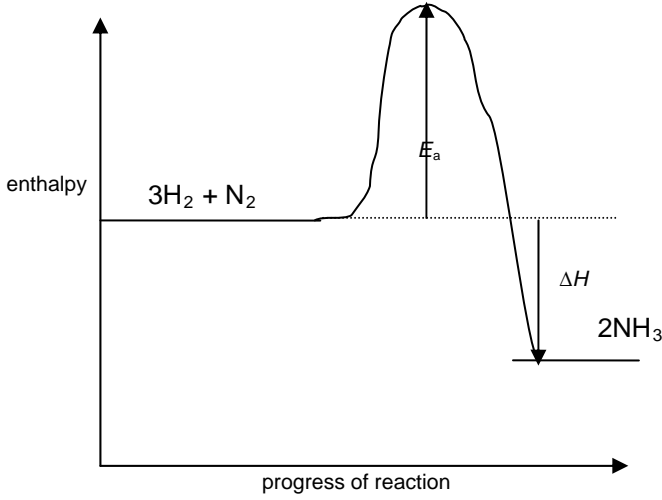


Question			Answer	Marks	Guidance
1	(a)	(i)	<p>2NH₃ added as product ✓</p> <p>ΔH labelled with product below reactant AND arrow downwards ✓</p> <p>E_a labelled correctly AND above reactants ✓</p> 	3	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</p> <p>IGNORE state symbol ALLOW product mark even if product line above the reactant line</p> <p>ALLOW -92 as a label for ΔH ALLOW 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>IGNORE arrows at both ends of activation energy line but DO NOT ALLOW arrow pointing down The E_a line must go to maximum (or near to the maximum) on the curve ALLOW if the line clearly shows an activation energy and is not an enthalpy change ALLOW 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	DO NOT ALLOW 46 with no sign
	(iii)	Any value between +1 to +249 (kJ mol ⁻¹) ✓	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	ALLOW correct multiples

Question		er	Marks	Guidance
(b)	(ii)	<p>CO and NO are adsorbed (onto surface) OR reactants are adsorbed (onto surface) ✓</p> <p>weakening of bonds OR chemical reaction OR new bonds are made OR carbon dioxide and nitrogen are made ✓</p> <p>CO₂ and N₂ desorbs (from the surface) OR products desorbs (from the surface) ✓</p>	3	<p>ALLOW CO and NO stick onto surface OR CO and NO form weak attractions to the surface OR gases are adsorbed onto surface OR gases bond to surface</p> <p>NOT absorb but allow ecf for deabsorb later on</p> <p>ALLOW lowers activation energy</p> <p>IGNORE alternative pathway</p> <p>Requires less energy is not sufficient</p> <p>ALLOW products leave (the surface) OR products diffuse away (from surface) OR weak attraction to surface is broken</p> <p>ALLOW deadsorb</p>

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

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

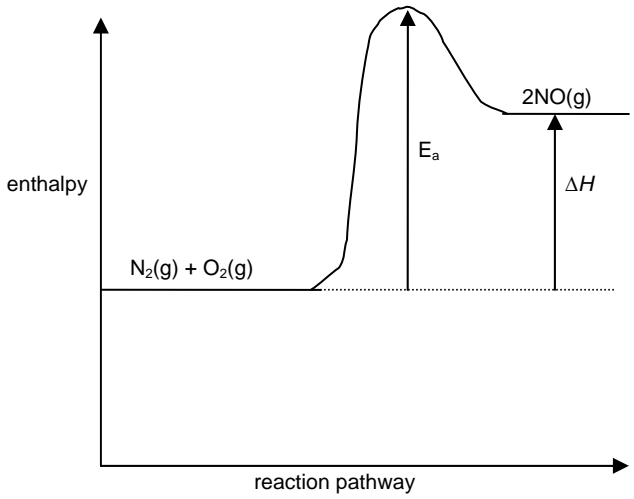
Question		Answer	Marks	Guidance
2	(a)	<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = $-162 \text{ (kJ mol}^{-1}\text{)}$ award 3 marks</p> <p>Energy associated with bond breaking = 3354 OR $(2 \times 805) + (4 \times 436) \checkmark$</p> <p>Energy associated with bond making = 3516 OR $(4 \times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

