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A' Level Chemistry

Year 1

Unit 5: Halogenoalkanes & Alkenes

Summer Examination Revision Pack

The questions in this pack should be attempted **AFTER** completing all other revision.

Grade Accelerator

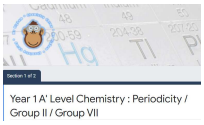
Recall Definitions
Drawing Diagrams
Using Equations
Drawing Graphs

Quizlet Classes

Flashcard Based
Games
Tests & Quizzes
Keyword Spell Checker

Condensed Notes

Keywords & Definitions
Key Concepts
Application
Key Skills



Online Forms

Take Time to Answer
Use Paper & Calculator
Work It Out
Review Missed Marks

Use the 3 Wave Process when completing these revision packs.

1. Complete the questions without assistance
(Can't answer a question? Leave it and move on)
2. Use your notes to fill any gaps after step 1
3. Use the mark scheme to fill in any remaining gaps.

1. Having gaps after step 1 is normal, that's why we are doing revision!
2. If your notes don't help during step 2, they are not good enough!
(Change your note taking method and try to understand the problem)
3. If you don't understand why the mark scheme answer is correct, **see Andy.**

If you struggle with the questions in the pack, **STOP!** and complete some more revision.

If you come to a complete dead-end, **STOP!** and speak to **Andy** asap.

5 Refrigerants are substances used to cool refrigerators and freezers. Until recently, many of the compounds used as refrigerants were chlorofluorocarbons (CFCs), but these are now known to form chlorine radicals. CFCs have been phased out in many countries by international agreement.

0 5 . 1 Write **two** equations to show how chlorine radicals react with ozone molecules in the upper atmosphere.

[2 marks]

1 _____

2 _____

0 5 . 2 Chloropentafluoroethane is a CFC that has been used as a refrigerant.

Draw its displayed formula.

[1 mark]

0 5 . 3 1,1,1-trifluoroethane (CF_3CH_3) is one of the molecules that has been used as a refrigerant in place of CFCs.

Explain why 1,1,1-trifluoroethane does not lead to the depletion of the ozone in the upper atmosphere.

[1 mark]

_____

_____

_____

0 5 . 4 One of the steps in the synthesis of 1,1,1-trifluoroethane (CF_3CH_3) is the reaction of 1,1-difluoroethane (CHF_2CH_3) with fluorine in a free-radical substitution reaction.

Write **two** equations to represent the propagation steps in this conversion of CHF_2CH_3 into CF_3CH_3

[2 marks]

Propagation step 1

Propagation step 2

0 5 . 5 A refrigerator contains 1.41 kg of 1,1,1-trifluoroethane (CF_3CH_3).

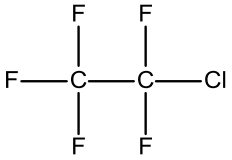
Calculate the number of molecules of 1,1,1-trifluoroethane in the refrigerator.
Give your answer to an appropriate number of significant figures.
(The Avogadro constant L = 6.022×10^{23} mol^{-1})

[2 marks]

0 5 . 6 There are growing concerns about the use of 1,1,1-trifluoroethane as a refrigerant as it is a greenhouse gas that absorbs some of Earth's infrared radiation.

Give **one** reason why bonds in molecules such as carbon dioxide and 1,1,1-trifluoroethane absorb infrared radiation.

[1 mark]

Question	Marking Guidance	Mark	Comments
05.1	M1 $\bullet Cl + O_3 \rightarrow \bullet ClO + O_2$ M2 $\bullet ClO + O_3 \rightarrow \bullet Cl + 2O_2$	1 1	M1 and M2 could be in either order. Credit the dot anywhere on the radical. Penalise absence of dot once only. Individual multiples acceptable but both need to be doubled if two marks are to be awarded. Ignore state symbols
05.2		1	Must be displayed formula
05.3	Does not contain Cl or does not release Cl (atoms/radicals) or no C-Cl bonds or C-F bond(s) strong / does not break / no F (atom/radicals) released	1	
05.4	M1 $CHF_2CH_3 + \bullet F \rightarrow \bullet CF_2CH_3 + HF$ M2 $\bullet CF_2CH_3 + F_2 \rightarrow CF_3CH_3 + \bullet F$	1 1	M1 and M2 could be in either order. Credit the dot anywhere on the radical. Penalise absence of dot once only.

05.5	M1 moles CF_3CH_3 = 1410/84(.0) (=16.8, 16.79 mol) M2 molecules = M1 x 6.022×10^{23} = 1.01×10^{25} (3sf only)	1 1	Correct answer scores both marks Allow M2 for M1 x Avogadro with answer to 3 sf (but must have attempted to calculate moles for M1) Ignore incorrect units

05.6	(bonds) vibrate/stretch/bend OR (as bonds) are polar	1	NOT polar molecules; 'they' = bonds

7 The alkene 3-methylpent-2-ene ($CH_3CH=C(CH_3)CH_2CH_3$) reacts with hydrogen bromide to form a mixture of 3-bromo-3-methylpentane and 2-bromo-3-methylpentane.

0 7 . 1 The alkene 3-methylpent-2-ene ($CH_3CH=C(CH_3)CH_2CH_3$) exists as *E* and *Z* stereoisomers.

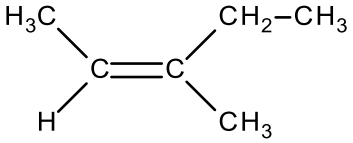
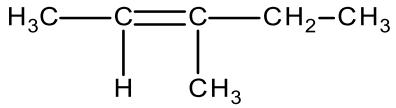
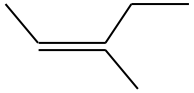
Draw the structure of *Z*-3-methylpent-2-ene.

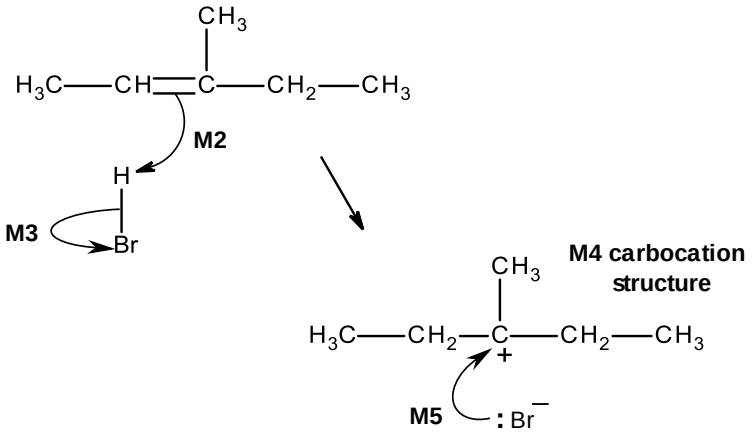
[1 mark]

0 7 . 2 Name and outline the mechanism for the formation of 3-bromo-3-methylpentane from this reaction of 3-methylpent-2-ene with hydrogen bromide.

Explain why more 3-bromo-3-methylpentane is formed in this reaction than 2-bromo-3-methylpentane.

