

Densities, Speeds of Sound, Viscosities, and Relative Permittivities for 1-Propanol + and 1-Butanol + Heptane at 298.15 K and 308.15 K

Nandhibatla V. Sastry* and Mahendra K. Valand

Department of Chemistry, Sardar Patel University, Vallabh Vidyanagar, 388120 Gujarat, India

The densities, speeds of sound, viscosities, and relative permittivities for the binary mixtures of 1-propanol + and 1-butanol + heptane at 298.15 K and 308.15 K are reported. The excess volumes V^E , isentropic compressibilities K_s^E , viscosity deviations, $\delta\eta$, relative permittivity deviations $\delta\epsilon$, and molar polarization deviations, δP_m were calculated from the experimental results.

Introduction

A literature survey on the binary mixtures of 1-alcohol + alkane shows that the viscosity, relative permittivity, and refractive index measurements are scarcely reported for these systems, while extensive and systematic studies on the effect of chain length of both the components on the excess volumes and excess enthalpies mostly at 298.15 K are reported (Treszczanowicz et al., 1993; Roux et al., 1993). The nonavailability of extensive data on the transport and dielectric properties of 1-alcohol + alkane binary mixtures prompted us to undertake systematic measurements of the above properties at different temperatures. The densities, speeds of sound, relative permittivities, and refractive indices for 1-heptanol + hexane and + heptane at 303.15 K and 313.15 K were reported by us recently (Sastry and Raj, 1996). In continuation of our earlier work, this paper reports similar experimental data for 1-propanol + and 1-butanol + heptane mixtures at 298.15 K and 308.15 K. The excess functions, namely the excess volumes and isentropic compressibilities, were calculated from the experimental results. Similarly, the deviations in viscosity, relative permittivity, and molar polarization were also expressed in terms of the mixture and pure component data.

Experimental Section

Materials. 1-Propanol, 1-butanol, and heptane were of SD fine chemicals and were further purified by the standard procedures (Riddick et al., 1986). The purity of these chemicals was ascertained by comparing their measured densities (ρ), speeds of sound (ν), viscosities (η), refractive indices (n_D) and relative permittivities (ϵ) at both measuring temperatures with reported literature values, and such a comparison is presented in Table 1.

Methods. Binary mixtures were prepared by mass on a single pan Mettler balance in stoppered glass bottles. The calculated mole fractions were accurate to ± 0.0001 .

The densities of the mixture and pure components were measured by a precalibrated bicapillary pycnometer with an accuracy of $\pm 0.0001 \text{ g}\cdot\text{cm}^{-3}$. The temperature during the density measurements was controlled to a precision of $\pm 0.01 \text{ deg}$.

The speeds of sound in the pure liquids and their mixtures were measured with a single crystal ultrasonic interferometer operating at a fixed frequency of 2 MHz. The temperature of the double jacketed interferometer cell was maintained by circulating the water from a thermostatic bath. The temperature in the interferometer cell was

Table 1. Densities (ρ), Speed of Sound (ν), Viscosities (η), Refractive Indices (n_D), and Relative Permittivity (ϵ) of Pure Liquids

