

OCR A - LEVEL CHEMISTRY A • H432

CHEMISTRY



EXAM QUESTION PACK

4.2.1-4.2.2 ALCOHOLS AND HALOALKANES

SCORE

/191

PERCENTAGE

%

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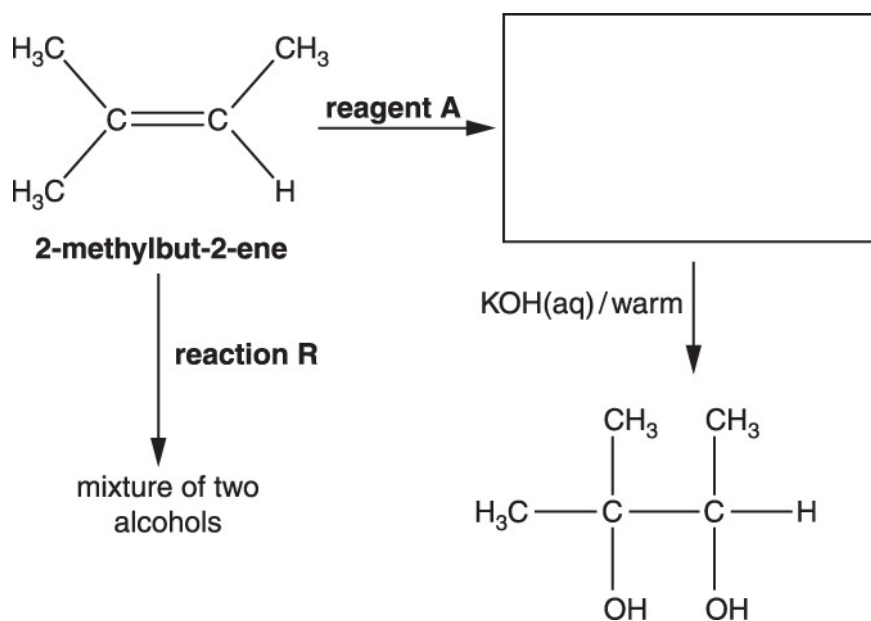
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1(a) The flowchart shows how 2-methylbut-2-ene can be converted into a number of organic products.

Complete the flowchart by drawing an organic structure in the box below.



(b) Identify reagent A.

[1]

[1]

(c) In the flowchart, **reaction R** forms a mixture of two alcohols that are structural isomers of $C_5H_{12}O$.

(i) State the reagents and conditions needed for **reaction R**.

-----[1]

(ii) What is meant by the term *structural isomers*?

-----[1]

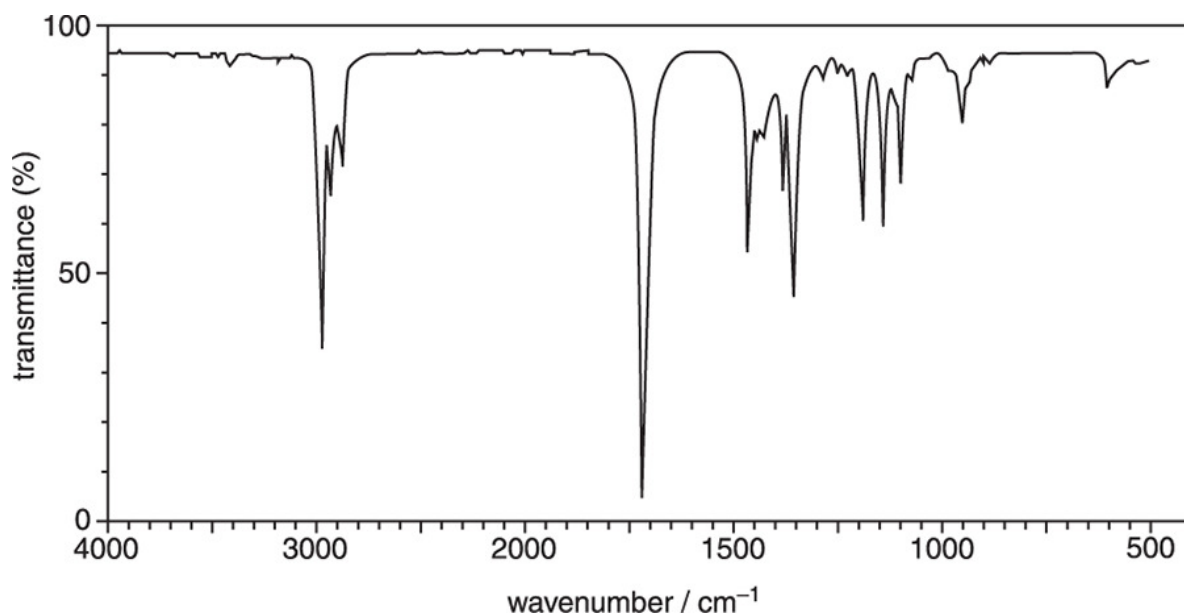
(iii) Draw the two structural isomers of $C_5H_{12}O$ formed in **reaction R**.

[2]

(iv) Suggest why 2-methylbut-2-ene is less soluble in water than either of the structural isomers formed.

-----[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 Which volume of oxygen gas, at room temperature and pressure, is required for complete combustion of 1.25×10^{-3} mol of propan-1-ol?

- A 105 cm^3
- B 120 cm^3
- C 135 cm^3
- D 120 cm^3

Your answer

[1]

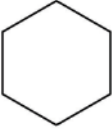
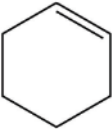
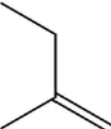
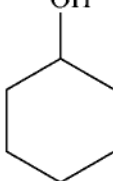
5 Which alcohol will **not** react with potassium dichromate(VI) in sulfuric acid?

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

Your answer

[1]

6(a) The organic compounds in the table below can be termed, aliphatic, alicyclic or aromatic.

E 	F 	G 
H 	I 	J 

Identify, using letters E, F, G, H, I, J, the compound(s) which are the following types.

Each response may contain more than one letter.

aliphatic _____

alicyclic _____

aromatic _____

[3]

(b) Compound I has one alkyl group.

What is the general formula of alkyl groups?

_____ [1]

(c) Compound H can be prepared in an elimination reaction by heating compound J with an acid catalyst.

A student carries out this preparation using 7.65 g of compound J.

The student obtains 2.05 g of compound H.

(i) Write an equation for this reaction, using molecular formulae.

Calculate the percentage yield of compound H.

Give your answer to **one** decimal place.

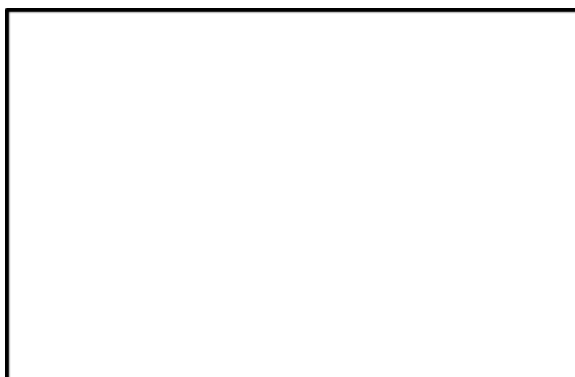
percentage yield = _____ % [4]

- (ii) Describe a simple test that the student could carry out to confirm the presence of the functional group in compound H.

Draw the structure of the organic product from the test.

test: _____

organic product =



[2]

7(a) Alcohols can be converted into haloalkanes in a substitution reaction.

Plan an experiment to prepare approximately 0.1 mol of 2-bromopentane, $\text{CH}_3\text{CHBrCH}_2\text{CH}_2\text{CH}_3$, from pentan-2-ol, $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_2\text{CH}_3$.

Your plan should include a calculation of the mass of alcohol required and details of the chemicals to be used in the reaction.

----- [2]

(b) * Alcohols can be converted into alkenes in an elimination reaction.

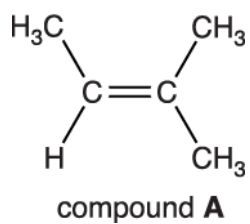
The elimination of H_2O from pentan-2-ol forms a mixture of organic products.

Give the names and structures of all the organic products in the mixture.

Your answer should explain how the reaction leads to the different isomers.

----- [6]

9 Compound **A** is an alkene.



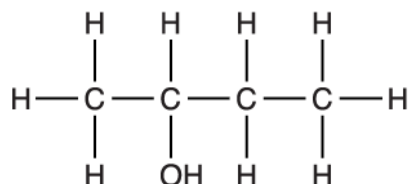
Compound **A** can be made from alcohol **B** by heating with an acid catalyst.

Suggest **two** possible structures for alcohol **B** .

--	--

[2]

10(a) This question is about the properties and reactions of butan-2-ol.



Some properties of butan-2-ol are listed in the table.

Melting point	-115 °C
Boiling point	99.5 °C

Why is butan-2-ol classified as a secondary alcohol?

----- [1]

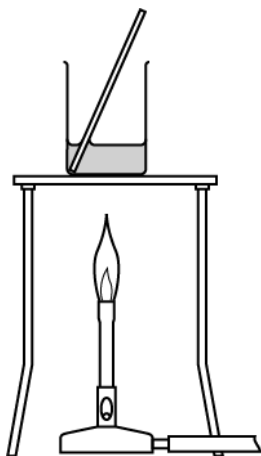
(b) Butan-2-ol can be oxidised by heating with an oxidising agent.

(i) Write an equation for the reaction.

Use [O] to represent the oxidising agent and show the structure of the organic product.

[2]

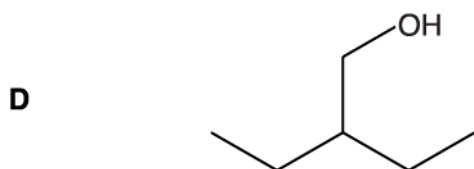
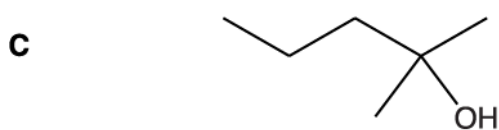
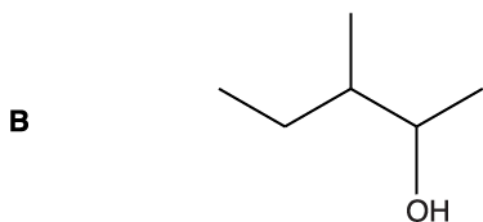
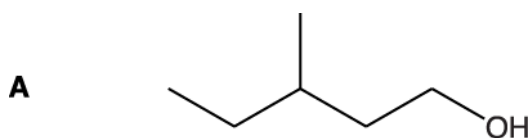
(ii) A student plans to carry out this oxidation using the apparatus shown in the diagram.



Give **one** reason why the apparatus is **not** suitable and describe a more suitable way of carrying out this oxidation.

----- [2]

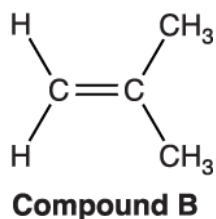
11 Which alcohol can be oxidised by $\text{K}_2\text{Cr}_2\text{O}_7$ and H_2SO_4 to form a ketone?



Your answer ☐

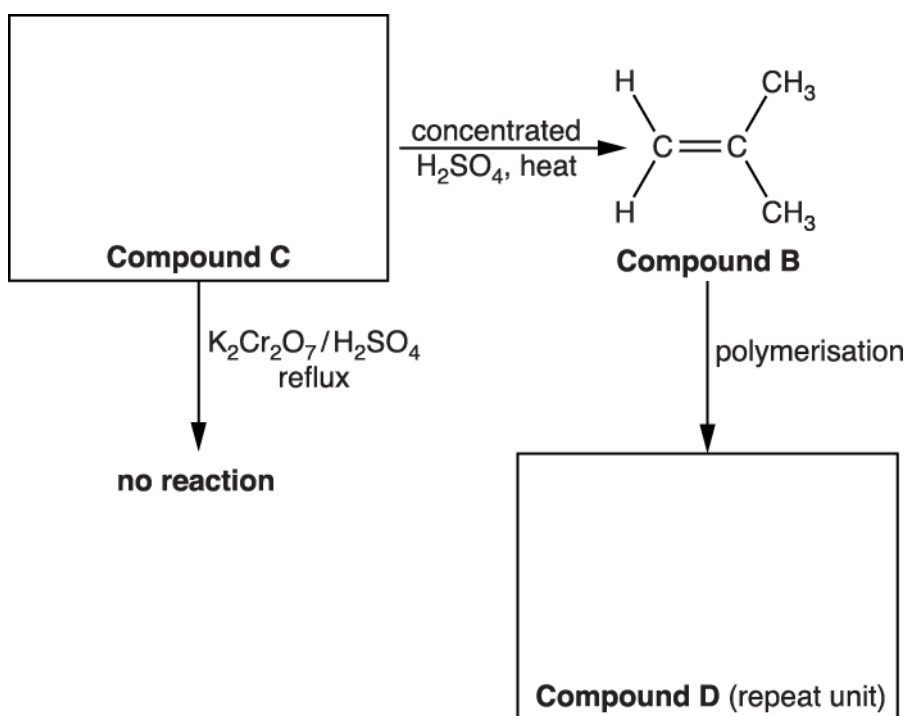
[1]

12 Compound **B**, shown below, can be used to synthesise organic compounds with different functional groups.



Some reactions involving compound **B** are shown in the flowchart below.

Complete the flowchart, showing the structures of organic compounds **C** and **D**.



[2]

13(a) At room temperature and pressure, the first four members of the alkanes are all gases but the first four alcohols are all liquids.

Explain this difference in terms of intermolecular forces.

----- [2]

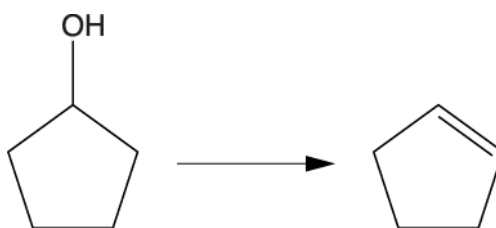
(b) The boiling points of 2-methylpropan-1-ol and butan-1-ol are shown below.

Alcohol	Boiling point / °C
2-methylpropan-1-ol	108
butan-1-ol	117

Explain why the boiling points are different.

----- [2]

- (c) Alkenes can be prepared from alcohols. Cyclopentene can be prepared from cyclopentanol as shown in the equation below.



A student plans to prepare 5.00 g of cyclopentene from cyclopentanol. The percentage yield of this reaction is 45.0%.

- (i) What is the name of this type of reaction?

-----[1]

- (ii) Calculate the mass of cyclopentanol that the student should use.

