

# Optical Characterization of Sucrose (C<sub>12</sub>H<sub>21</sub>O<sub>11</sub>) at Different Temperatures

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**ABSTRACT:** An innovative, simple and economic technique was used to determine the optical property, refractive index of the known concentration of transparent sucrose solution. An equilateral hollow glass prism, an optical spectrometer and a monochromatic light source (Na lamp) were employed in the present work. The angles of minimum deviation for different sucrose samples were determined and the values were used to compute the refractive indices of these samples. The relationship between the refractive indices and the sucrose concentrations of the samples were found to be linear. The effect of temperature on the minimum deviation angle of the sucrose samples was also recorded and it was found that the relationship is linear. The temperature variations with the refractive index was determined and was found to be in agreement with the expected result and with results computed by other methods. The results were compared with those obtained from commercial refractometers and it was found that this technique is quite reliable and can be safely used in the study of the optical properties of many other transparent liquids.

**KEYWORDS:** Sucrose, Refractive index, Spectrometer, Refractometer, Temperature.

## I. INTRODUCTION

In optics refractive index is one of the most important properties of any medium under investigation. The study of this optical property is extensively used in many scientific fields of research like communication systems, fiber optics, thick and thin films, advanced functional materials and conducting polymers. Thermal expansion coefficients for liquids can be calculated using temperature coefficient of refractive index [1]. Several techniques are reported in literature for the measurement of concentration and temperature dependence of refractive index of liquids [2-7]. Near IR and laser studies of refractive indices have been studied [8,9]. Refractive index of the universal solvent, water has been studied by many researchers [10-14]. Recently holographic measurements on transparent liquids were also studied [15-18]. Many researchers have revealed the optical properties of liquids using surface Plasmon resonance techniques [19-21]. In the present study we report a relatively simple and reliable technique, which can be helpful to measure the optical property, refractive index of the sucrose (C<sub>12</sub>H<sub>21</sub>O<sub>11</sub>) at different temperatures.

## II. RELATED WORK

According to electromagnetic theory light changes speed as it advances from one medium to another (for example, from air into the sucrose prism). This speed change causes the light to be refracted and to enter the new medium at a different angle (Huygens principle). The degree of bending of the light's path depends on the angle that the incident beam of light makes with the surface, and on the ratio between the refractive indices of the two media (Snell's law).

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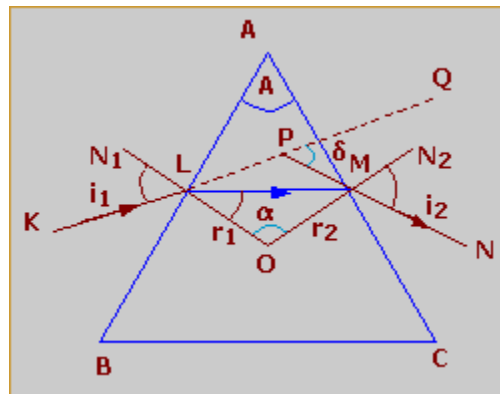


Fig.1 : Refraction through a prism and angle of minimum deviation  $\delta_M$

As a ray of light enters the transparent medium, the ray's direction is deflected, based on both the entrance angle and the material's refractive index. A beam passing through a sucrose prism is deflected twice: once entering, and again when exiting. The sum of these two deflections is called the deviation angle  $\delta$ . The deviation angle in a prism depends upon: Refractive index of the prism: The refractive index depends on the material and the wavelength of the light. The larger the refractive index, the larger the deviation angle  $\delta$ . Angle of the prism: The larger the prism angle, the larger the deviation angle. Angle of incidence: The deviation angle depends on the angle that the beam enters the object, called angle of incidence. The deviation angle first decreases with increasing incidence angle, and then it increases. There is an angle of incidence at which the sum of the two deflections is a minimum. The deviation angle at this point is called the "angle of minimum deviation  $\delta_M$ " (Fig.1). At the minimum deviation angle  $\delta_M$ , the incidence and exit angles of the ray are identical. The refractive index ( $\mu$ ) of a prism is measured by Snell's formula given as

$$\mu = \frac{\sin\left(\frac{A + \delta_M}{2}\right)}{\sin\left(\frac{A}{2}\right)}$$

Previously the work has been reported on transparent solutions like water, steam, seawater and some salt solutions. Based on the above theory we report the calculation of refractive index of sucrose solution of different concentration and at different temperatures.

