

Density and viscosity studies of binary mixtures of aniline+benzene and ternary mixtures of (aniline+benzene+*N,N*-dimethylformamide) at 298.15, 303.15, 308.15, and 313.15 K

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Abstract

Densities and viscosities of binary mixtures of aniline with benzene have been measured over the entire range of composition, at atmospheric pressure, and at 298.15, 303.15, 308.15, and 313.15 K. Excess molar volumes and deviations in viscosity have been calculated from the experimental data. Negative excess molar volume and negative deviations in viscosity for aniline+benzene systems are due to the interstitial accommodation of benzene molecules into aggregates of aniline. The excess molar volumes and deviations in viscosity have been fitted to the Redlich–Kister polynomial equation. Furthermore, densities and viscosities of ternary mixtures of aniline+benzene+*N,N*-dimethylformamide have been measured at atmospheric pressure, and at 298.15, 303.15, 308.15, and 313.15 K. From these data, excess molar volumes and viscosity deviations have been calculated. McAllister's three-body interaction model has been used to correlate the kinematic viscosities of binary and ternary liquid mixtures with mole fractions. Several empirical equations have been used to predict excess molar volumes and deviations in viscosity of ternary mixtures.

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1. Introduction

Knowledge of thermodynamic and transport properties of pure liquids and liquid mixtures is required for solution of many engineering problems such as design calculation, heat transfer, mass transfer, fluid flow and, so forth. Furthermore, excess thermodynamic and transport properties are useful in understanding the nature of molecular interactions in binary mixtures containing associated, nonassociated, polar, non-polar, protic, and aprotic liquids.

Aniline exists in associated form. It is predominantly used [1,2] as parent substance in the manufacture of several chemical products and intermediates. Its major uses are in the production of isocyanates, rubber chemicals, dyes and pigments, hydro-

quinone, drugs, and agriculture. It is also used as a solvent and has been used as an antiknock compound for gasolines. The

Table 1
Comparison of experimental densities (ρ) and viscosities (η) of pure liquids with literature values

Liquid	<i>T</i> (K)	ρ (g cm ⁻³)			η (mPa s)		
		Exptl	Lit	σ	Exptl	Lit	σ
Aniline	298.15	1.0172	1.0173 [10]	0.0001	3.690	3.770 [11]	0.08
	303.15	1.0129	1.0131 [10]	0.0002	3.190	3.170 [10]	0.02
	308.15	1.0086	1.0088 [10]	0.0002	2.800	2.770 [12]	0.03
	313.15	1.0042	1.0045 [10]	0.0003	2.420	2.400 [10]	0.02
Benzene	298.15	0.8734	0.8735 [13]	0.0001	0.603	0.601 [10]	0.002
	303.15	0.8682	0.8682 [13]	0.0000	0.568	0.569 [10]	0.001
	308.15	0.8629	0.8629 [13]	0.0000	0.531		
	313.15	0.8574	0.8576 [13]	0.0002	0.500	0.503 [14]	0.003
DMF	298.15	0.9445	0.9445 [15]	0.0000	0.803	0.802 [18]	0.001
	303.15	0.9398	0.9397 [16]	0.0001	0.756	0.752 [19]	0.004
	308.15	0.9351	0.9356 [16]	0.0005	0.710	0.707 [19]	0.003
	313.15	0.9302	0.9298 [17]	0.0004	0.673	0.664 [19]	0.009

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Table 2

Density, ρ , viscosity, η , excess molar volume, V^E , and deviations in viscosity, $\Delta\eta$ for aniline (1)+benzene (2) (at 298.15, 303.15, 308.15, and 313.15) K

