Chemical Bonding

Introduction

Chemical bonding may be defined as the combination of two or more atoms through rearrangement of electrons in their outer shells either by sharing of electrons amongst themselves or by the transfer of the electrons from one atom to another so that all the atoms attain the stable configuration of nearest inert gas.

Types of Bonds

1. Ionic Bond:-

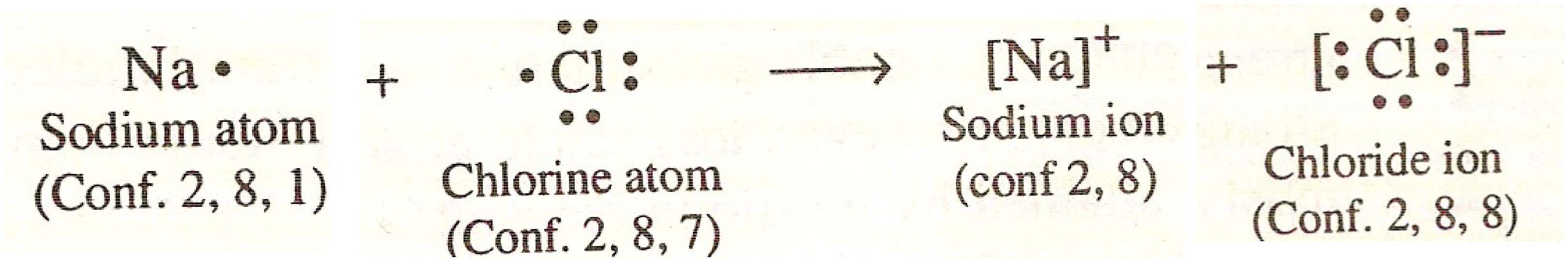
An ionic bond is formed-by the complete transference of one or more electrons from the outermost energy shell (called valency shell) of one atom of outermost energy shell of another dissimilar atom, so that both acquire stable inert gas configurations. The atom which loses the electrons become a positive ion (cation) while the other atom which gains electrons becomes a.negative ion (anion). These two oppositely charged ions combine due to electrostatic forces of attraction to form an electrovalent or ionic compound.

Types of Bonds

Examples of Ionic Bond:-

1. **Formation of sodium chloride :-**

When sodium atom (atomic number =11,electronic configuration 2, 8, 1) and a chlorine atom (atomic number 17, electronic configuration 2, 8, 7) react together, the outer electron of the sodium atoms is transferred to the chlorine atoms to produce sodium ions Na+ and chloride ions Cl^- These ions are held together by the forces of electrostatic attraction between them.

