Dynamic Viscosities of Diethyl Carbonate with Linear and Secondary Alcohols at Several Temperatures

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Dynamic viscosities have been determined for the binary mixtures diethyl carbonate + methanol, + ethanol, + 1-propanol, + 2-propanol, + 1-butanol, + 2-butanol, and + 1-pentanol at (293.15, 298.15, 303.15, and 313.15 K) and atmospheric pressure. Viscosity deviations for the binary systems were fitted to the Redlich−Kister equation. The UNIFAC−VISCO method, based on contribution groups, has been used to calculate the dynamic viscosities of the binary mixtures at the above temperatures. Root-mean-square deviations between experimental and calculated values are gathered.

1. Introduction

To continue the study and testing of new interaction parameters[1] of dialkyl carbonates to complete the UNIFAC−VISCO matrix, experimental dynamic viscosity data for the binary systems diethyl carbonate + methanol, + ethanol, + 1-propanol, + 2-propanol, + 1-butanol, + 2-butanol, and + 1-pentanol at (293.15, 298.15, 303.15, and 313.15 K) have been determined. Such mixtures are of interest, because of their applications[2] as fuel additives and because their use may reduce the vapor pressure of fuels and in turn reduce their emissions to the atmosphere by evaporation.

From the experimental dynamic viscosities have been calculated the viscosity deviations for the binary mixtures of diethyl carbonate with alcohols, and they were correlated using the Redlich−Kister[3] equation.

The viscosities, using pure-component data and group interaction parameters, have been calculated by applying the predictive UNIFAC−VISCO method.[4] The interaction parameters (CH_3OH/COOO) and (OH/COOO) were determined previously.[5] We have used our experimental data to calculate them, and we have incorporated them into the interaction parameter matrix. In a previous paper, we have determined the interaction parameters OCOO/alkanes.[1]

Experimental densities of the binary mixtures diethyl carbonate with alcohols have been determined previously[6] at these temperatures, and they are used to evaluate the dynamic viscosity in this study. No data are available in the literature to compare with our experimental data at these temperatures.

2. Experimental Section

Chemicals. The alcohols were supplied by Merck, and their mass fraction purities, specified by the manufacturer, were methanol > 99.8 mass %, ethanol > 99.9 mass %, 1-propanol > 99.8 mass %, 2-propanol > 99.9 mass %, 1-butanol > 99.8 mass %, 2-butanol > 99.5 mass %, and 1-pentanol > 99.0 mass %. Diethyl carbonate (>99.5 mass %) was supplied by Fluka. They were degassed by ultrasound and dried over molecular sieves (Aldrich) Type 4 Å, except methanol, for which Type 3 Å was used. The chemicals were kept in an inert argon atmosphere with a maximum content in water of 2×10^{-6} by mass fraction. The maximum water contents of the liquids were determined using a Metrohm 737 KF coulometer. The corresponding obtained values were negligible quantities for the liquids (<0.1 mass %). In Table 1, the solvents are compared with recent published density and dynamic viscosity values at 298.15 K. The densities were measured using an Anton Paar DSA-48 digital vibrating tube densimeter with an uncertainty of ±0.0001 g·cm^{-3}.

Table 1. Comparison of Density ρ and Dynamic Viscosity η with Literature Data at 298.15 K

	ρ/g·cm^{-3}		η/mPa·s	
component	expt	literature	expt	literature
diethyl carbonate	0.9691	0.969 26[a]	0.749	0.748[a]
		0.969 24[b]		0.749[c]
methanol	0.7866	0.786 64[a,d]	0.553	0.545[a,e]
				0.5513[d]
ethanol	0.7850	0.785 09[d]	1.105	1.0826[d]
				1.0832[f]
1-propanol	0.7995	0.799 50[e]	1.970	1.9430[d]
				1.968[h]
2-propanol	0.7809	0.781 26[a]	2.098	2.0436[d]
		0.780 90[i]		2.015[j]
1-butanol	0.8059	0.805 75[a]	2.620	2.571[d]
				2.5647[k]
				2.600[h]
2-butanol	0.8024	0.802 6[a]	3.115	2.998[d]
		0.802 5[j]		3.084[l]
1-pentanol	0.8109	0.810 80[a]	3.347	3.347[a]
				3.318[m]

[a] Riddick et al. (ref 7). [b] Francesconi and Comelli (ref 8). [c] Pal et al. (ref 9). [d] Das et al. (ref 10). [e] Saha et al. (ref 11). [f] Papaioannou et al. (ref 12). [g] Ortega (ref 13). [h] Papaioannou and Panayiotou (ref 14). [i] Aminabhavi and Gopalakrishna (ref 15). [j] Sovilj (ref 16). [k] Dominguez et al. (ref 17). [l] Cea et al. (ref 18). [m] El-Banna (ref 19).

