Viscosities of Some Alkali Metal Salts in 2-Methoxyethanol + Water at 298.15, 308.15, and 318.15 K

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The viscosities of solutions of lithium perchlorate ($LiClO_4$), lithium tetrafluoroborate ($LiBF_4$), lithium hexafluoroarsenate ($LiAsF_6$), and sodium perchlorate ($NaClO_4$) in 2-methoxyethanol (1) + water (2) have been measured at 298.15, 308.15, and 318.15 K. The data have been analyzed by the Jones−Dole equation for the associated as well as unassociated electrolytes to evaluate the viscosity *B* coefficients of the electrolytes. The resulting *B* coefficient and its dependence on temperature provide useful information regarding changes in the solvent structure.

Introduction

Recently, we have reported the results of conductivity (Das and Hazra, 1996) and viscosity (Das et al., 1999) measurements on some symmetrical tetraalkylammonium perchlorates in 2-methoxyethanol (1) + water (2) mixtures ranging in composition from 20 to 80 mass % 2-methoxyethanol. We have also reported (Das and Hazra, 1998) the conductances of lithium perchlorate, lithium tetrafluoroborate, lithium hexafluoroarsenate, and sodium perchlorate in the same solvent mixtures at 298.15 K. Now, we have extended the work on the alkali metal salts to study the viscometric behavior of these electrolytes at three different temperatures in the same solvent mixtures at $x_1 = 0.056$, 0.136, 0.262, and 0.486, and the results are reported in this communication.

Experimental Section

2-Methoxyethanol (ME; G.R.E. Merck, >99% pure) was distilled twice in an all glass distillation set, and the middle fraction distilling between 397.15 and 398.15 K was collected. The purified solvent had a specific conductance $< (1-3) \times 10^{-7}$ S·cm^{-1}. Triply distilled water with a specific conductance $< 10^{-6}$ S·cm^{-1} was used for the preparation of the solvent mixtures. The physical properties of ME + water mixtures at 298.15, 308.15, and 318.15 K have been reported in Table 1.

The salts were of Fluka purum or puriss grade. Lithium perchlorate was recrystallized three times from conductivity water and then dried under vacuum for several days. Lithium tetrafluoroborate and lithium hexafluoroarsenate were dried under vacuum at high temperatures and were used without further purification. Sodium perchlorate was recrystallized several times from water + methanol mixtures and dried under vacuum.

A stock solution for each salt was prepared by mass, and the working solutions were obtained by mass dilution. The conversion of the molality into molarity was done using the density values.

The densities ρ were measured with an Ostwald−Sprengel type pycnometer having a bulb volume of 25 cm^3 and an internal diameter of the capillary of about 0.1 cm. The pycnometer was calibrated at 298.15, 308.15, and 318.15 K with triply distilled water and benzene. The temperature of the bath was controlled to ±0.01 K. Details have been described earlier (Das and Hazra, 1993, 1995a; Saha et al., 1995). The reproducibility of the density measurements was $\pm(3 \times 10^{-5})$ g·cm^{-3}.

Table 1. Densities ρ and Viscosities η_0 of 2-Methoxyethanol (1) + Water (2) Mixtures at 298.15, 308.15, and 318.15 K

x_1	ρ/g·cm^{-3}	η_0/mPa·s
	298.15 K	
0.056	1.00240	1.5165
0.136	1.00690	2.3654
0.262	1.00233	2.8849
0.486	0.98672	2.5751
1.000	0.96002	1.5414
	308.15 K	
0.056	0.99680	1.1533
0.136	1.00030	1.7280
0.262	0.99472	2.1510
0.486	0.97810	2.0213
1.000	0.95356	1.2579
	318.15 K	
0.056	0.99267	0.9051
0.136	0.99327	1.2745
0.262	0.98657	1.5878
0.486	0.96960	1.6236
1.000	0.94715	1.0400

The kinematic viscosities ν were measured by means of a suspended Ubbelohde viscometer. The time of efflux was measured with a stopwatch to ±0.1 s. The viscometer was kept in a vertical position in a water thermostat controlled to ±0.01 K. The absolute temperature was determined with a calibrated platinum resistance thermometer and a Muller bridge. The efflux time for water at 298.15 K was about 540 s. The kinematic viscosity ν and the absolute viscosity η are given by the following equations:

$$\nu = Ct - K/t \quad (1)$$

$$\eta = \nu\rho \quad (2)$$

where t is the efflux time, ρ is the density, and C and K are the characteristic constants of the viscometer. The values of the constants C and K determined by using the density and viscosity values of water and benzene (Saha et al., 1995) were found to be 1.648×10^{-5} cm^2·s^{-2} and −0.023 316 47 cm^2, respectively. The estimated error of the viscosity measurements was ±0.4%.

