Densities, Viscosities, Refractive Indices, and Speeds of Sound of the Binary Mixtures of Bis(2-methoxyethyl) Ether with Nonane, Decane, Dodecane, Tetradecane, and Hexadecane at 298.15, 308.15, and 318.15 K

Tejraj M. Aminabhavi* and Bindu Gopalkrishna

Department of Chemistry, Karnatak University, Dharwad 580 003, India

Densities, viscosities, refractive indices, and speeds of sound for the binary mixtures of bis(2-methoxyethyl) ether with nonane, decane, dodecane, tetradecane, and hexadecane have been measured at 298.15, 308.15, and 318.15 K over the entire range of mole fractions. From these results, the excess molar volumes and deviations in viscosity, refractivity, speed of sound, and isentropic compressibility have been calculated. These results are fitted to the Redlich–Kister polynomial relation to estimate the binary interaction parameters. The excess molar volumes and deviations in isentropic compressibility are positive, while the deviations in viscosity, speed of sound, and molar refractivity are negative. The results show a trend with the chain length of the alkanes.

Introduction

The present paper forms a part of our ongoing program of research to measure physical properties of the binary mixtures containing *n*-alkanes and the prediction of their excess properties (*1–3*). In previous papers from this laboratory, the binary mixtures of bis(2-methoxyethyl) ether (also called diglyme) with different organic liquids have been studied (*3, 6–9*). A search of the literature indicates the nonavailability of physical data on binary mixtures of diglyme with higher *n*-alkanes, i.e., C_9, C_{10}, C_{12}, C_{14}, and C_{16}. In this paper, some new measurements on density, viscosity, refractive index, and speed of sound at 298.15, 308.15, and 318.15 K are presented for binary mixtures of diglyme with nonane, decane, dodecane, tetradecane, and hexadecane. From these properties, the excess molar volume and deviations in viscosity, molar refractivity, speed of sound, and isentropic compressibility have been calculated and used in the discussion of the binary interactions between mixing components.

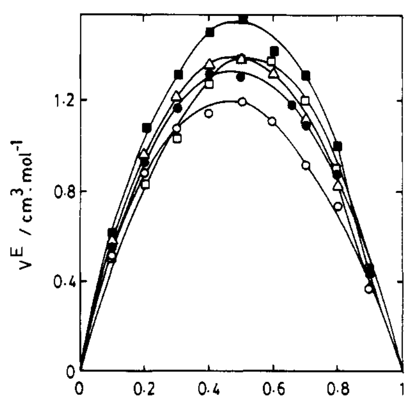

Figure 1. Excess molar volumes at 298.15 K for diglyme + nonane (○), + decane (●), + dodecane (Δ), + tetradecane (□), and + hexadecane (■); solid line, Redlich–Kister equation.

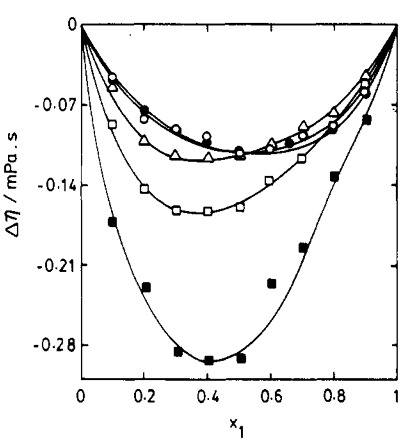

Figure 2. Deviations in viscosity at 298.15 K for diglyme + *n*-alkanes. Symbols and lines have the same meaning as given in Figure 1.

Experimental Section

Materials. Bis(2-methoxyethyl) ether was purchased from BDH, England. The analytical grade solvents nonane, decane, dodecane, tetradecane, and hexadecane were from S.D. Fine Chemicals, Bombay. All the solvents were used directly as received. The purity of these solvents was ascertained by comparing their density, ρ, viscosity, η, refractive index, n_D, and speed of sound, u, with the available literature data (Table 1). The GLC analyses were made using a flame ionization detector (Nucon series, model 5700/5765, with fused silica columns) having a sensitivity better than 10^{-8} g of fatty acid/μL of solvent. The GLC purity analysis for each liquid is also included in Table 1.

Binary mixtures were prepared by mixing the appropriate volumes of pure liquids in specially designed ground-glass air-tight bottles and weighed on a single-pan Mettler balance (Switzerland, model AE-240) to an accuracy of ±0.01 mg. The possible error in the mole fractions is estimated to be around ±0.0001.

Measurements. Densities of pure liquids and their binary mixtures in the mole fraction range of 0.1–0.9 were measured using a pycnometer having a bulb volume of 15 cm³ and a capillary with an internal diameter of 1 mm. The details of the measurement techniques are the same as given earlier (*1–9*). Densities at 298.15, 308.15, and 318.15 K are considered precise to 0.0001 g·cm^{-3}. An average of triplicate measurements was taken into account, and these were generally reproducible within ±0.0002 g·cm^{-3}.

