



# **CHEM F111 : General Chemistry**

## **Semester II: AY 2017-18**

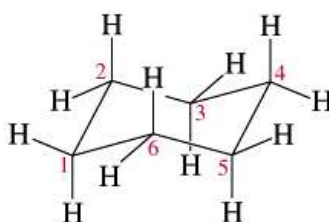
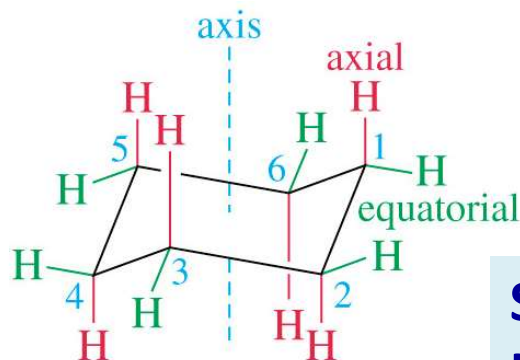
### **Lecture 32 (09-04-2018)**

## Summary of Lecture 33

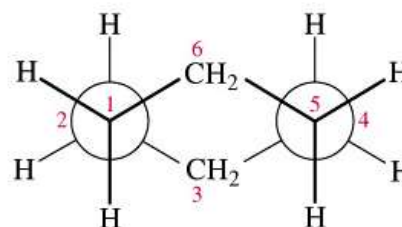


$$\text{Ring Strain} = \text{Angle strain} + \text{Torsional strain}$$

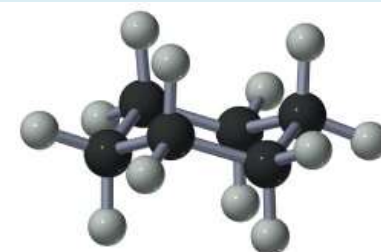
➤ Cycloalkanes with more than three carbon atoms in the ring are not flat molecules. They are puckered to reduce strain.



chair conformer of cyclohexane



Newman projection of the chair conformer



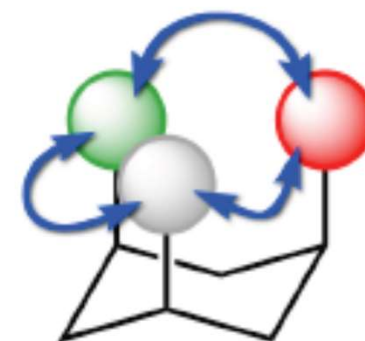
ball-and-stick model of the chair conformer of cyclohexane

**Stability of cyclohexane in different conformations:  
Half chair, Boat conformation, Twist-boat conformation**

**Strain of one H-X 1,3-diaxial interaction in kJ/mol**

**Disubstituted Cyclohexanes:**

**1,2 and 1,3 and 1,4-disubstituted cyclohexanes**



**Stereochemistry:** The branch of chemistry that deals with the spatial arrangement of atoms in molecules and effects of these arrangements on the physical and chemical as well as biochemical properties of substance.

**Stereoisomers** - Compounds that have the same molecular formula and the same connectivity, but different arrangement of the atoms in 3-dimensional space.

**The configuration of a molecule is the spatial arrangement of atoms or groups of atoms in the molecule and is independent of rotation about any single bond.**

## RELATIONSHIP BETWEEN SYMMETRY AND CHIRALITY

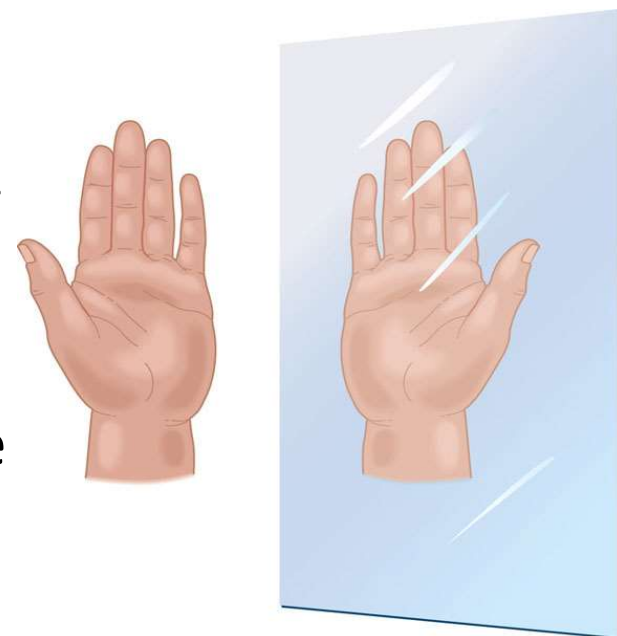
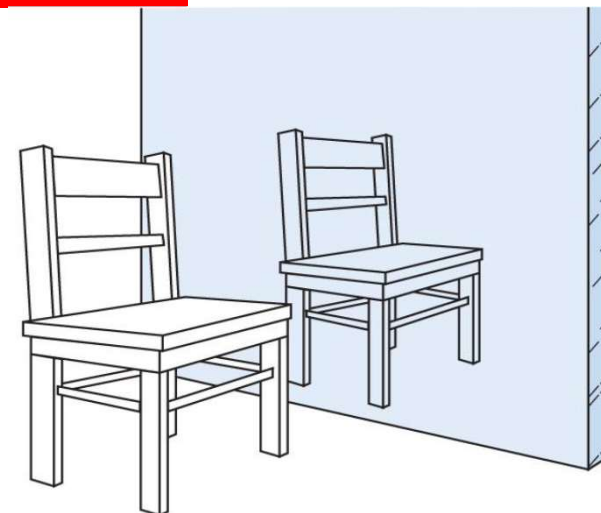
Asymmetric objects are chiral

Symmetric objects are achiral

### RELATIONSHIP BETWEEN OBJECTS AND THEIR MIRROR IMAGES

Symmetric objects are superimposable with their mirror images. They are one (the same).

