Volumetric and Viscometric Properties of Binary Liquid Mixtures of Ethylene Glycol Monomethyl Ether + 1-Hexanol, 1-Octanol, and 1-Decanol at Temperatures of T = (293.15, 298.15, 303.15, and 308.15) K

Gyan Prakash Dubey* and Krishan Kumar†

Department of Chemistry, Kurukshetra University, Kurukshetra 136 119, India

Density, viscosity, and speed of sound have been measured for the binary mixtures of ethylene glycol monomethyl ether ($CH_3OCH_2CH_2OH$) with 1-hexanol ($C_6H_{14}O$), 1-octanol ($C_8H_{18}O$), and 1-decanol ($C_{10}H_{22}O$) at temperatures of T = (293.15, 298.15, 303.15, and 308.15) K and at a pressure of 0.1 MPa as a function of composition. The experimental density, ρ, values were used to calculate the excess molar volumes, V_m^E. The isentropic compressibilities, κ_S, have also been calculated with experimental densities and speeds of sound data. The values of V_m^E were fitted to the Redlich−Kister polynomial equation and have been used to discuss the presence of significant interactions between polyether and alcohol molecules.

Introduction

Glycol ethers are important industrial solvents. They can be used as scrubbing liquids for the absorption of acid gases in the cleaning of exhaust air and gas streams from industrial production plants because of their favorable properties such as low vapor pressure, low toxicity, low viscosity, high chemical stability, and low melting temperature.[1] In last years, some authors have proposed new organic working pairs containing ethylene glycol ethers as absorbent fluids for absorption heat pumps and chillers.[2,3] In addition, the glycol ethers can also be used as polar additives in anionic polymerization and automotive brake fluid. Ethylene glycol monomethyl ether (EGMME, 2-methoxyethanol) is a colorless liquid which is miscible with alcohols and most organic solvents. It is widely used as solvents, especially in the printing ink and paint industries. Systematic studies of the thermodynamic excess properties of ether and alcohol mixtures are important from the viewpoint of understanding the molecular liquid structure and the intermolecular interactions dominated by the self-association of alcohols due to hydrogen bonding. Alcohols are the well-known solvents with protic and self-associated properties, which are used to study the hydrophobic effects.

Ethers and 1-alkanols are used in the chemical industry as a solvent for oils and petrol and are used in gasoline formulation as an enhancement of octane rating or fuel additives. The present work concerns the experimental measurements of densities, ρ, viscosities, η, and speed of sound, u, for binary mixtures of EGMME with 1-hexanol, 1-octanol, and 1-decanol at temperatures of T = (293.15, 298.15, 303.15, and 308.15) K and at atmospheric pressure. Furthermore, using experimental results, excess molar volumes, V_m^E, have been determined to gain a better understanding of the intermolecular interactions between the mixing components.

* To whom correspondence should be addressed. E-mail: gyan.dubey@rediffmail.com.
† E-mail: kukrishan@yahoo.co.in.

Experimental Section

Materials. EGMME (CAS Registry No.: 109-86-4 with a mass fraction purity of 0.995), 1-hexanol (mass fraction purity of 0.985), 1-octanol (mass fraction purity of 0.995), and 1-decanol (mass fraction purity of 0.995) were obtained from S. D. Fine Chemicals Ltd. All of the chemicals were partially degassed before use. The experimentally measured values of densities, viscosities, and speeds of sound of all of the pure components at T = 298.15 K are compared with literature[4−13] and are presented in Table 1.

Apparatus and Procedure. The EGMME + alcohol binary mixture can be prepared by weighing appropriate amounts of EGMME and alcohol on an Afcoset-ER-120A electronic balance, with a precision of ± 0.05 mg, by syringing each component into airtight stoppered bottles to minimize evaporation losses. The pure components were separately degassed by vacuum pump shortly before sample preparation. The accuracy of mole fractions was $\pm 1 \cdot 10^{-4}$.

