Density, Viscosity, Refractive Index, and Speed of Sound in the Binary Mixtures of Tri-*n*-butylamine + Triethylamine, + Tetrahydrofuran, + Tetradecane, + Tetrachloroethylene, + Pyridine, or + Trichloroethylene at (298.15, 303.15, and 308.15) K

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The results of densities, viscosities, and refractive indices at (298.15, 303.15, and 308.15) K and speed of sound at 298.15 K in the binary mixtures of tri-*n*-butylamine with triethylamine, tetrahydrofuran, tetradecane, tetrachloroethylene, pyridine, and trichloroethylene have been measured and used to calculate the excess molar volume, deviations in viscosity, molar refraction, and speed of sound. These results have been discussed to study the type of mixing behavior between the mixing molecules. The measured properties have been fitted to a polynomial equation to derive the coefficients and estimate the standard errors.

Introduction

Tri-*n*-butylamine is an industrially important liquid, which is used as an intermediate in the production of corrosion inhibitors, agrochemicals, petroleum, fuel, lubricant additives, photochemicals, pharmaceuticals, textile dyes, rubber auxiliaries, viscosity stabilizers, paints, and lacquers. Also, it is used as a catalyst in the production of polymers such as phenolic resins and polyurethane foams.

Mixing behaviors in liquid mixtures containing tri-*n*-butylamine are interesting due to the presence of an amine group coupled with the tri-*n*-butyl chain. Such studies on the excess thermodynamic properties of binary mixtures containing tri-*n*-butylamine have been reported earlier.[1,2] To present more data on binary mixtures of tri-*n*-butylamine with organic compounds, an effort is made in this study to include other liquids such as triethylamine, tetrahydrofuran, tetradecane, tetrachloroethylene, pyridine, and trichloroethylene. Studies on binary mixtures containing the above liquids with liquids other than tri-*n*-butylamines have been reported in the literature.[3−7] Physicochemical properties such as density, ρ, viscosity, η, and refractive index for the sodium D-line, n_D, at (298.15, 303.15, and 308.15) K and speed of sound, u, at 298.15K have been measured. Using these data, excess molar volume (V^E), deviation in viscosity ($\Delta\eta$), deviation in molar refraction (ΔR), and deviation in speed of sound (Δu) have been studied. These data are further fitted to a Redlich−Kister polynomial equation[8] to derive binary coefficients and estimate standard errors.

Experimental Section

Materials. High purity laboratory reagent grade samples of tri-*n*-butylamine and tetradecane, analytical reagent grade samples of triethylamine, and spectroscopic grade samples of tetrahydrofuran, pyridine, tetrachloroethylene, and trichloroethylene were procured from s. d. fine Chemicals, Mumbai, India. The mole percent purities of these liquids as determined by GC (HP 6890) using a FID detector were >99. These data are reported in Table 1, along with density and refractive index results measured at 298.15 K for pure liquids, and are compared with the literature values.

Table 1. Comparison of Experimental Densities (ρ) and Refractive Indices (n_D) of Pure Liquids with Literature Values at 298.15 K

liquid	mol % purity	ρ/kg·m^{-3} expt	ρ/kg·m^{-3} lit.	n_D expt	n_D lit.
tri-*n*-butylamine	>99.0	773.9	774.0[1]	1.4276	1.4280[22]
triethylamine	>99.5	723.2	722.8[22]	1.3992	1.3980 [22]
tetrahydrofuran	>99.7	882.9	883.7[22]	1.4049	1.4050 [23]
tetradecane	>99.0	760.7	759.9[11]	1.4282	1.4290[11]
tetrachloroethylene	>99.9	1616.0	1614.3[22]	1.5036	1.5032[22]
pyridine	>99.5	979.0	978.2[24]	1.5062	1.5074[24]
trichloroethylene	>99.5	1456.7	1455.5[13]	1.4752	1.4745[13]

Binary mixtures were prepared by mass[9] in stoppered conical flasks. The mass measurements accurate to ±0.01 mg were performed on a digital electronic balance (Mettler, AE 240, Switzerland). A set of nine compositions were prepared for each mixture, and their physical properties were measured at the respective compositions in the mole fraction scale from 0.1 to 0.9 in steps of 0.1. In all cases, the possible error in mole fraction was less than 0.0002.

