Surname	Centre Number	Candidate Number
First name(s)		0

GCSE

S25-3410UB0-1

3410UB0-1

MONDAY, 19 MAY 2025 – MORNING

CHEMISTRY – Unit 2:
Chemical Bonding, Application of Chemical Reactions and Organic Chemistry

HIGHER TIER

1 hour 45 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**6**	
2.	**7**	
3.	**7**	
4.	**10**	
5.	**5**	
6.	**6**	
7.	**9**	
8.	**6**	
9.	**9**	
10.	**5**	
11.	**10**	
Total	**80**	

3410UB01
01

ADDITIONAL MATERIALS

In addition to this examination paper you will need a calculator and a ruler.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid.

You may use a pencil for graphs and diagrams only.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

Question **11**(a) is a quality of extended response (QER) question where your writing skills will be assessed.

The Periodic Table is printed on the back cover of this paper and the formulae for some common ions on the inside of the back cover.

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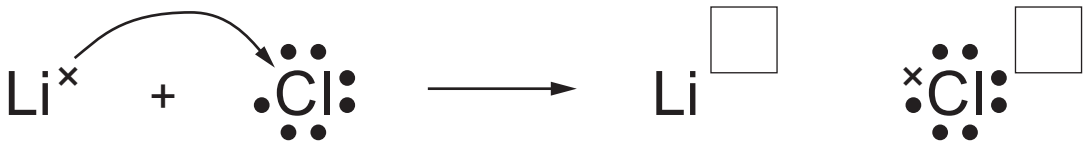
Answer **all** questions.

1. (a) Lithium reacts with chlorine to form the ionic compound lithium chloride.

(i) The diagram shows the electronic changes that occur when lithium reacts with chlorine to form lithium chloride. The ● and × symbols represent outer shell electrons.



(2,1) (2,8,7) (.....) (.....)

lithium atom chlorine atom lithium ion chloride ion

Complete the diagram by writing the electronic structures of the lithium and chloride ions in the brackets and their charges in the boxes. [2]

(ii) Give **two** properties of ionic compounds such as lithium chloride. [2]

Property 1 .....

Property 2 .....

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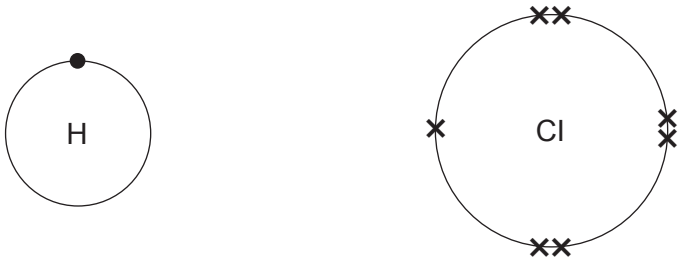
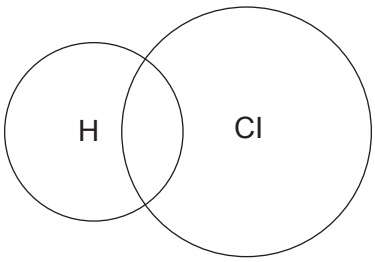
(b) The ● and × symbols in the diagram represent the outer shell electrons in an atom of hydrogen and an atom of chlorine.



Complete the diagram below to show the electrons in a molecule of hydrogen chloride.
[2]



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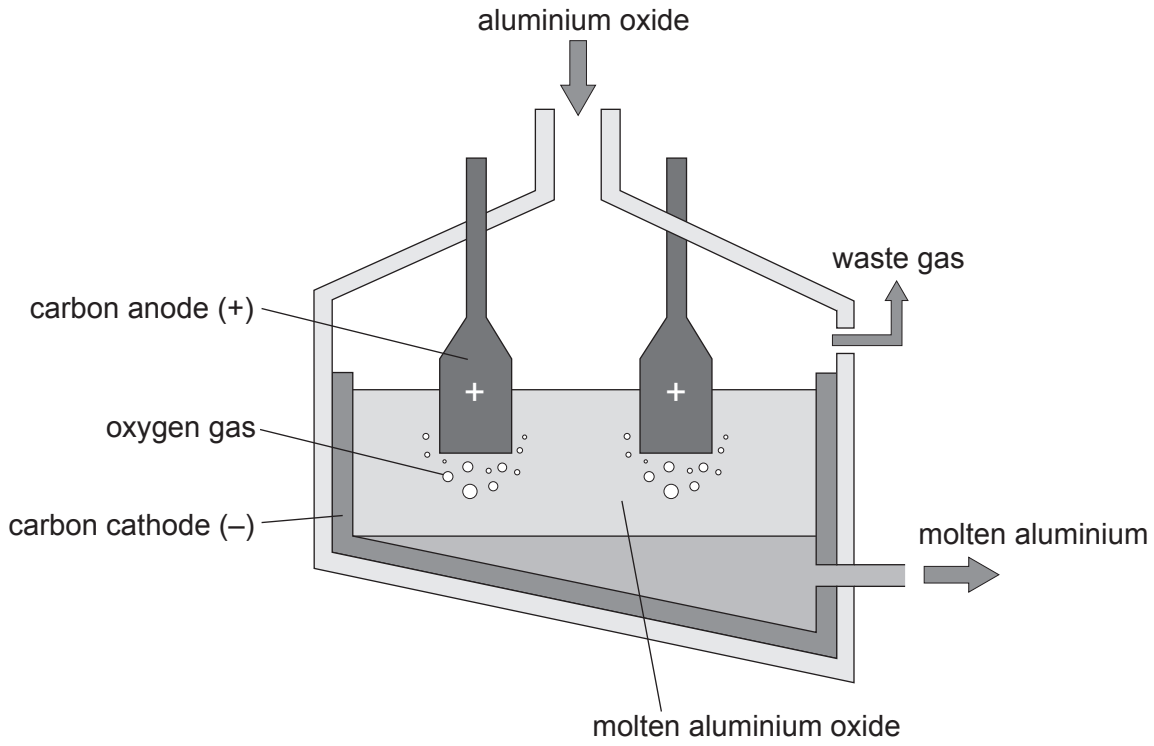
2. (a) The diagram shows a cell used in the electrolysis of aluminium oxide.

