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

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Densities and viscosities were measured for the five binary mixtures formed by methyl acetate, ethyl acetate, propyl acetate, ethyl propionate, and butyl acetate with nitroethane at (293.15, 303.15, and 313.15) K and atmospheric pressure. Densities were determined using a vibrating-tube densimeter. Viscosities were measured with an automatic Ubbelohde capillary viscometer. The estimated uncertainties are ±0.1 kg cm^{-3} and ±0.1% for density and viscosity, respectively. Excess volumes and viscosity deviations from the mole fraction average were derived. The kinematic viscosities were compared with McAllister's model.

Introduction

Mixing properties, such as excess molar volume and deviation in viscosity have been used as a qualitative and quantitative guide to understand the molecular interactions between the components of the mixture, to develop new theoretical models, and also to carry out engineering applications in the process industry. Data for 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 is available. Although many tabulated values of the above properties are generally available for the pure solvents, literature data for the various binary mixtures are often scarce. The present work aims to contribute to the development of a database for the molar volume and viscosity of binary mixtures.

In the present paper we report density and viscosity data for the five binary systems formed by methyl acetate, ethyl acetate, propyl acetate, ethyl propionate, and butyl acetate with nitroethane at atmospheric pressure over the entire composition range at temperatures 293.15 K, 303.15 K, and 313.15 K. These results are used to calculate excess volumes and deviations in viscosity. This work is part of our research program whose purpose is to study the thermodynamic properties of mixtures of nitroalkanes with various organic solvents. The common nitroalkanes such as nitromethane and nitroethane are solvents with high polarity and moderate boiling points, which are used in a variety of engineering applications. To the best of our knowledge, we are not aware of any previous extensive study on the mixing properties containing these solvents.

Experimental Section

The chemicals used were of analytical grade and obtained from Aldrich, Tedia, and Merck. All components were dried over molecular sieves (Aldrich, 0.3 nm). Nitroethane 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 with an Abbe refractometer, Atago RX-5000, with an accuracy of ±0.00001 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 temperature in the measuring cell was regulated to ±0.01 K. The uncertainty of the density measurements was $\pm 1 \times 10^{-5}$ g cm^{-3}.

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) was then calculated from the following relationship

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

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 K, 303.15 K, and 313.15 K. An average of at least two measurements was calculated, and these were reproducible within ±0.1 kg m^{-3} and ±0.1% for density and kinematic viscosity, respectively.

Results and Discussion

Tables 2−4 list the experimental densities, viscosities, and excess volumes of five binary mixtures methyl acetate + nitroethane, ethyl acetate + nitroethane, propy1 acetate + nitroethane, ethyl propionate + nitroethane, and butyl

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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.
nitroethane	1.050 48	1.05057[a]	0.6737	0.677[a]	1.39175	1.39193[a]
methyl acetate	0.933 64	0.9342[a]	0.3853	0.385[a]	1.36122	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]	1.37255	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]	1.38424	1.38442[a]
		0.8878[c]		0.5881[b]		1.3840[b]
		0.8883[a]				1.3846[d]
ethyl propionate	0.890 13	0.8898[a]	0.5239	0.5317[e]	1.38399	1.38394[a]
				(293.24 K)		1.3839[d]
butyl acetate	0.881 45	0.87636[a] (298K)	0.7279	0.7375[a]	1.39390	1.3942[a]
				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 + Nitroethane and Ethyl Acetate + Nitroethane

