CHEMISTRY

(FOR IIT, NEET, AIIMS)

Class – XI

Unit 4 : Chemical Bonding

Topic : Dipole Moment

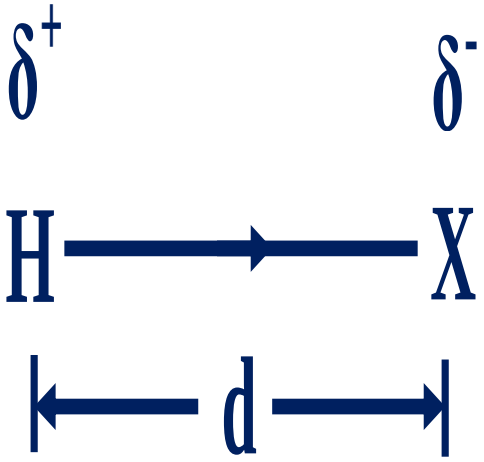
➢ Dipole Moment

- The polarity of a covalent molecule is measured in terms of its dipole moment. By definition,
- "The product of the charge present on one pole and the bond length of a bond is called dipole moment (bond moment) of the respective bond."
- Mathematically, Dipole moment,

$$\mu = e \times d$$

Where, e = charge on one atom

d = bond length



X is more electronegative than H

Fig.- Dipole moment in HX molecule

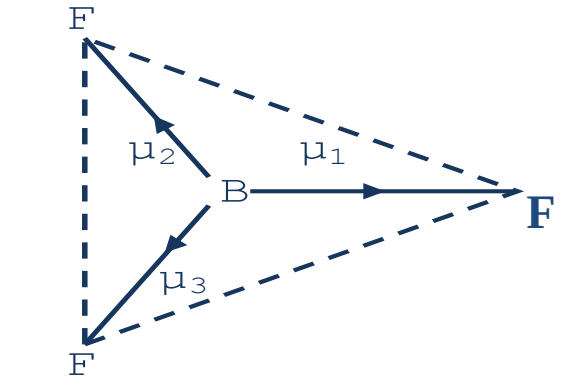
- For most of the covalent bonds, charge produced on the bonded atoms is of the order of 10^{-10} esu and the bond length is of the order of 10^{-8} cm. Hence, dipole moment of most of the covalent bonds is of the order of 10^{-18} esu-cm, which is called **1 Debye**. Thus,

$$\mu = 10^{-10} \text{ esu} \times 10^{-8} \text{ cm}$$

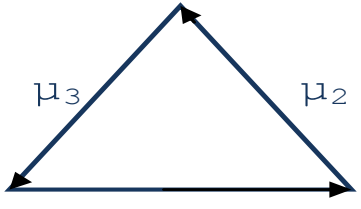
$$= 10^{-18} \text{ esu-cm}$$

$$= 1 \text{ Debye}$$

- Dipole moment is a vector quantity. Hence, if a molecule contains a number of polar covalent bonds, then the resultant dipole moment of molecule is obtained from vector sum of the bond moments of different bonds.
- Thus, a molecule having a number of polar covalent bonds, can have its dipole moment zero.
- For example, BF_3 has three polar B-F bonds, but its dipole moment is zero.



BF_3 Molecule



$\mu_{resultant} = 0$

- Here, vector sum of any two bond moments is equal in magnitude, but opposite in direction to the bond moment of third bond. Hence, resultant dipole moment of the molecule is zero.
- Similarly, CCl_4 has four polar C-Cl bonds, but its dipole moment is zero

➢ Applications of Dipole Moment

(1)Determination of percentage ionic character

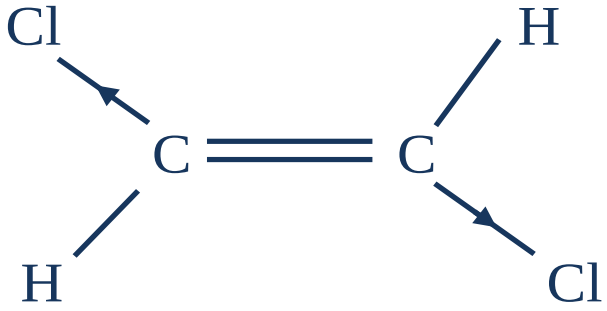
➢ The percentage ionic character in a polar covalent bond is given by following expression-

$$\%\text{age ionic character} = \frac{\textit{Observed dipole moment}}{\textit{Calculated dipole moment}} \times 100$$

