

Static Stereochemistry

for

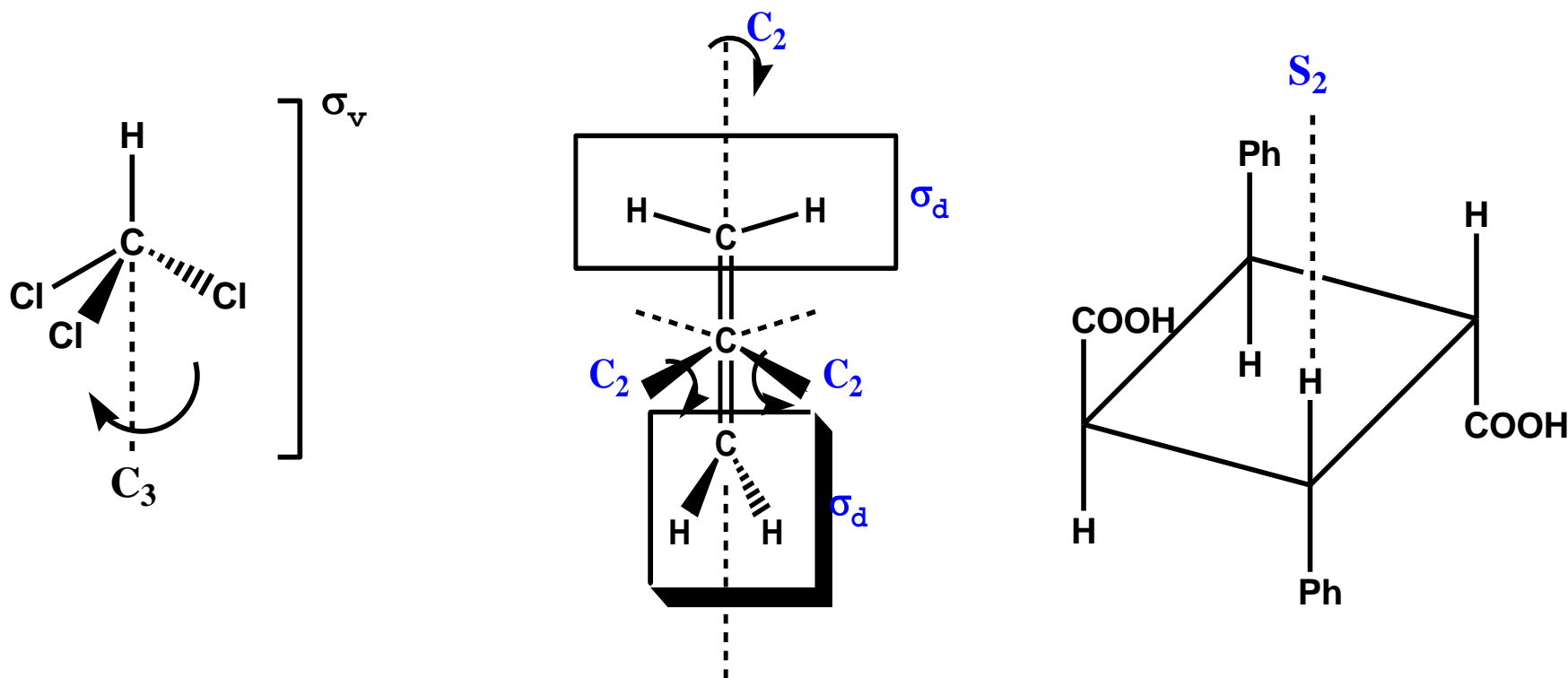
M.Sc 1st Semester

**Durgapur Government
College**

Molecular symmetry and Chirality

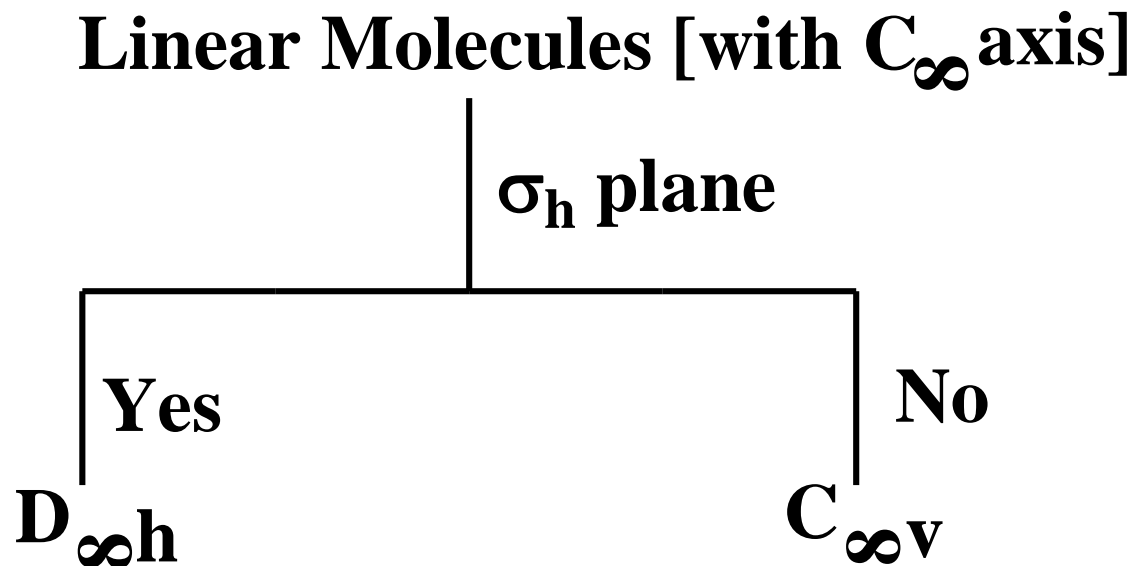
Symmetry operations

1. Simple or proper axis of symmetry: Rotation, C_n
2. Plane of Symmetry: Reflection, σ
3. Centre of Symmetry or Inversion centre: Inversion through a point, i
4. Improper or alternating axis of symmetry, Rotation-reflection, S_n



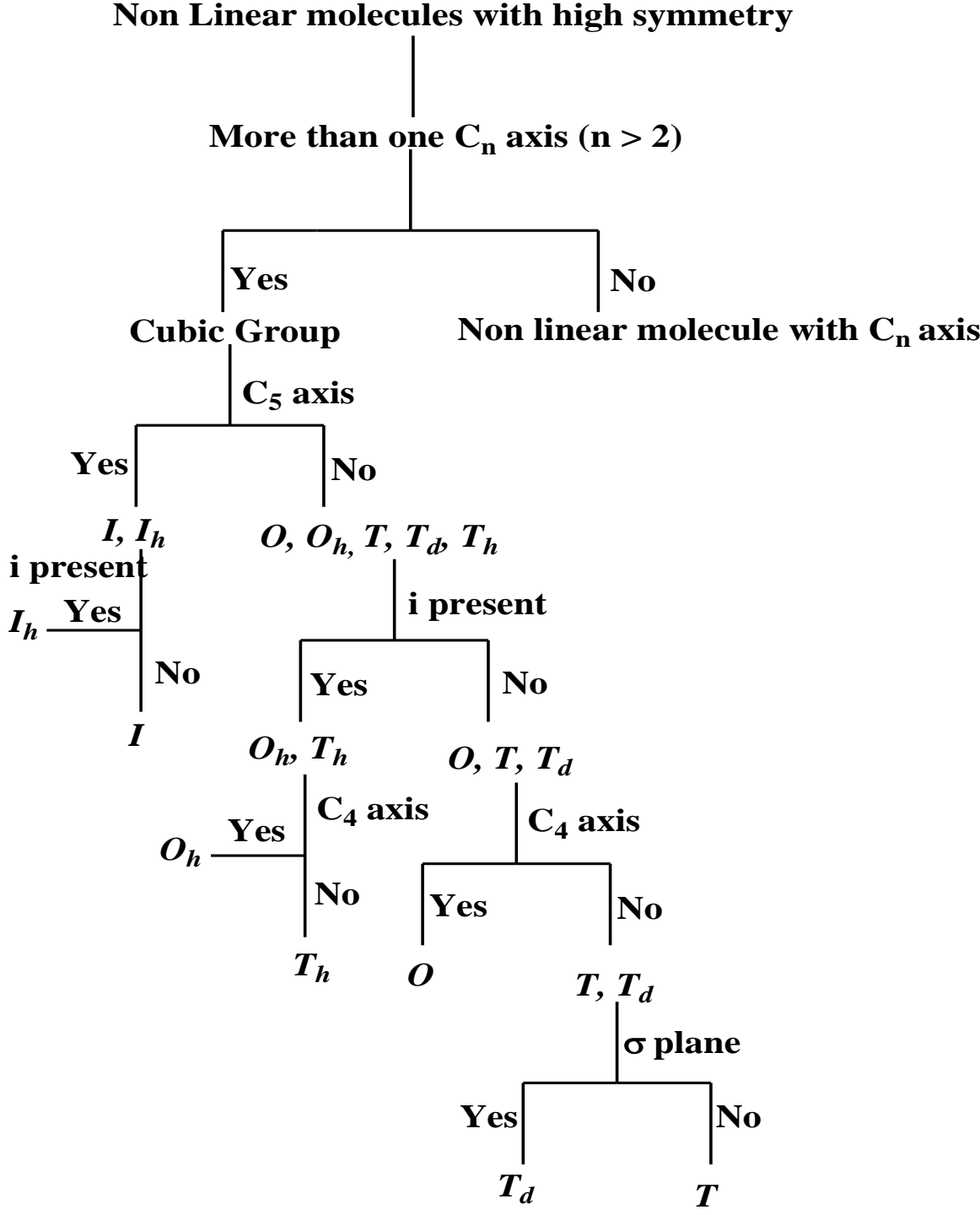
Molecular symmetry and Chirality

Classification of molecules into point groups



Molecular symmetry and Chirality

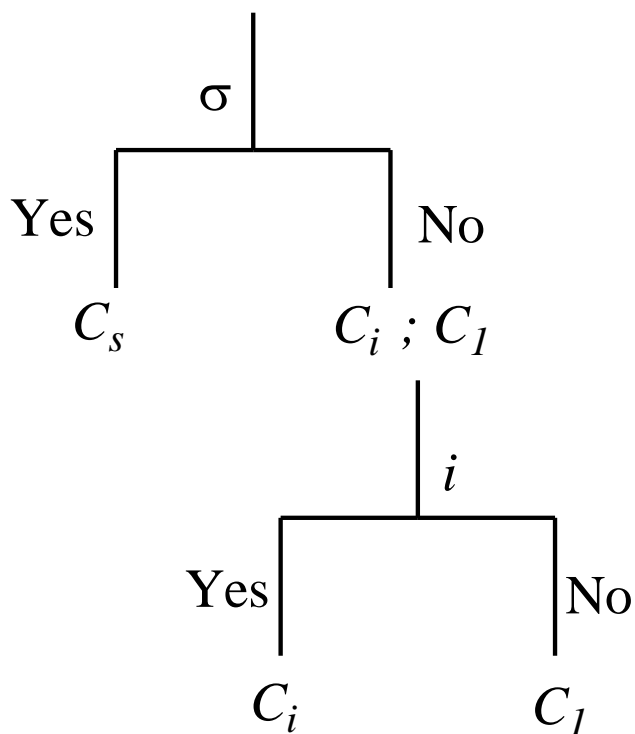
Classification of molecules into point groups



