO_2(g) + 2H_2O(l)$ **(2)**

iii) $2Al(s) + 3Cl_2(g) \longrightarrow 2AlCl_3(s)$ **(2)**

iv) $Cl_2(g) + 2KI(aq) \longrightarrow 2KCl(aq) + I_2(aq)$ **(2)**

v) $2Cu(NO_3)_2(s) \longrightarrow 2CuO(s) + 4NO_2(g) + O_2(g)$ **(2)**

b) i) $Pb^{2+}(aq) + 2Cl^-(aq) \longrightarrow PbCl_2(s)$ **(2)**

ii) $OH^-(aq) + H^+(aq) \longrightarrow H_2O(l)$ **(2)**

iii) $Mg(s) + 2H^+(aq) \longrightarrow Mg^{2+}(aq) + H_2(g)$ **(2)**

iv) $Al^{3+}(aq) + 3OH^-(aq) \longrightarrow Al(OH)_3(s)$ **(2)**

4. a) The Law of Conservation of Matter states that matter can neither be created nor destroyed during a chemical reaction. **(1)**

b) i) Mass of 1 mol KOH = 39 + 16 + 1 g = 56 g
∴ number of moles in 11.2 g KOH = $\frac{11.2}{56}$ mol
= **0.2 mol** **(2)**

ii) 2 mol KOH produces 1 mol K_2SO_4
∴ 0.2 mol KOH produces **0.1 mol K_2SO_4** **(1)**

iii) Mass of 1 mol K_2SO_4 = (2 × 39) + 32 + (4 × 16) g = 174 g
∴ mass of 0.1 mol K_2SO_4 = 0.1 × 174 g = **17.4 g** **(2)**

c) 2 mol NaCl forms 1 mol $PbCl_2$
∴ 0.3 mol NaCl forms 0.15 mol $PbCl_2$
Mass of 1 mol $PbCl_2$ = 207 + (2 × 35.5) g = 278 g
∴ mass of 0.15 mol $PbCl_2$ = 0.15 × 278 g = **41.7 g** **(3)**

d) Mass of 1 mol $Mg(HCO_3)_2$ = 24 + (2 × 1) + (2 × 12) + (2 × 3 × 16) g = 146 g
∴ number of moles in 3.65 g $Mg(HCO_3)_2$ = $\frac{3.65}{146}$ mol
= 0.025 mol
1 mol $Mg(HCO_3)_2$ produces 2 mol CO_2
∴ 0.025 mol $Mg(HCO_3)_2$ produces 0.05 mol CO_2
Volume of 1 mol CO_2 at stp = 22.4 dm^3
∴ Volume of 0.05 mol CO_2 at stp = 0.05 × 22.4 dm^3
= **1.12 dm^3** **(4)**

e) Volume of 1 mol $H_2O(g)$ at rtp = 24.0 dm^3
∴ number of moles in 960 cm^3 $H_2O(g)$ = $\frac{960}{24\,000}$ mol
= 0.04 mol
1 mol O_2 forms 2 mol $H_2O(g)$
∴ 0.02 mol O_2 forms 0.04 mol $H_2O(g)$
Volume of 1 mol O_2 at rtp = 24 000 cm^3
∴ volume of 0.02 mol O_2 at rtp = 0.02 × 24 000 cm^3
= **480 cm^3** **(3)**

f) Mass of 1 mol OH^- ions = 16 + 1 g = 17 g
∴ Number of moles in 12.75 g OH^- ions = $\frac{12.75}{17}$ mol
= 0.75 mol
3 mol OH^- ions form 1 mol $Fe(OH)_3$
∴ 0.75 mol OH^- ions form 0.25 mol $Fe(OH)_3$
Mass of 1 mol $Fe(OH)_3$ = 56 + (3 × 16) + (3 × 1) g = 107 g
∴ mass of 0.25 mol $Fe(OH)_3$ = 0.25 × 107 g
= **26.75 g** **(5)**

5. a) i) Molar concentration gives the number of moles of solute dissolved in 1 dm^3 of solution. **(1)**

ii) A standard solution is one whose concentration is known accurately. **(1)**

iii) Brianna would weigh 5.6 g of potassium hydroxide on a balance, transfer it to a beaker and add enough distilled water to dissolve the solid. She would pour the solution into a clean, 1 dm^3 volumetric flask and rinse the beaker over the flask, transferring the washings to the flask. She would then fill the flask with distilled water so the meniscus of the solution rests on the line on the neck, place a stopper on the flask and invert it to mix the solution. **(4)**

b) i) 1000 cm^3 $Na_2CO_3(aq)$ contains 0.24 mol Na_2CO_3
∴ 250 cm^3 $Na_2CO_3(aq)$ contains $\frac{0.24}{1000}$ × 250 mol Na_2CO_3 = 0.06 mol Na_2CO_3
Mass of 1 mol Na_2CO_3 = (2 × 23) + 12 + (3 × 16) g = 106 g
∴ mass of 0.06 mol Na_2CO_3 = 0.06 × 106 g
= **6.36 g** **(3)**

ii) 400 cm^3 $(NH_4)_2SO_4(aq)$ contains 6.6 g $(NH_4)_2SO_4$

$\therefore$ 1000 cm^3 $(NH_4)_2SO_4(aq)$ contains $\frac{6.6}{400} \times 1000$ g $(NH_4)_2SO_4$ = 16.5 g $(NH_4)_2SO_4$

Mass of 1 mol $(NH_4)_2SO_4$ = (2 × 14) + (2 × 4 × 1) + 32 + (4 × 16) g = 132 g

$\therefore$ number of moles in 16.5 g $(NH_4)_2SO_4 = \frac{16.5}{132}$ mol = 0.125 mol

Molar concentration of $(NH_4)_2SO_4(aq)$ = **0.125 mol dm^{-3}** **(3)**

iii) 1000 cm^3 $H_2SO_4(aq)$ contains 78.4 g H_2SO_4

$\therefore$ 200 cm^3 $H_2SO_4(aq)$ contains $\frac{78.4}{1000} \times 200$ g H_2SO_4 = 15.68 g H_2SO_4

Mass of 1 mol H_2SO_4 = (2 × 1) + 32 (4 × 16) g = 98 g

$\therefore$ number of moles in 15.68 g $H_2SO_4 = \frac{15.68}{98}$ mol = **0.16 mol** **(3)**

iv) Mass of 1 mol NaOH = 23 + 16 + 1 g = 40 g

$\therefore$ number of moles NaOH in 12.0 g = $\frac{12.0}{40}$ mol = **0.3 mol**

1000 cm^3 of the required solution contains 0.75 mol NaOH

$\therefore$ $\frac{1000}{0.75} \times 0.3$ cm^3 of the required solution contain 0.3 mol NaOH = **400 cm^3** **(3)**

A7 Acids, bases and salts

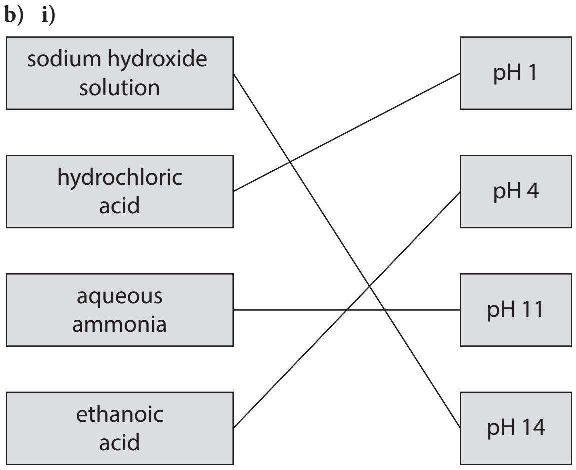
1. a) i) All acids contain **H^+ ions** and all alkalis contain **OH^- ions**. **(2)**

ii) When acids dissolve in water their molecules ionise and form H^+ ions in the solution. Each H^+ ion is a single proton and when acids react they can give these H^+ ions, or protons, to the other reactant. When a base reacts with an acid, the base accepts the H^+ ions, or protons, from the acid. **(3)**

iii) The hydrochloric acid donates its H^+ ions, or protons, to the OH^- ions of the sodium hydroxide, forming water. **(2)**

iv) An alkali is a base which is soluble in water. **(1)**

b) i)



(4)

ii) Sulfuric acid fully ionises when it dissolves in water and the solution contains a high concentration of H^+ ions. Ethanoic acid only partially ionises when it dissolves in water and the solution contains a low concentration of H^+ ions. **(2)**

2. a) i) Hydrogen **(1)**

ii) Place a burning splint at the mouth of the test tube. The splint should be extinguished with a squeaky pop. **(1)**

iii) $Mg(s) + H_2SO_4(aq) \longrightarrow MgSO_4(aq) + H_2(g)$ **(1)**

iv) $Mg(s) + 2H^+(aq) \longrightarrow Mg^{2+}(aq) + H_2(g)$ **(1)**

b) i) $CuCO_3(s) + 2HNO_3(aq) \longrightarrow Cu(NO_3)_2(aq) + CO_2(g) + H_2O(l)$ **(2)**

ii) $Zn(OH)_2(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + 2H_2O(g)$ **(2)**

iii) $Al_2O_3(s) + 3H_2SO_4(aq) \longrightarrow Al_2(SO_4)_3(aq) + 3H_2O(l)$ **(2)**

iv) $Ca(HCO_3)_2(aq) + 2HCl(aq) \longrightarrow CaCl_2(aq) + 2CO_2(g) + 2H_2O(l)$ **(2)**

c) i) $OH^-(aq) + H^+(aq) \longrightarrow H_2O(l)$ **(1)**

ii) $CO_3^{2-}(aq) + 2H^+(aq) \longrightarrow CO_2(g) + H_2O(l)$ **(2)**

iii) $HCO_3^-(aq) + H^+(aq) \longrightarrow CO_2(g) + H_2O(l)$ **(2)**

3. a) i) An acid anhydride is a compound which reacts with water to form an acid. **(1)**

ii) *Any two of the following:*
Carbon dioxide
Sulfur dioxide
Sulfur trioxide
Nitrogen dioxide **(2)**

b) i) Vitamin C **(1)**

ii) Lactic acid **(1)**

iii) Peter gave the correct advice. Sodium hydrogen carbonate would neutralise the methanoic acid in the sting, reducing the irritation caused by it. **(2)**

iv) The citric acid in the lime juice reacts with the iron(III) oxide in the rust stains making a soluble compound which can be washed away removing the rusty Fe^{3+} ions. **(2)**

4. a) i) Ammonia reacts with water to form a solution which contains OH^- ions. **(1)**

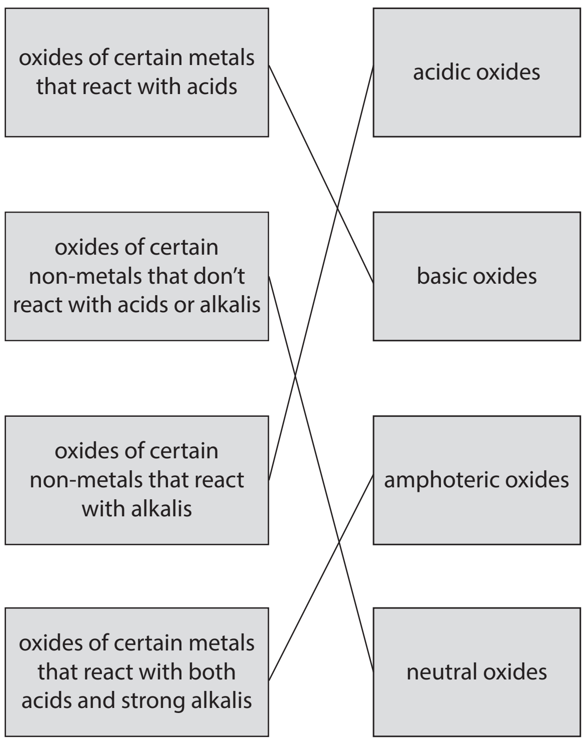
ii) *Any two of the following:*
Sodium hydroxide
Potassium hydroxide
Calcium hydroxide **(2)**

b) i) $Ca(OH)_2(s) + 2NH_4Cl(s) \longrightarrow CaCl_2(s) + 2NH_3(g) + 2H_2O(l)$ **(2)**

ii) $CuO(s) + (NH_4)_2SO_4(s) \longrightarrow CuSO_4(s) + 2NH_3(g) + H_2O(l)$ **(2)**

iii) Lead(III) hydroxide is amphoteric and it reacted with both the nitric acid and the sodium hydroxide to form soluble salts. **(2)**

c)



