Densities and Surface Tensions of Trimethylbenzene + Dimethyl Carbonate or + Diethyl Carbonate at 298.15 K and 313.15 K

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Densities and surface tensions for binary systems of (1,2,4-trimethylbenzene or 1,3,5-trimethylbenzene + dimethyl carbonate or diethyl carbonate) have been measured under normal atmospheric pressure over the entire mole fraction range at 298.15 K and 313.15 K. The excess molar volumes and the surface tension deviation have been calculated. The excess molar volumes and the values of the surface tension deviation are fitted to the Redlich−Kister polynomial equation. The excess molar volumes for all the binary systems are positive over the whole composition range, and the surface tension deviations are negative.

Introduction

The surface tension and density of liquid mixtures are very important physical properties for understanding and interpreting the nature of interactions between the molecules of the mixtures. They also affect most separation procedures, such as liquid−liquid extraction, gas absorption, and distillation. In the study of separating mixed xylene and trimethylbenzene, our group has developed a high-performance separation method named urging rectification,[1] which involves adding some special solvent (named urging solvent) to the rectification system to aid light component separation. The determination of excess functions of the mixtures involved is vital for selecting an urging solvent. In previous papers, the excess molar volumes and surface tensions at 298.15 K were presented for xylene + alkone (acetone or 2-butanone), xylene + ether (isopropyl ether or methyl *tert*-butyl ether), trimethylbenzene + ethylene glycol ester (ethylene glycol monomethyl ether or ethylene glycol dimethyl ether), trimethylbenzene + alkanol (1-butanol, or 2-methyl-1-propanol, 2-butanol, 2-methyl-2-propanol), trimethylbenzene + tetrahydrofuran, tetrachloromethane, or dimethyl sulfoxide.[2−6] Herein, excess molar volumes and surface tensions for 1,2,4-trimethylbenzene or 1,3,5-trimethylbenzene + dimethyl carbonate or diethyl carbonate at 298.15 K and 313.15 K are determined.

Experimental Section

Dimethyl carbonate, diethyl carbonate, 1,2,4-trimethylbenzene, and 1,3,5-trimethylbenzene were commercially available (Acros Organics). All the chemicals were stored over molecular sieve before use. The mass fraction of the substances, determined by PE auto system XL gas chromatograph, were as follows: dimethyl carbonate (99.57 %), diethyl carbonate (99.79 %), 1,2,4-trimethylbenzene (99.20 %), 1,3,5-trimethylbenzene (99.30 %). The mole fraction of each mixture was obtained by measuring the masses of the components using an Ohaus E12140 balance; the uncertainty of the mole fraction is estimated to be less than 1×10^{-4}.

Densities of the pure liquids and their mixtures were measured with an Anton Paar DMA 4500 vibrating-tube densimeter, thermostated at (298.15 ± 0.01) K and (313.15 ± 0.01) K. The uncertainty of the density is about 5×10^{-5} g·cm^{-3}. The surface tensions of the pure liquids and their mixtures were determined by the pendant drop method, using a Dataphysics OCA20 contact angle and surface tension measuring device. This instrument provides a computer-controlled display video camera (CCD) to take pictures and an electronic syringe unit to inject samples, so the surface tension of the sample can be determined rapidly. The surface tension was given by[7]

$$\sigma = \frac{g\Delta\rho d_e^2}{H} \quad (1)$$

In eq 1, g is the gravitational acceleration; $\Delta\rho$ is the density difference between the droplet and the surroundings; d_e is the largest diameter of the drop; and H is a correction factor, which depends on the shape of the drop, and is calculated by the Young-Laplace equation and performed via the computer. The software needs only the density data and a picture of the drop of liquid to calculate the surface tension. The uncertainty of the surface tension measured here is about ± 0.05 mN·m^{-1}. The densities and surface tensions of the pure compounds are given in Table 1 and compared with the literature values.

Table 1. Physical Properties of the Pure Components

	ρ/g·cm^{-3}		σ/mN·m^{-1}	
substance	exptl	lit.	exptl	lit.
	T = 298.15 K			
dimethyl carbonate	1.06297	1.06295[11]	28.63	28.58[18]
		1.06335[12]		
diethyl carbonate	0.96912	0.96900[13]	25.92	25.87[18]
		0.96923[14]		
		0.96926[15]		
1,2,4-trimethylbenzene	0.87164	0.87174[16]	29.29	29.19[18]
		0.87164[5]		29.25[5]
1,3,5-trimethylbenzene	0.86104	0.86109[17]	28.09	27.54[18]
		0.86103[5]		28.09[5]
	T = 313.15 K			
dimethyl carbonate	1.04463	1.04319[19]	26.62	26.57[18]
		1.04301[20]		
diethyl carbonate	0.95215	0.95232[11]	24.26	24.22[18]
		0.9522[21]		
1,2,4-trimethylbenzene	0.85950		27.67	27.66[18]
1,3,5-trimethylbenzene	0.84873	0.84880[22]	26.82	26.20[18]