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) + Nitroethane (2)					
		293.15 K			303.15 K			313.15 K	
0.0000	1.05048	0.6466	0.0000	1.03833	0.5824	0.0000	1.02617	0.5302	−0.0000
0.0500	1.04435	0.6262	−0.0221	1.03221	0.5649	−0.0284	1.01998	0.5137	−0.0298
0.1000	1.03850	0.6089	−0.0592	1.02632	0.5500	−0.0686	1.01423	0.5009	−0.0869
0.1500	1.03252	0.5933	−0.0832	1.02033	0.5358	−0.0974	1.00825	0.4894	−0.1228
0.2006	1.02639	0.5777	−0.0975	1.01426	0.5227	−0.1213	1.00221	0.4770	−0.1553
0.2501	1.02059	0.5633	−0.1212	1.00839	0.5102	−0.1452	0.99619	0.4668	−0.1741
0.2999	1.01472	0.5499	−0.1382	1.00244	0.4980	−0.1614	0.99033	0.4554	−0.2030
0.3500	1.00879	0.5377	−0.1491	0.99646	0.4869	−0.1735	0.98434	0.4462	−0.2200
0.4002	1.00287	0.5255	−0.1572	0.99050	0.4764	−0.1831	0.97834	0.4363	−0.2322
0.4501	0.99701	0.5138	−0.1624	0.98459	0.4663	−0.1891	0.97238	0.4273	−0.2396
0.5000	0.99116	0.5046	−0.1638	0.97869	0.4572	−0.1909	0.96642	0.4193	−0.2418
0.5499	0.98534	0.4944	−0.1629	0.97279	0.4481	−0.1878	0.96047	0.4123	−0.2340
0.6000	0.97941	0.4850	−0.1505	0.96690	0.4398	−0.1823	0.95452	0.4048	−0.2340
0.6499	0.97360	0.4762	−0.1408	0.96099	0.4309	−0.1683	0.94855	0.3959	−0.2194
0.6996	0.96796	0.4639	−0.1380	0.95524	0.4218	−0.1603	0.94277	0.3872	−0.2132
0.7499	0.96208	0.4563	−0.1167	0.94932	0.4138	−0.1387	0.93683	0.3808	−0.1940
0.8000	0.95636	0.4470	−0.1014	0.94354	0.4060	−0.1216	0.93074	0.3732	−0.1542
0.8501	0.95067	0.4384	−0.0836	0.93774	0.3999	−0.0975	0.92484	0.3669	−0.1248
0.8995	0.94501	0.4321	−0.0571	0.93198	0.3928	−0.0649	0.91914	0.3609	−0.1005
0.9499	0.93946	0.4219	−0.0438	0.92636	0.3842	−0.0483	0.91329	0.3527	−0.0668
1.0000	0.93364	0.4127	0.0000	0.92047	0.3757	0.0000	0.90717	0.3470	0.0000
				Ethyl Acetate (1) + Nitroethane (2)					
		293.15 K			303.15 K			313.15 K	
0.0000	1.05048	0.6466	0.0000	1.03833	0.5824	0.0000	1.02617	0.5302	0.0000
0.0501	1.04084	0.6354	−0.0296	1.02870	0.5737	−0.0320	1.01659	0.5223	−0.0416
0.1001	1.03152	0.6264	−0.0567	1.01939	0.5648	−0.0613	1.00718	0.5145	−0.0692
0.1504	1.02242	0.6176	−0.0805	1.01032	0.5568	−0.0887	0.99822	0.5074	−0.1105
0.2000	1.01371	0.6094	−0.1011	1.00157	0.5493	−0.1073	0.98941	0.4998	−0.1296
0.2505	1.00508	0.6016	−0.1176	0.99300	0.5422	−0.1294	0.98095	0.4945	−0.1658
0.3000	0.99688	0.5941	−0.1323	0.98479	0.5356	−0.1440	0.97272	0.4883	−0.1837
0.3500	0.98881	0.5873	−0.1428	0.97674	0.5296	−0.1567	0.96467	0.4828	−0.2011
0.4000	0.98097	0.5806	−0.1510	0.96888	0.5241	−0.1635	0.95675	0.4776	−0.2072
0.4501	0.97737	0.5734	−0.1600	0.96129	0.5172	−0.1735	0.94914	0.4728	−0.2197
0.5000	0.96590	0.5664	−0.1571	0.95384	0.5121	−0.1722	0.94168	0.4674	−0.2212
0.5499	0.95866	0.5594	−0.1542	0.94660	0.5068	−0.1691	0.93341	0.4627	−0.2189
0.6001	0.95159	0.5531	−0.1507	0.93948	0.5015	−0.1604	0.92729	0.4581	−0.2135
0.6500	0.94471	0.5469	−0.1414	0.93265	0.4961	−0.1551	0.92027	0.4536	−0.1927
0.7001	0.93799	0.5404	−0.1304	0.92591	0.4910	−0.1413	0.91351	0.4491	−0.1793
0.7499	0.93143	0.5343	−0.1122	0.91938	0.4861	−0.1249	0.90694	0.4442	−0.1610
0.8000	0.92512	0.5282	−0.1039	0.91304	0.4812	−0.1124	0.90052	0.4400	−0.1421
0.8495	0.91893	0.5224	−0.0822	0.90683	0.4764	−0.0871	0.89429	0.4358	−0.1161
0.8979	0.91301	0.5161	−0.0574	0.90095	0.4713	−0.0648	0.88832	0.4319	−0.0852
0.9500	0.90675	0.5107	−0.0238	0.89471	0.4664	−0.0312	0.88193	0.4278	−0.0355
1.0000	0.90099	0.5046	0.0000	0.88890	0.4618	0.0000	0.87608	0.4239	0.0000

