# Conductometric Titration

Compounds that wholly or partially dissociate into ions in water/solvents are electrolytes. The conductance depends on

- the concentration of the ions
- temperature of the solution
- nature of the ion (charge per ion, mobility/size etc.)

This experiment, we will use conductometry to determine the concentration of HCl

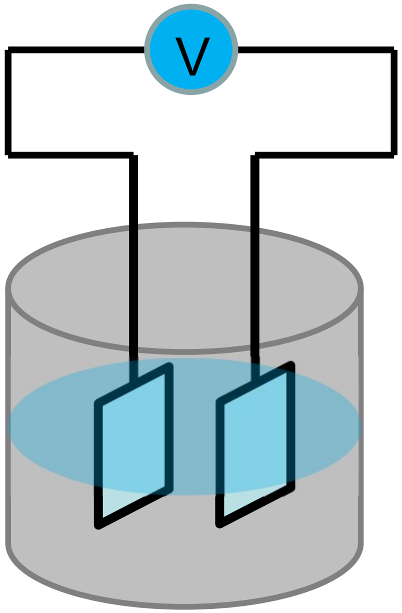
Total conductance of the solution follows **Ohm's Law**

$$\mathbf{i = V/R}$$

Where, i = current, V = potential difference, R = resistance (Ohms)

# Conductivity Measurement set-up

## Conductivity cell




## Electrodes

Two parallel plates (inert metal: Au, Pt) are used as electrodes. The resistance/conductance of an electrolyte is measured by immersing the electrodes in the electrolyte and applying an electric field between the electrodes. Electrodes are separated by 1 cm and the are is 1 $cm^2$.

## Primary Standard Solution

0.02 M KCl solution at 25 °C has a specific conductivity of $0.01286 \Omega^{-1}/cm$ and is used as a primary standard.

# Useful Terms

Specific Conductance ($\kappa$): The conductance of one $cm^3$ of a material, which is an inherent property of the material. Units of $\kappa$ is mhos/cm or Siemens/cm.

Molar Conductivity ($\Lambda_{mol}$): The conductivity of a solution that contains one mole of the substance (solute) in 1 liter. Unit of $\Lambda$ is S $cm^2$ $mol^{-1}$.

$$\Lambda_{mol} = \kappa/C$$

where C is concentration in mol/liter.

Equivalent Conductivity ($\Lambda_{eq}$): The conductivity per gram equivalent of the electrolyte.

$$\Lambda_{eq} = \kappa/C_{eq}$$

where $C_{eq}$ is the equivalent concentration of the electrolyte (gram equivalent in L)

# Molar conductivity of various ions at infinite dilution at 25°C

| Ions | Molar Conductivity (S cm$^2$ mol$^{-1}$ ) |
|---|---|
| $K^+$ | 73.52 |
| $Na^+$ | 50.11 |
| $Li^+$ | 38.69 |
| $H^+$ | 349.82 |
| $Ag^+$ | 61.92 |
| $F^-$ | 55.5 |
| $Cl^-$ | 76.34 |
| $Br^-$ | 78.4 |
| $OH^-$ | 198 |
| $CH_3COO^-$ | 41.0 |