$$= \frac{\textit{Experimental dipole moment}}{e \times d} \times 100$$

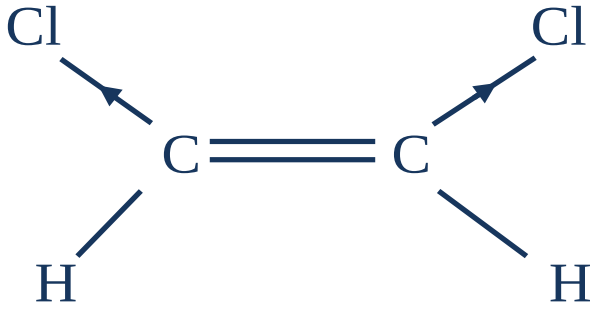
(2) Distinction between cis and trans isomers

- For an alkene of type $_{ab}C = C_{ab}$, cis isomer has a definite non-zero value of its dipole moment, while trans form has its dipole moment zero.
- For example, dipole moment of trans-1,2-dichloroethene is zero, while that of cis-1,2-dichloroethene is non-zero.



Trans-1,2-dichloroethene

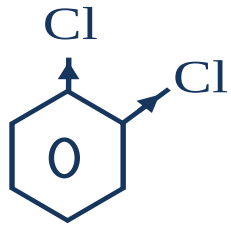
($\mu = 0$)



Cis-1,2-dichloroethene

($\mu \neq 0$)

(3) Distinction amongst ortho, meta and para disubstituted benzene- Here, ortho disubstituted benzene has highest value of its dipole moment, while para isomer has zero dipole moment. Dipole moment of meta isomer is in between ortho and para isomers. For example, the order of dipole moment of ortho, meta and para dichlorobenzene is as under-



Ortho-dichloro benzene

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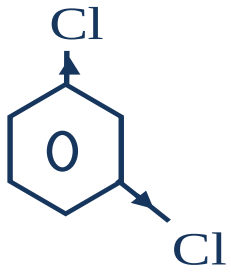

Meta-dichloro benzene

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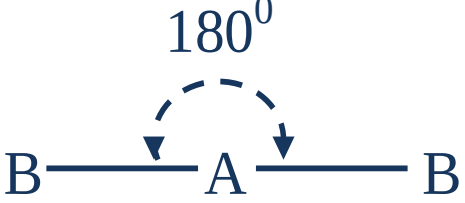
Para-dichloro benzene

(4)Determination of geometry of molecules-

- If a molecule has its dipole moment zero, its geometry is regular. On the other hand, if dipole moment of a molecule has a non-zero value, then its geometry is distorted. For example,

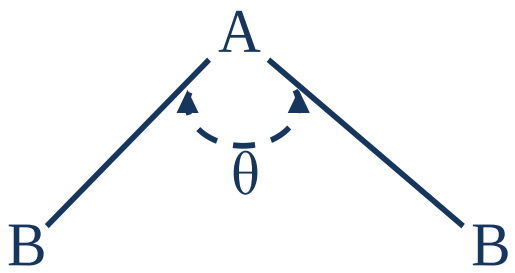
(a) Geometry of molecules of type AB_2- For molecule of type AB_2 following two geometries are possible-



($\mu = 0$)

Linear

e.g. BeF_2, $BeCl_2$, $ZnCl_2$, $CdCl_2$, $HgCl_2$, CO_2, CS_2 etc.



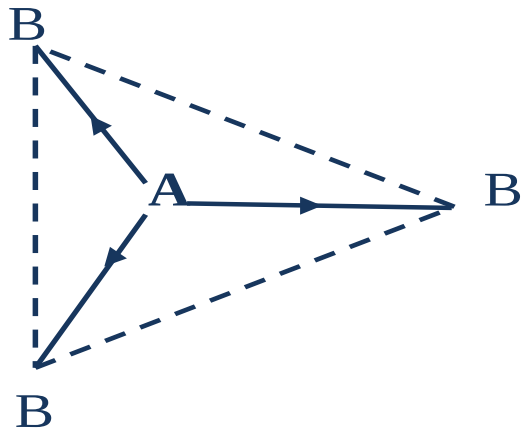
($\mu \neq 0$)

Angular, Bent or V-shaped

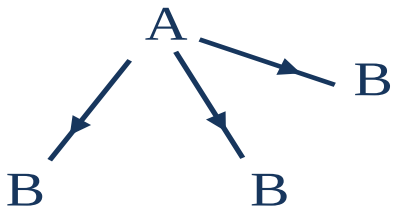
e.g. NO_2, H_2O, H_2S, H_2Se SO_2 etc.

