Science Education Collection

Polarimeter

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Overview

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This experiment will demonstrate the use of a polarimeter, which is an instrument used to determine the optical rotation of a sample. Optical rotation is the degree to which a sample will rotate polarized light. Optically active samples will rotate the plane of light clockwise (dextrorotatory), designated as *d* or (+), or counterclockwise (levorotatory), designated as *l* or (−).

Principles

The polarimeter is a quantitative method used to determine the optical rotation of a chiral molecule. A molecule is considered chiral if it is non-superimposable on its mirror image. More specifically, chiral molecules that are mirror images of one another are called enantiomers (**Figure 2**). Enantiomers have the same physical properties such as melting point, boiling point, and solubility; however, they differ in the degree to which they polarize light. A pure (*R*)-enantiomer of a compound will rotate light in an equal but opposite direction as its (*S*)-enantiomer. If a mixture of compounds is racemic, meaning it contains an equal mixture of (*R*)- and (*S*)-enantiomers, then its optical rotation will be zero. Thus, polarimetry is a way to characterize and distinguish the identity between a pair of enantiomers.

A polarimeter works by shining monochromatic light through a polarizer, which generates a beam of linearly polarized light. The polarized light will then rotate after it passes through a polarimetry cell containing the sample. An analyzer will then rotate counterclockwise or clockwise to allow the light to pass through and reach the detector (**Figure 1**). Using this instrument, the specific rotation of light can be calculated, which relates the observed optical rotation with the concentration of solution and cell pathlength. The specific rotation is defined by the following equation:

$$[\alpha] = \frac{\alpha_{obs}}{l * c}$$

where α_{obs} is the observed optical rotation value given by the polarimeter, *l* is the cell pathlength in dm, and *c* is the concentration of the solution in g/mL.

Moreover, the enantiomeric excess (*ee*), which is a measurement of how much of one enantiomer exists over the other in a mixture, can be determined by using specific rotation. The calculation of *ee* is given by the following equation:

$$ee = \frac{[\alpha]_{mixture}}{[\alpha]_{pure}}$$

where $\alpha_{mixture}$ is the specific rotation of the mixture of enantiomers and α_{pure} is the specific rotation of the pure enantiomer. Generally, if two out of three values in the equation are known (*i.e.*, *ee* and $\alpha_{mixture}$) then the third value (α_{pure}) can be calculated.
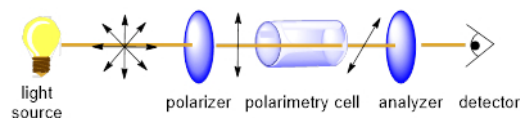

Figure 1. Concept behind the polarimeter.
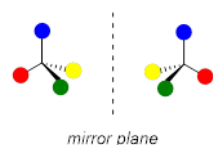

Figure 2. Chiral molecules that are mirror images of one another are enantiomers.

Procedure

1. Preparing the Polarimeter

1. Turn on instrument and let it warm up for 10 min.
2. Make sure instrument is set to "optical rotation" mode.

3. Prepare a blank sample in the polarimeter cell (1.5 mL total sample volume, 1 dm in length) containing only $CHCl_3$. Make sure there are no air bubbles present.
4. Place the blank cell in the holder and press "zero."

2. Preparation of Analyte Sample

1. Prepare a stock solution of 10-15 mg of the chiral analyte in 1.5 mL $CHCl_3$. Note the exact amount of compound used.

3. Measuring Optical Rotation

1. Fill the cell with 1.5 mL of the prepared stock solution containing the sample.
2. Place the cell in the holder and press "measure." The machine readout will give the optical rotation value. Remember to record the temperature as well.

4. Calculation of Specific Rotation

1. The specific rotation of a compound is defined by the following equation:

$$[\alpha] = \frac{\alpha}{l * c}$$

where α is the optical rotation value given by the polarimeter, *l* is the cell pathlength in dm, and *c* is the concentration of the solution in g/mL.

Results

Representative results for the measurement and calculation of specific rotation for Procedures 1-4.

Procedure Step	Reading on polarimeter
1.4	0.000
3.2	+0.563
4.1	$[\alpha]_{25}^{D} = +77°$ (*c* 0.73, $CHCl_3$)

Table 1. Representative results for procedures 1-4.

Applications and Summary

In this experiment, we have demonstrated the principles behind the polarimeter and how to measure and calculate the specific rotation of an optically active compound.

The polarimeter is an important instrument in the fine-chemical and pharmaceutical industries to assess the identity, purity, and quality of a compound. It is specifically used for the measurement of optical rotation of chiral compounds, which can be used to distinguish the identity of two enantiomers by confirming whether it is an (*R*) or (*S*) compound. This is especially important in pharmaceutical drug synthesis because one enantiomer is generally responsible for the biological effects while the other enantiomer is often less active and can have adverse effects. In addition, the polarimeter can be implemented to determine the unknown *ee* of a sample. If the *ee* value is unknown, this can be calculated using the polarimeter by determining the specific rotation.