Density, Viscosity, Refractive Index, and Speed of Sound of Ternary Systems: Polystyrene in 1,4-Dioxane + Tetrahydrofuran Mixtures at (298.15, 303.15, and 308.15) K

Udaya S. Toti, Mahadevappa Y. Kariduraganavar, Mrityunjaya I. Aralaguppi, and Tejraj M. Aminabhavi*

Department of Chemistry, Polymer Research Group, Karnatak University, Dharwad 580 003, India

Density, viscosity, refractive index, and speed of sound data are presented at (298.15, 303.15, and 308.15) K for polystyrene solutions of different concentrations in 1,4-dioxane + tetrahydrofuran mixtures over the entire composition range. These results are fitted to a fourth-order regression equation to derive the coefficients. The standard errors between the fitted and the experimental values have been calculated. Using the density and speed of sound data, adiabatic compressibility, molar compressibility, and specific acoustic impedance have been calculated.

Introduction

Thermodynamic and diffusion properties of polystyrene in single and mixed organic solvent systems have been studied in earlier literature by Aminabhavi and Munk (1979a−c). Comparatively, limited data are available on density, ρ, viscosity, η, refractive index, n_D, for the sodium D-line, and speed of sound, u, of polymer solutions in binary mixtures (Johri and Misra, 1984; Venkateswara Rao et al., 1993), but more data are available on polymers in single solvents (Varada Rajulu et al., 1991; Venkata Naidu et al., 1990; Karia and Parsania, 2000). However, to the best of our knowledge, no such data on polystyrene in 1,4-dioxane + tetrahydrofuran, that is, a ternary mixture, are available in the literature.

In this paper, we present the experimental results of ρ, η, and n_D at (298.15, 303.15, and 308.15) K and u at 298.15 K for polystyrene solutions of concentrations ranging from 2.5 to 10 mass % prepared in binary mixtures of 1,4-dioxane + tetrahydrofuran over the entire mixture composition. These data are analyzed using a linear regression equation to derive the coefficients, a_i. The standard errors, σ, are also calculated. From the speed of sound and density values, adiabatic compressibility, β_{ad}, molar compressibility, β_M, and specific acoustic impedance are calculated. Variations of these quantities versus mole fraction of the binary mixture and temperature are presented.

Experimental Section

Materials and Methods. High-purity spectroscopic grade samples of 1,4-dioxane, chloroform, and tetrahydrofuran (THF) were purchased from s.d. fine Chemicals Ltd., Mumbai, India. Polystyrene was purchased from General Electric Co. The GLC analyses of 1,4-dioxane, chloroform, and THF indicated a mole percent purity of 99.3, 99.5, and 99.6, respectively. These analyses were performed on a gas chromatograph, HP Series 6890, equipped with ChemStation software (Product No.G2070AA) using a flame ionization detector with a fused silica column. All the samples were used without further purification. Experimental values of ρ and n_D of the pure liquids are compared at 298.15 K with the published results in Table 1.

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

	ρ/g·cm^{-3}		n_D	
liquid (purity in mol %)	exptl	lit.	exptl	lit.
tetrahydrofuran (99.3)	0.8833	0.8825[a]	1.4050	1.4049[a]
1,4-dioxane (99.5)	1.0286	1.0280[a]	1.4192	1.4191[a]
chloroform (99.6)	1.4788	1.4797[b]	1.4432	1.4430[c]

[a] Marsh (1994). [b] Riddick et al. (1986). [c] Suri and Naorem (1987).

Table 2. Viscosity Results of Polystyrene in Chloroform at 303.15 K

polystyrene conc/g·dm^{-3}	flow time/s	kinematic visc/10^5 m^2·s^{-1}	relative visc [$\eta_r = (\eta - \eta_0)/\eta_0$]	(η_r/c)/ dm^{-3}·g^{-1}
0.005	14.98	4.76	0.413	82.64
0.010	20.43	6.49	0.927	92.74
0.015	27.23	8.64	1.569	104.59
0.020	34.98	11.10	3.300	114.98

Preparations of polystyrene solutions (Aminabhavi and Munk, 1979a−c) and binary mixtures and measurements of mass, density, speed of sound, refractive index, and

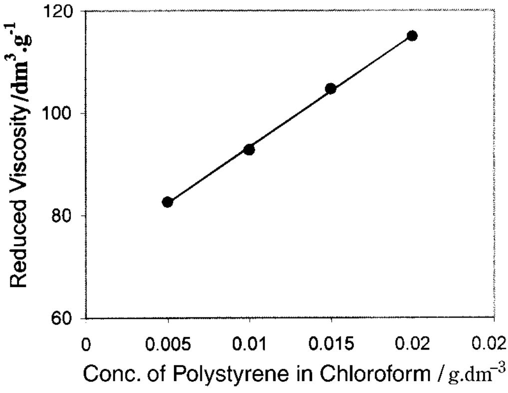

Figure 1. Plot of reduced viscosity versus concentration of polystyrene in chloroform at 303.15 K.

