Chemical Polarimeter

(Order Code CHEM-POL)

The Chemical Polarimeter is a device used for measuring the rotation of plane-polarized light caused by an optically active substance such as an organic, inorganic, or biological compound. A polarimeter can be used to determine distinctive properties of these samples without chemically modifying or destroying the sample.

How the Polarimeter Works

The Polarimeter is a vertical polarimeter that uses an LED source, a fixed polarizer, and a rotating polarizer (also called an analyzer) to detect changes in rotation of plane-polarized light in the presence of an optically active compound. The Polarimeter uses a light sensor and a bidirectional optical encoder to detect the quantity of light passing through the sample at each angle as the analyzer is manually rotated. A graph is produced that shows a clear change in the light's polarization with respect to angle. This allows the user to determine various characteristics, including the identity, of the specific chemical compound being investigated.

As shown in Figure 1, incident non-polarized light is transmitted through a fixed polarizer that only allows a certain orientation of light into the sample. The sample then rotates the light at a unique angle. As the analyzer is turned, the rotated light is maximally transmitted at that unique angle, allowing the user to determine properties of the sample. A (+) enantiomer rotates the plane of linearly polarized light clockwise, *dextro*, as seen by the detector. A (–) enantiomer rotates the plane counter-clockwise, *levo*.
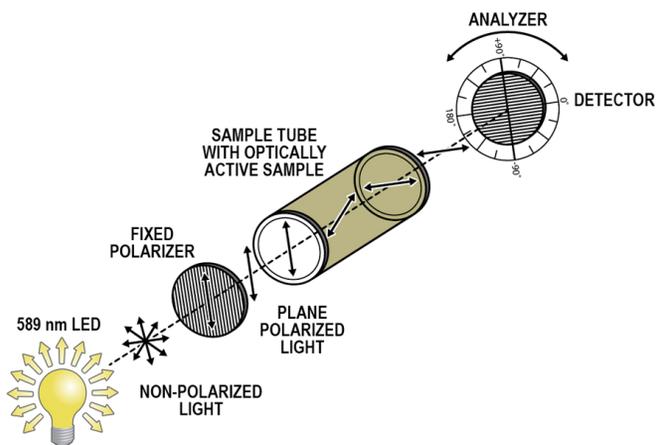

Figure 1: Schematic of the Polarimeter

What is included with the Polarimeter?

The Chemical Polarimeter includes

- Polarimeter
- 1 sample cell
- User's guide (this document)

Collect Data with the Polarimeter

This sensor can be used with the following interfaces to collect data:

- Vernier LabQuest® as a standalone device or with a computer
- Vernier LabQuest® Mini with a computer
- Vernier LabPro® with a computer
- TI-Nspire™ Lab Cradle with a TI-Nspire technology
- Vernier SensorDAQ® with a computer

Software Requirements

This sensor can be used with an interface and the following data-collection software:

- **Logger *Pro*** This computer program is used with LabQuest, LabQuest Mini, or LabPro. The Polarimeter requires Logger *Pro* 3.8.4.2 or newer.
- **LabQuest App** This program is used when LabQuest is used as a standalone device. The Polarimeter requires LabQuest App 1.6 or newer.
- **Data Quest** This program is used with TI-Nspire calculators.
- **LabVIEW** National Instruments LabVIEW™ software is a graphical programming language produced by National Instruments. It is used with SensorDAQ and can be used with a number of other Vernier interfaces. See www.vernier.com/labview for more information.

Using the Polarimeter

1. Connect the two Vernier Polarimeter cables to their respective ports on your Vernier interface. Start the data-collection program and choose New from the File menu.

    Note: If you are using Logger *Pro*, the graph should have Illumination on the y-axis and Angle on the x-axis; if this is not the case, make sure the Polarimeter's analyzer is plugged into DIG 1 on the interface and select New from the File menu.

2. Calibrate the Polarimeter.

    a. Pour distilled water or the appropriate solvent in the Polarimeter cell to a height of 10 cm. It is important to read the height to the nearest 0.1 cm. Read to the bottom of the meniscus.

    b. Place the cell in the Polarimeter.

