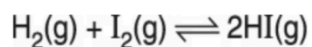




1. A student mixes hydrogen and iodine at room temperature and pressure and allows the mixture to reach dynamic equilibrium.



$$\Delta H = -9 \text{ kJ mol}^{-1} \quad \text{equilibrium 3.1}$$

- (i) A closed system is required for dynamic equilibrium to be established.

State **one** other feature of this dynamic equilibrium.

----- [1]

- (ii) The student heats the equilibrium mixture keeping the volume constant.

Predict how the composition of the equilibrium mixture changes on heating.

Explain your answer.

----- [2]

- (iii) Predict and explain what effect, if any, an increase in the pressure would have on the position of the equilibrium.

effect -----

explanation -----

----- [1]

2. State Le Chatelier's principle.

----- [1]



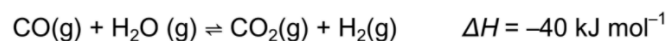
3. Which statement is **not** correct for a system in dynamic equilibrium?

- A The concentrations of products and reactants are the same.
- B The equilibrium can be achieved from both sides.
- C The rate of the forward reaction is equal to the rate of the reverse reaction.
- D The system is closed.

Your answer

[1]

4. Carbon monoxide reacts with steam in the following reaction equation:



Which change will shift the position of equilibrium to the right hand side of the equation?

- A decrease in pressure
- B increase in pressure
- C decrease in temperature
- D increase in temperature

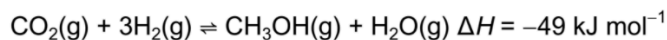
Your answer

[1]



5. Methanol, CH_3OH , is an important feedstock for the chemical industry.

In the manufacture of methanol, carbon dioxide and hydrogen are reacted together in the reversible reaction shown below.



High pressures and low temperatures would give a maximum equilibrium yield of methanol.

- (i) Explain this statement in terms of Le Chatelier's principle.

[3]

- (ii) Explain why the actual conditions used by the chemical industry might be different.

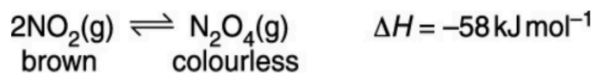
[2]



8. This question is about equilibrium and catalysts.

The equilibrium between NO_2 and N_2O_4 gases is set up in a gas syringe at room temperature.

The two gases are different in appearance.



Using Le Chatelier's principle, predict and explain how the following changes would affect the appearance of the equilibrium mixture.

- (i) The gas mixture is compressed by pushing in the plunger of the gas syringe.

[2]

- (ii) The gas syringe is placed in a warm water bath.

[2]

9. The reversible reaction below is allowed to reach equilibrium.



Which change in conditions would be expected to shift the equilibrium position towards the products?

- A decrease the pressure
- B decrease the temperature
- C increase the pressure
- D increase the temperature

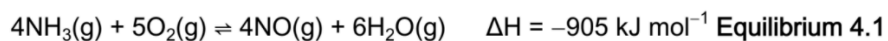
Your answer

[1]



10. The reaction of ammonia, NH_3 , with oxygen to form nitrogen monoxide, NO , is an important industrial process.

The equation for this reaction is shown in **equilibrium 4.1** below.

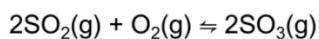


Predict the conditions of temperature and pressure for a maximum equilibrium yield of nitrogen monoxide in **equilibrium 4.1**.

- Explain your prediction in terms of le Chatelier's principle.
- State and explain how these conditions could be changed to achieve a compromise between equilibrium yield, rate and other operational factors.



11. The reversible reaction below is at equilibrium.



$$\Delta H = -197 \text{ kJ mol}^{-1}$$

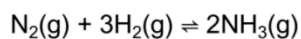
Which changes in pressure and temperature would shift the equilibrium position towards the products?

	Pressure	Temperature
A	Decrease	Decrease
B	Decrease	Increase
C	Increase	Decrease
D	Increase	Increase

Your answer

[1]

12. The reversible reaction below is at equilibrium.



What is the expression for K_c ?