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Table 2. Concentration c, Density ρ, and Relative Viscosity η_r of Lithium Perchlorate, Lithium Tetrafluoroborate, Lithium Hexafluoroarsenate, and Sodium Perchlorate in 2-Methoxyethanol (1) + Water (2) Mixtures at 298.15, 308.15, 318.15 K[a]

c/mol·dm^{-3}	ρ/g·cm^{-3}	η_r	c/mol·dm^{-3}	ρ/g·cm^{-3}	η_r	c/mol·dm^{-3}	ρ/g·cm^{-3}	η_r	c/mol·dm^{-3}	ρ/g·cm^{-3}	η_r
$LiClO_4$ at 298.15 K											
$x_1 = 0.056$ ($\Lambda° = 67.39$, $K_A = 4.02$)			$x_1 = 0.136$ ($\Lambda° = 50.07$, $K_A = 7.39$)			$x_1 = 0.262$ ($\Lambda° = 36.38$, $K_A = 17.06$)			$x_1 = 0.486$ ($\Lambda° = 31.79$, $K_A = 42.34$)		
0.01233	1.00388	1.0021	0.01163	1.00869	1.0030	0.01032	1.00420	1.0058	0.01054	0.98755	1.0068
0.02098	1.00492	1.0033	0.01978	1.00995	1.0048	0.02008	1.00597	1.0123	0.02061	0.98834	1.0133
0.02502	1.00540	1.0038	0.02505	1.01076	1.0059	0.02506	1.00688	1.0160	0.02595	0.98876	1.0168
0.03061	1.00607	1.0045	0.03106	1.01169	1.0071	0.03012	1.00780	1.0200	0.03120	0.98917	1.0203
0.04146	1.00737	1.0059	0.04032	1.01312	1.0091	0.04065	1.00971	1.0288	0.04002	0.98987	1.0265
0.05234	1.00867	1.0072	0.05224	1.01496	1.0115	0.05120	1.01162	1.0383	0.05010	0.99066	1.0336
$LiBF_4$ at 298.15 K											
$x_1 = 0.056$ ($\Lambda° = 64.64$, $K_A = 3.42$)			$x_1 = 0.136$ ($\Lambda° = 49.49$, $K_A = 5.57$)			$x_1 = 0.262$ ($\Lambda° = 35.56$, $K_A = 11.84$)			$x_1 = 0.486$ ($\Lambda° = 30.64$, $K_A = 44.40$)		
0.01006	1.00336	1.0021	0.01966	1.00939	1.0052	0.00986	1.00378	1.0063	0.01006	0.98732	1.0115
0.02132	1.00443	1.0039	0.02581	1.01017	1.0066	0.02008	1.00528	1.0137	0.02132	0.98798	1.0283
0.02568	1.00485	1.0045	0.03245	1.01101	1.0081	0.02542	1.00607	1.0179	0.02568	0.98824	1.0355
0.03094	1.00535	1.0053	0.04677	1.01282	1.0113	0.03010	1.00676	1.0219	0.03094	0.98855	1.0445
0.04120	1.00632	1.0067	0.06011	1.01461	1.0142	0.04125	1.00840	1.0317	0.03601	0.98886	1.0537
0.05582	1.00772	1.0086	0.07014	1.01578	1.0164	0.05060	1.00997	1.0406	0.04856	0.98960	1.0775
$LiAsF_6$ at 298.15 K											
$x_1 = 0.056$ ($\Lambda° = 45.37$, $K_A = 2.48$)			$x_1 = 0.136$ ($\Lambda° = 38.89$, $K_A = 4.36$)			$x_1 = 0.262$ ($\Lambda° = 23.71$, $K_A = 7.35$)			$x_1 = 0.486$ ($\Lambda° = 27.43$, $K_A = 25.87$)		
