CHAPTER 4

Insights on Optical Handedness of Chiral Materials using Newton's Rings

Abstract

Chiral materials (Enantiomers) as has been explained in previous chapters have ability to rotate plane of polarization in a direction dependent on their optical handedness, due to circular birefringence. Despite having similar physical and chemical properties, the optical and biological properties of the enantiomers are different. Some of the absorption based techniques to detect different enantiomers are polarimetry, optical rotatory dispersion (ORD) (Castiglioni et al., 2011), Circular Dichroism Spectroscopy (CD). (Berova et al., 2000; Snatzke, 1968) Circular dichroism spectroscopy is a traditional technique that has always been used to distinguish between optically active materials by examining the difference in absorption of left and right circularly polarized light. Some of the other novel techniques are Raman Optical Activity (ROA) (Barron, 2015) and Vibrational Circular Dichroism (VCD) (Magyarfalvi et al., 2011). In the present chapter, we have discussed a technique to study handedness of chiral samples (optical active) where Newton's rings are used as a novel analytical tool. It is an absorption-based technique that measures the refractive indices of both enantiomers in the presence of linearly polarized light (at different polarizing angles) and with circularly polarized light (right and left-handed). Based on refractive index values we were able to differentiate enantiomers. The method presented requires a 40 µl sample of each enantiomer which is very less compared to other traditional known methods that require large quantity of the sample to be filled in sample cavity.

4.1 Introduction

Chirality is a geometric attribute of a molecule. Chiral molecules exist in two stereoisomeric forms that are non-superimposable mirror images of each other. Their molecular formula, bond connectivity, functional groups, chemical and physical properties are identical except for their ability to rotate linear polarized light. Chiral molecule possesses a stereocenter known as the chiral center that makes the molecule non superimposable on its mirror image. A chiral center is a central carbon atom that is bonded to four distinct groups (Van't Hoff, 1874) Molecules that have tetrahedral geometry and a chiral center may exist as a pair of isomers. Kurt Mislow et al. modified the definition of chirality in 1984 and defined chirality in terms of symmetry.

For a molecule to be chiral, it must lack three symmetry elements: the plane of symmetry (σ), the center of symmetry (i), and the alternating axis of symmetry (S_n). (Mislow & Siegel, 1984)

Human hands also show chirality as they are non-superimposable mirror images of each other at any orientation. It is essential to differentiate enantiomers as chirality exists in our daily life, in biological molecules, plants, animals, drugs, foods and beverages. Most drugs made in pharmaceuticals are chiral in nature. Hence, chiral information is essential and valuable, but to differentiate enantiomers is a tedious task as these enantiomers physiochemical properties are the same but only differ in biological properties.

Some of the absorption-based techniques to investigate chiral materials are polarimetry, optical rotatory dispersion, and circular dichroism spectroscopy (CD). The polarimetry technique is inexpensive and can determine the optical rotation of a particular chiral molecule, but no information can be extracted regarding absolute configuration of the molecule. The technique (Polarimetry) requires a considerable amount of samples for the experiment.

In optical rotatory dispersion (ORD), optical rotation is measured as a function of wavelength and provides absolute configurational details of the molecule. Circular dichroism spectroscopy (CD) is an absorption spectroscopy and uses circularly polarized light to study the structural properties of optically active molecules. The difference in absorption of RCP and LCP light gives structural details of chiral materials. These methods are expensive and require a considerable amount of sample for study.

One of the well-known techniques to measure the refractive index of samples is the Abbe refractometer. The abbe refractometer has an accuracy of ±0.0002. In this technique, a sample is filled as a thin layer between two prisms. The bottom illuminating prism top's surface is matted and the upper prism is the measuring prism. The infinite number of rays are refracted at all angles from the sample before the light enters into the measuring prism. It requires smaller amount of sample for refractive index measurement but cannot distinguish between two optically active enantiomers.

Linearly polarized light is a combination of 50% right circularly polarized light (RCP) and 50% left circularly polarized light (LCP). When linearly polarized light transmits through a chiral sample, one of the circularly polarized components is absorbed more within the sample. This is circular birefringence. Due to the differential absorption of RCP and LCP within the chiral sample, the plane of polarization is rotated in a direction dependent on the enantiomer. Figure 4.1 depicts how plane polarized light enters and exits the chiral sample.

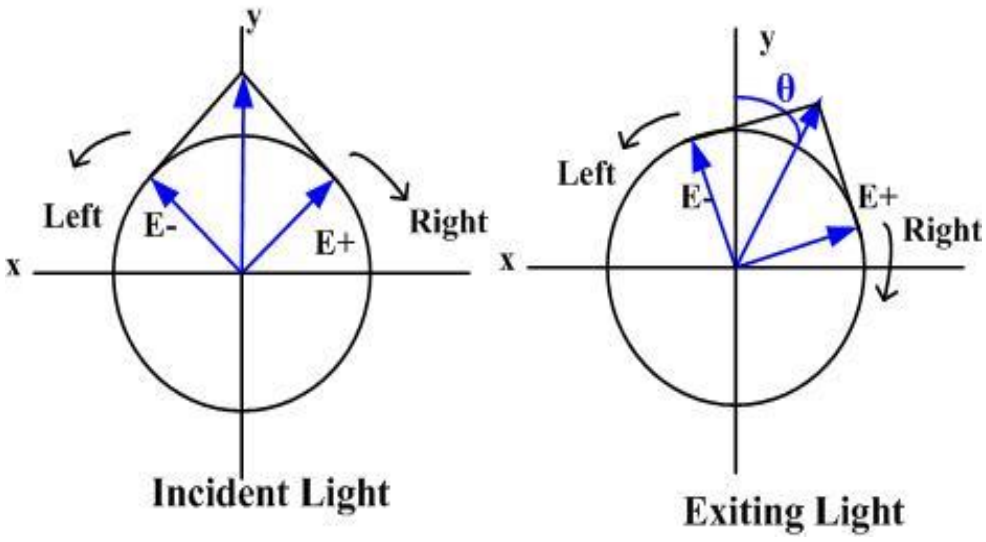


Figure 4.1: Plane polarized light is the vector sum of two oppositely rotating left and right circularly polarized light (a) No optical rotation when plane polarized light is incident in chiral sample. (b) As plane polarized light exits from chiral sample its plane of polarization is rotated.

