Research Article

Study of Transport Properties of Tris (hydroxymethyl)aminomethane Hydrochloride in 20% (v/v) Acetone-Water System at 303.15°K

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Viscometric properties of Tris-(hydroxymethyl)amino methane hydrochloride are measured in 20% (v/v) acetone-water system 303.15°K. The related parameters are the experimental values of viscosity (η) allow to determine relative viscosity (η_r), viscosity B -coefficient of the Jones-Dole equation, free energies of activation of viscous flow $\Delta\mu_1^{0\ddagger}$ and $\Delta\mu_2^{0\ddagger}$ per mole solvent, and solute, respectively. The excess molar volume, excess viscosity, excess Gibb's free energy, and interaction parameter of Grunberg and Nissan have also been calculated. These studies are of great help in characterizing the structure and properties of solutions. The addition of an organic solvent to water brings about a sharp change in the solvation of ions.

1. Introduction

The density is one of the key thermodynamic properties of electrolyte solutions and belongs with an equilibrium property, while the viscosity is one of the key transport properties of electrolyte solutions and belongs with a dynamic state property. Both of them are indispensable basic data to engineering design and process optimization. Knowledge of viscometric properties studied in binary solvent system is useful for engineering design of new applications. Viscosities are important physico-chemical parameters widely studied in aqueous, aqueous-organic, and others [1]. The density and viscosity are important basic data used in chemical engineering designs, solution theory, and molecular thermodynamics [2]. Physicochemical processes of electrolyte solutions are of considerable interest due to their importance in numerous industrial processes. Extensive experimental viscosity data are available for mixed-solvent system. In mixed-solvent electrolyte solutions, viscosity is affected by the concentration of electrolytes but also by the composition of the solvent. Even the viscosity of solvent mixtures may show a complex behavior and change significantly with composition. The knowledge of physico-chemical properties of liquid mixtures of two or more components are of theoretical and industrial

importance due to their wide range of applicability as solvent media in various physico-chemical processes. In the present investigation following parameters are measured by Viscosity data of tris (hydroxymethyl)aminomethane hydrochloride is measured in 20% (v/v) acetone-water system 303.15°K is used to determine B -coefficient (B) and constant characteristic of ion-ion interactions (A) excess viscosity (V^E), and excess molar free energy of activation of flow (G^E). The interaction parameters Gruenberg and Nissan (d) were also calculated and reported. The parameters are analyzed to be evaluated to understand solute-solvent interaction.

2. Experiment

A stock solution of 0.100 M tris (hydroxymethyl)amino-methane hydrochloride is prepared in 20% (v/v) acetone-water solvent by direct weighing. Mass dilution technique used for preparation of other concentrations. The concentration of the solutions involved in the experiment was taken in range from 0.010 M to 0.100 M. Mass dilution technique was applied to prepare the solution of different concentration. Viscosities were measured by capillary viscometer of Ostwald-Sprengel type (MaHaRaNa, Instruments MFG-Company

TABLE 1: Viscosities and densities of tris (hydroxymethyl)amino-methane hydrochloride in 20% (v/v) acetone-water system at 303.15°K.

Concentration (mol dm ⁻³)	Density (ρ) gm cm ⁻³	Viscosity (η) mPa s
0.0100	0.9436	0.9307
0.0200	0.9446	0.9678
0.0300	0.9458	1.0142
0.0400	0.9465	1.0344
0.0500	0.9475	1.1196
0.0600	0.9493	1.1671
0.0700	0.9506	1.2337
0.0800	0.9528	1.3015
0.0900	0.9541	1.3686
0.1000	0.9551	1.5004

TABLE 2: Excess molar volume and excess viscosity of tris (hydroxymethyl)aminomethane hydrochloride in 20% (v/v) acetone-water system at 303.15°K.

Concentration (mol dm ⁻³)	Excess molar volume (V^E)	Excess viscosity (η^E)
0.0100	1.2691	-0.0257
0.0200	0.2639	0.0113
0.0300	0.2360	0.0577
0.0400	0.2169	0.0780
0.0500	0.1935	0.1632
0.0600	0.1526	0.2107
0.0700	0.1206	0.2773
0.0800	0.0713	0.3452
0.0900	0.0396	0.4122
0.1000	0.0165	0.5441

(I am not related to MFG company commercially.), Ajmer India) with accuracy of 0.1 K. The Viscometer was calibrated with triple distilled water. Viscosity values were determined using the relation,

$$\eta = \rho \left(Kt - \frac{L}{t} \right), \quad (1)$$

where η is a viscosity, ρ is the density of the liquid, t is the flow time, and K and L are constants for given viscometer. The flow time was measured with digital stop watch with accuracy of ± 0.01 sec. The K and L were obtained by measuring the flow time of triple distilled water at temperature 303.15°K. All measurements were carried out in triplicate.

