Volumetric Properties and Viscosities of Binary Mixtures of *N*,*N*-Dimethylformamide with Methanol and Ethanol in the Temperature Range (293.15 to 333.15) K

Changsheng Yang,* Yue Sun, Yifu He, and Peisheng Ma

Key Laboratory for Green Chemical Technology of State Education Ministry, School of Chemical Engineering and Technology, Tianjin University, Tianjin 300072, PRC

Densities and viscosities of the binary mixtures of methanol + DMF and ethanol + DMF have been measured over several temperatures at atmospheric pressure. The measurements were carried out over the whole range of compositions, using a vibrating-tube density meter and an Ubbelohde viscometer. The densities are used to calculate excess molar volumes for each of the systems. The experimental values of excess molar volumes have been compared with those reported by other authors available in the literature. The Redlich–Kister equation was fitted to excess molar volumes, V^E, and viscosities, η.

Introduction

N,*N*-Dimethylformamide (DMF) has a large dipole moment and a high dielectric constant;[1] therefore, it may work as an aprotic protophilic solvent used in the synthesis of pharmaceuticals, in agricultural chemistry, and as a solvent for polymers. Alkanols are polar liquids, strongly self-associated by hydrogen bonding. From the liquid theoretical viewpoint, it will be interesting to explore the thermodynamic results and transport properties of the addition of the amide carbonyl group mixtures with alcohols to obtain some information on the molecular interactions.

A survey of the literature shows that very few measurements have been made on the densities and viscosities for these binary mixtures. Bai et al.[2,3] reported excess molar volumes for binary and ternary mixtures of (*N*,*N*-dimethylformamide + methanol + water) at 298.15 K, as well as of (*N*,*N*-dimethylformamide + ethanol + water) at the temperature 298.15 K. Zielkiewicz[4] reported the excess molar volumes in (*N*,*N*-dimethylformamide + methanol + water) at 313.15 K. Iloukhani and Rostami[5] gave the data of excess molar volumes for *N*,*N*-dimethylformamide with 1-alkanol at 303.15 K. However, there are no reports on excess molar volumes for binary mixtures of methanol + DMF and ethanol + DMF at other temperatures, and especially no viscosity data on these mixtures were previously reported in the literature.

In this work, the densities and viscosities for binary mixtures methanol + DMF and ethanol + DMF were measured at (293.15 to 333.15) K and atmospheric pressure. The results were used to calculate excess molar volumes. The Redlich–Kister equation was fitted to experimental data.

Experimental Section

Materials. The DMF, methanol, and ethanol were purchased from Tianjin Chemical Co. All chemicals are analytical reagent grade. Prior to use, they were stored over molecular sieves type 4 Å to remove traces of water. Before measurements, pure liquids were degassed ultrasonically. The mass fraction purities tested by GLC were as follows: DMF (>0.998), methanol (> 0.994), ethanol (> 0.995). The purity of the solvents was also ascertained by comparing their densities and viscosities with the corresponding literature values in Table 1. Our results obtained are in good agreement with those listed in the literature.

Apparatus and Procedure. The densities of the pure components and their mixtures were measured with a high-precision vibrating-tube digital density meter (Density/Specific Gravity Meter DA 505, KEM, Japan) whose measurement cell temperature was controlled automatically within ± 0.01 K of the selected value. The uncertainty in density measurements was $\pm 5 \cdot 10^{-5}$ g·cm^{-3}. Density measurements were reproducible to $\pm 3 \cdot 10^{-5}$ g·cm^{-3}.