### III. MATERIALS AND METHOD

Sucrose solution of different concentrations (5%, 7.5%, 10%, 15% and so on upto 85%) were prepared at room temperature by dissolving known weight of sugar in fixed volume of distilled water. Utmost care was taken to keep the samples pure. A clean and dry hollow glass prism was filled with the prepared sucrose solution and for every sample angle of minimum deviation  $\delta_M$  was measured using optical spectrometer adjusted by Schuster's method (Fig. 2). For the measured values of  $\delta_M$  and angle of prism  $A = 60^\circ$ , the refractive index ( $\mu$ ) of sample was computed using the Snell's formula stated earlier.

The Refractive index ( $\mu$ ) of the prepared sucrose solution of different concentrations was also measured by the commercial Digital (Palm Brix) Refractometer by placing the sample on the sensor platform of the meter and recording directly the display readouts. The values were recorded separately (table 1). To study the variation of refractive index ( $\mu$ ) with temperature the solution of different concentrations were heated up to  $80^\circ\text{C}$  and the observations were recorded during the gradual cooling of solution through  $65^\circ\text{C}$  to  $30^\circ\text{C}$ .

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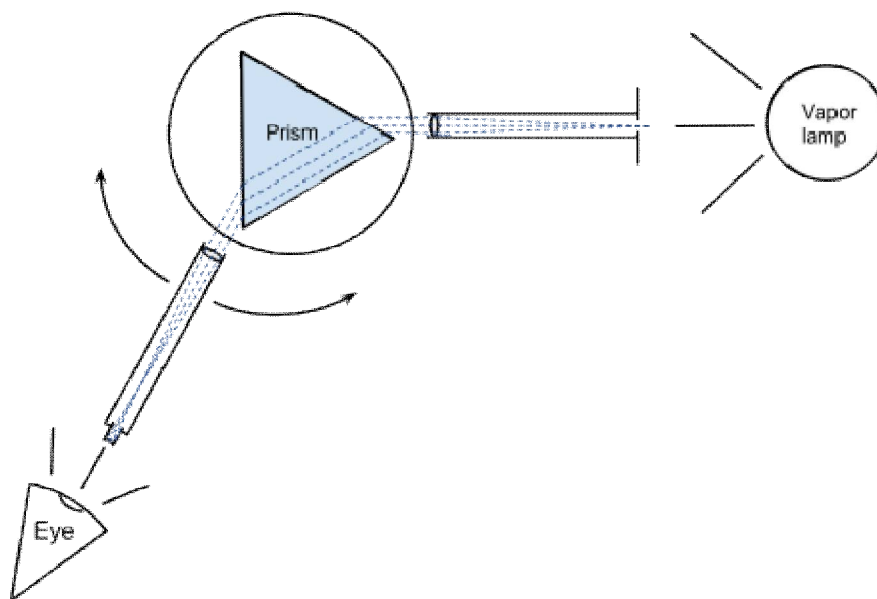


Fig.2 : Angle of minimum deviation  $\delta_M$

The observations for the angle of minimum deviation were recorded using the spectrometer, glass prism containing sucrose and the sodium lamp (used as the monochromatic source of light). The angle of minimum deviation and refractive index were recorded using both the sucrose prism and commercial digital refractometer as shown in the following table.

**Table 1:** Variation of minimum deviation angle  $\delta_M$  and refractive index ( $\mu$ ) with concentration for sucrose solution.

