ELEMENTRY IDEA OF BONDING

CONTENTS

INTRODUCTION

We know that different elements have different atomic numbers and electronic configurations. The properties of atoms depend upon their electronic configurations. Some atoms are more reactive than others. Noble gas (He, Ne, Ar, Kr, Xe and Rn) atoms are not reactive at all; they are inert and stable. Then the question arises why noble gases do not react to form compounds, while other elements do so? This can be answered by comparing the electronic configurations of noble gases with those of other elements. Also, it is important to understand how and why atoms react to form molecules and compounds. Atoms gain electrons in their outermost shells or lose them from their outermost shells, or share electrons with other atoms in such a way that their outermost shells become filled to capacity. They can do this by reacting with other atoms. As long as the outermost shell can accommodate more electrons, i.e., it is not full, an atom tends to combine with other atoms in order to fill its outermost shell. When the outermost shell is filled to capacity, the atom becomes stable.

The atoms of all other elements (elements other than the noble gases) have in their outermost shells less than 8 electrons, i.e., their outermost shells are not filled to capacity. Therefore, the atoms of these elements combine with other atoms to achieve stable configurations like those of the noble gases. It is the tendency on the part of an atom to achieve a stable configuration (like that of the noble gases) which is responsible for its chemical reactivity.

BONDS

We know that an atom tends to attain stability by acquiring the electronic configuration of its nearest noble gas. This can be achieved in anyone of the following manners during chemical combination:

1. By the transfer of electron(s) from one atom to another
2. By the sharing of valence electrons between the two combining atoms

There must be some kind of force which binds the atoms together in a molecule. The attractive force which holds together two atoms, two molecules, two ions or a combination of these is known as a chemical bond.

The two modes of attaining the electronic configuration of the nearest noble gas give rise to two types of bonds-the electrovalent bond and the covalent bond.

◈ The Electrovalent Bond :

In this type of bond, valence electrons are transferred from one atom to another. One atom donates its excess electrons to another atom so that both the atoms may acquire a stable noble gas configuration. The atom which loses electron becomes positively charged and is called the cation. The atom which takes up the electron lost by the first atom becomes negatively charged and is called the anion. These two oppositely charged ions are now held together by an electrostatic force of attraction. This force of attraction binding the two atoms together is known as an electrovalent or ionic bond.

Thus, the chemical bond formed between two atoms by the transfer of one or more valence electrons from one atom to the other is known as an electrovalent or ionic bond. It is also called a polar bond.

EXAMPLES- : Combination of sodium (Na) and chlorine (Cl) atoms to form sodium chloride (NaCl)

The atomic number of sodium is 11. So its electronic configuration is 2, 8, 1. It has only one electron in its outermost shell. The Na atom transfers this electron and becomes positively charged sodium ion (Na^+).

$$\underset{2,8,1}{Na} \xrightarrow{-1e} \underset{2,8}{[Na]^+}$$

Thus, the electronic configuration of the Na^+ ion is the same as that of neon which is the noble gas nearest to sodium in the periodic table.

Let us consider the chlorine atom (Cl). The atomic number of chlorine is 17. So its electronic configuration is 2, 8, 7. It has 7 electrons in its outermost shell. It, thus, lacks 1 electron to acquire a stable noble gas configuration. So a chlorine atom takes 1 electron transferred by the sodium atom and becomes negatively charged chloride ion (Cl^-).

$$\underset{(2,8,7)}{:\ddot{Cl}\cdot} + \text{ le} \longrightarrow \underset{(2,8,8)}{[:\ddot{Cl}:]^-}$$

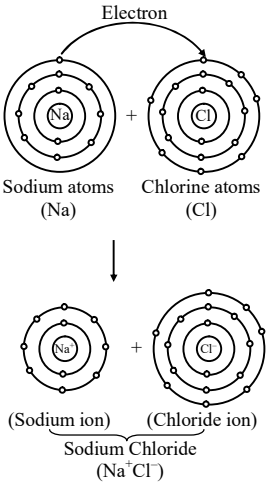
Thus, the chloride ion (Cl^-) attains the configuration of the nearest noble gas, argon. [Valence electrons are shown by dots around the symbol.]

The two ions (Na^+ and Cl^-) being oppositely charged, are now held together by electrostatic force of attraction as Na^+Cl^-.

$$\underset{(2,8,1)}{Na} + \underset{(2,8,7)}{Cl} \longrightarrow \underset{(2,8)}{Na^+} \quad \underset{(2,8,8)}{Cl^-}$$

$$\dot{Na} + :\ddot{Cl}\cdot \longrightarrow Na^+\underset{(2,8,8)}{[:\ddot{Cl}:]^-} \quad \text{or} \quad Na^+Cl^-$$

The formation of sodium chloride can be shown diagrammatically as in figure.



