International Journal of ChemTech Research
CODEN(USA): IJCRGG ISSN : 0974-4290
Vol.5, No.4, pp 1948-1958, April-June 2013

Ultrasonic Studies On Interionic Interactions Of Potassium Chloride In Aqueous Lactose Solution At Varying Molalities And Temperatures

Shashi Kant*, Parul, Kamini Sharma

Department of Chemistry, Himachal Pradesh University, Summer Hill, Shimla – 171005, INDIA.

Corres.author: sunshine.kamini@gmail.com

Abstract: The present experimental investigation was carried out in order to explore the possible molecular interionic interactions of potassium chloride in aqueous lactose solution at 303.15, 308.15K, 313.15 and 318.15 K. Experimental values of density (d), viscosity (η) and ultrasonic velocities (U) were carried out on the liquid ternary mixtures of water +lactose + potassium chloride. The binary solvent mixture of water + lactose was prepared under molality(m) basis. Potassium chloride was added under different molalities with these binary solvent mixtures. The related and relevant parameters correlated to our present study such as adiabatic compressibility, change and relative change in adiabatic compressibility, acoustic impedance (Z), intermolecular free length (L_f), Wada's constant (W), relative association (R.A.), relaxation time (τ) were determined. The present investigation has exploited the possible molecular associations such as ion-ion, ion-solvent, solute-solvent, solute-solute etc., which are identified and eventually discussed about the behavior of solute (potassium chloride) in the solvent mixture.
Keywords: Ultrasonic velocity, lactose, potassium chloride, adiabatic compressibility, free length, relaxation time.

Introduction:

Saccharides are very important for some physiological processes. They are not only the basic material for energy metabolism in organisms, but also play a significant role in the configuration of biological molecules [1, 2]. The study ofCarbohydrates / saccharides has become a subject of increasing interest because of the multidimensional physical, biochemical and industrially useful properties of these compounds [3-9]. In addition to their importance in the food, pharmaceutical and chemical industries, saccharides have received considerable attention for their ability to protect biological macromolecules [10, 11]. Sugars and polyols are well known stabilizing agents of proteins/enzymes [12, 13] in their native state owing to their ability to enhance the structure of water. Saccharides and their derivatives as the most abundant class of biomolecules are known to exist in wide range of forms, which is a reflection of their biological versatility and the great diversity of their biological functions such as structural, protective metabolic and recognition. The saccharide components of cell membranes are the receptors of biologically active components (enzymes, drugs etc.). Saccharides are able to stabilize the native state of proteins/enzymes [14-16]. Interactions of electrolytes with saccharides are very important in exploring the stability of polysaccharides in biological systems as well as in the chemical industry of saccharides. It is an essential component for maintaining cell viability, a natural cell-protecting agent, as well as an energy reservoir in many organisms [17]. It has been found that thedecomposition, synthesis, metabolism and transmembrane transport of saccharides have relationships with the concentration of metal ions in bodyfluid. So the study of the interaction between alkali metal halides and aqueous carbohydrates is valuable to examine the influence of electrolytes on some physiological behavior and helpful to understand the essence of some biological phenomena.

The present study investigates the behavior of potassium chloride in different composition of lactose by using acoustic measurements. In this paper, we report the densities and ultrasonic studies at different temperatures (i.e. 303.15-318.15K) over a wide concentration range. These data were used to calculate various acoustic parameters like adiabatic compressibility, change and relative change in adiabatic compressibility, acoustic impedance (Z), intermolecular free length (L_f), Wada's constant (W), relative association (R.A.), relaxation time (τ). These parameters are discussed in terms of various solute – cosolute interactions in aqueous solutions; thus the study contributes to a better understanding of the interactions taking place between solute and solvent.

Experimental:

Water used for solutions had specific conductance in the range 0.1- 1.0 x $10^{-6}\,\Omega^{-1}\text{cm}^{-1}$. Potassium chloride and lactose (Anala R) were dried over anhydrous calcium chloride for more than 48h and used as such. All the solutions were prepared by weight and conversion of molality to molarity was done by using the standard expression [18]. The concentration range of potassium chloride in 2, 4 and 6 wt. % of lactose was 0.01 to 0.12 m. The density and ultrasonic velocity was measured with the help of DSA (Density and Sound Analyser) 5000, Anton Paar, GmbH, Garz, Austria.

Theory And Calculations:

Using the measured data, some acoustical parameters such as adiabatic compressibility (β), change (Δβ) and relative change in adiabatic compressibility ($\Delta\beta/\beta_o$), acoustic impedance (Z), intermolecular free length (L_f), Wada's constant (W), relative association (R.A.), relaxation time (τ) were studied and evaluated by using the standard equations:

Adiabatic compressibility (β) $= \dfrac{1}{U^2\rho}$ (1)

Where U is the ultrasonic velocity and ρ is the density.

