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Viscosities and Densities of Some *n*-Alkoxyethanols with Trichloroethylene and Tetrachloroethylene at 298.15 K

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Viscosities at 298.15 K and atmospheric pressure for 12 binary (an alkoxyethanol + trichloroethylene or tetrachloroethylene) mixtures have been measured over the whole mole fraction range by an Ubbelohde viscometer. The alkoxyethanols were 2-(2-methoxyethoxy)ethanol, 2-(2-ethoxyethoxy)ethanol, 2-(2-butoxyethoxy)ethanol, 2-[2-(2-methoxyethoxy)ethoxy]ethanol, 2-[2-(2- ethoxyethoxy)ethoxy]ethanol. and 2-[2-(2-butoxyethoxy)ethoxy]ethanol. From the experimental data, deviations in viscosity are determined and fitted to the Redlich−Kister polynomial to estimate the binary interaction parameters.

Introduction

In earlier papers (Pal and Singh, 1995,1996), we reported the results of our measurements of the excess molar volumes of {C_2Cl_3H (1) + $H(CH_2)_\nu(OC_2H_4)_2OH$ (2)] and of {C_2Cl_4 (1) + $H(CH_2)_\nu(OC_2H_4)_3OH$ (2)}, for ν = 1, 2, and 4 at different temperatures at atmospheric pressure. These results suggested the relative importance of the hydrogen-bonding interactions between the alkoxyethanol and the chloroethene molecules. Experimental viscosity results in binary mixtures give information on the existence of specific interaction between the components, and they are very important in many practical problems concerning heat transport, mass transport, and fluid flow, etc. We thought it worthwhile to measure the viscosity of these mixtures in order to improve our understanding of the molecular interactions in (an alkoxyethanols + chloroethenes) mixtures. In the present study, measurements of viscosity were carried out for binary mixtures of trichloroethylene (C_2Cl_3H) and tetrachloroethylene (C_2Cl_4) with 2-(2-methoxyethoxy)ethanol ($CH_3(OC_2H_4)_2OH$), 2-(2-ethoxyethoxy)-ethanol ($C_2H_5(OC_2H_4)_2OH$), and 2-(2-butoxyethoxy)ethanol ($C_4H_9(OC_2H_4)_2OH$), 2-[2-(2-methoxyethoxy)ethoxy]ethanol ($CH_3(OC_2H_4)_3OH$), 2-[2-(2-ethoxyethoxy)ethoxy]ethanol ($C_2H_5(OC_2H_4)_3OH$), and 2-[2-(2-butoxyethoxy)ethoxy]ethanol ($C_4H_9(OC_2H_4)_3OH$) over the whole concentration range at 298.15 K at atmospheric pressure. This property has not been reported in literature except for trichloroethylene or tetrachloroethylene with 2-alkoxyethanols at higher temperatures (Venkatesulu et. al., 1997). Deviations in viscosity (ln $\Delta\eta$) values were based on mole fraction weighted addition of the logarithm of the viscosity of pure components. The results obtained for 12 binary systems are presented and discussed in this paper.

Experimental Section

Materials. Materials were the same as used in earlier studies (Pal and Singh, 1995, 1996). They were kept tightly sealed and protected from atmospheric moisture and CO_2. Prior to the measurements, all liquids were kept on molecular sieves type 4A to reduce water content and were partially degassed under vacuum. The composition of each mixture was obtained from the measured apparent masses of the components, with a precision of ±0.05 mg. All masses were corrected for buoyancy. The mole fraction error is estimated to be less than 2×10^{-4}.

