

Please check the examination details below before entering your candidate information

Candidate surname					Other names						
Centre Number					Candidate Number						
Pearson Edexcel International Advanced Level Monday 13 May 2024 Morning (Time: 1 hour 30 minutes) <table border="1"> <tr> <td>Paper reference</td> <td>WCH12/01</td> </tr> </table>										Paper reference	WCH12/01
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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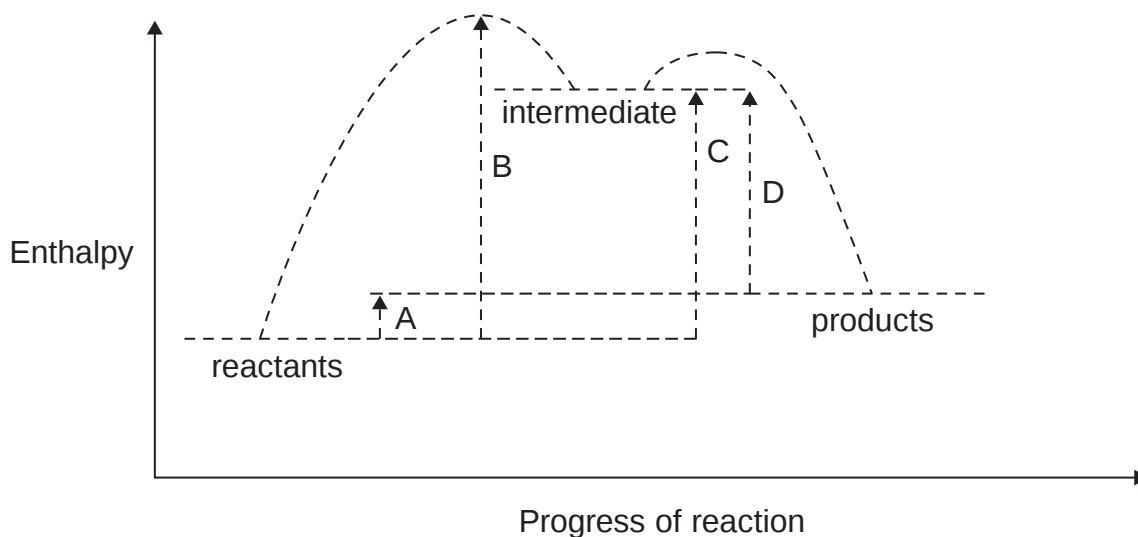
SECTION A

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 An enthalpy level diagram for a reaction with an intermediate is shown.



Which arrow shows the enthalpy change for this reaction?

- ☐ A arrow A
☐ B arrow B
☐ C arrow C
☐ D arrow D

(Total for Question 1 = 1 mark)

- 2 Sodium chloride dissolves in water to form a solution because of the interactions between the sodium chloride and water. What are these interactions?

- ☐ A dipole-dipole
☐ B hydrogen bonds
☐ C ion-dipole
☐ D London forces

(Total for Question 2 = 1 mark)



- 3 Which equation represents the reaction for which the enthalpy change, $\Delta_r H$, is the mean bond enthalpy of the C—Cl bond in CCl_4 ?

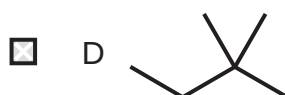
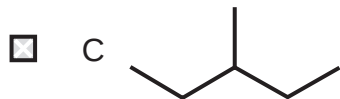
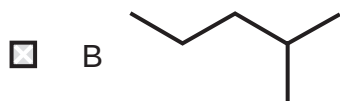
- ☐ A $\text{CCl}_4(\text{g}) \rightarrow \text{C}(\text{g}) + 4\text{Cl}(\text{g})$
☐ B $\frac{1}{4}\text{CCl}_4(\text{g}) \rightarrow \frac{1}{4}\text{C}(\text{g}) + \text{Cl}(\text{g})$
☐ C $\text{C}(\text{g}) + 4\text{Cl}(\text{g}) \rightarrow \text{CCl}_4(\text{g})$
☐ D $\frac{1}{4}\text{C}(\text{g}) + \text{Cl}(\text{g}) \rightarrow \frac{1}{4}\text{CCl}_4(\text{g})$

(Total for Question 3 = 1 mark)

- 4 This question is about boiling temperatures.

