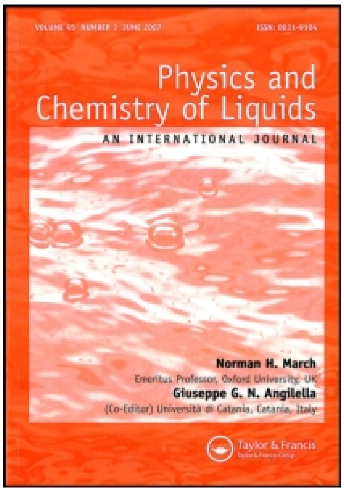

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Density and Viscosity of Methanol 1,2-Dichloroethane, Methanol 1,1,1-Trichloro Ethane, and Methanol 1,1,2,2-Tetrachloroethane Mixtures

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DENSITY AND VISCOSITY OF METHANOL + 1,2-DICHLOROETHANE, METHANOL + 1,1,1-TRICHLORO ETHANE, AND METHANOL + 1,1,2,2-TETRACHLOROETHANE MIXTURES†

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Density and viscosity measurements on the binary mixtures of methanol + 1,2-dichloroethane, methanol + 1,1,1-trichloroethane, and methanol + 1,1,2,2-tetrachloroethane 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; 1,2-dichloroethane; 1,1,1-trichloroethane; 1,1,2,2-tetrachloroethane

INTRODUCTION

In continuation of our investigations on the thermophysical properties of the binary systems formed by an aliphatic alcohol (methanol, ethanol, 1-propanol, 1-butanol) as one component and a chloroethane (1,2-dichloroethane, 1,1,1-trichloroethane, 1,1,2,2-tetrachloroethane) as the other component [1–5] this investigation on the

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density and viscosity of the binary mixtures mentioned in the title has been carried out. No published information on these mixtures is available for comparison.

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. The sources and methods of purification adopted for the chloroethanes is as described in our earlier paper [2]. Based on the comparison of the density and refractive-index measurements shown in Table I, as well as gas chromatographic study, the samples used in the present set of experiments are expected to be at least 99.9% pure.

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 required in the entire work are recorded using a Mettler balance accurate to ± 0.0001 g. The temperatures are maintained to within $\pm$ 0.05 K of the desired value by keeping the pycnometers in an electronically controlled water bath for sufficient length of time (usually 1 hour).

TABLE I Comparison of Refractive-index and Density of the Substances used in this work with Literature Data from Reference 6 at 293.15 K

Substance	*Refractive-index*		*Density, g/mL*	
	This Work	*Literature*	*This Work*	*Literature*
Methanol	1.3284	1.3284	0.7866*	0.78663*
1,2-Dichloroethane	1.4449	1.4451	1.2528	1.2529
1,1,1-Trichloroethane	1.4378	1.4377	1.3250	1.3249
1,1,2,2-Tetrachloroethane	1.4942	1.4942	1.5929	1.5930

* at 298.15 K

A HAAKE falling ball viscometer with provision to maintain the temperature of the test liquid to within $\pm$ 0.05 K of the desired value, is used to determine the viscosity of the liquids and liquid mixtures. When the experiments are conducted, care is taken to avoid entrainment of air bubbles or any particulate matter in the apparatus. Care is also taken to avoid parallax error. The time measurements are accurate to $\pm$ 0.05 sec. Based on the comparison of the data on pure liquids presented in Table II, and several other measurements with literature data, the measurements for the mixtures reported in this paper are expected to be accurate within $\pm$ 0.5%.

Mixture samples are prepared from weighed quantities of pure liquids and the constancy of the composition is cheched 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.

