Chapter 2: Chemical Bonding

* Chemical Bond :-

⇒ **Definition**: A chemical bond is defined as a force of attraction which holds together the constituent atoms in a molecule.

⇒ The electrons present in the outermost orbit (valence shell) are called valence electrons.

Following points are useful in understanding the combination of atoms:

1. **Electronic structure**:

Except inert gas elements, the atoms of all other elements have less than eight electrons in their valency shell. The valence electrons of two or more combining atoms rearrange to form molecules.

2. **Net attractive forces between atoms**:

When two atoms approach close to each other, two types of interactions come into play,

(i) Attractive forces between the electrons of one atom and nucleus of the other.

(ii) Repulsive forces due to inter-electronic and inter-nuclear repulsive interactions.

These two types of interactions counteract eachother. If the results of these forces is attraction, the two atoms combine. If the net result is repulsion, atoms donot combine.

3. **Octet rule**:

Kossel and Lewis (1916) observed that atoms of ~~all~~ inert gases contained 8 electrons in the valence shell and they are chemically inert. Thus, atoms having less than 8 electrons are reactive and capable of chemical combination. The atoms of such elements mutually share or transfer one or more valence electrons so as to complete their octets.

Thus, each combining atom has a tendency to attain inert gas configuration so as to form a compound.

4. **Lowering of energy**:

Net attraction always results in the decrease in energy. Since net force of attraction is the criterion for the formation of compound, it is clear that atoms combine with the net decrease in energy.

* Types of Chemical Bonds :-

There are three main types of Chemical bonds. These are:
(i) Electrovalent bond or Ionic bond (ii) Covalent bond (iii) Co-ordinate bond.

⇒(I) Electrovalent or Ionic bond :-

Such compounds which are formed by the transference of one or more electrons from one atom to the other are called electrovalent or ionic compounds and the type of linkage is called electrovalent linkage or bond.

This type of linkage is shown by two dissimilar atoms which form ions by the loss or gain of electrons. Atoms such as Na, K, Mg etc. commonly lose valence electrons to form cations (Na^+, K^+, Mg^{2+}). Also atoms having valency shell containing six or seven electrons tend to take up electrons to complete their octet and form negative ions i.e., anions (e.g. $Cl^{\ominus}$, Br^-, O^{2-}).

Example: 1. Formation of Sodium Chloride (NaCl)

In Sodium chloride, we have

$_{11}Na$; e = 11 and p = 11. $_{17}Cl$; e = 17, p = 17

Electronic configuration of $_{11}Na$: $1s^2\,2s^2\,2p^6\,3s^1$
Electronic configuration of $_{17}Cl$: $1s^2\,2s^2\,2p^6\,3s^2\,3p^5$

There is only one electron in the valency shell of sodium atom and seven valence electrons in case of Chlorine atom.

Sodium transfers its valence electron to Chlorine atom. Thus, sodium gets a unit positive (Na^+) and chlorine gets a unit negative charge (Cl^-). It is explained by placing dots representing the valence electrons around the atoms [Lewis electron dot structures].

$Na^{\times}$ $\xrightarrow{\text{Transfers valency electron}}$ $:\ddot{Cl}:$

2,8,1 → $[Na]^+$ 2,8

2,8,7 → $[:\ddot{Cl}:]^{\ominus}$ 2,8,8

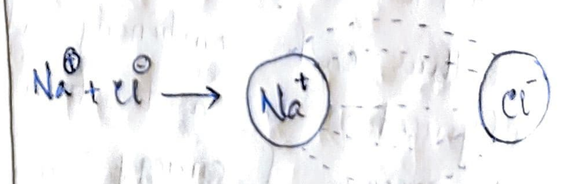


Fig: Formation of NaCl

Finally, the positive and the negatively charged ions get attracted by the electrostatic forces of attraction. $Na^{\oplus} + Cl^{\ominus} \longrightarrow NaCl$

Ionic bond is strong as it is formed by a large decrease in energy.