0.01061	1.00354	1.0025	0.01020	1.00799	1.0033	0.01015	1.00295	1.0061	0.01205	0.98900	1.0114
0.02091	1.00465	1.0042	0.02011	1.00906	1.0061	0.02004	1.00356	1.0112	0.02062	0.99062	1.0191
0.02523	1.00512	1.0048	0.02501	1.00958	1.0074	0.02496	1.00387	1.0136	0.02501	0.99145	1.0232
0.03011	1.00564	1.0055	0.03010	1.01013	1.0087	0.03012	1.00418	1.0162	0.03010	0.99241	1.0278
0.04001	1.00671	1.0070	0.03750	1.01093	1.0107	0.03998	1.00479	1.0210	0.04126	0.99452	1.0382
0.05407	1.00823	1.0089	0.05123	1.01240	1.0142	0.05046	1.00544	1.0261	0.05009	0.99618	1.0465
$NaClO_4$ at 298.15 K											
$x_1 = 0.056$ ($\Lambda° = 87.22$, $K_A = 3.18$)			$x_1 = 0.136$ ($\Lambda° = 56.06$, $K_A = 4.88$)			$x_1 = 0.262$ ($\Lambda° = 41.32$, $K_A = 10.64$)			$x_1 = 0.486$ ($\Lambda° = 33.30$, $K_A = 39.35$)		
0.01322	1.00436	1.0018	0.01206	1.00901	1.0028	0.01012	1.00392	1.0042	0.01050	0.98693	1.0070
0.02297	1.00581	1.0024	0.02075	1.01053	1.0042	0.02094	1.00562	1.0098	0.02009	0.98713	1.0147
0.03269	1.00725	1.0030	0.02614	1.01148	1.0050	0.02498	1.00626	1.0120	0.02518	0.98723	1.0193
0.04387	1.00891	1.0035	0.03115	1.01235	1.0058	0.03031	1.00709	1.0153	0.03106	0.98735	1.0249
0.05045	1.00988	1.0039	0.04056	1.01400	1.0071	0.04052	1.00870	1.0218	0.04089	0.98756	1.0347
0.05609	1.01072	1.0041	0.05118	1.01586	1.0086	0.05117	1.01037	1.0291	0.05061	0.98775	1.0451
$LiClO_4$ at 308.15 K											
$x_1 = 0.056$			$x_1 = 0.136$			$x_1 = 0.262$			$x_1 = 0.486$		
0.01226	0.99818	1.0025	0.01155	1.00185	1.0035	0.01023	0.99554	1.0071	0.01045	0.97943	1.0089
0.02086	0.99915	1.0040	0.01964	1.00293	1.0056	0.01989	0.99631	1.0149	0.02047	0.98071	1.0176
0.02487	0.99960	1.0046	0.02487	1.00363	1.0069	0.02481	0.99670	1.0193	0.02577	0.98138	1.0224
0.03043	1.00022	1.0055	0.03084	1.00443	1.0084	0.02980	0.99710	1.0240	0.03098	0.98205	1.0272
0.04122	1.00144	1.0072	0.04002	1.00556	1.0107	0.04018	0.99793	1.0342	0.03975	0.98317	1.0354
0.05203	1.00265	1.0089	0.05184	1.00724	1.0135	0.05055	0.99876	1.0451	0.04979	0.98445	1.0449
$LiBF_4$ at 308.15 K											
$x_1 = 0.056$			$x_1 = 0.136$			$x_1 = 0.262$			$x_1 = 0.486$		
0.01000	0.99766	1.0025	0.01952	1.00223	1.0057	0.00978	0.99573	1.0084	0.00997	0.97846	1.0140
0.02119	0.99862	1.0045	0.02562	1.00283	1.0073	0.01991	0.99679	1.0179	0.02112	0.97886	1.0335
