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Ultrasonic Studies and Compressibility behavior of Intermolecular interactions of L-Arginine in Aqueous Fructose solutions at 303, 308 and 313K

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Abstract:- *The Ultrasonic velocity (U), Density (ρ), and viscosity (η) have been measured for the mixtures of L-arginine in aqueous fructose (5% of fructose) at different concentration and at 303, 308 and 313K. From these measured values the various parameters such as adiabatic compressibility, free length, acoustic impedance and relaxation time have been computed. These parameters were critically analyzed and interpreted in terms of possible interactions. The results were discussed as structure-making/ structure breaking effect of the amino acid in the mixtures.*

Key words*: Ultrasonic velocity, adiabatic compressibility, free length, acoustic impedance.*

INTRODUCTION

In recent years, there has been increasing interest in the study of molecular interactions between binary and ternary liquid systems due to their applications in biosciences, foods and cosmetics, drug delivery, detergency, and biotechnological processes [1,2]. Molecular interactions (i.e. solute-solvent, solute-solute, and solvent-solvent-solvent) have great importance in biological chemistry, physical chemistry, surface chemistry, environmental chemistry, and geo chemistry [3]. Knowledge of the interactions responsible for stabilizing the native state of a solution is essential to understand its structure and function [4]. The sound ultrasonic velocity measurements are helpful to study the ion- solvent interactions in aqueous and non-aqueous solution in recent years Palani etal [5], kesavasamy etal.[6],Yan[7].

The study of molecular interactions in liquid mixtures provides an important insight into the conformational stability and unfolding behavior of globular proteins [8] [9]. Amino acids are the building blocks of all living organisms. It incorporate structural features of proteins, their physicochemical and thermodynamic properties in aqueous solutions and are found to provide valuable information on solute–solute and solute-solvent interactions that are important in understanding the stability of proteins[10]. Some of these interactions are found implicated in several bio-chemical and physiological processes in a living cell [11]. The choice of water for preparing mixed solvent is important and plays an unique role in determining the structure and stability[12]. There have been extensive study on volumetric and thermo-chemical property studies of amino acids in aqueous solutions and very few in aqueous saccharides solutions.

Ultrasonic Studies of amino acids in aqueous Fructose solutions are lacking. L-Arginine stimulates the production of growth hormone. It is very popular for its muscle building and fat burning effect among athletes [13]. However, to the best of our knowledge, no report is available in the literature on the physico-chemical solutions of arginine in aqueous-fructose at different temperatures. In the present work, the measured values of density, viscosity and ultrasonic velocity behavior of arginine with 5% fructose in water at different temperature were Studied and discussed.

Materials and methods

Analytical reagent grade Arginine, were purchased from Sd fine chemicals. Water used in the experiments was deionized and distilled prior to making solutions. Solutions of amino acid in aqueous fructose were prepared by mass on the molality scale with an accuracy of 0 to .1 g. The density of the solution was measured by 10 ml specific gravity bottle calibrated with double distilled water and acetone. The ultrasonic velocity was measured by a single crystal interferometer with an accuracy operating at a frequency of 2MHz at 303, 308 and 313K. The viscosity was measured by Ostwald's viscometer. An electronically operated constant temperature water bath is used to circulate water through the double walled measuring cell made up of steel containing the experimental solution at the desired temperature. The density, viscosity and ultrasonic velocity of the varying concentration of amino acid at different composition were measured at 303, 308 and 313K.

Theoretical aspects

From the speed of sound, density and viscosity various acoustical parameters have been calculated from the experimental data to investigate about the nature of molecular interaction between the components of the solution. The derived parameters are adiabatic compressibility, free length, acoustic impedance and relaxation Time of arginine in aqueous 5% fructose solution is

$\beta = 1/U^2 \rho \quad N^{-1}m^2$ (1)

$L_f = K \beta^{1/2} \quad m$ (2)

$Z = U \eta \quad kgm^{-2} s^{-1}$ (3)

$\tau = 4/3 \beta \eta \quad s$ (4)

RESULTS AND DISCUSSION

Table 1.Shows the measured values of the density, viscosity and ultrasonic velocity with different molality of arginine with aqueous fructose (5, % wt. of fructose) at 303, 308 and 313K. Table 2 shows the calculated Values of adiabatic compressibility and free length. The computed values of acoustic impedance and relaxation time shown inTable3.

