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 303.15K temperature and at frequency 2 MHz. 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 protein (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]
The ultrasonic velocity of gelatin+H₂O has been determined as 1474.7 m/s at 7% concentration. The variation of ultrasonic velocity is influenced by the ultrasonic velocity and the density (ρ). 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

<table>
<thead>
<tr>
<th>Conc. % (mole/lit)</th>
<th>u (m/s)</th>
<th>ρ (*10³ Kg/m³)</th>
<th>β (10⁻¹⁰ m²/s)</th>
<th>Z (*10⁻⁶ Kg/m² s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1450.3</td>
<td>0.9605</td>
<td>4.95</td>
<td>1.393</td>
</tr>
<tr>
<td>2</td>
<td>1460.7</td>
<td>0.9983</td>
<td>4.695</td>
<td>1.4581</td>
</tr>
<tr>
<td>3</td>
<td>1470.7</td>
<td>1.0055</td>
<td>4.598</td>
<td>1.4787</td>
</tr>
<tr>
<td>4</td>
<td>1471.6</td>
<td>1.02</td>
<td>4.527</td>
<td>1.501</td>
</tr>
<tr>
<td>5</td>
<td>1474.7</td>
<td>1.0268</td>
<td>4.478</td>
<td>1.514</td>
</tr>
<tr>
<td>6</td>
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<td>1.0288</td>
<td>4.462</td>
<td>1.5185</td>
</tr>
<tr>
<td>7</td>
<td>1477.7</td>
<td>1.0292</td>
<td>4.45</td>
<td>1.5208</td>
</tr>
<tr>
<td>8</td>
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<td>1.031</td>
<td>4.432</td>
<td>1.5251</td>
</tr>
<tr>
<td>9</td>
<td>1507.3</td>
<td>1.0326</td>
<td>3.927</td>
<td>1.6214</td>
</tr>
<tr>
<td>10</td>
<td>1510.2</td>
<td>1.0375</td>
<td>4.226</td>
<td>1.568</td>
</tr>
</tbody>
</table>

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

Figure 2: Plot of Variation of density with Concentration for gelatin + water system at 303.15K.
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 system at 303.15K.

References


Author Profile

Dr. Sangita U. Shinde received the B.Sc. with subjects Physics, Chemistry, Electronics, M.Sc. (Physics), M.Sc. (Computer Science) and Doctorate of Philosophy in Physics, degrees from Deogiri College, Dr. Babasaheb Ambedkar Marathwada University Aurangabad, and in S.R.T. Marathwada University, Nanded, and M.S.India in 1992, 1994, 2001 and 2007 respectively. During 1996-2009, she stayed in Vivekananda College, Aurangabad as Lecturer. She work as a Principle on non-aided college during 2009 to 2010. She is working as a Assistant Professor in Department of Physics in Pratishthan Mahavidyalaya, Paithan, Aurangabad, M.S., India since 2010 to up to till date.