

1.1	forward and reverse rates equal		1	AO1 5.6.2.1 5.6.2.3
	because no escape of reactants or products	allow closed system allow particles for reactants or products	1	AO2 5.6.2.1 5.6.2.3

1.2	equilibrium shifts	allow no longer in equilibrium	1	AO3 5.6.2.3 5.6.2.4 5.6.2.5 5.6.2.7
	to right-hand side	allow in favour of forward reaction	1	
	to produce more of any products or to reduce any reactants	allow correct references to Le Chatelier's Principle	1	
	(new) equilibrium will be established		1	

1.3	amount of chlorine gas increases		1	AO2 5.6.2.4 5.6.2.6
	(because) system shifts to counteract the change	allow (because) system shifts to take in energy allow (because) system shifts in endothermic direction	1	AO1 5.6.2.4 5.6.2.6

1.4	no change		1	AO2 5.6.2.4 5.6.2.7
	because equal numbers of molecules or moles (of gas) on each side		1	AO1 5.6.2.4 5.6.2.7

2.1	hydrogen	allow H ₂	1	AO1 4.10.4.1
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2.2	450 °C 200 atm / atmospheres	allow values in the range 400– 500 °C allow values in the range 150– 250 atm / atmospheres allow 1 mark if both values within range but no units given	1 1	AO1 4.10.4.1
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3.1	smaller yield (because) favours endothermic reaction	allow less methanol is produced allow (because) favours reverse reaction allow equilibrium / reaction shifts to the left allow equilibrium / reaction shifts to reduce the temperature ignore reference to forward reaction is exothermic ignore references to rate	1 1	AO2 4.6.2.4 4.6.2.6
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3.2	(yield) equilibrium position moves to the product side (because) fewer molecules / moles / particles on product side (rate) more collisions per unit time (because) more molecules / particles per unit volume	allow converse arguments allow equilibrium / reaction moves to the right allow equilibrium / reaction shifts to reduce the pressure allow (because) fewer molecules / moles / particles on the right allow (because) smaller volume on product side allow increases collision frequency / rate ignore more collisions alone ignore faster collisions do not accept any indication of more energetic / forceful collisions allow (gas) molecules / particles closer together ignore more molecules / particles alone	1 1 1 1	AO2 4.6.1.3 4.6.2.4 4.6.2.7
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3.3	no effect / change		1	AO3 4.6.1.4 4.6.2.3
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4.1	equilibrium shifts to right-hand side	allow towards the products allow in favour of the forward reaction	1	AO3
	(because) concentration of SO_3 decreases	this marking point is dependent on first marking point being awarded allow pressure decreases allow to increase the concentration of SO_3 allow to re-establish equilibrium	1	AO2 5.6.2.5 5.6.2.7

5.1	higher yield (of hydrogen or carbon monoxide or product) (because) fewer moles / molecules / particles on left hand side or (because) more moles / molecules / particles on right hand side	allow converse arguments in terms of higher pressure ignore references to rate allow more hydrogen or more carbon monoxide or more product allow equilibrium moves to the right allow equilibrium moves in the forward direction allow (because) the reverse reaction produces fewer moles / molecules / particles or allow (because) the forward reaction produces more moles / molecules / particles do not accept fewer / more atoms	1 1	AO2 4.6.2.4 4.6.2.7
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5.2	no effect (on yield of hydrogen)	allow position of equilibrium unaffected by pressure ignore references to rate of reaction	1	AO2 4.6.2.7
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5.3	350 (°C) and 285 (atmospheres) = 63 (%) and 450 (°C) and 200 (atmospheres) = 28 (%) $\frac{63}{28}$ = 2.25 (times greater)	an answer of 2.25 scores 3 marks	1 1 1	AO2 4.10.4.1
		allow a value between 62 (%) and 64 (%) inclusive		
		allow a correct expression using incorrectly determined value(s) for percentage yield		
		allow a correct calculation using incorrectly determined value(s) for percentage yield correctly evaluated and rounded to at least 2 significant figures		

