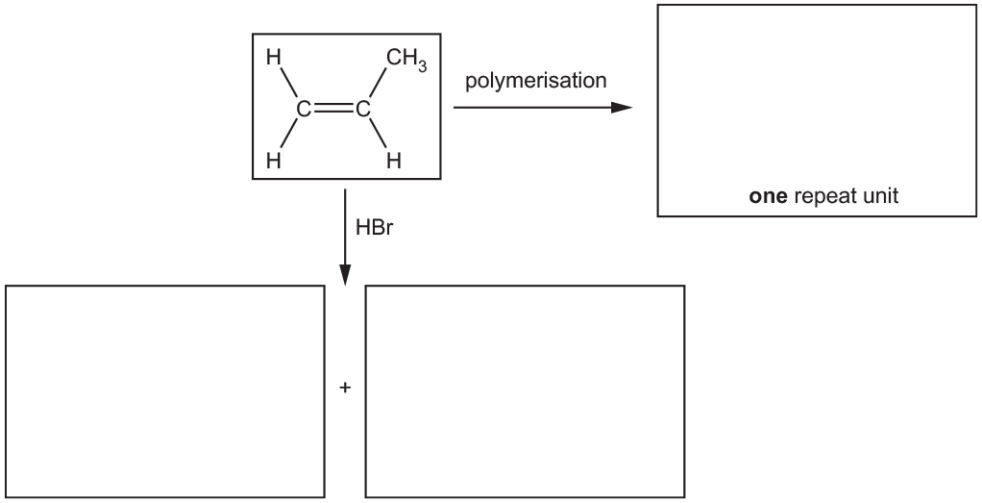
60(a). This question is about unsaturated hydrocarbons.

Two reactions of propene are shown below.

In the boxes, show the structures of the organic products of the reactions.

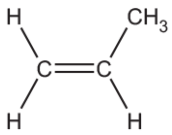


[3]

(b). Propene reacts with bromine.

Outline the mechanism for the reaction of propene with bromine, Br_2.
The structure of propene has been provided.

Show curly arrows, relevant dipoles and product(s).



[4]

(c). The 'alkynes' is a homologous series of hydrocarbons.

The table shows three alkynes.

Alkyne	Structural formula	Molecular formula
ethyne	HC≡CH	C_2H_2
propyne	$CH_3C{\equiv}CH$	C_3H_4
but-1-yne	$CH_3CH_2C{\equiv}CH$	C_4H_6

i. Explain what is meant by the term: **homologous series**.

[2]

ii. Suggest the general formula of the alkynes.

[1]

iii. Propyne reacts with bromine to form a saturated compound.

Write an equation for the reaction, showing the structure of the organic product.

[2]

iv. But-1-yne is a structural isomer of C_4H_6.

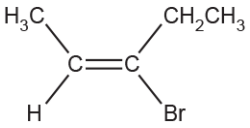
Draw the structures of **2** other structural isomers of C_4H_6.

[2]

v. Draw the structure of 2,5-dimethylhept-3-yne.

[1]

61. What is the name of the compound below?



A *E*-3-bromopent-2-ene

B *E*-3-bromopent-3-ene

C *Z*-3-bromopent-2-ene

D *Z*-3-bromopent-3-ene

Your answer ☐ **[1]**

62. Which statement about bonds is correct?

A The C=C bond in ethene is more polar than the C−C bond in ethane.

B A σ-bond is stronger than a π-bond.

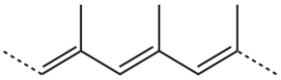
C The H−C−H bond angle in ethane is greater than the H−C−H bond angle in ethene.

D A σ-bond is formed from sideways overlap of p orbitals.

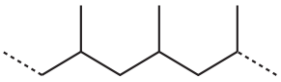
Your answer ☐ **[1]**

63. Which structure shows a section of poly(propene)?

A 

B 

C 

D 

Your answer ☐ **[1]**

64. Which alcohol reacts with an acid catalyst to form a mixture of stereoisomers?

A 3-methylbutan-2-ol

B pentan-1-ol

C 2-methylhexan-2-ol

D heptan-4-ol

Your answer ☐ **[1]**

65. $(CH_3)_3CCHBrCH_3$ has stereoisomers.

i. Explain the term stereoisomers and name this type of stereoisomerism.

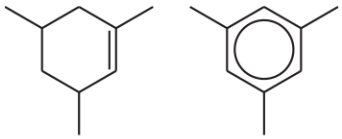
Explanation:

Type of stereoisomerism: **[1]**

ii. Draw 3D diagrams for the stereoisomers of $(CH_3)_3CCHBrCH_3$.

[2]

66. Compounds **B** and **C**, shown below, are unsaturated hydrocarbons containing nine carbon atoms.



B C

Compound **B** reacts with chlorine at room temperature, but compound C requires the presence of a halogen carrier.

In both reactions, the organic compound reacts with chlorine in a 1:1 molar ratio.

i. Draw the structures of the organic product of each reaction.

Organic product with **B**	Organic product with **C**

[2]

ii. Explain the relative resistance to chlorination of compound **C** compared with compound **B**.

[3]

iii. Outline the mechanism for the reaction of compound **C** with chlorine.

Show the role of the halogen carrier.

[5]

67. Alcohols can be used to prepare organic compounds with different functional groups.

$HOOC(CH_2)_2COOH$ and $HO(CH_2)_4OH$ react together to form polymer **E**.

i. Draw **one** repeat unit of polymer **E**.

The functional groups should be clearly displayed.

[2]

ii. Governments are encouraging the development of biodegradable polymers to reduce dependency on persistent plastic waste derived from fossil fuels.

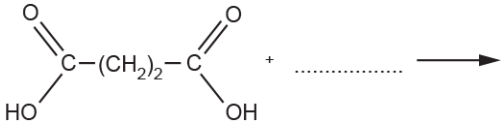
Polymer **E** is a biodegradable polymer.
Suggest why polymer **E** is able to biodegrade.

[1]

iii. A large yield of polymer **E** can be obtained by reacting a diacyl dichloride with $HO(CH_2)_4OH$.

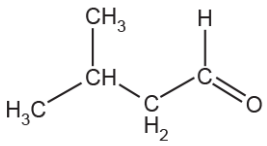
The diacyl dichloride is prepared from $HOOC(CH_2)_2COOH$.

Complete the equation for the formation of a diacyl dichloride from $HOOC(CH_2)_2COOH$.

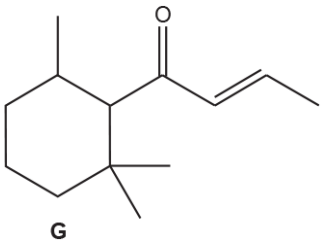


[3]

68. The carbonyl compounds, **F** and **G**, shown below, contribute to the flavour of coffee.



F



G

Describe suitable chemical tests, with observations, that would confirm the presence of the functional groups in **F** and **G**.

[4]

69. What is the number of unsaturated isomers (structural and stereoisomers) that have the molecular formula C_4H_8?

A 3

B 4

C 5

D 6

Your answer ☐ **[1]**

70. Which compound contains the smallest bond angle?

A bromoethane

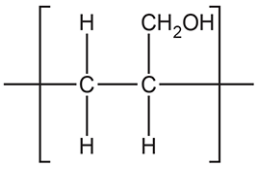
B ethanol

C ethane

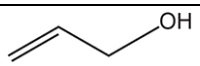
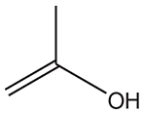
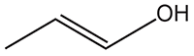
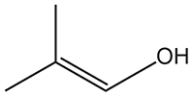
D ethene

Your answer ☐ **[1]**

71. The repeat unit of an addition polymer is shown below.

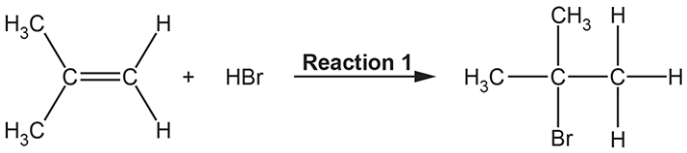


What is the monomer?

A	
B	
C	
D	

Your answer ☐ **[1]**

72(a). A student reacts methylpropene with hydrogen bromide, HBr, as shown in **Reaction 1**.



Methylpropene **Compound A**

Outline the reaction mechanism for **Reaction 1**. The structures of methylpropene and compound **A** have been provided. Include curly arrows and relevant dipoles.

name of mechanism.....

[4]

(b). When reacting methylpropene with HBr, a small amount of compound **B** also forms.

Compound **B** is a structural isomer of compound **A**.

i. Explain the term **structural isomer**.

[1]

ii. Show the structure for compound **B**.

[1]

73. Which type(s) of stereoisomerism is/are shown by 2,4-dimethylhex-2-ene?

A *E* / *Z* isomerism only.

B Optical isomerism only.

C Both *E* / *Z* isomerism and optical isomerism.

D Neither E / Z isomerism nor optical isomerism.

Your answer ☐ **[1]**

74(a). But-1-ene, $H_2C=CHCH_2CH_3$, and buta-1,3-diene, $H_2C=CH–CH=CH_2$, are unsaturated compounds used to make many organic products.

But-1-ene and buta-1,3-diene have σ-bonds and π-bonds.

i. Explain what is meant by the terms **σ-bond** and **π-bond**.

σ-bond

π-bond

[2]

ii. How many σ- and π-bonds are in one molecule of buta-1,3-diene?

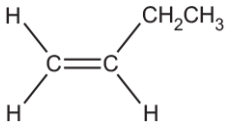
σ-bonds: ..... π-bonds: ..... **[2]**

(b). But-1-ene is reacted with hydrogen bromide, forming a mixture of two saturated organic products.

One of the organic products is formed in a much greater quantity than the other organic product.

i. Outline the reaction mechanism for the formation of this **major** organic product. The structure of but-1-ene has been provided.

Include curly arrows and relevant dipoles.



[4]

ii. Explain why one organic product is formed in a much greater quantity than the other organic product.

[2]

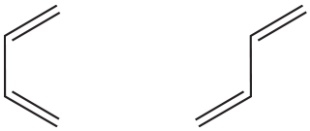
iii. Buta-1,3-diene is reacted with an excess of hydrogen bromide, forming a mixture of saturated organic products.

How many saturated organic products could be present in this mixture?

[1]

(c). A student thought that buta-1,3-diene can show stereoisomerism.

The student drew out skeletal formulae for the stereoisomers of buta-1,3-diene:



i. Explain the term **stereoisomerism**.

[1]

ii. Explain, with a reason, whether the student is correct or incorrect.

[1]

75. This question is about haloalkanes and polymers.

An oligomer is a polymer with a low molecular mass and a small number of repeat units.

An oligomer made from 2-chloro-1,1,2-trifluoroethene is used as a lubricating oil.

i. Draw the repeat unit of this oligomer.

[1]

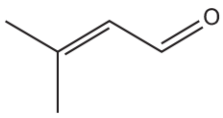
ii. The boiling point of the lubricating oil can be increased by increasing the number of repeat units.

Explain this statement.

[2]

76. This question is about organic synthesis.

Prenal, shown below, is used in the synthesis of some pharmaceuticals.

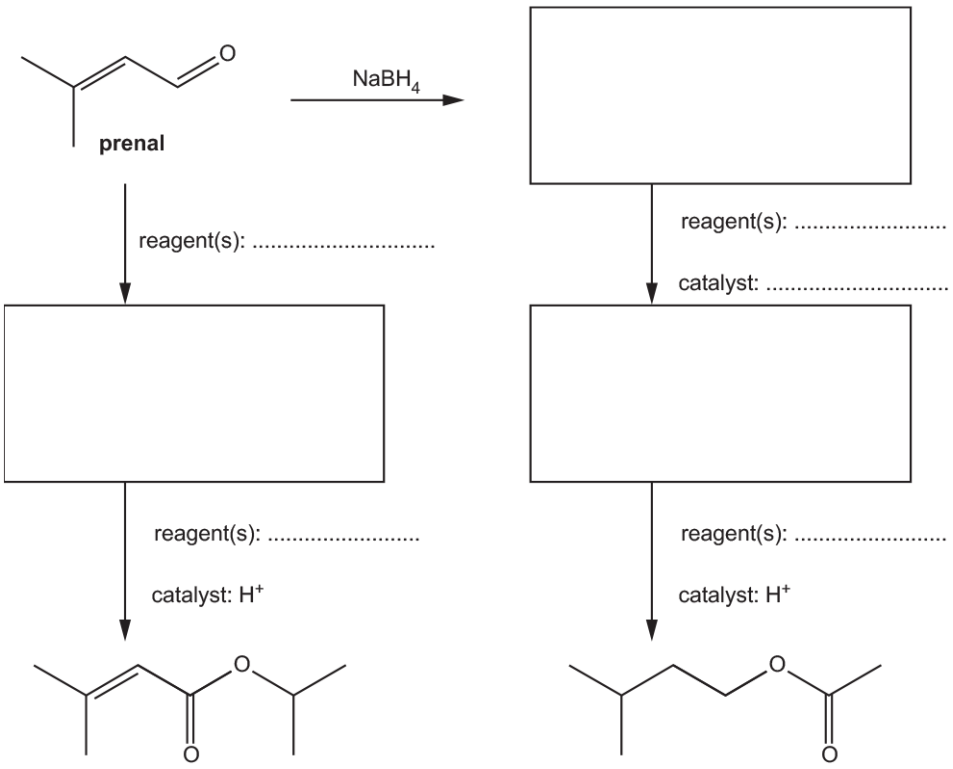


prenal

i. What is the systematic name for prenal?

[1]

ii. Complete the flowchart below for the synthesis of two compounds starting from prenal.



[7]

77. Compounds **D**, **E** and **F** are isomers with the molecular formula $C_5H_{10}O$.
One of the compounds is alicyclic.

A student carries out test-tube tests on the compounds.
The observations are shown below.

Compound	2,4-DNP	$H^+/Cr_2O_7^{2-}$, reflux	Bromine water
D	No change	Green solution	No colour change
E	Orange precipitate	No colour change	No colour change
F	Orange precipitate	No colour change	No colour change

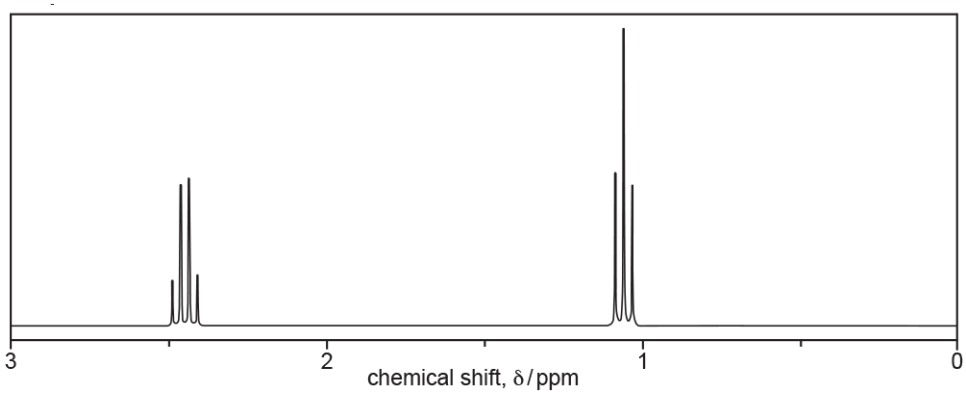
^{13}C NMR spectrum of D

Compound **D** has 3 peaks at δ / ppm: 24, 36, 73.

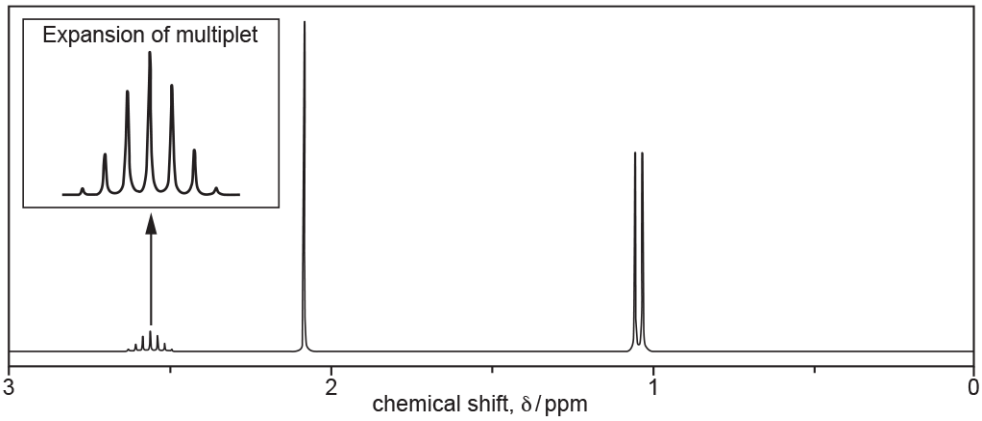
^{1}H NMR spectra of E and F

The integration data has been omitted.

Compound E



Compound F



Analyse the observations and results to identify the structures of **D**, **E** and **F**.

Explain your reasoning.

[6]

78. This question is about carboxylic acids.

Compound **D** is a *cis* stereoisomer of an unsaturated organic acid with the general formula $C_nH_{2n-1}COOH$.

A student plans to analyse acid **D** by carrying out a titration.

A student prepares a 100.0 cm^3 solution containing 3.215 g of acid **D**.

The student titrates 25.0 cm^3 samples of the solution of **D** with 0.150 mol dm^{-3} $Ba(OH)_2(aq)$ in the burette.

1 mol $Ba(OH)_2$ reacts with 2 mol of **D**.

The mean titre of $Ba(OH)_2(aq)$ is 23.50 cm^3.

Analyse the titration results to determine **two** possible structures for the *cis* stereoisomer of organic acid **D**.

Structures of 2 possible cis stereoisomers of acid D

[7]

79(a). 2-Bromobutane, $CH_3CH_2CHBrCH_3$, can be prepared by several different methods.

The relative molecular mass, M_r, of 2-bromobutane is 136.9.

2-Bromobutane can be prepared by reacting butane with bromine (**Reaction 5.1**).

$CH_3CH_2CH_2CH_3 + Br_2 \rightarrow CH_3CH_2CHBrCH_3 + HBr$ **Reaction 5.1**

The reaction is initiated by the formation of bromine radicals from bromine.

i. State the conditions for the formation of bromine radicals from bromine.

[1]

ii. Write two equations for the propagation steps in the mechanism for **Reaction 5.1**.

Use structural formulae for organic species and dots (·) for unpaired electrons on radicals.

$CH_3CH_2CH_2CH_3$ + ... → ..... + ...

..... + ... → ..... + ...

[2]

iii. The yield of $CH_3CH_2CHBrCH_3$ is only 30%.

Suggest **two** reasons why the yield of $CH_3CH_2CHBrCH_3$ is so low.

1

2

[2]

(b). 2-Bromobutane can also be prepared by reacting but-2-ene, $CH_3CH=CHCH_3$, with hydrogen bromide, HBr (**Reaction 5.2**).

$CH_3CH=CHCH_3 + HBr \rightarrow CH_3CH_2CHBrCH_3$ **Reaction 5.2**

Explain, in terms of atom economy, why **Reaction 5.2** is more sustainable than **Reaction 5.1**.

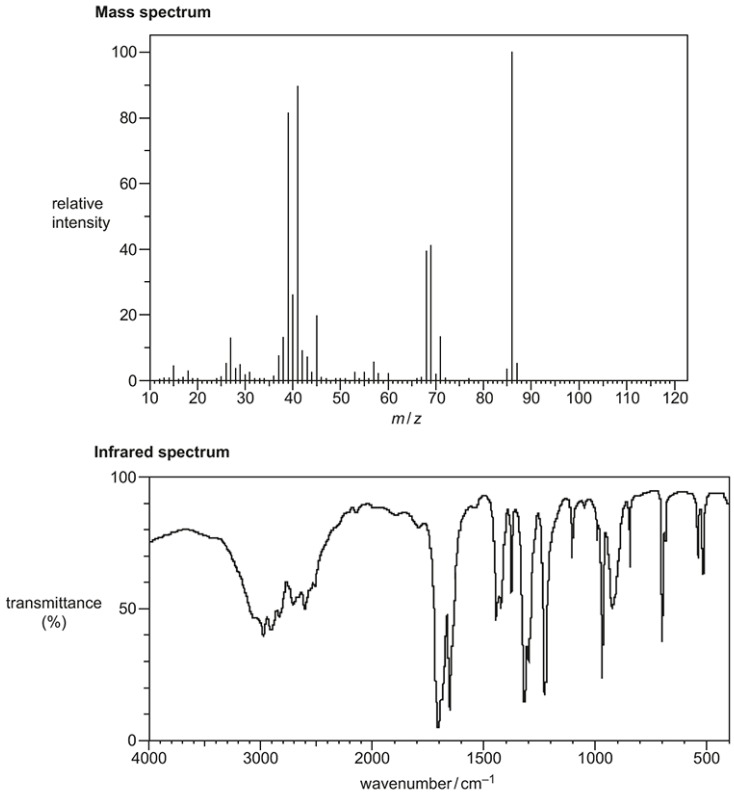
Include calculations to justify your answer.

[2]

80. * The organic compound **A** is unsaturated and is a *trans* stereoisomer.

Compound **A** has the following composition by mass: C, 55.8%; H, 7.0%; O, 37.2%.

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

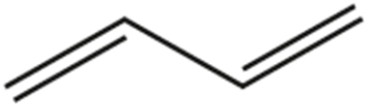


Use the information to determine the structure of compound **A**.

Explain your reasoning and show your working.

