Thermophysical Properties of Isoamyl Acetate or Methyl Benzoate + Hydrocarbon Binary Mixtures, at (303.15 and 313.15) K†

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Densities, viscosities, and refractive indices have been measured for the binary liquid mixtures of isoamyl acetate or methyl benzoate with (*o*-, *m*-, and *p*-) xylenes and ethylbenzene over the entire composition range at (303.15 and 313.15) K. From the experimental data, the values of viscosity deviations $\Delta\eta$ and deviation in molar refraction ΔR have been determined. The values of $\Delta\eta$ and ΔR have been fitted to the Redlich−Kister polynomial equation to determine the binary coefficients and the standard deviation. The predictive ability of several one-, two-, and three-parameter viscosity models was also tested. It was observed that the viscosities were best correlated with the McAllister equation.

Introduction

Considerable scientific and practical interest has been stimulated by investigation of organic liquid mixtures by viscosity and refractive index measurements. The thermodynamic behavior and physical properties of several esters in their binary mixtures are already reported.[1−8] However, studies in regard to the determination of densities, viscosities, and refractive indices of the binary liquid mixtures of isoamyl acetate and methyl benzoate at (303.15 and 313.15) K are still lacking. Isoamyl acetate and methyl benzoate are used in a variety of applications in industrial sectors. Isoamyl acetate is used as solvent for old oil colors, perfuming, shoe polish, metallic paints, and in photographic films, while methyl benzoate is a polar, nonprotogenic selective solvent with important application in purification of reagents. The interactions of these esters with hydrocarbons such as xylenes and ethylbenzene are important to enable analysis of the effect of their dissimilar geometric structures on the mixture properties. In this work, which is a part of our research[9,10] on the thermophysical properties of binary mixtures, we present the densities, viscosities, and refractive indices of binary systems (isoamyl acetate + *o*-xylene, *m*-xylene, *p*-xylene, or ethylbenzene) and (methyl benzoate + *o*-xylene, *m*-xylene, *p*-xylene, or ethylbenzene) at (303.15 and 313.15) K and atmospheric pressure. The experimental viscosities were used to test the applicability of the equations proposed by Hind et al.,[11] Heric,[12] Auslander,[13] and McAllister[14] (assuming three-body and four-body interactions).

Experimental Section

Materials. High purity analytical reagent grade (BDH, AR) samples of *o*-xylene, *m*-xylene, and *p*-xylene were purified as per the standard procedure given by Riddick et al.[15] Ethyl benzene, isoamyl acetate, and methyl benzoate, all (Fluka, AG) with a reported purity of > 99 %, on a mole fraction basis were used without further treatment. The purity of these liquids was verified by measuring their density, viscosity, and refractive index. Table 1 lists the densities, viscosities, and refractive indices measured for the pure components at (303.15 and 313.15) K along with a comparison of these values with the literature values[15−18] at 303.15 K.

Table 1. Comparison of Experimental Densities (ρ), Viscosities (η), and Refractive Indices (n_D) of Pure Liquids with Literature Values at 303.15 K

	T	ρ/kg·m^{-3}		η/mPa·s		n_D	
liquid	K	exptl	lit.	exptl	lit.	exptl	lit.
isoamyl acetate	303.15	862.3	861.9[15]	0.741	0.747[15]	1.3959	1.3957[15]
	313.15	852.8		0.649		1.3945	
methyl benzoate	303.15	1078.8	1079.0[15]	1.679	1.673[15]	1.5127	1.5123[15]
	313.15	1069.2		1.414		1.5083	
o-xylene	303.15	871.5	871.6[17]	0.695	0.693[17]	1.5001	1.5000[15]
	313.15	863.3	863.2[18]	0.621		1.4981	
m-xylene	303.15	855.3	855.8[15]	0.557	0.558[16]	1.4920	1.4919[15]
	313.15	847.1	846.7[18]	0.508		1.4901	
p-xylene	303.15	852.1	852.3[15]	0.566	0.568[15]	1.4911	1.4905[15]
	313.15	843.5	843.6[18]	0.517		1.4902	
ethylbenzene	303.15	857.6	858.3[17]	0.597	0.590[15]	1.4910	1.4907[15]
	313.15	849.2	849.4[18]	0.538		1.4891	