Apparatus and Procedures. The mixtures were prepared by adding known masses of the pure liquids into stoppered bottles to prevent preferential evaporation and to reduce possible errors in mole fraction calculations, using a Mettler AT-261 Delta Range balance with a precision of $\pm 10^{-5}$ g.

Dynamic viscosities were measured with an automated AMV 200 Anton Paar microviscometer. This apparatus is based on the rolling ball principle. A gold-covered steel ball rolls down the inside of an inclined, sample-filled glass

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Table 2. Viscosities η and Viscosity Deviations $\Delta\eta$ of Diethyl Carbonate with Alcohols at Several Temperatures

x_1	η/mPa·s	$\Delta\eta$/mPa·s	x_1	η/mPa·s	$\Delta\eta$/mPa·s	x_1	η/mPa·s	$\Delta\eta$/mPa·s	x_1	η/mPa·s	$\Delta\eta$/mPa·s
Diethyl Carbonate (1) + Methanol (2)											
	T = 293.15 K			T = 298.15 K			T = 303.15 K			T = 313.15 K	
0	0.591	0	0	0.553	0	0	0.514	0	0	0.450	0
0.0513	0.592	−0.009	0.0496	0.556	−0.007	0.0490	0.518	−0.005	0.0509	0.456	−0.003
0.1002	0.596	−0.015	0.0996	0.558	−0.015	0.0966	0.524	−0.008	0.0999	0.460	−0.007
0.1972	0.608	−0.023	0.1985	0.574	−0.018	0.1958	0.537	−0.013	0.2009	0.475	−0.010
0.2839	0.623	−0.026	0.2944	0.588	−0.023	0.2824	0.548	−0.018	0.2981	0.490	−0.012
0.4038	0.642	−0.031	0.4014	0.603	−0.029	0.3914	0.563	−0.023	0.4009	0.505	−0.014
0.5000	0.657	−0.036	0.4975	0.615	−0.032	0.4936	0.578	−0.027	0.5056	0.524	−0.013
0.5933	0.675	−0.037	0.6068	0.637	−0.035	0.5810	0.592	−0.029	0.6062	0.543	−0.012
0.6417	0.685	−0.037	0.7087	0.658	−0.034	0.6945	0.612	−0.030	0.7033	0.561	−0.011
0.7996	0.722	−0.034	0.8365	0.688	−0.029	0.7349	0.620	−0.030	0.8055	0.584	−0.005
0.9014	0.750	−0.025	0.9091	0.710	−0.021	0.8512	0.645	−0.026	0.9020	0.603	−0.003
0.9709	0.782	−0.007	0.9598	0.731	−0.010	0.9214	0.663	−0.021	0.9448	0.610	−0.003
1	0.795	0	1	0.749	0	1	0.699	0	1	0.623	0
Diethyl Carbonate (1) + Ethanol (2)											
	T = 293.15 K			T = 298.15 K			T = 303.15 K			T = 313.15 K	
0	1.194	0	0	1.105	0	0	0.972	0	0	0.826	0
0.0503	1.098	−0.076	0.0496	1.050	−0.037	0.0491	0.899	−0.060	0.0499	0.777	−0.039
0.0997	1.021	−0.133	0.0973	0.943	−0.127	0.0984	0.834	−0.111	0.1020	0.740	−0.065
0.1980	0.906	−0.209	0.1963	0.835	−0.200	0.1952	0.754	−0.165	0.2038	0.676	−0.109
0.3006	0.835	−0.239	0.2985	0.771	−0.228	0.2961	0.704	−0.187	0.3116	0.636	−0.127
0.4031	0.792	−0.241	0.398	0.728	−0.235	0.3946	0.673	−0.191	0.4001	0.613	−0.132
0.5031	0.770	−0.223	0.5057	0.714	−0.211	0.4859	0.661	−0.178	0.4971	0.600	−0.125
0.6063	0.761	−0.191	0.6032	0.708	−0.182	0.5995	0.649	−0.159	0.6023	0.590	−0.114
0.6898	0.755	−0.164	0.7035	0.703	−0.152	0.6959	0.648	−0.134	0.7058	0.591	−0.092
0.8066	0.759	−0.113	0.7999	0.702	−0.118	0.7862	0.649	−0.108	0.8065	0.596	−0.066
0.8950	0.770	−0.067	0.8989	0.714	−0.071	0.8911	0.661	−0.068	0.9022	0.608	−0.035
0.9450	0.776	−0.041	0.9283	0.721	−0.054	0.9254	0.669	−0.050	0.9518	0.616	−0.017
1	0.795	0	1	0.749	0	1	0.699	0	1	0.623	0
Diethyl Carbonate (1) + 1-Propanol (2)											
	T = 293.15 K			T = 298.15 K			T = 303.15 K			T = 313.15 K	
