Polarimetry & Polarimeters

A simple explanation

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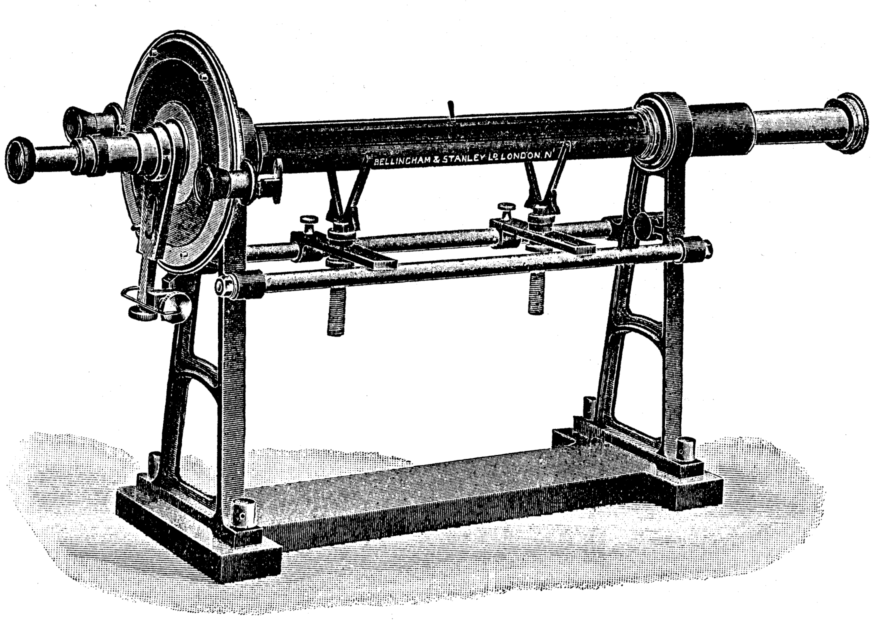
Polarimeters are optical instruments for measuring the rotation or 'twisting' of light. Industrial and academic laboratories use polarimeters for a variety of purposes ranging from simple quality control to fundamental research into complex chemical structures.

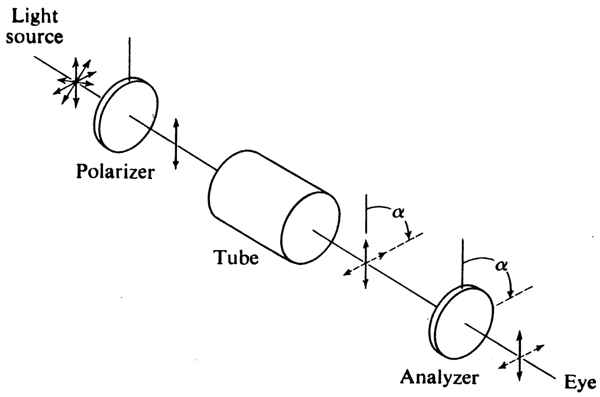
Bellingham + Stanley has been designing and manufacturing high quality polarimeters for 100 years.



Principle of polarimetry

Polarised light is light that has passed through a 'polariser', which forces the randomised electromagnetic waveforms into one plane. When this *plane-polarised light* then passes through an *optically active substance* (e.g. solution of an optically active chemical) the PLANE of polarisation is rotated by an amount which is characteristic of the test substance. Polarimeters detect the position of the PLANE and compare it to its original position, the difference being the rotation, normally expressed in angular degrees (°A).

A sample tube containing the test liquid (solution) is placed between two polarising elements (polaroid strip or a calcite crystal). The first element, the *polariser*, polarises the light before it passes into the sample. The second element, the *analyser*, can be rotated to counteract any rotation by the sample and hence locates the resultant angular position of the light plane and hence the amount of rotation caused by the sample.



In the sugar industry, the rotation is expressed on a different scale, the International Sugar Scale (ISS), denoted as °Z. Polarimeters that are designed for particular use in the sugar industry are called *Saccharimeter*.

Optical Rotation

Only certain chemicals are termed optically active - the origin of optical rotation is a complex area of chemistry and it is not really necessary to get involved with this in order to appreciate basic polarimetry. An example of an optically active molecule is a sugar. Water and other common solvents are not optically active and so when solutions are prepared, it is the dissolved optically active chemical (e.g. *the sugar* in water) that causes the rotation, not the solvent.

