Surname	Centre Number	Candidate Number
First name(s)		0

GCSE

3410UB0-1

Z22-3410UB0-1

FRIDAY, 27 MAY 2022 – 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.	**5**	
5.	**9**	
6.	**10**	
7.	**5**	
8.	**9**	
9.	**7**	
10.	**9**	
11.	**6**	
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** 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) The table shows the electronic structure of the elements present in potassium fluoride.

Element	Electronic structure
potassium	2,8,8,1
fluorine	2,7

The diagram shows the electron transfer that occurs when potassium reacts with fluorine to form potassium fluoride. The ● and × symbols are outer shell electrons.

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

A student was asked to draw a diagram showing the electronic structures and charges on the ions formed. There are **two** mistakes in the student's answer.

Student's answer

(2,8,8) (2,8,8)

(i) Circle the **two** mistakes in the student's answer. [2]

(ii) Name the type of bonding found in potassium fluoride. [1]

.....

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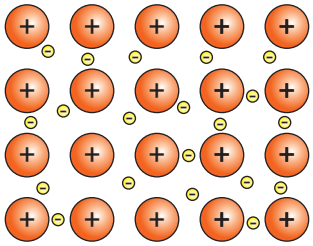
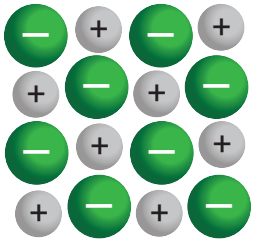
(iii) The diagrams show four different structures. Give the **letter** of the structure most likely to represent potassium fluoride. [1]

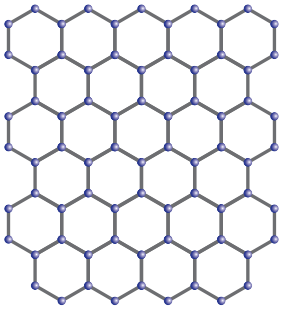


A

B



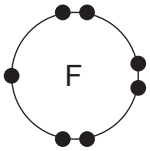
C



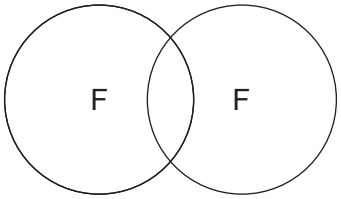
D

Letter .....

(b) The diagram shows the electrons in the outer shell of an atom of fluorine.



Complete the diagram to show the outer shell electrons in a molecule of fluorine. [2]



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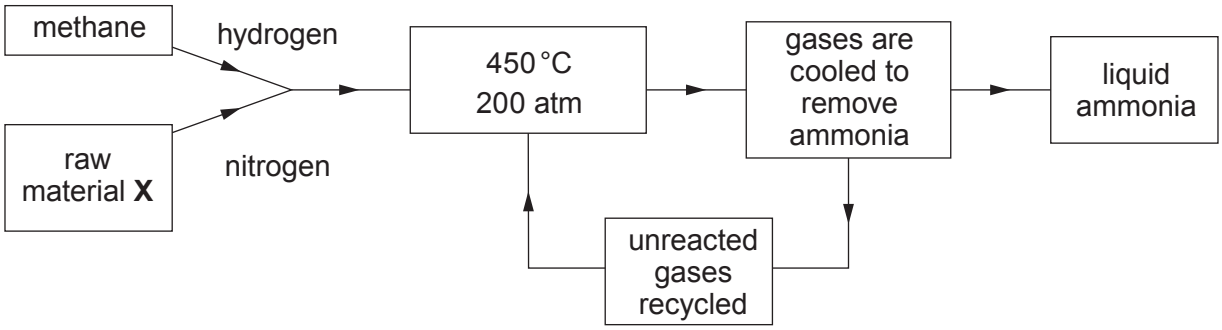
2. (a) The diagram outlines the manufacture of ammonia by the Haber process.



(i) Name the raw material **X**. ..... [1]

(ii) The pressure used in the Haber process is 200 atm. State why a higher pressure is **not** used. [1]

.....

(iii) At 450 °C, the reaction is very slow. Iron is used in the process to speed up the reaction. Give the name for a substance used to speed up a chemical reaction. [1]

.....

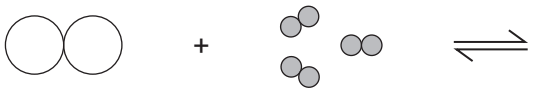
(iv) The reaction between nitrogen and hydrogen is represented by the equation below.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

Complete the equation below using the key: [2]

nitrogen gas, N_2

hydrogen gas, H_2



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(b) One of the main uses of ammonia is in the manufacture of fertilisers.

The table shows the results obtained when tests were carried out on three different fertilisers **A**, **B** and **C**.

Fertiliser	Test for positive ion	Test for negative ion
A	On adding sodium hydroxide solution and warming, a pungent smelling gas is formed which turns red litmus blue	On adding barium chloride solution a white precipitate forms
B	Lilac flame test	On adding silver nitrate solution a white precipitate forms
C	On adding sodium hydroxide solution and warming, a pungent smelling gas is formed which turns red litmus blue	On adding silver nitrate solution a white precipitate forms

Give the **letter** of the fertiliser which is ammonium sulfate. [1]

Letter .....

