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Archives of Physics Research, 2011, 2 (4):80-88
(http://scholarsresearchlibrary.com/archive.html)

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ISSN : 0976-0970
CODEN (USA): APRRC7

Ultrasonic studies on interaction of inorganic salts with fructose

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ABSTRACT

Ultrasonic velocity, density and viscosity have been measured for fructose in aqueous NaCl and $MgCl_2$ at 298.15K, 303.15K & 308.15K. Thermodynamic parameters such as adiabatic compressibility(β), acoustic impedance (z),intermolecular free length(L_f) and relative association number (R_A) have been obtained from the experimental data for the solutions of inorganic salts i.e. NaCl and $MgCl_2$ with fructose at various concentrations and temperatures, with a view to investigate the exact nature of the molecular interactions. Adiabatic compressibility and intermolecular free length decreases with increase in concentration and temperature and gradually increases with concentration of solutes. These parameters have further been used to interpret the hydrophilic part of the solute and molecular interactions in the solutions.

Key words: Acoustic, thermodynamic parameters, fructose, inorganic salts, molecular interaction, association.

INTRODUCTION

Sugars and NaCl these compounds are grouped together because of the similarity in their modes of action in preserving foods. At high concentration, salt exerts drying effect upon both food and micro organisms[1].One recent study[2] has shown that fructose causes a sodium sensitive increase in blood pressure. The effects of dietary fat, NaCl, and fructose on renal sodium and water transporter abundances and systematic blood pressure have been studied by Jian Song et al and coworkers[3]

Many other researchers have made attempts by making the use of an ultrasonic technique to explore the behavior of some carbohydrates, amino acids in aqueous and non aqueous solutions[4-6] The ultrasonic studies are of great importance in helping to understand the nature and extent of the patterns of molecular aggregation that exists in liquid mixtures, resulting from intermolecular interactions[7].Electrolytes [8]dissolving in water have been classified as structure makers or structure breakers, depending on the charge density. It has been reported that ions with low charge density are net structure breakers; ions with a high charge density show an opposite behavior and net structure makers. It is an interesting to explore the ionic processes accompanying the solution of strong electrolytes. Also the interactions of interactions of electrolytes with biomolecules such as fructose play vital role in understanding the nature of action of electrolytes and biomolecules in the biochemical process in the body system. Fructose is a component of sucrose. It is derived from the digestion of table sugar.

However, no efforts appear to have been made to collect the ultrasonic studies data of aqueous and mixed aqueous solution of fructose with inorganic salts. Hence an experimental study was carried out by authors and reported different acoustic and thermodynamic parameters of fructose in double distilled water and aqueous solution of electrolytes such as NaCl and $MgCl_2$.Following systems were taken at 298.15 ,303.15 and 308.15K.

System I- Aqueous NaCl + Fructose
System II- Aqueous $MgCl_2$ + Fructose

The adiabatic compressibility, acoustic impedance, intermolecular free length and relative association of fructose in aqueous solution of inorganic salts such as NaCl and $MgCl_2$at 298.15, 303.15 &303.15K have been studied in the present paper. Such data are expected throw light on the interaction between inorganic salts and biomolecules.

Experimental Details

AR grade fructose (99.8%), sodium chloride (99.9%) and magnesium chloride (98%) were obtained from fine chemical industries, Mumbai. All chemicals were used without further purification. Water used in the present investigation was double distilled. All chemicals used were dried over $CaCl_2$ in desiccators before use. The solutions were prepared in double distilled water. The concentration of fructose in aqueous NaCl and $MgCl_2$ were changed by weight percentage. The solutions were kept in the special air tight bottles and used within 12 hr after preparation to minimize decomposition due to bacterial contamination.

