6.EQUILIBRIUM

1 OMQ + 1 VSAQ + 2 SAQ [1 M + 2M + 4M + 4M = 11 M]

✎ CONCEPTS & DEFINITIONS ✎

1.1 Forward reaction: The reaction in which the reactants are converted into products is called forward reaction.

1.2 Backward reaction: The reaction in which products react back to give the reactants is called backward reaction or reverse reaction.

2. Reversible reactions: The reactions which can take place in both the forward and the backward directions are called reversible reactions.

3. Equilibrium state: The state at which the rate of the forward reaction is equal to the rate of the backward reaction in a reversible reaction is known as the equilibrium state.
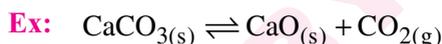
Chemical equilibrium is dynamic.

4. Types of equilibrium: **[AP 17]**

Homogeneous equilibrium: When the reactants and products are in the same physical state then the equilibrium is called homogeneous equilibrium.

Ex: $H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)}$
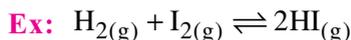
Heterogeneous equilibrium: When the reactants and products are in different physical states then the equilibrium is said to be heterogeneous equilibrium.

Ex: $CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$

5. Equilibrium constants (K_c, K_P):

For a general reaction, $aA + bB \rightleftharpoons cC + dD$

$$K_c = \frac{[C]^c [D]^d}{[A]^a [B]^b}; \qquad K_p = \frac{P_C^c P_D^d}{P_A^a P_B^b} \qquad\qquad K_p = K_c(RT)^{\Delta n}; \ \Delta n = (c+d)-(a+b)$$

6. Le-Chatlier's principle :   **[AP 16]**

If a chemical reaction at equilibrium is subjected to a change in temperature, pressure or concentration, the equilibrium position shifts in the direction, in which this change is reduced or nullified.

Factors effecting Equilibrium:

Effect of concentration: Increase in the concentration of the reactants in the reaction mixture, at equilibrium, favours the forward reaction (Reactants → Products)

Increase in the concentration of the products in the reaction mixture, favours the backward reaction. (Products → Reactants)

Effect of pressure: If the pressure is increased equilibrium shifts in such a direction in which there is decrease in no. of moles.

Effect of temperature:

Increase in the temperature of the system at equilibrium, shifts the equilibrium position in that direction in which temperature decreases or heat is absorbed. Thus endothermic reaction is favoured.

Note: A catalyst has no effect on the position of equilibrium.

7. Substances are broadly classified into three types. 1) Acids 2) Bases   3) Salts.

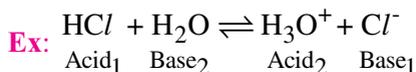8. **Bronsted acid - base theory** [Proton theory] :

8.1 **Acid:** "Bronsted acid is a proton donor".   **Ex:** HCl, H_2SO_4, CH_3COOH etc.,

8.2 **Base:** "Bronsted base is a proton acceptor."   **Ex:** NH_3, H_2O, OH^- etc.,

8.3 **Amphoteric substance:** A substance which can act as both proton donor and acceptor.

   Ex: Water

8.4 **Conjugate acids and bases:** A pair of 'acid and base' differing by 'one proton' is called conjugate acid - base pair.

   Ex: $\underset{\text{Acid}_1}{HCl} + \underset{\text{Base}_2}{H_2O} \rightleftharpoons \underset{\text{Acid}_2}{H_3O^+} + \underset{\text{Base}_1}{Cl^-}$

   HCl and Cl^- is a conjugate acid-base pair; H_3O^+ and H_2O is another conjugate acid - base pair.

9. **Lewis theory of acids and bases:** According to Lewis theory, electron pair acceptor is an acid; and electron pair donor is a base.

   The neutralisation between Lewis acids and bases is due to the formation of co-ordinate covalent bond.

