Exam Papers Practice

7.1 Equilibrium

Mark Schemes

Course	DP IB Chemistry
Section	7. Equilibrium
Topic	7.1 Equilibrium
Difficulty	Medium

To be used by all students preparing for DP IB Chemistry HL
Students of other boards may also find this useful

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The correct answer is **B** because:

- The numerator (top part) in the K_c equation is raised to the power of 4. The denominator is raised to the power of 2
- $K_c = \frac{[H_2(g)]^3\,[C_2H_2(g)]}{[CH_4(g)]^2}$
- Unit of $K_c = \frac{[\text{mol dm}^{-3}]^3\,[\text{mol dm}^{-3}]}{[\text{mol dm}^{-3}]^2}$
- **Maths tip:** when you are dividing indices you simply minus them
- 4 - 2 = 2, therefore the numerator units becomes $(\text{mol dm}^{-3})^2 = \text{mol}^2\ \text{dm}^{-6}$

A, C & D are incorrect as none of these units fit with the correct expression of K_c

2

The correct answer is **B** because:

- As the forward reaction is endothermic (as the sign of is positive) an increase in temperature would shift the position of equilibrium to the right-hand side of the reaction (to oppose the change) thus increasing the amount of $XY_2(g)$
- You can see there are more moles of gas on the right-hand side of the reaction
- As moles of a gas is proportional to volume, the volume will increase
- When you increase the temperature of any gas, you are giving the gases more kinetic energy, and therefore the gas molecules move further apart. This will result in an increased volume - this is thermal expansion

A is incorrect as thermal expansion is a thermodynamic law that cannot be ignored. When you increase the temperature of any gas, you are giving the gases more kinetic energy, and therefore the gas molecules move further apart. This will result in an increased volume

C & **D** are incorrect as the equilibrium shifts to the right, not the left. Remember the forward reaction is endothermic, so an increase in temperature would shift it to the right

3

The correct answer is **C** because:

- The equilibrium constant expression is $\frac{[\text{products}]}{[\text{reactants}]}$
- The first equilibrium constant expression is $\frac{[NH_3]^2}{[N_2]\,[H_2]^3}$ (this is "x")
- The second equilibrium constant expression is $\frac{[NH_3]^4}{[N_2]^2\,[H_2]^6}$
- To get the second expression from the first you would need to square it
  - $\frac{[NH_3]^2}{[N_2]\,[H_2]^3} \times \frac{[NH_3]^2}{[N_2]\,[H_2]^3} = \frac{[NH_3]^4}{[N_2]^2\,[H_2]^6}$
- So if the first value of K_c is x, the second must be x^2

Reminder: when multiplying numbers raised to a power, you add the powers together

4

The correct answer is **A** because:

- Sodium hydroxide neutralizes H^+ ions, so adding it will remove them from the equilibrium $H^+ + OH^- \rightarrow H_2O$
- According to Le Chatelier's Principle, the equilibrium will respond by shifting to the right to make more H^+ ions
- As the equilibrium shifts to the right, more MgS will also be made

B is incorrect as there are no gases present so changing the pressure will have no effect on the equilibrium and therefore no effect on the amount of MgS produced

C is incorrect as the reaction is at equilibrium so adding a catalyst will have no effect on the position of equilibrium, since it affects the rate of the forward and backward reaction equally

D is incorrect as the reaction is exothermic, so increasing the temperature will cause the position of equilibrium to shift in the endothermic direction, or backwards, reducing the amount of MgS produced

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The correct answer is **B** because:

- In a state of equilibrium there is no change in the concentrations of the substances present
- The equilibrium is dynamic, so reactants are continually changing into products and products are continually changing back into reactants
- However, they are changing at the same rate, so macroscopic properties such as concentration remain constant at equilibrium

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The correct answer is **B** because:

- A catalyst has no effect on the position of equilibrium when a reaction has reached equilibrium, because catalysts speed up forward and backward reactions equally
- A catalyst allows you to reach equilibrium faster because it offers an alternative reaction pathway of lower activation energy
- Since less energy is required, the reaction can be carried out at a lower temperature while proceeding at the same rate

Exam Tip:

You are not required to know specific details of industrial processes, but you should be able to apply principles of equilibrium to any given reaction, including industrial processes

7

The correct answer is **C** because:

- Adding a catalyst will have no effect on the position of equilibrium as catalysts increase the rate of the forward and backward reaction equally
- Reducing the oxygen concentration has the same effect as removing it from the equilibrium
    - According to Le Chatelier's principle, the equilibrium responds to the removal of a substance by trying to make more of it, so the equilibrium will shift to the right in this case to replace the oxygen
- Increasing the volume of the container has the same effect as reducing the pressure, since Boyle's law shows that pressure is inversely proportional to volume, PV = constant so $P \propto \frac{1}{V}$
- Reducing the pressure causes the equilibrium to shift in the direction that produces more gas molecules, in this case the right hand side

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The correct answer is **A** because:

- The equilibrium constant expression is $\frac{[products]}{[reactants]}$
- If K_c is greater than 1, then [products] > [reactants]
- If K_c is equal to 1, then [products] = [reactants]
- If K_c is less than 1, then [products] < [reactants]
- In this case K_c is so small that the reaction does not proceed

Extra info:

As a rough rule of thumb, if $K_c \geq 10^{10}$ then we say the reaction 'goes to completion'.

If $K_c \leq 10^{-10}$ then the reaction 'does not proceed'

Remember that K_c values are temperature dependent, so although a reaction may not occur at room temperature it could occur at a different temperature

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The correct answer is **B** because:

- The reaction quotient, Q, is a measure of how far a reaction is from reaching equilibrium
- It is measured in the same way as finding the equilibrium constant, but at non-equilibrium conditions, $Q = \frac{[products]}{[reactants]}$
- If $Q < K_c$ then in order to reach K_c the value of Q has to increase, which means the reaction is moving to the right
- If $Q > K_c$ then in order to reach K_c the value of Q has to decrease, which means the reaction is moving to the left
- If $Q = K_c$ then the reaction is at equilibrium

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The correct answer is **B** because:

- According to Le Chatelier's principle, the equilibrium responds to changes in temperature by shifting in the endothermic direction if you raise the temperature, and shifting in the exothermic direction if you lower the temperature
- This reaction is exothermic ($\Delta H^{\theta} = -26$ kJ), so the equilibrium will shift to the right when the temperature is lowered
- A shift to the right will increase the amount of products compared to the reactants since $K_c = \frac{[products]}{[reactants]}$ so the value of K_c will increase