# HYBRIDISATION

(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:

$$\text{Cl} \overset{\text{p-s}}{—} \text{Be} \overset{\text{p–p}}{——} \text{Cl}$$

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 newly formed orbitals are referred to as hybrid orbitals, and this phenomenon is known as hybridization.
Now after considering s–p hybridization in $BeCl_2$

$$\text{Cl} \overset{\text{p–sp}}{—} \text{Be} \overset{\text{sp–p}}{———} \text{Cl}$$

bond strength of both the bonds will be equal.

## Salient Features of Hybridisation

## Characteristic of Hybridization

(a) Hybridization involves a mixing of orbitals rather than electrons. Therefore, in hybridization, fully filled, half-filled, and empty orbitals may participate.
(b) The number of hybrid orbitals formed is always equivalent to the number of atomic orbitals that have participated in the hybridization process.
(c) Each hybrid orbital possesses two lobes, one larger and the other smaller. Bond formation occurs from the larger lobe.
(d) The number of hybrid orbitals on the central atom of a molecule or ion is equal to the sum of the number of σ bonds and lone pairs of electrons.
(e) An element can exhibit multiple hybridization states depending on experimental conditions.

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

(f) Hybrid orbitals are classified as sp, $sp^2$, $sp^3$, and so on.
(g) Hybrid orbitals exhibit greater directional properties compared to atomic orbitals, resulting in the formation of stronger sigma bonds.
The directional order of different hybrid orbitals is as follows:

$$sp < sp^2 < sp^3 < sp^3d < sp^3d^2 < sp^3d^3$$

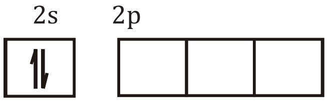
(h) Hybridized orbitals demonstrate axial overlapping and give rise to sigma bonds.

## Types Of Hybridisations

### (i) sp Hybridization

(a) In this hybridization, one s-orbital and one p-orbital of an atom are combined to form two new hybrid orbitals that are identical in shape and energy, referred to as sp hybrid orbitals.
(b) The two sp hybrid orbitals are aligned in a straight line with a bond angle of 180°.
(c) s-character 50%

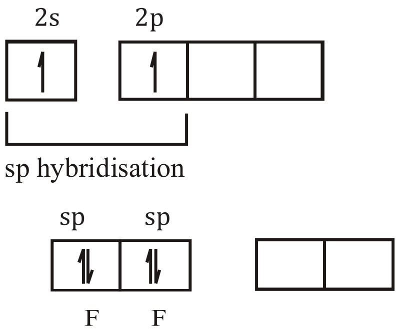
Be (ground state)



Be (excited state)

Be atom share two electrons

with F in $BeF_2$,



## (ii) $sp^2$ Hybridisation

(a) In this hybridization, one s-orbital and two p-orbitals combine to form three new $sp^2$ hybrid orbitals, all of which have the same shape and equivalent energy.

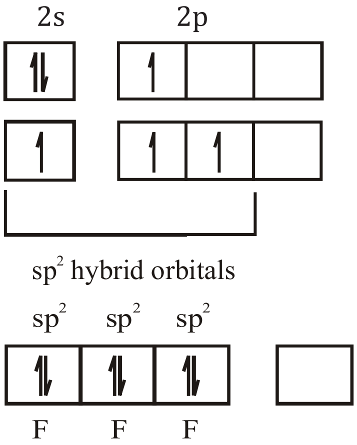
(b) The three $sp^2$ hybrid orbitals are arranged at an angle of 120°, resulting in a trigonal planar shape.

(c) Each orbital has 33.33% s-character.

B (ground state)

B (excited state)

B atom share 3 electrons with 3 F atoms in $BF_3$



## (iii) $sp^3$ Hybridisation

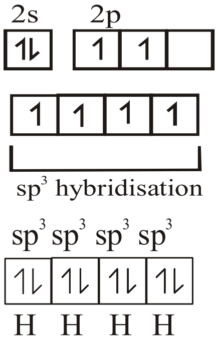
(a) In this hybridization one's orbital & three p orbitals of an atom of a molecule or ion, are mixed to give four new hybrid orbitals called as $sp^3$ hybrid orbitals.

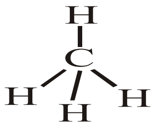
(b) The angle between these four hybrid orbitals will be 109° 28'

C (ground state)

C (excited state)

C atom share four electrons with 4 hydrogen atoms





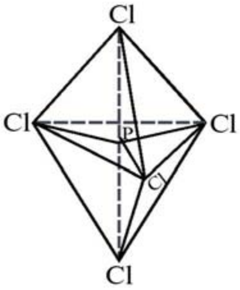
(c) The shape obtained from these hybrid orbitals would be tetrahedron.