Methods. Binary mixtures were prepared by mass in 25 cm^3 flasks. Mass measurements accurate to ± 0.01 mg were performed on a digital electronic balance (Mettler, AE.240, Switzerland). To prevent the samples from preferential evaporation, the mixtures were prepared by transferring aliquots via syringe into stoppered flasks. The mixtures were completely miscible over the whole composition range. A set of nine to ten compositions were prepared for each binary system. The possible uncertainty in the mole fraction was estimated to be less than ± 2·10^{-4}.

Densities were determined with a pycnometer as reported earlier,[10] in a transparent glass-walled water bath having a thermal stability. The uncertainty in the temperature during the measurements is ± 0.01 K because Pt 100 measuring sensors were used. Thus, the uncertainty in the density measurements was within ± 0.2 kg·m^{-3}.

Kinematic viscosities (ν) were measured using an Ubbelohde viscometer, calibrated with conductivity water. An electronic digital stopwatch with an uncertainty of ± 0.01 s was used for flow time measurements. At least three repetitions of each

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Table 2. Densities (ρ), Dynamic Viscosities (η), and Refractive Indices (n_D) for the Binary Mixtures

x_1	ρ / kg·m^{-3}	η / mPa·s	n_D	ρ / kg·m^{-3}	η / mPa·s	n_D	x_1	ρ / kg·m^{-3}	η / mPa·s	n_D	ρ / kg·m^{-3}	η / mPa·s	n_D
Isoamyl Acetate (1) + *o*-Xylene (2)													
	T = 303.15 K			T = 313.15 K				T = 303.15 K			T = 313.15 K		
0.0856	869.7	0.705	1.4903	861.4	0.622	1.4880	0.5481	866.0	0.718	1.4436	856.7	0.627	1.4375
0.1739	869.5	0.707	1.4806	860.8	0.623	1.4779	0.6564	865.0	0.722	1.4319	855.8	0.631	1.4258
0.2554	868.2	0.709	1.4721	859.8	0.623	1.4695	0.7531	864.1	0.726	1.4217	855.1	0.635	1.4157
0.3538	867.8	0.712	1.4620	859.1	0.624	1.4580	0.8542	863.7	0.731	1.4113	854.7	0.640	1.4062
0.4450	867.4	0.714	1.4530	858.4	0.625	1.4486	0.9538	863.2	0.738	1.4018	853.9	0.646	1.3961
Isoamyl Acetate (1) + *m*-Xylene (2)													
	T = 303.15 K			T = 313.15 K				T = 303.15 K			T = 313.15 K		
0.0877	855.8	0.561	1.4830	847.3	0.502	1.4811	0.6570	859.3	0.666	1.4297	850.3	0.587	1.4248
0.1726	856.5	0.572	1.4745	848.2	0.510	1.4724	0.7478	860.1	0.687	1.4207	851.1	0.603	1.4157
0.3736	858.2	0.605	1.4549	849.5	0.538	1.4520	0.8501	861.0	0.708	1.4101	851.9	0.623	1.4056
0.4421	858.4	0.619	1.4487	849.6	0.549	1.4456	0.9465	861.9	0.727	1.4014	852.8	0.638	1.3985
0.5478	858.8	0.643	1.4398	849.8	0.568	1.4350							
Isoamyl acetate (1) + *p*-Xylene (2)													
	T = 303.15 K			T = 313.15 K				T = 303.15 K			T = 313.15 K		
0.0960	852.4	0.573	1.4821	844.8	0.517	1.4811	0.5438	858.1	0.645	1.4397	849.6	0.570	1.4356
0.1713	853.6	0.584	1.4749	845.9	0.525	1.4740	0.6472	858.7	0.664	1.4293	850.1	0.584	1.4248
0.2823	854.5	0.600	1.4645	846.3	0.537	1.4621	0.7467	859.7	0.684	1.4193	850.7	0.600	1.4147
0.3819	856.7	0.617	1.4554	847.5	0.549	1.4523	0.8487	860.1	0.704	1.4100	851.3	0.615	1.4056