A
$$\frac{[\text{N}_2(\text{g})] [\text{H}_2(\text{g})]^3}{[\text{NH}_3(\text{g})]^2}$$

B
$$\frac{[\text{NH}_3(\text{g})]^2}{[\text{N}_2(\text{g})] [\text{H}_2(\text{g})]^3}$$

C
$$\frac{[\text{N}_2(\text{g})] + 3[\text{H}_2(\text{g})]}{2[\text{NH}_3(\text{g})]}$$

D
$$\frac{2[\text{NH}_3(\text{g})]}{[\text{N}_2(\text{g})] + 3[\text{H}_2(\text{g})]}$$

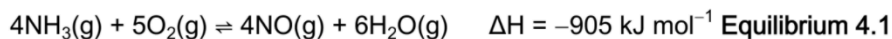
Your answer

[1]



13. The reaction of ammonia, NH_3 , with oxygen to form nitrogen monoxide, NO , is an important industrial process.

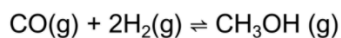
The equation for this reaction is shown in **equilibrium 4.1** below.



Write an expression for the equilibrium constant, K_c , in **equilibrium 4.1**.

[1]

14. A chemist investigates the equilibrium that produces methanol:



The chemist mixes $\text{CO}(\text{g})$ with $\text{H}_2(\text{g})$ and leaves the mixture to react until equilibrium is reached. The equilibrium mixture is analysed and found to contain the following concentrations.

Substance	Concentration/mol dm^{-3}
$\text{CO}(\text{g})$	0.310
$\text{H}_2(\text{g})$	0.240
$\text{CH}_3\text{OH}(\text{g})$	0.260

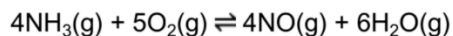
Calculate the numerical value of K_c for this equilibrium.

Give your answer to an **appropriate** number of significant figures.

$$K_c = \text{-----} \text{ dm}^6 \text{ mol}^{-2} [2]$$



15. Ammonia is used in the manufacture of nitric acid. The first stage of this process is a dynamic equilibrium.



- (i) When the temperature is increased, K_c for this reaction decreases.

State the effect, if any, on the equilibrium yield of NO in this reaction.

Explain your answer.

----- [1]

- (ii) Which element has been oxidised and which element has been reduced in the reaction?

Include signs with the oxidation numbers.

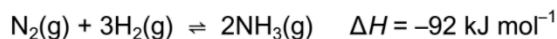
Oxidised ----- Oxidation number change from ----- to -----

Reduced ----- Oxidation number change from ----- to -----

[2]



16. Nitrogen can be reacted with hydrogen in the presence of a catalyst to make ammonia in the Haber process.



A mixture of N_2 and H_2 was left to react until it reached equilibrium. The equilibrium mixture had the following composition:

N_2	1.20 mol dm^{-3}
H_2	2.00 mol dm^{-3}
NH_3	$0.877 \text{ mol dm}^{-3}$

- (i) Calculate a value for K_c for this equilibrium.

$$K_c = \text{-----} \text{ dm}^6 \text{ mol}^{-2} \quad [3]$$

- (ii) Explain how the following changes would affect the amount of NH_3 present in the equilibrium mixture.

Use of a catalyst:

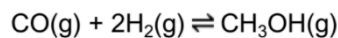
A higher temperature:

[3]



17. This question looks at equilibrium reactions used by industry for preparing important chemicals.

Methanol can be manufactured by reacting carbon monoxide with hydrogen.



An equilibrium mixture contains $3.10 \times 10^{-3} \text{ mol dm}^{-3}$ CO, $2.40 \times 10^{-3} \text{ mol dm}^{-3}$ H₂ and an unknown concentration of CH₃OH.

- (i) Write an expression for the equilibrium constant, K_c .

[1]

- (ii) The value of K_c for this equilibrium is $14.6 \text{ dm}^6 \text{ mol}^{-2}$.

Determine the equilibrium concentration methanol, CH₃OH(g).