Concentration (%) of sucrose in prism.	minimum deviation angle $\delta_M$ (°)	Refractive index ( $\mu$ )	minimum deviation angle $\delta_M$ (°)	Refractive index ( $\mu$ )	Avg. $\delta_M$ (°)	Avg. Refractive index ( $\mu$ )	Commercial Refractometer value ( $\mu$ )
5 %	23 <sup>0</sup> 54'	1.33696	24 <sup>0</sup> 36'	1.34603	24 <sup>0</sup> 15'	1.34150	1.34787
7.5 %	24 <sup>0</sup> 15'	1.34439	24 <sup>0</sup> 48'	1.34860	25 <sup>0</sup> 1'	1.34639	1.34921
10 %	24 <sup>0</sup>	1.33826	23 <sup>0</sup> 52'	1.33653	23 <sup>0</sup> 56'	1.34853	1.35124
15 %	24 <sup>0</sup> 21'	1.33869	24 <sup>0</sup>	1.33826	24 <sup>0</sup> 1'	1.35147	1.35745
20 %	24 <sup>0</sup> 37'	1.34624	25 <sup>0</sup> 38'	1.35931	25 <sup>0</sup> 7'	1.35368	1.35963
25 %	25 <sup>0</sup> 20'	1.35463	25 <sup>0</sup> 25'	1.35653	25 <sup>0</sup> 22'	1.35589	1.36421
30 %	24 <sup>0</sup> 33'	1.34537	25 <sup>0</sup> 37'	1.35824	25 <sup>0</sup> 5'	1.35725	1.36756
35 %	27 <sup>0</sup> 10'	1.37881	26 <sup>0</sup> 2'	1.36442	26 <sup>0</sup> 36'	1.36163	1.36925
40 %	26 <sup>0</sup>	1.36399	27 <sup>0</sup> 30'	1.38302	26 <sup>0</sup> 45'	1.36754	1.37357
45 %	26 <sup>0</sup> 35'	1.37142	26 <sup>0</sup> 40'	1.37248	26 <sup>0</sup> 37'	1.37184	1.37752
50 %	26 <sup>0</sup> 55'	1.37565	27 <sup>0</sup> 10'	1.37881	27 <sup>0</sup> 2'	1.37713	1.37963

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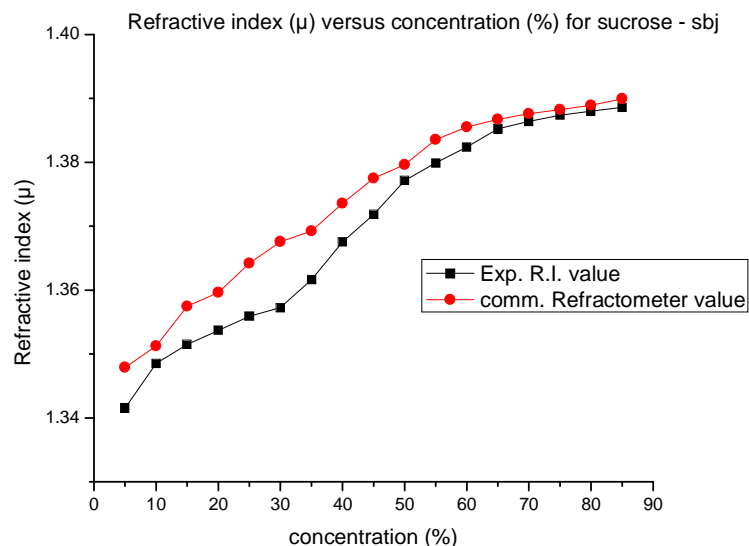
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55 %	27 <sup>0</sup>	1.37670	27 <sup>0</sup> 2'	1.37713	27 <sup>0</sup> 1'	1.37992	1.38358
60 %	27 <sup>0</sup> 46'	1.38638	27 <sup>0</sup> 8''	1.37839	27 <sup>0</sup> 27'	1.38239	1.38554
65 %	27 <sup>0</sup> 18'	1.38050	26 <sup>0</sup> 28'	1.36994	26 <sup>0</sup> 53'	1.38523	1.38671
70 %	27 <sup>0</sup> 35'	1.38407	27 <sup>0</sup> 20'	1.38092	27 <sup>0</sup> 27'	1.38639	1.38763
75 %	27 <sup>0</sup> 52'	1.38764	27 <sup>0</sup> 40'	1.38512	27 <sup>0</sup> 46'	1.38738	1.38826
80 %	28 <sup>0</sup> 2'	1.38973	28 <sup>0</sup>	1.38931	28 <sup>0</sup> 1'	1.38802	1.38894
85 %	28 <sup>0</sup>	1.38931	28 <sup>0</sup>	1.38931	28 <sup>0</sup>	1.38861	1.38992

## IV. RESULTS AND DISCUSSIONS

From experimental data the variation of refractive index ( $\mu$ ) with concentration (%) of sucrose and temperature ( $^{\circ}\text{C}$ ) was studied by plotting the corresponding graphs as shown below. From the graph1 the linear dependence of Refractive index ( $\mu$ ) with concentration (%) is evident. Commercial digital refractometer (Brix) showed little higher values of R.I. for lower concentrations (< 40 %) than those recorded with sucrose prism. But for higher concentrations (> 65 %) of sucrose the values obtained from both the procedures were in agreement.



