Surface Tensions, Refractive Indexes and Excess Molar Volumes of Hexane + 1-Alkanol Mixtures at 298.15 K

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Surface tensions and refractive indexes for binary mixtures of {hexane + ethanol, + 1-propanol, + 1-butanol, + 1-pentanol, + 1-hexanol, + 1-heptanol, and + 1-octanol} have been measured at 298.15 K. Surface tension deviations and changes of refractive index have been also calculated. Excess molar volumes of {hexane + ethanol, + 1-pentanol, and + 1-hexanol} mixtures have been determined at 298.15 K from density data and compared with literature.

Introduction

We have initiated with this work our studies on surface tension, which added to other thermodynamic and physical properties such as viscosity, refractive index, density, excess molar volumes, and excess molar enthalpies form part of our systematic research on nonaqueous binary mixtures.[1,2] Surface tension is a property of interest because of its applications in industrial chemistry, but there is a lack of reliable measurements on mixtures of practical interest.

We present here the excess molar volumes of {hexane + ethanol, + 1-pentanol, and + 1-hexanol} at 298.15 K, and our results have been compared with those from the literature. Also, surface tensions and refractive indexes of {hexane + ethanol, + 1-propanol, + 1-butanol, + 1-pentanol, + 1-hexanol, + 1-heptanol, and + 1-octanol} mixtures have been measured at 298.15 K.

Experimental Section

The purities and the sources of the chemicals employed were hexane (Fluka, ≥99.5), ethanol (Fluka, >99.8), 1-propanol (Sigma-Aldrich, ≥99.5), 1-butanol (Fluka, >99.5), 1-pentanol (Fluka, >99.0), 1-hexanol (Fluka, ≥99), 1-heptanol (Sigma, ≥99), and 1-octanol (Fluka, >99.5). The substances were degassed by ultrasound and dried over molecular sieves (Sigma type 0.4 nm) and otherwise used as supplied. Table 1 shows their measured physical properties compared with literature data.

All the mixtures were prepared by mass using a Mettler AT 201 balance with a accuracy of 1×10^{-8} kg.

Densities of the pure liquids and their mixtures were measured with an Anton Paar DMA 60/602 vibrating tube densimeter. The vibrating tube temperature was regulated to within ±0.01 K using a Haake F3 thermostat with an Anton Paar DT 100-20 digital thermometer. The calibration was made with doubly distilled water and with heptane (Sigma, >99). Excess molar volumes were determined from the density data as follows:

$$V_m^E = \frac{M}{\rho} - x_1\frac{M_1}{\rho_1} - x_2\frac{M_2}{\rho_2} \quad (1)$$

where M and M_i are the molar mass of the mixture and component i, respectively; ρ and ρ_i are the densities of the mixture and component i; x_i is the mole fraction of component i.

Table 1. Physical Properties of the Pure Components at 298.15 K

	ρ/g·cm^{-3}		n_D		σ/mN·m^{-1}	
substance	exptl	lit.	exptl	lit.	exptl	lit.
hexane	0.654 77	0.654 79[a]	1.372 3	1.372 26[b]	17.89	17.88[c]
ethanol	0.785 53	0.785 4[d]	1.359 3	1.359 41[b]	21.74	21.82[e]
1-propanol	0.799 62	0.799 60[f]	1.383 0	1.383 0[g]	23.39	23.39[h]
1-butanol	0.805 76	0.805 81[i]	1.397 3	1.397 3[j]	24.02	24.41[h]
1-pentanol	0.810 83	0.810 85[k]	1.408 0	1.408 0[b]	24.97	25.30[h]
1-hexanol	0.815 15	0.815 15[k]	1.415 9	1.415 7[b]	25.73	25.90[h]
				1.416 1[j]		
1-heptanol	0.818 75	0.818 71[l]	1.422 4	1.422 5[j]	26.47	26.5[j]
1-octanol	0.821 63	0.821 62[i]	1.427 4	1.427 5[j]	27.13	27.1[j]

[a] Reference 3. [b] Reference 4. [c] Reference 5. [d] Reference 6. [e] Reference 7. [f] Reference 2. [g] Reference 8. [h] Reference 9. [i] Reference 1. [j] Reference 10. [k] Reference 11. [l] Reference 12.

