PENANG SANGAM HIGH SCHOOL
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LESSON NOTES

Subject: Chemistry **Year/Level:** 12
Week 17

Strand	3 Quantitative Chemistry
Sub Strand	3. 3 Physical Chemistry
Content Learning Outcome	To discuss equilibrium constant, ionise equilibrium equations and calculate concentration of hydronium and hydroxide ions

Equilibrium Constant, Kc

- Every reversible reaction in equilibrium can be represented by an equilibrium constant, K_c.
- For a general reaction of the form: aA + bB $\rightleftharpoons$ cC + dD ; $K_c = \frac{[C]^c [D]^d}{[A]^a[B]^b}$

Example

For the reaction: $N_{2\,(g)} + 3H_{2\,(g)} \rightleftharpoons 2NH_{3\,(g)}$, $K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$

> **Note:** Pure solids and liquids are not included in the equilibrium constant expression. This is because they do not affect the reactant amount at equilibrium in the reaction, so they are disregarded and kept at 1. Therefore, even though reactants and products of solid and liquid states appear in the reaction equation, they are not included in the equilibrium constant expression.

Water Dissociation and K_w

- When water dissociates, it produces hydronium ions (H_3O^+) and hydroxide ions (OH^-).
- Pure water is a weak conductor of electricity because it contains very low concentrations of H^+ and OH^- ions resulting from the dissociation of water molecules.
- This results in an equilibrium system, where the dissociation equation of water is:

$$H_2O_{(l)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + OH^-_{(aq)}$$

OR

$$2H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + OH^-_{(aq)}$$

- The equilibrium constant expression (K_c), called K_w in the case of water is:

$$K_w = \frac{[H_3O^+][OH^-]}{[H_2O]^2}$$

> Note: [ ] refers to concentration.

- The K_w value is very small and this indicates that most water does not dissociate.
- Thus $[H_2O]$ is **very large** compared to the $[H_3O^+]$ and $[OH^-]$, and it is effectively constant. This allows the K_w expression to be simplified to:

$$K_w = [H_3O^+][OH^-]$$

This is called the **ionic product** of water.

- The value of K_w at 25°C is = 1×10^{-14} mol^2 L^{-2}
- In a neutral solution, there is equal concentration of H_3O^+ and OH^- ions.

$$[H_3O^+] = [OH^-] = 1 \times 10^{-7} \text{ mol L}^{-1}$$

- Therefore, the product of the concentrations of H_3O^+ and OH^- has a constant value of 1×10^{-14} mol^2 L^{-2} at 25 °C. i.e. $[H_3O^+][OH^-] = 1 \times 10^{-14}$ mol^2 L^{-2}

  <u>or</u> $(1 \times 10^{-7} \text{ mol L}^{-1}) \times (1 \times 10^{-7} \text{ mol L}^{-1}) = 1 \times 10^{-14} \text{ mol}^2 \text{ L}^{-2}$

- If the $[H_3O^+]$ and $[OH^-]$ changes in a solution, the ionic product can be used to calculate the concentration of the unknown.

Example

1. What is the $[H_3O^+]$ in a 0.1 mol L^{-1} KOH solution?

$$K_w = [H_3O^+][OH^-] = 1 \times 10^{-14} \text{ mol}^2 \text{ L}^{-2}$$

$$[H_3O^+] \times (0.1 \text{ mol L}^{-1}) = 1 \times 10^{-14} \text{ mol}^2 \text{ L}^{-2}$$

$$[H_3O^+] = \frac{1 \times 10^{-14} \text{ mol}^2 \text{L}^{-2}}{0.1 \text{ mol L}^{-1}}$$

$$[H_3O^+] = \underline{\mathbf{1 \times 10^{-13} \text{ mol L}^{-1}}}$$

$KOH \rightarrow K^+ + OH^-$

$KOH : OH^-$

1 : 1

0.1 mol L^{-1} : 0.1 mol L^{-1}

Activity

1. Find the hydronium ion concentration in:

i. 0.01 mol L^{-1} NaOH solution.

ii. 0.01 mol L^{-1} HNO_3 solution.

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2. Calculate the concentration of hydroxide ion in 0.01 mol/L HCl.

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