



Apparent molar volume and viscometric study of glucose in aqueous solution

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ABSTRACT

Densities and viscosities of glucose at different temperature (293.15, 303.15, and 313.15K) have been measured from experimental data. The apparent molar volume, limiting apparent molar volume, Jones-doles A and B coefficients were calculated. The results show strong solute -solvent interaction that indicates this selecting Carbohydrate is structure maker in aqueous solution.

Key Words: Limiting Apparent Molar Volume, Hepler Constant, Jones Dole Coefficient, stereo chemical effects

INTRODUCTION

Partial molar volume provided useful information about various types of interactions occurring in solutions. These studies are help us to characterize the structure and properties of the solutions. The structure of solution is imported to understand the nature of action of bio-molecules in body system (1-3). The study of such interactions of non electrolyte in solution is very significant & useful for investigate their physicochemical behavior.

Carbohydrate is the most abundant class of organic compounds found in living organism. They form numerous roles in living system from the storage and transport of energy to participation in immune-system. The study of carbohydrate has become subject of increasing interest, because of its, multidimensional physical, biomedical & industrial useful properties (4-5). Carbohydrate are not only biochemically important, but also non-electrolytes with hydrophilic hydroxyl group which having high affinity to water and salting out aptitude that are involving in intra-molecular hydrogen bonding with water. The thermodynamic properties of non-polar solutes in water interpreted by Frank(6) & Evan in terms of ordering of water molecules around the solute. Apolar molecule form hydrogen bonded network with water known as hydrophobic hydration. A polar solute in water reveal a tendency to aggregate "hydrophobic interaction", solute which impose order (or built iceberg formation) known as structure promoter and which decrease order known as structure breaker.

EXPERIMENTAL SECTION

Chemical D-glucose was used in the present study of analytical grade. Freshly distilled water with specific conductance of $\sim 10^{-6} \Omega \text{ cm}^{-1}$ was used to preparing solution throughout the experiment. The aqueous solution of glucose was made by weight and molalities were converted in to molarities using the standard expression (8). The density of solution was measured at 293.15, 303.15, and 313.15 k using. a single stem pycnometer made of borosil glass. The mass measurement were done on digital electronic balance (Sartorius GC103). Viscosity determines with U shaped Ostwald viscometer with sufficiently long reflux time more than 200sec. to avoid kinetic energy correction. The viscometer was averaged from three readings for each solution. The calibration of density bottle and viscometer (7-8) was done by using doubly distilled water. An average of triplet measurement was taken in to account. The density and viscosity measurements were carried out in a same thermostatic water-bath.

RESULTS AND DISCUSSION

Apparent molar volume -: The apparent molar volume can be calculated from density data using the following equation.

$$\Phi_v = M/d_0 - 1000(d-d_0)/d_0c$$

Where d_0 and d are the densities of solvent and solution respectively; c is the molar concentration in gram/liter and M is molecular weight of solute. The apparent molar volume can be considered to be the sum of the geometric volume of the solute molecules and changes that occur in to the solution due to its interaction with solvent. The calculated value of apparent molar volume at different temperature is given in Table 1. Apparent molar volume of solute varies with the square root of the molar concentration and obeys Masson's equation(9).

$$\Phi_v = \Phi_{v0} + S_v\sqrt{c}$$

Here is Φ_{v0} limiting apparent molar volume of the solute and S_v is the experimental slope. The Φ_v value have been found to be positive and increasing with increasing concentration which suggest that the overall structural order is enhanced in aqueous solution. The value of limiting apparent molar volume Φ_{v0} for glucose is positive and large; it shows that solute solvent interaction is strong in aqueous solution. It is evident from table that the Values of S_v are small and less positive for glucose in aqueous solution at different temperature .since S_v is a measure of ion- ion interaction so the results indicate the presence of weak ion- ion interaction . The Φ_v Value in water in present investigation have good agreement with reported value of Dey(10) etal 2003, Hoiland(11) & Ahluwalia(12-13). According to Gurney co-sphere overlap model the always produce overlap of the co-spheres of two ions or polar group or an ion with hydrophilic group positive volume change. On the other hand overlap of the co-spheres of an ion with that of hydrophobic groups result a negative volume change. Results indicate that ion-hydrophilic and hydrophilic-hydrophilic interactions predominate over the ion-hydrophobic and hydrophobic-hydrophobic interactions.

The temperature dependence of limiting apparent molar volume, Φ_{v0} for glucose in aqueous solution can be represented by following expression.

$$\Phi_{v0} = a_0 + a_1T + a_2T^2$$

Where T is temperature in Kelvin .The value of coefficient a_0 , a_1 and a_2 are calculated by differentiating above equation with respect to temperature, and following equation obtained.

$$\Phi_{v0} = 50.64 + .1899T + .000052T^2$$

$$\left(\frac{\partial \Phi_{v0}}{\partial T}\right)_p = a_1 + 2a_2T$$

The limiting apparent molar expansibilities for glucose in water obtained at different temperature are calculated. It is found that Φ_{E0} value increase with rise in temperature, this positive increase in Φ_{E0} with temperature may be approved to the presence of caging effect(14).

