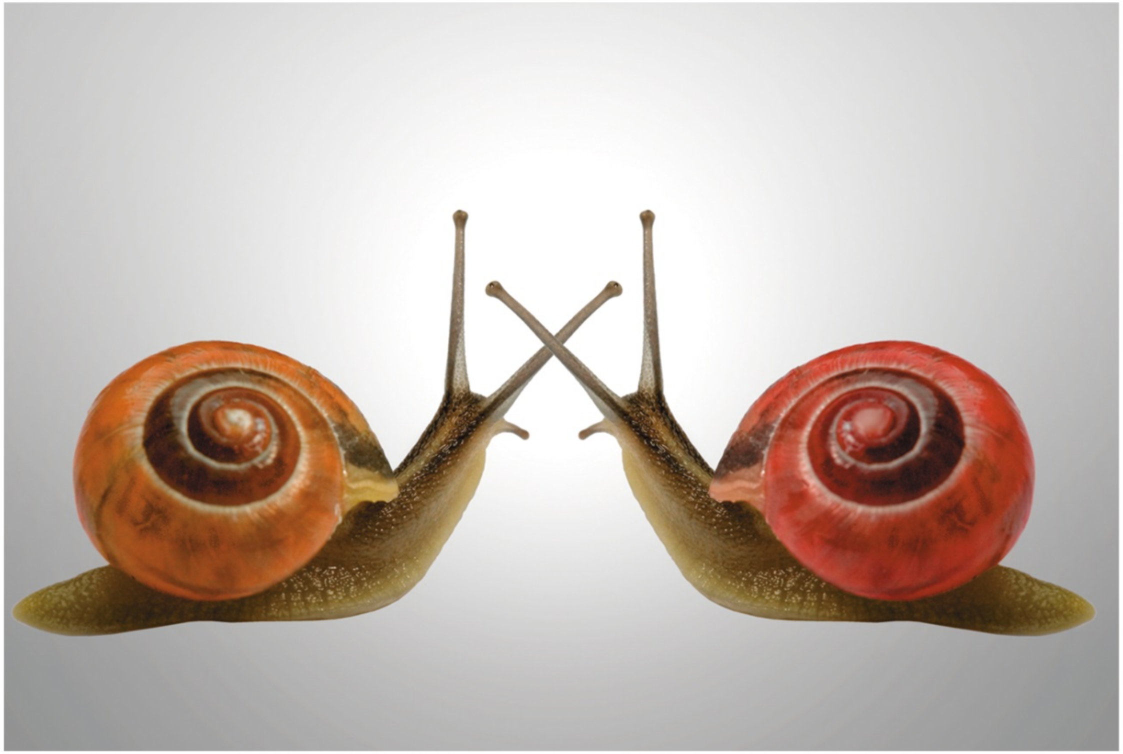
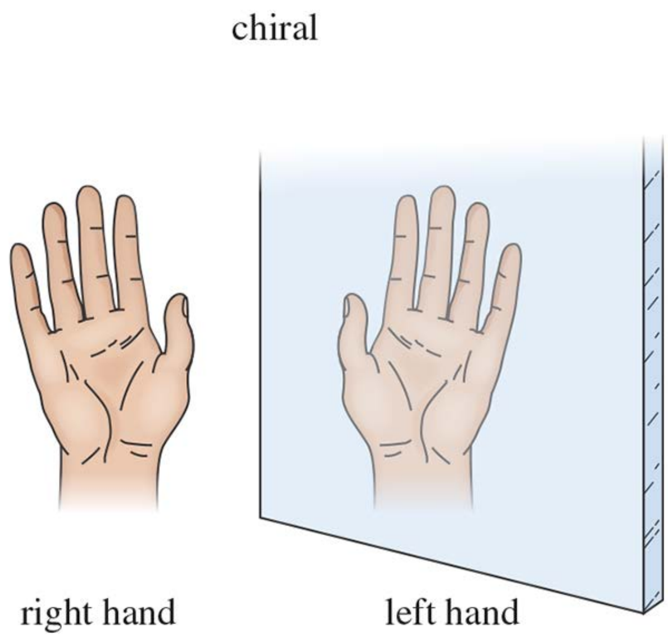


Organic Chemistry,
9th Edition
L. G. Wade, Jr.

Chapter 5 Lecture

Stereochemistry

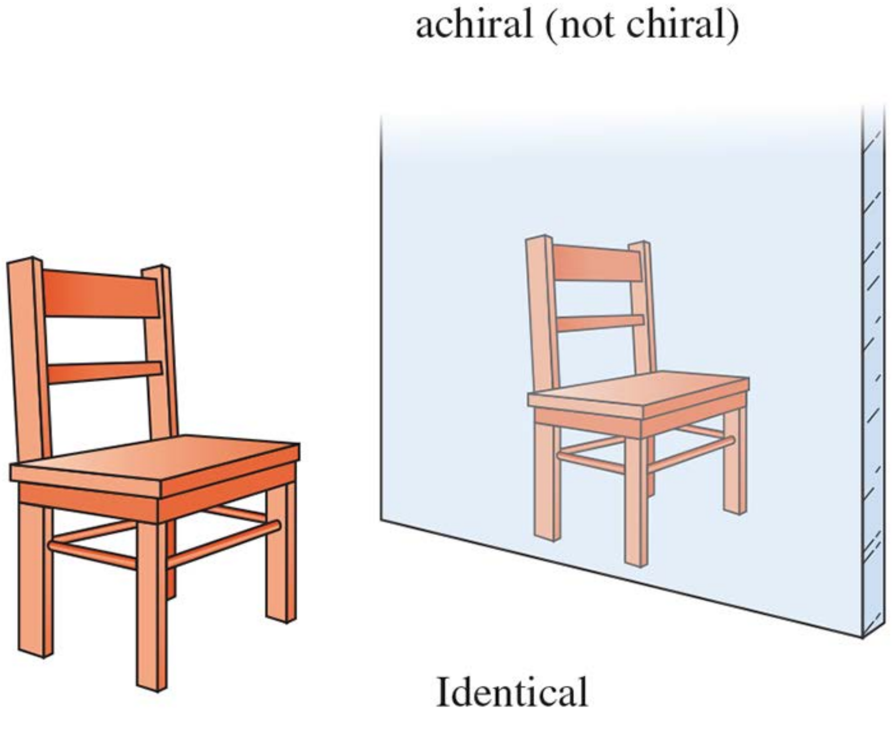
Chirality



- “Handedness”: Right-hand glove does not fit the left hand.
- An object is **chiral** if its mirror image is different from the original object.