- Some objects are not the same as their mirror images (technically, they have no plane of symmetry). They are different objects.
  - A right-hand glove is different than a left-hand glove. The property is commonly called “handedness”
- Asymmetric objects are non-superimposable with their mirror images (enantiomers). In the case of molecules, chiral molecules and their mirror images are different molecules.



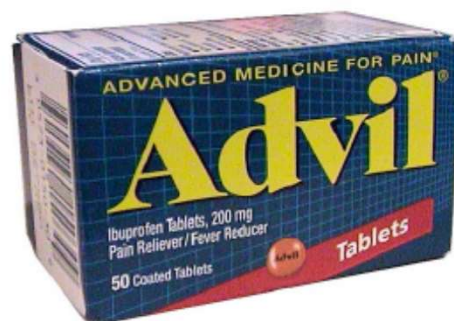
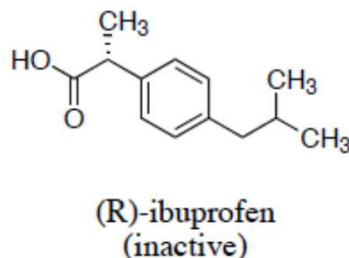
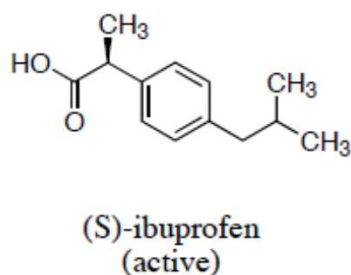
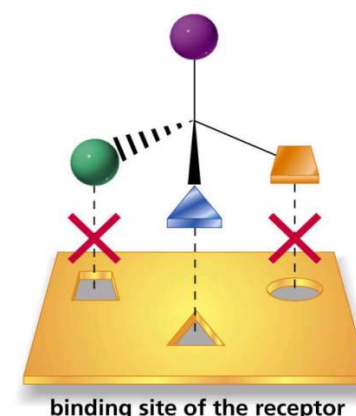
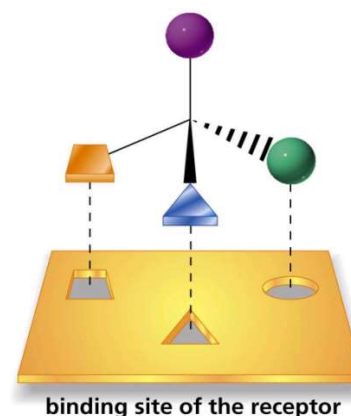
Left hand

Right hand

# Significance of asymmetry (Chirality)



- Handedness is important in organic, medicinal and biochemistry.
- Molecular handedness makes possible specific interactions between enzymes and substrates -effecting metabolism and pharmaceuticals.
- Organic molecules have handedness that results from substitution patterns on  $SP^3$  hybridized carbon.



Only (+)-glucose is able to help in animal metabolism, whereas (-)-glucose is unable to participate in the animal metabolism.



## Historical notes on (Chirality) optical activity

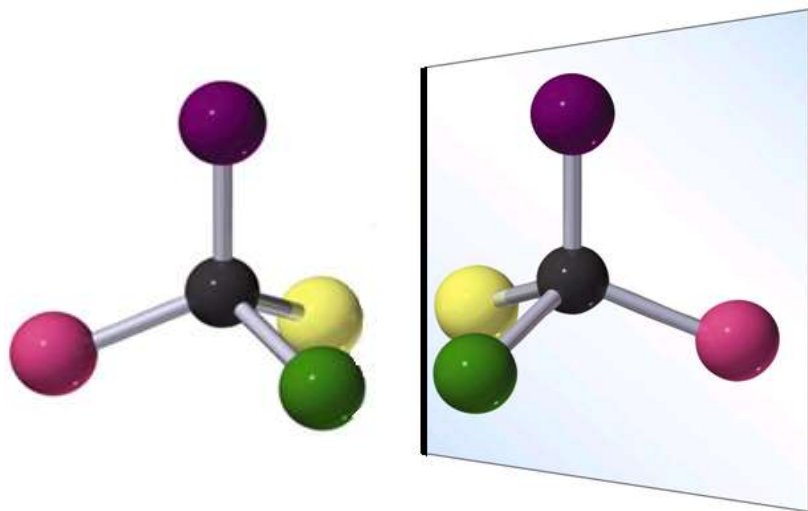
- J Baptiste Biot (1815), some organic compounds and quartz crystals have a +ve rotation, others –ve.
- **L Pasteur** (1848) separated ammonium tartrate crystals by hand into +ve & -ve rotating forms.



**Louis Pasteur** isolated first time the ammonium salt of tartaric acid in *d* and *l*-form and showed the way for the existence of Enantiomers (**Chirality**).