acetate + nitroethane, at three temperatures. The molar excess volumes, V^E, have been calculated from density data according to the equations

$$V^E = V - (x_1 V_1 + x_2 V_2) \quad (2)$$

with

$$V = (x_1 M_1 + x_2 M_2)/\rho \quad (3)$$

where V and ρ are the molar volume and density of the

Table 3. Experimental Densities (ρ), Kinematic Viscosities (ν), and ExcessVolumes (V^E) for Propyl Acetate + Nitroethane and Ethyl Propionate + Nitroethane

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) + Nitroethane (2)									
		293.15 K			303.15 K			313.15 K	
0.0000	1.05048	0.6466	0.0000	1.03833	0.5824	0.0000	1.02617	0.5302	0.0000
0.0500	1.03803	0.6478	−0.0188	1.02600	0.5828	−0.0226	1.01384	0.5298	−0.0192
0.1001	1.02636	0.6493	−0.0446	1.01441	0.5839	−0.0498	1.00235	0.5304	−0.0505
0.1500	1.01534	0.6510	−0.0672	1.00347	0.5849	−0.0740	0.99151	0.5308	−0.0793
0.2002	1.00471	0.6530	−0.0787	0.99287	0.5858	−0.0831	0.98093	0.5319	−0.0861
0.2500	0.99475	0.6548	−0.0926	0.98300	0.5874	−0.0996	0.97110	0.5325	−0.1023
0.2999	0.98525	0.6563	−0.1038	0.97352	0.5884	−0.1077	0.96171	0.5333	−0.1144
0.3500	0.97616	0.6579	−0.1125	0.96453	0.5899	−0.1203	0.95278	0.5343	−0.1287
0.4000	0.96750	0.6596	−0.1183	0.95599	0.5914	−0.1322	0.94423	0.5349	−0.1358
0.4500	0.95926	0.6607	−0.1246	0.94772	0.5925	−0.1308	0.93610	0.5356	−0.1438
0.5000	0.95133	0.6620	−0.1236	0.93993	0.5935	−0.1385	0.92831	0.5356	−0.1477
0.5499	0.94378	0.6628	−0.1228	0.93238	0.5939	−0.1328	0.92090	0.5363	−0.1524
0.6000	0.93650	0.6641	−0.1180	0.92518	0.5950	−0.1313	0.91371	0.5371	−0.1479
0.6500	0.92954	0.6645	−0.1118	0.91828	0.5952	−0.1266	0.90681	0.5364	−0.1390
0.7001	0.92284	0.6649	−0.1028	0.91167	0.5949	−0.1225	0.90018	0.5362	−0.1283
0.7500	0.91646	0.6644	−0.0952	0.90528	0.5949	−0.1088	0.89384	0.5364	−0.1158
0.8000	0.91026	0.6640	−0.0795	0.89911	0.5944	−0.0913	0.88771	0.5355	−0.0983
0.8501	0.90429	0.6634	−0.0625	0.89315	0.5937	−0.0702	0.88181	0.5348	−0.0799
0.9000	0.89855	0.6624	−0.0420	0.88745	0.5929	−0.0492	0.87615	0.5335	−0.0592