In recent work, linearly polarized light or circularly polarized light (RCP and LCP) was allowed to pass through the chiral sample, and reflection, refraction, (Ghosh & Fischer, 2006) and diffraction (Ghosh et al., 2007) were observed. Due to the circular birefringence of the enantiomers, angular dispersion was observed (by observing well-separated Gaussian beam profiles). Two spots were observed on the screen, one spot corresponds to the LCP, and the other corresponds to RCP. Experiments were performed on a microcell volume with a path length of 400 μm and a macroscopic cuvette with a path length of 2 cm. Regardless of the difference in optical path difference, the results were the same. Alternatively, a stack of prismatic cuvettes (20 interfaces) alternately filled with the R and S enantiomers was used for better detection.(Ghosh & Fischer, 2006) Further, these angular divergences were enhanced by total internal reflection at the interface of an optically active medium (Rajan & Ghosh, 2012b) and in other techniques, diffraction grating was used.(Rajan & Ghosh, 2012a)

Above results indicate optically active materials show two different refractive indices for LCP and RCP light. Lin et al. related these different refractive indices for RCP and LCP with the average refractive index and chiral parameter and calculated these values for the chiral sample by Drude-Born-Fedorov relations.(Lin & Su, 2003) (n_+ & n_-).

$$n_{\pm} = n \pm g \quad (1)$$

where n is the average refractive index, n_+ and n_- are the refractive indices of the LCP and RCP lights respectively in the chiral sample and g = n *f*. Where g is the chiral parameter (*f* is $k_0\beta/\sqrt{\varepsilon\mu}$ where β is the gyrotropy) and its value is very small ($g \approx 10^{-4} \sim 10^{-7}$).

$$\vec{D} = \varepsilon [\vec{E} + \beta\vec{\nabla} \text{ x } \vec{E}] \quad (2)$$

$$\vec{B} = \mu [\vec{H} + \beta\vec{\nabla} \text{ x } \vec{H}] \quad (3)$$

where β is the gyrotropy, ε is the average dielectric constant and μ is the permeability. By using Maxwell's equations and assuming plane wave solutions of frequency of ω_0 and wave vector $\vec{k}=k\hat{k}$, above equations can be modified as:

$$\vec{D} = \varepsilon [\vec{E} + if (\vec{k} \text{ x } \vec{E}) / nk_0] \quad (4)$$

$$\vec{B} = \mu [\vec{H} + if (\vec{k} \text{ x } \vec{H}) / nk_0] \quad (5)$$

Where n is average refractive index and *f* is $k_0\beta/\sqrt{\varepsilon\mu}$. A molecule is defined by the number of chiral parameters. Chiral parameters differentiate chiral molecules from achiral molecules.(Harris et al., 1999) In the current chapter, we present a unique absorption-based technique to distinguish enantiomers by measuring the refractive index of chiral samples. The method can be used in both research labs and companies.

The purpose of our experiment is to distinguish the optical handedness of chiral materials by measuring their refractive indices in the presence of linearly polarized light (at different polarizing angles) and circularly polarized light (both RCP and LCP). Newton's Interference rings device was modified and utilised as an analytical tool. (Ghalsasi et al., 2022)

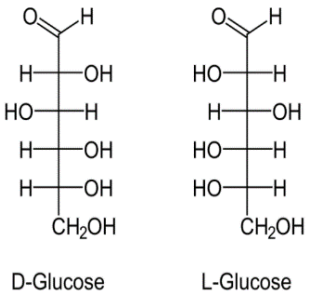
4.2 Materials and Methods

In the present work experiments were performed on commercially purchased chiral samples and all the samples were used as received. In the present work following samples were studied for the comparative study of the refractive indices of the enantiomers.

4.2.1 Chiral Samples for the Refractive Index Comparative Study

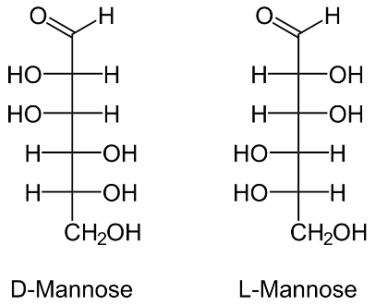
(a) D-Glucose ($C_6H_{12}O_6$) Sigma Aldrich (CAS 50-99-7),

L-Glucose ($C_6H_{12}O_6$) Sigma Aldrich (CAS 921-60-8)



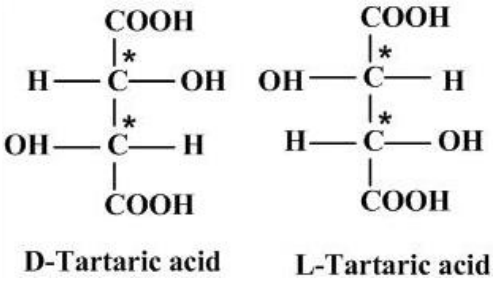
(b) D-Mannose ($C_6H_{12}O_6$) Sigma Aldrich (CAS 3458-28-4),