0.4503	857.8	0.628	1.4495	848.7	0.556	1.4454	0.9398	861.0	0.722	1.4017	851.6	0.634	1.3984
Isoamyl Acetate (1) + Ethylbenzene (2)													
	T = 303.15 K			T = 313.15 K				T = 303.15 K			T = 313.15 K		
0.0851	856.9	0.597	1.4802	848.8	0.533	1.4781	0.5380	860.1	0.649	1.4291	851.3	0.575	1.4276
0.1684	858.0	0.605	1.4701	849.1	0.541	1.4676	0.6532	861.1	0.666	1.4177	851.6	0.588	1.4168
0.2613	858.4	0.615	1.4593	849.7	0.549	1.4565	0.7513	861.6	0.681	1.4112	851.8	0.600	1.4099
0.3719	859.0	0.629	1.4471	850.3	0.559	1.4425	0.8475	862.0	0.703	1.4041	852.1	0.619	1.4035
0.4584	859.6	0.639	1.4376	850.9	0.567	1.4342	0.9401	862.3	0.726	1.3983	852.3	0.638	1.3965
Methyl Benzoate (1) + *o*-Xylene (2)													
	T = 303.15 K			T = 313.15 K				T = 303.15 K			T = 313.15 K		
0.0879	890.4	0.757	1.5006	882.3	0.664	1.4970	0.5939	991.7	1.160	1.5022	983.0	0.992	1.5017
0.1997	911.4	0.842	1.5007	902.1	0.720	1.4971	0.6852	1009.5	1.252	1.5055	1000.7	1.070	1.5038
0.3008	931.3	0.908	1.5010	922.8	0.785	1.4980	0.7980	1031.6	1.395	1.5083	1022.5	1.171	1.5062
0.3925	951.2	0.975	1.5012	942.6	0.836	1.4996	0.8981	1052.1	1.506	1.5110	1042.8	1.290	1.5085
0.4928	970.9	1.060	1.5016	962.4	0.910	1.5002	0.9485	1056.3	1.593	1.5115	1046.7	1.351	1.5101
Methyl Benzoate (1) + *m*-Xylene (2)													
	T = 303.15 K			T = 313.15 K				T = 303.15 K			T = 313.15 K		
0.1071	878.7	0.609	1.4933	870.6	0.544	1.4911	0.5978	985.7	1.023	1.5004	977.1	0.892	1.4960
0.2030	900.2	0.672	1.4943	891.9	0.598	1.4919	0.6867	1004.6	1.134	1.5033	995.8	0.978	1.4987
0.3034	922.3	0.739	1.4954	914.2	0.654	1.4927	0.8125	1029.6	1.316	1.5069	1021.9	1.122	1.5020
0.3924	941.4	0.824	1.4962	933.2	0.729	1.4933	0.8734	1043.8	1.403	1.5093	1034.8	1.191	1.5040
0.4909	962.7	0.923	1.4973	954.4	0.804	1.4941	0.9518	1059.6	1.565	1.5107	1050.7	1.317	1.5064
Methyl Benzoate (1) + *p*-Xylene (2)													
	T = 303.15 K			T = 313.15 K				T = 303.15 K			T = 313.15 K		
0.0958	873.0	0.616	1.4920	864.7	0.551	1.4913	0.5988	984.4	1.033	1.4982	975.7	0.889	1.4961
0.2055	898.1	0.693	1.4939	889.5	0.609	1.4922	0.6973	1006.2	1.152	1.5012	1000.4	0.992	1.4989
0.3011	919.3	0.759	1.4947	911.1	0.670	1.4932	0.7846	1024.4	1.269	1.5055	1013.0	1.093	1.5014
0.3990	940.9	0.839	1.4959	932.3	0.728	1.4945	0.9027	1056.0	1.450	1.5122	1047.3	1.253	1.5088
0.4951	961.9	0.922	1.4969	953.1	0.803	1.4952	0.9480	1059.2	1.561	1.5104	1050.3	1.322	1.5090
Methyl Benzoate (1) + Ethylbenzene (2)													
	T = 303.15 K			T = 313.15 K				T = 303.15 K			T = 313.15 K		
0.1033	877.9	0.656	1.4911	870.2	0.583	1.4888	0.5866	982.3	1.043	1.4978	973.7	0.925	1.4955
0.1927	898.9	0.701	1.4933	890.3	0.641	1.4900	0.6963	1000.3	1.170	1.5022	992.0	1.048	1.4985
0.2952	921.6	0.784	1.4945	912.7	0.687	1.4918	0.7953	1023.3	1.308	1.5054	1010.3	1.165	1.5014
0.3974	943.6	0.857	1.4958	935.0	0.750	1.4928	0.9016	1053.3	1.464	1.5090	1043.3	1.287	1.5044
0.4947	963.3	0.947	1.4968	954.1	0.824	1.4937	0.9510	1056.8	1.566	1.5092	1047.4	1.346	1.5064