Molecular symmetry and Chirality

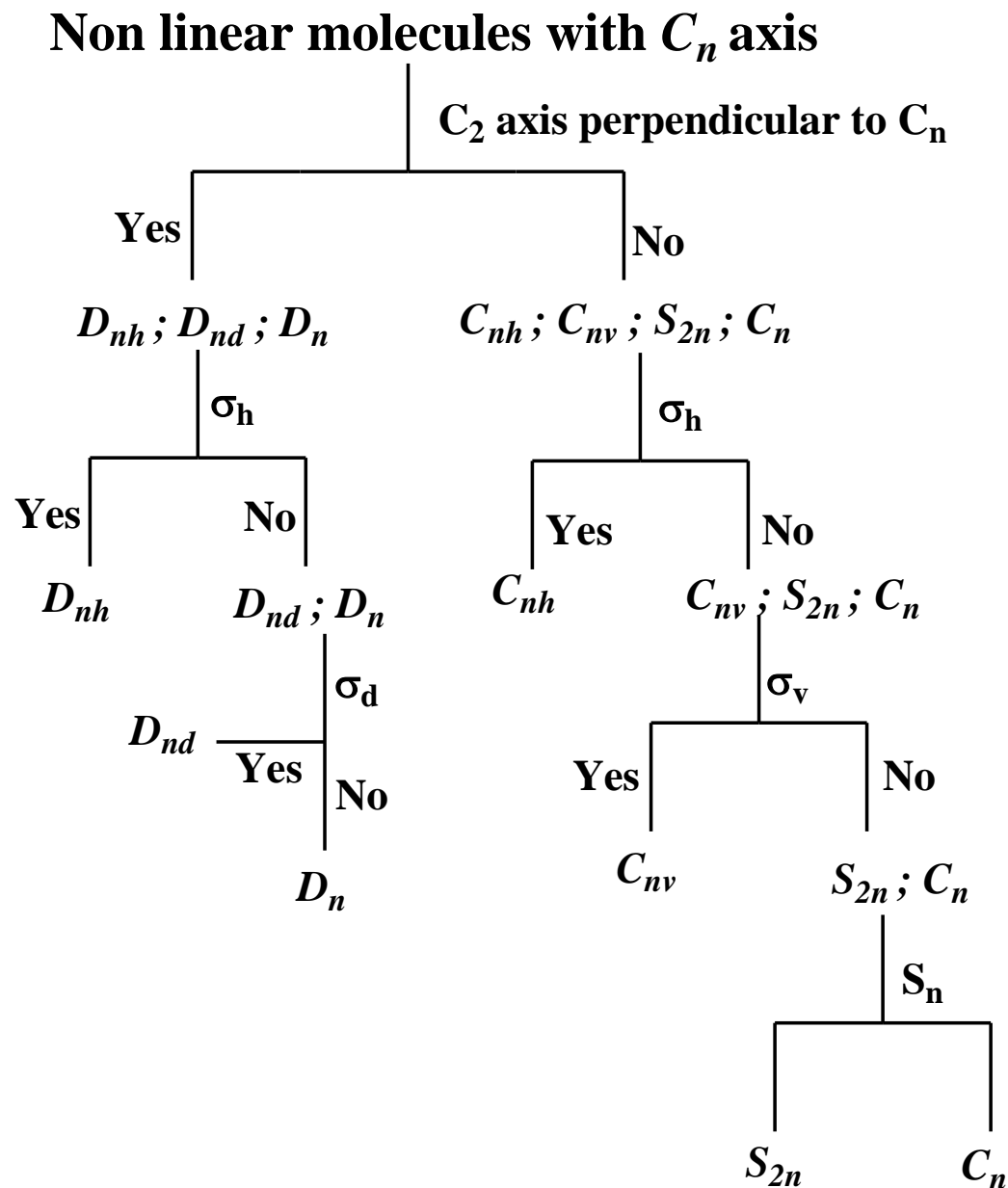
Classification of molecules into point groups

Non-linear molecules without C_n axis

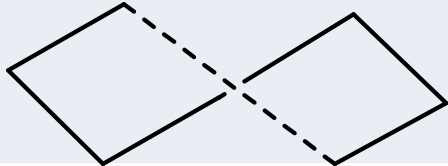
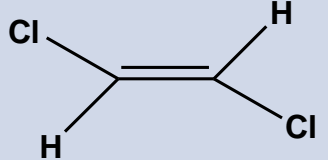
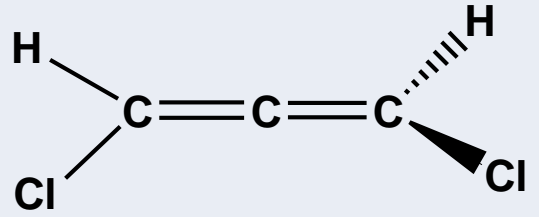


Molecular symmetry and Chirality

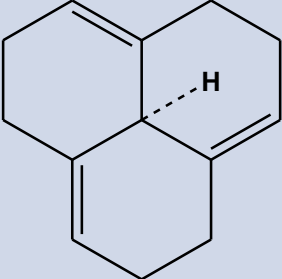
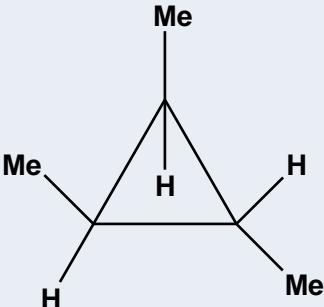
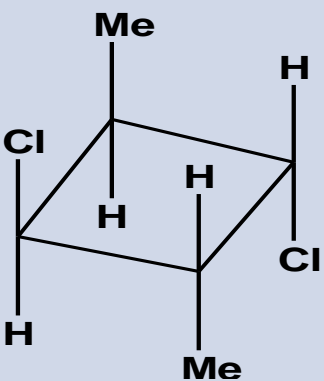
Classification
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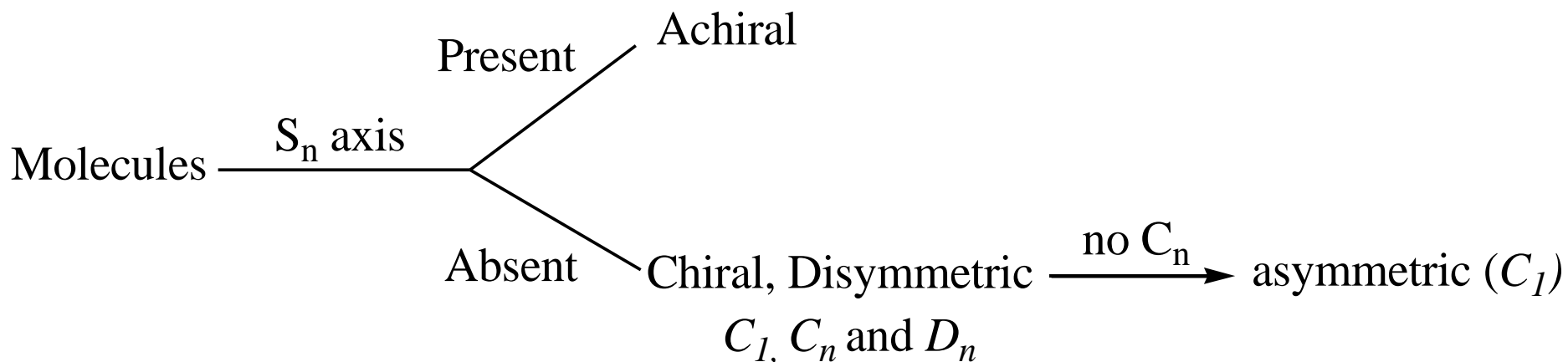
Molecular symmetry and Chirality

| Molecule | Symmetry Elements | Point Group |
|---|---|-----------------|
| CHCl ₃ | C ₃ (C _n), 3 × σ _v , no C ₂ and σ _h | C _{3v} |
| Benzene | C ₆ (C _n), 6 × C ₂ and σ _h | D _{6h} |
| Ethylene | C ₂ (C _n), 3 × C ₂ and 3 σ _d | D _{3d} |
|  | C ₂ (C _n), 2 × C ₂ ; No σ _n and σ _d | D ₂ |
|  | C ₂ (C _n), σ _h | C _{2h} |
|  | C ₂ (C _n) | C ₂ |
| Allene | C ₂ (C _n), 2 × C ₂ and 2 × σ _d | D _{2d} |
| Lactic Acid | No C _n , C _i and σ | C ₁ |