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(c) Ammonia reacts with chlorine to form nitrogen and hydrogen chloride.

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

$$2NH_3 + 3Cl_2 \longrightarrow N_2 + \boxed{}\,HCl$$

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3. (a) The list below shows part of the reactivity series.

sodium

aluminium

(carbon)

tin

copper

silver

(i) Tin is extracted from its ore by heating with carbon. Aluminium is extracted from its ore using a different method. Give the name of the method used to extract aluminium. [1]

.....

(ii) The equation shows the extraction of tin from tin oxide using carbon.

$$SnO_2 + C \longrightarrow Sn + CO_2$$

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

Carbon is reduced ☐

Tin is oxidised ☐

Tin oxide is reduced ☐

Carbon dioxide is oxidised ☐

(iii) When aluminium and copper(II) oxide are heated together, aluminium oxide and copper are formed.

Complete and balance the equation for this reaction. [3]

2Al + 3 ..... ⟶ ..... + ☐ Cu

copper(II) oxide aluminium oxide

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(b) A teacher wanted to find out the position of four metals **A**, **B**, **C** and **D** in the reactivity series.

She heated each metal in turn with oxides of the other three. The results were as follows.

A reduced the oxide of **C**

B reduced the oxide of **A**

B reduced the oxide of **C**

D reduced the oxide of **B**

Place the metals in order of reactivity. [2]

Most reactive .....

.....

.....

Least reactive .....

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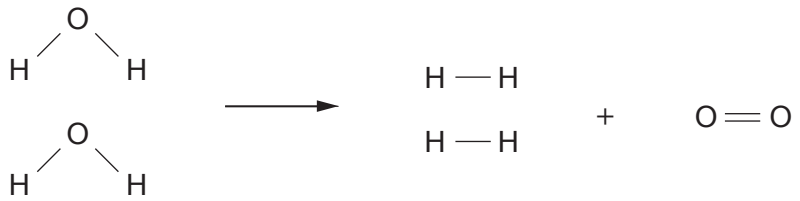
4. The equation shows the bonds which are broken and the bonds which are formed during the electrolysis of water.



(a) The total energy needed to break the bonds in the reactant is 1 856 kJ.

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

Energy = ... kJ

(b) The total energy released when the bonds in the products are formed is 1 370 kJ.

The bond energy for H — H is 436 kJ.

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

Energy = ... kJ

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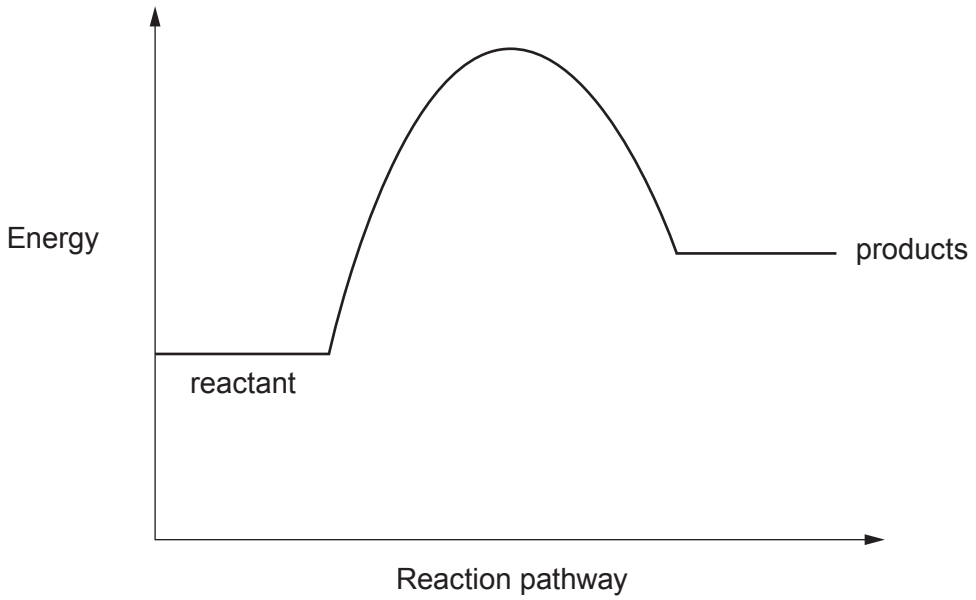
(c) The energy profile diagram shows the reaction to be endothermic. [1]

On the diagram below use the symbol (↕) to show the overall energy change for the reaction.



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5

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5. The chart describes the laboratory preparation of ethanol from glucose solution.

Process **A**		Process **B**		Process **C**
Yeast is added to glucose solution and left in a warm place until the reaction stops	→	Unreacted yeast is removed from ethanol solution	→	Ethanol is separated from the solution

The equation for the reaction occurring in process **A** is shown below.

$$C_6H_{12}O_6(aq) \longrightarrow 2C_2H_5OH(aq) + 2CO_2(g)$$

(a) (i) Give the name of the processes **A**, **B** and **C**. [3]

A .....

B .....

C .....

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(ii) A teacher wanted to show that ethanol is collected in process **C**.