The force that holds Na^+ and Cl^- ions together is called an electrovalent bond. As this bond exists between ions, it is also called an ionic bond. An electrovalent bond is polar, i.e., the positive and negative charges are separated. Compounds containing such bonds are called' electrovalent, or ionic, or polar compounds.

Note-

(a) In the formula of an ionic compound, the positive ion is written first,

(b) Charges on the ions of an ionic compound are usually not shown with the formula. So, sodium chloride is usually expressed as NaCl, not as Na^+Cl^-.

Compound	Formula	Ions involved
Sodium chloride	NaCl	Na^+ and Cl^-
Magnesium chloride	$MgCl_2$	Mg^{2+} and Cl^-
Magnesium oxide	MgO	Mg^{2+} and O^{2-}
Calcium chloride	$CaCl_2$	Ca^{2+} and Cl^-
Calcium oxide	CaO	Ca^{2+} and O^{2-}
Ammonium chloride	NH_4Cl	NH_4^+ and Cl^-
Barium chloride	$BaCl_2$	Ba^{2+} and Cr
Potassium nitrate	KNO_3	K^+ and NO_3^-
Ammonium sulphate	$(NH_4)_2SO_4$	NH_4^+ and SO_4^{2-}
Cupric sulphate	$CuSO_4$	Cu^{2+} and SO_4^{2+}
Cupric chloride	$CuCl_2$	Cu^{2+} and Cl^-

◈ **Electrovalency :**

When an element forms electrovalent bond, its valency is known as electrovalency.

The number of electrovalent or ionic bonds an atom can form is called its electrovalency. The electrovalency of an element is, therefore, equal to the number of electrons lost or gained by the atom to form an ion.

Elements which lose electrons show positive electrovalency and those which gain electrons show negative electrovalency. For example, in the formation of sodium chloride (Na^+Cl^-), the electrovalency of sodium (Na) is +1, while that of chlorine (Cl) is – l.

Elements which lose or gain one, two, three, ... , etc., electrons are said to be monovalent (or

univalent), divalent (or bivalent), trivalent, ... , etc., respectively.

Monovalent elements : Na, CI, F

Divalent elements : Mg, Ca, Ba, O

Trivalent elements : Al, B

◈ **Characteristics of electrovalent or ionic compounds :**

1. **Electrovalent compounds are made up of positively and negatively charged** ions. For example, sodium chloride (NaCl) is made up of Na^+ and Cl^- ions arranged in a definite order in three dimensions to form crystals.
2. **Electrovalent compounds have high melting and boiling points**. This is due to the presence of strong electrostatic forces of attraction between the positive and negative ions. A large amount of heat energy is required to break this force of attraction. Hence, the melting and boiling points of electrovalent compounds are high.
3. **Electrovalent compounds are usually soluble in water but insoluble in organic solvents such as benzene, acetone, carbon disulphide and carbon tetrachloride.**
4. **Electrovalent compounds conduct electricity in molten state and in their aqueous solutions**.

In solid electrovalent compounds the ions are held together in fixed positions and cannot move. Hence, such compounds in the solid state do not conduct electricity.

When an electrovalent compound is dissolved in water or is melted, the crystal structure breaks down. The ions now become free to move and can, therefore, conduct electricity.

That the ionic compounds in molten state or in solution become conductors of electricity.

➢ THE COVALENT BOND

The chemical bond formed when two atoms share electrons between them is known as a covalent bond.

The sharing of electrons between the two atoms takes place in such a way that both the atoms acquire the stable electronic configurations of their nearest noble gases.

There are three types of covalent bonds :

1. Single covalent bond
2. Double covalent bond
3. Triple covalent bond

◈ **Single covalent bond :**

A single covalent bond is formed when one pair of electrons is shared between two atoms.

EXAMPLES :

1. Formation of a hydrogen molecule (H_2) :

A molecule of hydrogen consists of two hydrogen atoms. Each hydrogen atom has one electron. When two atoms of hydrogen combine, one electron of each takes part in sharing. Thus, two electrons (one pair of electrons) are shared between the two atoms.

$$H^{\bullet} + {}^{\bullet}H \rightarrow H : H$$

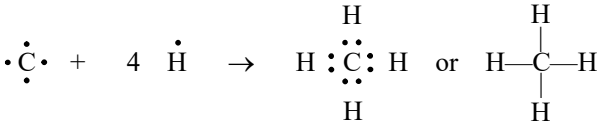
The shared electron pair always exists between the two atoms. The two dots between the two H atoms represent the pair of shared electrons. One pair of shared electrons gives a single bond. Such a bond is represented by a short line between the two atoms. Thus, a hydrogen molecule may be represented as in figure.

$$H : H \text{ or } H - H$$

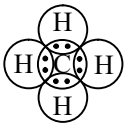
Once the bond is formed, the both atoms have a stable configuration of the noble gas helium.

2. Formation of a methane molecule (CH_4) :

A carbon atom has four electrons in its outermost shell (valence shell). It shares its valence electrons with those of four H atoms. Thus, an atom of carbon forms four single covalent bonds with four H atoms.