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10.1021/je060137q CCC: $33.50
Published on Web 05/28/2006

Table 2. Experimental Density ρ and Excess Molar Volumes V^E

x	ρ / g·cm^{-3}	V^E / cm^3·mol^{-1}	x	ρ / g·cm^{-3}	V^E / cm^3·mol^{-1}	x	ρ / g·cm^{-3}	V^E / cm^3·mol^{-1}	x	ρ / g·cm^{-3}	V^E / cm^3·mol^{-1}	x	ρ / g·cm^{-3}	V^E / cm^3·mol^{-1}
						$T = 298.15$ K								
						$(CH_3O)_2CO$ (x) + 1,2,4-$C_6H_3(CH_3)_3$ ($1 - x$)								
0	0.87164	0	0.2498	0.90122	0.404	0.4500	0.93135	0.527	0.6500	0.96890	0.502	0.8501	1.01710	0.293
0.0499	0.87693	0.106	0.2995	0.90807	0.454	0.5000	0.93996	0.534	0.6999	0.97971	0.476	0.8999	1.03125	0.209
0.0999	0.88255	0.196	0.3502	0.91553	0.485	0.5500	0.94904	0.535	0.7497	0.99122	0.435	0.9498	1.04657	0.104
0.1500	0.88853	0.267	0.4001	0.92326	0.506	0.5998	0.95857	0.531	0.7997	1.00368	0.370	1	1.06297	0
0.2000	0.89476	0.336												
						$(CH_3O)_2CO$ (x) + 1,3,5-$C_6H_3(CH_3)_3$ ($1 - x$)								
0	0.86104	0	0.2491	0.89185	0.429	0.4499	0.92332	0.587	0.6488	0.96247	0.575	0.8500	1.01367	0.351
0.0540	0.86708	0.114	0.3001	0.89928	0.475	0.4999	0.93232	0.600	0.7000	0.97417	0.544	0.8999	1.02884	0.251
0.1048	0.87295	0.229	0.3496	0.90677	0.525	0.5508	0.94203	0.602	0.7514	0.98683	0.490	0.9499	1.04518	0.138
0.1518	0.87880	0.303	0.4001	0.91484	0.565	0.5977	0.95157	0.587	0.7999	0.99960	0.426	1	1.06297	0
0.1998	0.88510	0.366												
						$(C_2H_5O)_2CO$ (x) + 1,2,4-$C_6H_3(CH_3)_3$ ($1 - x$)								
0	0.87164	0	0.2518	0.89323	0.114	0.4496	0.91154	0.140	0.6497	0.93130	0.122	0.8499	0.95236	0.069
0.0501	0.87581	0.027	0.2998	0.89755	0.127	0.5000	0.91638	0.142	0.6998	0.93641	0.116	0.9000	0.95782	0.053
0.1005	0.88010	0.047	0.3499	0.90217	0.132	0.5494	0.92122	0.138	0.7505	0.94172	0.102	0.9500	0.96345	0.025
0.1497	0.88428	0.075	0.4004	0.90689	0.136	0.5997	0.92624	0.131	0.8001	0.94700	0.085	1	0.96912	0
0.1994	0.88862	0.092												
						$(C_2H_5O)_2CO$ (x) + 1,3,5-$C_6H_3(CH_3)_3$ ($1 - x$)								
0	0.86104	0	0.2501	0.88412	0.198	0.4499	0.90428	0.261	0.6498	0.92607	0.249	0.8490	0.94964	0.156
0.0500	0.86543	0.058	0.2999	0.88901	0.220	0.5006	0.90964	0.266	0.7007	0.93190	0.234	0.9001	0.95606	0.113
0.1000	0.86994	0.104	0.3498	0.89396	0.242	0.5497	0.91493	0.267	0.7495	0.93762	0.214	0.9501	0.96249	0.064
0.1500	0.87461	0.135	0.3999	0.89908	0.253	0.6001	0.92047	0.262	0.8004	0.94371	0.186	1	0.96912	0
0.1999	0.87930	0.169												
						$T = 313.15$ K								
						$(CH_3O)_2CO$ (x) + 1,2,4-$C_6H_3(CH_3)_3$ ($1 - x$)								
0	0.85950	0	0.2491	0.88796	0.425	0.4509	0.91726	0.563	0.6500	0.95333	0.552	0.8502	1.00000	0.328
0.0505	0.86472	0.104	0.3003	0.89487	0.466	0.5008	0.92559	0.569	0.6995	0.96385	0.506	0.8976	1.01308	0.239
0.1012	0.87023	0.199	0.3498	0.90176	0.518	0.5507	0.93432	0.575	0.7505	0.97523	0.464	0.9504	1.02872	0.127
0.1500	0.87575	0.288	0.4010	0.90943	0.541	0.5998	0.94346	0.565	0.7994	0.98699	0.402	1	1.04463	0
0.2008	0.88192	0.354												
						$(CH_3O)_2CO$ (x) + 1,3,5-$C_6H_3(CH_3)_3$ ($1 - x$)								
0	0.84873	0	0.2489	0.87845	0.461	0.4498	0.90893	0.630	0.6488	0.94686	0.622	0.8479	0.99611	0.375
0.0505	0.85419	0.111	0.2985	0.88542	0.512	0.5001	0.91776	0.636	0.6992	0.95818	0.574	0.8997	1.01133	0.271
0.1046	0.86031	0.226	0.3500	0.89295	0.568	0.5492	0.92676	0.647	0.7489	0.96998	0.526	0.9501	1.02737	0.148
0.1500	0.86569	0.315	0.3983	0.90054	0.594	0.5999	0.93676	0.632	0.7995	0.98291	0.452	1	1.04463	0
0.2007	0.87213	0.386												
						$(C_2H_5O)_2CO$ (x) + 1,2,4-$C_6H_3(CH_3)_3$ ($1 - x$)								
0	0.85950	0	0.2507	0.87988	0.128	0.4499	0.89737	0.161	0.6481	0.91593	0.148	0.8473	0.93587	0.086
0.0508	0.86346	0.039	0.3007	0.88417	0.139	0.4981	0.90179	0.159	0.6990	0.92093	0.132	0.9001	0.94145	0.054
0.1005	0.86743	0.068	0.3520	0.88861	0.154	0.5498	0.90660	0.157	0.7499	0.92598	0.118	0.9499	0.94674	0.028
0.1486	0.87136	0.089	0.4006	0.89294	0.157	0.597	0.91106	0.151	0.8002	0.93106	0.101	1	0.95215	0
0.2012	0.87571	0.111												
						$(C_2H_5O)_2CO$ (x) + 1,3,5-$C_6H_3(CH_3)_3$ ($1 - x$)								
0	0.84873	0	0.2480	0.87064	0.201	0.4487	0.88994	0.276	0.6510	0.91105	0.262	0.8501	0.93370	0.152
0.0502	0.85295	0.059	0.2987	0.87533	0.234	0.5005	0.89518	0.282	0.6995	0.91640	0.244	0.9001	0.93969	0.111
0.1001	0.85731	0.099	0.3417	0.87945	0.248	0.5501	0.90030	0.280	0.7495	0.92197	0.226	0.9501	0.94576	0.071
0.1497	0.86170	0.137	0.4009	0.88520	0.266	0.5995	0.90552	0.274	0.8004	0.92784	0.191	1	0.95215	0
0.2010	0.86626	0.182												

