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

Changsheng Yang, Wei Xu, and Peisheng Ma*

Key Laboratory for Green Chemical Technology of State Education Ministry, School of Chemical Engineering and Technology, Tianjin University, Tianjin 300072, PR China

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Densities and viscosities for the dimethyl carbonate (DMC) + (hexane, heptane, chlorobenzene) binary systems have been experimentally determined from (293.15 to 353.15) K and at normal atmospheric pressure over the entire mole fraction range. Other mixing properties of interest such as the excess molar volumes and the viscosity deviations have also been obtained for each of the systems. The obtained properties have been compared with those reported by other authors in the literature and have been analyzed in terms of the molecular interactions present in this kind of mixture. The excess molar volumes for these three binary systems were positive over the whole composition range at all temperatures. On the contrary, the deviations of viscosity for DMC + hexane and DMC + heptane are negative, and those for DMC + chlorobenzene are very small.

Introduction

The thermodynamic study of esters of carbonic acid has attracting increasing interest because these chemicals having an extensive variety of applications in lithium battery technology, for the synthesis of policarbonates, pharmaceuticals, and agrochemicals, and as extraction solvents and solvents for natural and synthetic resins and polymers. Also, carbonate molecules have been proposed as lubricants for the new refrigerants for stationary air conditioners because of their thermal stability, miscibility with HFCs, and lubricity. Furthermore, to optimize the structural and interaction parameters of group-contribution models, a study of the physical property data of binary mixtures containing esters of carbonic acid has attracted considerable interest in the literature. However, there are also some inconsistencies in the published data.

Rodriguez et al.[1] investigated the viscosities of dimethyl carbonate with alkanes at 293.15 K, 298.15 K, 303.15 K, and 313.15 K, including hexane and heptane. Pardo et al.[2] determined excess molar volumes of dimethyl carbonate + heptane at 278.15 K, 288.15 K, 298.15 K, and 308.15 K. Fuente et al.[3] measured excess molar volumes of dimethyl carbonate with heptane at 298.15 K. No experimental data are available in the literature for the system of dimethyl carbonate with chlorobenzene. This paper presents the measured values of densities and viscosities for the binary systems DMC + hexane, heptane, and chlorobenzene from (293.15 to 343.15) K and at atmospheric pressure. The results were used to calculate excess molar volumes and deviations in viscosity over the entire mole fraction range for the mixtures. Experimental values were correlated by the Redlich−Kister equation. The root-mean-square deviations between experimental and calculated values are shown. A comparison between experimental and literature data has also been made.

Experimental Section

Materials. All of the chemicals used in this study were obtained from Tianjin Reagent Company. They were degassed ultrasonically and dried over 0.4-nm molecular sieves. The mass fraction purities tested by gas chromatography were as follows: dimethyl carbonate (>0.999), chlorobenzene (>0.995), hexane (0.995), and heptane (0.990). In Table 1, we show the densities and viscosities determined in this study and available from the literature.

Apparatus and Procedure. The densities of the pure components and their mixtures were measured with a high-precision vibrating-tube digital density meter (density/specific gravity meter DA 505, KEM, Japan) whose measurement cell temperature was controlled automatically within ±0.01 K of the selected value. Before each series of measurements, the instrument was calibrated at atmospheric pressure with doubly distilled water and dry air. Densities of both water and dry air at the various working temperatures were given by the manufacturer in the instruction manual. The calibration was accepted if the measurements were within $\pm 5 \times 10^{-5}$ g·cm^{-3} of the published values. The uncertainty in the density measurements was $\pm 5 \times 10^{-5}$ g·cm^{-3}. Density measurements were reproducible to $\pm 3 \times 10^{-5}$ g·cm^{-3}.

The liquid mixtures were prepared by weight using a BP210s balance accurate to within ±0.01 mg. The average uncertainty in the compositions (mole fraction) of the mixtures was estimated to be less than ±0.0001. The molar excess volumes were calculated from composition−density data with an uncertainty of better than ±0.002 cm^3·mol^{-1}. All molar quantities were based on the IUPAC relative atomic mass table.

The viscosities of pure liquids and the mixtures were measured at atmospheric pressure and at different temperatures using several Ubbelohde suspended-level viscometers. The viscometer was immersed in a well-stirred water bath (Lauda, Germany) with temperature control to within ±0.01 K. An electronic digital stopwatch with a readability of ±0.01 s was used for flow time measurement.

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* To whom correspondence should be addressed: E-mail: tjuyangchsh@yahoo.com.cn. Fax: 022-27403389. Tel: 022-27890907.