The following equation represents the overall reaction.

$$2Al_2O_3 \longrightarrow 4Al + 3O_2$$



(i) Give the **symbol** of the **ion** attracted to the positive electrode. [1]

.....

(ii) Oxygen is formed at the carbon anode. At the high temperature of the cell, the carbon anode burns. [1]

Name the gas formed when the carbon anode burns in oxygen.

.....

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(iii) During the process each aluminium ion, Al^{3+}, gains three electrons forming an aluminium atom at the cathode.

Tick (✓) the box next to the electrode equation for the process at the cathode. [1]

$Al^{3+} - 3e^- \longrightarrow Al$ ☐

$Al^{3+} + 3e^- \longrightarrow 3Al$ ☐

$Al^{3+} - 3e^- \longrightarrow Al_3$ ☐

$Al^{3+} + 3e^- \longrightarrow Al$ ☐

(iv) Aluminium is a good electrical conductor. It is used to make over-head power cables.

Give **one** other property of aluminium that makes it a suitable material for this use. [1]

.....

3410UB01 05

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(b) The ore most commonly used for the extraction process is bauxite, which contains a lot of impurities.

The UK has no bauxite deposits meaning it must be imported from other countries, including Australia and Guinea. Bauxite is processed forming aluminium oxide to be used in the electrolysis process.

Tick (✓) the box next to **two** statements that describe the requirements for the siting of an aluminium extraction plant in the UK. [2]

near a port to import bauxite	☐
nearby limestone quarries	☐
near a direct supply of electricity	☐
near a port to export bauxite	☐
nearby recycling centre	☐
nearby bauxite deposit	☐

(c) Aluminium reacts with chlorine to form aluminium chloride.

Complete the balancing of the symbol equation for this reaction. [1]

$$2Al + \square Cl_2 \longrightarrow 2AlCl_3$$

7

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3. (a) Sulfuric acid is produced by the contact process.

The flow diagram shows the main stages in the process.

Stage **1**	Stage **2**	Stage **3**	Stage **4**
Solid raw material **A** burns in gaseous raw material **B** to form sulfur dioxide, SO_2	SO_2 reacts with oxygen in the presence of a catalyst forming sulfur trioxide, SO_3 $2SO_2 + O_2 \rightleftharpoons 2SO_3$	SO_3 dissolves in concentrated sulfuric acid forming oleum, $H_2S_2O_7$	$H_2S_2O_7$ reacts with a small amount of water forming sulfuric acid

(i) Name the **two** raw materials used in stage **1**. [2]

Solid raw material **A** .....

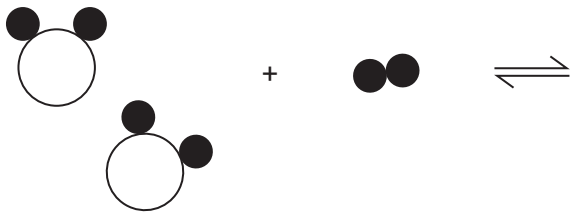
Gaseous raw material **B** .....

(ii) Name the catalyst used in stage **2**. [1]

.....

(iii) Use the symbol equation for the reaction in stage **2** to complete the diagram below. [2]

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$



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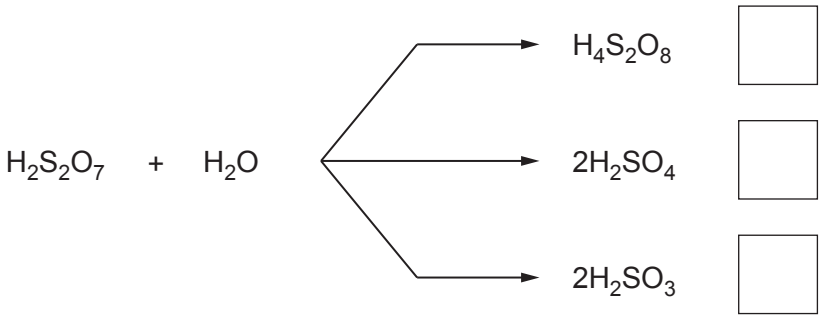
(iv) In stage **4**, one molecule of oleum, $H_2S_2O_7$, reacts with one molecule of water to form sulfuric acid.

Tick (✓) the box next to the product that correctly balances the equation for this reaction. [1]



3410UB01
09

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(b) The photograph shows concentrated sulfuric acid acting as a dehydrating agent in its reaction with sugar.

