Stereochemistry and Chirality

Chiral object or molecule: has a non-superimposable mirror image
Achiral object: not chiral, has a superimposable mirror image

1848 - Louis Pasteur separated the "right-handed" and "left-handed" forms of tartaric acid crystals (from wine)

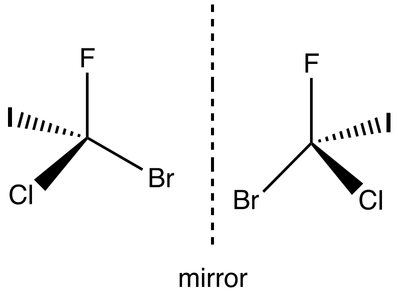
Resolution - Separation of right and left-handed forms (enantiomers)

1874 - J. van't Hoff and Le Bel proposed that differences are due to tetrahedral geometry of carbon
- Kolbe did not receive van't Hoff's idea very well
1901 - J. van't Hoff was the first recipient of the Nobel Prize in Chemistry

Enantiomers: molecules that are stereoisomers and are non-superimposable mirror images of each other

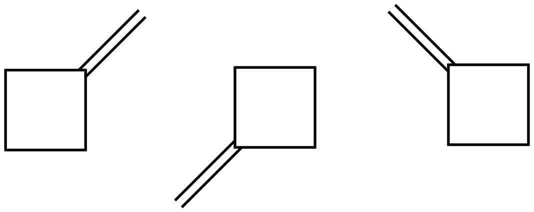
Diastereomers: stereoisomers that are not enantiomers

Enantiomers
Stereoisomers, non-superimposable mirror images
Example:



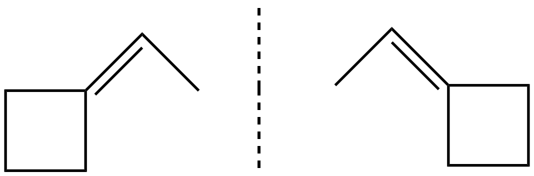
NON-SUPERIMPOSABLE → Enantiomers

Another Example:

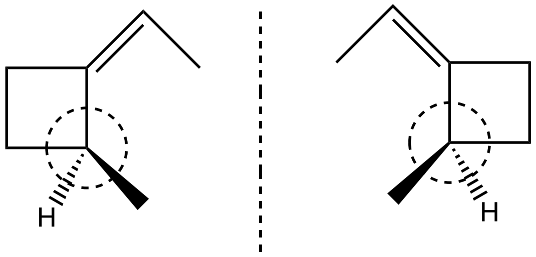


Identical structures, superimposable

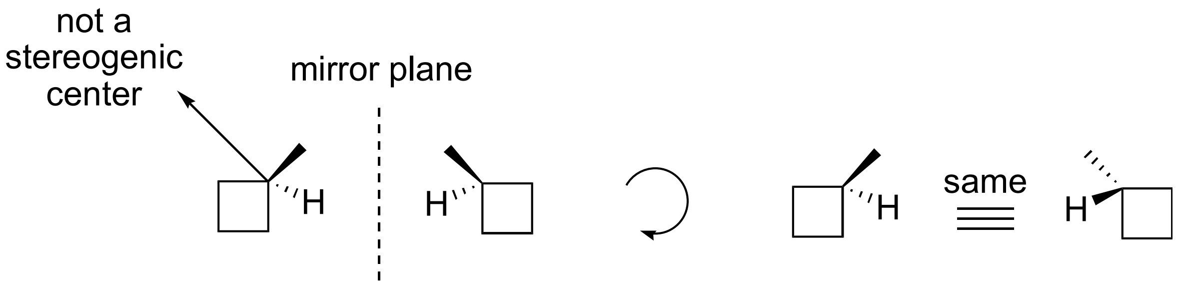
Another Example:



