Please check the examination details below before entering your candidate information

Candidate surname	Other names

Centre Number | Candidate Number

Pearson Edexcel International Advanced Level

Friday 13 October 2023

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:
Data Booklet, scientific calculator, 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 5 0 6 9 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 about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

1 The mean C–F bond enthalpy is +485 kJ mol^{-1}.

Which process has an enthalpy change of +1940 kJ mol^{-1}?

☒ **A** $C(g) + 4F(g) \rightarrow CF_4(g)$

☒ **B** $C(s) + 2F_2(g) \rightarrow CF_4(g)$

☒ **C** $CF_4(g) \rightarrow C(g) + 4F(g)$

☒ **D** $CF_4(g) \rightarrow C(s) + 2F_2(g)$

(Total for Question 1 = 1 mark)

2 Which expression gives the standard enthalpy change, in kJ mol^{-1}, for the reaction shown?

$$BaCO_3(s) \rightarrow BaO(s) + CO_2(g)$$

$\Delta_f H^{\ominus}$ values: $BaCO_3(s) = -1216\ kJ\ mol^{-1}$

$BaO(s) = -554\ kJ\ mol^{-1}$

$CO_2(g) = -394\ kJ\ mol^{-1}$

☒ **A** –554 – 394 + 1216

☒ **B** –554 – 394 – 1216

☒ **C** 554 + 394 + 1216

☒ **D** 554 + 394 – 1216

(Total for Question 2 = 1 mark)

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

3 The standard enthalpy changes of combustion for a series of alkanes are shown.

Alkane formula	$\Delta_c H^{\ominus}$ / kJ mol^{-1}
$C_2H_6(g)$	–1560
$C_3H_8(g)$	–2219
$C_4H_{10}(l)$	–2877
$C_5H_{12}(l)$	–3509

Another alkane has an enthalpy change of combustion of –6125 kJ mol^{-1}.

Which is the most likely formula for this alkane?

☒ **A** C_6H_{14}

☒ **B** C_7H_{16}

☒ **C** C_8H_{18}

☒ **D** C_9H_{20}

(Total for Question 3 = 1 mark)

4 Which row in the table shows the forces between the molecules in the liquid state?

	Molecule	London forces	Permanent dipole-dipole interaction	Hydrogen bonding
☒ **A**	BF_3	✗	✓	✗
☒ **B**	CH_4	✓	✗	✓
☒ **C**	NH_3	✓	✗	✗
☒ **D**	H_2S	✓	✓	✗

(Total for Question 4 = 1 mark)

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

5 Which of these isoelectronic compounds would be expected to have the **highest** boiling temperature?

☒ **A** butan-1-ol

☒ **B** 2-methylpropan-1-ol

☒ **C** 2-methylpropan-2-ol

☒ **D** pentane

(Total for Question 5 = 1 mark)

6 What is the value of n in the half-equation shown?

$$O_2(g) + 2H_2O(l) + ne^- \rightarrow nOH^-(aq)$$

☒ **A** 2

☒ **B** 3

☒ **C** 4

☒ **D** 5

(Total for Question 6 = 1 mark)

7 Which equation shows a disproportionation reaction?

☒ **A** $Cu + 4HNO_3 \rightarrow Cu(NO_3)_2 + 2H_2O + 2NO_2$

☒ **B** $I_2 + 5O_3 + H_2O \rightarrow 2HIO_3 + 5O_2$

☒ **C** $2MnO_4^- + MnO_2 + 4OH^- \rightarrow 3MnO_4^{2-} + 2H_2O$

☒ **D** $S_2O_3^{2-} + 2H^+ \rightarrow SO_2 + S + H_2O$

(Total for Question 7 = 1 mark)

8 When sodium bromide reacts with concentrated sulfuric acid, sodium hydrogensulfate is always formed.

What other product(s) are formed in this reaction?

