Partial Molar Volumes of Glucose in Aqueous and Various Alcohol Medium at Different Temperatures

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Abstract

The study of structural interactions by means of molar volume have received vital importance in physical chemistry. The apparent and partial molar volume of electrolytic solutions have proven to be a very useful tool in elucidating the solute-solute, solute-solvent and solvent-solvent interactions occurring in solution [1-5]. In present investigation the molar volumes of non-electrolytes (Glucose as a bio molecule) in solution found little and nearly linear with concentration[6].

Key words: Partial molar volumes, glucose, alcohol, temperature, apparent molar volume, non-electrolytes etc.

Introduction

The volumetric properties of aqueous solution of non-electrolytes found the best for the elucidation of solute-water interactions. In conjuction with other thermodynamic properties, these provide the information about the phenomena of hydrophobic hydration and specific hydrogen bonding. These properties are affected both by the steric configuration of alkyl group and relative strength of water–solute hydrogen bonds. The several systematic studies of bulk and molecular properties of dilute aqueous solution of solutes such as alcohols, amines and ethers are available [7] and have shed light on the nature of the interactions. The existing literature [8] shows that extensive work on partial molar volumes of both electrolytes and non electrolytes has been done, the investigation in multi component solution involving mixed solvents are rather scanty. How ever effects of poly hydroxy compound like carbohydrates on the water structure in various alcohols

(ethanol, ethylene glycol and glycerol)- water mixtures at different temperatures were studied in present research . The determination of volume properties of these ternary system at different temperatures are likely to provide insight into important aspect of solute - mixed solvent interaction, as these parameters are a more accurate measure to study the solute-solvent interactions. Partial molar study of solutions of glucose in aqueous- alcohol mixtures has been made at different temperatures. The very poor solubility of these, in water led us to use ethanol as a solvent. The rationale for selecting glucose as bio molecule is primirly based on their role in various physiological phenomena.

Much attention has been paid to the volumetric behavior of dilute aqueous solutions, where unit changes in many thermodynamic properties are observed [9], since the alcohol molecule in the water can be regarded as soluble alkanes [10]. The interesting volumetric behavior has been usually interpreted in terms of alkyl group - water interactions i.e. ice-berg or hydrophobic hydration. Sakurai et.al.[11], explained the hydrophilic group-water interactions using volumetric properties. They suggested that the large negative excess volumes for alcohols are due to geometrical factors, hydrophilic interactions are not due to hydrophobic interaction.

Experimental:

Material and Methods:

The glucose as bio molecule were from BDH/ SD fine chemicals, Analar grade and was used without further purification. Solution of different molalities were prepaired by dissolving accurately known weights of these compounds in double distilled water and in alcohol-water mixtures.

For each density measurements, three pyknometers of different volumes were used. A loop of metal wire was wound around the two limbs of a pyknometer, to suspend it in water bath and in balance. The pyknometers were washed with chromic acid and then with conductivity water followed by drying with dry air. The weights of pyknometers were taken on Mettler Zurich one pan balance which records weight to the fifth place. The pyknometers were then filled with distilled water by attaching a piece of rubber tubing to the end 'B' and sucking gently while end 'A' dips in water. Density of some solutions were determined by a high precision Anton-PAAR (DMA 603) digital read out densimeter. This is the most convenient and accurate method for measurement of density. In this, the measurement of natural vibration frequency of the tube, containing liquid under investigation is made. The natural vibrational frequency of the tube is related to the density of the liquid by

