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Thermodynamic Studies on Some Bio-Molecule Aqueous Solution at 303.15K Using Ultrasonic Technique

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Abstract: ***The ultrasonic velocity measurements find wide application in characterizing the physic-chemical behavior of liquid mixtures. Thermodynamic investigations make innovations in the study of molecular interactions of solute-solute, solute-solvent, solvent-solvent in liquids. The ultrasonic parameters are directly related to a number of thermodynamic parameters. The ultrasonic velocity and density measurements have been carried out for aqueous solution of Gelatin as a function of concentration, at 303.15Ktemperature and at frequency 2MHz. From the experimental data, thermodynamic parameters such as adiabatic compressibility (β) and specific acoustic impedance (Z) for the binary mixtures have been computed. These thermodynamic parameters have been further used to elicit the ion-ion and solute-solvent in the binary mixtures.***

Keywords: Ultrasonic velocity, density, adiabatic compressibility, acoustic impedance, gelatin.

1. Introduction

The study of molecular interaction in the liquid mixtures is of considerable in the elucidation of the structural properties of the molecules. The intermolecular interactions influence the structural arrangement along with the shape of the molecules [12]. Amino acids are among the simplest biomolecules that contain intramolecular hydrogen bonds. They serve as building blocks on more complex peptides and proteins. In aqueous medium amino acids exist as dipolar ions manifesting a unique hydration behavior which is linked to the vital biological phenomenon. Therefore the study of amino acids is important in unfolding the role of dipolar ions in the biological system [3,5,7,8,11,16].

The properties of side chain groups of amino acids in aqueous solution of metal complexes have been studied by many workers [10,14,17,19,21]. The biomolecule aspartic acid is a non-essential amino acid and important in antibody synthesis, immune system, production of immunoglobulin, cell functioning and in proper functioning and balancing of the brain. Volumetric and acoustical parameters of biomolecules, such as the partial molar volume, adiabatic compressibility can be used for discriminating water molecules solvating charged, polar and non-polar atomic groups [1,6,22]. Literature survey reveals that data on proptein (Gelatin) in aqueous solution is scanty. Hence it was found interesting to study the thermodynamic behavior of protein in aqueous medium.

In the present work, the study on aqueous protein interaction has been carried out using thermodynamic parameters. Ultrasonic velocity and density measurement of aqueous solution of protein at various concentrations at 303.15K temperature can be used to compute various thermodynamic parameters. The result obtained from these thermodynamic parameters was interpreted on the basis of molecular interactions.

2. Experimental Details

The gelatin (as a protein) used was purified AR grade sample in solid state. All chemicals were used without further purification. To prepare binary liquid mixture of gelatin+water system, the glass distilled water was used. To prepare gelatin+water mixture, gelatin from BDH were used. A standard solution of 10% gelatin was prepared. To enhance the dissolution, the mixture was kept in warm water bath during preparation. From above standard solution, solutions of concentration 1,2,3,4,5,6,7,8,9 and 10% were prepared by using a matter balance(Switzerland) with a precision of 0.01 mg.. These solutions were kept in special airtight bottles and used within 12 hours after preparation.

The ultrasonic velocity was measured by a single crystal interferometer (F-81, Mittal Enterprise, New Delhi.) operating at frequency of 2 MHz The interferometer was calibrated against the ultrasonic velocity of water used at T=298.15K. The present experimental value is 1497.08 ms-1 which is in good agreement with literature value [16] 1496.69 and accuracy in velocity measurement is +- 10ms-1.

The density measurements were carried out by using specific gravity bottle of 25 ml with an accuracy in measurements is +- 1x10-4 g/cm3. An average of triple measurements was taken into account. During experiment desire temperature was maintained constant by circulating water with the help of thermostatic water bath with accuracy in temperature +-0.1K.

3. Results and Discussion

The ultrasonic velocities and densities of binary liquid mixture of gelatin+water as a function of concentration at temperature 303.15K are presented in Table 1. Thermodynamic parameters such as adiabatic compressibility (β), intermolecular free length (Lf) and acoustic impedance (z) were calculated from empirical Jacobson's relations [1,6,21]

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$\beta = 1/u2p$ ……. (1)
$L = K/up1/2$ ……. (2)
$z = up$ ……. (3)

Where, K is temperature constant, u the ultrasonic velocity, ρ the density of solution. Calculated thermodynamic derived parameters are reported in Table 1.

Ultrasonic velocity of gelatin+water have been measured with the help of ultrasonic interferometer at 2 MHz Study of the variation of ultrasonic velocity of gelatin at various concentrations at 303.15K temperature in solvent of water shows the variations to be non-linear. This indicates that there is strong interaction in the gelatin+water systems. Adiabatic compressibility (β) is influenced by the ultrasonic velocity and the density (ρ). The variation of ultrasonic velocity of a system with concentration of gelatin in water can be expressed in terms of density and adiabatic compressibility by equation (4).

$$du/dc = u/2 \times 1/d \times d\square/dc + 1/\beta \times d\beta/dc \ldots\ldots\ldots (4)$$

The sign and magnitude of quantity dρ/dc and dβ/dc indicate that H-bonded structure of H2O is disrupted by increasing concentration of gelatin in water. Consequently, ultrasonic velocity of system increases depending on the structural properties of solutes [22]. The solute that increases the ultrasonic velocity is of structure maker [9,18] types.