0	2.198	0	0	1.970	0	0	1.707	0	0	1.361	0
0.0504	1.900	−0.227	0.0515	1.689	−0.218	0.0464	1.494	−0.166	0.0500	1.214	−0.110
0.1007	1.662	−0.395	0.0993	1.482	−0.367	0.0963	1.315	−0.295	0.1018	1.087	−0.199
0.2008	1.325	−0.591	0.2012	1.178	−0.546	0.1968	1.062	−0.447	0.2001	0.911	−0.302
0.3019	1.115	−0.659	0.3007	1.005	−0.598	0.2981	0.907	−0.500	0.3017	0.795	−0.343
0.4004	0.998	−0.638	0.4026	0.904	−0.574	0.3987	0.818	−0.487	0.3958	0.727	−0.342
0.5039	0.921	−0.570	0.5022	0.845	−0.512	0.4958	0.771	−0.436	0.5040	0.674	−0.315
0.6031	0.877	−0.475	0.6029	0.801	−0.433	0.5991	0.732	−0.371	0.6009	0.642	−0.276
0.7007	0.840	−0.375	0.7041	0.762	−0.348	0.6967	0.703	−0.302	0.7032	0.624	−0.218
0.7999	0.808	−0.268	0.8087	0.730	−0.253	0.8063	0.678	−0.216	0.7998	0.610	−0.161
0.9132	0.786	−0.131	0.9065	0.721	−0.142	0.9080	0.674	−0.118	0.8997	0.608	−0.089
0.9531	0.785	−0.076	0.9523	0.729	−0.078	0.9448	0.682	−0.073	0.9468	0.612	−0.050
1	0.795	0	1	0.749	0	1	0.699	0	1	0.623	0
Diethyl Carbonate (1) + 2-Propanol (2)											
	T = 293.15 K			T = 298.15 K			T = 303.15 K			T = 313.15 K	
0	2.386	0	0	2.098	0	0	1.763	0	0	1.325	0
0.0502	1.973	−0.333	0.0490	1.766	−0.266	0.0522	1.468	−0.239	0.0506	1.148	−0.141
0.1001	1.670	−0.557	0.0987	1.501	−0.464	0.0990	1.277	−0.381	0.0997	1.011	−0.244
0.2030	1.270	−0.793	0.1978	1.135	−0.696	0.1944	1.009	−0.547	0.2016	0.821	−0.363
0.3012	1.073	−0.834	0.2945	0.940	−0.761	0.2913	0.864	−0.589	0.3030	0.710	−0.402
0.3954	0.962	−0.795	0.3925	0.836	−0.733	0.3920	0.777	−0.569	0.4008	0.661	−0.383
0.5021	0.886	−0.701	0.4925	0.788	−0.646	0.4763	0.733	−0.523	0.4969	0.634	−0.342
0.6035	0.841	−0.585	0.5939	0.763	−0.534	0.5883	0.702	−0.435	0.5990	0.617	−0.287
0.6976	0.811	−0.465	0.7004	0.740	−0.413	0.6972	0.683	−0.338	0.7007	0.604	−0.229
0.8048	0.794	−0.312	0.7979	0.719	−0.303	0.7854	0.680	−0.247	0.8011	0.594	−0.169
0.9129	0.796	−0.138	0.8967	0.717	−0.171	0.8890	0.684	−0.133	0.9030	0.596	−0.095
0.9529	0.799	−0.071	0.9504	0.726	−0.090	0.9488	0.690	−0.063	0.9511	0.605	−0.052
1	0.795	0	1	0.749	0	1	0.699	0	1	0.623	0
Diethyl Carbonate (1) + 1-Butanol (2)											
	T = 293.15 K			T = 298.15 K			T = 303.15 K			T = 313.15 K	
0	2.941	0	0	2.620	0	0	2.255	0	0	1.754	0
0.0510	2.500	−0.332	0.0519	2.203	−0.320	0.0508	1.905	−0.271	0.0506	1.535	−0.162
0.1027	2.148	−0.573	0.0993	1.899	−0.535	0.1004	1.642	−0.457	0.1007	1.356	−0.284
0.2008	1.672	−0.838	0.1996	1.445	−0.802	0.2016	1.300	−0.642	0.2005	1.090	−0.437
0.2978	1.376	−0.926	0.2923	1.195	−0.878	0.3000	1.101	−0.687	0.2975	0.926	−0.492
0.4026	1.173	−0.904	0.3989	1.030	−0.844	0.3917	0.977	−0.669	0.4122	0.802	−0.486
0.5079	1.031	−0.820	0.5017	0.939	−0.742	0.5032	0.870	−0.602	0.5035	0.741	−0.444
0.6014	0.944	−0.706	0.6016	0.874	−0.620	0.5970	0.794	−0.532	0.6084	0.691	−0.375
0.7033	0.878	−0.554	0.7043	0.815	−0.487	0.7099	0.729	−0.421	0.7044	0.656	−0.301
0.7986	0.841	−0.386	0.8002	0.766	−0.357	0.8216	0.699	−0.278	0.8055	0.634	−0.209
0.9031	0.814	−0.189	0.8968	0.736	−0.206	0.9035	0.697	−0.152	0.9016	0.618	−0.116
0.9510	0.810	−0.090	0.9471	0.734	−0.114	0.9488	0.697	−0.082	0.9486	0.617	−0.064
1	0.795	0	1	0.749	0	1	0.699	0	1	0.623	0