Molecular symmetry and Chirality

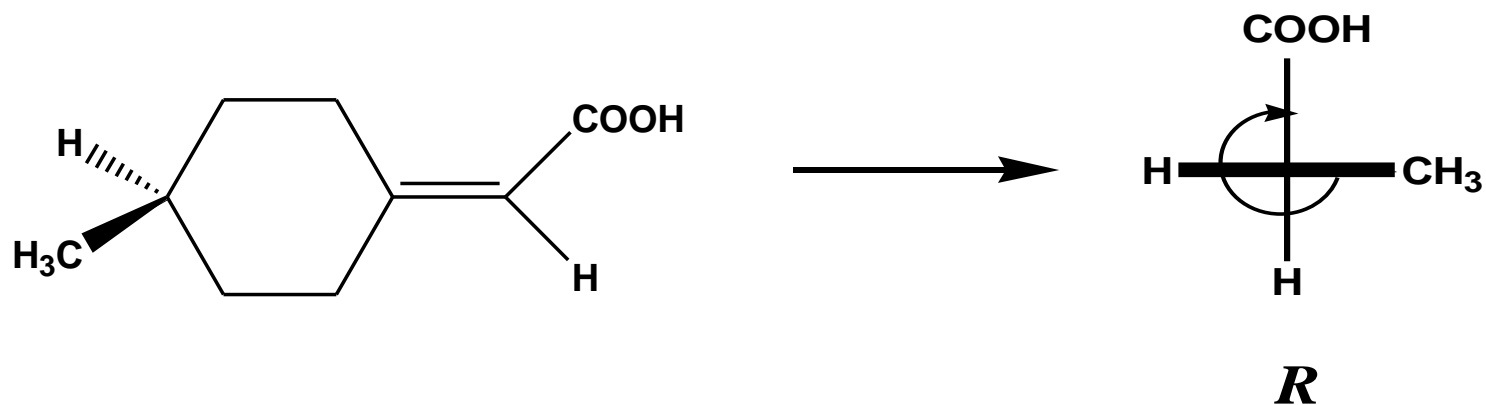
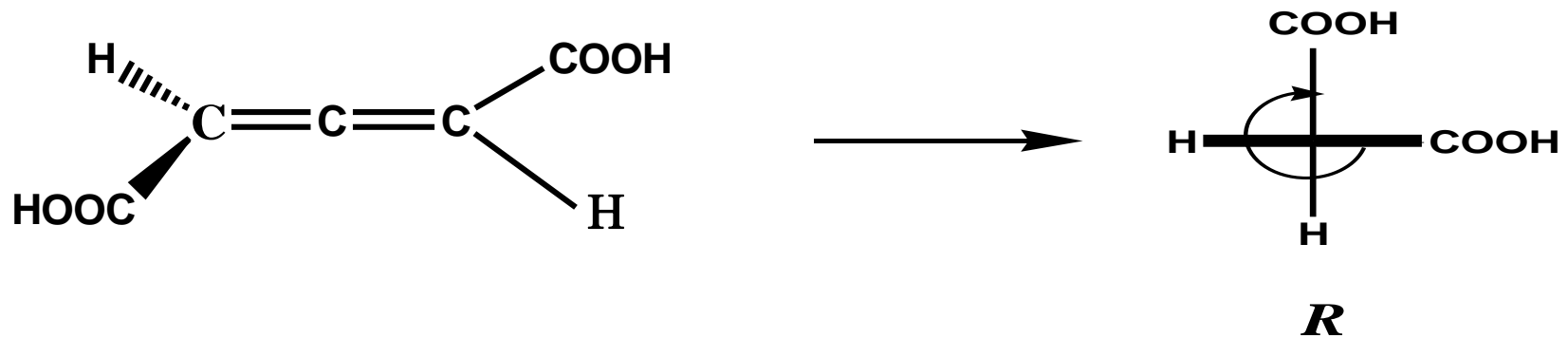
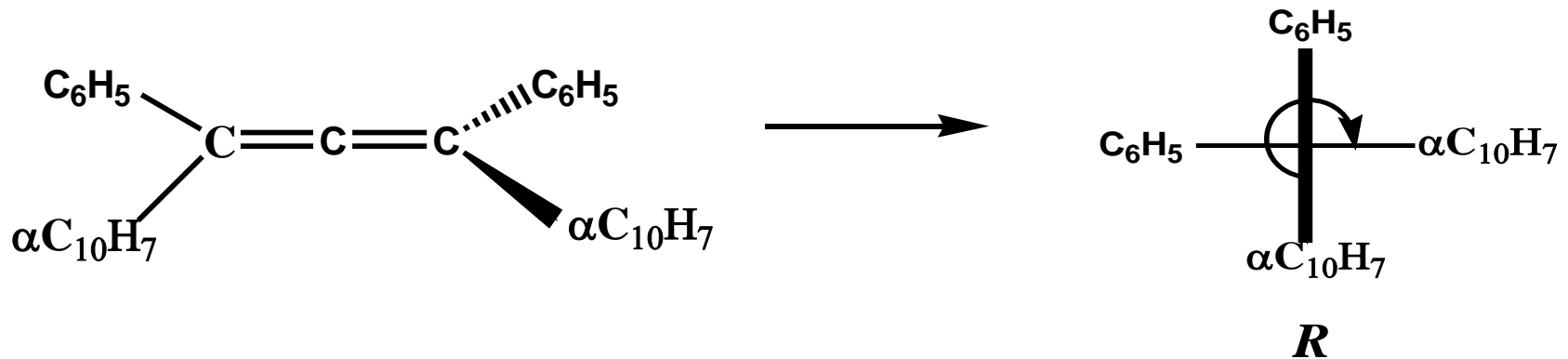
| Molecule | Symmetry Elements | Point Group |
|---|-------------------|-------------|
|  | $C_3 (C_n)$ | C_3 |
|  | σ | C_s |
|  | i | C_i |

Molecular symmetry and Chirality

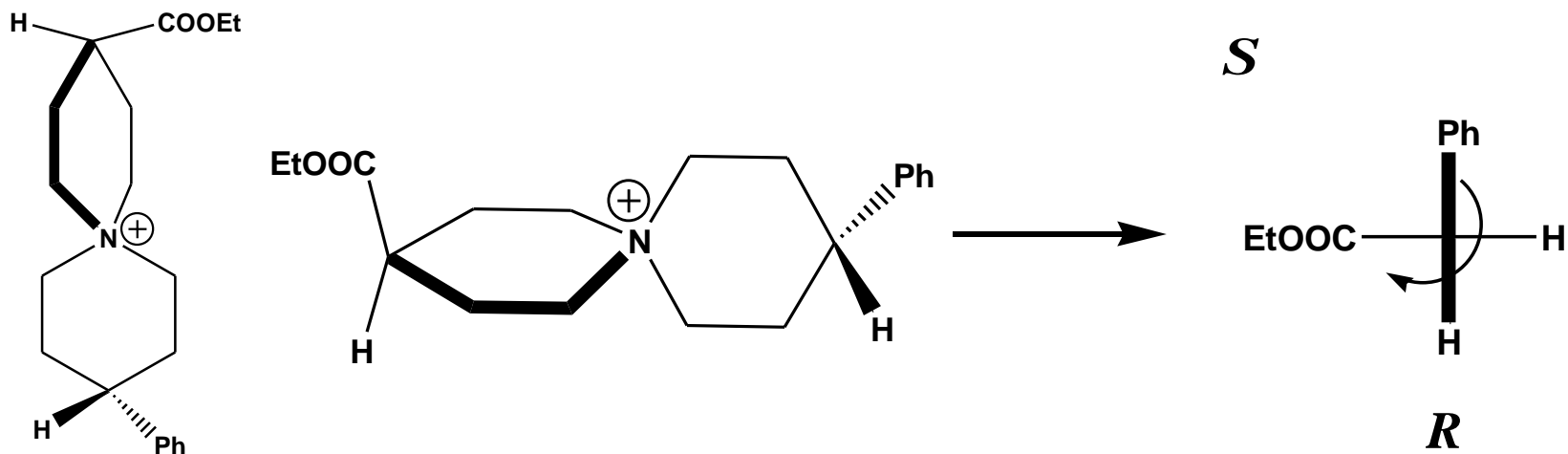
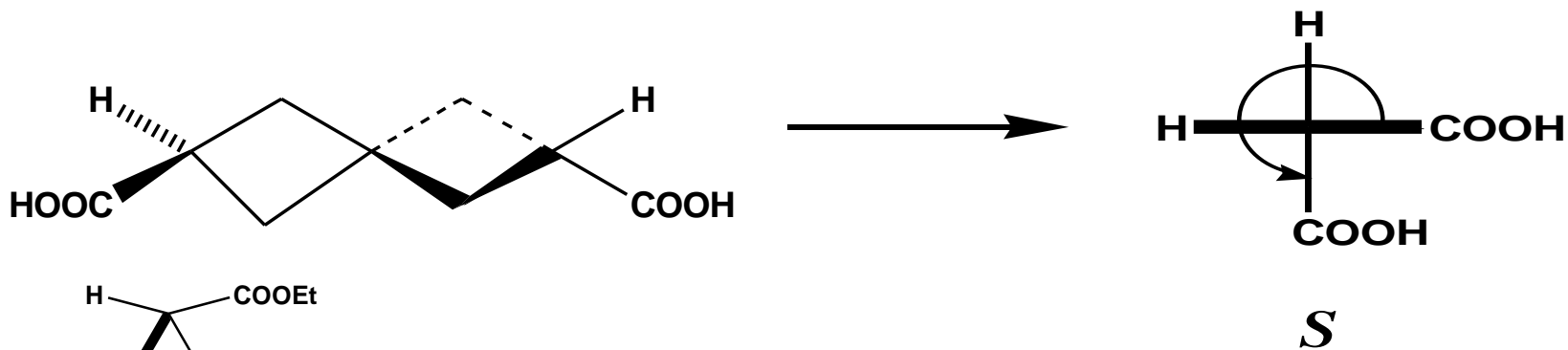
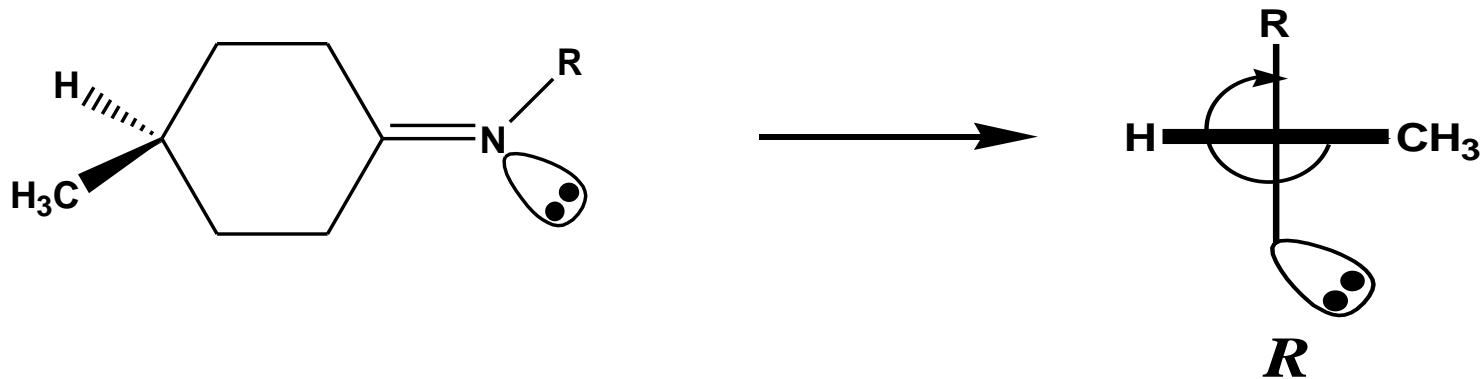


Chirality is a necessary and sufficient condition for the occurrence of enantiomerism and is determined by the absence of rotation-reflection symmetry (S_n axis of any order) in the molecule. All molecules belongs to the point groups C_1 , C_n and D_n lack reflection symmetry and are chiral while molecules belonging to rest of the point groups are achiral.