Result and Discussion

Excess molar volumes were determined from the density data:[8]

$$V^E = \frac{x_1 M_1 + x_2 M_2}{\rho} - x_1 \frac{M_1}{\rho_1} - x_2 \frac{M_2}{\rho_2} \qquad (2)$$

where M_i are the molar mass of component i, ρ and ρ_i are the densities of the mixture and component i, and x_i is the mole fraction of component i. Experimental ρ and V^E for four binary mixtures (dimethyl carbonate + 1,2,4-trimethylbenzene, dimethyl carbonate + 1,3,5-trimethylbenzene, diethyl carbonate + 1,2,4-trimethylbenzene, and diethyl carbonate + 1,3,5-trimethylbenzene) at 298.15 K are listed in Table 2, and the $V^E \sim x$ values are graphically presented in Figure 1. The values of ρ and V^E for these mixtures at 313.15 K are also listed in Table 2, and the $V^E \sim x$ values are graphically presented in Figure 2. The experimental results were fitted by the method of least squares with all points weighted equally to the smoothing equation:[9,10]

$$V^E/\mathrm{cm}^3\cdot\mathrm{mol}^{-1} = x(1-x)\sum_{i=0}^{k} A_i(1-2x)^i \qquad (3)$$

The parameters A_0, A_1, A_2, A_3, and A_4 and the standard deviations are given in Table 3.

