

PABNA UNIVERSITY OF SCIENCE AND TECHNOLOGY



**Faculty of Engineering & Technology**  
**Department of Information and Communication Engineering**

**Course name: Chemistry**  
**Course Code: CHEM-2201**

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**Session: 2021-2022**

**2<sup>nd</sup> Year 2<sup>nd</sup> Semester**

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## 4.(a) How is the specific conductance of an electrolyte solution determined?

**Specific conductance** ( $\kappa$ ), also called conductivity, measures how well a solution conducts electricity. It is defined as the conductance of a solution placed between two electrodes 1 cm apart with a cross-sectional area of 1 cm<sup>2</sup>.

### Experimental Method

The modified **Wheatstone Bridge method** is commonly used. The procedure is as follows:

#### Apparatus Required

- Conductivity cell (with two platinum electrodes, often coated with platinum black)
- Conductivity meter (or Wheatstone bridge setup with AC supply)
- Alternating current (AC) source (to prevent polarization)
- Standard KCl solution (for calibration)
- Unknown electrolyte solution
- Thermostatic water bath (to maintain constant temperature, usually 25°C)

#### Steps

##### 1. Calibration of Cell:

- Fill the conductivity cell with a standard KCl solution whose conductivity at the given temperature is known.
- Measure the conductance ( $G_{\text{standard}}$ ) of the standard solution.
- Calculate the **cell constant** ( $C$ ) using:

$$C = \kappa_{\text{standard}} \times \frac{1}{G_{\text{standard}}}$$

## 2. Measurement of Electrolyte Solution:

- Replace the standard KCl solution with the unknown electrolyte solution.
- Measure the conductance ( $G_{\text{unknown}}$ ) of the unknown solution.

## 3. Calculation:

- Find the specific conductance ( $\kappa_{\text{unknown}}$ ) using:

$$\kappa_{\text{unknown}} = C \times G_{\text{unknown}}$$

## Important Notes

- An **AC current** must be used to avoid electrolysis and polarization.
- **Temperature** should be kept constant because conductivity is temperature-dependent.
- Electrodes are often coated with **platinum black** to prevent polarization and increase effective surface area.

## 4.(b) Specific Conductance and Equivalent Conductance

### Definition of Specific Conductance

**Specific conductance** ( $\kappa$ ) is defined as the conductance of a solution placed between two electrodes 1 cm apart with a cross-sectional area of 1 cm<sup>2</sup>.

Mathematically, it is the reciprocal of specific resistance ( $\rho$ ):

$$\kappa = \frac{1}{\rho}$$

Its SI unit is S cm<sup>-1</sup> (Siemens per centimeter).

## Definition of Equivalent Conductance

**Equivalent conductance** ( $\Lambda_{\text{eq}}$ ) is defined as the conductance of a solution containing one gram-equivalent of electrolyte, when placed between two electrodes sufficiently far apart to avoid interaction between ions.

It is given by:

$$\Lambda_{\text{eq}} = \kappa \times V$$

where  $V$  is the volume (in  $\text{cm}^3$ ) containing one gram-equivalent of the electrolyte.

The SI unit of equivalent conductance is  $\text{S cm}^2\text{eq}^{-1}$ .

## Derivation of the Relationship between $\kappa$ and $\Lambda_{\text{eq}}$

Let,

$$V = \frac{1000}{N}$$

where  $N$  is the normality of the solution (gram-equivalents per liter).

Thus,

$$\Lambda_{\text{eq}} = \kappa \times \frac{1000}{N}$$

## Final Relation

$$\boxed{\Lambda_{\text{eq}} = \frac{1000 \kappa}{N}}$$

where:

- $\Lambda_{\text{eq}}$  = Equivalent conductance ( $\text{S cm}^2\text{eq}^{-1}$ )
- $\kappa$  = Specific conductance ( $\text{S cm}^{-1}$ )
- $N$  = Normality ( $\text{eq L}^{-1}$ )

## 5.(a) Defects of Rutherford's Model of Atom and Bohr's Suggestions

### Defects of Rutherford's Model

- According to classical electromagnetic theory, an electron revolving around the nucleus should continuously emit radiation, thereby losing

energy.

- As a result, the electron should spiral inward and eventually fall into the nucleus, making the atom unstable. However, atoms are stable in reality.
- Rutherford's model could not explain the discrete line spectra observed in the emission and absorption spectra of elements.

### Bohr's Suggestions to Remove These Defects

- Electrons revolve around the nucleus only in certain permitted circular orbits called **stationary orbits** without emitting radiation.
- The energy of an electron remains constant as long as it stays in a particular orbit.
- Electrons can absorb or emit energy only when they jump from one stationary orbit to another, and the energy absorbed or emitted is equal to the difference in energy between the two orbits.

## 5.(b) Quantum Numbers

### Definition

Quantum numbers are a set of numerical values that provide information about the location and energy of an electron in an atom.

### Number of Quantum Numbers

Each electron in an orbital is described by **four quantum numbers**.

### Significance of Each Quantum Number

#### 1. Principal Quantum Number ( $n$ ):

- It determines the main energy level or shell of the electron.
- It also relates to the size and energy of the orbital.
- $n = 1, 2, 3, \dots$  (K, L, M, N shells, respectively).

2. **Azimuthal Quantum Number ( $l$ ):**

- It determines the subshell or shape of the orbital.
- For a given  $n$ ,  $l$  can have values from 0 to  $(n - 1)$ .
- $l = 0$  (s-orbital),  $l = 1$  (p-orbital),  $l = 2$  (d-orbital),  $l = 3$  (f-orbital).

3. **Magnetic Quantum Number ( $m$ ):**

- It determines the orientation of the orbital in space.
- For a given  $l$ ,  $m$  can have integer values from  $-l$  to  $+l$  (including zero).

