

Densities and Viscosities of Electrolyte Solutions in Water + Propan-2-ol

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Abstract-Densities and viscosities of ternary systems comprising of water + propan-2-ol and an electrolyte have been measured at different solvent compositions and electrolyte concentrations at temperatures between (288.15 and 313.15) K. The electrolytes employed were LiCl, NaCl, KCl, KI and SrCl₂ most of which are either commonly found in natural water or have industrial applications. The concentrations of the electrolytes in various mixtures were increased to almost saturation and have been expressed in the temperature-independent molality (*m*) scale. Linear variation of densities with *m* can be expressed in terms of the gradient (the so-called *g*-factor) for different mixture compositions and the electrolytes. Viscosities of solutions have been explained using polynomials in *m*. With the exception of KI, for all the other electrolytes two immiscible phases are formed at the maximum working concentrations in the solvent mixtures having water mole fraction of 0.8.

Keywords- Viscosity; Density; Electrolyte Solution; Aqueous Propan-2-ol

I. INTRODUCTION

Lower alcohols (upto propanols) are completely miscible with water in all proportions [1]. Aqueous mixtures of such mono-hydric alcohols are important for being frequently employed as solvents in various extraction and separation processes as well as in a number of chemical syntheses [2-5]. Aqueous mixtures of alcohols are regarded as interesting “solvent systems” for their relatively higher solubility for many electrolytes [1, 6] which can be utilized in controlled precipitation of inorganic salts from their aqueous solutions by adding calculated amounts of alcohols as co-solvents [7, 8]. Besides its significance in chemistry, investigation of electrolyte solutions of aqueous alcohols may be important not only from the chemical engineering point of view but also for their usefulness in microbiology [9, 10]. Aqueous mixtures of alcohols exhibit higher viscosities than the individual pure solvents over the entire composition range [1] which may be attributed to further strengthening of the water-water hydrogen bonding due to hydrophobic interaction caused by the alkyl groups [11-15]. Formation of H-bonds between alcohol and water molecules also takes place as evident from appearance of one combined OH-peak in the proton NMR spectra particularly for the water rich mixtures [16, 17]. Aqueous mixtures of lower alcohols are thus regarded as simple model systems for investigation of solvent interactions in particular the hydrophobic effect [2]. Knowledge of thermodynamical and transport properties of such mixtures and their electrolyte solutions may provide insight into the solvent-solvent and solute-solvent interactions in addition to being significant for their further utilities from the engineering point of view [18, 19] in which regard data collected at higher electrolyte concentrations may also be quite useful. Changing the mixture composition or electrolyte concentration or even temperature may result in re-structuring of the liquid which should be reflected in densities and viscosities.

Aqueous mixtures of methanol and ethanol, and their various electrolyte solutions have been more abundantly investigated as compared to their higher analogues. The present study presents measurements of densities and viscosities of LiCl, NaCl, KCl, KI and SrCl₂ solutions in water(1) + propan-2-ol(2) at different compositions and temperatures. Since propan-2-ol is miscible with water in all proportions, its mole fractions (*x*₂) in the mixtures have been selected at suitable intervals to cover the entire composition range. However, the temperature range of study has been restricted from 288.15 K to 313.15 K to minimize the possibility of composition change. It has been tried to prepare electrolyte solutions of different strengths upto almost saturation but due to limited solubility of the selected electrolytes only saturated solution could be prepared. Electrolyte concentrations have been expressed in the temperature independent molality (moles of solute per 1000 g of solvent) scale which may also provide the ratio of solute to total moles of solvent in a given mixture so that a more realistic mutual comparison of the data is possible. Even though many variables like temperature, solvent composition, the electrolyte and its concentration tend to affect the density and viscosity values of the solutions, however, an attempt may be made to express the data in a concise form as suitable polynomials in temperature and electrolyte molality [20].

II. EXPERIMENTAL SECTION

A. Chemicals and Preparation of Samples

The chemicals [propan-2-ol >98 % (BDH), LiCl, NaCl, KCl, KI and SrCl₂.2H₂O (all) >99 % (BDH)] were used as such without further purification; doubly-distilled water was prepared as reported earlier [20]. Known masses of the two liquids were added together to prepare solvent mixtures of the desired mole fractions. A calculated mass of electrolyte was added to known amount of mixture to get the required molality, All the salts employed in the present study were free of the water of

hydration except strontium chloride which was available with stoichiometric formula of $\text{SrCl}_2 \cdot 2\text{H}_2\text{O}$; it was used as such and its water of hydration was adjusted in the calculations of both electrolyte concentration as well as the water mole fraction in the mixture. A digital balance, ER-180A from A & D, Japan (uncertainty within ± 0.1 mg) was used for the weighing.