[7 marks]

Question	Marking Guidance	Mark	Comments
07.1		1	Must show all 4 groups bonded to C=C Allow CH_3- for methyl group; allow C_2H_5 for ethyl group Allow correct structure of the style  Allow correct skeletal structure 

07.2	M1 <u>electrophilic addition</u>  NB the arrows here are double-headed M2 must show an arrow from the double bond towards the H atom of the H-Br molecule M3 must show the breaking of the H-Br bond M4 is for the structure of the tertiary carbocation M5 must show an arrow from the lone pair of electrons on the negatively charged bromide ion towards the positively charged atom (of either a secondary or) of a tertiary carbocation M6 3-bromo-3-methylpentane is <u>formed from 3^{y} carbocation</u> OR 2-bromo-3-methylpentane is <u>formed from 2^{y} carbocation</u> M7 <u>3^{y} carbocation more stable than 2^{y}</u>	1 1 1 1 1 1 1	**M2-M5** Penalise one mark from their total if half-headed arrows are used **M2** Ignore partial negative charge on the double bond **M3** Penalise incorrect partial charges on H-Br bond and penalise formal charges Penalise **M4** if there is a bond drawn to the positive charge Penalise only once in any part of the mechanism for a line and two dots to show a bond **Max 3 of any 4 marks (M2-5)** for wrong organic reactant or wrong organic product (if shown) or secondary carbocation **Max 2 of any 4 marks in the mechanism** for use of bromine Do not penalise the “correct” use of “sticks” For **M5**, credit attack on a partially positively charged carbocation structure but penalise **M4** **M6 is high demand and must refer to product being formed from/via correct class of carbocation** **M7 is high demand and must be clear answer refers to stability of carbocations (intermediates) not products** **Candidate that states that products are carbocations would lose M6 and M7** **M6,7** allow carbonium ion in place of carbocation; or a description of carbocation in terms of alkyl groups/ number of

			carbon atoms joined to a positive C
			When asked to outline a mechanism, candidates are **expected** to draw a mechanism with curly arrows (specification 3.3.1.2). On this occasion only we would allow a detailed description as shown. M2 must the describe the movement of a pair of electrons / curly arrow from the C=C towards the H atom of the H-Br molecule M3 must describe the breaking of the H-Br bond with the bonding pair of electrons moving to the Br / curly arrow from H-Br bond to Br M4 is for the structure of the tertiary carbocation (i.e. positive C bonded to one methyl and two ethyl groups) M5 must describe the movement of a pair of electrons from the Br^- ion to the positive C atom of the carbocation / curly arrow from the lone pair of electrons on the negatively charged bromide ion towards the positively charged C atom (of either a secondary or) of a tertiary carbocation

0 6 2-Methylpropan-1-ol can be prepared by reacting 1-bromo-2-methylpropane with dilute aqueous sodium hydroxide.

0 6 . 1 Name and outline the mechanism for this reaction.

[3 marks]

Name of mechanism _____

Mechanism

0 6 . 2 When 2.0 cm^3 of 1-bromo-2-methylpropane (M_r = 136.9) were reacted with an excess of sodium hydroxide, 895 mg of 2-methylpropan-1-ol (M_r = 74.0) were obtained.

The density of 1-bromo-2-methylpropane is 1.26 g cm^{-3}

Calculate the percentage yield for this reaction.

[3 marks]

Percentage yield _____

0 6 . 3 When 1-bromo-2-methylpropane reacts with hot, concentrated ethanolic potassium hydroxide rather than dilute aqueous sodium hydroxide, a different product is formed.

Name this organic product and name the mechanism for this reaction.

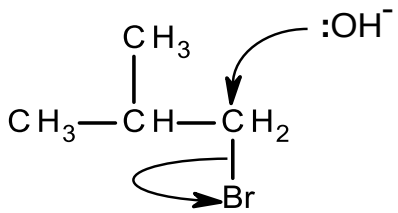
[2 marks]

Name of organic product _____

Name of mechanism _____

Turn over for the next question

8

Question	Marking Guidance	Mark	Comments
06.1	**M1** nucleophilic substitution  **M2** curly arrow from lone pair on O of OH^- to C of C-Br **M3** curly arrow from C-Br bond to the Br	1 1 1	Penalise **M3** for formal charge on C and/or Br of C-Br or incorrect partial charges on C-Br Max 1 out of 2 for **M2** & **M3** for incorrect reactant or product (ignore poorly drawn bond from C to OH group in product if shown) For SN2 penalise **M2** for any additional arrow(s) on NaOH penalise **M3** for any additional arrow(s) to/from the Br to/from anything else If SN1 mechanism given (loss of Br first followed by attack by OH^-) then: **M2** curly arrow from C-Br bond to the Br **M3** curly arrow from lone pair on O of OH^- to positive C atom of correct carbocation penalise **M2** for any additional arrow(s) to/from the Br to/from anything else penalise **M3** for any additional arrow(s) on NaOH If curly arrows represent an attempt at an elimination mechanism, cannot score **M2** or **M3**

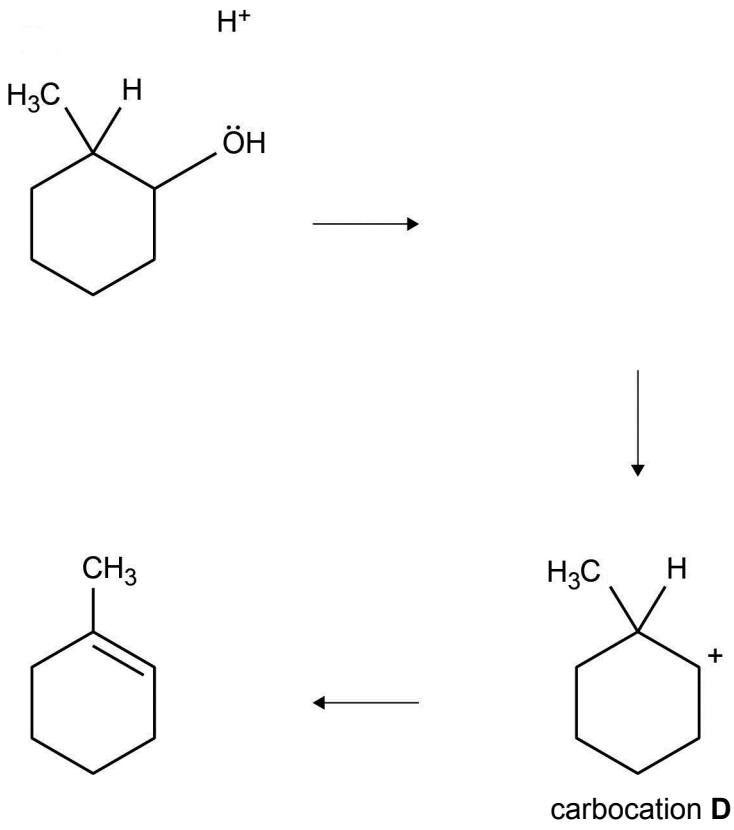
Question	Marking Guidance	Mark	Comments
06.2	**M1** Amount 1-bromo-2-methylpropane (= (2 x 1.26) / 136.9 = 2.52/136.9) = 0.0184 mol **M2** mass of 2-methylpropan-1-ol expected (= 0.0184 x 74.0) = 1.36 g **M3** % yield = 100 x (0.895/1.36) = 65.7% (65-67%)	1 1 1	Correct answer scores 3 marks; answer to at least 2sf and any individual marks for M1/2 should be at least 2sf; answers that are a factor of 10^x out score 2; Allow ECF through the question Alternative method: **M2** amount of 2-methylpropan-1-ol produced = 0.895/74.0 = 0.0121 mol **M3** % yield = 100 x (0.0121/0.0184) = 65.7% (65-67%) Allow 2 marks for 82.7-83% (comes from starting with 2 g not 2.52 g), with answers that are a factor of 10^x out from this scoring 1
06.3	**M1** methylpropene **M2** elimination	1 1	**M1** Do not allow any names with numbers for the position of the double bond. Allow 2-methylpropene but no other answer Ignore any drawn mechanism **M2** allow base (or basic) elimination but no other answer

0 7 Alcohols undergo dehydration in the presence of concentrated phosphoric acid, via a carbocation intermediate, to form alkenes.

0 7 . 1 Complete the mechanism for the conversion of 2-methylcyclohexanol into 1-methylcyclohexene via carbocation **D** by drawing

- the structure of the missing intermediate
- all necessary curly arrows.

[4 marks]



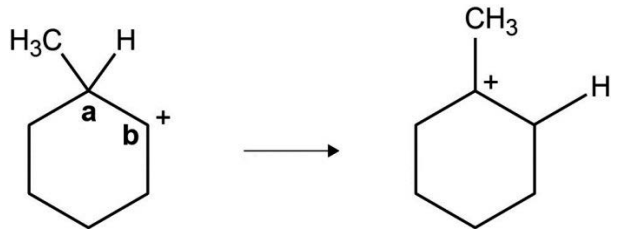
carbocation **D**

0 7 . 2 Draw the structure of a different cyclic alkene formed from carbocation **D**.