☒ **A** hydrogen bromide only

☒ **B** bromine and hydrogen bromide only

☒ **C** bromine, hydrogen bromide and sulfur dioxide only

☒ **D** bromine, hydrogen bromide, sulfur dioxide and sulfur only

(Total for Question 8 = 1 mark)

9 Which property **decreases** as Group 2 is descended?

- ☒ **A** atomic radius
- ☒ **B** reactivity of the elements
- ☒ **C** solubility of the sulfates
- ☒ **D** thermal stability of the nitrates

(Total for Question 9 = 1 mark)

10 In a neutralisation reaction, 20.0 cm^3 of 0.500 mol dm^{-3} nitric acid reacts with 10.0 cm^3 of 1.00 mol dm^{-3} aqueous sodium hydroxide.

$$HNO_3(aq) + NaOH(aq) \rightarrow NaNO_3(aq) + H_2O(l)$$

What is the concentration, in mol dm^{-3}, of the sodium nitrate solution produced?

- ☒ **A** 0.33
- ☒ **B** 0.50
- ☒ **C** 0.67
- ☒ **D** 1.0

(Total for Question 10 = 1 mark)

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

11 The equation for the reaction of sulfur dioxide with oxygen is shown.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta_r H = -192\,kJ\,mol^{-1}$$

(a) What is the effect of a **decrease** in temperature?

(1)

☒ **A** rate increases and yield decreases

☒ **B** rate increases and yield increases

☒ **C** rate decreases and yield decreases

☒ **D** rate decreases and yield increases

(b) What is the effect of an **increase** in pressure?

(1)

☒ **A** rate increases and yield decreases

☒ **B** rate increases and yield increases

☒ **C** rate decreases and yield decreases

☒ **D** rate decreases and yield increases

(Total for Question 11 = 2 marks)

12 A mixture of 1.0 cm^3 of 0.20 mol dm^{-3} potassium chromate(VI) and 5.0 cm^3 of 1.0 mol dm^{-3} sulfuric acid forms the equilibrium shown.

$$\underset{\text{yellow}}{2CrO_4^{2-}(aq)} + 2H^+(aq) \rightleftharpoons \underset{\text{orange}}{Cr_2O_7^{2-}(aq)} + H_2O(l)$$

What would be the effect, if any, on the colour of the solution if 5.0 cm^3 of 1.0 mol dm^{-3} sodium hydroxide were added?

☒ **A** no visible change

☒ **B** the mixture becomes colourless

☒ **C** the mixture becomes more yellow

☒ **D** the mixture becomes more orange

(Total for Question 12 = 1 mark)

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

13 Tertiary alcohols are used in the manufacture of petrol additives.

(a) Which of these is a tertiary alcohol?

(1)

☒ **A** 1-methylcyclopentanol

☒ **B** 2-methylcyclopentanol

☒ **C** 2-methylbutan-1-ol

☒ **D** 3-methylpentan-2-ol

(b) Which reagent reacts with tertiary alcohols?

(1)

☒ **A** acidified aqueous potassium dichromate(VI)

☒ **B** bromine water

☒ **C** phosphorus(V) chloride

☒ **D** sodium carbonate solution

(Total for Question 13 = 2 marks)

14 Infrared spectra may be used to identify organic compounds.

(a) When propan-2-ol is refluxed with excess acidified potassium dichromate(VI), the **product** will show a peak due to

(1)

☒ **A** O—H stretching at 3750 – 3200 cm^{-1}

☒ **B** C═O stretching at 1740 – 1720 cm^{-1}

☒ **C** C═O stretching at 1725 – 1700 cm^{-1}

☒ **D** C═O stretching at 1720 – 1700 cm^{-1}

(b) When propan-1-ol is heated with acidified potassium dichromate(VI), the **product** that is distilled off as it is formed will show a peak due to

(1)

☒ **A** O—H stretching at 3750 – 3200 cm^{-1}

☒ **B** C═O stretching at 1740 – 1720 cm^{-1}

☒ **C** C═O stretching at 1725 – 1700 cm^{-1}

☒ **D** C═O stretching at 1720 – 1700 cm^{-1}

(Total for Question 14 = 2 marks)

15 Separate solutions of 1-chloropropane and 1-bromopropane in ethanol are warmed with aqueous silver nitrate.

Why does the formation of a precipitate take longer with 1-chloropropane?

