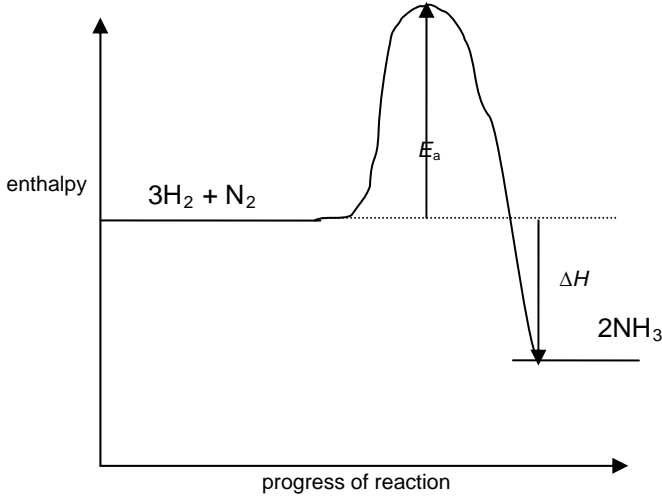


Question			Answer	Marks	Guidance
1	(a)	(i)	<p>2NH<sub>3</sub> added as product ✓</p> <p>ΔH labelled with product below reactant <b>AND</b> arrow downwards ✓</p> <p>E<sub>a</sub> labelled correctly <b>AND</b> above reactants ✓</p> 	3	<p><b>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</b></p> <p><b>IGNORE</b> state symbol <b>ALLOW</b> product mark even if product line above the reactant line</p> <p><b>ALLOW</b> -92 as a label for ΔH <b>ALLOW</b> this line even if it has a small gap at the top and bottom ie does not quite reach reactant or product line</p> <p>The curve must be drawn for this marking point</p> <p><b>IGNORE</b> arrows at both ends of activation energy line but <b>DO NOT ALLOW</b> arrow pointing down The E<sub>a</sub> line must go to maximum (or near to the maximum) on the curve <b>ALLOW</b> if the line clearly shows an activation energy and is not an enthalpy change <b>ALLOW</b> this line even if it has a small gap at the top and bottom ie does not quite reach the maximum or reactant line</p>

Question		er	Marks	Guidance
(a)	(ii)	$-46 \text{ (kJ mol}^{-1}\text{)} \checkmark$	1	<b>DO NOT ALLOW</b> 46 with no sign
	(iii)	Any value between +1 to +249 (kJ mol <sup>-1</sup> ) ✓	1	+ sign is ot needed
	(iv)	$+342 \text{ (kJ mol}^{-1}\text{)} \checkmark$	1	+ sign is ot needed
(b)	(i)	$2\text{CO} + 2\text{NO} \rightarrow 2\text{CO}_2 + \text{N}_2 \checkmark$	1	<b>ALLOW</b> correct multiples

Question		er	Marks	Guidance
(b)	(ii)	<p>CO and NO are adsorbed (onto surface) <b>OR</b> reactants are adsorbed (onto surface) ✓</p> <p>weakening of bonds <b>OR</b> chemical reaction <b>OR</b> new bonds are made <b>OR</b> carbon dioxide and nitrogen are made ✓</p> <p>CO<sub>2</sub> and N<sub>2</sub> desorbs (from the surface) <b>OR</b> products desorbs (from the surface) ✓</p>	3	<p><b>ALLOW</b> CO and NO stick onto surface <b>OR</b> CO and NO form weak attractions to the surface <b>OR</b> gases are adsorbed onto surface <b>OR</b> gases bond to surface</p> <p><b>NOT</b> absorb but <b>allow</b> ecf for deabsorb later on</p> <p><b>ALLOW</b> lowers activation energy</p> <p><b>IGNORE</b> alternative pathway</p> <p>Requires less energy is not sufficient</p> <p><b>ALLOW</b> products leave (the surface) <b>OR</b> products diffuse away (from surface) <b>OR</b> weak attraction to surface is broken</p> <p><b>ALLOW</b> deadsorb</p>

