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Density and Viscosity of LiCl, LiBr, LiI and KCL in Aqueous Methanol at 313.15K

V. V. KADAM[1]*, A. B. NIKUMBH[2], T. B. PAWAR[3] and V. A. ADOLE[4]

[1]Department of Chemistry, Arts, Science and Commerce College Surgana, Dist. Nashik,
Maharashtra, (Affiliated to SPPU Pune), India.
[2]Department of Chemistry, S.S.G.M. College, Kopargaon Dist. Ahemadnagar,
(Affiliated to SPPU Pune), India.
[3]Department of Chemistry, L.V.H. Arts, Science and Commerce College Panchavati,
Dist. Nashik, Maharashtra, (Affiliated to SPPU Pune), India.
[4]Department of Chemistry, Arts, Science and Commerce college, Manmad,
Dist. Nashik, Maharashtra, (Affiliated to SPPU Pune), India.
*Corresponding author E-mail: kadamvv18@gmail.com

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ABSTRACT

The densities and viscosities of electrolytes are essential to understand many physicochemical processes that are taking place in the solution. In the present research, the densities and viscosities of lithium halides, LiX (X = Cl, Br, I) and KCl in (0, 20, 40, 50, 60, 80 and 100) mass % of methanol + water at 313.15K were calculated employing experimental densities (ρ), the apparent molar volumes (φ_v) and limiting apparent molar volumes (φ^0_v) of the electrolytes. The (φ^0_v) of electrolyte offer insights into solute-solution interactions. In terms of the Jones-Dole equation for strong electrolyte solution, the experimental data of viscosity were explored. Viscosity coefficients A and B have been interpreted and discussed. The B-coefficient values in these systems increase with increase of methanol in the solvents mixtures. This implied that when the dielectric constant of the solvent decreases, so do the solvent-solvent interactions in these systems.

Keywords: Viscosity, Density, Apparent molar volume.

INTRODUCTION

The density and viscosity data of electrolyte solutions have been extremely valuable in determining whether or not ion-solvent interactions exist in aqueous and non-aqueous solutions.[1] For a better knowledge of many physicochemical processes that occur in the chemical industry and in nature, Crystallization, desalination, waste water treatment, pollution control, oil recovery, heat and mass transfer, fluid flow, mineral transport and deposition, corrosion, and other processes all rely on the transport properties (viscosity and thermal conductivity) of aqueous electrolyte solutions in a wide range of solvent concentrations, solution temperatures, and pressures. In many applications, these processes take place at high temperatures and pressures. For understanding ion-solvent interactions, temperatures and concentration dependencies of the viscosity of aqueous electrolyte solutions are indeed important.[2-9]

Viscosity is one of the important transport properties of electrolyte solutions and belongs to a dynamic state property, while density is one of the key thermodynamic features of electrolyte solutions and contributes to an equilibrium property.[10-12] Researchers have explored the use of density and viscosity of mixtures to derive thermodynamic properties like dynamic viscosity, kinematic viscosity, deviations in dynamic viscosity, excess molar volume, surface tension deviation, apparent molar volumes, etc.[13-16]. In this paper we report, limiting apparent molar volume (ϕ^0_v) of some lithium halides LiX (X= Cl Br I) in water + methanol at different temperature using density property. An attempt is to make determine the effect of variation of (ϕ^0_v) with methanol content for a given electrolyte. The viscosities of Lithium halides solution in (0, 20, 40, 50, 60, 80 and 100) mass % of methanol + water at different temperatures to see how changing the solvent content affects the viscosity B-coefficient.

EXPERIMENTAL

Water was distilled over alkaline $KMnO_4$ in a rapid fit system, and then distilled again over H_2SO_4. The electric conductance of distilled water varied between $1x10^{-6}$ and $9x10^{-77}$ Ω^{-1} cm^{-1}. Methanol with A.R. grade from SD Fine Chemical limited was directly used without further purification. LiCl anhydrous was from S D fine Chemicals limited Mumbai product no. 230374, batch no. KO_3Y/0703/1910/31 with purity 99%. LiBr anhydrous was from Sigma-Aldrich product no. 44987-3 batch no. MKBF4487V with purity 99.9%. LiI anhydrous was from Sigma-Aldrich product no. 43974-6 batch no. MKBD 2730 with purity 99.9%.KCl was from SD Fine Chemical limited Mumbai product no. 20198, batch no.KO_5, H10Y/0710/1408/31 with purity 99.5%.

