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Acoustical Behaviour of Glucose, Sucrose and Maltose in Aqueous Ammonium Chloride Solution(0.5 M) at different temperatures

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1.ABSTRACT

The ultrasonic velocity, density and viscosity of glucose, sucrose and maltose in 0.5M ammonium chloride solution at temperatures 303.15, 308.15 and 313.15K have been measured. The desired acoustical and thermodynamic parameters namely adiabetic compressibility, free length, specific acoustic impedance, free volume, internal pressure, molar cohesive energy, viscous relaxation time, Gibb's free energy, relative association, available volume, molal hydration number and Lennard-Jones potential have been calculated. The variation of these parameters with respect to the molarity and elevation of temperatures have been explained on the basis of solute-solvent interaction and structure forming tendency of solutes in the solvent. Results show that glucose, sucrose and maltose acts as structure promoters in aqueous 0.5 mol.dm-3 NH4Cl solutions. Also the Lennard Jones potential and cohesive energy data reveals the absence of repulsive forces in the solution system.

2.INTRODUCTION

Studies on interactions of non-ionic solutes with ionic ones in different solvents are significant for investigating their physicochemical behaviour. Ultrasonic velocity studies are extensively used to analyse the behaviour of electrolyte and non electrolyte solutions in aqueous1,2 and non aqueous3,4 solvent mixtures. Ultrasonic studies have been made for simple carbohydrates in water5 , but these studies in aqueous and non aqueous medium are rare. Frank and Kaulgud6,7 have studied the thermodynamic properties of several carbohydrate like ribose, galactose, monosaccharides and disaccharides in aqueous solutions. Ultrasonic studies have been carried by Rao8. The ultrasonic studies of carbohydrates/saccharides have become a subject of increasing interest because of their multidimensional physical, biochemical and industrially useful applications9-12. In addition to their importance to food, pharmaceutical and chemical industries, the simple monosaccharides have received considerable attention for their ability to protect biological macromolecules13. Most of the chemical and biological functions of glucose, sucrose and maltose take place in aqueous medium. The situation becomes interesting if a non electrolyte is also present in such solutions. Pioneering work in such ternary (electrolyte+ non-electrolyte+ water) systems has been done Debye, Mcdevit and Long16 and Robinson et al17,18. Non-electrolytes modify the structure of water. Taylor and Robinson19 and Kawaizumie et al20 classified mono and disaccharides as structure makers; indicating hydrogen bonding with –OH groups of sugars with water. Various thermodynamic12,21,22 and spectroscopic23,6 studies have shown that the hydration of saccharides depends upon the number of hydroxyl groups, the potential hydrogen bonding sites and relative positions of the next nearest hydroxyl groups within the carbohydrate molecules24. Very few attempts have been made to study the molecular interaction among the carbohydrates in the solutions. Hence the molecular association, physico-chemical behaviour and acoustic properties of multicomponent liquid mixtures of glucose, sucrose and maltose in aqueous ammonium chloride (0.5M) solutions at temperatures 303.15, 308.15, 313.15K by measuring ultrasonic velocity, density and viscosity have been studied. From the speed of sound, various acoustical and thermodynamic parameters have been computed from the experimental data with a view to investigate the nature of molecular interaction between the components of liquid mixtures. Earlier P. S. Nikam et al25 reported the interaction between NH+ 4 and H2O molecules resulting in higher degree of solvolysis and enhancement of structure modification of water by simple carbohydrates in presence of NH+ 4 ions.

1.EXPERIMENTAL

Ammonium Chloride (B.D.H AnalaR) was recrystallised from conductivity water. It was dried in vacuum at about 800C for 12 hours. Accurately weighed amount of the perfectly dried ammonium chloride (NH4Cl) was dissolved in conductivity water to give 0.5M solution. Glucose, sucrose and maltose (all 99.99% pure, John-Baker Inc, Colorado, USA) were used without further purification. Accurately known masses of sugars were dissolved in aqueous 0.5M NH4Cl to yield solutions of required molarities. All weights were recorded on Metler balance (Switzerland, Model Ae-240) with a precision of ±0.01mg. The solutions were allowed to stand for sometime before every measurement to avoid air bubbles.