Question		er	Marks	Guidance
(c)	(i)	<p><b>Any two from:</b></p> <p>IR (spectroscopy) ✓</p> <p>Mass spectrometry ✓</p> <p>UV (spectroscopy) ✓</p> <p>NMR ✓</p> <p>GC ✓</p>	2	<p><b>ALLOW</b> mass spec / MS / mass spectroscopy</p> <p><b>ALLOW</b> atomic absorption / AAS</p> <p><b>IGNORE</b> satellite imaging or thermal imaging</p>
	(ii)	<p><b>Any one from:</b></p> <p>Idea that pollution travels (across country) borders</p> <p><b>OR</b> idea that all countries contribute towards pollution</p> <p><b>OR</b> Cooperation means that scientists can share ideas</p> <p><b>OR</b> scientists can warn governments of risk</p> <p><b>OR</b> world-wide legislation can be introduced</p> <p><b>OR</b> allows monitoring of pollution in different countries</p> <p><b>OR</b> richer countries can help poorer countries introduce pollution controls</p> <p><b>OR</b> One country cannot control pollution unless all countries do ✓</p>	1	<p><b>ALLOW</b> some countries produce more pollution than others</p> <p><b>ALLOW</b> so protocols can be developed</p>
(d)		<p><b>Step 1</b> <math>\text{NO} + \text{O}_3 \rightarrow \text{NO}_2 + \text{O}_2</math> ✓</p> <p><b>Step 2</b> <math>\text{NO}_2 + \text{O} \rightarrow \text{NO} + \text{O}_2</math> ✓</p> <p><b>overall</b> <math>\text{O}_3 + \text{O} \rightarrow 2\text{O}_2</math> ✓</p>	3	

Question		er	Marks	Guidance
(e)	(i)	Reaction gives NO <b>OR</b> reaction gives NO <sub>2</sub> <b>OR</b> reaction gives a mixture of oxides <b>OR</b> activation energy too high <b>OR</b> rate of reaction is too slow ✓	1	<b>ALLOW</b> makes a mixture of oxides/products <b>ALLOW</b> reaction cannot be carried out experimentally <b>ALLOW</b> reaction does not take place nitrogen and oxygen do not react together is <b>not</b> sufficient <b>IGNORE</b> heat loss to surroundings <b>IGNORE</b> reference to bond enthalpy being a mean value
	(ii)	<b>FIRST, CHECK THE ANSWER ON ANSWER LINE</b> <b>IF answer = +82 (kJ mol<sup>-1</sup>) award 2 marks</b> <b>IF answer = -82 (kJ mol<sup>-1</sup>) award 1 mark</b>  $\Delta H = 193 - 111$ ✓  $= +82$ ✓	2	<b>ALLOW</b> 82  <b>ALLOW</b> one mark for -82 <b>ALLOW</b> one mark for +304 / -304
<b>Total</b>			<b>19</b>	

Question		Answer	Marks	Guidance
2	(a)	<p><b>FIRST, CHECK THE ANSWER ON ANSWER LINE</b>  <b>IF answer = <math>-162 \text{ (kJ mol}^{-1}\text{)}</math> award 3 marks</b></p> <p>Energy associated with bond breaking = 3354  <b>OR</b> <math>(2 \times 805) + (4 \times 436) \checkmark</math></p> <p>Energy associated with bond making = 3516  <b>OR</b> <math>(4 \times 415) + (4 \times 464) \checkmark</math></p> <p>Enthalpy change = <math>-162 \checkmark</math></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><b>IGNORE</b> sign</p> <p><b>IGNORE</b> sign</p> <p><b>ALLOW</b> ECF from wrong additions of energy associated with bond breaking and/or from bond making</p> <p><b>ALLOW</b> two marks for <math>(+162, (+)6870, -6870</math> or <math>(+)766</math></p> <p><b>ALLOW</b> one mark for <math>-766</math></p>
	(b) (i)	<p>Absorbs IR radiation <math>\checkmark</math></p> <p>Bonds vibrate <math>\checkmark</math></p>	2	<p><b>IGNORE</b> absorbs heat</p> <p><b>ALLOW</b> IR re-radiated</p> <p><b>DO NOT ALLOW</b> absorbs UV radiation</p> <p><b>DO NOT ALLOW</b> blocks IR radiation</p> <p><b>ALLOW</b> bonds stretch <b>OR</b> bonds bend</p> <p><b>IGNORE</b> molecule vibrates/rotates</p> <p><b>DO NOT ALLOW</b> bonds break</p>