composition reproducible to ± 0.05 s were obtained, and the results were averaged. Then, the dynamic viscosities were calculated as ($\eta = \nu\rho$). The uncertainties in dynamic viscosities are of the order of ± 0.005 mPa·s.

Refractive indices were measured using a thermostatted Abbe's refractometer (model R-8, India) which works with the wavelength corresponding to the D line of sodium. The instrument calibration was carried out with doubly distilled water. An average of three measurements was taken for each sample mixture. The uncertainty of the refractive indices thus estimated was less than ± $2 \cdot 10^{-4}$.

Results and Discussion

The experimental values of densities ρ, viscosities η, and refractive indices n_D for binary mixtures of isoamyl acetate with (*o*-, *m*-, and *p*-) xylenes or ethylbenzene at (303.15 and 313.15) K were listed in Table 2. From viscosity results, the deviation in the viscosity was calculated as

$$\Delta\eta = \eta - (x_1\eta_1 + x_2\eta_2) \quad (1)$$

where η_1, η_2, and η are, respectively, the viscosities of pure components (1 and 2) and the mixture.

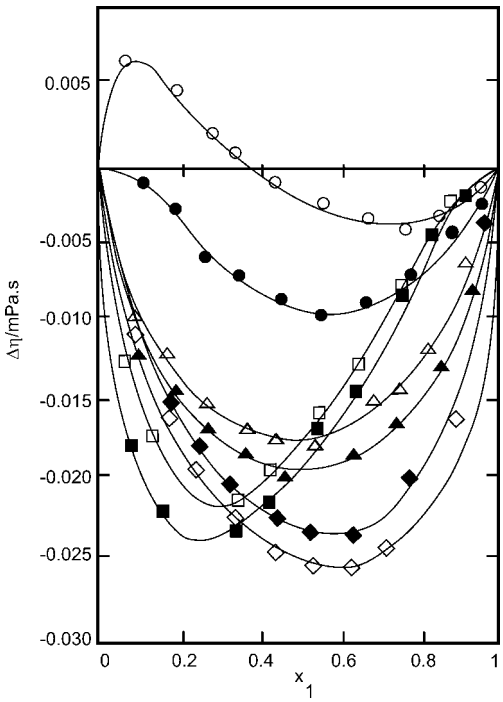

Figure 1. Deviations in viscosity $\Delta\eta$ vs mole fraction x_1 of isoamyl acetate + ○, *o*-xylene; + □, *m*-xylene; + Δ, *p*-xylene; + ◇, ethylbenzene, respectively, at 303.15 K and isoamyl acetate + ●, *o*-xylene; + ■, *m*-xylene; +▲, *p*-xylene; + ◆, ethylbenzene, respectively at 313.15 K.