### (iv) $sp^3d$ 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 $sp^3d$ hybrid orbitals.

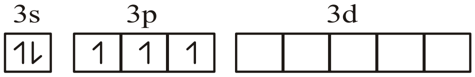
(b) Out of these five hybrid orbitals, three hybrid orbitals are at 120° angle and two hybrid orbitals are perpendicular to the plane of three hybrid orbitals that is trigonal planar, the shape of molecule becomes is trigonal bipyramidal.

For example, $PCl_5$ showing $sp^3d$ hybridization

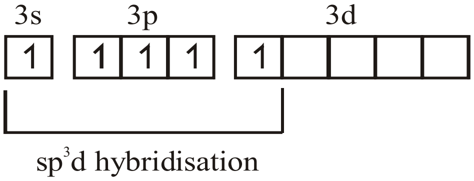


Structure of $PCl_5$

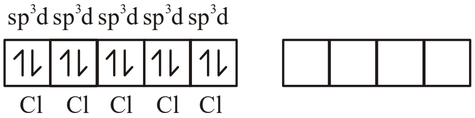
P (ground state)



P* (excited state)



P atom share five e with Cl



(c) In this hybridization, the $dz^2$ orbital undergoes hybridization with s and p orbitals. Consequently, five $sp^3d$ hybrid orbitals are generated, forming five sigma bonds with five Cl atoms, resulting in the formation of a $PCl_5$ molecule with a trigonal bipyramidal shape. Axial two P–Cl bonds are longer than equatorial three P–Cl bond due to repulsion between 3 equatorials b.p. of $e^-$ and 2 axials b.p. of $e^-$

### (v) $sp^3d^2$ Hybridisation

(a) In this hybridization, a combination of one s-orbital, three p-orbitals, and two d-orbitals results in the formation of six new hybrid orbitals, referred to as $sp^3d^2$ hybrid orbitals.

(b) The molecule derived from these six hybrid orbitals exhibits a symmetrical octahedral shape.

(c) The angles between all hybrid orbitals measure 90°.

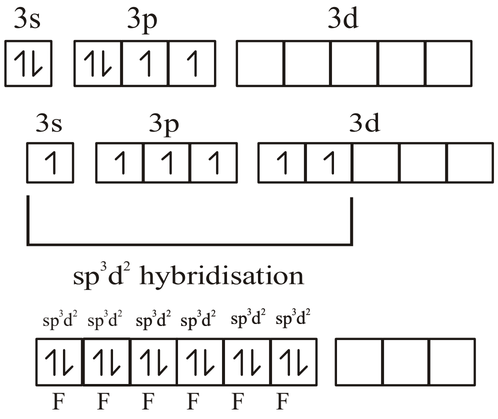
Ex. $SF_6$, $AlF_6^{-3}$, $PF_6^-$, $ICl_5$, $XeF_4$, $XeOF_4$, $ICl_4^-$,

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

$SF_6$ S (ground state)

S (II$^{nd}$ excited state)

S (after hybridization) share $6e^-$ with 6 F atoms



## (vi) $sp^3d^3$ Hybridisation

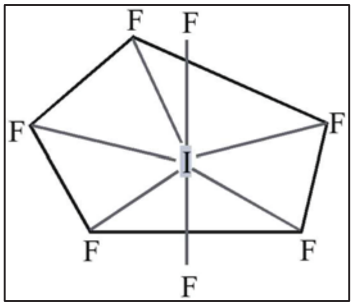
(a) In this hybridization, the combination of one s-orbital, three p-orbitals, and three d-orbitals results in the creation of seven new hybrid orbitals, referred to as $sp^3d^3$ hybrid orbitals.

(b) The d-orbitals involved in this hybridization are dxy and the orbitals.

(c) These seven $sp^3d^3$ orbitals are arranged in a pentagonal bipyramidal shape.

(d) The bond angles include five angles measuring 72° and ten angles measuring 90°.

(e) Examples illustrating $sp^3d^3$ hybridization include $IF_7$ and $XeF_6$.



### Important Conditions for Hybridisation

(i) Hybridization involves the blending or combination of orbitals within the atom's valence shell.

(ii) The orbitals participating in hybridization are required to exhibit a minimal difference in energy levels.

(iii) The promotion of electrons is not a mandatory prerequisite for hybridization.

(iv) Hybridization is not exclusively limited to half-filled orbitals; instead, even completely filled orbitals within the valence shell or vacant orbitals can participate in the hybridization process in certain instances.