The structure making/breaking capacity of solute in aqueous solution may be interpreted with the help of Helper(15) equation on the basis of sign of giving expression.

$$\left(\frac{\partial \Phi_{E0}}{\partial T}\right)_p = \left(\frac{\partial^2 \Phi_{v0}}{\partial T^2}\right)_p = - a_2$$

The sign of $\left(\frac{\partial^2 \Phi_{v0}}{\partial T^2}\right)_p$ second derivative of limiting apparent molar volume of solution with respect to temperature at constant pressure, which correspond to structure making or breaking properties of solution was determined .The value of $\left(\frac{\partial^2 \Phi_{v0}}{\partial T^2}\right)_p$ has been found to be positive for glucose suggesting structure making nature.

Table 1 Densities ρ and Viscosities η with calculated apparent molar volume of glucose in water at different temperatures

293.15K			
Conc.	D	η	ϕ_v
mol.d ⁻³ m	g.cm ⁻³	cp	cm ³ mol ⁻¹
0.05	1.001642	1.007196	111.35
0.1	1.005068	1.030698	111.51
0.15	1.008474	1.073648	111.70
0.2	1.011865	1.12254	111.87
0.25	1.015253	1.195858	111.99

303.15K			
conc.	d	η	ϕ_v
mol.d ⁻³ m	g.cm ⁻³	Cp	cm ³ mol ⁻¹
0.05	0.998997	0.82947	113.55
0.1	1.002331	0.87801	113.69
0.15	1.005635	0.9170	113.93
0.2	1.008948	0.95601	114.01
0.25	1.012228	0.99501	114.19

313.15K			
conc.	d	η	ϕ_v
mol.d ⁻³ m	g.cm ⁻³	Cp	cm ³ mol ⁻¹
0.05	0.995462	0.6884	115.65
0.1	0.998712	0.7229	115.79
0.15	1.001944	0.7574	115.95
0.2	1.005167	0.7919	116.07
0.25	1.008393	0.8265	116.14

Viscometric study:- Time of flow were determined for solute under study at chosen concentration and temperature from 20-40⁰C. The viscosity were determined from the formula $\eta/\eta_0 = t d / t_0 d_0$ where η , t , d are the absolute viscosity, time of flow & density of solution, while η_0 , t_0 , d_0 are same quantities for the solvent water. The viscosity data was analyzed according to Jones- dole(16) equation

$$\eta/\eta_0 = \eta_r = 1 + A c^{1/2} + B C$$

Where η_r is relative viscosity, c is molar concentration the constant A is the Falkenhagen coefficient and B is the Jones- dole coefficient. The determination of the viscosity parameter can be used to interpret the structural property and the solute solvent interaction. Viscosity of aqueous solution of glucose has been determined as a function of their concentrations. Viscosity data has been analyzed with the help of Jones-dole equation from the linear plots of $[(\eta/\eta_0)-1]/c^{1/2}$ versus $c^{1/2}$. The values of coefficients A & B of the Jones- Dole equation have been determined by computerized least square method and the result has been showed in Table (2). A and B coefficients are constant and characteristics of ion-ion and ion-solvent interaction respectively the value of A coefficients are negative for glucose indicating the presence of weak ion- ion interaction. The value of B - coefficient is positive which indicate the existence of ion- solvent interaction. The value of B - coefficient in aqueous solution decrease with the rise in temperature there why showing the ion solvent interaction further not improved with the increase in temperature. That further, supporting earlier conclusion drawn from Φ_{v0} and S_v . Recently it has been emphasized by many workers(17) that (dB/dT) is a better decisive factor for determine structure making/breaking nature of any solute rather than the B -coefficient. The value of (dB/dT) were calculated from the slope of the curve obtained by plotting B - coefficient value against temperatures and these values given in Table(2). Table (2) reveal that B - coefficient value decreases with rise in temperature, so derivative of temperature (dB/dT) is negative. This Negative (dB/dT) value reveal structure making capacity of glucose. These are in identical agreement with the conclusion drawn from helper equation as discussed earlier.

Table-2 Partial molar volumes at infinite dilution ϕ_{v0} , experimental slope S_v and viscosity A & B - coefficient at different temperature

T	ϕ_{v0}	S_v	B	A	dB/dT
K	cm ³ mol ⁻¹	m ³ ^{1/2} mol ^{-3/2}	m ³ mol ⁻¹	m ^{3/2} mol ^{-1/2}	
293.15	110.8	2.37	1.317	-0.3123	
303.15	113	2.3	1.151	-0.0797	-0.01194
313.15	115.23	1.82	1.079	-0.01908	

CONCLUSION

Different thermodynamic and spectroscopic study(18-22) showed that the hydration of carbohydrate did not depend only on hydroxyl group & potential site of hydrogen bonding, but also depend on their relative orientation. According to Frank & Evan this nonpolar solute in water promotes in its surrounding and enhanced hydrogen bond network of water. Consequently, the water molecules rearranges toward formation of a local cage like (clathrates) structure surrounding each solute molecule. On the basis of discussion of above result Glucose is structure promoter solute.

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