Densities of all solutions were determined using a 15 cm3 double arm Pycknometer26,27. The accuracy of density measurement of solution was ±0.00005g.cm3. The ultrasonic velocity was measured with an accuracy of 1 in 106 by using a digital frequency meter. Water was circulated around the measuring cell from the thermostat maintained at the desired temperature. The reproducibility in ultrasonic velocity measurements was ±0.03%. The temperature measurements were accurate to within ±0.01ºC.

Table-1:Values of density(ρ), Viscosity(η) and Ultrasonic Velocity(U) at 303.15, 308.15 and 313.15K

Molarity M(mol.dm^{-3})	Density ρ/(Kg.m^{-3})			Viscosity η (x10^{-3}Nsm^{-2})			Velocity U/(ms^{-1})		
	303.15	308.15	313.15	303.15	308.15	313.15	303.15	308.15	313.15
Glucose+0.5M Ammonium Chloride									
0.0125	1004.29	1002.65	1000.83	0.8118	0.7395	0.6742	1531.51	1542.85	1546.90
0.01875	1004.48	1002.84	1001.02	0.8134	0.7410	0.6755	1532.25	1543.55	1547.54
0.025	1004.67	1003.30	1001.21	0.8174	0.7446	0.6788	1532.98	1544.24	1548.18
0.0375	1005.04	1003.40	1001.58	0.8205	0.7475	0.6821	1534.46	1545.63	1549.45
0.05	1005.43	1003.78	1001.96	0.8245	0.7518	0.6867	1535.93	1547.02	1550.72
0.075	1006.17	1004.54	1002.72	0.8333	0.7590	0.6932	1538.90	1549.82	1553.28
0.1	1006.93	1005.29	1003.47	0.8413	0.7668	0.7011	1541.87	1552.62	1555.83
0.15	1008.43	1006.79	1004.97	0.8565	0.7799	0.7156	1547.89	1558.24	1560.96
0.2	1009.93	1008.30	1006.48	0.8724	0.7936	0.7314	1553.94	1563.93	1565.78
0.3	1012.92	1011.29	1009.47	0.9034	0.8247	0.7589	1566.21	1575.41	1576.45
Sucrose + 0.5M Ammonium Chloride									
0.00375	1004.26	1002.62	1000.80	0.8014	0.7237	0.6574	1530.59	1541.98	1546.11
0.005	1004.37	1002.74	1000.92	0.8027	0.7251	0.6577	1530.78	1542.15	1546.27
0.0076	1004.61	1002.97	1001.11	0.8038	0.7265	0.6584	1531.15	1542.50	1546.59
0.01	1004.84	1003.20	1001.38	0.8054	0.7280	0.6597	1531.52	1542.84	1546.92
0.015	1005.30	1003.67	1001.85	0.8094	0.7316	0.6610	1532.26	1543.53	1547.57
0.02	1005.77	1004.13	1003.31	0.8126	0.7345	0.6637	1533.00	1544.21	1548.20
0.03	1006.69	1005.06	1003.24	0.8189	0.7417	0.6689	1534.49	1545.59	1549.49
0.04	1007.62	1005.99	1004.17	0.8269	0.7489	0.6742	1535.98	1546.98	1550.79
0.06	1009.47	1007.85	1006.03	0.8413	0.7612	0.6860	1538.98	1549.76	1553.38
0.08	1011.32	1009.70	1007.89	0.8557	0.7756	0.6997	1542.01	1552.71	1555.50
Maltose + 0.5M Ammonium Chloride									
0.0025	1004.17	1002.53	1000.71	0.8098	0.7330	0.6755	1530.40	1541.88	1545.95
0.00375	1004.31	1002.67	1000.85	0.8110	0.7338	0.6729	1530.59	1542.05	1546.11
0.0050	1004.44	1002.80	1000.98	0.8118	0.7349	0.6738	1530.77	1542.22	1546.27
0.0075	1004.70	1003.06	1001.25	0.8130	0.7374	0.6755	1531.13	1542.56	1546.59
0.01	1004.97	1003.33	1001.51	0.8158	0.7392	0.6781	1531.50	1542.91	1546.91
0.015	1005.50	1003.86	1002.04	0.8197	0.7431	0.6811	1532.23	1543.59	1547.55
0.020	1006.03	1004.39	1002.57	0.8237	0.7467	0.6847	1532.96	1544.27	1548.19
0.030	1007.09	1005.45	1003.63	0.8317	0.7540	0.6916	1534.42	1545.65	1549.47
0.040	1008.14	1006.51	1004.69	0.8405	0.7612	0.6985	1535.89	1547.02	1550.75
0.060	1010.26	1008.62	1006.82	0.8565	0.7763	0.7125	1538.85	1549.79	1553.33

