CHEMICAL BONDING CLASS 8

INTRODUCTION

In previous classes we have studied that the atoms are the smallest particles of the elements but in most of the cases they do not exist as independent entities. For example, H atoms do not exist as such, but H_2 molecule has independent existence. This indicates that H_2 is more stable than H atoms. Similarly, chlorine, nitrogen and oxygen also exist in the form of diatomic molecules such as Cl_2, N_2, O_2 respectively. We also know that atoms of same elements combine to form molecules such as Cl_2, N_2, O_2 etc.. respectively. We also know that atoms of different elements combine to form molecules. For example, nitric acid molecule is made of one atom of H, one atom of nitrogen and three atoms of oxygen (HNO_3). In the formation of molecules, the atoms of different elements show different combining capabilities. For example, one atom of nitrogen can combine with three atoms of hydrogen to give ammonia (NH_3). whereas one oxygen atom combines with two hydrogen atoms to give water (H_2O) molecule. This binding force or connection is called chemical bond. Thus, **chemical bond may be defined as the force of attraction which holds various constituent entities (atoms or ions) together in different chemical substances.**

Valence Electrons

If bond formation between atoms is due to the electrons in them, the difference in the bonding properties of atoms must be related to the difference in their electronic distribution.

A chemical is formed bond between two atoms only if they come close to each other. When two atoms come close, each may affect the electronic arrangement in the other. The electrons in the inner shells (also called the kernel or core) are so tightly bound by the attractive force of the nucleus that they remain almost unaffected by the close approach of another atom. However, the electrons in the outermost shell of an atom, being relatively loosely bound, are available for bond formation. Since the tendency of an element to combine with another is defined as valency, the outermost shell of an atom is called the valence shell and the electrons in this shell are called the valence electrons.

The electronic theory of valency

The explanation of formation of a chemical bond in terms of valence electrons is known as electronic theory of valency.

Interestingly, we can understand the formation of a chemical bond by studying the electronic configuration of the noble gases, which normally do not form any chemical compounds. We know that all the noble-gas atoms, expect those of He, have eight electrons in their valence shell. G N Lewis put forth the idea that the existence of eight electrons in the valence shell makes the electronic arrangement especially stable, and that is why the noble gases are chemically inactive. As a corollary, we can infer that the other elements, which do not have eight electrons in their valence shell, try to achieve the stability of noble-gas configuration by forming chemical bonds. The group of eight electrons in the valence shell is called an octet. In general, the formation of bonds in governed by the octet rule:

Generally, **an atom tends to form bonds until it has eight electrons in its outermost shell.**

The formation of bonds in H and Li are exceptions to this rule. An H atom, which has only the K shell can achieve a maximum of two electrons – a duplet – as in He. When Li forms compounds, it too does so by achieving the electronic configuration of He. **So we can say that in general, in the formation of molecules every atom tends to achieve the electronic configuration of the nearest noble gas in the periodic table.**

In 1916, G N Lewis and Walter Kossel independently proposed the mechanisms by which atoms achieve the noble-gas configuration while combining. Their ideas led to the identification of two types of chemical bonds – the ionic bond (electrovalent bond) and the covalent bond. The two types of bonds arise due to the two different ways in which an atom can attain the stable configuration of a noble gas.

Types of Chemical Bonds

Chemical bonds are formed by the rearrangement of the electrons present in the outer shell of the atoms. The arrangement involve loss or gain of electrons by the atoms or mutual sharing of electrons by the atom in their attempt to attain the stable configuration of nearest noble gas. Depending upon the mode of rearrangement of electrons, the chemical bonds can be divided into three main categories.

1. Electrovalent bond or ionic bond (proposed by W.Kossel)

2. Covalent bond (proposed by G.N.Lewis)

3. Co-ordinate or dative bond.

Let us now discuss the details about the formation of these bonds.

Electrovalent Bond or Ionic Bond

Chemical bond formed by the transference of electrons from one atom to another is called electrovalent or ionic bond.

- In general, the metal atoms (having 1, 2 or 3 electrons in their outermost shell) lose their outermost electrons to acquire noble gas configuration and change into cations.
- The non-metal atoms (having 5, 6 or 7 electrons in their outer shell) gain electrons to acquire noble gas configuration and change into anions.
- Thus, when a metal and non-metal atom react, the metal atom loses electrons and forms a cation while a non-metal atom gains electrons and changes into anion.

- The oppositely charged ions so formed come close and are held together by the electrostatic force of attraction. This force of attraction is termed as electrovalent bond.
- The number of electrons lost by the metal atom or that gained by the non-metal atom while forming the electrovalent bond, is called the electrovalence of the atom.

Examples

1. Formation of Sodium Chloride (NaCl)

The atomic number of sodium is 11, so its electronic configuration is 2, 8, 1. Thus, sodium atom loses its outermost electron to attain the configuration of neon (2, 8) and becomes sodium ion (Na^+).

$$\dot{Na} \longrightarrow Na^+ + 1e^-$$

(2, 8, 1)	(2, 8)	Electron
Sodium atom	Sodium ion	

The atomic number of chlorine is 17, so its electronic configuration is 2, 8, 7. It gains the electron lost by sodium atom to acquire the configuration of noble gas argon (2, 8, 8) and changes into chloride ion (Cl^-)

$$:\ddot{\underset{\cdot\cdot}{Cl}}\cdot + 1e^- \longrightarrow [:\ddot{\underset{\cdot\cdot}{Cl}}:]^-$$

(2, 8, 7)		**(2, 8, 8)**
Chlorine atom	**Electron**	**Chloride ion**

The oppositely charged ions come close and are held together by the electrostatic force of attraction.