---

* To whom correspondence should be addressed. Fax: 91-836-747884. E-mail: rrist@bgl.vsnl.net.in.

10.1021/je000039j CCC: $19.00

Table 3. Experimental Values of Density, ρ, Refractive Index, n_D, Viscosity, η, and Speed of Sound, u, of Different Mass % Polystyrene Solutions in 1,4-Dioxane (1) + THF (2) Mixtures at Different Temperatures

x_1	ρ/g·cm^{-3}	n_D	η/mPa·s	u/m·s^{-1}	x_1	ρ/g·cm^{-3}	n_D	η/mPa·s	u/m·s^{-1}	x_1	ρ/g·cm^{-3}	n_D	η/mPa·s	u/m·s^{-1}
2.5 mass % of Polystyrene in 1,4-Dioxane (1) + THF (2)														
298.15 K														
0.0000	0.8871	1.4107	1.886	1284	0.3963	0.9422	1.4158	2.383	1307	0.7998	0.9996	1.4217	3.404	1337
0.0976	0.9007	1.4117	1.889	1287	0.4957	0.9558	1.4171	2.560	1313	0.9012	1.0148	1.4231	3.767	1347
0.1945	0.9140	1.4132	2.047	1292	0.5968	0.9705	1.4187	2.826	1319	1.0000	1.0294	1.4246	4.293	1358
0.2458	0.9205	1.4138	2.129	1295	0.7466	0.9922	1.4206	3.245	1332					
303.15 K														
0.0000	0.8813	1.4079	1.755		0.3963	0.9369	1.4132	2.202		0.7998	0.9938	1.4192	3.092	
0.0976	0.8948	1.4093	1.760		0.4957	0.9498	1.4147	2.341		0.9012	1.0088	1.4206	3.420	
0.1945	0.9082	1.4103	1.941		0.5968	0.9645	1.4160	2.588		1.0000	1.0236	1.4221	3.894	
0.2458	0.9148	1.4115	1.973		0.7466	0.9854	1.4180	2.955						
308.15 K														
0.0000	0.8759	1.4057	1.662		0.3963	0.9308	1.4104	2.058		0.7998	0.9883	1.4168	2.852	
0.0976	0.8892	1.4062	1.659		0.4957	0.9428	1.4123	2.182		0.9012	1.0032	1.4182	3.132	
0.1945	0.9026	1.4082	1.779		0.5968	0.9590	1.4133	2.409		1.0000	1.0179	1.4193	3.531	
0.2458	0.9090	1.4086	1.850		0.7466	0.9804	1.4153	2.732						
5.0 mass % Polystyrene in 1,4-Dioxane (1) + THF (2)														
298.15 K														
0.0000	0.8915	1.4144	4.186	1288	0.3963	0.9533	1.4223	5.999	1313	0.7975	1.0038	1.4270	8.317	1345
0.1010	0.9056	1.4166	4.531	1292	0.4989	0.9580	1.4232	6.177	1320	0.9000	1.0176	1.4280	9.007	1352
0.1987	0.9185	1.4180	5.537	1296	0.5994	0.9784	1.4244	6.965	1328	1.0000	1.0301	1.4287	9.579	1360
0.2503	0.9249	1.4187	5.616	1304	0.7496	0.9942	1.4247	7.652	1339					
303.15 K														
0.0000	0.8855	1.4122	3.908		0.3963	0.9474	1.4187	5.485		0.7975	0.9980	1.4243	7.525	
0.1010	0.8998	1.4144	4.205		0.4989	0.9522	1.4198	5.652		0.9000	1.0118	1.4250	8.109	
0.1987	0.9129	1.4154	4.462		0.5994	0.9728	1.4217	6.431		1.0000	1.0241	1.4261	8.573	
0.2503	0.9187	1.4159	4.624		0.7496	0.9883	1.4220	6.945						
308.15 K														
0.0000	0.8841	1.4104	3.669		0.3963	0.9418	1.4161	5.092		0.7975	0.9924	1.4216	6.896	
0.1010	0.8941	1.4110	3.964		0.4989	0.9461	1.4176	5.272		0.9000	1.0062	1.4228	7.405	
0.1987	0.9074	1.4130	4.175		0.5994	0.9669	1.4197	5.953		1.0000	1.0189	1.4234	7.780	
0.2503	0.9134	1.4141	4.341		0.7496	0.9827	1.4197	6.304						