[6]

81. What is the number of σ-bonds in the molecule below?



A 1

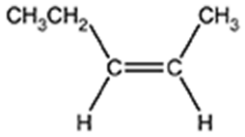
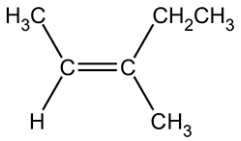
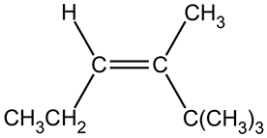
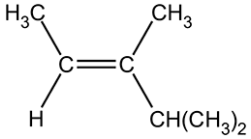
B 3

C 7

D 9

Your answer ☐ **[1]**

82. Which alkene is an *E* stereoisomer?

A	
B	
C	
D	

Your answer ☐ **[1]**

83(a). The alkene, $(CH_3)_3CCH=CH_2$, is used to make some perfumes.

i. What is the systematic name for $(CH_3)_3CCH=CH_2$?

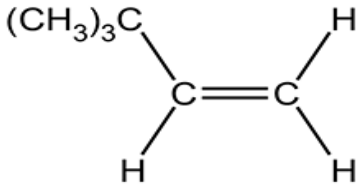
[1]

$(CH_3)_3CCH=CH_2$ decolourises bromine.

Outline the reaction mechanism for the reaction of $(CH_3)_3CCH=CH_2$ and bromine.

The structure of $(CH_3)_3CCH=CH_2$ has been provided.

Include curly arrows and relevant dipoles, the structure of the product and the name of the mechanism.



name of mechanism..... **[5]**

(b). The alkene $(CH_3)_3CCH=CH_2$ can be polymerised to form a polymer.

i. Draw **one** repeat unit for this polymer.

[1]

ii. State **one** advantage and **one** disadvantage of using combustion as a method for the disposal of a polymer after it has exceeded its useful life.

Advantage

Disadvantage

[1]

84. Which statement about absorption of radiation is correct?

A Infrared radiation can result in the breakdown of the ozone layer.

B Ultraviolet radiation can cause some polymers to photodegrade to benefit the environment.

C Ultraviolet radiation is linked to global warming.

D Ultraviolet radiation is used in modern breathalysers to measure ethanol in the breath.

Your answer ☐ **[1]**

85. What is the number of sigma bonds in a molecule of methylbenzene?

A 7

B 10

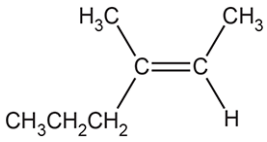
C 12

D 15

Your answer ☐ **[1]**

86(a). This question is about unsaturated hydrocarbons.

The unsaturated hydrocarbon **A**, shown below, is reacted with bromine.



Hydrocarbon A

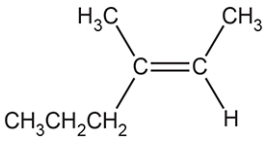
i. What is the systematic name of hydrocarbon **A**?

[1]

ii. Outline the mechanism for the reaction of hydrocarbon **A** with bromine.

The structure of hydrocarbon **A** has been provided.

Include curly arrows and relevant dipoles.



[3]

(b). Compounds **B** and **C** are **branched** hydrocarbons that are structural isomers of C_6H_{12}.

Compounds **B** and **C** both have stereoisomers.

• Compound **B** has *cis* and *trans* isomers but does **not** have optical isomers.

• Compound **C** has optical isomers but does **not** have *cis* and *trans* isomers.

i. What is meant by the term **structural isomers**?

[1]

ii. What is meant by the term **stereoisomers**?

[1]

iii. Draw structures for the *cis* and *trans* isomers of the branched hydrocarbon **B**.

***cis* isomer**	***trans* isomer**

[2]

iv. Draw 3D structures for the optical isomers of compound **C**.

Optical isomers	

[2]

v. Compounds **D** and **E** are two more structural isomers of C_6H_{12}.

Compounds **D** and **E** do **not** show stereoisomerism.

Table 16.1 shows NMR and infrared (IR) spectral data for **D** and **E**.

	Number of peaks in ^{1}H NMR spectrum	**Number of peaks in ^{13}C NMR spectrum**	**IR peak at 1620–1680 cm^{-1}**
D	1	1	No
E	1	2	Yes

Table 16.1

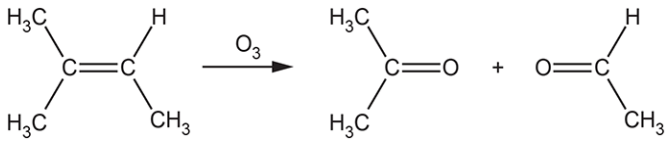
Draw the structures of **D** and **E** and explain how the spectral data in **Table 16.1** provides evidence for the structures.

D	**E**

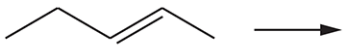
[4]

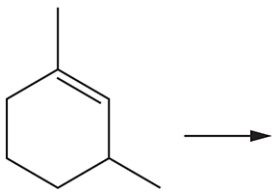
(c). 'Ozonolysis' is used in organic synthesis. Ozone breaks C=C bonds to form carbonyl compounds.

For example, the complete ozonolysis of methylbut-2-ene is shown below.



i. Draw the structures of the products you would expect from the ozonolysis of the **two** compounds below.



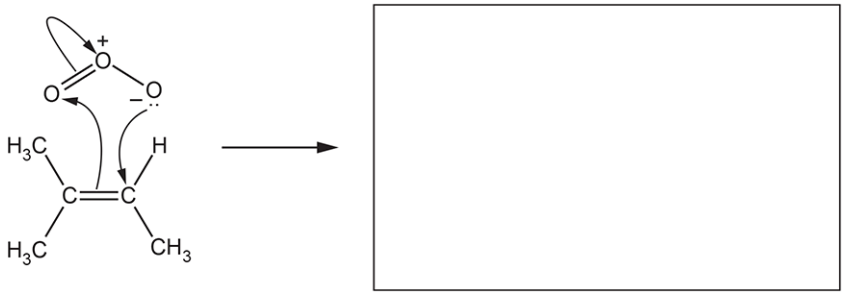


[2]

ii. The mechanism for ozonolysis takes place in several steps.

The curly arrows in the first step in the ozonolysis of methylbut-2-ene are shown below.

In the box, draw the structure(s) for the product(s) of this step.



[1]

87. This question is about polymers derived from carboxylic acid monomers.

i. Poly(pent-3-enoic acid) is an addition polymer.

Draw the structure of pent-3-enoic acid and **two** repeat units of this polymer.

Pent-3-enoic acid	
Two repeat units of poly(pent-3-enoic acid)	

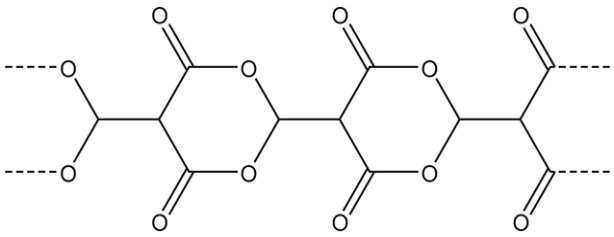
[2]

ii. Butanedicarboxylic acid and 1,4-dihydroxy-2-methylbenzene react to form a condensation polymer.

Draw **one** repeat unit of this condensation polymer.

[2]

iii. Three repeat units of a condensation polymer are shown below.



Draw the structure of the monomer required to form this polymer.

[1]

88. 1-phenylethanol is a naturally occurring compound found in many vegetables and flowers.

1-phenylethanol can be synthesised from 2-phenylethanol in two stages.

Suggest reagents, conditions and equations for each stage in the synthesis.

Show structures for organic compounds.

Stage 1

reagents and conditions .....

equation:

Stage 2

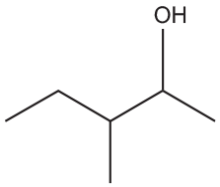
reagents and conditions .....

equation:

[4]

89(a). This question is about alkenes.

A mixture of alkenes is produced when water is eliminated from alcohol **A**.



Alcohol A

i. What is the systematic name of alcohol **A**?

[1]

ii. Alcohol **A** is refluxed with an acid catalyst.

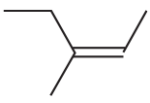
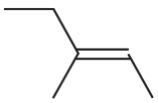
- A mixture of alkene isomers **B**, **C** and **D** is formed.
- Alkenes **B** and **C** show *E/Z* isomerism but alkene **D** does not.

Construct the equation for the formation of alkene **D** from alcohol **A**.

Show the structure of the organic product.

[2]

iii. The skeletal formulae of alkenes **B** and **C** are shown below.

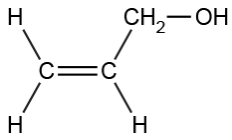
	Alkene B	**Alkene C**
Skeletal formula		
Isomer	*Z*	*E*

Use the Cahn-Ingold-Prelog priority rules to explain why alkene **B** is the *Z* isomer.

[2]

(b). A chemistry company is developing water-soluble polymers.

The chemists decide to use compound **E**, shown below, as the monomer.



Compound E

i. Draw a section of the polymer formed, showing **two** repeat units, and suggest why this polymer is likely to be soluble in water.

Section of polymer (**two** repeat units)

Reason for solubility in water

[2]

ii. Outline **two** ways that waste hydrocarbon polymers can be processed usefully, rather than being disposed of in landfill sites.

1

2

[2]

90. Which ion(s) contain(s) bond angles of approximately 120º?

1 CH_3COO^-

2 $C_6H_5O^-$

3 $(CH_3)_3C^+$

A 1, 2 and 3

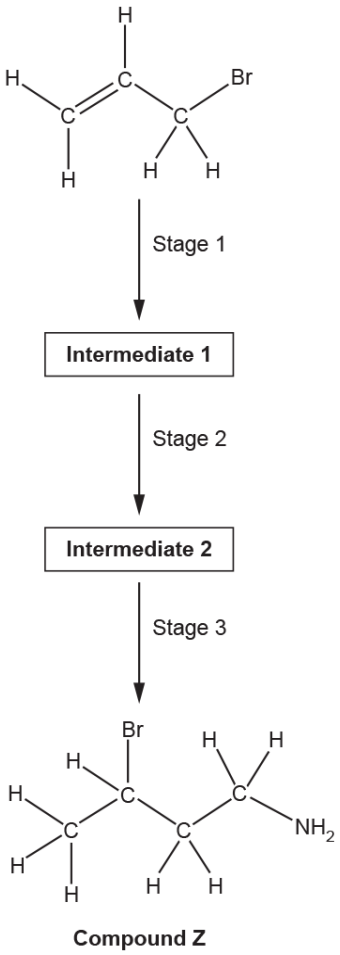
B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer ☐ **[1]**

91. A student intends to synthesise compound **Z**, as shown in the flowchart below.



Compound Z

Plan this synthesis showing reagents, the structures of **intermediate 1** and **intermediate 2**, and equations.

[6]

92. This question is about hydrocarbons.

The boiling points of some hydrocarbons containing 6 carbon atoms are shown below.

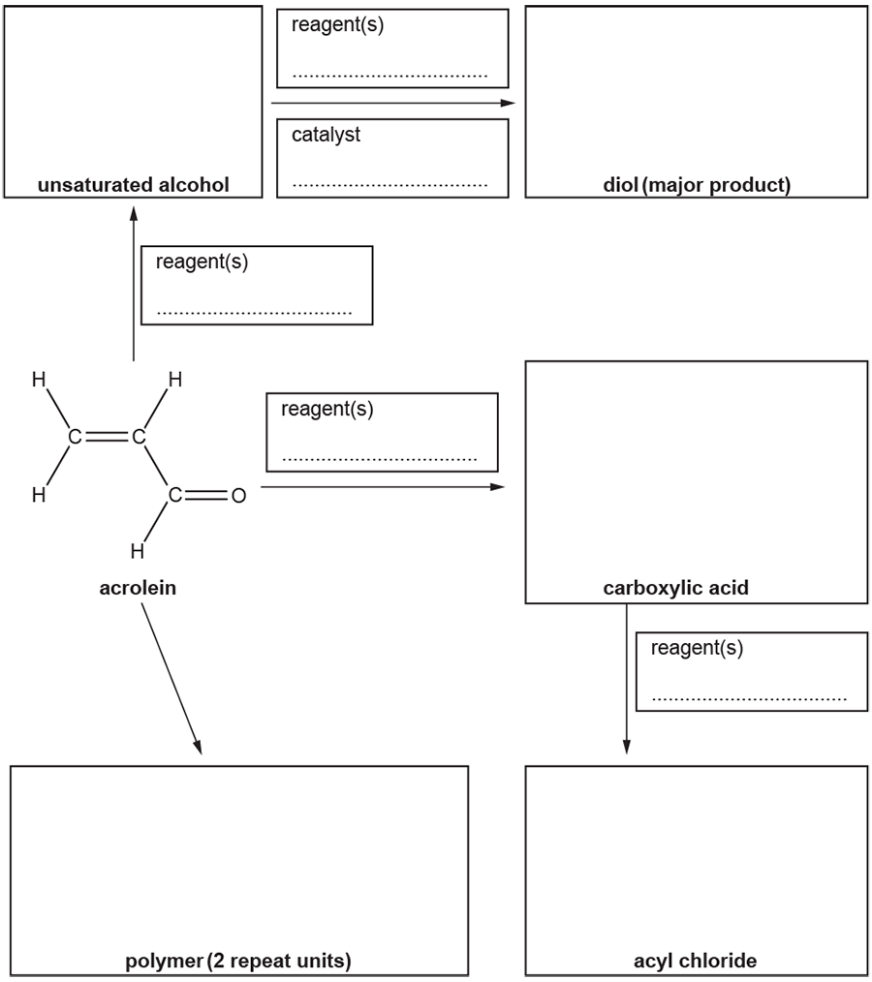
Hydrocarbon	**Boiling point / °C**
2,2-dimethylbutane	50
2-methylpentane	60
hexane	69

State and explain the trend in boiling points shown by these hydrocarbons.

[4]

93. This question is about reactions of acrolein, $H_2C=CHCHO$.

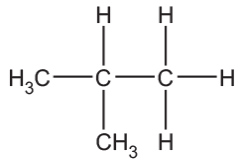
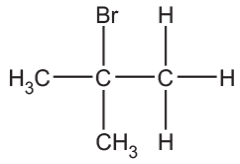
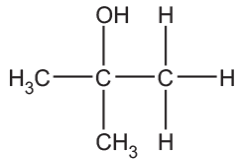
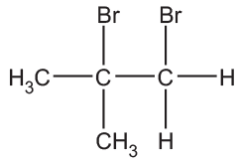
Complete the flowchart by filling in each box.



[9]

94. A student has planned the two-stage synthesis shown below.

Which compound could be the intermediate for this synthesis?

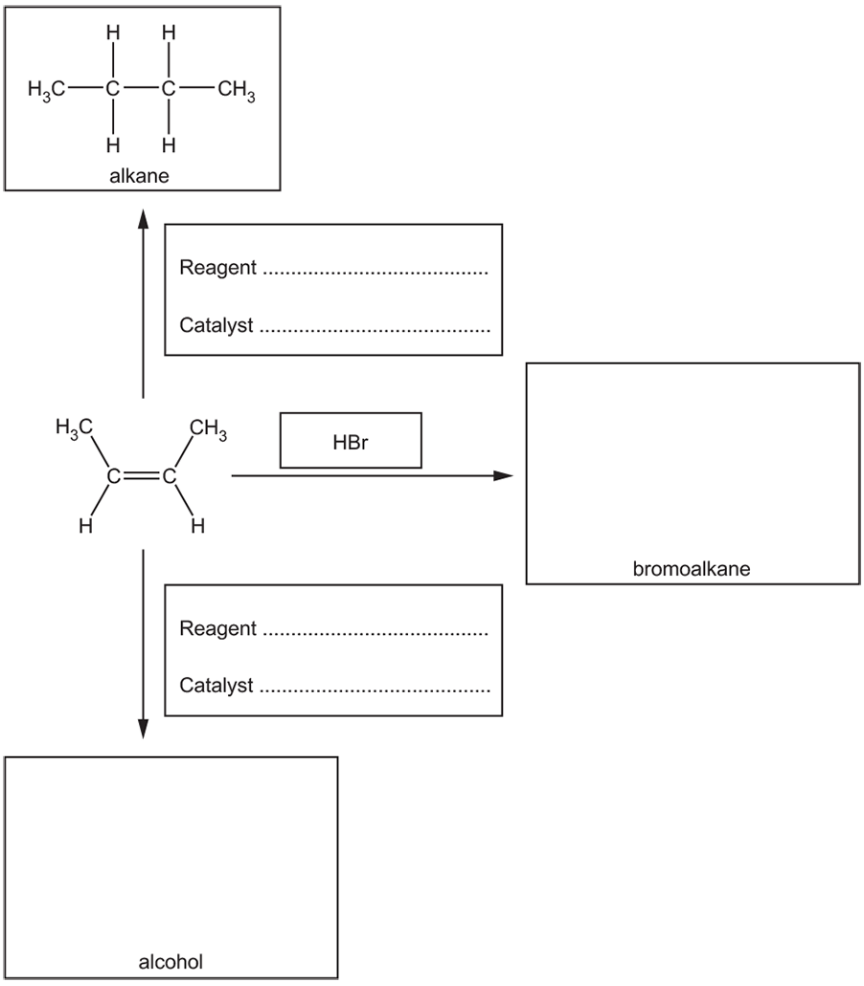
A	
B	
C	
D	

Your answer ☐ **[1]**

95. Alkenes are used in organic synthesis.

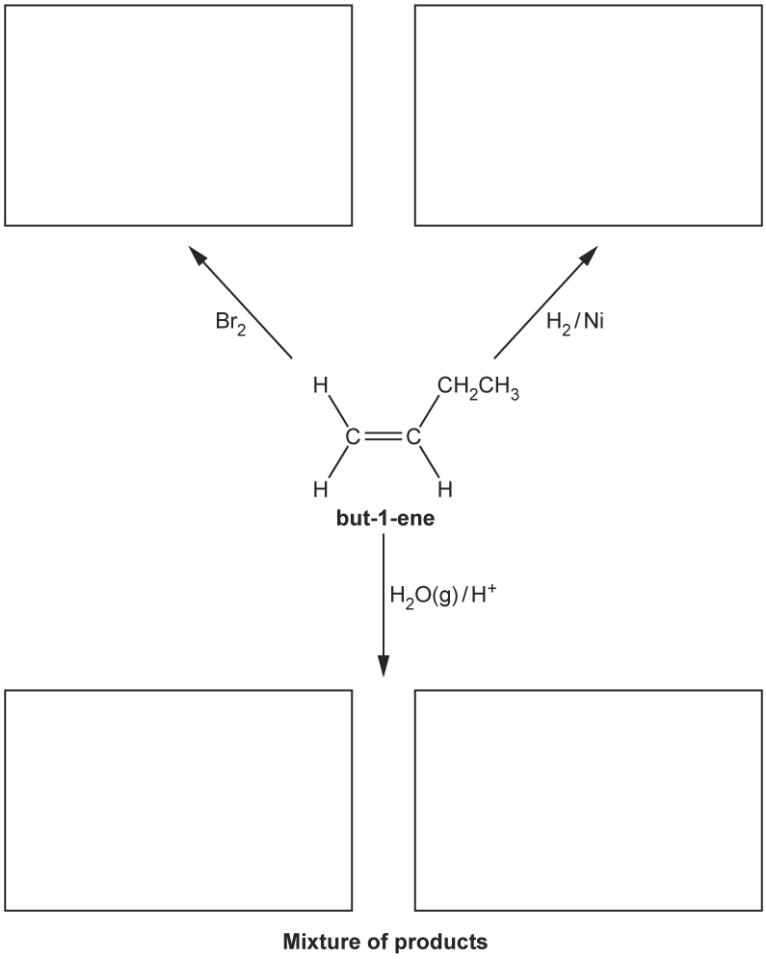
Three reactions of an alkene are shown in the flowchart.

Complete the flowchart to show the missing reagents, catalysts and the structures of organic products.



[4]

96(a). Complete the flowchart for the reactions of but-1-ene, by adding the structures of the organic products in each box.

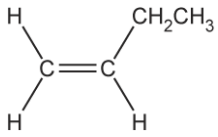


[4]

(b). HBr reacts readily with alkenes.

i. Outline the mechanism for the reaction of but-1-ene with HBr to form **2-bromobutane**.

Include curly arrows, relevant dipoles and the structure of the product.



[4]

ii. During this reaction, a small amount of **1-bromobutane** is also produced.

Explain why **2-bromobutane** is the major product.

