Viscosity and Density of Binary Mixtures of Ethyl Alcohol with *n*-Alkanes (C_6, C_8, and C_{10})

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In this work, we present values of viscosity η and density ρ of ethyl alcohol + hexane, + octane, and + decane over the whole composition range at T = (273.15, 275.65, 278.15, 280.65, 283.15, 285.65, 288.15, 290.65, 293.15, 295.65, and 298.15) K and at atmospheric pressure. The deviations of viscosities ($\Delta\eta$) have been calculated from the experimental data. The deviations have been correlated using the Redlich−Kister polynomial equation. The viscosity results have also been correlated by Grunberg−Nissan, Teja−Rice, and Hind correlation equations.

Introduction

For the past few decades, the properties of alcohols and alkanes have been the subject of considerable interest.[1−12] The thermophysical property data of pure compounds and their mixtures determined by these authors play an important role in both theory and applications. They were also employed in understanding the nature of different intermolecular interactions between alkanes and alcohols, which affect their thermodynamic properties.[11,12]

Mixtures of (alcohol + alkane) are of interest, especially the system ethyl alcohol + hydrocarbons. Such mixtures have been used in Brazil for decades as a substitute for petroleum fluids, where hydrated ethanol is incorporated with gasoline for flex-fuel technology, as a gasoline blend.[13−18] Ethyl alcohol has many advantages because it can be derived from biological sources and can be used in flex-fuel engines, namely, engines powered by regular gasoline and/or alcohol. The success of the Brazilian alcohol program has resulted in the reduction of importation of heavy petroleum, associated with an increase in farmers' income and the reduction in carbon dioxide emissions.

Here, we report the densities ρ and viscosities η at atmospheric pressure and at T = (273.15, 275.65, 278.15, 280.65, 283.15, 285.65, 288.15, 290.65, 293.15, 295.65, and 298.15) K for the binary mixtures of ethyl alcohol with *n*-alkanes (C_6, C_8, and C_{10}) over the whole composition range. The viscosity data have also been correlated by Grunberg−Nissan, Teja−Rice, and Hind correlation equations.

Experimental Section

Analytical grade ethyl alcohol, hexane, octane, and decane were respectively obtained from J. T. Baker, Vetec, Synth, and Cromoline. The claimed mass fraction purity for the chemicals was > 0.985, confirmed by chromatography analysis. The alkanes and the ethyl alcohol were used without further purification as their physical properties such as density and viscosity showed good agreement with literature values (see Table 1).

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Table 1. Comparison of Experimental Densities (ρ) and Viscosities (η) of Pure Liquids with the Literature Values at (298.15 and 293.15) K

	T	$10^{-3}\rho$/(kg·m^{-3})		η/(mPa·s)	
liquid	K	experimental	literature[a]	experimental	literature[a]
hexane	293.15	0.6598	0.65941	0.2979	0.3116
octane		0.7056	0.70256	0.5374	0.5452
decane		0.7310	0.72995	0.9133	0.906
ethyl alcohol		0.7902	0.78937	1.2103	1.189
hexane	298.15	0.6553	0.65489	0.2865	0.2968
octane		0.7016	0.69854	0.5087	0.5128
decane		0.7272	0.72614	0.8509	0.8406
ethyl alcohol		0.7859	0.78509	1.0991	1.0826

[a] Data from Thermodynamic Research Center (TRC) Databases for Chemistry and Engineering, TRC Thermodynamic Tables: http://trc.nist.gov/.

The densities ρ and dynamic viscosities η of pure liquids and their binary mixtures were determined using an Anton Paar SVM 3000 digital oscillation U-tube. The measuring cell contains a tube filled with sample, which rotates at constant speed. To calculate the kinematic viscosity from the measured dynamic viscosity, the density must be known. For this reason, the SVM 3000 also has a density cell using the well-known oscillating U-tube principle. Both the density cell and the viscosity cell are filled in one single procedure; the two different measurements occur simultaneously. The binary mixtures for the measurements of densities and viscosities were prepared by mass using an electronic balance (Tecnal Mark 210 A) accurate to 0.1 mg. Density and viscosity measurements have an uncertainty of ± 0.0005 g·cm^{-3} and ± 0.35 %, respectively. The temperature in the cell was regulated to ± 0.01 K. The uncertainty in mole fractions reported on this work is estimated to be lower than ± 1.8 × 10^{-3}.