By mixing known quantities of water and methanol in glass-stoppered flasks, methanol + water mixes of compositions (0, 20, 40, 50, 60, 80, and 100) mass percent methanol were prepared. A bicapillary pycnometer was used to measure the density of the solution, with an accuracy of ± 1×10^{-4} g/cm^3 as described earlier[17-19]. The pycnometer was placed in a temperature-controlled water bath with thermal stability of ± 0.01K for 15 min to attain thermal equilibrium. An Ubbelohde suspended level viscometer was used to measure viscosities[20-22]. Water conductivity was used to calibrate the device. For the flow time measurements, an electronic digital stop watch with a readability of ±0.01s was employed.

RESULTS AND DISCUSSION

The values of experimentally determined density for the pure liquids at are given in Table 1. Experimental densities (ρ) and viscosities (η) of pure liquids were in good agreement with literature values at different temperatures. The densities of LiCl, LiBr, LiI and KCl solutions having concentrations ranging between 0.005 to 0.05 M in 0, 20, 40, 50, 60, 80 and 100 wt% of water + methanol binary mixtures at different temperatures are measured. The observed densities ρ, of the solutions Lithium halides in water, methanol and methanol + water mixtures are used to calculate the apparent malar volumes ϕ_v using the equation.

$$\phi_v = [1000\ (\rho_0-\rho\ )/(Cx\rho_0\ )] + (M/\rho_0\ ) \qquad (1)$$

Where ρ and ρ_0 are the densities of solution and solvents respectively, C is the concentration in mol liter^{-1}. The densities ρ and apparent molar volumes ϕ_v, for LiCl, LiBr, LiI and KCl in different methanol + water mixtures at 313.15 K are given in the Table 2 and Table 3. The densities and viscosities of LiCl, LiBr, LiI and KCl were found to increase with the increase in concentration of electrolytes. ϕ_v varied linearly with $C^{1/2}$ over the concentration range. The electrolytes' limiting partial molar volume (ϕ^0_v) was calculated using computerised least square fitting of the Masson equation 2.

$$\phi_v = \phi^0_v + S_v\ C^{1/2} \qquad (2)$$

Where 'ϕ^0_v' is the limiting partial malar volume at infinite dilution and S_v is the experimental slope. The ϕ^0_v and S_v values are presented in Table 4. The ϕ^0_v is regarded as a measure of solute-solvent interactions. The ϕ^0_v for LiCl, LiBr and LiI is increases regularly as the size of lithium halide increases. As the solvent composition varies, the values of ϕ^0_v vary as well. Various researchers have seen a shift in

ϕ^0_v with different concentrations of other solvents in water in the case of electrolytes.[23-25] The S_v values of LiCl are negative in water and methanol mixtures at 50% methanol indicating some ion-ion interactions shown in Table 4. Similarly, the S_v values of LiBr are negative in water and methanol mixtures at 40% and 50% methanol and LiI shows it negative at 40, 50, 60% methanol indicating ion-ion interactions. The negative slope indicating the ionic dissociation of the electrolytes[26].