Change in adiabatic compressibility (Δβ) = ($\beta-\beta_o$) (2)

Where β and β_o are the adiabatic compressibility of solution and solvent respectively.

Relative change in adiabatic compressibility = ($\Delta\beta/\beta_o$) (3)

Acoustic impedance (Z) = Uρ (4)

Intermolecular free length (L_f) = $K\beta^{1/2}$ (5)

Wada's constant (W) = $\dfrac{M}{\rho}\;{}^{-1/7}$ (6)

Relative association (R.A.) = $\left(\dfrac{\rho}{\rho_o}\right)\left(\dfrac{U_o}{U}\right)^{1/3}$ (7)

Relaxation time (τ) = $\dfrac{4\eta}{3\rho U^2}$ (8)

Results And Discussion:

The experimental values of density (ρ), ultrasonic velocity (U), adiabatic compressibility, change and relative change in adiabatic compressibility for different molal compositions of potassium chloride in 2, 4 and 6 wt. % lactose at different temperatures (i.e.303.15K-318.15K) are shown in Table-1.

The results show that densities and ultrasonic velocities increases with increase in the concentration of lactose as well as with the concentration of potassium chloride. Moreover, the density decreases with increasing temperature in all the systems while the opposite trends are observed for ultrasonic velocity. The increase of ultrasonic velocity with temperature in all systems indicates a weakening of solute–solvent interactions at higher temperatures. As the temperature increases, hydrogen bonds between water and lactose molecules break.

It is clear from the Table-1 that the values of adiabatic compressibility (β) seems to decrease with increase of the solute content as well as with the rise in temperature. Such a decrease in adiabatic compressibility observed in the present system, generally, confirms the conclusions drawn from the velocity data. The increasing electrostrictive compression of water around the molecules may result in a large decrease in the compressibility of the solutions. The decrease in β is due to the increase in electrostriction compression of solvent around the molecules which results in a large decrease in the compressibility of solutions [19]**.** The compressibility appears to be decreasing with decrease in hydrogen bond strength formed by solute and solvent molecules. The behavior of compressibility depicts the existence of interaction between solute and solvent molecules in which the structural arrangement in the neighbourhood of consistent solutes is considerably affected. The sample plots of β Vs m for KCl in 2% lactose at different temperatures is shown in fig (1). The negative values of change in adiabatic compressibility (Δβ) and 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 with increase in concentration may be attributed to an overall increase in the cohesive forces in the solution[22]. These cohesive forces may be due to the interactions in the solution. The acoustic impedance (Z) of all the systems is found to increase with increase in the concentration of potassium chloride in 2, 4 and 6 wt. % lactose. The sample plots of Z vs m for KCl in 2% lactose at different temperatures is shown in fig (2). This is in agreement with the theoretical requirements as U and ρ both increases with increase in the concentration of the solute. This increase of Z values with solute concentration can be attributed to the effective solute-solvent interactions. A similar type of behavior has been obtained for tetra alkyl ammonium and alkali metal salts in methanol + chloro benzene mixtures [23]. Intermolecular free length (L_f) was obtained from adiabatic compressibility (β) using equation[24]:

Intermolecular free length (L_f) = $K\beta^{1/2}$

Where K is the temperature dependent constant (= (93.875 + 0.375T) × 10^{-8}))[25]. It is clear from table that ultrasonic velocity (U) increases and intermolecular free length (L_f) decreases with increase in concentration of potassium chloride in 2, 4 and 6 wt.% lactose at different temperatures (i.e.303.15K-318.15K). In general U and L_f have been reported to vary as the inverse of each other as in the present systems [26-27].The decrease in the value of L_f with the increase in molality indicates the presence of significant ion-solvent interaction between solute and solvent molecules due to which the structural arrangement in the neighbourhood of constituent ions is considerably affected [28]. The sample plots of $L_f$vs m for KCl in 2% lactose at different temperatures is shown in fig (3).

Wada's constant (W) has been calculated by standard equation [29]:

Wada's constant (W) = $\frac{M}{\circ}\;{}^{-1/7}$

It has been found that the values of Wada's constant (W) decreases with increase in concentration of solute and increases with increase in temperature. To obtain a firm impact of interactions in solutions, relative association (R.A.) was calculated by following relation[30]:

Relative association (R.A.) = $\left(\frac{\circ}{\circ_o}\right)\left(\frac{U_o}{U}\right)^{1/3}$

whereρ_o and Uo are the density and ultrasonic velocity of solvent respectively. Relative association is influenced by two factors (i) breaking up of the associated solvent molecules on addition of solute in it and (ii) the solvation of solute molecules. The former leads to decrease and later to increase of relative association. In the present study, the values of (R.A.) increase with increase in solute concentration showing significant ion-solvent interactions which increase with increase in solute concentration [23]. The sample plots of τ Vs m for KCl in 2% lactose at different temperatures is shown in fig (4).

