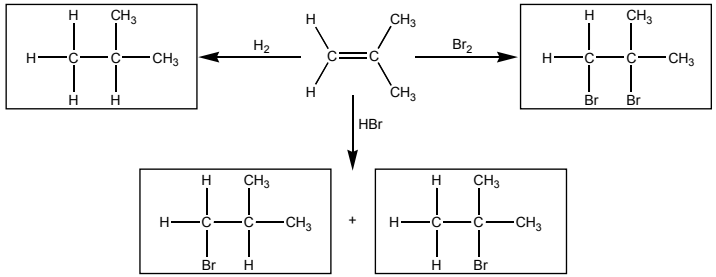
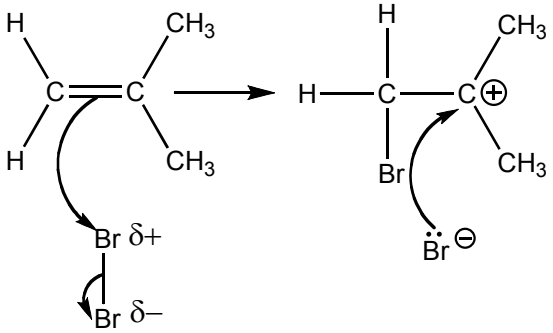
F322 Chains, Energy and Resources

Question			Expected Answers	Marks	Additional Guidance
1	(a)		C_nH_{2n+2} ✓	1	**ALLOW** $C_nH_{2(n+1)}$ ✓ **IGNORE** size of subscripts
	(b)	(i)	$C_8H_{18} + 8½O_2 \rightarrow 8CO + 9H_2O$ ✓	1	**ALLOW** any correct multiples **IGNORE** state symbols
		(ii)	limited supply of air **OR** not enough O_2 ✓	1	**ALLOW** use of air or oxygen **IGNORE** it is not completely oxidised
	(c)	(i)	$2CO + 2NO \rightarrow 2CO_2 + N_2$ ✓	1	**ALLOW** any correct multiples including fractions **IGNORE** state symbols
	(c)	(ii)	CO and NO are adsorbed (onto surface) **OR** reactants are adsorbed (onto surface) ✓ weakening of bonds **OR** lowers activation energy ✓ CO_2 and N_2 desorbs (from the surface) **OR** products desorbs (from the surface) ✓	3	**ALLOW** CO and NO stick onto surface **OR** CO and NO form weak attractions to the surface **OR** gases are adsorbed onto surface **NOT** absorb but **allow** ecf for deabsorb later on **IGNORE** alternative pathway Requires less energy is not sufficient **ALLOW** products leave the surface **OR** products diffuse away from surface **OR** weak attraction to surface is broken **ALLOW** deadsorb
	(d)		skeletal formula of a branched isomer of C_8H_{18} ✓ skeletal formula of a cyclic hydrocarbon **OR** skeletal formula of substituted arene of C_8H_{10}✓	2	**ALLOW** any ring between C_3 and C_8 with 8 carbon atoms per molecule **IGNORE** wrong names If two correct structural or displayed formulae drawn award one mark

Question			Expected Answers	Marks	Additional Guidance
	(e)		**Any TWO from:** atmospheric concentration ✓ ability to absorb infrared radiation ✓ residence time ✓	2	 **ALLOW** the amount of the gas **OR** abundance of gas **ALLOW** how much IR it absorbs **OR** ability to absorb heat **IGNORE** global warming potential / heat reflected / how much is produced **ALLOW** how long it stays in the atmosphere
			Any TWO from: deep in the oceans **OR** on the sea-bed ✓ storage in geological formations **OR** under the sea-bed ✓ by reaction (with metal oxides) to form carbonates ✓	2	 **ALLOW** piped into disused or partially filled oil wells **ALLOW** stored as a carbonate **OR** equation to show formation of suitable carbonate from an oxide **IGNORE** mineral storage **IGNORE** reforestation
			Total	13	

