Studies of Molecular Interactions of Sugar Alcohols in Water by Volumetric and Viscometric Measurement

Saroj P. Sahare

Department of Chemistry, Anand Niketan College, Warora, Chandrapur, Maharashtra, India

ABSTRACT

In this paper, Densities (ρ) and Viscosities (η) of sorbitol and mannitol have been measured in aqueous solution in the concentration range 0.05-0.5 M at 296 K. Apparent molar volume and partial molar volume were determined from the density parameter. Using Jones-Dole equation, viscosity coefficient A and B were calculated for sorbitol and mannitol solutions from the obtained viscosities. The results obtained from the parameters were correlated with solute-solute and solute- solvent interactions.

Keywords : Apparent molar volume, Partial molar volume, Jones-Dole equation, Sugars alcohols, Staurding equation

I. INTRODUCTION

Viscosity and density are two basic physical parameters of liquid and their values must be known for the physiochemical processes(adsorption, extraction, catalysis etc.). The viscosity (η), is need to be measure at very high precision with its temperature depends behavior to used as property to determine molecular information [1]. Density is the basic physical parameter used in the field of thermodynamics for the determination of heat transfer and mass transfer [2].

Along with constantly increasing living standard of human beings, a new quality food with non-sugar and low calorific value is introduced as sugar alcohols also called as pseudo sugars. They are having good qualities such as sweet in taste, suitable for diabetes people and no tooth decay and utilized in many aspects food, pharmacy, cosmetics and chemical engineering etc. Sorbital ((2S,3R,4R,5R)-hexane-1,2,3,4,5,6-hexol) and mannitol ((2R,3R,4R,5R)-hexane-1,2,3,4,5,6-

hexol) are important sugar alcohols [3]. These pseudo sugars are found in fruits and their importance revealed in the field of medical sciences [4].

In this paper, the physical parameters are calculated from the densities and viscosities obtained experimentally. Apparent molar volume, partial molar volume, Jone-Dole constant A and B are determined for sorbitol and mannitol sugar alcohols at various concentration at 298 K.

II. METHODS AND MATERIAL

Sorbitol and Mannitol used for experimental work were AR grade (purity ≥ 99 %), purchased from Loba Chemie. Double distilled water was used for the experimental purpose. The aqueous solutions of solutes at various concentration were prepared using electronic weighing balance (Model-AJO20 aiwa) with accuracy of ± 0.1 mg.

Densities of aqueous solution of sorbitol and mannitol were performed by using specific gravity bottle with relative measurement method (accuracy $\pm 0.1 Kg.m^{-3}$). Viscosities of the solutions of these sugar alcohols were determine by using Ostwald's viscometer with accuracy of $0.0001 Nsm^2$.

III. RESULTS AND DISCUSSION

Data obtained from density and viscosity of sorbitol and mannitol measured at 296 K in the concentration range of 0.05-0.5M are given in Table 1. Apparent molar volume calculated from the equation (1) [5]

$$\phi_v = M/\rho_o - 1000(\rho - \rho_o)/C\rho_o \qquad (1)$$

Where ϕ_v , M, ρ_o, ρ and C are the apparent molar volume, molar mass of the solute, density of solvent (water), density of solution and molarity respectively.

The apparent molar volume is defined as difference between volume of solution and volume of pure solvent per mole of solute. The change in volume is due to solute-solvent interactions. At infinite dilutions where solute-solvent interactions are completely vanished is called as partial molar volume [6].

Hydration of solute and solute-solvent structural interactions can be revealed by using apparent molar volume and partial molar volume. Hydration rate of solute-solvent interactions decreases as the concentration increases and solute-solute interactions increases it means solute-solvent interactions are replaced by solute-solute interactions [7].

Apparent molar volume was in good linear relationship with molar concentration of solute.As a result partial molar volume was calculated as a linear fit by using following equation (2)[8]

$$\phi_v = \phi^o_v + S_v C \qquad (2)$$

where, ϕ^o_v is partial molar volume, the values of ϕ^o_v were calculated by the least square regression analysis and S_v is the slope of the linear relation between ϕ_v and C. The values of ϕ^o_v and S_v for sorbitol and mannitol at 296 K in table 1.

Relative viscosity of sorbitol and mannitol aqueous solutions was calculated for concentration range 0.05-0.5 M assuming solutes as polymers monomer unit. The polymer species follow Staurding equation (3) [9] is given as follows:

$$(\eta - \eta_o)/\eta_o = kn \ Cn \qquad (3)$$

Where, η is viscosity of solution and η_o is the viscosity of water at 296K, C is concentration of solution in Molar and k is the constant. The obtained values of relative viscosity for sorbitol and mannitol are shown in table 2.