- (a) Which isomer has the **highest** boiling temperature?

(1)



- (b) Which compound has the **highest** boiling temperature?

(1)

- ☐ A pentane
☐ B cyclopentane
☐ C butan-1-ol
☐ D butane-1,4-diol

(Total for Question 4 = 2 marks)



P 7 5 7 7 9 R A 0 3 2 8

5 Steam is passed over heated magnesium.

Which reaction occurs most readily?

- ☐ A $\text{Mg} + \text{H}_2\text{O} \rightarrow \text{MgO} + \text{H}_2$
- ☐ B $\text{Mg} + 2\text{H}_2\text{O} \rightarrow \text{Mg}(\text{OH})_2 + \text{H}_2$
- ☐ C $2\text{Mg} + \text{H}_2\text{O} \rightarrow \text{Mg}_2\text{O} + \text{H}_2$
- ☐ D $2\text{Mg} + 2\text{H}_2\text{O} \rightarrow 2\text{MgOH} + \text{H}_2$

(Total for Question 5 = 1 mark)

6 What are the products formed when lithium nitrate and calcium nitrate are heated separately?

	Lithium nitrate	Calcium nitrate
☐ A	lithium nitrite and oxygen	calcium nitrite and oxygen
☐ B	lithium nitrite and oxygen	calcium oxide, nitrogen dioxide and oxygen
☐ C	lithium oxide, nitrogen dioxide and oxygen	calcium nitrite and oxygen
☐ D	lithium oxide, nitrogen dioxide and oxygen	calcium oxide, nitrogen dioxide and oxygen

(Total for Question 6 = 1 mark)

7 Group 2 compounds give different colours in a flame test.

The **best** explanation is that the cations have different

- ☐ A gaps between electronic energy levels
- ☐ B ionic radii
- ☐ C ionisation energies
- ☐ D numbers of electrons

(Total for Question 7 = 1 mark)

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



- 8 Two tests were performed on an unknown ionic compound.

Silver nitrate solution was added to an aqueous solution of the compound, forming a white precipitate.

A flame test carried out on the ionic compound gave a red flame.

The unknown compound could have been

- ☒ A calcium iodide
- ☐ B lithium bromide
- ☐ C potassium carbonate
- ☐ D strontium chloride

(Total for Question 8 = 1 mark)

- 9 Which compound needs exactly nine moles of oxygen (O_2) for complete combustion of one mole of the compound?

- ☐ A C_5H_{12}
- ☐ B $C_6H_{12}O$
- ☐ C C_6H_{14}
- ☐ D $C_6H_{14}O$

(Total for Question 9 = 1 mark)

- 10 Which solution remains clear on addition to barium chloride solution?

- ☐ A dilute sulfuric acid
- ☐ B silver nitrate solution
- ☐ C sodium nitrate solution
- ☐ D sodium sulfate solution

(Total for Question 10 = 1 mark)

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



11 In a titration, a conical flask containing 10.00 cm^3 of 1.00 mol dm^{-3} sulfuric acid is fully neutralised by 25.00 cm^3 of 0.80 mol dm^{-3} potassium hydroxide.

- (a) The titration is carried out using methyl orange as an indicator.
What would be the colour change at the end-point of the titration?

(1)

- ☒ **A** orange to red
☐ **B** red to orange
☐ **C** orange to yellow
☐ **D** yellow to orange

- (b) What is the concentration, in mol dm^{-3} , of the potassium sulfate solution produced by this reaction at the end-point, to 2 significant figures?

(1)

- ☐ **A** 0.010
☐ **B** 0.020
☐ **C** 0.29
☐ **D** 0.57

- (c) Information about the uncertainties in each reading used to measure the volumes of the solutions in this titration is shown.

Solution	Equipment used	Uncertainty / cm^3
sulfuric acid	pipette	± 0.04
potassium hydroxide	burette	± 0.05

(1)

Which statement is true?

