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Volumetric compressibility and transport studies on molecular interactions of mono, di and tri saccharides in aqueous sodium butyrate mixtures at 303.15 K

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ABSTRACT

Apparent molal compressibility (φ_K) and apparent molal volume(φ_V), of D(+)- galactose D(+)- lactose monohydrate D(+)- raffinose pentahydrate in aqueous and aqueous sodium butyrate solution (0.025, 0.05, 0.075 and 0.1) mol. dm^{-3} at 303.15 K have been determined from pure density and ultrasonic velocity measurements. Limiting apparent molal compressibility (φ_K^0) and limiting apparent molal volume (φ_V^0) and their constants S_K , S_V of these saccharides at infinite dilution were evaluated. Transfer adiabatic compressibility ($\Delta\varphi_K^0$), transfer volume ($\Delta\varphi_V^0$) of infinite dilution from water to aqueous sodium butyrate solution, molal hydration number (n_H) have been calculated. Viscosity A and B coefficients of Jones-Dole equation have been determined from viscosity measurements. The sign and magnitudes of these parameters have been interpreted in terms of solute-solvent and solute-co-solute interaction occurring in the ternary solutions.

Keywords: Ultrasonic velocity, apparent molal compressibility apparent molal volume, transfer volume, viscosity coefficients.

INTRODUCTION

Acoustical and thermodynamical properties of saccharides in aqueous and mixed aqueous solutions play pivotal role in the biological and industrial process. Binary and ternary aqueous solutions containing soluble carbohydrates (e.g., sucrose, glucose and fructose) and with additions of ethanol, salts, glycerol, etc., have been widely used as suitable immersion media while freezing fruits [1,2]. 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 [3-5].

Disaccharides can stabilize labile biomolecules in aqueous solutions by a combination of kinetic and specific effects [6,7]. The presence of salts modifies important properties of aqueous sachharide systems related to their protective role such as viscosity, water sorption, crystallization rate and glass transition temperature [8]. The studies of physico-chemical properties of saccharides in aqueous solutions of metal ions can improve the understanding of interactions of metal ions with saccarides residue of biologically important compounds. Aqueous solutions of sodium butyrate are biologically and chemically important as these are widely used in molecular biological applications. It can promote growth of beneficial bacteria and inhibit the growth of harmful bacteria in the gastrointestinal tract. It is an energy source of cell differentiation [9].

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 [10]. Solute-solvent interaction has great importance in biological chemistry, physical chemistry, surface chemistry, environmental chemistry and geochemistry. To understand the process occurring in living cells, the nature of ion hydration is prerequisite information. Acoustical studies on saccharides in organic salt solutions are missing in the literature and therefore it will also be interesting to study the molecular interactions of mono, di and tri saccharide in aqueous sodium butyrate solutions.

Hence in this study we report herein the apparent molal volume (φ_V), limiting apparent molal volume (φ_V^0), apparent molal compressibility (φ_K), limiting apparent molal compressibility (φ_K^0), and their constants (S_K, S_V), transfer adiabatic compressibility ($\Delta\varphi_K^0$), transfer volume ($\Delta\varphi_V^0$), molal hydration number (n_H) and viscosity of A and B coefficients of Jones–Dole equation of D(+)- galactose, D(+)- lactose monohydrate and D(+)- raffinose pentahydrate in aqueous and aqueous sodium butyrate solution (0.025, 0.05, 0.075 and 0.1) mol. dm^{-3} at 303.15 K are computed from the experimental density (ρ), viscosity (η) and ultrasonic velocity (U) of data. Their signs and magnitudes have been rationalized in terms of various interactions occurring in ternary solutions.

