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)

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 ▶

P75779RA

F:1/1/1/1/

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

Pearson

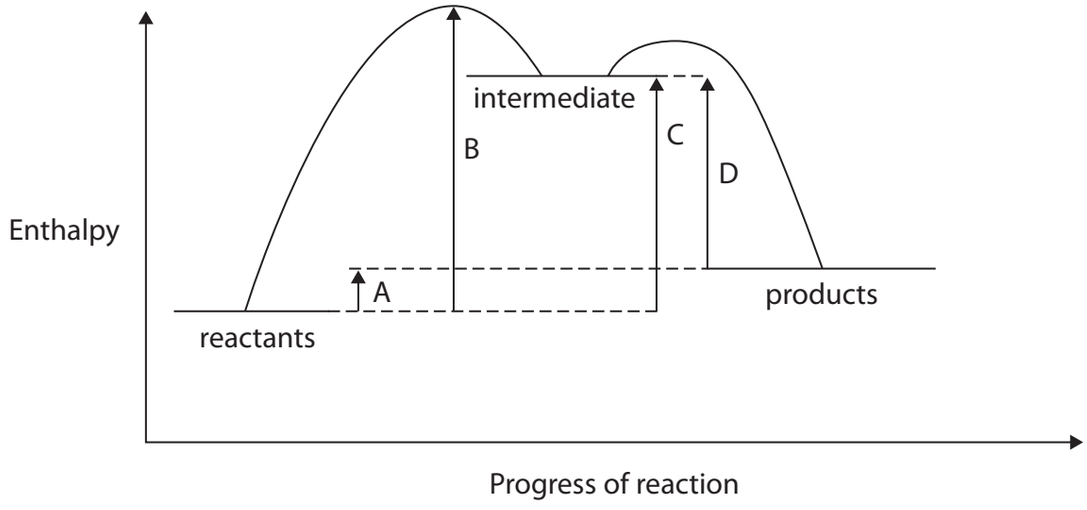
SECTION A

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 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?

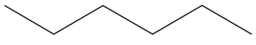
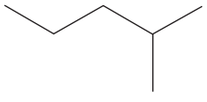
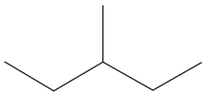
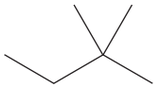
- ☒ **A** $CCl_4(g) \rightarrow C(g) + 4Cl(g)$
- ☒ **B** $\frac{1}{4}CCl_4(g) \rightarrow \frac{1}{4}C(g) + Cl(g)$
- ☒ **C** $C(g) + 4Cl(g) \rightarrow CCl_4(g)$
- ☒ **D** $\frac{1}{4}C(g) + Cl(g) \rightarrow \frac{1}{4}CCl_4(g)$

(Total for Question 3 = 1 mark)

4 This question is about boiling temperatures.

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

(1)

- ☒ **A** 
- ☒ **B** 
- ☒ **C** 
- ☒ **D** 

(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)

5 Steam is passed over heated magnesium.

Which reaction occurs most readily?

☒ **A** $Mg + H_2O \rightarrow MgO + H_2$

☒ **B** $Mg + 2H_2O \rightarrow Mg(OH)_2 + H_2$

☒ **C** $2Mg + H_2O \rightarrow Mg_2O + H_2$

☒ **D** $2Mg + 2H_2O \rightarrow 2MgOH + H_2$

(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 g cm^{-3}) are shaken and left to stand.
What colours are the two layers that form?

