Surname	Centre Number	Candidate Number
First name(s)		2

GCE AS/A LEVEL

2410U20-1

Z22-2410U20-1

FRIDAY, 27 MAY 2022 – AFTERNOON

CHEMISTRY – AS unit 2

Energy, Rate and Chemistry of Carbon Compounds

1 hour 30 minutes

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1. to 5.**	**10**	
Section B	**6.**	**15**	
	7.	**17**	
	8.	**10**	
	9.	**12**	
	10.	**16**	
	Total	**80**	

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ADDITIONAL MATERIALS

In addition to this examination paper, you will need a:
- calculator;
- **Data Booklet** supplied by WJEC.

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.

Section A Answer **all** questions.
Section B 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.

Candidates are advised to allocate their time appropriately between **Section A (10 marks)** and **Section B (70 marks)**.

INFORMATION FOR CANDIDATES

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

The maximum mark for this paper is 80.

Your answers must be relevant and must make full use of the information given to be awarded full marks for a question.

The assessment of the quality of extended response (QER) will take place in **Q9**(c).

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SECTION A

Answer **all** questions.

1. Bromine water can be used to test for alkenes.

(a) (i) State the expected colour change for a positive test for alkenes. [1]

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(ii) Draw the structure of the product formed when propene reacts with bromine water. [1]

(b) Identify another reagent that can be used to test for the presence of alkenes. [1]

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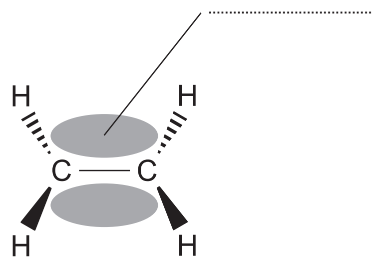
2. Bonds in hydrocarbons are formed by the overlap of orbitals between each atom.

(a) Draw an *s*-orbital and a *p*-orbital in the space below. [1]

(b) Name the type of bond shown in the diagram below. [1]



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3. A student suspects an unlabelled organic liquid is a carboxylic acid. Name the reagent(s) that must be added to the unknown organic liquid to test for the presence of a carboxylic acid. Give the expected observations for a positive result. [2]

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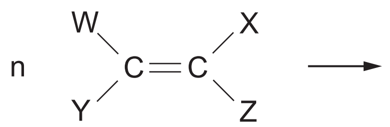
4. Complete the equation below to show the product of addition polymerisation. [1]



5. State the meaning of the term 'standard enthalpy change of formation'. [2]

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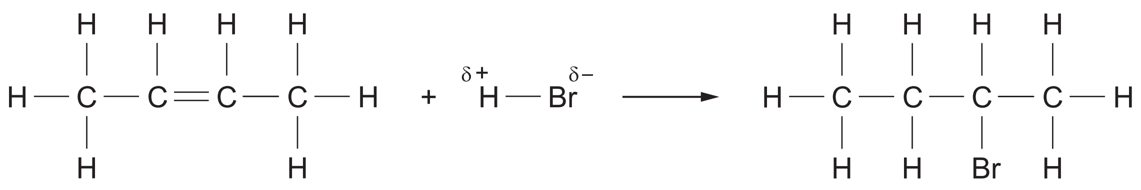
SECTION B

Answer **all** questions.

6. Butanone can be prepared from but-2-ene using a three-step synthesis.

(a) In the first step, but-2-ene is reacted with HBr to form 2-bromobutane.



