Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Tuesday 14 January 2025

Morning (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.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B).
- **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 ▶

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P 7 8 4 5 6 R 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 An alcohol can be attacked by a nucleophile because

☒ **A** the C—O bond is weak

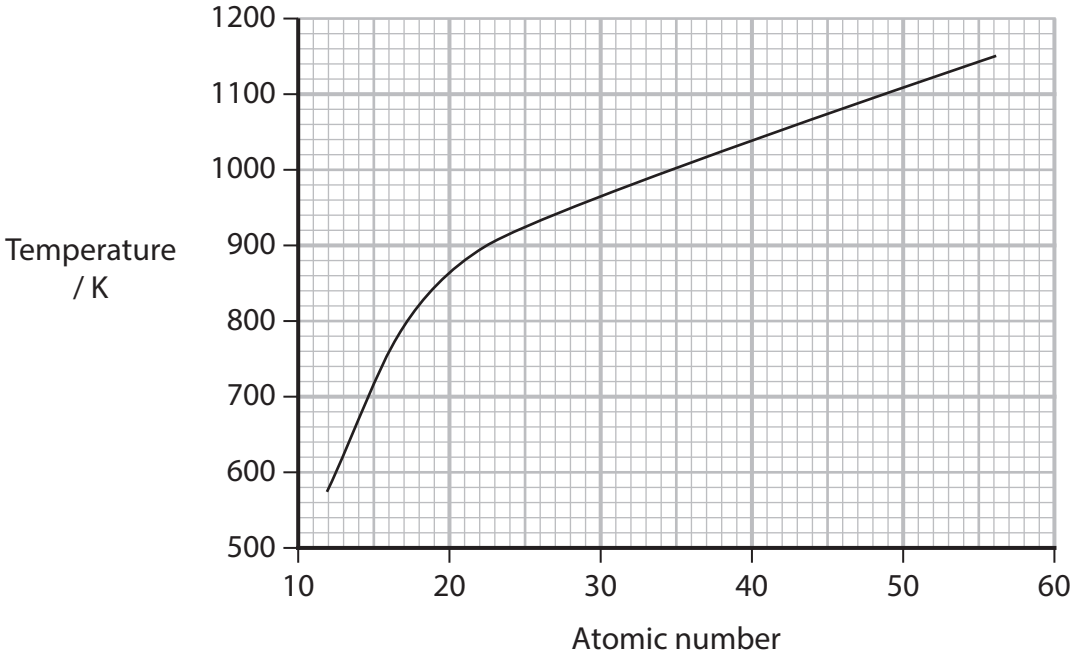
☒ **B** the C—O bond is polar

☒ **C** the O—H bond can form hydrogen bonds

☒ **D** the O—H bond is polar

(Total for Question 1 = 1 mark)

2 A student sketched a graph of the temperature (K) of the decomposition of some of the Group 2 nitrates against the metal's atomic number.



Use the graph to estimate the temperature, in °C, at which calcium nitrate decomposes.

☒ **A** 587°C

☒ **B** 767°C

☒ **C** 860°C

☒ **D** 1040°C

(Total for Question 2 = 1 mark)

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3 20 cm^3 of a saturated solution of barium nitrate at 80 °C was cooled to 20 °C. 9.32 g of crystals were precipitated.

The solubility of barium nitrate is 3.74 g per 100 g water at 20 °C.

What is the solubility of barium nitrate at 80 °C in g per 100 g water?

- ☒ **A** 13.1
- ☒ **B** 41.0
- ☒ **C** 46.6
- ☒ **D** 50.3

(Total for Question 3 = 1 mark)

4 What is the flame colour produced by strontium ions?

- ☒ **A** green
- ☒ **B** red
- ☒ **C** white
- ☒ **D** yellow

(Total for Question 4 = 1 mark)

5 Which order is correct for the solubilities of Group 2 sulfates?

- ☒ **A** barium > strontium > magnesium
- ☒ **B** calcium > strontium > magnesium
- ☒ **C** magnesium > barium > calcium
- ☒ **D** calcium > strontium > barium

(Total for Question 5 = 1 mark)

6 Which is the best solvent for chloroethane?

- ☒ **A** ethanol
- ☒ **B** hexane
- ☒ **C** hydrochloric acid
- ☒ **D** water

(Total for Question 6 = 1 mark)

7 The molecular masses and boiling temperatures of HF, HCl and HI are shown.

Compound	M_r	Boiling temperature / °C
HF	20.0	19.5
HCl	36.5	−85.0
HI	127.9	−35.1

(a) Which is the best estimate for the boiling temperature of HBr?

