Physico-chemical studies on some mono and disaccharides in aqueous media at 298.15 K

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The present study divulges about the structure-making and breaking behaviour of some mono and disaccharides, viz., glucose, fructose, sucrose and maltose in aqueous N-N dimethylacetamide (DMA) at 298.15 K. The experimental values of density, viscosity and speed of sound are carried out on the ternary mixtures of water + DMA + mono and disaccharides at 298.15 K. The binary solvent mixture (water+ DMA) is prepared at different mass percentages, say at 0%, 10%, 20%, 30% and 40%. The mono and disaccharides under study are added with aqueous binary solvent under different molarities at normal atmospheric pressure. The volumetric, compressibility, partial transfer volume and viscometric studies have been carried out to explore the possible interionic interactions existing in the solution. The present study notices that disaccharides (sucrose, maltose) behave as an effective structure-maker in aqueous solution comparatively with mono saccharides (glucose, fructose).

Keywords: Monosaccharides, Disaccharides, Partial transfer volume, Adiabatic compressibility

1 Introduction

Saccharides are very essential for energy metabolism in organisms and configuration of biological molecules. Saccharides have grasped more attention for their ability to protect biological macromolecules. Saccharides are important chemicals in life processes because of their conformational flexibility, saccharides play significant role in bimolecular recognition.

Simple sugars are called monosaccharides and include glucose (also known as dextrose), fructose and galactose. Glucose is also commonly referred to as dextrose and is included in many food products. It enters the blood stream very quickly. Glucose is a primary source of energy for the brain, so its psychological influences availability process. Fructose occurs naturally in fresh fruits, giving them their sweetness. Fructose, or fruit sugar, is a simple kenotic monosaccharide found in many plants. Fructose has a low glycemic index, meaning it has minimal impact on blood glucose levels¹. Sucrose is the organic compound commonly known as table sugar and sometimes called saccharose. They are carbohydrates and as this name implies, are composed of carbon, hydrogen and oxygen. In sucrose, the components glucose and fructose are linked through an ether bond between glucosyl subunit and the fructosyl unit². The bond is called a glycosidic linkage. Maltose also known as maltobiose or malt sugar is a disaccharide formed from two units of glucose. The table or granulated sugar most customarily used as food is sucrose and, maltose a disaccharide. Recently, so many works have been reported that the saccharides molecules is of considerable relevance for their interactions with other biomolecules.

The study of the interaction between saccharides and aqueous DMA is valuable to examine physiological behavior of solution. The DMA + Water solvent mixtures are mostly attractive and this system has been explored by many researchers³⁻⁵ with different experimental approaches, in order to understand non-bonding interactions such as hydrogen bonding, electrostatic and hydrophobic interactions that play important role in the stabilization of conformational of biological Various thermodynamic macromolecules. and spectroscopic studies have shown that the hydration of saccharides depends upon the number of hydroxyl groups the potential hydrogen bonding sites and relative position of the next nearest neighbor hydroxyl groups within the carbohydrate molecules.

The exhaustive literature survey revealed that only a very few and scarce attempts have been made to

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study the molecular interaction among the carbohydrates in aqueous solutions. Hence, the present attempt has been initiated to probe the molecular association, physico-chemical behavior and acoustical properties of three-component liquid mixtures of mono and disaccharides in aqueous N-N dimethylacetamide (DMA) solutions at 298.15K.