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Table 1. Comparison of Experimental and Literature Values of Densities, ρ, and Viscosities, η, for Pure Compounds

		ρ/g·cm^{-3}		η/m·Pas	
liquid	T/K	exptl	lit	exptl	lit
dimethyl carbonate	293.15	1.06954	1.06969[5] 1.0700[7]	0.6173	0.626[1] 0.623[5]
	298.15	1.06295	1.0638[1] 1.06339[2] 1.06350[3]	0.5771	0.585[1] 0.589[4] 0.579[5]
	303.15	1.05635	1.05635[5] 1.0565[7]	0.5403	0.536[1] 0.548[5]
	313.15	1.04301	1.04310[5] 1.04319[6] 1.0434[7]	0.4807	0.494[1] 0.486[5]
	323.15	1.02959	1.02994[8]	0.4270	
	333.15	1.01600		0.3893	
	343.15	1.00232		0.3527	
chlorobenzene	293.15	1.10674		0.8084	
	298.15	1.10133	1.1011[9] 1.1009[10] 1.1010[11]	0.7422	0.758[9] 0.756[10] 0.7562[11]
	303.15	1.09596	1.10003[9] 1.0958[10] 1.0955[11]	0.7053	0.7184[9] 0.714[10] 0.7155[11]
	313.15	1.08506	1.09394[9] 1.0851[10] 1.0844[11]	0.6310	0.6467[9] 0.635[10] 0.6370[11]
	323.15	1.07426	1.0888[9]	0.5677	0.5724[9]
	333.15	1.06332	1.0839[9]	0.5069	0.5198[9]
hexane	293.15	0.66200	0.65944[12]	0.3020	0.313[1] 0.3163[12]
	298.15	0.65494	0.65493[12] 0.6547[13]	0.2990	0.301[1] 0.3036[12] 0.298[13]
	303.15	0.65287	0.65036[12] 0.6501[13]	0.2774	0.282[1] 0.2914[12] 0.285[13]
	313.15	0.64355	0.64108[12]	0.2504	0.258[1] 0.2685[12]
	323.15	0.63407	0.63161[12]	0.2333	0.2482[12]
	333.15	0.62439	0.62195[12]	0.2114	0.2308[12]
heptane	293.15	0.68714		0.4038	0.411[1] 0.4101[15]
	298.15	0.67962	0.67951[3] 0.67979[2]	0.3881	0.388[1] 0.395[14]
	303.15	0.67861	0.6750[14] 0.6756[16]	0.3629	0.370[1] 0.375[14] 0.3665[15]
	313.15	0.66991	0.6664[14] 0.6660[16]	0.3274	0.334[1] 0.339[14] 0.3321[15]
	323.15	0.66116		0.2980	
	333.15	0.65226		0.2704	0.2760[15]
	343.15	0.64331		0.2487	

Experiments were repeated a minimum of four times at each temperature for all compositions, and the results were averaged. The viscosity of the liquid was then calculated from the following relationship

$$\nu = \frac{\eta}{\rho} = k(t - \theta) \tag{1}$$

where t is the flow time, ν is the kinematic viscosity, and k and θ are the viscometer constant and the Hagenbach correction factor, respectively.

The calibration of the viscometer was carried out with doubly distilled water and doubly distilled benzene. Care was taken to reduce evaporation during the measurements. The uncertainty in the values is within ±0.003 mPa·s.

In the experiment, the density and viscosity for one composition sample were measured at different temperatures. Densities and viscosities of pure compounds are reported in Table 1 together with the corresponding literature values.

Result and Discussion

Excess volumes and viscosity deviations were calculated from our measurements according to the following equations:

$$V^{E} = \frac{x_1M_1 + x_2M_2}{\rho} - \frac{x_1M_1}{\rho_1} - \frac{x_2M_2}{\rho_2} \tag{2}$$

where x_1 and x_2 are mole fractions, M_1 and M_2 are molar masses, and ρ_1 and ρ_2 are the densities of pure components 1 and 2, respectively. Quantities without subscripts refer to the mixture.

The viscosity deviations were calculated from the following relation

$$\Delta\eta = \eta - (x_1\eta_1 + x_2\eta_2) \tag{3}$$

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

The values of V^{E} and $\Delta\eta$ for each mixture were fit to the Redlich−Kister polynominal equation

$$Y = x_1(1 - x_1)\sum_{i=0}^{n} A_i(2x_1 - 1)^i \tag{4}$$

where $Y = V^{E}$ or $\Delta\eta$, A_i are adjustable parameters, and x_1 is the fraction of component 1.

In each case, the optimum number of coefficients A_i was determined from an examination of the variation of the standard derivation

$$\sigma(Y) = \left[\frac{\sum(Y_{\text{calcd}} - Y_{\text{exptl}})^2}{n - m}\right]^{1/2} \tag{5}$$

where n is the total number of experimental values and m is the number of parameters.