Question		er	Marks	Guidance
(b)	(ii)	<p>Any two from:</p> <p>(liquid) injected deep into the oceans ✓</p> <p>Stored in (old) geological formations OR stored underground in rocks OR stored in (old) mines OR stored in (old) oil wells ✓</p> <p>Stored by reaction with metal <u>oxides</u> OR reaction to form (solid) <u>carbonates</u> OR stored as a <u>carbonate</u> OR equation to show formation of metal carbonate ✓</p>	2	<p>DO NOT ALLOW reference to carbon being stored – the answer must either refer to carbon dioxide or not mention the name of the stored substance</p> <p>ALLOW store deep in the oceans OR on the sea-bed ✓ ALLOW stored deep under the sea DO NOT ALLOW dissolve CO₂ in the sea OR stored in ocean</p> <p>ALLOW stored under the sea bed ALLOW pumped into oil wells to force last bit of oil out</p> <p>IGNORE mineral storage</p>

Question		er	Marks	Guidance
(c)	(i)	<p>Homolytic ✓</p> <p>$\text{Br}_2 \longrightarrow 2\text{Br}$ ✓</p> <p>$\text{Br} + \text{C}_2\text{H}_6 \longrightarrow \text{HBr} + \text{C}_2\text{H}_5$ ✓</p> <p>$\text{C}_2\text{H}_5 + \text{Br}_2 \longrightarrow \text{C}_2\text{H}_5\text{Br} + \text{Br}$ ✓</p> <p>$\text{Br} + \text{C}_2\text{H}_5 \longrightarrow \text{C}_2\text{H}_5\text{Br}$</p> <p>OR $\text{Br} + \text{Br} \longrightarrow \text{Br}_2$</p> <p>OR $\text{C}_2\text{H}_5 + \text{C}_2\text{H}_5 \longrightarrow \text{C}_4\text{H}_{10}$ ✓</p> <p>Two names of steps linked to appropriate equations ✓</p> <p>OR</p> <p>three names of steps linked to appropriate equations ✓✓</p>	7	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</p> <p>IGNORE 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>DO NOT ALLOW 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 DO NOT ALLOW any marks for the equations in the propagation steps</p>

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

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

Question			Answer	Mark	Guidance
3	(b)	(i)	<p>2NO added for product ✓</p> <p>ΔH labelled with product above reactant AND arrow upwards ✓</p> <p>E_a labelled correctly AND above products ✓</p> 	3	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES</p> <p>IGNORE State symbol ALLOW product line above or below reactants line</p> <p>ALLOW (+)66 ALLOW line that has a small gap at the top and bottom</p> <p>IGNORE arrows at both ends of activation energy line The E_a line must go to maximum (or near to the maximum) on the curve ALLOW if the line clearly shows an activation energy and is not an enthalpy change ALLOW line that has a small gap at the top and bottom</p>
		(ii)	<p>Activation energy is the minimum amount of energy needed for the reactants to react ✓</p>	1	<p>ALLOW compounds OR elements OR molecules OR chemicals instead of reactants</p> <p>ALLOW 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	ALLOW at start rate of forward reaction is fast but rate of backward reaction is slow DO NOT ALLOW forward reaction is the same as backward reaction
		(ii)	Reaction is faster ✓ Increasing pressure mean more particles per unit volume OR increasing pressure gives more crowded particles OR increasing pressure gives more concentrated (particles) ✓ So more collisions per second OR higher collision frequency OR 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	ANNOTATE ANSWER WITH TICKS AND CROSSES ALLOW particles are closer together DO NOT ALLOW 'area' instead of 'volume' ALLOW increased rate of collision OR collisions are more likely OR there is a greater chance of collisions 'More collisions' or 'more successful collision' are not sufficient DO NOT ALLOW composition of equilibrium is the same (in question) ALLOW both sides of equation have same number of molecules (of gas)
		(iii)	Not a closed system ✓	1	ALLOW gases can escape OR gases are continuously entering OR it is an open system
	(d)		has an unpaired electron ✓	1	ALLOW plural: unpaired electrons has a lone electron is not sufficient
	(e)	(i)	$2\text{NO} + \text{O}_2 \rightarrow 2\text{NO}_2$ ✓	1	ALLOW any correct multiple including fractions IGNORE state symbols

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

Question			Expected Answers	Marks	Additional Guidance
4	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="1270 556 1953 987" 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="1260 1121 1974 1387" 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	