B.Sc.
Semester – II
Optics

Topic – Polarimetry

by

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History :

- Polarization by reflection was discovered in 1808 by **ÉTIENNE LOUIS MALUS.**

- He conducted experiments to verify Huygen's theories of light and rewrote the theory in analytical form his discovery of the polarization of light by reflection.

Étienne Louis Malus
(1775–1812)

Polarimetry :

- Polarimetry is the measurement and interpretation of the polarization of transverse waves.

- Polarimetry is one of the important instrumental method employed in the analysis.

- Polarimetry is a sensitive, non-destructive technique for measuring the optical activity compounds.

- This technique involves the measurement of change in the direction of vibration of polarized light when interact with an optically active compound.

- A substance is said to be optically active if it rotates the plane of the polarized light.

Polarimeter :

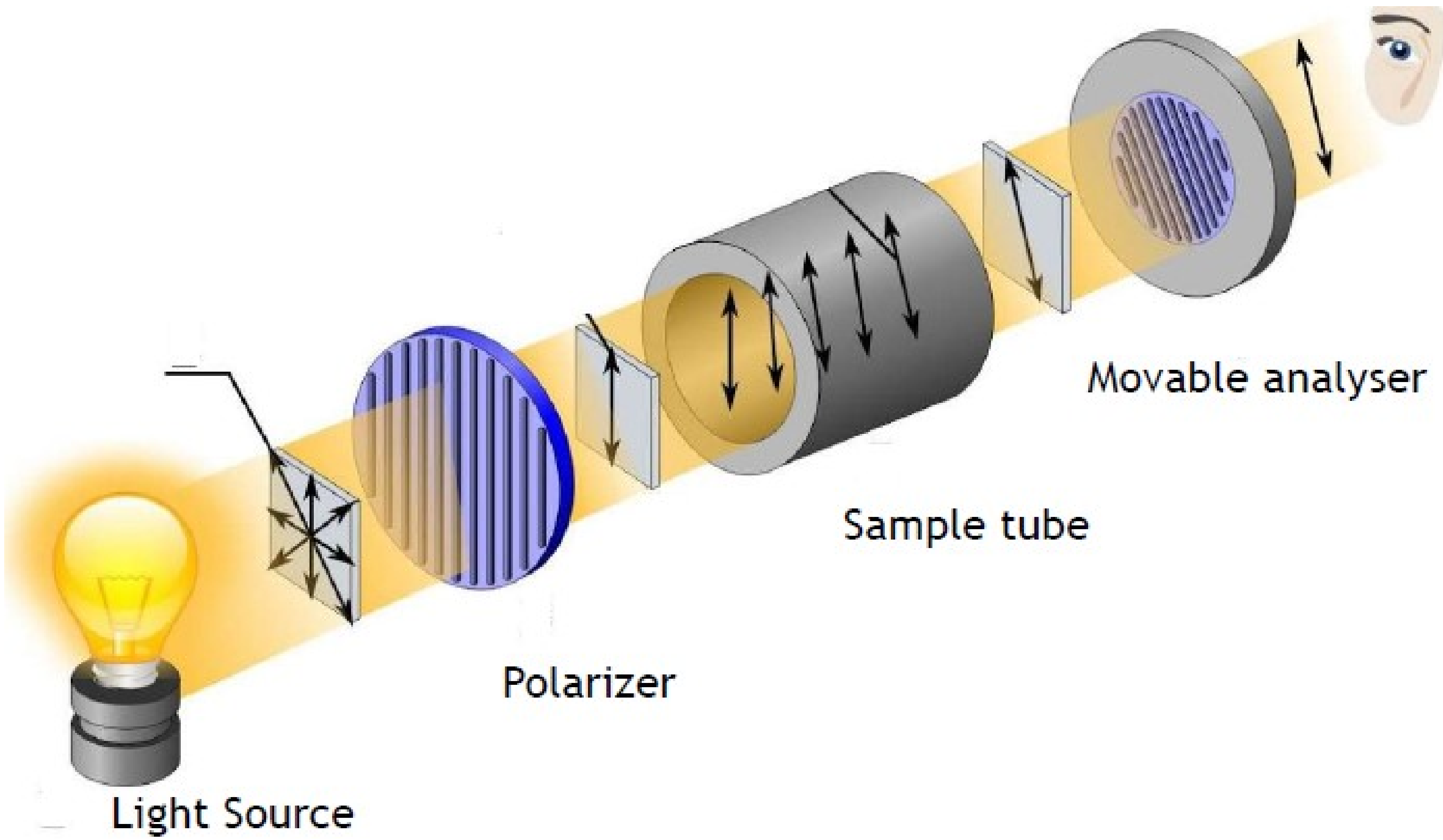
- Instrument measures the rotation of polarized light as it passes through an optically active substance and the tendency of the molecule to rotate the plane polarized light towards clock-wise or anti-clock wise direction whose extent of the rotation can be measured.

