

OCR A-LEVEL CHEMISTRY A • H432

CHEMISTRY



EXAM QUESTION PACK

4.2.4 ANALYTICAL TECHNIQUES

SCORE

/94

PERCENTAGE

%

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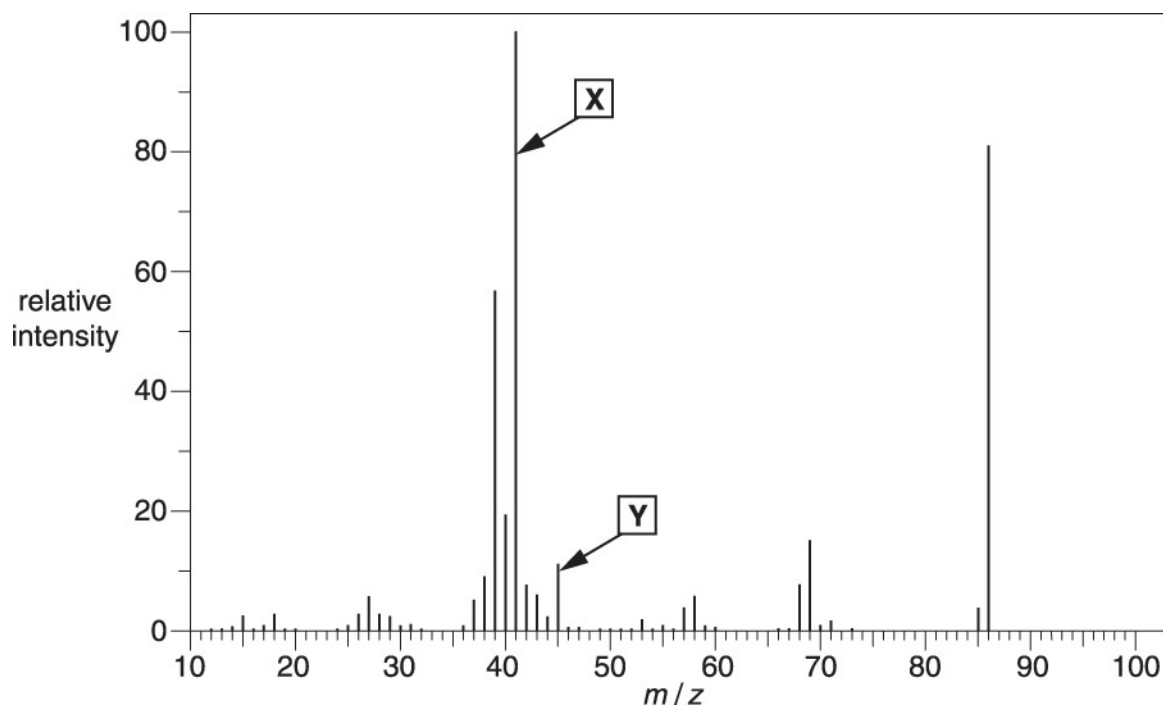
- 1 Compound **G** is a branched-chain organic compound that does not have *E* and *Z* isomers.

Elemental analysis of compound **G** gave the following percentage composition by mass:

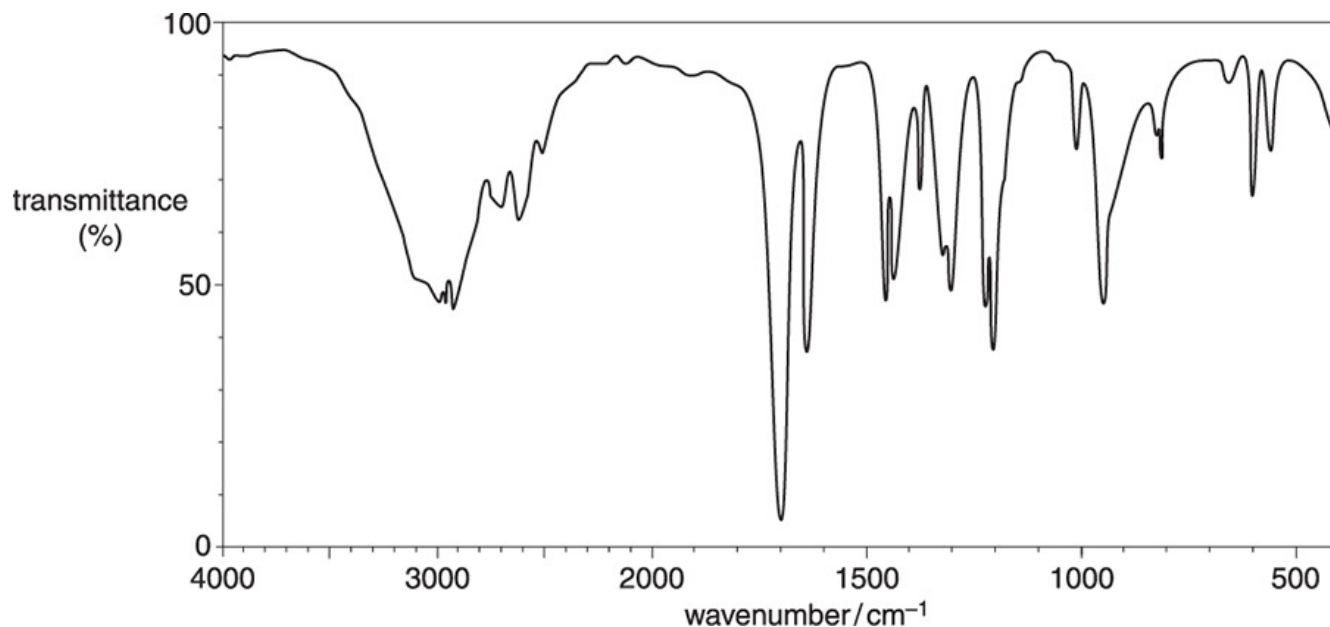
C, 55.8%; H, 7.0%; O, 37.2%.

The mass spectrum and infrared spectrum of compound **G** are shown below.

Mass spectrum



Infrared spectrum



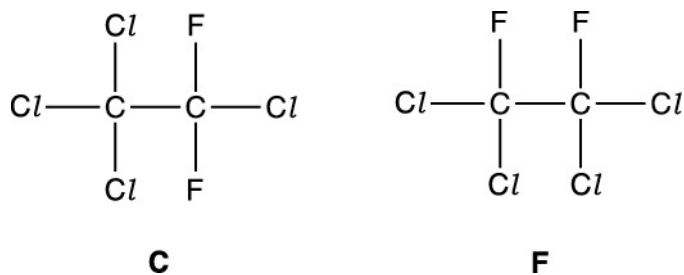
- Calculate the empirical and molecular formulae for compound G.
- Write the formulae for the particles responsible for peak X and peak Y in the mass spectrum.
- Draw the structure of compound G.



Explain fully how you arrive at a structure for compound G using all the evidence provided.

[7]

2 Compounds **C** and **F** can be analysed to obtain infrared and mass spectra.



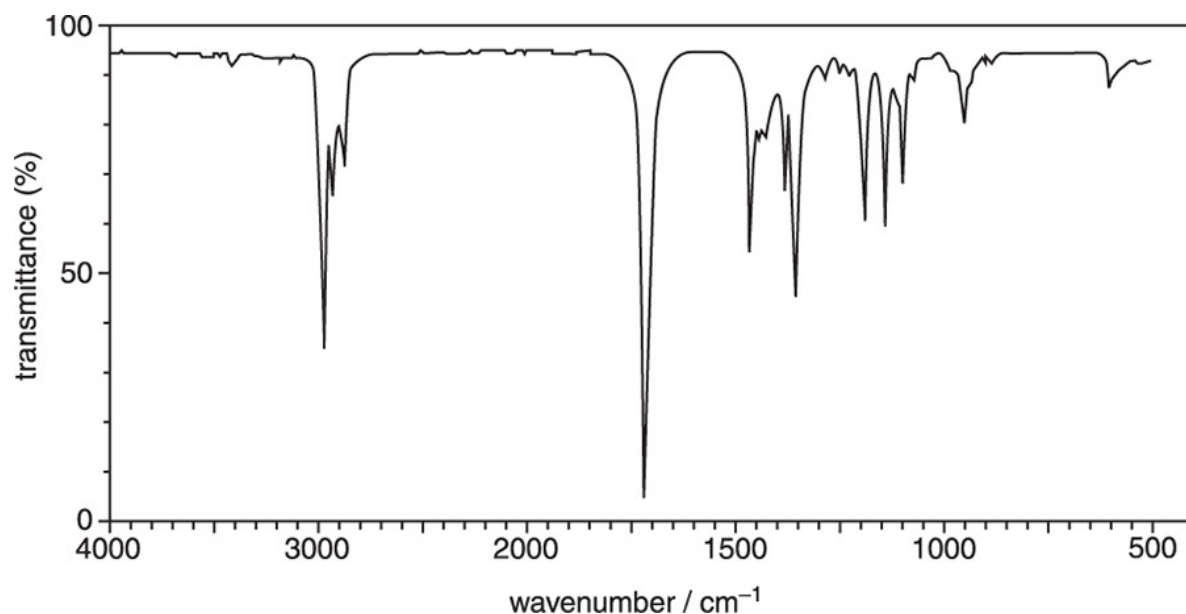
(i) What happens to molecules when infrared radiation is absorbed?

-----[1]

(ii) Suggest the molecular formulae of **two** ions responsible for peaks in the mass spectrum of **C** that are **not** in the mass spectrum of **F**.

-----[2]

3(a) The branched-chain alcohol J, $C_5H_{12}O$, was heated under reflux with excess $H_2SO_4 / K_2Cr_2O_7$ to form an organic compound K with the infrared spectrum below.



- Determine the structures for the branched-chain alcohol J and compound K.
Your answer should explain all your reasoning using the evidence given.
- Write an equation for the reaction of J when heated under reflux with excess $H_2SO_4 / K_2Cr_2O_7$ to form K.
Use [O] to represent the oxidising agent.



Your answer needs to be clear and well organised using the correct terminology.

[6]

(b) The alcohol J is soluble in water.

Explain why alcohol J is soluble in water.

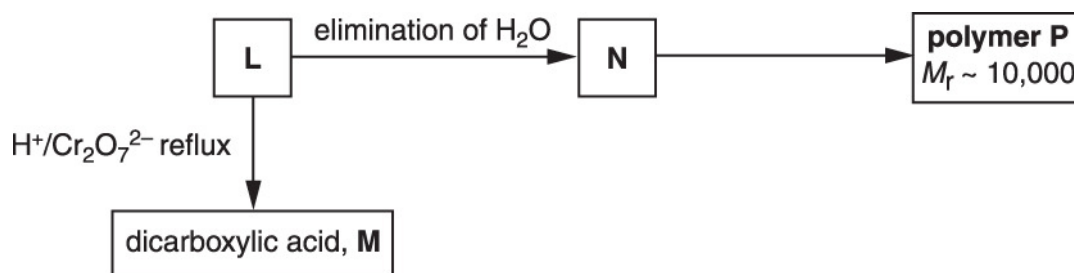
Use a labelled diagram to support your answer.

Include relevant dipoles and lone pairs.

----- [1]

4(a) L, M, N and P are straight-chain organic compounds containing C, H and O only.

