Study Material - Sem. 6 - C13T

- Polarimeters - Dr. T. Kar

Polarimeter

Polarimeter is an optical device designed for accurate determination of the angle of rotation of the plane of vibration produced by an optically active substance. When a polarimeter is calibrated to read directly the percentage of cane sugar in the solution, then it is called a saccharimeter.

A polarimeter in its simplest form consists of two Nicols capable of rotation about a common axis. The active substance is placed between them. Such an arrangement is not sensitive enough for accurate measurement. For this, various types of polarimeters have been designed for accurate measurement of the angle of rotation.

A. Laurent Half-shade Polarimeter

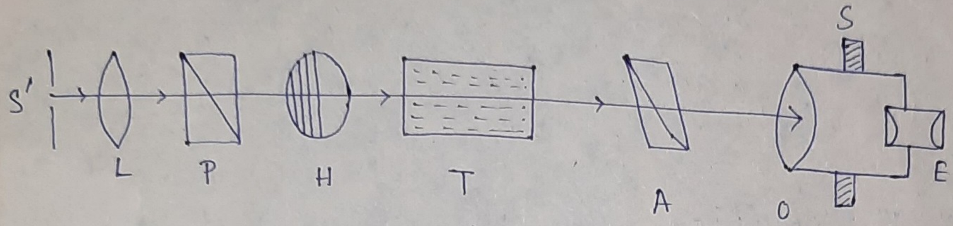

Fig. 1.

The construction of a Laurent half-shade polarimeter is shown in Fig. 1. S' is the slit kept at the focal plane of the convex lens L, so that the rays emerging from L will be parallel. The polarising Nicol P polarises this parallel light. This polarised light then falls on a half-shade plate H. T is a tube containing the solution of active substance. The analysing Nicol A, the objective O and an achromatic eye-piece E are kept in a tube which can be rotated about a horizontal axis and this angle of rotation can be recorded by two verniers rotating with the tube over a fixed circular scale S graduated in degrees.

Working of the Apparatus

The slit S' is illuminated by monochromatic light suitable for half-shade plate. Light from S' will be rendered parallel by the Lens L and after being polarised by the Nicol P, will pass out of the half-shade plate H. This light from H is received by the analyser A and the telescope in the absence of tube T. The tube containing the analyser is rotated until the two halves of the half-shade plate are equally bright. The readings R_1 of the verniers are noted from the scale S.

The tube T, containing the active solution is now put into its position when the two halves of the plate H will be unequally bright due to the rotation of the plane of polarisation by the solution. The tube containing the analyser is again rotated either towards right or towards left until the two halves of H again becomes equally bright. The readings R_2 of the verniers are again noted. Then $\theta = (R_2 \sim R_1)$ will be the angle of rotation.

Determination of the strength of solution

The length 'l' of the solution is measured and expressed in decimeter. If the specific rotation s of the substance is known, we can find the mass m of the active substance per cc of the solution from the relation $\theta = slm$. If m is known, we can find s, the specific rotation of the substance.

Action of half-shade plate

One half of the half-shade plate is made of glass while the other half is made of quartz whose axis is on the surface and parallel to the line of junction of glass and quartz. The thickness of both glass and quartz halves are equal. Let the direction

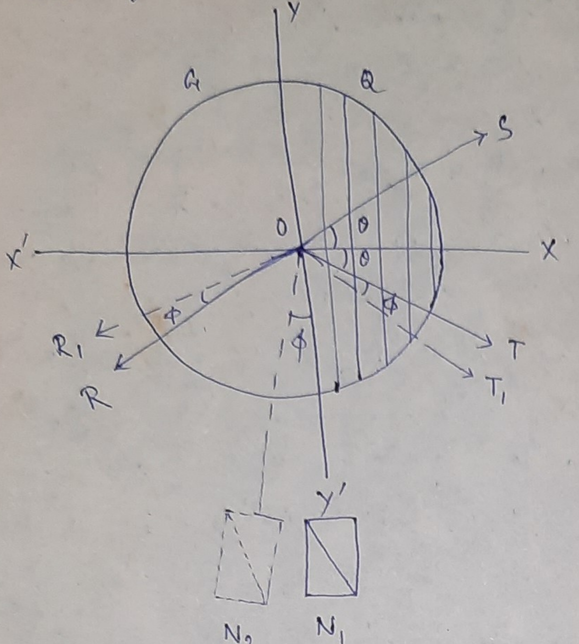

fig. 1.