Results and Discussion

Viscosity values, η, for binary systems along with their densities, ρ, at T = (273.15, 275.65, 278.15, 280.65, 283.15, 285.65, 288.15, 290.65, 293.15, 295.65, and 298.15) K are reported in Table 2. It should be noticed that these values are an average of at least three concurrent measurements. Figure 1 compares these experimental data to that of Papaioannou and

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Table 2. Dynamic Viscosity, η (mPa·s), Viscosity Deviation η (mPa·s), and Densities ρ (g·cm^{-3}) for the Binary Mixtures (x_1 Ethyl Alcohol with Hexane, Octane, or Decane ($1 - x_1$)) at Different Temperatures

Ethanol + Hexane						
	η/mPa·s		$\Delta\eta$/mPa·s		ρ/g·cm^{-3}	
x_1	T/K = 298.15	T/K = 295.65	T/K = 298.15	T/K = 295.65	T/K = 298.15	T/K = 295.65
0.198	0.3049	0.3161	−0.1379	−0.1416	0.6715	0.6739
0.302	0.3398	0.3499	−0.1866	−0.1963	0.6790	0.6814
0.401	0.3755	0.3949	−0.2306	−0.2355	0.6888	0.6911
0.101	0.2953	0.3016	−0.0695	−0.0736	0.6659	0.6682
0.496	0.4288	0.4437	−0.2536	−0.2674	0.6886	0.7009
0.600	0.5021	0.5401	−0.2639	−0.2595	0.7101	0.7124
0.701	0.5944	0.6182	−0.2528	−0.2673	0.7217	0.7240
0.793	0.7071	0.7377	−0.2141	−0.2260	0.7383	0.7406
0.901	0.8663	0.9052	−0.1418	−0.1504	0.7595	0.7617
			Ethanol + Octane			
0.095	0.4675	0.4796	−0.0543	−0.0605	0.6905	0.6926
0.192	0.4770	0.4908	−0.1067	−0.1151	0.6938	0.6959
0.294	0.5022	0.5197	−0.1465	−0.1553	0.6996	0.7017
0.399	0.5386	0.5566	−0.1771	−0.1896	0.7043	0.7065
0.496	0.5828	0.6039	−0.1948	−0.2079	0.7126	0.7147
0.602	0.6396	0.6643	−0.2057	−0.2193	0.7189	0.7211
0.691	0.7137	0.7428	−0.1883	−0.2012	0.7308	0.7329
0.807	0.8061	0.8415	−0.1699	−0.1811	0.7426	0.7447
0.911	0.9250	0.9560	−0.1173	−0.1371	0.7598	0.7620
			Ethanol + Decane			
0.098	0.8230	0.8534	−0.0523	−0.0547	0.7273	0.7294
0.198	0.8318	0.8635	−0.0682	−0.0718	0.7289	0.7309
0.301	0.8314	0.8638	−0.0943	−0.0995	0.7311	0.7331
0.397	0.8501	0.8848	−0.0993	−0.1046	0.7340	0.7360
0.501	0.8872	0.9255	−0.0881	−0.0922	0.7375	0.7395
0.602	0.9216	0.9620	−0.0787	−0.0832	0.7425	0.7445
0.694	0.9407	0.9830	−0.0824	−0.0872	0.7470	0.7490
0.799	0.9698	1.0138	−0.0795	−0.0849	0.7544	0.7565
0.905	1.0132	1.0600	−0.0623	−0.0676	0.7669	0.7691