7.5 mass % Polystyrene in 1,4-Dioxane (1) + THF (2)														
298.15 K														
0.0000	0.8955	1.4194	7.956	1295	0.3963	0.9565	1.4269	12.01	1320	0.7975	1.0074	1.4304	16.38	1348
0.1010	0.9108	1.4226	9.572	1305	0.4989	0.9614	1.4270	12.07	1327	0.9000	1.0192	1.4317	18.13	1355
0.1987	0.9286	1.4244	9.877	1311	0.5994	0.9812	1.4282	13.91	1336	1.0000	1.0309	1.4324	18.88	1363
0.2503	0.9330	1.4251	10.32	1315	0.7496	0.9960	1.4291	15.18	1343					
303.15 K														
0.0000	0.8902	1.4167	7.336		0.3963	0.9510	1.4238	10.96		0.7975	1.0016	1.4279	14.75	
0.1010	0.9155	1.4202	8.863		0.4989	0.9656	1.4240	11.50		0.9000	1.0134	1.4290	16.25	
0.1987	0.9273	1.4210	9.501		0.5994	0.9757	1.4256	12.68		1.0000	1.0252	1.4298	16.82	
0.2503	0.9308	1.4218	9.787		0.7496	0.9902	1.4266	13.75						
308.15 K														
0.0000	0.8845	1.4142	7.261		0.3963	0.9454	1.4206	10.20		0.7975	0.9959	1.4252	13.75	
0.1010	0.9100	1.4186	8.293		0.4989	0.9559	1.4222	11.05		0.9000	1.0075	1.4268	14.75	
0.1987	0.9217	1.4190	8.876		0.5994	0.9703	1.4235	11.69		1.0000	1.0195	1.4275	15.22	
0.2503	0.9274	1.4201	9.116		0.7496	0.9849	1.4246	13.46						
10.0 mass % Polystyrene in 1,4-Dioxane (1) + THF (2)														
298.15 K														
0.0000	0.9005	1.4233	11.69	1298	0.3946	0.9598	1.4296	16.55	1326	0.8035	1.0083	1.4342	22.57	1351
0.1010	0.9260	1.4258	12.50	1307	0.4957	0.9643	1.4306	16.89	1331	0.9000	1.0202	1.4350	24.74	1359
0.1987	0.9309	1.4272	12.95	1312	0.6002	0.9842	1.4320	19.38	1339	1.0000	1.0323	1.4359	27.15	1365
0.2500	0.9320	1.4278	13.89	1317	0.7505	0.9980	1.4337	21.33	1347					
303.15 K														
0.0000	0.8947	1.4218	10.70		0.3946	0.9541	1.4271	14.44		0.8035	1.0025	1.4316	19.36	
0.1010	0.9211	1.4243	11.48		0.4957	0.9586	1.4281	15.71		0.9000	1.0145	1.4325	21.21	
0.1987	0.9301	1.4252	12.50		0.6002	0.9783	1.4292	16.78		1.0000	1.0267	1.4335	24.33	
0.2500	0.9319	1.4258	13.22		0.7505	0.9924	1.4310	18.37						
308.15 K														
0.0000	0.8892	1.4191	9.395		0.3946	0.9487	1.4249	12.76		0.8035	0.9970	1.4296	16.82	
0.1010	0.9156	1.4222	10.37		0.4957	0.9530	1.4256	13.04		0.9000	1.0090	1.4302	18.38	
0.1987	0.9209	1.4226	10.91		0.6002	0.9728	1.4266	14.76		1.0000	1.0209	1.4310	19.80	
0.2500	0.9309	1.4230	11.34		0.7505	0.9869	1.4282	15.98						

viscosity of the pure liquids and their binary mixtures are the same as described previously (Aminabhavi and Raikar, 1993a; Aminabhavi et al., 1993b). Mass measurements (±0.01 mg) were made using an electronic single-pan Mettler balance (AE 240, Switzerland). The reproducibility in mole fraction of the mixtures was within ±0.0002 units. Solution densities were measured by using a pycnometer having a bulb volume of 10 cm^3 and a capillary bore with