$$d = A + B\,t^2$$

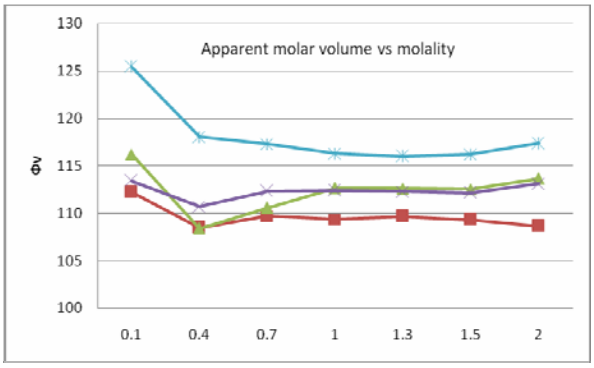
where d is the density of liquid under investigation. A, B are the instrumental constants and it is the oscillation period. This instrument, at proper temperature control gives accuracy up to $+\text{-}1.10^{-6}$gm/cm^{-3}. The density values were reproducible with = - 0.02 kg m^{-3} as described by Bayer [12] and Lewin and also Batio [13-14].

Table:1 Densities and apparent molar volume of glucose using Anton- PAAR densimeter at 25 ^{0}c.

Sr. No.	Conc. C in m/l	Density d in g/cm3	Apparent molar volume Φ_v in cm^{3}mol^{-1}	*Apparent molar volume Φ_v cm^{3}mol^{-1}
1	0.20092	1.0108	111.69	
2	0.40005	1.0244	112.03	
3	0.60011	1.0379	112.09	112.18
4	0.80039	1.0518	112.13	
5	1.00611	1.0652	112.19	

Table 2 Apparent molar volumes ϕ_v of glucose in 20% ethanol- water mixtures at different temperatures.

Sr. No.	Conc. (C) in m/l	Apparent molar volume Φ_v in cm^3mol^{-1}			
		15	25	35	45
1	0.1	112.26	116.20	113.43	125.42
2	0.4	108.50	108.40	110.71	118.05
3	0.7	109.69	110.58	112.34	117.31
4	1.0	109.36	112.66	112.39	116.30
5	1.3	109.64	112.62	112.29	116.01
6	1.5	109.32	112.54	112.15	116.23
7	2.0	108.66	113.67	113.11	117.36



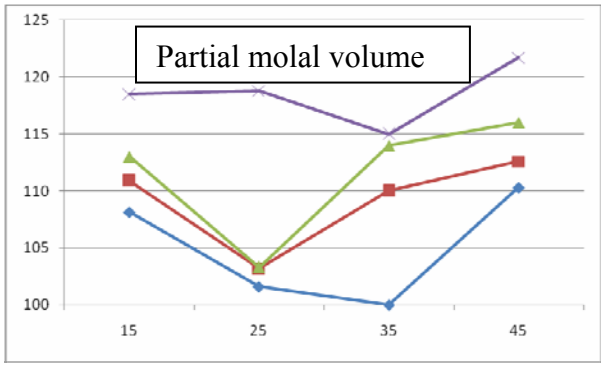


Table-3 The partial molar volume Φ^0_v and experimental slope Sv of glucose for different temperatures in several (aqueous , 20,40.60% ethanol - water mixtures)

Sr.No.	Conc. (C) in m/l	No. of data points	Temp t 0c	In aq. Φ^0_v	S_v	In 20% Φ^0_v	S_v	In 40% Φ^0_v	S_v	In 60% Φ^0_v	S_v
1	0.1-2.0	7	15	108.15	1.12	101.60	-5.25	100	4.22	110.30	1.6
2	0.1-2.0	7	25	110.90	0.25	103.20	7.50	110	1.12	112.60	2.5
3	0.1-2.0	7	35	113.00	-0.66	103.30	9.00	114	-3.71	116.00	-1.6
4	0.1-2.0	7	45	118.50	-2.00	118.80	4.66	115	-3.20	121.70	-2.4

Result and Disscussion:

