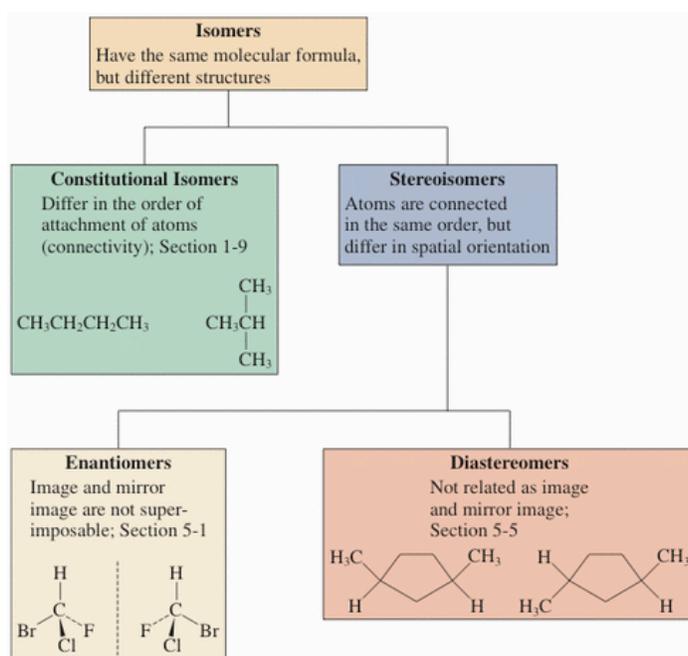


## STEREOCHEMISTRY: The Arrangement of Atoms in Space

**History:** (source: Hardinger; Thinkbook 14C: pgs11-13)

- **Late 17<sup>th</sup> century:** Christiaan Huygens - discovers plane-polarized light, which is light that has been filtered so that the electromagnetic components lie in a single plane.
- **1815:** Jean Baptiste Biot – certain natural organic compounds are optically active or can rotate plane-polarized light clockwise (+ dextrorotatory) and counterclockwise (- levorotatory). Also discovered that racemic acid is optically inactive.
- **1874:** Joseph Achille LeBel and Jacobus Henricus van't Hoff - proposed that a molecule having a tetrahedral carbon atom ( $sp^3$ ) with *four different* attachments may exist as a pair of isomers.

**Overview:**



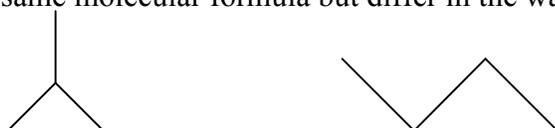
**Figure 5-1** Relations among **isomers** of various types. (Source: Vollhardt/ Schore's Organic Chemistry –eBook, 5<sup>th</sup> edition; Sec 5.1)

### **I. ISOMERS:**

#### **A) Constitutional isomers:**

Have the same molecular formula but differ in the way their atoms are connected.

Ex:



**Isobutene**

**C<sub>4</sub>H<sub>10</sub>**

**n-butane**

**C<sub>4</sub>H<sub>10</sub>**

**B) Stereoisomers (Configurational Isomers):** (source: Bruice 4<sup>th</sup> edition; pg.182)

Atoms are connected in the same way, but arranged differently in space

**1) Enantiomers:**

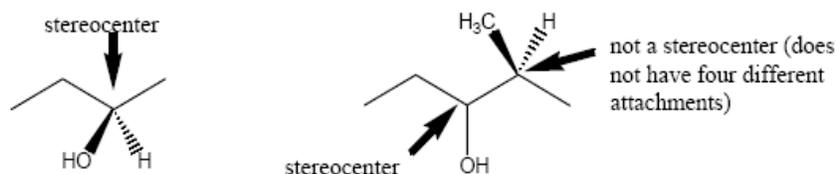
- Molecules with same molecular formula, contain at least one *chiral center*, and are nonsuperimposable mirror images (*chiral*) of each other.

*\*Note: Objects like the hand can be considered chiral because it's not the same as its mirror image.*

- Contain similar physical properties except for the direction of polarizing light therefore can't be separated.

Chiral Center (Stereocenter): can be an asymmetric carbon, nitrogen or phosphorus (with 4 different attachments).

