Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Time 1 hour 30 minutes

Paper reference **WCH12/01**

Chemistry

International Advanced Subsidiary/Advanced Level
UNIT 2: Energetics, Group Chemistry, Halogenoalkanes and Alcohols

You must have:
Scientific calculator, Data Booklet, ruler

Total Marks

Instructions

- Use **black** ink or ball-point pen.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions.
- Answer the questions in the spaces provided – *there may be more space than you need.*

Information

- The total mark for this paper is 80.
- The marks for **each** question are shown in brackets – *use this as a guide as to how much time to spend on each question.*
- In the question marked with an **asterisk** (*), marks will be awarded for your ability to structure your answer logically, showing how the points that you make are related or follow on from each other where appropriate.
- A Periodic Table is printed on the back cover of this paper.

Advice

- Read each question carefully before you start to answer it.
- Show all your working in calculations and include units where appropriate.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ▶

P71861A

B:1/1/1/1/

P 7 1 8 6 1 A 0 1 2 4

Pearson

SECTION A

Answer ALL the questions in this section.

You should aim to spend no more than 20 minutes on this section.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 Hydrogen reacts with oxygen to form steam.

$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(g) \qquad \Delta H = -242\,kJ\,mol^{-1}$$

Bond	Bond enthalpy / kJ mol^{-1}
H—H	436
O═O	498

What is the bond enthalpy of the O—H bond, in kJ mol^{-1}?

☒ **A** 221.5

☒ **B** 463.5

☒ **C** 588

☒ **D** 927

(Total for Question 1 = 1 mark)

2 Which equation shows the standard enthalpy change of formation of sodium chloride?

☒ **A** $Na(s) + \tfrac{1}{2}Cl_2(g) \rightarrow NaCl(s)$

☒ **B** $2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$

☒ **C** $Na(g) + Cl(g) \rightarrow NaCl(s)$

☒ **D** $Na^+(g) + Cl^-(g) \rightarrow NaCl(s)$

(Total for Question 2 = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

3 Some enthalpy changes of combustion are shown.

Substance	Enthalpy change of combustion / kJ mol^{-1}
$CH_3CHO(l)$	−1167
C(s)	−394
$H_2(g)$	−286

What is the enthalpy change of formation of ethanal, CH_3CHO, in kJ mol^{-1}?

☒ **A** +765

☒ **B** −765

☒ **C** +193

☒ **D** −193

(Total for Question 3 = 1 mark)

4 What is the mass of carbon formed when 1.80 g of propan-1-ol, C_3H_7OH, undergoes incomplete combustion according to the equation shown?

$$C_3H_7OH(l) + 2O_2(g) \rightarrow 2C(s) + CO(g) + 4H_2O(l)$$

☒ **A** 0.18 g

☒ **B** 0.36 g

☒ **C** 0.72 g

☒ **D** 1.08 g

(Total for Question 4 = 1 mark)

5 Which property **decreases** as Group 2 of the Periodic Table is descended?

☒ **A** reactivity of the elements

☒ **B** solubility of the hydroxides

☒ **C** solubility of the sulfates

☒ **D** thermal stability of the carbonates

(Total for Question 5 = 1 mark)

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6 How many structural isomers with the molecular formula $C_5H_{10}O$ react with Benedict's or Fehling's solutions?

- ☒ **A** 2
- ☒ **B** 3
- ☒ **C** 4
- ☒ **D** 5

(Total for Question 6 = 1 mark)

7 Butanenitrile can be formed by reacting 1-bromopropane with potassium cyanide.

Which is the correct mechanism and type of reaction that occurs?