The excess molar volume data and the viscosity deviations are presented in Table 2. Table 3 lists the values of parameters A_i together with the standard deviations.

The V^{E} against x_1 plots of three systems are shown in Figure 1 at 298.15 K and 323.15 K. The values are positive over the whole composition range, and a parabolic composition dependence is found. Excess molar volumes reflect the type of interactions taking place in the mixture. The packing effect in the binary systems containing dimethyl carbonate and alkanes is higher when the length of the chain of the alkanes and the temperature is lowered, probably because of the increase in molecular size. The excess molar volumes for dimethyl carbonate with chlorobenzene are smaller than for the other two systems. This means that $n-\pi$ complex formation between the free electrons of the −O−CO−O group and the aromatic ring is very important. Evidence of n interactions in alkyl carbonate with toluene[20] has been previously reported.

Figure 2 shows viscosity deviations for the binary mixtures of dimethyl carbonate with alkanes and chlorobenzene plotted against mole fraction together with the fitted curve obtained from the Redlich−Kister equation. The viscosity deviations for these systems at selected temperatures are negative over the entire composition. The values of viscosity deviation for dimethyl carbonate with chlorobenzene are smaller than for systems of dimethyl carbonate with alkanes.

Table 2. Densities (ρ), Viscosities (η), Excess Molar Volumes (V^E), and Viscosity Deviations ($\Delta\eta$) for the Binary Mixtures at Different Temperatures

