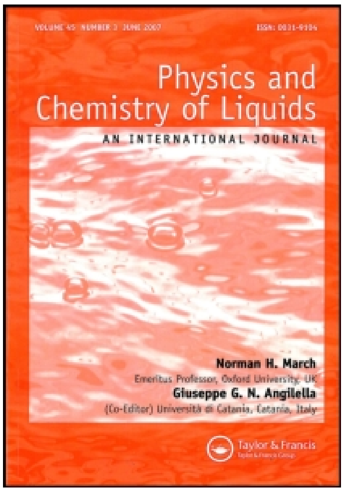

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Density and Viscosity of the Binary Mixtures Formed by *p*-Xylene with Methanol, *n*-Propanol and *n*-Butanol

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DENSITY AND VISCOSITY OF THE BINARY MIXTURES FORMED BY *p*-XYLENE WITH METHANOL, *n*-PROPANOL AND *n*-BUTANOL+

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

Keywords: Viscosity; methanol; *n*-propanol; *n*-butanol; *p*-xylene

INTRODUCTION

This investigation on the density and viscosity of the binary mixtures – methanol + *p*-xylene, *n*-propanol + *p*-xylene and *n*-butanol + *p*-xylene is undertaken in continuation of our studies on the density and viscosity of the binary mixtures containing alcohols, hydrocarbons and chloro-compounds [1–3]. No published information could be located for comparison purposes on these systems in the open literature.

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EXPERIMENTAL

Materials

Spectroscopic grade methanol, procured from SD's Fine Chemicals, Boisar (India) has been distilled twice fractionally after priliminary drying over silica gel. The middle fraction of the second distillation has been collected and stored in amber coloured bottles for use in the experiments. Extrapure AR grade *n*-propanol supplied by SISCO Research Laboratories, Bombay (India) has been further purified by fractionally distilling twice after storing over potassium carbonate to remove the traces of moisture.

AR grade *n*-butanol supplied by SD's Fine Chemicals, Boisar (India) is dried over potassium carbonate and fractionally distilled twice.

AR grade *p*-xylene supplied by E. Merck, Darmstadt (FRG) is dried over phosphorous pentoxide and fractionally distilled twice.

The purity of the substances used in the present work is expected to be atleast 99.8% based on the comparison of the refractive index and density data with the literature values given in Table I.

Methods

Measurements on the density of the pure liquids as well as mixtures are carried out using pycnometers, carefully calibrated by weighing double distilled water. The weights needed in the entire work are recorded using a Mettler balance accurate to ± 0.0001 g. The temperatures are maintained to within ± 0.05 K of the desired value by keeping the pycnometers in an electronically controlled water bath for sufficient length of time (usually 1h).

TABLE I Comparison of the density and refractive-index of the pure liquids used in the present work with the literature data [4, 5] at 293.15 K

Substance	*Refractive-index*		*Density, g/mL*	
	This work	*Literature* [5]	*This work*	*Literature* [4]
Methanol	1.3287	1.3288	0.7919	0.7920
n-Propanol	1.3849	1.3850	0.8041	0.8040
n-Butanol	1.3994	1.3993	0.8101	0.8100
p-Xylene	1.4957	1.4958	0.8011	0.8010

A Hoppler type falling ball viscometer with provision to maintain the temperature of the test liquid to within ● 0.05 K of the required value is used in the present set of experiments. During the experimentation, care is taken to avoid the entrainment of any air-bubbles or particulate matter. Care is also taken to avoid parallox error. The time measurements are accurate to ± 0.05 s. Based on a comparison of the pure liquid data presented in Table II, as well as several other measurements on pure liquids, the measurements on the viscosity of the pure liquids and mixtures presented in this paper are expected to be within ± 0.5% of their true values.

Mixture samples are prepared from weighed quantities of pure liquids and stirring well before carrying out the physical property measurements. The constancy of composition is checked after each experiment by means of gas chromatographic analysis. All the measurements have been carried our three times. The triplicate measurements are within ± 0.2% of the values recorded in Tables III – V.

TABLE II Comparison of pure liquid viscosity with the literature [6] data at 293.15 K

Substance	*Viscosity, cP*	
	This work	*Literature* [6]
Methanol	0.5944	0.5945
n-Propanol	2.1975	2.2000
n-Butanol	2.8749	2.8750
p-Xylene	0.6150	0.6160

TABLE III Density and viscosity of methanol + *p*-xylene mixtures

Mole	*Temp.* = 303.15 *K*		*Temp.* = 313.15 *K*		*Temp.* = 323.15 *K*	
fraction methanol	*Density g/mL*	*Viscosity cP*	*Density g/mL*	*Viscosity cP*	*Density g/mL*	*Viscosity cP*
1.0000	0.7910	0.5020	0.7760	0.4870	0.7660	0.4770
0.8965	0.7961	0.5059	0.7805	0.4863	0.7705	0.4742
0.8052	0.8005	0.5094	0.7845	0.4856	0.7745	0.4717
0.6920	0.8060	0.5137	0.7895	0.4848	0.7795	0.4695
0.5889	0.8111	0.5176	0.7941	0.4842	0.7840	0.4675
0.5008	0.8154	0.5209	0.7979	0.4836	0.7880	0.4655
0.4237	0.8192	0.5239	0.8013	0.4830	0.7925	0.4630
0.3111	0.8247	0.5282	0.8063	0.4824	0.7975	0.4605
0.2228	0.8291	0.5315	0.8102	0.4818	0.8025	0.4580
0.1235	0.8339	0.5353	0.8145	0.4813	0.8070	0.4530
0.0000	0.8400	0.5400	0.8200	0.4800	0.8100	0.4500