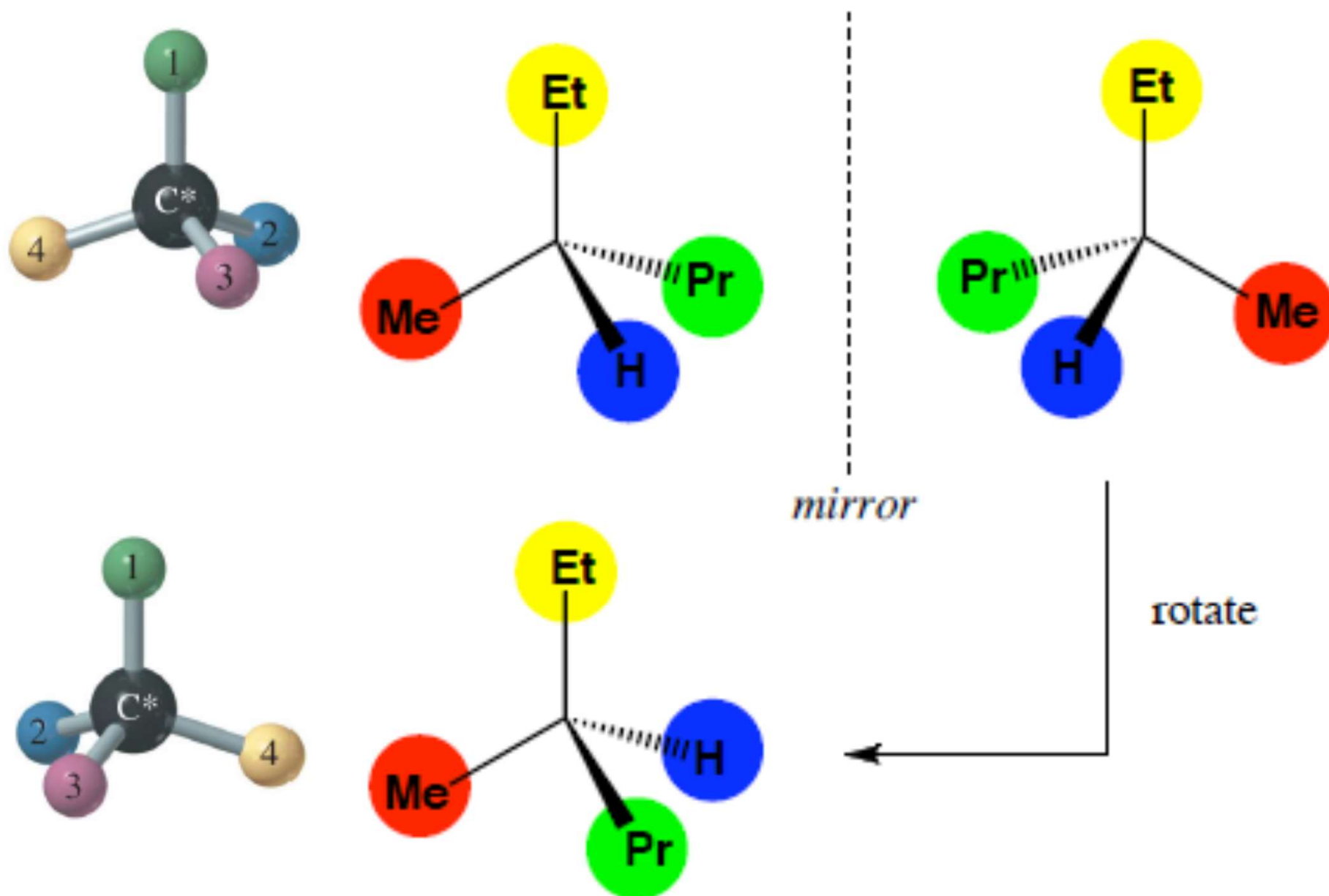
- **JH van't Hoff & JA Le Bel (1874)** proposed that carbon is tetravalent with tetrahedral bond geometry, and so molecules could exist in non-superimposable mirror image forms.
- One consequence of a tetrahedral arrangement of bonds to carbon is that, for the same molecular formula, and for same bonding if two different spatial arrangements are possible then that represents **two different compounds**.

# Tetrahedral arrangement



- Carbon has four different groups attached (**CHXYZ**).
- Molecule is not identical to its mirror image.
- We can not superimpose a model of the **CHXYZ** molecule on a model of its mirror image due to handedness.
- One might get two of the substituents superimposed, 'X' and 'Y' for example, but 'H' and 'Z' would be reversed & vice-versa.

# Tetrahedral arrangement

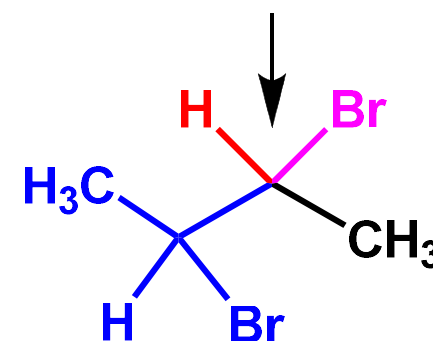
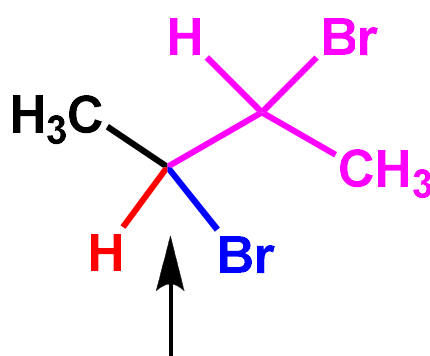
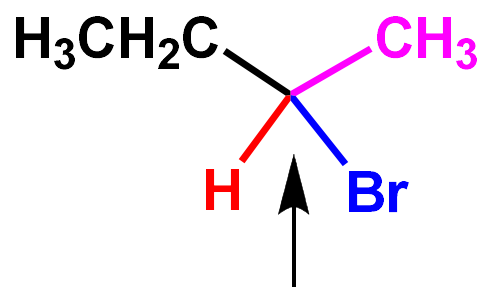