Show your working.

mass of cyclopentanol = ----- g [3]

14 Which alcohol reacts with an acid catalyst to form *E* and *Z* stereoisomers?

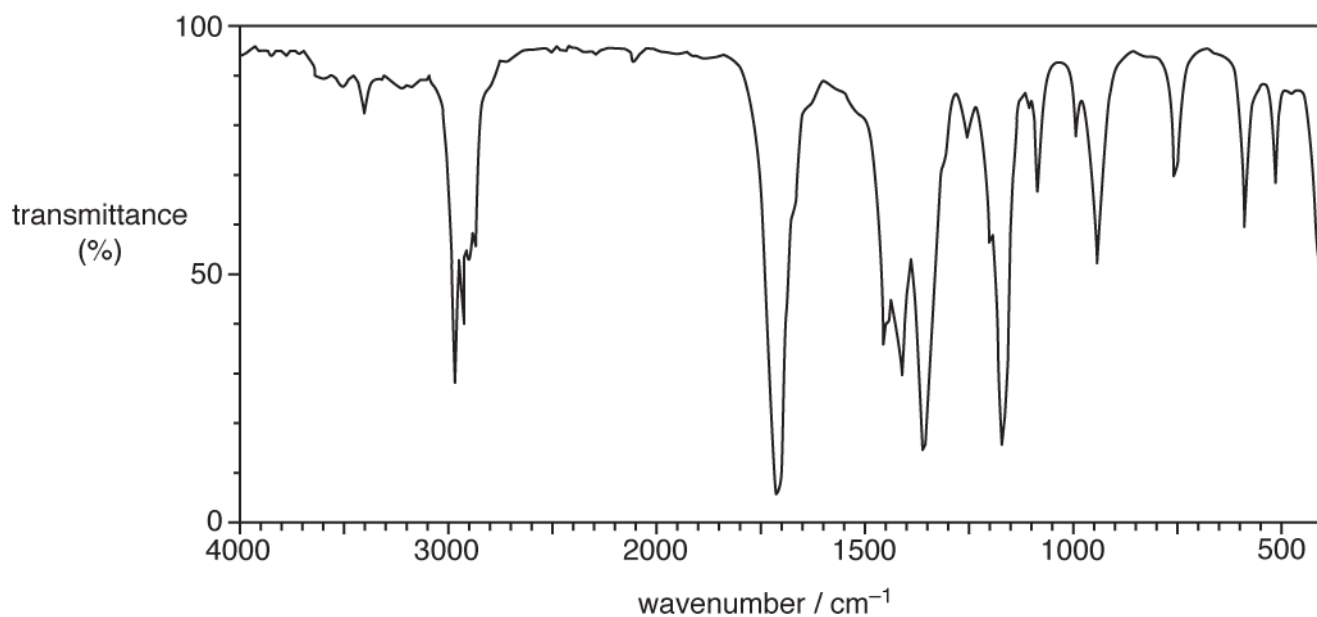
- A pentan-3-ol
- B pentan-1-ol
- C 2-methylbutan-2-ol
- D 2,2-dimethylpropan-1-ol

Your answer

[1]

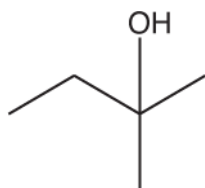
15 An alcohol A is heated under reflux with sulfuric acid and potassium dichromate(VI).

The organic compound formed produces the infrared spectrum below.

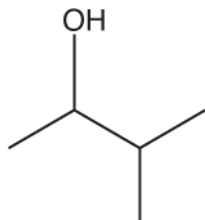


Which compound could be alcohol A?

A

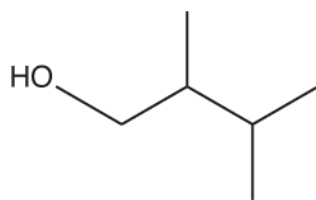
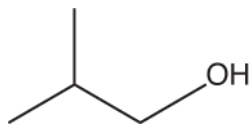


B



C

D



Your answer

[1]

16(a) The hydroxyl group, -OH , is responsible for many properties of alcohols.

Methanol, CH_3OH , is soluble in water because it has polar bonds.

Pauling electronegativity values for carbon, oxygen and hydrogen are shown below.

Element	Electronegativity
Carbon	2.5
Oxygen	3.5
Hydrogen	2.1

Use a labelled diagram to explain why methanol is soluble in water.

- Use displayed formulae showing one molecule of methanol and one molecule of water.
- Add partial charges δ^+ and δ^- to show the **two** most polar bonds in a methanol molecule and the polar bonds in a water molecule.
- Show all lone pairs.
- Label the most important intermolecular bond between the molecules.

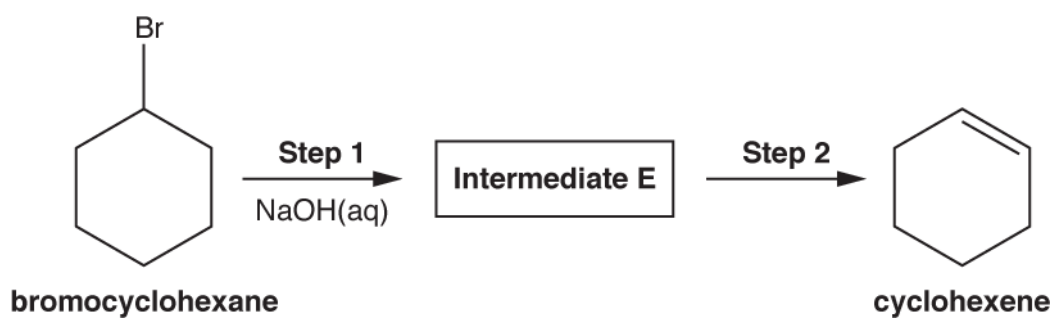
[2]

[illegible]

[6]

17 Organic compounds can be prepared in the laboratory using synthetic routes with two or more stages.

A student devises a two-stage synthesis of cyclohexene from bromocyclohexane.



- (i) Suggest the structure of **intermediate E** and the reagent(s) and conditions for **step 2**.

reagent(s) and conditions ----- [2]

- (ii) The student carries out this synthesis and obtains 1.23 g of pure cyclohexene from 5.50 g of bromocyclohexane.

Calculate the percentage yield of cyclohexene.

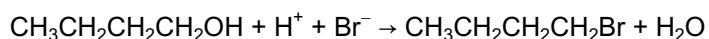
Give your final answer to an **appropriate** number of significant figures.

percentage yield = ----- % [3]

1-Bromobutane is an organic liquid with a boiling point of 102 °C.

A student prepares 1-bromobutane by reacting butan-1-ol with sulfuric acid and sodium bromide. The student boils the mixture for one hour.

The equation is shown below.



The student obtains a reaction mixture containing an organic layer (density = 1.27 g cm⁻³) and an aqueous layer (density = 1.00 g cm⁻³).

- (i) * Draw a labelled diagram to show how you would safely set up apparatus for the preparation. Outline a method to obtain a pure sample of 1-bromobutane from the reaction mixture.

----- [6]

- (ii) The student used 0.150 mol of butan-1-ol. The student obtained a 61.4% percentage yield of 1-bromobutane.

Calculate the mass of 1-bromobutane obtained.

Give your answer to **three** significant figures.

mass = ----- g [2]

Three reactions of an alcohol **E** are shown in Fig. 25.1.

(i) Complete Fig. 25.1 to show the structures of the organic products formed in the reactions.

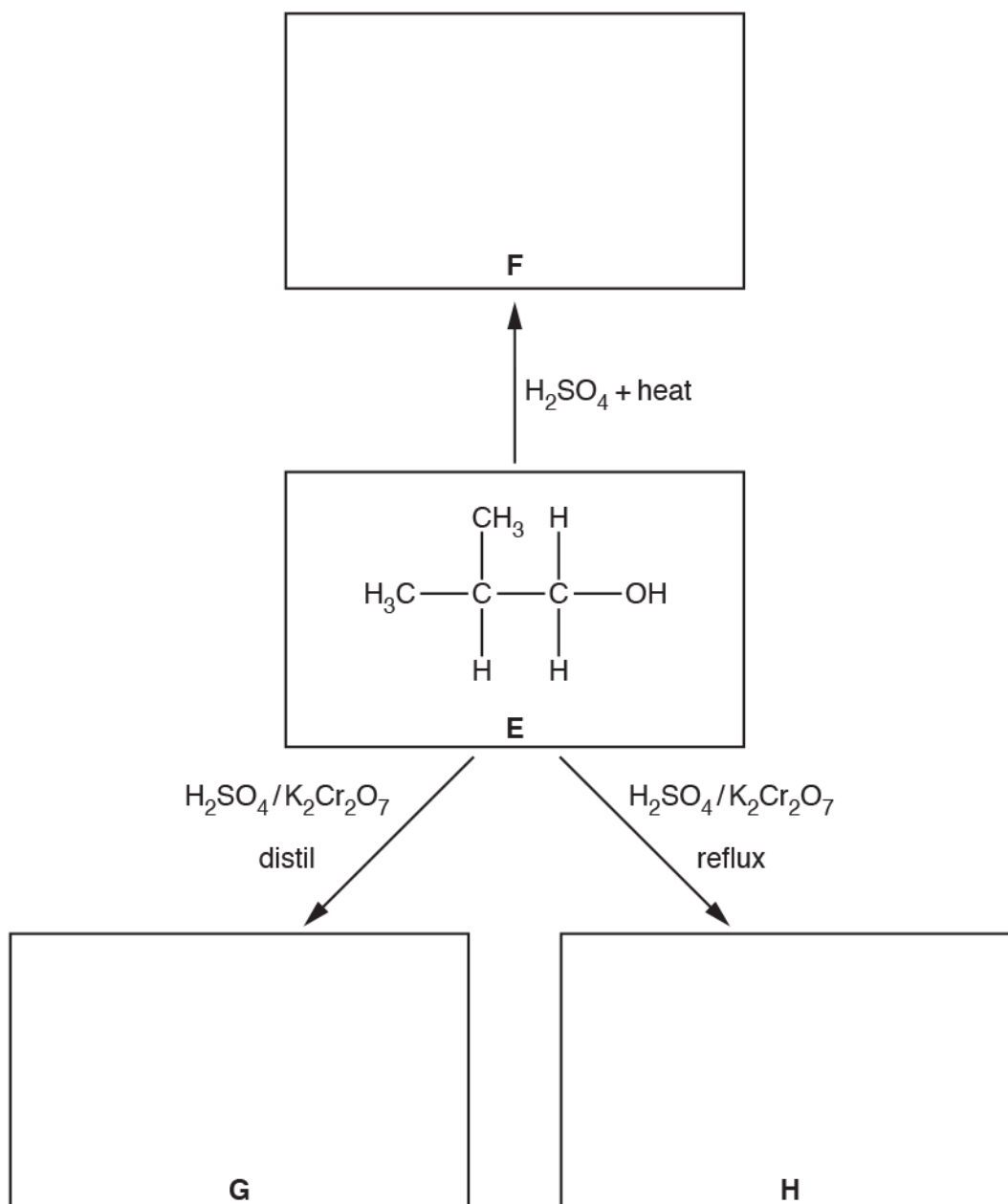


Fig. 25.1

[3]

(ii) What is the systematic name of alcohol E?

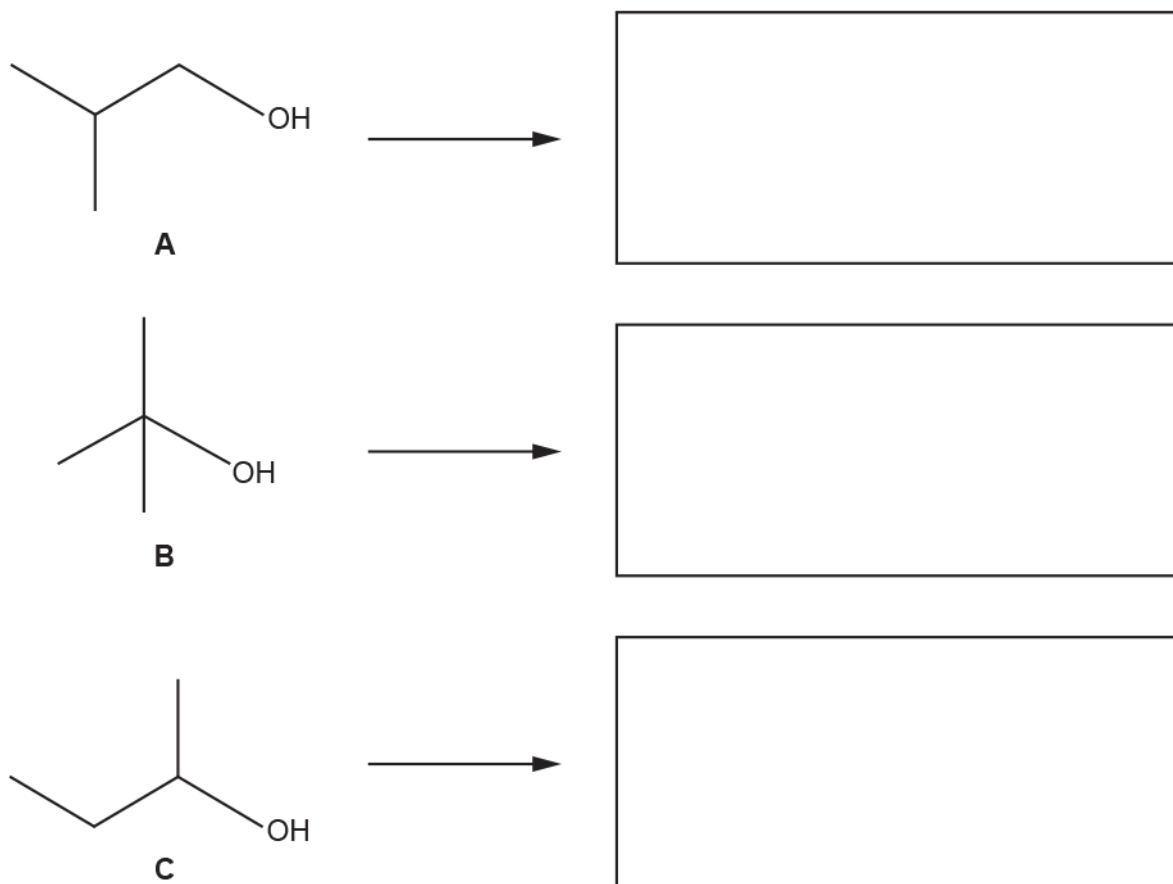
-----[1]

Three alcohols **A**, **B** and **C** are structural isomers of $C_4H_{10}O$.

Each alcohol is refluxed with acidified dichromate(VI), $H^+/Cr_2O_7^{2-}$.

(i) Draw the structures for the organic products.

If there is no reaction, write '**NONE**'.



[3]

(ii) Write the systematic name for alcohol **C**.

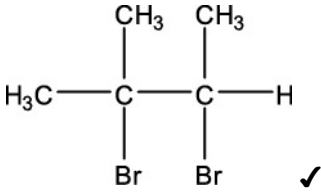
..... [1]

(iii) Complete the equation below for the complete combustion of alcohol **A**.

