Viscosities, Densities, and Excess Volumes at Various Temperatures for 2-Methoxyethanol (1) + 2-Butanone (2)

M. de Ruiz Holgado, C. de Schaefer, and E. L. Arancibia*

Cátedra de Fisicoquímica, Instituto de Ingeniería Química, Facultad de Ciencias Exactas y Tecnología, Universidad Nacional de Tucumán Avda Independencia 1800, 4000 San Miguel de Tucumán, Tucumán, Argentina

Densities (ρ) and viscosities (η) of binary mixtures of 2-methoxyethanol (1) + 2-butanone (2) at five temperatures, between 5 °C and 45 °C, are reported. Excess molar volumes (V^E) are calculated.

Introduction

The knowledge of transport and thermodynamic properties of binary liquid mixtures formed by one or more components associated through hydrogen bonds is important from theoretical and process design points of view.

This paper reports densities and viscosities of the 2-methoxyethanol (1) + 2-butanone (2) mixtures at different temperatures. 2-Methoxyethanol is a solvent of great industrial interest and theoretical importance in the study of solutions because it contains two functional groups. In previous works (Reddy et al., 1995; Corradini et al., 1994), some properties of binary mixtures of 2-methoxyethanol with water and other solvents have been studied.

Viscosities and densities were determined over the whole composition range of the mixtures, at five different temperatures in the range from 5 °C to 45 °C.

Experimental Section

Materials. 2-Methoxyethanol and 2-butanone, Merck, pro-analysis, containing less than 0.10% and 0.05% (w/w) of water, respectively (determined by Karl-Fischer method), were used. Solvents were passed through a column with molecular sieves (3 Å) and stored in them before using. Density and viscosity values of the pure components, together with literature values, at 25 °C, are included in Table 1.

Equipment and Procedure. Viscosities were measured with a Schott-Gerate viscosimeter, AVS 400 model, which contains a Ubbelohde calibrated viscosimeter using the range $0.2 \le \nu \le 3$ mm^2·s^{-1}. The error in viscosity was 10^{-3} mPa·s.

The dynamic viscosity η was determined from the following relationship:

$$\eta = \rho k(t - c) \tag{1}$$

where t, k, c, and ρ are respectively the flow time, the viscometer constant, the Hagenbach correction, and density. Measurements were made in a Lauda, FK model, thermostatic bath with a temperature control of ±0.02 °C. Densities were determined in a digital densimeter Anton Paar, DMA 45 model, with a resolution of 1×10^{-4} g·cm^{-3}.

Mixtures were prepared by weighing their components on a Mettler H315 balance with a resolution of 1×10^{-4} g, in closed bottles. Caution was taken to prevent evaporation. The estimated error in molar fraction was less than 1.5×10^{-4}.

* To whom correspondence should be addressed. Fax: 54-(481)-248025. E-mail: NORMA@UNTSOL.EDU.AR.

Table 1. Data for Pure Liquids at the Temperature 25 °C

liquid	TRC values	ρ/g·cm^{-3} exptl	ρ/g·cm^{-3} lit	η/mPa·s exptl	η/mPa·s lit
2-methoxyethanol	0.960 200	0.9601	0.960 02[a] 0.9602 88[b] 0.960 24[c]	1.552	1.5414[a]
2-butanone	0.800 02	0.7999	0.799 7[c] 0.799 71[d] 0.799 66[e]	0.378	0.374[e]

[a] Das and Hazra (1993). [b] Marcheselli et al. (1992). [c] Riddick et al. (1986). [d] Comelli and Francesconi (1994). [e] Petrino et al. (1995).

Results and Discussion

The values of density and absolute viscosity, for different molar fractions and temperatures, are shown in Table 2.

The density values obtained were converted into excess molar volumes (V^E), using the following equation:

$$V^E = x_1 M_1\left(\frac{1}{\rho} - \frac{1}{\rho_1}\right) + x_2 M_2\left(\frac{1}{\rho} - \frac{1}{\rho_2}\right) \tag{2}$$

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 that of the mixture at different temperatures, respectively. The values of V^E of the binary mixture are shown graphically in Figure 1.

