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Research Article

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Densities and viscosities of binary mixtures of methyl ethyl ketone with ethyl benzene at 303.15, 308.15, 313.15 K and atmospheric pressure

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ABSTRACT

The experimental densities and viscosities of Methyl Ethyl Ketone with Ethyl Benzene at temperatures of 303.15, 308.15 and 313.15 K were determined using a Ostwold-Sprengal- type pycnometer and Oswald Viscometer. From these data, excess molar volumes and viscosity deviations have been calculated. The computed quantities have been fitted to the Redlich-Kister equation to derive the coefficients and estimate the standard error values. The results are discussed in terms of the intermolecular interactions.

Keywords: Density**,** Ethyl Benzene, Excess molar volume, MEK, Viscosity deviation

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INTRODUCTION

The physical properties of a binary mixture such as viscosity and density are important from practical and theoretical points of view to understand liquid theory. These properties are extremely useful for the design of many types of transport and process equipment in chemical industries. A large amount of experiments [1-10] have been conducted to measure the densities and viscosities of liquid mixtures; however, reliable density and viscosity data over a wide range of composition and temperature for different systems are still needed.

Literature survey showed that no measurements have been previously reported for the Methyl Ethyl Ketone with Ethyl Benzene binary mixture. The objective of the present investigation was to find out the density (ρ), viscosity (η), Excess molar volume (V^E) and viscosity deviation (Δη) of pure MEK and Ethyl Benzene as well as for the binary system constituted by these chemicals at 303.15, 308.15 and 313.15K.

In the present paper, we report viscosity and density data for Methyl Ethyl Ketone with Ethyl Benzene at temperatures of 303.15 K, 308.15 K, and 313.15 K and at atmospheric pressure. The experimental data were used to calculate deviations in viscosity Δη and excess molar volumes V^E of the mixtures. The computed quantities have been fitted to the Redlich-Kister equation [11, 25] to derive the coefficients and estimate the standard error values. The results are discussed in terms of the intermolecular interactions.

EXPERIMENTAL SECTION

Materials

The chemicals used were of analytical grade and obtained from Adlab. All components were further purified according to methods recommended by Riddick and Bunger [11]. The purities of the chemicals given in Table 1 were verified by the measurement of the density and viscosity at 303.15 K and are in good agreement with literature values.

Apparatus and Procedure

Densities of the liquid and liquid mixtures were measured with an Ostwold-Sprengal- type pycnometer [1] having a bulk volume of 25 cm^3 and an internal diameter of the capillary of about 1 mm.

The pyknometer was calibrated at 303.15 K with doubly distilled water. A thermostatically controlled well-stirred water bath whose temperature was controlled to 0.01 K was used for all the measurements. Binary mixtures were prepared using an electronic balance Shimadzu, BL2205. The possible error in the mole fraction is estimated to be less than 0.0001. The kinematic viscosities were measured at the desired temperature using an Oswald Viscometer supplied by SAI Scientific Company, Madras. The viscometer was calibrated using water, and the two constants a and b of the viscometer in the relation [12, 13, 14, 16]

$$\nu = (at) - (b/t) \quad (1)$$

Where ν is the kinematic viscosity, a and b is the constants and t is the time, above equation (1) was obtained by measuring the flow time t with high-purity benzene at the working temperature. The averages of five sets of flow times were taken for the purpose of the calculations of viscosity. The flow time was measured with an accurate stopwatch having a precision of 0.01 s. Viscosities are reproducible to 0.003 m.Pa.s.

RESULTS AND DISCUSSION

Excess molar volume [15, 17-19] and viscosity deviations were calculated from our measurements according to the following equation

$$V^E = (x_1M_1 + x_2M_2)/\rho_m - (x_1M_1/\rho_1 + x_2M_2/\rho_2) \quad (2)$$

Where x_1 and x_2 are mole fractions, M_1 and M_2 are molar masses, and $\boldsymbol{\rho_1}$ and $\boldsymbol{\rho_2}$ are the densities of pure components 1 and 2, respectively. Quantities without subscripts refer to the mixture.

The viscosity deviations [20-24] were calculated from the following relation

$$\Delta\eta = \eta_{12} - (x_1\eta_1 + x_2\eta_2) \quad (3)$$

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

The values of V^E and Δη for each mixture were fitted to the Redlich-Kister polynomial equation [11, 25]

$$V^E = x_1x_2 \sum a_{i-1}(x1 - x2)^{i-1} \quad (4)$$

a_{i-1} are adjustable parameters, and x_1 and x_2 is the mole fraction of component 1 and 2.

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

$$\sigma(V^E) = [\sum(V^E_{exp} - V_{cal}{}^E)^2/(N - m)]^{1/2} \quad (5)$$

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

The Experimental 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.

