



## Thermodynamic and transport properties of some salts in aqueous-cysteine solutions at 303.15 K

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### ABSTRACT

Present paper reports apparent molar volumes, partial molar volumes and viscosity  $B$ -coefficients of  $\text{LiCl}$  and  $\text{MnCl}_2 \cdot 4\text{H}_2\text{O}$  in aqueous cysteine solutions of  $0.01 \text{ mol} \cdot \text{dm}^{-3}$  at 303.15 K. Results have been discussed in terms of different interactions in solution and effect of amino acid (cysteine) on volumetric and viscometric behavior of salts.

**Keywords:** Density, Viscosity, Ion-solvent interactions

### INTRODUCTION

Thermodynamic and transport properties of solution like density, viscosity, refractive index, apparent molar volumes, partial molar volumes and viscosity coefficients are useful to characterize structural aspects and interactions in solution [1-7]. Partial molar volume is important thermodynamic property which provides information about different interactions in solutions [8-10] and is useful for understanding molecular processes in solution. Ion-ion and ion-solvent interactions can be studied through their contribution to viscosity and viscosity  $B$ -coefficients. Physicochemical properties of aqueous solutions of salts and aqueous salt + amino acid solutions have been studied by many workers [11-15]. In our earlier studies, the structures and molecular interactions in various solutions have been studied [16-20].

Present paper reports the systematic study of apparent molar volumes, partial molar volumes and viscosity  $B$ -coefficients of aqueous-cysteine solution containing  $\text{LiCl}$  and  $\text{MnCl}_2 \cdot 4\text{H}_2\text{O}$  at 303.15 K which is lacking to the best of our knowledge.

### EXPERIMENTAL SECTION

All the chemicals used in present work were of AR grade. Stock solution of  $0.01 \text{ mol} \cdot \text{dm}^{-3}$  cysteine was prepared using double distilled water in calibrated flask. Weighing was done on single pan, electronic balance ( $e = \pm 0.001\text{g}$ ). Density of solution was measured using high precision single capillary pycnometer (Borosil). Pycnometer was calibrated with distilled water at 303.15 K. Pycnometer was kept in transparent walled constant temperature water bath for 15 min to attain thermal equilibrium. Average of three independent density measurements was considered. Viscosity of solution was measured by flow time method using Ostwald type viscometer at 303.15 K and atmospheric pressure. Viscometer was kept in transparent walled constant temperature water bath at 298.15 K for 10 min to attain the thermal equilibrium.

### RESULTS AND DISCUSSION

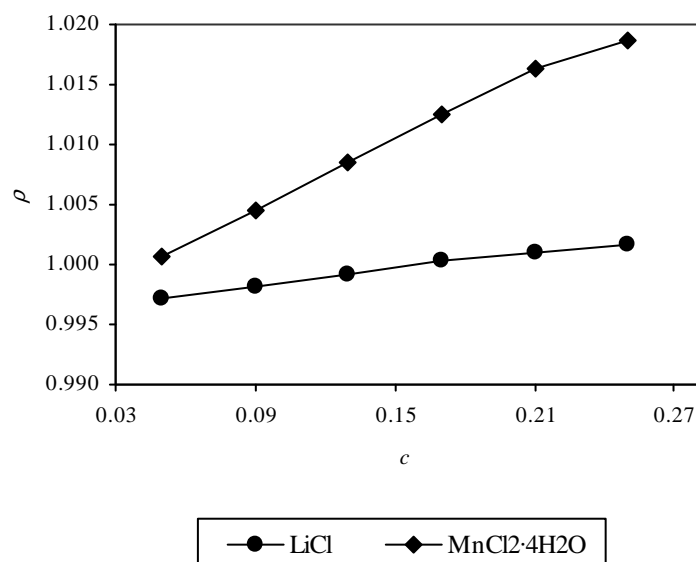
Density ( $\rho$ ), viscosity ( $\eta$ ), viscosity  $\eta_r - 1/\sqrt{c}$  parameter and apparent molar volume ( $\phi_v$ ) of different salts in aqueous-cysteine solutions at 303.15 K are reported in Table 1. Variation in density and viscosity with concentration of salts is presented graphically in Figure 1 and 2. It is seen that, density and viscosity increased with increase in