2. Formation of $MgCl_2$:

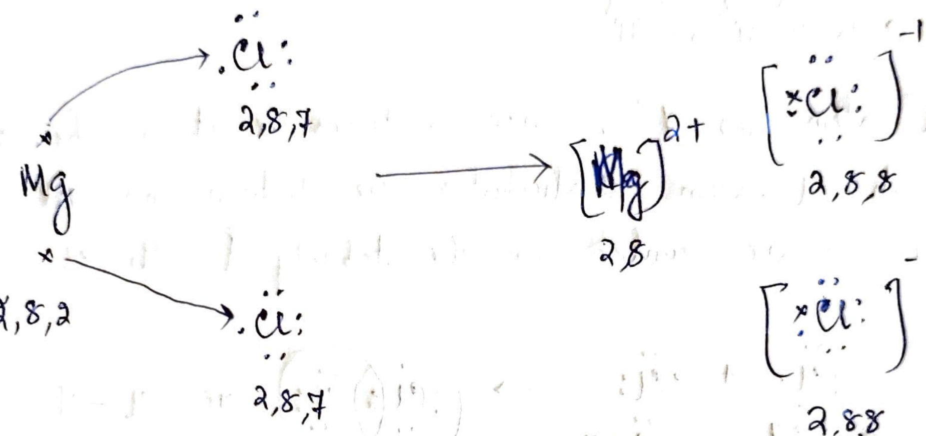
$_{12}Mg$; e = 12 and p = 12 $_{17}Cl$; e = 17, p = 17

Electronic configuration of $_{12}Mg$: $1s^2 2s^2 2p^6 3s^2$

Electronic configuration of $_{17}Cl$: $1s^2 2s^2 2p^6 3s^2 3p^5$

There are two valence electrons in case of Mg. It can attain inert gas configuration if it loses two electrons.

Also each chlorine atom has seven valence electrons. It attains inert gas configuration by gaining one electron. It can be explained as below :



Finally the oppositely charged ions get attracted by electrostatic forces of attraction.

$Mg^{2+} + 2Cl^{-} \longrightarrow MgCl_2$

The no. of electrons lost or gained by an atom during the formation of ionic bond, is called Electrovalency. Thus electrovalency of Na is 1 and that of Mg is 2.

(II) **Covalent bond** :-

Covalent bond is defined as the force of attraction which arises by the mutual sharing of electrons between the atoms. The compound so formed is called covalent compound.

This type of bond is formed between two atoms (similar or dissimilar) by the mutual sharing of electrons. The shared pairs of electrons are counted towards the stability of both the participating atoms. So covalent bond is directional in character.

When two atoms share a common pair of electrons between them, each of them attains the stable configuration of the nearest inert gas. In case of hydrogen atoms forming a covalent bond, a duplet ($2e^-$) is completed.

Example :- (1) Foremation of Hydrogen molecule (H_2) :-

Two atoms of hydrogen (H) Combine to forem H_2 molecule as follows :

$$_1H \rightarrow 1s^1$$

Electron Paire

$$\underset{1}{H} + \underset{1}{H} \longrightarrow \underset{2}{H} : \underset{2}{H} \quad \text{or} \quad H - H$$

Each hydrogen atom completes its duplet as Helium (He) and becomes stable.

(2) Foremation of Cl_2 molecule :-

Two atoms of Cl combine to forem Cl_2 molecule as follows :

$$_{17}Cl \rightarrow 1s^2\,2s^2\,2p^6\,3s^2\,3p^5$$

Each "Cl" atom has "7" valence electrons i.e. it is deficient of one electron. Each "Cl" atom contributes one electron and one electron paire so foremed are counted for the stability of both "Cl" atoms.

$$\underset{2,8,7}{:\ddot{Cl}\cdot} + \underset{2,8,7}{\times\ddot{Cl}\times} \longrightarrow \underset{2,8,8}{:\ddot{Cl}}\,\overset{\cdot}{\times}\,\underset{2,8,8}{\ddot{Cl}\times} \quad \text{or} \quad Cl - Cl$$

(3) Foremation of O_2 molecule :-

The electronic configuration of "O" is

$$_8O \rightarrow 1s^2\,2s^2\,2p^4$$

Each of "O" atom has "6" valence electrons. Thus it is deficient of 2 electrons, to become octet. Now, each oxygen atom shares "2" of its valence electrons with each other to forem a double covalent bond.

$$\underset{2,6}{:\dot{O}:} + \underset{2,6}{\times O \times} \longrightarrow \underset{2,8}{\dot{O}}\ \ \underset{2,8}{O} \quad \text{or} \quad :\ddot{O} = \ddot{O}\times$$

Double bond

(4) Foremation of N_2 molecule :-

The electronic configuration of "N" is ; $_7N \rightarrow 1s^2\,2s^2\,2p^3$

This indicates the presence of "5" valence electrons in "N" and it requires "3" more electrons to become octet. So, each Nitrogen atom shares "3" of its valence electrons with each other to forem a triple covalent bond.