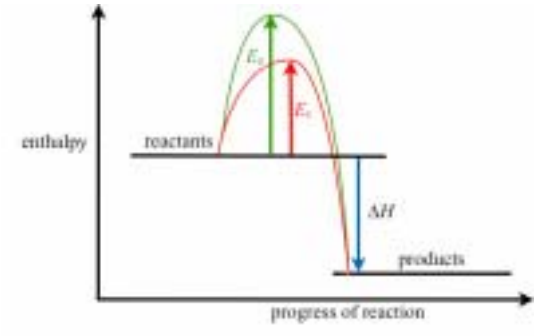
Question			Expected Answers	Marks	Additional Guidance
2	(a)	(i)	The enthalpy change for the complete combustion ✓ of 1 mol (of a substance) ✓	2	**ALLOW** energy change for combustion in excess oxygen **OR** energy released during complete combustion **OR** energy change for combustion in excess air **NOT** energy required This mark is not stand alone but must relate to statement about an enthalpy change even if the statement was not awarded a mark
	(b)	(i)	56.430 (kJ) ✓	1	**ALLOW** 56.43 (kJ) **OR** 56.4 kJ ✓ **OR** 56 kJ **ALLOW** -56.43 i.e. ignore sign
		(ii)	M_r [$CH_3(CH_2)_4OH$] = 88.0 ✓ n = 0.0200 mol ✓	2	**ALLOW** 88 **ALLOW** 0.02 **OR** ecf from wrong M_r **ALLOW** full marks for 0.02 with no working out
		(iii)	(–)2821.5 ✓ = (–)2820 (3 SF) ✓ correct minus sign ✓	3	**ALLOW correct substitution into formula**(b)(i) ÷ (b)(ii) e.g. 56.4 ÷ 0.02 this is essentially a mark for the working **ALLOW** ecf from i.e. answer from (b)(i) ÷ (b)(ii) The minus mark is stand alone and is independent of the numerical answer
	(c)	(i)	pressure: 100 kPa **OR** 101 kPa **AND** temperature: 298 K **OR** 25 °C ✓	1	**units needed** **ALLOW** 1 bar **OR** 1 atm **OR** 760 mmHg **ALLOW** any stated temperature so for example 100kPa and 40^{o}C would be credited with a mark **IGNORE** any reference to moles or concentration
		(ii)	6C(s) + 7H_2(g) → C_6H_{14}(l) ✓	1	**ALLOW** graphite / gr
		(iii)	many different hydrocarbons would form **OR** activation energy too high **OR** reaction too slow **OR** they don't react together ✓	1	**ALLOW** can form different isomers **OR** can form different structures **IGNORE** reaction may be reversible

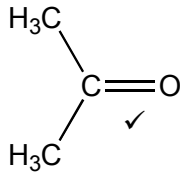
Question			Expected Answers	Marks	Additional Guidance
		(iv)	6 × –394 + 7 × –286 shown **OR** calculated as –4366 ✓ –4366 and –4163 added **OR** subtracted ✓ correct answer –4366 – (–4163) = –203 ✓	3	**ALLOW THREE** marks for –203 on its own with no working out or written on the answer line **ALLOW TWO** marks for +203,+3483, +1513, +1767 or -8529 on its own with no working out **ALLOW ONE** mark for or –3483, –1513, –1767 or +8529 on its own with no working out units **NOT** needed Positive sign not needed for endothermic answers
			Total	14	

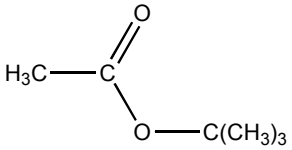
Question			Expected Answers	Marks	Rationale
3	(a)		 one mark for each correct structure ✓ ✓ ✓ ✓	4	**ALLOW** skeletal formula OR displayed formulae **IGNORE** molecular formulae **IF** two answers given e.g. name and structure then both must be correct to be given a mark **ALLOW** methylpropane **OR** $(CH_3)_3CH$ ✓ **ALLOW** 1,2-dibromo-methylpropane **OR** $CH_2BrCBr(CH_3)_2$ ✓ **ALLOW** 1-bromo-methylpropane **OR** $CH_2BrCH(CH_3)_2$ ✓ **ALLOW** 2-bromo-methylpropane **OR** $CH_3CBr(CH_3)_2$ ✓ **ALLOW** ecf if wrong carbon skeleton is used in all of the structures mark first structure wrong and then apply ecf for the rest
	(b)		curly arrow from double bond to $Br^{\delta+}$ and curly arrow from Br—Br bond pair to $Br^{\delta-}$ in 1st step ✓ curly arrow in 2nd step from bromide ion ✓ correct dipole shown on Br_2 ✓ correct carbocation shown ✓ 	4	Curly arrow must start from the double bond and not a carbon atom, other curly arrow must start from Br—Br bond **ALLOW** curly arrow from any part of bromide ion The bromide ion does not need to show a lone pair Dipole must be partial charge and not full charge Carbocation needs a full charge and not a partial charge (charges do not need to be surrounded by a circle) **ALLOW** carbocation on carbon 1 where electrophile attacks carbon 2 i.e. $^{+}CH_2CBr(CH_3)_2$