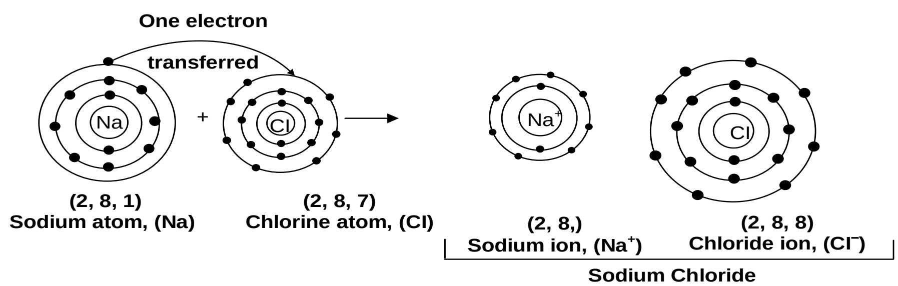
$$\overset{+}{Na} + [:\ddot{\underset{\cdot\cdot}{Cl}}:]^- \longrightarrow NaCl$$

The whole process of transference of electron from sodium to chlorine atom can be represented as

$$Na^{\cdot} + \cdot\ddot{\underset{\cdot\cdot}{Cl}}: \longrightarrow \overset{+}{Na} \quad [:\ddot{\underset{\cdot\cdot}{Cl}}:]^{-} \quad \text{Or} \quad NaCl$$

(2,8,1) Sodium atom	(2,8,7) Chlorine atom	(2,8) Sodium ion	(2, 8, 8) Chlorine ion	Sodium Chloride

It is now clear that in the formation of sodium chloride, sodium atom loses one electron, while chlorine atom gains one electron. Therefore, the electrovalency of sodium is + 1 and that of chlorine is –1. The formation of sodium chloride can be diagrammatically shown in figure



2. **Formation of Potassium Chloride (KCl)**

The formation of potassium chloride is similar to that of sodium chloride.

Potassium atom (at. No. = 19) has electronic configuration (2, 8, 8, 1)

Chlorine atom (at no. = 17) has electronic configuration (2, 8, 7)

Potassium atom transfers one electron from its outermost shell to chlorine atom and both of them acquire the configuration of nearest noble gas argon (2, 8, 8)

In this process potassium atom changes into potassium ion (K^+) and chlorine atom charges into chloride ion (Cl^-).

The oppositely charged ions are held together by electrostatic force of attraction

$$\dot{K} + \cdot\ddot{\underset{\cdot\cdot}{Cl}}: \xrightarrow{\text{Electron transfer}} \overset{+}{K} \quad [:\ddot{\underset{\cdot\cdot}{Cl}}:]^{-} \quad \text{or} \quad KCl$$

(2, 8, 8, 1) Potassium atom	(2, 8, 7) Chlorine atom	(2, 8, 8) Potassium ion	(2, 8, 8) Chloride ion	Potassium chloride

3. **Formation of Lithium Fluoride (LiF)**

Lithium atom (at. no. = 3) has electronic configuration (2, 1)

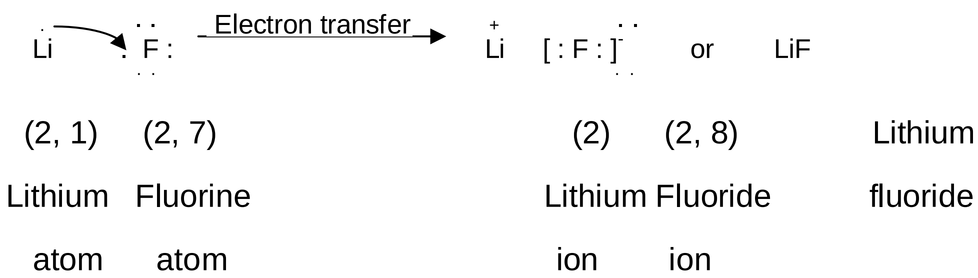
Fluorine atom (at. no. = 9) has electronic configuration (2, 7)

Lithium atom transfers its outermost electron to fluorine atom.

In this process lithium forms lithium ion (Li^+) and acquires configuration of helium

(2). On the other hand, fluorine changes into fluoride ion (F^-) and attains configuration of neon (2, 8).

The opposite charged lithium (Li^+) and fluoride (F^-) ions are held together by electrovalent bond.



4. Formation of Magnesium Chloride ($MgCl_2$)

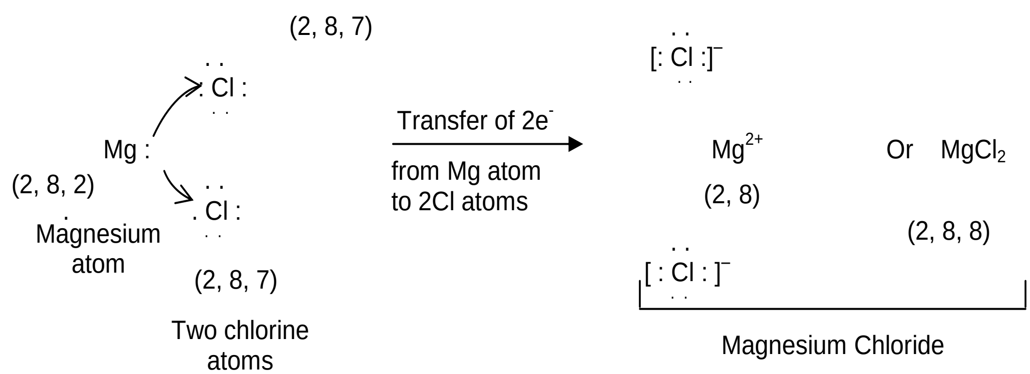
Magnesium atom (at. no. = 12) has electronic configuration (2, 8, 2).