Ultrasonic velocity was measured by a single crystal interferometer (F-81, Mittal Enterprises, and New Delhi) operating at frequency of 2 MHz. The source of ultrasonic waves was a quartz crystal excited by a radio frequency oscillator placed at the bottom of a double jacketed metallic cylinder container. The cell was filled with the desired solution and water at constant temperature was circulated in the outer jacket. The cell was allowed to equilibrate for 30 min prior to making the measurements. The interferometer was calibrated against the ultrasonic velocity of water used at T=298.15K.The present experimental value is 1497.59 ms^{-1} which is in good agreement with literature value[7] 1496.69 ms^{-1} and accuracy in the velocity measurement is =-1.0 ms^{-1}

The densities of the solutions were determined accurately using 25 ml specific gravity bottle and electronic balance and the accuracy in the density measurements is ± $1x10^{-4}$g.An average of triple measurements was taken into account. Sufficient care was taken to avoid any entrapment of air bubble. Viscosity was measured with pre-calibrated Ostwald type viscometer. The flow of time was measured by 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 and the accuracy of the viscosity measurement was ±0.5%.The experimental temperature was maintained constant by circulating water with the help of thermostatic water bath with an accuracy of temperature measurement ±0.1K.

Theory

The ultrasonic velocities ,densities and viscosities of fructose in pure water and in aqueous solutions of NaCl and $MgCl_2$ at 298.15 ,303.15 and 308.15K are presented in Table-1 andTable-2 respectively.Thermodynamic parameters such as adiabatic compressibility(β),intermolecular free length(L_f),acoustic impedance(z),and relative association(R_A), were calculated from empirical Jacobson's relations[9-11]

Adiabatic compressibility (β) is calculated by the relation

$$\beta = 1/u^2\rho \quad m^2N^{-1} \qquad \ldots\ldots (1)$$

Where u and ρ are ultrasonic velocity and density of aqueous solution of citric acid

Acoustic Impedance (z) is calculated by using formula

$$z = u \times \rho \text{ kg } m^{-1}s^{-1} \qquad \ldots\ldots\ldots (2)$$

Intermolecular free length (L_f) is obtained using formula

$$L_f = K/\rho^{1/2}u \quad A^0 \qquad \ldots\ldots\ldots (3)$$

Relative association (R_A) is obtained using the relation

$$R_A = \frac{\rho}{(\rho 0)x(u/u0)1/3} \qquad \ldots\ldots (4)$$

Where K is Jacobson's temperature dependent constant

Temp	303	308	313	318K
$Kx10^4$	6.31	6.36	6.42	6.47

And u the ultrasonic velocity, ρ the density of solution, u_0 the velocity of solvent,ρ_0 the density of solvent.

The important organic compounds[12] are carbohydrates, lipids, amino acids and proteins and nucleotides .Being organic all have carbon as an essential component. All have either C-C or C-H covalent bonds or both. Dehydration synthesis combines two carbohydrates units to form a disaccharide e.g. table sugar. Fructose is a simple reducing sugar found in many foods and is one of the three important dietary monosaccharide along with glucose and galactose. Fructose is contained in honey, fruits, berries, melons and in some root vegetables. Fructose has a composition similar to glucose but differs in chemical properties and in the physiological role, and less readily absorbed for utilization by the tissue cells. This is due to the difference in the position of the OH group in glucose and fructose[13.]Fructose is recommended for and consumed by, people with diabetes mellitus or hyperglycemia, because it does not raise blood glucose or insulin concentration since it is metabolized without the need of insulin. Excessive caloric intake and physical inactivity are likely important factors driving the obesity epidemic. Excessive fructose intake has a critical role in the epidemic of cardio renal disease. There is an epidemic that the unique ability of fructose to induce a increase in uric acid may be a major mechanism by which fructose can cardio renal disease. Fructose may cause obesity via several different mechanisms.[14]

RESULTS AND DISCUSSION

Saccharides are typical nonelectrolytes with several hydroxyl groups. Fructose is a ketohexose with formula $C_6H_{12}O_6$. Fructose has the highest solubility among all sugars. The hydration behavior of Saccharides has been found to be related to the number or configurations of OH groups. These are important chemicals in life process. NaCl is a salt of strong acid and strong base. Such salt when dissolved in water gives same number of positive and negative ions .Therefore it is neutral. When fructose is added to aqueous NaCl, there is weak association between NaCl and fructose molecules. Whereas $MgCl_2$ is a salt of strong acid and weak base. When $MgCl_2$ is mixed with water it forms an ionic solution. Being ionic solvent the aqueous $MgCl_2$ shows more association for fructose than aqueous NaCl.

