

OCR A-LEVEL CHEMISTRY A • H432

CHEMISTRY



EXAM QUESTION PACK

4.1.2-4.1.3 ALKANES AND ALKENES

SCORE

/256

PERCENTAGE

%

STEMUP

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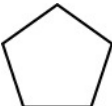
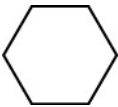
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1(a) This question is about cyclic organic compounds.

The table shows some information about cycloalkanes.

Cycloalkane	Skeletal formula	Boiling point / °C
Cyclopropane		-33
Cyclopentane		49
Cyclohexane		81

These cycloalkanes are members of the same homologous series and have the same general formula.

(i) What is meant by the term *homologous series*?

[2]

(ii) State the general formula for these cycloalkanes.

[1]

(iii) Explain the increase in boiling points of the cycloalkanes shown in the table.

[2]

(b) The C–C–C bond angles in **cyclohexane** are 109.5° .

State and explain the shape around each carbon atom in cyclohexane.

shape _____

explanation _____

[2]

(c) In the presence of ultraviolet radiation, **cyclohexane** reacts with bromine.

A mixture of cyclic organic compounds is formed, including $C_6H_{11}Br$.

(i) Complete the table below to show the mechanism of the reaction between bromine and cyclohexane to form $C_6H_{11}Br$.

Include all possible termination steps in your answer.

Step	Equation
Initiation	-----
Propagation	----- -----
Termination	----- ----- -----

[5]

(ii) The initiation step involves homolytic fission.

Explain why the initiation step is an example of *homolytic fission*.

[1]

(d) The reaction between cyclohexane and bromine in (f) also forms $C_6H_{10}Br_2$.

- (i) Write an equation, using molecular formulae, for the reaction of cyclohexane and bromine in the presence of ultraviolet radiation to form $C_6H_{10}Br_2$.

-----[1]

- (ii) Name **one** of the structural isomers of $C_6H_{10}Br_2$ formed in the reaction between cyclohexane and bromine.

-----[1]

2 Alkanes are used as fuels.

- (i) Construct an equation for the complete combustion of octane C_8H_{18} .

-----[1]

- (ii) Combustion of 36.48 g of octane produced 2.50 mol of carbon dioxide.

Show that this combustion was incomplete.

[2]

- 3 A student carries out the following experiment to investigate the reaction between hexane and chlorine. The chlorine is made by reaction of aqueous sodium chlorate(I) with dilute hydrochloric acid.

Procedure	Observations
1 cm ³ of hexane is mixed with 1 cm ³ dilute aqueous sodium chlorate(I) in a test-tube.	The mixture forms two colourless layers.
1 cm ³ dilute hydrochloric acid is slowly added to the mixture.	The acid mixes with the lower layer, which turns a pale green colour.
The tube is then stoppered and shaken.	The pale green colour moves to the upper layer, leaving the lower layer colourless.
The tube is placed under a bright light and shaken at regular intervals for about 10 minutes. The stopper is loosened regularly to release any pressure.	The pale green colour slowly disappears leaving two colourless layers after about 10 minutes.

The reaction of hexane with chlorine took place when the bright light was switched on.

- (i) Give the skeletal formula of **one** possible organic product of this reaction.

[1]

- (ii) Explain why this type of mechanism is likely to produce a mixture of organic products.

[1]

- 4 Which molecule has the highest boiling point?

- A 2,3-dimethylbutane
- B 2-methylheptane
- C 2,3,4-trimethylpentane
- D 3-ethylpentane

Your answer

[1]

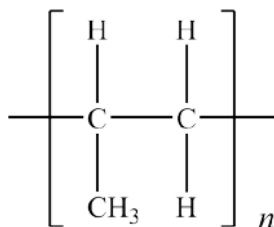
Describe fully, with equations, the mechanism for this reaction.

[5]

- 6 A large proportion of the world's output of organic chemicals is used to make addition polymers. These polymers have a variety of uses.

Poly(propene) is used to make packaging, textiles and rope.

A repeat unit for poly(propene) is shown below.



- (i) Explain why poly(propene) is a *saturated* hydrocarbon.

----- [1]

- (ii) State the bond angle around each carbon atom in poly(propene).

----- [1]

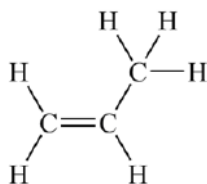
- (iii) After polymers have been used for packaging, the waste polymers need to be processed to save resources, for example, by recycling.

Describe **two** other ways in which waste poly(propene) can be processed in a sustainable way.

----- [2]

7 This question is about alkenes.

Propene, drawn below, contains both σ - and π -bonds. The C–H and C–C single bonds are σ -bonds. The C=C double bond is made up of a σ -bond and a π -bond.



(i) Describe how a σ -bond forms.

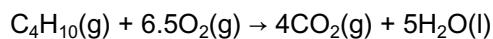
----- [1]

(ii) State the bond angle and shape around each carbon atom of the C=C double bond in propene.

bond angle: -----

shape: ----- [1]

- 8 Butane, C₄H₁₀, is a highly flammable gas, used as a fuel for camping stoves. Butane reacts with oxygen as in the equation below:



- (i) The use of portable heaters in enclosed spaces can result in potential dangers if incomplete combustion takes place.

Explain the potential danger of incomplete combustion.

-----[1]

- (ii) A portable heater is lit to heat a room.

The heater burns 600 g of butane and consumes 1.50 m³ of O₂, measured at room temperature and pressure.

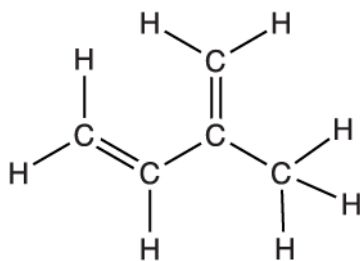
Determine whether this portable heater is safe to use.

Show **all** your working.

conclusion, with reason: -----

-----[3]

9 The displayed formula for a hydrocarbon is shown below.



How many σ and π bonds are present in a molecule of this hydrocarbon?

	σ bonds	π bonds
A	2	4
B	10	2
C	10	4
D	12	2

Your answer

[1]

10 Chlorine reacts with 1-chloropropane in the presence of ultraviolet radiation via a radical substitution mechanism.

Which equation shows a propagation step in the mechanism for this reaction?

- | | | | |
|---|---|---------------|---|
| A | Cl_2 | $\rightarrow$ | $\cdot\text{Cl}/ + \cdot\text{Cl}/$ |
| B | $\cdot\text{Cl}/ + \cdot\text{C}_3\text{H}_7\text{Cl}/$ | $\rightarrow$ | $\text{C}_3\text{H}_7\text{Cl}_2$ |
| C | $\text{C}_3\text{H}_7\text{Cl}/ + \cdot\text{Cl}/$ | $\rightarrow$ | $\text{C}_3\text{H}_7\text{Cl}_2 + \cdot\text{H}$ |
| D | $\cdot\text{Cl}/ + \text{C}_3\text{H}_7\text{Cl}/$ | $\rightarrow$ | $\cdot\text{C}_3\text{H}_7\text{Cl}/ + \text{HCl}/$ |

Your answer

[1]

- 11 At room temperature and pressure, the first four members of the alkanes are all gases but the first four alcohols are all liquids.

Explain this difference in terms of intermolecular forces.

[2]

- 12 Samples of four hydrocarbons are completely burnt under the same conditions of temperature and pressure.

Which sample produces the greatest volume of CO_2 ?

- A 0.4 mol C_2H_6
B 0.3 mol C_3H_8
C 0.2 mol C_4H_{10}
D 0.1 mol C_5H_{12}

Your answer

[1]

- 13 Which organic compound has the lowest boiling point?

- A 2,3,4-trimethylpentane
B 2,3-dimethylhexane
C 2-methylheptane
D octane

Your answer

[1]

14 Alkanes are saturated hydrocarbons with the general formula C_nH_{2n+2} .

A student carries out an experiment to measure the enthalpy change of combustion, $\Delta_c H$, of hexane.

The student finds that combustion of 1.29 g of hexane changes the temperature of 200 g of water from 20.5 °C to 65.5 °C.

(i) Calculate the enthalpy change of combustion, $\Delta_c H$, of hexane, in kJ mol^{-1} .

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

$\Delta_c H$ _____ kJ mol^{-1} [4]

(ii) The calculated value of $\Delta_c H$ for hexane from this experiment is different from the data book value.

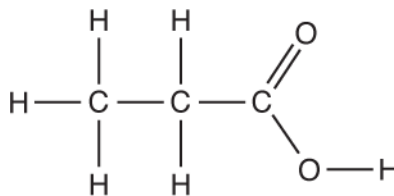
Suggest **two** reasons for this difference.

1 _____

2 _____

[2]

15(a) The displayed formula for propanoic acid is shown below.



- (i) State the shape and bond angle around a carbon atom in the alkyl group of propanoic acid. Explain the shape.

Shape

Bond angle

Explanation

.....
.....
.....

[2]

- (ii) Suggest a value for the C–O–H bond angle in propanoic acid.

.....

[1]

- (b) 2-Chloropropanoic acid, $\text{CH}_3\text{CHClCOOH}$, can be made by reacting propanoic acid with chlorine in a radical substitution reaction.

- (i) State the conditions for the reaction.

.....

[1]

- (ii) Write the overall equation for the reaction.

.....

[1]

- (iii) The first step in the reaction mechanism involves homolytic fission of a chlorine molecule to form two chlorine radicals.

Why is this step an example of *homolytic fission*?

----- [1]

(iv) Write **two** equations to show the propagation steps in the mechanism for this reaction.

Use dots, •, to show the unpaired electrons on radicals.

----- [2]

(v) Draw the displayed formula of the radical formed in the first propagation step.

Use a dot, •, to show the position of the unpaired electron.

[1]

(vi) Further substitution forms a mixture of organic products.

Draw the structure of an organic product formed from 2-chloropropanoic acid by further substitution.

[1]

16 1 mol of a compound reacts with 8 mol O_2 for complete combustion.

What is the formula of the compound?

- A C_4H_8
- B $\text{C}_4\text{H}_9\text{OH}$
- C $\text{C}_5\text{H}_{11}\text{OH}$
- D C_5H_{12}

Your answer

[1]

17 This question is about energy changes and rate of reaction.

Magnesium reacts with aqueous silver nitrate, $\text{AgNO}_3(\text{aq})$, as in **equation 23.1**.



A student carries out an experiment to determine the enthalpy change of this reaction, $\Delta_r H$.

- The student adds 25.0 cm^3 of $0.512 \text{ mol dm}^{-3}$ AgNO_3 to a polystyrene cup.
- The student measures the temperature of the solution.
- The student adds a small spatula measure of magnesium powder, stirs the mixture and records the maximum temperature

Temperature readings

Initial temperature	= 19.5°C
Maximum temperature	= 47.5°C

(i) Calculate $\Delta_r H$, in kJ mol^{-1} , for the reaction shown in **equation 23.1**.

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

Assume that the density and specific heat capacity, c , of the solution are the same as for water and that all the aqueous silver nitrate has reacted.

$\Delta_r H =$ kJ mol^{-1} [4]

- (ii) At the end of the experiment, the student adds a few drops of aqueous sodium chloride to the reaction mixture in the polystyrene cup to test whether all the aqueous silver nitrate has reacted.

Explain how the results would show whether all the aqueous silver nitrate has reacted. Include an equation with state symbols in your answer.

----- [2]

Compounds **A**, **B** and **C** are saturated hydrocarbons.

The structures and boiling points of **A**, **B** and **C** are shown below.

- Use the structures to explain what is meant by the term structural isomer.
- Explain the trend in boiling points shown by **A**, **B** and **C** in the table.

[5]

(b) Compounds **A**, **B** and **C** all react with chlorine in the presence of ultraviolet radiation to form organic compounds with the formula $C_5H_{11}Cl$.

(i) Name the mechanism for this reaction.

----- [1]

(ii) Complete the table to show the number of structural isomers of $C_5H_{11}Cl$ that could be formed from the reaction of chlorine with **A** and **B**.

	A	B
Number of structural isomers		

[2]

(iii) The reaction of compound **A** with excess chlorine forms a compound **D**, which has a molar mass of 175.5 g mol^{-1} .

Draw a possible structure for compound **D** and write the equation for its formation from compound **A**. Use molecular formulae in the equation.

Compound D

Equation ----- [2]

19 Under suitable conditions, butane, C_4H_{10} , reacts with chlorine by radical substitution. A mixture of organic compounds is formed, including C_4H_9Cl , and compounds **D** and **E**.

- (i) Complete the table below to show the mechanism for the initiation and propagation stages of the reaction of C_4H_{10} with chlorine to form C_4H_9Cl .

In your equations, use molecular formulae and 'dots' ($\cdot$) with any radicals.

Initiation	Equation -----
	Conditions -----
Propagation	----- $\rightarrow$ -----
	----- $\rightarrow$ -----

[3]

- (ii) Organic compound **D** is formed by substitution of **all** the H atoms in butane by Cl atoms.

Write the equation for the formation of compound **D** from butane.

Use molecular formulae.

----- [1]

(iii) Organic compound **E** is formed by the substitution of **some** of the H atoms in butane by C/ atoms.

A chemist found that 0.636 g of compound **E** has a volume of 78.0 cm³.

Under the conditions used, the molar gas volume is 32.5 dm³ mol⁻¹.

Determine the molecular formula of compound **E**.

molecular formula = ... [3]

END OF QUESTION PAPER

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
1	a	i	(series of compounds with the) same functional group OR same / similar chemical properties OR same / similar chemical reactions ✓ each successive/subsequent member differing by CH₂ ✓	2	IGNORE references to physical properties IGNORE has same general formula (in question) DO NOT ALLOW have the same empirical formula OR have the same molecular formula Examiner's Comments Many candidates were able to score both marks by specifying the same functional group and that each successive member varies by a CH₂ group. Some responses were imprecise and referred to just members differing by CH₂ group.
		ii	C _n H _{2n} ✓	1	Examiner's Comments Most candidates were able to state the general formula for the cycloalkanes.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	More carbons (in ring) OR more (surface area of) contact AND more van der Waals forces OR stronger van der Waals forces ✓ More energy needed to break the intermolecular forces ✓	2	Both answers need to be comparisons ALLOW ORA throughout ALLOW has more electrons OR larger (carbon) ring OR higher molecular mass IGNORE bigger molecule IGNORE chain instead of ring DO NOT ALLOW 'more contact between atoms' ALLOW 'VDW' for van der Waals 'More intermolecular forces' is not sufficient ALLOW it is harder to overcome the intermolecular forces ALLOW intermolecular bonds / van der Waals bonds ALLOW more energy is needed to separate molecules IGNORE more energy is needed to break bonds Examiner's Comments This was a well answered question and many candidates could relate the difference in boiling point to the increase in points of contact and stronger van derWaals' forces. A significant number of candidates referred to the breaking of bonds rather than intermolecular forces.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance								
	b		tetrahedral ✓ four bonding pairs repel OR four bonds repel ✓	2	Mark each point independently IGNORE surrounded by four atoms IGNORE four areas of electron charge repel IGNORE four electron pairs repel (<i>one could be lp</i>) DO NOT ALLOW atoms repel Examiner's Comments Most candidates were able to state the shape required. Explanations for the bond angle often focused on the four bond pairs around the carbon atom, however candidates did not always refer to repulsion between these electron pairs.								
	c	i	<table><tr><th>Step</th><th>Equation</th></tr><tr><td>Initiation (1 mark)</td><td>$\text{Br}_2 \rightarrow 2\text{Br}\cdot$ ✓</td></tr><tr><td>Propagation (2 marks)</td><td>$\text{C}_6\text{H}_{12} + \text{Br}\cdot \rightarrow \text{C}_6\text{H}_{11}\cdot + \text{HBr}$ ✓ $\text{C}_6\text{H}_{11}\cdot + \text{Br}_2 \rightarrow \text{C}_6\text{H}_{11}\text{Br} + \text{Br}\cdot$ ✓</td></tr><tr><td>Termination (2 marks)</td><td>$\text{C}_6\text{H}_{11}\cdot + \text{Br}\cdot \rightarrow \text{C}_6\text{H}_{11}\text{Br}$ $\text{C}_6\text{H}_{11}\cdot + \text{C}_6\text{H}_{11}\cdot \rightarrow \text{C}_{12}\text{H}_{22}$ $\text{Br}\cdot + \text{Br}\cdot \rightarrow \text{Br}_2$ Two correct ✓ All three correct ✓✓</td></tr></table>	Step	Equation	Initiation (1 mark)	$\text{Br}_2 \rightarrow 2\text{Br}\cdot$ ✓	Propagation (2 marks)	$\text{C}_6\text{H}_{12} + \text{Br}\cdot \rightarrow \text{C}_6\text{H}_{11}\cdot + \text{HBr}$ ✓ $\text{C}_6\text{H}_{11}\cdot + \text{Br}_2 \rightarrow \text{C}_6\text{H}_{11}\text{Br} + \text{Br}\cdot$ ✓	Termination (2 marks)	$\text{C}_6\text{H}_{11}\cdot + \text{Br}\cdot \rightarrow \text{C}_6\text{H}_{11}\text{Br}$ $\text{C}_6\text{H}_{11}\cdot + \text{C}_6\text{H}_{11}\cdot \rightarrow \text{C}_{12}\text{H}_{22}$ $\text{Br}\cdot + \text{Br}\cdot \rightarrow \text{Br}_2$ Two correct ✓ All three correct ✓✓	5	IGNORE state symbols IGNORE dots If an incorrect hydrocarbon with six C atoms is used: DO NOT ALLOW any marks for the propagation steps but ALLOW ECF for termination steps (<i>i.e.</i> 3 max) Examiner's Comments This question required candidates to apply their knowledge of the radical substitution mechanism and those who had prepared well scored full marks. A common misconception was to have hydrogen radicals being formed and reacted in propagation and termination steps.
Step	Equation												
Initiation (1 mark)	$\text{Br}_2 \rightarrow 2\text{Br}\cdot$ ✓												
Propagation (2 marks)	$\text{C}_6\text{H}_{12} + \text{Br}\cdot \rightarrow \text{C}_6\text{H}_{11}\cdot + \text{HBr}$ ✓ $\text{C}_6\text{H}_{11}\cdot + \text{Br}_2 \rightarrow \text{C}_6\text{H}_{11}\text{Br} + \text{Br}\cdot$ ✓												
Termination (2 marks)	$\text{C}_6\text{H}_{11}\cdot + \text{Br}\cdot \rightarrow \text{C}_6\text{H}_{11}\text{Br}$ $\text{C}_6\text{H}_{11}\cdot + \text{C}_6\text{H}_{11}\cdot \rightarrow \text{C}_{12}\text{H}_{22}$ $\text{Br}\cdot + \text{Br}\cdot \rightarrow \text{Br}_2$ Two correct ✓ All three correct ✓✓												

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	The breaking of a (Br-Br) bond AND forms (two) radicals OR the breaking of a (Br-Br) bond AND one electron (from the bond pair) goes to each atom / bromine ✓	1	ALLOW 'the breaking of a covalent bond' ALLOW the splitting of the bond in bromine ALLOW the breaking of a covalent bond where each atom keeps one of the bonding electrons IGNORE particle for atom ALLOW one electron goes to each product / species DO NOT ALLOW molecule or compound for atom IGNORE homolytic fission equations Examiner's Comments This question was better attempted than in previous sessions. Although many candidates were able to identify that radicals were formed, a significant number did not refer to the breaking of the covalent bond in Br₂.
	d	i	$\text{C}_6\text{H}_{12} + 2\text{Br}_2 \rightarrow \text{C}_6\text{H}_{10}\text{Br}_2 + 2\text{HBr} \quad \checkmark$	1	ALLOW molecular formula only. Examiner's Comments This question proved quite difficult for the vast majority of candidates who failed to apply their knowledge of radical substitution to an unfamiliar example. The most common incorrect answer was $\text{C}_6\text{H}_{12} + \text{Br}_2 \rightarrow \text{C}_6\text{H}_{10}\text{Br}_2 + \text{H}_2$.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	1,1-dibromocyclohexane OR 1,2-dibromocyclohexane OR 1,3-dibromocyclohexane OR 1,4-dibromocyclohexane ✓	1	Locant numbers MUST lowest possible e.g. DO NOT ALLOW 2,4-dibromocyclohexane etc. IGNORE structures Examiner's Comments Candidates were required to name one of the dibromocyclohexane compounds that could be formed from cyclohexane and the more able candidates were able to apply their understanding of nomenclature successfully. Common incorrect responses included straight chain dibromo compounds e.g. 1,2—dibromohexane and incorrect use of locant numbers e.g. 2,3—dibromocyclohexane.
			Total	15	

