

Research Article

Density and Viscosity Studies of Fructose Solutions in Water and in aqueous NaCl, NaBr, KCl and KBr solutions

Kailas H. Kapadnis and Apoorva P. Hiray

P.G. Department of Chemistry, L.V.H. College Panchavati Nashik, India.

Abstract

The densities and viscosities of fructose solutions in water and in 0.05, 0.1, 0.5, 1.00 M NaCl, NaBr, KCl and KBr have been measured at 298.15, 303.15, 308.15 and 313.15 K, from densities (ρ), the limiting partial molar volumes (φ_v^0) have been evaluated. The viscosity data have been analyzed with the help of the modified Jones-Dole equation and the corresponding viscosity B-coefficients have been calculated.

***Correspondence**

Kailas H. Kapadnis
P. G. Department of Chemistry, L. V. H.
College Panchavati Nashik, India.
Email: khkapadnis@yahoo.co.in

Keywords: Viscosity, density, fructose, Jones-Dole equation

Introduction

Studies on thermodynamic properties have been made on aqueous ternary systems containing carbohydrates and electrolytes from our own laboratory [1-4] It has been reported earlier [5,6] that mono and disaccharides are structure makers, suggesting hydrogen bonding with OH groups of sugars with water.

It would be interesting to examine whether the structure modification of water by these sugars gets enhanced or subdued in presence of an ion. In the present paper we report limiting apparent molar volumes (φ_v^0), experimental slopes (Sv) and viscosities B-coefficients which have been interpreted in terms of solute – solvent and solute – solute interactions.

Experimental

Water was distilled in quick fit apparatus over alkaline KMnO_4 followed by further distillation over H_2SO_4 . Then conductance of this distilled water was 5×10^{-6} mhos cm^{-1} . NaBr was purchased from Loba Chemie Indo- Australan Co. with purity greater than NaCl, KCl and KBr were procured from E. Merck with purity ranging between 99.5 and 99.8 %. All these electrolytes were vacuum dried and used without further purification. Fructose was supplied by General Chemical Division, Allied Chemical Corporation, Morristone MJ, USA with purity 99.8 %. The fructose solutions of different molarities were prepared by dissolving accurately weighed amount of fructose in (0.05, 0.1 and 1.0 M) aqueous solution of NaCl, NaBr, KBr. These solutions were allowed to stand for some time to attain thermal equilibrium with atmosphere. Densities of fructose solutions in water and in aqueous alkali halides were measured using bicapillary pycnometer, with an accuracy of $\pm 1 \times 10^{-4}$ g/cm^3 as

described previously [10,11]. The pycnometer was mounted in thermostated water bath with thermal stability of ± 0.01 K. The viscosity measurement was made using a suspended level Ubbelohde viscometer [12, 13].

The viscometer was clamped vertically in the bath and 25 cc fructose solutions were added from a calibrated burette. The viscometer was calibrated with triple distilled water using the viscosity and density values reported by Marsh [14] Viscosity values were determined using the relation

$$\eta_1 / \eta_2 = \rho_1 t_1 / \rho_2 t_2 \quad (1)$$

Where η_1 , ρ_1 , t_1 and η_2 , ρ_2 , t_2 are viscosity, density and flow time of solvent and solution, respectively. The flow time was measured with an electronic stop watch (accuracy of ± 0.01 s). A viscometer was selected having flow time of 250-300 s for redistilled water at 298.25 K. since all flow were greater than 200 s, and capillary radius (0.5mm) was for less than its length (50-60mm), The kinetic energy correction was found to be negligible. Accuracy of the viscosity measurement was ± 0.001 m.P.a.s.

