Densities and Viscosities of Four Alkyl Esters with Nitromethane Systems at (293.15, 303.15, and 313.15) K

Shu-Lien Lee and Chein-Hsiun Tu*

Department of Applied Chemistry, Providence University, Shalu 43301 Taichung Hsien, Taiwan, Republic of China

Densities and viscosities were measured for the four binary mixtures formed by methyl acetate, ethyl acetate, propyl acetate, and butyl acetate with nitromethane at (293.15, 303.15, and 313.15) K. Excess volumes and viscosity deviations from the mole fraction average were derived. The kinematic viscosities were compared with McAllister's model.

Introduction

Accurate knowledge of thermodynamic properties of organic liquid mixtures has relevance in understanding the molecular interactions between the components of the mixture, in developing new theoretical models, and also in carrying out engineering applications in the process industry. Data of these properties can be obtained experimentally or by using generalized methods that permit the calculation of the properties of mixtures. The development of a calculation method requires that an adequate database should be available. Although many tabulated values of the above properties are generally available for the pure solvents, literature data relative to various binary mixtures are often lacking.

In the present paper we report density and viscosity for the four binary systems formed by methyl acetate, ethyl acetate, propyl acetate, and butyl acetate with nitromethane at atmospheric pressure (nominal value 0.1 MPa) over the entire composition range at (293.15, 303.15, and 313.15) K. These results are used to calculate excess volumes and deviations in viscosity. The present work aims at contributing to the development of the database for the thermodynamic properties of mixtures of nitroalkanes with various organic solvents. The common nitroalkanes such as nitromethane and nitroethane are high-polarity and moderate boiling point solvents used in a variety of engineering applications. To the best of our knowledge, we are not aware of any extensive study on the mixing properties containing these solvents.

Experimental Section

Methyl acetate, ethyl acetate, propyl acetate, butyl acetate, and nitromethane were obtained from different suppliers. All components were dried over molecular sieves (Aldrich, 0.3 nm). Nitromethane was distilled through a glass column (23-mm i.d. and 470-mm long, Teflon mesh packing) under nitrogen. The other components were used without further purification. The purity of all chemicals was checked by gas chromatography and Karl Fischer titration. In all cases chemicals with a purity greater than 99.5 mass % were used for the experimental investigations. The measured properties of pure components are listed in Table 1 together with the literature values. Refractive indices, n_D, of pure chemicals were measured by an Abbe refractometer, Atago RX-5000, with an accuracy of ±0.000 01 unit.

All dried liquids were boiled to remove dissolved air. Solutions of different composition were prepared by mass in a 50-cm^3 Erlenmeyer flask provided with a joint stopper, using a Mettler AB204 balance accurate to within ±0.1 mg. Densities, ρ, of pure components and mixtures were measured by using a DMA-58 vibrating-tube densimeter (Anton-Paar, Austria), calibrated with deionized doubly distilled water and dry air. The stated uncertainty of the density measurements is $\pm 2 \times 10^{-5}$ g/cm^3. The temperature in the measuring cell was regulated to ±0.01 K.

The kinematic viscosities of pure components and liquid mixtures were determined with a calibrated Ubbelohde capillary viscometer supplied by SCHOTT-GERÄTE, Germany. The kinematic viscosity (ν) is then calculated from the following relationship

$$\nu \equiv \eta/\rho = k(t - \theta) \quad (1)$$

where t is the flow time, η is the absolute viscosity, and k and θ are, respectively, the viscometer constant and the Hagenbach correction (Hardy, 1962). The viscometer was kept in a D20 KP (LAUDA, Germany) thermostat controlled to ±0.01 K with a PID regulator. The accuracy of the flow-time measurement is ±0.01 s. The evaporation losses are negligible and can be controlled by the steps of flow times, which in less favorable cases do not exceed 0.04 s. The densities and viscosities of binary mixtures were measured at three temperatures: (293.15, 303.15, and 313.15) K. An average of at least two measurements was taken into account, and the standard deviations in these measurements were found not to exceed 0.1 kg/m^3 and 6×10^{-10} m^2/s for density and kinematic viscosity, respectively.