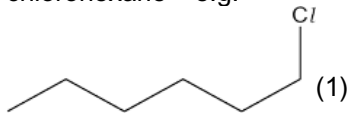
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
2		i	$\text{C}_8\text{H}_{18} + 12\frac{1}{2}\text{O}_2 \rightarrow 8\text{CO}_2 + 9\text{H}_2\text{O}$ ✓	1	ALLOW multiples e.g. $2\text{C}_8\text{H}_{18} + 25\text{O}_2 \rightarrow 16\text{CO}_2 + 18\text{H}_2\text{O}$ IGNORE state symbols Examiner's Comments Almost all candidates could provide a correctly balanced equation for the complete combustion of octane.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	$(n(\text{C}_8\text{H}_{18}) \text{ burned}) = 0.32 \text{ (mol)} \checkmark$ $(n(\text{CO}_2) \text{ from complete combustion}) = 2.56$ or 2.6 mol OR $(\text{ratio } n\text{CO}_2 / n\text{C}_8\text{H}_{18}) = 7.8(125)$ OR $(n \text{ C}_8\text{H}_{18} \text{ produce } 2.5 \text{ mol CO}_2) = 0.31(25)$ $\checkmark$	2	DO NOT ALLOW ECF from an incorrect moles of octane DO NOT ALLOW ECF from incorrect ratio from equation in (i) ALLOW the following alternate methods Method 1 $(\text{mass CO}_2 \text{ produced}) = 110 \text{ g } \checkmark$ $(\text{mass CO}_2 \text{ from complete combustion})$ $= 8 \times 0.32 \times 44 = 112.64 \text{ or } 112.6 \text{ or } 113 \text{ g}$ $\checkmark$ Method 2 $(n \text{ C}_8\text{H}_{18} \text{ to produce } 2.5 \text{ mol CO}_2) = 0.31(25) \checkmark$ $(\text{mass of octane required to produce } 2.50 \text{ mol CO}_2)$ $= 35.6 \text{ OR } 35.63 \text{ OR } 35.625 \text{ g } \checkmark$ Examiner's Comments Candidates coped well with this unfamiliar question. Almost all candidates recognised the need to calculate the number of moles of octane combusted and received the first mark. The majority of candidates were able to process this to show that 2.56 moles of carbon dioxide should have been produced. It was encouraging to see a range of alternative approaches adopted by candidates. For example, some used the calculated moles of octane and the amount of CO₂ given in the question to show that the reacting ratio was less than 8. The mark scheme allowed full marks for all valid responses.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	3	
3		i	any mono or multiple substituted chlorohexane – e.g. 	1	
		ii	(because) substitution can replace any H atom / multiple substitution <i>owtte</i> (1)	1	ignore vague statements about free radical reactions being random allow termination can join alkyl radicals to form larger hydrocarbons <i>owtte</i>
			Total	2	
4			B	1	
			Total	1	
5			Initiation $\text{Cl}_2 \rightarrow 2\text{Cl}\cdot$ (1) Propagation $\text{C}_2\text{H}_6 + \text{Cl}\cdot \rightarrow \text{C}_2\text{H}_5\cdot + \text{HCl}$ (1) $\text{C}_2\text{H}_5\cdot + \text{Cl}_2 \rightarrow \text{C}_2\text{H}_5\text{Cl} + \text{Cl}\cdot$ (1) Termination $\text{Cl}\cdot + \text{Cl}\cdot \rightarrow \text{Cl}_2$ OR $\text{C}_2\text{H}_5\cdot + \text{Cl}\cdot \rightarrow \text{C}_2\text{H}_5\text{Cl}$ OR $\text{C}_2\text{H}_5\cdot + \text{C}_2\text{H}_5\cdot \rightarrow \text{C}_4\text{H}_{10}$ (1) Initiation, propagation, termination used in correct context (1)	5	If the structure of the ethyl radical is drawn, the lone electron must be attached to a C atom
			Total	5	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
6		i	(because) molecule contains only single C–C bonds (1)	1	allow no multiple bonds / no double or triple bonds allow contains single bonds only
		ii	109.5°	1	
		iii	Combustion for energy production (alternative to fossil fuels) (1) Use as an organic feedstock (1)	2	
			Total	4	
7		i	Overlap of orbitals directly between the bonding atoms	1	allow a correct diagram
		ii	120° AND trigonal planar	1	allow planar triangle
			Total	2	
8		i	CO is toxic	1	allow responses linked to effect of CO in blood
		ii	<i>Calculation:</i> $n(\text{butane}) = 600/58.0 = 10.34 \text{ (mol)}$ AND $n(\text{O}_2) \text{ required} = 6.5 \times 10.34 = 67.2 \text{ (mol) (1)}$ $n(\text{O}_2) \text{ consumed} = 1.50 \times 10^3 / 24.0 = 62.5 \text{ (mol)}$ OR volume O₂ required for complete combustion = $67.2 \times 24.0/1000 = 1.61 \text{ m}^3 \text{ (1)}$ <i>Conclusion:</i> incomplete combustion / stove not safe to use AND $62.5 < 67.2$ OR $1.61 > 1.50 \text{ (1)}$	3	using 1 : 6.5 ratio allow number rounding to 67
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
9			D	1	<u>Examiner's Comments</u> B was a common incorrect answer with the sigma bond not counted as part of a double bond.
			Total	1	
10			D	1	<u>Examiner's Comments</u> Generally scored well.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
11			Alcohols have hydrogen bonds (and van der Waals' forces) ✓ Hydrogen bonds are stronger than van der Waals' forces (in alkanes) ✓	2	ANNOTATE ANSWER WITH TICKS AND CROSSES ALLOW reference to specific compounds e.g. comparing methane and methanol Second marking point requires BOTH types of intermolecular forces in response i.e comparison of hydrogen bonds AND van der Waals is essential DO NOT ALLOW the second mark for a comparison of van der Waals' and hydrogen bonds between alcohols and water ALLOW more energy required to break hydrogen bonds than van der Waals' forces ALLOW it is harder to overcome the hydrogen bonds than van der Waals' forces IGNORE more energy is needed to break bonds Examiner's Comments Many candidates attributed the difference in boiling point between alkanes and alcohols to the relative strength of hydrogen bonds compared with van der Waals' forces. Weaker responses simply identified alcohols as being able to form hydrogen bonds, but failed to compare these with van der Waals' forces.
			Total	2	
12			B	1	Examiner's Comments Able candidates answered this question correctly, with answer option A being a common distractor.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
13			A	1	Examiner's Comments The majority of candidates correctly identified answer option A as the lowest boiling point alkane. The common incorrect answer was D, the complete opposite as it is the least branched and longest chain.
			Total	1	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
14	i FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = $-2510 \text{ (kJ mol}^{-1}\text{)}$ award 4 marks IF answer = $2508 / 2507 \text{ (kJ mol}^{-1}\text{)}$ award 3 marks (not rounded to 3SF, ignore sign) IF answer = $+ 2510 \text{ (kJ mol}^{-1}\text{)}$ award 3 marks (incorrect sign) IF answer = $-2510000 \text{ (kJ mol}^{-1}\text{)}$ award 3 marks (used J instead of kJ) Moles $n(\text{C}_6\text{H}_{14}) = 0.0150 \text{ mol}$ ✓ Energy q calculated correctly = 37620 (J) OR 37.620 (kJ) ✓ Calculating ΔH Correctly calculates ΔH in kJ mol^{-1} AND to 3 or more SF ✓ Rounding AND sign calculated value of ΔH rounded to 3 SF AND '-' sign ✓	4	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC moles = $1.29/86.0$ IGNORE trailing zeros $q = 200 \times 4.18 \times 45.0$ ALLOW correctly rounded to 3 sig figs: 37.6 kJ ALLOW ECF from incorrect q ALLOW ECF from incorrect molar mass or incorrect moles of hexane to 3 SF or more correctly rounded IGNORE sign at this intermediate stage IGNORE working $\Delta H = 37.62/0.015 = 2508 \text{ (kJ mol}^{-1}\text{)}$ $\Delta H = 37.6/0.015 = 2507 \text{ (kJ mol}^{-1}\text{)}$ $\Delta H = -2510 \text{ (kJ mol}^{-1}\text{)}$ Final answer must have '-' sign and 3 SF Examiner's Comments A high proportion of candidates lost marks on this question for a variety of reasons including errors in the calculation of moles and / or energy change. Many candidates did not express their final answer to three significant figures and so failed to score the final mark. An incorrect or missing sign also resulted in loss of the final mark.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Any two from the following: ✓✓ • Heat released to the surroundings • Incomplete combustion • Non-standard conditions	3	ALLOW heat loss ALLOW incomplete reaction OR not everything burns IGNORE reference to evaporation Examiner's Comment: Almost all candidates scored at least one mark for this well-rehearsed practical question. There was some confusion regarding the use of average bond enthalpy values obtained from a data book which was not relevant to this question.
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
15	a	i	Tetrahedral AND 109.5(°) ✓ four bonded pairs repel OR four bonds repel ✓	2	Mark each point independently ALLOW range 109 – 110° IGNORE surrounded by four atoms IGNORE four areas of electron charge repel IGNORE four electron pairs repel (<i>one could be lp</i>) DO NOT ALLOW atoms repel Examiner's Comments This question was poorly answered. Many candidates ignored the instruction to give the shape around the carbon atom in the alkyl group and instead focussed on the bond angle and shape around the carbonyl carbon. Even candidates who could identify the correct shape and bond angle did not explain that it is due to the repulsion between four bonding pairs.
		ii	104.5(°) ✓	1	ALLOW range 104 – 105° Examiner's Comments Generally well answered but many examples of incorrect bond angles including 107, 120 and 180 were seen here.
	b	i	Ultraviolet (radiation)/UV ✓	1	ALLOW sunlight IGNORE temperature Examiner's Comments Most candidates scored this mark.
		ii	$\text{CH}_3\text{CH}_2\text{COOH} + \text{Cl}_2 \rightarrow \text{CH}_3\text{CHClCOOH} + \text{HCl}$ ✓	1	ALLOW $\text{C}_2\text{H}_5\text{COOH} + \text{Cl}_2 \rightarrow \text{C}_2\text{H}_4\text{ClCOOH} + \text{HCl}$ ALLOW $\text{C}_3\text{H}_6\text{O}_2 + \text{Cl}_2 \rightarrow \text{C}_3\text{H}_5\text{ClO}_2 + \text{HCl}$ Examiner's Comments Many candidates could write the overall equation but there was some confusion with propagation steps and some equations contained radicals or missed out HCl as a product.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	one electron from the bond (pair) goes to each atom / chlorine/radical ✓	1	ALLOW the breaking of a covalent bond where each atom keeps one of the bonding electrons IGNORE particle for atom ALLOW one electron from the bond goes to each product / species DO NOT ALLOW molecule or compound for atom IGNORE homolytic fission equations Examiner's Comments Homolytic fission is described in the specification in terms of each bonding atom receiving one electron from the bonded pair forming two radicals. A large proportion of candidates failed to match the essential points in this definition.
		iv	<i>Propagation step 1</i> $\text{Cl}\cdot + \text{CH}_3\text{CH}_2\text{COOH} \rightarrow \text{CH}_3\text{CHCOOH}\cdot + \text{HCl} \checkmark$ <i>Propagation step 2</i> $\text{CH}_3\text{CHCOOH}\cdot + \text{Cl}_2 \rightarrow \text{CH}_3\text{CHClCOOH} + \text{Cl}\cdot \checkmark$	2	ALLOW 1. $\text{Cl}\cdot + \text{C}_3\text{H}_6\text{O}_2 \rightarrow \text{C}_3\text{H}_5\text{O}_2\cdot + \text{HCl}$ 2. $\text{C}_3\text{H}_5\text{O}_2\cdot + \text{Cl}_2 \rightarrow \text{C}_3\text{H}_5\text{ClO}_2 + \text{Cl}\cdot$ ALLOW dot at any position on the radical ALLOW 1 mark if both equations correct but any dots omitted from radicals Examiner's Comments Generally well answered. Candidates took note of the instruction in the question and it was very rare to see radicals without their unpaired electron.
		v	✓	1	Dot shown in correct position ALLOW –OH Examiner's Comments Unfortunately, candidates who were not able to attempt equations for the propagation steps in part (iv) were then unable to suggest the structure of the radical formed in the first step. Many candidates did not present a fully displayed formula. However, formulae showing –OH were given credit in this question.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		vi	Any structure with two or more Cl atoms on alkyl chain (provided that one Cl is at C-2) e.g. ✓	1	ALLOW correct structural OR skeletal OR displayed formula OR mixture of the above DO NOT ALLOW C₃H₄Cl₂O₂ ALLOW further substitution into any or all of the 4 positions occupied by H atoms in the alkyl group, provided that at least one Cl is at C-2 Examiner's Comment: Generally well answered but it was clear from some of the structures drawn that some candidates did not understand what is meant by further substitution.
			Total	10	
16			D	1	<u>Examiner's Comments</u> Most candidates selected A or D, with D being the correct option. Presumably, A was chosen by halving the '8' in C₄H₈ without considering that each H₂O molecule contains two H atoms. The successful answer of D usually resulted from the candidate constructing equations.
			Total	1	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
17	FIRST, CHECK THE ANSWER ON ANSWER LINE IF $\Delta_r H = -457$ OR -458 (kJ mol^{-1}) award 4 marks IF $\Delta_r H = \pm 229$ OR 457 (kJ mol^{-1}) award 3 marks ----- <i>Energy released in J OR kJ</i> $= 25.0 \times 4.18 \times 28.0 = 2926$ (J) OR 2.926 (kJ)✓ <i>Correctly calculates $n(\text{AgNO}_3)$</i> $= 0.512 \times \frac{25.0}{1000} = 1.28 \times 10^{-2}$ (mol) ✓ ΔH per mole AgNO_3 in kJ AND 3 SF Answer <i>MUST</i> divide energy by $n(\text{AgNO}_3)$ $\pm \frac{2.926}{1.28 \times 10^{-2}} = \pm 228.59375$ $= \pm 229$ (kJ) ✓ 3 SF needed Sign NOT needed ΔH for 2 mol AgNO_3 AND – sign AND 3 SF $\Delta H_r = 2 \times -228.59375 = -457$ (kJ mol^{-1}) OR $2 \times -229 = -458$ (kJ mol^{-1}) ✓	4	FULL ANNOTATIONS MUST BE USED ----- ALLOW ECF throughout ----- ALLOW 2930 J OR 2.93 kJ DO NOT ALLOW < 3 SF IGNORE any sign and units i.e. ALLOW correctly calculated number in J OR kJ ----- Alternative approach using 1 mol Mg Energy released = 2926 (J) OR 2.926 (kJ) ✓ $n(\text{AgNO}_3) = 1.28 \times 10^{-2}$ (mol) ✓ $n(\text{Mg}) = \frac{1.28 \times 10^{-2}}{2} = 6.4 \times 10^{-3}$ (mol) ✓ $\Delta H_r = \frac{2.926}{6.4 \times 10^{-3}} = -457$ (kJ mol^{-1}) – sign AND 3 SF needed Examiner's Comments Candidates are well-versed with the relationship $q = mc\Delta T$ and most were able to calculate that 2.926 kJ of energy was released in this reaction. It was also common to see the amount of AgNO_3 correctly calculated as 1.28×10^{-3} mol. Candidates were expected to determine the amount of energy released from 1 mol AgNO_3 as 229 kJ and finally to multiply this value by 2 for the molar quantities in the equation to match the 'enthalpy change of reaction'. It was common to see –229 given as the final answer but this was rarely multiplied by 2. The question also required the final answer to be given to an appropriate number of significant figures. Many candidates seemed to be unaware that this reflects the least significant figure provided in the data, in this case 3

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					significant figures. The exemplar shows a typical response for 3 of the available 4 marks. Many omitted the negative sign in their ΔH value to consider the exothermicity of the reaction. Candidates are also advised to only round at the end of a multi-step calculation. Rounding of intermediate values introduces rounding errors in the final answer. Answer = -457 kJ mol^{-1} Exemplar 4 (i) Calculate ΔH, in kJ mol^{-1}, for the reaction shown in equation 23.1. Give your answer to an appropriate number of significant figures. Assume that the density and specific heat capacity, c, of the solution are the same as for water and that all the aqueous silver nitrate has reacted. $c = 4.18$ density = 1.00 g cm^{-3} $Q = mc\Delta T$ $\Delta T =$ $Q = 25 \times 4.18 \times 28$ $n = \frac{m}{M_r}$ $n = CV$ $Q = 2926 \text{ J}$ $n = \frac{25}{1000} \times 0.512$ $Q = 2.926 \text{ kJ}$ $n = 0.0128$ $\frac{2.926}{0.0128} = 228.60$ 228.59375 $\Delta H = 229 \text{ kJ mol}^{-1}$ [4]
		ii	$\text{Ag}^+(\text{aq}) + \text{Cl}^-(\text{aq}) \rightarrow \text{AgCl}(\text{s})$ ✓ State symbols required White precipitate AND $\text{AgNO}_3/\text{Ag}^+$ NOT ALL reacted OR NO white precipitate AND $\text{AgNO}_3/\text{Ag}^+$ ALL reacted ✓	2	ALLOW $\text{AgNO}_3(\text{aq}) + \text{NaCl}(\text{aq}) \rightarrow \text{AgCl}(\text{s}) + \text{NaNO}_3(\text{aq})$ Observation needs to be linked to conclusion Examiner's Comments Most candidates recognised that silver nitrate and chloride ions react together to form a white precipitate, but many did not make the link between this observation and whether any silver nitrate was left unreacted. Many candidates did not give a correct equation, with missing or incorrect state symbols being common. This question discriminated extremely well.
			Total	6	

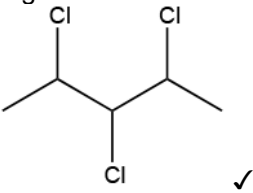
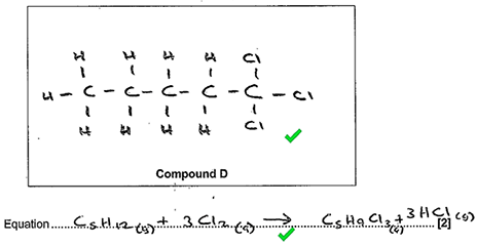
Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
18	a	Structural isomers: <i>1 mark</i> Different structural formulae AND same molecular formula ✓ Common molecular formula: <i>1 mark</i> C_5H_{12} for all 3 hydrocarbons ✓ Boiling point and branching: <i>1 mark</i> Boiling point decreases with more branching OR more methyl/alkyl groups/side chains OR shorter carbon chain ✓ Branching and London forces: <i>1 mark</i> <i>Could be seen anywhere within response</i> More branching gives less (surface) contact AND fewer/weaker London forces ✓ Energy and intermolecular forces: <i>1 mark</i> Less energy to break London forces/intermolecular forces/intermolecular bonds/ ✓	5	For 'structural': ALLOW different structure OR different displayed/ skeletal formula DO NOT ALLOW any reference to spatial/space/3D Same formula is not sufficient (no 'molecular') Different arrangement of atoms is not sufficient (no 'structure'/'structural') ALLOW 5 carbons and 12 hydrogens ALLOW for 2 marks: Different structural formulae AND same molecular formula ✓ of C_5H_{12} ✓ Comparisons needed throughout ORA throughout ALLOW comparison between any alcohols, e.g. A is least branched and has highest b pt C is most branched and has lowest b pt ALLOW induced dipole(–dipole) interactions IGNORE van der Waals'/vdw forces ALLOW SA for surface area ALLOW 'harder to overcome' intermolecular forces ALLOW more energy to separate the molecules IGNORE just 'bonds' <i>intermolecular/London forces required</i> <u>Examiner's Comments</u> This question discriminated well and resulted in a full range of marks. Most candidates were aware that structural isomers have different structural formulae