MATERIALS AND METHODS

Experimental Details

Analytical reagent (AR) grade and spectroscopic reagent (SR) grade with minimum assay of 99.9% of D(+)- galactose, D(+)- lactose monohydrate, D(+)- raffinose pentahydrate and sodium butyrate were obtained from E-merck Germany and SdFine chemicals, India, which were used as such without further purification. Water used in the experiment was deionised, distilled and degassed prior to making solutions. Aqueous solutions of sodium butyrate (0.025, 0.05, 0.075 and 0.1) mol·dm^{-3} were prepared by volume and used on the day they were prepared. Solutions of sachharide in the concentration range of 0.02-0.1 mol dm^{-3} were made by volume on the molarity concentration scale with precision of ± 1 × 10^{-4} g on an electronic digital balance

(Model: SHIMADZU AX-200). The density was determined using a specific gravity bottle by relative measurement method with an accuracy of ± 0.01 kgm^{-3}. An Ostwald's viscometer (10 ml) was used for the viscosity measurement. Efflux time was determined using a digital chronometer to within ±0.01s. An ultrasonic interferometer having the frequency of 3 MHz (MITTAL ENTERPRISES, New Delhi, Model: F-81) with an overall accuracy of ± 0.1% has been used for velocity measurement. An electronically digital operated constant temperature bath (RAAGA Industries) has been used to circulate water through the double walled measuring cell made up of steel containing the experimental solution at the desired temperature. The accuracy in the temperature measurement is ± 0.1 K.

Theory and Calculation

Using the measured data, the following volumetric, compressibility and transport parameters have been calculated using the standard relations.

$$\text{Adiabatic Compressibility } \beta = \frac{1}{U^2\rho} \qquad \ldots(1)$$

Molal hydration number has been computed using the relation

$$n_H = \left(\frac{n_1}{n_2}\right)\left[1 - \frac{\beta}{\beta_0}\right] \qquad \ldots(2)$$

where β and β_0 are adiabatic compressibility of solution and solvent respectively n_1 and n_2 are number of moles of solvent and solute, respectively

The apparent molal compressibility has been calculated from relation

$$\varphi_K = \frac{1000}{m\rho_0}\left(\rho_0\beta - \rho\beta_0\right) + \left(\frac{\beta_0 M}{\rho_0}\right) \qquad \ldots(3)$$

where β, ρ and β_0, ρ_0 are the adiabatic compressibility and density of solution and solvent respectively and m is the molal concentration of the solute, and M the molecular mass of the solute. φ_K is the function obtained by Gucker [11] from Debye Huckel theory [12] and is given by

$$\varphi_K = \varphi_K^0 + S_K m^{1/2} \qquad \ldots(4)$$

where φ_K^0 is the limiting apparent molal compressibility at infinite dilution and S_K is a constant. φ_K^0 and S_K of equation (4) have been evaluated by the least square method.

The apparent molal volume φ_V has been calculated using the relation

$$\varphi_V = \left(\frac{M}{\rho}\right) - \frac{1000\left(\rho - \rho_0\right)}{m\rho\rho_0} \qquad \ldots(5)$$

The apparent molal volume φ_V has been found to differ with concentration according to Masson's [13] empirical relation as

$$\varphi_V = \varphi_V^0 + S_V m^{1/2} \qquad \text{...(6)}$$

where φ_V^0 is the limiting apparent molal volume at infinite dilution and S_V is a constant and these values were determined by least square method.

Transfer volumes ($\Delta\varphi_V^0$) and transfer adiabatic compressibility ($\Delta\varphi_K^0$) of each saccharides from water to aqueous sodium butyrate solutions have been calculated by the equation

$$\Delta\varphi_y^0 = \varphi_y^0 \text{ (in aqueous sodium butyrate solution)} - \varphi_y^0 \text{ (in water)} \qquad \text{... (7)}$$

where φ_y^0 denotes limiting apparent molal compressibility (φ_K^0) and limiting apparent molal volume (φ_V^0)

The viscosity A and B coefficients for the sacharides in aqueous sodium butyrate solutions were calculated from the Jones-Dole equation [14,15].

$$\frac{\eta}{\eta_0} = 1 + Am^{1/2} + Bm \qquad \text{...(8)}$$

where, η and η_0 are the viscosities of the solution and solvent respectively and m is the molal concentration of the solute. A is determined by the ionic attraction theory of Falkenhagen-Vernon and therefore also called Falkenhagen coefficient [15], B or Jones-Dole coefficient is an empirical constant determined by solute-solvent interactions.

