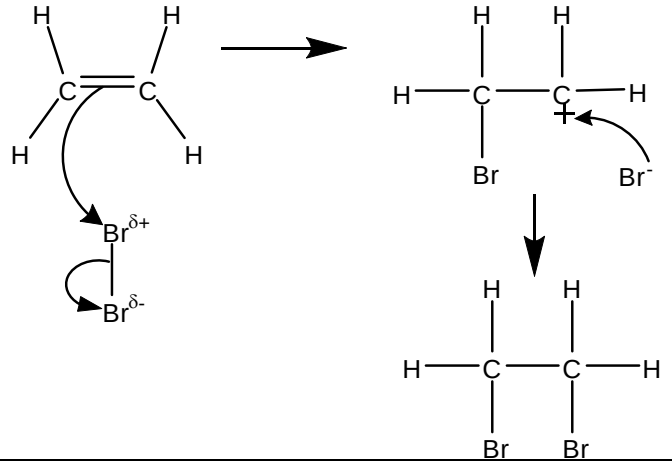
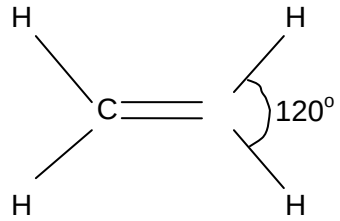
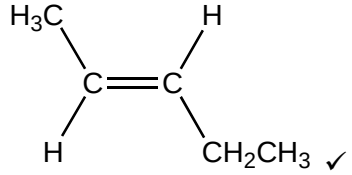
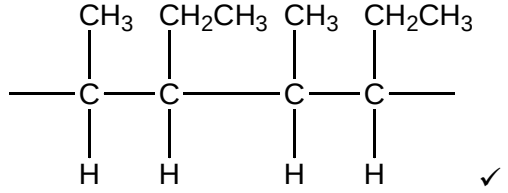
Question			Answer	Marks	Guidance
1	(a)		Because hydrocarbons have different boiling points ✓	1	**ALLOW** each fraction / component / substance / molecule / compound / fuel has a different boiling temperatures **ALLOW** condense at different temperatures **ALLOW** because van der Waals' forces differ with molecular size **IGNORE** references to volatility different strength of intermolecular forces is **not** sufficient
	(b)		***Any one from:*** Bio-fuels produce less carbon dioxide (overall) **OR** petrol or diesel produce more carbon dioxide (overall) ✓ Bio-fuels are renewable **OR** petrol and diesel are non-renewable ✓ Allows crude oil to be used to make other products **OR** petrochemicals (rather than petrol) **OR** Save crude oil **OR** no risk of large scale pollution from exploitation of crude oil ✓	1	**ASSUME** 'they' or 'it' refers to biofuels **ALLOW** bio-fuels are (more) carbon-neutral **OR** plants take up the carbon dioxide released during combustion **ALLOW** lower carbon footprint **ALLOW** plants are a renewable resource / crude oil non-renewable resource / bio-diesel is more sustainable / diesel is not sustainable / petrol and diesel are made from a finite resource / petrol and diesel will run out / bio-fuels will not run out **ALLOW** decrease the need for fossil fuels **IGNORE** can be used by diesel powered cars with or without any conversion
	(c)	(i)	Idea that **carbon–carbon** bonds can break anywhere ✓	1	The answer must refer to carbon–carbon bonds or the carbon chain **ALLOW** (carbon) **chain** can break anywhere Bonds can break anywhere is not sufficient