B. Viscosity and Density Measurement

Due to a fairly wide viscosity range of study two Ubbelohde viscometers (each of about 20 cm^3 capacity) having 36 s and 90 s flow times for water at 25°C were used for high and low viscosities, respectively. The viscometers were standardized employing literature viscosity values at 20°C for water (1.002 mPa's), aniline (4.467 mPa's) and nitrobenzene (1.98 mPa's) [both >99 % (BDH)] as references [21]; the values were also monitored from time to time. Flow time for each sample was the average of at least three runs read on a digital stopwatch (minimum detection limit 0.01 s and estimated uncertainty of reading within ± 0.05 s). The estimated uncertainty of the viscosity measurement is well within ± 3 %. Densities were determined using a 10 cm^3 density bottle calibrated with both water ($0.9982 \text{ g}\cdot\text{cm}^{-3}$) and carbon tetrachloride ($1.594 \text{ g}\cdot\text{cm}^{-3}$) [1] [>99 % (BDH)]. The estimated uncertainty in density determination is $\pm 0.0002 \text{ g}\cdot\text{cm}^{-3}$.

For the viscosity and density measurements, a water bath was employed whose temperature was controlled by an "Eyela thermistor, T-80, Japan" (equipped with an automatic temperature controlling sensor of $\pm 0.05^\circ\text{C}$ detection limit). A calibrated thermometer with graduation of 0.01°C , placed close to the sample, allowed noting temperature up to the second decimal place. Before measurements the solutions were kept in the thermo stated bath at the desired temperature for at least 20 minutes.

III. RESULTS AND DISCUSSION

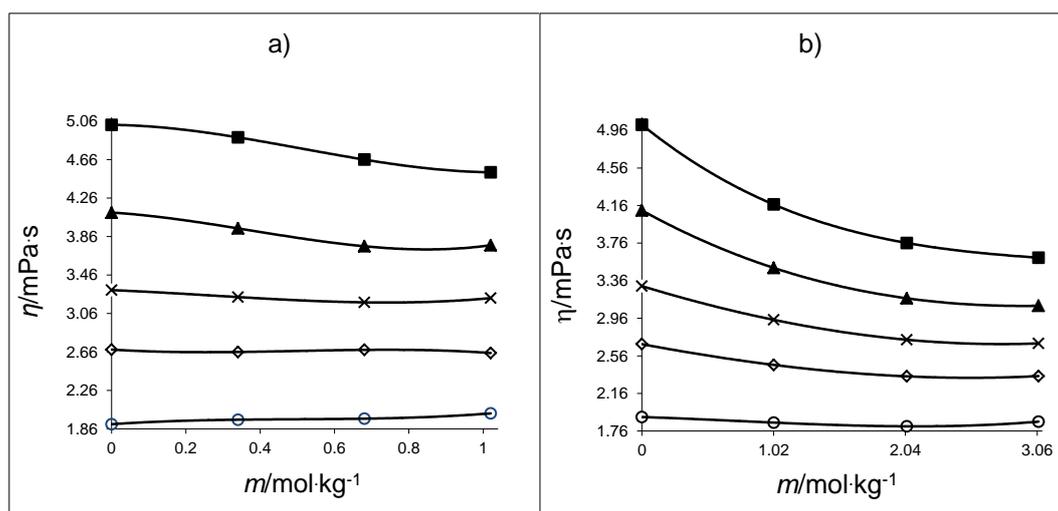
Viscosities and densities of the two solvents and their mixtures at different temperatures are presented in Table 1. Their values for the neat solvents at 293.15 K fairly agree with those reported in the literature [1] (comparison also given in Table 1). Viscosities and densities of solutions at different concentrations of various electrolytes are collected in Table 2. The data for pure water ($x_1 = 1$) are in good agreement with those reported in the literature [1, 22]. In all cases, density (ρ) of the system (which also changed with composition and temperature as well as the salt) was found to vary almost linearly with molality (m). This behavior for a given mixture and salt at the selected temperature may be expressed as:

$$\rho(x_1, T, m) = \rho^o(x_1, T) + g(x_1)m \quad (1a)$$

or

$$g(x_1) = \{\rho - \rho^o\}_{x_1, T}/m \quad (1b)$$

ρ^o is the mixture density while g being the concentration gradient of density or the so-called g -factor. The g -values for various systems are reported in Table 2 which remain almost unchanged with temperature for all the systems (with the exception of KCl in the mixture having $x_1 = 0.8$; here $g(T) = 0.49 - 0.0015 \cdot T/\text{K}$ appears to follow). It is to be noted that amongst the 1:1 electrolytes, quite high g -values have been obtained for KI that remained almost unchanged with the solvent composition.