0.9500	0.89302	0.6616	−0.0211	0.88193	0.5918	−0.0241	0.87067	0.5328	−0.0344
1.0000	0.88770	0.6605	0.0000	0.87663	0.5906	0.0000	0.86533	0.5329	0.0000
Ethyl Propionate (1) + Nitroethane (2)									
		293.15 K			303.15 K			313.15 K	
0.0000	1.05048	0.6466	0.0000	1.03833	0.5824	0.0000	1.02617	0.5302	0.0000
0.0500	1.03829	0.6421	−0.0216	1.02620	0.5782	−0.0244	1.01420	0.5290	−0.0345
0.1001	1.02674	0.6390	−0.0412	1.01472	0.5750	−0.0477	1.00275	0.5246	−0.0585
0.1499	1.01586	0.6359	−0.0583	1.00390	0.5732	−0.0679	0.99200	0.5225	−0.0825
0.2000	1.00545	0.6322	−0.0715	0.99352	0.5702	−0.0818	0.98172	0.5199	−0.1027
0.2500	0.99563	0.6304	−0.0868	0.98380	0.5688	−0.1036	0.97199	0.5189	−0.1220
0.3000	0.98619	0.6285	−0.0917	0.97441	0.5665	−0.1110	0.96270	0.5170	−0.1360
0.3523	0.97690	0.6266	−0.1040	0.96514	0.5649	−0.1232	0.95340	0.5154	−0.1433
0.4000	0.96877	0.6248	−0.1090	0.95705	0.5634	−0.1299	0.94531	0.5142	−0.1477
0.4500	0.96063	0.6232	−0.1129	0.94893	0.5622	−0.1336	0.93728	0.5127	−0.1577
0.5000	0.95283	0.6214	−0.1132	0.94113	0.5602	−0.1314	0.92959	0.5110	−0.1641
0.5508	0.94526	0.6197	−0.1125	0.93362	0.5589	−0.1344	0.92205	0.5101	−0.1615
0.6000	0.93820	0.6176	−0.1063	0.92660	0.5570	−0.1298	0.91505	0.5079	−0.1563
0.6499	0.93139	0.6154	−0.1043	0.91978	0.5550	−0.1242	0.90824	0.5064	−0.1488
0.6999	0.92488	0.6136	−0.1048	0.91325	0.5531	−0.1198	0.90167	0.5049	−0.1369
0.7500	0.91845	0.6117	−0.0851	0.90688	0.5516	−0.1037	0.89535	0.5033	−0.1232
0.8000	0.91236	0.6089	−0.0728	0.90083	0.5488	−0.0930	0.88929	0.5014	−0.1079
0.8500	0.90649	0.6060	−0.0574	0.89492	0.5464	−0.0696	0.88340	0.4996	−0.0831
0.9001	0.90084	0.6035	−0.0419	0.88928	0.5442	−0.0520	0.87782	0.4972	−0.0694
0.9497	0.89542	0.6006	−0.0213	0.88385	0.5422	−0.0264	0.87234	0.4934	−0.0334
1.0000	0.89013	0.5976	0.0000	0.87855	0.5391	0.0000	0.86702	0.4903	0.0000

Table 4. Experimental Densities (ρ), Kinematic Viscosities (ν), and ExcessVolumes (V^E) for Butyl Acetate (1) + Nitroethane (2)