Rotation and Specific Rotation

The rotation is a linear function of the concentration of both the test substance and the path length of the solution (= tube length). Therefore, doubling the concentration will double the angular rotation; doubling the tube length will also double the rotation.

Optical rotation measurements can be used to determine concentration and/or purity of a substance or simply to detect the presence of an optically active chemical in a mixture.

The *specific rotation* of a chemical is simply an angular rotation obtained under standard measuring conditions: concentration, tube length, temperature and wavelength. Most specific rotations refer to the sodium wavelength of 589 nm. Specific rotation is a unique characteristic of a chemical and can of course be any angle and often has a magnitude greater than ±90°. Some definitions of specific rotation are given below.

Calculation of Specific Rotation (optically active liquids/solutions)

$$[\alpha]^{t}_{\lambda} = \frac{\alpha}{10 \times l \times c}$$

or

$$[\alpha]^{t}_{\lambda} = \frac{\alpha}{10 \times l \times d \times p}$$

where

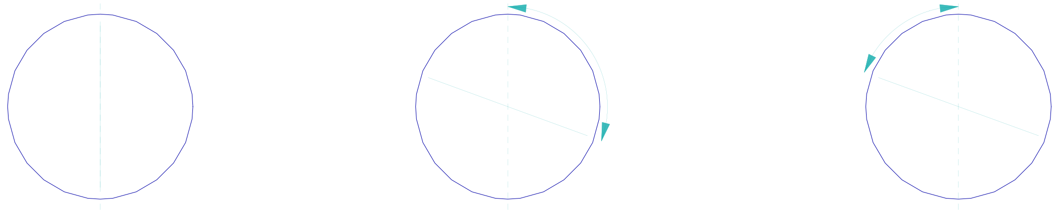
α	is the corrected optical rotation
$[\alpha]^{t}_{\lambda}$	is the specific rotation at t °C in the polarised light of wavelength λ.
l	is the length of the polarimeter tube in metres
d	is the relative density of the liquid or solution at 20 °C
c	is the concentration of the solute expressed in grams per mL of solution
p	is the concentration of the solute expressed in gram per gram solution

Wavelength

The sodium wavelength of 589 nm is by far the most common light source used in polarimetry and most experimental methods and published data are based on this wavelength. Another popular source is the Mercury 546 nm source and there is an increasing interest in the near infrared wavelength of 880 nm because of its ability to penetrate dark, highly coloured, light absorbing samples.

Angular Range – ambiguity

Polarimeters can only detect the position of the light PLANE before entering the sample and after transmitting through the sample. The angular difference (= rotation) can give an ambiguous result because a positive rotation of say 110° is the same PLANE position as a negative rotation of -70. Therefore, a sample with a rotation of +110° will display -70° on the default range° (see diagram).



0° Rotation | +110° Rotation | -70° Rotation

The instrument cannot decide itself how many times the plane has passed the 180° reference position along the sample path length. It is up to the user to either know the range (angular segment) in which the result will fall approximately or to be prepared to experiment to establish the absolute rotation. It is for this reason that, with automatic digital polarimeters such as the ADP Series, the user must select the measuring angular range, knowing (approximately) where the reading will fall.

For large angular rotations (greater magnitude than ±90°) it is customary for the user to vary systematically the concentration (or tube length) and measure corresponding rotations. In this way it is possible to tell the difference between a rotation of +270° and + 90°. With manual polarimeters or semi-automatic polarimeters, it is of course possible to display the full circle of ±180°. The result is still ambiguous, but the user can select one of two points on the circular scale or rotating drum, whichever is appropriate. The instrument does not decide which position is correct; the user does this.

With fully automatic polarimeters it is standard practice to provide a ±90° display. It is then up to the user still to experiment with concentrations or tube lengths to investigate the magnitude of the rotation. Thus when a reading of 45° is displayed the user may have to add 180° knowing that the absolute rotation is 225° (in this case a five-fold dilution will still give a reading of 45°.

Use of Polarimeters

Polarimeters are used for many purposes by technical people with varying knowledge of and experience with the technique. In some quality control applications the user may not fully understand the principles of polarimetry or perhaps have no real scientific appreciation at all and may simply follow a standard laboratory procedure and record measurements accordingly.

In other applications, for example R&D, the user may be required to be fully conversant with the principles and to be in a position to investigate optical properties of test materials, possibly for the first time.