- ☒ **A** 1-chloropropane is less soluble than 1-bromopropane
- ☒ **B** the C—CI bond is stronger than the C—Br bond
- ☒ **C** the C—CI bond is more polar than the C—Br bond
- ☒ **D** silver chloride is more soluble than silver bromide

(Total for Question 15 = 1 mark)

16 A sample of propane-1,2-diol with a mass of 1.52 g reacts completely with excess phosphorus(V) chloride.

What is the maximum mass, in grams, of the organic product?

[A_r values: H = 1.0 C = 12.0 O = 16.0 CI = 35.5]

- ☒ **A** 1.13
- ☒ **B** 1.89
- ☒ **C** 2.26
- ☒ **D** 4.52

(Total for Question 16 = 1 mark)

17 Which compound reacts with ammonia to form $CH_3CH(NH_2)CH_3$?

- ☒ **A** 1-chloropropane
- ☒ **B** 2-chloropropane
- ☒ **C** propane
- ☒ **D** propene

(Total for Question 17 = 1 mark)

TOTAL FOR SECTION A = 20 MARKS

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SECTION B

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

18 This question is about sodium hydroxide.

(a) (i) Write an **ionic** equation for the neutralisation reaction between aqueous sodium hydroxide and hydrochloric acid.
State symbols are not required.

(1)

(ii) State what is meant by standard enthalpy change of neutralisation, $\Delta_{neut}H^{\ominus}$.

(2)

.....

.....

.....

.....

(b) A student carried out an investigation to determine the enthalpy change of neutralisation of aqueous sodium hydroxide by hydrochloric acid.