(i) Circle the species that represents the electrophile. [1]

(ii) Name the type of bond fission that takes place in the H—Br bond in the first step of the mechanism. [1]

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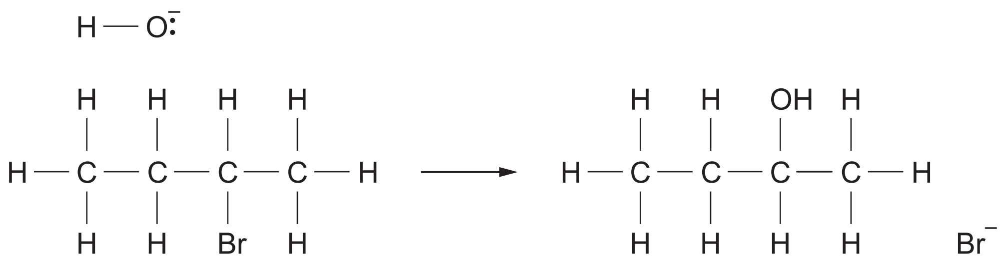
(b) In the second step, 2-bromobutane undergoes nucleophilic substitution to form butan-2-ol.



(i) Use curly arrows to complete the equation to show the mechanism of the nucleophilic substitution. Include any relevant partial charges. [2]

(ii) Give the reagents and conditions required for this nucleophilic substitution. [2]

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(iii) State the classification of alcohol to which butan-2-ol belongs. [1]

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(c) In the final step, butan-2-ol is heated with acidified potassium manganate(VII) to produce butanone.

(i) State the role of the acidified potassium manganate(VII) in this reaction. [1]

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(ii) Explain why butanone can be removed from the reaction as it is formed using distillation, leaving unreacted butan-2-ol in the reaction mixture. [2]

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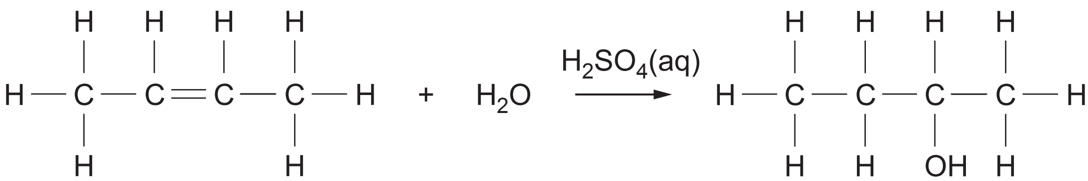
(d) Butan-2-ol can also be made directly by hydration of but-2-ene in the presence of dilute sulfuric acid, which acts as a catalyst.



(i) Suggest why the overall yield of the two-step synthesis is likely to be lower than the yield of the direct hydration. [1]

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(ii) Reaction of butan-2-ol with **concentrated** sulfuric acid results in the formation of three isomers with the formula C_4H_8.

I. Name the type of reaction used to form alkenes from alcohols. [1]

....

II. Give the structure and **name** of the three isomers formed. [3]

Structure	Structure	Structure
Name:	Name:	Name: ....

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Turn over.

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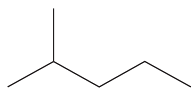
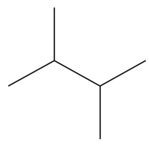
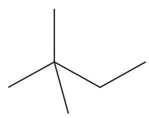
7. Petroleum ether (50–70) is a mixture of different alkanes extracted from crude oil which is commonly used as an organic solvent. The major components of petroleum ether (50–70) are the structural isomers of C_6H_{14}.

(a) (i) Give the meaning of the term 'structural isomer'. [1]

....

....

(ii) Complete the table below showing important information about the isomers of C_6H_{14}. [3]

Name	Shortened structural formula	Skeletal formula	Boiling temperature / °C
hexane	$CH_3CH_2CH_2CH_2CH_2CH_3$		69
2-methylpentane			62
3-methylpentane	$CH_3CH_2CH(CH_3)CH_2CH_3$		63
	$(CH_3)_2CHCH(CH_3)_2$		58
2,2-dimethylbutane	$CH_3C(CH_3)_2CH_2CH_3$		50

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(iii) State the relationship between the boiling temperature and the carbon chain length. Explain this relationship in terms of intermolecular forces. [2]

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(b) Hexane can be used as a fuel in a combustion reaction.