In order to acquire stable configuration of neon (2, 8), It loses 2 electrons from the outermost shell and gets converted into magnesium ion (Mg^{2+}).

Chloride atom (at. no. 17) has electronic configuration (2, 8, 7). It can acquire the configuration of argon. (2, 8, 8) by accepting one electron and getting converted into chloride (Cl^-) ion.

In order to accommodate 2 electrons lost by magnesium atom, two chlorine atoms are used each of which accepts one electron to form chloride ion. Thus, each magnesium ion react with two chloride ions.

Mg^{2+} ions and Cl^- ions are held together by electrostatic force of attraction.



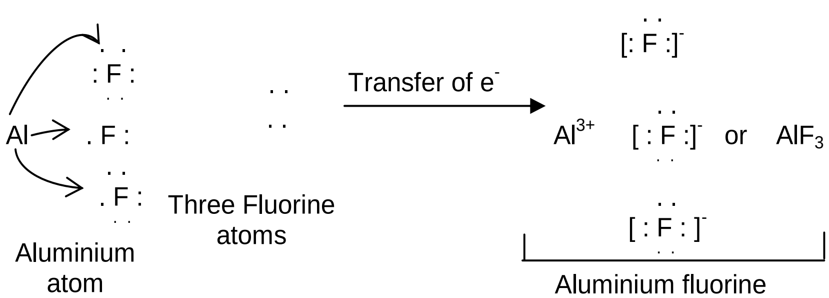
5. Formation of Aluminium Fluoride (AlF_3).

Aluminium atom (at no. = 13) has electronic configuration (2, 8, 3). It loses 3 electrons from the outermost shell to attain configuration of neon (2, 8) and in the process it changes into aluminium ion (Al^{3+}).

Fluorine atom (at. no. = 9) has electronic configuration (2, 7)

The three electrons lost by aluminium atom are taken up by three fluorine atoms (one each) to form three fluoride atoms, F^- (2, 8).

Al^{3+} and F^- ions are held up by electrostatic force of attraction.

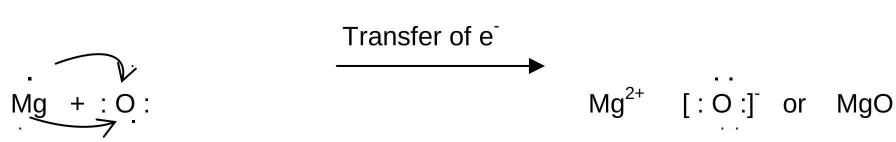


6. Formation of Magnesium Oxide (MgO).

Magnesium atom (at. no. = 12) has electronic configuration (2, 8, 2). It loses 2 electrons from the outermost shell to form Mg^{2+} ion and acquires the configuration of neon (2, 8).

Oxygen atom (at. no. = 8) has electronic configuration (2, 6). It gains 2 electrons lost by magnesium atom to form oxide (O^{2-}) ion and attains the configuration of neon (2, 8).

Thus 2 electrons are transferred from each magnesium atom to each oxygen atom.



(2, 8, 2) (2, 6) (2, 8) (2, 8) Magnesium

Magnesium oxygen Magnesium Oxide ion

atom atom

Electrovalent Compounds or Ionic Compounds

The chemical compounds in which the constituent units are held together by the electrovalent bond are called electrovalent compounds or ionic compounds.They are formed by the transference of electrons from one atom to the other.Electrovalent compounds are made up of oppositely charged ions, cations and anions.

These compounds are generally obtained by combination of metals and non–metallic elements. One of the important exceptions of ionic compound containing only non–metallic elements is NH_4Cl (ammonium chloride).

Some common ionic compounds are

1. Sodium fluoride(NaF)
2. Sodium sulphide(Na_2S)
3. Magnesium sulphide(MgS)
4. Barium Chloride($BaCl_2$)
5. Aluminium oxide(Al_2O_3)
6. Calcium fluoride(CaF_2)
7. Magnesium nitride Mg_3N_2
8. Potassium nitrate(KNO_3)
9. Calcium sulphide(CaS)
10. Sodium hydroxide(NaOH)

Properties of Electrovalent Compounds (or Ionic Compounds)

1. **Electrovalent or ionic compounds are made up of ions.** Electrovalent compounds consist of cations and anions. For example, sodium chloride is made up of sodium ion, Na^+ and chloride Cl^-. There is nothing like sodium chloride molecule.

2. **Electrovalent compounds are crystalline solids.** The ionic compounds have definite crystalline structures. It is due to the fact that the oppositely charged ions attract each other strongly and they pack up together to adopt a definite crystalline form.