Methods. Densities of liquids and liquid mixtures were measured within an accuracy of ±0.0001 g.cm^{-3} using a capillary-type pycnometer of capacity 10 cm^3. Experimental details and calibrations of the pycnometer and data measurements are the same as reported earlier.[9−11]

Viscosities were measured using a Cannon Fenske viscometer (size 75, ASTM D 445, Industrial Research Glassware Ltd., Roselle, NJ). An electronic digital stopwatch with a readability of ±0.01 s was used for flow time measurements. The measured viscosity values are accurate to ±0.001 mPa·s. The calibration methods of the pycnometer are the same as those reported earlier.[9,10]

Refractive indices for the sodium D-line were measured using a thermostatically controlled Abbe refractometer (Atago 3T, Japan). A minimum of three independent

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† CEPS Communication No. 19.

10.1021/je030147g CCC: $25.00
Published on Web 10/29/2003

Table 2. Experimental Density (ρ), Viscosity (η), Refractive Index (n_D), and Speed of Sound (u) of Binary Mixtures at Different Temperatures

x_1	ρ/kg·m^{-3}	η/mPa·s	n_D	u/m·s^{-1}	x_1	ρ/kg·m^{-3}	η/mPa·s	n_D	u/m·s^{-1}
Tri-*n*-butylamine (1) + Triethylamine (2)					Tri-*n*-butylamine (1) + Tetradecane (2)				
298.15 K					298.15 K				
0.0	723.3	0.367	1.3992	1123	0.0	760.7	2.032	1.4282	1315
0.1072	732.0	0.433	1.4052	1143	0.1081	761.9	1.930	1.4283	1303
0.2039	739.2	0.491	1.4104	1160	0.2058	762.9	1.842	1.4282	1292
0.3083	745.9	0.567	1.4131	1179	0.2802	763.8	1.774	1.4280	1287
0.4066	751.5	0.643	1.4164	1196	0.4095	765.3	1.668	1.4278	1283
0.5029	756. 4	0.719	1.4208	1210	0.5112	766.6	1.585	1.4278	1279
0.5905	760.2	0.801	1.4218	1221	0.6101	767.9	1.511	1.4278	1275
0.6928	763.7	0.899	1.4238	1232	0.7051	769.3	1.441	1.4279	1272
0.7914	767.1	1.003	1.4256	1236	0.7999	770.9	1.375	1.4281	1270
0.8942	770.6	1.118	1.4265	1246	0.8953	772.4	1.309	1.4280	1267
1.0	773.9	1.239	1.4276	1262	1.0	773.9	1.239	1.4276	1262
		303.15 K					303.15 K		
0.0	718.6	0.349	1.3958		0.0	757.0	1.827	1.4260	
0.1072	727.3	0.411	1.4031		0.1081	758.1	1.750	1.4258	
0.2039	734.6	0.464	1.4079		0.2058	759.2	1.671	1.4257	
0.3083	741.4	0.533	1.4116		0.2802	760.0	1.612	1.4256	
0.4066	747.2	0.602	1.4144		0.4095	761.5	1.518	1.4254	
0.5029	752.2	0.672	1.4178		0.5112	762.9	1.448	1.4254	
0.5905	756.0	0.746	1.4194		0.6101	764.2	1.386	1.4254	
0.6928	759.5	0.833	1.4213		0.7051	765.5	1.329	1.4255	
0.7914	763.0	0.923	1.4230		0.7999	767.0	1.274	1.4256	
0.8942	766.5	1.026	1.4241		0.8953	768.4	1.222	1.4255	
1.0	769.2	1.123	1.4255		1.0	769.2	1.124	1.4255	
		308.15 K					308.15 K		
