



Physical Properties of Zinc chloride in Aqueous Dextrose Solution

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Abstract

The apparent molar volume (ϕ_v), viscosity B-coefficient have been determined of zinc chloride in 2%, 4% and 6% aqueous solution of dextrose at 303.15K, 308.15K and 313.15 K from density (ρ) and viscosity (η) measurements respectively. The limiting apparent molar volumes (ϕ_v^0) and experimental slopes (S_V^*), derived from the Masson equation, have been interpreted in terms of solute-solvent and solute-solute interactions respectively. The viscosity data were analyzed using the Jones-Dole equation and the derived parameter B has also been interpreted in terms of solute-solvent interactions in the solutions. The structure making/breaking behavior of Zinc chloride is inferred from the sign of $(\delta^2 \phi_v^0 / \delta T^2)_P$ and dB/dT .

Keywords: Dextrose, solute-solvent interactions, density, viscosity, apparent molar volume.

Introduction

Zinc is very important for proper functioning of the enzyme system of animals. Human body contains about 2g of zinc. There are more than 20 zinc containing enzymes in the body which are responsible for proper absorption of CO₂ by red blood cells in muscles and other tissues and for maintaining proper pH in the muscles and tissue. Carbohydrates are an exceptionally important constituent of biological systems. They play an important role in animal and plant physiology. Carbohydrates are sources of energy for vital metabolic processes. The behavior of electrolytes in aqueous carbohydrates present in body fluids have recently been subject of interest¹⁻².

The volumetric and viscous behavior of solutes has been proven to be very useful in elucidating the various interactions occurring in solutions. Studies on the effect of concentration (molality), the apparent molar volumes of solutes have been extensively used to obtain information on solute-solute, solute-solvent, and solvent-solvent interactions³⁻⁷. In view of the above and in continuation of our studies, we have undertaken a systematic study on the density and viscosity of Zinc chloride in 2%, 4% and 6% aqueous solution of dextrose at 303.15K, 308.15K and 313.15K and we have attempted to report the limiting apparent molar volume (ϕ_v^0), experimental slopes (S_V^*), viscosity A and B-coefficients for Zinc chloride in aqueous solution of dextrose.

Material and Methods

Dextrose was purchased from Sd Fine Chemicals Limited. Its mass purity as supplied is 98%. Dextrose was recrystallized twice from aqueous ethanol solution and dried under vacuum at T=348 K for 6 h. Thereafter, it was stored over P₂O₅ in desiccators⁸. Anhydrous zinc chloride of A.R. grade was procured from Sigma-Aldrich, Germany and was used as purchased as its mass purity is 99.99%. Triply distilled water

with a specific conductance $<10^{-6}$ S cm⁻¹ was used for the preparation of different aqueous dextrose solutions.

The density (ρ) was measured by means of vibrating-tube Anton Paar Density-Meter (DMA 4500M) with a precision of 0.00001 x 10⁻³ (kg·m⁻³). It was calibrated by double-distilled water and dry air⁹. The temperature was automatically kept constant within ± 0.01 K.

The viscosity, η , was measured by means of a suspended Ubbelohde type viscometer, calibrated at the experimental temperatures with doubly distilled water and purified methanol. After attainment of thermal equilibrium, efflux times of flow were recorded with a stop watch. At least three repetitions of each data point were taken to average the flow time. The viscosity of solution, η , is given by the following equation:

$$\eta = (Kt - L/t)\rho$$

where K and L are the viscometer constants and t and F are the efflux time of flow in seconds and the density of the experimental liquid, respectively.

The mixtures were prepared by mixing known volume of solutions in airtight-stoppered bottles. Adequate precautions were taken to minimize evaporation losses during the actual measurements. Mass measurements for stock solutions were done on a Mettler AG-285 electronic balance with a precision of ± 0.0003 x 10⁻³ kg. The conversion of molarity into molality was accomplished using experimental density values. The uncertainty in molality of solution is estimated to be ± 0.0001 mol. kg⁻¹. The experimental values of densities (ρ), viscosities (η) along with the apparent molar volume (ϕ_v) and $(\eta/\eta_0 - 1)/\sqrt{m}$ values of zinc chloride in 2%, 4% and 6% aqueous solution of dextrose at 303.15K, 308.15K and 313.15 K are reported in table-1.

