REFRACTIVE INDEX OF SALT WATER: EFFECT OF WAVELENGTH AND CONCENTRATION

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ABSTRACT

The method of least deviation was used to measure the refractive index of (H_2O-NaCl) solutions for a wide range of wavelengths and concentrations. The deviation angle was measured and recorded to the accuracy of 0.32 minute/mm using a described electric circuit. The experimental formula correlating the refractive index to the concentration and wavelength: $\mu(\lambda, C) = 1.3167 + \frac{112.56}{\lambda} + 9.21\times10^{-3}C$, was obtained. The results calculated from this equation are in a good agreement with the available data.

INTRODUCTION

The optical properties of liquid solutions have a great importance for many applications, such as, in instrumentation, one can define easily the type of liquid and its concentration in solutions in a liquid sample from its refractive index [1-4]. Another one, is the growing application of light in communications through sea water, where the property of refractive index of this medium (sodium chloride-water) solution plays an important role. It helps in defining the possible propagated distance through which the light (optical carrier) can keep most of its power. So, the study of refractive index of (H_2O-NaCl) solutions has become necessary.

This field was studied before by many investigators. Grange et al. [1] have presented experimental data for the refractive index of (H_2O-NaCl) solutions with temperatures (between freezing and room temperature). The variations of refractive index of four liquid solutions with different concentrations were reported by Yunus and Abdul Rahman [3].They used the same conventional minimum deviation method used by Grange et al., and the same laser wavelength (0.6328) μm). Yunus [4] has reported the variations of the refractive index of rhodamine 6G in methanol for a concentration range of 5×10^{-6}-10^{-4} M at 0.6328 μm wavelength. He has improved the accuracy of the measurement of the angle of minimum deviation by using the geometrical optics.

The aim of the present work is to study, not only the effect of variations of (H_2O-NaCl) solution concentration on its refractive index, but also, the effect of the wavelength of a monochromatic light. The measurements were carried out on the solution with (0-3.42 molar) concentration range, using five light sources of wavelengths 0.6379, 0.5870, 0.5380, 0.4798, and 0.4253 μm at room temperature (298°K).

THEORY AND EXPERIMENTAL PROCEDURE

The method used in the present work, is based on measuring the angle of deviation for a collimated monochromatic light beam incident on a surface of a thin hollow glass prism. This prism of included angle 30° acts as a container of (H_2O-NaCl) solutions of different concentrations. The refracted beam was observed through a telescope equipped with a cross hair.

The collimated monochromatic light beam of wavelength λ is incident perpendicular to one surface of the prism as seen in Figure (1).

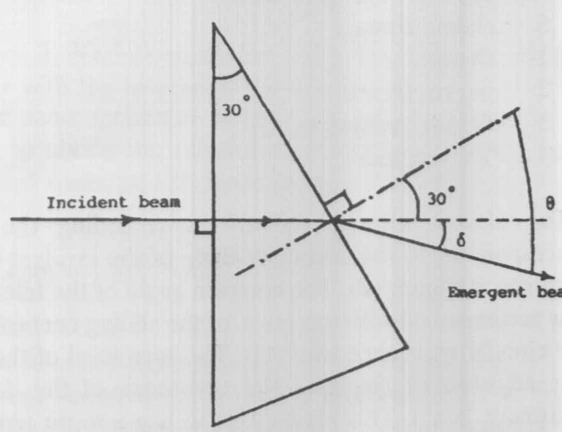

Figure 1. Nomenclature utilized in derivation of Eq.(1).

The relation between the deviation angle $\delta(\lambda,C)$ and the refractive index $\mu^*(\lambda,C)$ of the solution under test can be easily found by a direct application of Snell's law:

$$\mu^*(\lambda,C) = \frac{\sin\theta(\lambda,C)}{\sin 30°} = 2\sin[\delta(\lambda,C) + 30°] \qquad (1)$$

Before rotating the telescope, one must be sure that the point "O" is the center of the rotating table of the optical spectrometer. This procedure helped in measuring a deviation angle $\delta(\lambda,C)$ satisfying Eq. (1) accurately. The rotation angle of the telescope, which is equivalent to the deviation angle of the incident beam, was changed into emf in mV to be recorded by TY recorder which gave higher accuracy and quicker readings. This emf was produced on a circular resistance wire fixed in a groove around a wood desk.