The surface tensions σ and surface tension deviations $\delta\sigma$ for four binary mixtures (dimethyl carbonate + 1,2,4-trimethylbenzene, dimethyl carbonate + 1,3,5-trimethylbenzene, diethyl carbonate + 1,2,4-trimethylbenzene, and diethyl carbonate + 1,3,5-trimethylbenzene) at 298.15 K and 313.15 K are listed in Table 4. The values of surface tension deviations for these mixtures at 298.15 K and 313.15 K are graphically presented in Figures 3 and 4. The surface tension deviations $\delta\sigma$ are defined by[8]

$$\delta\sigma = \sigma - x_1\sigma_1 - x_2\sigma_2 \qquad (4)$$

Table 3. Least-Squares Parameters and Standard Deviations for Excess Molar Volumes from Equation 3

	A_0	A_1	A_2	A_3	A_4	σ / cm^3·mol^{-1}
			$T = 298.15$ K			
dimethyl carbonate + 1,2,4-trimethylbenzene	2.144	−0.193	0.402	0.148	−0.450	0.005
dimethyl carbonate + 1,3,5-trimethylbenzene	2.395	−0.362	0.216	0.135	0.127	0.005
diethyl carbonate + 1,2,4-trimethylbenzene	0.560	0.004	0.059	−0.130	−0.107	0.002
diethyl carbonate + 1,3,5-trimethylbenzene	1.069	−0.092	0.012	0.012	0.306	0.002
			$T = 313.15$ K			
dimethyl carbonate + 1,2,4-trimethylbenzene	2.294	−0.229	0.305	−0.027	−0.205	0.004
dimethyl carbonate + 1,3,5-trimethylbenzene	2.562	−0.339	0.239	−0.034	−0.027	0.006
diethyl carbonate + 1,2,4-trimethylbenzene	0.641	0.037	0.068	0.050	−0.005	0.002
diethyl carbonate + 1,3,5-trimethylbenzene	1.127	−0.073	−0.002	−0.027	0.181	0.004

Table 4. Surface Tensions σ

x	σ / mN·m^{-1}	dσ / mN·m^{-1}	x	σ / mN·m^{-1}	dσ / mN·m^{-1}	x	σ / mN·m^{-1}	dσ / mN·m^{-1}	x	σ / mN·m^{-1}	dσ / mN·m^{-1}
					$T = 298.15$ K						
	$(CH_3O)_2CO$ (x) + 1,2,4-$C_6H_3(CH_3)_3$ (1 − x)						$(CH_3O)_2CO$ (x) + 1,3,5-$C_6H_3(CH_3)_3$ (1 − x)				
0	29.29	0	0.5998	28.12	−0.77	0	28.09	0	0.6003	27.44	−0.97
0.0999	28.93	−0.29	0.6999	28.15	−0.68	0.1048	27.91	−0.24	0.7000	27.65	−0.82
0.2000	28.64	−0.52	0.7997	28.26	−0.50	0.1998	27.60	−0.60	0.7999	28.01	−0.51
0.3001	28.34	−0.75	0.8999	28.43	−0.27	0.3001	27.43	−0.83	0.8999	28.35	−0.23
0.4001	28.21	−0.82	1	28.63	0	0.3999	27.32	−0.99	1	28.63	0
0.5000	28.08	−0.88				0.4999	27.34	−1.03			
	$(C_2H_5O)_2CO$ (x) + 1,2,4-$C_6H_3(CH_3)_3$ (1 − x)						$(C_2H_5O)_2CO$ (x) + 1,3,5-$C_6H_3(CH_3)_3$ (1 − x)				
0	29.29	0	0.5997	26.94	−0.32	0	28.09	0	0.6001	26.41	−0.37
0.1005	28.85	−0.10	0.6998	26.66	−0.27	0.1000	27.71	−0.16	0.7007	26.26	−0.31
0.1994	28.41	−0.21	0.8001	26.39	−0.20	0.1999	27.37	−0.29	0.8004	26.14	−0.21
0.2998	27.98	−0.30	0.9000	26.13	−0.13	0.2999	27.01	−0.43	0.9001	26.01	−0.13
0.4001	27.58	−0.37	1	25.92	0	0.3999	26.76	−0.47	1	25.92	0
0.5000	27.23	−0.38				0.5006	26.56	−0.45			
					$T = 313.15$ K						
	$(CH_3O)_2CO$ (x) + 1,2,4-$C_6H_3(CH_3)_3$ (1 − x)						$(CH_3O)_2CO$ (x) + 1,3,5-$C_6H_3(CH_3)_3$ (1 − x)				
0	27.67	0	0.5996	26.06	−0.98	0	26.82	0	0.5998	25.62	−1.08
0.1008	27.23	−0.33	0.6993	26.08	−0.86	0.1009	26.42	−0.39	0.6999	25.86	−0.82
0.1999	26.82	−0.64	0.7998	26.16	−0.67	0.1994	26.04	−0.74	0.7994	26.08	−0.58
0.2996	26.51	−0.85	0.9000	26.37	−0.36	0.2996	25.80	−0.96	0.9000	26.38	−0.26
0.3991	26.29	−0.96	1	26.62	0	0.4016	25.63	−1.12	1	26.62	0
0.5000	26.11	−1.04				0.5004	25.55	−1.17			
	$(C_2H_5O)_2CO$ (x) + 1,2,4-$C_6H_3(CH_3)_3$ (1 − x)						$(C_2H_5O)_2CO$ (x) + 1,3,5-$C_6H_3(CH_3)_3$ (1 − x)				
0	27.67	0	0.6003	25.23	−0.39	0	26.82	0	0.5996	24.71	−0.57
0.1000	27.16	−0.17	0.6996	24.99	−0.30	0.0997	26.36	−0.208	0.7004	24.56	−0.47
0.2002	26.69	−0.30	0.8002	24.75	−0.20	0.1995	25.95	−0.355	0.8000	24.44	−0.34
0.3005	26.23	−0.42	0.8999	24.51	−0.09	0.2997	25.57	−0.482	0.8996	24.31	−0.20
0.3997	25.81	−0.50	1	24.26	0	0.4001	25.22	−0.578	1	24.26	0
0.5001	25.49	−0.48				0.5001	24.93	−0.615			