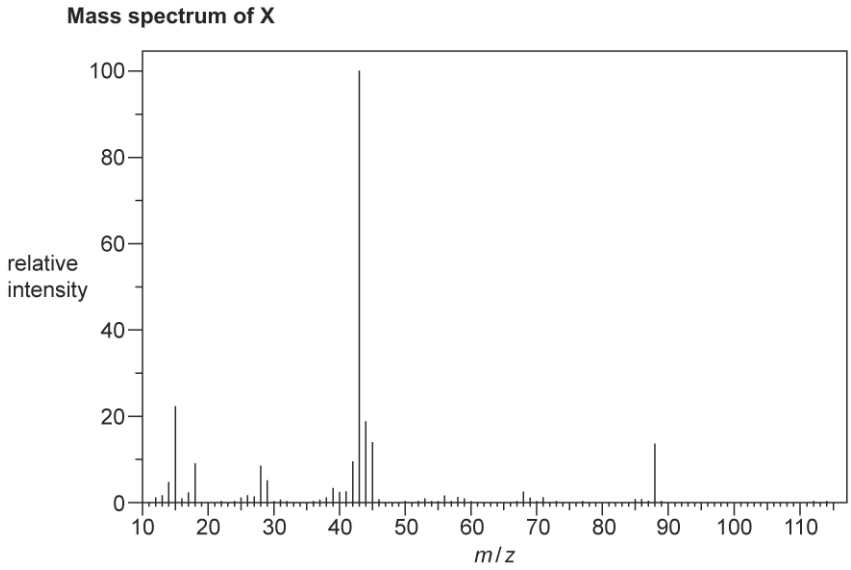
[2]

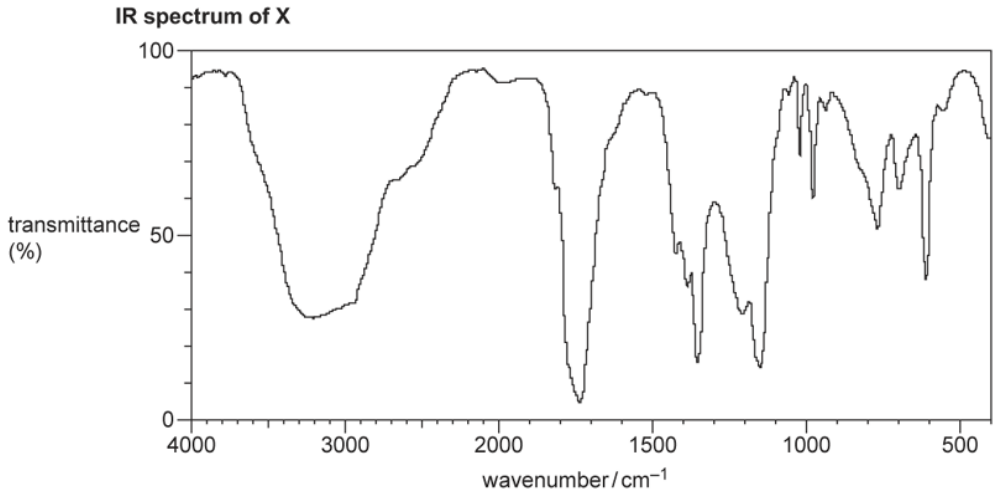
97. Compound **X** is an organic compound with **two** functional groups.

Compound **X** has the percentage composition by mass:
C, 40.91%; H, 4.54%; O, 54.55%.

Compound **X** does **not** decolourise bromine water.

A scientist analyses compound **X** using mass spectrometry and infrared spectroscopy.





Use all the information to determine a possible structure of compound **X**.

In your answer, make it clear how your conclusions are linked to the evidence.

[6]

98. Which property explains the low reactivity of alkanes?

A Low C–C bond enthalpy.

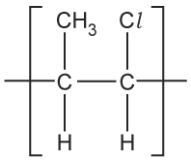
B Low bond enthalpy of π- bonds.

C Low polarity of σ- bonds.

D Low reactivity of carbon and hydrogen.

Your answer ☐ **[1]**

99. The repeat unit of an addition polymer is shown below.



Which statement about this addition polymer is correct?

A Combustion produces toxic alkaline fumes.

B The addition polymer is biodegradable.

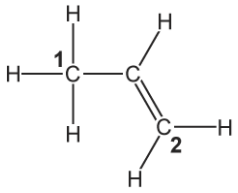
C The monomer is $H_3CCH{=}CHCl$.

D The repeat unit above is shown as a displayed formula.

Your answer ☐ **[1]**

100. This question is about hydrocarbons.

Propene, C_3H_6, has different bond angles and shapes around the carbon atoms. The displayed formula of a propene molecule is shown below.



Predict the bond angles and the names of the shapes around the C atoms **1** and **2** above, and explain why the bond angles and shapes are different.

Carbon atom	Bond angle	Name of shape
1		
2		

Explanation:

[5]

101. Hydrogen reacts much more readily with alkenes than with alkanes.

Why is this?

A Alkenes are polar molecules whereas alkanes are not.

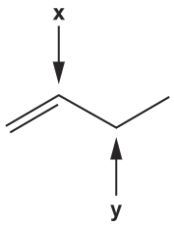
B All atoms in an alkane have a full outer shell of electrons.

C The bond enthalpy of C–C σ bonds is **higher** than that of **π** bonds.

D The bond enthalpy of C–C σ bonds is **lower** than that of **π** bonds.

Your answer ☐ **[1]**

102. The structure of but-1-ene is shown below.

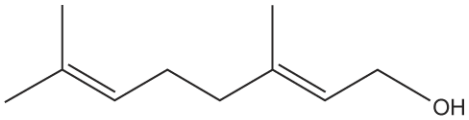


Which row has the correct **shape** around carbon atoms labelled **x** and **y**?

	x	y
A	Tetrahedral	Pyramidal
B	Trigonal planar	Tetrahedral
C	Trigonal planar	Pyramidal
D	Pyramidal	Tetrahedral

Your answer ☐ **[1]**

103. Geraniol, shown below, is a component in many natural oils.



Geraniol

Which pair of reagents identifies both functional groups in geraniol?

A Acidified dichromate(VI) and 2,4-dinitrophenylhydrazine.

B Bromine water and 2,4-dinitrophenylhydrazine.

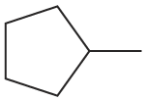
C Bromine water and acidified dichromate(VI).

D Tollens' reagent and aqueous silver nitrate in ethanol.

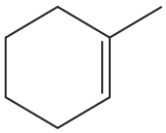
Your answer ☐ **[1]**

104. This question is about hydrocarbons.

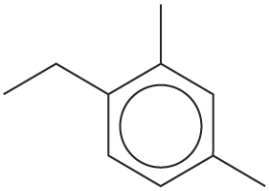
The structures of hydrocarbons **A–E** are shown below.



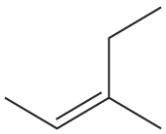
A



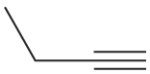
B



C



D



E

Explain why hydrocarbon **D** is a Z-stereoisomer.

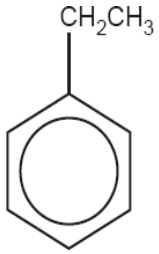
[2]

105. Alkenes and carbonyl compounds take part in addition reactions.

Describe **one** addition reaction of an alkene and **one** addition reaction of a carbonyl compound.
Include reagents and reaction mechanisms.

[6]

106. Ethylbenzene, $C_6H_5CH_2CH_3$, can be prepared by reacting benzene with chloroethane, CH_3CH_2Cl, in the presence of $AlCl_3$. The $AlCl_3$ acts as a halogen carrier.



Ethylbenzene

In the mechanism, chloroethane reacts with the halogen carrier to form a carbocation, which acts as the electrophile.

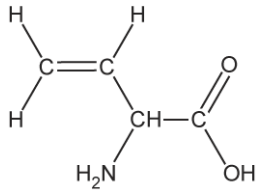
i. What is meant by the term **electrophile**?

[1]

ii. Outline the mechanism for this reaction, including the role of $AlCl_3$ as a halogen carrier.

[5]

107. The amino acid below can form addition and condensation polymers.



Draw **2** repeat units of these polymers.

Display the sections linking the monomers together.

addition polymer (2 repeat units)

condensation polymer (2 repeat units)

[3]

108. This question is about the analysis of organic compounds.

Compounds **F, G, H** and **I** are structural isomers.

A student carries out test-tube tests on the compounds.
The student records the observations after carrying out each test.
These are shown in **Table 5.1**.

In **Table 5.1**, 2,4-dintrophenylhydrazine has been abbreviated to 2,4−DNP.

Table 5.1

Compound	Test			
	2,4-DNP	**Acidified dichromate(VI) reflux**	**Bromine water**	**Tollens' reagent**
F	Orange solution	Green solution	Colourless solution	Colourless solution
G	Orange solution	Green solution	Orange solution	Colourless solution
H	Orange precipitate	Orange solution	Orange solution	Colourless solution
I	Orange precipitate	Green solution	Orange solution	Silver mirror

i. Write the formula of the species causing the colours after refluxing with acidified dichromate(VI).

Green solution

Orange solution **[2]**

ii. The student is provided with further information about compounds **F–I**.

- They all have the molecular formula $C_5H_{10}O$.
- One of the compounds is alicyclic.
- The other compounds are unbranched.

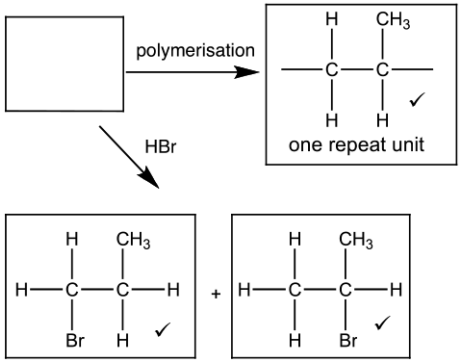
Use this further information and the student's observations in **Table 5.1** to answer the following.

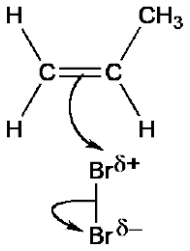
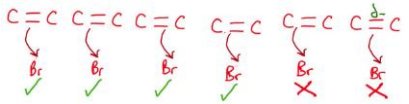
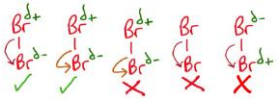
- How do the observations provide evidence for the possible functional groups in compounds **F–I**?
- Suggest a possible structure for each of the compounds **F–I**.

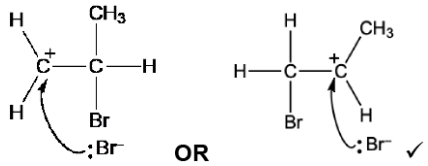
Show your reasoning.

[6]

END OF QUESTION PAPER

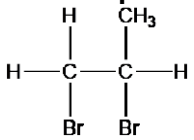
60	a			3 (AO2.5×3)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **For repeat unit,** • 'side bonds' required on either side of repeat unit from C atoms • **DO NOT ALLOW** > one repeat unit **IGNORE** brackets • **IGNORE** *n* **ALLOW** in either order **Examiner's Comments** This part was generally well-answered with well-prepared candidates scoring all three marks. The most common errors resulted from the products of reaction with HBr. The same structure was often drawn, reversed in one of the boxes. Candidates should take care to check that the atoms in a structure have the correct number of bonds. Some candidates added HBr across the C=C double bond but left the C=C bond intact in their final structures, showing carbon atoms with 5 bonds instead of 4.

	b		 **1st curly arrow** Curly arrow from double bond to Br of Br–Br ✓ **DO NOT ALLOW** partial charge on C=C **2nd curly arrow** Correct dipole on Br–Br **AND** curly arrow for breaking of Br–Br bond ✓ **3rd curly arrow** **Correct carbocation** with + charge on C with 3 bonds **AND** curly arrow from Br^- to C^+ of carbocation **DO NOT ALLOW** δ^+ on C of carbocation	4 (AO1.2) (AO1.2) (AO2.5) (AO2.5)	**ANNOTATE ANSWER** **For curly arrows, ALLOW straight or snake-like arrows and small gaps (see examples)** ---------- **1st curly arrow** must • go to a Br atom of Br–Br **AND** • start from, OR be traced back to any point across width of C=C  **2nd curly arrow must** • start from, **OR** be traced back to, **any part of** $^{\delta+}$Br–Br$^{\delta-}$ bond • **AND** go to Br $^{\delta-}$  **3rd curly arrow must** • go to the C^+ of carbocation **AND** • start from, **OR** be traced back to **any point across width** of lone pair on :Br^-



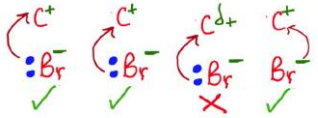
i.e. ***ALLOW*** *carbonium + on either C atom*

Correct product to match mechanism ✓



DO NOT ALLOW half headed or double headed arrows but allow **ECF** if seen more than once

- **OR** start from – charge on Br^- ion



(Lone pair ***NOT*** *needed if curly arrow shown from – charge on* Br^-*)*

ALLOW bromonium ion

ALLOW any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous

NOTE: For a mechanism with HBr,
ALLOW all marks **EXCEPT** for final product

Examiner's Comments

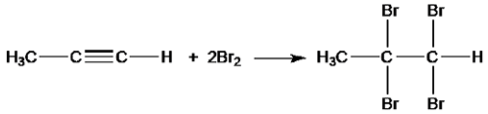
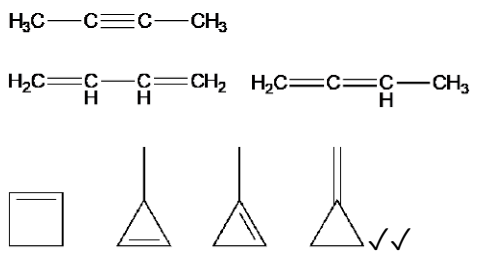
This question rewarded the well-prepared candidate and discriminated well. Conversely, many mechanisms showed little resemblance to the accepted mechanism for electrophilic addition.

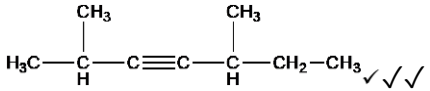
Mechanisms were often seen showing curly arrows going in the wrong direction and between the wrong bonds and atoms, with incorrect charges and dipoles, and partial charges used where full charges were required.

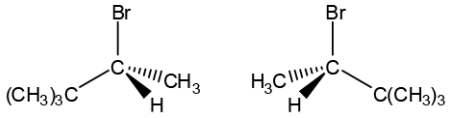
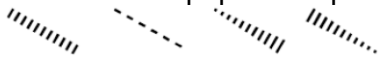
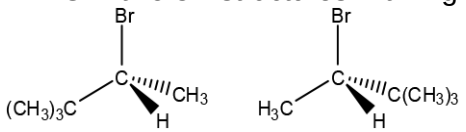
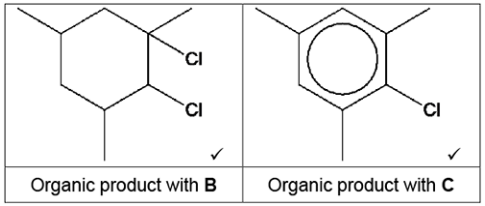
AfL

Writing mechanisms is an important skill in organic chemistry and

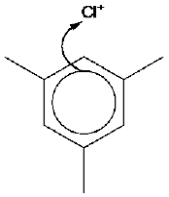
					candidates should learn and practice their writing. Our organic chemistry delivery guide contains links to some useful resources which can help students with their knowledge of mechanisms: https:/teachcambridge.org/item/c814aaeb-3e14-4ad8-b691-120110623bb8
	c	i	(series of organic compounds with the) same functional group **OR** same/similar reactions / chemical properties ✓ each successive member differs by CH_2 ✓	2 (AO1.1×2)	**IGNORE** reference to physical properties **IGNORE** same general formula **DO NOT ALLOW** same empirical **OR** molecular formula Differs by CH_2 is **not** sufficient (*no successive*) **ALLOW** differs by CH_2 each time **AW** **Examiner's Comments** Many candidates were aware that members of a homologous series have the same functional group and react in similar ways. A second mark was available for stating that the formula of successive members increases by CH_2. It is important to stress 'successive' in communicating this information.
		ii	C_nH_{2n-2} ✓	1 (AO3.2)	**ALLOW** $C_nH_{2(n-1)}$ **Examiner's Comments** This part required candidates to apply their understanding of a 'general formula' in a novel context. Many candidates analysed the provided formulae for the alkynes homologous series to derive the correct general formula of C_nH_{2n-2}. There was no real pattern in the incorrect responses which usually contained a mixture of numbers for the H atom, e.g. C_nH_{2n}, C_nH

					• n+1 .
		iii	 Left-hand side, i.e. Reactants, balanced with $2Br_2$ ✓ Right-hand side, i.e. Product ✓	2 (AO2.5) (AO2.6)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** C_3H_4 for $H_3CC{\equiv}CH$ *Questions asks only for structure of product* **ALLOW** $H_3CCBr_2CHBr_2$ **OR** $H_3CCBr_2CBr_2H$ **Examiner's Comments** Although attempted by most candidates, comparatively few responses could be credited. The key to success was again to use the information provided: the formation of a saturated compound. The commonest response seen showed addition of 1 Br_2 molecule to form the unsaturated $CH_3CBr{=}CHBr$ instead of the saturated $CH_3CBr_2{-}CBr_2$ by addition of 2 Br_2. This question was one of the most difficult on the exam paper.
		iv	Any **2** structures from: 	2 (AO3.2×2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **Examiner's Comments** Most candidates achieved 1 of the available 2 marks for drawing the structure of but-2-yne, $CH_3C{\equiv}CCH_3$. The structure of but-1-yne was then usually drawn in the other box despite it being provided already in the table at the start of part (c). A variety of creditworthy structures were seen, including H2C=CH–CH=CH_2, cyclobutene and isomers of methylcyclopropane.

		v	 ✓✓✓	1 (AO2.5)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **Examiner's Comments** It was encouraging to see the many correct structures drawn from the unfamiliar 2,5-dimethylhept-3-yne. Most candidates positioned the C≡C group and the two substituted CH_3 groups correctly. The commonest error was showing a main stem with 6, rather than 7 C atoms.
			Total	**15**	
61			**A**	1 (AO1.2)	
			Total	**1**	
62			**B**	1 (AO1.1)	
			Total	**1**	
63			**D**	1 (AO1.2)	
			Total	**1**	
64			**D**	1 (AO2.1)	
			Total	**1**	
65		i	**Stereoisomers** Same structural formula **AND**	1 (AO1.2)	**ALLOW** structure/displayed/skeletal formula **DO NOT ALLOW** same empirical formula **OR** same general formula

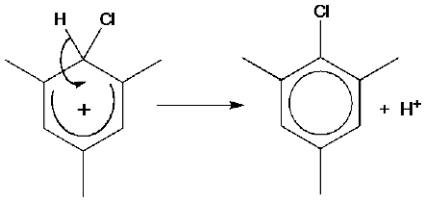
			Different arrangement (of atoms) in space **OR** different spatial arrangement (of atoms) **AND** **Type:** Optical ✓		**IGNORE** same molecular formula **IGNORE** references to chiral molecules/compounds
		ii	One 3D structure with correct groups attached to the chiral C ✓ Two 3D structures of (CH3)3CCHBrCH3 that are mirror images **AND** correct connectivity in both ✓ 	2 (AO2.5) (AO1.2)	**ALLOW** small slip in one of the groups OR use of C4H9 3D structures must have four central bonds with **at least two wedges**. For bond into paper accept:  **ALLOW** two 3D structures with 2 groups swapped e.g. 
			Total	**3**	
66		i	 Organic product with **B** ✓ Organic product with **C** ✓	2 (AO2.5×2)	
		ii	**Reactivity of B**	3 (AO1.1×3)	**ALLOW** labelled diagram to show delocalised system **IGNORE** charge density

			in B electrons are localised OR in B π-bond is localised ✓ **Reactivity of C** in C electrons are delocalised OR In C π-system / ring is delocalised In **B**, electron density is higher **AND** B is more susceptible to electrophilic attack **OR** B attracts/accepts the electrophile/Cl_2 more **OR** B polarises the electrophile/Cl_2 more ✓ **ORA**		**IGNORE** electronegativity **IGNORE** B is more reactive/reacts more readily (no reference to electrophile) **IGNORE** references to electron density spread around the π−ring ALLOW chlorine **Examiner's Comments** Candidates answered this question well. Many were able to correctly use the terms delocalised and localised in their responses and were able to provide comparisons for both electron density and attack of an electrophile.
		iii	**Generation of electrophile** $AlCl_3 + Cl_2 \rightarrow AlCl_4^- + Cl^+$ ✓ Attack of Cl^+	5 (AO1.2) (AO1.2) (AO2.5) (AO1.2) (AO1.2)	ANNOTATE ANSWER WITH TICKS AND CROSSES **ALLOW** $FeCl_3 + Cl_2 \rightarrow FeCl_4^- + Cl^+$ **ALLOW** use of Fe **NOTE**: curly arrows can be straight, snake-like, etc. ..... . but **NOT** double-headed or half-headed arrows **1st curly arrow** must



Curly arrow from π-bond to Cl^+ ✓

Intermediate and organic product



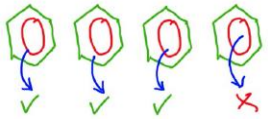
Correct intermediate ✓

Curly arrow from C–H bond to reform π-ring ✓

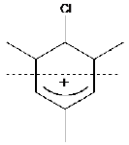
Regeneration of catalyst

$H^+ + AlCl_4^- \rightarrow AlCl_3 + HCl$ ✓

- start from, **OR** close to, **circle of benzene ring**



DO NOT ALLOW following intermediate:



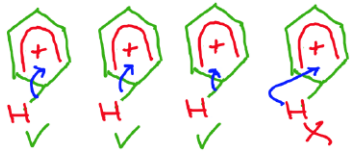
π-ring must cover 4 of the 6 sides of the benzene ring
AND
correct orientation, *i.e.* gap towards C–Cl

ALLOW + sign anywhere inside the 'hexagon' of the intermediate.