The equation represents the reaction.

$$C_{12}H_{22}O_{11} \longrightarrow 12C + 11H_2O$$

sugar — carbon — steam

Tick (✓) the box next to the statement that explains why this is a dehydration reaction. [1]

carbon, hydrogen and oxygen react to make sugar ☐

sugar turns black and expands up the beaker ☐

the reaction is exothermic ☐

the elements hydrogen and oxygen are removed from the sugar ☐

sugar splits up into carbon, hydrogen and oxygen ☐

7

Examiner only

4. (a) (i) Equations **A-E** represent reactions that take place in the blast furnace.

A	$C + O_2 \longrightarrow CO_2$
B	$CaCO_3 \longrightarrow CaO + CO_2$
C	$C + CO_2 \longrightarrow 2CO$
D	$Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$
E	$CaO + SiO_2 \longrightarrow CaSiO_3$

Choose the letter, **A-E**, of the equation that matches each of the following descriptions. [4]

	Letter
a decomposition reaction	
a reaction that is used to heat up the furnace	
a reaction that forms a reducing agent	
a neutralisation reaction	

3410UB01
11

(ii) The equation below shows another reaction that takes place in the blast furnace.

$$Fe_2O_3 + 3C \longrightarrow 2Fe + 3CO$$

Use the equation to explain the meaning of the term reduction. [2]

.....

.....

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(b) **Table 1** shows the colours of three metal nitrate solutions.

Table 1

Metal nitrate solution	Colour
silver nitrate	colourless
copper(II) nitrate	blue
iron(II) nitrate	green

The list below shows iron, copper and silver in their relative positions in the reactivity series.

Most reactive iron

copper

Least reactive silver

A student carried out a series of experiments. She added excess silver, copper and iron to solutions of silver nitrate, copper(II) nitrate and iron(II) nitrate.

Table 2 shows some of her observations. Two observations are missing.

Table 2

	Metal nitrate solution		
	silver nitrate	copper(II) nitrate	iron(II) nitrate
silver		no colour change	....
copper	colourless solution turns blue		no colour change
iron	colourless solution turns green	....	

Examiner only

(i) Use the information in **Table 1** and the relative positions of the metals in the reactivity series.

Complete Table 2 by putting in the missing observations. [2]

(ii) Copper reacts with silver nitrate solution forming silver and copper(II) nitrate solution.

Complete and balance the symbol equation for the reaction. [2]

$Cu + 2AgNO_3 \longrightarrow \square Ag + ...$

10

5. (a)

The range of colours in fireworks are formed by heating metals and their compounds.

Table 1 shows a list of substances which are commonly used in fireworks.

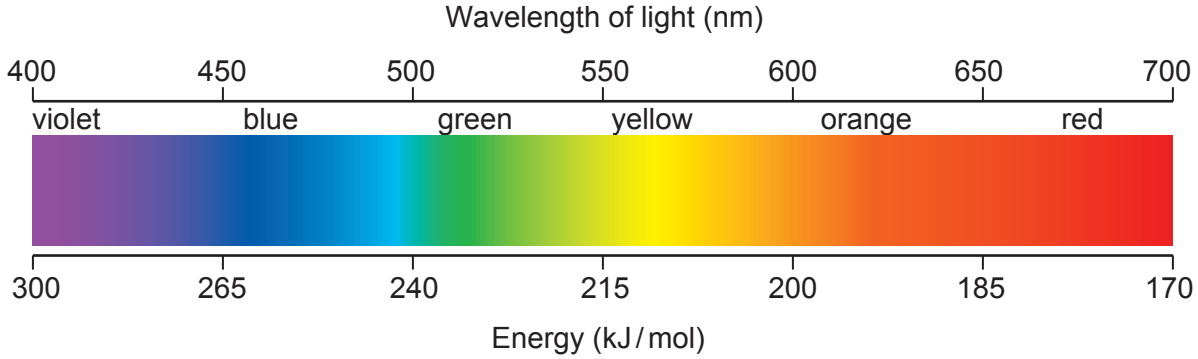
Some fireworks are restricted by law and these are only used in official public displays.

Fireworks generate energy in the form of sound, light and heat.

Different metal compounds release different amounts of light energy when fireworks are ignited. The amount of energy released determines the wavelength of light seen.

Colour	Metal or metal compound
red	strontium carbonate
orange	calcium chloride
green	barium chloride
blue	copper(II) chloride
violet	strontium carbonate and copper(II) chloride
white	magnesium powder

Table 1



Elements can also be added to create special effects as in **Table 2**.

Special effect	Element
glitter effect	aluminium
sparkly effect	iron
glow in the dark effect	phosphorus
smoke effect	zinc

Table 2

Examiner only

(i) Tick (✓) the box next to the correct statement. [1]

shorter wavelengths of light are given off by blue and violet fireworks ☐

shorter wavelengths of light are given off by red and orange fireworks ☐

longer wavelengths of light are given off by blue and violet fireworks ☐

longer wavelengths of light are given off by green and yellow fireworks ☐

(ii) The amount of energy released, which varies from metal to metal, is related to the wavelength of the light.

