Al-Mustaqbal University

College of Science

Drug Stereochemistry

Third Year Students / 2nd Semester

2025-2026

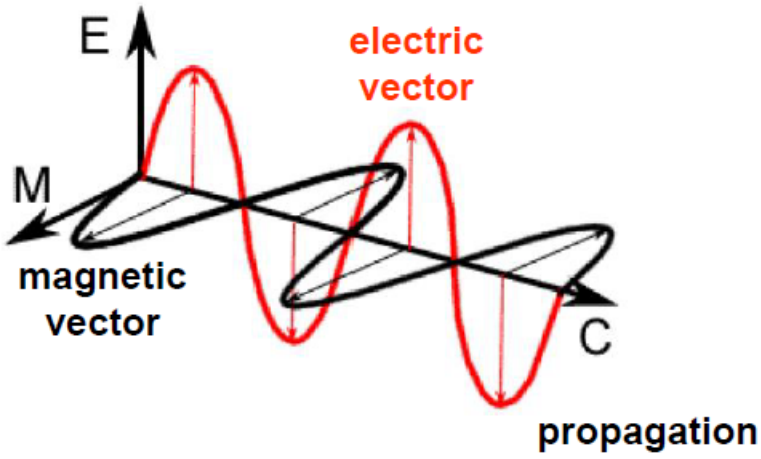
Optical Activity and Polarimeter

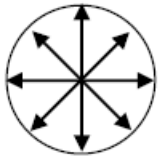
By

Prof. Dr. Naser Abdulhasan Naser

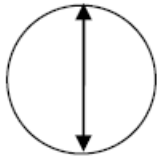
Optical Activity

- The physical properties of two enantiomers are identical except for how they interact with plane-polarized light.
- In ordinary light the electric vector oscillates in all planes perpendicular to the propagation direction.
- In plane polarized light the vector oscillates in a single plane. Polarized light is obtained with a polarizer.





