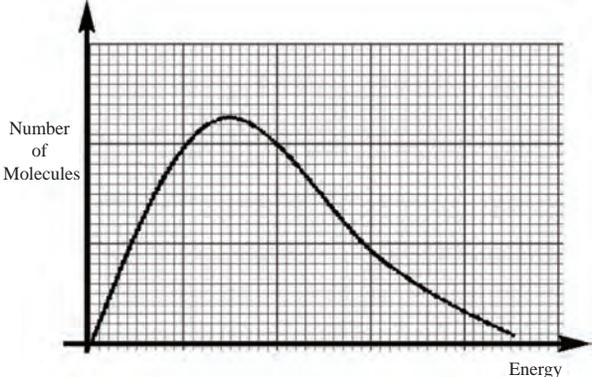
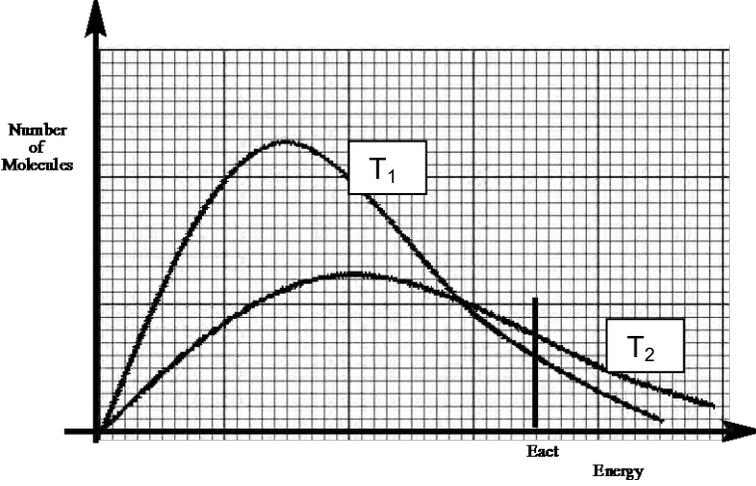


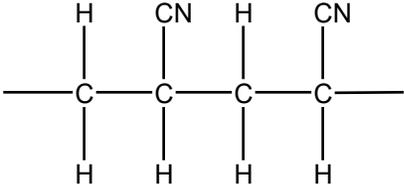
Question		Answer	Mark	Guidance
1	(a)	<p>Increased rate AND greater concentration of molecules / more molecules per (unit) volume ✓</p> <p>More collisions per second / more frequent collisions ✓</p>	2	<p>ALLOW particles for molecules IGNORE atoms</p> <p>Response must imply a volume and not area ALLOW more molecules in the same space OR more molecules in the same volume OR same number of molecules in a smaller volume</p> <p>IGNORE molecules are closer together (<i>no idea of volume</i>)</p> <p>ALLOW collisions more often OR increased rate of collision IGNORE more chance of collisions</p> <p>'more collisions' alone is not sufficient (<i>no rate</i>) IGNORE 'successful'</p>
3	(b)	The (position of a dynamic) equilibrium shifts to minimise (the effect of) any change ✓	1	<p>ALLOW suitable alternatives for 'shifts' and 'minimises'</p> <p>IGNORE 'reaction shifts'</p>

Question		Answer	Mark	Guidance
(c)	(i)	<p>Pressure: Right-hand side has fewer (gaseous) moles/molecules OR left-hand side has more (gaseous) moles/molecules ✓</p> <p>Temperature: Statement that: (Forward) reaction is exothermic OR (forward) reaction gives out heat OR reverse reaction is endothermic OR reverse reaction takes in heat ✓</p> <p>Equilibrium Lower temperature/cooling AND increasing pressure shifts (equilibrium position) to the right ✓</p>	3	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</p> <p>DO NOT ALLOW fewer atoms on right-hand side OR more atoms on left-hand side.</p> <p>IGNORE comments about the 'exothermic side' or 'endothermic side'</p> <p>Equilibrium mark is for stating that BOTH low temperature and high pressure shift equilibrium to the right (Could be separate statements)</p> <p>Note: ALLOW suitable alternatives for 'to right', e.g.: towards products OR towards CH₃OH / H₂O OR in forward direction OR favours the right</p> <p>IGNORE Increases yield of CH₃OH/products (<i>in question</i>)</p> <p>IGNORE responses in terms of rate</p>
	(ii)	<p>Low temperature gives a slow rate OR high temperatures needed to increase rate ✓</p> <p>High pressure is expensive (to generate) OR high pressure provides a safety risk ✓</p>	2	<p>ALLOW high pressure is dangerous IGNORE high pressure is explosive</p>