Examples:

Acidic oxides	Basic oxides
Carbon dioxide	Potassium oxide
Sulfur dioxide	Sodium oxide
Sulfur trioxide	Calcium oxide
Nitrogen dioxide	Magnesium oxide
Silicon dioxide	Iron(II) oxide
	Iron(III) oxide
	Copper(II) oxide

Amphoteric oxides	Neutral oxides
Aluminium oxide	Carbon monoxide
Zinc oxide	Nitrogen monoxide
Lead(II) oxide	Dinitrogen monoxide

(8)

5. a) i) A salt is a compound formed when some or all of the hydrogen ions in an acid are replaced by metal or ammonium ions. **(1)**

ii) An acid salt is formed when the H^+ ions in an acid are only partially replaced by metal or ammonium ions. And a normal salt is formed when all of the H^+ ions in an acid are replaced by metal or ammonium ions. **(2)**

iii) A dibasic acid produces two H^+ ions per molecule of acid when it dissolves in water. **(1)**

iv) Acid salt: $NaOH(aq) + H_2SO_4(aq) \longrightarrow NaHSO_4(aq) + H_2O(l)$

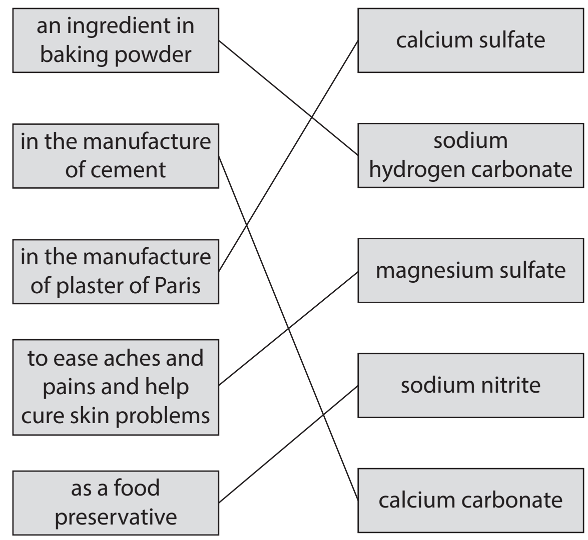
Normal salt: $2NaOH(aq) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l)$ **(3)**

b) i) A hydrated salt contains water of crystallisation, whereas an anhydrous salt does not contain any water of crystallisation. **(2)**

ii) Anhydrous: $CuSO_4$

Hydrated: $CuSO_4.5H_2O$ **(2)**

c) i)



(5)

ii) It may be carcinogenic, increasing the risk of developing cancer.

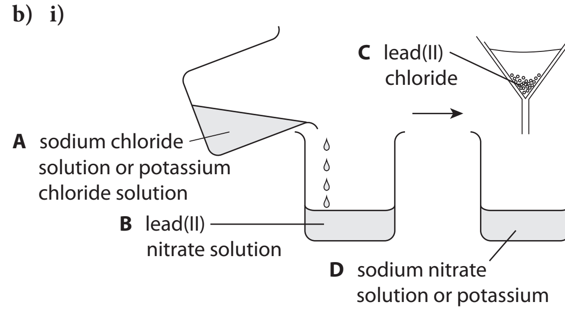
It may cause brain damage in infants. **(2)**

6. a) i)

Compound	Solubility
sodium carbonate	soluble
copper(II) nitrate	soluble
lead(II) sulfate	insoluble
zinc hydroxide	insoluble
calcium chloride	soluble
magnesium carbonate	insoluble
aluminium oxide	insoluble
potassium hydroxide	soluble
ammonium chloride	soluble
iron sulfate	soluble

(5)

b) i)



(4)

ii) $Pb^{2+}(aq) + 2Cl^-(aq) \longrightarrow PbCl_2(s)$ **(2)**

iii) Lynette washed the sample with distilled water whilst it was still in the filter funnel. **(1)**

c) i) Sulfuric acid **(1)**

ii) $CuCO_3(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + CO_2(g) + H_2O(l)$ **(1)**

iii) To ensure that all the acid has reacted and that no acid remains in the copper(II) sulfate solution. **(1)**

iv) Filtration **(1)**

v) So that the copper(II) sulfate that he produces is hydrated, containing water of crystallisation, instead of being anhydrous, containing no water of crystallisation. **(2)**

vi) Copper does not react with sulfuric acid. **(1)**

d) i) Titration **(1)**

ii) Sodium carbonate is soluble so when all the acid has finished reacting and excess carbonate is added, the carbonate dissolves making the sodium chloride impure. **(2)**

iii) He would use an indicator which is one colour in alkaline conditions and a different colour in acidic conditions. **(2)**

7. a) i) A neutralisation reaction is a reaction between a base and an acid to form a salt and water. **(1)**

ii) Acid in the mouth causes tooth decay. Sodium hydrogen carbonate in the toothpaste neutralises the acid in the mouth and the F^- ions in the toothpaste displace the OH^- ions in the calcium hydroxyapatite of tooth enamel forming calcium fluoroapatite which does not react with the acid in the mouth. **(3)**

iii) A substance taken to neutralise excess stomach acid, thereby relieving indigestion and acid reflux. **(2)**

iv) To neutralise any acid in his soil because most plants grow best in neutral soil. **(1)**

v) The lime reacts with the NH_4^+ ions in the fertiliser forming a salt, ammonia and water. The lime cannot then neutralise any acid in the soil and the NH_4^+ ions are no longer available to fertilise the plants.

$CaO(s) + 2NH_4^+(aq) \longrightarrow Ca^{2+}(aq) + 2NH_3(g) + H_2O(l)$ **(3)**

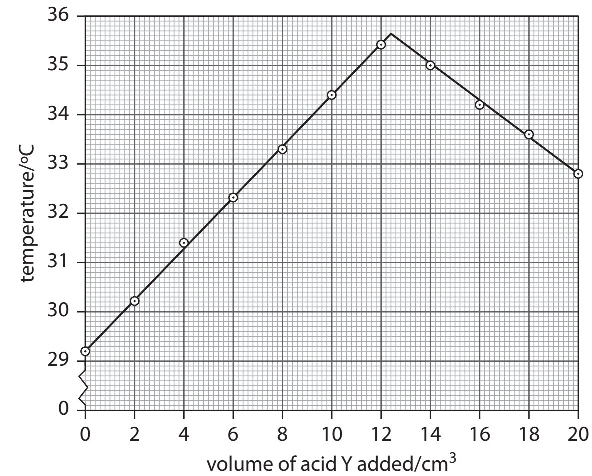
b) i) Because the reaction was producing heat and the polystyrene cup acted as an insulator, reducing the loss of heat to the surroundings. **(2)**

ii)

Volume of acid X added/cm³	Temperature of solution/°C
0	29.2
2	30.2
4	31.4
6	32.3
8	33.3
10	34.4
12	35.4
14	35.0
16	34.2
18	33.6
20	32.8

(3)

iii)



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iv) Volume of acid Y needed = 12.4 cm³ **(1)**

v) 1000 cm³ X(aq) contains 1.0 mol X

∴ 25 cm³ X(aq) contains $\frac{25}{1000} \times 1.0$ mol X

= 0.025 mol X

1000 cm³ Y(aq) contains 1.0 mol Y

∴ 12.4 cm³ Y(aq) contains $\frac{12.4}{1000} \times 1.0$ mol Y

= 0.0124 mol Y

0.025 mol alkali X neutralises 0.0124 mol acid Y

0.025:0.0124 is approximately 2:1

∴ **2 mol alkali X** neutralise **1 mol acid Y** **(3)**

8. a) i) A 25 cm³ pipette **(1)**

ii) The neutralisation point occurs in a reaction between an acid and an alkali when neither the H^+ ion nor the OH^- ion is present in excess and the solution is, therefore, neutral. **(1)**

iii) Phenolphthalein or methyl orange or screened methyl orange. **(1)**

b) i)

	Titration number		
	1	**2**	**3**
Final burette reading/cm³	15.3	16.6	18.9
Initial burette reading/cm³	0.5	1.9	4.2
Volume of acid added/cm³	14.8	14.7	14.7

(3)

ii) Volume of H_2SO_4(aq) needed = $\frac{14.8 + 14.7 + 14.7}{3}$ cm³

= **14.7 cm³** **(1)**

iii) 1000 cm³ NaOH(aq) contains 8.0 g NaOH

∴ 25 cm³ NaOH(aq) contains $\frac{8.0}{1000} \times 25$ g NaOH = 0.2 g NaOH

Mass of 1 mol NaOH = 23 + 16 + 1 g = 40 g

∴ number of moles in 0.2 g NaOH = $\frac{0.2}{40}$ mol = **0.005 mol** **(3)**

iv) $2NaOH(aq) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l)$ **(2)**

v) 2 mol NaOH neutralise 1 mole H_2SO_4

∴ 0.005 mol NaOH neutralises 0.0025 mol H_2SO_4

Number of moles of H_2SO_4 used in the titration = **0.0025 mol** **(1)**

vi) 14.7 cm³ H_2SO_4(aq) contains 0.0025 mol H_2SO_4
∴ 1000 cm³ H_2SO_4(aq) contains $\frac{0.0025}{14.7}$ × 1000 mol H_2SO_4 = 0.17 mol H_2SO_4
Molar concentration of H_2SO_4(aq) =
0.17 mol dm⁻³ **(1)**

vii) Mass of 1 mol H_2SO_4 = (2 × 1) + 32 + (4 × 16) g
= 98 g
∴ mass of 0.17 mol H_2SO_4 = 0.17 × 98 g = 16.66 g
Mass concentration of H_2SO_4 = **16.66 g dm⁻³** **(2)**