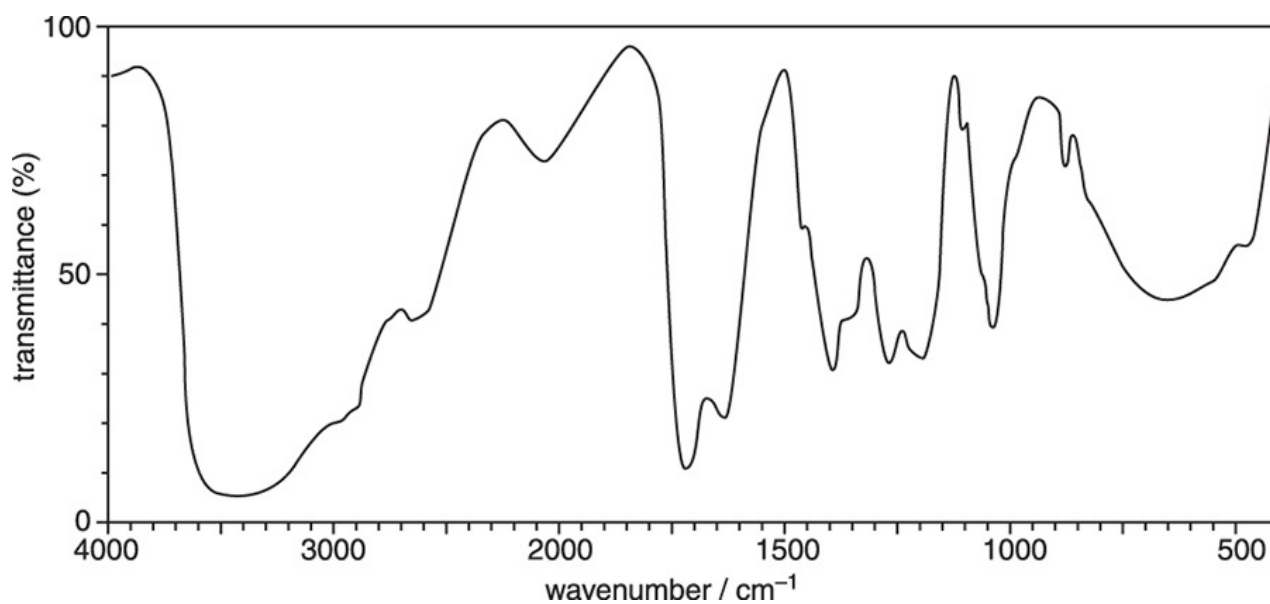
The flowchart shows reactions involving these compounds.



Analysis of compound L shows the following.

- Percentage composition by mass: C, 40.00%; H, 6.67%; O, 53.33%.
- Relative molecular mass of 90.0.
- The infrared spectrum below.

IR spectrum of L



Calculate the empirical and molecular formulae of compound L.

Show your working.

[3]

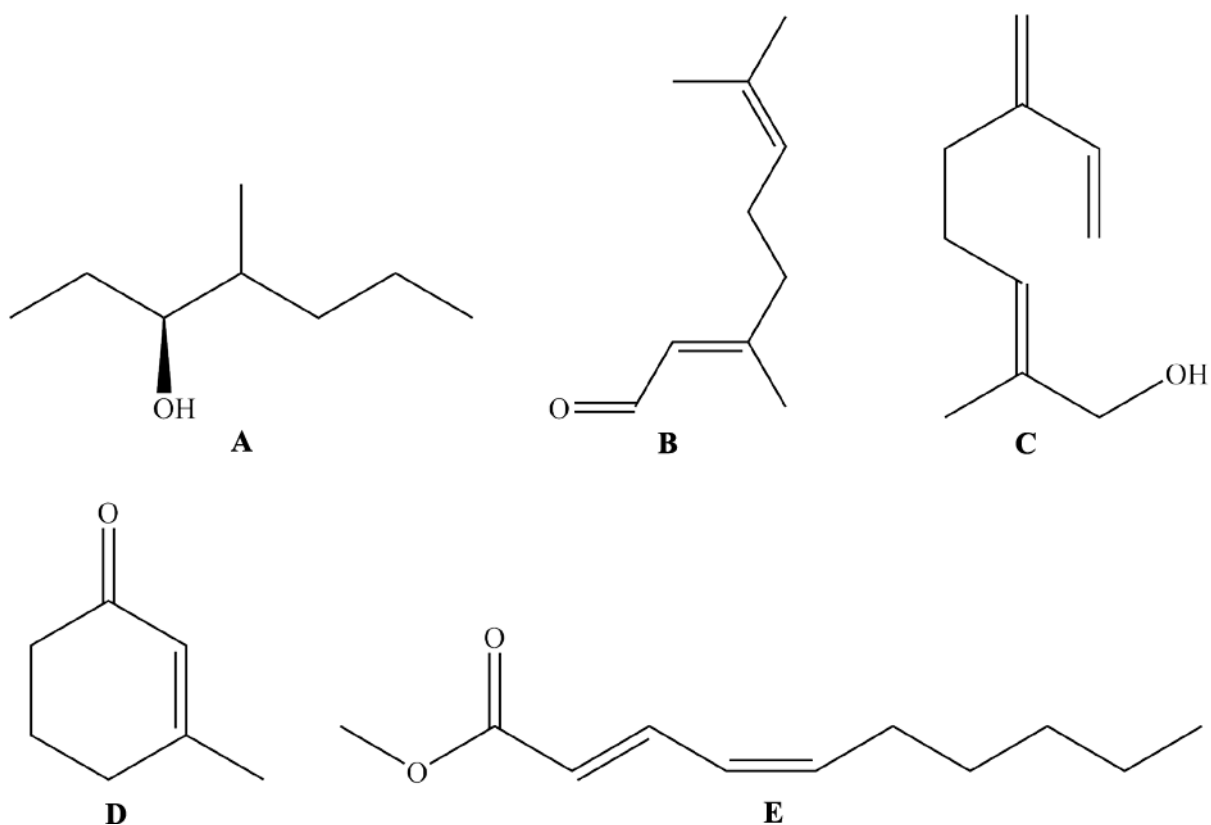
- Include an equation for the reaction of L to form M.

Blank lined area for writing the answer.

Estimate the number of repeat units in polymer **P** and write the equation for the formation of **P** from **N**.

[4]

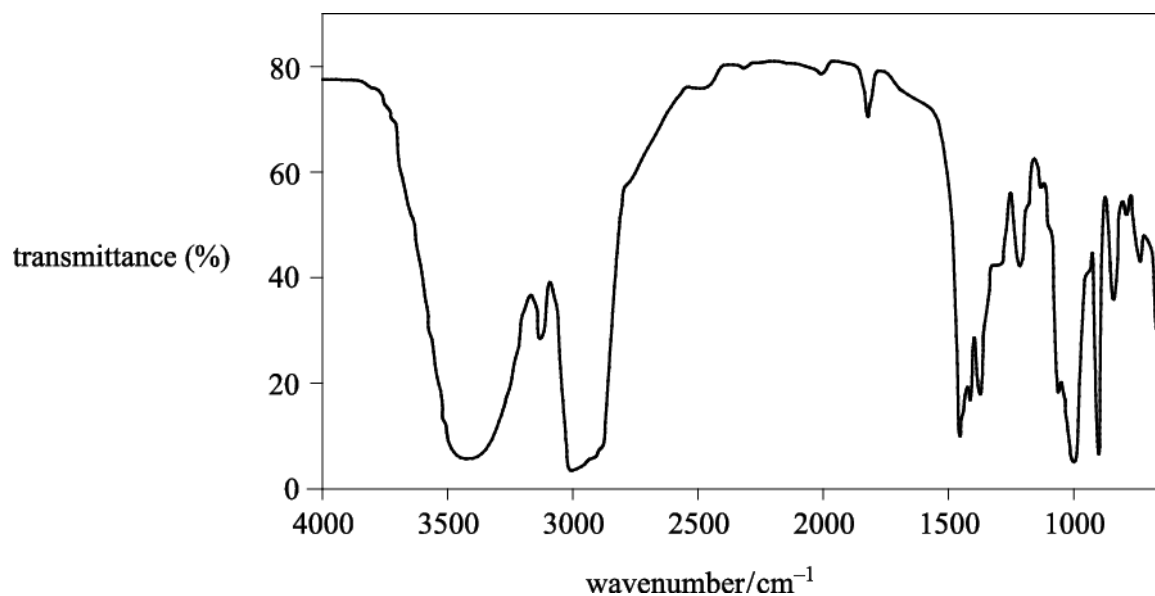
5 The organic compounds labelled A to E below are all produced by living organisms.



Analysis of one of the compounds A to E is shown below.

Percentage composition by mass: C, 78.94%; H, 10.53%; O 10.53%

Infrared spectrum:

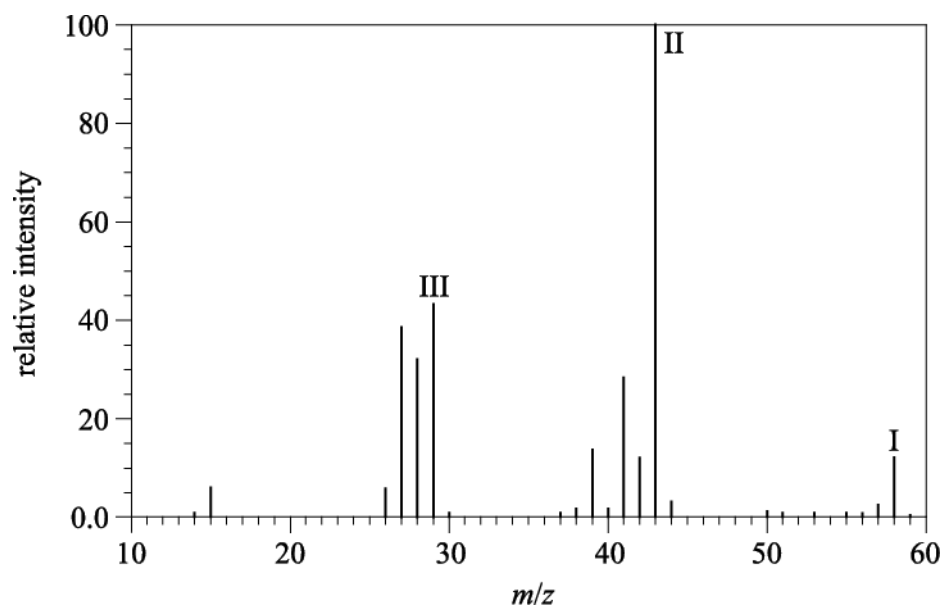


Use this information to identify the compound.

Explain your reasoning, referring to **all** the evidence provided.

[3]

6 Two students were provided with the mass spectrum of an alkane, shown below.



One student analysed peaks I and II and concluded that the alkane was one of two structures.

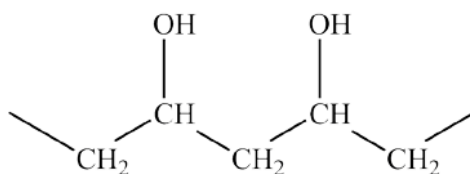
The other student analysed peaks I, II and III and was able to identify the alkane.

Analyse the peaks and explain why the two students obtained different conclusions.

[5]

7 Poly(ethenol) is used to make soluble laundry bags.

A section of the structure of poly(ethenol) is shown below.



(i) Draw a structure to represent one repeat unit of poly(ethenol).

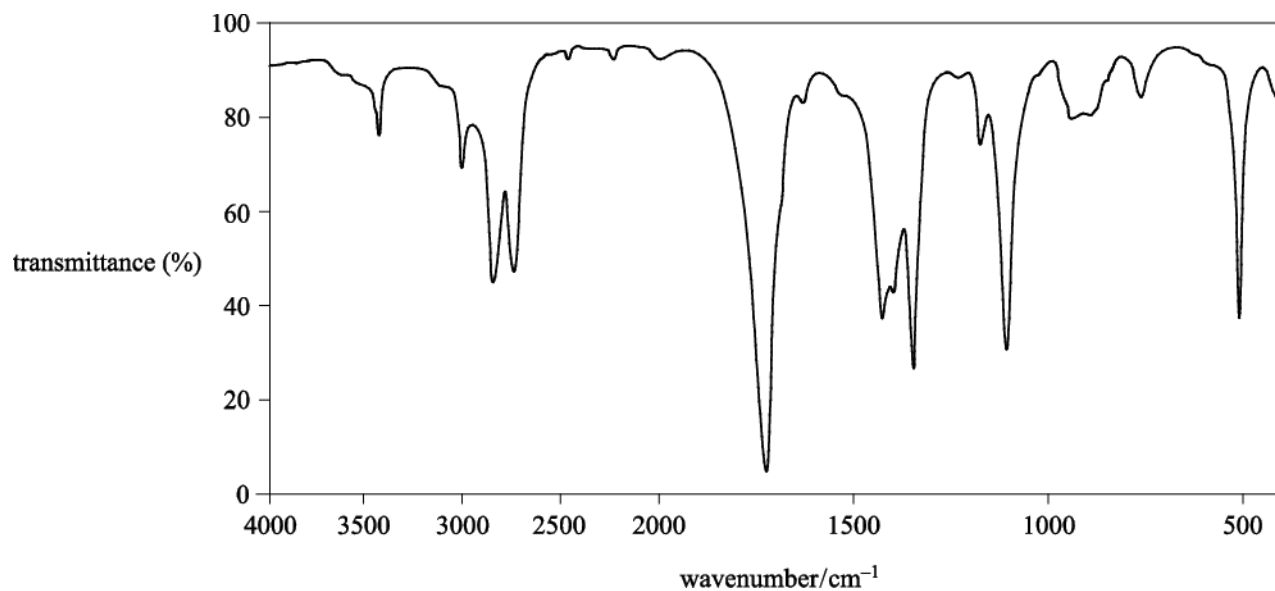
[1]

(ii) Poly(ethenol) is not manufactured from ethenol.