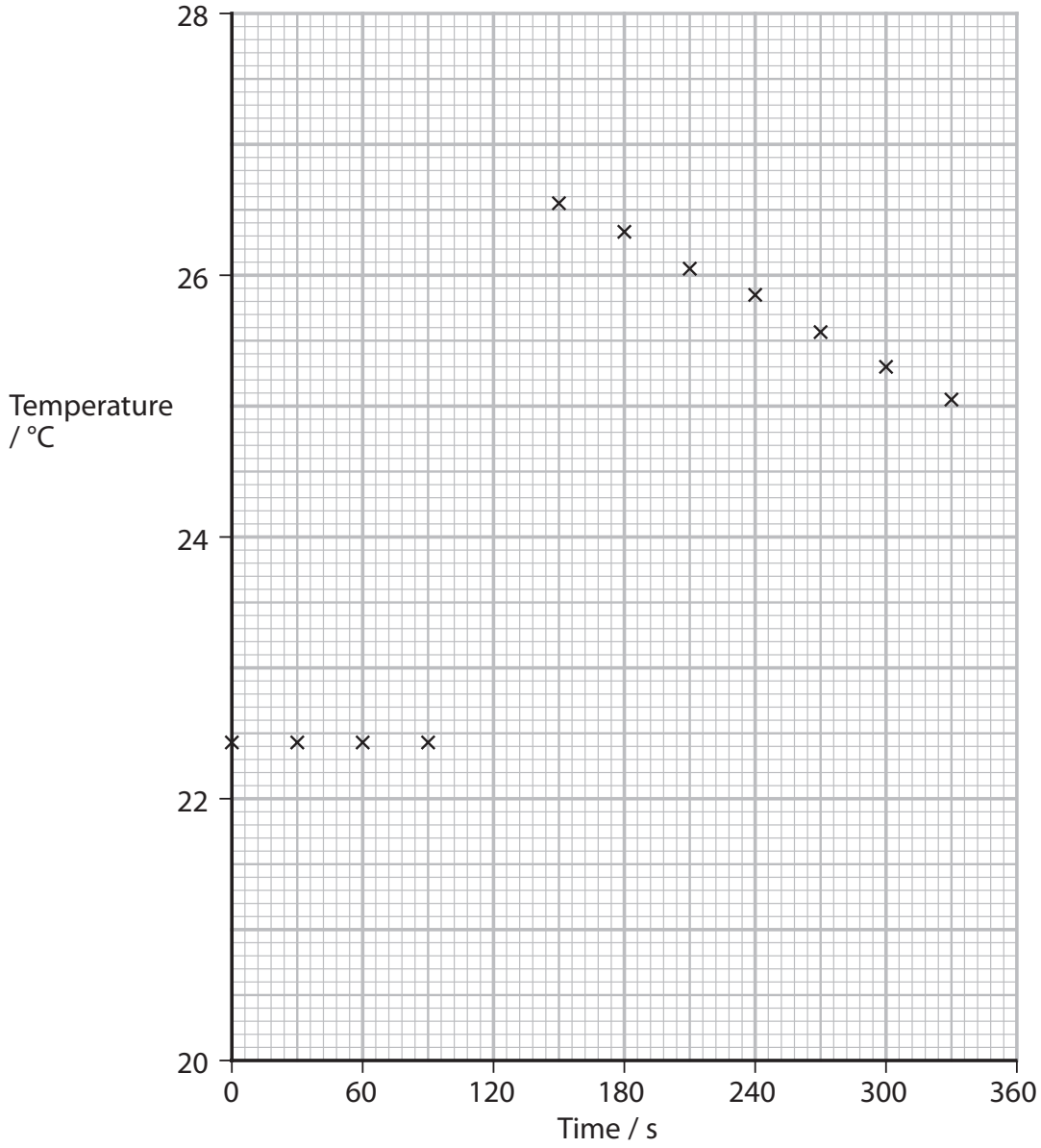
Method

- separate 25.0 cm^3 samples of 0.80 mol dm^{-3} sodium hydroxide and 0.80 mol dm^{-3} hydrochloric acid were left to reach room temperature
- after two minutes, the solutions were mixed in a copper calorimeter and the temperature was noted at 30 s intervals.

(i) Use the graph shown to determine the maximum temperature change, ΔT, in this experiment. You **must** show your working on the graph.

(2)

ΔT .....



(ii) Calculate the enthalpy change of neutralisation using your answers to (a) and (b)(i). Give a sign and units with your answer.
Assume: no energy is used to heat the container.
the specific heat capacity of the solution = 4.2 J °C^{-1} g^{-1}.
the densities of the solutions of NaOH and HCl are 1.0 g cm^{-3}.

(3)

(iii) Explain how, if at all, the enthalpy change of neutralisation obtained in (b)(ii) would differ if the heat capacity of the calorimeter was included in the calculation.

(2)

(c) Aqueous sodium hydroxide reacts with 1-bromopropane to produce propan-1-ol.

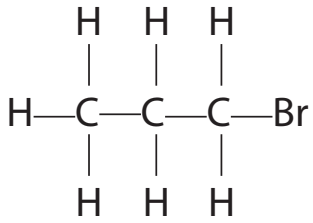
(i) State the type and mechanism of this reaction.

(1)

(ii) Complete the mechanism for this reaction.

Include curly arrows, and relevant lone pairs and dipoles.

(3)



(iii) Under different conditions, sodium hydroxide reacts with 1-bromopropane to form propene.
Name the type of reaction and a suitable solvent.

(2)

Type of reaction

.....

Suitable solvent

.....

(Total for Question 18 = 16 marks)

19 This question is about some of the elements in Group 7 of the Periodic Table.

(a) Mixtures of halide salts are found in brine solutions extracted from oil and gas wells.
Iodine, which is used as a dietary supplement, may be obtained from these mixtures.

A brine solution containing 2.49 g of a mixture of potassium iodide and potassium chloride was analysed.

Procedure

Step **1** Excess aqueous silver nitrate solution was added to the solution to completely precipitate the halide ions.

Step **2** Excess aqueous ammonia was added to the mixture.

Step **3** The mixture was filtered, and the solid was washed, dried and weighed.

The mass of the dried solid was 0.162 g.

(i) State the colour of the solid in Step **3**.

(1)

.....

(ii) Calculate the percentage by mass of potassium iodide in the mixture.
Give your answer to an appropriate number of significant figures.

[A_r values: Ag = 107.9 K = 39.1 I = 126.9]

(3)

(b) Chlorine gas may be prepared by heating concentrated hydrochloric acid with solid manganese(IV) oxide.

$$MnO_2(s) + 4HCl(aq) \rightarrow MnCl_2(aq) + Cl_2(g) + 2H_2O(l)$$

Show, by reference to oxidation numbers, that this is a redox reaction.

(2)

(c) Iodine may be obtained by bubbling chlorine gas through aqueous potassium iodide.