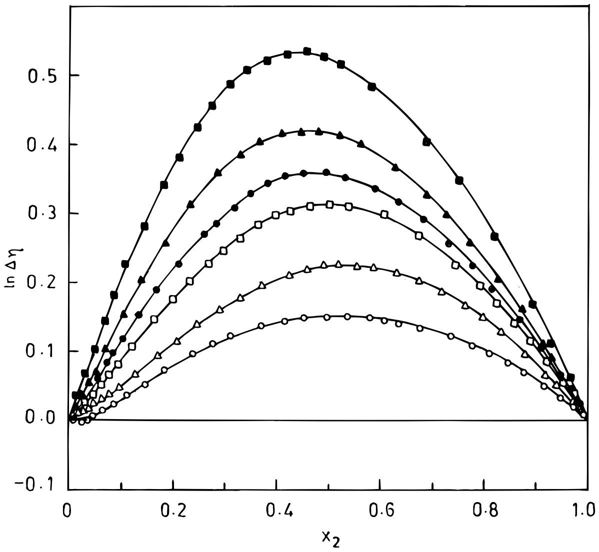

Figure 1. ln $\Delta\eta$ for C_2Cl_3H (1) + $H(CH_2)_\nu(OC_2H_4)_2OH$ (2) (○, ν = 1; △, ν = 2; □, ν = 4) and for C_2Cl_3H (1) + $H(CH_2)_\nu(OC_2H_4)_3OH$ (2) (●, ν = 1; ▲,ν = 2; ■, ν = 4) at 298.15 K. Solid curves were calculated from eq 4 using coefficients a_j of Table 3.

Apparatus. Viscosities of pure liquids and liquid mixtures were measured with a modified suspended level Ubbelohde viscometer, and the detailed procedure was described in our earlier paper (Pal and Singh, 1997). Computation of the viscosity (η) was done using the relation

$$\eta = \rho(At - B/t) \tag{1}$$

where A and B are the viscometer constants, ρ is the density, and t is the flow time for a given sample, respectively. Viscosities are reproducible to ±0.003 mPa·s. Densities of the pure components were measured using a double-armed pycnometer with an accuracy of 5 parts in 10^5. A thermostatically controlled, well-stirred water bath whose temperature was controlled to ±0.01 K was used for all the measurements. Densities of the liquid mixtures were computed from the excess molar volume (V_m^E), re-

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Table 1. Densities (ρ) and Viscosities (η) for the Mixtures of [$C_2Cl_3H + H(CH_2)_\nu\{OC_2H_4\}_nOH$] ($\nu = 1$, 2, and 4 and $n = 2$ and 3) at 298.15 K and Atmospheric Pressure

