Density and Viscosity at Various Temperatures for 2-Methoxyethanol + Acetone Mixtures

Cezary M. Kinart,*,† Wojciech J. Kinart,‡ and Aneta Ćwiklińska†

Department of Chemistry, University of Łódź, 90-236 Łódź, Pomorska 163, Poland, and Department of Organic Chemistry, University of Łodź, 90-136 Łódź, Narutowicza 68, Poland

Desities (ρ) at five temperatures, between (291.15 and 308.15) K, and viscosities (η) at three temperatures, between (293.15 and 303.15) K, of binary mixtures of 2-methoxyethanol (1) + acetone (2) are reported. Excess molar volumes (V^E) are calculated.

Introduction

This paper reports densities and viscosities of the 2-methoxyethanol + acetone mixtures at different temperatures. The knowledge of the physicochemical and thermodynamic properties of binary liquid mixtures formed by one or two components associated through hydrogen bonds is important from both theoretical and process design aspects.

Densities and viscosities were determined over the whole composition range of the mixtures, at (291.15, 293.15, 298.15, 303.15, and 308.15) K. We calculated the excesses molar volumes, which were fitted to the Redlich−Kister equation.[1]

Experimental Section

Materials. 2-Methoxyethanol and acetone, Merck, proanalysis, containing less than 0.05% (w/w) water, respectively (determined by Karl Fischer method), were used.

2-Methoxyethanol and acetone were further purified by the methods described by Piekarski and Tkaczyk[2] and Riddick et al.[3] The densities and viscosities for the pure solvents, at 298.15 K, were in good agreement with literature values (Table 1).

The mixtures were prepared by mass, with weighings accurate to $\pm 1 \times 10^{-4}$ g. Conversion to molar quantities was based on the relative atomic mass table of 1985 issued by IUPAC in 1986. The uncertainty in the mole fractions is less than 1×10^{-4}.

Measurements. Solvent densities were measured with a bicapillary type Lipkin pycnometer, with a capacity of ~90 cm^3. The maximum error in the density measurements was 4×10^{-5} g·cm^{-3}. The viscosities of the pure components and the mixtures were determined with a calibrated Ubbelhode suspended level viscometer. The viscometers were calibrated by using high-purity dioxane, toluene, and deionized water at the working temperatures. The viscosities were measured with an uncertainty of ±0.002 mPa·s. Each temperature was maintained with an uncertainly of ±0.01 K.

Results and Discussion

The experimental data of density (ρ) and viscosity (η) obtained from the measurements of the pure solvents and for the analyzed binary mixtures at all investigated temperatures are summarized in Table 2.

Table 1. Reference Density and Viscosity Values of 2-Methoxyethanol and Acetone, at 298.15 K

	ρ/g·cm^{-3}		η/mPa·s	
solvent	this work	lit.	this work	lit.
2-methoxyethanol	0.960 29	0.960 1[4]	1.544	1.5414[8]
		0.960 288[5]		
		0.960 24[3]		
acetone	0.785 44	0.784 50[7]	0.307	0.3029[3]
		0.783 45[7]		0.3040[9]
		0.784 00[7]		0.3075[10]
		0.784 40[6]		0.3160[11]

From the measured densities (see Table 2) the excess values of molar volumes V^E of the mixtures, at each investigated temperature, were fitted to the equation

$$V^E = x_1 M_1(\rho^{-1} - \rho_1^{-1}) + x_2 M_2(\rho^{-1} - \rho_2^{-1}) \qquad (1)$$

where M_1 and M_2 are the molar masses of the pure components and ρ_1, ρ_2, and ρ are the densities of the pure species (1 and 2) and of the mixtures at different temperatures, respectively. The values of V^E of the binary mixtures, at 298.15 K, are shown graphically in Figure 1.

