

3.3 ELECTRONIC THEORY OF VALENCY

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Syllabus [4 Hrs.]

Introduction

- Valence electrons and valence shell, core electrons, inert gas
- Concept of Lewis dot symbol
- Octet rule
- Basic assumptions of electronic theory of valency
- Chemical bond
- Types of chemical bond
 - Definition of electrovalent bond (ionic bond), electrovalency, and electrovalent compounds (ionic compounds) and electrovalent compounds like NaCl, MgO, CaS, MgCl₂, etc., with electron dot structure showing the formation of electrovalent compounds
 - General properties of ionic compounds
 - Definition of covalent bond, covalency and covalent compounds and covalent compounds H₂, Cl₂, O₂, N₂, CH₄, H₂O, NH₃, CO₂, CH₄, C₂H₂ etc. with electron dot structure showing the formation of covalent compounds
 - General properties of covalent compounds
 - Definition of coordinate covalent bond (dative bond), coordinate covalency and coordinate covalent compounds and coordinate covalent compounds like SO₂, SO₃, NH₄⁺, H₂SO₄, NaNO₃, CaCO₃, Na₂CO₃, Na₂SO₄ etc. with electron dot structure to represent the formation of coordinate covalent compounds
 - General properties of coordinate covalent compounds

Introduction

Atoms combine to form molecules and compounds. The main reason for this combination is the **tendency of atoms to attain a stable electronic configuration**.

The electrons present in the outermost shell play the most important role in chemical combination. These electrons are called **valence electrons**.

Atoms may become stable by:

- losing electrons, gaining electrons, or sharing electrons.

The force that holds atoms or ions together in a compound is called a **chemical bond**.

Valence shell: The **outermost shell** of an atom is called its **valence shell**.

Valence electrons: The electrons present in the valence shell are called **valence electrons**.

For example:

- Na (2, 8, 1) → 1 valence electron
- Mg (2, 8, 2) → 2 valence electrons
- Cl (2, 8, 7) → 7 valence electrons
- Ne (2, 8) → 8 valence electrons

Valence electrons are mainly responsible for the **chemical properties and bonding behaviour** of an element.

Core electrons

Electrons in shells other than the valence shell are called **core electrons**.

For example, sodium has the electronic configuration:

Na = 2, 8, 1

Here, 1 is the valence electron, and the remaining 10 electrons are core electrons.

Inert Gases and Stability

Noble or inert gases such as **He, Ne and Ar** are chemically less reactive because their outermost shells are filled.

- He has **2 electrons** in its only shell.
- Ne has **8 electrons** in its outermost shell.
- Ar has **8 electrons** in its outermost shell.

Other atoms tend to achieve a stable outer-shell configuration similar to a noble gas by **losing, gaining or sharing electrons**.

Octet Rule

The **octet rule** states that atoms tend to gain, lose or share electrons so that they have **eight electrons in their valence shell**, like a stable noble gas.

For example:

- Na loses one electron to form Na^+ .
- Cl gains one electron to form Cl^- .

Thus, both attain a stable outer shell.

Important exception

Hydrogen becomes stable with **2 electrons**, not 8. This is called the **duplet rule**.

Basic Assumptions of Electronic Theory of Valency

The important assumptions are:

1. Atoms combine to attain a **stable electronic configuration**.
2. The valence electrons are mainly responsible for the formation of chemical bonds.
3. Atoms may achieve stability by **losing, gaining or sharing electrons**.
4. The noble-gas configuration, generally an **octet**, is stable.

5. Chemical bonds are formed due to the interaction of the outermost electrons of atoms.
6. Depending on how electrons are involved, bonds may be **ionic, covalent or coordinate covalent**.

1. **What are the postulates of the electronic theory of valency?** [4]
 What are the basic assumptions of the electronic theory of valency?
 What are the assumptions of the electronic theory of valency and bonding? [2]
 Write down the assumptions of the electronic theory of valency. [3]
 What are the basic assumptions of the electronic theory of valency?
 Write a short note on: Assumptions of the electronic theory of valency 3
 Write a short note on the assumptions of the electronic theory of valency [2]

Chemical Bond

The **force of attraction that holds atoms or ions together in a molecule or compound is called a chemical bond**.

Types of chemical bonds

The main types discussed in this chapter are:

1. **Electrovalent (ionic) bond**
2. **Covalent bond**
3. **Coordinate covalent (dative) bond**

Electrovalent bond

A chemical bond formed by the **complete transfer of one or more electrons** from one atom to another is called an **electrovalent or ionic bond**.

