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Studies of Acoustic and Thermodynamic Properties of Electrolytes in Double Distilled Water at 303.15K

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Abstract: ***The ultrasonic velocity, density and viscosity at 303.15K have been measured . for electrolytes (NaCl and Mgcl$_2$) in double distilled water at 303.15K .From experimental data acoustical parameters such as adiabatic compressibility (β_a), acoustic impedance (z), intermolecular free length (L_f), relative association (R_A) have been estimated using the standard relations with various concentrations and temperatures, with a view to investigate the exact nature of the molecular interaction. Adiabatic compressibility and intermolecular free length decreases with increase in concentration and temperature and gradually increases with concentration of solutes. These parameters have further used to interpret the hydrophilic part o f the solute and molecular interactions in the solutions.***

Keywords: Acoustic, thermodynamic parameters, electrolytes, molecular interaction, hydrophilic components of the mixtures.

1. Introduction

The ultrasonic velocity (u) , density (ρ) and viscosity (η)can be used to study the physicochemical behavior and molecular interactions such as ion-solvent interaction and solvent-solvent in pure liquids, liquid mixtures and solutions[1-3].The nature and degree of molecular interactions in different solutions changes depending upon the nature of solvent, the structure of solute molecule and extent of solution taking place in the solution[4-5]. Acoustical impedance (z), adiabatic compressibility (β_a), intermolecular free length(L_f),relative association (R_A) are function of ultrasonic velocity .As these parameters throw more light on ion- ion and ion-solvent interactions, an ultrasonic and thermodynamic study of electrolytes.

NaCl and $MgCl_2$ having specialized properties like low melting but high boiling point. Both electrolytes are soluble in H_2O at 20^0C. Both electrolytes are insoluble in ether[6]. These electrolytes are also called as electrovalent compounds. NaCl is acts as a monovalent compound where $MgCl_2$ acts as a divalent compounds. As it occurs in metabolism of almost all living things , its interactions in an aqueous solution is of great value to the biological scientists.. It has wide applications in medicine and industry.

2. Experimental Section

All the chemicals used were of AR grade and dried over anhydrous $CaCl_2$ in desiccators before use. All solutions were prepared in deionized and distilled water (degassed by boiling), having specific conductivity ~ 10^{-6} S cm^{-1}. The stock solutions of 1M concentration were prepared by weighing the serine on a digital balance with an accuracy of ± 1 x 10^{-4} g. Solutions of NaCl & $MgCl_2$ were made by mass on the mole fraction scale. Uncertainties in solution concentrations were estimated at ± 1 x 10^{-5} mol kg^{-1} in calculations. The solutions were kept in the special air tight bottles and were used within 12 hrs after preparation to minimize decomposition due to bacterial contamination. Ultrasonic velocity was measured with a single crystal interferometer (F- 81, Mittal Enterprises, New Delhi) at 2MHz The interferometer was calibrated against the ultrasonic velocity of water used at T = 303.15K. The present experimental value is 1508.80 ms^{-1} which is in good agreement with literature value 1509.55 ms^{-1}. Accuracy in the velocity measurement was ± 1.0 ms^{-1}. The density measurements were performed with recalibrated specific gravity bottle with an accuracy of ± 2x10^{-2} kg m^{-3}. An average of triple measurements was taken into account. Sufficient care was taken to avoid any air bubble entrapment. Viscosity was measured with recalibrated Ostwald type viscometer. The flow of time was measured with a digital stop watch capable of registering time accurate to ± 0.1 s. An average of three or four sets of flow of times for each solution was taken for the purpose of calculation of viscosity. The accuracy of the viscosity measurements was ± 0.5 %. Accuracy in experimental temperature was maintained at ± 0.1K by means of thermostatic water bath.

3. Results and Discussion

From the measured values ultrasonic velocity(u), density(ρ) and viscosity (η) various acoustical parameters such as the adiabatic compressibility(β_a),acoustic impedance (z), intermolecular free length (L_f) and relative association (R_A) were calculated by using the following relations[7,8,9,10]

$$\text{Ultrasonic velocity } (u) = n\times\lambda \qquad (1)$$

$$\text{Adiabatic compressibility } (\beta_a) = 1/u^2\rho \qquad (2)$$

$$\text{Acoustic impedance } (z) = u.\rho \qquad (3)$$

$$\text{Intermolecular free length } (L_f) = K / u.\rho^{1/2} \qquad (4)$$

$$\text{Relative association } (R_A) = (\rho /\rho_o).\,(u_o / u)^{1/3} \qquad (5)$$

Where, K is the temperature dependant Jacobson constant[11].