Question			Answer	Marks	Guidance
1	(c)	(ii)		4	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC**
			Correct identification of $C_2H_3^+$ for m/z = 27 ✓		**ALLOW** $CHCH_2^+$ **DO NOT ALLOW** C_2H_3 (the positive charge is essential) **OR** CCH_3^+
			Some indication to explain how the identity of propene was deduced **OR** further analysis of the mass spectrum ✓		**ALLOW** Molecular ion/M^+/M is m/z = 42 **OR** m/z = 15 is CH_3 **ALLOW** mass spectrum shows M_r = 42 **ALLOW** idea that alkane $C_{12}H_{26}$ – C_3H_8 can only give $3C_3H_6$
			Correct identification of the alkene as C_3H_6 **OR** propene ✓		**ALLOW** prop-1-ene An incorrect formula for the alkene in the equation will not contradict this answer
			$C_{12}H_{26} \rightarrow C_3H_8 + 3C_3H_6$ ✓		**ALLOW** C_3H_6 from its use in an equation even if the equation is wrong providing there has not been an attempt elsewhere to identify the alkene **ALLOW** correct displayed **OR** structural **OR** skeletal **OR** molecular formulae in the equation

Question			Answer	Marks	Guidance
1	(d)			9	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **ALLOW** reactants even from incorrect equations **ALLOW** reactants or conditions over the arrow
			React with bromine **OR** $C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$ ✓		**ALLOW** Br_2 mark from the mechanism even if the mechanism is incorrect **IGNORE** conditions unless they would lead to a different reaction with ethene
			React with hydrogen bromide **OR** $C_2H_4 + HBr \rightarrow C_2H_5Br$ ✓		**IGNORE** conditions unless they would lead to a different reaction with ethene
			React with steam **OR** heat with water **OR** $C_2H_4 + H_2O(g) \rightarrow C_2H_5OH$ ✓		**ALLOW** temperature range between 100–400 ^oC if quoted **IGNORE** reference to pressure **IGNORE** hydrolysis Hydration is not sufficient but **DO NOT ALLOW** hydrogenation
			acid (catalyst) ✓		**ALLOW** H_2SO_4 **OR** H_3PO_4 **OR** H^+ **DO NOT ALLOW** HC*l*, HBr etc. **ALLOW** two stage process e.g. react with HBr one mark followed by KOH(aq) one mark

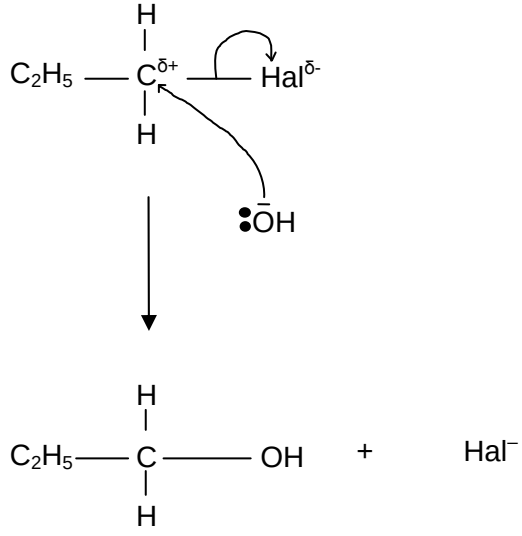
Question	Answer	Marks	Guidance
	Electrophilic addition ✓ Curly arrow from double bond to attack $Br^{\delta+}$ of Br–Br and breaking of Br–Br bond ✓ Correct dipoles shown on $Br^{\delta+}$–$Br^{\delta-}$ ✓ Correct carbonium / carbocation ion drawn ✓ Curly arrow from Br^- to the carbonium ion **and** correct product shown ✓ 		Curly arrow must start from the double bond and not a carbon atom and go the $Br^{\delta+}$; other curly arrow must start from Br–Br bond. **ALLOW** attack of Br–Br if dipoles not shown **DO NOT ALLOW** attack of $Br^{\delta-}$ Dipole must be partial charge and not full charge **DO NOT ALLOW** any other partial charges eg on the double bond Carbocation needs a full charge and not a partial charge (charges do not need to be surrounded by a circle) All atoms in the carbocation must be shown Br^- curly arrow must come from one lone pair on Br^- ion **OR** from minus sign on Br^- ion Lone pair does not need to be shown on Br^- ion **ALLOW** mechanism which goes via a cyclic bromonium ion instead of the carbocation **SEE EXTRA ADVICE ABOUT CURLY ARROWS ON PAGE 30**