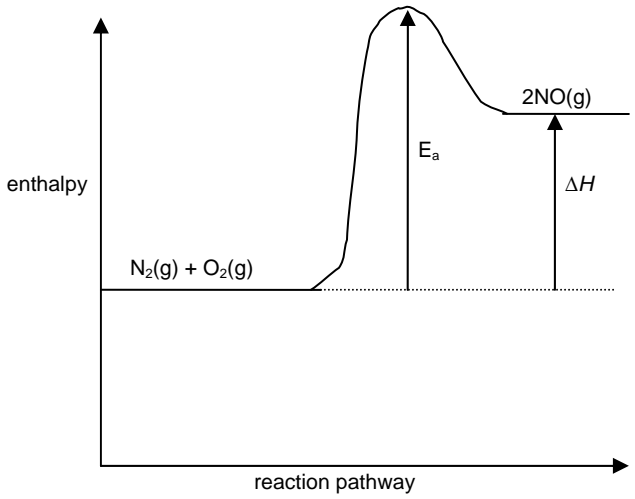
Question		er	Marks	Guidance
	(b) (ii)	<p><b>Any two from:</b></p> <p>(liquid) injected deep into the oceans ✓</p> <p>Stored in (old) geological formations  <b>OR</b> stored underground in rocks  <b>OR</b> stored in (old) mines  <b>OR</b> stored in (old) oil wells ✓</p> <p>Stored by reaction with metal <u>oxides</u>  <b>OR</b> reaction to form (solid) <u>carbonates</u>  <b>OR</b> stored as a <u>carbonate</u>  <b>OR</b> equation to show formation of metal carbonate ✓</p>	2	<p><b>DO NOT ALLOW</b> reference to carbon being stored – the answer must either refer to carbon dioxide or not mention the name of the stored substance</p> <p><b>ALLOW store deep</b> in the oceans <b>OR</b> on the <b>sea-bed</b> ✓  <b>ALLOW</b> stored deep under the sea  <b>DO NOT ALLOW</b> dissolve CO<sub>2</sub> in the sea <b>OR</b> stored in ocean</p> <p><b>ALLOW</b> stored under the sea bed  <b>ALLOW</b> pumped into oil wells to force last bit of oil out</p> <p><b>IGNORE</b> mineral storage</p>

Question		er	Marks	Guidance
(c)	(i)	<p>Homolytic ✓</p> <p><math>\text{Br}_2 \longrightarrow 2\text{Br}</math> ✓</p> <p><math>\text{Br} + \text{C}_2\text{H}_6 \longrightarrow \text{HBr} + \text{C}_2\text{H}_5</math> ✓</p> <p><math>\text{C}_2\text{H}_5 + \text{Br}_2 \longrightarrow \text{C}_2\text{H}_5\text{Br} + \text{Br}</math> ✓</p> <p><math>\text{Br} + \text{C}_2\text{H}_5 \longrightarrow \text{C}_2\text{H}_5\text{Br}</math></p> <p><b>OR</b> <math>\text{Br} + \text{Br} \longrightarrow \text{Br}_2</math></p> <p><b>OR</b> <math>\text{C}_2\text{H}_5 + \text{C}_2\text{H}_5 \longrightarrow \text{C}_4\text{H}_{10}</math> ✓</p> <p><b>Two</b> names of steps linked to appropriate equations ✓</p> <p><b>OR</b></p> <p><b>three</b> names of steps linked to appropriate equations ✓✓</p>	7	<p><b>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</b></p> <p><b>IGNORE</b> dot for radical and any state symbols for all equations</p> <p>If more than one termination step is written they must all be correct to be awarded the mark</p> <p><b>DO NOT ALLOW</b> termination steps with H</p> <p>initiation step linked to correct equation</p> <p>propagation step linked to one equation in which there is a radical on the left and a radical on the right</p> <p>termination step linked to equation involving two radicals:</p> <p>If no equations are given to link the names of the step then award one mark for mention of all three steps</p> <p>If halogen other than bromine do not give equation mark for initiation and only give one mark for all three terms linked to appropriate equations</p> <p>If hydrocarbons other than ethane are used <b>DO NOT ALLOW</b> any marks for the equations in the propagation steps</p>



