Study of Polarimeter. Experimental Determination of a Sugar Solution Concentration.

Polarimetry is the measurement of the polarisation of light. The instrument used to measure the state of polarisation is the *polarimeter*. Polarimetry measures various optical properties of a material: linear birefringence, circular birefringence (optical rotation or optical rotary dispersion), linear dichroism, circular dichroism and scattering.

Polarization (*polarisation*) is the property of electromagnetic waves, (light), that describes the direction of their transverse electric field $\vec{E}$.

Rotatory polarization consists in the rotation of the polarization of light $\vec{E}$ when it passes through materials.

First who observed the rotatory polarization, in quartz, was Dominique F.J. Arago (1811). Around this time, Jean Baptiste Biot also observed the effect in liquids and gases of organic substances such as turpentine. In 1822, Sir John F.W. Herschel discovered that different crystal forms of quartz rotated the linear polarization in different directions.

Optical rotation (*optical activity*) is the rotation of linearly polarized light as it travels through materials. It appears in solutions of chiral molecules such as sucrose (sugar), solids with rotated crystal planes such as quartz, and spin-polarized gases of atoms or molecules. Chirality is the property of an object of being non-superimposable on its mirror image. There are materials which rotates plane polarized light counterclockwise – *levorotation*, and materials which rotates plane polarized light clockwise – *dextrorotation*. Materials with these properties are said to have optical activity and consist of chiral molecules. Chiral centers that have opposite configurations rotate polarized light the same number of degrees, but in opposite directions. It is not possible to determine whether any chiral center will be laevorotatory or dextrorotatory directly from its configuration.

The *specific rotation* of a chemical compound $[\alpha]$ is defined as the observed angle of optical rotation α when light of 589 nanometer wavelength (the sodium D line) is passed through a sample with a path length of 0.1 meter and a sample concentration of 1 gram per millilitre. The specific rotation is given by:

$$[\alpha] = \frac{\alpha}{lc}. \qquad (1)$$

If the sample is a pure liquid, then in (1) its density ρ replaces the concentration c . The SI unit for the specific rotation is used degrees.

Optical rotatory dispersion is the variation in the optical rotation of a substance with a change in the wavelength of light.

The concentration of the sugar solution is given by the Biot law (1831):

$$\alpha = [\alpha] c\, l \qquad (2)$$

and

$$c = \frac{\alpha}{[\alpha] l}, \qquad (3)$$

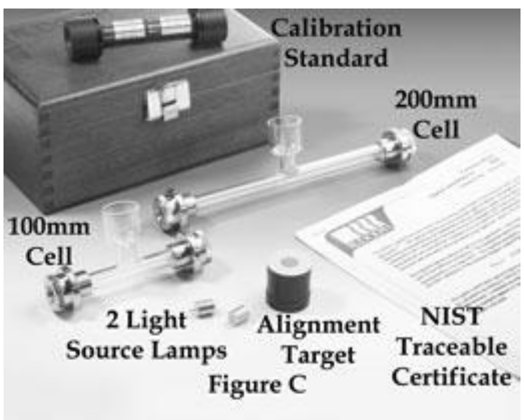
where α is the angle of optical rotation, l is the path length (tube length) and $[\alpha]$ is the specific rotation. For a pure liquid, then its density ρ replaces the concentration c and it follows:

$$\alpha = [\alpha] l \rho . \tag{4}$$

For given values of wavelength and temperature the specific rotation represents an intrinsic property of a material. Levorotatory rotation corresponds to a negative value and dextrorotatory rotation corresponds to a positive value. Examples:

Sucrose	+66.47°
cholesterol	−31.5°
Camphor	+44.26°
Penicillin V	+223°
taxol	−49°
(S)-bromobutane	+23.1°
(R)-bromobutane	−23.1°
(+)-cavicularin	+168.2°
Nicotine (in ethanol)	-30.0°
Strychnine (in ethanol)	-128.0°

This rotation can be measured with a polarimeter. The polarimeter consists of: a tube with flat glass ends, which contains the sample. In our case, the sample consists in a sugar solution. At each end of the tube a Nicol prism is attached. Between the first Nicol prism and the tube a quartz blade is placed. Light passes through the tube. The prism at the other end, which is attached to an eye-piece, is rotated until the quartz blade is light in the same color. The values of the angle of rotation can be read off of a scale (vernier micrometer). For a pure substance in solution the concentration of the sample can be calculated using the expression given by (3) with the color and tube length fixed, and with the specific rotation known.



Polarimeter*

Apparatus and Equipment

Polarimeter: a tube with flat glass ends, polarizer (Nicol prism), quartz blade, analyzer, a scale for reading the angle of rotation. The tube contains a sugar solution.

Measurements

1. Looking at the image through the eye-piece (without tube).
2. The tube is put in the polarimeter. Looking at the image through the eye-piece.
3. Rotating the analyzer still we obtain the angle of optical rotation.
4. Measuring the angle of optical rotation.
5. Calculating the concentration of the sugar solution using (3) with $\alpha_0 = 66{,}45 \deg ree \cdot cm^3 / g \cdot dm$.
6. Evaluation of the errors.

Results and errors

No. crt.	α (deg *ree*)	α_0 (deg $ree \cdot cm^3 / g \cdot dm$)	$c(gramm / cm^3)$

average value $\bar{c}$

(root) mean-square error E_a

confidence interval $c \in [\bar{c} - E_a, \bar{c} + E_a]$

percentage error E_r