0.0	713.7	0.332	1.3929		0.0	753.3	1.653	1.4236	
0.1072	722.8	0.388	1.4012		0.1081	754.4	1.570	1.4234	
0.2039	730.2	0.438	1.4054		0.2058	755.5	1.499	1.4234	
0.3083	737.1	0.499	1.4102		0.2802	756.3	1.450	1.4232	
0.4066	742.9	0.561	1.4122		0.4095	757.8	1.368	1.4231	
0.5029	747.9	0.625	1.4148		0.5112	759.1	1.310	1.4230	
0.5905	751.8	0.688	1.4169		0.6101	760.5	1.261	1.4230	
0.6928	755.4	0.767	1.4189		0.7051	761.9	1.216	1.4231	
0.7914	758.9	0.844	1.4204		0.7999	763.1	1.173	1.4231	
0.8942	762.4	0.934	1.4217		0.8953	764.4	1.135	1.4231	
1.0	765.7	1.028	1.4228		1.0	765.7	1.103	1.4228	
Tri-*n*-butylamine (1) + Tetrahydrofuran (2)					Tri-*n*-butylamine (1) + Tetrachloroethylene (2)				
298.15 K					298.15 K				
0.0	882.9	0.485	1.4049	1288	0.0	1616.0	0.875	1.5036	1033
0.1033	853.3	0.571	1.4120	1283	0.1040	1433.8	0.917	1.4872	1052
0.2033	833.4	0.656	1.4150	1278	0.2059	1295.5	0.958	1.4748	1073
0.3041	818.9	0.741	1.4180	1274	0.3068	1185.4	0.996	1.4659	1094
0.4012	808.1	0.818	1.4200	1271	0.4073	1095.0	1.033	1.4566	1116
0.5024	799.2	0.897	1.4229	1269	0.4967	1026.9	1.065	1.4506	1136
0.5974	792.5	0.967	1.4235	1267	0.6069	955.4	1.104	1.4437	1162
0.6814	787.5	1.028	1.4249	1266	0.6990	904.2	1.136	1.4396	1184
0.7898	782.1	1.100	1.4265	1264	0.8018	854.3	1.172	1.4350	1209
0.8941	777.8	1.167	1.4269	1263	0.9007	812.0	1.206	1.4316	1235
1.0	773.9	1.239	1.4276	1262	1.0	773.9	1.239	1.4276	1262
		303.15 K					303.15 K		
0.0	877.5	0.460	1.4026		0.0	1607.5	0.831	1.5005	
0.1033	847.9	0.539	1.4094		0.1040	1425.9	0.869	1.4842	
0.2033	828.4	0.618	1.4141		0.2059	1288.1	0.902	1.4721	
0.3041	814.2	0.693	1.4155		0.3068	1181.4	0.930	1.4656	
0.4012	803.5	0.763	1.4178		0.4073	1089.1	0.960	1.4539	
0.5024	794.7	0.833	1.4203		0.4967	1021.5	0.990	1.4479	
0.5974	788.2	0.896	1.4211		0.6069	949.9	1.018	1.4415	
0.6814	783.1	0.949	1.4226		0.6990	899.4	1.053	1.4367	
0.7898	777.9	1.014	1.4238		0.8018	849.4	1.081	1.4325	
0.8941	773.6	1.071	1.4246		0.9007	808.0	1.104	1.4289	
1.0	769.2	1.124	1.4254		1.0	769.2	1.124	1.4255	
		308.15 K					308.15 K		
0.0	871.2	0.439	1.3998		0.0	1597.5	0.791	1.4978	
0.1033	842.5	0.509	1.4068		0.1040	1418.2	0.818	1.4810	
0.2033	823.5	0.581	1.4132		0.2059	1281.3	0.844	1.4692	
0.3041	809.3	0.646	1.4130		0.3068	1172.5	0.869	1.4594	
0.4012	798.9	0.708	1.4156		0.4073	1083.2	0.893	1.4510	
0.5024	790.3	0.769	1.4178		0.4967	1015.9	0.914	1.4450	
0.5974	783.8	0.825	1.4188		0.6069	945.2	0.940	1.4392	
0.6814	778.9	0.871	1.4203		0.6990	894.7	0.961	1.4340	
0.7898	773.6	0.928	1.4212		0.8018	845.3	0.984	1.4298	
0.8941	769.4	0.976	1.4224		0.9007	803.4	1.006	1.4263	
1.0	765.7	1.020	1.4228		1.0	765.7	1.028	1.4228	

