Excess Molar Volumes and Viscosities of Diethylene Glycol Diethyl Ether with Dimethyl Carbonate, Diethyl Carbonate, and Propylene Carbonate at (298.15, 308.15, and 318.15) K

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Excess molar volumes, V_m^E, and viscosities, η, have been measured for the binary mixtures diethylene glycol diethyl ether + dimethyl carbonate, + diethyl carbonate, and + propylene carbonate at temperatures of (298.15, 308.15, and 318.15) K and atmospheric pressure over the whole range of mixture compositions. The excess molar volumes are fitted to a Redlich−Kister type polynomial equation to derive the binary coefficients and estimate the standard errors between the experimental and calculated quantities. The experimental results are compared with those of previous studies for binary mixtures containing esters of carbonic acid.

Introduction

Esters of carbonic acid are important fluids that find use as solvents for a variety of extractions of industrial importance, for resins, in the synthesis of pharmaceuticals, and for addressing the problem of agricultural chemicals. Thus, a study of physical property data on binary mixtures containing esters of carbonic acid has attracted considerable interest in the literature (Francesconi and Comelli, 1999; Muhuri and Hazra, 1995; Barthel et al., 1995; Francesconi and Comelli, 1997).

As a part of our systematic program of research on the physicochemical properties of binary liquid mixtures (Pal et al., 1999a,b; Pal and Kumar, 1998; Pal et al., 1998), we present here the experimental results of excess molar volume, V_m^E, and viscosity, η, at (298.15, 308.15, and 318.15) K and atmospheric pressure for the binary mixtures of diethylene glycol diethyl ether with dimethyl carbonate, diethyl carbonate, and propylene carbonate over the whole mole fraction range. The aim of this work is to provide data for the characterization of the molecular interactions of these mixtures and to examine the effects of replacing methyl by ethyl groups in polyethers.

To our knowledge there are no literature data on these systems.

Experimental Section

Chemicals. Dimethyl carbonate (Spectrochem, Bombay, >98 mass %), diethyl carbonate (Siscochem, Bombay, >99 mass %), and propylene carbonate (Merck-Schuchardt, >99 mass%) were the same as those used in earlier studies (Pal and Kumar, 1998). Diethylene glycol diethyl ether (Merck-Schuchardt, >98 mass %) was dried over $FeSO_4$ (A. R., BDH) and then fractionally distilled under reduced nitrogen pressure. Prior to measurements, all liquids were stored in contact with molecular sieves type 4A to reduce water content and were partially degassed at low pressure. The results of the measurements of their densities and viscosities at 298.15 K and atmospheric pressure are given in Table 1, together with some values taken from the literature.

Table 1. Comparison of Experimental Densities, ρ, and Viscosities, η, of Pure Liquids with Literature Values at 298.15 K

	ρ/g cm^{-3}		η/mPa s	
liquid	exptl	lit.	exptl	lit.
diethylene glycol diethyl ether	0.9035	0.903 3[a]	1.268	
dimethyl carbonate	1.0632	1.063 31[b] 1.063 059[c]	0.589	
diethyl carbonate	0.9690	0.969 25[b] 0.969 26[d]	0.749	
propylene carbonate	1.1988	1.198 83[e]	2.493	2.4711[e] 2.51[f]

[a] Roux et al. (1978). [b] Francesconi et al. (1997). [c] Negadi et al. (1993). [d] Riddick et al. (1986). [e] Muhuri and Hazra (1995). [f] Barthel et al. (1995).

Apparatus and Procedure. Excess molar volumes, reproducible to ±0.003 cm^3 mol^{-1}, were measured directly with a continuous dilution dilatometer, as described earlier by Dickinson et al. (1975). Details of its calibration, the experimental setup, and the measuring procedure have been described previously (Pal and Singh, 1994). The mole fraction of each mixture was obtained to an accuracy of 1×10^{-4} from the measured apparent masses of the components. All apparent masses were corrected for buoyancy. All molar quantities was based on the relative atomic mass table of 1986 issued by IUPAC (1986). Each run covered just over half of the mole fraction range, giving an overlap between two runs.