- ☒ **A** electrophilic addition
- ☒ **B** nucleophilic addition
- ☒ **C** electrophilic substitution
- ☒ **D** nucleophilic substitution

(Total for Question 7 = 1 mark)

8 What produces the colour in a flame test?

	Energy change of electrons	Movement of electrons
☒ **A**	energy absorbed	from ground state to excited state
☒ **B**	energy emitted	from ground state to excited state
☒ **C**	energy absorbed	from excited state to ground state
☒ **D**	energy emitted	from excited state to ground state

(Total for Question 8 = 1 mark)

9 Why is the boiling temperature of hydrogen iodide higher than that of hydrogen bromide?

- ☒ **A** hydrogen iodide has stronger London forces than hydrogen bromide
- ☒ **B** hydrogen iodide has a larger permanent dipole than hydrogen bromide
- ☒ **C** hydrogen iodide has stronger hydrogen bonds than hydrogen bromide
- ☒ **D** the H—I bond is stronger than the H—Br bond

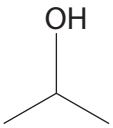
(Total for Question 9 = 1 mark)

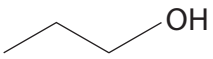
10 Which nitrate forms oxygen as the **only** gaseous product on heating?

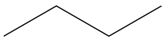
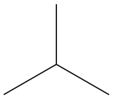
- ☒ **A** $LiNO_3$
- ☒ **B** $NaNO_3$
- ☒ **C** $Mg(NO_3)_2$
- ☒ **D** $Ca(NO_3)_2$

(Total for Question 10 = 1 mark)

11 Which compound has the **highest** boiling temperature?

- ☒ **A** 

- ☒ **B** 

- ☒ **C** 
- ☒ **D** 

(Total for Question 11 = 1 mark)

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12 Which compound does **not** form hydrogen bonds between its molecules?

- ☒ **A** HCl
- ☒ **B** H_2O
- ☒ **C** HF
- ☒ **D** NH_3

(Total for Question 12 = 1 mark)

13 What is the oxidation number of bromine in BrO_3^-?

- ☒ **A** +1
- ☒ **B** +3
- ☒ **C** +5
- ☒ **D** +7

(Total for Question 13 = 1 mark)

14 Which reaction is **not** a disproportionation?

- ☒ **A** $3Cl_2(g) + 6NaOH(aq) \rightarrow NaClO_3(aq) + 5NaCl(aq) + 3H_2O(l)$
- ☒ **B** $2H_2O_2(l) \rightarrow 2H_2O(l) + O_2(g)$
- ☒ **C** $Cl_2(g) + H_2O(l) \rightarrow HCl(aq) + HClO(aq)$
- ☒ **D** $Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$

(Total for Question 14 = 1 mark)

15 Which trend is **not** correct as Group 7 is descended?

- ☒ **A** atomic radius of the elements increases
- ☒ **B** boiling temperature of the elements increases
- ☒ **C** electronegativity of the elements decreases
- ☒ **D** reactivity of the elements increases

(Total for Question 15 = 1 mark)

