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Viscosities and Densities of Trichloroethylene or Tetrachloroethylene with 2-Alkoxyethanols at 303.15 K and 313.15 K

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Viscosities have been measured for binary liquid mixtures of trichloroethylene or tetrachloroethylene with 2-methoxyethanol, 2-ethoxyethanol, and 2-butoxyethanol at 303.15 K and 313.15 K, over the entire composition range. Viscosities were measured with an Ostwald viscometer.

Introduction

Experimental viscosity results exhibit information on the structure of liquids and are required in the design of processes which involve mass transfer, fluid flow, etc. This work is part of a research program dealing the experimental study of thermodynamic and transport properties, aimed at improving our understanding of the molecular interactions which characterize the physico-chemical behavior of nonelectrolyte solutions (Venkatesulu et al., 1996a,b). In this work we report viscosities of trichloroethylene and tetrachloroethylene with 2-methoxyethanol, 2-ethoxyethanol, and 2-butoxyethanol at 303.15 K and 313.15 K over the entire composition range.

Experimental Section

Materials. All the chemicals used were of analytical grade and purchased from commercial sources. Trichloroethylene and tetrachloroethylene were purified by the method described by Venkatesulu et al. (1996) and Venkatesulu and Rao (1992). The 2-alkoxyethanols were further purified by the methods described by Piekarski and Tkaczyk (1995). The purity of liquids was checked by comparing the measured density and viscosity data with those reported in the literature (Riddick et al., 1986; Venkatesulu and Rao, 1992). The purities of samples were further confirmed by GLC single sharp peaks. The measured densities and viscosities of these compound and those reported in the literature are listed in Table 1.

Apparatus. An Ostwald viscometer was used to measure the viscosities of pure liquids and liquid mixtures, and the detailed procedure was described in our earlier papers (Rao and Naidu, 1977; Ramadevi et al., 1996). The viscosities (η) of pure liquids and liquid mixtures were computed from the flow time and densities using the relation

$$\eta = k_v \rho t \quad (1)$$

where k_v is the viscometer constant, ρ is the density, and t is the flow time for a given sample, respectively. The uncertainty in the measured viscosity values is up to ±0.3%. Densities of pure compounds were measured with a bicapillary type pycnometer, with a capacity of 12 cm^3, which offers an accuracy of 2 parts in 10^5. The densities of binary mixtures were obtained from excess volumes (V^E) which had been determined previously (Venkatesulu and Rao, 1992), using the relation

$$\rho = \frac{x_1 M_1 + x_2 M_2}{V + V^E} \quad (2)$$

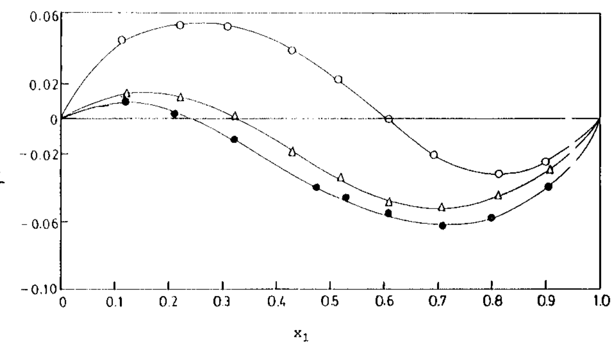

Figure 1. Δ ln η for trichloroethylene + 2-methoxyethanol (●), + 2-ethoxyethanol (△), and + 2-butoxyethanol (○) at 303.15 K.

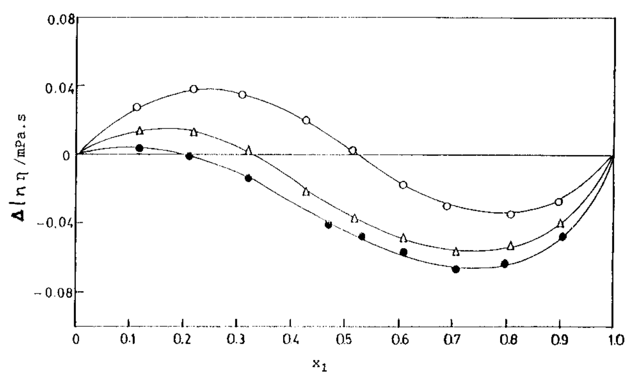

Figure 2. Δ ln η for trichloroethylene + 2-methoxyethanol (●), + 2-ethoxyethanol (△), and + 2-butoxyethanol (○) at 313.15 K.

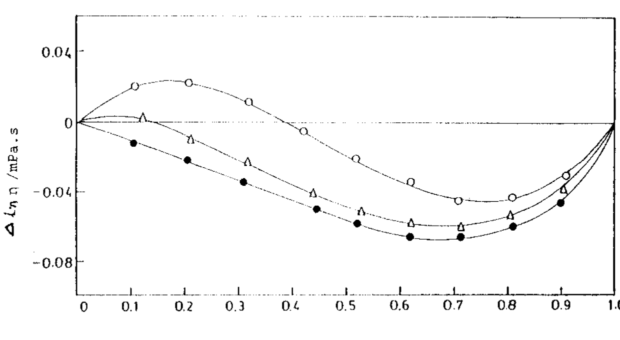

Figure 3. Δ ln η for tetrachloroethylene + 2-methoxyethanol (●), + 2-ethoxyethanol (△), and + 2-butoxyethanol (○) at 303.15 K.

where x_1 and x_2 denote the mole fractions and M_1 and M_2 are molar masses of components 1 and 2, respectively. V is the molar volume of the mixture. The η measurements were made at a constant temperature in a thermostat that could be maintained constant to ±0.01 K.

