Understanding Polarimetry

1. This experiment is written for data collection with the Vernier Go Direct Polarimeter and one of the following:
   - Instrumental Analysis app (version 1.2 or newer) running on a computer, Chromebook, or mobile device
   - LabQuest 3 (app version 3.0.3 or newer)
   - LabQuest 2 (app version 2.8.7 or newer)

   Visit **www.vernier.com/downloads** for information about how to download the most recent version for your device.

2. Sucrose is often used as a calibration standard for polarimeters, which is why it is suggested in this experiment. You may also use other sugars and should obtain similar results. Literature values for specific rotation were obtained from the CRC Handbook, determined in water at concentrations of 1–5 g per 100 mL of solution, at 20–25°C, and at 589 nm.

3. There are several ways to locate the angle at which the maximum illumination occurs:

   Using Instrumental Analysis

   a. Statistics: To simply get the angle with the highest illumination, highlight the peak of interest in Instrumental Analysis, as shown in Figure 1. Click or tap Graph Tools, , and select View Statistics. 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°.
   b. Examine: Click or tap the Illumination *vs*. Angle graph to find the data point associated with the peak that is closest to 0°. This method also lacks accuracy but is useful from a pedagogical standpoint as it connects the feature on the graph in a way that telling students to perform a curve fit and use the parameters does not.
   c. Cosine Squared: To incorporate all of the data into the fit, students can fit the data to its true waveform, a cosine squared, in Instrumental Analysis. Choose Curve Fit from the Graph Tools, . From the list of available General Equations, select Cosine Squared. 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 which undergoes numerous iterations and has the possibility of no convergence, which will result in an unreasonable answer. With all nonlinear fits, it is important to make sure the resulting value is reasonable based on the data presented in the graph. This method is the most time consuming; however, it will result in reproducibility of the angle of rotation measurement of ±0.1°.

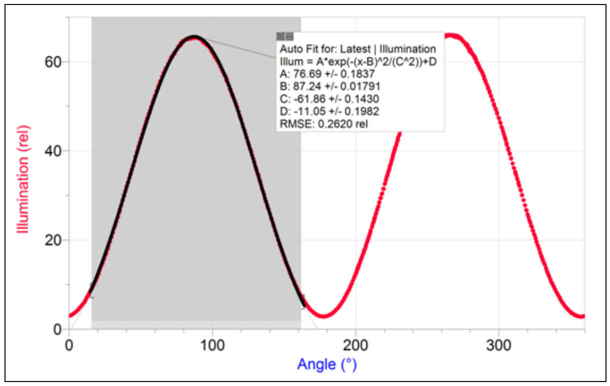

Figure 1 Selection for Statistics and Gaussian fits (applies to all supported software)

Using LabQuest 2 or 3

a. Statistics: To simply get the angle with the highest illumination, highlight the peak of interest in LabQuest App, as shown in Figure 1. 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°.

b. Gaussian: To improve your accuracy with a better fit, highlight the peak of interest using LabQuest App, as shown in Figure 1. Then, choose Curve Fit from the Analyze menu. From the list of available Equations, select Gaussian. 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.

c. Cosine Squared: To incorporate all of your data into the fit, you can fit the data to its true waveform, a cosine squared, in LabQuest App. Choose Curve Fit from the Analyze menu. From the list of available General Equations, select Cosine Squared. 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 which undergoes numerous iterations and has the possibility of no convergence, which will result in an unreasonable answer. With all nonlinear fits, it is important to make sure the resulting value is reasonable based on the data presented in the graph. This method is the most time consuming; however, it will result in reproducibility of the angle of rotation measurement of ±0.1°.

4. Based on the assumption that data analysis is done after the lab period, the student guide direct students to use Vernier Graphical Analysis app to analyze their data. Graphical Analysis is available as a free download for Windows®, MacOS®, Chome OS™, Android®, iPadOS®, and iOS; visit **www.vernier.com/download** to download the appropriate version. However, data analysis can also be done directly in LabQuest if laboratory time allows.

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

6. The illumination value for Go Direct Polarimeter should not be used for quantitative purposes. If you choose to use the value quantitatively, note that it is very sensitive to change. These

 © Vernier Software & Technology

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 path length.

HAZARD ALERTS

The chemical safety signal words used in this experiment (DANGER and WARNING) are part of the Globally Harmonized System of Classification and labeling of Chemicals (GHS). Refer to the Safety Data Sheet (SDS) that came with the chemical for proper handling, storage, and disposal information. These can also be found online from the manufacturer.

Sucrose, $C_{12}H_{22}O_{11}$: This chemical is considered nonhazardous according to GHS classifications. Treat all laboratory chemicals with caution. Prudent laboratory practices should be observed.

COMPOUND INFORMATION

Compound	Chemical formula	Molar mass (g/moL)	Specific rotation (°)
sucrose	$C_{12}H_{22}O_{11}$	342.3	+66.5

SAMPLE DATA

Part I Exploring path length

	Run 1	Run 2	Run 3	Run 4	Run 5
Sample height (cm)	2.0	4.0	6.0	8.0	10.0
Angle of rotation, α (°)	1.40	2.80	4.21	5.43	6.62

Part II Exploring concentration

	10% sample	20% sample	30% sample
Sample height (cm)	10.0	10.0	10.0
Angle of rotation, α (°)	6.61	13.01	19.68
Exact concentration (g/mL)	0.099	0.196	0.296

ANSWERS TO DATA ANALYSIS QUESTIONS

Part I Exploring path length

1. See Figure 2.

2. Linear or proportional are appropriate.

3. See Figure 2.

   $y = mx+b$

   $y = 0.6768x - 0.0$

   $x = 10.0$ cm

   $y = 6.77°$

4. 6.77° / (0.099 g/mL × 1.00 dm) = 68.38°

   ((66.5° - 68.38°) / 66.5°) × 100% = 2.8%

Part II Exploring concentration

5. See Sample Data. Sample calculation:

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

   $c = \alpha / [\alpha]\, l$

   6.61° / (66.5° × 1.00 dm) = 0.099 g/mL

6. See Figure 4.

7. Linear.

EXTENSION

The cosine squared fit should be the most accurate, if done properly. This method will result in an angle of rotation accuracy of ±0.1°. Using Statistics or Examine will result in an angle of rotation accuracy of ±2.0°.