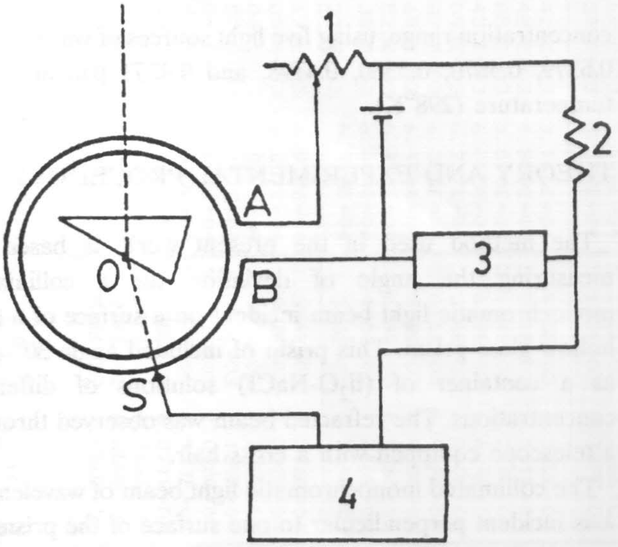

Figure 2. Block diagram of the electric circuit.
AB- circular resistance wire
S- sliding contact
1- rheostat
2- big resistance
3- decade resistance box
4- TY recorder

The electric circuit, utilized in recording the emf corresponding to the deviation angle of the incident beam is shown in Figure (2). The rotation angle of the telescope was accompanied with a motion of the sliding contact S on the circular resistance wire AB. The zero level of the emf was adjusted by changing the resistance of the decade resistance box 3. This enabled us to use a more sensitive scale of the recorder (0.005 mV/mm). Calibration of the instrument has been performed using suitable values of E R, and the Rheostat 1 which gave 1.075 deg/mV as showr by the calibration in Figure (3). Thus, the accuracy oi measurement is 0.322 min/mm.

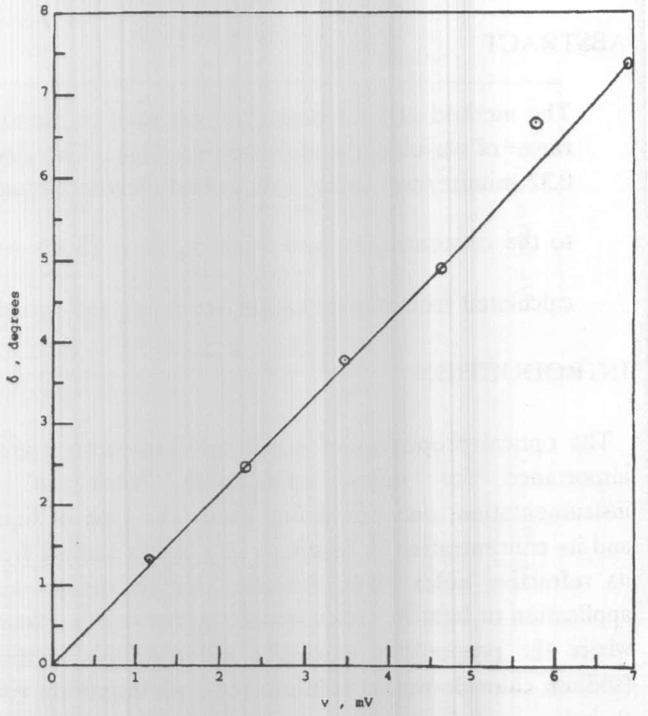

Figure 3. Calibration line relating the emf v with the deviation angle δ.