The kinematic viscosities of the pure components and the mixtures were measured at (298.15, 308.15, and 318.15) K and atmospheric pressure using an Ubbelohde suspended level viscometer. The viscometer was calibrated with thrice-distilled water and twice-distilled benzene. Care was taken to prevent evaporation during measurements. The other experimental details have been given previously (Pal and Singh, 1996). After multiplication by density, the dynamic

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Table 2. Excess Molar Volumes, V_m^E, for Binary Mixtures at Various Temperatures

x_1	V_m^E / $cm^3\ mol^{-1}$	x_1	V_m^E / $cm^3\ mol^{-1}$	x_1	V_m^E / $cm^3\ mol^{-1}$	x_1	V_m^E / $cm^3\ mol^{-1}$	x_1	V_m^E / $cm^3\ mol^{-1}$	x_1	V_m^E / $cm^3\ mol^{-1}$
Diethylene Glycol Diethyl Ether (1) + Dimethyl Carbonate (2)				Diethylene Glycol Diethyl Ether (1) + Diethyl Carbonate (2)				Diethylene Glycol Diethyl Ether (1) + Propylene Carbonate (2)			
298.15 K				298.15 K				298.15 K			
0.0158	0.010	0.3712	−0.030	0.0110	−0.005	0.4502	−0.118	0.0156	−0.049	0.3217	−0.800
0.0276	0.022	0.4512	−0.032	0.0325	−0.014	0.4942	−0.120	0.0489	−0.153	0.3379	−0.817
0.0511	0.028	0.5076	−0.034	0.0643	−0.026	0.5310	−0.120	0.0911	−0.272	0.3890	−0.869
0.0617	0.032	0.5751	−0.032	0.0850	−0.034	0.5727	−0.121	0.1412	−0.414	0.4221	−0.910
0.0867	0.030	0.6150	−0.030	0.1197	−0.046	0.6239	−0.117	0.1915	−0.551	0.4307	−0.910
0.1178	0.025	0.7042	−0.024	0.1444	−0.054	0.6645	−0.115	0.1989	−0.570	0.4921	−0.950
0.1543	0.020	0.7609	−0.021	0.1904	−0.068	0.7217	−0.106	0.2177	−0.607	0.5817	−0.941
0.2001	0.011	0.8303	−0.019	0.2342	−0.079	0.7717	−0.097	0.2444	−0.665	0.6800	−0.859
0.2351	−0.009	0.8778	−0.014	0.2863	−0.088	0.8378	−0.071	0.2560	−0.678	0.7526	−0.740
0.2643	−0.015	0.9248	−0.010	0.3420	−0.102	0.8952	−0.050	0.2723	−0.718	0.8648	−0.482
0.2980	−0.019	0.9551	−0.007	0.3601	−0.105	0.9465	−0.026	0.3044	−0.760	0.9806	−0.069
0.3019	−0.020			0.4006	−0.110	0.9752	−0.014				
308.15 K				308.15 K				308.15 K			
0.0016	0.001	0.3540	−0.042	0.0268	−0.019	0.4505	−0.145	0.0067	−0.027	0.3135	−0.846
0.0243	0.006	0.3950	−0.047	0.0553	−0.036	0.4604	−0.143	0.0186	−0.073	0.3435	−0.889
0.0545	0.010	0.4395	−0.047	0.0964	−0.053	0.4894	−0.143	0.0298	−0.115	0.3697	−0.920
0.0763	0.008	0.4484	−0.050	0.1434	−0.077	0.5204	−0.142	0.0458	−0.178	0.4014	−0.951
0.1031	0.004	0.4980	−0.051	0.1822	−0.087	0.5910	−0.140	0.0609	−0.226	0.4106	−0.960
0.1616	−0.010	0.5727	−0.048	0.2111	−0.095	0.6453	−0.138	0.0843	−0.304	0.4280	−0.973
0.2256	−0.026	0.6396	−0.043	0.2590	−0.107	0.6858	−0.134	0.1136	−0.394	0.4733	−1.000
0.2328	−0.025	0.7139	−0.039	0.2999	−0.119	0.7474	−0.118	0.1577	−0.522	0.5377	−1.007
0.2528	−0.030	0.7848	−0.035	0.3364	−0.130	0.7996	−0.105	0.1989	−0.623	0.6078	−0.983
0.2827	−0.034	0.8498	−0.023	0.3747	−0.139	0.8430	−0.092	0.2127	−0.656	0.6773	−0.917
0.3175	−0.038	0.9213	−0.012	0.3873	−0.143	0.8813	−0.071	0.2206	−0.667	0.7560	−0.784
0.3417	−0.041	0.9620	−0.008	0.4120	−0.144	0.9448	−0.037	0.2429	−0.710	0.8212	−0.650
				0.4202	−0.145	0.9906	−0.010	0.2681	−0.760	0.8952	−0.423
								0.2720	−0.765	0.9388	−0.260
								0.3113	−0.835		
318.15 K				318.15 K				318.15 K			
0.0177	−0.007	0.3435	−0.062	0.0216	−0.015	0.4062	−0.170	0.0050	−0.040	0.3856	−1.000
0.0407	−0.014	0.4120	−0.065	0.0457	−0.030	0.4433	−0.170	0.0169	−0.079	0.4331	−1.040
0.0573	−0.021	0.5002	−0.063	0.0891	−0.060	0.4883	−0.172	0.0350	−0.160	0.4820	−1.059
0.0784	−0.024	0.5409	−0.061	0.1140	−0.067	0.5265	−0.170	0.0539	−0.249	0.5333	−1.060
0.1057	−0.029	0.6058	−0.060	0.1418	−0.081	0.5992	−0.164	0.0717	−0.308	0.5745	−1.050
0.1329	−0.031	0.6879	−0.057	0.1867	−0.110	0.6632	−0.159	0.1049	−0.427	0.6223	−1.029
0.1664	−0.034	0.7190	−0.056	0.2154	−0.120	0.7285	−0.142	0.1567	−0.584	0.7110	−0.946
0.1974	−0.038	0.7607	−0.053	0.2477	−0.132	0.7616	−0.136	0.2069	−0.697	0.7868	−0.780
0.2398	−0.050	0.8051	−0.051	0.2950	−0.150	0.7826	−0.130	0.2540	−0.800	0.8421	−0.649
0.2677	−0.054	0.8508	−0.044	0.3083	−0.154	0.8206	−0.110	0.2743	−0.841	0.8977	−0.468
0.3049	−0.060	0.9234	−0.034	0.3386	−0.168	0.8644	−0.096	0.3003	−0.893	0.9240	−0.364
				0.3483	−0.168	0.9169	−0.060	0.3414	−0.950		
				0.3781	−0.170	0.9498	−0.040				