Table 5. Least-Squares Parameters and Standard Deviations for Surface Tensions from Equation 5

	A_0	A_1	A_2	A_3	A_4	σ / mN·m^{-1}
			$T = 298.15$ K			
dimethyl carbonate + 1,3,5-trimethylbenzene	−3.42	−0.43	0.57	0.53	−0.08	0.03
dimethyl carbonate + 1,2,4-trimethylbenzene	−4.11	−0.26	0.81	0.15	2.74	0.02
diethyl carbonate + 1,3,5-trimethylbenzene	−1.49	−0.38	1.01	0.90	−1.11	0.01
diethyl carbonate + 1,2,4-trimethylbenzene	−1.79	−0.87	0.56	1.15	−0.33	0.01
			$T = 313.15$ K			
dimethyl carbonate + 1,3,5-trimethylbenzene	−4.07	0.09	−0.13	0.10	0.73	0.02
dimethyl carbonate + 1,2,4-trimethylbenzene	−4.64	−0.69	2.05	−0.34	−0.85	0.03
diethyl carbonate + 1,3,5-trimethylbenzene	−1.90	−0.90	1.37	0.74	−1.05	0.02
diethyl carbonate + 1,2,4-trimethylbenzene	−2.46	−0.10	1.54	0.06	−1.99	0.01

The surface tensions data were fitted by the method of least squares with all points weighted equally to the smoothing equation:[10]

$$\delta\sigma/\mathrm{mN{\cdot}m^{-1}} = x(1-x)\sum_{i=0}^{k} A_i(1-2x)^i \qquad (5)$$

The parameters A_0, A_1, A_2, A_3, and A_4 and the standard deviations are given in Table 5.

Figures 1 and 2 show that V^E values are all positive for these binary mixtures at 298.15 K and 313.15 K. The maximum values of V^E follow the order: diethyl carbonate + 1,2,4-trimethylbenzene < diethyl carbonate + 1,3,5-trimethylbenzene < dimethyl carbonate + 1,2,4-trimethylbenzene < dimethyl carbonate + 1,3,5-trimethylbenzene. At the same time it can be seen that V^E curves are shifted in a regular way with increasing temperature (i.e., V^E becomes more positive at higher temperature).

It was suggested that V^E is the result of the contributions from several opposing effects, which may be divided into three types: physical, chemical, and structural effect. Physical effects make a positive contribution to V^E; chemical and structural effects make a negative contribution.[23] The V^E values are all positive for these binary mixtures. It indicates that the physical

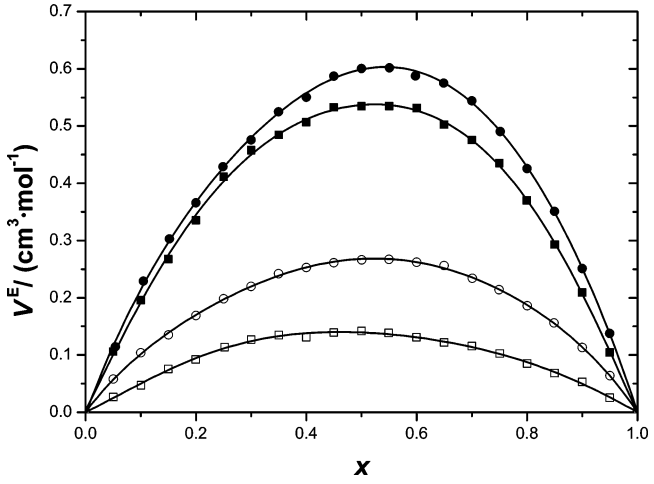

Figure 1. Excess molar volumes V^E for dimethyl carbonate (x) + ■, 1,2,4-trimethylbenzene (1 - x); + ●, 1,3,5-trimethylbenzene (1 − x) or for diethyl carbonate (x) + □, 1,2,4-trimethylbenzene; + ○, 1,3,5-trimethylbenzene (1 − x) at 298.15 K.