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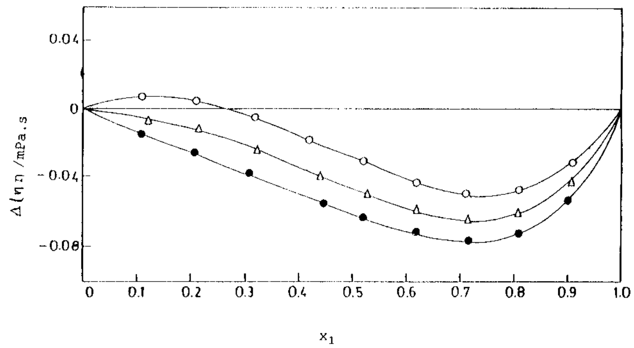

Figure 4. Δ ln η for tetrachloroethylene + 2-methoxyethanol (●), + 2-ethoxyethanol (△), and + 2-butoxyethanol (○) at 313.15 K.

Table 1. Viscosities (η) and Densities (ρ) of Pure Components at 298.15 K

	η/mPa·s		ρ/g·cm^{-3}	
component	exptl	lit.[a]	exptl	lit.[b]
trichloroethylene	0.530	0.532	1.451 36[c]	1.451 40[c]
tetrachloroethylene	0.796[c]	0.798[c]	1.606 36[c]	1.606 40[c]
2-methoxyethanol	1.597	1.600	0.960 20	0.960 24
2-ethoxyethanol	1.846	1.850	0.925 15	0.925 20
2-butoxyethanol	3.148	3.150	0.896 23	0.896 25

[a] Riddick et al. (1986). [b] Venkatesulu and Rao (1992). [c] At 303.15 K.

Table 2. Mole Fraction (x_1) of Trichloroethylene and Densities (ρ) and Viscosities (η) for the Mixtures of Trichloroethylene (1) + 2-Alkoxyethanols (2)

	303.15 K		313.15 K	
x_1	ρ/g·cm^{-3}	η/mPa·s	ρ/g·cm^{-3}	η/mPa·s
Trichloroethylene (1) + 2-Methoxyethanol (2)				
0.0000	0.955 84	1.476	0.946 17	1.189
0.1175	1.020 76	1.317	1.009 96	1.074
0.2132	1.072 19	1.181	1.060 51	0.981
0.3211	1.128 55	1.041	1.115 92	0.880
0.4746	1.205 82	0.860	1.191 93	0.746
0.5328	1.234 25	0.804	1.219 92	0.703
0.6149	1.273 65	0.731	1.258 74	0.648
0.7063	1.316 64	0.659	1.301 15	0.591
0.8042	1.361 89	0.597	1.345 87	0.543
0.9056	1.408 25	0.546	1.391 80	0.504
1.0000	1.451 34	0.515	1.434 62	0.486
Trichloroethylene (1) + 2-Ethoxyethanol (2)				
0.0000	0.921 18	1.643	0.912 29	1.293
0.1191	0.980 59	1.453	0.970 80	1.166
0.2226	1.032 96	1.286	1.022 34	1.052
0.3214	1.083 53	1.134	1.072 06	0.946
0.4322	1.140 89	0.976	1.128 44	0.829
0.5234	1.188 63	0.865	1.175 36	0.747
0.6128	1.235 97	0.769	1.221 91	0.676
0.7066	1.286 34	0.687	1.271 48	0.612
0.8105	1.343 24	0.614	1.327 57	0.555
0.9057	1.396 69	0.557	1.380 40	0.511
1.0000	1.451 34	0.515	1.434 62	0.486
Trichloroethylene (1) + 2-Butoxyethanol (2)				
0.0000	0.892 31	2.408	0.883 86	1.869
0.1147	0.938 40	2.110	0.929 19	1.646
0.2158	0.981 95	1.821	0.972 01	1.451
0.3119	1.026 04	1.568	1.015 34	1.271
0.4264	1.082 28	1.297	1.070 64	1.074
0.5157	1.129 24	1.111	1.116 82	0.934
0.6108	1.182 61	0.937	1.169 33	0.806
0.6870	1.228 21	0.817	1.214 23	0.718
0.8076	1.306 45	0.671	1.291 38	0.608
0.9043	1.375 70	0.582	1.359 76	0.537
1.0000	1.451 34	0.515	1.434 62	0.486

