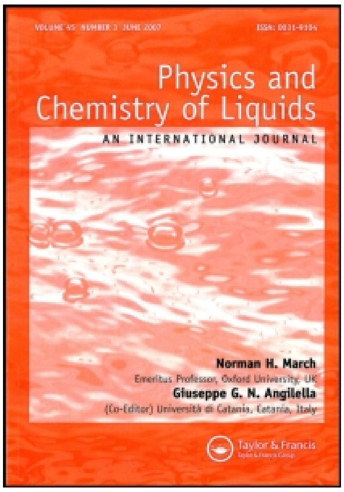

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Density and Viscosity of Ethanol *o*-Xylene, Ethanol *m*-Xylene, Ethanol *p*-Xylene and Methanol *o*-Xylene Mixtures

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DENSITY AND VISCOSITY OF ETHANOL + *o*-XYLENE, ETHANOL + *m*-XYLENE, ETHANOL + *p*-XYLENE AND METHANOL + *o*-XYLENE MIXTURES

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Density and viscosity measurements on the binary mixtures of ethanol + *o*-xylene, ethanol + *m*-xylene, ethanol + *p*-xylene and methanol + *o*-xylene at 303.15, 313.15 and 323.15 K are reported. The representation of the data by simple mixing rules is also studied.

Keywords: Binary mixtures; mixing rules

INTRODUCTION

In continuation of our investigations on the thermophysical properties of the binary mixtures formed by an aliphatic alcohol (methanol, ethanol, 1-propanol, 1-butanol) as one component and chloroethane (1,2-dichloroethane, 1,1,1-trichloroethane, 1,1,2,2-tetrachloroethane) or an aromatic hydrocarbon (benzene, toluene, *p*-xylene) as the other [1-6], this investigation on the binary mixtures noted in the

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* Corresponding author.

title has been taken up. No published information on the present set of systems is available for comparison.

EXPERIMENTAL

Materials

All the AR grade chemicals used in this work are further purified according to the methods described by Riddick *et al.* [7]. The purity of the substances is ascertained by measuring their density and refractive-index at 293.15 K, which compare well with the literature data as noted in Table I.

Methods

Measurements on the density of pure liquids as well as the mixtures are carried out using carefully calibrated pycnometers. The weights required in the entire work are recorded by means of a Mettler balance accurate to within ± 0.0001 g. The temperatures are maintained within ± 0.05 K of the desired values by immersing the pycnometers in electronically controlled water baths for sufficiently long time (usually 1 h).

A Hoppler type falling ball viscometer with provision to maintain the temperature of the liquid under investigation within ± 0.05 K of the desired value by circulating water from electronically controlled water bath is used for the experimentation. The time measurements are accurate to ± 0.05 s. During the experimentation, care is taken to see

TABLE I Comparison of the refractive-index and density of the pure substances used in the present work with the literature data [8, 9] at 293.15 K

Substance	*Refractive-index*		*Density, g/ml*	
	This work	*Literature* [9]	*This work*	*Literature* [8]
Ethanol	1.3611	1.3611	0.790	0.789
Methanol	1.3289	1.3288	0.791	0.791
o-Xylene	1.5055	1.5055	0.881	0.880
m-Xylene	1.4971	1.4972	0.863	0.864
p-Xylene	1.4957	1.4958	0.862	0.861

that no air bubbles are present in the pure liquid or mixture medium being studied. The absence of any particulate matter is also ensured. Based on a comparison of the pure liquid data given in Table II, as well as several other measurements with the literature data, the measurements for the mixtures reported in this paper are expected to be accurate within ±0.5%.

Mixtures samples are prepared from weighed quantities of pure liquids and the constancy of composition during experimentation is checked by periodically analysing the samples by means of gas chromatography. The values of density and viscosity are derived from atleast three measurements at each point of observation which do not deviate from each other by more than 0.2%. The observed values of density and viscosity as a function of composition and temperature are noted in Tables III–VI.