- ☐ **A** the percentage uncertainty of the volume of sulfuric acid is more than the percentage uncertainty of the volume of potassium hydroxide
☐ **B** the percentage uncertainty of the volume of sulfuric acid is 0.8%
☐ **C** the total percentage uncertainty is 0.8%
☐ **D** the percentage uncertainty of the volume of potassium hydroxide solution is 0.2%

(Total for Question 11 = 3 marks)



12 The boiling temperatures of the halogens increase down Group 7 because on descending the group the

- ☒ A bond polarities increase
- ☐ B covalent bond strengths increase
- ☐ C electronegativities increase
- ☐ D number of electrons in the molecule increase

(Total for Question 12 = 1 mark)

13 Bromine and chlorine each have two stable isotopes, ^{79}Br , ^{81}Br , ^{35}Cl and ^{37}Cl . Which statement is true?

- ☐ A the atomic radius of ^{81}Br is greater than that of ^{79}Br
- ☐ B the electronegativity of ^{35}Cl is greater than that of ^{37}Cl
- ☐ C the first ionisation energy of ^{37}Cl is greater than that of ^{79}Br
- ☐ D the mass spectrum of CH_2BrCl has two molecular ion peaks

(Total for Question 13 = 1 mark)

14 Cyclohexane (density = 0.78 g cm^{-3}) and aqueous iodine (density $> 1.0\text{ g cm}^{-3}$) are shaken and left to stand. What colours are the two layers that form?

	lower layer	upper layer
☐ A	brown	yellow
☐ B	yellow	purple
☐ C	yellow	brown
☐ D	purple	brown

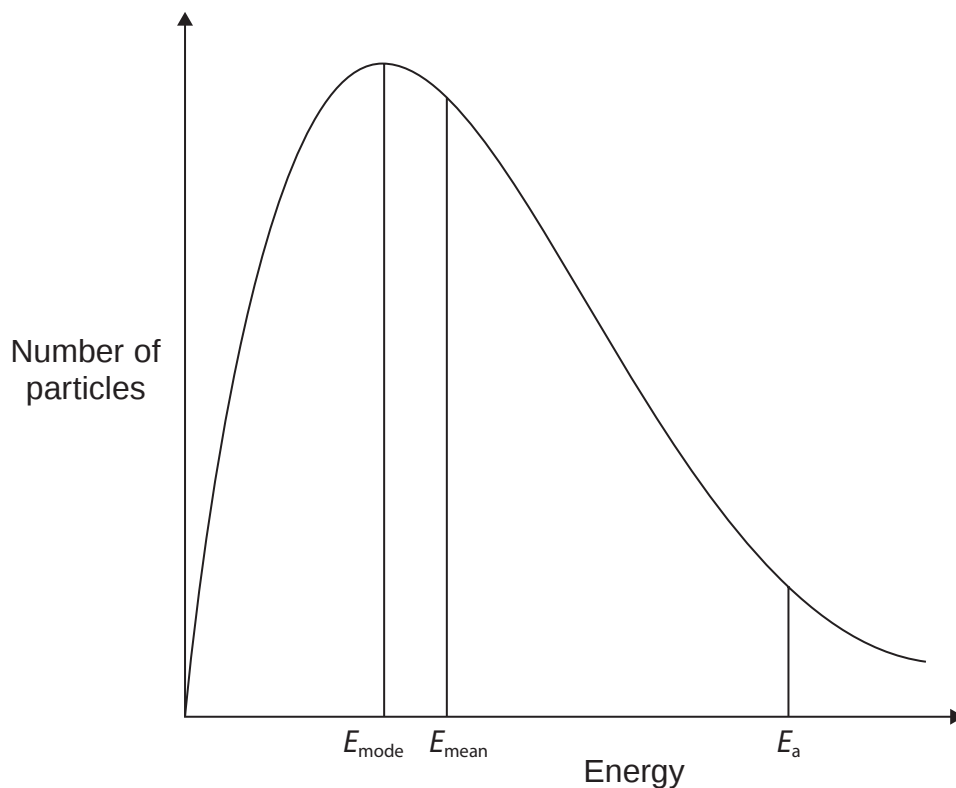
(Total for Question 14 = 1 mark)

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15 Four containers of the same dimensions hold samples of a gas.