$C_4H_{10}O$ $\rightarrow$ [1]

END OF QUESTION PAPER

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
1	a			1	ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above DO NOT ALLOW molecular formula ALLOW dichloro or diiodo compound instead of the dibromo compound as the only alternatives. Examiner's Comments This question required candidates to interpret the reaction scheme and suggest an intermediate compound that could be formed from 2-methylbut-2-ene that could be also hydrolysed to give the diol shown. The most able candidates demonstrated their understanding of this scheme and often suggested the correct dihalo compound. Most candidate favoured the dibromo compound however some chose to show the dichloro or diiodo compound. All of these responses received credit. A large proportion of structures suggested were obtainable from 2-methylbut-2-ene but could not be hydrolysed. These included the products of hydrogenation e.g. 2-methylbutane, or hydration e.g. 2-methylbutan-2-ol. Consequently only the most able candidates achieved a mark in part (b), as this was essentially dependant on part (a).

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b		Reagent A: correct halogen✓ e.g. Br ₂ / bromine	1	ALLOW C_l₂ if dichloro compound drawn ALLOW I₂ if diiodo compound drawn IGNORE state symbols Answer must match box from (a) to score Examiner's Comments This question required candidates to interpret the reaction scheme and suggest an intermediate compound that could be formed from 2-methylbut-2-ene that could be also hydrolysed to give the diol shown. The most able candidates demonstrated their understanding of this scheme and often suggested the correct dihalo compound. Most candidate favoured the dibromo compound however some chose to show the dichloro or diiodo compound. All of these responses received credit. A large proportion of structures suggested were obtainable from 2-methylbut-2-ene but could not be hydrolysed. These included the products of hydrogenation e.g. 2-methylbutane, or hydration e.g. 2-methylbutan-2-ol. Consequently only the most able candidates achieved a mark in part (b), as this was essentially dependant on part (a).

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	i	Steam AND acid catalyst ✓	1	ALLOW H^+ / named acid / H_2SO_4 / H_3PO_4 ALLOW $H_2O(g)$ ALLOW water only if a temperature of 100 °C or above is quoted. IGNORE any temperature given with steam IGNORE pressure Examiner's Comments One would expect the majority of candidates to do well in a question which required them to state the reagents and conditions required for the hydration of alkenes; however this was not the case. The most able candidates provided accurate responses which referred to both steam and the acid catalyst, which was often shown to be H_3PO_4. Other candidates stated only one of the two required responses and it was common to see the acid catalyst stated alongside a temperature and pressure but with no reference to steam. Some candidates stated the reagent as H_2O instead of steam and this was allowed if accompanied by a temperature of over 100 °C. Candidates should be encouraged to learn reagents and conditions required for organic reactions.
		ii	(compounds or molecules) having the same molecular formula but different structural formulae ✓	1	ALLOW different structure OR different displayed formula OR different skeletal formula for structure Same formula is not sufficient Different arrangement of atoms is not sufficient Examiner's Comments The majority of candidates were able to explain the term structural isomers.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	$\begin{array}{c} \text{CH}_3 \text{ CH}_3 \\ \quad \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{OH} \quad \text{H} \quad \checkmark \end{array}$ $\begin{array}{c} \text{CH}_3 \text{ CH}_3 \\ \quad \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{H} \quad \text{OH} \quad \checkmark \end{array}$	2	ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above ALLOW any vertical bond to OH DO NOT ALLOW OH⁻ Examiner's Comments Many candidates found this question difficult and a large number of candidates showed structures of alcohols with the molecular formula C₅H₁₂O, but that could not be formed from 2- methylbut-2-ene. Examples of these incorrect responses included 2-methylbutan-1-ol, pentan-1- ol, pentan-2-ol and pentan-3-ol. Only the most able could show the structures of both alcohols produced by the hydration of 2-methylbut-2-ene. Candidates should be reminded to check that any structures they suggest are consistent with the context of the question.
		iv	Does not contain OH group(s) OR does not contain hydroxyl group(s) OR is not an alcohol ✓ Does not form hydrogen bonds with water ✓	2	ALLOW ORA throughout DO NOT ALLOW OH⁻ (ions) / hydroxide (ions) 'Does not form hydrogen bonds' is not sufficient Examiner's Comments The majority of candidates were able to recognise that the key to the solubility of the isomers in water is that they contain the OH group whereas 2-methylbut-2-ene does not. Most candidates scored the second mark by accurately explaining that the OH group could form hydrogen bonds with water.

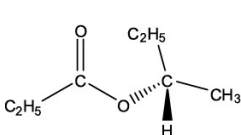
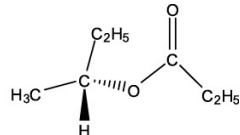
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d		Reagents: Acid / H^+ and (potassium or sodium) dichromate / $Cr_2O_7^{2-}$ seen once✓ Observations: Orange to Green OR Orange to Blue✓ Distillation / Distil produces aldehyde / CH_3CH_2CHO: ✓ $CH_3CH_2CH_2OH + [O] \rightarrow CH_3CH_2CHO + H_2O$ ✓ Reflux (of propan-1-ol) produces carboxylic acid / CH_3CH_2COOH✓ $CH_3CH_2CH_2OH + 2[O] \rightarrow CH_3CH_2COOH + H_2O$ ✓	6	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC ALLOW H_2SO_4 and $K_2Cr_2O_7$ ALLOW correct displayed formula OR correct structural formula OR skeletal formula OR a mixture of the above DO NOT ALLOW molecular formulae ALLOW C_3H_7OH for propan-1-ol in equations DO NOT ALLOW CH_3CH_2COH for aldehyde IGNORE further oxidation of aldehyde ALLOW $CH_3CH_2CO_2H$ for carboxylic acid Examiner's Comments This question differentiated well with some very good answers but also some weak responses. The most able candidates provided succinct and well-structured responses which demonstrated a good understanding of the oxidation of primary alcohols. Frequently, good candidates picked up five or six marks. The most common approach was to state the oxidising agent first and whilst most candidates were able recall that potassium dichromate was required, a significant proportion failed to state that an acid was also needed. Many candidates were able to give the colour change but a large number did not mention this. Candidates often referred to the production of the aldehyde and then the carboxylic acid and the majority of candidates were able to provide the correct conditions for these processes. Providing balanced equations for each reaction proved to be the most challenging aspect of this

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					question. A large proportion of candidates included hydrogen as the by-product rather than water, or specified no by-product at all. Another common error was the incorrect balancing of the complete oxidation equation. A significant proportion of responses did not use the correct amount of the oxidising agent when converting propan-1-ol to propanoic acid. The examiners were encouraged by the candidates' ability to provide correct structural formulae, however some candidates showed the aldehyde group as –COH. Candidates should be reminded that an aldehyde group is expected to be represented as –CHO in this type of formula.
			Total	14	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
2	Molar mass of B = 74 ✓ B-F clearly identified B/alcohol: <pre> H H OH H H — C — C — C — C — H H H H H ✓ </pre> C/ketone: <pre> H H O H H — C — C — C — C — H H H H ✓ </pre> D/carboxylic acid: <pre> H H O // H — C — C — C \ H H O — H ✓ </pre> E and F: <pre> H H O // H — C — C — C \ H H O — C — CH₃ H H H ✓ </pre> ✓ H₂O/water ✓	6	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC Check and annotate page 19 below this response Molar mass = $\frac{2.59}{0.035} = 74$ For structure of B, C, D or E / F ALLOW correct displayed OR correct structural formula OR correct 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 structures. IGNORE names of organic compounds E and F can be identified either way round ALLOW H₂O or displayed formula for mark For E and F – ALLOW the two optical isomers   Examiner's Comments Candidate were required to apply their knowledge of the reactions of alcohols to suggest the structures of the five compound B–F. Generally this question was answered well and most candidates scored three or more marks. The majority of candidates chose to use displayed formula. Other candidates opted to use skeletal formula and only a small proportion showed structural formulae.

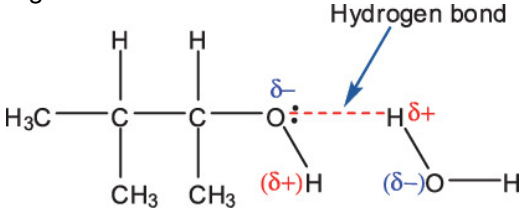
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					Almost all of the candidates were able to correctly calculate the molar mass of B as 74 g mol^{-1} which allowed most to suggest a structure for the compound. Many candidates used the information that B forms a ketone and provided the correct structure of butan-2-ol, although a significant proportion of candidates suggested B was butan-1-ol. The more able candidates identified the structure of C as butanone, but a large proportion of the cohort did not suggest a structure. Some candidates who used displayed formula for C often included an extra hydrogen atom on the carbonyl group. Most candidates were able to suggest a correct structure of carboxylic acid D and therefore deduced that the reaction between B and D was an esterification reaction. The most difficult part of this question was identifying E and F. The most able candidates provided a correct structure for the ester, however some candidates often missed one of the hydrogen atoms from their displayed formula. The most common incorrect response was to the structure of butyl propanoate. Some candidates identified the other compound formed in the reaction of B and D as water but a large proportion gave a second ester. In general the structures given by candidates were accurately drawn but candidates should be reminded to check their work carefully to ensure the correct number of atoms and bonds are present if using displayed formula.
			Total	6	

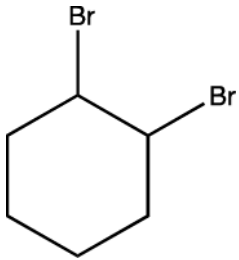
Mark Scheme

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

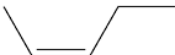
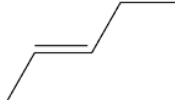
Mark Scheme

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	
4			C	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
5			D	1	
			Total	1	
6	a		Aliphatic = E, H, I, J (1) Alicyclic = E, H, J (1) Aromatic = F, G (1)	3	
	b		C_nH_{2n+1}	1	do not allow C_nH_{2n+1}
	c	i	<i>Equation:</i> $C_6H_{12}O \rightarrow C_6H_{10} + H_2O$ (1) <i>Calculation:</i> FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = 32.7 (%) award 3 marks theoretical yield = $7.65 / 100 = 0.0765$ (mol) (1) actual yield = $2.05 / 82 = 0.025$ (mol) (1) % yield = $(0.025 / 0.0765) \times 100\% = 32.7(\%)$ (1)	4	ignore state symbols allow $C_6H_{11}OH$ for $C_6H_{12}O$ If there is an alternative answer, check to see if there is any ECF credit possible using working below % yield must be to 1 dp allow theoretical and actual yield calculated in mass theoretical yield = $0.0765 \times 82 = 6.273$ g % yield = $(2.05 / 6.273) = 32.7(\%)$ allow ecf from calculated actual and theoretical yields
		ii	bromine water is decolourised (1)  (1)	2	allow bromine water turns colourless ignore 'goes clear' allow correct structural OR displayed OR skeletal formula OR mixture of the above
			Total	10	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
7	a		(Minimum) $n(\text{pentan-2-ol})$ required = $0.1 \times 88 = 8.8 \text{ g}$ (1) React the alcohol with a mixture of NaBr AND H_2SO_4 AND warm (to distil off the product) (1)	2	allow HBr
	b		<i>* Please refer to the marking instruction point 10 for guidance on how to mark this question.</i> (Level 3) Applies knowledge of elimination reactions to provide the correct names and structures of all three alkenes. AND Full, detailed explanation of formation of both types of isomers linked to the reaction, with clear understanding of both types of isomerism. <i>The explanations show a well-developed line of reasoning which is clear and logically structured. The information presented is relevant to the compounds drawn / named.</i> (5–6 marks) (Level 2) Applies knowledge of elimination reactions to provide the correct name and structure for pent-1-ene. AND Correct structures of stereoisomers of pent-2-ene but full names missing or incorrect. AND Explanation of formation of at least one type of isomers in some detail. <i>The explanations show a line of reasoning presented with some structure. The information presented is in the most-part relevant to the compounds drawn / named.</i> (3–4 marks)	6	Indicative scientific points may include: - the elimination can produce a double bond in either the 1- or the 2- position (through combination of the hydroxyl group with a hydrogen from either the 1st or the 3rd carbon) - this leads to the formation of structural isomers (pent-1-ene and pent-2-ene) - pent-2-ene exhibits stereoisomerism / <i>E/Z</i> isomerism / <i>cis-trans</i> isomerism because it has two different groups attached to each carbon atom - there are two possible isomers of pent-2-ene and three in total. Names and structures of alkenes  pent-1-ene  Z or cis-pent-2-ene  E or trans-pent-2-ene

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			(Level 1) Applies knowledge of elimination reactions to name and draw the structures of organic products. Either name OR structure should be correct for two compounds. AND Attempts to explain formation of one type of isomer. <i>The information about isomerism is basic and communicated in an unstructured way. The relationship to the compounds drawn / named may not be clear.</i> (1–2 marks) (0 marks) No response or no response worthy of credit.		
			Total	8	

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	
9			$\begin{array}{c} \text{CH}_3 \quad \text{CH}_3 \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{CH}_3 \\ \quad \\ \text{H} \quad \text{OH} \\ \checkmark \end{array}$ $\begin{array}{c} \text{CH}_3 \quad \text{CH}_3 \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{CH}_3 \\ \quad \\ \text{OH} \quad \text{H} \\ \checkmark \end{array}$	2	ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous ALLOW any vertical bond to OH, $\text{OH} \quad \text{OR} \quad \text{OH}$ e.g. ALLOW $\begin{array}{c} \end{array}$ $\begin{array}{c} \end{array}$ DO NOT ALLOW OH– Examiner's Comments Many candidates found it difficult to draw the structures for the two alcohols that could be dehydrated to produce compound A. This was surprising as it was a simple task to add water across the double bond of compound “A” resulting in two branched chained isomers. The most common incorrect answers were pentan-1-ol and pentan-2-ol, although some candidates shortened the chain length resulting in compounds containing only four carbon atoms.
			Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
10	a		The –OH group is attached to a carbon that is attached to one hydrogen atom OR The –OH group is attached to a carbon that is attached to two C atoms / alkyl groups/R groups ✓	1	ALLOW alcohol / hydroxyl / functional group for –OH Examiner's Comments The definition of a secondary alcohol was well known with most candidates being to express this to gain the mark available.
	b	i	Equation $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_3 + [\text{O}] \rightarrow \text{CH}_3\text{COCH}_2\text{CH}_3 + \text{H}_2\text{O}$ ✓ Structure of product could be allowed from equation $\text{CH}_3\text{COCH}_2\text{CH}_3$ ✓	2	ALLOW molecular formulae: $\text{C}_4\text{H}_{10}\text{O}$ and $\text{C}_4\text{H}_8\text{O}$ ALLOW $\text{C}_4\text{H}_9\text{OH}$ ALLOW C_2H_5 for CH_3CH_2 ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous Examiner's Comments The majority of candidates were able to identify the structure of the ketone formed in the oxidation of butan-2-ol but many were not able to construct a suitable equation. Water was often omitted from the equation on the right hand side whilst sometimes the equation was incorrectly balanced with a 2 being placed in front of the [O]. The most able candidates normally scored both marks.
		ii	Butan-2-ol/butanone is flammable OR Butan-2-ol / butanone is volatile / low boiling point OR	1	IGNORE vague answers about health and safety ALLOW alcohol for butan-2-ol ALLOW ketone for butanone
		ii	Butan-2-ol / butanone will evaporate / boil away ✓		