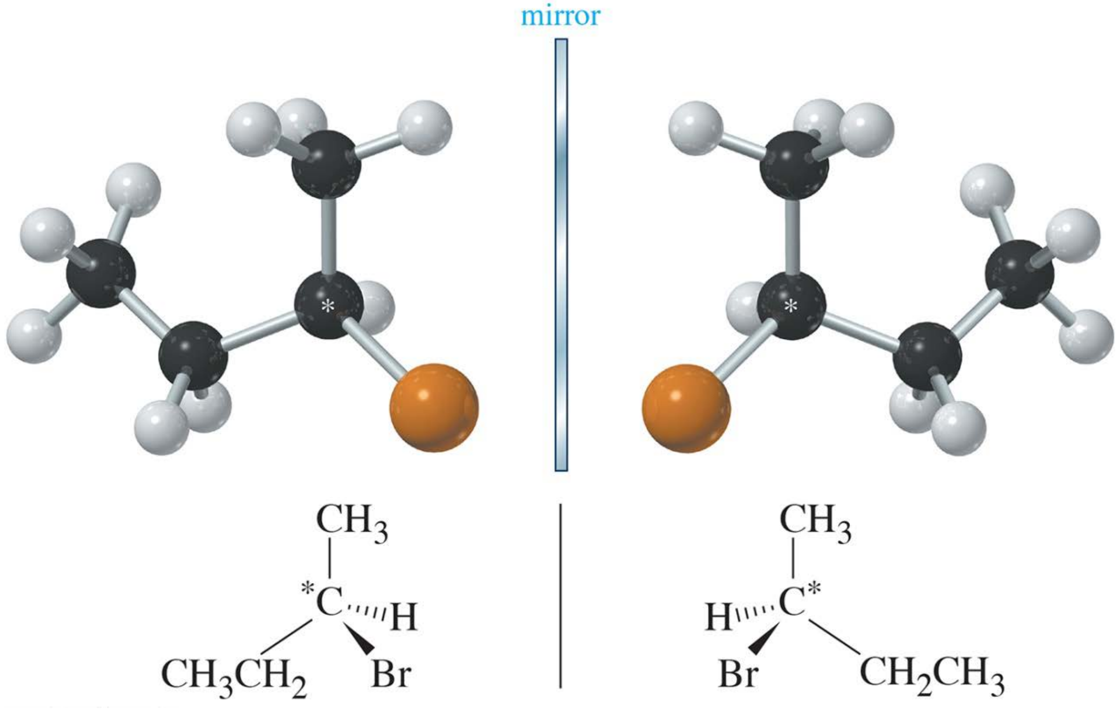
Achiral

- Mirror images that can be superposed are **achiral** (not chiral).



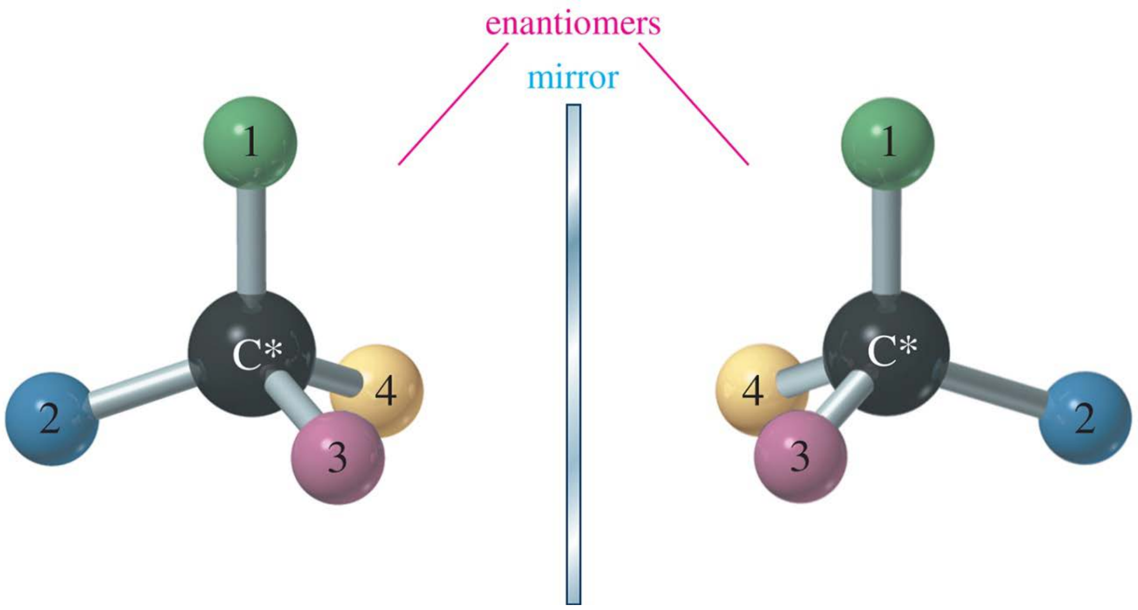
Stereoisomers

Enantiomers are compounds that are nonsuperimposable mirror images. Any molecule that is chiral must have an enantiomer.



Chiral Carbon Atom

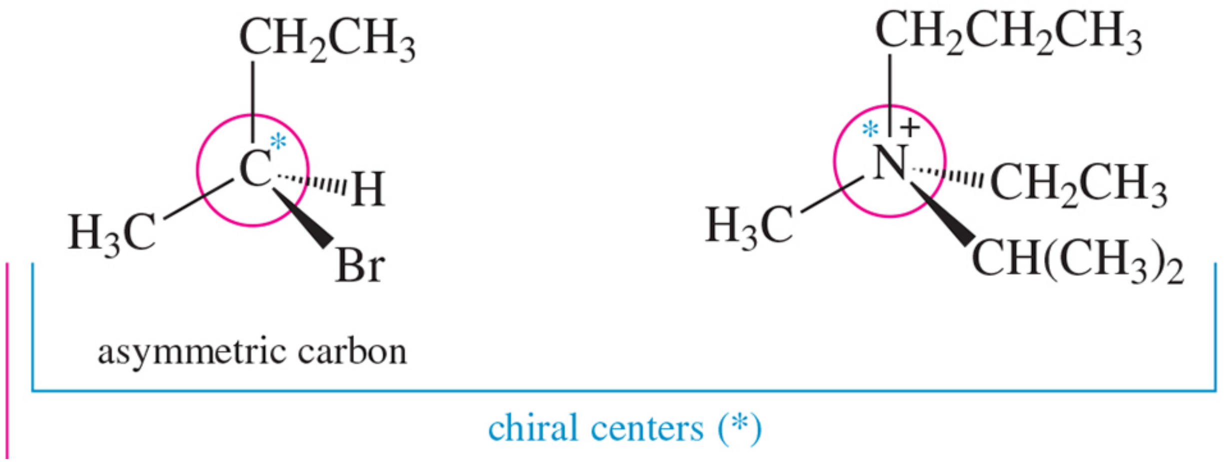
- Also called **asymmetric carbon** atom
- A carbon atom that is bonded to four different groups is chiral.
- Its mirror image will be a different compound (enantiomer).



Stereocenters

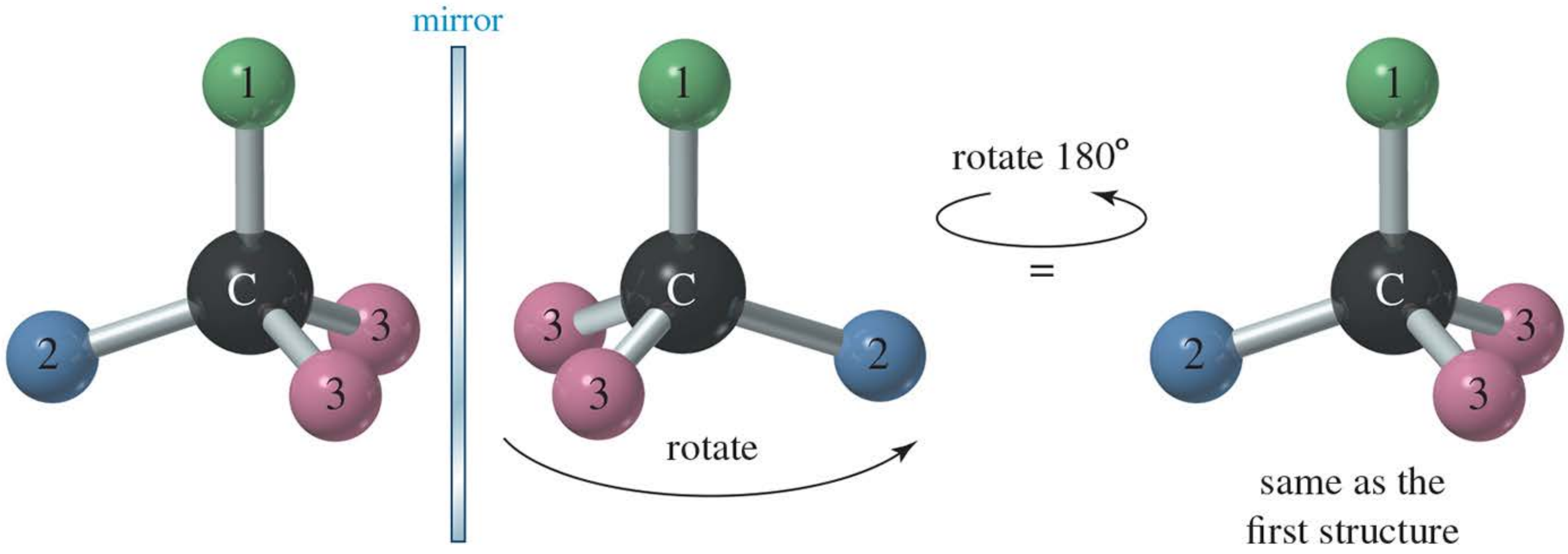
- An asymmetric carbon atom is the most common example of a **chirality center**.
- Chirality centers belong to an even broader group called **stereocenters***.* A **stereocenter** (or **stereogenic atom**) is any atom at which the interchange of two groups gives a stereoisomer.
- Asymmetric carbons and the double-bonded carbon atoms in cis-trans isomers are the most common types of stereocenters.