    Note: Because all of the measurements with the Polarimeter are relative, the analyzer will reset to 0.00° upon opening the data-collection program. If you would like to take measurements over multiple days, you can manually zero the analyzer when Illumination is at its minimum by choosing Zero from the Experiment menu (in Logger *Pro*) or the Sensors menu (in LabQuest App) prior to starting data collection.

c. Start data collection and slowly rotate the analyzer clockwise or counterclockwise as shown in Figure 2 until data collection stops (15 s). Slowly rotating the analyzer produces smoother curves. **Note:** If you are using a LabPro interface, only rotate the analyzer while data collection is active. Allow a few seconds at both the beginning and ending of data collection without moving the analyzer.
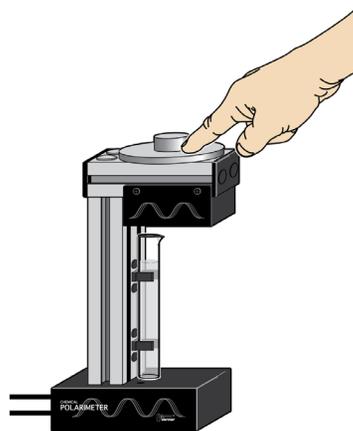
3. Record the first angle above 0° where the illumination is at a maximum for the blank. There are several ways to locate this angle:

Figure 2: Rotation of the analyzer

- Statistics: To simply get the angle with the highest illumination, highlight the peak of interest in Logger *Pro* or LabQuest App, as shown in Figure 3. Choose Statistics from the Analyze menu. Record the angle value where the illumination is at a maximum, as presented in the box. This method is the fastest and will result in reproducibility of the angle of rotation measurement of ±2.0°.

- Gaussian: To improve your accuracy with a better fit, highlight the peak of interest using Logger *Pro* or LabQuest App as shown in Figure 3. Then, choose Curve Fit from the Analyze menu. From the list of available Equations, select Gaussian. Select Try Fit in Logger *Pro*; in LabQuest App, the fit will run automatically. The B coefficient presented represents the angle at maximum illumination. This method will result in reproducibility of the angle of rotation measurement of ±0.3°. The data are not a true Gaussian, but the ease and accuracy of this methodology make it a good option. For best results, be consistent in the way you select your peaks.
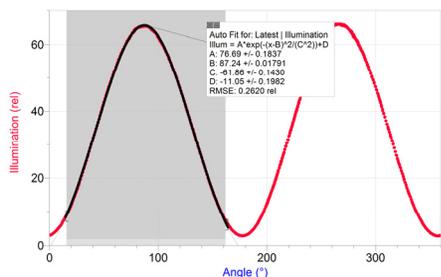

Figure 3: Selection for fits

- Cosine Squared: To incorporate all of your data into the fit, you can fit the data to its true waveform, a cosine squared, in either Logger *Pro* or LabQuest App. Choose Curve Fit from the Analyze menu. From the list of available General Equations, select Cosine Squared. Select Try Fit in Logger *Pro*; in LabQuest App, the fit will run automatically. In this fit, the x-value corresponding to the maximum y-value is obtained from the negative of the phase shift parameter, –C. This is a nonlinear fit that undergoes numerous iterations and may not converge,

which may result in an unreasonable answer. Make sure the resulting value is reasonable based on the data. This method is the most time consuming; however, it will result in reproducibility of the angle of rotation measurement of ±0.1°.

4. Store the run. In Logger *Pro*, do this by choosing Store Latest Run from the Experiment menu. In LabQuest App, you can store a run by tapping the file cabinet icon in the upper right of your screen.

5. You are now ready to add your optically active sample into the Polarimeter cell.
   a. Pour your sample in the Polarimeter cell to a height of 10 cm. It is important to read the height to the nearest 0.1 cm.
   b. Place the sample cell in the Polarimeter.
   c. Start data collection and slowly rotate the analyzer clockwise or counterclockwise until data collection stops.

6. Record the first angle above 0° where the illumination is at a maximum for the optically active sample. Repeat Step 3 to determine this angle using the same method as before.

7. Store each run as you did in Step 4. Helpful Tip: When using LabQuest App, multiple runs can be displayed on the same graph by tapping the button to the left of the file cabinet and selecting All Runs from the drop down menu.

8. To determine the observed angle of rotation for the optically active sample (α), subtract the blank's angle of maximum illumination (Step 3) from the angle of maximum illumination for the sample (Step 6).

9. A compound will consistently have the same specific rotation under identical experimental conditions. To determine the specific rotation of the sample, use Biot's law:

$$\alpha = [\alpha] \, \ell \, c$$

where α is the observed optical rotation in units of degrees, *[α]* is the specific rotation in units of degrees (the formal unit for specific rotation is degrees dm^{-1} mL g^{-1}, but scientific literature uses just degrees), ℓ is the length of the cell in units of dm, and c is the sample concentration in units of grams per milliliter.