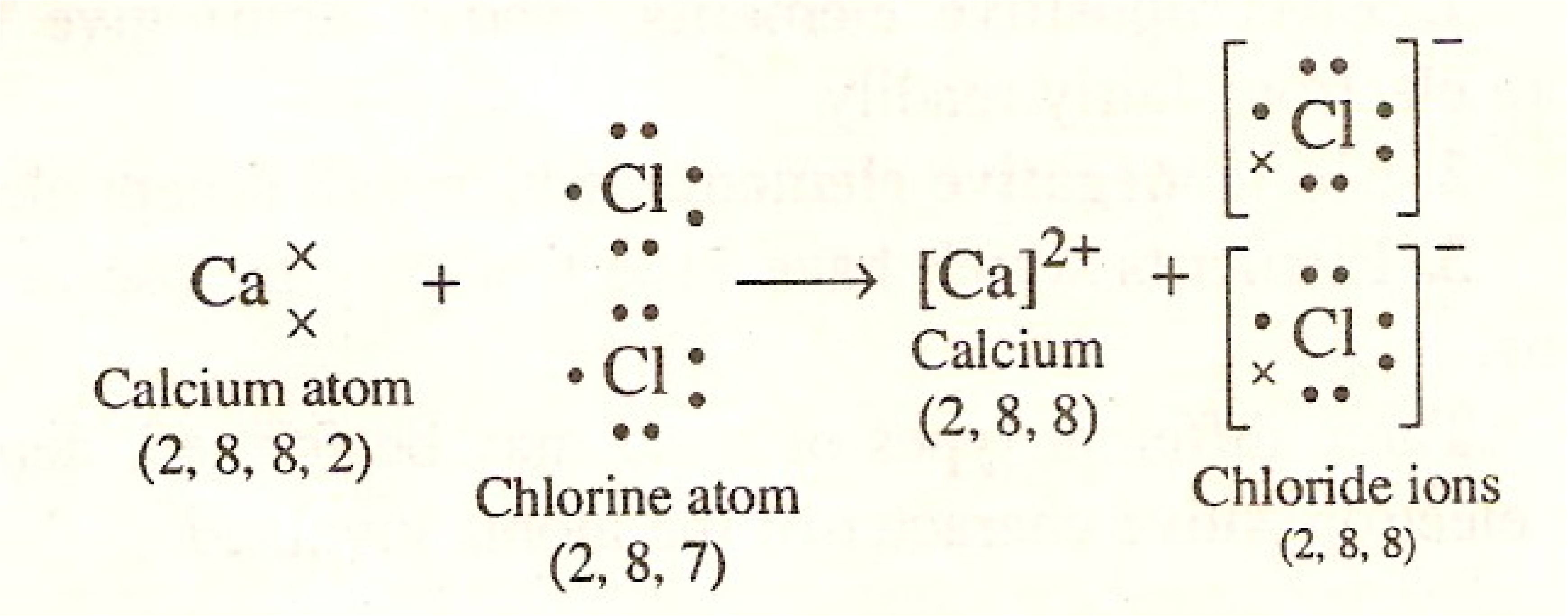


Types of Bonds

The number of electrons lost or gained by an atom, to acquire stable inert gas configuration is called the electrovalancy of the atom. Thus, electrovalancy of the sodium is + 1 and the chlorine is -1. The electropositive elements possess positive (+) electrovalancy, while the electronegative elements possess negative (-) electrovalancy.

2. **Formation of calcium chloride**: The formation of calcium chloride may be considered in a similar way: Ca atoms have two electrons in their outer shell. Ca is an electropositive element, so each Ca atom loses two electrons to two Cl atoms, forming a calcium ion Ca2+ and two chloride ions Cl-. Showing the outer electrons only. This may be represented as follows :

Types of Bonds



Types of Bonds

Factors Responsible for the Formation of Ionic Bonds

1. **Ionization Energy.:** The ionization energy of atom forming the electrovalent bond should be low, *i.e.,* a smaller amount of energy should be spent to pull out an electron from its outer energy level.

   Example: Alkali and alkaline earth metals.

2. **Electron affinity:** The electron affinity of two atoms forming an electrovalent bond should be high, *i.e.,* it should be able to accept an electron in its outer energy level.

   Example: Halogen and oxygen.

3. **Lattice energy:** The lattice energy should be high or size of ions should be small and their charge should be large.

Types of Bonds

Properties of Electrovalent or ionic Compounds

- They consist of oppositely charged ions held together by electrostatic forces of attraction.
- Electrovalent compounds are quite soluble in solvents of high dielectric constant and of polar nature. It is because the high dielectric constant of the solvent lowers the attractive forces between the ions of the lattice.
- The linkage between the ions is non-rigid and non-directional. Hence the ionic compounds do not exhibit any type of space isomerism.

Types of Bonds

Properties of Electrovalent or ionic Compounds

4.They possess high melting point and boiling point because binding energy is very high. Ionic compounds are made up of +ve and -ve ions arranged in a regular way in lattice. The attraction between ions is electrostatic and extending equally in all directions, melting of the compound involves breaking of the lattice. This requires considerable energy and so the melting and boiling points are usually high and compounds are very hard.

Types of Bonds

Properties of Electrovalent or ionicCompounds

5. X-ray diffraction studies indicates that the component parts of the ionic crystals are ions and not molecule.
6. Ionic solids have low conductance of electticity in solid state. When electro va-lent compounds are melted or dissolved in a solvent of high dielectric constant. The binding forces in the crystal lattice disappear and the component ions become mobile. It means that the melts or solutions of electrovalent compounds conduct electricity.