Examples of Chirality Centers



Asymmetric carbon atoms are examples of chirality centers, which are examples of stereocenters.

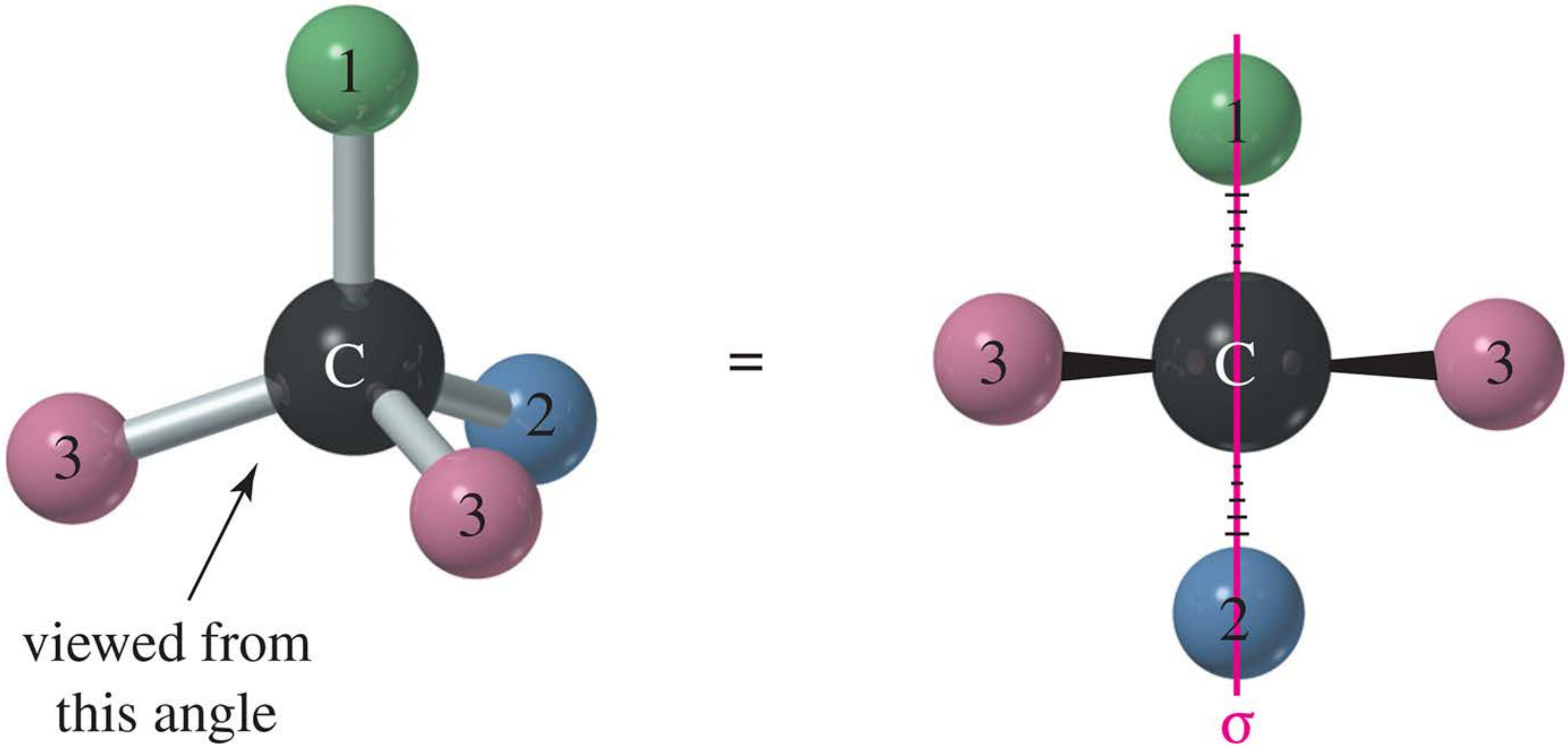
Achiral Compounds



Take this mirror image and try to superimpose it on the one to the left matching all the atoms. Everything will match.

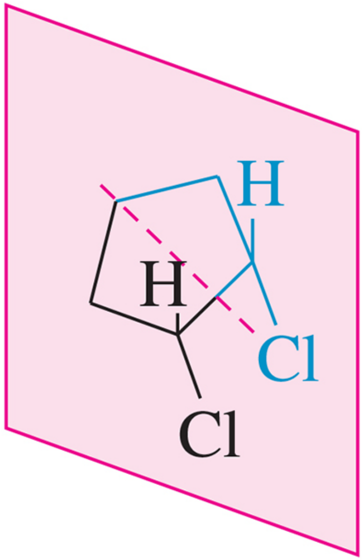
When the images can be superposed, the compound is **achiral**.

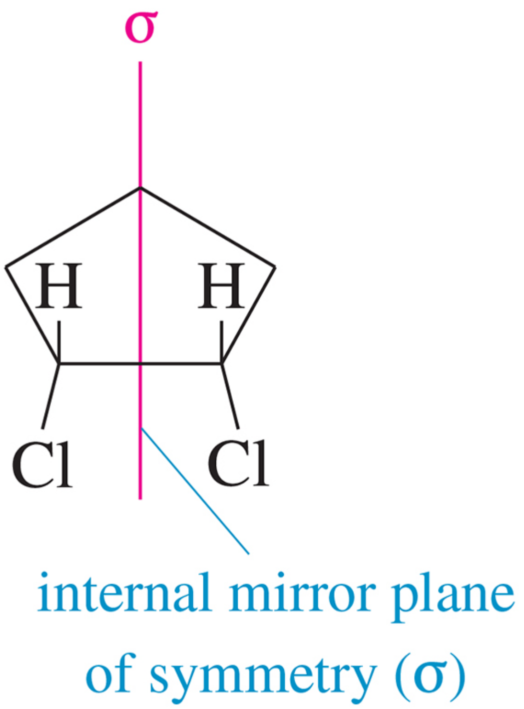
Planes of Symmetry



- A molecule that has a plane of symmetry is **achiral**.