2 Materials and Methods

All the chemicals used in this present work were procured from the standard and reputed concerns. Freshly prepared triply distilled water (sp. conductivity 10⁻⁶ ohm⁻¹cm⁻¹) was used for preparing the solutions at different concentrations. Aqueous solutions were prepared and used on the day they were prepared. The binary solvent mixture (water+ DMA) was prepared at different mass percentages. To prepare binary solvent, N-N dimethylacetamide (DMA) was added with water under different mass percentages, say at 0%, 10%, 20%, 30%, and 40%. The mono and disaccharides under study were separately added with aqueous binary solvent under different molarities for each mass percentage of binary solvent. The mixtures were kept in special air tight stopper glass bottles to avoid evaporation. The weighing was done by using an electronic digital balance (SHIMADZU AX-200, Japan Make) with a least count of 0.0001 g. The densities of ternary liquid mixtures were measured using a 5 mL capacity specific gravity bottle (made of VENZIL glass). The marks on the capillary were calibrated by using triply distilled water. The ultrasonic wave velocity in ternary liquid mixtures was measured using a single-crystal fixed frequency ultrasonic Interferometer (Mittal Enterprises, India. Model: F-81) operating at 2 MHz. The ultrasonic wave velocity data were reproducible within $\pm 2 \text{ ms}^{-1}$. The viscosities of ternary liquid mixtures were measured by Ostwald's Viscometer of 10 mL capacity. The viscometer was calibrated with triply distilled water. The viscometer containing the test liquid was allowed to stand for about 30 min in a thermostatic water bath so that the thermal fluctuations in viscometer were minimized. The time of flow was recorded in triplicate with a digital stopwatch (RACER, Japan Make) with an accuracy of ± 0.01 s. The temperature of the test liquids during the measurements was maintained with an electronically digital operated constant temperature bath (RAAGA Industries, Chennai) had been used to circulate water through the double walled measuring cell made up of steel containing the experimental solution at desired temperature, with an accuracy of 0.01 K

3 Results and Discussion

In both mono saccharrides (glucose, fructose) as well as disaccharides (sucrose and maltose) liquid systems, the present study notices the values of density increase with increase in molar concentration of solutes (mono and disaccharides) as well as mass percentage of solvent content (aqueous N-N dimethylacetamide (DMA)] are reported in Table 1.The other measured parameter ultrasonic wave velocity (U) is reported in the same table found to be increased with increase in same molar concentration of solutes (mono and disaccharides) as well as aqueous DMA content (solvent). The observed increase in the ultrasonic wave velocity in these solutions may be attributed to the cohesion brought about by the ionic hydration, resulting an increase of cohesion brought about by solute-solute and solute-solvent interaction in solution.

Incidentally, the density (ρ) which is a measure of solute-solvent interactions in the solution. The increase in effective density with concentration is due to the shrinkage in the volume which in turn is due to the presence of solute molecules and from the scrutiny of Table 1, the increasing effective density is observed in all the saccharrides systems, which may be attributed due to the structure-making behavior of the solute⁶.

Adiabatic compressibility (β) is given by

$$=\frac{1}{U^2} \qquad \dots (1)$$

Where U is ultrasonic wave velocity and ρ is density.

The adiabatic compressibility (β) of the solute can be expressed as the extent to which hydration around the solute molecule can be compressed. The perusal of Table 2, furnishing the values of adiabatic compressibility (β) decrease with increase in molar concentration of solute (mono and disaccharides) as well as mass percentage of aqueous DMA solvent. It may be corroborated that as a solute dissolves in a solvent, some of the solvent molecules are attached to the ions (produced from the solutes), because of solute-solvent interaction. Since, the solvent molecules are oriented in the ionic field, these molecules are more compactly packed in the primary salvation shells. As the water molecules are being compressed, they do not respond to a further application

