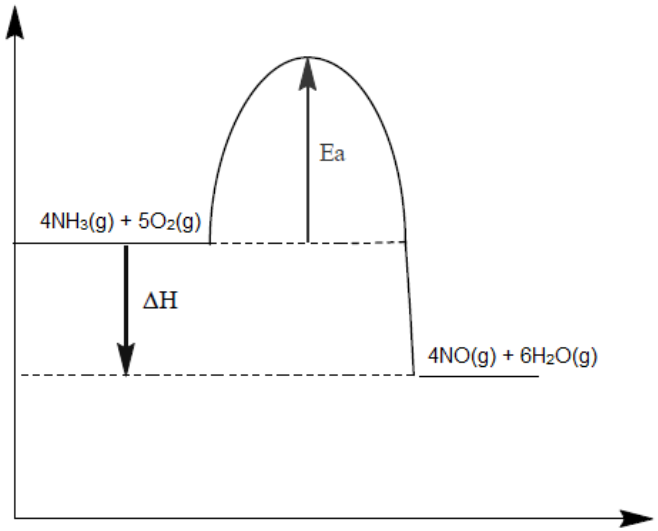
Question			Answer	Marks	Guidance
4	(a)	(i)	 **Reactants, products and E_a** Reactants on LHS **$4NH_{3(g)} + 5O_{2(g)}$** **AND** Products on RHS **$4NO_{(g)} + 6H_2O_{(g)}$** **AND** Activation energy correctly labelled / E_a ✓ ***ΔH*** *ΔH* labelled with product below reactant **AND** Arrow downwards ✓	2	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **IGNORE** state symbols ALLOW 1 mark for a correctly labelled endothermic diagram ***E_a*** **ALLOW** no arrowhead or arrowheads at both end of E_a line. E_a line must reach maximum (or near to maximum) on curve For E_a, **ALLOW** AE **OR** A_E ***ΔH*** **DO NOT ALLOW –*ΔH*** **DO NOT ALLOW** double headed arrow on *ΔH* **ALLOW** *ΔH* arrow even with small gap at the top and bottom, i.e. line does not quite reach reactant or product line. **ALLOW** –905 for *ΔH*

Question			Answer	Marks	Guidance
		(ii)	**FIRST CHECK ON ANSWER LINE** **If answer = 6.79 × 10^7 (kJ) award 4 marks** **If answer = 2.72 × 10^8 (kJ) award 3 marks** (no ÷ 4) --- ***n*(NH$_3$)** = $\frac{5.1 \times 10^6}{17}$ = 3.00 × 10^5 (mol) ✓ **Stoichiometry and ∆*H*** 1 mol NH$_3$ releases $\frac{905}{4}$ **OR** 226.25 (kJ) ✓ **Energy released** (3.00 × 10^5) × $\frac{905}{4}$ **OR** 67875000 (kJ) ✓ **Final answer to 3SF AND standard form** = 6.79 × 10^7 (kJ) ✓ *standard form* **AND** *3 SF required*	**4**	**IGNORE** (-) SIGN Throughout: **IGNORE** trailing zeroes in intermediate working, e.g. For *n*(NH$_3$) **ALLOW** 3 × 10^5 for 3.00 × 10^5 --- **ALLOW ECF** from incorrect *n*(NH$_3$) **OR** 905/4 **ALLOW 3 SF** up to calc value correctly rounded. Value will depend on intermediate rounding **Common Errors** 1.09 × 10^9 (x 4 instead of ÷ 4) 3 marks 2.72 × 10^8 (no ÷ 4) 3 marks 6.79 × 10^1 (no tonnes → g) 3 marks
	(b)		(K_c =) $\frac{[NO(g)]^4 [H_2O(g)]^6}{[NH_3(g)]^4 [O_2(g)]^5}$ ✓	**1**	Square brackets required **IGNORE** state symbols

Question			Answer	Marks	Guidance
4	(c)		***EQUILIBRIUM CONDITIONS*** **Temperature: 1 mark** (Forward) reaction is exothermic/Δ*H* is negative **OR** (Forward) reaction gives out heat ✓ **Pressure: 1 mark** Left-hand side has fewer (gaseous) moles **OR** 9 (gaseous) moles form 10 (gaseous) moles ✓ ***OPTIMUM EQUILIBRIUM CONDITIONS:* 1 mark** (for maximum yield of NO) Low temperature **AND** low pressure ✓ ***RATE:* 1 mark** Low temperature/pressure gives a slow rate/slower reaction so high temperatures / higher pressure needed to increase **rate OR frequency of collisions** ✓ ***INDUSTRIAL CONDITIONS* / OPERATIONAL FACTORS: 1 mark** High pressure provides a safety risk **OR** Higher temperatures increase energy costs / reduce yield / shift equilibrium to left **OR** (High) pressure is expensive (to generate) / uses a lot of energy ✓	5	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **ALLOW reverse arguments** Answer **MUST** relate temp/pressure to rate / frequency of collisions **ALLOW** Temperature / pressure not too high because yield reduced **IGNORE** stated temperatures and pressures **IGNORE** catalyst
			Total	**12**	