18. In the reaction below when temperature is increased the solution becomes blue. Explain if the forward reaction is exo or endo.

$[Co(H_2O)_6]^{2+} + 4Cl^- \rightleftharpoons [CoCl_4]^{2-} + 6H_2O$

9. Why is a closed system necessary for equilibrium to be established?

11.What is true about the rates of reactions of the forward and backward reaction at equilibrium?

15. What three factors can influence the position of equilibrium?

14. Why is the pressure chosen for a reversible reaction sometimes a compromise?

12. What effect does a catalyst have on the position of equilibrium?

What effect does a catalyst have on the rate at which equilibrium is reached?

7. What is true about the concentration of the reactants and products at equilibrium?

2. What is a dynamic equilibrium?

10. If the total pressure increases what would be the colour of the gas?

$N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$

AS Equilibria

17. What do we mean by position of equilibrium?

3. How does decreasing the temperature affect the position of equilibrium if the forward reaction is exothermic?

4. How does increasing the concentration of the reactants affect the position of equilibrium?

1. State Le Chateliers principle.

13. Why is it incorrect to say that increasing the pressure of a system at equilibrium will affect the position of equilibrium?

19. Explain why in many reversible reactions the product is removed from the reactor once it has formed.

5. Why is the temperature chosen for a reversible reaction sometimes a compromise?

6. How does increasing the temperature affect the position of equilibrium if the forward reaction is endothermic?

8. How does increasing the pressure affect the position of equilibrium for a reaction involving gases?

0 5 . 3 Methanol is made by the reaction of carbon monoxide with hydrogen.

$$CO + 2H_2 \rightleftharpoons CH_3OH \qquad \Delta H = -91 \text{ kJ mol}^{-1}$$

The reaction uses a copper-based catalyst, a pressure of 10 MPa and a temperature of 550 K

These conditions are used to provide a balance between equilibrium yield, reaction rate and cost.

Describe how the use of a catalyst, and changes in pressure and temperature, each affect equilibrium yield, reaction rate and cost.

[6 marks]

0 5 Nitrogen monoxide reacts with chlorine to form nitrosyl chloride (NOCl).

$$2NO(g) + Cl_2(g) \rightleftharpoons 2NOCl(g)$$

0 5 . 3 A different equilibrium mixture is prepared in a flask of volume 800 cm^3 at a different temperature.
At equilibrium this mixture contains 0.850 mol of NO and 0.458 mol of Cl_2
For the reaction at this temperature $K_c = 1.32 \times 10^{-2}\ mol^{-1}\ dm^3$

Determine the amount, in moles, of NOCl in this equilibrium mixture.

[4 marks]

24 This question is about ammonia, NH_3.

(a) In industry, ammonia is made from nitrogen and hydrogen. This is a reversible reaction, as shown in **equilibrium 24.1** below.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ $\Delta H = -92\,kJ\,mol^{-1}$ **Equilibrium 24.1**

(i) Explain how le Chatelier's principle can be used to predict the conditions of temperature and pressure for a maximum **equilibrium** yield of ammonia.

[4 marks]

<table>
<tr><td rowspan="5">05.3</td><td colspan="2">This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.</td><td>6</td><td rowspan="5">Stage 1
Describes the effect of catalyst use
1a use of a catalyst has no impact on equilibrium yield
1b use of a catalyst gives faster rate
1c use of catalyst lowers costs

Stage 2
Describes the effect of pressure
2a higher pressure gives a higher equilibrium yield
2b higher pressure gives a faster rate
2c the higher the pressure, the greater the cost

Stage 3
Describes the effect of temperature
3a lower temperature gives a higher equilibrium yield
3b higher temperature gives a faster rate
3c the higher the temperature, the greater the cost

Note that converse statements are fine (e.g. 1a higher temperature gives a lower equilibrium yield)</td></tr>
<tr><td>Level 3
(5-6 marks)</td><td>All stages are covered and each stage is generally correct and virtually complete.

(6 v 5) Answer is well structured, with no repetition or irrelevant points, and covers all aspects of the question. Accurate and clear expression of ideas with no errors in use of technical terms.</td><td></td></tr>
<tr><td>Level 2
(3-4 marks)</td><td>All stages are covered but stage(s) may be incomplete or may contain inaccuracies OR

two stages are covered and are generally correct and virtually complete

(4 v 3) Answer has some structure and covers most aspects of the question. Ideas are expressed with reasonable clarity with, perhaps, some repetition or some irrelevant points. If any, only minor errors in use of technical terms.</td><td></td></tr>
<tr><td>Level 1
(1-2 marks)</td><td>Two stages are covered but stage(s) may be incomplete or may contain inaccuracies OR

only one stage is covered but is generally correct and virtually complete

(2 v 1) Answer includes statements which are presented in a logical order and/or linked.</td><td></td></tr>
<tr><td>0 marks</td><td>Insufficient correct chemistry to gain a mark.</td><td></td></tr>
</table>

05.3	$1.32 \times 10^{-2} = \frac{[NOCl]^2}{\left[\frac{0.85}{0.800}\right]^2 \left[\frac{0.458}{0.800}\right]}$ $[NOCl]^2 = 8.53 \times 10^{-3}$ mol^{2}dm^{-6} $[NOCl] = 0.0924$ mol dm^{-3} $n(NOCl) = 0.0924 \times 0.800 = 0.0739$ mol (answer to 2sf or more)	M1 = divides mole quantities by 0.800 M2 = evaluates $[NOCl]^2$ M3 = $\sqrt{}$M2 M4 = M3 x 0.800 (allow ecf on an incorrect volume used in M1) If no division in M1 then max 3 M2 = 4.37×10^{-3} M3 = 0.0661 mol dm^{-3} M4 = 0.0529 mol If Kc upside down then can still score 4 M1 = divides mole quantities by 0.800 M2 = 48.96 M3 = 7.00 mol dm^{-3} M4 = 0.600 mol Incorrect rearrangement loses M2	1 1 1 1

Question			Answer	Marks	AO element	Guidance
24	(a)	(i)	**Pressure**: Right-hand side has fewer (gaseous) moles **OR** 4 (gaseous) moles form 2 (gaseous) moles ✓ High pressure ✓ **Temperature**: (Forward) reaction is exothermic/ΔH is negative **OR** (Forward) reaction gives out heat ✓ Low temperature ✓	4	AO1.2 AO2.1 AO1.2 AO2.1	***FULL ANNOTATIONS MUST BE USED*** --- **ALLOW** suitable alternatives for right-hand side, e.g.: towards NH_3/products **OR** forward direction **OR** increases yield For moles, **ALLOW** molecules/particles **ALLOW reverse** reaction is endothermic /ΔH is positive/takes in heat **ORA for** reverse reaction
		(ii)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **IF answer = 2.86×10^{-2} award 2 marks** --- **K_c expression** $(K_c =) \frac{[NH_3]^2}{[N_2][H_2]^3}$ **OR** $\frac{0.862^2}{1.25 \times 2.75^3}$ **OR** 0.02858 ..... ✓ **Answer to 3 SF and in standard form** $K_c = 2.86 \times 10^{-2}$ ✓	2	AO2.6 ×2	**IF** there is an alternative answer, check for any **ECF** credit possible using working below. --- **ALLOW** calculated value 0.02858291 correctly rounded to 3 or more SF for 1st marking point **ALLOW ECF to 3 SF and standard form** **ONLY** from inverted K_c expression → 3.50×10^1 **DO NOT ALLOW** $\frac{[NH_3]^2}{[N_2] + [H_2]^3}$ = 0.0337 (no marks) **IGNORE** attempts at units