I J R B A T, Vol. V, Issue (3), Sept-2017: 41-45 ISSN 2347 – 517X

INTERNATIONAL JOURNAL OF RESEARCHES IN BIOSCIENCES, AGRICULTURE AND TECHNOLOGY
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www.vmsindia.org

ULTRASONIC STUDIES OF AMINO ACID IN AQUEOUS SALT SOLUTION AT DIFFERENT TEMPERATURES

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Abstract

Densities, viscosities and ultrasonic velocities of an amino acid L-Serine at four different temperatures 288.15, 293.15, 298.15 and 303.15K for various concentrations (0.02 to 0.12) mol dm^{-3} in 2% of aqueous electrolytic solution have been measured. These measurements have been used to evaluate some important thermo-acoustic parameters such as Rao's constant (R), Wada's constant (W), molecular radius (ro), absorption coefficient (a/f2) and relaxation strength. The results are interpreted in terms of molecular interactions between the components of the mixture.

Keywords: L-Serine, Ultrasonic velocity, amino acids, aqueous electrolytic solution, molecular interactions

INTRODUCTION

Ultrasound waves are similar to sound waves, where both travel through a medium. Ultrasonic is the science of acoustics and the technology of sound. The frequency range of ultrasonic waves is greater than 20 kHz up to several MHz, which is beyond the audible limit. Ultrasonic studies at low amplitude provide valuable information regarding the structure and interactions taking place in pure liquids and multi component liquid mixtures. Ultrasonic velocity depends on material density and elasticity. Ultrasonic method has become a powerful tool in providing information regarding the physico-chemical properties of liquid system [1-5].

Amino acids are the fundamental, structural units of proteins, peptides and certain types of hormones and antibiotics participate in all the physiological processes of a living cell. Protein cannot exist without the correct combination of amino acids. Most of the studies on amino acids and biomolecules have been carried out in pure and mixed aqueous solutions [6-10].

L-serine is a non-essential amino acid occurring in natural form as the L-isomer. Serine is functionally important in many proteins. With an alcohol group, serine is needed for the metabolism of fats, fatty acids, and cell membranes, muscle growth and healthy immune system. It also helps in the production of antibodies [11]. Serine is used as a natural moisturizing agent in some cosmetics and skin care products. L-Serine, D-serine, Glycine and folate metabolism are very important for the development and the proper function of the central nervous system [12].

MATERIALS AND METHODS

The amino acid L-Serine [CAS No. 56-45-1, molecular weight 105.09] used in the present work is of analytical reagent grade with 99% purity obtained from HIMEDIA India Ltd. Double distilled water was used for the preparation of all the fresh solutions under study. Measurements of weights were done using digital balance having an accuracy of ±0.1mg. A digital constant temperature water bath having an accuracy of ±0.1K was used for measuring the densities, viscosities and velocities of solutions under study at desired temperatures. A stock solution of 2% aqueous NaCl was prepared by using double distilled water and it was used as a solvent for the preparation of L-Serine solution of different concentrations. The densities of aqueous solvent and solution of different concentration (0.02M to 0.12M) at different temperature range T= (288.15 to 303.15) K were measured by specific gravity bottle by relative measurement method with accuracy of ±0.1 $kg.m^{-3}$. The ultrasonic velocity of solvent and solution of different concentration at different temperature range (288.15 K to 303.15 K) was measured by using digital ultrasonic interferometer operating at frequency 2MHz (VI Microsystems Pvt. Ltd. Perungudi, Chennai) with an accuracy of ±0.1%. The interferometer was calibrated by measuring the speed of sound in double distilled water. The temperature of solution was kept constant during each measurement. The viscosity of solvent and all the solutions of L-Serine were measured using Ostwald's viscometer owing to its versatility. The accuracy of the viscosity measurement was ±0.1%.

PHYSICAL PARAMETERS

The following thermodynamic parameters are evaluated by using experimentally measured parameters such as density, viscosity and ultrasonic velocity. The molecular interactions are explained in terms of these parameters.