Table 1. Comparison of Experimental and Literature Values of Densities, ρ, and Viscosities, η, for Pure Compounds

		ρ/g·cm^{-3}		η/m·Pas	
liquid	T/K	exptl	lit.	exptl	lit.
DMF	298.15	0.94421	0.9445[6]	0.808	0.803[6]
			0.9442[7]		0.799[7]
			0.9439[8]		0.801[8]
			0.94387[9]		0.802[9]
	303.15	0.93945	0.9395[8]	0.760	0.756[6]
			0.9398[6]		0.754[8]
					0.752[10]
	313.15	0.92986	0.9302[6]	0.675	0.673[6]
			0.9298[11]		0.664[10]
methanol	293.15	0.79151	0.79154[12]	0.587	0.582[12]
	298.15	0.78682	0.7866[13]	0.547	0.549[13]
			0.78663[15]		
			0.7881[14]		0.5482[14]
	303.15	0.78206	0.78191[16]	0.510	0.512[17]
			0.7819[15]		0.504[15]
	313.15	0.77272	0.7725[15]	0.447	0.448[12]
			0.77260[12]		0.447[17]
	323.15	0.76322	0.7627[15]	0.394	0.400[15]
ethanol	293.15	0.78985	0.78824[17]	1.222	1.192[17]
	298.15	0.78562	0.7853[13]	1.109	1.077[13]
			0.78525[15]		1.09[15]
					1.112[14]
	303.15	0.78131	0.7808[15]	1.009	0.986[19]
			0.7810[18]		
	313.15	0.77256	0.7726[18]	0.840	0.823[18]

* To whom correspondence should be addressed. E-mail: yangchangsheng@tju.edu.cn. Fax: 022-27403389. Telephone: 022-27890907.

10.1021/je700430g CCC: $40.75
Published on Web 11/21/2007

Table 2. Densities (ρ), Viscosities (η), and Excess Molar Volumes (V^E) for the Binary Mixtures at Different Temperatures