Question	Answer	Mark	Guidance
(d)	 <p>Correct drawing of Boltzmann distribution curve ✓</p> <p>Axes labelled: y axis: (number of) molecules AND x axis: energy ✓</p> <p>Catalyst lowers the activation energy (by providing an alternative route) ✓</p> <p>(With a catalyst a) greater proportion of molecules with energy greater than activation energy OR (With a catalyst a) greater proportion of molecules with energy equal to the activation energy ✓</p>	4	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</p> <p>Curve must start at origin. The limit of acceptability is that the curve must start within the first small square nearest the origin.</p> <p>Curve must not touch the x-axis at higher energy</p> <p>IGNORE a slight inflexion on the curve</p> <p>DO NOT ALLOW two curves DO NOT ALLOW a curve that bends up at the end by more than one small square</p> <p>ALLOW particles instead of molecules on y axis DO NOT ALLOW enthalpy for x-axis label DO NOT ALLOW atoms instead of particles or molecules ALLOW ECF for the subsequent use of atoms (instead of molecules or particles)</p> <p>ALLOW annotations on Boltzmann distribution diagram</p> <p>ALLOW (with a catalyst) more molecules have sufficient energy to react</p> <p>IGNORE (more) successful collisions</p>
(e)	Allows reactions to take place at lower temperatures ✓	1	<p>ALLOW less heat (required) IGNORE references to pressure IGNORE references to less energy (<i>in question</i>) e.g. lowers E_a</p>
Total		13	

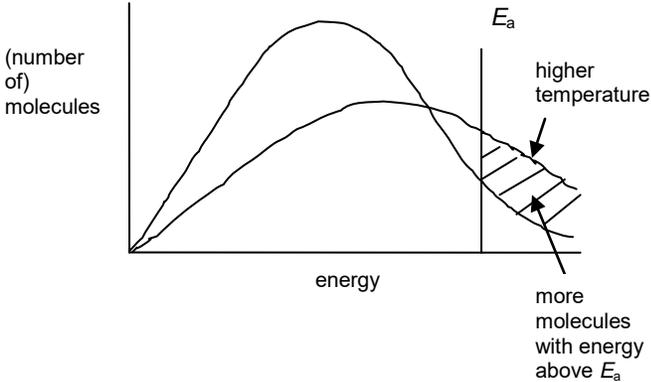
Question	Answer	Mark	Guidance
2 (a) (i)	 <p>axes labelled (number of) molecules and (kinetic) energy ✓</p> <p>Correct drawing of a two Boltzmann distributions i.e. both curves must start within the first small square nearest to the origin AND must not touch the x axis at high energy ✓</p> <p>Drawing of Boltzmann distribution at two different temperatures with higher and lower temperature clearly identified (ie $T_2 > T_1$) ✓</p> <p>QWC - (At a higher temperature) more molecules have energy above activation energy OR greater area under the curve above the activation energy ✓</p>	4	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</p> <p>Candidates do not need E_a on graph</p> <p>ALLOW particles instead of molecules on the y axis DO NOT ALLOW atoms instead of particles/molecules ALLOW ECF for the incorrect use of atoms (instead of molecules/particles) DO NOT ALLOW enthalpy on the x-axis</p> <p>DO NOT ALLOW increase of more than one small square at high energy end of curve.</p> <p>Maximum of curve for higher temperature to right AND lower than maximum of lower temperature curve AND above lower temp line at higher energy Higher temp line should intersect lower temp line once</p> <p>DO NOT ALLOW lower activation energy QWC requires more molecules have or exceed activation energy/E_a. IGNORE more molecules have enough energy to react for the QWC mark (as not linked to E_a) ORA if states the effect when the temperature is lower IGNORE (more) successful collisions</p>

