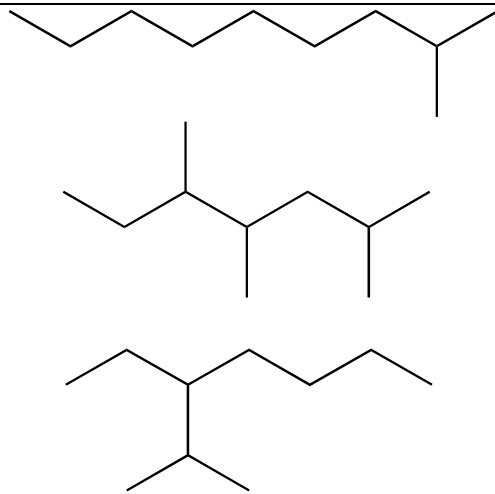


F322 Chains, Energy and Resources

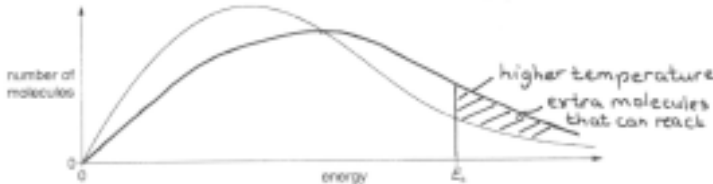
Question		Expected Answers	Marks	Additional Guidance
1	(a)	Fractional distillation ✓ Because fractions have different boiling points ✓	2	DO NOT ALLOW just 'distillation' For fractions, ALLOW components OR hydrocarbons OR compounds ALLOW condense at different temperatures ALLOW because van der Waals' 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.

Question		Expected Answers	Marks	Additional Guidance
				
	(iii)	<p>Decane has more surface contact OR branched chains have less surface contact ✓</p> <p>Decane has more van der Waals' forces OR branched chains have fewer van der Waals' forces ✓</p>	2	<p>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</p> <p>ALLOW Decane has stronger van der Waals' forces OR branched chains have weaker van der Waals' forces</p> <p>More intermolecular forces is not sufficient</p>
	(iv)	<p>Branched chains have more efficient combustion OR decane has less efficient combustion ✓</p>	1	<p>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</p> <p>ALLOW ORA for decane</p>

Question			Expected Answers	Marks	Additional Guidance
					Better fuel is NOT sufficient Burns more cleanly is NOT sufficient
	(c)	(i)	$\text{C}_{10}\text{H}_{22} + 15\frac{1}{2}\text{O}_2 \longrightarrow 10\text{CO}_2 + 11\text{H}_2\text{O}$ <p>All four species correct ✓</p> <p>balancing of four correct species ✓</p>	2	ALLOW any correct multiple IGNORE state symbols
		(ii)	$\text{N}_2 + \text{O}_2 \longrightarrow 2\text{NO} \quad \checkmark$	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)	$2\text{H}_2\text{O}_2 \longrightarrow 2\text{H}_2\text{O} + \text{O}_2$ ✓	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 ✓

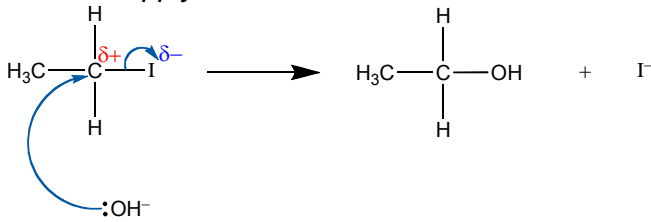
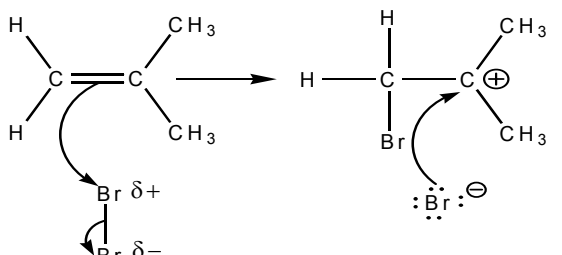
Question		Expected Answers	Marks	Additional Guidance
	(iv)	<p>Correct curve for higher temperature ✓</p> <p>Activation energy does not change OR clearly labelled on diagram, e.g. E_a OR E ✓</p> <p>More molecules have energy above activation energy OR more molecules have enough energy to react ✓</p>	3	<p>maximum of curve to right AND lower than maximum of original curve AND above dotted line at higher energy as shown in diagram below</p> <p>IGNORE minor point of inflexion of curve</p>  <p>Note that the diagram above would score all 3 marks</p> <p>More successful collisions is not sufficient</p>
(b)	(i)	<p>$\frac{34.0}{267.4} \times 100$ 267.4 ✓</p> <p>12.7% ✓</p>	2	<p>First mark for 267.4 OR (34.0 + 233.4) OR (169.3 + 98.1) at bottom of fraction with or without $\times 100$</p> <p>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</p>