(1)

- ☒ **A** 59°C
- ☒ **B** −20°C
- ☒ **C** −67°C
- ☒ **D** −90°C

(b) Why does HF not fit the pattern of the boiling temperatures of the other hydrogen halides?

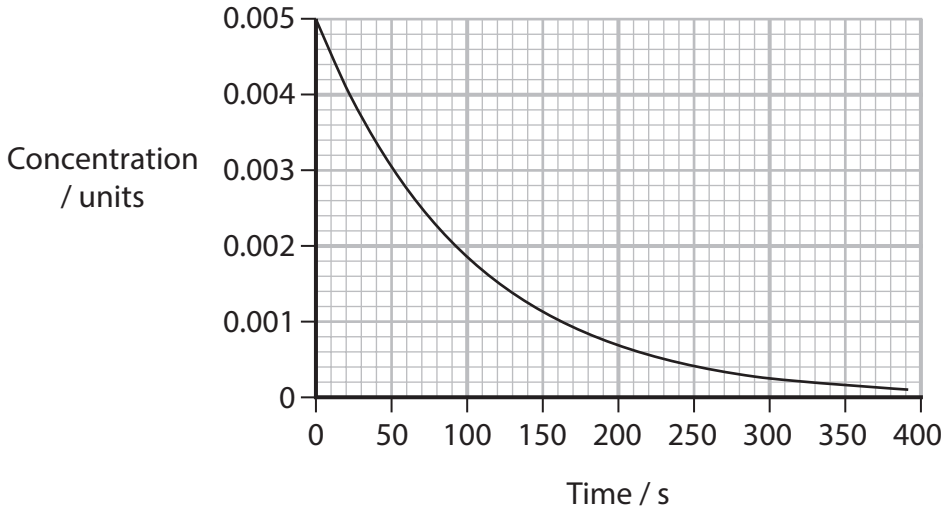
(1)

- ☒ **A** it forms hydrogen bonds
- ☒ **B** it is much smaller than the other hydrogen halides
- ☒ **C** the other halogens are all electronegative
- ☒ **D** fluorine is the most reactive

(Total for Question 7 = 2 marks)

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

8 An experiment measuring the concentration of a reactant over time produced the graph shown.



(a) What is the approximate value of the initial rate of reaction?

(1)

- ☒ **A** 4.5×10^{-5}
- ☒ **B** 1.8×10^{-5}
- ☒ **C** 1.3×10^{-5}
- ☒ **D** 2.0×10^{-6}

(b) What are the units for the rate of reaction?

(1)

- ☒ **A** mol s^{-1}
- ☒ **B** $\text{mol dm}^{-3}\text{ s}^{-1}$
- ☒ **C** $\text{mol dm}^{3}\text{ s}^{-1}$
- ☒ **D** $\text{dm}^{3}\text{ mol}^{-1}\text{ s}$

(Total for Question 8 = 2 marks)

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9 Concentrated sulfuric acid reacts with sodium iodide.

What is one role of the sulfuric acid?

- ☒ **A** oxidising agent
- ☒ **B** reducing agent
- ☒ **C** proton acceptor
- ☒ **D** lone pair donor

(Total for Question 9 = 1 mark)

10 Which equation is **not** an example of disproportionation?

- ☒ **A** $Cu_2O + H_2SO_4 \rightarrow Cu + CuSO_4 + H_2O$
- ☒ **B** $3HNO_2 \rightarrow HNO_3 + 2NO + H_2O$
- ☒ **C** $3ClO^- \rightarrow 2Cl^- + ClO_3^-$
- ☒ **D** $Mg + 2HCl \rightarrow MgCl_2 + H_2$