Table-1

Molality(m), experimental values of densities (ρ) and viscosities (η), along with the apparent molar volume (ϕ_V) and $(\eta/\eta_0 - 1)/\sqrt{m}$ values of Zinc chloride in 2%, 4% and 6% aqueous solution of dextrose at 303.15K, 308.15K and 313.15 K

m (mol. kg ⁻¹)	$\rho \times 10^3$ (kg. m ⁻³)	η (mPa. s)	$\phi_V \times 10^6$ (m ³ . mol ⁻¹)	$(\eta / \eta_0 - 1) / \sqrt{m}$ (mol. kg ⁻¹) ^{-1/2}
2% aqueous solution				
303.15K				
0.0100	1.00231	0.84550	66.1934	0.082
0.0200	1.00297	0.85161	68.1902	0.110
0.0400	1.00422	0.86302	70.9358	0.145
0.0602	1.00541	0.87437	72.8494	0.174
0.0804	1.00653	0.88530	74.6798	0.196
0.1006	1.00758	0.89641	76.4769	0.217
T = 308.15 K				
0.0100	1.00075	0.75713	68.2952	0.061
0.0200	1.00139	0.76185	70.2951	0.087
0.0400	1.00262	0.77115	72.5449	0.123
0.0602	1.00378	0.78092	74.4615	0.154
0.0804	1.00490	0.79094	75.9197	0.180
0.1006	1.00598	0.80049	77.1946	0.201
T = 313.15 K				
0.0100	0.99908	0.68572	70.4112	0.0404
0.0200	0.99971	0.68982	71.9136	0.0710
0.0400	1.00090	0.69765	74.4176	0.1074
0.0602	1.00203	0.70632	76.2538	0.1394
0.0804	1.00312	0.71528	77.6727	0.1668
0.1006	1.00418	0.72363	78.8245	0.1876
4% aqueous solution				
T = 303.15 K				
0.0100	1.00779	0.89129	66.8255	0.084
0.0200	1.00844	0.89721	68.8114	0.107
0.0400	1.00965	0.90887	72.0385	0.141
0.0602	1.01078	0.92074	74.4382	0.170
0.0804	1.01185	0.93225	76.3827	0.193
0.1006	1.01286	0.94451	78.1452	0.216
T = 308.15 K				
0.0100	1.00625	0.79878	68.9155	0.065
0.0200	1.00689	0.80369	70.4071	0.090
0.0400	1.00809	0.81436	73.1419	0.130
0.0602	1.00922	0.82453	75.2136	0.159
0.0804	1.01028	0.83444	77.1197	0.181
0.1006	1.01131	0.84451	78.5616	0.202
T = 313.15 K				
0.0100	1.00484	0.72218	71.0025	0.051
0.0200	1.00546	0.72653	72.4962	0.079
0.0400	1.00663	0.73568	74.9858	0.119
0.0602	1.00771	0.74469	77.3094	0.148
0.0804	1.00874	0.75413	79.0936	0.175
0.1006	1.00974	0.76287	80.4629	0.194
6% aqueous solution				
T = 303.15 K				
0.0100	1.01356	0.94153	67.4315	0.089
0.0200	1.01420	0.94803	69.4061	0.112
0.0400	1.01539	0.96043	72.6147	0.145
0.0602	1.01647	0.97309	75.4943	0.174

m (mol. kg ⁻¹)	$\rho \times 10^{-3}$ (kg. m ⁻³)	η (mPa. s)	$\phi_V \times 10^6$ (m ³ . mol ⁻¹)	$(\eta / \eta_0 - 1) / \sqrt{m}$ (mol. kg ⁻¹) ^{-1/2}
0.0804	1.01749	0.98556	77.6746	0.198
0.1006	1.01844	0.99707	79.6738	0.215
T = 308.15 K				
0.0100	1.01212	0.84253	69.5035	0.066
0.0200	1.01274	0.84802	71.4808	0.093
0.0400	1.01390	0.85915	74.4468	0.132
0.0602	1.01496	0.86973	77.0833	0.159
0.0804	1.01596	0.88059	79.1430	0.184
0.1006	1.01692	0.89056	80.7743	0.202
T = 313.15 K				
0.0100	1.01068	0.75839	71.5813	0.059
0.0200	1.01128	0.76307	73.5614	0.085
0.0400	1.01240	0.77285	76.5316	0.125
0.0602	1.01343	0.78229	79.0068	0.153
0.0804	1.01441	0.79246	80.8631	0.180
0.1006	1.01530	0.80228	82.8680	0.202

Results and Discussion

Apparent molar volumes (ϕ_V) were determined from the solution densities using the following equation¹⁰:

$$\phi_V = M / \rho - 1000 (\rho - \rho_0) / (m\rho\rho_0) \quad (1)$$

Where M is the molar mass of the salt, ρ_0 and ρ are the densities of solvent mixture and solution respectively and m is the molality of the solution.