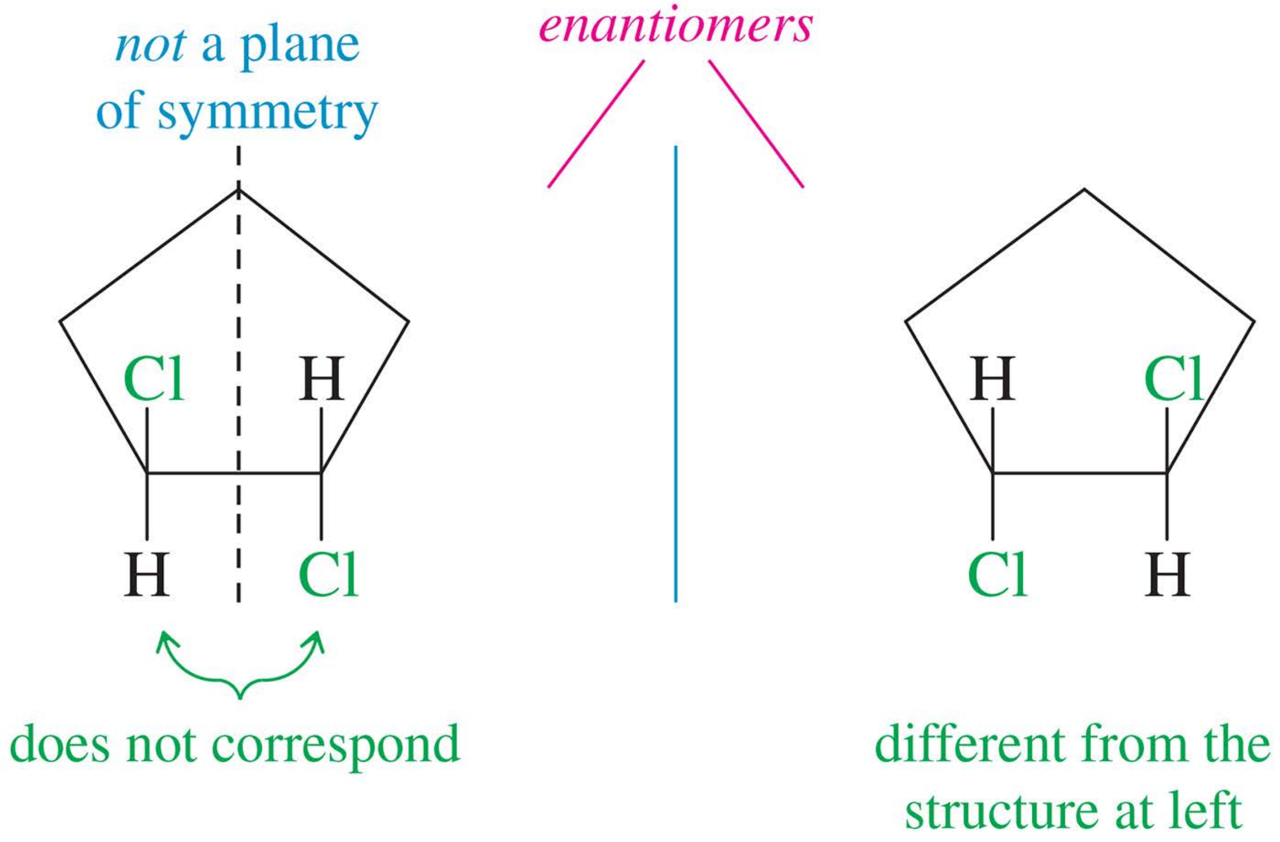
Cis Cyclic Compounds





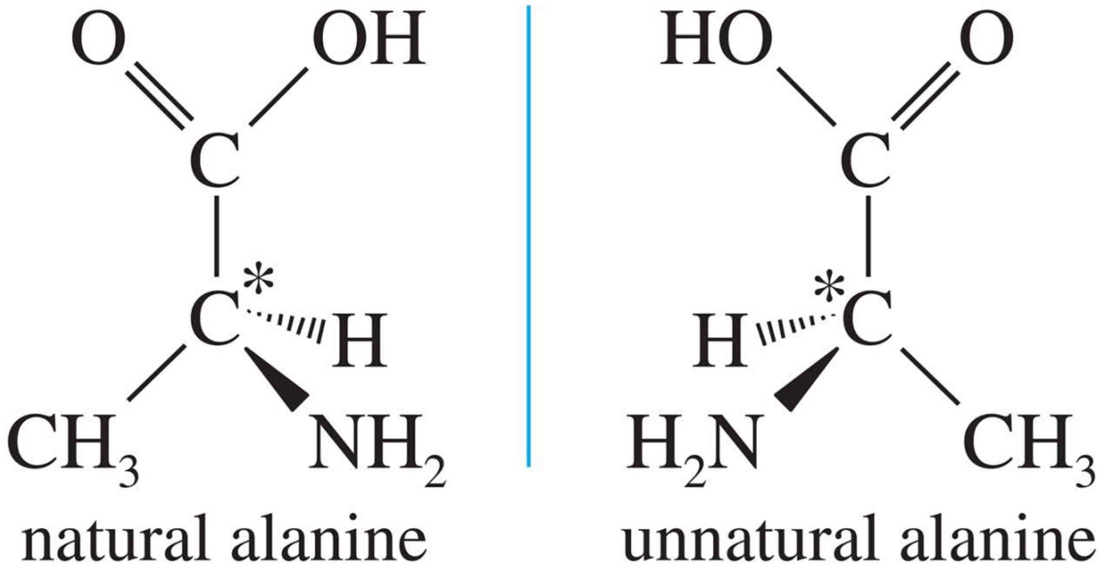
- *Cis*-1,2-dichlorocyclohexane is achiral because the molecule has an internal plane of symmetry. Both structures above can be superimposed.

Trans Cyclic Compounds



- *Trans*-1,2-dichlorocyclohexane does not have a plane of symmetry, so the images are nonsuperimposable and the molecule will have two enantiomers.

(R) and (S) Configuration



- Both enantiomers of alanine receive the same name in the IUPAC system: 2-aminopropanoic acid.
- Only one enantiomer is biologically active. In alanine only the left enantiomer can be metabolized by the enzyme.
- We need a way to distinguish between them.

Cahn–Ingold–Prelog Convention

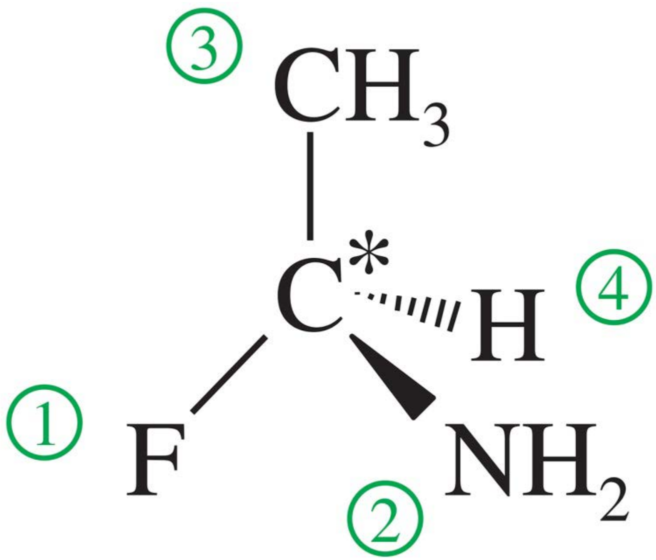
- Enantiomers have different spatial arrangements of the four groups attached to the asymmetric carbon.
- The two possible spatial arrangements will be called **configurations**.
- Each asymmetric carbon atom is assigned a letter, (*R*) or (*S*), based on its three-dimensional configuration.
- **Cahn–Ingold–Prelog** convention is the most widely accepted system for naming the configurations of chirality centers.

(*R*) and (*S*) Configuration: Step 1 Assign Priority

- Assign a relative “priority” to each group bonded to the asymmetric carbon. Group 1 would have the highest priority, group 2 second highest, etc.
- Atoms with higher atomic numbers receive higher priorities.

