JoVE: Science Education

Polarimeter

--Manuscript Draft--

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Overview:

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 (dextrarotatory), designated as *d* or (+) or counterclockwise (levarotatory), 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, will differ in the degree which they polarize light. A pure (*R*)-enantiomer of a compound will rotate light in an equal 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 ~~takes into account~~ with the concentration of solution and cell pathlength. The specific rotation ~~and~~ 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.

Procedure:

Commented [ASW1]: 1)What is the most common use of the polarimeter? Qualitative? Quantitative?
2) Similarly, you explain how concentration can be determined, but there are relationships between concentration, specific rotation, and enantiomeric excess/purity that need to be clarified. Do you always need to know 2 to determine the 3rd?

Commented [ASW2]: What is this? How is it different from observed optical rotation?

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1. Preparing the Polarimeter

   1.1. Turn on instrument and let it warm up for 10 min.
   1.2. Make sure instrument is set to “optical rotation” mode.
   1.3. 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.
   1.4. Place blank cell in holder and press “zero.”

2. Preparation of Analyte Sample

   2.1. 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

   3.1. Fill the cell with 1.5 mL of the prepared stock solution containing the sample.
   3.2. 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

   4.1. 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.

Representative 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.

Commented [K3]: These numbers in the representative results will depend on the final compound chosen for the optical rotation measurement. Perhaps (+) or (-) carvone. TBD.

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.

Applications

Commented [ASW4]: Provide more specific, concrete applications/ examples. This can extent to the more general concept of enantiomers in total, such as specific pharmaceuticals where this is important.
Include which specific applications could be filmed in your lab's setup.

~~The polarimeter is important for the measurement of optical rotation of chiral compounds, which can be used to distinguish the identity of two enantiomers.~~ The polarimeter is an ~~Moreover, the polarimeter is~~ important instrument in the fine-chemical and pharmaceutical industries ~~as an instrument~~ 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 specific rotation.

Legend:

Figure 1. Concept behind the polarimeter
Figure 2. Chiral molecules that are mirror images of one another are enantiomers

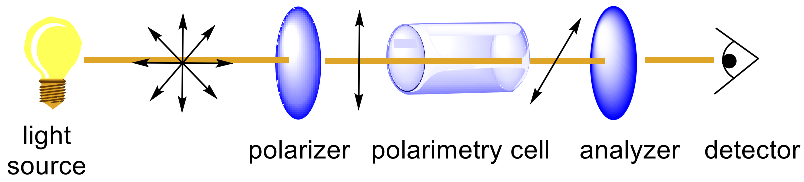

Figure 1

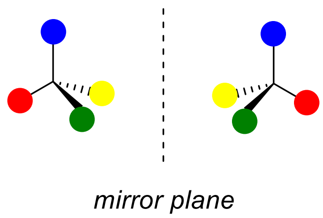

Figure 2