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Dielectric Measurement Study of Nitrobenzene and N, N-Diethylamine in Non-Polar Medium at Microwave Frequency

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Abstract
The dielectric behaviour of polar liquids like Nitrobenzene and N, N-Diethylamine in dilute solutions of non-polar solvent benzene have been studied at fixed microwave frequency 9.8 GHz (X band). Essentially each polar compound was prepared in benzene medium for few concentrations. The Dielectric constant (ε') and loss (ε") have been determined at room temperature. It is observed that dielectric constant and loss varies with concentration linearly showing the solutions were sufficiently dilute. The relaxation time and electric dipole moment of the systems is determined by a concentration variation method of Gopala Krishna based on Debye molecular model. These studies report a determination of relaxation time (τ), electric dipole moment (μ) of Polar liquids in benzene solution at room temperature.

Keywords: Dielectric constant, dilute solution, relaxation time, dipole moment

Introduction

Polar molecules have asymmetric distribution of positive and negative charges which on interaction with the microwave radiation contributes to dielectric permittivity. Studies of dielectric measurements of polar liquids, especially in dilute solutions in non-polar solvent have an important role in liquid state [1, 5]. Dielectric constant is an electrical property of substances, which is due to contribution from orientation, vibration and electronic polarization in polar liquid. Dielectric investigations mainly probe weak forces between the molecules and help to understand intermolecular re-orientational dynamics of the solute as well. In this investigation, measurements of dielectric constant and loss have been carried out in varying concentrations of Nitrobenzene and N, N-Diethylamine in a non-polar medium (benzene) at single microwave frequency (9.8 GHz) at room temperature. The results are discussed to interpret molecular structure in terms of relaxation time (τ) and electric dipole moment (μ) of the dipole in the medium.

Experimental

The chemicals have been obtained commercially with a purity of 99% specification and were used without any further purification. Dilute solutions of polar liquids were prepared at room temperature for few dilute concentrations in Benzene. The solution was mixed well and kept for 12 Hrs. in a well stopper volumetric flask to ensure good thermal equilibrium. These systems in non-polar benzene were assumed to be dilute solutions. The X-band microwave bench was used to measure the wavelength of the microwave radiation in liquid dielectric cell. The liquid sample was hold vertically in a liquid cell by supporting a thin mica sheet whose VSWR and attenuation were assumed negligible small. The liquid dielectric cell was attached at the end of microwave bench.

The Smyth's equations [6, 7] are used to calculate dielectric constant and dielectric losses at microwave frequency.

$$\varepsilon' = \frac{\{\lambda_0/\lambda_c\}^2}{\{\lambda_0/\lambda_d\}^2} \quad (1)$$

$$\varepsilon'' = \frac{2}{\pi}\frac{\{\lambda_0/\lambda_d\}^2}{\{\lambda_g/\lambda_d\}^2} \quad (2)$$

where, λ_0- Wavelength of microwave radiation.
λ_c- Cutoff wavelength in the wave guide.
λ_g- Wave-guide Wavelength
λ_d- Wavelength of microwave radiation in liquid medium.

The procedure of measurement on X-band is describe elsewhere [4, 6].
A Gopala Krishna method [8] based on Debye molecular model, is used to determine a relaxation time (τ) and electric dipole moment (μ).

$$\frac{\varepsilon^*-1}{\varepsilon^*-2} = \frac{\varepsilon_\infty-1}{\varepsilon_\infty-2} + \left[\frac{4\pi\eta\mu^2}{9KT}\right]\left[\frac{1}{jw\tau}\right] \quad (3)$$

Where,

$$\varepsilon^* = \varepsilon' - j\,\varepsilon''$$

$$\tau = \frac{(1/w)}{(dY/dX)} \quad (4)$$

$$\mu^2 = \frac{9KTM}{4\pi N d_0}\left\{1 + \left(\frac{dY}{dX}\right)^2\right\}\frac{dX}{dw} \quad (5)$$

Where, the meaning of symbols is standard and variation of X and Y are depending on concentrations of the polar liquid in non-polar medium.

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Result and Discussion

The Physical and Molecular constants of polar and non-polar compounds are mentioned in Table-1, below.

Table 1: The Physical and Molecular Constants of Polar and Non-Polar Compounds.

Comp.	Mol. Wt. gm	M.P. ⁰ C	B.P. ⁰ C	R.I. (n)	Density gm/cc (ρ)
Benzene	78.11	05	80	1.501	0.874
Nitrobenzene	123.11	6	210	1.5613	1.196
N, N- Diethylamine	123.11	6	210	1.5613	1.196

The determined values of dielectric constant (ε') and dielectric losses (ε") of Nitrobenzene and N, N- in benzene solutions are reported in Table-2 and Table-3 respectively.

The plots of Y verses X are linear which determine relaxation time (τ) (Fig.-1and Fig.-3) and the plots of X verses W (wt. fraction) which are also linear, determine the value of electric dipole moment (μ) (Fig.-2 and Fig.-4) of polar liquids in non-polar benzene medium.