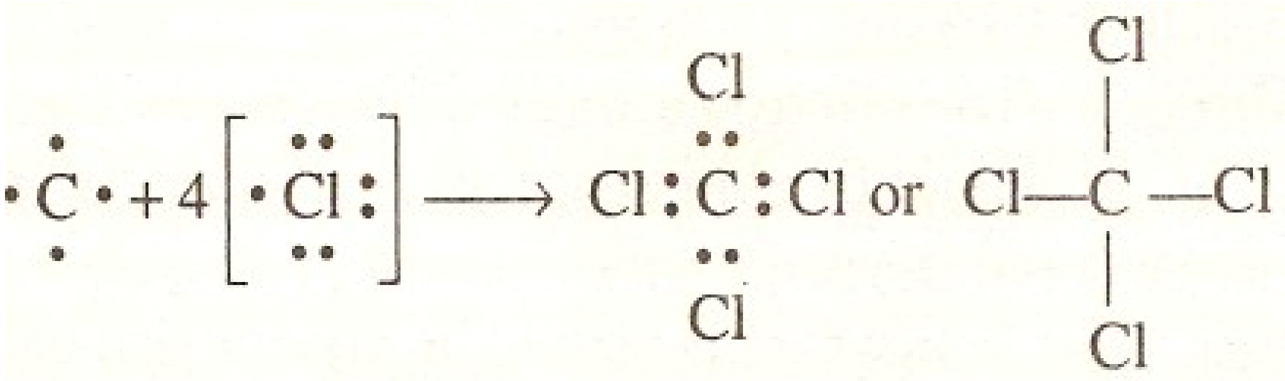
Types of Bonds

COVALENT BOND

When two electronegative atoms react together, both atoms have a tendency to gain electrons but neither atoms has any tendency to lose electrons. In such cases the atom share electrons so as to attain a noble gas configuration.

Examples :

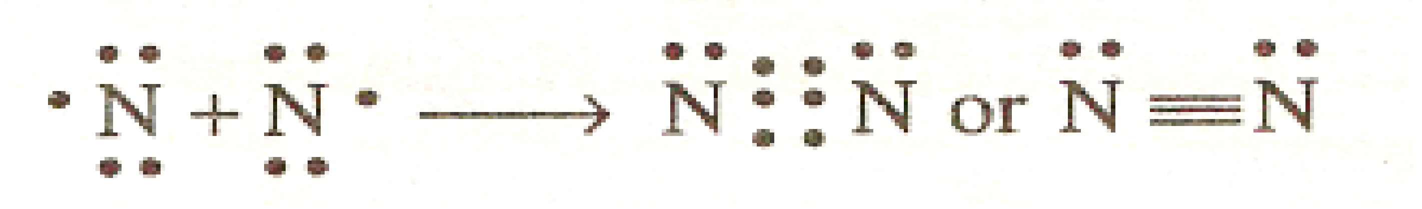
1. **Formation of tetrachloromethane:** A molecule of tetrachloromethane CCl4 is made up of one carbon and four chlorine atoms.



Types of Bonds

The carbon atom is four electrons short of the noble gas structure. So it forms four bonds and the chlorine atoms are one electorn short. So they each form one bond. By sharing electrons in this way both the carbon and all four chlorine atoms attain a noble gas structure.

2. Formation of nitrogen molecule: Nitrogen atom has five electrons in its outermost orbit, two atoms contribute three electrons each for sharing and resulting in the formation of a stable molecule .



Types of Bonds

Properties of Covalent Compounds

1. The compounds are generally gases or liquids at ordinary temperature. They are solids only when their molecular weight are high.
2. Covalent compounds in which vander Waal's forces are operative are normally insoluble in polar solvents of high organic solvents of low dielectric constant such as benzene and carbon tetrachloride.
3. The crystals of covalent compounds are of three types:

   (i) The most common type of covalent molecules are bound together by weak vander Waal's forces. These compounds are generally soft, easily fusible and volatile.

   Example: Sulphur, iodine etc.

Types of Bonds

(ii) The second types of covalent crystals result when the atoms unite witheach other to form a gaint molecule.

Example: Diamond, Si02 etc.

(iii) The third type of covalent crystals are known as layer lattice.

Example: Graphite.

4. Covalent compounds undergo molecular reactions in which molecules as such take part. These reactions are therefore, slow as compared to ionic reaction.

5. For melting a covalent compound where vander Waal's forces are operative, only a small amount of thermal energy is needed to overcome these forces. Hence, such a covalent compounds has low melting and boiling points.