Table1: Apparent molar volume (ϕ_v), partial molar volume (ϕ^o_v) and S_v for sorbitol and mannitol at 296k at various concentration

Concentration (mol dm^{-3})	$\sqrt{C}$	ϕ_v	
		Sorbitol	Monnitol
0.05	0.2236	136.4411	134.5082
0.1	0.3162	133.4335	132.5032
0.15	0.3872	132.4310	131.1665
0.2	0.4472	130.9273	129.4957
0.25	0.5	130.4260	128.8942
0.3	0.5477	127.7527	128.4932
0.35	0.5916	126.3587	127.0610
0.4	0.6324	124.9122807	125.7363
0.45	0.6708		125.3743
0.5	0.7071	124.1882484	124.4832
		123.6090226	
ϕ^o_v	(m^{3}mol^{-1})	136.85	134.6
S_v	(m^{3}Kg$^{1/2}$mol$^{-3/2}$)	-28.385	-21.21

Table 2: Relative viscosities (η/η_o) for sorbitol and mannitol at 296 K at various concentration

Concentration (C) (mol dm^{-3})	$\sqrt{C}$	(η/η_0) Sorbitol	Mannitol
0.05	0.2236	1.0537	1.0609
0.1	0.3162	1.0809	1.1072
0.15	0.3872	1.1396	1.1498
0.2	0.4472	1.1774	1.1818
0.25	0.5	1.2267	1.2433
0.3	0.5477	1.2692	1.2850
0.35	0.5916	1.3232	1.3232
0.4	0.6324	1.3602	1.3830
0.45	0.6708	1.4199	1.4482
0.5	0.7071	1.4974	1.5084

The results obtained from the data of viscosities of sorbitol and mannitol aqueous solutions are in agreement with equation (3) which is applicable for polymers. Therefore a graph is plotted of relative viscosity to the concentration of solutions of sugar alcohols shows linearity. The slope value (kn) for sorbitol and mannitol was shown in table 3.

Table 3: Parameters of Staurding and Jone-Done equation for sorbitol and mannitol at 296 K in aqueous solution

Sugar alcohols	$(\eta/\eta_0 -1)$ *vs.* C	$(\eta/\eta_0 -1)/\sqrt{C}$ *vs.* $\sqrt{C}$	B x 10^3/ $\phi^0{}_v$
Sorbitol	*kn*= 0.9543 dm^{3}mol^{-1}	B= 0.9388 dm^{3}mol^{-1}	6.86
Mannitol	*kn* = 0.9761 dm^{3}mol^{-1}	B= 0.9436 dm^{3}mol^{-1}	7.01

By examining Jone-Dole equation (4)[10], the structure making and breaking properties of solutes are also determined from viscosity coefficient B and intercept A.

$$(\eta/\eta_0) =1+ A + B\sqrt{C} \qquad (4)$$

Where, η/η_0 is the relative viscosity, A and B are constants, C is concentration of the solution. The graph is plotted of $(\eta/\eta_0 -1)/\sqrt{C}$ against $\sqrt{C}$ have linear relationship with slope B and intercept A. The values of B and A for sorbitol and mannitol are tabulated in table 3. In the present study, the studied sugar alcohols are non-electrolytes and hence magnitude of A is very small because very poor interionic interactions [11].

The value of partial molar volume for both sugar alcohols are positive which revealed that solutes interact by hydroxyl groups present in the solute molecules through hydrogen bonding. The solvation of solute can be determined from the magnitude of B/$\phi^0{}_v$. The values of B/$\phi^0{}_v$ from the parameters are tabulated in table 3. If the values of B/$\phi^0{}_v$, is greater than 2.5 it is solvated. Higher the magnitude higher would be association [12].

IV. REFERENCES

[1]. P. Bohuon, M. Le Maguer and A. L. Raoult-Wack, J. Chem. Eng. Data 1997, 42, 266-269

[2]. M. A. Jamal, M. K. Khosa, M. Rashad, I. H. Bukhari, S. Naz, Food Chemistry 146 (2014) 460–465

[3]. C. Zhu, Y. Ma and C. Zhou, J. Chem. Eng. Data 2010, 55, 3882–3885

[4]. X. Jiang, C. Zhu, Y. Ma, Journal of Molecular Liquids 188 (2013) 67–73

[5]. Millero, FJ., Surdo, AL., Shin, C., The Journal of Physical Chemistry, 1978. 82(9): p. 781-789.

[6]. Jamal M. A., Food Chemistry, 2014. 153(12): p. 140-444.

[7]. A. Gharsallaoui, B. Roge, J. Genotelle, M Mathlouthi, Food Chemistry 106 (2008) 1443–1453

[8]. J. Wawer, J Krakowiak, W. Grzybkowski, J. Chem. Thermodynamics 40 (2008) 1193–1199

[9]. R. Joshi and N. D. Kandpal, Der Pharmacia Lettre, 2015, 7 (10):126-133

[10]. R. S. Patil, V. R. Shaikh, P. D. Patil, A. U. Borse, K. J. Patil, Journal of Molecular Liquids (2014)

[11]. Thirumaran. S and Job Sabu, Journal of Experimental Sciences 2012, 3(1): 33-3

[12]. K. Araiab and T. Shikata, Chem.Phys., 2019, 21, 25379