F322 Chains, Energy and Resources

Question			Expected Answers	Marks	Additional Guidance
1	(a)		Fractional distillation ✓ Because fractions have different boiling points ✓	2	**DO NOT ALLOW** just 'distillation' For fractions, **ALLOW** components **OR** hydrocarbons **OR** compounds **ALLOW** condense at different temperatures **ALLOW** because van der Waals' forces differ between molecules **IGNORE** reference to melting points **IGNORE '**crude oil' **OR** 'mixture' has different boiling points' …… **but ALLOW** 'separates crude oil by boiling points
	(b)	(i)	Decane ✓	1	**DO NOT ALLOW** deceane
		(ii)	Skeletal formula of branched $C_{10}H_{22}$ ✓	1	Formula **must** be skeletal **AND** must not include any symbol, e.g. CH_3 Any possible skeletal formulae e.g.

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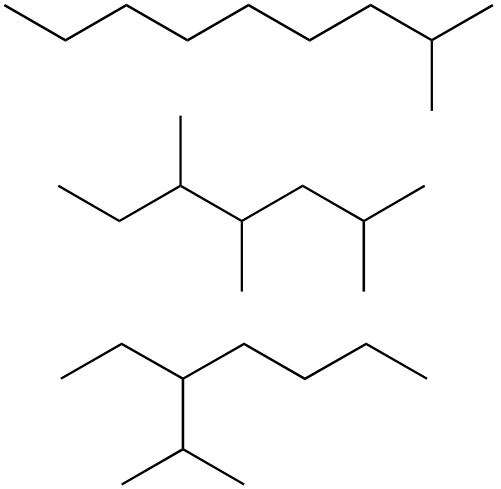
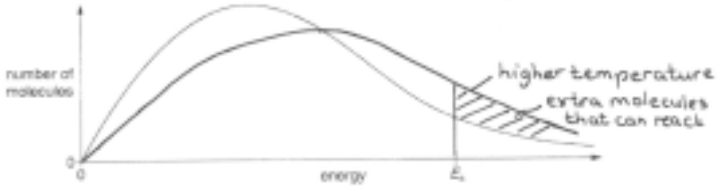
					
		(iii)	Decane has more surface contact **OR** branched chains have less surface contact ✓ Decane has more van der Waals' forces **OR** branched chains have fewer van der Waals' forces ✓	2	**Both answers need to be comparisons** Assume 'it' refers to decane **IGNORE** surface area **ALLOW** straight chains can get closer together **OR** branched chains cannot get as close to one another **IGNORE** branched chain are more compact **ALLOW** Decane has stronger van der Waals' forces **OR** branched chains have weaker van der Waals' forces More intermolecular forces is **not** sufficient
		(iv)	Branched chains have more efficient combustion **OR** decane has less efficient combustion ✓	1	**ALLOW** branched chains are easier to burn **OR** easier to combust **OR** burn better **OR** more efficient fuel **OR** less likely to produce pre-ignition or knocking **OR** increases octane rating **ALLOW** ORA for decane

Question			Expected Answers	Marks	Additional Guidance
					Better fuel is **NOT** sufficient Burns more cleanly is **NOT** sufficient
	(c)	**(i)**	$C_{10}H_{22} + 15½O_2 \longrightarrow 10CO_2 + 11H_2O$ All **four** species correct ✓ balancing of four correct species ✓	**2**	**ALLOW** any correct multiple **IGNORE** state symbols
		(ii)	$N_2 + O_2 \longrightarrow 2NO$ ✓	**1**	**ALLOW** any correct multiple including fractions **IGNORE** state symbols The mark is for the equation **IGNORE** writing