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})
		293.15 K			303.15 K			313.15 K	
0.0000	1.05048	0.6466	0.0000	1.03833	0.5824	0.0000	1.02617	0.5302	0.0000
0.0501	1.03560	0.6603	−0.0074	1.02362	0.5939	−0.0096	1.01167	0.5389	−0.0135
0.1000	1.02193	0.6734	−0.0147	1.01008	0.6052	−0.0176	0.99834	0.5474	−0.0262
0.1500	1.00924	0.6864	−0.0208	0.99759	0.6159	−0.0297	0.98596	0.5563	−0.0373
0.2001	0.99740	0.6990	−0.0234	0.98588	0.6263	−0.0341	0.97442	0.5656	−0.0458
0.2500	0.98648	0.7120	−0.0305	0.97509	0.6359	−0.0439	0.96374	0.5746	−0.0555
0.3000	0.97624	0.7241	−0.0346	0.96492	0.6468	−0.0458	0.95371	0.5838	−0.0607
0.3501	0.96663	0.7360	−0.0369	0.95543	0.6560	−0.0512	0.94432	0.5930	−0.0663
0.4000	0.95767	0.7466	−0.0400	0.94657	0.6648	−0.0562	0.93554	0.5998	−0.0702
0.4499	0.94923	0.7561	−0.0404	0.93822	0.6741	−0.0579	0.92727	0.6064	−0.0711
0.4999	0.94127	0.7667	−0.0402	0.93034	0.6815	−0.0585	0.91948	0.6134	−0.0726
0.5499	0.93377	0.7763	−0.0401	0.92290	0.6883	−0.0574	0.91212	0.6203	−0.0718
0.6000	0.92667	0.7838	−0.0393	0.91586	0.6940	−0.0559	0.90515	0.6252	−0.0698
0.6499	0.91997	0.7917	−0.0368	0.90924	0.6997	−0.0555	0.89858	0.6296	−0.0670
0.7001	0.91358	0.7981	−0.0332	0.90288	0.7057	−0.0483	0.89230	0.6345	−0.0612
0.7500	0.90756	0.8035	−0.0301	0.89691	0.7100	−0.0441	0.88637	0.6378	−0.0539
0.8000	0.90182	0.8087	−0.0253	0.89121	0.7153	−0.0373	0.88072	0.6422	−0.0455
0.8500	0.89637	0.8138	−0.0215	0.88578	0.7206	−0.0290	0.87536	0.6452	−0.0387
0.8996	0.89120	0.8209	−0.0147	0.88066	0.7236	−0.0219	0.87028	0.6476	−0.0293
0.9501	0.88620	0.8249	−0.0101	0.87567	0.7271	−0.0114	0.86532	0.6502	−0.0150
1.0000	0.88145	0.8258	0.0000	0.87096	0.7303	0.0000	0.86064	0.6527	0.0000

Table 5. Coefficients of McAllister's Models and Standard Deviations for Kinematic Viscosities

	three-body model			four-body model			
T/K	ν_{12}	ν_{21}	σ/(10^{-6} m^2 s^{-1})	ν_{1112}	ν_{1111}	ν_{2221}	σ/(10^{-6} m^2 s^{-1})
			Methyl Acetate + Nitroethane				
293.15	0.476 13	0.525 08	0.000 82	0.459 13	0.500 54	0.552 79	0.000 84
303.15	0.431 22	0.477 17	0.000 62	0.417 72	0.451 49	0.502 87	0.000 64
313.15	0.394 65	0.438 39	0.000 85	0.379 44	0.421 26	0.456 46	0.000 74
			Ethyl Acetate + Nitroethane				
293.15	0.547 22	0.583 41	0.000 60	0.533 05	0.570 61	0.595 00	0.000 34
303.15	0.496 49	0.524 78	0.000 29	0.486 34	0.512 36	0.537 22	0.000 25
313.15	0.452 86	0.478 72	0.000 39	0.443 43	0.469 00	0.488 86	0.000 27
			Propyl Acetate + Nitroethane				
293.15	0.686 91	0.637 98	0.005 85	0.657 50	0.701 25	0.622 79	0.005 07
303.15	0.603 78	0.592 33	0.003 29	0.595 48	0.605 28	0.584 73	0.003 32
313.15	0.543 12	0.536 21	0.000 63	0.536 29	0.545 79	0.530 30	0.000 32
			Ethyl Propionate + Nitroethane				
293.15	0.624 35	0.623 56	0.000 45	0.614 45	0.627 84	0.625 85	0.000 25
303.15	0.562 58	0.562 83	0.000 50	0.553 37	0.567 03	0.564 14	0.000 29
313.15	0.515 45	0.513 40	0.000 52	0.510 03	0.511 25	0.518 36	0.000 50
			Butyl Acetate + Nitroethane				
293.15	0.816 00	0.757 89	0.000 92	0.814 58	0.788 90	0.724 19	0.000 89
303.15	0.717 51	0.677 52	0.000 70	0.716 30	0.701 15	0.647 72	0.000 56
313.15	0.648 51	0.607 06	0.001 04	0.641 52	0.638 13	0.578 99	0.000 49