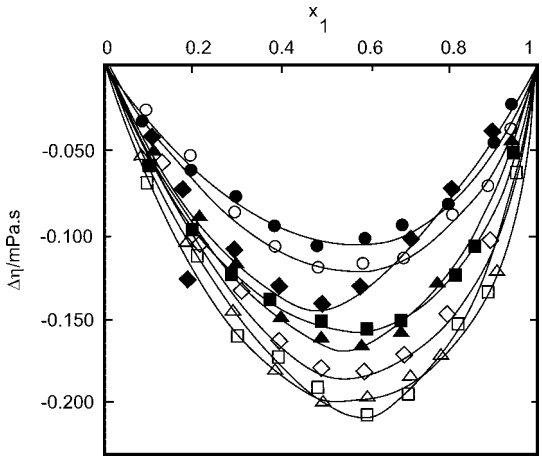

Figure 2. Deviations in viscosity $\Delta\eta$ vs mole fraction x_1 of methyl benzoate + ○, *o*-xylene; + □, *m*-xylene; + Δ, *p*-xylene; + ◇, ethylbenzene, respectively, at 303.15 K and methyl benzoate + ●, *o*-xylene; + ■, *m*-xylene; + ▲, *p*-xylene; + ◆, ethylbenzene, respectively at 313.15 K.

The refractive index values have been used to calculate the Lorentz−Lorentz[19] molar refraction, and deviations in the molar refraction have been calculated as

$$\Delta R = R_m - (R_1x_1 + R_2x_2) \tag{2}$$

where R_m is the molar refractivity of mixtures and R_1 and R_2 are the molar refractivities of pure components 1 and 2. All of the quantities ($\Delta\eta$ and ΔR) have been fitted to the Redlich−Kister[20] polynomial equation by the method of least-squares to derive binary coefficients A_0, A_1, and A_2.

$$\Delta y = x_1x_2[A_0 + A_1(x_1 - x_2) + A_2(x_1 - x_2)^2] \tag{3}$$

The variation in standard deviation (σ) was calculated using the relation

$$\sigma(y) = \left[\sum (y_{obs} - y_{cal})^2/(n - m)\right]^{1/2} \tag{4}$$

where n represents the number of data points and m is the number of coefficients. The calculated values of A_0, A_1, and A_2 along with the standard deviations (σ) are given in Table 3. The predictive ability of the following viscosity models such as the one-parameter Hind et al.,[11] two-parameter Heric,[12] and three-parameter Auslander,[13] McAllister[14] (four body interaction) was tested. The equations of these models applied to binary mixtures are as follows

Hind:

$$\eta = x_1^2\eta_1 + x_2^2\eta_2 + 2x_1x_2\eta_{12} \tag{5}$$

Heric:

$$\ln(\eta) = x_1 \ln(\eta_1) + x_2 \ln(\eta_2) + x_1 \ln(M_1) + x_2 \ln(M_2) - \ln(x_1M_1 + x_2M_2) + x_1x_2(\gamma_{12} + \gamma_{21}(x_1 - x_2)) \tag{6}$$

Auslander:

$$\eta = \frac{\eta_1x_1(x_1 + B_{12}x_2) + \eta_2(A_{21}x_2(B_{21}x_1 + x_2))}{x_1(x_1 + B_{12}x_2) + (A_{21}x_2)(B_{21}x_1 + x_2)} \tag{7}$$

McAllister (four body interaction model)

$$\ln \upsilon = x_1^4 \ln \upsilon_1 + 4x_1^3x_2 \ln \upsilon_{1112} + 6x_1^2x_2^2 \ln \upsilon_{1122} + 4x_1x_2^3 \ln \upsilon_{2221} + x_2^4 \ln \upsilon_2 - \ln[x_1 + (x_2M_2/M_1)] + 4x_1^3x_2 \ln[\{3 + (M_2/M_1)\}/4] + 6x_1^2x_2^2 \ln[\{1 + (M_2/M_1)\}/2] + 4x_1x_2^3 \ln[\{1 + (3M_2/M_1)\}/4] + x_2^4 \ln(M_2/M_1) \tag{8}$$

where ν_{1112}, ν_{1122}, and ν_{2221} represent the interaction parameters between unlike molecules. The average absolute deviations for all the binary systems were obtained by using the following relation.