Table 1: Variation of thermodynamic parameters at different concentrations (wt%) and different temperatures for the system (aqueous NaCl +Fructose) at 2 MHz.

Wt %	U m/s	P Kg/m3	η N s m^{-2}	$\beta x10^{-10}$ m^2N^{-1}	$zx10^6$ Nm-^{2}	L_f A^0	R_A
			298.15K				
0	1500.24	1060.4	10.9637	3.7684	1.6774	0 .3992	1.0000
1	1580.04	1067.02	11.221	3.7428	1.6909	0.3979	0.9915
2	1600.08	1081.1	11.332	3.6128	1.7298	0..3909	1.0020
3	1565.44	1090.5	11.447	3.7419	1.6416	0.3978	1.0189
4	1624.08	1108.1	11.551	3.4214	1.7996	0.3804	1.0177
5	1635.52	1121.4	11.780	3.3337	1.8340	0.3755	1.0275
			303.15K				
0	1583.60	1060.0	9.9150	3.7617	1.6786	0.4025	1.0000
1	1584.08	1068.4	11.1600	3.7300	1.6924	0.3972	1.0078
2	1664.64	1079.5	11.2750	3.3430	1.7961	0.3760	1.0016
3	1565.44	1087.2	11.7090	3.7533	1.7019	0.3984	1.0296
4	1634.44	1104.1	11.8060	3.3904	1.8045	0.3787	1.0307
5	1637.20	1195.0	11.9150	3.1219	1.9564	0.3634	1.1149
			308.15K				
0	1583.90	1058.0	9.1575	3.7675	1.6757	0.4065	1.0000
1	1575.08	1076.7	11.3210	3.7435	1.6958	0.3979	1.0194
2	1599.40	1081.3	11.4000	3.6152	1.7294	0.3910	1.0187
3	1503.20	1091.3	11.4750	4.0553	1.6404	0.3860	1.0252
4	1612.76	1109.4	11.5020	3.9076	1.7891	0.3828	1.0422
5	1632.68	1123.9	11.6520	3.3378	1.8349	0.3757	1.0516

u= Ultrasonic velocity, p = Density; η = Viscosity; β = Ad. Compressibility; Z = Acoustic impedance; L_f = Intermolecular free length; R_A =Relative association

Table 2: Variation of thermodynamic parameters at different concentrations (wt %) and different temperatures for the system (aqueous $MgCl_2$ +Fructose) at 2 MHz.

Wt%	U m/s	P Kg/m3	η N s m^{-2}	$\beta x10^{-10}$ m^2N^{-1}	$zx10^6$ Nm^{-2}	L_f A^0	R_A
			298.15K				
0	1606.5	1092.8	13.467	3.5456	1.7555	0.3872	1.0000
1	1550.18	1069.0	10.7583	3.8927	1.6571	0.4058	0.9899
2	1552.28	1067.0	11.2363	3.8895	1.6562	0.4056	0.9876
3	1524.16	1157.0	16.2613	3.7205	1.7634	0.3967	1.0774
4	1544.00	1075.0	19.8167	3.9020	1.6598	0.4062	0.9968
5	1561.2	1078.0	19.9520	3.8059	1.6825	0.4012	0.9959
			303.15K.				
0	1615.84	1092.4	12.338	3.5060	1.7051	0.5886	1.0000
1	1551.5	1067.0	10.0533	3.8934	1.6554	0.4058	0.9881
2	1498.24	1066.0	11.7071	4.1790	1.5971	0.4204	1.0103
3	1532.08	1153.2	13.9719	3.6943	1.7667	0.3953	1.0619
4	1513.84	1073.1	14.2134	4.0663	1.6245	0.4147	1.0039
5	1570.14	1076.0	15.3325	3.7647	1.6893	0.3975	0.9944
			308.15K				
0	1617.2	1090.4	11.2617	3.5066	176339	0.3921	1.0000
1	1530.7	1066.1	10.5321	4.0033	1.6318	0.4115	0.9957
2	1496.08	1065.0	9.7752	4.1950	1.5953	0.4270	1.0023
3	1541.55	1143.8	11.9225	3.6790	1.7632	0.3945	1.0658
4	1596.68	1071.5	11.5780	3.6607	1.7108	0.3935	0.9868
5	1599.7	1075.0	12.7189	3.6350	1.7196	0.3921	0.9931

