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Ultrasonic Study of Molecular Interactions in some Bio-Molecule Aqueous Solution at 308K

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Abstract: ***The ultrasonic velocity and density have been measured for the aqueous solution of Gelatin as a function of concentration, at 308Ktemperature. The ultrasonic velocity measurements of binary mixture were carried out at frequency 2MHz. The experimental data have been used to calculate the thermodynamic parameters such as adiabatic compressibility (β) and specific acoustic impedance (Z). These thermodynamic parameters have been further used to elicit in terms of molecular interactions present in the binary mixtures.***

Keywords: Ultrasonic velocity, density, adiabatic compressibility, acoustic impedance, Protein as a gelatin, molecular interaction

1. Introduction

When you submit your paper print it in two-column format, including figures and tables [5]. In addition, designate one author as the “corresponding author”. This is the author to whom proofs of the paper will be sent. Proofs are sent to the corresponding author only [3].

Physical properties of liquid mixtures are required in most of the engineering calculations where fluid flow or mixing is an important factor in many practical problems concerning mass transport applications. Ultrasonic studies on aqueous solutions of nonelectrolytes in the water rich region are extensive[3-5,11,12,15,18] while the studies in the organic rich region are very few[19,25]. A distinctive extrema in ultrasonic velocity versus concentration of organic solutes in the water rich region have been observed in many water + nonelctrolyte systems. This behavior has been attributed to the modification or stabilization of the hydrogen bonded structure of water by the organic solutes.

Ultrasonic velocity studies[6,26] in aqueous and non aqueous electrolyte solutions have led to new insights in the solvation process. Consequently, the characterization these interactions can assist in understanding the thermodynamic stability of proteins and their unfolding behavior. Electrolytes [10] dissolving in water have been classified as structure makers or structure breakers, depending on charge density. It has been reported that the interactions of electrolytes in aqueous solution of protein play a vital role in understanding the behavior of bioactive molecules in the body system[7,9,13,23,24]. The present paper is an extension of such studies which deals with the ultrasonic behavior of Gelatin(as a protein) in a water.

Experimental Details

Thepurified AR gradegelatin (as a protein) was used for sample preparation. All chemicals were used without further purification. Binary mixtures were prepared by mass in airtight bottles. To prepare binary liquid mixture of gelatin+water system, the glass distilled water and gelatin from BDH were used. A standared solution of 10% gelatin was preparedusing . To enhance the dissolution, the mixture was kept in warm water bath during preparation. From above standared solution, solutions of concentration 1,2,3,4,5,6,7,8,9 and 10% were prepared. These solutions were kept in special airtight bottles and used within 12 hours after preparation.

The ultrasonic velocity values were measured using a variable path single crystal interferometer model F-81 supplied by Mittal Enterprises, New Delhi with an accuracy +-2ms-1. In the present study, frequency of 2 MHz was employed and instrument was calibrated using water at T=298.15K. The present experimental value is 1497.08 ms-1 which is in good agreement with literature value[10] 1496.69.

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.

Results and Discussion:

The experimentally measured ultrasonic and densities of binary liquid mixture of gelatin+water at temperature 308.15K have been used to evaluate derived properties like adiabatic compressibility(β) and acoustic impedance (z) using well established equations i.e. empirical Jacobson’s relations[1,16,20]

$$\beta = 1/u2\boldsymbol{\rho} \quad \text{.....(1)}$$

$$z = u\boldsymbol{\rho} \quad \text{.....(2)}$$

Where, K is temperature constant, u the ultrasonic velocity, $\boldsymbol{\rho}$ 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 and at 308.15K temperature in solvent of water. It shows the variations to be non-linear. This indicates that there are strong interaction in the gelatin+waterystems. Adiabatic compressibility(β) is influenced by the ultrasonic velocity and the density ($\boldsymbol{\rho}$). The variation of ultrasonic

velocity of a system with concentration of gelatin in water at given temperature can be expressed in terms of density and adiabatic compressibility by equation(4)

$$du/dc=u/2x1/dx d\rho/dc+1/\beta x d\beta/dc \quad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

The sign and magnitude of quantity dq/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[14]. The solute that increase the ultrasonic velocity is of structure maker[17,2] types.

Plot Fig. 1. shows the 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 at 7% concentration is due to molecular interaction exists in gelatin+water. This is due to maximum possible association in aqueous Gelatin solution because of the presence of OH-groups. The protein occupy the interstitial space of water and tend to break the original ordered state of water due to its self-association. But with increase in concentration there occurs structural rearrangement as a result of hydration[8,21] leading to a comparatively more ordred state.

As shown in Fig.2.Density of gelatin+water binary system was determined as a function of concentration at 308.15K temperature. The variation of Density is a linear with concentration. Density increases with increase in concentration due to the presence of ions of particals due to increased electrostriction in binary system. This eletrostriction decreases the volume and hence increases the density[20]. This shows that there are dipole-dipole interaction 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 as shown in Fig. Initially from 1% to 6% concentration adiabatic compressibility decreases slowly and at 7% conc. there is a sudden increase. This show a sharp lower dip at 7% conc. This sharp dip may be due to association mechanism taking place at that concentration as shown in Fig.3.