The deviation of the viscosity from a mole fraction average was calculated by

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

where η_1, η_2, and η are the viscosities of 2-methoxyethanol, acetone, and the mixtures, respectively. The values of $\Delta\eta$ of the binary mixtures are shown graphically in Figure 2.

Excess volume and deviations of viscosity were fitted by a Redlich−Kister type equation:

V^E/cm^3·mol^{-1} or

$$\Delta\eta/\text{mPa·s} = x_1(1 - x_1)\sum_{j=0}^{k} A_j(2x_2 - 1)^j \qquad (3)$$

The parameters A_j of eq 3 were evaluated by the least-squares method. The values of these parameters, at each studied temperature, with standard deviation $\sigma(V^E)$, are summarized in Table 3.

* To whom correspondence should be addressed. E-mail: ckinart@krysia.uni.lodz.pl.
† Department of Chemistry, University of Łódź.
‡ Department of Organic Chemistry, University of Łodź.

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Table 2. Experimental Density and Viscosity for 2-Methoxyethanol (1) + Acetone (2) Binary Mixtures

	ρ/g·cm^{-3}					η/mPa·s		
x_1	T/K = 291.15	T/K = 293.15	T/K = 298.15	T/K = 303.15	T/K = 308.15	T/K = 293.15	T/K = 298.15	T/K = 303.15
0.0000	0.792 67	0.790 02	0.784 45	0.780 39	0.777 84	0.321	0.307	0.298
0.0508	0.803 31	0.800 45	0.794 53	0.790 33	0.787 56	0.373	0.356	0.342
0.1006	0.813 83	0.810 85	0.804 83	0.800 45	0.797 46	0.439	0.416	0.397
0.1509	0.824 46	0.821 45	0.815 49	0.810 93	0.807 80	0.507	0.477	0.453
0.2015	0.834 22	0.831 25	0.825 40	0.820 71	0.817 43	0.563	0.527	0.500
0.2496	0.844 31	0.841 43	0.835 70	0.830 92	0.827 52	0.613	0.572	0.541
0.2998	0.853 63	0.850 82	0.845 18	0.840 40	0.836 86	0.652	0.607	0.574
0.3510	0.862 73	0.860 02	0.854 42	0.849 66	0.846 04	0.688	0.640	0.603
0.3995	0.871 72	0.869 10	0.863 52	0.858 83	0.855 08	0.726	0.673	0.632
0.4503	0.880 46	0.877 92	0.872 35	0.867 71	0.863 87	0.767	0.709	0.663
0.5006	0.889 09	0.886 61	0.881 05	0.876 44	0.872 50	0.818	0.753	0.700
0.5504	0.897 38	0.894 94	0.889 40	0.884 79	0.880 75	0.875	0.804	0.742
0.6007	0.905 45	0.903 05	0.897 56	0.892 92	0.888 76	0.941	0.861	0.790
0.6496	0.913 41	0.911 05	0.905 62	0.900 93	0.896 67	1.012	0.923	0.845
0.6998	0.921 48	0.919 15	0.913 80	0.909 06	0.904 67	1.090	0.991	0.905
0.7502	0.929 60	0.927 31	0.922 05	0.917 26	0.912 77	1.170	1.062	0.969
0.8004	0.937 20	0.934 97	0.929 79	0.924 99	0.920 40	1.248	1.132	1.033
0.8511	0.945 16	0.943 03	0.937 92	0.933 17	0.928 49	1.333	1.209	1.106
0.8999	0.952 18	0.950 15	0.945 14	0.940 46	0.935 74	1.419	1.287	1.179
0.9503	0.959 71	0.957 84	0.953 00	0.947 40	0.943 70	1.542	1.398	1.278
1.0000	0.966 52	0.964 88	0.960 29	0.955 76	0.951 10	1.708	1.544	1.404