u= Ultrasonic velocity, p = Density; η = Viscosity; β = Ad. Compressibility; Z = Acoustic impedance; L_f = Intermolecular free length; R_A =Relative association

Figure-1: Variation of adiabatic compressibility with concentration and temperature for (aqueous NaCl+Fructose) at 2MHz.

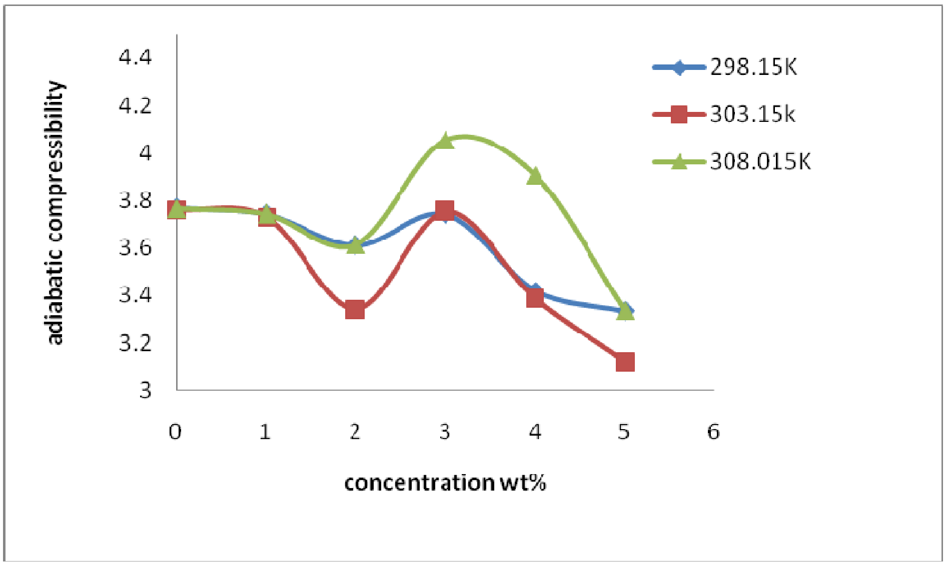


Figure-2: Variation of acoustic impedances with concentration and temperature for (aqueous NaCl+Fructose) at 2MHz