x_1	ρ/g·cm^{-3}	η/mPa·s	V^E/cm^3·mol^{-1}	$\Delta\eta$/mPa·s	x_1	ρ/g·cm^{-3}	η/mPa·s	V^E/cm^3·mol^{-1}	$\Delta\eta$/mPa·s
(x)DMC+ (1 − x_1)Chlorobenzene									
T = 293.15 K									
0.0000	1.10674	0.8084	0.0000	0.000	0.6518	1.08222	0.6805	0.1592	−0.003
0.1225	1.10219	0.7794	0.0628	−0.006	0.7445	1.07884	0.6567	0.1315	−0.009
0.2380	1.09784	0.7586	0.1115	−0.004	0.8332	1.07558	0.6449	0.0974	−0.003
0.3499	1.09369	0.7315	0.1382	−0.010	0.9182	1.07242	0.6244	0.0586	−0.008
0.4545	1.08967	0.7132	0.1620	−0.008	1.0000	1.06954	0.6163	0.0000	0.000
0.5559	1.08585	0.6980	0.1657	−0.004					
T = 298.15 K									
0.0000	1.10133	0.7422	0.0000	0.000	0.6518	1.07605	0.6427	0.1636	0.008
0.1225	1.09665	0.7318	0.0637	0.010	0.7445	1.07255	0.6226	0.1360	0.003
0.2380	1.09216	0.7193	0.1145	0.016	0.8332	1.06917	0.6017	0.1020	−0.003
0.3499	1.08788	0.6956	0.1419	0.011	0.9182	1.06593	0.5856	0.0601	−0.005
0.4545	1.08372	0.6864	0.1678	0.019	1.0000	1.06295	0.5771	0.0000	0.000
0.5559	1.07981	0.6627	0.1690	0.012					
T = 303.15 K									
0.0000	1.09596	0.7053	0.0000	0.000	0.6518	1.06991	0.6014	0.1663	0.002
0.1225	1.09112	0.6862	0.0669	0.001	0.7445	1.06628	0.5781	0.1392	−0.007
0.2380	1.08651	0.6624	0.1173	−0.004	0.8332	1.06278	0.5632	0.1050	−0.007
0.3499	1.08209	0.6460	0.1461	−0.003	0.9182	1.05945	0.5487	0.0604	−0.008
0.4545	1.0778	0.6408	0.1726	0.009	1.0000	1.05635	0.5433	0.0000	0.000
0.5559	1.07376	0.6134	0.1744	−0.002					
T = 313.15 K									
0.0000	1.08506	0.6310	0.0000	0.000	0.6518	1.05746	0.5322	0.1735	−0.002
0.1225	1.07997	0.6145	0.0670	0.002	0.7445	1.05356	0.5192	0.1486	−0.001
0.2380	1.07508	0.5875	0.1206	−0.008	0.8332	1.04986	0.4992	0.1106	−0.008
0.3499	1.07036	0.5709	0.1540	−0.008	0.9182	1.04632	0.4874	0.0633	−0.007
0.4545	1.06581	0.5630	0.1824	0.000	1.0000	1.04301	0.482	0.0000	0.000
0.5559	1.06154	0.5423	0.1827	−0.006					
T = 323.15 K									
0.0000	1.07426	0.5677	0.0000	0.000	0.6518	1.04496	0.4729	0.1842	−0.006
0.1225	1.0688	0.5546	0.0765	0.004	0.7445	1.04083	0.4591	0.1564	−0.007
0.2380	1.06363	0.5273	0.1315	−0.008	0.8332	1.03688	0.4468	0.1175	−0.008
0.3499	1.05861	0.5145	0.1678	−0.006	0.9182	1.03312	0.4365	0.0668	−0.006
0.4545	1.0538	0.5039	0.1962	−0.002	1.0000	1.02959	0.4319	0.0000	0.000
0.5559	1.04932	0.4878	0.1915	−0.004					
T = 333.15 K									
0.0000	1.07426	0.5677	0.0000	0.000	0.6518	1.04496	0.4729	0.1842	−0.006
0.1225	1.0688	0.5546	0.0765	0.004	0.7445	1.04083	0.4591	0.1564	−0.007
0.2380	1.06363	0.5273	0.1315	−0.008	0.8332	1.03688	0.4468	0.1175	−0.008
0.3499	1.05861	0.5145	0.1678	−0.006	0.9182	1.03312	0.4365	0.0668	−0.006
0.4545	1.0538	0.5039	0.1962	−0.002	1.0000	1.02959	0.4319	0.0000	0.000
0.5559	1.04932	0.4878	0.1915	−0.004					
T = 343.15 K									
0.0000	1.05244	0.4658	0.0000	0.000	0.6518	1.01967	0.3879	0.2001	−0.004
0.1225	1.04633	0.4550	0.0850	0.003	0.7445	1.01499	0.3770	0.1730	−0.005
0.2380	1.04054	0.4326	0.1464	−0.006	0.8332	1.01053	0.3678	0.1315	−0.004
0.3499	1.03493	0.4242	0.1855	−0.002	0.9182	1.00631	0.3609	0.0739	−0.001
0.4545	1.02951	0.4142	0.2207	0.000	1.0000	1.00232	0.3527	0.0000	0.000
0.5559	1.02452	0.3978	0.2118	−0.005					
(x)DMC + (1 − x_1)Hexane									
T = 293.15 K									
0.0000	0.66200	0.3020	0.0000	0.000	0.5893	0.85198	0.3939	0.7520	−0.094
0.0961	0.68568	0.3032	0.4674	−0.029	0.6906	0.89734	0.4270	0.5983	−0.093
0.1930	0.71234	0.3094	0.7269	−0.053	0.7928	0.94858	0.4715	0.3655	−0.080
0.2909	0.74199	0.3213	0.8641	−0.072	0.8960	1.00655	0.5420	0.0881	−0.042
0.3894	0.77482	0.3410	0.9007	−0.084	1.0000	1.06954	0.6173	0.0000	0.000
0.4890	0.81138	0.3647	0.8568	−0.091					
T = 298.15 K									
0.0000	0.65744	0.2886	0.0000	0.000	0.5893	0.84619	0.3709	0.7841	−0.086
0.0961	0.68092	0.2901	0.4834	−0.026	0.6906	0.89145	0.4024	0.6127	−0.083
0.1930	0.70738	0.2940	0.7531	−0.050	0.7928	0.94239	0.4472	0.3826	−0.067
0.2909	0.73680	0.3060	0.9008	−0.065	0.8960	1.00017	0.5031	0.0946	−0.041
0.3894	0.76942	0.3232	0.9404	−0.076	1.0000	1.06295	0.5734	0.0000	0.000
0.4890	0.80580	0.3449	0.8919	−0.083					
T = 303.15									
0.0000	0.65287	0.2774	0.0000	0.000	0.5893	0.84041	0.3502	0.8143	−0.082
0.0961	0.67614	0.2790	0.5018	−0.024	0.6906	0.88548	0.3808	0.6353	−0.078
0.1930	0.70237	0.2817	0.7871	−0.046	0.7928	0.93619	0.4221	0.4000	−0.064
0.2909	0.73162	0.2923	0.9352	−0.062	0.8960	0.99378	0.4748	0.1013	−0.038
0.3894	0.76404	0.3061	0.9765	−0.074	1.0000	1.05635	0.5403	0.0000	0.000
0.4890	0.80021	0.3252	0.9277	−0.081					