Table-1: Density (ρ), ultrasonic velocity (U), adiabatic compressibility (β), change (Δβ) and relative change in adiabatic compressibility (Δβ/β_o) for potassium chloride in 2, 4 and 6 wt. % Lactose at different temperatures (i.e. 303.15K, 308.15K, 313.15K, 318.15K)

Molality (m)	ρ x 10^{-3} (Kg m^{-3})	U (ms^{-1})	β x10^{10} (Pa^{-1})	-Δβx 10^{09} (Pa^{-1})	-Δβ/β_o x10^3
Potassium chloride in 2% aqueous Lactose					
Temperature = 303.15K					
0.00	1.0030	1514.98	4.3441	-	-
0.01	1.0035	1515.52	4.3385	0.5569	1.2821
0.02	1.0041	1516.11	4.3329	1.1208	2.5800
0.04	1.0050	1517.28	4.3220	2.2055	5.0769
0.06	1.0059	1518.25	4.3128	3.1334	7.2131
0.08	1.0067	1519.37	4.3029	4.1190	9.4817
0.10	1.0075	1520.30	4.2944	4.9690	11.4385
0.12	1.0082	1521.39	4.2852	5.8853	13.5477
Temperature = 308.15K					
0.00	1.0013	1525.36	4.2923	-	-
0.01	1.0019	1525.87	4.2870	0.52407	1.2210
0.02	1.0024	1526.57	4.2809	1.1351	2.6444
0.04	1.0033	1527.77	4.2701	2.2145	5.1594
0.06	1.0042	1528.54	4.2622	3.0104	7.0136
0.08	1.0050	1529.73	4.2521	4.0196	9.3648
0.10	1.0058	1530.56	4.2443	4.8012	11.1857
0.12	1.0065	1531.62	4.2355	5.6807	13.2348
Temperature = 313.15K					
0.00	0.9994	1534.23	4.2508	-	-
0.01	1.0000	1534.72	4.2458	0.5008	1.1781
0.02	1.0005	1535.49	4.2394	1.1393	2.6803
0.04	1.0014	1536.66	4.2290	2.1773	5.1222
0.06	1.0023	1537.30	4.2219	2.8915	6.8024
0.08	1.0031	1538.55	4.2116	3.9143	9.2084
0.10	1.0038	1539.27	4.2045	4.6238	10.8776
0.12	1.0045	1540.33	4.1959	5.4924	12.9209
Temperature = 318.15K					
0.00	0.9973	1541.64	4.2192	-	-
0.01	0.9978	1542.07	4.2146	0.4597	1.0895
0.02	0.9983	1542.92	4.2078	1.1322	2.6836
0.04	0.9992	1544.13	4.1974	2.1766	5.1588
0.06	1.0001	1544.57	4.1914	2.7731	6.5726
0.08	1.0009	1545.88	4.1810	3.8164	9.0453
0.10	1.0016	1546.53	4.1744	4.4735	10.6027
0.12	1.0023	1547.58	4.1658	5.3354	12.6458
Potassium chloride in 4% aqueous Lactose					
Temperature = 303.15K					
0.00	1.0106	1520.97	4.2775	-	-
0.01	1.0111	1521.36	4.2730	0.4565	1.0672
0.02	1.0117	1522.06	4.2668	1.0697	2.5007
0.04	1.0126	1523.14	4.2567	2.0806	4.8641