1.THEORY AND CALCULATIONS

Adiabetic Compressibility can be calculated from the speed of sound(U) and the density of the medium(ρ) using the equation as;

$$\beta = \frac{1}{U^2 \rho} \quad \text{----------(1)}$$

Intermolecular free length can be determined as;

$$L_f = K\sqrt{\beta} \quad \text{----------(2)}$$

Where K values from different temperatures were taken from the work of Jacobson30.

The acoustic impedance is the product of the velocity of ultrasound in a medium and its density and can be calculated by the relation31;

$$Z = U\rho \quad \text{----------(3)}$$

Suryanarayana32 obtained a relation for volume in terms of ultrasonic velocity(U) and the viscosity of liquid(η) as ;

$$V_f = \left(\frac{M_{eff} U}{K\eta}\right)^{3/2} \quad \text{----------(4)}$$

On the of statistical thermodynamics Suryanarayana[33] derived an expression for the determination of internal pressure by the use of free volume concept

$$\pi_i = bRT\left(\frac{K\eta}{U}\right)^{1/2}\left(\frac{\rho^{2/3}}{M_{eff}^{7/6}}\right) \quad \text{----------(5)}$$

Cohesion is the fundamental property of both solids and liquids. In solids we usually call it as binding energy and in liquids it is often mentioned as the internal pressure, the resultant of intermolecular forces. Molar cohesive energy is nothing but the product of π_i the internal pressure and V the molar volume.

The viscous relaxation time[34] is obtained usind equation;

$$\tau = \left(\frac{4\eta}{3\rho U^2}\right) \quad \text{----------(6)}$$

Gibb's free energy is calculated from the relation[35];

$$\Delta G = kT\ln\left(\frac{kT\tau}{h}\right) \quad \text{----------(7)}$$

Where τ is the viscous relaxation time, k is the Boltzmann's constant($1.23 \times 10^{-23} JK^{-1}$), T the absolute temperature and h is the Planck's constant (6.6×10^{-34} Js).

The relative association R_A has been determined using the standard formula[36];

$$R_A = \left(\frac{\rho}{\rho_0}\right)\left(\frac{U_0}{U}\right)^{1/3} \quad \text{----------(8)}$$

Where ρ_o and ρ are densities and U_o and U , the ultrasonic velocities of the solvent and the solution respectively.

Available volume is calculated using the relation

$$V_a = V_T\left(1-\frac{U}{U_\infty}\right) \quad \text{----------(9)}$$

Where U_∞ is the limiting velocity and is taken as $1600 ms^{-1}$.

Molal hydration number is obtained from the relation

$$H_n = \left(\frac{n_1}{n_2}\right)\left(1-\frac{\beta}{\beta_o}\right) \quad \text{----------(10)}$$

Where n_1 and n_2 are the number of moles of solute and solvent respectively. β and β_o are compressibility of solution and solvent respectively.

The Lennard Jones Potential 30 is calculated using the relation

The Lennard Jones Potential [30] is calculated using the relation

$$N = 6\left(\frac{V}{V_a}\right) - 13 \quad \text{----------(11)}$$

Where V refer to the molar volume of the mixture and V_a is the available volume.

5.RESULT AND DISCUSSION

The values of density, viscosity and ultrasonic velocity of 0.5M aqueous ammonium chloride solution in the presence of glucose, sucrose and maltose at 303.15, 308.15 and 313.15K temperatures are presented in Table-1. The acoustical parameters such as adiabetic compressibility, free length, specific acoustic impedance, free volume, internal pressure, molar cohesive energy , viscous relaxation time, Gibb's free energy, relative association , available volume, molal hydration number and Lennard Jones potential are presented in Tables 2-4.