Table 2 (Continued)

x_1	η/mPa·s	$\Delta\eta$/mPa·s	x_1	η/mPa·s	$\Delta\eta$/mPa·s	x_1	η/mPa·s	$\Delta\eta$/mPa·s	x_1	η/mPa·s	$\Delta\eta$/mPa·s
Diethyl Carbonate (1) + 2-Butanol (2)											
	T = 293.15 K			T = 298.15 K			T = 303.15 K			T = 313.15 K	
0	3.619	0	0	3.115	0	0	2.503	0	0	1.784	0
0.0512	2.892	−0.582	0.0509	2.485	−0.510	0.0517	2.023	−0.387	0.0511	1.503	−0.222
0.1031	2.341	−0.987	0.1010	2.001	−0.875	0.1132	1.623	−0.676	0.1026	1.280	−0.385
0.2021	1.652	−1.396	0.2020	1.379	−1.258	0.2267	1.211	−0.883	0.1988	0.996	−0.557
0.2997	1.289	−1.484	0.3002	1.071	−1.334	0.3316	1.021	−0.884	0.2955	0.830	−0.611
0.4023	1.092	−1.391	0.4040	0.937	−1.222	0.4467	0.890	−0.807	0.4041	0.738	−0.577
0.5115	0.979	−1.196	0.5003	0.888	−1.043	0.5422	0.809	−0.716	0.5084	0.690	−0.504
0.6070	0.910	−0.995	0.6008	0.858	−0.836	0.6426	0.739	−0.605	0.5983	0.662	−0.427
0.7070	0.861	−0.761	0.6963	0.813	−0.655	0.7416	0.698	−0.467	0.6988	0.636	−0.337
0.8038	0.825	−0.524	0.7987	0.752	−0.473	0.8281	0.684	−0.325	0.8034	0.610	−0.241
0.9089	0.804	−0.248	0.8999	0.709	−0.277	0.9196	0.691	−0.153	0.9022	0.601	−0.135
0.9524	0.803	−0.126	0.9466	0.712	−0.163	0.9494	0.697	−0.093	0.9523	0.606	−0.072
1	0.795	0	1	0.749	0	1	0.699	0	1	0.623	0
Diethyl Carbonate (1) + 1-Pentanol (2)											
	T = 293.15 K			T = 298.15 K			T = 303.15 K			T = 313.15 K	
0	3.979	0	0	3.347	0	0	2.932	0	0	2.256	0
0.0496	3.384	−0.437	0.0459	2.910	−0.318	0.0541	2.471	−0.340	0.0505	1.970	−0.204
0.1016	2.868	−0.787	0.0984	2.492	−0.599	0.0951	2.186	−0.534	0.1009	1.729	−0.362
0.2034	2.125	−1.206	0.2067	1.857	−0.953	0.1968	1.664	−0.829	0.2038	1.359	−0.564
0.3124	1.618	−1.366	0.3012	1.497	−1.067	0.2920	1.356	−0.924	0.3044	1.120	−0.639
0.3801	1.412	−1.357	0.4002	1.242	−1.065	0.3986	1.131	−0.911	0.4054	0.960	−0.634
0.5085	1.162	−1.198	0.5091	1.067	−0.957	0.4966	0.992	−0.831	0.5077	0.845	−0.582
0.6047	1.051	−1.003	0.5884	0.972	−0.846	0.5963	0.880	−0.720	0.5969	0.771	−0.510
0.7068	0.955	−0.774	0.6988	0.871	−0.661	0.6847	0.803	−0.600	0.7100	0.697	−0.400
0.8058	0.880	−0.533	0.7986	0.802	−0.470	0.7988	0.733	−0.415	0.8100	0.650	−0.283
0.9058	0.825	−0.270	0.9133	0.751	−0.223	0.8885	0.706	−0.242	0.9036	0.623	−0.157
0.9521	0.804	−0.144	0.9663	0.745	−0.092	0.9493	0.700	−0.112	0.9537	0.621	−0.078
1	0.795	0	1	0.749	0	1	0.699	0	1	0.623	0