3. **They are hard and brittle:** The crystalline lattice of an ionic solid is hard and not easily deformable because of the strong Coulombic forces of attraction between the oppositely charged ions. The lattice is, however, brittle. A large enough force applied on the lattice causes its layers to slide, which brings ions in one layer close to like ions in the adjacent layers.

4. **Electrovalent compounds have high melting and boiling points.** This is because in electrovalent compounds ions are held together by strong electrostatic force of attraction. Therefore, a lot of heat energy is required to overcome this force to melt or boil the compound. Hence electrovalent compounds have high melting and boiling points. For example, sodium chloride has melting point of 800^oC and boiling point of 1410^oC.

5. **Electrovalent compounds are soluble in water but insoluble in organic solvents.** Electrovalent compounds are soluble in water because high dielectric constant of water weakens the electrostatic force of attraction between ions. Electrovalent compounds are insoluble in organic solvents like alcohol, ether, chloroform, benzene acetone, etc., because they have low dielectric constants. For example, sodium chloride is soluble in water but insoluble in ether.

6. **Ionic compounds disassociate into ions when dissolved in water.** This is because high dielectric constant of water weakens the electrostatic attraction force due to which the electrovalent bonds break and ions get free. Therefore aqueous solutions of electrovalent compounds contain free ions. For example, aqueous solution of sodium chloride contains free sodium and chloride ions.

$$\underset{\text{solid}}{Nacl(s)} \xrightarrow{\text{water}} \underset{\text{Free ions}}{Na^{+}(aq) + Cl\ (aq)}$$

7. **Ionic compounds conduct electricity in molten state or when dissolved in water.** Ionic compounds do not conduct electricity in the solid state because in solid state the constituent ions have fixed positions and are not able to move. However, when these compounds are dissolved in water or melted, the crystal structure is broken down and ions become free to move which conduct electricity. In other words, aqueous solutions of ionic compounds are good conductors of electricity because they contain free ions.

8. **They undergo fast reactions in aqueous solutions.** Chemical reactions involve breaking and forming of bonds. The bond between a cation and an anion breaks as soon as the ionic compound dissolves in water. The ions being mobile in solution, they find their new partners in no time to form bonds with them.

Example: $Na^{+}\ Cl^{-}$ (aq.)+ $Ag^{+}\ NO_3^{-}$ ~~(aq.)~~ $\rightarrow$ AgCl (solid) + $NaNO_3$ (aq.)

(the rate of reaction is very fast)

Covalent Bond:

Chemical bond formed by the mutual sharing of electrons between two atoms is called **Covalent bond.** The sharing of electrons takes place in such a way so that each atom attains a stable configuration of noble gas.

This type of bond is formed when the combining atoms require 1, 2, 3 or 4 electrons for attaining the noble gas configuration or in other words, they have 7, 6, 5 or 4 electrons in their outermost shell.Covalent bond is generally formed between the non-metal atoms. The atoms taking part in bonding may belong to same or different elements.

The reacting atoms contribute equal number of electrons from their outermost shell for mutual sharing. The shared electrons become the common property of both the atoms and constitute a covalent bond between them.

The pair of electrons being shared by the two atoms is called a **bond pair.**

The covalent bond is represented by putting line (–) between the two atoms for each bond pair.The number of electrons which an atom contributes for sharing is called its **covalency.**

The covalent bonds are of **three types.**

Single covalent bond : When **one** electron pair is shared.

Double covalent bond: When **two** electron pairs are shared.

Triple covalent bond: When **three** electron pairs are shared.

Single Covalent Bond

A single covalent bond is formed between the two atoms when **one pair of electrons is** mutually shared by them.Both the atoms taking part in bonding contribute one electron each for sharing and the shared electrons become common property of both.A single bond between the two atoms is represented by putting one short line (–) between the two bonded atoms.

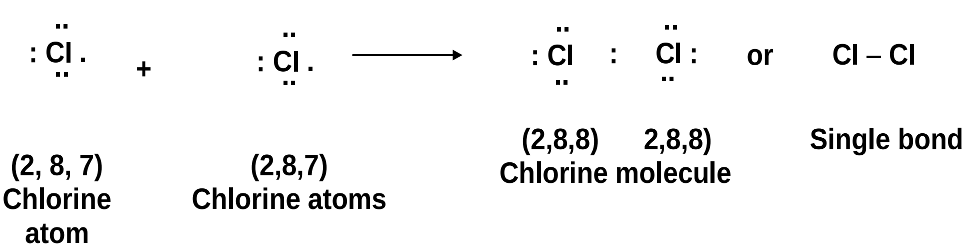
Examples

1, Formation of chlorine Molecule (Cl_2).

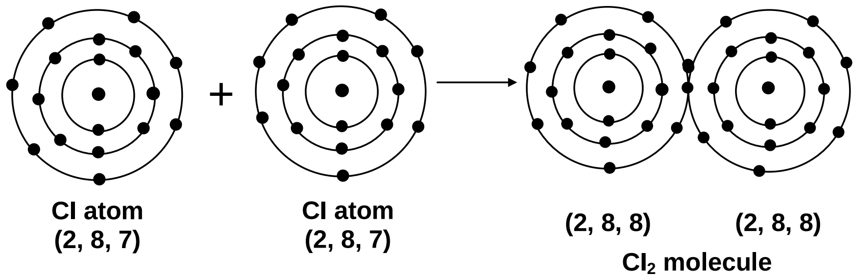
Atomic number of chlorine is 17 and its electronic arrangement is 2, 8, 7. This indicates that chlorine atom has 7 electrons in its outermost shell. In order to complete the octet and to acquire noble gas configuration it requires 1 electron.Now both the chlorine atoms contribute one electron for sharing and the shared electrons lie in between the two atoms.