Ethanol + Hexane						
	η/mPa·s		$\Delta\eta$/mPa·s		ρ/g·cm^{-3}	
x_1	T/K = 293.15	T/K = 290.65	T/K = 293.15	T/K = 290.65	T/K = 293.15	T/K = 290.65
0.101	0.3080	0.3147	−0.0779	−0.0819	0.6705	0.6728
0.198	0.3264	0.3366	−0.1467	−0.1525	0.6762	0.6786
0.302	0.3597	0.3728	−0.2071	−0.2154	0.6837	0.6860
0.401	0.3995	0.4330	−0.2564	−0.2496	0.6935	0.6958
0.496	0.4493	0.4980	−0.2922	−0.2752	0.7032	0.7055
0.600	0.5606	0.5822	−0.2744	−0.2902	0.7147	0.7170
0.701	0.6430	0.6691	−0.2829	−0.2996	0.7262	0.7285
0.793	0.7696	0.8031	−0.2391	−0.2534	0.7428	0.7451
0.901	0.9463	0.9898	−0.1597	−0.1696	0.7639	0.7660
			Ethanol + Octane			
0.095	0.4931	0.5072	−0.0616	−0.0671	0.6947	0.6968
0.192	0.5049	0.5195	−0.1201	−0.1294	0.6980	0.7001
0.294	0.5366	0.5541	−0.1623	−0.1732	0.7038	0.7059
0.399	0.5752	0.5946	−0.1997	−0.2134	0.7086	0.7108
0.496	0.6298	0.6543	−0.2154	−0.2283	0.7168	0.7189
0.602	0.6899	0.7168	−0.2321	−0.2473	0.7232	0.7253
0.691	0.7742	0.8071	−0.2122	−0.2255	0.7351	0.7372
0.807	0.8781	0.9164	−0.1924	−0.2054	0.7469	0.7491
0.911	0.9997	1.0460	−0.1461	−0.1558	0.7641	0.7663
			Ethanol + Decane			
0.098	0.8862	0.9207	−0.0562	−0.0567	0.7312	0.7331
0.198	0.8973	0.9321	−0.0748	−0.0777	0.7328	0.7348
0.301	0.8982	0.9348	−0.1045	−0.1085	0.7351	0.7370
0.397	0.9215	0.9608	−0.1097	−0.1137	0.7380	0.7400
0.501	0.9660	1.0094	−0.0961	−0.0988	0.7415	0.7435
0.602	1.0065	1.0529	−0.0856	−0.0881	0.7466	0.7486
0.694	1.0281	1.0762	−0.0913	−0.0947	0.7511	0.7531
0.799	1.0606	1.1103	−0.0900	−0.0947	0.7585	0.7606
0.905	1.1095	1.1623	−0.0726	−0.0771	0.7712	0.7733

Table 2.. Continued

Ethanol + Hexane						
	η/mPa·s		$\Delta\eta$/mPa·s		ρ/g·cm^{-3}	
x_1	T/K = 288.15	T/K = 285.65	T/K = 288.15	T/K = 285.65	T/K = 288.15	T/K = 285.65
0.101	0.3215	0.3283	−0.0864	−0.0914	0.6752	0.6775
0.198	0.3460	0.3549	−0.1599	−0.1687	0.6809	0.6832
0.302	0.3830	0.3934	−0.2280	−0.2415	0.6883	0.6906
0.401	0.4239	0.4614	−0.2870	−0.2795	0.6981	0.7004
0.496	0.5159	0.5343	−0.2910	−0.3084	0.7079	0.7101
0.600	0.6052	0.6290	−0.3068	−0.3250	0.7193	0.7215
0.701	0.6967	0.7257	−0.3174	−0.3365	0.7308	0.7330
0.793	0.8384	0.8754	−0.2685	−0.2854	0.7473	0.7495
0.901	1.0360	1.0848	−0.1801	−0.1916	0.7682	0.7704
			Ethanol + Octane			
0.095	0.5207	0.5351	−0.0693	−0.0765	0.6989	0.7010
0.192	0.5347	0.5505	−0.1351	−0.1458	0.7022	0.7043
0.294	0.5721	0.5906	−0.1815	−0.1948	0.7081	0.7102
0.399	0.6150	0.6363	−0.2250	−0.2408	0.7129	0.7150
0.496	0.6805	0.7070	−0.2393	−0.2549	0.7210	0.7231
0.602	0.7453	0.7758	−0.2616	−0.2787	0.7275	0.7296
0.691	0.8411	0.8763	−0.2390	−0.2559	0.7394	0.7415
0.807	0.9580	1.0016	−0.2175	−0.2319	0.7512	0.7533
0.911	1.0950	1.1469	−0.1660	−0.1775	0.7684	0.7705
			Ethanol + Decane			
0.098	0.9574	0.9963	−0.0565	−0.0570	0.7350	0.7370
0.198	0.9702	1.0100	−0.0792	−0.0820	0.7367	0.7387
0.301	0.9738	1.0154	−0.1122	−0.1164	0.7390	0.7410
0.397	1.0029	1.0477	−0.1172	−0.1212	0.7420	0.7440
0.501	1.0557	1.1054	−0.1013	−0.1037	0.7455	0.7475
0.602	1.1036	1.1584	−0.0893	−0.0898	0.7506	0.7527
0.694	1.1276	1.1826	−0.0979	−0.1012	0.7552	0.7573
0.799	1.1632	1.2195	−0.0996	−0.1049	0.7627	0.7647
0.905	1.2183	1.2776	−0.0822	−0.0878	0.7753	0.7774