When the reaction is complete, hexane is added and the mixture shaken. Two layers are formed.

State the colour of each layer.

(2)

Aqueous layer

Hexane layer

*(d) Explain why iodine is more soluble in hexane than in water, by considering the intermolecular forces in iodine, hexane and water and any intermolecular forces formed between iodine and the solvents.

Detailed descriptions of how the intermolecular forces form are **not** required.

(6)

(Total for Question 19 = 14 marks)

20 This question is about carbon dioxide.

(a) (i) Carbonate ions may be identified by their reaction with aqueous acid to produce carbon dioxide.
Give the **ionic** equation for this reaction. Include state symbols.

(2)

(ii) Limewater (an aqueous solution of calcium hydroxide) can be used to test for the presence of gaseous carbon dioxide.

State what would be **seen** when carbon dioxide is bubbled through limewater.

(1)

.....

.....

(b) A student determined the solubility of calcium hydroxide in water by titration with hydrochloric acid. The equation for the reaction is shown.

$$Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O$$

Procedure

- calcium hydroxide powder was added to distilled water and the mixture was stirred until no more solid dissolved.
The excess solid was filtered off to leave a saturated solution.
- 25.0 cm^3 portions of this solution were titrated with 0.0500 mol dm^{-3} hydrochloric acid with phenolphthalein as an indicator until two concordant titres were obtained.

The mean titre was 18.95 cm^3.

(i) Calculate the concentration of the saturated solution, in g dm^{-3}.

(4)

(ii) The student used the same procedure to determine the solubility of strontium hydroxide.

Explain whether or not the mean titre value for strontium hydroxide would be different from that for calcium hydroxide.

(2)

(c) Between 1960 and 2020 the amount of carbon dioxide in the atmosphere rose from 320 parts per million (ppm) to 420 ppm.

The recent rapid increase in the atmospheric carbon dioxide is affecting the chemistry of seawater.

Carbon dioxide dissolves in water to form carbonic acid, $H_2CO_3(aq)$.

The carbonic acid dissociates in water according to the equilibrium shown.

$$H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$

Explain, in terms of the equilibrium, the effect of the increase in atmospheric carbon dioxide on the acidity of seawater.

(3)

(Total for Question 20 = 12 marks)

TOTAL FOR SECTION B = 42 MARKS

SECTION C

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

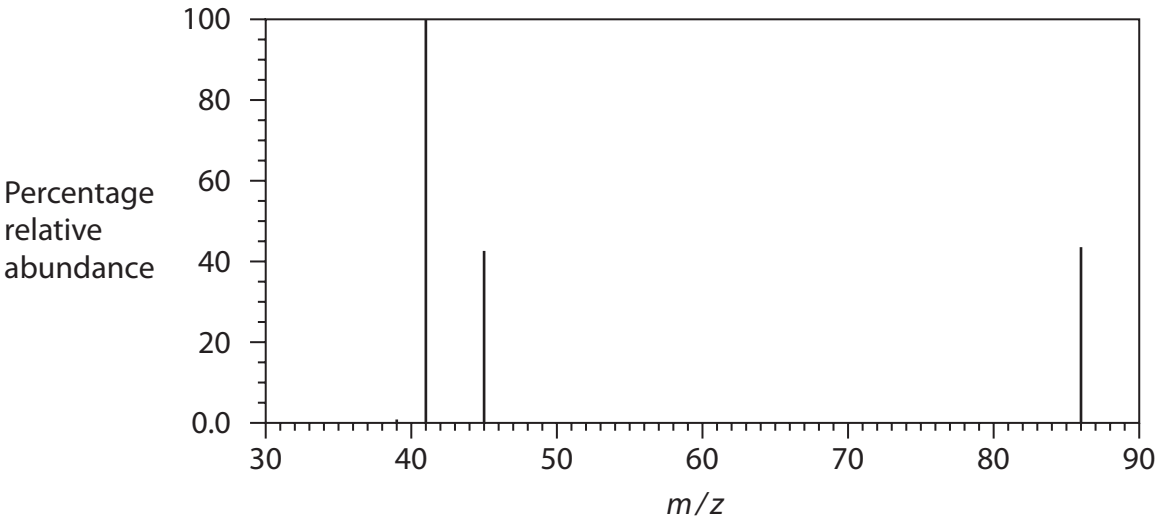
21 This question is about some organic molecules which are important in the production of adhesives and coatings.