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

Question		Expected Answers	Marks	Additional Guidance
3	(a)	Respiration ✓	1	IGNORE anaerobic
	(b)	(i) $100 \times 4.18 \times 17.3$ ✓ 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) $\Delta H_c = 1560$ (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

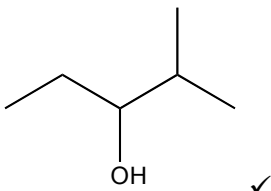
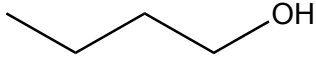
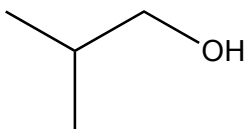
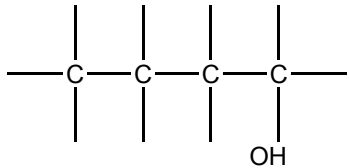
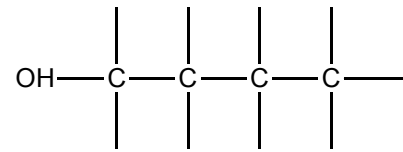
Question		Expected Answers	Marks	Additional Guidance
	(c)	+1250 ✓ +(-394 × 6) + (-286 × 6) OR -4080 ✓ -2830 ✓	3	ALLOW full marks for -2830 with no working out ✓✓✓ ALLOW for 2 marks: +2830 cycle wrong way around OR 1400 OR 860 one value not × 6 OR -5330 OR +5330 wrong sign for 1250 or 4080 OR +570 ✓✓ 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	

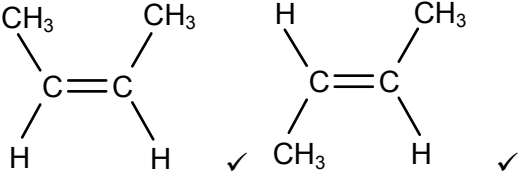
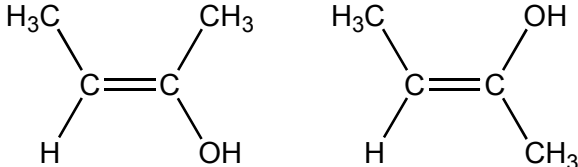
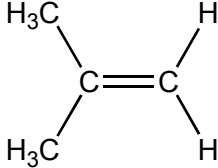
Question			Expected Answers	Marks	Additional Guidance
4	(a)	(i)	$\text{CH}_4 + \text{Br}_2 \longrightarrow \text{CH}_3\text{Br} + \text{HBr} \checkmark$	1	ALLOW any correct multiple IGNORE state symbols
		(ii)	Dibromomethane OR tribromomethane OR tetrabromomethane \checkmark	1	ALLOW 1,1-dibromomethane 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)	$\text{Br}_2 \longrightarrow 2\text{Br}$ OR homolytic fission of bromine \checkmark $\text{Br} + \text{CH}_4 \longrightarrow \text{HBr} + \text{CH}_3 \checkmark$ $\text{CH}_3 + \text{Br}_2 \longrightarrow \text{CH}_3\text{Br} + \text{Br} \checkmark$ $\text{Br} + \text{CH}_3 \longrightarrow \text{CH}_3\text{Br}$ OR $\text{Br} + \text{Br} \longrightarrow \text{Br}_2 \checkmark$ Ethane made when two methyl radicals react OR $\text{CH}_3 + \text{CH}_3 \longrightarrow \text{C}_2\text{H}_6 \checkmark$ 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 \checkmark BUT 3 names of steps linked to correct equations $\checkmark\checkmark$	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)	<p>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 ✓</p> <p>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 Br₂ ✓ Correct carbocation ion ✓ Curly arrow from one lone pair on Br⁻ ion OR from minus sign on Br⁻ ion ✓</p>	6	<p>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</p> <p>If curly half arrows drawn do not give a mark the first time used and then apply ECF</p>  <p>ALLOW mechanisms for other halogenoalkanes</p>  <p>ALLOW mechanisms for other halogens and hydrogen halides</p>
	<p>ALLOW Electrophilic substitution ✓ Example of electrophilic substitution ✓ Heterolytic fission ✓ Curly arrow from benzene ring to the electrophile (i.e. NO₂⁺ OR Br⁺) ✓ Correct intermediate ✓ Curly arrow to show loss of hydrogen ion ✓</p>		<p>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 H₂O ✓</p>
	Total	15	

