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Thermoacoustic analysis in binary mixture of pyridoxine hydrochloride with water at 303K

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ABSTRACT

In the present study Ultrasonic velocity (u), density (ρ) and viscosity (η) have been measured at 2MHz frequency in the binary mixtures of Pyridoxine Hydrochloride with water in the concentration range (0 to 0.1 M) at 303^0K using Ultrasonic interferometer technique. The measured value of ultrasonic velocity, density and viscosity have been used to estimate the acoustical parameters namely adiabatic compressibility (β_a), relaxation time (τ), acoustic impedance (z), free length (L_f), free volume (V_f) and internal pressure (P_i), with a view to investigate the nature and strength of molecular interaction in the binary mixture of Pyridoxine hydrochloride with water. The obtained result support the occurrence of Complex formation molecular association through intermolecular hydrogen bonding in the binary liquid mixtures.

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KEYWORDS

Ultrasonic velocity;
Binary mixture;
Molecular interaction;
Hydrogen bonding.

INTRODUCTION

Ultrasonic offer the most exciting and fascinating field of scientific research among the researcher since the ultrasonic and other related thermo acoustic parameters provide useful information regarding the structure of molecules, molecular order, molecular packing, inter and intra -molecular interaction[1,2] etc. Ultrasonic study of liquid and liquid mixture has gained much importance during the last two decades in assessing the nature of molecular interaction and investigating the physiochemical behavior of this system[3,4].

The review of literature reveals that lot of work has been done to investigate ultrasonic measurement of pure liquid and liquid mixture at different environment, but less effort has been made to investigate ultrasonic studies in binary mixture of B complex vitamins i-e Pyridoxine hydrochloride (Vit-B6) with water.

In the present Paper we have report the ultrasonic velocity, density and viscosity of Pyridoxine hydrochloride with water at 303^0K over entire range of molar concentrations. From these experimental value a number of thermodynamic parameters namely adiabatic compressibility, acoustic impedance, relaxation time, free length, free volume, internal pressure have been calculated. The variation of these parameters with molar concentration was found to be useful in understanding the nature of interactions between the components.

EXPERIMENTAL SECTION

Materials

Pyridoxine hydrochloride used in the present work was of Analytical Reagent (AR) grades with a minimum assay of 99.9%, they are used without purification. The various concentration of solution was prepared by adding sufficient amount of solvent water to Pyridoxine hydrochloride.

Methods

The ultrasonic velocity (U) have been measured in ultrasonic interferometer (Model-F-05) supplied by mittal enterprises, New Delhi operating at a frequency of 2 MHz with an accuracy of 0.1%. The viscosities (η) of binary mixtures were determined using Ostwald's viscometer by calibrating with double distilled water with an accuracy of ±0.001PaSec. The density (ρ) of these binary solution was measured accurately using 25 ml specific gravity bottle in an electronic balance precisely and accurately using weighting is 0.1mg. The basic parameter U, η, ρ were measured at various concentration (0.00 M to 0.1M) and temperature of 303^0K. The various acoustical parameters were calculated from U, η, ρ value using standard formulae.

Computation

In the Present study various thermo acoustical parameters were calculated using following relations.

1) Ultrasonic velocity (u)

The expression used to determine the ultrasonic velocity is

$$u = 2d/T \text{ (m/sec)}$$

$$= 2d \times \nu$$

$$= \lambda \times \nu \text{ (Here-2d=}\lambda\text{)}$$

Where, ν- is the frequency of the generator which is used to excite the crystal; (In the present investigation, a constant frequency (2 MHz) interferometer was employed and hence ' ν' value is 2 x 10^6 hertz.); d- Separation between the reflector and crystal; T –Travel time of ultrasonic wave.

2) Density (ρ)

The expression used to determine the density is

$$\rho = (W_{exp\ liquid}/W_w) \times \rho_w$$

Where: ρ - Density of experimental liquid; $W_{exp\ liquid}$ - Weight of experimental liquid; W_w - Weight of water; ρ_w -Density of water.

3) Viscosity (η)

The expression used to determine the viscosity is

$$\eta = \{(\rho \times t_{exp\ liquid)/}(\rho_w \times t_w)\} \times \eta_w$$

Where : η – Viscosity of experimental liquid; t_w _Flowing time of water; $t_{exp\ liquid}$ – Flowing time of experimental liquid; ρ_w –Density of water; η_w –Viscosity of water.

4) Adiabatic compressibility (β_a)

It has been calculated from the ultrasonic velocity and the density of the medium using the equation.

$$\beta_a = 1/U^2\rho.$$

5) Acoustic impedance (z)

Acoustic impedance in terms of ultrasonic velocity & density using equation.

$$Z = u.\rho$$

6) Intermolecular free length (L_f)

It has been determined as

$$L_f = k_j (\beta_a)^{1/2}$$

Where: k_j –Jacobian Constant (Temperature dependent); The value of Jacobian Constant at any temperature (T) is $k_j = (93.875 + 0.345 \times T) \times 10^{-8}$

7) Free volume (V_f)

Free volume in terms of ultrasonic velocity & viscosity.

$$V_f = (M.u/k_j.\ \eta)^{3/2}$$

Where: k_j –Temperature independent constant = 4.28 × 10^9; M – Effective molecular weight.