$$AAD = \frac{1}{N}\sum_{i=1}^{N} \frac{|(\eta_{cal} - \eta_{expt})|}{\eta_{expt}} \tag{9}$$

The one-parameter Hind, two-parameter Heric, and three-parameter Auslander equations were employed to correlate the

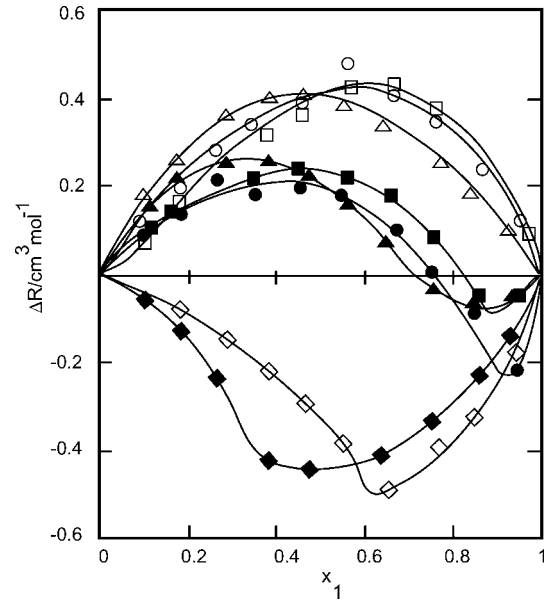

Figure 3. Deviations in molar refraction ΔR vs mole fraction x_1 of isoamyl acetate + ○, *o*-xylene; + □, *m*-xylene; + Δ, *p*-xylene; + ◇, ethylbenzene, respectively, at 303.15 K and isoamyl acetate + ●, *o*-xylene; + ■, *m*-xylene; + ▲, *p*-xylene; + ◆, ethylbenzene, respectively, at 313.15 K.

Table 3. Derived Parameters of Equation 3 for Various Functions and Standard Deviation of the Binary Mixture at (303.15 and 313.15) K

function	T/K	A_o	A_1	A_2	σ
		Isoamyl Acetate + *o*-Xylene			
$\Delta\eta$	303.15	−0.0104	−0.0482	0.0438	0.002
	313.15	−0.0375	−0.0273	0.0303	0.002
ΔR	303.15	1.2819	0.6373	1.3887	0.118
	313.15	1.0166	−1.5919	−3.5043	0.153
		Isoamyl Acetate + *m*-Xylene			
$\Delta\eta$	303.15	−0.0963	−0.0203	0.0551	0.009
	313.15	−0.0751	0.0907	−0.0785	0.002
ΔR	303.15	1.5901	0.5655	0.0176	0.045
	313.15	0.9598	−0.8389	−0.7922	0.044
		Isoamyl Acetate + *p*-Xylene			
$\Delta\eta$	303.15	−0.0506	0.0002	−0.1124	0.003
	313.15	−0.0717	−0.0148	−0.0849	0.002
ΔR	303.15	1.2704	−0.1858	1.3009	0.101
	313.15	0.6441	−1.3593	−0.0150	0.050
		Isoamyl Acetate + Ethylbenzene			
$\Delta\eta$	303.15	−0.1000	0.0065	−0.0420	0.002
	313.15	−0.0912	0.0184	−0.0428	0.003
ΔR	303.15	−1.0354	−1.4181	−1.1225	0.096
	313.15	−1.2034	−0.8662	−1.1195	0.144
		Methyl Benzoate + *o*-Xylene			
$\Delta\eta$	303.15	−0.4605	−0.2546	−0.0529	0.009
	313.15	−0.4184	−0.1020	0.0478	0.005
ΔR	303.15	−0.9908	1.1646	6.8052	0.246
	313.15	−0.9333	2.2581	8.7367	0.377
		Methyl Benzoate + *m*-Xylene			
$\Delta\eta$	303.15	−0.7640	−0.2935	−0.3246	0.007
	313.15	−0.5882	−0.2191	−0.3926	0.006
ΔR	303.15	−0.8115	1.3632	4.5433	0.119
	313.15	−1.0138	0.9293	4.3512	0.140
		Methyl Benzoate + *p*-Xylene			
$\Delta\eta$	303.15	−0.7566	−0.3550	−0.2870	0.008
	313.15	−0.6153	−0.1647	−0.1833	0.005
ΔR	303.15	−0.9482	0.7309	4.2016	0.137
	313.15	−1.1637	1.0865	6.2707	0.254
		Methyl Benzoate + Ethylbenzene			
$\Delta\eta$	303.15	−0.7192	−0.3383	−0.2889	0.009
	313.15	−0.5273	−0.0066	0.0809	0.010
ΔR	303.15	−0.5355	1.3350	3.5155	0.138
	313.15	−0.6176	1.9292	4.3197	0.179