x_2	ρ/g·cm^3	η/mPa·s	x_2	ρ/g·cm^3	η/mPa·s	x_2	ρ/g·cm^3	η/mPa·s	x_2	ρ/g·cm^3	η/mPa·s
C_2Cl_3H (1) + $CH_3(OC_2H_4)_2OH$ (2)											
0.0000	1.4558	0.529	0.1489	1.3740	0.742	0.4988	1.2083	1.587	0.8110	1.0832	2.730
0.0091	1.4504	0.537	0.1870	1.3544	0.817	0.5410	1.1902	1.725	0.8467	1.0700	2.882
0.0258	1.4408	0.553	0.2425	1.3267	0.926	0.5789	1.1743	1.849	0.8774	1.0590	3.015
0.0362	1.4349	0.567	0.2811	1.3078	1.009	0.6080	1.1623	1.948	0.9167	1.0450	3.194
0.0477	1.4284	0.582	0.3123	1.2929	1.082	0.6351	1.1513	2.044	0.9481	1.0341	3.329
0.0679	1.4172	0.610	0.3733	1.2643	1.237	0.6756	1.1351	2.194	0.9733	1.0254	3.449
0.0896	1.4054	0.643	0.4192	1.2434	1.356	0.7372	1.1110	2.433	0.9896	1.0199	3.531
0.1146	1.3920	0.685	0.4582	1.2260	1.467	0.7781	1.0955	2.596	1.0000	1.0164	3.565
C_2Cl_3H (1) + $C_2H_5(OC_2H_4)_2OH$ (2)											
0.0000	1.4558	0.529	0.1724	1.3440	0.823	0.5204	1.1645	1.902	0.8779	1.0242	3.423
0.0082	1.4499	0.539	0.2108	1.3216	0.910	0.5570	1.1484	2.042	0.9203	1.0098	3.621
0.0263	1.4372	0.563	0.2459	1.3017	0.997	0.5875	1.1353	2.163	0.9414	1.0028	3.723
0.0381	1.4291	0.580	0.2921	1.2765	1.117	0.6320	1.1167	2.342	0.9717	0.9929	3.857
0.0517	1.4199	0.602	0.3336	1.2546	1.235	0.6736	1.1000	2.519	0.9820	0.9895	3.895
0.0641	1.4116	0.620	0.3791	1.2314	1.376	0.7163	1.0831	2.701	1.0000	0.9839	3.978
0.0756	1.4041	0.639	0.4231	1.2097	1.528	0.7635	1.0652	2.912			
0.0944	1.3919	0.669	0.4570	1.1936	1.659	0.7976	1.0526	3.068			
0.1290	1.3702	0.736	0.4908	1.1779	1.788	0.8333	1.0398	3.224			
C_2Cl_3H (1) + $C_4H_9(OC_2H_4)_2OH$ (2)											
0.0000	1.4558	0.529	0.1624	1.3209	0.890	0.4614	1.1444	2.087	0.8875	0.9806	4.525
0.0067	1.4493	0.539	0.2002	1.2944	0.999	0.5031	1.1248	2.305	0.9174	0.9716	4.722
0.0185	1.4382	0.560	0.2310	1.2739	1.097	0.5400	1.1081	2.492	0.9489	0.9624	4.919
0.0282	1.4292	0.577	0.2680	1.2504	1.224	0.6007	1.0823	2.810	0.9678	0.9570	5.031
0.0462	1.4131	0.609	0.2998	1.2310	1.339	0.6745	1.0531	3.232	0.9829	0.9527	5.120
0.0623	1.3992	0.643	0.3306	1.2131	1.460	0.7406	1.0289	3.618	1.0000	0.9479	5.232
0.0798	1.3845	0.680	0.3622	1.1955	1.598	0.7898	1.0119	3.928			
0.0916	1.3749	0.708	0.4019	1.1743	1.789	0.8221	1.0012	4.116			
0.1239	1.3495	0.784	0.4263	1.1618	1.914	0.8567	0.9901	4.332			
C_2Cl_3H (1) + $CH_3(OC_2H_4)_3OH$ (2)											
0.0000	1.4558	0.529	0.1359	1.3685	0.869	0.4548	1.2135	2.382	0.8689	1.0764	5.459
0.0056	1.4518	0.538	0.1710	1.3485	0.983	0.4947	1.1977	2.633	0.9106	1.0654	5.813
0.0133	1.4463	0.554	0.2125	1.3260	1.134	0.5322	1.1835	2.875	0.9455	1.0564	6.128
0.0235	1.4392	0.574	0.2627	1.3001	1.342	0.5817	1.1655	3.210	0.9667	1.0511	6.324
0.0377	1.4296	0.603	0.2860	1.2886	1.451	0.6349	1.1471	3.596	0.9823	1.0473	6.438
0.0554	1.4179	0.645	0.3201	1.2723	1.615	0.6824	1.1314	3.953	1.0000	1.0430	6.586
0.0751	1.4053	0.694	0.3511	1.2580	1.784	0.7308	1.1162	4.320			
0.0865	1.3981	0.725	0.3864	1.2423	1.974	0.7791	1.1017	4.716			
0.1057	1.3863	0.778	0.4202	1.2278	2.172	0.8178	1.0905	5.027			
C_2Cl_3H (1) + $C_2H_5(OC_2H_4)_3OH$ (2)											
0.0000	1.4558	0.529	0.1458	1.3482	0.947	0.4818	1.1753	2.796	0.8733	1.0471	5.952
0.0053	1.4513	0.540	0.1858	1.3231	1.103	0.5230	1.1589	3.087	0.9136	1.0368	6.273
0.0167	1.4419	0.565	0.2345	1.2945	1.326	0.5639	1.1434	3.396	0.9317	1.0323	6.460
0.0260	1.4343	0.587	0.2866	1.2660	1.587	0.6278	1.1207	3.880	0.9672	1.0237	6.773
0.0395	1.4236	0.618	0.3318	1.2429	1.832	0.6904	1.1000	4.378	0.9806	1.0206	6.891
0.0528	1.4134	0.651	0.3679	1.2254	2.048	0.7278	1.0883	4.683	1.0000	1.0161	7.042
0.0728	1.3984	0.707	0.4108	1.2057	2.323	0.7721	1.0751	5.051			
0.1054	1.3752	0.809	0.4470	1.1898	2.559	0.8271	1.0595	5.521			
C_2Cl_3H (1) + $C_4H_9(OC_2H4)_3OH$ (2)											
0.0000	1.4558	0.529	0.1472	1.3244	1.064	0.4202	1.1656	2.968	0.8128	1.0303	6.968
0.0080	1.4473	0.550	0.1817	1.2996	1.242	0.4555	1.1499	3.288	0.8883	1.0116	7.840
0.0207	1.4342	0.583	0.2132	1.2783	1.421	0.4882	1.1362	3.585	0.9261	1.0028	8.238
0.0326	1.4223	0.620	0.2487	1.2559	1.641	0.5244	1.1218	3.929	0.9670	0.9938	8.732
0.0484	1.4072	0.671	0.2772	1.2390	1.839	0.5826	1.1002	4.489	0.9864	0.9896	8.939
0.0692	1.3881	0.742	0.3104	1.2203	2.088	0.6409	1.0804	5.100	1.0000	0.9868	9.109
0.0868	1.3727	0.809	0.3418	1.2036	2.329	0.6866	1.0659	5.591			
0.1122	1.3516	0.913	0.3841	1.1824	2.663	0.7428	1.0493	6.200			