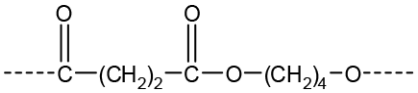
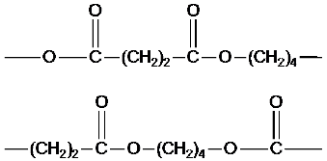
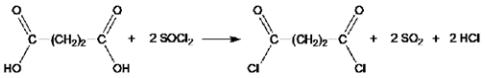
IGNORE partial charges on the chlorine in the intermediate

DO NOT ALLOW mark for intermediate if any CH_3 is missing

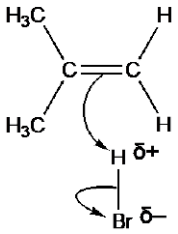
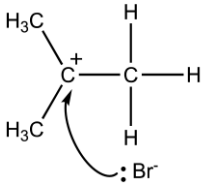
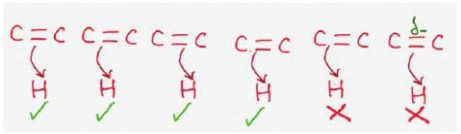
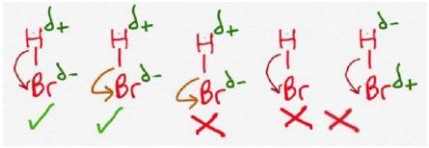
Curly arrow must start from, **OR** be traced back to, **any part of** C-H bond and go inside the 'hexagon'

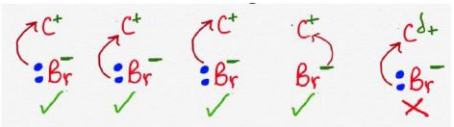
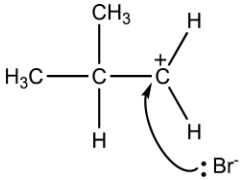
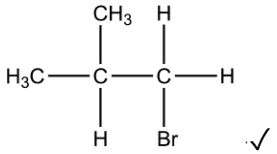


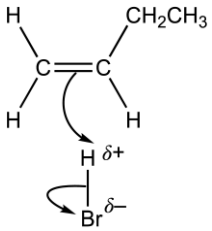
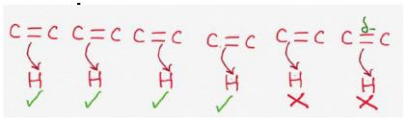
ALLOW use of $AlCl_4^-$ in the mechanism

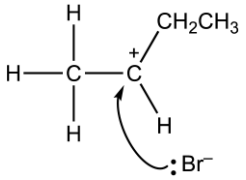
					ALLOW ECF for regeneration of an incorrect metal chloride catalyst e.g. $AgCl_3$
			Total	**10**	
67		i	 Ester link (must be displayed) ✓ Rest of structure ✓	2 (AO1.2) (AO2.5)	**ALLOW** the 'O' or C=O at either end, e.g.  **IGNORE** brackets **IGNORE** *n* End bonds' **MUST** be shown (solid or dotted) **DO NOT ALLOW** more than one repeat unit
		ii	the ester/ ester bond/ ester group /polyester can be broken down ✓ **OR** It can be hydrolysed ✓	1 (AO3.2)	**IGNORE** references to photodegradable 'Bond breaks' is not sufficient – no reference to ester bond
		iii	 $SOCl_2$ in equation ✓ Structure of diacyl dichloride ✓ Complete balanced equation ✓	3 (AO1.1) (AO1.2) (AO2.6)	**ALLOW** alternative approach using PCl_5 or PCl_3
			Total	**6**	

68			F/aldehyde **AND** Tollens' (reagent) **AND** Silver (mirror/precipitate/ppt/solid) ✓ G/alkene/C=C **AND** Bromine/Br2 **AND** goes colourless/decolourised ✓ G/ketone **AND** 2,4-dinitrophenylhydrazine **AND** orange/yellow/red precipitate ✓ G/ketone **AND** Tollens' (reagent) **AND** no silver mirror/no change/no reaction ✓	4 (AO2.3) (AO3.3) (AO3.3) (AO3.3)	**IGNORE** use of 2,4-DNP with F **ALLOW** ammoniacal silver nitrate **OR** Ag^+/NH_3 **ALLOW** black ppt **OR** grey ppt **ALLOW** bromine water/ $Br_2(aq)$ **ALLOW** errors in spelling for 2,4-DNP **ALLOW** 2,4(-)DNP **OR** 2,4(-)DNPH **ALLOW** Brady's reagent or Brady's Test **ALLOW** solid **OR** crystals **OR** ppt as alternatives for precipitate **ALLOW** ammoniacal silver nitrate **OR** Ag^+/NH_3 **ALLOW** black ppt **OR** grey ppt **ALLOW** alterative approach using acidified potassium dichromate for tests with F and/or G, with correct observations, alongside use of 2,4-DNP **Examiner's Comments** Candidates who found this question difficult often did not give a response that would identify all three of the functional groups (aldehyde, ketone and alkene). The use of Tollens' in identifying aldehydes was well demonstrated, however no reaction with Tollens' was less well demonstrated as a result for ketones.
			Total	**4**	
69			**B**	1 AO2.5	**ALLOW** 4
			Total	**1**	

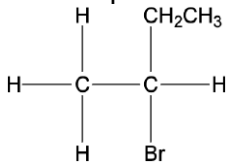
70			**B**	1 AO1.2	
			Total	**1**	
71			**A**	1 AO2.1	
			Total	**1**	
72	a		Curly arrows can be straight, snake-like, etc. but **NOT** double headed or half headed arrows **<u>1. Curly arrow from C=C to HBr and H–Br</u>** ***2 marks***  **DO NOT ALLOW** partial charge on C=C Curly arrow from C=C bond to H of H–Br ✓ Correct dipole shown on H–Br **AND** curly arrow that breaks H–Br bond ✓ **<u>2. Curly arrow from Br= to carbocation</u>** ***1 mark***  **DO NOT ALLOW** δ+ on C of carbocation Correct carbocation **AND** curly arrow from	4 AO1.2 AO1.2 AO2.5	**1st curly arrow must** • go to the H atom of H–Br **AND** • start from, **OR** be traced back to **any point across width** of C=C  **2nd curly arrow must** • start from, **OR** be traced back to **any part of** $^{\delta+}$H–Br$^{\delta-}$ bond **AND** • go to Br$^{\delta-}$  **3rd curly arrow must** • go to the C+ of carbocation **AND**

			Br^- to C^+ of **CORRECT** carbocation ✓ **3. Name of mechanism** ***1 mark*** Electrophilic addition ✓	AO1.1	• start from, **OR** be traced back to any point across width of lone pair on :Br^- • **OR** start from – charge of Br^- ion  *(Lone pair* **NOT** *needed if curly arrow shown from – charge of Br^- ion)* **IF** Br_2 is used instead of HBr contact your Team Leader **DO NOT ALLOW incorrect carbocation, i.e.** 
	b	i	Same **molecular** formula **AND** Different **structural** formulae ✓	1 AO1.1	Same formula is **not** sufficient (*no reference to molecular*) Different arrangement of atoms is not sufficient (*no reference to structure/structural*) For structural formulae, **ALLOW** structure/displayed/skeletal formulae
		ii	 ✓	1 AO2.5	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous
			Total	**6**	

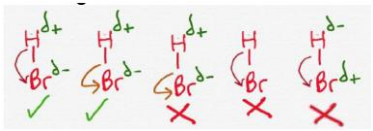
73			**B**	1 (AO1.2)	
			Total	**1**	
74	a	i	σ-bond: Overlap of **orbitals** between (bonding) atoms ✓ π-bond: **Sideways** overlap of (adjacent) **p-orbitals** ✓	2 (AO1.1×2)	**ALLOW** labelled diagrams **IGNORE** the type of orbital for σ-bond **DO NOT ALLOW** pi-orbital **Examiner's Comments** These definitions were known by few candidates. Many did not mention orbitals in their response.
		ii	σ-bonds: 9 ✓ π-bonds: 2 ✓	2 (AO1.2×2)	
	b	i	 Curly arrow from C=C bond to H of H–Br ✓ **DO NOT ALLOW** partial charge on C=C Correct dipole shown on H–Br **AND** curly arrow showing breaking of H–Br bond ✓ Correct carbocation **AND** curly arrow from Br^- to C^+ of carbocation ✓ **DO NOT ALLOW** δ+ on C of carbocation	4 (AO1.2×2) (AO2.5×2)	**NOTE**: curly arrows can be straight, snake like, etc. but **NOT** double headed or half headed arrows **1st curly arrow must** • go to the H atom of H–Br **AND** • start from, **OR** be traced back to **any point across width** of C=C  **2nd curly arrow must**



Correct product ✓

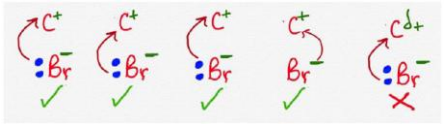


- start from, **OR** be traced back to **any part of** $^{\delta+}$H–Br$^{\delta-}$ bond
  AND
- go to Br$^{\delta-}$



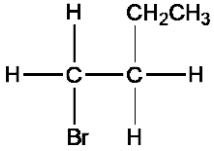
3rd curly arrow must

- go to the C+ of carbocation
  AND
- start from, **OR** be traced back to any point across width of lone pair on :Br$^-$
- **OR** start from – charge of Br$^-$ ion



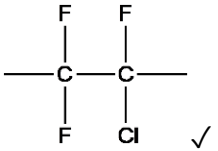
*(Lone pair **NOT** needed if curly arrow shown from – charge of Br$^-$ ion)*

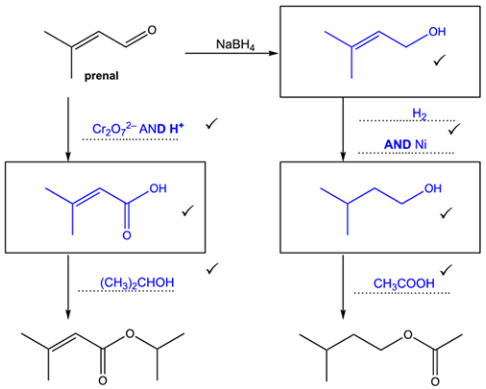
ALLOW ECF for product from incorrect carbocation, i.e.



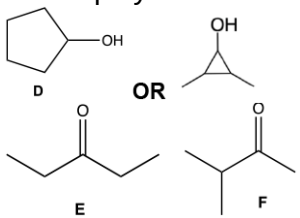
IF Br_2 is used instead of HBr contact your Team Leader

					Examiner's Comments This was answered well by students. Many candidates included correct dipoles and charges. Curly arrows were frequently well-positioned. Few candidates attempted to make the minor product.
		ii	(major product forms from) most/more stable intermediate/carbocation ✓ (major product forms from a) secondary carbocation **OR** carbocation bonded to more C atoms / more alkyl groups **OR** carbocation bonded to fewer H atoms ✓	2 (AO1.1) (AO1.2)	For carbocation, **ALLOW** carbonium ion or cation **IGNORE** descriptions of the major/minor product in terms of Markownikoff's rule e.g. H atom joins to C with most H **IGNORE** references to stability of the product --- **ALLOW ORA**, i.e. (minor product forms from) least/less stable intermediate/carbocation ✓ (minor product forms from a) primary carbocation **OR** carbocation bonded to less C atoms / less alkyl groups **OR** carbocation bonded to more H atoms ✓ **Examiner's Comments** ? **Misconception** Some candidates explained the formation of the major organic product in terms of the stability of the product, rather than referring to the stability of the intermediate. Many responses also stated Markownikoff's rule – rather than explaining their response.
		iii	3 ✓	1 (AO1.2)	

	c	i	Same structural formula **AND** Different arrangement (of atoms) in space **OR** different spatial arrangement (of atoms) ✓	1 (AO1.1)	**ALLOW** structure/displayed/skeletal formula **DO NOT ALLOW** same empirical formula **OR** same general formula **IGNORE** same molecular formula Reference to *E/Z* isomerism or optical isomerism is **not** sufficient
		ii	Student is **not** correct **AND** 2 groups on one carbon atom (of C=C) are the same **OR** C–C bond can rotate ✓	1 (AO3.1)	**DO NOT ALLOW** one side of C=C
			Total	**13**	
75		i	 ✓	1 (AO2.5)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous 'End bonds' **MUST** be shown **DO NOT ALLOW** more than 1 repeat unit **IGNORE** brackets **IGNORE** *n*
		ii	More points of contact / more surface interaction (between molecules) **AND** Stronger/more dipole(–dipole) interactions ✓	2 (AO2.1×2)	**Both answers need to be a comparison** **IGNORE** surface area **ALLOW** more electrons **ALLOW** induced/permanent dipole interactions

			More energy needed to break the intermolecular forces ✓		**ALLOW** London forces **ALLOW** van der Waals' forces (as permanent dipole-dipole and induced dipole-dipole interactions are present within this polymer) **IGNORE** IDID **Examiner's Comments** **Misconception** Too often candidates' responses linked more energy being needed to break covalent bonds. Candidates need to be clear that the energy is being used to overcome the intermolecular forces.
			Total	**3**	
76		i	3-methylbut-2-enal ✓	1 (AO1.2)	**IGNORE** lack of hyphens, or addition of commas
		ii		7 (AO1.2×4) (AO2.5×3)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** names of reagents and catalyst For oxidation, **ALLOW** $K_2Cr_2O_7$ for $Cr_2O_7^{2-}$ **ALLOW** H_2SO_4 for H^+ For left hand side esterification **IGNORE** C_3H_7OH **IF** esterification is given instead of hydrogenation contact your Team Leader

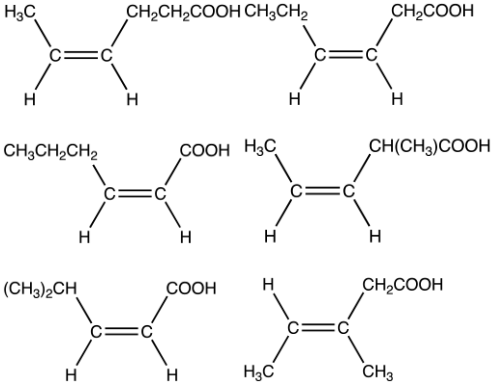
			Total	**8**	
77			*Refer to marking instructions on page 5 of mark scheme for guidance on marking this question.* **Level 3 (5–6 marks)** Compounds **D**, **E AND F** correctly identified **AND** Most of the observations and NMR data analysed. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Most of compounds **D**, **E AND F** correctly identified **AND** Some of the observations and NMR data analysed. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Most of compounds **D**, **E AND F** correctly identified **OR** Some of compounds **D**, **E AND F** correctly identified **AND** Analyses some of the observations or NMR data	6 (AO3.1×4) (AO3.2×2)	**Indicative scientific points may include:** **Observations from Test-tube tests** 2,4 DNP — **D** has no C=O; **E** and **F** have C=O present $H^+/Cr_2O_7^{2-}$ — **D** is primary **OR** secondary alcohol; **E** and **F** are ketones; *(negative test shows not aldehydes)* Br_2 — **D**, **E** and **F** have no C=C/are saturated **^{13}C NMR analysis** **D:** • 3 carbon environments/types of C • δ = 24, 36 ppm — **C–C** • δ = 73 ppm, — **C**–O **^{1}H NMR analysis** **E:** • δ = 2.4 ppm, quartet — CH_3–**CH_2**–C=O • δ = 1.1 ppm, triplet — **CH_3**–CH_2– **F:**

			OR Analyses most of the observations from the test-tube tests. **OR** Analyses most of the NMR data. **OR** Analyses some of the observations and NMR data *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** No response or no response worthy of credit.		• δ = 2.6 ppm, heptet/multiplet $(CH_3)_2$–**CH**–C=O • δ = 2.1 ppm, singlet, **CH_3**–C=O • δ = 1.1 ppm, doublet **CH_3**–CH– **Structures** **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous  **Examiner's Comments** Most candidates could correctly analyse the observations from the test-tube tests but were unable to link this to the NMR data to suggest structures for D, E and F. This limited their response to Level 1. Those that achieved Level 3 had worked through each piece of data in turn before clearly identifying structures for the three compounds.
			Total	**6**	
78			$n(Ba(OH)_2) = 0.150 \times \frac{23.50}{1000}$ = **3.525** × **10**$^{-3}$ (mol) ✓ n(**D**) in 25.0 cm^3 = 2 × 3.525 × 10^{-3} = **7.05** × **10**$^{-3}$ (mol) ✓ n(**D**) in 100 cm^3 = 7.05 × 10^{-3} × $\frac{100}{25.0}$ = **0.0282** (mol) ✓	7 (AO2.8×4) (AO3.2×1) (AO3.2×2)	**Use ECF throughout** Intermediate values for working to **at least 3 SF**. **TAKE CARE** as value written down may be truncated value stored in calculator. Depending on rounding, either can be credited. ----------

Molar mass (**D**) $= \frac{3.215}{0.0282} = 114$ (g mol^{-1}) ✓
Formula: = C_5H_9COOH
OR C_nH_{2n-1}: $M(C_5H_9) = 114 - 45 = 69$ ✓
If not stated, could be credited from structure
***cis* stereoisomers.**
The drawn stereoisomers must have

- Different groups attached to each C atom of C=C
- Each C of C=C has the same group on the same side

Any 2 *cis* isomers ✓✓ *Many possibilities*, e.g.



ALLOW correct structural, with '*cis*' part displayed
OR skeletal
OR displayed formula
OR mixture of above as long as non-ambiguous

ALLOW side chains as molecular formula, e.g. C_3H_7 for $(CH_3)_2CH$ **OR** $CH_3CH_2CH_2$

ALLOW Mass **D** in 25.0 cm^3 = $\frac{3.215}{4}$ = 0.80375 g

Molar mass (**D**) = $\frac{0.80375}{7.05 \times 10^{-3}}$ = 114

COMMON ERRORS:
Up to Molar mass = 114 (1st 4 marks)
M = 456 → 3/4 marks (mol in 100 cm_3 omitted)
M = $\frac{3.215}{7.05 \times 10^{-3}}$ = 456

M = 228 → 3/4 marks (*No × 2 for n(D)*)
$3.525 \times 10^{-3} \times \frac{100}{25.0} = 0.0141$
M = $\frac{3.215}{0.0141}$ = 228

M = 100.8 → 3/4 marks

23.50 instead of 25.00 and scaling by × $\frac{100}{23.50}$

$25.0 \times \frac{0.150}{1000} = 3.75 \times 10^{-3}$ ✗

→ $2 \times 3.75 \times 10^{-3} = 7.5 \times 10^{-3}$ ✓
→ $7.5 \times 10^{-3} \times \frac{100}{23.50} = 0.0319$ ✓
→ $\frac{3.215}{0.0319}$ → 100.8 ✓

THEN ALLOW ECF for carboxylic acid closest to calculated *M*(alkyl group) but must be C_nH_{2n-1}
e.g. For ***M(alkyl)* = 100**, **ALLOW** C_4H_7 (55)
For ***M(alkyl)* = 411**, **ALLOW** $C_{29}H_{57}$ (405)

			e.g. $C_3H_5O_2$ for CH_2CH_2COOH **IGNORE** poor connectivity to all groups		**OR** $C_{30}H_{59}$ (419) **THEN** judge *cis* isomers with closest match **ALLOW** 1 mark for 2 *trans* isomers shown instead of 2 *cis* isomers ***ECF*** *for Same error made twice.* **Examiner's Comments** As with Question 2, candidates had more success with the mole calculation in (b) than the descriptive response in (a). Most candidates followed a set procedure to show that the molar mass of the acid was 114, and to then show that the formula must be C_5H_9COOH. Correct cis stereoisomers were seen more rarely. One structure was often repeated in both boxes and the structures seen sometimes had C or H atoms missing. When errors were made with the calculation, these usually stemmed from the scaling up by a factor of 4 in going from 25 cm^3 to 100 cm^3. Some candidates omitted this stage, obtaining a molar mass value of 456. Others scaled up by a factor of 10 to 250 cm^3, obtaining a molar mass of 45.6. Both errors made it very difficult to make further progress. If candidates get into this situation, they are advised to check back through their calculation – it should be obvious that there is a critical error somewhere in the working.
			Total	**7**	
79	a	i	UV **OR** ultraviolet ✓	1 (AO1.1)	**ALLOW** Sunlight **IGNORE** Temperature **Examiner's Comments**

					Most candidates gave the correct response to this question. Incorrect responses included use of high temperatures and/or catalyst.
		ii	$CH_3CH_2CH_2CH_3 + Br\bullet \rightarrow CH_3CH_2\dot{C}HCH_3 + HBr$ ✓ $CH_3CH_2\dot{C}HCH_3 + Br_2 \rightarrow CH_3CH_2CHBrCH_3 + Br\bullet$ ✓	2 (AO 2.5 × 2)	**ALLOW** Displayed or Skeletal formulae **ALLOW 1 mark** if **BOTH** equations are 'correct' using molecular formulae, i.e. $CH_3CH_2CH_2CH_3 + Br\bullet \rightarrow C_4H_9\bullet + HBr$ $C_4H_9\bullet + Br_2 \rightarrow C_4H_9Br + Br\bullet$ ✓ **IGNORE** position of • within $CH_3CH_2CHCH_3$ • **ALLOW 1 mark** if incorrect structure of intermediate radical is used, e.g. $CH_3CH_2\mathbf{CH_2CH_2}\bullet$ for $CH_3CH_2\mathbf{CHCH_3}\bullet$ ✓ **Examiner's Comments** Candidates always find radical mechanisms tricky and this one had the added complexity of forming 2-bromo isomer. However, a majority of students still gained marks. Many candidates formed the incorrect radical removing H from C-1 i.e. $CH_3CH_2CH_2CH_2\cdot$ therefore scoring only 1 mark. Some responses were a little messy making it very easy to miss off a dot or H or Br. Many candidates reacted with Br· in the first step but added Br to the radical intermediate (as well as forming HBr). Candidates should always check equations so that they balance in terms of atoms.
		iii	Further substitution **OR** formation of di/ tri / etc. bromobutanes **OR** produces different termination products	2 (AO 3.2 × 2)	**ALLOW** multisubstitutation, including examples **ALLOW** an example of a different termination product **ALLOW** more than one hydrogen (atom) can be replaced

			OR more than one termination step ✓ Formation of 1-bromobutane **OR** (Br) subsitution in a different position ✓		**ALLOW** radicals react with each other to form other products **Examiner's Comments** Candidates found this question very challenging and few scored both marks. Many responses considered only the formation of HBr (other product) and/or general statements about other products with no indication of how they were formed. Some described losses due to the purification method or incomplete reaction (due to conditions such as T and P) or low atom economy. Some referred to the stability of the radical intermediate, showing possible confusion with electrophilic addition. Candidates who understood the mechanism were more confident in answering this question, at least recognising that further substitution was possible.
	b		% atom economy for butane and bromine (5.1) $= \frac{136.9}{217.8} \times 100 = 62.9\%$ ✓ atom economy for but-2-ene and HBr (5.2) is 100% ✓	2 (AO 2.2) (AO1.2)	Calculator: 62.85583104 **ALLOW** calculation for 5.2 **ALLOW** Calculations not expressed as a % i.e. 0.629 and 1. **Examiner's Comments** Despite the question asking for calculations to be included, many candidates didn't include them and so lost both marks. Some gained

<table>
<tr><td></td><td></td><td></td><td></td><td></td><td>one mark as recognised that 5.1 has 100% atom economy but either didn't or incorrectly calculated for 5.2 (30% was seen frequently). Care needs to be taken with rounding of final values.</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>7</td><td></td></tr>
<tr><td>80</td><td></td><td></td><td>Level 3 (5-6 marks)
A comprehensive description including most of the evidence to justify the correct structure of A (accept cis or trans).