	Tabl	e 1 – Valu	ies of dens	sity (), v	iscosity () and u	ltrasonic	wave vel	ocity (U)	of mone	and disac	charides a	t 298.15 I	ζ	
Molarity	Density (ρ), kg/m ³					Viscosity (η)x10 ⁻³ , Nsm ⁻²			Ultrasonic wave velocity (U),m/s						
M (mol.dm ⁻³)	0%	10%	20%	30%	40%	0%	10%	20%	30%	40%	0%	10%	20%	30%	40%
System I: A	queous DN	MA + Glu	cose												
0.00	997.1	1002.5	1004	1004.7	1005.2	0.9437	1.2658	1.4020	1.6204	1.8197	1560.75	1564.71	1569.75	1574.25	1583.11
0.02	998.43	1003.39	1004.65	1005.24	1005.61	0.9572	1.2778	1.4136	1.6532	1.8326	1562.26	1568.73	1572.01	1576.35	1585.27
0.04	999.67	1004.21	1005.16	1005.68	1005.94	0.9681	1.2870	1.4257	1.6793	1.8745	1563.9	1569.99	1573.63	1578.45	1587.46
0.06	1000.72	1004.87	1005.6	1005.95	1006.2	0.9829	1.2919	1.4467	1.6891	1.8993	1565.2	1572.01	1575.61	1580.91	1589.67
0.08	1001.81	1005.25	1005.95	1006.24	1006.42	0.9978	1.3017	1.4573	1.6927	1.9137	1566.57	1574.07	1577.64	1582.94	1591.03
0.10	1002.79	1005.85	1006.27	1006.5	1006.61	1.0103	1.3195	1.4692	1.7041	1.9302	1568.17	1575.98	1579.19	1585.15	1593.27
System II: A	Aqueous D	MA + Fr	uctose												
0.00	997.1	1002.5	1004	1004.7	1005.2	0.9437	1.2658	1.4020	1.6204	1.8197	1560.75	1564.71	1569.75	1574.25	1583.11
0.02	998.5	1003.77	1005.15	1005.78	1006.2	0.9679	1.2864	1.5565	1.6532	1.8637	1561.75	1568.72	1572.92	1577.27	1586.23
0.04	999.77	1004.85	1006.09	1006.59	1006.89	0.9686	1.3257	1.5897	1.6636	1.8843	1562.67	1571.32	1574.01	1579.80	1588.55
0.06	1000.59	1005.75	1006.75	1007.16	1007.57	0.9693	1.3553	1.6130	1.6708	1.9002	1564.01	1573.75	1576.26	1582.14	1590.50
0.08	1001.55	1006.15	1007.18	1007.73	1007.81	0.9703	1.3899	1.6432	1.6804	1.9181	1565.28	1575.32	1578.78	1584.70	1592.04
0.10	1001.95	1006.83	1007.78	1008.2	1008.05	0.9712	1.4199	1.6780	1.6989	1.9365	1566.98	1579.62	1582.01	1587.67	1594.27
System III:	Aqueous I	DMA +Su	crose												
0.00	997.1	1002.5	1004.1	1004.7	1005.2	0.9437	1.2658	1.4020	1.6204	1.8197	1560.75	1564.71	1569.75	1574.25	1583.11
0.02	999.85	1004.9	1005.91	1006.3	1006.63	0.9789	1.2808	1.4913	1.7956	1.9056	1566.34	1572.01	1575.21	1581.25	1589.24
0.04	1001.91	1006.45	1006.49	1007.45	1007.71	0.9982	1.2957	1.5016	1.8327	1.9237	1569.25	1573.97	1577.64	1583.27	1591.26
0.06	1002.85	1007.95	1007.23	1008.49	1008.63	1.0037	1.3001	1.5201	1.84793	1.9390	1572.10	1575.61	1579.81	1585.45	1593.28
0.08	1003.76	1008.89	1007.77	1009.08	1009.25	1.0108	1.3159	1.5437	1.8601	1.9503	1575.91	1577.07	1581.07	1587.34	1595.60
0.10	1004.65	1009.09	1008.25	1009.72	1010.05	1.1173	1.3254	1.5596	1.87705	1.9756	1577.29	1579.00	1584.56	1589.77	1598.01
System IV: Aqueous DMA + Maltose															
0.00	997.1	1002.5	1004	1004.7	1005.2	0.9437	1.2658	1.4020	1.6204	1.8197	1560.75	1564.71	1569.75	1574.25	1583.11
0.02	1001.2	1003.39	1007.5	1008.1	1008.4	0.9553	1.2898	1.4637	1.8566	1.9397	1567.62	1574.20	1576.23	1584.35	1592.57
0.04	1003.97	1004.21	1009.59	1010.22	1010.07	0.9607	1.3572	1.5136	1.8732	1.9638	1571.30	1575.75	1579.72	1586.27	1594.63
0.06	1005.72	1004.87	1011.42	1012.01	1012.1	0.9692	1.4703	1.5912	1.8996	1.9930	1574.57	1578.99	1581.21	1588.74	1596.87
0.08	1007.7	1005.25	1012.45	1013.01	1013.4	0.9825	1.5267	1.7216	1.9201	2.0056	1576.68	1579.05	1582.36	1590.25	1598.18
0.10	1009.1	1005.85	1013.68	1014.01	1014.01	1.0013	1.6915	1.8396	1.9436	2.0201	1577.15	1581.98	1584.83	1592.15	1601.01