[1 mark]

0 7 . 3 Carbocation **D** can undergo a type of reaction called a rearrangement to form carbocation **E**. In this reaction, a hydrogen atom and its bonding pair of electrons move from carbon **a** to carbon **b** as shown in **Figure 2.**

Figure 2



carbocation **D** carbocation **E**

Use your knowledge of carbocations to explain why this rearrangement takes place.

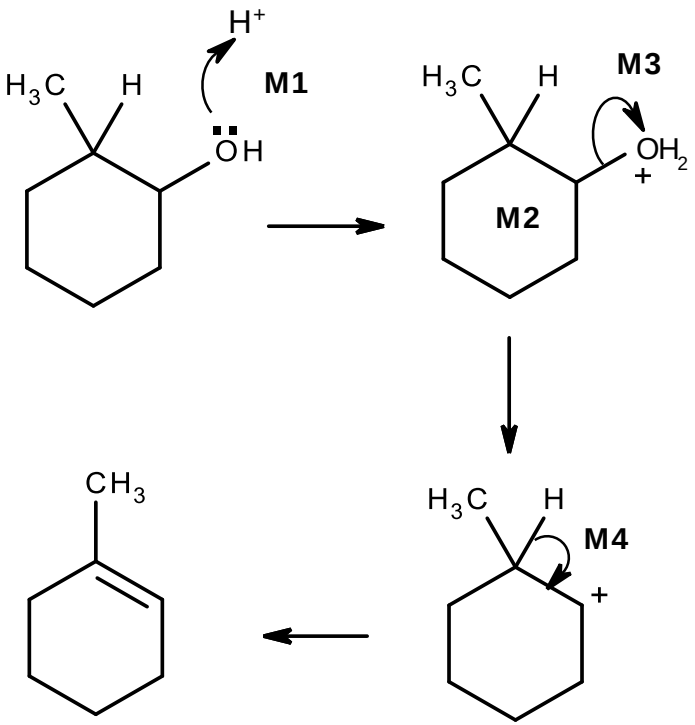
[2 marks]

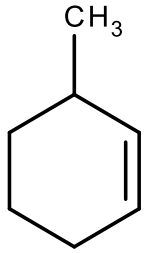
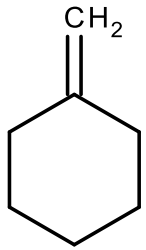
0 7 . 4 As a result of the rearrangement in Question **7.3**, a third alkene is formed in this reaction.

Draw the structure of this third alkene.

[1 mark]

Turn over for the next question

Question	Marking Guidance	Mark	Comments
07.1			Ignore other species that are drawn, but penalise any curly arrows to/from other species for **M1**/**3**/**4** as relevant (but allow attack by an anion of phosphoric acid on the H that is lost in **M4** in addition to the arrow specified) for **M2**, the O of the $^{+}OH_2$ group must be bonded to the ring
	M1 curly arrow from lone pair on O to H^+	1	
	M2 correct structure of intermediate with + on O	1	
	M3 curly arrow from C-O bond to O	1	
	M4 curly arrow from correct C-H bond towards correct C-C <u>bond</u>	1	

Question	Marking Guidance	Mark	Comments
07.2		1	Any correct structural representation
07.3	**M1** more stable (carbocation formed) **M2** changes from secondary to tertiary (carbocation)	1 1	For **M1** penalise more stable product For **M2** allow explanation via inductive effect with more alkyl / C groups attached or inductive effect from methyl group as alternatives Allow 2^o or 2^y for secondary and 3^o or 3^y for tertiary
07.4		1	Any correct structural representation

0 8 This question is about the structures of some organic molecules.

0 8 . 1 Draw the **skeletal** formula of 3-methylbutanal.

[1 mark]

0 8 . 2 Draw the **displayed** formula of $C_5H_{11}Br$ that is the major product of the reaction of 2-methylbut-2-ene with hydrogen bromide.

[1 mark]

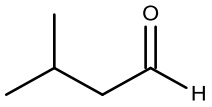
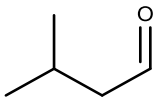
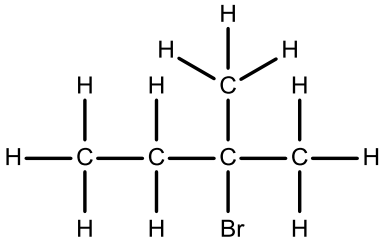
0 8 . 3 Thermal cracking of hydrocarbons produces molecules that are attacked by electrophiles because they have a region of high electron density.

Draw the structure of one of these molecules that contains four carbon atoms.

[1 mark]

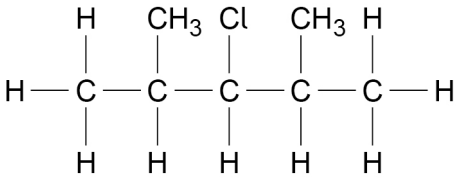
Turn over for the next question

3

Question	Marking Guidance	Mark	Comments
08.1	 or 	1	Must be a skeletal structure
08.2		1	Must be a displayed structure
08.3	Any correct structural representation of alkene with 4 C atoms, either: but-1-ene or but-2-ene or methylpropene	1	allow butadiene

0 6 Compound **A** is a halogenoalkane.

Compound A



0 6 . 1 Name Compound **A**.

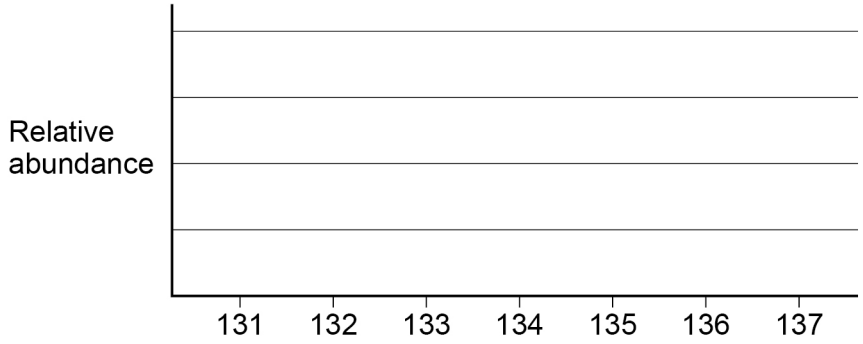
[1 mark]

0 6 . 2 Compound **A** has a relative molecular mass (M_r) of 134.5
The main isotope of hydrogen is ^{1}H
The main isotope of carbon is ^{12}C
Chlorine consists of two common isotopes, ^{35}Cl and ^{37}Cl, of which 75% is ^{35}Cl
The mass spectrum of **A** was recorded when **A** was ionised by electron impact to form $\mathbf{A}^{+}$ ions.

Draw, on **Figure 3**, the peaks for the main molecular ions in the mass spectrum of **A**.

[2 marks]

Figure 3



Question 6 continues on the next page

0 6 . 3 Reaction of **A** with warm, dilute aqueous sodium hydroxide forms alcohol **B**.

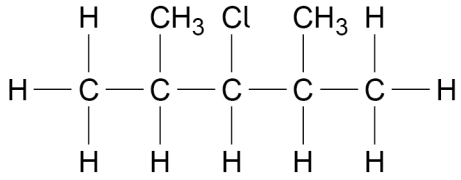
Name the mechanism for this reaction.

Outline the mechanism using the structure of **A** shown.
Include the structure of the product, alcohol **B**.

[4 marks]

Mechanism _____

Outline of mechanism



0 6 . 4 Reaction of **A** with hot, ethanolic potassium hydroxide gives alkene **C**.

Name the mechanism for this reaction.
State the role of the hydroxide ions.

