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2002

**XVIII**

1583

Time allowed  
**85 Minutes**

Score

**/71**

Percentage

**%**

**CHEMISTRY**

**OCR  
AS & A LEVEL**

**Mark Scheme**

**Module 3: Periodic table and energy**

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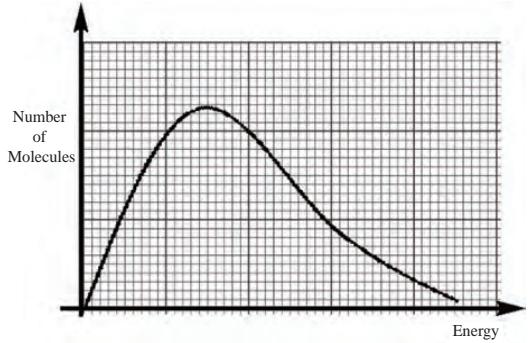


Question		Answer	Mark	Guidance
1	(a)	Increased rate <b>AND</b> greater concentration of molecules / more molecules per (unit) volume ✓  More collisions per second / more frequent collisions ✓	2	<b>ALLOW</b> particles for molecules <b>IGNORE</b> atoms  <b>Response must imply a volume and not area</b>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

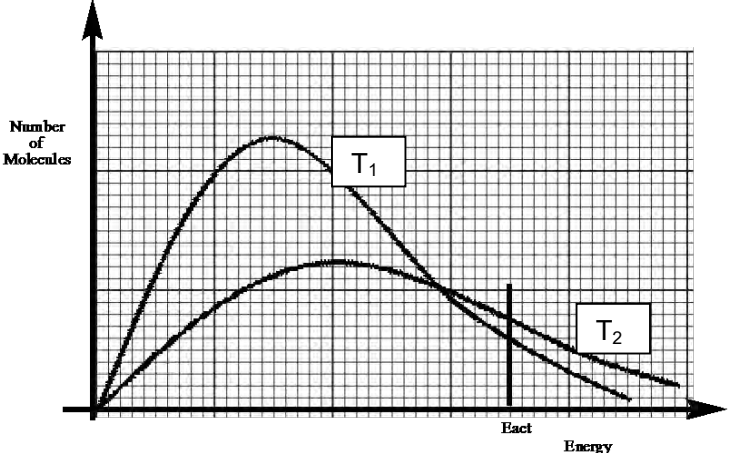


Question		Answer	Mark	Guidance
(c)	(i)	<p><b>Pressure:</b> Right-hand side has fewer (gaseous) moles/molecules <b>OR</b> left-hand side has more (gaseous) moles/molecules ✓</p> <p><b>Temperature:</b> Statement that: (Forward) reaction is exothermic <b>OR</b> (forward) reaction gives out heat <b>OR</b> reverse reaction is endothermic <b>OR</b> reverse reaction takes in heat ✓</p> <p><b>Equilibrium</b> Lower temperature/cooling <b>AND</b> increasing pressure shifts (equilibrium position) to the right ✓</p>	3	<p><b>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</b></p> <p><b>DO NOT ALLOW</b> fewer atoms on right-hand side <b>OR</b> more atoms on left-hand side.</p> <p><b>IGNORE</b> comments about the 'exothermic side' or 'endothermic side'</p> <p><b>Equilibrium mark</b> is for stating that <b>BOTH</b> low temperature and high pressure shift equilibrium to the right (Could be separate statements)</p> <p><b>Note: ALLOW</b> suitable alternatives for 'to right', e.g.: towards products <b>OR</b> towards CH<sub>3</sub>OH / H<sub>2</sub>O <b>OR</b> in forward direction <b>OR</b> favours the right</p> <p><b>IGNORE</b> Increases yield of CH<sub>3</sub>OH/products (<i>in question</i>)</p> <p><b>IGNORE</b> responses in terms of rate</p>
	(ii)	<p>Low temperature gives a slow rate <b>OR</b> high temperatures needed to increase rate ✓</p> <p>High pressure is expensive (to generate) <b>OR</b> high pressure provides a safety risk ✓</p>	2	<p><b>ALLOW</b> high pressure is dangerous <b>IGNORE</b> 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 <b>AND</b> 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 <b>OR</b> (With a catalyst a) greater proportion of molecules with energy equal to the activation energy ✓</p>	4	<p><b>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</b></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><b>IGNORE</b> a slight inflexion on the curve</p> <p><b>DO NOT ALLOW</b> two curves <b>DO NOT ALLOW</b> a curve that bends up at the end by more than one small square</p> <p><b>ALLOW</b> particles instead of molecules on y axis <b>DO NOT ALLOW</b> enthalpy for x-axis label <b>DO NOT ALLOW</b> atoms instead of particles or molecules <b>ALLOW ECF</b> for the subsequent use of atoms (instead of molecules or particles)</p> <p><b>ALLOW</b> annotations on Boltzmann distribution diagram</p> <p><b>ALLOW</b> (with a catalyst) more molecules have sufficient energy to react</p> <p><b>IGNORE</b> (more) successful collisions</p>
(e)	Allows reactions to take place at lower temperatures ✓	1	<p><b>ALLOW</b> less heat (required) <b>IGNORE</b> references to pressure <b>IGNORE</b> references to less energy (<i>in question</i>) e.g. lowers <math>E_a</math></p>
<b>Total</b>	<b>13</b>		