(i) Write an equation for the complete combustion of hexane in excess oxygen. [2]

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(ii) The enthalpy change of combustion ($\Delta_c H^\theta$) for hexane is approximately $-4160\,kJ\,mol^{-1}$. Explain why the enthalpy change of combustion for the isomers of hexane should be similar. [2]

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(iii) 2,2-dimethylbutane is the isomer of C_6H_{14} which ignites most readily. Suggest a reason for this. [1]

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(iv) When hexane burns in a limited supply of oxygen it undergoes a different reaction known as incomplete combustion:

$$C_6H_{14} \quad + \quad 6.5O_2 \longrightarrow 6CO \quad + \quad 7H_2O$$

The bond enthalpy values for the bonds present in these molecules are given below:

Bond	Average bond enthalpy / kJ mol^{-1}
C—C	348
C—H	413
O═O	495
C≡O (in CO)	1072
O—H	464

I. Using a Hess cycle or otherwise, calculate the enthalpy change of this reaction. [3]

enthalpy change = ... kJ mol^{-1}

II. **Use the enthalpy values** from parts (b)(ii) and (b)(iv) I. to explain quantitatively why it is important to maintain an excess of oxygen while burning hexane as a fuel. [2]

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III. State a health hazard associated with the incomplete combustion of hexane. [1]

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8. Compound **A** contains only carbon, hydrogen and an unknown halogen.

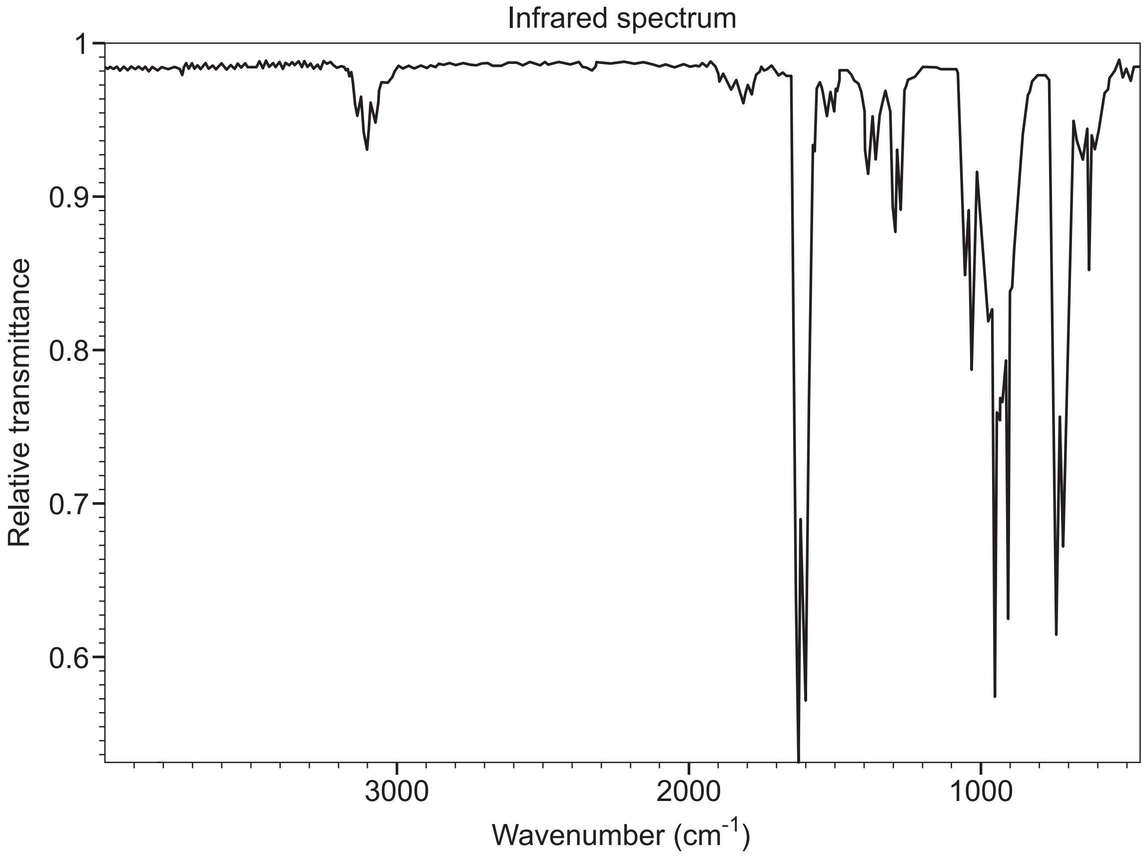
Refluxing compound **A** in aqueous sodium hydroxide followed by the addition of nitric acid and aqueous silver nitrate produces a white precipitate.