ported earlier (Pal and Singh, 1995, 1996), using the relation

$$\rho = \frac{x_1 M_1 + x_2 M_2}{V_{\mathrm{m}}^{\mathrm{E}} + V°} \tag{2}$$

where x_1 and x_2 denote the mole fractions and M_1 and M_2 are molecular masses of components 1 and 2, respectively. $V°$ stands for ideal molar volume.

Results and Discussion

The experimental results of viscosities and densities for 12 binary mixtures of trichloroethylene or tetrachloroethylene with 2-(2-methoxyethoxy)ethanol, 2-(2-ethoxyethoxy)-ethanol, 2-(2-butoxyethoxy)ethanol, 2-[2-(2-methoxyethoxy)-ethoxy]ethanol, 2-[2-(2-ethoxyethoxy)ethoxy]ethanol, and 2-[2-(2-butoxyethoxy)ethoxy]ethanol for a number of mole fractions at 298.15 K and atmospheric pressure are listed in Tables 1 and 2. Deviations in viscosity were obtained from the following empirical relationship (Aucejo et al., 1995; Ramadevi et al., 1996)

$$\ln \Delta\eta = \ln \eta - \sum_{i=1}^{2} x_i \ln \eta_i \tag{3}$$

where η is the viscosity of the mixtures in m Pa·s and x_i and η_i are the mole fractions and the viscosity of the pure

Table 2. Densities (ρ) and Viscosities (η) for the Mixtures of [C_2Cl_4 + $H(CH_2)_\nu(OC_2H_4)_nOH$] (ν = 1, 2, and 4 and n = 2 and 3) at 298.15 K and Atmospheric Pressure