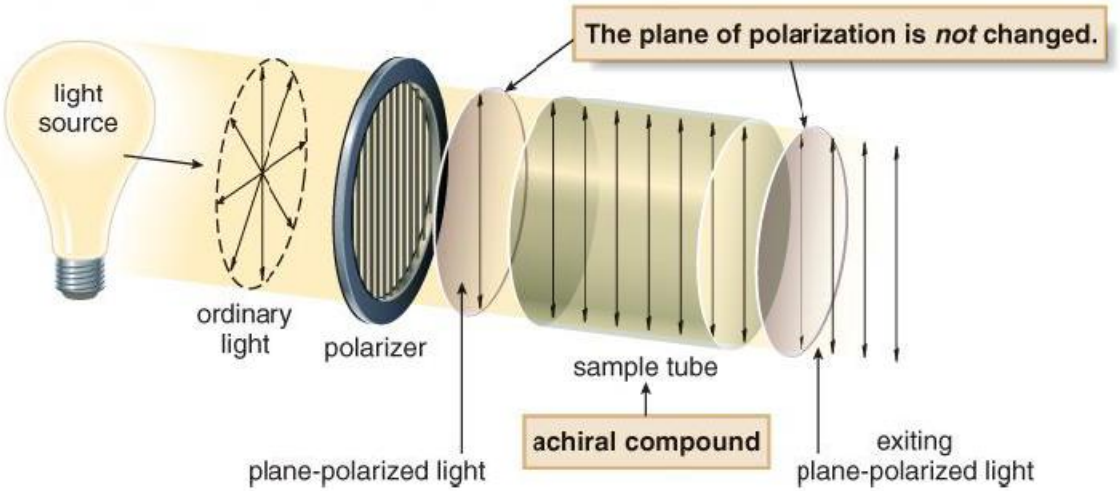
unpolarized light



plane-polarized light

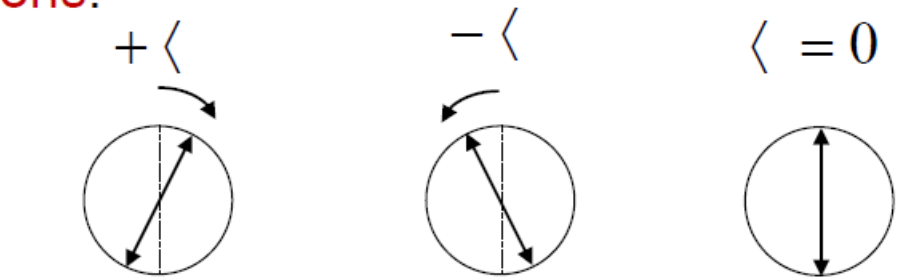
Optical Activity

- In a polarimeter polarized light travels through a sample tube containing an organic compound.
- With achiral compounds, the light that exits the sample tube remains unchanged. A compound that does not change the plane of polarized light is said to be optically inactive.



Optical Activity

- Two enantiomers rotate plane-polarized light to an equal extent but in opposite directions.

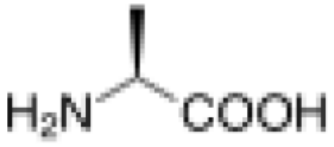


dextrorotatory (+) Optically active

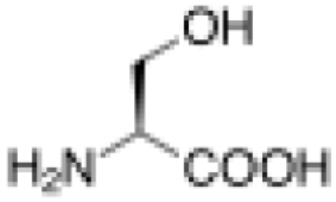
levorotatory (–) Optically active

Optically inactive

- No relationship exists between *R* and *S* prefixes and the (+) and (-) designations that indicate optical rotation.



(*S*)-(+)



(*S*)-(-)

Optical Activity

- Specific rotation is a standardized physical constant for the amount that a chiral compound rotates plane-polarized light. Specific rotation [α] is defined using a specific sample tube length (l, in dm), concentration (c in g/mL for pure liquids [=d]; g/100mL for solutions), temperature (generally 25^0C) and wavelength (generally 589 nm).

$$\textbf{specific rotation} = [\alpha] = \frac{\alpha}{l \times c}$$

α = observed rotation (°)
l = length of sample tube (dm)
c = concentration (g/ml or g/100ml)

[dm = decimeter
1 dm = 10 cm]

Racemic Mixtures

- An equal amount of two enantiomers is called a racemic mixture or a racemate. A racemic mixture is optically inactive. Because two enantiomers rotate plane-polarized light to an equal extent but in opposite directions, the rotations cancel, and no rotation is observed.

Property	(+) Enantiomer	(-) Enantiomer	Racemic mixture
melting point	identical		may be different
boiling point	identical		may be different
optical rotation	+ α	- α	0

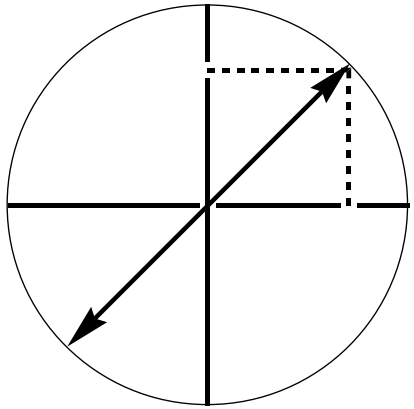
Click to Flip

Which of these are **true** and which are **false** about stereochemistry?

• A molecule with a single chiral center can exist as a pair of enantiomers.	T	F
• Meso compounds have chiral centers but are achiral overall due to the presence of a plane of symmetry	T	F
• Molecules that are non-superimposable mirror images of each other are called diastereomers	T	F
• A molecule with three chiral centers can have a maximum of eight stereoisomers.	T	F
• A molecule with an (*R*) configuration of its chiral center can be converted to its (S) isomer through a series of bond rotations	T	F
• Interconverting any two substituents on a chiral center will flip the chirality from (*S*) to (*R*) or vice-versa	T	F
• Diastereomers are stereoisomers with identical melting points and boilng points	T	F
• The enantiomer of (*R,R*)-tartaric acid is (*S, S*) tartaric acid	T	F
• Enantiomers with an (*R*) configuration rotate plane-polarized light to the right, and enantiomers with an (*S*) configuration rotate plane-polarized light to the left	T	F
• The only way it is possible for molecules to be chiral is for there to be a carbon attached to 4 different substituents	T	F

