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Densities and partial molar volumes of fructose and sucrose in water and 0.05M (NaCl, NaBr, KCl, and KBr) aqueous solutions at 303.15K

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ABSTRACT

Measurements of densities of fructose and sucrose in water and 0.05M (NaCl, NaBr, KCl, and KBr) aqueous solutions have been undertaken as a function of molarity, at atmospheric pressure, and at T = 303.15K. Densities have been correlated with molarity of the solutions. Furthermore, partial molar volumes have been calculated from experimental density values. Results are interpreted in terms of solute-solute and solute-solvent interactions.

KEYWORDS

Sugars;
Alkali halides;
Aqueous solutions;
Density;
Partial molar volume.

INTRODUCTION

The soaking operations include candying and semi candying, osmotic dehydration, brining and curing, emersion, chilling and freezing. In the field of soaking operations, the mixed blends (sugar + water + alkali halides) at low temperatures (303.15K) are used either for vegetable or animal tissues. To understand the soaking operations with mixed blends, it is necessary to take into account physical properties of (sugar + water + alkali halides).

Direct contacting of food stuff with aqueous solutions has been widely used in the field of engineering. The food includes fruit, vegetables, meat and fish. They can be osmoticaly treated proceeding the conventional processing. Binary and ternary aqueous solutions of sugars, inorganic salts, alcohol, and polyols can be used as osmotic agents. To understand the osmotic treatment, it is necessary to know in hand physical properties of (sugar + water + inorganic salts). The most important physical property density will useful for this. From densities of the aqueous solutions, partial molar volumes can be calculated. Partial molar volumes are useful to calculate the effect of the pressure on ion-equilibrium for engineering and oceanographic.

Therefore, in this paper, we report densities and partial molar volumes of fructose and sucrose in water and 0.05M (NaCl, NaBr, KCl, and KBr) aqueous solutions, at (303.15K), and at atmospheric pressure.

EXPERIMENTAL

Sucrose (A.R. Grade purity > 99.5%, BDH), NaBr (A.R. Grade purity > 99.5%, Loba Chem.),

TABLE 1 : Densities (ρ) and apparent molar volumes ($V_{\phi,m}$) of fructose in water and 0.05 M (NaCl, NaBr, KCl, and KBr) aqueous solutions at T = 303.15 K

M(mol·dm^{-3})	$10^{-3}\cdot\rho$ (kg·m^{-3})	$10^6\cdot V_{\phi,m}$ (m^3·mol^{-1})	M(mol·dm^{-3})	$10^{-3}\cdot\rho$(kg·m^{-3})	$10^6\cdot V_{\phi,m}$ (m^3·mol^{-1})
Fructose + Water			**Fructose + NaCl**		
0.0000	0.9956		0.0000	0.9894	
0.0309	0.9977	112.146	0.0302	0.9914	114.197
0.0506	0.999	112.772	0.0702	0.9941	113.149
0.0703	1.0003	112.964	0.0914	0.9954	114.327
0.0900	1.0016	113.008	0.1116	0.9967	114.415
0.1100	1.0029	113.165	0.1310	0.9979	114.810
0.1300	1.0042	113.228	0.1506	0.9991	115.155
0.1501	1.0054	113.956	0.1715	1.0004	115.277
0.1702	1.0066	114.479	0.1926	1.0016	115.942
0.1922	1.0079	114.963	0.2108	1.0026	116.557
0.2097	1.0089	115.419			
Fructose + NaBr			**Fructose + KCl**		
0.0000	1.0001		0.0000	0.9917	
0.0107	1.0008	114.644	0.1110	0.9985	118.554
0.0309	1.0021	115.190	0.1302	0.9996	119.014
0.0533	1.0035	115.913	0.1504	1.0007	119.725
0.0703	1.0045	117.041	0.1703	1.0018	120.130
0.0901	1.0057	117.334	0.1902	1.0029	120.423
0.1123	1.007	117.888	0.2100	1.0040	120.606
0.1313	1.0081	118.269	**Fructose + KBr**		
0.1501	1.0092	118.440	0.0000	1.0059	
0.1716	1.0103	119.485	0.1080	1.0122	120.686
0.1899	1.0113	119.823	0.1320	1.0135	121.275
0.2101	1.0124	120.123	0.1540	1.0147	121.555
			0.1703	1.0155	122.215
			0.1901	1.0165	122.693
			0.2106	1.0175	123.236