A8 Oxidation-reduction reactions

1. a) i) Oxidation: The loss of electrons by an element in its free state or an element in a compound.
ii) Reduction: The gain of electrons by an element in its free state or an element in a compound. **(2)**

b) i) Type of reaction: Reduction
Reason: Each Fe^{3+} ion has gained one electron to form an Fe^{2+} ion. **(2)**
ii) Type of reaction: Oxidation
Reason: The aluminium atom has lost three electrons to form an Al^{3+} ion. **(2)**
iii) Ionic half equation: $O_2(g) + 4e^- \longrightarrow 2O^{2-}(s)$ **(2)**
Type of reaction: Reduction
Reason: Each oxygen atom in an oxygen molecule gains two electrons to form an O^{2-} ion. **(2)**

c) i) Oxidation: The increase in the oxidation number of an element in its free state or an element in a compound. **(1)**
ii) Reduction: The decrease in the oxidation number of an element in its free state or an element in a compound. **(1)**

d) i) (oxidation number of S) + 3(−2) = 0
(oxidation number of S) + (−6) = 0
oxidation number of S = **+6**
Alternative name: Sulfur(VI) oxide **(2)**
ii) (oxidation number of N) + 2(−2) = −1
(oxidation number of N) + (−4) = −1
oxidation number of N = −1 + 4
= **+3**
Alternative name: Nitrate(III) ion **(2)**
iii) (oxidation number of Cl) + 4(−2) = −1
(oxidation number of Cl) + (−8) = −1
oxidation number of Cl = −1 + 8
= **+7**
Name: Chlorate(VII) ion **(2)**
iv) Oxidation number of N in NH_3:
(oxidation number of N) + 3(+1) = 0
(oxidation number of N) + (+3) = 0
oxidation number of N = **−3**
Oxidation number of N in N_2 = **0**
The oxidation number of nitrogen increases from −3 to 0, therefore the ammonia has been oxidised. **(3)**

e) i) $Mg(s) + CuSO_4(aq) \longrightarrow MgSO_4(aq) + Cu(s)$
(0) (+2) – (+2) – (0)
Magnesium has been oxidised because its oxidation number has increased from 0 to +2. Copper (II) sulfate has been reduced because the oxidation number of the Cu^{2+} ion has decreased from +2 to 0. **(2)**
ii) $Fe_2O_3(s) + 3CO(g) \longrightarrow 2Fe(s) + 3CO_2(g)$
(+3)(−2) (+2)(−2) (0) (+4)(−2)
Carbon monoxide has been oxidised because the oxidation number of the carbon atom increased from +2 to +4. Iron(III) oxide has been reduced because the oxidation number of each Fe^{3+} ion decreased from +3 to 0. **(2)**

2. a) i) An oxidising agent causes the oxidation number of an element in its free state or an element in a compound to increase. **(1)**
ii) A reducing agent causes the oxidation number of an element in its free state or an element in a compound to decrease. **(1)**

b) i) $S(s) + O_2(s) \longrightarrow SO_2(g)$
(0) (−2)
Sulfur is acting as a reducing agent because it caused the oxidation number of each oxygen atom in the oxygen molecule to decrease from 0 to −2. **(2)**
ii) $Mg(s) + S(s) \longrightarrow MgS(s)$
(0) (+2)
Sulfur is acting as an oxidising agent because it caused the oxidation number of the magnesium atom to increase from 0 to +2. **(2)**

c) $CH_4(g) + 4CuO(s) \longrightarrow 4Cu(s) + CO_2(g) + 2H_2O(g)$
(−4)(+1) (+2)(−2) (0) (+4)(−2) (+1)(−2)
Copper(II) oxide is the oxidising agent because it caused the oxidation number of the carbon atom in the methane molecule to increase from −4 to +4. Methane is the reducing agent because it caused the oxidation number of the Cu^{2+} ion in the copper(II) oxide to decrease from +2 to 0. **(2)**

d) i)

Test reagent	Results of test if		
	Josh's suggestion is correct	**Richard's suggestion is correct**	**Matthieu's suggestion is correct**
Acidified potassium manganate(VII) solution	Remains purple	Remains purple	Turns colourless
or			
Acidified potassium dichromate(VI) solution	Remains orange	Remains orange	Turns green
Potassium iodide solution	Turns brown	Remains colourless	Remains colourless

(6)

ii) Explanation: The reducing agent in the bottle reduces the purple MnO_4^- ion to the colourless Mn^{2+} ion.
Reagent: Acidified potassium dichromate(VI) solution
Or
Explanation: The reducing agent in the bottle reduces the orange dichromate(VI) ion to the green Cr^{3+} ion.
Reagent: Acidified potassium manganate(VII) solution. **(2)**

iii) Acidified hydrogen peroxide or sulfur dioxide **(1)**

e) i) Enzymes in the cells on the cut surface are exposed to oxygen in the air and they oxidise certain chemicals in the cells to brown compounds called melanins. **(1)**

ii) Sodium chlorate(I) oxidises coloured chemicals in stains to their colourless form. **(1)**

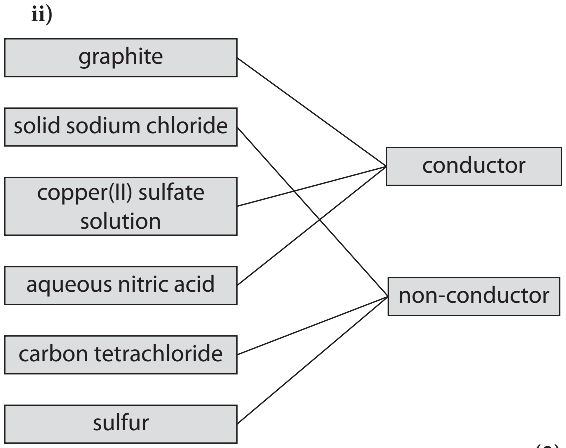
iii) Sodium sulfite prevents oxidation which causes food to spoil and prevents browning by reducing any melanins back to their colourless form. **(2)**

iv) Oxygen and moisture in the air oxidise the iron in the nails forming hydrated iron(III) oxide which is rust. **(1)**

A9 Electrochemistry

1. a) i) A conductor allows electricity to pass through, whereas a non-conductor does not allow electricity to pass through. **(1)**

ii)



(3)

b) i) An electrolyte is a compound that forms ions when molten or in aqueous solution. **(1)**

ii) A strong electrolyte is fully ionised when dissolved in water, so the solution has a high concentration of ions. A weak electrolyte is partially ionised when dissolved in water, so the solution has a low concentration of ions. **(2)**

iii) Pure water contains an extremely low concentration of H^+ ions and OH^- ions which have been formed by ionisation of water molecule. **(2)**

iv)

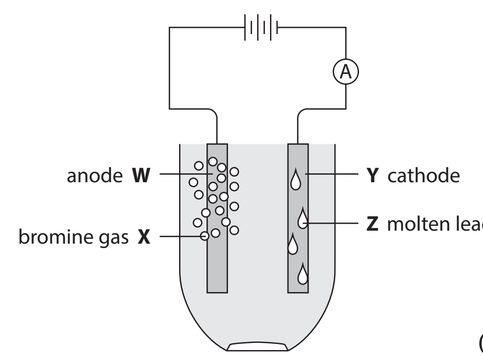
Metallic conduction	Electrolytic conduction
mobile electrons carry the electricity through the metal	mobile ions carry the electricity through the electrolyte
the metal remains unchanged	the electrolyte decomposes

(4)

c) i) Electrolysis is the chemical change which occurs when an electric current is passed through an electrolyte.
The anode is the positive electrode, connected to the positive terminal of the battery.
The cathode is the negative electrode, connected to the negative terminal of the battery. **(3)**

ii) Oxidation occurs at the anode because anions lose electrons at the anode. Reduction occurs at the cathode because cations gain electrons at the cathode. **(2)**

d) i)



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ii) **X:** $2Br^-(l) \longrightarrow Br_2(g) + 2e^-$
Z: $Pb^{2+}(l) + 2e^- \longrightarrow Pb(l)$ **(4)**

2. a) A series which places metals in order of the ease with which they ionise. **(1)**

b) A reaction would occur. The atoms of metal F would ionise and the Zn^{2+} ions from the zinc sulfate would be discharged because metal F is higher than zinc in the electrochemical series. **(2)**

c) A reaction would not occur. The atoms of metal G will remain as atoms and the H^+ ions in the acid will remain as ions because metal G is lower than hydrogen in the electrochemical series. **(2)**

d) $Mg(s) + CuSO_4(aq) \longrightarrow MgSO_4(aq) + Cu(s)$ **(1)**

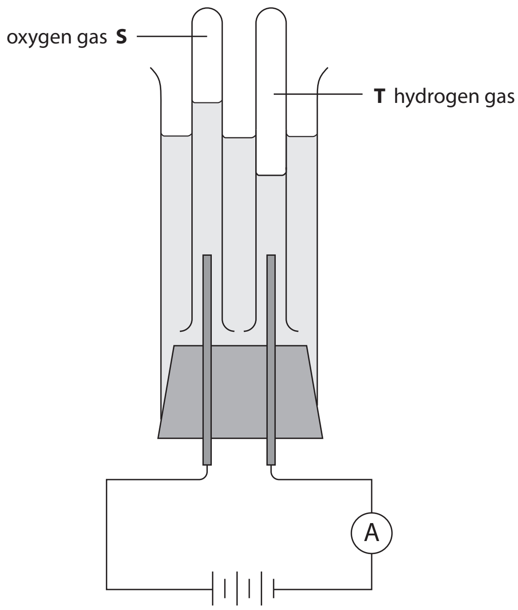
3. a) The nature of the anode
The concentration of the electrolyte
The position of the anion in the electrochemical series of anions **(3)**

b) i) In Cell A, the OH^- ions would be discharged in preference to the Cl^- ions and oxygen gas would be produced. In Cell B, the Cl^- ions would discharged in preference to OH^- ions and chlorine gas would be produced. **(2)**

ii) The H^+ ions would be discharged in preference to the Na^+ in both cells and hydrogen gas would be produced. **(1)**

iii) In Cell A the electrolyte becomes more concentrated and in Cell B the electrolyte becomes alkaline. **(2)**

c) i)



(2)

ii) **S:** $4OH^-(aq) \longrightarrow 2H_2O(l) + O_2(g) + 4e^-$
T: $2H^+(aq) + 2e^- \longrightarrow H_2(g)$ **(4)**

iii) The volume of oxygen is half the volume of hydrogen because for every 4 mol of electrons, 1 mol of oxygen and 2 mol of hydrogen are produced. **(2)**

d) i) Observation: Effervescence occurred around the anode.
Reason: The OH^- ions were discharged in preference to the SO_4^{2-} ions and oxygen gas was produced. **(2)**

ii) Observation: Pink copper was deposited and the cathode increased in size.
Reason: The Cu^{2+} ions were discharged in preference to the H^+ ions and copper was produced.
$Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$ **(4)**

iii) Observation: The electrolyte gradually became a paler blue.
Reason: The blue Cu^{2+} ions were being removed from it at the cathode. **(2)**

iv) Observation: The anode decreased in size.
Reason: The anode ionised since this required less energy than discharging either anion.
$Cu(s) \longrightarrow Cu^{2+}(aq) + 2e^-$ **(4)**

4. a) i) The Faraday constant (96500C) is the size of the electrical charge on one mole of electrons. **(1)**

ii) The quantity of electricity or electrical charge flowing through the electrolytic cell. **(1)**

b) i) Quantity of electricity = 2.5 × [(2 × 60 × 60) + (8 × 60) + 40] C = **19 300 C** **(1)**

ii) $4OH^-(aq) \longrightarrow 2H_2O(l) + O_2(g) + 4e^-$ **(1)**

iii) 4 mol electrons form 1 mol O_2
∴ 4 × 96 500 C form 1 mol O_2
and 19 300 C form $\frac{1}{4 \times 96\,500} \times 19\,300$ mol O_2
= **0.05 mol O_2** **(2)**

c) Mass of 1 mol H_2 = 2g
∴ number of moles in 3.0 g $H_2 = \frac{3.0}{2}$ mol = 1.5 mol
$2H^+(g) + 2e^- \longrightarrow H_2(g)$
2 mol electrons form 1 mol H_2
∴ 2 × 96 500 C form 1 mol H_2
and 1.5 × 2 × 96 500 C form 1.5 mol H_2 = 289 500 C
289 500 C = 5.0 × time
∴ time = $\frac{289\,500}{5.0}$ s = 57 900 s = **16 hours 5 minutes** **(4)**