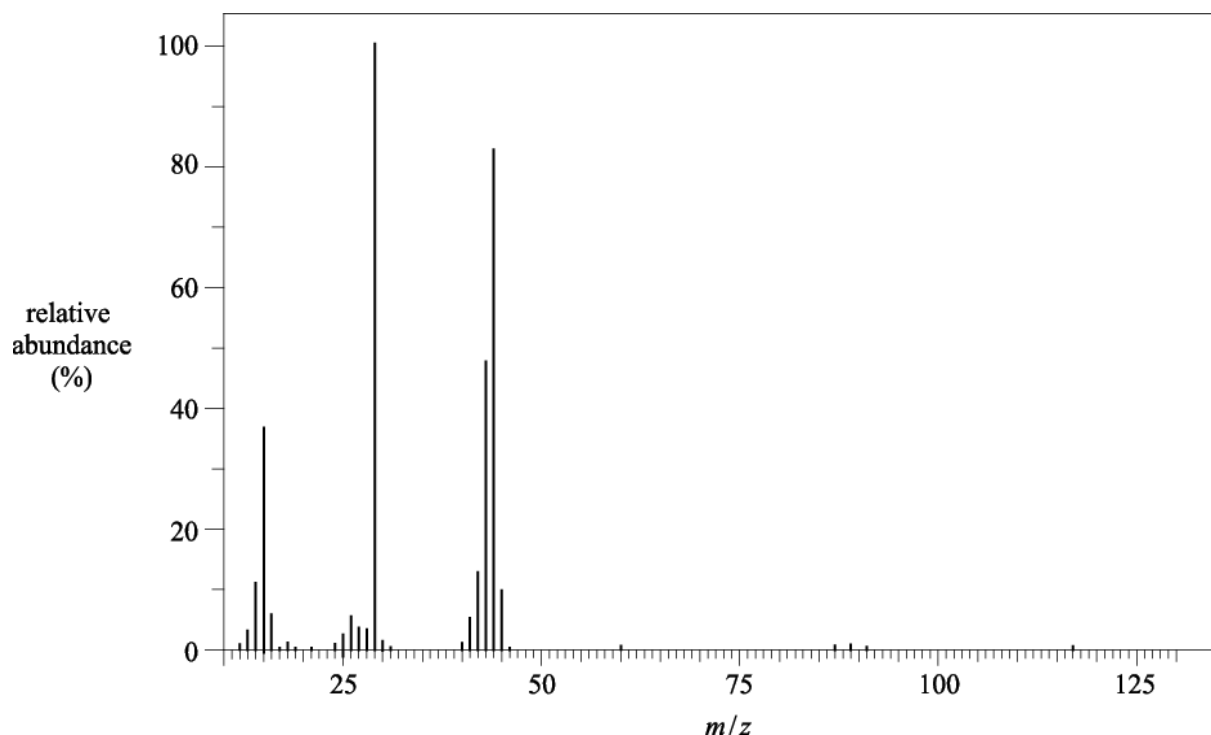
Ethenol is unstable and it forms a more stable structural isomer.

Analysis of the structural isomer gave the following data.

Infrared spectrum



Mass spectrum



Use **all** the data to show that the isomer is **not** ethenol.

Identify the structural isomer of ethenol.

In your answer you should make clear how your explanation is linked to the evidence.

[4]

8 * You are provided with three alcohols that are structural isomers: $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$, $\text{CH}_3\text{CH}_2\text{CHOHCH}_3$ and $(\text{CH}_3)_3\text{COH}$. You do not know which is which.

You have access to normal laboratory apparatus and chemicals, Quickfit apparatus, and an infrared spectrometer.

Describe a plan that would allow you to identify the three alcohols using the same experimental set up and method.

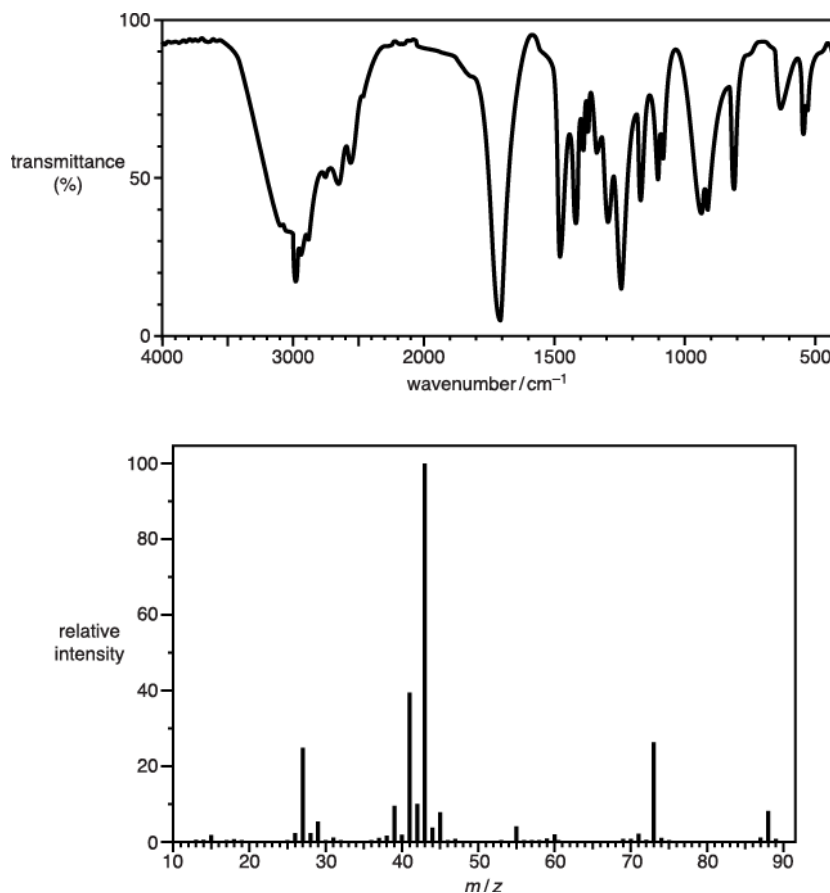
You should provide

- equations using structural formulae for any reactions
- a description of how you will identify the three alcohols from any observations and results.

[6]

- 9 * Organic compound C has the following percentage composition by mass:
C, 54.5%; H, 9.1%; O, 36.4%.

The infrared spectrum and mass spectrum of compound C are shown below.



In the mass spectrum, a secondary carbocation is responsible for the peak with the greatest relative intensity.

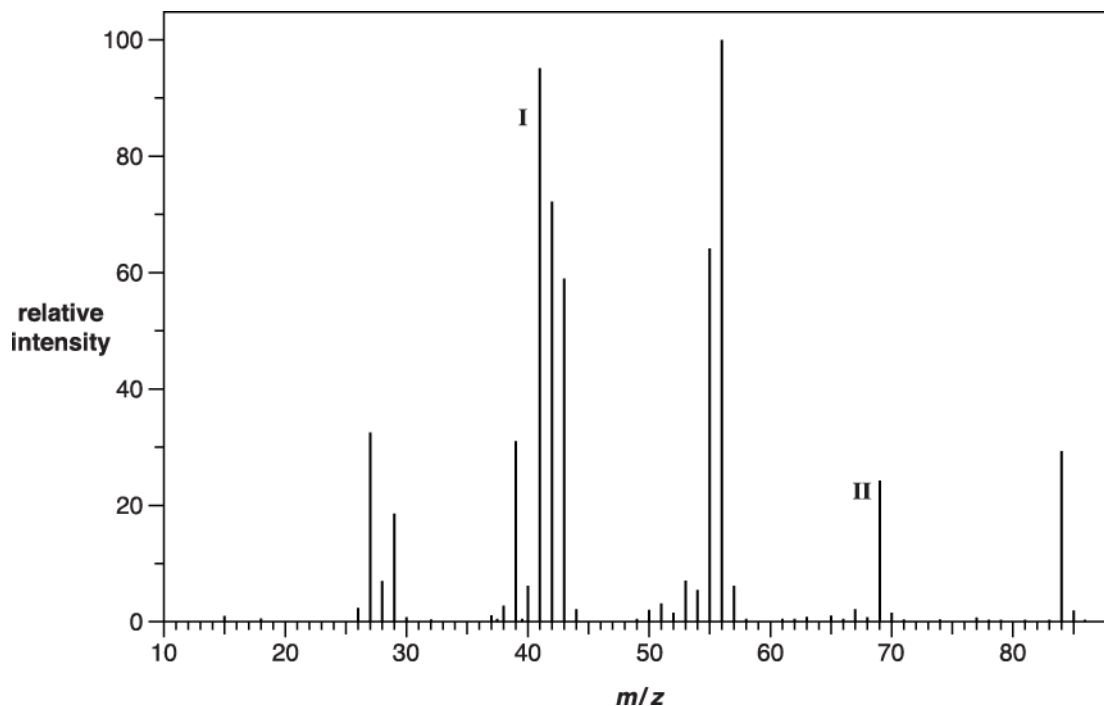
Identify compound C.

In your answer you should make clear how your conclusion is linked to all the evidence.

----- [6]

10 This question is about several unsaturated hydrocarbons.

The mass spectrum of an alkene is shown below.



(i) The empirical formula of the alkene is CH_2 .

Use the empirical formula and the mass spectrum to confirm the molecular formula as C_6H_{12} .

[1]

(ii) Further analysis showed that the alkene was hex-2-ene.

Suggest possible structures for the species responsible for the labelled peaks I and II in the mass spectrum of hex-2-ene shown opposite.

peak I	peak II
--------	---------

[3]

11(a) A student was provided with a mixture of two structural isomers. Each isomer has the percentage composition by mass C, 29.29%; H, 5.70%; Br, 65.01%. The relative molecular mass of each isomer is less than 150.

Determine the structures of the two structural isomers.

Show your working.

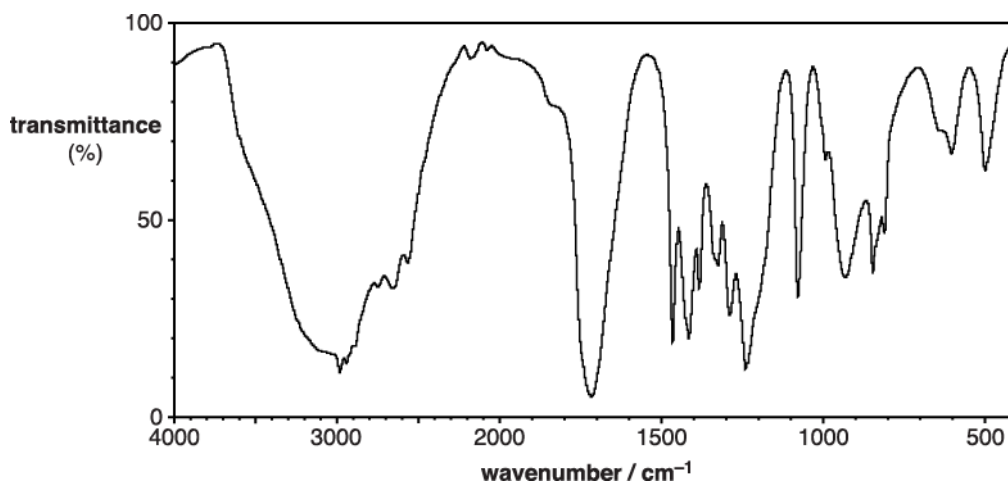


In your answer you should link the evidence with your explanation.

[5]

- (b) The student heats the mixture of the two structural isomers from (a) under reflux with aqueous sodium hydroxide to form two compounds, E and F. The student separates the two compounds.

Compound E is heated under reflux with acidified potassium dichromate(VI) to form compound G, which gives the infrared spectrum below.



- (i) Analyse the information and spectrum to determine the structures of E, F and G.

Include an equation for the formation of G from E.



In your answer you should link the evidence with your explanation.