Density, ρ, and speed of sound, u, were measured by using a digital vibrating tube density and speed of sound analyzer (Anton Paar DSA 5000), having two integrated Pt 100 thermometers with a proportional temperature controller that kept the sample at the required temperature. The apparatus was calibrated at working temperatures with dry air, double toluene,[10,12] cyclohexane,[10,13] and distilled water.[14] The temperature in the cell was regulated to ± 0.001 K with an in-built solid state thermostat by the Peltier method. The uncertainty in the density measurement is $\pm 2 \cdot 10^{-3}$ kg·m^{-3} and for the speed of sound ± 0.1 m·s^{-1}. To perform the measurement, one out of a total of 10 individual measuring methods was selected, and the measuring cell was filled with the sample. An acoustic signal informed us when the measurement was completed. The results are automatically converted (including temperature compensation wherever necessary) into concentration, specific gravity, or other density-related units using the built-in conversion tables and functions.

The kinematic viscosities ν (= η/ρ) of pure liquids and liquid mixtures were measured at T = 298.15 K and at atmospheric pressure using an Ubbelohde suspended-level viscometer. The

10.1021/je9005344
Published on Web 03/05/2010

Table 1. Experimental and Literature Values of Densities (ρ*), Viscosities (η*), and Speeds of Sound (u*) of Pure Liquid Components at T/K = 298.15

	$\rho^* \cdot 10^{-3}$/kg·m^{-3}		η^*/mPa·s		u^*/m·s^{-1}	
components	exptl	lit.	exptl	lit.	exptl	lit.
$C_6H_{14}O$	0.815265	0.815533[4]	4.439	4.594[5]	1303.2	1304.72[5]
$C_8H_{18}O$	0.821794	0.821181[6]	7.143	7.498[7]	1347.6	1348.00[8]
$C_{10}H_{22}O$	0.826470	0.826640[9]	11.192	11.735[7]	1379.9	1380.01[5]
$CH_3OCH_2CH_2OH$	0.960978	0.960240[10]	1.512	1.541[11]	1343.5	1343.45[10]
C_6H_6	0.873710	0.87370[12]	0.604	0.604[12]	1299.1	1299.2[12]
C_6H_{12}	0.773790	0.77389[10]	0.902	0.898[12]	1253.3	1253.2[13]
C_7H_8	0.862194	0.86219[10]	0.556	0.556[12]	1304.7	1304.3[12]

viscometer was calibrated so as to determine the two constants C_1 and C_2 in the equation $\eta/\rho = C_1t - C_2/t$, obtained by measuring the flow time t with double-distilled water[10] and cyclohexane.[12] The viscometer is filled with liquid or liquid mixtures, and its limbs were closed with Teflon caps, taking due precautions to minimize the evaporation losses. The flow time measurements were made by using an electronic stopwatch with a precision of ± 0.1 s. An average of four or five sets of flow times for each liquid or liquid mixture was taken for calculating the viscosity. The measured values of kinematic viscosities were converted to dynamic viscosities after multiplication by the density. The uncertainty in the viscosity measurements, based on our work on several pure liquids, was ± 0.003 mPa·s. In viscosity measurements, the temperature of the samples was controlled by using a water bath equipped with a thermostat with an accuracy of ± 0.01 K. The uncertainties in density, viscosity, and speed of sound are determined by comparing the experimental values of standard liquids with their literature values at that temperature.

Results and Discussion

Density, ρ, speed of sound, u, excess molar volume, V_m^E, and isentropic compressibility, κ_S, determined by means of the Laplace equation ($\kappa_S = \rho^{-1}u^{-2}$), and viscosity, η, at temperatures of T = (293.15, 298.15, 303.15, and 308.15) K and p = 0.1 MPa for ($CH_3OCH_2CH_2OH$ + $C_6H_{14}O$, + $C_8H_{18}O$, or + $C_{10}H_{22}O$) are reported in Table 2.

Excess molar volumes, deviation in speeds of sound, and deviation in isentropic compressibilities were derived respectively from the expressions

$$V_m^E = \sum_{i=1}^{2} x_i M_i(\rho^{-1} - \rho_i^{-1}) \quad (1)$$

where ρ_i is the density of the pure components, ρ is the density of the mixtures, and x_i is the mole fraction. The viscosity deviations are calculated from their linear dependence by using the following relation.

The experimental results were fitted in the Redlich−Kister polynomial equation[15]

$$Y(x) = x_1x_2\sum_{i=1}^{p} A_i(x_1 - x_2)^i \quad (2)$$

where p is the number of estimated parameters of A_i. The standard deviation was calculated using the relation:

$$\sigma = [\sum_{i=1}^{n} \{Y(x)_{exptl} - Y(x)_{cal}\}^2/n]^{1/2} \quad (3)$$

where $Y(x)_{exptl}$ and $Y(x)_{cal}$ are the values of the experimental and calculated properties (ρ, η, V_m^E), respectively, and n is the number of experimental data points. The calculated values of the coefficients (A_i) along with standard deviations (σ) are reported in Table 3.