➢Thus, if a molecule of type AB_2, has its dipole moment zero, then the geometry of molecule is linear. On the other hand, if it has a definite non-zero value of its dipole moment, then its geometry is angular, bent or V-shaped.

(b)Geometry of molecules of type AB_3- For molecule of type AB_3 following two geometries are possible-



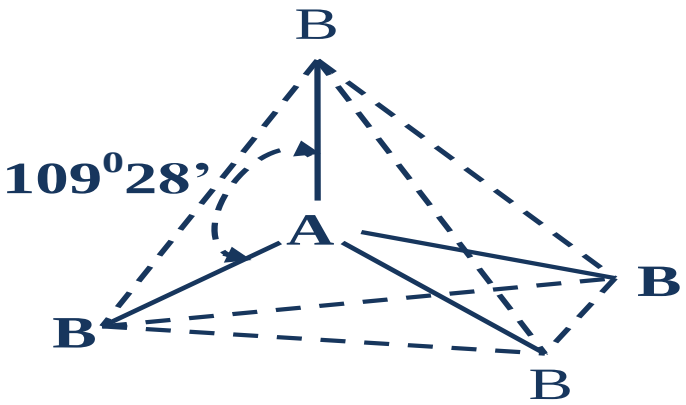
($\mu = 0$)
Trigonal Planar
e.g. BF_3, BCl_3, $AlCl_3$ etc.



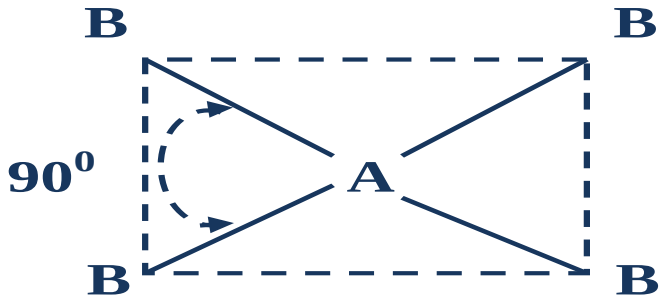
($\mu \neq 0$)
Trigonal pyramidal
e.g. NH_3, PH_3, AsH_3, NF_3, NCl_3 etc.

- Thus, if a molecule of type AB_3 has its dipole moment zero, then the geometry of molecule is trigonal Planar. On the other hand, if it has a definite non-zero value of its dipole moment, then its geometry is trigonal pyramidal.

(c) Geometry of molecules of type AB_4- For molecule of type AB_4, following two regular geometries are possible-



(μ = 0)
Tetrahedral
e.g. CH_4, CF_4, CCl_4
NH_4^+, $NiCl_4$ etc.



(μ = 0)
Square planar
e.g. XeF_4, $[Ni(CN)_4]^{2-}$ etc.

➢Thus, if a molecule of type AB_4 has its dipole moment zero, then the geometry of molecule is either tetrahedral or square planar. On the other hand, if it has a definite non-zero value of its dipole moment, then its geometry is distorted.

➢ For example, SF_4 has sea-saw shaped geometry.

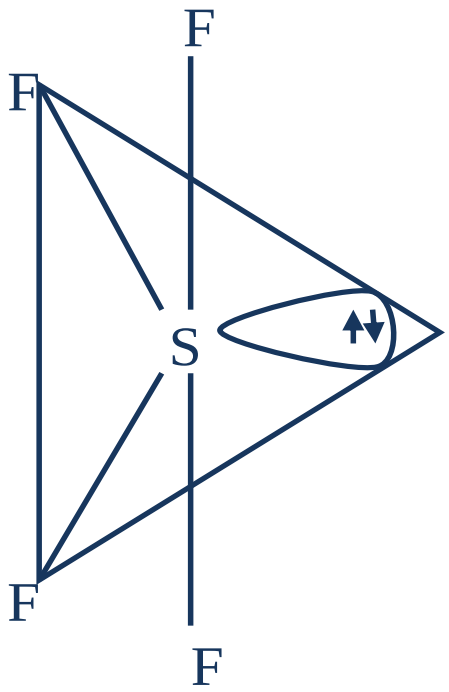
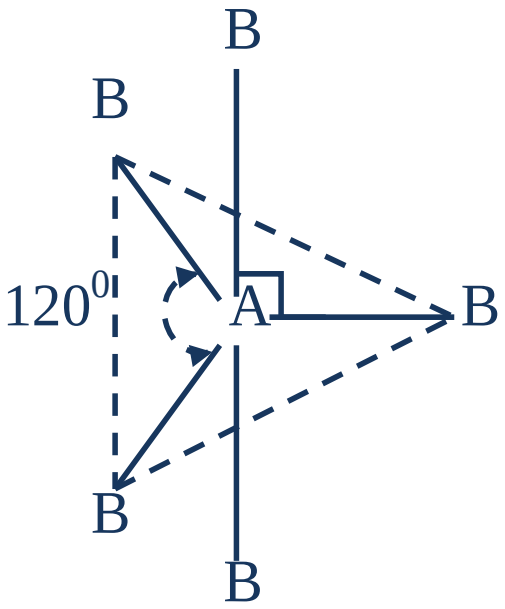