of pressure, and hence the solutions become harder to compress, resulting in decrease in compressibility values. A plausible qualitative interpretation of the behavior of these mixtures in aqueous composition has been suggested. N,N-dimethylacetamide is used as solvent in chemical and biological processes, belonging to the amide group which is hig ly polar, aprotic solvent and its molecules are associated through dipolar interactions, and it has no hydrogen bonding in pure state. Therefore, DMA acts as an aprotic protophilic medium with high dielectric constant and it is considered as a dissociating solvent. Thus, the addition of DMA in the mixture causes dissociation of hydrogen bonded structures. Mixing of DMA with the saccharides would induce mutual dissociation of dipolar interactions with subsequent formation of new dipolar interactions between the component molecules. indicates The observed trend that interstial accommodation of water in the molecular network of DMA is much greater and involves the formation geometrical effects resulting from the accommodation

of molecules of different size into the cavities of the molecular network of same stable structure between the two unlike molecules resulting in decrease in compressibility⁷ in the present study.

The apparent molar compressibility (ϕ_k) and apparent molar volume (v_k) , of the solution were calculated by using the relations

$$\varphi_{\mathrm{K}} = \frac{1000}{m\rho_0} (\rho_0 \beta - \rho \beta_0) + \left(\frac{\beta_0 M}{\rho_0}\right) \qquad \dots (2)$$

$$\varphi_{\rm V} = \frac{1000}{m\rho_0} (\rho_0 - \rho) + \left(\frac{M}{\rho_0}\right) \qquad \dots (3)$$

Where *m* is the molar concentration of the solute (mono and disaccharides), ρ and ρ_0 are the densities of the solution and the solvent (aqueous DMA), respectively. *M* is the molar mass of the solute (mono and disaccharides), and β , β_0 are the adiabatic compressibilities of the solution and the solvent (aqueous DMA), respectively.

Table 2 – Values of adiabatic compressibility () of mono and disaccharides at 298.15 K											
Molarity	Adiabatic compressibility()10 ⁻¹⁰ , m ² N ⁻¹										
M, (mol.dm ⁻³)	0%	10%	20%	30%	40%						
System I Aqueous DMA +Glucose											
0.00	4.117	4.074	4.042	4.016	3.969						
0.02	4.103	4.049	4.031	4.003	3.957						
0.04	4.090	4.041	4.017	3.991	3.944						
0.06	4.078	4.027	4.007	3.977	3.932						
0.08	4.067	4.014	3.994	3.971	3.925						
0.10	4.055	4.002	3.985	3.954	3.913						
System II: A	Aqueous	DMA + Fri	uctose								
0.00	4.117	4.074	4.042	4.016	3.969						
0.02	4.106	4.048	4.021	3.996	3.949						
0.04	4.097	4.031	4.011	3.981	3.935						
0.06	4.085	4.014	3.997	3.966	3.923						
0.08	4.071	4.005	3.983	3.951	3.914						
0.10	4.064	3.981	3.964	3.934	3.903						
System III:	Aqueous	DMA + Su	icrose								
0.00	4.117	4.074	4.042	4.016	3.969						
0.02	4.106	4.026	4.006	3.974	3.933						
0.04	4.097	4.011	3.991	3.959	3.919						
0.06	4.085	3.996	3.978	3.944	3.905						
0.08	4.071	3.985	3.969	3.933	3.891						
0.10	4.064	3.974	3.951	3.918	3.877						
System IV: Aqueous DMA + Maltose											
0.00	4.117	4.074	4.042	4.016	3.969						
0.02	4.064	4.011	3.995	3.951	3.933						
0.04	4.034	3.992	3.969	3.934	3.919						
0.06	4.011	3.971	3.954	3.914	3.905						
0.08	3.991	3.966	3.944	3.903	3.891						
0.10	3.984	3.946	3.927	3.891	3.877						

Table 3 reports about the evaluated values of the apparent molar compressibility (φ_k) and apparent molar volume (φ_v) of mono saccharrides (glucose and fructose) and disaccharides (sucrose and maltose) in aqueous N-N dimethyalacetamide (DMA) solution at 298.15 K, from the evaluation of these parameters, it is observed that (i) the values of the apparent molar compressibility (φ_k) and apparent molar volume (φ_v) are all negative over the entire molarity range of solutes (mono and disaccharidies), and (ii) the negative values of both parameters, φ_k and φ_v are found to be increased with increasing molarities (*M*) of solute and solvent content.