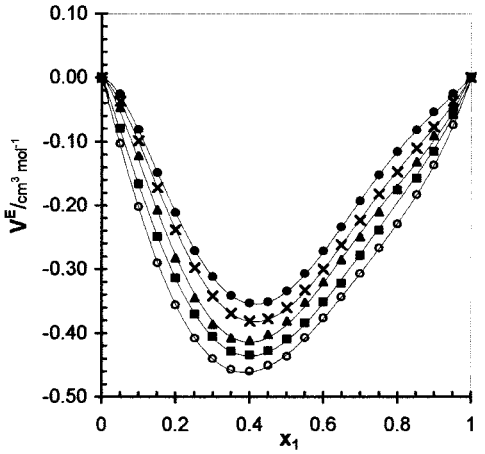

Figure 1. Excess molar volumes (V^E) for 2-methoxyethanol (1) + acetone (2), at 291.15 K (○), 293.15 K (■), 298.15 K (▲), 303.15 K (×), and 308.15 K (●).

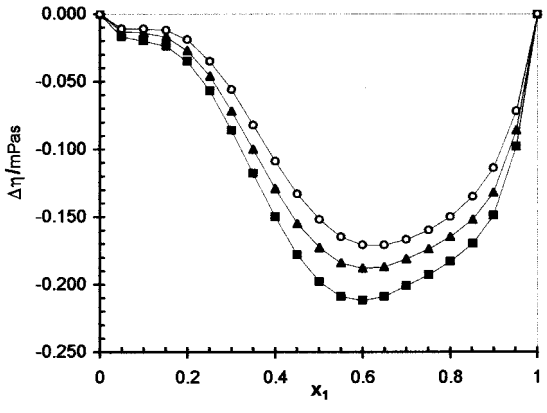

Figure 2. Deviations of viscosity ($\Delta\eta$) for 2-methoxyethanol (1) + acetone (2), at 293.15 K (■), 298.15 K (▲), and 303.15 K (○).

Standard deviation values were obtained from

$$\sigma = \left[\frac{\sum(X_{\text{exptl}} - X_{\text{calcd}})^2}{n - p}\right]^{1/2} \qquad (4)$$

where n is the number of experimental points, p is the number of parameters, and X_{exptl} and X_{calcd} are the experimental and calculated properties.

Table 3. Parameters A_i of Equation 3 and Standard Deviations σ

	A_0	A_1	A_2	A_3	A_4	σ
			T/K = 291.15 K			
V^E/cm^3·mol^{-1}	−1.6555	0.8511	−0.4437	−0.6718	0.3392	0.009
			T/K = 293.15 K			
V^E/cm^3·mol^{-1}	−1.5840	0.7965	−0.0342	−0.7088	0.2721	0.005
$\Delta\eta$/mPa·s	−0.7908	−0.6236	0.9754	−0.4155	−1.8760	0.002
			T/K = 298.15 K			
V^E/cm^3·mol^{-1}	−1.4685	0.9187	−0.1021	−1.1200	0.9815	0.005
$\Delta\eta$/mPa·s	−0.6916	−0.6004	0.8174	−0.3333	−1.5641	0.001
			T/K = 303.15 K			
V^E/cm^3·mol^{-1}	−1.3904	0.7904	0.5625	−1.0251	0.2112	0.006
$\Delta\eta$/mPa·s	−0.6007	−0.6435	0.6766	−0.1064	−1.2642	0.001
			T/K = 308.15 K			
V^E/cm^3·mol^{-1}	−1.2780	0.7720	0.6895	−0.9302	0.3209	0.006

Figure 1 shows that V^E values are all negative and that they become less negative when temperature decreases, with the minimum lying always near $x_1 = 0.4$. The trends in the viscosity deviation values are all negative too, and they become less negative when temperature decreases (see Figure 2), with the minimum lying always near $x_1 = 0.6$.

The conclusion to be drawn from all these results is that the molecules of a 2-methoxyethanol + acetone mixed solvent may be joined by dipolar and/or hydrogen bonds to form stable adducts of 2:3 and 3:2 stoichiometry.

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