Exp. 38. Specific rotation of cane sugar solution

Object

To determine the specific rotation of cane sugar solution.

Apparatus

Polarimeter with a sensitive detecting device (Half-shade or Biquartz), sodium lamp (with half-shade or Biquartz polarimeter) or white light (for Biquartz polarimeter only), 100 c.c. flask, beaker, funnel and pipette.

A polarimeter consists of two Nicols (analyser and polariser) which can be rotated about a common axis and the substance, of which the rotation is to be determined, is placed in a tube in between them.

Half-shade Polarimeter : The half-shade plate is placed between the polariser and the tube (fig. 38.1). It consists of a circular plate, one half of which is made of quartz plate cut parallel to the optic axis i.e., along *AOA′* and of such thickness that it produces a retardation of half-a-wavc-lengih (of sodium light) between the ordinary and extra-ordinary rays. The other half of the plate is of glass and of such thickness that the transmitted light is of same intensity as that coming out of quartz.

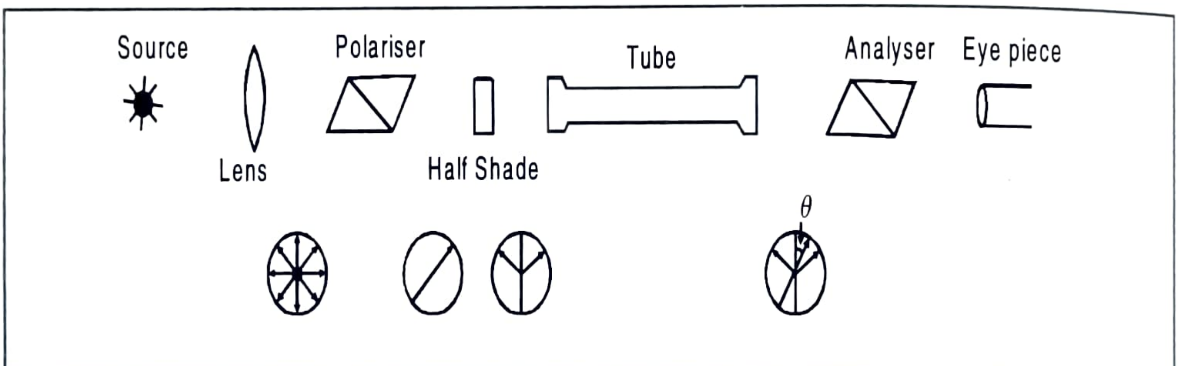

Fig. 38.1

Action of the half-shade plate : Let *POP′* represent the direction of the principal plane of the polarising Nicol inclined at an angle with the direction of the optic axis *AOA′* (fig. 38.2). The plane of vibration of the polarised light will come out of the polarising Nicol along the plane through *POP′*, perpendicular to the plane of the paper and fall on the half-shade plate.

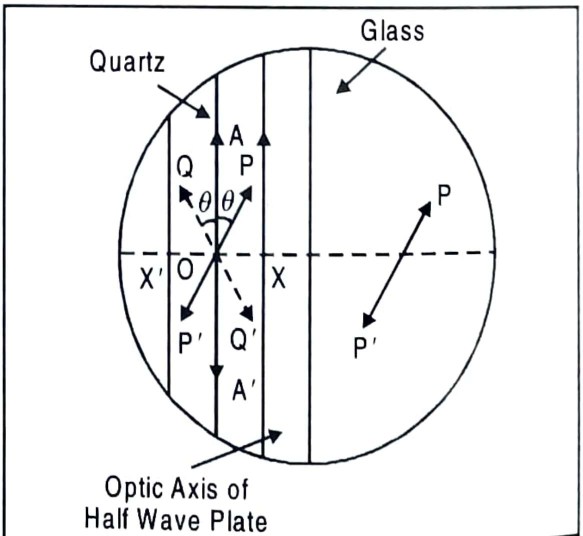

Fig. 38.2

The incident vibration, just on entering the crystal, is resolved into two components *OA* (extra-ordinary) and *OX* (ordinary). On emergence, component

OX develops a phase difference π and is, therefore, represented by OX'. The resultant of OA and OX' i.e., OQ represents the direction of vibration of the light waves emerging from the quartz portion being rotated through twice the angle AOP.

