



Q1.

This question is about the equilibrium reaction between hydrogen and carbon dioxide.



What effect would the following changes have on the rate of reaction and the yield of carbon monoxide?

(a) **Increase** in temperature.

(1)

	Rate	Yield of CO
<input type="checkbox"/> A	increase	increase
<input type="checkbox"/> B	increase	decrease
<input type="checkbox"/> C	increase	no change
<input type="checkbox"/> D	no change	decrease

(b) **Increase** in pressure.

(1)

	Rate	Yield of CO
<input type="checkbox"/> A	increase	increase
<input type="checkbox"/> B	increase	decrease
<input type="checkbox"/> C	increase	no change
<input type="checkbox"/> D	no change	no change



Q2.

- (a) Ozone, O₃, is formed when oxygen is exposed to ultraviolet (UV) radiation or to an electric discharge. Ozone is a blue gas whereas oxygen is colourless. When the two gases are mixed, an equilibrium is established as shown in the following equation.



- (i) When the temperature of the pale blue equilibrium mixture is increased at constant volume, the colour darkens. Explain this observation in terms of the changes to the equilibrium.

(2)

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- (ii) State and explain what you would **see** if the pressure of the system at equilibrium were increased.

(2)

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- (iii) A small amount of oxygen gas containing the isotope ¹⁸O is added to the equilibrium mixture. After a few hours, ozone containing ¹⁸O is detected. Given that the equilibrium position is **not** affected, explain this observation.

(1)

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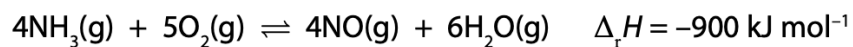
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**Q3.**

Ammonia is used in the manufacture of nitric acid.

The equation for one step in this manufacturing process is:



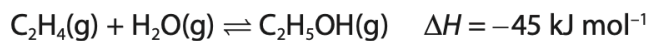
Write the expression for the equilibrium constant, K_c , for this reaction.

(1)



Q4.

Ethene reacts with steam to form ethanol in a reversible reaction.



At 300°C and a pressure of 65 atm, the equilibrium yield of ethanol is 5%.

- (i) State the effect, if any, on the yield of ethanol when the temperature is **increased**.

(1)

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- (ii) State the effect, if any, on the yield of ethanol when the pressure is **decreased**.

(1)

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- (iii) What is the expression for the equilibrium constant, K_c , for this reaction?

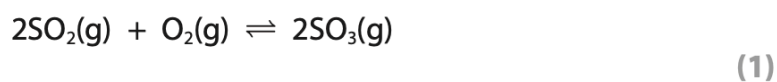
(1)

- A $\frac{[\text{C}_2\text{H}_4(\text{g})] + [\text{H}_2\text{O}(\text{g})]}{[\text{C}_2\text{H}_5\text{OH}(\text{g})]}$
- B $\frac{[\text{C}_2\text{H}_4(\text{g})][\text{H}_2\text{O}(\text{g})]}{[\text{C}_2\text{H}_5\text{OH}(\text{g})]}$
- C $\frac{[\text{C}_2\text{H}_5\text{OH}(\text{g})]}{[\text{C}_2\text{H}_4(\text{g})] + [\text{H}_2\text{O}(\text{g})]}$
- D $\frac{[\text{C}_2\text{H}_5\text{OH}(\text{g})]}{[\text{C}_2\text{H}_4(\text{g})][\text{H}_2\text{O}(\text{g})]}$



EQUILIBRIUM I (10)

(c) (i) Write the expression for the equilibrium constant K_c for this reaction.



(ii) What are the units, if any, of the equilibrium constant, K_c ? (1)

- A mol dm^{-3}
- B $\text{dm}^3 \text{mol}^{-1}$
- C no units
- D $\text{mol}^2 \text{dm}^{-6}$



Q1.

Correct Answer	Reject	Mark
A		(1)

Correct Answer	Reject	Mark
C		(1)



Q2.