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance				
					but the same molecular formulae. It was common though for candidates to refer to different arrangements of atoms in space, clearly confusing with stereoisomerism. The best candidates used the structures (as in the question) to show that the common molecular formula was C5H12. Candidates were expected to link the amount of surface contact between molecules with induced dipole–dipole forces or London forces. ‘Contact’ or the name of the intermolecular forces was often omitted. Finally, candidates were expected to link the amount of branching to the strength of the intermolecular forces and the energy needed to change state. Lower ability candidates often let themselves down by being unable to construct a well-reasoned response. There was often a gulf between the clear responses of able candidates and those of lower ability candidates.				
	b	i	Radical substitution ✓	1	ALLOW Free radical substitution <u>Examiner’s Comments</u> Most candidates identified this reaction as radical substitution.				
		ii	<table><tr><td>A</td><td>B</td></tr><tr><td>3 ✓</td><td>2 ✓</td></tr></table>	A	B	3 ✓	2 ✓	2	<u>Examiner’s Comments</u> Most candidates achieved at least one mark, particularly for isomer A. Successful candidates often drew structures of the isomers alongside the table to help with their response.
A	B								
3 ✓	2 ✓								

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
iii	Structure of D Structure of a trichloro isomer of A, e.g.  ALLOW any trichloro isomer of A CHECK carefully Equation $C_5H_{12} + 3Cl_2 \rightarrow C_5H_9Cl_3 + 3HCl$ ✓ Molecular formulae required NO ECF from incorrect structure of D	2	ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous) IGNORE molecular formula ALLOW multiples, e.g. $2C_5H_{12} + 6Cl_2 \rightarrow 2C_5H_9Cl_3 + 6HCl$ Examiner's Comments Many candidates correctly drew the structure of compound D but comparatively few were able to construct a correct equation. For this equation, candidates needed to apply their knowledge and understanding of monosubstitution of alkanes to substitution of three H atoms by three Cl atoms. This task proved to be one of the most difficult questions on this paper. The exemplar shows an excellent response. The candidate has drawn a trisubstituted structure that fits the molar mass of 175.5 g mol^{-1} and a correct equation for its formation. Many attempts at this equation showed H_2 as the second product rather than HCl. Exemplar 6 (iii) The reaction of compound A with excess chlorine forms a compound D, which has a molar mass of 175.5 g mol^{-1}. Draw a possible structure for compound D and write the equation for its formation from compound A. Use molecular formulae in the equation. 

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	10	

Mark Scheme

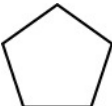
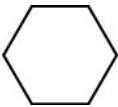
Question			Answer/Indicative content	Marks	Guidance
19		i	Initiation $\text{Cl}_2 \rightarrow 2\text{Cl}\cdot \text{ AND UV } \checkmark$ Propagation $\text{C}_4\text{H}_{10} + \text{Cl}\cdot \rightarrow \text{C}_4\text{H}_9\cdot + \text{HCl } \checkmark$ $\text{C}_4\text{H}_9\cdot + \text{Cl}_2 \rightarrow \text{C}_4\text{H}_9\text{Cl} + \text{Cl}\cdot \checkmark$	3 (AO1.1) (AO2.5) (AO2.5)	Dots NOT required for initiation IGNORE temperature OR pressure Dots required in each propagation equation ALLOW 1 mark for BOTH propagation equations with any dots missing or extra dots e.g. $\text{C}_4\text{H}_{10} + \text{Cl} \rightarrow \text{C}_4\text{H}_9 + \text{HCl}$ $\text{C}_4\text{H}_9\cdot + \text{Cl}_2 \rightarrow \text{C}_4\text{H}_9\text{Cl} + \text{Cl}$ DO NOT ALLOW charges <u>Examiner's Comments</u> A minority of Many candidates scored all 3 marks for this part, showing that most had thoroughly learnt the mechanism for radical substitution. The equation and conditions for the initiation step were well-known but the equations for the propagation steps often included errors. It was common for dots to be omitted for some radicals and $\text{C}_4\text{H}_9\text{Cl}\cdot$, rather than $\text{C}_4\text{H}_9\cdot$, was often shown for one of the products in the first propagation stage. $\text{H}\cdot$ was then shown as the other product.
		ii	$\text{C}_4\text{H}_{10} + 10 \text{Cl}_2 \rightarrow \text{C}_4\text{Cl}_{10} + 10 \text{HCl } \checkmark$	1 (AO2.6)	ALLOW structural formulae, e.g. $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3 + 10\text{Cl}_2$ $\rightarrow \text{CCl}_3\text{CCl}_2\text{CCl}_2\text{CCl}_3 + 10\text{HCl}$ <u>Examiner's Comments</u> Only the highest attaining candidates were able to write the correct equation. Although most candidates did identify the organic product as C_4Cl_{10}, the other product was usually seen as 5H_2 rather than 10HCl.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	$n(\text{E}) = \frac{78.0}{32500} = 2.4(0) \times 10^{-3} \text{ (mol)} \checkmark$ $M(\text{E}) = \frac{0.636}{2.4(0) \times 10^{-3}} \text{ OR } 265 \checkmark$ Molecular formula = C ₄ H ₄ Cl ₆ ✓	3 (AO3.1×2) (AO3.2)	ALLOW ECF from incorrect $n(\text{E})$ ALLOW ECF from incorrect $M(\text{E})$ from $n(\text{E})$ COMMON ERROR $n(\text{E}) = \frac{78.0}{24000} = 3.25 \times 10^{-3} \text{ (mol)} \quad \times$ $M(\text{E}) = \frac{0.636}{3.25 \times 10^{-3}} = 195.69 \text{ OR } 196 \quad \checkmark$ (3SF or more) Molecular formula = C ⁴ H ⁶ Cl ⁴ ✓
			Total	7	

1(a) This question is about cyclic organic compounds.

The table shows some information about cycloalkanes.

Cycloalkane	Skeletal formula	Boiling point / °C
Cyclopropane		-33
Cyclopentane		49
Cyclohexane		81

In the absence of ultraviolet radiation, **cyclopropane** undergoes an addition reaction with bromine.

Suggest the structure of the organic product formed in this reaction.

[1]

(b) Petrol contains both **cyclohexane**, C_6H_{12} , and hexane.

Cyclohexane can be prepared from hexane.

(i) Construct the equation for this reaction.

-----[1]

(ii) Suggest **one** advantage of adding cyclohexane to hexane in petrol.

-----[1]

(c) **Cyclobutane** is another cycloalkane.

There are several **unsaturated** isomers of cyclobutane that are alkenes.

Two of these isomers are stereoisomers.

(i) Explain what is meant by the term *stereoisomers*.

----- [1]

(ii) Draw these **two** stereoisomers.

[2]

2(a) Chloroethene, CH_2CHCl , can be polymerised to form poly(chloroethene).

Write an equation, using displayed formulae, to show the formation of this polymer.

[2]

(b) Incineration of plastics containing poly(chloroethene) produces waste gases that can damage the environment.

Incineration carried out in the presence of oxygen produces carbon dioxide, carbon monoxide and hydrogen chloride as waste gases and one other non-toxic product.

(i) Write an equation for the incineration of the monomer, chloroethene, with oxygen.

[1]

(ii) Chemists have developed ways of removing hydrogen chloride from these waste gases.

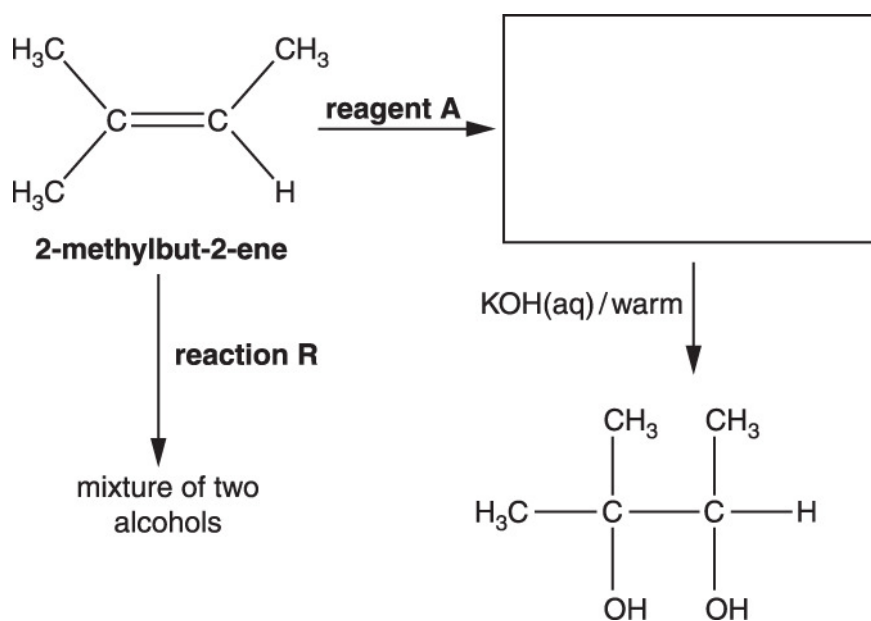
Sodium hydrogencarbonate, $\text{NaHCO}_3(\text{s})$, is frequently used in industry for this purpose.

Explain how sodium hydrogencarbonate removes hydrogen chloride.

[1]

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

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



(b) Identify reagent A.

[1]

-----[1]

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

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

-----[1]

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

-----[1]

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

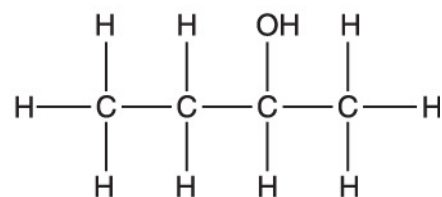
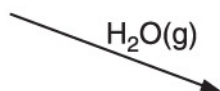
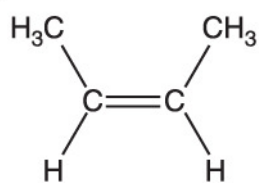
[2]

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

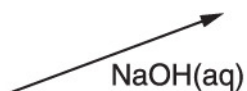
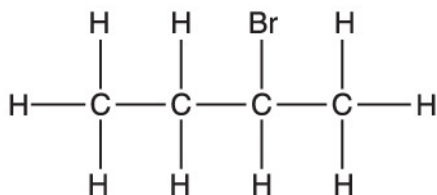
-----[2]

4 Butan-2-ol can be prepared using two different methods.

Method 1



Method 2

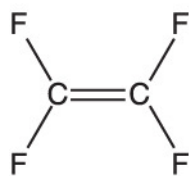


butan-2-ol

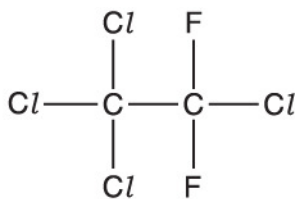
State the catalyst required for **Method 1**.

-----[1]

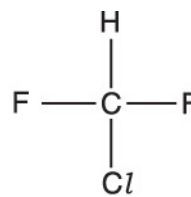
5(a) This question is about the compounds shown below.



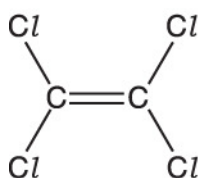
B



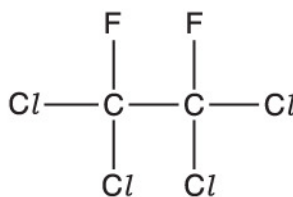
C



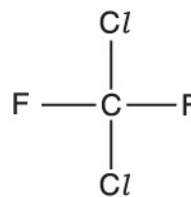
D



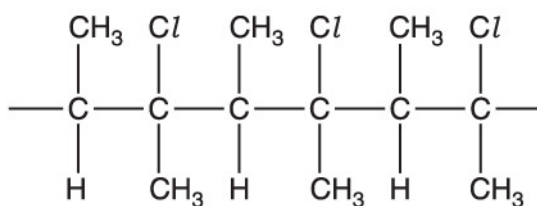
E



F



G



H

Which compound, **B** to **H**, could be used to make the polymer PTFE?

-----[1]

(b) Polymer H can be disposed of by combustion. One environmental problem is the production of toxic gases, such as CO.

(i) Draw the structure of the monomer needed to produce polymer H.

[1]

(ii) Give the formula of an acidic toxic gas that could form during combustion of polymer H.

-----[1]

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

Part of the $\text{C}=\text{C}$ double bond in allyl bromide is called a π -bond.

Draw a labelled diagram to show the formation of the π -bond.

[2]

(b) Allyl bromide, $\text{CH}_2=\text{CHCH}_2\text{Br}$, reacts with bromine, Br_2 .

(i) Outline the mechanism of this reaction.

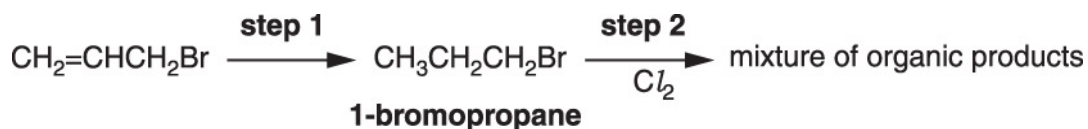
Include curly arrows, relevant dipoles and the structures of the intermediate and final product(s).

[4]

(ii) Name the type of mechanism.

[1]

(c) Allyl bromide is reacted as shown below.



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

[1]

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

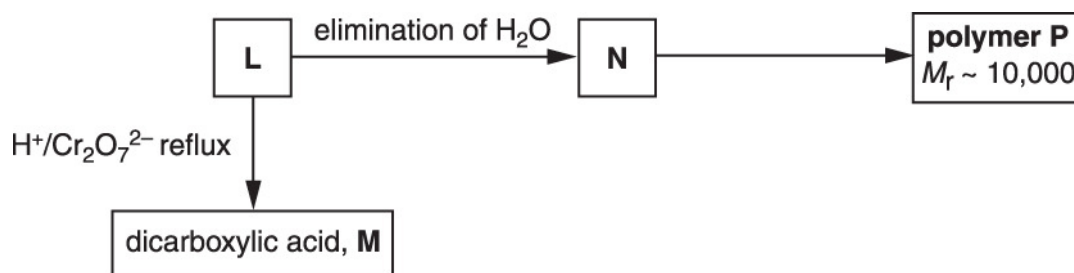
[5]

Suggest **two** reasons why.

[2]

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

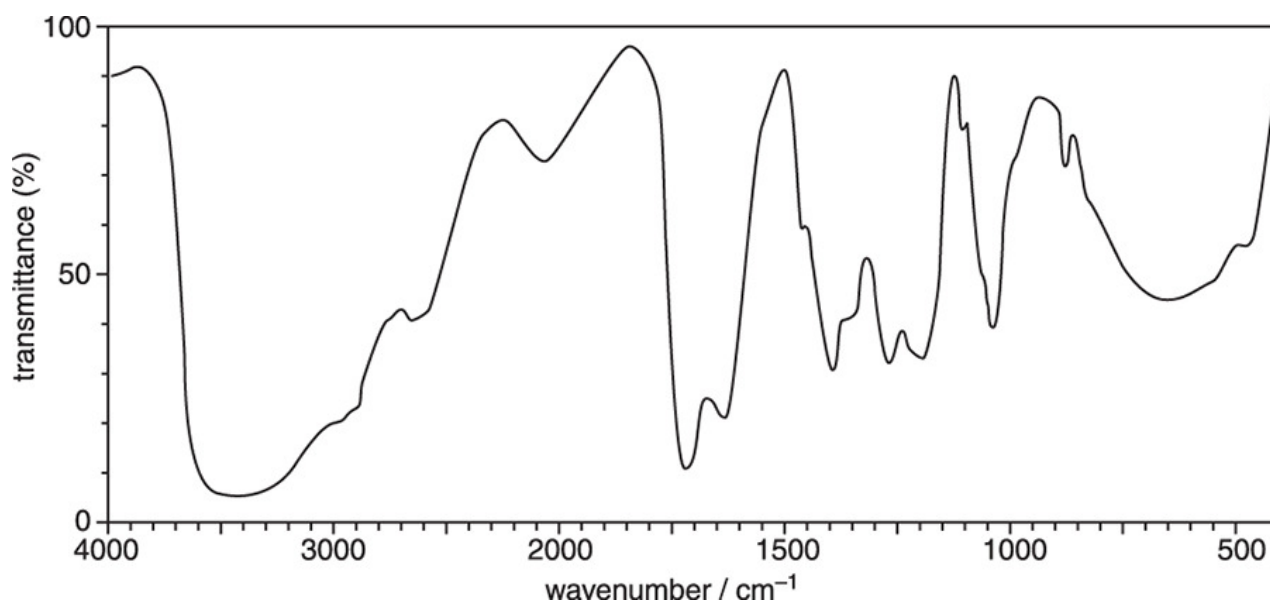
The flowchart shows reactions involving these compounds.



Analysis of compound L shows the following.

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

IR spectrum of L



Calculate the empirical and molecular formulae of compound L.

Show your working.

[3]

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

Blank lined paper for writing.

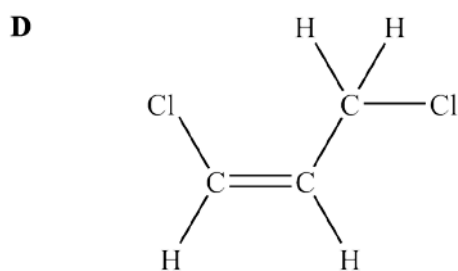
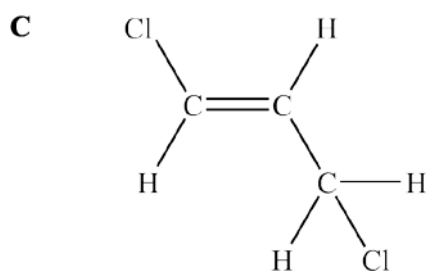
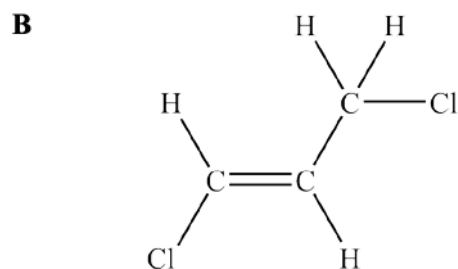
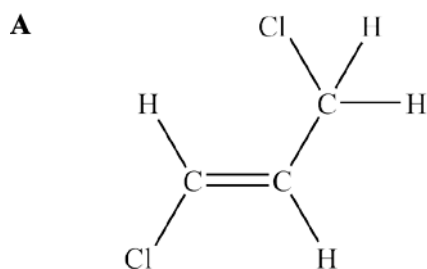
(c) Determine the structures of compounds **N** and **P**.

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

[4]

- 8 Three of the following displayed formulae represent the same isomer of $C_3H_4Cl_2$ but one structure represents a different isomer, **X**.

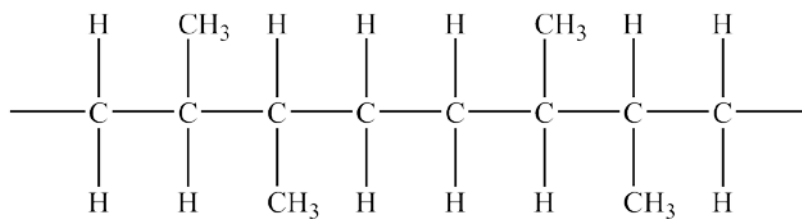
Which displayed formula represents **X**?