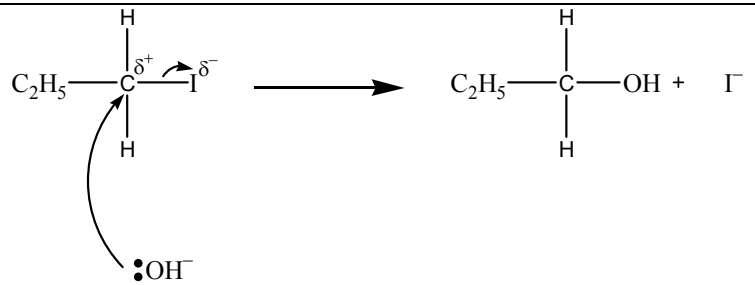
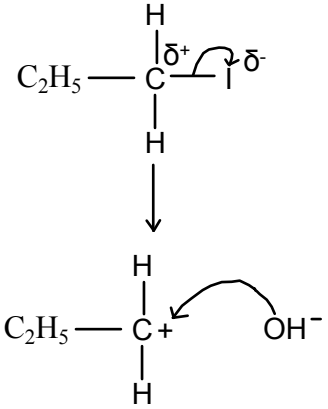
Question			Expected Answers	Marks	Rationale
	(c)	(i)	C_6H_{10} ✓	1	
		(ii)	M_r(cyclohexanol) = 100 ✓ amount of cyclohexanol = 0.0765 mol ✓ percentage yield = 35.0% ✓	3	**ALLOW** full marks for correct answer with no or limited working out **ALLOW** ecf from wrong molar mass i.e. 7.65 ÷ molar mass **ALLOW** ecf from wrong amount in moles i.e. [0.0268 ÷ moles] × 100 **ALLOW** 35% **ALLOW** two marks for 0.35% If M_r of 82 is used then % yield will be 28.7 or 29 and this is worth two marks
	(d)	(i)	(sum of) the molecular masses of the desired product ÷ sum of molecular masses of all products × 100 ✓	1	**ALLOW** (sum of) the molecular masses of the desired product ÷ sum of molecular masses of all reactants × 100 ✓
		(ii)	this preparation is addition **OR** has 100% atom economy **OR** there is only one product ✓ preparation from cyclohexanol has less than100% atom economy **OR** H_2O is produced as well **OR** calculated atom economy = 82% ✓	2	**ALLOW** no by products formed **ALLOW** other substances formed **OR** cyclohexene is not the only product
			Total	15	

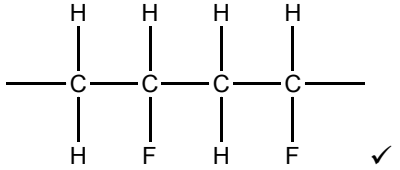
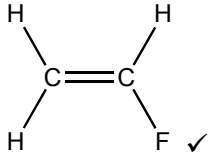
Question			Expected Answers	Marks	Additional Guidance
4	(a)		high pressure as fewer moles (of gas) on right-hand side OR high pressure as volume of products less than that of reactants ✓ low temperature as (forward) reaction is exothermic ✓	2	**ALLOW** ora **ALLOW** fewer particles **OR** fewer molecules **ALLOW** ora
	(b)		Too expensive to use a high pressure ✓ Too slow to use a low temperature ✓	2	**ALLOW** high pressures provide a safety risk **OR** high pressure is too dangerous **ALLOW** with low temperature molecules cannot overcome activation barrier
	(c)	(i)	$Cl + O_3 \rightarrow ClO + O_2$ ✓ $ClO + O \rightarrow Cl + O_2$ ✓ overall: $O_3 + O \rightarrow 2O_2$ ✓ **OR** $Cl + CH_4 \rightarrow CH_3 + HCl$ ✓ $CH_3 + Cl_2 \rightarrow CH_3Cl + Cl$ ✓ overall: $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$ ✓	3	Marks must come from one or other of the radical process and not from both of them. If two processes are described then an incorrect step in one process will contradict a correct step in the other process. **ALLOW** overall equation mark even if the steps are wrong the radicals do **NOT** need a single dot **IGNORE** any state symbols **ALLOW** $Cl + O_3 \rightarrow ClO + O_2$ ✓ $ClO + O_3 \rightarrow Cl + 2O_2$ ✓ overall: $2O_3 \rightarrow 3O_2$ ✓ **ALLOW** any saturated hydrocarbon including cyclic **ALLOW** ecf for second step and overall reaction if wrong hydrocarbon used e.g. C_2H_4 is used in first step