Refractive indexes (n_D) were measured with an Atago RX-1000 automatic refractometer with a reproducibility in the refractive index of 1×10^{-4}, and the temperature was regulated to better than ±0.1 K using a Polyscience 9101 thermostat. The changes of refractive index (Δn_D) were calculated by

$$\Delta n_D = n_D - x_1 n_{D,1} - x_2 n_{D,2} \quad (2)$$

where n_D and $n_{D,i}$ are the refractive indexes of the mixture and the component i, respectively, and x_i is the mole fraction of component i.

Surface tension (σ) was determined using a Lauda TVT1 automated tensiometer, which employs the principle of the drop volume. This technique consists of measuring the volume of a drop detaching from a capillary with a circular cross section. The surface tension can be determined as follows:

$$\sigma = \frac{\Delta\rho g V}{2\pi r_{cap} f\left(\frac{r_{cap}}{a}\right)} \quad (3)$$

$$a = \left(\frac{2\sigma}{\Delta\rho g}\right)^{1/2} \quad (4)$$

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Table 2. Excess Molar Volumes V_m^E at 298.15 K

x	V_m^E/ cm^3·mol^{-1}	x	V_m^E/ cm^3·mol^{-1}	x	V_m^E/ cm^3·mol^{-1}
		x Hexane + (1 − x) Ethanol			
0.0465	0.0760	0.4264	0.3864	0.7172	0.3820
0.1035	0.1431	0.4790	0.3794	0.8142	0.3326
0.1604	0.2001	0.5353	0.3972	0.8397	0.3072
0.2162	0.2634	0.5649	0.3952	0.9076	0.2328
0.2647	0.3023	0.6334	0.3977	0.9244	0.2115
0.3082	0.3303	0.6678	0.3917		
		x Hexane + (1 − x) 1-Pentanol			
0.0489	−0.0608	0.5332	−0.1173	0.8868	0.0474
0.1111	−0.1112	0.5782	−0.0938	0.9302	0.0549
0.1507	−0.1358	0.6297	−0.0646	0.9751	0.0506
0.1915	−0.1678	0.6807	−0.0395	0.9788	0.0412
0.2602	−0.1767	0.7064	−0.0231	0.9840	0.0402
0.3474	−0.1842	0.7624	0.0127	0.9893	0.0346
0.4201	−0.1712	0.7669	−0.0027	0.9949	0.0237
0.4791	−0.1423	0.8378	0.0260		
		x Hexane + (1 − x) 1-Hexanol			
0.0544	−0.0746	0.5141	−0.2414	0.8052	−0.0792
0.1696	−0.2159	0.5316	−0.2327	0.8592	−0.0328
0.1966	−0.2313	0.5778	−0.2144	0.9095	−0.0029
0.2542	−0.2584	0.5885	−0.2208	0.9594	0.0264
0.3128	−0.2726	0.6629	−0.1848	0.9812	0.0251
0.3579	−0.2759	0.7088	−0.1509	0.9898	0.0220
0.4556	−0.2664				

where $\Delta\rho$ is the density difference between liquid and vapor phase, g is the gravitational acceleration; V is the drop volume, $2r_{cap}$ is the outer diameter of the capillary, and f is a correction function. Detailed instrument design and experimental procedure have been described elsewhere.[13] The accuracy of the method is ±0.01 mN·m^{-1}. A Lauda RC6 CP thermostatic bath controlled the temperature to better than ±0.1 K. The surface tension deviations ($\delta\sigma$) were calculated by

$$\delta\sigma = \sigma - x_1\sigma_1 - x_2\sigma_2 \tag{5}$$

where σ and σ_i are the surface tensions of the mixture and the component i, and x_i is the mole fraction of component i.

The density data for {x hexane + (1 − x) ethanol, + 1-pentanol, and + 1-hexanol} mixtures were measured in this work, while the {x hexane + (1 − x) 1-propanol, + 1-butanol} systems were taken from ref 14, and {x hexane + (1 − x) 1-heptanol, + 1-octanol} mixtures were taken from ref 15.