Table 2 (Continued)

x_1	ρ/kg·m^{-3}	η/mPa·s	n_D	u/m·s^{-1}	x_1	ρ/kg·m^{-3}	η/mPa·s	n_D	u/m·s^{-1}
Tri-*n*-butylamine (1) + Pyridine (2)					Tri-*n*-butylamine (1) + Trichloroethylene (2)				
298.15 K					298.15 K				
0.0	979.0	0.885	1.5062	1412	0.0	1456.7	0.595	1.4752	1028
0.0977	927.2	0.895	1.4866	1363	0.0996	1299.3	0.652	1.4632	1054
0.1951	890.5	0.914	1.4708	1333	0.1953	1186.7	0.713	1.4563	1084
0.2949	862.6	0.941	1.4606	1308	0.2913	1098.3	0.776	1.4502	1108
0.3938	841.3	0.971	1.4513	1290	0.3902	1025.1	0.842	1.4448	1129
0.4898	824.7	1.002	1.4464	1282	0.4875	966.3	0.909	1.4402	1151
0.5884	810.8	1.038	1.4403	1278	0.5906	914.7	0.978	1.4370	1170
0.6899	799.0	1.077	1.4359	1275	0.6843	875.0	1.041	1.4346	1187
0.7846	789.9	1.122	1.4333	1271	0.7846	838.1	1.105	1.4318	1205
0.8869	781.6	1.175	1.4303	1266	0.8835	806.5	1.167	1.4298	1227
1.0	773.9	1.239	1.4276	1262	1.0	773.3	1.239	1.4276	1262
		303.15 K					303.15 K		
0.0	973.7	0.820	1.5025		0.0	1447.1	0.571	1.4722	
0.0977	922.3	0.833	1.4830		0.0996	1291.8	0.622	1.4604	
0.1951	885.6	0.849	1.4685		0.1953	1180.1	0.675	1.4530	
0.2949	858.0	0.872	1.4574		0.2913	1092.1	0.730	1.4469	
0.3938	836.8	0.898	1.4491		0.3902	1019.6	0.788	1.4417	
0.4898	820.3	0.925	1.4428		0.4875	961.0	0.846	1.4377	
0.5884	806.5	0.957	1.4376		0.5906	909.8	0.907	1.4343	
0.6899	794.7	0.993	1.4335		0.6843	870.3	0.962	1.4315	
0.7846	785.7	1.031	1.4300		0.7846	833.7	1.018	1.4295	
0.8869	777.5	1.077	1.4277		0.8835	802.2	1.071	1.4272	
1.0	769.2	1.124	1.4255		1.0	769.2	1.124	1.4255	
		308.15 K					308.15 K		
0.0	968.6	0.766	1.5016		0.0	1439.5	0.549	1.4690	
0.0977	917.4	0.771	1.4795		0.0996	1284.4	0.592	1.4576	
0.1951	880.7	0.783	1.4662		0.1953	1173.3	0.637	1.4495	
0.2949	853.3	0.804	1.4542		0.2913	1086.0	0.684	1.4436	
0.3938	832.2	0.825	1.4470		0.3902	1013.9	0.734	1.4386	
0.4898	815.9	0.848	1.4392		0.4875	955.8	0.783	1.4352	
0.5884	802.1	0.876	1.4348		0.5906	904.9	0.835	1.4317	
0.6899	790.5	0.909	1.4311		0.6843	865.7	0.882	1.4284	
0.7846	781.6	0.940	1.4268		0.7846	829.1	0.930	1.4270	
0.8869	773.3	0.979	1.4252		0.8835	797.8	0.976	1.4246	
1.0	765.7	1.028	1.4228		1.0	765.7	1.028	1.4228	

readings were taken for each composition, and the average value was considered in all calculations. Refractive index data are accurate to ±0.0001 units.

Speed of sound was measured using a variable path single-crystal interferometer (Mittal Enterprises, model M-84, New Delhi). A crystal-controlled high-frequency generator was used to excite the transducer at a frequency of 1 MHz. The frequency was measured within an accuracy of 1 in 10^4 using a digital frequency meter. The interferometer cell was filled with the test liquid, and water was circulated around the measuring cell from a thermostat maintained at 298.15 ± 0.01 K. Details of the speed of sound measurements have been given earlier,[12] and these values are accurate to ±2 in 1000 m·s^{-1}.

In all the property measurements, temperature was controlled within an accuracy of ±0.01 K using a constant-temperature bath. A Julabo immersion cooler (FT 200, Julabo Labortechnik, Gmbh, Germany) was used to cool the water bath. This unit was installed at the intake of a heating circulator to draw the heat away from the circulating bath liquid. An immersion probe was connected to the instrument with a flexible and insulated tube. To prevent the immersion probe from icing, it was completely immersed in the bath liquid.

At least three independent readings of all the physical property (ρ, η, n_D, and u) measurements were taken for each composition, and the averages of these values are presented in Table 2.

Results and Discussion

Excess molar volumes (V^E) of the binary mixtures of tri-*n*-butylamine + triethylamine, + tetrahydrofuran, + tetradecane, + pyridine, + tetrachloroethylene, or + trichloroethylene have been calculated as

$$V^E = V_m - V_1x_1 - V_2x_2 \quad (1)$$

where V_m is the molar volume of the mixture and V_1 and V_2 are the molar volumes of pure components 1 and 2 of the mixture. The results of excess molar volume are reproducible to ±0.005 × 10^{-6} m^3·dmol^{-1}. Generally, the principal solvent, tri-*n*-butylamine, is regarded as component 1 of the mixture. These data at 298.15 K are displayed in Figure 1. It is observed that, for mixtures of tri-*n*-butylamine + pyridine, + tetrahydrofuran, or + tetradecane, V^E data are positive. These positive V^E values vary in the order pyridine > tetrahydrofuran > tetradecane because of the repulsive forces operating between the component liquids of the mixtures. These data vary in accordance with their dipole moments and dielectric constants. For instance, the dielectric constants of pyridine, tetrahydrofuran, and tetradecane are respectively, 12.91, 7.58, and 4.7 in comparison with 2.29 of tri-*n*-butylamine. The molar volumes of tetrahydrofuran and pyridine are almost identical, that is, 81.66 and 80.79 cm^3/mol, respectively, and hence, the shapes as well as the magnitude of V^E for mixtures containing these liquids are almost identical.

