Class-XI

# CHEMICAL BONDING AND MOLECULAR STRUCTURE HYBRIDISATION

### ✤ HYBRIDISATION THEORY

(a) It is introduced by Pauling and slater, to explain equivalent nature of covalent bonds in a molecule.

Consider an example of Be compound: -

If it is formed without hybridization then -

р-s р-р Cl —— Be ——— Cl

both the Be–Cl bonds should have different parameters and p–p bond strength > s–p bond strength.

Practically bond strength and distance of both the Be–Cl bonds are same.

This problem may overcome if hybridization of s and p-orbital occurs.

(b) Definition: Mixing of different shapes and approximate equal energy atomic orbitals, and redistribution of energy to form new orbitals, of same shape & same energy. These new orbitals are called hybrid orbitals. and the phenomenon is called hybridization. Now after considering s-p hybridization in BeCl<sub>2</sub>

> р-sp sp-р Cl —— Be —— Cl

bond strength of both the bonds will be equal.

### Characteristic of Hybridization

- (a) Hybridization is a mixing of orbitals and not electrons. Therefore, in hybridization full filled, half-filled and empty orbitals may take part.
- (b) Number of the hybrid orbitals formed is always be equivalent to number of atomic orbitals which have taken part in the process of hybridization.

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- (c) Each hybrid orbital having two lobes, one is larger and other is smaller. Bond will be formed from large lobe.
- (d) The number of hybrid orbitals on central atom of a molecule or ion = number of  $\sigma$  bonds + lone pair of electrons.
- (e) One element can represent many hybridizations state depending on experimental conditions

**Ex.** C showing sp,  $sp^2$  and  $sp^3$  hybridization in its compounds.

- (f) Hybrid orbitals are differentiated as sp,  $sp^2$ ,  $sp^3$  etc.
- (g) The directional properties in hybrid orbital is more than atomic orbitals. Therefore, hybrid orbitals form stronger sigma bond. The directional property of different hybrid orbitals will be in following order.

$$\mathsf{sp} < \mathsf{sp}^2 < \mathsf{sp}^3 < \mathsf{sp}^3\mathsf{d} < \mathsf{sp}^3\mathsf{d}^2 < \mathsf{sp}^3\mathsf{d}^3$$

(h) Hybridize orbitals show axial overlapping & form  $\sigma$  bond

### **TYPES OF HYBRIDISATIONS**

### sp Hybridization

- (a) In this hybridization one s- & one p- orbital of an atom are mixed to give two new hybrid orbitals which are equivalent in shape & energy known as sp hybrid orbitals.
- (b) These two sp hybrid orbitals are arrange in straight line & at bond angle 180°.
- (c) s-character 50%





## sp<sup>2</sup> Hybridisation

- (a) In this hybridization one s & two p orbitals are mixed to give three new sp<sup>2</sup> hybrid orbitals which all are in same shape & equivalent energies.
- (b) These three  $sp^2$  hybrid orbitals are at angle of  $120^\circ$  & giving trigonal planar shape.
- (c) s-character 33.33% in each orbital.



# ${\rm sp}^3$ Hybridisation

- (a) In this hybridization one's orbital & three p orbitals of an atom of a molecule or ion, are mixed to give four new hybrid orbitals called as sp<sup>3</sup> hybrid orbitals.
- (b) The angle between these four hybrid orbitals will be 109° 28'



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(c) The shape obtained from these hybrid orbitals would be tetrahedron.

### ${\rm sp}^{3}{\rm d}$ Hybridisation

- (a) In this hybridization one's orbital, three p orbitals and one d orbital are mixed to give five new hybrid orbitals which are equivalent in shape and energy called as sp<sup>3</sup>d hybrid orbitals.
- (b) Out of these five hybrid orbitals, three hybrid orbitals are at 120° angle and two hybrid orbitals are perpendicular to the plane of three hybrid orbitals that is trigonal planar, the shape of molecule becomes is trigonal bipyramidal.

For example, PCl5 showing sp $^3$ d hybridization



Structure of PCl<sub>5</sub>



P (ground state)





(c) In this hybridization  $dz^2$  orbital is hybridized with s and p orbitals.

In this way five  $sp^3d$  hybrid orbitals form five sigma bonds with five Cl atoms and give a molecule of PCl<sub>5</sub>, shape of this molecule is trigonal bipyramidal.

Axial two P-Cl bonds are longer than equatorial three P-Cl bond due to repulsion

between 3 equatorials b.p. of e<sup>-</sup> and 2 axial b.p. of e<sup>-</sup>

### $sp^{3}d^{2}$ Hybridisation

- (a) In this hybridization, one s-orbital, three p-orbitals & two d-orbitals are mixed to give six new hybrid orbitals known as  $sp^3d^2$  hybrid orbitals.
- (b) The shape of molecule obtained from above six hybrid orbitals will be symmetrical octahedral.
- (c) The angle between all hybrid orbitals will be 90°.

**Ex.** SF<sub>6</sub>, AlF<sub>6</sub><sup>-3</sup>, PF<sub>6</sub><sup>-</sup>, ICl<sub>5</sub>, XeF<sub>4</sub>, XeOF<sub>4</sub>, ICl<sub>4</sub><sup>-</sup>,

(d) Two 'd' orbital participates in the hybridization are  $dx^2-y^2$  and  $dz^2$ .

<b>SF</b> <sub>6</sub> S (ground state)	3s 3p 3d   1L 1L 1
	3s 3p 3d   1 1 1 1
S (II <sup>nd</sup> excited state)	sp <sup>3</sup> d <sup>2</sup> hybridisation
	$sp^3d^2 sp^3d^2 sp^3d^2 sp^3d^2 sp^3d^2 sp^3d^2$
S (after hybridization) share $6e^-$ with 6 F atoms $F = F = F = F = F$	

### $sp^{3}d^{3}$ Hybridisation

- (a) In this hybridization, one s-orbital, three p-orbitals & three d-orbitals are mixed to give seven new hybrid orbitals known as  $sp^3d^3$  hybrid orbitals.
- (b) In this hybridization d-orbitals used are  $d_{XV}$ , & orbitals.
- (c) These seven  $sp^3d^3$  orbitals are configurated in pentagonal bipyramidal shape.
- (d) Five bond angles are of  $72^{\circ}$  & ten bond angles of  $90^{\circ}$ .
- (e) The following examples showing  $sp^3d^3$  hybridization –IF<sub>7</sub> & XeF<sub>6</sub>.



### **Co-Ordinate Covalent Bond:**

- (a) It is a covalent bond in which the shared electron pair come from one atom is called coordinate bond.
- (b) Necessary conditions for the formation of co-ordinate bond are
  - (i) Octet of donor atom should be complete and should have atleast one lone pair of electrons.
  - (ii) Acceptor atom should have a deficiency of at least one pair of electrons.
- (c) Atom which provide electron pair for shairing is called donor.
- (d) Other atom which accepts electron pair is called acceptor. That is why it is called donor-acceptor or dative bond or Dipolar Bond.



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BF<sub>3</sub> is electron deficient compound.

F



Ex.



N20

 $N \equiv N: \rightarrow O$ ;