Ethanol + Hexane						
	η/mPa·s		$\Delta\eta$/mPa·s		ρ/g·cm^{-3}	
x_1	T/K = 283.15	T/K = 280.65	T/K = 283.15	T/K = 280.65	T/K = 283.15	T/K = 280.65
0.101	0.3352	0.3422	−0.0970	−0.1024	0.6798	0.6820
0.198	0.3635	0.3722	−0.1789	−0.1893	0.6855	0.6878
0.302	0.4042	0.4154	−0.2562	−0.2715	0.6929	0.6952
0.401	0.4766	0.4927	−0.2962	−0.3135	0.7027	0.7049
0.496	0.5537	0.5741	−0.3270	−0.3467	0.7124	0.7147
0.600	0.6543	0.6809	−0.3445	−0.3652	0.7238	0.7261
0.701	0.7562	0.7884	−0.3573	−0.3794	0.7352	0.7374
0.793	0.9147	0.9561	−0.3033	−0.3226	0.7517	0.7539
0.901	1.1365	1.1914	−0.2041	−0.2176	0.7725	0.7747
			Ethanol + Octane			
0.095	0.5505	0.5664	−0.0783	−0.0862	0.7030	0.7051
0.192	0.5669	0.5841	−0.1524	−0.1649	0.7064	0.7085
0.294	0.6105	0.6308	−0.2040	−0.2194	0.7125	0.7148
0.399	0.6587	0.6822	−0.2539	−0.2723	0.7171	0.7192
0.496	0.7348	0.7643	−0.2683	−0.2865	0.7231	0.7252
0.602	0.8067	0.8399	−0.2955	−0.3161	0.7317	0.7338
0.691	0.9146	0.9555	−0.2706	−0.2889	0.7436	0.7457
0.807	1.0474	1.0966	−0.2462	−0.2630	0.7554	0.7576
0.911	1.2020	1.2605	−0.1887	−0.2024	0.7726	0.7747
			Ethanol + Decane			
0.098	1.0380	1.0825	−0.0527	−0.0686	0.7389	0.7408
0.198	1.0530	1.0990	−0.0802	−0.0965	0.7406	0.7425
0.301	1.0598	1.1074	−0.1171	−0.1338	0.7429	0.7448
0.397	1.0956	1.1471	−0.1221	−0.1366	0.7460	0.7479
0.501	1.1594	1.2173	−0.1025	−0.1126	0.7495	0.7515
0.602	1.2193	1.2821	−0.0855	−0.0926	0.7547	0.7567
0.694	1.2417	1.3052	−0.1021	−0.1103	0.7593	0.7613
0.799	1.2796	1.3438	−0.1088	−0.1183	0.7668	0.7688
0.905	1.3408	1.4081	−0.0927	−0.1010	0.7795	0.7816