RESULTS AND DISCUSSION

The experimental values of density (ρ), viscosity (η) and ultrasonic velocity (U), for different molarity of each of the three saccharides D(+)- galactose , D(+)- lactose monohydrate and D(+)-raffinose pentahydrate in aqueous and aqueous sodium butyrate solution (0.025, 0.05, 0.075 and 0.1) mol. dm^{-3} at 303.15K are shown in Table-1.
The values of adiabatic compressibility (β), molal hydration number (n_H), apparent molal compressibility (φ_K) and apparent molal volume (φ_V), limiting apparent molal compressibility (φ_K^0) limiting apparent molal volume (φ_V^0) and their constants (S_K, S_V), transfer adiabatic compressibility ($\Delta\varphi_K^0$) ,transfer volume ($\Delta\varphi_V^0$) and viscosity A and B coefficients of Jones-Dole equation are given in Tables 2-4.

The values of density (ρ) and ultrasonic velocity (U) (Table-1) are increases with increasing the concentration of saccharides and sodium butyrate in all systems studied. This increasing behaviour shows a strong electrolytic nature in which the interactions may be attributed to the cohesion brought by the hydroxyl group of saccharides in aqueous sodium butyrate mixtures.

From Table-2, it is observed that the values of adiabatic compressibility decreases with increase in molarity of saccharides and sodium butyrate content in the mixtures. The decrease in compressibility imply that there is enhanced molecular association in these systems on increase in solute content, as the new entities (formed due to molecular association) become compact and less compressible [16]. The compressibility appears to be decreasing with increase in hydrogen bond strength formed by solute and solvent molecules. This behaviour indicates significant interaction between solute and solvent molecules due to which the structural arrangement in the neighbourhood of constituent solutes is considerably affected.

Hydration is due to interaction between solute and water molecules present in the solvent. From the Table-2 the values of (n_H) are positive in all systems and it is found to increase with increasing the molarity of saccharides as well as sodium butyrate. The positive values of n_H indicate an appreciable solvation of solutes [17]. This is an added support not only for the structure promoting tendency of the solutes but also for the presence of appreciable dipole-dipole interactions between solute and water molecules. The decreasing value of n_H shows the strength of interaction gets weakened between the solute-solvent molecules, but however it increases the solute-co-solute interaction in the mixtures[18]. Further, this decreasing trend indicates that the addition of electrolytes introduces a dehydration effect on saccharides in solution [19].

The values of φ_K and φ_V (Table-3) are all negative over the entire range of molarity and these values are increases with increasing the molarity of saccharide as well as with increasing the concentration of sodium butyrate. The negative values of φ_K indicate hydrophilic and ionic interaction occurring in these system [15]. The negative values of φ_V indicate electrostrictive solvation of ions [20]. Further the increasing behaviour of φ_K and φ_V suggests the existence of strong solute-solvent interaction in all system studied.

The limiting apparent molal compressibility $\varphi^0{}_K$ provides information about solute-solvent interactions and S_K that of solute-co- solute interactions in the solutions. From Table–4 it is observed that φ_K^0 values are negative and it increases with increasing the concentration of sodium butyrate in all systems studied. Appreciable negative values of φ_K^0 and its behaviour for all system reinforce our earlier view that existence of solute-solvent interactions. Further the values of S_K exhibits positive and it decreases with increasing the concentration of sodium butyrate in all the three saccharides. This behaviour shows the strong solute-solute interactions exist in the mixtures. It is well known that solutes causing electrostriction lead to decrease in the compressibility of the solution.