10. To calculate a percent optical purity (or enantiomeric excess):

$$\% \text{ optical purity} = \frac{\text{specific rotation of sample}}{\text{specific rotation of pure enantiomer}} \times 100\%$$

The value for the pure enantiomer can be obtained from literature or it can be measured using a neat sample, taking into account the purity of that sample as described by the manufacturer.

Potential Uses for this Sensor

The following is a partial list of activities and experiments that can be performed using this sensor.

- Determine sugar solution purity by optical rotation.
- Characterize the purity of organic and inorganic syntheses yielding chiral products.

- Determine the enantiometric purity of optically active compounds.
- Resolve racemic mixtures.
- Study the kinetics of acid-catalyzed or enzyme-catalyzed hydrolysis.
- Explore the optical activity of amino acids.
- Investigate reactions of natural products by optical rotation.

Calibration

Because you are taking relative measurements of optical rotation, you should perform a new calibration each time you use the Polarimeter. See the section on "Using the Polarimeter" above for these instructions.

Specifications

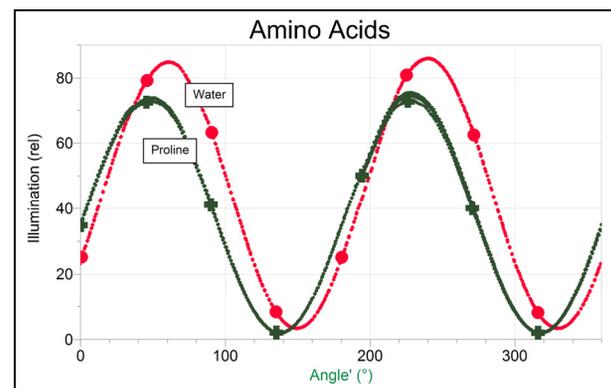| Encoder Resolution	0.25°
Accuracy (optical rotation measurements)	±1°
Sensitivity	typically up to OD 2
Optical Encoder	Bidirectional, quadrature encoder, 360 cycle per revolution
Light Source	LED
Wavelength (nominal)	589 nm

Additional Tips

1. Due to the nature of light transmission, it is important that the sample be transparent and homogeneous. The sample can have a moderate amount of color (up to OD of 2) but make sure it is not too dark to ensure that light will still pass through it onto the detector.

2. The illumination value should not be used as a quantitative value for this device. If you choose to use it for this purpose, note that this value is very sensitive to change. These slight variations can be brought on by several different variables in the sample including inhomogeneity (such as particulates and bubbles), height of the sample in the cell, concentration of the sample, and aberrations in the glass cell or pathlength.

3. The standard in polarimetry is to use a 10 cm pathlength. However, since it is not always feasible to have this large of a sample volume, you can accurately take readings with sample heights lower than 10 cm. To remain within the ±1° accuracy of the device, keep sample heights between 2 cm (~5 mL) and 10 cm (~ 25 mL). Outside of this region, there can be deviations in the light path that decrease the accuracy of the detector.

4. The unit is made with three feet for best stability during measurements.

5. A package of four additional sample cells is available. Order code: CELLS-POL.

> **Note:** This product is to be used for educational purposes only. It is not appropriate for industrial, medical, research, or commercial applications.
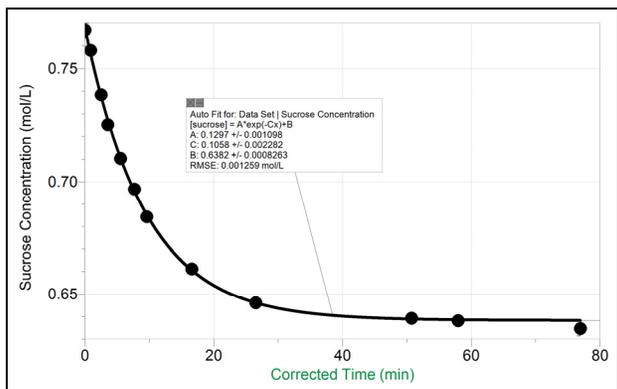
Sample Data

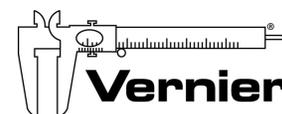*Determine sugar solution purity by optical rotation*

Explore the optical activity of amino acids

Study the kinetics of acid-catalyzed hydrolysis

Warranty

Vernier warrants this product to be free from defects in materials and workmanship for a period of five years from the date of shipment to the customer. This warranty does not cover damage to the product caused by abuse or improper use.

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