Inorganic Chemistry

M.S.C. / First Semester

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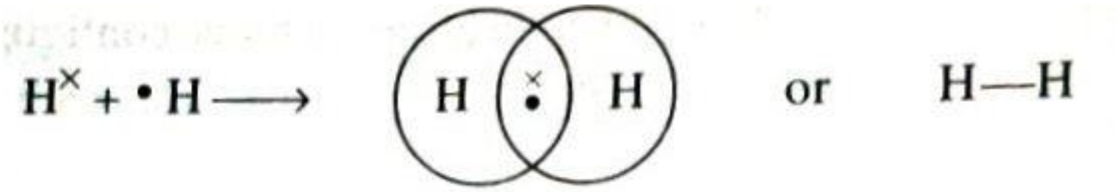
<u>Covalent Bond :-</u>

The second mode of combination was first proposed by Lewis, in 1916, that there are atoms which attain noble gas configuration by sharing one or more electron pairs when each atom contributes equally. The pair or pairs of electrons become a common property of both. Such a bond is possible between similar and dissimilar atoms. In this bond the atoms do not acquire any charge as the electron or electrons are not lost completely. The electrons, which are shared, occupy such a position in between the nuclei of the two atoms where there is maximum force of attraction from the two nuclei. The bond is, therefore, termed as non-polar bond.

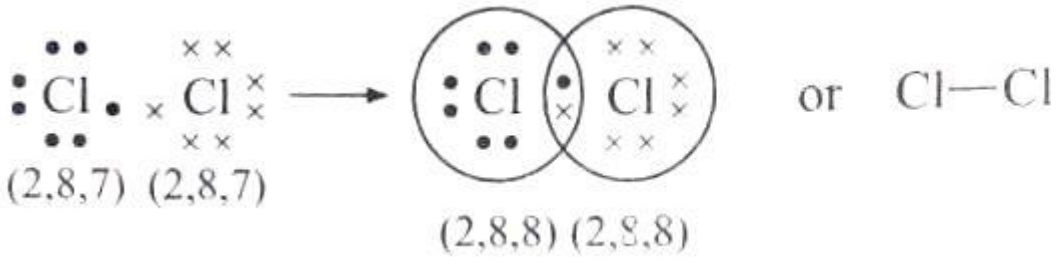
"**A chemical bond formed by sharing one or more electron pairs between atoms when each atom contributes equally is called a covalent bond**."

Covalent bond may be single, double or a triple bond. Double and triple covalent bonds are called **multiple covalent bonds**. Single covalent bond is formed by sharing of only one electron pair. This bond is represented by single dash ( ). Double and triple covalent bonds are formed when atoms bonded together share two or three electron pairs, respectively. These bonds are represented by double dash (=) and triple dash (≡) respectively. Some examples of covalent bonding are given below

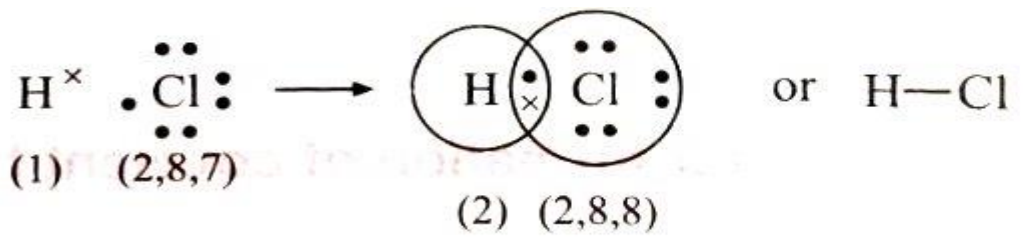
(i) Formation of hydrogen molecule : In the formation of hydrogen molecule, each hydrogen atom contributes one electron and then the pair is shared between two atoms. Both the atoms acquire stable configuration of helium. Thus, the molecule consists of one single covalent bond.



