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, and 308.15 K

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Experimental values of density, viscosity, and refractive index at 298.15, 303.15, and 308.15 K, and the speed of sound at 298.15 K, for the binary mixtures of 2-chloroethanol with *n*-alkanols (C_1−C_6) are presented over the entire mole fraction range. Using these data, excess molar volume and deviations in viscosity, $\Delta\eta$, speed of sound, Δu, and isentropic compressibility, Δk_S, have been calculated. Excess quantities and deviations have been fitted to the Redlich−Kister equation to derive the binary coefficients with the standard errors between the experimental and calculated quantities. Sign and magnitude of the mixing quantities have been discussed to study the nature of molecular interactions in binary mixtures.

Introduction

The mixture thermodynamic properties derived from a measurement of density, viscosity, and speed of sound are useful to design engineering processes. A search of the literature indicated that the binary mixtures of 2-chloroethanol with *n*-alkanols have not been studied extensively. An attempt is made here to present the experimental results of density, ρ, viscosity, η, and refractive index, n_D, with the sodium D-line for the binary mixtures of 2-chloroethanol with methanol, ethanol, propan-1-o1, butan-1-o1, and hexan-1-o1 at 298.15, 303.15, and 308.15 K over the entire range of mixture mole fraction, but the results of speed of sound, u, are reported only at 298.15 K. From the values of ρ, η, and u, the excess molar volume, V^E, and deviations in viscosity, $\Delta\eta$, speed of sound, Δu, and isentropic compressibility, Δk_S, have been calculated. These quantities have been fitted to the Redlich−Kister equation (Redlich and Kister, 1948) to derive the coefficients, A_i, and standard errors, σ, between the experimental and the calculated quantities.

Experimental Section

Materials. High-purity spectroscopic and HPLC-grade methanol, propan-1-ol, and butan-1-ol were purchased from s.d. fine Chemicals Ltd., Mumbai, India. Ethanol was purchased from E. Merck. Pentan-1-ol and hexan-1-ol were obtained from Fluka. 2-Chloroethanol was purchased from SISCO Research Lab. The purity of the liquid samples was tested using a gas chromatograph (HP 6890 series) with a FID detector using a packed column. In all the cases, their guaranteed purities were >99.5%, and hence the samples were used without further purification. Experimental values of ρ and n_D of the pure liquids are compared in Table 1 at 298.15 K, and these values show good agreement with the published results. Mixtures were prepared by mass in glass stoppered bottles and used on the same day. An electronic Mettler balance, model AE 240, with a precision of ±0.01 mg was used. The error in mole fraction is around ±0.0002.

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

	ρ/g·cm^{-3}		n_D	
liquid (mol % purity)	exptl	lit.	exptl	lit.
2-chloroethanol (99.7)	1.1980	1.1966[c]	1.4416	1.4418[c]
methanol (99.6)	0.7868	0.7866[a]	1.3275	1.3274[b]
ethanol (99.8)	0.7862	0.7861[d]	1.3608	1.3595[b]
propan-1-ol (99.6)	0.8001	0.7994[d]	1.3848	1.3833[b]
butan-1-ol (99.4)	0.8071	0.8056[d]	1.3984	1.3974[b]
pentan-1-ol (99.8)	0.8109	0.8109[e]	1.4079	1.4077[b]
hexan-1-ol (99.6)	0.8152	0.8152[b]	1.4147	1.4160[b]

[a] Won et al., 1981. [b] Ortega et al., 1986. [c] Riddick et al., 1986. [d] Rauf et al., 1983. [e] Garcia et al., 1991.

Measurements. Densities of liquids and their mixtures were measured using a pycnometer having a bulb volume of 15 cm^3 and a capillary bore with an internal diameter of 1 mm. Density values are accurate to ±0.0002 g·cm^{-3}.