At all temperatures the density, viscosity and velocity of the solutions increase with increasing glucose, sucrose and maltose concentrations as shown in Table-1 and the same decreases with increasing temperatures. The density increases with increasing concentration of solutes suggest a moderate strong electrolyte nature in which the solute tends to attract the solvent molecules. The gradual increase in density, viscosity and velocity with solute concentrations at all temperatures may be due to association between solute and solvent molecules. The decrease in density, viscosity and velocity with temperature indicates decrease in intermolecular forces due to increase in thermal energy of the system, which causes increase in volume expansion and ultimately increase in free path length.

Table-2; Values of adiabetic compressibility (β), free length (L_f), specific acoustic impedance (Z) and free volume (V_f) at 303.15, 308.15 and 313.15K

Molarity M (mol.dm^{-3})	Adiabetic Compressibility B/($\times10^{-10}$ m^{2}N^{-1})			Free Length L_f/($\times10^{-10}$ m)			Specific Acoustic Impedance Z/($\times10^4$ Kgm^{-2}s^{-1})			Free Volume V_f/($\times10^{-8}$m^{3}mol^{-1})		
	303.15	308.15	313.15	303.15	308.15	313.15	303.15	308.15	313.15	303.15	308.15	313.15
Glucose + 0.5M Ammonium Chloride												
0.0125	4.2452	4.1900	4.1755	0.4111	0.4116	0.4142	153.81	154.70	154.81	6.8379	6.0112	5.2534
0.01875	4.2403	4.1853	4.1713	0.4109	0.4114	0.4140	153.91	154.80	154.91	7.1289	6.2673	5.4761
0.025	4.2355	4.1800	4.1670	0.4106	0.4112	0.4138	154.01	154.93	155.00	7.4516	6.5501	5.7231
0.0375	4.2278	4.1717	4.1587	0.4102	0.4107	0.4134	154.21	155.08	155.19	8.0287	7.0578	6.1749
0.05	4.2160	4.1626	4.1503	0.4097	0.4103	0.4129	154.42	155.28	155.38	8.6146	7.5821	6.6426
0.075	4.1967	4.1444	4.1335	0.4087	0.4094	0.4121	154.83	155.68	155.75	9.7888	8.6000	7.5313
0.1	4.1774	4.1264	4.1169	0.4078	0.4085	0.4113	155.26	156.06	156.12	10.9330	9.6134	8.4308
0.15	4.1389	4.0906	4.0837	0.4059	0.4067	0.4096	156.10	156.88	156.87	13.1540	11.5439	10.1727
0.20	4.1005	4.0548	4.0526	0.4040	0.4049	0.4079	156.94	157.70	156.59	15.3220	13.4223	11.8967
0.30	4.0246	4.9841	3.9860	0.4001	0.4012	0.4044	158.64	159.32	159.13	19.4720	17.1333	15.1392
Sucrose + 0.5M Ammonium Chloride												
0.00375	4.2504	4.1947	4.1800	0.4114	0.4119	0.4144	153.71	154.60	154.73	6.5404	5.6800	4.9335
0.005	4.2489	4.1933	4.1786	0.4113	0.4118	0.4144	153.74	154.63	154.77	6.6807	5.8000	5.0304
0.0076	4.2458	4.1904	4.1802	0.4111	0.4117	0.4142	153.82	154.70	154.67	6.9542	6.0421	5.2336
0.01	4.2428	4.1876	4.1731	0.4110	0.4116	0.4141	153.89	154.77	154.90	7.2163	6.2703	5.4304
0.015	4.2368	4.1819	4.1677	0.4108	0.4113	0.4138	154.04	154.91	155.05	7.7780	6.7579	5.8265
0.02	4.2307	4.1763	4.1582	0.4104	0.4110	0.4135	154.18	155.05	155.33	8.3370	7.2432	6.2457
0.03	4.2186	4.1650	4.1516	0.4098	0.4104	0.4130	154.47	155.34	155.45	9.4752	8.2562	7.0978
0.04	4.2066	4.1537	4.1408	0.4092	0.4099	0.4125	154.76	155.62	155.72	10.6722	9.2973	7.9709
0.06	4.1825	4.1312	4.1194	0.4081	0.4088	0.4114	155.35	156.19	156.27	13.1162	11.4071	9.7934
0.08	4.1585	4.1080	4.1006	0.4069	0.4076	0.4103	155.94	156.77	156.77	15.6495	13.6452	11.7240
Maltose + 0.5M Ammonium Chloride												
0.0025	4.2519	4.1956	4.1812	0.4114	0.4120	0.4145	153.68	154.58	154.70	6.5177	5.6761	5.0414
0.00375	4.2502	4.1941	4.1797	0.4114	0.4119	0.4144	153.72	154.62	154.74	6.6584	5.7651	5.1089
0.005	4.2487	4.1926	4.1783	0.4113	0.4118	0.4143	153.76	154.65	154.78	6.7947	5.9182	5.2162
0.0075	4.2456	4.1897	4.1754	0.4111	0.4117	0.4142	153.83	154.73	154.85	7.0638	6.1702	5.4310
0.010	4.2424	4.1867	4.1726	0.4110	0.4115	0.4141	153.91	154.81	154.92	7.3564	6.4160	5.6591
0.0150	4.2361	4.1808	4.1670	0.4107	0.4112	0.4138	154.07	154.95	155..07	7.9268	6.9182	6.0941
0.020	4.2298	4.1749	4.1613	0.4104	0.4109	0.4135	154.22	155.11	155.22	8.5081	7.4248	6.5444
0.030	4.2173	4.1631	4.1501	0.4098	0.4104	0.4129	154.52	155.41	155.51	9.6976	8.4629	7.4619
0.040	4.2049	4.1513	4.1388	0.4092	0.4098	0.4124	154.84	155.71	155.80	10.9360	9.5277	8.4054
0.060	4.1799	4.1278	4.1164	0.4080	0.4086	0.4113	155.46	156.32	156.39	13.4760	11.7485	10.3658