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	(Heat under) reflux OR a description of reflux with vertical condenser and a round bottomed or pear shaped flask with source of heat. ✓	1	DO NOT ALLOW any reference to closed system. Examiner's Comments Another question requiring candidates to evaluate a practical activity where responses were on the whole disappointing. Very few candidates were able to access both of the marks with the harder of the two marks being for suggesting why the apparatus was not suitable for the experiment. Clearly many candidates were able to suggest a better method of carrying out the experiment with reflux being often quoted.
			Total	5	
11			B	1	<u>Examiner's Comments</u> Generally scored well.
			Total	1	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
12	Compound C: $ \begin{array}{c} \text{H} \quad \text{CH}_3 \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{OH} \\ \quad \\ \text{H} \quad \text{CH}_3 \quad \checkmark \end{array} $ CARE: Tertiary alcohol Compound D: (repeat unit) $ \left[\begin{array}{c} \text{H} \quad \text{CH}_3 \\ \quad \\ -\text{C}-\text{C}- \\ \quad \\ \text{H} \quad \text{CH}_3 \end{array} \right]_n \checkmark $	2	For structures: ALLOW correct structural OR skeletal OR displayed formula OR mixture of the above Connectivity IGNORE connectivity of bonds to CH₃ e.g. ALLOW CH₃- ALLOW any vertical bond to OH, e.g. ALLOW OH OR OH DO NOT ALLOW OH- DO NOT ALLOW more than one repeat unit REQUIRED: Side links (dotted lines fine) NOT REQUIRED: Brackets and 'n' REQUIRED: Examiner's Comments This part was answered well. If a mark was lost, it was almost always due to compound C, especially at the low scoring end of the range. Many struggled with the structure of a tertiary alcohol or omitted H atoms from the structure. Compound D was generally drawn correctly by candidates of all abilities. If the mark was not credited, it was usually due to not removing the double bond, or drawing more than one repeat unit.
	Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
13	a		Alcohols have hydrogen bonds (and van der Waals' forces) ✓ Hydrogen bonds are stronger than van der Waals' forces (in alkanes) ✓	2	ANNOTATE ANSWER WITH TICKS AND CROSSES ALLOW reference to specific compounds e.g. comparing methane and methanol Second marking point requires BOTH types of intermolecular forces in response i.e comparison of hydrogen bonds AND van der Waals is essential DO NOT ALLOW the second mark for a comparison of van der Waals' and hydrogen bonds between alcohols and water ALLOW more energy required to break hydrogen bonds than van der Waals' forces ALLOW it is harder to overcome the hydrogen bonds than van der Waals' forces IGNORE more energy is needed to break bonds Examiner's Comments Many candidates attributed the difference in boiling point between alkanes and alcohols to the relative strength of hydrogen bonds compared with van der Waals' forces. Weaker responses simply identified alcohols as being able to form hydrogen bonds, but failed to compare these with van der Waals' forces.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b		2-methylpropan-1-ol has less surface (area of) contact OR fewer points of contact ✓ 2-methylpropan-1-ol has fewer / weaker van der Waals' forces OR less energy required to break van der Waals' forces in 2-methylpropan-1-ol ✓	2	ANNOTATE ANSWER WITH TICKS AND CROSSES Both answers need to be comparisons ALLOW ORA throughout Reference to just surface area / closeness of molecules is not sufficient IGNORE reference to H bonds IGNORE less energy is needed to break bonds Examiner's Comments Most candidates recognised that 2-methylpropan-1-ol is branched and communicated both marking points succinctly. Weaker responses identified that 2-methylpropan-1-ol would have weaker intermolecular forces, but failed to specify these as van der Waals' forces.
	c	i	Elimination OR dehydration ✓	1	Examiner's Comments Many candidates correctly named the type of reaction. There were a significant number of incorrect responses, the most common of which included hydrolysis, dehydrogenation and condensation.

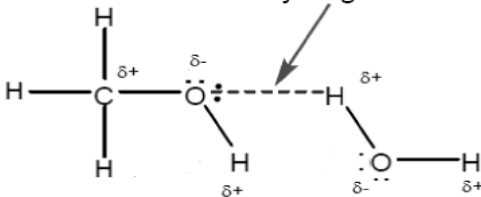
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	IF answer = 14.0 OR 14.1 g award 3 marks ----- actual $n(\text{C}_5\text{H}_8) \text{ produced} = \frac{5.00}{68.0} = 0.0735 \text{ (mol)} \checkmark$ theoretical $n(\text{C}_5\text{H}_9\text{OH}) = n(\text{C}_5\text{H}_8) = 0.0735 \times \frac{100}{45.0} = 0.163 \text{ (mol)} \checkmark$ Mass of $\text{C}_5\text{H}_9\text{OH} = 0.163 \times 86.0 = 14.0 \text{ (g)}$ OR 14 g OR 14.1 g $\checkmark$ (use of unrounded values in calculator throughout)	3	ANNOTATE ANSWER WITH TICKS AND CROSSES ALLOW ECF at each stage ALLOW 3 SF up to calculator value correctly rounded for intermediate values ALLOW expected mass $\text{C}_5\text{H}_8 = 5.00 \times \frac{100}{45.0} = 11.111 \text{ (g)}$ ALLOW Mass $\text{C}_5\text{H}_9\text{OH}$ reacted = $0.0735 \times 86.0 = 6.321 \text{ (g)}$ ALLOW Mass of $\text{C}_5\text{H}_9\text{OH}$ used = $6.321 \times \frac{100}{45.0} = 14.0 \text{ OR } 14 \text{ (g)}$ ALLOW 2 SF up to calculator value correctly rounded for mass of $\text{C}_5\text{H}_9\text{OH}$ Note: 2.84 OR 2.85 g would get 2 marks (use of 45.0/100 instead of 100/45.0) 13.76 OR 13.8 would get 2 marks (use of 0.16 for moles $\text{C}_5\text{H}_9\text{OH}$) Examiner's Comments Candidates coped well with this calculation based on percentage yield. Most were able to calculate the moles of cyclopentene produced and the strongest scaled this correctly to give the moles of cyclopentanol required. A common mistake was to scale by a factor of 45/100, rather than 100/45. However, error carried forward marks were awarded and the majority of candidates scored two or three marks. Answer: 14.1 g
			Total	8	

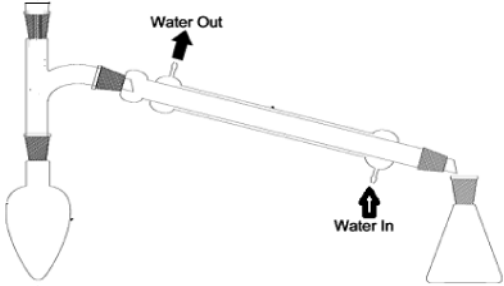
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
14			A	1	Examiner's Comments Candidates found this question challenging, with only the more able candidates obtaining the correct alcohol. Answer option C was a common incorrect answer.
			Total	1	
15			B	1	Examiner's Comments Just over half of the candidates identified the correct alcohol. The common incorrect answer was C.
			Total	1	

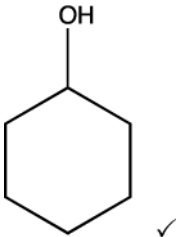
Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
16	a	Displayed formulae of CH₃OH and H₂O AND C–O AND O–H polar bonds shown on CH₃OH molecule with δ⁺ and δ⁻ AND Both O–H polar bonds shown on H₂O molecule with δ⁺ and δ⁻ ✓ Two lone pairs shown on both oxygen atoms AND Hydrogen bond / H-bond labelled and in the correct position between the H on water and the oxygen lone pair on methanol ✓	2	Must be displayed formulae  IGNORE δ⁺ shown on other H atoms ALLOW hydrogen bond between the H on methanol (OH) and the oxygen lone pair on water Examiner's Comment: Candidates did not cope well with the requirement to produce a hydrogen bonding diagram that was expected to match the content of all four of the bullet points listed in the question. Perhaps candidates did not read the question carefully enough but some diagrams did not include displayed formulae, dipoles were often missing from the methanol molecule, lone pairs were absent from oxygen atoms and the hydrogen bond was marked in an incorrect position. This resulted in a low scoring question for a diagram that had produced much higher scores when asked on papers from the legacy specification.
	b	<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 explanation with all three scientific points covered thoroughly. <i>There is a well-developed description with a logical structure including correct chemical equations and an explanation with a clear line of reasoning including a fully labelled diagram.</i> Level 2 (3–4 marks) The candidate attempts all three scientific	6	Indicative scientific points <u>1. Oxidation reaction forming aldehyde</u> - acid / H⁺ AND dichromate / Cr₂O₇²⁻ - heat AND distillation - organic product is butanal / CH₃CH₂CH₂CHO - CH₃CH₂CH₂CH₂OH + [O] → CH₃CH₂CH₂CHO + H₂O <u>2. Oxidation reaction forming carboxylic acid</u> - acid / H⁺ AND dichromate / Cr₂O₇²⁻

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			points but explanations are incomplete. OR Explains two scientific points thoroughly with no omissions. <i>The description has a line of reasoning presented with some structure and includes correct structural formulae and an accurate diagram of a distillation apparatus.</i> Level 1 (1–2 marks) A simple explanation based on at least two of the main scientific points OR The candidate explains one scientific point thoroughly with few omissions. <i>The description may be communicated in an unstructured way but it includes the correct reagents and conditions for the formation of the aldehyde.</i> <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks—No response or no response worthy of credit.		• heat under reflux • organic product is butanoic acid / $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$ • $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + 2[\text{O}] \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{COOH} + \text{H}_2\text{O}$ 3. Distillation • diagram of apparatus with condenser • condenser has water flow • collection of organic product • product is separated to prevent further oxidation (to carboxylic acid)  Examiner's Comment: A very wide range of responses was seen in the second question marked using a level of response mark scheme and a greater proportion of candidates were able to access the highest level in this question. Diagrams of a distillation apparatus were often disappointing and many poor answers failed to identify the oxidation products. A Level 1 response usually named the oxidising agent and included a crude diagram of a distillation apparatus. Diagrams in Level two responses often included more detail with a condenser cooled by water flow and an indication of where butanal can be collected. A Level three response was expected to include balanced equations for the oxidation reactions.
			Total	8	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
17		i	 Acid (catalyst) AND heat ✓	2	ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous ALLOW (heat under) reflux ALLOW H₃PO₄ OR H₂SO₄ OR H⁺ DO NOT ALLOW other named acids IGNORE concentration / pressure IGNORE water / steam Examiner's Comments Candidates who were able to give the structure of the intermediate were not always able to state the conditions for the elimination of water from an alcohol. The presence of an acid catalyst and heat are stated in the specification. Some candidates confused this reaction with addition reactions of alkenes suggesting that a Ni catalyst or the presence of steam is required.

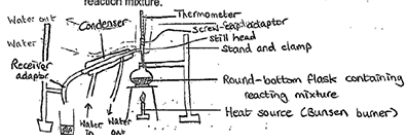
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = 44.4(%) award all 3 marks for calculation <i>Amount cyclohexene (m / M)</i> = 1.23/82 OR 0.0150 mol ✓ <i>Amount of bromocyclohexane (m / M)</i> = 5.50/162.9 OR 0.0338 mol ✓ % yield = (0.0150/0.0338) × 100 = 44.4(%) ✓ Final answer must be to 3 significant figures	3	If there is an alternative answer, check to see if there is any ECF credit possible ALLOW 3 SF: 0.0338 up to calculator value of 0.033763044 correctly rounded Common ECFs (2 marks) • Incorrect M_r → incorrect moles of cyclohexene • Incorrect M_r → incorrect moles of 2- bromocyclohexane e.g. ALLOW two marks for use of incorrect mass of bromocyclohexane with other calculations correct e.g. (5.50/163) = 0.033742331 → 44.5% ALLOW calculation in mass <i>Theoretical mass yield:</i> $m(\text{C}_6\text{H}_{10}) = 0.0338 \times 82 = 2.77 \text{ g}$ % yield = (1.23/2.77) × 100 = 44.4% Examiner's Comment: Although some candidates simply calculated 1.23/5.50, most followed an effective strategy for the calculation of percentage yield. Many gained full marks but a large number of candidates relied on the application of error carried forward when they made one or more careless errors during the calculation of molar mass and / or moles. Intermediate answers were sometimes rounded to 2 significant figures and marks were lost by candidates who presented their final answer to 2 or 4 significant figures.
			Total	5	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
18	<i>Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Correctly labelled diagram of reflux apparatus that works, with no safety problems AND An appreciation of most of the purification steps required to gain a pure sample <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) Labelled diagram of apparatus (either reflux or distillation) but with safety/procedural problems OR clear diagram of reflux apparatus without labelling AND Some details of further purification steps <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) Diagram of apparatus (reflux OR separation OR distillation) drawn with no labelling OR labelled diagram with significant safety/procedural AND / OR Few or imprecise details about further purification stages <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.	6	Indicative scientific points may include: Apparatus set up for reflux: • round-bottom/pear shaped flask • heat source • condenser <i>Detail: water flow in condenser bottom to top; open system.</i> Purification • Use of a separating funnel to separate organic and aqueous layers <i>Detail: Collect lower organic layer density greater</i> • Drying with an anhydrous salt, <i>Detail: e.g. MgSO_4, CaCl_2, etc.</i> • Redistillation <i>Detail: Collect fraction distilling at 102°C.</i> <u>Examiner's Comments</u> Candidates were not prepared to answer this type of question and the diagrams were hard to give credit to. Many had significant safety implications such as open beakers of butan-1-ol being heated by a Bunsen burner. Most mis-read the question and just outlined the method for purification and struggled to recall the practical details. Very few candidates mentioned the use of anhydrous salts, referring instead to 'boiling off' the water.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			Exemplar 4 $\text{Alcohol} \xrightarrow[\text{10}]{\text{Reflux}} \text{Halalkane}$ 5 (a) 1-Bromobutane is an organic liquid with a boiling point of 102°C. A student prepares 1-bromobutane by reacting butan-1-ol with sulfuric acid and sodium bromide. The student boils the mixture for one hour. The equation is shown below. $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + \text{H}^+ + \text{Br}^- \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br} + \text{H}_2\text{O}$ The student obtains a reaction mixture containing an organic layer (density = 1.27 g cm⁻³) and an aqueous layer (density = 1.00 g cm⁻³). (i)* Draw a labelled diagram to show how you would safely set up apparatus for the preparation. Outline a method to obtain a pure sample of 1-bromobutane from the reaction mixture.  Heat under reflux. Do perform a distillation. Heat the reaction mixture in a round-bottom flask at just over 100°C. The butan-1-ol will react with sulfuric acid and sodium bromide to form 1-bromobutane, which evaporates and condenses and is collected in a flask. Water has a boiling point of 100°C so also evaporates and condenses and collects in the flask. Add the mixture in the collecting flask to a separating funnel. The organic layer should settle below the aqueous layer as it is denser. To confirm, add distilled water to the separating funnel, invert the funnel, and allow the layers to settle. The layer that gets bigger is the aqueous layer. Open the tap and run off the lower organic layer into a conical flask. Add drying agent to remove traces of water.