I. Tick (✓) the box next to the chemical test that the teacher would carry out to positively identify the liquid as ethanol. [1]

add bromine water ☐

add acidified potassium dichromate solution ☐

add silver nitrate solution ☐

add barium chloride solution ☐

II. Tick (✓) the box next to the observation you would expect. [1]

orange to colourless ☐

orange to green ☐

green to orange ☐

colourless to green ☐

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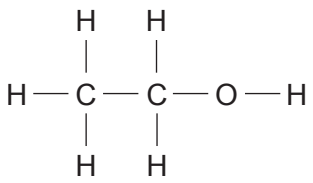
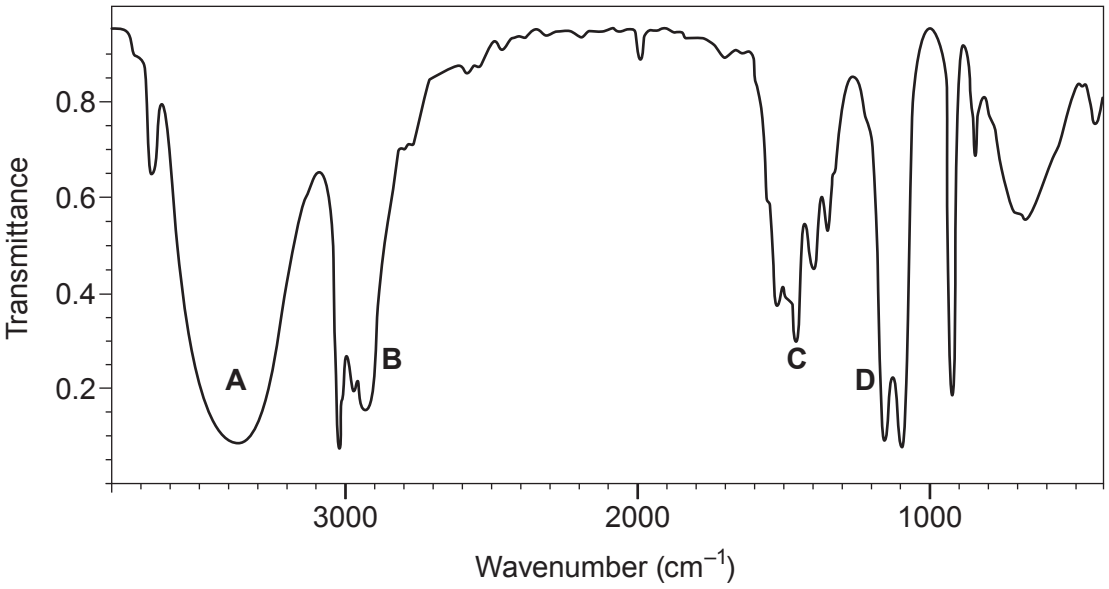
(b) Alcohols can also be identified using infrared spectroscopy.

Bond	Wavenumber (cm^{-1})
C = C	1620 to 1670
C = O	1650 to 1750
C — H	2800 to 3100
O — H	2500 to 3550

(i) The structural formula and the infrared spectrum of ethanol are shown.





Give the **letter** of the peak that can be used to identify an alcohol. [1]

Letter .....

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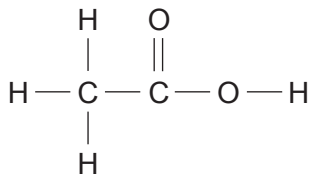
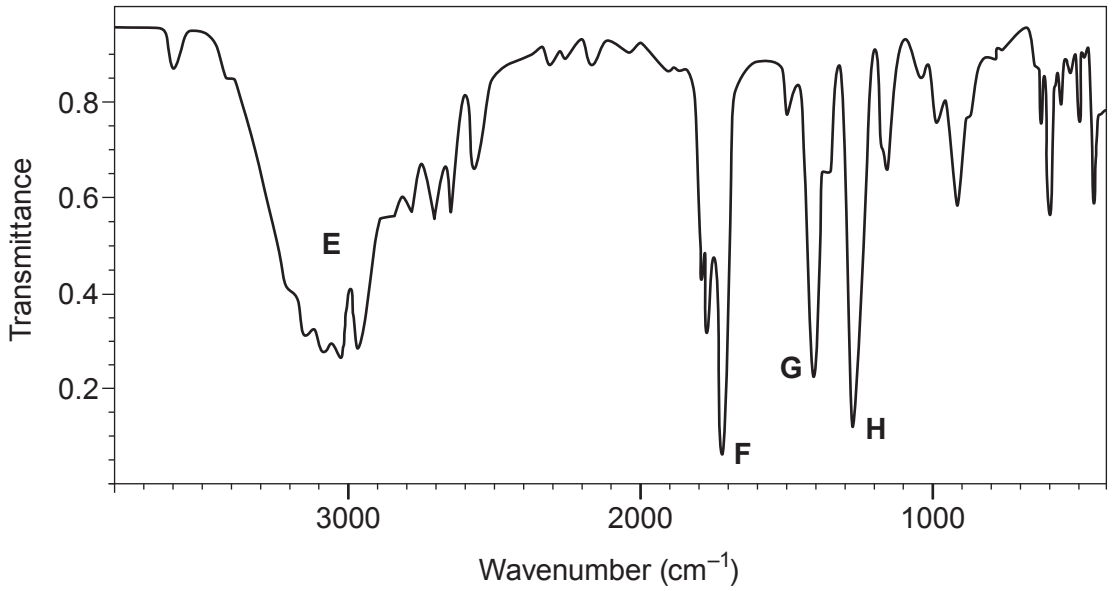
(ii) The structural formula and the infrared spectrum of ethanoic acid are shown.