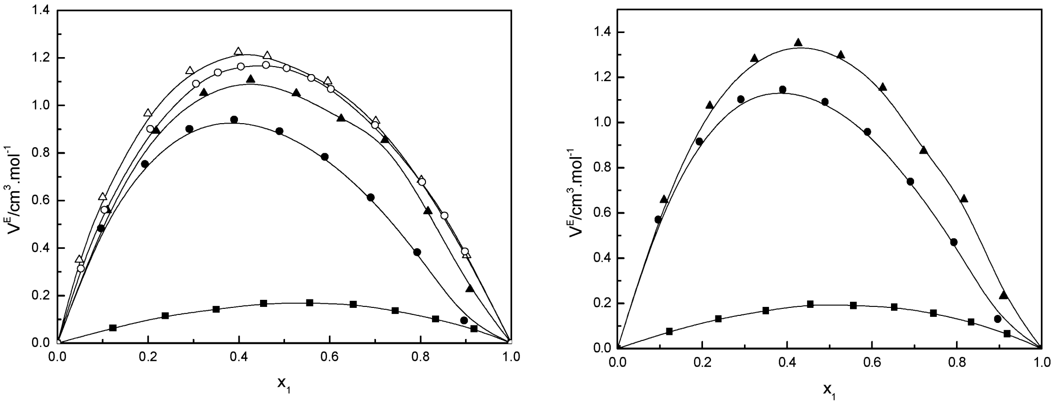
Table 2. (Continued)