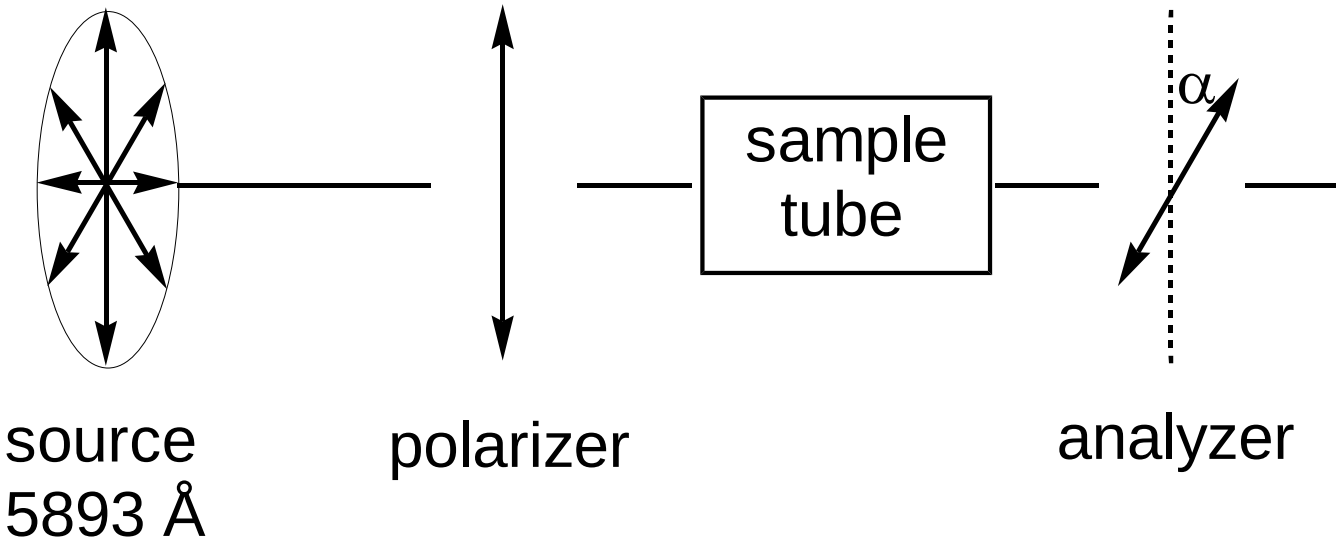
Plane-polarized light

Ordinary light is a moving wave whose vibrations take place in all directions perpendicular to the direction in which the light is travelling. One can envisage each vibration as the vector of two vibrations which are mutually at right angles.



One of these components can be eliminated by passing ordinary light through a polarizer - Polaroid filter. The resulting light is said to be polarized - all its vibrations are parallel to a single plane.

Polarimeter



Optical activity

An optically active compound is one which rotates the plane of polarization.

If from the vantage point of the observer the rotation is in the clockwise direction, the sample is said to be dextrorotatory. The angle of rotation, α, is considered to be positive (+).

If the rotation is in the counterclockwise direction, the sample is said to be levorotatory and the angle, α, is then negative (-).

There is no correlation between (+)/(-) and (R)/(S). Thus (R)-2-chlorobutane is the levorotatory enantiomer.

Specific rotation

α is proportional to the concentration of the sample and the length of the sample tube:

$$[\alpha]_{\lambda}^{t} = \frac{\alpha}{l \times c}$$

α - angle of rotation measured in degrees

t - temperature

λ - wavelength of light

l - length of sample cell

c - concentration in grams of substance contained in 1 mL of solution

Racemic mixtures

An equimolar mixture of two enantiomers.

Prefix the name with ±.

