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Effect of Temperature on Thermophysical Properties of Ethanol + Aliphatic Alcohols (C_4–C_5) Mixtures

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Summary. Speeds of sound, densities, and refractive indices of the binary mixtures containing ethanol + (2-methyl-1-propanol, 2-methyl-1-butanol, 1-pentanol, or 3-methyl-1-butanol) were measured at $288.15 \leq T/\mathrm{K} \leq 323.15$ and atmospheric condition in the whole compositional range. The effect of temperature was analyzed by several chemical terms.

Keywords. Aliphatic alcohols; Thermodynamics; Thermochemistry; Mixing properties; Model comparison.

Introduction

The interactions among unlike molecules depend on charge distribution, molecular geometry, and the main interaction force among those key molecular groups. As a part of our research program on thermodynamics of mixing related to chemical processes, we have conducted several studies on the properties of binary and multicomponent mixtures, which are involved in separation units for recovering industrial solvents, food engineering, or pharmacological applications [1–6, 9].

Ethanol has been used as distillation entrainer or extractive solvent in the chemical industry. The experimental values of the derived properties studied here (excess molar volumes, changes of refractive indices on mixing, and changes of isentropic compressibility), provide information about ethanol solvent interactions as the mole fraction of ethanol is increased. We present a study of the effect of temperature on these properties. For this purpose, the density, refractive index on mixing, and speed of sound of ethanol + (2-methyl-1-propanol, 2-methyl-1-butanol, 1-pentanol, or 3-methyl-1-butanol) in the temperature range 288.15–323.15 K and atmospheric pressure were measured. The corresponding derived quantities were computed. The values of partial molar excess volumes as well as the corresponding limiting quantities were determined and commented upon. An attempt has also been made to calculate the measured values by using different theoretical procedures [7].

Data Correlation

The physical properties of the binary mixtures are given in Tables 1 and 2, applying Eq. (1) to compute the corresponding derived quantities:

$$\Delta Q = Q - \sum_{i=1}^{N} x_i \cdot Q_i \qquad (1)$$

In this equation, Q is a physical property of the mixture, Q_i is the property of the pure components,

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x_i the mole fraction of component i in the mixture, N is the number of components, and Δ means the variation of the quantity. The derived properties at the measurement temperature are listed in the same tables. A modified *Redlich-Kister* type equation was used to correlate the values of the derived quantities, as a function of temperature for the corresponding binary mixtures, a generalized set of parameters has been computed. The parameters are those corresponding to the fitting equations which are expressed as:

$$\Delta Q = x_i x_j \sum_{p=0}^{m} B_p (x_i - x_j)^p \tag{2}$$

$$B_p = \sum_{q=0}^{2} B_{pq} T^q \tag{3}$$

where m is the limit of the expansion according to the *Bevington* [8] test, B_{pq} are the fitting parameters, and T is the temperature expressed by K. The correlation was made by the least squares method, using a routine according to the *Marquardt* algorithm. Such parameters were gathered for these mixtures at the temperature range in Table 3. The root mean square deviation is expressed by Eq. (4). In this equation the value of the property and the number of experimental data are represented by z and n, respectively.

$$\sigma = \sqrt{\frac{\sum_{i}^{n} (z_{\text{exp}} - z_{\text{pred}})^2}{n}} \tag{4}$$

In the open literature, no values of the studied mixtures have been published, except those data at 298.15 for the systems ethanol + (2-methyl-1-propanol and 2-methyl-1-butanol) gathered in an earlier work of the authors [9]. Figures 1–3 show the excess properties against ethanol molar fraction as well as the curves fitted. Two facts need to be pointed out, first the expansive trend of the mixtures and second, the influence of temperature, which decreases the expansive tendency by increasing the H-bond potency when it rises. For the mixtures containing 1-pentanol or 3-methyl-1-butanol, an expansive trend is observed at the whole range of composition and temperatures.

Derived Properties

The temperature dependence of volume has been expressed as isobaric expansibility or thermal expansion coefficient (α). The data reported in literature normally give only values of thermal expansion coefficients both of pure compounds and its mixtures, showing the relative changes in density, calculated by means of $(-\Delta\rho/\rho)$ as a function of temperature, and assuming that α remains constant in any thermal range. The corresponding expressions for pure chemicals or mixtures are indicated in Appendix A.

The isothermal coefficient of pressure excess molar enthalpy can be derived accurately from volumetric measurements by application of the following expression:

$$\left(\frac{\partial H^{\text{E}}}{\partial P}\right)_{T,x} = V^{\text{E}} - T\left(\frac{\partial V^{\text{E}}}{\partial T}\right)_{P,x} \tag{5}$$

This property stands for the dependence of excess molar enthalpy of mixing with pressure at fixed composition and temperature. In Fig. 5, the variation of this coefficient for these mixtures is shown where a sigmoid trend and lower values can be observed for 2-methyl-1-propanol.