Tick (✓) the box next to the statement which best describes the relationship between energy and wavelength. [1]

as the energy increases the wavelength increases ☐

as the energy decreases the wavelength increases ☐

the wavelength changes with changes in energy ☐

as the energy decreases the wavelength decreases ☐

(iii) Tick (✓) the box next to the mixture you would choose to make a sparkly, smoky orange firework. [1]

iron, zinc and calcium chloride ☐

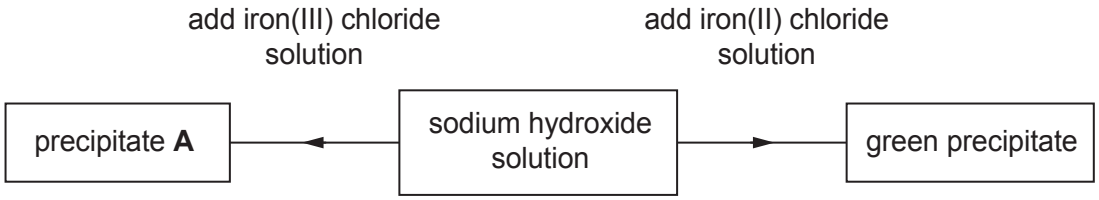
aluminium, magnesium and strontium carbonate ☐

barium chloride, phosphorus and calcium chloride ☐

iron, magnesium and zinc ☐

Examiner only

(b) The flow diagram shows the reactions between sodium hydroxide solution and two different chlorides of iron.



(i) Give the colour of precipitate **A**. [1]

.....

(ii) Give the chemical formula of the green precipitate. [1]

.....

5

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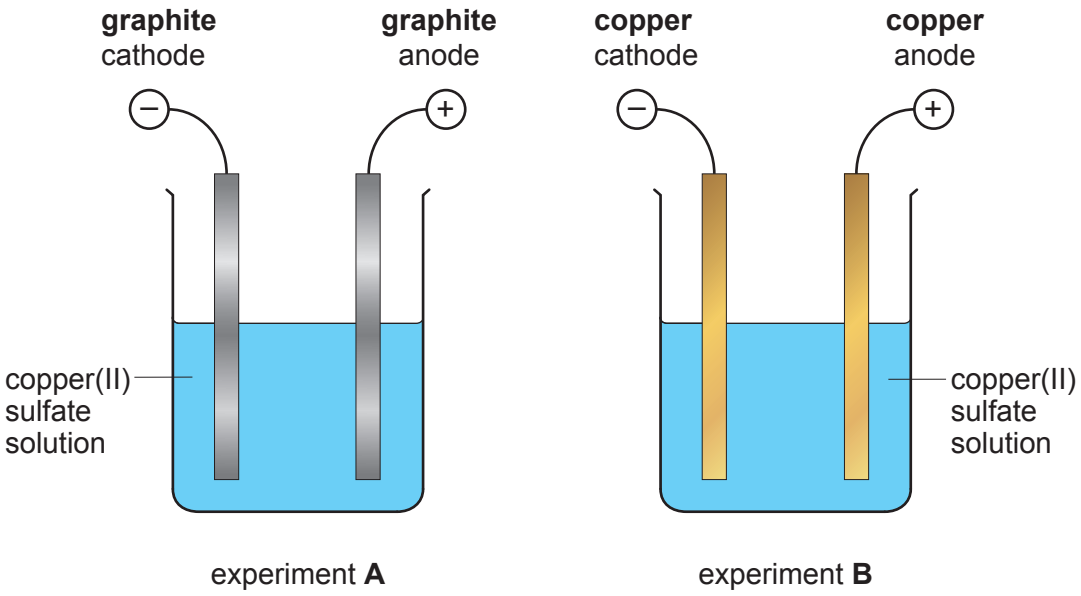
6. (a) The diagrams show the apparatus used in two experiments.

The electrolyte in both experiments is copper(II) sulfate solution. Experiment **A** uses graphite electrodes and experiment **B** uses copper electrodes.



experiment **A** experiment **B**

Tick (✓) the box next to **two** statements that describe what happens during the experiments. [2]

the mass of **both** cathodes increases ☐

Cu^{2+} ions enter the solution at **both** anodes ☐

Cu^{2+} ions gain electrons at **both** cathodes ☐

the blue colour of copper(II) sulfate solution turns paler in **both** beakers as Cu^{2+} ions are removed ☐

the blue colour of copper(II) sulfate solution remains the same in both beakers ☐

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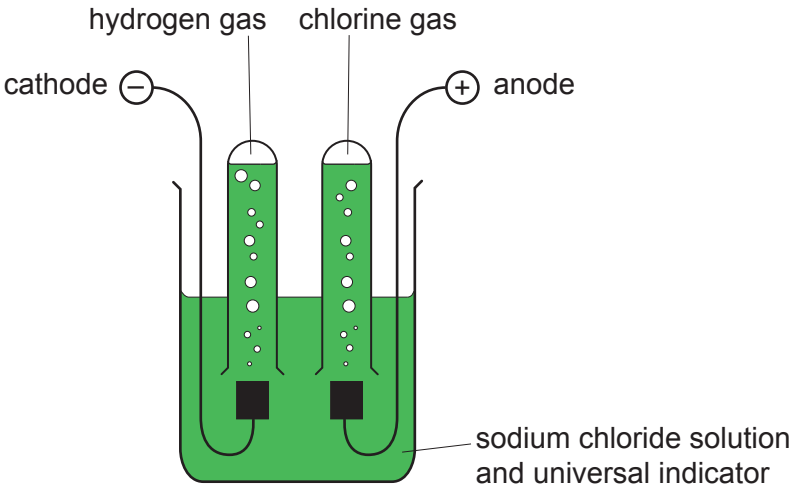
(b) The diagram shows apparatus that can be used to show the electrolysis of sodium chloride solution.



The solution with the indicator is green before the electrolysis starts.