Reactions performed using an achiral reagent can form products have a tetrahedral stereogenic centre. However the product will be a racemic mixture.

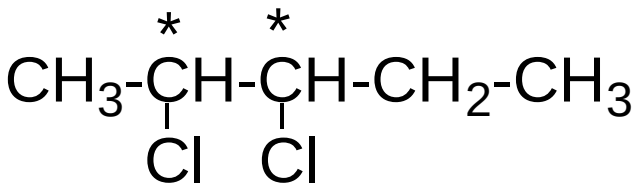
If the reagent is chiral, one can often produce a single enantiomer of the product molecule.

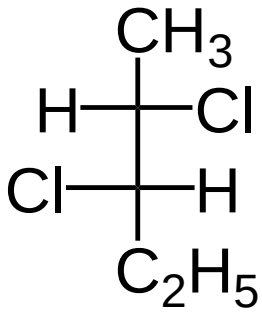
Molecules with more than one stereogenic centre

$CH_3CHClCHClCH_2CH_3$

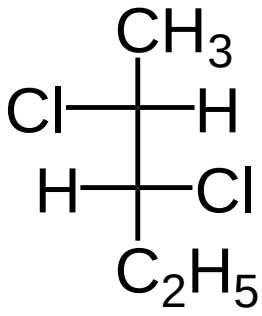
How many stereoisomers exist for this compound?

2,3-dichloropentane



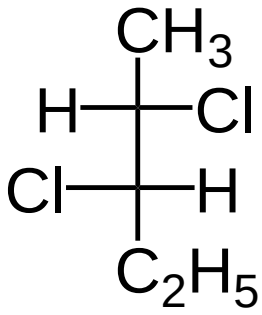


(2S,3S)

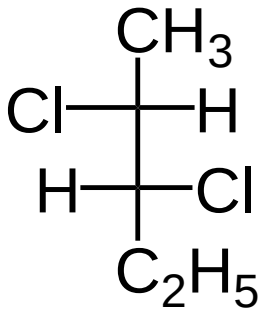


(2R,3R)

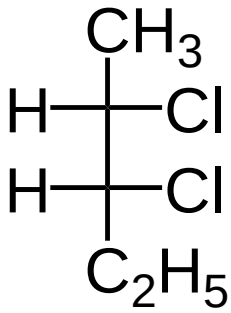
2,3-dichloropentane



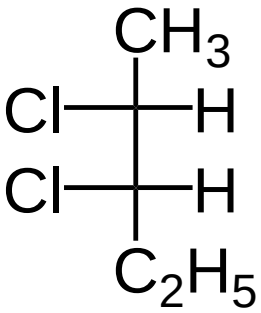
(2S,3S)



(2R,3R)



(2S,3R)



(2R,3S)

How many stereoisomers exist?

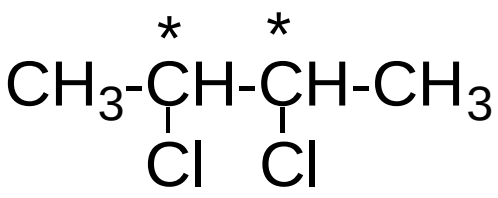
The **maximum** number of stereoisomers that can exist is equal to

$$\mathbf{2^n}$$

where n is the number of tetrahedral stereogenic carbons in the molecule.

2,3-dichlorobutane

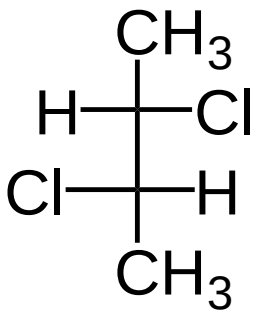
Look at 2,3-dichlorobutane. Are there four different isomeric forms?

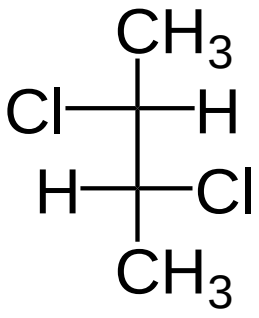


There are two tetrahedral stereogenic carbons.....2^n?