Results and Discussion

Experimental excess molar volumes (V_m^E) of binary mixtures {x hexane + (1 − x) ethanol, + 1-pentanol, and + 1-hexanol} at 298.15 K are listed in Table 2. The results were fitted to a equation of the form

$$Q^E = x(1-x)\frac{\sum_{k=0}^{N} A_k(2x-1)^k}{1 + B_0(2x-1)} \tag{6}$$

where Q^E represents here V_m^E x is the mole fraction of hexane; A_k and B_0 are parameters obtained by the unweighted least-squares method. The number of parameters was determined using an F-test.[16] The parameters A_i and B_0 are shown in Table 5. Figure 1 shows the excess molar volumes presented in this work besides other {x hexane + (1 − x) 1-alkanol} mixtures obtained from literature.[14,15,17−20] Figure 2 shows the equimolar excess molar volumes of {0.5 hexane + 0.5 1-alkanol} against number of carbon atoms of 1-alkanols, n. The results show that excess molar volumes of {x hexane + (1 − x) 1-alkanol} decreases as the chain length of 1-alkanol increases. In the case of {x hexane + (1 − x) ethanol}, V_m^E's are positive and the maximum is skewed toward low mole fractions of ethanol, while the curves of {x hexane + (1 − x) 1-pentanol, + 1-hexanol} are S-shaped.

Table 3 lists the surface tensions for {x hexane + (1 − x) ethanol, + 1-propanol, + 1-butanol, + 1-pentanol, +

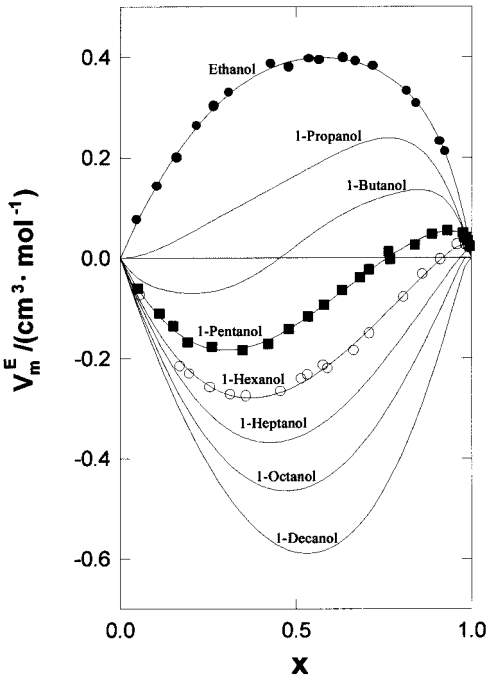

Figure 1. Experimental excess molar volumes V_m^E of ●, {x hexane + (1 − x) ethanol}; ■, {x hexane + (1 − x)1-pentanol}; ○, {x hexane + (1 − x) 1-hexanol}. From Jiménez et al.:[14] {x hexane + (1 − x) 1-propanol} and {x hexane + (1 − x) 1-butanol}. From Jiménez et al.:[15] {x hexane + (1 − x) 1-heptanol} and {x hexane + (1 − x) 1-octanol}. From Heintz et al.:[18] {x hexane + (1 − x) 1-decanol}.

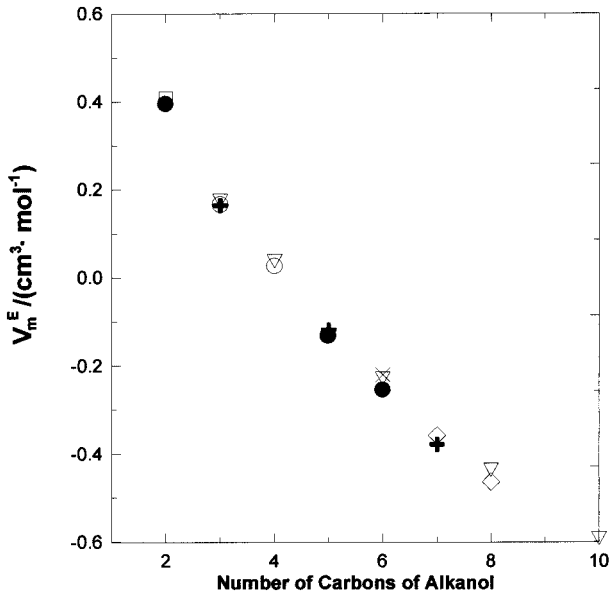

Figure 2. Excess molar volumes for {0.5 hexane + 0.5 1-alkanol} against number of carbon atoms of 1-alkanols: ●, this work; ○, Jiménez et al.;[14] ◇, Jiménez et al.;[15] ▽, Heintz et al.;[18] □, Marsh and Burfitt;[17] +, Iglesias et al.;[19] ×, Treszczanowicz and Benson.[20]