0.02553	0.99897	1.0053	0.03221	1.00348	1.0090	0.02520	0.99733	1.0233	0.02544	0.97901	1.0418
0.03076	0.99945	1.0062	0.04640	1.00489	1.0126	0.02983	0.99782	1.0281	0.03065	0.97920	1.0522
0.04095	1.00032	1.0080	0.05962	1.00619	1.0159	0.04086	0.99896	1.0403	0.03566	0.97938	1.0625
0.05547	1.00157	1.0105	0.06955	1.00717	1.0184	0.05011	0.99992	1.0509	0.04808	0.97983	1.0894
$LiAsF_6$ at 308.15 K											
$x_1 = 0.056$			$x_1 = 0.136$			$x_1 = 0.262$			$x_1 = 0.486$		
0.01055	0.99794	1.0028	0.01013	1.00123	1.0040	0.01007	0.99536	1.0088	0.01193	0.97925	1.0144
0.02079	0.99905	1.0048	0.01997	1.00228	1.0074	0.01987	0.99599	1.0163	0.02040	0.98006	1.0242
0.02509	0.99952	1.0056	0.02484	1.00259	1.0091	0.02477	0.99630	1.0201	0.02473	0.98048	1.0294
0.02994	1.00040	1.0065	0.02989	1.00306	1.0108	0.02989	0.99663	1.0240	0.02975	0.98096	1.0353
0.03979	1.00111	1.0082	0.03723	1.00373	1.0133	0.03968	0.99725	1.0314	0.04074	0.98202	1.0485
0.05377	1.00263	1.0107	0.05085	1.00499	1.0179	0.05008	0.99792	1.0391	0.04942	0.98286	1.0589
$NaClO_4$ at 308.15 K											
$x_1 = 0.056$			$x_1 = 0.136$			$x_1 = 0.262$			$x_1 = 0.486$		
0.01314	0.99866	1.0020	0.01197	1.00172	1.0032	0.01004	0.99578	1.0050	0.01041	0.97867	1.0093
0.02284	1.00003	1.0028	0.02059	1.00275	1.0049	0.02076	0.99691	1.0114	0.01993	0.97919	1.0202
0.03250	1.00140	1.0035	0.02593	1.00339	1.0058	0.02476	0.99734	1.0139	0.02498	0.97947	1.0267
0.04361	1.00297	1.0042	0.03089	1.00398	1.0067	0.03003	0.99790	1.0176	0.03082	0.97979	1.0346
0.05015	1.00390	1.0046	0.04020	1.00509	1.0084	0.04013	0.99896	1.0249	0.04059	0.98033	1.0488
0.05576	1.00467	1.0048	0.05070	1.00634	1.0101	0.05065	1.00008	1.0329	0.05026	0.98086	1.0640
$LiClO_4$ at 318.15 K											
$x_1 = 0.056$			$x_1 = 0.136$			$x_1 = 0.262$			$x_1 = 0.486$		
0.01221	0.99398	1.0029	0.01147	0.99465	1.0041	0.01014	0.98670	1.0085	0.01037	0.97138	1.0110
0.02077	0.99491	1.0046	0.01950	0.99561	1.0065	0.01970	0.98682	1.0176	0.02031	0.97309	1.0219
0.02477	0.99534	1.0053	0.02469	0.99623	1.0081	0.02456	0.98689	1.0226	0.02557	0.97400	1.0279
0.03030	0.99593	1.0064	0.03061	0.99694	1.0098	0.02950	0.98695	1.0279	0.03075	0.97489	1.0340
0.04104	0.99709	1.0084	0.03972	0.99804	1.0124	0.03974	0.98708	1.0395	0.03947	0.97639	1.0444
0.05181	0.99825	1.0105	0.05144	0.99944	1.0158	0.04996	0.98721	1.0517	0.04946	0.97810	1.0566