2,3-dichlorobutane

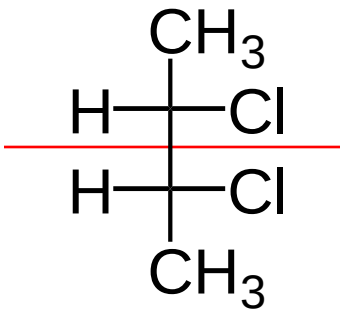
(2S,3S)

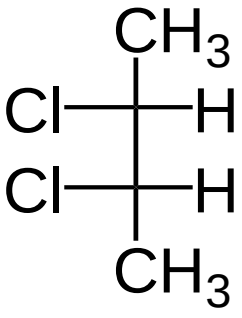




(2R,3R)

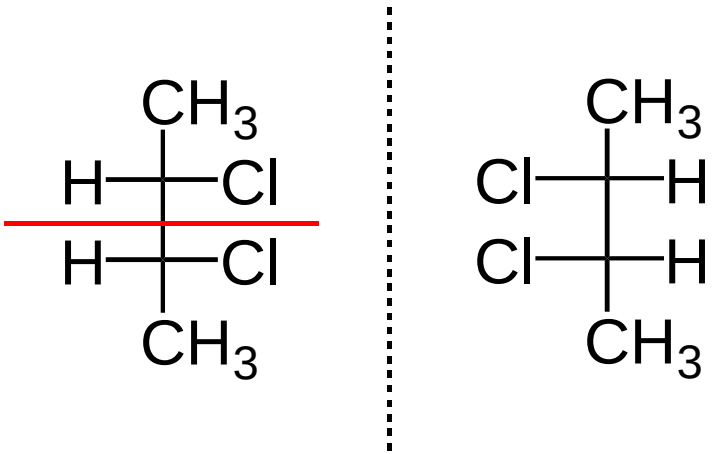
(2S,3R)?



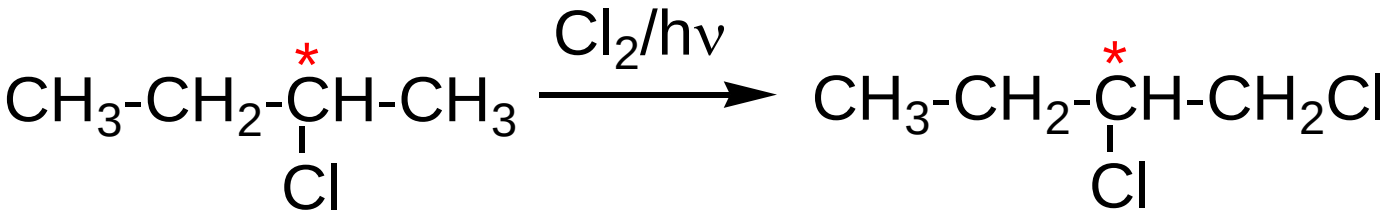


meso compounds

A meso compound is one which is superimposable on its mirror image even though it contains stereogenic centres. The molecule is achiral.