Table 1,2 and 3

As shown in Table-1, it is found that the ultrasonic velocity increases with increase in concentration of arginine and it increases with increase in temperature. The increase in ultrasonic velocity in any solution indicates the maximum association among the molecules of a solution [14] which suggests that solute-solvent interaction also increases. The existence of molecular interactions between solute and solvent molecules is responsible for the observed increase in the ultrasonic velocity of these mixtures. The increase in ultrasonic velocity in these solutions may be attributed to the cohesion brought about by ionic hydration [15].

Figure 1

The increase in density and viscosity with the increasing concentration of solutes suggests that the solute tends to attract the solvent molecules. Simultaneously the value of density and viscosity decreases slightly as the temperature increases. Similar trend is observed by some authors in amino acid in aqueous sugar solution [16].The gradual increase in density; viscosity and velocity with solute concentration at all temperatures are due to association between solute and solvent molecules. A rise in temperature leads to less ordered structure and more spacing between the molecules. The same decrease with temperature indicates, decrease in intermolecular forces due to increase in thermal energy of the system [5, 16].

Viscosity is another important parameter to understand the structure and interactions occurring in the solutions. Viscosity variations are attributed to structural changes. The structural changes influence the viscosity to a greater extent than they affect density and compressibility. As shown in Table 1, Fig 1, the viscosity increases with increasing solute concentration and decrease with increasing temperature. This increasing trend indicates the existence of molecular interactions in these mixtures [16].

Figure 2

From the Table-2, and Fig-2, the adiabatic compressibility shows decreasing trend with increase in the concentrations of amino acid. The decreasing trend of adiabatic compressibility for amino acids in aqueous fructose solution at all temperatures generally confirms the conclusion drawn from the velocity data. The increasing electrostrictive compression of water around the molecules results in a large decrease in the compressibility of solutions. The decrease in the compressibility implies that there are enhanced molecular associations in this system with increases in the solute content, as the new entities (formed due to molecular association) become compact and less compressible [17].

From Table 2 and fig3, Intermolecular Free Length (L_f) decreases with the increase in concentration of solute and increases with the increase of temperature for L-Arginine solutions. The decreasing compressibility brings the molecules to closer approach resulting in decreasing L_f with increasing concentration. Increasing temperature leads to increase in mean free distance between molecules and increase of free length [18].

Figure 3 and 4

Table-3 shows specific acoustic impedance (Z) increases with concentration and also with temperature for solutions of L-Arginine with Fructose (aq). This may be due to the variation of pressure from particle to particle [19]. The increase in Z values with solute concentration can be attributed to the effective solute-solvent interactions. Similar type of behavior has been observed for some amino acids studied in various solvent systems [20]. Since the acoustic impedance is a measure of the resistance offered by the liquid medium to the sound wave and is a function of the elastic property of the medium, gets affected by the structural changes of the solution. The increasingly higher values with increase in the solute concentration shows that the solution medium in each case starts gaining its elastic property [21]. The relaxation time is in the order 10^{-10} sec is due to structural relaxation process[22, 23] showing the presence of molecular interactions and in such a situation it is suggested that the molecules get rearranged due to co-operative process[24]. This suggest that the closed packing of molecules inside the shield.

In general, [25] the types of interactions occurring between arginine and fructose can be classified as follows (a) The hydrophilic–ionic interaction between OH groups of fructose and zwitterions of arginine. (b) Hydrophilic–hydrophobic interaction between the OH groups of fructose molecule and non-polar (–CH2) in side chain of arginine molecule. Arginine in aqueous-sugar solutions can be explained by considering the size of primary and secondary salvation layers around the zwitterions. At higher temperatures the solvent from the secondary salvation layer of arginine zwitter ions is released into the bulk of the solvent, resulting in the expansion of the solution [26], [27]. This further supports the conclusion that the hydrophilic– ionic group interactions between OH groups of fructose with zwitter ions dominate in these systems.

CONCLUSION

In the present study, the experimental values for the density, viscosity and ultrasonic velocity of, L-arginine in aqueous fructose solutions at different temperatures were measured. From these data an attempt has been made to explain the existence of hydrogen bonding and hydrophilic interactions that occur between the Zwitter ionic centre of the amino acids and the –OH group of fructose. It is concluded that there exist strong solute-solvent interactions, which increases with increase in amino acid concentration. Hence it is evident that the ultrasonic velocity measurements in a given medium serve as a powerful probe in characterizing the physico-chemical properties of that medium.