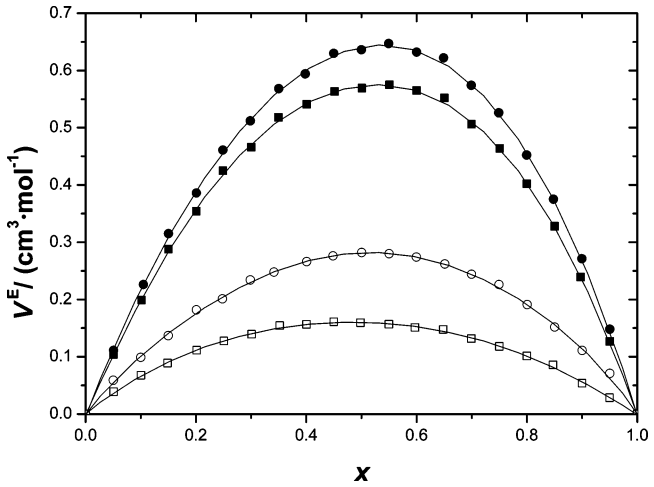

Figure 2. Excess molar volumes V^E for dimethyl carbonate (x) + ■, 1,2,4-trimethylbenzene (1 − x); + ●, 1,3,5-trimethylbenzene (1 − x) or for diethyl carbonate (x) + □, 1,2,4-trimethylbenzene; + ○, 1,3,5-trimethylbenzene (1 − x) at 313.15 K.

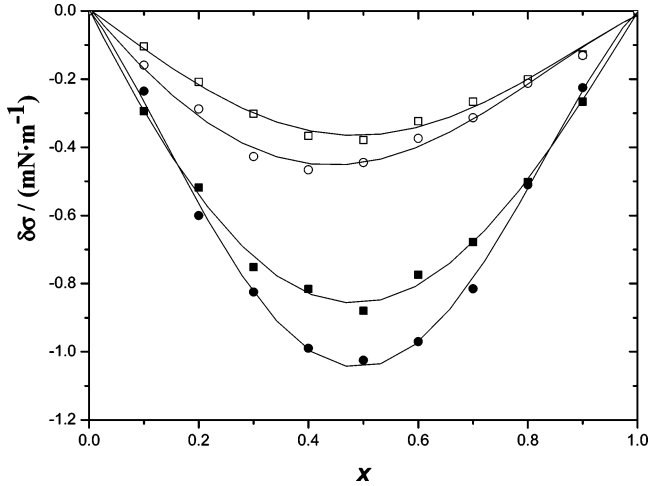

Figure 3. Surface tension deviation $\delta\sigma$ dimethyl carbonate (x) + ■, 1,2,4-trimethylbenzene (1 − x); + ●, 1,3,5-trimethylbenzene (1 − x) or for diethyl carbonate (x) + □, 1,2,4-trimethylbenzene; + ○, 1,3,5-trimethylbenzene (1 − x) at 298.15 K.

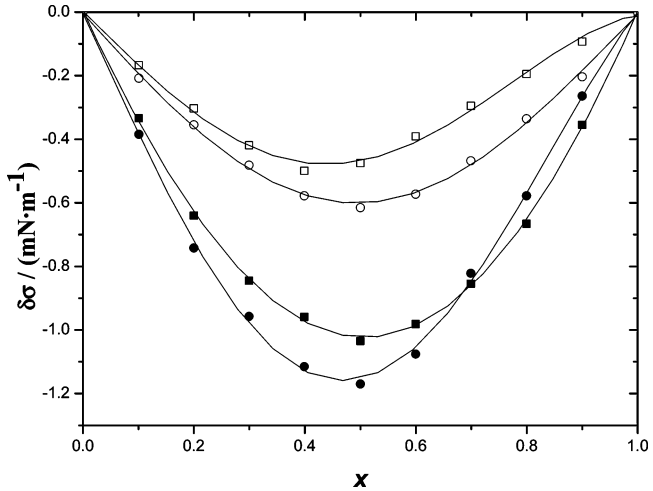

Figure 4. Surface tension deviation $\delta\sigma$ dimethyl carbonate (x) + ■, 1,2,4-trimethylbenzene (1 − x); + ●, 1,3,5-trimethylbenzene (1 − x) or for diethyl carbonate (x) + □, 1,2,4-trimethylbenzene; + ○, 1,3,5-trimethylbenzene (1 − x) at 313.15 K.