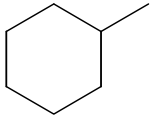
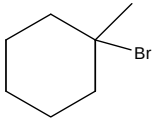
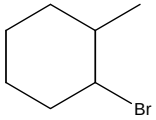
Question			Answer	Marks	Guidance
1	(e)		Correct shape ✓  120° ✓ Three areas of electron density repel each other ✓	3	**IGNORE** any name of shape given **ALLOW** 115–125° **ALLOW** even if it is the C–C–H shown on a diagram. **ALLOW** three or four electron pairs repel **OR** three or four bonds repel **IGNORE** does not have any lone pairs **DO NOT ALLOW** atoms repel / electrons repel **DO NOT ALLOW** has lone pair which repels more
	(f)	(i)	 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous)
		(ii)	 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** CH_3 and C_2H_5 groups above or below chain **ALLOW** bond to ethyl and methyl group to any part of ethyl or methyl group **IGNORE** any brackets drawn **ALLOW two** or more repeat units but has to have a whole number of repeat units (*ie* does not have to be two) 'End bonds' **MUST** be shown and can be dotted **IGNORE** *n*
			Total	**21**	

Question			Answer	Mark	Guidance
2	(a)		$\text{Atom economy} = \dfrac{\text{sum of (all) } M_r \text{ of desired product(s)}}{\text{sum of (all) } M_r \text{ of (all) products}}$ ✓	1	**ALLOW** $\text{Atom economy} = \dfrac{\text{sum of (all) } M_r \text{ of desired product(s)}}{\text{sum of (all) } M_r \text{ of (all) reactants}}$ **ALLOW** for the numerator: 'sum of' to be crossed out and replaced by 'molecular mass of the desired product(s)' **ALLOW** for the denominator: 'sum of molecular masses of all products'
	(b)	(i)	Process **5** ✓	1	**ALLOW** $C_8H_{18} \rightarrow C_2H_4 + C_6H_{14}$
		(ii)	Process **1** ✓	1	**ALLOW** $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3 \rightarrow (CH_3)_2CHCH_2CH_2CH(CH_3)_2$
		(iii)	Process **2** ✓ water is a waste product ✓	2	**ALLOW** $CH_3CH_2OH + CH_3COOH \rightarrow CH_3COOCH_2CH_3 + H_2O$ **ALLOW** it is a condensation reaction **ALLOW** water is a by-product / water is a non-desirable product **ALLOW** process 2 has an 83% atom economy **IGNORE** it forms more than one product / it forms a waste product
	(c)	(i)	Less waste products **OR** better sustainability **OR** get 100% atom economy ✓ (Stops) greenhouse gas emitted **OR** (stops) gas that (may) cause global warming ✓	2	**ALLOW** no waste products / there is no longer a waste product **ALLOW** increase atom economy

Question			Answer	Mark	Guidance
	(c)	(ii)	High percentage yield with a simple reason e.g. because the aim is to manufacture ethanol; to reduce waste; increases sustainability ✓ **BUT** High percentage yield because there is very efficient conversion from **reactant** to product **OR** to reduce the waste of **starting** materials ✓✓ **OR** High atom economy with a simple reason e.g. because it is cheaper or makes less harmful products; to reduces waste; increases sustainability ✓ **BUT** High atom economy to reduce the amount of waste **products** **OR** less **by products** **OR** more desired **product** ✓✓	**2**	No marks for just percentage yield or for atom economy. Marks are for the quality of the explanation Marks are awarded as follows **One** mark – a simple reason that is not fully correct whether a choice has been made or not **Two** marks – a choice must be made and the reason must be correct
			Total	**9**	