Question		Expected Answers	Marks	Additional Guidance
5	(a)	Cracking ✓	1	ALLOW catalytic or thermal cracking ✓
	(b)	(i)	1	ALLOW correct formula if no name given: e.g. H ₃ PO ₄ OR H ₂ SO ₄ OR H ⁺ ✓ ALLOW correct name of acid even if an incorrect formula is used IGNORE heterogeneous OR homogeneous
		(ii)	1	DO NOT ALLOW 'reaction shifts' The idea of a shift in equilibrium is essential
		(iii)	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)	3	
	(c)	Propene ✓	1	ALLOW prop-1-ene ✓ DO NOT ALLOW prop-2-ene
	(d)	(i)	1	
		(ii)	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)	<p>Any two marks from the following:</p> <p>Develop photodegradable polymers ✓</p> <p>Develop biodegradable polymers OR develop compostable polymers ✓</p> <p>Develop techniques for cracking polymers OR develop use as a chemical feedstock ✓</p> <p>Develop ways of making polymers from plant-based substances OR reduce the need to use finite raw materials such as crude oil ✓</p> <p>Designing processes with high atom economy OR reduce waste products during manufacture ✓</p> <p>Develop ways of sorting AND recycling polymers ✓</p>	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 ₃ CH ₂ CH ₂ CH ₂ OH OR (CH ₃) ₂ CHCH ₂ OH ✓ ALLOW  OR 	1	ALLOW displayed formula ALLOW sticks (i.e. no H shown bonded to C) ALLOW  <i>sticks OK and -OH is OK</i> DO NOT ALLOW OH shown as below  <i>sticks OK but OH- is not OK</i>
				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 ₃ COOCH ₂ CH ₂ OOCCH ₃ 1 mark for each ester end of molecule ✓✓	2	ALLOW displayed formula OR skeletal formula ALLOW sticks CH ₃ COOCH ₂ CH ₂ OH shows one of the two ester groups and scores one mark
(f)	(i)		2	DO NOT ALLOW  i.e. no ECF
	(ii)	<i>E/Z</i> ✓	1	ALLOW <i>cis-trans</i> IGNORE geometric
	(iii)	CH ₃ CH ₂ CH=CH ₂ OR but-1-ene ✓	1	If but-1-ene given in part (i), ALLOW but-2-ene OR CH ₃ CH=CHCH ₃ i.e. ECF from (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 <ul style="list-style-type: none"> 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)	<p>Mark scheme for F = propanone and propanal</p> <p>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 ✓</p> <p>$m/z = 45$ indicates loss of CH_3 OR $m/z = 45$ indicates presence of CH_3CHOH OR CH_2CH_2OH OR C_2H_5O ✓</p> <p>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 ✓</p> <p>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 ✓</p> <p>Identification and equation F is CH_3COCH_3 OR propanone ✓</p> <p>E is $CH_3CHOHCH_3$ OR propan-2-ol ✓</p> <p>$CH_3CHOHCH_3 + [O] \longrightarrow CH_3COCH_3 + H_2O$ ✓</p> <p>If F has been incorrectly identified as propanal, mark identification and equation as ECF, so max = 2 ALLOW E is $CH_3CH_2CH_2OH$ ✓</p> <p>ALLOW: $CH_3CH_2CH_2OH + [O] \rightarrow CH_3CH_2CHO + H_2O$ ✓</p>	7	<p>Mark scheme for F = propanoic acid</p> <p>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 ✓</p> <p>$m/z = 45$ indicates loss of CH_3 OR $m/z = 45$ indicates presence of CH_3CHOH OR CH_2CH_2OH OR C_2H_5O ✓</p> <p>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 ✓</p> <p>IR shows absorption at 1700 cm^{-1} due to C=O OR absorption at 1700 cm^{-1} indicates a carboxylic acid ✓</p> <p>Identification and equation F is CH_3CH_2COOH OR propanoic acid ✓</p> <p>E is $CH_3CH_2CH_2OH$ OR propan-1-ol ✓</p> <p>$CH_3CH_2CH_2OH + 2[O] \longrightarrow CH_3CH_2COOH + H_2O$ ✓</p>
	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. $\text{C}_3\text{H}_7\text{OH} + [\text{O}] \rightarrow \text{C}_2\text{H}_5\text{CHO} + \text{H}_2\text{O} \checkmark$; $\text{C}_3\text{H}_8\text{O} + [\text{O}] \rightarrow \text{C}_3\text{H}_6\text{O} + \text{H}_2\text{O} \checkmark$; $\text{C}_3\text{H}_7\text{OH} + [\text{O}] \rightarrow \text{C}_2\text{H}_5\text{COH} + \text{H}_2\text{O} \checkmark$