* To whom correspondence should be addressed.

0021-9568/94/1739-0529$04.50/0

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

liquid (mol % purity)	$\rho/(g\cdot cm^{-3})$ expt	$\rho/(g\cdot cm^{-3})$ lit.	$\eta/(mPa\cdot s)$ expt	$\eta/(mPa\cdot s)$ lit.	n_D expt	n_D lit.
diglyme (>99.4)	0.9399	0.9397 (*13*) 0.9392 (*14*)	0.991	0.990 (*15*)	1.4058	1.4060 (*13*)
nonane (>99.6)	0.7145	0.7139 (*16*)	0.655	0.657 (*17*)	1.4034	1.4042 (*16*)
decane (>99.5)	0.7265	0.7262 (*16*)	0.831	0.843 (*18*)	1.4101	1.4098 (*16*)
dodecane (>99.2)	0.7461	0.7457 (*16*)	1.324	1.345 (*17*)	1.4192	1.4197 (*16*)
tetradecane (>99.7)	0.7608	0.7599 (*1*)	2.025	2.035 (*1*)	1.4270	1.4260 (*1*)
hexadecane (>99.3)	0.7707	0.7703 (*18*)	3.005	3.078 (*19*)	1.4338	1.4328 (*20*)

Viscosities were measured with a Cannon Fenske viscometer (size 100) supplied by Industrial Research Glassware Ltd., New Jersey. An electronic stop watch with a precision of ±0.01 s was used to measure the flow times. Triplicate

Table 2. Experimental Densities (ρ), Viscosities (η), Refractive Indices (n_D), and Speeds of Sound (u) of Binary Mixtures at Different Temperatures

x_1	$\rho/(g\cdot cm^{-3})$	$\eta/(mPa\cdot s)$	n_D	$u/(m\cdot s^{-1})$	x_1	$\rho/(g\cdot cm^{-3})$	$\eta/(mPa\cdot s)$	n_D	$u/(m\cdot s^{-1})$
Bis(2-methoxyethyl) Ether (1) + Nonane (2)									
298.15 K									
0.0000	0.7145	0.655	1.4034	1209	0.5963	0.8305	0.747	1.4018	1219
0.0991	0.7305	0.642	1.4028	1204	0.6999	0.8559	0.794	1.4027	1230
0.2003	0.7481	0.640	1.4019	1200	0.7997	0.8817	0.836	1.4036	1250
0.3005	0.7670	0.665	1.4017	1204	0.8970	0.9092	0.898	1.4049	1262
0.3982	0.7868	0.691	1.4014	1199	1.0000	0.9399	0.992	1.4058	1284
0.5023	0.8089	0.712	1.4017	1210					
308.15 K									
0.0000	0.7068	0.577	1.3989	1166	0.5963	0.8213	0.647	1.3973	1180
0.0991	0.7224	0.559	1.3983	1164	0.6999	0.8465	0.685	1.3978	1196
0.2003	0.7398	0.560	1.3972	1162	0.7997	0.8720	0.718	1.3990	1205
0.3005	0.7585	0.579	1.3970	1163	0.8970	0.8995	0.768	1.4001	1224
0.3982	0.7779	0.600	1.3968	1164	1.0000	0.9301	0.845	1.4012	1250
0.5023	0.7998	0.618	1.3968	1175					
318.15 K									
0.0000	0.6990	0.505	1.3938	1126	0.5963	0.8121	0.561	1.3918	1140
0.0991	0.7143	0.490	1.3935	1125	0.6999	0.8372	0.591	1.3924	1158