Temperature (K)	x_1	$10^3 \rho$ (kg m ⁻³)	η (mPa s)	V^E (cm ³ mol ⁻¹)	$\Delta\eta$ (mPa s)
298.15	0.0000	0.8734	0.603	0.000	0.000
	0.1039	0.8907	0.710	-0.205	-0.214
	0.2282	0.9104	0.830	-0.354	-0.477
	0.3729	0.9258	1.100	-0.449	-0.654
	0.4341	0.9416	1.211	-0.474	-0.732
	0.5562	0.9595	1.483	-0.499	-0.837
	0.6562	0.9736	1.803	-0.474	-0.826
	0.7656	0.9882	2.217	-0.378	-0.749
	0.8661	1.0012	2.767	-0.261	-0.510
	0.9088	1.0065	3.029	-0.194	-0.379
303.15	1.0000	1.0172	3.690	0.000	0.000
	0.0000	0.8682	0.568	0.000	0.000
	0.1039	0.8856	0.657	-0.211	-0.183
	0.2282	0.9056	0.781	-0.381	-0.385
	0.3729	0.9210	0.965	-0.469	-0.580
	0.4341	0.9370	1.093	-0.505	-0.613
	0.5562	0.9550	1.371	-0.528	-0.655
	0.6562	0.9692	1.648	-0.503	-0.641
	0.7656	0.9839	1.991	-0.405	-0.584
	0.8661	0.9969	2.495	-0.277	-0.344
308.15	0.9088	1.0021	2.745	-0.196	-0.206
	1.0000	1.0129	3.190	0.000	0.000
	0.0000	0.8629	0.531	0.000	0.000
	0.1039	0.8805	0.589	-0.225	-0.178
	0.2282	0.9007	0.736	-0.407	-0.313
	0.3729	0.9229	0.910	-0.493	-0.468
	0.4341	0.9323	1.012	-0.532	-0.504
	0.5562	0.9504	1.224	-0.553	-0.569
	0.6562	0.9467	1.476	-0.526	-0.544
	0.7656	0.9795	1.790	-0.425	-0.478
313.15	0.8661	0.9926	2.179	-0.295	-0.317
	0.9088	0.9978	2.443	-0.208	-0.150
	1.0000	1.0086	2.800	0.000	0.000
	0.0000	0.8574	0.500	0.000	0.000
	0.1039	0.8753	0.562	-0.250	-0.137
	0.2282	0.8956	0.689	-0.432	-0.249
	0.3729	0.9180	0.842	-0.524	-0.374
	0.4341	0.9274	0.928	-0.557	-0.405
	0.5562	0.9456	1.124	-0.574	-0.444
	0.6562	0.9601	1.337	-0.555	-0.423

thermodynamic and transport properties of binary and ternary mixtures of aniline with associated, nonassociated, protic, aprotic, polar, and nonpolar liquids have been reported by many authors previously [3–7]. We have already reported [8] excess molar volumes and viscosity deviations of binary mixtures of aniline with *N,N*-DMF. Takagi has reported [9] excess molar volumes of binary mixtures of aniline+benzene at 298.15 K and at various pressures. There are no reports on excess molar volumes and viscosity deviations of ternary mixtures of aniline+benzene+*N,N*-DMF. Therefore, in the present paper, we report densities, viscosities, excess molar volumes and deviations in viscosity of aniline+benzene and aniline+benzene+*N,N*-

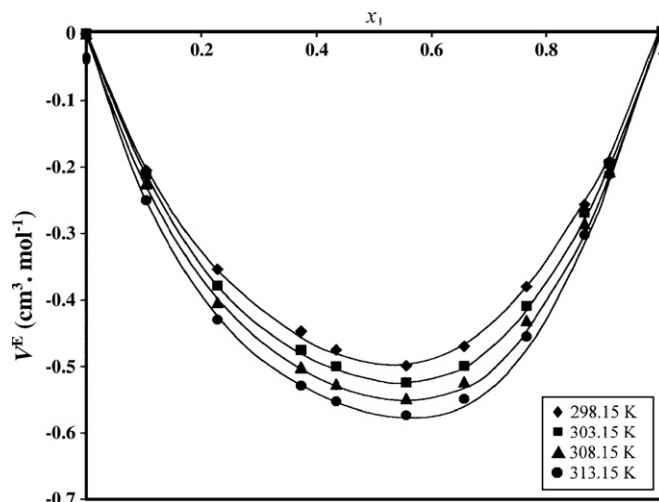


Fig. 1. Variation of V^E with mole fractions of aniline (x_1) for binary systems of aniline+benzene at various temperatures.

Dimethylformamide at 298.15, 303.15, 308.15, and 313.15 K and at atmospheric pressure.

2. Experimental section

Aniline (S.D. Fine Chemicals, purity>99%) was dried over caustic potash for about 2 days and distilled twice. Benzene (S.D. Fine Chemicals, purity>99%) was further purified by means of a simple distillation technique with first and last 20% of the distillate being discarded. DMF (S.D. Fine Chemicals, analytical reagent, purity>99.5%) was directly used. The purity of the solvents was ascertained by comparing the experimental values of densities and viscosities with those reported in the literature. The experimental and literature values of densities and viscosities along with deviations (σ) between experimental and literature values are included in Table 1. Our experimental values of densities and viscosities match very well with those reported in the literature.