[6]

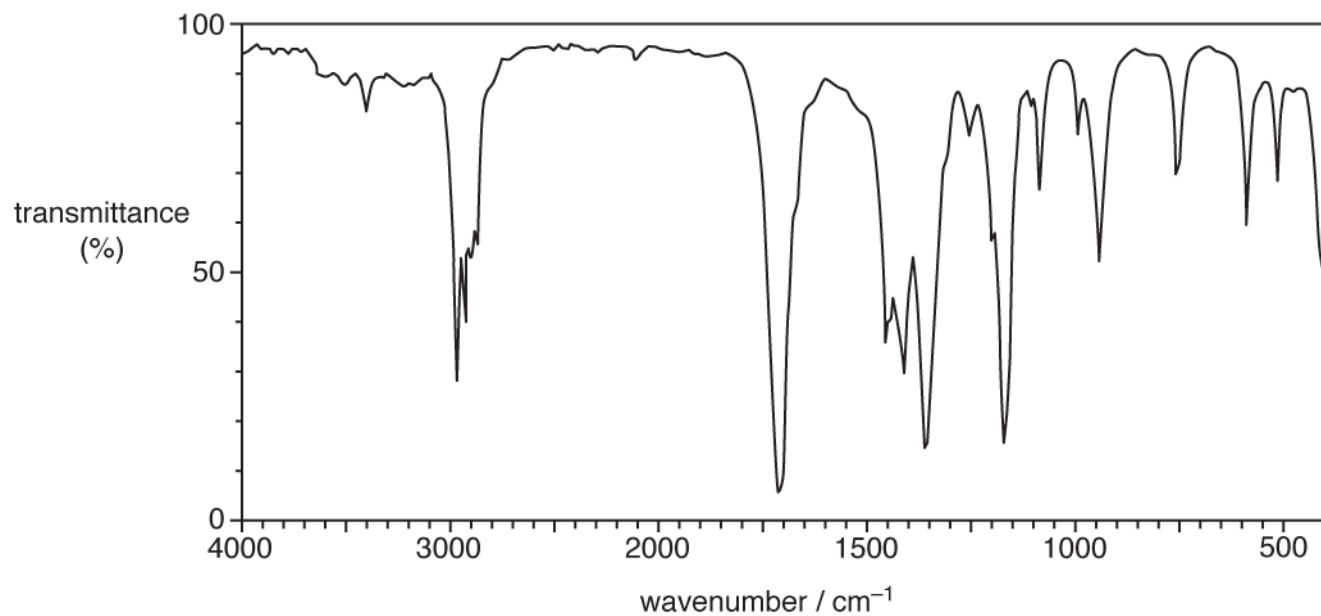
- (ii) Compound **G** is heated with compound **F** in the presence of a small amount of concentrated sulfuric acid to form organic compound **H**.

Draw the structure of the organic compound **H**.

[2]

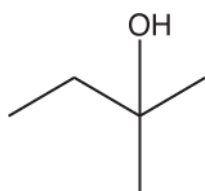
- 12 An alcohol **A** is heated under reflux with sulfuric acid and potassium dichromate(VI).

The organic compound formed produces the infrared spectrum below.

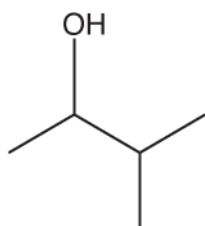


Which compound could be alcohol A?

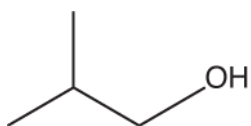
A



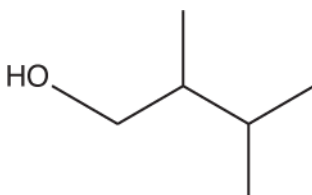
B



C



D



Your answer

[1]

13 Which alcohol is **not** likely to have a fragment ion at $m/z = 43$ in its mass spectrum?

- A $\text{CH}_3\text{CH}_2\text{CH}(\text{OH})\text{CH}_3$
- B $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$
- C $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_2\text{CH}_3$
- D $(\text{CH}_3)_2\text{CHCH}_2\text{OH}$

Your answer

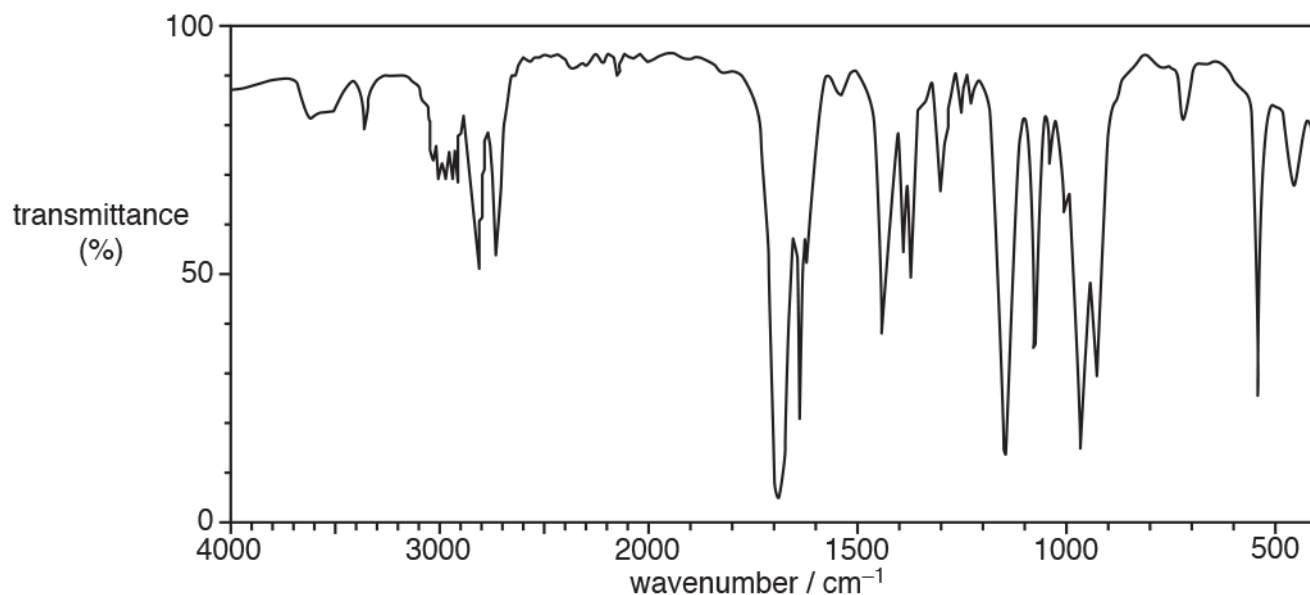
[1]

14 * Compound F is a *trans* stereoisomer which is a useful intermediate in organic synthesis.

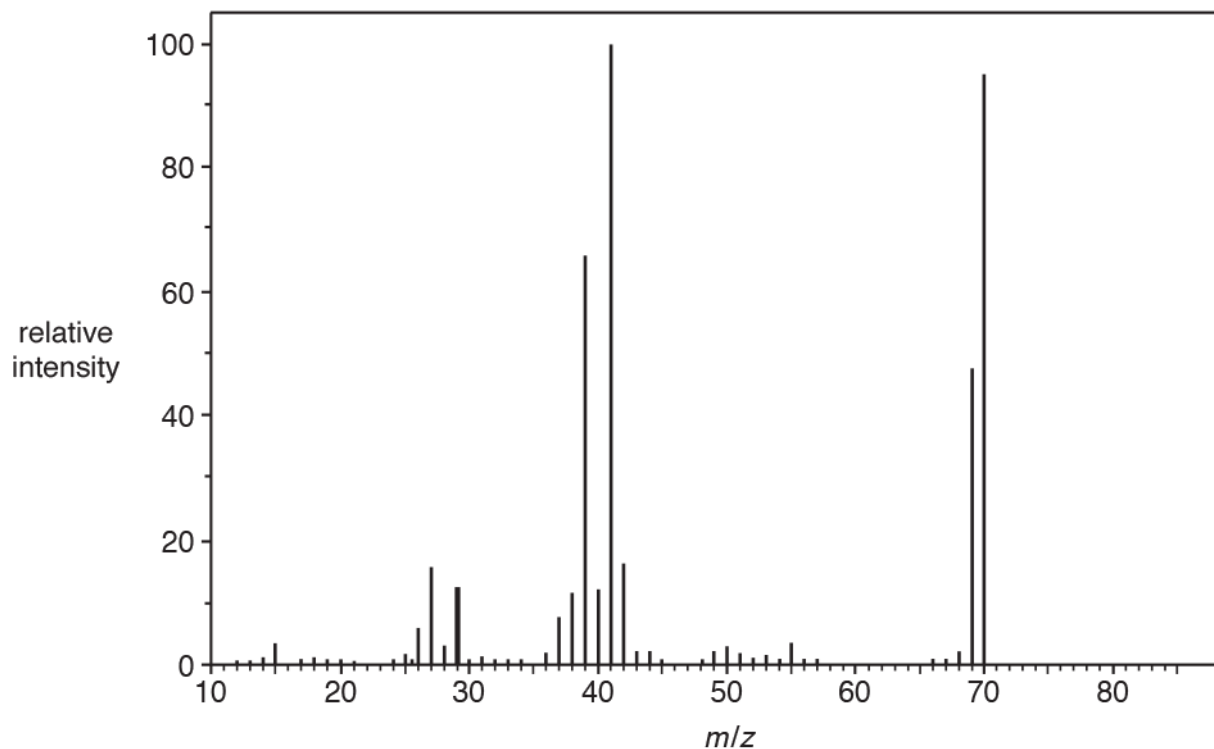
The results of elemental and spectral analysis of compound F are shown below.

Percentage composition by mass: C, 68.6 %; H, 8.6 %; O, 22.8 %.

Infrared spectrum



Mass spectrum



In the mass spectrum, the peak with the greatest relative intensity is caused by the loss of a functional group from the molecular ion of compound F.

Determine the structure of compound F.

Explain your reasoning and show your working.

[6]

15 Which alcohol is likely to have a fragment ion at $m/z = 31$ in its mass spectrum?

- A $\text{CH}_3\text{CH}_2\text{CH}(\text{OH})\text{CH}_3$
- B $\text{CH}_3\text{CH}_2\text{CH}_2\text{C}(\text{OH})(\text{CH}_3)_2$
- C $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_2\text{CH}_3$
- D $(\text{CH}_3)_2\text{CHCH}_2\text{OH}$

Your answer

[1]

16 An alcohol can be prepared by hydrolysing the haloalkane $\text{C}_2\text{H}_5\text{CHBrCH}_3$ with aqueous sodium hydroxide.

(i) Outline the mechanism for this reaction.

Show curly arrows and relevant dipoles.

[3]

(ii) The infrared (IR) spectrum for $\text{C}_2\text{H}_5\text{CHBrCH}_3$ is shown in Fig. 25.2.

The C–Br bond absorption is labelled.

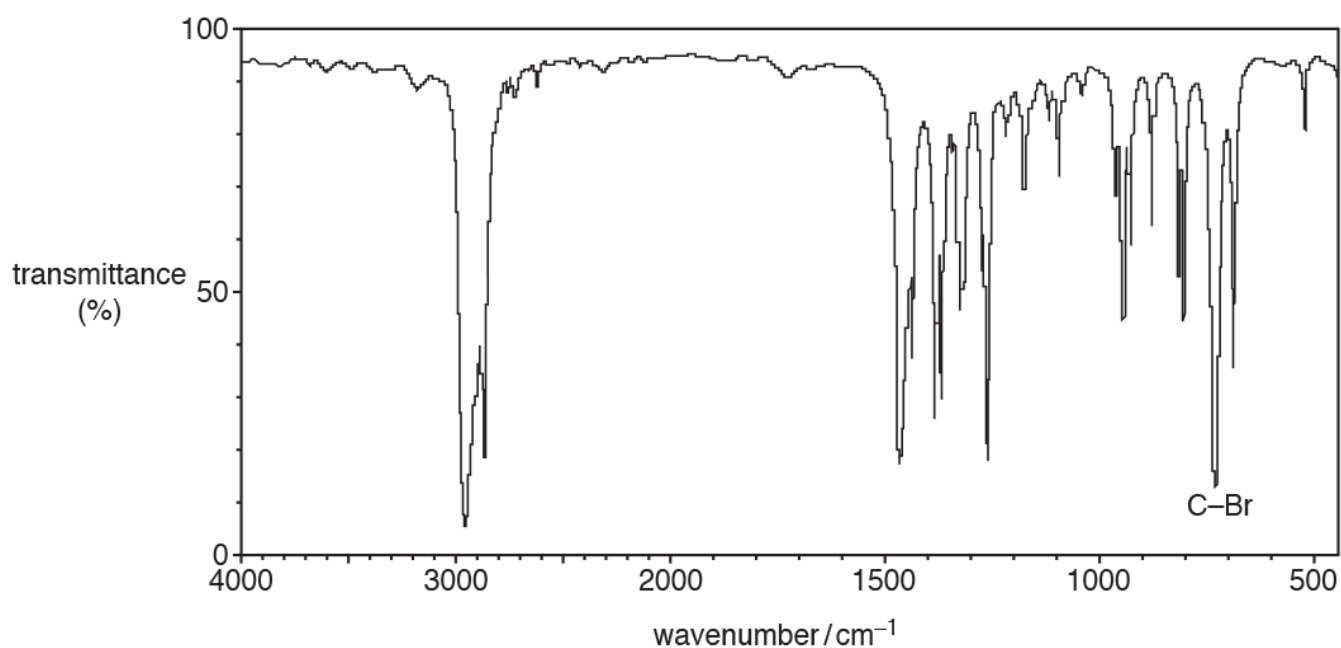


Fig. 25.2

Outline how IR spectroscopy could be used to show that the bromoalkane functional group has reacted and that the alcohol functional group has formed.