viscosity, η, was deduced with a relative error of ±0.003 mPa s. All the measurements were carried out in a thermostatically controlled, well-stirred water bath with temperature controlled to ±0.01 K.

Results and Discussion

The experimental results of the excess molar volumes and viscosities of the different binary mixtures for a number of mole fractions at atmospheric pressure and at (298.15, 308.15, and 318.15) K are reported in Tables 2 and 3.

From the measured values of excess molar volumes, the densities of liquid mixtures were calculated using the following equation:

$$\rho = (x_1M_1 + x_2M_2)/(V_m^E + x_1V_1^\circ + x_2V_2^\circ) \qquad (1)$$

where x_1 and x_2 are the mole fractions, M_1 and M_2 are the molar masses, and V_i° stands for the molar volumes of the pure components, respectively.

The viscosity deviations can be calculated from the following relationship (Aucejo et al., 1996; Ramadevi et al., 1996)

$$\Delta \ln \eta = \ln \eta - [x_1 \ln \eta_1 + x_2 \ln \eta_2] \qquad (2)$$

where η is the dynamic viscosity of the mixtures and η_1 and η_2 are the viscosities of components 1 and 2.

The values of V_m^E and $\Delta \ln \eta$ at various temperatures for all mixtures were fitted to the Redlich−Kister type equation (Redlich−Kister, 1948)

$$Y = x_1x_2\sum_{i=1}^{k}A_i(x_1 - x_2)^{i-1} \qquad (3)$$

where A_i are the polynomial coefficients, which were obtained by fitting the equation to the experimental result with a least-squares regression method with all points weighted equally. The correlated results are given in Table

Table 3. Densities, ρ, and Viscosities, η, for Binary Mixtures at Various Temperatures