Rao's constant (R)

$R = V_m U^{1/3}$ ---------- (1)

Where, V_m is molar volume

Wada's constant (W)

$W = \beta_a{}^{1/7} V_m$ ---------- (2)

Molecular radius

$r_o = (3M_{eff}/16\pi\rho V_m)^{1/3} [1 - \left(\gamma RgT / M_{eff} U^2\right) \left(\frac{M_{eff} U^2}{3\gamma RgT}\right) + 1) - 1\Big)^{1/3}$ ----------- (3)

Absorption coefficient

$\left(\frac{\alpha}{f^2}\right) = \frac{8\eta\pi^2}{3\rho U^3}$ ----------- (4)

Relaxation strength

$r = 1 - \left(\frac{U}{U_\infty}\right)^2$ -----------(5)

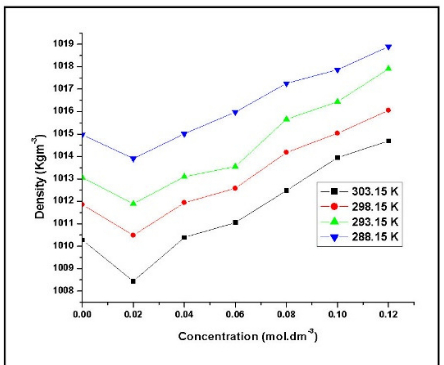

Fig.1 (a)

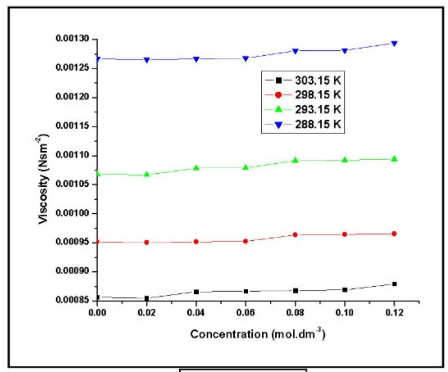

Fig.1 (b)

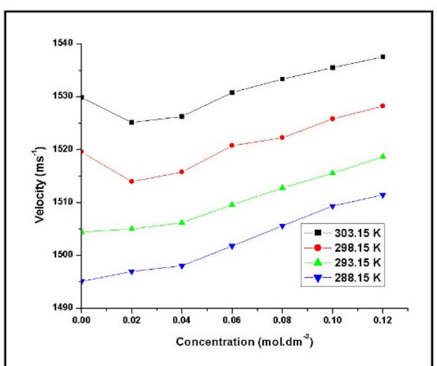

Fig.1 (c)

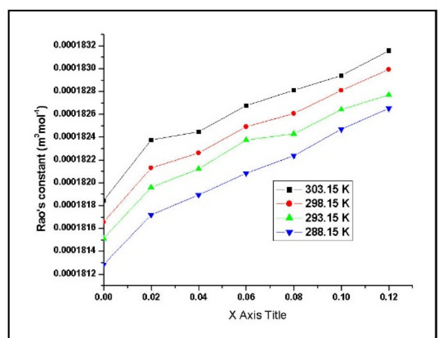

Fig.1 (d)

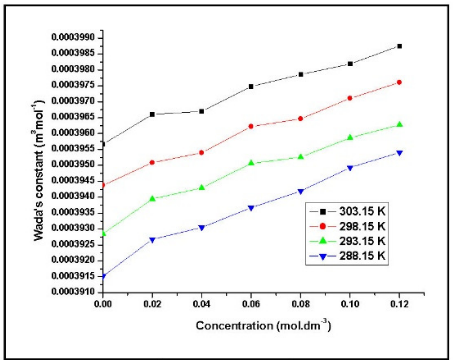

Fig.1 (e)

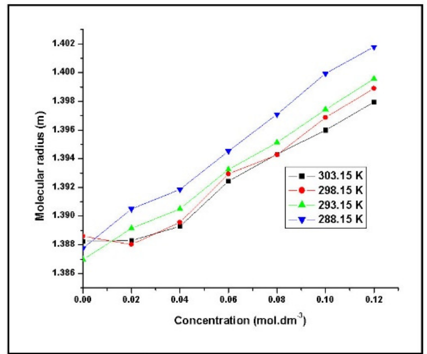

Fig.1 (f)

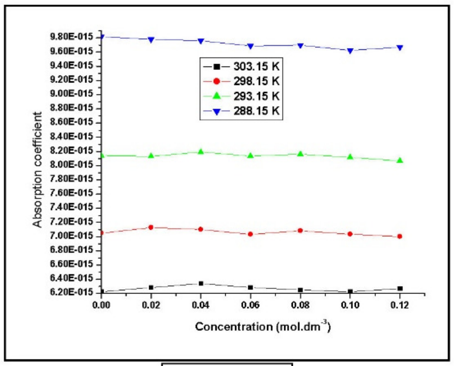

Fig.1(g)