Axial chirality

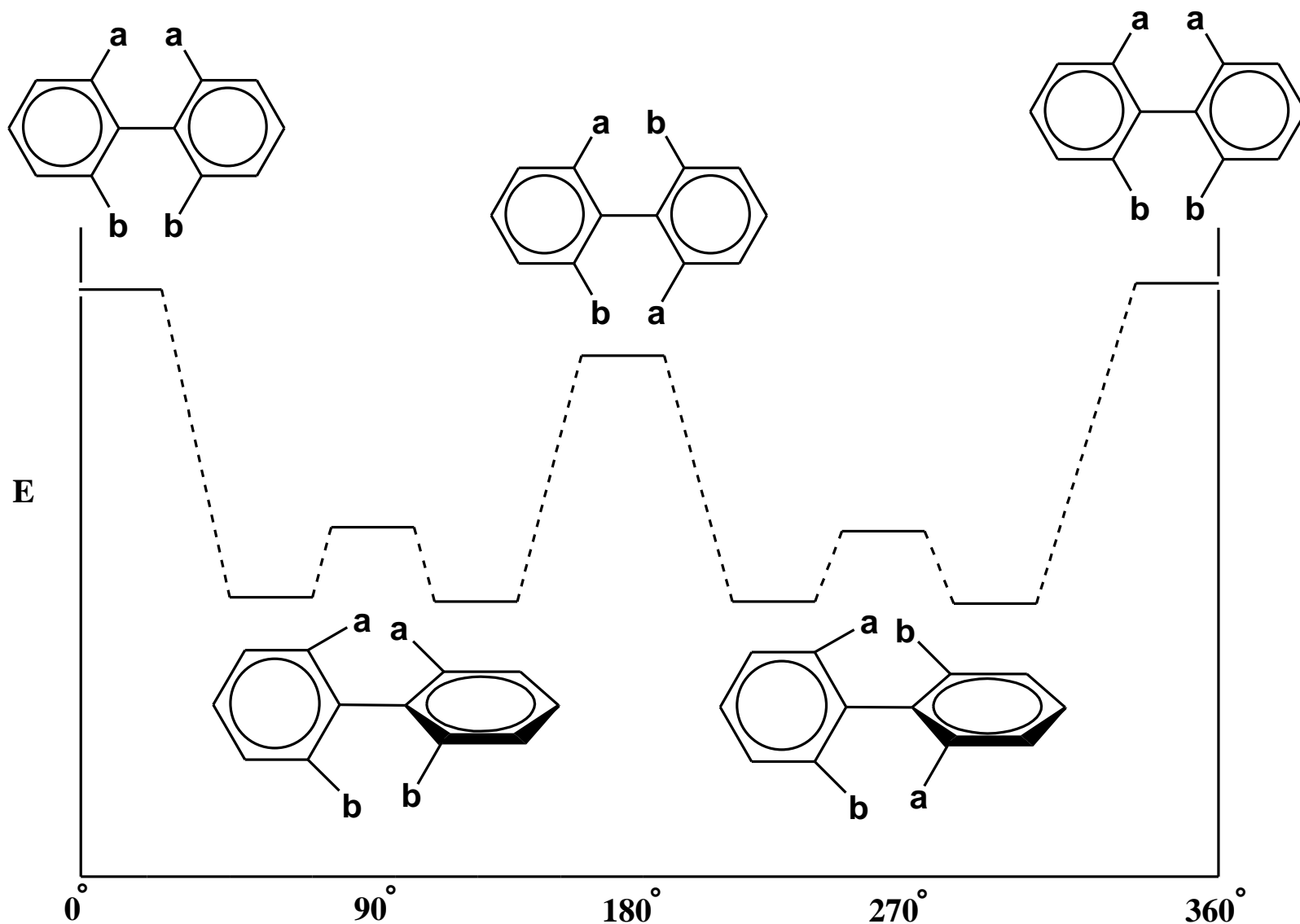


Axial chirality

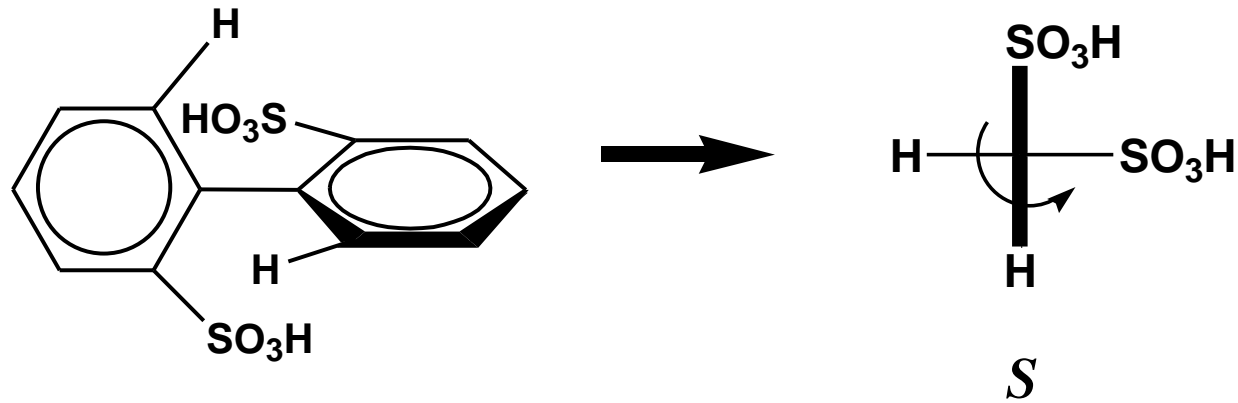


Axial chirality

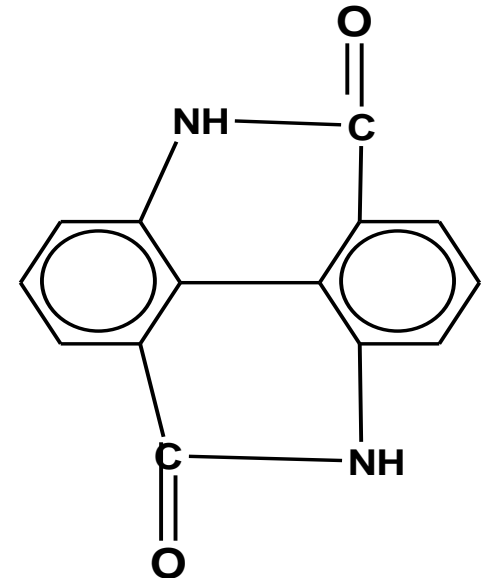
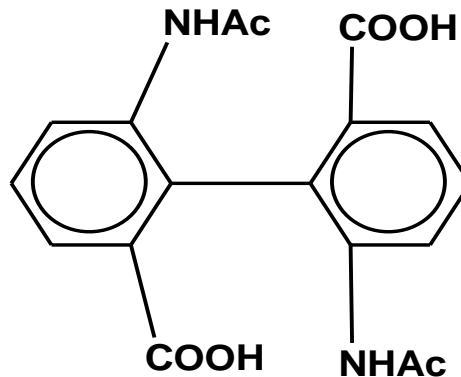
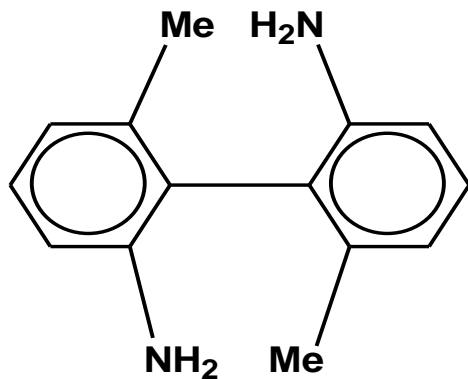
Atropisomerism



Axial chirality

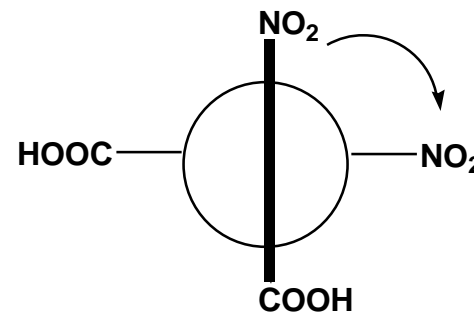
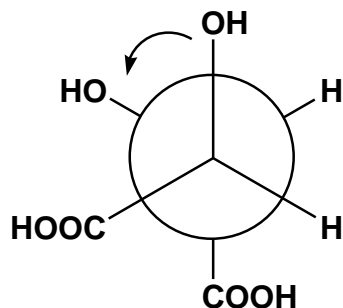
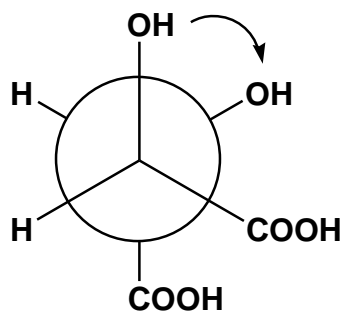
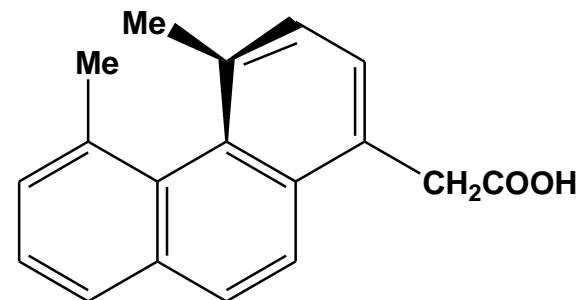
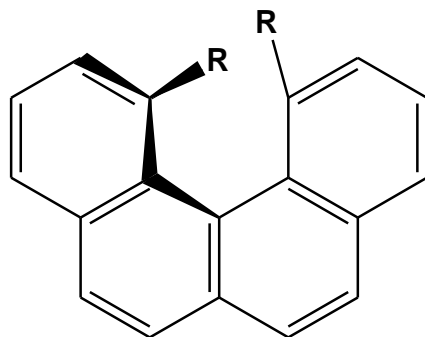
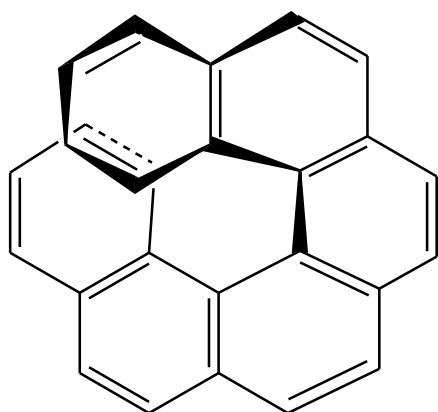