Refractive indices for the sodium D-line were measured using a thermostatically controlled Abbe Refractometer (Bellingham and Stanley Ltd, England). A minimum of three independent readings were taken for each composition. The refractive index values are accurate to ±0.0002 units. Calibration procedures of the pycnometer and refractometer are the same as given earlier (Aminabhavi and Bindu, 1994; Aralaguppi et al., 1991)

Viscosities were measured using a Schott-Gerate Viscometer, model AVS 350. The unit performs automated measurements of the flow-through times in capillary viscometers. Efflux times were determined on a digital display at an accuracy of 0.01 s. An AVS/S measuring stand was used for optoelectronic sensing of the meniscus. The LED in the upper part of the measuring stand generates light in the near-infrared range, which is transmitted through a glass fiber cable to the measuring levels. The light beam passes through the viscometer and reaches the input end of another light guide cable on the other side, which conducts light to a receiver in the upper part of the measuring stand. When the liquid meniscus passes through the measuring level, the light beam is darkened briefly by the optical lens effect of the meniscus and thereafter

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Table 2. Experimental Values of Density (ρ), Refractive Index (n_D), Viscosity (η), and Speed of Sound (u) of the Binary 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-Chloroethanol + Methanol														
298.15 K														
0.0000	0.7868	1.3275	0.505	1108	0.3927	1.0045	1.3898	1.099	1252	0.7977	1.1460	1.4279	2.130	1352
0.0960	0.8500	1.3449	0.615	1128	0.4944	1.0464	1.4002	1.321	1260	0.8997	1.1731	1.4346	2.450	1355
0.2122	0.9180	1.3667	0.777	1200	0.5980	1.0838	1.4113	1.591	1290	1.0000	1.1980	1.4416	2.810	1359
0.2939	0.9593	1.3759	0.910	1212	0.6969	1.1163	1.4222	1.869	1312					
303.15 K														
0.0000	0.7818	1.3260	0.472		0.3927	1.0000	1.3897	1.003		0.7977	1.1408	1.4255	1.884	
0.0960	0.8456	1.3437	0.572		0.4944	1.0412	1.3981	1.195		0.8997	1.1679	1.4316	2.140	
0.2122	0.9130	1.3670	0.721		0.5980	1.0788	1.4087	1.434		1.0000	1.1924	1.4385	2.448	
0.2939	0.9543	1.3733	0.834		0.6969	1.1112	1.4185	1.632						
308.15 K														
0.0000	0.7761	1.3252	0.441		0.3927	0.9932	1.3861	0.913		0.7977	1.1340	1.4234	1.675	
0.0960	0.8397	1.3427	0.529		0.4944	1.0345	1.3979	1.084		0.8997	1.1610	1.4301	1.890	
0.2122	0.9071	1.3656	0.662		0.5980	1.0720	1.4072	1.287		1.0000	1.1854	1.4326	2.150	
0.2939	0.9481	1.3722	0.767		0.6969	1.1044	1.4157	1.456						
2-Chloroethanol (1) + Ethanol (2)														
298.15 K														
0.0000	0.7862	1.3608	1.007	1152	0.3931	0.9645	1.3963	1.450	1224	0.7947	1.1240	1.4270	2.222	1320
0.0955	0.8315	1.3696	1.086	1162	0.4925	1.0060	1.4042	1.610	1250	0.8984	1.1618	1.4346	2.538	1336
0.2589	0.9063	1.3845	1.262	1192	0.5932	1.0467	1.4124	1.798	1282	1.0000	1.1980	1.4416	2.810	1359
0.2902	0.9200	1.3876	1.302	1205	0.6938	1.0858	1.4196	2.001	1304					
303.15 K														
0.0000	0.7820	1.3587	0.918		0.3931	0.9598	1.3943	1.306		0.7947	1.1189	1.4254	1.958	
0.0955	0.8276	1.3671	0.987		0.4925	1.0009	1.4021	1.447		0.8984	1.1566	1.4321	2.197	
0.2589	0.9017	1.3820	1.140		0.5932	1.0417	1.4100	1.601		1.0000	1.1924	1.4385	2.448	
0.2902	0.9154	1.3853	1.174		0.6938	1.0810	1.4177	1.772						