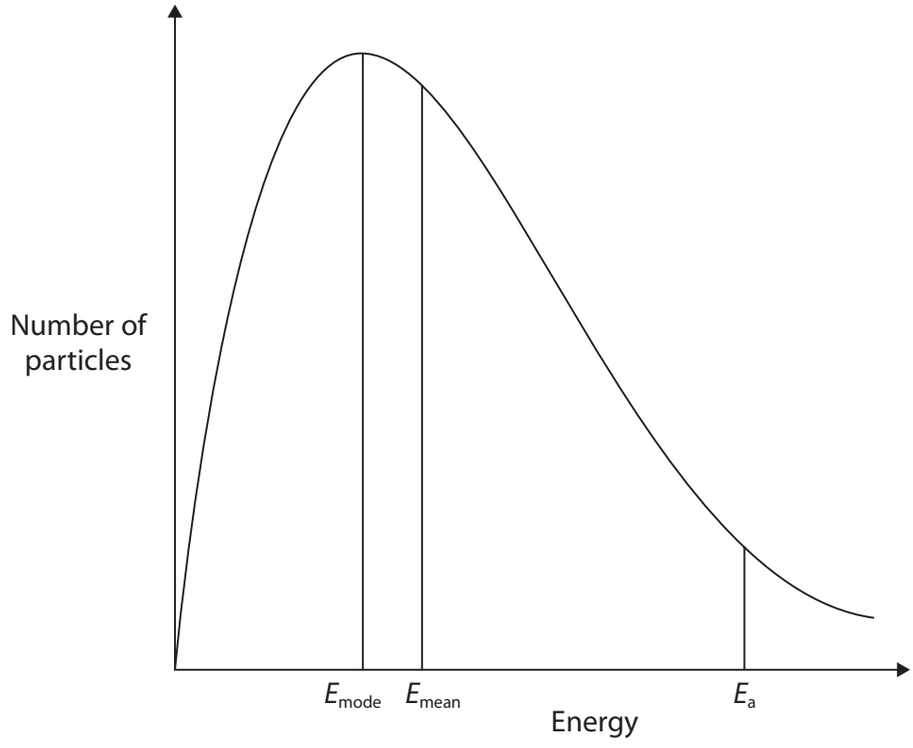
	lower layer	upper layer
☒ **A**	brown	yellow
☒ **B**	yellow	purple
☒ **C**	yellow	brown
☒ **D**	purple	brown

(Total for Question 14 = 1 mark)

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

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.

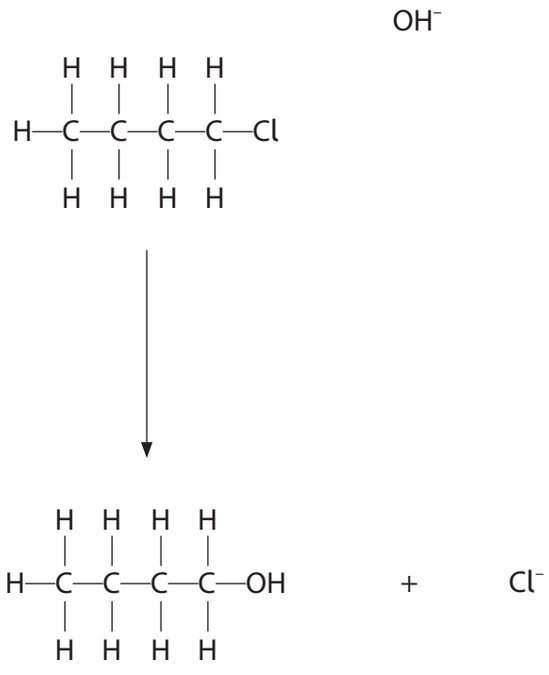
(1)

.....

.....

(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)

.....

.....

.....

.....

.....

.....

(Total for Question 16 = 7 marks)

