Chemistry 110

Bettelheim, Brown, Campbell & Farrell

Ninth Edition

Introduction to General, Organic and Biochemistry

Chapter 15

Chirality

The Handedness of Molecules
Types of Isomerism

In this chapter we study enantiomers and diastereomers.
Isomerism – Some Definitions

- Constitutional Isomers – Have different molecular frameworks.
- Stereoisomers – Have different geometries but the same constitution, *i.e.* the same atom connectivity.
  - *Achiral* – Do not have a tetrahedral stereocenter - *cis/trans* isomers are one example.
  - *Chiral* – Have one or more tetrahedral stereocenters
    - Enantiomers – are *mirror* images that cannot be superimposed – have “handedness”.
    - Diastereomers – do not superimpose but are not mirror images.
Some Consequences:

Diastereomers

- Have different physical (mp, bp, density, etc.) and chemical properties.

Enantiomers

- Have identical physical properties with one important exception.
  - Their chemical reactivity with achiral molecules are identical but with chiral molecules there are important, but subtle, differences in reactivity.
Differentiating Enantiomers

- Enantiomers will have the same IUPAC name. To give each enantiomer a unique name: R/S system.

- The R/S system is a way to distinguish between enantiomers without having to draw them and point to one or the other.

- The first step in assigning an R or S configuration to a stereocenter is to arrange the groups on the stereocenter in order of priority
  
  The priority is based on atomic number, the higher the atomic number, the higher the priority!
  
  If the atomic number is the same, the atomic number of the first point of difference determines the priority!

  See Table 15.1, p 427 in your text!
Because Molecules can have Handedness!

We Must Differentiate Enantiomers

tetrahedral stereocenters
Asparagine – an aminoacid

Mirror images – Can you assign R/S designators to the stereocenter in these enantiomers
To summarize what we have learned!

- Molecules are “chiral” if their mirror images do not superimpose – *cheir*, Gk. “hand”.

- *Enantiomers* have *opposite* chirality.

- *Diastereomers* are chiral isomers but are not mirror images.

- If three dimensional molecules superimpose they are the *same compound*!

- Molecules whose mirror images are superimposible are “*achiral*”.
To summarize what we have learned!

- **Tetrahedral Stereocenter (TS)** – Since Carbon can be tetrahedral it becomes a tetrahedral stereocenter if it is bonded to four different groups! These groups are different combinations of atoms or functionalities.

- This TS carbon is commonly called a *chiral carbon atom*.

- Chiral carbon atoms in a compound, if any, are commonly marked with an asterisk (*).
Consequences of Having One or More Tetrahedral Stereocenters (TS)

- The number of stereoisomers of a molecule with _n_ different TS = 2\(^n\) = (2\(^n\)/2 enantiomer pairs).

- *Different* means that each TS has *four different groups* attached which have at least one difference.

- Each tetrahedral stereocenter must have its own R/S designation since each creates a pair of enantiomers.

- If *two (or more!)* TS have the *same sets* of four groups attached things get complicated. *Meso compounds* and *optically active diastereomers* can result. No general rule applies to these cases!
Conventions

If the rotation (in degrees) of second polarizer with the observer facing the source is:

Clockwise = $+ \ or \ d, \ dextrorotatory, \ to \ the \ right$

Counterclockwise = $- \ or \ l, \ levorotatory, \ to \ the \ left$

$[\alpha]_{D}^{20}$ is an important physical constant, on a par with mp, bp, density, etc. for an optically (enantiomERICALLY) pure compound.
The One Physical Property Exception
Optical Activity – *Light is chiral!*

Chiral Molecules Rotate Plane Polarized Light

Observed Rotation \( \equiv \alpha = [\alpha] c l \)

- \( c \) = concentration in g/mL, *notice Not g/100 mL!*
- \( l \) = pathlength through sample in decimeters
- \([\alpha]\) = specific rotation (a constant of proportionality)
- \([\alpha]_{D}^{20}\) = specific rotation (temperature and wavelength of light specified, sodium vapor lamp "D" line, intense yellow

\[ [\alpha]_{D}^{20} = \frac{\alpha}{c l} \]
Definitions and Observations

- *Racemic Mixture* – a 1:1 mixture of enantiomers, has no observed optical rotation.

- *Enantiomers* – sometimes called *optical isomers* normally have large differences in biological properties.

- In General the body can use only one enantiomer, the other enantiomer can be completely inactive, have a different function, or as in the case of *thalidomide* be very dangerous, causing birth defects or even death!
What kind of isomers are glucose and fructose?

How many tetrahedral stereocenters are in fructose? In glucose?

How many different tetrahedral stereocenters are in fructose? In glucose?

How many stereoisomers are possible in fructose? In glucose?

How many enantiomer pairs are in fructose? In glucose?
Which of the Following has Stereoisomers?
Write the Four Different Groups Attached to Each Tetrahedral Stereocenter

1. 
- CH₃
- H₂NCHCOOH
- H₂NCHCOOH
- H₂NCHCOOH
- CH₂CO₂H
- HOOCCHCOOH
- HOOCCHCOOH
- HOOCCHCOOH
- HOOCCHCOOH

2. 
- CH₂CO₂H
- HOOCCHCOOH
- HOOCCHCOOH
- HOOCCHCOOH
- CH₂CO₂H
- HOOCCHCOOH
- HOOCCHCOOH
- HOOCCHCOOH
- HOOCCHCOOH

3. 
- CH₂CO₂CH₃
- CH₂CO₂CH₃
- CH₂CO₂CH₃
- CH₂CO₂CH₃
- CH₂CO₂CH₃
- CH₂CO₂CH₃
- CH₂CO₂CH₃
- CH₂CO₂CH₃
- CH₂CO₂CH₃

4. 
- H₂NCHCOOH
- H₂NCHCOOH
- H₂NCHCOOH
- H₂NCHCOOH
- H₂NCHCOOH
- H₂NCHCOOH
- H₂NCHCOOH
- H₂NCHCOOH
- H₂NCHCOOH

5. 
- CH₂
- CH₂
- CH₂
- CH₂
- CH₂
- CH₂
- CH₂
- CH₂
- CH₂
One Formula Has 2 Tet. Stereocenters

The top and bottom also reflect like mittens do!

L-tartaric acid
mp 170°C
α$^D_20$ +11.98°

D-tartaric acid
mp 170°C
[α]$^D_20$ -11.98°

meso-tartaric acid
mp 140°C

Can you determine the R/S designations for the chiral stereocenters?