3. Result and Discussion

3.1. Viscosities and Densities. The values of viscosities and densities are reported in Table 1. Viscosities of the solution are increasing with the increase in concentration.

3.2. Excess Molar Volume and Excess Viscosity

3.2.1. Excess Molar Volume. It is calculated from following expression:

$$V^E = V - (X_1 V_1 + X_2 V_2), \quad (2)$$

where V = Molar volume of Tris-(hydroxymethyl)amino methane hydrochloride solution, V_1 = Molar volume of mixed solvent, V_2 = Molar volume of solute, X_1 = Mole fraction of solvent, and X_2 = Mole fraction solute.

The data are shown in Table 2.

3.2.2. Excess Viscosity. The mixing of different compounds gives rise to solutions that generally do not behave ideally. The deviation from ideality is expressed by many thermodynamic properties, particularly by excess or residual extensive properties. Excess thermodynamic properties of mixtures correspond with the difference among the actual property and the property if the system behaves ideally and thus are useful in the study of molecular interactions and arrangements. In particular, they reflect the interactions that take place among solute-solute, solute-solvent, and solvent-solvent species. The excess viscosity (η^E) has been evaluated from the observed viscosity of the solution and that of its pure components using the relation [3]

$$\eta^E = \eta - (X_1 \eta_1 + X_2 \eta_2), \quad (3)$$

where η_2 = viscosity of solute.

The data presented in Table 2 show that the η^E values are positive in the entire concentration range at both the temperatures. This shows the presence of specific solute-solvent interactions such as hydrogen bond formation in these systems [4].

3.3. B-Coefficients. The Jones-Dole equation was used to analyze the viscosities following the equation [5]

$$\eta_r = \frac{\eta}{\eta_1} = 1 + A c^{1/2} + B c, \quad (4)$$

where A = constant characteristic of ion-ion interactions, B = constant characteristic of ion-solvent interactions, and c = molar concentrations.

The values of relative viscosities are presented in Table 3. The Falkenhagen coefficient A is also given for electrolytes. The B -coefficients obtained as slope of straight line have been recorded in Table 3.

Einstein [6] proposed an equation

$$\eta = \eta_1 (1 + 2.5\nu), \quad (5)$$

where ν = aggregate volume of the particles in a unit volume of solution.

The previous equation describes the concentration dependence of the relative viscosity of solution of electrolyte. The coefficient of ν is 2.5ν . The term 2.5ν is taken to be valid for electrolyte and it is equivalent to the product in BC in the Jones-Dole equation. The data are presented in Table 3.

3.4. Activation Parameter. The viscosity data have also been analyzed on the basis of a transition state theory of relative viscosity as suggested by Rama Rao et al. [7]. The viscosity B -coefficient is expressed by equation

$$B = \frac{(\bar{V}_1^0 - \bar{V}_2^0)}{1000} + \frac{[(\bar{V}_1^0/1000)\Delta\mu_2^{0\#} - \Delta\mu_1^{0\#}]}{RT}, \quad (6)$$

where $\bar{V}_1^0$ = partial molar volume of solvent, $\bar{V}_2^0$ = partial molar volume of solute, $\Delta\mu_1^{0\#}$ = free energy of activation per mole of solvent, $\Delta\mu_2^{0\#}$ = free energy of activation per mole of solute, B = viscosity B -coefficient. R = universal Gas constant ($8.314 \text{ JK}^{-1} \text{ mol}^{-1}$), and T = temperature (303.15°K).

3.4.1. Solvent Activation Parameter: $\Delta\mu_1^{0\#}$. $\Delta\mu_1^{0\#}$ is calculated from equation proposed by Eyring et al.

$$\Delta\mu_1^{0\#} = RT \ln \left(\frac{\eta_1 \bar{V}_1^0}{HN} \right), \quad (7)$$

where N = Avogadro's number ($6.023 \times 10^{23} \text{ gm-atom}$), H = Planck's constant ($6.626 \times 10^{-34} \text{ J-sec}$), and η_1 = viscosity of solvent.