Partial Molar Excess Volumes

Expression for the partial molar excess volume, should be written as:

$$\overline{V}_i^{\text{E}} = V^{\text{E}} + \left(\frac{\partial V^{\text{E}}}{\partial x}\right) \cdot (1 - x) \tag{6}$$

Taking into account Eq. (2) at constant temperature, then:

$$\overline{V}_1^{\text{E},\infty\infty} = \sum_{p=0}^{N} (-1)^p A_p(T) \tag{7}$$

$$\overline{V}_2^{\text{E},\infty\infty} = \sum_{p=0}^{N} A_p(T) \tag{8}$$

In Fig. 6 the values of limiting partial molar excess volumes at 298.15 K for the binary mixtures are plotted *vs.* x_1. These values describe the solvent behaviour at infinite dilution. A closer packing can be observed as the ethanol concentration increases. A repulsive tendency is observed for the mixture ethanol + 2-methyl-1-propanol, as commented above in terms of excess molar volumes. A strong effect of ethanol molecules on the partial excess volume can be observed. The values of $\overline{V}_1^{\text{E},\infty\infty}$ decrease by each increment of the ethanol concentration or by diminution of steric hindrance (shorter chain).

Table 1. Density, speed of sound, and derived quantities as a function of composition and temperature (288.15–323.15 K) for the binary systems

Ethanol + 2-Methyl-1-propanol					
323.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.77774	0	1102.5	1057.7	0
0.0521	0.77792	−0.077	1102.8	1057.1	−6.4
0.1036	0.77738	−0.066	1101.1	1061.0	−8.1
0.1551	0.77684	−0.058	1099.5	1064.7	−10.0
0.2064	0.77626	−0.047	1098.3	1068.0	−12.4
0.2575	0.77566	−0.036	1095.9	1073.4	−12.6
0.3084	0.77501	−0.022	1094.2	1077.7	−13.9
0.3591	0.77440	−0.016	1092.6	1081.7	−15.4
0.4096	0.77376	−0.009	1089.5	1088.7	−14.0
0.4598	0.77312	−0.006	1087.9	1092.9	−15.3
0.5099	0.77241	0.001	1085.6	1098.5	−15.2
0.5598	0.77122	0.054	1082.0	1107.5	−11.7
0.6095	0.77043	0.062	1079.6	1113.6	−11.0
0.6590	0.76965	0.065	1077.1	1120.0	−10.0
0.7083	0.76896	0.056	1074.9	1125.6	−9.9
0.7574	0.76801	0.067	1071.9	1133.3	−7.5
0.8063	0.76713	0.068	1069.2	1140.4	−5.8
0.8550	0.76627	0.063	1066.4	1147.6	−3.9
0.9035	0.76531	0.063	1063.7	1154.8	−2.1
0.9519	0.76437	0.057	1060.7	1162.8	0.6
1	0.76402	0	1058.8	1167.5	0
320.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	$\kappa_S{}^E$/T Pa^{-1}	$\delta\kappa_S$/T Pa^{-1}
0	0.77971	0	1110.9	1039.2	0
0.0521	0.77991	−0.078	1111.2	1038.5	−6.2
0.1036	0.77938	−0.067	1109.6	1042.2	−8.0
0.1551	0.77883	−0.057	1108.0	1045.9	−9.7
0.2064	0.77826	−0.045	1106.7	1049.1	−12.0
0.2575	0.77767	−0.035	1104.5	1054.1	−12.4
0.3084	0.77701	−0.020	1102.6	1058.7	−13.3
0.3591	0.77641	−0.015	1101.0	1062.6	−14.8
0.4096	0.77578	−0.008	1098.1	1068.9	−13.7
0.4598	0.77515	−0.005	1096.4	1073.3	−14.7
0.5099	0.77444	0.003	1094.1	1078.6	−14.7
0.5598	0.77327	0.055	1090.5	1087.6	−11.1
0.6095	0.77248	0.063	1088.1	1093.4	−10.5
0.6590	0.77172	0.066	1085.5	1099.7	−9.5
0.7083	0.77102	0.059	1083.3	1105.2	−9.2
0.7574	0.77011	0.068	1080.3	1112.6	−7.0
0.8063	0.76923	0.070	1077.6	1119.5	−5.4
0.8550	0.76839	0.065	1074.8	1126.5	−3.5
0.9035	0.76742	0.066	1072.2	1133.6	−1.6
0.9519	0.76655	0.055	1069.3	1141.0	0.7
1	0.76620	0	1067.5	1145.4	0
318.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.78182	0	1119.4	1020.8	0
0.0521	0.78202	−0.077	1119.6	1020.2	−6.0
0.1036	0.78150	−0.067	1118.0	1023.8	−7.7