Table 4. Estimated Parameters and Standard Errors Calculated from Eq 3

property	T/K	a_0	a_1	a_2	a_3	σ
2.5 mass % Polystyrene in 1,4-Dioxane (1) + THF (2)						
ρ/g·cm^{-3}	298.15	1.029	−0.148	0.001	0.006	3.2×10^{-4}
	303.15	1.024	−0.155	0.024	−0.013	4.9×10^{-4}
	308.15	1.027	−0.131	−0.007	0.125	7.8×10^{-4}
η/mPa·s	298.15	4.129	−3.736	0.250	3.131	1.2×10^{-2}
	303.15	3.717	−2.936	−1.651	6.101	2.2×10^{-2}
	308.15	3.429	−3.114	1.149	−0.817	1.6×10^{-2}
n_D	298.15	1.424	−0.006	−0.040	0.066	1.7×10^{-4}
	303.15	1.424	−0.003	−0.071	−0.097	3.0×10^{-4}
	308.15	1.420	−0.002	−0.011	0.030	3.5×10^{-4}
u/m·s^{-1}	298.15	1361	−161.3	244.9	−293.6	0.898
5.0 mass % Polystyrene in 1,4-Dioxane (1) + THF (2)						
ρ/g·cm^{-3}	298.15	1.072	−0.550	1.322	−1.700	3.7×10^{-3}
	303.15	1.031	−0.208	0.279	−0.408	3.9×10^{-3}
	308.15	1.018	−0.211	0.282	−0.401	4.0×10^{-3}
η/mPa·s	298.15	9.383	0.715	−38.34	77.32	0.168
	303.15	9.154	−12.08	21.68	−28.47	0.168
	308.15	8.430	−12.21	25.21	−33.79	0.165
n_D	298.15	1.429	0.000	−0.042	0.058	9.6×10^{-4}
	303.15	1.426	−0.008	−0.008	0.000	7.1×10^{-4}
	308.15	1.424	−0.015	0.014	−0.012	6.4×10^{-4}
u/m·s^{-1}	298.15	1361	−88.6	18.9	−8.7	1.751
7.5 mass % Polystyrene in 1,4-Dioxane (1) + THF (2)						
ρ/g·cm^{-3}	298.15	1.036	−0.171	0.073	0.003	3.7×10^{-3}
	303.15	1.030	−0.186	0.201	−0.225	2.5×10^{-3}
	308.15	1.010	0.035	−0.584	0.796	1.9×10^{-3}
η/mPa·s	298.15	20.99	−33.72	62.13	−73.11	0.404
	303.15	18.22	−21.67	21.49	−10.37	0.326
	308.15	15.55	−6.826	−13.14	21.88	0.126
n_D	298.15	1.435	−0.037	0.076	−0.076	3.7×10^{-4}
	303.15	1.432	−0.037	0.092	−0.124	4.4×10^{-4}
	308.15	1.427	−0.005	−0.029	0.047	4.6×10^{-4}
u/m·s^{-1}	298.15	1361	−61.4	−54.9	116.5	1.637
10.0 mass % Polystyrene in 1,4-Dioxane (1) + THF (2)						
ρ/g·cm^{-3}	298.15	1.043	−0.208	0.334	0.701	4.3×10^{-3}
	303.15	1.039	−0.294	0.700	0.699	4.2×10^{-3}
	308.15	1.023	−0.149	0.059	0.059	3.9×10^{-3}
η/mPa·s	298.15	28.1	−39.3	74.1	−99.5	0.499
	303.15	23.81	−30.38	48.23	−49.17	0.156
	308.15	20.49	−24.59	36.96	−40.43	0.298
n_D	298.15	1.434	0.019	−0.110	0.157	2.3×10^{-4}
	303.15	1.431	0.027	−0.146	0.215	3.1×10^{-4}
	308.15	1.430	0.013	−0.090	0.125	3.6×10^{-4}
u/m·s^{-1}	298.15	1368	−107.9	128.7	−145.3	0.948

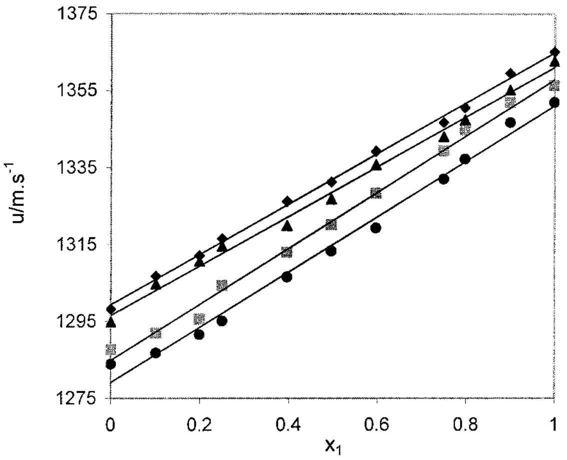

Figure 2. Plot of speed of sound versus mole fraction of 1,4-dioxane for (●) 2.5 mass %, (■) 5.0 mass %, (▲) 7.5 mass %, and (◆) 10.0 mass % solutions of polystyrene in 1,4-dioxane (1) + THF (2) mixtures at 298.15 K.

an internal diameter of 1 mm. Density values are accurate to ±0.0005 g·cm^{-3}).