0.2003	0.7316	0.490	1.3929	1124	0.7997	0.8626	0.620	1.3937	1170
0.3005	0.7500	0.507	1.3920	1125	0.8970	0.8898	0.662	1.3951	1185
0.3982	0.7693	0.523	1.3914	1125	1.0000	0.9202	0.728	1.3967	1203
0.5023	0.7909	0.538	1.3914	1134					
Bis(2-methoxyethyl) Ether (1) + Decane (2)									
298.15 K									
0.0000	0.7265	0.831	1.4101	1239	0.6592	0.8452	0.834	1.4045	1234
0.1008	0.7405	0.798	1.4088	1229	0.7010	0.8553	0.846	1.4047	1238
0.2018	0.7559	0.788	1.4075	1222	0.7987	0.8801	0.869	1.4046	1254
0.3025	0.7727	0.787	1.4066	1222	0.9013	0.9093	0.915	1.4053	1264
0.3984	0.7900	0.790	1.4058	1219	1.0000	0.9399	0.992	1.4058	1284
0.4993	0.8101	0.800	1.4055	1221					
308.15 K									
0.0000	0.7189	0.717	1.4055	1190	0.6592	0.8360	0.716	1.3998	1196
0.1008	0.7326	0.689	1.4040	1186	0.7010	0.8460	0.726	1.4003	1198
0.2018	0.7478	0.682	1.4029	1183	0.7987	0.8707	0.746	1.4004	1206
0.3025	0.7645	0.679	1.4017	1182	0.9013	0.8995	0.784	1.4007	1224
0.3984	0.7815	0.680	1.4013	1179	1.0000	0.9301	0.845	1.4012	1250
0.4993	0.8013	0.688	1.4008	1182					
318.15 K									
0.0000	0.7114	0.619	1.4009	1158	0.6592	0.8270	0.618	1.3955	1150
0.1008	0.7249	0.597	1.3993	1151	0.7010	0.8369	0.627	1.3956	1158
0.2018	0.7399	0.590	1.3980	1147	0.7987	0.8613	0.643	1.3958	1173
0.3025	0.7563	0.589	1.3971	1143	0.9013	0.8900	0.674	1.3961	1186
0.3984	0.7731	0.589	1.3963	1141	1.0000	0.9202	0.728	1.3967	1203
0.4993	0.7930	0.597	1.3961	1142					
Bis(2-methoxyethyl) Ether (1) + Dodecane (2)									
298.15 K									
0.0000	0.7461	1.324	1.4192	1282	0.6015	0.8340	1.020	1.4108	1249
0.1009	0.7568	1.236	1.4179	1271	0.7024	0.8560	1.001	1.4093	1250
0.1998	0.7687	1.157	1.4165	1263	0.8008	0.8802	0.981	1.4082	1257
0.2993	0.7822	1.110	1.4150	1257	0.9003	0.9085	0.980	1.4076	1268
0.4034	0.7981	1.074	1.4136	1252	1.0000	0.9399	0.992	1.4058	1284
0.5021	0.8150	1.043	1.4119	1250					
308.15 K									
0.0000	0.7386	1.106	1.4161	1241	0.6015	0.8251	0.865	1.4059	1212
0.1009	0.7492	1.038	1.4142	1233	0.7024	0.8468	0.849	1.4048	1213
0.1998	0.7609	0.976	1.4118	1225	0.8008	0.8708	0.837	1.4039	1219
0.2993	0.7742	0.940	1.4097	1218	0.9003	0.8988	0.835	1.4025	1229
0.4034	0.7899	0.909	1.4084	1214	1.0000	0.9301	0.845	1.4012	1250
0.5021	0.8064	0.884	1.4071	1212					