Your answer

[1]

9 A section of a polymer chain is shown below.



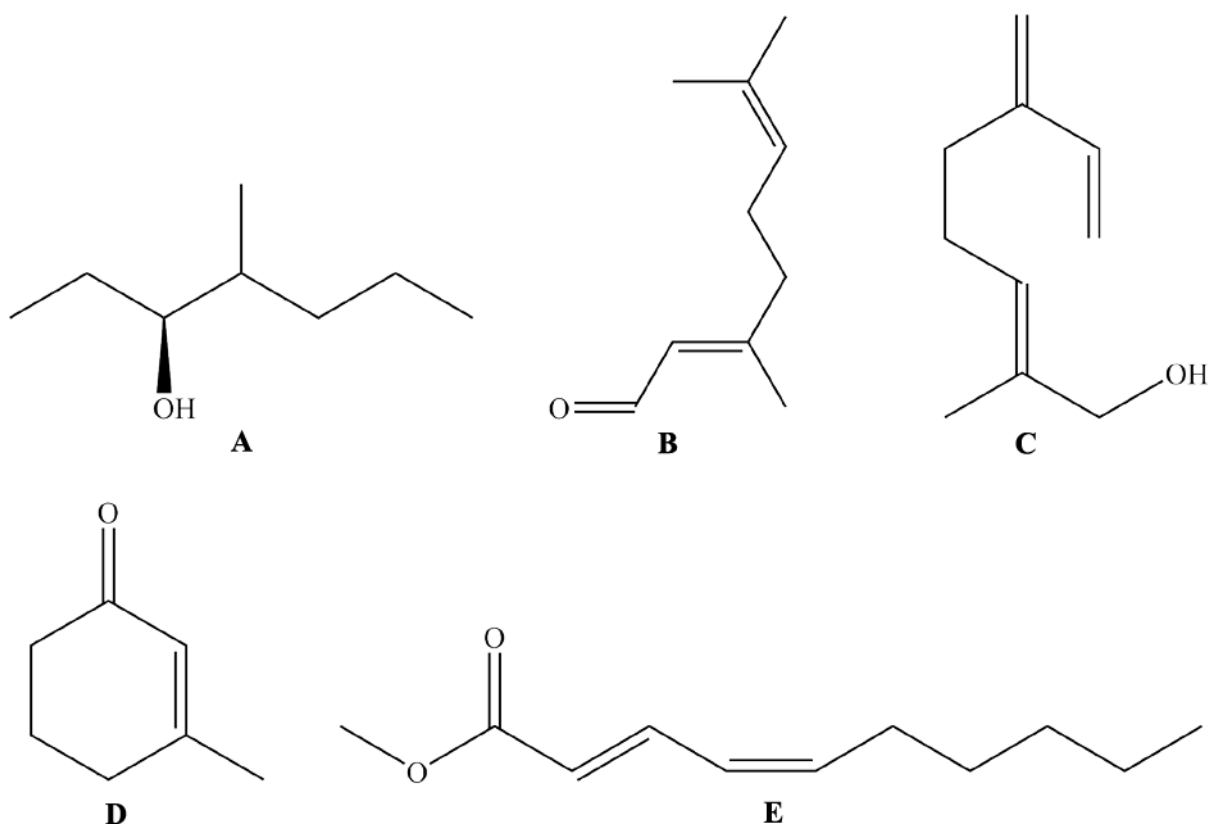
Identify the monomer that would give rise to this section of addition polymer.

- A *E*-But-2-ene
- B *Z*-But-2-ene
- C Methylpropene
- D Propene

Your answer

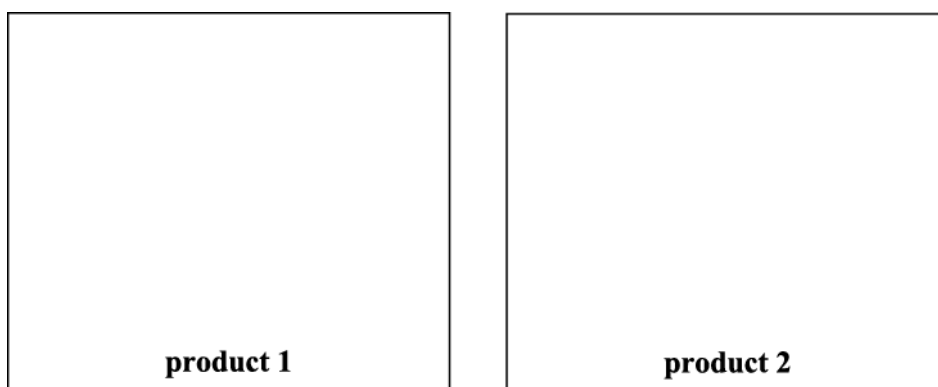
[1]

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



Compound **D** reacts readily with hydrogen chloride in an addition reaction. Two products are formed in this reaction, but one of the products is formed in much greater amounts than the other.

(i) Draw the structure of **both** possible addition products of this reaction.



[2]

(ii) State and explain which of the two possible products will be formed in greater amounts.

Include a diagram of the intermediate in the mechanism of this reaction in your answer.

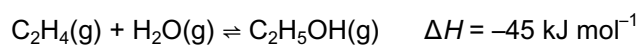
----- [2]

- (iii) 4.125 g of compound **D** is reacted with an excess of hydrogen chloride. The mixture of products contains 95% by mass of one product and 5% by mass of the other product.

Calculate the mass of each product formed.

[2]

- 11 Every year, two million tonnes of ethanol are produced worldwide by hydration of ethene obtained from crude oil.



This reaction is typically carried out using a catalyst at 300 °C and 6000 kPa.

The catalyst allows the reaction to reach equilibrium more quickly at the given temperature and pressure.

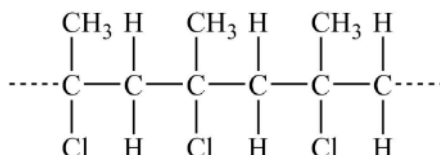
- (i) State the catalyst used in this reaction.

-----[1]

- (ii) Outline how a catalyst increases the rate of a chemical reaction.

-----[2]

A section of a halogenated polymer is shown.



- (i) Draw the structure of the monomer that could be used to make this polymer.

[1]

- (ii) Combustion of this polymer produces HCl, which is a toxic gas.

Describe how HCl is removed from the waste gases produced.

[1]

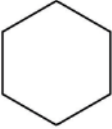
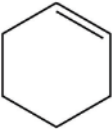
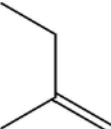
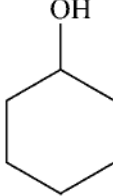
- (iii) Polymers made from natural foods such as corn starch are replacing halogenated polymers.

An advantage of this is that these polymers do not produce toxic gases on combustion.

State **one** other advantage of using polymers made from natural foods.

[1]

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

E 	F 	G 
H 	I 	J 

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

Each response may contain more than one letter.

aliphatic _____

alicyclic _____

aromatic _____

[3]

(b) Compound I has one alkyl group.

What is the general formula of alkyl groups?

_____ [1]

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

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

The student obtains 2.05 g of compound H.

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

Calculate the percentage yield of compound H.

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

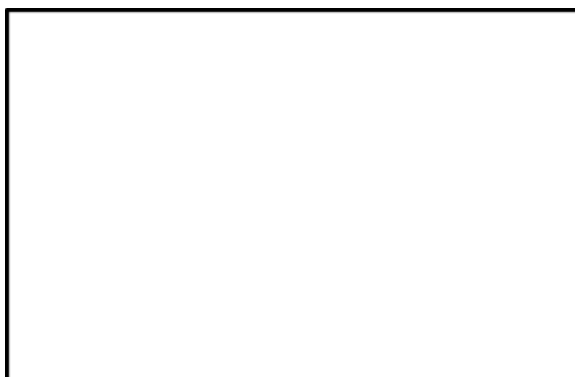
percentage yield = _____ % [4]

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

Draw the structure of the organic product from the test.

test: _____

organic product =



[2]

14 Iodine monobromide, I-Br, is a polar molecule.

Heterolytic fission of the I-Br bond forms an electrophile.

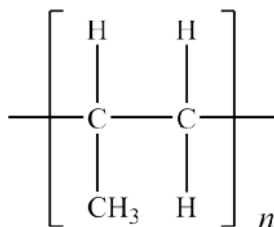
State the meaning of the term *electrophile* and suggest the formula of the electrophile formed from IBr.

----- [2]

15(a) A large proportion of the world's output of organic chemicals is used to make addition polymers. These polymers have a variety of uses.

Poly(propene) is used to make packaging, textiles and rope.

A repeat unit for poly(propene) is shown below.



- (i) Explain why poly(propene) is a *saturated* hydrocarbon.

----- [1]

- (ii) State the bond angle around each carbon atom in poly(propene).

----- [1]

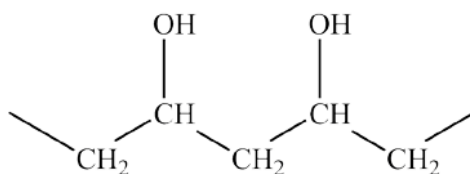
- (iii) After polymers have been used for packaging, the waste polymers need to be processed to save resources, for example, by recycling.

Describe **two** other ways in which waste poly(propene) can be processed in a sustainable way.

----- [2]

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

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



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

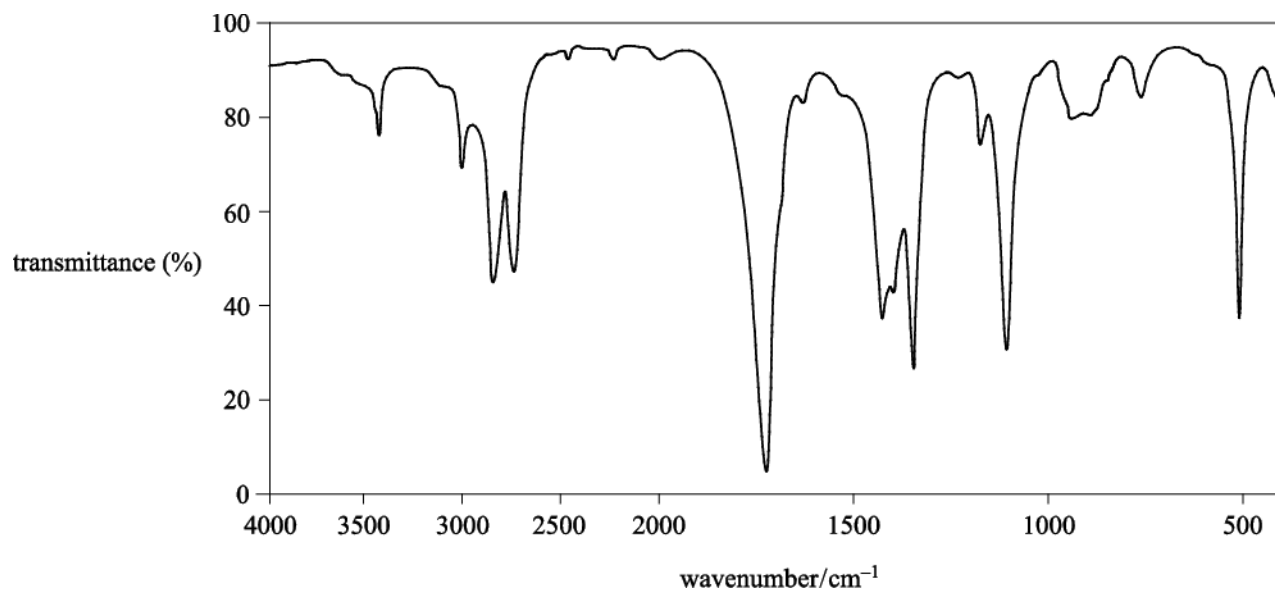
[1]

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

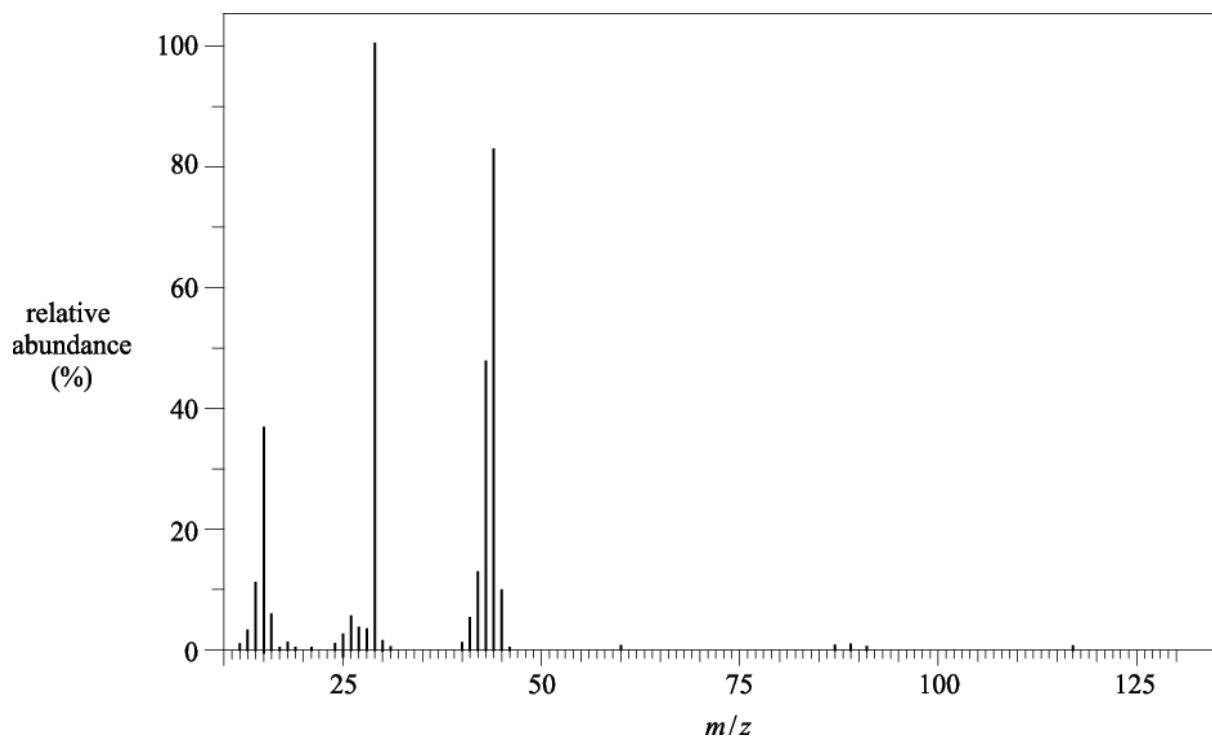
Ethenol is unstable and it forms a more stable structural isomer.

Analysis of the structural isomer gave the following data.

Infrared spectrum



Mass spectrum



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

Identify the structural isomer of ethenol.

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

[4]

16 * Alcohols can be converted into alkenes in an elimination reaction.

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

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

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

[6]

17(a) Propene reacts with bromine, Br₂. In this reaction, bromine acts as an electrophile.

(i) Outline the mechanism of this reaction.

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

[4]

(ii) What does a curly arrow represent in a reaction mechanism?

----- [1]

(b) Pent-1-ene, CH₃CH₂CH₂CH=CH₂, is an alkene with molecular formula C₅H₁₀.

(i) Pent-1-ene does **not** show stereoisomerism.

Explain why.

----- [1]

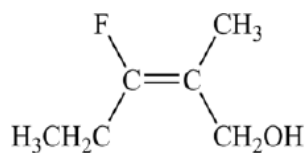
(ii) A structural isomer of pent-1-ene shows *cis*—*trans* stereoisomerism.

Draw structures for the *cis* and *trans* isomers of this structural isomer of pent-1-ene.

<i>cis</i> isomer	<i>trans</i> isomer

[2]

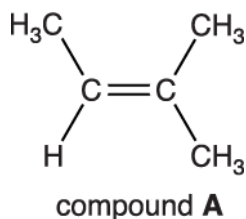
(c) The following molecule shows *E/Z* isomerism.



Use the Cahn—Ingold—Prelog priority rules to identify whether this alkene is an *E* or *Z* stereoisomer. Explain how you came to your decision.

----- [1]

18(a) Compound A is an alkene.



The C=C bond in a molecule of compound A has restricted rotation because it comprises a σ bond and a π bond.

- (i) Describe **one** difference between the σ bond and the π bond.

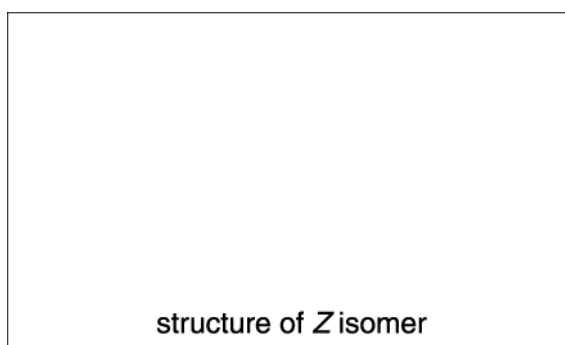
[1]

- (ii) Explain why compound A does **not** have *E/Z* isomers.

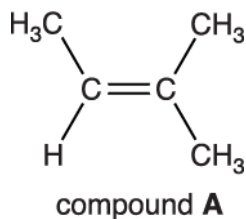
[1]

- (iii) A structural isomer of compound A has *E/Z* isomers.

Draw the structure of the *Z* isomer and then name this isomer.



- (b) *Compound **A** reacts with hydrogen bromide to form a mixture of two different organic products.



Give the structures of the **two** possible organic products of the reaction.

Outline the mechanism, using the 'curly arrow' model, for the formation of one of the organic products from compound **A**.

Explain which of the two organic products is more likely to be formed.

[6]

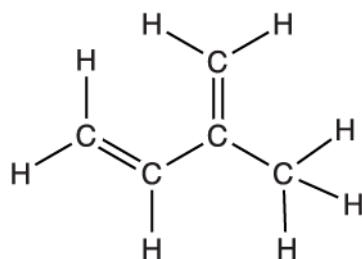
19 Which compound has non-polar molecules?

- A *E*-1,2-dichlorobut-2-ene
 B *E*-2,3-dichlorobut-2-ene
 C *Z*-2,3-dichlorobut-2-ene
 D *Z*-1,4-dichlorobut-2-ene

Your answer

[1]

20 The displayed formula for a hydrocarbon is shown below.



How many σ and π bonds are present in a molecule of this hydrocarbon?

	σ bonds	π bonds
A	2	4
B	10	2
C	10	4
D	12	2

Your answer

[1]

21 A reaction sequence is shown below:



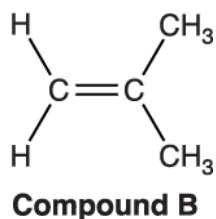
Which type of reaction mechanism is involved in each step?

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

Your answer

[1]

22(a) Compound **B**, shown below, can be used to synthesise organic compounds with different functional groups.



- (i) Compound **B** is a member of a homologous series.

Name the homologous series and state its general formula.