Question			Expected Answers	Marks	Additional Guidance
	(d)	(i)	Species with an unpaired electron ✓	1	**ALLOW** atom, molecule or particle with an unpaired electron **ALLOW** 'has an unpaired electron' **ALLOW** particle formed by homolytic fission **DO NOT ALLOW** particle with a single electron **OR** particle with a free electron
		(ii)	catalyst ✓	1	
		(iii)	$O + O_2 \longrightarrow O_3$ **OR** O reacts with O_2 to make ozone **OR** the reaction is reversible ✓ Rate of formation of ozone is the same as rate of decomposition ✓	2	**ALLOW** $O_2 + O \rightleftharpoons O_3$ **OR** $O_3 \rightleftharpoons O_2 + O$ ✓✓ **ALLOW** is in equilibrium **OR** $\rightleftharpoons$ in **correct** equation **OR** has steady state condition ✓ **IGNORE** other equations involving ozone
		(iv)	absorbs (harmful) UV ✓	1	**ALLOW** 'keeps out UV' **OR** 'filters UV' **ALLOW** increased UV could cause skin cancer **OR** increased UV could cause cataracts **OR** increased UV could cause mutation of crops ✓ **IGNORE** gamma
			Total	15	

Question			Expected Answers	Marks	Additional Guidance
2	(a)	(i)	$2H_2O_2 \longrightarrow 2H_2O + O_2$ ✓	1	**ALLOW** any correct multiple including fractions **IGNORE** state symbols
		(ii)	More crowded particles **OR** more particles per (unit) volume ✓ more collisions per second **OR** more frequent collisions ✓	2	**ALLOW** particles are closer together **DO NOT ALLOW** 'area' instead of 'volume' **IGNORE** 'more concentrated particles' **ALLOW** collisions more often **OR** increased rate of collision **OR** collisions are more likely **OR** there is a greater chance of collisions 'More collisions' is **not** sufficient
		(iii)	**Any two from the following:** Reaction takes alternative route ✓ Activation energy is lowered ✓ More molecules have energy above activation energy **OR** more molecules have enough energy to react ✓	2	 **ALLOW** catalyst changes reaction mechanism **ALLOW** an alternative approach using adsorption particles **adsorbed** onto surface ✓ so bonds weakened as a result of the adsorption ✓

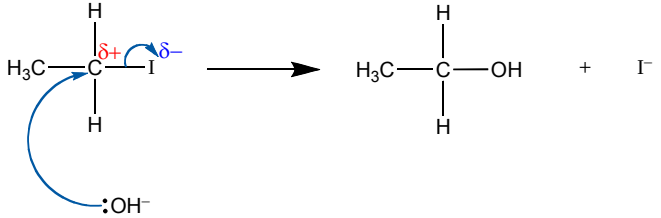
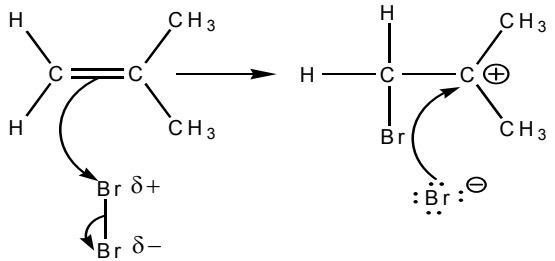
Question			Expected Answers	Marks	Additional Guidance
		(iv)	Correct curve for higher temperature ✓ Activation energy does not change **OR** clearly labelled on diagram, e.g. E_a **OR** E ✓ More molecules have energy above activation energy **OR** more molecules have enough energy to react ✓	3	maximum of curve to right **AND** lower than maximum of original curve **AND** above dotted line at higher energy as shown in diagram below **IGNORE** minor point of inflexion of curve  Note that the diagram above would score all 3 marks More successful collisions is **not** sufficient
	(b)	(i)	$\frac{34.0}{}$ × 100 **267.4** ✓ 12.7% ✓	2	First mark for 267.4 **OR** (34.0 + 233.4) **OR** (169.3 + 98.1) at **bottom** of fraction with or without × 100 **ALLOW** from 2 sig figs up to calculator value **ALLOW** full marks for 13 **OR** 12.7 **OR** 12.72 **OR** 12.715 up to calculator value with no working out 12.71 scores one mark only **NO ECF** for this part from incorrect numbers in first expression