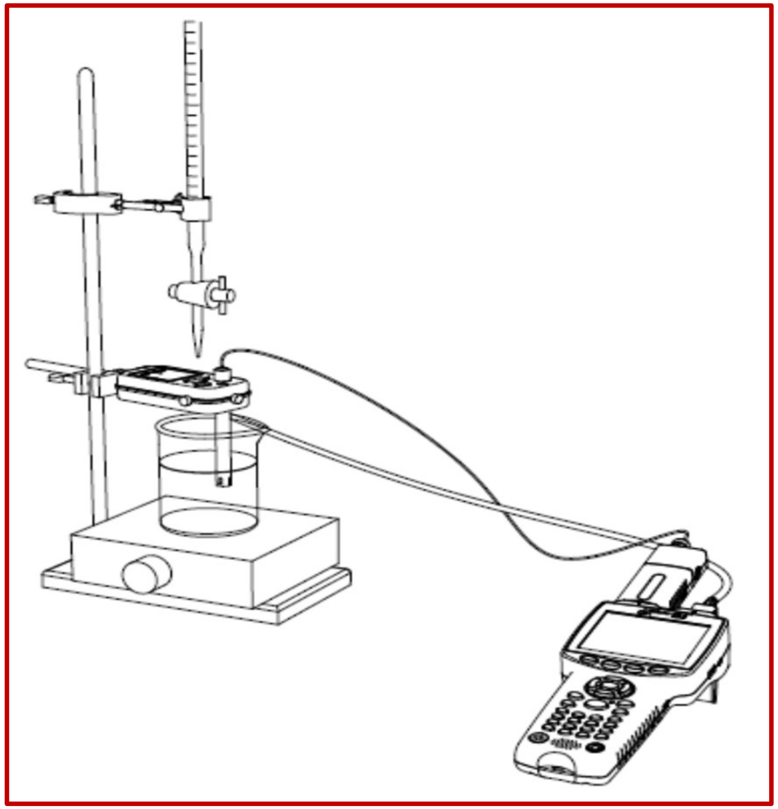
# Applications of Conductometry

To determine

- Solubility of sparingly soluble salts
- Ionic product of water
- Basicity of organic acids
- Salinity of sea water (oceanographic work)
- Chemical equilibrium in ionic reactions
- Conductometric titration

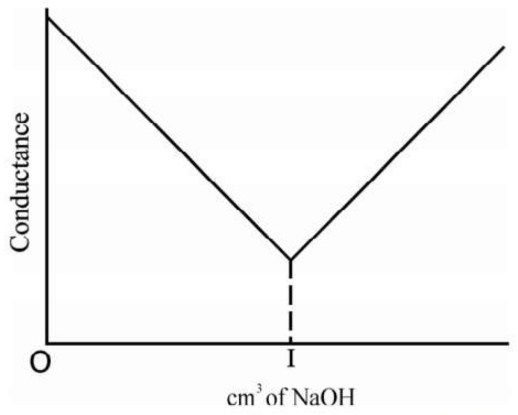
## Conductometric Titration

The determination of end point of a titration by means of conductivity measurements is known as conductometric titration.

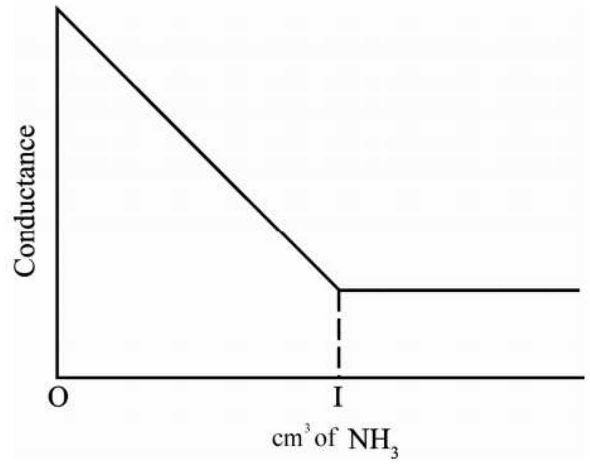


# Types of Conductometric Titrations

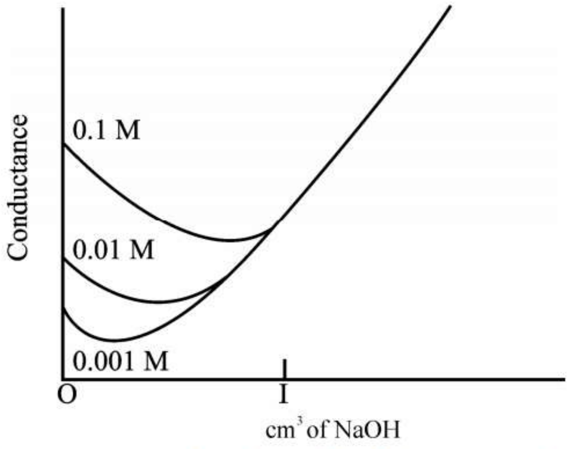
Acid Base Titration
Precipitation Titration
Redox Titration



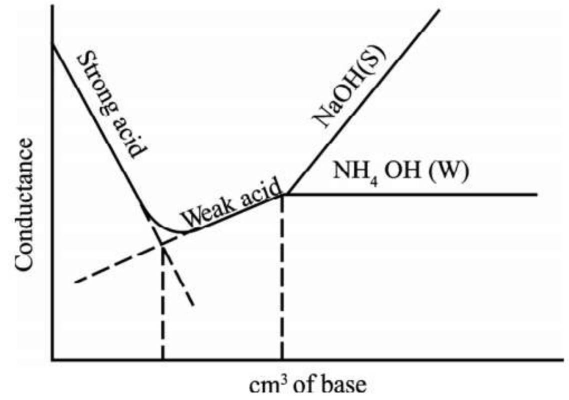

**Conductometric titration of a strong acid (HCl) vs. a strong base (NaOH)**




**Conductometric titration of a strong acid ($H_2SO_4$) vs. a weak base ($NH_4OH$)**




**Conductometric titration of a weak acid (acetic acid) vs. a strong base (NaOH)**




**Conductometric titration of a mixture of a strong acid (HCl) and a weak acid ($CH_3COOH$) vs. a strong base (NaOH) or a weak base ($NH_4OH$)**

