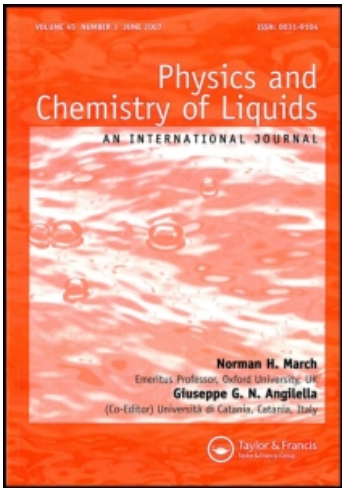

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Density and Viscosity of Methanol Trichloroethylene, *n*-Propanol Trichloroethylene and *n*-Butanol Trichloroethylene Mixtures

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DENSITY AND VISCOSITY OF METHANOL + TRICHLOROETHYLENE, *n*-PROPANOL + TRICHLOROETHYLENE AND *n*-BUTANOL + TRICHLOROETHYLENE MIXTURES

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

Keywords: Density; viscosity; mixtures; methanol; *n*-propanol; *n*-butanol; trichloroethylene

INTRODUCTION

In continuation of our investigations on the thermophysical properties of the binary systems formed by an aliphatic alcohol (methanol, ethanol, *n*-propanol, *n*-butanol) as one component and chloroethane (1,2-dichloroethane, 1,1,1-trichloroethane, 1,1,2,2-tetrachloroethane) as the other component [1–6], this study on the density and viscosity of the binary mixtures noted in the title has been carried out. No published data on these mixtures is available for comparison.

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EXPERIMENTAL

Materials

Spectrographic grade methanol procured from SDS Fine Chemicals, Boisar, India has been distilled twice after drying over silica gel. The middle fraction of the second distillation (boiling at 336.45 K, corresponding to the local atmospheric pressure) has been stored in amber coloured bottles for use in the experiments.

n-Propanol supplied by E. Merck, Bombay, India is purified by adding a small quantity of sodium metal and refluxing for 2 h. followed by treatment with anhydrous sodium carbonate, drying over calcium hydroxide and distillation.

A R grade *n*-butanol procured from SDS Fine Chemicals, Boisar, India has been purified by washing with dilute sulfuric acid and sodium bisulfite solution to remove the bases, aldehydes, ketones. Esters are removed by boiling for 1.5 h with 20% sodium hydroxide solution. The alcohol is dried with potassium carbonate followed by barium oxide. The final purification is by means of careful distillation.

Trichloroethylene supplied by Ranbaxy Laboratories, SAS Nagar, Punjab, India is treated with potassium carbonate solution followed by water. After drying over potassium carbonate and calcium chloride trichloroethylene distilled twice, each time collecting the middle 40% fraction.

Methods

Measurements on the density of the pure liquids as well as the mixtures are carried out using pycnometers, carefully calibrated by weighing double distilled water. The weights required 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).

A Haake falling ball viscometer with provision to maintain the temperature of the test liquid to within ± 0.05 K of the desired value, is used to determine the viscosity of the pure liquids and mixtures. When the experiments are conducted, care is taken to avoid entrainment of any air bubbles or particulate matter in the apparatus. Care is also

TABLE I Comparison of Refractive-index and Density of the substances used in the present work with Literature data at 293.15 K

Substance	*Refractive-index*		*Density, g/mL*	
	This work	*Literature* [8]	*This work*	*Literature* [7]
Methanol	1.3288	1.3288	0.7911	0.7910
n-Propanol	1.3489	1.3850	0.8041	0.8040
n-Butanol	1.3994	1.3993	0.8101	0.8100
Trichloroethylene	1.4764	1.4765	1.4621	1.4620

taken to avoid parallax error. The time measurements are accurate to ± 0.05 s. Based on the comparison of the data on pure liquids with the literature data presented in Table I, and several other measurements, collected earlier with the literature data, the measurements of the viscosity reported in this paper are expected to be within $\pm 0.5\%$.