3.4.2. Solvent Activation Parameter: $\Delta\mu_2^{0\#}$. Solvent activation parameter, $\Delta\mu_2^{0\#}$, is derived from following expression:

$$\Delta\mu_2^{0\#} = \Delta\mu_1^{0\#} + \left(\frac{RT}{\bar{V}_1^0} \right) [1000B - \bar{V}_1^0 - \bar{V}_2^0]. \quad (8)$$

The values of solvent $\Delta\mu_1^{0\#}$ and solute $\Delta\mu_2^{0\#}$ and activation free energies are given in Table 4.

According to Feakins model, the greater the value of $\Delta\mu_2^{0\#}$ is, the greater the structure ability of the solute is. The values of $\Delta\mu_2^{0\#}$ are very large as compared to those of $\Delta\mu_1^{0\#}$, which suggests that the formation of transition state is accompanied with breaking and distortion of intermolecular bonds.

3.5. Excess Free Energy of Activation for Viscous Flow G^E and Interaction Parameter d

3.5.1. Excess Free Energy of Activation for Viscous Flow G^E . The extra-thermodynamic property, excess Gibb's free energy of activation of flow (G^E) for the solution has been computed from the Eyring equation [8]

$$G^E = RT [\ln \eta V - (X_1 \ln \eta_1 V_1 + X_2 \ln \eta_2 V_2)]. \quad (9)$$

The values are listed in Table 5. The value of G^E increases with the increase in concentration of solute and also increases with the increase in temperature suggesting the interactions became stronger.

TABLE 3: B -coefficient, A , B of tris (hydroxymethyl)amino methane hydrochloride in 20% (v/v) acetone-water system at 303.15°K .

Concentration (mol dm ⁻³)	B_c	A	B
0.0100	-0.0057		
0.0200	-0.0458		
0.0300	-0.0959		
0.0400	-0.1178		
0.0500	-0.2099	0.1031	-6.5591
0.0600	-0.2612		
0.0700	-0.3331		
0.0800	-0.4065		
0.0900	-0.4789		
0.1000	-0.6214		

TABLE 4: Activation parameters of tris (hydroxymethyl)amino-methane hydrochloride in 20% (v/v) acetone-water system at 303.15°K .

Concentration (mol dm ⁻³)	$\Delta\mu_1^{0\#}$ (in kJ mol ⁻¹) 10^5	$\Delta\mu_2^{0\#}$ (in kJ mol ⁻¹) 10^5
0.0100	2.6244	-6.4836
0.0200	2.6283	-6.4798
0.0300	2.6329	-6.4752
0.0400	2.6348	-6.4732
0.0500	2.6426	-6.4654
0.0600	2.6467	-6.4613
0.0700	2.6522	-6.4558
0.0800	2.6575	-6.4505
0.0900	2.6624	-6.4456
0.1000	2.6714	-6.4365

TABLE 5: Excess molar free energy of activation of flow (G^E) and Grunberg and Nissan constant tris (hydroxymethyl)amino methane hydrochloride in 20% (v/v) acetone-water system at 303.15°K .

Concentration (mol dm ⁻³)	Excess molar free energy of activation of flow (G^E)	Grunberg and Nissan (d)
0.0100	16.9678	0.0001
0.0200	56.1698	0.0004
0.0300	103.0463	-0.0012
0.0400	122.8588	-0.0007
0.0500	202.7112	-0.0003
0.0600	243.5637	-0.0002
0.0700	299.0243	-0.0002
0.0800	351.6797	-0.0003
0.0900	401.7946	-0.0001
0.1000	494.6975	-0.0001

3.5.2. Interaction Parameter d . The impact of solute on viscosity is understood in terms of parameter d , which is regarded as a measure of the strength of interaction

between components of solution. It has been estimated using relationship proposed by Gruenberg and Nissan [9]

$$\ln \eta = X_1 \ln \eta_1 + X_2 \ln \eta_2 + X_1 X_2 d, \quad (10)$$

where d = Gruenberg and Nissan parameter:

$$D \propto \frac{W}{RT}, \quad (11)$$

where W = interaction energy.

The values of d are reported in Table 5.

4. Conclusion

Knowledge of transport properties is important in all these applications to understand the molecular interactions. Viscosity increases as a function of concentration and decreases in increase in temperatures. The values of B -coefficient show solute-solvent interactions in the present systems. The values, $\Delta\mu_2^{0\ddagger}$, are very large as compared to those of $\Delta\mu_1^{0\ddagger}$ which suggests that the formation of transition state is accompanied with breaking and distortion of intermolecular bonds. Volumetric data are used to test molecular theories or models of solution to extend our understanding about molecular interactions among components.

Conflict of Interests

The author declare that she has no commercial relations with MFG Company.

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