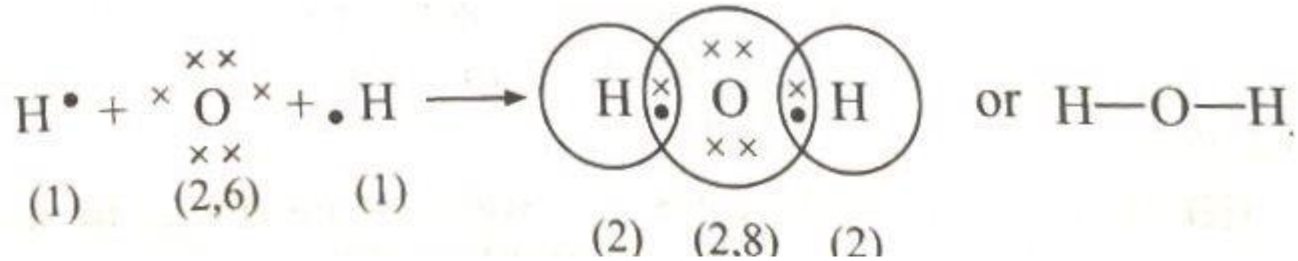
(ii) Formation of chlorine molecule: Chlorine atom has seven electrons in the valency shell. In the formation of chlorine molecule, each chlorine atom contributes one electron and then the pair of electrons is shared between two atoms. Both the atoms acquire stable configuration of argon.



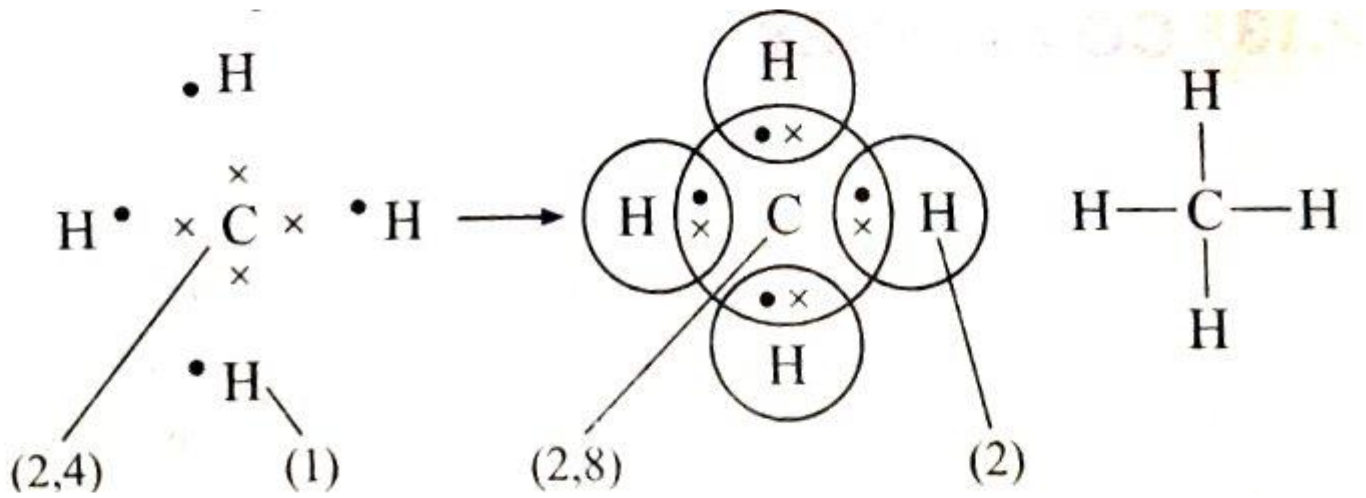
(iii) Formation of HCI molecule : Both hydrogen and chlorine contribute one electron each and then the pair of electrons is equally shared. Hydrogen acquires the configuration of helium and chlorine acquires the configuration of argon



(iv) Formation of water molecule : Oxygen atom ha 6 valency electrons. It can achieve configuration of neon by sharing two electrons, one with each hydrogen atom.



(v) Formation of methane : carbon has four electrons in the valency shell . It can achieve stable configuration of neon by sharing four electrons with four hydrogen atoms, one with each hydrogen atom.Each hydrogen atom acquires helium configuration.