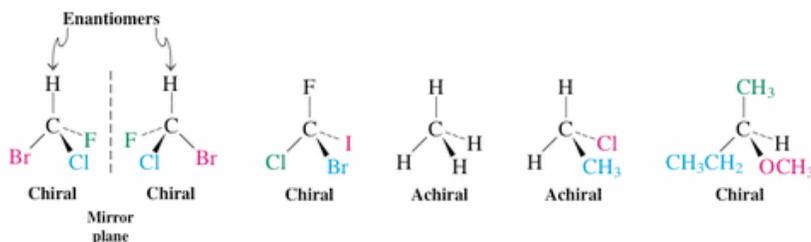
Ex: (Hardinger online tutorial; Stereochemistry – Identifying stereocenter)



a. Isomers with One Asymmetric Carbon:

- Can exist as 2 different isomers both of which are nonsuperimposable images of each other (analogous to left and right hand).

Ex: (Source: Vollhardt/ Schore's Organic Chemistry –ebook, 5<sup>th</sup> edition; 5.2)

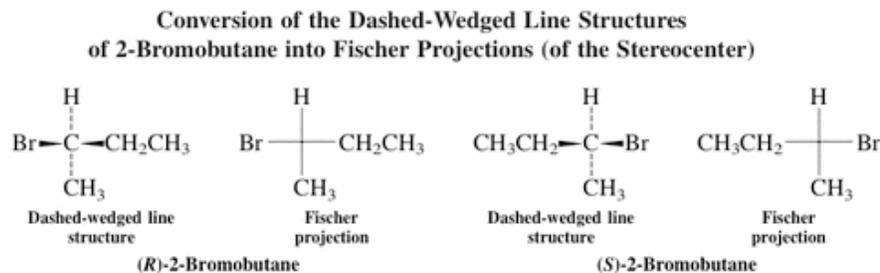


- Enantiomers can be drawn using: (source: Bruice 4<sup>th</sup> edition; pg.186-187)
  1. *Perspective Formulas (Dashed-wedged):* Show two of the bonds to the asymmetric carbon in the plane of the paper, one bond as a solid wedge protruding out of the paper, and the fourth as a hatched wedge extending behind the paper.

2. *Fischer Projection*: Asymmetric carbon is shown as the point of intersection of two perpendicular lines; horizontal lines represent bonds that project out of the plane, and vertical lines represent the bonds that extend back.

*\*Note: A Fischer projection can only be rotated 180° in the plane of the paper.*

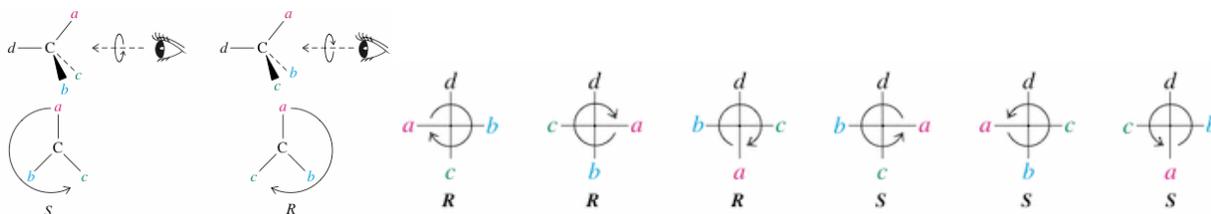
(Vollhard/ Schore's Organic Chemistry –eBook, 5<sup>th</sup> edition; 5.4)



- The R, S System of Nomenclature: A pair of enantiomers with one chiral center will have one R and one S configuration. R, S configuration depends on the arrangement or group around the asymmetric carbon atom. (source: Bruice 4<sup>th</sup> edition; pg.188-192)

- Rank the groups (or atoms) bonded to the asymmetric carbon in order of priority. The higher the atomic number of the atoms directly attached to the asymmetric carbon, the higher the priority. If two atoms right next to the asymmetric carbon are equal, then look to the next atoms that they are attached to.
- Orient the molecule so that the group with the lowest priority points away from the viewer (attached to hatched wedge in Perspective Formula or vertical bond of Fischer projection). Draw an arrow from the highest priority to lowest priority group. If arrow points clockwise, the asymmetric carbon has the R configuration, if it points counterclockwise, it has an S configuration.

*\*Note: If lowest priority group points toward the viewer, than the orientation is reversed → clockwise = S, counterclockwise = R*



**Figure 5-6** Assignment of R or S configuration at a tetrahedral stereocenter. The group of lowest priority is placed as far away from the observer as possible. The color scheme the priority of substituents—in decreasing order, red > blue > green > black. (Source: Vollhardt/ Schore's Organic Chemistry –ebook, 5<sup>th</sup> edition; Sec 5.3)

- Optical Activity: (source: Bruice 4<sup>th</sup> edition; pg.192-195)

Plane-polarized Light: Produced by passing normal light through the path of propagation. Oscillates in a single direction.

Optically Active: Compound that rotates light (Chiral compounds).