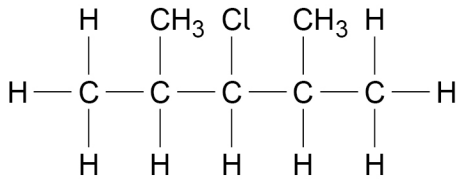
Outline the mechanism using the structure of **A** shown.
Include the structure of the product, alkene **C**.

[6 marks]

Mechanism _____

Role of hydroxide ions _____

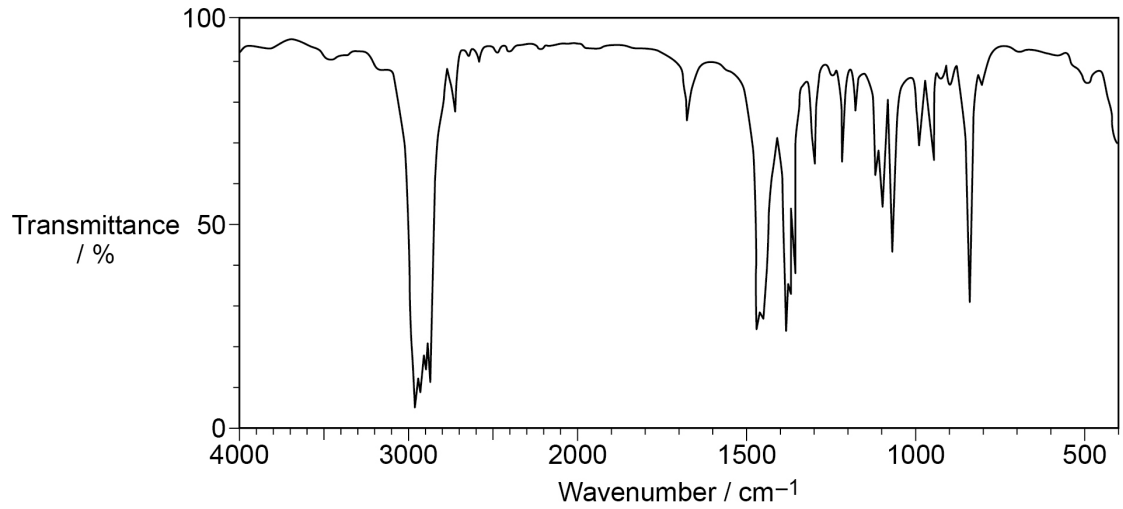
Outline of mechanism



Question 6 continues on the next page

0 6 . 5 The infrared spectrum in **Figure 4** is that of either alcohol **B** or alkene **C**.

Figure 4



Tick the box that shows the correct compound.
Explain your answer with reference to a bond and the wavenumber of its absorption.

[1 mark]

Alcohol **B** ☐ Alkene **C** ☐

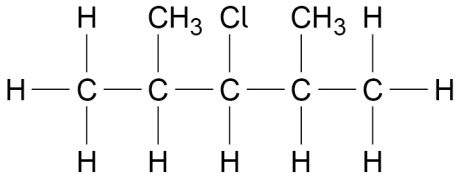
Explanation _____

_____

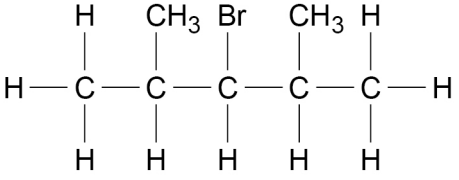
_____

0 6 . 6 Compound **D** reacts with dilute aqueous sodium hydroxide in a similar way to **A** to form alcohol **B**.

Compound A



Compound D

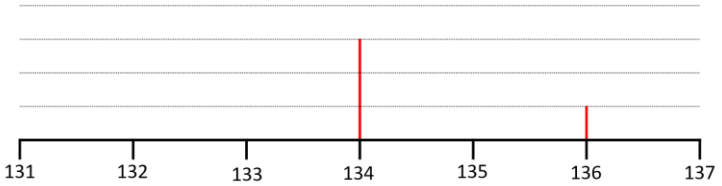


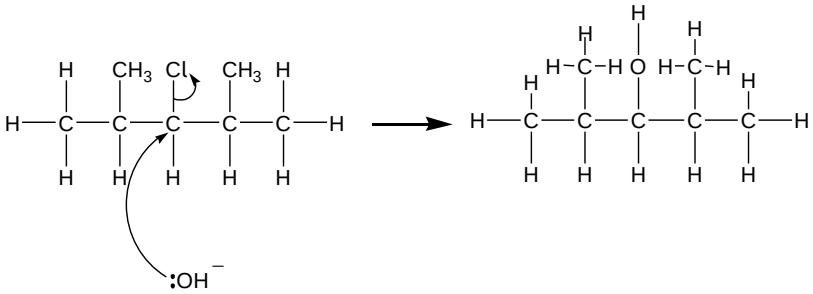
Explain why **D** reacts more quickly than **A** with dilute aqueous sodium hydroxide at the same temperature.

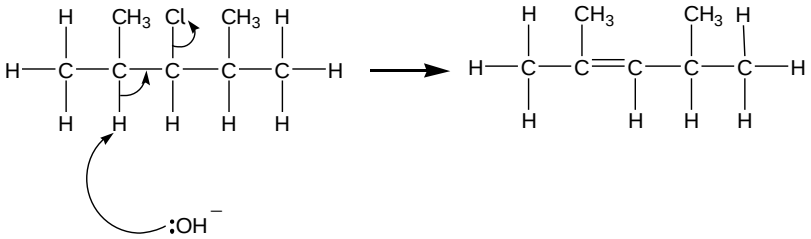
[1 mark]

15

Turn over for the next question

Question	Marking Guidance	Mark	Comments
6.1	3-chloro-2,4-dimethylpentane	1	This answer only apart from slips with commas and dashes
6.2	**M1** lines at 134 and 136 **M2** line at 134 to be three times higher than line at 136 	1 1	**M1** is for drawing the correct two lines (if other lines are drawn, penalise **M1** (but ignore any additional very small lines at 135 or 137) **M2** is for the line at 134 being three times as big as the one at 136 (ignore other lines) Accept cross to represent top of lines; if bars drawn – they should be narrow (less than 10% of division) and clear which value they refer to.

6.3	**M1** nucleophilic substitution  **M2** curly arrow from lone pair on O of OH^- to C of C–Cl **M3** curly arrow from C–Cl bond to the Cl **M4** correct structure of alcohol (in any form)	1 1 1 1	Penalise **M3** for formal charge on C and/or Cl of C–Cl or incorrect partial charges on C– Cl; ignore other partial charges on uncharged atoms For SN2: penalise **M2** for any additional arrow(s) on NaOH, or for covalent NaOH; penalise **M3** for any additional arrow(s) to/from the Cl to/from anything else If SN1 mechanism given (loss of Cl first followed by attack by OH^-) then: **M2** curly arrow from C–Cl bond to the Cl **M3** curly arrow from lone pair on O of OH^- to positive C atom of correct carbocation penalise **M2** for any additional arrow(s) to/from the Cl to/from anything else penalise **M3** for any additional arrow(s) on NaOH If curly arrows represent an attempt at an elimination mechanism, cannot score **M2** or **M3** **M4** is independent **M4** ignore presence of non-organic products

6.4	**M1** elimination **M2** base  **M3** curly arrow from lone pair on O of OH^- to H on one of the C atoms adjacent to the C–Cl **M4** curly arrow from a correct C-H bond adjacent to the C–Cl to a correct C-C bond. Only award if an arrow is shown attacking the H atom of a correct adjacent C-H bond in **M3** **M5** curly arrow from C–Cl bond to the Cl (mark is independent **M6** correct structure of alkene (in any form)	1 1 1 1 1 1	**M1** allow base elimination (but nothing else) **M2** allow proton acceptor Penalise **M5** for formal charge on C and/or Cl of C–Cl or incorrect partial charges on C–Cl; ignore other partial charges on uncharged atoms For E2: penalise **M3** for any additional arrow(s) on KOH, or for covalent KOH; penalise **M5** for any additional arrow(s) to/from the Cl to/from anything else If E1 mechanism given (loss of Cl first followed by attack by OH^-) then: **M3** curly arrow from C–Cl bond to the Cl **M4** curly arrow from lone pair of OH^- to a correct H on the correct C adjacent to C^+ on the carbocation **M5** curly arrow from a correct C-H bond to a correct C-C bond penalise **M3** for any additional arrow(s) to/from the Cl to/from anything else penalise **M4** for any additional arrow(s) on KOH If curly arrows represent an attempt at a substitution mechanism, cannot score **M3** or **M4** **M6** is independent **M6** ignore presence of non-organic products

