5. CHEMICAL BONDING

The chemical reactions between atoms of different elements take place as a result of bond formation between them to give new molecules. When two or more atoms come together and react with each other, a chemical bond of some kind is formed between them. This bond is formed between the electrons in the outermost orbit of the atom reactions and chemical bonding). It is seen that the elements of the zero group (inert gases or noble gases) do not react with any other atom—their outermost orbits contain eight electrons. Hence, atoms of different elements combine or undergo chemical reactions (or bonding) to attain eight electrons in their outermost orbits. There are basically two ways in which this can be attained.

Electrovalent (Ionic) Bond An electrovalent bond is formed when electrons from one atom are completely transferred to another atom of a different element. It is also called an ionic bond.

Consider the formation of sodium chloride (NaCl) by combination of one atom of sodium with one atom of chlorine:

Electronic configuration of sodium (Z=11) is 2, 8, 1 or $1s^2$, $2s^2$, $2p^6$, $3s^1$.

Electronic configuration of the nearest noble gas, neon (Z=10) is 2, 8, or $1s^2$, $2s^2$, $2p^6$.

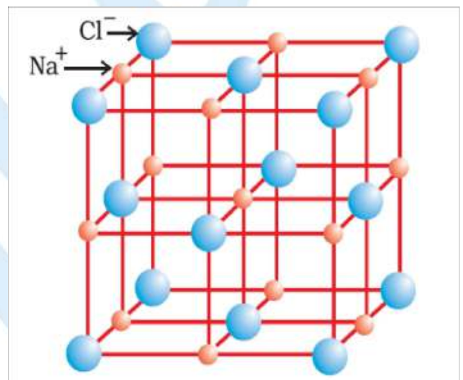
Electronic configuration of the nearest noble gas, argon (Z=18) is 2, 8, 7 or $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^5$.

Electronic configuration of the nearest noble gas, argon (Z=18) is 2, 8, 8 or $1s^2$, $2s^2$, $2p^6$, $3s^2$, $3p^6$.

Sodium attains the nearest noble gas electronic configuration (of neon) by losing its outermost, $3s^1$ electron. The result of the loss of this electron is that sodium develops a positive charge because atom as a whole is electrically neutral. Chlorine attains the nearest noble gas configuration of argon by accepting the electron released by sodium. The result of the acceptance of the electron by chlorine is that it gets a negative charge (because electron is negatively charged).

Na	$\rightarrow$	$Na^+ + e^-$
[Ne] $3s^1$		[Ne]
$Cl + e^-$	$\rightarrow$	Cl^-
[Ne] $3s^2\,3p^5$		[Ne] $3s^2\,3p^6$ or [Ar]
$Na^+ + Cl^-$	$\rightarrow$	NaCl or Na^+Cl^-

Such structures which show arrangement of valence electrons of various atoms are called Lewis structures. The sodium ion (Na^+) and chloride ions (Cl^-), thus formed, are held together by the strong electrostatic forces of attraction as they are oppositely charged ions. The diagrammatic representation of formation of NaCl from sodium and chlorine atoms is shown in Fig. 5.1. In all electrovalent compounds, the different species are held together by such forces.



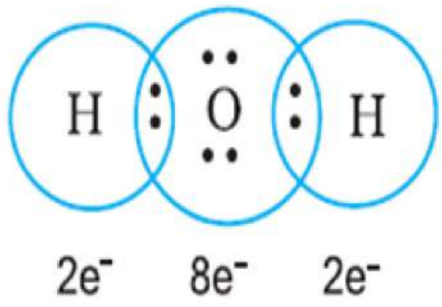
Rock salt structure

Fig 5.1

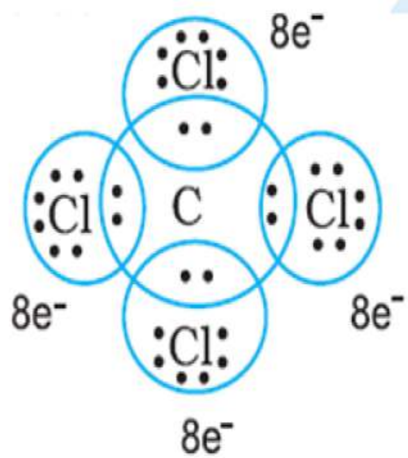
Covalent (Chemical) Bond A bond formed by the sharing of a pair of electrons between two atoms of the same or different elements, when each atom contributes one electron pair is called a covalent bond.