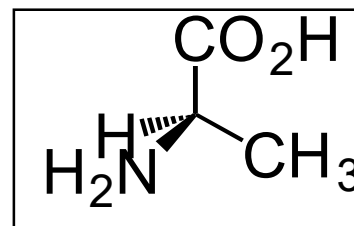
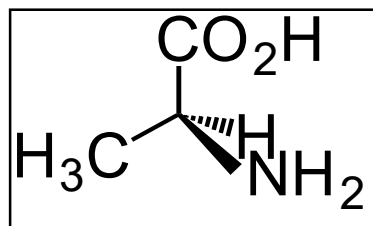
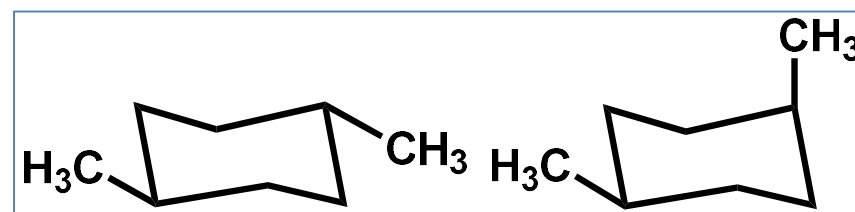
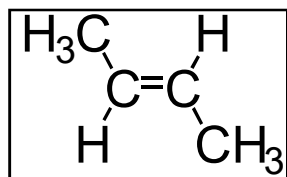
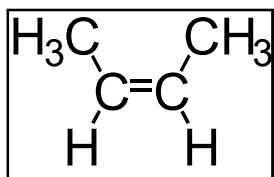
# Chiral center and stereocenter



**Chiral center** – A carbon that is bonded to four different groups of atoms. (do not confuse with “chiral”)



**Stereogenic center** - A center where a swapping of groups leads to a stereoisomer.



## Some definitions



**Stereoisomers** – compounds with the same connectivity, different arrangement in space: **conformation** and **configuration**

**Enantiomers** – stereoisomers that are non-superimposable mirror images; only properties that differ are direction (+ or -) of optical rotation.

**Diastereomers** – stereoisomers that are not mirror images; different compounds with different physical properties.

**Asymmetric center** –  $sp^3$  carbon with 4 different groups attached.

**Optical activity** – the ability of a molecule to rotate the plane of plane-polarized light.

**Chiral compound** – a compound that is optically active (**achiral compound** will not rotate plane polarized light).

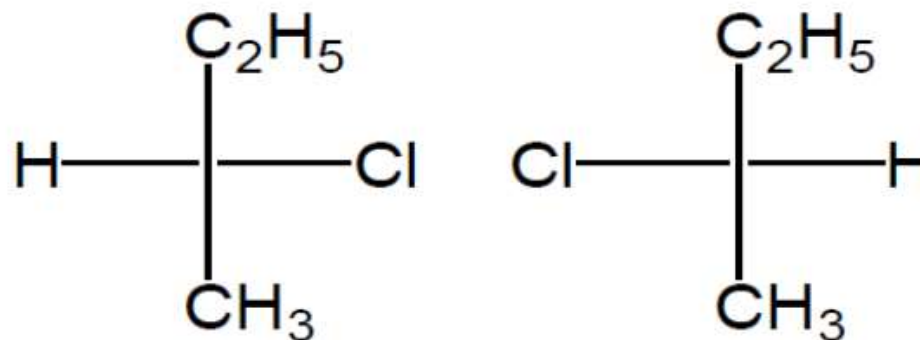
**Racemic mixture:** An equimolar mixture of two enantiomers (will be optically inactive).

# How do we “name” an enantiomers??



**A problem:** How can we look at the two Lewis structures and decide if they represent two identical compounds or a pair of enantiomers??

How can we name them?



The two isomers are different and therefore they should have different names.

As a result the Cahn–Ingold–Prelog (CIP) **R–S** notational system is developed that designate the configuration of atoms around a stereogenic center as **R** or **S**.

Configuration means how atoms or groups are arranged around a stereocenter in stereoisomers.

# Cahn-Ingold-Prelog rules

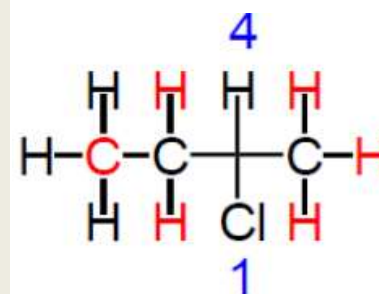
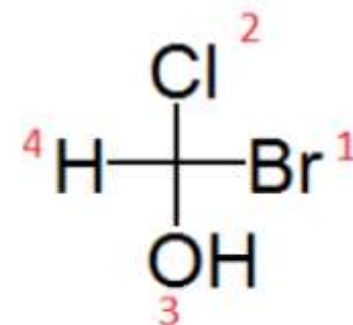
## THE *R/S* SYSTEM



Chemists use the letters *R* and *S* to represent the configuration about an asymmetric carbon. For any pair of enantiomers with one asymmetric carbon, one will have the *R* configuration and the other will have the *S* configuration. The *R,S* system was devised by Cahn, Ingold, and Prelog (CIP rules).

**Step 1:** Each of the four groups attached to the stereocenter is assigned a priority. Priority is first assigned on the basis of the atomic number of the atom that is directly attached to the stereocenter.

- The group with the lowest atomic number is given the lowest priority, the group with next higher atomic number is given the next higher priority, and so on.
- If priority cannot be determined by (i) its determined by similar comparison of the next atoms in the group, working outward in ranks from stereocenters.