Elemental analysis of compound **A** indicates it contains 39.02% carbon and 3.25% hydrogen by mass.

When bromine is added to compound **A**, 123 g of compound **A** reacts with 320 g of bromine.

The ^{1}H NMR spectrum of compound **A** consists of only one peak. The ^{13}C NMR spectrum of compound **A** consists of two peaks.

The infrared spectrum and simplified mass spectrum are shown below and overpage.



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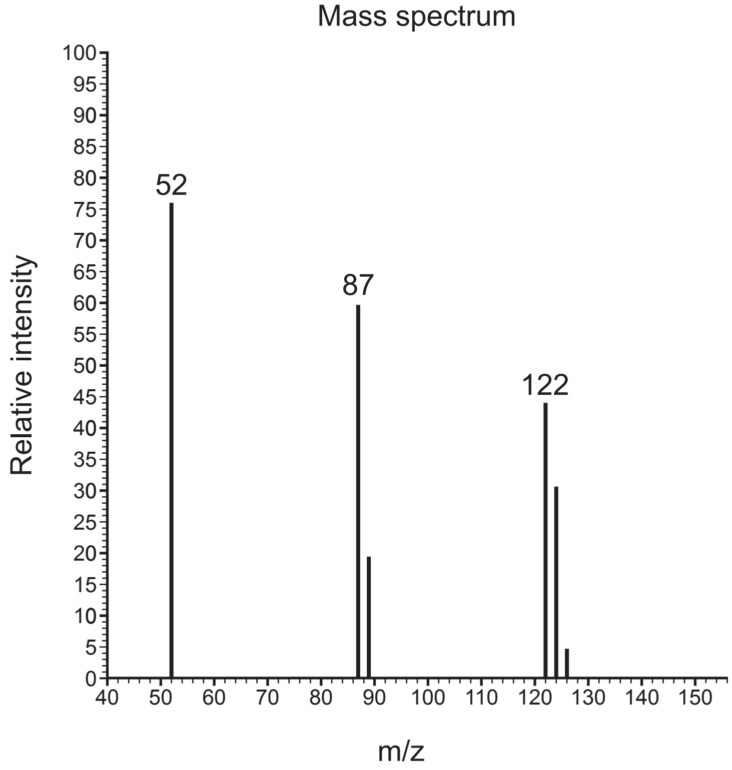

Use **all** of the data provided to determine the identity of compound **A**. Explain your answer using information from all of the data sources provided. [10]

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9. Chloe was investigating the effect of using catalysts on the rate of reaction.

She added 50 cm^3 of 0.1 $mol\,dm^{-3}$ iron(III) nitrate solution to 50 cm^3 of 0.2 $mol\,dm^{-3}$ sodium thiosulfate solution. The reaction forms a deep violet iron(III) complex which is unstable and is gradually reduced to form a light green iron(II) complex.

Chloe monitored the rate of reaction by measuring the absorption of light at a wavelength of 500 nm every 10 seconds for two minutes using a data logger.