of vibration of the polarised light on the half-shade plate be parallel to RS. If θ be the angle which the direction of vibration OS of a ray of light on quartz (Q), makes with OX (a line perpendicular to the axis of quartz which is parallel to YY'), then the vibration of this ray of light on the quartz half will be resolved into two vibrations. One parallel to the axis of the quartz known as extraordinary ray (E-ray) and another perpendicular to the axis known as ordinary ray (O-ray). This two rays travel with unequal speed within the quartz and hence a path difference will be created. The thickness of the quartz is such that a path difference of $\frac{\lambda}{2}$ or a phase difference of π will be introduced between the emergent O- and E-rays and they will combine to form a linear vibration whose direction will be parallel to OT and inclined with OX by the same angle θ, but on other side of OX. The directions of vibration of the rays of light, incident on the glass half (G), will remain unchanged on emergence, i.e, ~~parallel to the~~ vibration of the rays of light from the glass half will remain parallel to OR. Now, if the principal section of the analyser be kept in the position N_1, so that it bisects the ∠ROT, then the amplitude of light received by the analyser at

N_1, from both the glass half and the quartz half will be equal and both halves will appear equally bright.

If now the tube containing the active solution be placed in its position, the vibration parallel to OR and OT from glass half and quartz half respectively will equally rotated in the same direction by the same angle ϕ and the resolved parts of their amplitudes in a direction parallel to the principal section of the analyser at N_1 will be unequal and hence the two halves G and Q will appear unequally bright. When the tube ~~rotating~~ containing the analyser is rotated by an angle ϕ to bring the analysing Nicol at N_2 so that its principal section may bisect the angle between the new directions OR_1 and OT_1, the two halves G and Q will again become equally bright.

Rotatory Dispersion

According to Biot, the rotation (θ) of the plane of polarisation by an optically active substance will approximately follow the relation: $\theta = A + \frac{B}{\lambda^2}$, which resembles Cauchy's formula for normal dispersion. The relation between θ and λ can be graphically ~~rep~~ represented by a curve shown in Fig. 1.

~~Suppose a slight~~

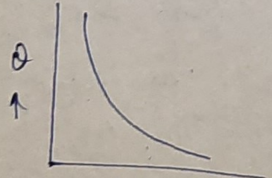

Fig. 1.

Let a slit S_1 is illuminated by a monochromatic light of wavelength λ and the incident light is made parallel by the lens L_1 and is then polarised by a Nicol P whose shorter diagonal is kept vertical (Fig. 2.)

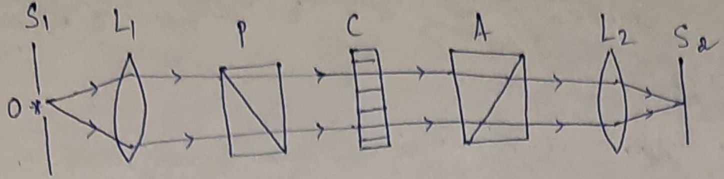

Fig. 2.

Thus the vibration of the light from P will be vertical. This light is then cut off by another Nicol A (analysing Nicol) whose shorter diagonal is therefore horizontal. Thus no light will pass out of lens L_2 and the screen S_2 will remain dark. If now a quartz crystal C, whose axis is perpendicular to the surface, be introduced between P and A, then polarised light from P will travel along the optic axis of C. After emergence from C the vibration of the polarised light will rotate by an angle θ and a component OE_1 of this rotated vibration will enter the analyser A and will be converged on the screen S_2 by the lens L_2 (Fig. 3.). Thus the screen will be illuminated. The emergent light from C can be cut off by rotating the analyser A so that its principal section may be perpendicular to OR.

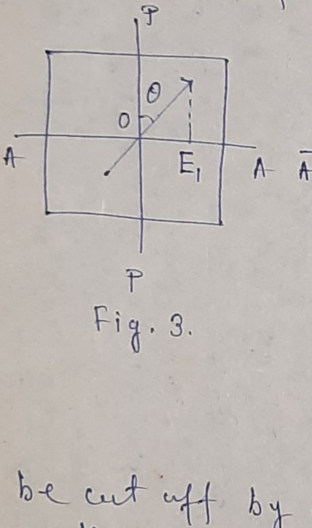

Fig. 3.