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Table 1 Values of density (ρ), viscosity (η) and ultrasonic velocity (U) of Arginine in aqueous 5% fructose solution

Molality (mol/Kg)	ρ Kgm^{-3}			η x 10^{3} Nsm^{-2}			U ms^{-1}		
	Temperature (K)								
	303K	308K	313K	303K	308K	313K	303K	308K	313K
0	1022	1011	0927	0.8009	.7487	.6904	1491.9	1516.2	1545.6
0.21	1024	1022	1017	.8573	.7564	.6959	1494.5	1521.6	1583.2
0.42	1027	1021	1019	.8877	.7908	.7309	1502.5	1524.8	1561.3
0.63	1029	1024	1020	.8992	.8024	.7560	1508.4	1530.0	1566.8
0.84	1032	1030	1021	.9476	.8676	.7651	1511.8	1534.5	1574.0
1.05	1035	1028	1023	.9699	.8496	.7587	1527.8	1539.0	1583.0

Table 2 Values Adiabatic compressibility, free length of Arginine in aqueous 5% fructose solution

Molality (mol/Kg)	Adiabatic compressibility x10^{-10} N^{-1}m^{2}			Free length x10^{-11} m		
	303K	308K	313K	303K	308K	313K
0	4.39612	4.30265	4.51571	4.18353	4.13882	4.24005
0.21	4.37228	4.22618	4.07591	4.17217	4.10187	4.02829
0.42	4.31321	4.21258	4.02581	4.14389	4.09527	4.00345
0.63	4.27122	4.17174	3.99367	4.12367	4.07537	3.98744
0.84	4.23967	4.12315	3.95335	4.10841	4.05156	3.96726
1.05	4.13930	4.10705	3.90088	4.05949	4.04365	3.94085

Table 3 Values, Acoustic impedance and Relaxation Time of Arginine in aqueous 5% fructose solution

Molality (mol/Kg)	Acoustic impedance $x\ 10^{-6}\ kgm^{-2}\ s^{-1}$			Relaxation Time $x10^{-10}$ s		
	303K	308K	313K	303K	308K	313K
0	1.5247	1.5328	1.4327	4.6933	4.29412	4.15582
0.21	1.5303	1.5550	1.5796	4.99656	4.26118	3.78095
0.42	1.5430	1.5568	1.5909	5.10384	4.44064	3.9223
0.63	1.5521	1.5667	1.5981	5.11962	4.46209	4.02462
0.84	1.5601	1.5805	1.6070	5.35534	4.76847	4.03193
1.05	1.5812	1.5820	1.6194	5.3516	4.6513	3.94514

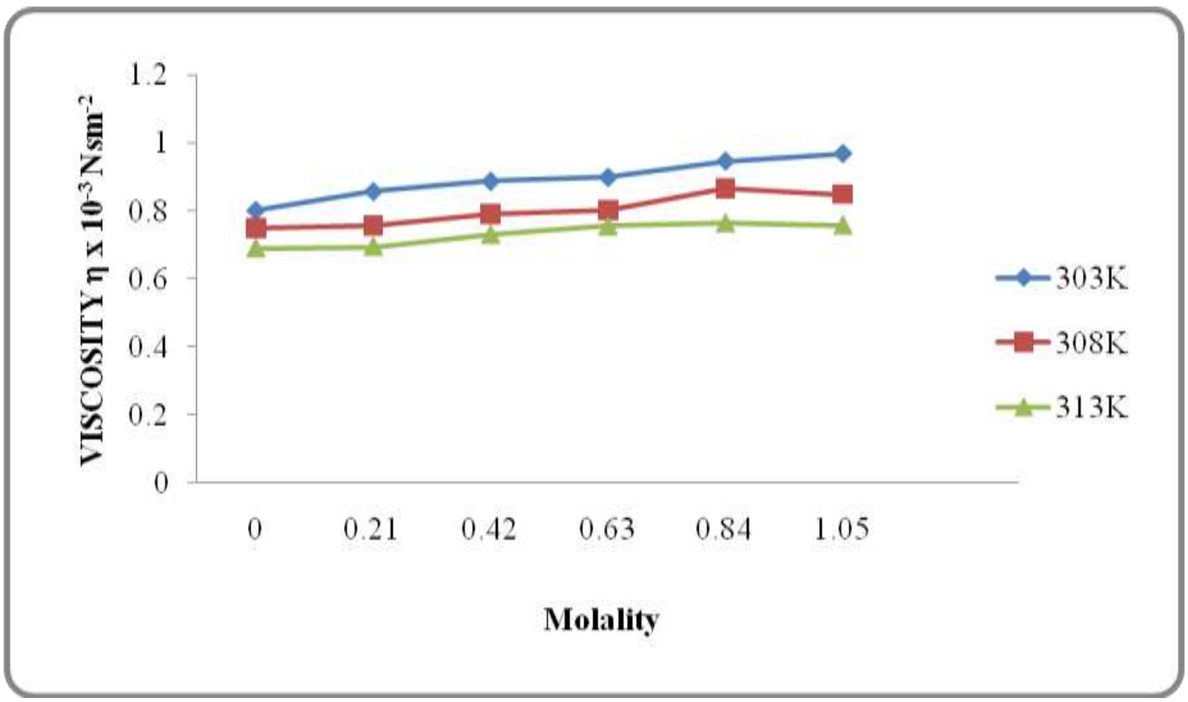

Fig 1 Plot of Viscosity vs. Molality

Fig.2 shows the plot of Viscosity of amino acid in aqueous fructose solution over the entire composition range respectively.