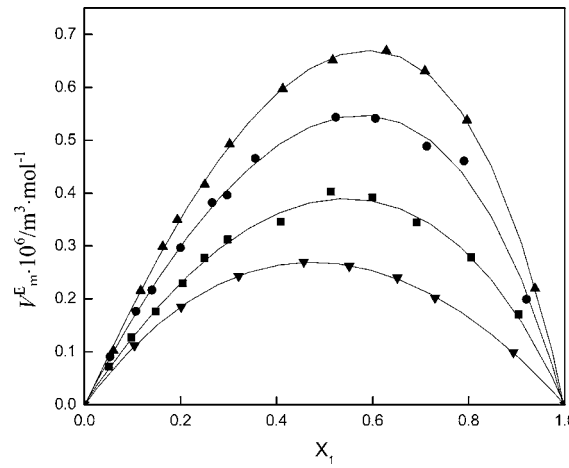

Figure 1. Excess molar volumes against mole fractions x_1CH_3 at T = 298.15 K. ■, (OCH_2CH_2OH + $C_6H_{14}O$); ●, (OCH_2CH_2OH + $C_8H_{18}O$); ▲, (OCH_2CH_2OH + $C_{10}H_{22}O$); ▼, ref 16. The solid curves have been derived from the Redlich−Kister eq 2.

Figure 1 shows that excess molar volumes are positive over the entire range of composition increasing magnitude with the increase in number of carbon atom in alcohol molecules. The maximum positive value of V_m^E is obtained for the $CH_3OCH_2CH_2OH$ + $C_{10}H_{22}O$ mixture. It indicates that interaction between EGMME and alcohol molecules is weak. This kind of interaction is also affected by temperature and composition. The interaction becomes weaker with increasing the temperature as suggested by increasing values of V_m^E with the rise in temperature. The positive value of V_m^E can be visualized as being due to a closer approach of the unlike molecules having significantly different molecular sizes. Because of mixing, the already existing self-association of ether and alcohol molecules breaks, and the system shows weak intermolecular interactions. The longer the chain length of the alcohol molecules, the weaker the interaction between liquid components will be. To the best of our knowledge, no data in literature are available for a comparison of the excess molar volume values of the studied systems at T = 298.15 K. However, a comparison has been made with the values reported by Ramana Reddy et al.[16] for the binary mixtures of 2-ethoxyethanol (an alkoxy alkanol of the series of EGMME) + pentanol at T = 308.15 K that support our results. For the comparison, the data points of excess molar volume of 2-ethoxyethanol + pentanol at T = 308.15 K have been shown in Figure 1.

Table 2. Densities (ρ), Excess Molar Volumes (V_m^E), Speeds of Sound (u), Isentropic Compressibilities (κ_S), and Viscosity (η) for Binary Mixtures from T = (293.15 to 308.15) K