(*continued*)

Table 1 (*continued*)

Ethanol + 2-Methyl-1-propanol					
318.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0.1551	0.78095	−0.056	1116.3	1027.5	−9.3
0.2064	0.78038	−0.044	1115.1	1030.5	−11.6
0.2575	0.77978	−0.032	1112.8	1035.7	−11.8
0.3084	0.77915	−0.019	1110.9	1039.9	−12.8
0.3591	0.77855	−0.013	1109.4	1043.7	−14.2
0.4096	0.77794	−0.008	1106.7	1049.4	−13.7
0.4598	0.77730	−0.003	1104.7	1054.1	−14.2
0.5099	0.77662	0.004	1102.5	1059.3	−14.2
0.5598	0.77543	0.058	1098.8	1068.1	−10.6
0.6095	0.77465	0.066	1096.5	1073.8	−10.0
0.6590	0.77391	0.067	1093.9	1079.9	−9.0
0.7083	0.77321	0.061	1091.6	1085.3	−8.7
0.7574	0.77231	0.070	1088.7	1092.5	−6.5
0.8063	0.77145	0.071	1085.9	1099.2	−4.9
0.8550	0.77063	0.065	1083.2	1105.9	−3.2
0.9035	0.76967	0.066	1080.6	1112.7	−1.5
0.9519	0.76883	0.054	1077.6	1120.0	0.8
1	0.76848	0	1075.9	1124.1	0
315.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.78376	0	1127.7	1003.4	0
0.0521	0.78397	−0.078	1127.9	1002.6	−5.9
0.1036	0.78346	−0.068	1126.4	1006.1	−7.7
0.1551	0.78293	−0.058	1124.8	1009.6	−9.3
0.2064	0.78235	−0.045	1123.5	1012.7	−11.4
0.2575	0.78175	−0.031	1121.1	1017.7	−11.4
0.3084	0.78113	−0.019	1119.3	1021.9	−12.4
0.3591	0.78054	−0.012	1117.7	1025.5	−13.9
0.4096	0.77992	−0.006	1115.2	1030.9	−13.5
0.4598	0.77931	−0.003	1113.1	1035.7	−13.8
0.5099	0.77863	0.005	1110.8	1040.8	−13.7
0.5598	0.77744	0.058	1107.2	1049.3	−10.2
0.6095	0.77667	0.067	1104.8	1054.9	−9.6
0.6590	0.77595	0.067	1102.3	1060.7	−8.7
0.7083	0.77526	0.062	1100.1	1065.9	−8.5
0.7574	0.77438	0.069	1097.0	1073.0	−6.3
0.8063	0.77352	0.072	1094.4	1079.5	−4.7
0.8550	0.77271	0.066	1091.6	1086.1	−3.0
0.9035	0.77177	0.068	1089.0	1092.7	−1.3
0.9519	0.77093	0.056	1086.1	1099.7	0.9
1	0.77063	0	1084.3	1103.6	0
313.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.78580	0	1135.9	986.2	0
0.0521	0.78603	−0.080	1136.2	985.5	−5.8
0.1036	0.78552	−0.068	1134.6	989.0	−7.4
0.1551	0.78498	−0.056	1133.0	992.3	−9.0
0.2064	0.78442	−0.044	1131.8	995.3	−11.1

(*continued*)

Table 1 (*continued*)