Table 1: Ultrasonic velocities and densities of Gelatin in aqueous solution at 308.15K

Conc. % (mole/lit)	u (m/s)	ρ (*10^3 Kg/m^3)	β (10-10 m2/s)	Z (*10^{-6} Kg/m^2 s)
1	1460.1	0.959	4.891	1.4002
2	1470.1	0.9959	4.646	1.464
3	1477.2	1.0052	4.559	1.4848
4	1479.2	1.0196	4.482	1.5081
5	1484.53	1.0254	4.425	1.5222
6	1487.13	1.0288	4.395	1.5299
7	1600.9	1.0312	3.784	1.6508
8	1538.7	1.0319	4.093	1.5877
9	1515	1.0365	4.203	1.5702
10	1501.6	1.0371	4.276	1.5573

In binary system it is observed that values of acoustic impedance (z) vary with increase in solute concentration at 308.15K temperature. As shown in Fig.4, the curve exhibits exactly reverse variation compared to adiabatic compressibility (β). Because adiabatic compressibility and acoustic impedance are inversely related to each other [14]. This indicates the presence of molecular association between solute-solvent molecules in the binary system.

Conclusions

For binary mixture of aqueous Gelatin ultrasonic velocity and density have been measured at 308.15K. The variation in ultrasonic velocity, density and other related thermodynamic parameters such as adiabatic compressibility and acoustic impedance for given system shows the variation to be non-linear. Consequently, ultrasonic velocity of system increases depending on the structural properties of solutes. This behavior indicates significant interaction exist between the solute and solvent molecules suggesting structure promoting behavior. This provides useful information about inter and intera molecular interactions of the mixture as existing in the liquid system.

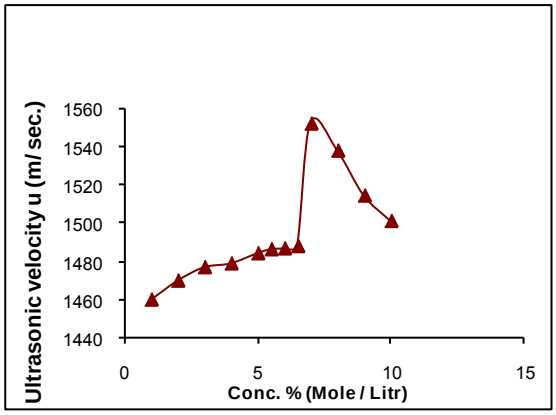

Figure 1 : Plot of Variation of ultrasonic velocity (u) with Conc. for gelatin + water system at 308.15K

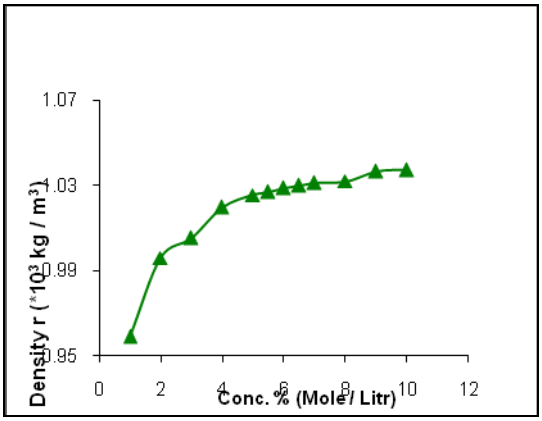

Figure 2 : Plot of Variation of density with Conc. for gelatin + water system at 308.15K

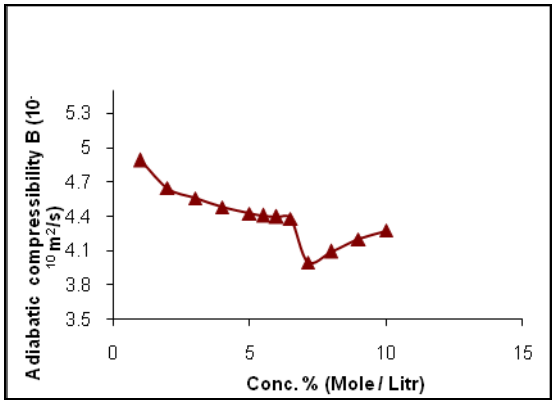

Figure 3 : Plot of Variation of adiabatic compressibility (β).with Conc for gelatin + water system at 308.15K

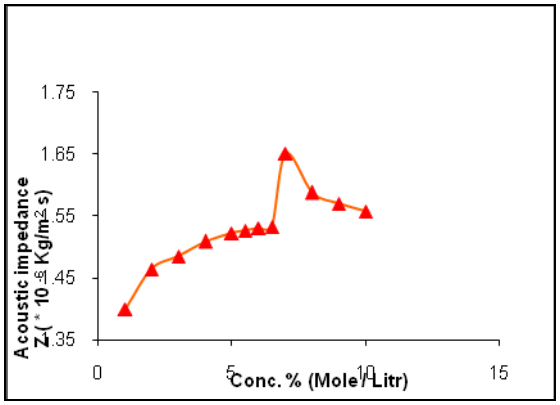

Figure 4 : Plot of Variation of acoustic impedance (z) with. Conc for gelatin + water system at 308.15K

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