- achiral
- no stereogenic center



- enantiomers
- dashed circle is stereogenic center carbon atom

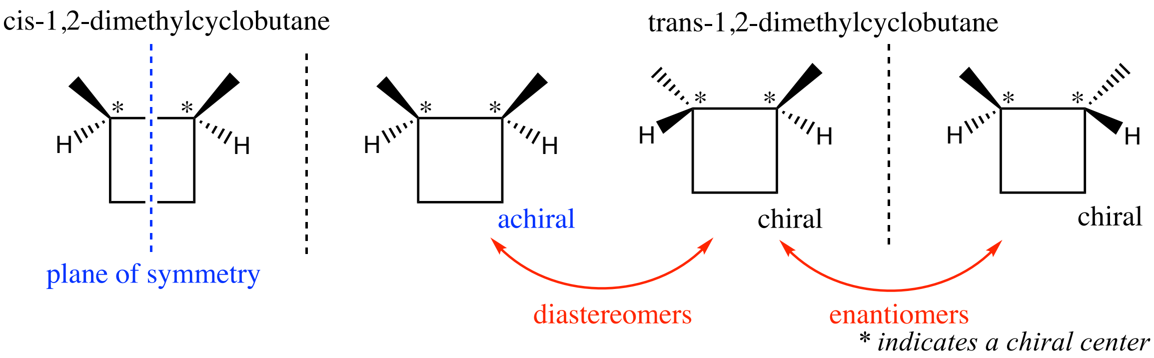


chiral?
No, both structures are achiral (not chiral)
and different drawings of same molecule

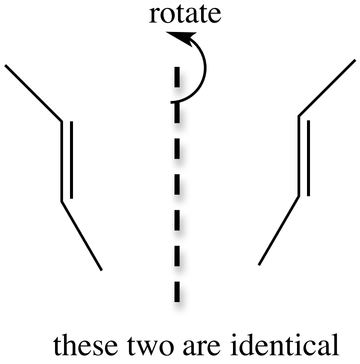
- identical compounds

If there is <u>plane of symmetry</u> within a molecule, then the molecule is **achiral** (not chiral)

However, can chiral centers exist within an achiral molecule?
Yes! These are called <u>*meso*</u> compounds!



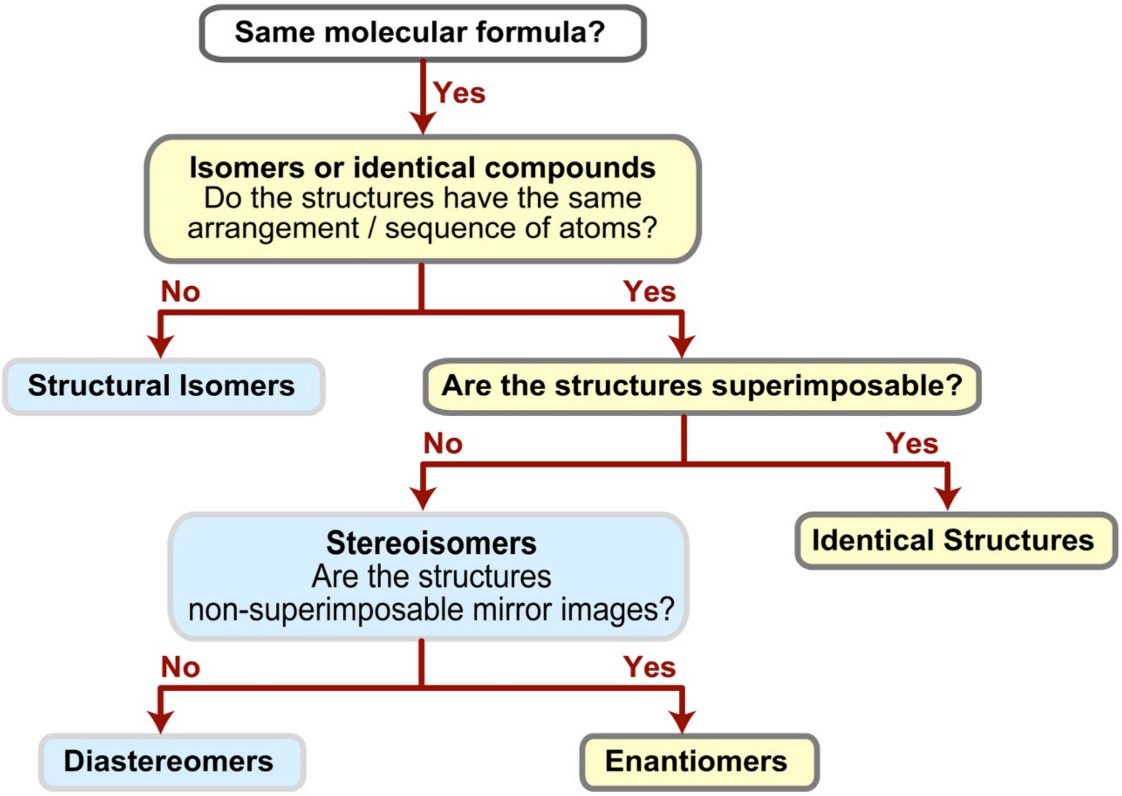
Note: a chiral center (or stereogenic centers) exists if *4 different groups* are attached to the carbon in question