308.15 K														
0.0000	0.7765	1.3569	0.834		0.3931	0.9535	1.3924	1.179		0.7947	1.1120	1.4228	1.735	
0.0955	0.8216	1.3651	0.897		0.4925	0.9948	1.3998	1.297		0.8984	1.1500	1.4299	1.932	
0.2589	0.8958	1.3803	1.034		0.5932	1.0352	1.4077	1.432		1.0000	1.1854	1.4326	2.150	
0.2902	0.9094	1.3827	1.065		0.6938	1.0741	1.4151	1.579						
2-Chloroethanol + Propan-1-ol														
298.15 K														
0.0000	0.8001	1.3848	1.743	1216	0.3912	0.9455	1.4053	1.920	1245	0.8071	1.1141	1.4278	2.428	1320
0.0990	0.8356	1.3898	1.761	1225	0.4924	0.9854	1.4105	2.028	1256	0.8959	1.1524	1.4347	2.600	1340
0.1945	0.8706	1.3942	1.802	1232	0.5924	1.0253	1.4172	2.148	1275	1.0000	1.1980	1.4416	2.810	1359
0.2948	0.9083	1.3997	1.842	1240	0.6930	1.0663	1.4221	2.281	1296					
303.15 K														
0.0000	0.7961	1.3824	1.546		0.3912	0.9411	1.4027	1.735		0.8071	1.1091	1.4258	2.160	
0.0990	0.8314	1.3875	1.580		0.4924	0.9805	1.4080	1.813		0.8959	1.1473	1.4326	2.300	
0.1945	0.8664	1.3923	1.620		0.5924	1.0203	1.4143	1.891		1.0000	1.1924	1.4385	2.448	
0.2948	0.9038	1.3973	1.670		0.6930	1.0613	1.4203	2.020						
308.15 K														
0.0000	0.7911	1.3803	1.376		0.3912	0.9353	1.4006	1.542		0.8071	1.1027	1.4239	1.880	
0.0990	0.8263	1.3857	1.400		0.4924	0.9745	1.4062	1.606		0.8959	1.1405	1.4304	2.001	
0.1945	0.8611	1.3901	1.440		0.5924	1.0149	1.4124	1.678		1.0000	1.1854	1.4326	2.150	
0.2948	0.8982	1.3950	1.480		0.6930	1.0551	1.4178	1.760						
2-Chloroethanol+ Butan-1-ol														
298.15 K														
0.0000	0.8071	1.3984	2.624	1256	0.3928	0.9313	1.4108	2.616	1240	0.7957	1.0955	1.4298	2.731	1310
0.0970	0.8350	1.4015	2.590	1235	0.4937	0.9684	1.4151	2.641	1255	0.8961	1.1441	1.4349	2.781	1330
0.1922	0.8640	1.4049	2.593	1226	0.5925	1.0072	1.4200	2.672	1270	1.0000	1.1980	1.4416	2.810	1359
0.2941	0.8972	1.4077	2.597	1230	0.6943	1.0499	1.4248	2.702	1285					
303.15 K														
0.0000	0.8034	1.3957	2.306		0.3928	0.9271	1.4098	2.288		0.7957	1.0904	1.4278	2.400	
0.0970	0.8312	1.3997	2.290		0.4937	0.9639	1.4137	2.316		0.8961	1.1387	1.4324	2.428	
0.1922	0.8602	1.4022	2.350		0.5925	1.0026	1.4176	2.363		1.0000	1.1924	1.4385	2.448	
0.2941	0.8931	1.4060	2.271		0.6943	1.0451	1.4226	2.380						
308.15 K														
0.0000	0.7985	1.3936	2.030		0.3928	0.9215	1.4073	2.027		0.7957	1.0841	1.4258	2.120	
0.0970	0.8263	1.3974	2.028		0.4937	0.9582	1.4114	2.047		0.8961	1.1321	1.4304	2.140	
0.1922	0.8550	1.4000	2.029		0.5925	0.9967	1.4153	2.075		1.0000	1.1854	1.4326	2.150	
0.2941	0.8878	1.4027	2.026		0.6943	1.0390	1.4206	2.100						
2-Chloroethanol (1) + Pentan-1-ol (2)														
298.15 K														
0.0000	0.8109	1.4079	3.555	1268	0.3946	0.9199	1.4179	3.138	1288	0.8018	1.0852	1.4314	2.980	1328
0.0959	0.8339	1.4105	3.401	1272	0.4922	0.9535	1.4191	3.088	1294	0.8986	1.1371	1.4349	2.920	1345
0.1940	0.8596	1.4125	3.282	1278	0.5939	0.9923	1.4229	3.045	1302	1.0000	1.1980	1.4416	2.810	1359
0.2912	0.8875	1.4147	3.200	1282	0.6962	1.0353	1.4272	3.020	1315					
303.15 K														
0.0000	0.8072	1.4065	3.086		0.3946	0.9157	1.4149	2.731		0.8018	1.0802	1.4287	2.620	
0.0959	0.8303	1.408	2.941		0.4922	0.9491	1.4177	2.705		0.8986	1.1319	1.4335	2.560	
0.1940	0.8557	1.4106	2.860		0.5939	0.9877	1.4213	2.690		1.0000	1.1924	1.4385	2.448	
0.2912	0.8834	1.4126	2.780		0.6962	1.0303	1.4251	2.661						