TABLE II Comparison of pure liquid viscosity with Literature data [10] at 293.15 K

Substance	*Viscosity cP*	
	This work	*Literature*
Ethanol	1.2000	1.1900
Methanol	0.5943	0.5945
o-Xylene	0.6148	0.6150
m-Xylene	0.8490	0.8500
p-Xylene	0.6158	0.6160

TABLE III Density and viscosity of ethanol + *o*-Xylene mixtures

Mole fraction of Ethanol	*Temperature* = 303.15 *K*		*Temperature* = 313.15 *K*		*Temperature* = 323.15 *K*	
	Density g/ml	*Viscosity cP*	*Density g/ml*	*Viscosity cP*	*Density g/ml*	*Viscosity cP*
1.0000	0.7800	1.0400	0.7500	0.7100	0.7600	0.5090
0.9055	0.7906	1.0114	0.7624	0.7045	0.7705	0.5155
0.8025	0.8021	0.9803	0.7760	0.6975	0.7821	0.5226
0.7065	0.8128	0.9513	0.7887	0.6910	0.7928	0.5293
0.6012	0.8246	0.9195	0.8026	0.6838	0.8046	0.5365
0.5050	0.8354	0.8905	0.8153	0.6773	0.8154	0.5431
0.4032	0.8468	0.8597	0.8287	0.6704	0.8268	0.5502
0.3015	0.8582	0.8290	0.8422	0.6635	0.8382	0.5572
0.2012	0.8694	0.7987	0.8554	0.6566	0.8494	0.5641
0.1015	0.8806	0.7686	0.6566	0.6499	0.8606	0.5716
0.0000	0.8920	0.7380	0.8820	0.6430	0.8720	0.5780

TABLE IV Density and viscosity of Ethanol + *m*-Xylene mixtures

Mole fraction of Ethanol	*Temperature* = 303.15 *K*		*Temperature* = 313.15 *K*		*Temperature* = 323.15 *K*	
	Density g/ml	*Viscosity cP*	*Density g/ml*	*Viscosity cP*	*Density g/ml*	*Viscosity cP*
1.0000	0.7800	1.0400	0.7500	0.7110	0.7600	0.5090
0.9132	0.7960	0.9880	0.7520	0.6880	0.7620	0.5040
0.8080	0.8040	0.9490	0.7580	0.6650	0.7660	0.4990
0.7132	0.8140	0.8980	0.7700	0.6500	0.7740	0.4940
0.6005	0.8980	0.8450	0.7800	0.6280	0.7820	0.4890
0.5127	0.8220	0.8000	0.7860	0.5970	0.7860	0.4840
0.4123	0.8250	0.7500	0.8000	0.5740	0.7920	0.4790
0.2175	0.8400	0.6540	0.8060	0.5270	0.8020	0.4700
0.0000	0.8460	0.5470	0.8100	0.4780	0.8080	0.4580

TABLE V Density and viscosity of Ethanol + *p*-Xylene mixtures

Mole fraction of Ethanol	*Temperature* = 303.15 *K*		*Temperature* = 313.15 *K*		*Temperature* = 323.15 *K*	
	Density g/ml	*Viscosity cP*	*Density g/ml*	*Viscosity cP*	*Density g/ml*	*Viscosity cP*
1.0000	0.7800	1.0400	0.7500	0.7110	0.7600	0.5090
0.7139	0.8140	0.9030	0.7870	0.6500	0.7710	0.4990
0.6013	0.8260	0.8480	0.7950	0.6230	0.7760	0.4920
0.5135	0.8320	0.8060	0.7970	0.6000	0.7790	0.4900
0.4131	0.8420	0.7560	0.8000	0.5850	0.7830	0.4860
0.2969	0.8470	0.6970	0.8040	0.5560	0.7880	0.4780
0.1033	0.8520	0.5990	0.8060	0.5060	0.7960	0.4640
0.0000	0.8570	0.5500	0.8100	0.4780	0.8000	0.4570