4. **Spin Quantum Number ( $s$ ):**

- It represents the spin of the electron.
- The spin quantum number can have two possible values:  $+\frac{1}{2}$  (clockwise spin) or  $-\frac{1}{2}$  (counterclockwise spin).

## 6(a) Comparison of Properties of Ionic and Covalent Compounds

Ionic Compounds	
Formed by the complete transfer of electrons from one atom to another.	Formed by the sharing of electrons between atoms.
Generally hard and brittle.	Generally soft and malleable.
High melting and boiling points.	Low melting and boiling points.
Conduct electricity in molten state or aqueous solution.	Generally do not conduct electricity.
Usually soluble in water but insoluble in organic solvents.	Usually soluble in organic solvents but insoluble in water.

### Examples

- **Ionic compounds:** Sodium chloride (NaCl), Magnesium oxide (MgO)
- **Covalent compounds:** Methane (CH<sub>4</sub>), Carbon dioxide (CO<sub>2</sub>)

## 6(b) Co-ordinate Covalent Bond

### Definition

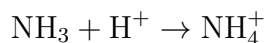
A **co-ordinate covalent bond** (also called a dative bond) is a type of covalent bond in which **both electrons** in the shared pair come from the **same atom**.

### Difference from Normal Covalent Bond

- In a normal covalent bond, each atom contributes **one electron** to the shared pair.
- In a co-ordinate covalent bond, **both electrons** are donated by the same atom.

### Example

Formation of ammonium ion ( $\text{NH}_4^+$ ):



Here, nitrogen donates a lone pair of electrons to a proton ( $\text{H}^+$ ) to form a co-ordinate bond.

## 7(a) Hydrogen Bonds

### Definition

A **hydrogen bond** is a special type of dipole-dipole interaction that occurs when a hydrogen atom covalently bonded to a highly electronegative atom (such as F, O, or N) is attracted to another electronegative atom.

### Types of Hydrogen Bonding

- **Intermolecular Hydrogen Bonding:** Hydrogen bond formed between two different molecules.  
*Example:* Hydrogen bonding in water ( $\text{H}_2\text{O}$ ), ammonia ( $\text{NH}_3$ ), and hydrogen fluoride ( $\text{HF}$ ).

- **Intramolecular Hydrogen Bonding:** Hydrogen bond formed within the same molecule.

*Example:* Ortho-nitrophenol (in organic compounds).

## Why Water has Abnormally High Boiling Point

Water ( $\text{H}_2\text{O}$ ) forms extensive **intermolecular hydrogen bonds**. Each water molecule can form up to four hydrogen bonds (two through its lone pairs and two through its hydrogen atoms). These strong hydrogen bonds require a large amount of energy to break, resulting in an abnormally high boiling point compared to other group 16 hydrides like  $\text{H}_2\text{S}$ ,  $\text{H}_2\text{Se}$ , etc.

## 7(b) Bond Angles of $\text{H}_2\text{O}$ and $\text{NH}_3$

### Explanation

Although the central atoms in both  $\text{H}_2\text{O}$  and  $\text{NH}_3$  are  **$\text{sp}^3$  hybridized**, their bond angles are not the ideal tetrahedral angle ( $109.5^\circ$ ) due to the presence of lone pairs.

- In  $\text{NH}_3$ , there are three bond pairs and one lone pair on nitrogen.
- In  $\text{H}_2\text{O}$ , there are two bond pairs and two lone pairs on oxygen.

### Reason for Deviation

- Lone pairs occupy more space than bond pairs because lone pairs are localized closer to the nucleus, causing greater repulsion.
- In  $\text{NH}_3$ , the repulsion between the one lone pair and bond pairs slightly reduces the bond angle to  $107^\circ$ .
- In  $\text{H}_2\text{O}$ , the presence of two lone pairs causes even greater repulsion, further reducing the bond angle to  $104.5^\circ$ .

### Summary

Bond Angle in  $\text{NH}_3 = 107^\circ$

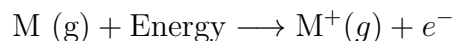
Bond Angle in  $\text{H}_2\text{O} = 104.5^\circ$



## 8(a) Ionization Potential

### Definition

The **ionization potential** (or ionization energy) of an element is the amount of energy required to remove the most loosely bound electron from an isolated gaseous atom to form a cation.



### Why the First Ionization Potential is Less than the Second

- The first ionization potential refers to the energy required to remove the first electron.
- After the removal of one electron, the atom becomes a positively charged ion.
- Due to the increased effective nuclear charge, it becomes more difficult to remove the second electron.
- Hence, the **second ionization potential** is always **higher** than the first.

### Variation of Ionization Potential with Atomic Volume

- Ionization potential **decreases** as the atomic volume **increases**.
- Larger atomic size means the outermost electron is farther from the nucleus and less tightly held.
- Thus, less energy is required to remove it.
- Across a period (left to right), atomic volume decreases, so ionization potential increases.
- Down a group, atomic volume increases, so ionization potential decreases.

## 8(b) f-block Elements

### Definition

The **f-block elements** are those elements in which the last electron enters the **(n-2)f** orbital. These elements are also called **inner transition elements**.

### Why Called Inner Transition Elements

- The f-block elements include the **lanthanides** (elements from atomic number 58 to 71) and **actinides** (elements from atomic number 90 to 103).
- They are called **inner transition elements** because they involve the filling of inner f-orbitals while the outer orbitals (such as 5d or 6d) remain incomplete or start filling afterward.
- Unlike d-block (transition) elements where d-orbitals are involved in bonding, in f-block elements, the f-orbitals are buried inside the atom, and hence their transition is termed "inner."