Table 1. Comparison of Experimental and Literature Values of Densities (ρ) and Viscosities (η) for pure compounds

Liquid	Temperature T/K	P ($g.cm^{-3}$)		η (m pa.s)	
		Exptl	Lit	Exptl	Lit
MEK	303.15	1.0945	1.0957	0.7179	0.7180
	308.15	1.0904	1.0905	0.6793	0.6749
	313.15	1.0848	1.0848	0.6312	0.6311
EthylBenzene	303.15	0.8536	0.8538	0.5685	0.5688
	308.15	0.7890	0.7889	0.3460	0.3464
	313.15	0.7844	0.7844	0.3368	0.3368

Table 2. Experimental Densities (ρ), Viscosities (η), Excess Molar Volumes (V^E), and Viscosity Deviations (Δη) for MEK with Ethyl Benzene at Different Temperatures

X_1	ρ ($g.cm^{-3}$)	V^E (cm^{-3}. gmole)	γ (c.S)	η (m pa.s)	Δη (m pa.s)
		T=303.15K			
0	1.0957	0.0000	0.7180	0.7867	0.0000
0.1117	1.04113	0.2258	0.6951	0.7236	-0.0354
0.2206	0.9170	0.3632	0.6857	0.6287	-0.0651
0.3267	0.9138	0.4712	0.6661	0.6086	-0.0851
0.4301	0.9048	0.5278	0.6345	0.5740	-0.0985
0.5310	0.8576	0.5570	0.6054	0.5191	-0.0983
0.6294	0.8449	0.5601	0.5601	0.4732	-0.0905
0.7254	0.8445	0.5159	0.5339	0.4508	-0.0785
0.8191	0.8377	0.4213	0.5334	0.4468	-0.0652
0.9106	0.7990	0.2684	0.5288	0.4225	-0.0342
1.0000	0.7850	0.0000	0.3559	0.2828	0.0000
		T=308.15K			
0	1.0904	0.0000	0.6793	0.7407	0.0000
0.1117	0.9987	0.1586	0.6629	0.6621	-0.0235
0.2206	0.9658	0.2953	0.6389	0.6170	-0.0495
0.3267	0.8995	0.4256	0.6157	0.5538	-0.0666
0.4301	0.8584	0.4985	0.5591	0.4799	-0.0792
0.5310	0.8201	0.5269	0.5390	0.4420	-0.0796
0.6294	0.8055	0.5270	0.5305	0.4273	-0.0753
0.7254	0.8023	0.4596	0.5290	0.4244	-0.0654
0.8191	0.8001	0.3521	0.5201	0.4241	-0.0503
0.9106	0.7999	0.2019	0.5192	0.4053	-0.0218
1.0000	0.7890	0.0000	0.3460	0.2729	0.0000
		T=313.15K			
0	1.0848	0.0000	0.6311	0.6847	0.0000
0.1117	1.0229	0.0996	0.6188	0.6330	-0.0192
0.2296	0.9956	0.2336	0.6031	0.6005	-0.0395
0.3267	0.9843	0.3596	0.6019	0.5925	-0.0556
0.4301	0.9533	0.4486	0.5751	0.5482	-0.0670
0.5310	0.8899	0.4999	0.5477	0.4874	-0.0706
0.6294	0.8517	0.4989	0.5389	0.4590	-0.0653
0.7254	0.8366	0.4269	0.5311	0.4443	-0.0524
0.8191	0.8299	0.3021	0.5291	0.4391	-0.0395
0.9106	0.7998	0.1596	0.5406	0.4324	-0.0158
1.0000	0.7844	0.0000	0.3368	0.2641	0.0000

Table 3. Parameters of the Redlich Kister Constants and standard deviations SD for Excess Volume of Methyl Ethyl Ketone with Ethyl Benzene

Temperature T/K	a_1	a_2	a_3	a_4	a_5	SD
303.15	0.4640	0.2255	-0.2576	0.8132	-0.7095	0.9987
308.15	-0.9461	-0.5205	0.3579	0.9812	-0.8637	0.0852
313.15	-0.8079	0.1402	0.3452	0.9786	-0.5392	0.9991

Standard deviations SD for Viscosity Deviation

303.15	-0.9617	0.1609	-0.8743	-0.5976	0.5607	0.7025
308.15	-0.46517	0.3869	-0.4587	-0.3678	0.8116	0.8950
313.15	-0.8315	0.6016	-0.2801	-0.4811	0.4969	0.9876

V^E against x_1 plots of the three Different temperatures are shown in Figure 1, The V^E values of binary mixtures result from the chemical, physical, and structural characteristics of liquids. Physical effects contribute to positive V^E; chemical and structural effects contribute to negative V^E. In the negative V^E values are attributed to changes in free volume in the mixture of electron donor-acceptor type interactions between MEK and Ethyl Benzene (Ethyl Benzene being a π-electron donor). In the present system positive V^E arises due to breaking of H-bonds in the self-associated MEK and steric hindrance due to the bulky Ethyl Benzene. The sigmoidal shape of V^E observed in the Methyl Ethyl Ketone with Ethyl Benzene systems is attributed to varying interactions between relatively large positive and negative contributions; their magnitudes are sensitive to the length of the component molecules.