Types of Bonds

COORDINATE BOND

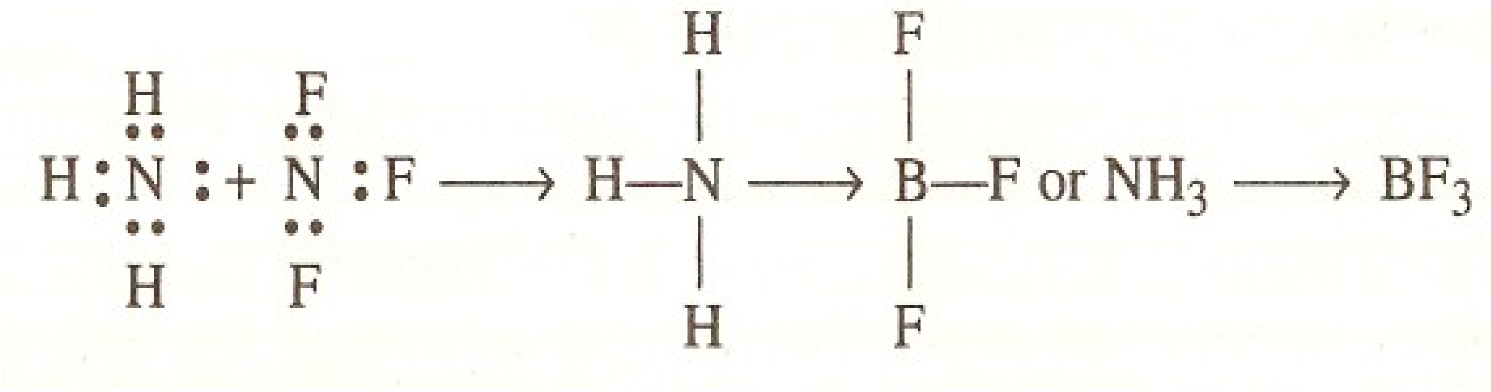
A covalent bond results from the sharing of a pair of electrons between two atoms where each atom contributes one electron to the bond. It is also possible to have an electron. pair bond where both electrons originates from one atom and none from the other. Such bonds are called coordinate bonds Since in coordinate bonds, two electrons are shared by two atoms, they differ from normal covalent bond only in the way they are formed; and once formed they are identical to normal covalent bonds.

Covalent bonds are usually shown as straight lines joining the two atoms, and coordinate bonds as arrows indicating which atom is donating the electrons.

Types of Bonds

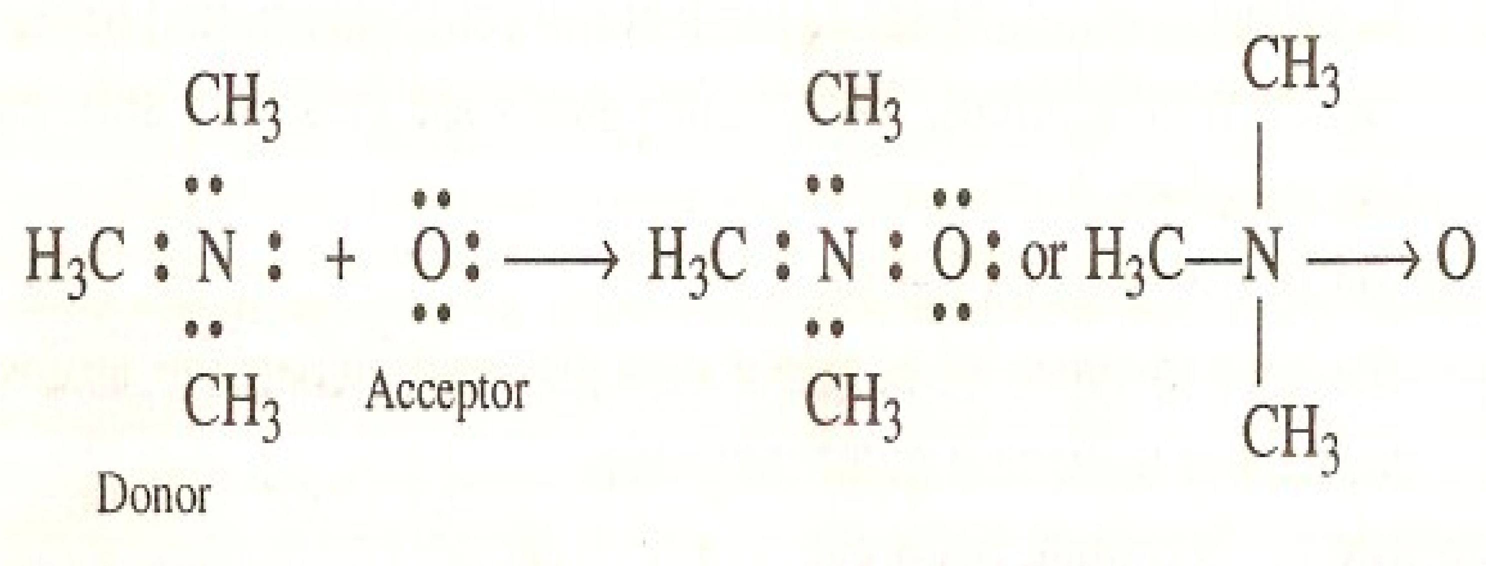
Examples:

