

Viscosity Studies of $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ in Mixed Solvents at Different Temperatures

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ABSTRACT

The viscosity studies help to determine the ion-ion interaction and ion-solvent interaction between solute and the mixed solvent. The viscosity of the $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ at 10%, 20% and 30 % (w/w) of Propan-2-ol+Water mixture at 30°, 35° and 40°C has been measured. The ions appear to interact and the ion solvent interaction or structure breaking effect of the anions changes with the change in Propan-2-ol content.

Keywords: Viscosity, Mixed Solvents, Potassium Sulfate, Jones-Dole Equation

I. INTRODUCTION

Physicochemical Properties of solution provide a very useful tool in elucidating the structural interactions among the components. Such properties are dependent upon temperature and composition of the solutions. The addition of organic solvent to the aqueous solution of electrolyte brings a change in ion-solvent and reactivity of dissolved electrolyte.^{1, 2} Physicochemical properties involving determination of density, partial molar volume and viscosity provide important information in studying ion-ion and ion-solvent interactions and also help to examine the structure making and structure breaking effects of electrolytes. The present paper aims to measure the viscosity of the solution at different solvent composition to investigate ion-ion and ion-solvent interactions in the electrolytic solutions. The viscosity data are analysed which indicates the formation of transition state is accompanied by the rupture and distortion of intermolecular forces. From the viscosity measurement, A (Falkenhagen Co-efficient) and B (Jones-Dole Co-efficient) are calculated. A is measure of ionic interaction and B is measure of effective solvodynamic volume solvated ion which gives information about the structural effect induced by solute solvent interaction.

In the present communication, viscosity of Na_2SO_4 solutions at 10%, 20% and 30 % (w/w) of Propan-2-ol+Water mixture at 30°, 35° and 40°C have been studied and an attempt has been made to enquire about net structure breaking or net structure making effect in Propan-2-ol + water mixtures.

II. METHODS AND MATERIAL

Samples of analytical reagents Na_2SO_4 and K_2SO_4 were dried at 120°C. Solutions were then prepared from dried sample by distilled water. Analytical grade (E. Merck) was used for preparing solvent mixture. Before using the solvent, it was dried over molecular sieve and all solutions were prepared in double distilled water. Viscosity of the solution was measured by using a calibrated Ostwald viscometer at 30, 35 and 40 °C respectively with the help of water thermostat maintained at the required temperature accurate to within $\pm 0.05\text{K}$. The estimate error of the viscosity was of the order of $\pm 0.005\%$.

III. RESULT AND DISCUSSION

From Jones-Dole Equation, $\eta_r = 1 + A\sqrt{C} + BC$
Where η_r = Relative Co-efficient of Viscosity
C = Concentration of the solution

A and B are constants

$$\text{Or } \eta_r = 1 + A\sqrt{C} + BC$$

$$\text{Or } \frac{\eta_r - 1}{\sqrt{C}} = A + B\sqrt{C}$$

The relative co-efficient of viscosity of sodium sulphate in 10, 20 and 30% propan-2-ol-water at different temperature are shown in Table-1, 2 and 3 for comparison. The viscosity data are analysed in terms of Jones-Dole equation as the plot $(\eta_r - 1)/C^{1/2}$ vs. $C^{1/2}$ is linear. The intercept and the slope gave the value of “A”, which measures of ion-ion interaction and “B” measures of ion-solvent interaction in the **solution** and data are presented in Table-4 and Table-5 respectively.

Table 1. VALUES OF η_r OF Na_2SO_4 AT 30°C IN PROPAN-2-OL - WATER

Concentration (mol dm ⁻³)	Propan-2-ol + water (wt. %) (η_r)		
	10%	20%	30%
0.1000	1.0764	1.0805	1.0807
0.0750	1.0583	1.0615	1.0616
0.0500	1.0400	1.0421	1.0423
0.0250	1.0213	1.0224	1.0225
0.0100	1.0095	1.0100	1.0101
0.0075	1.0075	1.0078	1.0079
0.0050	1.0053	1.0056	1.0056
0.0025	1.0031	1.0032	1.0032
0.0001	1.0016	1.0016	1.0016

Table 2. VALUES OF η_r OF Na_2SO_4 AT 35°C IN PROPAN-2-OL - WATER

Concentration (mol dm ⁻³)	Propan-2-ol + water (wt. %) (η_r)		
	10%	20%	30%
0.1000	1.0743	1.0777	1.0811
0.0750	1.0567	1.0593	1.0619
0.0500	1.0389	1.0407	1.0424