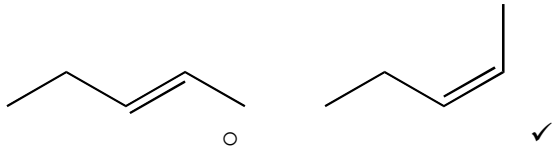
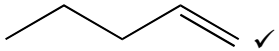
Question			Expected Answers	Marks	Additional Guidance
		(ii)	ΔH shown **and** products below reactants ✓ E_a shown ✓ E_c shown < E_a ✓  	3	**NOT** double headed arrows but apply ecf for more than one double headed arrow **ALLOW** one mark if two correctly labelled curves are drawn but the arrows are not shown or are incorrectly drawn The arrows must be positioned as closely as possible to the maximum height of the curves but allow some degree of bod
	(d)		**Any FOUR from:** catalyst not used up in reaction ✓ reactions take place at lower temperatures ✓ with lower energy demand **OR** lower activation energy **OR** use less fuel ✓ so less carbon dioxide emitted into atmosphere **OR** so fossil fuels last longer ✓ different reactions can be used ✓ with better atom economy **OR** less waste ✓ less hazardous chemicals ✓ catalysts or enzymes can generate specific products ✓	4	 **ALLOW** catalysts can work at room temperature **OR** enzymes work at room temperature **IGNORE** cheaper
			Total	**14**	

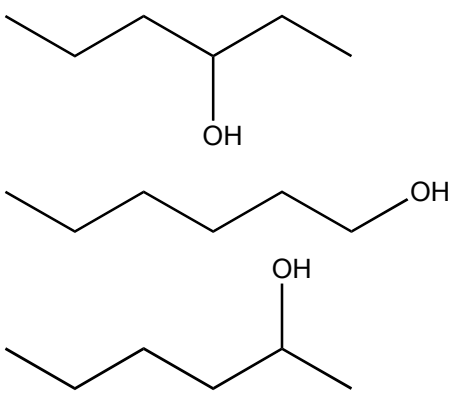
Question			Expected Answers	Marks	Additional Guidance
5	(a)		**method 1:** fermentation of sugars or carbohydrates **OR** reaction with yeast with sugar or carbohydrates ✓ $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ ✓ **method 2:** hydration of ethene OR reaction of ethene with water **OR** reaction of steam with ethene ✓ $C_2H_4 + H_2O \rightarrow C_2H_5OH$ ✓	**4**	**ALLOW** sugar from equation **ALLOW** C_2H_6O in equation **ALLOW** correct multiples **IGNORE** state symbols **ALLOW** ethene from the equation **IGNORE** mention of any catalyst **ALLOW** C_2H_6O in equation **OR** H_2O over the arrow **ALLOW** correct multiples **IGNORE** state symbols
	(b)	(i)	$(CH_3)_2CO$ **OR**  ✓ $(CH_3)_2CHOH + [O] \longrightarrow (CH_3)_2CO + H_2O$ ✓	**2**	If name and formula given both need to be correct **ALLOW** propanone **OR** acetone **IGNORE** propone **NOT** incorrect named compound **ALLOW** $C_3H_8O + [O] \rightarrow C_3H_6O + H_2O$ **ALLOW** O instead of [O] **ALLOW** correct multiples **IGNORE** state symbols
		(ii)	CH_3CH_2COOH **OR** propanoic acid ✓ Any number or range of numbers between 1750–1640 (cm^{-1}) for C=O ✓ Any number or range of numbers between 2500–3300 (cm^{-1}) for O–H ✓	**3**	 **ALLOW** C=O and O—H marks independent of compound identified **i.e. stand alone marks** **ALLOW** correct bonds shown by the appropriate absorption on the IR spectrum **IGNORE** reference to C—O bond
	(c)	(i)	2-methylpropan-2-ol ✓	**1**	**ALLOW** methylpropan-2-ol **OR** tertiarybutanol

Question			Expected Answers	Marks	Additional Guidance
		(ii)	ester ✓	1	
		(iii)	$CH_3CO_2C(CH_3)_3$ **OR** $CH_3COOC(CH_3)_3$ **OR**  ester group shown ✓ rest of molecule ✓	2	**ALLOW** skeletal formula **OR** displayed formula **ALLOW** ester linkage even if rest of structure is wrong
			Total	**13**	

