Viscosities of binary liquid mixtures of octan-2-ol with benzene and halobenzenes at 308.15 K

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Abstract

Viscosities η of binary mixtures of octan-2-ol with benzene, chlorobenzene and bromobenzene have been measured over the entire range of composition at 308.15 and atmospheric pressure. The viscosity data have been correlated using Kendall-Monroe, Grunberg-Nissan, Tamura-Kurata, Hind-Mclaughlin Ubbelohde and Katti-Chaudhary viscosity models, and McAllister's three-body interaction model at given temperature.

Keywords: Octan-2-ol; Aromatic hydrocarbon; Aromatic halohydrocarbon.

1. Introduction

This paper is a continuation of our work related to the study of transport properties of binary mixtures of higher alcohols with aliphatic haloalkanes and aromatic halohydrocarbons. The measurements of these properties have been utilized in recent years in understanding the nature of molecular systems and physico-chemical behavior of binary and multi-component liquid mixtures [1-6]. In an attempt to explore the nature of interactions occurring between the mixing components, viscosities, η, of binary mixtures of octan-2-ol with benzene (ben), chlorobenzene (Cl-ben) and bromobenzene (Br-ben) have been measured over the entire range of composition at 308.15 K and atmospheric pressure. The viscosity data have been correlated using Kendall-Monroe, Grunberg-Nissan, Tamura-Kurata, Hind-Mclaughlin Ubbelohde and Katti-Chaudhary viscosity models, and McAllister's three-body interaction model at different temperatures.

2. Experimental Section

The mole fraction purity of the liquids from s. d. fine Chemical Ltd. was as follows: benzene (99.7 %), chlorobenzene (99.7 %), bromobenzene (99.0 %) and from Merck chemicals ltd. was as follows octan-2-ol (99.9 %). The mass fraction of water for liquids under test was as follow: benzene (0.05 %), chlorobenzene (0.03 %), bromobenzene (0.05 %) and octan-2-ol (0.03 %). Prior to experimental measurements, all liquids were stored in dark bottles over 0.4 nm molecular sieves to reduce water content and were partially degassed with a vacuum pump under nitrogen atmosphere.

Kinematic viscosities ν at 308.15 K were measured with a modified Ubbelohde suspended-level viscometer. The viscometer was suspended in a thermostatted water bath maintained to ±0.01 K. An electronic digital stop watch with uncertainty to ± 0.01s was used for flow time measurements. At least four flow time measurements were performed for each composition and temperature, and the results were averaged. Calibration of the viscometer was carried out with high purity benzene (99.7 mol %) and toluene (99.7 mol %). The compositions of the mixture are given in mole fraction and were determined by using an analytical balance with an accuracy of ± 0.0001 g. The possible uncertainty in the mole fractions was estimated to be less than ± 0.0001. The equation for viscosity, according to Poiseuille's law is

$$\eta = \rho\nu = \rho(kt - c/t) \qquad (1)$$

where *k* and c are the viscometer constants and *t*, η and ν are the efflux time, dynamic viscosity and kinematic viscosity, respectively. The uncertainly in the viscosity measurements was of the order of ± 0.003 mPa·s.

The experimental results for viscosities η , viscosities calculated by various models are reported in Table 1 for binary liquid mixtures at 308.15 K.

Table 1: The experimental values for viscosity η , theoretical values of Viscosity by various models for benzene / halo benzenes (1) + octan-2-ol(2) at T=308.15 K.