Table 2 (Continued)

x_1	ρ/(g·cm^{-3})	η/(mPa·s)	n_D	u/(m·s^{-1})	x_1	ρ/(g·cm^{-3})	η/(mPa·s)	n_D	u/(m·s^{-1})
Bis(2-methoxyethyl) Ether (1) + Dodecane (2)									
318.15 K									
0.0000	0.7314	0.935	1.4114	1207	0.6015	0.8166	0.743	1.4016	1173
0.1009	0.7417	0.880	1.4097	1196	0.7024	0.8378	0.728	1.4002	1174
0.1998	0.7532	0.830	1.4080	1188	0.8008	0.8615	0.720	1.3988	1178
0.2993	0.7663	0.801	1.4064	1182	0.9003	0.8891	0.719	1.3976	1189
0.4034	0.7818	0.780	1.4049	1176	1.0000	0.9202	0.728	1.3967	1203
0.5021	0.7979	0.757	1.4033	1174					
Bis(2-methoxyethyl) Ether (1) + Tetradecane (2)									
298.15 K									
0.0000	0.7608	2.025	1.4270	1317	0.5940	0.8345	1.275	1.4146	1266
0.0987	0.7694	1.835	1.4252	1304	0.6981	0.8551	1.187	1.4122	1264
0.2023	0.7799	1.672	1.4232	1293	0.7958	0.8780	1.113	1.4102	1265
0.3020	0.7915	1.550	1.4210	1285	0.8986	0.9067	1.044	1.4079	1269
0.4002	0.8039	1.448	1.4191	1277	1.0000	0.9399	0.992	1.4058	1284
0.5033	0.8191	1.345	1.4167	1270					
308.15 K									
0.0000	0.7536	1.646	1.4231	1278	0.5940	0.8259	1.068	1.4098	1229
0.0987	0.7620	1.503	1.4212	1263	0.6981	0.8463	0.996	1.4073	1227
0.2023	0.7729	1.380	1.4190	1254	0.7958	0.8687	0.938	1.4053	1227
0.3020	0.7832	1.290	1.4168	1246	0.8986	0.8972	0.888	1.4033	1230
0.4002	0.7958	1.205	1.4145	1238	1.0000	0.9301	0.845	1.4012	1250
0.5033	0.8108	1.122	1.4118	1232					
318.15 K									
0.0000	0.7464	1.356	1.4190	1241	0.5940	0.8174	0.902	1.4054	1189
0.0987	0.7546	1.248	1.4165	1231	0.6981	0.8375	0.848	1.4032	1187
0.2023	0.7647	1.153	1.4142	1218	0.7958	0.8595	0.800	1.4014	1189
0.3020	0.7755	1.070	1.4120	1210	0.8986	0.8875	0.760	1.4015	1192
0.4002	0.7877	1.009	1.4099	1201	1.0000	0.9202	0.728	1.3967	1203
0.5033	0.8025	0.945	1.4074	1192					
Bis(2-methoxyethyl) Ether (1) + Hexadecane (2)									
298.15 K									
0.0000	0.7707	3.005	1.4338	1342	0.6013	0.8364	1.568	1.4188	1282
0.1013	0.7778	2.629	1.4310	1326	0.7004	0.8547	1.400	1.4157	1276
0.2067	0.7865	2.359	1.4288	1315	0.7997	0.8773	1.262	1.4124	1271
0.3071	0.7965	2.101	1.4261	1306	0.9021	0.9065	1.106	1.4094	1270
0.4030	0.8073	1.900	1.4242	1296	1.0000	0.9399	0.992	1.4058	1284
0.5078	0.8213	1.721	1.4211	1289					
308.15 K									
0.0000	0.7637	2.381	1.4293	1305	0.6013	0.8279	1.290	1.4143	1244
0.1013	0.7706	2.107	1.4265	1294	0.7004	0.8460	1.173	1.4113	1238
0.2067	0.7793	1.885	1.4245	1286	0.7997	0.8683	1.058	1.4083	1234
0.3071	0.7888	1.712	1.4216	1275	0.9021	0.8969	0.934	1.4046	1239
0.4030	0.7997	1.552	1.4178	1264	1.0000	0.9301	0.845	1.4012	1250
0.5078	0.8133	1.414	1.4166	1250					
318.15 K									
0.0000	0.7568	1.920	1.4254	1267	0.6013	0.8197	1.080	1.4094	1205
0.1013	0.7630	1.690	1.4222	1255	0.7004	0.8373	0.984	1.4066	1198
0.2067	0.7717	1.515	1.4205	1244	0.7997	0.8596	0.890	1.4038	1195
0.3071	0.7814	1.385	1.4174	1231	0.9021	0.8875	0.799	1.3997	1197
0.4030	0.7919	1.288	1.4146	1220	1.0000	0.9202	0.728	1.3967	1203
0.5078	0.8054	1.178	1.4119	1211					

measurements of flow times were reproducible within ±0.01 s. The calibration procedures of the viscometers and the experimental details are the same as given earlier (*1–9*). Viscosities are accurate to ±0.001 mPa·s.

Refractive indices were measured for the sodium-D line with a thermostated Abbe refractometer (Bellingham and Stanley Ltd., London). The refractometer was calibrated by means of a glass test piece of known refractive index supplied by the manufacturer. Water was circulated into the instrument through a thermostatically controlled bath. Mixtures were directly injected into the prism assembly of the instrument using an air-tight hypodermic syringe, and the refractive index measurements were done when the liquids or the mixtures attained the constant temperature of the refractometer. This procedure was repeated at least three times, and the average of these readings was taken for the calculation of refractive index values. Refractive indices are accurate to ±0.0002 unit.

Speed of sound results were obtained using a variable-path single-crystal interferometer (Mittal Enterprises, New

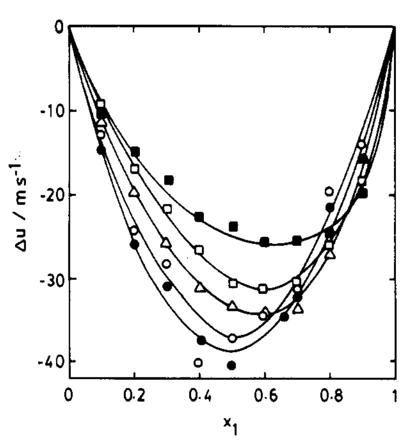

Figure 3. Deviations in speed of sound at 298.15 K for diglyme + *n*-alkanes. Symbols and lines have the same meaning as given in Figure 1.