Images courtesy www.embibe.com

# Conductometric Titration: Strong Acid *Vs* strong Base

$$NaOH\,(aq) + HCl\,(aq) \longrightarrow NaCl\,(aq) + H_2O$$

## Experimental Protocol

1. Take NaOH (0.1 N) solution in a 50 mL burette and adjust zero reading.
2. Pipette out 25 mL of the given HCI solution in a 100/150 mL beaker. Add 25 mL of water to this.
3. Now add the NaOH solution from the burette in (2 drops) 0.2 mL increments and record the conductivity after mixing the solution.
4. Continue the titration till you reach the initial conductivity value.
5. Repeat the experiment twice.
6. Plot the graph of volume of NaOH vs conductance and determine the equivalance point of the titration.
7. Calculate the normality of HCl solution.

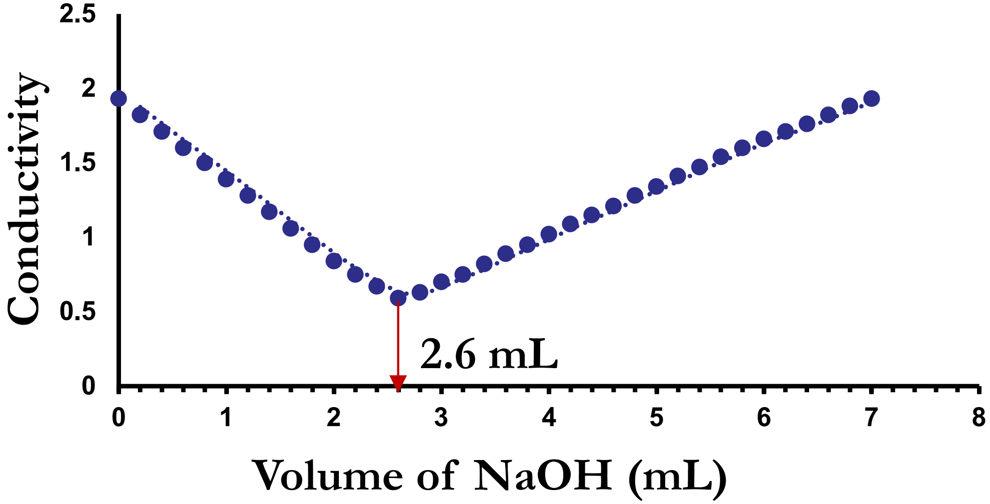
# Observations

Given Concentration of NaOH solution = 0.1 M

| Vol. NaOH | Conductance |
|---|---|
| 0 | 1.93 |
| 0.2 | 1.82 |
| 0.4 | 1.71 |
| 0.6 | 1.6 |
| 0.8 | 1.5 |
| 1 | 1.39 |
| 1.2 | 1.28 |
| 1.4 | 1.17 |
| 1.6 | 1.06 |
| 1.8 | 0.95 |
| 2 | 0.84 |
| 2.2 | 0.75 |
| 2.4 | 0.67 |
| 2.6 | 0.59 |
| 2.8 | 0.63 |
| 3 | 0.7 |
| 3.2 | 0.75 |
| 3.4 | 0.82 |
| 3.6 | 0.89 |
| 3.8 | 0.95 |
| 4 | 1.02 |
| 4.2 | 1.09 |
| 4.4 | 1.15 |
| 4.6 | 1.21 |
| 4.8 | 1.28 |
| 5 | 1.34 |

