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Ultrasonic Studies on Molecular Interaction of Maltose in Aqueous NaCl Solution

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Abstract: Density and Ultrasonic velocity of Maltosein 1M aqueous NaCl solution at 298.15K, 303.15K, 308.15K and 313.15K were recorded. Various ultrasonic and solution parameters such as adiabatic compressibility, molar volume, molar ultrasonic velocity, Wada's constant, molar hydration number and relative association have been calculated using the experimental data. The trend in variation of these properties has been utilized to identify and discuss the possible molecular interactions present in the system under investigation.

Keywords: Ultrasonic velocity, adiabatic compressibility, relative association, hydration number

INTRODUCTION

Carbohydrates as well as sodium ion play a vital role in the lives of living organisms. Carbohydrates exhibit numerous roles in living systems from the storage and transport of energy to participation in immune system. Sodium ion on the other hand, is the major components of the cation of extracellular fluid.

Carbohydrates and salts are physiologically important in association with water in biochemical reactions[1,2]. Understanding the behavior of these in dilute aqueous solutions is of utmost importance in biology and medicine. Several investigations have been carried out in aqueous solutions of carbohydrates[3-9].The behavior of salts in dilute solutions has evoked interest due to its importance since a long time[10-12].

The molecular association, physico-chemical behavior and acoustic properties of multicomponent liquid mixtures of Maltose 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.

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)

RESULTS AND DISCUSSION

The experimental ultrasonic velocity (u) and density (d) values have been used to compute the adiabatic compressibility, molar volume, molar ultrasonic velocity, Wada's constant, molar hydration number and relative association using the relations[13]

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

$$V = \frac{m}{d}$$

$$R = V\ u^{1/3}$$

$$R_A = V_{m(}1 - \frac{u}{u\infty})$$

$$n_H = \frac{n1}{n2}(1 - \frac{\beta}{\beta_0})$$

$$W = V\beta^{-1/7}$$

Where symbols have their usual meanings.
The change in molar volume and relative change in molar volume have been computed as

$$\Delta V = V - V_o$$

$$\frac{\Delta V}{Vo} = (V - V_o)/V_o$$

Table 1 displays the variation of experimentally determined density and ultrasonic velocity along with the calculated parameters. Both d and u values are found to increase with increasing concentration of Sucrose. Adiabatic compressibility (β) decreases with increasing concentration (**Fig.1**) due to enhanced molecular associations in the system due to increase in solute content. The new entities formed due to molecular association become compact and less compressible[14].As the temperature rises compressibility of the solution

increases[15,16]. With increase in solute concentration the electrostatic forces break the water structure and with close packing structure around the solute molecules, compressibility decrease[17].

Table 1 : Density (**d**/g.cm^{-3}), Ultrasonic velocity (**u**/m.s^{-2}) and derived parameters adiabatic compressibility (**βX**10^{11}/m^{2}N^{-1}), molar volume(**V,/** cm^{3}mol^{-1}), molar ultrasonic velocity (**R X10^6/** m mol^{-1} s$^{-1/3}$), Hydration number (n_H), relative association(R_A), Wada's constant (**B**) for Malose + aqueous NaCl (1M) at 298.15K, 303.15K, 308.15K and 313.15K

Temperature:-298.15K

Molarity (Maltose)	d	U	β	V	R	n_H	R_A	B
0	1.0362	1557.2	39.799	18.063	209.36	-		148.28
0.01	1.0365	1559.2	39.685	18.113	210.03	0.2852	0.9999	148.75
0.02	1.037	1561.8	39.534	18.159	210.69	0.3324	0.9998	149.22
0.03	1.0376	1562.6	39.471	18.204	211.24	0.2747	1.0002	149.62
0.04	1.0385	1566.4	39.245	18.243	211.87	0.3475	1.0003	150.06
0.05	1.0395	1568.4	39.108	18.281	212.39	0.3472	1.0008	150.45
0.06	1.0407	1569.8	38.993	18.314	212.85	0.3374	1.0016	150.79
0.07	1.042	1573.6	38.756	18.346	213.39	0.3741	1.0021	151.18
0.08	1.0433	1576.2	38.581	18.378	213.88	0.3826	1.0028	151.54
0.09	1.0445	1577.8	38.458	18.412	214.35	0.3742	1.0036	151.89

Temperature:-303.15K

Molarity (Maltose)	d	U	β	V	R	n_H	RA	B
0	1.0293	1563.6	39.738	18.184	211.05	-		149.31
0.01	1.0297	1565	39.652	18.232	211.68	0.2176	1.0001	149.75
0.02	1.0301	1567.8	39.495	18.281	212.37	0.3062	0.9999	150.24
0.03	1.0305	1569.4	39.399	18.329	213.01	0.2845	0.9999	150.69
0.04	1.0313	1572	39.238	18.371	213.60	0.3144	1.0002	151.11
0.05	1.0324	1573.2	39.137	18.406	214.07	0.3027	1.0010	151.47
0.06	1.0335	1575.6	38.976	18.442	214.60	0.3196	1.0015	151.85
0.07	1.0347	1577.8	38.822	18.476	215.09	0.3292	1.0022	152.21
0.08	1.036	1579.2	38.705	18.508	215.53	0.3250	1.0032	152.54
0.09	1.0372	1581.6	38.543	18.541	216.03	0.3342	1.0038	152.91