Masson found that the apparent molar volumes, ϕ_V , vary with the square root of the molal concentration, \sqrt{m} by the linear equation:

$$\phi_V = \phi_V^0 + S_V^* \sqrt{m} \quad (2)$$

Where ϕ_V^0 is the limiting apparent molar volume and S_V^* is the experimental slope. The plots of ϕ_V against \sqrt{m} of Zinc chloride in 2%, 4% and 6% aqueous solution of dextrose at 303.15K, 308.15K and 313.15 K was linear with positive slopes.

The values of ϕ_V^0 and S_V^* of Zinc chloride in 2%, 4% and 6% aqueous solution of dextrose at 303.15K, 308.15K and 313.15 K are reported in table-2.

ϕ_V^0 value indicates the extent of solute-solvent interaction¹¹. A perusal of table-2 and figure-1 shows that ϕ_V^0 values for zinc chloride are positive and increase with the increase in

temperature which may be due to decrease in hydrogen bonding between water molecules with increase in temperature, making more free water molecules available for solvation of metal ions and hence solute-solvent interactions increases with increase in temperature. So the interactions between the zinc chloride and the solvent molecules increase with increase in temperature and decrease with increase in percentage of dextrose in solution.

The parameter S_V^* is the volumetric virial coefficient that characterizes the pair-wise interaction of solvated species in solution. The sign of S_V^* is determined by the interaction between the solute species¹²⁻¹⁴. In the present study S_V^* values were found to be positive and decrease with increase in temperature in 2%, 4% and 6% aqueous dextrose solution which may be due to more solvation of metal ions with rise in temperature.

The variation of ϕ_V^0 with temperature of zinc chloride in aqueous solution of dextrose follows the polynomial,

$$\phi_V^0 = a_0 + a_1 T + a_2 T^2 \quad (3)$$

over the temperature range under investigation where a_0 , a_1 and a_2 are the coefficients and T is the temperature in K. Values of the coefficients of the above equation for zinc chloride in aqueous solution of dextrose at different temperatures are reported in table-3.

Table-2

Limiting apparent molar volume (ϕ_V^0) and experimental slope (S_V^*) of Zinc chloride in 2%, 4% and 6% aqueous solution of dextrose at 303.15K, 308.15K and 313.15 K

Wt. % of dextrose in water	$\phi_V^0 \times 10^6$ (m ³ . mol ⁻¹)			$S_V^* \times 10^6$ (m ³ . mol ^{-3/2} . kg ^{1/2})		
	303.15 K	308.15 K	313.15 K	303.15 K	308.15 K	313.15 K
2%	61.54	64.39	66.46	46.67	40.63	39.31
4%	61.51	64.19	66.33	52.62	45.28	44.57
6%	61.48	64.11	66.28	57.3	52.86	52.01

