ISSN (Print 0974-2115) (Online 2349-8552)
www.jchps.com Journal of Chemical and Pharmaceutical Sciences

A study of acoustical parameters of $ZnSO_4$ with concentration of PVA using ultrasonic interferometer

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ABSTRACT

We have narrates that the parameters of acoustical such as attenuation coefficient, relaxation time, absorption coefficient, intermolecular free length, and molar volume for aqueous solution of $ZnSO_4$ have been measured in various concentrations (0.1 to 1.0 M) of poly vinyl alcohol (PVA) using ultrasonic interferometer under the frequencies of one MHz and three MHz at 303 and 318 K. The study reveals that the acoustical parameter changes is due to the change in mole concentrations. This is because of solute-solvent interactions and tendency in structure changes in solute and solvent. It is observed that acoustical parameter values decreases with increase in molar concentration of PVA in Zn^{2+} ions in aqueous solutions.

KEY WORDS: Ultrasonic velocity, Viscosities, Acoustical Parameters, Adiabatic Compressibility, Molecular Association.

1. INTRODUCTION

High frequency acoustic waves are also known Ultrasonic waves as having the frequency above 20 kHz. Nowadays, the ultrasonic technique has found to be the most powerful tool among the tools of recently used. The nature of intermolecular interactions in the liquid mixtures has an impact on structural arrangement and the shape of the molecules (Shinde, 2010; Ravichandran, 2010; Panday, 1996). The ultrasonic studies are mostly used to calculate the intermolecular interaction of various binary mixture solutions. Interaction of molecules in the liquid mixture has more importance in the clarification of the molecular structure and its property. To investigate the properties of liquid mixtures consisting of polar as well as non-polar components finds applications in industries and technological processes (2004). Besides, these acoustical parameters are pivotal in studying the molecular interactions and physicochemical behavior in binary molecular liquid mixtures (Kannappan, 2006; Palani, 2008). Yet, acoustical parameters are used to understand various kinds of association, molecular packing, molecular motion, physico-chemical behavior. These parameters are also responsible for determining the types of intermolecular interactions and the strength influenced by the sound wave on pure components of chemical mixtures. As a part of the current research, acoustic properties of chemical diatomic molecular mixture of aqueous solution of $ZnSO_4$ has been measured using ultrasonic interferometer with various concentrations (0.1 to 1.0 M) of PVA at 303 and 318 K temperatures. Measurement of density (ρ) and ultrasonic velocity (ν) with different mole concentration at respective temperatures are obtained. From this data, acoustical parameters like absorption coefficient, intermolecular free length, attenuation coefficient, relaxation time and molar volume values are computed. The molecular interactions between mixtures of compounds are explained from the obtained data.

2. MATERIALS AND METHODS

100 ml solution of zinc sulphate (ZS) (99.5% purity, Zigma Aldrich) and PVA (Zigma Aldrich) are prepared by using 1 M of zinc sulphate and PVA with various concentration from 0 M to 1 M in steps of 0.2. Totally 10 sets of aqueous solution were prepared and their acoustical parameters were obtained at two different temperatures (303 K and 318 K) maintained at constant temperature.

Table.1. Ratio for solute and solvent in a 100 ml aqueous solution

Volume of solute + solvent	Zinc sulphate for 1 M	PVA
100 ml	16.147 gms	0 gms (0 M)
		0.88 gms (0.2 M)
		1.76 gms (0.4 M)
		2.64 gms (0.6 M)
		3.52 gms (0.8 M)
		4.4 gms (1.0 M)

The velocities are obtained using ultrasonic interferometer with least count accuracy of 0.01 mm. From the home made ostwald viscometer, the viscosity was measured and homemade specific gravity bottle is used for measuring the density of aqueous solution and the experiment was repeated for 5 times with constant temperature and molarity**.**

Physical parameters used for ultrasonic investigation: The velocity of ultrasonic sound in aqueous solution ZS with the different concentrations of PVA has been determined and plotted as graph. It is observed that the velocity

decreases abruptly at 0.4 M and steadily increases up to 1M this is due to strong ionic dipole interactions. This can be confirmed and discussed in following sections.

Free length (L_f): Difference of temperature does not affect free length in the material. From the Jacobson's a semi-empirical relation the free length can be determined and graph was plotted fig.1, from the graph it is found that free length decreases as concentration increased from 0 to 0.2 M and then increases as concentration increases for the temperature the free length increases linearly (Ravichandran, 2010).

$$L_f = K (\beta_a)^{1/2} \text{ m}$$

Where, K-is the temperature dependent constants.