The volume behaviour of a solute at infinite dilution is satisfactorily represented by φ_V^0 which is independent of the solute-solute interactions and provides information concerning solute-solvent interactions. Table-4 reveals that the values of φ_V^0 are negative and it increases with the addition of sodium butyrate contents in all the systems studied. The increase in φ_V^0 may be attributed to the increased hydrophilicity of the saccharides. The magnitude of φ_V^0 is in the order D(+)-galactose > D(+)- lactose monohydrate > D(+)- raffinose pentahydrate. Further it is evident from the Table-4 that S_V is positive in all the three systems suggesting the presence of strong solute-solute interaction[21]. The positive S_V values are associated with hydrophilic solutes.

The values of transfer adiabatic compressibility ($\Delta\varphi_K^0$) and transfer volume ($\Delta\varphi_V^0$) are by definition free from solute-solute interactions and therefore provide information regarding solute-solvent interactions. The values of $\Delta\varphi_K^0$ and $\Delta\varphi_V^0$ (Table-4) are positive and it increases with increase in the concentration of sodium butyrate in all systems suggests that the existence of solute-solvent interactions in ternary solutions. In the presently studied ternary systems the following types of interactions are possible among solute (saccharide) and co-solute (sodium butyrate);

i) Hydrophilic – ionic interactions between the hydrophilic sites (-OH, – C = O and – O –) of the saccharides and the ions (Na^+/CH_3COO^-) of the co-solute;
ii) Hydrophobic-ionic interactions between the hydrophobic parts of the saccharide molecules and the ions of the co-solute.

According to the co-sphere overlap model [22], first types of interactions contribute positively whereas the later type of interactions makes negative contributions to $\Delta\varphi_K^0$ and $\Delta\varphi_V^0$ values. The significant positive $\Delta\varphi_K^0$ and $\Delta\varphi_V^0$ values (Figs. 1 & 2) observed for mono, di and tri saccharides studied suggest that the hydrophilic-ionic interactions predominate over the hydrophobic-ionic interactions and the increase in $\Delta\varphi_K^0$ and $\Delta\varphi_V^0$ values with concentration of sodium butyrate indicates the strengthening of the hydrophilic-ionic interactions over the entire range of concentration.

Table 1. **Values of density (ρ) viscosity (η) and ultrasonic velocity (U) of mono, di and tri saccharides in aqueous sodium butyrate mixtures at 303.15 K for**

