

Conductometry

Introduction to Conductometry

Definition:

- Conductometry is the measurement of the electrical conductance (or conductivity) of a solution, which depends on the presence and mobility of ions.
- It is used to monitor changes in ion concentration, especially during titrations.

Principle:

- Conductance increases with increasing number of **free ions** in the solution.
- As a reaction progresses (e.g., during a titration), the number and type of ions change, leading to measurable changes in conductivity.
- The **conductance (G)** is the reciprocal of resistance:

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

- The **specific conductance (κ)** is given by:

$$\kappa = G \times \frac{l}{A}$$

- Where:
 - l = distance between electrodes
 - A = cross-sectional area of electrodes

Instrumentation:

1. Conductivity Cell:

- Two **platinum electrodes** (usually platinized) fixed at a known distance.
- Immersed in the solution.

2. AC Source:

- Alternating current (typically 1 kHz) is used to prevent **electrolysis** and **polarization**.

3. Conductivity Bridge or Meter:

- Measures conductance directly or indirectly by resistance.

4. Thermometer:

- Conductivity is **temperature-dependent**, so temperature control or compensation is essential.

Conductivity and Its Units

- **Conductivity (κ) or specific conductance** is the ability of a solution to conduct electricity and is defined as the reciprocal of resistivity.
- It is represented by the Greek letter κ (kappa).
- **Unit:**
 - In the SI system, it is expressed in siemens per meter (S/m), but in practical chemistry, millisiemens per centimeter (mS/cm) or microsiemens per centimeter (μ S/cm) are also commonly used.

Types of Conductivity

1. **Specific Conductivity (κ):** Conductivity of 1 cm³ of a solution. It depends on the concentration of ions and their mobility.
2. **Equivalent Conductivity (Λ_e):** Conductivity of a solution containing 1 gram-equivalent of electrolyte placed between electrodes 1 cm apart.
 - $\Lambda_e = \kappa \times 1000 / C$
 - where C = concentration in g eq/L
3. **Molar Conductivity (Λ_m):** Conductivity of a solution containing 1 mole of electrolyte placed between electrodes 1 cm apart.
 - $\Lambda_m = \kappa \times 1000 / M$
 - where M = molar concentration (mol/L)

Ionic Mobility and Conductivity

- The ability of ions to carry electric current is influenced by:
 - **Size of the ion**
 - **Hydration of ions** (hydrated ions are larger and move slower)
 - **Charge on the ion**
 - **Temperature** (higher temperature increases ion mobility)
- **Cations and anions** contribute differently to the total conductivity depending on their mobility.

Factors Affecting Conductivity

1. Concentration of Ions:

- Higher the number of free ions, higher the conductivity.
- However, for strong electrolytes, conductivity increases with dilution due to decreased ion-pairing.
- For weak electrolytes, conductivity increases sharply with dilution due to more ionization.

2. Temperature:

- Conductivity increases with temperature due to increased ion mobility.

3. Nature of Electrolyte:

- Strong electrolytes (e.g., HCl, NaCl) ionize completely and have high conductivity.
- Weak electrolytes (e.g., CH_3COOH , NH_4OH) ionize partially and show lower conductivity.

4. Nature of Solvent:

- Polar solvents like water support ionization and thus conductivity.
- Non-polar solvents do not favor ionization, leading to low conductivity.

Advantages:

- Can be used with colored or turbid solutions
- No need for indicator
- Suitable for very dilute solutions
- Simple and rapid technique

Limitations:

- Conductivity affected by temperature and impurities
- Not selective; measures total ionic content
- Requires frequent calibration of the cell constant

Applications of Conductometry

1. Determination of Drug Purity

- Measuring conductivity of drug solutions can reveal ionic impurities or degradation products.

2. Titration of Pharmaceuticals

- Weak acids (e.g., aspirin) and weak bases (e.g., alkaloids) can be titrated without relying on visual indicators.
- Conductometric assay methods are official for some APIs in pharmacopoeias.

3. Water Quality and Purity Testing

- Bulk pharmaceutical water (e.g., WFI – Water for Injection) is tested for ionic content via conductometry.
- USP and IP specify conductivity limits for various grades of water.

4. Determination of Dissociation Constants

- K_a of weak electrolytes can be estimated from conductivity at different concentrations.

5. Monitoring Reactions

- Hydrolysis or degradation reactions that release or consume ions can be tracked conductometrically.

6. Electrolyte Formulations

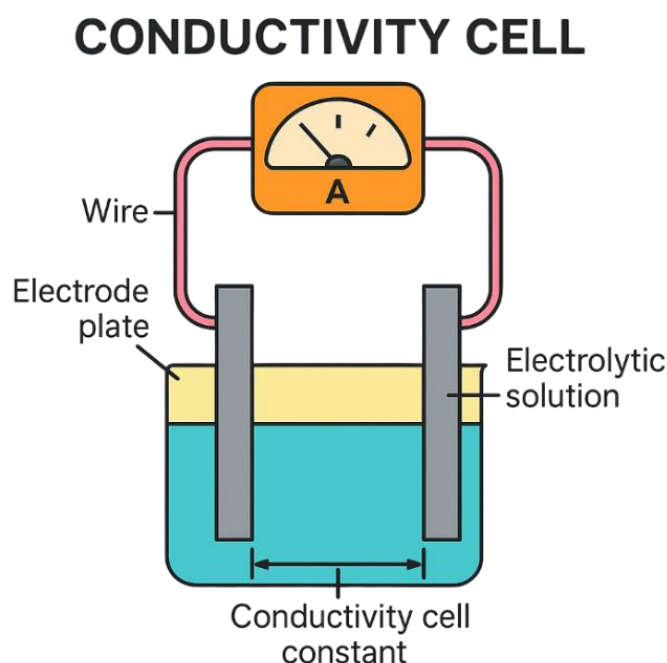
- In parenteral or oral electrolyte solutions, conductometry ensures correct ionic strength and balance.

Conductivity Cell

Definition

- A conductivity cell is a specially designed electrode assembly used to measure the electrical conductivity of a solution.
- It consists of two electrodes (typically made of inert metal like platinum) placed at a fixed distance from each other and submerged in the electrolyte solution.
- It is connected to a conductivity meter that measures the conductance.
- The primary purpose of the conductivity cell is to provide a stable and reproducible geometry for measuring conductivity, which is critical because conductivity depends on both the area of electrodes and the distance between them.

Basic Structure of a Conductivity Cell



- A typical conductivity cell consists of:
- **Two platinum electrodes** that are:
 - Coated with platinum black to prevent polarization and increase surface area.
 - Fixed at a known distance apart.
 - Usually arranged parallel to each other.



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