x_1	$\rho \cdot 10^{-3}$ / kg·m^{-3}	$V_m^E \cdot 10^6$ / m^3·mol^{-1}	u / m·s^{-1}	κ_S / TPa^{-1}	η / mPa·s
		T/K = 293.15			
		$x_1CH_3OCH_2CH_2OH + x_2C_6H_{14}O$			
0.0516	0.823245	0.0700	1319.2	698.01	4.203
0.0979	0.827405	0.1233	1318.4	695.31	4.000
0.1486	0.832198	0.1718	1317.7	692.01	3.764
0.2049	0.837755	0.2238	1317.3	687.84	3.486
0.2500	0.842351	0.2702	1316.9	684.55	3.257
0.2987	0.847639	0.3035	1316.3	680.85	3.122
0.4088	0.860712	0.3363	1317.3	677.02	2.675
0.5134	0.874132	0.3918	1318.6	657.96	2.438
0.5991	0.886614	0.3814	1321.2	646.17	2.250
0.6915	0.901590	0.3351	1325.9	630.93	2.092
0.8050	0.922045	0.2715	1334.2	609.27	1.858
0.9039	0.942547	0.1665	1345.0	586.45	1.737
		$x_1CH_3OCH_2CH_2OH + x_2C_8H_{18}O$			
0.0535	0.828636	0.0885	1362.0	650.55	7.447
0.1073	0.832242	0.1723	1359.3	650.33	6.742
0.1407	0.834668	0.2100	1357.9	650.00	6.355
0.2002	0.839135	0.2899	1354.9	649.17	5.659
0.2659	0.844444	0.3736	1351.9	647.99	4.991
0.2973	0.847294	0.3865	1350.5	647.07	4.779
0.3559	0.852613	0.4547	1348.0	645.46	4.259
0.5233	0.870970	0.5311	1342.3	637.26	3.272
0.6059	0.881954	0.5291	1340.4	631.12	2.863
0.7126	0.898662	0.4767	1339.7	620.03	2.432
0.7903	0.912569	0.4513	1340.9	609.42	2.150
0.9202	0.942675	0.1950	1349.3	582.62	1.772
		$x_1CH_3OCH_2CH_2OH + x_2C_{10}H_{22}O$			
0.0606	0.832950	0.1006	1393.1	618.63	11.479
0.1173	0.835952	0.2112	1389.5	619.58	10.191
0.1631	0.838564	0.2943	1386.6	620.24	9.351
0.1934	0.840414	0.3420	1384.7	620.56	8.764
0.2510	0.844262	0.4092	1380.8	621.26	7.828
0.3025	0.847887	0.4840	1377.5	621.54	7.137
0.4130	0.856970	0.5860	1370.2	621.54	5.850
0.5170	0.867321	0.6390	1363.6	620.08	4.593
0.6285	0.880912	0.6557	1356.6	616.81	3.746
0.7087	0.892252	0.6180	1352.5	612.23	3.119
0.7965	0.909015	0.5267	1349.5	604.07	2.574
0.9382	0.944534	0.2161	1352.5	578.78	1.840
		T/K = 298.15			
		$x_1CH_3OCH_2CH_2OH + x_2C_6H_{14}O$			
0.0516	0.819629	0.0717	1302.2	719.44	3.788
0.0979	0.823749	0.1270	1301.5	716.72	3.612
0.1486	0.828504	0.1763	1300.8	713.25	3.329
0.2049	0.834013	0.2299	1300.5	708.98	3.101
0.2500	0.838571	0.2772	1300.0	705.57	2.955
0.2987	0.843810	0.3123	1299.4	701.84	2.775
0.4088	0.856785	0.3459	1300.5	697.98	2.435
0.5134	0.870100	0.4027	1301.6	678.32	2.207
0.5991	0.882495	0.3919	1304.2	666.14	2.038
0.6915	0.897370	0.3445	1308.8	650.50	1.890
0.8050	0.917699	0.2784	1317.1	628.14	1.706
0.9039	0.938079	0.1705	1327.8	604.58	1.602
		$x_1CH_3OCH_2CH_2OH + x_2C_8H_{18}O$			
0.0535	0.825138	0.0903	1345.0	669.90	6.475
0.1073	0.828704	0.1765	1342.3	669.70	5.801
0.1407	0.831104	0.2165	1340.6	669.44	5.490
0.2002	0.835528	0.2968	1337.9	668.62	5.141
0.2659	0.840786	0.3821	1334.9	667.45	4.428
0.2973	0.843606	0.3961	1333.6	666.54	4.200
0.3559	0.848877	0.4655	1331.1	664.91	3.239
0.5233	0.870970	0.5435	1325.3	656.64	2.919
0.6059	0.867068	0.5412	1323.4	650.30	2.583
0.7126	0.877961	0.4886	1322.6	639.08	2.204
0.7903	0.908335	0.4607	1323.9	628.13	1.965
0.9202	0.938234	0.1991	1332.1	600.59	1.631