Give your answer to **three** significant figures.

equilibrium concentration of CH₃OH(g) = dm⁶ mol⁻²[2]

END OF QUESTION PAPER



Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
1		i	<p>Rate of the forward reaction is equal to the rate of the reverse reaction ✓</p> <p>OR</p> <p>concentrations do not change ✓</p>	1	<p>ALLOW both reactions occur at same rate</p> <p>IGNORE conc. of reactants = conc. of products</p> <p>Examiner's Comments</p> <p>A good proportion of candidates recognised the need to provide one of the key features of a dynamic equilibrium as outlined in the specification.</p>
		ii	<p>More H₂ and I₂ OR less HI ✓</p> <p>(equilibrium position shifts) to the left AND (Forward) reaction is exothermic OR reverse reaction is endothermic OR in the endothermic direction ✓</p>	2	<p>Mark each point independently</p> <p>ALLOW more reactants OR less products</p> <p>Note: ALLOW suitable alternatives for to the left e.g. towards reactants OR towards H₂ / I₂ OR in reverse direction OR favours the left.</p> <p>ALLOW gives out heat for exothermic ALLOW takes in heat for endothermic</p> <p>IGNORE responses in terms of rate</p> <p>Examiner's Comments</p> <p>This question required candidates to apply le Chatelier's Principle to the equilibrium and in addition predict the effect it would have on the composition of the mixture. Most candidates were able to predict and explain the shift in the position of equilibrium and the most able stated the effect on the composition of the mixture. Candidates should be encouraged to read questions carefully to ensure they address all aspects in their response.</p>



Question			Answer/Indicative content	Marks	Guidance
		iii	No effect AND Same number of (gaseous) moles on both sides ✓	1	ALLOW same number of molecules on each side Examiner's Comments This question was answered very well and most candidates picked up this mark.
			Total	4	
2			The (position of a dynamic) equilibrium shifts to minimise (the effect of) any change ✓	1	ALLOW suitable alternatives for 'shifts' and 'minimises' IGNORE 'reaction shifts' Examiner's Comments Most candidates were able to describe le Chatelier's principle.
			Total	1	
3			A	1	
			Total	1	
4			C	1	
			Total	1	



Question		Answer/Indicative content	Marks	Guidance
5	i	<p>Pressure: Right-hand side has fewer (gaseous) moles / molecules OR left-hand side has more (gaseous) moles / molecules ✓</p> <p>Temperature: Statement that: (Forward) reaction is exothermic OR (forward) reaction gives out heat OR reverse reaction is endothermic OR reverse reaction takes in heat ✓</p> <p>Equilibrium Lower temperature / cooling AND increasing pressure shifts (equilibrium position) to the right ✓</p>	3	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</p> <p>DO NOT ALLOW fewer atoms on right-hand side OR more atoms on left-hand side.</p> <p>IGNORE comments about the 'exothermic side' or 'endothermic side'</p> <p>Equilibrium mark is for stating that BOTH low temperature and high pressure shift equilibrium to the right (Could be separate statements)</p> <p>Note: ALLOW suitable alternatives for 'to right', e.g.: towards products OR towards CH₃OH / H₂O OR in forward direction OR favours the right</p> <p>IGNORE Increases yield of CH₃OH / products (<i>in question</i>)</p> <p>IGNORE responses in terms of rate</p> <p>Examiner's Comments</p> <p>A good discrimination was achieved by this question. The most able candidates gave succinct responses which related the low temperature and high pressure to the change in equilibrium position. Candidates are encouraged to write as accurately as possible in this type of question. For example, the effect of pressure is best explained by reference the relative number of moles on each side of the equation. A statement about the nature of the forward reaction, in this case exothermic, is appropriate to explain the effect of temperature.</p>



Question			Answer/Indicative content	Marks	Guidance
		ii	<p>Low temperature gives a slow rate OR high temperatures needed to increase rate ✓</p> <p>High pressure is expensive (to generate) OR high pressure provides a safety risk ✓</p>	2	<p>ALLOW high pressure is dangerous IGNORE high pressure is explosive</p> <p>Examiner's Comments</p> <p>Most candidates identified high pressures as either dangerous or requiring expensive equipment. The strongest responses linked low temperature with a slow rate of reaction.</p>
			Total	5	