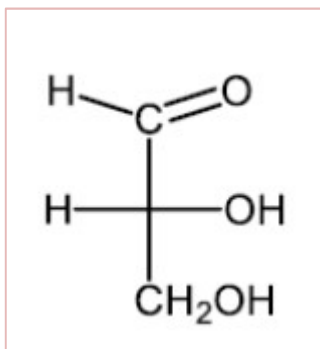


# Cahn-Ingold-Prelog rules

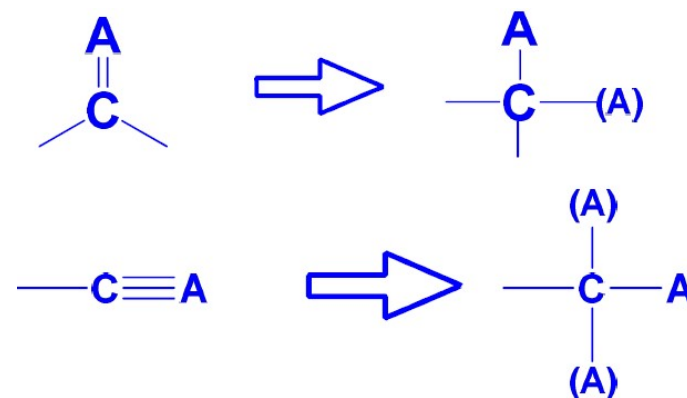
## THE *R/S* SYSTEM



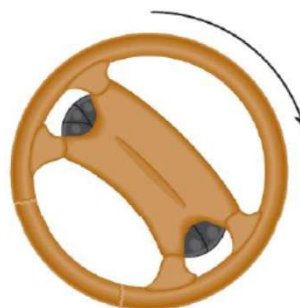
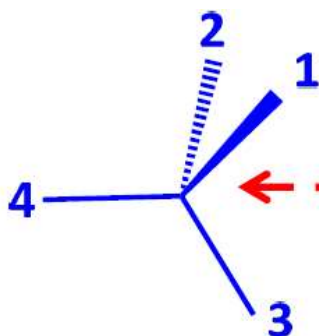
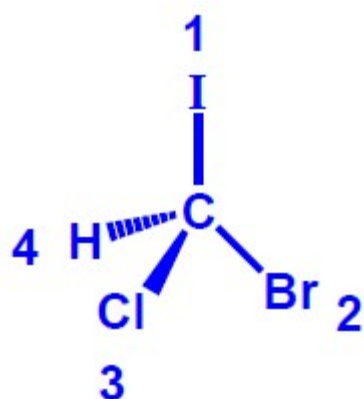
iii. A double or triple bond to an atom, **A**, is considered as equivalent to two or three single bonds to **A**.



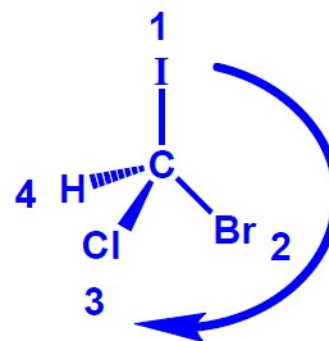
The sequence is therefore –OH, –CHO, –CH<sub>2</sub>OH, –H



Look at the molecule with the lowest priority group facing away:



right turn

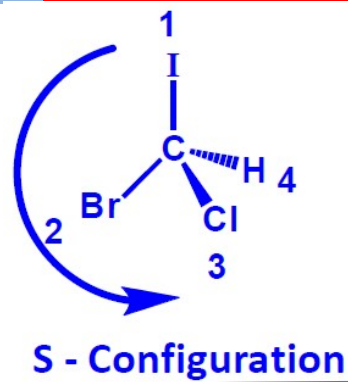
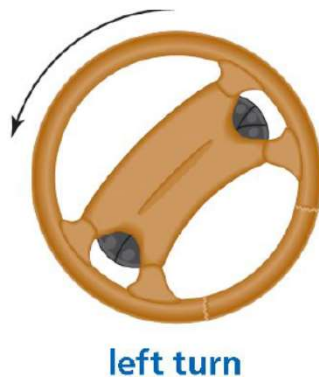
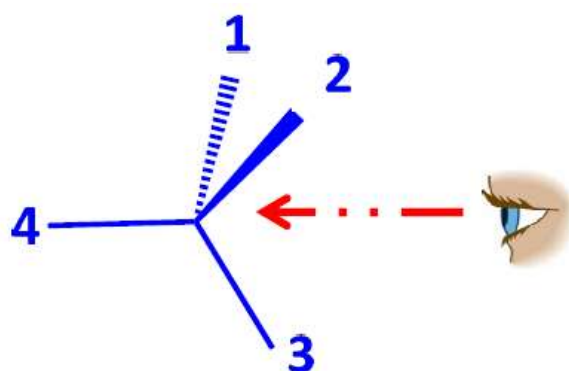