contributions are dominant. Figures 1 and 2 show that the V^E values for dimethyl carbonate + trimethylbenzen are more positive than diethyl carbonate + trimethylbenzene. It may be explained as follows: the structures of dimethyl carbonate and diethyl carbonate are similar and the molecular weight of dimethyl carbonate is smaller than that of diethyl carbonate; however, the value of density of dimethyl carbonate is larger than that of diethyl carbonate. In a sense, it shows that the packing of molecules inside the dimethyl carbonate is more compact than in diethyl carbonate. After adding the trimethylbenzene, the structures of the binary systems become incompact, so the increase of the V^E for dimethyl carbonate + trimethylbenzene should be more than diethyl carbonate + trimethylbenzene. The V^E values for dimethyl carbonate or diethyl carbonate + 1,3,5-trimethylbenzene are more positive than dimethyl carbonate or diethyl carbonate + 1,2,4-trimethylbenzene. This is similar to our previous result of trimethylbenzene + ethylene glycol ester or butanol.[2,5] It is possibly because 1,3,5-trimethylbenzene is symmetrical and nonpolar. The dipole−dipole interaction is weaker than 1,2,4-trimethylbenzene.

Figures 3 and 4 show that the surface tension deviations $\delta\sigma$ at 298.15 K and 313.15 K are negative for these binary systems. The minimum values of $\delta\sigma$ follow the order: dimethyl carbonate + 1,3,5-trimethylbenzene < dimethyl carbonate + 1,2,4-trimethylbenzene < diethyl carbonate + 1,3,5-trimethylbenzene < diethyl carbonate + 1,2,4-trimethylbenzene. The surface tension deviations $\delta\sigma$ can be considered to be the result of two aspects: one is the surface region, and the other is the bulk region. For the surface region, the surface tension deviations indicate different distributions of unlike components between the surface and the bulk region. The negative value of $\delta\sigma$ indicates that the surface concentration of the lower surface tension component is higher than its bulk concentration. For the bulk region, the surface tension deviations relate to chemical effects, physical effects, and dipolar−dipolar interaction. The physical effects and dipolar−dipolar interaction make negative contribution to the surface tension deviations, and the chemical effects make positive contribution. For these binary systems, the physical effects are more dominant than the chemical effects, which results in a decrease in surface tension. It can also be observed from Figures 3 and 4 that $\delta\sigma$ curves are shifted in a regular way with increasing temperature (i.e., $\delta\sigma$ becomes more negative at higher temperature). This is similar to our previous result of trimethylbenzene + ethylene glycol ester.[2]

Acknowledgment

The authors acknowledge and appreciate the assistance of C. Zheng, P. Fang, T. Zhang, J. Peng, and X. Niu in obtaining some experimental data.

Supporting Information Available:

Two tables showing the experimental density data at 298.15 K and 313.15 K. This material is available free of charge via the Internet at http://pubs.acs.org.