Results and Discussion

Tables 2 and 3 list the experimental densities, viscosities, and excess volumes of four binary mixtures methyl acetate + nitromethane, ethyl acetate + nitromethane, propy1 acetate + nitromethane, and butyl acetate + nitromethane, at the three temperatures. The molar excess volumes, V^E, have been calculated from density data according to the equations

* To whom correspondence should be addressed. E-mail: chtu@simon.pu.edu.tw.

10.1021/je980207w CCC: $18.00
Published on Web 12/17/1998

Table 1. Comparison of Measured Densities, Viscosities, and Refractive Indices of Pure Components with Literature Values at 293.15 K

	ρ/g·cm^{-3}		η/mPa·s		n_D	
compound	this work	lit.	this work	lit.	this work	lit.
nitromethane	1.137 54	1.13816[a]	0.6561	0.647[a]	1.382 52	1.38188[a]
methyl acetate	0.933 64	0.9342[a]	0.3853	0.385[a]	1.361 22	1.3614[a]
		0.9333[c]		0.3864[c]		1.3611[c]
ethyl acetate	0.900 62	0.90063[a]	0.4548	0.4508[a]	1.372 55	1.37239[a]
		0.9005[b]		0.4544[b]		1.3725[b]
		0.90099[c]				
propyl acetate	0.887 70	0.8878[b]	0.5863	0.585[a]	1.384 24	1.38442[a]
		0.8878[c]		0.5881[b]		1.3840[b]
		0.8883[a]				1.3846[d]
butyl acetate	0.881 45	0.87636[a]	0.7279	0.7375[a]	1.393 90	1.3942[a]
		(298K)		0.7322[e]		

[a] Riddick et al., 1986. [b] Palaiologou, 1996. [c] Qin et al., 1992. [d] TRC, 1996. [e] Viswanath and Natarajan, 1989.

Table 2. Experimental Densities (ρ), Kinematic Viscosities (ν), and ExcessVolumes (V^E) for Methyl Acetate + Nitromethane and Ethyl Acetate + Nitromethane