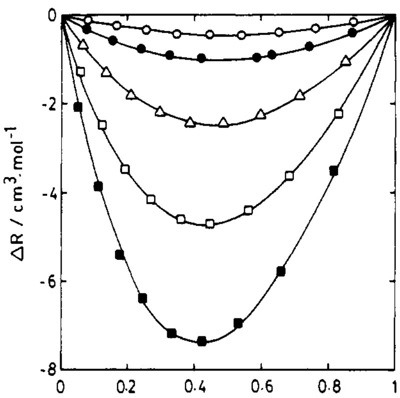

Figure 4. Deviations in molar refractivity at 298.15 K for diglyme + *n*-alkanes. Symbols and lines have the same meaning as given in Figure 1.

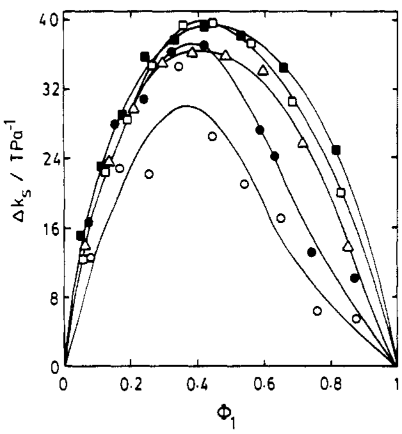

Figure 5. Deviations in isentropic compressibility at 298.15 K for diglyme + *n*-alkanes. Symbols and lines have the same meaning as given in Figure 1.

Delhi, model M-84) as per the experimental details given earlier (*1–9*). The cell used was of 4 MHz. Speed of sound data are accurate to ±2 m·s^{-1}.

In all the property measurements, an INSREF, model 016 AP, thermostat was used within the temperature control of ±0.01 K at the desired temperature as checked by means of a calibrated thermometer with an accuracy of ±0.1 K. The results of binary mixtures compiled in Table 2 are the averages of at least three independent measurements for each composition of the mixture.

Results and Discussion

Excess molar volumes of the binary mixtures have been calculated as

$$V^E/(\mathrm{cm^3{\cdot}mol^{-1}}) = V_m - V_1x_1 - V_2x_2 \qquad (1)$$

where V_1, V_2, and V_m are the molar volumes of components 1 and 2 and of the mixture, respectively, and x_1 and x_2 represent the mole fractions of components 1 and 2. The molar volume of the mixture and those of the individual components are calculated as

$$V_m = \frac{M_1x_1 + M_2x_2}{\rho_m} \qquad V_1 = \frac{M_1}{\rho_1} \qquad V_2 = \frac{M_2}{\rho_2} \qquad (2)$$

where M_1 and M_2 are the molecular weights and ρ_1, ρ_2, and ρ_m represent the densities of pure components 1 and 2 and of the binary mixture, respectively.

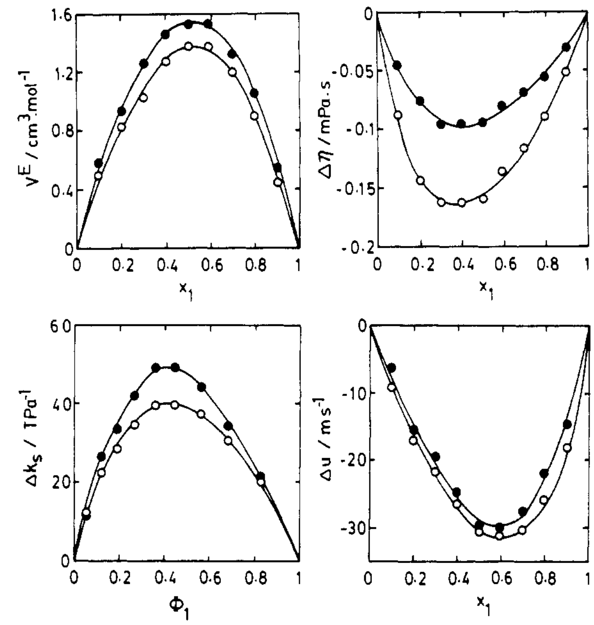

Figure 6. Temperature dependence of excess molar volume, and deviations in viscosity, speed of sound, and isentropic compressibility for diglyme + tetradecane at 298.15 K (O) and 318.15 K (●); solid line, Redlich–Kister equation.

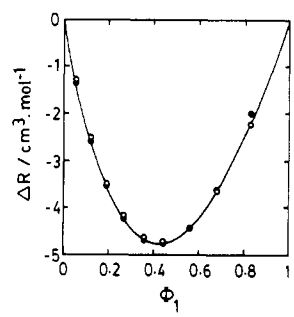

Figure 7. Temperature dependence of the deviations in molar refractivity for diglyme + tetradecane at 298.15 K (O) and 318.15 K (●); solid line, Redlich–Kister equation.