In the case of mixtures of tri-*n*-butylamine + tetrachloroethylene, or + trichloroethylene, the V^E versus x_1 plots exhibit sigmoidal trends and their variations are almost identical; that is, at higher amounts of tri-*n*-butylamine (i.e., beyond $x_1 = 0.8$), V^E values are negative. Trichloroethylene, having a dielectric constant of 0.82 and dipole

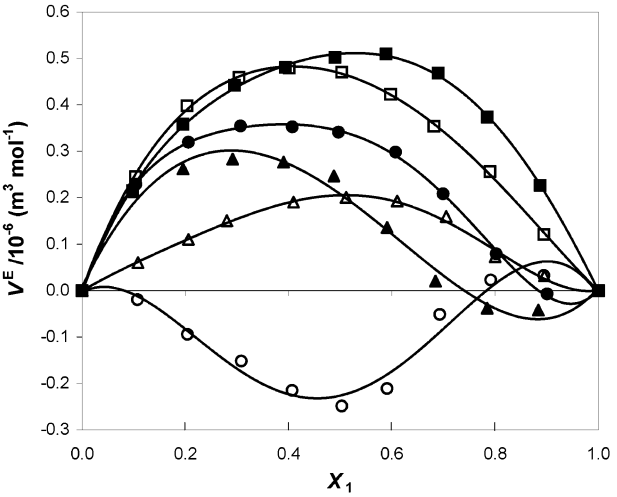

Figure 1. Excess molar volume vs mole fraction of tri-*n*-butylamine with (○) tri-*n*-ethylamine, (□) tetrahydrofuran, (△) tetradecane, (●) tetrachloroethylene, (■) pyridine, and (▲) trichloroethylene at 298.15 K.

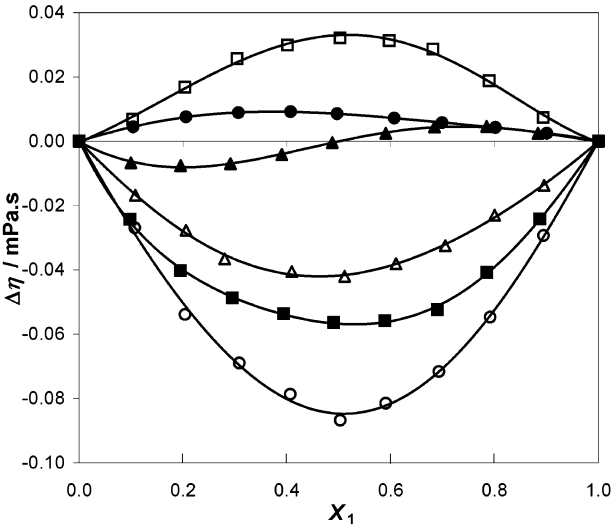

Figure 2. Deviations in viscosity vs mole fraction at 298.15 K for the same mixtures presented in Figure 1.

moment of 0.80 D, exhibits lower positive values of V^E than tetrachloroethylene, which has a dielectric constant of 2.28 with zero dipole moment. Such positive trends have also been observed earlier.[13] On the other hand, for the binary mixture of tri-*n*-butylamine + triethylamine, the V^E values are negative up to $x_1 = 0.8$, but beyond that, V^E becomes positive. It may be noted that the dielectric constants as well as the dipole moments of tri-*n*-butylamine and triethylamine are almost identical, that is, 2.29, 2.423, 0.78, and 0.87 D, respectively.

We have also computed deviation in viscosity ($\Delta\eta$), deviation in molar refractivity (ΔR), and deviation in speed of sound (Δu) using the following general equation.[12,14−17]

$$\Delta Y = Y_m - Y_1 x_1 - Y_2 x_2 \qquad (2)$$

where ΔY represents the desired deviation in $\Delta\eta$, ΔR, Δu, and Δk_s, respectively, whereas Y_1 and Y_2 represent the respective pure liquid property, viz., η, R, u, and k_s (=1/$u^2\rho$) of the pure components 1 and 2 of the mixture. While computing $\Delta\eta$ values, mole fraction was used, but for calculating ΔR and Δu of the mixtures, volume fraction ϕ_i (=$\sum x_i v_i / \sum_{i=1}^{2} x_i v_i$) was used.[10,16,18−20]