0.0250	1.0207	1.0217	1.0225
0.0100	1.0093	1.0097	1.0101
0.0075	1.0073	1.0076	1.0079
0.0050	1.0052	1.0054	1.0056
0.0025	1.0030	1.0031	1.0032
0.0010	1.0015	1.0016	1.0016

Table 3. VALUES OF η_r OF Na_2SO_4 AT 40°C IN PROPAN-2-OL - WATER

Concentration (mol dm ⁻³)	Propan-2-ol + water (wt. %) (η_r)		
	10%	20%	30%
0.1000	1.0722	1.0765	1.0817
0.0750	1.0551	1.0584	1.0623
0.0500	1.0379	1.0401	1.0427
0.0250	1.0202	1.0213	1.0226
0.0100	1.0091	1.0096	1.0101
0.0075	1.0071	1.0075	1.0079
0.0050	1.0051	1.0054	1.0056
0.0025	1.0029	1.0031	1.0032

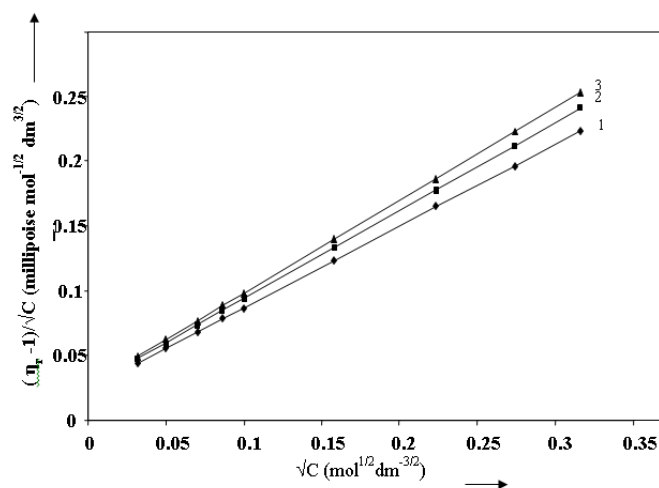


Figure 1 : Plot of $\eta_r - 1/\sqrt{C}$ vs \sqrt{C} of sodium sulfate at 30°C for 10% propan-2-ol + water [1], 20% propan-2-ol + water [2] and 30% propan-2-ol + water [3]

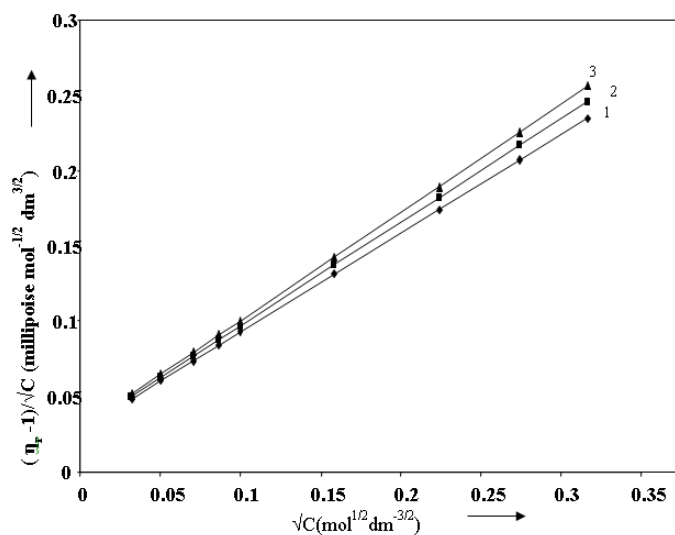


Figure 2: Plot of $\eta_r - 1/\sqrt{C}$ vs \sqrt{C} of sodium sulfate at 35°C for 10% propan-2-ol +water [1], 20% propan-2-ol+water[2] and 30% propan-2-ol +water [3]

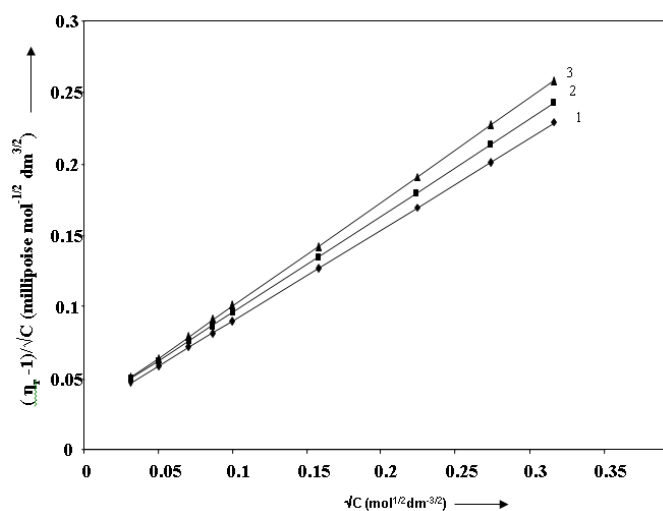


Figure 3: Plot of $\eta_r - 1/\sqrt{C}$ vs \sqrt{C} of sodium sulfate at 40°C for 10% propan-2-ol +water [1], 20% propan-2-ol+water[2] and 30% propan-2-ol +water [3]