Question	Answer/Indicative content	Marks	Guidance
6	<p>* Please refer to the marking instruction point 10 for guidance on how to mark this question.</p> <p>(Level 3) All/most points covered and clearly linked. Must have points taken across all of the headings in the indicative points for Level 3.</p> <p><i>The explanations show a well-developed line of reasoning linked to appropriate suggestions which is clear and logically structured. The compromises are relevant and well thought out and clearly linked to the explanations.</i></p> <p style="text-align: right;">(5–6 marks)</p> <p>(Level 2) Suggests correct conditions with explanations OR comments on compromises with reference to yield AND rate effect.</p> <p><i>The explanations are linked to appropriate suggestions and show a line of reasoning with some structure. The compromises are relevant but may not be clearly linked to the explanation.</i></p> <p style="text-align: right;">(3–4 marks)</p> <p>(Level 1) Comments on conditions with some explanation OR comments on compromise with reference to yield OR rate.</p> <p><i>The comments about yield / rate with explanation are basic and communicated in an unstructured way. The compromises may not be relevant with lack of reasoning.</i></p> <p style="text-align: right;">(1–2 marks)</p> <p>No response or no response worthy of credit. (0 marks)</p>	6	<p>Indicative scientific points may include</p> <p>Yield</p> <ul style="list-style-type: none"> • Increasing pressure increases yield of SO₃ • Decreasing temperature increases yield of SO₃ <p>Explanation</p> <ul style="list-style-type: none"> • (pressure) more moles / molecules on the reactant side ORA • (temp.) the forward reaction is exothermic ORA <p>Rate</p> <ul style="list-style-type: none"> • Increasing pressure increases rate • Increasing temperature increases rate <p>Compromise</p> <ul style="list-style-type: none"> • Choose a higher temperature which creates a reduced yield but in a shorter space of time <p>ignore reference to increase pressure leading to safety / cost issues</p>
	Total	6	



Question		Answer/Indicative content	Marks	Guidance
7	a	<p>EQUILIBRIUM CONDITIONS 3 MAX 4 marking points <input type="checkbox"/> 3 max ✓✓✓ Mark first three CORRECT responses seen</p> <p>Temperature: (Forward) reaction is exothermic/ΔH is negative OR (Forward) reaction gives out heat ✓</p> <p>Pressure: Right-hand side has fewer (gaseous) moles OR 3 (gaseous) moles form 2 (gaseous) moles ✓</p> <p>Equilibrium shift Correct equilibrium shift in terms of temperature ✓</p> <p>Correct equilibrium shift in terms of pressure ✓</p> <hr/> <p>INDUSTRIAL CONDITIONS Low temperature gives a slow rate/slower reaction OR high temperatures needed to increase rate ✓<input type="checkbox"/></p> <p>(High) pressure provides a safety risk OR (High) pressure is expensive (to generate) /uses a lot of energy ✓<input type="checkbox"/></p>	5	<p>FULL ANNOTATIONS MUST BE USED</p> <hr/> <p>ALLOW suitable alternatives for 'towards right', e.g.: towards SO_3/products OR in forward direction OR 'favours the right'</p> <p>ALLOW reverse reaction is endothermic /ΔH is positive/takes in heat</p> <p>For moles, ALLOW molecules/particles</p> <p>ORA for reverse reaction</p> <p>IGNORE responses in terms of activation energy</p> <p>ALLOW high pressure is dangerous/explosive</p> <p>ALLOW 'These conditions are expensive' <i>Statement subsumes pressure as 'these' will apply to pressure (required for this mark) and temperature</i></p> <p>ALLOW ORA e.g. Lower pressure → less danger/uses less energy</p> <p>IGNORE 'It's expensive' <i>Link with pressure required</i></p> <p>Examiner's Comments</p> <p>This longer answer was answered very well with the majority of candidates able to score 4 or 5 marks. Most candidates explained how the position of equilibrium shifts in response to low temperature and high pressure. The commonest omission was the link between low temperature and a slow reaction rate.</p>



