Optical Rotation of Chiral Materials

Optical rotation (also referred as optical activity) is the rotation of the plane of polarization of linearly polarized light as it travels through certain materials. It occurs only in chiral materials, those lacking microscopic mirror symmetry. The normal modes are waves that are circularly, rather than linearly polarized. Waves with right- and left-circular polarizations travel at different phase velocities.

Unlike other sources of birefringence which alter a beam's state of polarization, optical activity can be observed in fluids. This can include gases or solutions of chiral molecules such as sugars, molecules with helical secondary structure such as some proteins and DNA, and also chiral liquid crystals. It can also be observed in chiral solids such as quartz.

The rotation of the plane of polarization may be either clockwise, to the right (dextrorotary – d-rotary), or left (levorotary – l-rotary) depending on which stereoisomer is present (or dominant). For instance, sucrose and camphor are d-rotary whereas cholesterol is l-rotary. For a given substance, the angle by which the polarization of light of a specified wavelength is rotated is proportional to the path length through the material and (for a solution) proportional to its concentration. The rotation is not dependent on the direction of propagation, unlike the Faraday effect where the rotation is dependent on the relative direction of the applied magnetic field.

Optical activity is measured using a linearly polarized light beam and polarimeter (a rotating polarizer). This is a tool particularly used in the sugar industry to measure the sugar concentration of syrup, and generally in chemistry to measure the concentration or enantiomeric ratio of chiral molecules in solution. The specific rotation is given by: \( \rho = \)
\[ \frac{\Delta \theta}{c \cdot l} \] where \( \Delta \theta \) is the measured angular rotation, \( c \) is the concentration of the solution, and \( l \) is the cuvette length.

**Experiment:**

1) In this experiment you will measure three types of solutions: i) pure water, ii) granulated sugar (sucrose) in water (25 g in 100 ml), and iii) corn syrup (glucose) in water (25 g in 100 ml).

2) Prepare an optical beam from a He-Ne laser to have a linearly polarized light.

3) Insert the long cuvette in the optical path of the polarized optical beam.

4) Set the rotating polarizer after the cuvette.

5) Place a photodetector to collect the beam after the rotating polarizer.

5) Fill in the cuvette with the first solution (pure water).

6) Perform measurements of light intensity as you rotate the polarizer over a range of 180°.

7) Empty and rinse the cuvette, then fill it with the next solution (sugar in water). Repeat step (6).

8) Empty and rinse the cuvette, then fill it with the next solution. (corn syrup in water) Repeat step (6).

9) Measure and take of the cuvette length.

**Analysis:**

For each solution, plot your results of the light intensity against the angle in the rotating polarizer. Find the rotation angle of solutions
(ii) and (iii) with respect to the pure water (i). Determine the specific rotation for each molecule. Compare your results with the literature results.

Questions to consider:

1. If we use back reflection from a mirror to get a double pass through the solution what would happen: double the rotation or erase the rotation? Explain your answer.

2. Predict what concentration is needed for each solution to obtain a 90° rotation.

3. Explain how liquid crystal displays work and why their light is polarized.
Sucrose

α-D- Glucopyranose
D-fructose