(i) Complete the electrode equation for the reaction at the cathode. [1]

$2H^+ + \square \longrightarrow H_2$

(ii) Explain the meaning of the term oxidation in relation to the formation of chlorine at the anode. [2]

.....

.....

(iii) During the electrolysis process the colour of the universal indicator turns from green to purple.

Choose the letter, **A**, **B** or **C**, next to the statement that explains this colour change. [1]

A Na^+ and Cl^- ions remain in the electrolyte keeping the electrolyte neutral

B Na^+ and OH^- ions remain in the electrolyte turning the solution alkaline

C H^+ and Cl^- ions remain in the electrolyte turning the solution acidic

Letter .....

6

Examiner only

7. (a) Methanol, ethanol, propanol and butanol belong to the alcohol family.

Alcohol	Molecular formula
methanol	CH_3OH
ethanol	C_2H_5OH
propanol	C_3H_7OH
butanol	C_4H_9OH

(i) Give the general formula for the alcohol family of compounds. [1]

.....

(ii) Alcohols give out heat energy when they are burned.

The table below shows values for the energy given out when 1.0 g of each alcohol is burned.

Alcohol	Number of carbon atoms	Energy given out (kJ)
methanol	1	22.6
ethanol	2	29.8
propanol	3	33.6
butanol	4	36.2

I. Plot the energy given out against the number of carbon atoms in each alcohol on the grid opposite. Draw a suitable curve.

One point has been plotted for you. [3]

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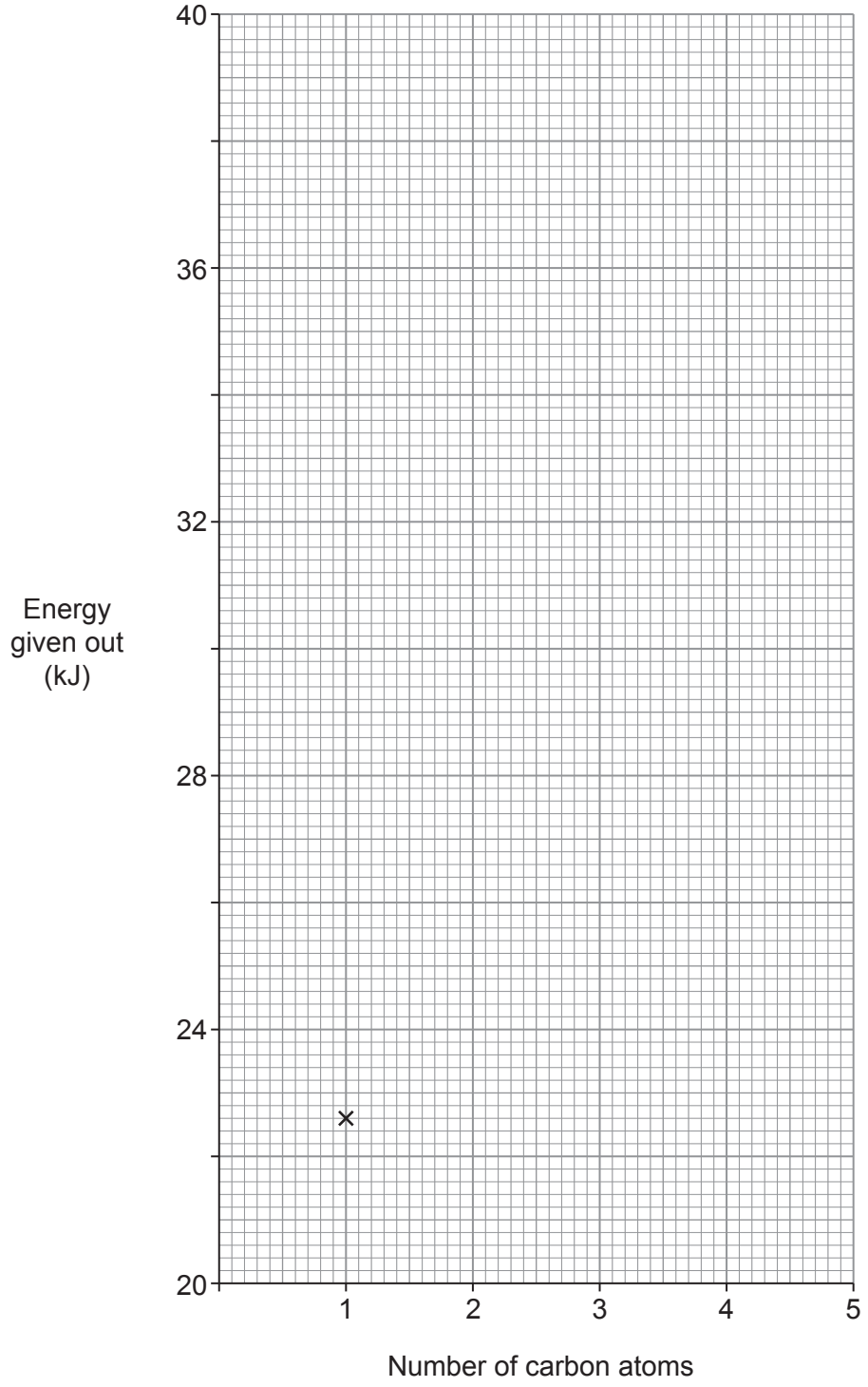


II. The molecular formula of pentanol is $C_5H_{11}OH$.

Use your graph to predict the energy given out when 1.0 g of pentanol is burned. Show clearly how you got this answer. [1]