Table 2 (Continued)

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)
							308.15 K							
0.0000	0.8026	1.4047	2.689		0.3946	0.9104	1.4127	2.401		0.8018	1.0740	1.4267	2.323	
0.0959	0.8255	1.4070	2.580		0.4922	0.9437	1.4159	2.384		0.8986	1.1253	1.4319	2.250	
0.1940	0.8507	1.4088	2.500		0.5939	0.9820	1.4196	2.378		1.0000	1.1854	1.4326	2.150	
0.2912	0.8784	1.4105	2.441		0.6962	1.0247	1.4228	2.340						
						2-Chloroethanol+ Hexan-1-ol								
							298.15 K							
0.0000	0.8152	1.4147	4.274	1306	0.3953	0.9115	1.4208	3.406	1345	0.7968	1.0719	1.4304	2.983	1363
0.0970	0.8352	1.4171	3.930	1315	0.5314	0.9564	1.4227	3.241	1354	0.8982	1.1293	1.4345	2.921	1362
0.1953	0.8577	1.4185	3.700	1324	0.5962	0.9809	1.4248	3.175	1358	1.0000	1.1980	1.4416	2.810	1359
0.2962	0.8834	1.4191	3.544	1335	0.7121	1.0301	1.4275	3.057	1362					
							303.15 K							
0.0000	0.8116	1.4135	3.603		0.3953	0.9076	1.4192	2.909		0.7968	1.0671	1.4277	2.551	
0.0970	0.8316	1.4141	3.330		0.5314	0.9521	1.4206	2.780		0.8982	1.1241	1.4325	2.529	
0.1953	0.8540	1.4151	3.180		0.5962	0.9766	1.4230	2.718		1.0000	1.1924	1.4385	2.448	
0.2962	0.8795	1.4152	3.068		0.7121	1.0255	1.4251	2.615						
							308.15 K							
0.0000	0.8080	1.4123	3.022		0.3953	0.9034	1.4173	2.494		0.7968	1.0618	1.4272	2.237	
0.0970	0.8278	1.4125	2.824		0.5314	0.9468	1.4185	2.380		0.8982	1.1190	1.4304	2.208	
0.1953	0.8503	1.4136	2.680		0.5962	0.9721	1.4184	2.329		1.0000	1.1854	1.4326	2.150	
0.2962	0.8756	1.4148	2.572		0.7121	1.0207	1.4239	2.276						