Table 3. Surface Tensions at 298.15 K

x	σ/mN·m^{-1}	x	σ/mN·m^{-1}	x	σ/mN·m^{-1}
		x Hexane + (1 − x) Ethanol			
0.0448	21.10	0.4366	18.33	0.7584	17.97
0.1625	19.74	0.4700	18.28	0.7963	17.95
0.2116	19.26	0.4974	18.16	0.8500	17.93
0.2559	18.98	0.5863	18.12	0.9067	17.91
0.3034	18.83	0.6452	18.06	0.9347	17.89
0.3745	18.56	0.6841	18.02		
		x Hexane + (1 − x) 1-Propanol			
0.0612	22.44	0.4621	18.96	0.7447	18.25
0.2219	20.62	0.5304	18.69	0.7838	18.20
0.2837	20.07	0.5603	18.60	0.8416	18.11
0.3050	19.88	0.6287	18.46	0.8740	18.06
0.3606	19.46	0.6858	18.34	0.9579	17.95
		x Hexane + (1 − x) 1-Butanol			
0.0717	23.09	0.5116	19.22	0.7897	18.30
0.2085	21.49	0.5790	18.93	0.8532	18.19
0.2650	20.98	0.6162	18.80	0.8966	18.08
0.3854	20.02	0.6957	18.57	0.9488	17.99
0.4738	19.46	0.7309	18.44		
		x Hexane + (1 − x) 1-Pentanol			
0.0593	24.07	0.4599	20.07	0.6903	18.84
0.0825	23.86	0.4848	19.86	0.7744	18.57
0.2114	22.25	0.5547	19.43	0.8418	18.32
0.2250	22.08	0.5915	19.25	0.8854	18.22
0.3406	20.94	0.6517	19.01	0.9408	18.08
0.3938	20.52				
		x Hexane + (1 − x) 1-Hexanol			
0.0642	24.82	0.4212	20.87	0.7185	19.00
0.0853	24.52	0.4835	20.40	0.7808	18.75
0.2244	22.75	0.5214	20.13	0.8068	18.61
0.2597	22.38	0.5836	19.73	0.8840	18.30
0.3215	21.79	0.6174	19.52	0.9170	18.22
0.3550	21.45	0.6722	19.23		
		x Hexane + (1 − x) 1-Heptanol			
0.0724	25.62	0.3850	21.82	0.6473	19.61
0.0959	25.21	0.4528	21.16	0.6999	19.29
0.2476	23.32	0.5157	20.63	0.7438	19.01
0.2851	22.88	0.5534	20.32	0.8020	18.69
0.3501	22.18	0.6145	19.87	0.8965	18.35
		x Hexane + (1 − x) 1-Octanol			
0.0450	26.44	0.4141	21.76	0.6704	19.58
0.1039	25.66	0.4795	21.16	0.7903	18.90
0.1802	24.58	0.5215	20.72	0.8184	18.70
0.2707	23.53	0.5794	20.26	0.8917	18.42
0.3112	22.97	0.6428	19.73	0.9451	18.21
0.3823	22.10				