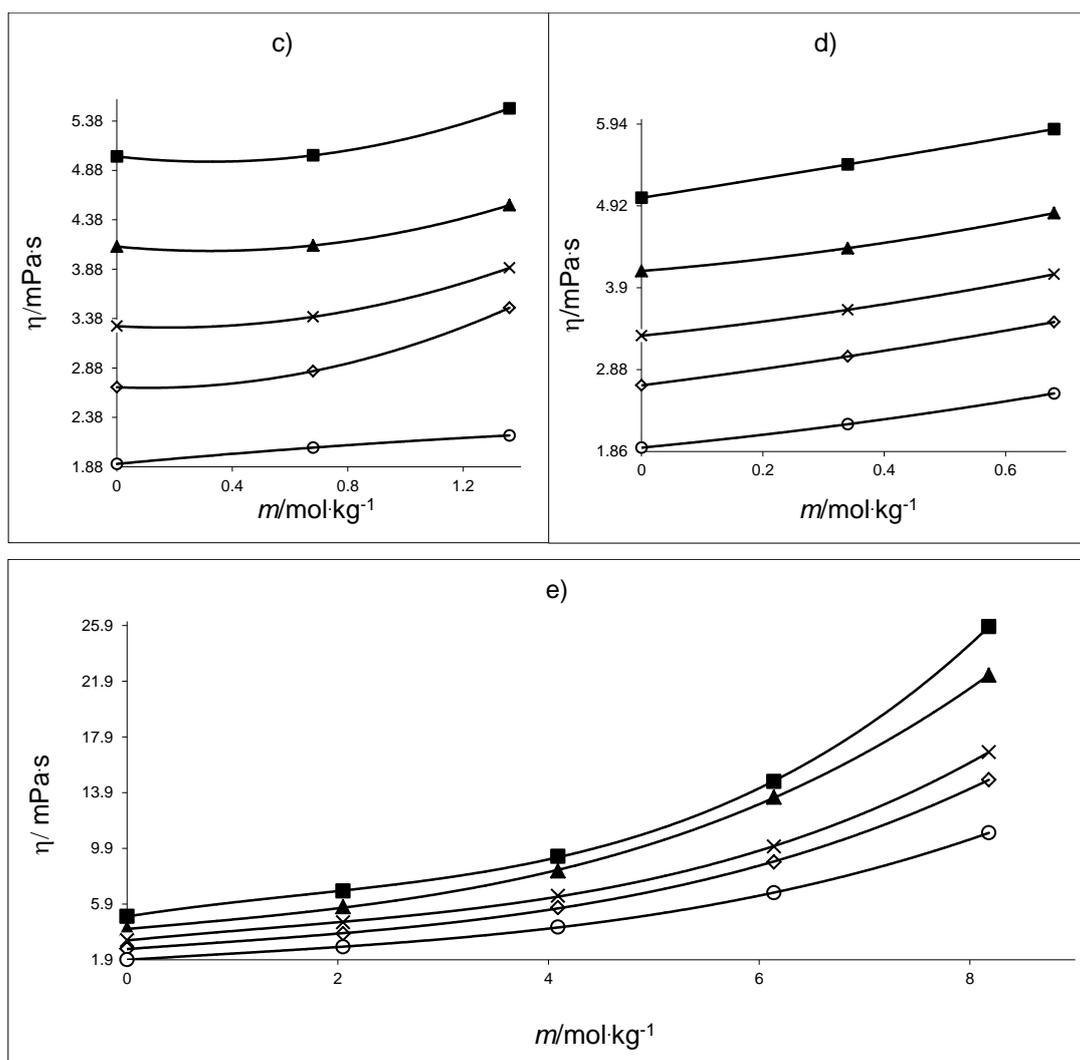


Fig. 1 Viscosity η vs. electrolyte molality, m in water(1) + propan-2-ol(2) at $x_1 = 0.8$ and different temperatures: ■, 288K; ▲, 293K; ×, 298K; ◇, 303K; ○, 313K; KCl (a), KI (b), NaCl (c), SrCl₂ (d), LiCl (e)

On the other hand, the viscosities show significant variation with the solution composition. Typical viscosity versus molality isotherms for different electrolytes in the solvent mixture containing $x_1 = 0.8$ (x_1 is the water mole fraction in the solvent mixture namely, water + propan-2-ol) are given in Fig. 1a-e. A distinct decreasing trend of the viscosity for KI (as in Fig. 1b) in various mixtures is due to its so-called structure breaking behaviour [23]. Again with the exception of KI, another interesting feature at the highest working concentration of the electrolytes and $x_1 = 0.8$ is the formation of two distinct phases; this phenomenon is exhibited by SrCl₂ also for $x_1 = 0.6$. One possibility for this behaviour, particularly in the water rich mixtures, is that hydrophobic self-assembly of the alcohol takes place [24-26]. When an electrolyte is added, water molecules get engaged in the solvation of its ions to form more organized solvate thereby increasing viscosity of the system. This has occurred in case of all the electrolytes employed in this study; KCl being on the border line while on addition of KI due to structure breaking I, the viscosity has decreased. Viscosity (η) versus molality isotherms for the entire data was made to fit to a generalized third order polynomial:

$$\eta(T) = b_0 + b_1 m + b_2 m^2 + b_3 m^3 \quad (2)$$

Eq. (2) can be re-written in a more familiar form as:

$$(\eta - \eta^0)/m = b_1 + b_2 m + b_3 m^2 \quad (3)$$

In which b_0 has been replaced by the solvent viscosity η^0 , while b_1 and b_2 are similar to the interaction coefficients reported in literature [24, 27] while b_3 remains negligibly small. The coefficients along with standard deviation(σ) for the relevant isotherms are listed in Table 3.

