Asian Journal of Chemistry; *Vol. 23, No. 3 (2011), 1360-1362*

ASIAN JOURNAL OF CHEMISTRY

www.asianjournalofchemistry.co.in

Apparent Molal Volumes and Partial Molar Volumes of Aqueous Solutions of Some Biologically Important Compounds at 308 and 318 K

P. SAHAYA AMUTHA* and X. ROSARIO RAJKUMAR

Department of Chemistry, Holy Cross College, Tiruchirappalli-620 002, India

*Corresponding author: E-mail: amudoss@gmail.com

(*Received*: 9 June 2010; *Accepted*: 17 November 2010) AJC-9306

Apparent molal volumes (φ_v), partial molar volumes (φ_v^0) of aqueous solutions of seven biologically important compounds [glucose, sucrose, urea, citric acid, tartaric acid, ascorbic acid and oxalic acid] in different molality [0.1-1.0 mol/kg] at two different temperatures [308 and 318 K] have been determined. For density measurements sprengel and Ostwald pyknometer has been used. Partial molar volumes (φ_v^0) at infinite dilution have been obtained from φ_v values using the Masson equation. φ_v^0 values are positive for all the compounds studied and apparent molal volumes increase with increase in concentration of ascorbic acid. It decreases with increase in concentrations of other compounds [glucose, sucrose citric acid, tartaric acid and oxalic acid]. Variations in φ_v values with change in solute concentrations are discussed in terms of solute-solvent interactions and electrostriction.

Key Words: Apparent molal volume, Partial molar volume, Density, Masson equation, Electrostriction, Glucose, Sucrose, Urea, Citric acid, Tartaric acid, Ascorbic acid, Oxalic acid.

INTRODUCTION

The reaction medium plays an important role in determining reactivity, which is reflected in thermodynamic, transport and spectral properties[1,2]. In order to gain insight into the mechanism of such interactions, thermodynamic and transport studies involving solute in mixed solvent systems are highly useful. The volumetric and viscometric studies of electrolytes at infinite dilution in solvent systems have contributed to our knowledge about electrolyte-non electrolyte-water interactions. By examining the apparent molal volumes and partial molar volumes of solutes as a function of size, nature, temperature and composition of the mixed solvent, it is possible to study the effect of these parameters on solute- water interactions with the hope of obtaining a better understanding of the interactions in solutions.

The importance of carbohydrates[3-6] to living things can hardly be over emphasized. The energy stores of most animals and plants are both carbohydrates and lipid in nature. Carbohydrates are generally available as an immediate energy source, whereas lipids act as a long-term energy resource and tend to be utilized at a slower rate.

Urea plays an important role[7] in the metabolism of nitrogen containing compounds by animals and is the main nitrogen containing substance in the urine of mammals.

Carboxylic acids are very important biologically active compounds[7]. They have long chains of carbon atoms attached to them are called fatty acids. They are important in the formation of fat in the body. Many carboxylic acids are present in the foods and drinks we ingest. Ascorbic acid is a water soluble antioxidant. Body requires vitamin C for normal physiological functions. It helps in the metabolism of tyrosine, folic acid and tryptophan.

Apparent molal volumes and partial molar volumes of aqueous solutions of glucose, sucrose, urea, citric acid, tartaric acid, ascorbic acid and oxalic acid at two different temperatures (308 and 318 K) have not been reported so far and hence need for the title investigation.

EXPERIMENTAL

All the compounds (AR, Qualigens) of highest purity grade were used without further purification. However they were dried in an oven and kept over anhydrous calcium chloride for 48 h before use. The solutions were prepared in doubly distilled deionized water having specific conductance less than 1×10^{-6} ohm^{-1} cm^{-1} and it was degassed before use. All the solutions were prepared by weight using Mettler balance having an accuracy of ± 0.01 mg.

Sprengel and Ostwald pyknometer[8] which was essentially a U-tube in shape with side arms being made up of small bore capillary used to measure the densities of solutions. Measurements were done in a water thermostat having an accuracy of ± 0.01 K.

