

Organic Chemistry

Review of Stereochemistry

CHIRALITY: A chiral carbon atom is defined by *all of the following* criteria:

- Only sp^3 carbon atoms can be chiral (not sp^2 or sp . Other atoms like N and S can be chiral).
- The sp^3 hybridized carbon atom must be bonded to 4 unique substituents.
- A chiral molecule is one that has no "plane of symmetry".
- The site of the chiral atom is referred to as a "chiral center"

ENANTIOMERS AND DIASTEREOMERS

Configurational stereoisomers have exactly the same molecular formula, the same skeletal structure, the same position of substituents and functional groups and the same functional groups. They differ only in the three-dimensional orientation of substituents around a chiral carbon atom.

A. ENANTIOMERS

Enantiomers are non-superimposable mirror image isomers that arise due to the chirality of an atom or of the overall molecule.

- "Non-superimposable" means that two enantiomers are structurally identical but cannot be laid on top of each other and have all their bonds overlap.
- Enantiomers typically have at least one chiral carbon atom, but may have more than one
- An enantiomeric relationship can be identified by comparing the chiral center configurations of one isomer with the chiral center configurations of a second isomer. *If all chiral centers are inverted in one structure compared to the other, then the two isomers are enantiomers*
- PHYSICAL PROPERTIES:** Enantiomers have identical physical properties (i.e., energy, boiling point, melting point, densities, etc.) except that they rotate the plane of polarized light in different directions.
- OPTICAL ISOMERS:** Enantiomers are often referred to as "optical isomers" since a single enantiomer will rotate a plane of polarized light in one direction or another. **THE DIRECTION OF ROTATION (i.e., positive or negative) DOES NOT INDICATE ANYTHING ABOUT THE STRUCTURE OF THE ENANTIOMER.**
 - DEXTROROTATORY:** (+, d-) A dextrorotatory enantiomer rotates a plane of polarized light to the right or in a positive direction.
 - LEVOROTATORY:** (-, l-) A levorotatory enantiomer rotates a plane of polarized light to the left or in a negative direction.
 - A 1:1 mixture of enantiomers is referred to as a "racemic" mixture.

B. DIASTEREOMERS

Diastereomers are non-superimposable, non-mirror image stereoisomers.

- Diastereomers arise in molecules with more than one chiral center.
- A diastereomeric relationship can be identified by comparing the chiral center configurations of one isomer with the chiral center configurations of a second isomer. *If some but not all chiral centers are inverted in one structure compared to the other, then the two isomers are diastereomers.*
- PHYSICAL PROPERTIES:** Diastereomers have different physical properties including optical rotation.
- MESO COMPOUNDS:** A meso compound contains at least two chiral centers and a plane of symmetry. While it may appear that a meso compound has two enantiomers, the two "enantiomers" are actually the same exact compound.

DESIGNATING STEREOCHEMISTRY: There are commonly accepted methods for designating stereoisomers.

A. OPTICAL ROTATION METHOD ((+) d-, (-) l-)

Enantiomers are often referred to as "optical isomers" since a single enantiomer will rotate a plane of polarized light in one direction or another (referred to as optical rotation). **THE DIRECTION OF ROTATION (i.e., positive or negative) DOES NOT INDICATE ANYTHING ABOUT THE STRUCTURE OF THE ENANTIOMER.**

- DEXTROROTATORY:** (+, d-) A dextrorotatory enantiomer rotates a plane of polarized light to the right or in a positive direction.
- LEVOROTATORY:** (-, l-) A levorotatory enantiomer rotates a plane of polarized light to the left or in a negative direction.

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B. CAHN-INGOLD-PRELOG (CIP) METHOD (R-, S-)

The Cahn-Ingold-Prelog method is used to designate absolute configuration of a chiral center. The following rules are used to designate the absolute configuration of a chiral center using the CIP method.

1. Locate the chiral carbon.
2. Using sequence or priority rules, rank the four substituents bonded to the chiral carbon atom (1 = highest priority, 4 = lowest priority).
3. Rotate the molecule so that the substituent of lowest priority is directed back.
4. Draw a curved arrow starting at the substituent of highest priority and move it in order of decreasing priority.
5. If the arrow rotates CLOCKWISE, then the configuration of that chiral center is "R".
6. If the arrow rotates COUNTERCLOCKWISE, then the configuration of the chiral center is "S".
7. For a molecule with more than one chiral center, the total possible number of sets of enantiomers is 2^{n-1} .