M/(mol.dm^{-3})	ρ/ (kg m^{-3})					η/(×10^{-3} Nsm^{-2})					U/(m.s^{-1})				
	Water + sodium butyrate														
	0M	0.025M	0.05M	0.075M	0.05M	0M	0.025M	0.05M	0.075M	0.05M	0M	0.025M	0.05M	0.075M	0.05M
System I: Water + sodium butyrate+ D(+)-galactose															
0	995.7	1006.9	1022.7	1024.1	1032.9	0.7977	0.8158	0.8725	0.8587	1.0467	1510.0	1527.0	1572.6	1588.8	1599.0
0.02	1012.7	1018.3	1027.3	1029.3	1045.0	0.8198	0.8315	0.8961	0.9086	1.1965	1524.1	1533.6	1582.2	1596.6	1603.2
0.04	1018.3	1023.8	1034.8	1042.1	1052.0	0.8233	0.8443	0.9116	0.9392	1.2517	1530.2	1546.8	1595.4	1609.2	1616.4
0.06	1027.2	1031.1	1043.9	1049.4	1058.0	0.8289	0.8532	0.9457	0.9636	1.3194	1542.1	1550.4	1619.4	1620.6	1627.2
0.08	1032.7	1043.8	1056.8	1056.8	1065.0	0.8399	0.8708	0.9739	0.9871	1.3541	1554.1	1555.2	1626.0	1636.2	1648.2
0.1	1048.3	1051.1	1061.2	1069.6	1089.0	0.8651	0.8893	1.0186	1.0083	1.4057	1563.0	1566.0	1642.2	1643.4	1678.8
System II : Water + sodium butyrate+ D(+)-lactose monohydrate															
0	995.7	1006.9	1022.7	1024.1	1032.9	0.7977	0.8158	0.8725	0.8587	1.0467	1510.0	1527.0	1572.6	1588.8	1599.0
0.02	1009.8	1015.0	1031.1	1038.3	1047.6	0.8203	0.8344	0.9036	1.0209	1.1447	1539.6	1551.0	1602.6	1608	1623.6
0.04	1011.4	1017.5	1037.0	1057.5	1063.4	0.8284	0.8565	0.9207	1.1871	1.2629	1551.0	1558.2	1615.2	1624.2	1630.8
0.06	1013.5	1021.4	1051.3	1076.4	1081.7	0.8365	0.8781	0.9580	1.2743	1.2970	1555.2	1570.2	1627.2	1626.0	1647.6
0.08	1017.7	1025.6	1058.8	1080.6	1087.8	0.8500	0.9006	0.9881	1.3235	1.388	1571.4	1578.6	1645.2	1640.4	1658.4
0.1	1021.6	1034.9	1062.5	1083.2	1099.0	0.8668	0.9331	1.0301	1.3966	1.4408	1588.2	1591.8	1660.8	1647.6	1680.0
System III : Water + sodium butyrate+ D(+)-raffinose pentahydrate															
0	995.7	1006.9	1022.7	1024.1	1032.9	0.7977	0.8158	0.8725	0.8587	1.0467	1510.0	1527.0	1572.6	1588.8	1599.0
0.02	1014.2	1021.7	1034.9	1040.6	1066.0	0.8214	0.8491	0.9249	1.0469	1.1531	1551.6	1557.6	1626.0	1613.4	1634.4
0.04	1014.6	1023.6	1038.4	1062.5	1082.5	0.8345	0.8654	0.9394	1.2372	1.3090	1557.0	1576.2	1634.4	1634.4	1641.6
0.06	1017.9	1024.1	1057.0	1077.1	1095.3	0.8389	0.8801	0.9840	1.2918	1.3349	1572.2	1586.4	1646.4	1642.8	1654.8
0.08	1019.9	1026.7	1063.4	1081.7	1100.4	0.8504	0.9102	1.0071	1.3429	1.4346	1583.4	1600.2	1653.6	1648.8	1667.4
0.1	1023.6	1037.9	1067.6	1084.3	1104.5	0.8701	0.9430	1.0552	1.4127	1.4746	1594.2	1609.8	1660.8	1655.4	1694.4

Table 2. Values of adiabatic compressibility (β), molal hydration number (n_H) of mono, di and tri saccharides in aqueous sodium butyrate mixtures at 303.15 K for

M/(mol.dm^{-3})	β/ (× 10^{-10} m^2 N^{-1})					n_H				
	Water + sodium butyrate									
	0M	0.025M	0.05M	0.075M	0.05M	0M	0.025M	0.05M	0.075M	0.05M
System I: Water + sodium butyrate+ D(+)-galactose										
0	4.4035	4.2594	3.9539	3.8683	3.7864	-	-	-	-	-
0.02	4.2508	4.1756	3.8886	3.8114	3.7144	96.30	56.91	41.07	34.47	41.79
0.04	4.1942	4.0826	3.7968	3.7057	3.6382	65.94	57.09	49.37	49.19	47.01
0.06	4.0936	4.0347	3.6527	3.5750	3.5694	65.10	47.89	63.11	59.14	57.73
0.08	4.0091	3.9612	3.5791	3.4833	3.4558	62.13	47.24	58.90	58.22	57. 20
0.1	3.9050	3.8795	3.4438	3.4018	3.2212	62.83	47.86	64.14	56.45	55.65
System II : Water + sodium butyrate+ D(+)-lactose monohydrate										
0	4.4035	4.2594	3.9539	3.8683	3.7864	-	-	-	-	-
0.02	4.1540	4.0767	3.7762	3.6973	3.6318	155.79	116.75	110.70	102.47	88.81
0.04	4.0735	4.0119	3.6964	3.5845	3.5360	103.98	78.86	80.93	85.83	72.61
0.06	4.0087	3.9233	3.6219	3.5138	3.4055	83.00	70.84	69.64	71.54	73.70
0.08	3.9019	3.8298	3.5670	3.4389	3.3425	79.04	67.50	60.82	64.95	64.35
0.1	3.7693	3.7448	3.4123	3.4008	3.2387	79.92	64.47	68.09	56.56	65.22
System III : Water + sodium butyrate+ D(+)-raffinose pentahydrate										
0	4.4035	4.2594	3.9539	3.8683	3.7864	-	-	-	-	-
0.02	4.0779	4.0341	3.7425	3.6916	3.5722	124.35	144.06	132.92	106.89	124.20
0.04	4.0249	3.8826	3.6316	3.5234	3.4828	72.09	118.71	101.31	104.32	88.04
0.06	3.9025	3.7789	3.5262	3.4475	3.3772	63.71	100.44	89.62	84.85	79.09
0.08	3.8381	3.6837	3.4845	3.4005	3.2959	53.97	88.57	73.77	70.75	71.10
0.1	3.7300	3.6432	3.3959	3.3655	3.0145	50.68	76.99	70.16	60.84	89.52

