Refractive index of solutions at high concentrations

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The refractive index of liquid solutions at the He–Ne laser wavelength, 0.6328 μm, is presented. The measurements were carried out using the conventional minimum deviation method of an equilateral hollow glass prism. The refractive indices of sucrose, sodium chloride, glucose, and caster sugar solutions for a range of density varying from distilled water to a saturated condition were measured. The result shows that at higher concentrations a slight curvature can be seen from the plot of refractive index vs concentration of solution. However, the refractive index of sucrose shows a linear relationship with concentration. The accuracy of the measurements is estimated to be better than 0.3%.

The refractive index n is a basic optical property of materials and its accurate value is often needed in many branches of physics and chemistry. Although numerous methods for measuring the refractive index of a liquid solution are available from textbooks,[1] the most suitable and easiest method was reported earlier.[2,3] The authors have reported that the use of an equilateral hollow prism would allow measurement of the refractive index of most ordinary liquids, thus opening up the possibility of studying small variations in the refractive index of a solution with concentration.

The aim of this short paper is to report the variations of refractive index which occur when the concentration of a solution is altered from distilled water to a saturated condition. The theory and method have been discussed elsewhere.[2–5] Regarding Fig. 1, a collimated light beam is incident at an angle α on one face of the prism including angle A. The angle of deviation D is found to be a minimum if α and β are equal. The refractive index of the prism can be determined by using Snell's law:

$$n = \frac{\sin[(A + D)/2]}{\sin(A/2)} \,. \tag{1}$$

To perform the experiment, an equilateral hollow prism is fixed on a spectrometer table. A 5-mW He–Ne laser at 0.6328-μm wavelength was used as the light source. A schematic representation of the apparatus setup is shown in Fig. 2. Initially, with no liquid in the prism the collimated laser beam passes through the prism and the position T_1 of the telescope is recorded. Once the prism is filled with liquid, one surface of the prism is irradiated with a collimated laser beam. The prism is then rotated, and the point at which the refracted beam changes direction indentifies the minimum angle of deviation and can be measured by moving the telescope to position T_2 (see Fig. 2).

Our measurements were carried out with four liquid solutions, that is, sucrose, sodium chloride, glucose, and caster sugar, and the results obtained are presented in Figs. 3–6. All the data points on the graphs represent three independent measurements carried out at a particular concentration of solution. However, the data points presented did not account for the error in measurement of concentration, which is estimated at <2%. The dashed lines in Figs. 3 and 4 represent data reported in Ref. 3. At low concentration, <10 g/100 mliter, the present values of refractive index for NaCl are in good agreement with the data reported in Ref. 3, but at higher concentrations the refractive index is observed to be slightly higher and a slight curvature can be seen. In Figs. 5 and 6, the linear part of the graph can only be observed with a solution concentration <12 and 24 g/100 mliter, respectively.

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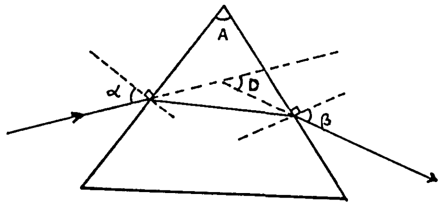

Fig. 1. Nomenclature in derivation of minimum deviation.

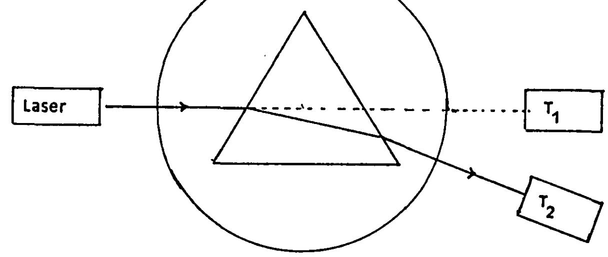

Fig. 2. Experimental setup to measure the prism's deviation minimum.

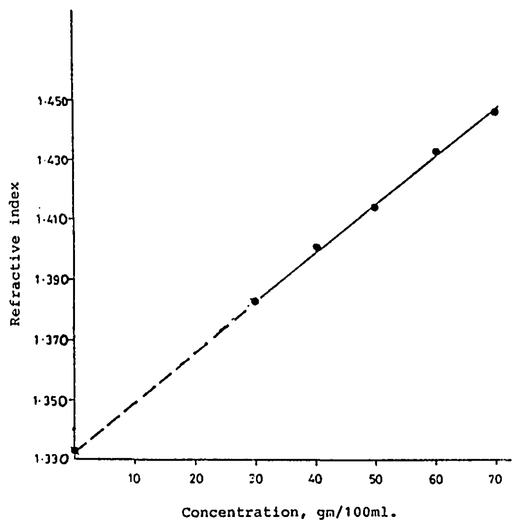

Fig. 3. Index of refraction variation with concentration for sucrose.