x_1	ρ/g cm^{-3}	η/mPa s	x_1	ρ/g cm^{-3}	η/mPa s	x_1	ρ/g cm^{-3}	η/mPa s	x_1	ρ/g cm^{-3}	η/mPa s
Diethylene Glycol Diethyl Ether (1) + Dimethyl Carbonate (2)											
298.15 K											
0.0000	1.0632	0.589	0.1383	1.0228	0.718	0.4435	0.9633	0.959	0.8183	0.9188	1.189
0.0109	1.0598	0.604	0.1877	1.0109	0.760	0.5274	0.9513	1.021	0.9068	0.9110	1.229
0.0541	1.0460	0.641	0.2422	0.9990	0.808	0.6085	0.9409	1.072	0.9643	0.9063	1.258
0.0935	1.0346	0.677	0.3409	0.9801	0.886	0.7154	0.9289	1.136	1.0000	0.9035	1.268
308.15 K											
0.0000	1.0508	0.520	0.1383	1.0118	0.624	0.4435	0.9541	0.811	0.8183	0.9110	0.986
0.0109	1.0473	0.532	0.1877	1.0003	0.654	0.5274	0.9425	0.855	0.9068	0.9034	1.019
0.0541	1.0341	0.563	0.2422	0.9887	0.689	0.6085	0.9325	0.894	0.9643	0.8988	1.037
0.0935	1.0232	0.593	0.3409	0.9704	0.752	0.7154	0.9209	0.942	1.0000	0.8961	1.048
318.15 K											
0.0000	1.0377	0.472	0.1383	1.0000	0.546	0.4435	0.9440	0.697	0.8183	0.9020	0.831
0.0109	1.0343	0.480	0.1877	0.9888	0.571	0.5274	0.9327	0.727	0.9068	0.8945	0.857
0.0541	1.0216	0.502	0.2422	0.9776	0.604	0.6085	0.9230	0.761	0.9643	0.8901	0.872
0.0935	1.0110	0.523	0.3409	0.9598	0.651	0.7154	0.9116	0.798	1.0000	0.8874	0.881
Diethylene Glycol Diethyl Ether (1) + Diethyl Carbonate (2)											
298.15 K											
0.0000	0.9690	0.749	0.1858	0.9530	0.863	0.4971	0.9309	1.041	0.8683	0.9099	1.214
0.0221	0.9670	0.763	0.2214	0.9502	0.890	0.5997	0.9246	1.092	0.9296	0.9069	1.239
0.0409	0.9653	0.776	0.2775	0.9459	0.923	0.6836	0.9198	1.133	0.9694	0.9050	1.255
0.0945	0.9606	0.812	0.3669	0.9395	0.972	0.7747	0.9148	1.170	1.0000	0.9035	1.268
308.15 K											
0.0000	0.9577	0.658	0.1858	0.9429	0.741	0.4971	0.9221	0.879	0.8683	0.9023	1.009
0.0221	0.9558	0.667	0.2214	0.9403	0.758	0.5997	0.9162	0.917	0.9296	0.8994	1.027
0.0409	0.9543	0.675	0.2775	0.9363	0.784	0.6836	0.9116	0.947	0.9694	0.8975	1.040
0.0945	0.9499	0.699	0.3669	0.9302	0.822	0.7747	0.9069	0.979	1.0000	0.8961	1.048
318.15 K											
0.0000	0.9438	0.578	0.1858	0.9305	0.643	0.4971	0.9115	0.747	0.8683	0.8932	0.849
0.0221	0.9421	0.584	0.2214	0.9281	0.656	0.5997	0.9060	0.775	0.9296	0.8905	0.862
0.0409	0.9407	0.592	0.2775	0.9245	0.677	0.6836	0.9018	0.801	0.9694	0.8887	0.871
0.0945	0.9368	0.609	0.3669	0.9190	0.707	0.7747	0.8975	0.825	1.0000	0.8874	0.881
Diethylene Glycol Diethyl Ether (1) + Propylene Carbonate (2)											
298.15 K											
0.0000	1.1988	2.493	0.2136	1.0976	2.225	0.4970	1.0065	1.833	0.8704	0.9256	1.377
0.0130	1.1914	2.474	0.2570	1.0811	2.179	0.5874	0.9838	1.717	0.9264	0.9158	1.316
0.0542	1.1693	2.418	0.3304	1.0556	2.080	0.6907	0.9606	1.589	0.9628	0.9096	1.289
0.1089	1.1424	2.353	0.4267	1.0259	2.940	0.7876	0.9410	1.474	1.0000	0.9035	1.268
0.1594	1.1198	2.288									
308.15 K											
0.0000	1.1897	2.041	0.2136	1.0894	1.827	0.4970	0.9988	1.504	0.8704	0.9181	1.148
0.0130	1.1824	2.024	0.2570	1.0730	1.782	0.5874	0.9763	1.404	0.9264	0.9083	1.101
0.0542	1.1605	1.982	0.3304	1.0477	1.702	0.6907	0.9531	1.306	0.9628	0.9022	1.071
0.1089	1.1339	1.923	0.4267	1.0182	1.589	0.7876	0.9335	1.219	1.0000	0.8961	1.048
0.1594	1.1115	1.875									
318.15 K											
0.0000	1.1780	1.718	0.2136	1.0793	1.506	0.4970	0.9895	1.227	0.8704	0.9095	0.957
0.0130	1.1709	1.703	0.2570	1.0631	1.466	0.5874	0.9671	1.152	0.9264	0.8997	0.922
0.0542	1.1495	1.658	0.3304	1.0379	1.390	0.6907	0.9442	1.076	0.9628	0.8935	0.901
0.1089	1.1233	1.605	0.4267	1.0086	1.297	0.7876	0.9248	1.010	1.0000	0.8874	0.881
0.1594	1.1012	1.555									