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)	<p>Any five from the following:</p> <p>Developing carbon capture AND storage ✓</p> <p>One example of CCS ✓</p> <p>Second example of CCS ✓</p> <p>Provide evidence to governments OR international conferences (e.g. Kyoto) OR reports to United Nations etc ✓</p> <p>Educating society OR writing in journals OR producing documentaries OR writing books OR making posters ✓</p> <p>Monitoring atmospheric changes ✓</p> <p>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 CO₂ ✓</p> <p>(Develop) more efficient engines for transport OR lean burn engines OR hybrid engines OR electric cars ✓</p> <p>Find uses for carbon dioxide OR named use: e.g. dry cleaning OR making decaffeinated coffee OR blowing agent OR fizzy drinks, etc ✓</p>	5	<p>carbon, capture AND storage required ALLOW CCS</p> <p>Examples of CCS</p> <p>deep in the oceans OR on the sea-bed ✓ DO NOT ALLOW dissolve CO₂ in the sea OR stored in ocean</p> <p>storage in geological formations OR piped into disused or partially filled oil wells or porous rocks OR under the sea-bed ✓</p> <p>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</p> <p>ALLOW idea of biofuels only if linked to carbon-neutrality</p> <p>IGNORE reforestation IGNORE reference to CFCs</p> <p>DO NOT ALLOW use less carbon dioxide</p>

Question		Expected Answers	Marks	Additional Guidance
	(c)	<p>Any two from the following:</p> <p>There are times when CO₂ has a high concentration and the temperature is also high</p> <p>OR</p> <p>There are times when CO₂ has a low concentration and the temperature is low ✓</p> <p>It is impossible to measure with certainty the average temperature years ago ✓</p> <p>There are other gases that may cause a greenhouse effect</p> <p>OR</p> <p>There are other factors that may cause a greenhouse effect ✓</p> <p>There are very few anomalous results ✓</p>	2	<p>ALLOW a (positive) correlation between temperature and carbon dioxide concentration but DO NOT ALLOW just 'a correlation'</p> <p>IGNORE 'graphs are the same shape' IGNORE 'graphs are similar'</p>
		Total	10	