Introduction to Stereochemistry

"Master Organic Chemistry"
masterorganicchemistry.com
2014 Version

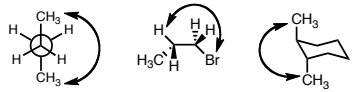
Note - this sheet is not meant to be comprehensive. Your course may provide additional material, or may not cover some of the reactions shown here. Your course instructor is the final authority.

Symbols

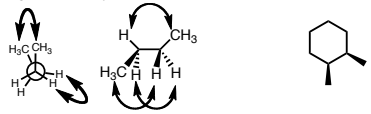
			Example
▬	**"wedge"**	denotes a group pointing "out of the page"	
·····	**"dash"**	denotes a group pointing "into the page"	
∿∿	**"squiggle"**	undefined (mixture of stereoisomers) Rarely used.	

Terms

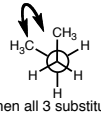
anti two groups on adjacent carbons oriented at 180° to each other



syn two groups on adjacent carbons oriented at 0° to each other

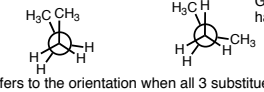


gauche two groups on adjacent carbons oriented at 60° to each other



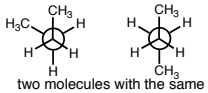
Generally, gauche interactions between bulky groups are intermediate in torsional strain between the anti and syn relations

eclipsed when all 3 substituents overlap completely with all 3 substituents on a neighboring carbon.



Generally, eclipsed conformations have the highest torsional strain

staggered refers to the orientation when all 3 substituents on a carbon are arranged at a 60 deg angle to all 3 substituents on another carbon.

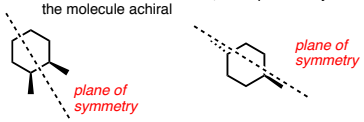


isomers two molecules with the same molecular formula, but different in their structures

configuration the 3-D arrangement of bonds around a carbon.

racemic mixture a 50:50 mixture of two enantiomers

Meso compound: A molecule with stereocenters, but a plane of symmetry that makes the molecule achiral



Cis on the same side of a double bond or ring

Trans on opposite sides of a double bond or ring.

Chiral molecule a molecule with an enantiomer; cannot possess a plane of symmetry

Stereocenter Has 4 different constituents

Torsional Strain Strain that arises from the proximity of bonds (and the electrons in them) - generally eclipsing

Types of isomers

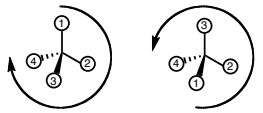
Isomers: same empirical formula, different structural formula.

Type	Connectivity?	Configuration?	3-D Shape?	Physical properties	Example
Conformational isomers	*Same*	*Same*	*Different*	*Identical, as long as they can interconvert through bond rotation*	staggered eclipsed
Constitutional isomers	*Different*			*Different boiling points, melting points, and other physical properties*	1-butanol 2-butanol
Stereoisomers	*Same*	*Different*			
Enantiomers →	*Stereoisomers that are non-superimposable mirror images*			*Identical. Differ in optical rotation*	(*R*)-2-butanol (*S*)-2-butanol
Diastereomers →	*Stereoisomers that are **NOT** non-superimposable mirror images*			*Different boiling points, melting points, etc.*	*trans*-2-butene *cis*-2-butene; (trans)-cyclohexane 1,2-diol (cis)-1,2-cyclohexanediol

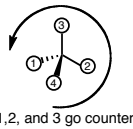
Note: another name for stereoisomers is "configurational isomers": they have the same connectivity, but differ in the configurations of the carbons.

The R,S convention

Rank according to atomic number
Put #4 ranked substituent in back.



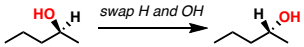
What if #4 is in the front? One approach is to trace 1,2 and 3 as you normally would. Then flip!



1,2, and 3 go counterclockwise.
4 ranked substituent is in front
Therefore, flip: *this is R !*

The single swap rule:

Single swap rule: switching any two groups on a stereocenter will flip (R) to (S) and vice versa.



(S)-2-pentanol (R)-2-pentanol

works for any other two groups as well
(e.g. OH and CH_3, H and CH_3, OH and $CH_2CH_2CH_3$, etc.)

Recognizing Enantiomers/Diastereomers Using Only Their Names

Diastereomers: same name, but R/S designations are not exactly opposite

Example:(2S, 3R)-2-bromo-3-chlorobutane and (2S, 3S)-2-bromo-3-chlorobutane
(2S, 3S, 4S, 5R)-2-bromo-3-chloro-4-methyl-5-propyldecane
and (2S, 3R, 4R, 5S)-2-bromo-3-chloro-4-methyl-5-propyldecane
also, diastereomers will have the same name, but differ in E/Z (or cis/trans).

e.g. (Z)-2-butene and (E)-2-butene.
cis-1,2-dimethylcyclohexane and trans-1,2-dimethylcyclohexane

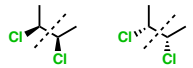
Enantiomers: same name, but have all stereocenters have opposite R/S designations

Example: (R)-2-butanol, (S)-2-butanol

(2S, 3R)-2-bromo-3-chlorobutane and (2R, 3S)-2-bromo-3-chlorobutane
(2S, 3S, 4S, 5R)-2-bromo-3-chloro-4-methyl-5-propyldecane
and (2R, 3R, 4R, 5S)-2-bromo-3-chloro-4-methyl-5-propyldecane

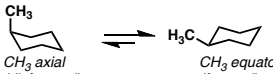
Important exception: If the molecule has a mirror plane, then it is **meso**, and the two "enantiomers" are in fact the same molecule

Example: (2R,3S)-2,3-dichlorobutane and (2S,3R)-2,3-dichlorobutane are **the same**



Cyclohexane chair conformations

in the cyclohexane chair conformation: all C–C bonds staggered



Chair flips: all axial groups become equatorial, and all equatorial groups become axial.

BUT all groups that are "up" stay "up" and all groups that are "down" stay "down."

Bulky groups prefer the equatorial position.

The bulkier the group, the greater the energy difference will be.
Bulkiness:
tertiary C (3°) > secondary C (2°) > primary C (1°), methyl (CH_3) >> H

The energy difference between two different chair forms (in ΔG) is related to the equilibrium constant by
$K = e^{-(\Delta G/RT)}$

Omissions, Mistakes, Suggestions?

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