10 Reaction rates and equilibrium
Answers to practice questions

Question number	Answer	Marks	Guidance
1 (a)	1: The enthalpy change, ΔH; 2: The activation energy, E_a	B1 B1	
1 (b)	ΔH is unaffected as it is the difference between the reactants and products E_a decreases as a catalyst allows an alternative route of lower activation energy	B1 B1	
2 (a) (i)	T_1 = lower temperature; T_2 = higher temperature axes labelled number of molecules and (kinetic) energy Drawing of two Boltzmann distribution at **two** different temperatures starting within the first small square of the origin AND not touching x axis at high energy Higher temperature curve (T_2) has lower maximum AND maximum shifted to higher energy At the higher temperature more molecules have energy above activation energy	 B1 B1 B1 B1	Candidates do not need Ea on graph **ALLOW** particles instead of molecules on the y axis **DO NOT ALLOW** atoms instead of particles/molecules **ALLOW ECF** for the incorrect use of atoms (instead of molecules/particles) **DO NOT ALLOW** enthalpy on the x-axis **DO NOT ALLOW** increase of more than one small square at high energy end of curve. Maximum of curve for higher temperature to right **AND** lower than maximum of lower temperature curve **AND** above lower temp line at higher energy Higher temp line should intersect lower temp line once **DO NOT ALLOW** lower activation energy **QWC** requires more molecules have or exceed activation energy/E_a. **IGNORE** more molecules have enough energy to react for the **QWC** mark (as not linked to E_a) **ORA** if states the effect when the temperature is lower **IGNORE** (more) successful collisions
2 (a) (ii)	concentration is reduced and the rate of reaction decreases	B1 B1	**Correct effect on rate must be linked to reason for the first marking point.** **ALLOW** molecules are further apart

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			IGNORE less crowded **ALLOW** particles or atoms for molecules **ALLOW** 'space' for volume **DO NOT ALLOW** area instead of volume **ALLOW** collisions occur less often **OR** decreased rate of collision **IGNORE** less chance of collisions 'less collisions' alone is **not** sufficient **IGNORE** successful
3 (a) (i)	1 mark for $2NH_3$ added as product below reactant 1 mark for ΔH labelled with product **AND** arrow downwards 1 mark for *Ea* labelled correctly **AND** above reactants	B1 x 3	**IGNORE** state symbol **ALLOW** product mark even if product line above the reactant line **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 The curve must be drawn for this marking point **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
3 (a) (ii)	$\Delta_f H = -92/2 = -46\ kJ\ mol^{-1}$	B1	**DO NOT ALLOW** 46 with no sign
3 (a) (iii)	Any value between +1 to +249 $kJ\ mol^{-1}$	B1	+ sign is not needed
3 (a) (iv)	$250 + 92 = 342\ kJ\ mol^{-1}$	B1	+ sign is not needed
4 (a)	Equilibrium position shifts to right to opposes the increase in SO_2 concentration	B1	

Question number	Answer	Marks	Guidance
4 (b)	Equilibrium position shifts to the right side as there are fewer gaseous molecules on the right	B1	
4 (c)	Equilibrium position shifts to left as the formation of reactants in the endothermic direction	B1	
4 (d)	Equilibrium position does not move as a catalyst speeds up forward and reverse reaction by the same amount	B1	
5 (a)	Equilibrium position shifts to left as there are fewer gaseous molecules on the left	B1 B1	**Note: ALLOW** suitable alternatives for 'to left', eg: towards CH_4 or H_2O / towards reactants **OR** in backward direction **OR** in reverse direction **OR** decreases yield of CO or H_2/products **ALLOW** 'favours the left', as alternative for 'shifts equilibrium to left' **ALLOW** fewer molecules on reactant side **OR** smaller volume on the left hand side **ALLOW ORA** if specified **IGNORE** responses in terms of rate
5 (b)	Equilibrium position shifts to right as the formation of reactants in the endothermic direction	B1 B1	**Note: ALLOW** suitable alternatives for 'to right', eg: towards CO or H_2 / towards products **OR** in forward direction **OR** increases yield of CO or H_2/products **OR** decreases amount of CH_4 or H_2O/reactants **ALLOW** 'favours the right', as alternative for 'shifts equilibrium to right' **ALLOW** reaction takes in heat **ALLOW** reverse reaction gives out heat **ALLOW ORA** if specified **IGNORE** responses in terms of rate
5 (c) (i)	increases the rate without shifting equilibrium too much to the left	B1	**ALLOW** if greater pressure used it increases safety risk **ALLOW** if greater pressure used it is more expensive **ALLOW** higher pressure will shift equilibrium position even more to the left

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			It is a compromise on its own is **not** sufficient but **ALLOW** compromise between rate and yield **OR** between rate and safety
5 (c) (ii)	1 mark for "Boltzmann distribution drawn with axes of 'number of molecules' and 'energy'" 1 mark for "Catalyst allows the reaction to proceed via a different route with lower activation energy" 1 mark for "There are then more molecules with energy above the activation energy with a catalyst"	B1 x 3	Boltzmann distribution - must start at origin and must not end up at 0 on *y*-axis ie must not touch *x*-axis **ALLOW** particles **OR** moles as y-axis label **IGNORE** minor point of inflexion in the curve **DO NOT ALLOW** two curves **DO NOT ALLOW** atoms but credit atoms if used in a second marking point **DO NOT ALLOW** enthalpy for x-axis label **ALLOW** this mark from a labelled diagram more collisions per second is not sufficient
6 (a)	High pressures as there are fewer moles of gas molecules on the right-hand side Low temperatures as the forward reaction is exothermic	B1 B1	**ALLOW** ora **ALLOW** fewer particles **OR** fewer molecules **ALLOW** ora
6 (b)	High pressures are very expensive to generate Reaction rate may be too slow at a low temperature	B1 B1	**ALLOW** high pressures provide a safety risk **OR** high pressure is too dangerous **ALLOW** with low temperature molecules cannot overcome activation barrier
7 (a) (i)	$K_c = \frac{[NO_2(g)]^2}{[N_2O_4(g)]}$	B1	
7 (a) (ii)	$[NO_2(g)] = \sqrt{K_c \times 0.50}$ $= \sqrt{5.0 \times 10^{-3} \times 0.50} = 0.0500 \text{ mol dm}^{-3}$	B1	
7 (b) (i)	$K_c = \frac{[NH_3(g)]^2}{[N_2(g)]\,[H_2(g)]^3}$	B1	
7 (b) (ii)	$K_c = \frac{1.54^2}{9.35 \times 0.32^3} = 7.74$	B2	

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8 (a) (i)	$K_c = \frac{[HI(g)]^2}{[H_2(g)]\,[I_2(g)]}$	B1	
8 (a) (ii)	$35.0 = \frac{(1.507 \times 10^{-2})^2}{(2.10 \times 10^{-4}) \times [I_2(g)]}$ $\therefore [I_2(g)] = \frac{(1.507 \times 10^{-2})^2}{(2.10 \times 10^{-4}) \times 35.0}$ $= 0.0309\ \text{mol dm}^{-1}$	B2	
8 (b)	Rate of forward reaction = rate of reverse reaction AND Concentrations are constant	B1	
8 (c)	Equilibrium position shifts to left as the formation of reactants in the endothermic direction	B1 B1	
8 (d)	Equilibrium position does not change as there are the same number of gaseous molecules on both sides of the equation	B1 B1	