x_1	ρ/ (g·cm^{-3})	ν/ (10^{-6} m^2·s^{-1})	V^E/ (cm^3·mol^{-1})	ρ/ (g·cm^{-3})	ν/ (10^{-6} m^2·s^{-1})	V^E/ (cm^3·mol^{-1})	ρ/ (g·cm^{-3})	ν/ (10^{-6} m^2·s^{-1})	V^E/ (cm^3·mol^{-1})
				Methyl Acetate (1) + Nitromethane (2)					
		293.15 K			303.15 K			313.15 K	
0.0000	1.137 54	0.5768	0.0000	1.123 94	0.5251	0.0000	1.110 29	0.4769	0.0000
0.0500	1.123 75	0.5643	−0.0456	1.110 25	0.5135	−0.0517	1.096 67	0.4666	−0.0569
0.1002	1.110 48	0.5540	−0.0895	1.097 03	0.5051	−0.0992	1.083 58	0.4597	−0.1127
0.1500	1.097 80	0.5466	−0.1286	1.084 40	0.4973	−0.1417	1.071 08	0.4531	−0.1638
0.2000	1.085 40	0.5381	−0.1567	1.072 13	0.4896	−0.1773	1.058 82	0.4461	−0.2012
0.2502	1.073 42	0.5298	−0.1818	1.060 13	0.4820	−0.2017	1.046 84	0.4395	−0.2275
0.3000	1.061 96	0.5218	−0.2030	1.048 64	0.4745	−0.2212	1.035 49	0.4328	−0.2559
0.3503	1.050 70	0.5138	−0.2153	1.037 40	0.4669	−0.2342	1.024 26	0.4264	−0.2700
0.4001	1.039 92	0.5061	−0.2227	1.026 68	0.4598	−0.2447	1.013 56	0.4198	−0.2820
0.4500	1.029 57	0.4985	−0.2319	1.016 38	0.4531	−0.2565	1.003 25	0.4136	−0.2931
0.5008	1.019 24	0.4909	−0.2281	1.006 09	0.4457	−0.2543	0.993 02	0.4072	−0.2945
0.5500	1.009 71	0.4828	−0.2308	0.996 59	0.4383	−0.2580	0.983 56	0.4014	−0.3006
0.6000	1.000 10	0.4751	−0.2140	0.987 01	0.4314	−0.2416	0.974 05	0.3947	−0.2884
0.6500	0.991 07	0.4672	−0.2130	0.977 92	0.4248	−0.2350	0.964 82	0.3887	−0.2704
0.7000	0.982 16	0.4592	−0.1971	0.969 01	0.4177	−0.2171	0.955 86	0.3825	−0.2471
0.7500	0.973 54	0.4510	−0.1791	0.960 52	0.4103	−0.2068	0.947 38	0.3766	−0.2360
0.8000	0.965 09	0.4436	−0.1509	0.952 07	0.4035	−0.1762	0.938 81	0.3705	−0.1933
0.8500	0.956 98	0.4352	−0.1262	0.943 82	0.3963	−0.1378	0.930 61	0.3646	−0.1561
0.9000	0.949 03	0.4282	−0.0922	0.935 89	0.3896	−0.1022	0.922 59	0.3587	−0.1099
0.9500	0.941 31	0.4202	−0.0549	0.928 16	0.3825	−0.0607	0.914 82	0.3532	−0.0614
1.0000	0.933 64	0.4127	0.0000	0.920 47	0.3757	0.0000	0.907 17	0.3470	0.0000
				Ethyl Acetate (1) + Nitromethane (2)					
		293.15 K			303.15 K			313.15 K	
0.0000	1.137 54	0.5768	0.0000	1.123 94	0.5251	0.0000	1.110 29	0.4769	0.0000
0.0501	1.117 62	0.5754	−0.0432	1.104 12	0.5236	−0.0448	1.090 62	0.4729	−0.0496
0.1000	1.099 13	0.5741	−0.0793	1.085 81	0.5221	−0.0868	1.072 51	0.4714	−0.0996
0.1500	1.081 79	0.5731	−0.1071	1.068 55	0.5206	−0.1154	1.055 28	0.4700	−0.1267
0.2000	1.065 57	0.5718	−0.1295	1.052 44	0.5191	−0.1403	1.039 33	0.4685	−0.1578
0.2501	1.050 31	0.5695	−0.1452	1.037 29	0.5169	−0.1586	1.024 23	0.4669	−0.1757
0.3000	1.036 08	0.5674	−0.1590	1.023 16	0.5146	−0.1746	1.010 22	0.4649	−0.1959
0.3500	1.022 66	0.5648	−0.1681	1.009 82	0.5117	−0.1848	0.996 95	0.4623	−0.2071
0.4000	1.009 94	0.5618	−0.1682	0.997 23	0.5092	−0.1895	0.984 47	0.4596	−0.2158
0.4500	0.997 99	0.5585	−0.1685	0.985 38	0.5060	−0.1928	0.972 78	0.4572	−0.2272
0.5000	0.986 73	0.5548	−0.1682	0.974 13	0.5028	−0.1887	0.961 53	0.4544	−0.2190
0.5500	0.976 09	0.5513	−0.1664	0.963 52	0.4996	−0.1845	0.951 01	0.4513	−0.2179
0.6000	0.965 98	0.5468	−0.1597	0.953 51	0.4956	−0.1812	0.941 03	0.4484	−0.2130
0.6500	0.956 35	0.5422	−0.1475	0.943 94	0.4918	−0.1691	0.931 47	0.4448	−0.1971
0.7000	0.947 21	0.5370	−0.1338	0.934 84	0.4874	−0.1539	0.922 37	0.4412	−0.1769
0.7500	0.938 54	0.5321	−0.1202	0.926 22	0.4828	−0.1398	0.913 76	0.4380	−0.1587
0.8000	0.930 34	0.5267	−0.1101	0.917 98	0.4779	−0.1206	0.905 61	0.4342	−0.1431
0.8500	0.922 47	0.5217	−0.0931	0.910 15	0.4742	−0.1020	0.897 77	0.4301	−0.1181
0.8999	0.914 79	0.5162	−0.0558	0.902 58	0.4704	−0.0699	0.890 20	0.4264	−0.0801
0.9500	0.907 66	0.5106	−0.0414	0.895 44	0.4655	−0.0489	0.883 02	0.4253	−0.0489
1.0000	0.900 62	0.5050	0.0000	0.888 39	0.4621	0.0000	0.876 03	0.4240	0.0000