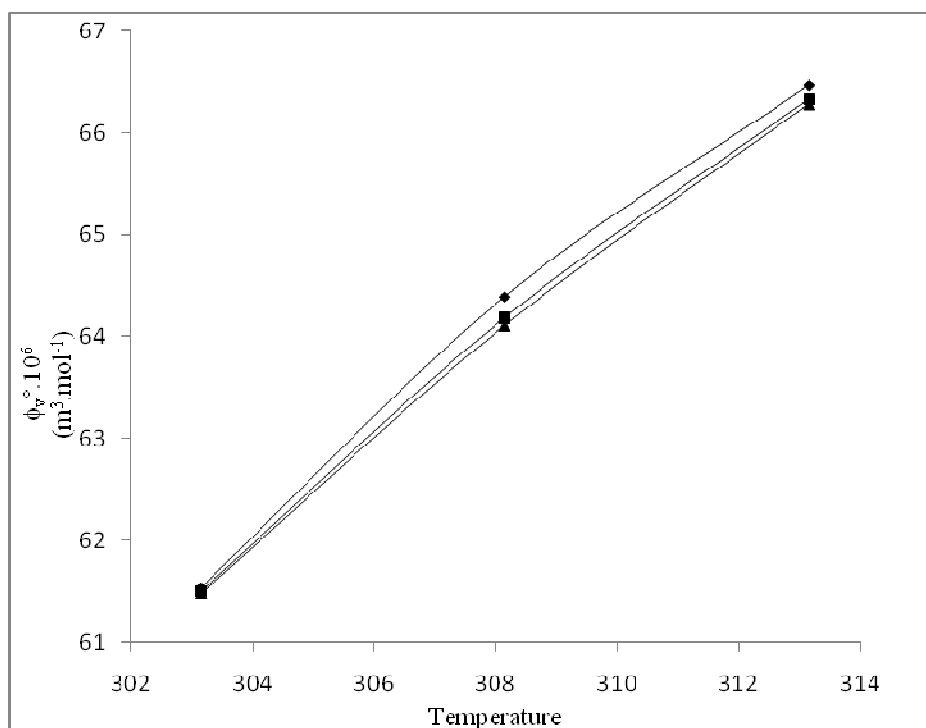


Figure-1

Limiting apparent molar volumes (ϕ_v^0) of zinc chloride in 2% (—◆—), 4% (—■—) and 6% (—▲—) aqueous dextrose solutions at different temperatures

Table-3

Values of Coefficients for Zinc chloride in 2%, 4% and 6% aqueous solution of dextrose

Wt. % of dextrose in water	$a_0 \times 10^6$ (m ³ ·mol ⁻¹)	$a_1 \times 10^6$ (m ³ ·mol ⁻¹ ·K ⁻¹)	$a_2 \times 10^6$ (m ³ ·mol ⁻¹ ·K ⁻²)
2%	-1306.4376	7.62308	-0.0116
4%	-1109.8677	7.13804	-0.0108
6%	-1071.3188	6.88952	-0.0104

The limiting apparent molar expansibilities (Φ_E^0) can be obtained by the following equation:

$$\Phi_E^0 = (\delta\phi_v^0/\delta T)_P = a_1 + 2a_2T \quad (4)$$

The values of Φ_E^0 of the studied compounds at 303.15K, 308.15K and 313.15 K are determined and reported in table-4.

It is found from table-4 that the values of Φ_E^0 decrease with a rise in temperature, which may be ascribed to the absence of caging or packing effects¹⁵⁻¹⁶.

During the past few years it has been emphasized by different workers that S_V^* is not the sole criterion for determining the structure-making or breaking nature of any solute. Hepler developed a technique of examining the sign of $(\delta^2\phi_v^0/\delta T^2)_P$ for

the solute in terms of long-range structure-making and breaking capacity of the solute in the mixed solvent systems using the general thermodynamic expression¹⁷,

$$(\delta\Phi_E^0/\delta T)_P = (\delta^2\phi_v^0/\delta T^2)_P = 2a_2 \quad (5)$$

Table-4

Limiting Apparent Molar Expansibilities (Φ_E^0) for Zinc chloride in 2%, 4% and 6% aqueous solution of dextrose at 303.15K, 308.15K and 313.15 K

Wt. % of dextrose in water	$\Phi_E^0 \times 10^6$ (m ³ ·mol ⁻¹ ·K ⁻¹)			$(\delta\Phi_E^0/\delta T)_P$
	303.15 K	308.15 K	313.15 K	
2%	0.46	0.492	0.336	Negative
4%	0.59	0.482	0.374	Negative
6%	0.572	0.48	0.388	Negative

On the basis of this expression, it has been deduced that the structure making solutes should have positive values, whereas structure-breaking solutes should have negative values. In our present investigation, it is evident from table-4 that $(\delta^2\phi_v^0/\delta T^2)_P$ values are negative for zinc chloride in aqueous solution of dextrose, suggesting thereby that zinc chloride acts as a structure breaker in aqueous dextrose solution.

The viscosity data has been analyzed using the Jones–Dole

equation¹⁸:

$$(\eta / \eta_0 - 1) / \sqrt{m} = A + B \sqrt{m} \quad (6)$$

Where, η_0 and η are the viscosities of the solvent mixture and solution, respectively. A and B values as reported in table-5, are the viscosity co-efficients estimated by a least square method. The A and B values are obtained from the straight line by plotting $(\eta / \eta_0 - 1) / \sqrt{m}$ against \sqrt{m} for zinc chloride in 2%, 4% and 6% aqueous solution of dextrose at 303.15K, 308.15K and 313.15 K respectively.

A perusal of table-5 shows that the values of the A coefficient increase with the increase in percentage of dextrose in the solution and decrease with the increase in temperature. This may be interpreted as more solvation of metal ions takes place at higher temperature. The effect of solute-solvent interaction on the solution viscosity can be inferred from the B-coefficient¹⁹⁻²⁰.