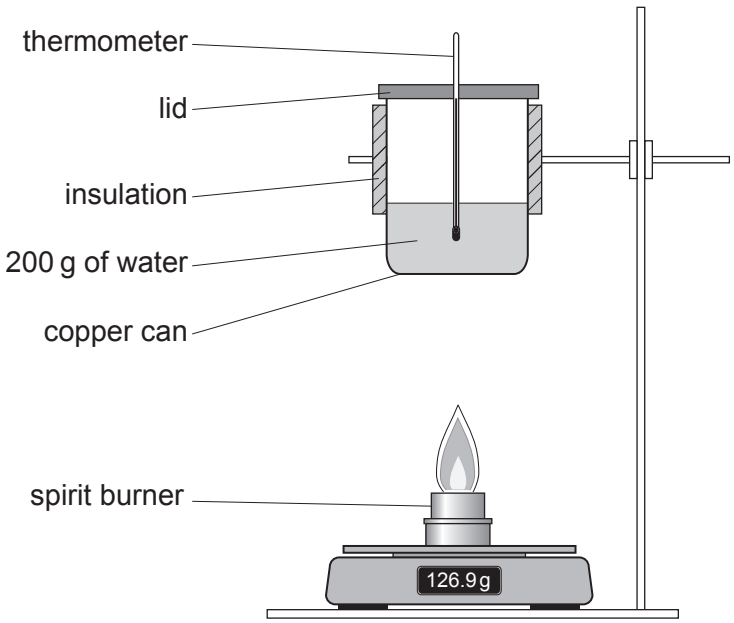
Energy given out = ... kJ

Examiner only

(b) A group of students was asked to find the experimental values for the energy given out when alcohols burn.

Four students each burned 1.0 g of an alcohol and recorded the temperature rise of 200 g of water.

The diagram shows the apparatus used by each of the students.



They used their results to calculate the energy given out for each alcohol.

All the students' experimental values are **lower** than expected.

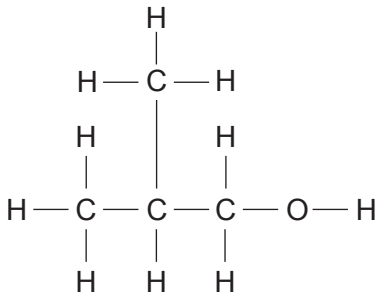
State **one** improvement to the apparatus that would give results closer to the expected values. Give a reason for your answer. [2]

.....

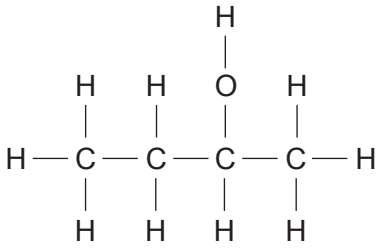
.....

Examiner only

(c) (i) The diagrams below show the structures of four isomers with the formula C_4H_9OH.



A



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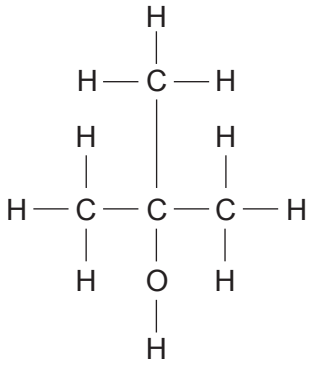

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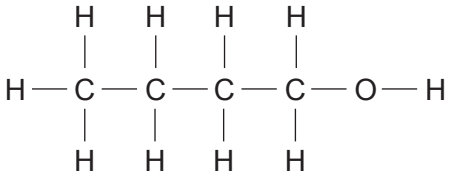

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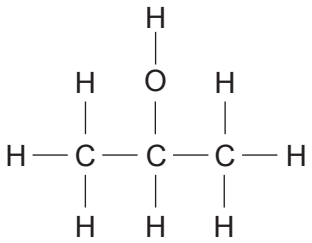
Give the **letter** of 2-methylpropan-2-ol. [1]

Letter .....

(ii) The diagram below shows the structure of one isomer with the formula C_3H_7OH.



Name this isomer. [1]

.....

9

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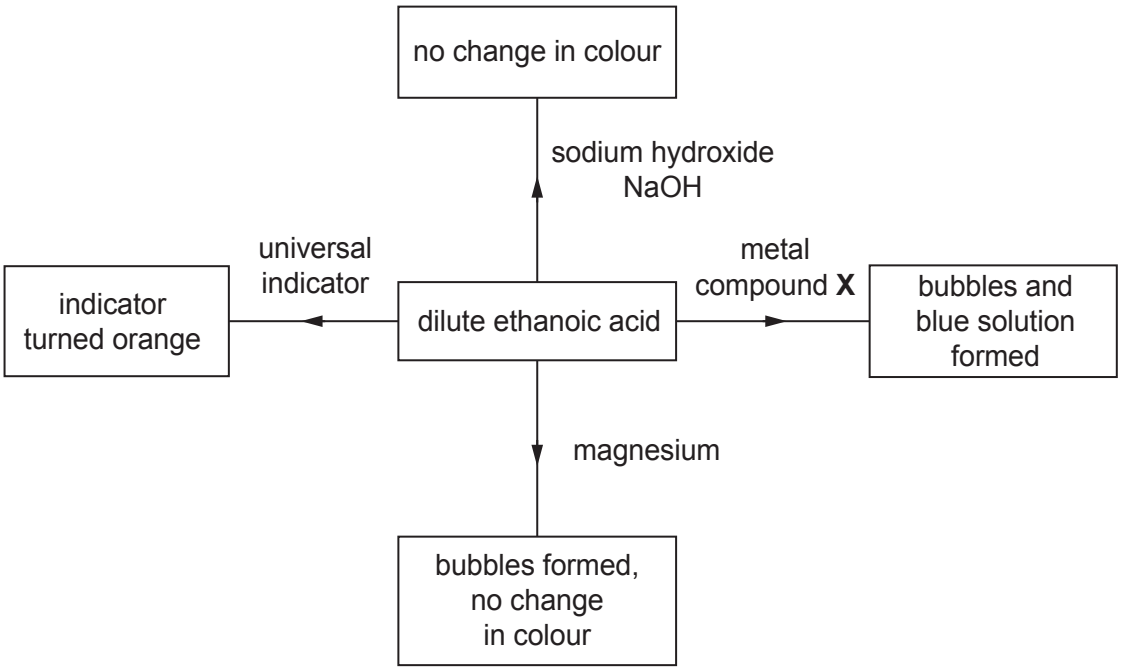
8. The diagram below shows the observations recorded by a student when different substances were added to dilute ethanoic acid, CH_3COOH.