5. a) i) Anodising is used to increase the thickness of the layer of aluminium oxide on the surface of aluminium objects such as saucepans and window frames. **(1)**

ii) The aluminium oxide layer protects the saucepan against corrosion.
The aluminium oxide layer readily absorbs dyes so the saucepan can be attractively coloured. **(2)**

b) i) The anode: a lump of silver
The cathode: the spoon to be plated
The electrolyte: silver nitrate solution **(3)**

ii) At the anode: $Ag(s) \longrightarrow Ag^+(aq) + e^-$
At the cathode: $Ag^+(aq) + e^- \longrightarrow Ag(s)$ **(2)**

iii) Quantity of electricity = 2.0 × [(32 × 60) + 10] C
= **3860 C**
1 mol electrons form 1 mol Ag
∴ 96 500 C form 1 mol Ag
and 3860 C form $\frac{1}{96\,500} \times 3860$ mol Ag =
0.04 mol Ag
Mass of 1 mol Ag = 108 g
∴ mass of 0.04 mol Ag = 0.04 × 108 g = **4.32 g**
(3)

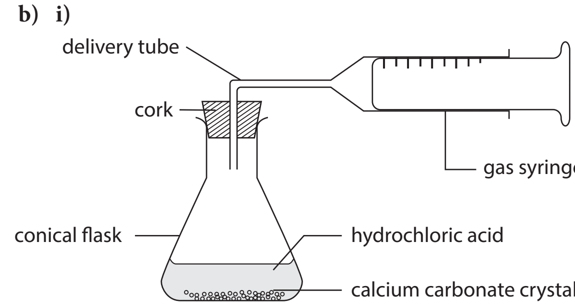
c) i) The anode would be made out of the lump of impure copper, the cathode would be a thin strip of pure copper and the electrolyte would be copper(II) sulfate solution. The copper atoms in the anode ionise and enter the electrolyte and Cu^{2+} ions from the electrolyte are discharged at the cathode forming pure copper. **(4)**

ii) The H^+ ions in the electrolyte would be preferentially discharged at the cathode and not the ions of the metal to be purified, since the H^+ ions are lower in the electrochemical series.
(2)

A10 Rates of reaction

1. a) Rate of reaction is a measured change in the concentration of a reactant or product with time at a stated temperature. **(1)**

b) i)



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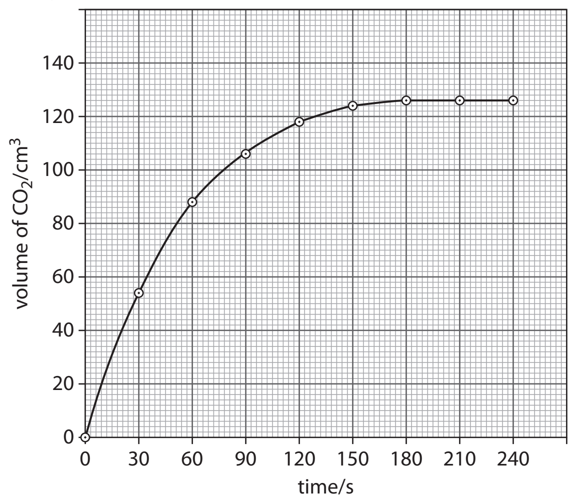
ii)



(3)

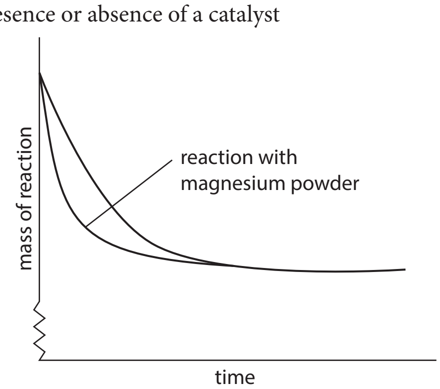
iii) Volume of CO_2 produced in the first minute = 88 cm^3
Average rate of reaction in the first minute
$= \frac{88}{60}$ $cm^3\ s^{-1}$ = **1.47 $cm^3\ s^{-1}$** **(1)**
Volume of CO_2 produced in the second minute
$= 118 - 88\ cm^3 = 30\ cm^3$
Average rate of reaction in the second minute
$= \frac{30}{60}$ $cm^3\ s^{-1}$ = **0.50 $cm^3\ s^{-1}$** **(1)**

iv) The concentration of the reactant particles was higher in the first minute than in the second minute because many of the particles had collided and reacted by the second minute. The frequency of collision between the particles was, therefore, higher in the first minute than in the second minute. **(3)**

v) The reaction had reached completion and stopped because all the calcium carbonate had reacted and there was none left to react. **(1)**

2. a) Concentration
Temperature
Surface area or particle size
Presence or absence of a catalyst **(4)**

b) i)



(2)

ii) The magnesium powder had a larger surface area than the ribbon which caused the rate of reaction to be faster because the frequency of particle collisions was higher. **(2)**

iii) Effect: The rate of the reaction would increase.
Explanation: The reactant particles gained kinetic energy which caused them to move faster and to collide more frequently. The particles also collided with more energy, therefore more collisions occurred with sufficient activation energy for the particles to react. Both factors increased the chances of effective collisions. **(4)**

iv) Effect: The rate of reaction would decrease
Explanation: The number of particles per unit volume of acid has decreased. The particles would, therefore, collide less frequently decreasing the chances of effective collisions. **(3)**

c) i) A catalyst alters the rate of a reaction without itself undergoing any permanent chemical change. **(1)**

ii) A catalyst provides an alternative pathway for a reaction which requires less activation energy than the normal pathway, therefore, more collisions occur with sufficient activation energy for the particles to react which increases the chances of effective collisions. **(2)**

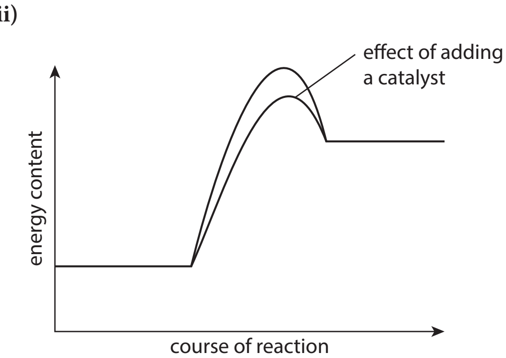
A11 Energetics

1. a) An exothermic reaction produces heat, causing the reaction mixture and its surroundings to get hotter. An endothermic reaction absorbs heat, causing the reaction mixture and its surroundings to get colder. **(2)**

b) i) The reaction is endothermic because the energy content of the products is greater than the energy content of the reactants, therefore, energy is absorbed from the surroundings. **(2)**

ii) **A:** Enthalpy of the reactants
B: Activation energy
C: Enthalpy change
D: Enthalpy of the products **(4)**

iii)



(1)

iv) Positive **(1)**

c) i) Exothermic **(1)**

ii) The enthalpy change, ΔH, is negative indicating that energy was lost during the reaction. **(1)**

iii) The energy content of the reactants is greater than the energy content of the products, therefore, energy is released to the surroundings. **(2)**

2. a) i) Heat of neutralisation is the heat change which occurs when 1 mol of water is produced in a reaction between an acid and an alkali. **(1)**

ii) The energy change is for the common reaction occurring in both reactions between the OH^- ions of the alkali and the H^+ ions of the acid which produces 1 mol of water. **(2)**

b) i) Average initial temperature $\frac{29.5 + 29.9}{2}$ °C = 29.7 °C

∴ temperature increase = 35.8 − 29.7 °C = **6.1 °C** **(2)**

ii) Mass of solution = 100 g

Heat change for the reaction = 100 × 4.2 × 6.1 J = **2562 J** **(1)**

iii) The density of the solution is 1 g cm^{-3}.

Negligible heat is lost to the surroundings. **(2)**

iv) $2NaOH(aq) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l)$ **(2)**

v) 1000 cm^3 NaOH(aq) contains 1.0 mol NaOH

∴ 50 cm^3 NaOH(aq) contains $\frac{1.0}{1000} \times 50$ mol NaOH = 0.05 mol NaOH

2 mol NaOH produces 2 mol H_2O

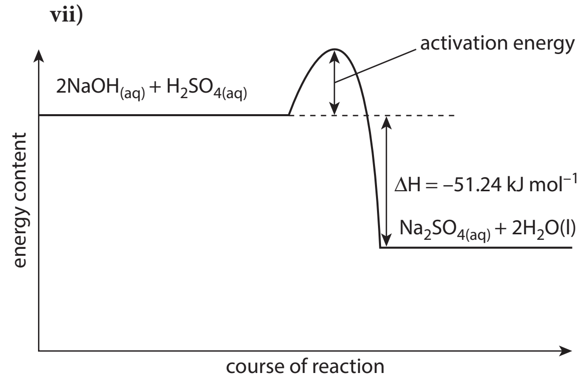
∴ 0.05 mol NaOH produces **0.05 mol H_2O** **(2)**

vi) Heat change for making 0.05 mole H_2O = 2562 J

∴ heat change for making 1 mol H_2O = $\frac{2562}{0.05}$ J = 51 240 J = **51.24 kJ**

Heat of neutralisation, ΔH, = **−51.24 kJ mol^{-1}** **(1)**

vii)



(3)

c) The heat of solution is the heat change which occurs when 1 mol of solute dissolves in such a volume of solvent that further dilution by the solvent produces no further heat change. **(1)**

d) i) Mass of 1 mol KNO_3 = 39 + 14 + (3 × 16) g = 101 g

∴ number of moles in 6.06 g = $\frac{6.06}{101}$ mol = 0.06 mol

Heat change for dissolving 0.06 mol KNO_3 = 75 × 4.2 × 5.7 J = 1795.5 J

∴ heat change for dissolving 1 mol KNO_3 = $\frac{1795.5}{0.06}$ J = 29 925 J = **29.925 kJ**

Heat of solution, ΔH, = **+29.925 kJ mol^{-1}** **(3)**

ii) Endothermic **(1)**

iii) More energy is absorbed from the surroundings to break the ionic bonds between the K^+ ions and the NO_3^- ion and the intermolecular forces between the water molecules than is released when the attractions form between the ions and the water molecules during solvation. **(3)**

B1 Sources of hydrocarbon compounds

1. a) i) Hydrocarbons are organic compounds containing carbon and hydrogen atoms only. **(1)**

ii) Methane
Ethane
Propane
Butane **(2)**

iii) Petroleum is an oily liquid that is a complex mixture of solid and gaseous hydrocarbons dissolved in liquid hydrocarbons. **(2)**

iv) Fractional distillation **(1)**

v) Crude oil is separated into different fractions in a **fractionating tower**. **(1)**

vi) Crude oil is heated and the vapours rise up the fractionating tower. The temperature of the tower decreases upwards and the vapours condense on bubble caps at different levels up the tower depending on their boiling points; the lower the boiling point, the higher the vapour will rise before condensing. The liquids are tapped off at different levels and any gases that don't condense are removed at the top of the tower. **(4)**

b) *Any four of the following named fractions:*

Name of fraction	Use 1	Use 2
refinery gas	as fuel	to manufacture many petrochemicals
petrol or gasoline	as fuel	as solvents
kerosene oil or paraffin	as fuel	cracked into smaller hydrocarbons
diesel oil	as fuel	cracked into smaller hydrocarbons
fuel oils, lubricating oils and waxes	as fuels and lubricants	to make polishing waxes, petroleum jelly, candles
bitumen or asphalt	for surfacing roads	for roofing

(8)

2. a) i) Long-chain hydrocarbon molecules are broken down into shorter chain hydrocarbon molecules by breaking carbon–carbon bonds. **(1)**

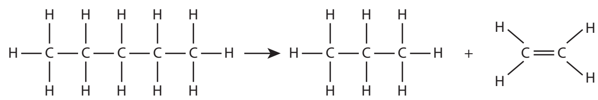
ii) Thermal cracking: This uses a high temperature and a high pressure.

