

PGI Semester II  
INORGANIC CHEMISTRY

Symmetry Element

A symmetry element is a geometrical entity such as line, a plane, or a point, with respect to which one or more symmetry operations may be carried out.

Symmetry operations

A symmetry operation is a movement of a body such that, after the movement has been carried out, every point of the body is coincident with an equivalent point of the body in its original orientation.

or in simple words we can say that

operation of symmetry element i.e symmetry operation is a process which we apply on the element to define the symmetry.

Types of symmetry element:

There are four types of symmetry elements.

- a) Proper axis of symmetry (C)
- b) Plane of Symmetry ( $\sigma$ )
- c) Improper axis of symmetry (S)
- d) Centre of Inversion (i)

One or more symmetry operations are associated with one symmetry element.

Identity is considered as symmetry operation.

So, The four kinds of symmetry Elements and operations required in specifying molecular symmetry are.

S.No	Symmetry Elements	Symmetry operations.
1.	Proper axis of symmetry ( $C_n$ )	one or more rotation about the axis
2.	Plane of symmetry ( $\sigma$ )	Reflection in plane
3.	Improper axis of symmetry ( $S_n$ )	one or more repetitions of the sequence rotation followed by reflection in a plane perpendicular to the rotation axis.
4.	Centre of Inversion ( $i$ )	Inversion of all atoms through centre.

### Significance of different symmetry element

1.  $C_n \rightarrow$  an  $n$ -fold axis of rotation.

Rotation by  $360^\circ/n$  leaves the molecule unchanged. For example in case of  $H_2O$  molecule is  $C_2$  axis.

\* Some molecules have more than one  $C_n$  axis, in which case the one with the highest value of  $n$  is called the principal axis. For example  $BF_3$  contain both  $C_2$  and  $C_3$  axis. So, the principal axis in this case is  $C_3$ .

• Principle axis  $\rightarrow$  The principle axis of a molecule is the highest order proper rotation axis.

2.  $\sigma$  → a plane of symmetry.

A plane of symmetry is an imaginary plane that bisects a molecule into halves that are mirror images of each other. There are three types of plane of symmetry.

- Vertical plane ( $\sigma_v$ )
- Horizontal plane ( $\sigma_h$ )
- Dihedral plane ( $\sigma_d$ )

Vertical plane ( $\sigma_v$ )

A mirror plane that includes the axis is called a vertical mirror plane.

Horizontal plane ( $\sigma_h$ )

A mirror plane which is perpendicular to the axis is called horizontal plane.

Dihedral plane ( $\sigma_d$ )

A vertical plane that bisects the angle between two  $C_2$  axes is called a dihedral mirror plane ( $\sigma_d$ ).

3.  $i$  → centre of symmetry or centre of inversion

If a molecule can be brought into an equivalent configuration by changing the coordinates  $(x, y, z)$  of every atom, where the origin of coordinates lies at a point within the molecule, into  $(-x, -y, -z)$ , then the point at which the origin lies is said to be a centre of symmetry or centre of inversion.

4.  $S_n$  - an n-fold improper rotation axis. (Improper axis of rotation)

An important rotation may be thought of as taking place in two steps: First a proper rotation and then a reflection through a plane perpendicular to the rotation axis.

Then the axis about which this occurs is called an axis of improper rotation or Improper axis.

$E \rightarrow$  the identity - The identity operation consists of doing nothing and corresponding symmetry element is entire molecule.