L-Mannose ($C_6H_{12}O_6$) Sigma Aldrich (CAS 10030-80-5)



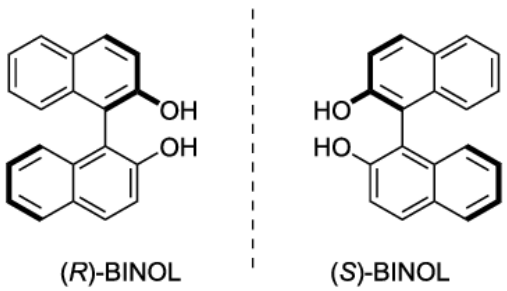
(c) D-Tartaric acid ($C_4H_6O_6$) Sigma Aldrich (CAS 147-71-7),

L-Tartaric acid ($C_4H_6O_6$) Sigma-Aldrich (CAS 87-69-4).



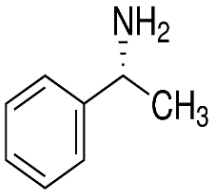
(d) (R)-(+)-1,1′-Bi-2-naphthol (R BINOL) ($C_{20}H_{14}O_2$) (Synthesized in lab)

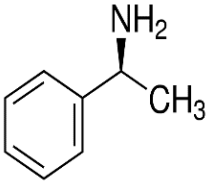
(S)-(-)-1,1'-Bi-2-naphthol (S BINOL) ($C_{20}H_{14}O_2$) (Synthesized in lab)



(e) (R)-(+)- Alpha methyl benzyl amine $C_6H_5CH(CH_{3)}NH_2$ Sigma Aldrich (CAS 3886-69-9),

(S)-(-)- Alpha methyl benzyl amine $C_6H_5CH(CH_3)NH_2$ Sigma Aldrich (CAS 2627-86-3)

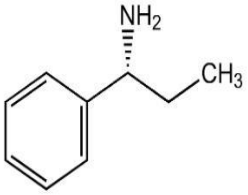


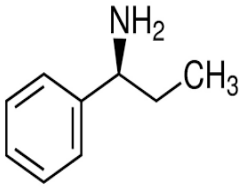


(R)-(+)- Alpha methyl benzyl amine (S)-(-)-Alpha methyl benzyl amine

(f) (R)-(+)-Alpha ethyl benzyl amine $C_6H_5CH(C_2H_5)NH_2$ Fluka (CAS 3082-64-2)

(S)-(-)-Alpha ethyl benzyl amine $C_6H_5CH(C_2H_5)NH_2$ Fluka (CAS 3789-59-1)





(R)-(+)-Alpha ethyl benzyl amine (S))-(-)-Alpha ethyl benzyl amine

We collected data based on the number of chiral centers and the type of chirality present in the molecule. Where both enantiomers of glucose (D/L),mannose (D/L), and tartaric acid (D/L) are molecules with multiple chiral centers, (R/S)-alpha methyl benzyl amine and (R/S)-alpha-ethyl benzyl amine are single chiral center molecules and BINOL (R/S) is an axial chiral molecule. Solvents (conductivity water and methanol) were used to prepare samples for study. List of samples and sample concentration prepared to perform experiment is listed in Table 4.1.

Table 4.1: List of samples studied and sample concentration

Sample	Sample concentration prepared
Glucose	**10mg** (sample) **+.1ml** (conductivity water)
Mannose	**10mg** (sample) **+.1ml** (conductivity water)
Tartaric acid	**8mg** (sample)**+.1ml** (conductivity water)
BINOL	**5mg** (sample) **+.2m**l (methanol)
Alpha methyl benzyl amine	**7µl** (sample) + **.1ml** (methanol)
Alpha ethyl benzyl amine	**7µl** (sample) + **.1ml** (methanol)

4.2.2 Interference Rings Setup as an Analytical Tool

The chapter presents the novel method where Newton's Rings setup is modified to distinguish enantiomers. Modifications made to the optics is to generate linearly polarized, right and left-handed circularly polarized light. In this novel technique, Interference rings formed in the setup is used as an analytical tool to observe optical handedness of chiral materials. Data is analysed by comparing the refractive index data of chiral enantiomers with the kind of chirality present in the molecule. For better results, the molar concentration of both enantiomers was kept constant, and a 40 µl sample was filled into the sample cavity. Schematic arrangement of Newton's Rings setup is shown in Figure 4.2.