Results and discussion

The measured ρ value of fructose solution in water and aqueous NaCl, NaBr, KCl and KBr solutions at 298.15, 303.15, 308.15 and 313.15 K are used to calculate the apparent molar volumes φ_v using the equation,

$$\varphi_v = [1000 (\rho_0 - \rho) / (C \times \rho_0)] + (M / \rho_0) \quad (2)$$

where ρ and ρ_0 are the densities of solution and solvent respectively, M, is the molecular weight of the solute, C, is the concentration in mol L^{-1} . The φ_v value varied linearly with the concentration in conformity with Redlich – Mayer equation as reported

earlier by Nikam et. al [1-4]. Fig.1 gives representative graphs of ϕ_v versus C for fructose in water and in aqueous NaCl at 298.15 K. Similar graphs are also plotted for other systems such as fructose in water and in aqueous NaCl at 303.15, 308.15 and 313.15 K, fructose in water and in aqueous NaBr at 298.15, 303.15, 308.15 and 313.15 K, fructose in water and in aqueous KCl at 298.15, 303.15, 308.15 and 313.15 K and fructose in water and in aqueous KBr at 298.15, 303.15, 308.15 and 313.15 K.

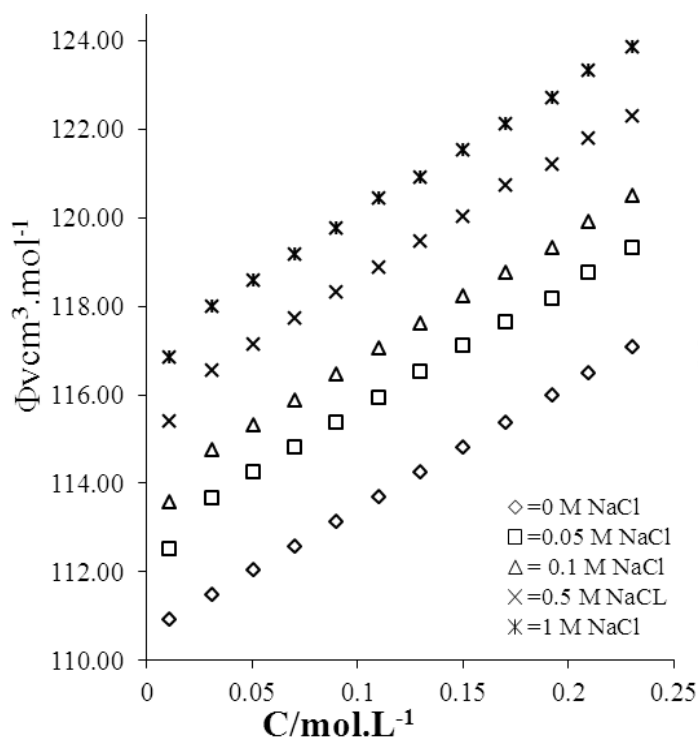


Figure 1 ϕ_v vs C for fructose in water and in aqueous NaCl at 298.15 K

The limiting partial molar volume of fructose in aqueous electrolyte solutions were obtained by computerized least Square fitting of the equation

$$\phi_v = \phi_v^0 + S_v C \quad (3)$$

where ϕ_v^0 is the limiting apparent molar volume at infinite dilution and S_v is experimental slope. The ϕ_v^0 and S_v values are presented in Table 1.

ϕ_v^0 values of fructose in pure water at 298.15K in the present investigation (110.61) agrees well with the literature value 110.4 obtained by Edward[7] and Kaulgud et al [8] as well Nikam et al [2]calculated ϕ_v^0 values of fructose in water at 298.15 K as 110.75. The ϕ_v^0 values of fructose in water and aqueous NaCl, NaBr, KCl and KBr solution are large and positive. This indicates the presence of strong solute-solvent interaction. It is further observed the ϕ_v^0 in all systems increase slightly with increase in temperature suggesting decrease in solute-solvent interactions at elevated temperature. The ϕ_v^0 values of fructose in aqueous solution in presence of added electrolytes are higher than those for fructose in pure water. The ϕ_v^0 values are positive and increase in solutions with

increasing concentration of each electrolyte. This suggests that the structure – making tendency of fructose is enhanced in the presence of ions of electrolyte. The ϕ_v^0 values of fructose in aqueous NaBr are higher than those in aqueous NaCl as well The ϕ_v^0 values of fructose in aqueous KBr are higher than those in aqueous KCl presumably due to introduction of voluminous Br^- ion.