$I > Br > Cl > S > F > O > N > {}^{13}C > {}^{12}C > Li > {}^{2}H > {}^{1}H$

Assign Priorities

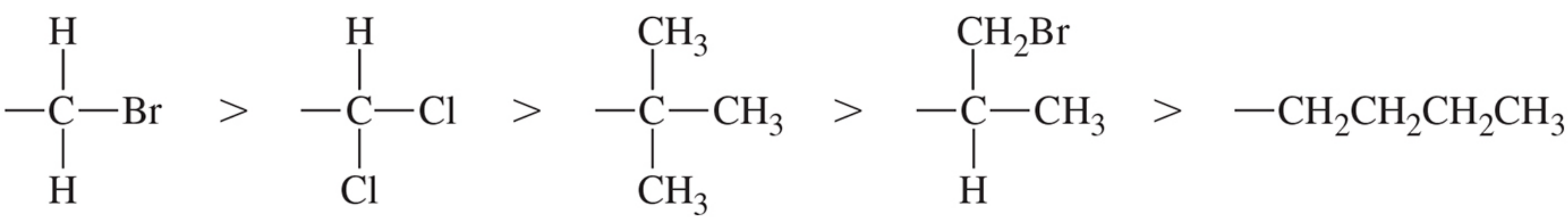


Atomic number: F > N > C > H

(R) and (S) Configuration: Breaking Ties

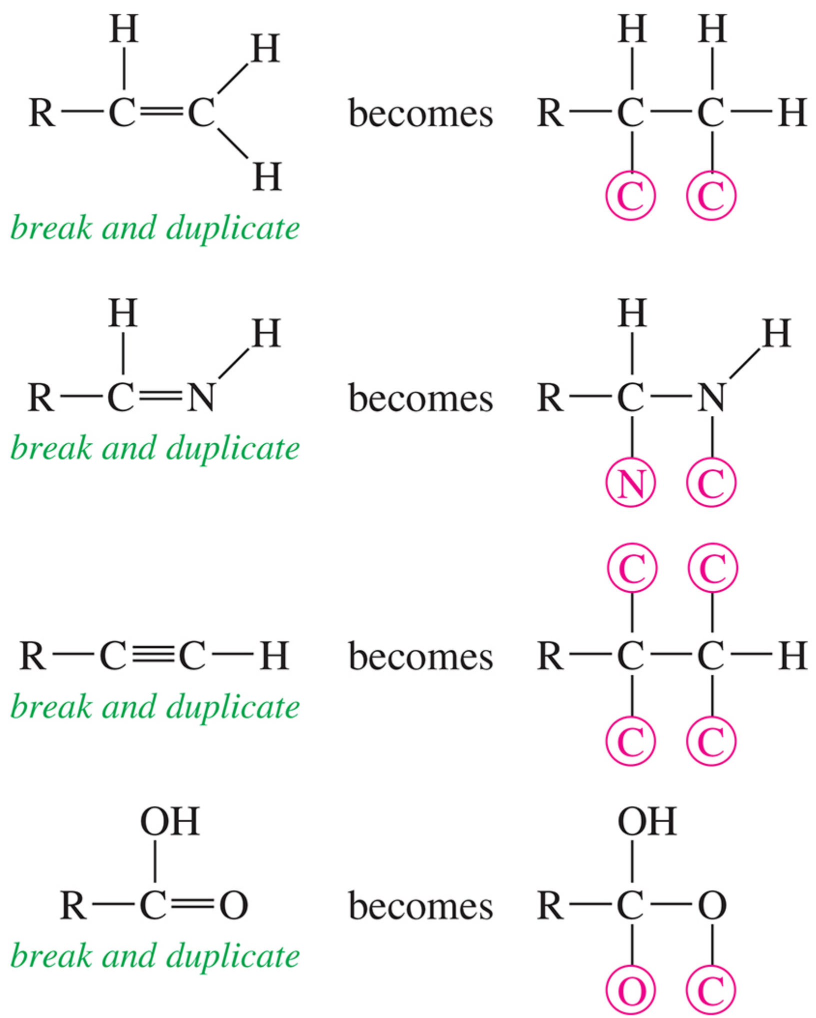
In case of ties, use the next atoms along the chain of each group as tiebreakers.

Examples



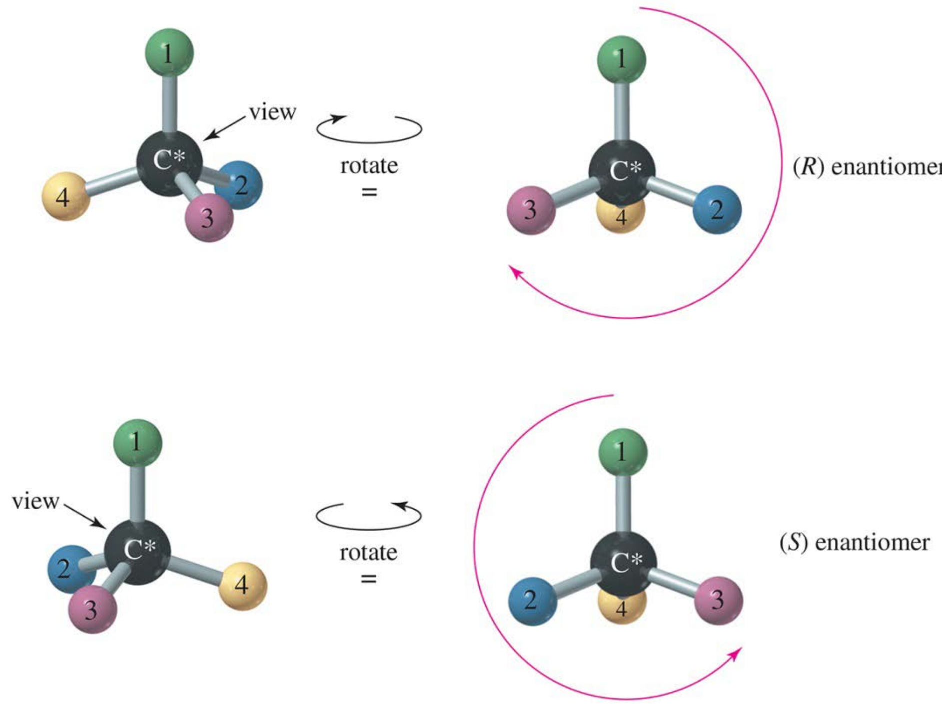
(R) and (S) Configuration: Multiple Bonds

Treat double and triple bonds as if each were a bond to a separate atom.

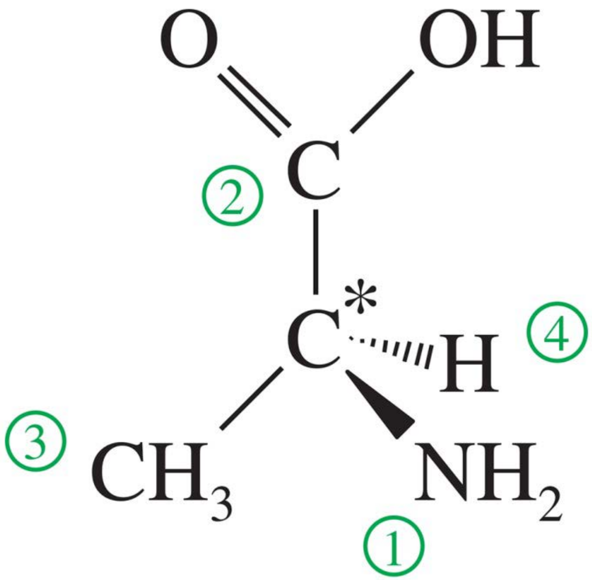


(R) and (S) Configuration: Step 2

- Working in 3-D, rotate the molecule so that the lowest priority group is in back.
- Draw an arrow from the highest to lowest priority group.
- Clockwise = (*R*)
  Counterclockwise = (*S*)