Question		er	Marks	Guidance
(c)	(ii)	<p><b>Any two from:</b></p> <p>More than one C–H bond can be substituted <b>OR</b> multi-substitution can occur <b>OR</b> more than one substitution can happen ✓</p> <p>Lots of termination steps ✓</p> <p>termination steps can give products that will also react with (bromine) radicals ✓</p>	2	<p><b>ALLOW</b> equations or examples of multi substitution</p> <p><b>ALLOW</b> an equation to illustrate formation of other products eg butane</p> <p><b>ALLOW</b> examples of other products that can be formed in termination steps eg bromobutane</p> <p><b>ALLOW</b> examples of products eg butane reacting with bromine radicals to give bromobutane</p>
		<b>Total</b>	<b>16</b>	

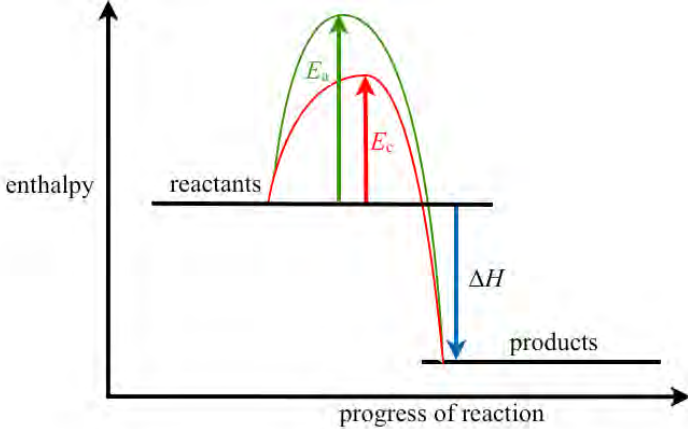
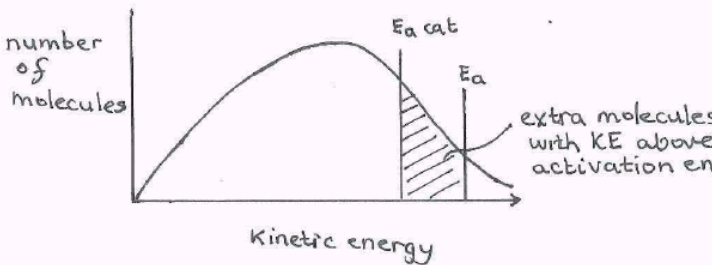
Question			Answer	Mark	Guidance
3	(a)	(i)	Reaction in which energy enters the system (from the surroundings) ✓	1	<b>ALLOW</b> reaction that absorbs energy <b>ALLOW</b> takes energy in (from the surroundings) <b>ALLOW</b> enthalpy of products have higher enthalpy than enthalpy of reactants <b>ALLOW</b> heat instead of energy <b>ALLOW</b> correct reference in terms of bond breaking and bond making <b>IGNORE</b> incorrect reference to bond breaking or bond making
		(ii)	+33 ✓	1	+ sig is <b>not</b> required <b>DO NOT ALLOW</b> -33

Question			Answer	Mark	Guidance
3	(b)	(i)	<p>2NO added for product ✓</p> <p><math>\Delta H</math> labelled with product above reactant <b>AND</b> arrow upwards ✓</p> <p><math>E_a</math> labelled correctly <b>AND</b> above products ✓</p> 	3	<p><b>ANNOTATE ANSWER WITH TICKS AND CROSSES</b></p> <p><b>IGNORE</b> State symbol <b>ALLOW</b> product line above or below reactants line</p> <p><b>ALLOW</b> (+)66 <b>ALLOW</b> line that has a small gap at the top and bottom</p> <p><b>IGNORE</b> arrows at both ends of activation energy line The <math>E_a</math> line must go to maximum (or near to the maximum) on the curve <b>ALLOW</b> if the line clearly shows an activation energy and is not an enthalpy change <b>ALLOW</b> line that has a small gap at the top and bottom</p>
		(ii)	<p>Activation energy is the <b>minimum</b> amount of energy needed for the reactants to react ✓</p>	1	<p><b>ALLOW</b> compounds <b>OR</b> elements <b>OR</b> molecules <b>OR</b> chemicals instead of reactants</p> <p><b>ALLOW</b> minimum energy needed to start a reaction</p>