The ϕ^0_v values for lithium halides in water and water + methanol are plotted against molecular weight of corresponding halide ions using an equation of the form

$$\phi^0_v = \phi^0_v \text{ (Li)} + b \text{ (Mol. Wt. of halide ions)} \qquad (3)$$

Where 'b' is constant and ϕ^0_v (Li) is the limiting ionic partial molar volume of Li^+ ions. The plot of ϕ^0_v of electrolytes versus molecular weight of corresponding halide ions is given in the Fig. 1. An excellent linear relationship was observed for all lithium halides solutions in all solvents with γ greater than 0.9999. The extrapolation of graphs of ϕ^0_v versus molecular weight of halide ion to zero ionic formula weight gives the partial molar volume of Li^+ ion. The Table 5 represents the value of ionic partial malar volumes of all the ions in all solvents at 313.15K. It demonstrates that the ionic partial molar volumes of halides ions (X^-) fluctuate with the solvent composition over time, peaking at 20% methanol. There are no more holes in the binary solvents at 20% methanol, and the dissolving of the third component, the solute, necessitates the solvent's maximum expansion to accommodate the solute. As a result, there should be a peak in the partial molar volume of the halides ions (X^-).

The viscosities of solutions of the LiCl, LiBr, LiI and KCl in water methanol and methanol-water mixtures are measured at 313.15 K. The observed viscosities η, of Lithium halides in water, methanol and methanol + water mixtures at 313.15K are analysed with the help of Jones-Dole equation[22].

$$\eta_r = (\eta / \eta_o) = 1 + AC^{1/2} + BC \qquad (4)$$

Where η is the viscosity of the solution and η_o is the viscosity of the solvent, and C is the molar concentration. A is the measure of long range Columbic forces between ions, while B reflects the effect of ion- solvent interactions. Plots of $(\eta_r - 1)/C^{1/2}$ versus $C^{1/2}$ for the electrolytes are straight lines with intercept equal to A, and the slope give the values of the viscosity B-coefficients. The A and B coefficients obtained with a computerised least square method are listed in Table 6. Fig. 2 depicts plots of $(\eta_r - 1)/C^{1/2}$ versus $C^{1/2}$ of LiCl in different methanol + water mixtures at 313.15 K.

There is a slow variety in ionic B esteems as the methanol content in the blended dissolvable increments. Both methanol and water are solvents which have intermolecular hydrogen holding. The expansion of methanol to water, first reinforces the three dimensional construction of the water, then, at that point further expansion of methanol causes depolymerisation of water structure, however intermolecular communication among methanol and water lead to arrangement of methanol-water edifices with a greater hydrodynamic element.

The B values of all lithium halides electrolytes (LiCl, LiBr, and LiI) are positive in all solvent compositions and continuously increases with increase of methanol. These positive B-parameters indicate structure making tendency of lithium halides in these solvent mixture. The B-coefficient of the KCl solutions in 50 to 100 wt% methanol are positive and continuously increases with increases of methanol. These positive B-parameters indicate structure making tendency of KCl in these solvents mixtures. The B-coefficient of KCl falls from solution in water to those in 20 to 40 wt% methanol but then rises again in the subsequent solvent mixtures. A-coefficients either positive or negative are very low in magnitudes indicating weak solute- solute interaction.

Table 1: Comparison of Experimental Densities (ρ) and Viscosities (η) of Pure Liquids with Literature Values at different temperatures

Temp. K)	ρ_o (g/ cm³)		η_0 (m Pa s)	
	Expl.	Lit.	Expl.	Lit.
		Water		
298.15	0.99706	0.997127 0.9970528	0.8944	0.894928 0.890329
303.15	0.9957	0.995727	0.7987	0.8003
308.15	0.99405	0.9944063	0.7195	0.72127
313.15	0.99208	0.992327 0.992231	0.6538	0.65427 0.6526332
		Methanol		
298.15	0.78662	0.7866228	0.549	0.54433
303.15	0.78139	(0.7825-0.78181)33	0.5126	0.50727
308.15	0.7764	0.77699034	0.4787	0.47427
313.15	0.7713	0.772327	0.4477	0.45027

Table 2: Densities ρ, apparent molar volumes ϕ_v, and viscosities η, for LiCl and LiBr in different methanol + water mixtures at 313.15K