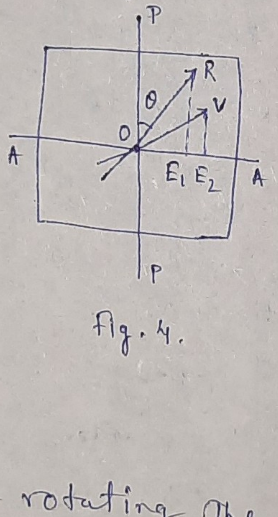

Fig. 4.

If the source S emits white light (which contains various wavelengths), the violet light will be rotated more ($\because \theta \propto \frac{1}{\lambda^2}$ & $\lambda_r > \lambda_v$) (about 4 times) than red light (Fig. 4). Hence, the greater component OE_2 of the violet light will be transmitted through the analyser (A) than that (OE_1) of the red light. As a result, the image formed by L_2

on the screen S_2 will be coloured (Fig. 4). This phenomena is known as rotatory dispersion.

If the principal plane of the analyser is kept perpendicular to the vibration of greenish-yellow rays (which is effective in producing illumination) then they will be cut off. The illumination of the field would then be minimum due to the absence of intense part of the visible spectrum. The colour of the emergent beam from analyser would be greyish-violet due to the combination of less intense red and violet parts of the visible spectrum. This greyish-violet colour is called tint of passage. For when the analyser is rotated to one side from this position, the field would be red due to the transmission of greater component of red light through the analyser while the rotation of the analyser to the other side will allow a greater component of blue light to pass through it, and the field would be blue. This transition from red to blue is very rapid and consequently it is employed to construct a sensitive polarimeter known as Bi-quartz polarimeter.

Bi-quartz Polarimeter

Its construction is the same as that of Laurent's polarimeter, the only modification is that bi-quartz is substituted in place of half-shade plate.

Working of the apparatus

White light from the slit S' is rendered parallel by the lens L and is then plane polarised by Nicol P (Fig. 1.)

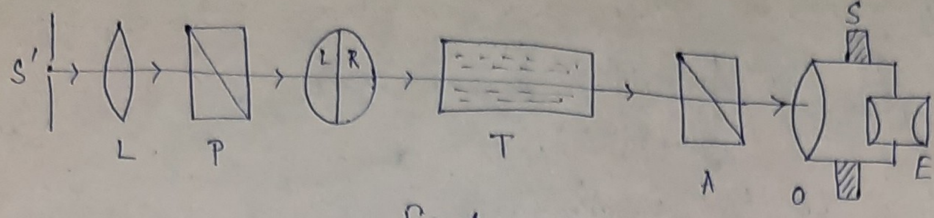

fig. 1.

The emergent light from P passes out of the bi-quartz. This light from the bi-quartz is then received by the analyser A and the telescope (the tube T now being absent). The tube containing the analyser is then rotated until the tint of passage is obtained when the field of view becomes of greyish-violet colour. The readings (R_1) of the verniers are noted from the scale S over which the verniers move.

The tube T, containing the active solution is now introduced in its place when the field of the telescope becomes either red or blue due to the rotation of the plane of polarisation by the solution. The tube containing the analyser is again rotated, either towards right or towards left, until the tint of passage, viz., the greyish-violet colour reappears. The readings (R_2) of the verniers are again noted from the scale S. The angle of rotation of the plane of polarisation by the active substance is given by the mean value of $\theta = (R_2 \sim R_1)$.

Determination of the strength of the solution

[same as in the case of Laurent's half-shade polarimeter]

Action of bi-quartz

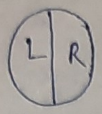

Fig. 1.

Biquartz consists of two semi-circular plates of quartz of equal thickness cut perpendicular to the axis (Fig. 1). One semi-circular plate L is left-handed quartz while the other semi-circular plate R is right-handed quartz. When plane polarised white light passes through them, rotatory dispersion will be produced by each. The thickness of each plate is such that greenish-yellow part of the spectrum is rotated by 90° by each of them. If the principal section of the analyser (A) is kept parallel to that of the polariser (P), then the greenish-yellow part of the spectrum will be cut off from both the plates and both the plates will appear greyish-violet, which is the tint of passage. When the incident light is passing through the active substance, its vibration will be rotated during this passage and consequently one half of quartz will appear red and another half will appear blue. The transition from red to blue is very rapid and hence by rotating the tube containing the analyser A, by a certain angle θ, the colours of the two halves of bi-quartz can be brought back to greyish-violet.

Advantages

This apparatus is more sensitive than Laurent's polarimeter; besides it can be worked with white light, while Laurent's polarimeter can be worked with a light of particular wavelength suitable for half-shade plate.