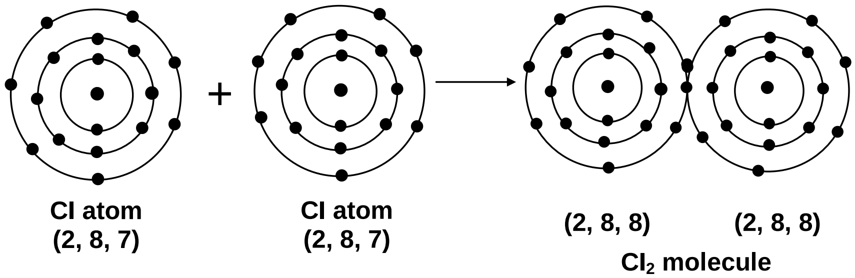
These shared electrons are responsible for the formation of bond between the because they hold both the chlorine atoms together.

The shared electrons are counted with both the chlorine atoms for the purpose of determining the inert gas configuration. In case of chlorine molecule when we count the shared electrons with both the chlorine atoms we find that each one of them attain the configuration of argon (2, 8, 8).



The formation of chlorine molecule can be diagrammatically represented as follows





2. Formation of Hydrogen Molecule (H_2).

The atomic number of hydrogen is 1 and it has 1 electron in K shell.

Both the H atoms which come close to form hydrogen molecule require one electron each to form duplet and to acquire the configuration of He.

Both the H atoms contribute one electron each and the two electrons are shared by them. This results in the formation of single covalent bond between the H atoms.

On counting shared electrons with both the H atoms we find that they require the configuration of nearest noble gas helium (2).

$$\dot{H} + \dot{H} \longrightarrow H:H \quad \text{or} \quad H-H$$

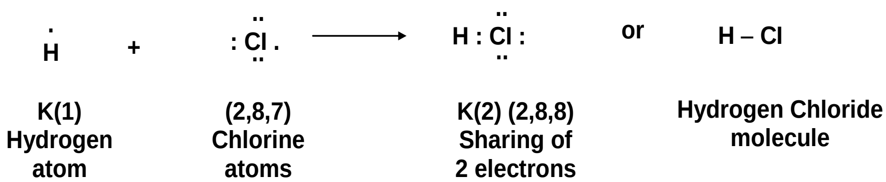
K(1) Hydrogen atom	K (1) Hydrogen atoms	K(2) K (2) Shared of two electrons	Hydrogen molecule

3. Formation of Hydrogen Chloride (HCl) Molecule.

H atom (at. no. = 1) has one electron in its K shell while Cl atom (Z = 17) has 7 electrons in its outermost shell because configuration of chlorine is (2, 8, 7).

Now H atom needs one electron to attain configuration of helium. Chlorine atom also needs 1 electron to attain the configuration of argon (2, 8, 8).

Both H atom and chlorine atom contribute one electron each for sharing and the shared electrons lie in between the two atoms forming a single covalent bond between them as shown below



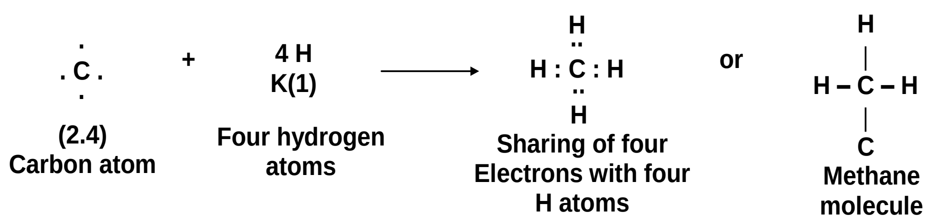
4. Formation of Methane (CH_4) Molecule.

Carbon atom (at. no. = 6) has electronic configuration (2, 4) indicating that it has four electrons in the outermost shell. H atom (at. no. = 1) has 1 electron in its K shell. Carbon atoms needs four electrons for completing its octet and to attain the configuration of nearest noble gas neon (2, 8).

Thus carbon atom contributes its four electrons for sharing with four H atoms separately. Each of four H atoms mutually shares 2 electrons with carbon atom.

On counting the electrons we find that carbon atom completes its octet and each of four H atoms completes its duplet.

Thus carbon atom forms four single bonds with four H atoms as shown below.

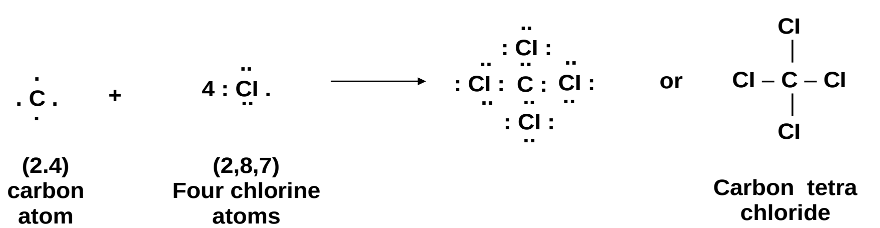


5. Formation of Carbon Tetrachloride (CCl_4) Molecule.

Carbon atom (2, 4) has 4 electrons in the outermost shell.