		LiCl				LiBr	
C/mol.dm^{-3}	ρ/g.cm^{-3}	ϕv/cm^3. mol^{-1}	η/mPa s	C/mol.dm^{-3}	ρ/g.cm^{-3}	ϕ_v /cm^3. mol^{-1}	η/mPa s 0% Methanol
0.0050	0.99228	18.99	0.6603	0.0059	0.99252	25.39	0.6603
0.0120	0.99244	19.09	0.6612	0.0103	0.99279	25.45	0.6608
0.0160	0.99253	19.14	0.6617	0.0160	0.99314	25.55	0.6614
0.0207	0.99264	19.19	0.6622	0.0206	0.99343	25.59	0.6619
0.0257	0.99276	19.24	0.6628	0.0270	0.99382	25.68	0.6625
0.0310	0.99288	19.28	0.6634	0.0303	0.99402	25.70	0.6628
0.0351	0.99298	19.31	0.6639	0.0360	0.99437	25.75	0.6633
0.0420	0.99313	19.36	0.6646	0.0400	0.99461	25.80	0.6637
0.0454	0.99321	19.38	0.6650	0.0462	0.99499	25.88	0.6643
0.0508	0.99334	19.42	0.6656	0.0515	0.99531	25.93	0.6647
20 % Methanol							
0.0051	0.95795	13.05	0.9663	0.0053	0.95814	24.68	0.9680
0.0105	0.95811	13.10	0.9677	0.0123	0.95858	24.81	0.9705
0.0168	0.95830	13.15	0.9691	0.0162	0.95882	24.88	0.9717
0.0201	0.95840	13.17	0.9698	0.0203	0.95908	24.95	0.9728
0.0256	0.95856	13.21	0.9710	0.0267	0.95948	25.02	0.9745
0.0305	0.95871	13.24	0.9720	0.0294	0.95965	25.05	0.9752
0.0365	0.95888	13.27	0.9732	0.0347	0.95998	25.11	0.9765
0.0413	0.95903	13.29	0.9741	0.0408	0.96036	25.17	0.9779
0.0474	0.95921	13.32	0.9753	0.0457	0.96067	25.20	0.9791
0.0510	0.95931	13.33	0.9760	0.0528	0.96111	25.26	
40 % Methanol							
0.0058	0.92147	9.74	1.4296	0.0051	0.92162	22.35	1.1280
0.0127	0.92170	9.75	1.4368	0.0111	0.92202	22.30	1.1318
0.0155	0.92180	9.75	1.4393	0.0158	0.92233	22.27	1.1344
0.0209	0.92198	9.76	1.4438	0.0220	0.92274	22.24	1.1375
0.0268	0.92218	9.77	1.4483	0.0247	0.92292	22.23	1.1388
0.0336	0.92240	9.78	1.4532	0.0314	0.92337	22.20	1.1419
0.0355	0.92247	9.78	1.4545	0.0350	0.9236	22.18	1.1435
0.0400	0.92262	9.78	1.4575	0.0428	0.92412	22.15	1.1468
0.0467	0.92284	9.79	1.4619	0.0448	0.92426	22.14	1.1476
0.0525	0.92303	9.80	1.4656	0.0513	0.92469	22.12	
50 % Methanol							
0.0052	0.90038	7.05	1.1174	0.0065	0.90065	17.83	1.1086
0.0103	0.90056	7.00	1.1263	0.0104	0.90093	17.77	1.1122
0.0168	0.90080	6.96	1.1354	0.0153	0.90128	17.70	1.1162
0.0200	0.90091	6.94	1.1394	0.0211	0.90169	17.63	1.1205
0.0260	0.90113	6.91	1.1463	0.0263	0.90206	17.58	1.1241
0.0296	0.90126	6.89	1.1502	0.0319	0.90246	17.53	1.1279
0.0362	0.90150	6.86	1.1570	0.0340	0.90261	17.51	1.1292
0.0418	0.90171	6.84	1.1625	0.0416	0.90315	17.46	1.1340
0.0456	0.90184	6.83	1.1660	0.0445	0.90336	17.44	1.1358
0.0513	0.90205	6.81	1.1712	0.0502	0.90376	17.41	
60 % Methanol							
0.00497	0.86746	2.96	1.0232	0.0055	0.86767	14.63	1.0103
0.0111	0.86770	2.98	1.0369	0.0105	0.86804	14.64	1.0160
0.0158	0.86789	2.99	1.0456	0.0164	0.86848	14.65	1.0220
0.0205	0.86808	3.00	1.0534	0.0216	0.86886	14.66	1.0268
0.0251	0.86826	3.01	1.0604	0.0263	0.86921	14.67	1.0310
0.0314	0.86851	3.02	1.0695	0.0313	0.86958	14.68	1.0353
0.0356	0.86868	3.03	1.0752	0.0362	0.86994	14.69	1.0395
0.0409	0.86889	3.04	1.0821	0.0392	0.87017	14.69	1.0419
0.0452	0.86906	3.05	1.0875	0.0462	0.87068	14.70	1.0475
0.0505	0.86927	3.06		0.0509	0.87103	14.71	
80 % Methanol							
0.0050	0.83033	-1.20	0.7993	0.0056	0.83055	10.85	0.7873
0.0100	0.83054	-1.16	0.8098	0.0102	0.8309	10.98	0.7921
0.0165	0.83083	-1.12	0.8209	0.0153	0.8313	11.09	0.7968
0.0196	0.83096	-1.10	0.8256	0.0214	0.83177	11.21	0.8020
0.0249	0.83119	-1.08	0.8332	0.0253	0.83207	11.30	0.8051
0.0306	0.83143	-1.05	0.8407	0.0327	0.83264	11.42	0.8108