TABLE IV Density and viscosity of *n*-propanol + *p*-xylene mixtures

Mole fraction *n*-propanol	Temp. = 303.15 K Density g/mL	Temp. = 303.15 K Viscosity cP	Temp. = 313.15 K Density g/mL	Temp. = 313.15 K Viscosity cP	Temp. = 323.15 K Density g/mL	Temp. = 323.15 K Viscosity cP
1.0000	0.7920	1.7020	0.7820	1.3360	0.7720	1.1110
0.9018	0.7967	1.5879	0.7857	1.2519	0.7757	1.0461
0.7965	0.8017	1.4655	0.7897	1.1618	0.7803	0.9765
0.6954	0.8066	1.3482	0.7935	1.0752	0.7840	0.9096
0.5949	0.8016	1.2312	0.7972	0.9892	0.7877	0.8432
0.4969	0.8067	1.1174	0.8010	0.9053	0.7914	0.7785
0.3990	0.8117	1.0036	0.8048	0.8215	0.7951	0.7137
0.2969	0.8258	0.8850	0.8086	0.7342	0.7988	0.6463
0.1997	0.8304	0.7721	0.8124	0.6509	0.8025	0.5820
0.0996	0.8352	0.6557	0.8162	0.5653	0.8062	0.5158
0.0000	0.8400	0.5400	0.8200	0.4800	0.8100	0.4500

TABLE V Density and viscosity of *n*-butanol + *p*-xylene mixtures

Mole fraction *n*-butanol	Temp. = 303.15 K Density g/mL	Temp. = 303.15 K Viscosity cP	Temp. = 313.15 K Density g/mL	Temp. = 313.15 K Viscosity cP	Temp. = 323.15 K Density g/mL	Temp. = 323.15 K Viscosity cP
1.0000	0.7980	2.2620	0.7875	1.7920	0.7925	1.3920
0.9006	0.8022	2.0908	0.7907	1.6615	0.7852	1.2984
0.8030	0.8062	1.9227	0.7939	1.5335	0.7879	1.2048
0.7003	0.8106	1.7459	0.7971	1.4035	0.7906	1.1112
0.6059	0.8145	1.5833	0.8003	1.2738	0.7933	1.0176
0.5033	0.8188	1.4067	0.8035	1.1440	0.7962	0.9240
0.3898	0.8236	1.2112	0.8067	1.0140	0.7989	0.8304
0.2988	0.8274	1.0545	0.8099	0.8838	0.8016	0.7368
0.2009	0.8315	0.8859	0.8131	0.7543	0.8043	0.6432
0.1019	0.8357	0.7154	0.8163	0.6238	0.8070	0.5496
0.0000	0.8400	0.5400	0.8200	0.4800	0.8100	0.4500

RESULTS AND DISCUSSION

The densities and viscosities measured in the present work are noted in Tables III–V. The law of additive volumes, rearranged for convinence as

$$\rho_m = \rho_1\rho_2/(\rho_2 x_1 + \rho_1 x_2) \tag{1}$$

represents the density measurements of this work with an average absolute deviation of 0.5%.

Linear law

$$\eta_m = \eta_1 x_1 + \eta_2 x_2 \tag{2}$$

Arrhenius equation

$$\eta_m = e^{(x_1 \ln \eta_1 + x_2 \ln \eta_2)} \tag{3}$$

Kendall and Monroe equation

$$\eta_m = (x_1 \eta_1^{1/3} + x_2 \eta_2^{1/3})^3 \tag{4}$$

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

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

and

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

have been used to calculate the mixture viscosity. A summary of the results of comparison given in Table VI shows that the linear law is

TABLE VI Representation of the viscosity data by some common mixing rules

System	*No. of data points*	*Percent average absolute dev.*			
		Linear law	*Arrhenius equation*	*Kendall and Monroe equation*	*Lobe's equation*
Methanol + *p*-Xylene	33	0.45	0.40	0.87	2.02
n-Propanol + *p*-Xylene	33	0.12	0.14	1.00	1.55
n-Butanol + *p*-Xylene	33	0.24	0.32	1.07	1.76
Overall	99	0.27	0.31	0.98	1.78

preferable with an overall average absolute deviation of 0.27%, comparable to 0.31% for Arrhenius equation, while the Kendall and Monroe equation and Lobe's equation represent the data with an average absolute deviation of 0.98% and 1.78% respectively.

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