-----[2]

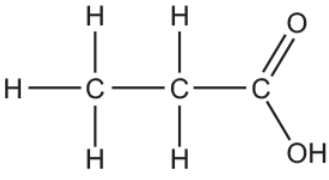
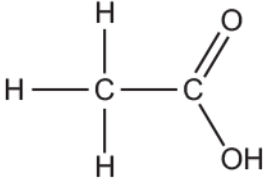
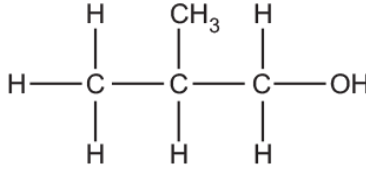
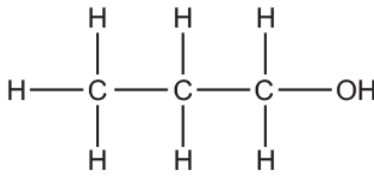
17 Which statement about infrared radiation is **not** correct?

- A The energy from IR radiation causes some covalent bonds to vibrate more.
- B Absorption of IR radiation by some atmospheric gases is linked by some scientists to global warming.
- C IR radiation is used to monitor gases causing air pollution.
- D The action of IR radiation on CFCs in the upper atmosphere leads to the formation of chlorine radicals.

Your answer

[1]

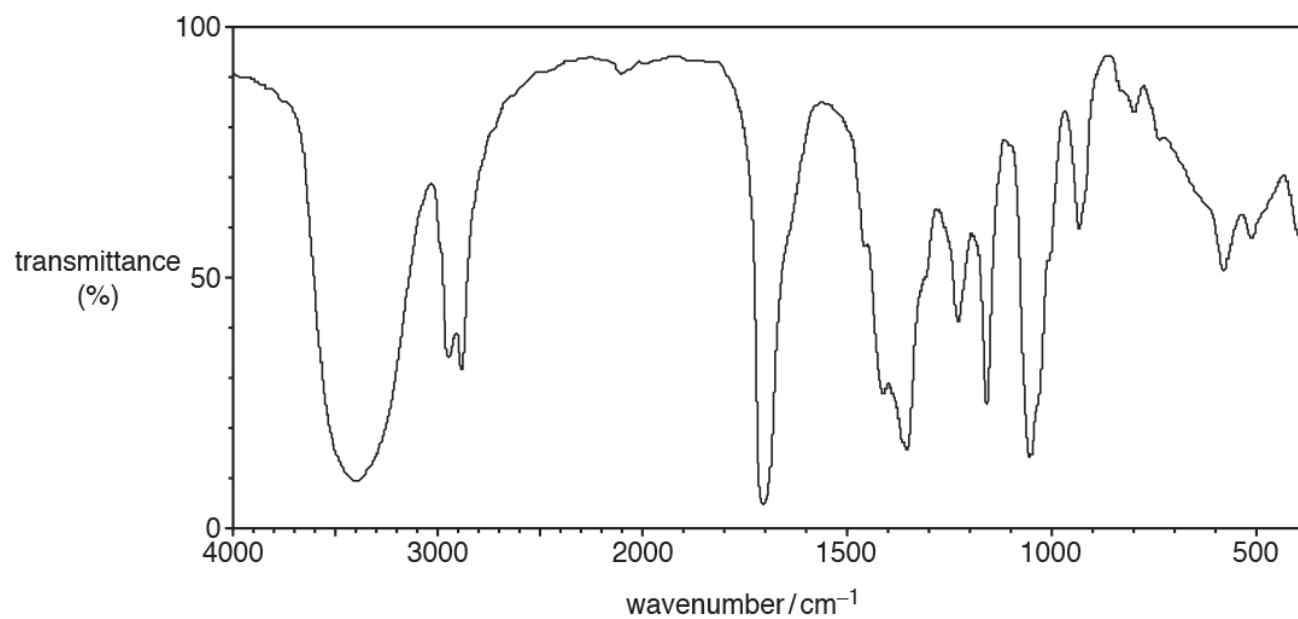
18 Which compound is **not** likely to have a fragment ion at $m/z = 43$ in its mass spectrum?

A	
B	
C	
D	

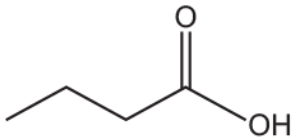
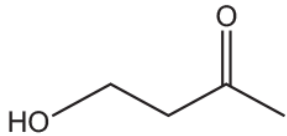
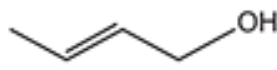
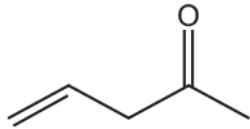
Your answer

[1]

19 An unknown compound produces the infrared spectrum below.



Which compound could have produced the infrared spectrum?

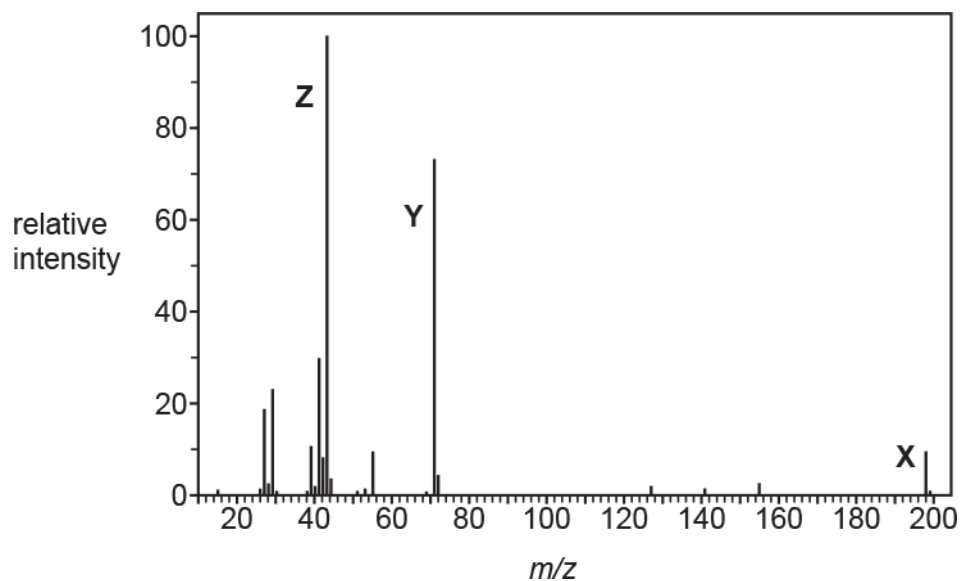
A	
B	
C	
D	

Your answer

[1]

20(a) This question is about 1-iodopentane, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{I}$.

The mass spectrum of 1-iodopentane is shown below.



(i) What information is given by the peak labelled X ($m/z = 198$)?

----- [1]

(ii) Write the structural formulae of the ions responsible for the peaks labelled Y and Z.

Y ($m/z = 71$) -----

Z ($m/z = 43$) ----- [2]

(b) 2-Iodo-2-methylbutane is an isomer of 1-iodopentane.

(i) Draw the structure of 2-iodo-2-methylbutane.

[1]

(ii) Suggest **one** similarity and **one** difference between the mass spectra of 1-iodopentane and 2-iodo-2-methylbutane.

Similarity

.....

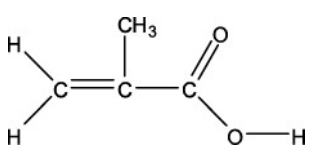
Difference

.....

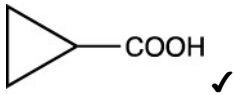
[2]

END OF QUESTION PAPER

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
1	Molecular formula for G: 2 marks Mole ratio C : H : O = $\frac{55.8}{12.0} : \frac{7.0}{1.0} : \frac{37.2}{16.0}$ OR 4.65 : 7.0 : 2.33 / 2.325 OR 2 : 3 : 1 OR C₂H₃O ✓ Molecular formula of G C₄H₆O₂ ✓ Mass spectrum for G: 2 marks Peak X or peak 41 indicates C₃H₅⁺ ✓ Peak Y or peak 45 indicates COOH⁺ ✓ Infrared for G: 1 marks Peak at 1640–1750 cm⁻¹ indicates presence of C=O AND Peak at 2500–3300 cm⁻¹ (indicates the presence of) –OH group linked carboxylic acid / COOH QWC ✓ Structure of G: 2 marks Correct structure:  ✓✓	7	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC ALLOW mass of C = 0.558 × 86 or 48 AND mass of H = 0.07 × 86 or 6 AND mass of O = 0.372 × 86 = 32 + charge required for each response ALLOW one mark if both formulae are correct but with no charge/incorrect charge ALLOW any possible fragments that contain C, H and / or O that have the correct mass. E.g. Peak X indicates C₂OH⁺, Peak Y indicates C₂H₅O⁺ Unfeasible fragments are not allowed e.g. C₃H₉⁺ (too many H atoms) LOOK ON THE SPECTRUM for labelled absorbance which can be given credit Candidates must link absorbance to bond in order to gain the mark ALLOW 1700 cm⁻¹ For 2500–3300 cm⁻¹, ALLOW 2900 cm⁻¹ or any stated wavenumber with range 2500–3300 cm⁻¹ ALLOW wavenumber range up to 2400–3500 cm⁻¹ ALLOW structural, skeletal or displayed formula. DO NOT ALLOW ECF from incorrect molecular formula Examiner's Comments This question allowed the candidates to demonstrate their understanding of the more complex aspects of the course and

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			1 mark for one of the following structures of C₄H₆O₂: H₂C≡CH—CH₂—COOH OR H₃C—CH≡CH—COOH OR 		use their problem-solving skills to tie together the all of the evidence. The calculation of the empirical formula was completed well and most candidates were able to determine the molecular formula of G. Many of the more able candidates were able to identify one, if not both, of the ions responsible for peaks X and Y in the mass spectrum. A number of candidates were able to show correct fragments but omitted the positive charge. Candidates should be reminded to include the correct charge when suggesting particles responsible for peaks in mass spectra. The majority of candidates were able to recognise the characteristic absorptions in the IR spectrum. The strongest responses attributed these peaks to the appropriate bonds and deduced that G was a carboxylic acid. Two marks were available for the structure of G. The most able candidates were able to interpret all the information and provide the correct branched carboxylic acid. Some candidates recognised that the number of hydrogen atoms present suggested the presence of a carbon- carbon double bond, but suggested a straight chain compound. Other candidates provided a cyclic carboxylic acid. These two approaches were awarded one mark. The most common incorrect structure seen for G was butanoic acid.
			Total	7	