TABLE 1 VISCOSITIES η_0 AND DENSITIES ρ_0 FOR WATER (1) + PROPAN-2-OL (2) MIXTURES AT DIFFERENT WATER MOLE FRACTIONS x_1 AND TEMPERATURES T

x_1	T/K					
	Parameter	288.15	293.15	298.15	303.15	313.15
1.0	$\eta^0/\text{mPa}\cdot\text{s}$	1.142	^a 1.000	0.892	0.796	0.657
	$\rho^0/\text{g}\cdot\text{cm}^{-3}$	0.9989	^b 0.9982	0.9966	0.9953	0.9921
0.8	$\eta^0/\text{mPa}\cdot\text{s}$	5.021	4.109	3.303	2.685	1.909
	$\rho^0/\text{g}\cdot\text{cm}^{-3}$	0.9177	0.9160	0.9134	0.9112	0.9057
0.6	$\eta^0/\text{mPa}\cdot\text{s}$	4.915	4.069	3.425	2.877	2.113
	$\rho^0/\text{g}\cdot\text{cm}^{-3}$	0.8629	0.8603	0.8581	0.8558	0.8299
0.4	$\eta^0/\text{mPa}\cdot\text{s}$	4.915	4.069	3.425	2.877	2.113
	$\rho^0/\text{g}\cdot\text{cm}^{-3}$	0.8629	0.8603	0.8581	0.8558	0.8299
0.2	$\eta^0/\text{mPa}\cdot\text{s}$	3.595	3.109	2.660	2.210	1.682
	$\rho^0/\text{g}\cdot\text{cm}^{-3}$	0.8041	0.8017	0.7994	0.7968	0.7933
0.0	$\eta^0/\text{mPa}\cdot\text{s}$	2.701	^a 2.423	1.919	1.697	1.333
	$\rho^0/\text{g}\cdot\text{cm}^{-3}$	0.7931	^b 0.7902	0.7873	0.7840	0.7784

^{a, b} Corresponding literature values [1] of viscosities^a and densities^b for water and propan-2-ol are 1.002 mPa·s and 0.9982 g·cm⁻³, and 2.428 mPa·s and 0.7848 g·cm⁻³, respectively.

TABLE 2 VISCOSITIES η AND DENSITIES ρ OF VARIOUS ELECTROLYTE SOLUTIONS OF MOLALITY M IN WATER (1) + PROPAN-2-OL (2) AT DIFFERENT TEMPERATURES T AND WATER MOLE FRACTIONS x_1 IN SOLVENT MIXTURES; G IS CONCENTRATION GRADIENT OF DENSITY; FOR MIXTURES WITHOUT ELECTROLYTE REFER TO TABLE 1

$m/\text{mol}\cdot\text{kg}^{-1}$	Parameter	T/K				
		288.15	293.15	298.15	303.15	313.15
Lithium chloride						
		$x_1 = 1.0$ $g/10^3\cdot g^2\cdot\text{cm}^{-3}\cdot\text{mol}^{-1} = (3.70 \pm 0.03)10^{-2}$				
3.0	$\eta/\text{mPa}\cdot\text{s}$	1.788	1.592	1.426	1.251	1.008
	$\rho/\text{g}\cdot\text{cm}^{-3}$	1.0644	1.0629	1.0620	1.0610	1.0589
6.0	$\eta/\text{mPa}\cdot\text{s}$	2.757	2.449	2.308	1.929	1.568
	$\rho/\text{g}\cdot\text{cm}^{-3}$	1.1171	1.1159	1.1151	1.1138	1.1120
9.0	$\eta/\text{mPa}\cdot\text{s}$	3.432	3.023	2.708	2.375	1.793