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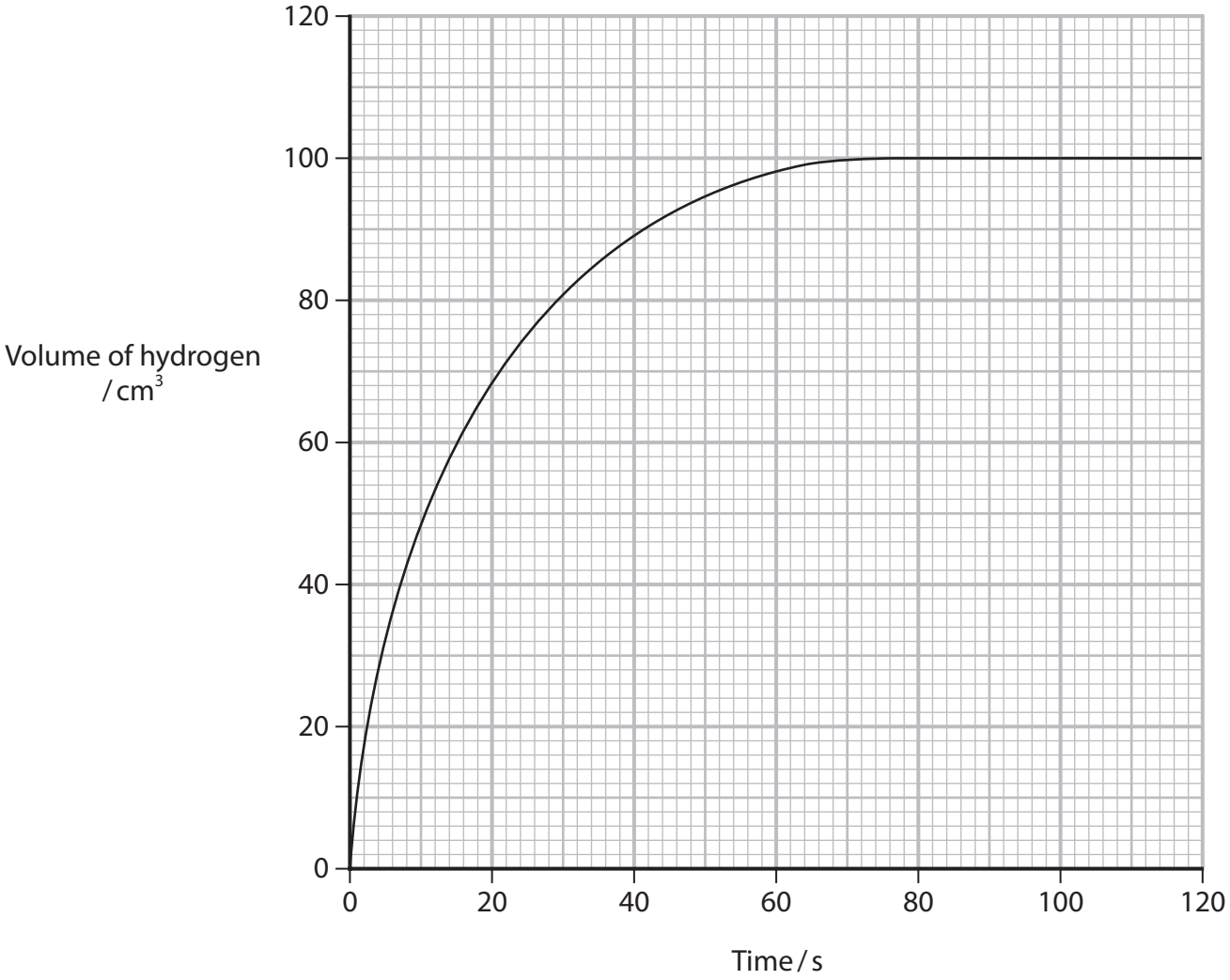
16 The results of an experiment to determine the rate of the reaction between magnesium and hydrochloric acid are shown.



What is the **approximate** rate of reaction in $cm^3 s^{-1}$ at 40 seconds?

- ☒ **A** 0.75
- ☒ **B** 1.3
- ☒ **C** 2.2
- ☒ **D** 6.0

(Total for Question 16 = 1 mark)

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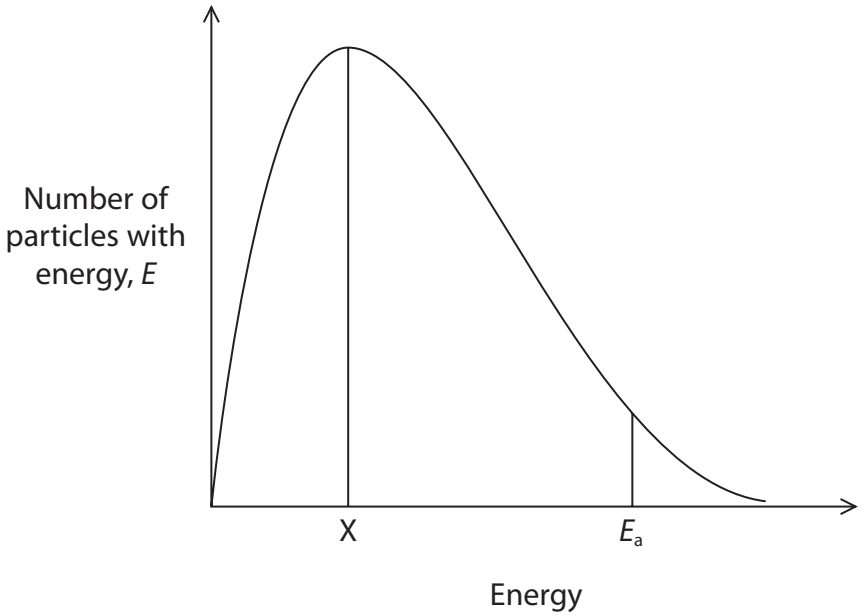
17 A Maxwell-Boltzmann distribution curve for the particles present in a reaction mixture is shown.