Catalytic cracking: This uses a catalyst and slightly lower temperatures and much lower pressures than used in thermal cracking. **(4)**

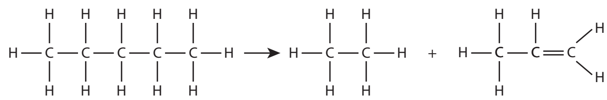
iii) Cracking increases production of the smaller, more useful hydrocarbon molecules. Fractional distillation produces insufficient of these molecules and an excess of the larger, less useful molecules. **(2)**

Cracking increases production of the more useful alkenes. Fractional distillation does not produce these molecules and cracking always results in the formation of at least one alkene. **(2)**

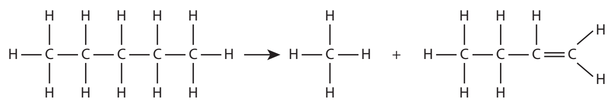
b)



propane ethene



ethane propene

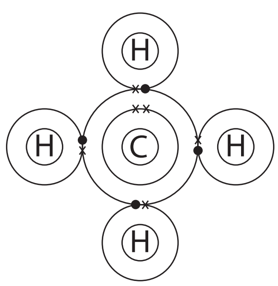


methane butene

(9)

B2 Organic chemistry – an introduction

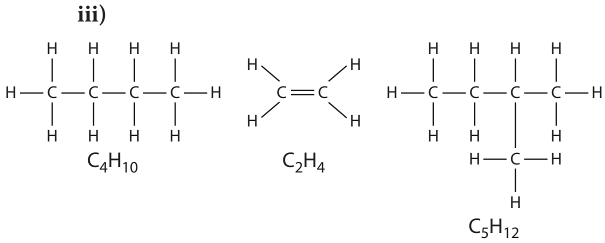
1. a) i)



(2)

ii) A carbon atom has four valence electrons, so it can bond covalently with other carbon atoms in very many ways and it can bond covalently with atoms of other non-metallic elements. **(1)**

iii)



(3)

b) i) A group of organic compounds which all possess the same functional group **(1)**

ii) *Any four of the following:*
All members have the same functional group.
All members can be represented by the same general formula.
Each member differs from the member before or after it by a $-CH_2-$ group.
Each member differs from the member before or after it by a relative molecular mass of 14.
All members possess similar chemical properties.
Members show a gradual change in their physical properties as their molar mass increases.
All members can be prepared by the same general method. **(4)**

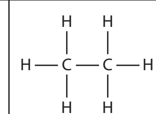
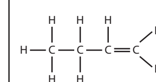
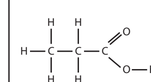
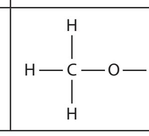
c) i) A and C **(1)**

ii) The alkene series. **(1)**

iii) They both contain the carbon–carbon double bond **(1)**

iv) C_nH_{2n} **(1)**

d) Complete the following table.

Name of compound	Name of homologous series	Condensed formula	Fully displayed structural formula
ethane	alkane	CH_3CH_3 or C_2H_6	
butene	alkene	$CH_3CH_2CH{=}CH_2$ or C_4H_8	
propanoic acid	alkanoic acid or carboxylic acid	CH_3CH_2COOH or C_2H_5COOH	
methanol	alcohol or alkanol	CH_3OH	

(6)

e) i) Butanoic acid

ii) Butene

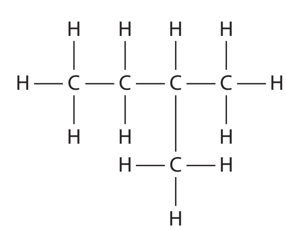
iii) Pentane

iv) Ethanol **(4)**

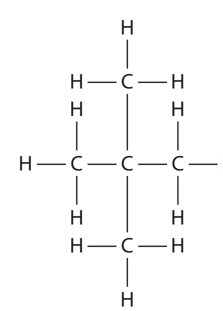
2. a) i) The occurrence of two or more organic compounds with the same molecular formula but different structural formulae. **(1)**

ii) By branching the chain of carbon atoms
By changing the position of the functional group **(2)**

b)



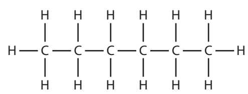
2-methylbutane



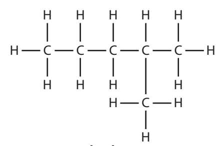
2,2-dimethylpropane

(2)

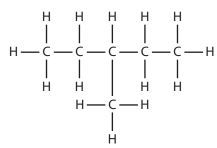
c) i) *Any two of the following:* **(4)**



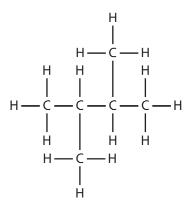
hexane



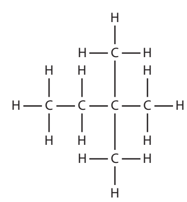
2-methylpentane



3-methylpentane

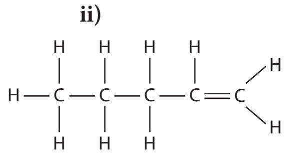


2,3-dimethylbutane

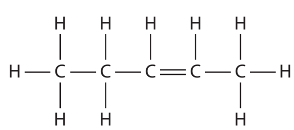


2,2-dimethylbutane

ii)



pent-1-ene
or 1-pentene



pent-2-ene
or 2-pentene

(4)

B3 Reactions of carbon compounds

1. a) i) They contain only single bonds between carbon atoms. **(1)**

ii) Alkanes are relatively unreactive because the single bonds between the carbon atoms are strong. **(2)**

b) i) $CH_4(g) + 2O_2(g) \longrightarrow 2CO_2(g) + 2H_2O(g)$
$C_3H_8(g) + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(g)$ **(2)**

ii) The reactions are exothermic because they give out heat energy to the surroundings. **(2)**

iii) The flame would be clear, blue and non-smoky. **(1)**

iv) The ratio of carbon to hydrogen atoms in methane is low, therefore all the carbon is converted to carbon dioxide and no unreacted carbon remains in the flame. **(2)**

c) i) Light **(1)**

ii) Type of reaction: Substitution
Explanation: The hydrogen atoms in each methane molecule are replaced, one at a time, by chlorine atoms. **(2)**

iii) Equation: $CH_4(g) + Cl_2(g) \longrightarrow CH_3Cl(g) + HCl(g)$
Names of products: Monochloromethane and hydrogen chloride **(2)**

iv) Equation: $CH_4(g) + 4Cl_2(g) \longrightarrow CCl_4(l) + 4HCl(g)$
Name of organic product: Tetrachloromethane **(3)**

d) i) *Any three of:*
Alkanes burn very easily when they are ignited.
Alkanes release large amounts of energy when they burn.
Alkanes burn with a clean, non-smoky flame.
Alkanes are easy to transport and store. **(3)**

ii) Alkanes are non-polar molecules, therefore they can dissolve non-polar solutes. **(1)**

iii) Biogas is mainly methane mixed with some carbon dioxide. It is produced by bacteria breaking down waste organic matter, such as manure, anaerobically in a biogas digester. **(2)**

iv) *Any two of:*
It reduces the demand for non-renewable fossil fuels.
It reduces the amount of waste which has to be disposed of.
It recycles soil nutrients, since the waste can be used as fertiliser. **(2)**

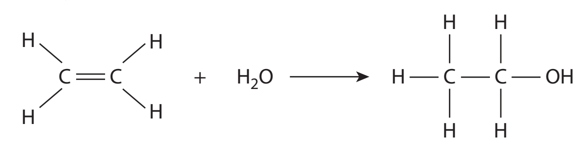
2. a) i) They contain a carbon–carbon double bond in their molecules. **(1)**

ii) Alkenes are reactive because one bond in the carbon–carbon double bond can break and the carbon atom at either side can share its fourth valence electron with atoms of other elements which also have a valence electron to share. **(3)**

b) i) It requires the water to be in the form of steam, a temperature of 300°C, a pressure of 70 atm and a catalyst of phosphoric acid in sand. **(4)**

ii) Addition **(1)**

iii)

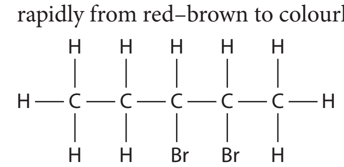


(1)

iv) Ethanol **(1)**

c) i) The bromine solution would change colour rapidly from red–brown to colourless. **(1)**

ii)



2,3-dibromopentane **(2)**

d) i) Conditions: A temperature of 150°C, a pressure of 5 atm and a nickel catalyst. **(3)**
Equation: $C_3H_6(g) + H_2(g) \longrightarrow C_3H_8(g)$

ii) Propane **(1)**

e) i) Acidified potassium manganate(VII) solution. **(1)**

ii) The acidified potassium manganate(VII) solution would remain purple when added to the cyclohexane because no reaction occurs. The acidified potassium manganate(VII) solution would turn colourless when added to the cyclohexene because the cyclohexene oxidises the purple MnO_4^- ion to the colourless Mn^{2+} ion. **(4)**

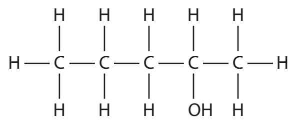
3. a) i) B and D **(1)**

ii) Series: Alcohol series or alkanol series
Reason: They both contain the hydroxyl functional group. **(2)**

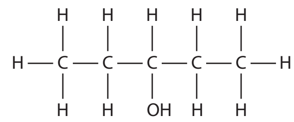
iii) An ester **(1)**

iv) Soluble. D is polar because its molecules contain the polar hydroxyl group. Water is also polar and polar solutes dissolve in polar solvents. **(3)**

v)



pentan-2-ol
or 2-pentanol



pentan-3-ol
or 3-pentanol

(4)

b) i) Name and molecular formula of P: Glucose, $C_6H_{12}O_6$
Type of reaction: Fermentation or anaerobic respiration **(3)**

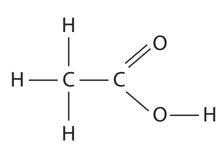
ii) Fractional distillation **(1)**

iii) Equation: $2C_2H_5OH(l) + 2Na(s) \longrightarrow 2C_2H_5ONa(alc\ sol) + H_2(g)$
Identity of R: Sodium ethoxide **(3)**

iv) Conditions: Q must be heated to 170°C in the presence of excess concentrated sulfuric acid or Q must be vapourised and its vapour passed over heated aluminium oxide.
Equation: $C_2H_5OH(l) \longrightarrow C_2H_4(g) + H_2O(g)$ **(3)**

v) Dehydration **(1)**

vi) Identity of T: Ethanoic acid
Structural formula of T:



(2)

vii) Reagent: Acidified potassium dichromate(VI) or acidified potassium manganate(VII)
Type of reaction: Oxidation **(2)**

c) i) To determine the alcohol content of a driver's breath. **(1)**

ii) The driver blows over orange acidified potassium dichromate(VI) crystals. If ethanol vapour is present it will oxidise the orange $Cr_2O_7^{2-}$ ion in the crystals to the green Cr^{3+} ion and the crystals will turn green. **(3)**