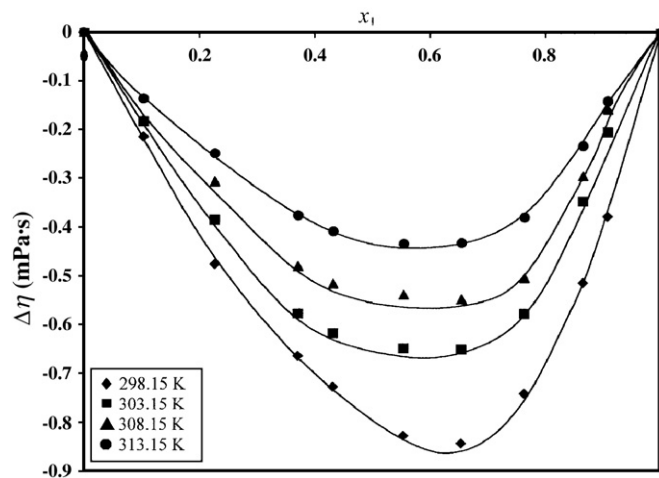


Fig. 2. Variation of $\Delta\eta$ with mole fractions of aniline (x_1) for binary systems of aniline+benzene at various temperatures.

Table 3
Parameters and standard deviations, σ , of Eqs. (4) and (5) for aniline (1)+benzene (2)

Property	T (K)	a_0	a_1	a_2	a_3	a_4	a_5	σ
V^E	298.15	−1.980	−0.384	−0.184	1.299	−0.403	−1.264	0.002
	303.15	−2.079	−0.390	−0.583	1.190	0.316	−1.070	0.004
	308.15	−2.177	−0.361	−0.734	1.166	0.423	−1.103	0.006
	313.15	−2.279	−0.336	−0.885	0.963	0.507	−0.512	0.004
$\Delta\eta$	298.15	−3.146	−1.640	−1.371	1.642	1.515	−2.007	0.009
	303.15	−2.556	−0.440	−1.308	−3.296	2.695	5.244	0.005
	308.15	−2.128	−0.288	−1.090	−4.700	1.979	7.861	0.017
	313.15	−1.707	−0.386	−0.462	−1.982	0.884	3.573	0.005

Binary and ternary mixtures were prepared by mixing a known mass of each liquid in an airtight, stoppered glass bottle. The masses were recorded on an Adairdutt balance to an accuracy of $\pm 1 \times 10^{-4}$ g. The uncertainty in the mole fractions was $\pm 1 \times 10^{-4}$ g. Care was taken to avoid contamination during mixing.

The densities of degassed pure liquids, binary and ternary mixtures were measured using a 15-cm³ double-arm pycnometer in a transparent glass-walled water bath having a thermal stability of ± 0.01 K. The pycnometer was calibrated using conductivity water having a conductivity of $< 1 \times 10^{-6} \Omega^{-1}\text{cm}^{-1}$. The uncertainty in the density measurements was within $\pm 1 \times 10^{-4} \text{ g cm}^{-3}$.

Dynamic viscosities (η) were measured using an Ubbelohde suspended-level viscometer, calibrated with conductivity water. An electronic digital stopwatch with an accuracy of ± 0.01 s was used for flow-time measurements. At least three repetitions of each data point obtained were reproducible to ± 0.05 s, and results were averaged. Since all flow times were > 300 s, kinetic energy corrections were not applied. The dynamic viscosity of the liquids was calculated using

$$\eta/\eta_0 = (\rho t)/(\rho_0 t_0) \quad (1)$$

where ρ , ρ_0 , t , t_0 ; and η , η_0 refer to density, flow time, and viscosity of liquids and water, respectively. The uncertainty in the viscosity measurements was ± 0.003 mPa s. All the measurements were made at atmospheric pressure and at 298.15, 303.15, 308.15, and 313.15 K

3. Results and discussion

3.1. Binary mixtures

Experimental values of densities (ρ) and viscosities (η) of binary mixtures of aniline with benzene at 298.15, 303.15, 308.15, and 313.15 K are included in Table 2.