x_1	ρ / $g \cdot cm^{-3}$	η / $mPa \cdot s$	V^E / $cm^3 \cdot mol^{-1}$	x_1	ρ / $g \cdot cm^{-3}$	η / $mPa \cdot s$	V^E / $cm^3 \cdot mol^{-1}$
(x_1) Methanol + (1−x_1) DMF							
T = 293.15 K							
0.0000	0.94895	0.863	0.0000	0.6000	0.88658	0.693	−0.4368
0.0998	0.94181	0.835	−0.1201	0.6997	0.86936	0.665	−0.4220
0.2000	0.93368	0.809	−0.2248	0.8000	0.84869	0.640	−0.3618
0.3000	0.92438	0.782	−0.3123	0.8998	0.82322	0.613	−0.2271
0.4002	0.91369	0.754	−0.3816	1.0000	0.79151	0.587	0.0000
0.5000	0.90123	0.723	−0.4249				
T = 298.15 K							
0.0000	0.94421	0.808	0.0000	0.6000	0.88175	0.649	−0.4368
0.0998	0.93703	0.782	−0.1186	0.6997	0.86456	0.622	−0.4237
0.2000	0.92889	0.758	−0.2241	0.8000	0.84391	0.596	−0.3635
0.3000	0.91958	0.734	−0.3121	0.8998	0.81849	0.572	−0.2292
0.4002	0.90889	0.705	−0.3826	1.0000	0.78682	0.547	0.0000
0.5000	0.89640	0.678	−0.4245				
T = 303.15 K							
0.0000	0.93945	0.760	0.0000	0.6000	0.87684	0.608	−0.4346
0.0998	0.93215	0.736	−0.1109	0.6997	0.85966	0.584	−0.4224
0.2000	0.92401	0.713	−0.2185	0.8000	0.83902	0.559	−0.3623
0.3000	0.91470	0.688	−0.3084	0.8998	0.81364	0.534	−0.2283
0.4002	0.90402	0.663	−0.3812	1.0000	0.78206	0.510	0.0000
0.5000	0.89148	0.636	−0.4209				
T = 313.15 K							
0.0000	0.92986	0.675	0.0000	0.6000	0.86729	0.540	−0.4441
0.0998	0.92272	0.655	−0.1263	0.6997	0.85011	0.517	−0.4301
0.2000	0.91456	0.635	−0.2339	0.8000	0.82951	0.493	−0.3689
0.3000	0.90521	0.612	−0.3221	0.8998	0.80420	0.470	−0.2327
0.4002	0.89453	0.589	−0.3956	1.0000	0.77272	0.447	0.0000
0.5000	0.88196	0.565	−0.4333				
T = 323.15 K							
0.0000	0.92092	0.608	0.0000	0.6000	0.85757	0.483	−0.4257
0.0998	0.91320	0.588	−0.0852	0.6997	0.84042	0.460	−0.4187
0.2000	0.90501	0.569	−0.1990	0.8000	0.81982	0.438	−0.3609
0.3000	0.89561	0.549	−0.2914	0.8998	0.79457	0.415	−0.2288
0.4002	0.88491	0.528	−0.3712	1.0000	0.76322	0.394	0.0000
0.5000	0.87228	0.506	−0.4115				
(x_1) Ethanol + (1−x_1) DMF							
T = 293.15 K							
0.0000	0.94895	0.863	0.0000	0.6000	0.86707	0.886	−0.2219
0.0999	0.93812	0.871	−0.0983	0.7000	0.85004	0.919	−0.2017
0.2000	0.92578	0.876	−0.1624	0.8000	0.83144	0.970	−0.1568
0.3000	0.91289	0.882	−0.1972	0.9001	0.81142	1.067	−0.0902
0.4000	0.89861	0.881	−0.2203	1.0000	0.78985	1.222	0.0000
0.5001	0.88309	0.872	−0.2309				
T = 298.15 K							
0.0000	0.94421	0.808	0.0000	0.6000	0.86249	0.825	−0.2175
0.0999	0.93340	0.819	−0.0956	0.7000	0.84549	0.852	−0.1946
0.2000	0.92106	0.818	−0.1566	0.8000	0.82696	0.897	−0.1500
0.3000	0.90823	0.822	−0.1941	0.9001	0.80705	0.977	−0.0860
0.4000	0.89396	0.821	−0.2164	1.0000	0.78562	1.109	0.0000
0.5001	0.87846	0.813	−0.2251				
T = 303.15 K							
0.0000	0.93945	0.760	0.0000	0.6000	0.85782	0.769	−0.2074
0.0999	0.92864	0.770	−0.0885	0.7000	0.84091	0.791	−0.1897
0.2000	0.91632	0.767	−0.1524	0.8000	0.82244	0.828	−0.1452
0.3000	0.90351	0.770	−0.1876	0.9001	0.80260	0.897	−0.0813
0.4000	0.88923	0.767	−0.2080	1.0000	0.78131	1.009	0.0000
0.5001	0.87376	0.759	−0.2184				
T = 313.15 K							
0.0000	0.92986	0.675	0.0000	0.6000	0.84842	0.670	−0.1971
0.0999	0.91906	0.682	−0.0825	0.7000	0.83160	0.685	−0.1766
0.2000	0.90676	0.680	−0.1413	0.8000	0.81328	0.712	−0.1350
0.3000	0.89395	0.681	−0.1756	0.9001	0.79364	0.762	−0.0765
0.4000	0.87971	0.674	−0.1975	1.0000	0.77256	0.840	0.0000
0.5001	0.86429	0.668	−0.2069				
T = 323.15 K							
0.0000	0.92092	0.608	0.0000	0.6000	0.83898	0.590	−0.1883
0.0999	0.90948	0.610	−0.0754	0.7000	0.82226	0.598	−0.1675