	$\rho/\text{g}\cdot\text{cm}^{-3}$	1.1642	1.1631	1.1618	1.1607	1.1582
12.0	$\eta/\text{mPa}\cdot\text{s}$	5.413	4.719	3.798	3.262	2.631
	$\rho/\text{g}\cdot\text{cm}^{-3}$	1.2026	1.2015	1.2000	1.1986	1.1955
15.0	$\eta/\text{mPa}\cdot\text{s}$	9.411	8.022	6.840	6.317	5.172
	$\rho/\text{g}\cdot\text{cm}^{-3}$	1.2464	1.2454	1.2440	1.2425	1.2356
		$x_1 = 0.8$ $g/10^3\cdot g^2\cdot\text{cm}^{-3}\cdot\text{mol}^{-1} = (1.80 \pm 0.02)10^{-2}$				
2.05	$\eta/\text{mPa}\cdot\text{s}$	6.839	5.699	4.593	3.777	2.831
	$\rho/\text{g}\cdot\text{cm}^{-3}$	0.9617	0.9560	0.9346	0.9269	0.9245
4.09	$\eta/\text{mPa}\cdot\text{s}$	9.322	8.286	6.491	5.650	4.249
	$\rho/\text{g}\cdot\text{cm}^{-3}$	0.9954	0.9931	0.9687	0.9677	0.9631
6.14	$\eta/\text{mPa}\cdot\text{s}$	14.71	13.58	10.04	8.927	6.714
	$\rho/\text{g}\cdot\text{cm}^{-3}$	1.0942	1.0894	1.0601	1.0565	1.0536
8.18	$\eta/\text{mPa}\cdot\text{s}$	25.82	22.34	16.81	14.83	11.02
	$\rho/\text{g}\cdot\text{cm}^{-3}$	1.1256	1.1228	1.0937	1.091	1.0872
(10.23) ^a lower phase	$\eta/\text{mPa}\cdot\text{s}$	20.89	18.07	13.61	13.08	10.07
	$\rho/\text{g}\cdot\text{cm}^{-3}$	1.3079	1.3069	1.2743	1.273	1.2706
(10.23) ^a Upper phase	$\eta/\text{mPa}\cdot\text{s}$	46.01	40.01	28.52	25.22	17.37
	$\rho/\text{g}\cdot\text{cm}^{-3}$	0.9933	0.9894	0.9858	0.9822	0.9780
		$x_1 = 0.6$ $g/10^3\cdot g^2\cdot\text{cm}^{-3}\cdot\text{mol}^{-1} = (2.01 \pm 0.06)10^{-2}$				
1.55	$\eta/\text{mPa}\cdot\text{s}$	7.776	6.353	5.256	4.344	3.067
	$\rho/\text{g}\cdot\text{cm}^{-3}$	0.9014	0.8963	0.8912	0.8861	0.8644
3.10	$\eta/\text{mPa}\cdot\text{s}$	12.061	9.859	8.206	6.606	4.624
	$\rho/\text{g}\cdot\text{cm}^{-3}$	0.9270	0.9236	0.9205	0.9172	0.8883
4.66	$\eta/\text{mPa}\cdot\text{s}$	20.20	18.11	14.39	11.99	8.298
	$\rho/\text{g}\cdot\text{cm}^{-3}$	0.9577	0.9532	0.9499	0.9464	0.9176
		$x_1 = 0.4$ $g/10^3\cdot g^2\cdot\text{cm}^{-3}\cdot\text{mol}^{-1} = (2.23 \pm 0.19)10^{-2}$				
1.25	$\eta/\text{mPa}\cdot\text{s}$	8.046	6.830	5.748	4.734	3.452
	$\rho/\text{g}\cdot\text{cm}^{-3}$	0.8550	0.8533	0.8520	0.8515	0.8488
	$\eta/\text{mPa}\cdot\text{s}$	14.88	12.21	10.06	8.268	5.601