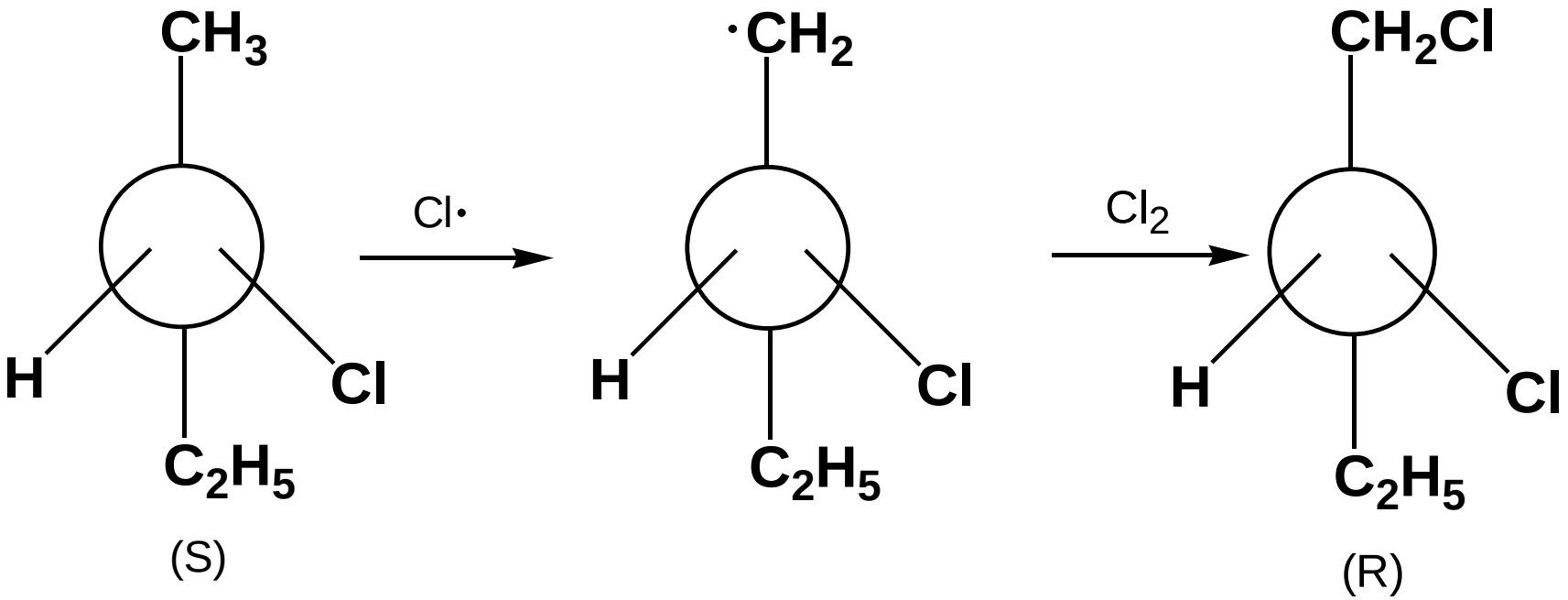


Relating configurations - chlorination of 2-chlorobutane



Consider the formation of one of the products, 1,2-dichlorobutane.

Chlorination of 2-chlorobutane



A reaction which does not involve breaking a bond to a stereogenic centre, proceeds with **retention** of configuration about this centre.

Racemic mixtures

An equimolar mixture of two enantiomers.