Fig.- SF_4 molecule (Sea-saw shaped)

($\mu \neq 0$)

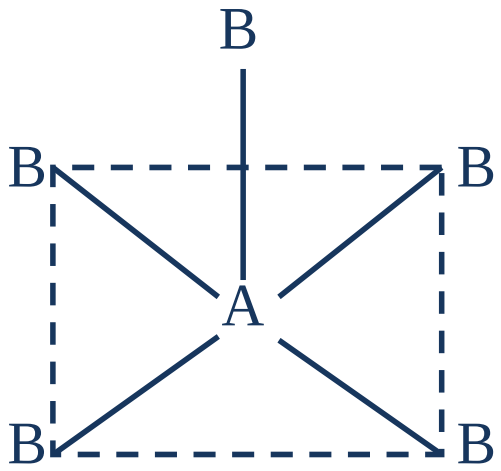
(d) Geometry of molecules of type AB_5- For molecule of type AB_5 following two geometries are possible-



($\mu = 0$)

Trigonal bipyramidal

e.g. PF_5, PCl_5



($\mu \neq 0$)

Square pyramidal

e.g. ClF_5, $XeOF_4$

(e) Geometry of molecules of type AB_6- For molecule of type AB_6, if dipole moment is zero, then the molecule has octahedral geometry. For example, SF_6 molecule.

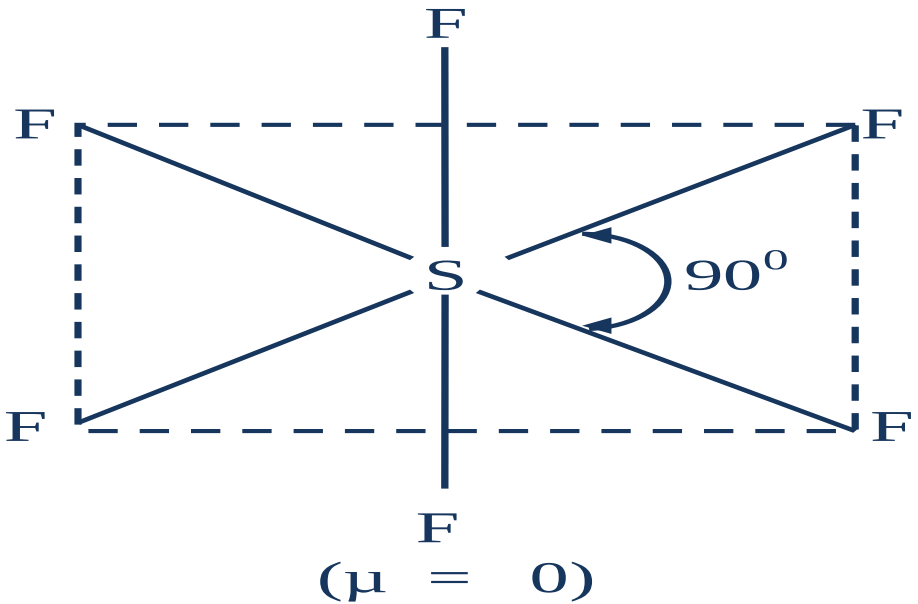


Fig.- SF_6 molecule (octahedral)

- However, if its dipole moment has a definite non-zero value, then its geometry gets distorted. For example, XeF_6 has distorted octahedral geometry.

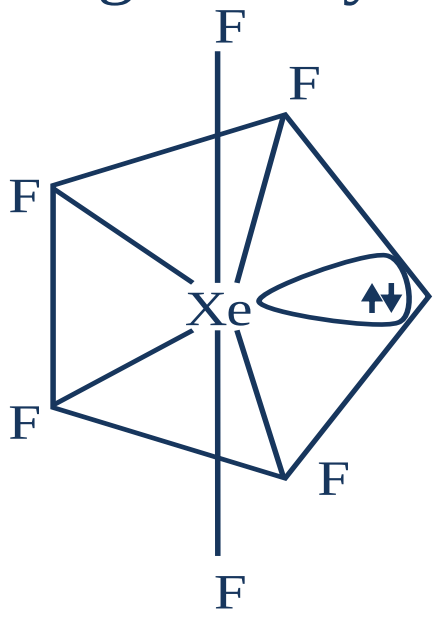


Fig.- XeF_6 molecule (distorted octahedral)

(f) Geometry of molecules of type AB_7- For molecule of type AB_7, if dipole moment is zero, then the molecule has pentagonal bipyramidal geometry. For example, IF_7 molecule.