RESULTS AND DISCUSSION

Apparent molal volumes (φ_v) of the various solutes in water at 308 and 318 K were calculated from the experimentally measured densities from the following equation.

$$\varphi_v = \frac{1000}{mdd_0} \times (d_0 - d) + \frac{M}{d}$$

where M = molecular mass of the solute, m = molality (mol kg^{-1}) of the solution, d and d_0 are the densities (kg m^{-3}) of solution and solvent, respectively. The concentration 'C' on the molal scale was used (Tables 1 and 2). The plots of φ_v against square root of concentration were found to be linear with negative slopes for glucose, sucrose, urea, citric, tartaric and oxalic acids. The positive slope was obtained for ascorbic acid. The partial molar volumes (φ_v^0) were calculated by plotting the experimental values of φ_v against the square root of molal concentration (C) using Masson's equation[9,10].

$$\varphi_v = \varphi_v^0 + S_v^* C^{1/2}$$

where φ_v^0 = partial molar volume at infinite dilution and S_v^* = experimental slope. The values of φ_v^0 and S_v^* along with standard errors are listed in Table-3. It is evident that S_v^* is negative for all the solutes except ascorbic acid in aqueous mixtures at 308 K. These results indicate that the above solutes mix ideally with water and there is a perfect solvation of these molecules resulting into the absence of solute-solute interactions[11-13].

TABLE-1
MOLALITIES (m), DENSITIES (d), APPARENT MOLAL VOLUMES (φ_v) FOR THE CHOSEN SOLUTES IN WATER AT 308 K

Glucose	Molality (m)	0.1034	0.2060	0.3038	0.4051	0.5047	0.5964	0.6957	0.7962	0.8721	0.9801
	Density (d)	1.0015	1.0081	1.0143	1.0204	1.0274	1.0321	1.0379	1.0433	1.0483	1.0536
	Apparent molal volume (φ_v)	118.76	116.29	115.34	114.10	112.96	112.00	111.24	110.50	110.20	109.10
Sucrose	Molality (m)	0.1006	0.2029	0.3016	0.4033	0.5075	0.6081	0.7088	0.7594	0.8065	0.9639
	Density (d)	1.0077	1.0194	1.0312	1.0416	1.0539	1.0645	1.0731	1.0788	1.0837	1.0976
	Apparent molal volume (φ_v)	217.30	216.30	215.20	217.64	214.51	213.99	213.40	213.30	212.80	212.40
Urea	Molality (m)	0.1023	0.2062	0.2907	0.4012	0.5003	0.6012	0.7081	0.8041	0.9172	0.9954
	Density (d)	0.9968	0.9988	1.0008	1.0018	1.0027	1.0044	1.0065	1.0068	1.0081	1.0098
	Apparent molal volume (φ_v)	44.49	44.00	43.70	43.45	43.20	42.95	42.70	42.45	42.25	42.15
Citric acid	Molality (m)	0.1008	0.2041	0.3050	0.4063	0.5046	0.6086	0.7100	0.8096	0.9064	1.0169
	Density (d)	1.0046	1.0086	1.0162	1.0220	1.0301	1.0362	1.0399	1.0491	1.0543	1.0619
	Apparent molal volume (φ_v)	141.10	140.10	139.36	138.90	138.10	137.47	137.46	136.66	136.30	135.82
Ascorbic acid	Molality (m)	0.1010	0.2010	0.3054	0.4079	0.4984	0.6132	0.7038	0.8096	0.9060	1.0230
	Density (d)	1.0115	1.0187	1.0244	1.0310	1.0365	1.0438	1.0489	1.0553	1.0603	1.0666
	Apparent molal volume (φ_v)	64.95	72.50	78.15	85.21	89.60	92.44	94.83	96.22	101.10	103.50
Tartaric acid	Molality (m)	0.1016	0.2034	0.3024	0.4076	0.5063	0.6071	0.7048	0.8150	0.9121	1.0149
	Density (d)	1.0022	1.0049	1.0127	1.0165	1.0237	1.0290	1.0346	1.0409	1.0457	1.0490
	Apparent molal volume (φ_v)	93.10	92.55	92.20	91.70	91.36	91.49	90.78	90.50	90.33	90.20
Oxalic acid	Molality (m)	0.1029	0.2060	0.3065	0.4102	0.5156	0.6180	0.7157	0.8191	0.9224	1.0258
	Density (d)	0.9830	0.9872	0.9915	0.9959	1.0002	1.0042	1.0079	1.0112	1.0152	1.0183
	Apparent molal volume (φ_v)	105.80	104.50	103.00	102.50	101.00	102.20	99.50	98.84	97.50	96.00