Question			Answer	Mark	Guidance
3	(a)		Compound of hydrogen and carbon only ✓	1	**ALLOW** contains hydrogen and carbon only **DO NOT ALLOW** 'it contains hydrogen and carbon' **DO NOT ALLOW** a mixture of hydrogen and carbon only
	(b)		**F** ✓	1	**ALLOW** cyclobutane
	(c)		$C_5H_{10}O$ ✓	1	**ALLOW** any order **IGNORE** structural or displayed formula
	(d)		**D** and **E** **OR** **F** and **G** ✓	1	**ALLOW** pentanal and pentan(-3-)one **ALLOW** cyclobutane and but(-2-)ene Award mark if both pairs are given
	(e)	(i)	Tetrahedral ✓ Four (single) bonds (around carbon atom) **OR** four (single) bond pairs (around carbon atom) **OR** (carbon) bonded to four groups ✓	2	**IGNORE** incorrect bond angle If shape is not given, explanation mark **can** be credited If shape is incorrect, explanation mark **cannot** be credited
		(ii)	Trigonal planar ✓	1	**ALLOW** planar triangle **IGNORE** if incorrect bond angle is stated
	(f)	(i)	**G** ✓	1	**ALLOW** but-2-ene
		(ii)	Non rotating (carbon–carbon) double bond ✓ Each carbon atom of the double bond attached to (two) different groups/atoms ✓	2	

Question	Answer	Mark	Guidance
(g)	**Equation** $C_3H_7X + KOH \rightarrow C_3H_7OH + KX$ **OR** $C_3H_7X + OH^- \rightarrow C_3H_7OH + X^-$ ✓ **Structure of product** $CH_3CH_2CH_2OH$ ✓ **Reaction mechanism** QWC - nucleophilic substitution ✓ dipole shown on C–Hal bond, $C^{\delta+}$ and $Hal^{\delta-}$ ✓ curly arrow from HO^- to carbon atom of C–Hal bond ✓ curly arrow from C–Hal bond to the halogen atom ✓	10	**ANNOTATE ANSWER WITH TICKS AND CROSSES** X = Br or Cl **ALLOW** molecular, structural, displayed or skeletal formula in equation **ALLOW** $C_3H_7X + H_2O \rightarrow C_3H_7OH + HX$ **ALLOW** equation from the mechanism **IGNORE** incorrect equations **ALLOW** structural, displayed or skeletal formula of product if seen **ONCE** in equation, mechanism or drawn out **If two mechanism shown award marks from the mechanism that gives the higher mark**  The curly arrow must start from the oxygen lone pair or the negative charge on the oxygen of ^-OH ion No need to show lone pair on the oxygen atom

Question	Answer	Mark	Guidance
(g)	**Type of bond fission** QWC - heterolytic ✓ **Reasons for the difference in rate of hydrolysis** 1-bromopropane reacts faster (than 1-chloropropane) **OR B** reacts faster (than **C**) **OR** C–Br reacts faster ✓ Because the C–Br bond is weaker **OR** C–Br has a lower bond enthalpy **OR** C–Br bond is longer ✓ C–Br is more easy to break ✓		**ALLOW S_N1 mechanism** dipole shown on C–Hal bond, $C^{\delta+}$ and $Hal^{\delta-}$ ✓ curly arrow from C–Hal bond to the halogen atom ✓ curly arrow from OH^- to correct carbocation ✓ **IGNORE** bromine reacts faster than chlorine **ALLOW** ora **ALLOW** less energy to break C–Br **ALLOW** ora **ALLOW** ora
(h)	With H_2  ✓ With HBr  ✓  ✓	**3**	**ALLOW** methylcyclohexane **ALLOW** 1-bromo-1-methylcyclohexane **ALLOW** 1-bromo-2-methylcyclohexane **ALLOW** 2-bromo-1-methylcyclohexane
	Total	**23**	