concentration of salts. For given concentration of salts in aqueous cysteine solution, density of  $\text{MnCl}_2 \cdot 4\text{H}_2\text{O}$  solution is greater than LiCl solution whereas, viscosity of LiCl solution is greater than  $\text{MnCl}_2 \cdot 4\text{H}_2\text{O}$ . A change in density and viscosity indicates structural rearrangement and existence of interactions among components of solution.

**Table 1.** Density ( $\rho$ ), viscosity ( $\eta$ ), viscosity  $\eta_r-1/\sqrt{c}$  parameter and apparent molar volume ( $\varphi_v$ ) of different salts in aqueous-cysteine solutions at 303.15 K

$c$ (mol · dm <sup>-3</sup> )	$\sqrt{c}$ (mol <sup>1/2</sup> · dm <sup>-3/2</sup> )	$\rho$ (g · cm <sup>-3</sup> )	$\eta$ (m Pa s)	$\eta_r-1/\sqrt{c}$	$\varphi_v$ (cm <sup>3</sup> · mol <sup>-1</sup> )
LiCl + aqueous cysteine (0.01 mol · dm <sup>-3</sup> ) solutions					
0.05	0.224	0.9972	0.828	0.171	18.43
0.09	0.300	0.9982	0.839	0.173	18.85
0.13	0.361	0.9992	0.851	0.187	18.29
0.17	0.412	1.0003	0.863	0.198	17.44
0.21	0.458	1.0010	0.878	0.221	18.67
0.25	0.500	1.0017	0.893	0.239	19.50
$\text{MnCl}_2 \cdot 4\text{H}_2\text{O}$ + aqueous cysteine (0.01 mol · dm <sup>-3</sup> ) solutions					
0.05	0.224	1.0006	0.847	0.275	105.63
0.09	0.300	1.0045	0.871	0.307	103.21
0.13	0.361	1.0085	0.887	0.309	100.62
0.17	0.412	1.0125	0.899	0.307	99.61
0.21	0.458	1.0163	0.914	0.318	99.29
0.25	0.500	1.0186	0.923	0.314	105.25

**Figure 1:** Variation in the density with concentration of salts in aqueous-cysteine solutions at 303.15 K



Relative viscosity was calculated and fitted to *Jones-Dole* equation and viscosity *A* and *B*-coefficients were determined from the plots of  $\eta_r-1/\sqrt{c}$  versus  $\sqrt{c}$  (Figure 3, Table 2). Viscosity *B*-coefficient is useful for understanding solvation of solute, structure making or breaking ability of solute and solute-solvent interactions [21]. In present systems positive values of *B*-coefficient is associated with strong solute-solvent interactions, structure making (ordering) ability of salts and solvation of ions [22-23].

Figure 2: Variation in the viscosity with concentration of salts in aqueous-cysteine solutions at 303.15 K

