ISSN 2250-3153

Molecular Interactions in Binary Mixture of Sucrose in Aqueous NaCl Solution

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Abstract- Density and Ultrasonic velocity Sucrose in 1M NaCl at 298.15K, 303.15K, 308.15K and 313.15K have been measured. Various ultrasonic and solution parameters such as adiabatic compressibility, change and relative change in adiabatic compressibility, acoustic impedance, available volume and free length have been calculated using these data. The present investigation has been used to exploit the possible molecular interactions which are identified and eventually discussed about the behavior of solute (Sucrose) in the solvent 1 M solution of NaCl)

I. Introduction

Ultrasonic and density measurements are being used as a very useful tool for gaining informations on the solution properties [1-5]. Studies on interactions of non-ionic solutes with ionic ones in different solvents are significant and important for understanding their physic-chemical behavior [6-8].

The study of carbohydrates has become a subject of increasing interest because of the multidimensional physical, biochemical and industrially useful properties of these compounds [9-15]. Most of the chemical and biological functions of carbohydrates take place in aqueous medium. The situation becomes interesting if an electrolyte is also present in such solutions.

The molecular association, physico-chemical behavior and acoustic properties of multicomponent liquid mixtures of Sucrose in 1 M NaCl at temperatures 298.15, 303.15, 308.15, 313.15K have been studied by measuring ultrasonic velocity and density. Various acoustic and thermodynamic parameters have been computed using the experimental data with a view to investigate the nature of interaction between the components of the liquid mixtures.

II. EXPERIMENTAL

Ultrasonic velocity at 2MHz has been measured by single by single crystal ultrasonic interferometer manufactured by M/s Mittal Enterprises. The accuracy of the velocity is found to be ±0.04%.

Density measurements has been carried out using pyknometer having well-fitted glass cap in order to prevent changes in composition due to evaporation. The accuracy of density measurement is within the range ±0.005 g/ml. All the chemicals used in the present work are from BDH (AR Grade)

III. RESULTS AND DISCUSSION

Ultrasonic velocity and density have been experimentally determined for the system 1 M NaCl + Sucrose, at various temperatures.

The acoustic parameters viz. adiabatic compressibility, acoustic impedance, freelength, free volume are calculated using the experimentally determined density and ultrasonic velocity using the relations [16].

$$\beta = \frac{1}{u^2 d}$$

$$Z = u.d$$

$$L_f = K\sqrt{\beta}$$

$$V_a = V_m \left(1 - \frac{u}{u\infty}\right)$$

where symbols have their usual meanings.

The change in adiabatic compressibility and relative change in adiabatic compressibility have been computed as

$$\Delta\beta = \beta - \beta_o$$

$$\frac{\Delta\beta}{\beta o} = (\beta - \beta_o)/ \beta_o$$

The experimentally determined density and ultrasonic velocity along with the calculated parameters are listed in Table 1. Both d and u values are found to increase with increasing concentration of Sucrose. Adiabatic compressibility (β) decreases with increasing concentration due to electrostatic forces of ions on the surrounding water molecules. As the temperature rises compressibility of the solution increases [17, 18]. With increase in solute concentration the electrostatic forces break the water structure and with close packing structure around the solute molecules, compressibility decrease [19].

The negative values of change in adiabatic compressibility (Δβ) and the relative change in adiabatic compressibility ($\Delta\beta/\beta_o$) are due to solute-solvent interactions [20, 21]. Such an increase in Δβ and $\Delta\beta/\beta_o$ values (**Fig. 1**) with increase in concentration may be attributed to an overall increase in the cohesive forces in the solution [22].

The acoustic impedance (Z) of all the systems is found to increase with increase in the concentration of Sucrose. The increase in Z values (**Fig. 2**) may be due to the effective solute-solvent interactions [23].