$$V^E = V - (x_1V_1 + x_2V_2) \quad (2)$$

with

$$V = (x_1M_1 + x_2M_2)/\rho \quad (3)$$

where V and ρ are the molar volume and density of the mixture. x_1 , V_1, M_1, x_2, V_2, and M_2 are the mole fraction, molar volume, and molecular weight of pure components 1 and 2, respectively.

The dependence of the excess molar volume on the mole fraction at 303.15 K is displayed in Figure 1. It is found that mixtures of nitromethane with methyl acetate, ethyl

Table 3. Experimental Densities (ρ), Kinematic Viscosities (ν), and Excess Volumes (V^E) for Propyl Acetate + Nitromethane and Butyl Acetate + Nitromethane

x_1	ρ/ (g·cm^{-3})	ν/ (10^{-6} m^2·s^{-1})	V^E/ (cm^3·mol^{-1})	ρ/ (g·cm^{-3})	ν/ (10^{-6} m^2·s^{-1})	V^E/ (cm^3·mol^{-1})	ρ/ (g·cm^{-3})	ν/ (10^{-6} m^2·s^{-1})	V^E/ (cm^3·mol^{-1})
Propyl Acetate (1) + Nitromethane (2)									
		293.15 K			303.15 K			313.15 K	
0.0000	1.137 54	0.5768	0.0000	1.123 94	0.5251	0.0000	1.110 29	0.4769	0.0000
0.0501	1.112 27	0.5870	−0.0057	1.099 07	0.5294	−0.0140	1.085 65	0.4816	−0.0147
0.1000	1.089 83	0.5975	−0.0197	1.076 72	0.5378	−0.0214	1.063 51	0.4876	−0.0229
0.1500	1.069 43	0.6072	−0.0277	1.056 58	0.5484	−0.0333	1.043 55	0.4942	−0.0349
0.2001	1.050 92	0.6163	−0.0377	1.038 22	0.5558	−0.0416	1.025 38	0.5018	−0.0447
0.2500	1.034 09	0.6243	−0.0457	1.021 53	0.5630	−0.0480	1.008 82	0.5074	−0.0495
0.3000	1.018 68	0.6316	−0.0552	1.006 26	0.5695	−0.0566	0.993 68	0.5126	−0.0573
0.3500	1.004 48	0.6386	−0.0612	0.992 20	0.5744	−0.0624	0.979 77	0.5172	−0.0645
0.4000	0.991 39	0.6444	−0.0670	0.979 25	0.5787	−0.0689	0.966 93	0.5211	−0.0700
0.4504	0.979 16	0.6494	−0.0699	0.967 12	0.5825	−0.0698	0.954 93	0.5244	−0.0720
0.5001	0.967 97	0.6535	−0.0721	0.956 05	0.5855	−0.0724	0.943 95	0.5280	−0.0731
0.5500	0.957 47	0.6569	−0.0697	0.945 66	0.5878	−0.0700	0.933 67	0.5299	−0.0714
0.6000	0.947 68	0.6598	−0.0689	0.935 97	0.5897	−0.0690	0.924 08	0.5314	−0.0709
0.6500	0.938 53	0.6616	−0.0678	0.926 92	0.5911	−0.0683	0.915 13	0.5332	−0.0713
0.7000	0.929 97	0.6634	−0.0675	0.918 45	0.5922	−0.0681	0.906 74	0.5341	−0.0706
0.7500	0.921 94	0.6639	−0.0675	0.910 51	0.5931	−0.0687	0.898 86	0.5345	−0.0691
0.8000	0.914 37	0.6649	−0.0653	0.903 02	0.5933	−0.0665	0.891 45	0.5349	−0.0673
0.8500	0.907 21	0.6640	−0.0595	0.895 93	0.5930	−0.0600	0.884 44	0.5347	−0.0618
0.9000	0.900 41	0.6632	−0.0485	0.889 21	0.5923	−0.0498	0.877 79	0.5344	−0.0516