Table 2 Continued

x_1	ρ / $g \cdot cm^{-3}$	η / mPa·s	V^E / $cm^3 \cdot mol^{-1}$	x_1	ρ / $g \cdot cm^{-3}$	η / mPa·s	V^E / $cm^3 \cdot mol^{-1}$
			T = 323.15 K				
0.2000	0.89718	0.604	−0.1276	0.8000	0.80404	0.616	−0.1236
0.3000	0.88439	0.603	−0.1620	0.9001	0.78450	0.651	−0.0688
0.4000	0.87017	0.596	−0.1860	1.0000	0.76367	0.705	0.0000
0.5001	0.85481	0.592	−0.1944				
			T = 333.15 K				
0.0000	0.91064	0.549	0.0000	0.6000	0.82938	0.522	−0.1774
0.0999	0.89980	0.547	−0.0676	0.7000	0.81271	0.527	−0.1576
0.2000	0.88749	0.543	−0.1163	0.8000	0.79455	0.537	−0.1148
0.3000	0.87473	0.540	−0.1507	0.9001	0.77520	0.559	−0.0631
0.4000	0.86051	0.533	−0.1772	1.0000	0.75453	0.597	0.0000
0.5001	0.84516	0.524	−0.1813				

Table 3. Coefficients of the Redlich–Kister Equation and Standard Deviation for Excess Molar Volumes and Viscosity Deviations of Mixtures

T (K)	property	A_0	A_1	A_2	A_3	σ
		(x_1) Methanol + (1−x_1) DMF				
293.15	$V^E/cm^3 \cdot mol^{-1}$	−1.694	−0.625	−0.373	−0.183	0.0119
	$\Delta\eta$/mPa·s	−0.006	−0.050	−0.009	0.066	0.0040
298.15	$V^E/cm^3 \cdot mol^{-1}$	−1.695	−0.627	−0.378	−0.228	0.0113
	$\Delta\eta$/mPa·s	0.001	−0.055	−0.013	0.082	0.0040
303.15	$V^E/cm^3 \cdot mol^{-1}$	−1.689	−0.613	−0.317	−0.327	0.0146
	$\Delta\eta$/mPa·s	0.004	−0.036	0.000	0.041	0.0044
313.15	$V^E/cm^3 \cdot mol^{-1}$	−1.730	−0.606	−0.416	−0.226	0.0180
	$\Delta\eta$/mPa·s	0.016	−0.028	0.004	0.015	0.0024
323.15	$V^E/cm^3 \cdot mol^{-1}$	−1.663	−0.638	−0.155	−0.562	0.0287
	$\Delta\eta$/mPa·s	0.020	−0.020	−0.012	0.012	0.0022
		(x_1) Ethanol + (1−x_1) DMF				
293.15	$V^E/cm^3 \cdot mol^{-1}$	−0.917	−0.032	−0.207	0.142	0.0082
	$\Delta\eta$/mPa·s	−0.0657	−0.635	−0.238		0.0223
298.15	$V^E/cm^3 \cdot mol^{-1}$	−0.898	−0.018	−0.173	0.134	0.0030
	$\Delta\eta$/mPa·s	−0.562	−0.557	−0.177		0.0192
303.15	$V^E/cm^3 \cdot mol^{-1}$	−0.872	−0.009	−0.125	0.096	0.0145
	$\Delta\eta$/mPa·s	−0.487	−0.485	−0.124		0.018
313.15	$V^E/cm^3 \cdot mol^{-1}$	−0.823	−0.003	−0.100	0.074	0.0073
	$\Delta\eta$/mPa·s	−0.353	−0.358	−0.077		0.0082
323.15	$V^E/cm^3 \cdot mol^{-1}$	−0.777	−0.037	−0.035	0.134	0.0069
	$\Delta\eta$/mPa·s	−0.261	−0.251	−0.050		0.0084
333.15	$V^E/cm^3 \cdot mol^{-1}$	−0.734	−0.039	0.015	0.112	0.0098
	$\Delta\eta$/mPa·s	−0.189	−0.188	−0.035		0.0071

The liquid mixtures were prepared by weight using a BP210s balance accurate to within ± 0.1 mg. The average uncertainty in the compositions (mole fraction) of the mixtures was estimated to be less than ± 0.0001. The molar excess volumes were calculated from composition−density data with an uncertainty better than ± 0.002 $cm^3 \cdot mol^{-1}$. All molar quantities were based on the IUPAC relative atomic mass table.