(Total for Question 10 = 1 mark)

11 Which is a displacement reaction that results in a visible colour change in solution?

- ☒ **A** $2NaCl + At_2 \rightarrow 2NaAt + Cl_2$
- ☒ **B** $2NaBr + I_2 \rightarrow 2NaI + Br_2$
- ☒ **C** $2NaI + Br_2 \rightarrow 2NaBr + I_2$
- ☒ **D** $2NaF + Cl_2 \rightarrow 2NaCl + F_2$

(Total for Question 11 = 1 mark)

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12 A sample of 25.0 cm^3 of 0.205 mol dm^{-3} sulfuric acid was titrated with sodium hydroxide solution. The titre obtained was 14.60 cm^3.

(a) What is the concentration of the sodium hydroxide solution?

(1)

☒ **A** 0.176 mol dm^{-3}

☒ **B** 0.239 mol dm^{-3}

☒ **C** 0.351 mol dm^{-3}

☒ **D** 0.702 mol dm^{-3}

(b) What is the percentage error in the titre?

[The burette is accurate to 0.05 cm^3 per reading]

(1)

☒ **A** 0.10%

☒ **B** 0.34%

☒ **C** 0.40%

☒ **D** 0.68%

(Total for Question 12 = 2 marks)

13 Calcium carbonate can be heated to produce calcium oxide.

$$CaCO_3 \rightarrow CaO + CO_2$$

What is the atom economy, by mass, for the formation of calcium oxide?

☒ **A** 44.0%

☒ **B** 56.0%

☒ **C** 78.6%

☒ **D** 100%

(Total for Question 13 = 1 mark)

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14 What is the concentration, in mol dm^{-3}, when 64.5 g of sodium nitrate is dissolved in water to form 750 cm^3 of solution?

[M_r $NaNO_3$ = 85.0]

☒ **A** 0.086

☒ **B** 0.113

☒ **C** 0.759

☒ **D** 1.012

(Total for Question 14 = 1 mark)

15 A volume of 10.0 cm^3 of magnesium chloride solution was added to an excess of sodium hydroxide solution, forming a precipitate of magnesium hydroxide. After filtering and drying, 0.398 g of magnesium hydroxide was obtained.

What was the concentration of the magnesium chloride solution?

[M_r $Mg(OH)_2$ = 58.3]

☒ **A** 0.00683 mol dm^{-3}

☒ **B** 0.0137 mol dm^{-3}

☒ **C** 0.683 mol dm^{-3}

☒ **D** 1.37 mol dm^{-3}

(Total for Question 15 = 1 mark)

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16 Magnesium nitrate decomposes on heating according to the equation shown.

$$2Mg(NO_3)_2 \rightarrow 2MgO + 4NO_2 + O_2$$

One mole of magnesium nitrate is completely decomposed.

(a) What is the maximum volume of gas formed at 600 K and 101 000 Pa?

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

(1)

☒ **A** 0.025 m^3

☒ **B** 0.099 m^3

☒ **C** 0.123 m^3

☒ **D** 0.247 m^3

(b) What is the percentage yield if 25.0 g of magnesium oxide is produced?

[M_r MgO = 40.3]

(1)

☒ **A** 13.6 %

☒ **B** 16.9 %

☒ **C** 31.0 %

☒ **D** 62.0 %

(Total for Question 16 = 2 marks)

TOTAL FOR SECTION A = 20 MARKS

SECTION B

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

17 Rhubarb stems contain ethanedioic acid. Ethanedioic acid reacts with acidified potassium manganate(VII), $KMnO_4$, and decolorises the solution.

(a) The ionic equation for this reaction is shown.

$$2MnO_4^- + 6H^+ + 5C_2H_2O_4 \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$

(i) Deduce the oxidation number changes for manganese and carbon.

(2)

Manganese from ..... to .....

Carbon from ..... to .....

(ii) Write the ionic half-equation for the reduction.

(1)

(iii) Write the ionic half-equation for the oxidation.

(1)

(b) A student carried out an experiment using rhubarb juice as a source of ethanedioic acid.