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 <b>AND</b> must not touch the x axis at high energy ✓</p> <p>Drawing of Boltzmann distribution at <b>two</b> different temperatures with higher and lower temperature clearly identified ( ie <math>T_2 &gt; T_1</math>) ✓</p> <p><b>QWC</b> - (At a higher temperature) more molecules have energy above activation energy <b>OR</b> greater area under the curve above the activation energy ✓</p>	4	<p><b>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</b></p> <p>Candidates do not need <math>E_a</math> on graph</p> <p><b>ALLOW</b> particles instead of molecules on the y axis <b>DO NOT ALLOW</b> atoms instead of particles/molecules <b>ALLOW ECF</b> for the incorrect use of atoms (instead of molecules/particles) <b>DO NOT ALLOW</b> enthalpy on the x-axis</p> <p><b>DO NOT ALLOW</b> increase of more than one small square at high energy end of curve.</p> <p>Maximum of curve for higher temperature to right <b>AND</b> lower than maximum of lower temperature curve <b>AND</b> above lower temp line at higher energy Higher temp line should intersect lower temp line once</p> <p><b>DO NOT ALLOW</b> lower activation energy <b>QWC</b> requires more molecules have or exceed activation energy/<math>E_a</math>. <b>IGNORE</b> more molecules have enough energy to react for the <b>QWC</b> mark (as not linked to <math>E_a</math>) <b>ORA</b> if states the effect when the temperature is lower <b>IGNORE</b> (more) successful collisions</p>





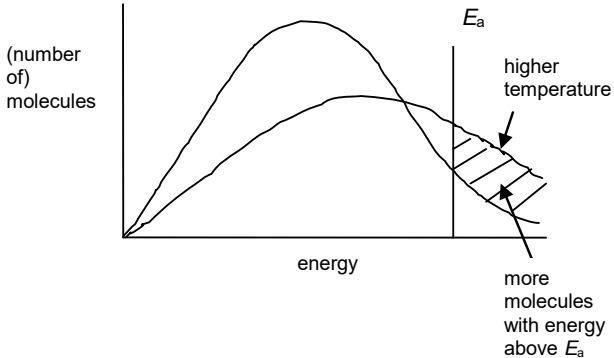
Question		Answer	Marks	Guidance
3	(a)	$\begin{array}{cccc} \text{H} & \text{CN} & \text{H} & \text{CN} \\   &   &   &   \\ \text{---C---} & \text{C---} & \text{C---} & \text{C---} \\   &   &   &   \\ \text{H} & \text{H} & \text{H} & \text{H} \end{array} \quad \checkmark$	1	<b>ALLOW</b> correct structural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



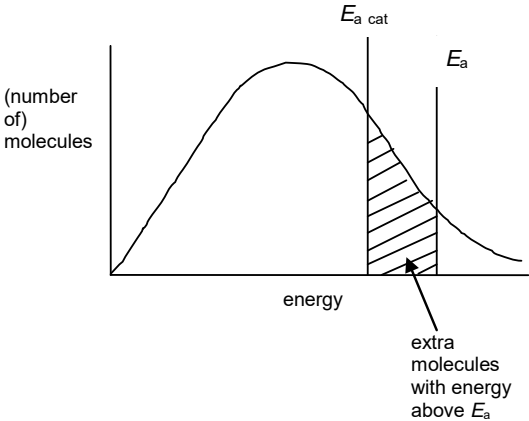
Question	Answer	Marks	Guidance
(c)	<p><b>QWC – Linking effect with explanation</b></p> <p>(as temperature rises) position of equilibrium changes to <b>minimise effect</b> of temperature rise by <b>absorbing energy</b> <b>OR</b> (as pressure rises) position of equilibrium changes to <b>minimise</b> the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