The ρ values have been used to calculate the excess molar volumes (V^E) using the following equation

$$V^E (\text{cm}^3 \text{mol}^{-1}) \approx (x_1 M_1 + x_2 M_2) / \rho_{\text{mix}} - (x_1 M_1) / \rho_1 - (x_2 M_2) / \rho_2 \quad (2)$$

where x_1 , x_2 ; M_1 , M_2 ; and ρ_1 , ρ_2 are mole fractions, molecular weights and densities of pure components 1 and 2, respectively, and ρ_{mix} is the density of the binary mixture.

The viscosity deviations ($\Delta\eta$) were calculated by using the equation

$$\Delta\eta (\text{mPa s}) = \eta_{\text{mix}} - x_1 \eta_1 - x_2 \eta_2 \quad (3)$$

where η_{mix} is the viscosity of binary mixture and η_1 , η_2 are viscosities of components 1 and 2, respectively. Variations of V^E and $\Delta\eta$ with mole fractions of aniline (x_1) for binary mixtures of aniline+benzene at 298.15, 303.15, 308.15, and 313.15 K are represented in Figs. 1 and 2, respectively. The V^E and $\Delta\eta$ values for binary mixtures of aniline with benzene are negative over the entire range of composition and at all temperatures. The negative excess molar volumes become more negative while the negative deviations in viscosity values become less negative at higher temperatures.

V^E is the resultant of contributions from several opposing effects [20]. These may be divided arbitrarily into three types, namely, chemical, physical, and structural. Physical contributions, which are nonspecific interactions between the real species present in the mixture, contribute a positive term to V^E . The chemical or specific intermolecular interactions result in a volume decrease, and these include charge-transfer type forces and other complex-forming interactions. This effect contributes negative values to V^E . The structural contributions are mostly negative and arise from several effects, especially from interstitial accommodation and changes of free volume. In other words, structural contributions arising from the geometrical fitting (interstitially accommodated) of one component into the other due to the differences in the free volume and molar volume between components lead to negative contribution to V^E .

The molar volumes of aniline at 298.15, 303.15, 308.15, and 313.15 K are 91.565, 91.954, 92.346, and 92.750 cm³ mol^{−1}, respectively, and those of benzene are 89.432, 89.968, 90.521, and 91.101 cm³ mol^{−1} at 298.15, 303.15, 308.15, and 313.15 K, respectively. These molar volume values of aniline and benzene

Table 4
Parameters of McAllister's model and standard percentage deviation for kinematic viscosities at various temperatures

System	T (K)	b_{12}	b_{21}	σ (%)
Aniline (1)+benzene (2)	298.15	1.646	1.086	3.39
	303.15	1.658	0.958	2.77
	308.15	1.734	0.771	2.99
	313.15	1.479	0.773	2.14

Table 5

Density, ρ , viscosity, η , excess molar volume, V_{123}^E , and deviations in viscosity, $\Delta\eta_{123}$ for aniline (1)+benzene (2)+*N,N*-DMF (3) at 298.15, 303.15, 308.15, and 313.15 K