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

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

where η_1, η_2, and η are the absolute viscosities of the 2-methoxyethanol, 2-butanone, and the mixtures, respectively.

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

$$V^E/\text{cm}^3\text{·mol}^{-1} \text{ or } \Delta\eta/\text{mPa·s} = x_1(1 - x_1)\sum_{i=0}^{n} A_i(1 - 2x_1)^i \tag{4}$$

A_i are adjustable parameters calculated by the least-squares method. The values of these parameters, at each studied temperature, together with the standard deviation σ, are summarized in Table 3.

Standard deviation values were obtained from

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

S0021-9568(96)00137-9 CCC: $12.00

Table 2. Densities and Viscosities at Different Temperatures

	ρ/g·cm^{-3}					η/mPa·s				
x_1	278.15 K	288.15 K	298.15 K	308.15 K	318.15 K	278.15 K	288.15 K	298.15 K	308.15 K	318.15 K
0.0000	0.8207	0.8103	0.7999	0.7893	0.7785	0.469	0.419	0.378	0.342	0.311
0.1014	0.8362	0.8260	0.8158	0.8053	0.7947	0.543	0.478	0.423	0.378	0.339
0.2118	0.8535	0.8435	0.8334	0.8231	0.8127	0.621	0.540	0.474	0.419	0.373
0.3001	0.8675	0.8576	0.8477	0.8375	0.8272	0.691	0.603	0.530	0.469	0.418
0.3864	0.8811	0.8714	0.8616	0.8516	0.8413	0.776	0.674	0.591	0.521	0.463
0.4984	0.8988	0.8893	0.8797	0.8698	0.8597	0.935	0.802	0.695	0.607	0.534
0.6010	0.9151	0.9057	0.8962	0.8864	0.8765	1.105	0.938	0.805	0.696	0.607
0.6950	0.9301	0.9207	0.9113	0.9017	0.8920	1.321	1.107	0.938	0.802	0.692
0.8004	0.9468	0.9375	0.9282	0.9186	0.9090	1.632	1.344	1.120	0.945	0.803
0.9019	0.9627	0.9534	0.9442	0.9348	0.9254	2.006	1.625	1.334	1.108	0.931
1.0000	0.9784	0.9692	0.9601	0.9509	0.9417	2.439	1.931	1.552	1.264	1.042

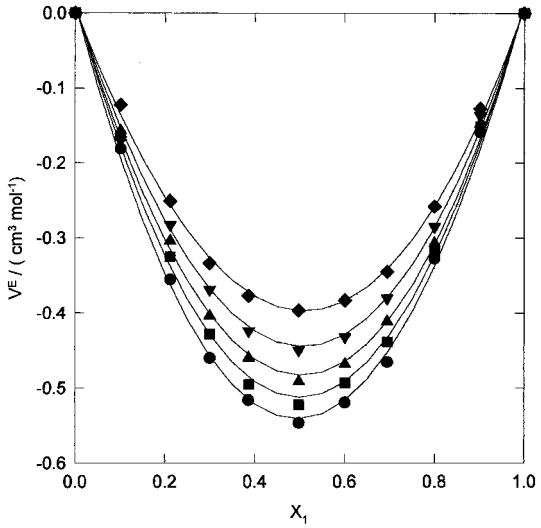

Figure 1. Excess molar volume of 2-methoxyethanol (1) + 2-butanone (2) at different temperatures: (◆) 5 °C; (▼) 15 °C; (▲) 25 °C; (■) 35 °C; (●) 45 °C. Continous curves were calculated from eq. 4.

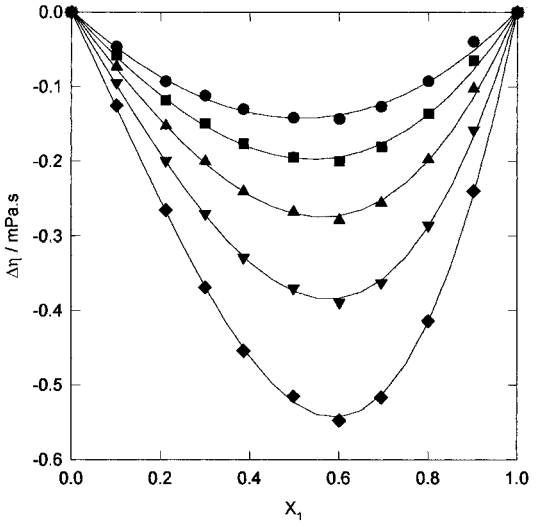

Figure 2. Deviations of absolute viscosity of 2-methoxyethanol (1) + 2-butanone (2) at different temperatures. Continuous curves were calculated from eq 4. Symbols as in the legend to Figure 1.