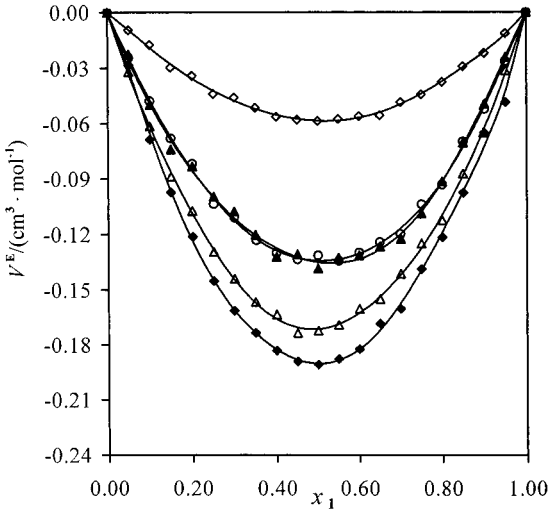

Figure 1. Excess volume variation with mole fraction at 303.15 K: methyl acetate (1) + nitroethane (2) (◆), ethyl acetate (1) + nitroethane (2) (△), ethyl propionate (1) + nitroethane (2) (○), propyl acetate (1) + nitroethane (2) (▲), butyl acetate (1) + nitroethane (2) (◇).

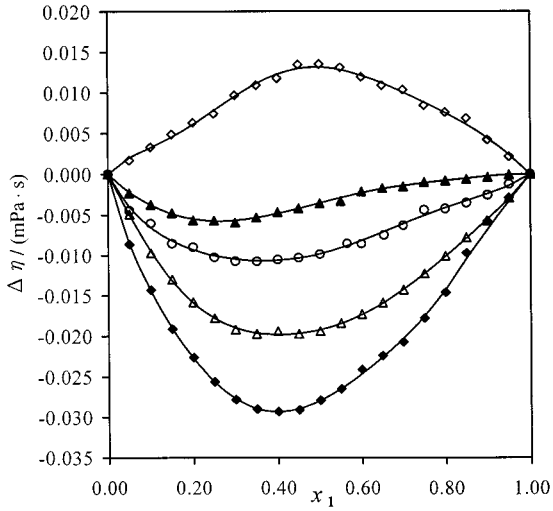

Figure 2. Viscosity deviation variation with mole fraction at 303.15 K: methyl acetate (1) + nitroethane (2) (◆), ethyl acetate (1) + nitroethane (2) (△), ethyl propionate (1) + nitroethane (2) (○), propyl acetate (1) + nitroethane (2) (▲), butyl acetate (1) + nitroethane (2) (◇).

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.

In the system studied, excess molar volumes are negative and increase systematically from 293.15 K to 313.15 K through the whole range of mole fractions. Figure 1 shows the excess molar volumes for the five mixtures at 303.15 K. The V^E results of the mixtures follow the sequence methyl acetate < ethyl acetate < propy1 acetate ≈ ethyl propionate < butyl acetate, and the minima of the curves are located near equimolar compositions. The negative V^E values suggest specific interactions between the mixing components. The interactions in these mixtures may be classified as dipole−dipole type forces resulting from the polarizability of ester molecules by the dipoles of nitroethane molecules.

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

$$\Delta\eta = \eta - (x_1\eta_1 + x_2\eta_2) \qquad (4)$$

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 < ethyl propionate < propy1 acetate < butyl acetate with the positive values for the mixture butyl acetate + nitroethane. 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

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

and the four-body model is given by

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

where ν_{12}, ν_{21}, ν_{1112}, ν_{1122}, and ν_{2221} are the model parameters. Table 5 records the calculated results. It is shown that McAllister's model is adequate for those five systems.

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