Refractive indices for the sodium D-line were measured using a thermostatically controlled Abbe Refractometer (Atago 3T, Japan). A minimum of three independent readings were taken for each composition. Refractive index values are accurate to ±0.0001 units. Calibration of the refractometer was explained earlier (Aralaguppi et al., 1991).

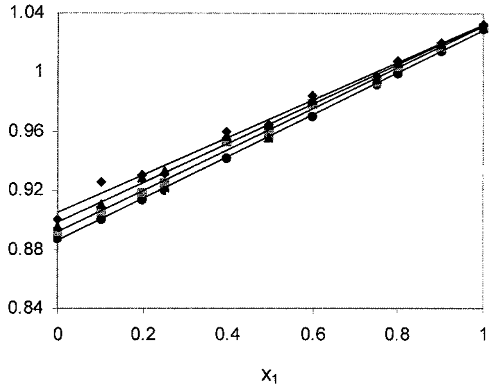

Figure 3. Plot of density versus mole fraction of 1,4-dioxane for polystyrene solutions in 1,4-dioxane (1) + THF (2) mixtures at 298.15 K. Symbols are the same as those given in Figure 2.

Viscosities were measured using a Cannon Fenske viscometer (size 100 and 300, Industrial Research Glassware, Ltd., Rosella, NJ). An electronic digital stopwatch with a readability of ±0.1 s was used for the flow time

Table 5. Results of Adiabatic Compressibility (β_{ad}/cm^2·dyne^{-1}), Molar Compressibility (β_M/cm^3·(cm^2)$^{-1/7}$·mol^{-1}·dyne$^{1/7}$), and Specific Acoustic Impedance (Z/g·cm^{-2}·s^{-1}) at 298.15 K

mole fraction of 1,4-dioxane	$10^{11}\beta_{ad}$ (eq 4)	β_M (eq 5)	$10^{-2}Z$ (eq 6)
2.5 mass % Polystyrene in 1,4-Dioxane (1) + THF (2)			
0.0000	6.839	2368	1139
0.1010	6.704	2365	1159
0.1987	6.558	2366	1181
0.2500	6.477	2384	1192
0.3963	6.217	2410	1231
0.4957	6.065	2391	1256
0.5964	5.919	2368	1281
0.7496	5.680	2361	1322
0.7975	5.594	2366	1337
0.9000	5.433	2371	1367
1.0000	5.268	2373	1398
5.0 mass % Polystyrene in 1,4-Dioxane (1) + THF (2)			
0.0000	6.765	2424	1148
0.1010	6.615	2422	1170
0.1987	6.486	2395	1190
0.2500	6.355	2426	1206
0.3963	6.085	2406	1252
0.4957	5.989	2428	1265
0.5964	5.667	2370	1300
0.7496	5.607	2429	1332
0.7975	5.509	2424	1350
0.9000	5.376	2426	1376
1.0000	5.276	2427	1397
7.5 mass % Polystyrene in 1,4-Dioxane (1) + THF (2)			
0.0000	6.665	2483	1160
0.1010	6.449	2477	1188
0.1987	6.269	2503	1217
0.2500	6.202	2475	1227
0.3963	6.000	2464	1263
0.4957	5.908	2486	1276
0.5964	5.712	2473	1311
0.7496	5.566	2487	1338
0.7975	5.468	2475	1357
0.9000	5.342	2482	1381
1.0000	5.223	2485	1405
10.0 mass % Polystyrene in 1,4-Dioxane (1) + THF (2)			
0.0000	6.583	2539	1170
0.1010	6.365	2517	1202
0.1987	6.238	2503	1222
0.2500	6.190	2545	1227
0.3963	5.923	2519	1273
0.4957	5.851	2541	1284
0.5964	5.665	2527	1318
0.7496	5.554	2539	1344
0.7975	5.437	2532	1362
0.9000	5.306	2539	1387
1.0000	5.198	2539	1409

measurements. The measured viscosity values are accurate to 0.001 mPa·s. Calibration of the viscometer was described earlier (Aminabhavi and Raikar, 1993a; Aminabhavi et al., 1993b).