R - Configuration

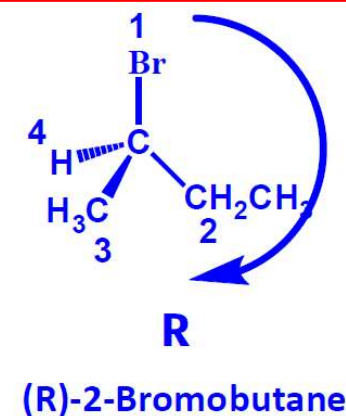
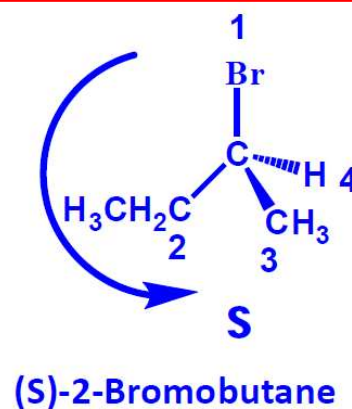
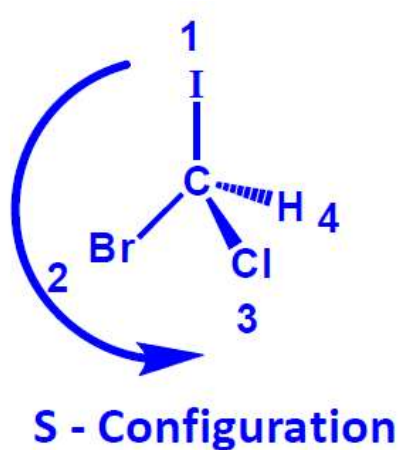
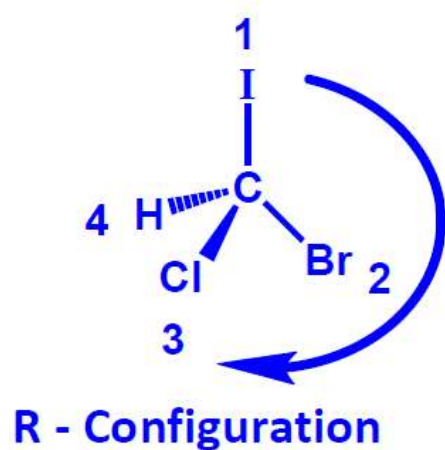
If substituents appears in a **clockwise sense** then the configuration of the chiral carbon is (*R*)

# Cahn-Ingold-Prelog rules

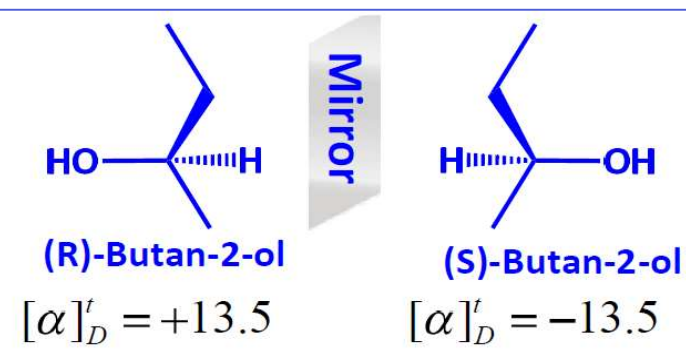
## THE *R/S* SYSTEM



If substituents appears in anticlockwise sense then the configuration of the chiral carbon is (S)



The sign of optical rotation is not related to the *R,S* designation. Either of them can be dextrorotatory or levorotatory.



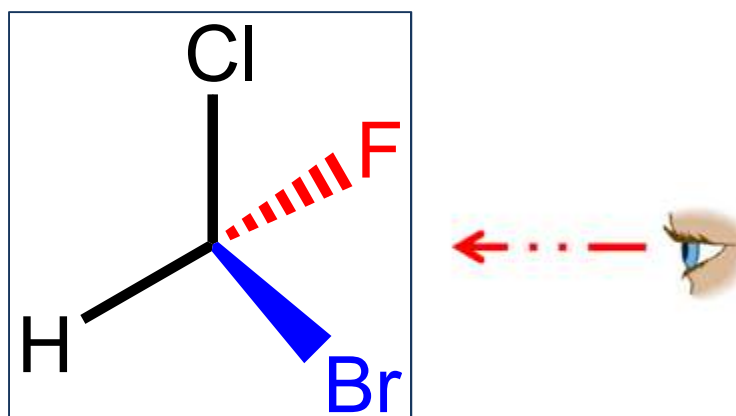


# Representation of Stereoisomers



How do we represent a three dimensional molecule on to a two dimensional plane?