Give the **letter** of the peak that can be used to distinguish ethanoic acid from ethanol. [1]

Letter .....

(c) Ethanol is found in alcoholic drinks.

(i) Give **one** health problem associated with alcohol abuse over a **long** period of time. [1]

.....

(ii) Give **one** social problem associated with the excessive intake of alcohol (binge drinking) during an evening. [1]

.....

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6. (a) Kerosene is one of the fractions separated during the fractional distillation of crude oil.

Kerosene contains dodecane, $C_{12}H_{26}$. Dodecane undergoes a further process **A** to form smaller, more useful hydrocarbons, ethene, butene and one molecule of hydrocarbon **X**.

(i) Name process **A**. [1]

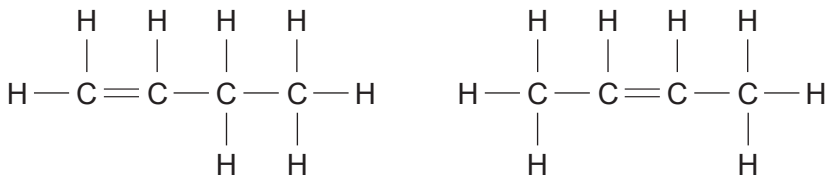
.....

(ii) Complete the equation for this reaction. [1]

$$C_{12}H_{26} \longrightarrow C_2H_4 + C_4H_8 + \text{.....}$$

dodecane ethene butene hydrocarbon **X**

(b) C_4H_8 has three isomers. The diagrams below show two of the three isomers.



The third isomer is methylpropene. Draw its structure. [1]

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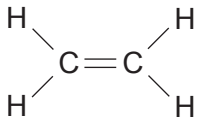
(c) (i) Polyethene is made from ethene by addition polymerisation. Draw the structure of the repeating unit for polyethene. [1]

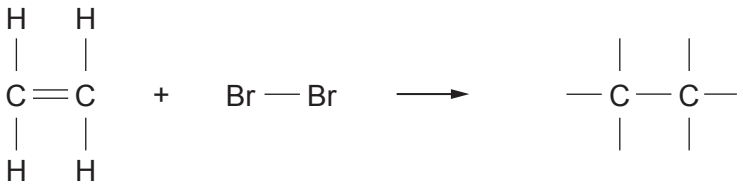


ethene

repeating unit for polyethene

(ii) The presence of the double bond in ethene can be confirmed using bromine water.

I. Complete the equation for the reaction between ethene and bromine. [1]



II. Tick (✓) the box next to the name of the product formed. [1]

1,2-dibromoethene ☐

1,1-dibromoethane ☐

1,2-dibromoethane ☐

1,1-dibromoethene ☐

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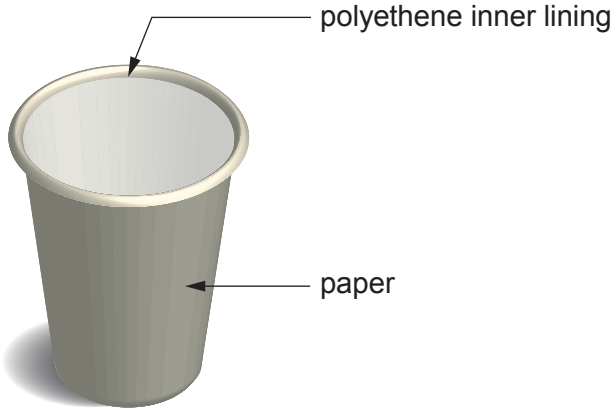
(d) In the UK, around 3 billion disposable coffee cups are used every year. Each paper coffee cup is lined with polyethene which is impossible to remove at a recycling plant. If the automated machine that sorts waste at a recycling centre detects a plastic lining, it rejects the cup sending it to general household waste.



(i) Most general household waste is disposed of in landfill sites.

Apart from using landfill sites, give the **other** disposal method of general household waste. State an environmental problem associated with the method. [2]

Method .....

Problem .....

.....

(ii) Recycling helps to conserve raw materials. Name the raw material used to make polyethene. Give the main reason why it is important to conserve this raw material. [2]

Raw material .....

Main reason .....

.....

10

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7.

