Surname	Centre Number	Candidate Number
First name(s)		0

GCSE

S24-3410UB0-1

3410UB0-1

FRIDAY, 17 MAY 2024 – 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.	**7**	
2.	**7**	
3.	**6**	
4.	**8**	
5.	**9**	
6.	**9**	
7.	**13**	
8.	**9**	
9.	**8**	
10.	**4**	
Total	**80**	

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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 **9**(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.

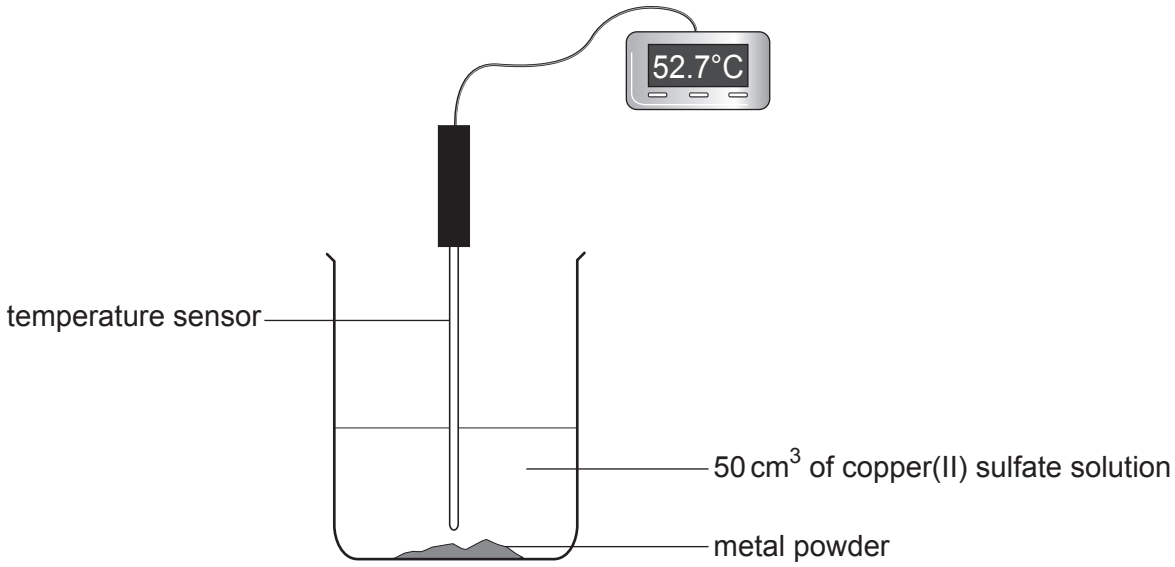
1. The list below shows part of the reactivity series.

magnesium
zinc
iron
nickel

A student investigated the temperature rise when four different metal powders were added to excess copper(II) sulfate solution.

The same mass of each metal was added to 50 cm^3 samples of copper(II) sulfate solution.

The maximum temperature for each reaction was measured. The temperature rise was calculated in each case and used to find the energy given out.



The results are shown in the table below.

Metal	Temperature rise (°C)	Energy given out (J)
magnesium	40.5	8500
zinc	33.0	6900
iron	23.2	4900
nickel	19.0	4000

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(a) In one of the reactions, the initial temperature was 19.7 °C and the maximum temperature was 52.7 °C.

State which one of the four metals was used in this reaction. [1]

.....

(b) Tick (✓) the box next to the conclusion the student can draw from the results. [1]

The higher the metal in the reactivity series, the greater the energy given out ☐

The lower the metal in the reactivity series, the greater the energy given out ☐

The energy given out is not related to the metal's position in the reactivity series ☐

(c) The word equation below represents the reaction between iron and nickel(II) sulfate solution.

iron + nickel(II) sulfate ⟶ iron(II) sulfate + nickel

Iron(II) sulfate contains Fe^{2+} and SO_4^{2-} ions.

Complete the symbol equation for the reaction. [2]

$Fe + NiSO_4 \longrightarrow$ ..... + ...

(d) The experiment shows that a more reactive metal will replace a less reactive metal in its compounds.

Give the term used to describe this type of reaction. [1]

.....

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(e) When the experiment was repeated using **titanium**, the temperature rise recorded was 35.4 °C.