0.06	1.0135	1524.21	4.2470	3.0509	7.1324
0.08	1.0143	1525.28	4.2376	3.9948	9.3392
0.10	1.0151	1526.28	4.2288	4.8751	11.3971
0.12	1.0158	1527.66	4.2181	5.9405	13.8876
Temperature = 308.15K					
0.00	1.0089	1531.17	4.2278	-	-
0.01	1.0094	1531.48	4.2238	0.3939	0.9316
0.02	1.0099	1532.23	4.2176	1.0158	2.4026
0.04	1.0109	1533.29	4.2079	1.9895	4.7059
0.06	1.0117	1534.29	4.1988	2.9013	6.8625
0.08	1.0126	1535.37	4.1894	3.8351	9.0711
0.10	1.0133	1536.31	4.1812	4.6713	11.0491
0.12	1.0141	1537.67	4.1706	5.7193	13.5278
Temperature = 313.15K					
0.00	1.0070	1539.84	4.1882	-	-
0.01	1.0075	1540.10	4.1847	0.3538	0.8446
0.02	1.0080	1540.89	4.1784	0.9831	2.3473
0.04	1.0089	1541.93	4.1690	1.9250	4.5961
0.06	1.0098	1542.89	4.1602	2.8007	6.6871
0.08	1.0106	1543.94	4.1512	3.7067	8.8504
0.10	1.0114	1544.84	4.1431	4.5142	10.7782
0.12	1.0121	1546.18	4.1328	5.5433	13.2356
Temperature = 318.15K					
0.00	1.0043	1547.02	4.1607	-	-
0.01	1.0048	1547.24	4.1574	0.3236	0.7779
0.02	1.0052	1548.06	4.1511	0.9581	2.3029
0.04	1.0061	1549.12	4.1417	1.8985	4.5630
0.06	1.0070	1550.02	4.1334	2.7298	6.5608
0.08	1.0078	1551.08	4.1244	3.6291	8.7225
0.10	1.0086	1551.95	4.1165	4.4141	10.6091
0.12	1.0094	1553.26	4.1065	5.4205	13.0278
Potassium chloride in 6% aqueous Lactose					
Temperature = 303.15K					
0.00	1.0183	1527.17	4.2109	-	-
0.01	1.0188	1528.29	4.2026	0.8266	1.96307
0.02	1.0192	1528.74	4.1982	1.2689	3.0134
0.04	1.0201	1529.87	4.1883	2.2513	5.3464
0.06	1.0209	1530.82	4.1798	3.1062	7.3765
0.08	1.0217	1531.97	4.1704	4.0463	9.6093
0.10	1.0224	1532.92	4.1623	4.8576	11.5360
0.12	1.0231	1534.07	4.1533	5.7560	13.6695
Temperature = 308.15K					
0.00	1.0165	1537.11	4.1636	-	-
0.01	1.0170	1538.19	4.1558	0.7844	1.8839
0.02	1.0175	1538.61	4.1516	1.1994	2.8807
0.04	1.0183	1539.66	4.1424	2.1164	5.0832
0.06	1.0192	1540.71	4.1335	3.0105	7.2304
0.08	1.0199	1541.66	4.1253	3.8302	9.1992
0.10	1.0207	1542.61	4.1173	4.6340	11.1298
0.12	1.0213	1543.73	4.1085	5.5098	13.2332
Temperature = 313.15K					
0.00	1.0146	1545.57	4.1260	-	-
0.01	1.0151	1546.40	4.1196	0.6365	1.5426
0.02	1.0155	1546.98	4.1147	1.1281	2.7342

0.04	1.0164	1547.98	4.1059	2.0032	4.8552
0.06	1.0172	1548.97	4.0975	2.8521	6.9124
0.08	1.0180	1550.08	4.0885	3.7466	9.0804
0.10	1.0187	1551.03	4.0806	4.5415	11.0070
0.12	1.0194	1551.95	4.0729	5.3086	12.8663
Temperature = 318.15K					
0.00	1.0124	1552.56	4.0978	-	-
0.01	1.0129	1553.46	4.0912	0.6638	1.6200
0.02	1.0133	1553.92	4.0870	1.0855	2.6491
0.04	1.0142	1554.93	4.0783	1.9548	4.7703
0.06	1.0150	1555.98	4.0696	2.8256	6.8955
0.08	1.0157	1556.82	4.0621	3.5720	8.7169
0.10	1.0165	1557.77	4.0542	4.3591	10.6377
0.12	1.0172	1558.74	4.0464	5.1438	12.5525

Table-2: Acoustic impedance (Z), intermolecular free length (L_f), Wada's constant (W), relative association (R.A.), relaxation time (τ) for Sodium chloride in 2, 4 and 6 wt. % Lactose at different temperatures (i.e. 303.15K, 308.15K, 313.15K, 318.15K)

Molality (m)	Z x 10^{-6} (Kg $m^{-2}s^{-1}$)	L_f x 10^{11} (m)	W x 10^4 (m^3mol^{-1} $Pa^{1/7}$)	R.A	τ X 10^{13}(s)
Potassium chloride in 2% aqueous Lactose					
Temperature = 303.15K					
0.00	1.5195	4.3260	-	-	-
0.01	1.5209	4.3232	3.9796	1.0005	4.7782
0.02	1.5223	4.3217	3.9801	1.0009	4.7799
0.04	1.5249	4.3183	3.9816	1.0018	4.7811
0.06	1.5272	4.3150	3.9835	1.0026	4.7817
0.08	1.5296	4.3121	3.9855	1.0033	4.7827
0.10	1.5317	4.3091	3.9877	1.0039	4.7830
0.12	1.5339	4.3062	3.9901	1.0045	4.7835
Temperature = 308.15K					
0.00	1.5274	4.3389	-	-	-
0.01	1.5287	4.3367	3.9929	1.0005	4.2610
0.02	1.5302	4.3353	3.9935	1.0010	4.2626
0.04	1.5329	4.3319	3.9951	1.0018	4.2636
0.06	1.5349	4.3290	3.9969	1.0026	4.2649
0.08	1.5374	4.3259	3.9989	1.0033	4.2654
0.10	1.5394	4.3233	4.0010	1.0040	4.2665
0.12	1.5415	4.3204	4.0035	1.0046	4.2672
Temperature = 313.15K					
0.00	1.5334	4.3566	-	-	-
0.01	1.5347	4.3546	4.0060	1.0005	3.8008
0.02	1.5362	4.3531	4.0066	1.0010	3.8019
0.04	1.5388	4.3495	4.0083	1.0018	3.8022
0.06	1.5408	4.3463	4.0102	1.0025	3.8028
0.08	1.5433	4.3432	4.0123	1.0032	3.8034
0.10	1.5451	4.3400	4.0146	1.0038	3.8036
0.12	1.5473	4.3370	4.0171	1.0044	3.8039
Temperature = 318.15K					
0.00	1.5374	4.3789	-	-	-
0.01	1.5387	4.3771	4.0189	1.0005	3.4657