0.9499	0.893 99	0.6619	−0.0365	0.882 86	0.5918	−0.0379	0.871 50	0.5334	−0.0390
1.0000	0.887 70	0.6605	0.0000	0.876 63	0.5906	0.0000	0.865 33	0.5329	0.0000
Butyl Acetate (1) + Nitromethane (2)									
		293.15 K			303.15 K			313.15 K	
0.0000	1.137 54	0.5768	0.0000	1.123 94	0.5251	0.0000	1.110 29	0.4769	0.0000
0.0500	1.107 98	0.6002	0.0128	1.094 73	0.5412	0.0149	1.081 34	0.4914	0.0214
0.1000	1.082 12	0.6252	0.0295	1.069 19	0.5598	0.0328	1.056 12	0.5058	0.0406
0.1500	1.059 50	0.6475	0.0376	1.046 84	0.5786	0.0427	1.034 10	0.5238	0.0484
0.2000	1.039 38	0.6669	0.0493	1.026 98	0.5966	0.0548	1.014 47	0.5396	0.0628
0.2500	1.021 54	0.6866	0.0519	1.009 36	0.6131	0.0585	0.997 09	0.5525	0.0659
0.3000	1.005 47	0.7045	0.0574	0.993 43	0.6277	0.0696	0.981 31	0.5652	0.0819
0.3500	0.990 98	0.7208	0.0604	0.979 17	0.6431	0.0697	0.967 27	0.5768	0.0795
0.4000	0.977 83	0.7358	0.0629	0.966 22	0.6539	0.0698	0.954 50	0.5872	0.0788
0.4500	0.965 94	0.7490	0.0559	0.954 40	0.6651	0.0708	0.942 86	0.5972	0.0773
0.5000	0.955 00	0.7627	0.0536	0.943 65	0.6754	0.0642	0.932 22	0.6059	0.0737
0.5500	0.944 92	0.7714	0.0538	0.933 68	0.6847	0.0668	0.922 41	0.6142	0.0731
0.6000	0.935 71	0.7818	0.0446	0.924 59	0.6932	0.0578	0.913 41	0.6200	0.0671
0.6500	0.927 21	0.7911	0.0328	0.916 17	0.7005	0.0497	0.905 14	0.6248	0.0541
0.7000	0.919 27	0.7989	0.0271	0.908 35	0.7071	0.0423	0.897 43	0.6312	0.0454
0.7500	0.911 92	0.8054	0.0166	0.901 39	0.7126	0.0293	0.890 54	0.6368	0.0363
0.8000	0.905 03	0.8113	0.0103	0.894 64	0.7176	0.0174	0.883 88	0.6392	0.0239
0.8500	0.898 58	0.8157	0.0051	0.888 29	0.7217	0.0106	0.877 64	0.6444	0.0131
0.8999	0.892 53	0.8203	0.0023	0.882 31	0.7252	0.0096	0.871 75	0.6483	0.0101
0.9500	0.886 81	0.8232	0.0019	0.876 71	0.7282	0.0031	0.866 21	0.6506	0.0052
1.0000	0.881 45	0.8258	0.0000	0.871 13	0.7302	0.0000	0.860 70	0.6526	0.0000

acetate, or propyl acetate have negative values of V^E. For mixtures of nitromethane with butyl acetate, V^E is positive. The V^E results of the mixtures follow the sequence methyl acetate < ethyl acetate < propyl acetate < butyl acetate. The same sequence also holds true at other temperatures, viz., 293.15 and 313.15 K. The above sequence is in accordance with the molecular size differences between the components of the mixtures. In all the system studied the magnitude of V^E increases systematically from 293.15 K to 313.15 K through the whole range of mole fractions.