(a) The violet complex appears black at the beginning of the reaction. State the name of the technique used to monitor the rate of reaction by measuring the absorption of light. [1]

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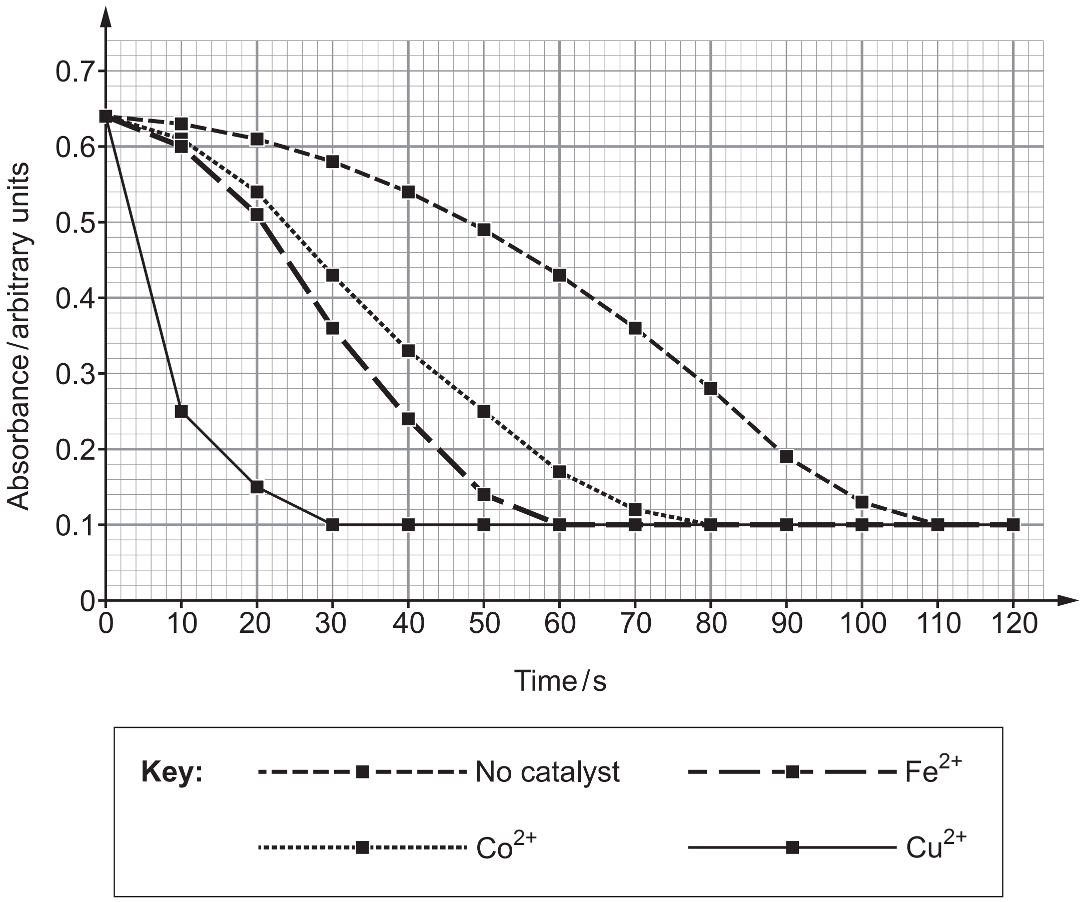
(b) Chloe repeated the experiment three times adding 1 cm^3 of a different catalyst each time at a concentration 0.10 $mol\,dm^{-3}$. Below is a graph showing her results:



(i) State which catalyst is the most effective. Explain your answer. [2]

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(ii) Calculate the initial rate of reaction for the reaction catalysed by the copper(II) ions. [2]

rate = ... s^{-1}

(iii) Each catalysed reaction contained the same number of moles of catalyst at the beginning of the reaction. Calculate the moles of catalyst left at the end of the reaction. [1]

moles = ... mol

Examiner only

(c) Increasing temperature and the addition of a catalyst are two ways of increasing the rate of a reaction.