Assign Priorities



alanine

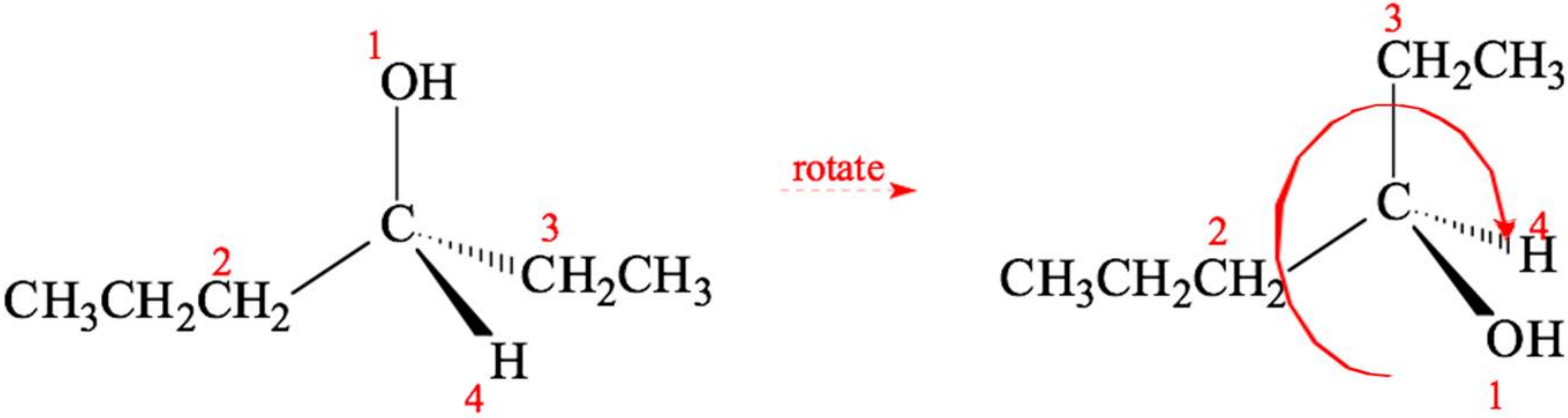
Counterclockwise

(*S*)

Draw an arrow from Group 1 to Group 2 to Group 3 and back to Group 1. Ignore Group 4.

Clockwise = (*R*) and Counterclockwise = (*S*)

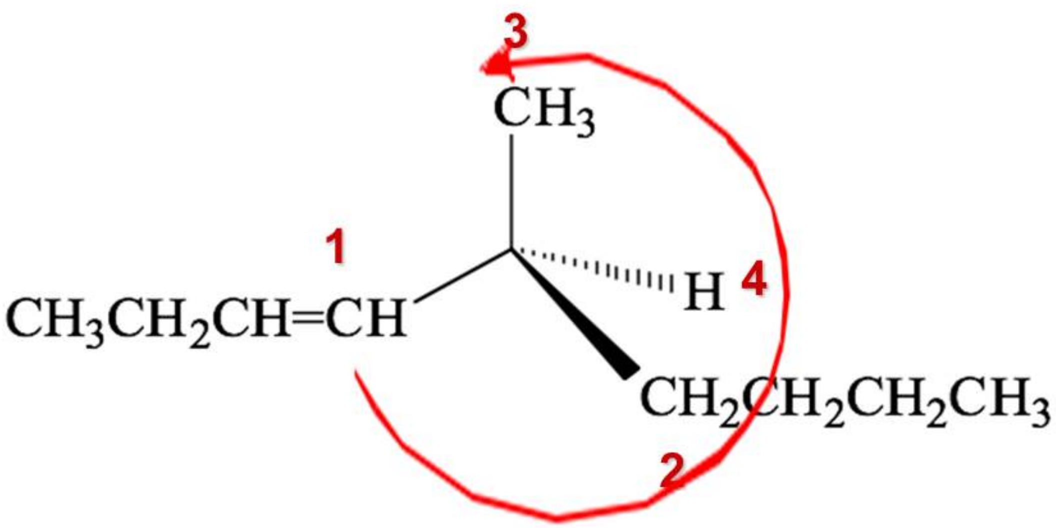
Example



Clockwise
(*R*)

When rotating to put the lowest priority group in the back, keep one group in place and rotate the other three.

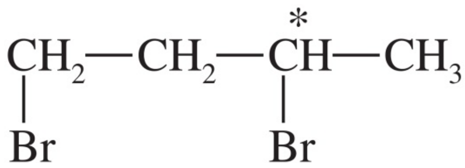
Example (Continued)



Counterclockwise
(*S*)

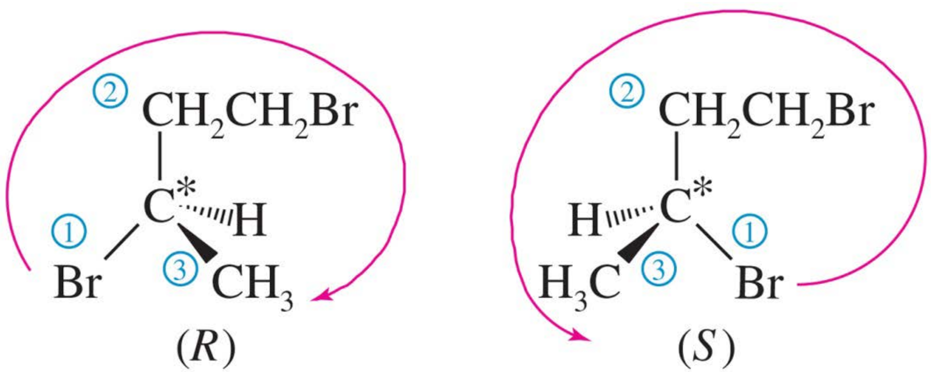
Solved Problem 1

Draw the enantiomers of 1,3-dibromobutane and label them as (*R*) and (*S*). (Making a model is particularly helpful for this type of problem.)