(a) Which statement is correct?

(1)

- ☒ **A** position X represents the mean energy of the particles
- ☒ **B** activation energy, E_a, is the mean energy of the particles that react
- ☒ **C** the area under the curve to the right of the activation energy, E_a, represents the number of particles with enough energy to react
- ☒ **D** adding a catalyst moves the activation energy, E_a, to the right

(b) What happens to the distribution curve when the temperature of the gas is **decreased**?

(1)

	Position of the peak	Height of the peak
☒ **A**	shifts to the right	lower
☒ **B**	shifts to the right	higher
☒ **C**	shifts to the left	lower
☒ **D**	shifts to the left	higher

(Total for Question 17 = 2 marks)

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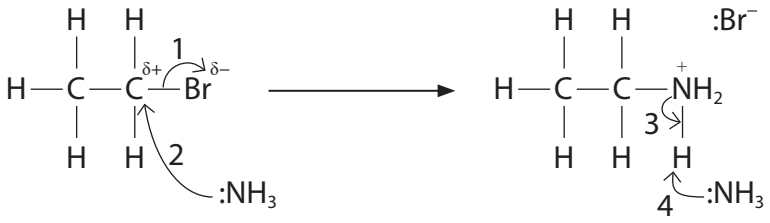
18 Part of a reaction mechanism is shown.



Which curly arrow in the mechanism is **not** correct?

- ☒ **A** arrow 1
- ☒ **B** arrow 2
- ☒ **C** arrow 3
- ☒ **D** arrow 4

(Total for Question 18 = 1 mark)

19 A student carries out two sets of titrations, one using methyl orange and the other using phenolphthalein as indicators.
The conical flask contains sodium hydroxide solution and the burette contains hydrochloric acid.

What are the colour changes at the end-points?

	Methyl orange	Phenolphthalein
☒ **A**	red to orange	colourless to pink
☒ **B**	yellow to orange	pink to colourless
☒ **C**	red to orange	pink to colourless
☒ **D**	yellow to orange	colourless to pink

(Total for Question 19 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

Answer ALL the questions. Write your answers in the spaces provided.

20 A student carries out two experiments and uses the results to determine the enthalpy change when anhydrous copper(II) sulfate forms hydrated copper(II) sulfate, $CuSO_4 \cdot 5H_2O$.

$$CuSO_4(s) + 5H_2O(l) \rightarrow CuSO_4 \cdot 5H_2O(s)$$

(a) In the first experiment, the student determines the enthalpy change when hydrated copper(II) sulfate dissolves in water.

$$CuSO_4 \cdot 5H_2O(s) + aq \rightarrow CuSO_4(aq)$$

10.68 g of hydrated copper(II) sulfate is added to distilled water in a polystyrene cup to give 55.0 g of solution.
The mixture is stirred and the temperature change determined.

Results

Initial temperature = 21.0 °C

Minimum temperature = 18.5 °C

Calculate the enthalpy change for this reaction.
Give your answer to an appropriate number of significant figures.
Include a sign and units.