Calculate the energy given out during the reaction between **titanium** and 50 cm^3 of copper(II) sulfate solution. Give your answer to the nearest 100 J. [2]

energy given out (J) = volume of solution × 4.2 × temperature rise

Energy given out = ... J

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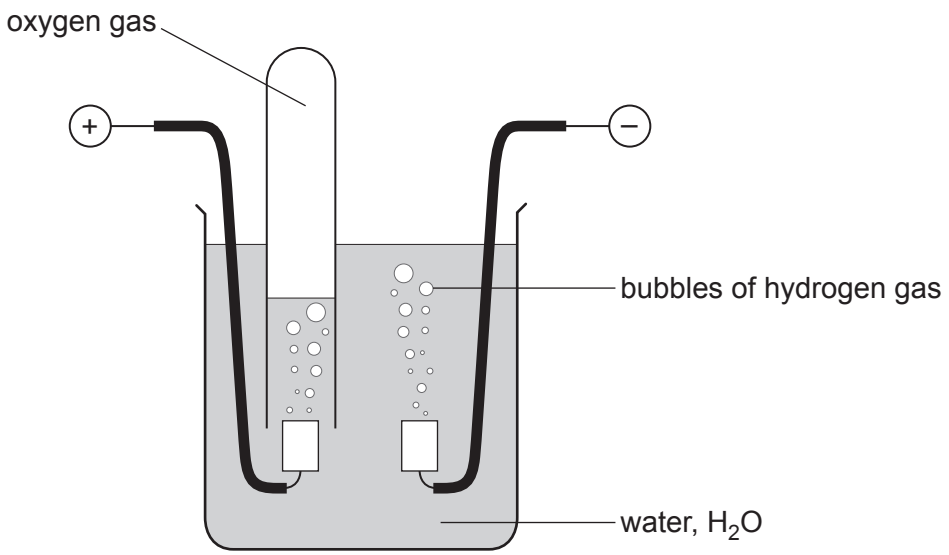
2. (a) The diagram shows the apparatus used by a student to investigate the electrolysis of water.



(i) The student collected a sample of the oxygen formed in a test tube.

Give the test the student would carry out to show the presence of oxygen in the test tube. Include the observation the student would expect. [1]

.....

.....

(ii) Use the formula of water, H_2O.

Give the volume of hydrogen that would form in the same time as 10 cm^3 of oxygen. [1]

..... cm^3

Examiner only

(b) The table shows information about the electrolysis of three different electrolytes. The table is incomplete.

Electrolyte	Ions present in the electrolyte		Observations	
	Positive ion(s)	Negative ion(s)	At the negative (−) electrode	At the positive (+) electrode
molten lead(II) bromide	Pb^{2+}	.....	grey metal **A** formed	orange gas formed
aqueous copper(II) chloride	..... and H^+	Cl^- and OH^-	brown metal formed	green-yellow gas **B** formed
aqueous compound **C**	Zn^{2+} and H^+	I^- and OH^-	grey metal formed	brown solution formed

(i) Complete the table by adding the **symbols** of the missing **ions**. [2]

(ii) Name substances **A**, **B** and **C**. [3]

Metal **A** .....

Gas **B** .....

Compound **C** .....

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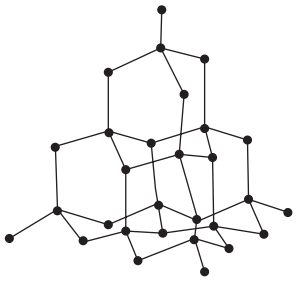
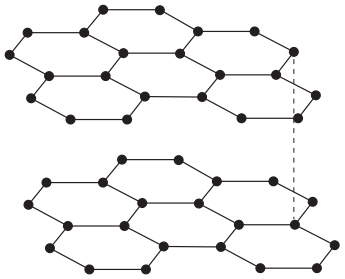
3. The diagrams show the structure of diamond and graphite.



diamond



graphite

(a) Name the atom being represented by a • in both diagrams. [1]

.....

(b) Name the type of **bonding** found in both diamond and graphite. [1]

.....

Examiner only

(c) The table shows some properties of graphite.

Properties of graphite
soft
high melting point
insoluble in water
conducts electricity

Use only properties from the table to answer this question.

Give **two** properties of graphite that are **different** from those of diamond. Give a use relating to each property. [4]

Property 1 .....