x_1	η	η(K–M)	η(G–N)	η(T–K)	η(HIN)	η(K–C)
	mPa s	mPa s	mPa s	mPa s	mPa s	mPa s
			Benzene (1) + Octan-2-ol (2)			
0.0000	5.178	5.178	5.178	5.178	5.178	5.178
0.0555	4.689	4.739	4.575	4.735	4.621	4.538
0.1239	4.101	4.233	3.928	4.208	3.983	3.86
0.1912	3.577	3.771	3.38	3.71	3.408	3.296
0.2386	3.224	3.467	3.041	3.373	3.034	2.951
0.3153	2.703	3.010	2.563	2.853	2.483	2.47
0.4353	2.018	2.379	1.961	2.114	1.757	1.876
0.4865	1.764	2.139	1.749	1.83	1.497	1.67
0.6072	1.264	1.639	1.336	1.246	1.004	1.275
0.6941	0.986	1.331	1.101	0.913	0.753	1.054
0.7432	0.876	1.176	0.987	0.763	0.649	0.948
0.8011	0.754	1.009	0.867	0.625	0.562	0.837
0.8599	0.667	0.856	0.76	0.534	0.513	0.74
0.9090	0.608	0.741	0.682	0.501	0.503	0.668
0.9541	0.580	0.645	0.616	0.508	0.517	0.61
1.0000	0.556	0.556	0.556	0.556	0.556	0.556
			Chlorobenzene (1) + Octan-2-ol (2)			
0.0000	5.178	5.178	5.178	5.178	5.178	5.178
0.0637	4.507	4.714	4.565	4.647	4.542	4.54
0.1236	3.906	4.305	4.054	4.169	3.988	4.014
0.1894	3.291	3.883	3.559	3.668	3.428	3.508
0.2474	2.818	3.535	3.174	3.249	2.977	3.118
0.3131	2.369	3.167	2.787	2.803	2.513	2.729
0.3740	1.981	2.848	2.47	2.418	2.129	2.413
0.4525	1.641	2.471	2.115	1.965	1.699	2.062
0.5014	1.467	2.254	1.92	1.71	1.467	1.87
0.5867	1.238	1.906	1.622	1.321	1.131	1.58
0.6813	1.080	1.564	1.345	0.978	0.858	1.312
0.7429	1.000	1.365	1.19	0.812	0.737	1.164
0.8098	0.929	1.169	1.043	0.688	0.657	1.024
0.8776	0.867	0.990	0.912	0.629	0.629	0.9
0.9446	0.786	0.833	0.799	0.644	0.655	0.793
1.0000	0.716	0.716	0.716	0.716	0.716	0.716
			Bromobenzene (1) + Octan-2-ol (2)			
0.0000	5.178	5.178	5.178	5.178	5.178	5.178
0.0495	4.559	4.861	4.774	4.759	4.68	4.742
0.1184	3.795	4.442	4.264	4.202	4.038	4.181
0.1814	3.250	4.080	3.846	3.721	3.503	3.727
0.2506	2.769	3.706	3.433	3.223	2.971	3.293
0.2943	2.532	3.482	3.196	2.928	2.666	3.05
0.3711	2.178	3.111	2.818	2.447	2.187	2.679
0.4297	1.961	2.846	2.56	2.115	1.87	2.433
0.5077	1.738	2.517	2.253	1.723	1.514	2.149
0.5834	1.554	2.223	1.99	1.402	1.241	1.911
0.6524	1.418	1.976	1.777	1.166	1.053	1.719
0.7315	1.275	1.716	1.561	0.969	0.911	1.521
0.8025	1.174	1.503	1.389	0.865	0.849	1.363
0.8722	1.093	1.312	1.239	0.838	0.849	1.221
0.9483	1.030	1.123	1.094	0.901	0.918	1.086
1.0000	1.005	1.005	1.005	1.005	1.005	1.005

Table 2

McAllister (ν_{12} , ν_{21}) interaction parameters and standard percentage deviations ($\sigma\%$) for benzene / halobenzenes (1) + octan-2-ol (2) at T= 308.15 K.

SYSTEM	T/K	ν_{12}	ν_{21}	(σ %
Ben+octan-2-ol	303.15	0.9835	4.0917	0.064
Cl-ben+octan-2-ol	303.15	1.0043	2.4382	0.095
Br-ben+octan-2-ol	303.15	1.0613	2.2385	0.012

3. Results and Discussion

Kendall and Monroe [7] derived the following equations for analyzing the viscosity of binary liquid mixtures based on zero adjustable parameter:

$$\eta = (x_1\eta_1^{1/3} + x_2\eta_2^{1/3})^3 \qquad (2)$$

Grunberg and Nissan [8] suggested the following semiempirical model containing one adjustable parameter to estimate the dynamic viscosity of binary liquid mixtures in terms of pure component data and to interpret the molecular interactions in these mixtures:

$$\eta = \exp[\sum_{i=1}^{j} (x_i \ln \eta_i) + G_{12}\prod_{i=1}^{j} x_i] \qquad (3)$$

where G_{12} is an interaction parameter which is a function of the composition and temperature of binary liquid mixtures. This parameter may be regarded as an approximate measure of the strength of molecular interactions of octan-2-ol with benzene, chlorobenzene and bromobenzene.

Tamura and Kurata [9] proposed the following relation between the viscosity of binary liquid mixtures and their pure components:

$$\eta = \sum_{i=1}^{j} x_i\phi_i\eta_i + 2T_{12}\prod_{i=1}^{j}[x_i\phi_i]^{1/2} \qquad (4)$$

where T_{12} is the interaction parameter and ϕ_i is the volume fraction of the i^{th} pure component in the binary mixtures.

Hind- McLaughlin -Ubbelohde [10] suggested the following viscosity model to interpret the molecular interactions:

$$\eta = \sum_{i=1}^{j} x_i^{\,2}\eta_i + 2H_{12}\prod_{i=1}^{j} x_i \qquad (5)$$

where H_{12} is the Hind interaction parameter and is attributed to unlike pair interactions.