	298.15 K		308.15 K	
	this work	lit.	this work	lit.
	Heptane			
$\rho/\text{g}\cdot\text{cm}^{-3}$	0.6794	0.679 46 ^a	0.6709	0.670 86 ^j
n_D	1.3850	1.3851 ^a	1.3800	1.3805 ^k
$\nu/\text{m}\cdot\text{s}^{-1}$	1131	1129.85 ^b	1095	
$\eta/\text{mPa}\cdot\text{s}$	0.3901	0.3906 ^c	0.3520	0.3525 ^c
ϵ	1.9135		1.8935	
	1-Propanol			
$\rho/\text{g}\cdot\text{cm}^{-3}$	0.7996	0.799 75 ^d	0.7920	0.7920 ^l
n_D	1.3631	1.3832 ^f	1.3790	1.3793 ^f
$\nu/\text{m}\cdot\text{s}^{-1}$	1211	1205.17 ^e	1180	1182 ^l
$\eta/\text{mPa}\cdot\text{s}$	1.9425	1.943 ^d	1.5620	1.537 ^d
ϵ	20.3313	20.33 ^g	20.2294	
	1-Butanol			
$\rho/\text{g}\cdot\text{cm}^{-3}$	0.8060	0.8060 ^d	0.8002	
n_D	1.3967	1.3967 ^f	1.3926	1.3927 ^f
$\nu/\text{m}\cdot\text{s}^{-1}$	1245	1240 ^h	1210	1208 ^d
$\eta/\text{mPa}\cdot\text{s}$	2.5700	2.5710 ^d	2.0000	2.0000 ^d
ϵ	17.5050	17.43 ⁱ	16.5600	16.56 ⁱ

^a TRC Tables (1977). ^b Junquera et al. (1988). ^c TRC Tables (1992). ^d TRC Tables (1994). ^e Kiyohara and Benson (1979). ^f Ortega (1982). ^g Riddick and Bunger (1970). ^h Aminabhavi et al. (1993). ⁱ D'Aprano et al. (1979). ^j Wiczorek (1984). ^k Blanco et al. (1993). ^l Rattan et al. (1987).

maintained to a precision of $\pm 0.02 \text{ deg}$. The measured speeds of sound were accurate to $\pm 0.15\%$. The isentropic compressibilities, K_s , were obtained from the following relation

$$K_s = 1/\nu^2\rho \quad (1)$$

where ν is the speed of sound and ρ is the density.

The viscosities were calculated from the measured flow times, t , in an Ubbelohde suspended type viscometer by using the following relation

$$\eta = \rho\{At - B/t\} \quad (2)$$

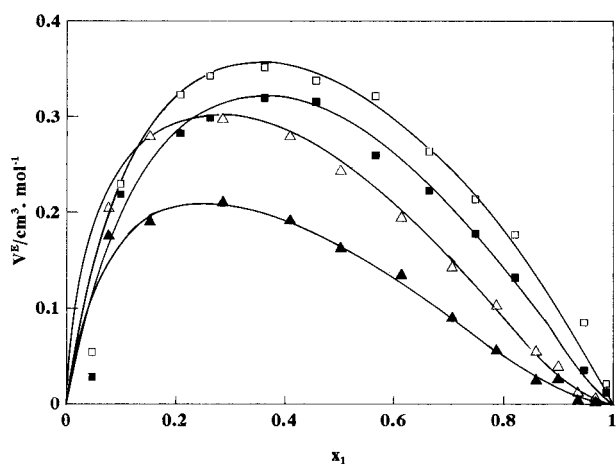
where ρ is density and A and B are viscometer calibration constants which were determined from the measured flow times and densities of the triple distilled water and double distilled cyclohexane. The measured viscosities were found to be accurate up to $\pm 0.003 \text{ mPa}\cdot\text{s}$.

The relative permittivity measurements were made with a Universal Dielectrometer (Type OH-301 of Radelkis, Hungary) at a fixed frequency of 3 MHz. The stainless steel cells of the Dielectrometer in which the measuring

* Corresponding author. Telefax: 0091-2692-46475. Email: sastry@pcbs.indiagate.com.

Table 2. Densities (ρ) and Excess Volumes (V^E) of 1-Alkanol + Heptane Mixtures at 298.15 K and 308.15 K