Table 2: The Determined Values of Dielectric Constant (ε') and Dielectric Loss (ε") of Nitrobenzene in Benzene Solution

S.N.	Wt. fraction (W)	ε'	ε"	X	Y
1	0.0021	2.5681	0.014	0.027233	0.002013
2	0.0129	2.7101	0.1577	0.033099	0.021301
3	0.0241	2.824	0.1814	0.036796	0.023352
4	0.0466	2.8098	0.2833	0.038434	0.036611
5	0.0813	2.9677	0.4011	0.045702	0.048444

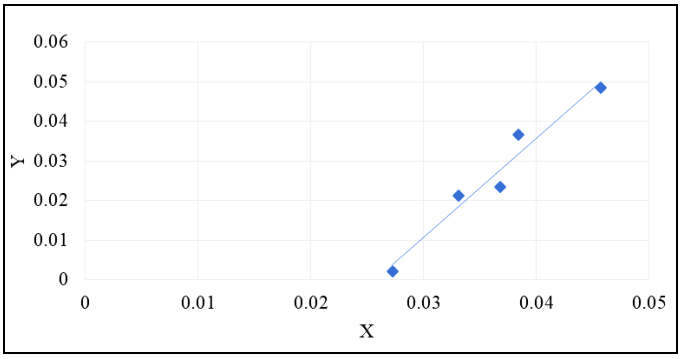

Fig 1: Linear behaviour relation of Y and X for nitrobenzene in benzene

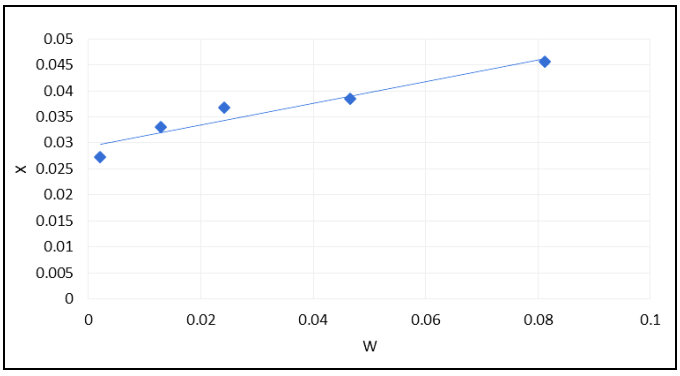

Fig 2: Linear behaviour of X and W for nitrobenzene in benzene

Table 3: The Determined Values of Dielectric Constant (ε') and Dielectric Loss (ε") of N, N-Diethylamine in Benzene Solution

S.N.	Wt. fraction (W)	ε'	ε"	X	Y
1	0.2211	2.3012	0.1019	0.019474	0.016515
2	0.3044	2.3817	0.1913	0.026563	0.029835
3	0.3837	2.4792	0.2573	0.034409	0.038347
4	0.4613	2.6517	0.2819	0.043465	0.03894
5	0.5514	2.7811	0.3812	0.053488	0.049713

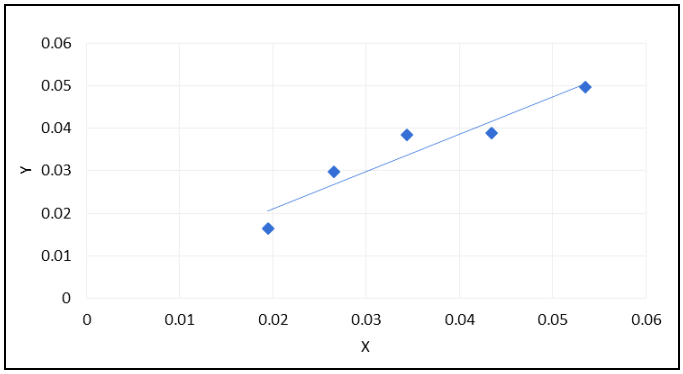

Fig 3: Linear behaviour relation of y and x for N, n-diethylamine in benzene

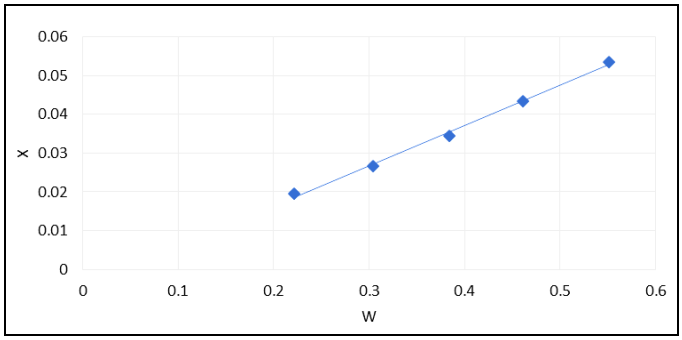

Fig 4: Linear behaviour of x and w for N, n-diethylamine in benzene

Conclusions

The values of dielectric constant (ε') and dielectric loss (ε") of polar liquids in dilute solution of benzene increase as function of concentration of polar substance. The concentrations of the solution were sufficiently dilute to minimize the solute-solute interaction. The value of relaxation time and electric dipole moment of polar molecules in non-polar benzene are obtained and compared with literature value [9, 13].

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