

## Chapter 5 - Learning Objectives and Terminology - Klein

*Chiral* chemical compounds can occur as mirror images known as *enantiomers*. A chiral compound has “handedness.” Organic compounds can contain *asymmetric*, tetrahedral carbon atoms that can lead to an asymmetric and hence chiral compound. Asymmetric carbons are also called *stereogenic* carbons, or *stereocenters*.

Some chemical compounds (or conformations thereof) contain *symmetry* – as identified by the presence of *reflectional symmetry* elements known as *mirror planes* ( $\sigma$ ) or a *center of symmetry* (aka *point of inversion*, or *i*) – and are therefore not chiral. If a molecule has one of these symmetries then it is *achiral*.

Identify asymmetric carbons by noting 4 different groups attached, as specified by the Cahn-Ingold-Prelog (CIP) rules (aka the *sequence* rules). This leads to the *configuration* for an asymmetric carbon as either *R* (*rectus*) or *S* (*sinister*). The *absolute* configuration of an asymmetric center is the exact assignment of R or S, whereas the *relative* configuration is a correlation between asymmetric centers when the exact assignment is not necessarily known.

*Enantiomers* are stereoisomers that are *non-superimposable mirror images*. *Diastereomers* are stereoisomers that are non-superimposable and not mirror images. *Meso compounds* are chemical compounds that contains asymmetric centers, but overall are achiral because of symmetry – a mirror plane ( $\sigma$ ) or center of symmetry (*i*). Asymmetric centers can also be in other “places,” not on an atom, and are usually a form of *axial chirality* (like a screw axis) and in the case of biphenyls can form *atropoisomers*.

Chiral compounds are *optical active*: they can rotate *plane-polarized light*. The rotation is either to the right (clockwise) which is known as *dextrorotatory* (+ or *d*) or to the left *levorotatory* (- or *l*). The magnitude of this rotation is given by the *specific rotation*,  $[\alpha]$ . The terms in the equation relate to observed rotation ( $\alpha$ ), path length (*l*), concentration (*c*), temperature (T) and wavelength ( $\lambda$ ) of the light used for the measurement (usually sodium D line, 589.3 nm). Use this relationship to calculate specific rotation, observed rotation or *optical purity*. This rotation is measured using a *polarimeter*.

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

*Enantiomers* have exactly the same *magnitude* for the specific rotation, but *opposite* sign. Achiral molecules are said to be *optically inactive*.

A 50:50 mixture of enantiomers is called a *racemic mixture* (or *racemate*). The specific rotation of any racemate is exactly equal to zero. Anything other than a 50:50 mixture of enantiomers has a nonzero value from which can be calculated the *optical purity* (aka *enantiomeric excess*, or %ee) and the percentage of each enantiomer. (where *d* and *l* are the percentages of the (+) and the (-) isomers in the sample)

$$\frac{|d-l|}{d+l} \times 100 = \frac{[\alpha]_{\text{exp}}}{[\alpha]_{\text{lit}}} \times 100 = \text{optical purity} = \% \text{ ee}$$

The physical separation of enantiomers is called a *resolution*. Two common methods used for resolutions are *classical* and *enzymatic*. Surprisingly, many resolutions are accomplished by *spontaneous* resolutions – a saturated solution of a racemate is seeded with a few crystals of one enantiomer which affects the crystallization of just one enantiomer.

Enantiomers have identical physical properties such as mp and bp. Racemates usually have different mp compared to the pure enantiomer. Diastereomers have different mp, bp, density, index of refraction ( $n_D$ ), etc..

*Fischer projections* are useful 2-D presentations for chiral compounds, particularly sugars. Also, *erythro* and *threo* are common descriptors used with Fischer projections.

Other elements can be asymmetric, e.g., sulfur or phosphorus. Nitrogen undergoes rapid *pyramidal inversion* which interconverts any potentially asymmetric nitrogen and is rarely isolated as asymmetric, unless highly constrained and cannot attain an intermediate planar  $sp^2$  geometry.