TABLE-2
MOLALITIES (m), DENSITIES (d), APPARENT MOLAL VOLUMES (φ_v) FOR THE CHOSEN SOLUTES IN WATER AT 318 K

Glucose	Molality (m)	0.1009	0.2035	0.3031	0.4052	0.5074	0.6026	0.7042	0.8108	0.9115	1.0026
	Density (d)	0.9900	0.9969	1.0038	1.0125	1.0159	1.0211	1.0263	1.0315	1.0349	1.0418
	Apparent molal volume (φ_v)	141.30	139.00	137.20	135.57	134.40	134.14	132.30	131.05	131.80	128.10
Sucrose	Molality (m)	0.1016	0.2039	0.3034	0.4054	0.5042	0.6093	0.7093	0.8104	0.9095	1.0126
	Density (d)	0.9902	0.9943	0.9978	1.0030	1.0073	1.0113	1.0150	1.0183	1.0223	1.0254
	Apparent molal volume (φ_v)	317.00	315.00	313.50	312.10	311.30	310.00	309.61	308.02	306.90	306.50
Urea	Molality (m)	0.1017	0.2071	0.3043	0.4097	0.4977	0.6071	0.7032	0.8086	0.9137	1.0250
	Density (d)	0.9932	0.9952	0.9969	0.9986	0.9996	1.0004	1.0014	1.0021	1.0038	1.0058
	Apparent molal volume (φ_v)	61.40	60.35	57.40	55.90	54.70	53.90	52.61	51.38	50.41	49.80
Citric acid	Molality (m)	0.0999	0.2082	0.3122	0.4074	0.5073	0.6069	0.7067	0.8175	0.9167	1.0126
	Density (d)	0.9883	0.9952	1.0021	1.0056	1.0142	1.0211	1.0297	1.0384	1.0436	1.0488
	Apparent molal volume (φ_v)	178.80	172.40	168.00	164.80	161.20	160.00	156.44	151.23	150.52	149.65
Ascorbic acid	Molality (m)	0.1032	0.2028	0.3041	0.4076	0.5035	0.6125	0.7081	0.7845	0.9105	1.0148
	Density (d)	0.9934	0.9986	1.0073	1.0125	1.0211	1.0246	1.0315	1.0367	1.0418	1.0470
	Apparent molal volume (φ_v)	126.10	125.20	123.70	122.80	121.87	123.00	120.81	118.62	119.70	119.24
Tartaric acid	Molality (m)	0.1005	0.2047	0.3050	0.3897	0.5072	0.6093	0.7099	0.8097	0.9073	1.0162
	Density (d)	0.9798	0.9952	1.0004	1.0055	1.0142	1.0176	1.0228	1.0297	1.0331	1.0366
	Apparent molal volume (φ_v)	118.40	115.80	115.00	112.60	110.87	111.19	108.55	107.40	104.65	105.30
Oxalic acid	Molality (m)	0.0972	0.2032	0.3021	0.4062	0.5020	0.6060	0.7077	0.8129	0.9145	1.0212
	Density (d)	0.9330	0.9952	0.9986	1.0021	1.0056	1.0090	1.0107	1.0159	1.0211	1.0246
	Apparent molal volume (φ_v)	114.10	112.10	110.60	109.30	108.10	107.00	106.50	105.19	104.15	103.90