Table 3. Values of apparent molal compressibility (φ_K) and apparent molal volume (φ_V) of mono, di and tri saccharides in aqueous sodium butyrate mixtures at 303.15 K for

M/(mol.dm^{-3})	- φ_K /(×10^{-7} m^2 N^{-1})					- φ_V /(×10^{-3} m^3 mol^{-1})				
	Water + sodium butyrate									
	0M	0.025M	0.05M	0.075M	0.05M	0M	0.025M	0.05M	0.075M	0.05M
System I: Water + sodium butyrate+ D(+)-galactose										
0.02	11.41	7.03	4.15	3.83	5.81	845.21	555.12	217.01	245.21	563.54
0.04	7.73	6.42	5.10	5.77	5.45	555.96	409.46	285.45	421.90	438.52
0.06	7.49	5.60	6.39	6.48	5.15	513.85	388.82	331.72	393.04	383.61
0.08	6.98	5.79	6.33	6.36	5.60	450.24	438.60	394.34	377.41	366.40
0.1	7.31	5.76	6.59	6.39	7.71	503.33	417.71	354.70	415.53	498.32
System II : Water + sodium butyrate+ D(+)-lactose monohydrate										
0.02	16.88	12.95	10.65	11.95	10.42	983.62	624.54	398.84	665.75	677.80
0.04	10.99	8.82	7.89	10.60	9.05	609.81	476.91	336.50	771.32	692.81
0.06	9.21	7.86	7.42	9.43	9.33	579.00	430.96	443.21	790.84	727.64
0.08	8.60	7.80	6.61	8.21	8.06	510.12	484.64	416.71	638.49	609.92
0.1	8.82	7.35	6.98	7.04	7.72	535.34	442.90	365.92	532.61	539.91
System III : Water + sodium butyrate+ D(+)-raffinose pentahydrate										
0.02	21.34	15.5	13.08	12.68	13.46	738.72	722.21	579.15	775.81	693.41
0.04	12.64	13.11	9.65	12.59	10.57	707.62	713.90	370.42	881.34	738.51
0.06	11.38	11.51	9.38	10.58	9.78	662.05	702.01	528.14	801.16	721.46
0.08	9.48	10.14	7.87	8.74	8.95	524.91	593.82	467.41	649.92	679.72
0.1	9.36	8.58	7.34	7.43	10.16	563.12	490.14	410.90	541.74	585.50

Viscosity variation is attributed to the structural changes. From Table-1 it is observed that the values of viscosity increases with increasing the concentration of saccharides as well as sodium butyrate in the mixtures. This increasing trend indicates the existence of molecular interactions occurring in these systems.

