JOURNAL OF CHEMICAL & ENGINEERING DATA

SHORT ARTICLE

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Viscometric Behavior of Binary Mixtures of Butan-2-one with Benzene at T = (303.15, 313.15, and 323.15) K

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ABSTRACT: Viscosities of binary liquid mixtures of butan-2-one with benzene were measured at a number of mole fractions at T = (303.15, 313.15, and 323.15) K and atmospheric pressure. The viscometric behavior is discussed on the basis of structural and geometrical effects between the components. In addition, kinematic viscosities were calculated using the UNIFAC−VISCO model. The predicted kinematic viscosities are in good agreement with the experimental ones.

INTRODUCTION

The nature of the interaction among polar and nonpolar liquid mixtures is important for understanding their behavior in analytical applications such as conductometric, potentiometric, and electroanalytical techniques that work in mixed solvents, chromatographic applications, etc.[1−4] These data are also useful in process engineering design applications and other related areas and have drawn considerable attention from many investigators.[5−20] In this work, which is a part of our research[21−26] on the accumulation of physical property data of binary organic liquid mixtures, we present here viscosity data for binary mixtures of butan-2-one with benzene at T = (303.15, 313.15, and 323.15) K. The density data for the same system were reported previously.[23]

The aprotic and protophilic liquid butan-2-one (dipole moment, μ_1 = 2.8 D; relative permittivity at 20 °C, $\varepsilon^{20°C}$ = 18.5)[27] herein is considered as the solute, while the apolar, aprotic, and nonprotophilic liquid benzene (μ_1 = 0 D, $\varepsilon^{20°C}$ = 2.28)[27] is considered as the solvent. Both liquids are widely used as solvents in scientific studies and industrial applications. The experimental data are interpreted using some previous observations for the binary systems. In addition, kinematic viscosities predicted using the UNIFAC−VISCO model[28,29] are compared with the experimental ones.

In the literature, there are reports on the viscometric behavior of binary systems of butan-2-one with benzene at temperatures other than those reported in this work,[30−36] and Jayalakshmi and Reddy[37] have reported data at T = 303.15 K. However, no experimental viscosity data for mixtures of butan-2-one with benzene under comparable conditions at T = (313.15 and 323.15) K are available.

EXPERIMENTAL SECTION

Butan-2-one (Merck, 0.98 mass fraction purity) and benzene (BDH, 0.99 mass fraction purity) were used without further treatment. The solvent purity was ascertained by comparing the densities and viscosities of the liquids with the available literature data (Table 1).

Table 1. Comparison of Experimental Densities (ρ_{exp}) and Viscosities (η_{exp}) of Pure Liquids with Literature Values at T = 303.15 K

	ρ_{exp}/g·cm^{-3}			η_{exp}/mPa·s		
liquid	exp	lit	ref	exp	lit	ref
butan-2-one	0.7946	0.7946	40	0.367	0.366	40
		0.7948	41		0.372	42
benzene	0.8681	0.8683	41	0.564	0.562	40
		0.8684	43		0.560	43

All of the binary mixtures were prepared by mass on an analytical balance (B204-S, Mettler Toledo, Greifensee, Switzerland) with an uncertainty of ± 0.0001 g and operating in a drybox. Mixtures were made just before use and were completely miscible over the whole composition range. Caution was taken to prevent evaporation of the samples after preparation. The uncertainty in the mole fraction was estimated to be less than $\pm 1 \cdot 10^{-4}$. The densities of liquids were measured using a 25 mL specific gravity bottle that had previously been calibrated with redistilled water with an average uncertainty of 0.0002 g·cm^{-3}. The uncertainties in the viscosities were on the order of ± 0.005 mPa·s. An A-type Ostwald viscometer previously calibrated with redistilled water was used to measure the viscosities. An electronic digital stopwatch with an uncertainty of ± 0.01 s was used for flow time measurements. A transparent glass-walled thermostatic water bath was used, and the uncertainty in the temperature during the measurements was ± 0.05 K. For all of the mixture compositions and the pure solvents, triplicate measurements were performed, and the average of these values was considered in all calculations.

Special Issue: John M. Prausnitz Festschrift

Received: November 11, 2010
Accepted: January 18, 2011
Published: February 08, 2011

Table 2. Composition and Experimental Viscosities (η_{exp}) for Binary Mixtures of Butan-2-one (1) with Benzene (2) at T = (303.15, 313.15, and 323.15) K

	η_{exp}/mPa·s		
x_1	T = 303.15 K	T = 313.15 K	T = 323.15 K
0	0.564	0.498	0.442
0.1010	0.534	0.473	0.422
0.1999	0.508	0.448	0.403
0.2988	0.478	0.427	0.384
0.3969	0.452	0.409	0.369
0.4996	0.432	0.393	0.354
0.5988	0.417	0.378	0.343
0.6993	0.401	0.367	0.333
0.7931	0.389	0.355	0.324
0.8961	0.376	0.345	0.316
1	0.367	0.334	0.306

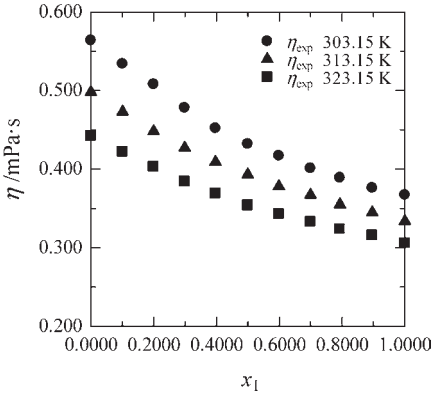

Figure 1. Experimental viscosities for the system butan-2-one (1) + benzene (2) at T = (303.15, 313.15, and 323.15) K.