4, in which the tabulated standard deviation was defined as

$$\sigma = [\sum(Y_{exp} - Y_{cal})^2/(n - k)]^{1/2} \qquad (4)$$

where n is the number of measurements and k is the number of estimated parameters. Y refers to V_m^E/cm^3 mol^{-1} or Δ ln[η/mPa s].

Figures 1 and 2 show V_m^E and $\Delta \ln \eta$ data for the three mixtures at 298.15 K. We have not reported the experimental data at (308.15 or 318.15) K, as the curves are similar. The excess molar volumes are negative over the entire range of composition for the systems diethylene glycol diethyl ether + diethyl carbonate and + propylene carbonate. For the system diethylene glycol diethyl ether + dimethyl carbonate, a change of sign occurs at 298.15 and 308.15 K. The binary mixtures with propylene carbonate show strongly negative V_m^E values that increase with an increase in temperature while, for the mixtures with dimethyl carbonate or diethyl carbonate, V_m^E shows a negligible temperature dependence. This behavior may be compared with the V_m^E results of the mixtures of diethylene glycol dimethyl ether with esters of carbonic acid (Pal and Kumar, 1998): a marked increase in V_m^E at all three temperatures is evident here. With the replacement of a methyl group by an ethyl group in the polyether chain, V_m^E becomes more negative with a rise in temperature. The negative values of V_m^E suggest a specific intermolecular interaction occurring in the mixing process. This is very important with propylene carbonate. The temperature

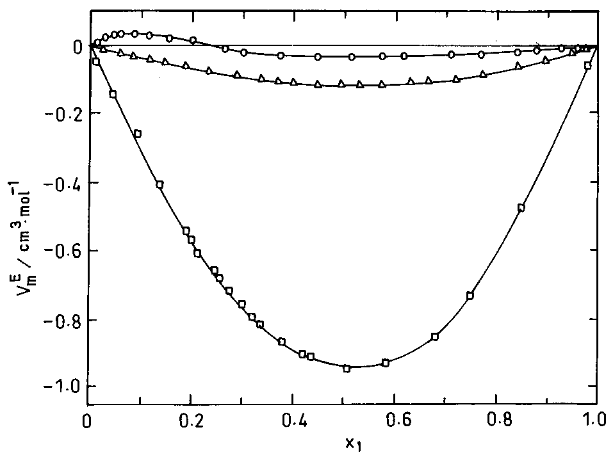

Figure 1. Comparison of the excess molar volumes, V^E_m, of different mixtures at 298.15 K: ○, dimethyl carbonate; △, diethyl carbonate; □, propylene carbonate. Solid curves were calculated from eq 3 using coefficient A_i of Table 4.

Table 4. Smoothing Coefficients, A_i, and Standard Deviations, $\sigma(Y(x))$, of Eq 3 for the Binary Mixtures at Various Temperatures