This candidate was credited 4 marks for this level 2 answer. Although they have drawn distillation apparatus instead of reflux, they have considered the boiling point of the product, detailed using a separating funnel, a drying agent and that the lower organic layer would be drawn off first.

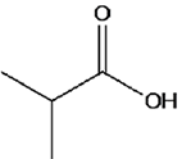
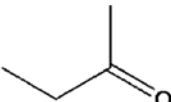
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 12.6 (g) award 2 marks • $n(1\text{-bromobutane}) = 0.150 \times \frac{61.4}{100} = 0.0921 \text{ (mol)} \checkmark$ • Mass 1-bromobutane = $0.0921 \times 136.9 = 12.6 \text{ (g)} \checkmark$ 3 SF required	2	Common errors: 33.4 ($0.150 \times 100/61.4 = 0.244 \times 136.9$) 1 mark ALLOW ECF for incorrect moles or incorrect M_r of 1-bromobutane (provided answer is to 3 SF) DO NOT ALLOW 6.82 (using M_r of butan-1-ol) ALLOW calculation using masses, e.g. • Theoretical = $0.150 \times 136.9 = 20.535 \text{ (g)} \checkmark$ (ALLOW 20.535 rounded back to 20.5) • Actual mass = $20.535 \times \frac{61.4}{100} = 12.6 \text{ (g)} \checkmark$ (20.5 also gives 12.6) <u>Examiner's Comments</u> This question was well answered, but a significant number of candidates incorrectly used the M_r of butan-1-ol when calculating the mass of 1-bromobutane.
			Total	8	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
19		i	F ✓ G ✓ H ✓	3	ALLOW correct structural OR displayed OR skeletal formulae OR mixture of the above (as long as unambiguous) IGNORE molecular formula ALLOW CH₃- ALLOW 1 mark for G AND H combined if structures are correct but in wrong boxes <u>Examiner's Comments</u> Part (i) discriminated extremely well and rewarded the well-prepared candidate. Compound F proved to be the most difficult option, with a large variety of responses, many appearing to be guesses. Candidates were much more successful with compounds G and H, although these were sometimes shown in reverse order. A significant number of candidates drew structures containing C=C or C=O bonds in which the carbon atom had five bonds. Candidates should check drawing of organic structures carefully to ensure that all carbon atoms have four bonds. There were some good responses for part (ii), with many clearly shown and correct systematic names.
		ii	2-methylpropan-1-ol ✓ <i>Both numbers required</i>	1	IGNORE absence of hyphen or use of dots or commas as separators DO NOT ALLOW 2-methylprop-1-ol OR 2-methpropan-1-ol OR 2-methypropan-1-ol
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
20		i	A →  ✓ B → NONE ✓ C →  ✓	3 (AO2.5) (AO1.2) (AO2.5)	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous DO NOT ALLOW STICKS IN STRUCTURES <u>Examiner's Comments</u> Part 25(a)(i) discriminated extremely well and rewarded well-prepared candidates. Most candidates recognised that B is a tertiary alcohol and will not react with acidified dichromate. The structure from A was often shown as an aldehyde rather than a carboxylic acid. It was also common for candidates to replace the OH group of A with the carboxyl COOH group, gaining a carbon atom in the chain in the process. The ketone oxidation product from C proved to be easier. Part 25(a)(ii) proved to be difficult. Candidates need to be careful in identifying the longest carbon chain to derive the stem of an organic name. Many candidates thought that alcohol C was a branched propanol, with 1-methylpropan-1-ol being seen very often instead of the correct name of butan-2-ol. In part 25(a)(iii), less than half the candidates wrote a correctly-balanced equation for this reaction. Although 4CO_2 and $5\text{H}_2\text{O}$ were usually seen for the products, oxygen was usually seen as $6\frac{1}{2}\text{O}_2$, rather than 6O_2. Candidates need to look very closely at the formula of the organic compound so that the O in $\text{C}_4\text{H}_{10}\text{O}$ is accounted for in the balancing.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	butan-2-ol ✓	1 (AO1.2)	IGNORE lack of hyphens, or addition of commas ALLOW butane-2-ol DO NOT ALLOW butan-3-ol OR but-2-ol <u>Examiner's Comments</u> Part 25(a)(i) discriminated extremely well and rewarded well-prepared candidates. Most candidates recognised that B is a tertiary alcohol and will not react with acidified dichromate. The structure from A was often shown as an aldehyde rather than a carboxylic acid. It was also common for candidates to replace the OH group of A with the carboxyl COOH group, gaining a carbon atom in the chain in the process. The ketone oxidation product from C proved to be easier. Part 25(a)(ii) proved to be difficult. Candidates need to be careful in identifying the longest carbon chain to derive the stem of an organic name. Many candidates thought that alcohol C was a branched propanol, with 1-methylpropan-1-ol being seen very often instead of the correct name of butan-2-ol. In part 25(a)(iii), less than half the candidates wrote a correctly-balanced equation for this reaction. Although 4CO_2 and $5\text{H}_2\text{O}$ were usually seen for the products, oxygen was usually seen as $6\frac{1}{2}\text{O}_2$, rather than 6O_2. Candidates need to look very closely at the formula of the organic compound so that the O in $\text{C}_4\text{H}_{10}\text{O}$ is accounted for in the balancing.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	$C_4H_{10}O + 6O_2 \rightarrow 4CO_2 + 5H_2O$ ✓	1 (AO2.6)	<u>Examiner's Comments</u> Part 25(a)(i) discriminated extremely well and rewarded well-prepared candidates. Most candidates recognised that B is a tertiary alcohol and will not react with acidified dichromate. The structure from A was often shown as an aldehyde rather than a carboxylic acid. It was also common for candidates to replace the OH group of A with the carboxyl COOH group, gaining a carbon atom in the chain in the process. The ketone oxidation product from C proved to be easier. Part 25(a)(ii) proved to be difficult. Candidates need to be careful in identifying the longest carbon chain to derive the stem of an organic name. Many candidates thought that alcohol C was a branched propanol, with 1-methylpropan-1-ol being seen very often instead of the correct name of butan-2-ol. In part 25(a)(iii), less than half the candidates wrote a correctly-balanced equation for this reaction. Although $4CO_2$ and $5H_2O$ were usually seen for the products, oxygen was usually seen as $6\frac{1}{2}O_2$, rather than $6O_2$. Candidates need to look very closely at the formula of the organic compound so that the O in $C_4H_{10}O$ is accounted for in the balancing.
			Total	5	

1(a) 1-Bromobutane, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br}$, reacts with methoxide ions, CH_3O^- , by nucleophilic substitution.

Suggest how the methoxide ion can act as a nucleophile.

----- [1]

(b) Using the 'curly arrow' model, suggest the mechanism for this reaction.

Show any relevant dipoles.

[3]

(c) 1-Iodobutane also reacts with methoxide ions.

Indicate, by placing a tick in one of the boxes, how the use of 1-iodobutane would affect the rate of reaction compared with that of 1-bromobutane.

1-Iodobutane does not change the rate	
1-Iodobutane increases the rate	
1-Iodobutane decreases the rate	

Explain your answer.

----- [1]

(d) The ethanoate ion, CH_3COO^- acts as a nucleophile when reacting with 1-bromobutane in a substitution reaction.

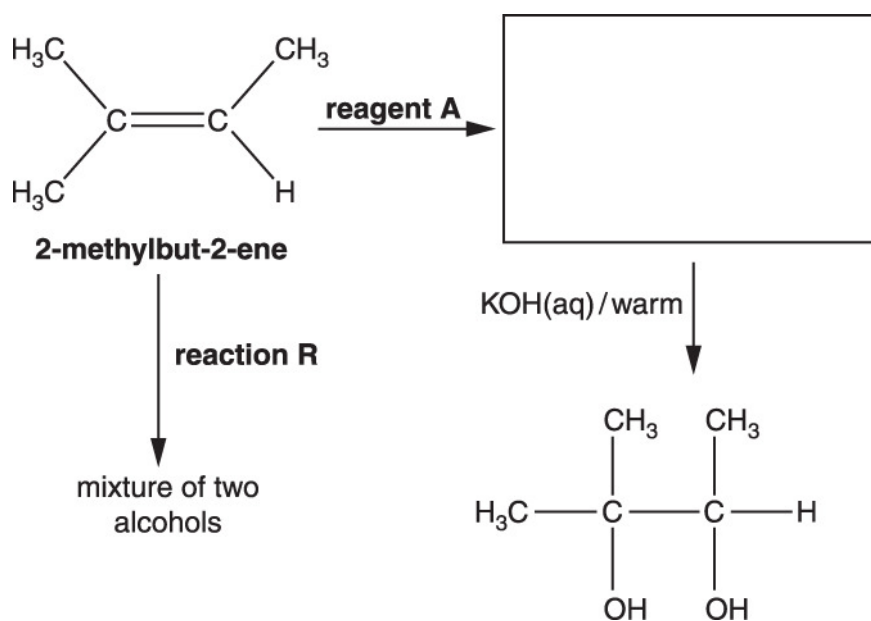
Draw the skeletal formula and give the name of the organic product formed in this reaction.

skeletal formula

name of product _____ [2]

2(a) The flowchart shows how 2-methylbut-2-ene can be converted into a number of organic products.

Complete the flowchart by drawing an organic structure in the box below.



(b) Identify reagent A.

[1]

-----[1]

(c) In the flowchart, **reaction R** forms a mixture of two alcohols that are structural isomers of $C_5H_{12}O$.

(i) State the reagents and conditions needed for **reaction R**.

-----[1]

(ii) What is meant by the term *structural isomers*?

-----[1]

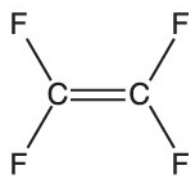
(iii) Draw the two structural isomers of $C_5H_{12}O$ formed in **reaction R**.

[2]

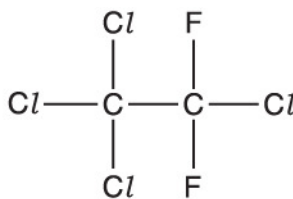
(iv) Suggest why 2-methylbut-2-ene is less soluble in water than either of the structural isomers formed.

-----[2]

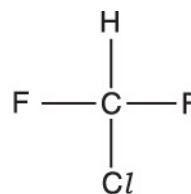
3 This question is about the compounds shown below.



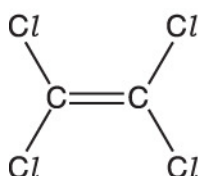
B



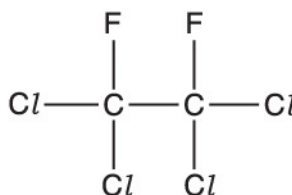
C



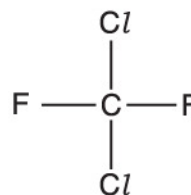
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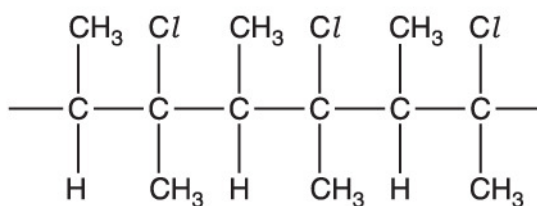
E



F



G



H

Compound **G** was once used as a propellant in aerosols. Compound **G** has been linked with depletion of the ozone layer in the stratosphere.

(i) State **two** properties that made compound **G** suitable for use as an aerosol.

1

2

4(a) Reaction mechanisms use curly arrows and can involve electrophiles and nucleophiles.

(i) What does a *curly arrow* represent in mechanisms?

----- [1]

(ii) What is meant by the term *nucleophile*?

----- [1]

(b) Allyl bromide, $\text{CH}_2=\text{CHCH}_2\text{Br}$, reacts with aqueous sodium hydroxide.

(i) Outline the mechanism of this reaction.

Include curly arrows, relevant dipoles and final product(s).

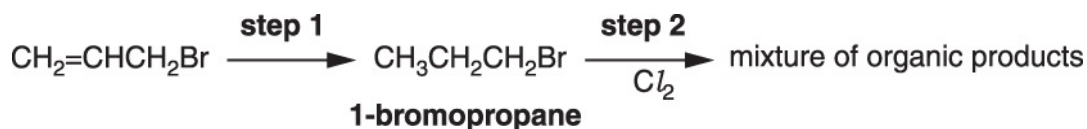
[3]

(ii) Name the type of mechanism.

----- [1]

(c) Allyl bromide, $\text{CH}_2=\text{CHCH}_2\text{Br}$, is used in the production of polymers.

Allyl bromide is reacted as shown below.



(i) State the reagents and conditions for **step 1**.

----- [1]

(ii) In **step 2**, 1-bromopropane reacts with chlorine by radical substitution.

Outline the mechanism for the monochlorination of 1-bromopropane.

In your mechanism, you can show the formula of 1-bromopropane as $\text{C}_3\text{H}_7\text{Br}$.

Include the names of the three stages in this mechanism, state the essential conditions and all termination steps.

[5]

(iii) Radical substitution produces a mixture of organic products.

Suggest **two** reasons why.

[2]

5 Haloalkanes can undergo hydrolysis.

A student carries out an experiment to find the relative rate of hydrolysis of 1-chloropropane, $\text{C}_3\text{H}_7\text{Cl}$, 1-bromopropane, $\text{C}_3\text{H}_7\text{Br}$, and 1-iodopropane, $\text{C}_3\text{H}_7\text{I}$.

The student adds 2 cm^3 of ethanol to 2 cm^3 of aqueous silver nitrate to three test tubes labelled A, B and C.

The student adds 5 drops of a different haloalkane to each test-tube in rapid succession and shakes each tube. The student measures the time for a precipitate to form in each test-tube.

The results are shown below.

Test tube	Haloalkane	Time taken for reaction to take place
A	$\text{C}_3\text{H}_7\text{Cl}$	about half an hour
B	$\text{C}_3\text{H}_7\text{Br}$	a few minutes
C	$\text{C}_3\text{H}_7\text{I}$	a few seconds

- (i) Write an ionic equation involving aqueous silver nitrate for formation of **one** of the precipitates.

-----[1]

- (ii) What do the experimental results tell you about the carbon–halogen bond enthalpies?

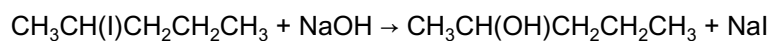
-----[1]

- (iii) How could the student modify their experiment so that it could be completed in less time?

-----[1]

6 Alcohols are used in organic synthesis.

Pentan-2-ol can be prepared by the alkaline hydrolysis of 2-iodopentane.