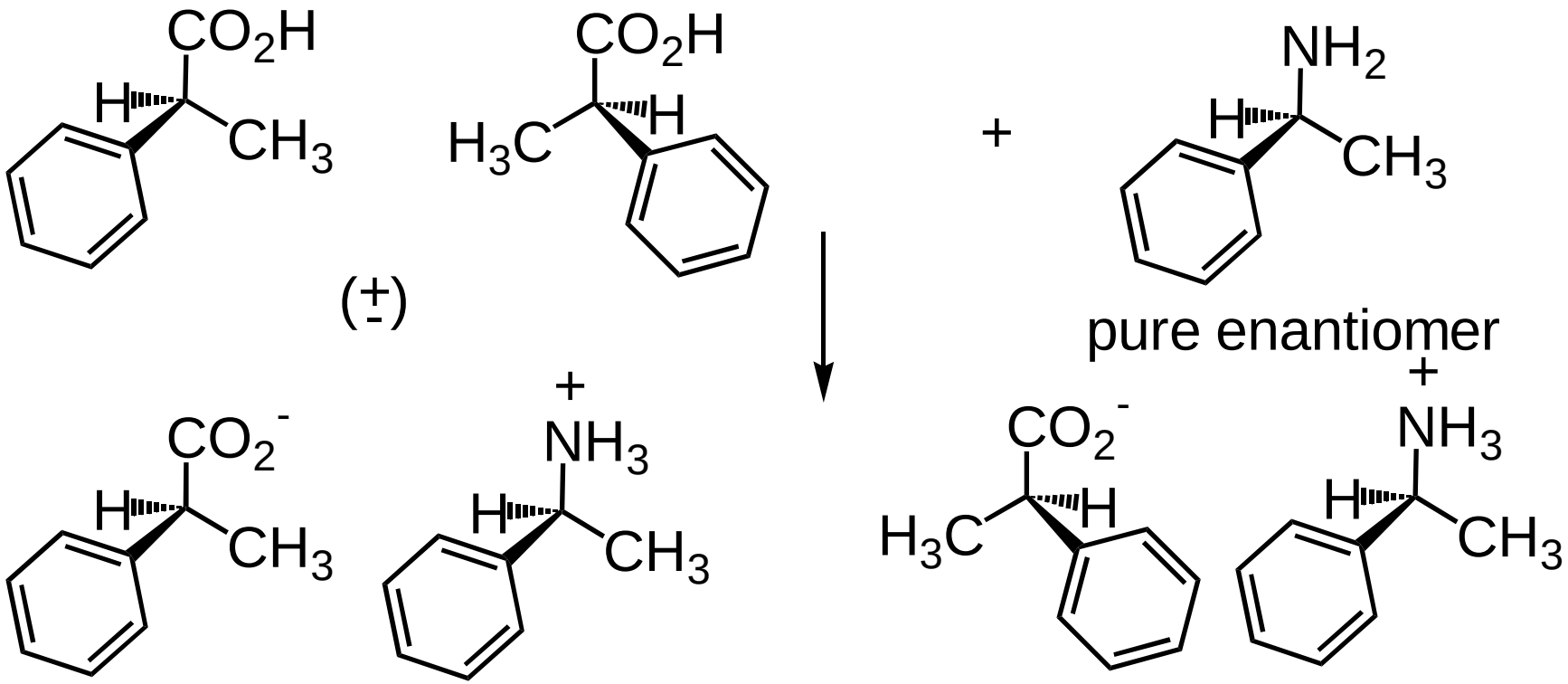
Prefix the name with ±.

A problem.....How can we separate a pair of enantiomers?

The racemic mixture must be converted into a pair of diastereomers.

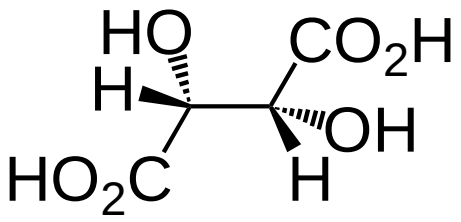
Resolution of enantiomers

To do this, we react a racemic mixture with an optically pure compound:

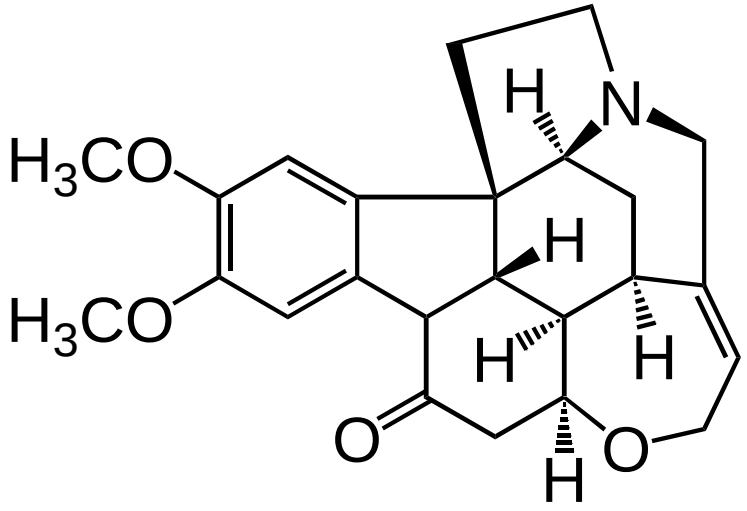


This mixture consists of salts that are diastereomers. They can be separated by conventional means.

Optically active natural products



(+)-tartaric acid



(-)-brucine