The trends of these two parameters from Figs 1 and 2 clearly emphasizing the existence of solutesolvent interaction in the solution and their negative deviations indicate the presence of hydrophilic-ionic interactions occurring in the liquid systems. Since, more number of water molecules are available at lower concentration of aqueous DMA, the chances for the penetration of solute molecules in the solvent molecules are highly favored.⁸ The increasing values of apparent molar compressibility (φ_k) and apparent molar volume (φ_v) with addition of solute and solvent concentration in the present study revealing the strengthening of the solutesolvent interaction in the solution. The larger values of these parameters (apparent molar compressibility (φ_k) and apparent molar volume (φ_v)) are reported for disaccharides comparing to monosaccharides.

The values of limiting apparent molar compressibility $\binom{0}{k}$ and its slope (S_k) , limiting apparent molar volume $\binom{0}{v}$ and its slope (S_v) , have been obtained by using method of linear regression of $\binom{0}{k}$ and $\binom{0}{v}$ vs. molarity of saccharides from the following relations⁹.

$$\varphi \kappa = \varphi_{\kappa}^{0} + S \kappa m^{\frac{1}{2}} \qquad \dots (4)$$

$$\varphi_{\rm V} = \varphi_{\rm V}^0 + S_{\rm V} m^{\frac{1}{2}} \qquad \dots (5)$$

Where the intercepts, $_{k}^{0}$ or, $_{v}^{0}$ provide a measure of solute-solvent interactions, and the experimental slope, S_{k} or S_{v} regarding solute-solute interaction. The variations of $_{k}^{0}$, S_{k} , $_{v}^{0}$ and S_{v} with percentages of four liquid systems at 298.15 K are shown in Figs 3-6, respectively.

Tables 4 and 5 report that limiting apparent molar compressibility ($_{k}^{0}$) and limiting apparent molar volume ($_{v}^{0}$) values exhibiting negative deviations in the present study and increase with the further addition of solvent content (aqueous DMA) suggesting the presence of strong solute-solvent interactions. The reported S_{k} and S_{v} values (from Figs 4 and 6) in the present investigation are positive and exhibit a decreasing trend,(except in System-III) when the concentration of solvent increases^{10,11}. The decreasing positive values of S_{k} and S_{v} clearly advocating the existence of weak solute-solute interaction in the solution.

Moreover, the increase of k^0 and v^0 values with increase of solvent (aqueous DMA) may decrease the electrostriction of water molecules. The decreasing electrostriction due to ionic-hydrophilic interactions between the ions of the mono and disaccharides and methyl group at carbonyl carbon in DMA causing the larger values of $\binom{0}{k^0}$ and $\binom{0}{v^0}$ in disaccharides comparatively with mono saccharides. The presence