0.0364	0.83168	-1.01	0.8480	0.0345	0.83278	11.46	0.8122
0.0407	0.83187	-0.99	0.8531	0.0388	0.83311	11.54	0.8154
0.0454	0.83207	-0.97	0.8586	0.0464	0.83369	11.63	0.8209
0.0520	0.83236	-0.95		0.0517	0.8341	11.69	
100 % Methanol							
0.0053	0.77248	-1.75	0.0053	0.0059	0.77273	7.55	0.4597
0.0100	0.77269	-1.68	0.0100	0.0103	0.77308	8.12	0.4598
0.0155	0.77293	-1.65	0.0155	0.0167	0.77359	8.56	0.4605
0.0206	0.77315	-1.61	0.0206	0.0214	0.77397	8.69	0.4612
0.0269	0.77342	-1.56	0.0269	0.0259	0.77432	8.97	0.4620
0.0290	0.77351	-1.54	0.0290	0.0326	0.77485	9.19	0.4633
0.0365	0.77384	-1.50	0.0365	0.0371	0.7752	9.50	0.4642
0.0403	0.77401	-1.49	0.0403	0.0413	0.77553	9.62	0.4651
0.0450	0.77421	-1.47	0.0450	0.0447	0.7758	9.62	0.4659
0.0492	0.77439	-1.45	0.0492	0.0498	0.7762	9.88	

Table 3: Densities ρ, apparent molar volumes ϕ_v, and viscosities η, for LiI and KCl in different methanol + water mixtures at 313.15K