$Y(x)$	A_1	A_2	A_3	A_4	A_5	$\sigma(Y(x))$
Diethylene Glycol Diethyl Ether (1) + Dimethyl Carbonate (2)						
298.15 K						
V^E_m/cm^3 mol^{-1}	−0.134	0.065	0.094	−0.566	0.425	0.003
Δ ln[η/mPa s]	0.589	−0.162	0.084	−0.049		0.003
308.15 K						
V^E_m/cm^3 mol^{-1}	−0.195	0.019	0.007	−0.254	0.299	0.002
Δ ln[η/mPa s]	0.514	−0.131	0.106	−0.114		0.003
318.15 K						
V^E_m/cm^3 mol^{-1}	−0.260	0.034	0.012	−0.192	−0.283	0.003
Δ ln[η/mPa s]	0.435	−0.135	0.012	0.054		0.003
Diethylene Glycol Diethyl Ether (1) + Diethyl Carbonate (2)						
298.15 K						
V^E_m/cm^3 mol^{-1}	−0.480	−0.108	−0.012	0.073		0.001
Δ ln[η/mPa s]	0.271	−0.078	0.005	0.003		0.002
308.15 K						
V^E_m/cm^3 mol^{-1}	−0.582	−0.036	−0.113	−0.038		0.003
Δ ln[η/mPa s]	0.227	−0.021	−0.040	0.040		0.001
318.15 K						
V^E_m/cm^3 mol^{-1}	−0.693	0.050	−0.192	−0.215	0.166	0.003
Δ ln[η/mPa s]	0.193	−0.052	−0.055	0.069		0.002
Diethylene Glycol Diethyl Ether (1) + Propylene Carbonate (2)						
298.15 K						
V^E_m/cm^3 mol^{-1}	−3.780	−0.422	−0.199	−0.005	0.487	0.004
Δ ln[η/mPa s]	0.121	−0.139	0.133	−0.018	−0.451	0.002
308.15 K						
V^E_m/cm^3 mol^{-1}	−4.029	−0.393	−0.152	0.062	−0.229	0.003
Δ ln[η/mPa s]	0.116	−0.170	−0.028	0.150		0.003
318.15 K						
V^E_m/cm^3 mol^{-1}	−4.259	−0.360	−0.580	0.027	−0.473	0.004
Δ ln[η/mPa s]	−0.004	−0.126	0.030	0.114		0.003

coefficient $(\partial V^E_m/\partial T)_P$ is negative for all the mixtures over the whole mole fraction range.

Figure 2 shows that the deviation in viscosity Δ ln η is positive over the entire composition range for all systems, showing an inversion of sign for mixtures of diethylene glycol diethyl ether with propylene carbonate at all temperatures. The viscosities of all three binary mixtures decrease with the increase of temperature. The η results of the mixtures at all three temperatures follow the sequence dimethyl carbonate < diethyl carbonate < propylene carbonate. At any particular temperature, as x_1 increases, the η values of dimethyl carbonate and diethyl carbonate increase whereas that for propylene carbonate decreases. A further comparison of data at different temperatures shows that the temperature coefficient $(\partial\eta/\partial T)_P$ is decreasing for the three mixtures with increasing temperature.

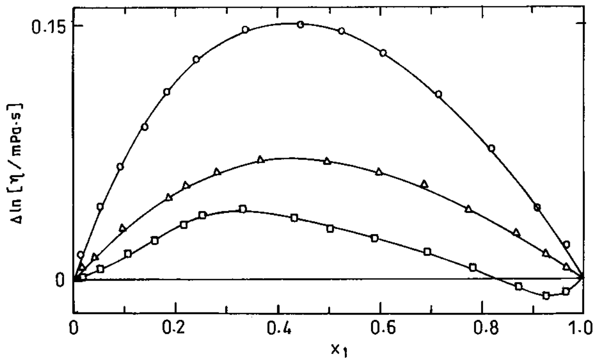

Figure 2. Comparison of viscosity deviations, Δ ln η, of different mixtures at 298.15 K: ○, dimethyl carbonate; △, diethyl carbonate; □, propylene carbonate. Solid curves were calculated from eq 3 using coefficient A_i of Table 4.

Literature Cited

Aucejo, A.; Burguet, M. C.; Munoz, R.; Sanchotello, M. Densities, Viscosities, and Refractive Indices of Some Binary Liquid Systems of Methanol + Isomers of Hexanol at 298.15 K. *J. Chem. Eng. Data* **1996**, *41*, 508−510.

Barthel, J.; Utz, M.; GroB, K.; Gores, H. J. Temperature and Composition Dependence of Viscosity I. Propylene Carbonate-Dimethoxyethane Mixtures and Thermodynamics of Fluid Flow. *J. Solution Chem.* **1995**, *24*, 1109−1123.

Dickinson, E.; Hunt, D. C.; McLure, I. A. Excess Volume of Mixing of Nearly Spherical Molecules 2. Mixtures Containing Cyclic Dimethyl Siloxanes. *J. Chem. Thermodyn.* **1975**, *7*, 731−740.