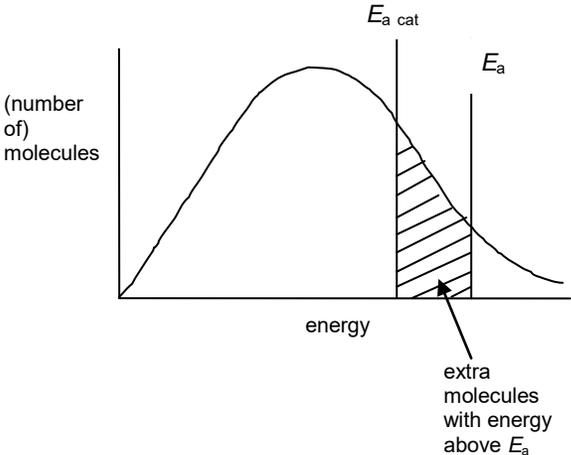
Question		Answer	Mark	Guidance
(a)	(ii)	(Decreasing the pressure) decreases the rate of reaction AND Decreased concentration of molecules OR Number of molecules remains the same but the volume increases OR Less molecules per (unit) volume ✓ Less frequent collisions ✓	2	Correct effect on rate must be linked to reason for the first marking point. ALLOW molecules are further apart IGNORE less crowded ALLOW particles or atoms for molecules ALLOW 'space' for volume DO NOT ALLOW area instead of volume ALLOW collisions occur less often OR decreased rate of collision IGNORE less chance of collisions 'less collisions' alone is not sufficient IGNORE successful
(b)	(i)	$\text{C}_6\text{H}_{12}\text{O}_6 \longrightarrow 2\text{C}_2\text{H}_5\text{OH} + 2\text{CO}_2 \checkmark$ Temperature: Between 20 °C and 45 °C inclusive AND Condition: Absence of oxygen OR anaerobic ✓	2	ALLOW correct molecular OR structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous) IGNORE state symbols DO NOT ALLOW acidic or alkaline conditions If there is a contradiction or an incorrect answer in any condition given then do not award this mark. ALLOW conditions shown in the equation A limited supply of oxygen is not sufficient IGNORE pressure IGNORE yeast (in question) ALLOW Lack of oxygen
(b)	(ii)	$2\text{NO} + 2\text{CO} \longrightarrow 2\text{CO}_2 + \text{N}_2 \checkmark$	1	ALLOW multiples IGNORE state symbols
Total			9	

Question		Answer	Marks	Guidance
3	(a)	 $ \begin{array}{cccc} \text{H} & \text{CN} & \text{H} & \text{CN} \\ & & & \\ \text{---C} & \text{---C} & \text{---C} & \text{---C---} \\ & & & \\ \text{H} & \text{H} & \text{H} & \text{H} \end{array} $	1	<p>ALLOW correct structural OR displayed OR skeletal formula OR mixture of the above (as long as unambiguous)</p> <p>ALLOW two or more repeat units but has to be a whole number of repeat units</p> <p>ALLOW vertical bond to CN to any part of the CN</p> <p>End bonds MUST be shown as either dotted or normal line</p> <p>IGNORE brackets</p> <p>IGNORE n</p>
	(b)	All the reactants are made into the desired product OR it is an addition reaction ✓	1	<p>ALLOW there are no waste (products) OR there are no by-products OR only one product is made</p> <p>ALLOW an addition polymer is made</p> <p>DO NOT ALLOW all the products are useful</p> <p>IGNORE additional reaction</p>