(a) The formula of the salt formed when magnesium reacts with ethanoic acid is $Mg(CH_3COO)_2$.

Underline the name of this salt. [1]

magnesium ethoxide **magnesium ethane** **magnesium hydrogencarbonate** **magnesium ethanoate**

(b) Complete the symbol equation for the reaction between sodium hydroxide and ethanoic acid. [2]

$NaOH + CH_3COOH \longrightarrow$ ..... + ...

(c) Name the metal compound **X** in the diagram. [1]

.....

Examiner only

(d) Universal indicator turns orange in dilute ethanoic acid showing that it has a pH of 3.

Predict how the observation would be different if universal indicator were added to dilute hydrochloric acid rather than dilute ethanoic acid. Give your reasoning. [2]

.....

.....

6

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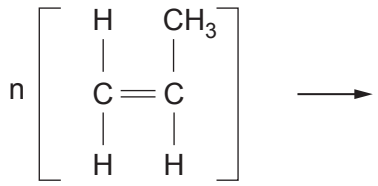
9. (a) Propene undergoes addition polymerisation forming polypropene.

(i) Complete and balance the equation for this reaction. [2]



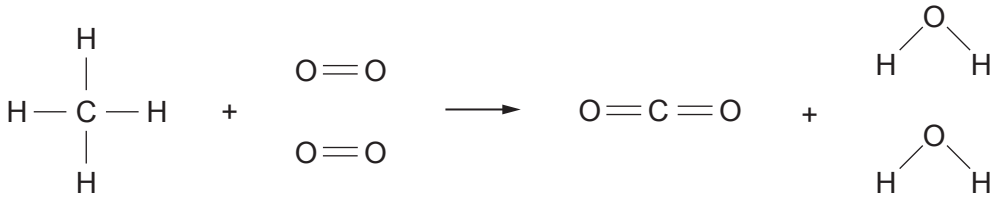
(ii) Use the reaction in part (i) above to explain the meaning of addition polymerisation. [2]

.....

.....

.....

(b) The equation shows the bonds which are broken and the bonds which are formed during the combustion of methane.



(i) The bond energy of an O = O bond is 498 kJ. The energy needed to break all the bonds in the reactants is 2648 kJ.

Calculate the energy needed to break **one** C — H bond. [2]

Energy = ... kJ

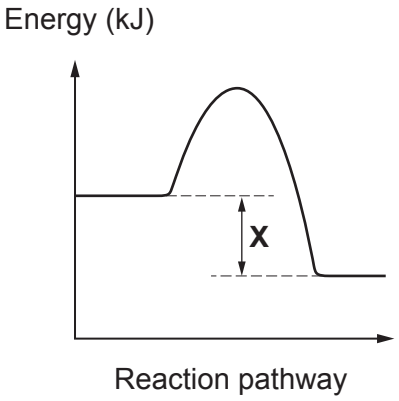
Examiner only

(ii) The bond energy of an O — H bond is 464 kJ. The total energy released when the bonds in the products are formed is 3466 kJ.

Calculate the energy released when making **one** C ═ O bond. [2]

Energy = ... kJ

(iii) Use information given in parts (i) and (ii) to find the value of **X** in the energy level diagram below. [1]



X = ... kJ

9

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10. Sodium hydrogencarbonate, also known as sodium bicarbonate, belongs to the group of medicines called antacids. Antacids relieve heartburn or acid indigestion by neutralising excess stomach acid.

The recommended adult dose is 1-5 g in a 200 cm^3 glass of water.

A student made up a dose of sodium hydrogencarbonate solution by adding one heaped teaspoon of powder to 200 cm^3 of water.

To determine the concentration of the sodium hydrogencarbonate solution, 20.0 cm^3 of the solution was titrated with dilute hydrochloric acid of concentration 0.40 mol/dm^3. The endpoint was determined using an indicator.

The procedure was repeated three times and the mean volume of dilute hydrochloric acid solution needed to neutralise 20.0 cm^3 of the sodium hydrogencarbonate solution was found to be 12.5 cm^3.