The deviation of the viscosity from the mole fraction average is given by

$$\Delta\eta = \eta - (x_1\eta_1 + x_2\eta_2) \tag{4}$$

where η, η_1, and η_2 are the absolute viscosities of the mixture and the viscosities of pure components 1 and 2, respectively. Figure 2 indicates that the deviations in viscosity $\Delta\eta$ follow the sequence methyl acetate < ethyl acetate < propyl acetate < butyl acetate. It was found that the mixtures of nitromethane with methyl acetate or ethyl acetate have negative values of $\Delta\eta$. For mixtures of nitromethane with propyl acetate or butyl acetate, positive values of $\Delta\eta$ are observed. McAllister's multibody interaction model (McAllister, 1960) is widely used for correlating the kinematic viscosity of liquid mixtures with mole fraction. The three-body model is defined as

$$\ln \nu = x_1^3 \ln \nu_1 + 3x_1^2x_2 \ln \nu_{12} + 3x_1x_2^2 \ln \nu_{21} + x_2^3 \ln \nu_2 - \ln(x_1 + x_2M_2/M_1) + 3x_1^2x_2 \ln[(2 + M_2/M_1)/3] + 3x_1x_2^2 \ln[(1 + 2M_2/M_1)/3] + x_2^3 \ln(M_2/M_1) \tag{5}$$

and the four-body model is given by

$$\ln \nu = x_1^4 \ln \nu_1 + 4x_1^3x_2 \ln \nu_{1112} + 6x_1^2x_2^2 \ln \nu_{1122} + 4x_1x_2^3 \ln \nu_{2221} + x_2^4 \ln \nu_2 - \ln(x_1 + x_2M_2/M_1) + 4x_1^3x_2 \times \ln[(3 + M_2/M_1)/4] + 6x_1^2x_2^2 \ln[(1 + M_2/M_1)/2] + 4x_1x_2^3 \times \ln[(1 + 3M_2/M_1)/4] + x_2^4 \ln(M_2/M_1) \tag{6}$$

Table 4. Coefficients of McAllister's Models and Standard Deviations for Kinematic Viscosities

	three-body model			four-body model			
T/K	ν_{12}	ν_{21}	$\sigma/(10^{-6}\mathrm{m^2 \cdot s^{-1}})$	ν_{1112}	ν_{1122}	ν_{2221}	$\sigma/(10^{-6}\mathrm{m^2 \cdot s^{-1}})$
			Methyl Acetate + Nitromethane				
293.15	0.471 25	0.512 64	0.001 07	0.450 10	0.502 20	0.521 25	0.000 54
303.15	0.427 96	0.465 78	0.000 75	0.410 56	0.453 12	0.475 63	0.000 47
313.15	0.390 47	0.425 99	0.000 60	0.376 30	0.412 81	0.434 89	0.000 50
			Ethyl Acetate + Nitromethane				
293.15	0.548 92	0.578 99	0.000 41	0.534 54	0.567 33	0.574 79	0.000 20
303.15	0.494 11	0.525 19	0.000 55	0.482 11	0.514 60	0.520 74	0.000 28
313.15	0.443 67	0.472 54	0.001 37	0.429 71	0.473 18	0.463 66	0.000 55
			Proply Acetate + Nitromethane				
293.15	0.679 88	0.671 24	0.000 30	0.672 26	0.675 62	0.642 56	0.000 24
303.15	0.603 76	0.600 68	0.002 45	0.595 69	0.606 47	0.575 24	0.002 48
313.15	0.547 06	0.538 60	0.001 37	0.536 49	0.551 54	0.514 86	0.001 17
			Butyl Acetate + Nitromethane				
293.15	0.816 93	0.795 39	0.000 76	0.820 70	0.794 98	0.732 94	0.000 57
303.15	0.726 71	0.696 01	0.001 11	0.721 62	0.714 14	0.641 21	0.001 09
313.15	0.646 03	0.626 32	0.001 17	0.642 10	0.639 19	0.578 10	0.001 15