Scientists make 'new fuel' discovery

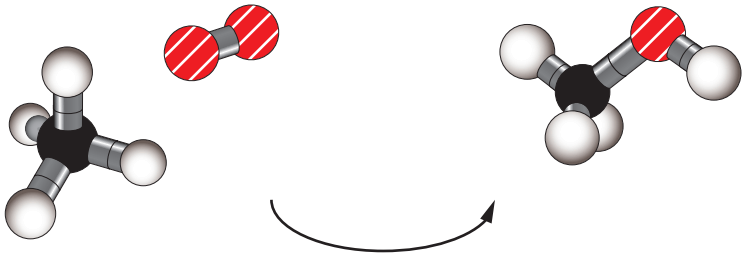
Methanol is vital in manufacturing a wide range of fuels and chemicals. Methanol is produced from methane found in natural gas. At the moment methane is condensed into liquid natural gas at the site where it is extracted and transported in pressurised containers.

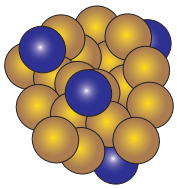
Traditionally, methanol is created by converting methane into hydrogen and carbon monoxide molecules at high temperature, then rearranging the atoms in a different order in a second highly pressurised process. The current two-stage process is very energy intensive, as it burns a lot of fossil fuel to achieve high temperatures.

Stage 1 $2CH_4 + O_2 \rightleftharpoons 2CO + 4H_2$

Stage 2 $CO + 2H_2 \rightleftharpoons CH_3OH$

Scientists have discovered a new way of creating greener and cheaper methanol from methane using gold palladium nano-particles to initiate a one-stage chemical reaction that can be done at temperatures no higher than 50 °C. In this new process the gold palladium nano-particles act as a catalyst enabling methane and oxygen to combine, forming methanol in a single stage reaction.





gold palladium nano-particle catalyst

The discovery opens up the prospect of easily converting methane into methanol at the site where the methane is extracted, so that methanol can be transported as a liquid at atmospheric pressure.

Nano-particles have very different and unique properties from their bulk form.

Bulk gold	**Gold nano-particles**
• shiny	• found in a range of colours (100 nm purple; 20 nm red; 1 nm yellow)
• always gold colour	• never gold colour
• inert	• very good catalysts
• conducts electricity	• semi-conductors
• melting point 1 064 °C	• range of melting points

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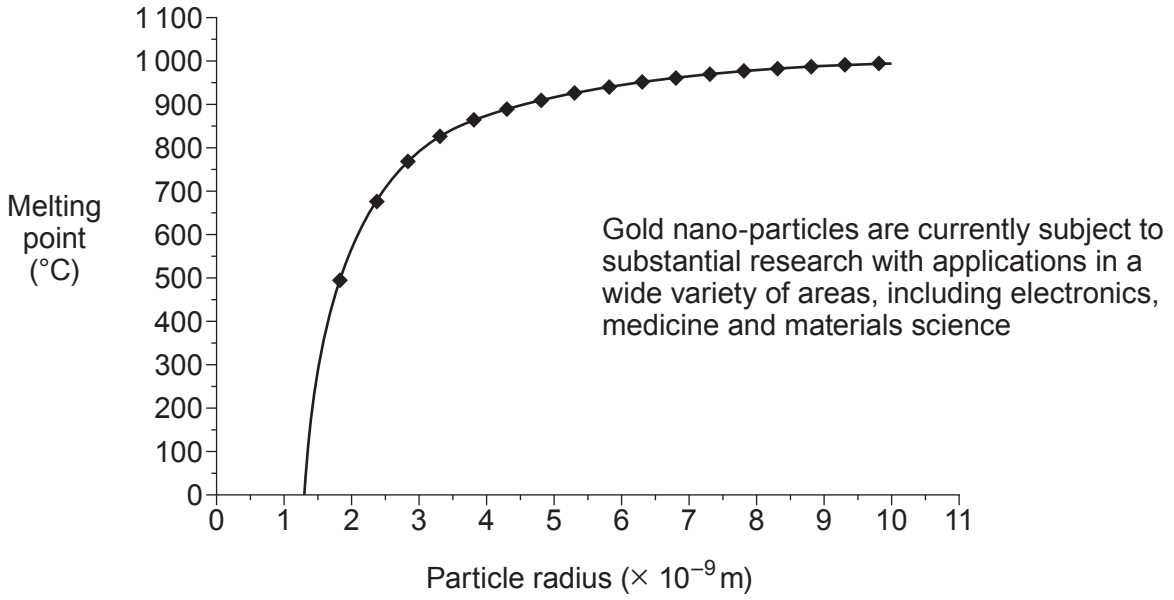

(a) Tick (✓) the box next to the **two** statements which support the opinion that the new method is more **environmentally friendly**. [2]

It is cheaper than the traditional method ☐

It uses less energy ☐

It reduces carbon dioxide emissions ☐

It uses gold nano-particles ☐

It uses more fuel ☐

(b) Complete the balanced equation for the **new** method of converting methane to methanol. [2]

$2CH_4$ + ... → ☐ .....