Katti and Chaudhary [11] proposed the following expression to interpret the molecular interactions.

$$\ln \eta V = x_1 \ln V_1\eta_1 + x_2 \ln V_2\eta_2 + x_1x_2W_{vis}/RT \qquad (6)$$

where W_{vis} is an adjustable parameter and V_1 and V_2 are molar volumes of the first and second components, respectively.

The values of experimental viscosity, η and the values of $\Delta\eta$ obtained using various viscosity models for the binary mixture of octan-2-ol with benzene at 308.15 K are given in table 1. It has been observed that the values for experimental viscosity and viscosity calculated using various viscosity models Kendall-Monroe, Hind-Mclaughlin Ubbelohde, Grunberg-Nissan, Tamura-Kurata and Katti-Chaudhary viscosity model are similar. The values for experimental viscosity and viscosity calculated using Kendall-Monroe, Hind-Mclaughlin Ubbelohde and Katti-Chaudhary viscosity model are almost same but values for Grunberg-Nissan and Tamura-Kurata are little deviated as compared to the curve for the experimental values of viscosity. Hence the experimental viscosity correlated well with the viscosity calculated using various viscosity models.

The values of experimental viscosity, η and the values of $\Delta\eta$ obtained using various viscosity models for the binary mixture of octan-2-ol with chlorobenzene at 308.15 K are given in table 1. It has been observed that the values for

experimental viscosity and viscosity calculated using various viscosity models Kendall-Monroe, Hind-Mclaughlin Ubbelohde, Grunberg-Nissan, Tamura-Kurata and Katti-Chaudhary viscosity model are similar.

The values of experimental viscosity, η and the values of $\Delta\eta$ obtained using various viscosity models for the binary mixture of octan-2-ol with bromobenzene at 308.15 K are given in table 1. It has been observed that the values for experimental viscosity and viscosity calculated using various viscosity models Kendall-Monroe, Hind-Mclaughlin Ubbelohde, Grunberg-Nissan, Tamura-Kurata and Katti-Chaudhary viscosity model are similar.

The values of experimental viscosity, η and the values of $\Delta\eta$ obtained using various viscosity models for all the binary mixtures decrease with the increase of temperature.

McAllister's three-body interaction model [12,13] has been widely used to correlate the kinematic viscosities of binary liquid mixtures with mole fraction. The three-body interaction model is defined as:

$$\ln \nu = x_1^3 \ln \nu_1 + x_2^3 \ln \nu_2 + 3x_1^2 x_2 \ln \nu_{12} + 3x_1 x_2^2 \ln \nu_{21} - \ln[x_1 + (x_2 M_2 / M_1)] + 3x_1^2 x_2 \ln[(2/3) + (M_2 / 3M_1)] + 3x_1 x_2^2 \ln[(1/3) + (2M_2 / 3M_1)] + x_2^3 \ln(M_2 / M_1) \quad (7)$$

where ν, ν_1, ν_2 are the kinematic viscosities of the mixture, first and the second component respectively. ν_{12}, ν_{21} are model parameters; M_i and x_i are the molecular weight and mole fraction of the i^{th} pure component in the mixture. The correlating ability of Eq. (7) was tested by calculating the standard percentage deviations $\sigma\%$, using the relation

$$\sigma = \sum[(\eta_{\exp} - \eta_{cal}) / \eta_{\exp})^2 / (N - m)]^{1/2} \quad (8)$$

where η_{expt} and η_{cal} are the experimental and calculated values of viscosity respectively, N represents the number of data points and m represents the number of coefficients.

Table 2 records the model parameters ν_{12} *and* ν_{21} along with the standard deviations calculated using Eq. (8). It is observed that the values of both the parameters are positive and the McAllister's three-body interaction model is adequate for correlating the kinematic viscosities of the binary mixtures investigated.

4. Conclusion

In this paper viscosities of the binary mixtures of octan-2-ol with benzene, chlorobenzene, and bromobenzene have been experimentally determined at 308.15 K and the atmospheric pressure for the whole composition range and comparison with the data available in the literature has been made for the pure liquids and the binary mixtures. For the viscosities good accordance has been found between the experimental and the literature values. The observed values over the entire composition range for the studied mixtures confirm the weak physical intermolecular interactions between octan-2-ol and the aromatic-hydrocarbon molecules.

Acknowledgements

Authors are grateful to the Kurukshetra University authorities for providing the necessary facilities to carry out the research work and to the University Grants Commission, New Delhi for the award of Senior research fellowship to one of the authors (Jasbir Sangwan)

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