1. **Combination of Ammonia and boron trifluoride :** Ammonia may donate its loan pair to borontrifluoride and by this means the boron atom attains a share in eight electrons.



Types of Bonds

2. Oxidatiion of trimethylamine: The formation of co-ordinate bond is that of oxidation of trimethylamine $(CH_3)_3N$ to trimethylamine oxide $(CH_3)_2NO$.



Types of Bonds

Properties of Coordinate Compound

1. Coordinate compounds are not ionized in solution or in the fused state. Hence, they do not conduct electricity.
2. Coordinate compounds are generally insoluble in polar solvenets like H_20, liquid NH_3 etc. but are soluble in non-polar solvents like benzene, CCl_4 etc.
3. Due to the semipolar nature of the bond, these compounds have melting and boiling points higher than those of the covalent compounds but lower than those of the electrovalent compounds.
4. Since the coordinate bond is rigid and directional, these compounds show space isomerism.

ATOMIC ORBITAL THEORY OF COVALENT BOND

According to orbital concept, a covalent bond is formed by the overlapping of atomic orbitals. This overlapping can take place either along the axes of orbitals or perpendicular to their axes. Thus, it gives rise to two types of bond σ and π bonds.

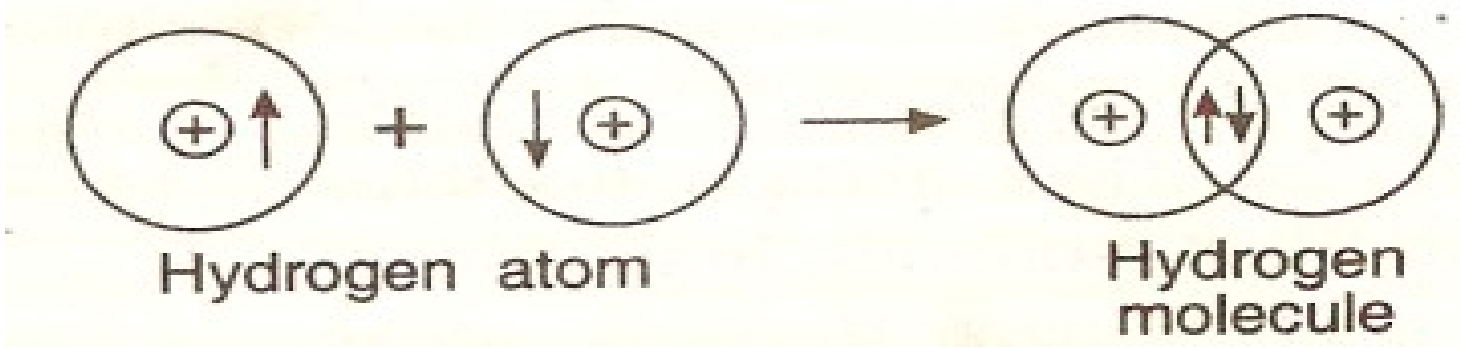
1. **Sigma bond** (σ): The σ bond formed as a result of end to end overlapping, *i.e.,* the electron density is concentrated in between the two atoms and a line joining the two atoms. σ bond is very strong due to the maximum overlapping in the σ bond. The overlapping may be of 3 types :

(i) *s-s* overlapping (ii) *s-p* overlapping (iii) *p-p* overlapping.