x_2	ρ/g·cm^3	η/mPa·s	x_2	ρ/g·cm^3	η/mPa·s	x_2	ρ/g·cm^3	η/mPa·s	x_2	ρ/g·cm^3	η/mPa·s
C_2Cl_4 (1) + $CH_3(OC_2H_4)_2OH$ (2)											
0.0000	1.6147	0.846	0.1769	1.4920	1.092	0.4877	1.2975	1.796	0.8427	1.0985	2.948
0.0072	1.6094	0.852	0.2025	1.4752	1.139	0.5213	1.2778	1.900	0.8844	1.0764	3.109
0.0147	1.6039	0.859	0.2433	1.4487	1.216	0.5632	1.2534	2.030	0.9138	1.0610	3.225
0.0261	1.5956	0.869	0.2755	1.4281	1.279	0.5988	1.2329	2.140	0.9381	1.0488	3.323
0.0417	1.5843	0.884	0.3041	1.4099	1.340	0.6333	1.2133	2.253	0.9613	1.0363	3.414
0.0604	1.5711	0.911	0.3353	1.3904	1.413	0.6701	1.1926	2.366	0.9780	1.0277	3.478
0.0868	1.5527	0.948	0.3740	1.3664	1.504	0.7061	1.1726	2.480	0.9885	1.0223	3.521
0.1038	1.5410	0.975	0.4127	1.3427	1.596	0.7414	1.1532	2.593	1.0000	1.0164	3.565
0.1347	1.5201	1.023	0.4577	1.3155	1.712	0.7892	1.1272	2.754			
C_2Cl_4 (1) + $C_2H_5(OC_2H_4)_2OH$ (2)											
0.0000	1.6147	0.846	0.1758	1.4719	1.135	0.4889	1.2585	1.949	0.8540	1.0549	3.335
0.0123	1.6040	0.859	0.2057	1.4496	1.196	0.5216	1.2385	2.063	0.8945	1.0346	3.519
0.0256	1.5925	0.874	0.2427	1.4226	1.278	0.5734	1.2075	2.246	0.9227	1.0208	3.640
0.0478	1.5736	0.903	0.2829	1.3941	1.371	0.6176	1.1819	2.412	0.9398	1.0125	3.718
0.0645	1.5597	0.928	0.3332	1.3594	1.493	0.6576	1.1592	2.552	0.9556	1.0049	3.786
0.0824	1.5450	0.956	0.3756	1.3310	1.610	0.6972	1.1372	2.699	0.9736	0.9963	3.873
0.0970	1.5332	0.979	0.4139	1.3058	1.717	0.7396	1.1147	2.858	0.9888	0.9892	3.936
0.1126	1.5208	1.012	0.4562	1.2789	1.843	0.8033	1.0808	3.119	1.0000	0.9839	3.978
0.1488	1.4925	1.081									
C_2Cl_4 (1) + $C_4H_9(OC_2H_4)_2$ OH (2)											
0.0000	1.6147	0.846	0.1188	1.4902	1.090	0.4295	1.2421	2.160	0.7734	1.0473	3.894
0.0092	1.6042	0.859	0.1559	1.4554	1.186	0.4585	1.2231	2.288	0.8415	1.0155	4.283
0.0253	1.5862	0.883	0.1903	1.4247	1.289	0.4917	1.2019	2.445	0.8983	0.9903	4.615
0.0385	1.5718	0.910	0.2322	1.3890	1.413	0.5310	1.1778	2.635	0.9290	0.9771	4.805
0.0481	1.5615	0.929	0.2748	1.3545	1.557	0.5750	1.1518	2.845	0.9482	0.9691	4.918
0.0583	1.5508	0.950	0.3127	1.3252	1.691	0.6181	1.1275	3.066	0.9696	0.9603	5.061
0.0816	1.5268	1.001	0.3556	1.2934	1.851	0.6660	1.1016	3.310	0.9831	0.9548	5.131
0.0932	1.5151	1.030	0.3911	1.2683	2.000	0.7112	1.0781	3.548	1.0000	0.9479	5.232
C_2Cl_4 (1) + $CH_3(OC_2H_4)_3OH$ (2)											
0.0000	1.6147	0.846	0.1201	1.5121	1.162	0.4933	1.2688	2.812	0.8860	1.0866	5.597
0.0078	1.6074	0.862	0.1568	1.4839	1.280	0.5379	1.2450	3.072	0.9108	1.0768	5.820
0.0160	1.6000	0.883	0.2009	1.4515	1.432	0.5783	1.2243	3.326	0.9403	1.0654	6.053
0.0295	1.5877	0.915	0.2413	1.4231	1.592	0.6154	1.2058	3.560	0.9649	1.0561	6.276
0.0470	1.5723	0.956	0.2894	1.3908	1.795	0.6587	1.1850	3.856	0.9807	1.0502	6.411
0.0598	1.5613	0.989	0.3457	1.3547	2.047	0.7026	1.1646	4.163	1.0000	1.0430	6.586
0.0696	1.5531	1.016	0.3797	1.3339	2.209	0.7393	1.1481	4.431			
0.0802	1.5442	1.046	0.4041	1.3193	2.334	0.7870	1.1274	4.797			
0.0924	1.5342	1.081	0.4620	1.2861	2.640	0.8264	1.1108	5.117			
C_2Cl_4 (1) + $C_2H_5(OC_2H_4)_3OH$ (2)											
0.0000	1.6147	0.846	0.1487	1.4737	1.290	0.4633	1.2550	2.863	0.8471	1.0725	5.684
0.0072	1.6070	0.863	0.1926	1.4378	1.459	0.5019	1.2333	3.105	0.9061	1.0499	6.191
0.0185	1.5951	0.892	0.2354	1.4048	1.634	0.5442	1.2105	3.384	0.9387	1.0379	6.486
0.0339	1.5793	0.931	0.2903	1.3649	1.893	0.5861	1.1889	3.665	0.9502	1.0337	6.589
0.0489	1.5643	0.969	0.3204	1.3442	2.052	0.6345	1.1650	4.013	0.9795	1.0233	6.871
0.0609	1.5526	1.008	0.3495	1.3248	2.207	0.6893	1.1394	4.413	1.0000	1.0161	7.042
0.0867	1.5283	1.081	0.3887	1.2997	2.429	0.7441	1.1150	4.852			
0.1081	1.5089	1.154	0.4239	1.2782	2.631	0.8008	1.0911	5.303			
C_2Cl_4 (1) + $C_4H_9(OC_2H_4)_3OH$ (2)											
0.0000	1.6147	0.846	0.1471	1.4492	1.408	0.4588	1.2157	3.550	0.8037	1.0537	6.872
0.0067	1.6059	0.864	0.1840	1.4149	1.601	0.4910	1.1973	3.816	0.8566	1.0343	7.450
0.0173	1.5923	0.895	0.2264	1.3781	1.828	0.5348	1.1736	4.198	0.9013	1.0187	7.964
0.0345	1.5709	0.950	0.2617	1.3495	2.046	0.5760	1.1525	4.576	0.9283	1.0097	8.260
0.0476	1.5552	0.995	0.3067	1.3152	2.351	0.6201	1.1312	4.978	0.9521	1.0019	8.528
0.0600	1.5408	1.040	0.3480	1.2859	2.660	0.6577	1.1139	5.357	0.9738	0.9950	8.793
0.0815	1.5167	1.124	0.3770	1.2664	2.889	0.7089	1.0916	5.881	1.0000	0.9868	9.109
0.1063	1.4902	1.227	0.4150	1.2421	3.192	0.7558	1.0723	6.354			