Table 4. Values of limiting apparent molar compressibility (φ^0_K), limiting apparent molar volume (φ^0_V) and their constants S_K and S_V, transfer adiabatic compressibility ($\Delta\varphi^0_K$) transfer volumes ($\Delta\varphi^0_V$) and A & B coefficients of Jones-Dole equation of saccharides in aqueous sodium acetate mixtures at 308.15 K for

Saccharides	M/(mol.dm^{-3})	$-\varphi^0_K$ / ($\times10^{-8}$ m^2 N^{-1})	$-\varphi^0_V$ / ($\times10^{-3}$ m^3 mol^{-1})	S_K / ($\times10^{-8}$ N^{-1} m^{-1} mol^{-1})	S_V / ($\times10^{-3}$ m^3 L^{½} mol$^{-3/2}$)	$\Delta\varphi^0_K$ /($\times10^{-3}$ m^3 mol^{-1})	$\Delta\varphi^0_V$ /($\times10^{-3}$ m^3 mol^{-1})	A / (dm$^{3/2}$. mol$^{-1/2}$)	B / (dm^3. mol^{-1})
D(+)-galactose	0.00	24.90	1035.1	82.33	1946.4	-	-	0.1162	0.3286
	0.025	7.94	592.8	7.70	636.8	16.96	442.3	0.0125	0.8092
	0.05	2.28	101.4	14.46	1908.5	22.62	933.7	0.0192	1.0477
	0.075	3.50	194.7	72.73	741.8	21.40	840.4	0.1093	1.1984
	0.1	4.10	587.0	7.78	577.4	20.80	448.1	0.6427	1.2986
D(+)-lactose monohydrate	0.00	21.61	1223.8	45.19	2447.5	-	-	0.1249	0.3985
	0.025	16.01	701.7	29.78	884.7	5.60	522.1	0.0457	0.9542
	0.05	12.89	381.5	20.98	44.6	8.73	1223.8	0.0912	1.5745
	0.075	16.06	864.2	27.90	778.2	5.56	359.6	0.8534	2.3712
	0.1	12.15	794.9	13.36	577.5	9.46	428.9	0.0860	3.2718
D(+)-raffinose pentahydrate	0.00	27.00	1470.6	68.93	3177.4	-	-	0.1551	0.4354
	0.025	21.33	945.3	49.57	1269.2	5.67	525.3	0.0966	1.1247
	0.05	16.89	609.5	31.32	583.3	10.11	861.2	0.3182	1.6047
	0.075	17.43	1079.7	30.42	1475.1	9.57	390.9	0.2688	2.4214
	0.1	20.45	817.0	37.00	562.2	6.55	653.6	0.1846	3.4184

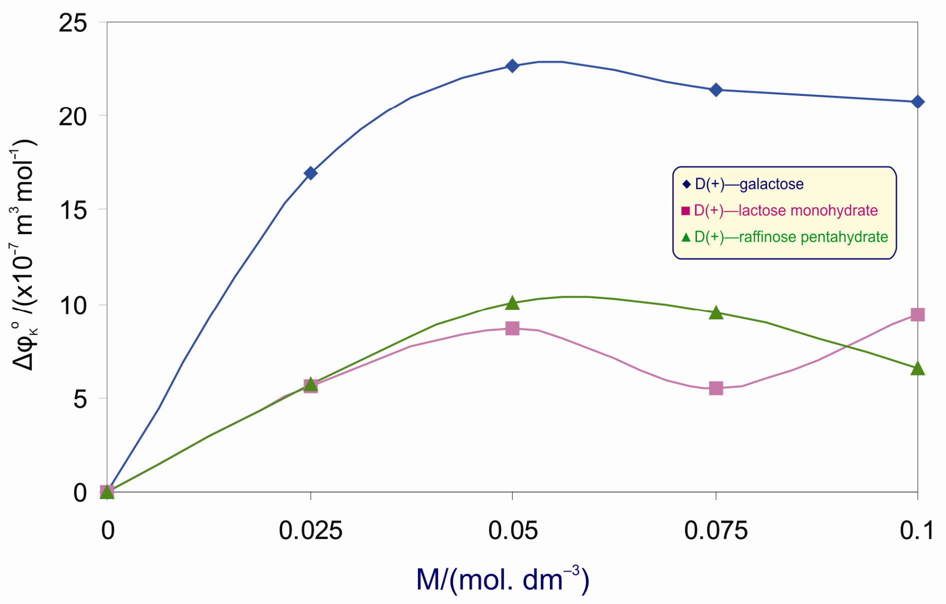

Fig. 1. Variation of transfer adiabatic compressbility ($\Delta\varphi^0_K$) of mono,di and tri saccharides with molarity of aqueous sodium butyrate solutions at 303.15 K