Homologous series

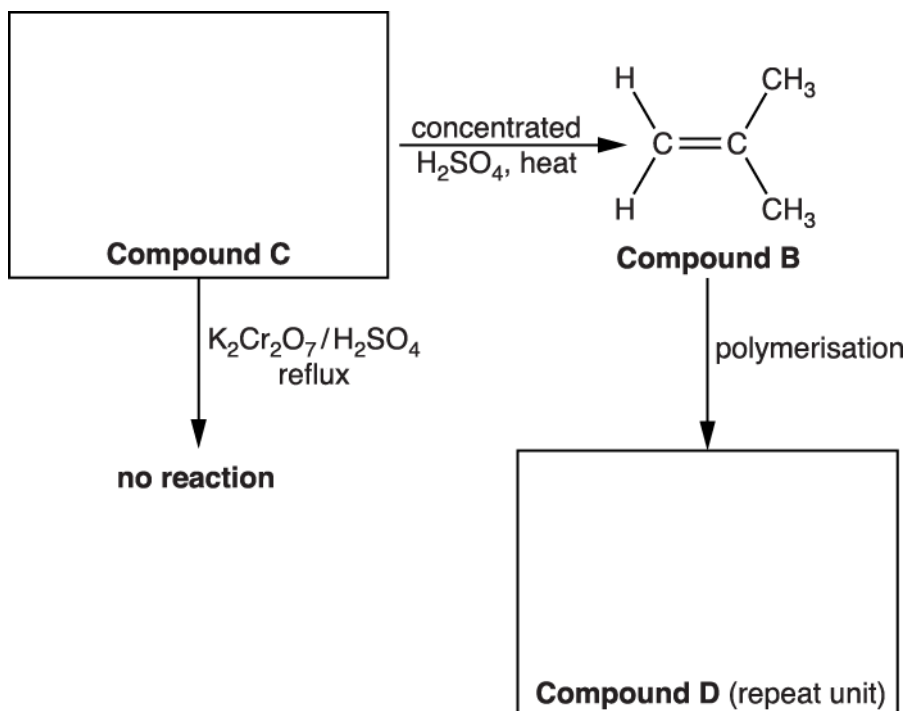
General formula

- (ii) What reagents and conditions are needed to convert compound **B** into a saturated hydrocarbon?

..... **[1]**

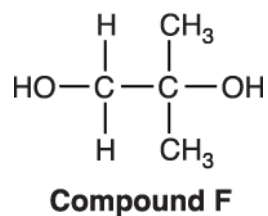
(b) Some reactions involving compound **B** are shown in the flowchart below.

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



[2]

(c) The structure of compound F is shown below.



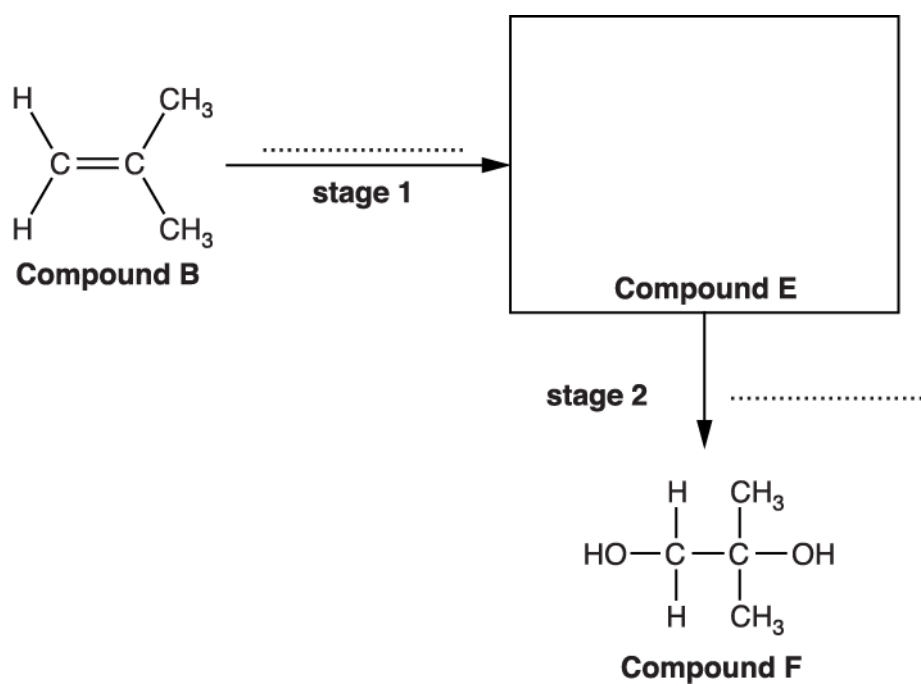
(i) What is the empirical formula of compound F?

-----[2]

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

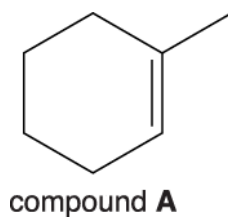
The synthesis first prepares compound E, as shown in the flowchart.

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



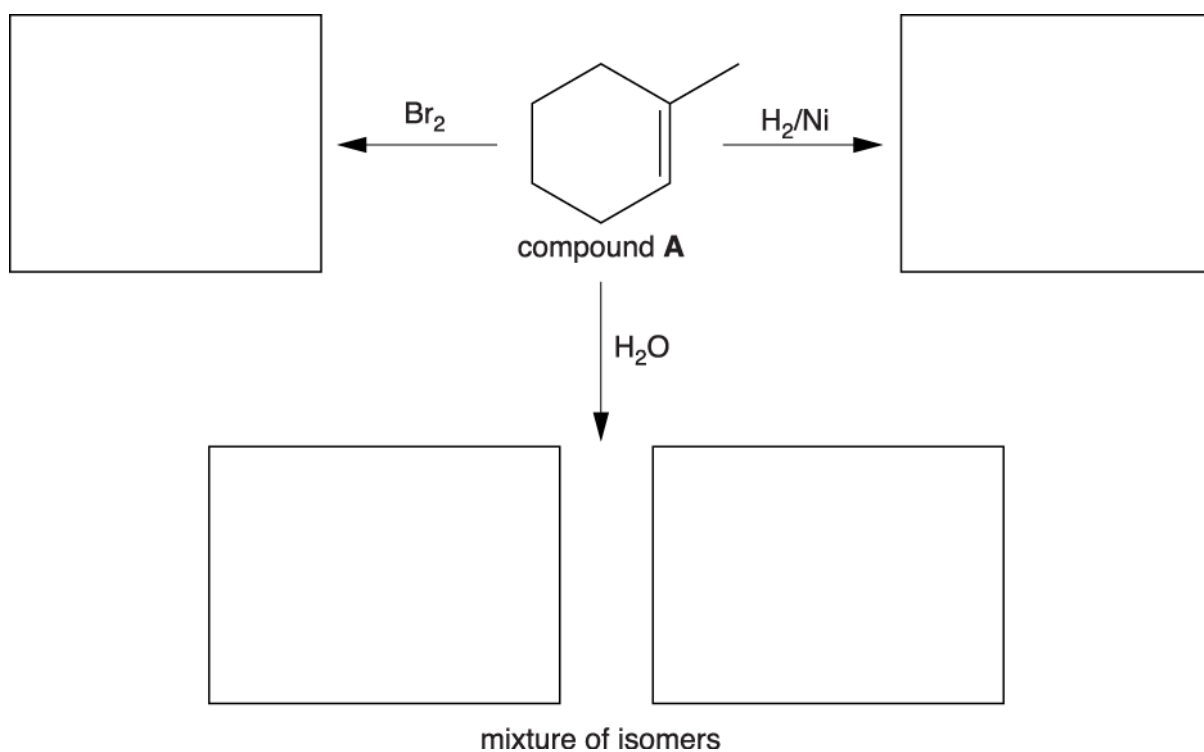
[3]

- 23 Compound **A** is an unsaturated hydrocarbon that can be used as the starting material for the production of organic compounds.



The flowchart shows three **addition** reactions of compound **A**.

- (i) In the boxes below, show the structures of the organic products formed in the reactions.



[4]

- (ii) What are the essential conditions for the reaction of compound **A** with H_2O ?

-----[2]

- (iii) Using curly arrows, outline the mechanism for the reaction of compound **A** with Br_2 .

[3]

(iv) Name the mechanism in part (iii).

[1]

24(a) Hex-2-ene shows *E/Z* isomerism.

(i) Draw the skeletal formulae of *E*-hex-2-ene and *Z*-hex-2-ene.

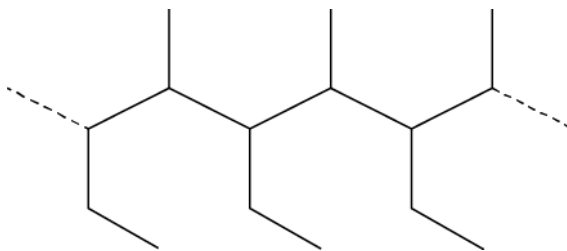
<i>E</i> -hex-2-ene	<i>Z</i> -hex-2-ene

[2]

(ii) State and explain the features of a hex-2-ene molecule that lead to *E* and *Z* isomers.

[2]

(b) A section of a polymer that can be made from an unsaturated hydrocarbon **B** is shown below.



(i) Add brackets to the section of the polymer to show **one** repeat unit.

[1]

(ii) Draw the structure of hydrocarbon **B**.

[1]

(iii) The polymer has a relative molecular mass of 50,000.

Calculate the number of monomer molecules required to make one molecule of the polymer.

number of monomer molecules = _____ [1]

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

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

Your answer

[1]

26 Cyclohexene is reacted with bromine to prepare the organic compound **F**.

Give the structure of compound **F** and outline the mechanism for this reaction.

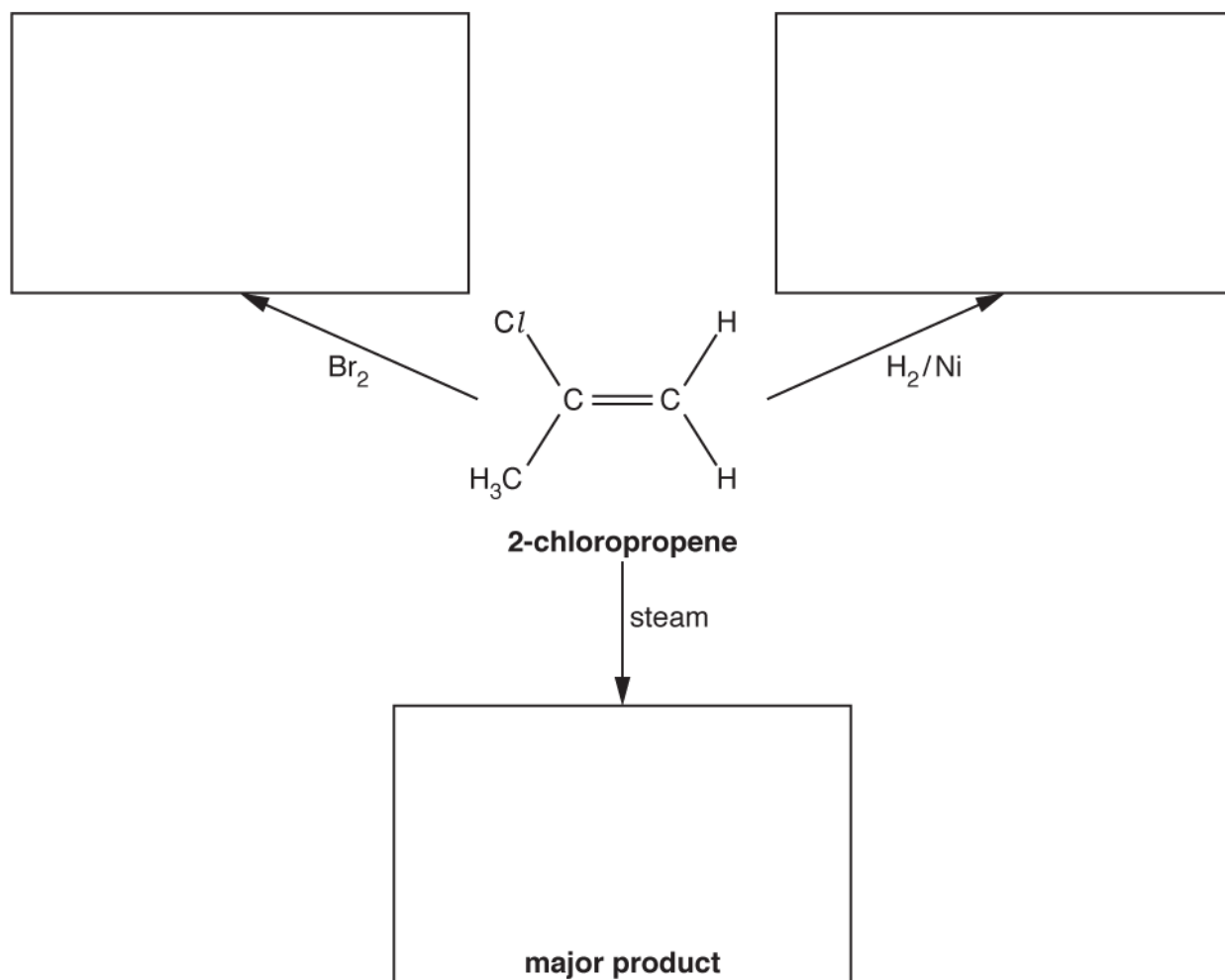
Include curly arrows, charges and relevant dipoles.

[4]

27(a) This question is about 2-chloropropene, $\text{C}_3\text{H}_5\text{Cl}$.

Three reactions of 2-chloropropene are shown in the flowchart below.

(i) Complete the flowchart to show the organic products formed in the reactions.



[3]

(ii) The reaction of 2-chloropropene with steam requires a catalyst.

State a suitable catalyst for this reaction.

-----[1]

(b) 2-chloropropene can be polymerised to form poly(2-chloropropene).

(i) Write a balanced equation for the formation of this polymer.

The equation should include the structure of the repeat unit of the polymer.

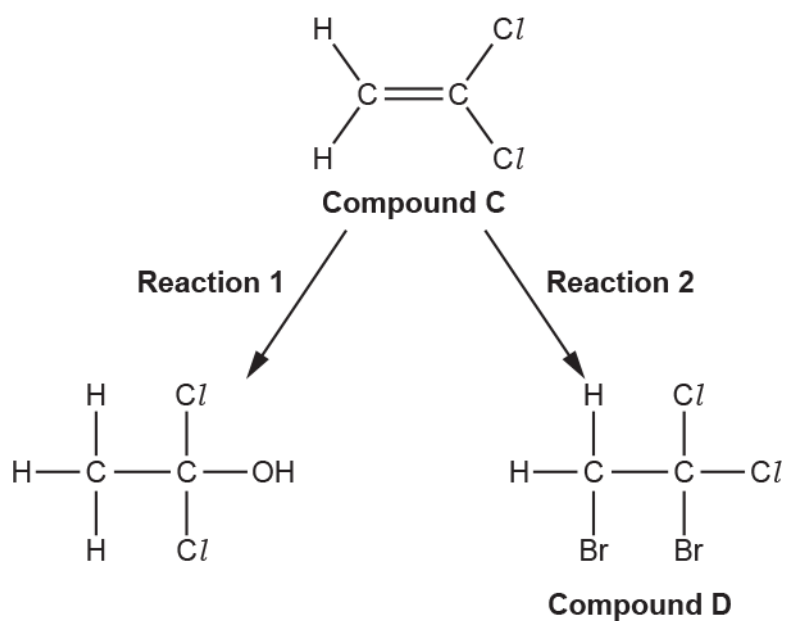
[2]

(ii) After their useful life, waste polymers can be disposed of by combustion.

State **one** particular problem with disposal of poly(2-chloropropene) by combustion.

----- [1]

28(a) Two reactions of compound **C** are shown in the flowchart below.



State the reagents and conditions for **reaction 1**.

.....
..... [1]

(b) In **reaction 2**, compound **C** reacts with bromine to form compound **D**.

(i) Give the systematic name of compound **D**.

-----[1]

(ii) Outline the mechanism for **reaction 2**.

Include curly arrows, charges and relevant dipoles.

[3]

(c) Compound **C** forms an addition polymer **E**.

(i) Write a balanced equation for this reaction.

Show displayed formulae.

[2]

(ii) State **one** advantage and **one** disadvantage of using combustion as a method for the disposal of waste polymer **E**.

Advantage -----

Disadvantage -----

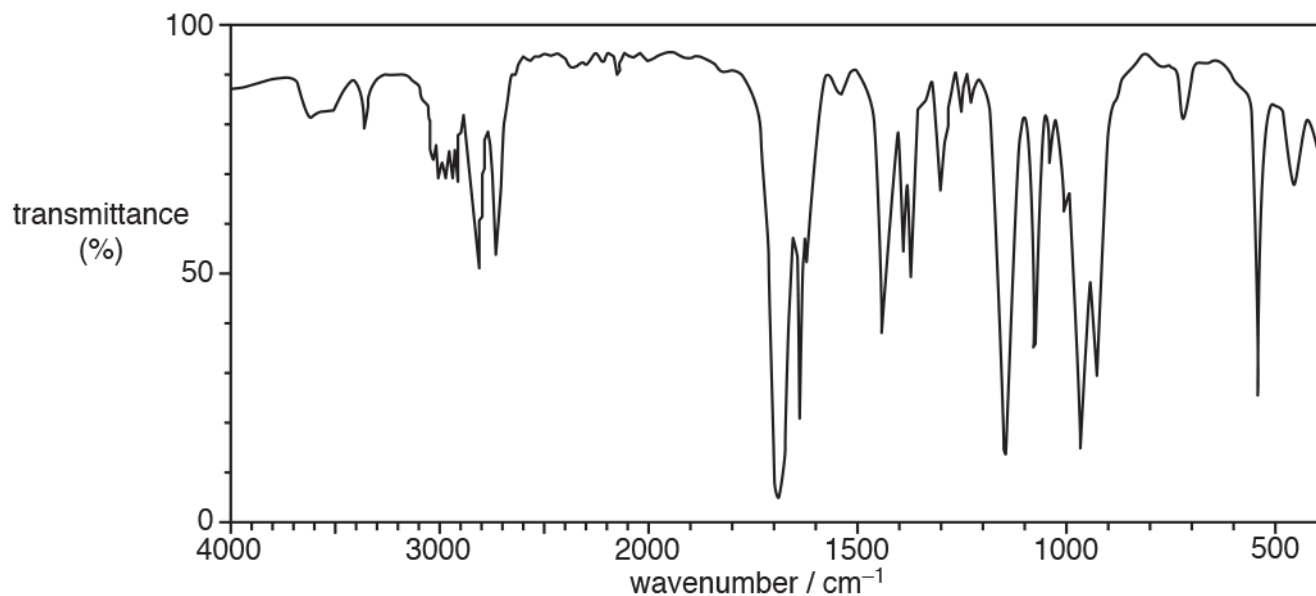
[2]

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

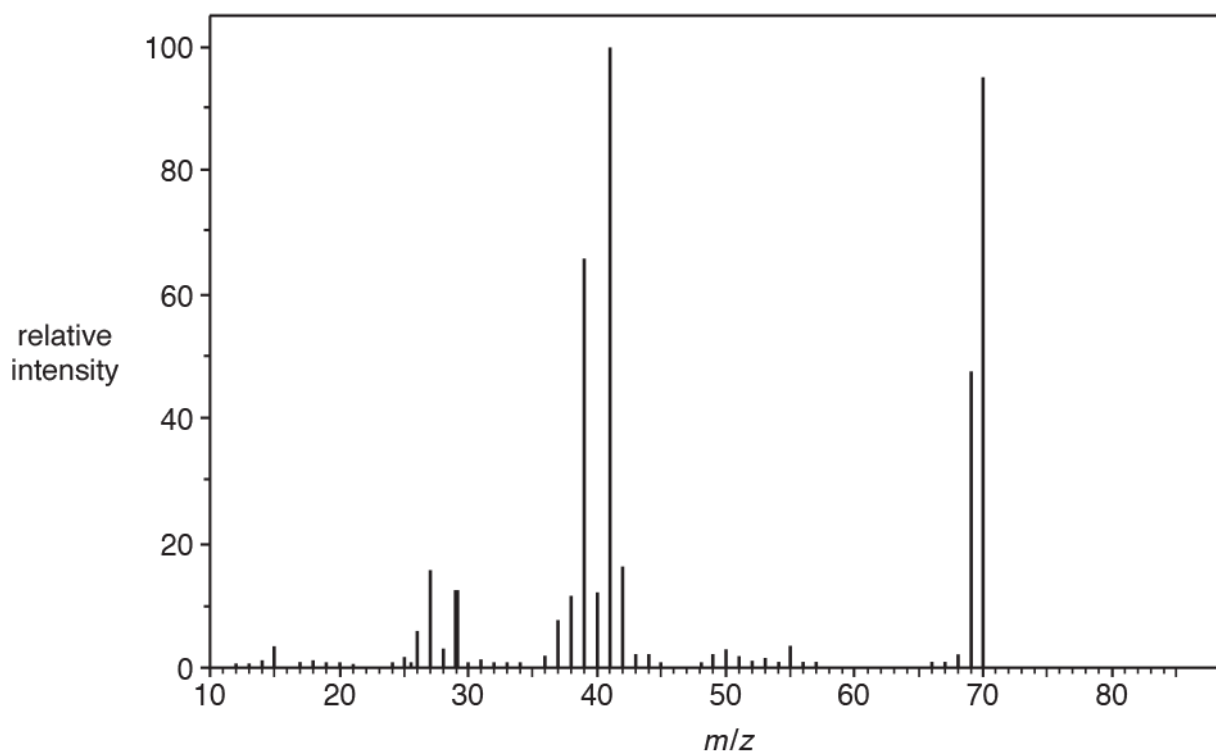
The results of elemental and spectral analysis of compound **F** are shown below.