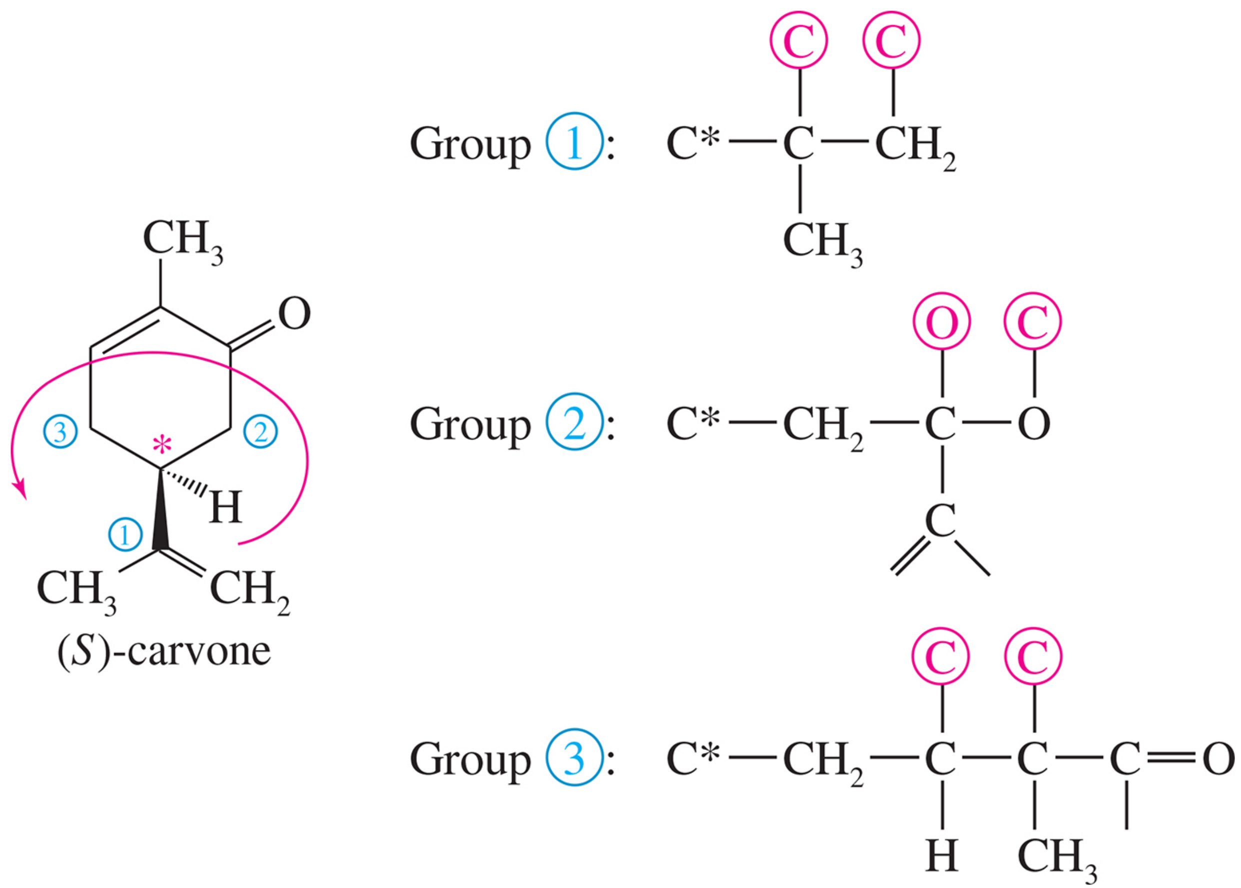


Solution

The third carbon atom in 1,3-dibromobutane is asymmetric. The bromine atom receives first priority, the ($–CH_2CH_2Br$) group second priority, the methyl group third, and the hydrogen fourth. The following mirror images are drawn with the hydrogen atom back, ready to assign (*R*) or (*S*) as shown.



Configuration in Cyclic Compounds

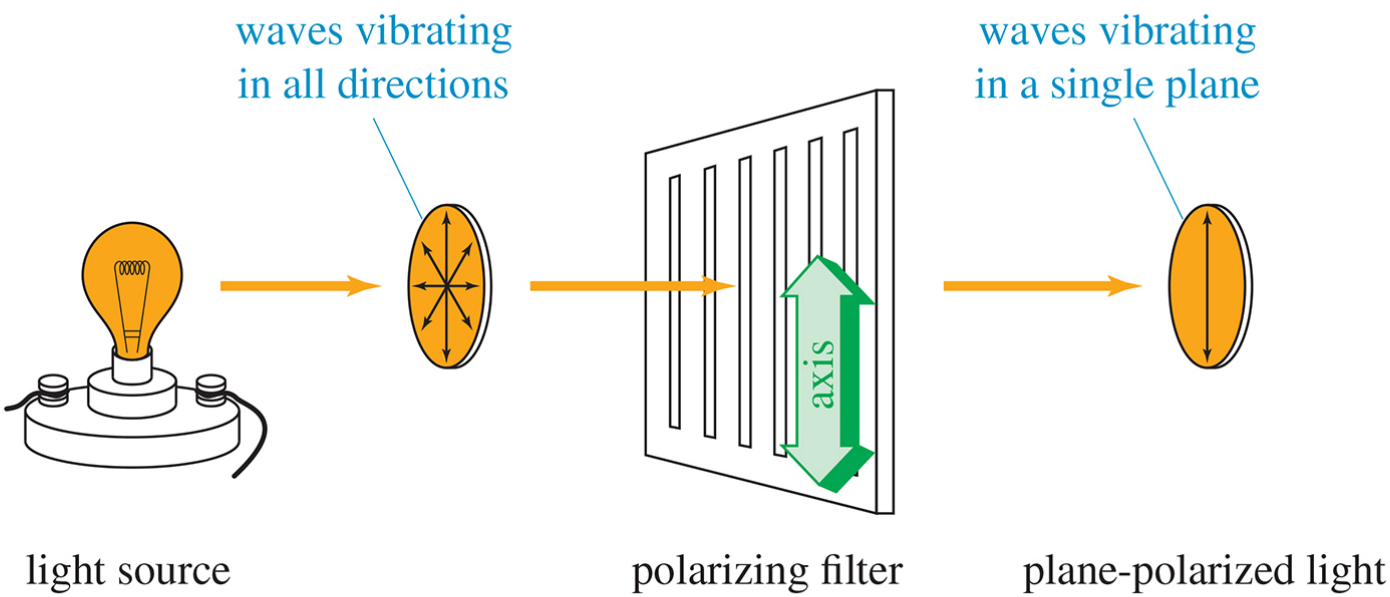


Properties of Enantiomers

- Same boiling point, melting point, and density
- Same refractive index
- Rotate the plane of polarized light in the same magnitude, but in opposite directions.
- Different interaction with other chiral molecules
  - Active site of enzymes is selective for a specific enantiomer.
  - Taste buds and scent receptors are also chiral. Enantiomers may have different smells.

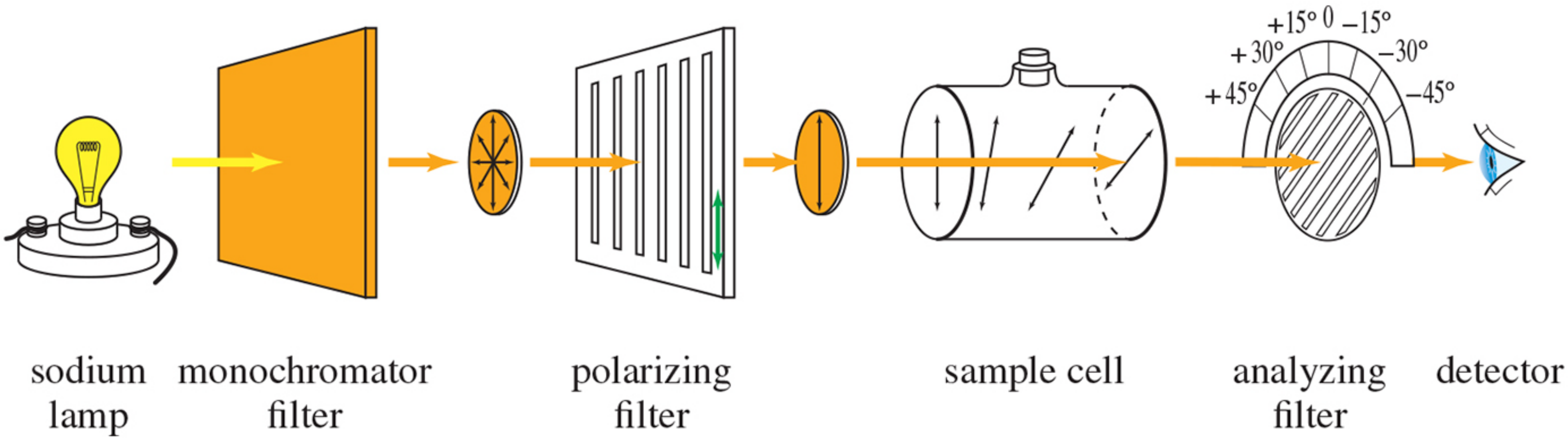
Polarized Light

Plane-polarized light is composed of waves that vibrate in only one plane.