For Container 1, the diagram of the Maxwell-Boltzmann distribution of molecular energy for this gas shows the activation energy, E_a , the mean molecular energy, E_{mean} , and the most probable molecular energy, E_{mode} .



- (a) For Container 2, the temperature is increased.
For which values would the **energy value** change?

(1)

- ☐ A E_a only
- ☐ B E_{mode} only
- ☐ C E_{mode} and E_{mean} only
- ☐ D E_a , E_{mode} and E_{mean}



- (b) For Container 3, at the same temperature as Container 1, the pressure is lower.
For which values would the **number of particles** at that value change?

(1)

- ☒ A E_a only
☐ B E_{mode} only
☐ C E_{mode} and E_{mean} only
☐ D E_a , E_{mode} and E_{mean}

- (c) For Container 4, at the same temperature and pressure as Container 1, the walls of the container act as a catalyst for the reaction of the gas.
For which values would the **energy value** change?

(1)

- ☐ A E_a only
☐ B E_{mode} only
☐ C E_{mode} and E_{mean} only
☐ D E_a , E_{mode} and E_{mean}

(Total for Question 15 = 3 marks)

TOTAL FOR SECTION A = 20 MARKS



SECTION B

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

16 This question is about the reactions of halogenoalkanes.

- (a) When halogenoalkanes are heated with potassium hydroxide, the products depend on the conditions.
- (i) State what condition, other than a suitable temperature and concentration of potassium hydroxide, would give a high yield of but-1-ene and but-2-ene from 2-chlorobutane.

(1)

- (ii) Give the type of reaction occurring in (a)(i).

(1)

- (b) (i) State what condition, other than a suitable temperature and concentration of potassium hydroxide, would give a high yield of butan-1-ol from 1-chlorobutane.

(1)

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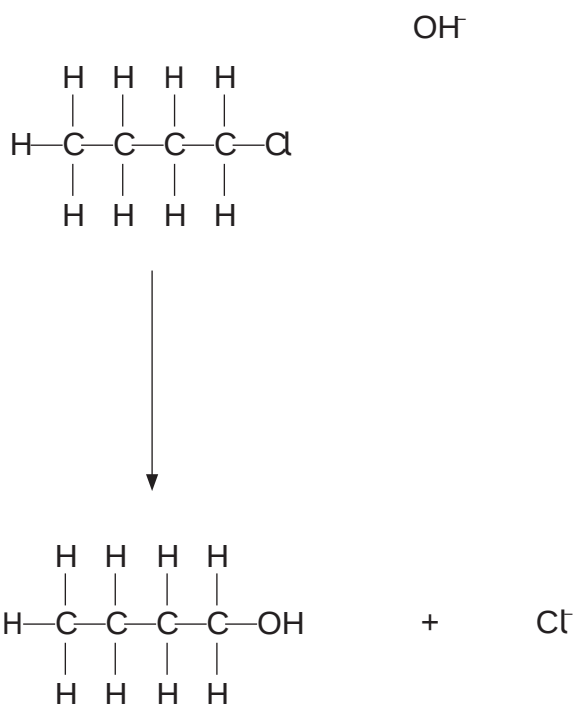
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- (ii) Complete the mechanism for the reaction of potassium hydroxide with 1-chlorobutane to form butan-1-ol. Use curly arrows and show relevant dipoles and lone pairs.

(2)



- (iii) Give **two** reasons why, under the conditions used in (b)(ii), the reaction between potassium hydroxide and 2-iodo-2-methylpropane is faster than the reaction between potassium hydroxide and 1-chlorobutane.