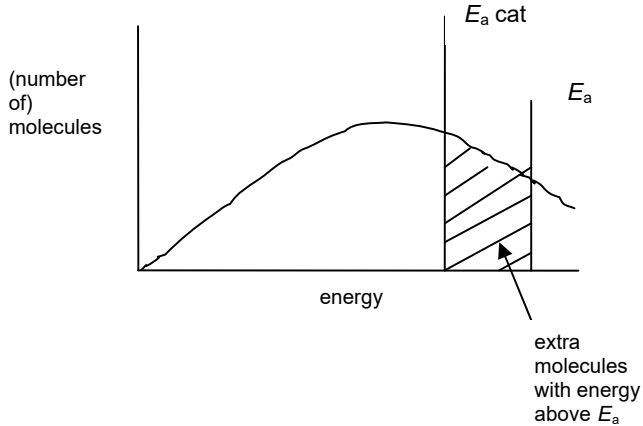
Question		Answer	Marks	Guidance
	(d)	<p><b>FIRST, CHECK THE ANSWER ON ANSWER LINE</b>  <b>IF</b> answer = 95.5, award <b>2 marks</b>.</p> <p>actual amount propenenitrile is 210 (mol) ✓</p> <p>% yield = 95.454545 ✓</p>	2	<p><b>IF</b> there is an alternative answer, check to see if there is any <b>ECF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

Question	Answer	Marks	Guidance
(e)	<p><b>Boltzmann distribution</b></p> <p>Correct drawing of one Boltzmann distribution (could be temperature or catalyst) ✓</p> <p>axes labelled (number of) molecules and energy ✓</p> <p><b>Increasing the temperature</b></p> <p>Correct drawing of Boltzmann distribution at <b>two</b> different temperatures with higher and lower temperature clearly identified ✓</p> <div style="text-align: center;">  </div>	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><b>ALLOW</b> a slight inflexion in the Boltzmann curve</p> <p><b>ALLOW</b> particles instead of molecules <b>DO NOT ALLOW</b> atoms instead of particles or molecules <b>DO NOT ALLOW</b> number of particles at activation energy <b>DO NOT ALLOW</b> enthalpy <b>ONLY</b> 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 <b>AND</b> lower than maximum of lower temperature curve <b>AND</b> 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><b>Adding a catalyst</b></p>  <p>idea that activation energy is lowered with a catalyst ✓</p>		<p><b>ALLOW</b> <math>E_c</math> OR <math>E_{cat}</math> for activation energy of catalysed reaction</p> <p><b>ALLOW</b> activation lowered shown on Boltzmann distribution diagram</p>
	<p><b>Collision theory</b> reaction is faster with catalyst <b>AND</b> 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 <b>OR</b> more successful collisions (with increased temperature or when catalyst is used) ✓</p>		<p><b>ALLOW</b> more molecules with energy above activation energy <b>OR</b> more molecules that overcome the activation energy <b>OR</b> more molecules have enough energy to react <b>ALLOW</b> this marking point <b>once</b> either in terms of using a catalyst or increasing the temperature</p> <p><b>ALLOW</b> this marking point <b>once</b> either in terms of using a catalyst or increasing the temperature <b>ALLOW</b> more collisions involving particles with energy above the activation energy More collisions per second is <b>not</b> sufficient</p>
	<b>Total</b>	<b>16</b>	

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

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

Question		er	Marks	Guidance
	(d)	<p><b>FIRST, CHECK THE ANSWER ON ANSWER LINE</b>  <b>IF answer = 91.2 (%) award 3 marks</b></p> <p>theoretical amount of hydrogen = <math>3.75 \times 10^7</math> (mol) ✓            actual amount of hydrogen made = <math>3.42 \times 10^7</math> (mol) ✓            % = 91.2 ✓</p>	3	<p><b>IF</b> there is an alternative answer, check to see if there is any <b>ECF</b> credit possible using working below</p> <p>IF ECF, <b>ANNOTATE WITH TICKS AND CROSSES, etc</b></p> <p>Answer must have <b>three</b> significant figures  <b>ALLOW</b> ECF from incorrect theoretical and actual amounts of hydrogen</p> <p><b>ALLOW</b> 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><b>ALLOW</b> alternative approach based on the mass of hydrogen rather than the amount of hydrogen            Theoretical amount of hydrogen = <math>3.75 \times 10^7</math> (mol) ✓            Theoretical mass of hydrogen made = 75 (tonnes) ✓            Percentage = 91.2 ✓</p>
	(e) (i)	$\text{CO} + 2\text{H}_2 \rightarrow \text{CH}_3\text{OH}$ ✓	1	<p><b>ALLOW</b> correct multiples  <b>ALLOW</b> CH<sub>4</sub>O  <b>IGNORE</b> state symbols</p>
	(ii)	<p><b>Any two from:</b></p> <p>Carbon monoxide is toxic <b>OR</b> poisonous ✓            Increases atom economy of the process <b>OR</b> gives 100% atom economy ✓            Methanol is a fuel ✓</p>	2	<p><b>IGNORE</b> harmful or dangerous</p> <p><b>ALLOW</b> uses a waste product <b>OR</b> CO is then a desired product <b>OR</b> CO is no longer a waste product <b>OR</b> reduces amount of waste product</p> <p><b>ALLOW</b> other uses of methanol eg petrol additive, solvent or organic feedstock</p>