**Graph 1 :** Refractive index ( $\mu$ ) versus concentration (%) for sucrose solution.

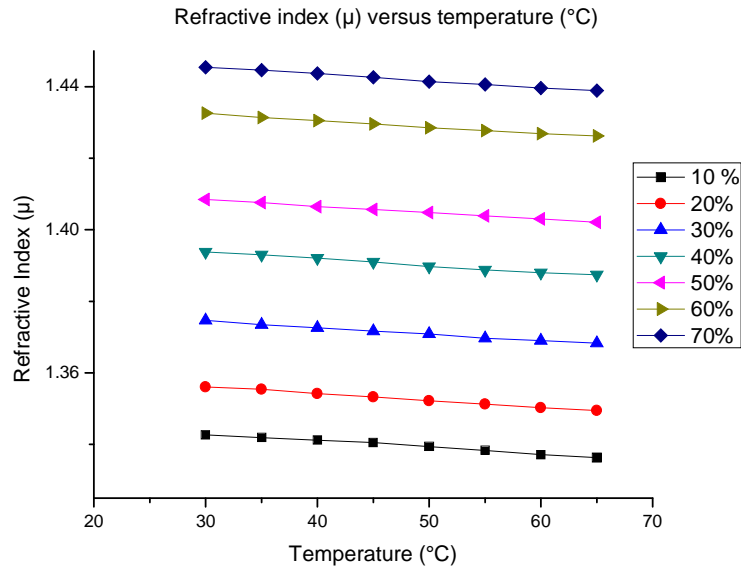
According to the graph 2, as shown below, the values of refractive indices decrease with increasing temperature.

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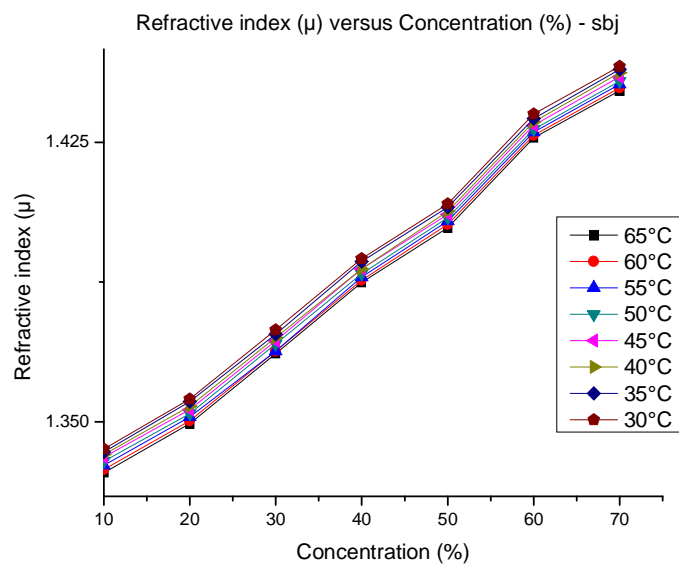
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**Graph 2 :** Refractive index ( $\mu$ ) versus temperature ( $^{\circ}\text{C}$ ) for different concentration (%) of sucrose solution.

The interpretations of graph 3 were quite clear showing the gradual rise in R.I. values with the concentrations with higher temperatures having low R.I. values in agreement with graph 2 values..



**Graph 3 :** Refractive index ( $\mu$ ) versus Concentration (%) at different temperatures.

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## V. CONCLUSIONS

An innovative, simple and economic technique was used to determine the optical property, refractive index of the known concentration of transparent sucrose solution. Experimental and commercial digital refractometer (Brix) results showed that this method could be safely employed to study the dependence of refractive index of solutions on their concentration as well as on the temperature. Linear dependence of refractive index of sucrose ( $C_{12}H_{21}O_{11}$ ) at different temperatures with their concentration was observed and the values and trend were in agreement with the literature.

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