Question Number	Acceptable Answers	Reject	Mark
(a)(i)	<p>More O₃ is formed/equilibrium shifts to the right (1)</p> <p>Because (increase in temperature) favours endothermic reaction ALLOW (Forward) reaction is endothermic</p> <p>ALLOW ΔH is positive for endothermic (1)</p> <p>IGNORE references to rate and pressure change</p>	<p>equilibrium shifts to the left (scores zero overall)</p>	2

Question Number	Acceptable Answers	Reject	Mark
(a)(ii)	<p>The mixture becomes darker ALLOW: more blue/bluer (1)</p> <p>(Increase in pressure) favours side with fewer moles/molecules (of gas) (so equilibrium shifts to the right) (1)</p> <p>IGNORE references to rate</p> <p>Marks are stand alone</p>	<p>Just 'more ozone' Blue gas formed Mixture becomes blue</p> <p>Atoms/particles</p>	2

Question Number	Acceptable Answers	Reject	Mark
(a)(iii)	<p>The equilibrium is dynamic OR Forward & reverse reactions still occurring OR O₃ continues to be formed from O₂ at the same rate as O₃ decomposes OR O₃ continues to be formed from O₂ with no nett change in composition</p>		1



Q3.

(c)	$K_c = \frac{[\text{NO}(\text{g})]^4[\text{H}_2\text{O}(\text{g})]^6}{[\text{NH}_3(\text{g})]^4[\text{O}_2(\text{g})]^5}$	(1)	State symbols not essential	1
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Q4.

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(i)	<ul style="list-style-type: none"> (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
(c)(ii)	<ul style="list-style-type: none"> (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
(c)(iii)	D $\left(\frac{[\text{C}_2\text{H}_5\text{OH}(\text{g})]}{[\text{C}_2\text{H}_4(\text{g})][\text{H}_2\text{O}(\text{g})]} \right)$	(1)



Q5.

Question Number	Acceptable Answer	Additional Guidance	Mark																				
* (a)	<p>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.</p> <table border="1" style="width: 100%; text-align: center;"> <thead> <tr> <th>Number of indicative marking points seen in answer</th> <th>Number of marks awarded for indicative marking points</th> </tr> </thead> <tbody> <tr><td>6</td><td>4</td></tr> <tr><td>5-4</td><td>3</td></tr> <tr><td>3-2</td><td>2</td></tr> <tr><td>1</td><td>1</td></tr> <tr><td>0</td><td>0</td></tr> </tbody> </table> <p>The following table shows how the marks should be awarded for structure and lines of reasoning.</p> <table border="1" style="width: 100%; text-align: center;"> <thead> <tr> <th></th> <th>Number of marks awarded for structure and sustained lines of reasoning</th> </tr> </thead> <tbody> <tr> <td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.</td> <td>2</td> </tr> <tr> <td>Answer is partially structured with some linkages and lines of reasoning.</td> <td>1</td> </tr> <tr> <td>Answer has no linkages between points and is unstructured.</td> <td>0</td> </tr> </tbody> </table>	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		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	<p>Guidance on how the mark scheme should be applied:</p> <p>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).</p> <p>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).</p> <p>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.</p> <p>If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).</p> <p>Comment: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning.</p>	(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																						
	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																						



<p>* (a)</p>	<p>Indicative content:</p> <ul style="list-style-type: none"> IP1 increase in temperature will increase rate IP2 (but) increase in temperature will decrease yield/move the equilibrium to the LHS/ produce less SO₃ 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 	<p>Decreased yield with no reference to exothermic reaction does not get IP2.</p> <p>Allow increases yield of reactants/SO₂ and O₂ (with reference to exothermic reaction)</p> <p>Increased yield with no reference to number of moles does not get IP5.</p> <p>Award one mark for IP2 and IP5 if correct references to yield in both but reasons not given</p> <p>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.</p> <p>Ignore any reference to catalyst</p>	
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Question Number	Acceptable Answer	Additional Guidance	Mark
(c)(i)	$K_c = \frac{[\text{SO}_3]^2}{[\text{O}_2][\text{SO}_2]^2}$	Do not award just K or K_p . must be square brackets do not accept partial pressures ignore units or lack of units ignore state symbols Allow x sign in the denominator but not +	(1)

Question Number	Answer	Mark
(c)(ii)	<p>(c)(ii). The only correct answer is B</p> <p>A is not correct because it refers to the inverted expression for K_c</p> <p>C is not correct because units do not cancel for concentration²/concentration³</p> <p>D is not correct because it refers to concentration³/concentration or similar ratio of powers</p>	(1)