

7. Polarimetry

Background

Half shade principle
Optical rotatory power
Optical activity
Specific rotation

Aim of the experiment

To determine the specific rotation of an optically active substance by polarimeter.

Apparatus required

A Polarimeter
Optically active substance (known weight)
A measuring cylinder
A beaker
A scale
Distilled water
Sodium light source

Theory

Let a plane polarized monochromatic light of wavelength λ pass through a column of solution of length l centimeter (i.e., $l/10$ decimeter) and containing m gm of an active substance per cm^3 at a given temperature. Then the plane of polarization of the light is rotated through an angle θ given by

$$\theta = \frac{slc}{10}, \quad \dots(1)$$

where s is the specific rotation of the solution, and c is the concentration of the solution ($c = (m \text{ gms})/\text{cm}^3$). The quantity s is defined as the rotation produced by a column of solution of length l decimeter and containing 1 gm of the active substance per cm^3 of the solution under the experimental condition, i.e. at the temperature of the solution and for the wavelength used.

If 100 cm^3 of the solution contains m gms of the active substance, the strength of the solution (or the concentration) is $c = \frac{m}{100} = m\%$. Hence

$$\theta = \frac{slm}{1000}, \quad \dots(2)$$

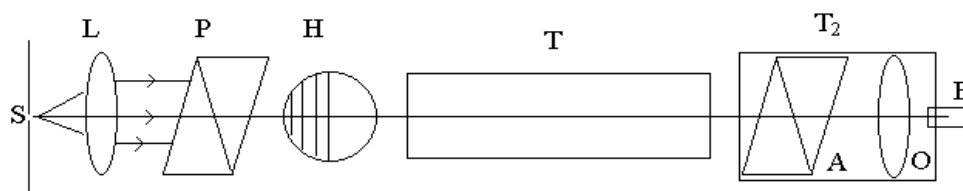
$$\text{or, } s = \frac{1000\theta}{lm}, \quad \text{or } s = \frac{10\theta}{lc}. \quad \dots(3)$$

Equation (1) shows that for a given length l , the plot of θ versus c will be a straight line. This plot is known as the calibration curve of the polarimeter for the active solution. This plot can be used to find the concentration c of an unknown solution of the same solute by measuring the rotation θ produced by it.

From a set of values of c and θ , and by measuring the length of the tube containing the solution, the specific rotation of the solution, s , can be determined from Eq. (3).

Procedure

1. Clean the polarimeter tube, beaker, flask and measuring cylinder with water.
2. Fill the polarimeter tube with distilled water. As you rotate the analyzer through 360° , you observe four uniform illumination positions- two of these are weak in intensity and the other two are strong. Choose one of the weak uniform illuminations accurately by observing through the eye-piece and note the angle of rotation on the scale.
3. Rotate the analyzer by approximately 180° to record the other uniform illumination reading.
4. Rotate the analyzer by another 180° and note the readings for uniform illumination.
5. Repeat the step 4.
6. Prepare the solution of appropriate strength by dissolving a known amount of active substance in a known volume of distilled water.
7. Fill the polarimeter tube with the solution of known concentration. Note the rotation produced in by adjusting the scale and observing uniform illumination through the eye-piece.
8. Repeat the steps 3, 4, & 5.
9. Prepare solutions of different known concentrations by proper dilution of the parent solution.
10. Repeat steps 7 & 8 for different concentrations.
11. Now prepare an unknown concentration solution and repeat 7 & 8.
12. Plot a graph of θ versus c .
13. From the graph obtain the unknown concentration.



S – Slit
 L – Collimating lens
 P – Polarizing nicol
 H – Half-shade plate
 T – Tube containing solution
 A – Analysing nicol
 O,E – Objective and eyepiece of the observing telescope
 T₂ – Tube housing A and the observing telescope

Fig. 1 Experimental set up to measure the specific rotations for an optically active solution by polarimeter

Observations

Length of the polarimeter tube:

Wavelength of the light used:

Room temperature:

Vernier constant (Least Count) of the polarimeter:

Table 1

Rotation of plane of polarization when tube contains distilled water

Sl.No.		C.S.R	V.S.R.	Total	Mean
1.	1 st Uniform illumination position				(R ₀)
2.					
3.	2 nd Uniform illumination position				$\approx R_0 + 180^\circ$
4.					

