Partial molar volumes of transfer of some biologically important compounds from water to aqueous sodium chloride and potassium chloride solutions at 308 & 318K

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ABSTRACT

Apparent molal volumes (φ_v) of three biologically important compounds [Fructose, galactose and succinic and] in water and in 0.5 mol kg^{-1} aqueous sodium chloride and potassium chloride solutions at 308 & 318K have been determined from density measurements using a sprengel and Ostwald pyknometer partial molar volumes (V^o_2) at infinite dilution obtained from values have been used to calculate partial molar volumes of transfer $V^o_{2,tr}$ for the various compounds from water to aqueous sodium chloride/potassium chloride solutions. $V^o_{2,tr}$values are negative for all the three compounds studied. The $V^o_{2,tr}$values have been rationalized in terms of cosolute – water interations using a cosphere overlap hydration model.

Key words: Apparent molalvolume,partial molar volume, transfervolume, density,cosolute- water interactions,cosphere overlap hydration model.

INTRODUCTION

Knowledge of various solute- solvent and solute-solute interactions is very important to understand various fundamental phenomena. In addition to the scientific interest, mixing volume effects are important from both theoretical and practical point of view. Partial molar volumes and especially their values at infinite dilution are useful in examination of ion-ion and ion-water interactions[1,2].

By examining the apparent molal volumes and partial molar volumes of solutes as a function of size, nature, temperature and composition of mixed solvent it is possible to study the effect of these parameters on solute-water interactions, solute-cosolute with the hope of obtaining a better understanding of the interactions in solutions[3].

The importance of carbohydrates to living things can hardly be over emphasized.The energy stores of most animals and plants are both carbohydrates and lipids in nature. Carbohydrates are generally available as an immediate energy source[4]. Fructose, fruit sugar, is a simple monosaccharide found in many foods. Galaclose, a nutritive sweetner is having a role in treatment of focal segmental glomerulosclerosis which is a kidney disease resulting in kidney failure and proteinuria.

Succinate, anion part of succinic acid is a component of the citric acid cycle and is capable of donating electrons to the electron transport chain by the reaction[5].

$$\text{Succinate} + \text{FAD} \rightarrow \text{Fumarate} + \text{FADH}_2$$

(flavinadenine dinucleotide)

This is catalysed by the enzyme succinate dehydrogenase.

Partial molar volumes and transfer volumes of fructose, galactose and succinic acid have not been reported in detail 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 45h 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[6] 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 on accuracy of ±0.01K.

RESULTS AND DISCUSSION

Apparent molal volumes (φ_v) of the various solutes in water and in 0.5mol kg^{-1} aqueous Nacl / Kcl solutions were calculated from the experimentally measured densities from the following equation.

$$\varphi_v = 1000/(mddo) \times (do-d) + M/d$$

Where M is the molecular mass of the solute, m is molality (mol kg^{-1}) of the solution, d and do are the densities (kgm^{-3}) of solution and solvent respectively. The partial molar volumes ($V^o_2 = \varphi_V^o$) at infinite dilution were calculated by plotting the experimental values of φ_v against the square root of molal concentration (C) using Masson's equation[7,8].

$\varphi_v = \varphi_v^o + SvC^{1/2}$ where $ö_v^o$ is the partial molar volume at infinite dilution and S_v is the experimental slope. The values of $ö_v^o$ along with standard errors are listed inTable 1.

The partial molar volumes of transfer ($v^o_{2,tr}$) of solutes from water to aqueous Nacl and Kcl solutions at infinite dilution have been estimated as follows

$$V^o_{2,tr} = V^o_{2(inaq.\ Nacl/Kcl)} - V^o_2(\text{in water})$$

$V^o_{2,tr}$ values are summarized in Table 2, which are negative for all the three compounds[9]. The magnitude of $V^o_{2,tr}$ for the chosen compounds is greater in Nacl than in KCl.

Franks and collaborators[10,11] reported that partial molar volume at infinite dilution of a non-electrolyte is a combination of the following two factors

$$V^o_2 = V_{int} + V_s$$

where V_{int} is the intrinsic molar volume of the non hydrated solute and V_s is the volume due to its interaction with water. Shahidiet al[12] modified the above equation as

$$V^o_2 = V_{v,w} + V_{void} - V_{shrinkage}$$

Where $V_{v,w}$is the vanderwaal's volume, V_{void} is the associated void or empty volume and $V_{shinkage}$ is the volume of shrinkage. It has been assumed that $V_{v,w}$and V_{void} have the same magnitude in water and in aqueous Nacl/Kcl solutions. The negative volume change accompanying the transfer of compounds can be attributed to the increase in $V_{shrinkage}$. Because of the increase in interactions of solute and cosolute with water structure thus causing in $V_{shrinkage}$.

Negative $V^o_{2,tr}$ results from the increased effect of solute and cosolute on water structure.