8) Internal pressure (P_i)

Internal pressure in terms of ultrasonic velocity, density & viscosity.

$$P_i = b.R_g.T.(k_j.\ \eta/u)^{1/2}.\ (\rho^{2/3}/M^{7/6})$$

Where: b- Cubic packing factor (assume 2 for all liquid mixtures); R_g –Gas constant; k_j _Temp independent Constant; M- Effective molecular weight.

RESULTS AND DISCUSSION

The measured ultrasonic velocity, density and related thermo acoustical parameters of Pyridoxine hydrochloride with water at 303^0K were shown graphically in figure 1.1 to 1.8.

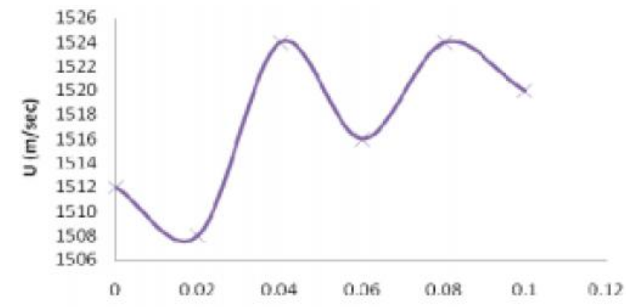

Fig.1.1 Variation of ultrasonic velocity with concentration.

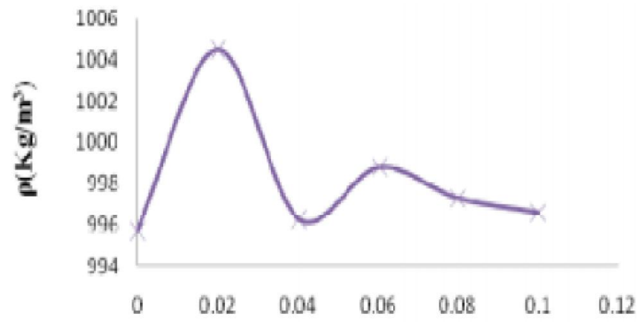

Fig.1.2 Variation of density with concentration.

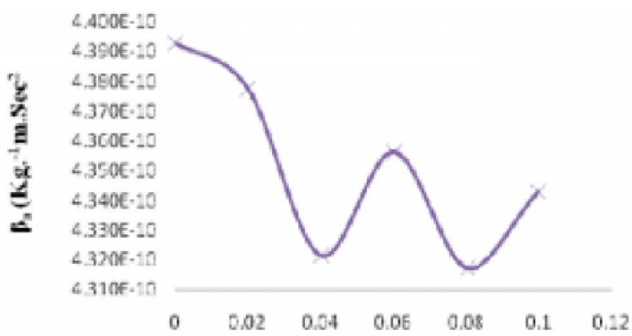

Fig.1.3 Variation of adiabatic compressibility with concentration.