0.02	1.5403	4.3753	4.0197	1.0009	3.4658
0.04	1.5429	4.3718	4.0214	1.0017	3.4662
0.06	1.5447	4.3684	4.0234	1.0025	3.4665
0.08	1.5472	4.3652	4.0255	1.0032	3.4671
0.10	1.5490	4.3621	4.0279	1.0038	3.4674
0.12	1.5511	4.3590	4.0303	1.0044	3.4680
Potassium chloride in 4% aqueous Lactose					
Temperature = 303.15K					
0.00	1.5371	4.2927	-	-	-
0.01	1.5383	4.2910	4.0363	1.0005	4.8427
0.02	1.5398	4.2891	4.0370	1.0010	4.8434
0.04	1.5424	4.2859	4.0385	1.0018	4.8445
0.06	1.5448	4.2826	4.0403	1.0026	4.8449
0.08	1.5472	4.2796	4.0423	1.0033	4.8451
0.10	1.5494	4.2769	4.0444	1.0040	4.8460
0.12	1.5519	4.2743	4.0467	1.0047	4.8467
Temperature = 308.15K					
0.00	1.5448	4.3062	-	-	-
0.01	1.5459	4.3048	4.0499	1.0005	4.3059
0.02	1.5474	4.3026	4.0507	1.0009	4.3059
0.04	1.5499	4.2990	4.0524	1.0017	4.3062
0.06	1.5523	4.2958	4.0543	1.0025	4.3066
0.08	1.5547	4.2929	4.0562	1.0032	4.3072
0.10	1.5568	4.2901	4.0583	1.0039	4.3078
0.12	1.5593	4.2872	4.0606	1.0045	4.3079
Temperature = 313.15K					
0.00	1.5506	4.3244	-		-
0.01	1.5516	4.3226	4.0632	1.0004	3.8417
0.02	1.5532	4.3212	4.0639	1.0009	3.8428
0.04	1.5556	4.3176	4.0657	1.0017	3.8431
0.06	1.5579	4.3143	4.0676	1.0024	3.8433
0.08	1.5603	4.3115	4.0695	1.0032	3.8440
0.10	1.5624	4.3086	4.0716	1.0039	3.8445
0.12	1.5649	4.3057	4.0738	1.0045	3.8448
Temperature = 318.15K					
0.00	1.5536	4.3484	-	-	-
0.01	1.5546	4.3467	4.0780	1.0004	3.4962
0.02	1.5562	4.3449	4.0789	1.0009	3.4965
0.04	1.5586	4.3416	4.0806	1.0017	3.4971
0.06	1.5608	4.3383	4.0826	1.0024	3.4972
0.08	1.5632	4.3354	4.0846	1.0031	3.4977
0.10	1.5653	4.3322	4.0868	1.0038	3.4980
0.12	1.5678	4.3293	4.0890	1.0044	3.4983
Potassium chloride in 6% aqueous Lactose					
Temperature = 303.15K					
0.00	1.5550	4.2591	-	-	-
0.01	1.5569	4.2549	4.0967	1.0003	4.9778
0.02	1.5581	4.2528	4.0976	1.0006	4.9780
0.04	1.560.64	4.2493	4.0996	1.0014	4.9790
0.06	1.5629	4.2462	4.1017	1.0021	4.9796
0.08	1.5652	4.2431	4.1040	1.0027	4.9800
0.10	1.5673	4.2401	4.1064	1.0033	4.9802
0.12	1.5695	4.2379	4.1088	1.0039	4.9823