Table 2 (Continued)

c/mol·dm^{-3}	ρ/g·cm^{-3}	η_r	c/mol·dm^{-3}	ρ/g·cm^{-3}	η_r	c/mol·dm^{-3}	ρ/g·cm^{-3}	η_r	c/mol·dm^{-3}	ρ/g·cm^{-3}	η_r
					$LiBF_4$ at 318.15 K						
	$x_1 = 0.056$			$x_1 = 0.136$			$x_1 = 0.262$			$x_1 = 0.486$	
0.00996	0.99349	1.0028	0.01937	0.99474	1.0067	0.00970	0.98718	1.0105	0.00988	0.96984	1.0163
0.02111	0.99441	1.0052	0.02543	0.99520	1.0085	0.01973	0.98780	1.0220	0.02093	0.97011	1.0382
0.02542	0.99477	1.0061	0.03196	0.99569	1.0105	0.02497	0.98813	1.0284	0.02521	0.97021	1.0474
0.03062	0.99520	1.0072	0.04603	0.99676	1.0147	0.02955	0.98842	1.0342	0.03037	0.97033	1.0588
0.04077	0.99603	1.0093	0.05912	0.99775	1.0185	0.04046	0.98910	1.0485	0.03534	0.97045	1.0702
0.05523	0.99723	1.0123	0.06895	0.99850	1.0214	0.04959	0.98967	1.0612	0.04763	0.97075	1.0995
					$LiAsF_6$ at 318.15 K						
	$x_1 = 0.056$			$x_1 = 0.136$			$x_1 = 0.262$			$x_1 = 0.486$	
0.01051	0.99384	1.0030	0.01006	0.99410	1.0047	0.00999	0.98746	1.0114	0.01182	0.96985	1.0176
0.02071	0.99498	1.0053	0.01983	0.99491	1.0089	0.01974	0.98833	1.0215	0.02019	0.97002	1.0299
0.02499	0.99545	1.0063	0.02466	0.99531	1.0109	0.02458	0.98877	1.0265	0.02447	0.97011	1.0363
0.02982	0.99599	1.0073	0.02967	0.99573	1.0130	0.02967	0.98922	1.0288	0.02943	0.97021	1.0437
0.03963	0.99708	1.0094	0.03696	0.99634	1.0160	0.03940	0.99009	1.0416	0.04026	0.97044	1.0603
0.05356	0.99863	1.0122	0.05047	0.99746	1.0216	0.04974	0.99102	1.0520	0.04880	0.97061	1.0734
					$NaClO_4$ at 318.15 K						
	$x_1 = 0.056$			$x_1 = 0.136$			$x_1 = 0.262$			$x_1 = 0.486$	
0.01309	0.99439	1.0025	0.01188	0.99425	1.0036	0.00995	0.98728	1.0059	0.01032	0.97040	1.0116
0.02274	0.99566	1.0035	0.02048	0.99495	1.0056	0.02057	0.98803	1.0132	0.01976	0.97113	1.0260
0.03235	0.99562	1.0044	0.02572	0.99593	1.0067	0.02453	0.98834	1.0162	0.02478	0.97151	1.0346
0.04341	0.99838	1.0053	0.03064	0.99579	1.0078	0.02976	0.98868	1.0203	0.03058	0.97196	1.0452
0.04992	0.99923	1.0058	0.03986	0.99655	1.0097	0.03974	0.98939	1.0286	0.04027	0.97271	1.0642
0.05549	0.99996	1.0062	0.05025	0.99741	1.0118	0.05014	0.99013	1.0378	0.04988	0.97345	1.0844

[a] Units: $\Lambda°$/S·cm^2·mol^{-1}; K_A/dm^{-3}·mol^{-1}.

Table 3. Theoretical A/dm$^{3/2}$·mol$^{-1/2}$ Coefficients of Electrolytes in 2-Methoxyethanol (1) + Water (2) at 298.15 K

electrolyte	$x_1 =$ 0.056	$x_1 =$ 0.136	$x_1 =$ 0.262	$x_1 =$ 0.486	$x_1 =$ 1.000
$LiClO_4$	0.0083	0.0074	0.0115	0.0147	0.0227
$LiBF_4$	0.0085	0.0075	0.0117	0.0152	0.0231
$LiAsF_6$	0.0111	0.0091	0.0153	0.0167	
$NaClO_4$	0.0055	0.0062	0.0085	0.0139	0.0264

In all cases the experiments were performed at least in five replicates for each composition and at each temperature, and the results were averaged.

Results

The relative viscosity η_r and density ρ data for the electrolyte solutions as functions of molar concentration (c) in different solvent mixtures at 298.15, 308.15, and 318.15 K are given in Table 2. The $\Lambda°$ and K_A values (Das and Hazra, 1998) for the electrolytes at 298.15 K have also been included in the same table. At 0.056 and 0.136 mole fraction of ME in ME + water mixtures, $LiClO_4$ and $LiBF_4$ are almost in an unassociated state whereas $NaClO_4$ and $LiAsF_6$ remain unassociated at 0.056, 0.136, and 0.262 mole fraction of ME in the mixtures. At the higher percentages of ME, however, all these salts are found to be moderately associated. The viscosity data in cases where the electrolytes were found to be in an unassociated state were analyzed by the Jones−Dole equation, as described earlier by us (Muhuri and Hazra, 1993)

$$\eta_r = 1 + Ac^{1/2} + Bc \qquad (3)$$

whereas for the electrolytes in an associated state the data were analyzed (Crudden et al., 1986; Das and Hazra, 1992) with the help of eq 4.

$$[\eta_r - 1 - A(\alpha c)^{1/2}]/\alpha c = B + B'[(1 - \alpha)/\alpha] \qquad (4)$$

Here, A, B, and B' are the characteristic constants and α is the degree of dissociation of the ion pair.