Using your knowledge of the Boltzmann distribution and particle theory, explain how the rate of reaction is increased using these two different methods.
You may use a diagram(s) to support your answer. [6 QER]

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10. The crystallisation of sodium ethanoate from a super-saturated solution is used to release heat in reusable hand warmers.

(a) A super-saturated solution of sodium ethanoate was made by dissolving 320 g of hydrated sodium ethanoate ($CH_3COONa.3H_2O$) in 60 cm^3 of hot water. It was then allowed to cool to room temperature, which was measured as 17 °C.

A thermometer was added to the solution, which caused the sodium ethanoate to start crystallising. The temperature of the process was recorded every 30 seconds for 3 minutes. The results are shown below:

Time / s	Temperature / °C
0	17
30	27
60	35
90	41
120	40
150	39
180	38

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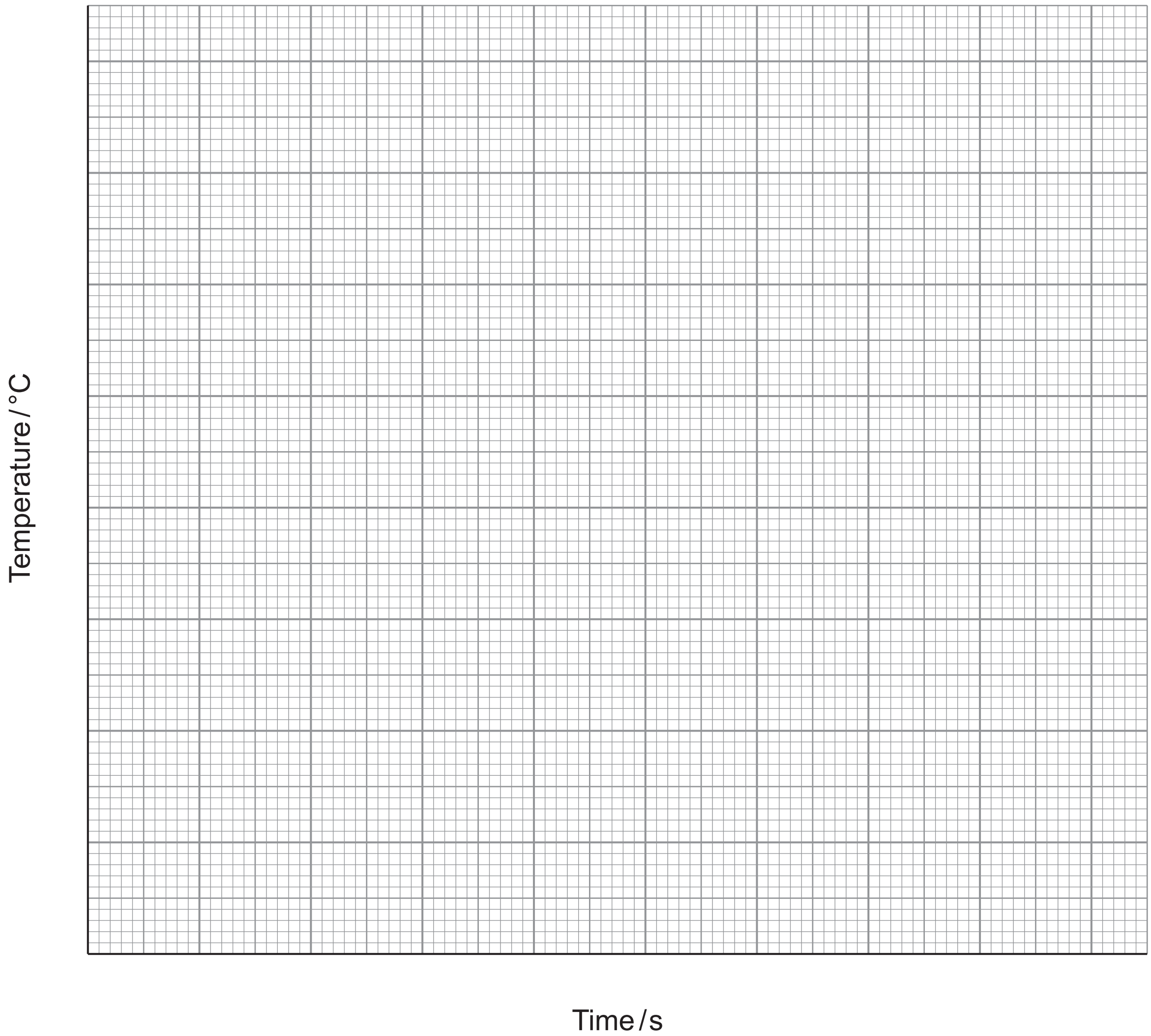
(i) Plot the results on the graph paper below. [2]