From Table-2, it is found that the adiabetic compressibility decreases with increase in concentration of the solute as well as temperature. The compressibility volumes are larger in maltose than sucrose and glucose. Intermolecular free length decreases with molar concentration of solute but it increases with temperature in all the systems. The specific acoustic impedance increases with increasing solute concentrations as well as temperatures.

The decrease in adiabetic compressibility is attributed to the influence of the electrostatic field of the ions on the surrounding solvent molecules. The decrease in free length with increase in solute concentration indicates that there is a significant interaction between solute and solvent molecules, suggesting a structure promoting behavior on the addition of solute. Due to thermal expansion of liquids, an increase in temperature causes free length to increase. The behavior of acoustic impedance can be explained on the basis of lyophobic interaction between solute and solvent molecules, which increases the intermolecular distance and becomes responsible for the propagation of ultrasonic waves. The values of free volume Vf increases with increasing concentration of solute and decreases with increases in temperature in all system. A close look at the values of the free volume in reveals that it is relatively higher for glucose than for sucrose and maltose. The highest value of free volume indicates solute solvent interaction is less in glucose than in any other two systems.

The following observations have been made from Table-3;(a) the values of internal pressure πi decreases with increase in concentration of solute and temperature, (b) the molar cohesive energy in all the system decreases with increase in concentration of solute as well as temperature, (c) as the concentration of the solute increases, the values of τ

and ΔG increase, but the same show reverse trend for increase in temperature.

Table-3; Values of internal pressure(π_i), molar cohesive energy($\pi_i V_m$), viscous relaxation time(τ) and Gibb's free energy(ΔG) at 303.15, 308.15 and 313.15K

