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Viscosities and Densities of Octane + Butan-1-ol, Hexan-1-ol, and Octan-1-ol at 298.15 K

Carlos Franjo, Consolación P. Menaut, Eulogio Jiménez,[*] José Luis Legido,[†] and Maria I. Paz Andrade[‡]

Departamento de Física, Facultad de Ciencias, Universidad de La Coruña, La Coruña, Spain

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Viscosities and densities have been measured for octane + butan-1-ol, hexan-1-ol and octan-1-ol at 298.15 K and at atmospheric pressure. Kinematic viscosities were determined using a capillary viscosimeter, and densities were measured by vibrating-tube densimetry. The results were fitted to the equations of Grunberg−Nissan, McAllister, Auslander, and Teja. The experimental excess molar volumes were compared with the results obtained with the Nitta−Chao model.

Introduction

Forming part of our theoric and experimental studies on thermodynamic, dielectric, and transport properties of an alkan-1-ol + an *n*-alkane (*1*−*10*), we report here the viscosities of octane + butan-1-ol + hexan-1-ol and + octan-1-ol at 298.15 K and at atmospheric pressure. Kinematic viscosities were determined using a capillary viscosimeter, and densities were measured by vibrating-tube densimetry.

The results were used to calculate the viscosity deviations and excess molar volumes. The results were fitted to polynomials. The viscosities were used to test the semiempirical relations of Grunberg−Nissan (*11*), McAllister (*12*, *13*), Auslander (*14*), and Teja (*15*, *16*). The excess molar volumes were used to the test the group contribution model of Nitta−Chao (*17*) based on the Carnahan−Starling hard-sphere equation (*18*) with the old parameters of Nitta et al. (*17*) and the new parameters of Fernández et al. (*9*).

Experimental Section

The following Fluka chemicals were used: octane (x > 0.995), butan-1-ol (x > 0.995), hexan-1-ol (x > 0.995), and octan-1-ol (x > 0.995). The substances were degassed and dried over molecular sieves (Union Carbide, type 0.4 nm). The measured densities and viscosities of the pure component liquids are listed in Table 1 together with published values.

Table 1. Data for Pure Liquids at 298.15 K

liquid	ϱ/(g·cm^{-3}) exp	ϱ/(g·cm^{-3}) lit.	η/(mPa·s) exp	η/(mPa·s) lit.
octane	0.698 50	0.698 46 (*19*) 0.698 49 (*20*)	0.506	0.5128 (*30*) 0.508 (*26*)
butan-1-ol	0.805 81	0.805 80 (*3*) 0.805 75 (*21*)	2.550	2.563 (*27*) 2.550 (*21*)
hexan-1-ol	0.815 32	0.815 15 (*22*) 0.815 3 (*23*)	4.862	4.52 (*29*) 4.592 (*28*)
octan-1-ol	0.821 62	0.821 61 (*24*) 0.821 1 (*25*)	7.596	7.363 (*28*) 7.55 (*29*)

Table 2. Densities, Viscosities, Excess Molar Volumes, and Viscosity Deviations at 298.15 K

x	ϱ/(g·cm^{-3})	η/(mPa·s)	V^E/(cm^3·mol^{-1})	$\Delta\eta$/(mPa·s)
		(x)octane + (1 − x)butan-1-ol		
0.0832	0.790 24	2.013	0.0815	−0.368
0.1173	0.784 51	1.840	0.1023	−0.471
0.1519	0.778 96	1.681	0.1241	−0.559
0.2113	0.769 99	1.443	0.1668	−0.675
0.3040	0.757 49	1.152	0.2128	−0.777
0.3599	0.750 63	1.017	0.2409	−0.798
0.4942	0.735 99	0.788	0.2961	−0.752
0.6053	0.725 59	0.676	0.3192	−0.637
0.7044	0.717 34	0.615	0.3272	−0.497
0.8459	0.707 32	0.555	0.2496	−0.266
0.9189	0.702 76	0.525	0.1831	−0.147
		(x)octane + (1 − x)hexan-1-ol		
0.0510	0.807 77	4.054	−0.0175	−0.586
0.1118	0.799 02	3.290	−0.0283	−1.085
0.1835	0.788 90	2.593	−0.0120	−1.470
0.3569	0.766 04	1.552	0.0398	−1.756
0.5094	0.747 62	1.074	0.0944	−1.569
0.5642	0.741 42	0.955	0.1039	−1.450
0.6167	0.735 62	0.857	0.1154	−1.319
0.6701	0.729 88	0.770	0.1283	−1.173
0.7288	0.723 77	0.686	0.1383	−1.001
0.8387	0.712 95	0.566	0.1231	−0.643
0.9370	0.703 84	0.511	0.0878	−0.269
		(x)octane + (1 − x)octan-1-ol		
0.0566	0.814 57	6.369	−0.0250	−0.826
0.1294	0.805 56	5.058	−0.0614	−1.620
0.2321	0.792 81	3.637	−0.0913	−2.313
0.3530	0.777 72	2.469	−0.0904	−2.625
0.4724	0.762 81	1.705	−0.0659	−2.541
0.5270	0.756 01	1.452	−0.0501	−2.408
0.6297	0.743 31	1.094	−0.0250	−2.037
0.7780	0.725 12	0.764	0.0120	−1.317
0.8294	0.718 83	0.683	0.0301	−1.033
0.9163	0.708 29	0.572	0.0512	−0.527
0.9985	0.698 66	0.491	0.0053	−0.026