6.5	**C** as C=C 1620-1680 cm^{-1} OR no O-H 3230-3550 cm^{-1}	1	need the correct compound and an explanation full wavenumber range or value(s) within the range on this occasion candidates do not need to refer to the O-H bond being O-H alcohol as opposed to O-H acid – just reference to O-H with wavenumbers is required

6.6	C–Br is weaker than C–Cl or C–Br has lower bond enthalpy than C–Cl or C–Br breaks more easily C–Cl	1	Must compare the C–Br and C–Cl bonds specifically Ignore references to bond length, size of atoms, shielding, electronegativity and polarity Penalise idea that bromine is more reactive than chlorine

Do not write outside the box

0 2 Bromoethane reacts with potassium cyanide to form compound **D**.

$$CH_3CH_2Br + KCN \rightarrow CH_3CH_2CN + KBr$$

Compound **D**

0 2 . 1 Outline the mechanism for this reaction.

[2 marks]

0 2 . 2 Give the IUPAC name of **D**.

[1 mark]

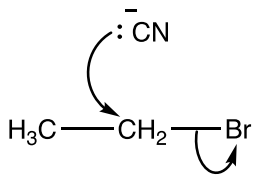
0 2 . 3 Calculate the percentage atom economy for the formation of **D** in this reaction.

Give your answer to the appropriate number of significant figures.

[2 marks]

% atom economy _____

5

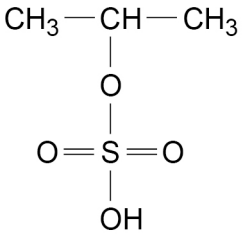
Question	Marking guidance	Additional Comments/Guidelines	Mark
02.1	 **M1** arrow from lone pair on C of CN^- to the C of the CH_2 group **M2** arrow from the C–Br bond to the Br	All arrows are double-headed. Penalise one mark from the total for **2.1** if half headed arrows are used. Do not penalise the "correct" use of "sticks" Penalise only once in mechanism for a line and two dots to show a bond Allow the minus sign to be anywhere on the CN^- ion **M2** penalise formal charges or incorrect partial charges on C–Br bond SN1: allow SN1 mechanism with **M1** for breakage of C–Br bond and **M2** for attack by CN^- on correct carbocation **Max 1 of 2 marks** for wrong organic reactant Ignore wrong organic product (if shown) *Extra arrows or incorrect covalent bonds:* Penalise the mark for breaking of C–Br bond for any extra arrows involving Br or covalent bond in KBr Penalise the mark for attack by CN^- for any extra arrows involving CN or covalent bond in KCN	2

Question	Marking guidance	Additional Comments/Guidelines	Mark
02.2	propan<u>e</u>nitrile	ignore any gaps, hyphens, commas allow propane-1-nitrile	1
02.3	**M1** $\frac{\mathbf{55}(.\mathbf{0})}{\mathbf{108.9+65.1}}$ (x 100) or $\frac{\mathbf{55}(.\mathbf{0})}{\mathbf{174}(.\mathbf{0})}$ (x 100) or $\frac{\mathbf{55}(.\mathbf{0})}{\mathbf{55}(.\mathbf{0})+\mathbf{119}(.\mathbf{0})}$ (x 100) **M2** 31.6(%) (must be 3sf)	31.6 scores 2 marks; 32 scores 1 mark no ECF	1 1

Do not write outside the box

0 6 Propene reacts with concentrated sulfuric acid to form two isomers, **E** and **F**.

The structure of **E** is shown.



0 6 . 1 Name and outline the mechanism for the formation of **E** in this reaction.

[5 marks]

Name of mechanism _____

Mechanism

Do not write outside the box

0 6 . 2 Draw the structure of **F**.

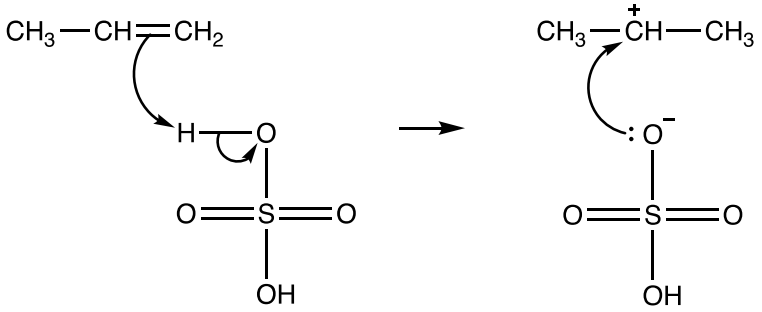
[1 mark]

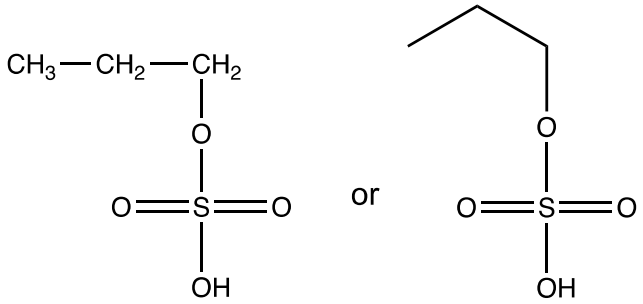
0 6 . 3 Explain why more of isomer **E** than isomer **F** is formed in this reaction.

[2 marks]

8

Turn over for the next question

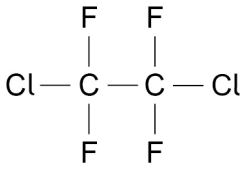
Question	Marking guidance	Additional Comments/Guidelines	Mark
06.1	**M1** <u>electrophilic addition</u>  **M2** must show an arrow from the double bond towards the H atom of the H_2SO_4 molecule **M3** must show the breaking of the H-O bond in H_2SO_4 **M4** is for the structure of the correct carbocation **M5** must show an arrow from the lone pair of electrons on the negatively charged oxygen of HSO_4^- towards the positively charged atom of <u>their</u> carbocation drawn	All arrows are double-headed. Penalise one mark from the total for **M2-5** if half headed arrows are used. Do not penalise the "correct" use of "sticks" Penalise only once in any part of the mechanism for a line and two dots to show a bond For **M2/3**, the full structure of H_2SO_4 does not need to be shown, but the key features for the mechanism should be shown and the formula must be correct. Penalise only once in **M2/3** an incorrect but genuine attempt at the structure of sulfuric acid **M2** ignore partial negative charges on the double bond **M3** penalise incorrect partial charges on the H–O bond and penalise formal charges Penalise **M4** if there is a bond drawn to the positive charge **Max 3 of 4 marks (M2-5)** for wrong organic reactant or wrong carbocation (ignore structure of product) If attack is shown from C=C to H^+ rather than H_2SO_4, then allow **M2** but not **M3** For **M5**, credit attack on a partially positively charged carbocation structure, but penalise **M4** for the structure of the carbocation. For **M5**, the full structure of HSO_4^- is not essential, but attack must come from a lone pair on an individual oxygen on HSO_4^-, but the – sign could by anywhere on the ion (e.g. $:OSO_3H^-$)	1 1 1 1 1

06.2	 or	Any correct structural formula, including OSO_3H bonded through O to correct C	1

06.3	**M1** idea that **E** is formed from/via more stable carbocation **M2** idea that 2^y carbocation is more stable than 1^y carbocation	**M1-2** Allow carbonium ion in place of carbocation **M2** Allow descriptions in terms of number of alkyl groups attached to positive C atom Ignore reference to inductive effect Penalise **M1** if answer suggests that the products are carbocations (but could score **M2**) In order to access **M1** and/or **M2** there must be some reference to carbocations (carbonium ions) by name or structure or description	1 1

Do not write outside the box

0 9 The compound 1,2-dichlorotetrafluoroethane is a CFC that was previously used in refrigerators as a coolant.