4. a) i) $C_nH_{2n+1}COOH$ **(1)**

ii) Propanoic acid: CH_3CH_2COOH or C_2H_5COOH
Methanoic acid: HCOOH **(2)**

iii) Explanation: Alkanoic acids and inorganic acids ionise when dissolved in water to form H^+ ions and the reactions of aqueous acids are due to the presence of H^+ ions.
Equation: $CH_3COOH(aq) \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$ **(3)**

iv) Difference: The reaction between the metal and the alkanoic acid would be slower or less vigorous.
Reason: The solutions of alkanoic acids have a lower concentration of H^+ ions because alkanoic acids are weak acids which are only partially ionised in water, whereas inorganic acids are strong acids which are fully ionised in water. **(3)**

v) Ethanoic acid and sodium hydroxide:
$NaOH(aq) + CH_3COOH(aq) \longrightarrow CH_3COONa(aq) + H_2O(l)$

Ethanoic acid and calcium carbonate:
$CaCO_3(s) + 2CH_3COOH(aq) \longrightarrow (CH_3COO)_2Ca(aq) + CO_2(g) + H_2O(l)$ **(3)**

b) i) Ethanol **(1)**

ii) Oxidation **(1)**

iii) Equation: $CH_3COOH(l) + C_2H_5OH(l) \rightleftharpoons CH_3COOC_2H_5(l) + H_2O(l)$
Identity of Z: Ethyl ethanoate **(2)**

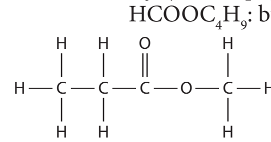
iv) Esterification **(1)**

v) Equation: $2CH_3COOH(aq) + Mg(s) \longrightarrow (CH_3COO)_2Mg(aq) + H_2(g)$
Identity of Y: Magnesium ethanoate **(2)**

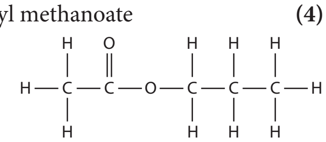
5. a) i) Compounds formed when an alkanoic acid reacts with an alcohol. **(1)**

ii) Reason 1: The acid acts as a catalyst to speed up the reaction.
Reason 2: The acid removes the water produced. This favours the forward reaction and increases the yield of ethyl ethanoate. **(2)**

b) i) $C_3H_7COOC_2H_5$: ethyl butanoate
$HCOOC_4H_9$: butyl methanoate **(4)**



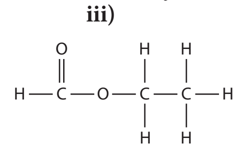
methyl propanoate



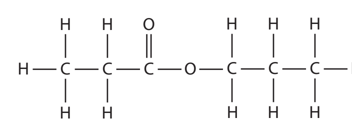
propyl ethanoate

ii) Methyl butanoate: $CH_3CH_2CH_2COOCH_3$ or $C_3H_7COOCH_3$
Butyl ethanoate: $CH_3COOC_4H_9$ or $CH_3COOCH_2CH_2CH_2CH_3$ **(2)**

iii)



ethyl methanoate



propyl propanoate

(2)

c) i) The ester molecules are broken down into smaller molecules by reacting with water. **(1)**

ii) $CH_3COOC_2H_5(l) + NaOH(aq) \longrightarrow CH_3COONa(aq) + C_2H_5OH(aq)$ **(1)**

iii) Product 1: Propanoic acid, CH_3CH_2COOH or C_2H_5COOH
Product 2: Methanol, CH_3OH **(4)**

d) i) Saponification **(1)**

ii) $(C_{17}H_{35}COO)_3C_3H_5(l) + 3NaOH(aq) \longrightarrow 3C_{17}H_{35}COONa(aq) + C_3H_5(OH)_3(aq)$ **(2)**

iii) Sodium octadecanoate and glycerol **(2)**

e) i) A chemical which is added to water to remove dirt from things like clothing. **(1)**

ii) Soapy detergents are made from animal fats and vegetable oils, whereas soapless detergents are made from petroleum. **(2)**

iii) Advantage:
Any one of the following:
They lather easily and don't form unpleasant scum when used in hard water.
They are made from a renewable resource which will not run out.

Disadvantages:
Any two of:
They contain phosphates which cause eutrophication in aquatic environments, eventually leading to the death of aquatic organisms.
Some are non-biodegradable and cause foam to build up in sewage systems and on waterways, which makes sewage treatment difficult and leads to the death of aquatic organisms.
They are manufactured from petroleum and the supplies of petroleum are limited. **(3)**

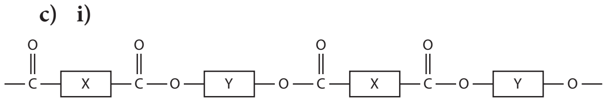
6. a) A macromolecule formed by linking together 50 or more small molecules, known as monomers, usually in chains. **(1)**

b)

Addition polymerisation	**Condensation polymerisation**
one product, the polymer, is produced	two products are produced: the polymer and another compound composed of small molecules
the monomers which make up the polymer are all the same	the polymer is usually made from more than one type of monomer
the empirical formula of the polymer is the same as that of the monomer that formed it	the empirical formula of the polymer is different from that of the monomers that formed it

(6)

c) i)



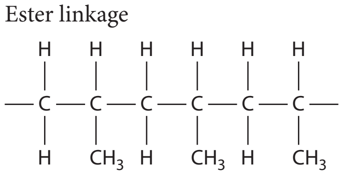
(2)

ii) Type of polymerisation: Condensation polymerisation
Type of polymer: Polyester **(2)**

iii) *Any one of:*
Polyethylene terephthalate
Terylene
Dacron **(1)**

iv) Ester linkage **(1)**

v)

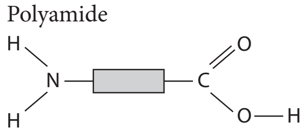


(1)

vi) Type of polymerisation: Addition polymerisation
Type of polymer: Polyalkene **(2)**

d) i) Polyamide **(1)**

ii)



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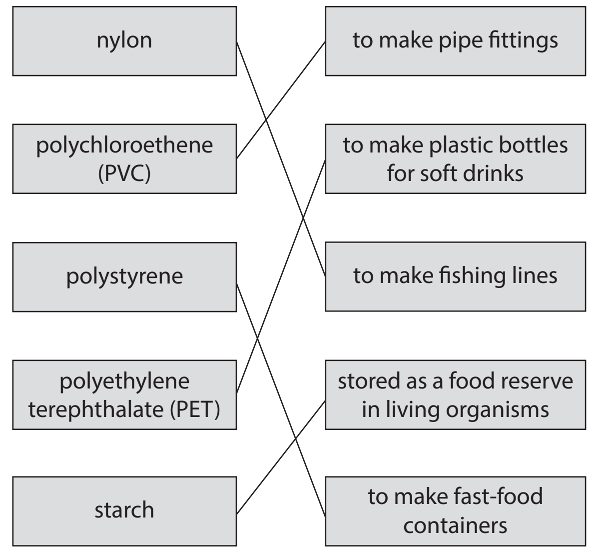
e)



(5)

C1 Characteristics of metals

1. a) i) A metal is an element whose atoms have a small number of valence electrons. This number is usually 1, 2 or 3. **(1)**

ii) Metals are solid at room temperature: Room temperature is not hot enough to break the strong electrostatic forces of attraction between the cations and delocalised electrons.
Metals are malleable: The atoms in a metal are all of the same type and size so, if force is applied, the atoms can roll over each other into new positions without the metallic bond breaking.
Metals conduct electricity: The delocalised electrons from each metal atom are free to move and carry electricity. **(3)**

iii) Metals have high melting and boiling points.
Metals have a shiny luster.
Metals have a high density. **(3)**

iv) When metals react to form ionic compounds the metal atoms lose electrons. These lost electrons are given to the other reactant, causing that reactant to gain electrons (be reduced). **(2)**

v) $Ca \longrightarrow Ca^{2+} + 2e^-$ **(1)**

b) i) $X(s) + H_2O(g) \longrightarrow XO(s) + H_2(g)$ **(1)**

ii) Magnesium **(1)**

c) i)

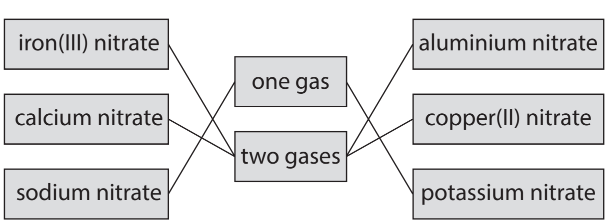
Metal	Reaction when heated in air	Reaction with water	Reaction with dilute hydrochloric acid
copper	does not burn, but forms an oxide coating if heated very strongly	does not react with water or steam	no reaction occurs
sodium		reacts vigorously with cold water	reacts violently
aluminium	burns when heated strongly, especially if powdered	reacts with steam but does not react with cold or hot water	a vigorous reaction occur

(8)

ii) The reaction between sodium and water:
$2Na(s) + 2H_2O(l) \longrightarrow 2NaOH(aq) + H_2(g)$
Aluminium reacting with oxygen:
$4Al(s) + 3O_2(g) \longrightarrow 2Al_2O_3(s)$
Aluminium reacting with hydrochloric acid:
$2Al(s) + 6HCl(aq) \longrightarrow 2AlCl_3(aq) + 3H_2(g)$ **(6)**

2. a) i) $CuO(s) + 2HCl(aq) \longrightarrow CuCl_2(aq) + H_2O(l)$ **(2)**
ii) $CaCO_3(s) + 2HNO_3(aq) \longrightarrow Ca(NO_3)_2(aq) + CO_2(g) + H_2O(l)$ **(2)**
iii) $Mg(OH)_2(s) + H_2SO_4(aq) \longrightarrow MgSO_4(aq) + 2H_2O(l)$ **(2)**

b) i)



(3)

ii) Copper(II) nitrate: $2Cu(NO_3)_2(s) \longrightarrow 2CuO(s) + 4NO_2(g) + O_2(g)$ **(4)**
Sodium nitrate: $2NaNO_3(s) \longrightarrow 2NaNO_2(s) + O_2(g)$ **(4)**

c) Potassium carbonate is not decomposed by heat whereas magnesium carbonate is decomposed forming magnesium oxide and carbon dioxide.
$MgCO_3(s) \longrightarrow MgO(s) + CO_2(g)$ **(3)**

C2 Reactivity and extraction of metals

1. a) i) A list of metals arranged in order from the most reactive to the least reactive. **(1)**
ii) How easily the atoms of the metal ionise. **(1)**
iii) R, calcium, magnesium, aluminium, zinc, iron, Q **(3)**

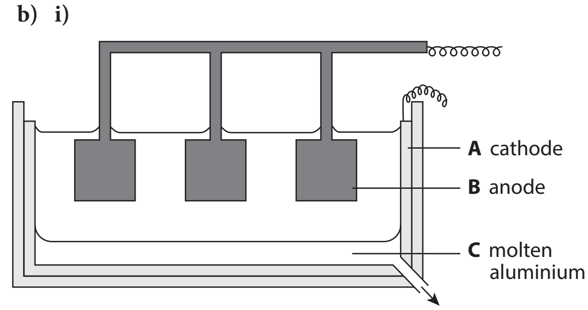
b) i) Metal Y. **(1)**
ii) $2X(OH)_3(s) \longrightarrow X_2O_3(s) + 3H_2O(g)$ **(2)**
iii) There would be a violent reaction. **(1)**

c) i) A reaction in which a metal in its free state takes the place of another metal in a compound. **(1)**
ii) Calcium, Z, iron **(1)**
iii) $Mg(s) + ZnCl_2(aq) \longrightarrow MgCl_2(aq) + Zn(s)$ **(1)**

d) i) Identity of the pink solid: Copper
Ionic equation: $Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$ **(3)**
ii) Reason: The zinc atoms in the strip ionised and entered the solution.
Ionic equation: $Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^-$ **(3)**
iii) It would gradually turn paler blue. **(1)**
iv) The Cu^{2+} ions, which give the copper(II) sulfate solution its blue colour, were being discharged from the solution. **(2)**