The reaction mixture is boiled for 20 minutes.

- (i) State the most appropriate technique that could be used to boil the reaction mixture for 20 minutes.

-----[1]

- (ii) Describe the mechanism for the alkaline hydrolysis of 2-iodopentane.

In your answer, include the name of the mechanism, curly arrows and relevant dipoles.

name of mechanism: -----

[4]

7 Nitrogen forms several different oxides.

N_2O is a useful anaesthetic and NO has been linked to the depletion of ozone in the stratosphere.

NO radicals catalyse the breakdown of ozone in the stratosphere.

Write **two** equations to show how NO radicals catalyse this breakdown.

----- [2]

8 A reaction sequence is shown below:



Which type of reaction mechanism is involved in each step?

	Step 1	Step 2
A	electrophilic addition	electrophilic substitution
B	electrophilic addition	nucleophilic substitution
C	nucleophilic addition	electrophilic substitution
D	nucleophilic addition	nucleophilic substitution

Your answer

[1]

9 When heated with $\text{NaOH}(\text{aq})$, 1-iodobutane is hydrolysed at a much faster rate than 1-chlorobutane.

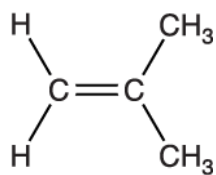
Which statement explains the different rates?

- A The C–I bond enthalpy is greater than the C–C/ bond enthalpy.
B The C–I bond is less polar than the C–C/ bond.
C The C–I bond has a C atom with a greater δ^+ charge than in the C–C/ bond.
D The C–I bond requires less energy to break than the C–C/ bond.

Your answer

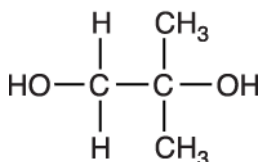
[1]

10 Compound **B**, shown below, can be used to synthesise organic compounds with different functional groups.



Compound B

The structure of compound **F** is shown below.



Compound F

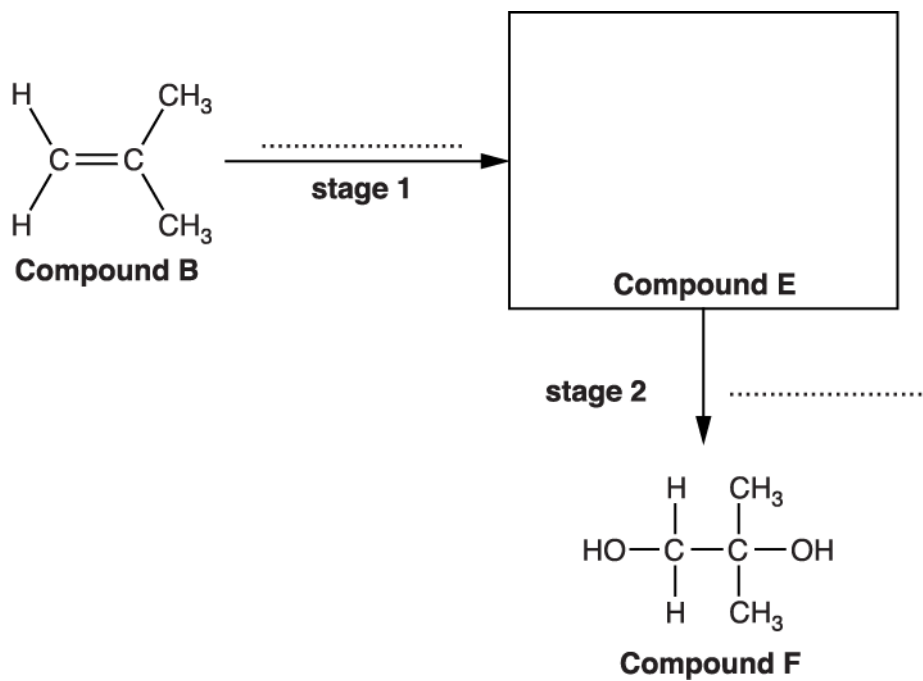
- (i) What is the empirical formula of compound **F**?

-----[2]

- (ii) A student plans a two-stage synthesis for preparing compound **F** from compound **B**.

The synthesis first prepares compound **E**, as shown in the flowchart.

Draw the structure of compound **E** in the box and state the reagents for each stage on the dotted lines.



[3]

- 11 Alcohols can be prepared from halogenoalkanes. 2,2-dimethylpropan-1-ol can be prepared by hydrolysis of a chloroalkane with aqueous sodium hydroxide.

(i) Write the equation for this reaction.

Use structures for the organic compounds.

[1]

(ii) Outline the mechanism for this reaction.

Show curly arrows and relevant dipoles.

[2]

12 In the stratosphere, nitrogen oxides can catalyse the breakdown of ozone.

(i) State **two** sources of nitrogen oxides in the stratosphere.

----- [1]

(ii) Write equations to show how nitrogen monoxide catalyses the breakdown of ozone.

----- [2]

13(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.

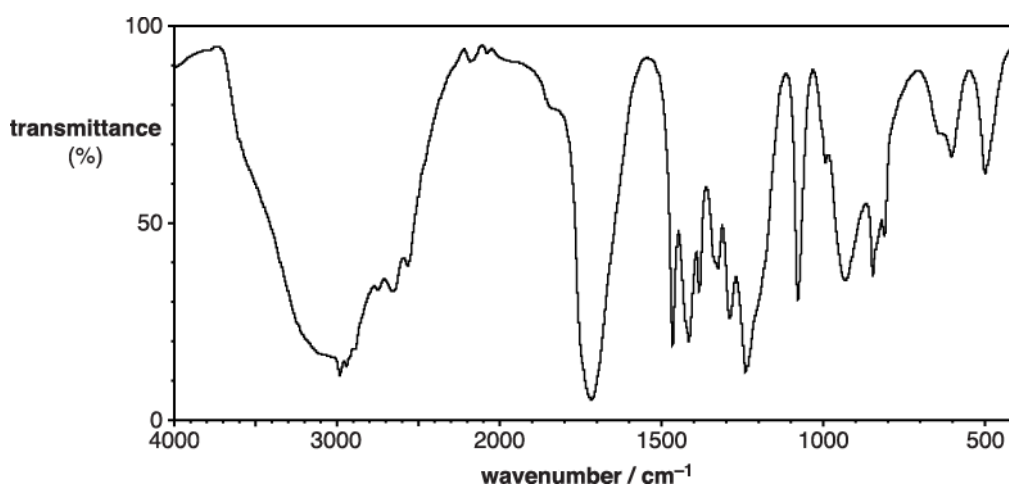


In your answer you should link the evidence with your explanation.

[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.

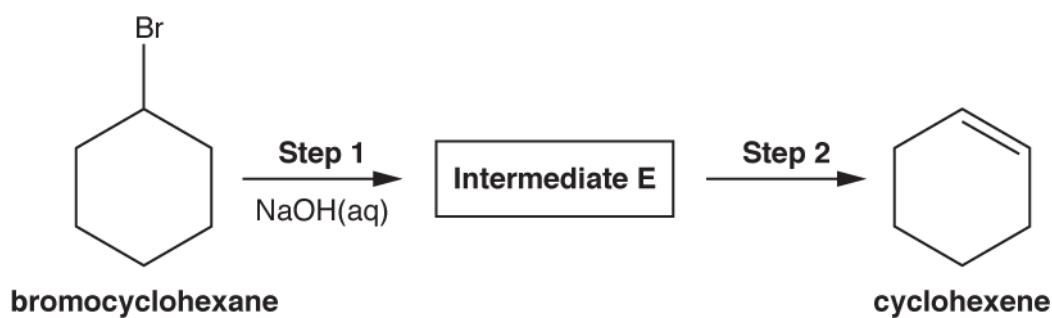
[6]

- Draw the structure of the organic compound H.

[2]

14 Organic compounds can be prepared in the laboratory using synthetic routes with two or more stages.

A student devises a two-stage synthesis of cyclohexene from bromocyclohexane.



- (i) Suggest the structure of **intermediate E** and the reagent(s) and conditions for **step 2**.

reagent(s) and conditions ----- [2]

- (ii) The student carries out this synthesis and obtains 1.23 g of pure cyclohexene from 5.50 g of bromocyclohexane.

Calculate the percentage yield of cyclohexene.

Give your final answer to an **appropriate** number of significant figures.

percentage yield = ----- % [3]

15 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.

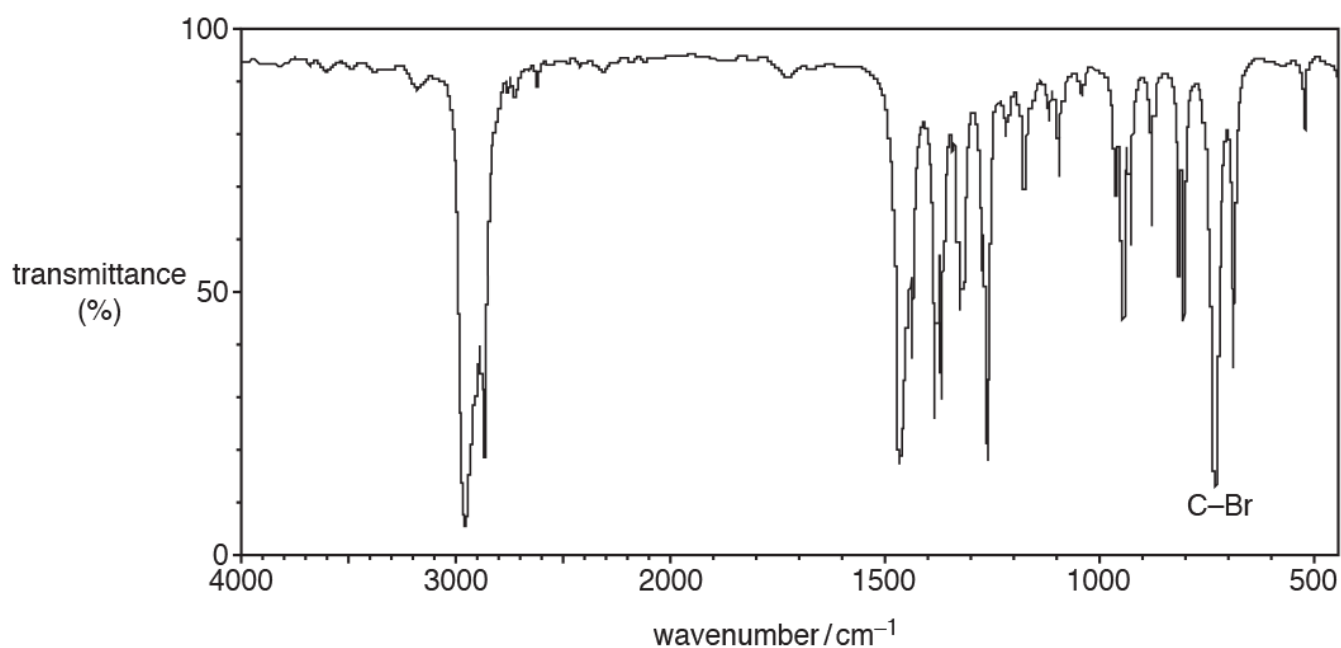


Fig. 25.2

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

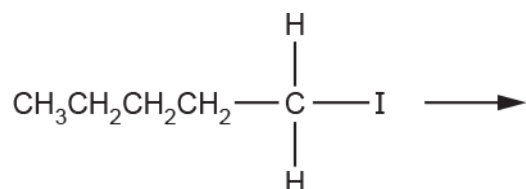
----- [2]

16 This question is about 1-iodopentane, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{I}$.

1-iodopentane can be hydrolysed by aqueous sodium hydroxide.

(i) Outline the mechanism for this reaction.

Include curly arrows, relevant dipoles and the final product(s).



[3]

(ii) 1-iodopentane can also be hydrolysed by water using aqueous silver nitrate, with ethanol as the solvent.

A student uses this method to compare the rates of hydrolysis of 1-iodopentane and 1-bromopentane.

What measurement and observation would allow the student to compare the rates of hydrolysis?

----- [1]

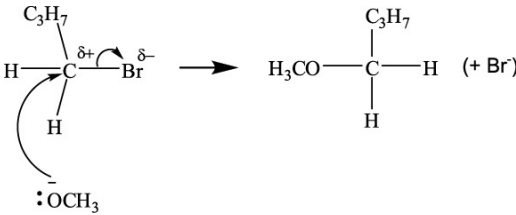
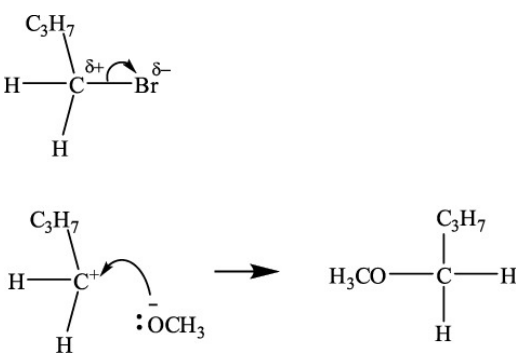
(iii) 1-iodopentane was found to react faster than 1-bromopentane.

Explain why.

----- [2]

END OF QUESTION PAPER

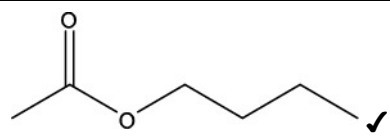
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
1	a		It is an electron pair donor OR can donate a lone pair ✓	1	Examiner's Comments Most candidates were able to state that the methoxide ion acted as an electron pair donor. In some cases imprecise responses such as 'donates electrons' were seen. Candidates should be encouraged to give specific answers when asked to explain scientific terms.
	b		 Dipole shown on the C-Br bond, Cδ^+ and Brδ^- and curly arrow from the C-Br bond to the Br atom ✓ Curly arrow from :$\ddot{\text{O}}\text{CH}_3$ to carbon atom in the C-Br bond ✓ Correct organic product ✓ S_N1 mechanism 	3	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC IGNORE connectivity to C₃H₇ throughout IGNORE alkyl group in first marking point. Curly arrow must start from C-Br bond and not from C atom. Dipole must be partial charge and not full charge CH₃O⁻ curly arrow must come from one lone pair on O of CH₃O⁻ ion OR from negative sign on O of the CH₃O⁻ ion ALLOW arrow from lone pair on O in OCH₃⁻ Lone pair not required DO NOT ALLOW CH₃O⁻ DO NOT ALLOW incorrect connectivity of CH₃O group in the final product -CH₃O IGNORE Brδ^- as a product ALLOW S_N1 mechanism Dipole shown on the C-Br bond, Cδ^+ and Brδ^- and curly arrow from C-Br bond to the Br atom ✓ curly arrow from CH₃O⁻ to carbonium ion ✓ correct organic product ✓ Examiner's Comments This question required candidates to apply their knowledge of the nucleophilic substitution mechanism in an unfamiliar context.