TABLE 2: Densities (ρ) and apparent molar volumes ($V_{\phi,m}$) of sucrose in water and 0.05M (NaCl, NaBr, KCl, and KBr) aqueous solutions at T = 303.15K

M (mol·dm^{-3})	$10^{-3}\cdot\rho$ (kg·m^{-3})	$10^6\cdot V_{\phi,m}$ (m^3·mol^{-1})	M (mol·dm^{-3})	$10^{-3}\cdot\rho$ (kg·m^{-3})	$10^6\cdot V_{\phi,m}$ (m^3·mol^{-1})
Sucrose + Water			**Sucrose + NaCl**		
0.0000	0.9956		0.0000	0.9894	
0.0300	0.9996	209.046	0.0110	0.9908	214.718
0.0505	1.0022	209.868	0.0305	0.9934	210.966
0.0705	1.0048	210.125	0.0502	0.9960	210.312
0.0918	1.0075	210.297	0.0702	0.9985	211.674
0.1105	1.0099	210.361	0.0902	1.0010	212.435
0.1305	1.0124	210.484	0.1112	1.0036	212.330
0.1500	1.0148	210.583	0.1298	1.0059	212.366
0.1700	1.0173	210.659	0.1503	1.0084	212.762
0.1907	1.0198	210.688	0.1705	1.0108	213.140
0.2106	1.0222	210.763			
Sucrose + NaBr			**Sucrose + KCl**		
0.0000	1.0001		0.0000	0.9917	
0.0101	1.0014	213.301	0.1103	1.0050	219.613
0.0302	1.0039	216.972	0.1298	1.0072	220.300
0.0494	1.0062	217.482	0.1502	1.0095	220.978
0.0701	1.0087	218.023	0.1701	1.0117	221.151
0.0933	1.0114	218.272	0.1901	1.0139	221.464
0.1103	1.0134	218.433	0.2102	1.0161	221.680
0.1309	1.0158	218.605	**Sucrose + KBr**		
0.1501	1.0181	218.709	0.0000	1.0059	
0.1703	1.0204	218.889	0.1110	1.0191	219.879
0.1904	1.0226	219.025	0.1301	1.0213	220.093
0.2103	1.0249	219.176	0.1497	1.0235	220.245
			0.1712	1.0259	220.394
			0.1901	1.0280	220.552
			0.2110	1.0303	220.748

KCl (A.R. Grade purity > 99.5%, E-Merck) and KBr (A.R. Grade purity > 99.5%, E-Merck) were used in the present investigation without further purification. Masses were recorded on a Dhona balance with a precision of $\pm 1\cdot10^{-7}$kg. All the solutions were prepared in triply distilled demonized water. The densities (ρ) of aqueous solutions were measured with the help of a $15\cdot10^{-6}$m^3 double arm pycnometer [1, 2, 3]. The pycknometer was placed in glass walled thermostat having the thermal stability of $\pm$ 0.01K. The accuracy in the density measurements was $\pm 1\cdot10^{-7}$kg·m^{-3}.

RESULTS AND DISCUSSION

Densities of fructose and sucrose in water and 0.05M (NaCl, NaBr, KCl and KBr) aqueous solutions are reported in TABLE 1 and TABLE 2, respectively.

Densities are correlated with molarity of solutions by polynomial equation.

$$\rho = A_o + A_1 M + A_2 M^2 \quad (1)$$

M is molarity of the solution. TABLE 3 summarizes the correlation parameters A_{o}, A_1, and A_2.