0 9 . 1 Molecules of 1,2-dichlorotetrafluoroethane can break down in the upper atmosphere to form chlorine radicals.

Give an equation to show the breakdown of one molecule of 1,2-dichlorotetrafluoroethane to form one chlorine radical and one other species.

[1 mark]

0 9 . 2 Give **two** equations to show how chlorine radicals catalyse the decomposition of ozone.

[2 marks]

Question 9 continues on the next page

Question	Marking guidance	Additional Comments/Guidelines	Mark
09.1	$CF_2ClCF_2Cl \rightarrow \bullet CF_2CF_2Cl + \bullet Cl$ or $C_2F_4Cl_2 \rightarrow \bullet C_2F_4Cl + \bullet Cl$	Any correct structure or molecular formula for reactant and/or product The dots can be shown anywhere around each radical	1
09.2	**M1** $Cl\bullet + O_3 \longrightarrow ClO\bullet + O_2$ **M2** $ClO\bullet + O_3 \longrightarrow Cl\bullet + 2O_2$	**M1** and **M2** could be in either order Credit the dot anywhere on the radical Penalise absence of dot once only Individual multiples acceptable but both need to be equivalent multiples for both marks to be awarded Ignore state symbols (Accept alternative pair of equations for **M2** (both needed for **M2**) $O_3 \longrightarrow O + O_2$ $ClO\bullet + O \longrightarrow Cl\bullet + O_2$)	1 1

Do not write outside the box

0 6 This question is about poly(chloroethene), commonly known as PVC.

0 6 . 1 Give an equation, showing structural formulas, for the conversion of chloroethene into poly(chloroethene).

[3 marks]

0 6 . 2 State what you would observe if bromine water was added to poly(chloroethene). Explain this observation.

[2 marks]

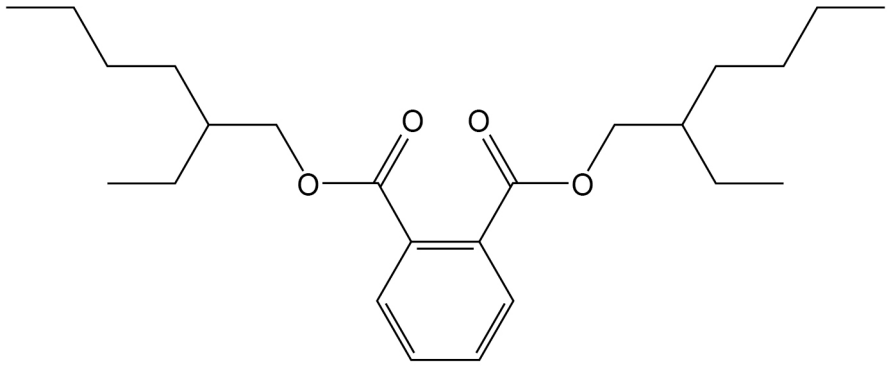
Observation _____

Explanation _____

_____

_____

0 6 . 3 Plasticisers are often added during the manufacture of PVC. The structure of the plasticiser DEHP is shown.



Deduce the molecular formula of DEHP and state why a plasticiser is added to PVC.

[2 marks]

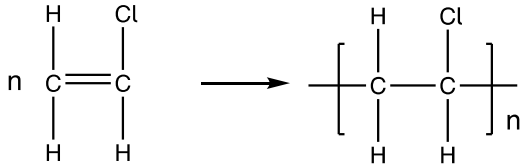
Molecular formula _____

Why a plasticiser is added _____

_____

_____

7

Question	Marking guidance	Additional Comments/Guidelines	Mark
06.1	**M1** structure of chloroethene **M2** structure of PVC **M3** correct use of n on both sides of equation 	Allow any correct structural representations of monomer and polymer **M2** allow correct repeating unit, but penalise incorrect use of bracket in **M3** **M2** and **M3** could score as ECF from incorrect **M1**	1 1 1
06.2	**M1** no reaction / yellow-orange **M2** polymer is saturated / does not contain double bond(s)	**M1** ignore brown; ignore red; ignore 'nothing'; ignore 'no observation'	1 1
06.3	**M1** $C_{24}H_{38}O_4$ **M2** makes it more flexible	**M2** allow make less brittle; ignore making more elastic	1 1

Do not write outside the box

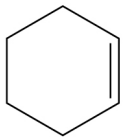
0 2 Alkenes react with bromine (Br_2)

0 2 . 1 Name and outline the mechanism for the reaction of cyclohexene with Br_2

[5 marks]

Name of mechanism _____

Outline of mechanism



Do not write outside the box

0 2 . 2 Explain why there is an attraction between a C=C double bond and Br_2

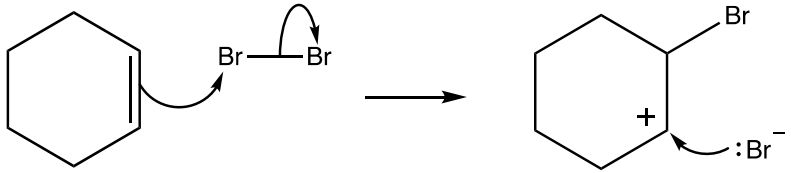
[3 marks]

0 2 . 3 Draw the skeletal formula of the halogenoalkane formed when buta-1,3-diene (CH_2=CHCH=CH_2) reacts with an excess of Br_2

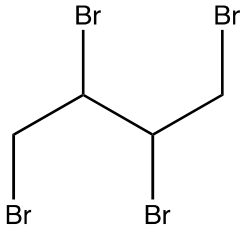
[1 mark]

9

Turn over for the next question

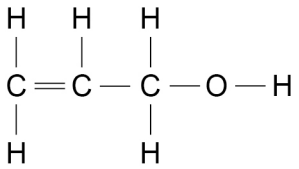
Question	Marking guidance	Additional Comments/Guidelines	Mark
02.1	**M1** electrophilic addition  **M2** must show an arrow from the double bond towards a Br atom in a Br–Br molecule **M3** must show the breaking of the Br–Br bond **M4** is for the structure of the correct carbocation **M5** must show an arrow from the lone pair of electrons on the Br^- towards the positively charged atom of <u>their</u> carbocation	All arrows are double-headed. Penalise one mark from the total for **M2-5** if half headed arrows are used. Do not penalise the "correct" use of "sticks" Penalise only once in any part of the mechanism for a line and two dots to show a bond **M2** ignore partial negative charges on the double bond **M3** penalise incorrect partial charges on the Br–Br bond and penalise formal charges Penalise **M4** if there is a bond drawn to the positive charge **Max 3 of 4 marks (M2-5)** for wrong organic reactant or wrong carbocation (ignore structure of product) For **M5**, credit attack on a partially positively charged carbocation structure, but penalise **M4** for the structure of the carbocation	1 1 1 1 1

Question	Marking guidance	Additional Comments/Guidelines	Mark
02.2	**M1** C=C electron rich / area of high electron density **M2** Br-Br becomes polarised **M3** δ+ Br attracted to C=C	**M1** ignore idea that C=C is negative or highly electronegative	1 1 1

Question	Marking guidance	Additional Comments/Guidelines	Mark
02.3		Must be skeletal structure	1

Do not write outside the box

0 7 Prop-2-en-1-ol is a natural chemical found in garlic. It is also used in the production of plasticisers.



0 7 . 1 Prop-2-en-1-ol can be prepared by reacting 3-chloroprop-1-ene with dilute aqueous sodium hydroxide.

Name the mechanism for this reaction.