Thus, there will be two plane polarised beams, one passing out of the glass portion and the other passing out of the quartz portion. *If* OP and OQ, are equally inclined to NON' (principal section of the analyser), two halves of the field will appear equally bright (fig. 38.3(*b*)). A slight rotation of the analyser from this setting either in the clockwise direction or in the anti-clockwise direction (fig. 38.3(*a*) and 38.3*c*) causes one component greater than the other and therefore either the quartz portion appears brighter than the glass or vice-versa. Thus, the analyser can be set accurately so that the two halves of the field are equally bright.

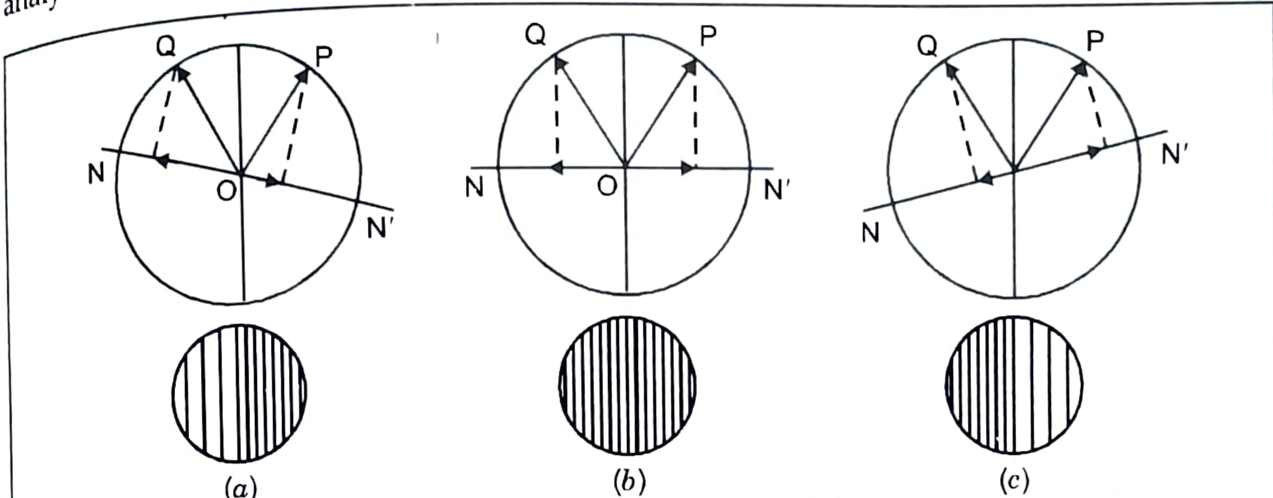

Fig. 38.3

Biquartz Polarimeter : The arrangement has been shown in fig. 38.4, where A, P are analyser and polariser, T *is* the tube and E *is* the eye-piece. In this polarimeter, the half-shade plate is replaced by a biquartz plate B which consists of two semi-circular plates of quartz one made of right-handed while the other of left-handed

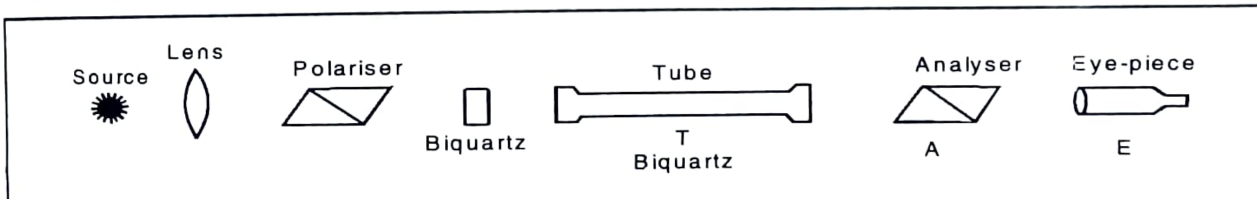

Fig. 38.4

quartz. The thickness of each plate is chosen to be near about 3.75 mm so that the yellow light (λ = 5600 A.U.) may be rotated through 90°. These plates are cut so that the optic axis lies at right angles to its faces. When plane polarised white light is incident normally on the biquartz plate, along N_1AN_1 (principal section of polariser), component colours are rotated through different angles where it is maximum for violet, least for red and 90° for yellow (fig. 38.5).