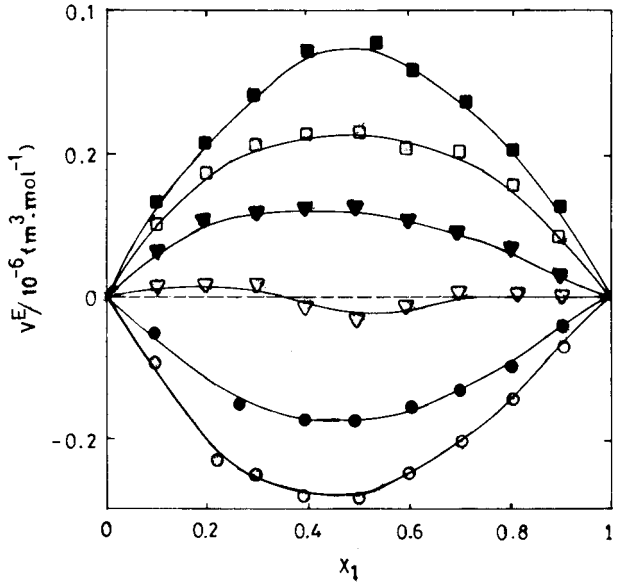

Figure 1. Excess molar volume vs mole fraction at 298.15 K for the binary mixtures of 2-chloroethanol with (○) methanol, (●) ethanol, (▽) propan-1-ol, (▼) butan-1-ol, (□) pentan-1-ol, and (■) hexan-1-ol.

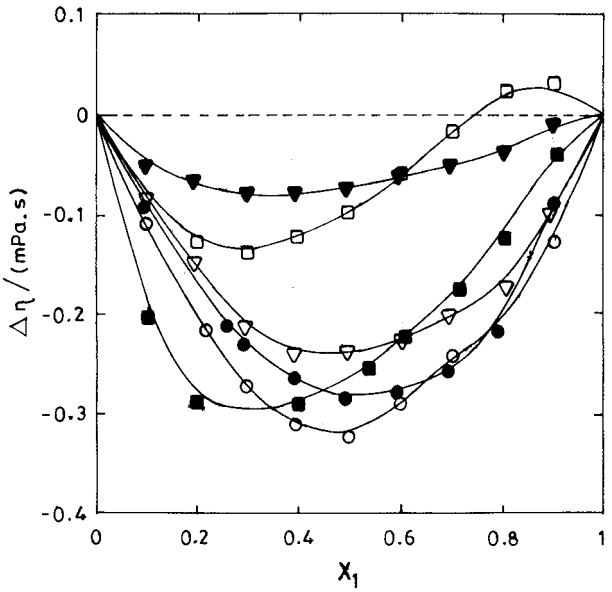

Figure 2. Deviation in viscosity vs mole fraction at 298.15 K for the binary mixtures of 2-chloroethanol + *n*-alkanols. Symbols are the same as given in Figure 1.

intensified for a brief period. This fluctuation of light beam produces a measuring signal that can be evaluated precisely.

The temperature of the bath (Schott-Gerate, model CT 050/2) was maintained constant within ±0.01 K. The estimated error in the viscosity measurement was ±0.001 mPa·s. Approximately 5 cm^3 volume of the liquid was taken in the viscometer. The liquid was allowed to equilibrate to the desired bath temperature ranging from 7 to 10 min depending upon the viscosity of the liquid. The viscosity of the liquid/mixture was calculated using

$$\eta = t \cdot k \cdot \rho \qquad (1)$$

where k is the viscometer constant (0.010 35 mm^2/s^2), ρ is the density of liquid, and t is the efflux time in seconds. The viscometer constant k was determined by using comparative measurements with reference viscometers, of which the constants were determined at the Physikalisch-Technischen Bundesanstalt, D-38116 Braunschweig. The instrument constant, k, is valid for liquids with a surface tension of 20 to 30 mN/m and an acceleration of fall of 9.8125 m/s^2. For temperatures up to 100 °C, it is not required to pay attention to the heat expansion of the viscometer.