It is usually formed between a **metal and a non-metal**.

Example: Formation of NaCl

Sodium:

Na = 2, 8, 1

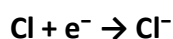
Sodium loses one electron:



Chlorine:

Cl = 2, 8, 7

Chlorine gains one electron:



The oppositely charged ions attract each other:



Thus, NaCl is an ionic compound.

Lewis representation



The chlorine ion has a complete octet.

Examples of Ionic Compounds

- NaCl MgO CaS MgCl₂

Electrovalency

The **number of electrons lost or gained by an atom during the formation of an ionic bond is called its electrovalency.**

Examples:

- $\text{Na} \rightarrow \text{Na}^+ \rightarrow \text{electrovalency} = 1$
- $\text{Mg} \rightarrow \text{Mg}^{2+} \rightarrow \text{electrovalency} = 2$
- $\text{Cl} \rightarrow \text{Cl}^- \rightarrow \text{electrovalency} = 1$
- $\text{O} \rightarrow \text{O}^{2-} \rightarrow \text{electrovalency} = 2$

General Properties of Ionic Compounds

Ionic compounds generally:

1. are **hard and crystalline solids**.
2. have **high melting and boiling points**.
3. are generally soluble in **water** and other polar solvents.
4. are generally insoluble in organic solvents.
5. conduct electricity in the **molten state or aqueous solution**.
6. do not conduct electricity in the **solid state** because their ions cannot move freely.

Remember

Solid ionic compound $\rightarrow$ ions fixed $\rightarrow$ does not conduct

Molten/aqueous ionic compound $\rightarrow$ ions free to move $\rightarrow$ conducts

- | | |
|---|-----|
| 2. What do you mean by an electrovalent bond? | |
| 3. Define the term electrovalency. | 2 |
| 4. Give the Lewis dot formula of NaCl. | 1 |
| 5. Write the general properties of ionic compounds. | [3] |

Covalent bond

A chemical bond formed by the **mutual sharing of one or more pairs of electrons** between atoms is called a **covalent bond**.

It is usually formed between **non-metal atoms**.

The shared electrons help the atoms achieve a stable electronic configuration.

Types of Covalent Bonds

According to the number of electron pairs shared:

Single covalent bond

One pair of electrons is shared.

Example:



Double covalent bond

Two pairs of electrons are shared.

Example:



Triple covalent bond

Three pairs of electrons are shared.

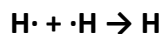
Example:



3.4.12 Formation of H_2

Each hydrogen atom has one electron and needs one more electron to achieve a duplet.

Therefore, two hydrogen atoms share one pair of electrons.



or



Thus, a single covalent bond is formed.

3.4.13 Formation of Cl_2

Each chlorine atom has seven valence electrons. Each needs one more electron to complete its octet.

Two chlorine atoms share one pair of electrons:



Thus, a single covalent bond is formed.

3.4.14 Formation of O_2

Each oxygen atom has six valence electrons and needs two more electrons to complete its octet.

Therefore, two pairs of electrons are shared.



Thus, oxygen contains a **double covalent bond**.

3.4.15 Formation of N_2

Each nitrogen atom has five valence electrons and needs three more electrons to complete its octet.

Therefore, three pairs of electrons are shared.



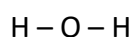
Thus, nitrogen contains a **triple covalent bond**.

3.4.18 Formation of H_2O

Oxygen has six valence electrons. It shares one electron with each of two hydrogen atoms.

Thus, two O–H covalent bonds are formed.

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Oxygen has two lone pairs.

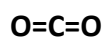
3.4.19 Formation of CO₂

Carbon has four valence electrons and needs four more electrons.

Each oxygen atom needs two electrons.

Therefore, carbon shares two pairs of electrons with each oxygen atom.

The structure is:



Thus, CO₂ contains **two double covalent bonds**.

3.4.20 Formation of C₂H₂

In acetylene (ethyne), each carbon atom forms:

- one bond with hydrogen, and
- three shared pairs with the other carbon atom.

The structure is:



Thus, C₂H₂ contains a **triple covalent bond** between the two carbon atoms.

3.4.21 Covalency

The **number of electron pairs shared by an atom during covalent bond formation is called its covalency**.

Examples:

- H₂ → covalency of H = 1
 - O₂ → covalency of O = 2
 - N₂ → covalency of N = 3
 - CH₄ → covalency of C = 4
-

3.4.22 General Properties of Covalent Compounds

Covalent compounds generally:

1. have **low melting and boiling points**.
2. are generally **poor conductors of electricity**.