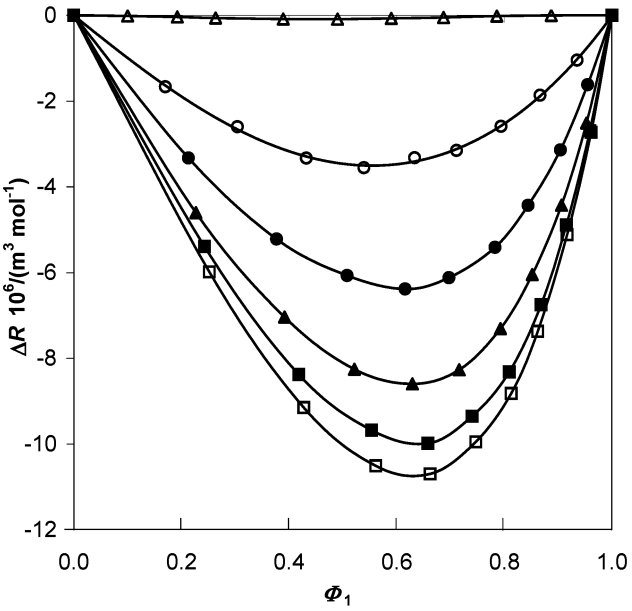

Figure 3. Deviations in molar refraction (ΔR) vs volume fraction at 298.15 K for the same mixtures presented in Figure 1.

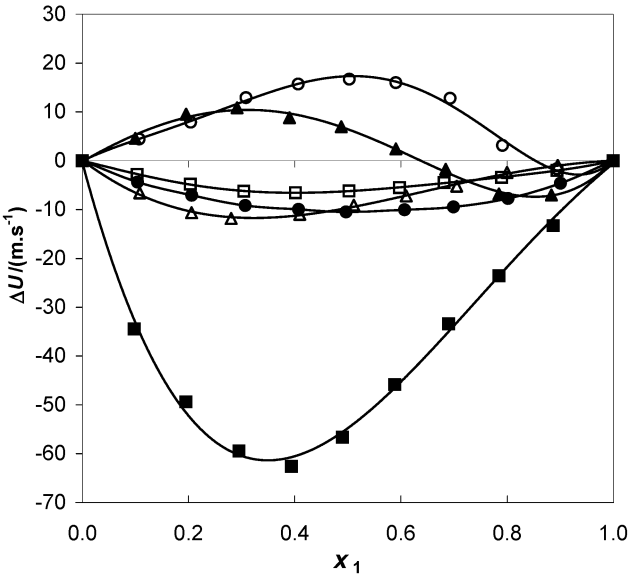

Figure 4. Deviations in speed of sound (Δu) vs mole fraction at 298.15 K for the same mixtures presented in Figure 1.

The plots of $\Delta\eta$ versus x_1 at 298.15 K are displayed in Figure 2. It is observed that large negative values of $\Delta\eta$ are observed for tri-*n*-butylamine + triethylamine, + pyridine, or + tetradecane. Negative $\Delta\eta$ values for these mixtures vary in the order triethylamine > pyridine > tetradecane. The positive $\Delta\eta$ values are observed for mixtures of tri-*n*-butylamine + tetrahydrofuran and + tetrachloroethylene, while for mixtures of tri-*n*-butylamine + trichloroethylene an incipient inversion occurs at about $x_1 = 0.5$, giving negative and positive values on either side of the equimolar composition of the mixture.

The results of deviations in molar refraction (ΔR) plotted as a function of ϕ_i of tri-*n*-butylamine at 298.15 K displayed in Figure 3 indicate negative values for all the mixtures, except that for tri-*n*-butylamine + tetradecane, which is almost zero. The negative ΔR values vary in the order tetrahydrofuran > pyridine > trichloroethylene > tetrachloroethylene > triethylamine > tetradecane.

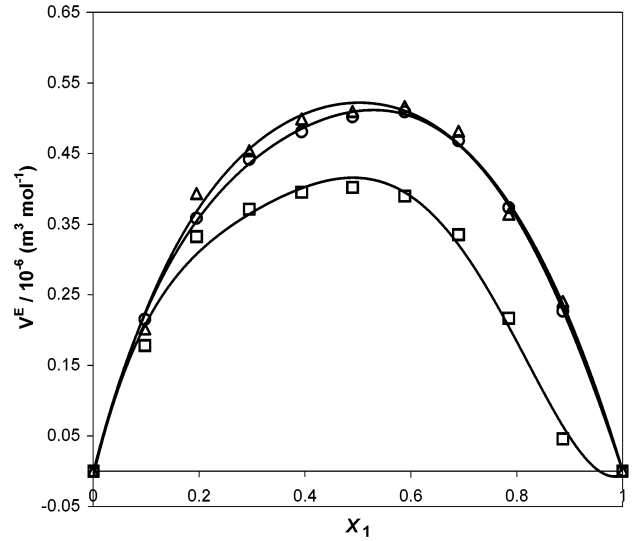

Figure 5. Effect of temperature on V^E for tri-*n*-butylamine + pyridine. Mixture at (○) 298.15 K, (□) 303.15 K, and (△) 308.15 K.