The speed of sound values were measured using a variable-path single-crystal interferometer (Mittal Enterprises, model M-84, New Delhi) as described earlier (Aralaguppi et al., 1991). The interferometer was used at a frequency of 1 kHz and was calibrated using water and benzene. The speed of sound values are accurate to ±2 m·s^{-1}. The isentropic compressibility, k_S, was calculated using $k_S = 1/(u^2\rho)$.

In all the property measurements (except viscosity), an INSREF, model 016 AP, thermostat was used at a constant digital temperature display accurate to ±0.01 K. The results of ρ, η, n_D, and u compiled in Table 2 represent the average of at least three independent measurements for each composition of the mixture.

Results and Discussion

Values of excess molar volume, V^E, and deviations in viscosity, $\Delta\eta$, speed of sound, Δu, and isentropic compress-

Table 3. Derived Redlich−Kister Parameter Values (A_i) and Standard Errors for the Binary Mixtures

function	temp/K	A_0	A_1	A_2	σ
		2-Chloroethanol (1) + Methanol (2)			
$V^E/10^{-6}$(m^3·mol^{-1})	298.15	−1.135	−0.330	0.171	0.014
	303.15	−1.262	−0.351	−0.062	0.009
	308.15	−1.258	−0.401	−0.203	0.009
$\Delta\eta$/(mPa·s)	298.15	−1.254	−0.057	−0.119	0.013
	303.15	−0.987	−0.012	−0.173	0.011
	308.15	−0.804	−0.022	−0.l44	0.006
Δu/(m·s^{-1})	298.15	172.7	−6.6	53.0	1.702
Δk_S/(TPa^{-1})	298.15	−383.53	62.15	−61.96	1.756
		2-Chloroethanol (1) + Ethanol (2)			
$V^E/10^{-6}$(m^3·mol^{-1})	298.15	−0.718	−0.157	0.180	0.006
	303.15	−0.744	−0.127	−0.221	0.007
	308.15	−0.770	−0.109	−0.055	0.007
$\Delta\eta$/(mPa·s)	298.15	−1.152	0.114	0.009	0.013
	303.15	−0.909	0.108	−0.173	0.004
	308.15	−0.741	0.103	−0.172	0.003
Δu/(m·s^{-1})	298.15	−2.7	−105.8	−75.8	2.785
Δk_S/(TPa^{-1})	298.15	−227.9	−73.9	81.0	2.410
		2-Chloroethanol (1) + Propan-1-ol (2)			
$V^E/10^{-6}$(m^3·mol^{-1})	298.15	-0.072	0.085	0.300	0.009
	303.15	−0.076	0.133	0.097	0.012
	308.15	−0.117	0.233	0.161	0.016
$\Delta\eta$/(mPa·s)	298.15	−0.966	0.021	−0.148	0.011
	303.15	−0.731	0.049	0.166	0.007
	308.15	−0.617	0.155	−0.116	0.005
Δu/(m·s^{-1})	298.15	−114.0	−4.6	110.7	1.418
Δk_S/(TPa^{-1})	298.15	−85.1	−4.66	−103.3	1.748
		2-Chloroethanol (1) + Butan-1-ol (2)			
$V^E/10^{-6}$(m^3·mol^{-1})	298.15	0.471	0.205	0.091	0.005
	303.15	0.458	0.206	0.039	0.004
	308.15	0.448	0.185	0.008	0.003
$\Delta\eta$/(mPa·s)	298.15	−0.297	−0.198	−0.097	0.005
	303.15	−0.232	−0.118	0.283	0.027
	308.15	−0.163	−0.138	−0.178	0.004
Δu/(m·s^{-1})	298.15	−211.2	−104.5	−100.2	1.689
Δk_S/(TPa^{-1})	298.15	10.20	−185.1	214.2	3.144
		2-Chloroethanol (1) + Pentan-1-ol (2)			
$V^E/10^{-6}$(m^3·mol^{-1})	298.15	0.913	0.119	0.254	0.009
	303.15	0.919	0.083	0.154	0.013
	308.15	0.891	0.118	0.119	0.009
$\Delta\eta$/(mPa·s)	298.15	−0.394	−0.763	0.168	0.006
	303.15	−0.247	−0.839	0.112	0.006
	308.15	−0.147	−0.758	0.150	0.007
Δu/(m·s^{-1})	298.15	−75.9	19.8	33.2	1.148
Δk_S/(TPa^{-1})	298.15	−93.61	4.47	−37.42	0.692
		2-Chloroethanol (1) + Hexan-1-ol (2)			
$V^E/10^{-6}$(m^3·mol^{-1})	298.15	1.381	0.072	−0.083	0.012
	303.15	1.340	0.038	−0.229	0.012
	308.15	1.213	0.195	−0.586	0.017
$\Delta\eta$/(mPa·s)	298.15	−1.058	−0.862	−0.545	0.017
	303.15	−0.861	−0.418	−0.377	0.025
	308.15	−0.741	−0.424	−0.165	0.012
Δu/(m·s^{-1})	298.15	79.8	−31.1	−21.8	0.477
Δk_S/(TPa^{-1})	298.15	−188.4	66.2	1.05	0.697