SAMPLE GRAPHS

Part I Exploring path length

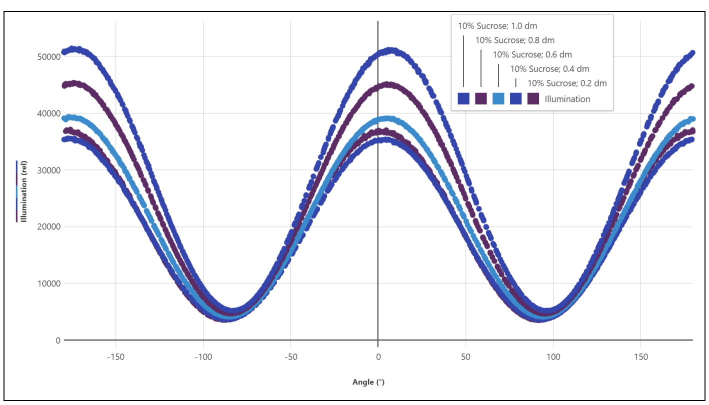

Figure 2 Optical rotation data for sucrose at varying path lengths

© *Vernier Software & Technology*

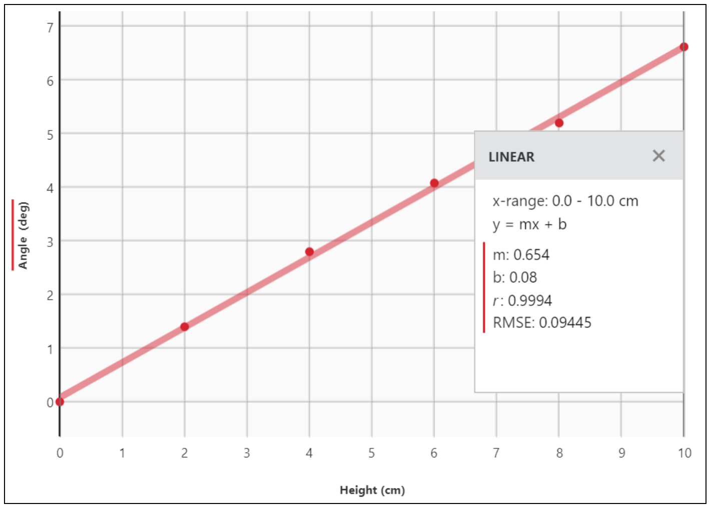

Figure 3 Relationship between sample cell height and corrected angle of rotation for sucrose

Part II Exploring concentration

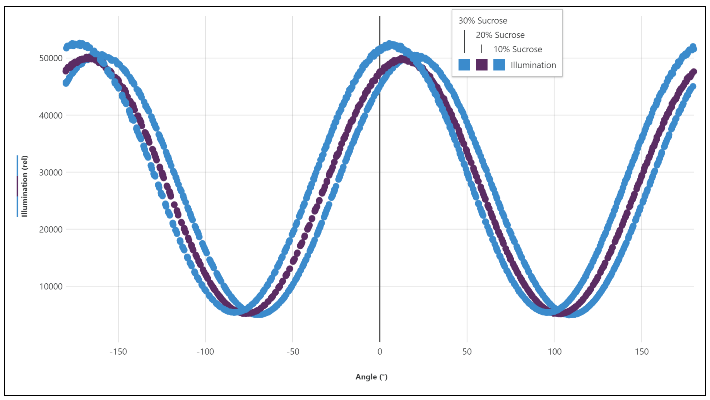

Figure 4 Optical rotation data for 10 cm height sucrose at varying concentrations

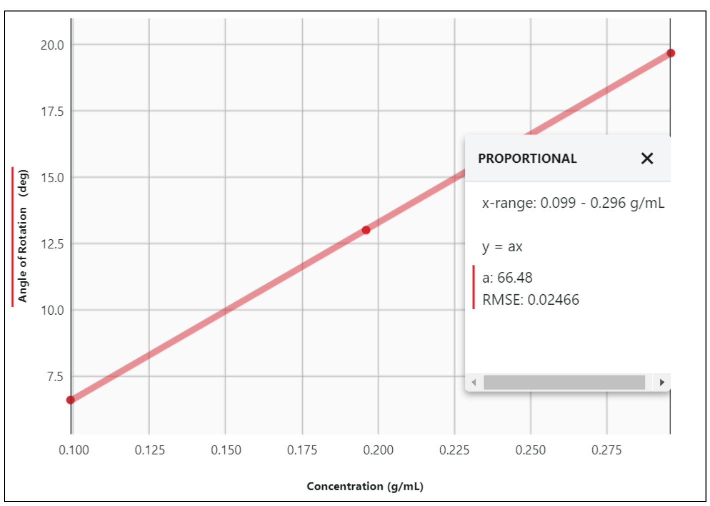

Figure 5 Relationship between concentration and angle of rotation for sucrose