## Wedge-and-dash drawing



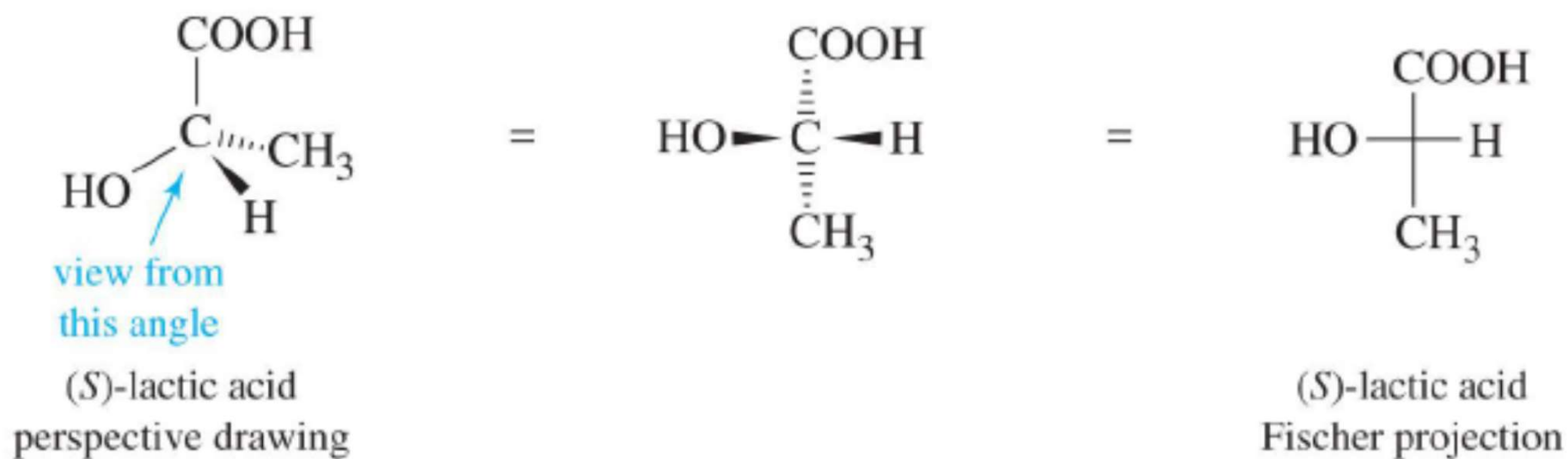
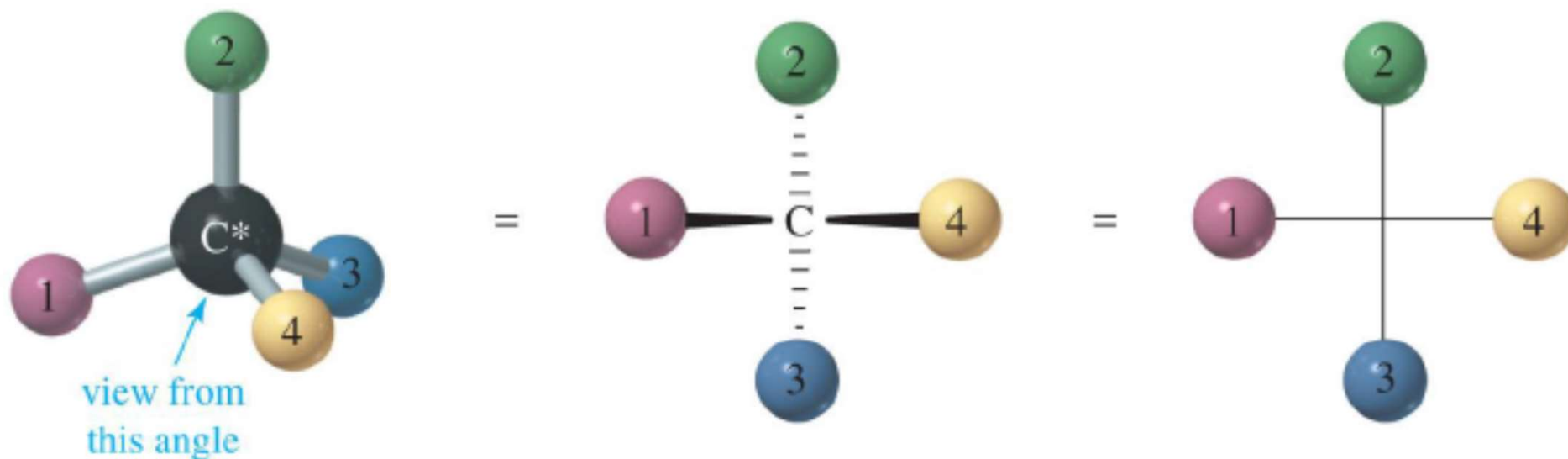
**Fischer projection formula** (also called cross formula).

- Provides a rapid means of depicting molecules with chiral carbons.
- Allows for convenient comparison of stereochemistry especially when more than one chiral carbon exists.

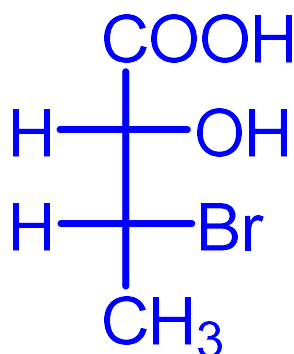
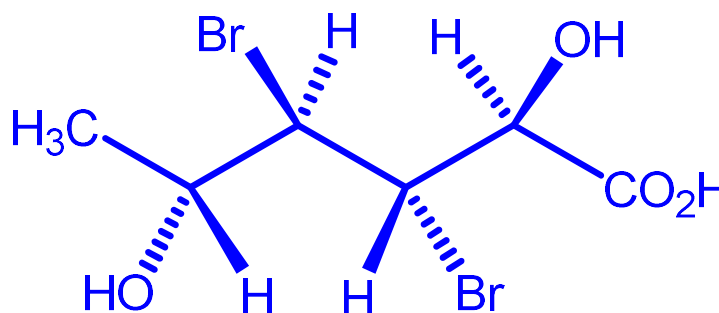
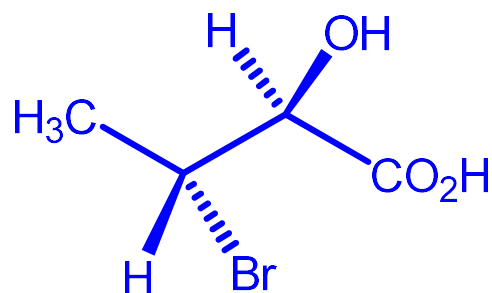
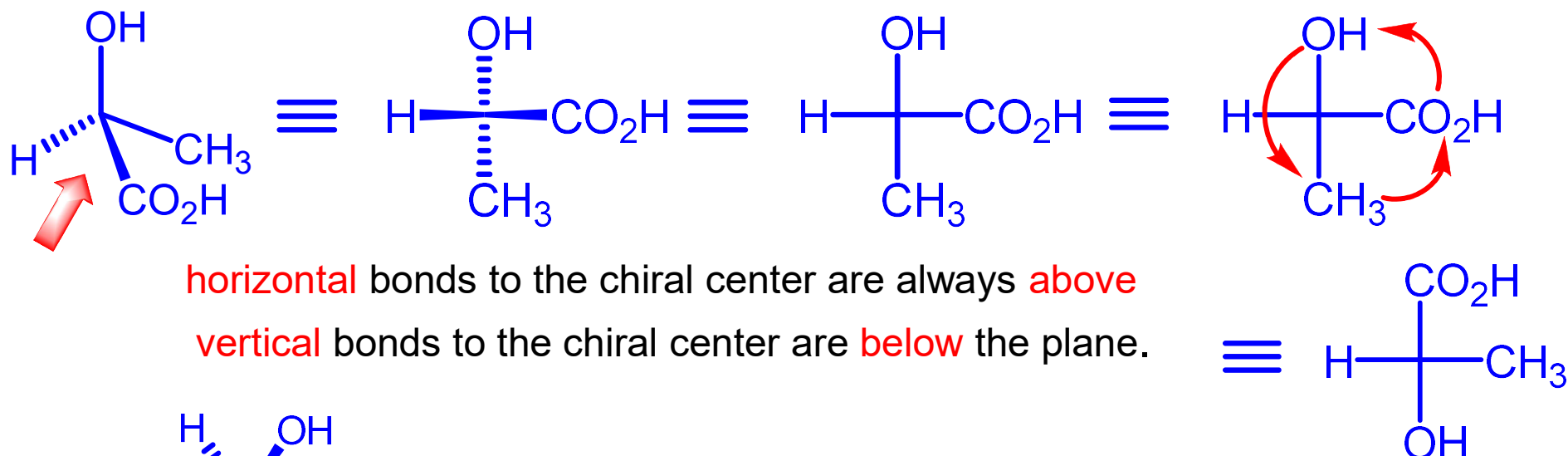
How is Fischer's formula drawn?