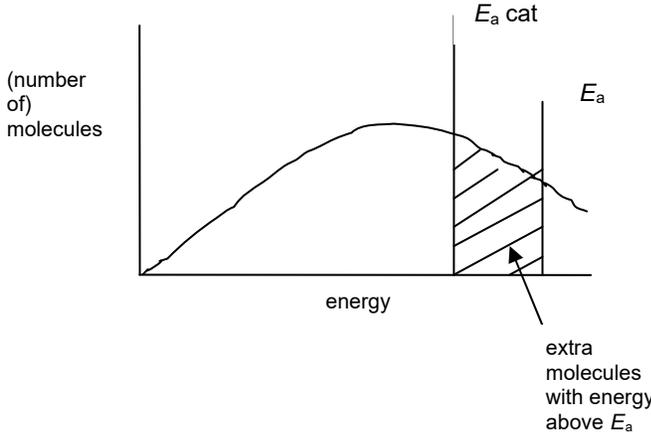
Question	Answer	Marks	Guidance
(c)	<p>QWC – Linking effect with explanation</p> <p>(as temperature rises) position of equilibrium changes to minimise effect of temperature rise by absorbing energy OR (as pressure rises) position of equilibrium changes to minimise the pressure increase by reducing the pressure and making fewer gas molecules ✓</p> <p>as temperature rises the position of equilibrium shifts to the left AND increase in pressure shifts the equilibrium to the left ✓</p> <p>relates change with temperature to the (forward) reaction being exothermic OR reaction releases energy or heat OR reverse reaction is endothermic OR reverse reaction takes in heat or energy ✓</p> <p>change with pressure because there are fewer moles of reactants OR more moles of products ✓</p> <p>removing the catalyst does not change the position of equilibrium ✓</p>	5	<p>ALLOW suitable alternatives for ‘to the left’ eg moves to the reactant side OR towards $C_3H_6(g)$ or $NH_3(g)$ or O_2 OR moves in reverse direction IGNORE responses in terms of rate</p> <p>This mark is dependent on correct change in position of equilibrium</p> <p>Moves towards the endothermic direction is not sufficient</p> <p>ALLOW fewer molecules of reactant This mark is dependent on correct change in position of equilibrium</p> <p>ALLOW equilibrium does not move OR catalyst has no effect on the equilibrium</p>

Question		Answer	Marks	Guidance
	(d)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 95.5, award 2 marks.</p> <p>actual amount propenenitrile is 210 (mol) ✓</p> <p>% yield = 95.454545 ✓</p>	2	<p>IF there is an alternative answer, check to see if there is any ECF credit possible using working below</p> <p>ALLOW theoretical mass of propenenitrile = 11660 g OR 11.66 kg ALLOW 11700 OR 11.7kg</p> <p>ALLOW 95 up to calculator value of 95.454545 correctly rounded up</p> <p>ALLOW 95 up to calculator value of 95.128205 correctly rounded up if 11.7kg is used'</p> <p>ALLOW ecf from wrong actual mass or actual amount</p> <p>DO NOT ALLOW ecf if percentage yield is above 100%</p>

Question	Answer	Marks	Guidance
(e)	<p>Boltzmann distribution</p> <p>Correct drawing of one Boltzmann distribution (could be temperature or catalyst) ✓</p> <p>axes labelled (number of) molecules and energy ✓</p> <p>Increasing the temperature</p> <p>Correct drawing of Boltzmann distribution at two different temperatures with higher and lower temperature clearly identified ✓</p> 	7	<p>Look at the first Boltzmann distribution on the paper: If it is the temperature one then both curves will have to be correct</p> <p>Boltzmann distribution – must start at origin and must not end up at 0 on y-axis ie must not touch x-axis</p> <p>ALLOW a slight inflexion in the Boltzmann curve</p> <p>ALLOW particles instead of molecules DO NOT ALLOW atoms instead of particles or molecules DO NOT ALLOW number of particles at activation energy DO NOT ALLOW enthalpy ONLY penalise the incorrect use of atoms (instead of molecules or particles) the first time it is seen</p> <p>Maximum of curve for higher temperature to right AND lower than maximum of lower temperature curve AND above lower temp line at higher energy as shown in diagram below Higher temperature line should intersect the lower temperature only once</p>

Question	Answer	Marks	Guidance
	<p>Adding a catalyst</p>  <p>idea that activation energy is lowered with a catalyst ✓</p>		<p>ALLOW E_c OR E_{cat} for activation energy of catalysed reaction</p> <p>ALLOW activation lowered shown on Boltzmann distribution diagram</p>
	<p>Collision theory reaction is faster with catalyst AND when temperature is increased ✓</p> <p>Greater proportion of molecules with energy above activation energy (with increased temperature or when catalyst is used) ✓</p> <p>more effective collisions OR more successful collisions (with increased temperature or when catalyst is used) ✓</p>		<p>ALLOW more molecules with energy above activation energy OR more molecules that overcome the activation energy OR more molecules have enough energy to react ALLOW this marking point once either in terms of using a catalyst or increasing the temperature</p> <p>ALLOW this marking point once either in terms of using a catalyst or increasing the temperature ALLOW more collisions involving particles with energy above the activation energy More collisions per second is not sufficient</p>
	Total	16	