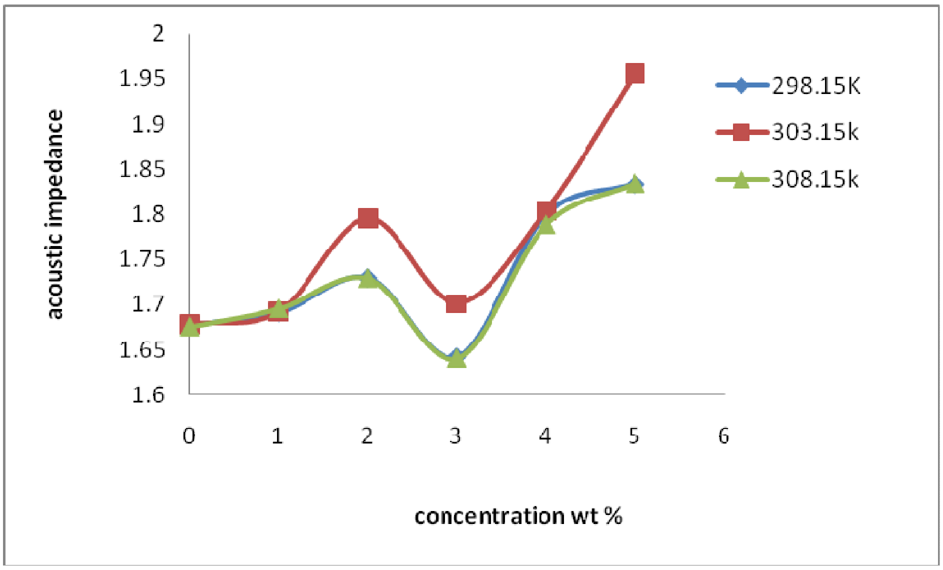
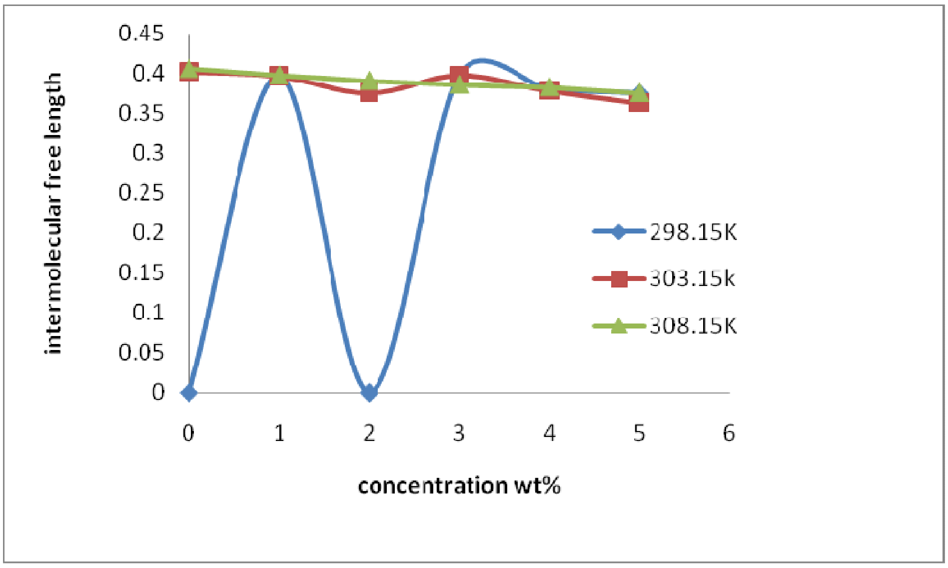


Figure-3: Variation of intermolecular free lengths with concentration and temperature for (aqueous NaCl+Fructose) at 2MHz.



From table -1 and table-2 it is seen that the values of ultrasonic velocities in both the solution increases with increase in concentration and temperature. But the values of ultrasonic velocities in aqueous NaCl are greater than that in aqueous $MgCl_2$. It is also seen that the values of intermolecular free length in aqueous NaCl are less as compared to the values in aqueous $MgCl_2$, this suggests that the solute solvent interaction in case of aqueous $MgCl_2$ is more than in case aqueous NaCl. This may be confirmed by the viscosities values (the viscosity is directly proportional to concentration of solution) suggesting more association. From table-1 and table-2 it is also seen that the values of adiabatic compressibility and the values of intermolecular free lengths decrease with concentration but the values of acoustic impedances and relative association increase with concentration and temperature. The decrease in adiabatic compressibility in the respective solutions may be attributed to the influence of hydroxyl groups on the electrostatic field of metal ions Na^+, Mg^{++}.The hydration of fructose depends upon number of hydroxyl groups and the potential of H bonding sites[15].As aqueous $MgCl_2$ is more ionic than aqueous NaCl, the molecular interaction between fructose with $MgCl_2$ is strong than NaCl. The results are also depicted by figures 1-8.

Figure-4: Variation of relative association with concentration and temperature for (aqueous NaCl+Fructose) at 2MHz.