The deviations in viscosity, $\Delta\eta$, molar refractivity, ΔR, speed of sound, Δu, and isentropic compressibility, Δk_s, have been calculated from the general relation

$$\Delta Y = Y_m - Y_1C_1 - Y_2C_2 \qquad (3)$$

where ΔY refers to $\Delta\eta$, ΔR, Δu, and Δk_s. Y_m is the measured mixture property under question, whereas Y_i refer to the properties of the pure components of the mixture. The terms C_1 and C_2 are mixture compositions expressed as mole fraction for $\Delta\eta$ and Δu. For calculating ΔR and Δk_s, the volume fraction, ϕ_i, defined by eq 4

$$\phi_i = x_iV_i/\sum_{i=1}^{2} x_iV_i \qquad (4)$$

is used for C_i.

The excess molar volumes as well as other properties, viz., $\Delta\eta$, Δu, ΔR, and Δk_s, have been fitted to the Redlich–Kister (*10*) relation

$$\Delta Y \text{ or } V^E = C_1C_2\sum_{i=0}^{4} A_i(C_2 - C_1)^i \qquad (5)$$

to estimate the binary interaction coefficients A_i by the method of nonlinear least squares (Marquardt algorithm). The standard errors, σ, between the calculated and the

Table 3. Estimated Parameters of Excess Functions for Mixtures

function	T/K	A_0	A_1	A_2	A_3	A_4	σ	function	T/K	A_0	A_1	A_2	A_3	A_4	σ
Bis(2-methoxyethyl) Ether (1) + Nonane (2)															
V^E/(cm^3·mol^{-1})	298.15	4.670	0.665	0.913	0.605	−0.874	0.029	Δk_s/TPa^{-1}	298.15	102.59	−116.34	−74.30	72.81	135.40	4.039
	308.15	5.075	0.708	0.563	0.762	0.200	0.035		308.15	89.12	−79.11	98.97	89.54	−102.43	3.476
	318.15	5.322	0.640	0.367	1.170	0.451	0.033		318.15	92.30	−124.87	−107.21	106.31	124.87	2.652
$\Delta\eta$/(mPa·s)	298.15	−0.430	0.047	−0.174	0.014	−0.150	0.005	ΔR/(cm^3·mol^{-1})	298.15	−1.863	0.258	0.223	−0.147	0.538	0.013
	308.15	−0.361	0.022	−0.126	−0.013	−0.215	0.003		308.15	−1.866	0.223	0.052	−0.064	0.744	0.017
	318.15	−0.306	0.032	−0.118	−0.008	−0.171	0.003		318.15	−2.073	0.148	0.518	−0.918	0.852	0.015
Δu/(m·s^{-1})	298.15	−154.26	−16.81	95.35	23.03	−130.25	2.901								
	308.15	−139.87	−4.19	−16.23	84.90	−9.81	2.370								
	318.15	−130.40	−10.94	101.17	24.85	−104.52	1.546								
Bis(2-methoxyethyl) Ether (1) + Decane (2)															
V^E/(cm^3·mol^{-1})	298.15	5.259	0.360	1.255	0.211	−1.206	0.020	Δk_s/TPa^{-1}	298.15	137.46	−116.90	−130.23	58.22	281.40	1.314
	308.15	5.605	0.290	0.960	0.290	−0.409	0.014		308.15	128.07	−59.39	41.24	110.79	−17.30	2.587
	318.15	5.620	0.319	2.417	0.265	−2.583	0.039		318.15	181.24	−106.73	−243.98	33.78	315.87	1.953
$\Delta\eta$/(mPa·s)	298.15	−0.440	0.020	−0.075	0.121	−0.315	0.002	ΔR/(cm^3·mol^{-1})	298.15	−4.047	0.428	−0.211	0.327	0.442	0.013
	308.15	−0.368	0.022	−0.009	0.077	−0.318	0.002		308.15	−4.001	0.625	0.103	0.192	−0.001	0.025
	318.15	−0.305	0.022	−0.038	0.091	−0.243	0.001		318.15	−4.010	0.820	0.046	−0.125	−0.231	0.005
Δu/(m·s^{-1})	298.15	−161.57	−0.78	101.73	−10.04	−174.15	1.648								
	308.15	−149.64	24.98	37.30	84.45	−113.71	1.633								
	318.15	−159.79	37.63	110.32	−64.99	−106.82	1.787								
Bis(2-methoxyethyl) Ether (1) + Dodecane (2)															
V^E/(cm^3·mol^{-1})	298.15	5.538	0.277	0.654	1.605	−1.664	0.013	Δk_s/TPa^{-1}	298.15	144.34	−31.30	17.39	−68.15	−7.85	0.639
	308.15	5.812	−0.055	1.036	1.698	−2.034	0.014		308.15	156.06	−32.64	48.53	8.66	−33.68	0.752