Question	Answer/Indicative content	Marks	Guidance
b	<p><i>Value of K_c 1 mark</i> K_c is small OR $K_c < 1$ AND equilibrium (position) is towards left ✓</p> <p><i>Calculation: FIRST CHECK ANSWER</i> IF $[\text{SO}_3] = 0.876$ OR 0.88 (mol dm^{-3}) award all 3 marks available for calculation</p> <hr/> <p><i>K_c expression 1 mark</i> $\frac{[\text{SO}_3]^2}{[\text{SO}_2]^2[\text{O}_2]} \text{ OR } \frac{[\text{SO}_3]^2}{2.00^2 \times 1.20} \checkmark$</p> <p><i>Evaluation of K_c $[\text{SO}_2]^2[\text{O}_2]$ 1 mark</i> $K_c[\text{SO}_2]^2[\text{O}_2] = 0.160 \times 2.00^2 \times 1.20$ $= 0.768 \checkmark$</p> <p><i>Calculation of $[\text{SO}_3]$</i> <i>ONLY available from correct evaluation for 2nd mark</i> $[\text{SO}_3] = \sqrt{(0.160 \times 2.00^2 \times 1.20)}$ $= 0.876$ (mol dm^{-3}) ✓</p>	4	<p>FULL ANNOTATIONS MUST BE USED</p> <p>ALLOW suitable alternatives for 'towards left, e.g.: towards SO_2/O_2 OR towards reactants OR in reverse direction OR 'favours the left</p> <p>Square brackets required in K_c expression</p> <p>ALLOW ECF from $\frac{[\text{SO}_3]}{[\text{SO}_2]^2[\text{O}_2]}$, i.e. no $[\text{SO}_3]^2$</p> <p>ALLOW 0.77 (2 SF)</p> <p>ALLOW 0.88 (2 SF) up to calculator value of 0.876356092 correctly rounded</p> <p>IF K_c expression is inverted 2nd and 3rd marks are available by ECF:</p> $[\text{SO}_3]^2 = \frac{2.00^2 \times 1.20}{0.160} \text{ OR } 30 \checkmark$ $[\text{SO}_3] = \sqrt{30} = 5.48 \text{ OR } 5.5 \checkmark$ <p>Any other K_c expression → NO MARKS, e.g. $\frac{[\text{SO}_3]^2}{[\text{SO}_2]^2 + [\text{O}_2]} \rightarrow \sqrt{0.832} \rightarrow 0.912$ NO Marks</p> <p>Examiner's Comments</p> <p>Given that K_c is new to AS level in the reformed specification, this part was attempted well. However, writing a correct K_c did cause problems for weaker candidates, who sometimes inverted the expression, used the + sign from the equation, obtaining a denominator of $[\text{SO}_2]^2 + [\text{O}_2]$, or omitted the square from $[\text{SO}_2]^2$ and $[\text{SO}_3]^2$.</p> <p>Some excellent answers were seen and this part differentiated very well between candidates of different abilities.</p> <p>Answer: $[\text{SO}_3] = 0.876 \text{ mol dm}^{-3}$</p>
	Total	9	



Question			Answer/Indicative content	Marks	Guidance
8		i	<p>Equilibrium (position) shifts to right AND turns paler (brown) ✓</p> <p>Right-hand side has fewer (gaseous) moles / molecules OR left-hand side has more (gaseous) moles / molecules ✓</p>	2	<p>ALLOW turns colourless</p> <p>IGNORE initially goes darker (brown)</p> <p>Note: ALLOW suitable alternatives for 'to right', e.g.: towards products OR towards N_2O_4 OR in forward direction OR favours the right</p> <p>IGNORE responses in terms of rate</p> <p>Examiner's Comments</p> <p>The effect of pressure on the position of an equilibrium is well known by candidates. Most were able to apply le Chatelier's principle accurately stating the equilibrium shifted to the right as that was the side with fewest moles of gas. However a significant proportion of the cohort did not comment on the effect on the appearance of the equilibrium mixture.</p>