[1 mark]

0 7 . 2 Prop-2-en-1-ol can also be formed from $HOCH_2CH_2CH_2OH$ in the presence of an acid catalyst.

$$HOCH_2CH_2CH_2OH \longrightarrow CH_2{=}CHCH_2OH + H_2O$$

Name and outline a mechanism for this reaction.

[4 marks]

Name of mechanism _____

Outline of mechanism

Do not write outside the box

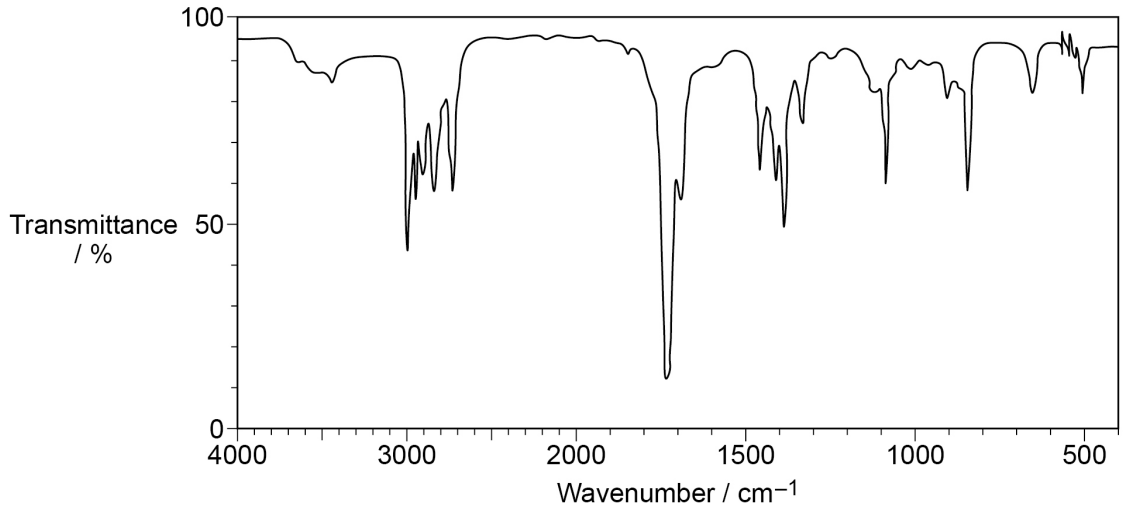
0 7 . 3 Prop-2-en-1-ol forms an addition polymer.

Draw the repeating unit of poly(prop-2-en-1-ol).

[1 mark]

0 7 . 4 **Figure 3** shows the infrared spectrum of a functional group isomer of prop-2-en-1-ol.

Figure 3



This isomer reacts with acidified potassium dichromate(VI) to form a green solution.

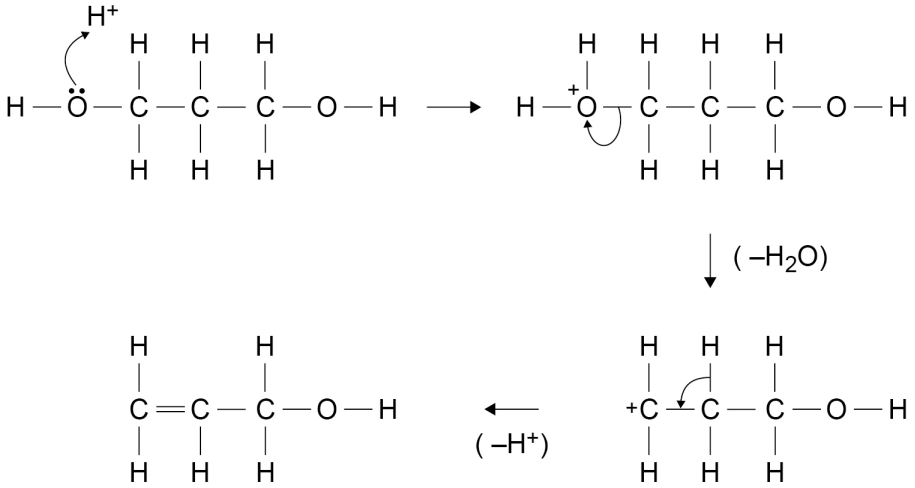
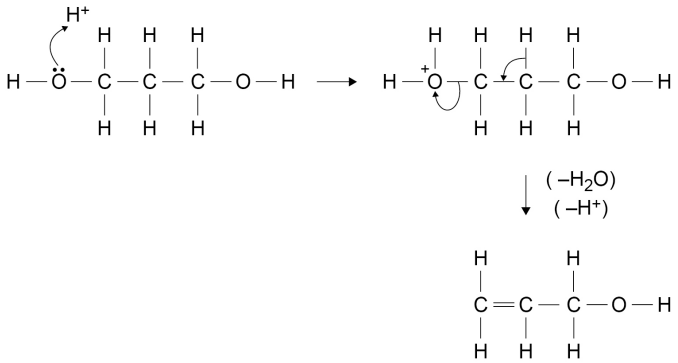
Draw the structure of this isomer.

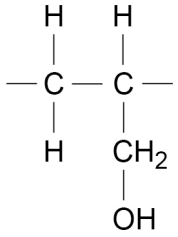
[1 mark]

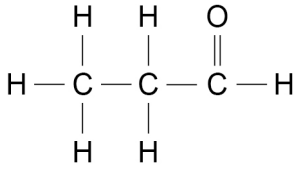
7

Turn over ►

Question	Marking guidance	Additional Comments/Guidelines	Mark
07.1	nucleophilic substitution		1

Question	Marking guidance	Additional Comments/Guidelines	Mark
07.2	**M1** elimination  **M2** arrow from lone pair on O to H^+ **M3** 1st intermediate **and** arrow from C–O^+H_2 bond to O **M4** 2nd intermediate (carbocation) **and** arrow from a correct C–H bond to correct C–C to form C=C	**Max 2 of 3 marks (M2-4)** for wrong organic reactant (ignore structure of product) **M3** and **M4** can be scored in one concurrent step: **M3** for correct intermediate and arrow from C–O^+H_2 bond to O **M4** for arrow from a correct C–H bond to correct C–C to form C=C 	1 1 1 1

Question	Marking guidance	Additional Comments/Guidelines	Mark
07.3		Any correct structural representation Ignore any brackets and/or n	1

Question	Marking guidance	Additional Comments/Guidelines	Mark
07.4		Structure in any form	1

Do not write outside the box

0 3 This question is about isomers.

Hex-2-ene has the molecular formula C_6H_{12}

0 3 . 1 Draw the displayed formula of a **position** isomer of hex-2-ene that exists as *E* and *Z* isomers.

[1 mark]

0 3 . 2 Draw the displayed formula of a **chain** isomer of hex-2-ene that does **not** exist as *E* and *Z* isomers.

[1 mark]

Butanal has the molecular formula C_4H_8O

0 3 . 3 Draw the skeletal formula of a **functional group** isomer of butanal that has an absorption in the range 1680–1750 cm^{-1} in its infrared spectrum.

[1 mark]

Do not write outside the box

0 3 . 4 Draw the skeletal formula of a structural isomer of butanal that has an absorption in the range 3230–3550 cm^{-1} in its infrared spectrum.

[1 mark]

0 3 . 5 Several saturated halogenoalkanes contain 17.8% carbon, 3.0% hydrogen and 79.2% bromine by mass.

Calculate the empirical formula of these compounds.

Give the IUPAC names of **two** saturated halogenoalkanes that have this empirical formula.