Question			Expected Answers	Marks	Additional Guidance
6	(a)	(i)	 C–I curly arrow from the bond not from carbon atom ✓ curly arrow from the OH^- ✓ correct partial charges on C—I ✓	3	no need to show any lone pairs on oxygen but must have a clear negative sign rather than partial negative charge **IGNORE** lone pairs **IGNORE** products of this reaction **ALLOW** curly arrow from a negative charge or from any part of hydroxide ion If S_N1 mechanism is given then use the mark scheme below correct partial charges on C—I ✓ C–I curly arrow from the bond not from carbon atom ✓ curly arrow from the OH^- to the **correct** carbocation ✓ 
		(ii)	nucleophilic substitution ✓	1	
	(b)		C–I bonds broken more easily ✓ C–I bonds are weaker **OR** have less bond enthalpy **OR** C–I bonds are longer ✓	2	**ALLOW** ora e.g. C—Br bonds are stronger **OR** broken less easily

Question			Expected Answers	Marks	Additional Guidance
	(c)		**Any TWO from:** CFCs take many years to reach the ozone layer **OR** long residence time ✓ CFCs are still being used ✓ there are other ozone depleting substances ✓	2	 **IGNORE** because chlorine radicals stay in the stratosphere **ALLOW** other named ozone depleting substances e.g. NO and HFCs
	(d)	(i)	 ✓	1	Free bonds at bond ends must be present **ALLOW** minor slip e.g. missing one hydrogen and left as a stick **ALLOW** more than two repeat units but must be a whole number of repeat units **IGNORE** brackets, use of numbers and n in the drawn structure
		(ii)	 ✓	1	**ALLOW** skeletal formula **ALLOW** CH_2CHF
	(e)		**Any two from:** separation into types and recycling **OR** sort plastics, melt and remould ✓ combustion for energy generation ✓ used for cracking **OR** feedstock for plastics or chemicals ✓	2	**IGNORE** biodegradable used as a fuel is insufficient releases energy is insufficient **ALLOW** burning plastics to release energy **ALLOW** organic feedstock / raw materials to make organic compounds
			Total	12	

Question			Expected Answers	Marks	Additional Guidance
7	(a)		**Structural isomer** compounds with the same molecular formula ✓ but with different structural formulae ✓ **Stereoisomer** compounds with the same structural formula ✓ but with different arrangements in space ✓ **Evidence** of using M_r of 70 to **calculate** molecular formula of C_5H_{10} ✓ **F** and **G** are  ○ ✓ Correct identification of the *E* and *Z* isomers ✓ **H is**  ✓ ***E/Z* happens because** double bonds restricts rotation ✓ different groups on each carbon of the double bond ✓	11	**ALLOW** same molecular formula ✓ but different structures✓ Second marking point is **DEPENDENT** on first mark **ALLOW** compounds with the same structure Second marking point is **DEPENDENT** on first mark This is the QWC mark **IGNORE** wrong names of **F**, **G** and **H** **ALLOW** structural or displayed formulae for **F**, **G** and **H** e.g. **H is** $CH_3CH_2CH_2CHCH_2$ **ALLOW** identification using *trans* and *cis* and **ALLOW** this marking point as identification of another example of identifying *E/Z* or *cis* and *trans* if not done for **F** and **G** **ALLOW** one mark if no structures drawn but correct names given for **F**, **G** and **H** i.e *E*-pent-2-ene, *Z*-pent-2-ene and pent-1-ene **ALLOW** ecf on structures if wrong molecular formula used or consistent error or slip such as having just sticks

Question	Expected Answers	Marks	Additional Guidance
(b)	from IR absorption, **J** contains O–H **OR** from IR **J** is an alcohol✓ C : H : O = $\frac{70.59}{12.0}$: $\frac{13.72}{1.0}$: $\frac{15.69}{16.0}$ **OR** 5.8825 : 13.72 : 0.9806 ✓ empirical formula = $C_6H_{14}O$ ✓ (from mass spectrum), M_r = 102 ✓ evidence that it has been shown that the empirical formula is the molecular formulae e.g. M_r of $C_6H_{14}O$ = 102 so empirical formula is molecular formula ✓  One mark for each correct structure ✓ ✓ ✓	8	This is a QWC mark **ALLOW two** marks for correct empirical formula with no working out This is a QWC mark **ALLOW** structural or displayed formulae **IGNORE** incorrect names **ALLOW** one minor slip in drawing structures e.g. one missing hydrogen but **ALLOW** ecf for bigger slips such as showing just sticks and no hydrogen atoms **ALLOW** bond to H in OH **ALLOW one** mark for three isomers of $C_6H_{13}OH$ whether branched or unbranched as a catch mark if no other mark has been awarded for the structures If more than three isomers of $C_6H_{13}OH$ drawn • 1 branched and 3 unbranched award **two** marks • any other combination award **one** mark **ALLOW** one mark for hexan-1-ol, hexan-2-ol and hexan-3-ol if structures not drawn
	Total	**19**	