ISSN 2250-3153

Intermolecular free length L_f is obtained from the adiabatic compressibility (β). It is clear from the table that the ultrasonic velocity is increasing while intermolecular free length is decreasing (**Fig. 3**) with increase in Sucrose concentration at different temperatures. In general Ultrasonic velocity and L_f varies inversely [24, 25]. Decrease in L_f values indicate the ion-solvent interaction [26]. Due to thermal expansion of liquids, an increase in temperature causes free length to increase. Available volume decreases with increasing concentration of Sucrose which seems to be due to solute-solvent interaction.

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Table 1 : Density (**d**/g.cm^{-3}), Ultrasonic velocity (**u**/m.s^{-2}) and derived parameters adiabatic compressibility (**β**/10^{-11}m^{2}N^{-1}), change in adiabatic compressibility(**Δβ**/10^{-11}m^{2}N^{-1}), relative change in adiabatic compressibility (**Δβ/β**/10^2), Acoustic impedance (**Z**/10^{-3}kgm^{-2}s^{-1}), Free length (**L_f**),available volume (**V_a**/cm^{-3}mol^{-1}) for Sucrose + aqueous NaCl (1M) at 298.15K, 303.15K, 308.15K and 313.15K

Temperature:-298.15K

Molarity (Sucrose)	**d**	**u**	**β**	**Δβ**	**Δβ/β0**	**Z**	**Lf**	**Va**
0	1.0362	1557.2	39.798			1613.57	39.429	1.510
0.01	1.0364	1558.8	39.709	-0.089	-0.224	1615.54	39.385	1.453
0.02	1.0368	1561.4	39.562	-0.236	-0.595	1618.86	39.311	1.361
0.03	1.0373	1563.2	39.452	-0.347	-0.871	1621.51	39.257	1.297
0.04	1.038	1565.4	39.314	-0.484	-1.216	1624.89	39.188	1.219
0.05	1.0391	1567.2	39.183	-0.616	-1.547	1628.48	39.123	1.154
0.06	1.0403	1569.2	39.038	-0.761	-1.911	1632.44	39.050	1.083
0.07	1.0415	1572.8	39.814	-0.984	-2.472	1638.07	38.938	0.955
0.08	1.0427	1574.4	38.091	-1.107	-2.783	1641.63	38.876	0.898
0.09	1.0438	1577.2	38.513	-1.285	-3.23	1646.28	38.787	0.799

Temperature:-303.15K

Molarity (Sucrose)	d	u	β	Δβ	Δβ/β0	Z	Lf	V_a
0	1.0293	1563.6	39.738			1609.41	39.777	1.293
0.01	1.0295	1564.2	39.700	-0.038	-0.096	1610.34	39.758	1.271
0.02	1.0299	1566.6	39.563	-0.175	-0.441	1613.44	39.689	1.186
0.03	1.0304	1568.4	39.453	-0.285	-0.717	1616.08	39.634	1.121
0.04	1.0311	1570.8	39.306	-0.432	-1.088	1619.65	39.560	1.035
0.05	1.0322	1572.4	39.184	-0.554	-1.394	1623.03	39.499	0.978
0.06	1.0334	1574.2	39.049	-0.689	-1.734	1626.78	39.431	0.913
0.07	1.0346	1576.6	38.885	-0.853	-2.146	1631.15	39.348	0.827
0.08	1.0358	1578.2	38.761	-0.977	-2.458	1634.70	39.285	0.770
0.09	1.0369	1580.4	38.613	-1.125	-2.832	1638.72	39.210	0.691

Temperature:-308.15K

Molarity (Sucrose)	d	u	β	Δβ	Δβ/β0	Z	Lf	V_a
0	1.0217	1567.4	39.840			1601.41	39.954	1.167
0.01	1.0219	1568.6	39.771	-0.069	-0.172	1602.95	39.920	1.123
0.02	1.0223	1569.8	39.695	-0.145	-0.364	1604.81	39.881	1.080
0.03	1.0228	1571.2	39.605	-0.235	-0.590	1607.02	39.836	1.030
0.04	1.0235	1573.4	39.467	-0.373	-0.936	1610.37	39.767	0.950
0.05	1.0246	1575.2	39.335	-0.505	-1.268	1613.95	39.700	0.885
0.06	1.0258	1576.8	39.209	-0.631	-1.584	1617.48	39.637	0.827
0.07	1.027	1579.2	39.044	-0.796	-1.997	1621.84	39.553	0.741
0.08	1.0282	1581.2	38.900	-0.940	-2.359	1625.79	39.480	0.669
0.09	1.0293	1583.6	38.741	-1.099	-2.759	1630.00	39.399	0.583