The student used different volumes of rhubarb juice and a constant volume of manganate(VII) as shown. An indication of rate was calculated using $1 \div t$.

(i) Complete the table.

(1)

Rhubarb juice / cm^3	Acidified manganate(VII) / cm^3	Deionised water / cm^3	Time (t) / s	$1 \div t$ / s^{-1}	$(1 \div t) \times 10^3$ / s^{-1}
5	1	5	398	0.00251	2.51
6	1	4	329	0.00304	3.04
7	1	3	289	0.00346	3.46
8	1	2	261		
9	1	1	249	0.00402	4.02
10	1	0	245	0.00408	4.08

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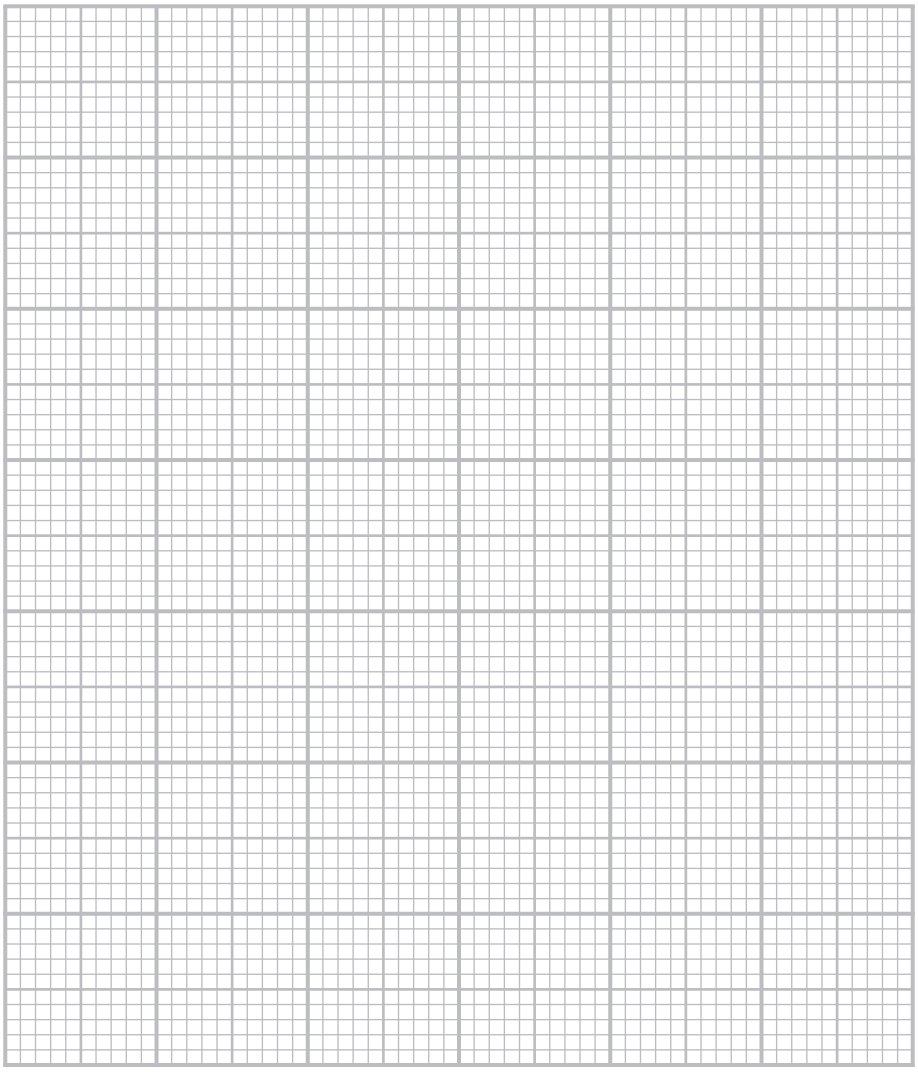
(ii) Plot a graph of the rate of reaction, as represented by $(1 \div t) \times 10^3$, against the volume of rhubarb juice.

(4)



(iii) Explain why a rate of reaction is greater at higher concentrations.

(2)

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.....