For the evaluation of B coefficients from eq 3, the plots of $(\eta_r - 1)/c^{1/2}$ versus $c^{1/2}$ were constructed and were found to be linear in all cases over the whole concentration range of the electrolytes studied. The B coefficients for the electrolytes were evaluated from these plots by the least-squares treatment. For the evaluation of B coefficients from eq 4, the method suggested earlier by us (Das and Hazra, 1992) was followed. The values of α were calculated from the conductance data (Das and Hazra, 1998) using the equation described in the literature (Crudden et al., 1986). The A values were calculated theoretically from the physical parameters of the solvent and the limiting ionic equivalent conductances using the Falkenhagen and Vernon equation and are given in Table 3. These A values have been used for the analysis of the data. In view of the weak

Table 4. Viscosity B/dm^3·mol^{-1} Coefficients of Electrolytes in 2-Methoxyethanol (1) + Water (2) at 298.15, 308.15, and 318.15 K

electrolyte	T/K	$x_1 = 0.056$	$x_1 = 0.136$	$x_1 = 0.262$	$x_1 = 0.486$	$x_1 = 1.000$
$LiClO_4$	298.15	0.107 (±0.002)	0.186 (±0.001)	0.296 (±0.002)	0.424 (±0.003)	0.260 (±0.003)
	308.15	0.139 (±0.002)	0.223 (±0.002)	0.420 (±0.002)	0.609 (±0.003)	0.480 (±0.005)
	318.15	0.169 (±0.002)	0.262 (±0.002)	0.565 (±0.001)	0.786 (±0.002)	0.693 (±0.008)
$LiBF_4$	298.15	0.114 (±0.003)	0.200 (±0.001)	0.400 (±0.002)	0.313 (±0.007)	0.273 (±0.003)
	308.15	0.145 (±0.003)	0.233 (±0.001)	0.623 (±0.002)	0.801 (±0.001)	0.493 (±0.004)
	318.15	0.179 (±0.002)	0.271 (±0.001)	0.846 (±0.005)	1.063 (±0.001)	0.713 (±0.003)
$LiAsF_6$	298.15	0.108 (±0.002)	0.239 (±0.003)	0.449 (±0.001)	0.750 (±0.003)	
	308.15	0.145 (±0.001)	0.317 (±0.001)	0.707 (±0.004)	1.006 (±0.004)	
	318.15	0.182 (±0.002)	0.395 (±0.001)	0.969 (±0.002)	1.263 (±0.002)	
$NaClO_4$	298.15	0.014 (±0.002)	0.105 (±0.001)	0.230 (±0.005)	0.288 (±0.004)	0.394 (±0.004)
	308.15	0.026 (±0.002)	0.105 (±0.002)	0.313 (±0.005)	0.387 (±0.006)	0.322 (±0.005)
	318.15	0.037 (±0.001)	0.170 (±0.002)	0.399 (±0.001)	0.468 (±0.002)	0.256 (±0.008)

temperature dependence of the *A* coefficients, the *A* values at 298.15 K were utilized at the other two temperatures, viz., at 308.15 and 318.15 K.

Discussion

The viscosity *B* coefficients for all the electrolytes in the mixed solvents are all found to be large and positive (Table 4). For the electrolytes, the *B* values reach maxima ($NaClO_4$ at 298.15 K being an exception) in the vicinity of 0.486 mole fraction of ME followed by a decrease up to pure 2-methoxyethanol (Das and Hazra, 1995b). The results must be due to an increase in hydrophobic interactions and consequent structural modifications that occur in solution. Furthermore, the d*B*/d*T* values are positive, indicating the structure-breaking properties of these electrolytes in ME + water mixtures.

The reason for the observed change in the viscosity *B* coefficients may be attributed to the structural changes and changed ion−solvent interactions in ME + water mixtures. Intermolecular hydrogen bonding gives water a distinct geometrical structure in the form of three-dimensional arrays. The addition of ME to water first strengthens the three-dimensional structure of water. Further addition of ME causes depolymerization of the water structure, but intermolecular interactions between ME and water lead to the formation of ME−water complexes with bigger hydrodynamic entities. Viscosity thus increases up to a mole fraction of ME in the neighborhood of 0.486, after which the ME−water structure breaks down, leading to a decrease in viscosity in this region. This behavior of the mixed solvents has also been manifested by their excess properties (Das and Hazra, 1993).

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