In the present investigation, the apparent molar volume Φ_v, of bio molecule glucose are determined in an aqueous, 20%,40% and 60% ethanol-water mixed solvents. The Φ_v, values of glucose in 20%

ethanol-water medium at four different temperatures have been presented in table-1 and 2. Bio molecule – mixed solvent is a ternary system and the effect of bio molecule on the structure modification of a medium can be understood by compairing the ternary system with the corresponding binary one. The solute - solvent interaction is guessed from the magnitude of partial molar volume Φ^0_v, which is apparent molar volume at infinite dilution. It is derived from Φ_v by the equation (1),

$$\Phi_v = \Phi^0_v + S_v m \quad (1)$$

Where, m is the molality of a solute and S_v is the experimental slope. S_v depends on the solute – solvent interaction because it is the variation of Φ_v with concentration of a solute. The derived Φ^0_v values along with S_v parameters of glucose are set out in table-3, at four different temperatures as in aqueous, 20%, 40% and 60% ethanol – water mixtures. These values are discussed from three aspects which are,

(i) Variation of Φ^0_v with the percentage or mole fraction of organic solvents,

(ii) Variation of Φ^0_v with the temperatures,

(iii) Variation of S_v with the percentage of organic solvent and temperatures. These are discussed below in the same sequence.

In the case of ethanol-water ternary system, Φ^0_v decreases on the first addition of ethanol and increases further. Thus at 20% ethanol where the mole fraction of ethanol is 0.07, the Φ^0_v is lowest. A plot of Φ^0_v versus their molality of ethanol fig 1a, 1b shows a break in the same region as witnessed for binary system. The decrease in Φ^0_v of glucose, when the medium is changed from 0 to 0.071mole fraction of ethanol is due to a decrease in glucose – water interaction. In the ternary system, in addition to depolarization of ethanol, hydrogen bonding between – OH groups of glucose and ethanol is possible. Thus, in 20% ethanol-water, depolarization of ethanol and hydrogen bonding, both are responsible for a significant in Φ^0_v values. The variation of Φ^0_v is shown by parabolic curves were obtained for all the four temperatures. The variation of Φ^0_v with temperature is much less for the organic solvent with three –OH groups than one with two -OH groups. This means that the organic solvent-water interaction is not being affected much with temperature.

The increase of temperature increases Φ^0_v for all the ternary systems. The $d\Phi^0_{v/dt}$ between 15 to 45^0c are presented in table-4. It can be seen from this table that the $d\Phi^0_v/dt$ is higher in ethanol-water system than the ethylene glycerol-water and glycerol-water systems. This is due to the higher viscosity and density of ethylene glycol and glycerol than ethanol. The effect is minium in the case of glycerol which also confirmed the predominant viscosity effect.

Table: 4 dϕ0v / dt for glucose in aqueous, ethanol-water,ethylene glycol-water and glycerol-water mixtures at different temperatures

Medium	Percentage	$d\Phi^0_v$ / dt
Aqueous	0.0	0.335
Ethanol-water	20	0.345
	40	0.480
	60	0.380
Ethylene glycol-water	20	0.155
	40	0.198
	60	0.068
Glycerol-water	20	0.142
	40	0.081
	60	0.253

The S_v parameter is negative in 20% ethanol-water mixture at all the four temperatures. This shows reduction in solute-solvent interaction. This is due to the decrase in the glucose association which means more association between glucose and ethanol. In general, S_v values represents quantitative estimate of solute-solute interactions. Studies conducted on variety of hydrophilic, hydrophobic and amphiphilic solute in the past have shown [15] that, positive S_v values are associated with solute having hydrophilic characters, while negative values are assigned to hydrophobic solute as proposed by Gurney [16].

Conclusion

The values of partial molar volume Φ^0_v, for glucose are almost half than the sucrose, lactose and maltose as bio molecules. The enhanced solute-solvent interaction in the case of other bio molecules can be understood from their structural difference with glucose. The S_v parameter is positive for lactose and maltose while it is negative for glucose and sucrose.

Acknowledgement

The authors are thankful to Dr. R.K. Ippar Principal, Vaidyanath Arts, Science and Commerce college, Parli-vaijnath, Dist-Beed for encouragement and U.G.C. New Delhi for a research grants

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