TABLE-3
PARTIAL MOLAR VOLUMES (φ^0_v) AND EXPERIMENTAL SLOPES (S^*_v) FOR THE CHOSEN SOLUTES AT 308 AND 318 K

	Glucose		Sucrose		Urea		Citric acid		Ascorbic acid		Tartaric acid		Oxalic acid	
	308 K	318 K	308 K	318 K	308 K	318 K	308 K	318 K	308 K	318 K	308 K	318 K	308 K	318 K
φ^0_v	122.97 (0.20*)	147.00 (0.24)	220.12 (0.76)	322.10 (1.15)	45.60 (0.03)	66.70 (0.06)	143.6 (1.08)	192.00 (0.21)	46.5 (0.05)	129.3 (1.14)	94.5 (0.02)	124.30 (0.01)	109.40 (0.11)	118.9 (0.13)
S^*_v	-13.98	-18.33	-7.72	-15.22	-3.46	-17.14	-7.83	-43.64	55.88	-10.00	-4.5	-20.00	-12.5	-15.00

*Standard error given in parenthesis.

It is evident from Table-3 that φ_v^0 values are positive for all the solutes in various molal mixtures of water at 308 K, thereby showing the presence of very strong solute-solvent interactions[14]. The relative values of φ_v^0 in case of sucrose are much larger as compared to all the other solutes thereby suggesting that solute-solvent interactions are much stronger in case of sucrose as compared with those of other solutes.

The positive slope obtained for ascorbic acid in aqueous mixtures at 308 K, indicate the decrease in electrostriction[15] which brings about shrinkage in the volume of solvent. Electrostriction primarily reflects electrolyte solvent interactions. The values of φ_v^0 are positive and large for all the solutes in various molal mixtures of water at higher temperature 318 K, showing the presence of very strong solute-solvent interactions which are further strengthened with the rise in temperature attributed to the increase in solvation[16,17].

Apparent molal volumes, partial molar volumes, viscosities, adiabatic compressibilities of various biologically important compounds such as galactose, fructose, succinic acid and malic acid in water and in various solvents is under investigation.

REFERENCES

1. M.P. Pena, E. Vercher and A. Martinez-Andreu, *J. Chem. Eng. Data*, **43**, 626 (1998).
2. J.D. Pandey and Y. Akhtar, *Indian J. Chem.*, **36A**, 614 (1997).
3. B. Ernst, G.W. Hart and P. Sinay, Carbohydrates in Chemistry and Biology, Vol. 1, Wiley-VCH Verlag Weinheim (2000).
4. R. Polacek, R. Behrends and U. Kaatze, *J. Phy. Chem. B*, **105**, 2894 (2001).
5. D.P. Miller and J.J. De Pablo, *J. Phy. Chem. B*, **104**, 8876 (2000).
6. R.J. Woods, R.A. Dwek, C.J. Edge and B.F. Reid, *J. Phys. Chem.*, **99**, 3832 (1995).
7. W.F. Boron, Medical Physiology: A Cellular and Molecular Approach, Elsevier/Saunders ISBN 1-4160-2328-3, Vol. I, 837 (2008).
8. D.P. Shoemaker and C.W. Garland, Experiments in Physical Chemistry, MCGraw Hill, NewYork, edn. 2, p. 131 (1967).
9. P.K. Banipal, T.S. Banipal, B.S. Lark and J.C. Ahluwalia, *J. Chem. Soc. Faraday Trans*, **93**, 81 (1997).
10. S. Palik, C. Klofutar and M. Kac, *J. Chem. Eng. Data*, **35**, 41 (1990).
11. M.L. Parmar, B. Bhardwaj and S.C. Attri, *J. Indian Chem. Soc.*, **75**, 402 (1998).
12. P.K. Banipal, G. Kaur and T.S. Banipal, *Indian J. Chem.*, **43A**, 35 (2004).
13. M.L. Parmar, R.K. Awasthi and M.K. Guleria, *Indian J. Chem.*, **43A**, 41 (2004).
14. M.L. Parmar and R.C. Thakur, *Indian J. Chem.*, **45A**, 1631 (2006).
15. R.K. Wadi, Vinita and R. Kakkar, *Indian J. Chem.*, **39A**, 598 (2000).
16. P. Rathore and M. Singh, *Indian J. Chem.*, **45A**, 2650 (2006).
17. P. Ramasami and R. Kakkar, *J. Chem. Thermodynamics*, **38**, 1385 (2006).