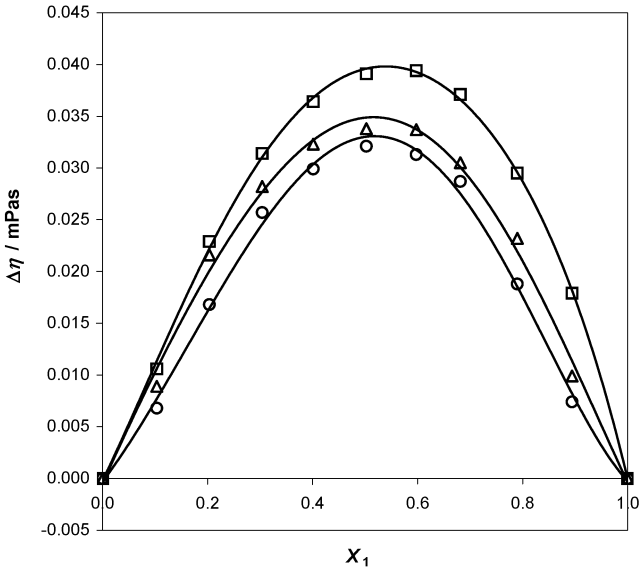

Figure 6. Effect of temperature on $\Delta\eta$ for tri-*n*-butylamine + tetrahydrofuran. Mixture at (○) 298.15 K, (□) 303.15 K, and (△) 308.15 K.

The results of Δu versus x_1 of the binary mixtures at 298.15 K are presented in Figure 4. A large negative Δu is observed in the case of tri-*n*-butylamine + pyridine, whereas sigmoidal trends with an inversion in sign are observed for mixtures of tri-*n*-butylamine with triethylamine or trichloroethylene. On the other hand, for mixtures of tri-*n*-butylamine with tetrahydrofuran, tetrachloroethylene, or tetradecane, Δu values are negative and vary almost identically over the entire composition range.

The effect of temperature on V^E is displayed in Figure 5 for mixtures of tri-*n*-butylamine + pyridine. It is observed that V^E values change with temperature in the order 303.15 < 298.15 < 308.15 K. Similarly, the effect of temperature on $\Delta\eta$ is displayed in Figure 6 for mixtures of tri-*n*-butylamine + tetrahydrofuran. $\Delta\eta$ values change with temperature in the order 298.15 < 308.15 < 303.15 K.

All the quantities (V^E, $\Delta\eta$, ΔR, Δu, and k_s) have been fitted to a Redlich and Kister[8] equation by the method of least-squares using the Marquardt algorithm[21] to derive the binary coefficient (A_j) and estimate the standard deviation (σ) as follows:

$$V^E(\Delta Y) = x_1 x_2 \sum_{j=1}^{k} A_j (x_2 - x_1)^{j-1} \qquad (3)$$

In each case, the optimum number of coefficients (A_j) was

Table 3. Derived Parameters of Eq 3 for Various Functions of the Binary Mixtures at Different Temperatures