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

Infrared spectrum



Mass spectrum



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

Determine the structure of compound F.

Explain your reasoning and show your working.

[6]

30 A student reacts pent-2-ene with bromine in the laboratory.

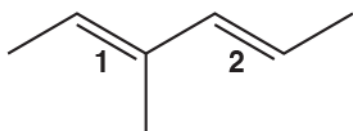
Which compound is formed?

- A 1,1-dibromopentane
- B 1,2-dibromopentane
- C 2,2-dibromopentane
- D 2,3-dibromopentane

Your answer

[1]

31 The molecule below has two double bonds, labelled 1 and 2.



The arrangement around each double bond can be identified as *E* or *Z*.

Which row in the table is correct for double bond 1 and double bond 2?

	Double bond 1	Double bond 2
A	<i>E</i>	<i>Z</i>
B	<i>Z</i>	<i>E</i>
C	<i>E</i>	<i>E</i>
D	<i>Z</i>	<i>Z</i>

Your answer

[1]

32 What is the best description for the bonding between the carbon atoms in an ethene molecule?

- A One σ -bond and one π -bond
- B One π -bond
- C Two σ -bonds
- D Two π -bonds

Your answer

[1]

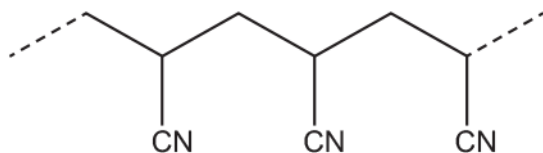
33 Which statement about an electrophile is correct?

- A It is an electron pair acceptor.
- B It is a proton donor.
- C It is a negative ion.
- D It is a species with an unpaired electron.

Your answer

[1]

34 A section of a polymer is shown below.



Which monomer could form this polymer?

- A $\text{CH}_3\text{CH}(\text{OH})\text{CN}$
- B $\text{HOCH}_2\text{CH}_2\text{CN}$
- C $\text{H}_2\text{C}=\text{CHCN}$
- D $\text{NCCH}=\text{CHCN}$

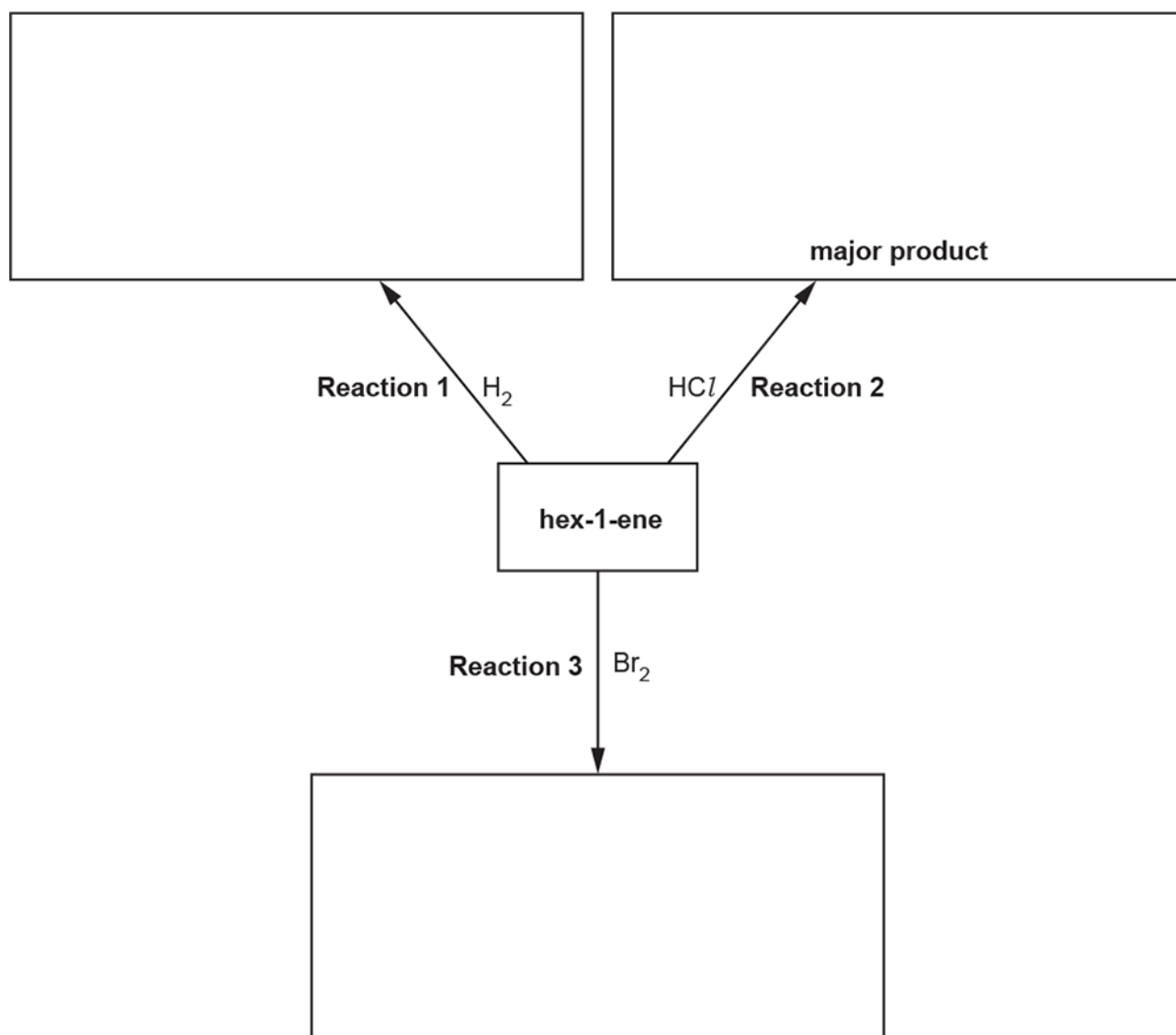
Your answer

[1]

35 This question is about hex-1-ene, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}=\text{CH}_2$.

Hex-1-ene is reacted with H_2 , HCl and Br_2 as shown in the flowchart below.

(i) Complete the flowchart to show the structures of the organic products of these reactions.



[3]

(ii) State the catalyst needed in reaction 1.

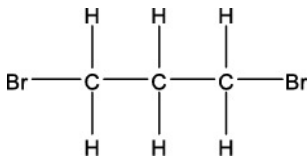
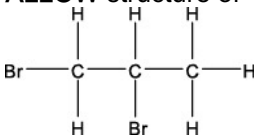
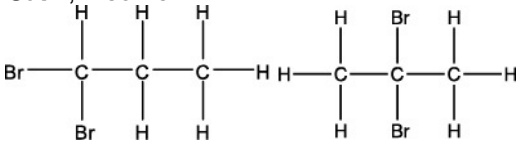
----- [1]

(iii) What would you observe in **reaction 3**?

----- [1]

END OF QUESTION PAPER

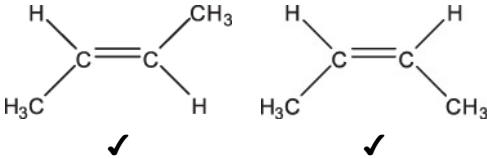
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
1	a		 ✓	1	ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous) ALLOW structure of 1,2-isomer  IGNORE molecular formula DO NOT ALLOW, structure of 1,1-isomer OR 2,2-isomer  Examiner's Comments Candidates generally struggled with this question which required application of knowledge. Common incorrect responses included products of a substitution reaction e.g. 1,2- dibromocyclopropane.
	b	i	$C_6H_{14} \rightarrow C_6H_{12} + H_2$ ✓	1	ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous) ALLOW any correct multiple IGNORE state symbols Examiner's Comments Most candidates were able to provide the correct equation.

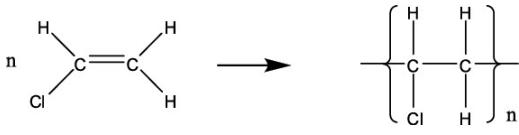
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Cyclohexane will burn more efficiently ✓	1	KEY IDEA IS COMBUSTION OR BURNING Assume 'it' refers to cyclohexane ALLOW ORA for hexane ALLOW cyclohexane allows smoother burning OR promotes more efficient combustion OR increases octane number OR reduces knocking OR less likely to produce pre-ignition OR burns better OR easier to burn OR combusts more easily OR improves combustion OR burns more cleanly DO NOT ALLOW cyclohexane ignites more easily IGNORE cyclohexane increase volatility of fuel IGNORE reference to boiling points IGNORE cyclohexane gives a better fuel Examiner's Comments The importance of cyclohexane to the petroleum industry was well known.
	c	i	(Compounds with the) same structural formula but a different arrangement (of atoms) in space ✓	1	ALLOW different spatial arrangement of atoms. DO NOT ALLOW different displayed formula. Examiner's Comments Although many candidates were able to provide the correct definition, some responses did not state that stereoisomers have the same structural formula.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii		2	ALLOW displayed OR skeletal formula OR mixture of the above. ALLOW structures in either order IGNORE molecular formula IGNORE structural formula IGNORE names IGNORE E/Z and cis / trans labels ALLOW 1 mark for a pair of E/Z isomers of an incorrect hydrocarbon structure with four C atoms e.g. C, or CH or CH₂ instead of CH₃ groups. Examiner's Comments This question required candidates to identify isomers of cyclobutane that would exhibit stereoisomerism and proved challenging for some. The more able candidates were able to provide two correct structures. A significant number of candidates suggested cyclic alkenes, which were not isomers of cyclobutane.
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
2	a		 Correct polymer with side links ✓ Balanced equation for formation of correct polymer - correct use of n in the equation and brackets ✓	2	Displayed formulae MUST be used to award each mark n on LHS can be at any height to the left of formula AND n on the RHS must be a subscript (essentially below the side link) Examiner's Comments The majority of candidates were able to show the displayed formula for the correct polymer. Surprisingly, many candidates failed to score the second mark because they did not consider balancing the equation on the left-hand side by inserting an n before the chloroethene monomer.
	b	i	$\text{CH}_2\text{CHCl} + 2\text{O}_2 \rightarrow \text{CO} + \text{CO}_2 + \text{HCl} + \text{H}_2\text{O}$ ✓	1	ALLOW any other correctly balanced equation with the same reactants and products ALLOW $\text{C}_2\text{H}_3\text{Cl}$ for CH_2CHCl Examiner's Comments The stronger candidates were able identify that the other non-toxic product was water and therefore could to provide a suitable equation for this unfamiliar question. A significant number of candidates found this question difficult and it was common to see equations where hydrogen had been stated as the other product. A smaller proportion of candidates attempted to balance the equation using only the three products stated in the question.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Sodium hydrogencarbonate neutralises HCl ✓	1	Assume that 'it' refers to sodium hydrogencarbonate but DO NOT ALLOW other chemicals e.g. sodium ALLOW NaHCO₃ is a base ALLOW forms a salt or sodium chloride or NaCl ALLOW equation to show formation of NaCl from NaHCO₃ and HCl even if not balanced. IGNORE reacts Examiner's Comments The examiners expected candidates to recognise that sodium hydrogencarbonate would neutralise the acidic gas and most candidates communicated this well. Responses such as 'sodium hydrogencarbonate is a base' and 'NaHCO₃ forms a salt' were accepted. Weaker candidates often used less precise language and responses such as 'NaHCO₃ reacts with the HCl' did not receive credit.
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
3	a		$ \begin{array}{c} \text{CH}_3 \quad \text{CH}_3 \\ \quad \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{Br} \quad \text{Br} \quad \checkmark \end{array} $	1	ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above DO NOT ALLOW molecular formula ALLOW dichloro or diiodo compound instead of the dibromo compound as the only alternatives. Examiner's Comments This question required candidates to interpret the reaction scheme and suggest an intermediate compound that could be formed from 2-methylbut-2-ene that could be also hydrolysed to give the diol shown. The most able candidates demonstrated their understanding of this scheme and often suggested the correct dihalo compound. Most candidate favoured the dibromo compound however some chose to show the dichloro or diiodo compound. All of these responses received credit. A large proportion of structures suggested were obtainable from 2-methylbut-2-ene but could not be hydrolysed. These included the products of hydrogenation e.g. 2-methylbutane, or hydration e.g. 2-methylbutan-2-ol. Consequently only the most able candidates achieved a mark in part (b), as this was essentially dependant on part (a).

Mark Scheme

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

Mark Scheme

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

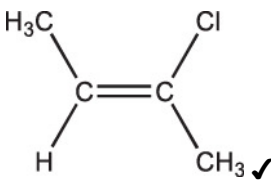
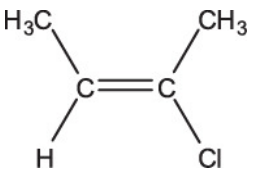
Mark Scheme

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

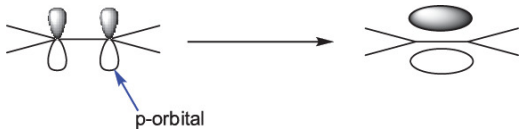
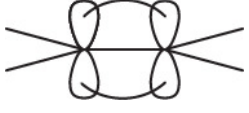
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
4			Acid ✓	1	ALLOW H^+ / named mineral acid / H_2SO_4 / H_3PO_4 DO NOT ALLOW 'weak acid' e.g. ethanoic acid IGNORE pressure IGNORE temperature Examiner's Comments This question was answered well and the majority of candidates identified a suitable catalyst for the hydration of an alkene. A common incorrect response was nickel.
			Total	1	

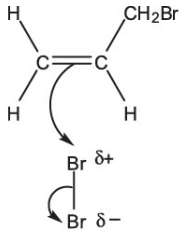
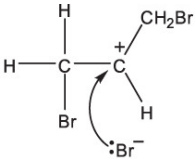
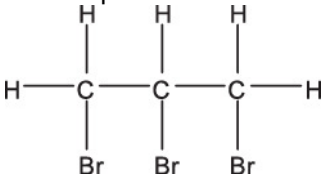
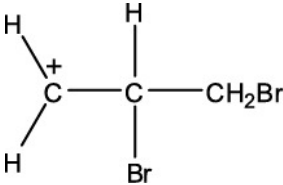
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
5	a		B ✓	1	ALLOW CF_2CF_2 OR C_2F_4 OR tetrafluoroethene Examiner's Comments The majority of candidates were able to identify B as the monomer required to make PTFE.
	b	i		1	ALLOW correct structural OR displayed OR skeletal OR mixture of the above ALLOW <i>E</i> isomer  Examiner's Comments The monomer of polymer H was correctly identified by the majority of the cohort. However, a small proportion of candidates simply drew the repeat unit of H.
		ii	HCL ✓	1	DO NOT ALLOW Cl_2 IGNORE names IGNORE nitrogen oxides / NO_x Examiner's Comments Most candidate were able to provide the formula of HCl. Common incorrect answers included C/O and Cl_2.
			Total	3	

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
6	a	 First mark diagram on left with p-orbitals labelled OR unlabelled diagram AND the statement: (sideways) overlap of p orbitals ✓ Second mark (labelled) diagram on right showing π-bond ✓	2	Note: A diagram is required for each mark DO NOT ALLOW C=C in one diagram but ALLOW ECF for subsequent use in another diagram. The bonds shown in the diagram are required ALLOW ECF for missing bonds in second diagram IGNORE any atoms joined to the bonds ALLOW a diagram where the p-orbitals are linked for second mark.  e.g. Examiner's Comments Most candidates produced reasonable diagrams to illustrate the formation of a π- bond. A common mistake was showing a C=C group rather a C—C bond in the centre of each structure. Omission of the peripheral bonds was also frequently seen. Although over half of the cohort received some credit in this part it was clear that many candidates found this question difficult. Only the most able scored both marks.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
b i	Curly arrow from double bond to Br of Br-Br ✓ Correct dipole shown on Br-Br AND curly arrow showing breaking of Br-Br bond ✓  Correct carbocation with + charge on C with 3 bonds AND curly arrow from Br⁻ to C⁺ of carbocation ✓  Correct product: ✓ 	4	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC Curly arrow must start from bond and go to correct atom DO NOT ALLOW any other partial charges e.g. shown on double bond ALLOW carbocation on terminal CH₂  DO NOT ALLOW $\delta+$ on C of carbocation. Curly arrow must come from a lone pair on Br⁻ OR from the negative sign of Br⁻ ion (then lone pair on Br⁻ ion does not need to be shown) Examiner's Comments There were many excellent attempts at this mechanism and it is clearly well understood by candidates at this level. Consequently the majority of candidates scored three or four marks. In some cases the placement of the curly arrow from the C=C group was the cause for a candidate to only score three marks. Curly arrows should be drawn accurately. Where an arrow is expected to come from a bond, candidates are encouraged to start the arrow touching the bond.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Electrophilic addition ✓	1	<u>Examiner's Comments</u> The name of this mechanism was also well known by most candidates.
	c	i	H ₂ AND Ni (catalyst) ✓	1	ALLOW name or formula for each IGNORE any stated temperature and pressure Examiner's Comments To score the mark in this question candidates had to state that both hydrogen and nickel were required for step 1. It was often the case that only one of these was stated. Although hydrogen was often seen as a reagent it was common to see an incorrect catalyst, such as H₂SO₄.