$$\underset{2,5}{:\dot{N}:} + \underset{2,5}{\times N \times} \longrightarrow \underset{2,8}{:N}\ \vdots\ \underset{2,8}{N\times} \quad \text{or} \quad :N \equiv N\times$$

Triple bond

N_2 molecule

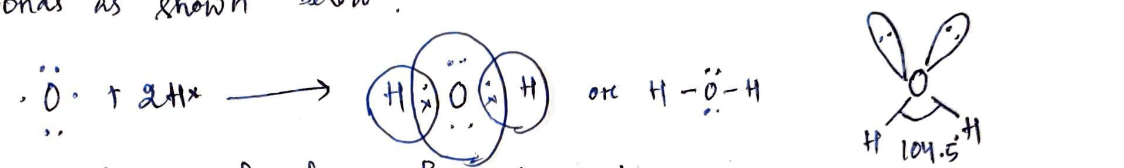
⑤ Formation of H_2O molecule :-

It is formed by the combination of one Oxygen atom and two hydrogen atoms. The electronic configuration of "O" and "H" are

$_8O \rightarrow 1s^2 2s^2 2p^4$ or 2, 6

$_1H \rightarrow 1s^1$ or 1

Thus the central "O" atom requires two more electrons to become octet while each "H" atom requires one electron to become duplet. So each hydrogen atom mutually shares its electron with an electron of Oxygen forming two covalent bonds as shown below :



It is found that the structure of water is angular with bond angle equal to 104.5°.

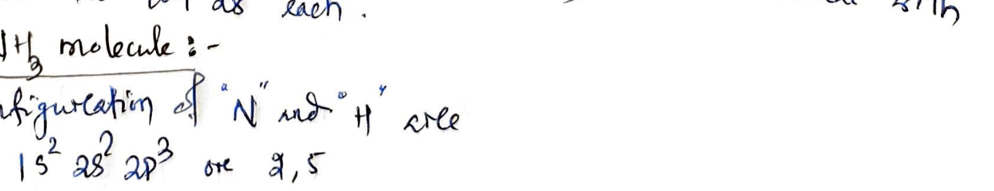
⑥ Formation of CH_4 molecule :-

$CH_4 \Rightarrow C + 4H$; The electronic configuration of "C" and "H" are :

$_6C \rightarrow 1s^2 2s^2 2p^2$ and $_1H \rightarrow 1s^1$

or 2, 4 or 1

Thus the central atom "C" requires four more electrons to become octet and "H" requires one more electron to become duplet. So each hydrogen shares its electron with one valence electron of Carbon to form four single bonds.



It is found that the structure of methane (CH_4) is tetrahedral with bond angles equal to 109° 28' each.

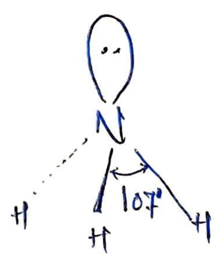
⑦ Formation of NH_3 molecule :-

The electronic configuration of "N" and "H" are

$_7N \rightarrow 1s^2 2s^2 2p^3$ or 2, 5

$_1H \rightarrow 1s^1$ or 1

Thus the central "N" atom needs three more electrons to become octet and each "H" atom requires "1" more e^- to become duplet. Each Hydrogen atom shares its



Pyramidal

valence electron of Nitrogen to form three single covalent bonds. The shape of NH_3 is Pyramidal with a bond angle of 107°.

(III) Co-ordinate Bond :-

The chemical bond formed by the partial donation and partial sharing of a lone pair of electrons between two atoms (or ions) is called a co-ordinate or dative bond.

A co-ordinate bond is formed when an atom with complete octet (after mutual sharing) donates its pair of electrons to the other atom. The donated pair is counted for the stability of both the atoms.

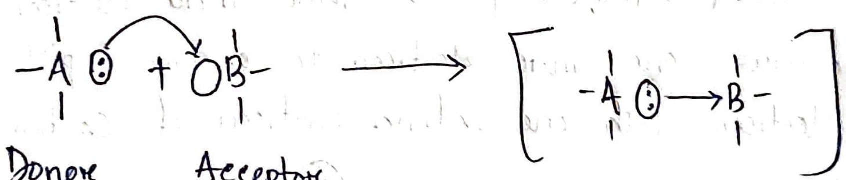
(i) This type of bond is formed between two dissimilar atoms A & B.