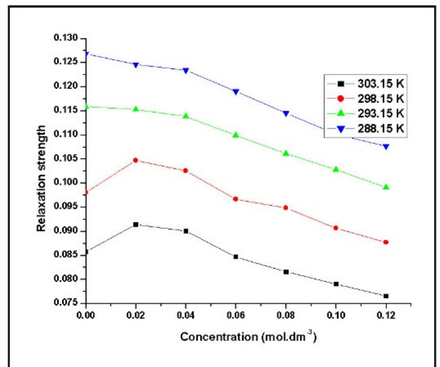

Fig.1(h)

RESULT AND DISCUSSION

The variation of experimentally measured values of density, viscosity and ultrasonic velocity and the various thermoacoustic parameters of L-Serine in 2% aqueous solution of sodium chloride of different concentration (0.02 to 0.12) mol dm^{-3} at different temperature range T= (288.15, 293.15, 298.15 and 303.15) K are as given in fig.1 a-h.

Density of the L-Serine aqueous 2% NaCl solution in the present investigation increases with molar concentration at constant temperature and as usual decreases with temperature at certain concentration as depicted in Fig.1 (a). No abnormal changes are observed in the variation of density. This shows that density has no influence on molecular association or dissociation and the variation observed is due to increase of L-Serine solute particles in aqueous 2% NaCl solvent and nothing else. Similar observations are made by various researchers [13-14].The viscosity variation of L-Serine aqueous 2% NaCl solution is as shown in Fig. 1(b). Amino acids when dissolved in aqueous solution forms zwitterions having NH_4^+ and COO^- groups at the two ends of the molecule. The Na^+ ions furnished by the salt get attracted towards the negative end and Br^- ions of the salt towards the positive end of zwitterions. Also the dipoles of the water get strongly aligned to the cations and anions of the salt as well as towards the zwitterions by electrostatic forces. These interactions lead to the formation of cohesive forces and intermolecular hydrogen bonding in the present system upon increment of the solute in the solvent. The decreasing trend in viscosity of the solution with the rise in temperature is due to increase in molecular agitation which results in weakening of cohesive forces among the components of solution [17]. Ultrasonic velocity is an important parameter which provides information regarding nature and extent of molecular interaction and is greatly affected by the concentration and the temperature. It depends upon the change in elastic properties of liquid solution during its propagation. Ultrasonic velocity of the solution increases with concentration as well as with temperature as shown in Fig.1(c). As the concentration increases compressibility of the solution decreases and hence ultrasonic velocity increases indicating clearly rise in solute-solvent interactions resulting in the greater molecular association through hydrogen bonding among the components in the solution [18].

The values of Rao's constant and Wada constant [Fig.1 (d) and Fig.1 (e)] of L-serine solution shows increase in their respective values due to increase in concentration. These variations leads to conclusion that medium is closely packed and favors the increase in solute-solvent interactions. The orders of these constant is found to be same as compared to the literature data [21-23].
Most of the physiochemical properties of matter depend on size of the molecules. From Fig.1 (f), it is observed that molecular radius of L-serine solution increases with increase in concentration and decreases with increase in temperature. Increase in molecular radius indicates greater association among components due to increase in intermolecular hydrogen bonding and dispersion forces between solute and solvent molecules. As temperature increases, molecular radius also increases because as temperature increases hydrogen bonding and dispersion forces between the solute and solvent molecules become weak.

When ultrasound wave moves through matter, continuous loss of energy takes place which is called attenuation. Several factors contribute to this reduction in energy. One of the most significant is the absorption of the ultrasound energy by the material and its conversion into heat. When ultrasound waves interact with particles of the medium, a part of the ultrasonic energy is converted into heat due to viscosity and thermal conduction. From Fig.1 (g), it is found that absorption coefficient shows very slight variation with composition but large variation with temperature. As temperature increases absorption coefficient decreases. This is because at high temperature, the thermal motion of the molecules increases and intermolecular forces of attraction becomes weak. Hence due to weak intermolecular forces, less absorption of sound wave will occur. Hence absorption coefficient decreases with increase in temperature.

Relaxation strength is directly related to adiabatic compressibility. If by the addition of solute to a solvent, the values of relaxation strength decreases then it indicates solute- solvent interaction in the system. This happens because of formation of complex [24] by solvent molecules around solute molecules. It is observed from fig 1(h), that relaxation strength of L-serine solutions decreases with increase in concentration which suggest the greater molecular association between solute and solvent molecules.

Relaxation strength depends on the factor [1-U/Uo]. Here U indicates ultrasonic velocity of solution and Uo is constant. As the values of ultrasonic velocity increases with increase in temperature, relaxation strength values decreases with increases in temperature.

CONCLUSION

It is concluded that strength of intermolecular interaction increases with increase in concentration of L-Serine which indicates solute-solvent interactions.

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