	318.15	6.088	0.090	1.271	1.409	−2.045	0.023		318.15	174.28	−40.82	58.49	−76.14	−78.36	0.655
$\Delta\eta$/(mPa·s)	298.15	−0.449	−0.163	−0.349	0.133	0.264	0.003	ΔR/(cm^3·mol^{-1})	298.15	−9.896	1.936	−0.273	0.184	0.842	0.012
	308.15	−0.357	−0.098	−0.268	0.073	0.239	0.003		308.15	−10.199	3.097	1.772	−0.796	1.695	0.023
	318.15	−0.286	−0.070	−0.252	0.044	0.234	0.002		318.15	−10.046	1.948	−0.397	0.151	−0.117	0.008
Δu/(m·s^{-1})	298.15	−133.92	45.78	−53.96	−20.70	44.76	0.568								
	308.15	−134.00	42.42	−38.33	49.37	−1.67	0.538								
	318.15	−126.76	36.25	−51.65	−6.05	51.39	0.646								
Bis(2-methoxyethyl) Ether (1) + Tetradecane (2)															
V^E/(cm^3·mol^{-1})	298.15	5.507	−1.345	−1.152	2.831	1.186	0.019	Δk_s/TPa^{-1}	298.15	157.36	−46.82	−24.05	19.37	105.95	0.525
	308.15	5.932	−1.149	−2.149	1.412	2.057	0.095		308.15	178.20	−51.90	0.03	61.95	177.71	1.197
	318.15	6.170	−0.807	−0.353	1.467	0.587	0.029		318.15	190.60	−86.55	−51.99	73.39	103.20	1.393
$\Delta\eta$/(mPa·s)	298.15	−0.622	−0.288	−0.277	0.036	0.035	0.003	ΔR/(cm^3·mol^{-1})	298.15	−18.503	5.212	−1.946	0.146	0.599	0.018
	308.15	−0.465	−0.149	−0.171	−0.063	−0.006	0.004		308.15	−18.750	5.240	−1.015	0.396	−0.639	0.030
	318.15	−0.369	−0.165	−0.144	0.109	0.077	0.003		318.15	−18.697	5.379	−0.772	3.608	1.796	0.014
Δu/(m·s^{-1})	298.15	−120.65	45.95	−9.22	14.68	−62.47	0.534								
	308.15	−128.22	36.47	17.87	54.13	−184.56	0.527								
	318.15	−115.48	42.90	19.39	5.07	−36.35	1.223								
Bis(2-methoxyethyl) Ether (1) + Hexadecane (2)															
V^E/(cm^3·mol^{-1})	298.15	6.103	−0.118	1.579	1.572	−2.846	0.046	Δk_s/TPa^{-1}	298.15	156.28	−25.21	27.89	−9.18	113.89	1.141
	308.15	6.364	−0.610	1.518	1.964	−2.663	0.025		308.15	187.37	−23.22	−54.30	13.65	21.28	1.695
	318.15	6.644	−0.941	0.832	4.744	1.245	0.036		318.15	193.11	−52.32	23.83	−31.37	−64.54	1.240
$\Delta\eta$/(mPa·s)	298.15	−1.083	−0.549	0.006	0.011	−0.738	0.012	ΔR/(cm^3·mol^{-1})	298.15	−28.644	9.620	−2.932	1.442	−1.847	0.031
	308.15	−0.773	−0.416	−0.027	0.034	−0.507	0.004		308.15	−28.359	10.290	−6.250	0.801	3.355	0.081
	318.15	−0.555	−0.366	−0.550	−0.120	0.125	0.003		318.15	−28.573	10.544	−3.926	−1.099	−0.767	0.047
Δu/(m·s^{-1})	298.15	−97.22	33.95	−16.42	49.55	−147.18	0.537								
	308.15	−99.07	98.37	10.11	−20.93	−68.71	1.067								
	318.15	−93.09	47.41	−17.17	13.93	12.54	0.906								

experimental values have been estimated by using

$$\sigma(\Delta Y \text{ or } V^E) = [\sum_{i=1}^{m}\{(\Delta Y \text{ or } V^E)_{\text{expt}} - (\Delta Y \text{ or } V^E)_{\text{calc}}\}^2/(m-p)]^{1/2} \quad (6)$$

where m is the number of data points and p is the number of estimated parameters. The results of A_i and σ are presented in Table 3.

Excess volumes at 298.15 K, presented in Figure 1, are positive over the entire range of mole fractions. This suggests that the mild dispersion-type interactions are present in these mixtures. At equimolar compositions of the mixtures, the V^E values for diglyme with dodecane or tetradecane are almost identical, but hexadecane-containing mixtures show the highest value of V^E at $x_1 = 0.5$, while diglyme + nonane mixtures exhibit the lowest V^E at $x_1 = 0.5$. This shows the dependence of V^E on the chain length of n-alkanes.