x_1	x_2	$10^3 \rho$ (kg m ⁻³)	η (mPa s)	V_{123}^E (cm ³ mol ⁻¹)	$\Delta\eta_{123}$ (mPa s)
Aniline (x_1)+Benzene (x_2)+(1- x_1 - x_2) <i>N,N</i> -DMF					
298.15 K					
0.4031	0.5144	0.9456	1.223	-0.726	-0.641
0.7543	0.0952	0.9991	2.531	-0.457	-0.431
0.3901	0.4325	0.9508	1.290	-0.745	-0.553
0.5965	0.1883	0.9834	2.020	-0.665	-0.467
0.3320	0.3822	0.9515	1.259	-0.869	-0.426
0.4212	0.2302	0.9686	1.589	-0.760	-0.384
0.2910	0.3049	0.9542	1.301	-0.869	-0.281
0.4494	0.0881	0.9851	1.837	-1.028	-0.246
0.2329	0.2496	0.9531	1.212	-0.794	-0.213
0.1835	0.2096	0.9517	1.146	-0.741	-0.145
0.1316	0.1705	0.9494	0.993	-0.639	-0.156
0.1263	0.1202	0.9507	1.030	-0.445	-0.114
0.0775	0.0820	0.9491	0.969	-0.391	-0.041
0.0557	0.0322	0.9502	0.943	-0.297	-0.014
303.15 K					
0.4031	0.5144	0.9408	1.135	-0.738	-0.505
0.7543	0.0952	0.9947	2.326	-0.466	-0.248
0.3901	0.4325	0.9460	1.201	-0.754	-0.423
0.5965	0.1883	0.9790	1.853	-0.688	-0.319
0.3320	0.3822	0.9467	1.178	-0.679	-0.314
0.4212	0.2302	0.9641	1.480	-0.783	-0.258
0.2910	0.3049	0.9495	1.266	-0.883	-0.141
0.4494	0.0881	0.9805	1.687	-1.036	-0.146
0.2329	0.2496	0.9484	1.116	-0.808	-0.160
0.1835	0.2096	0.9470	1.065	-0.754	-0.098
0.1316	0.1705	0.9449	0.948	-0.667	-0.096
0.1263	0.1202	0.9461	0.962	-0.461	-0.079
0.0775	0.0820	0.9450	0.900	-0.447	-0.029
0.0557	0.0322	0.9456	0.876	-0.308	-0.010
308.15 K					
0.4031	0.5144	0.9362	1.055	-0.775	-0.405
0.7543	0.0952	0.9903	2.119	-0.477	-0.150
0.3901	0.4325	0.9414	1.108	-0.786	-0.339
0.5965	0.1883	0.9746	1.715	-0.714	-0.208
0.3320	0.3822	0.9421	1.092	-0.911	-0.243
0.4212	0.2302	0.9596	1.370	-0.810	-0.179
0.2910	0.3049	0.9450	1.136	-0.920	-0.127
0.4494	0.0881	0.9761	1.547	-1.062	-0.086
0.2329	0.2496	0.9439	1.038	-0.842	-0.114
0.1835	0.2096	0.9425	0.993	-0.787	-0.063
0.1316	0.1705	0.9404	0.893	-0.698	-0.061
0.1263	0.1202	0.9415	0.909	-0.478	-0.043
0.0775	0.0820	0.9404	0.829	-0.463	-0.028
0.0557	0.0322	0.9410	0.812	-0.319	-0.008
313.15 K					
0.4031	0.5144	0.9313	0.976	-0.780	-0.312
0.7543	0.0952	0.9857	1.883	-0.482	-0.091
0.3901	0.4325	0.9365	1.011	-0.806	-0.269
0.5965	0.1883	0.9700	1.565	-0.735	-0.118
0.3320	0.3822	0.9371	0.987	-0.922	-0.200
0.4212	0.2302	0.9549	1.253	-0.833	-0.116
0.2910	0.3049	0.9403	1.046	-0.956	-0.083
0.4494	0.0881	0.9717	1.390	-1.102	-0.053
0.2329	0.2496	0.9392	0.957	-0.875	-0.080
0.1835	0.2096	0.9378	0.907	-0.819	-0.050

Table 5 (continued)

x_1	x_2	$10^3 \rho$ (kg m ⁻³)	η (mPa s)	V_{123}^E (cm ³ mol ⁻¹)	$\Delta\eta_{123}$ (mPa s)
Aniline (x_1)+Benzene (x_2)+(1- x_1 - x_2) <i>N,N</i> -DMF					
308.15 K					
0.1316	0.1705	0.9357	0.845	-0.724	-0.028
0.1263	0.1202	0.9368	0.864	-0.503	-0.009
0.0775	0.0820	0.9356	0.786	-0.479	-0.008
0.0557	0.0322	0.9364	0.764	-0.348	-0.001

differ considerably; hence, nonassociated benzene molecules are interstitially accommodated into clusters of aniline, yielding a negative contribution to observed V^E values. This implies that the complex-forming interactions are almost absent in aniline+benzene systems, and therefore, observed $\Delta\eta$ values are negative.

The results of V^E and $\Delta\eta$ are fitted in the Redlich–Kister equation [21]

$$Y = x_1 x_2 \sum a_i (x_1 - x_2)^i \quad (4)$$

where Y refers to V^E (cm³ mol⁻¹) or $\Delta\eta$ (mPa s) and x_1 and x_2 are the mole fractions of components 1 and 2, respectively. The coefficients a_i were obtained by fitting Eq. (4) to experimental results using a least-squares regression method. In each case, the optimum number of coefficients is ascertained from the examination of the variation in standard deviation (σ).