Use .....

Property 2 .....

Use .....

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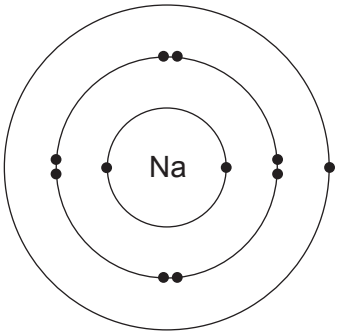
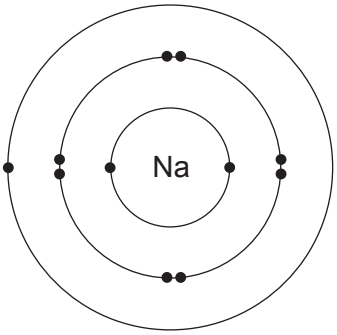
4. (a) Sodium reacts with oxygen to form the ionic compound sodium oxide.

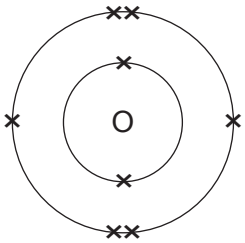
In the following diagrams, dots and crosses represent electrons in sodium and oxygen atoms.



sodium atom



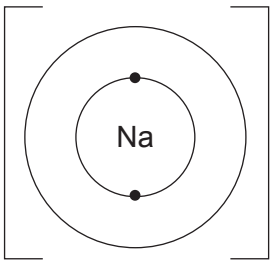
sodium atom



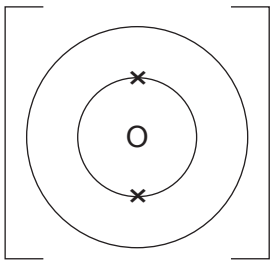
oxygen atom

(i) Complete the diagrams below.

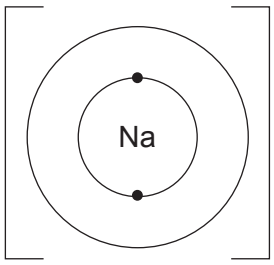
- Complete the electronic structures of the sodium ions and the oxide ion formed.
- Give the charges on the sodium and oxide ions. [3]



sodium ion



oxide ion



sodium ion

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

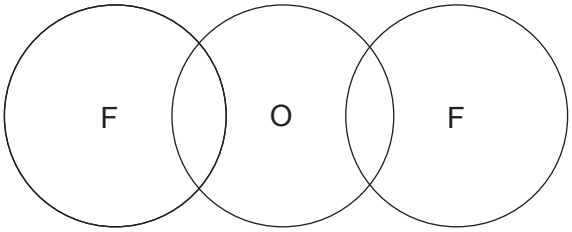
$4Na + O_2 \longrightarrow$ ☐ .....

Examiner only

(b) (i) The table shows the electronic structure of the elements present in oxygen difluoride, F_2O.

Element	Electronic structure
fluorine	2,7
oxygen	2,6

Complete a dot and cross diagram to show the bonding in a molecule of oxygen difluoride. [2]



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(ii) Tick (✓) the box next to the statement that explains why oxygen difluoride has low melting and boiling points. [1]

bonds within the molecules are strong ☐

bonds within the molecules are weak ☐

bonds between the molecules are strong ☐

bonds between the molecules are weak ☐

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5. (a) The symbol equations below show three reactions that produce salts.

(i) Complete the symbol equation for each reaction. [3]

A $Zn(s) + 2HNO_3(aq) \longrightarrow Zn(NO_3)_2(aq) +$ .....(g)

B $MgO(s) + 2$ ..... $(aq) \longrightarrow MgCl_2(aq) + H_2O(l)$

C $Pb(NO_3)_2(aq) + 2NaCl(aq) \longrightarrow$ ..... $(s) + 2NaNO_3(aq)$

(ii) Give the **letter**, **A**, **B** or **C**, of the reaction that forms a precipitate. [1]

.....