Table 3 -	- Values of a	pparent molar	compressibi	lity $(-\phi_K)$ and	l apparent mo	olar volume (-	ϕ_V) of mono	and disaccha	arides at 298.	15 K	
Molarity $M \pmod{dm^{-3}}$	Appa	arent molar co	mpressibility	ν (-φ _K)x10 ⁻⁸ m	Apparent molar volume $(-\phi_v)x m^3 mol^{-1}$						
	0%	10%	20%	30%	40%	0%	10%	20%	30%	40%	
System I: Aqueous DMA + Glucose											
0.00	-	-	-	-	-	-	-	-	-	-	
0.02	9.4384	14.051	8.4512	7.4721	6.9524	64.6328	44.4315	27.4333	26.9476	20.4274	
0.04	9.3954	10.280	7.3102	7.3421	6.8734	63.1369	42.6772	26.4292	-24.4358	18.417	
0.06	8.8504	9.4646	7.1496	7.2755	6.7510	59.4808	39.419	24.9231	20.7521	16.5741	
0.08	8.6360	8.8147	6.9865	7.0248	6.1201	58.1513	34.2811	23.0403	19.16	15.1502	
0.10	8.5420	8.5041	6.6366	6.9223	6.1396	56.2569	33.404	21.6098	17.9053	13.9942	
System II: Aqueous DMA + Fructose											
0.00	-	-	-	-	-	-	-	-	-	-	
0.02	8.3829	15.5734	12.7577	12.0014	11.7173	-68.1227	63.4792	52.5359	54.0746	50.0809	
0.04	7.9987	13.3054	9.6463	10.7816	10.1113	-65.6298	58.7172	49.7746	47.2928	42.2906	
0.06	7.6276	12.1441	9.2213	9.9150	9.2194	-57.3204	54.1223	44.1686	41.0134	39.5261	
0.08	7.5393	10.4969	8.9305	9.5943	8.1062	-54.9106	45.5592	38.4783	37.8735	32.6157	
0.10	7.2441	11.1325	8.8445	9.5218	7.7483	-47.881	43.229	36.7718	34.9855	28.4693	
System III: Aqu	ieous DMA	+ Sucrose									
0.00	-	-	-	-	-	-	-	-	-	-	
0.02	11.1633	28.5631	21.6310	24.0842	20.6843	-135.266	119.959	90.5303	80.0355	71.5314	
0.04	9.8261	19.8244	15.0424	16.8595	10.5332	-118.814	98.6554	59.6541	68.7324	62.736	
0.06	9.1762	16.6610	12.8202	14.4113	7.1245	-94.7163	90.7188	52.04	63.1232	57.1233	
0.08	9.1108	14.3698	10.9585	12.5624	5.4092	-82.2937	79.7329	45.722	54.6664	50.5481	
0.10	8.3523	12.6244	10.8873	11.7530	4.4376	-74.6409	65.724	41.3297	50.0957	48.4122	
System IV: Aqueous DMA + Maltose											
0.00	-	-	-	-	-	-	-	-	-	-	
0.02	34.7997	39.8072	30.5332	38.9812	24.4041	-202.555	44.2519	171.358	170.441	160.474	
0.04	27.8018	26.7856	23.8618	26.0271	17.3685	-170.148	42.4975	137.454	138.29	122.025	
0.06	23.6839	22.5244	19.5647	21.7558	15.1631	-142.394	39.2392	122.142	122.048	115.239	
0.08	21.1061	17.8168	16.4131	18.2254	17.7334	-131.384	34.1014	104.444	104.004	102.675	
0.10	18.2401	16.7992	15.3227	16.2872	12.6947	-118.995	33.2244	95.8349	93.1799	88.2005	



Fig. 1 – Variation of apparent molar compressibility (ϕ_k) with molarities (*M*) for four liquid systems at 298.15 K



Fig. 2 – Variation of apparent volume (φ_v) with molarities (*M*) for four liquid systems at 298.15 K



Fig. 3 – Variation of limiting apparent molar compressibility (φ°_{k}) with percentages for four liquid systems at 298.15 K



Fig. 4 – Variation of S_k with percentages for four liquid systems at 298.15 K



Fig. 5 – Variation of limiting apparent molar volume (ϕ°_{v}) with percentages for four liquid systems at 298.15 K



Fig. 6 – Variation of S_v with percentages for four liquid systems at 298.1 K

$(-\phi_{K}^{0})$ and its a	associate constant ($S_{\rm K}$) of at 298.15 K	mono and disaccharide
Percentage (%)	Limiting apparent motion $(-\Phi_{\nu}^{0} \times 10^{-1})$	lar compressibility ⁸ m ² N ⁻¹)
	-φ _K ⁰	S _K
System I: Aque	eous DMA + Glucose	
0	10.3563	5.8328
10	17.3890	30.2292
20	9.5360	9.4037
30	7.1448	1.7613
40	7.8301	5.3210
System II: Aqu	eous DMA + Fructose	
0	9.2623	6.3438
10	19.0528	27.5141
20	18.1985	35.0904
30	13.8182	14.5762
40	13.4637	18.9116
System III: Aq	ueous DMA + Sucrose	
0	13.0484	14.8601
10	39.3518	88.3460
20	28.7706	61.1777
30	32.2751	68.9316
40	31.0110	90.1587
System IV: Aq	ueous DMA + Maltose	
0	47.1237	92.7928
10	55.0514	130.3669
20	42.1860	88.7833
30	54.1750	126.2113
40	30.2143	55.0357