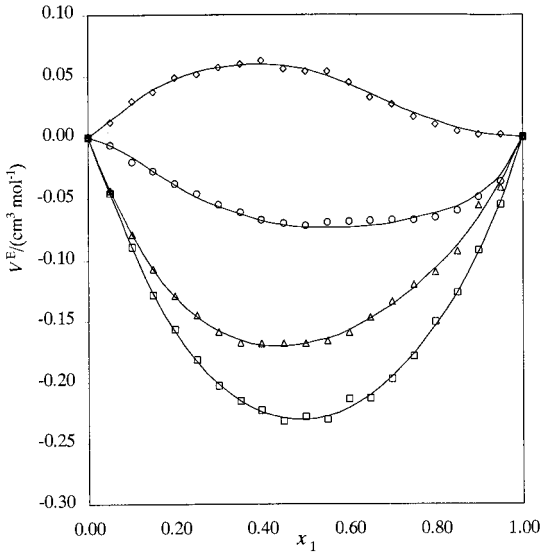

Figure 1. Excess volume variation with mole fraction at 303.15 K: methyl acetate (1) + nitromethane (2) (□), ethyl acetate (1) + nitromethane (2) (△), propyl acetate (1) + nitromethane (2) (○), butyl acetate (1) + nitromethane (2) (◇).

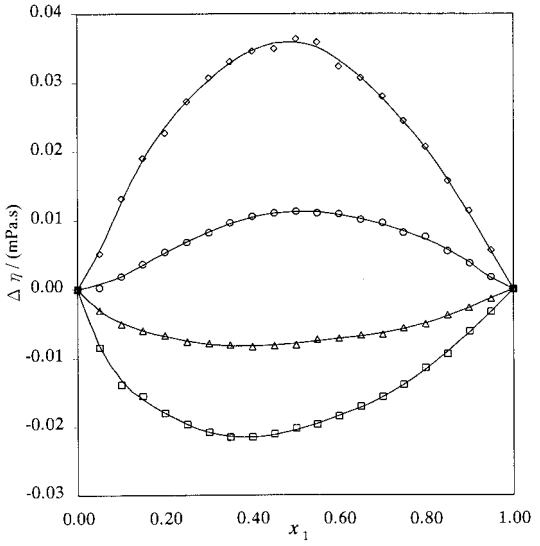

Figure 2. Viscosity deviation variation with mole fraction at 303.15 K: methyl acetate (1) + nitromethane (2) (□), ethyl acetate (1) + nitromethane (2) (△), propyl acetate (1) + nitromethane (2) (○), butyl acetate (1) + nitromethane (2) (◇).

where ν_{12}, ν_{21}, ν_{1112}, ν_{1122}, and ν_{2221} are the model parameters. Table 4 records the calculated results. It is shown that McAllister's model is adequate for those four systems.

Literature Cited

Hardy, R. C. *NBS Monogr. (U. S.)* **1962**, *No. 55*.

McAllister, R. A. The Viscosity of Liquid Mixtures. *AIChE J.* **1960**, *6*, 427−431.

Palaiologou, M. M. Densities, Viscosities, and Refractive Indices of Some Alkyl Esters with 4-Chlorotoluene Systems at (293.15, 298.15, and 303.15) K. *J. Chem. Eng. Data* **1996**, *41*, 1036−1039.

Qin, A.; Hoffman, D. E.; Munk, P. Excess Volume of Mixtures of Selected Alkyl Esters and Ketones with Aromatic Hydrocarbons, *J. Chem. Eng. Data* **1992**, *37*, 66−70.

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

TRC Data Bases for Chemistry and Engineering—TRC Thermodynamic Tables, Version 1.1; Thermodynamic Research Center, The Texas A&M University System: College Station, TX, 1994.

Viswanath, D. S.; Natarajan, G. *Data Book on the Viscosity of Liquids*; Hemisphere: New York, 1989.

Received for review August 24, 1998. Accepted October 7, 1998.

JE980207W