capillary. The apparatus is equipped with an automatic timer (±0.01 s) so the time taken for the ball to roll a fixed distance between two magnetic sensors allows one to evaluate the viscosity of the fluid mixture. The time measuring range is from (12 to 250) s; the accuracy and the precision in this apparatus are ±0.01 s and ±0.1 s, respectively. The capillary was placed in a block, thermostated with a PolyScience controller bath model 9010 with a temperature stability of $\pm 10^{-2}$ K. Apparatus calibration was made periodically, using three fluids of known viscosity, Millipore quality water and degassed and dried Fluka quality[7] octane and 1-pentanol as reference liquids. These reference fluids have mass fraction purities of >99.5 mass %. The uncertainty in the dynamic viscosity and the mole fraction were estimated as better than 2×10^{-3} mPa·s and 5×10^{-5}, respectively.

3. Results and Discussion

The experimental dynamic viscosities of the binary mixtures diethyl carbonate + methanol, + ethanol, + 1-propanol, + 2-propanol, + 1-butanol, + 2-butanol, and + 1-pentanol at (293.15, 298.15, 303.15, and 313.15 K) and atmospheric pressure are given in Table 2. The experimental densities of these binary mixtures at the above temperatures have been published previously.[6] Figure 1 shows graphically the viscosities and the calculated values, obtained from the UNIFAC−VISCO method, for the binary mixtures diethyl carbonate with 1-propanol and 1-butanol at (293.15, 298.15, 303.15, and 313.15) K, respectively.

The viscosity deviations are calculated from experimental viscosities of the pure components and the mixture by the equation

$$\Delta\eta/\text{mPa·s} = \eta - \sum_{i=1}^{N}(\eta_i^0 x_i) \qquad (1)$$

where η and η_i^0 are the viscosity of the mixture and the pure component, respectively; x_i represents the mole fraction of the pure component, and N is the number of components in the mixture.