Temperature = 308.15K					
0.00	1.5625	4.2734	-	-	-
0.01	1.5644	4.2694	4.1102	1.0002	4.3604
0.02	1.5655	4.2678	4.1111	1.0007	4.3615
0.04	1.5679	4.2640	4.1132	1.0013	4.3617
0.06	1.5702	4.2611	4.1153	1.0020	4.3627
0.08	1.5724	4.2581	4.1175	1.0027	4.3634
0.10	1.5745	4.2551	4.1199	1.0033	4.3637
0.12	1.5767	4.2522	4.1225	1.0039	4.3643
Temperature = 313.15K					
0.00	1.5681	4.2922	-	-	-
0.01	1.5697	4.2888	4.1232	1.0003	3.8830
0.02	1.5710	4.2870	4.1242	1.0007	3.8834
0.04	1.5733	4.2835	4.1263	1.0014	3.8838
0.06	1.5756	4.2801	4.1285	1.0020	3.8839
0.08	1.5779	4.2770	4.1308	1.0027	3.8845
0.10	1.5800	4.2736	4.1333	1.0032	3.8846
0.12	1.5820	4.2705	4.1358	1.0038	3.8850
Temperature = 318.15K					
0.00	1.5718	4.2775	-	-	-
0.01	1.5734	4.3119	4.1363	1.0003	3.5270
0.02	1.5746	4.3104	4.1372	1.0007	3.5275
0.04	1.5769	4.3069	4.1393	1.0014	3.5279
0.06	1.5793	4.3036	4.1416	1.0020	3.5283
0.08	1.5813	4.3003	4.1439	1.0027	3.5288
0.10	1.5834	4.2974	4.1463	1.0033	3.5297
0.12	1.5855	4.2949	4.1486	1.0039	3.5314

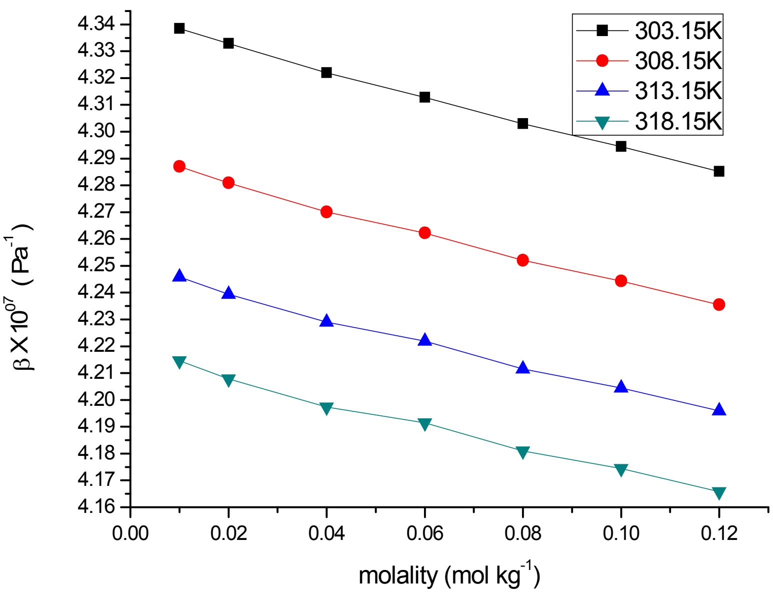

Fig 1: Plots of β vs m for KCl in 2% lactose at different temperatures.

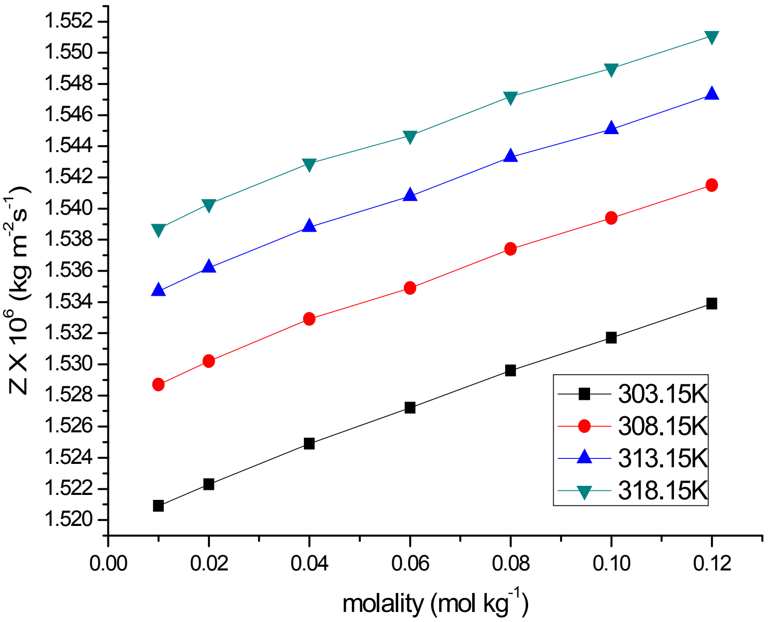

Fig 2: Plots of Z vs m for KCl in 2% lactose at different temperatures.