ibility, Δk_S, have been calculated as

$$V^E/(\text{m}^3\ \text{mol}^{-1}) = V_m - V_1x_1 - V_2x_2 \qquad (2)$$

Here, V_m refers to the molar volume of the mixture calculated as

$$V_m = \frac{M_1x_1 + M_2x_2}{\rho_m} \qquad (3)$$

where M_1 and M_2 are the molecular weights of components 1 and 2, ρ_m is mixture density, x_1 and x_2 are the respective mole fractions, and V_1 and V_2 are the individual component molar volumes. The values of $\Delta\eta$, Δu, and Δk_S are calculated using the general equation

$$\Delta Y = Y_m - Y_1x_1 - Y_2x_2 \qquad (4)$$

while in computing the Δk_S results, the volume fraction, ϕ_i

$$\phi_i = \frac{x_1V_1}{\sum_i x_iV_i} \qquad (5)$$

was used. The results of V^E, $\Delta\eta$, Δu, and Δk_S have been fitted to the Redlich−Kister polynomial equation (Redlich and Kister, 1948). It was found that for the solution of the third-degree polynomial, the agreement between the

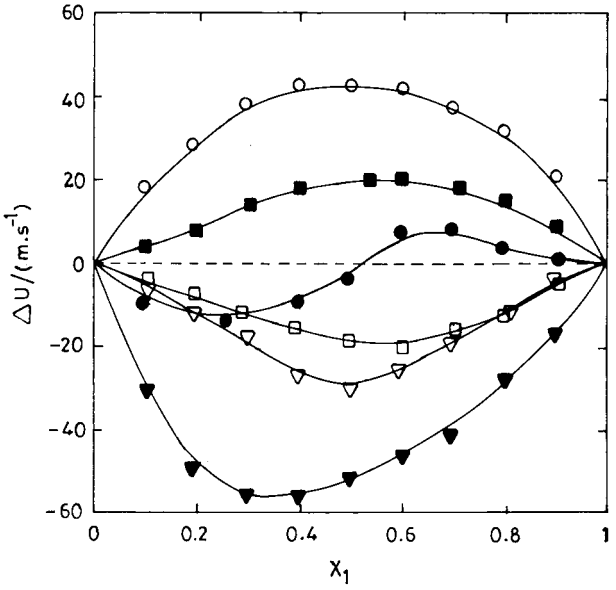

Figure 3. Deviation in speed of sound vs mole fraction at 298.15 K for the binary mixtures of 2-chloroethanol + *n*-alkanols. Symbols have the same meaning as given in Figure 1.