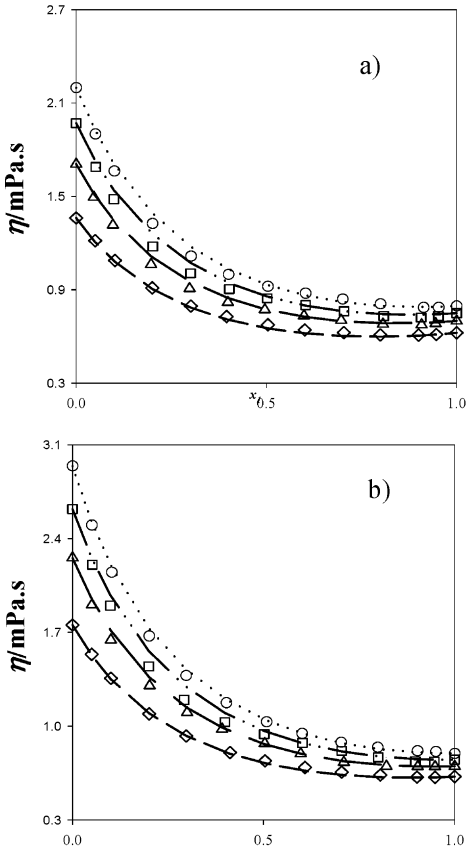

Figure 1. Experimental viscosity data η for the binary mixtures of diethyl carbonate with (a) 1-propanol and (b) 1-butanol at (○) 293.15 K, (□) 298.15 K, (△) 303.15 K, and (◇) 313.15 K and curves of calculated values by using the UNIFAC−VISCO method at (···) 293.15 K, (−··−··−) 298.15 K, (− − −) 303.15 K, and (- - -) 313.15 K.

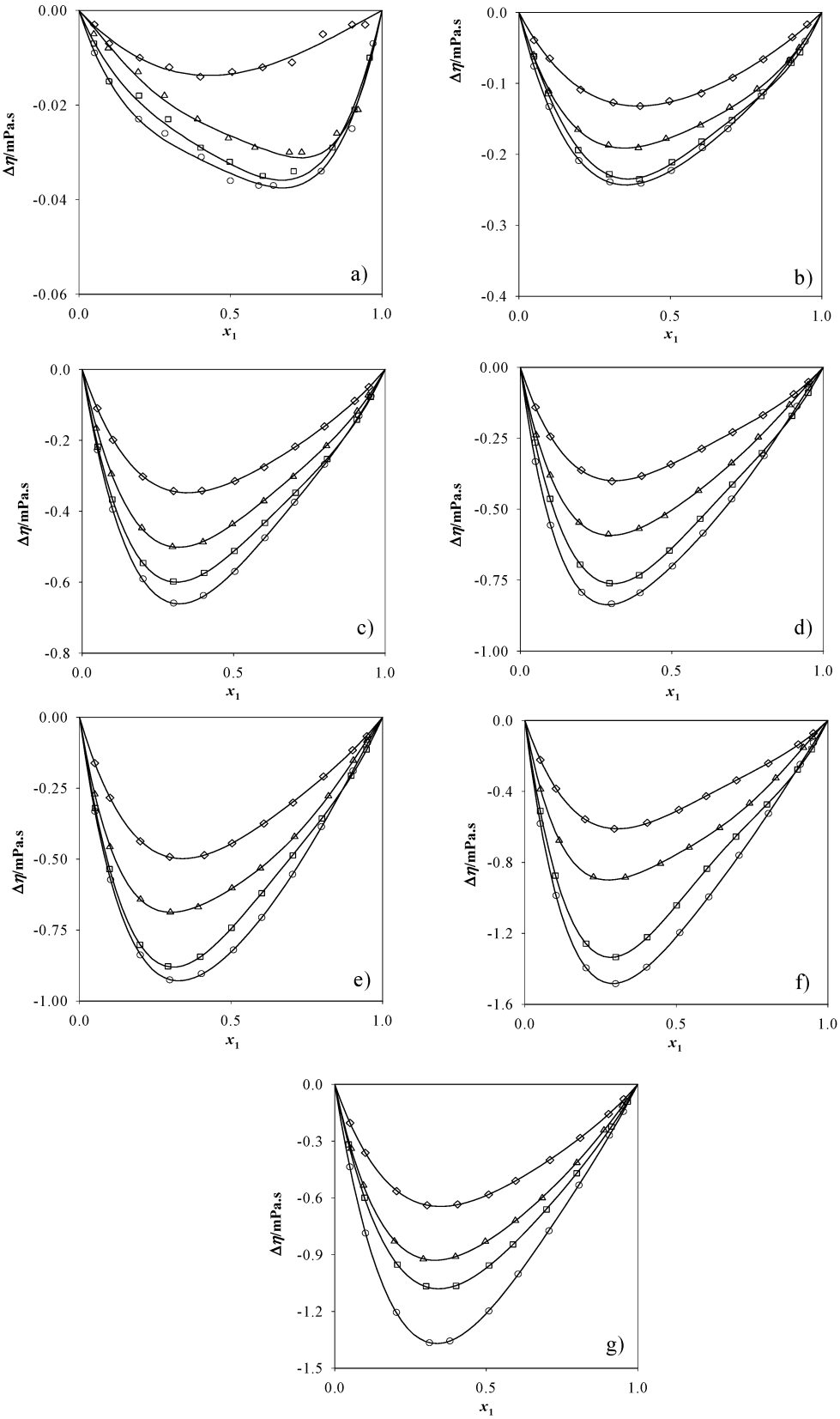

Figure 2. Curves of viscosity deviations $\Delta\eta$ from eq 2 for the binary mixtures of diethyl carbonate with (a) methanol, (b) ethanol, (c) 1-propanol, (d) 2-propanol, (e) 1-butanol, (f) 1-pentanol, and (g) 2-butanol at (○) 293.15 K, (□) 298.15 K, (△) 303.15 K, and (◇) 313.15 K.