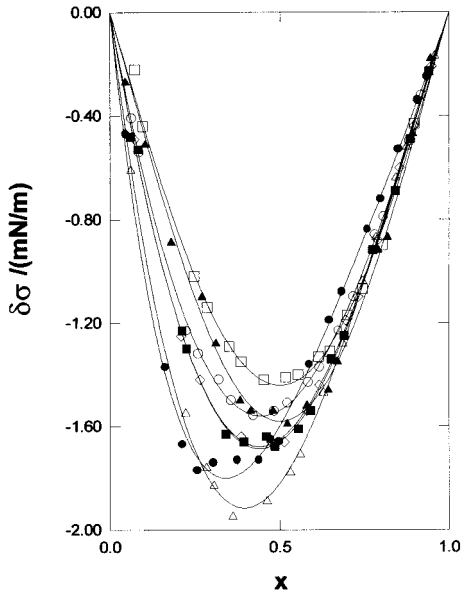

Figure 3. Surface tension deviations of ●, {x hexane + (1 − x) ethanol}; △, {x hexane + (1 − x) 1-propanol}; ◇, {x hexane + (1 − x) 1-butanol}; ■, {x hexane + (1 − x) 1-pentanol}; ○, {x hexane + (1 − x) 1-hexanol}; □, {x hexane + (1 − x) 1-heptanol}; ▲, {x hexane + (1 − x) 1-octanol} at 298.15 K.

Table 4. Refractive Indexes at 298.15 K

x	n_D	x	n_D	x	n_D
		x Hexane + (1 − x) Ethanol			
0.1604	1.3619	0.5863	1.3674	0.7584	1.3694
0.2162	1.3627	0.6334	1.3679	0.7963	1.3698
0.3745	1.3649	0.6452	1.3681	0.8397	1.3703
0.4366	1.3657	0.6678	1.3684	0.9067	1.3711
0.5353	1.3669	0.7172	1.3689		
		x Hexane + (1 − x) 1-Propanol			
0.0612	1.3819	0.3547	1.3774	0.6858	1.3737
0.1019	1.3812	0.3606	1.3773	0.7447	1.3732
0.1485	1.3804	0.4621	1.3760	0.7838	1.3729
0.2219	1.3793	0.5304	1.3752	0.8416	1.3726
0.2837	1.3784	0.5603	1.3750	0.8740	1.3725
0.3050	1.3781	0.6287	1.3742	0.9579	1.3723
		x Hexane + (1 − x) 1-Butanol			
0.0717	1.3952	0.4114	1.3851	0.7309	1.3772
0.1312	1.3933	0.4738	1.3834	0.7897	1.3760
0.1742	1.3919	0.5116	1.3824	0.8532	1.3747
0.2085	1.3909	0.5790	1.3808	0.8966	1.3738
0.2650	1.3892	0.6957	1.3780	0.9488	1.3729
0.3854	1.3858				
		x Hexane + (1 − x) 1-Pentanol			
0.0593	1.4059	0.3406	1.3955	0.6517	1.3837
0.0825	1.4051	0.3938	1.3935	0.6903	1.3823
0.1366	1.4031	0.4599	1.3909	0.7744	1.3794
0.2114	1.4004	0.4848	1.3900	0.8418	1.3770
0.2250	1.3998	0.5547	1.3873	0.8854	1.3757
0.2921	1.3973	0.5915	1.3860	0.9408	1.3740
		x Hexane + (1 − x) 1-Hexanol			
0.0642	1.4135	0.4212	1.3986	0.6722	1.3871
0.0853	1.4127	0.4835	1.3958	0.7185	1.3849
0.1679	1.4095	0.5214	1.3941	0.7808	1.3820
0.2597	1.4057	0.5836	1.3913	0.8840	1.3774
0.3215	1.4030	0.6174	1.3896	0.9170	1.3759
0.3550	1.4015				
		x Hexane + (1 − x) 1-Heptanol			
0.0558	1.4201	0.3763	1.4059	0.6174	1.3936
0.0886	1.4188	0.4160	1.4039	0.6703	1.3908
0.1607	1.4157	0.4517	1.4022	0.7212	1.3880
0.2187	1.4132	0.5271	1.3983	0.7438	1.3868
0.2608	1.4113	0.5380	1.3977	0.9263	1.3765
0.3000	1.4095	0.5590	1.3967		
		x Hexane + (1 − x) 1-Octanol			
0.0450	1.4257	0.3823	1.4105	0.6704	1.3944
0.1039	1.4232	0.4141	1.4089	0.7903	1.3870
0.1742	1.4203	0.4795	1.4055	0.8184	1.3848
0.1802	1.4201	0.5215	1.4032	0.8917	1.3799
0.2707	1.4160	0.5794	1.3998	0.9451	1.3762
0.3112	1.4141	0.6428	1.3962		

1-hexanol, + 1-heptanol, and + 1-octanol} mixtures. Figure 3 shows the surface tension deviations for the mentioned systems. As can be noted, the surface tension increases as the chain length of the 1-alkanol does; nevertheless the surface tension deviation does not present the same behavior.

