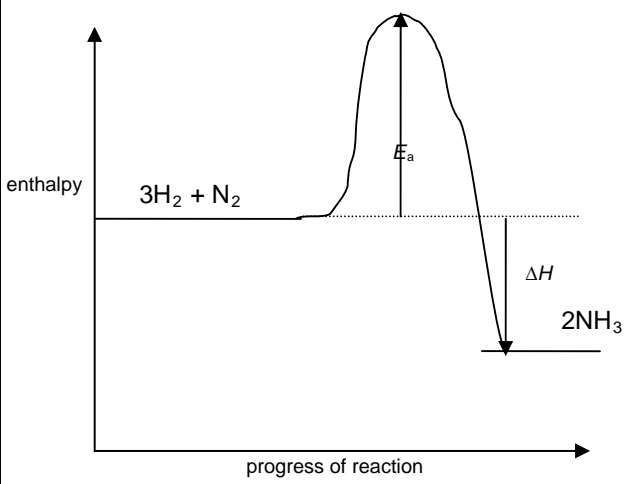


Question			Answer	Marks	Guidance
1	(a)	(i)	<p>2NH₃ added as product ✓</p> <p>ΔH labelled with product below reactant AND arrow downwards ✓</p> <p>E_a labelled correctly AND above reactants ✓</p> 	3	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</p> <p>IGNORE state symbol ALLOW product mark even if product 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</p> <p>ALLOW IR re-radiated</p> <p>DO NOT ALLOW absorbs UV radiation</p> <p>DO NOT ALLOW blocks IR radiation</p> <p>ALLOW bonds stretch OR bonds bend</p> <p>IGNORE molecule vibrates/rotates</p> <p>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>

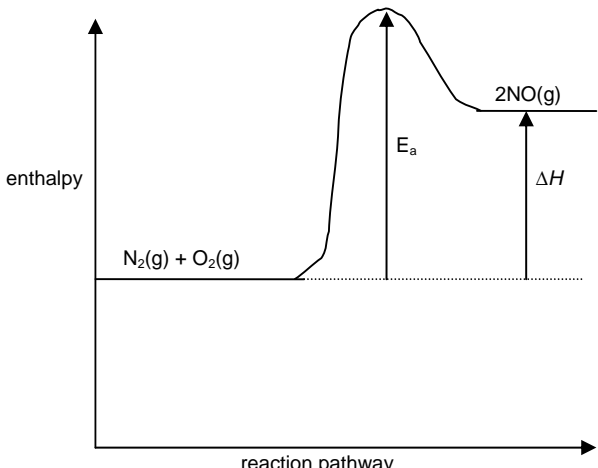
Question		er	Marks	Guidance
(c)	(i)	<p>Homolytic ✓</p> <p>$\text{Br}_2 \longrightarrow 2\text{Br}$ ✓</p> <p>$\text{Br} + \text{C}_2\text{H}_6 \longrightarrow \text{HBr} + \text{C}_2\text{H}_5$ ✓</p> <p>$\text{C}_2\text{H}_5 + \text{Br}_2 \longrightarrow \text{C}_2\text{H}_5\text{Br} + \text{Br}$ ✓</p> <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)	$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ ✓	1	IGNORE state symbols
		(ii)	Bond breaking absorbs energy AND bond forming releases energy ✓ More energy released than absorbed ✓	2	ALLOW bond breaking is endothermic AND bond forming is exothermic DO NOT ALLOW bond forming requires energy The second marking point is dependent on the correct identification of the energy changes during bond breaking and bond making ALLOW exothermic change transfers more energy than endothermic change OR bond forming 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' IGNORE reference to strong and weak bonds IGNORE reference to number of bonds broken or made IGNORE enthalpy of products is less than enthalpy of reactants
	(b)	(i)	(Enthalpy change) when one mole of a substance ✓ is completely combusted OR burns in excess oxygen ✓	2	ALLOW energy released DO NOT ALLOW energy required ALLOW element OR compound OR molecule DO NOT ALLOW one mole of atoms ALLOW reacts fully with oxygen
		(ii)	Would make carbon dioxide and water instead OR activation energy (too) high OR rate is (too) slow OR do not react together ✓	1	ALLOW will make other compounds (containing carbon and hydrogen or carbon, oxygen and hydrogen) ALLOW reaction cannot be carried out experimentally IGNORE heat is lost to the surroundings

Question			Answer	Mark	Guidance
3	(b)	(iii)	(+)2801 ✓ + -)394 × 6 + (-)286 × 6 OR (-)4080 ✓ -1279 ✓	3	IGNORE sign IGNORE sign ALLOW full marks for -1279 with no working out ✓✓✓ Unit not needed ALLOW ECF enthalpy change of combustion of carbon dioxide and water – enthalpy of combustion of glucose ALLOW for 2 marks: +1279 cycle wrong way around OR +151 OR +691 one value not × 6 OR -6881 OR +6881 wrong sign for 2801 or 4080 OR +2121 ✓✓ correct cycle but not × 6 ALLOW for 1 mark: -151 OR -691 cycle wrong way around and one value not × 6 OR -2121 cycle wrong way around and not × 6 OR -3481 OR +3481 ✓ wrong sign and not × 6 Note: There may be other possibilities
			Total	9	

Question			Answer	Mark	Guidance
4	(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
(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>		<p>3</p> <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>	<p>1</p>	<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
(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
(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	
5	a	<p>Low pressure because more (gas) molecules on right hand side of equation OR low pressure because $\Delta V = \text{positive}$ ✓</p> <p>Low temperature because the (forward) reaction is exothermic ✓</p>	2	ALLOW low pressure because more (gas) moles on right hand side of equation	
	b	<p>Increased pressure speeds up reaction / ora ✓</p> <p>900 °C increases the rate OR increased temperature speeds up reaction / ora ✓</p> <p>Idea that high enough temperature without compromising yield OR idea that high enough pressure without compromising yield ✓</p>	3	<p>ANNOTATE WITH TICKS AND CROSSES</p> <p>ALLOW 'pushes gases through system'</p>	
	c	i	$5.68 \times 10^7 / 5.7 \times 10^7$ ✓	1	ALLOW two or more significant figures Calculator answer is 5.6812500×10^7
		ii	Used to heat the incoming gases ✓	1	<p>ALLOW used to heat rest of factory OR sold to the national grid</p> <p>Provide energy to create conditions is not sufficient because one condition is pressure</p>
Total			7		