By Dr. Akhilesh Prasad ; Assiatant Professor; Department of chemistry: H.D. Jain College, Ara

UG SEM IV (7T) UNIT II

Unit 2: Conductance (12 Lectures)

Conductance, specific conductance (conductivity); equivalent and molar conductance; their variation with dilution for weak and strong electrolytes; Kohlrausch's law of independent migration of ions; transference number and its experimental determination using Hittorf and Moving Boundary methods; ionic mobility; applications of conductance measurements; determination of degree of ionization of weak electrolyte; solubility and solubility product of sparingly soluble salts; ionic product of water; hydrolysis constant of a salt; conductometric titrations (acid–base only).

Conductance:

Conductance is the ability of a material or an electrical circuit to **allow electric current to flow easily** through it.

If a solution allows current to pass through it **easily**, it has **high conductance**.
If it **opposes** the flow of current, it has **low conductance**.

Conductance is the **reciprocal (opposite)** of resistance.

G= $\frac{1}{R} = \frac{I}{V}$

- **High resistance → Low conductance**
- **Low resistance → High conductance**

The SI unit of conductance is Ω^{-1} or mho or **Siemens (S)**.

A solution has higher conductance if it contains more free ions that can move and carry electric charge.

Example:

Salt solution → high conductance

Pure water → very low conductance

Specific Conductance (Conductivity)

Specific conductance, also called **conductivity**, is the measure of how **well a material allows electric current to flow through it**.

 It tells us about the **nature of the material itself**, not its shape or size.

Conductivity (σ) is the reciprocal of **resistivity (ρ)**

It depends on **material**, not size

$$\sigma = \frac{1}{\rho} = \frac{1}{R}\frac{l}{A}$$

Where:

- L = length of conductor
- A = cross-sectional area
- R = resistance

 Good conductor → **high conductivity**

 Poor conductor → **low conductivity**

Specific conductance is the conductance of a material of **unit length and unit cross-sectional area**.

SI Unit Siemens per metre (S/m)

Examples

- **Copper, silver** → very high conductivity
- **Glass, rubber** → very low conductivity

Equivalent Conductance (Λ_eq):

The conductance of a solution containing one gram-equivalent of an electrolyte, when placed entire solution between two electrodes 1 cm apart and of sufficiently large area is called Equivalent conductance .

$\mathbf{\Lambda_e q} = \frac{\boldsymbol{k \times 1000}}{\boldsymbol{N}}$

where:

k= specific conductance (S cm^{-1})

N = normality of the solution (eq L^{-1})

Unit: S cm^2 eq^{-1}

Important Points

On dilution, equivalent conductance increases.

For strong electrolytes, it increases slowly with dilution.

For weak electrolytes, it increases sharply due to increased ionization.

At Infinite Dilution Equivalent conductance reaches a maximum value $\boldsymbol{\Lambda_{eq}^{0}}$.

Molar conductance (Λ_m) : The conductance of all the ions produced by one mole of an electrolyte when it is dissolved in solution and entire solution placed between two electrodes 1 cm apart is called molar conductivity.

$$\Lambda_m = \frac{k \times 1000}{M}$$

Where:

Λ_m = molar conductance ($S\ cm^2\ mol^{-1}$)

k = specific conductance ($S\ cm^{-1}$)

M= molar concentration ($mol\ L^{-1}$)

1000 = conversion factor ($L \rightarrow cm^3$)

 Variation of Molar Conductance with Dilution

Strong Electrolytes (NaCl, HCl, KNO_3)

Completely ionized in solution

Λ_m increases slightly with dilution

Reason: reduced inter-ionic attraction

At infinite dilution → reaches limiting molar conductance (Λ_m^0)

 Plot: Λ_m vs $\sqrt{C}$ → straight line

Weak Electrolytes (CH_3COOH, NH_4OH)

Partially ionized

Λ_m increases sharply with dilution

Reason: degree of ionization increases

Λ_m^0 cannot be measured directly

 Plot: highly curved

 Limiting Molar Conductance (Λ_m^0)

Molar conductance at infinite dilution

Inter-ionic attractions become negligible

□ **Importance of Molar Conductance**

✔To compare conducting power of electrolytes

✔To distinguish strong and weak electrolytes

✔To calculate:

Degree of dissociation

Dissociation constant (Ka)

Kohlrausch's Law of Independent Migration of Ions

At infinite dilution, each ion migrates independently of the other ions and contributes a definite value to the molar conductance of the electrolyte, irrespective of the nature of the other ion present.

$\Lambda_m^0 = \boldsymbol{\lambda_+^0} + \boldsymbol{\lambda_-^0}$

Where:

Λ_m^0 = limiting molar conductance of the electrolyte

$\boldsymbol{\lambda_+^0}$= limiting ionic conductance of the cation

$\boldsymbol{\lambda_-^0}$ = limiting ionic conductance of the anion

□ Explanation

At infinite dilution, inter-ionic attractions become negligible

Each ion moves independently under the influence of the electric field

Total conductance = sum of individual ionic conductances

Hence, the conductance of an electrolyte is additive in nature.

Example

For NaCl at infinite dilution:

Λ_m^0 (NaCl) $= \boldsymbol{\lambda_{Na^+}^0} + \boldsymbol{\lambda_{Cl^-}^0}$

□ Applications of Kohlrausch's Law

1. Determination of Limiting Molar Conductance of Weak Electrolytes:

Example: CH_3COOH

2 Calculation of Degree of Dissociation (α)

3 Determination of Dissociation Constant (Ka)

4 Determination of Individual Ionic Conductance

Using known values of strong electrolytes

Helps find � of ions like H^+, OH^-, etc.

 Limitations of Kohlrausch’s Law

❌Applicable only at infinite dilution

❌Not valid at high concentrations due to inter-ionic interactions

 One-Line Exam Answer

Kohlrausch’s law states that at infinite dilution, ions migrate independently and the limiting molar conductance of an electrolyte is the sum of the limiting ionic conductances of its ions.