Table 4 - Values of limiting apparent molar compressibility

of large values of $_{v}^{0}$ and $_{k}^{0}$ reported in disaccharides in aqueous DMA solution clearly suggesting that disaccharides serve as an effective structure-maker in the solution. Because of the presence of methyl group at carbonyl carbon in DMA,² the electron density of carbonyl oxygen atom in DMA is greater than that of OH groups in saccharides molecules makes carbonyl carbon of acetamide, a strong proton acceptor in this study.

The partial transfer volume (Δ_v^0) investigation of mono and disaccharides in aqueous DMA solution was calculated by using the relation,

$$\Delta_v^0 = \int_v^0 (aqueous DMA \text{ solution}) - \int_v^0 (in \text{ water}) \dots (6)$$

The present investigation from Table 6 furnishing the partial transfer volume $(\Delta \phi_v^0)$ studies in aqueous DMA solution exhibiting positive deviations in all the mono and disaccharides liquid systems and increase with further addition of aqueous solvent (DMA). The increasing behavior suggests stronger and more extensive interactions between mono and disaccharides

associate constant (S_v) of mono and disaccharides at 298.15 K Percentage Limiting Apparent molar volume $(-\phi_v^0 \times 10^{-8} \text{ m}^2 \text{ N}^{-1})$ (%) -Φ⁰ Sv System I: Aqueous DMA + Glucose -195.1512 359.8595 0 10 -160.5673 292.9547 20 -121.5932 268.1882 30 -103.9226 170.5537 40 -90.3465 135.4721 System II: Aqueous DMA + Fructose 0 86.1781 115.6046 10 -81.9389 121.9842 -67.4550 20 97.4826 30 -69.2596 110.5699 -67.3059 121.1062 40 System III: Aqueous DMA + Sucrose -187.5529 364.4931 0 10 292.9569 -160.406320 -133.8493268.1913 30 -103.7604 170.5467 40 90.2465 135.7308 System IV: Aqueous DMA + Maltose 0 -267.004480.5068 10 -55.012768.9695 20 -228.0397 429.3985 30 -224.0806 415.4563 40 -208.6258 383.4603

Table 5 – Values of limiting apparent molar volume $(-\phi_v^0)$ and its

Table 6 – Values of partial transfer volume ($\Delta \varphi_v^0$), viscosity *B* coefficient of Jones -Dole equation of Mono and disaccharides at 298.15 K

Saccharides	Aqueous DMA in percentage %	Partial transfer volume $(\Delta \phi_v^0)$	Falkenhagen coefficient A , $(dm^{3/2}.mol^{-1/2})$	B, (dm ^{3/2} .mol ⁻¹)
Glucose	0	-	-0.7569	3.8891
	10	34.5839	0.0146	0.3340
	20	73.5581	0.0200	0.5605
	30	91.2286	0.1508	0.6547
	40	104.8047	0.2310	0.7671
Fructose	0	-	0.0035	0.5047
	10	4.2392	0.0846	0.5142
	20	18.7231	0.1199	0.6 230
	30	16.9185	0.1324	0.7211
	40	18.8722	0.1466	0.8407
Sucrose	0	-	0.0302	-1.2602
	10	27.1466	0.0373	-0.3498
	20	53.7036	0.2185	-0.4805
	30	83.7925	0.2358	-0.5500
	40	97.3064	0.2896	-0.3909
Maltose	0	-	0.0132	0.5837
	10	211.9913	0.0655	0.5082
	20	38.9643	0.2132	0.3938
	30	42.9234	0.2321	0.2225
	40	58.3782	0.2399	0.2417