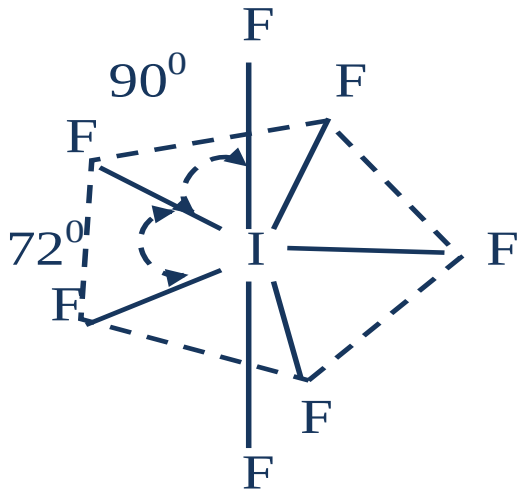
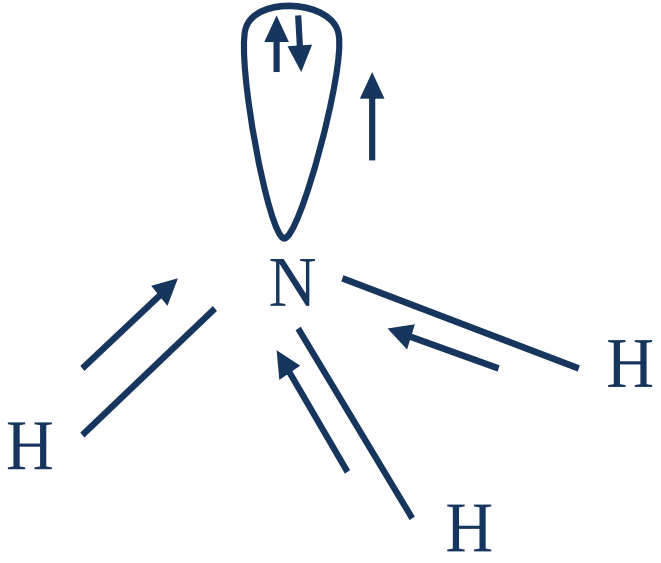
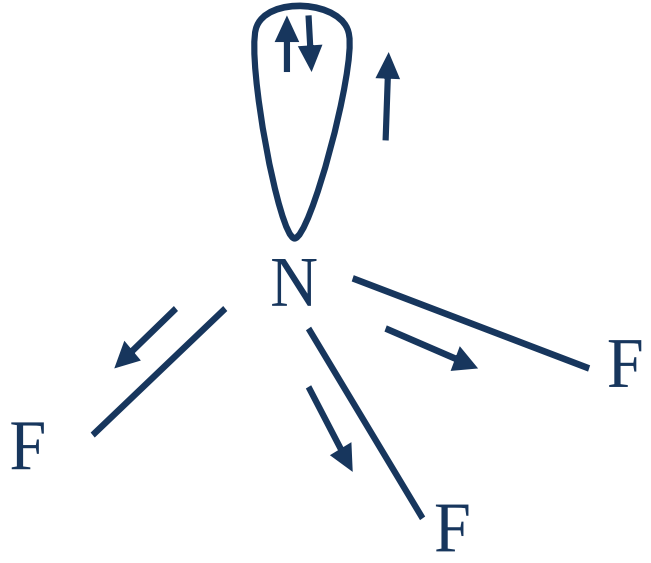


Fig.-IF_7 molecule (Pentagonal bipyramidal)

- However, if its dipole moment has a definite non-zero value, then its geometry gets distorted.
- **Q.** Amongst NH_3 and NF_3 which has more dipole moment and why ?
- **Ans.-** In NH_3, resultant dipole moments of three N-H bonds and dipole moment of lone pair operate in same direction, while in NF_3, resultant dipole moments of three N-F bonds and dipole moment of lone pair operate in opposite directions.



NH_3 molecule



NF_3 molecule

➢Thus, resultant dipole moment of NH_3 will be more than that of NF_3.

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