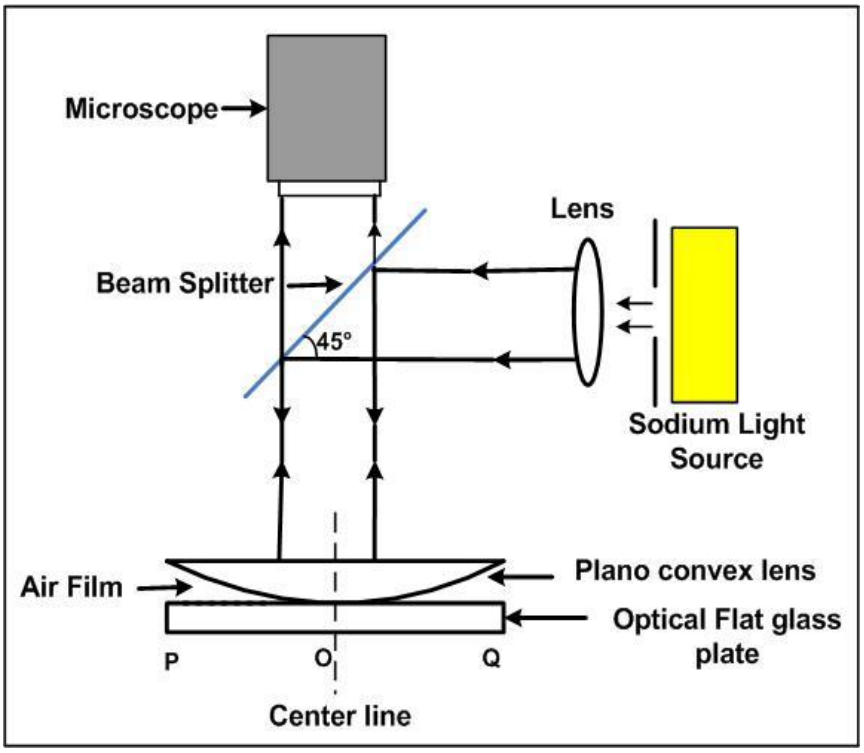


Figure 4.2: Schematic arrangement of Newton's Rings Setup.

Newton's Rings are concentric alternate dark and bright circular rings formed due to destructive and constructive interference. Both monochromatic and polychromatic light sources can form interference Rings.

In our present work, an extended monochromatic sodium light source (5893 Å) is used to perform experiments. Light falls on the beam splitter inclined at 45˚ to the horizontal. After reflection from the beam splitter light falls normally on the thin film that is formed between the plano-convex lens (of large radius of curvature) and a plain glass plate, where the convex surface of the plano-convex lens is in contact with a plain glass plate.

A wedge-shaped air film of variable thickness is formed between a plano-convex lens and a plain glass plate. The incident ray is partly reflected from the upper surface of the film and the remaining part of the ray is transmitted through the film, and is reflected from the lower surface of the thin air film. Circular interference rings are observed due to the division of amplitude of waves. Multiple times reflection and refraction take place in wedge-shaped air film. Rays reflected from the upper and lower surfaces of the thin film interfere and a circular interference pattern is observed. Interference patterns will be constructive (bright rings) or destructive (dark rings), entirely dependent on the path difference between the interfering rays.

Plano-convex lens of dimensions (radius = 2.08 cm, thickness at center = 3.53 mm and Radius of curvature = 128.7 cm) is placed on plane glass plate (radius = 2.08 cm and thickness = 3.8 mm). At the point of contact, the thickness of the air film is zero, and as the radius increases, the thickness of the film increases. A thin wedge-shaped air film of variable thickness is formed between plano-convex lens and plain glass plate. Alternate bright and dark Newton interference rings formed with a monochromatic sodium light source is shown in Figure 4.3.

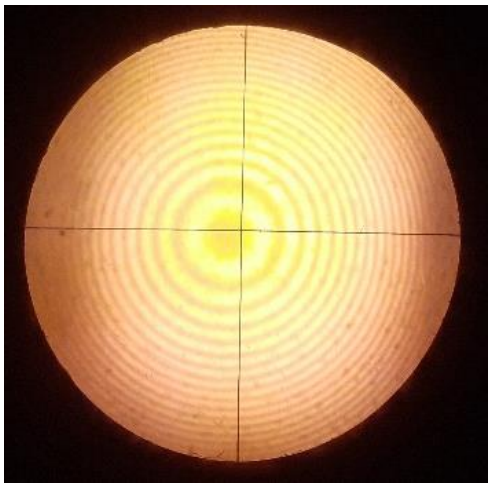


Figure 4.3: Newton Rings formed with monochromatic sodium light source.

4.2.3 Experimental Techniques

To observe the optical handedness of chiral samples interference rings were observed first with air film and then with a sample film. The same molar concentration of both enantiomers was prepared, and 40 µl of both enantiomers were filled in the wedge shaped sample cavity at a time. Ring diameters of the alternate dark rings were measured with the help of horizontal Vernier scale and cross wires provided on the instrument , ranging from the 4^{th} to the 20^{th} dark ring. Readings were taken manually with proper care. Then the square of diameters of dark rings (D^2) was plotted against the ring order, first with air film and then with chiral film (one enantiomer). Significant slope values were calculated for both enantiomers. By dividing the slope value for air by the slope value for the sample, the refractive index of the sample (optically active chiral sample) is calculated with Eq. 6.

$$\mu = \frac{D^2_{m+q(air)} - D^2_{m(air)}}{D^2_{m+q(liq)} - D^2_{m(liq)}} \qquad (6)$$

μ is the refractive index of the enantiomer filled in the sample cavity, D_m is the diameter or m^{th} ring, and D_{m+q} is the diameter or $m+q^{th}$ ring. The experiment was performed in two parts: In the first part of the experiment: linearly polarized light was used to observe difference in optical handedness, while in the second part of the experiment, LCP and RCP light is used to observe the difference.