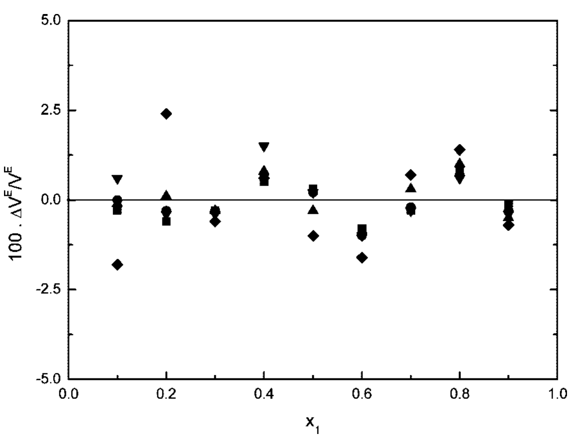

Figure 1. Fractional deviations $\Delta V^E = V^E_{exptl} - V^E_{calcd}$ of the experimental excess volumes from values V^E_{calcd} obtained with the correlation of the Redlich–Kister equation for the system methanol (1) + DMF (2) at different mole fractions, x_1, and different temperatures T: ■, 293.15 K; •, 298.15 K; ▲, 303.15 K; ▼, 313.15 K; solid triangle pointing left, 323.15 K.

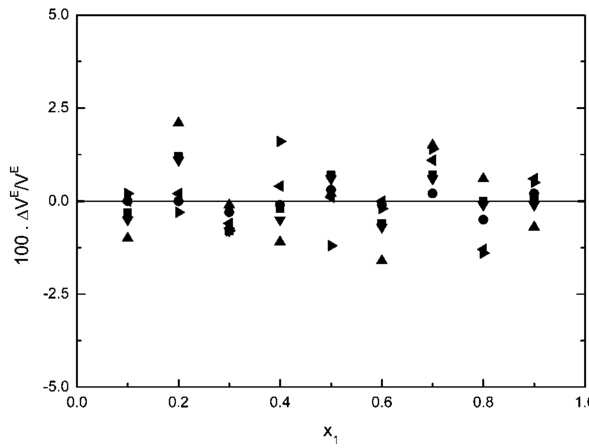

Figure 2. Fractional deviations $\Delta V^E = V^E_{exptl} - V^E_{calcd}$ of the experimental excess volumes from values V^E_{calcd} obtained with the correlation of the Redlich–Kister equation for the system methanol (1) + DMF (2) at different mole fractions, x_1, and different temperatures T: ■, 293.15 K; •, 298.15 K; ▲, 303.15 K; ▼, 313.15 K; solid triangle pointing left, 323.15 K; solid triangle pointing right, 333.15 K.

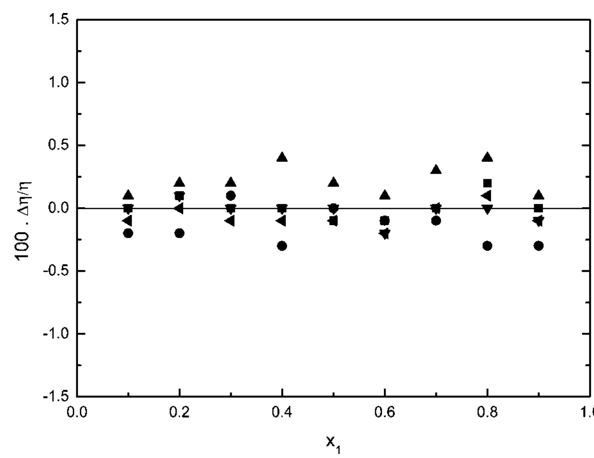

Figure 3. Fractional deviations $\eta = \eta_{exptl} - \eta_{calcd}$ of the experimental viscosities from values η_{calcd} obtained with the correlation of eq 3 for the system methanol (1) + DMF (2) at different mole fractions, x_1, and different temperatures T: ■, 293.15 K; •, 298.15 K; ▲, 303.15 K; ▼, 313.15 K; solid triangle left, 323.15 K.