3. are generally insoluble or less soluble in water.
4. are generally soluble in organic solvents.
5. may exist as gases, liquids or soft solids.

Note: These are general properties. There are important exceptions, such as giant covalent substances.

- | | |
|---|---------------------------------------|
| <p>6. What do you mean by a covalent bond? Explain with examples.</p> <p>Define a covalent bond.</p> <p>Explain a covalent bond with an example.</p> <p>Write a short note on a covalent bond.</p> | <p>2.5</p> <p>1</p> <p>2</p> |
| <p>7. What do you mean by electrovalent and covalent bonds?</p> | |
| <p>8. Show the difference between electrovalent and covalent compounds with examples.</p> <p>What are the differences between electrovalent and covalent compounds?</p> | <p>[3]</p> <p>[2+2]</p> |
| <p>9. Draw the Lewis structure of H₂SO₄.</p> | <p>[1]</p> |
| <p>10. Write down the electron dot structure of: a) H₂O b) NH₃ c) C₂H₂</p> | |

Coordinate covalent bond

A **coordinate covalent bond** is a covalent bond in which the **shared pair of electrons is supplied by only one atom**.

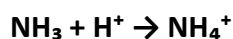
It is also called a **dative bond**.

Example: NH₄⁺

Ammonia (NH₃) contains a lone pair of electrons on nitrogen.

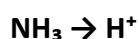
Hydrogen ion (H⁺) has no electrons.

Nitrogen donates its lone pair to H⁺:



The donated electron pair forms a coordinate covalent bond.

It may be represented as:



The arrow shows the direction in which the electron pair is donated.

3.4.24 Coordinate Covalency

The **number of coordinate covalent bonds formed by an atom is called its coordinate covalency**.

3.4.25 Coordinate Bond in Common Compounds

Coordinate bonding is used to represent the bonding in species such as:

- NH_4^+
- H_2SO_4
- SO_3
- HNO_3
- CO_3^{2-}
- SO_4^{2-}

For examination purposes, students should be able to **draw the required Lewis/electron-dot structures**.

11. Write down the electron-dot structure of: a) H_2SO_4 b) SO_3 c) CH_4 [3]
12. Write down the Lewis structure of H_2SO_4 and CaCO_3 . [2.5+2.5]
13. Define electrovalency. Draw the Lewis structure of H_2SO_4 . [1+2]
14. Write down the electron dot structure of H_2SO_4 , NH_3 and Cl_2 .
15. Draw Lewis dot formulas for the formation of the following compounds. (any THREE) a. SO_3 b. CO_2 c. HNO_3 d. CaCO_3 [3+1]
16. What are the differences between electrovalent and covalent compounds? [2+2]

3.4.4 Lewis Dot Symbols

A **Lewis dot symbol** represents the valence electrons of an atom by dots placed around its chemical symbol.

Examples:

Na• → sodium has 1 valence electron

Mg•• → magnesium has 2 valence electrons

Cl with seven dots → chlorine has 7 valence electrons

Lewis dot symbols are useful for showing how atoms form chemical bonds.

3.4.5 Ionic vs Covalent Compounds

Ionic compounds

Formed mainly by transfer of electrons

Usually formed between metal and non-metal

Consist of ions

Covalent compounds

Formed by sharing of electrons

Usually formed between non-metals

Usually consist of molecules

Generally have high melting and boiling points

Conduct electricity in molten or aqueous state

Generally soluble in water

Example: NaCl, MgO

Generally have low melting and boiling points

Generally do not conduct electricity

Generally less soluble in water

Example: H₂O, CO₂, CH₄

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Quick Revision

Remember these definitions

Valence electrons: Electrons present in the outermost shell of an atom.

Chemical bond: Force of attraction that holds atoms or ions together.

Ionic bond: Bond formed by complete transfer of electrons.

Electrovalency: Number of electrons lost or gained by an atom during ionic bond formation.

Covalent bond: Bond formed by mutual sharing of electron pairs.

Covalency: Number of electron pairs shared by an atom in covalent bonding.

Coordinate covalent bond: Covalent bond in which the shared electron pair is supplied by only one atom.

Octet rule: Atoms tend to achieve eight electrons in their valence shell to attain stability.

1.

Exam Focus: Questions from this chapter commonly ask you to **define a bond, state the assumptions of electronic theory, draw Lewis structures, and distinguish ionic and covalent compounds.**

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