Relaxation time (τ): The resistance created by viscous forces due to the flow of sound waves measured as classical absorption factor. Associated with it there is a relaxation time defined by

$$\tau = 4\eta / (3 \rho v^2) \text{ Sec}$$

Where η is the solvent viscosity (Nsm^{-2}). Velocity, density and viscosity of the experimental liquid are found out by direct experimental methods and the variation in the relaxation time (Kannappan, 1992; Ravichandran, 1991; Venkata Ramana, 2001) is shown in fig.2. As the concentration increases, there is gradual decrease in relaxation time.

Absorption coefficient (α/f^2): Absorption coefficient $(\alpha/f^2) = 8 \pi^2 \eta /(3\rho v^3)$

Attenuation coefficient (α): Attenuation coefficient $(\alpha) = (8 \pi^2 \eta/3\rho v^3) f^2$

The ultrasonic wave generated by the ultrasonic interferometer and its frequency is f (1 and 3 MHz). A graph is plotted between attenuation coefficient and concentration of solution.

Molar volume (V_m): Molar volume $(V_m) = M_{eff}/\rho$

Where, M_{eff} is the effective molecular weight (g/mol). The molar volume decreases as concentration increases. There is a change in beak at high temperature and high concentration.

Theory and determinations: The physico-chemical properties of aqueous solutions can be studied using the ultrasonic wave propagation and used to differentiate electrolytes and non-electrolytes with PVA of the interacting components. The polarity of the solvent and ion-size are the factors determine ion-dipole interaction in the solvents and its strength. The di-pole strength of the ions is directly proportional to its size and magnitude of the dipole charge and the distance between them are inversely proportional. In this study, to determine the different parameters by using densities ultrasonic velocity and viscosities of Zinc Sulphate in PVA solution at 303 K and 318 K. The data are used to calculate various properties of acoustic waves due to various interactions of di-atomic molecules. The specific gravity bottle is used to measure the density of aqueous solution. The viscosity was measured an Ostwald's viscometer (Tack Bletz, 1967). The accuracy of the velocity measurement was ±0.1 ms^{-1}, ultrasonic velocity was ± 0.1 kgm^{-3}, and the density was ±0.0001 Nsm^{-2}. For the various concentration of Zinc sulphate in PVA at the temperatures (303 K and 318 K) the values of viscosity, ultrasonic velocity and density at the frequencies 1 MHz and 3 MHz are measured. The measured quantities such as Intermolecular free length, Relaxation time, Absorption coefficient, Attenuation coefficient, Molar volume, were calculated using the standard formula is shown in graphs (fig.1 to 5).

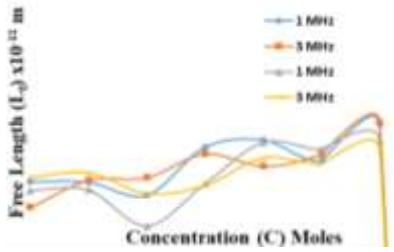

Figure.1. Ultrasonic Free length (L_f) with various concentrations in the solution $ZnSO_4$ and PVA at 303K and 318K temperature at 1 and 3 MHz frequencies

Figure.2. Ultrasonic Relaxation time (τ) with various concentrations in the solution $ZnSO_4$ and PVA at 303 K and 318 K temperature at 1 and 3 MHz frequencies

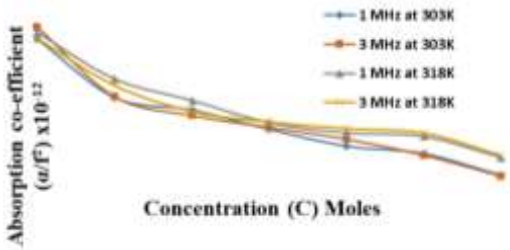

Figure.3. Ultrasonic Absorption co-efficient (α/f^2) with various concentration in the solution $ZnSO_4$ and PVA at 303 K and 318 K temperatures at 1 and 3 MHz frequencies

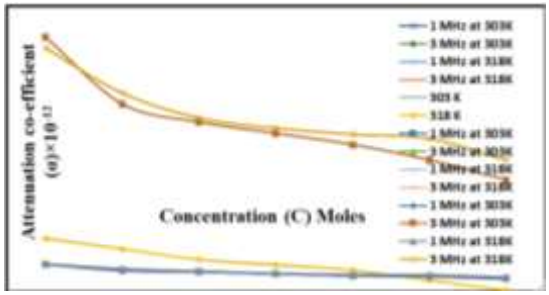

Figure.4. Ultrasonic Attenuation co-efficient(α) with various concentrations in the solution $ZnSO_4$ and PVA at 303 K and 318 K temperature at 1 and 3 MHz frequencies