x_1	298.15 K		308.15 K	
	$\rho/\text{g}\cdot\text{cm}^{-3}$	$V^E/\text{cm}^3\cdot\text{mol}^{-1}$	$\rho/\text{g}\cdot\text{cm}^{-3}$	$V^E/\text{cm}^3\cdot\text{mol}^{-1}$
1-Propanol (1) + Heptane (2)				
0.0468	0.6822	0.028	0.6736	0.054
0.0989	0.6847	0.219	0.6762	0.230
0.2079	0.6921	0.283	0.6835	0.323
0.2621	0.6962	0.299	0.6876	0.343
0.3620	0.7045	0.320	0.6960	0.352
0.4569	0.7135	0.316	0.7051	0.338
0.5667	0.7257	0.260	0.7171	0.322
0.6636	0.7380	0.223	0.7296	0.264
0.7478	0.7503	0.178	0.7420	0.214
0.8202	0.7623	0.132	0.7540	0.177
0.9458	0.7871	0.035	0.7789	0.085
0.9873	0.7965	0.012	0.7888	0.021
1-Butanol (1) + Heptane (2)				
0.0770	0.6851	0.117	0.6763	0.206
0.1523	0.6912	0.192	0.6825	0.281
0.2853	0.7035	0.212	0.6950	0.299
0.4094	0.7165	0.193	0.7082	0.281
0.5024	0.7273	0.164	0.7189	0.245
0.6136	0.7415	0.136	0.7338	0.196
0.7055	0.7546	0.091	0.7472	0.144
0.7866	0.7672	0.057	0.7601	0.104
0.8595	0.7795	0.026	0.7728	0.056
0.8998	0.7866	0.027	0.7802	0.040
0.9352	0.7933	0.005	0.7871	0.013
0.9675	0.7995	0.003	0.7935	0.007

**Figure 1.** Excess volumes of 1-alkanol + heptane mixtures versus alkanol mole fraction: 1-propanol + heptane at (■) 298.15 K and (□) 308.15 K; 1-butanol + heptane at (▲) 298.15 K and (△) 308.15 K.

liquids are filled, were thermostated (± 0.02 deg) by circulating the water from a constant temperature water bath. Measured relative permittivities were accurate up to ± 0.0002 .

The refractive indices for the sodium D line were measured with an Abbe research refractometer. The measuring temperature was controlled by circulating water from a thermostated water bath. Measured refractive indices were accurate up to ± 0.0002 .

Results

The experimental densities (ρ) and excess volumes, V^E , of 1-propanol + and 1-butanol + heptane binary mixtures over the entire mole fraction range at 298.15 K and 308.15 K are given in Table 2, and the V^E values are also graphically represented in Figure 1. The experimental speed of sound, ν , isentropic compressibilities, K_s , and excess isentropic compressibilities, K_s^E , of the binary

Table 3. Volume Fraction, ϕ_1 , of 1-Alkanol, Speed of Sound, ν , Isentropic Compressibility, K_s , and Excess Isentropic Compressibilities, K_s^E , Computed from Eq 3 for 1-Alkanol + Heptane Mixtures at 298.15 K and 308.15 K

ϕ_1	298.15 K			308.15 K			
	$\nu/\text{m}\cdot\text{s}^{-1}$	K_s/TPa^{-1}	K_s^E/TPa^{-1}	$\nu/\text{m}\cdot\text{s}^{-1}$	K_s/TPa^{-1}	K_s^E/TPa^{-1}	
1-Propanol (1) + Heptane (2)							
0.0244	1127	1155	8	0.0243	1091	1247	11
0.0529	1124	1155	13	0.0528	1089	1248	14
0.1180	1123	1146	16	0.1179	1087	1238	17
0.1533	1123	1139	17	0.1529	1086	1232	18
0.2243	1124	1123	17	0.2238	1087	1215	18
0.3001	1128	1101	15	0.2994	1090	1193	17
0.3999	1135	1070	12	0.3992	1096	1160	14
0.5013	1143	1036	9	0.5006	1104	1125	11
0.6018	1154	1000	6	0.6010	1113	1087	8
0.6992	1167	964	3	0.6986	1124	1049	5
0.8989	1194	891	0.5	0.8986	1150	971	1
0.9754	1207	862	0.1	0.9753	1161	940	0.2
1-Butanol (1) + Heptane (2)							
0.0494	1130	1144	6	0.0492	1092	1240	9
0.1007	1130	1133	8	0.1003	1093	1227	10
0.1993	1136	1101	6	0.1984	1097	1195	8
0.3018	1144	1066	2	0.3007	1105	1157	5
0.3863	1153	1034	-2	0.3851	1112	1123	1
0.4975	1166	992	-5	0.4962	1125	1076	-2
0.5990	1180	952	-7	0.5977	1138	1034	-3
0.6968	1194	915	-7	0.6957	1152	991	-3
0.7923	1208	879	-6	0.7914	1167	950	-2
0.8485	1218	857	-5	0.8478	1177	925	-1
0.9000	1227	837	-4	0.8995	1187	901	-1
0.9489	1235	820	-0.5	0.9486	1198	879	-0.5