The binary viscosity deviations were fitted to a Redlich−Kister type equation,

$$\Delta\eta/\mathrm{mPa\cdot s} = x_1(1 - x_1)\sum_{p=0}^{M} B_p(x_1 - x_2)^p \qquad (2)$$

where x is the mole fraction, B_p is the fitting parameter, and M is the degree of the polynomic expansion, which was optimized using the F-test.[20] In Table 2, the viscosity deviations of the binary mixtures, at several temperatures, are given. The fitting parameters are given in Table 3, together with the root-mean-square deviations. These

Table 3. Fitting Parameters and Root-Mean-Square Deviations between Experimental and Calculated Values of σ for Diethyl Carbonate with Alcohols at Several Temperatures

T/K	B_0/mPa·s	B_1/mPa·s	B_2/mPa·s	B_3/mPa·s	σ/mPa·s
Diethyl Carbonate (1) + Methanol (2)					
293.15	−0.1376	−0.0599	−0.1206		0.001
298.15	−0.1248	−0.0656	−0.0997		0.001
303.15	−0.1060	−0.0539	−0.0937		0.001
313.15	0.0538	−0.0167	0.0019		0.001
Diethyl Carbonate (1) + Ethanol (2)					
293.15	−0.8941	0.4806	−0.3402		0.001
298.15	−0.8572	0.5159	−0.3127	−0.3109	0.002
303.15	−0.7070	0.3265	−0.3943		0.001
313.15	−0.5052	0.2019	−0.1012		0.001
Diethyl Carbonate (1) + 1-Propanol (2)					
293.15	−2.2830	1.6920	−1.1376		0.001
298.15	−2.0546	1.4862	−1.2880		0.001
303.15	−1.7414	1.2071	−1.0008		0.002
313.15	−1.2651	0.7328	−0.4949		0.001
Diethyl Carbonate (1) + 2-Propanol (2)					
293.15	−2.8043	2.0392	−1.8249	1.1236	0.001
298.15	−2.5520	2.0819	−1.5496		0.001
303.15	−2.0141	1.4204	−1.2290	0.6615	0.002
313.15	−1.3641	1.0128	−0.8331		0.001
Diethyl Carbonate (1) + 1-Butanol (2)					
293.15	−3.3110	2.0529	−1.3884	0.8112	0.001
298.15	−2.9821	2.3189	−1.7649		0.001
303.15	−2.4224	1.3467	−1.5210	1.0882	0.001
313.15	−1.7853	1.1400	−0.6911		0.001
Diethyl Carbonate (1) + 2-Butanol (2)					
293.15	−4.8816	3.9690	−3.1391	1.3743	0.001
298.15	−4.1709	4.0860	−3.4035		0.001
303.15	−3.0241	1.9008	−2.3395	1.7591	0.002
313.15	−2.0437	1.6418	−1.2934		0.001
Diethyl Carbonate (1) + 1-Pentanol (2)					
293.15	−4.8457	3.991	−1.6781		0.001
298.15	−3.8839	2.4566	−1.4158		0.001
303.15	−3.3263	2.0031	−1.5367	0.5134	0.002
313.15	−2.3508	1.3640	−0.8671		0.001

values are calculated by applying the values of the experimental and calculated property, and the numbers of experimental data are represented by $\Delta\eta_{exp}$, $\Delta\eta_{cal}$, and n_{DAT}, respectively.

$$\sigma = \left(\sum_{i}^{n_{DAT}} (\Delta\eta_{exp} - \Delta\eta_{calc})^2/(n_{DAT} - n_p)\right)^{1/2} \qquad (3)$$

Figure 2 shows viscosity deviations for the binary mixtures diethyl carbonate with alcohols at 293.15, 298.15, 303.15, and 313.15 K, respectively, plotted against mole fraction together with the fitted curve, obtained from the Redlich−Kister equation. The viscosity deviations for these systems at these temperatures are negative over the entire composition range for all of the binaries at the above temperatures.