x_1	ρ/g·cm^{-3}	η/mPa·s	V^E/cm^3·mol^{-1}	$\Delta\eta$/mPa·s	x_1	ρ/g·cm^{-3}	η/mPa·s	V^E/cm^3·mol^{-1}	$\Delta\eta$/mPa·s
(x)DMC + (1 − x_1)Hexane (Continued									
T = 313.15 K									
0.0000	0.64355	0.2504	0.0000	0.000	0.5893	0.82862	0.3163	0.8845	−0.070
0.0961	0.66641	0.2513	0.5381	−0.021	0.6906	0.87334	0.3417	0.6858	−0.068
0.1930	0.69221	0.2555	0.8505	−0.039	0.7928	0.92365	0.3763	0.4339	−0.057
0.2909	0.72104	0.2645	1.0135	−0.053	0.8960	0.98084	0.4229	0.1157	−0.034
0.3894	0.75305	0.2770	1.0597	−0.063	1.0000	1.04301	0.4807	0.0000	0.000
0.4890	0.78882	0.2938	1.0070	−0.069					
T = 323.15 K									
0.0000	0.63407	0.2339	0.0000	0.000	0.5893	0.81669	0.2880	0.9586	−0.060
0.0961	0.65655	0.2333	0.5707	−0.019	0.6906	0.86107	0.3101	0.7390	−0.057
0.1930	0.68190	0.2344	0.9163	−0.037	0.7928	0.91098	0.3404	0.4708	−0.047
0.2909	0.71027	0.2423	1.1025	−0.048	0.8960	0.96780	0.3781	0.1307	−0.029
0.3894	0.74192	0.2536	1.1459	−0.056	1.0000	1.02959	0.4270	0.0000	0.000
0.4890	0.77728	0.2681	1.0913	−0.060					
T = 333.15 K									
0.0000	0.62439	0.2114	0.0000	0.000	0.5893	0.80452	0.2639	1.0424	−0.052
0.0961	0.64644	0.2130	0.6155	−0.015	0.6906	0.84853	0.2842	0.8042	−0.050
0.1930	0.67136	0.2167	0.9915	−0.029	0.7928	0.89813	0.3117	0.5085	−0.041
0.2909	0.69925	0.2239	1.2053	−0.039	0.8960	0.95454	0.3447	0.1502	−0.026
0.3894	0.73055	0.2340	1.2433	−0.047	1.0000	1.01600	0.3893	0.0000	0.000
0.4890	0.76550	0.2466	1.1863	−0.052					
(x) DMC + (1 − x_1)Heptane									
T = 293.15 K									
0.0000	0.68714	0.4038	0.0000	0.000	0.6252	0.86751	0.4541	0.8994	−0.083
0.1099	0.70987	0.3932	0.5337	−0.034	0.7218	0.91010	0.4774	0.7117	−0.081
0.2176	0.73533	0.3924	0.8527	−0.058	0.8165	0.95771	0.5078	0.4702	−0.070
0.3229	0.76359	0.4001	1.0112	−0.073	0.9092	1.01141	0.5511	0.1560	−0.047
0.4259	0.79480	0.4139	1.0596	−0.081	1.0000	1.06954	0.6173	0.0000	0.000
0.5266	0.82938	0.4321	1.0037	−0.084					
T = 298.15 K									
0.0000	0.68291	0.3831	0.0000	0.000	0.6252	0.86186	0.4261	0.9438	−0.076
0.1099	0.70539	0.3737	0.5589	−0.030	0.7218	0.90423	0.4500	0.7462	−0.070
0.2176	0.73061	0.3723	0.8934	−0.052	0.8165	0.95163	0.4779	0.4915	−0.061
0.3229	0.75868	0.3796	1.0526	−0.065	0.9092	1.00504	0.5169	0.1695	−0.039
0.4259	0.78963	0.3911	1.1086	−0.073	1.0000	1.06295	0.5734	0.0000	0.000
0.5266	0.82398	0.4095	1.0508	−0.074					
T = 303.15 K									
0.0000	0.67861	0.3629	0.0000	0.000	0.6252	0.85624	0.4015	0.9792	−0.072
0.1099	0.70093	0.3559	0.5670	−0.027	0.7218	0.89837	0.4230	0.7755	−0.068
0.2176	0.72589	0.3530	0.9229	−0.048	0.8165	0.94553	0.4491	0.5118	−0.059
0.3229	0.75373	0.3585	1.0912	−0.062	0.9092	0.99870	0.4793	0.1785	−0.045
0.4259	0.78446	0.3719	1.1497	−0.067	1.0000	1.05635	0.5403	0.0000	0.000
0.5266	0.81856	0.3855	1.0942	−0.071					
T = 313.15 K									
0.0000	0.66991	0.3274	0.0000	0.000	0.6252	0.84482	0.3588	1.0606	−0.064
0.1099	0.69178	0.3200	0.6101	−0.024	0.7218	0.88649	0.3777	0.8405	−0.060
0.2176	0.71632	0.3195	0.9889	−0.041	0.8165	0.93318	0.4020	0.5562	−0.051
0.3229	0.74368	0.3248	1.1785	−0.052	0.9092	0.98581	0.4335	0.2041	−0.033
0.4259	0.77395	0.3316	1.2442	−0.061	1.0000	1.04301	0.4807	0.0000	0.000
0.5266	0.80758	0.3435	1.1879	−0.065					
T = 323.15 K									
0.0000	0.66116	0.2980	0.0000	0.000	0.6252	0.83328	0.3251	1.1537	−0.054
0.1099	0.68257	0.2905	0.6572	−0.022	0.7218	0.87450	0.3403	0.9140	−0.051
0.2176	0.70662	0.2920	1.0732	−0.034	0.8165	0.92024	0.3615	0.6592	−0.042
0.3229	0.73352	0.2932	1.2801	−0.046	0.9092	0.97284	0.3906	0.2316	−0.025
0.4259	0.76334	0.2997	1.3505	−0.053	1.0000	1.02959	0.4270	0.0000	0.000
0.5266	0.79647	0.3118	1.2966	−0.054					
T = 333.15									
0.0000	0.65226	0.2704	0.0000	0.000	0.6252	0.82151	0.2946	0.0000	−0.050
0.1099	0.67320	0.2666	0.7085	−0.017	0.7218	0.86231	0.3099	0.7822	−0.046
0.2176	0.69676	0.2648	1.1632	−0.032	0.8165	0.90807	0.3291	1.2612	−0.038
0.3229	0.72319	0.2670	1.3896	−0.042	0.9092	0.95974	0.3543	1.5074	−0.024
0.4259	0.75253	0.2730	1.4694	−0.048	1.0000	1.01600	0.3893	1.5998	0.000
0.5266	0.78519	0.2828	1.4126	−0.050					
T = 343.15 K									
0.0000	0.64331	0.2487	1.2610	0.000	0.6252	0.80967	0.2725	1.3744	−0.041
0.1099	0.66369	0.2437	0.9957	−0.016	0.7218	0.85005	0.2851	1.0814	−0.039
0.2176	0.68683	0.2429	0.6632	−0.028	0.8165	0.89495	0.3015	0.7672	−0.032
0.3229	0.71279	0.2462	0.2566	−0.036	0.9092	0.94654	0.3252	0.2846	−0.018
0.4259	0.74163	0.2512	0.0000	−0.042	1.0000	1.00232	0.3527	0.0000	0.000
0.5266	0.77379	0.2603	1.2610	−0.043					

Table 3. Coefficients of the Redlich−Kister Equation and Standard Deviation for Excess Molar Volumes and Viscosity Deviations of Mixtures