RESULTS AND DISCUSSION

Figure (4) shows the emf measured by the recorder for the distilled water at different wavelengths. The results show the increasing of the emf with decreasing wavelength. From the calibration line given in Figure (3), the deviation angle $\delta(\lambda,C)$ corresponding to an emf $v(\lambda,C)$ in mV is given by:

$$\delta(\lambda,C) = 1.075\, v(\lambda,C). \quad \text{degrees} \qquad (2)$$

From equations (1) and (2), the refractive index $\mu^*(\lambda,C)$ was obtained experimentally. A series of measurements of the refractive index for (H_2O-NaCl) solution was performed at temperature 298 °K for different concentrations C with a step of 5 gm/100 ml (0.855 molar) starting with the distilled water. Figure (5) is the plot of the refractive index of distilled water calculated from Figure (4), against the inverse of the wavelength. The values $\mu^*(\lambda,C)$ of refractive index for different concentrations and wavelengths are presented in Table I.

Table I.

Wavelength (^{o}A)	Refractive index $\mu(\lambda,C)$ at $T=298^{o}$K					[Straight line fit]		
	Concentration in molar					$\mu(\lambda,0)$	m_λ x10^{-3} (molar^{-1})	$\sum[\mu(\lambda,C)-\mu^{*}(\lambda,C)]^2$ x10^{-6}
	0	0.855	1.710	2.565	3.420			
6379	1.3330	1.3432	1.3516	1.3579	1.3651	1.3344	9.23	5.61
5870	1.3350	1.3439	1.3526	1.3590	1.3667	1.3357	9.18	2.27
5380	1.3367	1.3469	1.3532	1.3608	1.3691	1.3376	9.21	3.04
4798	1.3390	1.3490	1.3558	1.3635	1.3710	1.3400	9.18	2.49
4253	1.3420	1.3526	1.3590	1.3670	1.3743	1.3432	9.23	3.95

These data were then used to determine the correlation between the refractive index and concentration for different wavelengths.

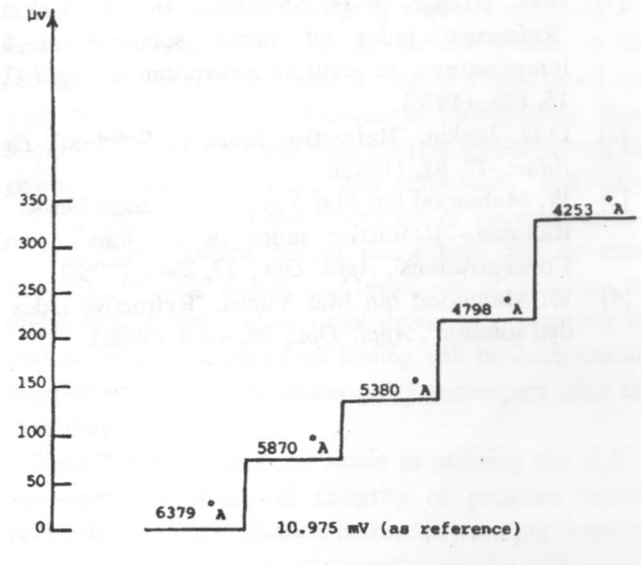

Figure 4. The emf measured by the TY recorder for the distilled water at different wavelengths.

Using the method of least squares, straight line relation between the calculated refractive index $\mu(\lambda,C)$ and the concentration C was obtained in the form:

$$\mu(\lambda,C) = \mu(\lambda,0) + m_\lambda C , \quad (3)$$

where $\mu(\lambda,0)$ is the refractive index of the distilled water at wavelength λ, and m_λ is the slope of the refractive index-concentration line at the same wavelength. Table I includes also the values of $\mu(\lambda,0)$ and m_λ for each wavelength used, and the sum of the deviation squares $\Sigma [\mu(\lambda,C)-\mu^{*}(\lambda,C)]^2$, where $\mu(\lambda,C)$ is the calculated refractive index, while $\mu^{*}(\lambda,C)$ is its experimental value.