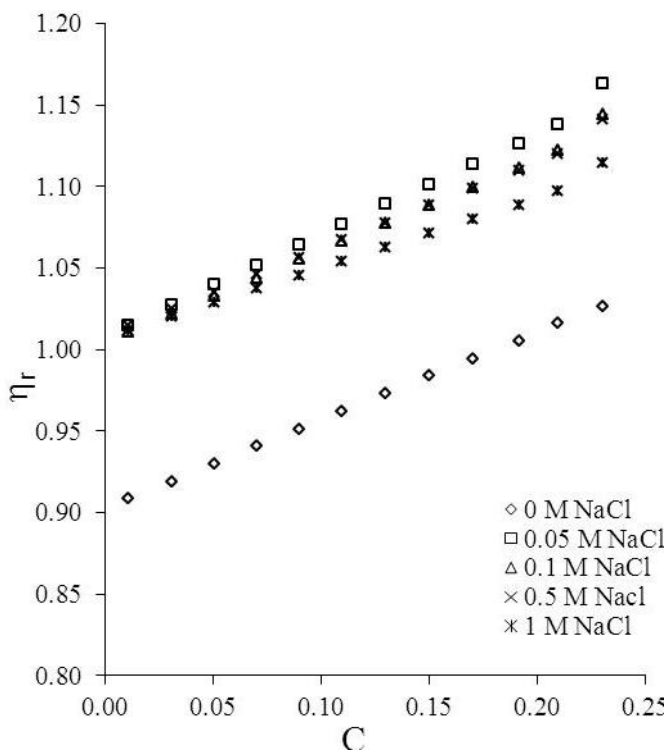


Figure 2 η_r vs C of fructose in water and in aqueous NaCl at 298.15 K

The relative viscosity (η_r) data of fructose solutions in water as well as in aqueous alkali solution are analyzed with the help of equation

$$\eta_r = 1 + BC \quad (4)$$

The Fig. 2 gives representative graphs η_r versus C for fructose in water and in aqueous NaCl at 298.15 K. similar plots have been obtained for solution at all temperatures for all systems

The values of B obtained from the slopes of these plots are listed in Table 2. The B values are positive for fructose solutions in water and in aqueous NaCl, NaBr, KCl and KBr at all temperatures which suggest that fructose acts as structure promoter in these solutions. The B values of fructose solutions in aqueous NaCl, NaBr, KCl and KBr are lower than those in pure water. This could be explained on the basis that electrolyte is hydrated [1,2] and reacts with fructose. This leaves less water for sugar molecules for hydration. The positive B and negative dB/Dt [11] values in all solution studied in the present investigation, make fructose as a structure promoter.

Table 1 ϕ_v^0 and S_v values of fructose in water and in aqueous NaCl, NaBr, KCl and KBr solutions at different temperatures

Fructose in	$\phi_v^0(\text{cm}^3 \text{mol}^{-1})$				$S_v(\text{cm}^3 \text{L}^{1/2} \text{mol}^{3/2})$			
	298.15K	303.15K	308.15K	313.15K	298.15K	303.15K	308.15K	313.15K
water	110.61	111.07	111.56	112.02	28.01	30.06	31.51	32.15
0.05M NaCl	111.66	112.12	112.61	113.08	28.33	30.31	31.72	32.32
0.1M NaCl	112.72	113.2	113.66	114.13	28.71	30.72	32.01	32.66
0.5M NaCl	114.49	115.36	115.85	116.29	29.16	31.13	32.32	32.86
01M NaCl	115.94	116.4	116.91	117.33	29.32	31.25	32.45	32.92
0.05MNaBr	114.85	115.83	116.74	117.77	30.51	32.62	33.73	34.84
0.1M NaBr	116.2	117.15	118.05	118.96	30.93	33.07	34.15	35.24
0.5M NaBr	116.2	117.15	118.05	118.96	30.93	33.07	34.15	35.24
01M NaBr	120.86	121.75	122.95	123.82	31.76	33.93	34.85	36.05
0.05MKCl	112.21	112.67	113.01	113.36	29.22	31.21	33.71	34.36
0.5M KCl	114.42	114.81	115.25	115.58	31.35	33.35	35.83	36.68
0.05MKBr	116.61	117.6	118.62	119.81	31.22	33.21	35.71	36.36
0.5M KBr	121.98	122.76	123.66	124.38	33.35	35.36	37.84	38.68