Temperature:-308.15K

Molarity (Maltose)	d	U	β	V	R	n_H	RA	B
0	1.0217	1567.4	39.840	18.319	212.80	-		150.36
0.01	1.0221	1569.4	39.723	18.368	213.46	0.2937	1.0000	150.83
0.02	1.0225	1571	39.626	18.417	214.09	0.2678	1.0000	151.28
0.03	1.0229	1572.2	39.550	18.466	214.72	0.2421	1.0002	151.72
0.04	1.0237	1574.6	39.399	18.507	215.31	0.2765	1.0004	152.15
0.05	1.0248	1576	39.287	18.543	215.79	0.2775	1.0012	152.51
0.06	1.0259	1578.2	39.136	18.579	216.31	0.2946	1.0018	152.88
0.07	1.0271	1580.4	38.981	18.613	216.80	0.3079	1.0025	153.25
0.08	1.0284	1582.2	38.843	18.645	217.26	0.3127	1.0034	153.59
0.09	1.0296	1584.8	38.671	18.678	217.77	0.3260	1.0040	153.97

Temperature:-313.15K

Molarity (Maltose)	d	U	β	V	R	n_H	RA	B
0	1.0144	1570.8	39.953	18.451	214.48	-		151.39
0.01	1.0147	1573.2	39.819	18.502	215.19	0.3344	0.9998	151.88
0.02	1.0152	1574.4	39.739	18.549	215.79	0.2676	1.0000	152.31
0.03	1.0157	1575.8	39.649	18.596	216.40	0.2536	1.0002	152.75
0.04	1.0164	1577.2	39.551	18.640	216.97	0.2513	1.0006	153.16
0.05	1.0176	1578.6	39.435	18.674	217.44	0.2594	1.0015	153.50
0.06	1.0187	1580.6	39.293	18.710	217.95	0.2755	1.0022	153.88
0.07	1.0199	1582.8	39.137	18.744	218.44	0.2917	1.0029	154.24
0.08	1.0212	1584.6	38.999	18.776	218.90	0.2986	1.0038	154.59
0.09	1.0224	1586.4	38.865	18.810	219.38	0.3027	1.0046	154.94

The change in molar volume (ΔV) is found to increases with increasing concentration of maltose as well as increasing temperature. This may be ascribed as the characteristic for the presence of hydrogen bonding or weak dipole-dipole interaction[18].

The relative association (R_A) for the system is found to increase with increase in the concentration of Maltose. The increase in R_A values indicates that the solvation of solute is more effective over the breaking of solvent structure[19].

The molar sound velocity (R) and their compressibility (W) for the system is found to be in increasing trend with molarity. This indicates the enhancement of the magnitude of interaction (**Fig**. 2)

The plot shown in **(Fig.3)** depicts the nature of variation of hydration number with composition and temperature. The hydration number (n_H) is the number of solvent molecules rigidly bound to the ions. The positive values of hydration number indicate significant interaction among solute and solvent molecules. In present case the hydration number increases with increasing concentration of maltose at all investigated temperatures. It seems that the presence of NaCl enhances the hydration and hence works as structure maker for the sysem[20, 21]

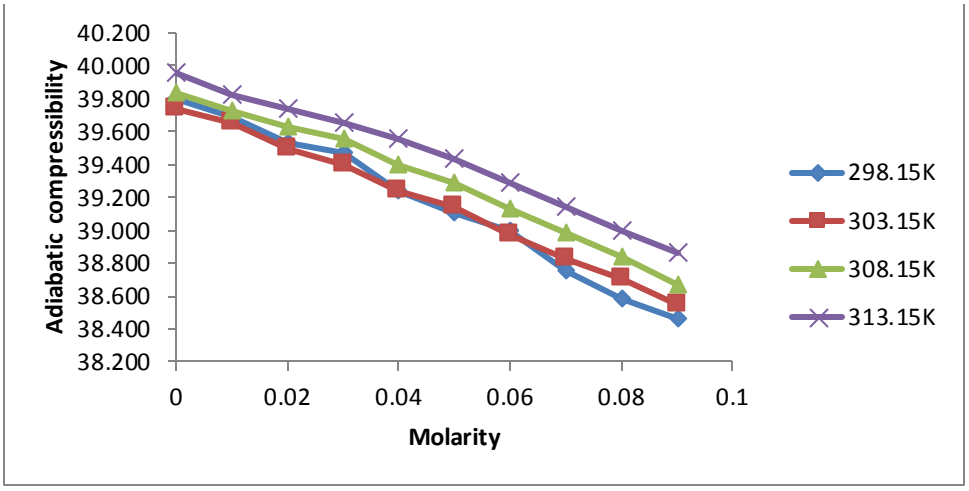

Fig 1:- Plot of adiabatic compressibility as a function of concentration at various temperatures