dynamic viscosities, while the three-parameter McAllister (4 body) equation was employed to correlate the kinematic viscosities. Table 4 summarizes the results obtained. Comparison of these values indicates that the McAllister equation correlates the viscosities excellently. However, the application of the Auslander equation has yielded 100AAD values ranging from 0.01 to 0.12.

The results of variation in viscosity deviations of binary systems consisting of isoamyl acetate at (303.15 and 313.15) K as displayed in Figure 1 show negative deviations over the entire composition range except for the system isoamyl acetate + *o*-xylene which exhibits both positive and negative deviation at 303.15 K. It may be noted that the absolute deviation values increase with an increase in temperature for the systems isoamyl acetate + *o*-xylene and isoamyl acetate + *p*-xylene. Further, the viscosity deviations at 313.15 K for these systems are more negative than at 303.15 K indicating that these values are smaller at higher temperature. On the other hand, an opposite trend is observed for isoamyl acetate + *m*-xylene and isoamyl acetate + ethylbenzene systems. Figure 2 displays the dependence of $\Delta\eta$ on x_1 at (303.15 and 313.15) K for the binary systems of methyl benzoate. Here, it is observed that the behavior of all the systems is identical with large negative deviation over the entire composition range at both the temperatures investigated. The $\Delta\eta$ increases systematically with an increase in temperature. The negative values of $\Delta\eta$ were attributed to the dispersion, induction, and dipolar forces.

The results of ΔR vs x_1 at (303.15 and 313.15) K for the systems of isoamyl acetate are shown in Figure 3. Here the systems isoamyl acetate + *o*-xylene, + *m*-xylene, and + *p*-xylene exihibit a positive deviation at 303.15 K. However, on increasing the temperature to 313.15 K, these systems show a negative deviation at the higher concentration of ester, whereas for isoamyl acetate + ethylbenzene the ΔR values are completely negative at both the temperatures studied. Figure 4 displays the dependence of ΔR on x_1 for the methyl benzoate systems. Here all the systems show both positive and negative

Table 4. Adjustable Parameters and Average Absolute Deviation (AAD) of Several Correlations for the Absolute and Kinematic Viscosities of Binary Systems