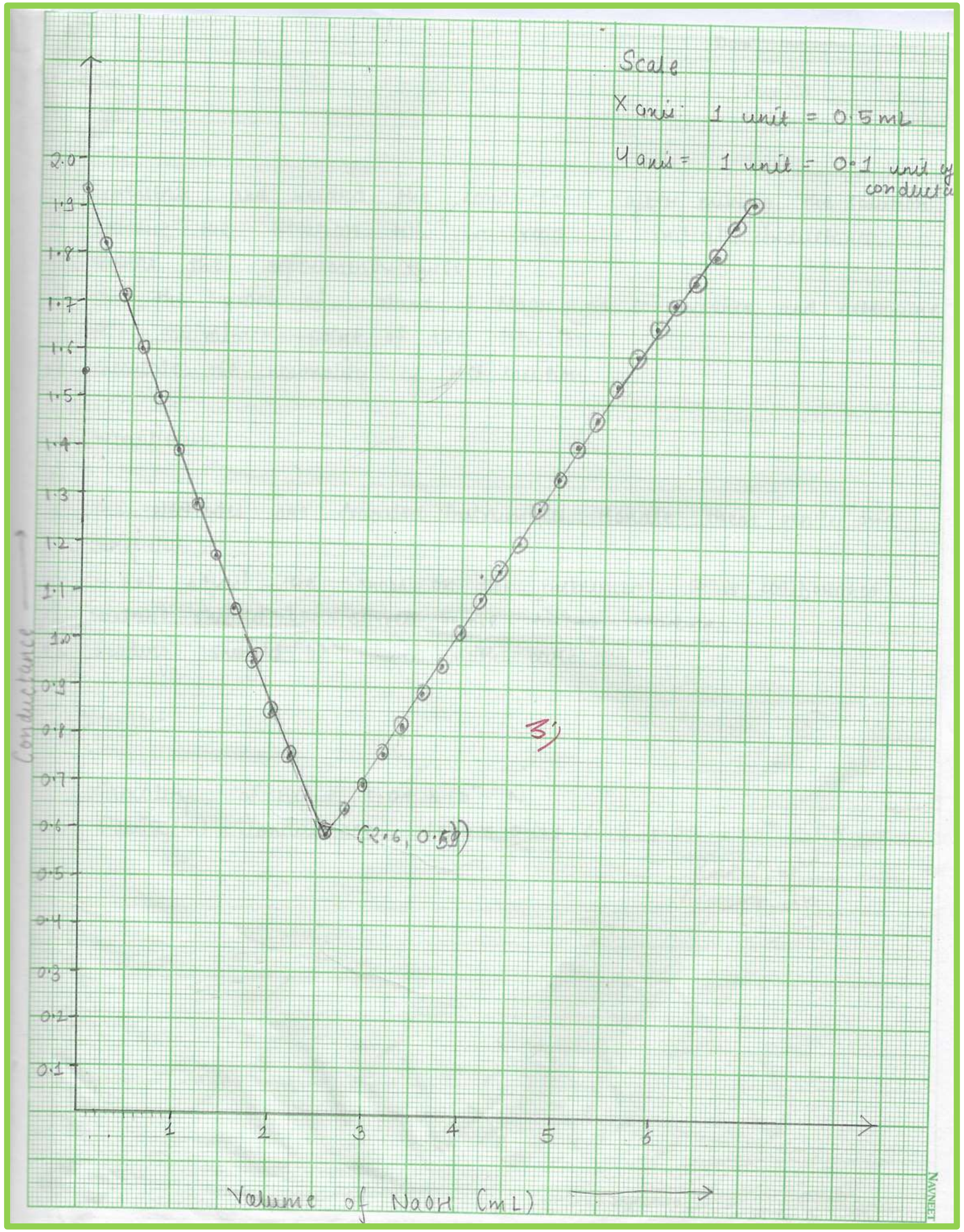
| Vol. NaOH | Conductance |
|---|---|
| 5.2 | 1.41 |
| 5.4 | 1.47 |
| 5.6 | 1.54 |
| 5.8 | 1.6 |
| 6 | 1.66 |
| 6.2 | 1.71 |
| 6.4 | 1.76 |
| 6.6 | 1.82 |
| 6.8 | 1.88 |
| 7 | 1.93 |

Conductivity vs Volume of NaOH



# Observations

Image of a graph Conductivity vs Volume of NaOH



# Observations and Calculations

From graph;

Note the end point of titration (in this case when 2.6 mL of NaOH was consumed)

At the end point;

**moles of NaOH = moles of HCl**

$$M_{NaOH} \times V_{NaOH} = M_{HCl} \times V_{HCl}$$

$$0.1 \times 2.6 = M_{HCl} \times 25$$

**Molarity of HCl = 0.01 M**

Conductometric titration was performed to determine the concentration of a given acid sample

**Molarity of given HCl = 0.01 M**

# Advantages of Conductometric Titrations

- No need of indicator
- Colored or dilute solutions or turbid suspensions can be used for titrations
- Temperature is maintained constant throughout the titration
- End point can be determined accurately, and errors are minimized as the end point is being determined graphically