ATOMIC ORBITAL THEORY OF COVALENT BOND

(i) **s-s overlapping:** Since the *s* orbital is spherically symmetrical, so due to its overlapping with another *s*-orbital the maximum overlapping take place.

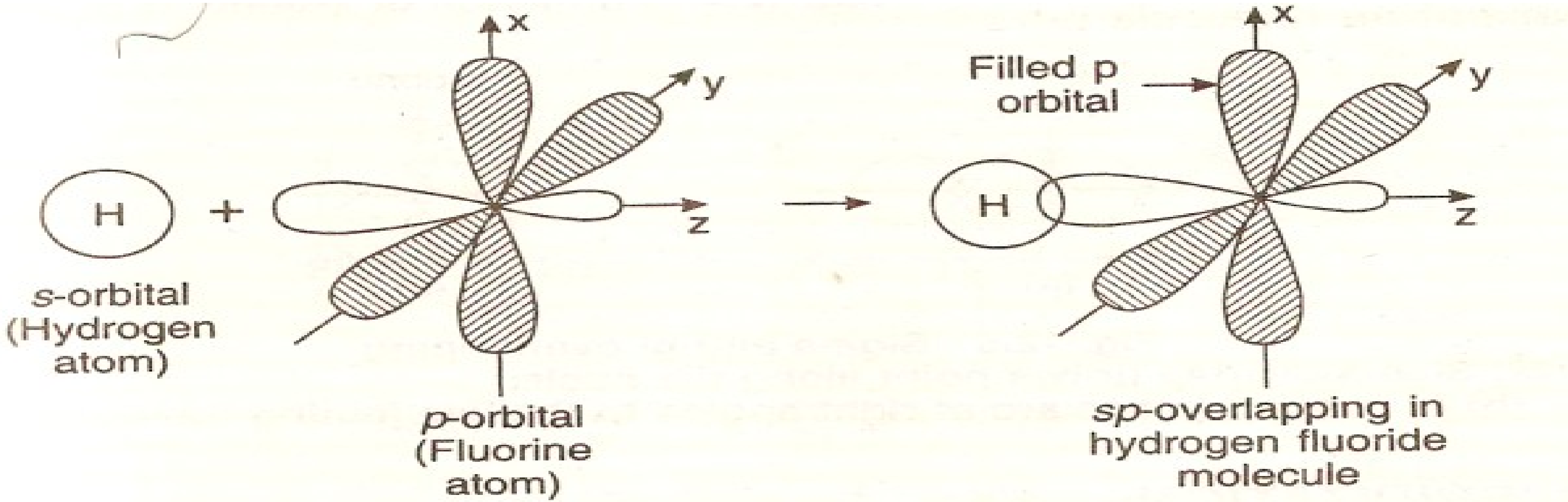
Example: Hydrogen atom ($1s^1$) has a single electron. When their s orbital overlap with each other form a covalent bond, this type of overlapping is called s-s overlapping.



ATOMIC ORBITAL THEORY OF COVALENT BOND

(ii) s-p overlapping: Formation of σ bond as a resuslt of *s*-p overlapping is illustrated by the formation of halogen acids like hydrogen fluoride molecule, and hydrogen chloride molecule .

Example: The outer electronic configuration of fluorine atom is $2s^2p^5$. It needs one electron more in its outer shell to acquire the stable s^2p^6 configuration and this type of overlapping is called s-p overlapping.