	Hind		Heric			Auslander				McAllister (4 body interaction)			
T/K	η_{12}	100 AAD	γ_{12}	γ_{21}	100 AAD	B_{12}	A_{21}	B_{21}	100 AAD	ν_{1112}	ν_{1122}	ν_{2221}	100 AAD
						Isoamyl Acetate + *o*-Xylene							
303.15	0.718	0.10	0.0175	−0.0554	0.02	−0.6027	0.6324	4.6327	0.12	0.8424	0.8121	0.8776	0.01
313.15	0.635	0.09	−0.0314	−0.0242	0.01	2.5614	0.9740	−0.6946	0.01	0.7435	0.7176	0.7716	0.01
						Isoamyl Acetate + *m*-Xylene							
303.15	0.647	0.20	−0.0543	0.1094	0.03	1.2578	0.7779	0.7974	0.01	0.7991	0.7506	0.6909	0.01
313.15	0.579	0.26	−0.1027	0.1663	0.05	1.2889	0.7266	0.8278	0.03	0.7021	0.6908	0.6008	0.02
						Isoamyl Acetate + *p*-Xylene							
303.15	0.653	0.21	−0.0537	0.0213	0.02	0.9812	0.8807	1.0332	0.02	0.7853	0.7566	0.7183	0.01
313.15	0.583	0.03	−0.1014	0.0264	0.04	0.9440	0.8508	1.0811	0.04	0.6875	0.6857	0.6395	0.02
						Isoamyl Acetate + Ethylbenzene							
303.15	0.669	0.32	−0.1171	−0.0060	0.03	0.0514	1.3065	1.4533	0.02	0.7733	0.7627	0.7368	0.02
313.15	0.594	0.31	−0.1281	0.0176	0.04	−0.0976	1.3205	1.5602	0.03	0.6902	0.6862	0.6572	0.03
						Methyl Benzoate + *o*-Xylene							
303.15	1.187	0.78	−0.0008	−0.1249	0.04	0.6988	1.0166	0.7597	0.05	1.2890	1.0671	1.0410	0.04
313.15	1.018	0.70	−0.0623	−0.0198	0.06	0.5303	1.1062	1.1061	0.03	1.1072	0.9396	0.8749	0.03
						Methyl Benzoate + *m*-Xylene							
303.15	1.116	1.23	−0.1800	−0.0285	0.07	0.2506	2.3297	0.3968	0.05	1.1290	1.0175	0.7791	0.04
313.15	0.961	0.30	−0.1969	0.0036	0.08	0.2031	2.8051	0.3657	0.04	0.9594	0.9338	0.6767	0.04
						Methyl Benzoate + *p*-Xylene							
303.15	1.123	1.37	−0.1705	−0.1172	0.04	0.3045	2.0418	0.3786	0.05	1.1224	1.0040	0.8247	0.05
313.15	0.966	1.35	−0.2119	0.0046	0.03	0.3254	1.3755	0.8252	0.03	1.0038	0.8581	0.7234	0.03
						Methyl Benzoate + Ethylbenzene							
303.15	1.138	1.14	−0.1785	−0.0636	0.06	0.2975	1.9033	0.5178	0.05	1.1739	1.0055	0.8506	0.06
313.15	0.976	0.92	−0.1000	−0.1497	0.06	1.3230	0.5473	−0.8750	0.06	1.1801	0.7913	0.7936	0.10

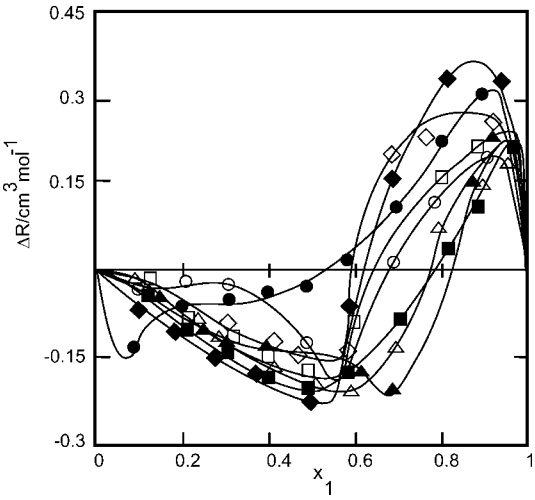

Figure 4. Deviations in molar refraction ΔR vs mole fraction x_1 of methyl benzoate + ○, *o*-xylene; + □, *m*-xylene; + Δ, *p*-xylene; + ◇, ethylbenzene, respectively, at 303.15 K and methyl benzoate + ●, *o*-xylene; + ■, *m*-xylen; + ▲, *p*-xylene; + ◆, ethylbenzene, respectively, at 313.15 K.

deviations. The curves are more or less sigmoidal. From these variations of ΔR, it is found that the effect of temperature on ΔR is considerable in all the binary mixtures investigated. The positive deviations in ΔR values on a mole fraction dependence are considered due to the presence of significant interactions in the mixtures, whereas negative deviations in ΔR values indicate weak interactions between the components of the mixture.[21] In all of the figures, the points represent data calculated from eqs 1 and 2, while smooth curves are drawn from the best fitted data calculated from eq 4.

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