Table 2a. Continued

x_1	$\rho \cdot 10^{-3}$ / kg·m^{-3}	$V_m^E \cdot 10^6$ / m^3·mol^{-1}	u / m·s^{-1}	κ_S / TPa^{-1}	η / mPa·s
		$x_1CH_3OCH_2CH_2OH + x_2C_{10}H_{22}O$			
0.0606	0.829505	0.1023	1375.9	636.78	9.653
0.1173	0.832457	0.2152	1372.4	637.81	8.800
0.1631	0.835060	0.2987	1369.5	638.46	8.019
0.1934	0.836878	0.3497	1367.5	638.95	7.552
0.2510	0.840695	0.4165	1363.7	639.58	6.856
0.3025	0.844280	0.4930	1360.4	639.96	6.099
0.4130	0.853268	0.5975	1353.1	640.10	4.133
0.5170	0.863518	0.6518	1346.5	638.47	4.090
0.6285	0.876980	0.6690	1339.6	635.45	3.310
0.7087	0.888913	0.6306	1335.3	630.88	2.807
0.7965	0.904836	0.5379	1332.3	622.64	2.332
0.9382	0.940097	0.2195	1335.3	596.54	1.693
		T/K = 303.15			
		$x_1CH_3OCH_2CH_2OH + x_2C_6H_{14}O$			
0.0516	0.815993	0.0724	1285.5	741.54	3.221
0.0979	0.820074	0.1295	1284.7	738.79	3.093
0.1486	0.824786	0.1806	1284.1	735.28	2.905
0.2049	0.830247	0.2357	1283.7	730.91	2.697
0.2500	0.834763	0.2846	1283.3	727.42	2.566
0.2987	0.839961	0.3204	1282.7	723.59	2.433
0.4088	0.852828	0.3562	1283.6	719.63	2.148
0.5134	0.866048	0.4130	1284.8	699.49	1.943
0.5991	0.878355	0.4020	1287.3	686.97	1.797
0.6915	0.893130	0.3540	1291.9	670.83	1.691
0.8050	0.913334	0.2848	1300.1	647.34	1.527
0.9039	0.933591	0.1742	1310.7	623.45	1.436
		$x_1CH_3OCH_2CH_2OH + x_2C_8H_{14}O$			
0.0535	0.821625	0.0911	1328.2	690.192	5.399
0.1073	0.825153	0.1794	1325.5	689.762	4.894
0.1407	0.827528	0.2195	1323.9	689.498	4.663
0.2002	0.831905	0.3029	1321.1	688.708	4.281
0.2659	0.837111	0.3899	1318.1	687.564	3.776
0.2973	0.839904	0.4047	1316.8	686.673	3.588
0.3559	0.845122	0.4752	1314.2	685.064	3.209
0.5233	0.863148	0.5555	1308.5	676.696	2.543
0.6059	0.873942	0.5540	1306.5	670.345	2.274
0.7126	0.890382	0.4920	1305.7	658.774	1.950
0.7903	0.904076	0.4706	1306.9	647.615	1.753
0.9202	0.933772	0.2029	1315.0	619.290	1.470
		$x_1CH_3OCH_2CH_2OH + x_2C_{10}H_{22}O$			
0.0606	0.826050	0.1045	1358.9	655.49	7.925
0.1173	0.828982	0.2194	1355.4	656.65	7.221
0.1631	0.831539	0.3049	1352.5	657.36	6.275
0.1934	0.833342	0.3558	1350.6	657.82	5.685
0.2510	0.837111	0.4255	1346.8	658.58	5.154
0.3025	0.840662	0.5023	1343.5	658.99	4.243
0.4130	0.849553	0.6097	1336.2	659.27	3.514
0.5170	0.859697	0.6657	1329.6	658.00	2.870
0.6285	0.873028	0.6834	1322.6	654.83	2.471
0.7087	0.884854	0.6440	1318.4	650.20	2.055
0.7965	0.900644	0.5489	1315.3	641.83	1.527
0.9382	0.935630	0.2039	1318.15	615.13	1.470
		T/K = 308.15			
		$x_1CH_3OCH_2CH_2OH + x_2C_6H_{14}O$			
0.0516	0.812325	0.0749	1268.9	764.50	2.748
0.0979	0.816370	0.1333	1267.2	761.65	2.661
0.1486	0.821037	0.1864	1267.5	758.17	2.504
0.2049	0.826451	0.2430	1267.0	753.69	2.369
0.2500	0.830930	0.2927	1266.6	750.13	2.218
0.2987	0.836084	0.3295	1206.0	822.31	2.107
0.4088	0.848853	0.3662	1266.9	733.91	1.958
0.5134	0.861965	0.4245	1268.0	721.49	1.754
0.5991	0.874185	0.4130	1270.6	708.61	1.572
0.6915	0.888857	0.3638	1275.0	692.02	1.494
0.8050	0.908936	0.2923	1283.2	668.17	1.364
0.9039	0.929076	0.1781	1293.7	643.12	1.276