.....

.....

(c) Another student suggested that the reaction between manganate(VII) and rhubarb juice could be used to find the concentration of ethanedioic acid in rhubarb juice.

Outline an experiment that could be carried out to find this concentration.

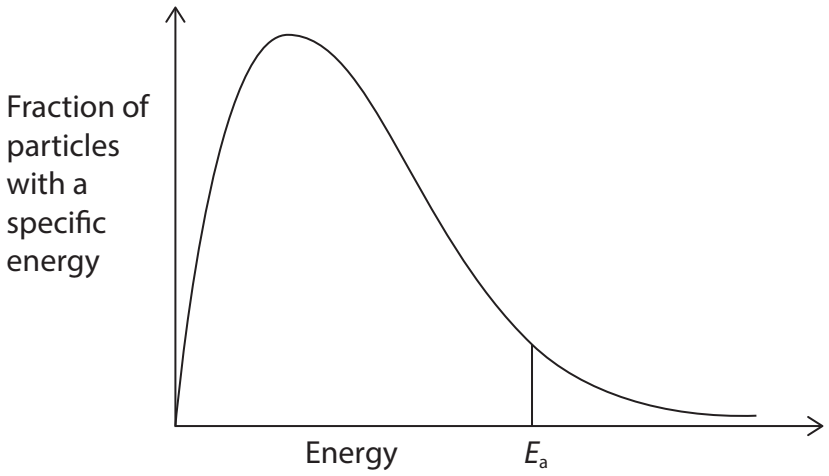
Details of the apparatus and calculations are not needed.

(2)

(d) The Maxwell–Boltzmann distribution for the particles in a reaction is shown.

(i) Draw a curve to represent the distribution at a higher temperature.

(1)



(ii) Explain why increasing the temperature increases the rate of reaction.

(3)

(Total for Question 17 = 17 marks)

18 Water is a molecule that is essential for life and it has some unusual properties.

(a) Draw a diagram to show hydrogen bonding between two H_2O molecules in ice.

Include bond angles and relevant dipoles and lone pairs in your answer.

(3)

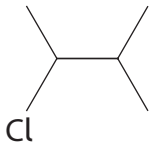
(b) Compare and contrast the effect of intermolecular forces on the properties of water and ammonia, using the data shown.

(3)

Molecule	M_r	Boiling temperature / K	Density at 223 K / kg m^{-3}	Density at 278 K / kg m^{-3}
NH_3	16.0	240	698	0.763
H_2O	18.0	373	926	1000

(Total for Question 18 = 6 marks)

19 Compound **X** is a halogenoalkane.



X

(a) Name compound **X**.

(1)

.....

(b) The reaction of **X** with hot, concentrated ethanolic KOH produces two isomers.

(i) Name this type of reaction.

(1)

.....

(ii) Draw the structure of the two isomers.

(2)

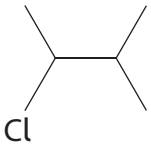
Isomer 1

Isomer 2

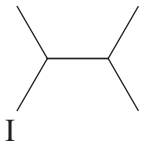
(c) (i) Complete the reaction mechanism for compound **X** reacting with cold, dilute aqueous potassium hydroxide.

Include curly arrows and relevant lone pairs and dipoles.

(3)



(ii) Compound **Y** also reacts with cold, dilute aqueous potassium hydroxide.



Y

Explain how the rate of reaction will compare with that of compound **X**.

(2)

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.....

(d) State the role of the hydroxide ion in each of the reactions (b) and (c).

(2)

Role in (b) .....

Role in (c) .....

(Total for Question 19 = 11 marks)

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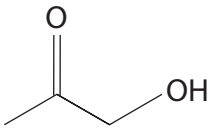
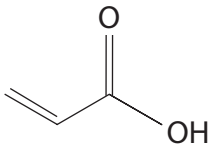
***20** A bottle has lost its label. The content of the bottle is thought to be one of 1-hydroxypropanone, propenoic acid or butan-1-ol.