mixtures are given in Table 3. The K_s^E values were calculated as

$$K_s^E = K_s - K_s^{\text{id}} \quad (3)$$

where K_s is the isentropic compressibility of the mixture and K_s^{id} is the isentropic compressibility of the ideal solution and was calculated by the following relation

$$K_s^{\text{id}} = \sum_i \phi_i \{ K_{s,i} + TV_i(\alpha_i)^2 / C_{p,i} \} - T(\sum_j x_j V_j) (\sum_j \phi_j \alpha_j)^2 / (\sum_j x_j C_{p,j}) \quad (4)$$

where T is the temperature, x_i is the mole fraction of component i in the mixture, $K_{s,i}$, V_i , α_i , and $C_{p,i}$ are the isentropic compressibility, molar volume, isobaric thermal expansivity, and molar heat capacities for the pure components. ϕ_i is the ideal volume fraction of component i in the mixture and is defined by the relation

$$\phi_i = x_i V_i / (\sum_j x_j V_j) \quad (4a)$$

The values of α_i and V_i were calculated from the measured densities, and the molar heat capacities of 1-alcohols and heptane were interpolated from the literature compilations (Zabransky et al., 1990; Ruzicka et al., 1991).

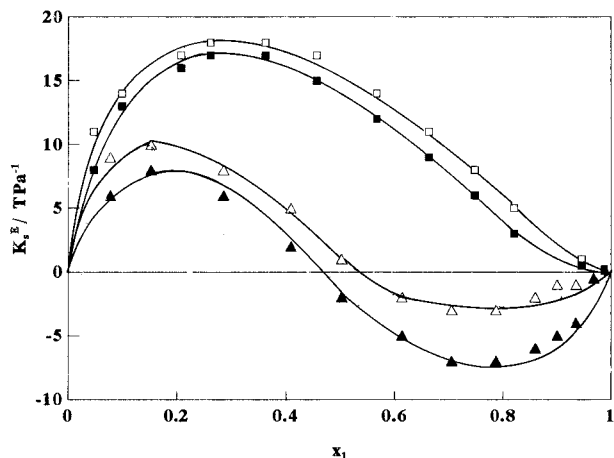
The excess volumes, V^E , and excess isentropic compressibilities, K_s^E , were mathematically represented by a Redlich-Kister type equation,

$$Y^E = x_1(1 - x_1) \sum_{i=0}^n a_i (2x_1 - 1)^i \quad (5)$$

where Y^E is either V^E ($\text{cm}^3\cdot\text{mol}^{-1}$) or K_s^E (TPa^{-1}), x_1 is the 1-alkanol mole fraction, and a_i are the coefficients. The values of the coefficients a_i were obtained by a multiple regression analysis based on the least squares method and

Table 4. Coefficients a_i of Eq 5 with Standard Deviation, σ , for the Least Squares Representations of V^E , K_s^E , and $\delta\eta$ of 1-Alcohol + Heptane Mixtures at 298.15 K and 308.15 K