The σ was calculated using

$$\sigma(Y) = (\sum (Y_{\text{exptl}} - Y_{\text{cal}})^2 / (n - m))^{1/2} \quad (5)$$

where n is the number of data points and m is the number of coefficients. The calculated values of a_i along with standard deviations (σ) are given in Table 3.

Kinematic viscosities (ν) of the binary liquid mixtures are calculated from their dynamic viscosities and densities.

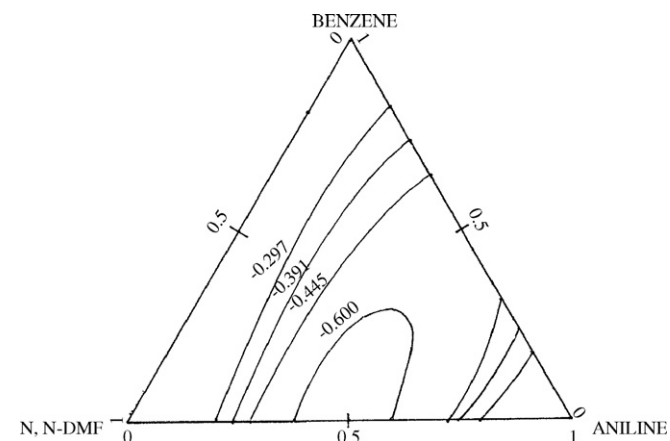


Fig. 3. Excess molar volume isolines for aniline+benzene+*N,N*-DMF at 298.15 K.

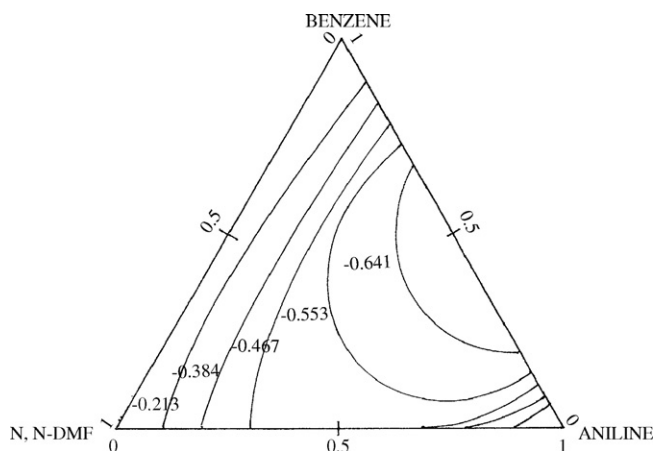


Fig. 4. Isolines for deviations in viscosity for aniline+benzene+N,N-DMF at 298.15 K.

McAllister's three-body interaction model [22] has been used to correlate the kinematic viscosities of binary liquid mixtures.

$$\ln v = x_1^3 \ln v_1 + x_2^3 \ln v_2 + 3x_1^2 x_2 \ln b_{12} + 3x_2^2 x_1 \ln b_{21} - \ln(x_1 + x_2 M_2 / M_1) + 3x_1^2 x_2 \ln(2/3 + M_2 / 3M_1) + 3x_2^2 x_1 \ln(1/3 + 2M_2 / 3M_1) + x_2^3 \ln(M_2 / M_1) \quad (6)$$

where v_1 , v_2 , M_1 , and M_2 are the kinematic viscosities and molecular weights of components 1 and 2, respectively. The model parameters b_{12} and b_{21} are determined from least square fitting.

The percentage standard deviation was calculated by using the following equation.

$$\sigma (\%) = \left(\sum (100(v_{\text{exptl}} - v_{\text{cal}}) / v_{\text{exptl}})^2 / (n - m) \right)^{1/2} \quad (7)$$

where n represents the number of experimental points and m number of coefficients. Table 4 includes the different parameters and percentage standard deviation. From Table 4, it is clear that McAllister's three-body interaction model is suitable to correlate the kinematic viscosities of the binary mixtures studied.