There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.

Level 2 (3–4 marks)
Explains two scientific points thoroughly with few omissions.
AND
an attempt at a feasible structure with either a C=C OR COOH

There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.

Level 1 (1–2 marks)
The correct empirical formula
AND a simple description based on at least one of the main scientific points.
OR
Some aspects from two scientific points are</td><td>6
(AO 3.1 × 3)
(AO 3.2 × 3)</td><td>LOOK AT THE SPECTRA for labelled peaks
Indicative scientific points may include:

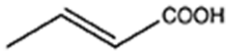
<u>Empirical formula</u>
• empirical formula = C_2H_3O

<table>
<tr><th>element</th><th>%mass</th><th>A_r</th><th>moles</th><th>ratio</th></tr>
<tr><td>C</td><td>55.8</td><td>12</td><td>4.65</td><td>2</td></tr>
<tr><td>H</td><td>7.0</td><td>1</td><td>7.0</td><td>3</td></tr>
<tr><td>O</td><td>37.2</td><td>16</td><td>2.325</td><td>1</td></tr>
</table>

<u>Spectra and molecular formula</u>
Mass spectrum

• (molecular ion peak m/z = 86)
• molar mass = 86 g mol^{-1}
• molecular formula = $C_4H_6O_2$

Infrared absorption;</td></tr>
</table>

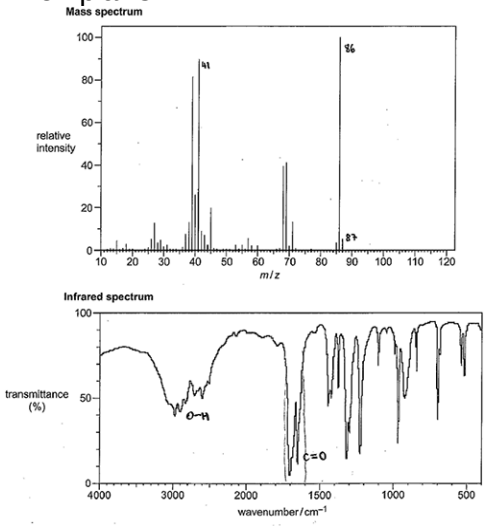
			given *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** No response or no response worthy of credit.		• broad peak at 2500–3300 cm^{-1}, due to O–H in carboxylic acid, • peak at 1630–1820 cm^{-1} due to C=O (peak at 1620–1680 cm^{-1} due to C=C) • **<u>Functional groups, structure and stereochemistry</u>** • alkene / C=C • carboxylic acid / −COOH • mass spectrum; peak at 41 due to loss of COOH • Correct structural formula: $CH_3CH=CHCOOH$ i.e. *cis* **OR** *trans* • *trans* isomer indicates C=C bond with 2 different groups attached to both double bonded carbons • *trans:* common groups on opposite sides of double bond • Correct structure:  **NOTE:** *Correct trans assignment with justification would be an example of a well-developed line of reasoning that is substantiated*.

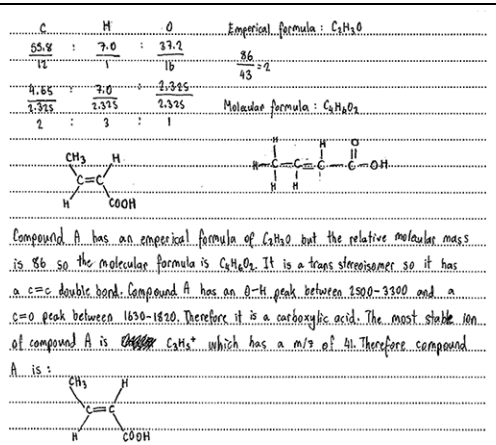
					Examiner's Comments About a third of candidates were given Level 3 for this question. The key to answering this style of question well is to make sure all the information provided is used and to avoid contradictory statements, e.g. "structure contains carboxylic acid from IR" but then not present in final structure drawn, or a structure that doesn't match the molecular formula given. A significant number of candidates did not include C=C despite being told in the question that it was "unsaturated and is a trans stereoisomer", plus the C=C bond is shown in the IR and molecular formula needed unsaturation. The M+1 peak did confuse some candidates who then tried to add an extra H to final structure. It is very important that any structure given is feasible in terms of bonding; many candidates gave structures with C with 5 bonds (with both C=C and C=O attached), limiting them to achieving only L1. Some candidates gave a *cis* structure rather than trans. Other candidates ignored the O-H peak (from the carboxylic acid) in the IR spectrum, attributing this to a C-H bond as it was not as smooth or as prominent as they may have seen in other spectra. Some listed the bonds observed in the IR without linking to their position – this can easily be done by annotating the spectra. Many candidates had messy answers with lots of rough working which was then not crossed out – this made their answer very confusing. Note that no marks were given for just the empirical formula calculation and some attempted to produce a structure from the empirical formula without determining the M_r from the M^+ peak in mass spectrum.

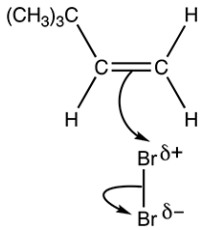
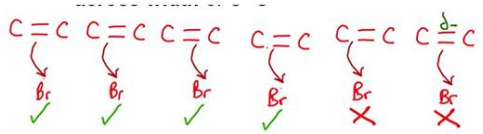
OCR support

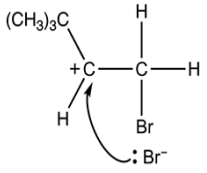
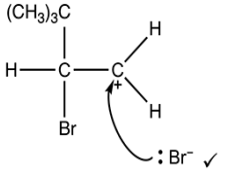
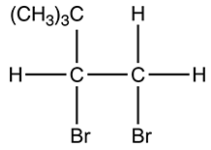
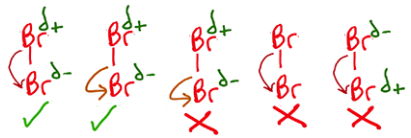
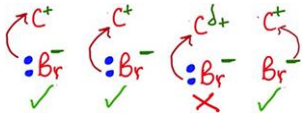
We have put together a range of online resources to support teaching of organic chemistry: https:/www.ocr.org.uk/qualifications/as-a-level-gce-chemistry-a-h032-h432-from-2015/deliveryguide/module-cam04-module-4-core-organic-chemistry/delivery-guide-cadg012-organicchemistry-as

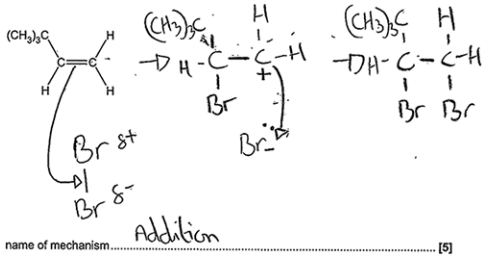
Exemplar 3

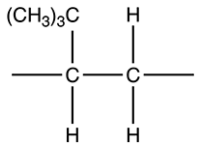


					 This is an example of a good response which achieved L3 6 marks. Empirical and molecular formula are determined. Spectra have been annotated to aid their interpretation, but they have also included the key IR peaks as well as a MS fragment in their response. The correct structure for A is clearly drawn out. The response is clear and concise, with all information presented being relevant.
			Total	**6**	
81			**D**	1(AO1.2)	**ALLOW** 9 **Examiner's Comments** Candidates found this question difficult with very many choosing option B rather than the correct option D. Candidates are advised to draw out all bonds displayed when tackling such as question as the answer of B (3) results from considering just the three bonds shown in the skeletal formula and omitting the other 6 C–H bonds.
			Total	**1**	

82			**D**	1(AO1.2)	**Examiner's Comments** This was a difficult question, requiring candidates to use CIP rules along carbon chains. Higher-attaining candidates rose to the challenge but a variety of responses were seen, suggesting that many candidates guessed.
			Total	**1**	
83	a	i	3,3-dimethylbut-1-ene ✓ **CARE**: Look for **di**methyl	1 (AO1.2 ×1)	**IGNORE** lack of hyphens, or addition of commas or spaces **ALLOW** full stops or spaces between numbers e.g. 3.3 dimethyl but-1-ene **DO NOT ALLOW** meth **OR** methy **Examiner's Comments** Candidates had difficulty in naming this compound correctly as 3,3-dimethylbut-1-ene. Many counted an incorrect number of carbons in the chain, numbered substituents from the wrong end (e.g. 1,1,1-) or used insufficient numbering (e.g. 3-dimethyl). Hex-1-ene was a common incorrect answer, presumably as there are six carbon atoms and one C=C double bond in the alkene
		ii	**ANNOTATE ANSWER WITH TICKS AND CROSSES**  or	5 (AO1.2) (AO1.2) (AO2.5) (AO2.5) (AO1.1)	**For curly arrows, ALLOW straight or snake-like arrows and small gaps (see examples):** **1st curly arrow** must • go to a Br atom of Br–Br **AND** • start from, **OR** be traced back to **any point across width** of C=C 

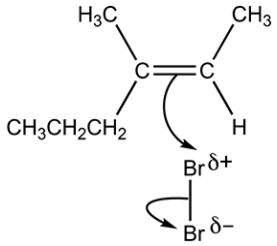
			1st curly arrow (from ANY alkene) Curly arrow from double bond to Br of Br–Br ✓ **DO NOT ALLOW** partial charge on C=C **2nd curly arrow** Correct dipole on Br–Br **AND** curly arrow for breaking of Br–Br bond ✓ **3rd curly arrow** **Correct carbocation** with + charge on C with 3 bonds **AND** curly arrow from Br^- to C^+ of carbocation **DO NOT ALLOW** δ+ on C of carbocation or  **OR**  ✓ *i.e.* ***ALLOW*** *carbonium + on either C atom* **Correct product to match mechanism/intermediate** ✓ or  **DO NOT ALLOW** half headed or double headed		**2nd curly arrow** must • start from, **OR** be traced back to, **any part** of $^{\delta+}Br–Br^{\delta-}$ bond • **AND** go to $Br^{\delta-}$  **IGNORE** connectivity of CH_3 groups in carbocation and product and **ALLOW** C_4H_9 **3rd curly arrow** must • go to the C^+ of carbocation **AND** • start from, **OR** be traced back to **any point across width** of lone pair on $:Br^-$ • **OR** start from – charge on Br^- ion  *(Lone pair NOT needed if curly arrow shown from – charge on Br⁻)* **ALLOW** bromonium ion **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **NOTE: For a mechanism with HBr, ALLOW all marks EXCEPT for final product mark** **<u>Examiner's Comments</u>** Many candidates answered the mechanism proficiently. However, many mistakes were seen with the direction of arrows, and confusing δ+/ δ– and +/– charges. In the intermediate carbocation, the C=C was often left intact and δ– used on the bromide ion attacking the

			arrows but allow **ECF** if seen more than once Name of mechanism: Electrophilic addition ✓		intermediate. Some less successful responses did not position curly arrows accurately. One common error was showing one or more C atoms missing from the $(CH_3)C$ groups. Candidates should take great care when drawing organic structures to make sure that all groups have been drawn accurately. Exemplar 1  name of mechanism ..... [5] This exemplar has been included to emphasise the importance of accurately placed curly arrows and use of charges. It was only possible to award this response 1 out of 5 marks. With a few improvements, this response could easily have been 5/5. The start of the first curly arrow has been placed accurately starting from the C=C double bond but the arrow should have finished at the $Br^{\delta+}$: 0 marks The Br–Br dipole is correct but there is no curly arrow showing it breaking: 0 marks The intermediate carbocation is correct but the curly arrow should have been shown from a lone pair on the Br^- ion to the + charge of the carbocation: 0 marks

					The product is correct: 1 mark The reaction type is addition but the name of the mechanism is electrophilic addition: 0 marks **Assessment for learning** Reactions mechanisms are the organic chemist's way of communicating electron transfers in organic chemistry. Candidates must use curly arrows, dipoles and charges appropriately and accurately. AS Chemistry includes three important reaction mechanisms: electrophilic addition, nucleophilic substitution and radical substitution. This paper includes two of these in Questions 21 (a) (i) and 26 (a). It is essential that candidates learn these three mechanism types.
	b	i	 or Correct polymer with side links ✓	1 (AO2.5 ×1)	**For repeat unit,** • 'side bonds' required on either side of repeat unit from C atoms • **ALLOW** more than one repeat unit • **ALLOW** C_4H_9 for $C(CH_3)_3$ **IGNORE** brackets • **IGNORE** *n* **IGNORE** connectivity of $C(CH_3)_3$ group

					Examiner's Comments Most candidates drew out the correct repeat unit although some less successful responses showed the molecule instead of the polymer. Missing 'side' bonds were very few as were attempts to connect to the CH_3 group leaving the C=C intact. Where candidates made an error, it was often from missing out a C or a 3 from the side chain.
		ii	**Advantage:** Energy/electricity (produced) **AND** **Disadvantage:** CO_2 produced **OR** gases causing global warming/climate change **OR** greenhouse gases, e.g CO_2 **BOTH advantage and disadvantage** ✓	1 (AO1.1 ×1)	**ALLOW** reduced use of fossil fuels **IGNORE** produced CO_2 and H_2O **ALLOW** less landfill / less harm to wildlife or environment (*not just harmful*) **ALLOW** toxic/poisonous (waste) products/gases, e.g. CO **IGNORE** harmful/dangerous **Examiner's Comments** The responses to this question were highly variable. Many candidates correctly identified the disadvantage, usually in terms of CO_2 release and global warming, but an advantage was less frequently seen. When it was seen it was almost universally about releasing energy. General hazard comments such as 'harmless'; and 'dangerous' as too general and are never given marks at AS or A Level.
			Total	**8**	
84			B	1 (AO1.1)	**Examiner's Comments** Candidates found this multiple choice question challenging. While

					some identified B as the correct answer, many candidates selected C.
			Total	**1**	
85			D	1 (AO1.2)	**ALLOW** 15 (correct number of sigma bonds) **Examiner's Comments** This question discriminated well, with higher ability candidates correctly identifying D. Often students overlooked the sigma bonds in the aromatic ring and selected B.
			Total	**1**	
86	a	i	3-methylhex-2-ene ✓	1 (AO1.2)	**IGNORE** lack of hyphens, or addition of commas **DO NOT ALLOW** 3-methyhex-2-ene OR 3-methhex-2-ene OR 3-methlyhex-2-ene OR 3-methylhexan-2-ene **IGNORE** references to *E/Z* or *cis/trans*
		ii	**ANNOTATE ANSWER WITH TICKS AND CROSSES**	3 (AO1.2×1) (AO2.5×2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** connectivity of $CH_3CH_2CH_2$ and CH_3 groups in carbocation and product **ALLOW** C_3H_7 for $CH_3CH_2CH_2$ **DO NOT ALLOW** half headed or double headed arrows but allow **ECF** if seen more than once

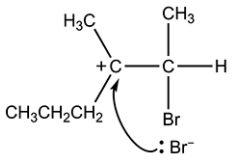


Curly arrow from C=C bond to $Br^{\delta+}$ of Br–Br

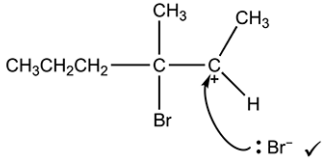
AND

Correct dipole on Br–Br
AND
curly arrow for breaking of Br–Br bond ✓

Correct carbocation to match mechanism
AND curly arrow from Br^- to C^+ of carbocation



OR



✓

DO NOT ALLOW use of HBr but ECF for subsequent use

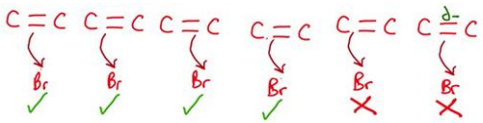
For curly arrows, ALLOW straight or snake-like arrows and small gaps (see examples):

DO NOT ALLOW partial charge on C=C

1st curly arrow must

- go to a Br atom of Br–Br

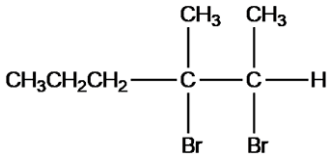
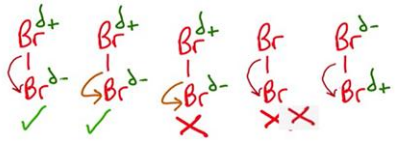
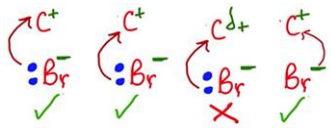
AND
start from, **OR** be traced back to **any point across width** of C=C



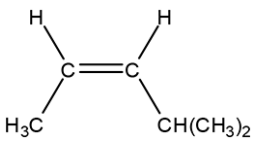
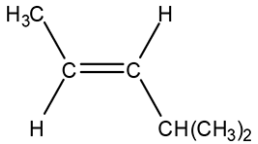
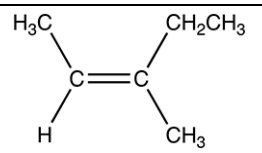
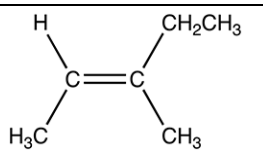
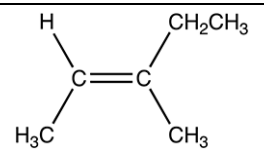
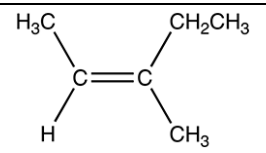
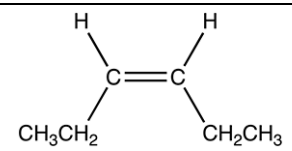
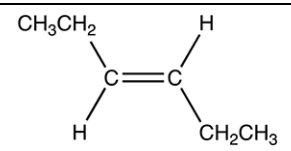
2nd curly arrow must

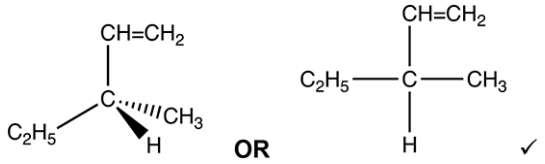
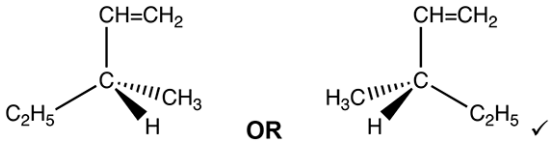
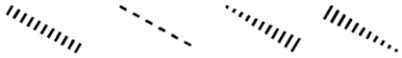
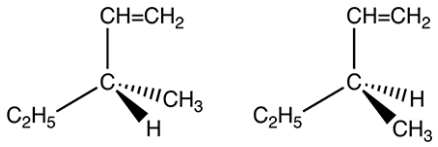
• start from, **OR** be traced back to, **any part of** $^{\delta+}Br–Br^{\delta-}$ bond

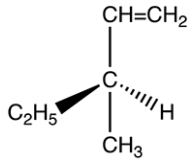
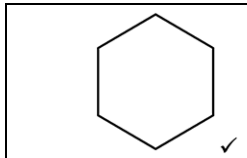
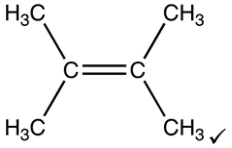
• **AND** go to Br $^{\delta-}$

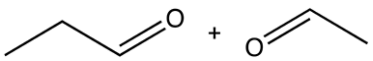
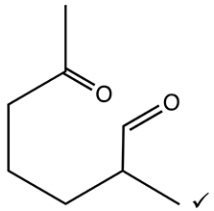
			i.e. ALLOW *carbonium + on either C atom* **----------** **<u>Correct product to match mechanism</u>** ✓ 		 **3rd curly arrow** must • go to the C^+ of carbocation **AND** • start from, **OR** be traced back to **any point across width** of lone pair on $:Br^-$ • **OR** start from – charge on Br^- ion  *(Lone pair **NOT** needed if curly arrow shown from – charge on Br^-)* **ALLOW** bromonium ion (Contact TL) **<u>Examiner's Comments</u>** The majority of candidates were able to correct name hydrocarbon **A**

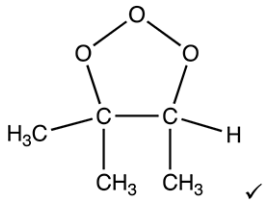
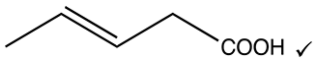
					as 3-methylhex-2-ene. A number of responses used incorrect numbering or suggested 3-methylhexan-2-ene as the name. Candidates are familiar with the mechanism for the bromination of hydrocarbons. So, the majority of candidates scored 3 marks. Common errors included the use of HBr rather than Br_2 or putting a dipole on the carbon-carbon double bond.
	b	i	Same **molecular** formula **AND** Different **structural** formulae ✓ **OR** Both have the **molecular** formula C_6H_{12} **AND** Different **structural** formulae ✓	1 (AO1.1)	Same formula is **not** sufficient *(no reference to molecular)* Different arrangement of atoms is **not** sufficient *(no reference to structure/structural)* For 'structural formulae', **ALLOW** structure/displayed/skeletal formulae/functional groups **DO NOT ALLOW** any reference to spatial/space
		ii	Same structural formula **AND** Different arrangement (of atoms) in **space** **OR** different **spatial** arrangement (of atoms) ✓	1 (AO1.1)	**ALLOW** structure/displayed/skeletal formula **DO NOT ALLOW** same empirical formula **OR** same general formula **IGNORE** same molecular formula Reference to *E/Z* isomerism or optical isomerism is **not** sufficient
		iii	Correct identification of *cis* **AND** *trans* isomers of 4-methylpent-2-ene ✓✓	2 (AO1.2) (AO2.5)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous

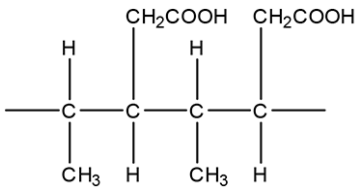
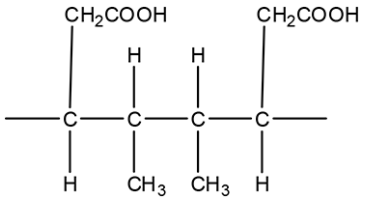
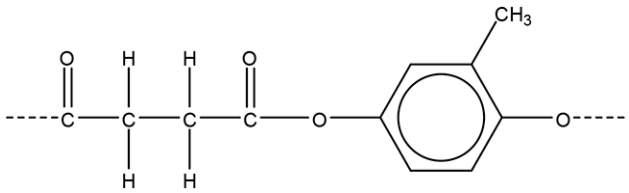
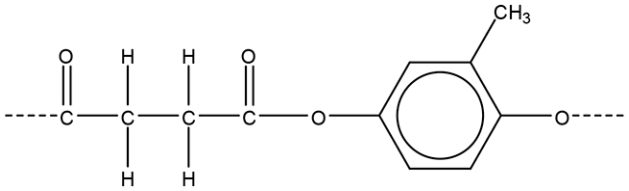
					C_3H_7 is **not** sufficient (could be unbranched)
					**ALLOW** one mark if *cis* **AND** *trans* isomers of 4-methylpent-2-ene are in the wrong boxes
			cis isomer		
			trans isomer		
			OR		**ALLOW** the isomers of 3-methylpent-2-ene in either box
			Identification of 3-methylpent-2-ene as *cis* **AND** *trans* isomers ✓✓		
					
					*cis* isomer
					*trans* isomer
			cis isomer		*Ambiguity with cis/trans identification system*
			trans isomer		**ALLOW** one mark for correct identification of *cis* **AND** *trans* isomers of unbranched C_6H_{12} e.g.
					