Question			Answer	Mark	Guidance
3	(c)	(i)	Rate of forward reaction slows down and rate of backward reaction speeds up ✓  (Until) rate of forward reaction is the same as the rate of the backward reaction ✓	2	<b>ALLOW</b> at start rate of forward reaction is fast but rate of backward reaction is slow  <b>DO NOT ALLOW</b> forward reaction is the same as backward reaction
		(ii)	Reaction is faster ✓  Increasing pressure mean more particles per unit volume <b>OR</b> increasing pressure gives more crowded particles <b>OR</b> increasing pressure gives more concentrated (particles) ✓  So more collisions per second <b>OR</b> higher collision frequency <b>OR</b> collisions more often ✓  (Changes of pressure) do not change the (position of) equilibrium ✓  Both sides of equation have same number of moles (of gas) ✓	5	<b>ANNOTATE ANSWER WITH TICKS AND CROSSES</b>  <b>ALLOW</b> particles are closer together <b>DO NOT ALLOW</b> 'area' instead of 'volume'  <b>ALLOW</b> increased rate of collision <b>OR</b> collisions are more likely <b>OR</b> there is a greater chance of collisions  'More collisions' or 'more successful collision' are <b>not</b> sufficient  <b>DO NOT ALLOW</b> composition of equilibrium is the same (in question)  <b>ALLOW</b> both sides of equation have same number of molecules (of gas)
		(iii)	Not a closed system ✓	1	<b>ALLOW</b> gases can escape <b>OR</b> gases are continuously entering <b>OR</b> it is an open system
	(d)		has an unpaired electron ✓	1	<b>ALLOW</b> plural: unpaired electrons has a lone electron is <b>not</b> sufficient
	(e)	(i)	$2\text{NO} + \text{O}_2 \rightarrow 2\text{NO}_2$ ✓	1	<b>ALLOW</b> any correct multiple including fractions <b>IGNORE</b> state symbols

Question			Answer	Mark	Guidance
3	(e)	(ii)	<p>NO is not consumed  <b>OR</b> overall reaction is <math>O_3 + O \rightarrow 2O_2</math> ✓</p> <p><math>NO + O_3 \rightarrow NO_2 + O_2</math> ✓</p> <p><math>NO_2 + O \rightarrow NO + O_2</math> ✓</p>	3	<p><b>ANNOTATE ANSWER WITH TICKS AND CROSSES</b></p> <p><b>ALLOW</b> <math>2O_3 \rightarrow 3O_2</math>  <b>OR</b> It is a chain reaction  <b>OR</b> NO is reformed  <b>OR</b> mechanism of ozone depletion is changed  <b>OR</b> NO made can react with more ozone</p> <p><b>IGNORE dots</b></p> <p><b>ALLOW</b> <math>NO_2 + O_3 \rightarrow NO + 2O_2</math></p>
		(iii)	<p><b>ANY TWO FROM:</b></p> <p>To identify the functional groups (in pollutants)  <b>OR</b> to identify the bonds (in pollutants) ✓</p> <p>Match spectrum to known pollutants  <b>OR</b> each pollutant will have a different spectrum ✓</p> <p>Idea that you can measure the concentration or abundance of pollutant ✓</p>	2	<p><b>ALLOW</b> a named bond  <b>IGNORE</b> any specific wavenumber or range of wavenumbers</p> <p><b>ALLOW</b> match spectrum to database or datasheet</p>
			<b>Total</b>	<b>21</b>	

Question			Expected Answers	Marks	Additional Guidance
4	a	i	Branched chain alkane of formula C <sub>5</sub> H <sub>12</sub> to C <sub>9</sub> H <sub>20</sub> 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 ✓  $2\text{CO} + 2\text{NO} \rightarrow \text{N}_2 + 2\text{CO}_2$ ✓	2	<b>ALLOW</b> any correct multiples <b>IGNORE</b> state symbols

Question	Expected Answers	Marks	Additional Guidance
<p><b>c</b></p> <p><b>ii</b></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 <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>	<p>7</p>	<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>  <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> 

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>	