<u>Conditions for formation of covalent bonds</u>

To form a stable covalent molecule, for example (AB), we must take into account the conditions that must be met by the atoms involved in forming the molecule

1- Ionic bonding should not be possible, and the requirements for ionic bonding can be summarized as follows:

(a) The ability of an atom to lose one or two electrons (rarely three) without exerting much energy

(b) The ability of the atoms of an element to receive one or two electrons (rarely three electrons) without the need to expend energy

If these two conditions are provided, the possibility of obtaining an ionic bond is possible, but if they are not provided then the possibility of forming a bond with common electrons (covalent bond) is possible.

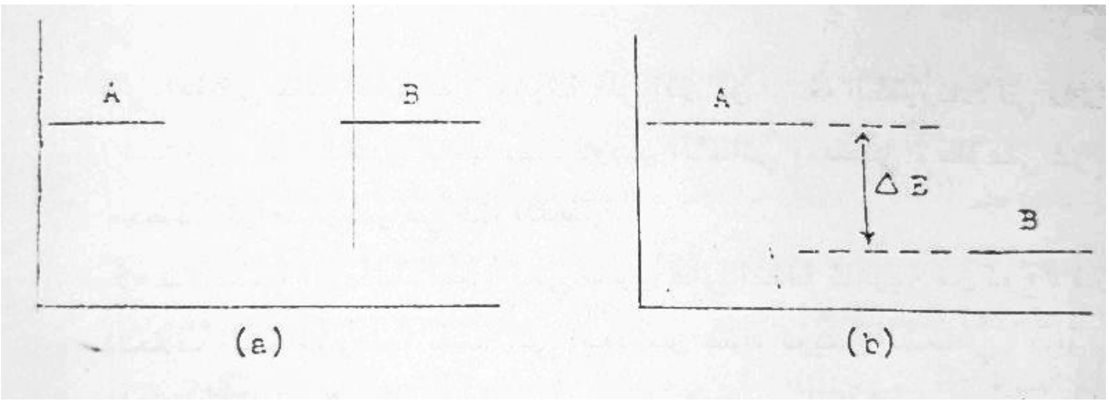
That is, the energy of the electrons for the atom A is equal or close to the energy of the electrons for the atom B as a condition for the union of the two atoms to form a bond with common electrons (covalent bond). But if there is a difference in the energy of the electrons for the two atoms (A and B), the electron moves from the atom that has high energy to the atom that has low energy, and a positive ion and a negative ion are formed (so the ionic bond is formed),

So the conditions favour the formation of covalent bonds:

(i) Electronegativity : electron or electrons to the other atom if tie electronegativity difference between the two atoms is zero or very small (less than 1.6). Such atoms prefer to share electrons, i.e., form An atom will not transfer the covalent bonds.

(ii) When both the atoms are short in electrons in the valency shell in comparison to stable noble configuration, then such atoms complete the outermost shell by sharing electrons. Except hydrogen which has one electron in valency shell, such atoms have 5, 6 or 7 valency electrons. The non- metals of group VA, VIA and VIIA satisfy this condition

The following diagram shows the covalent and ionic bond formation according to the energy of the electrons



2- It is known that a covalent bond consists of the participation of two electrons, so that the source of each electron is a specific atom. This necessitates the couple spin of these two electrons as they form the bond. This is a consequence of the (Pauli) principle of exception (The Pauli Exclusion Principle states that, in an atom or molecule, no two electrons can have the **same** four electronic quantum numbers. As an orbital can contain a maximum of only two electrons, the two electrons must have opposing spins. This means if one is assigned an up-spin (+1/2), the other must be down-spin (-1/2)) .

3-The orbital of bonded atoms must overlap, meaning that they fill the same space of space as a condition for the occurrence of conjunction

4- Most of the atoms have a maximum number of electrons equal to eight in the valence shell (the outer shell), which is called the Lewis Octet Rule or the Lewis Octet Structure. This rule applies to atoms of elements from lithium to fluorine. Because they contain one orbital of type (S) and three orbitals of type (P) in the valence shell, so the sum of the four orbitals and the sum of the electronic pairs involved in forming bonds are four, which is the maximum and this applies to all atoms that have secondary coatings of type (S and P).