In the two halves, the colours are rotated in opposite direction but symmetrically. The planes of vibration of the different colours i.e., red, orange, yellow, blue and violet are represented respectively by AR, AO. AT, AB and AV.

When the principal section of the analyser N_2AN_2, is parallel to N_1AN_1 (fig. 38.5(*b*)), the wavelength of the yellow colour (λ = 5600 A.U.), is completely quenched from both the halves. As all the other colours would be inclined equally in both the halves, the resultant colours produced in each half would be the same. This resultant is greenish-violet called *'sensitive tint'* (fig. 38.5(*b*)). If the analyser is slightly rotated from this setting in the anti-clockwise direction, the transmitted components of the longer wavelengths (predominantly red) increases while those of the shorter wavelengths (predominantly violet and blue) decreases. The left half will appear pink and the right half will appear blue. The appearance is reversed when the analyser is rotated in the clockwise direction (fig. 38.5(*a*) and 38.5(*c*)).

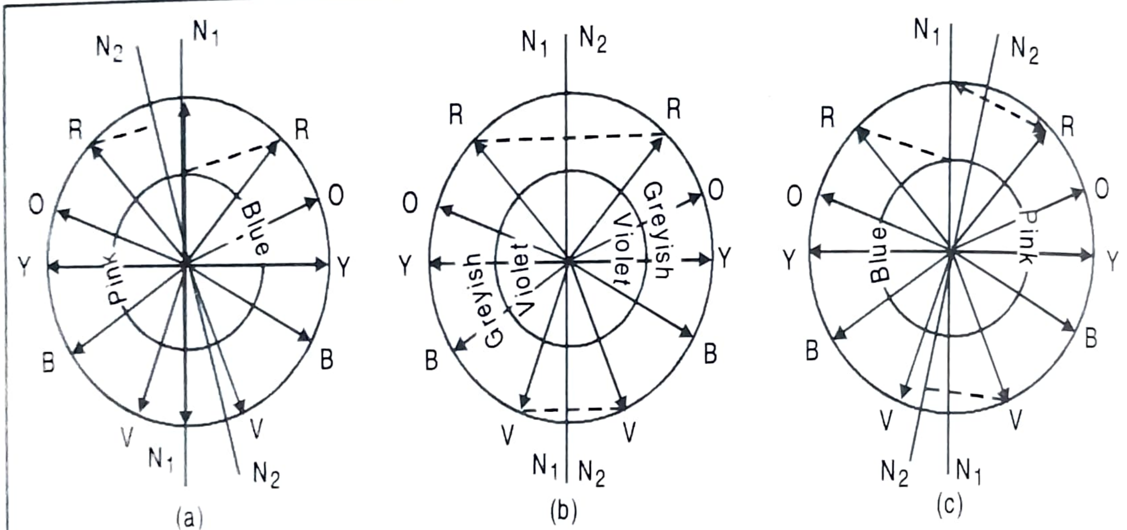

Fig. 38.5

Action of the biquartz with sodium light (wavelengths 5896 A.U. and 5890 A.U.)

Let the plane polarised sodium light from the polariser (principal section being along N_1ON_1) be incident on the biquartz. On emergence through the plate, the incident vibration of the yellow light (λ = 5890 A.U. and 5896 A.U.) is rotated through $\pm 80°$ along OP_1 and OP_2 (fig. 38.6). Thus, the field of view is again divided into two halves and the analyser can be set for the equality of brightness of the two halves as in half-shade polarimeter.