Molarity M mol.dm^{-3}	Internal Pressure $\pi_i/(\times 10^6 Nm^{-2})$			Molar Cohesive Energy $\pi_i V_m/(m^3Nm^{-2}mol^{-1})$			Viscous Relaxation Time $\tau/(\times 10^{-13}s)$			Gibb's Free Energy $\Delta G/(\times 10^{-21}KJmol^{-1})$		
	303.15	308.15	313.15	303.15	308.15	313.15	303.15	308.15	313.15	303.15	308.15	313/15
Glucose + 0.5M Ammonium Chloride												
0.0125	6.7281	6.4963	6.2877	1004.700	971.530	942.027	4.5950	4.1312	3.7535	1.5432	1.4206	1.3103
0.01875	6.5378	6.3129	6.1099	976.287	944.096	915.399	4.5987	4.1350	3.7569	1.5446	1.4221	1.3118
0.025	6.3713	6.1531	5.9544	951.414	920.195	892.091	4.6161	4.1495	3.7715	1.5507	1.4279	1.3183
0.0375	6.0555	5.8476	5.6627	904.264	874.508	848.394	4.6229	4.1578	3.7822	1.5531	1.4311	1.3230
0.05	5.7845	5.5885	5.4147	863.803	835.763	811.238	4.6348	4.1726	3.8000	1.5572	1.4370	1.3308
0.075	5.3403	5.1569	4.9966	797.463	771.216	748.604	4.6628	4.1942	3.8204	1.5670	1.4455	1.3400
0.10	4.9877	4.8183	4.6716	744.813	720.581	699.899	4.6859	4.2189	3.8485	1.5750	1.4551	1.3520
0.15	4.4666	4.3134	4.1901	666.993	645.073	627.768	4.7265	4.2537	3.8965	1.5790	1.4687	1.3728
0.20	4.1048	3.9627	3.8590	612.979	592.624	578.167	4.7697	4.2905	3.9521	1.6037	1.4829	1.3964
0.30	3.6371	3.5183	3.4245	543.127	526.164	513.071	4.8478	4.3809	4.0334	1.6300	1.5172	1.4305
Sucrose + 0.5M Ammonium Chloride												
0.00375	6.8139	6.5505	6.3284	1692.385	1628.080	1575.205	4.5417	4.0476	3.6638	1.5244	1.3869	1.2698
0.005	6.7215	6.4628	6.2391	1669.437	1606.277	1552.969	4.5475	4.0541	3.6643	1.5265	1.3896	1.2700
0.0076	6.5320	6.2823	6.0582	1622.373	1561.431	1507.928	4.5504	4.0591	3.6697	1.5275	1.3916	1.2725
0.01	6.3598	6.1266	5.9119	1582.088	1522.733	1471.515	4.5562	4.0648	3.6707	1.5296	1.3939	1.2729
0.015	6.0626	5.8313	5.6186	1505.796	1449.324	1398.521	4.5723	4.0793	3.6731	1.5363	1.3998	1.2741
0.020	5.7856	5.5650	5.3660	1436.994	1383.130	1335.638	4.5838	4.0900	3.6797	1.5393	1.4041	1.2771
0.030	5.3120	5.1150	4.9240	1319.364	1271.259	1225.635	4.6062	4.1189	3.7026	1.5472	1.4157	1.2875
0.040	4.9279	4.7450	4.5641	1223.956	1179.337	1136.043	4.6379	4.1476	3.7223	1.5583	1.4271	1.2963
0.060	4.3311	4.1687	4.0122	1075.740	1036.109	998.668	4.6917	4.1928	3.7678	1.5770	1.4450	1.3166
0.080	3.8934	3.7509	3.6129	967.031	932.263	899.288	4.7445	4.2481	3.2481	1.5951	1.4665	1.3420
Maltose + 0.5M Ammonium Chloride												
0.0025	6.9512	6.6901	6.5101	1761.568	1697.924	1653.780	4.5909	4.1005	3.7658	1.5418	1.4083	1.3158
0.00375	6.8548	6.5961	6.4028	1737.151	1674.076	1626.529	4.5959	4.1036	3.7500	1.5436	1.4095	1.3087
0.005	6.7598	6.5064	6.3153	1713.081	1651.309	1604.284	4.5987	4.1083	3.7538	1.5446	1.4114	1.3104
0.0075	6.5770	6.3366	6.1478	1666.75	1608.202	1561.743	4.6022	4.1193	3.7607	1.5458	1.4158	1.3135
0.010	6.4114	6.1740	5.9943	1624.783	1566.938	1522.744	4.6146	4.1264	3.7726	1.5501	1.4187	1.3188
0.0150	6.1020	5.8776	5.7042	1546.366	1491.708	1449.042	4.6298	4.1423	3.7842	1.5555	1.4250	1.3240
0020	5.8261	5.6118	5.4476	1476.454	1424.269	1383.855	4.6455	4.1565	3.7990	1.5610	1.4307	1.3304
0.030	5.3549	5.1583	5.0083	1357.050	1309.166	1272.252	4.6768	4.1853	3.8269	1.5718	1.4420	1.3427
0.040	4.9701	4.7854	4.6473	1259.53	1214.520	1180.562	4.7123	4.2133	3.8546	1.5840	1.4530	1.3548
0.060	4.3731	4.2120	4.0912	1108.229	1068.989	1039.286	4.7746	4.2726	3.9106	1.6053	1.4760	1.3788