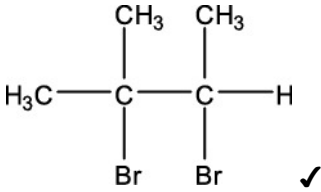
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					The first mark was awarded for showing the dipole on the C-Br bond and the curly arrow to demonstrate the heterolytic fission of the bond. This proved to be the most accessible mark and most candidates scored it. The second mark was awarded for the curly arrow from the methoxide ion to the C atom of the C-Br bond. The more able candidates were able to show their understanding and provided accurately drawn arrows. A common misconception was to start the curly arrow from a lone pair on the C atom of the methoxide ion. The third mark was awarded for the correct organic product and was often scored by the stronger candidates. As a consequence of showing nucleophilic attack from the C atom of the CH_3O^- ion, a significant number of responses showed the incorrect connectivity, as the nucleophile was joined via the C atom rather than the O atom. Unfortunately a number of candidates attempted to show the mechanism using OH^- ions as the nucleophile rather than CH_3O^-. Although they were able to score the first mark no other marks were awarded. A very small proportion of candidates chose to show the $\text{S}_{\text{N}}1$ mechanism rather than the expected $\text{S}_{\text{N}}2$ and full credit was allowed if the response was correct.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c		1-Iodobutane increases the rate  AND C—I bonds are weaker (than C—Br) OR C—I bond has a lower bond enthalpy OR C—I bond needs a smaller amount of energy to break OR C—I bond is easier to break ✓	1	All statements must be comparative ALLOW ORA IGNORE C—I bond is longer IGNORE polarity and references to electronegativity Examiner's Comments Many candidates were able to predict that the rate of the reaction would increase. In addition to this the Mark Scheme required candidates to explain this by referring to the effect of the different C-halogen bond. Most candidates were able to identify that the C-I bond would be weaker. Some candidates often referred to 1-iodobutane having weaker bonds but failed to specify which bond. Other candidates referred to the reactivity of iodine and bromine.
	d		 butyl ethanoate ✓	2	ALLOW only skeletal formula DO NOT ALLOW ECF from incorrect structure. ALLOW butylethanoate ALLOW butanyl for butyl DO NOT ALLOW butly Examiner's Comments This question required candidates to interpret the information and deduce that an ester would be produced. Many candidates found this challenging but the strongest candidates were able to provide a correct skeletal formula and name for the product. Common incorrect responses showed carboxylic acid structures and names.
			Total	7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
2	a			1	ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above DO NOT ALLOW molecular formula ALLOW dichloro or diiodo compound instead of the dibromo compound as the only alternatives. Examiner's Comments This question required candidates to interpret the reaction scheme and suggest an intermediate compound that could be formed from 2-methylbut-2-ene that could be also hydrolysed to give the diol shown. The most able candidates demonstrated their understanding of this scheme and often suggested the correct dihalo compound. Most candidate favoured the dibromo compound however some chose to show the dichloro or diiodo compound. All of these responses received credit. A large proportion of structures suggested were obtainable from 2-methylbut-2-ene but could not be hydrolysed. These included the products of hydrogenation e.g. 2-methylbutane, or hydration e.g. 2-methylbutan-2-ol. Consequently only the most able candidates achieved a mark in part (b), as this was essentially dependant on part (a).

Mark Scheme

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	b		Reagent A: correct halogen✓ e.g. Br ₂ / bromine	1	ALLOW C_l₂ if dichloro compound drawn ALLOW I₂ if diiodo compound drawn IGNORE state symbols Answer must match box from (a) to score Examiner's Comments This question required candidates to interpret the reaction scheme and suggest an intermediate compound that could be formed from 2-methylbut-2-ene that could be also hydrolysed to give the diol shown. The most able candidates demonstrated their understanding of this scheme and often suggested the correct dihalo compound. Most candidate favoured the dibromo compound however some chose to show the dichloro or diiodo compound. All of these responses received credit. A large proportion of structures suggested were obtainable from 2-methylbut-2-ene but could not be hydrolysed. These included the products of hydrogenation e.g. 2-methylbutane, or hydration e.g. 2-methylbutan-2-ol. Consequently only the most able candidates achieved a mark in part (b), as this was essentially dependant on part (a).

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	c	i	Steam AND acid catalyst ✓	1	ALLOW H^+ / named acid / H_2SO_4 / H_3PO_4 ALLOW $\text{H}_2\text{O}(\text{g})$ ALLOW water only if a temperature of 100°C or above is quoted. IGNORE any temperature given with steam IGNORE pressure Examiner's Comments One would expect the majority of candidates to do well in a question which required them to state the reagents and conditions required for the hydration of alkenes; however this was not the case. The most able candidates provided accurate responses which referred to both steam and the acid catalyst, which was often shown to be H_3PO_4. Other candidates stated only one of the two required responses and it was common to see the acid catalyst stated alongside a temperature and pressure but with no reference to steam. Some candidates stated the reagent as H_2O instead of steam and this was allowed if accompanied by a temperature of over 100°C. Candidates should be encouraged to learn reagents and conditions required for organic reactions.
		ii	(compounds or molecules) having the same molecular formula but different structural formulae ✓	1	ALLOW different structure OR different displayed formula OR different skeletal formula for structure Same formula is not sufficient Different arrangement of atoms is not sufficient Examiner's Comments The majority of candidates were able to explain the term structural isomers.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	$\begin{array}{c} \text{CH}_3 \text{ CH}_3 \\ \quad \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{OH} \quad \text{H} \quad \checkmark \end{array}$ $\begin{array}{c} \text{CH}_3 \text{ CH}_3 \\ \quad \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{H} \quad \text{OH} \quad \checkmark \end{array}$	2	ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above ALLOW any vertical bond to OH DO NOT ALLOW OH⁻ Examiner's Comments Many candidates found this question difficult and a large number of candidates showed structures of alcohols with the molecular formula C₅H₁₂O, but that could not be formed from 2- methylbut-2-ene. Examples of these incorrect responses included 2-methylbutan-1-ol, pentan-1- ol, pentan-2-ol and pentan-3-ol. Only the most able could show the structures of both alcohols produced by the hydration of 2-methylbut-2-ene. Candidates should be reminded to check that any structures they suggest are consistent with the context of the question.
		iv	Does not contain OH group(s) OR does not contain hydroxyl group(s) OR is not an alcohol ✓ Does not form hydrogen bonds with water ✓	2	ALLOW ORA throughout DO NOT ALLOW OH⁻ (ions) / hydroxide (ions) 'Does not form hydrogen bonds' is not sufficient Examiner's Comments The majority of candidates were able to recognise that the key to the solubility of the isomers in water is that they contain the OH group whereas 2-methylbut-2-ene does not. Most candidates scored the second mark by accurately explaining that the OH group could form hydrogen bonds with water.
			Total	8	

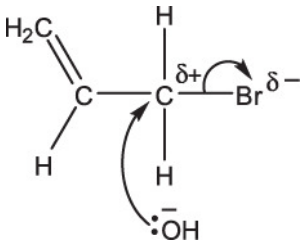
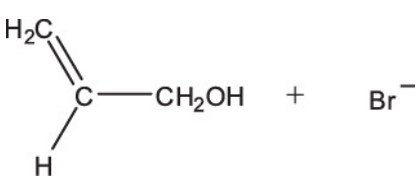
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
3		i	ANY TWO FROM THE FOLLOWING ✓ Low reactivity OR will not burn / non-flammable Volatile OR low boiling point non-poisonous OR non-toxic	1	ALLOW inert OR stable DO NOT ALLOW inflammable ALLOW it is a gas IGNORE easily compressed IGNORE not harmful IGNORE references to solubility Examiner's Comments Stronger candidates were able to identify two suitable properties of G. Although the majority were able state a single property it was often accompanied by a repetitive or incorrect statement. Vague statements, which included 'it is a CFC' and 'it is easily compressed' were also frequently seen.
		ii	<i>Benefit of ozone layer to life (1 mark)</i> Ozone absorbs UV (radiation) UV at Earth's surface is reduced ✓ OR <i>Maintenance of O₃ concentration (1 mark)</i> $O_3 \rightleftharpoons O_2 + O$ ✓ <i>Production of radicals from G (1 mark)</i>	5	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC For all equations, IGNORE dots on radicals Essential idea for first mark is that UV is removed in some way. ALLOW Prevents UV damaging life or stated type of damage, e.g. cataracts, skin cancer, mutation, crop damage DO NOT ALLOW ozone absorbs IR ALLOW $O_3 \rightarrow O_2 + O$ AND $O_2 + O \rightarrow O_3$ DO NOT ALLOW $2O_3 \rightleftharpoons 3O_2$

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			$\text{CF}_2\text{Cl}_2 \rightarrow \text{Cl} + \text{CF}_2\text{Cl} \checkmark$ <i>Breakdown of O_3 (2 marks)</i> $\text{Cl} + \text{O}_3 \rightarrow \text{ClO} + \text{O}_2 \checkmark$ OR $\text{ClO} + \text{O} \rightarrow \text{Cl} + \text{O}_2$ $\text{ClO} + \text{O}_3 \rightarrow \text{Cl} + 2\text{O}_2 \checkmark$		OR $\text{O}_3 + \text{O} \rightarrow 2\text{O}_2$ for this mark DO NOT ALLOW equations with other CFCs DO NOT ALLOW $\text{CF}_2\text{Cl}_2 \rightarrow 2\text{Cl} + \text{CF}_2$ These are the only acceptable equations IGNORE overall equation (<i>does not show role of catalyst</i>) e.g. $\text{O}_3 + \text{O} \rightarrow 2\text{O}_2$ Examiner's Comments This question was answered very well. Almost all candidates were able to recall the benefit of the ozone layer. The equations showing the catalytic breakdown of ozone with Cl radicals were reproduced accurately by the majority of the cohort. Although most candidates were able to explain how the concentration of ozone was maintained in words, the statements were not always accompanied by the relevant equations. The majority of candidates did not provide an equation to show the formation of Cl radicals from G and consequently only the strongest candidates received full marks.
		iii	D $\checkmark$	1	ALLOW CHF_2Cl ALLOW B OR C_2F_4 OR CF_2CF_2 Examiner's Comments The majority of candidates suggested a suitable compound from the selection provided.
			Total	7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
4	a	i	Movement of an electron pair ✓	1	ALLOW movement of a lone pair OR movement of a bond Examiner's Comments Although the definition of a curly arrow was well known, many imprecise responses were seen. The most common was that a curly arrow represents the movement of electrons. Candidates should be aware that it is important to refer to an electron pair, when describing the meaning of a curly arrow.
		ii	Electron pair donor ✓	1	ALLOW can donate a lone pair Examiner's Comments Most candidates could state the correct definition. However, as with part (i) a significant number of candidates failed to specify 'electron pair' and stated that a nucleophile is an electron donor.
	b	i	 curly arrow from HO⁻ to carbon 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 ✓ 	3	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC Curly arrow must come from lone pair on O of HO⁻ OR OH⁻ OR from minus sign on HO⁻ ion (No need to show lone pair if curly arrow came from negative charge on O) ALLOW S_N1 mechanism: Dipole shown on C-Br bond, C^{δ+} and Br^{δ-}, AND curly arrow from C-Br bond to Br atom ✓ Correct carbocation AND curly arrow from HO⁻ to carbocation Curly arrow must come from lone pair on O of HO⁻ OR OH⁻ OR from minus sign on HO⁻ ion (No need to show lone pair if curly arrow came from negative charge on O) ✓ correct organic product AND Br⁻ ✓

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			correct organic product AND Br ⁻ ✓		Examiner's Comments This question discriminated well and most candidates were able to score at least one mark, often by showing the curly arrow and dipole on the C-Br bond. The best responses included neatly drawn structures and accurately placed curly arrows. The use of NaOH, rather than OH⁻, by a lot of candidates led to difficulties for both the first and third marking points. The latter of which was missed as candidates stated the inorganic product as NaBr and neglected to show the Br⁻ ion formed from the heterolytic fission of the C—Br bond. Candidates are advised to only show the relevant ions when drawing mechanisms.
		ii	Nucleophilic substitution ✓	1	Examiner's Comments The majority of candidates could name this mechanism as nucleophilic substitution.
c	i		H ₂ AND Ni (catalyst) ✓	1	ALLOW name or formula for each IGNORE any stated temperature and pressure Examiner's Comments To score the mark in this question candidates had to state that both hydrogen and nickel were required for step 1. It was often the case that only one of these was stated. Although hydrogen was often seen as a reagent it was common to see an incorrect catalyst, such as H₂SO₄.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	(Initiation) $\text{Cl}_2 \rightarrow 2\text{Cl} \text{ AND UV } \checkmark$ (Propagation) $\text{C}_3\text{H}_7\text{Br} + \text{Cl} \rightarrow \text{C}_3\text{H}_6\text{Br} + \text{HCl} \checkmark$ $\text{C}_3\text{H}_6\text{Br} + \text{Cl}_2 \rightarrow \text{C}_3\text{H}_6\text{BrCl} + \text{Cl} \checkmark$ (Termination) Two from the three termination equations below $\checkmark$ $2\text{Cl} \rightarrow \text{Cl}_2$ $\text{C}_3\text{H}_6\text{Br} + \text{Cl} \rightarrow \text{C}_3\text{H}_6\text{BrCl}$ $2\text{C}_3\text{H}_6\text{Br} \rightarrow \text{C}_6\text{H}_{12}\text{Br}_2$ names of steps initiation, propagation and termination linked to one correct equation for each step in this mechanism $\checkmark$	5	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC DO NOT ALLOW any ECF in this question IGNORE references to temperature THROUGHOUT, ALLOW correct molecular formulae OR structural OR displayed OR skeletal OR mixture of the above IGNORE dots IGNORE state symbols IGNORE one incorrect termination equation Examiner's Comments This question required candidates to apply their knowledge of the radical substitution mechanism to form a bromochloroalkane. Examiners were encouraged by the number of excellent attempts and it is clear that candidates had prepared well for this type of question. Consequently most candidates scored four or five marks. A common reason for a candidate only scoring four marks was the omission of UV radiation as an essential condition.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	further substitution OR produces different termination products OR More than one termination step✓ substitution at different positions along chain ✓	2	IGNORE mixture of organic products (<i>in question</i>) ALLOW dichloro / multichloro / dibromo / multibromo compounds formed OR an example of a further substitution product OR an example of a different termination product ALLOW more than one hydrogen (atom) can be replaced ALLOW radicals react with each other to form other products ALLOW forms different structural isomers ALLOW a hydrogen (atom) on a different carbon (atom) can be replaced Examiner's Comments Candidates often found it difficult to provide clearly written explanations for this question. The majority of responses focused on further substitution or the idea of different termination steps. Only the best candidates recognised that chlorination of 1-bromopropane would produce a mixture of structural isomers.
			Total	14	
5		i	$\text{Ag}^+ + \text{Cl}^- \rightarrow \text{AgCl}$ OR $\text{Ag}^+ + \text{Br}^- \rightarrow \text{AgBr}$ OR $\text{Ag}^+ + \text{I}^- \rightarrow \text{AgI}$	1	
		ii	Bond enthalpy decreases $\text{C}-\text{Cl} > \text{C}-\text{Br} > \text{C}-\text{I}$	1	allow chlorine–carbon bonds are strongest.
		iii	Heat the test tubes in a water bath.	1	
			Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
6		i	Reflux	1	
		ii	Nucleophilic substitution (1) <i>Mechanism</i> Curly arrow from lone pair on OH⁻ to δ⁺ carbon atom (1) Curly arrow and dipole on C-I bond (1) Correct products (1)	4	The curly arrow must start from the oxygen atom of the OH⁻ and must start from either the lone pair or the negative charge do not allow attack by NaOH
			Total	5	
7			Propagation step 1 $\text{NO}\cdot + \text{O}_3 \rightarrow \text{NO}_2\cdot + \text{O}_2 \checkmark$ Propagation step 2 $\text{NO}_2\cdot + \text{O} \rightarrow \text{NO}\cdot + \text{O}_2 \checkmark$	1 1	ALLOW one mark for both correct symbol equations with (any or all) dots missing or extra dots e.g. $\text{NO} + \text{O}_3 \rightarrow \text{NO}_2\cdot + \text{O}_2$ $\text{NO}_2 + \text{O} \rightarrow \text{NO} + \text{O}_2\cdot$ Examiner's Comments Many incorrect equations or correct symbol equations containing incorrect radicals were observed. A large proportion of candidates scored no marks on this question although the most able often provided both equations to gain two marks.
			Total	2	
8			B	1	<u>Examiner's Comments</u> Generally scored well.
			Total	1	
9			D	1	<u>Examiner's Comments</u> Generally scored well.
			Total	1	