TABLE VI Density and viscosity of Methanol + *o*-Xylene mixtures

Mole fraction of Methanol	*Temperature* = 303.15 *K*		*Temperature* = 313.15 *K*		*Temperature* = 323.15 *K*	
	Density g/ml	*Viscosity cP*	*Density g/ml*	*Viscosity cP*	*Density g/ml*	*Viscosity cP*
1.0000	0.7880	0.5020	0.7730	0.4870	0.7630	0.4770
0.9014	0.7983	0.5253	0.7840	0.5070	0.7720	0.4870
0.8049	0.8083	0.5480	0.7942	0.5170	0.7860	0.4970
0.7069	0.8184	0.5712	0.8050	0.5230	0.7930	0.5070
0.6038	0.8292	0.5955	0.8180	0.5590	0.8080	0.5150
0.5039	0.8396	0.6190	0.8290	0.5650	0.8150	0.5250
0.4060	0.8497	0.6422	0.8390	0.5798	0.8300	0.5350
0.3033	0.8396	0.6190	0.8500	0.5950	0.8360	0.5470
0.2169	0.8497	0.6422	0.8600	0.6080	0.8500	0.5560
0.1169	0.8798	0.6664	0.8710	0.8500	0.8570	0.5760
0.0000	0.8920	0.7380	0.8820	0.6430	0.8720	0.5780

RESULTS AND DISCUSSION

The law of additive volumes rearranged for convenience as

$$\rho_m = \rho_1\, \rho_2/(\rho_2\, X_1 + \rho_1\, X_2) \tag{1}$$

represents the density measurements on the mixtures of the present work with an average absolute deviation of 0.55%.
Linear law

$$\eta_m = \eta_1\, X_1 + \eta_2\, X_2 \tag{2}$$

Arrhenius equation

$$\eta_m = e^{(X_1 \log \eta_1 + X_2 \log \eta_2)} \tag{3}$$

Kendall and Monroe equation

$$\eta_m = \left(X_1\, \eta_1^{1/3} + X_2\, \eta_2^{1/3}\right)^3 \tag{4}$$

and Lobe's equation

$$(\eta_m/\rho_m) = \phi_1(\eta_1/\rho_1)e^{\phi_2 \beta} + \phi_2(\eta_2/\rho_2)e^{\phi_1 \alpha} \tag{5}$$

with

$$\alpha = -1.7 \ln\left[(\eta_2/\rho_2)/(\eta_1/\rho_1)\right] \tag{6}$$

$$\begin{aligned}\beta = {} & 0.27 \ln\left[(\eta_2/\rho_2)/(\eta_1/\rho_1)\right] \\ & + 1.3 \ln\left[(\eta_2/\rho_2)/(\eta_1/\rho_1)\right]^{0.5}\end{aligned} \tag{7}$$

$$\phi_1 = V_1/(V_1 + V_2) \tag{8}$$

and

$$\phi_2 = V_2/(V_1 + V_2) \tag{9}$$

have been used to calculate the mixture viscosity. A summary of the comparisons given in Table VII shows that (on an overall basis) the

TABLE VII Representation of the viscosity data by simple mixing rules

Mixture	*Number of Data Points*	*Percent Average Absolute Deviation*			
		Linear law	*Arrhenius equation*	*Kendall and Monroe equation*	*Lobe's equation*
Ethanol + *o*-Xylene	33	0.72	0.95	0.48	2.26
Ethanol + *m*-Xylene	27	1.01	1.01	1.47	2.66
Ethanol + *p*-Xylene	24	1.51	1.51	2.54	3.53
Methanol + *o*-Xylene	33	0.40	0.47	0.42	3.15
Over all	117	0.91	0.98	1.23	2.90

linear law gives the best results with an average absolute deviation of 0.91%, comparable to the Arrhenius equation with 0.98% and Kendall and Monroe equation with 1.23, while Lobe's equation gives worse results with an average absolute deviation of 2.90%.

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