The refractive indexes for {x hexane + (1 − x) ethanol, + 1-propanol, + 1-butanol, + 1-pentanol, + 1-hexanol, + 1-heptanol, and + 1-octanol} mixtures are presented in Table 4. Figure 4 shows the changes of refractive index. The refractive indexes increase with increasing chain length of the 1-alkanol, and the changes of refractive index have the same behavior with the exception of {hexane + ethanol}.

The surface tensions and the refractive indexes were fitted to a polynomial equation:

$$Q = Q_2 + \sum_{i=0}^{n} A_i x^{i+1} \qquad (7)$$

where $Q = \sigma$ or n_D; $Q_2 = \sigma_2$ or $n_{D,2}$, the surface tension or the refractive index for the 1-alkanol, respectively; A_i are the fitting parameters and x is the mole fraction of hexane.

Table 5. Parameters A_k, B_0, and A_i of Eqs 6 and 7 and Standard Deviations *s*

	eq	A_0	A_1	A_2	A_3	A_4	B_0	s
				x Hexane + (1 − x) Ethanol				
V_m^E/cm^3·mol^{-1}	6	1.5767	−0.9117	0.3497			−0.7608	0.006
σ/mN·m^{-1}	7	−16.640	29.404	−24.301	7.685			0.03
$\delta\sigma$/mN·m^{-1}	6	−6.39	4.49	−1.94				0.04
n_D	7	0.017 81	−0.009 46	0.004 64				0.000 04
Δn_D	6	0.002 53	−0.002 30	−0.000 88				0.000 02
				x Hexane + (1 − x) 1-Propanol				
σ/mN·m^{-1}	7	−15.833	14.822	−0.507	−5.800	1.813		0.019
$\delta\sigma$/mN·m^{-1}	6	−7.28	3.54					0.02
n_D	7	−0.017 42	0.003 21	0.003 46				0.000 06
Δn_D	6	−0.008 29	−0.001 73	−0.001 34				0.000 06
				x Hexane + (1 − x) 1-Butanol				
σ/mN·m^{-1}	7	−13.830	8.349	2.481	−3.133			0.016
$\delta\sigma$/mN·m^{-1}	6	−6.60	1.89	0.76				0.016
n_D	7	−0.028 91	−0.020 20	0.071 90	−0.081 32	0.033 53		0.000 04
Δn_D	6	−0.008 23		−0.000 76	−0.006 32			0.000 04
				x Hexane + (1 − x) 1-Pentanol				
V_m^E/cm^3·mol^{-1}	6	−0.5309	1.4130	−0.7495			−0.9796	0.005
σ/mN·m^{-1}	7	−14.701	7.931	3.022	−3.330			0.02
$\delta\sigma$/mN·m^{-1}	6	−6.64	1.84	0.78				0.03
n_D	7	−0.034 23	−0.010 54	0.009 05				0.000 04
Δn_D	6	−0.002 97	−0.004 59	−0.001 09				0.000 04
				x Hexane + (1 − x) 1-Hexanol				
V_m^E/cm^3·mol^{-1}	6	−1.0208	1.7065	−0.5777			−0.9774	0.007
σ/mN·m^{-1}	7	−15.035	8.381	0.660	−1.850			0.014
$\delta\sigma$/mN·m^{-1}	6	−6.15	1.55	0.47				0.018
n_D	7	−0.035 67	−0.016 33	0.008 38				0.000 04
Δn_D	6	0.003 79	−0.004 39	−0.001 14				0.000 04
				x Hexane + (1 − x) 1-Heptanol				
σ/mN·m^{-1}	7	−12.869	−1.415	11.164	−5.459			0.03
$\delta\sigma$/mN·m^{-1}	6	−5.76		1.29				0.04
n_D	7	−0.039 17	−0.013 92	0.002 98				0.000 04
Δn_D	6	0.009 43	−0.001 62					0.000 05
				x Hexane + (1 − x) 1-Octanol				
σ/mN·m^{-1}	7	−15.026	7.711	−14.240	24.945	−12.624		0.03
$\delta\sigma$/mN·m^{-1}	6	−6.32		1.76				0.04
n_D	7	−0.038 39	−0.011 93	−0.009 02	0.004 23			0.000 07
Δn_D	6	0.017 79						0.000 08