TABLE II Comparison of Pure Liquid Viscosity with Literature Data from Reference 6 at 293.15 K

Substance	*Viscosity, cP*	
	This Work	*Literature*
Methanol	0.5943	0.5945
1,2-Dichloroethane	0.8389	0.8400
1,1,1-Trichloroethane	0.8582	0.8580
1,1,2,2-Tetrachloroethane	1.7703	1.7700

TABLE III Density and Viscosity of Methanol + 1,2-Dichloroethane 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	0.7818	0.5155	0.7726	0.4500	0.7630	0.3958
0.7970	0.9355	0.5492	0.9241	0.4752	0.9127	0.4268
0.6780	1.0030	0.5869	0.9893	0.5097	0.9778	0.4504
0.5810	1.0453	0.6074	1.0306	0.5380	1.0175	0.4795
0.4720	1.0851	0.6322	1.0731	0.5511	1.0602	0.4952
0.3650	1.1277	0.6567	1.1135	0.5681	1.0998	0.5132
0.2348	1.1763	0.6751	1.1625	0.5910	1.1485	0.5327
0.1072	1.2142	0.7025	1.2042	0.6133	1.1848	0.5533
0.0000	1.2396	0.7313	1.2236	0.6456	1.2088	0.5763

TABLE IV Density and Viscosity of Methanol + 1, 1, 1-Trichloroethane Mixtures

Mole fraction	*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	0.7818	0.5155	0.7726	0.4500	0.7630	0.3958
0.7324	1.0383	0.5727	1.0239	0.4994	1.0129	0.4407
0.6504	1.0799	0.6235	1.0621	0.5385	1.0502	0.4802
0.5596	1.1247	0.6475	1.1108	0.5590	1.0805	0.4895
0.4759	1.1684	0.6595	1.1531	0.5696	1.1235	0.5098
0.3154	1.2253	0.6754	1.2064	0.5820	1.1935	0.5110
0.2205	1.2545	0.7030	1.2398	0.6169	1.2198	0.5365
0.1553	1.2752	0.7120	1.2579	0.6245	1.2418	0.5498
0.0000	1.3203	0.7410	1.3038	0.6601	1.2867	0.5810

TABLE V Density and Viscosity of Methanol + 1, 1, 2, 2-Tetrachloroethane 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	0.7818	0.5155	0.7726	0.4500	0.7630	0.3958
0.7799	1.1259	0.6932	1.1134	0.6135	1.1007	0.5396
0.6741	1.2193	0.8195	1.2060	0.7392	1.1922	0.6445
0.5010	1.3441	0.9298	1.3295	0.8435	1.3153	0.7325
0.4576	1.3746	1.0806	1.3600	0.9200	1.3458	0.8384
0.3298	1.4356	1.1176	1.4197	1.0149	1.4021	0.8728
0.2000	1.4959	1.2165	1.4804	1.1109	1.4653	0.9525
0.1133	1.5299	1.3102	1.5136	1.2155	1.5025	1.0346
0.0000	1.5784	1.4626	1.5646	1.3082	1.5491	1.1653

RESULTS AND DISCUSSION

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

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

represents the density measurements of this work with an average absolute deviation of 0.55%.

Linear law

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

Arrhenius equation

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

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

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

have been used to calculate the mixture viscosity. A summary of the comparisons given in Table VI shows that (on an overall basis) the linear law gives the best results with an average absolute deviation of 1.94%, comparable to the Arrhenius equation with 2.98% and Kendall and Monroe equation with 2.1%. Lobe's equation fails giving a much higher average absolute deviation of 9.97%.

TABLE VI Representation of the Viscosity Data by Simple Mixing Rules

System	*Number of Points Data*	*Percent average absolute deviation*			
		Linear Law	*Arrhenius Equation*	*Kendall and Monroe Equation*	*Lobe's Equation*
Methanol + 1,2-Dichloroethane	27	0.77	1.04	0.85	7.77
Methanol + 1,1,1-Trichloroethane	27	1.58	2.14	1.89	7.75
Methanol + 1,1,2,2-Tetrachloroethane	27	3.47	5.76	3.56	14.40
Overall	81	1.94	2.98	2.10	9.97

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