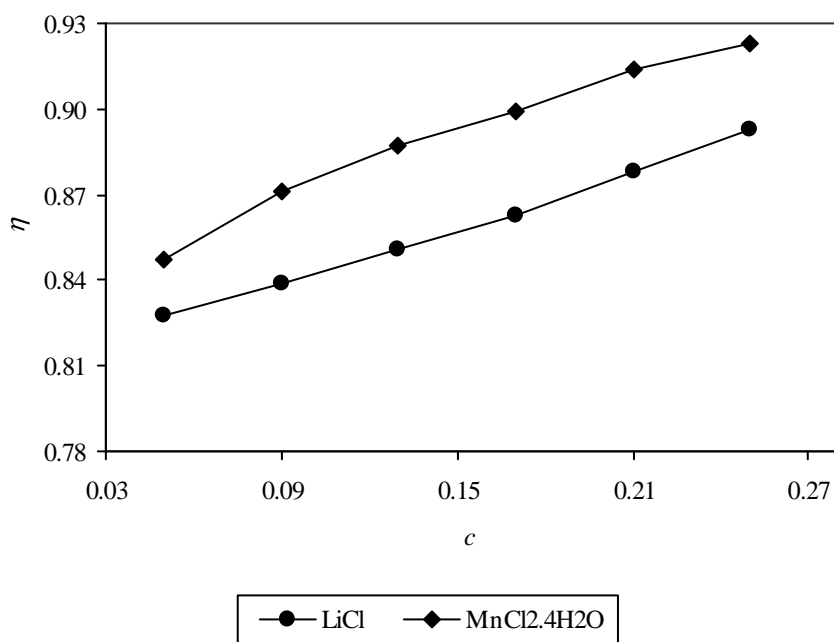
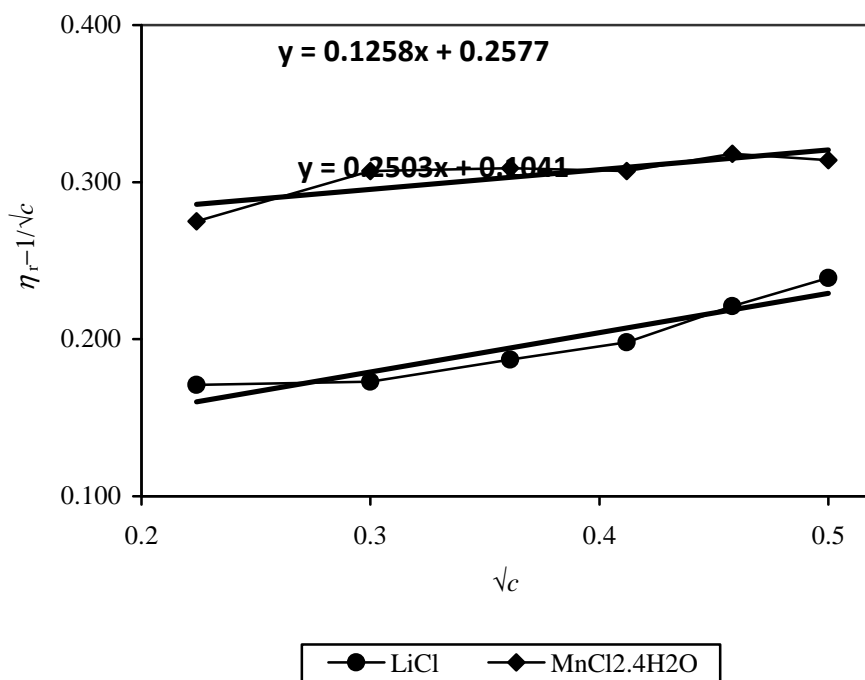


Figure 3. Jones-Dole plots for salts + aqueous-cysteine solutions at 303.15 K



Apparent molar volume of salts in aqueous cysteine solutions were calculated by using standard relation [24] and were fitted to the Massons relation [25]. From the plots of  $\phi_v$  versus  $\sqrt{c}$  (Massons relation, Figure 4),  $\phi_v^0$  was determined as a intercept and  $S_v$  as slope of the lines. The  $\phi_v^0$  and  $S_v$  values are reported in Table 2. The  $\phi_v^0$  is apparent molar volume at infinite dilution which represents solute-solvent (ion-solvent) interactions in solution and  $S_v$  is experimental slope which represents solute-solute (ion-ion) interactions.