Table 3. Estimated Parameters of Eq 4 and Standard Deviation σ(ln $\Delta\eta$) for the Mixtures of [C_2Cl_3H + $H(CH_2)_\nu(OC_2H_4)_nOH$] (ν = 1, 2, and 4 and n = 2 and 3) at 298.15 K and Atmospheric Pressure

C_2Cl_3H (1) +	a_0	a_1	a_2	a_3	a_4	σ(ln $\Delta\eta$)
$CH_3(OC_2H_4)_2OH$ (2)	0.5934	0.0116	0.0290	0.2765	−0.3384	0.003
$C_2H_5(OC_2H_4)_2OH$ (2)	0.8945	0.1756	−0.2541	0.0493		0.003
$C_4H_9(OC_2H_4)_2OH$ (2)	1.2495	0.0100	−0.3251	0.1346		0.004
$CH_3(OC_2H_4)_3OH$ (2)	1.4231	−0.1639	−0.2874	0.2758		0.002
$C_2H_5(OC_2H_4)_3OH$ (2)	1.6672	−0.3429	−0.2616	0.3803		0.002
$C_4H_9(OC_2H_4)_3OH$ (2)	2.0934	−0.5829	−0.2143	0.3677		0.003

components, respectively. The results of ln $\Delta\eta$ are fitted using an empirical equation of the form

$$\ln \Delta\eta = x_1 x_2 \sum_{j=0}^{k} a_j (x_2 - x_1)^j \qquad (4)$$

where a_j is the polynomial coefficient and k is the polynomial degree. The values of the coefficients a_j were evaluated by the method of least squares and are given in Tables 3 and 4, along with the standard deviation. The results for ln $\Delta\eta$ are graphically represented in Figures 1 and 2.