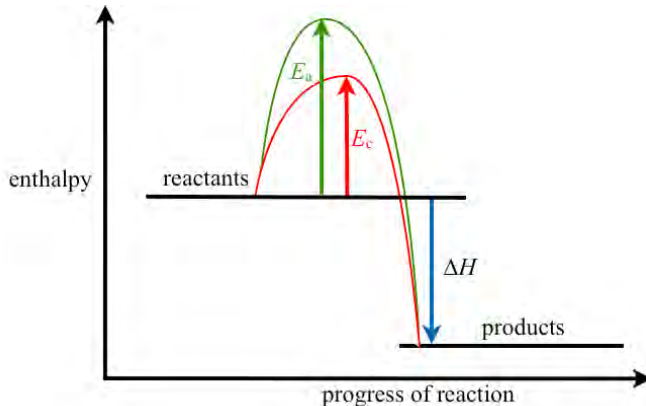
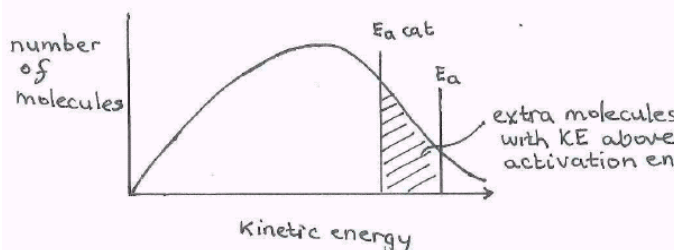


Question		er	Marks	Guidance
	(f)	Unsaturated (vegetable) oils <b>OR</b> oils containing C=C bonds ✓  (reacted with hydrogen) in the presence of a nickel catalyst ✓	2	<b>ALLOW</b> unsaturated fats <b>OR</b> unsaturated lipids <b>OR</b> unsaturated ester <b>ALLOW</b> oils become more saturated <b>IGNORE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



Question			Expected Answers	Marks	Additional Guidance
5	a	i	Branched chain alkane of formula $C_5H_{12}$ to $C_9H_{20}$ e.g. 2-methylpentane, 3-methyloctane ✓	1	Must have position number <b>but ALLOW</b> methylbutane <b>DO NOT ALLOW</b> 1-methylpentane or 2-ethylpentane etc <b>DO NOT ALLOW</b> incorrect nomenclature e.g. 2-methypentane etc
	b	i	Vibrate (more) ✓	1	<b>ALLOW</b> bend / stretch / oscillate <b>IGNORE</b> rotate <b>NOT</b> break / molecules vibrate
		ii	Incomplete combustion ✓	1	<b>ALLOW</b> not enough oxygen
		iii	NO for photochemical smog <b>OR low level</b> ozone ✓  CO is toxic ✓	2	<b>ALLOW</b> NO can (eventually) cause acid rain <b>OR</b> can result in respiratory irritation <b>OR</b> can (eventually) depletes high level ozone <b>OR</b> depletes ozone layer <b>IGNORE</b> greenhouse gas  <b>ALLOW</b> poisonous <b>OR</b> kills <b>OR</b> lethal <b>ALLOW</b> CO reduces the capacity of blood to carry oxygen Oxygen combines with haemoglobin is insufficient  <b>IGNORE</b> CO is harmful / suffocates / greenhouse gas
	c	i	Makes nitrogen <b>AND</b> carbon dioxide ✓  $2CO + 2NO \rightarrow N_2 + 2CO_2$ ✓	2	<b>ALLOW</b> any correct multiples <b>IGNORE</b> state symbols



Question		Expected Answers	Marks	Additional Guidance
c	ii	<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 <b>OR</b> different reaction mechanism <b>OR</b> 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 <math>\Delta H</math> label – arrow should go down. Ignore a small gap between at either end of <math>\Delta H</math> 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 <b>OR</b> more successful collisions ✓</p>	7	<p><b>ANNOTATE WITH TICKS AND CROSSES</b></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><b>ALLOW</b> vertical line with no arrows</p> <p><b>DO NOT ALLOW</b> arrow just pointing downwards</p> <p>Marks can be awarded via, reaction profile, in words or from Boltzmann</p> <div style="text-align: center;">  </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 style="text-align: center;">  </div>

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