(2)

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(Total for Question 16 = 7 marks)

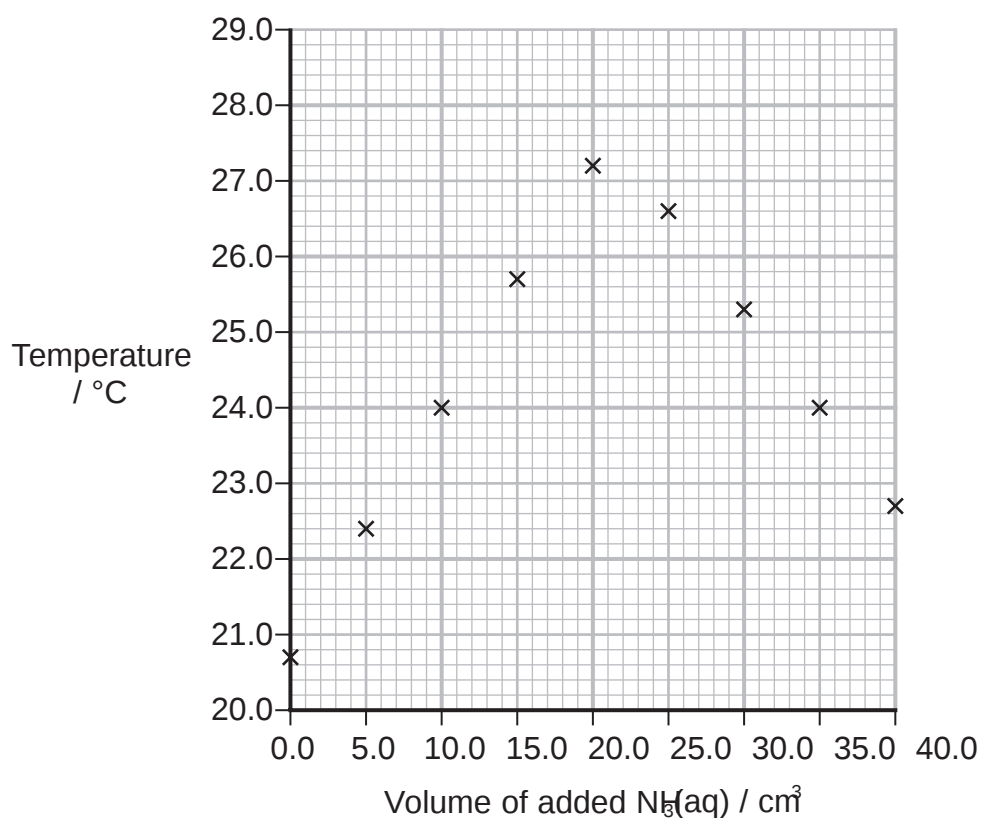


- 17** In a titration between a weak acid and a weak base indicators do not give a distinct colour change, so other techniques must be used.
One technique is thermometric titration.

Procedure

- Step 1** The temperature of 30.0 cm^3 of dilute ethanoic acid in a polystyrene cup is recorded.
- Step 2** Ammonia solution of concentration 1.30 mol dm^{-3} is added to the acid in the polystyrene cup in separate 5.00 cm^3 portions.
After each addition the mixture is stirred and the temperature measured.

A student carried out the experiment and plotted the graph shown.



- (a) Find the end-point volume and the maximum temperature by adding appropriate lines of best fit to the graph.

(3)

End-point volume =

Maximum temperature =

- (b) Calculate the number of moles of ammonia added at the end-point.

(1)

- (c) The reaction that occurs is shown.



Calculate the enthalpy change of neutralisation for this reaction, in kJ mol^{-1} .
Give your answer to an appropriate number of significant figures and include a sign with your answer.

[Assume that the density of all solutions is 1.00 g cm^{-3} and that the specific heat capacity of all solutions is $4.18 \text{ J g}^{-1} \text{ } ^\circ\text{C}^{-1}$]

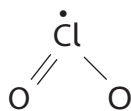
(5)

(Total for Question 17 = 9 marks)