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(b) (i) The equation below shows the reaction between dilute hydrochloric acid and sodium hydroxide solution.

$$HCl + NaOH \longrightarrow NaCl + H_2O$$

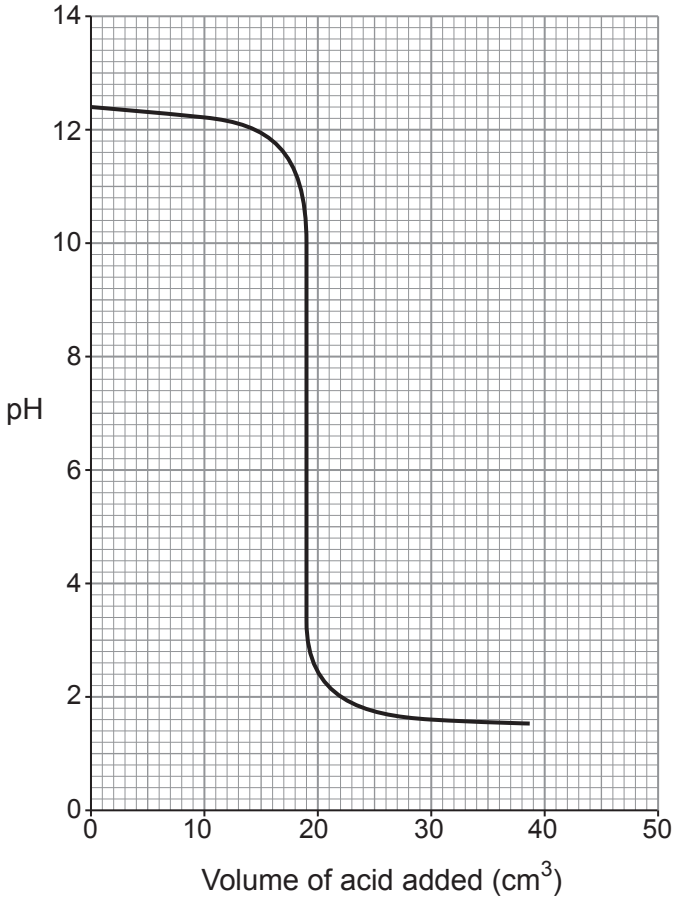
Give the term used to describe the reaction between an acid and an alkali to form a salt and water. [1]

.....

(ii) Eleanor carried out an investigation to find how the pH changes when dilute hydrochloric acid is added to sodium hydroxide solution.

She gradually added dilute hydrochloric acid to 25.0 cm^3 of sodium hydroxide solution.

The graph shows how the pH of the reaction mixture changed **as the acid was added**.



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Use the graph to answer parts I–III.

I. Sodium hydroxide is an alkali. Give the pH of the sodium hydroxide solution before any acid was added. [1]

.....

II. Give the volume of acid needed to completely react with the sodium hydroxide solution. [1]

..... cm^3

III. Tick (✓) the box next to the statement that correctly describes the concentrations of the acid and the alkali used in this investigation. [1]

the acid and the alkali have the same concentration	☐
the acid has a lower concentration than the alkali	☐
the concentration of the acid is half of the concentration of the alkali	☐
the acid has a higher concentration than the alkali	☐

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(iii) Eleanor measured the pH using a pH sensor. Freddie did a similar experiment but used universal indicator solution to measure the pH.

The table shows the colours of universal indicator at different pH values.

Colour	red	orange	yellow	green	blue	navy blue	purple
pH	0–2	3–4	5–6	7	8–9	10–12	13–14

Suggest why the data Eleanor collected could be more useful than Freddie's data. [1]

.....

.....

9

Examiner only

6. The main stages in the manufacture of sulfuric acid are given below.

Stage 1 $S + O_2 \longrightarrow SO_2$

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

Stage 3 production of sulfuric acid from sulfur trioxide

(a) State the meaning of the symbol $\rightleftharpoons$ used in the **stage 2** equation. [1]

.....

(b) The temperature used in **stage 2** is 450 °C. This results in a good yield but a low rate.

Name the **compound** used as a catalyst to increase the rate. [1]

.....

(c) Dissolving sulfur trioxide in water to form sulfuric acid is too exothermic to be carried out safely in one step.

Give the **two** steps carried out in **stage 3** to convert sulfur trioxide safely into sulfuric acid. [2]

Step 1 .....

.....

Step 2 .....

.....