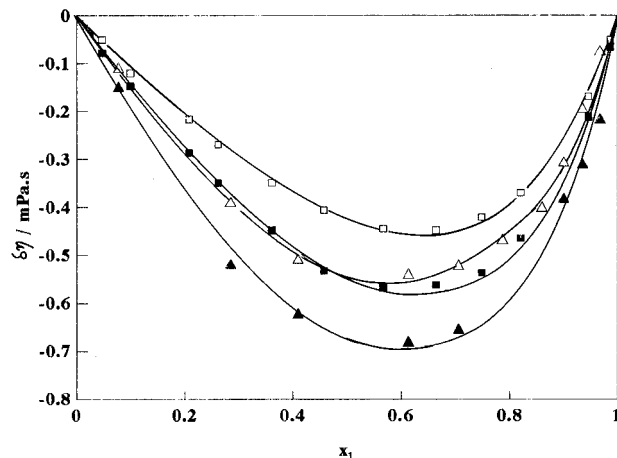
T/K	$\text{cm}^3\cdot\text{mol}^{-1}$					TPa^{-1}					$\text{mPa}\cdot\text{s}$			
	a_0	a_1	a_2	a_3	σ	a_0	a_1	a_2	a_3	σ	a_0	a_1	a_2	σ
1-Propanol + Heptane														
298.15	-1.2970	-1.1211	-0.2441	1.0423	0.001	52.4799	-81.0652	43.2052		0.10	-2.1987	-1.2425	-0.6285	0.001
308.15	1.3999	-1.0702	0.3379	1.2029	0.001	53.4170	-23.8537	82.2380	-107.836	0.40	-1.6904	-0.9471	-0.5692	0.001
1-Butanol + Heptane														
298.15	0.6994	-0.8478	0.2925		0.001	-6.5681	-77.7426	36.3544		0.20	-2.7693	-1.5812	-0.7685	0.001
308.15	1.0024	-1.3506	0.7073		0.001	3.0984	-76.2122	65.6048		0.40	-2.1791	-1.2459	-0.6322	0.001

**Figure 2.** Excess isentropic compressibilities of 1-alkanol + heptane mixtures versus alkanol mole fraction: 1-propanol + heptane at (■) 298.15 K and (□) 308.15 K; 1-butanol + heptane at (▲) 298.15 K and (△) 308.15 K.**Table 5. Experimental Viscosities (η_{exp}) and Viscosity Deviations ($\delta\eta$) for 1-Alkanol + Heptane Mixtures at 298.15 K and 308.15 K**

x_1	298.15 K		308.15 K	
	$\eta_{\text{exp}}/\text{mPa}\cdot\text{s}$	$\delta\eta/\text{mPa}\cdot\text{s}$	$\eta_{\text{exp}}/\text{mPa}\cdot\text{s}$	$\delta\eta/\text{mPa}\cdot\text{s}$
1-Propanol (1) + heptane (2)				
0.0468	0.3930	-0.070	0.3551	-0.054
0.0989	0.4030	-0.141	0.3600	-0.121
0.2079	0.4331	-0.280	0.3821	-0.221
0.2621	0.4540	-0.343	0.4018	-0.267
0.3620	0.4992	-0.453	0.4432	-0.347
0.4569	0.5760	-0.523	0.4920	-0.412
0.5667	0.6900	-0.580	0.5902	-0.448
0.6636	0.8320	-0.588	0.7000	-0.455
0.7478	0.9990	-0.552	0.8319	-0.425
0.8202	1.1873	-0.476	0.9800	-0.365
0.9458	1.6591	-0.199	1.3465	-0.150
0.9873	1.8727	-0.050	1.5060	-0.041
1-Butanol (1) + Heptane (2)				
0.0770	0.4210	-0.137	0.3698	-0.109
0.1523	0.4560	-0.266	0.3920	-0.211
0.2853	0.5468	-0.465	0.4571	-0.365
0.4094	0.6670	-0.616	0.5432	-0.484
0.5024	0.7870	-0.698	0.6232	-0.557
0.6136	0.9824	-0.745	0.7769	-0.586
0.7055	1.2041	-0.724	0.9444	-0.570
0.7866	1.4525	-0.652	1.1356	-0.513
0.8595	1.7515	-0.512	1.3630	-0.405
0.8998	1.9420	-0.410	1.5150	-0.320
0.9352	2.1440	-0.285	1.6660	-0.227
0.9675	2.3424	-0.157	1.8210	-0.125

are given in Table 4. The K_s^E values for the binary mixtures at both the temperatures are also shown graphically in Figure 2.

