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Acoustical Studies of Some Bio-Molecule Aqueous Solution at Different Temperatures Using Ultrasonic Technique

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Abstract: ***Acoustic 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 interactions of urea and molecular dynamics, solute in solvent have been investigated by ultrasonic technique. The ultrasonic velocities and densities have been measured for aqueous solution of Gelatin as a function of concentration, at four different temperatures 298.15K, 303.15K, 308.15K and 313.15K and frequency 2MHz. The experimental data have been used to compute the thermodynamic properties namely adiabatic compressibility (), intermolecular free length () and specific acoustic impedance () for the binary mixtures with a view to investigate the solute-solute and solute-solvent interactions. 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, intermolecular free length, gelatin

1. Introduction

The ultrasonic study of liquids plays an important role in understanding the nature and strength of molecular interactions [18, 19]. A large number of studies have been made on the molecular interaction in liquid systems by various physical methods like, Raman effect [15], Nuclear Magnetic Resonance, ultra violet and ultrasonic method[6, 10]. In recent years ultrasonic technique has become a powerful tool in providing information regarding the molecular behavior of liquids and solids owing to its ability of characterizing physiochemical behavior of the medium.

The thermodynamics and transport properties of liquid mixtures have been extensively use [5, 22] to study the departure of a real liquid mixture behavior from ideality. Further, these properties have been widely used to study the intermolecular interaction between the various species in the mixture [1,3,4].

Most of the chemical and biological functions of biomolecules take place in aqueous medium. Ultrasonic waves are established an effective means for analyzing certain physical properties of the materials. The study of propagation of ultrasonic waves in liquid systems and solids is now rather well established. In recent year, there are extensive study of thermodynamics property of electrolytes in aqueous [7,8] or non-aqueous solution but very few on aqueous protein as temperature dependence [9,12,16] was reported.

In the present investigation the ultrasonic the ultrasonic velocity and density measurement of aqueous solution of protein at various concentrations and at various temperature can be used to compute various thermodynamic parameters. The used to compute various thermodynamic parameters. The results obtained from these thermodynamic parameters were 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/cm^3. 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 at various temperatures 298.15,

303.15, 308.15 and 313.15K are presented in Table 1-4. Thermodynamic parameters such as adiabatic compressibility (β), intermolecular free length (L_f) and acoustic impedance (z) were calculated from empirical Jacobson's relations [13, 16, 21]

$$\beta = 1/u^2p \quad (1)$$

$$L=K/up^{1/2} \quad (2)$$

$$z=up \quad (3)$$

Where, K is temperature constant, u the ultrasonic velocity, p the density of solution. Calculated thermodynamic derived parameters are reported in Table 1-4.

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 temperatures 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 (p). The variation of ultrasonic velocity of a system with concentration of gelatin in water in water can be expressed in terms of density and adiabatic compressibility by equation (4).

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

The sign and magnitude of quantity dq/dc and dβ/dc indicate that H-bonded structure of H_2O is disrupted by increasing concentration of gelatin in water and urea in water. Consequently, ultrasonic velocity of system increases depending on the structural properties of solutes [11]. The solute that increase the ultrasonic velocity is of structure maker [2,14] types.

The ultrasonic velocity of gelatin+H_2O has been determined at 298.15, 303.15, 308.15 and 313.15K. 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. Similar trend are observed for all temperature. Sharp peak is due to molecular interaction exists in gelatin+water as shown in Fig.1.

Density of gelatin+water and urea+water binary system was determined as a function of concentration and temperature as shown in Fig.2-3. Density is known to be a measure of ion-solvent and solvent-solvent interactions. As expected for given composition density increased with the increase in concentration of gelatin in binary mixture of gelatin+water and of urea in binary mixture of urea+water. 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 [17, 20]. This shows that there is 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 conc.

In binary system it is observed that a value of acoustic impedance (z) varies with increase in solute concentration at various temperature. As shown in Fig.7-8, the curve exhibits exactly reverse variation compared to adiabatic compressibility (β). Because adiabatic compressibility and acoustic impedance are inversely related to each other [17]. This indicates significant interaction in the system. It also indicates the presence of molecular association between solute-solvent molecules in the binary system.