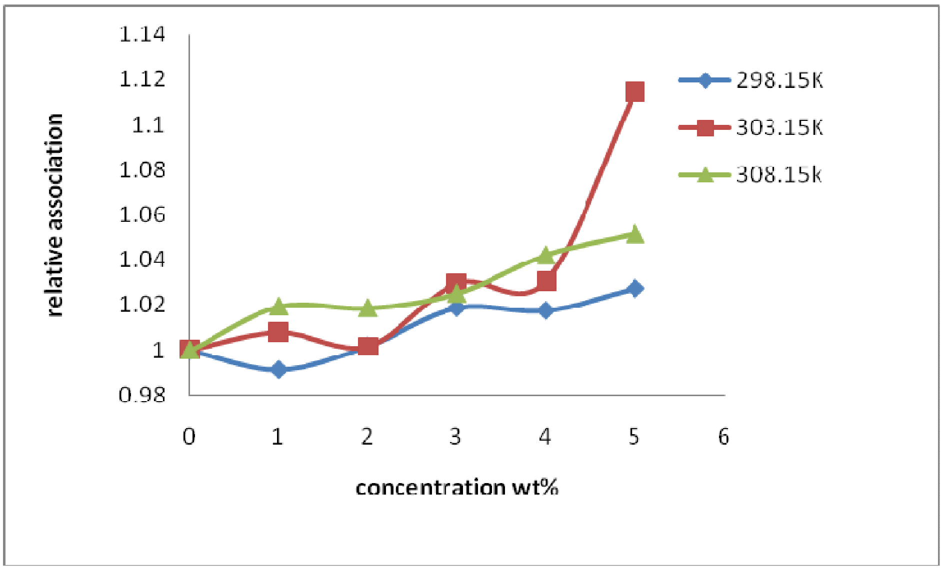


Figure-5: Variation of adiabatic compressibility with concentration and temperature for (aqueous $MgCl_2$+Fructose) at 2MHz.

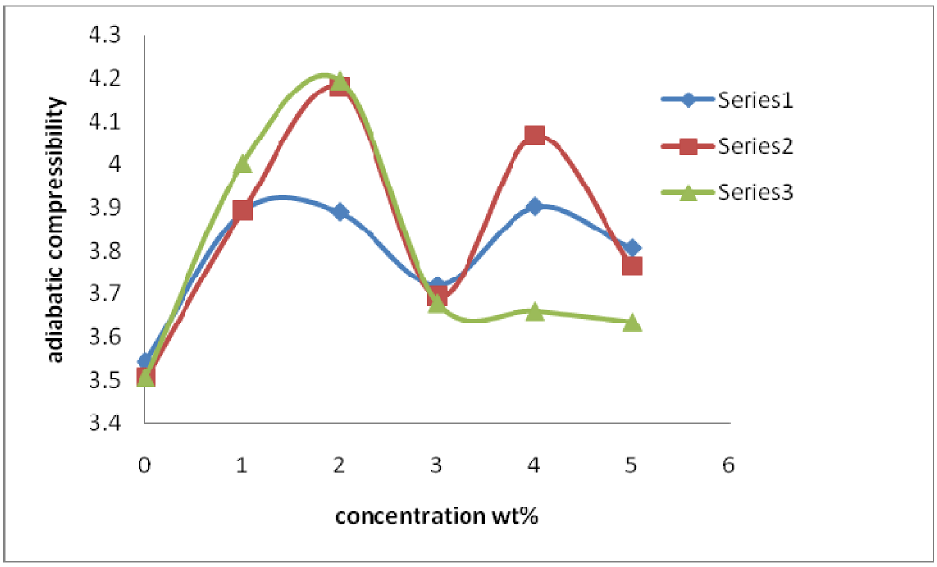


Figure-6: Variation of acoustic impedances with concentration and temperature for (aqueous $MgCl_2$+Fructose) at 2MHz.