[4 marks]

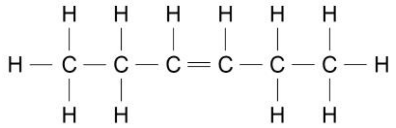
Empirical formula _____

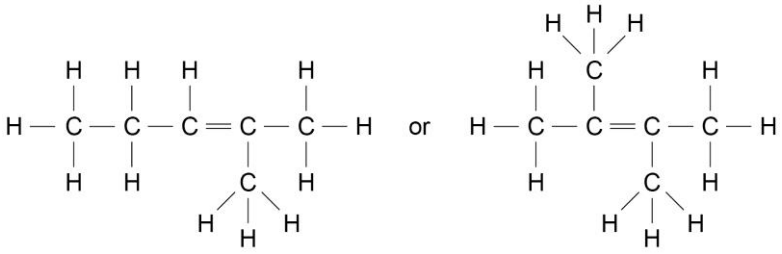
Names of halogenoalkanes

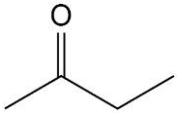
1 _____

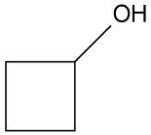
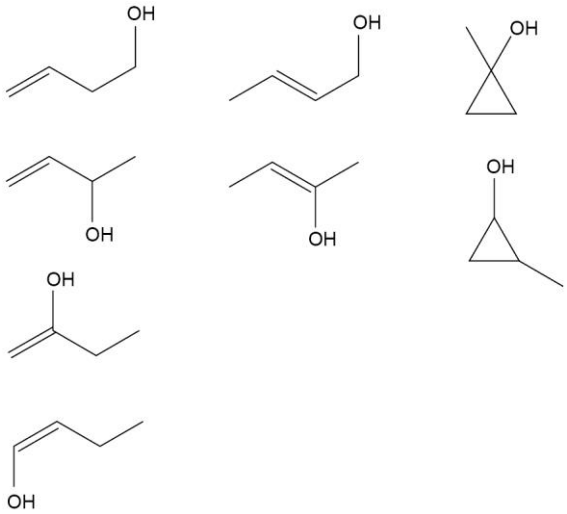
2 _____

8

Question	Marking guidance	Additional Comments/Guidelines	Mark
03.1		**Displayed** formula of hex-3-ene (*E* or *Z* isomer) Award 1 mark if correct compounds given in 3.1 and 3.2 but they are not displayed formulas	1 (AO2)

Question	Marking guidance	Additional Comments/Guidelines	Mark
03.2		**Displayed** formula of 2-methylpent-2-ene or 3,4-dimethylbut-2-ene Allow molecules that are both chain and position isomers, e.g. 2-methylpent-1-ene, 3-methylpent-1-ene, 4-methylpent-1-ene, 3,3-dimethylbut-1-ene, 2,3-dimethylbut-1-ene, 2-ethylbut-1-ene Award 1 mark if correct compounds given in 3.1 and 3.2 but they are not displayed formulas	1 (AO2)

Question	Marking guidance	Additional Comments/Guidelines	Mark
03.3		**<u>Skeletal</u>** formula Award 1 mark if correct compounds given in 3.3 and 3.4 but they are not skeletal formulas	1 (AO2)

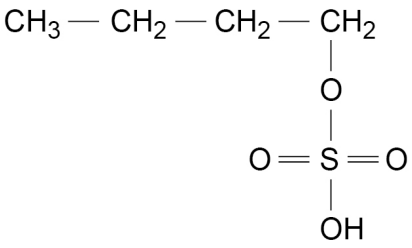
Question	Marking guidance	Additional Comments/Guidelines	Mark
03.4		**Skeletal** formula Alternative answers:  Award 1 mark if correct compounds given in 3.3 and 3.4 but they are not skeletal formulas	1 (AO3)

Question	Marking guidance	Additional Comments/Guidelines	Mark
03.5	**M1** divide %s by relative atomic masses: C $\frac{17.8}{12.0}$ = 1.48 H $\frac{3.0}{1.0}$ = 3.00 Br $\frac{79.2}{79.9}$ = 0.99 **M2** **(**1.48 : 3.00 : 0.99 = 3 : 6 : 2) empirical formula = $C_3H_6Br_2$ **M3, 4** any 2 of: 1,1-dibromopropane 1,2-dibromopropane 1,3-dibromopropane 2,2-dibromopropane	Allow ECF from **M1** to **M2** for a correct empirical formula for their working in **M1** Allow ECF from **M2** to **M3/4** for compounds that are saturated halogenoalkanes	1 1 2 (2 x AO2, 2 x AO3)

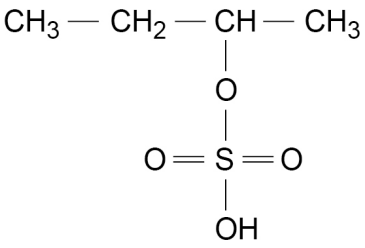
Do not write outside the box

Butan-1-ol can be manufactured by reacting steam with but-1-ene in the presence of the catalyst, concentrated sulfuric acid.

In the first part of this process, but-1-ene reacts with concentrated sulfuric acid to form compounds **W** and **X**.



Compound **W**



Compound **X**

Butan-1-ol is then made from compound **W**.

0 7 . 6 Name and outline a mechanism to show the conversion of but-1-ene into compound **W** in the first part of this process.

[5 marks]

Name of mechanism _____

Outline of mechanism

Do not write outside the box

0 7 . 7 There is a very low yield of butan-1-ol from but-1-ene in this manufacturing process.

Explain why.

[2 marks]

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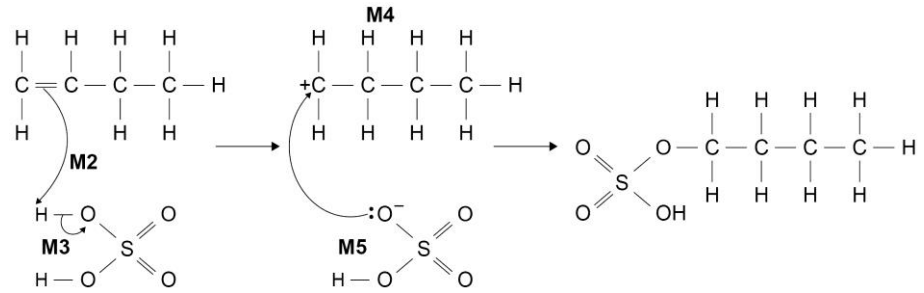
Turn over for Section B

Question	Marking guidance	Additional Comments/Guidelines	Mark
07.6	**M1** electrophilic addition  **M2** must show an arrow from the double bond towards the H atom of the H_2SO_4 molecule **M3** must show the breaking of the H-O bond in H_2SO_4 **M4** is for the structure of the correct carbocation **M5** must show an arrow from the lone pair of electrons on the correct oxygen of HSO_4^- towards the positively charged atom of <u>their</u> carbocation drawn	All arrows are double-headed. Penalise one mark from the total for **2-5** if half headed arrows are used Do not penalise the "correct" use of "sticks" Penalise only once in any part of the mechanism for a line and two dots to show a bond For **M2 / 3**, the full structure of H_2SO_4 does not need to be shown, but the key features for the mechanism should be shown and the formula must be correct. Penalise only once in **M2 / 3** an incorrect but genuine attempt at the structure of sulfuric acid **M2** ignore partial negative charges on the double bond **M3** penalise incorrect partial charges on the H–O bond and penalise formal charges Penalise **M4** if there is a bond drawn to the positive charge **Max 3 of 4 marks (M2-5)** for wrong organic reactant or wrong carbocation (ignore structure of product) If attack is shown from C=C to H^+ rather than H_2SO_4, then allow **M2** but not **M3** For **M5**, credit attack on a partially positively charged carbocation structure, but penalise **M4** for the structure of the carbocation For **M5**, the full structure of HSO_4^- is not essential, but attack must come from a lone pair on an individual oxygen on HSO_4^-, but the – sign could by anywhere on the ion (eg $:OSO_3H^-$)	1 1 1 1 1 (1 x AO1, 4 x AO2)

Question	Marking guidance	Additional Comments/Guidelines	Mark
07.7	**M1** formed from/on/via less stable carbocation **M2** (formed from) primary rather than secondary carbocation	**M1** must be clear that it is the stability of the carbocation that matters rather than the stability of the alcohol **M2** allow 1 mark for primary carbocation is less stable than secondary carbocation even if not clear that product is formed from a carbocation (but must be clear that the alcohols are not the carbocations)	1 1 (1 x AO1, 1 x AO3)