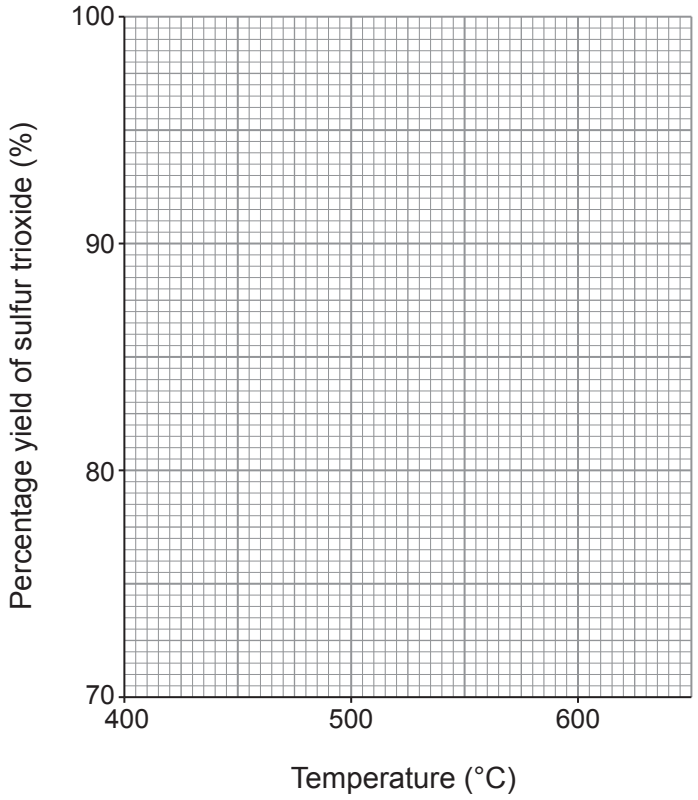
Examiner only

(d) The catalyst used in **stage 2** will **not** work below 400 °C and **breaks down** above 620 °C.

The table shows the yield of sulfur trioxide at different temperatures.

Temperature (°C)	400	450	500	550	600
Percentage yield of sulfur trioxide (%)	99.0	96.5	92.5	86.0	76.5

Plot this data on the grid and draw a suitable line. [3]



(e) State what happens to the percentage yield of sulfur trioxide when the temperature is increased. [1]

.....

(f) Use your graph to give the temperature range that produces a yield of 90–99% of sulfur trioxide. [1]

..... to ..... °C

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Examiner only

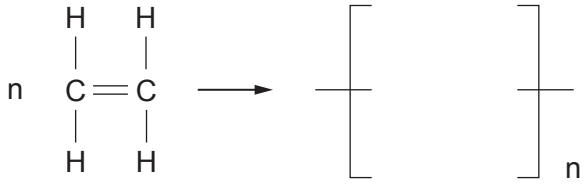
7. The first three members of the alkene family are shown below.

C_2H_4 C_3H_6 C_4H_8

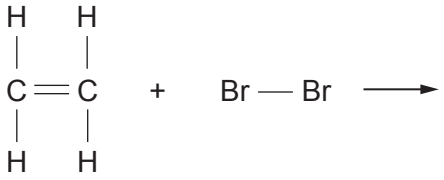
(a) (i) Give the **general** formula of the alkene family. [1]

.....

(ii) I. Complete the equation for the polymerisation of ethene by drawing the structure of the repeating unit. [1]



II. Complete the equation by drawing the structure of the product formed when ethene reacts with bromine. [1]



III. Name the type of reaction that occurs in parts I and II above. [1]

.....

(iii) Ethene burns in air forming carbon dioxide and water.

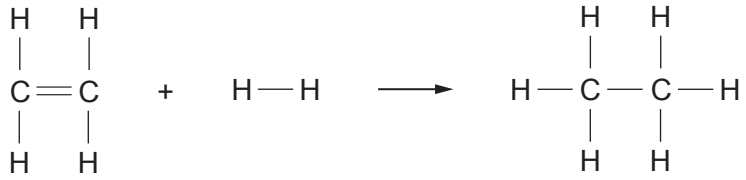
Complete and balance the equation for this reaction. [2]

$C_2H_4 + 3O_2 \longrightarrow$ ☐ ..... + ☐ H_2O

Examiner only

(b) Ethene reacts with hydrogen, forming ethane.

The equation shows the bonds that are broken and the bonds that are formed in the production of ethane.