Consider the formation of hydrogen molecule (H_2). Electronic configuration of the nearest nobel gas (He) (Z = 2) is $2s^2$.

The outer shell of hydrogen atom has one electron which is one short of nearest noble gas (He). Therefore, hydrogen atoms combine to give hydrogen molecule (H_2), in which the hydrogen atoms contributing one electron to the shared pair. In this way, both the hydrogen atoms attain the nearest noble gas configuration, i.e. of helium as shown in Fig. 5.2. Similarly, the formation of water, ammonia and carbon tetrachloride can be represented as shown in Fig. 5.2.



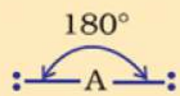
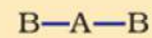
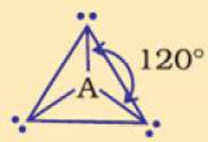
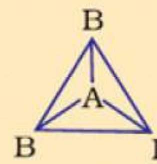
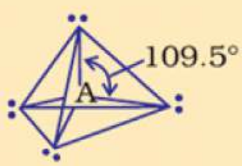
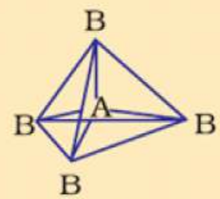
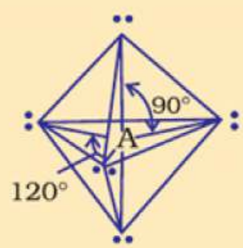
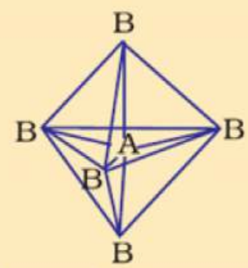
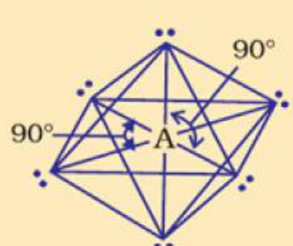
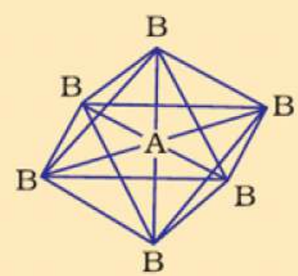
H atoms attain a duplet of electrons and O, the octet



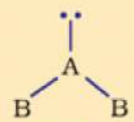
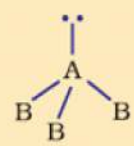
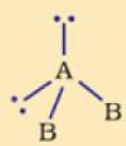
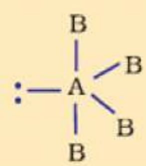
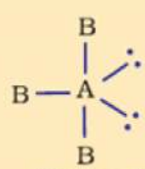
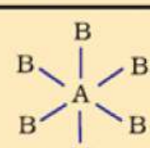
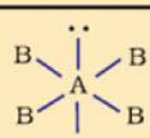
Each of the four Cl atoms along with the C atom attains octet of electrons

Shapes of Molecules We have discussed that ionic bonds arise due to electrostatic attractions. Since the forces of attraction between oppositely charged species are non-directional, i.e. the strength of interaction between two charges depends on the distance but not on the direction, the structure is determined almost entirely by the relative sizes of the ions. Covalent bonds are, however, directional and the shape of a covalently bonded molecule is decided by the directions of the covalently bonded molecule is decided by the direction of the covalent bonds. Molecules showing different geometrical patterns, viz. Linear, round, flat and spiral shapes are known. Also known are linear, triangular, square planar, pyramidal, octahedral and many other arrangements. Many physical and chemical properties are the result of the shape that a molecule has. For example, some of the unique properties of the water molecule are due to the angular shape of H2O, a linear arrangement of the three atoms would drastically alter these properties. Similarly, the biologically important DNA molecule partly owes its physicochemical behavior to its double spiral shape. Also, proteins owe their catalytic activity to their special helical shape.