		LiI				KCl	
$C/mol.dm^{-3}$	$\rho/g.cm^{-3}$	$\phi_v/cm^3.mol^{-1}$	η/mPa s	$C/mol.dm^{-3}$	$\rho/g.cm^{-3}$	$\phi_v/cm^3.mol^{-1}$	η/mPa s
0 % Methanol							
0.0051	0.99265	37.23	0.6599	0.0054	0.99241	29.26	0.6599
0.0101	0.99314	37.27	0.6603	0.0099	0.99261	29.48	0.6601
0.0156	0.99367	37.30	0.6607	0.0158	0.99287	29.78	0.6604
0.0201	0.99411	37.32	0.6610	0.0203	0.99307	29.96	0.6605
0.0251	0.99459	37.34	0.6613	0.0253	0.99329	30.08	0.6607
0.0299	0.99505	37.36	0.6616	0.0296	0.99348	30.19	0.6609
0.0344	0.99549	37.38	0.6619	0.0352	0.99373	30.24	0.6610
0.0400	0.99603	37.40	0.6623	0.0402	0.99395	30.31	0.6612
0.0500	0.99699	37.43	0.6629	0.0450	0.99416	30.39	0.6613
				0.0501	0.99438	30.48	0.6615
20 % Methanol							
0.0053	0.95833	36.12	0.9749	0.0152	0.95854	27.01	0.9663
0.0109	0.95888	36.25	0.9799	0.0208	0.95882	26.64	0.9666
0.0201	0.95979	36.38	0.9860	0.0254	0.95904	26.86	0.9669
0.0251	0.96028	36.45	0.9888	0.0304	0.95928	27.01	0.9672
0.0313	0.96089	36.51	0.9920	0.0352	0.95950	27.41	0.9674
0.0349	0.96125	36.55	0.9938	0.0401	0.95974	27.32	0.9677
0.0398	0.96173	36.60	0.9961	0.0463	0.96003	27.55	0.9679
0.0523	0.96296	36.71	1.0014	0.0504	0.96022	27.70	0.9681
0.0554	0.96326	36.74	1.0027	0.0554	0.96046	27.70	0.9683
40 % Methanol							
0.0056	0.92187	30.81	1.1244	0.0152	0.92211	22.01	1.1223
0.0098	0.92231	30.77	1.1258	0.0202	0.92237	22.24	1.1223
0.0199	0.92338	30.70	1.1287	0.0254	0.92265	22.42	1.1223
0.0261	0.92403	30.66	1.1305	0.0305	0.92292	22.59	1.1223
0.0306	0.92451	30.64	1.1317	0.0351	0.92316	22.78	1.1223
0.0354	0.92502	30.62	1.1330	0.0401	0.92342	22.99	1.1223
0.0412	0.92563	30.59	1.1346	0.0451	0.92368	23.16	1.1223
0.0496	0.92652	30.56	1.1368	0.0503	0.92395	23.30	1.1223
0.0551	0.92710	30.54	1.1382	0.0551	0.92420	23.40	1.1223
50 % Methanol							
0.0047	0.90071	25.78	1.1029	0.0051	0.90048	19.65	1.0990
0.0107	0.90137	25.65	1.1064	0.0108	0.90080	20.17	1.1000
0.0203	0.90244	25.50	1.1114	0.0201	0.90131	20.92	1.1016
0.0249	0.90295	25.44	1.1136	0.0266	0.90167	21.22	1.1027
0.0319	0.90373	25.36	1.1169	0.0318	0.90195	21.51	1.1037
0.0350	0.90408	25.33	1.1184	0.0351	0.90212	21.73	1.1043
0.0399	0.90462	25.27	1.1206	0.0416	0.90247	21.93	1.1054
0.0504	0.90579	25.18	1.1252	0.0497	0.90291	22.13	1.1069
0.0551	0.90632	25.14	1.1273	0.0551	0.90319	22.27	1.1079
60 % Methanol							
0.0049	0.86782	22.27	1.0070	0.0054	0.86759	14.86	1.0007
0.0109	0.86851	22.23	1.0125	0.0094	0.86784	15.18	1.0019
0.0225	0.86984	22.18	1.0217	0.0230	0.86866	15.77	1.0058