Disappearance of atropisomerism by formation of ring through ortho position



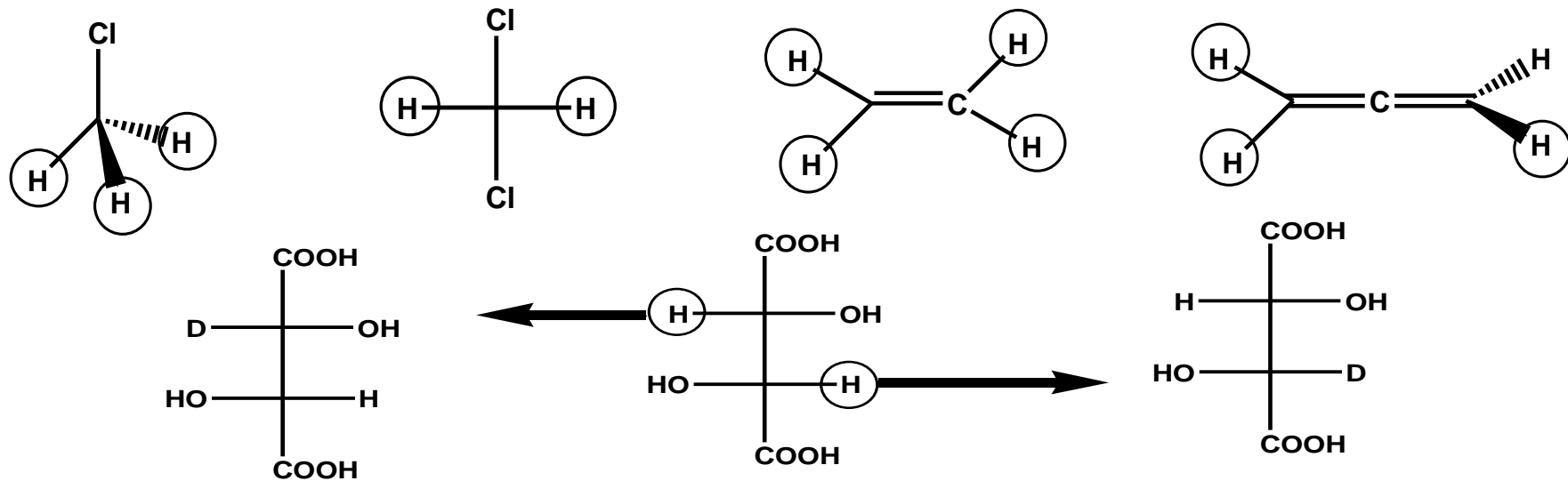
Helicity

The assignment of chiral designation to the helix is done on the basis of rotation. If moving from one end to other along the axis, the helix describes a clockwise direction, it is designated as *P* and if it describes an anticlockwise direction, it is designated *M*.

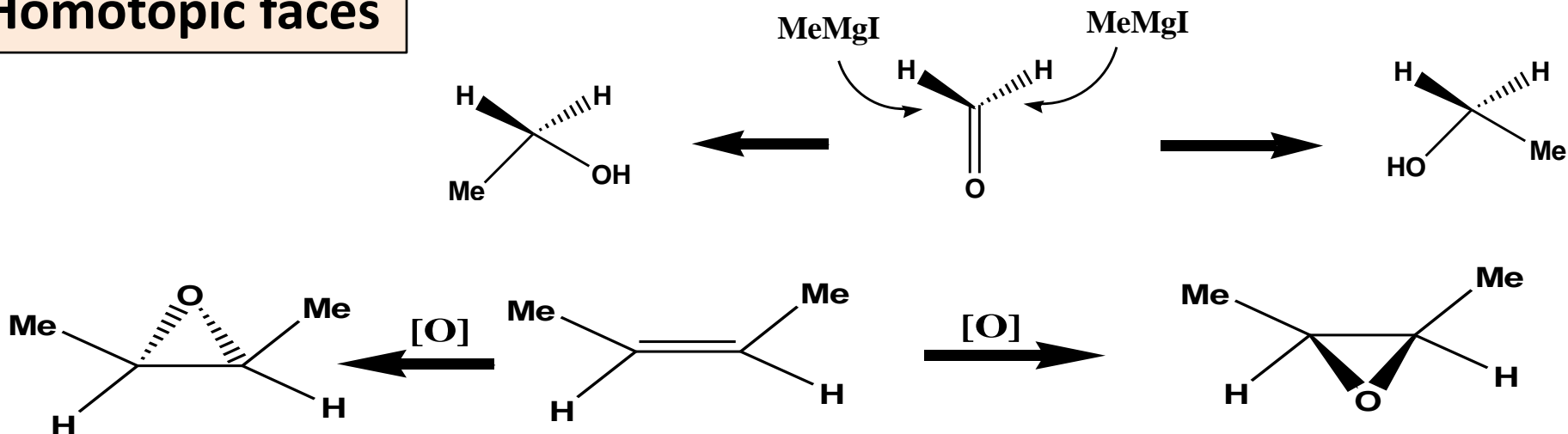


Topicity

Homotopic ligands

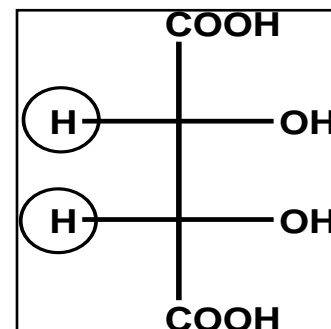
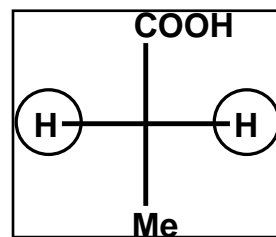
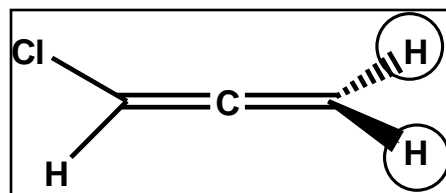
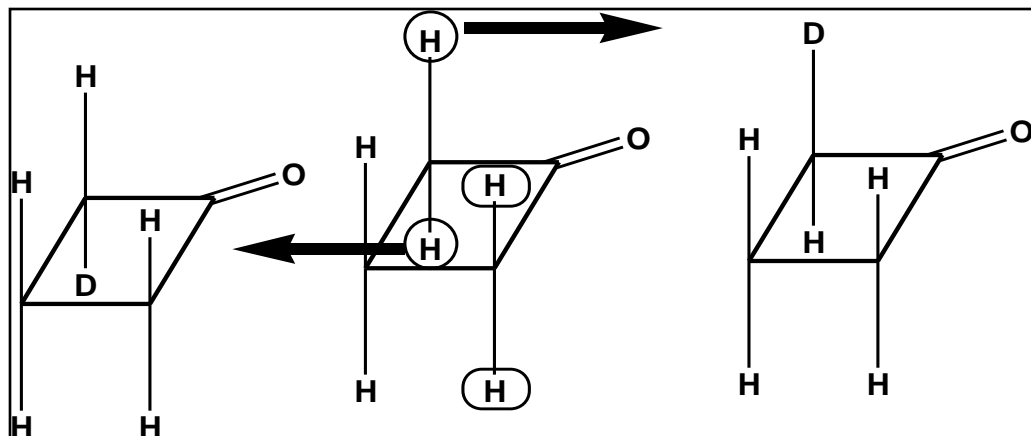


Homotopic faces

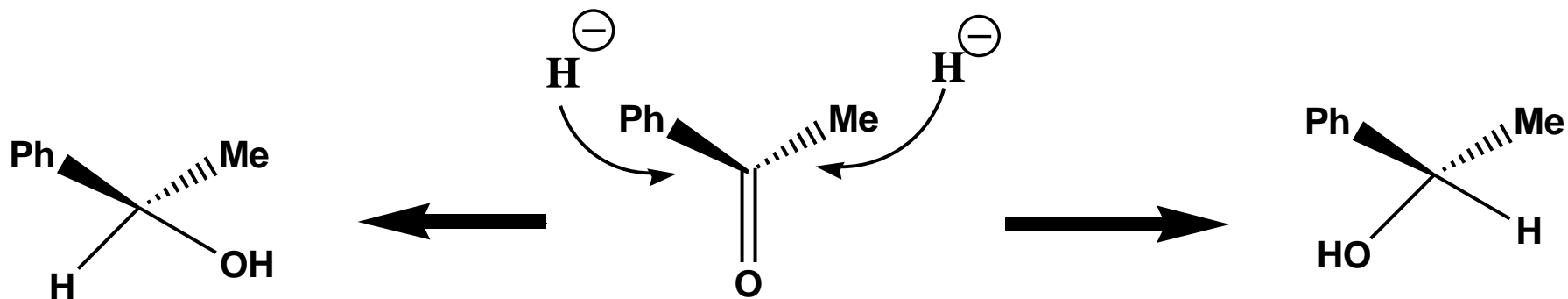


Topicity

Enantiotopic ligands

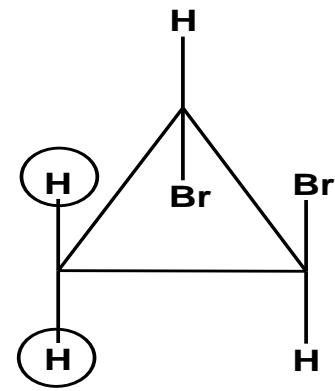
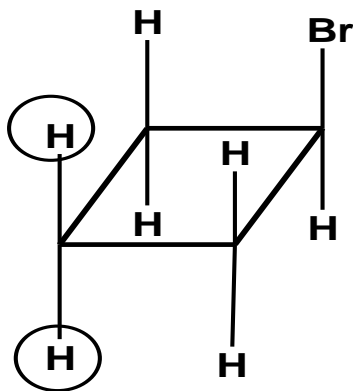
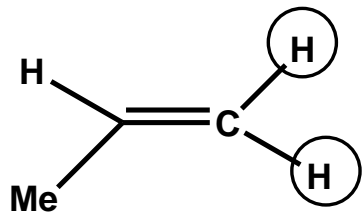