Chlorine atom (2, 8, 7) has 7 electrons in the outermost shell.

Thus, carbon atom shares its 4 electrons separately with four chlorine atoms, as shown below.



6. Formation of Water (H_2O) Molecule.

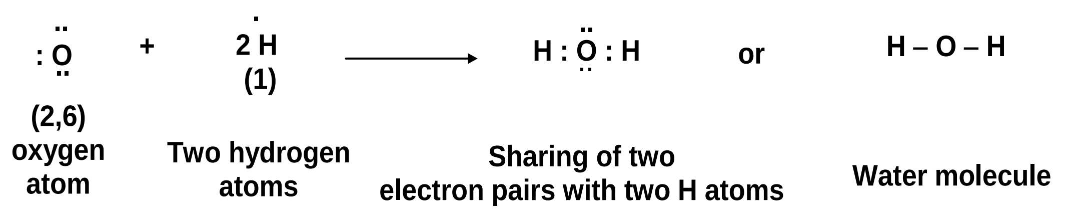
Hydrogen (at. no. = 1) has one electron in its K shell.

Oxygen (at. no. = 8) has electronic configuration (2, 6) which indicates that it has 6 electrons in the outermost shell.

Oxygen atom needs 2 electrons for attaining the configuration of nearest noble gas neon (2, 8).

Oxygen atom shares two of its electrons with two different H atoms. One electron with one H atom and 2nd electron with other H atom. In this way oxygen completes its octet and both the H atoms complete duplet.

Thus in water molecule, O atom forms two single bonds with two different H atoms as shown below.



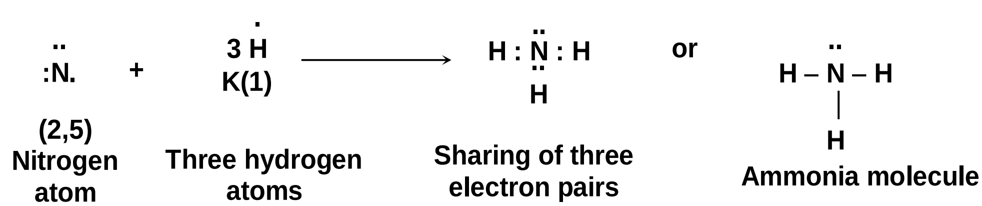
7. **Formation of Ammonia (NH_3) Molecule).**

Nitrogen atom (at. no. = 7) has configuration (2, 5), which indicates that it has 5 electrons in its outermost shell. It needs 3 more electrons for completing the octet.

Hydrogen atom has one electron in its K (shell).

Nitrogen atom completes its octet by sharing three of its electrons with three different H atoms. In other words

N atom shares three electron pairs with three H atoms forming three single covalent bond as shown below.

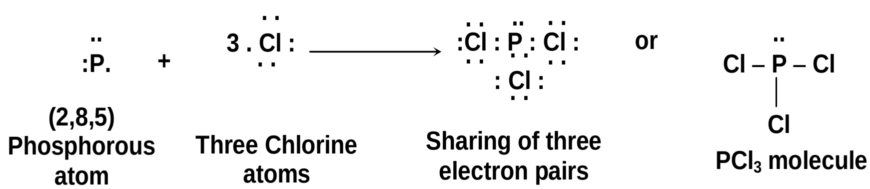


8. **Formation of PCl_3 molecule:**

Phosphorus atom (at.no.=15) has configuration (2, 8, 5), which indicates that it has 5 electrons in its outermost shell. It needs 3 more electrons for completing the octet.

Chlorine atom (atomic number = 17) has configuration (2, 8, 7), which indicates that it has 7 valence electrons. It needs 1 electron to complete the octet.

So, one phosphorous atom combines with 3 chlorine atoms by sharing 3 pairs of electrons and give PCl_3 molecule.



Double Covalent Bond:

A double covalent bond is formed between the two atoms when **two pairs of electrons** are mutually shared by them.

In this process both the atoms taking part in bonding contribute two electrons each for sharing. The shared pairs of electrons lie between the two atoms, and hold them together.

A double bond between the two atoms is represented by putting two short lines (=) between the two bonded atoms.

Examples:

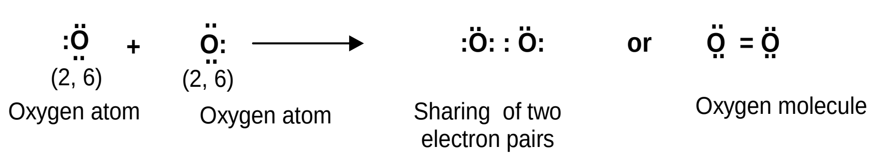
1. **Formation of Oxygen (O_2) Molecule.**

The atomic number of oxygen is 8 and its electronic configuration (2, 6) indicates the presence of six electrons in its outermost shell.

Each of the oxygen atom needs two electrons for completing its octet of electrons in the outer shell.

Both the O atoms contribute two electrons each for sharing and the four shared electrons lie in between them.

These shared electrons belong to both the atoms and hold them together to form a double covalent bond.