The experimental viscosities and viscosity deviations, $\delta\eta$, for 1-alcohol + heptane mixtures are given as a function of temperature at both the temperatures in Table 5. The viscosity deviations were calculated from the measured

**Figure 3.** Viscosity deviations of 1-alkanol + heptane mixtures versus alkanol mole fraction: 1-propanol + heptane at (■) 298.15 K and (□) 308.15 K; 1-butanol + heptane at (▲) 298.15 K and (△) 308.15 K.**Table 6. Relative Permittivity (ϵ), Relative Permittivity Deviation ($\delta\epsilon$), and Molar Polarization Deviation (δP_m) for 1-Alkanol + Heptane Mixtures at 298.15 K and 308.15 K**

x_1	298.15K			308.15K		
	ϵ	$\delta\epsilon$	$\delta P_m/\text{cm}^3\cdot\text{mol}^{-1}$	ϵ	$\delta\epsilon$	$\delta P_m/\text{cm}^3\cdot\text{mol}^{-1}$
1-Propanol (1) + Heptane (2)						
0.0468	2.0467	-1.285	1.4	1.7904	-1.515	-5.3
0.0989	2.3771	-2.342	6.8	1.7660	-2.920	-8.4
0.2079	3.1001	-4.068	13.9	2.0228	-5.102	-6.6
0.2621	3.6727	-5.781	18.2	2.2702	-7.130	-3.6
0.3620	4.7546	-6.412	22.1	2.9935	-8.112	3.5
0.4569	6.1593	-7.050	24.1	4.3990	-8.745	13.1
0.5667	7.9952	-6.912	23.0	6.1944	-8.635	16.4
0.6636	9.9529	-6.448	19.9	9.3296	-6.980	19.4
0.7478	12.2487	-5.495	16.5	11.7513	-5.902	16.3
0.8202	14.4008	-4.085	12.6	14.2431	-4.149	12.8
0.9458	18.5608	-0.577	4.2	18.0772	-0.964	4.1
0.9873	20.2867	0.554	1.2	19.7845	0.151	1.0
1-Butanol (1) + Heptane (2)						
0.0770	2.1941	-0.920	3.0	1.9068	-1.116	-3.9
0.1523	2.4123	-1.876	3.6	2.0000	-2.123	-5.6
0.2853	3.1408	-3.221	8.1	2.3758	-3.702	-4.7
0.4094	4.3157	-3.981	13.4	3.0400	-4.858	-0.9
0.5024	5.6667	-4.080	16.4	4.1569	-5.105	6.0
0.6136	8.4115	-4.069	19.8	5.8559	-5.037	10.0
0.7055	9.2803	-3.633	18.3	7.1887	-4.422	11.1
0.7866	11.0448	-3.133	14.4	9.5122	-3.918	9.1
0.8595	12.4763	-2.838	7.4	11.5964	-2.903	6.9
0.8998	14.0177	-1.925	5.8	12.6034	-2.487	4.7
0.9352	15.0307	-1.464	3.7	13.7496	-1.860	3.1
0.9675	16.2393	-0.759	1.9	15.2763	-0.807	1.8