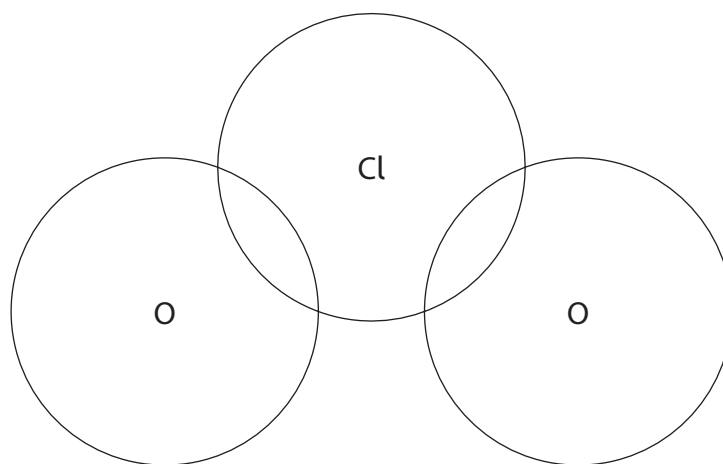
P 7 5 7 7 9 R A 0 1 3 2 8

- 18** Chlorine dioxide, ClO_2 , can be used to treat water to make it safe for drinking. The molecule is a free radical. One suggested structure is shown.



- (a) (i) Complete the dot-and-cross diagram for this structure.
Use dots (•) for oxygen electrons and crosses (×) for chlorine electrons.

(2)



- (ii) Give the reason why chlorine dioxide is not a linear molecule.

(1)

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- (b) Chlorine dioxide can be made from potassium chlorate(V), KClO_3 , in a two-step process.

Step 1 Potassium chlorate(V) reacts with concentrated sulfuric acid to form compound **A**.

Step 2 Compound **A** then undergoes a disproportionation reaction to form chlorine dioxide and hydrogen chlorate(VII), HClO_4 .

- (i) State the meaning of the Roman numerals in chlorate(V) and chlorate(VII).

(1)

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- (ii) State the oxidation number of chlorine in chlorine dioxide.

(1)

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- (iii) In Step 2, compound **A** undergoes disproportionation.
Deduce the possible range of oxidation numbers for the chlorine in compound **A**. Justify your answer.

(2)

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- (iv) Compound **A** has $M_r = 84.5$, and a composition by mass of H = 1.18%, Cl = 42.01 % and the remainder is oxygen.

Deduce the molecular formula of compound **A**, showing **all** your working.

(4)

- (v) Write an equation for each of the two steps in the formation of chlorine dioxide, using your answers in (b).
State symbols are not required.

(2)

(Total for Question 18 = 13 marks)

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- 19** One industrial preparation of ethanol is by the catalysed hydration of ethene via a reversible reaction.



- (a) The hydration of ethene requires a catalyst which is coated onto a solid silicon dioxide support.

Identify, by name or formula, the catalyst used.

(1)

- (b) Under these conditions, the conversion of ethene to ethanol is 5 % at equilibrium but the overall yield of ethanol for the process is 95 %.

Suggest what happens to the equilibrium mixture containing ethanol so that the overall yield of ethanol becomes 95 %.

(2)

- (c) The temperature used is 300 °C and the pressure used is 7 MPa. These, and the amount of water present in the reaction mixture, are all compromises.

(i) Explain why the temperature used is a compromise.

(2)





(ii) Explain why a manufacturer might suggest a pressure of greater than the compromise pressure of 7 MPa.

(2)

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(iii) At pressures greater than 7 MPa, a waxy solid forms which melts over a range of temperatures.
Identify, by name or formula, this solid.

(1)

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(iv) Give **one** other reason for not operating the process at a pressure greater than 7 MPa. Do not include safety considerations in your answer.

(1)

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(v) Increasing the amount of water in the reaction mixture, without changing the pressure, might also be suggested.

Suggest **one** advantage and **one** disadvantage of increasing the amount of water.

(2)

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(Total for Question 19 = 11 marks)

TOTAL FOR SECTION B = 40 MARKS

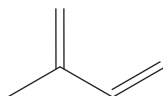


SECTION C

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

- 20 Terpenes and terpenoids are groups of chemicals found in plants. They contribute to the smell and taste of the plant, and so are used in flavourings and perfumes.

Both terpenes and terpenoids have carbon skeletons based on one or more units of the compound isoprene.



isoprene

Terpenes are made up of two or more isoprene units joined together, while terpenoids have additional functional groups, often containing oxygen.

Limonene and myrcene are both terpenes composed of two isoprene units.

Menthol, linalool and citronellol are terpenoids containing an -OH group.

- (a) (i) Give the IUPAC name for isoprene.