Temperature:-313.15K

Molarity (Sucrose)	d	u	β	Δβ	Δβ/β0	Z	Lf	V_a
0	1.0144	1570.8	39.953			1593.42	40.2321	1.052
0.01	1.0146	1572.2	39.874	-0.079	-0.198	1595.15	40.1923	1.002
0.02	1.015	1573.2	39.808	-0.145	-0.364	1596.80	40.1589	0.965
0.03	1.0155	1574.8	39.707	-0.246	-0.615	1599.21	40.1082	0.907
0.04	1.0162	1576	39.619	-0.334	-0.835	1601.53	40.0638	0.864
0.05	1.0173	1577.8	39.486	-0.467	-1.168	1605.10	39.9965	0.798
0.06	1.0185	1579.2	39.370	-0.583	-1.459	1608.42	39.9375	0.747
0.07	1.0197	1581.6	39.204	-0.749	-1.874	1612.76	39.8534	0.660
0.08	1.0209	1583.6	39.059	-0.894	-2.236	1616.70	39.7797	0.587
0.09	1.022	1585.2	38.939	-1.014	-2.539	1620.07	39.7181	0.529

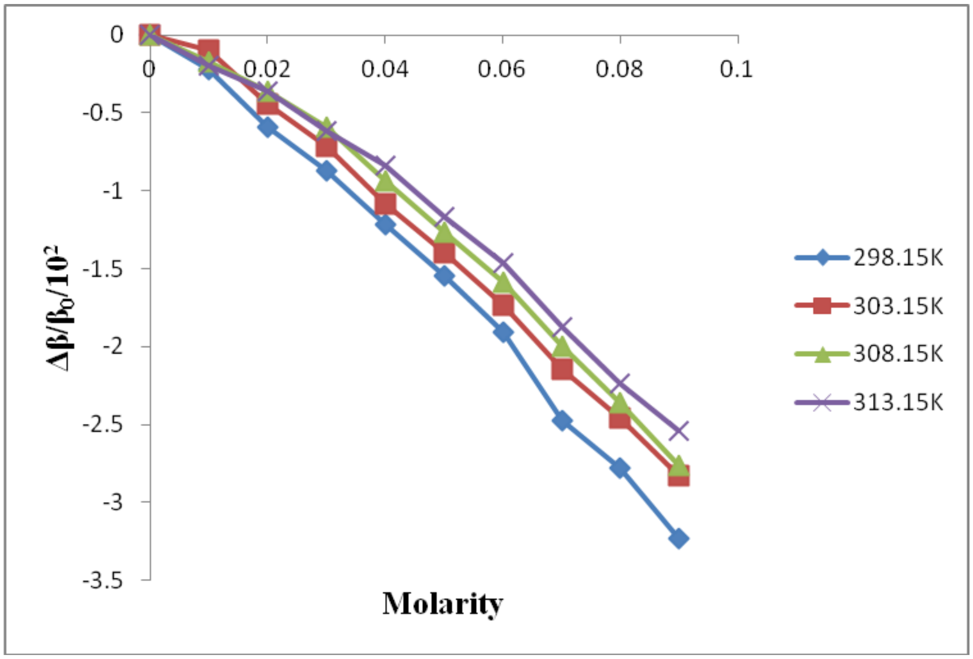

Fig 1:- Plot of relative change in adiabatic compressibility as a function of concentration at various temperatures