Geometry of Molecules in which the Central Atom has No Lone Pair of Electrons

Number of electron pairs	Arrangement of electron pairs	Molecular geometry	Examples
2	 Linear	 Linear	$BeCl_2$, $HgCl_2$
3	 Trigonal planar	 Trigonal planar	BF_3
4	 Tetrahedral	 Tetrahedral	CH_4, NH_4^+
5	 Trigonal bipyramidal	 Trigonal bipyramidal	PCl_5
6	 Octahedral	 Octahedral	SF_6

Shape (geometry) of Some Simple Molecules/Ions with Central Ions having One or More Lone Pairs of Electrons(E).

Molecule type	No. of bonding pairs	No. of lone pairs	Arrangement of electron pairs	Shape	Examples
AB_2E	2	1	 Trigonal planar	Bent	SO_2, O_3
AB_3E	3	1	 Tetrahedral	Trogonal pyramidal	NH_3
AB_2E_2	2	2	 Tetrahedral	Bent	H_2O
AB_4E	4	1	 Trigonal bi-pyramidal	See saw	SF_4
AB_3E_2	3	2	 Trigonal bi-pyramidal	T-shape	ClF_3
AB_5E	5	1	 Octahedral	Square pyramid	BrF_5
AB_4E_2	4	2	 Octahedral	Square planar	XeF_4

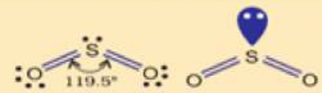
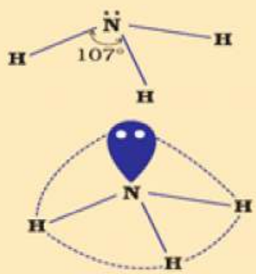
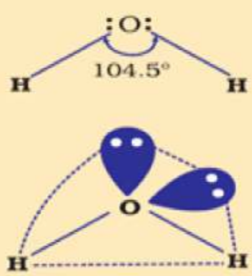
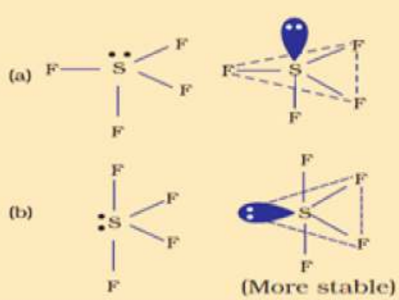
Theories of Chemical Bonding

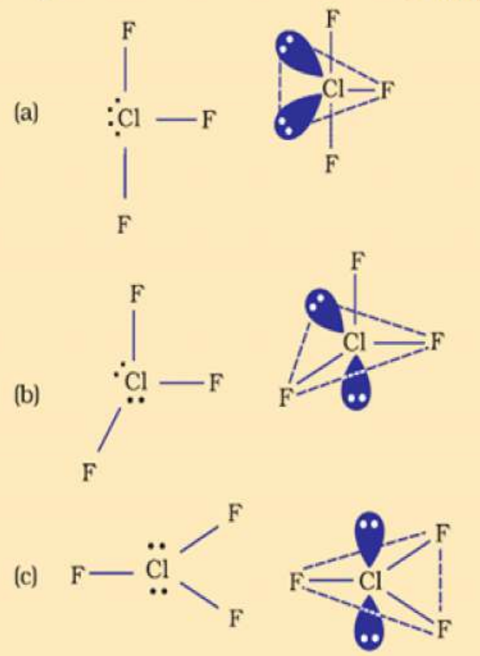
There are mainly two theories to explain the geometries of chemical compounds.

1. MO (Molecular Orbital) Theory According to this theory, a covalent bond is formed when two half filled orbitals of the two atoms come nearer and overlap each other to form a new bigger orbital known as molecular orbital (MO). When two atomic orbitals overlap each other, two MOs are produced, namely bonding (having lesser energy than the energies of the separate atomic orbitals) and anti bonding (having higher energy than the energies of the two separate atomic orbitals). These two new MOs spread over both the atoms and either may contain two electrons.