Table 2b. Continued

x_1	$\rho \cdot 10^{-3}$ / kg·m^{-3}	$V_m^E \cdot 10^6$ / m^3·mol^{-1}	u / m·s^{-1}	κ_S / TPa^{-1}	η / mPa·s
		$x_1CH_3OCH_2CH_2OH + x_2C_8H_{18}O$			
0.0535	0.818089	0.0937	1311.5	710.63	4.496
0.1073	0.821583	0.1832	1308.9	710.46	4.118
0.1407	0.823931	0.2248	1307.2	710.30	3.921
0.2002	0.828261	0.3104	1304.4	709.54	3.537
0.2659	0.833414	0.3922	1301.4	708.44	3.258
0.2973	0.836178	0.4148	1300.1	707.55	3.181
0.3559	0.841346	0.4864	1297.5	705.97	2.817
0.5233	0.859203	0.5688	1296.5	697.57	2.217
0.6059	0.869902	0.5673	1289.7	691.14	1.990
0.7126	0.886205	0.5114	1288.8	679.37	1.751
0.7903	0.899757	0.4848	1290.0	667.88	1.436
0.9202	0.929291	0.2052	1298.0	638.75	1.343
		$x_1CH_3OCH_2CH_2OH + x_2C_{10}H_{22}O$			
0.0606	0.822580	0.1058	1342.2	674.86	6.627
0.1173	0.825482	0.2218	1338.6	676.03	5.998
0.1631	0.828008	0.3093	1335.8	676.85	5.540
0.1934	0.829786	0.3621	1333.8	677.40	5.261
0.2510	0.833512	0.4337	1330.0	678.27	4.794
0.3025	0.837024	0.5119	1326.7	678.74	4.383
0.4130	0.845819	0.6218	1319.4	679.17	3.672
0.5170	0.855861	0.6789	1312.8	677.98	3.051
0.6285	0.869056	0.6978	1305.7	674.94	2.491
0.7087	0.880773	0.6576	1301.5	670.31	2.154
0.7965	0.896427	0.5603	1298.3	661.80	1.537
0.9382	0.931137	0.2284	1301.1	634.42	1.350

Table 3. Coefficients A_i of the Redlich−Kister Equation 2 along with Standard Deviations (σ) for Binary Mixtures at T = (293.15 to 308.15) K for Excess Molar Volume (V_m^E)

T/K	A_0	A_1	A_2	A_3	A_4	σ
			$x_1CH_3OCH_2CH_2OH + x_2C_6H_{14}O$			
293.15	1.4796	0.2742	0.2324			0.0089
298.15	1.5465	0.2804	0.1615			0.0111
303.15	1.5892	0.2857	0.1500			0.011
308.15	1.6359	0.2778	0.1257			0.0107
			$x_1CH_3OCH_2CH_2OH + x_2C_8H_{18}O$			
293.15	2.2584	0.7256	−0.0473			0.0305
298.15	2.1465	0.6363	0.2868			0.0149
303.15	2.1918	0.6404	0.2701			0.0165
308.15	2.2462	0.6790	0.2852			0.0622
			$x_1CH_3OCH_2CH_2OH + x_2C_{10}H_{22}O$			
293.15	2.5361	0.8210	0.6604	0.2715	−0.4220	0.0069
298.15	2.5860	0.8459	0.6835	0.2622	−0.4574	0.0072
303.15	2.6407	0.8702	0.6869	0.2549	−0.4575	0.0070
308.15	2.6940	0.8922	0.7059	0.2708	−0.495	0.0070

Conclusions

In this paper, an attempt is made to measure densities, viscosities, and speed of sound at T = (293.15, 298.15, 303.15, and 308.15) K over the entire range of mixture composition of EGMME with 1-hexanol, 1-octanol, and 1-decanol. Out of these measured data, the excess molar volumes have been calculated and correlated by a Redlich−Kister type polynomial equation to derive the coefficients and standard deviations.

Positive deviations are observed in the case of V_m^E for all binary mixtures. On the whole it can be concluded that the strength of bonding is expected to decrease with an increase in the chain length of alcohols as well as with rise of temperature. The present results of V_m^E corroborate this fact.

Literature Cited

(1) Li, X. X.; Liu, Y. X.; Wei, X. H. Density, Viscosity, and Surface Tension at 293.15 K and Liquid-liquid Equilibria from 301.15 to 363.15 K under Atmospheric Pressure for the Binary Mixture of Diethylene Glycol Diethyl Ether + Water. *J. Chem. Eng. Data* **2004**, *49*, 1043–1045.