Mixture samples are prepared from weighed quantities of the pure liquids and the constancy of the composition is checked after each experiment by gas chromatographic analysis. All the measurements have been carried out three times. The triplicate measurements are within $\pm 0.2\%$ of the values given in Tables III–V.

RESULTS AND DISCUSSION

The densities and viscosities measured in the present work are presented in Tables II–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 all the mixture density measurements of the present 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

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

TABLE II Comparison of the pure liquid viscosity data at 293.15 K with Literature data from Ref. [9]

Substance	*Viscosity, cP*	
	This work	*Literature*
Methanol	0.5944	0.5945
n-Propanol	2.1925	2.2000
n-Butanol	2.8749	2.8750
Trichloroethylene	0.6219	0.6220

TABLE III Density and viscosity of methanol + trichloroethylene 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	0.7910	0.5020	0.7760	0.4870	0.7660	0.4770
0.9011	0.8560	0.5080	0.8400	0.4920	0.8290	0.4760
0.7560	0.9520	0.5180	0.9360	0.4970	0.9230	0.4750
0.5963	1.0570	0.5300	1.0400	0.5050	1.0260	0.4740
0.4460	1.1562	0.5400	1.1382	0.5110	1.2320	0.4730
0.3071	1.2480	0.5500	1.2294	0.5180	1.2130	0.4735
0.1523	1.3510	0.5600	1.3390	0.5240	1.3240	0.4730
0.000	1.4620	0.5710	1.4420	0.5310	1.4230	0.4720

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

Mole fraction of n-Propanol	*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	0.7920	1.7020	0.7820	1.3360	0.7720	1.1110
0.9543	0.8890	1.5370	0.8880	1.2190	0.8780	1.0180
0.6998	0.9930	1.3700	0.9800	1.0950	0.9680	0.9190
0.5454	1.0960	1.1930	1.0810	0.9700	1.0680	0.8200
0.3927	1.1980	1.0190	1.1820	0.8480	1.1670	0.7220
0.2530	1.2910	0.8600	1.2740	0.7350	1.2580	0.6340
0.1062	1.3910	0.6920	1.3720	0.6170	1.3530	0.5390
0.0240	1.4450	0.5980	1.4260	0.5500	1.4050	0.4870
0.0000	1.4620	0.5710	1.4420	0.5310	1.4230	0.4720

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

Mole fraction on n-Butanol	*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	0.7980	2.2620	0.7875	1.7920	0.7825	1.3290
0.8476	0.8980	2.0005	0.8870	1.5990	0.8790	1.2520
0.6960	0.9993	1.7470	0.9860	1.4080	0.9760	1.1110
0.5452	1.0990	1.4920	1.0840	1.2180	1.0730	0.9730
0.3954	1.1990	1.2400	1.1810	1.0300	1.1690	0.8350
0.2464	1.3000	0.9800	1.2800	0.8140	1.2640	0.6980
0.0983	1.3720	0.6690	1.3530	0.6010	1.3350	0.5200
0.0000	1.4620	0.5710	1.4420	0.5310	1.4230	0.4720

TABLE VI Representation of the viscosity data by simple mixing rules

System	*Number of data points*	*Percent average absolute deviation*			
		Linear law	*Arrhenius equation*	*Kendall and Monroe equation*	*Lobe's equation*
Methanol + Trichloroethylene	24	0.47	0.57	0.90	1.98
n-Propanol + Trichloroethylene	27	0.22	0.24	1.05	1.81
n-Butanol + Trichloroethylene	24	0.14	0.15	1.31	1.65
Overall	75	0.28	0.32	1.09	1.81

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

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

$$\beta = 0.27\ \ln\left[\frac{(\eta_2/\rho_2)}{(\eta_1/\rho_1)}\right] + 1.3\ln\left[\frac{(n_2/\rho_2)}{(n_1/\rho_1)}\right]^{0.5} \tag{7}$$

have been used to calculate the mixture viscosity. A summary of the comparisons given in Table VI shows that on an overall basis the linear law is preferable with an average absolute deviation of 0.28%, comparable to the Arrhenius equation with 0.32%, Kendall and Monroe equation with 1.09% and Lobe's equation with 1.81%.

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