5.12 Physical Properties of Stereoisomers

A. Optical Activity

**** Enantiomers have identical chemical and physical properties EXCEPT when interacting with chiral substances/fields

- light consists of electromagnetic waves perpendicular to light beam
- polarizer blocks all light except 1 plane
- plane polarized light oscillates in a single plane

![Diagram of light source, polarizer, and plane-polarized light](image)
5.12 Physical Properties of Stereoisomers

A. Optical Activity

- **Polarimeter** - measures how a sample will rotate polarized light
- **Achiral compounds** - no optical rotation - optically inactive

![Diagram of light source, polarizer, sample tube, and achiral compound showing the plane of polarization is not changed.](image)
5.12 Physical Properties of Stereoisomers

A. Optical Activity

- Chiral compounds - optical rotation - optically active
5.12 Physical Properties of Stereoisomers

A. Optical Activity

- Clockwise Rotation - dextrorotary - labeled d or (+)
- Counterclockwise Rotation - levorotary - labeled l or (–)
- no relationship exists between R or S and (+) or (–)
- BUT enantiomers rotate light in opposite directions

\[(S)-(-)-\text{glyceraldehyde}\]

\[(S)-(+)\text{-lactic acid}\]
5.12 Physical Properties of Stereoisomers

B. Racemic Mixtures

- racemic mixtures: equal amounts of each enantiomer
- racemic mixtures may behave differently from pure enantiomers

<table>
<thead>
<tr>
<th>Property</th>
<th>A alone</th>
<th>B alone</th>
<th>Racemic A + B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Melting point</td>
<td>identical to B</td>
<td>identical to A</td>
<td>may be different from A and B</td>
</tr>
<tr>
<td>Boiling point</td>
<td>identical to B</td>
<td>identical to A</td>
<td>may be different from A and B</td>
</tr>
<tr>
<td>Optical rotation</td>
<td>equal in magnitude but opposite in sign to B</td>
<td>equal in magnitude but opposite in sign to A</td>
<td>0°</td>
</tr>
</tbody>
</table>
5.12 Physical Properties of Stereoisomers

C. Specific Rotation

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

- \( \alpha \) = observed rotation (°)
- \( l \) = length of sample tube (dm)
- \( c \) = concentration (g/mL)

\[
\text{dm} = \text{decimeter} \\
1 \text{ dm} = 10 \text{ cm}
\]
5.12 Physical Properties of Stereoisomers

D. Enantiomeric Excess

• sometimes one enantiomer can be amplified
• Enantiomeric Excess (ee) = % of one enantiomer - % of the other enantiomer
• \( ee = \%A - \%B \)
• \( ee = 50 \) means 75% of one enantiomer and 25% of the other (i.e. 75% R, 25% S)
• can be calculated by specific rotation

\[
ee = \frac{[\alpha] \text{ mixture}}{[\alpha] \text{ pure enantiomer}} \times 100\%
\]
5.12 Physical Properties of Stereoisomers

E. Diastereomer Physical Properties

- different physical properties (including optical rotation)
- different chemical properties

<table>
<thead>
<tr>
<th>Property</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>A + B (1:1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>melting point (°C)</td>
<td>171</td>
<td>171</td>
<td>146</td>
<td>206</td>
</tr>
<tr>
<td>solubility (g/100 mL H₂O)</td>
<td>139</td>
<td>139</td>
<td>125</td>
<td>139</td>
</tr>
<tr>
<td>[α]</td>
<td>+13</td>
<td>−13</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>R,S designation</td>
<td>R,R</td>
<td>S,S</td>
<td>R,S</td>
<td>-</td>
</tr>
<tr>
<td>d,l designation</td>
<td>d</td>
<td>l</td>
<td>none</td>
<td>d,l</td>
</tr>
</tbody>
</table>
5.13 Chemical Properties of Enantiomers

- enantiomers have the same chemical properties except with chiral reagents
- biological molecules are usually chiral
Chirality and the Origin of Life

Panspermia

Pulsar

Earth's Rotation