Table:4 $A \times 10^3 (\text{dm}^3 \text{mol}^{-1/2}) \text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$

Solvent	Temperature (°C)	10%	20%	30%
Propan-2-ol +water	30	31.3	32.1	33.2
	35	30.2	31.5	32.1
	40	29.1	30.1	31.2
Dioxane	30	31.7	31.5	33.6
	35	30.6	31.4	32.6

+water	40	29.5	30.4	31.6
Glycol +water	30	31.6	32.6	33.6
	35	30.6	31.7	33.2
	40	30.0	30.1	31.5
Glycerol +water	30	31.8	32.8	33.6
	35	30.9	31.9	33.3
	40	30.2	30.5	31.7

Table-5 $B(\text{dm}^3 \text{mol}^{-1}) \text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$

Solvent	Temp (°C)	10%	20%	30%
Propan-2-ol +water	30	0.26	0.29	0.37
	35	0.27	0.30	0.38
	40	0.32	0.33	0.42
Dioxane +water	30	0.29	0.32	0.40
	35	0.30	0.33	0.41
	40	0.35	0.36	0.45
Glycol +water	30	0.30	0.35	0.44
	35	0.31	0.36	0.45
	40	0.37	0.39	0.50
Glycerol +water	30	0.32	0.37	0.46
	35	0.33	0.38	0.48
	40	0.39	0.41	0.53

A Values: A values are the measure of ion-ion interactions, which are positive for all electrolytes studied and increase with increase in concentration of organic solvent increases (Table-4). These values decrease with increase in temperature for all the salts which one should expect in view of more thermal agitation at higher temperatures and reduction of attractive forces.

Dependence of B on temperature: According to Stokes and Miles [7], the viscosity of a dilute

electrolytic solution incorporates that of the solvent plus the contribution from other sources. These values increase due to shape and size of the ion, alignment of orientation of the polar molecules of ionic field and the distortion of the solvent structure by the ions. Therefore, B coefficient can be discussed in terms of these viscosity effects at different temperatures.

The B coefficient of salts increases with increase in temperature. This indicates that the viscosity decreases due to solvent structure. (Table -5) The lesser the value of B, lesser is the distortion and hence the ion-solvent interaction. The ion-solvent interaction is of the order, $\text{Br}^- < \text{NO}_3^- < \text{Cl}^- < \text{I}^- < \text{SO}_4^{2-}$. According to Stokes and Mills [7], the lesser the value of dB/dT , greater is the ion-solvent interaction in the present case, the plot of B vs. T is linear and dB/dT is of the order: $\text{Br}^- < \text{NO}_3^- < \text{Cl}^- < \text{I}^- < \text{SO}_4^{2-}$. This indicates that the order of the ion-solvent interaction is $\text{Br}^- < \text{NO}_3^- < \text{Cl}^- < \text{I}^- < \text{SO}_4^{2-}$ as reported [8, 9].

Dependence of B on propan-2-ol content: The increase in B coefficient with increase in propan-2-ol content in the solvent mixture (Table-5) maybe attributed due to the large size of the solvent molecules and also to the strong association between water and propan-2-ol through hydrogen bonding and for solvated ions it would lead to larger values of and consequently, the B coefficient becomes larger with increase in propan-2-ol content in the molecules.

Propan-2-ol is more basic and less acidic than water. A water molecule is hydrogen bonded with $-\text{OH}$ of propan-2-ol molecule. A cation will react more strongly with the oxygen atom of propan-2-ol + water mixtures and an anion will react less strongly with hydrogen atoms. This type of ion-solvent interaction is in the primary sheath.

Addition of small amounts of propan-2-ol to water may give rise to one of these two effects: if propan-2-ol is accommodated, then it may cause a break down in the three dimensional water structure. It is seen from the viscosity data [10, 11, 12] that B coefficient are positive in propan-2-ol and water mixtures. The values also increase with increase in propan-2-ol content, but the difference in B does not remain the same which shows that the solvation sphere [13, 14] of the ion differs. This indicates that propan-2-ol is not accommodated in the solvent structure [15-20] and hence, it breaks down the

three-dimensional water structures and the additive law does not hold good.

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