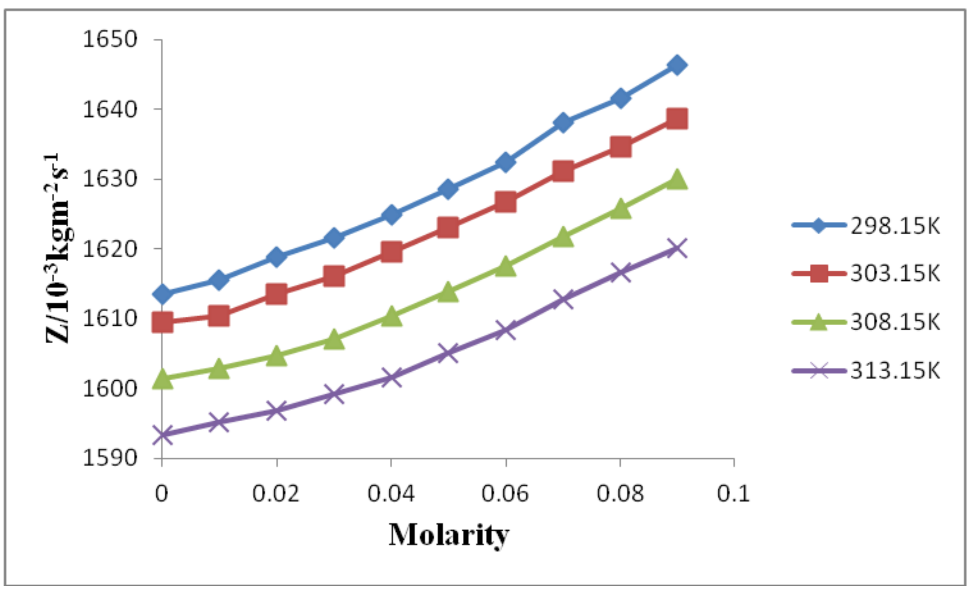

Fig 2:- Plot of Acoustic impedance as a function of concentration at various temperatures

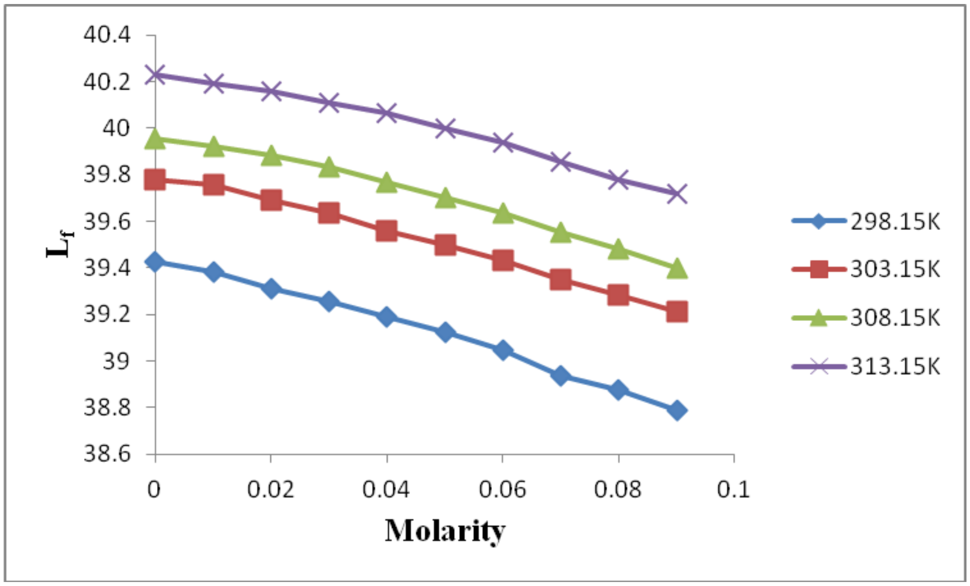

Fig 3:- Plot of Free length as a function of concentration at various temperatures