The variation in ultrasonic velocity depends on the intermolecular free length (L_f) on mixing which is a predominant factor in determining the variation of ultrasonic velocity in the fluids and their solution. It has been observed in the present study that in gelatin+water system intermolecular free length (L_f) decreases up to 6% conc. with increase in conc. There is a sharp lower dip at 7% conc. for all temperatures may be due to association mechanism taking place at that conc. as shown in Fig.7. This behaviour indicates significant interaction exist between the solute and solvent molecules suggesting structure promoting behavior.

4. Conclusions

Ultrasonic velocity and density have been measured for gelatin+water binary system at 298.15, 303.15, 308.15 and 313.15K. The variation in ultrasonic velocity, density and other related thermodynamic parameters such as adiabatic compressibility, acoustic impedance and intermolecular free length of gelatin+water binary system at various concentrations and temperature shows the variation to be non-linear. Consequently, ultrasonic velocity of system increases depending on the structural properties of solutes. It is well known that solutes causing electrostriction lead to decrease in the compressibility of the solution. Hydrophilic solutes often show negative compressibility. The solute that increases the ultrasonic velocity is of structure maker. The non-linearly confirms presence of solute-solvent, ion-ion, dipole-dipole, ion-solvent interactions. The observed molecular interaction, complex formation and hydrogen bond formation are responsible for the hetromolecular interaction in the liquid mixture. This provides useful information about inter and intera molecular interactions of the mixture as existing in the liquid system.

Future scope was to find out the different excess parameters which may helps to predict molecular interactions in a system.

Table 1: Ultrasonic velocities and densities of Gelatin in aqueous solution at 298.15K

Conc. % (mole/lit)	u (m/s)	ρ (*10^3 Kg/m^3)	β (10-10 m2/s)	Z (* 10^{-6} Kg/m^2 s)	L_f (* 10^{-6} m)
1	1440.23	0.9625	5.009	1.3862	0.1401
2	1443.22	0.9987	4.807	1.4413	0.1372
3	1458.13	1.0076	4.668	1.4692	0.1353
4	1461.2	1.0217	4.584	1.4929	0.134
5	1466.13	1.0271	4.529	1.5058	0.1332
5.5	1468.51	1.0296	4.504	1.5119	0.1329
6	1469.4	1.0301	4.496	1.5136	0.1327
6.5	1470.66	1.0322	4.479	1.518	0.1325
7	1523.73	1.0337	4.167	1.575	0.1278
8	1504.8	1.035	4.267	1.5574	0.1293
9	1500.2	1.0384	4.29	1.5578	0.1297
10	1482.5	1.0395	4.377	1.541	0.131

Table 2: Ultrasonic velocities and densities of Gelatin in aqueous solution at 303.15K

Conc. % (mole/lit)	u (m/s)	ρ (*103 Kg/m3)	β (10-10 m2/s)	Z (* 10-6 Kg/m2 s)	Lf (* 10-6 m)
1	1450.3	0.9605	4.95	1.393	0.1404
2	1460.7	0.9983	4.695	1.4581	0.1367
3	1470.7	1.0055	4.598	1.4787	0.1353
4	1471.6	1.02	4.527	1.501	0.1343
5	1474.7	1.0268	4.478	1.514	0.1335
5.5	1476	1.0288	4.462	1.5185	0.1333
6	1477.7	1.0292	4.45	1.5208	0.1331
6.5	1479.3	1.031	4.432	1.5251	0.1328
7	1570.3	1.0326	3.927	1.6214	0.125
8	1521.1	1.033	4.184	1.5712	0.1291
9	1510.2	1.0375	4.226	1.568	0.1297
10	1496.9	1.038	4.299	1.5537	0.1308