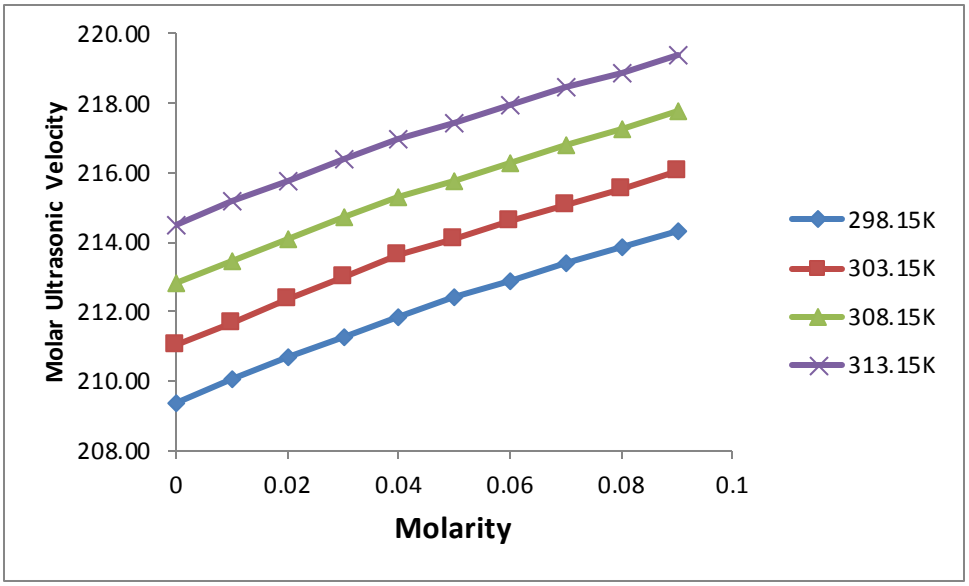

Fig 2:- Plot of Molar ultrasonic velocity as a function of concentration at various temperatures

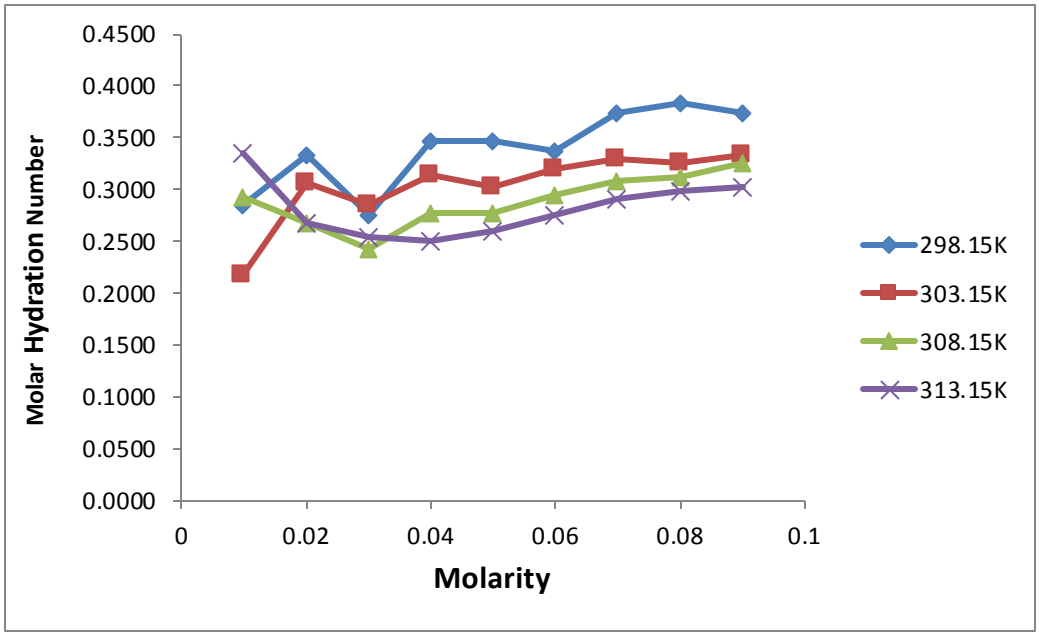

Fig 3:- Plot of Molar hydration number as a function of concentration at various temperatures

CONCLUSION: The trend in variation of these properties has been utilized to identify and discuss the possible molecular interactions present in the system under investigation.

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