Table 2
Rotation of plane of polarization when tube is filled with solution

Sl. No.	Weight of active substance 'm' (gm)	Strength of active substance 'c'		C.S.R	V.S.R	Total (R)	Mean (R) $(a+b)/2$ & $(c+d)/2$	$\theta = R_0 \sim R$
1			1 st uniform illumination	a)			(R)	
				b)				
			2 nd uniform illumination	c)			$\approx R + 180^0$	
				d)				
2			1 st Uniform illumination	a)			(R)	
				b)				
			2 nd Uniform illumination	c)			$\approx R + 180^0$	
				d)				
3			1 st Uniform illumination	a)			(R)	
				b)				
			2 nd Uniform illumination	c)			$\approx R + 180^0$	
				d)				
4	Unknown		1 st Uniform illumination	a)			(R)	
				b)				
			2 nd Uniform illumination	c)			$\approx R + 180^0$	
				d)				

Results

Plot a graph of θ vs c using the least squares fitting method.

Table 3

Determination of the specific rotation of the solution from the plot

l (cm)	c (gm/cm ³)	θ (degree)	$s = \frac{10\theta}{lc}$ (degree cm ³ decimeter ⁻¹ gm ⁻¹)

Note: In the calculations, ' l ' has to be considered in cm . The factor of 10 in the numerator will take care of the conversion to dm^{-1} .

Table 4

Determination of the concentration of a given sugar solution

θ	l (cm)	s From table 3	$c = \frac{10\theta}{ls}$ (gm/cm ³)

Error calculation

The specific rotation of a substance is given by

$$s = \frac{10\theta}{lc}$$

$$\therefore \frac{\delta s}{s} = 2 \frac{\delta \theta}{\theta} + 2 \frac{\delta l}{l} + \frac{\delta c}{c}$$

$$c = \frac{m}{V}$$

$$\text{Therefore, } \frac{\delta c}{c} = \frac{\delta m}{m} + \frac{\delta V}{V}$$

$$\text{Or, } \frac{\delta s}{s} = 2 \frac{\delta \theta}{\theta} + 2 \frac{\delta l}{l} + \frac{\delta m}{m} + \frac{\delta V}{V}$$

l and θ are obtained as a difference of two scale readings, each with an error equal to the least count of the instrument (δl and $\delta \theta$ respectively). Hence, the factor '2' appears in the above expression.

θ is the angle of rotation corresponding to the chosen point on the graph for determining the specific rotation. Here, m is the weight of the optically active substance dissolved in V volume of distilled water.

Discussion

1. In preparing the sugar solution, some sugar should be powdered with a pestle and mortar before taking the weight. The sugar should be dissolved completely in distilled water. The water should not be heated to assist dissolving. The solution should be filtered to make it dust free.
2. When the tube is filled with the solution, care should be taken to remove air bubbles.
3. After placing the tube containing the solution in its position, it should be allowed to stand there for some time (at least five minutes) so that the temperature may become uniform, and then readings should be taken.
4. Since the specific rotation depends on temperature, the temperature of the solution of each concentration and also of the unknown solution would be noted while measuring the corresponding angles of rotation. So, a thermometer should be placed alongside the tube containing the solution, and after suitable intervals of time, the temperature is to be noted.
5. While measuring the angles of rotation, the two halves of the half-shade plate should be equally bright. Failure to judge the equality of brightness will introduce errors. To minimize those errors, four readings should be taken for each concentration.

Questions

1. How does polarized light differ from the ordinary light?
2. What is optic axis? Name uniaxial and biaxial crystals.
3. What do you understand by polarized light and the plane of polarization?
4. What is an 'optically active substance'?
5. What are the factors on which the optical activity of a substance depends?
6. How does the optical activity depend on (i) wavelength, and (ii) temperature?
7. What type of crystals does exhibit optical activity?
8. How does the optical activity depend on the state of the substance?
9. Define specific rotation. Does it depend on the wavelength of light used and temperature of the solution?
10. What do you mean by (i) molecular rotation, and (ii) rotatory dispersion?
11. How are the specific rotations of pure liquids and pure solids defined?
12. Distinguish between natural and magnetic rotation of the plane of polarization.
13. Can you perform this experiment using white light instead of sodium light?

References

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2. Text book of Physical Chemistry by S. Glasston 541 GLA/T
3. Organic Chemistry by L.O. Smith 547 SMI/O
4. Organic Chemistry by R.T. Morrison and R.N. Boyd

Graph : Polarimeter