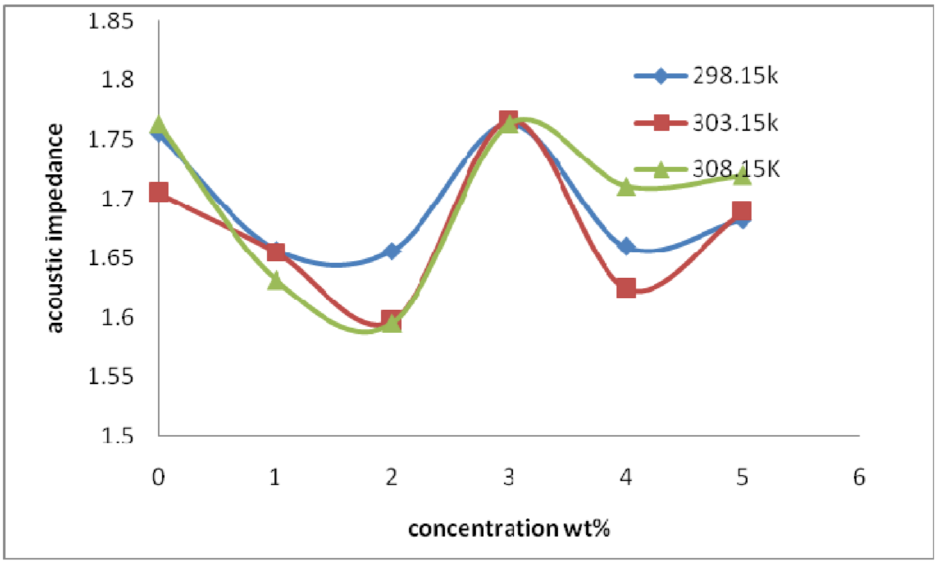


Figure-7:Variation of intermolecular free length with concentration and temperature for (aqueous $MgCl_2$+Fructose) at 2MHz.

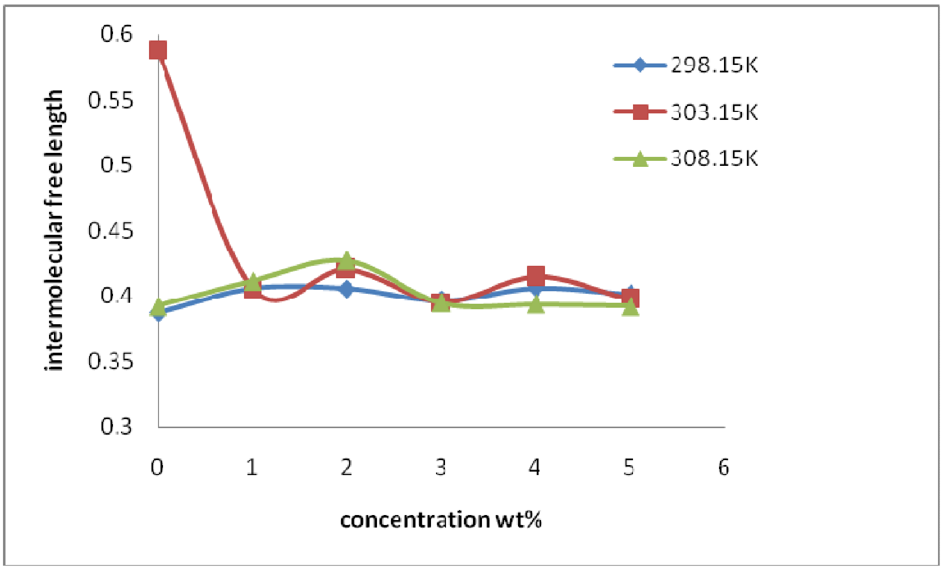
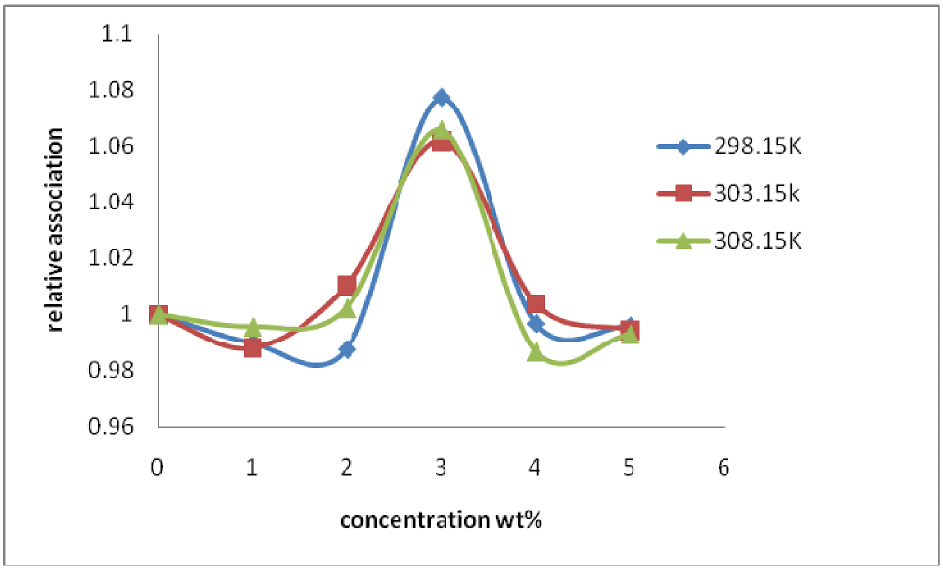