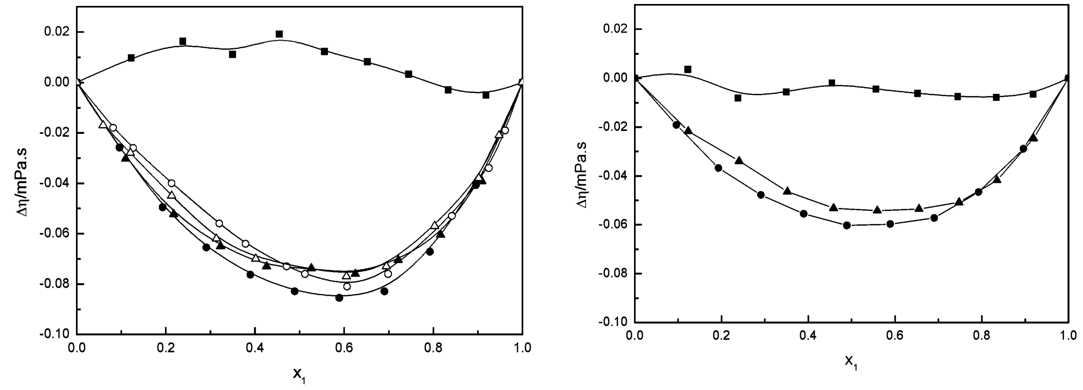
T/K	property	A_0	A_1	A_2	A_3	σ
(x)DMC+ $(1 - x_1)$Chlorobenzene						
293.15	V^E/cm^3·mol^{-1}	0.764	0.191	−0.560	−0.136	0.0178
	$\Delta\eta$/mPa·s	−0.033	−0.001	0.005	−0.011	0.0059
298.15	V^E/cm^3·mol^{-1}	0.786	0.206	−0.577	−0.149	0.0177
	$\Delta\eta$/mPa·s	0.005	−0.053	−0.027	−0.004	0.0039
303.15	V^E/cm^3·mol^{-1}	0.807	0.201	−0.593	−0.146	0.0177
	$\Delta\eta$/mPa·s	−0.003	−0.039	−0.026	0.013	0.0030
313.15	V^E/cm^3·mol^{-1}	0.846	0.234	−0.628	−0.174	0.0169
	$\Delta\eta$/mPa·s	−0.016	−0.030	−0.011	0.013	0.0037
323.15	V^E/cm^3·mol^{-1}	0.907	0.202	−0.666	−0.141	0.0182
	$\Delta\eta$/mPa·s	−0.023	−0.036	0.002	0.015	0.0048
333.15	V^E/cm^3·mol^{-1}	0.958	0.213	−0.698	−0.148	0.0194
	$\Delta\eta$/mPa·s	−0.013	−0.035	0.006	0.020	0.0030
343.15	V^E/cm^3·mol^{-1}	1.005	0.215	−0.737	−0.147	0.0194
	$\Delta\eta$/mPa·s	−0.015	−0.028	0.013	0.024	0.0029
(x)DMC + $(1 - x_1)$Hexane						
293.15	V^E/cm^3·mol^{-1}	3.972	−3.453	−3.048	2.972	0.1143
	$\Delta\eta$/mPa·s	−0.452	−0.159	0.328	0.157	0.0131
298.15	V^E/cm^3·mol^{-1}	2.896	−2.429	−3.122	2.874	0.0854
	$\Delta\eta$/mPa·s	−0.426	−0.160	0.315	0.152	0.0128
303.15	V^E/cm^3·mol^{-1}	4.082	−3.132	−3.019	2.615	0.1046
	$\Delta\eta$/mPa·s	−0.397	−0.149	0.302	0.148	0.0113
313.15	V^E/cm^3·mol^{-1}	4.500	−3.399	−3.268	2.722	0.1106
	$\Delta\eta$/mPa·s	−0.352	−0.141	0.274	0.142	0.0111
323.15	V^E/cm^3·mol^{-1}	4.880	−3.622	−3.560	2.896	0.1168
	$\Delta\eta$/mPa·s	−0.306	−0.123	0.244	0.130	0.0102
333.15	V^E/cm^3·mol^{-1}	5.305	−3.872	−3.870	3.094	0.1251
	$\Delta\eta$/mPa·s	−0.265	−0.116	0.212	0.120	0.0088
(x)DMC + $(1 - x_1)$Heptane						
293.15	V^E/cm^3·mol^{-1}	4.836	−2.502	−3.835	2.235	0.1212
	$\Delta\eta$/mPa·s	−0.418	−0.164	0.261	0.127	0.0146
298.15	V^E/cm^3·mol^{-1}	3.358	−1.189	−3.756	1.999	0.1050
	$\Delta\eta$/mPa·s	−0.390	−0.158	0.254	0.127	0.0139
303.15	V^E/cm^3·mol^{-1}	4.922	−1.962	−3.731	1.695	0.1108
	$\Delta\eta$/mPa·s	−0.364	−0.164	0.234	0.122	0.0139
313.15	V^E/cm^3·mol^{-1}	5.458	−2.195	−4.078	1.790	0.1177
	$\Delta\eta$/mPa·s	−0.323	−0.147	0.223	0.126	0.011
323.15	V^E/cm^3·mol^{-1}	5.981	−2.311	−4.447	1.917	0.1341
	$\Delta\eta$/mPa·s	−0.278	−0.126	0.206	0.121	0.0096
333.15	V^E/cm^3·mol^{-1}	6.486	−2.505	−4.856	2.064	0.1378
	$\Delta\eta$/mPa·s	−0.252	−0.122	0.187	0.111	0.0084
343.15	V^E/cm^3·mol^{-1}	7.087	−2.672	−5.268	2.209	0.1562
	$\Delta\eta$/mPa·s	−0.219	−0.101	0.168	0.103	0.0077