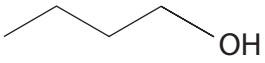
1-hydroxypropanone

$C_3H_6O_2$



propenoic acid

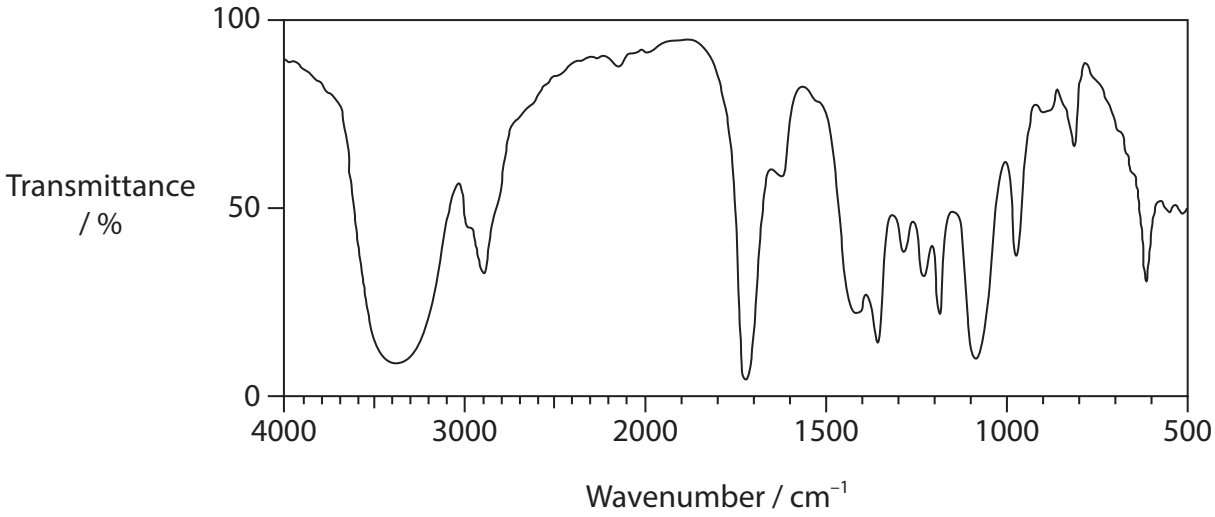
$C_3H_4O_2$

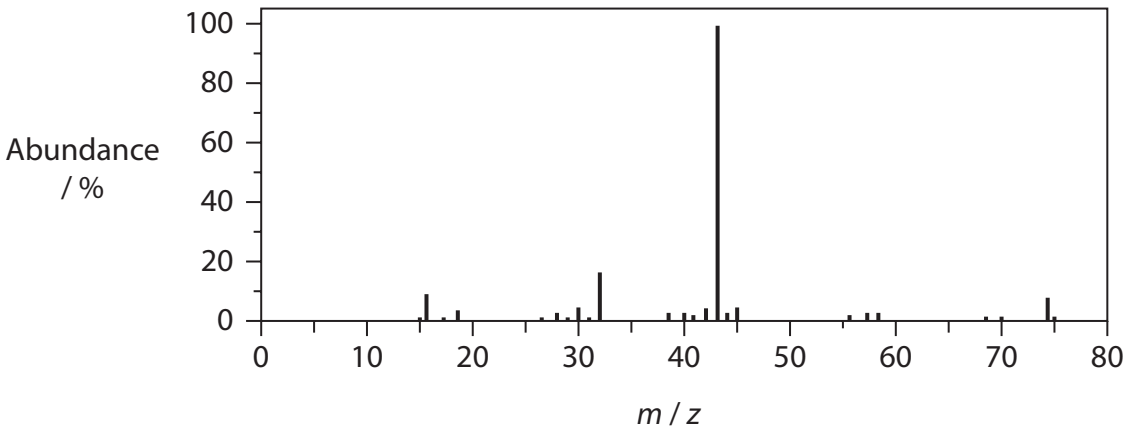


butan-1-ol

$C_4H_{10}O$

The infrared and mass spectra of the unknown compound are shown.





Compare and contrast the spectra shown with the expected spectra of the three possible compounds, and so identify the unknown.