The viscosity average molecular mass of polystyrene was calculated by measuring its solution viscosities in 0.005, 0.010, 0.015, and 0.020 g·dm^{-3} concentrations in chloroform at 303.15 K using a Schott Gerate viscometer (AVS 250, Germany). The detailed procedure of the viscometer was described earlier (Aminabhavi and Kamalika, 1998). These data are compiled in Table 2. From the plot of reduced viscosity versus concentration (Figure 1), the intrinsic viscosity, $[\eta]$, of the polystyrene solution, calculated by the well-known Huggins approach using the least-squares method, was found to be 71.52. Using the constant values of $k = 4.9 \times 10^{-3}$ and $a = 0.794$ (Gowarikar et al., 1986) in the Mark−Houwink−Sakurada equation,

$$[\eta] = k\bar{M}_\eta^a \tag{1}$$

we got a value of 1.8×10^6 for $\bar{M}_\eta$.

The speed of sound was measured using a variable path single-crystal interferometer (Mittal Enterprises, Model M-84, New Delhi). The data were collected at a frequency of 1 MHz, and the instrument was calibrated using water and benzene (Aminabhavi and Raikar, 1993a; Aminabhavi et al., 1993b). Values of the measured speed of sound are accurate to ±2 m·s^{-1}. In all property measurements, an INSREF, model 016 AP, thermostat was used with a constant digital temperature display accurate to ±0.01 K. The results of ρ, η, n_D, and u presented in Table 3 represent the average values of three independent measurements for each mixture composition and temperature.

Results and Discussion

Experimental values of ρ, n_D, η, and u have been fitted to the linear regression equation of the type

$$Y(t) = \sum_{i=0}^{n} a_i x_1^i \tag{2}$$

Values of the coefficients, a_i, were derived by the method of least squares using the Marquardt algorithm (1963). Here, Y refers to ρ, n_D, u, and η; x_i refers to mole fraction of the i-th component in the binary organic mixture. The value of $n = 3$ was used in these calculations.

Standard deviations, σ, between the fitted quantities (eq 2) and the experimental values were calculated using

$$\sigma = \left[\frac{\sum (Y_{cal} - Y_{obs})^2}{n - m}\right]^{1/2} \tag{3}$$

where n is the number of data points and m is the number of coefficients. The fitted parameters, a_i, and σ values are presented in Table 4.

From density and speed of sound data, adiabatic compressibility, β_{ad}, molar compressibility, β_M, and specific acoustic impedance, Z, were calculated using

$$\beta_{ad} = 1/(u^2\rho) \tag{4}$$

$$\beta_M = (M/\rho)(\beta_{ad})^{-1/7} \tag{5}$$

$$Z = \rho u \tag{6}$$

These data are presented in Table 5.

Figure 2 displays the dependence of speed of sound on mole fraction of 1,4-dioxane at 298.15 K for different polystyrene solutions. The speed of sound values increase linearly with increasing concentration of 1,4-dioxane in the mixture. With increasing concentration of polystyrene, speeds of sound also increase. Speed of sound data at higher temperatures, that is, at (303.15 and 308.15) K, did not show much variation, and hence, we did not attempt to measure these data. The density versus mole fraction plots at 298.15 K presented in Figure 3 show an increase in density with increasing composition of 1,4-dioxane in the mixture. Since an almost similar dependency of ρ on x_1 is observed at all the temperatures, we have presented the data only at 298.15 K.

Viscosity versus mole fraction plots at 298.15 K presented in Figure 4 also show an increase with increasing concentration of polystyrene. However, a decrease in solution viscosity with increasing temperature is observed. The dependence of refractive index on mole fraction of 1,4-

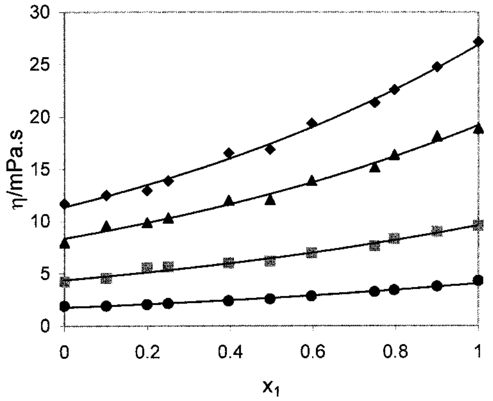

Figure 4. Plot of viscosity versus mole fraction of 1,4-dioxane for polystyrene solutions in 1,4-dioxane (1) + THF (2) mixtures at 298.15 K. Symbols are the same as those given in Figure 2.