(ii) Use your graph to calculate the maximum temperature change for this crystallisation. [2]

maximum temperature change = ... °C

Examiner only

(iii) Use the **total mass** of the sodium ethanoate solution and the temperature change from the graph to calculate the enthalpy change of crystallisation per mole of sodium ethanoate. Assume the density of water is 1.00 $g\,cm^{-3}$ and the specific heat capacity of sodium ethanoate solution is 4.18 $J\,K^{-1}\,g^{-1}$.

$M_r(CH_3COONa.3H_2O) = 136$ [4]

enthalpy change = ... $kJ\,mol^{-1}$

(iv) Suggest a reason why the experimental enthalpy change is often lower than the theoretical enthalpy change. [1]

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(b) Sodium ethanoate can be made in a neutralisation reaction. Complete the following equation: [2]

.... + ... $\longrightarrow$ CH_3COONa + CO_2 + H_2O

(c) The carboxylic acid used to produce sodium ethanoate can be produced using an oxidation reaction.

(i) Name the reagents and give the expected observations. [2]

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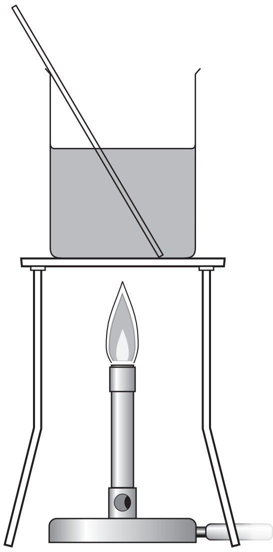
(ii) A student proposed that the apparatus below should be used to perform this oxidation reduction experiment.



The teacher said that this would not work and would be unsafe. Draw a labelled diagram of the apparatus that should be used in this experiment. [3]

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END OF PAPER

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

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

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FRIDAY, 27 MAY 2022 – AFTERNOON

CHEMISTRY – AS unit 2
Data Booklet

Avogadro constant	N_A	$= 6.02 \times 10^{23}\ \text{mol}^{-1}$
molar gas constant	R	$= 8.31\ \text{J mol}^{-1}\ \text{K}^{-1}$
molar gas volume at 273 K and 1 atm	V_m	$= 22.4\ \text{dm}^3\ \text{mol}^{-1}$
molar gas volume at 298 K and 1 atm	V_m	$= 24.5\ \text{dm}^3\ \text{mol}^{-1}$
Planck constant	h	$= 6.63 \times 10^{-34}\ \text{J s}$
speed of light	c	$= 3.00 \times 10^{8}\ \text{m s}^{-1}$
density of water	d	$= 1.00\ \text{g cm}^{-3}$
specific heat capacity of water	c	$= 4.18\ \text{J g}^{-1}\ \text{K}^{-1}$
ionic product of water at 298 K	K_w	$= 1.00 \times 10^{-14}\ \text{mol}^2\ \text{dm}^{-6}$
fundamental electronic charge	e	$= 1.60 \times 10^{-19}\ \text{C}$

temperature (K) = temperature (°C) + 273

$1\ \text{dm}^3 = 1000\ \text{cm}^3$
$1\ \text{m}^3 = 1000\ \text{dm}^3$
1 tonne = 1000 kg
$1\ \text{atm} = 1.01 \times 10^5\ \text{Pa}$