(2) Esteve, X.; Conesa, A.; Coronas, A. Liquid Densities, Kinematic Viscosities, and Heat Capacities of Some Alkylene Glycol Dialkyl Ethers. *J. Chem. Eng. Data* **2003**, *48*, 392–397.

(3) Ku, H. C.; Tu, C. H. Densities and Viscosities of Seven Glycol Ethers from 299.15 to 343.15 K. *J. Chem. Eng. Data* **2000**, *45*, 391–394.

(4) Wankhede, D. S.; Wankhede, N. N.; Lande, M. K.; Arbad, B. R. Molecular Interaction in Propylene Carbonate + n-Alkanols at 25 °C. *J. Solution Chem.* **2005**, *34*, 233–243.

(5) Al-Jiwaz, A. S.; Al-Kandary, J. A.; Abdul-latif, A. H. M. Acoustic and Excess Properties of [Cholorobenzene + 1- Hexanol; or 1-Heptanol; or 1-Octanol; or 1- Nonanol; or 1-Decanol] at (298.15; 303.15; 308.15; 313.15 K). *J. Chem. Eng. Data* **2007**, *52*, 206–214.

(6) Dewand, R. K.; Mehta, S. K.; Prashar, R.; Balr, K. Topological Investigation on Asssociation of Alkanols, Excess volume of Pyridine-Alkanol (C_1-C_{10}) Mixtures. *J. Chem. Soc., Faraday Trans.* **1991**, *87*, 1561–1568.

(7) Franca Faria, M. A.; F. De Sa, C.; Lima, G. R.; Filho, J. I. B. C.; Martins, R. J.; Cardoso, M. J. E. de M.; Barcia, O. E. Measurement of Density and Viscosity of Binary 1-Alkanol Systems (C_8-C_{11}) at 101 kPa and Temperature from (283.15-313.15) K. *J. Chem. Eng. Data* **2005**, *50*, 1938–1943.

(8) Lobe, V. M. MS Thesis, University of Rochester, New York, 1973.

(9) Ostwald, G.; Schmittecker, B.; Wagner, D.; Lichtenthaler, R. N. Excess Enthalpy and Excess Volumes of Alkanol + n-Heptane Mixture at High Pressure. *Fluid Phase Equilib.* **1986**, *27*, 119–135.

(10) Riddick, J. A.; Bunger, W. B.; Sakano, F. K. *Organic Solvents, Physical Properties and Method of Purification*, 4th ed.; Wiley-Interscience: New York, 1986.

(11) Muhuri, P. K.; Hazara, D. K. Density and Viscosity of Propylene Carbonate + 2- methoxyethanol at 298.15, 308.15, and 318.15 K. *J. Chem. Eng. Data* **1995**, *40*, 582–585.

(12) Al-Kandary, J. A.; Al-Jimaz, A. S.; Abdul-Latif, A.-H. M. Viscosities, Densities, and Speeds of Sound of Binary Mixtures of Benzene, Toluene, *o*-Xylene, *m*-Xylene, *p*-Xylene, and Mesitylene with Anisole at (288.15, 293.15, 298.15, and 303.15) K. *J. Chem. Eng. Data* **2006**, *51*, 2074–2082.

(13) Rai, R. D.; Shukla, R. K.; Shukla, A. K.; Pandey, J. D. Ultrasonic Speed and Isentropic Compressibilities of Ternary Liquid Mixtures at (298.15 ± 0.01K). *J. Chem. Thermodyn.* **1989**, *21*, 125–129.

(14) Douheret, G.; Davis, M. I.; Hernandez, M. E.; Flores, H. Excess Molar Volumes of Some Polyethers + Water system. *J. Indian Chem. Soc.* **1993**, *70*, 395–401.

(15) Redlich, O.; Kister, A. T. Algebric Represention of Thermodynamic Properties and Classification of Solution. *Ind. Eng. Chem.* **1948**, *40*, 345–348.

(16) Ramana Reddy, K. V.; Rambabu, K.; Devarajulu, T.; Krishnaiah, A. Excess Volumes of (2-Ethoxyethanol + Alcohols) at 308.15 K. *Phys. Chem. Liq.* **1996**, *31*, 9–13.

Received for review June 26, 2009. Accepted February 21, 2010.

JE9005344