2. a) i) The extraction of a metal from its ore is a **reduction** process. **(1)**
ii) The position of the metal in the reactivity series. **(1)**
iii) Method: Electrolysis of the molten ore of metal A.
Explanation: Metal A is high up in the reactivity series therefore it forms stable ions which are hard to reduce and need a powerful method of reduction, this being electrolysis. **(3)**

b) i)



(3)

ii) Bauxite or hydrated aluminium oxide **(1)**
iii) Na_3AlF_6 **(1)**
iv) It reduces the melting point of the ore which reduces the amount of energy used during its electrolysis.
The solution produced is a better conductor than the molten ore on its own. **(4)**
v) At the anode: $2O^{2-}(l) \longrightarrow O_2(g) + 4e^-$
At the cathode: $Al^{3+}(l) + 3e^- \longrightarrow Al(l)$ **(4)**

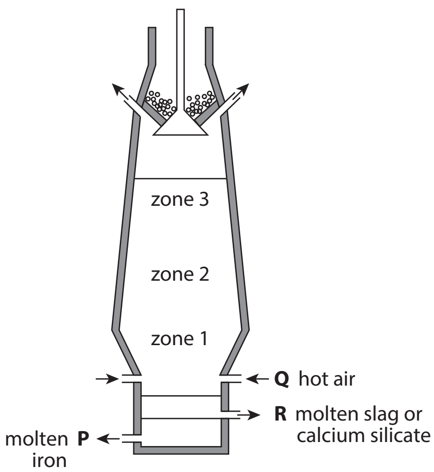
3. a) i) Carbon monoxide. (1)

ii) Iron is in the middle of the reactivity series and its ions are less stable than those of metals higher up and easier to reduce. A less powerful method of reduction which uses less energy and is less expensive than electrolysis will reduce the iron ions. (3)

iii) Haematite or iron(III) oxide
Magnetite or iron(II, III) oxide (2)

b) i) Coke or carbon (2)
Limestone or calcium carbonate

ii)



(3)

iii) Zone 1: $C(s) + O_2(g) \longrightarrow CO_2(g)$
Zone 2: $CO_2(g) + C(s) \longrightarrow 2CO(g)$
Zone 3: $Fe_2O_3(s) + 3CO(g) \longrightarrow 2Fe(s) + 3CO_2(g)$
or $Fe_3O_4(s) + 4CO(g) \longrightarrow 3Fe(s) + 4CO_2(g)$ (5)

iv) The reaction between the coke and the oxygen in the air is exothermic. (1)

v) To heat the air that enters at the bottom of the blast furnace. (1)

vi) Heat in the upper part of the furnace causes the calcium carbonate to decompose to form calcium oxide and carbon dioxide. The calcium oxide reacts with the silicon dioxide to form calcium silicate or slag which melts, runs down to the bottom of the blast furnace and is removed. (4)

vii) Pig iron. (1)

C3 Uses of metals

1. a) i) *Any two of the following:*
It is resistant to corrosion
It is light in weight
It is malleable (2)

ii) It is a good conductor of electricity
It is resistant to corrosion (2)

iii) *Any two of the following:*
It is malleable and ductile
It is strong
It is easily welded (2)

iv)

Aluminium	Lead
Any two of the following: To make window frames; To make cooking utensils; To make overhead electrical cables; To make foil for cooking	To make weights for fishing and diving; As a radiation shield or as a shield for X-rays

(4)

b) i) A mixture of two or more metals (1)

ii) The atoms of the metals in an alloy usually have different sizes. This changes the regular pattern of the atoms and makes it more difficult for them to slide over each other when force is applied. (2)

iii) About 95% aluminium and 5% magnesium. (2)

iv) *Any two of the following:*
It is more workable than aluminium.
It is more resistant to corrosion than aluminium.
It is lighter in weight than aluminium. (2)

v) Steel (1)

vi) Carbon (1)

vii) Name of alloy: Solder
Composition: About 60% lead and 40% tin
Use: To join metal items together
Reason for use: It has a lower melting point than lead, so it melts more easily when joining the metals. (5)

C4 Impact of metals on living systems and the environment

1. a) i) The surface of the metal is damaged by reacting with chemicals in the environment, mainly oxygen and moisture. The metal surface is usually oxidised to the metal oxide. (2)

ii) Advice: Use aluminium.
Explanation: When aluminium corrodes it forms aluminium oxide which protects the metal from further corrosion because it is fairly unreactive and adheres to the metal. (3)

iii) When iron corrodes it forms hydrated iron(III) oxide or rust which does not adhere to the metal and so peels off. This exposes fresh iron to oxygen and moisture, and more rust forms and peels off. This continues causing the iron to gradually wear away. (3)

b) i) To keep air containing oxygen and moisture out of the tubes (1)

ii) To remove any dissolved oxygen (1)

iii) To prevent oxygen from the air dissolving back into the water (1)

iv) To absorb moisture from the air (1)

v)

Test tube	Observations
A	rusts
B	does not rust
C	rusts
D	does not rust

(4)

vi) Tube C **(1)**

2. a)

Metal ion	Role in living organisms
iron	needed for the formation of haemoglobin in red blood cells
magnesium	needed for the formation of chlorophyll in green plant
calcium	needed for the formation of calcium phosphate in bones and teeth
zinc	important for the immune system to function properly *or* important for cells and tissues to grow and repair themselves

(4)

b) i) Mercury remains in the environment and concentrates up food chains so that the top consumers, such as large fish, contain high concentrations of it in their tissues. **(2)**

ii) Name of disease: Minamata disease
Symptoms: Mercury damages the central nervous system which causes muscular co-ordination, hearing, sight, speech and the sense of touch to be impaired. **(3)**

iii) *Any two of the following metal ions:*

Metal ion: Lead
Source: Disused lead-acid batteries *or* recycling of lead-acid batteries *or* extraction and refining of lead *or* using leaded petrol *or* lead based paints.

Harmful effect: It damages body tissues and organs, especially nervous tissue, *or* it affects the normal formation of red blood cells resulting in anaemia, *or* it affects brain development in children

Metal ion: Cadmium
Source: Disused nickel–cadmium batteries, *or* the combustion of fossil fuels, *or* cigarette smoke, *or* the combustion of fossil fuels, *or* the extraction and refining of metals, *or* the manufacture of paint and certain plastics
Harmful effect: It damages the lungs, kidneys and liver *or* it leads to osteoporosis
Metal ion: Arsenic
Source: Mining of certain metals, *or* the extraction and purification of metals, *or* the combustion of fossil fuels.
Harmful effect: It damages the nervous system and heart, *or* it can cause cancer **(4)**

iv) Recycling any items containing heavy metals **(1)**

C5 Non-metals

1. a) i) A non-metal is an element whose atoms usually have a large number of valence electrons. This number is usually 5, 6, 7 or 8. **(2)**

ii) Melting and boiling points: They usually have low melting and boiling points.
Conductivity: They are poor conductors of electricity and heat.
Luster: Solid non-metals are dull.
Hardness: Solid non-metals are brittle.
Density: They usually have low densities. **(5)**

b) i) When non-metals react with metals, the non-metal atoms gain electrons from the metal atoms causing the metal atoms to lose electrons (be oxidised). **(2)**

ii)

non-metal	Equation for the reaction with calcium	Name of the product
oxygen	$2Ca(s) + 2O_2(g) \longrightarrow 2CaO(s)$	calcium oxide
hydrogen	$Ca(s) + H_2(g) \longrightarrow CaH_2(s)$	calcium hydride
nitrogen	$3Ca(s) + N_2(g) \longrightarrow Ca_3N_2(s)$	calcium nitride
chlorine	$Ca(s) + Cl_2(g) \longrightarrow CaCl_2(s)$	calcium chloride
sulfur	$Ca(s) + S(s) \longrightarrow CaS(s)$	calcium sulfide

(10)

iii) $2KI(aq) + Cl_2(g) \longrightarrow 2KCl(aq) + I_2(aq)$ **(2)**

iv) If the oxygen supply is limited:
$2C(s) + O_2(g) \longrightarrow 2CO(g)$
If the oxygen supply is plentiful:
$C(s) + O_2(g) \longrightarrow CO_2(g)$ **(3)**

c) i) Hydrogen
Carbon
Sulfur **(3)**

ii) Oxygen **(1)**

2. a) i)

	Oxygen	Carbon dioxide
Liquid X	hydrogen peroxide	hydrochloric acid
Solid Y	manganese(IV) oxide	calcium carbonate
Liquid Z	concentrated sulfuric acid	concentrated sulfuric acid

(6)

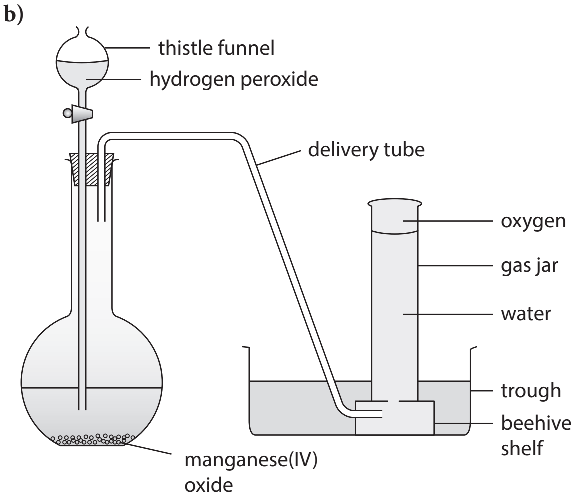
ii) To remove any water vapour from the gas **(1)**

iii) Anhydrous calcium chloride **(1)**

iv) Upward displacement of air **(1)**

v) Carbon dioxide is denser than air so sinks, displacing the air upwards **(1)**

b)



(3)

c) **i)** Calcium hydroxide and ammonium chloride **(2)**

ii) $Ca(OH)_2(s) + 2NH_4Cl(s) \longrightarrow CaCl_2(s) + 2NH_3(g) + 2H_2O(g)$ **(2)**

iii) Calcium oxide **(1)**

iv) Ammonia reacts with concentrated sulfuric acid. **(1)**

v) Downward displacement of air **(1)**

vi) Ammonia is less dense than air so it rises displacing the air downwards. **(1)**

vii) Because ammonia reacts with water to form ammonium hydroxide solution. **(1)**

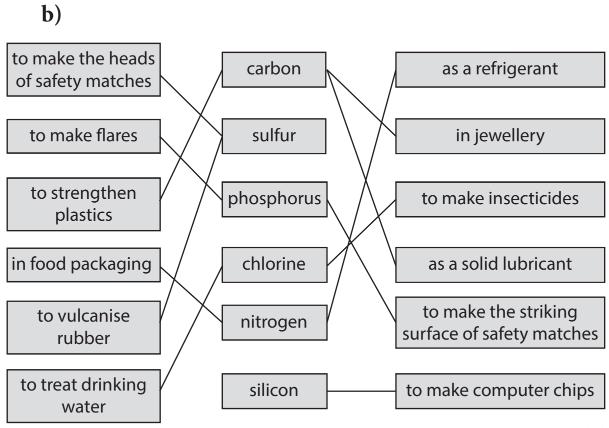
3. a) **i)** Oxygen is essential for the acetylene or hydrogen to burn and produce a high-temperature flame. **(1)**

ii) Oxygen is used to ease certain medical disorders because it is essential for respiration. **(1)**

iii) Carbon dioxide is non-flammable and denser than air, therefore it smothers flames when sprayed on them. **(2)**

iv) Carbon dioxide sublimes at −78.5 °C, therefore keeps food items extremely cold and does not leave any liquid when it changes to a gas. **(2)**

b)