0.0254	0.87017	22.17	1.0238	0.0267	0.86888	16.00	1.0069
0.0301	0.87071	22.16	1.0272	0.0305	0.86911	16.21	1.0080
0.0352	0.87129	22.15	1.0307	0.0362	0.86944	16.52	1.0097
0.0410	0.87196	22.13	1.0347	0.0430	0.86984	16.78	1.0117
0.0498	0.87297	22.11	1.0406	0.0528	0.87041	17.17	1.0146
0.0551	0.87358	22.10	1.0441	0.0551	0.87055	17.22	1.0153
				80 % Methanol			
0.0061	0.83083	19.39	0.7858	0.0058	0.83049	11.92	0.7788
0.0110	0.83140	19.56	0.7900	0.0106	0.83079	12.07	0.7804
0.0199	0.83245	19.77	0.7967	0.0203	0.83141	12.72	0.7837
0.0242	0.83295	19.86	0.7998	0.0255	0.83174	12.90	0.7856
0.0319	0.83385	19.99	0.8049	0.0317	0.83213	13.23	0.7877
0.0354	0.83426	20.06	0.8072	0.0365	0.83243	13.37	0.7894
0.0413	0.83495	20.15	0.8110	0.0401	0.83265	13.50	0.7907
0.0508	0.83605	20.30	0.8169	0.0512	0.83334	13.83	0.7946
0.0551	0.83655	20.36	0.8195	0.0551	0.83358	13.94	0.7960
				100 % Methanol			
0.0067	0.77307	15.13	0.4574	0.0057	0.77266	2.60	0.4638
0.0103	0.77351	15.46	0.4569	0.0107	0.77302	2.99	0.4653
0.0197	0.77464	16.10	0.4567	0.0206	0.77373	3.50	0.4686
0.0253	0.77531	16.44	0.4570	0.0261	0.77412	3.76	0.4705
0.0312	0.77602	16.71	0.4574	0.0309	0.77446	3.92	0.4721
0.0357	0.77656	16.93	0.4579	0.0358	0.77481	4.08	0.4738
0.0410	0.77719	17.18	0.4585	0.0411	0.77518	4.29	0.4756
0.0520	0.77850	17.60	0.4600	0.0508	0.77586	4.62	0.4790
0.0551	0.77887	17.71	0.4604	0.0556	0.77619	4.77	0.4806

Table 4: Apparent molar volumes, (ϕ^0_v, cm^3 mol^{-1}) and experimental slopes (S_v cm^3 L$^{1/2}$ mol$^{-3/2}$), along with correlation coefficient, γ, of Lithium halides in different water + methanol at 313.15K.

Electrolyte	Mass% methanol	ϕ^0_v/cm^3 mol^{-1}	S_v/cm^3 L$^{1/2}$ mol$^{-3/2}$	γ
LiCl				
	0	18.79	2.78	0.9998
	20	12.91	1.86	0.9993
	40	9.17	0.39	0.9868
	50	7.16	-1.56	-0.9996
	60	2.91	0.64	0.9951
	80	-1.33	1.63	0.9960
	100	-1.89	2.01	0.9975
LiBr				
	0	25.09	3.58	0.9955
	20	24.41	3.75	0.9993
	40	22.46	-1.48	-0.9991
	50	18.07	-2.99	-0.9992
	60	14.59	0.54	0.9933
	80	10.41	5.65	0.9988
	100	6.50	15.19	0.9951
LiI				
	0	37.14	1.31	0.9995
	20	35.85	3.77	0.9998
	40	30.94	-1.70	-0.9998
	50	26.05	-3.87	-0.9999
	60	22.34	-1.02	-0.9983
	80	18.91	6.15	0.9997
	100	13.74	16.91	0.9999
KCl				
	0	28.74	8.00	0.9891
	20	25.58	9.00	0.8923
	40	20.40	12.90	0.9981
	50	18.52	16.50	0.9962
	60	13.68	14.83	0.9943
	80	10.81	13.35	0.9968
	100	1.59	13.39	0.9996

Table 5: Ionic partial molar volumes, φ^0_v of ions in various methanol + water mixtures at 313.15K

%Methanol	K^+	Cl^-	Br^-	I^-	Li^+
0	20.71	8.03	14.33	26.38	10.76
20	16.81	8.77	20.27	31.71	4.14
40	13.56	6.84	20.13	28.61	2.33
50	11.80	6.72	17.63	25.61	0.44
60	6.93	6.75	18.43	26.18	-3.84
80	3.63	7.18	18.92	27.42	-8.51
100	-4.19	5.78	14.17	24.41	-7.67

Table 6: Parameters of Jones-Dole Equation A and B along with correlation coefficient, γ, for Lithium halides in different water + methanol at 313.15K