					

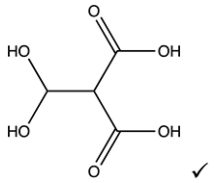
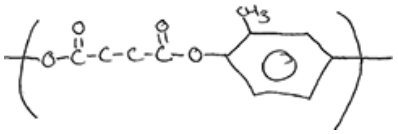
					cis isomer | *trans* isomer
		iv	Correct groups attached to chiral carbon of compound C seen **once** e.g.  OR ✓ Two **3D structures** of compound C that are mirror images with correct connectivity in both  OR ✓	2 (AO2.5×2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous For C_2H_5–, ALLOW CH_3CH_2– For –CH=CH_2, ALLOW –C_2H_3 OR –$CHCH_2$ For bond into paper accept:  **ALLOW** two 3D structures with 2 groups swapped e.g.  **DO NOT ALLOW** a bond angle of 180° e.g.

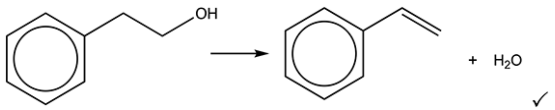
					
		v	 ✓  ✓ **D** **E** Two of the following for **D** ✓ • All H are equivalent/in the same chemical environment/ the same type • All C are equivalent/ in the same chemical environment/ the same type • No C=C present Two of the following for **E** ✓ • All H are equivalent/ in the same chemical environment/ the same type	4 (AO2.5×2) (AO2.2×2)	**ALLOW** 1 mark for structures if shown in wrong boxes. **CHECK** table 16.1 for annotations that may be worthy of credit **Examiner's Comments** The majority of candidates were able to correctly define a structural isomer. This definition was well known by candidates with the majority of responses given the mark. Some candidates omitted the reference to structural formula. This question required candidates to link their knowledge of *cis* and *trans* isomers with branched hydrocarbons. Higher ability candidates were able to do this. The majority of candidates scored 1 mark for correctly drawing *cis* and *trans* isomers of an unbranched hydrocarbon.

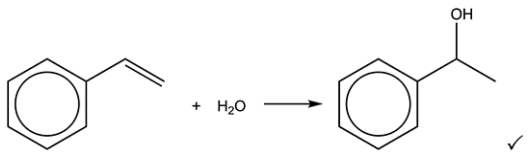
			• 2 C environments • C=C present		This question discriminated well. Candidates were required to identify the groups around a chiral carbon This question discriminated well. Candidates were required to identify the groups around a chiral carbon and then draw the two corresponding optical isomers. Incorrect responses frequently had incorrect connectivity around the chiral carbon, bond angles of 180° or 2D structures. Most candidates were able to correctly draw the structure of D and E. Many candidates did not explain their answers in terms of the number of different hydrogen and carbon environments or the presence/absence of a carbon-carbon double bond.
	c	i	 **BOTH** structures required for ✓ 	2 (AO3.1×1) (AO3.2×1)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous
		ii		1 (AO3.2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous

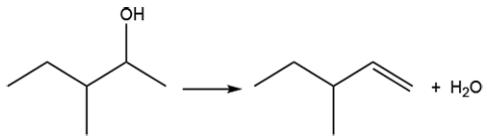
			 ✓		**Examiner's Comments** Most candidates were able to score 1 mark for correctly drawing the structures of the two aldehyde products of the first reaction. The second reaction proved more challenging, with most candidates incorrectly drawing two products. Few candidates were given this mark. A common error was to produce multiple products (rather than a ring structure) or to put positive/negative charges on the oxygen atoms within the ring structure.
			Total	**17**	
87		i	**Pent-3-enoic acid**  ✓ **2 repeat units of polymer**	2 (AO1.2) (AO2.5)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** either the *E* or *Z* isomer **ALLOW ECF** from pent-2-enoic acid **OR** pent-4-enoic acid **ONLY** **For repeat unit,** • 'side bonds' required on either side of repeat unit from C atoms • **2** repeat units required

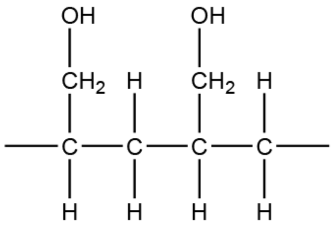
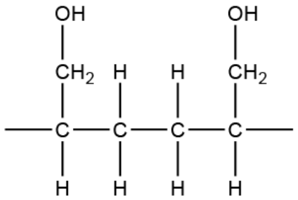
			 ✓		**IGNORE** connectivity of CH_2COOH in polymer **IGNORE** brackets **IGNORE** *n* --- **ALLOW** any consistent repeat unit: CH_2COOH and CH_3 groups can alternate or be on opposite sides of chain e.g. 
		ii	 ester link ✓ **ONE** repeat units of correct polymer ✓	2 (AO1.2) (AO2.5)	end –O– may be at either side e.g.  **ALLOW** CH_3 to be on position 2 or 3 of the aromatic ring

					‘End bonds’ **MUST** be shown (do not have to be dotted) **IGNORE** brackets **IGNORE** *n*
		iii	 ✓	1 (AO3.2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **Examiner’s Comments** Most candidates were given at least 1 mark with many correctly drawing the structure of pent-3-enoic acid. Common errors included drawing pent-2-enoic acid or propenoic acid, suggesting a lack of knowledge of prefixes. The second mark required candidates to draw two repeat units, frequently candidates tried to draw repeat units linking the carboxylic acid groups rather than identifying that it is the carbon-carbon double bond that breaks. This question differentiated well. Candidates who scored 1 mark had often shown an ester link but their structure was missing hydrogen atoms from the carbon chain (as shown in exemplar 1) or the methyl group was missing from the ring. **Exemplar 1**  This type of response was seen frequently by examiners. The candidate has correctly drawn the ester link but has omitted the

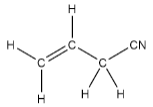
					hydrogen atoms from the carbon chain. This question proved difficult for candidates with the majority of candidates not scoring the mark. A significant proportion of candidate had identified the monomer but drew structures that combined skeletal and displayed formulae. This resulted in ambiguous structures being given that had missing hydrogen atoms on the carbons. **Drawing of organic structures** Candidates need practice at drawing structures that are not ambiguous. They should check the number of bonds on each atom and make sure the appropriate number of hydrogen atoms are drawn.
			Total	**5**	
88			**Stage 1** *Reagents*: H_2SO_4 ✓  ✓ **Stage 2** *Reagents*: Steam/H_2O(g) **AND** acid/H^+ (catalyst) ✓	4 (AO3.1) (AO2.6) (AO3.1) (AO2.6)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** H^+ **OR** HCl **OR** H_3PO_4 **DO NOT ALLOW** other named acids **IGNORE** concentration/pressure **IGNORE** water/steam For steam, **ALLOW** H_2O with temperature ≥100°C **ALLOW** use of H_3PO_4/H_2SO_4 as catalyst **DO NOT ALLOW** HCl **IGNORE** pressure

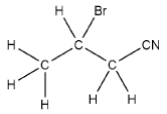
			 ✓		**Examiner's Comments** This question proved challenging with only the most able being given full marks. The reagents and conditions were not well known and candidates did not include water in their equations to make sure they were balanced.
			Total	**4**	
89	a	i	3-methylpentan-2-ol ✓	1 (AO 2.1)	**IGNORE** lack of hyphens or addition of commas **ALLOW** 3-methylpentane-2-ol **DO NOT ALLOW** 2-methylpentan-3-ol 3-methylpent-2-ol 3-methpentan-2-ol 3-methypentan-2-ol 3-methlypentan-2-ol **Examiner's Comments** A significant number of candidates lost the mark for missing -an- in their answer i.e. 3-methylpent-2-ol. Others lost the mark for incorrect spelling of methyl.
		ii		2 (AO 2.7 × 2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous

			 Correct structure of organic product ✓ Balanced equation ✓		**DO NOT ALLOW** additional reactants such as H^+ or [O] in the equation. **ALLOW** incorrect isomer 3-methylpent-2-ene for balancing mark. **Examiner's Comments** Most candidates did not score either mark here, despite the structures for B and C being given in the table below for (iii). Many thought this was oxidation, showing [O] in equations and giving a carbonyl product. Many had alkenes but still with the -OH present. Some attempted to use structural or displayed formulae but errors were made in giving the correct number of H atoms. For those that did have the correct structure, they often did not give an equation, added the acid as a reactant , or missed off the water as a product.
		iii	Priority groups on same side ✓ High(est) priority groups are CH_3CH_2 and CH_3 **OR** Low(est) priority groups are CH_3 and H ✓	2 (AO 3.1 × 2)	**ALLOW** suitable alternatives to 'priority' e.g. Groups with highest atomic number or more important groups etc. **ALLOW** priority groups are both on the top **IGNORE** references to relative mass of groups, Ar, Mr, **ALLOW** identification by name e.g. ethyl and methyl, or by circling on the structure. **IF** 'priority' is not mentioned **ALLOW** 1 mark for CH_3CH_2 and CH_3 are on same side **OR** H and CH_3 are on same side **Examiner's Comments**

					Many responses made no reference to 'priority' and/or discussed alkene C, suggesting that they didn't read the question fully. Candidates often struggled to find the right language to express themselves, such as reference to 'functional groups' or 'molecules' rather than priority groups. Lots discussed using *Mr* to assign priority with only a few stating correctly that it is atomic number that is used for CIP rules. Many, despite stating that priority groups are on the same side, didn't identify these groups so didn't get the second mark.
	b	i	**Section of polymer**  ✓ - **Reason for solubility in water**	2 (AO 2.5) (AO 3.1)	**ALLOW** correct structural **OR** displayed **OR** skeletal formula. **ALLOW** alternating side chains i.e.  **IGNORE** brackets and use of 'n' **IGNORE** incorrect connectivity for $-CH_2OH$ **DO NOT ALLOW** -HO End bonds **MUST** be shown (solid or dotted) **DO NOT ALLOW** one repeat unit *Question asks for 2 repeat units.* -

			OH/alcohol groups form hydrogen bonds with water ✓		**DO NOT ALLOW** 'it forms hydrogen bonds' **Examiner's Comments** Most candidates were able to gain credit for their structure, with only a few missing out by only drawing one repeat unit, keeping the C=C, having no end bonds or missing/extra Hs. Lots struggled to gain the second mark for the reason for solubility in water as they didn't refer to H-bonding. There were quite a few misconceptions highlighted in the responses to this question. These included the misunderstanding that a H-bond is an an intermolecular force between -OH on alcohol and water, rather than the covalent bond in the molecule. Some thought the -OH would behave as an alkali, even referring to ions, so would 'fully dissociate'. Some described a reaction with water and breaking apart, perhaps confusing with condensation polymers which can be hydrolysed.
		ii	Any two ✓✓ • Recycled (to make other plastic materials) • Combustion to generate energy / electricity • As (organic) feedstock	2 (AO 1.1 × 2)	**IGNORE** Reused **ALLOW** Used as a fuel to generate energy / electricity **Examiner's Comments** About a quarter of candidates didn't gain any credit here as they struggled to identify useful processes. Lots referred to cracking or breaking down into smaller chains, possibly thinking about fractional distillation of crude oil and how we make better use of larger fractions. Some identified possible use as a fuel but didn't say to generate energy/electricity. We also saw reference made to photodegradable/biodegradable polymers which isn't relevant to hydrocarbon polymers. There was evidence of the misunderstanding

					of the use as 'feedstock' with reference being made to animals (livestock or animal feed) or as food to eat.
			Total	**9**	
90			**A**	1 (AO1.2)	**Examiner's Comments** Fewer than a third of candidates gave the correct response, A. Most identified that compounds 1 and 2 contain a bond angle of approximately 120° and consequentially selected option B. Only the most able candidates were able to apply their understanding of shapes to deduce that the carbocation would also exhibit trigonal planar geometry.
			Total	**1**	
91			**Level 3 (5–6 marks)** A **three** stage synthesis in the **correct** order **AND** Equations for each stage are mostly correct **AND** Most reagents correct *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Synthesis includes at least **two** stages in **any** order **OR** uses NH_3 and HBr in the **correct** order (without chain extension) **AND** some of the reagents and some equations correct	6 (AO3.3 ×6)	**Mark second page as SEEN** **Indicative scientific points may include:** **IGNORE conditions** ***Stage 1: Reaction with CN^-*** • Reagents: CN^- (in ethanol) • Equation: $H_2C{=}CHCH_2Br + CN^- \rightarrow H_2C{=}CHCH_2CN + Br^-$ **Intermediate 1**  ***Stage 2: Addition of HBr to C=C***

			There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence. **Level 1 (1–2 marks)** Planned synthesis includes reagents for **any** two stages **OR** Describes one stage with reagents and equation mostly correct *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 mark** No response or no response worthy of credit.		• Reagents**:** HBr • Equation: $H_2C{=}CHCH_2CN + HBr \rightarrow CH_3CHBrCH_2CN$ **Intermediate 2**  ***Stage 3: Reduction of CN*** • Reagents: H_2 (with Ni) • Equation: $H_3CCHBrCH_2CN + 2H_2 \rightarrow CH_3CHBrCH_2CH_2NH_2$ ***Needs CN^- before HBr*** ***– CN^- would react with both Br atoms*** ***Needs HBr before H_2*** ***– H_2 would react with C=C*** **<u>Alternative three stage syntheses:</u>** ***Alternative using $LiAlH_4$*** ***Caution - Can be done as stage 2 or 3*** • Reagents: LiAlH4 • Equation:

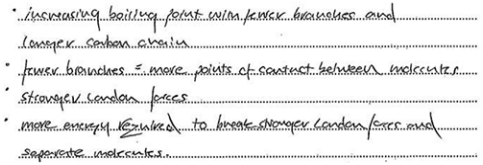
					$H_2C=CHCH_2CN + 4[H] \rightarrow H_2C=CHCH_2CH_2NH_2$ **OR** $H_3CCHBrCH_2CN + 4[H] \rightarrow CH_3CHBrCH_2CH_2NH_2$ ***Needs CN^- before HBr and $LiAlH_4$*** ***Can have HBr and $LiAlH_4$ in any order*** ***Alternative using radical substitution:*** ***Stage 1: Reaction with CN^-*** • Reagents: CN^- (in ethanol) • Equation: $H_2C=CHCH_2Br + CN^- \rightarrow H_2C=CHCH_2CN + Br–$ ***Stage 2: Reduction of CN and C=C*** • Reagents: H_2 (with Ni) • Equation: $H_2C=CHCH_2CN + 3H_2 \rightarrow CH_3CH_2CH_2CH_2NH_2$ **Stage 3: Reaction with Br_2** • Reagents: Br_2 (with UV) • Equation: $CH_3CH_2CH_2CH_2NH_2 + Br_2 \rightarrow CH_3CHBrCH_2CH_2NH_2 + HBr$ ***Needs CN^- before H_2*** ***Needs H_2 before Br_2***

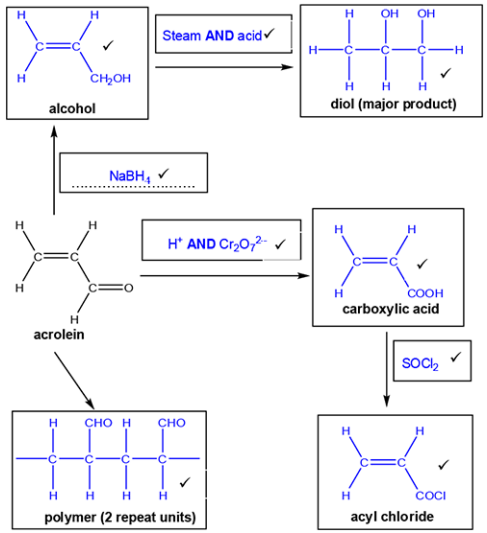
					Two stage synthesis using NH_3 and HBr forming product with no lengthening of carbon chain ***Stage 1: Reaction of NH_3*** • Reagents: NH_3 (in ethanol) • Equation: $H_2C=CHCH_2Br + NH_3 \rightarrow H_2C=CHCH_2NH_2 + HBr$ ***OR*** *$2\ NH_3 \rightarrow NH_4Br$* ***Stage 2: Addition of HBr to C=C*** • Reagents: HBr • Equation: $H_2C=CHCH_2NH_2 + HBr \rightarrow CH_3CHBrCH_2NH_2$ ***Needs NH_3 before HBr*** ***– HBr would react with C=C*** **Examiner's Comments** This challenging level of response question was generally well attempted. Many candidates recognised the reagents required in this synthesis but fewer candidates were able to deduce three correct reagents in the right order with equations to achieve Level 3. Most candidates achieved Level 2 4 marks. Many correctly identified suitable reagents but carried out the stages in the wrong order. A common error was to carry out electrophilic addition with HBr first then react with cyanide ion, not realising both Br groups would react and the reaction would not be selective. Alternatively, having introduced the nitrile group then carried out the reduction first, not realising that the C=C would also be reduced.