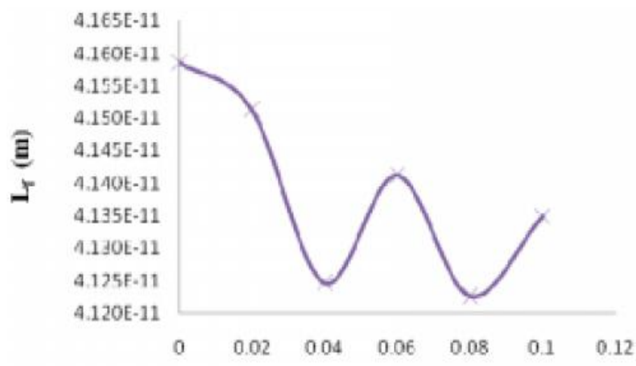

Fig. 1.4 Variation of free length with concentration

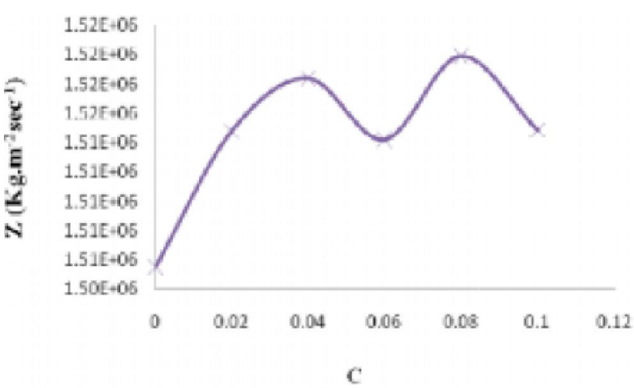

Fig. 1.5 Variation of acoutic impedance with concentration

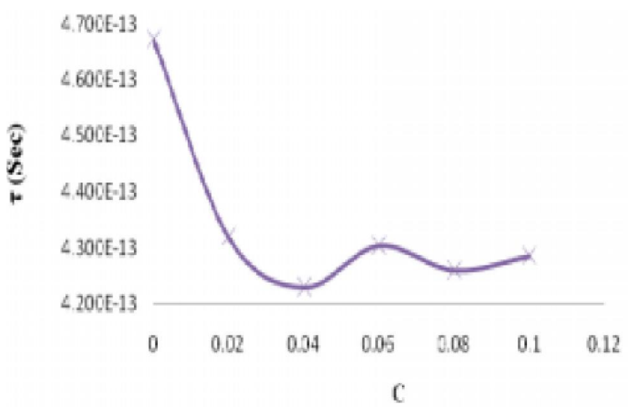

Fig. 1.6 Variation of relaxation time with concentration

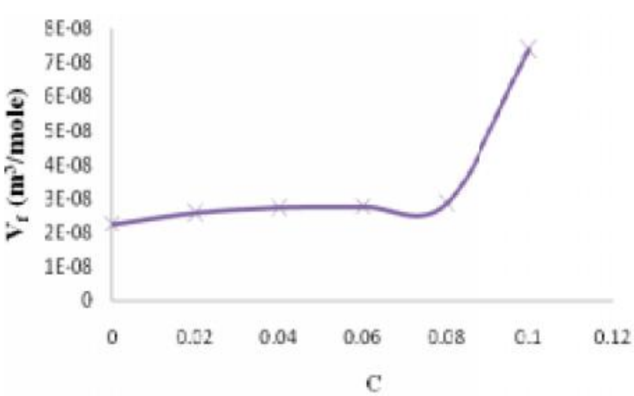

Fig.1.7 Variation of free volume with concentraation

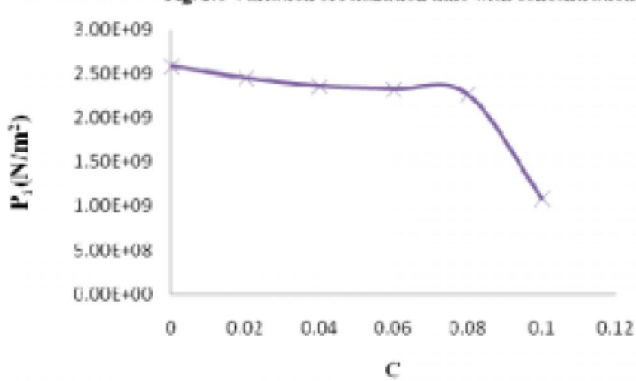

Fig.1.8 Variation of internal pressure with concentration

It is observed that ultrasonic velocity and acoustic impedance shows nonlinear increasing variation with increase in molar concentration. This indicates the complex formation and intermolecular weak association may be due to hydrogen bond formation[5]. This behavior is the result of structural changes occurring in the mixture[6].

The peak at molar concentration 0.04 & 0.08 is due to formation of strong hydrogen bond, therefore the maximum association can occur at these molar concentrations whereas, dip at 0.06 molar concentrations shows the weakening of hydrogen bond & shows maximum dissociation. Thus complex formation can occurs at these molar concentrations between the component molecules.

Adiabatic compressibility (β_a) shows an inverse behavior compared to the ultrasonic velocity. Adiabatic compressibility nonlinearly decreases with increase in concentration of pyridoxine hydrochloride. The increasing electrostrictive compression of water around the solute molecules results in a large decrease in the compressibility of mixtures[7]. The decrease in compressibility implies that there is an enhanced molecular association in the system with increase in solute concentration.

The opposite trend of ultrasonic velocity and adiabatic compressibility indicate association among interacting Pyridoxine Hydrochloride and water molecules. In the present system of aqueous Pyridoxine Hydrochloride, free length varies nonlinearly with increase in molar concentration suggest the significant interaction between solute and solvent due to which structural arrangement is also affected[8]

Relaxation time decreases with increase in concentration. The relaxation time which is order of 10^{-12} sec is due to structural relaxation[9,10] process in such a case it is suggested that molecule get rearranged due to cooperative process[11,12].

Nonlinear trend of density with concentration indicates the structure-making and breaking property of solvent due to the formation and weakening of H-bonds[13].

The free volume increases & internal pressure decreases with increases in molar concentration indicate the association through hydrogen bonding[14]. It shows the increasing magnitude of interaction between the pyridoxine Hydrochloride and water.

CONCLUSIONS

The ultrasonic study of the liquid mixtures serves as a probe to detect the molecular association arising from the hydrogen bonding between the molecules of pyridoxine and water. The non-linear variation of thermo-acoustical parameters with concentration reveals the complex formation between the components molecules.

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