4.2.3.1 Changes Made in Our Experimental Setup:

Part 1: In first part of the experiment, a linear polarizer is kept just in front of the extended sodium light source and linearly polarized light is produced which is allowed to fall on the sample cavity, as shown in Figure 4.4. Readings were recorded with light polarized linearly at different angles varying with 30° intervals for both enantiomers by measuring the diameters of alternate dark interference rings. At different polarizing angles refractive index values for both enantiomers were measured. (Ghalsasi et al., 2022)

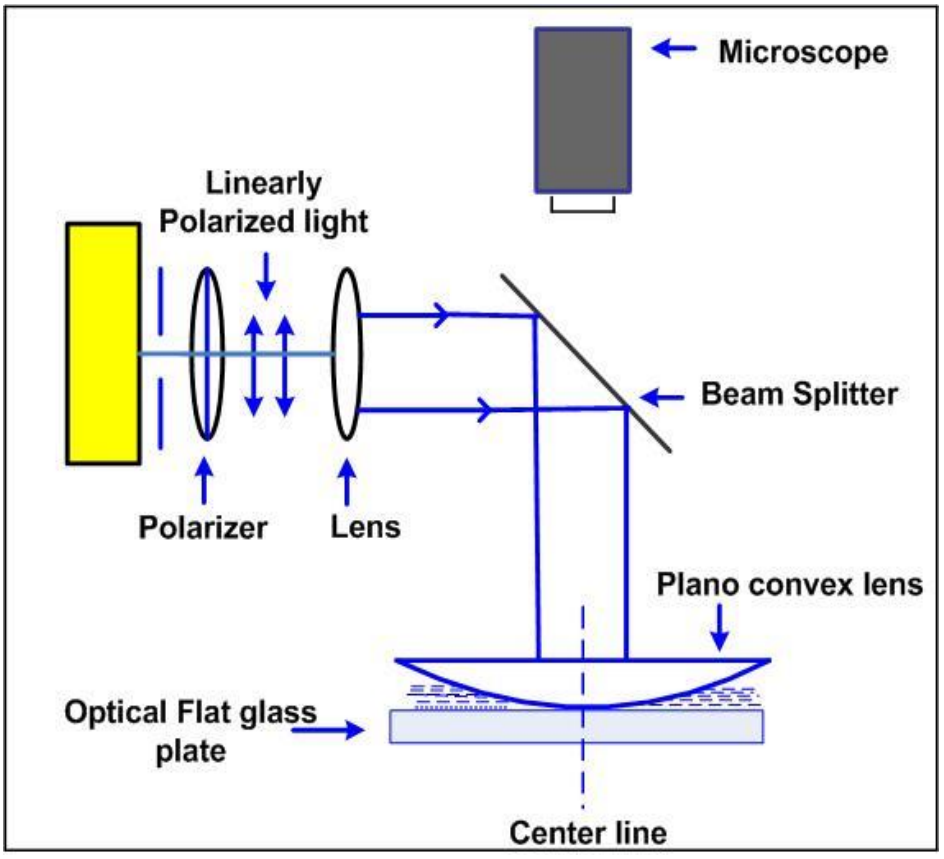


Figure 4.4: Modified Newton's Ring Setup, polarized light falls on the cavity chamber.

Part 2: In the second part of the experiment the circularly polarized light is generated by using a linear polarizer and a quarter wave plate. To generate RCP and LCP light, the fast axis of a quarter wave plate (multiple order quarter wave plate-5893 Å Holmarc) is oriented at +45° (-45°) with respect to the transmission axis of the polarizer. The circularly polarized light thus generated falls on the beam splitter and it reflects light on the sample as shown in Figure 4.5. (Ghalsasi et al., 2022)

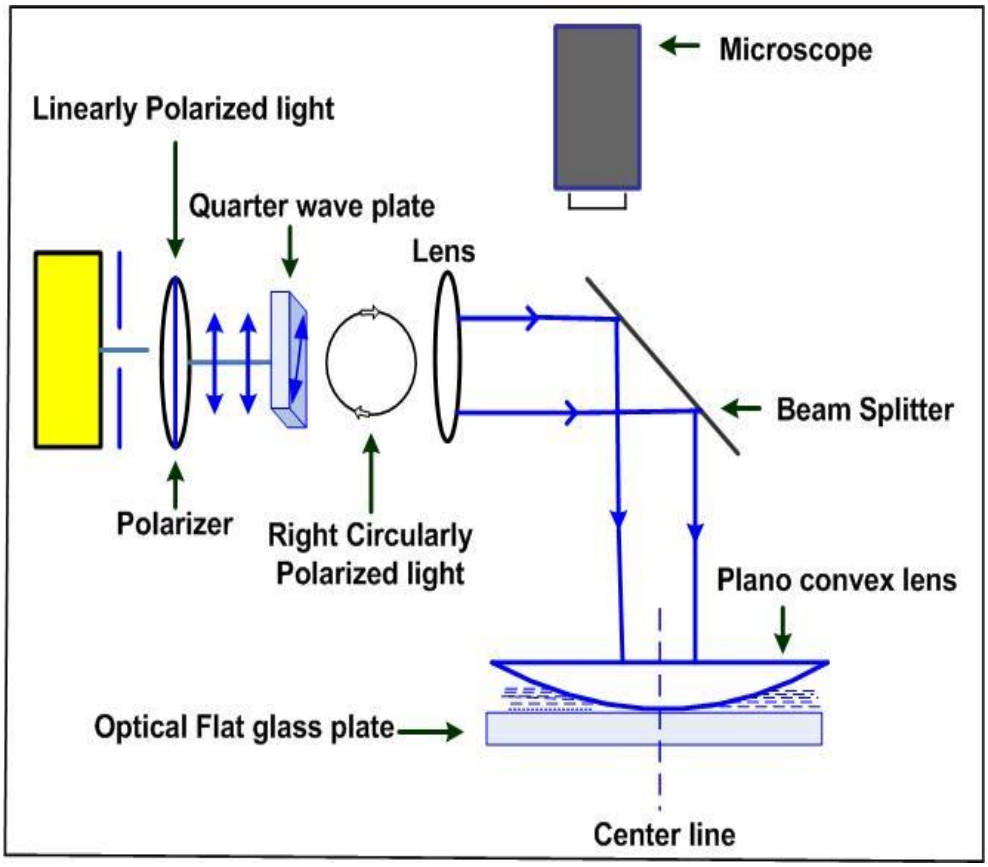


Figure 4.5: Schematic of modified Newton's rings setup. Circularly polarized light is generated by placing quarter wave plate in the path.