The viscosities of pure liquids and the mixtures were measured at atmospheric pressure and at different temperatures using an Ubbelohde suspended-level viscometer which was calibrated with doubly distilled water. The uncertainty of viscosity results was within ± 0.003 mPa·s.

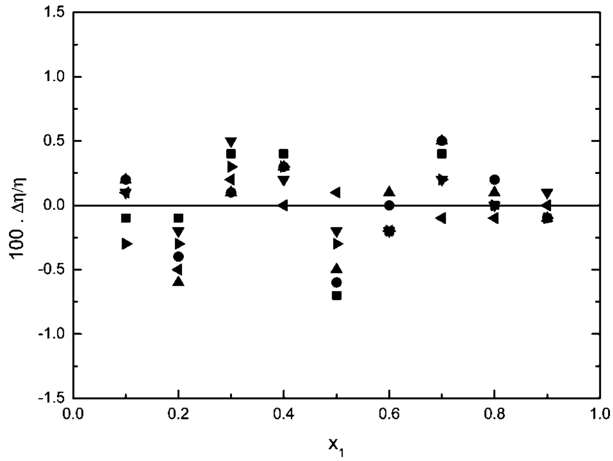

Figure 4. Fractional deviations $\eta = \eta_{\text{exptl}} - \eta_{\text{calcd}}$ of the experimental viscosities from values η_{calcd} obtained with the correlation of eq 3 for the system ethanol (1) + DMF (2) at different mole fractions, x_1, and different temperatures T: ■, 293.15 K; •, 298.15 K; ▲, 303.15 K; ▼, 313.15 K; solid triangle pointing left, 323.15 K; solid triangle pointing right, 333.15 K.

The density and viscosity values and those from the literature for all the pure compounds are listed in Table 1. The details of the methods and techniques used to determine densities and viscosities have been described previously.[20,21]

Result and Discussion

Excess volumes and viscosity deviations were calculated from our measurements according to the following equations:[20]

$$V^{\mathrm{E}} = \frac{x_1M_1 + x_2M_2}{\rho} - \frac{x_1M_1}{\rho_1} - \frac{x_2M_2}{\rho_2} \tag{1}$$

where x_1 and x_2 are mole fractions; M_1 and M_2 are the molar masses; and ρ_1 and ρ_2 are the densities of pure components 1 and 2, respectively. Quantities without subscripts refer to the mixture.

The Redlich–Kister equation[21] is fitted to the experimental excess volumes, V^{E}, for each binary mixture.

$$V^{\mathrm{E}} = x_1(1 - x_1)\sum_{i=0}^{n} A_i(2x_1 - 1)^i \tag{2}$$

where A_i are adjustable parameters. The viscosities are correlated with the equation

$$\eta = x_1\eta_1 + (1 - x_1)\eta_2 + x_1(1 - x_1)\sum_{i=0}^{n} A_i(2x_1 - 1)^i \tag{3}$$

where η is the viscosity of mixtures and η_1 and η_2 are the viscosities of components 1 and 2, respectively.

In each case, the optimum number of coefficients A_i was determined from an examination of the variation of the standard derivation

$$\sigma(Y) = \left[\sum (Y_{\text{calcd}} - Y_{\text{exptl}})^2/(n - m)\right]^{\frac{1}{2}} \tag{4}$$

where n is the total number of experimental values and m is the number of parameters.

The densities, viscosities, and excess molar volume data are presented in Table 2. Table 3 lists the values of the parameters A_i together with the standard deviations.