Question			Expected Answers	Marks	Additional Guidance
		(ii)	**Any three from the following**: Oxygen comes from air ✓ No poisonous materials formed **OR** no poisonous materials involved ✓ No waste products formed **OR** atom economy is 100% ✓ Anthraquinone is regenerated **OR** recycled **OR** used again **OR** Anthraquinone acts as a catalyst ✓	3	 **IGNORE** hydrogen comes from the air **IGNORE** harmful **ALLOW** higher atom economy
	(c)		Bond breaking absorbs energy **AND** bond making releases energy ✓ More energy released than absorbed ✓	2	**ALLOW** bond breaking is endothermic **AND** bond making is exothermic **ALLOW** exothermic change transfers more energy than endothermic change **OR** bond making transfers more energy than bond breaking **OR** '(the sum of the) bond enthalpies in the products is greater than the (sum of the) bond enthalpies in the reactants' **OR** '(the sum of the) bond enthalpies of the bonds made is greater than (the sum of) the bond enthalpies of the bonds broken' **IGNORE** reference to strong and weak bonds **IGNORE** enthalpy of products is less than enthalpy of reactants
			Total	15	

Question			Expected Answers	Marks	Additional Guidance
3	(a)		Respiration ✓	1	**IGNORE** anaerobic
	(b)	(i)	100 × 4.18 × 17.3 ✓ 7.23 (kJ) ✓	2	**ALLOW** 7231 J ✓ **ALLOW** 7.23 with no working out **ALLOW** from 7.2 up to calculator value of 7.2314 **ALLOW** from 0.060 up to calculator value for 1 mark (i.e. ECF from use of *m* = 0.831 in first stage) **IGNORE** sign
		(ii)	M_r = 180 ✓ amount = 4.62 × 10^{-3} (mol) ✓	2	 **ALLOW** 4.6 × 10^{-3} **OR** 4.62 × 10^{-3} **OR** 4.617 × 10^{-3} up to calculator value **DO NOT ALLOW** 0.005 **ALLOW** ECF from wrong M_r
		(iii)	ΔH_c = 1560 (kJ) **OR** 1570 (kJ) but answer must be to 3 sig fig ✓ minus sign ✓	2	**ALLOW** ECF from 'answer to **(i)** ÷ answer to **(ii)**' but answer must be to 3 sig fig minus mark is an independent mark

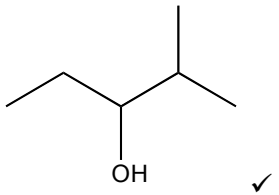
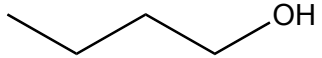
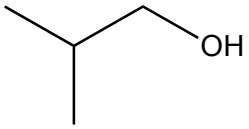
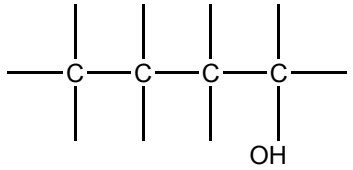
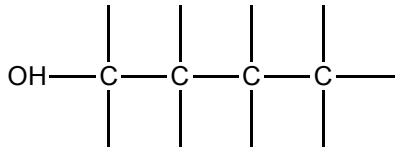
Question	Expected Answers	Marks	Additional Guidance
(c)	+1250 ✓ +(−394 × 6) + (−286 × 6) **OR** –4080 ✓ −2830 ✓	3	**ALLOW** full marks for −2830 with no working out ✓✓✓ **ALLOW for 2 marks:** +2830 cycle wrong way around **OR** 1400 **OR** 860 one value not × 6 **OR** –5330 **OR** +5330 wrong sign for 1250 or 4080 **OR** +570 ✓✓ correct cycle but not × 6 **ALLOW for 1 mark:** –1400 **OR** –860 cycle wrong way around and one value not × 6 **OR** –570 cycle wrong way around and not × 6 **OR** –1930 **OR** +1930 ✓ wrong sign and not × 6 **Note:** There may be other possibilities.
(d)	**Any two from the following:** Heat released to the surroundings ✓ Incomplete combustion **OR** incomplete reaction **OR** not everything burns ✓ Non-standard conditions ✓	2	 **ALLOW** heat loss **IGNORE** reference to evaporation
	Total	12	