It overlap of the two atomic orbits takes place along their axis, the resulting bonding MOs are known as sigma (ó) orbitals and the bond formed is called a ó bond. On the other hand, if overlapping of the two atomic orbitals takes place sideways, the resulting MOs are known as pi (ð) orbitals and the bond formed by them is called a ð bond.

Shapes of Molecules containing Bond Pair and Lone Pai

Molecule type	No. of bonding pairs	No. of lone pairs	Arrangement of electrons	Shape	Reason for the shape acquired
AB_2E	4	1		Bent	Theoretically the shape should have been triangular planar but actually it is found to be bent or v-shaped. The reason being the lone pair-bond pair repulsion is much more as compared to the bond pair-bond pair repulsion. So the angle is reduced to 119.5 from 120 .
AB_3E	3	1		Trigonal pyramidal	Had there been a bp in place of lp the shape would have been tetrahedral but one lone pair is present and due to the repulsion between lp-bp (which is more than bp-bp repulsion) the angle between bond pairs is reduced to 107 from 109.5 .
AB_2E_2	2	2		Bent	The shape should have been tetrahedral if there were all bp but two lp are present so the shape is distorted tetrahedral or angular. The reason is lp-lp repulsion is more than lp-bp repulsion which is more than bp-bp repulsion. Thus, the angle is reduced to 104.5 from 109.5 .
AB_4E	4	1		See-saw	In (a) the lp is present at axial position so there are three lp—bp repulsions at 90 . In(b) the lp is in an equatorial position, and there are two lp—bp repulsions. Hence, arrangement (b) is more stable. The shape shown in (b) is described as a distorted tetrahedron, a folded square or a see-saw.

Molecule type	No. of bonding pairs	No. of lone pairs	Arrangement of electrons	Shape	Reason for the shape acquired
AB_3E_2	3	2		T-shape	In (a) the lp are at equatorial position so there are less lp-bp repulsions as compared to others in which the lp are at axial positions. So structure (a) is most stable. (T-shaped).

OXIDATION AND REDUCTION

Oxidation is a process in which a substance adds on oxygen or loses hydrogen. The current definition of oxidation is the process in which a substance loses electrons. Reduction, on the other hand, is a process in which a substance adds on hydrogen or loses oxygen. In modern terms, reduction is the process in which a substance gains electrons.

Oxidation and reduction always occur simultaneously. If one substance is oxidised, another is reduced. The reaction in which this oxidation-reduction process occurs is called a redox reaction.

Oxidising agents are substances which bring about the oxidation of other substances, e.g. potassium permanganate, potassium dichromate, nitric acid, hydrogen peroxide, etc.

Reducing agents are substance which bring about the reduction of other substances, e.g. hydrogen sulphide, hydrogen, carbon, sulphur dioxide, etc.

There are a number of oxidation-reduction reactions that are of industrial use. The production of metals from their ores invariably involves these two processes. Organic compounds are also synthesised by various oxidation-reduction techniques.

METALLIC CORROSION

Many metals when exposed to atmosphere, react with air or water in the environment to form undesirable compounds on their surfaces. This process is called corrosion. Almost all metals except the least active metals such as gold, platinum undergo corrosion. In the case of iron, the corrosion is called rusting. The red or orange coating that forms on the surface of iron when exposed to air and moisture is called rust. Chemically, rust is a hydrated form of ferric oxide, Fe_2O_3 xH_2O Rusting of iron is gradually caused by moisture, CO_2 and O_2 present in air. It is observed that rusting takes place only when iron is in contact with moist air. The reaction may be written as:

$4Fe$ + $3O_2$ + $3H_2O$

Fe_2O_3 + $2Fe(OH)_3$

Iron Oxygen Water Iron

oxide Iron hydroxide

(from air)

Fe_2O_3 + xH_2O $Fe_2O_3\,xH_2O$

Rust

Iron does not rust in dry air and in vacuum. The process of corrosion is speeded up when the two metals are in contact with each other. Rusting of iron can be prevented by coating it with form zinc compounds and protect the iron from rusting. This type of coated iron is called galvanized iron or G.I.