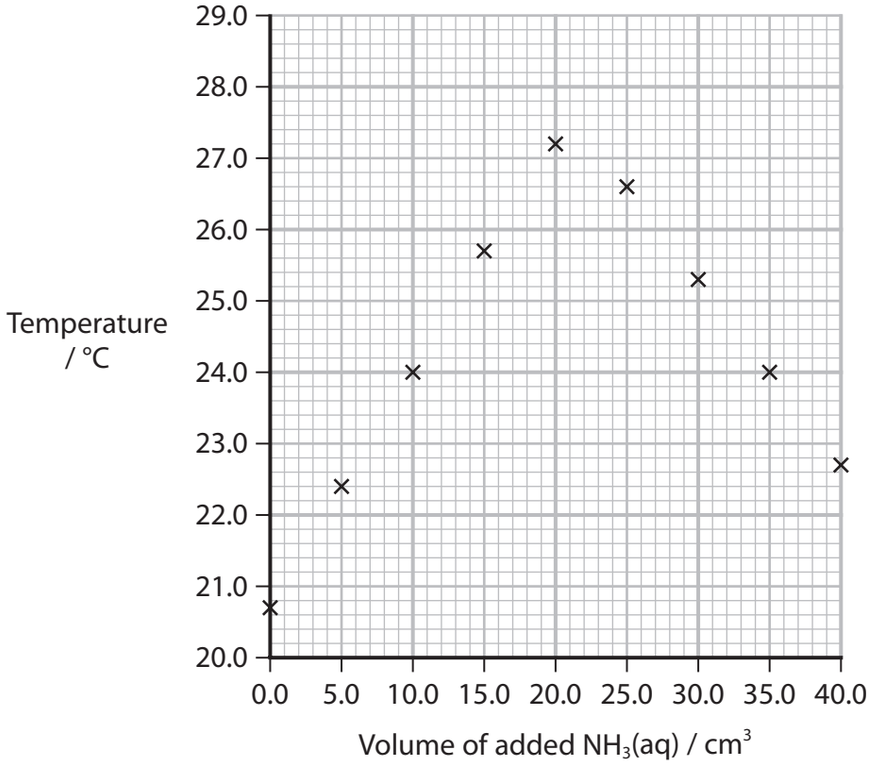
17 In a titration between a weak acid and a weak base indicators do not give a distinct colour change, so other techniques must be used.
One technique is thermometric titration.

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.

$$CH_3COOH(aq) + NH_3(aq) \rightarrow CH_3COONH_4(aq)$$

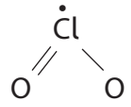
Calculate the enthalpy change of neutralisation for this reaction, in kJ mol^{-1}. Give your answer to an appropriate number of significant figures and include a sign with your answer.

[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 J g^{-1} °C^{-1}]

(5)

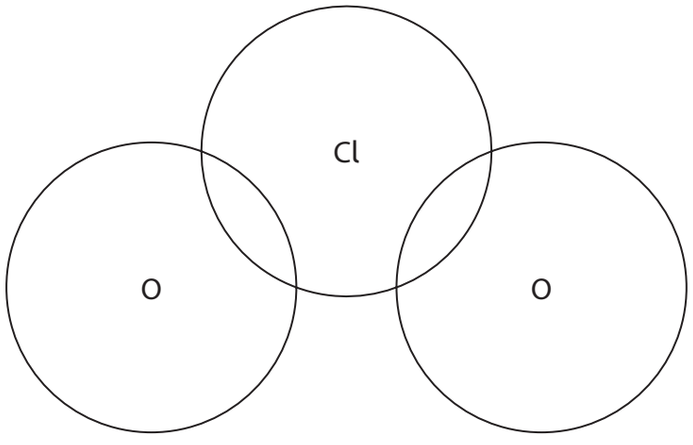
(Total for Question 17 = 9 marks)

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)

.....

.....

.....

.....

(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)

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

(1)

(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)

(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)

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

$$H_2O + CH_2{=}CH_2 \rightleftharpoons CH_3CH_2OH \qquad \Delta_r H = -42 \text{ kJ mol}^{-1}$$

(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)

.....

.....

.....

.....

.....

.....

DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA DO NOT WRITE IN THIS AREA

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

(2)

(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)

(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)

(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)

.....

.....

.....

.....

.....

.....

.....

(Total for Question 19 = 11 marks)

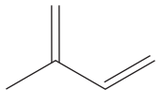
TOTAL FOR SECTION B = 40 MARKS

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)

.....