(6)

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(Total for Question 20 = 6 marks)

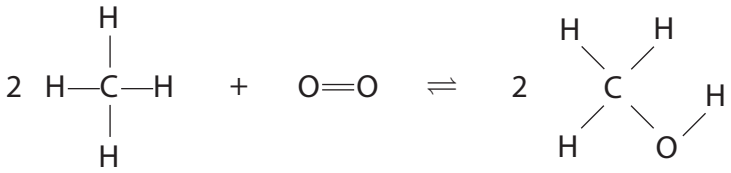
TOTAL FOR SECTION B = 40 MARKS

SECTION C

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

21 Methanol has been considered as an alternative fuel for many years. Bacteria that metabolise methane could be used for the large-scale production of the alcohol.

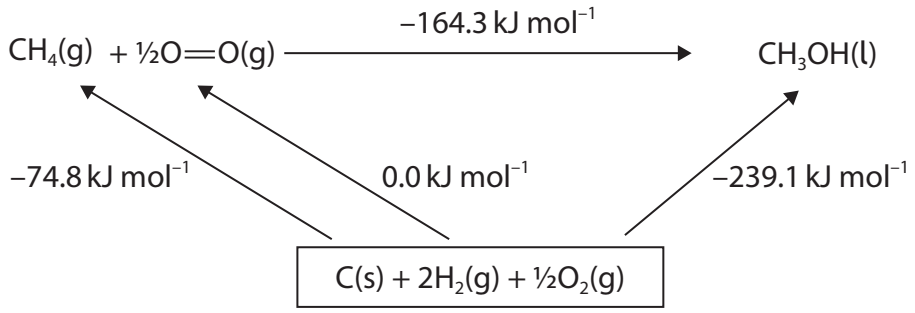
(a) Calculate the enthalpy change per mole of methanol produced, using the bond enthalpies shown.



Bond	Enthalpy / kJ mol^{-1}
O═O	498
C—H	413
C—O	336
O—H	464

(3)

(b) A Hess cycle for the reaction is shown.



State why the standard enthalpy change of formation of oxygen is 0.0 kJ mol^{-1}.

(1)

.....

.....

(c) The standard enthalpy change of reaction to form methanol from methane calculated in part (a) is less accurate than the value given in the Hess cycle in part (b).

Give **two** reasons for this difference.

(2)

.....

.....

.....

.....

(d) One problem when using bacteria to convert methane to methanol is that the methanol is quickly converted into methanal.

(i) State the type of reaction taking place as methanol is converted into methanal.

(1)

.....

(ii) Give the reagents and conditions that are needed for this reaction in the laboratory. Include in your answer any colour change seen.

(4)

Reagents .....

.....

Conditions .....

Colour change .....

(e) In industry, methanol can be synthesised in a two-step process.
The first step produces CO, CO_2 and H_2 in two reactions as shown.

$$CH_4 + H_2O \rightarrow CO + 3H_2 \qquad CO + H_2O \rightarrow CO_2 + H_2$$

This step requires a temperature of 850 °C and a pressure of 2500 kPa.

The second step requires a pressure of 8000 kPa but does not require heating as the forward reactions are exothermic.

$$CO + 2H_2 \rightleftharpoons CH_3OH \qquad CO_2 + 3H_2 \rightleftharpoons CH_3OH + H_2O$$

This leads to a yield of around 5 %. Unreacted gases are recycled.

Scientists would prefer a one-step synthesis using a catalyst.

(i) Suggest **two** possible advantages, other than increasing the yield, of a one-step synthesis reaction.

(2)

.....

.....

.....

.....

.....

(ii) Many different catalysts have been used, including MoO_3, WO_3 and Re.

State **two** characteristics that all these catalysts have in common.

(2)

.....

.....

(iii) A one-step process is being developed.
This is carried out at 101 kPa and 800 °C.

$$CH_4 + \tfrac{1}{2}O_2 \rightleftharpoons CH_3OH \qquad \Delta H = -164.3\,kJ\,mol^{-1}$$

Deduce how the reaction conditions could be changed to increase the yield, explaining why such changes may not be economical.

(5)

(Total for Question 21 = 20 marks)

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

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