Table 2.. Continued

Ethanol + Hexane						
	η/mPa·s		$\Delta\eta$/mPa·s		ρ/g·cm^{-3}	
x_1	T/K = 278.15	T/K = 275.65	T/K = 278.15	T/K = 275.65	T/K = 278.15	T/K = 275.65
0.101	0.3492	0.3563	−0.1089	−0.1154	0.6843	0.6865
0.198	0.3812	0.3904	−0.2010	−0.2132	0.6900	0.6923
0.302	0.4269	0.4388	−0.2884	−0.3062	0.6975	0.6997
0.401	0.5119	0.5294	−0.3300	−0.3502	0.7076	0.7098
0.496	0.5956	0.6182	−0.3679	−0.3906	0.7169	0.7192
0.600	0.7090	0.7386	−0.3875	−0.4115	0.7283	0.7305
0.701	0.8224	0.8583	−0.4034	−0.4292	0.7397	0.7419
0.793	1.0003	1.0467	−0.3432	−0.3659	0.7561	0.7583
0.901	1.2496	1.3115	−0.2321	−0.2479	0.7768	0.7790
			Ethanol + Octane			
0.095	0.5830	0.6003	−0.0889	−0.0972	0.7072	0.7092
0.192	0.6019	0.6206	−0.1726	−0.1862	0.7118	0.7139
0.294	0.6520	0.6743	−0.2305	−0.2474	0.7172	0.7195
0.399	0.7069	0.7329	−0.2866	−0.3072	0.7213	0.7234
0.496	0.7951	0.8280	−0.3010	−0.3213	0.7294	0.7315
0.602	0.8751	0.9122	−0.3332	−0.3565	0.7359	0.7380
0.691	1.0082	1.0541	−0.2943	−0.3149	0.7478	0.7499
0.807	1.1484	1.2032	−0.2768	−0.2965	0.7597	0.7617
0.911	1.3227	1.3888	−0.2125	−0.2281	0.7768	0.7789
.						
			Ethanol + Decane			
0.098	1.1301	1.1813	−0.0726	−0.0771	0.7427	0.7446
0.198	1.1479	1.2001	−0.1021	−0.1091	0.7444	0.7464
0.301	1.1584	1.2133	−0.1403	−0.1483	0.7468	0.7487
0.397	1.2026	1.2627	−0.1415	−0.1478	0.7499	0.7518
0.501	1.2811	1.3509	−0.1122	−0.1125	0.7534	0.7554
0.602	1.3534	1.4320	−0.0877	−0.0827	0.7587	0.7607
0.694	1.3738	1.4483	−0.1108	−0.1132	0.7633	0.7654
0.799	1.4125	1.4861	−0.1218	−0.1289	0.7709	0.7729
0.905	1.4801	1.5566	−0.1044	−0.1123	0.7836	0.7857

Ethanol + Hexane			
x_1	η/mPa·s T/K = 273.15	$\Delta\eta$/mPa·s T/K = 273.15	ρ/g·cm^{-3} T/K = 273.15
0.101	0.3638	−0.1230	0.6888
0.198	0.4000	−0.2270	0.6945
0.302	0.4511	−0.3261	0.7020
0.401	0.5478	−0.3725	0.7121
0.496	0.6415	−0.4162	0.7214
0.600	0.7700	−0.4379	0.7327
0.701	0.8963	−0.4577	0.7441
0.793	1.0961	−0.3908	0.7604
0.901	1.3773	−0.2657	0.7811
		Ethanol + Octane	
0.095	0.6185	−0.1012	0.7133
0.192	0.6401	−0.1966	0.7159
0.294	0.6980	−0.2617	0.7196
0.399	0.7603	−0.3260	0.7255
0.496	0.8635	−0.3398	0.7322
0.602	0.9516	−0.3794	0.7401
0.691	1.1030	−0.3354	0.7520
0.807	1.2616	−0.3167	0.7639
0.911	1.4594	−0.2443	0.7810
		Ethanol + Decane	
0.098	1.2363	−0.0820	0.7465
0.198	1.2572	−0.1157	0.7483
0.301	1.2726	−0.1566	0.7507
0.397	1.3280	−0.1536	0.7538
0.501	1.4290	−0.1094	0.7574
0.602	1.5226	−0.0710	0.7627
0.694	1.5297	−0.1142	0.7674
0.799	1.5653	−0.1359	0.7749
0.905	1.6387	−0.1204	0.7877

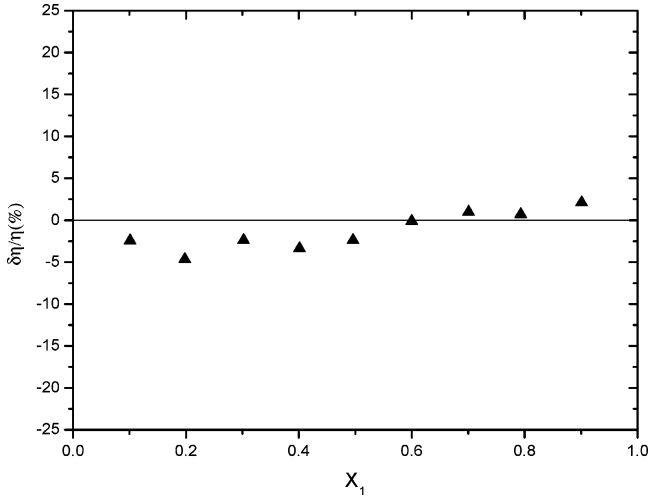

Figure 1. Deviations of experimental viscosity values vs ethyl alcohol mole fraction, x_1, at 298.15 K. ▲ (Papaioannou and Panayiotou),[19] x ethyl alcohol + $(1 - x)$ hexane.