					The lowest scoring responses were often incomplete and despite identifying some reagents did not give equations. Candidates are encouraged to read the questions carefully so they can make sure their response covers all the detail required. Many candidates used molecular formula in their equations. It is usually preferrable in organic chemistry to give structures. Some gave surplus information such as the mechanisms and reaction conditions for each reaction. The key to answering this question well was knowing reagents for different functional group interconversions as well as planning each step to make sure of a logical synthesis. Some candidates were seemingly confused by the term 'intermediate' and gave an intermediate as in a mechanism, e.g. carbocation. **OCR support** A useful resource for teaching how to identify functional groups and practice at devising synthetic routes is the Topic exploration pack on Organic synthesis. This should be used in conjunction with the reaction pathways summaries.
			Total	**6**	
92			**Trend for all 3 hydrocarbons (1 mark):**	4 (AO1.1) (AO1.2 X3)	**ANNOTATE WITH TICKS AND CROSSES** **Comparisons** needed throughout **ORA** throughout Must have link between rank order of branching and boiling point for

			Boiling point increases with less branching **OR** less methyl/alkyl groups/side chains ✓ **Explanation with comparison (3 marks):** **Branching and surface contact** (Less branching gives) more (surface) contact / interaction (between molecules) ✓ **Surface contact and London forces** (More surface contact) gives more /stronger induced dipole(–dipole) interactions/ London forces ✓ **Energy and intermolecular forces** More energy to break induced dipole(–dipole) interactions/ London forces/intermolecular forces/intermolecular bonds (with less branching) ✓		all 3. **ALLOW** Hexane is least branched/straight chain and has highest bp **AND** 2,2-dimethylbutane is most branched and has lowest bp. **IGNORE** Chain length Surface area alone is **not** sufficient, must have idea of contact. **DO NOT ALLOW** arguments comparing different numbers of electrons (as all have the same number). **IGNORE** van der Waals'/vdW forces **OR** IDID **OR** IDD **ALLOW** 'more energy to break intermolecular forces' if intermolecular forces are not identified or incorrect. **IGNORE** harder to overcome/break intermolecular forces (no reference to energy) **IGNORE** just 'bonds' intermolecular/London forces required **<u>Examiner's Comments</u>** Most candidates attempted this question, gaining at least 1 mark, with over half scoring 3 or more marks. Responses often lacked clarity as many candidates struggled to articulate their ideas. It was common to see lengthy responses often with unnecessary repetition and sometimes even contradictions. A good strategy adopted by some was to draw skeletal formulae for the compounds next to the data provided. This enabled them to focus their response more easily on the extent of branching. Many candidates were unable to give a clear trend for the first

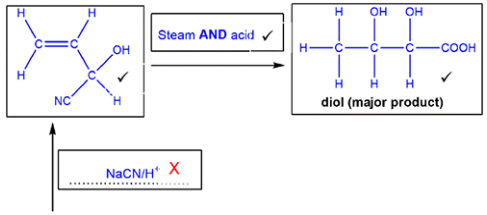
					marking point, as asked for in the question, but were able gain credit by a lengthier comparison of all three as indicated in the extra guidance. However, this mark was often lost through incomplete explanation, not referring to boiling point at all or an attempt to compare just chain length. The most common error for the second mark was omission of 'contact' or 'interaction' with reference only to surface area or 'packing' of molecules. Some lost this mark for a change in number of electrons. The third marking point was the most frequently awarded. Some candidates lost the mark for not explicitly naming the intermolecular forces as London forces/induced dipole-dipole interactions or for incorrectly using van der Waals. Some lost the mark for not explicitly indicating how increased or decreased contact would affect the strength or magnitude of London forces, e.g. 'less contact to form London forces'. The final mark was harder to obtain as it needed to be clear that **energy** was required to break **intermolecular** forces. For example, 'less energy to break bonds' or 'easier to separate the molecules' or 'more energy to boil' were not sufficient. ? **Misconception** Responses often highlighted that candidates lacked understanding about what London forces are, e.g. indicating that they form 'between atoms' or referring to induced dipole-dipole forces as something else. Intermolecular forces are difficult to fully comprehend as they can't be visualised making this a challenging topic to teach. OCR have produced a 'Bonding' teaching guide with lots of useful

					suggestions and resources. This includes a link to this Salters A Level chemistry revision activity on intermolecular bonding Exemplar 1  This exemplar shows a clear, concise response. The candidate has drawn skeletal structures next to the table. The trend is stated first followed by a detailed explanation, presented as a bullet point list, with all 4 marking points awarded.
			Total	**4**	
93				9 (AO1.2 ×4) (AO2.5 ×5)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** Correct names instead of formula for all reagents throughout e.g. For H^+ and $Cr_2O_7^{2-}$, **ALLOW** acidified dichromate For Steam and acid • For steam, **ALLOW** $H_2O(g)$ **OR** H_2O with T ≥ 100°C • For acid, **ALLOW** H^+ **OR** H_2SO_4 **OR** H_3PO_4 • Note both needed for 1 mark. **ALLOW** either way round.



Only possible alternative that can gain credit:

Reaction with $NaCN/H^+$



For $NaBH_4$

- **IGNORE** water / aqueous /acid
- **ALLOW** $LiAlH_4$

For $SOCl_2$, **ALLOW** PCl_5 **OR** $COCl_2$

- **IGNORE** H^+ OR HCl

For H^+ and $Cr_2O_7^{2-}$, **ALLOW** H_2SO_4 **AND** $K_2Cr_2O_7$ **OR** $Na_2Cr_2O_7$
ALLOW Tollens' reagent

IGNORE connectivity except
DO NOT ALLOW -COH for aldehyde

For polymer **ALLOW** alternating side chains.
IGNORE brackets and use of 'n'
'End bonds' **MUST** be shown (solid or dotted)

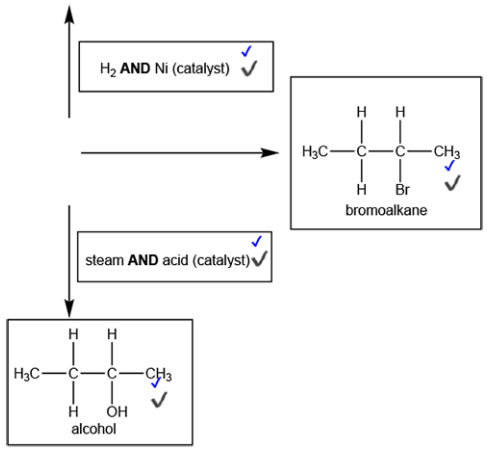
IF $NaCN/H^+$ reacted with acrolein instead of $NaBH_4$

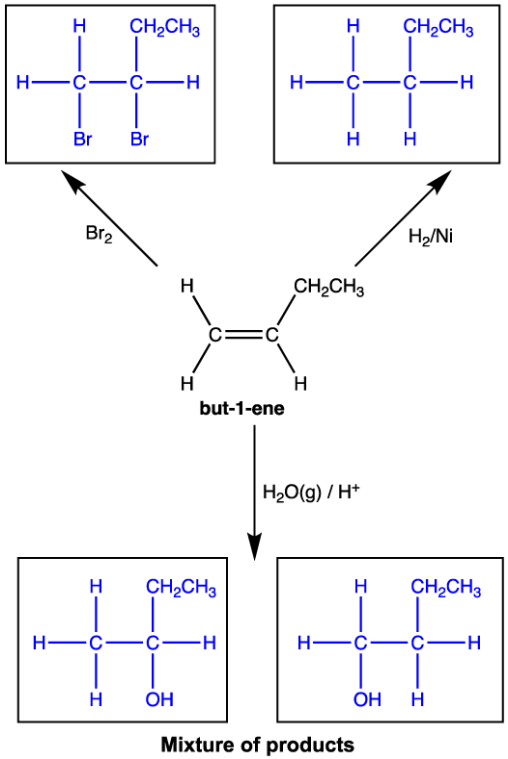
- No mark for NaCN/H+ **OR** HCN
- Unsaturated alcohol award mark for product as shown
- Final product must have CN hydrolysed as shown

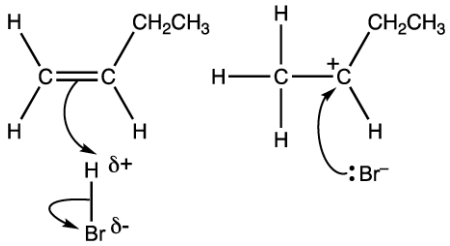
Examiner's Comments

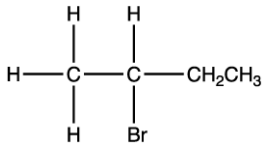
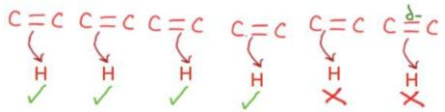
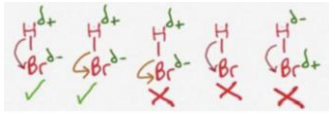
This question discriminated well. Many candidates were able to demonstrate an excellent knowledge of organic reactions and it was not uncommon to see scores of at least 7 marks. This question identified which candidates had learned their synthetic routes including necessary reagents and conditions. Marks were often lost

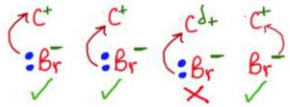
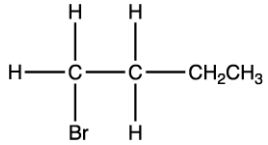
					for small details such as missing Hs (check all Cs have four bonds) or not specifying that steam is required for hydration of alkenes or missing the acid needed for oxidation. Many suggested the use of NaOH or just a mixture of acids to product the diol. The minor 1,3-diol or 1,1-diol product was often seen. The sequence leading to an acyl chloride from acrolein was usually the most well answered. However, quite a few tried to use HCl to make the acyl chloride. Many lost marks for the polymer for incorrect connectivity on the aldehyde, e.g. -COH or attempting to make a polymer via connection of the aldehyde group. **OCR support** This topic guide provides a summary of synthetic routes. Copies of the summary posters without the conditions can be found on Teach Cambridge. This should be used in conjunction with the organic synthesis topic exploration pack.
			Total	**9**	
94			**D**	1 (AO 2.7)	**Examiner's Comments** Candidates find it difficult to identify an intermediate within a synthesis and less than half selected the correct option, D.
			Total	**1**	
95				4 (AO1.2) (AO2.5)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous

				(AO1.2) (AO2.5)	**ALLOW** Pt **OR** Pd for Ni **ALLOW** $H_2O(g)$ for steam *(g)* ***OR*** *temperature >100°C required* **For acid,** **ALLOW H+/H_2SO_4/H_3PO_4** **ALLOW** small slip in acid formula e.g. phosphoric acid as H_2PO_3, etc **ALLOW** vertical bond to any part of OH, i.e. OH OH OH | | | **BUT DO NOT ALLOW** –HO **OR** OH– **Examiner's Comments** Most candidates drew correct structures for the bromoalkane and alcohol molecules, although some added Br and/or OH groups on the terminal carbon atoms. Some added two Br or OH groups. The reagents and catalysts caused the main problems, with a wide variety of incorrect responses. For the hydrogenation step, nickel was often omitted and H_2SO_4 or $K_2Cr_2O_7$ were common incorrect reagents. For the hydration step, water/H_2O was often seen as the reagent rather than steam or $H_2O(g)$. It was also common to see water stated as the reagent, without a (g)

					state symbol to infer that it is steam. Overall, this question discriminated very well with most candidates gaining at least 2 of the available 4 marks.
			Total	**4**	
96	a		 one mark for each correct structure ✓✓✓✓	4	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW** structure if H(s) are missing from ONE structural formula .....**BUT ALLOW** any further omissions as **ECF** Take care with numbers of carbons **IGNORE** connectivity, e.g. **ALLOW** OH CH2CH3 But **DO NOT ALLOW** -HO **Examiner's Comments** Most candidates scored all 4 marks here. Candidates seemed very knowledgeable about the addition reactions of alkenes. Some of the most common errors seen included: • 2,3-dibromobutane, rather than 1,2-dibromobutane • Repeating the same alcohol in bottom boxes • Missing H atoms from structures • Keeping double bonds • Missing CH_2CH_3 group (with H instead)

					• H_2 as a second product on reaction with water and some gave oxidation products rather than alcohols e.g. aldehyde, ketone, carboxylic acid here • Ni added to the organic molecule for hydrogenation Incorrect connectivity from vertical bonds to CH_2CH_3 and OH groups was not penalised in this question but would have had a significant impact on marks if it had. Some lost the mark for incorrect connectivity for OH groups when drawn horizontally i.e. OH-C. **Drawing organic structures** Ensure students get lots of practice drawing organic structures using different types of formula including displayed, structural and skeletal. It is important to check structures carefully to ensure C has 4 bonds, O 2 bonds and H only 1 bond. Under pressure it is very easy to make slips. For exams, remind candidates not to draw in pencil then rub out - the structure beneath often shows up when the paper is scanned. If corrections are needed, cross out the incorrect structure and redraw clearly.
	b	i	 **1st curly arrow (from ANY alkene)**	4	**Throughout**, **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **For curly arrows,** **ALLOW straight or snake-like arrows and small gaps (see examples)** **DO NOT ALLOW** half headed or double headed arrows but allow **ECF** if seen more than once

			Curly arrow from double bond to H of H–Br ✓ **DO NOT ALLOW** partial charge on C=C **2nd curly arrow** Correct dipole on H–Br **AND** curly arrow for breaking of H–Br bond ✓ **3rd curly arrow** Correct carbocation with + charge on C **AND** curly arrow from Br^- to C+ of carbocation ✓ **DO NOT ALLOW** δ+ on C of carbocation **Correct product** (***independent mark***) ✓ 		**1st curly arrow** must • go to a H atom of H-Br • **AND** • start from, **OR** be traced back to **any point across width** of C=C  **2nd curly arrow** must • start from, **OR** be traced back to, **any part of** $^{\delta+}H–Br^{\delta-}$ bond • **AND** go to $Br^{\delta-}$  **ALLOW ECF** for 2nd and 3rd curly arrow marking points if used Br_2 instead of HBr

					3rd curly arrow must • go to the C^+ of carbocation **AND** • start from, **OR** be traced back to **any point across width** of lone pair on $:Br^-$ • **OR** start from - charge on Br^- ion  *(Lone pair **NOT** needed if curly arrow shown from - charge on Br^-)* **IGNORE** connectivity of alkyl groups in carbocation and product **IF** drawn both intermediates and products with no labelling **ALLOW** 3rd curly arrow mark **BUT NOT** product mark, unless clearly labelled as'2-bromobutane' or 'major' product **ALLOW ECF** for product from incorrect carbocation. e.g. 1-bromobutane: 

					Examiner's Comments Approximately half of candidates scored all 4 marks. Very few scored no marks as they were able to give the correct structure of the named product (2-bromobutane). The most common reasons for losing marks included: • Adding dipoles to C=C • Missing dipoles on H-Br or reversed dipole on H-Br (i.e. δ+ Br) • Missing charge on bromide ion or adding δ- • Arrows the wrong way round or not coming from a bond or lone pair (or negative charge for bromide ion) Some attempted a radical mechanism. **OCR Support** For ideas on teaching this topic please look at our Topic Exploration Pack: Electrophilic Addition and Markownikoff's rule: https:/teachcambridge.org/item/b4220e86-bc04-492c-b354-8103687ce594
		ii	(major product forms from) most/more stable intermediate/carbocation ✓ major product forms from a) secondary carbocation **OR** carbocation bonded to more C	2	**ALLOW** carbonium ion for carbocation **IGNORE** descriptions of the major/minor product in terms of Markownikoff's rule e.g. H atom joins to C with most H

			atoms / more alkyl groups **OR** carbocation bonded to fewer H atoms ✓		**IGNORE** references to stability of the product **ALLOW ORA** **Examiner's Comments** Over half of candidates didn't gain any credit for their response here. Answers often focused on Markownikoff's rule, i.e. adding H to C with most H atoms already attached, or described the stability of the product. Students need more support in understanding that the more stable carbocation will be formed in preference and result in forming more product. Many referred to the 'secondary haloalkane' being more stable, rather than the 'secondary carbocation'. Some stated that 2-bromobutane is a 'secondary carbocation', showing some misunderstanding about the terminology used here. **OCR Support** We have a useful PowerPoint Presentation for teaching about Markownikoff's rule and carbocation stability: https:/ocr.org.uk/Images/250388-markownikoff-s-rule-presentation.ppt
			Total	**10**	
97			**Level 3 (5-6 marks)** A comprehensive description including most of the evidence to justify the correct structure of **X**. *There is a well-developed line of reasoning which*	6	**LOOK ON THE SPECTRA** for labelled peaks. **Indicative scientific points may include:** **1. Empirical formula**

			is clear and logically structured. The information presented is relevant and substantiated **Level 2 (3-4 marks)** Explains **two** scientific points with few omissions **OR** some aspects from all **three** **AND** an attempt at a feasible structure with either a C=O **OR** COOH *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1-2 marks)** Determines the correct empirical/molecular formula **OR** Some aspects from two scientific points are given *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant* **0 marks** - No response worthy of credit.		

Element	%mass	Ar	moles	ratio
C	40.91	12	3.41	3
H	4.54	1	4.54	4
O	54.55	16	3.41	3

Empirical formula = $C_3H_4O_3$
ALLOW Alternative method using M_r of 88 i.e.
C = 88 x (40.91/100) x 12 = 3 etc.

2. Spectra and Molecular formula

Mass spectrum

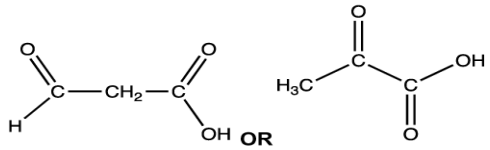
- molecular ion peak *m/z* or M_r = 88
- molecular formula = $C_3H_4O_3$

IR

- peak at 2500 to 3500 cm^{-1} is O-H
- peak at 1630 to1820 cm^{-1} is C=O

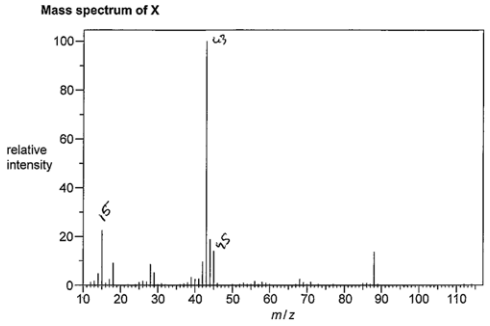
3. Functional groups and structure of X

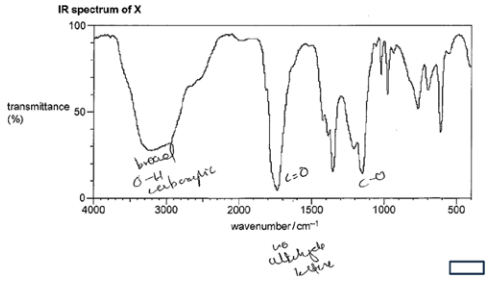
- **X** contains a carboxylic acid
- **X** doesn't decolourise Br_2 so no C=C bond
- Mass spectrum fragment peak(s) identified e.g.
  - *m/z* = 43 for CH_3CO^+

					- *m/z* = 29 C*H*O$^+$ - *m/z* =15 due to CH_3^+ • ***Structure of X***  Aspects of the communication statement might typically have been met when evidence is presented in a logical and clear order making good use of all the evidence given. Some points which may be seen where communication is good include: • Easy to follow layout on empirical formula calculation • Empirical formula is same as molecular formula i.e. not given as $CH_{1.33}O$ • IR peaks linked clearly to bond it refers to not just functional groups • Positive charge given on MS fragments • MS fragments plausible for the molecular formula determined. • No additional irrelevant/incorrect information given **Examiner's Comments** Over a third of candidates achieved Level 3, gaining 5 or 6 marks. A correct structure (either aldehyde or ketone) alone was not enough to award Level 3 and candidates were expected to give a

					comprehensive description of how the evidence helped them determine the structure. The biggest challenge for many candidates was finding the correct empirical formula. The ratio worked out to 1:1.33:1 so many incorrectly rounded this to either 1:1:1 or 1:2:1, which meant they struggled to find a molecular formula that worked and added up to 88. Incorrect molecular formulas seen included $C_3H_3O_3$, which adds to 87 (often the extra H was just added to make it fit), or $C_4H_8O_2$, which does add to 88. Most candidates could analyse the IR spectrum, identifying peaks corresponding to C=O or O-H. Candidates should identify bonds present before making conclusions about the functional groups. Many were able to use mass spectra to determine the M_r value from the M+ peak. Some did go on to make use of other peaks, identifying fragments and confirming whether the structure was an aldehyde or ketone depending on analysis. For example, CHO^+ at m/z = 29 suggests an aldehyde, or conversely CH_3^+ at m/z = 15 suggests a ketone. Candidates should always be encouraged to comment on all the data provided. This can be through good annotation of the spectra and notes added to the first page of the question. Many candidates didn't mention the evidence from the bromine test. If candidates pieced together information to give a structure that is chemically feasible containing either a C=O or COOH group then they could achieve Level 2. Without a structure they were limited to Level 1. The most common incorrect structures seen included butanoic acid,

					2-hydroxypropenoic acid or structures with 2 × C=O and an alcohol OH.