The relevant bond energies are shown in the table.

Bond	Bond energy (kJ)
C — H	412
H — H	436
C = C	612

(i) Use the information in the table to show that the **total** energy needed to break all the bonds in the **reactants** is 2696 kJ. [2]

(ii) The **total** energy released when the bonds in the **products** are formed is 2820 kJ.

Calculate the energy released when forming a C—C bond. [2]

Energy = ... kJ

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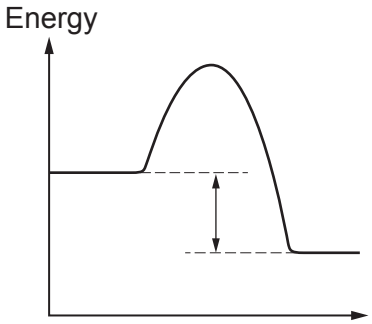
(iii) Use the total energy values given in parts (i) and (ii) to answer this question.

Tick (✓) the box next to the energy profile diagram that shows the reaction taking place. [1]



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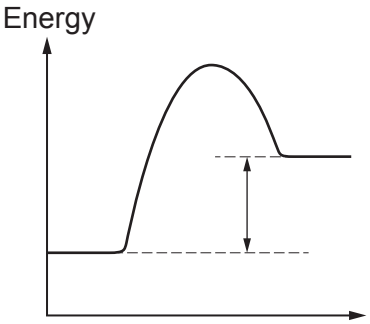

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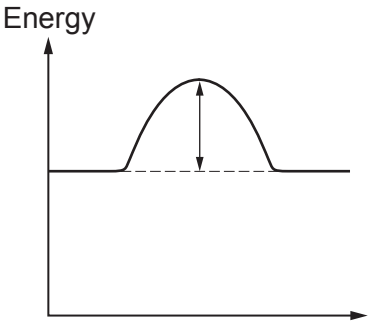

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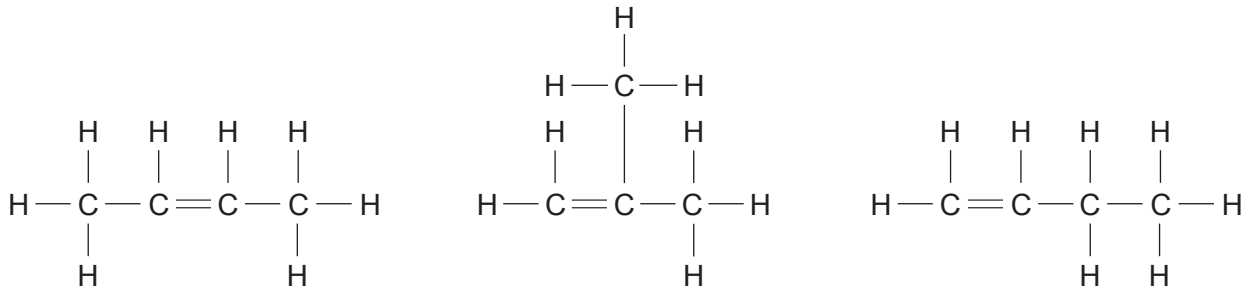
(c) Isomers **A**, **B** and **C** all have the molecular formula C_4H_8.



A **B** **C**

Give the **letter** of the structure fitting each of the following names. [2]

but-1-ene .....

but-2-ene .....

2-methylpropene .....

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8. (a)

Fuelling the Future

The main fuel used as a petrol substitute for cars is bioethanol. Bioethanol fuel is mainly produced by the fermentation of sugar.

The main sources of the sugar required to produce bioethanol are corn, maize and wheat. These crops absorb carbon dioxide from the atmosphere.

The use of pure bioethanol in car engines is only possible if the engines are designed for that purpose. For this reason, bioethanol-petrol mixtures called 'blends' are used.

Bioethanol-petrol mixtures have "E" numbers that describe the percentage of bioethanol in the mixture by volume. See **Diagram 1**.

Pure bioethanol is hard to vaporise. This makes it difficult to start a car when the weather is cold, which is why the fuels are almost always a bioethanol-petrol mixture.