- In principle, a pair of crossed polarizers (a pair with their pass axes perpendicular to each other) may be used as polarimeter.

- No light will emerge from such a combination.

- If an optically active substance is introduced between them, the plane of polarization of the light emerging from it may be rotated by a certain angle (let it be α)and the second polarizer will not be able to block the light now.

- The second polarizer will have to be rotated by an angle α in the same sense to make the field of view dark again. The angle of rotation can thus be measured by fitting a circular scale to the second polarizer.



Specific Rotation :

$$[\alpha]_{\lambda}^{T} = \frac{\alpha}{l.c}$$

$[\alpha]_{\lambda}^{T}$ = specific rotation

λ = wavelength of light

T = temperature

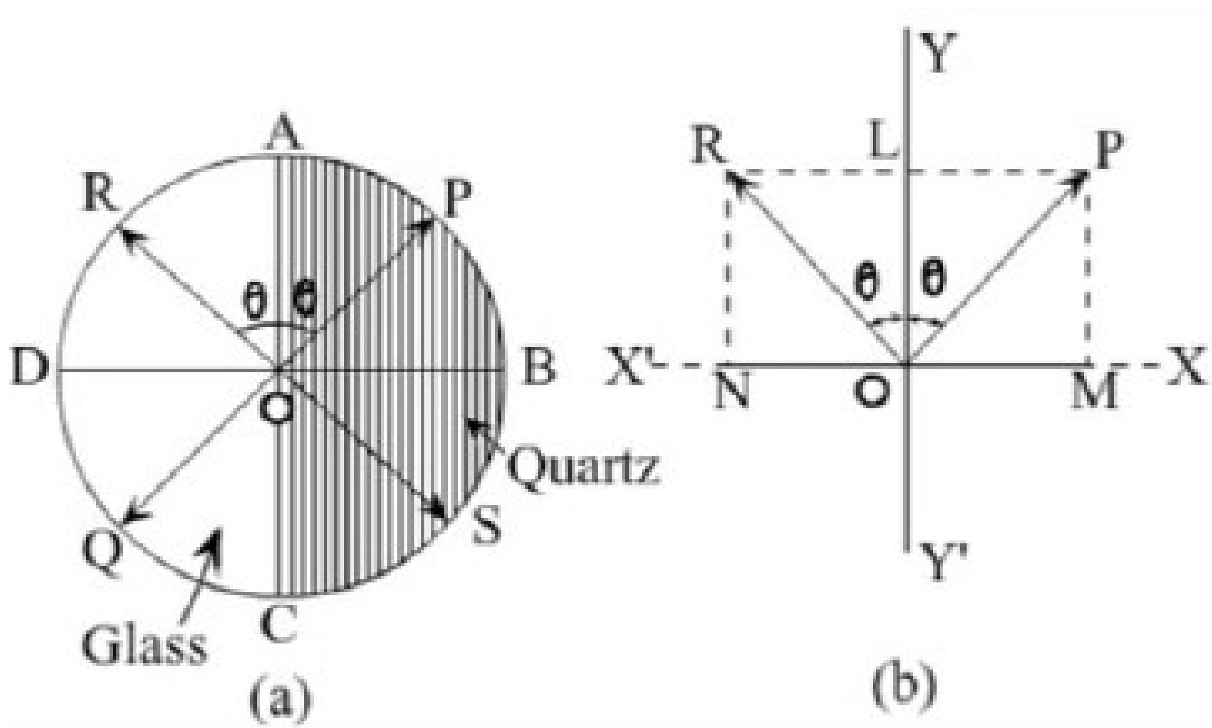
α = observed rotation in degrees

l = cell path in decimeters

c = concentration (gm/100ml)