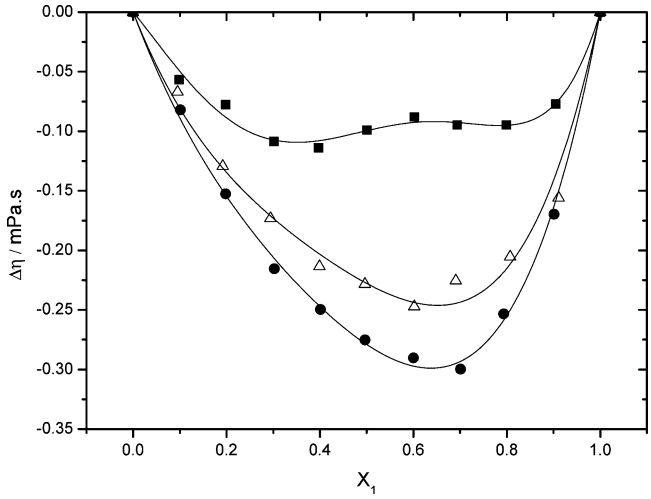

Figure 2. Deviation of dynamic viscosity from the mole fraction average of the binary mixtures x at 290.65 K. Experimental results: ●, x ethyl alcohol + $(1 - x)$ hexane; △, x ethyl alcohol + $(1 - x)$ octane; ■, x ethyl alcohol + $(1 - x)$ decane. Lines are calculated from Redlich−Kister polynomials.

Panayiotou.[19] These authors measured the viscosity of four binary alkanol + alkane mixtures of ethanol and 1-propanol with hexane and heptane at 298.15 K. It can be observed that there is a good agreement between the experimental results found in this work and those of Papaioannou and Panayiotou,[19] with a maximum deviation of 5 %. It should be noticed that this large discrepancy is due to the difference on composition between the binary mixture prepared on this work and those found in the literature. For this reason, we could not use other experimental data found in the literature for the systems studied in this work.

Viscosity deviation values were correlated by means of the Redlich−Kister polynomial,[21] which for binary mixtures is

$$\Delta\eta = x_1(1 - x_1)\sum_{j=1}^{k} A_j(1 - 2x_1)^j \qquad (1)$$

where $\Delta\eta$ is the viscosity deviation, x_1 is the mole fraction of ethyl alcohol, A_j is a parameter, and k is the degree of the polynomial expansion. A_j values were obtained by a nonlinear least-squares fitting procedure. The corresponding standard deviations are given by

$$\sigma(\Delta\eta) = \sqrt{\frac{\sum(\Delta\eta - \Delta\eta_{cal})}{(n - p)}} \qquad (2)$$

where the subscript cal refers to calculated data and n and p are the number of experimental points and number of parameters retained in the respective equation. The adjustable parameters, A_k, and standard deviations, σ, calculated using eq 2 for viscosity deviations are listed in Table 3.

The results shown in Figure 2 and Table 2 indicate that $\Delta\eta$ values are slightly negative. It should be noticed that this

