Find the specific rotation of sugar solution by using a polarimeter

Objectives:

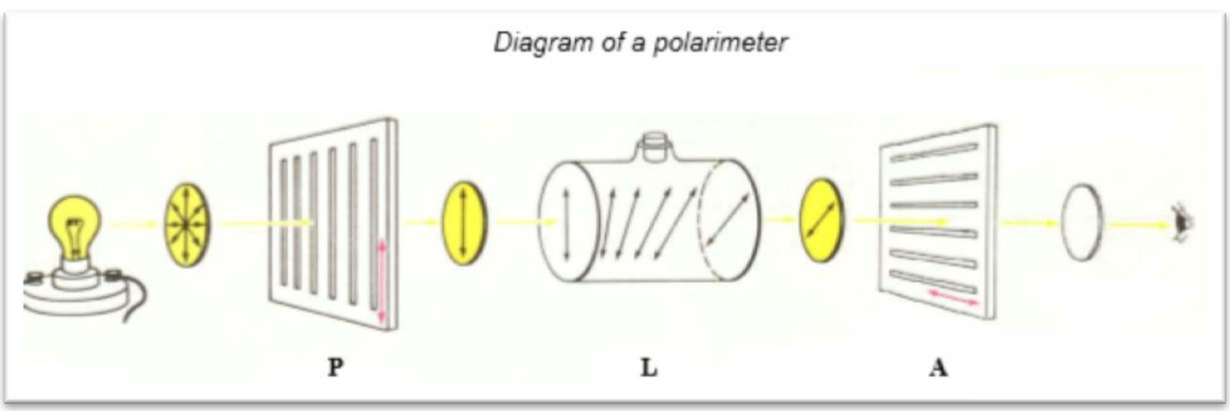
- determine the specific rotation S
- determine the unknown concentration of sugar solution

Introduction:

Polarimetry is a technique of measuring the "polarization" of light. Most of the light we encounter every day is a chaotic mixture of light waves vibrating in all directions. Anisotropic crystalline solids, and samples containing an excess of one enantiomer of a chiral molecule, can rotate the orientation of plane-polarized light. Such substances are said to have optical activity. Measurement of this change in polarization orientation is called polarimetry, and the measuring instrument is called a polarimeter. These measurements are useful for studying the structure of anisotropic materials and for checking the purity of chiral mixtures. A sample that contains only one enantiomer of a chiral molecule is said to be optically pure. The enantiomer that rotates light to the right, or clockwise when viewing in the direction of light propagation, is called the dextrorotatory (d) or (+) enantiomer, and the enantiomer that rotates light to the left, or counter clockwise, is called the levorotatory (l) or (-) enantiomer. Polarimeter is a type of instrument for measuring the optical rotation of a substance. By measuring the optical rotation, the polarimeter can be used in analyzing the concentration, content, and purity of a substance.

Instrumentation:

The simplest polarimeter consists of a monochromatic light source, a polarizer, a sample cell, a second polarizer, which is called an analyzer, and a light detector.



P is the polarizer for producing linear polarized light. A is the rotating polarizer (the analyzer) for measuring the rotary angle combined with the angle scale. Normally, the adjustment of total darkness at crossed polarizers (the transmission axes of polarizer and analyzer are perpendicular to each other) is complicated. For more exact measurements with polarimeter we use the integrated half-shade optics. It is performed by an additional polarizer p1 I p2. Thus, the image observed is subdivided into three separated fields of different light intensities (see fig.2) In the case of crossed polarizeranalyzer without an optically active sample, the initial position of analyzer is then close to the zero point on the angular scale of polarimeter.