Cosphere overlap model developed by Gurney[13] has been used to explain the $V^o_{2,tr}$data. The properties of water molecules in the hydration cosphere depend on the nature of solute species[14,15]. This model explains that when two solute molecules approach each other their hydration cospheres overlap and some of this cosphere material is displaced resulting in a change in the thermodynamic properties[16,17] as volume, heat capacity, entropy and enthalpy.

Overlap between solutes and ions of Nacl/Kcl comes into play because of the interactions between the ions of Nacl/kcl and hydrophilic sites solute molecule and interactions between the ions of cosolute and hydrophobic groups of the solute molecules[16].

The hydrophilic-ionic type interactions contribute positively, whereas the hydrophobic – ionic type interactions contribute negatively to $V^o_{2,tr}$values. The significant negative $V^o_{2,tr}$values obtained for the studied compounds suggest that the hydrophobic – ionic interactions are dominating over the hydrophilic-ionic interactions[17].

Table 1: Partial molar volumes at infinite dilution (V^o_2) of the chosen compounds in aqueous solutions of Nacl and Kcl at 308 & 318K

	$V^o_2 x10^6$ (m^3mol^{-1})					
	308K			318K		
Compound	**water**	**0.5mNacl**	**0.5m kcl**	**Water**	**0.5mNacl**	**0.5m Kcl**
Fructose	75.5±.02	68.4±.006	71.3±.01	77.5±.007	67.7±.03	70.1±.009
Galactose	118.5±.01	106.9±.02	108.8±.005	122.0±.008	105.8±.03	107.4±.01
Succinic acid	52.0±.02	49.5 ±.01	50.6±.02	57.0±.005	48.4±.006	49.4±.002

Table 2: Partial molar volumes of transfer at infinite dilution ($V^o_{2,tr}$) of the chosen compounds from water to aqueous solutions of Nacl and Kcl at 308 & 318K

	308K		318K	
Compound	**0.5mNacl**	**0.5mKcl**	**0.5mNacl**	**0.5mKcl**
Fructose	-7.1	-4.2	-9.8	-7.4
Galactose	-11.6	-9.7	-16.2	-14.6
Succinic acid	-2.5	-1.4	-8.7	-7.6

The largest magritudes of transfer volumes in case Nacl is cosolute than when it is Kcl indicate that cosolute water interactions is more in Nacl than in Kcl. The difference in values is due to the difference in size of the cations[18,19].

The increase in V^o_2& $V^o_{2,tr}$at higher temperature 318K is due to the strengthening of interaction with the rise in temperature.

Apparent molal volumes, partial molar volumes, viscosities, adiabatic compressibilitiesof various biologically important compounds such as malonic acid malic acid and maleic acid in water and in various solvents is under investigation.

REFERENCES

1. PolacekR,Behrends R &Kaatze U, *J physchem B*, **105**: 2894 (2001)
2. Miller D P & de Pablo JJ, *J physchem* B, **104**: 8876 (2000)
3. Woods R J,Dwek R A,Edge C J& Reid B F, *J phys chem,* **99**: 3832 (1995)
4. Ernst B,Hart G W&Sinay P,*Carbohydrates in chemistry and Biology* (Wiley-vchverlagweinheim) 1 (2000)
5. Walter.F.Boron,Medicalphysiology:A cellular and molecular approach Elsevier/Saunders ISBN 1-4160-2328-3: 837
6. Shoemaker DP&Garland CW,Experiments in physical chemistry(McgrawHill,New york) 131(1967)
7. Banipal P K,Banipal TS,Lark BS&Ahluwalia JC,*J chemsoc Faraday Trans,* **93**: 81 (1997)
8. PalikS,Klofutarc&Kac M, *J. Chem.Eng Data,* **35**: 41 (1990)
9. Goldberg R N&Tewari Y B, *J physchem Ref Data* Suppl, **18**: 809 (1989)
10. ShahidiF,Farrel PG&Edward JT, *J Sol Chem,* **5**: 807 (1976)
11. Franks F, Quickenden M A, ReidDS & Watson B,*Trans Faraday Soc*, **66**: 582 (1970)
12. Bondi A, *J Phys Chem*, **58**: 929 (1957).
13. Gurney R W,Ionic process in solution(McGrawHill,New york) (1953).
14. Franks F,PedleyM&Reid DS, *J Chemsoc Faraday Trans* **72**: 359 (1976).
15. Friedman HL&Krishnan C V, *J Sol Chem*, **2**: 37 (1973).
16. Desnoyers J E,ArelM,PerronG&Jolicoeur C, *J physchem* **73**: 3346 (1969).
17. Mishra A K&Ahluwalia J C,*Int J peptide protein* **Res**, 21: 322 (1983).
18. Banipal T S,SharmaS,Lark B S&Banipal P K, *Indian J Chem,* 38A: 1106 (1999).
19. Parmar ML,Thakur RC, *Indian J Chem*, **45**A: 1631-1637 (2006).