(1)

- (ii) The peaks with the highest intensity in the mass spectrum of isoprene are at $m/z = 68$ and $m/z = 53$. Identify the species responsible for these two peaks.

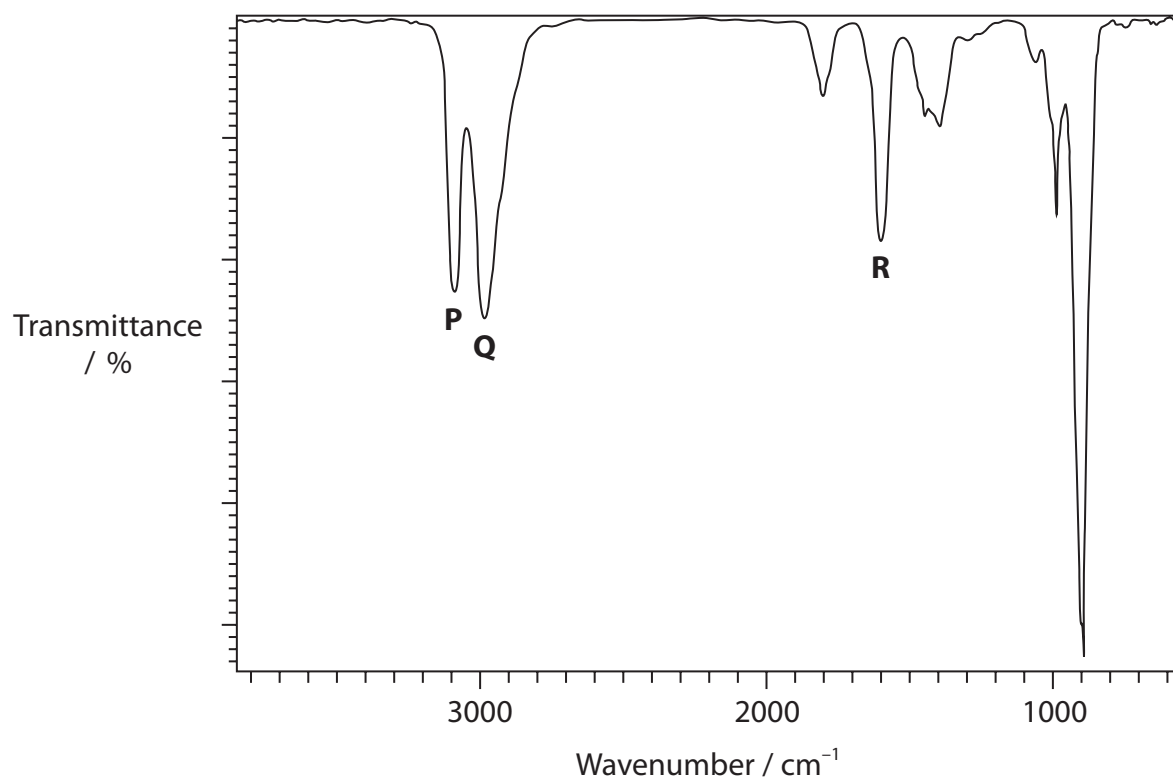
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$m/z = 68$

$m/z = 53$



(iii) The infrared spectrum of isoprene is shown.



State the origins of the peaks labelled **P**, **Q** and **R**. You may use a labelled diagram.

Use the Data Booklet as a source of information.

(3)

P

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Q

.....

R

.....



P 7 5 7 7 9 R A 0 2 1 2 8

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CC(C)=CC

(2)

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(1)

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- (iii) 5 g samples of myrcene and limonene were completely hydrogenated.
Calculate the volume of hydrogen required to hydrogenate each sample.
Include the unit with your answer.

Assume the volume of 1 mol of hydrogen = $24\,000\text{ cm}^3$

(4)

- (iv) Give the IUPAC name of the product formed by complete hydrogenation
of myrcene.

(1)



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CC(C)=CC(C)(O)C=CCC(C)=CCCC(C)CO

citronellol

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(6)



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(Total for Question 20 = 20 marks)

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





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P 7 5 7 7 9 R A 0 2 7 2 8

The Periodic Table of Elements

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

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

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

* Lanthanide series
* Actinide series

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