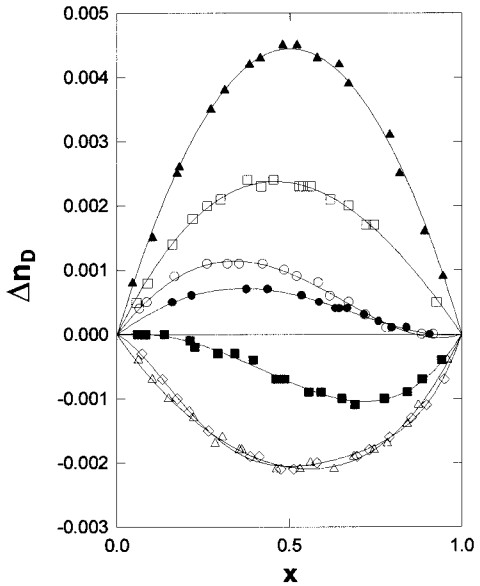

Figure 4. Changes of refractive index of ●, {x hexane + (1 − x) ethanol}; △, {x hexane + (1 − x) 1-propanol}; ◇, {x hexane + (1 − x) 1-butanol}; ■, {x hexane + (1 − x) 1-pentanol}; ○, {x hexane + (1 − x) 1-hexanol}; □, {x hexane + (1 − x) 1-heptanol}; ▲, {x hexane + (1 − x) 1-octanol} at 298.15 K.

The A_i parameters are shown in Table 5. Note that in this equation we have included two constraints to ensure that the values of Q for the pure components are those given in Table 1.

On the other hand, the results of surface tension deviations and changes of refractive index were fitted to eq 6, where $Q^E = \delta\sigma$ or Δn_D. The corresponding parameters A_k and B_0 are shown in Table 5.

Literature Cited

(1) Franjo, C.; Jiménez, E.; Iglesias, T. P.; Legido, J. L.; Paz Andrade, M. I. Viscosities and Densities of Hexane + Butan-1-ol, + Hexan-1-ol, and + Octan-1-ol at 298.15 K. *J. Chem. Eng. Data* **1995**, *40*, 68−70.

(2) Jiménez, E.; Franjo, C.; Segade, L.; Legido, J. L.; Paz Andrade, M. I. Viscosities and Densities for the 1-Propanol + *n*-Heptane System at Several Temperatures. *J. Solution Chem.* **1998**, *27*, 569−579.

(3) *API Technical Data Book—Petroleum Refining*, 3rd ed.; API: Washington, DC, 1976; Vol. 1.

(4) Riddick, J. A.; Bunger, W. B.; Sakano, T. K. *Organic Solvents. Physical Properties and Methods of Purification*; Wiley: New York, 1986.

(5) *TRC Thermodynamic Tables. Hydrocarbons*; Thermodynamics Research Center, The Texas A&M University System: College Station, Txs.

(6) Nikam, P. S.; Jadhav, M. C.; Hasan, M. Density and Viscosity of Mixtures of Nitrobenzene with Methanol, Ethanol, Propan-1-ol, Propan-2-ol, Butan-1-ol, 2-Methylpropan-1-ol, and 2-Methylpropan-2-ol at 298.15 and 303.15 K. *J. Chem. Eng. Data* **1995**, *40*, 931−934.

(7) Vázquez, G.; Alvarez, E.; Navaza, J. M. Surface Tension of Alcohol + Water from 20 to 50 °C. *J. Chem. Eng. Data* **1995**, *40*, 611−614.

