Mark Scheme

Q1.

Question Number	Answer	Additional Guidance	Mark
(i)	• sum of bond energies of all reactants (1) • sum of bond energies of all products (1) • calculation of $\Delta_r H$ (1)	Example of calculation $945 + (3 \times 436) = (+)2253$ (kJ mol^{-1}) $6(N-H) = 6 \times 391 = (-)2346$ (kJ mol^{-1}) $-2346 + 2253 = -93$ (kJ mol^{-1}) TE from either/both M1 and M2 Correct answer with no working scores 3	(3)

Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: • the equation in 9(a)(i) is for the formation of two moles of ammonia (1) • the bond energies in the table are mean / not specific to ammonia (1)	Ignore any references to differing conditions for the Haber process Ignore heat losses	(2)

Question Number	Answer	Mark
(iii)	The only correct answer is D (100 %) A is not correct because this is the percentage of hydrogen B is not correct because this is half the atom economy for making ammonia C is not correct because this is the percentage of nitrogen	(1)

Question Number	Answer	Mark
(iv)	The only correct answer is C $\quad K_c = \dfrac{[NH_3]^2}{[N_2][H_2]^3}$ A is not correct because this expression shows molar quantities, not powers and is inverted B is not correct because this expression shows molar quantities, not powers D is not correct because this expression is for the reverse equation	(1)

Q2.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An explanation which makes reference to the following points: • a catalyst increases the rate at which the reaction moves towards equilibrium / decreases the time a reaction takes to arrive at a particular yield of product / (provides a reaction pathway with) a lower activation energy **(1)** • allows milder conditions to be used (lowering cost) **(1)**	Allow a catalyst increases the rate of attainment of equilibrium / decreases the time a reaction takes to arrive at equilibrium Do not award just 'a catalyst increases the rate of reaction' Allow lower temperature and/or lower pressure and/or lower energy conditions Allow more product for the same energy Do not award just 'decreases the cost'	**(2)**

Q3.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • equilibrium position shifts to the left **(1)** • (because) the hydroxide ions combine with/neutralise the H⁺ ions to remove them from the equilibrium **(1)**	'Equilibrium moves to the right' scores (0) Allow Hydroxide ions react with H⁺ ions to make water/ hydroxide ions react with H⁺ ions to reduce their number/concentration Ignore reference to 'more products formed'	**(2)**

Q4.

Question Number	Answer	Mark
(i)	The only correct answer is B decrease/increase *A is not correct because an increase in pressure results in an increase in yield* *C is not correct because an increase in temperature results in a decrease in yield* *D is not correct because an increase in temperature results in a decrease in yield*	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	An explanation which makes reference to the following points: • (The yield of methanol decreases because a rise in temperature causes) the equilibrium shifts to the endothermic direction (which is the backward reaction) **(1)** • (The yield of methanol increases because) the equilibrium shifts to the side of fewer moles (of gas molecules) **(1)**	Allow TE on incorrect answers in (b)(i). e.g. if candidate gives forward reaction is endothermic allow increase in yield due to rise in temperature shifts the equilibrium to the endothermic direction can be awarded Allow the forward reaction is exothermic so the reaction favours the left hand side	(2)

Q5.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • (increasing the temperature) will move the equilibrium position to the right/ in forward direction **(1)** • because the (forward) reaction is endothermic **(1)**	Allow more products will form M2 conditional on M1	(2)

Q6.

Question Number	Answer	Mark
	The only correct answer is D $K_c = \dfrac{[H_2O]^4}{[H_2]^4}$ A is not correct because the solids should not be included in the expression and the powers of the remaining substituents have been omitted B is not correct because the solids should not be included in the expression C is not correct because the powers of the substituents have been omitted	(1)

Q7.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to any **three** of the following points: • the equilibrium position will shift to the right OR this will favour forward reaction (1) • (in an equilibrium) removal of product decreases rate of back reaction / rate of formation of reactant(s) (1) • time to attain / reach equilibrium may be too long (1) • unreacted reactants can be recycled (1)		(3)

Q8.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following points: • yield (of NO) decreases **(1)** • increase in pressure shifts equilibrium (position) to the side of fewer moles (of gas molecules) **(1)**	if M1 and M2 are contradictory then do not award any marks allow 9 mol on LHS and 10 mol on RHS, may be shown above the equation allow more moles of product allow fewer moles of reactant allow marking points in either order	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: (on increasing the pressure) • Rate increases because there are more molecules per unit volume **(1)** so increase in frequency of collisions (between reacting molecules) **(1)**	allow increase in concentration of (gas) molecules allow any implication of more particles in a given volume, e.g. particles are closer together allow more collisions per unit time ignore just 'more collisions'/'more successful collisions' with no reference to time allow answers based on a solid catalyst	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to: • heterogeneous: (the catalyst is in) a different phase/state to the reactants **(1)** • increases the rate of the forward and backward / reverse reactions **(1)**	ignore reference to products	**(2)**

Q9.

Question Number	Acceptable Answer	Additional Guidance	Mark
*	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content.	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points that is partially structured with some linkages and lines of reasoning, scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages). In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning. If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s). Comment: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning.	(6)

Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points
6	4
5-4	3
3-2	2
1	1
0	0

The following table shows how the marks should be awarded for structure and lines of reasoning.