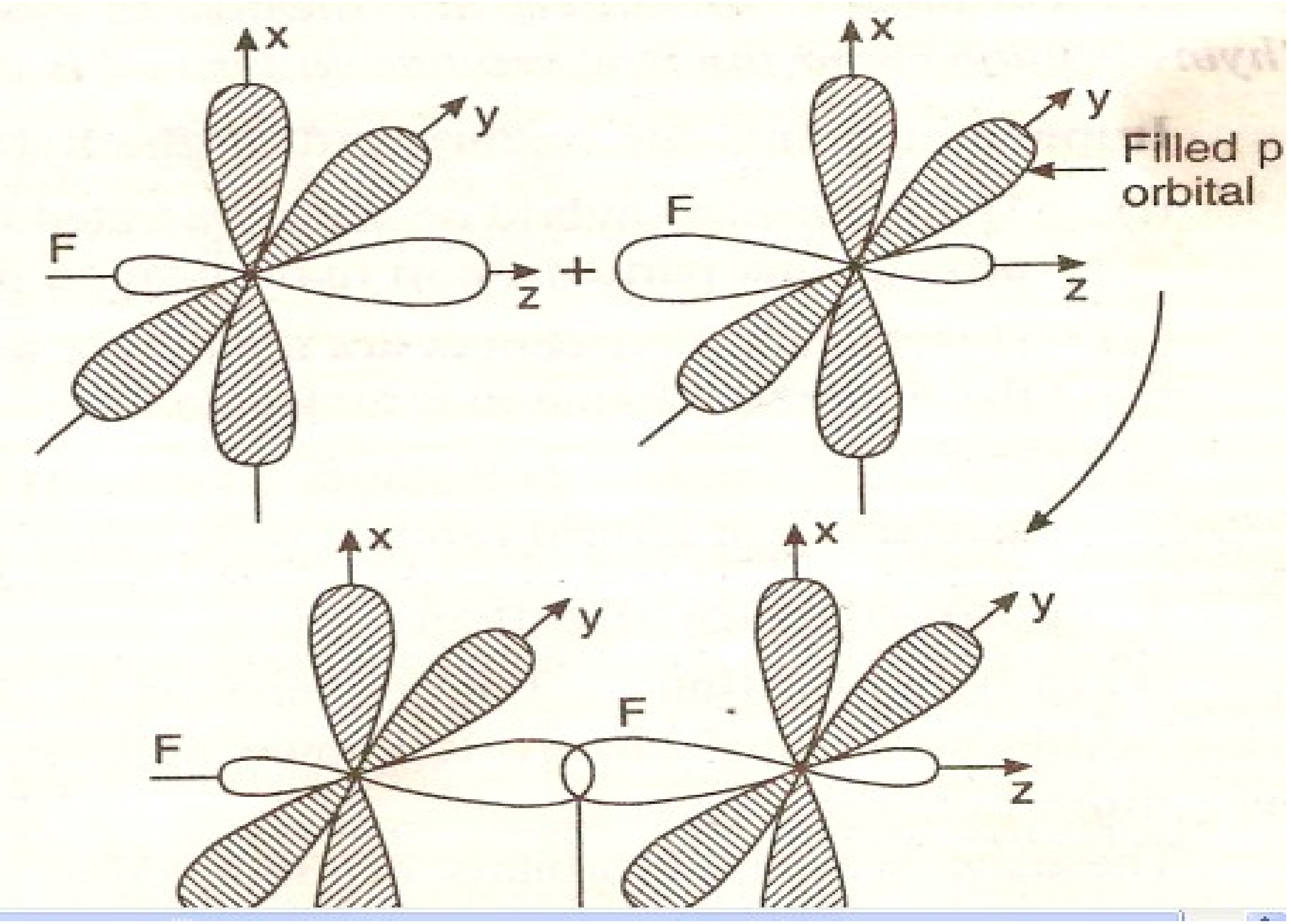


ATOMIC ORBITAL THEORY OF COVALENT BOND

(iii) p-p overlapping: Formation of σ bond as a result of axial overlapping of *p*-*p* orbitals is illustrated by the formation of halogen molecules (fluorine or chlorine).

Example : In the formation of fluorine molecule the half filled p-orbital of one atom overlaps with a similar p-orbitals of another atom to form F_2 molecule. This type of overlapping is called p-p overlapping.

ATOMIC ORBITAL THEORY OF COVALENT BOND



ATOMIC ORBITAL THEORY OF COVALENT BOND

(2) Pi (π) bond: . The bond formed as a result of sideways overlapping of *p*-*p* orbitals is known as a π bond. In this case the electron density also concentrates between the atoms, but on either side of the line joining the atoms.

Example: Formation of Pi bond in N_2 Molecule.