For a mixture of Methyl Ethyl Ketone with Ethyl Benzene, these two molecules are nonpolar. There are only physical intermolecular forces between unlike molecules. Owing to the difference in shape, size, and free volume, the excess volumes are positive for mixtures of MEK with Ethyl Benzene. The positive V^E values result from breaking up of H- bonding in aromatic compounds and also the size of these molecules. The excess molar volumes decrease with increasing temperature.

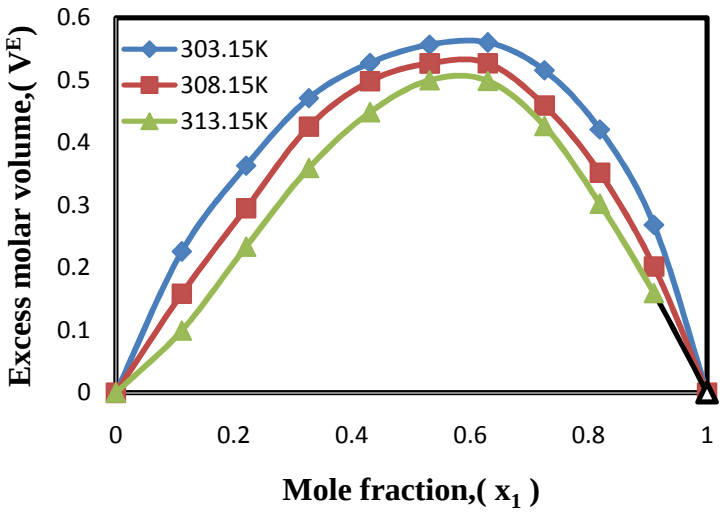

Figure 1. Excess molar volume (V^E) for Methyl Ethyl Ketone with Ethyl benzene at 303.15, 308.15and313.15K

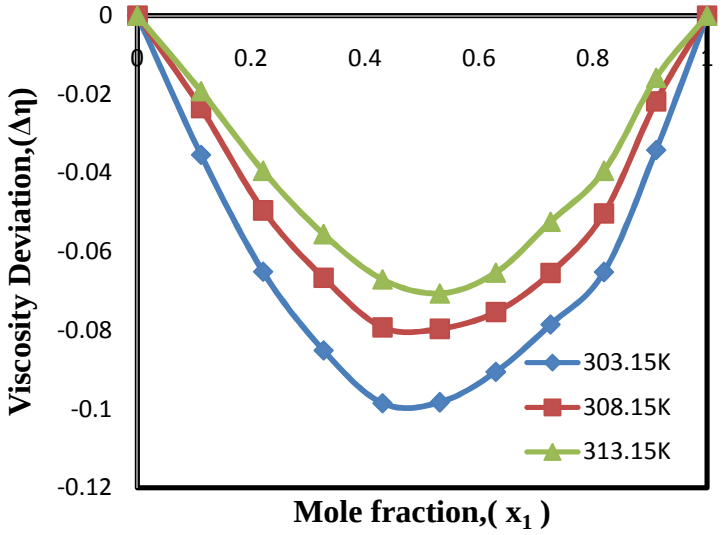

Figure 2. Deviation in Viscosity (Δη) for Methyl Ethyl Ketone with Ethylbenzene at 303.15, 308.15 and 313.15K

Figure 2 illustrate the viscosity deviations for these three different temperature binary mixture, 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. For Methyl Ethyl Ketone with Ethyl Benzene mixture, the curves are almost symmetrical. The Δη values are negative for binary mixture and increase with increasing temperature. Very small viscosity deviations are observed for the system Methyl Ethyl Ketone with Ethyl Benzene at 303.15, 308.15 and 313.15 K, indicating that at high temperature these systems are likely close to ideal systems.

CONCLUSION

Densities and viscosities for Methyl Ethyl Ketone with Ethyl Benzene at temperatures of 303.15, 308.15 and 313.15 K, have been experimentally determined 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 the binary mixtures of Methyl Ethyl Ketone with Ethyl Benze are positive. On the contrary, the deviations in viscosity for these systems at selected temperatures are all negative over the entire composition. The absolute viscosity deviations for Methyl Ethyl Ketone with Ethyl Benze are much large.

NOMECULATURE

ρ	Density
η	Viscosity
V^E	Excess molar volume

$\Delta\eta$	Viscosity deviation
ν	Kinematic viscosity
MEK	Methyl ethyl ketone

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