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(c) Tick (✓) the box next to the **true** statement. [1]

The melting points of gold nano-particles and bulk gold are the same ☐

Gold nano-particles have a fixed melting point value ☐

Smaller gold nano-particles have higher melting points than larger gold nano-particles ☐

The melting point of gold nano-particles depends on their size ☐

5

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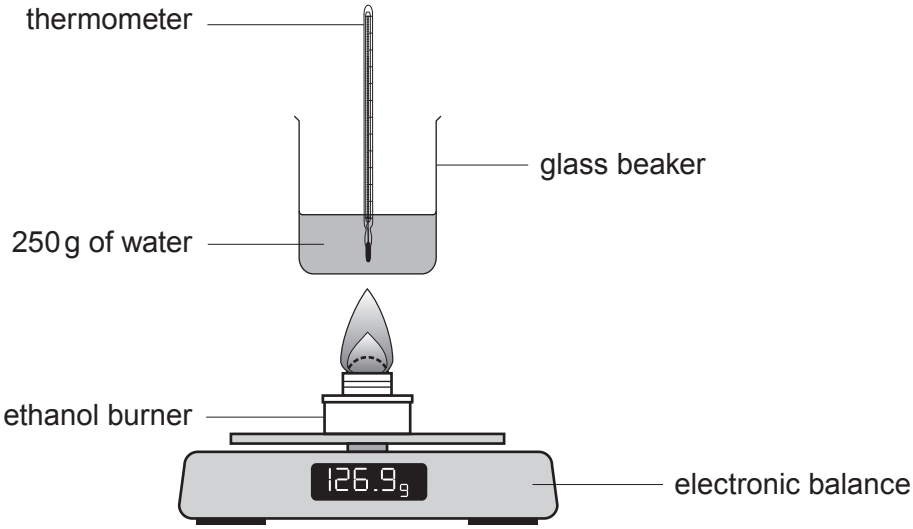
8. Mountaineers often choose an ethanol burner when hiking in extremely cold conditions.

ethanol burner

A group of students was asked to investigate how the mass of ethanol burned is related to the amount of energy given out.



Four students each burned a different mass of ethanol and recorded the temperature rise of 250 g of water. The diagram shows the apparatus used by each of the students.
They used their results to calculate the energy given out.

The table shows the students' results.

Student	Mass of ethanol burned (g)	Energy given out ($J \times 10^4$)
A	1.1	2.2
B	1.8	3.6
C	2.9	5.8
D	4.2	8.4

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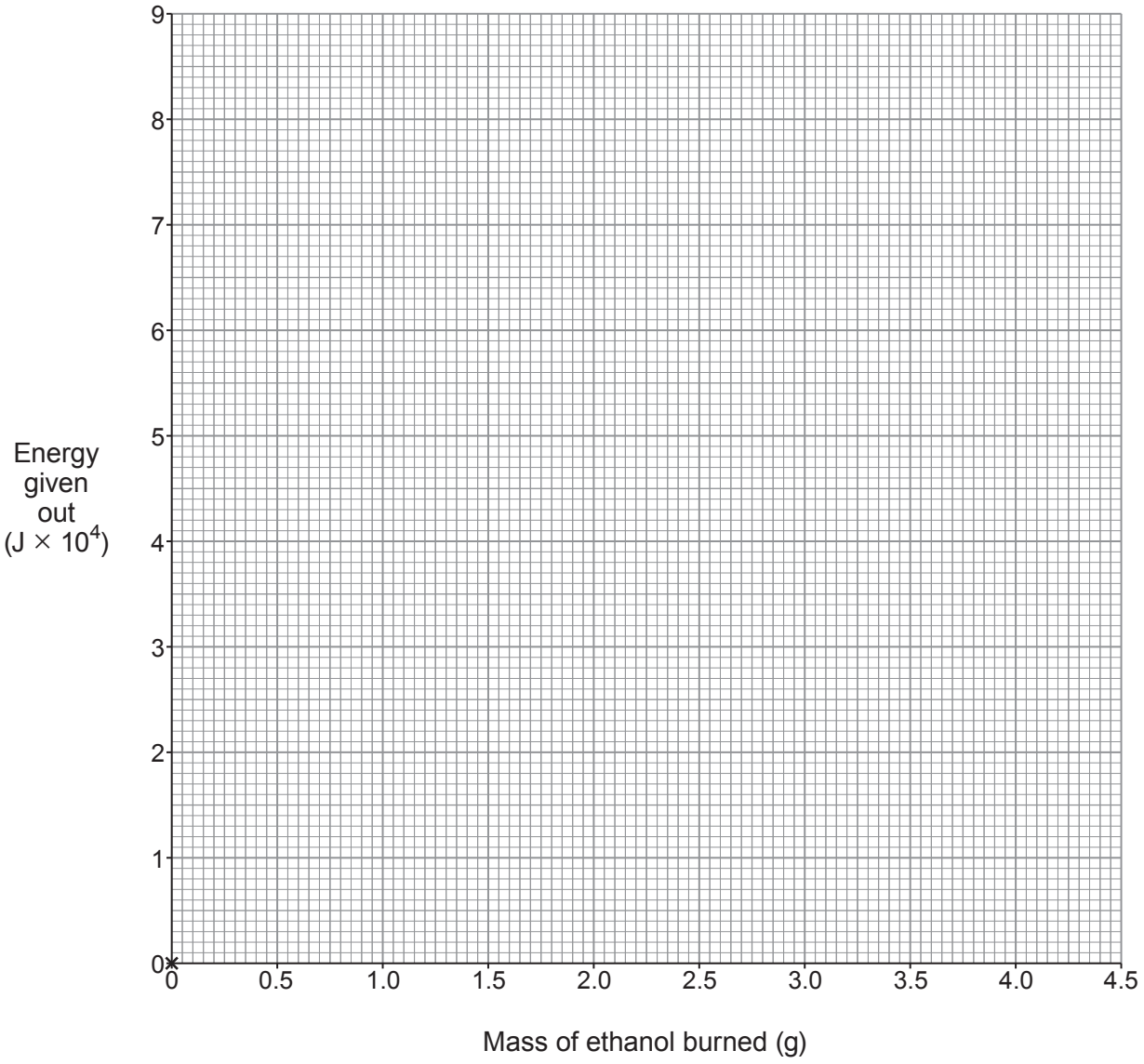
(a) The temperature rise can be calculated using the formula below.