Question			Answer/Indicative content	Marks	Guidance
		ii	<p>Equilibrium (position) shifts to left AND turns darker / deeper (brown) ✓</p> <p>(Forward) reaction is exothermic OR (forward) reaction gives out heat OR reverse reaction is endothermic OR reverse reaction takes in heat ✓</p>	2	<p>ALLOW turns brown</p> <p>Note: ALLOW suitable alternatives for 'to left', e.g.: towards reactants OR towards NO₂ OR in reverse direction OR favours the left</p> <p>IGNORE comments about the 'exothermic side' or 'endothermic side'</p> <p>ALLOW 'equilibrium (position) shifts left AND in the endothermic direction' for second marking point</p> <p>IGNORE responses in terms of rate</p> <p>Examiner's Comments</p> <p>As with part (a)(i), candidates demonstrated an excellent grasp of le Chatelier's principle but it was only the most able candidates who referred to the appearance of the equilibrium mixture. Candidates should be encouraged to read questions carefully to ensure they include all the required information in their responses.</p>
			Total	4	
9			B	1	<p>Examiner's Comments</p> <p>This question discriminated very well with most able candidates obtaining the correct answer.</p>
			Total	1	



Question	Answer/Indicative content	Marks	Guidance
10	<p>EQUILIBRIUM CONDITIONS</p> <p>Temperature: 1 mark (Forward) reaction is exothermic/ΔH is negative OR (Forward) reaction gives out heat ✓</p> <p>Pressure: 1 mark Left-hand side has fewer (gaseous) moles OR 9 (gaseous) moles form 10 (gaseous) moles ✓</p> <p>OPTIMUM EQUILIBRIUM CONDITIONS: 1 mark (for maximum yield of NO) Low temperature AND low pressure ✓</p> <p>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 ✓</p> <p>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 ✓</p>	5	<p>ANNOTATE ANSWER WITH TICKS AND CROSSES ETC</p> <p>ALLOW reverse arguments</p> <p>Answer MUST relate temp/pressure to rate / frequency of collisions</p> <p>ALLOW Temperature / pressure not too high because yield reduced</p> <p>IGNORE stated temperatures and pressures</p> <p>IGNORE catalyst</p> <p><u>Examiner's Comments</u></p> <p>Most candidates answered this question very well, with the most common mark being 4/5. Many candidates put a lot of effort into explaining, in depth, Le Chatelier's principle, which was not required. The first three marking points were credited to most candidates. Responses were confident in their descriptions of equilibrium shifts and many candidates then went on to qualify their answers with operational factor considerations and/or rate. The explanation for pressure was described less commonly than temperature and many candidates did not appreciate that increased rate would lead to a decreased equilibrium yield.</p> <p>Exemplar 3</p>



Question		Answer/Indicative content	Marks	Guidance
				<p>(e) Predict the conditions of temperature and pressure for a maximum equilibrium yield of nitrogen monoxide in equilibrium 4.1.</p> <p><i>to P ↓</i></p> <ul style="list-style-type: none"> Explain your prediction in terms of Le Chatelier's principle. State and explain how these conditions could be changed to achieve a compromise between equilibrium yield, rate and other operational factors. <p><i>low temperature so as to shift the position of equilibrium to the right while favouring forward reaction. This is because forward reaction is exothermic (ΔH = -ve). low pressure so as to shift position of equilibrium to the right, as a decrease in pressure causes the equilibrium to move towards the direction with more gas molecules (right). These two conditions will minimise the change caused so maximum product (i.e. NO and H₂O) are formed. A higher temperature is used so as to increase the rate of reaction. Otherwise reaction is too slow. A slightly higher pressure is also used to increase reaction rate but not too high pressure as it is dangerous and doesn't promote safety for workers.</i></p> <p>This candidate scored all five marks for this well-reasoned approach to the question.</p>
		Total	5	
11		C	1	<p>Examiner's Comments</p> <p>This question was a good discriminator with well-prepared candidates usually selecting the correct option of C. Incorrect responses were reasonably evenly split across the other options, suggesting guesses and poor preparation.</p>
		Total	1	
12		B	1	<p>Examiner's Comments</p> <p>Most candidates responded with the correct response of B. The most common incorrect response was the inverse expression shown in A.</p>
		Total	1	
13		$(K_c =) \frac{[\text{NO}(\text{g})]^4 [\text{H}_2\text{O}(\text{g})]^6}{[\text{NH}_3(\text{g})]^4 [\text{O}_2(\text{g})]^5} \checkmark$	1	<p>Square brackets required</p> <p>IGNORE state symbols</p> <p>Examiner's Comments</p> <p>Generally, this question was well answered with only a small proportion of candidates adding the values together instead of multiplying.</p>
		Total	1	