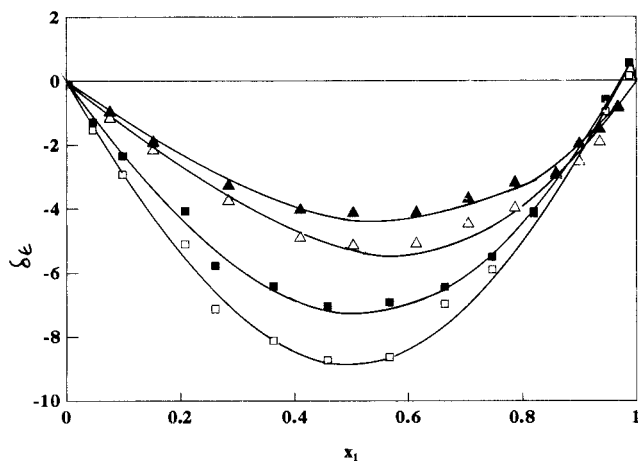
viscosities, η_{12} , of the mixture and η_i of the pure components by

$$\delta\eta = \eta_{12} - (x_1\eta_1 + x_2\eta_2) \quad (6)$$

The viscosity deviations were fitted through eq 5, and the

Table 7. Coefficients a_i and Standard Deviation, σ , for the Least Squares Representation of $\delta\epsilon$ and δP_m for 1-Alkanol + Heptane Mixtures at 298.15 K and 308.15 K

T/K	$\delta\epsilon$					$\delta P_m/\text{cm}^3\cdot\text{mol}^{-1}$				
	a_0	a_1	a_2	a_3	σ	a_0	a_1	a_2	a_3	σ
1-Propanol + Heptane										
298.15	-33.0864	-20.4431	28.3271	54.7408	0.001	97.8339	-21.7480	-39.0471	57.6709	0.50
308.15	-36.8567	-5.8072	20.2644	26.8962	0.020	56.1221	109.8228	-92.4961	1.9607	0.40
1-Butanol + Heptane										
298.15	-16.2636	-5.2220	-3.1833		0.120	66.6686	64.4143	-22.2642	-68.2591	0.03
308.15	-19.9517	-6.2887	-2.2175		0.001	19.7067	93.5259	-27.0746	-39.9206	0.01

**Figure 4.** Dielectric constant deviations of 1-alkanol + heptane mixtures versus alkanol mole fraction: 1-propanol + heptane at (■) 298.15 K and (□) 308.15 K; 1-butanol + heptane at (▲) 298.15 K and (△) 308.15 K.

values of the fitting coefficients are given in Table 4. The values of $\delta\eta$ are also shown as a function of the 1-alcohol mole fraction in Figure 3.

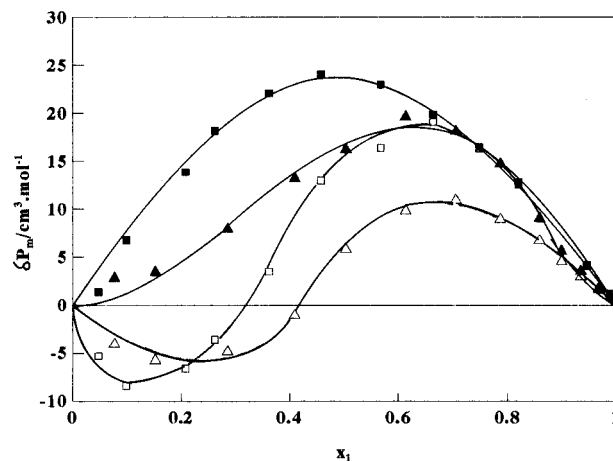
The relative permittivity (ϵ), relative permittivity deviation ($\delta\epsilon$), and molar polarization deviation (δP_m) for both mixtures are given in Table 6. The $\delta\epsilon$ and δP_m values were calculated by