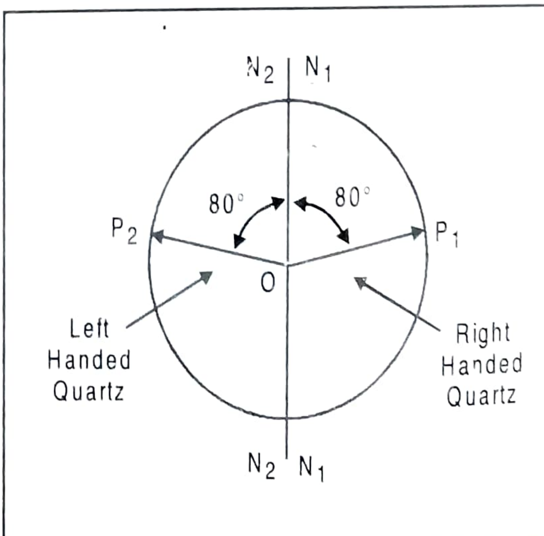

Fig. 38.6

Biquartz Soleil compensated type polarimeter : In addition to biquartz polarimeter, one right handed rotation quartz disc R and a pair of left handed rotation quartz wedges L are inserted between the tube and the analyser. The thickness of the wedges can be increased or decreased by sliding them on each other by micrometer screws. The net effect of R and L is thus left handed rotation or right handed rotation according as the thickness of L is greater or less than that of R. The rotation produced by the solution can be neutralised by introducing a required degree of right or left handed rotation. The arrangement has been shown in fig. 38.7.

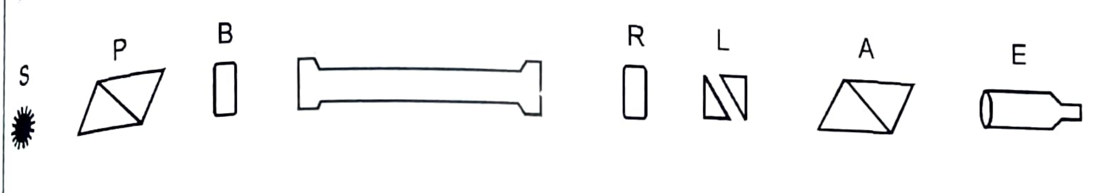

Fig. 38.7

Theory

The amount of rotation of the plane of polarisation of light when it passes through optically active substances like quartz, sugar solution etc. depends :

(*i*) directly on the thickness (l) of the optically active substance actually traversed by the polarised light,

(*ii*) directly on the concentration (c) of the substance in solution,

(*iii*) inversely at the square of the wavelength of light, and

(*iv*) on temperature. It generally decreases with the rise in temperature. However, this variation is negligibly small.

For a particular wavelength at constant temperature, the rotation is given by

$$\theta = \alpha lc = \alpha\, lx/v$$

where x gm of the substance (sugar) is dissolved in v c.c. and α is the specific rotation of cane sugar solution.

$$\therefore \qquad \alpha = \frac{\theta v}{lx}, \quad l \text{ being measured in decimetre.}$$

Procedure

(*i*) A sugar solution of known strength is prepared in distilled water (say 10 gm in 100 c.c.).

(*ii*) Vernier constant of the circular scale attached with the apparatus is noted.

(*iii*) The polarimeter tube is filled with distilled water in such a way that no air-bubble remains inside the tube and placed in the proper position.

(*iv*) The slit is illuminated by sodium light (with half-shade or biquartz polarimeter) or white light (with biquartz polarimeter only) and the eye-piece is focussed until the field of view or a vertical line in the field of view is sharp. Unequal illumination or different colours will be seen in the two halves of the field of view. The analyser is rotated till the two portions of the view are of the *same intensity* using sodium light or appear *greyish-violet* using white light. The reading of the analyser is noted on the graduated circular scale. The analyser is rotated through 180° and the reading is also noted repeating the above procedure.

(*v*) The tube is next filled with the prepared solution. The field of view will have again unequal illumination in the two halves (using sodium light) or the matching of the colours will be found to be disturbed (using white light). The procedure (*iv*) is repeated and the scale readings are noted. The differences between the (*iv*) and (*v*) readings separately for each position are determined. The mean of these two readings gives the angle of rotation of the plane of polarisation.

The above procedure is repeated with the solution of different strengths. Plotting a graph between the strength of the solution on X-axis and θ along Y-axis, a straight line will be obtained.

Observations

Room temperature = ... °C

Length of the tube = ... dm

Mass of sugar dissolved = ... gm

Volume of the solution = ... c.c.