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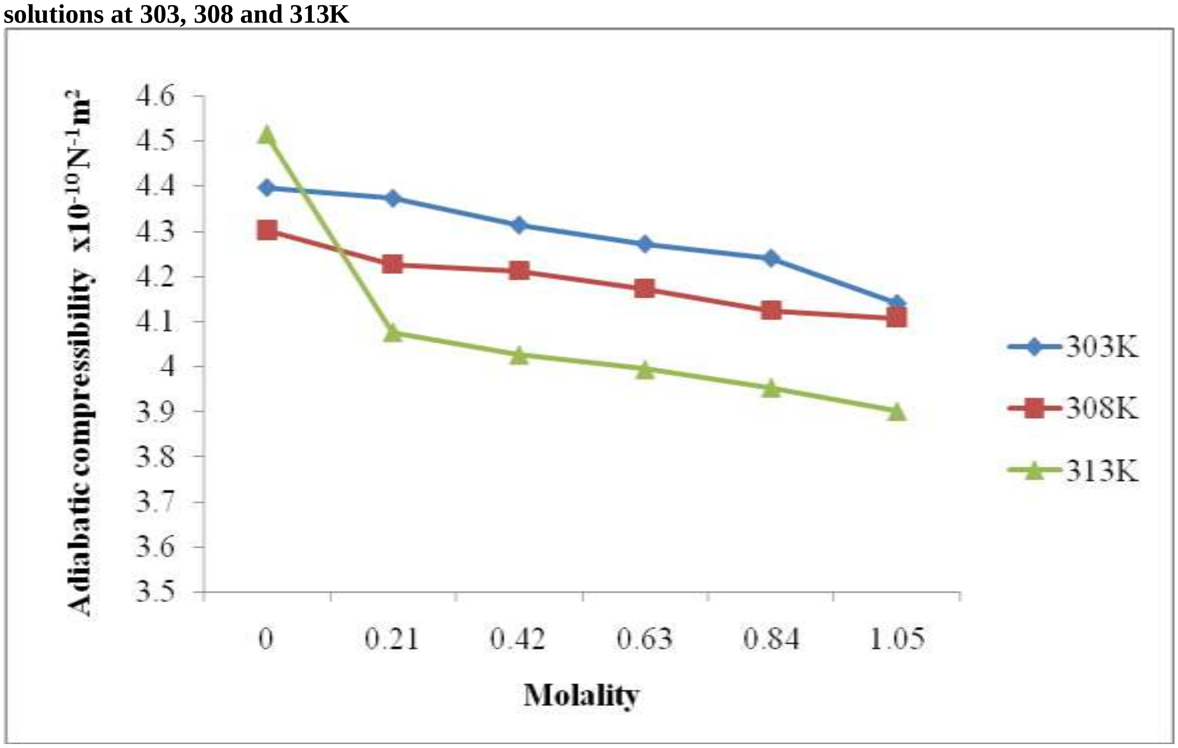

Fig 2 Plot of Adiabatic Compressibility vs. Molality

Fig.2 shows the plot of adiabatic compressibility of amino acid in aqueous fructose solution over the entire composition range respectively.