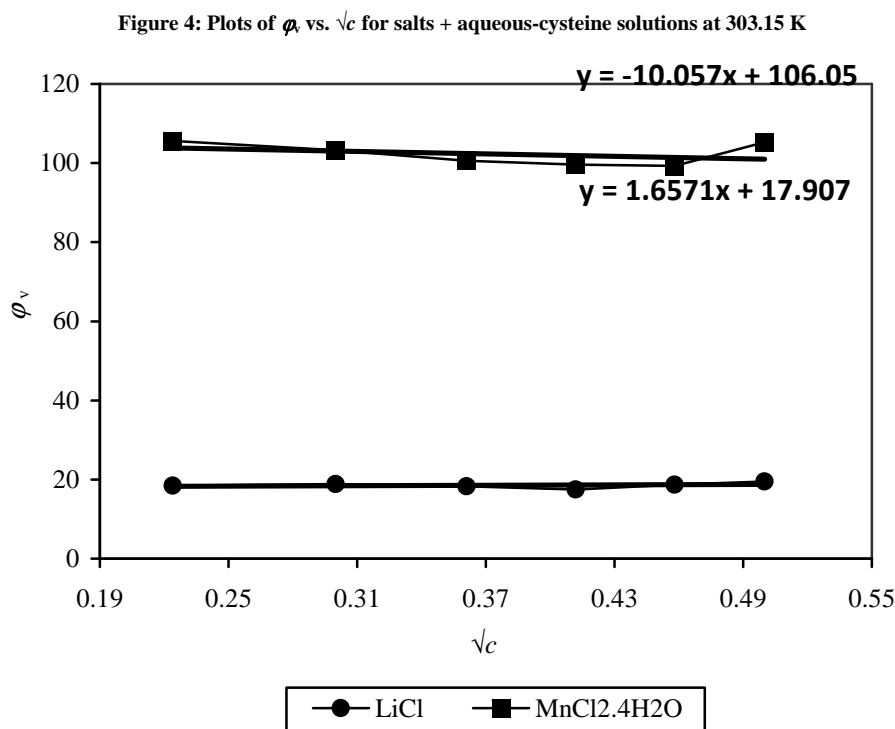


Table 2. The  $\phi_v^0$ ,  $S_v$ , viscosity  $A$  and  $B$ -coefficients, and partial molar volume of transfer ( $\Delta_{tr}\phi_v^0$ ) for salts + aqueous-cysteine solutions at 303.15 K

Parameters	LiCl + Aq. Cysteine	MnCl <sub>2</sub> ·4H <sub>2</sub> O + Aq. Cysteine
$\phi_v^0$ (cm <sup>3</sup> · mol <sup>-1</sup> )	17.91 (17.67) <sup>a</sup>	106.05 (98.42) <sup>b</sup>
$S_v$ (cm <sup>3</sup> · kg <sup>3/2</sup> · mol <sup>-3/2</sup> )	-1.66 (1.67) <sup>a</sup>	-10.06
$A$ (dm <sup>3/2</sup> · mol <sup>-1/2</sup> )	0.1041 (0.0095) <sup>a</sup>	0.2255
$B$ (dm <sup>3</sup> · mol <sup>-1</sup> )	0.250 (0.145) <sup>a</sup>	0.194 (0.449) <sup>b</sup>
$\Delta_{tr}\phi_v^0$ (cm <sup>3</sup> · mol <sup>-1</sup> )	0.24	7.63

Foot note: a=Ref. No. [26]; b= Ref. No. [27].

The  $\phi_v^0$  values are positive in each case which indicates presence of strong ion-solvent interactions [28]. The  $S_v$  parameter is negative for all salt solutions which are due to weak ion-ion interactions. Negative values of  $S_v$  are due to weak ion-ion interactions and structure promotion effect of salts on structure of water. From the results obtained, it is conformed that, present systems are characterized by i) ion-charged/hydrophilic group or ion-ion interactions between ions from salts (solute) and polar zwitterionic head groups of amino acid (co-solute), cysteine and ii) ion-hydrophobic interactions between ions from salts (solute) and hydrophobic parts of the amino acids.

## CONCLUSION

Present study yielded reliable values of  $\phi_v^0$  values of salts. It is concluded that strong ion-solvent interactions exists in salts + aqueous-cysteine solution. Original structural fittings in aqueous cysteine solution are characterized by zwitterions-water interactions through hydration in electrostatic manner which modifies upon addition of salts due to new ion-hydrophilic and ion-hydrophobic interactions.

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