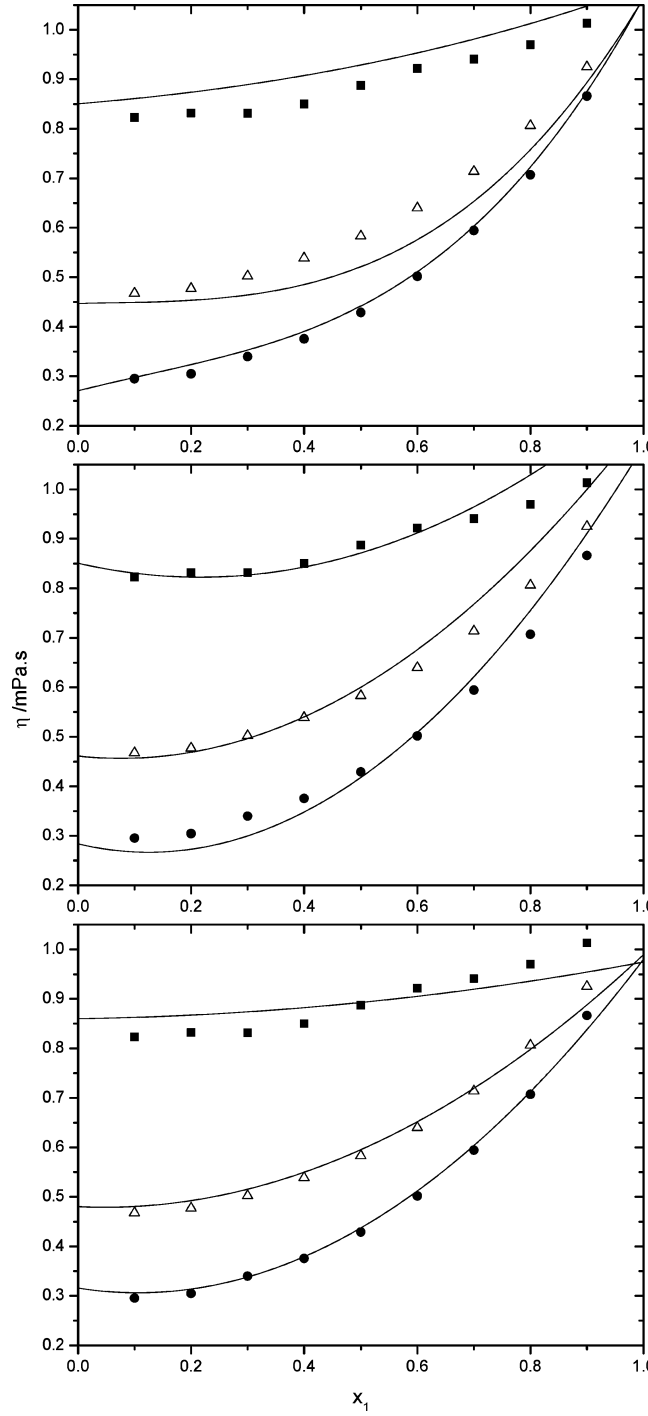

Figure 3. Viscosity values vs ethyl alcohol mole fraction, x, at 298.15 K. Full lines correspond to the correlation obtained by methods of Grunberg−Nissan[22] (top graph), Teja−Rice[23] (middle graph), and Hind and collaborators[24] (bottom graph). Experimental results: ●, x ethyl alcohol + $(1 - x)$ hexane; △, x ethyl alcohol + $(1 - x)$ octane; ■, x ethyl alcohol + $(1 - x)$ decane.

Table 3. Estimated Parameters of Eq 3 for Viscosity Deviation ($\Delta\eta$) of the Binary Mixtures (Ethyl Alcohol with Hexane, Octane, or Decane), at Different Temperatures, along with the Standard Deviation (σ)