Electrolyte	Mass% methanol	A/dm$^{3/2}$. mol$^{-1/2}$	B/dm^3. mol^{-1}	γ
LiCl				
	0	0.0085	0.1471	0.9995
	20	0.0162	0.1645	0.9997
	40	0.0883	0.2053	0.9998
	50	0.2171	0.3354	1.0000
	60	0.3009	0.538	1.0000
	80	0.3584	0.6271	1.0000
	100	-0.0276	0.8181	0.9999
LiBr				
	0	0.0090	0.1180	0.9991
	20	0.0414	0.1392	0.9995
	40	0.0596	0.2303	0.9999
	50	0.0866	0.3471	0.9999
	60	0.1077	0.5428	1.0000
	80	0.1292	0.6135	1.0000
	100	-0.1322	0.8034	1.0000
LiI				
	0	0.0045	0.0859	0.9987
	20	0.1415	0.1159	0.9995
	40	0.0150	0.2003	0.9999
	50	0.0395	0.3106	0.9999
	60	0.0755	0.4915	1.0000
	80	0.0985	0.5708	1.0000
	100	-0.1862	0.7240	1.0000
KCl				
	0	0.0089	0.0230	09724
	20	0.0143	0 .0125	0.9417
	40	0.0045	-0.0141	-0.9906
	50	-0.0032	0.1721	0.9998
	60	-0.0029	0.3026	0.9943
	80	-0.0074	0.4728	1.0000
	100	-0.0152	0.7809	0.9999

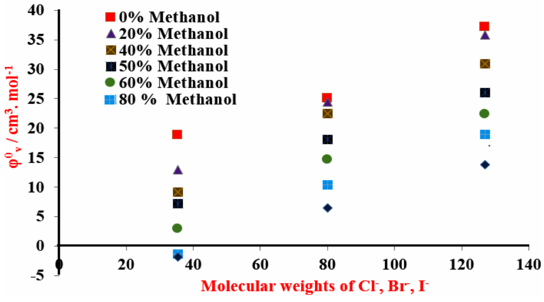

Fig. 1. Plots of ϕ^0_v versus Molecular weights of Cl^-, Br^-, I^- in different methanol + water mixtures at 313.15 K

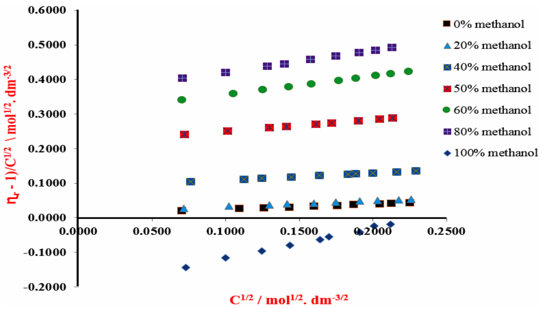

Fig. 2. Plots of $(\eta_r\text{-}1)/C^{1/2}$ versus $C^{1/2}$ of LiCl in different methanol + water mixtures at 313.15 K

CONCLUSION

In summary, density and viscosity of four alkali chlorides and iodides namely LiCl, LiBr, LiI and KCl in aqueous methanol at 313.15 K were calculated using the electrolytes' experimental densities, apparent molar volumes, and limiting apparent molar volumes. The experimental data on viscosity of these electrolytes were interpreted using the Jones-Dole equation for strong electrolyte solutions. The densities and viscosities of LiCl, LiBr, LiI and KCl were found to increase with the increase in concentration of electrolytes. The apparent molar volumes varied linearly with $C^{1/2}$ over the concentration range. Our investigation on density and viscosity of the electrolytic solution studied in the revealed that when the dielectric constant of the solvent decreases, so also the solvent-solvent interactions in these systems. Furthermore, the experimental densities and viscosities of pure liquids were found to be in acceptable concurrence with reported values at various temperatures. In all solvent compositions, the B values of all lithium halide electrolytes are positive and increase with increasing methanol concentration. These positive B-parameters imply that lithium halides in these solvent mixtures have a tendency to form structures.

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Conflict of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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