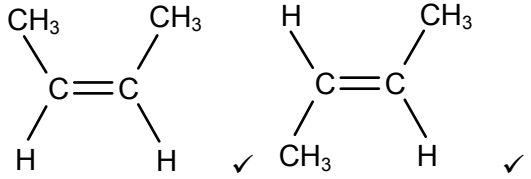
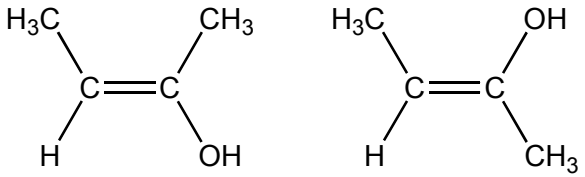
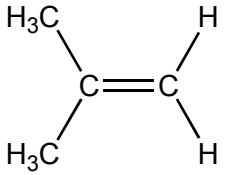
Question			Expected Answers	Marks	Additional Guidance
4	(a)	(i)	$CH_4 + Br_2 \longrightarrow CH_3Br + HBr$ ✓	1	**ALLOW** any correct multiple **IGNORE** state symbols
		(ii)	Dibromomethane **OR** tribromomethane **OR** tetrabromomethane ✓	1	**ALLOW** 1,1-dibromomethane **OR** 1,1,1-tribromomethane etc **ALLOW** 1-dibromomethane **DO NOT ALLOW** 2,2-dibromomethane etc **ALLOW** correct formulae e.g. CH_2Br_2
		(iii)	$Br_2 \longrightarrow 2Br$ **OR** homolytic fission of bromine ✓ $Br + CH_4 \longrightarrow HBr + CH_3$ ✓ $CH_3 + Br_2 \longrightarrow CH_3Br + Br$ ✓ $Br + CH_3 \longrightarrow CH_3Br$ **OR** $Br + Br \longrightarrow Br_2$ ✓ Ethane made when two methyl radicals react **OR** $CH_3 + CH_3 \longrightarrow C_2H_6$ ✓ **Quality of Written Communication** – Consists of initiation step linked to correct equation propagation step linked to one equation in which there is a radical on the left and a radical on the right termination step linked to correct equation: 2 names of steps linked to correct equations ✓ **BUT** 3 names of steps linked to correct equations ✓✓	7	**All equations can be described in words** Radicals do **NOT** need a single dot **IGNORE** any state symbols **ALLOW** any other suitable termination If no equations are given to link the names of the step then award one mark for mention of all three steps

Question	Expected Answers	Marks	Additional Guidance
(b)	**EITHER** Nucleophilic substitution ✓ Example of nucleophilic substitution ✓ Heterolytic fission ✓ C–I curly arrow ✓ Correct dipole on C— I bond ✓ OH^- curly arrow from one lone pair on O of OH^- ion **OR** from minus sign on OH^- ion ✓ **OR** Electrophilic addition ✓ Example of electrophilic addition ✓ Heterolytic fission ✓ Curly arrow from C=C bond to Br—Br bond and Dipole and curly arrow associated with Br_2 ✓ Correct carbocation ion ✓ Curly arrow from one lone pair on Br^- ion **OR** from minus sign on Br^- ion ✓	6	The example mark can be awarded as an example of the name of the mechanism given or if the name is wrong can be given as an example of a reasonably correct drawn mechanism *If **curly half arrows** drawn do not give a mark the first time used and then apply ECF*  **ALLOW** mechanisms for other halogenoalkaes  **ALLOW** mechanisms for other halogens and hydrogen halides
	ALLOW Electrophilic substitution ✓ Example of electrophilic substitution ✓ Heterolytic fission ✓ Curly arrow from benzene ring to the electrophile (i.e. NO_2^+ OR Br^+) ✓ Correct intermediate ✓ Curly arrow to show loss of hydrogen ion ✓		**ALLOW** Nucleophilic addition ✓ Example of nucleophilic addition ✓ Heterolytic fission ✓ Correct dipole on carbonyl group ✓ Curly arrow from lone pair on H^- ion **OR** from minus sign on H^- to C=O carbon and breaking of C=O bond ✓ Curly arrow from carbonyl oxygen to either H^+ or H_2O ✓
	Total	**15**	