Data: Specific heat capacity of the solution = 3.70 J g^{-1} $°C^{-1}$
Molar mass $CuSO_4 \cdot 5H_2O$ = 249.6 g mol^{-1}

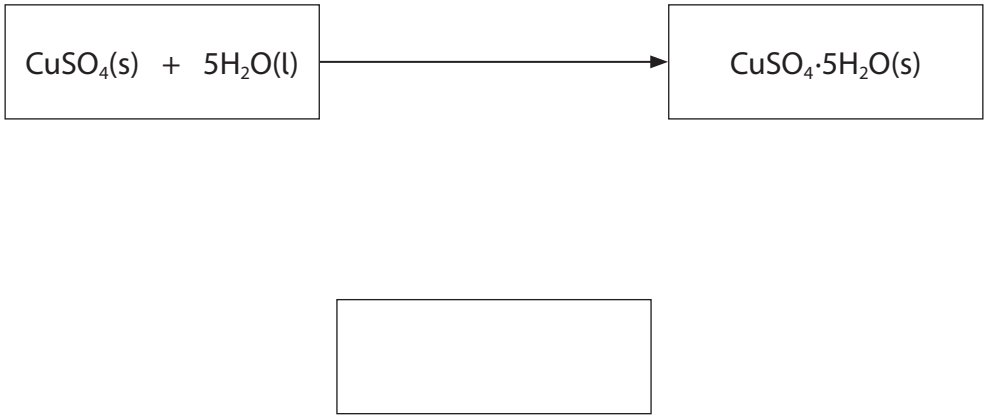
(4)

(b) In the second experiment, the student determined the enthalpy change of the reaction when anhydrous copper(II) sulfate dissolves in water.

$$CuSO_4(s) + aq \rightarrow CuSO_4(aq) \qquad \Delta H = -67.4\,kJ\,mol^{-1}$$

(i) Complete the Hess cycle.

(2)



(ii) Calculate the enthalpy change when anhydrous copper(II) sulfate forms hydrated copper(II) sulfate. Include a sign and units.

(2)

(Total for Question 20 = 8 marks)

21 This question is about sulfuric acid.

(a) Sulfuric acid is manufactured in a three-step process.

Step **1** $S(s) + O_2(g) \rightarrow SO_2(g)$

Step **2** $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

Step **3** $SO_3(g) + H_2O(l) \rightarrow H_2SO_4(l)$

(i) At room temperature and pressure, sulfur is a solid and oxygen a gas.

Explain why sulfur and oxygen exist in different states by referring to the intermolecular forces involved.

(2)

(ii) Step **2** is a reversible reaction.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -196\,kJ\,mol^{-1}$$

State the effect on the position of equilibrium when the temperature and pressure are increased. Justify your answers.

(4)