trans-2-butene is achiral

All stereoisomers that are not enantiomers are diastereoisomers!

How to Determine Relationships Among Structures



R/S Nomenclature:

R and S designation of stereoisomers

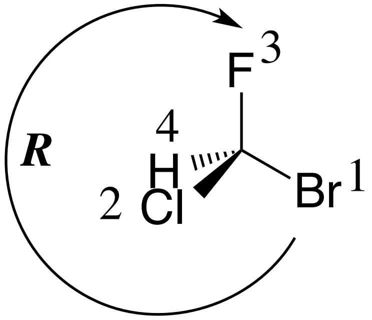
- R = Rectus (right, clockwise)
- S = Sinister (left, counterclockwise)

Labeling a stereogenic center as R or S:

- Identify all stereogenic centers (i.e. 4 different substituents)
- Assign priority based on atomic number (similar to *E* and *Z*). If you cannot decide, go to the next set of atoms.
- With the lowest priority group pointing back, count 1, 2, 3:
  - Clockwise → R configuration
  - Counterclockwise → S configuration

Each stereogenic center in a molecule is analyzed separately

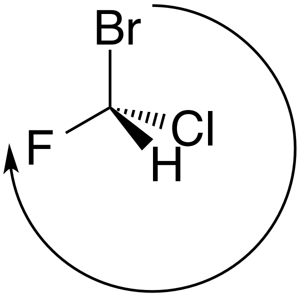
Example:



Place lowest priority to the back

1,2,3 --> clockwise = "R"
1,2,3 --> counterclockwise = "S"

What if the lowest priority group is pointing forward?

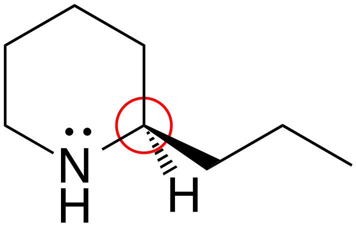


Counting 1, 2, 3 gives clockwise, BUT the smallest group is pointing forward, so the configuration is opposite of what you get if the smallest group is back

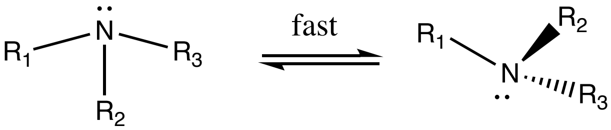
In this case, the configuration of the stereogenic center is "***S***"

CONIINE: Poison hemlock, potent neurotoxin

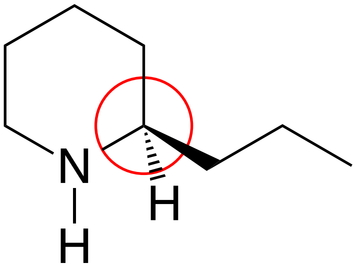
Stereogenic center (chiral centers or asymmetric centers) is circled in red



At room temperature the lone pair on nitrogen sits above or below and inverts freely like an umbrella → not chiral