function	temp/K	A_1	A_2	A_3	σ
Tri-*n*-butylamine (1) + Triethylamine (2)					
V^E/(10^{-6} m^3·mol^{-1})	298.15	−0.902	−0.507	1.901	0.0317
	303.15	−1.362	0.318	1.237	0.0865
	308.15	−1.193	−0.476	1.822	0.0386
$\Delta\eta$/mPa·s	298.15	−0.339	0.011	0.050	0.0028
	303.15	−0.264	−0.022	0.079	0.0023
	308.15	−0.227	0.010	0.017	0.0016
$\Delta R/10^6$ (m^3·mol^{-1})	298.15	−13.82	−3.313	−0.019	0.0548
	303.15	−13.71	−4.124	−0.436	0.0523
	308.15	−13.40	−4.182	0.074	0.0330
Δu/m·s^{-1}	298.15	69.22	19.75	−90.97	1.370
Tri-*n*-butylamine (1) + Tetrahydrofuran (2)					
V^E/(10^{-6} m^3·mol^{-1})	298.15	1.8732	0.760	0.222	0.0126
	303.15	1.5013	1.474	−0.307	0.0534
	308.15	1.7476	0.681	0.422	0.0118
$\Delta\eta$/mPa·s	298.15	0.1321	−0.007	−0.075	0.0013
	303.15	0.1583	−0.034	−0.001	0.0015
	308.15	0.1396	−0.006	−0.035	0.0018
$\Delta R/10^6$ (m^3·mol^{-1})	298.15	−39.75	−21.52	−12.27	0.1146
	303.15	−39.93	−21.55	−13.48	0.1350
	308.15	−39.59	−21.31	−12.96	0.0972
Δu/m·s^{-1}	298.15	−24.94	−8.67	−0.85	0.241
Tri-*n*-butylamine (1) + Tetradecane (2)					
V^E/(10^{-6} m^3·mol^{-1})	298.15	0.8251	0.097	−0.596	0.0155
	303.15	0.2334	0.952	−1.354	0.0390
	308.15	0.3530	0.496	−0.523	0.0153
$\Delta\eta$/mPa·s	298.15	−0.167	−0.022	0.015	0.0015
	303.15	−0.089	−0.118	0.278	0.0040
	308.15	−0.239	0.003	−0.015	0.0020
$\Delta R/10^6$ (m^3·mol^{-1})	298.15	−0.347	0.133	0.441	0.0043
	303.15	−0.596	−0.107	−0.122	0.0138
	308.15	−0.485	0.112	0.212	0.0068
Δu/m·s^{-1}	298.15	−38.68	−39.81	−5.04	0.412
Tri-*n*-butylamine (1) + Tetrachloroethylene (2)					
V^E/(10^{-6} m^3·mol^{-1})	298.15	1.372	1.127	−0.302	0.0316
	303.15	0.955	1.306	−1.274	0.2688
	308.15	1.274	1.083	−0.653	0.0301
$\Delta\eta$/mPa·s	298.15	0.034	0.016	0.006	0.0003
	303.15	0.044	−0.027	0.090	0.0039
	308.15	0.021	0.006	−0.003	0.0001
$\Delta R/10^6$ (m^3·mol^{-1})	298.15	−24.25	−10.34	−5.074	0.0498
	303.15	−24.22	−10.64	−6.278	0.0750
	308.15	−24.43	−10.28	−5.233	0.0429
Δu/m·s^{-1}	298.15	−41.68	3.08	−12.44	0.170
Tri-*n*-butylamine (1) + Pyridine (2)					
V^E/(10^{-6} m^3·mol^{-1})	298.15	2.040	−0.013	0.561	0.0126
	303.15	1.660	0.606	−0.312	0.0550
	308.15	2.089	0.044	0.581	0.0189
$\Delta\eta$/mPa·s	298.15	−0.227	−0.002	−0.057	0.0023
	303.15	−0.176	−0.027	0.013	0.0015
	308.15	−0.180	−0.018	−0.046	0.0009
$\Delta R/10^6$ (m^3·mol^{-1})	298.15	−36.86	−20.12	−12.34	0.1335
	303.15	−36.94	−20.51	−13.75	0.1379
	308.15	−36.97	−20.06	−13.92	0.1715
Δu/m·s^{-1}	298.15	−219.76	−159.50	−33.20	2.444
Tri-*n*-butylamine (1) + Trichloroethylene (2)					
V^E/(10^{-6} m^3·mol^{-1})	298.15	0.8279	1.646	−0.197	0.022
	303.15	0.2647	2.044	−1.387	0.017
	308.15	0.7146	1.621	−0.220	0.035
$\Delta\eta$/mPa·s	298.15	−0.000	−0.064	−0.033	0.0006
	303.15	0.023	−0.089	0.021	0.0007
	308.15	0.005	−0.054	−0.016	0.0008
$\Delta R/10^6$ (m^3·mol^{-1})	298.15	−32.27	−15.76	−9.476	0.0698
	303.15	−32.57	−16.04	−10.04	0.1200
	308.15	−32.52	−15.93	−9.274	0.0945
Δu/m·s^{-1}	298.15	25.77	81.47	−52.26	1.008

determined from an examination of the variation of standard deviation (σ) as calculated by

$$\sigma = (\sum (Y^{E}_{cal} - Y^{E}_{obs})^2/(n - m))^{1/2} \quad (4)$$

Here, n is the number of measurements and m is the number of coefficients used in fitting the data. The estimated values of A_j and σ for V^E, $\Delta\eta$, ΔR, and Δu are presented in Table 3. In all cases, the best fit was found by using only three adjustable fitting coefficients in eq 3.

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Received for review March 17, 2003. Accepted July 7, 2003. This research was funded by the Department of Science and Technology, New Delhi, India (SP/S1/H-09/2000).

JE030147G