5- Atoms that contain secondary shells of type (d), their valence shell extends far beyond Lewis Octet Structure and since the orbital (d) appears first time in the third period (n = 3) and beyond, which contain nonmetals of equivalent numbers As well as high transitional elements, in the case of nonmetals, the number of electrons in the valence shell is the determining factor for the number of covalent bonds, and thus the upper limit of covalent equivalence is (5,6,7,8) in the sums (Vb, VIb, VIIb) and 0 groups , respectively.

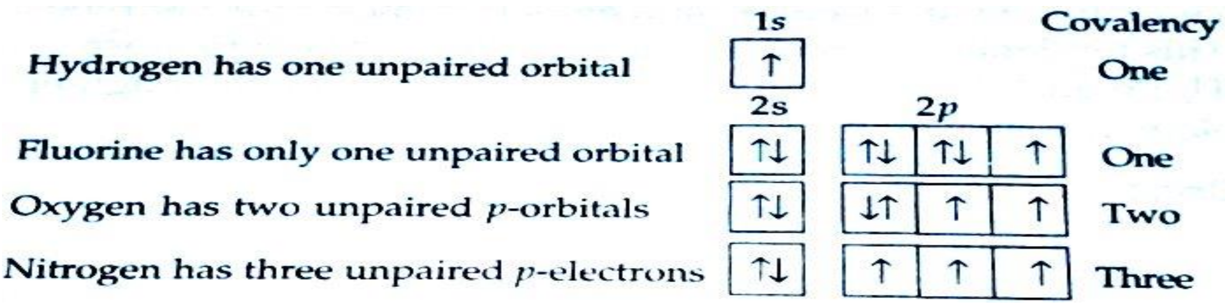
6-The repulsion between the electrons that form bonding electrons and the electrons that do not participate in the formation of bonds (non bonding electrons) should be the least possible, as these electrons can assume a specific position so as to avoid repulsion with each other.

7- The molecule is in the lowest possible energy state, while the bond that connects its components is at the highest possible energy for the purpose of stabilizing the molecule.

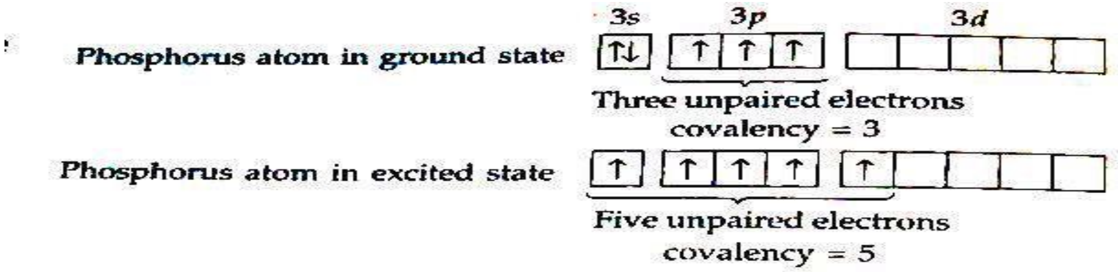
Covalency :-

It is defined as the number of electrons contributed by an atom of the element for sharing with other atoms as to achieve noble gas configuration. It can also be defined as the number of covalent bonds formed by the atom of the element with other atoms. The usual covalency of an element except hydrogen (which has covalency 1) is equal to 8- group number of Mendeleevs table to which an element belongs .this is true for the elements belonging to IV ,V ,VI and VII groups.