- We draw two lines [one **vertical** and one/(two or more) **horizontal** line(s)] depending upon the number of stereocenter/(s) in the molecule.
- The **point of intersection** of these lines is considered as representing the **stereocenter**.
- The formula can be drawn **only for molecules with stereocenter**.
- In the Fischer projection, the **horizontal** bonds to the chiral center are always **above** the plane and the **vertical** bonds to the chiral center are **below** the plane.

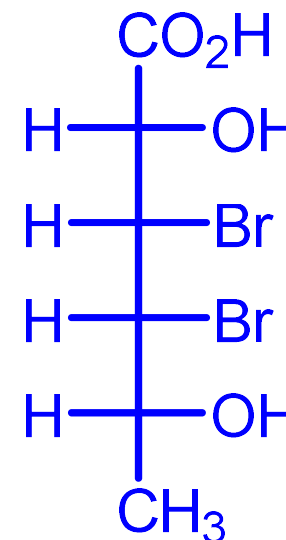
# Fischer projection formula



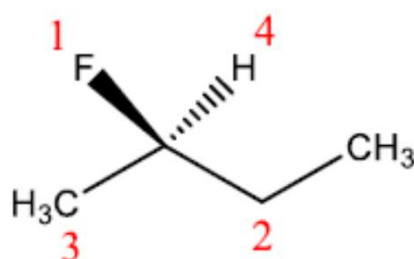
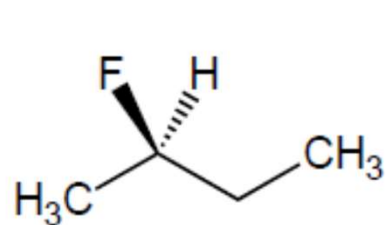
# Translating 3-D formulas into Fischer formulas



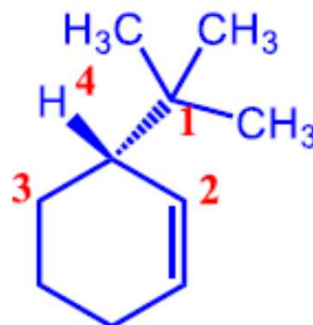
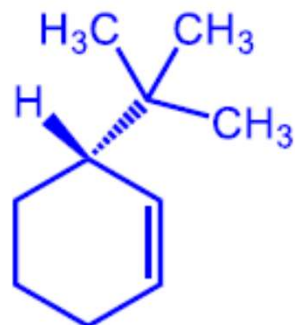
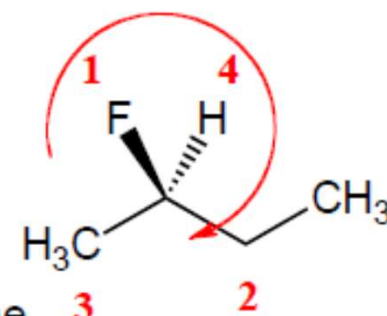
Conventions: Main carbon chain extends from top to bottom. All atoms/groups eclipsed



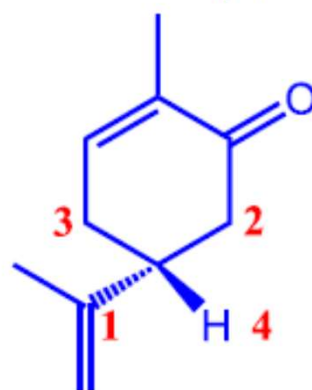
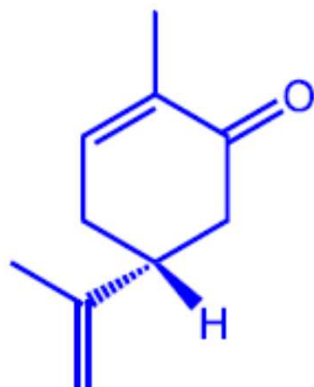
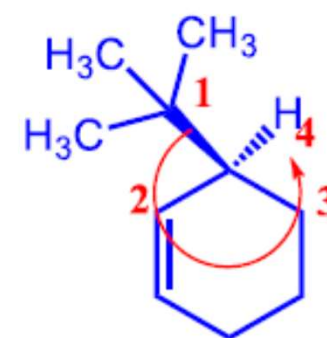
# Assigning absolute configuration



(R)-2-Fluorobutane



(S)-3-tert-butylcyclohexene



(R)-carvone