Literature Cited

(1) Zou Y.; Li Y.; Feng M.; Che G. Separating mixed xylene by urging rectification. Chinese Patent 1105898-A, CN1053386-C, 1997.
(2) Deng, J.; Yang, Y.; Wang, P.; Ouyang, G.; Huang, Z. Excess molar volumes, surface tensions of trimethylbenzene + ethylene glycol ester at 298.15 K and 313.15 K. *J. Chem. Eng. Data* **2006**, *51*, 725−729.
(3) Ouyang, G.; Yang, Y.; Lu, S.; Huang, Z.; Kang, B. Excess molar volumes and surface tensions of xylene with acetone or 2-butanone at 298.15 K. *J. Chem. Eng. Data* **2004**, *49*, 330−332.
(4) Ouyang, G.; Lu, G.; Pan C.; Yang Y.; Huang, Z.; Kang, B. Excess molar volumes and surface tensions of xylene with isopropyl ether or methyl *tert*-butyl ether at 298.15 K. *J. Chem. Eng. Data* **2004**, *49*, 732−734.
(5) Pan, C.; Ouyang, G.; Lin, J.; Rao, Y.; Zhen, X.; Lu, G.; Huang, Z. Excess molar volumes and surface tensions of 1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene with 1-butanol, 2-methyl-1-propanol, 2-butanol, and 2-methyl-2-propanol at 298.15 K. *J. Chem. Eng. Data* **2004**, *49*, 1744−1747.
(6) Pan, C.; Ke, Q.; Ouyang, G.; Zhen, X.; Yang, Y.; Huang, Z. Excess molar volumes and surface tensions of trimethylbenzene with tetrahydrofuran tetrachloromethane and dimethyl sulfoxide at 298.15 K. *J. Chem. Eng. Data* **2004**, *49*, 1839−1842.
(7) Menke, T. J.; Funke, Z.; Maier, R. D.; Kressler, J. Surface tension measurements on ethene−butene random copolymers and different polypropenes. *Macromolecules* **2000**, *33*, 6120−6125.
(8) Jimenez, E.; Casas, H.; Segade, L.; Franjo, C. Surface tensions, refractive indexes and excess molar volumes of hexane + 1-alkanol mixtures at 298.15 K. *J. Chem. Eng. Data* **2000**, *45*, 862−866.
(9) Wang, H. J.; Zhu, C.; Chen, M. Z.; Liu, H. L. Excess volumes of (a polar liquid + an aromatic hydrocarbon) at the temperature 298.15 K. *J. Chem. Thermodyn.* **1995**, *27*, 991−996.
(10) Redlich, O.; Kister, A. Algebraic representation of thermodynamic properties and the classification of solutions. *Ind. Eng. Chem.* **1948**, *40*, 345−348.
(11) Yang, C.; Xu, W.; Ma, P. Excess molar volumes and viscosities of binary mixtures of dimethyl carbonate with chlorobenzene, hexane, and heptane from (293.15 to 353.15) K and at atmospheric pressure. *J. Chem. Eng. Data* **2004**, *49*, 1802−1808.
(12) Comelli, F.; Francesconi, R. Excess properties of binary mixtures of esters of carbonic acid + three aryl alcohols at 308.15 K. *J. Chem. Eng. Data* **2005**, *50*, 191−195.
(13) Resa, J. M.; Gonzalez, C.; Ortiz de Landaluce, S.; Goenaga, J. M. Vapor−liquid equilibrium and mixing properties of methanol + diethyl carbonate and vinyl acetate + diethyl carbonate systems. *J. Chem. Eng. Data* **2005**, *50*, 1212−1217.
(14) Francesconi, R.; Comelli, F. Excess molar enthalpies, densities, and excess molar volumes of diethyl carbonate in binary mixtures with seven *n*-alkanols at 298.15 K. *J. Chem. Eng. Data* **1997**, *42*, 45−48.
(15) Riddick, J. A.; Bunger, W. B. *Organic Solvents Techniques of Chemistry*, 4th ed.; Wiley: New York, 1986; Vol. II.
(16) Andrzej, A. Excess volumes of (phenol + butyl benzene or propylbenzene or isopropyl benzene or 1,2,4-trimethylbenzene or ethyl benzene) at 318.15 and 348.15 K. *J. Chem. Thermodyn.* **1990**, *22*, 55−60.
(17) Wilhelm, E.; Faradjzadeh, A.; Grolier, J. P. E. Molar excess heat capacities and excess volumes of 1,2-dichloroehane + cyclooctane, + mesitylene, and + tetrachloromethane. *J. Chem. Thermodyn*. **1979**, *11*, 979−984.
(18) Lange, N. A., Ed. *Handbook of Chemistry*, 15th ed.; McGraw-Hill: New York, 1999.
(19) Ottani, S.; Vitalini, D.; Comelli, F.; Castellari, C. Densities, viscosities, and refractive indices of new mixtures of poly(ethylene glycols) + dialkyl carbonates at 313.15 K. *J. Chem. Eng. Data* **2004**, *49*, 148−154.
(20) Yang, C.; Lai, H.; Liu, Z.; Ma, P. Densities and viscosities of diethyl carbonate + toluene, + methanol, and + 2-propanol from (293.15 to 363.15) K. *J. Chem. Eng. Data* **2006**, 51, 584−589.
(21) Rodriguez, A.; Canosa, J.; Tojo, J. Density, refractive index, and speed of sound of binary mixtures (diethyl carbonate + alcohols) at several temperatures. *J. Chem. Eng. Data* **2001**, *46*, 1506−1515.
(22) Comelli, F.; Francesconi, R. Excess molar enthalpies and excess molar volumes of propionic acid + octane, + cyclohexane, + 1,3,5-trimethylbenzene, + oxane, or + 1,4-dioxane at 313.15 K. *J. Chem. Eng. Data* **1996**, *41*, 101−104.
(23) Treszczanowicz, A. J.; Kiyohara, O.; Benson, G. C. Excess molar volumes for *n*-alkanes binary mixtures of decan-1-ol + *n*-pentane, + *n*-hexane, + *n*-octane, + *n*-decane, and + *n*-hexadecane. *J. Chem. Thermodyn.* **1981**, *13*, 253−260.

Received for review March 25, 2006. Accepted May 3, 2006. The authors acknowledge the financial support of the Sun Yat-sen University, the National Key Basic Research and Development Program of China (G 2000026302), and the Guangdong Natural Science Foundation (04300564).

JE060137Q