Least count of the vernier = ...

Sr. No.	Reading on analyser for equal illumination or sensitive tint in degrees													Rotation in degrees		
	With distilled water						With sugar solution									
	First position			Second position 180° apart			Strength of solution per 100 c.c.	First position			Second position (180° apart)					
	Main scale	Vernier	Total (a)	Main scale	Vernier	Total (b)		Main scale	Vernier	Total (c)	Main scale	Vernier	Total (d)	θ_1 (= $c \sim a$)	θ_2 (= $d \sim b$)	Mean $\theta = \frac{\theta_1 + \theta_2}{2}$
1																
2.																
3.																
⋮																

Calculations

$$\alpha = \frac{\theta}{l} \times \frac{v}{x}$$

= ... degrees per unit concentration per decimetre.

% error :

Result

The specific rotation of cane sugar solution (correct to significant figures) at °C corresponing to the ... = degrees per unit concentration per decimetre.

The graph between concentration and rotation is a straight line. Thus, the rotation is proportional to concentration.

Precautions

(i) There should be no air-bubble in the tube while filling it with solution or distilled water.

(ii) While taking one set of observations, the polariser should not be disturbed.

(iii) The cap of the tube should not be tightened beyond a limit as it may strain the glass. Strained glass may produce elliptically polarised light which might interfere with the setting.

(iv) Two positions at ±90° may appear where the equal illumination remains for a long range. These readings should not be taken.

Note : The modern commercial method of obtaining polarised light is with a *Polaroid* invented by E. H. Land. Polaroid is a film of *nitro cellulose* in which ultra-microscopic crystals *of herapathite* (an organic compound) are embedded in such a manner that the optic axis of all of them are parallel. Each crystal transmits only one beam of polarised light, the other being absorbed (fig. 38.8).

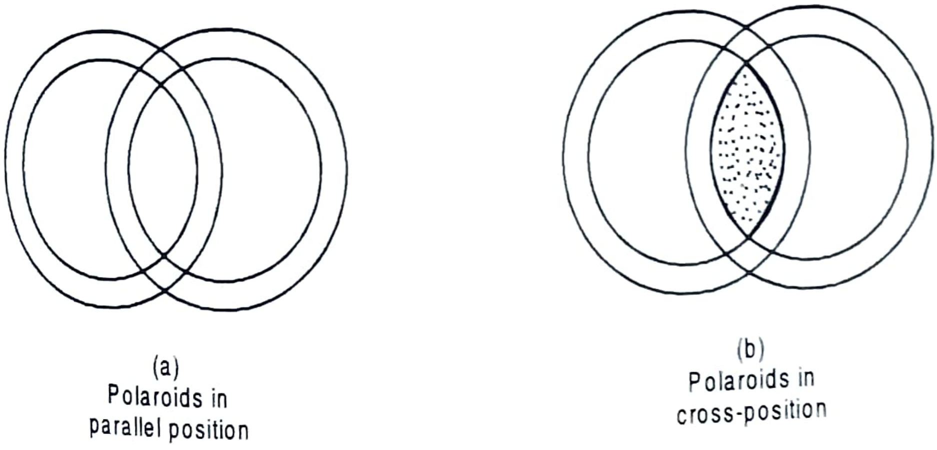

Fig. 38.8

QUESTIONS

(i) What do you understand by polarisation of light ? How do you say that light waves are transverse ?

(ii) How will you produce plane, circularly and elliptically-polarised light ? How would you distinguish between them and an unpolarised beam of light ?

(iii) Explain the working of a tourmaline crystal, a nicol prism and a polaroid. What are their practical applications ?

(iv) What is double refraction ? How is it explained ?

(v) Define crystallographic axis, optic axis, and principal section of a crystal.

(vi) What are Dextro-rotatory and Laevo-rotatory substances ? Is there any substance which is common to both the types ?

(vii) Explain the function of a half-shade plate or a biquartz.

(viii) Define specific rotation. On what factors does it depend ?

(ix) What practical application do you know of the measurement of specific rotation ?

(x) Discuss the merits and demerits of the various types of polarimeters

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