Enantiotopic faces

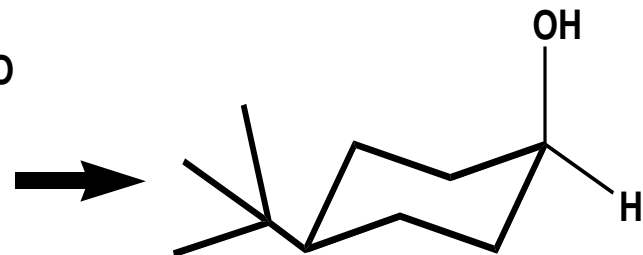
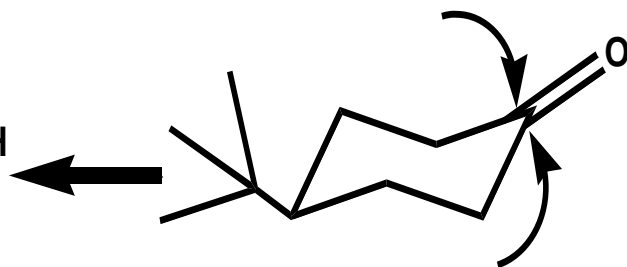
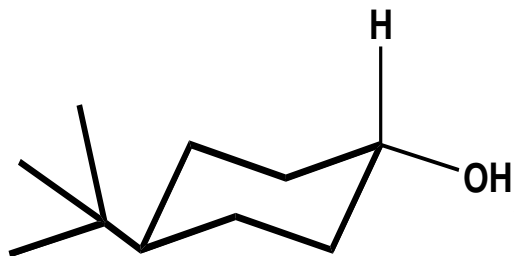
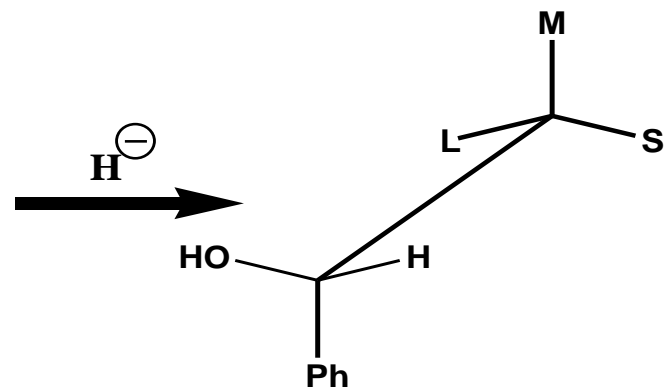
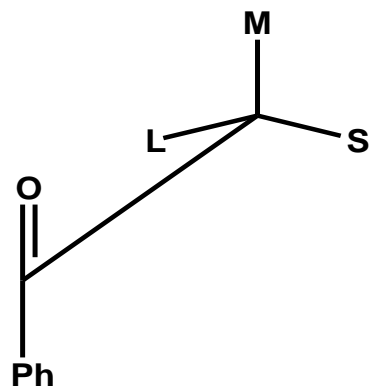
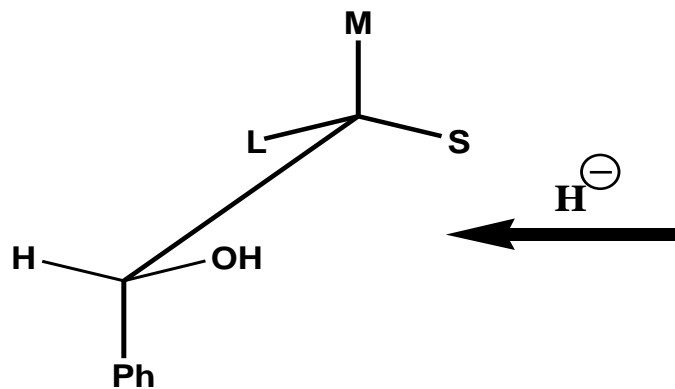


Topicity

Diastereotopic ligands



Diastereotopic faces



Prostereoisomerism

Molecules with stereoheterotopic ligands and faces are prostereogenic and an appropriate chemical (or biochemical) reaction transforms them into stereoisomers.

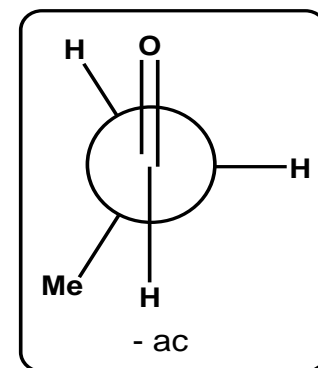
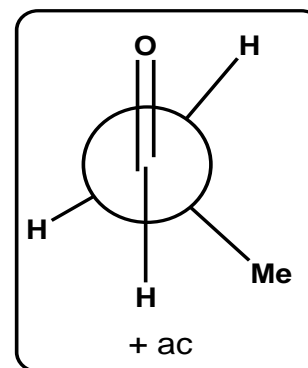
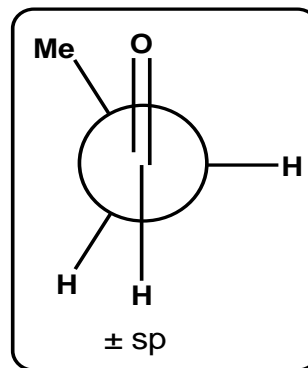
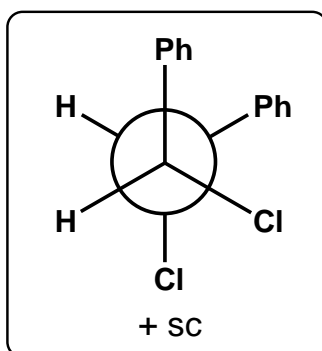
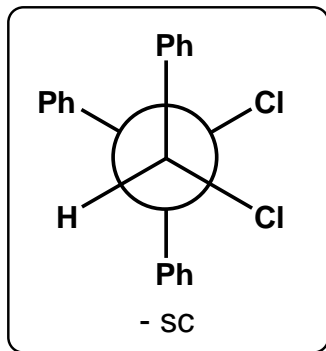
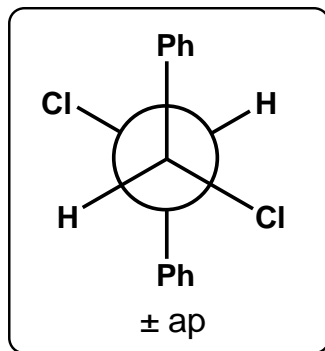
The stereochemical outcome and the relative rates of reactions depend on the topic relationship of the ligands (or faces) , the nature of the reagents (chiral and achiral) and the reaction conditions in general.

In reactions with heterotopic ligands or faces, one or the other of the stereoisomers is formed in excess leading to what is known as stereoselective synthesis.

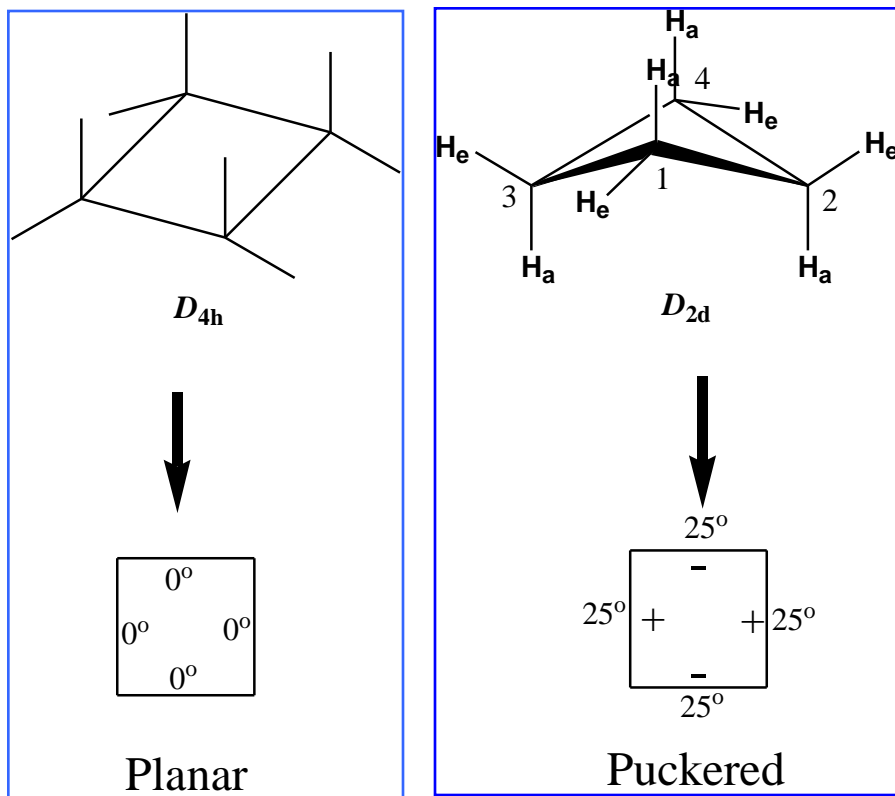
The reactions can be carried out using laboratory reagents and biochemical reactions mediated with enzymes.