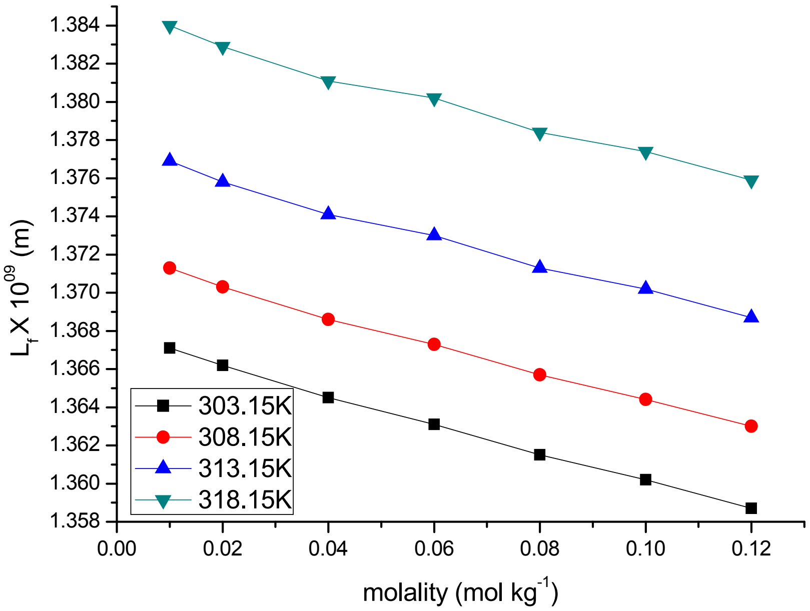

Fig 3: Plots of L_f vs m for KCl in 2% lactose at different temperatures.

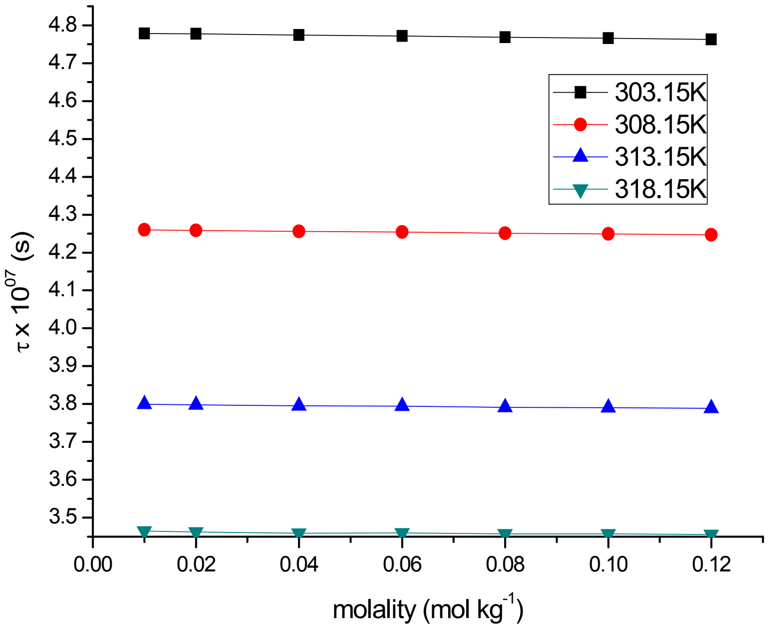

Fig 4: Plots of τ vs m for KCl in 2% lactose at different temperatures.

Conclusion:

In the light of the above discussion, it may be concluded that there are existence of powerful molecular interactions in the systems studied. Both the solute-solute interactions and solute-solvent interactions are possible in the systems. There is uniform increase in density and decrease in intermolecular free length with increase in concentration indicating the loosening of intermolecular forces due to thermal agitation of the molecules in aqueous lactose at different temperatures (i.e.303.15K-318.15K).

References:

[1] Barone G.,Physical chemistry of aqueous solutions of oligosaccharides, Thermochim. Acta., 1990, 162, 17-30.

[2] ZhuoK., Wang J., Cao Y. and Lu J., Thermodynamics of the Interaction of HCl with D-Fructose in Water, J. Phys. Chem. B., 1998, 102, 3574-3577.

[3] Goldberg R. N. and Tewari Y. B., Thermodynamic and transport properties of carbohydrates and their monophosphates: the pentoses and hexoses, J. Phys. Chem. Ref. Data., 1989, 18, 809-881.

[4] Boerio-Goates J.,Heat-capacity measurements and thermodynamic functions of crystalline α-[D]-glucose, J. Chem. Thermodyn., 1991, 23, 403-409.

[5] PutnamR. L. and Boerio-Goates J.,Heat capacity measurements and thermodynamic functions of crystalline [D]-sucrose, J. Chem. Thermodyn., 1993, 25, 607- 613.

[6] Goldberg R. N. and Tewari Y. B.,A calorimetric and equilibrium investigatino of the hydrolysis of lactose,J. Biol. Chem., 1989, 264, 9897-9900.

[7] Goldberg R. N., Tewari Y. B., and Ahluwalia J. C., Thermodynamics of the hydrolysis of sucrose, J. Biol. Chem., 1989, 264, 9901-9904.

[8] Goldberg R. N. and Tewari Y. B., Thermodynamics of hydrolysis of disaccharides. Lactulose, alpha-D-melibiose, palatinose, D-trehalose, D-turanose and 3-o-beta-D-galactopyranosyl-D-arabinose, Biophys. Chem., 1991, 40, 59-67.