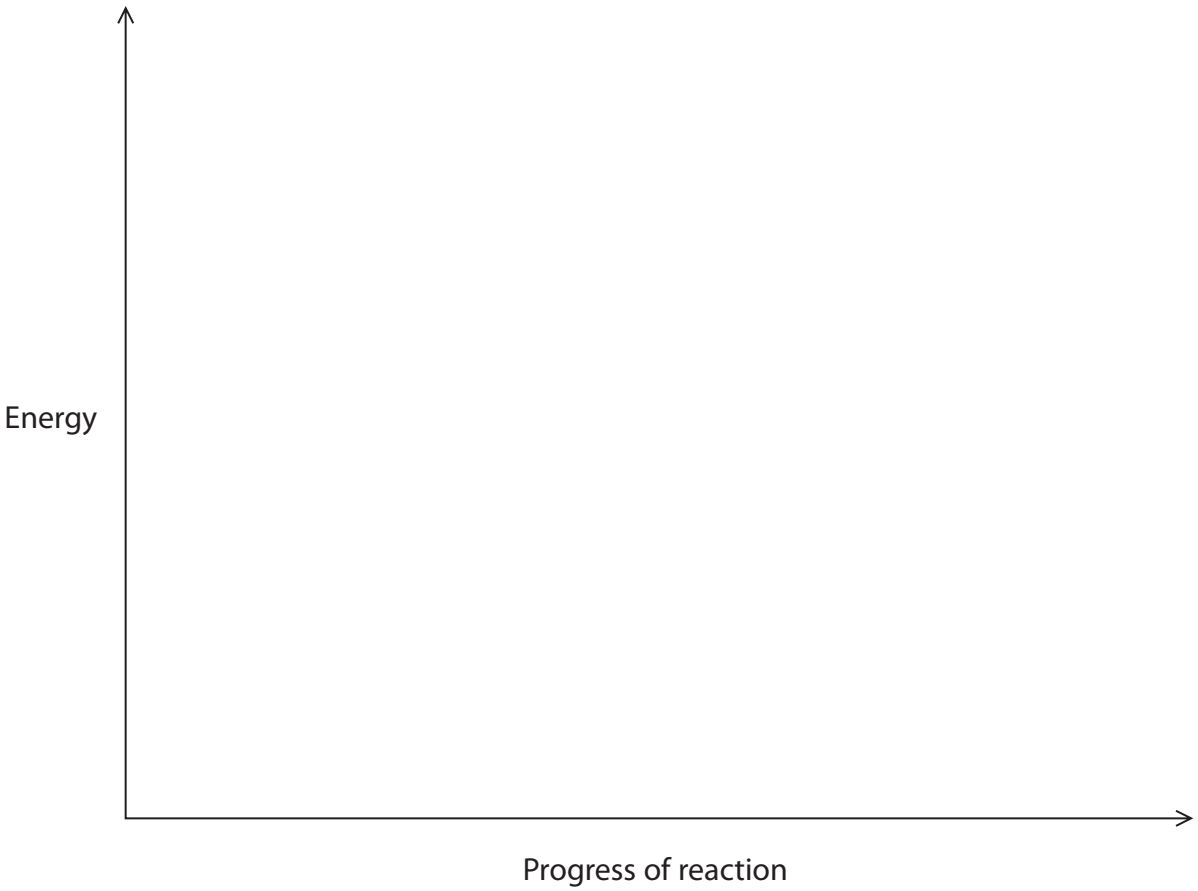
Increasing temperature at constant pressure

Increasing pressure at constant temperature

(iii) Vanadium(V) oxide, V_2O_5, is used to catalyse the reaction in Step **2**.

Complete the reaction profile to show both the catalysed and uncatalysed reactions.
Label the activation energy and the enthalpy change.
Your diagram does not have to be to scale.

(4)



(iv) Explain how the use of a catalyst makes this reaction more sustainable.

(2)

.....

.....

.....

*(b) Concentrated sulfuric acid reacts with solid potassium chloride and with solid potassium iodide.

Compare and contrast these reactions to show the difference in reducing ability of these two halide ions.
In your answer describe what would be observed and identify the products formed.

(6)

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(c) Dilute sulfuric acid is used in many laboratories. It is often supplied as concentrated sulfuric acid and then diluted.
A technician makes 500 cm^3 of 1.5 mol dm^{-3} sulfuric acid by adding 40.5 cm^3 of concentrated sulfuric acid to distilled water.

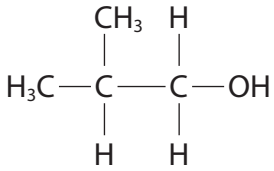
Calculate the concentration of the **concentrated** sulfuric acid, in mol dm^{-3}.

(2)

(Total for Question 21 = 20 marks)

22 This question is about the four structural isomers with the formula $C_4H_{10}O$ which are alcohols.

One of the isomers, 2-methylpropan-1-ol, is shown.



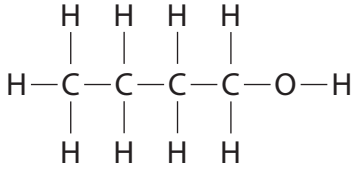
(a) 2-methylpropan-1-ol is a primary alcohol.

Explain what is meant by the terms *alcohol* and *primary*.

(2)

(b) Complete the table for the other three structural isomers of $C_4H_{10}O$ which are alcohols.