energy given out (J) = 4.2 × temperature rise (°C) × mass of water (g)

Use this formula to calculate the temperature rise recorded by student **D**. [2]

Temperature rise = ... °C

(b) Plot the energy given out against mass of ethanol burned on the grid below and draw a suitable line. [3]



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(c) Describe the relationship between the mass of ethanol burned and the energy given out. [2]

.....

.....

.....

(d) All the recorded temperature rises were **lower** than expected.

Explain **one** piece of advice you would give the students to resolve this problem. [2]

.....

.....

.....

9

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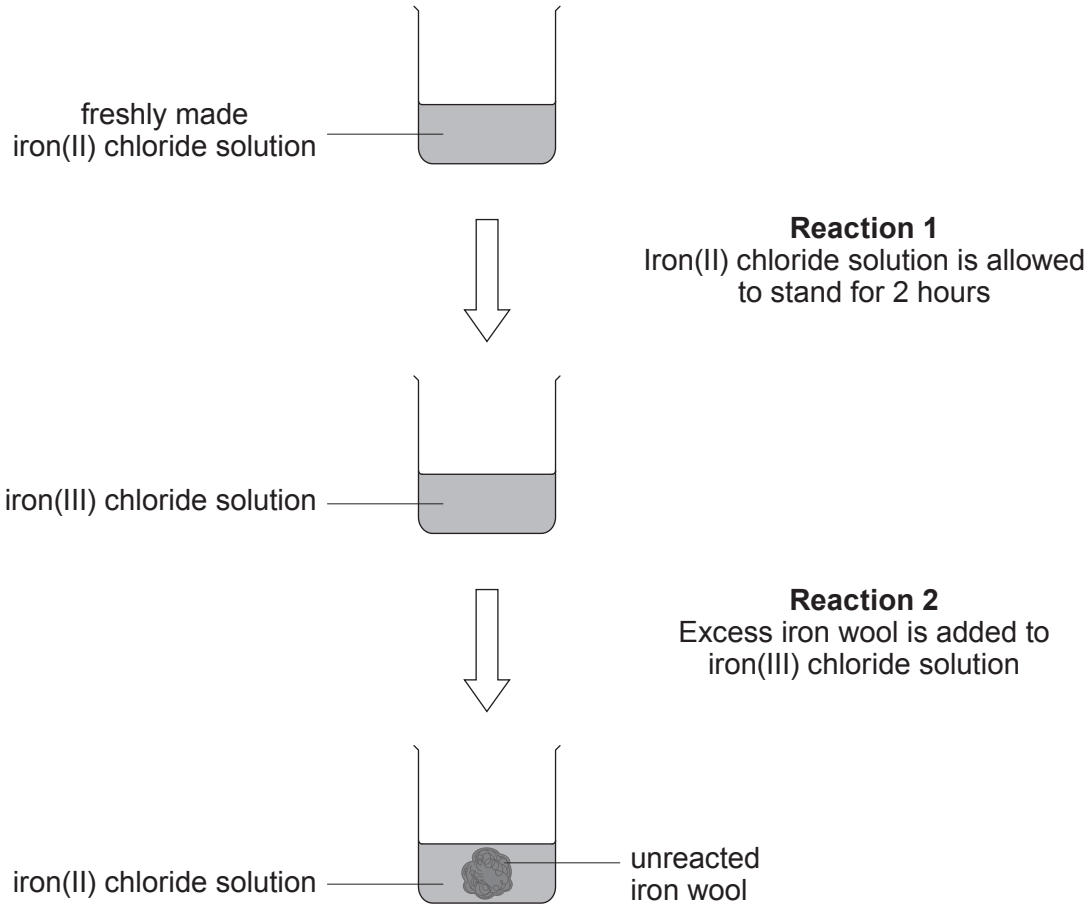
9. Transition metals have the ability to form ions with different charges. Iron and copper are transition metals.

(a) A teacher carried out a series of reactions to show that iron can form Fe^{2+} and Fe^{3+} ions.



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(i) State what you would expect to **see** during the reactions that shows iron is a transition metal. [1]

.....

(ii) In **reaction 2**, iron reacts with iron(III) chloride forming iron(II) chloride, $FeCl_2$.

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

$$Fe + 2 \text{ .....} \longrightarrow \boxed{}\ FeCl_2$$

II. Explain the meaning of the term *oxidation* in relation to **reaction 2**. [2]

.....