5.4	any one from: - the energy costs would be high(er) - the equipment would need to be strong(er) - high(er) pressures are (more) dangerous	allow converse arguments in terms of low(er) pressure ignore energy / cost unqualified allow the equipment would be (more) expensive (to build / maintain) allow (more) dangerous because (greater) risk of explosion	1	AO1 4.10.4.1
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5.5	higher temperatures produce a lower (percentage) yield (of ammonia)	allow converse allow correct reference to shift in equilibrium ignore references to pressure	1	AO2 4.6.2.6 4.10.4.1
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5.6	world population has increased any one from: • demand for fertiliser has increased • increased demand for other specified ammonia-based products e.g. nitric acid, drugs, dyes, explosives	allow more food needed	1 1	AO3 AO1 4.10.4.1 4.10.4.2
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6.1	when a reversible reaction occurs in apparatus which prevents the escape of reactants and products (equilibrium is reached) when the forward and reverse reactions occur at (exactly) the same rate	allow when a reversible reaction occurs in a sealed system	1 1	AO1 5.6.2.3
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6.2	(as pressure increases) the equilibrium position shifts to the right hand side	allow (as pressure increases) the percentage of product / dinitrogen tetroxide / N_2O_4 increases	1	AO2 5.6.2.4, 5.6.2.6 5.6.2.7
	(because) there are less moles / molecules (of dinitrogen tetroxide) on right hand side	allow (because) there are more moles / molecules (of nitrogen dioxide) on left hand side	1	

6.3	(as temperature increases) equilibrium position shifts to left hand side		1	AO2
	(because the forward) reaction is exothermic or (because) the backward reaction is endothermic		1	AO2
	(so) the percentage of product / dinitrogen tetroxide / N_2O_4 decreases		1	AO3 5.6.2.4 5.6.2.6 5.6.2.7

7.1	becomes (more) red		1	AO2 4.6.2.4 4.6.2.5
	(because the position of) equilibrium moves to the right	allow (because) the concentration of FeSCN^{2+} (ions) increases allow (because) the forward reaction is favoured	1	
	(so that) the (increase in the) concentration of thiocyanate (ions) is reduced	allow (so that) the increase in the concentration of thiocyanate (ions) is counteracted	1	

7.2	(the position of) equilibrium moves to the left	allow the concentration of Fe^{3+} (ions) increases allow the reverse reaction is favoured	1	AO2 4.6.2.4 4.6.2.6
	(so that) the (increase in the) temperature is reduced	allow (so that) the increase in the temperature is counteracted	1	
	(therefore) the forward reaction is exothermic	allow (therefore) the forward reaction releases energy (to the surroundings)	1	

7.3	no change in equilibrium position		1	AO2 4.6.2.7
	(because) no gases are present	allow (because) only aqueous solutions are present	1	

8.1	(when) the apparatus prevents the escape of reactants and products (and the) forward and reverse reactions occur at same rate	allow (in a) closed system	1 1	AO1 5.6.2.3
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8.2	equilibrium position stays the same	allow no effect	1	AO3 5.6.1.4 5.6.2.3
	increases the rate of the forward and the reverse reaction by the same amount		1	

8.3	the yield of ammonia increases		1	AO2 5.6.2.4 5.6.2.7
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8.4	yield of ammonia decreases		1	AO2
	(because) system shifts in endothermic direction	allow (because) system shifts to counteract the change allow (because) system shifts to transfer in energy (from the surroundings)	1	5.6.2.4 5.6.2.6

Question 10 continued

Question	Answers	Mark	AO/ Spec. Ref
9.1	Level 3: Relevant points (reasons/causes) are identified, given in detail and logically linked to form a clear account.	5–6	AO2 4.6.1.3 4.6.2.4 4.6.2.6 4.6.2.7 4.7.2.2
	Level 2: Relevant points (reasons/causes) are identified, and there are attempts at logical linking. The resulting account is not fully clear.	3–4	
	Level 1: Points are identified and stated simply, but their relevance is not clear and there is no attempt at logical linking.	1–2	
	No relevant content	0	
	Indicative content Rate • higher temperature gives higher rate • because more frequent collisions • higher pressure gives higher rate • because more frequent collisions • a catalyst can be used to give a higher rate • because the activation energy is reduced Yield • higher temperature gives lower yield • because the reaction is exothermic • higher pressure gives higher yield • because there are more molecules on left hand side Other factors • higher temperatures use more energy so costs increase • higher pressures use more energy so costs increase • higher pressures require stronger reaction vessels so costs increase Compromise • chosen temperature is a compromise between rate and yield • chosen temperature is a compromise between rate and cost (of energy used) • chosen pressure is a compromise between rate and cost (of energy used) • chosen pressure is a compromise between yield and cost (of energy used)		