Optically Inactive: Compound that do not rotate light (Achiral compounds).

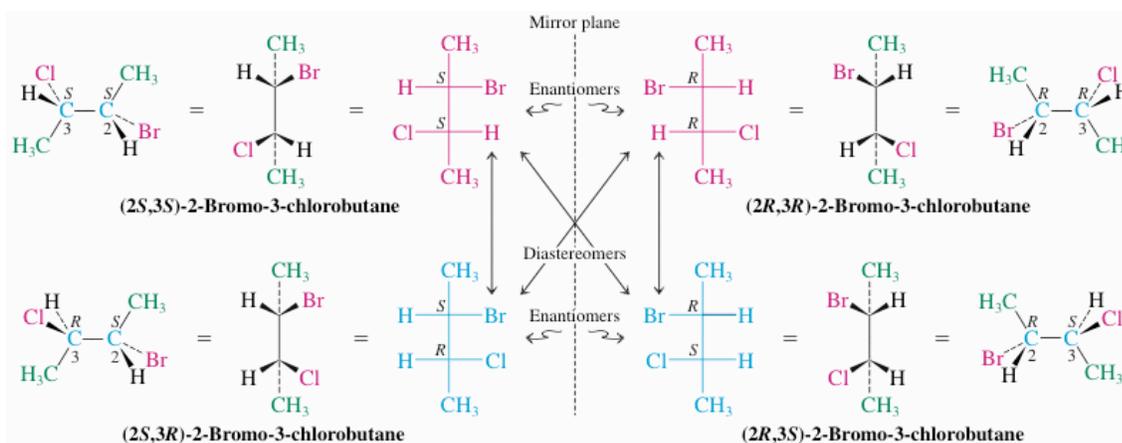
Enantiomers DO NOT rotate light in the same direction. Knowing whether a chiral molecule has the R or S configuration does not tell us the direction that the compound rotates the plane of polarization. R and S can rotate light either to the right (+) or the left (-).

Racemic Mixture: A mixture of equal amount of two enantiomers with one rotating light to the right and the other rotate the plane in the opposite direction. Ex: R(-) and S(+). They are optically inactive, and have an **observed specific rotation** of 0°.

b. Isomers with More than One Asymmetric Carbon:

- The more asymmetric carbons a compound has, the more stereoisomers are possible for the compound. A compound can have a maximum of 2<sup>n</sup> stereoisomers where n = # of asymmetric carbons.
- R, S configuration should be determined for each stereocenter by looking at them individually.

Ex: (Source: Vollhardt/ Schore's Organic Chemistry – eBook, 5<sup>th</sup> edition, Sec 5.5, Figure 5-7)



- The presence of more than one stereocenter gives rise to diastereomers.

**2) Diastereomers:**

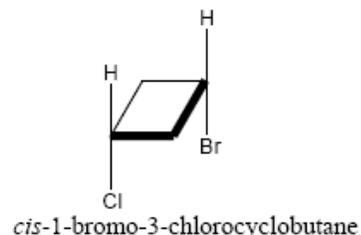
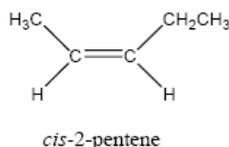
\_ They are stereoisomers that are not enantiomers, in other words, they are not related to each other as objects and mirror images.

\_ Diastereomers have different physical and chemical properties.

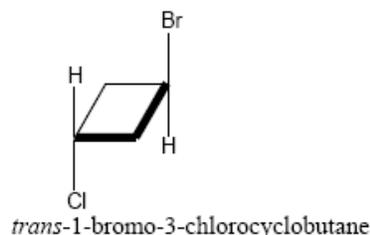
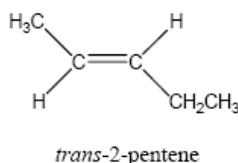
\_ In molecules with more than one stereocenters, if one stereocenter is not the mirror image of the other than the molecules are considered diastereomers.

a. Cis-Trans (Geometric) Isomers: Result from restricted rotation, which can be caused by a double bond or by a cyclic structure. (source: Bruice 4<sup>th</sup> edition; pg 183)

i. Cis Isomer: Hydrogens on **same** side as double bond or the ring.



2. Trans Isomer: Hydrogens on **opposite** side of double bond or ring.



b. Meso Compounds: Have two or more asymmetric carbons and a plane of symmetry and is achiral.

Plane of symmetry: Cuts the molecule in half and one half is the mirror image of the other half.

Ex: (Source: Vollhardt/ Schore's Organic Chemistry – eBook, 5<sup>th</sup> edition, Sec 5.6)

#### Meso Compounds with Multiple Stereocenters