RESULTS AND DISCUSSION

The binary compositions and experimental viscosities (η_{exp}) at all of the investigated temperatures are summarized in Table 2. Values of η_{exp} for the binary mixtures of butan-2-one and benzene as a function of the mole fraction of butan-2-one (x_1) at T = (303.15, 313.15, and 323.15) K are shown in Figure 1. It can be observed that upon the addition of butan-2-one to benzene, the viscosity decreases slowly up to a substantial concentration of ketone. The viscosity of a mixture strongly depends on the structures and bond enthalpies of the liquids and consequently on the molecular interactions between the components of the mixture.[38] The positive values of η_{exp} can be attributed to the dispersion-type interaction between butan-2-one and benzene.[39] Butan-2-one, like all other linear ketones, has a stiff propanone skeleton and is less inflexible than other linear organic solvents.[10] However, a butan-2-one molecule has a light molecular structure relative to the other linear ketones. Therefore, in the low-concentration region, a butan-2-one molecule may be able to orient itself into a less flow-resistant arrangement as a result of the dispersion force created from the apolar organic solvent benzene, resulting in a decrease in the viscosity. The inflexible nature of butan-2-one becomes the major influencing force in the high-concentration region. The viscosity values reveal that the magnitude of the positive η_{exp} values decreases with increasing temperature [i.e., $(d\eta_{exp}/dT)_p$ is negative].

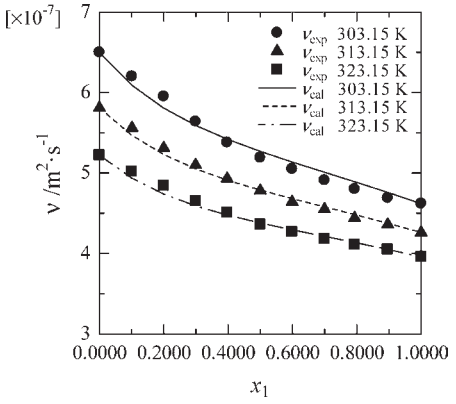

Figure 2. Kinematic viscosities for the butan-2-one (1) + benzene (2) system at T = (303.15, 313.15, and 323.15) K.

Table 3. Comparison of the Kinematic Viscosities Predicted Using the UNIFAC−VISCO Model and the Experimental Values

T/K	AAD/%	$\lvert E_{\nu,i}\rvert_{max}$/%
303.15	1.21	2.4
313.15	0.64	1.7
323.15	0.70	2.1

In Figure 2, kinematic viscosities predicted using the UNIFAC−VISCO model are compared with the experimental values. Experimental kinematic viscosities (ν_{exp}) were calculated from the experimental viscosities η_{exp} (Table 2) and the densities ρ_{exp} obtained in our previous study[23] using the following equation:

$$\nu_{exp}/m^2\cdot s^{-1} = \frac{(\eta_{exp}/Pa\cdot s)}{(\rho_{exp}/kg\cdot m^{-3})} \quad (1)$$

It should be noted that the unit for the viscosities was changed in the calculations. As can be seen from the figure, the kinematic viscosities obtained using the UNIFAC−VISCO model are in good agreement with the experimental ones. The relative errors ($E_{\nu,i}$) and the absolute average differences (AAD), values of which are shown in Table 3, were computed using the following equations:

$$E_{\nu,i} = \frac{\nu_{exp,i} - \nu_{cal,i}}{\nu_{exp,i}} \times 100\ \% \quad (2)$$

$$AAD = \frac{1}{N_p}\sum_{i=1}^{N_p} |E_{\nu,i}| \quad (3)$$

where i denotes the i-th experimental data value and N_p is the number of experimental data values at each temperature. At each of the temperatures studied, the maximum error was observed at around 0.2 mol fraction of butan-2-one but was only about 2.0 %. Therefore, the UNIFAC−VISCO model seems to have a sufficient predictability for the system over the temperature range studied.

CONCLUSIONS

Viscosities for binary mixtures of butan-2-one with benzene have been measured at several temperatures over the whole composition range. A systematic change with increasing temperature was observed for η_{exp}. Interactions between the components in

dx.doi.org/10.1021/je1011604 |J. Chem. Eng. Data 2011, 56, 1718–1721

binary mixtures have been used to interpret the observed viscometric behavior. Furthermore, the kinematic viscosities predicted using the UNIFAC−VISCO model are in good agreement with the experimental ones.

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ACKNOWLEDGMENT

The authors are grateful to the Kanazawa University authorities for providing the necessary opportunities to accomplish the research work. I.M.M.R. acknowledges the support from the Japanese Government (Monbukagakusho: MEXT) Scholarship program that facilitated this research.

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