Question			Expected Answers	Marks	Additional Guidance
5	(a)		Cracking ✓	1	**ALLOW** catalytic or thermal cracking ✓
	(b)	(i)	Acid ✓	1	**ALLOW** correct formula if no name given: e.g. H_3PO_4 **OR** H_2SO_4 **OR** H^+ ✓ **ALLOW** correct name of acid even if an incorrect formula is used **IGNORE** heterogeneous **OR** homogeneous
		(ii)	The position of equilibrium will shift so as to minimise the effect of any change in conditions ✓	1	**DO NOT ALLOW** 'reaction shifts' The idea of a shift in equilibrium is essential
		(iii)	Low temperature **AND** high pressure ✓ Low temperature because the (forward) reaction is exothermic ✓ High pressure because there are fewer moles (of gas) on the right hand side ✓	3	One mark for conditions. This mark is independent of the reasons for conditions One mark for reason for the chosen temperature One mark for reason for the chosen pressure **ALLOW** fewer moles of products
		(iv)	(60 atmosphere pressure is a) high pressure may be too expensive **OR** may cause safety problems ✓ (300 ºC is sufficiently high) to give a fast rate of reaction ✓ without shifting equilibrium to the left **OR** compromising equilibrium yield ✓	3	
	(c)		Propene ✓	1	**ALLOW** prop-1-ene ✓ **DO NOT ALLOW** prop-2-ene
	(d)	(i)	—CH_2CHCl— + $2\frac{1}{2}O_2 \longrightarrow 2CO_2 + H_2O + HCl$ ✓	1	
		(ii)	Alkali **OR** base **OR** carbonate ✓	1	**ALLOW** correct formula of or named carbonate **OR** alkali **OR** base Correct name and wrong formula does **not** score

Question			Expected Answers	Marks	Additional Guidance
	(e)		**Any two marks from the following**: Develop photodegradable polymers ✓ Develop biodegradable polymers **OR** develop compostable polymers ✓ Develop techniques for cracking polymers **OR** develop use as a chemical feedstock ✓ Develop ways of making polymers from plant-based substances **OR** reduce the need to use finite raw materials such as crude oil ✓ Designing processes with high atom economy **OR** reduce waste products during manufacture ✓ Develop ways of sorting **AND** recycling polymers ✓	**2**	
			Total	**14**	

Question			Expected Answers	Marks	Additional Guidance
6	(a)	(i)	2-Methylpropan-2-ol ✓	1	**ALLOW** methylpropan-2-ol
	(b)		 ✓	1	Formula **must** be skeletal **AND** not include any symbol except for OH
	(c)	(i)	Same **molecular** formula but different structural formulae ✓	1	**ALLOW** Same molecular formula but different arrangement of atoms **OR** Same molecular formula but different structures **OR** Same molecular formula but different displayed formulae **DO NOT ALLOW** Same molecular formula but different spatial arrangement of atoms
		(ii)	$CH_3CH_2CH_2CH_2OH$ **OR** $(CH_3)_2CHCH_2OH$ ✓ **ALLOW**  **OR** 	1	**ALLOW** displayed formula **ALLOW** sticks (i.e. no H shown bonded to C) **ALLOW**  *sticks OK and –OH is OK* **DO NOT ALLOW** OH shown as below  *sticks OK but OH– is not OK* **ALLOW** correct ethers