(8) Aminabhavi, T. M.; Gopalkrishna, B. Densities, Viscosities, and Refractive Indices of the Binary Mixtures of Bis(2-methoxyethyl)

Ether with 1-Propanol, 1-Butanol, 2-Methyl-1-propanol, and 2-Methyl-2-propanol. *J. Chem. Eng. Data* **1994**, *39*, 865−867.
(9) Daubert, T. E.; Danner, R. P. *Physical and Thermodynamic Properties of Pure Chemicals: Data Compilation*; Hemisphere Publishing Corporation: Bristol, PA, 1989.
(10) *TRC Thermodynamic Tables. Non-Hydrocarbons*; Thermodynamics Research Center, The Texas A&M University System: College Station, Txs.
(11) Tanaka, R.; Toyama, S.; Murakami, S. Heat Capacities of $\{xC_nH_{2n+1}OH + (1-x)C_7H_{16}\}$ for $n = 1$ to 6 at 298.15 K. *J. Chem. Thermodyn.* **1986**, *18*, 63−73.
(12) Legido, J. L.; Jiménez, E.; Franjo, C.; Segade, L.; Paz Andrade, M. I. Excess Molar Volumes of Ternary Mixtures of Di-*n*-butyl ether + 1-Heptanol + *n*-Octane at the Temperature of 298.15 K. *Fluid Phase Equilib.* **1997**, *136*, 315−321.
(13) Miller, R.; Hofmann, A.; Hartmann, R.; Schano, K.-H.; Halbig, A. Measuring Dynamic Surface and Interfacial Tensions. *Adv. Mater.* **1992**, *4*, 370−374.
(14) Jiménez, E.; Franjo, C.; Menaut, C. P.; Segade, L.; Legido, J. L.; Paz Andrade, M. I. Excess Molar Volumes of $\{x_1CH_3CH_2COOCH_2CH_3 + x_2CH_3(CH_2)_4CH_3 + (1-x_1-x_2)CH_3(CH_2)_2OH$ or $CH_3(CH_2)_3OH\}$ at the Temperature 298.15 K. *J. Chem. Thermodyn.* **1997**, *29*, 117−124.
(15) Jiménez, E.; Franjo, C.; Segade, L.; Legido, J. L.; Paz Andrade, M. I. Excess Molar Volumes of Ternary Mixtures of $\{x_1CH_3CH_2COOCH_2CH_3 + x_2CH_3(CH_2)_4CH_3 + (1-x_1-x_2)CH_3(CH_2)_6OH$ or $CH_3(CH_2)_7OH\}$ at the Temperature of 298.15 K. *J. Chem. Eng. Data* **1997**, *42*, 262−265.
(16) Bevington, P. R.; Robinson, D. K. *Data Reduction and Error Analysis for the Physical Sciences*, 2nd ed.; McGraw-Hill: Singapore. 1994.
(17) Marsh, K. N.; Burfitt, C. Excess Volumes for Alcohols + Nonpolar Solvents. I. Ethanol + Cyclohexane, + *n*-Hexane, + Benzene, + Carbon Tetrachloride, + Cyclopentane, and + *p*-Xylene. *J. Chem. Thermodyn.* **1975**, *7*, 995−968.
(18) Heintz, A.; Schmittecker, B.; Wagner, D.; Lichtenthaler, R. N. Excess Volumes of Binary 1-Alkanol/Hexane Mixtures at Temperatures Between 283.15 and 323.15 K. *J. Chem. Eng. Data* **1986**, *31*, 487−492.
(19) Iglesias, T. P.; Legido, J. L.; Romaní, L.; Peleteiro, J.; Franjo, C. Relative Permittivities, Densities, and Excess Molar Volumes of $\{xCH_3(CH_2)_4CH_3 + (1-x)CH_3(CH_2)_vOH\}$ ($v = 2$, 4, and 6) at the Temperature 298.15 K. *J. Chem. Thermodyn.* **1994**, *26*, 797−802.
(20) Treszczanowicz, A. J.; Benson, G. C. Excess Volumes for *n*-Alkanols + *n*-Alkanes. III. Binary Mixtures of Hexan-1-ol + *n*-Pentane, + *n*-Hexane, + *n*-Octane, and + *n*-Decane. *J. Chem. Thermodyn.* **1980**, *12*, 173−179.

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