The ultrasonic velocity of gelatin+H2O has been determined at 303.15K. The resulted values are shown in Table1. Ultrasonic velocity increased with the increase in concentration but at 7% concentration we get sharp peak i.e. variation of ultrasonic velocity is non-linear. Sharp peak is due to molecular interaction exists in gelatin+water as shown in Fig.1.

Density of gelatin+water binary system was determined as a function of concentration at temperature 303.15K as shown in Fig.2. Density is known to be a measure of ion-solvent and solvent-solvent interactions. Density increases with increase in concentration due to the presence of ions of particles due to increased electrostriction in binary system. This electrostriction decreases the volume and hence increases the density [13,16]. This shows that there are dipole-dipole interactions between binary system.

The adiabatic compressibility (β) is a measure of intermolecular association or repulsion. The variation of adiabatic compressibility with mole fraction of geltin+water binary system is shown in Fig.3 which is a non-linear. The non-linear behavior may be due to association mechanism taking place in binary system.

In binary system it is observed that a value of acoustic impedance (z) varies with increase in solute concentration at 303.15K temperature. As shown in Fig.4, the curve exhibits exactly reverse variation compared to adiabatic compressibility (β). Because of adiabatic compressibility and acoustic impedance are inversely related to each other [16]. This indicates significant interaction in the system. It also indicates the presence of molecular association between solute-solvent molecules in the binary system.

4. Conclusions

In the present study, experimental results for ultrasonic velocity and density are reported for gelatin+water binary system as a function of concentration at 303.15K. The variation in ultrasonic velocity and density suggest that a molecular interaction exist between solute and solvent molecules. The other related thermodynamic parameters such as adiabatic compressibility and acoustic impedance of gelatin+water binary system at various concentrations at 303.15K temperature show the variation to be non-linear. From non-linear variation, it can be concluded that the existence of solute-solvent, ion-ion, dipole-dipole, ion-solvent interactions. The solute that increases the ultrasonic velocity is of structure maker.

5. Table and Figures

Table 1: Ultrasonic velocities and densities of Gelatin in aqueous solution at 303.15K

Conc. % (mole/lit)	u (m/s)	ρ (*103 Kg/m^3)	β (10-10 m^2/s)	Z (* 10-6 Kg/m^2 s)
1	1450.3	0.9605	4.95	1.393
2	1460.7	0.9983	4.695	1.4581
3	1470.7	1.0055	4.598	1.4787
4	1471.6	1.02	4.527	1.501
5	1474.7	1.0268	4.478	1.514
5.5	1476	1.0288	4.462	1.5185
6	1477.7	1.0292	4.45	1.5208
6.5	1479.3	1.031	4.432	1.5251
7	1570.3	1.0326	3.927	1.6214
8	1521.1	1.033	4.184	1.5712
9	1510.2	1.0375	4.226	1.568
10	1496.9	1.038	4.299	1.5537

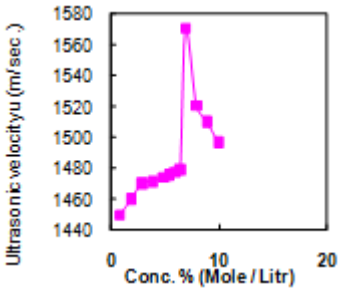

Figure 1: Plot of Variation of ultrasonic velocity (u) with Concfor gelatin + water system at 303.15K.

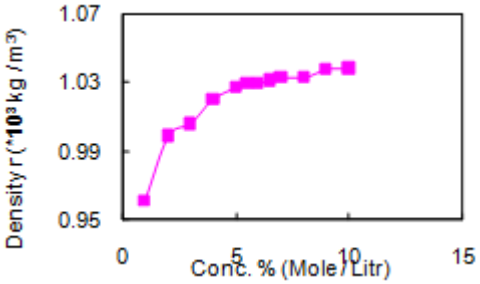

Figure 2: Plot of Variation of density with Conc. For gelatin + water systemat 303.15K

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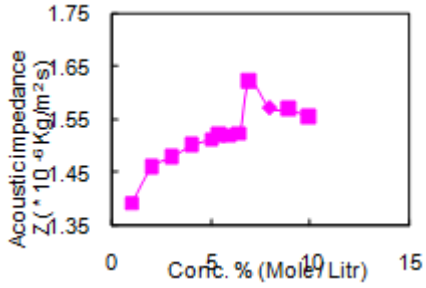

Figure 3: Plot of Variation of adiabatic compressibility (β) with Conc. for gelatin + water system at 303.15K.

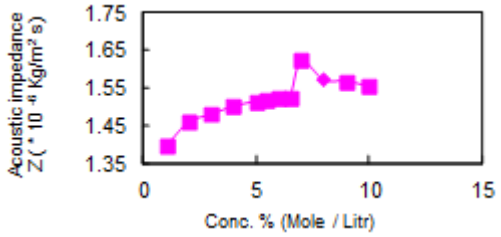

Figure 4: Plot of Variation of acoustic impedance (z) with Conc.for gelatin + water systemat 303.15K

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