Quite opposite behavior is seen for the dependence of $\Delta\eta$ on x_1 at 298.15 K (Figure 2). The negative $\Delta\eta$ values increase from hexadecane to nonane. The $\Delta\eta$ versus x_1 curves for nonane and decane are similar. The same observations are seen for Δu at 298.15 K (Figure 3).

The deviations in molar refractivity have been calculated using the Lorentz–Lorenz (*11, 12*) mixing rule using volume fraction instead of mole fraction averages. The dependence of ΔR on ϕ_1 at 298.15 K is shown in Figure 4. Here, a systematic dependence of ΔR on the alkane chain length is observed. The negative values of ΔR increase considerably from nonane to hexadecane.

The results of Δk_s calculated on the basis of the volume fraction are presented in Figure 5. The positive values of Δk_s are observed for all the binary mixtures at all compositions. However, there is no systematic dependence of Δk_s on the size of the n-alkanes.

The effect of temperature on the V^E, $\Delta\eta$, Δu, and Δk_s show a systematic increase with temperature. This dependence is shown in Figure 6 for the diglyme + tetradecane mixtures. The effect of temperature on ΔR is not very significant for all the mixtures, and hence, the dependence is shown by a single curve for all temperatures (Figure 7).

Literature Cited

(1) Aralaguppi, M. I.; Aminabhavi, T. M.; Balundgi, R. H.; Joshi, S. S. *J. Phys. Chem.* **1991**, *95*, 5299.
(2) Aminabhavi, T. M.; Raikar, S. K.; Aralaguppi, M. I.; Khinnavar, R. S.; Balundgi, R. H. *Indian J. Technol.* **1993**, *31*, 739.
(3) Aminabhavi, T. M.; Aralaguppi, M. I.; Bindu, G.; Khinnavar, R. S. *J. Chem. Eng. Data*, submitted for publication.
(4) Aminabhavi, T. M.; Aralaguppi, M. I.; Harogoppad, S. B.; Balundgi, R. H. *Fluid Phase Equilib.* **1992**, *72*, 211.
(5) Aralaguppi, M. I.; Aminabhavi, T. M.; Balundgi, R. H. *Fluid Phase Equilib.* **1992**, *71*, 99.
(6) Aminabhavi, T. M.; Phayde, H. T. S.; Khinnavar, R. S.; Bindu, G.; Hansen, K. C. *J. Chem. Eng. Data*, in press.
(7) Aminabhavi, T. M.; Phayde, H. T. S.; Khinnavar, R. S. *Collect. Czech. Chem. Commun.*, in press.
(8) Aminabhavi, T. M.; Phayde, H. T. S.; Aralaguppi, M. I.; Khinnavar, R. S. *J. Chem. Eng. Data* **1993**, *38*, 540.
(9) Aminabhavi, T. M.; Phayde, H. T. S.; Khinnavar, R. S.; Bindu, G. *J. Chem. Eng. Data* **1993**, *38*, 542.
(10) Redlich, O.; Kister, A. T. *Ind. Eng. Chem.* **1948**, *40*, 345.
(11) Lorentz, H. A. *Weid. Ann.* **1880**, *9*, 641.
(12) Lorenz, L. *Weid. Ann.* **1880**, *11*, 70.
(13) Treszczanowicz, A. J.; Halpin, C. J.; Benson, G. C. *J. Chem. Eng. Data* **1982**, *27*, 321.
(14) Dethlefsen, C.; Hvidt, A. *J. Chem. Thermodyn.* **1985**, *17*, 193.
(15) Daubert, T. E.; Danner, R. P. *Physical and Thermodynamic Properties of Pure Chemicals, Data Compilation*; Hemisphere Publishing Corp.: Washington, DC, 1992; Part I.
(16) Cayetano, Y.; Alfredo, M.; Pilar, P.-T.; Juan, J. C. *J. Chem. Eng. Data* **1993**, *38*, 512.
(17) Chevalier, J. L. E.; Petrino, P. J.; Gaston-Bonhomme, Y. H. *J. Chem. Eng. Data* **1990**, *35*, 206.
(18) Asfour, A. F. A.; Siddique, M. H. *J. Chem. Eng. Data* **1990**, *35*, 192.
(19) Awwad, A. M.; Al-Azzawi, S. F.; Salman, M. A. *Fluid Phase Equilib.* **1986**, *31*, 171.
(20) Heric, E. L.; Corsey, B. M. *J. Chem. Eng. Data* **1971**, *16*, 185.

Received for review December 11, 1993. Accepted March 24, 1994.®

® Abstract published in *Advance ACS Abstracts*, May 15, 1994.