Densities of the pure components and their mixtures were measured with an Anton Paar Model DMA 60/602 densimeter with a resolution of ±2 × 10^{-6} g·cm^{-3} and kinematic viscosities by the automatic Schott−Geräte measuring system with a resolution of ±5 × 10^{-4} mm^{-2}·s. The temperature was regulated to <±0.01 K. The experimental techniques has been described previously (*1*, *31*). The precision of the mole fractions (x) is estimated to better than ±1 × 10^{-4}.

Results and Discussion

Densities and viscosities are listed in Table 2. Viscosity increments were calculated by

$$\Delta\eta = \eta - (x_1\eta_1 + x_2\eta_2) \tag{1}$$

The experimental values of $\Delta\eta$ and V^E, at the temperature T = 298.15 K, are also in Table 2. A function of the

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[*] To whom the correspondence should be addressed.

[†] Departamento de Física Aplicada, Facultad de Ciencias, Universidad de Vigo, 36200 Vigo, Spain.

[‡] Departamento de Física Aplicada, Facultad de Física, Universidad de Santiago, 15706 Santiago de Compostela, Spain.

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Table 3. Parametrs A_i of Eq 2 and Standard Deviations σ

	A_0	A_1	A_2	A_3	A_4	A_5	σ
			(x)octane + (1 − x)butan-1-ol				
$\Delta\eta$/mPa·s	−2.9735	1.6365	−0.4966				0.005
V^E/cm^3·moll^{-1}	1.1781	0.7083	0.6575				0.007
			(x)octane + (1 − x)hexan-1-ol				
$\Delta\eta$/mPa·s	−6.3466	3.8108	−2.3967	0.4091			0.002
V^E/cm^3·mol^{-1}	0.3490	0.5558	0.1490	0.5711			0.006
			(x)octane + (1 − x)octan-1-ol				
$\Delta\eta$/mPa·s	−9.9169	4.9288	−1.4720				0.006
V^E/cm^3·mol^{-1}	00.2283	0.4974	−0.3316		1.1111	0.4252	0.006

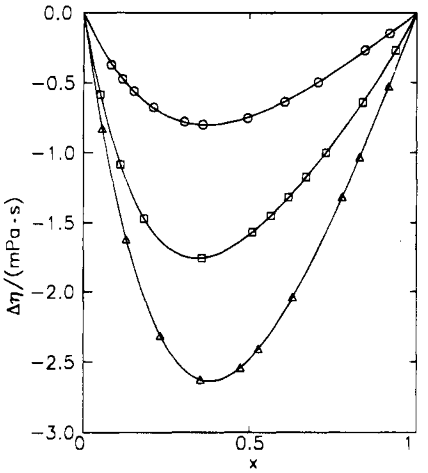

Figure 1. Experimental $\Delta\eta$ at 298.15 K of $x\mathrm{CH_3(CH_2)_6CH_3}$ + (1 − x)$\mathrm{CH_3(CH_2)}_n\mathrm{OH}$; (○) n = 3, (□) n = 5; (△) n = 7. The curves have been calculated from eq 2.

Table 4. Values of V^E (x = 0.5) at 298.15 K

system	V^E/(cm^3·mol^{-1}) exp	V^E/(cm^3·mol^{-1}) lit.
octane + butan-1-ol	0.2945	0.3151 (31) 0.2723 (32) 0.2907 (8)
octane + hexan-1-ol	0.0872	0.094 (33)
octane + octan-1-ol	−0.0571	−0.095 (34)

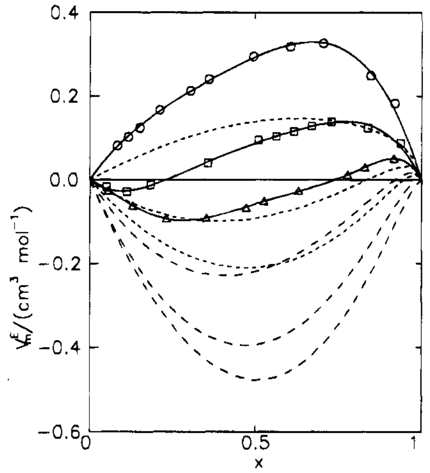

Figure 2. Experimental V^E at 298.15 K of $x\mathrm{CH_3(CH_2)_6CH_3}$ + (1 − x)$\mathrm{CH_3(CH_2)}_n\mathrm{OH}$: (○) n = 3, (□) n = 5, (△) n = 7. The curves have been calculated from eq 2 (− −), Nitta−Chao model with parameters of Nitta et al. (- - -), and (—) Nitta−Chao model with parameters of Fernández et al.