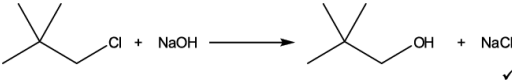
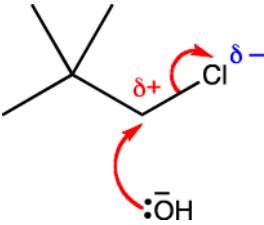
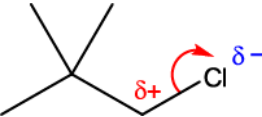
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
10		i	C ₂ H ₅ O ✓	1	ALLOW elements in any order DO NOT ALLOW any other answer <u>Examiner's Comments</u> This part was answered well by most candidates. Some candidates however wrote the molecular rather than the empirical formula, or attempted to show the empirical formula as C₂H₄OH instead of C₂H₅O.

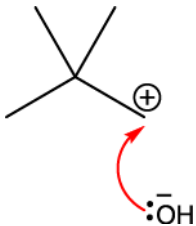
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Question			Answer/Indicative content	Marks	Guidance
		ii	Compound E: $ \begin{array}{c} \text{H} \quad \text{CH}_3 \\ \quad \\ \text{Br}-\text{C}-\text{C}-\text{Br} \\ \quad \\ \text{H} \quad \text{CH}_3 \end{array} \quad \checkmark $ Stage 1: Compound E: Bromine/Br₂ ✓ Stage 2: NaOH/KOH OR OH⁻ ✓ <i>Only award if intermediate contains at least one halogen atom</i>	3	For structures: ALLOW correct structural OR skeletal OR displayed formula OR mixture of the above ALLOW dichloro/diiodo compound IGNORE connectivity of bonds to CH₃ ALLOW chlorine/Cl₂ OR iodine/I₂ IGNORE conditions, e.g. u.v. DO NOT ALLOW H₂O IGNORE conditions NOTE: Max of 2 marks available for monobrominated intermediate 1 mark Reagent: HBr AND Intermediate: CH₃C(CH₃)₂Br OR BrCH₂CH(CH₃)₂ 1 mark Intermediate: CH₃C(CH₃)₂Br OR BrCH₂CH(CH₃)₂ AND Reagent: NaOH <u>Examiner's Comments</u> This demanding part was answered poorly by weaker candidates and was good for differentiating higher ability candidates. The mark scheme allowed some credit for using a hydrogen halide to obtain a monosubstituted haloalkane for compound E. Surprisingly, reaction mechanism names were often given instead of reagents. Many candidates seemed to guess, sometimes showing the same reagents for both stages in the hope of getting a mark. Many showed an intermediate containing no halogen atom.
			Total	4	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
11	i 	1	ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above ALLOW equation with OH^- as reactant and Cl^- product e.g $(\text{CH}_3)_3\text{CCH}_2\text{Cl} + \text{OH}^- \rightarrow (\text{CH}_3)_3\text{CCH}_2\text{OH} + \text{Cl}^-$ IGNORE equations with $\text{KOH} / \text{H}_2\text{O}$ as reactant (<i>question states sodium hydroxide</i>) IGNORE molecular formulae (<i>question requires structures</i>) Examiner's Comments Most candidates were able to identify the correct chloroalkane required to produce 2,2-dimethylpropan-1-ol and provided a correctly balanced equation. A small but significant proportion of candidates failed to show the inorganic product in their equation. Candidates are encouraged to check equations carefully to ensure the correct formulae appear on both sides.
	ii  curly arrow from HO^- to carbon atom of $\text{C}-\text{Cl}$ bond ✓ Dipole shown on $\text{C}-\text{Cl}$ bond, $\text{C}^{\delta+}$ and $\text{Cl}^{\delta-}$ AND curly arrow from $\text{C}-\text{Cl}$ bond to Cl atom ✓	2	Curly arrow must come from lone pair on O of HO^- OR OH^- OR from minus sign on O of HO^- ion (No need to show lone pair if curly arrow came from negative charge) NOTE: ALLOW mechanism involving ANY halogenoalkane as structures have been assessed in (i) ----- ALLOW $\text{S}_{\text{N}}1$ mechanism: First mark Dipole shown on $\text{C}-\text{Cl}$ bond, $\text{C}^{\delta+}$ and $\text{Cl}^{\delta-}$ AND curly arrow from $\text{C}-\text{Cl}$ bond to Cl atom ✓  Second mark

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					Correct carbocation AND curly arrow from HO^- to carbocation  Note: '+' is fine for charge (circle used for clarity) Curly arrow must come from lone pair on O of HO^- OR OH^- OR from minus sign on O of HO^- ion (No need to show lone pair if curly arrow came from negative charge) ✓ ----- Examiner's Comments The mechanism of the hydrolysis of a primary halogenoalkane was well known and consequently most candidates scored both marks. A small, but significant, proportion of candidates started their curly arrow from the H atom of the hydroxide ion. Candidates should be advised to take care when drawing mechanisms to ensure curly arrows are used accurately.
			Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
12		i	Thunderstorms / lightning AND aircraft ✓	3	IGNORE car engines Examiner's Comments This question required candidates to state two sources of nitrogen oxides in the stratosphere. Whilst most candidates identified one, this was often accompanied by vague or irrelevant statements such as 'car engines' or 'the burning of fossil fuels'. Consequently only the strongest candidates scored in this part.
		ii	$\text{NO} + \text{O}_3 \rightarrow \text{NO}_2 + \text{O}_2$ ✓ $\text{NO}_2 + \text{O} \rightarrow \text{NO} + \text{O}_2$ ✓	2	ALLOW $\text{NO}_2 + \text{O}_3 \rightarrow \text{NO} + 2\text{O}_2$ IGNORE dots IGNORE $\text{O} + \text{O}_3 \rightarrow 2\text{O}_2$ IGNORE $2\text{O}_3 \rightarrow 3\text{O}_2$ Examiner's Comments The majority of candidates were able to provide the two equations that describe the catalytic role of NO in ozone depletion. A small but, significant proportion, of candidates provided equations involving N atoms.
			Total	3	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
13	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

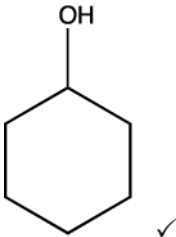
Mark Scheme

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.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	13	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
14		i	 Acid (catalyst) AND heat ✓	2	ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous ALLOW (heat under) reflux ALLOW H_3PO_4 OR H_2SO_4 OR H^+ DO NOT ALLOW other named acids IGNORE concentration / pressure IGNORE water / steam Examiner's Comments Candidates who were able to give the structure of the intermediate were not always able to state the conditions for the elimination of water from an alcohol. The presence of an acid catalyst and heat are stated in the specification. Some candidates confused this reaction with addition reactions of alkenes suggesting that a Ni catalyst or the presence of steam is required.

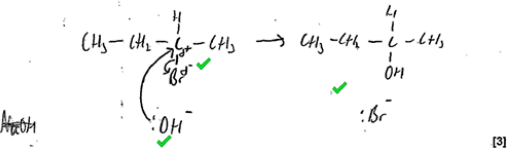
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Question			Answer/Indicative content	Marks	Guidance
		ii	FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = 44.4(%) award all 3 marks for calculation <i>Amount cyclohexene (m / M)</i> = 1.23/82 OR 0.0150 mol ✓ <i>Amount of bromocyclohexane (m / M)</i> = 5.50/162.9 OR 0.0338 mol ✓ % yield = (0.0150/0.0338) × 100 = 44.4(%) ✓ Final answer must be to 3 significant figures	3	If there is an alternative answer, check to see if there is any ECF credit possible ALLOW 3 SF: 0.0338 up to calculator value of 0.033763044 correctly rounded Common ECFs (2 marks) • Incorrect M_r → incorrect moles of cyclohexene • Incorrect M_r → incorrect moles of 2- bromocyclohexane e.g. ALLOW two marks for use of incorrect mass of bromocyclohexane with other calculations correct e.g. (5.50/163) = 0.033742331 → 44.5% ALLOW calculation in mass <i>Theoretical mass yield:</i> $m(\text{C}_6\text{H}_{10}) = 0.0338 \times 82 = 2.77 \text{ g}$ % yield = (1.23/2.77) × 100 = 44.4% Examiner's Comment: Although some candidates simply calculated 1.23/5.50, most followed an effective strategy for the calculation of percentage yield. Many gained full marks but a large number of candidates relied on the application of error carried forward when they made one or more careless errors during the calculation of molar mass and / or moles. Intermediate answers were sometimes rounded to 2 significant figures and marks were lost by candidates who presented their final answer to 2 or 4 significant figures.
			Total	5	

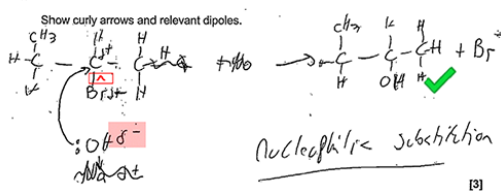
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
15	i	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 <u>Examiner's Comments</u> As with 25(a)(i), this question rewarded the

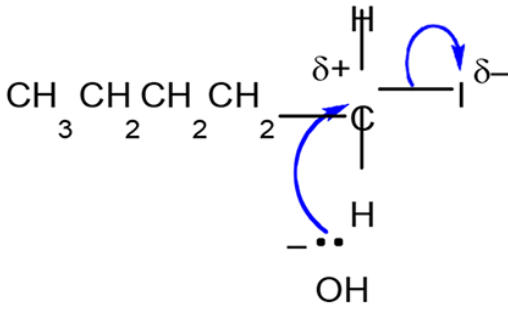
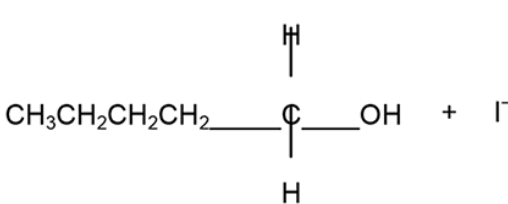
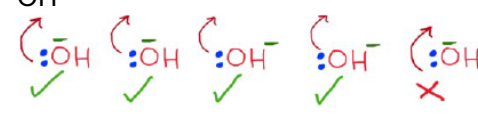
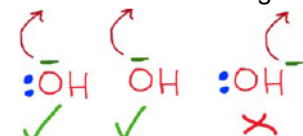
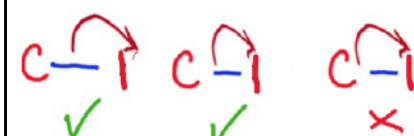
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			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.  Exemplar 8

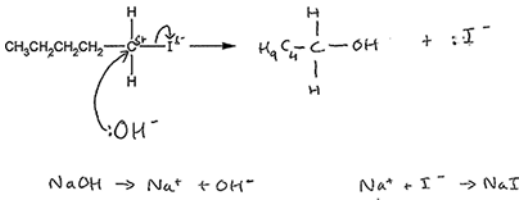
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					(b) An alcohol can be prepared by hydrolysing the haloalkane $C_2H_5CH_2Br$ 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 Examiner's Comments 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	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
16	i Curly arrow from HO^- to carbon atom of C-I bond ✓ Dipole shown on C-I bond, $\text{C}^{\delta+}$ and $\text{I}^{\delta-}$ AND curly arrow from C-I bond to I atom ✓  IGNORE presence of Na^+ but OH^- needed i.e. Na^+OH^- can be allowed if the criteria are met ----- Correct organic product AND I^- ✓  IGNORE presence of Na^+ but I^- needed i.e. Na^+I^- can be allowed BUT NaI does not show I^-	3(AO2.5×3)	ANNOTATE ANSWER WITH TICKS AND CROSSES NOTE: curly arrows can be straight, snake-like, etc. but NOT double headed or half headed arrows 1st curly arrow must - go to the C of C-I 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-I bond and go to I  Examiner's Comments Those that had learnt this important mechanism scored all 3 marks with very precisely drawn arrows and partial charges. Although many candidates wrote out the correct organic product, many wrote NaI instead of I^- which lost them the final mark.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					Exemplar 4  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{I} + \text{OH}^- \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + \text{I}^-$ $\text{NaOH} \rightarrow \text{Na}^+ + \text{OH}^-$ $\text{Na}^+ + \text{I}^- \rightarrow \text{NaI}$ This candidate scored all 3 marks. The lone pair of electrons on the oxygen and partial charges on the C-I bond are clearly marked on the diagram and the arrows are precisely drawn. Connectivity is good on the organic product and I⁻ identified as the additional product.
		ii	Time for precipitate to appear ✓	1(AO3.3)	Time AND precipitate required <i>Question asks for measurement</i> Examiner's Comments The question asked for the measurement AND observation, many students did not answer both parts and therefore did not gain any marks. "How fast" and "how long" were not given as they did not detail the measurement.
		iii	C-I bond is weaker (than C-Br bond) OR C-I bond has a lower bond enthalpy (than C-Br bond) ✓ Carbon – halogen bond breaks ✓	2(AO3.2)	For 2 marks, ALLOW C-I is broken more easily (than C-Br) as the bond is weaker There must be a comparison between C-Br and C-I bonds Examiner's Comments Answers were too vague to be given in most cases. Candidates referred to bonds being broken or overcome, but did not specify C-I bonds breaking, or discussed iodine and bromine in terms of reactivities.
			Total	6	