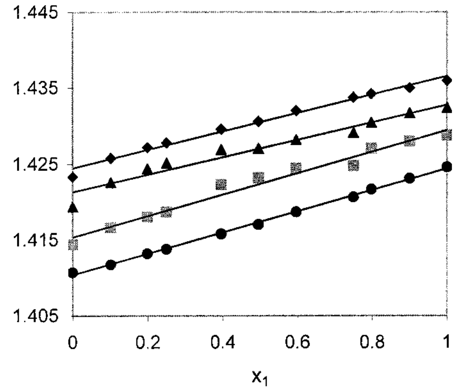

Figure 5. Plot of refractive index versus mole fraction of 1,4-dioxane for polystyrene solutions in 1,4-dioxane (1) + THF (2) mixtures at 298.15 K. Symbols are the same as those given in Figure 2.

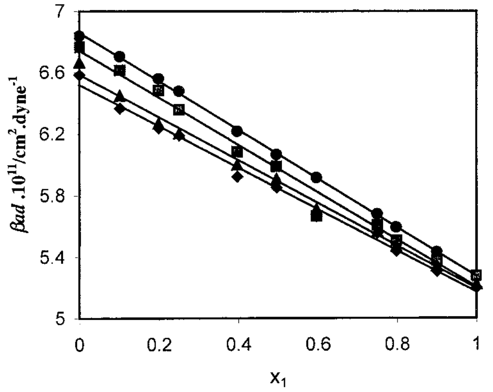

Figure 6. Plot of adiabatic compressibility versus mole fraction of 1,4-dioxane for polystyrene solutions in 1,4-dioxane (1) + THF (2) mixtures at 298.15 K. Symbols are the same as those given in Figure 2.

dioxane at 298.15 K presented in Figure 5 shows linear variations at all the temperatures. The refractive index values decrease slightly with increasing temperature. However, to avoid redundancy, the plots at higher temperatures are not presented.

Results of adiabatic compressibility, molar adiabatic compressibility, and acoustic impedance at 298.15 K are presented respectively in Figures 6, 7, and 8. Adiabatic compressibility values for all polystyrene concentrations decrease with increasing composition of 1,4-dioxane in the mixture, but the molar adiabatic compressibility exhibits no clear-cut dependence on the binary mixture composition.

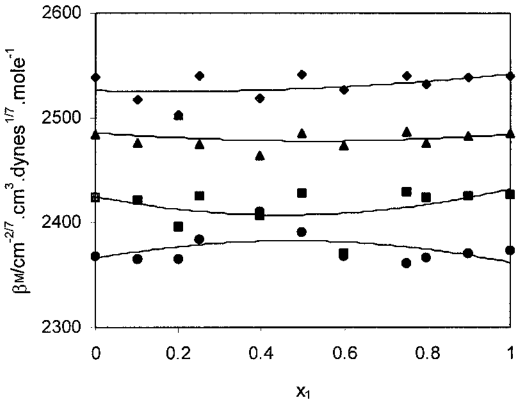

Figure 7. Plot of molar adiabatic compressibility versus mole fraction of 1,4-dioxane for polystyrene solutions in 1,4-dioxane (1) + THF (2) mixtures at 298.15 K. Symbols are the same as those given in Figure 2.

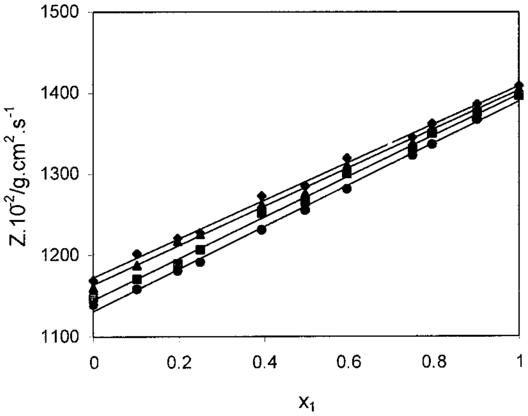

Figure 8. Plot of acoustic impedance versus mole fraction of 1,4-dioxane for polystyrene solutions in 1,4-dioxane (1) + THF (2) mixtures at 298.15 K. Symbols are the same as those given in Figure 2.

On the other hand, acoustic impedance values increase linearly with increasing composition of 1,4-dioxane in the mixture.

Literature Cited

Aminabhavi, T. M.; Munk, P. Preferential Adsorption onto Polystyrene in Mixed Solvent Systems. *Macromolecules* **1979a**, *12*, 607−613.

