Chemistry Study Materials for Class 11
(NCERT Based Notes of Chapter- 07)
Ganesh Kumar Date: -28/11/2020

Equilibrium

Ionic equilibrium in solution

Equilibrium involving ions is called ionic equilibrium.

E.g. dissociation of acetic acid in water

$$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$$

Electrolytes and non-electrolytes

Based on the ability to conduct electricity, Michael Faraday divided substances into two – electrolytes and non-electrolytes.

Electrolytes are substances which conduct electricity in molten state or in solution state. e.g. All acids, bases and almost all salts

Non- electrolytes are substances which do not conduct electricity in molten state or in solution state. e.g. sugar, urea etc.

Electrolytes are further classified into two - strong electrolytes and weak electrolytes.

Strong electrolytes are electrolytes which dissociate almost completely in aqueous solution.

E.g. strong acids like HCl, HNO_3, H_2SO_4 etc., strong bases like NaOH, KOH etc. and salts like NaCl, KCl, Na_2SO_4, K_2SO_4, KNO_3, $NaNO_3$ etc.

Electrolytes which dissociate only partially in aqueous solution are called weak electrolytes. E.g. weak acids like CH_3COOH, formic acid (HCOOH) etc., weak bases like $Mg(OH)_2$, $Ca(OH)_2$, NH_4OH etc. and some salts like $CaSO_4$, $BaSO_4$ etc.

A weak electrolyte dissociates only partially in aqueous solution and so equilibrium is formed between the ions and the unionized molecules. This type of equilibrium involving ions in aqueous solution is called ionic equilibrium.

Acids, Bases and Salts

Acid – base concepts:

1. **Arrhenius concept**: *According to this concept acids are substances which give hydrogen ion (H^+) or hydronium ion (H_3O^+) in aqueous solution and bases are substances which give hydroxyl ion (OH^-) in aqueous solution*.

   e.g. HCl is an acid since it produces H_3O^+ in aqueous solution.

   $$HCl(l) + H_2O(l) \rightleftharpoons H_3O^+(aq) + Cl^-(aq)$$

   e.g. for base is NaOH; $NaOH_{(s)} + H_2O_{(l)} \rightleftharpoons Na^+ + OH^-(aq)$

Note: H+ ions exist in water as hydronium ions (H_3O^+); $H^+ + H_2O \rightleftharpoons H_3O^+$

Limitations: this concept is applicable only to aqueous solutions. Also it could not account for the basicity of substances like NH_3 which do not possess OH^- ion.

2. **The Bronsted – Lowry concept:**

   According to this concept acids are proton (H^+) donors and bases are (H^+) acceptors. For example in the reaction;

   $$NH_3(l) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

   Here NH_3 is a base since it accepts an H^+ ion to form NH_4^+ and H_2O is an acid since it donates an H^+ ion to form OH^- . In the reverse reaction, NH_4^+ is an acid and OH^- is a base.

   The acid base pair that differs by only one proton is called a conjugate acid – base pair.

   An acid formed from a base is called conjugate acid and a base formed from an acid is called conjugate base.

   $$NH_3(l) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

   base acid conj. acid conj. base

   In general Acid – H+ → Conjugate base; Base + H+ → Conjugate acid

   $$HCl + H_2O \rightleftharpoons H_3O^+ + Cl^-$$

   Acid base conj. acid conj. Base

If the acid is strong, its conjugate base is weak and vice versa. So in the above example Cl- is a weak conjugate base of the strong acid HCl.

Water can act both as acid and base. So it is an amphoteric substance.

3. Lewis concept:

According to this concept acids *are electron pair acceptors and bases are electron pair donors.*

Substances which donate electron pair are called Lewis bases and substances which accept electron pair are called Lewis acids.

Example for Lewis acids are BF_3, $AlCl_3$, H^+, Co^{3+}, Mg^{2+} etc.

Example for Lewis bases are NH_3, H_2O, OH^-, Cl^-, Br^- etc.

For a substance to act as Lewis acid it should contain vacant orbitals and for a substance to act as Lewis base, it should contain lone pairs of electrons

e.g. for acid – base reaction is $BF_3 + NH_3 \rightarrow BF_3 \leftarrow NH_3$

All cations are Lewis acids and all anions are Lewis bases.

The ionization constant of water (The ionic product of water)

Water is a weak electrolyte and hence it ionizes only partially as:

$$H_2O \rightleftharpoons H^+ + OH^-$$

$$\text{Or, } H_2O + H_2O \rightleftharpoons H_3O^+ + OH^-$$

The dissociation constant, $K = \frac{[H^+][OH^-]}{[H_2O]}$ or, $K = \frac{[H_3O^+][OH^-]}{[H_2O]}$

$$\text{Or, } Kw = [H^+][OH^-] \quad \text{or, } Kw = [H_3O^+][OH^-]$$

Where Kw is called ionization constant of water or ionic product of water

It is defined as **the product of the molar concentration of hydrogen ion (hydronium ion) and hydroxyl ion in water or in any aqueous solution**.

For pure water at 298K, $[H^+] = [OH^-] = 10^{-7}M$.

Therefore, $Kw = [H^+][OH^-] = 10^{-7} \times 10^{-7} = 10^{-14}M^2$

The value of Kw is temperature dependent.

By knowing the concentrations of H_3O^+ and OH^- ions, we can predict the nature of an aqueous solution.

If $[H_3O^+] > [OH^-]$, the solution is acidic

If $[H_3O^+] < [OH^-]$, the solution is basic

If $[H_3O^+] = [OH^-]$, the solution is neutral

The p^H scale

p^H is defined as the negative logarithm of the hydrogen ion or hydronium ion concentration in moles per litre (i.e. molarity).

i.e. $p^H = -\log[H^+]$ or $p^H = -\log[H_3O^+]$

Negative logarithm of hydroxyl ion concentration in mol/L is called p^{OH}.

i.e. $p^{OH} = -\log[OH^-]$

For pure water, at 298K (25^0c), $[H^+] = 10^{-7}$. Therefore p^H of pure water is 7.

The p^H scale was introduced by Sorensen. It contains numbers from 0 to 14. If the pH is less than 7, the solution is acidic, if it is greater than 7, it is basic and if it is 7, the solution is neutral.

If the p^H is 0, 1, 2 etc., the solution is a strongly acidic and if it is 12, 13, 14 etc, it is strongly basic. The p^H of our blood is 7.4 and that of our saliva is 6.4.

So blood is slightly basic and saliva is slightly acidic.

Relation between p^H and p^{OH}

We know that $Kw = [H^+][OH^-] = 10^{-14}$ at 298K

Taking negative logarithm on both sides:

$$-\log Kw = -\log[H^+] + -\log[OH^-] = -\log 10^{-14}$$

Or, $p^{Kw} = p^H + p^{OH} = 14$

Thus by knowing the p^H, we can calculate p^{OH} as $p^{OH} = 14 - p^H$

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