$$\delta A = A - A^\circ \quad (7)$$

where δA is either $\delta\epsilon$ or δP_m , A is the property of the real mixture, and A° is the property of the pure components. The values of the pure components were evaluated as mole fraction averages. The molar polarizations were calculated from the measured relative permittivity and density data by the well-known Clausius–Mosotti equation. The data of $\delta\epsilon$ and δP_m were fitted to eq 5, and the values of the fitting coefficients are given in Table 7. $\delta\epsilon$ and δP_m are also represented graphically in Figures 4 and 5, respectively, for both the mixtures at two temperatures. The relative permittivity deviations in general were found to be large and negative in the whole range of mole fraction. The $\delta\epsilon$ values for both the mixtures and at the two temperatures showed small changes in the alcohol rich regions, in contrast to the appreciable variations in the middle alcohol mole fraction range. It can be seen from Figure 5 that the δP_m values for both the mixtures at 298.15 K were observed to be positive and the curves showed a sigmoidal nature with the initial negative values followed by positive regions at 308.15 K.

Discussion

The dependence of V^E on the alcohol mole fraction as shown in Figure 1 is typical and follows the trend similar to the other lower alcohol + heptane mixtures as reported in the literature. The V^E values for both the mixtures were found to be positive over the entire range of mole fraction

**Figure 5.** Molar polarization deviations of 1-alkanol + heptane mixtures versus alkanol mole fraction: 1-propanol + heptane at (■) 298.15 K and (□) 308.15 K; 1-butanol + heptane at (▲) 298.15 K and (△) 308.15 K.

and were skewed toward the lower alcohol mole fractions. The curves are characterized by an initial sharp rise with high positive slopes followed by appreciable differences with either an increase in the carbon chain length of the alcohol or a rise in the temperature. Our fitted $V_{0.5}^E = 0.324 \text{ cm}^3\cdot\text{mol}^{-1}$ for 1-propanol + heptane mixtures at 298.15 K is found to be in reasonable agreement with the previously reported literature values of $0.2964 \text{ cm}^3\cdot\text{mol}^{-1}$ (Treszczanowicz and Benson, 1977) and $0.312 \text{ cm}^3\cdot\text{mol}^{-1}$ (Van Ness et al., 1967) for the same mixtures and at the same temperature. Similarly, our $V_{0.5}^E = 0.175 \text{ cm}^3\cdot\text{mol}^{-1}$ at 298.15 K and $V_{0.5}^E = 0.251 \text{ cm}^3\cdot\text{mol}^{-1}$ at 308.15 K for 1-butanol + heptane mixtures are in close agreement with the values of $0.1797 \text{ cm}^3\cdot\text{mol}^{-1}$ (Suehnel and Wittig, 1981), $0.1881 \text{ cm}^3\cdot\text{mol}^{-1}$ (Treszczanowicz and Benson, 1977) at 298.15 K, and $0.2529 \text{ cm}^3\cdot\text{mol}^{-1}$ (Kumar, 1984) at 308.15 K, respectively.

The excess isentropic compressibilities, as shown in Figure 2 for 1-propanol + heptane mixtures, were found to be positive over the whole range of mole fraction at both temperatures, and the curves were sigmoidal in nature with initial positive regions followed by negative lobes at higher alcohol mole fractions in the case of 1-butanol + heptane mixtures. Upon comparison of equimolar K_s^E results at 298.15 K with the published results of Kiyohara and Benson (1979) for the mixtures of heptane with 1-propanol and 1-butanol, we find that our $K_s^E = 13 \text{ TPa}^{-1}$ for 1-propanol + heptane mixtures is 1% lower than the literature value of 14 TPa^{-1} . For the 1-butanol + heptane mixture, our $K_s^E = -1.6 \text{ TPa}^{-1}$ is about 5.3% more negative than the published value of -0.3 TPa^{-1} . No experimental data were, however, found for the present mixtures at 308.15 K with which a comparison of our values could be made. The temperature coefficients of V^E for the two binary mixtures were found to be negative, and those of K_s^E were observed to be positive. The sharp rise in the V^E

and K_S^E values in the dilute alcohol regions suggests the dominance of dispersing interactions in the form of rupture of the hydrogen bonds of alcohol molecules by unlike heptane molecules. These observations are further supported by large negative $\delta\eta$ (Figure 3) and $\delta\epsilon$ values (Figure 4).

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