2.50	$\rho/\text{g cm}^{-3}$	0.8806	0.8785	0.8770	0.8753	0.8735
$x_1 = 0.2$						
1.05	$\eta/\text{mPa s}$	7.093	5.931	4.950	3.998	2.889
	$\rho/\text{g cm}^{-3}$	0.8293	0.8276	0.8263	0.8258	0.8232
Sodium chloride						
$x_1 = 1.0$ $g/10^3 \cdot \text{g}^2 \cdot \text{cm}^3 \cdot \text{mol}^{-1} = (2.73 \pm 0.02) \cdot 10^{-2}$						
1.0	$\eta/\text{mPa s}$	1.126	1.047	0.929	0.838	0.689
	$\rho/\text{g cm}^{-3}$	1.0380	1.0372	1.0362	1.0348	1.0320
2.0	$\eta/\text{mPa s}$	1.275	1.118	0.988	0.888	0.725
	$\rho/\text{g cm}^{-3}$	1.0750	1.0736	1.0719	1.0705	1.0674
3.0	$\eta/\text{mPa s}$	1.384	1.209	1.061	0.957	0.778
	$\rho/\text{g cm}^{-3}$	1.1094	1.1078	1.1066	1.1044	1.1012
4.0	$\eta/\text{mPa s}$	1.519	1.311	1.158	1.043	0.843
	$\rho/\text{g cm}^{-3}$	1.1415	1.1394	1.1374	1.1352	1.1317
5.0	$\eta/\text{mPa s}$	1.687	1.479	1.306	1.185	0.947
	$\rho/\text{g cm}^{-3}$	1.1711	1.1688	1.1667	1.1646	1.1606
6.0	$\eta/\text{mPa s}$	1.858	1.652	1.457	1.332	1.129
	$\rho/\text{g cm}^{-3}$	1.1991	1.1968	1.1945	1.1925	1.1863
$x_1 = 0.8$ $g/10^3 \cdot \text{g}^2 \cdot \text{cm}^3 \cdot \text{mol}^{-1} = (3.47 \pm 0.07) \cdot 10^{-2}$						
0.68	$\eta/\text{mPa s}$	5.032	4.120	3.398	2.848	2.074
	$\rho/\text{g cm}^{-3}$	0.9429	0.9416	0.9392	0.9374	0.9325
1.36	$\eta/\text{mPa s}$	5.508	4.528	3.893	3.489	2.197
	$\rho/\text{g cm}^{-3}$	0.9646	0.9625	0.9609	0.9592	0.9559
(2.05) ^a lower phase	$\eta/\text{mPa s}$	3.231	2.809	2.394	2.067	1.616
	$\rho/\text{g cm}^{-3}$	1.1171	1.1158	1.1148	1.1139	1.1107
(2.05) ^a upper phase	$\eta/\text{mPa s}$	4.733	4.001	3.372	2.861	2.163
	$\rho/\text{g cm}^{-3}$	0.8938	0.8938	0.8914	0.8887	0.8833
$x_1 = 0.6$						
0.52	$\eta/\text{mPa s}$	5.082	4.247	3.521	2.903	2.120
	$\rho/\text{g cm}^{-3}$	0.8813	0.8790	0.8765	0.8730	0.8655
Potassium chloride						
$x_1 = 1.0$ $g/10^3 \cdot \text{g}^2 \cdot \text{cm}^3 \cdot \text{mol}^{-1} = (1.66 \pm 0.02) \cdot 10^{-2}$						
0.50	$\eta/\text{mPa s}$	1.097	0.972	0.866	0.779	0.635
	$\rho/\text{g cm}^{-3}$	1.0208	1.0201	1.0192	1.0181	1.0157
1.00	$\eta/\text{mPa s}$	1.068	0.945	0.841	0.765	0.633
	$\rho/\text{g cm}^{-3}$	1.0438	1.0434	1.0420	1.0409	1.0382
1.50	$\eta/\text{mPa s}$	1.036	0.925	0.833	0.759	0.629
	$\rho/\text{g cm}^{-3}$	1.0639	1.0630	1.0615	1.0603	1.0580
2.00	$\eta/\text{mPa s}$	1.001	0.911	0.821	0.749	0.631
	$\rho/\text{g cm}^{-3}$	1.0841	1.0831	1.0819	1.0802	1.0773
2.50	$\eta/\text{mPa s}$	0.999	0.901	0.821	0.740	0.624
	$\rho/\text{g cm}^{-3}$	1.1033	1.1021	1.1009	1.1001	1.0966
3.00	$\eta/\text{mPa s}$	0.983	0.896	0.809	0.740	0.626
	$\rho/\text{g cm}^{-3}$	1.1217	1.1198	1.1183	1.1169	1.1138
$x_1 = 0.8$ $g(T)/10^3 \cdot \text{g}^2 \cdot \text{cm}^3 \cdot \text{mol}^{-1} = (5.0 \pm 1.8) \cdot 10^{-2}$						
0.34	$\eta/\text{mPa s}$	4.891	3.945	3.231	2.660	1.956
	$\rho/\text{g cm}^{-3}$	0.9426	0.9321	0.9224	0.9120	0.8954
0.68	$\eta/\text{mPa s}$	4.660	3.759	3.176	2.682	1.967
	$\rho/\text{g cm}^{-3}$	0.9646	0.9551	0.9459	0.9360	0.9199
1.02	$\eta/\text{mPa s}$	4.528	3.770	3.220	2.649	2.022
	$\rho/\text{g cm}^{-3}$	0.9866	0.9763	0.9676	0.9566	0.9404
(1.36) ^a lower phase	$\eta/\text{mPa s}$	^b -----	2.385	2.110	1.846	1.517
	$\rho/\text{g cm}^{-3}$	-----	0.9993	0.6326	0.7623	0.2848
(1.36) ^a upper phase	$\eta/\text{mPa s}$	^b -----	4.462	3.923	3.407	2.374
(1.36) ^a upper phase	$\rho/\text{g cm}^{-3}$	-----	0.5340	0.4724	0.4115	0.3392