The relative deviations of the excess molar volumes and viscosity were calculated by the equation

$$\mathrm{RD}\% = \frac{(y_{\text{exptl}} - y_{\text{calcd}}) \cdot 100}{y_{\text{exptl}}} \tag{5}$$

where $y = V^{\mathrm{E}}$ or η; y_{exptl} are the experimental values; and y_{calcd} are calculated values obtained with eq 1 and eq 3, respectively. The average absolute deviations were calculated by

$$\mathrm{AAD}\% = \frac{\sum |(y_{\text{exptl}} - y_{\text{calcd}}) \cdot 100/y_{\text{exptl}}|}{n} = \frac{\sum |\Delta y|}{n} \tag{6}$$

The relative deviation of the excess molar volumes and viscosity at different mole fraction and temperatures for systems of methanol and ethanol with DMF are shown in Figure 1 to Figure 4, respectively. It can be seen from the figures that the relative deviation values of the excess molar volumes for these two binary systems are within ± 2.5 %, and the values for viscosities are within ± 1.0 %.

The V^{E} values for mixtures of methanol + DMF and ethanol + DMF obtained in this work compare with those reported by Wang et al.[2,3] and Zielkiewicz[4] for these mixtures. For the system of methanol with DMF, the absolute average deviation of the experimental excess molar volumes from values obtained with the correlation of the Redlich–Kister equation given by Wang et al. and Zielkiewicz under 9 mole fractions at 293.15 K is 12.6 % and 2.1 %, respectively. For systems of ethanol with DMF, the absolute average deviation between experimental values with the values given by Wang et al.[3] at 313.15 K is 20.5 %. Our results are different from those of Iloukhani and Rostami[5] which are positive at 313.15 K.

From Table 2, it can be seen that V^{E} values are negative for these two binary mixtures over the entire range of compositions. The viscosities decrease with mole fraction of DMF.

Conclusions

Densities and viscosities of the binary mixtures of methanol + DMF and ethanol + DMF have been experimentally measured over several temperatures at atmospheric pressure. The excess molar volume and viscosity were correlated using the Redlich–Kister polynomial equation, and the coefficients and the standard deviation values are given. The excess molar volumes for these two binary systems were negative over the whole composition range and at all temperatures.

Literature Cited

(1) Riddick, J. A.; Bunger, W B.; Sakano, T. K. *Organic Solvents*; 4th ed.; Wiley-Inter Science: NY, 1986.
(2) Bai, T. C.; Yao, J.; Han, S. J. Excess molar volumes for the ternary mixture *N,N*-dimethylformamide + methanol + water at the temperature 298.15 K. *J. Chem. Eng. Data* **1999**, *44*, 491–496.
(3) Bai, T. C.; Yao, J.; Han, S. J. Excess molar volumes for binary and ternary mixtures of (N,N-dimethylformamide + ethanol + water) at the temperature 298.15 K. *J. Chem. Thermodyn.* **1998**, *30*, 1347–1361.
(4) Zielkiewicz, J. Excess volumes in (N,N-dimethylformamide + methanol + water) at the temperature 313.15 K. *J. Chem. Thermodyn.* **1995**, *27*, 415–422.
(5) Iloukhani, H.; Rostami, Z. Measurement of some thermodynamic and acoustic properties of binary solutions of *N,N*-dimethylformamide with 1-alkanols at 30° and comparison with theories. *J. Solution Chem.* **2003**, *32*, 541–562.
(6) Pandarinath, S. N.; Sanjeevan, J. K. Excess molar volumes and deviations in viscosity of binary mixtures of N,N-Dimethylformamide with aniline and benzonitrile at (298.15, 303.15, 308.15, and 313.15) K. *J. Chem. Eng. Data* **2003**, *48*, 972–976.
(7) Han, K.; Oh, J.; Park, S.; Gmehling, J. Excess molar volumes and viscosity deviations for the ternary system N,N-dimethylformamide + N-methylformamide + water and the binary subsystems at 298.15 K. *J. Chem. Eng. Data* **2005**, *50*, 1951–1955.
(8) Baragi, J. G.; Aralaguppi, M. I.; Aminabhavi, T. M.; Kariduraganavar, M. Y.; Kittur, A. S. Density, viscosity, refractive index, and speed of sound for binary mixtures of anisole with 2-chloroethanol, 1,4-dioxane,

tetrachloroethylene, tetrachloroethane, DMF, DMSO, and diethyl oxalate at (298.15, 303.15, and 308.15) K. *J. Chem. Eng. Data* **2005**, *50*, 910–916.