Question		Answer	Marks	Guidance	
4	(a)	<p>(equilibrium position shifts) to the left ✓</p> <p>(because there are) fewer moles (of gas) on the reactant side OR (there are) more moles (of gas) on product side ✓ This explanation mark is dependent on the correct shift of the equilibrium</p>	2	<p>Note: ALLOW suitable alternatives for 'to left', eg: towards CH₄ or H₂O / towards reactants OR in backward direction OR in reverse direction OR decreases yield of CO or H₂/products ALLOW 'favours the left', as alternative for 'shifts equilibrium to left'</p> <p>ALLOW fewer molecules on reactant side OR smaller volume on the left hand side ALLOW ORA if specified IGNORE responses in terms of rate</p>	
	(b)	<p>(equilibrium position shifts) to the right ✓</p> <p>(because forward) reaction is endothermic OR reverse reaction is exothermic ✓ This explanation mark is dependent on the correct shift of the equilibrium</p>	2	<p>Note: ALLOW suitable alternatives for 'to right', eg: towards CO or H₂ / towards products OR in forward direction OR increases yield of CO or H₂/products OR decreases amount of CH₄ or H₂O/reactants ALLOW 'favours the right', as alternative for 'shifts equilibrium to right'</p> <p>ALLOW reaction takes in heat</p> <p>ALLOW reverse reaction gives out heat</p> <p>ALLOW ORA if specified IGNORE responses in terms of rate</p>	
	(c)	(i)	<p>Gives a high rate of reaction OR reaction is fast OR reasonable rate of reaction without shifting equilibrium too much to the left ✓</p>	1	<p>ALLOW if greater pressure used it increases safety risk ALLOW if greater pressure used it is more expensive ALLOW higher pressure will shift equilibrium position even more to the left</p> <p>It is a compromise on its own is not sufficient but ALLOW compromise between rate and yield OR between rate and safety</p>

Question	er	Marks	Guidance
(c) (ii)	<p>y-axis label is '(fraction of or number of) molecules' AND x-axis label is 'energy' AND correct curve ✓</p> <p>Lowers activation energy ✓</p> <p>More molecules with energy above activation energy with a catalyst OR more effective collisions OR more successful collisions ✓</p> 	3	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</p> <p>Boltzmann distribution - must start at origin and must not end up at 0 on y-axis ie must not touch x-axis ALLOW particles OR moles as y-axis label IGNORE minor point of inflexion in the curve</p> <p>DO NOT ALLOW two curves DO NOT ALLOW atoms but credit atoms if used in a second marking point DO NOT ALLOW enthalpy for x-axis label</p> <p>ALLOW this mark from a labelled diagram</p> <p>more collisions per second is not sufficient</p>

Question		er	Marks	Guidance
	(d)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 91.2 (%) award 3 marks</p> <p>theoretical amount of hydrogen = 3.75×10^7 (mol) ✓ actual amount of hydrogen made = 3.42×10^7 (mol) ✓ % = 91.2 ✓</p>	3	<p>IF there is an alternative answer, check to see if there is any ECF credit possible using working below</p> <p>IF ECF, ANNOTATE WITH TICKS AND CROSSES, etc</p> <p>Answer must have three significant figures ALLOW ECF from incorrect theoretical and actual amounts of hydrogen</p> <p>ALLOW answer that uses grams rather than tonnes where theoretical amount of hydrogen = 37.5 (mol) and actual amount of hydrogen = 34.2 (mol)</p> <p>ALLOW alternative approach based on the mass of hydrogen rather than the amount of hydrogen Theoretical amount of hydrogen = 3.75×10^7 (mol) ✓ Theoretical mass of hydrogen made = 75 (tonnes) ✓ Percentage = 91.2 ✓</p>
	(e) (i)	<p>$\text{CO} + 2\text{H}_2 \rightarrow \text{CH}_3\text{OH}$ ✓</p>	1	<p>ALLOW correct multiples ALLOW CH_4O IGNORE state symbols</p>
	(ii)	<p>Any two from:</p> <p>Carbon monoxide is toxic OR poisonous ✓ Increases atom economy of the process OR gives 100% atom economy ✓ Methanol is a fuel ✓</p>	2	<p>IGNORE harmful or dangerous</p> <p>ALLOW uses a waste product OR CO is then a desired product OR CO is no longer a waste product OR reduces amount of waste product</p> <p>ALLOW other uses of methanol eg petrol additive, solvent or organic feedstock</p>