Pictorially, a methane molecule may be represented as in Figure.



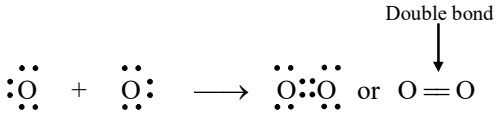
◈ Double covalent bond :

A double covalent bond is formed when two pairs of electrons are shared between the two combining atoms. A sharing of two pairs of electrons is shown by marking two short lines between the symbols of the two atoms.

EXAMPLES :

1. Formation of an oxygen molecule (O_2) :

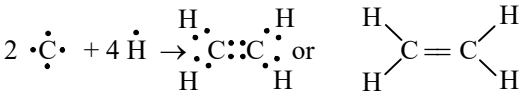
An atom of oxygen contains six electrons in its valence shell. It requires two more electrons to attain a stable eight-electron configuration (octet). This is achieved when each of the two oxygen atoms shares its two electrons with the other, resulting in the formation of a stable oxygen molecule.



Pictorially, the oxygen molecule may be represented as in figure.

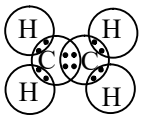
2. Formation of an ethylene molecule (C_2H_4) :

In the formation of an ethylene molecule (C_2H_4), each of the two C atoms combines with two H atoms to form two single covalent bonds. The remaining two electrons of each C atom form a double bond between the two C atoms.



(Ethylene molecule)

Pictorially, a molecule of ethylene (C_2H_4) may be represented a in figure.



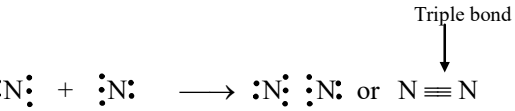
◈ Triple covalent bond :

A triple covalent bond is formed when three pairs of electrons (six electrons) are shared between the two combining atoms. A triple bond is shown by marking three short lines between the two symbols of the atoms.

EXAMPLES :

1. Formation of a nitrogen molecule (N_2) :

An atom of nitrogen has five electrons in its valence shell. It requires three more electrons to attain the stable octet. This is achieved when two nitrogen atoms combine together by sharing three electrons each to form a nitrogen molecule.

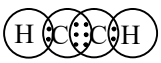


Pictorially, a nitrogen molecule can be represented as in figure.

2. Formation of an acetylene molecule (C_2H_2) :

In an acetylene molecule, two C atoms combine with two H atoms. Each C atom shares three of its valence electrons with the other C atom. One electron of each C atom is shared with one electron of a H atom.

Thus, in a molecule of acetylene, there is a triple covalent bond between the two C atoms and each C atom is joined to one H atom by a single covalent bond. Pictorially, a molecule of acetylene may be represented as in figure.



◈ Characteristics of covalent compounds :

1. Covalent compounds are made up of neutral molecules. Hence, the forces of attraction between the molecules are weaker than those found in ionic compounds. Therefore, covalent compounds are usually volatile liquids or gases.
2. **The melting and the boiling points of covalent compounds are generally low.** Since covalent compounds are made up of neutral molecules, the forces of attraction between the molecules are very weak. So, a comparatively small amount of heat energy is required to break these weak intermolecular forces of attraction. Hence, they have low melting and boiling points.
3. Covalent compounds are insoluble in water but soluble in organic solvents.

4. Covalent compounds do not conduct electricity. This is because they are made up of neutral molecules, not ions, and do not produce ions in the molten state or in aqueous solutions.

➢ BONDING IN METALS

As you know, metals are hard solids and they are made up of atoms. It has been established that the atoms in a metal are very closely packed together.

The force that holds the atoms closely together in a metal is known as the metallic bond.

Metal atoms lose one, two or three electrons to form positively charged ions, called cations.

The electrons thus lost move freely in the metal, i.e., these electrons become mobile, but the cations do not leave their positions. So in a metal lattice it is assumed that the metal ions are immersed in a sea of electrons. Due to the presence of mobile electrons, metals are good conductors of heat and electricity.

➢ POINT TO REMEMBER

- A chemical bond is the force of attraction which holds together the atoms in a molecule.
- An electrovalent bond is formed as a result of complete transfer of electron(s) from one atom to another.
- Atoms which can lose electrons and form positive ions are said to be electropositive.
- Atoms which can gain electrons and form negative ions are said to be electronegative.
- The total number of electrons lost or gained by an atom to attain the stable configuration of the nearest noble gas is known as the valency of the atom.
- The number of electrovalent bonds an atom can form is called its electrovalency.
- Covalent bonds are formed by the mutual sharing of electrons between the combining atoms.
- Compounds containing covalent bonds are called covalent compounds.
- The. total number of electrons shared by a given atom in the formation of covalent bonds to attain the stable configuration of its nearest noble gas is known as its covalency.
- The force that holds the atoms closely together in a metal is known as the metallic bond.