` The internal pressure is found to decrease with increase in concentration of solute. The reduction πi may be due to the loosening of cohesive forces leading to the breaking up of the structure of solvent37. The viscous relaxation time shows the presence of molecular interaction by the addition of solute concentration at a given temperature and the same is confirmed by the Gibb's free energy parameter. The increasing values of Gibb's free energy suggest that the closer approach of unlike molecules is due to hydrogen bonding. The reduction of ΔG with temperature in all the system indicates the need for smaller time for the co-operative process or the rearrangement of molecules in the mixture decreases the energy that leads to dissociation.

The following observations can be made from Table-4; (a) relative association increases with increase in concentration of solute as well as temperature in all the system, (b) available volume decreases with increase in concentration of solute as well as temperature in all the system, (c) molal hydration numbers are positive and decreases with increase in concentration of solute as well as temperature in all the system, (d) Lennard Jones potentials are positive and increases with increasing solute concentrations as well as temperature in all the system indicates the presence of molecular association between solute and solvent with addition of solutes, which is in accordance with that reported by Jahagirdar and Shanlarwar38.

The positive values of molal hydration number indicate an appreciable solvation of solutes39. This is an added support for the structure promoting nature of the solutes as well as the presence of dipole-dipole interaction between solute and water molecules. Molal hydration number mostly remains constant or show minor decrease with increasing concentration of solute which confirms little solute solvent interaction and at high temperatures the values of Hn decreases, which show weakening of solute solvent interaction.

The Lennard Jones potential values are positive and increase in all system. The positive values of LJP shows the absence of repulsive forces and dominance of attractive forces in the system. The magnitude of LJP is higher in glucose as compared to sucrose and maltose.

Table-4: Values of relative association(R_A), available volume(V_a), molal hydration number(H_n) and Lennard jones potential(N) at 303.15, 308.15 and 313.15K