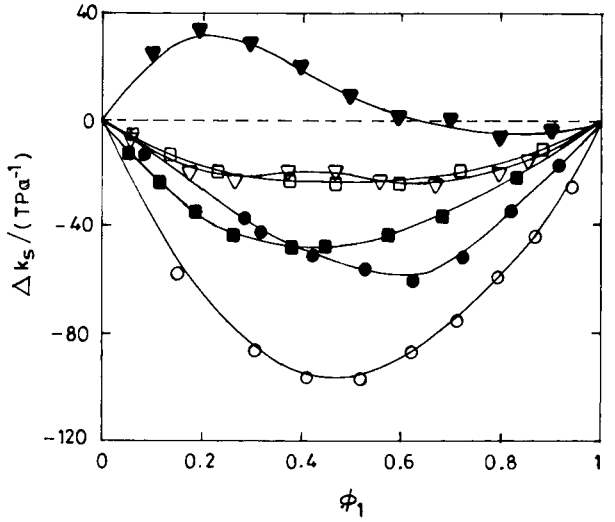

Figure 4. Deviation in isentropic compressibility vs mole fraction at 298.15 K for the binary mixtures of 2-chloroethanol + *n*-alkanols. Symbols have the same meaning as given in Figure 1.

experimental values and the calculated ones was satisfactory. The derived parameters, A_0, A_1, and A_2, and the estimated standard errors, σ, are presented in Table 3. The curves presented in all the figures are the calculated values, and the points represent the experimental values.

The results of V^E are presented in Figure 1. For the binary mixtures of 2-chloroethanol + methanol or + ethanol, the negative values of V^E are observed. The V^E values of the 2-chloroethanol + methanol mixture are more negative than those observed for the 2-chloroethanol + ethanol mixture. For the mixtures of 2-chloroethanol with butan-1-ol, pentan-1-ol, or hexan-1-ol, the positive V^E values increase systematically in the order stated for the liquids. However, in the case of the 2-chloroethanol + propan-1-ol mixture, the V^E values are almost close to the ideal behavior as these vary in the close vicinity of zero V^E.

Figure 2 shows the dependence of $\Delta\eta$ on x_1 at 298.15 K. It is found that the $\Delta\eta$ vs x_1 curves for the mixtures of 2-chloroethanol + methanol, + ethanol, + propan-1-ol, and + butan-1-ol show a systematic trend; i.e., the negative $\Delta\eta$ values decrease from methanol to butan-1-ol. With mixtures containing higher *n*-alkanols, i.e., for 2-chloroethanol + pentan-1-ol or + hexan-1-ol, the curves are slightly sigmoidal. In the higher concentration regions of the 2-chloroethanol + pentan-1-ol mixture, the $\Delta\eta$ values are positive. At any rate, the trends in the variations of $\Delta\eta$ curves for both pentan-1-ol or hexan-1-ol containing mixtures are almost identical and show a slight sigmoidal trend. A systematic variation of $\Delta\eta$ values with temperature is observed, i.e., these values increase with increasing temperature. However, the temperature-dependent curves are not presented to avoid redundancy.

The Δu vs x_1 curves at 298.15 K are presented in Figure 3, and their variations are very different than V^E and $\Delta\eta$ results. For instance, the Δu values for 2-chloroethanol + methanol or + hexan-1-ol mixtures are positive, while for the mixtures of 2-chloroethanol + pentan-1-ol, + propan-1-ol, + butan-1-ol, the negative Δu values increase respectively, in the order given above for the liquids. For the 2-chloroethanol + ethanol mixture, a sigmoidal trend is observed.

The results of Δk_S vs ϕ_1 at 298.15 K are presented in Figure 4. It is observed that a large negative value is observed for the 2-chloroethanol + methanol mixture, whereas for the 2-chloroethanol + butan-1-ol mixture, the Δk_S vs ϕ_1 curve is sigmoidal. In the case of the mixtures 2-chloroethanol + propan-1-ol or + pentan-1-ol, the plots of Δk_S vs ϕ_1 are almost identical. Similarly, for the mixtures of 2-chloroethanol + ethanol or + hexan-1-ol, the curves vary almost identically.

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