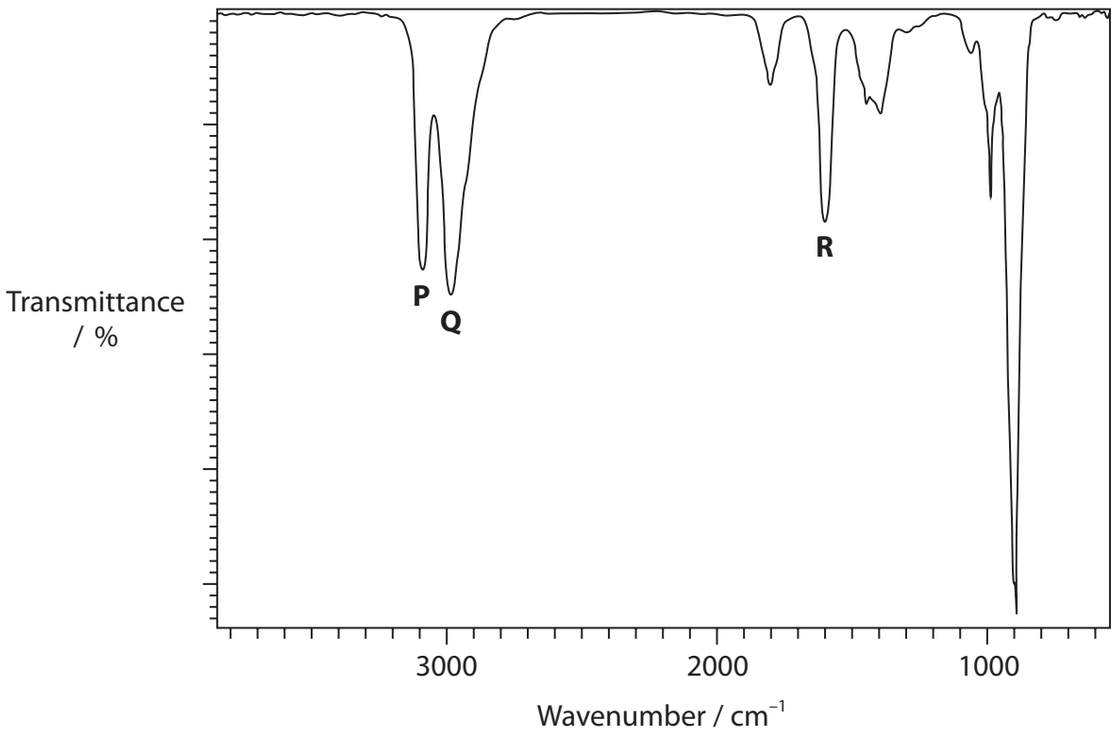
(ii) The peaks with the highest intensity in the mass spectrum of isoprene are at $m / z = 68$ and $m / z = 53$.
Identify the species responsible for these two peaks.

(2)

$m / z = 68$

$m / z = 53$

(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 .....

.....

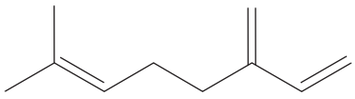
Q .....

.....

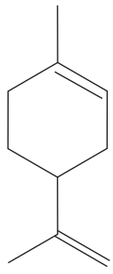
R .....

.....

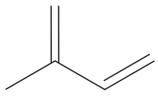
(b) (i) Show that myrcene and limonene are terpenes by comparing the molecular and/or empirical formulae of myrcene, limonene and isoprene.



myrcene



limonene



isoprene

(2)

.....

.....

.....

.....

.....

(ii) Both myrcene and limonene can be completely hydrogenated by reaction with hydrogen.
State the conditions required for hydrogenation of alkenes.

(1)

.....

(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 cm^3

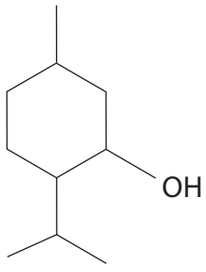
(4)

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

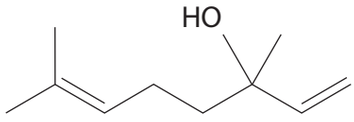
(1)

.....

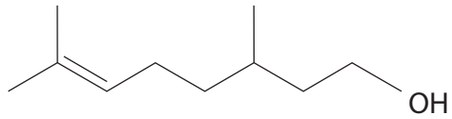
*(c) Three students were asked to carry out a single chemical test to unambiguously identify the presence of the −OH group in the three terpenoid compounds, menthol, linalool and citronellol.



menthol



linalool



citronellol

The first student tried using acidified potassium dichromate(VI) to oxidise the alcohols.

The second tried acidified potassium manganate(VII), an oxidising agent similar to potassium dichromate(VI).

The third student tried using phosphorus(V) chloride.

Criticise the three students' suggestions by linking the expected results, and the actual observations that would be made, for each test and the structures of the three alcohols.

(6)

(Total for Question 20 = 20 marks)

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

BLANK PAGE

BLANK PAGE

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)						(8)					(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)		(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

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