(a) Compound **X** is a liquid containing carbon, hydrogen and oxygen only.
A sample of **X**, with a mass of 1.92 g, contains 1.08 g carbon and 0.131 g hydrogen.

(i) Use these data to calculate the empirical formula of **X**.

(3)

(ii) The mass spectrum of **X** is shown.



Deduce the molecular formula of **X**, using the mass spectrum and your answer to (a)(i).

(2)

.....

.....

(iii) Reagents were added to separate samples of **X** to identify the functional groups in the molecule.

Complete Table 1.

(2)

Table 1

Reagent	Observation	Functional group
bromine water	bromine water decolourised	
aqueous sodium carbonate	effervescence	

(iv) Using your answer to (a)(iii) and the mass spectrum, complete Table 2.

(2)

Table 2

Peak in mass spectrum	Formula of ion
$m/z = 41$	
$m/z = 45$	

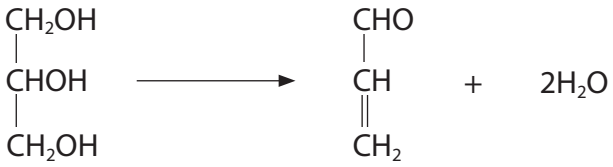
(v) **X** does **not** show geometric isomerism.

Draw a possible **displayed** formula of **X**.

(1)

(b) Propenoic acid can be produced industrially from propane-1,2,3-triol, a by-product of the manufacture of biodiesel.

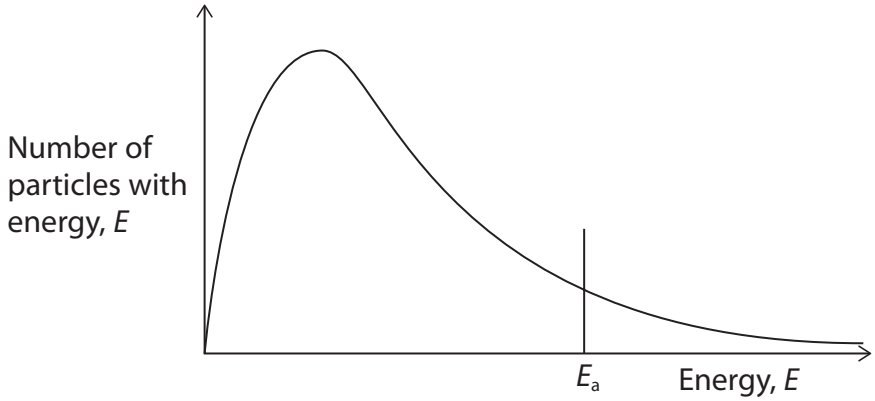
The first step is a dehydration reaction to convert gaseous propane-1,2,3-triol to propenal. This reaction requires a solid catalyst.



(i) Explain how a catalyst increases the rate of this reaction.

Use the Maxwell–Boltzmann distribution shown and refer to the collision theory.

(3)



(ii) The propenal is then oxidised to propenoic acid.
Write an equation for this reaction using [O] to represent the oxygen from the oxidising agent.

(1)

(c) One synthetic route for the production of propenoic acid uses propene, derived from crude oil, as a starting material.

propene → propane-1,2-diol → prop-2-en-1-ol → propenoic acid

(i) Suggest suitable reagents and conditions for the conversion of propene to propane-1,2-diol.

(2)

.....

.....

.....

(ii) Suggest why the production of propenoic acid from propane-1,2,3-triol is more sustainable than its production from propene.

(2)

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(Total for Question 21 = 18 marks)

TOTAL FOR SECTION C = 18 MARKS
TOTAL FOR PAPER = 80 MARKS

The Periodic Table of Elements

1	2											3	4	5	6	7	0 (8) (18)
							1.0 H hydrogen 1										4.0 He helium 2
(1)	(2)											(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							

Key: relative atomic mass / **atomic symbol** / name / atomic (proton) number

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

* Lanthanide 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
* Actinide series	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