(ii) Atom A has one or more lone pairs of electrons. Atom B is short of a pair of electrons than the nearest inert gas configuration.

(iii) Atom A donates its lone pair of electrons to the atom B. As a result, both atoms get inert gas configuration. Atom A is called donor while atom B called acceptor atom. The bond formed is called co-ordinate or dative bond.

(iv) The dative bond is shown by ($\rightarrow$) sign. The head of the arrow is towards the acceptor atom while the tail is towards the donor atom, i.e. $A \rightarrow B$.

(v) The dative bond is a directional bond.



Donor Acceptor

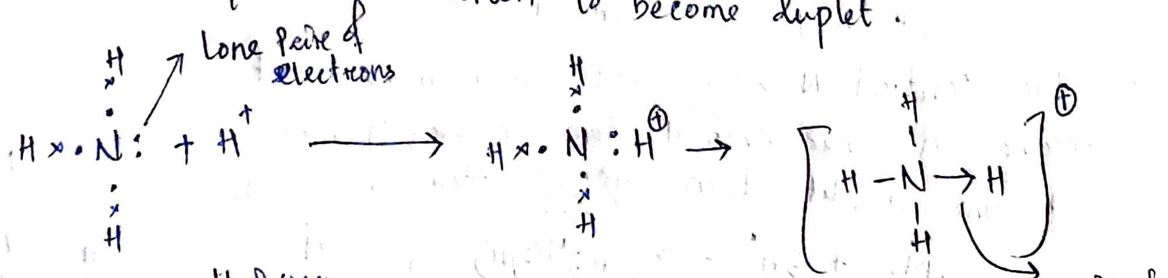
Since co-ordinate bond has some polar character, it is also known as dative or semi-polar bond or co-ionic bond.

Example :- (1) Formation of ammonium ion (NH_4^+) :-

Ammonium ion (NH_4^+) is formed by the combination of NH_3 and H^+ ion.

$$NH_3 + H^+ \longrightarrow NH_4^{\oplus}$$

Ammonia contains a lone pair of electrons over "N" while "H^+" ion contains no electron and requires two electron to become duplet.



Ammonia molecule Hydrogen ion Ammonium ion

Thus, the unshared pair of electrons over nitrogen in NH_3 is partially shared with H^+ ion and a co-ordinate bond is formed.

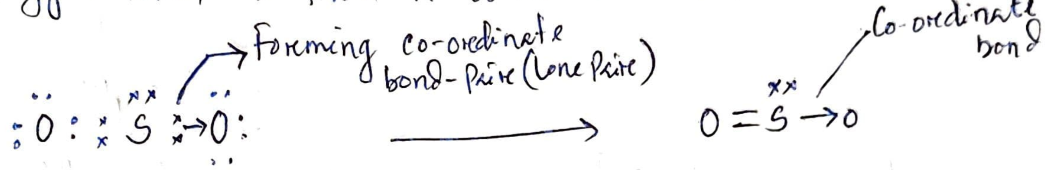
③ **Formation of Sulpher dioxide (SO_2) molecule :-**

The electronic configuration of "S" and "O" are

$_{16}S \rightarrow 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$ and $_8O \rightarrow 1s^2\ 2s^2\ 2p^4$

2, 8, 6   2, 6

The electronic configurations indicate ~~that~~ the presence of 6 valence ~~shell~~ electrons in each of "S" and "O". The central sulpher atom forms a double covalent bond by sharing two of its valence electrons with two valence electrons of one of the oxygen atoms. One of the lone pair of electrons of the central sulpher atom is partially shared with another oxygen atom to form a co-ordinate bond.



$\boxed{N:B}$: **Comparison of Ionic and Covalent Compounds :-**

Ionic Compounds	Covalent Compounds
1. These are formed by the transfer of one or more electrons from one atom to another.	These are formed by the sharing of one or more electrons between the bonded atoms.
2. These consist of ions.	These consist of individual atoms/molecules.
3. These are hard solids with high melting and boiling points.	These exist as gases, liquids or soft solids with low melting and boiling points.
4. These are soluble in water but insoluble in organic solvents.	These are insoluble in water but soluble in organic solvents.
5. These conduct electricity in fused as well as in aqueous solutions.	These donot conduct electricity.
6. These undergo ionic reactions which are very fast.	These undergo molecular reactions which are very slow.
7. These donot show isomerism.	These show isomerism.