3.2. Ternary mixtures

Table 5 lists experimental values of densities (ρ) and viscosities (η) of ternary mixtures (aniline+benzene+N,N-DMF) at 298.15, 303.15, 308.15 and 313.15 K. The ρ values have been used to calculate the excess molar volumes (V_{123}^E) using the following equation

$$V_{123}^E (\text{cm}^3 \text{mol}^{-1}) = (x_1 M_1 + x_2 M_2 + x_3 M_3) / \rho_{\text{mix}} - (x_1 M_1) / \rho_1 - (x_2 M_2) / \rho_2 - (x_3 M_3) / \rho_3 \quad (8)$$

where x_1 , x_2 , x_3 , M_1 , M_2 , M_3 , ρ_1 , ρ_2 and ρ_3 are mole fractions, molecular weights and densities of pure components 1, 2 and 3, respectively, and ρ_{mix} is the density of the ternary mixture. The

viscosity deviations ($\Delta\eta_{123}$) were calculated by using the equation

$$\Delta\eta_{123} (\text{mPa s}) = \eta_{\text{mix}} - x_1 \eta_1 - x_2 \eta_2 - x_3 \eta_3 \quad (9)$$

where η_{mix} is the viscosity of ternary mixture and η_1 , η_2 , and η_3 are viscosities of components 1, 2 and 3, respectively. At all temperatures, the excess molar volume and viscosity deviation values of the ternary mixtures are negative. The excess molar volume values become more negative and deviation in viscosities values becomes less negative at higher temperatures. Figs. 3 and 4 show the excess molar volume isolines and isolines for deviations in viscosity for aniline+benzene+N,N-dimethylformamide at 298.15 K. The excess molar volumes and deviations in viscosities of ternary mixtures have been predicted from the corresponding properties of their constituent binary subsystems [23] by the equation of Radjkovic et al. [24], the equation of Kohler [25], and the equation of Scatchard et al. [26]. Small deviations between experimental and predicted values have been obtained.

The kinematic viscosities of ternary mixtures are calculated from their dynamic viscosities and densities. Kinematic viscosities of ternary mixtures are correlated by using the McAllister equation [27] of the following type

$$\begin{aligned} \ln v = & x_1^3 \ln v_1 + x_2^3 \ln v_2 + x_3^3 \ln v_3 + 3x_1^2 x_2 \ln b_{12} \\ & + 3x_1^2 x_3 \ln b_{13} + 3x_2^2 x_1 \ln b_{21} + 3x_2^2 x_3 \ln b_{23} \\ & + 3x_3^2 x_1 \ln b_{31} + 3x_3^2 x_2 \ln b_{32} \\ & + 6x_1 x_2 x_3 \ln c_{123} - \ln(x_1 M_1 + x_2 M_2 + x_3 M_3) \\ & + x_1^3 \ln M_1 + x_2^3 \ln M_2 \\ & + x_3^3 \ln M_3 + 3x_1^2 x_2 \ln[(2M_1 + M_2)/3] \\ & + 3x_1^2 x_3 \ln[(2M_1 + M_3)/3] + 3x_2^2 x_1 \ln[(2M_2 + M_1)/3] \\ & + 3x_2^2 x_3 \ln[(2M_2 + M_3)/3] + 3x_3^2 x_1 \ln[(2M_3 + M_1)/3] \\ & + 3x_3^2 x_2 \ln[(2M_3 + M_2)/3] \\ & + 6x_1 x_2 x_3 \ln[(M_1 + M_2 + M_3)/3] \end{aligned} \quad (10)$$

where M_1 , M_2 , and M_3 are molecular weights of component 1, 2, and 3, respectively. v_1 , v_2 , and v_3 are the kinematic viscosities of components 1, 2, and 3, respectively. The equation consists of seven constants comprising six binary and one ternary constant. The ternary constant c_{123} is determined from least square fitting. The six binary constants b_{12} , b_{21} , b_{23} , b_{32} , b_{13} , b_{31} may be determined from three binary systems [23] of components 1 and 2, 2 and 3, and 3 and 1.

4. Conclusion

From the density and viscosity studies of binary mixtures of aniline+benzene, it is revealed that negative excess molar volumes and negative values of deviations in viscosity for aniline+benzene mixtures are due to the interstitial accommodation of benzene molecules into aggregates of aniline. The excess molar volumes and viscosity deviations of aniline+benzene+N,N-dimethylformamide systems are also negative. With increase of temperature, excess molar volumes of both

binary and ternary mixtures become more negative while deviations in viscosity become less negative. The kinematic viscosities of binary and ternary mixtures are well correlated with mole fractions by using the McAllister three-body interaction model.

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