Density values have been used to calculate the partial molar volumes of fructose and sucrose in water and

TABLE 3 : Correlation coefficients of equation 1

System	A_0	A_1	A_2
Fructose + Water	0.9955	0.0707	–0.0327
Fructose + NaCl	0.9893	0.0696	–0.0308
Fructose + NaBr	1.0001	0.0647	–0.0303
Fructose+ KCl	0.9926	0.0568	–0.0044
Fructose + KBr	1.0057	0.0641	–0.0391
Sucrose + Water	0.9956	0.1319	–0.0273
Sucrose + NaCl	0.9894	0.1330	–0.0435
Sucrose + NaBr	1.0002	0.1229	–0.0259
Sucrose + KCl	0.9922	0.1191	–0.0249
Sucrose + KBr	1.0061	0.1204	–0.0265

0.05M (NaCl, NaBr, KCl and KBr) aqueous solutions. To calculate apparent molar volumes ($V_{\phi, m}$) of fructose and sucrose in water and 0.05M (NaCl, NaBr, KCl and KBr) aqueous solutions following equation [4, 5] was used.

$$V_{\phi, m} = [\text{Molar mass of solute}/\rho] - [(\rho - \rho_o)/(M\rho\rho_o)] \quad (2)$$

M is the molarity of the solution, ρ and ρ_0 are densities of the solution and solvent, respectively. Apparent molar volumes ($V_{\phi, m}$) of fructose and sucrose in water and 0.05M (NaCl, NaBr, KCl and KBr) aqueous solutions are included in TABLE and TABLE 2. Partial molar volumes ($V^o_{\phi, m}$) have been calculated by using the Masson's equation [6, 7].

$$V_{\phi, m} = V^o_{\phi, m} + V_S m^{1/2} \quad (3)$$

In this equation, $V^o_{\phi, m}$, and V_S, are solute, solvent, and temperature dependent empirical parameters. $V^o_{\phi, m}$, and V_S have been calculated by the least square fitting of the apparent molar volume data in the equation 3. TABLE 4 compiles $V^o_{\phi, m}$ and V_S values of fructose and sucrose in water and 0.05M (NaCl, NaBr, KCl and KBr) aqueous solutions, respectively.

Information regarding solute-solvent and solute – solute interactions can be obtained from $V^o_{\phi, m}$ and V_S values. From TABLE 4, it is clear that the $V^o_{\phi, m}$ values of fructose and sucrose are large and positive. The positive values of $V^o_{\phi, m}$ indicate the strong solute-solvent interactions. The V_S values are positive and smaller than $V^o_{\phi, m}$, suggesting the dominance of solute-solvent interactions over solute-solute interactions. The $V^o_{\phi, m}$ values of sucrose in water and 0.05M (NaCl, NaBr, KCl and KBr) aqueous solutions are larger than $V^o_{\phi, m}$ values of fructose in water and 0.05M (NaCl, NaBr, KCl and KBr) aqueous solutions.

TABLE 4 : Partial molar volume $V^o\phi_{, m}$ and solute – solute interaction parameter V_S of fructose and sucrose at T = 303.15)K

System	$10^6 \cdot V^o_{\phi, m}$ ($m^3 \cdot mol^{-1}$)	V_S
Fructose + Water	111.592	16.76
Fructose + NaCl	112.907	15.226
Fructose + NaBr	114.589	27.585
Fructose+ KCl	116.306	21.429
Fructose + KBr	117.926	24.978
Sucrose + Water	209.378	7.546
Sucrose + NaCl	212.003	3.289
Sucrose + NaBr	215.711	19.801
Sucrose + KCl	217.664	19.983
Sucrose + KBr	218.976	8.366

CONCLUSIONS

1. Partial molar volumes of fructose and sucrose in water and 0.05M (NaCl, NaBr, KCl and KBr) aqueous solutions are positive.
2. Partial molar volumes of fructose in water and 0.05M (NaCl, NaBr, KCl and KBr) aqueous solutions smaller than partial molar volumes of sucrose in water and 0.05M (NaCl, NaBr, KCl and KBr) aqueous solutions.
3. The partial molar volumes of fructose and sucrose increase with the addition of alkali halides in solvent like water.

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