Empirical formulae:

	C	H	O
mass	40.91	4.54	54.55
Mr	12	1	16
moles	3.41	4.54	3.41
ratio	1	1.3	1

CHO = 29 = 44 = C_2H_4O

Molecular formulae

m/z = 88 (molecular mass) = 88

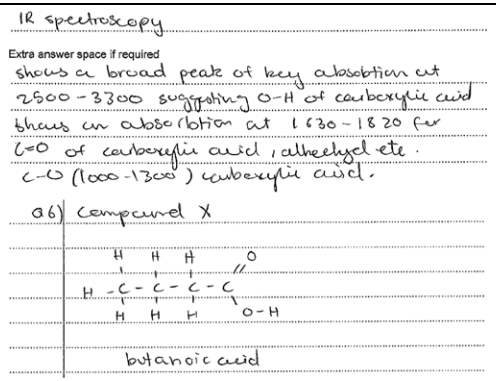
$C_4H_8O_2$

mass spectroscopy = (fragment ions)

m/z 15 = CH_3^+

m/z 43 = $C_3H_7^+$

m/z 45 = $CH_3CH_2O^+$

					 This response achieved Level 2 - 4 marks. Despite a correct calculation for empirical formula, they rounded incorrectly to CHO. They then state that molecular formula is C4H8O2 which matches the M_r value determined from the mass spectrum but not their empirical formula. They demonstrated good analysis of the IR spectrum and have even looked at potential fragments from the mass spectrum. The response meets the Level 2 descriptor as they have a feasible structure with a COOH group and have some analysis of all three scientific points. The communication is good with a clearly laid out calculation and bonds identified from IR and MS fragments have a positive charge.
			Total	**6**	
98			**C**	1	**Examiner's Comments** Some candidates chose B as the correct option. The other options were chosen randomly, suggesting that many had not learnt this specification content and had guessed.
			Total	**1**	

<table>
<tr><td>99</td><td></td><td></td><td>C</td><td>1</td><td><u>Examiner's Comments</u>

This question proved to be an excellent discriminator with most above average candidates choosing monomer (option C).</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>1</td><td></td></tr>
<tr><td>100</td><td></td><td></td><td>
<table>
<tr><th>Carbon atom</th><th>Bond angle</th><th>Name of shape</th></tr>
<tr><td>1</td><td>109.5</td><td>tetrahedral</td></tr>
<tr><td>2</td><td>120</td><td>trigonal planar</td></tr>
</table>

2 OR 3 correct ✓

4 correct ✓

Number of electron pairs

In C1/109.5°, 4 bonded pairs/bonding regions/bonds ✓

In C2/120°, 3 bonded regions/bonds ✓</td><td>5</td><td>ALLOW 109−110 for C1

ALLOW 118−122 for C2
ALLOW planar triangle

ALLOW table responses if in wrong columns

IGNORE areas of electron density

For bonded pairs

ALLOW bp, bonded groups, bonded atoms

Bonded/bonding essential

For C2, ALLOW

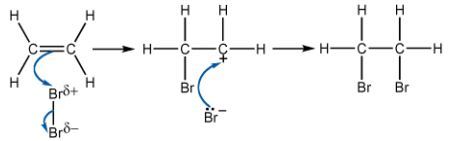
• 3 bonded areas/environments
• 3 bonded pairs/groups/atoms
• 2 bonded pairs and 1 double bond
• 2 bonded pairs and 1 bonded region</td></tr>
</table>

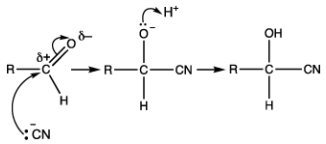
			Electron pair repulsion Electron pairs/bonded pairs repel (as far apart as possible) ✓ ***Electron pairs/bonded pairs essential*** ***DO NOT ALLOW 'bonded atoms' for this mark***		**DO NOT ALLOW** 'atoms repel' **IGNORE** • electrons repel • bonds repel • electron region **OR** electron density • lone pairs repel more *irrelevant here* • shapes, even if wrong **Examiner's Comments** The bond angles and shapes rewarded the well-prepared candidates, with many being given both available marks for this part of the question. This part discriminated very well. For the explanation, most candidates identified 4 and 3 for C1 and C2, but candidates often linked 4 and 3 to atoms, rather than to electron pairs or bonded pairs for C1 and to bonding regions for C2. A mark was available for stating that 'electron pairs repel', but this important fact was often omitted despite being the main principle that determines molecular shapes. The question discriminated well, giving a good spread of marks across the five available. **Misconception**

					Many students think that molecular shapes are determined solely by lone pairs or by repulsion between bonded atoms. The principle behind molecular shapes is called electron pair repulsion theory because it is based on repulsion between electron pairs, which may be bonded pairs or lone pairs, but **not** atoms.
			Total	**5**	
101			**C**	1	**Examiner's Comments** Approximately two thirds of candidates gave the correct answer C. The most common incorrect response seen was D, confusing the strength of the σ and π bonds, possibly as a C=C bond is stronger than C-C. Some gave D assuming alkenes are polar due to their reactivity and showing a misunderstanding of the term 'polar'.
			Total	**1**	
102			**B**	1	**Examiner's Comments** A large majority of candidates were able to correctly identify shape at x as being trigonal planar and y as being tetrahedral. The most common incorrect responses seen were for getting one of these incorrect i.e. D incorrect for x or C incorrect for y.
			Total	**1**	
103			**C**	1	**Examiner's Comments**

					The majority of candidates were able to correctly identify the two functional groups and the correct corresponding test i.e. alkene using bromine water and primary alcohol using 2,4-dinitrophenylhydrazine. The most common incorrect response was B.
			Total	**1**	
104			Priority groups are on the same side (Highest) priority groups are CH_3 **AND** C_2H_5 **OR** Low(est) priority groups CH_3 **AND** H	2	**ALLOW** suitable alternatives to 'priority' e.g. Groups with highest atomic **number** or more important groups or major groups etc. **IGNORE** references to (relative) mass of groups including Ar or Mr **ALLOW** suitable alternatives to 'same side' e.g. priority groups are both on the top **OR** above the C=C **IGNORE** priority groups in same plane **OR** adjacent **IGNORE** Use of 'molecules' instead of groups **ALLOW** identification by name e.g. ethyl and methyl **IF** 'priority' is not mentioned **ALLOW** one mark for 'CH_3CH_2 and CH_3 are on same side' **OR** 'H and CH_3 are on same side' **<u>Examiner's Comments</u>** Many candidates misunderstood the question instead explaining how a molecule shows stereoisomerism i.e. same structural arrangement but a different arrangement of atoms in space. Some gave details specific to alkenes i.e. restricted rotation around C=C and each carbon of C=C has 2 different groups attached. Just over a quarter of candidates did not score any marks here. Many that did recognise that the 'priority groups' are on the same

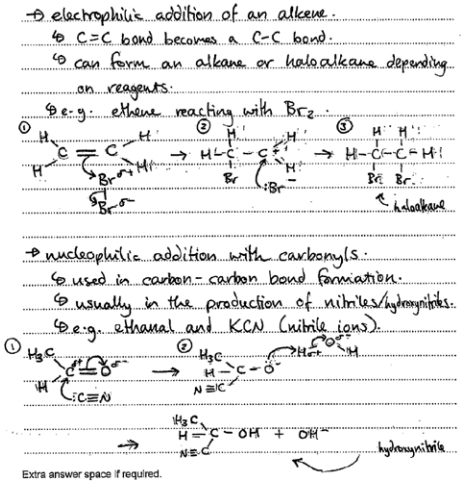
					side' but did not then go on to score the second mark by identifying which groups they were referring. A significant number of candidates (including those gaining marks) described priority in terms of highest M_r or mass, suggesting that the Cahn-Ingold-Prelog priority rules of using atomic number are not well understood. Many framed their answer in terms of the methyl groups, possibly showing confusion with cis-trans isomerism. Note that same 'plane' was not accepted as all the molecule is planar, so all groups are in the same plane. Teachers are recommended to encourage students to stick with conventional terminology i.e. Z: same side E: opposite sides. **OCR support** A useful PowerPoint presentation has been produced by OCR to help with teaching about CIP rules.
			Total	**2**	
105			*Refer to marking instructions on page 5 of mark scheme for guidance on marking this question.* **Level 3 (5-6 marks)** Describes addition reactions including the mechanisms of **one** alkene **AND one** carbonyl compound **AND** some additional details *There is a well-developed line of reasoning which is clear and logically structured. The information*	6	**Indicative scientific points may include:** **Reaction of alkene and mechanism** • Suitable reaction, e.g. alkene and Br_2 **OR** X_2 **OR** HX **OR** H_2O **OR** H_2 **OR** polymerisation *May be shown within mechanism* • Mechanism, e.g.

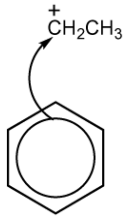
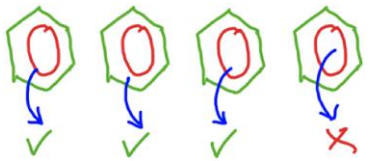
			presented is relevant and substantiated. **Level 2 (3-4 marks)** Describes an addition reaction including the mechanism of **one** alkene **OR one** carbonyl compound **AND** some additional details **OR** Describes addition reactions including an attempt to give the mechanism of **one** alkene **AND one** carbonyl compound *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1-2 marks)** Selects suitable reagents for addition reactions of **one** alkene **AND one** carbonyl compound. **OR** Attempts to describe an addition reaction including an attempt to give the mechanism of **one** alkene **OR one** carbonyl compound. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*		 **ALLOW** mechanism for H_2 **AND** H_2O to be shown as electrophilic addition even though incorrect - consider impact on communication statement. **ALLOW** suitable non-specification alternative e.g. HCN **Additional details (NOT INCLUSIVE)** • Electrophilic addition • Systematic names of reactants and/or products • Details of functional group interconversion e.g. alkene to dibromo • Details on reagents required e.g. - H_2 with Ni Catalyst - $H_2O(g)$ with H_3PO_4 catalyst • Explanation of major and minor product from electrophilic addition of HX with unsymmetrical alkene • Explanation of carbocation intermediate stability • Heterolytic fission

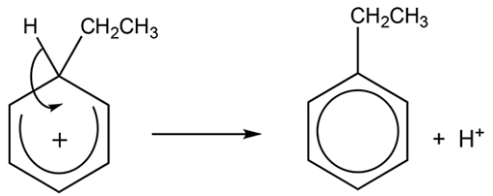
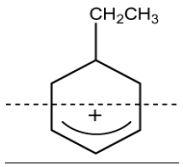
					Reaction of carbonyl compound and mechanism Suitable reactions, e.g. • Aldehyde or ketone and HCN **OR** H^- e.g. RCHO + HCN → RCH(OH)CN *May be shown within mechanism* • Mechanisms, e.g.  **OR** H_2O instead of H^+ for 2nd stage **ALLOW** suitable non-specification alternative e.g. H_2O, NH_3, 1° amine **IGNORE** reactions with carboxylic acids (or derivatives) i.e. addition-elimination mechanism (condensation reaction) **Additional details (NOT INCLUSIVE)** • Nucleophilic addition • Systematic names of reactants and/or products • Details of functional group interconversion e.g. aldehyde to hydroxynitrile • In reduction, aldehydes form 1° alcohols and ketones form 2° alcohols

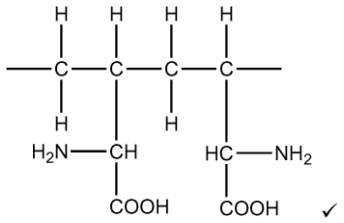
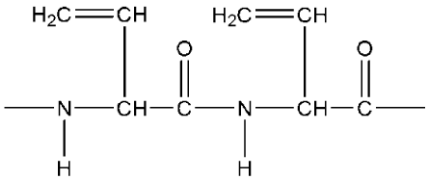
					• Details on reagents required e.g. - formation of hydroxynitriles with $NaCN/H^+(aq)$ - formation of alcohols with $NaBH_4$ • Heterolytic fission Aspects of the **communication statement** being met might typically include: • Curly arrows starting from lone pairs / negative charges / bonds. • All reactants and intermediates have relevant charges and dipoles. • Mechanisms given are chemically feasible for the reactions. • No additional incorrect reactants have been included. **<u>Examiner's Comments</u>** A very good proportion of candidates scored all 6 marks, giving well-drawn mechanisms with some additional details such as mechanism names, functional group interconversions or other additional reaction information. Some attempted to 'describe' the mechanism using only words rather than drawing it out with a conventional curly arrow mechanism. Candidates may need more clarity on what 'describe' means in an organic chemistry context. Equally, a few gave just the mechanisms with no additional details, limiting themselves to Level

					2. Candidates were usually more confident with the addition to alkenes using an electrophilic addition mechanism. Some gave additional details about major and minor products, although not always relevant as for a symmetrical alkene. Some represented the addition of hydrogen or water to alkenes via an electrophilic addition mechanism. While not correct it showed an understanding of mechanisms and a correct addition reaction for alkenes, so credit was given. Some candidates included incorrect reagents for reactions, such as acid catalysts with addition of a hydrogen halide, or incorrect conditions, such as the requirement for ultraviolet light on addition of a halogen. The addition to carbonyl compounds was not always as well-described. Some candidates struggled to identify carbonyl compounds, selecting carboxylic acids or their derivatives, with attempts at addition-elimination mechanism i.e. condensation reactions. Some gave incorrect reagents for carbonyls, including H_2O and HBr. However, some used off-specification reactions such as the addition of H_2O to form a geminal diol which was given but as the mechanism differs from the nucleophilic addition mechanism taught in this specification, full credit was rarely achieved. Some also considered oxidation of aldehyde or ketone to be an addition reaction. Most who presented a correct mechanism for addition to a carbonyl used the reaction with cyanide rather than reduction with $NaBH_4$. Common errors included arrows coming from the N of CN^-, a lack of putting dipoles on carbonyl bonds, missing charges on O in intermediates or showing the wrong direction of arrows.

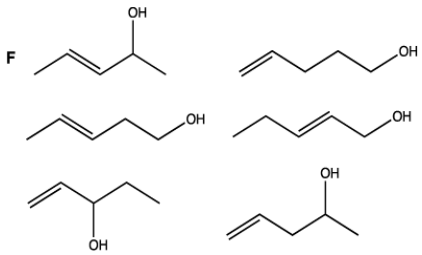
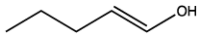
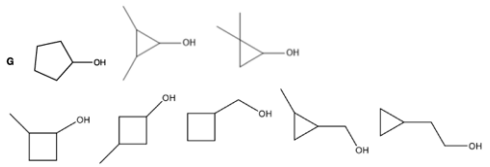
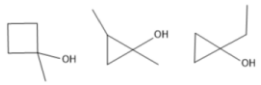
					OCR support The OCR Guide to Level of Response questions can be found on Teach Cambridge and can be used to help your students better understand this type of question. Exemplar 1  Level 3 – 6 marks Two correct addition mechanisms have been shown, one for an alkene and one for a carbonyl compound. Additional details include the names of the mechanisms, names of the functional groups in the products, and the fact that a C-C bond is formed in the second mechanism. All curly arrows, charges and dipoles are correctly positioned so this response was also given the communication mark.

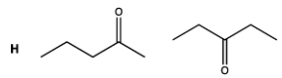
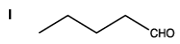
			Total	**6**	
106		i	**ALLOW correct Kekulé representation of benzene throughout question 21** An electron pair acceptor ✓	1	**ALLOW** gains an electron pair / lone pair **Examiner's Comments** Most candidates were able to give the correct definition here. A common error was omission of 'pair' of electrons. Manyalso described that electrophiles are 'species attracted to areas of high electron density'or words to that effect, either alongside the accepted definition gaining credit or as the sole definition not gaining a mark.
		ii	**Generation of electrophile** $AlCl_3 + CH_3CH_2Cl \rightarrow CH_3CH_2^+ + AlCl_4^-$ ✓ **Electrophilic substitution**  Curly arrow from π-bond to $^+CH_2CH^3$ ✓ ----------	5	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** C_2H_5Cl **AND** $C_2H_5^+$ **ALLOW** positive charge anywhere on CH_2CH_3 e.g. $CH_2CH_3^+$ **NOTE**: curly arrows can be straight, snake-like, etc. but **NOT** double headed or half headed arrows **1st curly arrow** must • start from, **OR** close to **circle of benzene ring AND** • go to anywhere on $^+CH_2CH^3$ 

			 Correct intermediate ✓ Curly arrow from C–H bond to reform π-ring **AND** H^+ as product ✓ **Regeneration of catalyst** $H^+ + AlCl_4^- \rightarrow AlCl_3 + HCl$ ✓		**DO NOT ALLOW** the following intermediate:  π-ring should cover approximately 4 of the 6 sides of the benzene ring structure **AND** 'horseshoe' the right way, *i.e.* gap towards C with CH_2CH_3 **ALLOW** + sign anywhere inside the 'hexagon' of intermediate **Examiner's Comments** Most candidates were well prepared for this question, with over half of candidates gaining all 5 marks. A significant number of candidates showed halogenation, generating Cl^+ as an electrophile, instead ofalkylation. Others attempted to substitute the ethylbenzene ring rather than benzene. Further commonerrors included incorrect connectivity in the ethyl group on the intermediate, curly arrows coming fromhydrogen atoms rather than C-H bond to reform the π-ring and omission of an H^+ ion at the end ofmechanism.
			Total	**6**	
107			**Addition polymer**	3	For **BOTH** structures, **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous 'End bonds' **MUST** be shown (with either a solid or dashed line) **BUT ALLOW ECF IF** end bonds omitted in both structures

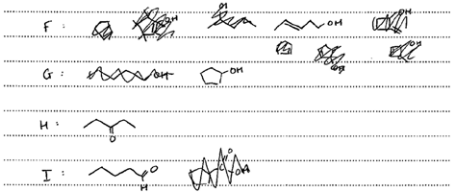
			 ✓ **Condensation polymer**  Amide link ✓ 2 repeat units of correct polymer ✓		**DO NOT ALLOW** more than 2 repeat units **BUT ALLOW ECF** in subsequent structure **IGNORE** connectivity of side groups in both diagrams --- **CARE: ALLOW** any consistent repeat unit: side groups can alternate or be on opposite sides of chain **ALLOW** NH in amide link i.e. without bond shown **ALLOW** −NH− at either end **IGNORE** brackets **IGNORE** *n* or subscript numbers **ALLOW** C_2H_3 as side chain for condensation polymer **ALLOW** 1 mark if correct structures given by wrong way round **Examiner's Comments** In general, candidates found it easier to give the correct addition polymer rather than the condensation polymer. Some lost the mark for using molecular formula on side chains rather than displaying thesection correctly. The condensation polymer was generally less well answered, with candidates oftenstruggling to give a correct amide bond – many had an oxygen atom retained between the carbonylcarbon and the amine group's nitrogen atom, giving C–O–N. Another common error was the omission ofhydrogen atoms from nitrogen or from the carbon attached to C_2H_3. Just over a quarter of candidates didnot score any marks. Some candidates drew ester linkages instead of amide linkages and struggled toinclude the side chains i.e. trying to incorporate the alkene into the main polymer chain.
			Total	**3**	

108		i	Green solution Cr^{3+} **OR** $[Cr(H_2O)_6]^{3+}$ ✓ Orange solution $Cr_2O_7^{2-}$ ✓ Formulae **AND** charges must be correct	2	**Green solution** **IGNORE** H^+ **ALLOW** $Cr_2(SO_4)_3$ **OR** $CrCl_3$ **OR** Cr^{+3} Orange solution **IGNORE** H^+ **ALLOW** $K_2Cr_2O_7$ **OR** $Na_2Cr_2O_7$ **DO NOT ALLOW** Cr^{6+} **ALLOW** 1 mark for correct formulae but wrong way round **<u>Examiner's Comments</u>** Although high attaining candidates responded with the formulae of chromium-containing species, it was common to see organic compounds being suggested. Consequently, a large proportion of candidates did not score either of the 2 marks. Many candidates seem to expect to only give organic species in their responses on this paper and would benefit from understanding that inorganic species may also need to be provided.
		ii	**Level 3 (5-6 marks)** Reaches a comprehensive conclusion to determine possible correct structures for **ALL** of **F**, **G**, **H** and **I** **AND ALL** functional groups of **F**, **G**, **H** and **I**	6	Indicative scientific points may include: **<u>Identity of F, G, H and I showing CORRECT structures</u>**

			There is a well-developed line of reasoning which is clear and logically structured. *The information presented is relevant and substantiated.* **Level 2 (3-4 marks)** Reaches a conclusion to determine possible **correct** structures for two of **F**, **G**, **H** and **I** **AND most** functional groups of **F**, **G**, **H** and **I** *There is a line of reasoning presented with some structure.* *The information presented is relevant and supported by some evidence.* **Level 1 (1-2 marks)** Reaches a simple conclusion to determine a possible correct structure for one of **F**, **G**, **H** and **I** **OR** some functional groups of **F**, **G**, **H** and **I** *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*		 **ALLOW** enols for F, e.g.  For **G**, **DO NOT ALLOW** tertiary -OH. e.g.  For **G, DO NOT ALLOW** tertiary -OH. e.g. 

					  **IGNORE** names, even if incorrect For communication, a typical 'logical structure' would link functional groups to **SOME** of the test results, e.g. **2,4-DNP** **H** and **I** have carbonyl group/aldehyde or ketone **$H^+/Cr_2O_7^{2-}$** **F**, **G** and **I** are primary or secondary alcohols or aldehydes **Bromine** **F** is unsaturated/has C=C **Tollens** **I** is aldehyde ***Correct functional groups may be shown in correct structures*** **Examiner's Comments** This Level of Response question was answered well with many candidates identifying compounds **F-I** correctly to reach Level 3. Structures were usually shown skeletally and this practice is to be recommended. Not only is it far quicker and clearer, it eliminates writing every atom in a displayed or structural formula. Some candidates were not given marks for missing hydrogen atoms or for

					‘sticks’ being shown. In these structures, the chemical meaning of a stick is a terminal CH_3 group. Candidates were also asked to show how the results of the chemical tests helped the identification of the unknown compounds and this formed the basis of the communication strand of the LOR mark. Candidates answered this part of the analysis extremely well and most were given marks for their good communication skills. This question differentiated very well between well-prepared and less confident candidates. The latter often did not know how the results of these organic tests can be used to identify the functional groups present. It was common for such candidates to identify only one of the four compounds, scoring within Level 1 only. **OCR Support** To better prepare candidates, we recommend using either the digital multiple choice quizzes on Teach Cambridge or creating targeted practise materials using ExamBuilder. If you are unsure of how to access these or ways to make the most of them, get in touch via science@ocr.org.uk. Exemplar 3

					Show your reasoning. with 2,4-DNP [6] F and G form orange solutions so are not ketones / aldehydes H and I are ketones / aldehydes because they form an orange precipitate F, G and I are all primary or secondary alcohols because they turn green with $K_2Cr_2O_7 / H_2SO_4$. F is an alkene because it forms a colourless solution with bromine water I is an aldehyde because it forms a silver mirror with Tollen's reagent.  This exemplar is concise and very clear. The candidate has clearly linked the result of each test to the functional groups that must be present. The candidate has drawn skeletal formulae and clearly has experimented with many possible structures before deciding on which must be correct. Notice that the candidate has crossed out the structures that they have rejected. This is an important exam technique - if two structures are drawn, with one correct and the other incorrect, the correct structure cannot be given marks. The response is clearly at Level 3 for the four correct structures and the good communication ensures that the communication strand can be given. This response received all 6 marks.
			Total	**8**	