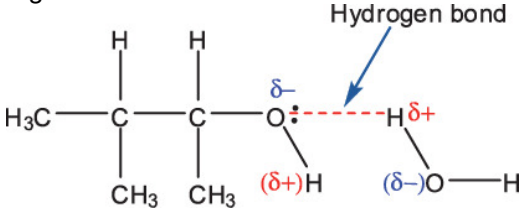
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
2		i	bond vibrates (more) OR bond bends (more) OR bond stretches (more) ✓	1	BOND essential IGNORE molecule vibrates / rotates Assume “It” refers to the molecule and is insufficient DO NOT ALLOW any reference to bond breaking DO NOT ALLOW a stated bond if not present in C and F e.g. C–O, C–H not present Examiner's Comments Most candidates identified that IR radiation would cause the bonds within the molecule to vibrate. However, there were many examples of vague responses such as ‘they vibrate’. Candidates are advised identify the subject of their statement and avoid the use of words such as ‘they’ and ‘it’ in their responses.
		ii	C_3C^+ ✓ CF_2C^+ ✓	2	ALLOW 1 mark for C_3C AND CF_2C/ <i>i.e. no + charge used</i> ALLOW 1 mark for C_3C^- AND CF_2C^- <i>i.e. — charge used on both</i> Examiner's Comments The majority of candidates identified the formulae of the two ions, although not all candidates specified the correct charge. Candidates should be aware that fragmentation in a mass spectrometer produces positive ions.
			Total	3	

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
3	a	QWC: Evidence of the IR absorption at 1720 (cm⁻¹) for presence of C=O / carbonyl group ✓ QWC: No carboxylic acid OH absorption in IR OR no peak between 2500–3300 cm⁻¹ AND so J is a secondary alcohol OR so K is a ketone ✓ Alcohol J $ \begin{array}{c} \text{OH} \quad \text{H} \\ \quad \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{CH}_3 \\ \quad \\ \text{H} \quad \text{CH}_3 \end{array} $ ✓✓ Compound K Structure of a carbonyl compound that could be obtained from alcohol J ✓ Equation Balanced equation for conversion of J to K ✓ e.g. $\text{CH}_3\text{CHOHCH}(\text{CH}_3)_2 + [\text{O}] \rightarrow \text{CH}_3\text{COCH}(\text{CH}_3)_2 + \text{H}_2\text{O}$	6	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC LOOK ON THE SPECTRUM for labelled peaks which can be given credit BOTH IR at ~ 1720 (cm⁻¹) AND C=O required ALLOW ranges from <i>Data Sheet</i>, i.e. C=O within range 1640–1750 cm⁻¹; IGNORE any reference to C-O absorption For structures of J and K, ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above IGNORE any names given for J and K ALLOW 1 mark for the structure of an alcohol with the molecular formula C₅H₁₂O DO NOT ALLOW pentan-1-ol (<i>primary and unbranched</i>) or 2-methylbutan-2-ol (<i>branched but tertiary</i>) DO NOT ALLOW any marks for J and K if more than one structure is given for J Note: ‘sticks’ in either J and / or K will lose only 1 mark ALLOW 1 mark for: $ \begin{array}{c} \text{O} \quad \text{H} \\ \quad \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{CH}_3 \\ \quad \\ \quad \text{CH}_3 \end{array} $ IF a structure is not given for J NOTE: structures for J and K could be awarded from the equation, even if not labelled. ALLOW molecular formulae in equation i.e. C₅H₁₂O + [O] → C₅H₁₀O + H₂O DO NOT ALLOW equations that form a carboxylic acid Examiner's Comments This question discriminated well and most

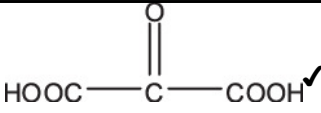
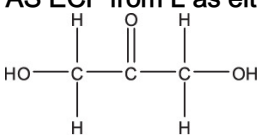
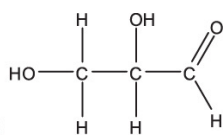
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					candidates were able to score at least one mark, by identifying the C=O peak in the IR spectrum provided. The most able candidates gave succinct responses that included both the correct structures of J and K as well as a balanced equation. In addition, they included reference to the absence of a carboxylic acid O-H peak in the IR spectrum concluding that K must be a ketone. This marking point was missed by a large proportion of the cohort and often a branched primary alcohol for J and corresponding aldehyde for K were suggested. Some candidates incorrectly identified the C—H peak in the spectrum as an O—H and suggested that K was a carboxylic acid.
	b		Labelled diagram showing at least one H-bond between alcohol molecule and water ✓ e.g. 	1	IF diagram is not labelled ALLOW Hydrogen bonds / H bonds from text Diagram should include role of an O lone pair and dipole charges on each end of H bond. IGNORE alcohol R group, even if wrong ALLOW structural OR displayed OR skeletal formula OR mixture of the above Examiner's Comments The majority of candidates were able to draw a diagram to show the hydrogen bond between an alcohol and water. However, a significant proportion lacked the accuracy required at this level and failed to show the role of the lone pair. It was also common to see responses that omitted the relevant dipoles. The question asked for the inclusion of relevant dipoles and lone pairs and candidates are advised to double check diagrams to ensure these key features are not neglected.
			Total	7	

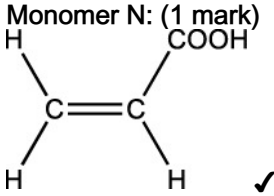
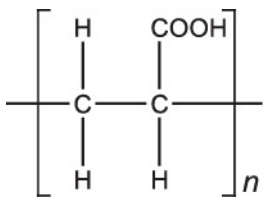
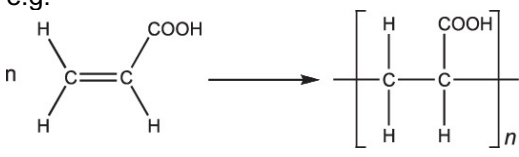
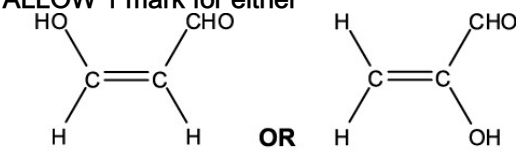
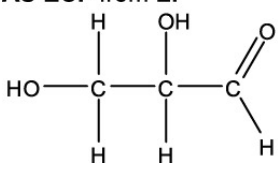
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
4	a		Mole ratio C : H : O is 3.33 : 6.67 : 3.33 ✓ Empirical formula is CH₂O ✓ Molecular formula is C₃H₆O₃ AND use of 90 OR 3 + 30 ✓	3	ALLOW $\frac{40.00}{12.0} : \frac{6.67}{1.0} : \frac{53.33}{16.0}$ ALLOW mass of C = 0.400 × 90 or 36 AND mass of H = 0.06677 × 90 or 6 AND mass of O = 0.5333 × 90 or 48 Examiner's Comments Almost all candidates were able to correctly calculate the empirical formula of L. Although the majority also deduced the correct molecular formula, not all included their working. A small, but significant, proportion of candidates omitted this part of the question. Candidates are advised to show all working when required.
	b		Evidence of carboxylic acid (1 mark) IR: 1550–1800 cm⁻¹ AND C=O / carbonyl AND 2300–3700 cm⁻¹ AND O–H in carboxylic acid ✓ Evidence of alcohol (1 mark) (broad) 3200–3700 cm⁻¹ linked to O–H in alcohol OR (is a primary) alcohol as oxidised (to a COOH) OR is an alcohol as it forms a carboxylic acid OR is an alcohol as water is eliminated. ✓ Identifications (2 marks)	5	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC LOOK ON THE SPECTRUM for labelled peaks which can be given credit ALLOW ranges from <i>Data Sheet</i>: C=O within range 1640–1750 cm⁻¹; (broad) O–H within range 2500–3300 cm⁻¹ (broad) O–H within range 3200–3550 cm⁻¹ For ALL structures: ALLOW correct structural OR skeletal OR displayed formula OR mixture of the above IGNORE names ----- FOR M: ALLOW 1 mark for

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	L: <pre> H H HO — C — C — COOH H H ✓ </pre> M: <pre> H HOOC — C — COOH H ✓ </pre> Equation (1 mark) $C_3H_6O_3 + 2[O] \rightarrow C_3H_4O_4 + H_2O$ ✓		 AS ECF from L as either  OR  Equation: $C_3H_6O_3 + 4[O] \rightarrow C_3H_2O_5 + 2H_2O$ ✓ ----- ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above in equation Examiner's Comments This question allowed candidates to demonstrate their knowledge and problem solving skills to tie together all the evidence provided. It was common to see candidates identify the ranges of the characteristic peaks for a carboxylic acid in the IR spectrum but a significant proportion did not identify the relevant bond that each peak referred to. Many candidates interpreted the flowchart given at the start of the question to comment on the presence of an alcohol group in L, and using their molecular formula from part (a), deduced structures for both L and M. The strongest candidates were also able to provide a correctly balanced equation for the formation of M. The most common incorrect structure for L was 1,3-dihydroxypropanone, however, error carried forward marks were awarded to candidates who provided the corresponding dicarboxylic acid as the oxidation product M.

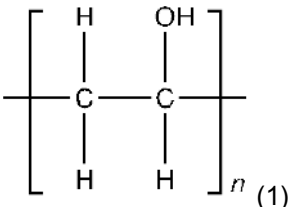
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
c	Monomer N: (1 mark)  Polymer P: (1 mark) Section showing at least one repeat unit of a polymer formed from N with side links ✓ e.g.  Repeat units (1 mark) $n = 10000/72 = 139$ ✓ Equation (1 mark) Balanced equation for formation of P from N ✓ e.g. 	4	For ALL structures: ALLOW correct structural OR skeletal OR displayed formula OR mixture of the above IGNORE names ALLOW 1 mark for either  AS ECF from L:  ----- For P: ALLOW ECF from an alkene with molecular formula $C_3H_4O_2$ ALLOW one or more repeat units but has to have a whole number of repeat units ALLOW repeat unit with no brackets and absence of n MUST be a whole number. ALLOW 138 OR 140 ----- For equation, ALLOW molecular OR structural OR skeletal OR displayed formulae OR mixture of the above e.g. ALLOW $nC_3H_4O_2 \rightarrow (C_3H_4O_2)_n$ n on LHS can be at any height to the left of formula AND n on the RHS must be a subscript (essentially below the side link if displayed / skeletal formula is used)

