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Viscosities and Densities for Propylene Carbonate + Toluene at 15, 20, 25, 30, and 35 °C

George Moumouzias and George Ritzoulis*

Laboratory of Physical Chemistry, Department of Chemistry, Aristotelian University of Thessaloniki, 54006 Thessaloniki, Greece

Viscosities and densities for propylene carbonate + toluene have been measured at 15, 20, 25, 30, and 35 °C. The "interaction parameter" obtained from the Grundberg and Nissan equation, the deviation in viscosity ($\Delta\eta$), and excess volume (V^E) are discussed.

Introduction

This work continues our previous systematic study on the thermodynamic and physical properties of binary liquid mixtures where one or both components are dipolar-aprotic solvents (*1-3*). These solvents are used in many chemical and electrochemical works as media where various reactions take place. A number of aprotic solvents are also used in lithium batteries since their molecules have no active hydrogen atoms which react with lithium in order to evolve hydrogen. This reaction is harmful for the batteries because of the pressure that develops into the cell.

In many cases the properties of a pure solvent are inferior to those of mixtures of two or more solvents. Thus, it is important to examine the physical properties of mixtures.

In this work we present the experimental results of densities and viscosities of propylene carbonate + toluene at 15, 20, 25, 30, and 35 °C.

Experimental Section

Kinematic viscosities were measured at 15, 20, 25, 30, and 35 °C with Ubbelohde suspended-level viscometers. The viscometers were calibrated with doubly distilled water, benzene, and toluene. The absolute viscosity η was computed from the measured kinematic viscosity and density of the solution. The temperature in the measuring cell was regulated to ±0.01 °C. The precision in η was less than ±0.5%.

All liquids and their mixtures were filtered. Special care was taken in order to prevent evaporation of the liquid.

Densities of the liquids were measured with an Anton-Paar DMA 60 602 vibrating tube densimeter. It was calibrated with double-distilled water and air. The temperatures were regulated with an accuracy of ±0.01 °C using a Haake ultrathermostat and measured by a precise digital thermometer (DT-100 Anton-Paar). The estimated error in density was $\pm 5 \times 10^{-6}$ g cm^{-3}.

Propylene carbonate (Merk zur synthese >99%) was distilled, and the middle part was collected. Before distillation it was kept for about 4 days over molecular sieves.

Toluene (Merk extra pure >99.5%) was double distilled, and the middle fraction was used.

All solutions were prepared by mass.

Results

The experimental values of densities and viscosities for propylene carbonate (1) + toluene (2) are given in Table I.

Excess volumes V^E were determined from the density measurements using the equation

Table I. Experimental Values of Viscosity η and Density ρ for Propylene Carbonate (1) + Toluene (2)

x_1	$\eta/(10^{-3}$ Pa s)	$\rho/(g\ cm^{-3})$	x_1	$\eta/(10^{-3}$ Pa s)	$\rho/(cm^{-3})$
		288.15 K			
1.0000	3.086	1.2087	0.3757	1.0869	0.9845
0.8904	2.507	1.1663	0.2789	0.9350	0.9535
0.7831	2.0378	1.1263	0.1841	0.8221	0.9249
0.6780	1.6801	1.0880	0.0911	0.7278	0.8978
0.5752	1.4144	1.0517	0.000	0.6299	0.8712
0.4744	1.2335	1.0172			
		293.15 K			
1.0000	2.7635	1.2034	0.3757	1.0058	0.9799
0.8904	2.2561	1.1612	0.2789	0.8738	0.9490
0.7831	1.856	1.1211	0.1841	0.7726	0.9205
0.6780	1.5290	1.083	0.0911	0.6805	0.8933
0.5752	1.2917	1.0467	0.000	0.5925	0.8667
0.4744	1.1494	1.0123			
		298.15 K			
1.000	2.5009	1.1978	0.3757	0.9358	0.9755
0.8904	2.0483	1.1561	0.2789	0.8139	0.9449
0.7831	1.690	1.1163	0.1841	0.7190	0.9160
0.6780	1.4044	1.0784	0.0911	0.6333	0.8889
0.5752	1.1946	1.0423	0.000	0.5563	0.8621
0.4744	1.0736	1.0080			
		303.15 K			
1.000	2.2743	1.1926	0.3757	0.8694	0.9706
0.8904	1.8687	1.1508	0.2789	0.7586	0.9400
0.7831	1.5491	1.1111	0.1841	0.6689	0.9112
0.6780	1.3036	1.0733	0.0911	0.5934	0.8842
0.5752	1.1026	1.0373	0.000	0.5272	0.8574
0.4744	0.9983	1.0030			
		308.15 K			
1.000	2.0797	1.1873	0.3757	0.8243	0.9661
0.8904	1.7101	1.1455	0.2789	0.7171	0.9356
0.7831	1.4199	1.1060	0.1841	0.6294	0.9066
0.6780	1.2025	1.0681	0.0911	0.5572	0.8793
0.5752	1.0299	1.0323	0.000	0.4981	0.8526
0.4744	0.9407	0.9982			

$$V^E = x_1M_1(1/d - 1/d_1) + x_2M_2(1/d - 1/d_2) \qquad (1)$$

where M_i is the molecular weight of component i, x_i is the mole fraction of component i, d_i is the density of the pure component i, and d is the density of the mixture. The results were fitted to a Redlich-Kister (*4*) type equation:

$$V^E/(\text{cm}^3\ \text{mol}^{-1}) = x_1\ (1 - x_1)\sum a_i\ (1 - 2x_1)^j \qquad (2)$$

The number of coefficients a_i is ascertained by the examination of the variation of the standard deviation with j. The values of coefficient a_i and the standard error are summarized in Table II.