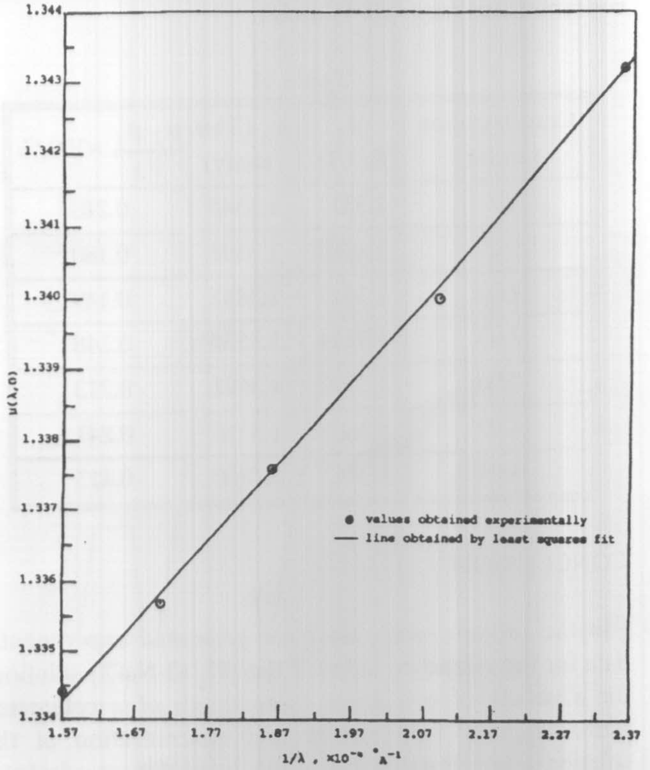

Figure 5. Variations of the refractive index of distilled water with the inverse of the wavelength.

The same technique of the simple least-squares fit was used to obtain the refractive index-dispersion line of the distilled water $\mu(\lambda,0)$ from column 7 in Table I:

$$\mu(\lambda,0) = 1.3167 + \frac{112.56}{\lambda}, \quad (4)$$

where λ is in Angstrom units. From the slopes m_λ at the different wavelengths, it is seen that the lines are almost parallel and the average slope m_{av} ($9.21\text{x}10^{-3}$ molar^{-1}) can be taken for all wavelengths used. Thus, the best line fit,

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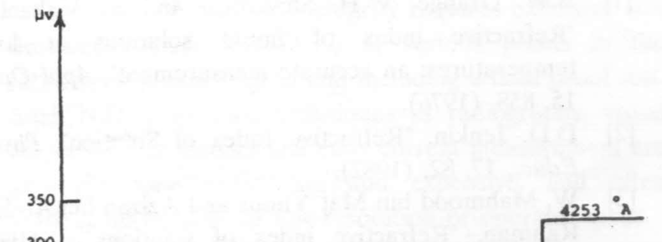

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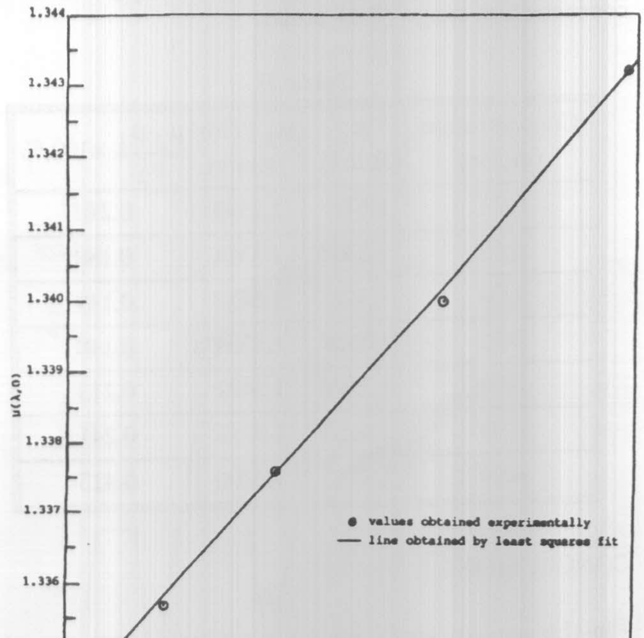

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