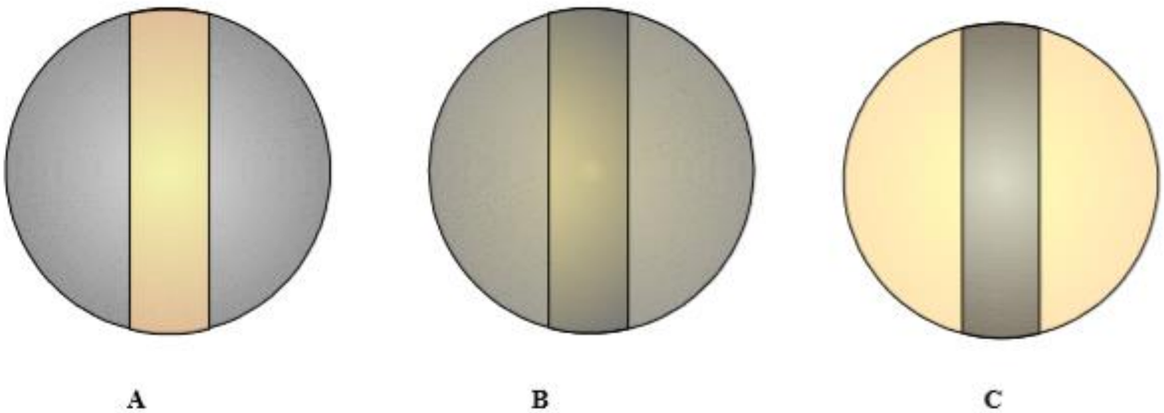


Fig. 2: Schematic presentation of the image of the half-shadow field

A– the central region is brighter than the lateral segment

B–three areas show approximately equal darkness (read the angle of polarization!)

C– the central region is darker than the lateral segment

When an optically active substance is present in the beam, it rotates the polarization of the light reaching the analyzer, so that there is a component that reaches the detector. The angle at which the analyzer must be rotated to return to the minimum detector signal is the optical rotation θ.

The amount of optical rotation depends on the number of optically active species through which the light passes, and thus, depends on both the sample path length and the analyte concentration. Specific rotation θ, provides a normalized quantity for the correction of this dependence, and is defined as:

$$\theta = S.l.c \quad \text{(if l is in cm, then } S=10.\theta/l.c\text{)} \ldots\ldots\ldots(1)$$

where

θ- measured optical rotation in degrees

l - sample path length

c - concentration of the sample

S - specific rotation

If the specific rotation and the sample path length are known and optical rotation angle is measured, we can determine the concentration:

$$c = \frac{\theta}{S.l} \quad \ldots\ldots\ldots\ (2)$$

Apparatus :

Polarimeter with sodium lamp, a balance, measuring cylinder, beaker, sugar, filter paper.

Procedure:

- Measure the length of the polarimeter tube without its caps.
- Note down the least count of the polarimeter circular scale by dividing the smallest division on the circular scale by the number of divisions on the vernier scale.
- Take the polarimeter tube and clean well both the sides such that it is free from dust. Now fill the tube with pure water and see that no air bubble is enclosed in it. Place the tube in its posit ion inside the polarimeter. Switch on the source of light, wait for 5 minutes then look through the eyepiece.
- Take the first reading at equal intensity position and read the both verniers in the circular scale and note down θ_1 and θ_2 calculate the mean angle θ_0 for pure water (mostly $\theta_0 = 0.00^\circ$).
- Prepare a sugar solution of known strength by dissolving the known amount of sugar (say 20 gm) into 100 ml of water. This gives c= 20/100= 0.2 g/cc (20% solution).
- Take the polarimeter tube and remove the pure water. Fill it with the prepared sugar solution and again place it in the polarimeter. Note the reading of both verniers as θ' and θ" in the table and find their means as $\theta_1 = (\theta' + \theta'')/2$, the difference of θ_1 and θ_0 gives the rotation produce θ i.e. $\theta = (\theta_1 - \theta_0)$.
- Now take the 50 cc of 20% solution, add 50 cc of distilled water and mix thoroughly to get c= 0.1 g/cc (10% solution). Rinse and fill the tube with the solution and place it in the proper position and repeat the above procedure to find the rotation $\theta = (\theta_2 - \theta_0)$.
- Again take 50 cc of 10 % solution mix with 50 cc of pure water to get 5% solution. Repeat the above procedure to find θ.
- Calculate the specific rotation of the sugar using the relation S= 10.θ/l.c for each observation. Find out mean specific rotation.
- Now take the solution of unknown concentration and note down the value of rotation.
- Plot the graph between known values of concentration c and rotation θ. Plot the rotation θ for the solution of unknown concentration and determine the concentration of that solution.

Mass of sugar =……g

Total vol. of the prepared solution =……cc

Temperature of the solution t=…….˚C

Length of the polarimeter tube l=……..cm

Least count of the polarimeter scale =……..

No.of obs.	Concentration c (g/cc)	Readings on circular + vernier scale			Rotation $\theta = (\theta_n - \theta_0)$	Specific rotation $S = 10.\theta / l.c$
		θ'	θ''	$\theta_n = (\theta' + \theta'')/2$		
1						
2						
3						
4						

Sources of error and Precautions:

(i) The polarimeter tube should be well cleaned.
(ii) Water used should be dust free.
(iii) Whenever a solution is changed, rinse the tube with the new solution under examination.
(iv) There should be no air bubble inside the tube.
(v) The position of analyzer should be set accurately.
(vi) The temperature and wavelength of light used should be stated.
(vii) Reading should be taken when three areas of the field of view become equally dark.