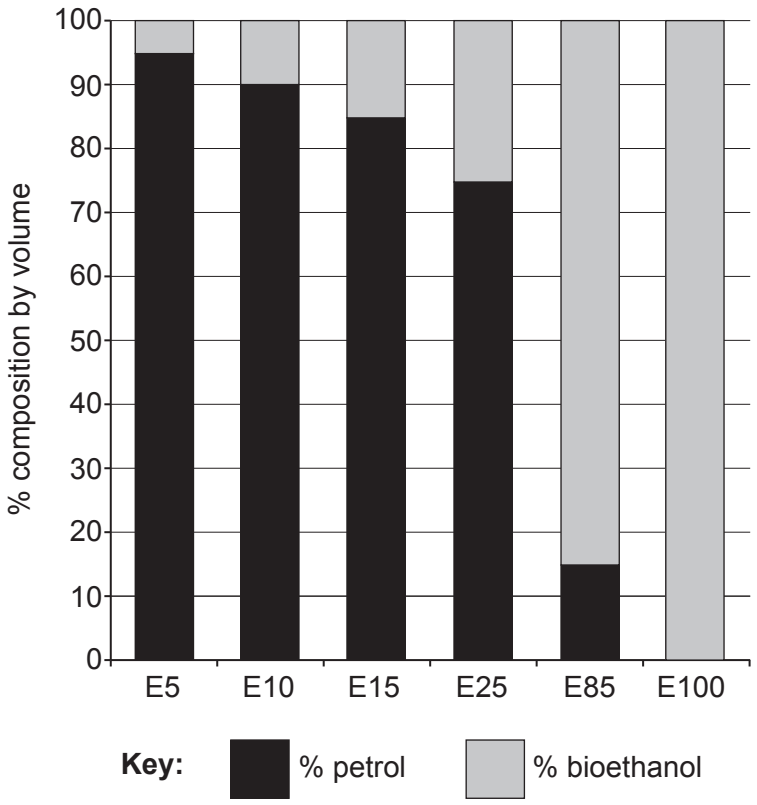

Diagram 1

Diagram 2 shows three properties of some fuels.

Property	Petrol	E10	E20	E30	E40	E60	Bioethanol
Density (kg / m^3)	747.4	750.8	760.5	778.2	779.2	781.2	789.0
Flash point (°C)	−65	−40	−20	−15	−13.5	−1.0	12.5
Energy value (MJ / kg)	44.40	44.22	42.08	40.48	38.50	35.84	29.78

Diagram 2

The flash point is the lowest temperature at which the fuel ignites.

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Some people claim that bioethanol is 'carbon neutral' because the plants that are the source of the bioethanol absorb carbon dioxide as they grow. This compensates for the carbon dioxide released when bioethanol is burned. However, carbon dioxide is also emitted during the construction of the fermentation factory, during fermentation and when bioethanol is transported around the world.

In some parts of the world, large areas of forest have been cleared and burned to develop the bioethanol industry. Deforestation to make space for crops has a devastating effect on the environment because it drastically reduces the number of trees that can capture carbon dioxide emissions. The amount of land needed to grow the biomass material is considered the main drawback of bioethanol as a fuel.

(i) Tick (✓) the box next to the ratio of bioethanol : petrol in the E20 fuel blend. [1]

80% bioethanol : 20% petrol ☐

20% bioethanol : 20% petrol ☐

20% bioethanol : 80% petrol ☐

(ii) Tick (✓) the box next to the statement that describes the effect of increasing the percentage of bioethanol in a fuel blend. [1]

the energy value decreases ☐

the density decreases ☐

the flash point decreases ☐

(iii) Give **one** reason that undermines the claim that burning bioethanol is 'carbon neutral'. [1]

.....

.....

Examiner only

(b) The molecular formula for ethanol is C_2H_5OH.

(i) Draw the structure of ethanol. [1]

(ii) When ethanol is exposed to air it slowly forms ethanoic acid.

When ethanoic acid reacts with magnesium carbonate, a salt is formed.

I. Give the name of the salt. [1]

.....

II. The negative ion in the salt has the formula CH_3COO^-.

Underline the correct formula of the salt. [1]

$MgCH_3COO$ **Mg_2CH_3COO** **$Mg_2(CH_3COO)_2$** **$Mg(CH_3COO)_2$**

Examiner only

(c) A student carries out a series of chemical tests on solutions of three unknown compounds, **A**, **B** and **C**.