10.1	the effects of changing conditions on the position of an equilibrium (in a closed system)	allow the effects of changing conditions on the yield of an equilibrium reaction (in a closed system)	1	AO1 5.6.2.4
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10.2	(when) the forward and reverse reactions have the same rate		1	AO1 5.6.2.3
	in apparatus which prevents the escape of reactants and products	allow in a closed system	1	

10.3	yield increases (because) there are more moles (of gas) on the left hand side	allow (because) there are fewer moles (of gas) on the right hand side	1 1	AO2 5.6.2.1 5.6.2.2 5.6.2.3 5.6.2.4 5.6.2.7
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10.4	yield decreases (because) the system shifts in the endothermic direction		1 1	AO2 5.6.2.1 5.6.2.2 5.6.2.3 5.6.2.4 5.6.2.6
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11.1	water vapour was produced	allow steam for water vapour	1	AO2 4.3.1.3 4.6.2.2
	(so) water (vapour) escaped (from the tube)	allow water was produced as a gas allow (so) the mass of the water (vapour) was not measured	1	

11.2	endothermic (reaction)	allow reversible (reaction) allow (thermal) decomposition (reaction)	1	AO1 4.6.2.2
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Question	Answers	Mark	AO / Spec. Ref.
12.1	Level 3: Relevant points (reasons/causes) are identified, given in detail and logically linked to form a clear account.	5–6	AO1 4.6.1.3 4.6.1.4 4.6.2.6 4.6.2.7 4.10.4.1
	Level 2: Relevant points (reasons/causes) are identified, and there are attempts at logical linking. The resulting account is not fully clear.	3–4	
	Level 1: Points are identified and stated simply, but their relevance is not clear and there is no attempt at logical linking.	1–2	
	No relevant content	0	
	Indicative content rate • higher temperature gives higher rate because of more frequent collisions • higher temperature gives higher rate because more particles have the activation energy • higher pressure gives higher rate because of more frequent collisions • use of catalyst gives higher rate because the activation energy is lowered equilibrium • higher temperature shifts the position of equilibrium to the left because reaction is exothermic • higher pressure shifts the position of equilibrium to the right because more molecules on left-hand side • use of catalyst has no effect on the position of equilibrium other factors • higher temperature (than 450°C) uses more energy so increases costs • higher pressure (than 200 atmospheres) uses more energy so increases costs • higher pressure (than 200 atmospheres) requires stronger reaction vessels so increases costs • use of a catalyst reduces energy costs compromise • the temperature chosen is a compromise between rate of reaction and position of equilibrium • the temperature chosen is a compromise between rate and cost • the pressure chosen is a compromise between yield / rate and cost		

13.1	reversible reaction	allow a reaction that can go both ways	1	AO1 5.6.2.1
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13.2	shifts towards the left hand side		1	AO3 5.6.2.3 5.6.2.4 5.6.2.6
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14.1	(energy =) $\frac{15.0}{2.99} \times 1.47$ = 7.37 (kJ)		1 1	AO2 4.6.2.2
		allow 7.37458194 correctly rounded to at least 2 significant figures		

14.2	shifts to the left		1	AO2 4.6.2.1 4.6.2.4 4.6.2.6
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14.3	the mixture is a lighter shade of brown		1	AO2 4.6.2.4 4.6.2.7
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14.4	no effect (on equilibrium position) (because) there are equal numbers of (gas) moles / molecules on each side (of the equation)	allow (equilibrium position) stays the same	1 1	AO2 4.6.2.4 4.6.2.7
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14.5	no effect (on equilibrium position)	allow (equilibrium position) stays the same	1	AO2 4.6.2.3 4.6.2.4
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14.6	add more hydrochloric acid		1	AO2 4.6.2.4 4.6.2.5
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14.7	(because the) forward and reverse reactions are taking place at (exactly) the same rate	ignore references to closed systems allow for 1 mark (because) the reactions are taking place at (exactly) the same rate	2	AO1 4.6.2.3
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