Question			Expected Answers	Marks	Additional Guidance
	(d)		Has O–H (bonds) **OR** has hydroxyl (groups) **OR** has hydroxy (groups) ✓ Forms hydrogen bonds with water (molecules) ✓	**2**	**ALLOW** marks from a diagram of hydrogen bonding **IGNORE** reference to alcohol functional group **DO NOT ALLOW** 'forms hydrogen bonds'
	(e)		$CH_3COOCH_2CH_2OOCCH_3$ 1 mark for each ester end of molecule ✓✓	**2**	**ALLOW** displayed formula **OR** skeletal formula **ALLOW** sticks $CH_3COOCH_2CH_2OH$ shows one of the two ester groups and scores one mark
	(f)	**(i)**	 ✓ ✓	**2**	**DO NOT ALLOW**  i.e. no ECF
		(ii)	*E/Z* ✓	**1**	**ALLOW** *cis-trans* **IGNORE** geometric
		(iii)	$CH_3CH_2CH{=}CH_2$ **OR** but-1-ene ✓	**1**	If but-1-ene given in part **(i)**, **ALLOW** but-2-ene **OR** $CH_3CH{=}CHCH_3$ i.e. ECF from **f(i)** **DO NOT ALLOW** methylpropene: 

Question	Expected Answers	Marks	Additional Guidance
From the evidence, candidates may have identified compound **F** as propanone, propanal or propanoic acid • The mark scheme for **F** = propanone and propanal is shown in the 'Expected Answers' column. • The mark scheme for **F** = propanoic acid is shown in the 'Additional Guidance' column. If **F** is propanone or propanoic acid, then maximum score = 7; **but** if **F** is propanal then maximum score = 6			
(g)	**Mark scheme for F = propanone and propanal**	**7**	**Mark scheme for F = propanoic acid**
	mass spec of E– Remember to check the spectrum **Quality of Written Communication –** mass spec gives M^+ or molecular ion of 60 **OR** mass spec gives parent ion of 60 **OR** highest *m*/*z* (**ALLOW** *m*/*e*) value is 60 ✓ *m*/*z* = 45 indicates loss of CH_3 **OR** *m*/*z* = 45 indicates presence of CH_3CHOH **OR** CH_2CH_2OH **OR** C_2H_5O ✓		**mass spec of E– Remember to check the spectrum** **QWC –** mass spec gives M^+ or molecular ion of 60 **OR** mass spec gives parent ion of 60 **OR** highest *m*/*z* (**OR** *m*/*e*) value is 60 ✓ *m*/*z* = 45 indicates loss of CH_3 **OR** *m*/*z* = 45 indicates presence of CH_3CHOH **OR** CH_2CH_2OH **OR** C_2H_5O ✓
	IR of F – Remember to check the spectrum IR shows no broad absorption between 2500 to 3300 cm^{-1} so no O—H bond **OR** no broad absorption between 2500 to 3300 cm^{-1} so not a carboxylic acid ✓ IR shows absorption at 1700 cm^{-1} due to a C=O bond **OR** absorption at 1700 cm^{-1} indicates a ketone **OR** aldehyde present ✓		**IR of F– Remember to check the spectrum** IR shows (broad) absorption somewhere between 3500 and 2500 cm^{-1} suggests carboxylic acid **OR** O–H bond ✓ IR shows absorption at 1700 cm^{-1} due to C=O **OR** absorption at 1700 cm^{-1} indicates a carboxylic acid ✓
	Identification and equation **F** is CH_3COCH_3 **OR** propanone ✓ **E** is $CH_3CHOHCH_3$ **OR** propan-2-ol ✓ $CH_3CHOHCH_3 + [O] \longrightarrow CH_3COCH_3 + H_2O$ ✓		**Identification and equation** **F** is CH_3CH_2COOH **OR** propanoic acid ✓ **E** is $CH_3CH_2CH_2OH$ **OR** propan-1-ol ✓ $CH_3CH_2CH_2OH + 2[O] \longrightarrow CH_3CH_2COOH + H_2O$ ✓
	If **F** has been incorrectly identified as propanal, mark identification and equation as ECF, so max = 2 **ALLOW E** is $CH_3CH_2CH_2OH$ ✓ **ALLOW**: $CH_3CH_2CH_2OH + [O] \rightarrow CH_3CH_2CHO + H_2O$ ✓		
	Total	**19**	

Extra guidance for marking of Q6(g)

If **E** has **not** been identified **OR** if **F** has been identified as a **ketone or aldehyde**,
use the **left-hand** mark scheme

If **F** has been identified as a **carboxylic acid**,
use the **right-hand** mark scheme

Mass spec

These two marking points stand as **independent** marks whichever compounds have been identified.