	Number of marks awarded for structure and sustained lines of reasoning
Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.	2
Answer is partially structured with some linkages and lines of reasoning.	1
Answer has no linkages between points and is unstructured.	0

Indicative content:

- IP1 increase in temperature will increase rate

- IP2 (but) increase in temperature will decrease yield/move the equilibrium to the LHS/ produce less SO_3 **because** it is an exothermic reaction (in the forward direction)

- IP3 increase in temperature increases **energy** costs

- IP4 increase in pressure has no effect on rate (because all the active sites are already occupied on a heterogeneous catalyst).
  OR
  increase in pressure will increase rate (of reaction)

- IP5 increase in pressure will move position of eqm to RHS/increase yield **because** there are less moles/molecules (of gas) on the RHS

- IP6 but increased pressure increases (construction and running) costs/reduces economic viability

Decreased yield with no reference to exothermic reaction does not get IP2.

Allow increases yield of reactants/SO_2 and O_2 (with reference to exothermic reaction)

Increased yield with no reference to number of moles does not get IP5.

Award one mark for IP2 and IP5 if correct references to yield in both but reasons not given

Allow IP3 and IP6 if increased costs of higher temperature and pressure are mentioned together **provided** that the temperature costs are linked to energy costs. Otherwise only IP6 can be awarded.

Ignore any reference to catalyst

Q10.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• K_c expression **(1)**	$(K_c =)$ $\dfrac{[N_2(g)]^2 [H_2O(g)]^6}{[NH_3(g)]^4[O_2(g)]^3}$ ignore missing state symbols do not award round brackets	
	• units based on their K_c expression **(1)**	mol dm^{-3} or mol/dm^3	**(2)**

Q11.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following: • at lower temperatures (below 50°C) the reaction will be slow **(1)** • at higher temperatures (above 80°C) yield will be lower <u>because</u> (forward) reaction is exothermic **(1)**	allow reverse argument allow other products produced at higher temperatures	**(2)**

Question Number	Acceptable Answer	Mark
(ii)	**The only correct answer is A** *B is not correct because separating funnel is inappropriate for an industrial process* *C is not correct because not a separation process* *D is not correct because both will react with alkaline solution*	**(1)**

Q12.

Question Number	Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • (increasing the pressure) decreases the yield **(1)** • as the right hand side / products contain more moles of gas **(1)** • (increasing the pressure) increases the rate of reaction **(1)** • as collisions occur at an increased frequency **(1)**	Award 4 moles of product formed from 2 moles of reactant Allow more particles in a given volume / particles are more likely to collide Ignore more collisions are of the correct orientation	**(4)**

Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following points: • at higher temperatures the yield of product would be less (as forward reaction is exothermic) **(1)** • at lower temperatures the reaction would be slower **(1)** • (500 K is a compromise) giving a reasonable yield at a reasonable rate / between yield and rate **(1)**		**(3)**

Q13.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An answer which makes reference to the following points: • the concentration / amount of all components / of all reactants and products is constant **(1)** • the rate of the forward reaction is equal to the rate of the backward reaction **(1)**	Allow concentrations remain constant Do not award the concentration / amount of reactants and products are equal / the same Ignore in a closed system	**(2)**

Q14.

Question Number	Answer		Additional Guidance	Mark
(i)			Example of calculation	(2)
	• calculation of the moles of NO present at equilibrium	(1)	$2 - 1.82 = 0.18$ (mol)	
	• calculation of the moles of Cl_2 present at equilibrium	(1)	$1 - \dfrac{1.82}{2} = 0.09$ (mol) Allow TE	

Question Number	Answer	Additional Guidance	Mark
(ii)	• line starting at 2.00 and ending at 0.18 (1) • line starting at 1.00 and ending at 0.09 (1) • line starting at 0.00 and ending at 1.82 (1)	 Ignore lack of labels Allow any reasonable curves, curving in the direction shown, with no maximum or minimum Do not award straight lines If no marks awarded, allow (1) for 3 correct starting points and / or (1) for 3 correct finishing points Ignore lines going past T_{eq} unless they are clearly far from horizontal (allow the line to go up or down by 1 square from value at T_{eq} Allow TE on answers to (i)	(3)

Question Number	Answer	Mark
(iii)	The only correct answer is **B** ($K_c = \dfrac{[NOCl]^2}{[NO]^2[Cl_2]}$) **A** is not correct because this is multiplying [NOCl] and [NO] by 2 rather than squaring **C** is not correct because this is multiplying by 2 and is upside down **D** is not correct because this is upside down	(1)

Question Number	Answer	Additional Guidance	Mark
(iv)	An answer that makes reference to the following points: • equilibrium shifts to favour the endothermic direction (which is the backward reaction)	Answer must make reference to either exo- or endothermic or to significance of negative ΔH Allow the backward reaction is endothermic (so yield decreases) Allow the forward reaction is exothermic so reaction shifts to the left Ignore just forward reaction is exothermic Do not award 'the rate of the forward reaction decreases'	(1)

Q15.

Question Number	Acceptable Answers	Additional Guidance	Mark
(i)	• (yield) decreases / lower yield	Allow less ethanol is produced Ignore equilibrium shifts to the left but do not allow equilibrium shifts to the right Ignore any reference to Le Chatelier's principle Do not allow high temperature favours the exothermic direction	(1)

Question Number	Acceptable Answers	Additional Guidance	Mark
(ii)	• (yield) decreases / lower yield	Allow less ethanol is produced Ignore equilibrium shifts to the left but do not allow equilibrium shifts to the right Ignore any reference to Le Chatelier's principle Ignore fewer collisions	(1)

Question Number	Answer	Mark
(iii)	**D** $\dfrac{[C_2H_5OH(g)]}{[C_2H_4(g)][H_2O(g)]}$	(1)