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Table II. Parameters a_i from Equations 2 and 4 and Standard Error of Regression σ for Propylene Carbonate (1) + Toluene (2)

	288.15 K	293.15 K	298.15 K	303.15 K	308.15 K
			Equation 2		
a_0	−1.7812	−1.8073	−0.0184	−2.0714	−2.2562
a_1	−0.9858	−0.8171	−2.0785	−0.7598	−0.3953
a_2	0.6219	0.1271	3.262	0.3049	−0.4994
a_3	1.5783	1.3905	−3.07	1.41113	1.0557
a_4	−1.7601	−1.1651	1.932	−1.4812	
$\sigma/(cm^3\ mol^{-1})$	5×10^{-2}	5.2×10^{-2}	3.4×10^{-3}	4.6×10^{-2}	6.9×10^{-2}
			Equation 4		
a_0	−2.3587	−2.0247	−1.7604	−1.5563	−1.3561
a_1	−1.2636	−1.1239	−1.0157	−0.8491	−0.8480
a_2	−0.0421	−0.05385	−0.1406	−0.1871	−0.2871
a_3	0.3782	0.3788	0.3847	0.2880	0.3645
$\sigma/(mPa\ s)$	5.4×10^{-2}	5.6×10^{-2}	5.4×10^{-2}	5.2×10^{-2}	5.2×10^{-2}

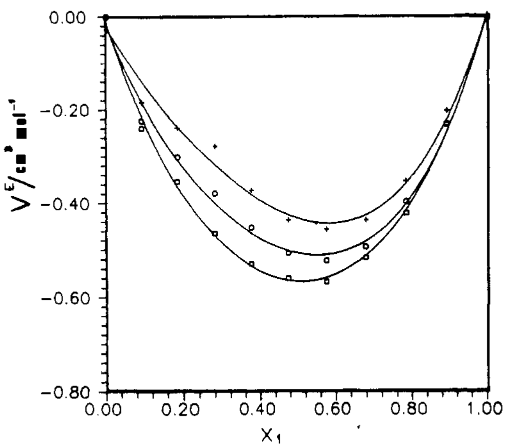

Figure 1. Excess volume V^E for propylene carbonate (1) + toluene (2): +, 15 °C; ○, 25 °C; □, 35 °C.

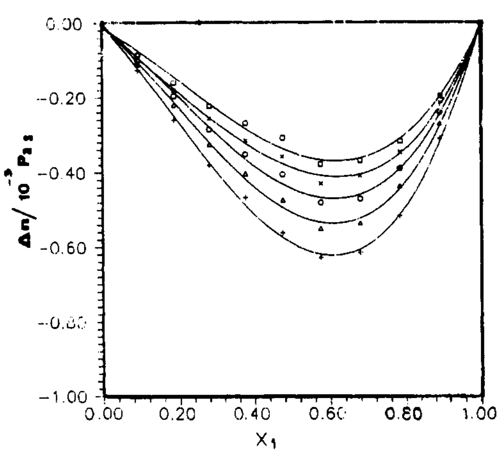

Figure 2. Viscosity deviation $\Delta\eta$ for propylene carbonate (1) + toluene (2): +, 15 °C; ○, 25 °C; ×, 30 °C; □, 35 °C.

Dynamic Viscosities. The viscosity deviation is given by

$$\Delta\eta = \eta - x_1\eta_1 - x_2\eta_2 \quad (3)$$

where η, η_1, and η_2 are the dynamic viscosities of the mixture, pure component 1, and pure component 2, respectively. The results are well represented by the equation

$$\Delta\eta/(10^{-3}\ \mathrm{Pa\ s}) = x_1(1-x_1)\sum a_i(1-2x_1)^j \quad (4)$$

Equation 3 gives the deviation of the viscosity in the mixture from the simple additivity rule.

Grunberg and Nissan (*5*) have suggested the following empirical equation to describe the viscosity of real mixtures:

$$\ln\eta = x_1 \ln\eta_1 + x_2 \ln\eta_2 + x_1x_2d_w \quad (5)$$

where $d_w = \omega_{visc}/RT$ which is called the "interaction parameter". It is regarded as a measure of the strength of the interaction.

Discussion

The excess volume results exhibit negative deviations over the entire mole fraction range at all temperatures.

Figure 1 shows the variation of V^E against x_1. An increase of temperature causes the minimum to become more negative. The same phenomenon has been observed by other researchers (*1, 6, 7*). The minimum of V^E is at $x_1 \approx 0.5$ at all temperatures.

The negative deviation in V^E usually occurs in systems formed by molecules of different geometry.

$\Delta\eta$ values are negative over the whole composition range at all temperatures, and the minimum increases with the temperature, showing a trend to zero. The minimum of $\Delta\eta$ is at $x_1 \approx 0.6$ (Figure 2).

The values of the d_w parameter, which also gives an estimation of nonideality of the system, are also negative for the entire mole fraction.

The negative values of $\Delta\eta$ and d_w indicate interactions which according to some researchers (*9–11*) are due to dispersion forces which are developed between molecules of unequal size.

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Registry No. Propylene carbonate, 108-32-7; toluene, 108-88-3.