Plane of Symmetry

Plane of Symmetry is defined as an imaginary Plane that bisects the molecule in Such a way that the two Parts are mirror images of each Other.

It should be noted that the operation of reflection gives a Configuration equivalent to the Original one.

If the Operation is Carried out twice on the molecule, we get the Original Configuration.

i.e. $\sigma.\sigma. = \sigma^2 = E$

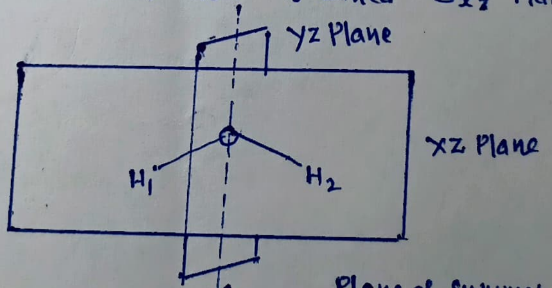
The plane of symmetry Can be Classified into three types:-

(a) Vertical Plane(σ_v):- The plane passing through the Principal axis and one of the subsidiary axis (if present) is Called Vertical Plane.

(b) Horizontal Plane(σ_h):- The plane which is perpendicular to the principal axis is Called Horizontal Plane.

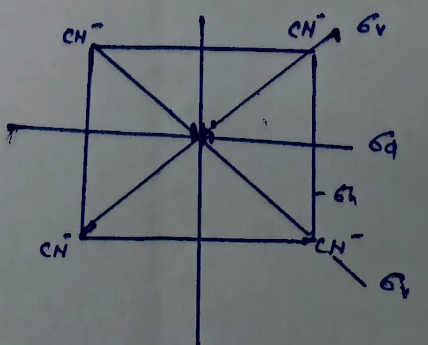
(c) Dihedral Plane (σ_d):- The plane passing through the Principal axis but bisecting an angle between two subsidiary axis (C_2) is called dihedral plane.

Now Consider water (H_2O) molecule. It has two symmetry planes ie σ_{xz} & σ_{yz}. One is passing through oxygen atom and bisecting the angle ∠HOH Called as σ_{yz} Plane. The Other plane of symmetry is passing through oxygen atom and two H-atom is called σ_{xz} Plane.



Plane of symmetry in H_2O molecule.

In case of square planar $[Ni(CN)_4]^{2-}$ there are four σ_v Planes and one σ_h Plane. Two σ_v Planes pass through C_4 axis, Ni(II) ion and two CN^- ions at opposite Corners. Two σ Plane pass through C_4 axis, Ni(II) ion and between two CN^- and is called σ_d. The molecular plane passing through Ni(II) ion and four CN^- ion is Called σ_h



Similarly in hexagonal Planar Benzene molecule, $S\sigma_v$ and one σ_h are Present.

Improper axis of Symmetry or Rotational - reflection axis of Symmetry (S_n):-

This operation is Combination of a rotation (C_n) with reflection(σ) in a plane perpendicular to the rotational axes.

After this Composite Operation, it leaves the molecule in an indistinguishable Configuration.

$$S_n = C_n \cdot \sigma_h$$

If any molecule Contains C_n and σ_h operations, then it is generally contains S_n.

$$S_2 = C_2 \cdot \sigma_h = i$$

S_2 is i because after the rotation by 180° and then reflection in a plane perpendicular to C_2 produce i.

$$S_3 = C_3 \cdot \sigma_h$$

BCl_3 Contains S_3. BCl_3 molecule after C_3 and then $\sigma_h \perp C_3$ produce indistinguishable Configuration.

As C_n generates n operations. i.e $C_n^1, C_n^2, C_n^3 ---- C_n^n = E$ and S_n also generates n Such Operations when n is even but generates $2n$ operations when n is odd.

If n = odd

i.e. $n = 3$

$$S_3^1 = C_3^1 \cdot \sigma_h^1 = C_3 \cdot \sigma_h$$

$$S_3^2 = C_3^2\,\sigma_h^2 = C_3^2 \cdot E = C_3^2$$

$$S_3^3 = C_3^3\,\sigma_h^3 = E \cdot \sigma_h^2 \cdot \sigma_h = E \cdot E \cdot \sigma_h = \sigma_h$$

We know $\left[\begin{array}{c} C_3^3 = E \\ \sigma \cdot \sigma = \sigma^2 = E \end{array} \right]$

$$S_3^4 = C_3^4 \cdot \sigma_h^4 = C_3^3 \cdot C_3^1 \cdot \sigma_h^2 \cdot \sigma_h^2 = E \cdot C_3^1 \cdot E \cdot E = C_3^1$$

$$S_3^5 = C_3^5 \cdot \sigma_h^5 = C_3^3 \cdot C_3^2 \cdot \sigma_h^2 \cdot \sigma_h^2 \cdot \sigma_h = E \cdot C_3^2 \cdot E \cdot E \cdot \sigma_h = C_3^2 \sigma_h$$

$$S_3^6 = C_3^6\,\sigma_h^6 = C_3^3 \cdot C_3^3 \cdot \sigma_h^2 \cdot \sigma_h^2 \cdot \sigma_h^2 = E \cdot E \cdot E \cdot E \cdot E = E$$