Laurent's Half Shade Polarimeter :

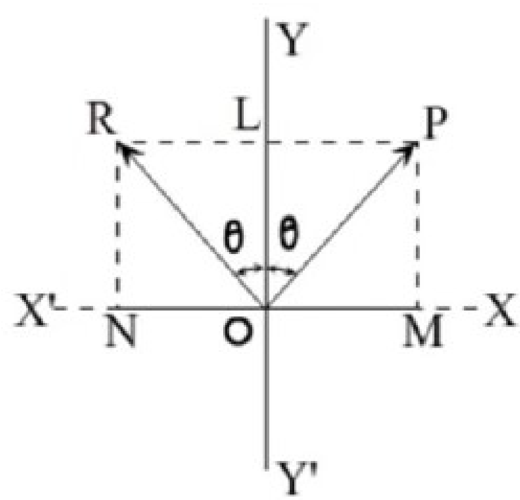
- Consists of a semi-circular half wave plate ABC of quartz (cut parallel to optic axis) so that it introduces a phase change of π between the extra-ordinary and the ordinary rays passing through it, and a semi-circular glass plate ADC.



- The thickness of the glass plate is such that it absorbs same amount of light as the quartz plate.

- Let the plane a vibration of the plane polarized light incident normally on the half shade device be along PQ making an angle θ with AC. The vibrations emerge from the glass plate part of the half shade device as such i.e., there is no change along the plane PQ.

- Inside the quartz plate which is doubly refracting, the light is divided into two components as we know, one ordinary component XX' and the other extraordinary component parallel to the optic axis along YY' .



- The two components travel along the same direction through separation but with different velocities. The ordinary component moves with greater velocity than the extraordinary component.

- On emergence, a phase difference of π is introduced between them.

- Due to this phase difference the direction of the ordinary component gets reversed. If the initial position of the ordinary component is represented by OM, then the final position is represented by ON. Now, on emergence the resultant of the extraordinary OL and ordinary component ON will be OR making an angle theta with the y axis.

- The vibrations of the beam emerging out of the quartz portion of the half shade device will be along RS. That is the change.

- The essential parts of this polarimeter are a monochromatic light source, a convex lens which changes the incident light beam into a parallel one. A polarization which makes this light plane polarized then, the Laurent's half shade device and then a tube containing the optically active experimental substance.

- The light beam emerging from this cube passes through an analyzer. This analyzer is capable of rotation about a common axis. The rotation of the analyzer can be read on a circular scale fitted with verniers. The light after passing through the analyzer is viewed through a telescope which is focused on the half shade device. If the pass direction of the analyzing polarizer which is capable of being rotated and if it is fitted with the circular scale.

- When the past direction is parallel to PQ then light from the glass portion will pass unobstructed while the light from the quartz portion will be partly obstructed. Due to this, the last half will appear brighter than the quartz half.

- On the other hand, if the pass direction of the analyzer is parallel to RS, light from the quartz portion will pass unobstructed, but the light from the glass portion will be partly obstructed. Thus the quartz half will appear brighter than the glass half. If however, the past direction of the analyzer is parallel to AC, y axis it equally inclined to the two planes polarized lights.