Figure 3 shows that for dimethyl carbonate with hexane and heptane the excess molar volumes at equimolar fraction increase with increasing temperature whereas for dimethyl carbonate with chlorobenzene the excess molar volumes are weakly dependent on temperature. As shown in Figure 4, the viscosity deviations at equimolar fractions increase with temperature for dimethyl carbonate with hexane and heptane, and the viscosity deviations are almost constant with temperature for the mixture of dimethyl carbonate with chlorobenzene.



(a) T=298.15 K (b) T= 323.15 K

Figure 1. Excess volumes, V^E, against mole fraction for the following systems: DMC + chlorobenzene, ■, this work; DMC + hexane, ●, this work; DMC + heptane, ▲, this work; DMC + heptane □, Pardo[2]; DMC + heptane, ○, Fuente.[3] Solid curves, calculated with Redlich−Kister equations; symbols, experimental values.



(a) T=298.15 K

(b) T= 323.15 K

Figure 2. Viscosity deviation, Δ*η*, against mole fraction for the following systems: DMC + chlorobenzene, ■ this work; DMC + hexane, ●, this work; DMC + hexane ○, Rodriguez[1]; DMC + heptane, ▲, this work; DMC + heptane □, Rodriguez.[1] Solid curves, calculated with Redlich−Kister equations; symbols, experimental values.

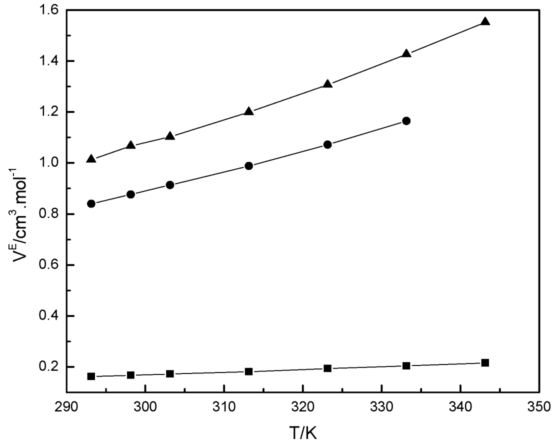


Figure 3. Dependence of excess volume, V^E, on temperature at the equimolar fraction for the following systems: DMC + chlorobenzene, ■; DMC + hexane, ●; DMC + heptane, ▲.

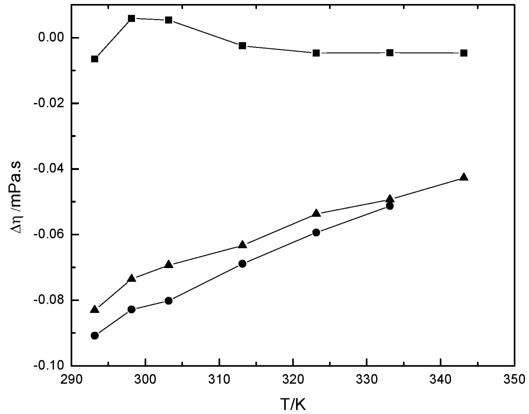


Figure 4. Dependence of the viscosity deviations, Δ*η*, on temperature at the equimolar fraction for the following systems: DMC + chlorobenzene, ■; DMC + hexane, ●; DMC + heptane, ▲.

Conclusions

Densities and viscosities for the dimethyl carbonate (DMC) + (hexane, heptane, chlorobenzene) binary systems have been experimentally determined from (293.15 to 353.15) K and at normal atmospheric pressure over the entire mole fraction range. The excess molar volume and viscosity deviations were correlated using the Redlich−Kister polynomial equation. The excess molar volumes for these three binary systems were positive over the whole composition range and at all temperatures. On the contrary, the deviations in viscosity for DMC + hexane and DMC + heptane were negative, and those for DMC + chlorobenzene were very small.

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