Mark Scheme

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

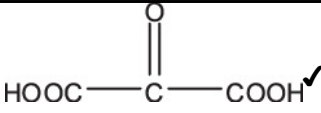
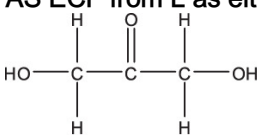
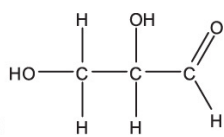
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	further substitution OR produces different termination products OR More than one termination step✓ substitution at different positions along chain ✓	2	IGNORE mixture of organic products (<i>in question</i>) ALLOW dichloro / multichloro / dibromo / multibromo compounds formed OR an example of a further substitution product OR an example of a different termination product ALLOW more than one hydrogen (atom) can be replaced ALLOW radicals react with each other to form other products ALLOW forms different structural isomers ALLOW a hydrogen (atom) on a different carbon (atom) can be replaced Examiner's Comments Candidates often found it difficult to provide clearly written explanations for this question. The majority of responses focused on further substitution or the idea of different termination steps. Only the best candidates recognised that chlorination of 1-bromopropane would produce a mixture of structural isomers.
			Total	15	

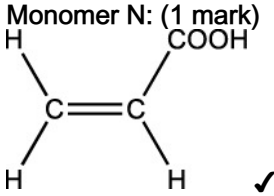
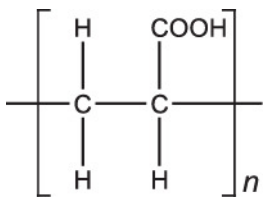
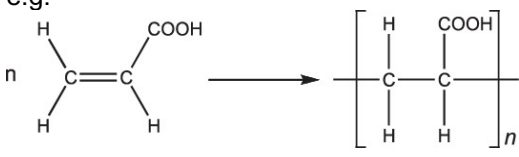
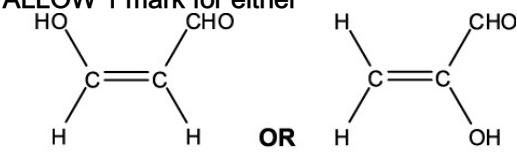
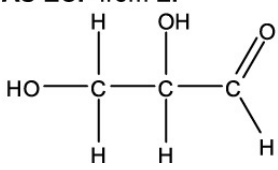
Mark Scheme

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

Mark Scheme

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

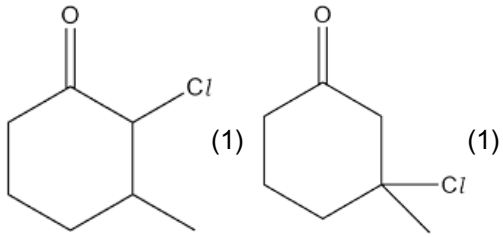
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Question	Answer/Indicative content	Marks	Guidance
c	Monomer N: (1 mark)  Polymer P: (1 mark) Section showing at least one repeat unit of a polymer formed from N with side links ✓ e.g.  Repeat units (1 mark) $n = 10000/72 = 139$ ✓ Equation (1 mark)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

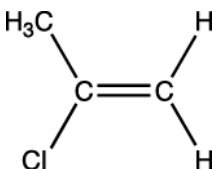
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					ALLOW use of calculated value for n in equation e.g. $139\text{C}_3\text{H}_4\text{O}_2 \rightarrow (\text{C}_3\text{H}_4\text{O}_2)_{139}$ Examiner's Comments This was a very demanding question and the strongest candidates were able to identify both N and P in addition to calculating the number of repeat units the polymer. However, not all included the polymerisation equation. Some candidates who were unable to deduce a correct structure for L in part (b) approached this part as a 'fresh start'. Using both the molecular formula from (a) and the information in the flowchart worked out the molecular formula of N and built a response from there.
			Total	12	
8			D	1	
			Total	1	
9			D	1	
			Total	1	

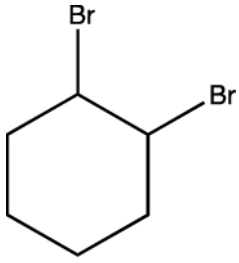
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
10		i		2	allow any unambiguous structure or formula. allow ecf on the second structure for hydrogen atom errors if candidate tries to convert to a displayed / structural formula, but the carbon skeleton must be correct.
		ii	correct structure of either possible carbocation intermediate shown (1) the tertiary halogenoalkane (which will be labelled as either product 1 or product 2) is identified as the one formed in greater amounts ... because the carbocation more stable on C3 than C2 <i>owtte</i> (1)	2	If both carbocations are drawn, only one needs to be correct to score the mark. allow ecf from (i) for correct justification of product formed in greater amount based on incorrect structures.
		iii	<i>Amount of D that reacts</i> $M(D: C_7H_{16}O) = 110 \text{ (g mol}^{-1}\text{)}$ AND $n(C_7H_{16}O) =$ $\frac{4.125}{110} =$ 0.0375 (mol) (1) <i>Masses of two products formed</i> $M(\text{product: } C_7H_{17}OCl) = 146.5 \text{ (g mol}^{-1}\text{)}$ AND Mass of 95% product = $0.0375 \times \frac{95}{100} \times 146.5 = 5.22 \text{ g}$ AND	2	

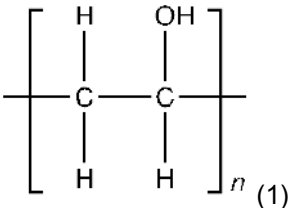
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Question			Answer/Indicative content	Marks	Guidance
		iii	$\text{Mass of 5\% product} = 0.0375 \times \frac{5}{100} \times 146.5 = 0.27 \text{ g (1)}$		allow mass of both products $= 0.0375 \times 146.5 = 5.49 \text{ g}$ Mass of 95% product = $\frac{95}{100} \times 5.49 = 5.22 \text{ g}$ Mass of 5% product = $\frac{5}{100} \times 5.49 = 0.27 \text{ g}$ allow 'product 1' and 'product 2' if linked to correct mass given labelling in (i) and reasoning in (ii) (allow ecf from (ii)).
			Total	6	
11		i	phosphoric acid / H_3PO_4	1	if both name and formula are given, the formula must be correct, but allow minor errors in an attempt at the name
		ii	(allows the reaction to proceed via a route with) lower activation energy ... (1) ... so that a greater proportion of molecules exceed the activation energy (1)	2	allow a sketch of an energy profile diagram as long as the catalysed and uncatalysed E_a are both labelled allow 'more molecules exceed the activation energy' allow a sketch of a Boltzmann distribution as long as both axes and both E_a values are labelled
			Total	3	
12		i	Structure of 2-chloropropene 	1	allow any unambiguous structure allow $\text{CH}_3\text{CCl}=\text{CH}_2$ (Double bond must be shown)
		ii	HC/ gas is passed through alkali / carbonate	1	
		iii	Reduces the dependency on finite resources OR Biodegradable OR Photodegradable	1	allow crude oil OR petroleum OR fossil fuels for 'finite resources' allow 'rots naturally'
			Total	3	

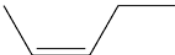
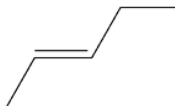
Mark Scheme

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

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
15	a	i	(because) molecule contains only single C–C bonds (1)	1	allow no multiple bonds / no double or triple bonds allow contains single bonds only
		ii	109.5°	1	
		iii	Combustion for energy production (alternative to fossil fuels) (1) Use as an organic feedstock (1)	2	
	b	i	 $\left[\begin{array}{cc} \text{H} & \text{OH} \\ & \\ -\text{C} & -\text{C}- \\ & \\ \text{H} & \text{H} \end{array} \right]_n \quad (1)$	1	
		ii	Evidence against ethenol: No infrared absorption between 3200 and 3600 cm⁻¹ from O–H (1) Evidence for isomer: Infrared absorption between 1640 and 1750 cm⁻¹ indicates C=O (1) Mass spectrum: fragmentation peak at m/z = 29 suggests CHO⁺ OR fragmentation peak at m/z = 15 suggests CH₃ (1) Identification: Ethanal / CH₃CHO (1)	4	ignore molecular ion peak at m/z confirms molecular mass of 44 g mol ⁻¹
			Total	9	

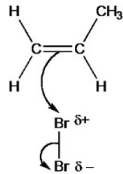
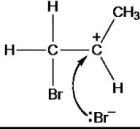
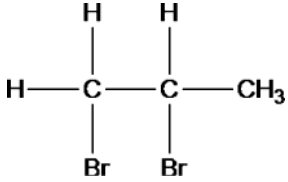
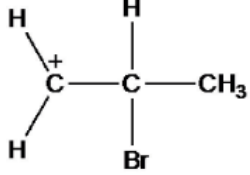
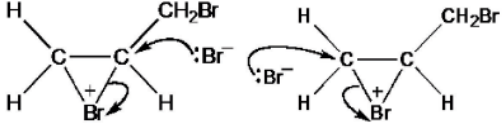
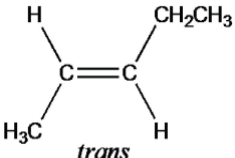
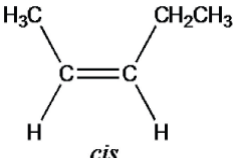
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
16	<i>* Please refer to the marking instruction point 10 for guidance on how to mark this question.</i> (Level 3) Applies knowledge of elimination reactions to provide the correct names and structures of all three alkenes. AND Full, detailed explanation of formation of both types of isomers linked to the reaction, with clear understanding of both types of isomerism. <i>The explanations show a well-developed line of reasoning which is clear and logically structured. The information presented is relevant to the compounds drawn / named.</i> (5–6 marks) (Level 2) Applies knowledge of elimination reactions to provide the correct name and structure for pent-1-ene. AND Correct structures of stereoisomers of pent-2-ene but full names missing or incorrect. AND Explanation of formation of at least one type of isomers in some detail. <i>The explanations show a line of reasoning presented with some structure. The information presented is in the most-part relevant to the compounds drawn / named.</i> (3–4 marks) (Level 1) Applies knowledge of elimination reactions to name and draw the structures of organic products. Either name OR structure should be correct for two compounds. AND Attempts to explain formation of one type of isomer.	6	Indicative scientific points may include: - the elimination can produce a double bond in either the 1- or the 2- position (through combination of the hydroxyl group with a hydrogen from either the 1st or the 3rd carbon) - this leads to the formation of structural isomers (pent-1-ene and pent-2-ene) - pent-2-ene exhibits stereoisomerism / <i>E/Z</i> isomerism / <i>cis-trans</i> isomerism because it has two different groups attached to each carbon atom - there are two possible isomers of pent-2-ene and three in total. Names and structures of alkenes  pent-1-ene  Z or <i>cis</i>-pent-2-ene  E or <i>trans</i>-pent-2-ene

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			<i>The information about isomerism is basic and communicated in an unstructured way. The relationship to the compounds drawn / named may not be clear.</i> (1–2 marks) (0 marks) No response or no response worthy of credit.		
			Total	6	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
17 a i	Curly arrow from double bond to Br of Br-Br (1) Correct dipole shown on Br-Br AND curly arrow showing breaking of Br-Br bond (1)  Correct carbocation with + charge on C with 3 bonds AND curly arrow from Br⁻ to C⁺ of carbocation (1)  Correct product: (1) 	4	Curly arrow must start from bond and go to correct atom do not allow partial charges on C=C bond allow carbocation on terminal CH₂  do not allow δ+ on C of carbocation Curly arrow must come from a lone pair on Br⁻ OR from the negative sign of Br⁻ ion (then lone pair on Br⁻ ion does not need to be shown) allow formation of bromonium intermediate and curly arrows, i.e.: 
	ii	1	allow movement of a lone pair
b	i	1	allow a stereoisomer must have 2 different groups attached to each carbon of the C=C double bond
	ii	2	allow correct skeletal OR displayed formula OR mixture but must clearly show arrangement around C=C  <i>trans</i> (1)  <i>cis</i> (1)

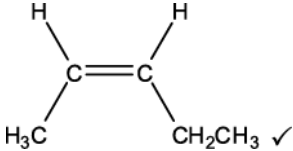
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c		<i>E</i> isomer AND F takes priority over the carbon on the left hand side (as it has a higher atomic number) AND CH ₂ OH takes priority over the CH ₃ group on the right hand side	1	<i>E</i> with no explanation is insufficient
			Total	9	

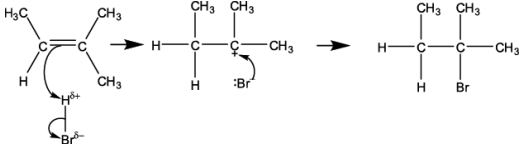
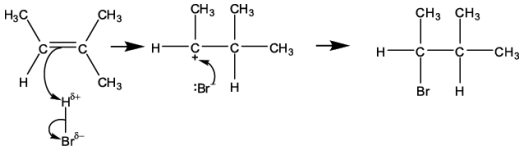
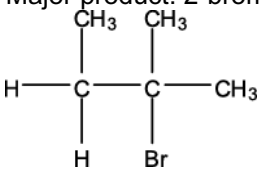
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
18	a	i	Any one from: • σ bond is between bonding atoms/nuclei AND π bond is above and below the bonding atoms / nuclei • σ bond has direct/head-on overlap of orbitals AND π bond has sideways overlap • π bond has a lower bond enthalpy / is weaker than a σ bond • σ bond has electron density between bonding atoms AND π bond has electron density above and below bonding atoms ✓	1	IGNORE the length of the σ bond and π bond IGNORE the type of orbital for σ bond Examiner's Comments The vast majority of candidates were unable to describe the difference between a σ and a π bond. The simplest answer was that the π bond was the weaker bond or the σ bond was the stronger. Many candidates attempted to describe how the two different bonds were formed. It was clear that candidates understood the concept of the sideways overlap of the p orbitals to form the π bond but were unable to describe the formation of the σ bond. A common misconception was that the σ bond could only be formed by the overlapping of the s orbitals. The best candidates were able to articulate that the σ bond results from the head on overlap of orbitals resulting in the bond forming directly between two atoms whereas the π bond results in the electron density being located above and below the plane of the bonding atoms.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	One carbon atom (in double bond) is attached to two groups which are identical / the same ✓	1	ALLOW - One carbon atom in (double bond) is not attached to (two) different groups/groups of atoms - Right-hand carbon is attached to two groups that are the same/two methyl groups. - Two groups are the same on right-hand side - Three groups are the same (on the double bond) DO NOT ALLOW - Two groups on the same side of the double bond <i>Must be right-hand side; Same side could be top or bottom</i> - Functional groups OR molecules for groups Examiner's Comments This question required candidates to apply their knowledge of <i>E/Z</i> isomerism to suggest why compound A did not have <i>E/Z</i> isomers. Whilst it was clear that many candidates understood the concept of <i>E/Z</i> isomerism many found it difficult to apply this concept and articulate an explanation.
		iii	 ✓	1	Mark Independently ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous ALLOW C₂H₅ for CH₂CH₃ IGNORE connectivity of alkyl groups BUT DO NOT ALLOW –CH₃CH₂
		iii	(Z-)pent-2-ene ✓	1	DO NOT ALLOW trans-pent-2-ene Examiner's Comments Most candidates were able to draw the structural isomer of compound A and provide a suitable name.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
b	<i>Please refer to marking instructions on page 4 of mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) A comprehensive description with all three scientific points explained thoroughly. <i>There is a well-developed and detailed description of the mechanism, including correct structures, accurately drawn curly arrows and using charges and dipoles consistently. Candidates compare tertiary and secondary carbocation stability to justify major product.</i> Level 2 (3–4 marks) Attempts to describe all three scientific points but explanations may be incomplete. OR Explains two scientific points thoroughly with no omissions. <i>The description has some structures with reasonably accurate curly arrows and some charges and dipoles identified.</i> Level 1 (1–2 marks) A simple description based on at least two of the main scientific points OR Explains one scientific point thoroughly with few omissions. <i>The description is communicated in an unstructured way, including some use of curly arrows, charges or dipoles.</i> 0 marks No response worthy of credit.	6	Throughout: ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above if unambiguous Indicative scientific points 1. Two possible products of reaction $\text{CH}_3\text{C}(\text{CH}_3)\text{BrCH}_2\text{CH}_3$ $\text{CH}_3\text{CHBrCH}(\text{CH}_3)\text{CH}_3$ IGNORE names where correct structures are present 2. Mechanism for formation of either product. Curly arrow from $\text{C}=\text{C}$ to attack the H atom of the HBr Correct dipole on H–Br Curly arrow from H–Br bond to Br Carbocation with full positive charge on carbon atom Curly arrow from negative charge on Br^- or lone pair on Br^- to carbon atom with positive charge  or  3. Major organic product Major product: 2-bromo-2-methylbutane 

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					Major product is formed from the most stable carbocation intermediate OR –Br is attached to carbon atom with the least hydrogens attached OR the carbon with the most –CH₃ groups attached OR the –H is attached to the carbon atom with most hydrogens attached Examiner's Comments The first of the six mark level of response questions required candidates to draw the mechanism of electrophilic addition, outline the two possible products and explain which one of these products would be the most likely to be formed. The most common mark for this question was five marks mainly due to candidates not being able to explain the formation of the major product in terms of the formation of the more stable tertiary carbocation in the intermediate stage of the mechanism. Candidate scoring five marks frequently quoted Markownikoff's rule as an explanation. Varying degrees of competence was displayed in the production of the mechanism. The correct positioning of curly arrows was a skill that the most candidates had clearly mastered with many accurate mechanisms being submitted. Weaker candidates clearly need more time to develop these skills.
			Total	10	
19			B	1	Examiner's Comments Candidates struggled with this very different polarity question. The majority of candidates are clearly used to applying symmetry to much simpler molecules.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
20			D	1	<u>Examiner's Comments</u> B was a common incorrect answer with the sigma bond not counted as part of a double bond.
			Total	1	
21			B	1	<u>Examiner's Comments</u> Generally scored well.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
22	a	i	Alkene AND C_nH_{2n} ✓	1	IGNORE branched before alkene <u>Examiner's Comments</u> This part was answered very well. Most candidates identified Compound B as a member of the alkenes and showed the correct general formula of C_nH_{2n}.
		ii	Hydrogen/ H_2 AND Ni (catalyst) ✓	1	ALLOW Pt OR Pd OR Rh ALLOW hydrogenation for hydrogen IGNORE any temperature and pressure stated <u>Examiner's Comments</u> A surprisingly large number of candidates answered this part poorly. Many candidates identified either hydrogen or nickel, but not both. Other common errors included steam and H_3PO_4. This was an easy question and the incorrect answers reflected that many candidates had not learnt organic reagents and conditions for the reactions in the specification.

Mark Scheme

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

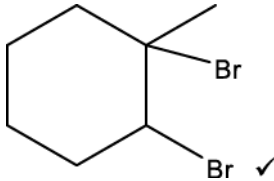
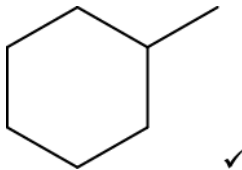
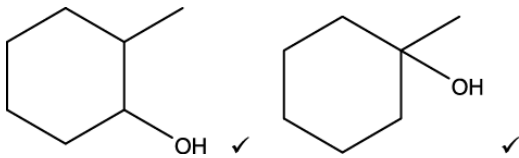
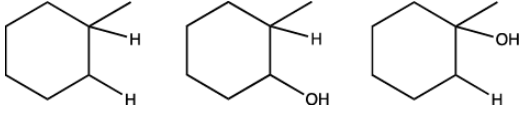
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	i	C_2H_5O ✓	1	ALLOW elements in any order DO NOT ALLOW any other answer <u>Examiner's Comments</u> This part was answered well by most candidates. Some candidates however wrote the molecular rather than the empirical formula, or attempted to show the empirical formula as C_2H_4OH instead of C_2H_5O.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Compound E: $ \begin{array}{c} \text{H} \quad \text{CH}_3 \\ \quad \\ \text{Br}-\text{C}-\text{C}-\text{Br} \\ \quad \\ \text{H} \quad \text{CH}_3 \end{array} \quad \checkmark $ Stage 1: Compound E: Bromine/Br₂ ✓ Stage 2: NaOH/KOH OR OH⁻ ✓ <i>Only award if intermediate contains at least one halogen atom</i>	3	For structures: ALLOW correct structural OR skeletal OR displayed formula OR mixture of the above ALLOW dichloro/diiodo compound IGNORE connectivity of bonds to CH₃ ALLOW chlorine/Cl₂ OR iodine/I₂ IGNORE conditions, e.g. u.v. DO NOT ALLOW H₂O IGNORE conditions NOTE: Max of 2 marks available for monobrominated intermediate 1 mark Reagent: HBr AND Intermediate: CH₃C(CH₃)₂Br OR BrCH₂CH(CH₃)₂ 1 mark Intermediate: CH₃C(CH₃)₂Br OR BrCH₂CH(CH₃)₂ AND Reagent: NaOH <u>Examiner's Comments</u> This demanding part was answered poorly by weaker candidates and was good for differentiating higher ability candidates. The mark scheme allowed some credit for using a hydrogen halide to obtain a monosubstituted haloalkane for compound E. Surprisingly, reaction mechanism names were often given instead of reagents. Many candidates seemed to guess, sometimes showing the same reagents for both stages in the hope of getting a mark. Many showed an intermediate containing no halogen atom.
			Total	8	

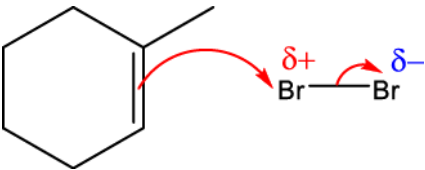
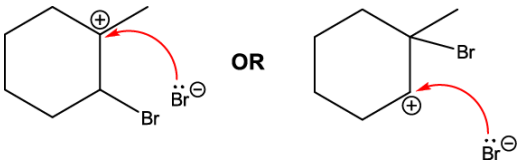
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
23	i Product from Br₂  Product from H₂/Ni  Mixture of isomers from H₂O 	4	ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above IGNORE names WATCH for missed methyl stick ALLOW added H shown, i.e.  ALLOW in either order Examiner's Comments Most of the candidates were able to show correct structures for all four organic products. The majority of these candidates used skeletal formulae. A small proportion of responses included incomplete structures. These included a missing Br atom on the product from the reaction of compound A with Br₂ or a missing methyl group. Candidates should be advised to check structures carefully, especially when using skeletal formulae.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Steam OR temperature $\geq 100^{\circ}\text{C}$ ✓ acid (catalyst) ✓	2	ALLOW $\text{H}_2\text{O}(\text{g})$ IGNORE pressure IGNORE High temperature / reflux ALLOW H^+ / named mineral acid / H_2SO_4 / H_3PO_4 DO NOT ALLOW 'weak acid' e.g. ethanoic acid Examiner's Comments Most candidates were able to state that an acid catalyst was required for the reaction of compound A with H_2O. However, although many candidates recognised the need for the reaction to be heated only the strongest responses referred to temperatures above 100°C. It was not uncommon to see vague responses that simply referred to a high temperature. Candidates should be encouraged to give precise conditions for the hydration reaction of an alkene.