Her results are recorded in the table.

	Add dilute HCl	Add $BaCl_2(aq)$	Add NaOH(aq)	Add $AgNO_3(aq)$
A	gas given off turns limewater milky		pungent smelling gas given off that turns damp red litmus paper blue	
B	no reaction	white precipitate forms	green precipitate forms	no reaction
C	no reaction	no reaction	blue precipitate forms	white precipitate forms

Draw a line from the unknown compound to its correct chemical name. [3]

Unknown compound	**Chemical name**
	copper(II) chloride
	iron(II) chloride
A	ammonium sulfate
B	iron(III) chloride
	copper(II) carbonate
C	ammonium carbonate
	iron(II) sulfate

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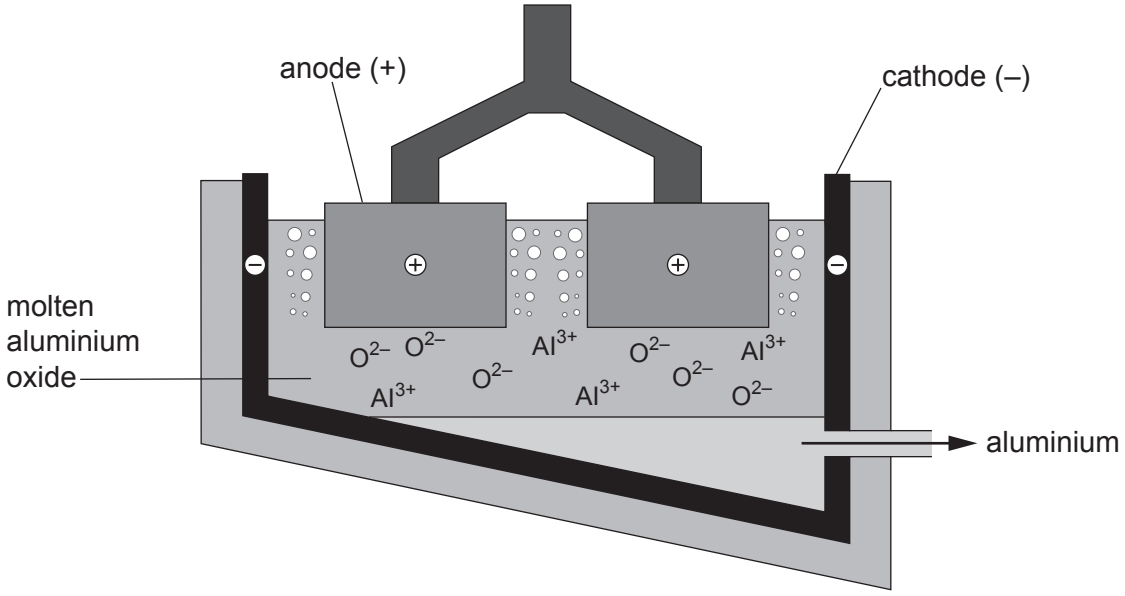
9. (a) The diagram shows a model of the cell used in the extraction of aluminium from molten aluminium oxide.



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The overall equation for the reaction is shown below.

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

Aluminium oxide contains Al^{3+} and O^{2-} ions.

Explain, in terms of these ions, the formation of both products. Include electrode equations to support your answer. [6 QER]

.....

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(b) Apart from a workforce and local transport infrastructure, explain **one** other important factor when choosing a site for an aluminium extraction plant in the UK. [2]

.....

.....

8

Examiner only

10. A technician prepared 250 cm^3 of a 0.50 mol/dm^3 solution of citric acid, $C_6H_8O_7$.

(a) Calculate the number of moles of citric acid in the solution. [2]

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

$$1\,dm^3 = 1000\,cm^3$$

Number of moles = ... mol

(b) Calculate the mass of citric acid in the solution. [2]

$A_r(H) = 1$ $A_r(C) = 12$ $A_r(O) = 16$

$$\text{number of moles} = \frac{\text{mass (g)}}{M_r}$$

Mass = ... g

4

END OF PAPER

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

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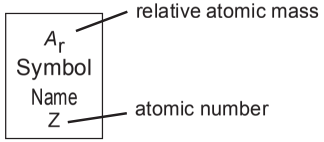
FORMULAE FOR SOME COMMON IONS

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



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