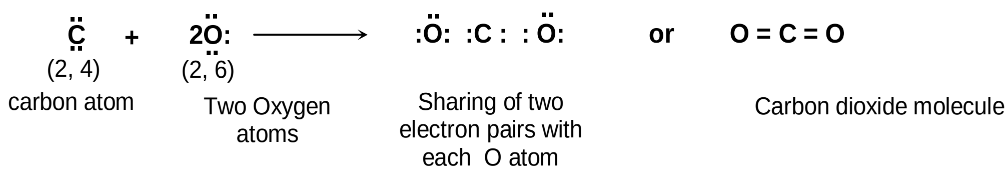
2. **Formation of Carbon Dioxide (CO_2) Molecule.**

The carbon atom [at. no. = 6 and electronic configuration (2, 4)] has four electrons in its outermost shell.

The oxygen atom [at. no. = 8 and electronic configuration (2, 6)] has six electrons in its outermost shell.

Each O atom needs 2 electrons whereas C atom requires 4 electrons for attaining stable configuration of 8 electrons in the outer shell.

The carbon atom shares two of its electrons with two electrons of one oxygen atom and the other two electrons with second oxygen atom. In other words, carbon atom shares two electron pairs with each of the two oxygen atoms forming two carbon to oxygen double bonds as shown below.



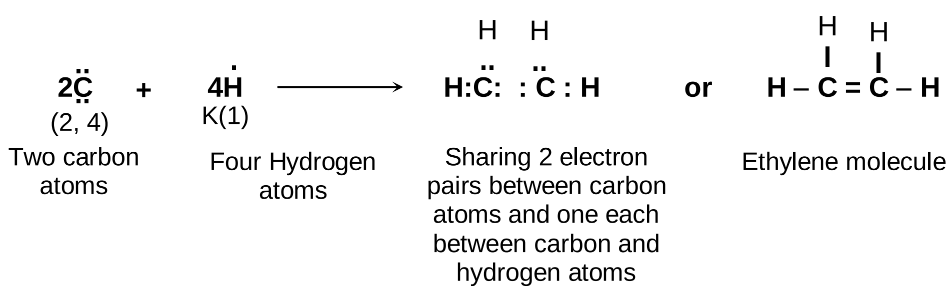
3. **Formation of Ethylene (C_2H_4) Molecule.**

In the formation of ethylene molecule two carbon atoms (2, 4) and four hydrogen atoms are involved.

Each carbon atom shares two of the four electrons with two electrons of the other carbon atom mutually to form carbon-carbon double bond.

The two remaining outer shell electrons are shared with two hydrogen atoms forming two single bonds.

Thus each of the carbon atom shares two electron pairs with carbon atom and one electron pair with each of the two H atoms as shown below:



Triple Covalent Bond:

A triple covalent bond is formed between the two atoms when **three electron pairs** are mutually shared by them.

In this process, each of the atom taking part in bonding contributes lie three electrons for sharing. The six shared electrons are three pairs of electrons which between the atoms and hold them together.

The triple bond is represented by putting three lines $(\equiv)$ between the two atoms.

Examples:

1. Formation of Nitrogen(N_2) Molecule.

Nitrogen (at.no. 7) atom has configuration (2, 5) indicating the presence of five electrons in the outermost shell. Each N atom needs three electrons for attaining stable noble gas configuration of eight electrons in the outer shell.

Both the nitrogen atoms contribute three electrons for sharing and the six electrons or three pairs of electrons are shared mutually by them.

These six electrons belong to both the nitrogen atoms and hold them together to form N_2 molecule. The two N atoms in N_2 molecule are held by triple covalent bond as shown

:N̈.	+	.N̈:	⟶	:N⋮ ⋮N:	or	N ≡ N
(2, 5)		(2, 5)		(2, 8) (2, 8)		
Nitrogen atom		Nitrogen atom		Sharing of three electron pairs		Nitrogen molecule

2. Formation of Acetylene (C_2H_2) Molecule.

Acetylene molecule contains two carbon atoms [configuration (2, 4)] and two hydrogen atoms K(1).Each carbon atom shares three of its four electrons with three electrons of the other carbon atom to form carbon-carbon triple bond.

The remaining one electron of each C atom is shared with one electron of hydrogen atom to form single bond.In short, each carbon atom shares three electron pairs with other carbon atom and one electron pair with hydrogen atom to form acetylene molecule.

2C̤̈	+	2Ḣ	⟶	H:C⋮ ⋮C:H	or	H – C ≡ C – H
(2, 4)		K(1)				
Two carbon atoms		Two Hydrogen atoms		Sharing 3 electron pairs between carbon atoms and one electron pair between carbon and hydrogen		Acetylene molecule

COVALENT COMPOUNDS

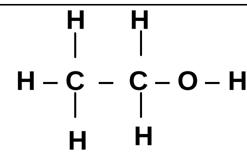
The chemical compounds in which the constituent atoms are held by covalent bonds are called **covalent compounds.**

They are formed by mutual sharing of electrons between the atoms forming the molecule.

In covalent compounds, the smallest independently existing units are molecules which are made up of atoms held together by covalent bonds. Hence the covalent compounds are also called **molecular compounds.**

Covalent compounds are generally made up of non-metal elements. Some common covalent compounds along with their formulae and bond structures are given in table.