function	T/K	A_0	A_1	A_2	A_3	σ/mPa·s	R^2
			Ethanol + Hexane				
$\Delta\eta$/mPa·s	298.15	−1.016	0.409	−0.223		0.005	0.998
	295.65	−1.041	0.431	−0.301		0.009	0.995
	293.15	−1.122	0.456	−0.252		0.012	0.992
	290.65	−1.116	0.521	−0.453		0.006	0.997
	288.15	−1.206	0.534	−0.415		0.012	0.992
	285.65	−1.251	0.596	−0.512		0.008	0.996
	283.15	−1.326	0.635	−0.552		0.008	0.996
	280.65	−1.405	0.680	−0.599		0.009	0.996
	278.15	−1.488	0.729	−0.645		0.010	0.996
	275.65	−1.579	0.781	−0.701		0.010	0.996
	273.15	−1.681	0.701	−0.761		0.008	0.996
			Ethanol + Octane				
$\Delta\eta$/mPa·s	298.15	−0.772	0.329	−0.328		0.004	0.989
	295.65	−0.818	0.364	−0.423		0.007	0.981
	293.15	−0.857	0.399	−0.457		0.008	0.980
	290.65	−0.911	0.419	−0.505		0.009	0.980
	288.15	−0.960	0.456	−0.536		0.009	0.979
	285.65	−1.024	0.478	−0.593		0.010	0.979
	283.15	−1.081	0.522	−0.620		0.011	0.978
	280.65	−1.155	0.548	−0.685		0.012	0.978
	278.15	−1.210	0.564	−0.704		0.014	0.972
	275.65	−1.294	0.597	−0.776		0.015	0.973
	273.15	−1.572	0.651	−0.831		0.012	0.972
			Ethanol + Decane				
$\Delta\eta$/mPa·s	298.15	−0.352	−0.137	−0.393	0.405	0.007	0.977
	295.65	−0.370	−0.147	−0.428	0.454	0.007	0.978
	293.15	−0.383	−0.165	−0.461	0.526	0.008	0.977
	290.65	−0.398	−0.181	−0.490	0.594	0.008	0.979
	288.15	−0.407	−0.199	−0.520	0.686	0.008	0.978
	285.65	−0.417	−0.225	−0.563	0.787	0.008	0.978
	283.15	−0.412	−0.256	−0.591	0.945	0.009	0.975
	280.65	−0.451	−0.310	−0.724	0.966	0.014	0.972
	278.15	−0.450	−0.372	−0.801	1.074	0.012	0.985
	275.65	−0.451	−0.444	−0.919	1.244	0.014	0.957
	273.15	−0.440	−0.544	−1.070	1.472	0.018	0.936

behavior was observed for all binary mixtures formed over the whole mole fraction range at all studied temperatures. The magnitude of the viscosity deviations ($\Delta\eta$) follows the sequence: hexane < octane < decane (the $\Delta\eta$ values are negative for all of these systems and become less negative with an increase in chain length of the alkane).

Several semiempirical relations have been proposed in the literature to estimate the viscosity of liquid mixtures in terms of pure component data. In this work, the methods proposed by Grunberg−Nissan,[22] Teja−Rice,[23] and Hind and collaborators[24] were examined.

Grunberg−Nissan[22] suggested a logarithmic relation between the viscosity of a liquid mixture and that of its pure components:

$$\eta = \exp\left[\sum_{i=1}^{2}(x_i \ln \eta_i) + G_{12}\prod_{i=1}^{2} x_i\right] \qquad (3)$$

where G_{12} is a constant that is regarded as a measure of the strength of the molecular interactions between the mixing components.

Teja−Rice[23] developed the following equation for the viscosity of binary liquid mixtures:

$$\ln(\eta\xi) = \ln(\eta\xi)^{(r1)} + \frac{\omega - \omega^{(r1)}}{\omega^{(r2)} - \omega^{(r1)}}[\ln(\eta\xi)^{(r2)} - \ln(\eta\xi)^{(r1)}] \qquad (4)$$

where the superscripts (r1) and (r2) refer to two (nonspherical) reference fluids and $\eta\xi$ is the reduced viscosity of the two substances at the same reduced temperature T_R and reduced pressure p_R.

Hind et al.[24] suggested the following equation for binary mixtures:

$$\eta_{mix} = x^2\eta_{11} + 2x(1-x)\eta_{12} + (1-x)^2\eta_{22} \qquad (5)$$

where η_{11} and η_{22} are the viscosity for pure compounds and η_{12} is an adjustable parameter related to unlike pair interactions.

From Figure 3 it is observed that, as expected, because of the presence of ethyl alcohol, the model proposed by Teja−Rice[23] presents the best correlation with the experimental data when compared with the other two models studied.

Conclusions

In this paper, viscosities and densities of binary mixtures of ethyl alcohol with *n*-alkanes (C_6, C_8, and C_{10}) at temperatures of (273.15, 275.65, 278.15, 280.65, 283.15, 285.65, 288.15, 290.65, 293.15, 295.65, and 298.15) K and at atmospheric pressure were measured. The physical property data for these systems will be useful from a theoretical point of view and also in the formulation of the gasoline mixtures for flex-fuel technology. Viscosities deviations are calculated using experimental data. For our results, it was suggested that the viscosity in these mixtures depends upon the length of the hydrocarbon molecule.

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