(9) Riddick, J. A.; Bunger, W B.; Sakano, T. K. *Techniques of chemistry willy organic solvent physical properties and methods of purification*, 4th ed.; Wiley-Inter Science: NY, 1986.

(10) Shrikant, S. J.; Tejraj, M. A.; Ramachandra, H. B. Densities and viscosities of binary mixtures of nitrobenzene with cyclohexane and *N*,*N*-dimethylformamide. *J. Chem. Eng. Data* **1990**, *35*, 185–187.

(11) Chan, G.; Knapp, H. Densities and excess molar volumes for sulfolane + ethylbenzene, sulfolane + 1-methylnaphthalene,water + N,N-dimethylformamide, water + methanol, water + N-formylmorpholine, and water + N-methylpyrrolidone. *J. Chem. Eng. Data* **1995**, *40*, 1001–1004.

(12) Yang, C.; Lai, H.; Ma, P. Densities and viscosities of diethyl carbonate + toluene, + methanol, and + 2-propanol from (293.15 to 363.15) K. *J. Chem. Eng. Data* **2006**, *51*, 584–589.

(13) Tu, C.; Lee, S.; Peng, I. Excess volumes and viscosities of binary mixtures of aliphatic alcohols (C_1-C_4) with nitromethane. *J. Chem. Eng. Data* **2001**, *46*, 151–155.

(14) Dimple, A.; Mukhtar, S. Densities and viscosities of binary liquid mixtures of trichloroethylene and tetrachloroethylene with some polar and nonpolar solvents. *J. Chem. Eng. Data* **2004**, *49*, 1218–1224.

(15) Gomez, A. C.; Solimo, H. N. Density, Viscosity, excess molar volume, viscosity deviation, and their correlations for formamide + three alkan-1-ols binary systems. *J. Chem. Eng. Data* **2002**, *47*, 796–800.

(16) Kijevcanin, M. L.; Ribeiro, I. S. A.; Ferreira, A. G. M.; Fonseca, I. M. A. Densities, viscosities, and surface and interfacial tensions of the ternary mixture water + ethyl butyrate + methanol at 303.15 K. *J. Chem. Eng. Data* **2003**, *48*, 1266–1270.

(17) Djojoputro, H.; Ismadji, S. Density and viscosity of binary mixtures of ethyl-2-methylbutyrate and ethyl hexanoate with methanol, ethanol, and 1-propanol at (293.15, 303.15, and 313.15) K. *J. Chem. Eng. Data* **2005**, *50*, 1343–1347.

(18) Tu, C.; Liu, C.; Wang, W.; Chou, Y. Volumetric and viscometric properties of binary mixtures of aliphatic alcohols (C_1-C_4) with nitroethane from 293.15 K to 313.15K. *J. Chem. Eng. Data* **2000**, *45*, 450–456.

(19) Aminabhavi, T. M.; Patil, V. B. Density, viscosity, and speed of sound in binary mixtures of 1-chloronaphthalene with methanol, ethanol, propan-1-ol, butan-1-ol, pentan-1-ol, and hexan-1-ol in the temperature range (298.15–308.15) K. *J. Chem. Eng. Data* **1998**, *43*, 504–508.

(20) Yang, C.; Yu, W.; Tang, D. Densities and viscosities of binary mixtures of *m*-cresol with ethylene glycol or methanol over several temperatures. *J. Chem. Eng. Data* **2006**, *51*, 935–939.

(21) Yang, C.; Liu, Z.; Ma, P. Excess molar volumes and viscosities of binary mixtures of *p*cresol with ethylene glycol and methanol at different temperature and atmospheric pressure. *J. Chem. Eng. Data* **2006**, *51*, 457–461.

Received for review July 28, 2007. Accepted October 13, 2007.

JE700430G