Table 3. Parameters A_i of Equation 4 and Standard Deviations σ

	A_0	A_1	A_2	σ
	T = 278.15 K			
V^E/(cm^3·mol^{-1})	−1.613	0.068	0.228	0.006
$\Delta\eta$/mPa·s	−2.099	0.852	0.058	0.005
	T = 288.15 K			
V^E/(cm^3·mol^{-1})	−1.814	0.050	0.315	0.005
$\Delta\eta$/mPa·s	−1.510	0.510	0.103	0.004
	T = 298.15 K			
V^E/(cm^3·mol^{-1})	−1.972	0.037	0.350	0.005
$\Delta\eta$/mPa·s	−1.093	0.284	0.113	0.004
	T = 308.15 K			
V^E/(cm^3·mol^{-1})	−2.103	0.001	0.457	0.005
$\Delta\eta$/mPa·s	−0.795	0.135	0.106	0.004
	T = 318.15 K			
V^E/(cm^3·mol^{-1})	−2.208	−0.050	0.379	0.007
$\Delta\eta$/mPa·s	−0.579	0.035	0.091	0.005

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.

Figure 1 shows that V^E values are all negative and that they become less negative when the temperature decreases, with the minimum lying always near $x_1 = 0.5$. The range of maximum V^E values is between −0.4 and −0.55 cm^3·mol^{-1}. The trends in the viscosity deviation values are similar to those of the excess volumes, the maximum $\Delta\eta$ are between −0.55 and −0.15 mPa·s at different temperatures, as can be seen in Figure 2 with the minimun near $x_1 = 0.6$.

Literature Cited

Comelli, F.; Francesconi, R. Densities and excess molar volumes of dimethyl carbonate + six methyl n-alkyl ketones at 298.15 K and atmospheric pressure. *J. Chem. Eng. Data* **1994**, *39*, 108−110.

Corradini, F.; Marcheselli, L.; Marchetti, A.; Tagliazuchi, M.; Tassi, L.; Tosi, G. 2-Methoxyethanol-water solvent system: static relative permittivity from −10 to + 80 °C. *J. Chem. Soc., Faraday Trans.* **1994**, *90* (6), 859−864.

Das, B.; Hazra, D. K. Viscosities and excess molar volumes for 2-methoxy-1-ethanol + water at different temperatures. *J. Chem. Eng. Data* **1993**, *38*, 361−363.

Marcheselli, L.; Marchette, M.; Tagliazuchi, M.; Tassi, L.; Tosi, G. N,N-Dimethylformamide-2-methoxyethanol solvent system. Densities and excess molar volumes at various temperatures. *J. Chem. Soc., Faraday Trans.* **1992**, *28* (21), 3159−3163.

Petrino, P. J.; Gaston-Bonhomme, Y. H.; Chevalier, J. L. E. Viscosity and density of binary liquid mixtures of hydrocarbons, esters, ketones, and normal chloroalkanes. *J. Chem. Eng. Data* **1995**, *40*, 136−140.

Reddy, V. K.; Rambabu, K.; Devarajulu, T.; Krishnaiah, A. Volume of mixing, speed of sound, and viscosity of methyl cellosolve with aliphatic alcohols at 308.15 K. *J. Chem. Eng. Data* **1995**, *40*, 124−127.

Riddick, J. A.; Bunger, W. B.; Sakano, T. K. *Organic Solvents*, 4th ed.; John Wiley and Sons: New York, 1986.

Received for review April 12, 1996. Accepted August 13, 1996.[⊗] The present work was financed by a CIUNT (Consejo de Investigaciones de la Universidad Nacional de Tucumán) research grant.

JE960137Y

[⊗] Abstract published in *Advance ACS Abstracts*, October 1, 1996.