Figure-8: Variation of relative association with concentration and temperature for (aqueous $MgCl_2$+Fructose)at 2MHz.



REFERENCES

[1] Encyclopedia of biotechnology-3Microbial biotechnology,C D Swarnalatha Dagurumurthi Bhaskar Rao DPH public. NewDelhi, pp229.
[2] Catena C, Cavarape A, Novello M, Giacchetti G , and Sechi I.A. *Kidney Int* 64:2163-2171,**2003**.
[3] Jian Song, Xinqun Hu, Min Shi, Mark A. Knepper, and Carolyn A. Ecelbarger, *Am. J .Physiol Renal Physiol* , Aug **2004** pp204-211.
[4] S Shakeel Ahmad ,Khalil A Nasir & Rabina Saleem, *Pak J Sci Ind Res* ,**2004**,47(5),349-55.
[5] S.R.Kanhekar, Pravina Pawar & G.K.Bichile, *Ind J of Pure & Appl Phys*, 48,feb **2010** ,95-99.
[6] Prakash O,Prasad S,Pandey SV and Prakash s *Ind J Pure and Appl Phy* 20 (**1982**)631.
[7] S.Thirumaran,S.Sudha, *J Chem Pharm Res* , **2010**,2(1:327-337).
[8] Jahagirdar B.V. Arbad B.R. Smt Patil C& Shankarwar A .G. *Indian J Pure & Applied Phys*, 38(**2000**),645.
[9] Shashikant A Ikhe & M.L.Narwade, *Indian J Chem*, 44A(**2005**)1203.
[10] Palani R.Sarvanam S & Geetha A, *Asian J of Chem*., 19 No 7 (**2007**)5113.
[11] Thiyagarajan R & Palaniapan L, *Indian J Pure & Appl Phys*,46 (**2008**) 852.
[12] Everyday Chemistry ,J.R. Partington, 3rd edi,McMillan&comp London -p491.
[13] Biomolecules ,Mohan P Arora ,Himalaya publi. house ,1st edition ,p127.
[14] Richard J Johnson,Mark S. Segal, Yuri Saulin,Takahiko Nakagawa,Daniel I.Feig ,Duk Hec Kang, Michael S. Gersch, Steven Benner ,Laura C. Sanchez –Lozada, *American Journal of Clinical Nuitrition*, vol.86, no.4, 899-906,oct **2007**.
[15] A.N.Kannappan and R.Palani , *Indian J Pure & Appl Phys,* 45 (**2007**) 573.