Results Obtained Using the UNIFAC−VISCO Method. The UNIFAC−VISCO predictive method has been used to calculate the experimental values at several temperatures. Interaction parameters carbonate−alkane (CH_3/OCOO and CH_2/OCOO) and carbonate−alcohol (OH/OCOO and CH_3OH/OCOO) have been calculated previously[1,5] from our experimental data.

In Table 4, the root-mean-square deviations between experimental and calculated values are summarized. In view of the results, we can say that good predictions have been obtained from the new interaction parameters. The worst results are obtained for the binary mixture diethyl carbonate with secondary alcohols.

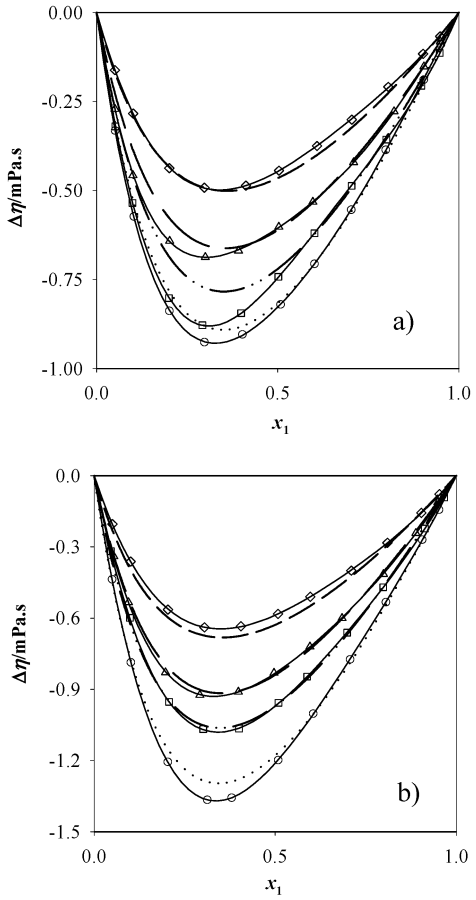

Figure 3. Curves of viscosity deviations $\Delta\eta$ from eq 2 (—) at (○) 293.15 K, (□) 298.15 K, (△) 303.15 K, and (◇) 313.15 K and curves of calculated values of viscosity deviations $\Delta\eta$ from the UNIFAC−VISCO method at (···) 293.15 K, (—··—··—) 298.15 K, (– – –) 303.15 K, and (- - -) 313.15 K for the binary mixtures of diethyl carbonate with (a) 1-butanol and (b) 1-pentanol.

Table 4. Root-Mean-Square Deviations of Dynamic Viscosity $\sigma(\eta)$/mPa·s Resulting from the UNIFAC−VISCO Model at Several Temperatures for the Binary Mixtures

	T/K			
system	293.15	298.15	303.15	313.15
	diethyl carbonate +			
methanol	0.004	0.006	0.010	0.022
ethanol	0.035	0.027	0.030	0.049
1-propanol	0.034	0.040	0.027	0.015
2-propanol	0.114	0.113	0.078	0.033
1-butanol	0.028	0.060	0.034	0.014
2-butanol	0.210	0.220	0.105	0.060
1-pentanol	0.037	0.012	0.014	0.030

In Figure 3, the calculated values, obtained by applying the UNIFAC−VISCO method, and the viscosity deviations for the binary mixture diethyl carbonate with alcohols that obtain the best results at (293.15, 298.15, 303.15, and 313.15 K), respectively, are shown graphically.

4. Conclusions

In this paper, we have determined the dynamic viscosities of the binary mixtures diethyl carbonate + methanol, + ethanol, + 1-propanol, + 2-propanol, + 1-butanol, + 2-butanol, and + 1-pentanol at (293.15, 298.15, 303.15, and 313.15 K) and atmospheric pressure and the viscosity deviations have been calculated and fitted to the Redlich−Kister equation.

The UNIFAC−VISCO method, based on interaction parameters, has been applied to the above systems. The

interaction parameters carbonate−alkane and carbonate−alcohol have been calculated previously and used to calculate the dynamic viscosities of these systems. The results obtained are shown graphically and in terms of root-mean-square deviations. Analysis shows that the worst results are obtained for the binary mixtures diethyl carbonate with secondary alcohols at low temperatures.

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