(co-solute) and DMA (solute). The enhancement of ionic-hydrophilic interactions between the -OH ions of the saccharides molecules and methyl group at carbonyl carbon in DMA, a strong proton-acceptor resulting in positive deviation in the present investigation. Moreover, these interactions will reduce the structure breaking effect of DMA in water and therefore this factor may opt for contributing to positive value of $\Delta \phi_v^{0}$ in the present study. The partial transfer volume ($\Delta \phi_v^{0}$) study is attributed in terms of strength of solute-co-solute interactions on the basis of Co-Sphere Overlap Model¹². The overlap of ions of co-solute (mono and disaccharides) and solute (DMA) comes into play because of the interaction between ionic-hydrophilic interaction between the - OH ions of mono and disaccharides and the polar group of methyl group at carbonyl carbon in DMA. Since the present study points out the increasing positive values of $\Delta \phi_v^0$, (from Fig. 7) suggesting the dominance of hydrophilic-ionic interactions over ionic-hydrophobic interactions in the present study.

Sucrose is formed due to the elimination of a molecule of water from the combination of a-Dglucose and β -D-glucose. The fructose possess the furonose ring structure in the sucrose molecules, the pyranose ring is the dominant and more stable form in the ketohexose. For sucrose formation both the carboxyl groups of individual units are involved in the formation of glycosidic bond and subsequent structural variation with rearrangement of molecule within the solution in addition to the presence of active group, may be attributed for the observed changes. It may be noted that sucrose does not contain active group and it does not exhibit mutual rotation¹³. In case of maltose, free carbonyl or free hemi acetyl active group exist along with all the forms and the presence of such free carbonyl or hemi acetyl group may also be attributed for the more pronounced interaction in this saccharide¹².

The evaluated earlier parameters in the present investigation so far stressing a more enhanced molecular interactions existing in disaccharides comparatively with mono saccharides, as disaccharides such as maltose is due to the availability of hemiacetyl group, where free sites are more available and the presence of large number of OH groups in saccharide molecules. Moreover, these are prime factors responsible for the enhancement of strong interactions in disaccharides.

The viscosity study has been carried out by incorporating the Jones-Dole semi empirical equation¹⁴



Fig. 7 – Variation of for partial transfer volume ($\Delta \phi^{o}_{\nu}$) for four liquid systems at 298.15 K

$$\frac{\binom{\eta}{\eta_0} - 1}{m^{\frac{1}{2}}} = A + Bm^{\frac{1}{2}} \qquad \dots (7)$$

Where η and η_0 are the viscosities of the solution and solvent respectively and 'm' is the molar concentration of the solute. A is known as Falkenhagen coefficient which characterizes the ionic interaction and B is the Jones-Dole or viscosity Bcoefficient which relating the solute-solvent interactions.

The variation of relative viscosity in the present study with mono and disaccharides with aqueous DMA can be represented by the Jones - Dole equation^{15,16}. The present study notices that values of A and B are positive, and A coefficients are seemed much smaller in magnitude as compared to Bcoefficient, advocating a weak ion-ion interactions in the solution. The close scrutiny of Table 6 shows the B coefficient increase with increasing concentration of DMA (except in System-IV)¹⁷ advocating an enhancement of solute-solvent interaction in the liquid systems, which may be as interpreted earlier, due to greater hydrophilic-ionic group interactions with the presence of more hydroxy group in saccharrides molecules.

4 Conclusions

The volumetric, compressibility, partial transfer volume and viscometric studies carried out on monosaccharrides (glucose and fructose) and disaccharides (sucrose and maltose) in aqueous DMA at 298.15 K have been sequentially reported as:

- (i) All the mono and disaccharides exhibit an increasing trend of ultrasonic wave velocity with molarity.
- (ii) The strength of interactions is found to be molarity sensitive of the saccharides.

- (iii) The partial transfer volume study predicts the dominance of ionic-hydrophilic group of interactions over ion-ion-hydrophobic group of interactions.
- (iv) It is very obvious that disaccharides (sucrose and maltose) are more effective structure-makers in the aqueous solution comparatively with mono saccharides (glucose and fructose).
- (v) The present investigation also observes a weak solute-solute and ion-ion interactions.

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