Aminabhavi, T. M.; Munk, P. Excess Polarizability and Volume of Mixing and Their Effect on the Partial Specific Volume and the Refractive Increment of Polymers in Mixed Solvents. *Macromolecules* **1979b**, *12*, 1186−1194.

Aminabhavi, T. M.; Munk, P. Measurement of Diffusion Coefficient of Polymer Solution Using Ultracentrifuge. *Macromolecules* **1979c**, *12*, 1194−1196.

Aminabhavi, T. M.; Raikar, S. K. A Study on Mixing Properties of Binary Mixtures of Bromoform with Aliphatic Alcohols. *J. Chem. Eng. Data* **1993a**, *38*, 310−319.

Aminabhavi, T. M.; Raikar, S. K.; Balundgi, R. H. Volumetric, Acoustic, Optical, and Viscometric Properties of Binary Mixtures of 2-Methoxyethanol with Aliphatic Alcohols (C_1−C_8), *Ind. Eng. Chem. Res.* **1993b**, *32*, 931−936.

Aminabhavi, T. M.; Banerjee, K. Density, Viscosity, Refractive Index, and Speed of Sound in Binary Mixtures of 2-Chloroethanol with Alkanols (C_1−C_6) at 298.15, 303.15, 308.15 K. *J. Chem. Eng. Data* **1998**, *43*, 509−513.

Aralaguppi, M. I.; Aminabhavi, T. M.; Balundgi, R. H.; Joshi, S. S. Thermodynamic Interactions in Mixtures of Bromoform with Hydrocarbons. *J. Phys. Chem.* **1991**, *95*, 5299−5308.

Chowdoji Rao, K.; Venkata Naidu, A.; Varada Rajulu, A. Acoustical Parameters of Poly(vinyl pyrrolidone) in N,N-Dimethyl Formamide Solutions. *Eur. Polym. J.* **1990**, *26* (6), 657−659.

Gowarikar, V. R.; Viswanathan, N. V.; Jayadev, S. *Polymer Science*; Wiley Eastern Ltd.: New Dehli, 1986.

Johri, G. K.; Misra, R. C. Ultrasonic Study of 2,6-Lutidine Solutions in Benzene and Carbon tetrachloride. *Acustica* **1984**, *56*, 66−68.

Karia, F. D.; Parsania, P. H. Ultrasonic Velocity Studies and Allied Parameters of Poly(4,4′-cyclohexylidene-R,R′-diphenylene diphenyl methane-4,4′-disulfonate) Solutions at 30 °C. *Eur. Polym. J.* **2000**, *36*, 519−524.

Marquardt, D. W. An Algorithm for Least Squares Estimation of Nonlinear Parameters. *J. Soc. Ind. Appl. Math.* **1963**, *11*, 431−441.

Marsh, K. N. *TRC Data Bases for Chemistry and Engineering*−*TRC Thermodynamic Tables*; Texas A & M University System: College Station, TX, 1994.

Riddick, J. A.; Bunger, W. B.; Sakano, T. K. Techniques of Chemistry, Organic Solvents. *Physical Properties and Methods of Purification*; John Wiley & Sons: New York, 1986; Vol. II.

Suri, S. K.; Naorem, H. Excess Molar Volumes, Speeds of Sound, and Isentropic Compressibilities of Binary Mixtures of Furfural with Some Aromatic Hydrocarbons. *J. Chem. Eng. Data* **1987**, *32*, 462−466.

Varada Rajulu, A.; Chowdoji Rao, K.; Venkata Naidu, S. Ultrasonic Studies of Poly(vinyl pyrrolidone) in N,N-Dimethyl Formamide Solutions. *Acta Polym.* **1991**, *42*, 336−337.

Venkata Naidu, S.; Varada Rajulu, A.; Chowdoji Rao, K. Ultrasonic Velocities and Rao Formalism of Poly(Vinyl Pyrrolidone) in N,N-Dimethyl Formamide Solution, *J. Polym. Mater.* **1990**, *7*, 149−153.

Venkateswara Rao, A.; Raman, G. K.; Varada Rajulu, A. Acoustical Parameters of Polystyrene in Binary Mixture. *Asian J. Chem.* **1993**, *5*, 582−592.

Received for review January 31, 2000. Accepted June 19, 2000. This research was supported by the generous grants received from the Department of Science and Technology [SP/S1/H-26/96(PRU)], and All India Council for Technical Education [8017/RDII/PHA/208/98] New Delhi.

JE000039J