4.3 Results and Discussions

4.3.1 Part 1: Optically Active Molecules under Linearly Polarized Light

In the first part of the experiment, both enantiomers of chiral samples were studied under linearly polarized light and the difference in transmitted light intensity was monitored. The highest sample concentration was prepared for each enantiomer and it was ensured that interference rings should be clearly visible (while collecting data). When the linearly polarized light transmits through the enantiomer solutions of equal concentration, each enantiomer was

found to have different refractive index. Thus the refractive index data was analyzed and correlated to the optical handedness of the enantiomers.

The refractive index of the sample indirectly gives details of the amount of light absorbed by each enantiomer. Our results indicate that refractive index was found to be higher for (L) Glucose, (L) Mannose, (S) BINOL, and (L) Tartaric acid and their R.I values were 0.02 more compared to their opposite enantiomers (D) Glucose, (D) Mannose, (R) BINOL, and (D) Tartaric acid. On the other hand, (R) Alpha methyl benzyl amine and (R) Alpha ethylbenzyl amine were found to have nearly .03 more refractive index than (S) Alpha methyl benzyl amine and (S) Alpha ethyl benzyl amine. Despite the changes in the angle of linear polarization, only one enantiomer had a higher refractive index than the other. Differences in refractive index (R.I.) values of both enantiomers can be observed in Figure 4.6. It was observed that the levorotatory chiral samples that have more than one chiral center or those possess axial chirality, show a higher refractive index compared to the dextrorotatory samples, while the R enantiomers that possess only one chiral center, show higher refractive index than S enantiomers. In our investigation, a 40 µl (small quantity) sample can reveal a difference in refractive index values whereas commercially available refractometers cannot distinguish enantiomers on the basis of refractive indices.

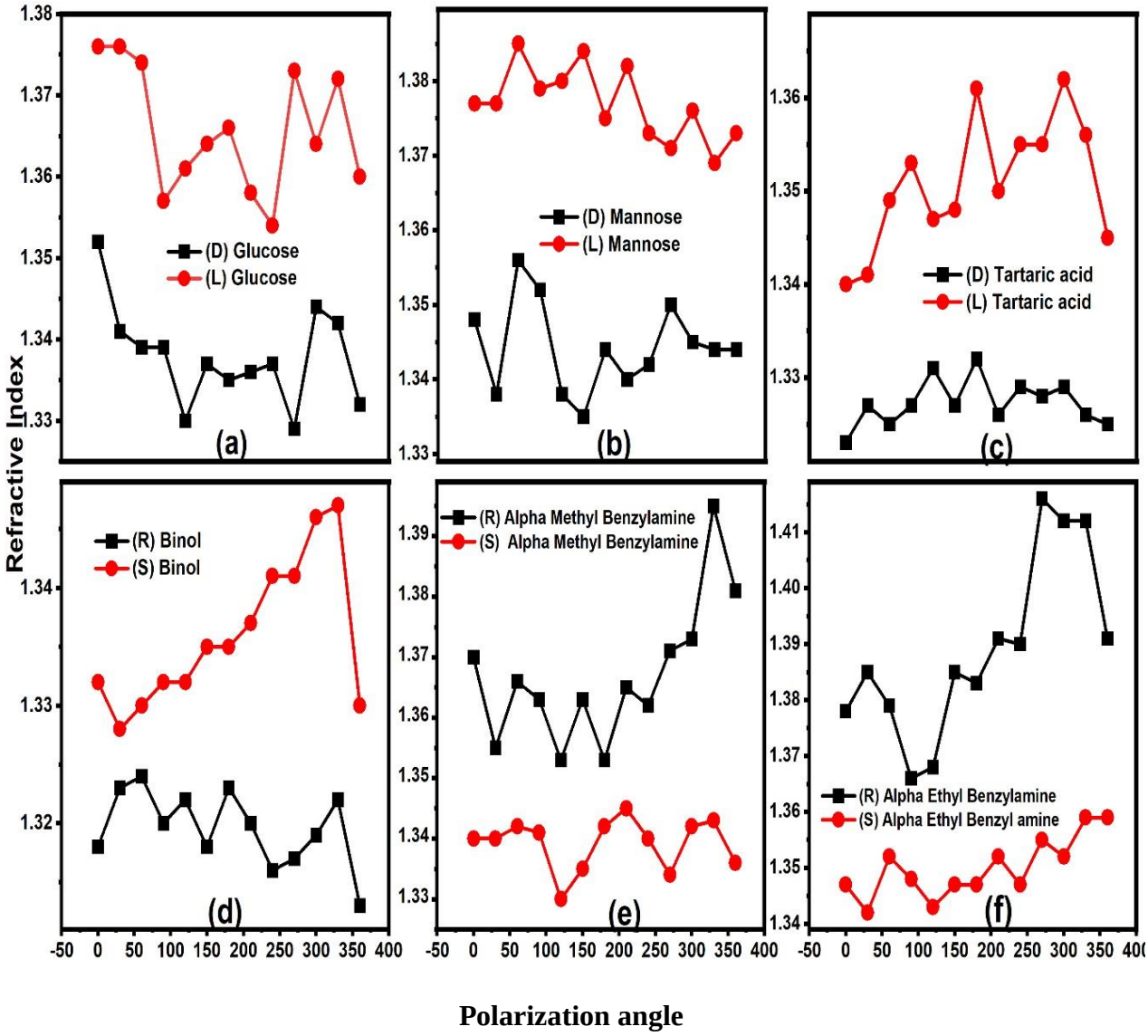


Figure 4.6 Plot corresponds to Refractive index of both enantiomers of Glucose, Mannose, Tartaric acid, BINOL, Alpha methyl benzyl amine and Alpha ethyl benzyl amine with respect to different polarizing angles in the interval of 30°.