(5)

Name		butan-2-ol	
Displayed formula			
Classification of alcohol			tertiary

(c) 2-methylpropan-1-ol can be oxidised to 2-methylpropanoic acid, in a two-step process.

$$(CH_3)_2CHCH_2OH \xrightarrow{\text{Step 1}} (CH_3)_2CHCHO \xrightarrow{\text{Step 2}} (CH_3)_2CHCOOH$$

(i) Identify by name or formula the reagents needed to prepare the oxidising mixture.

(2)

.....

.....

(ii) Write the equation for Step **1** using [O] to represent the oxygen from the oxidising agent.

(1)

(iii) Infrared spectroscopy provides information on functional groups.

In an experiment, a sample of 2-methylpropan-1-ol was treated with an oxidising agent.

Show that infrared spectroscopy can be used to show that both the alcohol and the aldehyde are present in the resulting mixture.
In your answer refer to any relevant wavenumber ranges and bonds responsible for the infrared spectrum.
Refer to page 7 of the Data Booklet.

(2)

.....

.....

.....

.....

.....

(Total for Question 22 = 12 marks)

TOTAL FOR SECTION B = 40 MARKS

SECTION C

Answer ALL the questions. Write your answers in the spaces provided.

23 This question is about bicycles.

Bicycle frames have been made from steel and aluminium for many years but more recently titanium has been used.

Titanium is a metal that is extracted from its ore, impure titanium oxide (TiO_2), in a two-step process.

Step **1**

The titanium oxide reacts with chlorine in the presence of carbon to form titanium(IV) chloride ($TiCl_4$) and carbon monoxide.

Step **2**

The titanium(IV) chloride reacts with magnesium.

$$TiCl_4 + 2Mg \rightarrow Ti + 2MgCl_2$$

(a) (i) Write the equation for Step **1**.
State symbols are not required.

(1)

(ii) Explain why Step **2** is a redox reaction.
Refer to relevant oxidation numbers in your answer.

(2)

(b) Titanium(IV) chloride is a liquid that reacts violently with water, producing white smoke. This reaction has been used to produce naval smoke screens to hide ships.

Suggest the type of reaction taking place **and** the compound producing the white smoke.

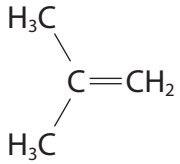
(2)

Type of reaction

Compound

(c) Many bicycles use an inner tube inside the tyre.

A common material used for inner tubes is the addition polymer formed from 2-methylpropene.

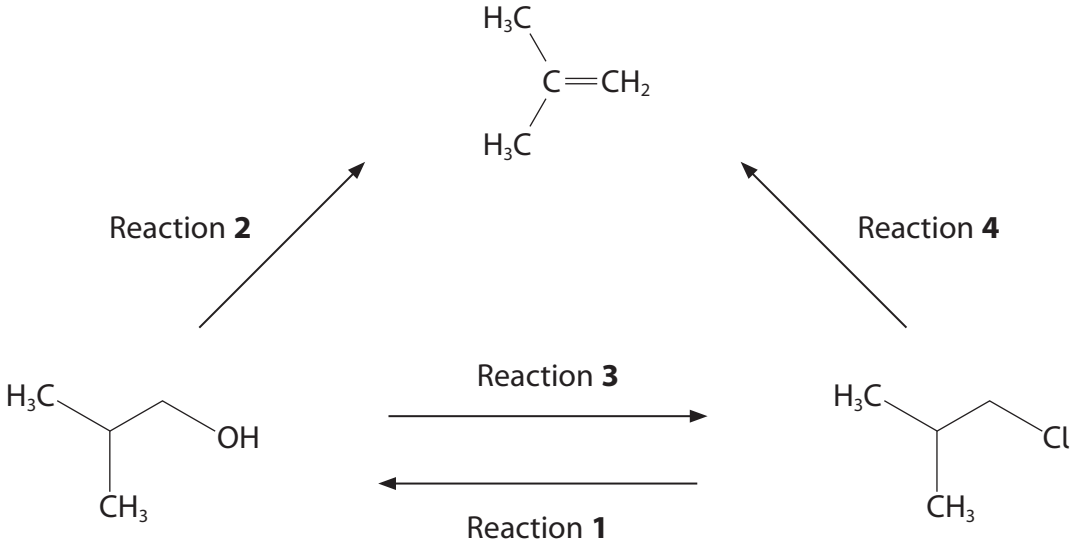


2-methylpropene

Draw a section of the polymer showing two repeat units.