Question		er	Marks	Guidance
	(f)	Unsaturated (vegetable) oils OR oils containing C=C bonds ✓ (reacted with hydrogen) in the presence of a nickel catalyst ✓	2	ALLOW unsaturated fats OR unsaturated lipids OR unsaturated ester ALLOW oils become more saturated IGNORE unsaturated compound DO NOT ALLOW unsaturated hydrocarbon ALLOW Pt OR Pd
		Total	16	

Question			Expected Answers	Marks	Additional Guidance
5	a	i	Branched chain alkane of formula C ₅ H ₁₂ to C ₉ H ₂₀ e.g. 2-methylpentane, 3-methyloctane ✓	1	Must have position number but ALLOW methylbutane DO NOT ALLOW 1-methylpentane or 2-ethylpentane etc DO NOT ALLOW incorrect nomenclature e.g. 2-methypentane etc
	b	i	Vibrate (more) ✓	1	ALLOW bend / stretch / oscillate IGNORE rotate NOT break / molecules vibrate
		ii	Incomplete combustion ✓	1	ALLOW not enough oxygen
		iii	NO for photochemical smog OR low level ozone ✓ CO is toxic ✓	2	ALLOW NO can (eventually) cause acid rain OR can result in respiratory irritation OR can (eventually) depletes high level ozone OR depletes ozone layer IGNORE greenhouse gas ALLOW poisonous OR kills OR lethal ALLOW CO reduces the capacity of blood to carry oxygen Oxygen combines with haemoglobin is insufficient IGNORE CO is harmful / suffocates / greenhouse gas
	c	i	Makes nitrogen AND carbon dioxide ✓ $2\text{CO} + 2\text{NO} \rightarrow \text{N}_2 + 2\text{CO}_2$ ✓	2	ALLOW any correct multiples IGNORE state symbols

Question	Expected Answers	Marks	Additional Guidance
<p>c ii</p>	<p>One activation energy correctly labelled on enthalpy profile diagram ✓</p> <p>Idea that activation energy is lowered ✓</p> <p>Catalyst has a different reaction pathway OR different reaction mechanism OR two curves drawn on profile ✓</p> <p>Correct diagram of reaction profile for exothermic reaction with product below reactants with y axis as enthalpy or energy and ΔH label – arrow should go down. Ignore a small gap between at either end of ΔH line ✓</p> <p>Drawing of Boltzmann distribution – axes labelled number of molecules and energy ✓</p> <p>More molecules with energy above activation energy with a catalyst ✓</p> <p>More effective collisions OR more successful collisions ✓</p>	<p>7</p>	<p>ANNOTATE WITH TICKS AND CROSSES</p> <p>With the line/arrow no more than 1 mm from top of curve or reactant line – arrow can be double headed for activation energy</p> <p>ALLOW vertical line with no arrows</p> <p>DO NOT ALLOW arrow just pointing downwards</p> <p>Marks can be awarded via, reaction profile, in words or from Boltzmann</p> <div data-bbox="1283 588 1969 1020" data-label="Figure"> </div> <p>Boltzmann distribution – must start at origin and must not end up at 0 on y-axis i.e. must not touch x-axis</p> <div data-bbox="1270 1157 1990 1423" data-label="Figure"> </div>

Question		Expected Answers	Marks	Additional Guidance
	d	<p>Any two benefits from:</p> <p>Save crude oil OR no risk of large scale pollution from exploitation of crude oil ✓</p> <p>Biodiesel is renewable OR diesel is non-renewable ✓</p> <p>Use of biodiesel is (more) carbon-neutral OR plants take up the carbon dioxide released during combustion ✓</p> <p>and one disadvantage</p> <p>Land not used to grow food crops OR (rain)forests have to be cut down to provide land OR food prices may rise because less is grown ✓</p>	3	<p>ANNOTATE WITH TICKS AND CROSSES</p> <p>ALLOW decrease the need for fossil fuels</p> <p>ALLOW plants are a renewable resource / crude oil non-renewable resource / biodiesel is more sustainable / diesel is not sustainable</p> <p>ALLOW lower carbon footprint IGNORE can be used by diesel powered cars with or without any conversion</p> <p>IGNORE comments about availability / fertilisers / pesticides</p> <p>Destroys habitats is not sufficient</p>
		Total	17	