[9] Birch G. G. and Shamil S.,Structure sweetness and solution properties of small carbohydrate molecules,J. Chem. Soc., Faraday Trans., 1988, 84, 2635-2640.

[10] Arakawa T., Kita Y. and Carpenter J. F.,Protein-solvent interactions in pharmaceutical formulations, Pharm. Res., 1991, 8, 285-291.

[11] Miller D. P. and De Pablo J. J.,Calorimetric solution properties of simple saccharides and their significance for the stabilization of biological structure and function, J. Phys. Chem. B., 2000, 104, 8876-8883.
[12] Gupta M. N.,Thermostabilisation of proteins, Biotechnol. Appl. Biochem., 1991, 14, 1-11.
[13] Timasheff S. N. and Arakawa T., Stabilization of protein structure by solvents, IRL Press, Oxford, 1989, 331-345.
[14] Zhuo K., Liu G., Wang Y., Qiuhe R. and Wang J.,Activity coefficients and conductivities of calcium nitrate in glucose/galactose–water mixtures,Fluid Phase Equilibria, 2007, 258, 78-82.
[15] Ernst B., Hart G. W. and Sinay P., Carbohydrates in Chemistry and Biology, Eds.; Wiley-VCH: Weinheim, New York, 2000, 135–154.
[16] MillerD. P., De Pablo J. J., and Corti H. R., Viscosity and Glass Transition Temperature of Aqueous Mixtures of Trehalose with Borax and Sodium Chloride, J. Phys. Chem. B., 1999, 103, 10243-10249.
[17] ZhuoR., Liu H., Zhang H. and Wang Y., Activity Coefficients and Volumetric Properties for the NaI + Maltose + Water System, J. Chem. Eng. Data, 2008, 53, 57-62.
[18] Ward G.K. and Millero F.J., The effect of pressure on the ionization of boric acid in aqueous solutions from molal-volume data, J. Soln. Chem., 1974, 3, 417.
[19] Riyazudden and Khan Imran, Interactions in L-alanine–/L-proline–/L-valine–/L-leucine–aqueous KCl/KNO_3 systems at different temperatures: An isentropic compressibility study, J. ThermochimicaActa, 2009, 483, 45.
[20] Aswar A. S., Interaction studies on biomolecules in aqueous medium, *J. Pure Appl. Ultrason*ics, 1998, **20,** 82.
[21] Ali A., Nain A.K., Kumar N. and Ibrahim M., Study of molecular interactions in binary mixtures of acetonitrile with amides through ultrasonic speed measurements, J. *Pure Appl. Ultrasonics*, 2002, 24**,** 27-35.
[22] PandeyD. and Akhtar Y., Ultrasonic studies of aqueous concentrated electrolytic solutions at 298.15 K, J. Pure Appl. Ultrasonics, 1996, 18, 108-113.
[23] Syal V.K., Lal G., Bisht P., Chauhan S., Ultrasonic measurements of some 1:1 electrolytes in chlorobenzene + methanol mixtures, J. Mol. Liquids, 1995, 63, 317-328.
[24] Mehta N.M., Karia F.D., Parsania P.H., Effect of temperature on ultrasonic velocity and thermodynamic parameters of bisphenol-C-formaldehyde-acrylate resin solutionsFluid Phase Equilibria, 2007, 262, 61-68.
[25] Ali A., Nain A. K., Kamil M.,Physico-chemical studies of non-aqueous binary liquid mixtures at various temperatures, ThermochimicaActa, 1996, 274, 209-221.
[26] Endo Harumi, NomotoOtohiko, Sound Velocity in Aqueous Non-Electrolyte Solutions, Bulletin of the Chemical Society of Japan, 1976, 49(10), 2849-2851.
[27] Azhagiri S., Jayakumar S., Padmanaban R., Gunasekaran S. andSrinivasan S., Acoustic and Thermodynamic Properties of Binary Liquid Mixtures of Benzaldehyde in Hexane and Cyclohexane, J. Solution Chem., 2009, 38, 441-448.
[28] Reddy R.R., Rama Gopal K., Narasimhulu K., Siva Sankara Reddy L., Kumar K. Raghavendra, Venkatesulu A., Krishna Reddy C.V., Correlations between Moelwyn–Hughes parameter, available volume and intermolecular free-lengths in liquid systems, J. Mol. Liq., 2008, 140, 48-53 .
[29] Yadava S.S., YadavAniruddh, Ultrasonic study on binary liquid mixtures between some bromoalkanes and hydrocarbons, Ultrasonics, 2005, 43, 732-735.
[30] SinhaAnuradha, Roy M.N., Densities, Viscosities, and Sound Speeds of Some Acetate Salts in Binary Mixtures of Tetrahydrofuran and Methanol, J. Chem. Eng. Data, 2006, 51, 1415-1423.

*****