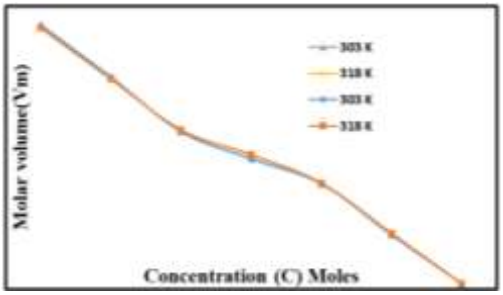

Figure.5. Ultrasonic Molar volume (V) with various concentration in the Zn and PVA at 303 K and 318 K temperature at 1 and 3 MHz frequencies

3. RESULTS AND DISCUSSION

The study of intermolecular free length: The fig.4.5, shows the relation between intermolecular free length against the concentration. In this figure there is a decreases in the intermolecular free length from the concentration 0.2 M and attains the minimum value at 0.4 M. It further increases at concentration 0.5 M and decreases from concentration 0.8 M. This is for the temperature 303 K at 1 MHz. The same trend is observed for 303 K at 3 MHz also. But the difference is free length increases at concentration 0.8 M. At temperature 318 K at frequency 1 MHz free length decreases at concentration 0.1 M and further increases at concentration 0.4 M and decreases at the concentrations 0.5 M to 0.8 M. The same trend is observed for 318 K at 3 MHz also. Intermolecular free length is used calculate the attraction force between the molecules inside the solution. The value of intermolecular free length decreases as concentration of PVA increases, these indicates association between solute – solvent molecules. This also indicates that, there is a strong interaction between the ion and solvent molecules. Also it suggests that a new structure may be formed due to the addition of salts with PVA.

The study of relaxation time: The graph is plotted for relaxation time against the concentration for various temperatures and frequencies as shown in fig. 4.7. At the temperature 303 K at 1 MHz relaxation time decreases with increasing concentrations from 0.2 M to 1.0 M. This is same the temperature 303 K at 3 MHz. At temperature 318K at 1 MHz relaxation time decreases with increasing the concentrations from 0.2 M to 1.0 M. The same trend is obtained for 318 K at 3 MHz.

The study of absorption coefficient: The fig. 4.8 shows the absorption coefficient against the concentration for different temperatures and frequencies. At the temperature 303K and the frequency of ultrasonic is 1 MHz, the decreases in absorption coefficient with that of concentration form 0.2 M to 1.0 M. The same trend is observed for the temperature 303 K at 3 MHz also. At temperature 318 K and at frequencies one and three MHz, the above trend is observed as the concentration increases. The decrease in the value defines the dissociation of molecules and association for increasing nature.

The study of attenuation co-efficient: The graph is plotted for Attenuation coefficient against the concentration for various temperatures and frequencies are shown in fig 4.9. At temperature 303 K at 1 MHz the attenuation coefficient value decreases as the concentration increases from 0 to 1.0 M. The same trend is observed in the temperature 303 K at frequency 3 MHz. At temperature 318 K at the frequencies 1 and 3 MHz the above trend is observed as there are decreases when the concentration is increased.

The study of molar volume: The fig. 4.10 shows graph between the molar volume and the concentration with different temperatures. At the temperature 303 K the molar volume decreases as concentration increases and has same trend for the temperature 318 K.

4. CONCLUSION

In the present investigation the density, ultrasonic velocity, and viscosity studies for the solutions of ZS in PVA at the temperatures 303 K and 318 K were studied using ultrasonic interferometer. From the above three parameters and their coefficient were determined. The ultrasonic velocity at the frequencies 1 MHz and 3 MHz gives the density and viscosity the solutions were obtained using specific gravity bottle and Ostwald viscometer respectively. It may be concluded that the solute-solvent interactions exist in the systems of ZS includes PVA studied and structural changes may occur after about 0.2 M concentration. The ultrasonic study of ZS aqueous solutions in PVA is the presence of strong ion-dipole interactions. ZS has both weak and strong interaction with PVA solution due to the repulsion caused by the election pairs of the ligands. The concentration, nature of solvent, nature of the solute and nature of the constituent in solution and its position play a major role in determining the interactions occurring in the solutions.

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