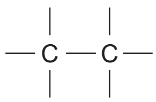
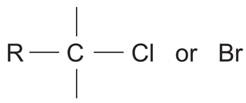
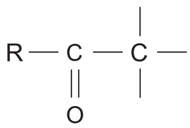
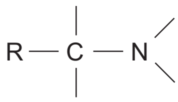
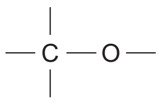
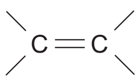
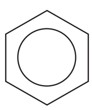
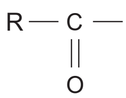
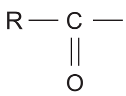
Multiple	Prefix	Symbol
10^{-9}	nano	n
10^{-6}	micro	μ
10^{-3}	milli	m

Multiple	Prefix	Symbol
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G

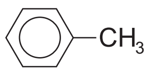
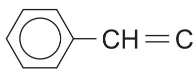
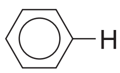
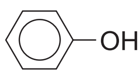
Infrared absorption values

Bond	Wavenumber / cm^{-1}
C—Br	500 to 600
C—Cl	650 to 800
C—O	1000 to 1300
C=C	1620 to 1670
C=O	1650 to 1750
C≡N	2100 to 2250
C—H	2800 to 3100
O—H (carboxylic acid)	2500 to 3200 (very broad)
O—H (alcohol / phenol)	3200 to 3550 (broad)
N—H	3300 to 3500

^{13}C NMR chemical shifts relative to TMS = 0

Type of carbon	Chemical shift, δ (ppm)
	5 to 40
	10 to 70
	20 to 50
	25 to 60
	50 to 90
	90 to 150
	110 to 125
	110 to 160
 (carboxylic acid / ester)	160 to 185
 (aldehyde / ketone)	190 to 220

^{1}H NMR chemical shifts relative to TMS = 0

Type of proton	Chemical shift, δ (ppm)
$-CH_3$	0.1 to 2.0
$R-CH_3$	0.9
$R-CH_2-R$	1.3
$CH_3-C\equiv N$	2.0
$CH_3-C(=O)-$	2.0 to 2.5
$-CH_2-C(=O)-$	2.0 to 3.0
	2.2 to 2.3
$HC-Cl$ or $HC-Br$	3.1 to 4.3
$HC-O$	3.3 to 4.3
$R-OH$	4.5 *
$-C=CH$	4.5 to 6.3
$-C=CH-CO$	5.8 to 6.5
	6.5 to 7.5
	6.5 to 8.0
	7.0 *
$R-C(=O)H$	9.8 *
$R-C(=O)OH$	11.0 *

*variable figure dependent on concentration and solvent

THE PERIODIC TABLE

Key

A_r — relative atomic mass
Symbol
Name
Z — atomic number

Group: 1, 2 (s block); d block; 3, 4, 5, 6, 7, 0 (p block); f block

Period	1	2											3	4	5	6	7	0
1	1.01 H Hydrogen 1																	4.00 He Helium 2
2	6.94 Li Lithium 3	9.01 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
3	23.0 Na Sodium 11	24.3 Mg Magnesium 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	40.0 Ar Argon 18
4	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
5	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	98.9 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
6	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
7	(223) Fr Francium 87	(226) Ra Radium 88	(227) Ac ▸▸ Actinium 89															

f block

▸ Lanthanoid elements	140 Ce Cerium 58	141 Pr Praseodymium 59	144 Nd Neodymium 60	(147) Pm Promethium 61	150 Sm Samarium 62	(153) 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
▸▸ Actinoid elements	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