Question		Answer/Indicative content	Marks	Guidance
14		<p>FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 14.6 (dm⁶ mol⁻⁶) award 2 marks</p> <hr/> <p>K_c expression $(K_c =) \frac{[\text{CH}_3\text{OH}]}{[\text{CO}][\text{H}_2]^2}$ OR $\frac{0.26}{0.31 \times 0.24^2}$ OR 14.56 ✓</p> <p>Answer to 3 SF 14.6 (dm⁶ mol⁻²) ✓</p>	2	<p>FULL ANNOTATIONS MUST BE USED</p> <hr/> <p>IF there is an alternative answer, check to see if there is any ECF credit possible using working below.</p> <hr/> <p>ALLOW calculated value 14.5609319 correctly rounded to 3 or more SF for 1st marking point</p> <p>ALLOW ECF to 3 SF ONLY from inverted K_c expression → 0.0687</p> <p>DO NOT ALLOW $\frac{[\text{CH}_3\text{OH}]}{[\text{CO}] + [\text{H}_2]^2} = 0.707$ (no marks)</p> <p>Examiner's Comments Most candidates were able to obtain a value of 14.56 using a correct K_c expression, but a significant number of candidates were unable to give their answer to an appropriate number of significant figures. Candidates should use the least accurate data provided, here three significant figures, and to indicate the appropriate number of significant figures in the final answer. Other common errors included the inverted K_c expressions and use of $[\text{CO}] + [2\text{H}_2]$, rather than $[\text{CO}][\text{H}_2]^2$, as the denominator. Answer = 14.6 dm⁶ mol⁻²</p>
		Total	2	
15	i	Yield decreases AND Equilibrium (position) has moved to the left	1	allow moved towards reactants OR moved towards CO and H ₂
	ii	Oxidised Nitrogen AND -3 AND +2 (1) Reduced Oxygen AND 0 AND -2 (1)	2	
		Total	3	



Question			Answer/Indicative content	Marks	Guidance
16	i	<p><i>Expression:</i> $K_c = \frac{[\text{NH}_3]^2}{[\text{H}_2]^3[\text{N}_2]}$ (1)</p> <p><i>Calculation:</i> $= (0.877)^2 / (2.00)^3 (1.20)$ (1)</p> <p>$= 0.0801$ ✓ (dm⁶ mol⁻²)</p>	3	<p>square brackets required</p> <p>allow from 1 sig fig up to calculator display</p> <p>correct answer alone scores all marks</p>	
	ii	<p><i>Catalyst:</i> No effect, it only changes the rate of reaction (1)</p> <p><i>Higher temperature:</i> Forward reaction is exothermic (1) so position of equilibrium moves to the left and there will be less NH₃ (1)</p>			
			Total	6	
17	i	$K_c = \frac{[\text{CH}_3\text{OH}]}{[\text{CO}][\text{H}_2]^2}$	1		
	ii	<p>$[\text{CH}_3\text{OH}] = 14.6 \times (3.10 \times 10^{-3}) \times (2.40 \times 10^{-3})^2$ (1)</p> <p>$= 2.61 \times 10^{-7}$ (mol dm⁻³) (1)</p>			
			Total	3	