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					ALLOW use of calculated value for n in equation e.g. $139\text{C}_3\text{H}_4\text{O}_2 \rightarrow (\text{C}_3\text{H}_4\text{O}_2)_{139}$ Examiner's Comments This was a very demanding question and the strongest candidates were able to identify both N and P in addition to calculating the number of repeat units the polymer. However, not all included the polymerisation equation. Some candidates who were unable to deduce a correct structure for L in part (b) approached this part as a 'fresh start'. Using both the molecular formula from (a) and the information in the flowchart worked out the molecular formula of N and built a response from there.
			Total	12	
5			(broad) peak at 3300–3600 (cm^{-1}) for O–H (therefore A or C) (1) molar ratio: C : H : O $\frac{78.94}{12.0} : \frac{10.53}{1.0} : \frac{10.53}{16.0}$ OR 6.58 : 10.53 : 0.658 (1) 10 : 16 : 1 OR $\text{C}_{10}\text{H}_{16}\text{O}$, therefore C (1)	3	allow 3200–3600 cm^{-1} ignore references to the peak at ~2900 for C–H allow annotation of the spectrum to identify the bond responsible for the peak instead of quoting the wavenumber. Conclusion may also follow from empirical formula followed by IR data.
			Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
6			I = $\text{C}_4\text{H}_{10}^+$ (1) II = C_3H_7^+ (1) III = C_2H_5^+ (1) C_3H_7^+ could be $\text{CH}_3\text{CH}_2\text{CH}_2^+$ or $\text{CH}_3\text{CHCH}_3^+$ OR C_3H_7^+ could be from $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$ or $\text{CH}_3\text{CH}(\text{CH}_3)_2$ (1) CH_3CH_2^+ could only be from $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$ (1)	5	THROUGHOUT: if any charge is missing, do not allow 1st formula but allow subsequent formulae by ecf allow + charge anywhere
			Total	5	
7		i	 $\left[\begin{array}{cc} \text{H} & \text{OH} \\ & \\ -\text{C} & - & \text{C}- \\ & \\ \text{H} & \text{H} \end{array} \right]_n$ (1)	1	
		ii	Evidence against ethenol: No infrared absorption between 3200 and 3600 cm^{-1} from O–H (1) ii Evidence for isomer: Infrared absorption between 1640 and 1750 cm^{-1} indicates C=O (1) Mass spectrum: fragmentation peak at $m/z = 29$ suggests CHO^+ OR fragmentation peak at $m/z = 15$ suggests CH_3 (1) Identification: Ethanal / CH_3CHO (1)	4	ignore molecular ion peak at m/z confirms molecular mass of 44 g mol^{-1}
			Total	5	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
8	<i>* Please refer to the marking instruction point 10 for guidance on how to mark this question.</i> (Level 3) Candidate provides a method for identifying the alcohols AND provides all supporting evidence from IR spectrum AND gives details of reagents and conditions and correct equations. <i>The explanation is detailed and well structured. The information is clearly supported by details of reactions and evidence of oxidation product.</i> (5–6 marks) (Level 2) Candidate provides a basic method AND provides some supporting evidence from IR spectrum AND gives details of reagents and conditions with some attempt at equations. <i>The explanation has some structure. The information is supported by some details of reactions and evidence from IR spectrum.</i> (3–4 marks) (Level 1) Candidate attempts to describe a basic method AND gives some supporting evidence from IR spectrum OR details of reagents and conditions with some attempt at equations. <i>The explanation is basic and lacks structure. The information is supported by limited evidence from the reactions and oxidation products and would not lead to identification.</i> (1–2 marks)	6	Indicative scientific points may include Identification of alcohols Based on recognition of alcohols as primary, secondary and tertiary (stated or implied by method). Basic procedure involves reflux followed by use of IR to identify different oxidation products. Reactions - stated reagents ($\text{H}^+/\text{Cr}_2\text{O}_7^{2-}$ and conditions (reflux)) - equations using [O] including structural formulae $\text{CH}_3\text{CH}_2\text{CHOHCH}_3 + [\text{o}] \rightarrow \text{CH}_3\text{CH}_2\text{COCH}_3 + \text{H}_2\text{O}$ $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + 2[\text{o}] \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{COOH} + \text{H}_2\text{O}$ Identification of oxidation product - IR: carboxylic acid from broad OH absorption and C=O - IR: carbonyl / ketone from C=O and no OH - tertiary alcohol from lack of C=O and OH peak in IR OR no colour change in reflux.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			No response or no response worthy of credit. (0 marks)		
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance																				
9			<i>Please refer to marking instructions on page 4 of mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) A comprehensive description with all three scientific points explained thoroughly. C identified as a carboxylic acid containing four carbon atoms linked to the peak in the mass spectrum at 43. <i>The explanation makes use of all the evidence including the secondary carbocation in justifying the correct structure of C.</i> Level 2 (3–4 marks) Attempts all three scientific points but explanations may be incomplete. OR Explains two scientific points thoroughly with few omissions. <i>The analysis is clear and includes some interpretation o IR and MS peaks.</i> Level 1 (1–2 marks) A simple explanation based on at least two of the main scientific points. OR Explains one scientific point thoroughly with few errors. <i>The analysis is communicated in an unstructured way and includes interpretation of peaks from IR OR MS spectrum</i> 0 marks – No response worthy of credit.	6	LOOK ON THE SPECTRA for labelled peaks. Indicative scientific points may include: 1. Molecular formula <table><tr><td>Element</td><td>% mass</td><td>Ar</td><td>moles</td><td>ratio</td></tr><tr><td>C</td><td>54.5</td><td>12</td><td>4.54</td><td>2</td></tr><tr><td>H</td><td>9.1</td><td>1</td><td>9.1</td><td>4</td></tr><tr><td>O</td><td>36.4</td><td>16</td><td>2.28</td><td>1</td></tr></table> - empirical formula = C₂H₄O - molecular ion peak <i>m/z</i> or Mr = 88 - molecular formula = C₄H₈O₂ 2. Infrared spectrum - peak at 2500-3500 (cm⁻¹) is O–H - peak at 1630-1820 (cm⁻¹) is C=O - C is a carboxylic acid ALLOW stated values within the ranges above IGNORE references to C–O peaks 3. Identifying the carboxylic acid (CH₃CH₂CH₂COOH OR (CH₃)₂CHCOOH) - Mass spectrum peak at <i>m/z</i> = 43 = C₃H₇(⁺) - secondary carbocation: CH₃C⁺HCH₃ - compound C: (CH₃)₂CHCOOH IGNORE name of carboxylic acid if structure given Examiner's Comments The final question on the paper was a six mark level of response question which required candidates to identify a molecule	Element	% mass	Ar	moles	ratio	C	54.5	12	4.54	2	H	9.1	1	9.1	4	O	36.4	16	2.28	1
Element	% mass	Ar	moles	ratio																					
C	54.5	12	4.54	2																					
H	9.1	1	9.1	4																					
O	36.4	16	2.28	1																					

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					from a range of data. Most candidates were able to process the percentage composition data to arrive at an empirical formula but less able candidates then failed to use the data from the mass spectrum to arrive at the molecular formula. Candidates were generally able to use the infrared spectrum to identify the presence of –OH and C=O and could link this to the carboxyl functional group. The best candidates were able to identify the peak in the mass spectrum at 43 and to link this to a C_3H_7^+ fragment which led to the assumption that the carboxylic acid was butanoic acid. Many outstanding candidates were able to discuss the peak at 43 being that of a branched chain secondary carbocation and linked this to the correct branched product. Some answers were unstructured and disorganised and candidates should be encouraged when analysing data to organise their answer sequentially and discuss each piece of data in turn.
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
10		i	Evidence that 84 (M^+ peak) = 6×14 (mass of CH_2) ✓ e.g. $\frac{84}{14} = 6$	1	IGNORE use of molecular formula e.g. $(6 \times 12) + (12 \times 1) = 84$ (<i>use of empirical formula required</i>) Examiner's Comments This question required candidates to use the m/z value for the molecular ion peak and the mass of the empirical formula to confirm the molecular formula of the alkene as C_6H_{12}. The most common method employed was to divide 84 by 14 to show that the molecular formula contained 6 empirical formula units. Although many candidates scored this mark, a significant proportion neglected to use the empirical formula and simply showed that the Mr of C_6H_{12} was equal to 84. Candidates should be encouraged to take note of all the supplementary information provided with a question, as it is likely to be required in the response.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	<i>Structures of species 2 marks</i> peak I $\text{CH}_3\text{CH}=\text{CH}$ ✓ peak II $\text{CH}_3\text{CH}=\text{CHCH}_2\text{CH}_2$ OR $\text{CH}=\text{CHCH}_2\text{CH}_2\text{CH}_3$ ✓ + charge on BOTH CORRECT species 1 mark $\text{CH}_3\text{CH}=\text{CH}^+$ AND $\text{CH}_3\text{CH}=\text{CHCH}_2\text{CH}_2^+$ ✓ peak I peak II	3	ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above ALLOW 1 mark if both correct structures are shown but in the incorrect columns ALLOW 1 mark for both correct structures if one or both have an 'end bond' ALLOW 1 mark for BOTH molecular formulae correct C_3H_5 AND C_5H_9 peak I peak II ALLOW 'charge mark' for + charge on BOTH fragments with correct molecular formulae ALLOW 'charge mark' for + charge on BOTH CORRECT molecular formulae ALLOW + change anywhere in structures OR outside brackets Examiner's Comments In general the attempts at this question were good, and the majority of candidates chose to show the fragments as displayed formulae. A common incorrect response for the fragment that gave rise to peak I was $\text{CH}_3\text{CH}_2\text{C}$. Some candidates failed to show the positive charge on each fragment, although this was less common than in previous sessions.
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
11	a		<i>Empirical / molecular formula 3 marks</i> Mole ratio C : H : Br is 2.44 : 5.70 : 0.814 ✓ (Empirical formula) = C₃H₇Br ✓ QWC (Molecular formula) = C₃H₇Br AND relative mass linked to 150 evidence ✓ <i>Structural isomers 2 marks</i> CH₃CH₂CH₂Br ✓ CH₃CHBrCH₃ ✓	5	ANNOTATE ANSWER WITH TICKS AND CROSSES ALLOW $\frac{29.29}{12.0} : \frac{5.70}{1.0} : \frac{65.01}{79.9}$ Evidence could include a calculation of the relative mass of C₃H₇Br as 122.9 linking to M_r being less than 150 ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous) DO NOT ALLOW missing H atom(s) in a displayed formula for one structure but ALLOW missing H atoms in subsequent structure Note: structures from an incorrect molecular formula will be credited on their merits. Please consult TL for advice on how to mark the subsequent parts of this question Examiner's Comments Calculation of empirical formula has always been a strength of candidates at this level. Consequently the vast majority were able to deduce the structures of the two isomers correctly. A significant number of candidates failed to secure full marks as they did not link the M_r of the empirical formula with the information about the M_r of the isomers being less than 150. Some candidates tried to use the value of 150 to determine the formula of C and D, ultimately ending up with an incorrect answer. However, error carried forward marks were allowed through subsequent parts of this question where appropriate.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b	i	<i>Infrared for G 2 marks</i> 1700 cm⁻¹ AND C=O/carbonyl group ✓ (broad) 2300–3600 cm⁻¹ AND O–H in carboxylic acid ✓ <i>Structures 3 marks</i> CH₃CH₂CH₂OH ✓ CH₃CHOHCH₃ ✓ CH₃CH₂COOH ✓	6	ANNOTATE ANSWER WITH TICKS AND CROSSES LOOK ON THE SPECTRUM for labelled peaks which can be given credit ALLOW ranges from <i>Data Sheet</i>: C=O within range 1640–1750 cm⁻¹; (broad) O–H within range 2500–3300 cm⁻¹ ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous) ALLOW CH₃CH₂CO₂H for carboxylic acid IGNORE names IGNORE labels DO NOT ALLOW missing H atom(s) in a displayed formula for one structure but ALLOW missing H atoms in subsequent structures

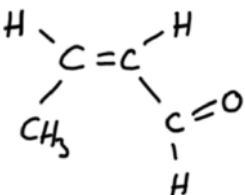
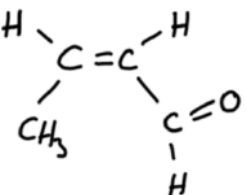
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Question			Answer/Indicative content	Marks	Guidance
		i	<i>Equation for formation of G 1 mark</i> $\text{C}_3\text{H}_8\text{O} + 2[\text{O}] \rightarrow \text{C}_3\text{H}_6\text{O}_2 + \text{H}_2\text{O} \checkmark$		ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above in equation Examiner's Comments Candidates were well prepared for a structural determination question and examiners were encouraged by the number of high quality of responses to this question. Most candidates were able to interpret the key peaks in the IR spectrum and identified the O-H bond of a carboxylic acid and C=O bond accurately. Most candidates identified all three structures correctly. Only the strongest responses included a correct equation for the formation of G by oxidation of E. Many responses failed to include this and others often had H₂ as the inorganic product. Candidates are advised to revise oxidation reactions of alcohols thoroughly as it is often the case that incorrect equations are frequently seen in responses to exam questions.
		ii	2 marks for correct ester. $\text{CH}_3\text{CH}_2\text{COOCH}(\text{CH}_3)_2 \checkmark\checkmark$ Award 1 mark for: $\text{CH}_3\text{CH}_2\text{COOCH}_2\text{CH}_2\text{CH}_3$ OR Ambiguous ester: $\text{CH}_3\text{CH}_2\text{COOC}_3\text{H}_7 \checkmark$	2	ANNOTATE ANSWER WITH TICKS AND CROSSES ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous) ALLOW $\text{C}_2\text{H}_5\text{CO}_2\text{CH}(\text{CH}_3)_2$ IF there is one bond and its H missing from the correct ester award 1 mark Examiner's Comments Most candidates were able to show the structure of the ester formed from propanoic acid (G and propan-2-ol (F) correctly. Some candidates used the incorrect alcohol, propan-1-ol (E) and such responses received only one of the two marks available.