(2)

(d) A reaction scheme involving 2-methylpropene is shown.



(i) For Reaction **1**, give the name or formula of a suitable reagent, stating the conditions for the reaction.

(2)

Reagent

.....

Conditions

.....

(ii) For Reaction **2**, give the name or formula of a suitable reagent, stating the type of reaction taking place.

(2)

Reagent

.....

Type of reaction

.....

(iii) For Reaction **3**, give the name or formula of a suitable reagent, writing an equation for the reaction taking place.

(2)

Reagent

.....

Equation

(iv) For Reaction **4**, the reagent used is potassium hydroxide (KOH).

Give the conditions required for this reaction, stating the role of the hydroxide ions in this reaction.

(2)

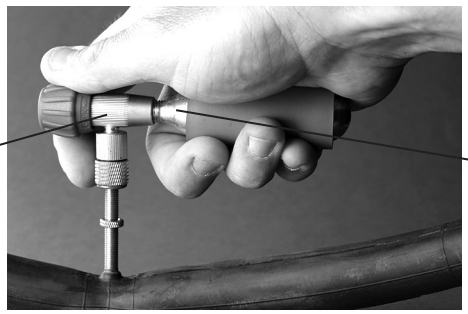
Conditions

.....

Role of hydroxide ions

.....

(e) Many cyclists carry a small cylinder of carbon dioxide to inflate their inner tube if it is punctured. The carbon dioxide is stored under pressure.



(Source: © Douglas Sacha/Getty Images)

A gas cylinder contains 16.0 g of carbon dioxide (CO_2).
The cylinder has a volume of 20 cm^3.

Calculate the pressure in the cylinder at 25 °C. Include units in your answer.
Assume that all the CO_2 in the cylinder is a gas.

[$pV = nRT$ $R = 8.31\ J\,mol^{-1}\,K^{-1}$]

(5)

(Total for Question 23 = 20 marks)

TOTAL FOR SECTION C = 20 MARKS
TOTAL FOR PAPER = 80 MARKS

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The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8)
							1.0 H hydrogen 1										(18) 4.0 He helium 2
(1)	(2)		Key: relative atomic mass / atomic symbol / name / atomic (proton) number									(13)	(14)	(15)	(16)	(17)	
6.9 Li lithium 3	9.0 Be beryllium 4											10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	95.9 Mo molybdenum 42	[98] Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	138.9 La* lanthanum 57	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	[209] Po polonium 84	[210] At astatine 85	[222] Rn radon 86
[223] Fr francium 87	[226] Ra radium 88	[227] Ac* actinium 89	[261] Rf rutherfordium 104	[262] Db dubnium 105	[266] Sg seaborgium 106	[264] Bh bohrium 107	[277] Hs hassium 108	[268] Mt meitnerium 109	[271] Ds darmstadtium 110	[272] Rg roentgenium 111							

Elements with atomic numbers 112-116 have been reported but not fully authenticated

* Lanthanide series

* Actinide series

140 Ce cerium 58	141 Pr praseodymium 59	144 Nd neodymium 60	[147] Pm promethium 61	150 Sm samarium 62	152 Eu europium 63	157 Gd gadolinium 64	159 Tb terbium 65	163 Dy dysprosium 66	165 Ho holmium 67	167 Er erbium 68	169 Tm thulium 69	173 Yb ytterbium 70	175 Lu lutetium 71
232 Th thorium 90	[231] Pa protactinium 91	238 U uranium 92	[237] Np neptunium 93	[242] Pu plutonium 94	[243] Am americium 95	[247] Cm curium 96	[245] Bk berkelium 97	[251] Cf californium 98	[254] Es einsteinium 99	[253] Fm fermium 100	[256] Md mendelevium 101	[254] No nobelium 102	[257] Lr lawrencium 103