Conformation of Acyclic systems (Klyne Prelog Terminology)

| Torsion angle (θ) | Designation | Symbol | Reference for n-butane |
|----------------------------|-----------------------|----------|------------------------|
| $0^\circ \pm 30^\circ$ | \pm syn-periplanar | \pm sp | eclipsed |
| $+60^\circ \pm 30^\circ$ | + syn-clinal | + sc | gauche |
| $+120^\circ \pm 30^\circ$ | + anti-clinal | + ac | eclipsed |
| $180^\circ \pm 30^\circ$ | \pm anti-periplanar | \pm ap | anti |
| $-120^\circ \pm 30^\circ$ | - anti-clinal | - ac | eclipsed |
| $-60^\circ \pm 30^\circ$ | - syn clinal | - sc | gauche |



Conformation of Cyclic systems (Cyclobutane)



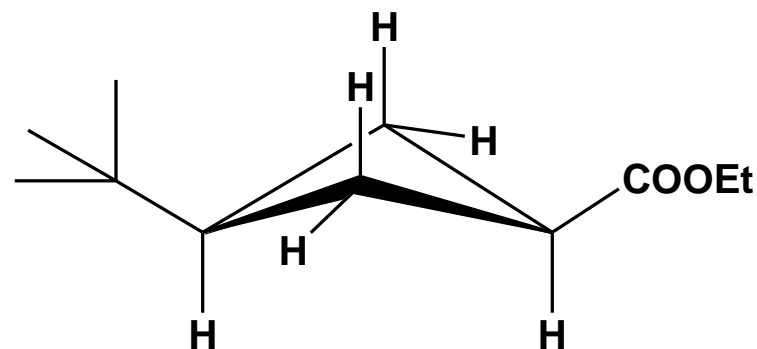
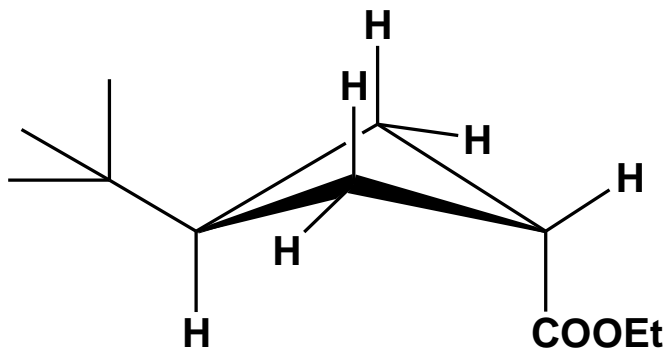
Existence of axial and equatorial bonds in puckered structure as in case of cyclohexane. The energy gap for interchange of equatorial and axial conformers is 6.0 kJ/mole and in some cases it is 4.5 kJ/mole.

Planar has the pairs of adjacent hydrogens eclipsed and suffers from torsional and angle strain.

The puckering of the ring with one carbon atom either above or below the plane of the other three relieves some of the torsional strain and non-bonded interaction at the expense of angle deformation (increased angle strain).

Raman spectra, electron diffraction experiments and X-ray data of substituted cyclobutanes confirm the puckered conformation with angle of puckering (the angle between C1-C2-C3 and C3-C4-C1 planes) of approximately 35° (the torsion angles are alternatively $+25^\circ$ and -25°).

Conformation of Cyclic systems (Cyclobutane)



For cyclobutane puckered system, substituents are preferable placed in equatorial positions.

Bromocyclobutane exists predominantly in the equatorial form with very little of the axial conformer.

Disubstituted cyclobutane such as the 1,2-dicarboxylic acids show diastereoisomerism (*cis* and *trans* isomerism), the *trans* having diequatorial and the *cis* having equatorial-axial substituents.

Like cyclohexanes, *cis* 1,3-disubstituted cyclobutanes are more stable than the *trans* isomers. Their conformations as e,e and e,a respectively being confirmed by electron diffraction experiments.

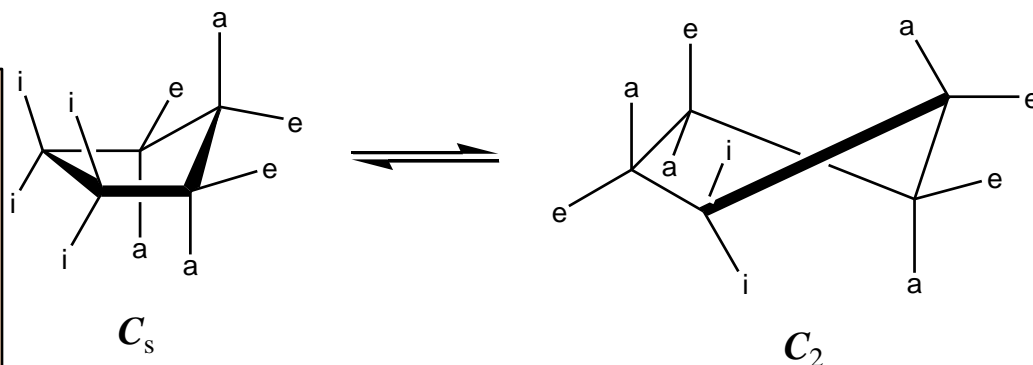
Conformation of Cyclic systems (Cyclopentane)

Planar conformation of cyclopentane (D_{5h} point group) is highly strained because of the eclipsing interactions among adjacent H's even though angle strain is almost nil.

Two puckered conformations are present: Envelope (C_s conformer) and half chair (C_2 conformer).

In the C_s conformer, four carbon atoms are in a plane with the fifth either up and down.

In the C_2 conformer, three carbon atoms are in a plane with the fourth and fifth alternately up and down.



Pseudorotation: For the cyclopentane, interconversion of ten envelope and ten half chair form takes place, which have very low energy barriers, i.e. 2.5 kJ/mole. This movement is called pseudorotation.

The planar form is less stable than the half-chair and envelope forms by about 20 kJ/mole.

The structures show three types of bonds, axial, equatorial and isoclinal.

Conformation of Cyclic systems (Cyclopentane)

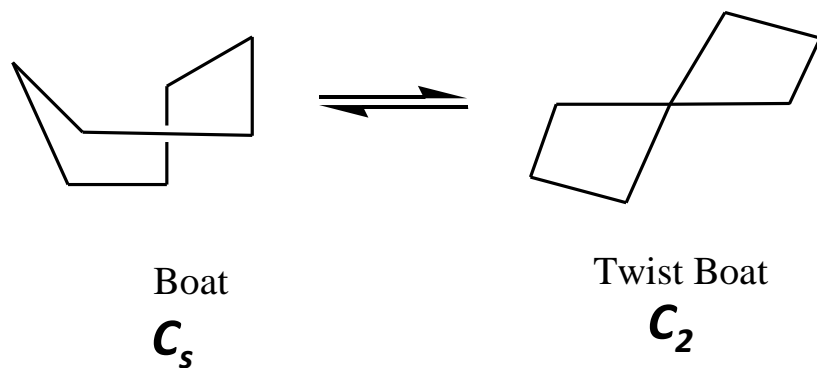
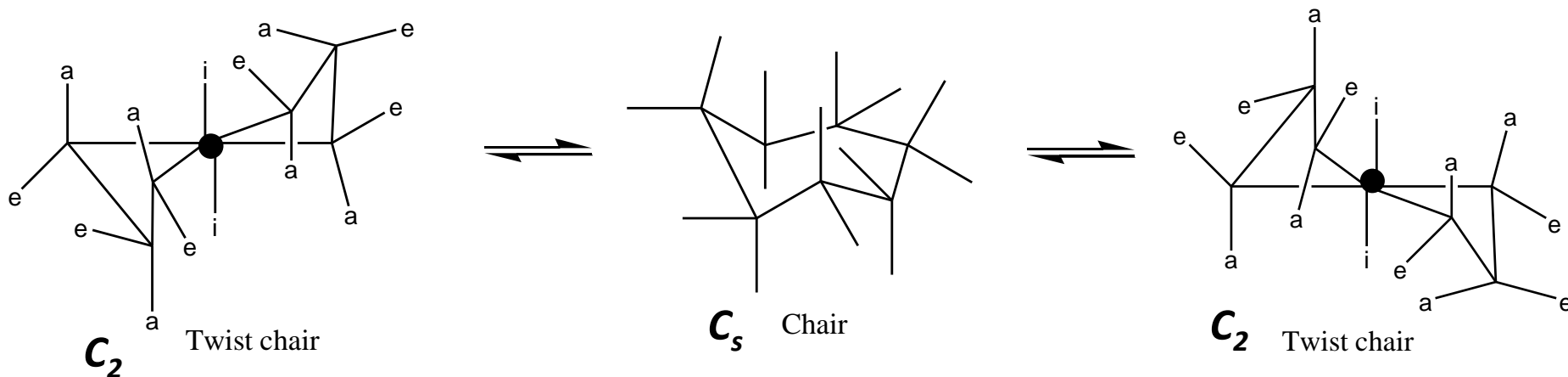


The cis and trans isomers of 1,2-dimethyl cyclohexanes respectively exist in e,a and e,e envelope conformations, the difference in enthalpy between the two is 7.15 kJ/mole which is slightly less than that of the dimethylcyclohexanes.

The cis and trans isomers of 1,3-dimethyl cyclohexanes respectively exist in e,e and e,a envelope conformations, the difference in enthalpy between the two is 2.25 kJ/mole. This also reconfirms the puckered structure.

For cyclopentanone, the more favourable conformation is the half chair form with the carbonyl carbon in the middle of the three atom plane. It is because the eclipsing interactions with the substituents on two adjacent carbon atoms disappear.