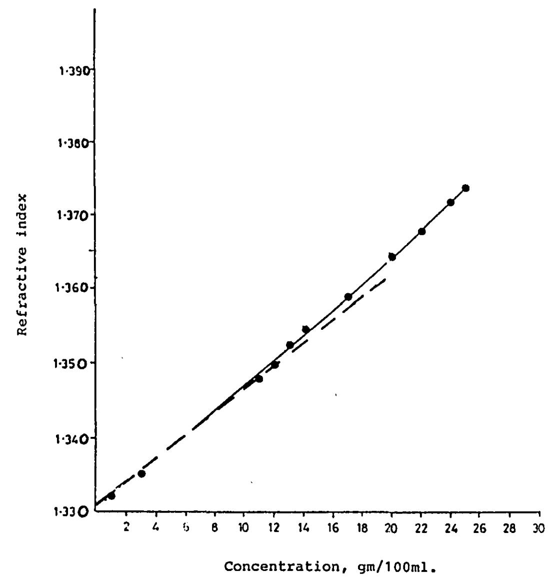

Fig. 4. Index of refraction variation with concentration for sodium chloride.

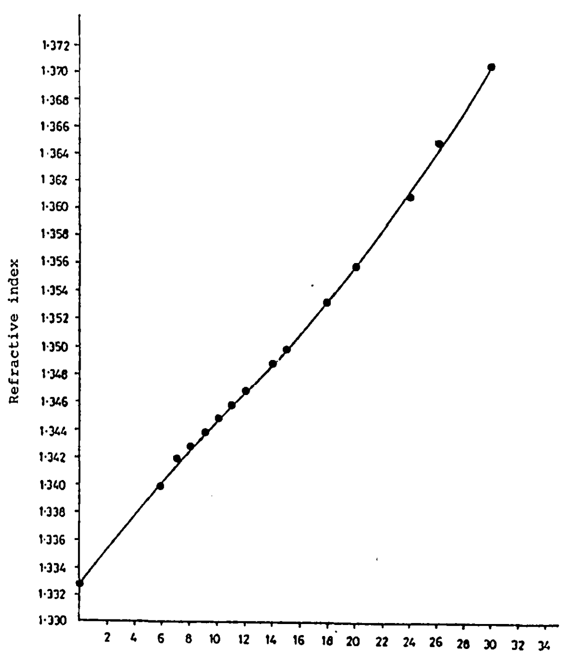

Fig. 5. Index of refraction variation with concentration for glucose.

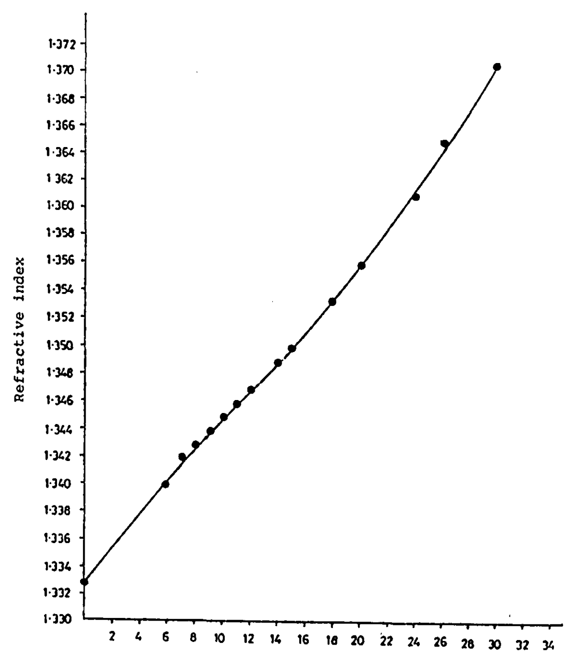

Fig. 6. Index of refraction variation with concentration for caster sugar.

In this work, the value of angle A was determined by measuring the angle of minimum deviation when the prism was filled with distilled water. Thus by using Eq. (1), the value of A was determined as $(60.0 \pm 0.1)°$, and this is necessarily the same as the accuracy of D. Therefore the error analysis indicated that the accuracy of determination of refractive index is estimated to be of the order of 0.3%.

In view of the fact that the present measurement of refractive index was carried out at only one wavelength [He–Ne laser (0.6328 μm)] it is impossible to draw any physical explanation for the nonlinearity relation between refractive index and solution concentration.

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