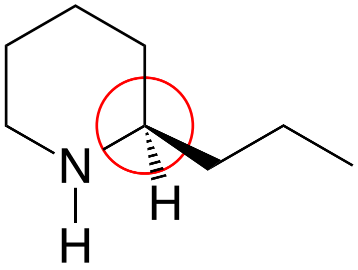


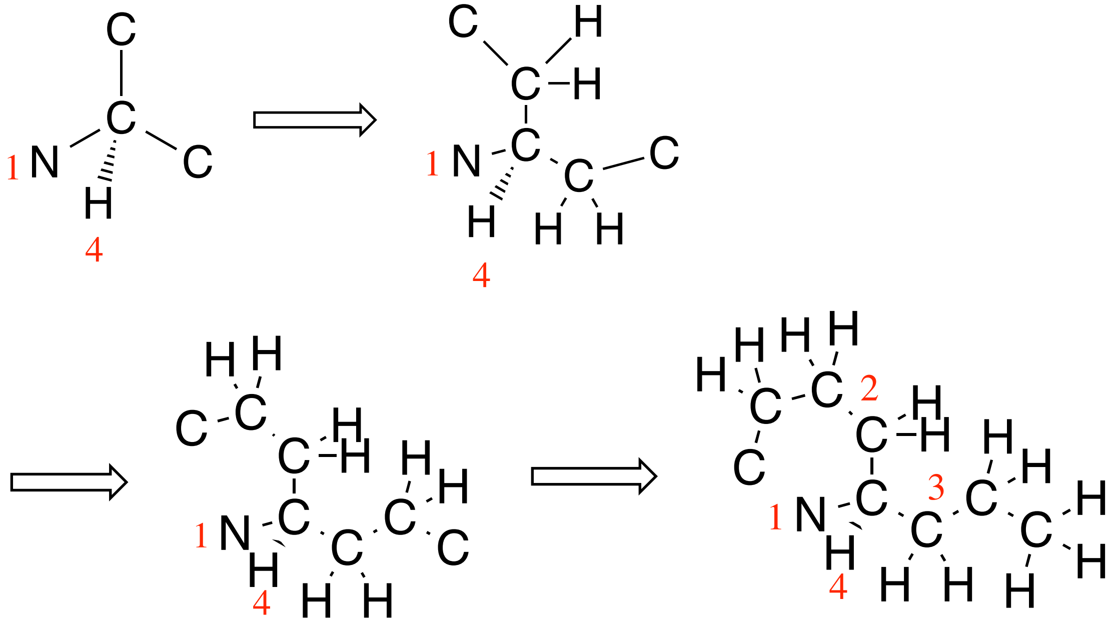
(nitrogen inversion)



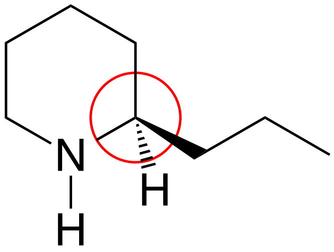
Determining R/S configuration of the stereocenter:

- We can assign highest priority to the N and lowest to the H, but cannot immediately tell which carbon attached to the stereocenter is of higher/lower priority. When this is the case, we look at the next substituents in the chain.

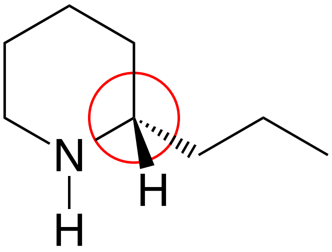




- We cannot tell at the second attached carbon, so we move on to the third.
- We still cannot tell at the third, so we move on to the fourth.
- At the fourth carbon we can see a difference. The carbon that is part of the propyl group ends in a CH_3 so it is bonded to three H, and the other carbon is bonded to two H and one C. The propyl group gets lower priority (3) and the other group gets higher priority (2).
- Counting 1,2,3 → clockwise is *R*. This is the *R* enantiomer.



R - enantiomer of coniine



S - enantiomer of coniine - invert EVERY stereocenter

Another Example

Cholesterol