.....

.....

(b) Name the reagent used to identify copper(II) ions in solution. Give the observation expected. [2]

Reagent .....

Observation .....

7

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10. (a) Some household cleaners are a concentrated solution of ammonia.

To determine the concentration of an ammonia solution, 10.0 cm^3 of a household cleaner was titrated with dilute sulfuric acid of concentration 1.5 mol / dm^3.

The end-point was determined by using the indicator methyl orange.

The procedure was repeated three times and the mean volume of dilute sulfuric acid needed to neutralise 10.0 cm^3 of the ammonia solution was found to be 12.0 cm^3.

(i) Use the equation below to calculate the number of moles of sulfuric acid in 12.0 cm^3 of the 1.5 mol / dm^3 solution. [2]

$$\text{concentration} = \frac{\text{number of moles}}{\text{volume}}$$

Number of moles of sulfuric acid = ... mol

(ii) Ammonia solution reacts with sulfuric acid according to the equation below.

$$2NH_3(aq) + H_2SO_4(aq) \longrightarrow (NH_4)_2SO_4(aq)$$

Use the equation for the reaction to find the number of moles of ammonia in 10.0 cm^3 of the household cleaner. [1]

Number of moles of ammonia = ... mol

(iii) Calculate the concentration of ammonia in mol / dm^3. [2]

Concentration of ammonia = ... mol / dm^3

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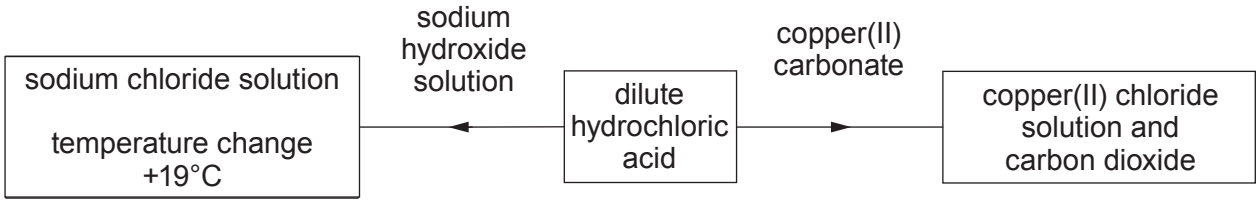
(b) The diagram shows two reactions of dilute hydrochloric acid.



(i) Predict the temperature change if dilute ethanoic acid, CH_3COOH, is added to sodium hydroxide instead of dilute hydrochloric acid. Give the reason for your answer. [2]

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(ii) A salt is formed when ethanoic acid is added to copper(II) carbonate.

I. Give the name of the salt.

..... [1]

II. The negative ion present in the salt is CH_3COO^-.

<u>Underline</u> the correct formula of the salt. [1]

$Cu(CH_3COO)_2$ **$CuCH_3COO$** **Cu_2CH_3COO** **$Cu_2(CH_3COO)_2$**

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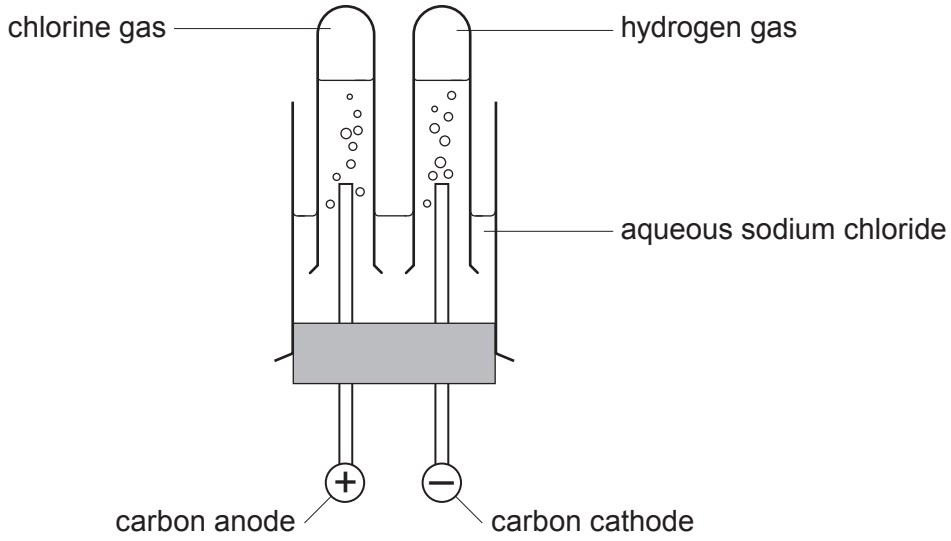
11. The diagram shows the laboratory apparatus that can be used to model the manufacture of aqueous sodium hydroxide (NaOH), chlorine (Cl_2) and hydrogen (H_2) from aqueous sodium chloride, NaCl.



Aqueous sodium chloride contains the ions Na^+, Cl^-, OH^- and H^+.

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Explain, in terms of ions, the formation of each of the **three** products. Include equations to support your answer. [6 QER]

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END OF PAPER

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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+}		

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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

A_r — relative atomic mass
Symbol
Name
Z — atomic number

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