The ln $\Delta\eta$ versus composition plots in Figure 1 show that the viscosity deviations (ln $\Delta\eta$) are positive for trichloro-

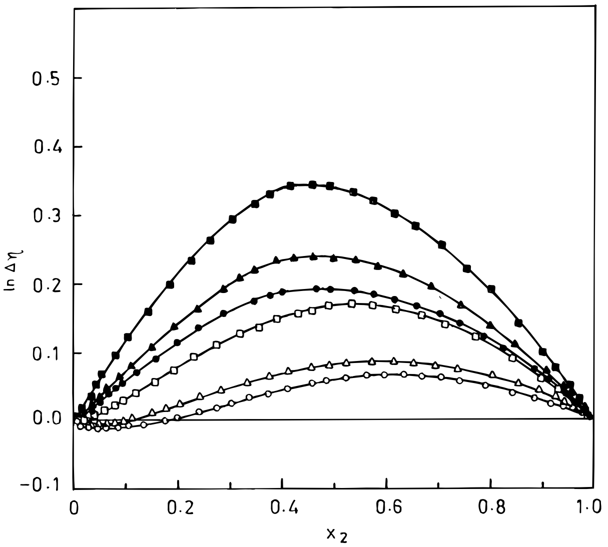

Figure 2. ln Δη for C_2Cl_4 (1) + $H(CH_2)_\nu(OC_2H_4)_2OH$ (2) (○, ν = 1; △, ν = 2; □, ν = 4) and for C_2Cl_3H (1) + $H(CH_2)_\nu(OC_2H_4)_3OH$(2) (○, ν = 1; ▲, ν = 2; ■, ν = 4) at 298.15 K. Solid curves were calculated from eq 4 using coefficients a_j of Table 4.

Table 4. Estimated Parameters of Eq 4 and Standard Deviation σ (ln Δη) for the Mixtures of [C_2Cl_4 + $H(CH_2)_\nu(OC_2H_4)_nOH$] (ν = 1, 2, and 4 and n = 2 and 3) at 298.15 K and Atmospheric Pressure

C_2Cl_3H (1) +	a_0	a_1	a_2	a_3	σ(ln Δη)
$CH_3(OC_2H_4)_2OH$ (2)	0.2300	0.2157	−0.2091	0.0543	0.003
$C_2H_5(OC_2H_4)_2OH$ (2)	0.3293	0.1654	−0.1641	0.1465	0.003
$C_4H_9(OC_2H_4)_2OH$ (2)	0.6640	0.1081	−0.2758	0.1829	0.002
$CH_3(OC_2H_4)_3OH$ (2)	0.7604	−0.0721	−0.1134	0.1669	0.001
$C_2H_5(OC_2H_4)_3OH$ (2)	0.9508	−0.0836	−0.2023	0.1681	0.002
$C_4H_9OC_2H_4)_3OH$ (2)	1.3575	−0.2522	−0.2993	0.2077	0.003

ethylene mixtures with the exception of 2-(2-methoxyethoxy)ethanol, whereas Figure 2 shows that the viscosity deviations (ln Δη) are positive for tetrachloroethylene mixtures with the exception of 2-(2-methoxyethoxy)ethanol, 2-(2-ethoxyethoxy)ethanol, and 2-(2-butoxyethoxy)ethanol over the entire range of compositions. For each chloroethene, the magnitudes of η and ln Δη increase with the same aliphatic chain for each addition of a $-OC_2H_4-$ group in the two homologous series. Our results and the results of Venkatesulu et al. (1997) show that, for each n-alkoxyethanol, the η and ln Δη increase from tetrachloroethylene to trichloroethylene. It is also noted that the difference between the maximum ln Δη of the trichloroethylene or tetrachloroethylene mixtures formed with the members of each homologous series of the alkoxyethanol with the same aliphatic chain increases as the alkyl chain lengthens. It was suggested previously (Pal and Singh, 1995, 1996; Venkatesulu and Rao, 1992) that the volume behaviors of chloroethenes + n-alkoxyethanols are the result of diverse and opposing effects accompanying the differences in the molecular size and the shape of the components, breaking of the hydrogen bonding of the self-associated alkoxyethanols, and the complex formation between π-electrons of chloroethene and oxygen (−O−) in alkoxyethanol molecules.

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