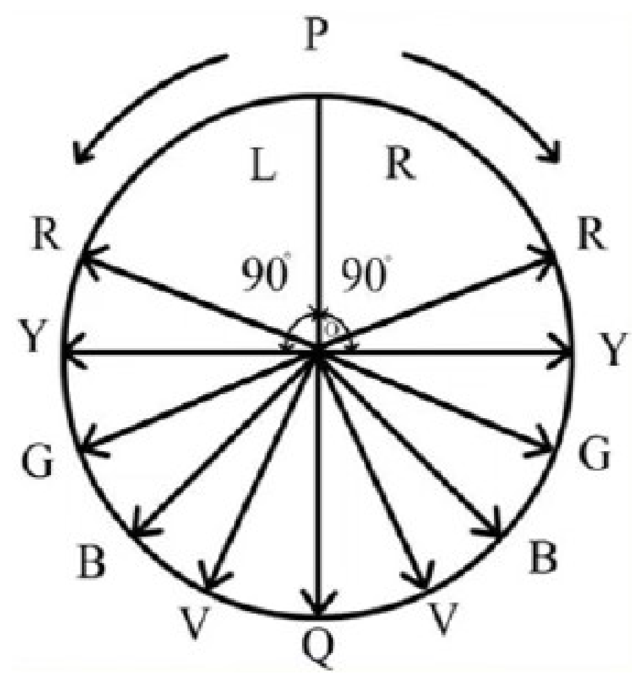
- Hence the field of view, in the two halves, will be equally bright because the half shade device serves the purpose of dividing the field of view in 2 halves. A little change in the direction of the pass direction of the analyzer, makes one half brighter other half darker.

- In the experiment to begin with, the experimental tube is filled with water; the telescope is focused on the half shade device and analyzer is rotated till the 2 halves are equally bright. This position is noted on the circular scale.

- The tube is then filled with the optically active solution and placed in position. The analyzer is rotated and it brought to a position such that the two halves are equally bright again. This new position is noted and the difference between the two regions gives the angle of rotation, pretty accurately.

Biquartz Polarimeter :

- It consists of a white light source, a convex lens as before, which renders the light into a parallel beam, the polarizer changes the incident beam into a plane polarized beam, then a biquartz plate, then the experimental tube containing the active substance and a polarizer working as an analyzer as before. A telescope is fitted with a circular scale and is focused on the biquartz plate.



- Biquartz plate consists of two semicircular plates of quartz. One of left handed quartz L and other of right handed quartz R, each of thickness about 3.75 millimeters. Both are cut perpendicular to the optic axis. This means that propagation here is along the optic axis now. They are joined together along the diameter PQ.

- When the plane polarized white light passes through a biquartz plate normally, along the optic axis the phenomena of rotary dispersion occurs because the planes of vibrations of different colors are rotated through different angles. Remember, we have seen that the amount of rotation is proportional to 1 upon lambda square and rotation will be in one sense for the left handed portion and other direction for the right handed portion. The amount of rotation is maximum for violet which has the minimum wavelength and least for red.

- The sense of rotation is opposite in the two halves. The amount of rotation also depends on the thickness. For a thickness of 3.75 millimeters, the rotation of the plane of polarization for yellow light is about 90 degrees. Hence YOY is a straight line.

- If the pass direction of the analyzer is parallel to POQ, the yellow light will not be transmitted through the analyzer, Malus Law and the appearance of two halves will be similar. The two halves will have a grayish violet tint called the tint of the passage. When the analyzer is rotated to one side from this position, one half of the field of view appears blue, while the other half appears red.

- When the analyzer is rotated in the opposite direction, the colors are interchange the first half which was bluish earlier now appears red and the second half which was reddish earlier now appears blue.

- The position dependence of the tint of passage is very sensitive and is used for accurate determination of the angle of optical rotation.

Applications of Polarimeters :

- To determine product purity by measuring specific rotation and optical rotation of amino acids, amino sugars, antibiotics, dextrose, steroids, cocaine, diuretics, tranquilizers, analgesics, codeine, serums, vitamins, etc.

- To measure the ratio of enantiomers in solutions.

- Many optically active chemicals such as tartaric acid, are stereoisomers, a polarimeter can be used to identify which isomer is present in a sample .

- With a known concentration of a sample, polarimetry may also be applied to determine the specific rotation (a physical property) when characterizing a new substance.