Results and Discussion

The experimental results of viscosities and densities of trichloroethylene with 2-methoxyethanol, 2-ethoxyethanol, and 2-butoxyethanol and of tetrachloroethylene with 2-methoxyethanol, 2-ethoxyethanol, and 2-butoxyethanol at 303.15 K and 313.15 K are listed in Tables 2 and 3, respectively. The Δ ln η are fitted using the smoothing equation

$$\Delta \ln \eta = x_1 x_2 [a_0 + a_1(x_1 - x_2) + a_2(x_1 - x_2)^2] \quad (3)$$

the values of parameters a_0, a_1, and a_2 are obtained by the

Table 3. Mole Fraction (x_1) of Tetrachloroethylene and Densities (ρ) and Viscosities (η) of the Mixtures of Tetrachloroethylene (1) + 2-Alkoxyethanol (2)

	303.15 K		313.15 K	
x_1	ρ/g·cm^{-3}	η/mPa·s	ρ/g·cm^{-3}	η/mPa·s
Tetrachloroethylene (1) + 2-Methoxyethanol (2)				
0.0000	0.955 84	1.476	0.946 17	1.189
0.1062	1.040 61	1.365	1.029 85	1.111
0.2046	1.115 00	1.273	1.103 28	1.049
0.3091	1.189 91	1.178	1.177 24	0.985
0.4453	1.281 75	1.066	1.267 92	0.907
0.5214	1.330 44	1.009	1.316 03	0.866
0.6184	1.390 09	0.943	1.375 02	0.819
0.7146	1.446 92	0.890	1.431 29	0.778
0.8062	1.499 25	0.846	1.483 21	0.747
0.9015	1.552 34	0.808	1.536 01	0.727
1.0000	1.606 36	0.796	1.589 87	0.731
Tetrachloroethylene (1) + 2-Ethoxyethanol (2)				
0.0000	0.921 18	1.643	0.912 29	1.293
0.1174	1.004 37	1.513	0.994 28	1.201
0.2104	1.069 53	1.396	1.058 65	1.132
0.3230	1.147 56	1.272	1.135 83	1.049
0.4392	1.227 13	1.149	1.214 51	0.968
0.5276	1.287 10	1.065	1.273 79	0.910
0.6168	1.347 25	0.992	1.333 18	0.857
0.7085	1.408 88	0.926	1.394 00	0.809
0.8053	1.473 95	0.869	1.458 29	0.769
0.9054	1.541 61	0.822	1.525 33	0.739
1.0000	1.606 36	0.796	1.589 87	0.731
Tetrachloroethylene (1) + 2-Butoxyethanol (2)				
0.0000	0.892 31	2.408	0.883 86	1.869
0.1139	0.956 93	2.167	0.947 61	1.689
0.2084	1.013 15	1.954	1.003 17	1.543
0.3166	1.080 59	1.716	1.069 84	1.381
0.4172	1.146 40	1.510	1.134 89	1.240
0.5191	1.216 37	1.327	1.203 99	1.113
0.6215	1.290 39	1.170	1.277 03	0.998
0.7098	1.357 55	1.049	1.343 31	0.913
0.8124	1.440 07	0.939	1.424 81	0.831
0.9087	1.522 63	0.854	1.506 56	0.771
1.0000	1.606 36	0.796	1.589 87	0.731

Table 4. Estimated Parameters of Eq 3 and Standard Deviation σ(Δ ln η) for the Mixtures of Trichloroethylene (1) + 2-Alkoxyethanols (2)

trichloroethylene (1)+	T/K	mPa·s a_0	a_1	a_2	σ(Δ ln η)
2-methoxyethanol (2)	303.15	−0.1638	−0.3395	−0.0222	0.002
	313.15	−0.1640	−0.3507	−0.1393	0.003
2-ethoxyethanol (2)	303.15	−0.1223	−0.3193	0.0510	0.002
	313.15	−0.1212	−0.3703	−0.0533	0.003
2-butoxyethanol (2)	303.15	0.0855	−0.4535	−0.0167	0.003
	313.15	0.0209	−0.3864	−0.0617	0.002

Table 5. Estimated Parameters of Eq 3 and Standard Deviation σ(Δ ln η) for the Mixtures of Tetrachloroethylene (1) + 2-Alkoxyethanols (2)

tetrachloroethylene (1) +	T/K	mPa·s a_0	a_1	a_2	σ(Δ ln η)
2-methoxyethanol (2)	303.15	−0.2148	−0.2218	−0.1506	0.003
	313.15	−0.2377	−0.2595	−0.2254	0.002
2-ethoxyethanol (2)	303.15	−0.1885	−0.2493	0.0034	0.002
	313.15	−0.1843	−0.2619	−0.1462	0.001
2-butoxyethanol (2)	303.15	−0.0693	−0.3502	−0.0119	0.002
	313.15	−0.1155	−0.2804	−0.0725	0.001

method of least squares and are reported in Tables 4 and 5, along with the standard deviation. The results for $\Delta \ln \eta$ are graphically represented in Figures 1−4.

The algebraic values of $\Delta \ln \eta$ at 303.15 K and 313.15 K fall in the order 2-butoxyethanol > 2-ethoxyethanol > 2-methoxyethanol. The algebraic values of $\Delta \ln \eta$ at both temperatures for these systems fall in the order 2-butoxyethanol > 2-ethoxyethanol > 2-methoxyethanol.

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