Molarity M (mol.dm^{-3})	Relative Association (R_A)			Available Volume $V_a/(\times 10^6 m^3 mol^{-1})$			Molal Hydration Number (Hn)			Lennard Jones Potential (N)		
	303.15	308.15	313.15	303.15	308.15	313.15	303.15	308.15	313.15	303.15	308.15	313.15
Glucose + 0.5M Ammonium Chloride												
0.0125	1.00006	1.00009	1.0001	6.3922	5.3417	4.9721	10.241	9.682	8.986	21.5836	28.1057	30.8370
0.01875	1.00009	1.00013	1.00016	6.3231	5.2763	4.9122	10.241	9.675	8.983	21.9614	28.6154	31.3718
0.0250	1.00012	1.00017	1.00016	6.2550	5.2118	4.8522	10.225	9.671	8.981	22.3422	29.1304	31.9198
0.0375	1.00017	1.00024	1.00020	6.1168	5.0818	4.7333	10.227	9.664	8.969	23.1403	30.2074	33.0484
0.050	1.00027	1.00032	1.00031	5.9796	4.9520	4.6144	10.215	9.665	8.960	23.9695	31.3411	34.2351
0.07500	1.00032	1.00046	1.00041	5.7025	4.6902	4.3747	10.204	9.641	8.940	25.7665	33.8153	36.8233
0.10	1.00042	1.00060	1.00061	5.4253	4.4290	4.1360	10.192	9.626	8.923	27.7472	36.5820	39.6997
0.15	1.00060	1.00087	1.0030	4.8634	3.9032	3.6556	10.162	9.595	8.884	32.4545	43.2545	46.6246
0.20	1.00076	1.00110	1.0012	4.2988	3.3714	3.2042	10.132	9.564	8.724	38.4250	52.1286	55.0230
0.30	1.0010	1.00150	1.0022	3.1536	2.2983	2.2051	10.074	9.503	8.771	57.0987	82.5344	85.8427
Sucrose + 0.5M Ammonium Chloride												
0.00375	1.00023	1.00025	1.00025	10.7746	9.0127	8.3834	15.944	15.074	14.428	7.6648	11.7715	13.8699
0.0050	1.00031	1.00035	1.00043	10.7452	8.9863	8.3586	15.923	15.074	14.357	7.7215	11.8503	13.9499
0.0076	1.00046	1.00049	1.00049	10.6877	8.9319	8.3088	15.914	15.074	14.392	7.8329	12.0016	14.1114
0.01	1.00061	1.00065	1.00081	10.6302	8.8791	8.2574	15.910	15.061	14.397	7.9454	12.1503	14.2799
0.015	1.00091	1.00096	1.00099	10.5154	8.7719	8.1563	15.906	15.057	14.384	8.1743	12.4576	14.6181
0.020	1.00121	1.00130	1.00130	10.4005	8.6663	8.0583	15.897	15.048	14.366	8.4081	12.7679	14.9540
0.030	1.00180	1.00190	1.00190	10.1692	8.4519	7.8576	15.884	15.035	14.350	8.8950	13.4214	15.6679
0.040	1.00240	1.00250	1.00250	9.9379	8.2360	7.6554	15.871	15.018	14.350	9.4046	14.1141	16.4253
0.060	1.00360	1.00370	1.00370	9.4722	7.8041	7.2525	15.847	14.099	14.321	10.5061	15.6144	18.0600
0.080	1.00480	1.00500	1.00500	9.0018	7.3459	6.9227	15.822	14.650	14.056	11.7343	17.3994	19.5397
Maltose + 0.5M Ammonium Chloride												
0.0025	1.00019	1.00019	1.00020	11.0237	9.2191	8.5814	16.527	17.888	15.104	7.1928	11.3583	13.2482
0.00375	1.00028	1.00028	1.00030	10.9936	9.1921	8.5560	16.509	17.162	15.066	7.2480	11.4298	13.3261
0.0050	1.00037	1.00038	1.00039	10.9651	9.1652	8.5306	16.500	16.800	15.075	7.3007	11.5017	13.4045
0.0075	1.00055	1.00055	1.00065	10.9081	9.1112	8.4799	16.492	16.437	15.066	7.4067	11.6467	13.5627
0.010	1.00072	1.00073	1.00090	10.8495	9.0557	8.4291	16.487	16.255	15.048	7.5170	11.7978	13.7228
0.015	1.00150	1.00145	1.00017	10.7338	8.9478	8.3274	16.474	16.065	15.039	7.7380	12.0967	14.0489
0.020	1.00144	1.00265	1.00016	10.6182	8.8400	8.2258	16.467	15.970	15.035	7.9639	12.4029	14.3830
0.030	1.00260	1.00335	1.00280	10.3870	8.6211	8.0226	16.448	15.866	15.017	8.4306	13.0479	15.0767
0.040	1.00330	1.00455	1.00350	10.1541	8.4038	7.8194	16.435	15.800	14.998	8.9220	13.7215	15.8063
0.060	1.00428	1.00516	1.00470	9.6853	7.9644	7.4100	16.404	15.731	14.968	9.9831	15.1957	17.3989

5.CONCLUSION

Since the glucose show greater association between –OH groups of solute and water than in sucrose and maltose which lead to higher ultrasonic velocity, which is the direct result of hydrogen bonding between solute and solvent molecules. The solute solvent interaction flows the order Glucose>Sucrose>Maltose. The hydrophilic attraction between the solute and solvent molecules promotes the structure making characteristics of the solvent at higher concentrations of solute. Structure forming tendency is due to higher solvophilicity and structure breaking tendency is due to solvophobicity. The interaction tends to be weaker due to presence to weak intermolecular forces and thermal dispersion forces with elevation of temperatures. The lowering values of βad clearly indicate complex formation between solute and solvent in addition to complexes formed between sugars and water through hydrogen bonding.

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