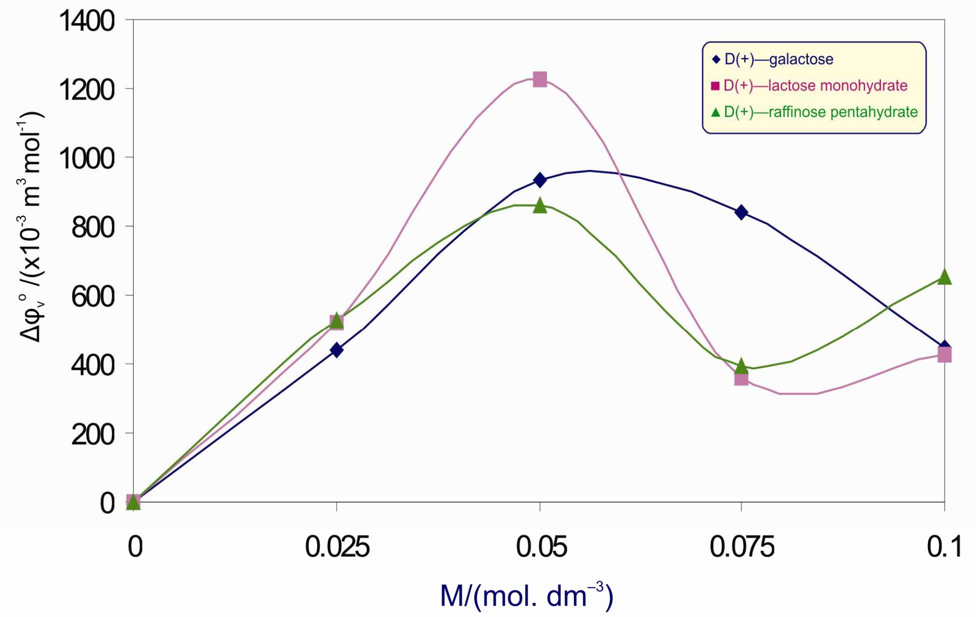

Fig. 2. Variation of transfer volume ($\Delta\varphi_V^0$) of mono,di and tri saccharides with molarity of aqueous sodium butyrate solutions at 303.15 K

In order to shed more light in this, the role of viscosity A and B coefficients has also been obtained. From Table-4 it is observed that the values of A and B are positive and these values are increases with increasing the concentration of sodium butyrate in all systems studied. Since A is a measure of solute-solute interactions, it is evident that there is a strong solute-solute interactions in the mixtures studied. The B-coefficient measures the size and shape effects, as well as the structural effects, induced by solute-solvent interaction [19]. The positive B values suggest the presence of strong solute-solvent interaction. The magnitude of B is in order : D (+)-raffinose > D(+)- lactose > D(+) - galactose. The larger magnitude of B values shows structure making capacity of the solute.

CONCLUSION

In summary, from the magnitudes of φ_V^0 and viscosity B-coefficient values it can be concluded that D(+)-raffinose pentahydrate mixtures possess the strong solute-solvent interaction than the other two saccharides. The transfer adiabatic compressibility $\Delta\varphi_K^0$ and transfer volume $\Delta\varphi_V^0$ suggest the predominance of hydrophilic-ionic interactions over hydrophobic-ionic interactions. From the co-sphere overlap model it can be concluded that solute-co-solute interactions are dominating over the solute-solvent interactions.

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