Name of Compound	Formula	Bond Structure
Water	H_2O	H — Ö — H
Hydrogen Sulphide	H_2S	H — S̈ — H
Carbon dioxide	CO_2	**O = C = O**
Carbon disulphide	CS_2	**S = C = S**
Hydrogen chloride	HCl	**H – Cl**
Hydrogen Cyanide (Prussic acid)	HCN	**H – C ≡ N**
Ammonia	NH_3	**H – N – H** | **H**
Phosphine	PH_3	**H – P – H** | **H**
Methane	CH_4	**H** | **H – C – H** | **H**
Ethane	C_2H_6	H H | | H – C – C – H | | H H
Ethylene	C_2H_4	**H – C = C – H** | | **H H**

Acetylene	C_2H_2	**H – C ≡ C – H**
Ethyl alcohol	C_2H_5OH	
Hydrogen peroxide	H_2O_2	**H – O – O – H**

Properties of Covalent Compounds

Some of the characteristic properties of Covalent compounds are as follows:

1. **Covalent compounds are made of individual molecules.** Covalent compounds are not made of ions, but instead they consist of molecules.

2. **Physical state.** Covalent compounds, generally exist as gases or liquids. Only some of them are volatile solids. This is due to weak forces of attraction between their molecules.

3. **Melting and boiling points.** Covalent compounds have usually low melting points and low boiling points. For example, naphthalene has a low melting point of 353 K (80°C) and carbon tetrachloride has a low boiling point of 350 K (77°C). Covalent compounds are made up of electrically neutral molecules. So, the force of attraction between the molecules of a covalent compound is very weak. Only a small amount of heat energy is required to break these weak intermolecular forces. As a result of this, the covalent compounds generally, have **low melting points and low boiling points.**

4. **Solubility.** Covalent compounds are usually insoluble in water but they are soluble in organic solvents. For example, naphthalene is insoluble in water but dissolves in organic solvents like ether. Some of the covalent compounds like glucose, sugar and urea etc, are, however, soluble in water. The polar covalent compounds like hydrogen chloride and ammonia are also soluble in water.

5. **Electrically Conductivity.** Covalent compounds do not conduct electricity because they do not contain ions. For example, covalent compounds like glucose, cane sugar, urea, alcohol and carbon tetra chloride etc., do not conduct electricity (because they do not contain ions). Some polar covalent compounds such as hydrogen chloride gas, however, conduct electricity when dissolved in water. This is due to the fact that hydrogen chloride chemically reacts with water to form hydrochloric acid containing ions.

   $$HCl + H_2O \longrightarrow H_3O^+ + Cl^-$$

   The aqueous solution of NH_3 also produces ions, but to a very small extent.

$NH_3 + H_2O \longrightarrow NH_4^+ + OH^-$

Hence it is a poor conductor of electricity.

6. **They undergo reaction slowly.** In contrast to the reactions of ionic compounds, which are instantaneous, those involving covalent compounds are slow. This is because the bonds in the reacting molecules are first broken and then new bonds are formed to yield the product molecules.

For example, Hydrogen molecule reacts with Chlorine molecule to give hydrochloric acid.

$H_2 + Cl_2 \longrightarrow 2\,HCl$ (the rate of the reaction is very slow)

Difference between Ionic and Covalent Compounds

Some important differences between ionic and covalent compounds have been given in table.

S.No.	Property	Electrovalent Compounds	Covalent Compounds
1.	Physical State	Usually Crystalline Solids	Usually liquids or gases. Only a few are solids
2.	Melting and boiling points	Generally high	Generally low
3.	Nature of bonding	Ionic in nature since they consists of ions	Non-Ionic since covalent compounds consists of molecules
4.	Solubility	Generally, soluble in water, but insoluble in organic solvents.	Generally, insoluble in water, but soluble in organic solvents.
5.	Dissociation in solution	Dissociate in solutions to give ions.	Do not dissociate since they do not have ions.
6.	Electrical Conductivity	Good conductors of electricity in molten state or in solutions	Bad conductors of electricity.
7.	Nature of reactions	Ionic reactions which are generally fast	Molecular reactions which are generally slow

Compounds Containing both Ionic as well as Covalent Bonds

During the study of chemistry we come across many chemical compounds which contain Both covalent as well as electrovalent bonds. For example, consider sodium hydroxide (NaOH).

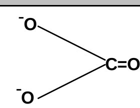
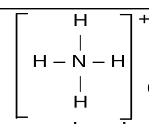
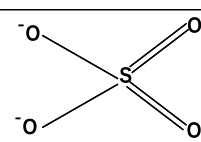
The compound is made of two oppositely charged ion sodium (Na^+) ions and hydroxide (OH^-) ion. These ions are held up by electrovalent bond.

Hydroxide ion (OH^-) which is a diatomic ion. The oxygen atom and hydrogen atom in hydroxide ion are bonded by covalent bond $(O - H)^-$.

Hence NaOH (Sodium Hydroxide) contains both **ionic** as well as **covalent** bonds.

Other examples of the compounds containing Electrovalent as well as Covalent Bonds have been given in table.

Compounds containing Electrovalent as well as Covalent Bonds.

S.No.	Compound	Formula	Ions and their Structures
1.	Calcium Carbonate	$CaCO_3$	**Ca^{2+}** **Calcium ion**  **Carbonate ion**
2.	Calcium Carbide	CaC_2	Ca^{2+} Calcium ion; $^-C\equiv C^-$ Carbide ion
3.	Potassium Cyanide	KCN	K^+ Potassium ion; $^-C\equiv N$ Cyanide ion
4.	Ammonium Chloride	NH_4Cl	 Ammonium ion; Cl^- Chloride ion
5.	Sodium Sulphate	Na_2SO_4	**Na^+** **Na^+** **Sodium ions**  **Sulphate ion**