Table 2 B values of fructose in water and in aqueous NaCl, NaBr, KCl and KBr solutions at different temperatures

Fructose in	B(dm ³ mol ⁻¹)			
	298.15K	303.15K	308.15K	313.15K
water	0.603	0.545	0.494	0.432
0.05M NaCl	0.613	0.557	0.506	0.444
0.1M NaCl	0.554	0.506	0.458	0.413
0.5M NaCl	0.530	0.481	0.435	0.396
01M NaCl	0.425	0.419	0.413	0.406
0.05MNaBr	0.620	0.603	0.581	0.559
0.1M NaBr	0.559	0.486	0.451	0.438
0.5M NaBr	0.470	0.458	0.446	0.437
01M NaBr	0.458	0.446	0.432	0.418
0.05MKCl	0.410	0.395	0.382	0.370
0.5M KCl	0.468	0.441	0.431	0.412
0.05MKBr	0.477	0.469	0.460	0.454
0.5MKBr	0.434	0.420	0.404	0.388

References

- [1] P. S. Nikam, H. R. Ansari and M. Hasan, *J. Ind. Chem. Soc.*, 1999, 76, 344.
- [2] P. S. Nikam, H. R. Ansari and M. Hasan *J. Mol. Liq.*, 2000, 87, 97.
- [3] P. S. Nikam, H. R. Ansari and M. Hasan *J. Mol. Liq.*, 2000, 84, 169.
- [4] P. S. Nikam, H. R. Ansari and M. Hasan *J. Pure Appl. Ultrason.*, 1998, 20, 5.
- [5] J. B. Taylor and J. S. Rawlinsion, *Trans. Faraday Soc.*, 1955, 57, 1183.
- [6] F. Kawaizumi, B. Nisho, H. Nomura and Y. Migahara, *J. Chem. Thermodyn.*, 1981, 13, 89.
- [7] J. T. Edward, F. Shahidi and F. J. G. Farrell, *J. Soln. Chem.*, 1976, 5, 807.
- [8] M. L. Parmar and S. K. Bhardwaj, *J. Ind. Chem. Soc.*, 1997, 74, 353.
- [9] K. N. Marsh, "Recommended Reference Materials for the Realization of Physico-Chemical Properties", Blakwell Scientific Publications, Oxford, UK, 1987.

- [10] A. L. Surdro, C. Shine and F. J. Milero, *J. Chem. Eng. Data.*, 978, 23, 197. F. Frank, J. R. Ravenhill and D. S. Reid, *J. Soln. Chem.*, 1972, 1, 3.
- [11] H. Hoiland and H. Holvik, *J. Soln. Chem.*, 1978, 7, 587.
- [12] J. T. Edward and F. Shahidi, *J. Soln. Chem.*, 1976, 5, 807.
- [13] P. S. Nikam and A. R. Hiray, *Ind. J. Pure Appl. Phys.*, 1988, 26, 37.

© 2013, by the Authors. The articles published from this journal are distributed to the public under "Creative Commons Attribution License" (<http://creativecommons.org/licenses/by/3.0/>). Therefore, upon proper citation of the original work, all the articles can be used without any restriction or can be distributed in any medium in any form.

Received : 28th April 2013
 Revised : 11th May 2013
 Accepted : 13th May 2013
 Online : 16th May 2013