9.1 **Types of Lewis acids:**

   i) All cations like Ag^+, Co^{+3}, Cu^{+2}, Fe^{+3} etc.

   ii) Molecules in which the central atom has incomplete octet and possessing vacant orbital.
      Ex: BF_3, BCl_3, $AlCl_3$, $FeCl_3$.

   iii) Compounds in which the central atom has available d-orbitals and may expands its octet.
      Ex: SiF_4, $SnCl_4$, SF_4, TeF_4.

   iv) Molecules having multiple bonds between atoms of dissimilar electro negativities
      Ex: CO_2, SO_2, SO_3, NO_2

   v) Elements with an electron sextet **Ex:** S, O.

9.2 **Types of Lewis bases:**

   i) All anions like Cl^-, OH^-, CN^-, NH_2^-, F^-, SCN^- (thio cyanate ion)

   ii) Molecules with one or two lone pairs of electrons on the central atom.
      Ex: $H_2\overset{..}{O}$, $\overset{..}{N}H_3$, C_5H_5 N (pyridine)

   iii) Molecules with multiple bonds   **Ex:** CO, NO, $HC \equiv CH$, $H_2C = CH_2$.

10. **Ionic product of water(K_w):** 'The product of $[H^+]$ and $[OH^-]$ ion concentration in pure water or in aqueous solution is called ionic product of water'. Thus $K_w = [H^+][OH^-]$

11. **Ionic equilibrium:** The equilibrium which is established between un-ionised molecules and ions in the solutions of weak electrolytes is called ionic equilibrium.

12. **Measurement of concentration of solutions – pH scale:**

    pH scale: "The negative value of the logarithms to the base 10 of hydrogen ion [H^+ ion] concentration in a solution is known as pH of the solution".

    Calculation of pH or pOH of a solution:

    $pH = -\log[H^+]$ or $[H^+] = 10^{-pH}$; $pOH = -\log[OH^-]$ or $[OH^-] = 10^{-pOH}$

    $pH + pOH = 14$ (at 25°C)

    Classification of aqueous solutions in terms of pH value

    Neutral solution: $[H^+] = 1.0 \times 10^{-7}$ M. $\therefore pH = 7$

    Acidic solution: $[H^+] > 1.0 \times 10^{-7}$ M $\therefore pH < 7$

    Basic solution: $[H^+] < 1.0 \times 10^{-7}$ M $\therefore pH > 7$

13. **Buffer solutions:** The solutions which maintain constant pH are called buffer solutions.

    A solution which resists any change in its pH value on dilution or on addition of a small amount of strong acid or a strong alkali is known as buffer solution.   **[AP 15]**

    Types of buffer solutions:

    i) Acid buffer solutions ii) Base buffer solutions.

    1) **Acid buffer solutions:** A mixture of a weak acid and its salt with a strong base is called an acid buffer.

    2) **Base buffer solutions:** A mixture of weak base and its salt with a strong acid is called basic buffer.

14. **Salt Hydrolysis:** The reaction of a salt with water to form an acid and a base is called Salt hydrolysis. Hydrolysis of salts is the reverse process of neutralisation.

    $Salt + Water \rightleftharpoons Acid + Base$
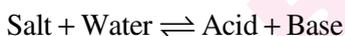
15. **Solubility product :** The product of the concentrations of the cation and the anion in a saturated solution of a salt at room temperature is called solubility product.

    Thus, $\mathbf{K_{sp} = [M^{n+}][A^{n-}]}$

16. **Common ion effect :** The solubility of an electrolyte (salt, acid, base) in water decreases on addition of an electrolyte (acid, base or salt) which has one ion (cation or anion) common with the electrolyte is called common ion effect.

IMPORTANT FORMULAE

1. $pH + pOH = 14$ **2.** $pH = -\log[H^+]$; $pOH = -\log[OH^-]$

3.1. $pH = pK_a + \log_{10}\left[\dfrac{salt}{acid}\right]$, (Acidic buffer)   **3.2.** $pOH = pK_b + \log_{10}\left[\dfrac{salt}{base}\right]$, (Basic buffer)

☞ For **Chem Beats** of this chapter Refer Page **No. 207**