(6)

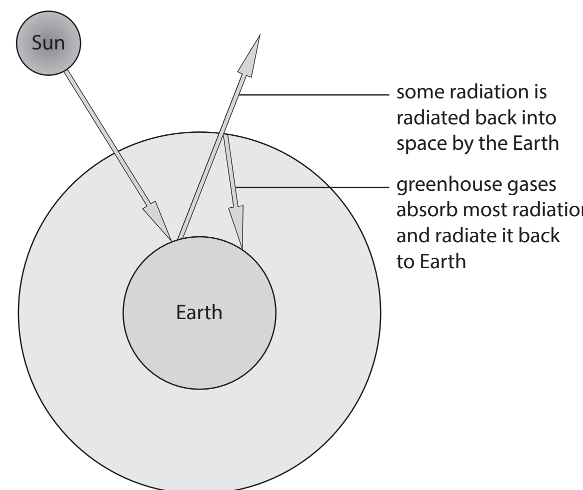
c) As a bleaching agent: sodium chlorate(I) and sulfur dioxide
As a food preservative: sulfur dioxide
To make ceramics: metal silicates
In the manufacture of glass: sodium carbonate and silicon dioxide
To soften hard water: sodium carbonate
To manufacture fertilisers: ammonia, phosphoric acid and sulfuric acid **(5)**

4. a) **i)** Chlorfluorocarbons **(1)**

ii) CFCs break down the ozone in the upper atmosphere which allows more ultraviolet light to reach the Earth's surface. This is leading to increased numbers of people developing skin cancer, cataracts and depressed immune systems. **(3)**

b) **i)** Burning fossil fuels
Deforestation **(2)**

ii)



(3)

iii) It is contributing to the Earth gradually getting warmer, known as global warming. Global warming is starting to cause polar ice caps and glaciers to melt, sea levels to rise, low-lying coastal areas to flood, changes in the global climate, more severe weather patterns and ocean acidification. **(4)**

c) **i)** The rapid growth of green plants and algae in aquatic environments **(1)**

ii) Fertilisers used in agriculture
Synthetic detergents or soapless detergents **(2)**

iii) The water turns green and the plants and algae that die and are decomposed by aerobic bacteria. This uses up the dissolved oxygen and the shortage of oxygen then causes the death of other aquatic organisms **(3)**

d) **i)** Combustion of fossil fuels, especially coal **(1)**

ii) Acid rain **(1)**

e) Most plastics are non-biodegradable so require large areas of land for their disposal.
Some plastics release toxic chemicals which remain in the environment after their disposal.
Some plastics produce toxic chemicals if they are disposed of by being burnt in incinerators. **(3)**

5. a) i) When water evaporates from the surface of organisms it removes a lot of heat energy which makes sweating and transpiration efficient cooling methods. **(2)**

ii) The bodies of living organisms can absorb a lot of heat energy without their temperatures changing much, so they can survive extremes of temperature. Also, the temperatures of large bodies of water do not change as much as atmospheric temperatures change, so aquatic organisms do not experience extreme temperature changes. **(4)**

b) i) Water has a maximum density at 4°C *or* as water cools down below 4°C its density decreases. **(1)**

ii) When a lake or a pond freezes, ice forms at the surface and the warmer, denser water stays below the ice, which allows aquatic organisms to survive under the ice. **(2)**

c) i) Water molecules are polar, therefore water can dissolve both ionic compounds and covalent compounds that are polar. **(2)**

ii) *Any two of the following:*
So that chemicals in the cells of organisms can be dissolved and chemical reactions can occur
So that useful substances can be dissolved and absorbed by living organisms
So that useful substances can be dissolved and carried around the bodies of organisms
So that waste products can be dissolved and excreted from organisms **(2)**

iii) *Any two of the following:*
Water can become polluted as a result of dissolved chemicals.
Water can become hard.
Mineral salts can be leached out of the soil. **(2)**

d) i) Tube A **(1)**

ii) Dissolved calcium and magnesium salts *or* the presence of Ca^{2+} and Mg^{2+} ions in the water. **(2)**

iii) $2C_{17}H_{35}COONa(aq) + Ca^{2+}(aq) \longrightarrow (C_{17}H_{35}COO)_2Ca(s) + 2Na^+(aq)$ **(2)**

iv) *Any one of the following:*
Scum forms an unpleasant grey, greasy layer around sinks and showers.
Scum discolours clothes.
Hard water wastes soap as more is needed.
Hard water causes limescale to build up in kettles, around taps and showerheads and in hot-water pipes. **(1)**

v) Types: Temporary hardness and permanent hardness
Differences: Temporary hardness is caused by dissolved calcium hydrogen carbonate and magnesium hydrogen carbonate and can be removed by boiling the water. Permanent hardness is caused by dissolved calcium sulfate and magnesium sulfate and cannot be removed by boiling. **(4)**

6. a) i) It kills micro-organisms in the water. **(1)**

ii) Dissolved Ca^{2+} and Mg^{2+} ions are removed. **(1)**

b) i) Method: Any dissolved calcium and magnesium hydrogen carbonate decompose forming insoluble calcium and magnesium carbonate which precipitate out.
Equation: $Ca(HCO_3)_2(aq) \longrightarrow CaCO_3(s) + H_2O(l) + CO_2(g)$ **(2)**

ii) Method: The dissolved Ca^{2+} and Mg^{2+} ions react with the CO_3^{2-} ions from the sodium carbonate forming insoluble calcium and magnesium carbonate which precipitate out.
Equation: $Ca^{2+}(aq) + CO_3^{2-}(aq) \longrightarrow CaCO_3(s)$ **(2)**

iii) Method: The Ca^{2+} or Mg^{2+} ions displace the Na^+ ions in the ion-exchange resin and they are absorbed into the resin.
Equation: $Ca^{2+}(aq) + Na_2Z(s) \longrightarrow CaZ(s) + 2Na^+(aq)$ **(3)**

7. a) i) The utilisation of a set of principles that reduces or eliminates the use and generation of hazardous substances in the design, manufacture and application of chemical products. **(1)**

ii) *Any three of the following:*
It reduces pollution.
It reduces wastage.
It reduces the use of energy.
It reduces the use of natural resources.
Safer products are produced. **(3)**

b) i) Prevent **waste**.
Design safer **chemicals** and **products**.
Minimise the potential for **accidents**.
Increase energy **efficiency**.
Use **catalysts** rather than stoichiometric reagents.
Analyse in real-time to prevent **pollution**. **(7)**

ii) Maximise atom economy: Chemical processes which incorporate most or all of the starting materials into the final products should be used.

Use renewable feedstocks: The raw materials used in chemical processes should be renewable.

Design for degredation: Chemical products should be designed so that they break down into harmless products when their useful life ends. **(3)**

C6 Qualitative analysis

1. a) i) Cation: Ca^{2+} ion
Anion: I^- ion **(2)**

ii) $Ca^{2+}(aq) + 2OH^-(aq) \longrightarrow Ca(OH)_2(s)$ **(2)**

iii) Calcium hydroxide is basic so it did not react with the sodium hydroxide. **(1)**

iv) $Ag^+(aq) + I^-(aq) \longrightarrow AgI(s)$ **(1)**

b) i) Shakira would make a solution of each solid in distilled water and add aqueous ammonia to each until it was in excess and she would look to see if the precipitate remained or dissolved. **(2)**

ii) A white precipitate would form in each and then dissolve in X and remain in Y. **(2)**

iii)

Test	Observations	Inferences
	• A white precipitate formed. • The precipitate dissolved in excess.	
	• A white precipitate formed. • The precipitate remained in excess.	
	• A bright yellow precipitate formed.	
	• A brown gas was evolved. • The glowing splint relit.	

(7)

iv) Concentrated sulfuric acid and copper turnings. **(2)**

v) A blue solution and a brown gas would be formed on heating. **(2)**

c)

Test	Observations	Inferences
		• Ammonia gas was produced. • NH_4^+ ions present.
		• Fe^{2+} ions present. <u>Ionic equation</u>: $Fe^{2+}(aq) + 2OH^-(aq) \longrightarrow Fe(OH)_2(s)$
		• CO_3^{2-}, SO_3^{2-} or SO_4^{2-} ions present. • SO_4^{2-} ions present. <u>Ionic equation</u>: $Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$

(8)

2. a) **Q**: Copper(II) carbonate
R: Copper(II) oxide
S: Carbon dioxide
T: Copper(II) nitrate
U: Copper(II) hydroxide
V: Calcium carbonate **(6)**

b) i) $CuCO_3(s) \longrightarrow CuO(s) + CO_2(g)$ **(1)**

ii) $Ca(OH)_2(aq) + CO_2(g) \longrightarrow CaCO_3(s) + H_2O(l)$ **(2)**

iii) $CuO(s) + 2HNO_3(aq) \longrightarrow Cu(NO_3)_2(aq) + H_2O(l)$ **(2)**

c) $Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)$ **(2)**

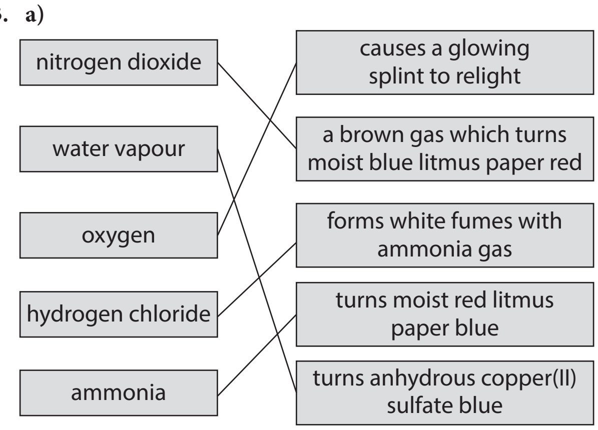
d) i) A blue precipitate would form, but it would dissolve forming a deep blue solution on the addition of excess aqueous ammonia. **(2)**

ii) Copper(II) hydroxide is basic and does not react with sodium hydroxide, however, it does react with ammonium hydroxide forming a soluble salt which dissolves. **(1)**

e) $CaCO_3(s) + CO_2(g) + H_2O(l) \longrightarrow Ca(HCO_3)_2(aq)$ **(1)**

f) Add dilute hydrochloric or nitric acid to Q and test the gas produced using limewater. Effervescence should occur and a white precipitate should form in the limewater *or*
Add a few drops of concentrated sulfuric acid to Q and test the gas produced using limewater. Effervescence should occur and a white precipitate should form in the limewater. **(2)**

3. a)



(5)

b) i) Sulfur dioxide **(1)**

ii) Sulfur dioxide is a reducing agent and it reduced the purple MnO_4^- ion to the colourless Mn^{2+} ion. **(2)**

c) i) Chlorine **(1)**

ii) The chlorine reacted with the water in the paper and formed two acids, hydrochloric acid and chloric(I) acid. Both acids caused the litmus to turn red and the chloric(I) acid oxidised the red litmus to a colourless compound. **(3)**

iii) $Cl_2(g) + H_2O(l) \longrightarrow HCl(aq) + HClO(aq)$ **(1)**

iv) By its colour, it is a yellow-green gas. **(1)**

d) The heat causes hydrogen to react explosively with the oxygen in the air. **(1)**

e) Anhydrous cobalt(II) chloride is blue and water vapour changes it to hydrated cobalt(II) chloride which is pink. **(2)**