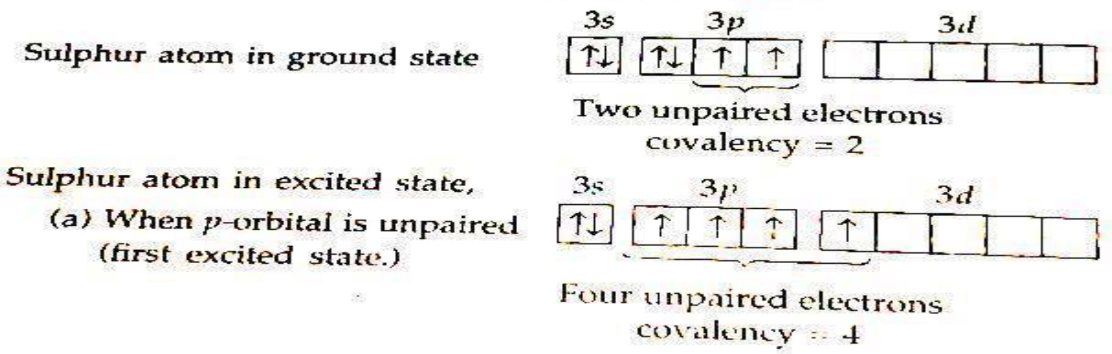
Generally , the covalency of an element is equal to the total number of unpaired electrons in s- and p-orbitals of the valency shell.



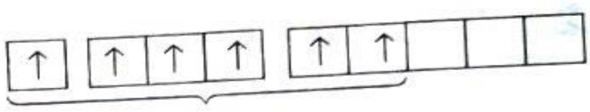
These four elements do not possess d-orbitals in their valency shell. However, the elements having vacant d-orbitals in their valency shell like P, S, Cl, Br, I, show variable covalency by increasing the number of unpaired electrons under excited conditions, ie., unpairing the paired orbitals and shifting the electrons to vacant d-orbitals. [Such shifting is not possible in the case of H, N, O and F because d-orbitals are not present in their valency shell] Phosphorus shows 3 and 5 covalencies.



Sulphur atom shows 2, 4 and 6 covalencies.



(b) When s- and p-orbitals are unpaired (second excited state.)



Covalent Compounds:-

The compounds .containing a covalent bond or a number of covalent bonds are termed as covalent compounds. Compounds such as HCl, CH_4, CO_2, SiO_2, H_2O, NH_3, PCl_3 , SO_2 , etc., are some of the examples of covalent compounds. All organic compounds and the compounds formed by the combination of two different non-metals are covalent in nature.

Covalent Molecules of Elements:-

Some of elements are known to exist in molecular forms under ordinary conditions. These molecules also possess covalent bond or bonds. For example, halogens, sulphur, oxygen, nitrogen, hydrogen, phosphorus, etc, exist in molecular forms. Carbon and silicon have complex structure. In these structures the atoms are also linked by covalent bonds.

Comparison Between Ionic and Covalent Bonds

Ionic bond	Covalent bond
1. Formed by the transference of electron or electrons from electro positive (metal) to electro-negative (non-metal) atoms. Such a bond is possible between dissimilar atoms.	Formed by sharing of electrons between two non-metal atoms when the electrons are equally contributed by both the atoms. Such a bond is possible between similar and dissimilar atoms.
2. Consists of electrostatic force between atoms.	Consists of shared pair or pairs of electrons which are attracted by both the nuclei.
3. Non-rigid and non-directional, does not cause isomerism.	Rigid and directional, causes space and structural isomerism.
4. It is a weak bond, since the electrostatic force between the ions can be broken easily.	It is strong bond, since the paired electrons cannot be separated easily.
5. It is polar in nature.	It is non-polar if the electronegativity difference is zero or small.

Comparison Between Ionic and Covalent Compounds:-

Ionic compounds	Covalent compounds
1. Crystalline solids at room temperature.	Gases, liquids or soft solids under ordinary conditions.
2. High melting and boiling points.	Low melting and boiling points with the exception of giant molecules.
3. Hard and brittle.	Soft and waxy with the exception of giant molecules.
4. Freely soluble in water and in polar solvents. Insoluble in non-polar solvents.	Usually insoluble in water and in polar solvents. Soluble in non-polar solvents.
5. In solid state bad conductors of electricity. Good conductors in molten state and in solutions.	Bad conductors of electricity with few exceptions having layer lattice structure.
6. Undergo ionic reactions. Rates of reactions are very high. Reactions are fast and instantaneous.	Undergo molecular reactions. Rates of reactions are low. Reactions are slow.