Potassium iodide						
$x_1 = 1.0$		$g/10^3 \cdot g^2 \cdot cm^{-3} \cdot mol^{-1} = (10.5 \pm 0.2) \cdot 10^{-2}$				
1.50	$\eta/mPa \cdot s$	0.855	0.778	0.702	0.646	0.546
	ρ/gcm^{-3}	1.1665	1.1654	1.1640	1.1627	1.1596
3.00	$\eta/mPa \cdot s$	0.747	0.681	0.622	0.576	0.497
	ρ/gcm^{-3}	1.3089	1.3069	1.3048	1.3034	1.2995
4.50	$\eta/mPa \cdot s$	0.706	0.645	0.597	0.558	0.486
	ρ/gcm^{-3}	1.4330	1.4305	1.4281	1.4265	1.4223
6.00	$\eta/mPa \cdot s$	0.668	0.618	0.564	0.534	0.465
	ρ/gcm^{-3}	1.5405	1.5368	1.5355	1.5330	1.5279
7.50	$\eta/mPa \cdot s$	0.638	0.595	0.547	0.509	0.448
	ρ/gcm^{-3}	1.6348	1.6312	1.6285	1.6245	1.6209
$x_1 = 0.8$		$g/10^3 \cdot g^2 \cdot cm^{-3} \cdot mol^{-1} = (10.1 \pm 0.1) \cdot 10^{-2}$				
1.02	$\eta/mPa \cdot s$	4.172	3.497	2.944	2.464	1.850
	ρ/gcm^{-3}	1.0343	1.0317	1.0291	1.0260	1.0212
2.05	$\eta/mPa \cdot s$	3.762	3.173	2.732	2.342	1.810
	ρ/gcm^{-3}	1.1348	1.1322	1.1300	1.1274	1.1230
3.07	$\eta/mPa \cdot s$	3.605	3.093	2.693	2.345	1.860
	ρ/gcm^{-3}	1.2206	1.2171	1.2134	1.2132	1.2074
$x_1 = 0.6$		$g/10^3 \cdot g^2 \cdot cm^{-3} \cdot mol^{-1} = (10.63 \pm 0.06) \cdot 10^{-2}$				
0.78	$\eta/mPa \cdot s$	4.644	3.817	3.202	2.699	2.046
	ρ/gcm^{-3}	0.9492	0.9469	0.9435	0.9417	0.9353
1.55	$\eta/mPa \cdot s$	4.558	3.850	3.279	2.809	2.143
	ρ/gcm^{-3}	1.0268	1.0243	1.0205	1.0189	1.0125
$x_1 = 0.4$						
0.63	$\eta/mPa \cdot s$	4.590	3.858	3.276	2.795	2.066
	ρ/gcm^{-3}	0.8972	0.8945	0.8916	0.8882	0.8823
Strontium chloride						
$x_1 = 1.0$		$g/10^3 \cdot g^2 \cdot cm^{-3} \cdot mol^{-1} = (5.47 \pm 0.08) \cdot 10^{-2}$				
0.74	$\eta/mPa \cdot s$	1.252	1.109	0.995	0.889	0.728
	ρ/gcm^{-3}	1.0985	1.0973	1.0960	1.0949	1.0920
1.36	$\eta/mPa \cdot s$	1.386	1.231	1.090	0.975	0.806
	ρ/gcm^{-3}	1.1762	1.1749	1.1733	1.1718	1.1680
1.91	$\eta/mPa \cdot s$	1.518	1.367	1.219	1.098	0.896
	ρ/gcm^{-3}	1.2409	1.2390	1.2373	1.2353	1.2323
2.38	$\eta/mPa \cdot s$	1.745	1.542	1.356	1.225	0.985
	ρ/gcm^{-3}	1.2925	1.2904	1.2869	1.2865	1.2820
2.79	$\eta/mPa \cdot s$	2.018	1.781	1.579	1.418	1.149
	ρ/gcm^{-3}	1.3364	1.3334	1.3308	1.3290	1.3253
3.16	$\eta/mPa \cdot s$	2.245	1.969	1.733	1.550	1.238
	ρ/gcm^{-3}	1.3725	1.3720	1.3700	1.3670	1.3617
$x_1 = 0.8$		$g/10^3 \cdot g^2 \cdot cm^{-3} \cdot mol^{-1} = (11.8 \pm 0.2) \cdot 10^{-2}$				
0.34	$\eta/mPa \cdot s$	5.437	4.394	3.626	3.045	2.201
	ρ/gcm^{-3}	0.9592	0.9568	0.9535	0.9510	0.9457
0.68	$\eta/mPa \cdot s$	5.877	4.831	4.068	3.474	2.584
	ρ/gcm^{-3}	0.9980	0.9957	0.9947	0.9925	0.9888
(1.02) ^a lower phase	$\eta/mPa \cdot s$	5.382	4.608	3.983	3.327	2.504
	ρ/gcm^{-3}	1.1538	1.1516	1.1693	1.1771	1.1929
(1.02) ^a upper phase	$\eta/mPa \cdot s$	5.995	4.965	4.130	4.289	2.228
	ρ/gcm^{-3}	0.9685	0.9672	0.9669	0.9282	0.9044
$x_1 = 0.6$						
0.26	$\eta/mPa \cdot s$	5.243	4.343	3.649	3.052	2.239