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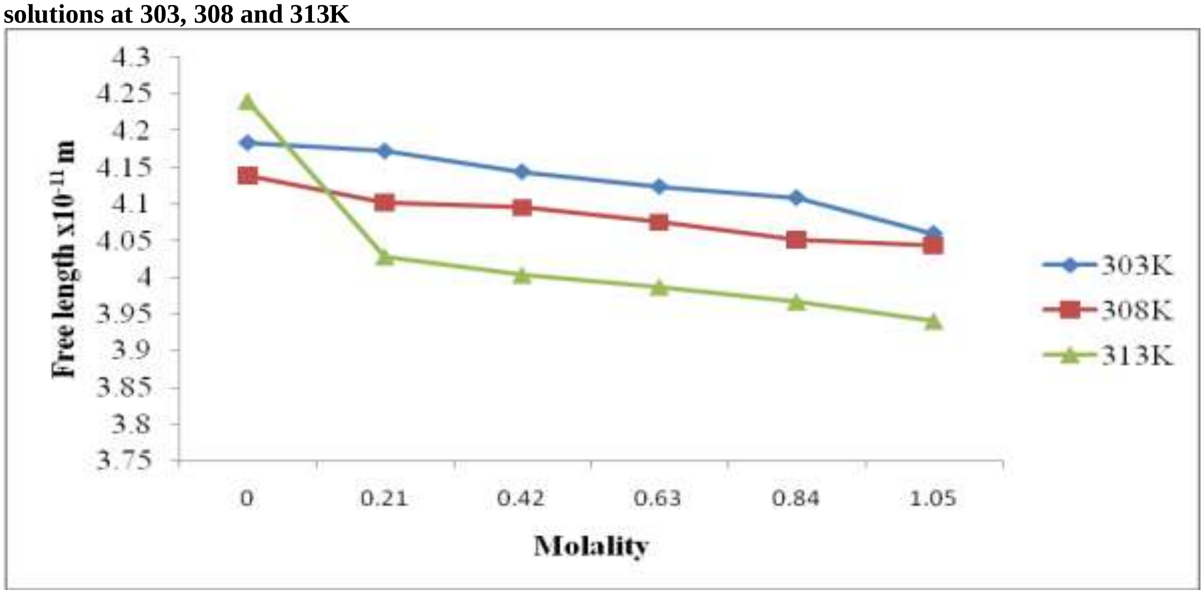

Fig 3 Plot of Free Length vs. Molality

Fig.3shows the plot of free length of amino acid in aqueous fructose solution over the entire composition range respectively.

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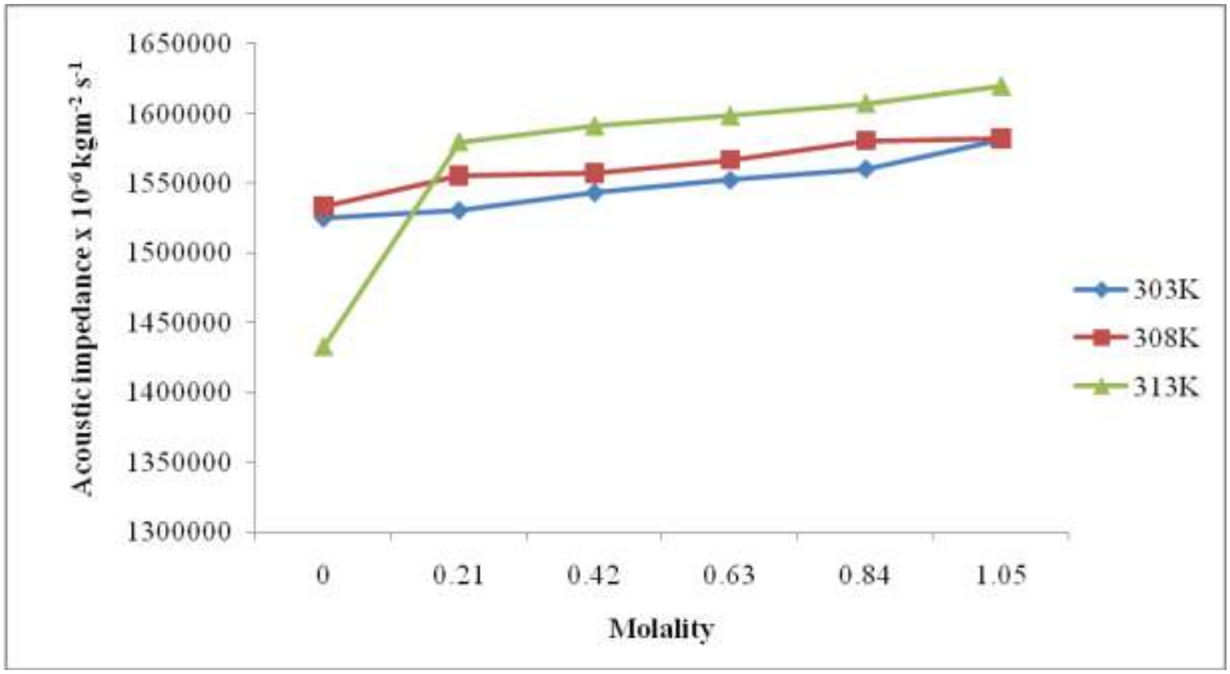

Fig 4 Plot of Acoustic Impedance vs. Molality

Fig.4 shows the plot of acoustic impedance of amino acid in aqueous fructose solution over the entire composition range respectively.

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