4.3.2 Part 2: Optically Active Molecules under Circularly Polarized Light

In the second part of the experiment, both enantiomers of chiral samples were studied under both handed circularly polarized light, and the difference in refractive indices was compared. Both enantiomers show different refractive indices when right and left circularly polarized light transmits through them.

To check the effect of circularly polarized light, the second part of the experiment is analyzed, in two parts, Parts 2a and 2b. In Part 2a, the refractive indices of both enantiomers are

compared with respect to one type of circularly polarized light, while in Part 2b, the refractive index of a particular sample is compared with both types of circularly polarized light.

The calculated refractive index values indicate that various samples interact with left and right handed circularly polarized light in different proportions. μ_{RCP} is the refractive index of the sample when RCP is incident on the sample and μ_{LCP} denotes the refractive index of a sample when illuminated with LCP.

Part 2a: Comparison of the Refractive Indices of Both Enantiomers with One Type of Circularly Polarized Light:

Refractive indices of enantiomers were compared by observing one handed circularly polarized light. Results show only one of the enantiomers shows higher refractive index when circularly polarized light (either LCP or RCP) falls on both enantiomers. Refractive index Comparative study chart for both enantiomers with one type of circularly polarized light is shown in Table 4.2.

Table 4.2: Refractive index comparison study for both samples with the particular CP light.

Sample filled in cavity	Type of circular polarized light	Comparison of the Refractive Indices of Both Enantiomers with One Type of Circularly Polarized Light
Glucose	**RCP**	$(\mu_D)_{RCP} < (\mu_L)_{RCP}$ **1.346 < 1.348**
	LCP	$(\mu_D)_{LCP} < (\mu_L)_{LCP}$ **1.340 < 1.351**
Mannose	**RCP**	$(\mu_D)_{RCP} < (\mu_L)_{RCP}$ **1.339 < 1.341**
	LCP	$(\mu_D)_{LCP} < (\mu_L)_{LCP}$ **1.335 < 1.343**
Tartaric acid	**RCP**	$(\mu_D)_{RCP} < (\mu_L)_{RCP}$ **1.335 < 1.340**

	LCP	**$(\mu_D)_{LCP} < (\mu_L)_{LCP}$** **1.331 < 1.345**
BINOL	**RCP**	**$(\mu_R)_{RCP} < (\mu_S)_{RCP}$** **1.324 < 1.356**
	LCP	**$(\mu_R)_{LCP} < (\mu_S)_{LCP}$** **1.318 < 1.352**
Alpha methyl benzyl amine	**RCP**	**$(\mu_R)_{RCP} > (\mu_S)_{RCP}$** **1.367 > 1.337**
	LCP	**$(\mu_R)_{LCP} > (\mu_S)_{LCP}$** **1.357 > 1.320**
Alpha ethyl benzyl amine	**RCP**	**$(\mu_R)_{RCP} > (\mu_S)_{RCP}$** **1.365 > 1.355**
	LCP	**$(\mu_R)_{LCP} > (\mu_S)_{LCP}$** **1.354 > 1.352**

Comparative refractive index analysis of chiral samples under circularly polarized light indicates enantiomers showing different refractive indices. Experimental results indicate chiral molecules that have more than one chiral center, or if it is an axially chiral molecule, then their levorotatory samples show higher refractive index. While samples that have only one chiral center as Alpha methyl benzyl amine and Alpha ethyl benzyl amine, their R handed samples show higher refractive index. The experiments performed with linearly polarized light in Part 1 are consistent with the results of Part 2a, where circularly polarized is used. (Ghalsasi et al., 2022)

Part 2b: Comparison of the Refractive Index of a Particular Sample with Both Types of Circularly Polarized Light:

In this part of the experiment, one particular enantiomer's refractive index values were analysed with both types of circularly polarized light. μ_{RCP} and μ_{LCP} are the R.I values when RCP and LCP fall on the sample. Experimental results indicate dextrorotatory samples for glucose, mannose, and tartaric acid show higher refractive index when RCP is incident on them, while levorotatory samples show higher refractive index when LCP is incident on them. BINOL is an axial chiral molecule, results indicate that both enantiomers show higher refractive index when RCP is incident on them.

Alpha methyl benzyl amine and Alpha ethyl benzyl amine are chiral molecules with one chiral center present in them. The similarity was found in their results. The refractive index for both of these enantiomers was found to be higher when RCP was used as compared to LCP. Refractive index comparison for particular sample with both CP lights is shown in Table 4.3.

Table 4.3: Refractive index comparison for particular sample with both CP lights.