	$\rho/\text{g cm}^{-3}$	0.8909	0.8889	0.8870	0.8850	0.8800
(0.52) ^a lower phase	$\eta/\text{mPa s}$	4.732	4.102	3.593	3.068	2.432
	$\rho/\text{g cm}^{-3}$	1.2917	1.2892	1.2764	1.2736	1.2674
(0.52) ^a upper phase	$\eta/\text{mPa s}$	4.879	4.073	3.396	2.823	2.016
	$\rho/\text{g cm}^{-3}$	0.8994	0.8968	0.8900	0.8813	0.8688

a: Two phases separate out; values in parentheses being the intended molality in the system if not separated out.

b: The electrolyte salts out.

TABLE 3 COEFFICIENTS OF THE VISCOSITY POLYNOMIAL $H(T)/\text{MPa s} = B_0 + B_1(M/\text{MOL KG}^{-1}) + B_2(M/\text{MOL KG}^{-1})^2 + B_3(M/\text{MOL KG}^{-1})^3$

Electrolyte	coeff.	T/ K				
		288.15	293.15	298.15	303.15	313.15
			$x_1 = 1.0$			
LiCl	b_0	1.0823	0.9517	0.8097	0.7178	0.5933
	b_1	0.4455	0.3878	0.4446	0.4094	0.3406
	b_2	-0.0611	-0.0507	-0.0625	-0.0632	-0.0556
	b_3	0.0046	0.0037	0.0040	0.0040	0.0035
	$\sigma/\text{mPa s}$	± 0.2250	± 0.1882	± 0.2922	± 0.2916	± 0.2265
NaCl	b_0	1.142	0.9998	0.8927	0.7973	0.6547
	b_1	0.0293	0.0414	0.0276	0.0338	0.0470
	b_2	0.0194	0.0068	0.0082	0.0036	-0.0107
	b_3	-0.0007	0.0007	0.0005	0.0009	0.0027
	$\sigma/\text{mPa s}$	± 0.0039	± 0.0087	± 0.0073	± 0.0077	± 0.0070
KCl	b_0	1.142	1.0004	0.8930	0.7955	0.6555
	b_1	-0.0945	-0.0640	-0.0724	-0.0344	-0.0436
	b_2	0.0199	0.0091	0.0269	0.0059	0.0231
	b_3	-0.0020	-0.0002	-0.0040	-0.0002	-0.0040
	$\sigma/\text{mPa s}$	± 0.0024	± 0.0010	± 0.0036	± 0.0025	± 0.0040
KI	b_0	1.1380	0.9980	0.8896	0.7952	0.9560
	b_1	-0.2411	-0.1887	-0.1596	-0.1312	-0.0961
	b_2	0.0447	0.0336	0.0287	0.0243	0.0180
	b_3	-0.0029	-0.0021	-0.0018	-0.0016	-0.0012
	$\sigma/\text{mPa s}$	± 0.0157	± 0.0080	± 0.0114	± 0.0061	± 0.0064
SrCl ₂	b_0	1.1442	1.0014	0.8942	0.7984	0.6582
	b_1	0.1319	0.1336	0.1248	0.0992	0.0819
	b_2	-0.0053	-0.0021	-0.0086	0.0092	0.0068
	b_3	0.0238	0.0183	0.0172	0.0114	0.0084
	$\sigma/\text{mPa s}$	± 0.0252	± 0.0188	± 0.0219	± 0.0187	± 0.0206
LiCl	b_0	5.0113	4.1216	3.2943	2.6757	1.9050
	b_1	1.1967	0.6538	0.7480	0.5488	0.4620
	b_2	-0.2413	-0.0052	-0.1003	-0.0339	-0.0282
	b_3	0.0496	0.0242	0.0258	0.0181	0.0132
	$\sigma/\text{mPa s}$	± 0.0813	± 0.1060	± 0.0732	± 0.0783	± 0.0337
NaCl	b_0	4.9967	4.0883	3.2821	2.6600	1.9112
	b_1	0.0695	0.0617	0.1865	0.2945	0.2378
	b_2	0.1490	0.1272	0.1282	0.1531	-0.0135
	b_3	0.0370	0.0316	0.0318	0.0380	-0.0033
	$\sigma/\text{mPa s}$	± 0.0367	± 0.0313	± 0.0315	± 0.0377	± 0.0033
KCl	b_0	5.0210	4.1090	3.3030	2.6850	1.9090
	b_1	-0.0377	-0.2353	-0.1564	-0.2426	0.2696

	b_2	-1.3019	-1.0420	-0.2811	-0.6445	-0.5017
	b_3	0.8481	0.9287	0.3477	0.4325	0.3392
	$\sigma/\text{mPa}\cdot\text{s}$	0	0	0	0	0
KI	b_0	5.0210	4.1090	3.3030	2.6850	1.9090
	b_1	-1.1116	-0.7584	-0.4175	-0.2578	-0.0444
	b_2	0.3046	0.1633	0.0608	0.0366	-0.0243
	b_3	-0.0302	-0.0078	0.0034	0.0037	0.0109
	$\sigma/\text{mPa}\cdot\text{s}$	0	0	0	0	0
SrCl_2	b_0	5.020	4.1037	3.2989	2.6826	1.9059
	b_1	1.2299	0.8785	0.9816	1.0771	0.8830
	b_2	0.0253	0.1605	0.1257	0.0729	0.0961
	b_3	0.0190	0.1200	0.0904	0.0545	0.0719
	$\sigma/\text{mPa}\cdot\text{s}$	± 0.0018	± 0.0113	± 0.0089	± 0.0051	± 0.0068
$x_1 = 0.6$						
LiCl	b_0	4.9150	4.0690	3.4250	2.8770	2.1130
	b_1	1.8947	1.8206	1.2624	1.1794	0.7394
	b_2	-0.1955	-0.4630	-0.1950	-0.3082	-0.1826
	b_3	0.1058	0.1543	0.0920	0.1019	0.0663
	$\sigma/\text{mPa}\cdot\text{s}$	0	0	0	0	0
KI	b_0	4.8925	4.0524	3.4075	2.8601	2.1034
	b_1	-0.3156	-0.2996	-0.2611	-0.2044	-0.0723
	b_2	0.1038	0.0766	0.0808	0.0777	0.0444
	b_3	0.0183	0.0135	0.0143	0.0137	0.0078
	$\sigma/\text{mPa}\cdot\text{s}$	± 0.0293	± 0.0217	± 0.0228	± 0.0220	± 0.0125
$x_1 = 0.4$						
LiCl	b_0	3.8352	3.1899	2.6921	2.2583	1.6768
	b_1	3.2223	2.8151	2.3746	1.9215	1.3993
	b_2	0.2828	0.1874	0.1356	0.1141	0.0403
	b_3	0.0693	0.0460	0.0332	0.0280	0.0099
	$\sigma/\text{mPa}\cdot\text{s}$	± 0.1557	± 0.1031	± 0.0746	± 0.0628	± 0.0222

IV. CONCLUSION

The ternary system consisting water, propan-2-ol and an electrolyte has been investigated in the present work. Significant changes in interactions are reflected in terms of viscosity and density on varying the solvent composition, electrolyte concentration and temperature. It is observed that there is a relationship between viscosities and charge densities of the ions; ions with higher charge densities form compacter solvation sphere resulting in increase of viscosity. The solvent mixture having water mole fraction of $x_1 = 0.8$ appears to be more structured and at which also the phase separation takes place.

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