Conformation of Cyclic systems (Cycloheptane)

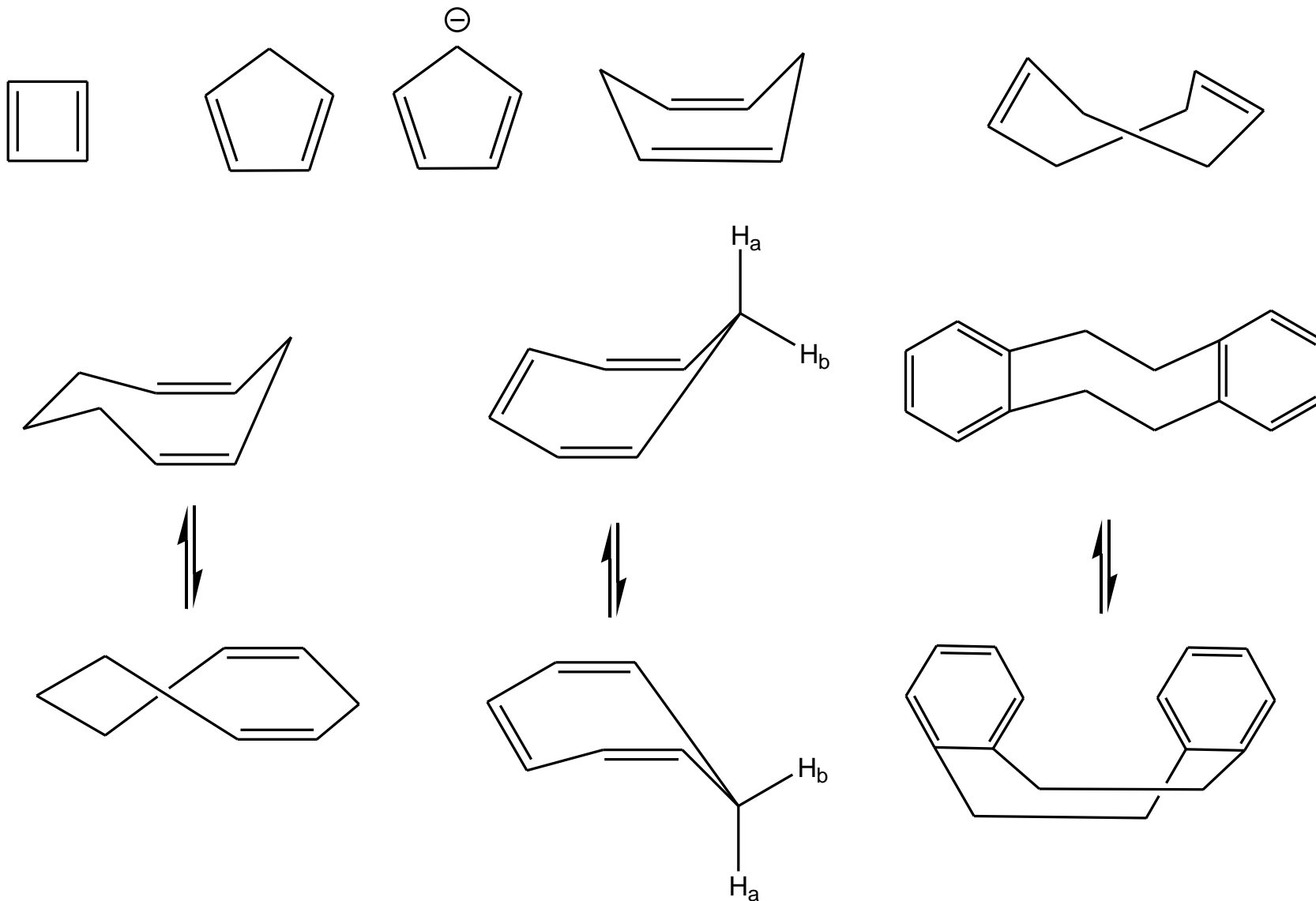


Cycloheptane exists in two sets of conformers, one set consisting of chair and twist chair forms and the other consisting of boat and twist boat forms separated by an energy barrier of approximately 35.0 kJ/mole.

Cycloheptanone exists as a mixture of conformers with C=O either at C-1, C-2 or C-7. Cycloheptene has the preferred conformation as chair form since presence of double bonds inhibits pseudorotation.

The two enantiomeric twist-chair conformers appear to be the preferred conformers.

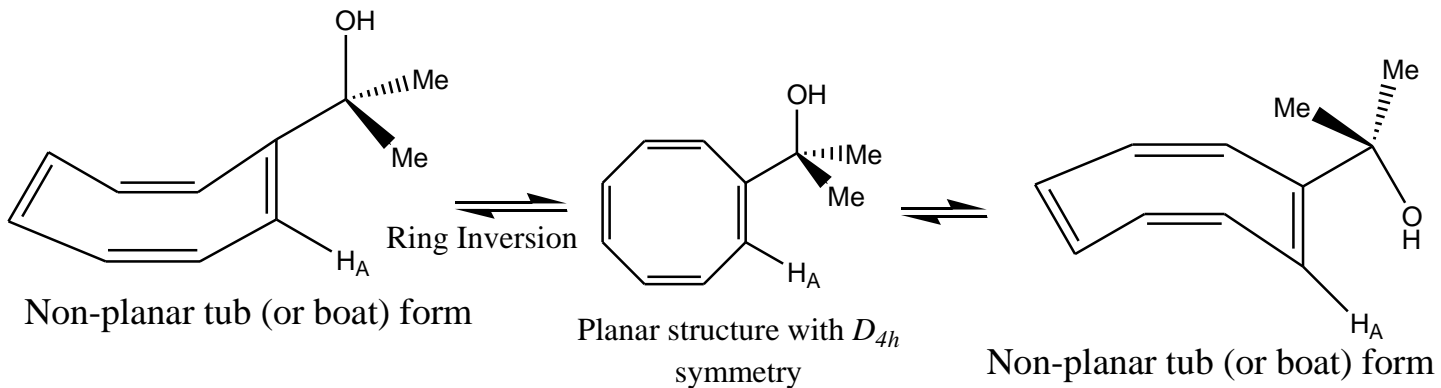
Conformations of rings with multiple double bonds



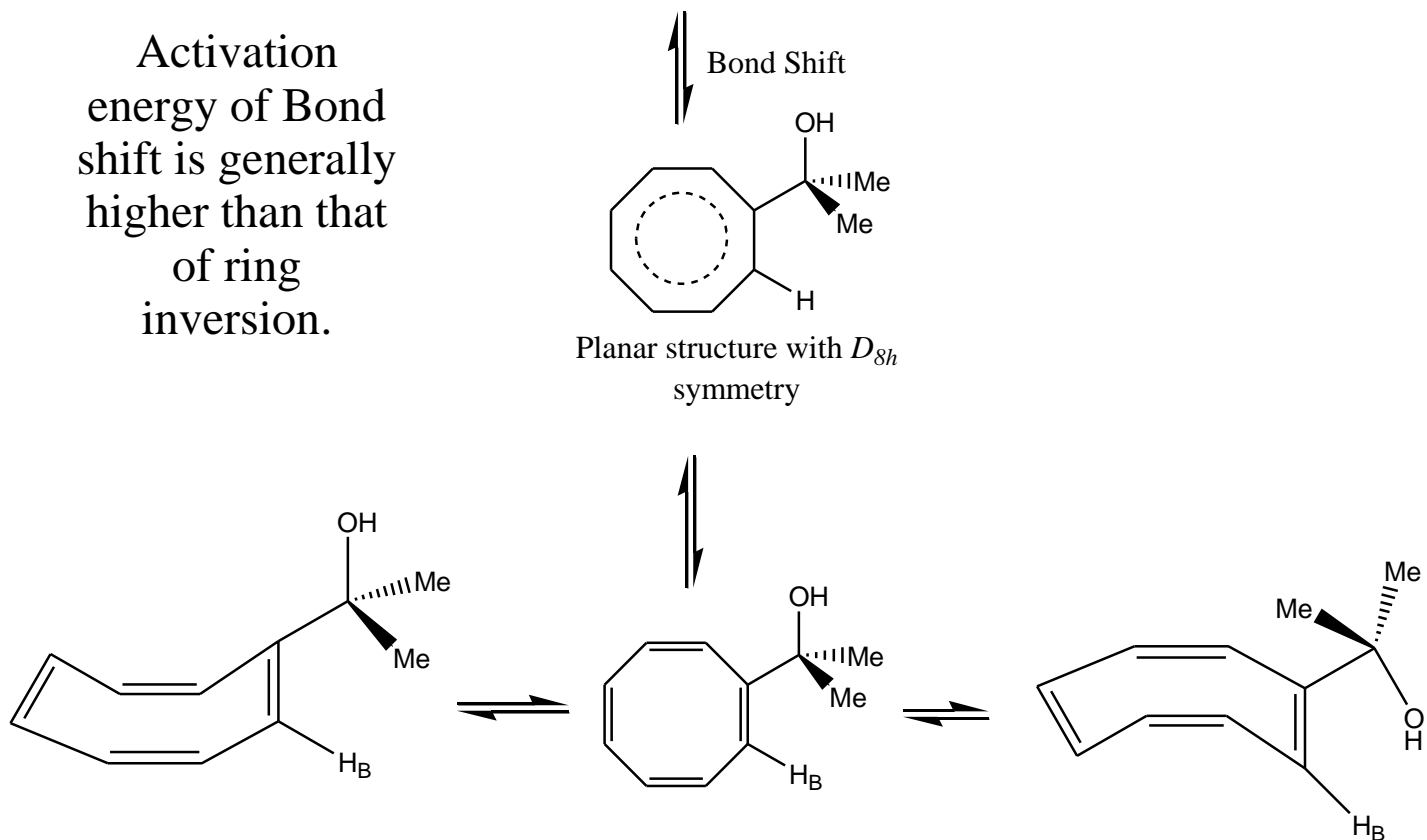
Conformations of rings with multiple double bonds

1. Cyclobutadiene is antiaromatic according to Huckel's rule.
2. Cyclopentadiene is quite stable with more or less planar conformation.
3. Cyclopentadienyl anion is aromatic according to Huckel's rule.
4. 1,3-and 1,4-cyclohexadiene are known and the latter exists as a flattened boat form.
5. Cycloheptatriene is non-planar having boat like structure in which the two allylic hydrogens are non-equivalent but interchangeable by ring inversion.
6. The cis,cis 1,3 and cis,cis-1,4-cyclooctadienes have non-planar conformations and both of them show a barrier to ring inversion of approximately 33.5 kJ/mole at -100 degree celsius. A relatively rigid boat-chair and a mobile twist-boat are suggested for cis,cis-1,4-cyclooctadiene. A twist boat is suggested for cis,cis 1,5-cyclooctadiene.
7. Dibenzo-1,5-cyclooctadiene is known to exist in a chair and a boat conformation.

Conformations of Cyclooctatetraene



Activation energy of Bond shift is generally higher than that of ring inversion.



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