(a) Use the equation below to calculate the number of moles of hydrochloric acid in 12.5 cm^3 of the 0.40 mol/dm^3 solution. [2]

$$\text{concentration (mol/dm}^3\text{)} = \frac{\text{number of moles}}{\text{volume (dm}^3\text{)}}$$

Number of moles = ... mol

Examiner only

(b) Sodium hydrogencarbonate reacts with hydrochloric acid according to this equation.

$$NaHCO_3(aq) + HCl(aq) \longrightarrow NaCl(aq) + H_2O(l) + CO_2(g)$$

The equation shows that 1 mol of hydrochloric acid neutralises 1 mol of sodium hydrogencarbonate.

Calculate the mass of sodium hydrogencarbonate in 20.0 cm^3 of the solution. [2]

$M_r(NaHCO_3) = 84$

Mass = ... g

(c) Did the student use a mass of sodium hydrogencarbonate within the recommended dose?

Give your reasoning. [1]

.....

.....

5

Examiner only

11. (a) The table shows information about the manufacture of ammonia by the Haber process.

Reaction	The forward reaction is exothermic $N_2 + 3H_2 \rightleftharpoons 2NH_3$
Conditions used	iron catalyst 450°C 200 atm

Explain why these conditions are used.

Your answer should include reference to the yield and the rate of the reaction. [6 QER]

Examiner only

(b) The table shows the results obtained when tests were carried out on fertilisers **A** and **B**.

Fertiliser	Test for positive ion	Test for negative ion
A	add sodium hydroxide solution and warm • pungent smelling gas is formed which turns red litmus paper blue	add barium chloride solution • white precipitate is formed
B	flame test • lilac flame seen	add silver nitrate solution • white precipitate is formed

(i) Name the pungent smelling gas that turns red litmus paper blue. [1]

.....

(ii) Use the information given to identify fertilisers **A** and **B**. [2]

A .....

B .....

(iii) Phosphoric acid is used in the manufacture of some fertilisers.

Balance the equation for the production of phosphoric acid. [1]

$$P_4O_{10} + \square\, H_2O \longrightarrow \square\, H_3PO_4$$

10

END OF PAPER

Question number	Additional page, if required. Write the question number(s) in the left-hand margin.

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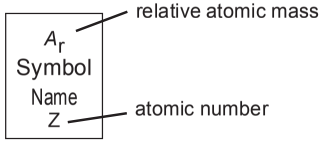
FORMULAE FOR SOME COMMON IONS

POSITIVE IONS		NEGATIVE IONS	
Name	**Formula**	**Name**	**Formula**
aluminium	Al^{3+}	bromide	Br^{-}
ammonium	NH_4^{+}	carbonate	CO_3^{2-}
barium	Ba^{2+}	chloride	Cl^{-}
calcium	Ca^{2+}	fluoride	F^{-}
copper(II)	Cu^{2+}	hydroxide	OH^{-}
hydrogen	H^{+}	iodide	I^{-}
iron(II)	Fe^{2+}	nitrate	NO_3^{-}
iron(III)	Fe^{3+}	oxide	O^{2-}
lithium	Li^{+}	sulfate	SO_4^{2-}
magnesium	Mg^{2+}		
nickel	Ni^{2+}		
potassium	K^{+}		
silver	Ag^{+}		
sodium	Na^{+}		
zinc	Zn^{2+}		

THE PERIODIC TABLE

1	2	Group										3	4	5	6	7	0
							1 H Hydrogen 1										4 He Helium 2
7 Li Lithium 3	9 Be Beryllium 4											11 B Boron 5	12 C Carbon 6	14 N Nitrogen 7	16 O Oxygen 8	19 F Fluorine 9	20 Ne Neon 10
23 Na Sodium 11	24 Mg Magnesium 12											27 Al Aluminium 13	28 Si Silicon 14	31 P Phosphorus 15	32 S Sulfur 16	35.5 Cl Chlorine 17	40 Ar Argon 18
39 K Potassium 19	40 Ca Calcium 20	45 Sc Scandium 21	48 Ti Titanium 22	51 V Vanadium 23	52 Cr Chromium 24	55 Mn Manganese 25	56 Fe Iron 26	59 Co Cobalt 27	59 Ni Nickel 28	63.5 Cu Copper 29	65 Zn Zinc 30	70 Ga Gallium 31	73 Ge Germanium 32	75 As Arsenic 33	79 Se Selenium 34	80 Br Bromine 35	84 Kr Krypton 36
86 Rb Rubidium 37	88 Sr Strontium 38	89 Y Yttrium 39	91 Zr Zirconium 40	93 Nb Niobium 41	96 Mo Molybdenum 42	99 Tc Technetium 43	101 Ru Ruthenium 44	103 Rh Rhodium 45	106 Pd Palladium 46	108 Ag Silver 47	112 Cd Cadmium 48	115 In Indium 49	119 Sn Tin 50	122 Sb Antimony 51	128 Te Tellurium 52	127 I Iodine 53	131 Xe Xenon 54
133 Cs Caesium 55	137 Ba Barium 56	139 La Lanthanum 57	179 Hf Hafnium 72	181 Ta Tantalum 73	184 W Tungsten 74	186 Re Rhenium 75	190 Os Osmium 76	192 Ir Iridium 77	195 Pt Platinum 78	197 Au Gold 79	201 Hg Mercury 80	204 Tl Thallium 81	207 Pb Lead 82	209 Bi Bismuth 83	210 Po Polonium 84	210 At Astatine 85	222 Rn Radon 86
223 Fr Francium 87	226 Ra Radium 88	227 Ac Actinium 89															

Key



36