Samples filled in cavity	Enantiomers	Comparison of the Refractive Index of a Particular Sample with Both Types of Circularly Polarized Light
Glucose	**D**	$\mu_{RCP} > \mu_{LCP}$ **1.346 > 1.340**
	L	$\mu_{RCP} < \mu_{LCP}$ **1.348 < 1.351**
Mannose	**D**	$\mu_{RCP} > \mu_{LCP}$ **1.339 > 1.335**
	L	$\mu_{RCP} < \mu_{LCP}$ **1.341 < 1.343**
Tartaric acid	**D**	$\mu_{RCP} > \mu_{LCP}$ **1.335 > 1.331**
	L	$\mu_{RCP} < \mu_{LCP}$ **1.340 < 1.345**
BINOL	**R**	$\mu_{RCP} > \mu_{LCP}$ **1.324 > 1.318**
	S	$\mu_{RCP} > \mu_{LCP}$ **1.356 > 1.352**

Alpha methyl benzyl amine	**R**	**$\mu_{RCP} > \mu_{LCP}$** **1.367 > 1.357**
	S	**$\mu_{RCP} > \mu_{LCP}$** **1.337 > 1.320**
Alpha ethyl benzyl amine	**R**	**$\mu_{RCP} > \mu_{LCP}$** **1.365 > 1.354**
	S	**$\mu_{RCP} > \mu_{LCP}$** **1.355 > 1.352**

To get better results it is essential to take good concentration of the sample in the cavity. Refractive index values are measured for different polarizing angles and with different handed circularly polarized light. From Table 4.2 and Table 4.3 it is evident that the resolution of this technique depends upon the incident angle of polarization and handedness of circularly polarized light. Since the same molar concentration of 40 µl of both enantiomers was filled in the cavity, the differences in the refractive indices are not concentration dependent.

In summary, refractive index data for both enantiomers was collected with plane polarized and circularly polarized light (both handed). The first part of the experiment, which only allows plane polarized light to fall on enantiomers, The results indicate that one enantiomer shows higher refractive index than the other enantiomer. Levorotatory samples of Glucose, Mannose, Tartaric acid, and BINOL show higher refractive index, but dextrorotatory Alpha methyl benzyl amine and Alpha ethyl benzyl amine show higher refractive index at different polarizing angles than the levorotatory enantiomer.

When chiral samples interact with only circularly polarized, light either RCP or LCP light shows a high refractive index value. RCP and LCP are chiral, and refractive index values for them differ as they travel at different velocities within the sample due to the difference in absorption. In Part 2a, refractive indices of both enantiomers is compared and one type of circularly polarized light. Part 2a, findings indicate only one enantiomer of a chiral molecule

shows higher refractive index and these results exactly match the first part of the experiment where only plane polarized light is utilized to differentiate enantiomers. Results clearly indicate plane polarized data of first part (Part 1) agrees with (Part 2a)

While in the Part 2b of the experiment, refractive index comparison of the particular sample is done with right (RCP) and left circularly polarized (LCP) light. It is observed for Glucose, Mannose, and Tartaric acid, dextrorotatory enantiomers show higher refractive index when RCP is used , while levorotatory enantiomers show higher refractive index when LCP is used.

Again difference in refractive index was observed as per difference in chiral centers and type of chirality present in the molecule. The chiral dextrorotatory enantiomers having more than one chiral center showed higher refractive index for RCP and levorotatory enantiomers showed more refractive index for LCP. Molecules with one chiral center and axial chiral molecule results indicate both enantiomers show higher refractive index for RCP. Based on this phenomenon, it can be anticipated that chiral samples with only one chiral center, such as alpha methyl benzyl amine, or samples with axial chirality, such as BINOL, both enantiomers show higher refractive index for RCP. Our modified Newton's rings apparatus is an inexpensive technique, requires very less amount of sample (40 µl) and is able to differentiate number of enantiomers based on their refractive indices.

4.4 Error analysis

Random error in a measurement = $\frac{L.C}{2}$

Diameter of ring (D) = D_{right} -D_{left}

Hence measured values with uncertainties are

Left reading of the ring = $\pm \frac{L.C}{2}$, Right reading of the ring= $\pm \frac{L.C}{2}$

Then the uncertainty ΔD is $\Delta D = \sqrt{\frac{L.C^2}{4} + \frac{L.C^2}{4}}$

L.C of the instrument = .01mm=.001cm

Hence uncertainty ΔD = $\frac{.01}{\sqrt{2}} = .007mm$

Refractive index of sample $\mu = \frac{D^2_{m+q(air)} - D^2_{m(air)}}{D^2_{m+q(liq)} - D^2_{m(liq)}}$

$$\frac{\Delta\mu}{\mu} = (2\frac{\Delta Dm + q}{Dm + q} + 2\frac{\Delta Dm}{Dm})air + (2\frac{\Delta Dm + q}{Dm + q} + 2\frac{\Delta Dm}{Dm})sample$$

$$= (\frac{2*.007}{4.02} + \frac{2*.007}{3.27})_{air} + \frac{2*.007}{3.72} + \frac{2*.007}{2.8})_{sample}$$

$$\frac{\Delta\mu}{\mu} = .011$$

4.5 Conclusion

In summary, we have presented a novel, inexpensive, and innovative method to observe the optical handedness of chiral materials. We modified the Newton's rings setup available in undergraduate labs to differentiate enantiomers of chiral molecules. We utilized the interference technique and circular birefringence of chiral molecules to distinguish and observe the optical handedness of chiral molecules. The focus of the study is to use interference rings as an analytical tool to distinguish the optical handedness of chiral enantiomers by observing differences in refractive indices. Results indicate the number of chiral centers present in the chiral molecule, and the type of chirality present in the molecule affects the refractive index value (indirectly absorption of light).