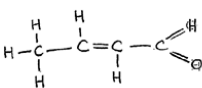
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Question			Answer/Indicative content	Marks	Guidance
			Total	13	
12			B	1	Examiner's Comments Just over half of the candidates identified the correct alcohol. The common incorrect answer was C.
			Total	1	
13			A	1	Examiner's Comments Fewer than half the candidates obtained the correct alcohol (A). The common incorrect answer was C.
			Total	1	

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance																				
14		<i>Please refer to the marking instructions on page 5 of the mark scheme for guidance on how to mark this question.</i> Level 3 (5-6 marks) A comprehensive description including most of the evidence to justify the correct structure of F (accept <i>cis</i> or <i>trans</i>). <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) The candidate attempts all three scientific points, but explanations are incomplete. OR Explains two scientific points thoroughly with few omissions. AND an attempt at a feasible structure based on deduction from correct molecular formula <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) The correct empirical formula AND a simple description based on at least one of the main scientific points. OR The candidate explains one scientific point thoroughly with few omissions. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 No response or no response worthy marks of credit.	6	LOOK AT THE SPECTRA for labelled peaks Indicative scientific points may include: <u>Empirical formula</u> - empirical formula = C₄H₆O <table><thead><tr><th>element</th><th>% mass</th><th>Ar</th><th>moles</th><th>ratio</th></tr></thead><tbody><tr><td>C</td><td>68.6</td><td>12</td><td>5.72</td><td>4</td></tr><tr><td>H</td><td>8.6</td><td>1</td><td>8.60</td><td>6</td></tr><tr><td>O</td><td>22.8</td><td>16</td><td>1.43</td><td>1</td></tr></tbody></table> <u>IR and spectra and molecular formula</u> - infrared absorption; 1630–1820 cm^{–1}, due to C=O (aldehyde/ketone/carbonyl group) - molar mass = 70 g mol^{–1} (mass spectrum molecular ion peak <i>m/z</i> = 70) - molecular formula = C₄H₆O <u>Functional groups, structure and stereochemistry</u> - alkene / C=C - aldehyde / –CHO (C₃H₅⁺ fragment) - mass spectrum; peak at 41 due to C₃H₅⁺ (loss of CHO) <i>E/Z</i> or <i>cis-trans</i> isomer: <i>E/Z</i> or <i>cis-trans</i> isomer:  <i>cis</i>  <i>trans (correct structure)</i> <u>Examiner's Comments</u> This question was a good discriminator. Most candidates were able to deduce the empirical formula and the C=O peak on the IR spectrum. However, many mistook the C-H peaks around 3000 cm^{–1} for an	element	% mass	Ar	moles	ratio	C	68.6	12	5.72	4	H	8.6	1	8.60	6	O	22.8	16	1.43	1
element	% mass	Ar	moles	ratio																				
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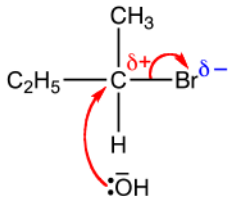
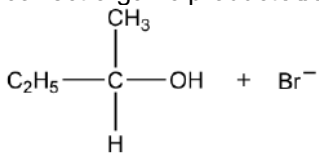
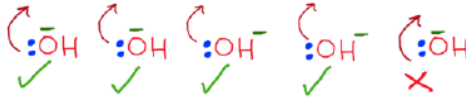
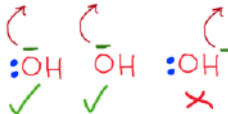
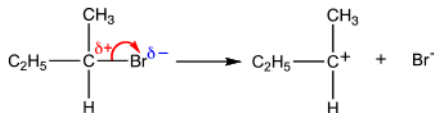
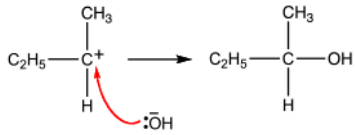
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			alcohol O-H peak or assumed from the empirical formula that it was an alcohol so made the spectra 'fit' their hypothesis. At AS, the exposure of candidates to IR and MS spectra is not as comprehensive as in the second year of A Level and this was evident. There was very little annotation of the spectra and candidates should be encouraged to do this as it is helpful to them in their deductions (and to the examiners for crediting marks). Analysis of the IR spectrum was much more detailed than the mass spectrum. Most candidates just referred to the molecular ion peak and made no attempt, or an incorrect attempt, at discerning the peak at 41. Those that did quickly realised what the structure was and gained 5 or 6 marks. Some candidates, despite ascertaining that a <i>trans</i> stereoisomer should be drawn, drew the <i>cis</i> version instead. Exemplar 5 In the mass spectrum, the peak with the greatest relative intensity is caused by the loss of a functional group from the molecular ion of compound F. Determine the structure of compound F. Explain your reasoning and show your working. $C : H : O = 68.6 : 8.6 : 22.8$ $= 12 : 1 : 16$ $= 5.716 : 8.6 : 1.425$ $= 4.011 : 6.03 : 1$ Empirical formula of compound F is C_4H_6O. The M^+ peak on mass spectrum ~~is~~ ^{has} at an m/z value of 70, so the molecular mass of compound F is 70 g mol^{-1}, so the molecular formula of compound F is C_4H_6O. The infrared spectrum shows an absorbance peak at in the range $1630-1820 \text{ cm}^{-1}$, indicating the presence of a $C=O$ bond. There is no absorbance peak in the range $2500-3300 \text{ cm}^{-1}$ so there is no O-H bond, so compound F is not a carboxylic acid. Compound F is not a carbonyl compound. The mass spectrum shows a fragmentation peak at 41 m/z, indicating the presence of a CH_2CHCH^+ fragment from the loss of 10 a CHO functional group. Compound F is an aldehyde. It is a <i>trans</i> stereoisomer, so the hydrogens attached to the carbons on the double bond are opposite each other. 

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					Exemplar 6 Explain your reasoning and show your working. <table><tr><td>C</td><td>H</td><td>O</td></tr><tr><td>68.6</td><td>8.6</td><td>22.8</td></tr><tr><td><u>2</u></td><td><u>1</u></td><td><u>16</u></td></tr></table> = 9.76 : 8.6 : 1.425 = 4.0 : 6.0 : 1 empirical formula = C_4H_6O Mr : $(12 \times 4) + (6 \times 1) + (16) = 70$ F Mr = 70 → molecular formula = ~~C_4H_6O~~ Peak at 2.9 → ~~$CH_2=CH$~~ } mass spectrum. Peak at 41 → $H_2C=CH_2CH_2S$ IR Spectrum → Peak at 1630-1820 indicates the presence of a C=O group → Peak at 1620 → 1630 indicates the presence of a C=C group. Structure = Like most candidates, the crucial information about F being a <i>trans</i> isomer was not picked up so they drew the double bond in the wrong place.	C	H	O	68.6	8.6	22.8	<u>2</u>	<u>1</u>	<u>16</u>
C	H	O												
68.6	8.6	22.8												
<u>2</u>	<u>1</u>	<u>16</u>												
			Total	6										
15			D	1	Examiner's Comments Overall, candidates answered this question well with many selecting the correct response of D. From scripts, successful candidates drew vertical lines to isolate likely fragments.									
			Total	1										

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16	i ANNOTATE ANSWER WITH TICKS AND CROSSES ----- Curly arrows 2 marks curly arrow from OH⁻ to C atom of C-Br bond ✓ dipole shown on C-Br bond, C^{δ+} and Br^{δ-}, AND curly arrow from C-Br bond to Br atom  IGNORE incorrect R groups for curly arrow marks IGNORE presence of Na⁺/Na but OH⁻ needed i.e. Na⁺OH⁻; NaOH⁻ can be allowed with correct use of curly arrow ----- Products 1 mark correct organic product AND Br⁻ ✓  IGNORE presence of Na⁺ but Br⁻ needed i.e. Na⁺Br⁻/NaBr⁻ can be allowed BUT NaBr does NOT show Br⁻ NOTE: curly arrows can be straight, snake-like, etc. but NOT double headed or half headed arrows	3	1st curly arrow must - go to the C of C-Br AND - start from, OR be traced back to any point across width of lone pair on O of OH⁻  OR start from - charge on O of ⁻OH ion  (Lone pair NOT needed if curly arrow shown from O⁻) 2nd curly arrow must start from, OR be traced back to, any part of C-Br bond and go to Br  ----- ALLOW S_N1 mechanism for 2 curly arrow marks First mark Dipole shown on C-Br bond, C^{δ+} and Br^{δ-}, AND curly arrow from C-Br bond to Br atom  Second mark Curly arrow from OH⁻ AND to correct carbocation  Use curly arrow criteria in guidance above Examiner's Comments As with 25(a)(i), this question rewarded the

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			well-prepared candidate. The large number of proposed mechanisms showed little resemblance to the accepted mechanism for nucleophilic substitution. Mechanisms were often seen showing curly arrows going in the wrong direction and between the wrong bonds and atoms, charges and dipoles were often incorrect, and partial charges used where full charges were required. Two exemplars are shown. The first exemplar shows clear curly arrows, the role of the lone pair and all charges correct. The second exemplar shows a typical muddled response. Although the curly arrow from the hydroxide ion has been accurately drawn, the hydroxide ion has a partial charge rather than a $-$ charge. There is also no curly arrow showing breaking of the C–Br bond. The only mark available is for the correct organic product and a Br^- ion. Some mechanisms were so poor that it was impossible to credit many candidates with any marks. Writing mechanisms is an important skill in organic chemistry and it is recommended that candidates learn and practice their writing. Exemplar 7 (b) An alcohol can be prepared by hydrolysing the haloalkane $\text{C}_2\text{H}_5\text{CHBrCH}_3$ with aqueous sodium hydroxide. (i) Outline the mechanism for this reaction. Show curly arrows and relevant dipoles. [3] Exemplar 8

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					(b) An alcohol can be prepared by hydrolysing the haloalkane $C_2H_5CH_2BrCH_3$ with aqueous sodium hydroxide. (i) Outline the mechanism for this reaction. Show curly arrows and relevant dipoles. [3]
	ii		Disappearance of peak at $500-800\text{ cm}^{-1}$ OR C–Br peak ✓ Appearance of peak at $3200-3600\text{ cm}^{-1}$ OR alcohol O–H peak	2	ALLOW value within range $500-800\text{ cm}^{-1}$ ALLOW value within range $3200-3600\text{ cm}^{-1}$ DO NOT ALLOW responses that only describe the spectrum shown <u>Examiner's Comments</u> This part discriminated very well with able candidates identifying that the absorption for the C–Br bond would disappear, with a new peak appearing for the alcohol O–H bond. A significant number of candidates did not seem to understand what was required, with many interpreting the spectrum as that of the alcohol, rather than predicting how the spectrum would change during the reaction. A common error was to interpret the absorption for a C–H bond at $\sim 3000\text{ cm}^{-1}$ as that of an O–H bond.
			Total	5	
17			D	1 (AO1.1)	<u>Examiner's Comments</u> Less than half the candidates correctly chose option D. This part discriminated well, with less able candidates selecting the incorrect A and C in similar amounts. A small number of candidates selected B.
			Total	1	

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18			A	1 (AO2.5)	<u>Examiner's Comments</u> Candidates found this part difficult. Less than half the candidates selected the correct option A, with 'B' being the main distractor. From annotations on scripts, successful candidates often drew rings around parts of the structures which helps in identifying parts of a structure that might fragment.
			Total	1	
19			B	1 (AO2.5)	<u>Examiner's Comments</u> Able candidates selected option B, identifying that the O–H peak matches an alcohol rather than carboxylic acid from the wavenumbers. Many candidates opted for option A, the carboxylic acid, which would have a much broader O–H peak with slightly lower wavenumber range. Annotations were common on the spectrum and a sizeable number labelled the C–H peak with O–H, a clear misconception which was also mentioned in the report for H032/01 from June 2018.
			Total	1	

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20	a	i	Molecular mass ✓	1(AO1.1)	IGNORE 'relative' IGNORE 'molecular ion' alone, answer must relate to mass ALLOW M_r / molar mass <u>Examiner's Comments</u> This was generally well answered. The most common incorrect answer was atomic mass.
		ii	Y: $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2^+$ ✓ Z: $\text{CH}_3\text{CH}_2\text{CH}_2^+$ ✓ <i>If positive charge is missing but the structures of Y AND Z are correct, award one mark</i>	2(AO3.2×2)	FOR ONE MARK ALLOW $\text{C}_5\text{H}_{11}^+$ AND C_3H_7^+ ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous <u>Examiner's Comments</u> Most students gained one mark on this question as they omitted the + sign or wrote the molecular formula instead of the structural formula.
	b	i	✓	1(AO1.1)	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous <u>Examiner's Comments</u> This was well answered by most candidates

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		ii	Similarity Both have a peak at ($m/z =$) 198 (X) OR 71 (Y) OR 29 ✓ Difference 2-iodo-2-methylbutane has no peak at ($m/z =$) 43 (Z) ✓	2(AO3.2× 2)	ALLOW same molecular ion peak / M_r IGNORE statements where no specific ion peak is suggested e.g. “different ion peaks” <u>Examiner’s Comments</u> Most candidates answered the similarity part correctly, many wrote vague answers to the difference and were not specific. A common error focused on the peak at $m/z = 71$, very few recognised that the Z peak at 43 would not be present for 2-iodo-2-methylbutane
			Total	6	