Francesconi, R.; Comelli, F. Vapour-liquid Equilibria, Excess Molar Enthalpies, and Excess Molar Volumes of Dialkyl Carbonates + Methyl *tert*-Butyl Ether at 298.15 K. *J. Chem. Eng. Data* **1997**, *42*, 697−701.

Francesconi, R.; Comelli, F. Excess Molar Enthalpies and Excess Molar Volumes of Binary Mixtures Containing Dimethyl Carbonate + Four Butanol Isomers at (288.15, 298.15, and 313.15) K. *J. Chem. Eng. Data* **1999**, *44*, 44−47.

Francesconi, R.; Comelli, F.; Ottani, S. Excess Molar Enthalpies and Excess Molar Volumes of Dialkyl Carbonates + Acetic or Propionic Acid at 298.15 K. *J. Chem. Eng. Data* **1997**, *42*, 702−704.

IUPAC Commission on Atomic Weights and Isotopic Abundances 1985. *Pure Appl. Chem.* **1986**, *58*, 1677−1692.

Muhuri, P. K.; Hazra, D. K. Densities and Viscosity of Propylene Carbonate + 2- Methoxyethanol at 298.15, 308.15, and 318.15 K. *J. Chem. Eng. Data* **1995**, *40*, 582−585.

Negadi, L.; Blondel, A.; Mokbel, I.; Ait-Kaci, A.; Jose, J. Int. DATA Ser., Sel. *Data Mixtures, Ser. A* **1993**, *21* (3), 169−194.

Pal, A.; Singh, Y. P. Excess Molar Volumes and Apparent Molar Volumes of $\{x\mathrm{H(CH_2)O(CH_2)_2O(CH_2)_2OH} + (1 - x)\mathrm{H_2O}\}$ at the Temperature 298.15 K. *J. Chem Thermodyn.* **1994**, *26*, 1063−1070.

Pal, A.; Singh, Y. P. Viscosity in Water + Ethylene Glycol Dimethyl, + Diethylene Glycol Dimethyl, + Triethylene Glycol Dimethyl, and + Tetraethylene Glycol Dimethyl Ethers at 298.15 K. *J. Chem. Eng. Data* **1996**, *41*, 1008−1011.

Pal, A.; Kumar, A. Excess Molar Volumes, Viscosities, and Refractive Indices of Diethylene Glycol Dimethyl Ether with Dimethyl Carbonate, Diethyl Carbonate, and Propylene Carbonate at (298.15, 308.15, and 318.15) K. *J. Chem. Eng. Data* **1998**, *43*, 143−147.

Pal, A.; Dass, G.; Kumar, A. Excess Molar Volumes, Viscosities, and Refractive Indices of Triethylene Glycol Dimethyl Ether with Dimethyl Carbonate, Diethyl Carbonate, and Propylene Carbonate at 298.15 K. *J. Chem. Eng. Data* **1998**, *43*, 738−741.

Pal, A.; Dass, G.; Kumar, A. Excess Molar Volumes, Viscosities, and Refractive Indices of Tetraethylene Glycol Dimethyl Ether with Dimethyl Carbonate, Diethyl Carbonate, and Propylene Carbonate at 298.15 K. *J. Chem. Eng. Data* **1999a**, *44*, 1−5.

Pal, A.; Kumar, H.; Kumar, A.; Dass, G. Excess Molar Volumes and Viscosities of Mixtures of Some *n*-Alkoxyethanols with Dialkyl Carbonates at 298.15 K. *Fluid Phase Equilib.* **1999b**, *166*, 245−258.

Ramadevi, R. S.; Venkatesu, P.; Rao, P. M. V. Viscosities of Binary Liquid Mixtures of *N*,*N*-Dimethylformamide with Substituted Benzenes at 303.15 and 313.15 K. *J. Chem. Eng. Data* **1996**, *41*, 479−481.
Redlich, O.; Kister, A. T. Algebraic Representation of Thermodynamic Properties and the Classification of Solution. *Ind. Eng. Chem.* **1948**, *40*, 345−348.
Riddick, J. A.; Bunger, W. B.; Sakano, T. K. *Organic Solvents*, 4th ed.; Wiley-Interscience: New York, 1986.
Roux, G.; Perron, G.; Desnoyers, J. E. The Heat Capacities and Volumes of Some Low Molecular Weight Amides, Ketones, Esters, and Esters in Water over the Whole Solubility Range. *J. Solution Chem.* **1978**, *56*, 2808−2814.

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