The viscosity B-coefficient is also a valuable tool to provide information concerning the solvation of the solute in solution. From table-5 and figure-2, it is evident that the values of the B-coefficient are positive, thereby suggesting the presence of strong solute-solvent interactions which are strengthened with the increase temperature and decrease with the increase in percentage of dextrose in its aqueous solution. This is in agreement with the results obtained from density measurements.

It has been reported in a number of studies that dB/dT is a better criterion for determining the structure-making/breaking nature of any solute rather than simply the value of the B-coefficient²¹⁻²². It is found from table-5 that the values of the B-coefficient increase with a rise in temperature (positive dB/dT) suggesting the structure-breaking tendency of zinc chloride in aqueous dextrose solution.

Table-5
Values of Jones-Dole coefficients, A and B of Zinc chloride in 2%, 4% and 6% aqueous solution of dextrose at 303.15K, 308.15K and 313.15 K

Wt. % of dextrose in water	A (kg. mol ⁻¹)			B (kg ^{1/2} . mol ^{-1/2})		
	303.15 K	308.15 K	313.15 K	303.15 K	308.15 K	313.15 K
2%	.02	-.004	-.026	.618	.645	.676
4%	.022	.001	-.015	.605	.635	.665
6%	.028	.004	-.007	.589	.628	.659

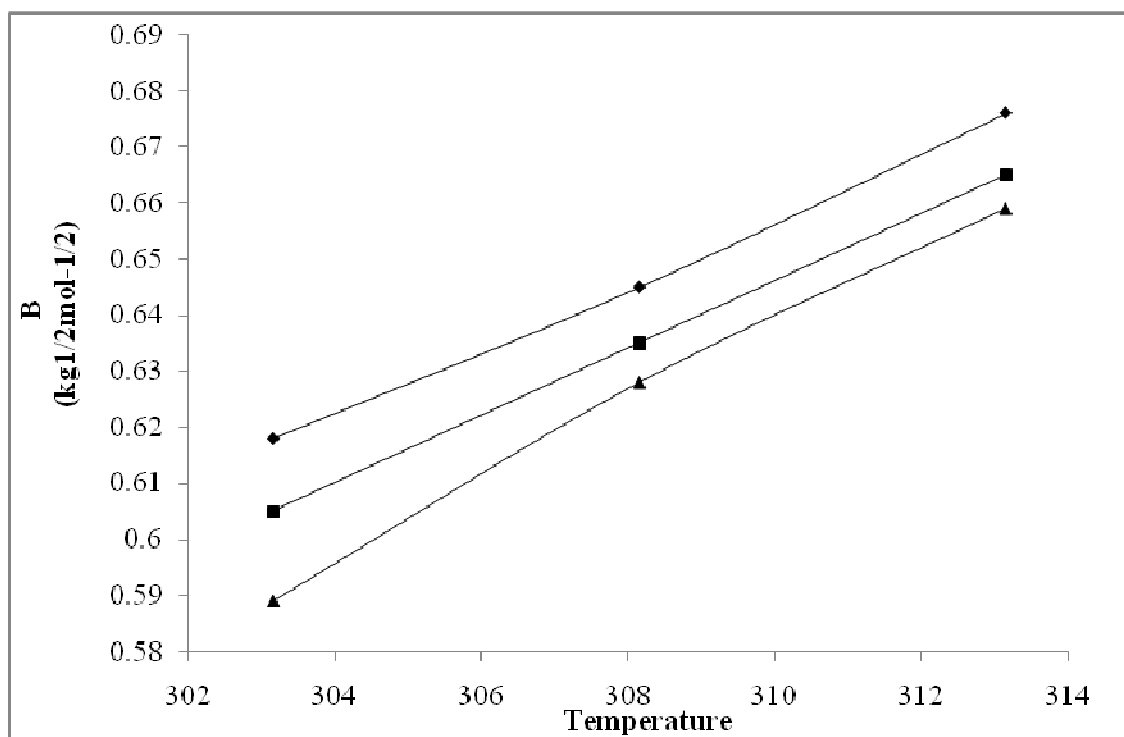


Figure-2
Jones-Dole coefficient B of zinc chloride in 2% (—◆—), 4% (—■—) and 6% (—▲—) aqueous dextrose solutions at different temperatures

Conclusion

The values of the limiting apparent molar volume (ϕ_v^0) and viscosity B-coefficient indicate the presence of strong solute-solvent interactions which decreases with increase in percentage of dextrose in its aqueous solution and predominates at higher temperature whereas the solute-solute interaction intensifies at lower temperature.

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