The positive sign for fragment ions is not required. **IGNORE** negative charge.
The mass spec may well be on the actual spectrum.

IR mark

These stand as **independent** marks whichever compounds have been identified.
The IR analysis may well be on the actual spectrum.

Identification marks

If both structure and name are given they must **both** be correct
but allow 'propanol' drawn with the correct structure because the position number of the –OH has been clearly identified

ALLOW ECF for identification of **F** e.g. if **E** is pentan-2-ol ✗ then an answer of pentan-2-one for **F** will be given a mark ✓ as ECF

ALLOW identification marks for **E** and **F** from equation

Equation mark

ALLOW ECF for any correct equation showing the oxidation of **any** alcohol to the appropriate product.
ALLOW molecular formulae in equations,
i.e. $C_3H_7OH + [O] \rightarrow C_2H_5CHO + H_2O$ ✓ ; $C_3H_8O + [O] \rightarrow C_3H_6O + H_2O$ ✓ ; $C_3H_7OH + [O] \rightarrow C_2H_5COH + H_2O$ ✓

Question			Expected Answers	Marks	Additional Guidance
7	(a)	(i)	Infrared (radiation absorbed) ✓ by (C–H) bond vibration ✓	2	**ALLOW** bond stretching **OR** bond bending **DO NOT ALLOW** molecules vibrating
		(ii)	Greater concentration of carbon dioxide **OR** more carbon dioxide is being made ✓	1	**ALLOW** carbon dioxide is the main contributor to global warming **DO NOT ALLOW** any response that states that CO_2 causes ozone depletion **ALLOW** C=O bonds absorb IR more readily than C–H bonds **ALLOW** carbon dioxide has a greater greenhouse effect

Question			Expected Answers	Marks	Additional Guidance
7	(b)		**Any five from the following:** Developing carbon capture **AND** storage ✓ One example of CCS ✓ Second example of CCS ✓ Provide evidence to governments **OR** international conferences (e.g. Kyoto) **OR** reports to United Nations etc ✓ Educating society **OR** writing in journals **OR** producing documentaries **OR** writing books **OR** making posters ✓ Monitoring atmospheric changes ✓ Develop alternative energy sources ✓ One example of an alternative energy source e.g. develop fuel cells **OR** developing solar power **OR** fuels that do not produce CO_2 ✓ (Develop) more efficient engines for transport **OR** lean burn engines **OR** hybrid engines **OR** electric cars ✓ Find uses for carbon dioxide **OR** named use: e.g. dry cleaning **OR** making decaffeinated coffee **OR** blowing agent **OR** fizzy drinks, etc ✓	**5**	carbon, capture **AND** storage required **ALLOW** CCS **Examples of CCS** **deep** in the oceans **OR** on the **sea-bed** ✓ **DO NOT ALLOW** dissolve CO_2 in the sea **OR** stored in ocean storage in geological formations **OR** piped into disused or partially filled oil wells or porous rocks **OR** under the sea-bed ✓ by reaction with metal oxides **OR** reaction to form (solid) carbonates **OR** stored as a carbonate **OR** equation to show formation of metal carbonate ✓ **IGNORE** mineral storage **ALLOW** idea of biofuels only if linked to carbon-neutrality **IGNORE** reforestation **IGNORE** reference to CFCs **DO NOT ALLOW** use less carbon dioxide

Question			Expected Answers	Marks	Additional Guidance
	(c)		**Any two from the following:** There are times when CO_2 has a **high** concentration and the temperature is also **high** **OR** There are times when CO_2 has a **low** concentration and the temperature is **low** ✓ It is impossible to measure with certainty the average temperature years ago ✓ There are other gases that may cause a greenhouse effect **OR** There are other factors that may cause a greenhouse effect ✓ There are very few anomalous results ✓	**2**	**ALLOW** a (positive) correlation between temperature and carbon dioxide concentration but **DO NOT ALLOW** just 'a correlation' **IGNORE** 'graphs are the same shape' **IGNORE** 'graphs are similar'
			Total	**10**	