The values of K x 10^4 are taken as 207.556 x 10^{-8},209.431 x 10^{-8} and 211.306 x 10^{-8} at 303.15, 308.15and 313.15K. T is the absolute temperature, ρ_0, ρ and u_0, u are the density and ultrasonic velocity of solvent and solution respectively.

The experimentally measured values of ultrasonic velocity (u), density (ρ) and viscosity (η) of the solutions and calculated values of acoustical parameters such as adiabatic compressibility (β_a),acoustic impedance (z), intermolecular free length (L_f) and relative association (R_A) are reported in Table -1 for the systems (water + NaCl) and Table-2 for the system (water+ $MgCl_2$) respectively.

Table 1: Ultrasonic velocities, densities, adiabatic compressibility's, acoustic impedances, free lengths ,relative association numbers of NaCl in double distilled water at 2MHz at 303.15K.

Double distilled Water +NaCl

m mol kg^{-1}	u ms^{-1}	ρ Kg m^{-3}	η $Nm^{-2}s$	βx10^{-10} m^2N^{-1}	zx10^{-6} Nm^{-2}	L_f A^0	R_A
NaCl + Serine							
0.000	1551.80	1058.11	1.06195	3.92502	1.64180	0.41120	1.05285
0.008	1564.88	1064.54	1.16268	3.83071	1.66816	0.40623	1.057 85
0.017	1593.18	1078.71	1.37615	3.65472	1.71745	0.39679	1.06339
0.026	1601.16	1081.52	1.55944	3.60831	1.73085	0.39426	1.06458
0.034	1618.12	1087.01	1.61528	3.51368	1.75890	0.38905	1.06674
0.043	1651.64	1094.01	1.87772	3.35085	1.80689	0.37994	1.06630

Table 2: Ultrasonic velocities, densities, adiabatic compressibility's, acoustic impedances, free lengths ,relative association numbers of $MgCl_2$ in double distilled water at 2MHz at 303.15K.

Double distilled Water +$MgCl_2$

m mol kg^{-1}	u ms^{-1}	ρ Kg m^{-3}	η $Nm^{-2}s$	βx10^{-10} m^2N^{-1}	zx10^{-6} Nm^{-2}	L_f A^0	R_A
$MgCl_2$ + Serine							
0.000	1560.51	1058.38	1.06103	3.88131	1.65101	0.40891	1.05089
0.008	1581.00	1064.78	1.17284	3.74601	1.68851	0.40172	1.05622
0.017	1599.76	1081.34	1.38746	3.61468	1.72934	0.39817	1.06489
0.026	1618.88	1096.66	1.56448	3.48142	1.74234	0.39461	1.07540
0.034	1627.20	1100.24	1.38931	3.43346	1.78992	0.38459	1.07749
0.043	1642.80	1116.85	1.89523	3.32024	1.83336	0.38384	1.08969

From the tables 1- and table -2, we observe the trends of all acoustical parameters with variation in concentration and temperature. The ultrasonic velocity increases with molal concentration of solute as well as rise in temperature. This increase in ultrasonic velocity in the aqueous solution of electrolytes may be attributed to the cohesion brought by the ionic hydration .The increase in density with molal concentration suggest a solute-solvent interaction exist between the electrolytes and water .In other words the increase in density may be interpreted to the structure maker of the solvent due to H-bonding[12,13].The viscosity is an important parameter in understanding the structure as well as molecular interaction occurring in the solutions. From above tables, values of viscosities increase with concentration but decreases with temperature. These variations attributed to structural changes [14].The values of adiabatic compressibility (β_a) show decreasing trend with concentration as well as temperature which suggest the making and breaking of H-bonding. The intermolecular free length depends upon the intermolecular attractive and repulsive forces. Eyring and Kincaid[15] have proposed that L_f is a predominating factor in determining the variation of ultrasonic velocity of solution. The values of intermolecular free length listed in the table 1 & table2 which shows decreasing trend with concentration and temperature Hence it can be concluded that there is significant interaction between solute and solvent molecules due to which the structural arrangement is also affected. Thus it is clear from the above parameters that there is a strong association between water and electrolytes molecules showing hydrophilic nature[16].

4. Conclusion

A strong intermolecular H-bonding interaction exist between electrolytes and water. From the acoustical parameters it is concluded that H-bonding interaction is very strong at higher temperature and concentration.

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