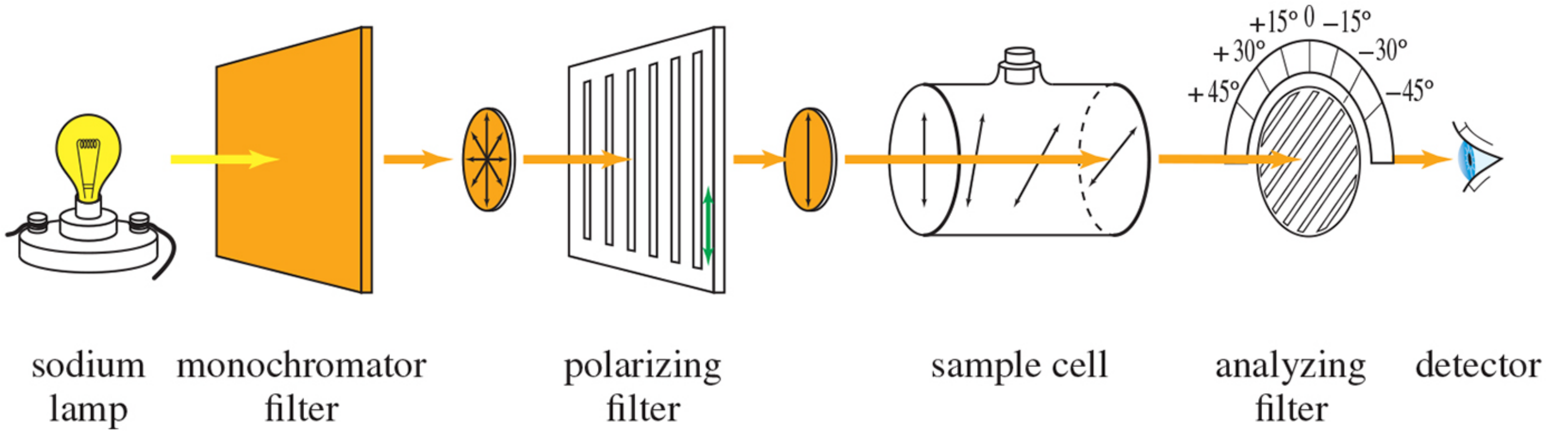


Optical Activity

- Enantiomers rotate the plane of polarized light in opposite directions, but in the same number of degrees.



Polarimeter



Clockwise

Dextrorotatory (+)

Counterclockwise

Levorotatory (–)

Not related to (*R*) and (*S*)

Specific Rotation

Observed rotation depends on the length of the cell and concentration, as well as the strength of optical activity, temperature, and wavelength of light.

$$[\alpha] = \frac{\alpha\,(\text{observed})}{c \bullet l}$$

where α (observed) is the rotation observed in the polarimeter, *c* is concentration in g/mL, and *l* is length of sample cell in *decimeters*.

Solved Problem 2

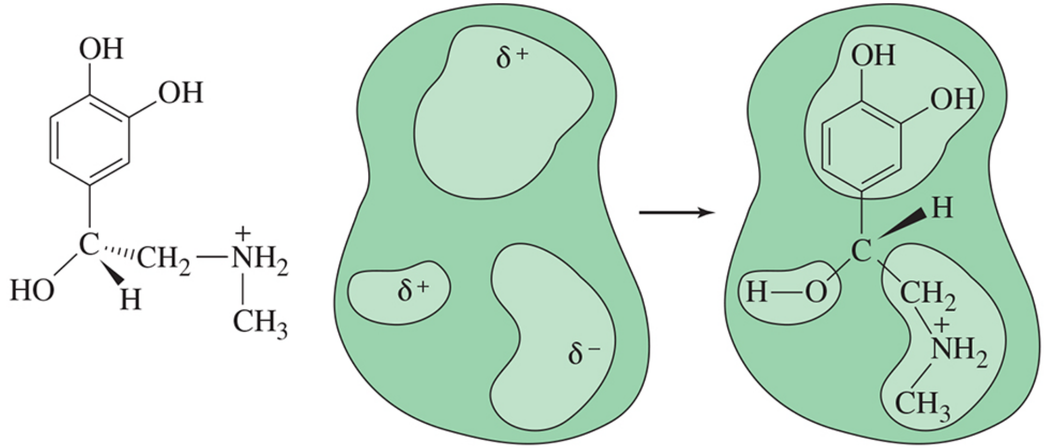
When one of the enantiomers of 2-butanol is placed in a polarimeter, the observed rotation is 4.05° counterclockwise. The solution was made by diluting 6 g of 2-butanol to a total of 40 mL, and the solution was placed into a 200-mm polarimeter tube for the measurement. Determine the specific rotation for this enantiomer of 2-butanol.

Solution

Since it is levorotatory, this must be (–)-2-butanol The concentration is 6 g per 40 mL = 0.15 g/mL, and the path length is 200 mm = 2 dm. The specific rotation is

$$[\alpha]_{\mathrm{D}}^{25} = \frac{-4.05^\circ}{(0.150)(2.00)} = -13.5^\circ$$

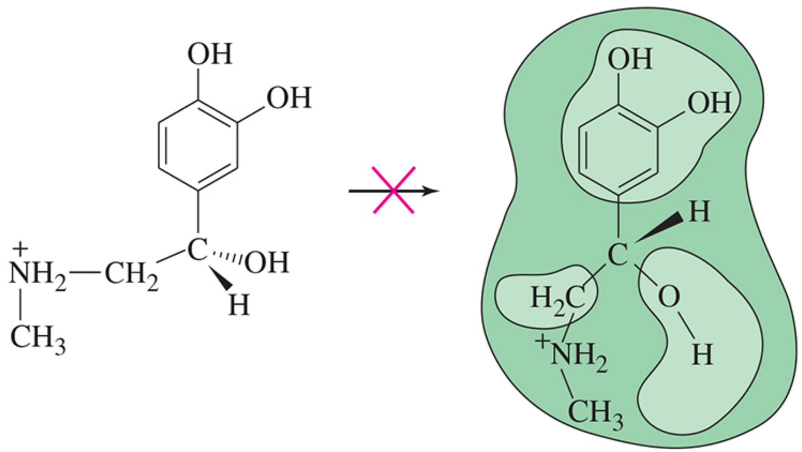
Biological Discrimination



(*R*)-(−)-epinephrine
natural epinephrine

enzyme active site

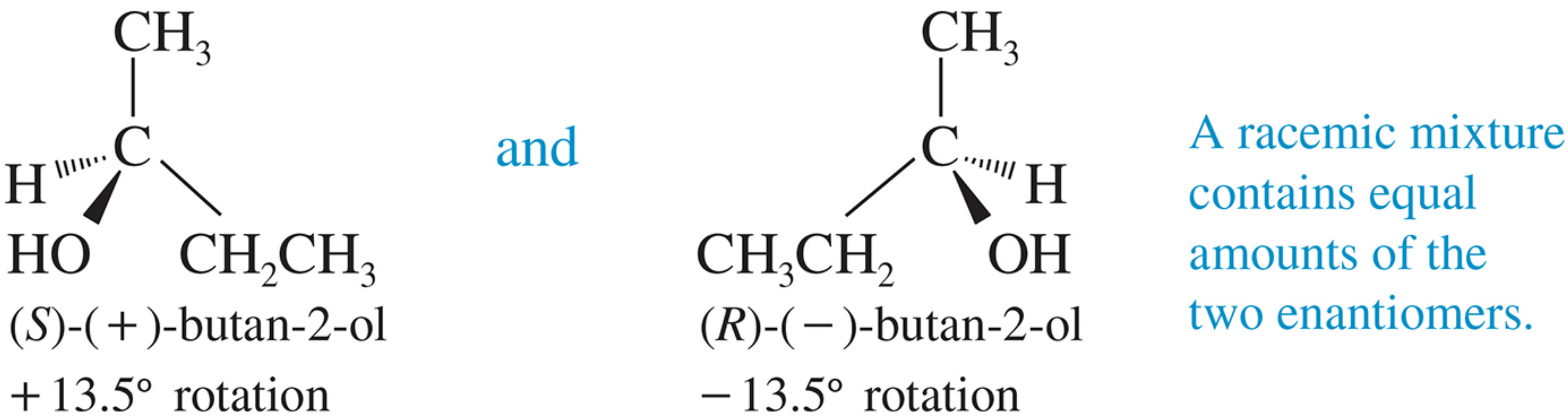
enzyme–substrate complex



(*S*)-(+)-epinephrine
unnatural epinephrine

does not fit the enzyme's active site

Racemic Mixtures



- Equal quantities of *d*- and *l*-enantiomers
- Notation: (*d,l*) or (±)
- No optical activity
- The mixture may have different boiling point (b. p.) and melting point (m. p.) from the enantiomers!

Start 9/26/16 after this slide