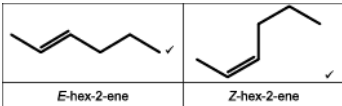
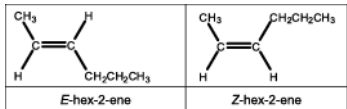
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
iii	Curly arrow from double bond to Br of Br-Br ✓ Correct dipole shown on Br-Br AND curly arrow showing breaking of Br-Br bond ✓  ----- Correct carbocation with + charge on C AND curly arrow from Br⁻ to C⁺ of carbocation ✓  Note: '+' and '-' are fine for charge (circles used for clarity)	3	ANNOTATE ANSWER WITH TICKS AND CROSSES Curly arrow must start from bond and go to correct atom DO NOT ALLOW any other partial charges e.g. shown on C=C bond DO NOT ALLOW δ+ on C of carbocation. IF C atoms are displayed IGNORE missing bonds to H atoms Curly arrow must come from a lone pair on Br⁻ OR from the negative sign of Br⁻ ion (then lone pair on Br⁻ ion does not need to be shown) Examiner's Comments The mechanism of the reaction of compound A with Br₂ was well known and consequently the majority of candidates scored all three marks. A common reason for scoring only two marks was inaccurate placement of the curly arrow from the bromide ion to the carbocation intermediate. This arrow should start from either a lone pair or the minus sign of the bromide ion.

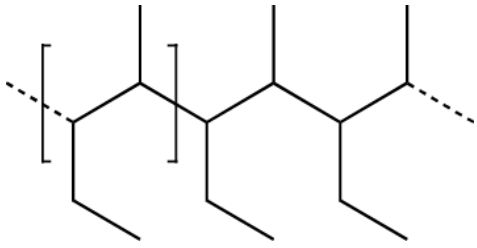
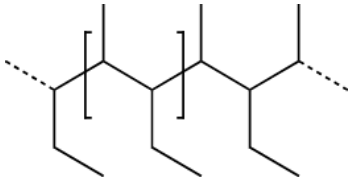
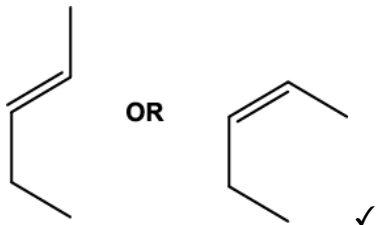
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	electrophilic addition ✓	1	Examiner's Comments Most of the candidates were able to name the mechanism correctly. However it was not uncommon to see incorrect responses which included electrophilic substitution and nucleophilic addition.
			Total	10	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
24	a	i		2	ALLOW 1 mark if skeletal formulae of both <i>E</i> and <i>Z</i> hex-2-ene are shown but in the incorrect columns IF correct unambiguous structural OR displayed OR mixture of formulae are shown ALLOW 1 mark if both stereoisomers are in the correct columns e.g the following scores 1 mark  IF the skeletal formula of <i>E</i> hex-3-ene is shown in the first box ALLOW 1 mark for the skeletal formula of <i>Z</i> hex-3-ene as ECF Examiner's Comments It was anticipated that most candidates would be able to provide the skeletal formulae for the <i>E</i> and <i>Z</i> isomers of hex-2-ene but this proved not to be the case. A large number of responses displayed the C=C group and gave structural formulae for the side chains, while others confused <i>E</i> and <i>Z</i>, placing the isomers in the incorrect columns. A number of candidates opted to use an ambiguous formula and it was not uncommon to see C₃H₇ attached to a C=C group. Candidates should be made aware of the importance of showing each C atom when a question requires structural detail.
		ii	(carbon-carbon) double bond does not rotate OR has restricted rotation ✓ Each carbon atom of the double bond attached to (two) different groups / atoms ✓	2	Examiner's Comments Most candidates recognised that the C=C group had restricted rotation which resulted in <i>E/Z</i> isomerism. However, many struggled to explain that each C atom in the C=C group was bonded to different groups with sufficient clarity.

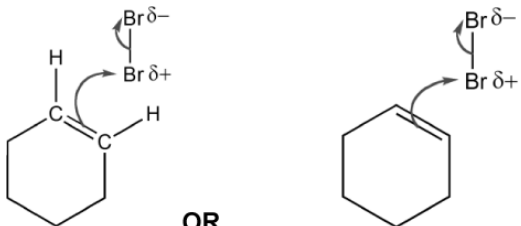
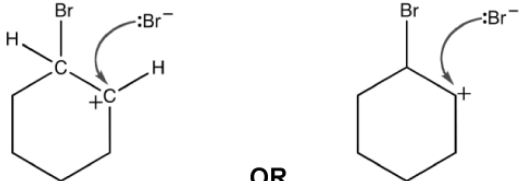
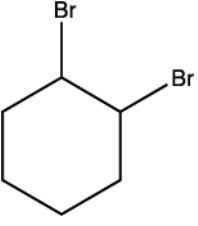
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b	i	 One repeat unit shown ✓ (could be any of the three repeat units shown)	1	ALLOW repeat unit at any point along the section provided that it works, e.g.  Examiner's Comments The majority of candidates were able to use brackets to show the repeat of the polymer shown. A number of candidates placed brackets inaccurately, often intersecting carbon atoms in the backbone.
		ii	Structure of pent-2-ene: 	1	ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous) Examiner's Comments Candidates found this part more difficult than part (c)(i). Many candidates correctly drew the structure of pent-2-ene as hydrocarbon B but a wide range of other responses was seen. Two common incorrect responses were the structures of either 2-methylpent-2-ene or 2-methylpentane.
		iii	(50,000/70 =) 714 OR 715 ✓	1	MUST be a whole number Examiner's Comments Many candidates were able to use the repeat unit identified in (c)(i) or the monomer in (c)(ii) to determine the number of monomer molecules in the polymer.
			Total	7	

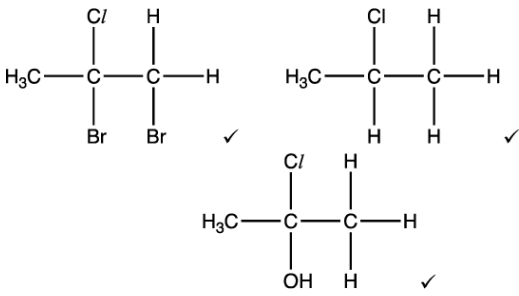
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
25			A	1	Examiner's Comments Candidates found this question challenging, with only the more able candidates obtaining the correct alcohol. Answer option C was a common incorrect answer.
			Total	1	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
26	Curly arrow from double bond to Br of Br-Br ✓ Correct dipole shown on Br-Br AND curly arrow showing breaking of Br-Br bond ✓  OR Correct carbocation with + charge on C with 3 bonds AND curly arrow from Br⁻ to C⁺ of carbocation ✓  OR Correct product:  ✓	4	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC Curly arrow must start from bond and go to correct atom DO NOT ALLOW any other partial charges e.g. shown on double bond DO NOT ALLOW missing H on displayed formulae (penalise once only) DO NOT ALLOW δ^+ on C of carbocation. Curly arrow must come from a lone pair on Br⁻ OR from the negative sign of Br⁻ ion (then lone pair on Br⁻ ion does not need to be shown) IGNORE wording if diagrams are correct Maximum of two marks for mechanism based on incorrect structure of cyclohexene Examiner's Comment: The precise setting out of a reaction mechanism was a skill that a good number of candidates have mastered with many accurate mechanisms being drawn. Others need more time to develop these skills; many errors being made with the position of dipoles and curly arrows. Despite making errors in the mechanism, many achieved one mark for drawing a correct final structure.
	Total	4	

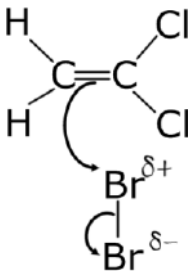
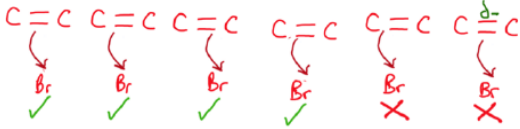
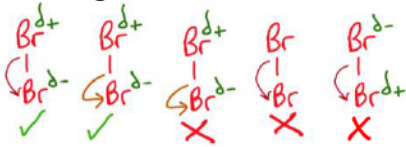
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
27	a	i		3	ALLOW structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous) For connectivity, ALLOW $\begin{array}{c} \\ \text{OH} \end{array}$ $\begin{array}{c} \\ \text{CH}_3 \end{array}$ CH_3- $\text{C}_3\text{H}-$ DO NOT ALLOW $\text{OH}-$ Examiner's Comments This part was generally well answered with the majority of candidates scoring two or three marks. The most common errors were the omission of the C/atom from each structure, or identifying the minor product instead of the major product from the reaction with steam. For addition products of an alkene, candidates are advised to copy the alkene but with a single rather than a double bond, then to add the reagent across where the double bond was. This might have prevented the omission of the C/atom on so many of the structures seen.
		ii	$\text{H}^+/\text{acid}/\text{H}_2\text{SO}_4/\text{H}_3\text{PO}_4$ ✓	1	ALLOW HCl IGNORE (aq) OR 'dilute' OR concentrated Examiner's Comments Most candidates correctly identified an acid catalyst, with the most common response being phosphoric acid. Common mistakes were nickel, zinc and acidified dichromate.

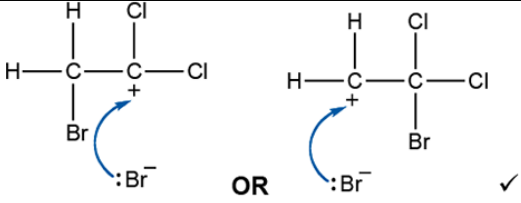
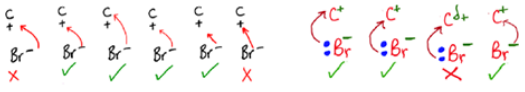
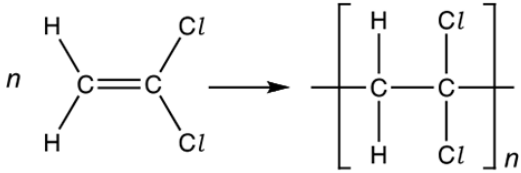
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b	i	$n \begin{array}{c} \text{Cl} \quad \text{H} \\ \diagdown \quad / \\ \text{C} = \text{C} \\ / \quad \diagdown \\ \text{H}_3\text{C} \quad \text{H} \end{array} \longrightarrow \left[\begin{array}{cc} \text{Cl} & \text{H} \\ & \\ -\text{C} & - & \text{C}- \\ & \\ \text{CH}_3 & \text{H} \end{array} \right]_n$ Correct repeat unit (<i>n</i> and brackets not required) ✓ Equation balanced with <i>n</i> ✓ TAKE CARE of '<i>n</i>' position on both sides of equation.	2	For monomer, ALLOW correct molecular OR structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous) For repeat unit, DO NOT ALLOW molecular formula NOTE: 'side bonds' ARE required on either side of repeat unit from C atoms ALLOW section of polymer containing more than one repeat unit NO ECF from incorrect repeat unit Examiner's Comments The majority of candidates correctly drew the repeat unit but only a few wrote a full equation, balanced with <i>n</i>. The most common error was omission of the '<i>n</i>' before the monomer. Candidates are reminded of the importance of balancing equations.
		ii	Formation of HCl/hydrochloric acid/ OR chlorine ✓	1	ALLOW Cl or Cl₂ for chlorine IGNORE toxic waste products <i>Response must reflect chlorine in some way</i> Examiner's Comments Most candidates realised that the combustion would produce toxic/harmful gases, but the majority either incorrectly identified the problem gas as CO₂/CO or did not identify the gas at all. Others referred to ozone damage and global warming. Good responses referred to the formation of chlorine compounds such as hydrogen chloride.
			Total	7	

Mark Scheme

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28	a		steam AND Acid/H ⁺ (catalyst) ✓	1	Examiner's Comments Many candidates knew the answer to this question but forgot that water must be in the gaseous state. There were numerous responses stating nickel as the catalyst, but most knew that an acid catalyst was required.
	b	i	1,2-dibromo-1,1-dichloroethane✓	1	Examiner's Comments This question was generally well answered, although some candidates made careless mistakes such as not writing -di or writing 1,2-dibromo-1-dichloroethane
		ii	 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	3	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC 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 $\delta^+ \text{Br} - \delta^-$ bond • AND go to δ^-  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⁻

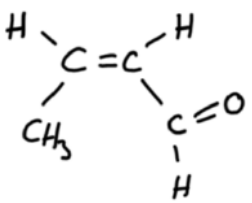
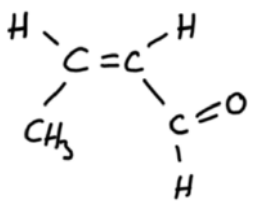
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
	 <i>i.e. ALLOW carbonium + on either C atom</i> 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[–]) <u>Examiner's Comments</u> Many candidates gained all three marks on this question and the diagrams were clear and easy to read. Lower ability candidates had incorrect dipoles or curly arrows that could not be traced back to the correct origin. Candidates should be encouraged to consider what the arrows mean rather than memorising mechanisms with no understanding.
c i	 Correct polymer with side links and brackets ✓ Equation balanced with <i>n</i> ✓ TAKE CARE of '<i>n</i>' position on both sides of equation.	2	For repeat unit, - displayed formula required 'side bonds' required on either side of repeat unit from C atoms ALLOW section containing more than one repeat unit DO NOT ALLOW ECF from incorrect repeat unit <i>n</i> on LHS at any height to the left of the formula <i>n</i> on RHS must be subscript <u>Examiner's Comments</u> Most candidates correctly drew the repeat unit and were credited with one mark, but many placed the <i>n</i> position in the wrong place on the left-hand side of the equation or forgot to write it in at all.

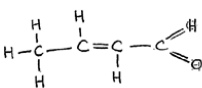
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Advantage (1 mark) Energy production / (energy) used to produce electricity ✓ Disadvantage (1 mark) Formation of HCl/products of combustion cause acid rain OR Formation of CO₂/gases that cause global warming / greenhouse gases OR Formation of CO ✓	2	ALLOW reduced use of fossil fuels ALLOW less landfill / less harm to wildlife ALLOW chlorine/Cl OR Cl₂ ALLOW toxic/poisonous waste products <u>Examiner's Comments</u> With all the media interest in plastic pollution this question was answered well, although many gave the answer 'quick and efficient' as an advantage which was not credited. Candidates should beware of vague statements such as these. Many wrote 'harmful' instead of toxic, or 'bad for the environment' instead of being specific about the environmental issue.
			Total	9	

Mark Scheme

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

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

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance									
					Exemplar 6 Explain your reasoning and show your working. <table><tr><td>C</td><td>H</td><td>O</td></tr><tr><td>68.6</td><td>8.6</td><td>22.8</td></tr><tr><td><u>2</u></td><td><u>1</u></td><td><u>16</u></td></tr></table> = 9.76 : 8.6 : 1.425 = 4.0 : 6.0 : 1 empirical formula = C₄H₆O Mr : (12 × 4) + (6 × 1) + (16) = 70 F Mr = 70 → molecular formula = C₄H₆O Peak at 2.9 → CH₂=CH } mass spectrum. Peak at 41 → H₂C=CH₂CH₂S IR Spectrum → Peak at 1630-1820 indicates the presence of a C=O group → Peak at 1620 → 1630 indicates the presence of a C=C group. Structure = Like most candidates, the crucial information about F being a <i>trans</i> isomer was not picked up so they drew the double bond in the wrong place.	C	H	O	68.6	8.6	22.8	<u>2</u>	<u>1</u>	<u>16</u>
C	H	O												
68.6	8.6	22.8												
<u>2</u>	<u>1</u>	<u>16</u>												
			Total	6										
30			D	1	Examiner's Comments Most candidates chose the correct option of D but a sizeable number chose B and C, the other options containing a '2' in their names. The best strategy here is to draw out the carbon skeleton of pent-2-ene from which it is clear that bromine atoms must be added at carbon positions 2 and 3.									
			Total	1										

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
31			C	1	Examiner's Comments This was a difficult question but higher ability candidates selected the correct option of C. The main discriminator was B, which identifies the 1 double bond as Z. CIP analysis is required to show that the double bond is E. This is a good 'hard' example for illustrating E/Z isomerism.
			Total	1	
32			A	1 (AO1.1)	Examiner's Comments Candidates answered this question well with over two-thirds choosing the correct option A. Option D was the most common incorrect response suggesting that candidates are uncertain about the nature of a C=C double bond.
			Total	1	
33			A	1 (AO1.1)	
			Total	1	
34			C	1 (AO1.2)	Examiner's Comments This part discriminated well. Although most candidates did select C as the correct structure, many were diverted into selecting option D, the other alternative containing a double C=C bond. In identifying a monomer for an addition polymer, candidates are advised to identify the repeat unit and then to replace the single C–C bond with a double bond to give the monomer.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
35		i	Product with H₂ <pre> H H H H H H H — C — C — C — C — C — C — H H H H H H H </pre> Product with HCl <pre> H H H H H H H — C — C — C — C — C — C — H H H H H Cl H </pre> Product with Br₂ <pre> H H H H H H H — C — C — C — C — C — C — H H H H H Br Br </pre>	3(AO1.2x3)	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous ALLOW part molecular formulae but not full <u>Examiner's Comments</u> Most candidates answered this question well and achieved full marks. The most common errors were to put the chlorine on the wrong carbon, or to put both bromines on the same carbon.
		ii	Nickel/Ni ✓	1(AO1.2)	ALLOW Pt OR Pd OR Rh <u>Examiner's Comments</u> Most candidates correctly stated nickel, although it was spelled incorrectly a lot of the time, which was ignored. "Acid" was the most common incorrect answer
		iii	(orange to) colourless OR bromine is decolourised ✓	1(AO1.2)	ALLOW 'it decolourises / turns colourless' IGNORE colour change <u>Examiner's Comments</u> Many candidates wrote the colour change the wrong way around, or thought that a gas would be evolved, or wrote "clear" instead of "colourless". A large proportion merely stated what type of reaction it was, rather than what they would observe.
			Total	5	