Table 3: Ultrasonic velocities and densities of Gelatin and urea 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)	L_f (* 10^{-6} m)
1	1460.1	0.959	4.891	1.4002	0.1407
2	1470.1	0.9959	4.646	1.464	0.1371
3	1477.2	1.0052	4.559	1.4848	0.1358
4	1479.2	1.0196	4.482	1.5081	0.1346
5	1484.53	1.0254	4.425	1.5222	0.1338
5.5	1486.66	1.027	4.406	1.5267	0.1335
6	1487.13	1.0288	4.395	1.5299	0.1333
6.5	1488.33	1.03	4.383	1.5329	0.1332
7	1600.9	1.0312	3.784	1.6508	0.1237
8	1538.7	1.0319	4.093	1.5877	0.1287
9	1515	1.0365	4.203	1.5702	0.1304
10	1501.6	1.0371	4.276	1.5573	0.1315

Table 4: Ultrasonic velocities and densities of Gelatin and urea in aqueous solution at 313.15K

Conc. % (mole/lit)	u (m/s)	β (10-10 m2/s)	Z (* 10^{-6} Kg/m^2 s)	L_f (* 10^{-6} m)
1	1472.1	4.816	1.4104	0.1409
2	1480.33	4.585	1.4732	0.1375
3	1486.8	4.502	1.4939	0.1362
4	1489.86	4.428	1.1515	0.1351
5	1491.2	4.389	1.528	0.1345
5.5	1492.26	4.38	1.5298	0.1344
6	1493.6	4.368	1.5327	0.1342
6.5	1494.93	4.346	1.539	0.1338
7	1549	4.057	1.5911	0.1293
8	1544	4.073	1.5903	0.1296
9	1520	4.184	1.5722	0.1313
10	1506	4.255	1.5605	0.1324

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

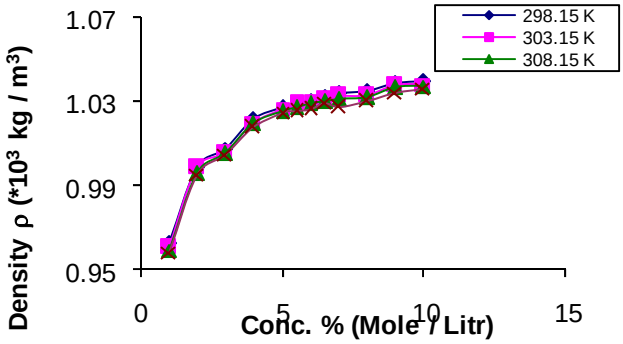

Figure 2: Plot of Variation of density with Conc. For gelatin + water system

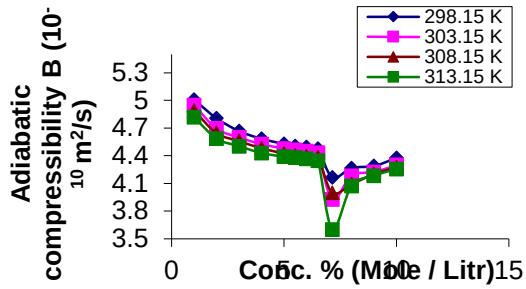

Figure 3: Plot of Variation of adiabatic compressibility (β) with Conc. for gelatin + water system

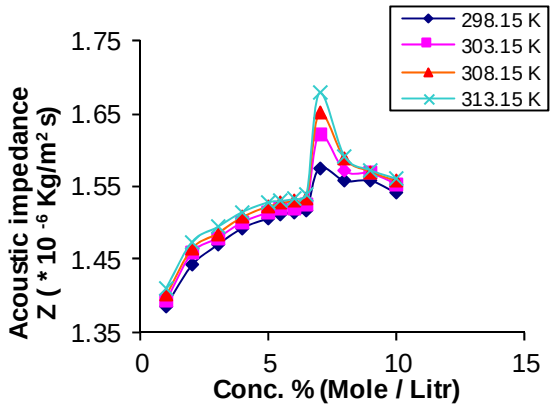

Figure 4: Plot of Variation of acoustic impedance (z) with Conc for gelatin + water system

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