Table 5. Parameters for the Semiempirical Relations of Grunberg−Nissan (*11*), McAllister (*12, 13*), Auslander (*14*), and Teja (*15, 16*) and Standard Deviations σ

				σ/ mPa·s
	(x)octane + (1 − x)butan-1-ol			
Grunberg−Nissan	d_w = 1.4019			0.012
McAllister	η_{12} = 0.0095	η_{21} = 0.0033		0.011
Auslander	B_{12} = 0.5826	B_{21} = 0.5217	A_{21} = 0.1668	0.006
Teja	α_{12} = 0.0379			0.029
	(x)octane + (1 − x)hexan-1-ol			
Grunberg−Nissan	d_w = 1.4355			0.015
McAllister	η_{12} = 0.6405	η_{21} = 1.4483		0.012
Auslander	B_{12} = 0.8072	B_{21} = 0.4212	A_{21} = 0.1965	0.013
Teja	α_{12} = −0.0649			0.028
	(x)octane + (1 − x)octan-1-ol			
Grunberg-Nissan	d_w = 0.6831			0.066
McAllister	η_{12} = 0.7889	η_{21} = 2.7221		0.006
Auslander	B_{12} = 0.6221	B_{21} = 0.5109	A_{21} = 0.1908	0.006
Teja	α_{12} = 0.3687			0.050

form

$$Q = x_1x_2\sum_{i=0}^{m} A_i(x_1 - x_2)^i \qquad (2)$$

was fitted to the experimental values where either $Q = \Delta\eta$/(mPa·s) or Q = V^E/(cm^3·mol^{-1}). The parameters A_i and the corresponding standard deviations s given in Table 3 were calculated using the unweighted least-squares method, with the degree of the polynomial previously optimized through the application of the F test (*32*).

Table 4 shows the differences between our experimental excess molar volumes and literature values.

Figures 1 and 2 show the experimental $\Delta\eta$ and V^E plotted against x together with the fitted curve. The $\Delta\eta$ is negative and decreases when the alkan-1-ol carbon atom number increases. The V^E increases when the 1-alkanol carbon atom number increases. These results show that V^E changes from negative to sigmoid for octane + butan-1-ol and octane + hexan-1-ol systems, and V^E is positive for the system which contain octan-1-ol. In Figure 2, also we compared the predictions of the Nitta−Chao model with the old parameters of Nitta et al. (*17*) and the new parameters of Fernández et al. (*9*) with the experimental V^E values.

Table 5 shows the parameters calculated and the standard deviations between experimental values obtained using the semiempirical relations of Grunberg−Nissan (*11*), McAllister (*12, 13*), Auslander (*14*), and Teja (*15, 16*). The values of T_C and V_C for pure components were obtained from ref 28.

Figure 3 shows the experimental excess molar volumes (x = 0.5) at 298.15 K plotted against carbon atom number of alkan-1-ol. V^E increases when the n-alkane carbon atom number increases. Figure 4 shows the experimental viscosities increments (x = 0.5) at 298.15 K plotted against carbon atom number of alkan-1-ol. $\Delta\eta$ increases when the n-alkane carbon atom number increases. In both figures, n-hexane values were obtained in our previous studies (*1*).

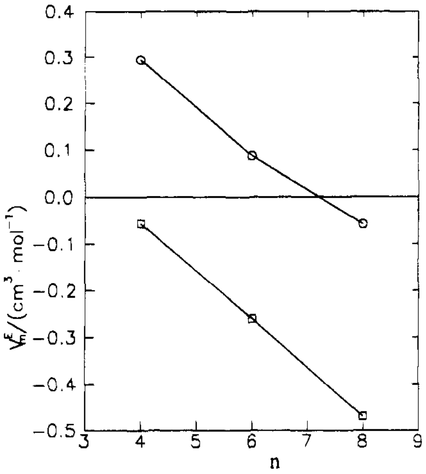

Figure 3. Experimental V^E at 298.15 K of $0.5CH_3(CH_2)_mCH_3$ + $0.5CH_3(CH_2)_nOH$: (○) $m = 6$, (□) $m = 4$.

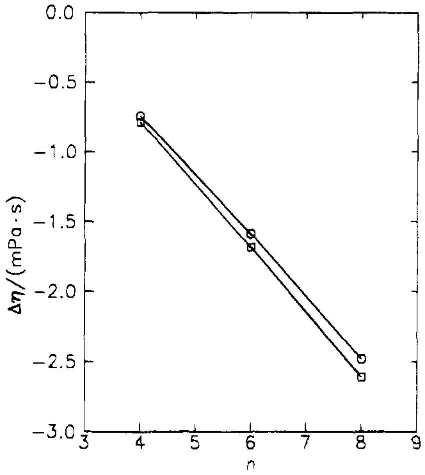

Figure 4. Experimental $\Delta\eta$ at 298.15 K of $0.5CH_3(CH_2)_mCH_3$ + $0.5CH_3(CH_2)_nOH$: (○) $m = 6$, (□) $m = 4$.

Registry numbers supplied by authors: *n*-octane, 111-65-9; butan-1-ol, 71-36-3; hexan-1-ol, 111-27-3; octan-1-ol, 111-87-5.

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