Ethanol + 2-Methyl-1-propanol					
313.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0.2575	0.78381	−0.030	1129.5	1000.1	−11.2
0.3084	0.78320	−0.018	1127.6	1004.2	−12.0
0.3591	0.78260	−0.010	1126.0	1007.9	−13.3
0.4096	0.78202	−0.006	1123.7	1012.7	−13.4
0.4598	0.78140	−0.002	1121.4	1017.6	−13.4
0.5099	0.78072	0.006	1119.1	1022.8	−13.1
0.5598	0.77955	0.060	1115.4	1031.1	−9.7
0.6095	0.77880	0.067	1113.1	1036.4	−9.2
0.6590	0.77807	0.069	1110.5	1042.1	−8.3
0.7083	0.77738	0.064	1108.3	1047.2	−8.0
0.7574	0.77653	0.070	1105.3	1054.0	−6.0
0.8063	0.77569	0.071	1102.7	1060.3	−4.5
0.8550	0.77489	0.066	1100.0	1066.6	−2.9
0.9035	0.77395	0.068	1097.3	1073.1	−1.2
0.9519	0.77311	0.058	1094.4	1080.0	1.0
1	0.77285	0	1092.7	1083.7	0
310.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.78781	0	1144.2	969.5	0
0.0521	0.78807	−0.082	1144.5	968.7	−5.8
0.1036	0.78756	−0.070	1142.8	972.2	−7.2
0.1551	0.78700	−0.055	1141.2	975.7	−8.6
0.2064	0.78646	−0.045	1140.0	978.4	−10.7
0.2575	0.78584	−0.028	1137.6	983.3	−10.6
0.3084	0.78526	−0.018	1135.8	987.2	−11.6
0.3591	0.78465	−0.009	1134.3	990.6	−13.0
0.4096	0.78408	−0.006	1132.0	995.3	−13.1
0.4598	0.78346	0.000	1129.7	1000.2	−12.9
0.5099	0.78281	0.007	1127.3	1005.2	−12.7
0.5598	0.78164	0.060	1123.6	1013.3	−9.3
0.6095	0.78088	0.069	1121.3	1018.6	−8.8
0.6590	0.78017	0.070	1118.7	1024.2	−7.9
0.7083	0.77949	0.065	1116.6	1028.9	−7.8
0.7574	0.77866	0.071	1113.5	1035.7	−5.7
0.8063	0.77782	0.073	1110.9	1041.7	−4.3
0.8550	0.77705	0.066	1108.2	1047.9	−2.7
0.9035	0.77612	0.068	1105.6	1054.2	−1.1
0.9519	0.77532	0.057	1102.7	1060.8	1.0
1	0.77505	0	1101.0	1064.4	0
308.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.78978	0	1152.5	953.3	0
0.0521	0.79006	−0.083	1152.8	952.5	−5.6
0.1036	0.78956	−0.072	1151.2	955.7	−7.1
0.1551	0.78901	−0.057	1149.5	959.1	−8.5
0.2064	0.78848	−0.046	1148.3	961.8	−10.5
0.2575	0.78786	−0.029	1146.0	966.5	−10.5

(*continued*)

Table 1 (*continued*)

Ethanol + 2-Methyl-1-propanol					
308.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0.3084	0.78729	−0.020	1144.1	970.3	−11.4
0.3591	0.78667	−0.008	1142.5	973.9	−12.4
0.4096	0.78612	−0.006	1140.5	978.0	−13.0
0.4598	0.78550	0.000	1138.0	983.0	−12.6
0.5099	0.78485	0.007	1135.7	987.9	−12.3
0.5598	0.78368	0.062	1131.9	995.9	−9.0
0.6095	0.78293	0.071	1129.6	1001.0	−8.4
0.6590	0.78226	0.069	1127.1	1006.3	−7.6
0.7083	0.78157	0.067	1124.8	1011.2	−7.3
0.7574	0.78077	0.070	1121.9	1017.5	−5.5
0.8063	0.77994	0.073	1119.3	1023.4	−4.1
0.8550	0.77918	0.066	1116.6	1029.4	−2.6
0.9035	0.77826	0.069	1113.9	1035.6	−0.9
0.9519	0.77748	0.057	1111.1	1041.9	0.9
1	0.77724	0	1109.4	1045.4	0
305.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.79174	0	1160.7	937.5	0
0.0521	0.79204	−0.084	1161.1	936.6	−5.5
0.1036	0.79155	−0.073	1159.4	939.8	−7.0
0.1551	0.79100	−0.057	1157.9	943.0	−8.3
0.2064	0.79047	−0.046	1156.6	945.7	−10.3
0.2575	0.78985	−0.028	1154.2	950.3	−10.2
0.3084	0.78928	−0.018	1152.4	954.0	−11.1
0.3591	0.78867	−0.007	1150.7	957.6	−12.0
0.4096	0.78813	−0.005	1148.8	961.4	−12.7
0.4598	0.78751	0.003	1146.2	966.5	−12.1
0.5099	0.78688	0.008	1144.0	971.1	−12.0
0.5598	0.78572	0.062	1140.2	978.9	−8.6
0.6095	0.78498	0.072	1137.9	983.8	−8.1
0.6590	0.78431	0.071	1135.3	989.2	−7.3
0.7083	0.78363	0.069	1133.1	993.8	−7.0
0.7574	0.78285	0.071	1130.2	1000.0	−5.2
0.8063	0.78202	0.075	1127.6	1005.7	−3.9
0.8550	0.78129	0.067	1124.9	1011.5	−2.5
0.9035	0.78039	0.069	1122.2	1017.5	−0.8
0.9519	0.77963	0.056	1119.5	1023.5	0.9
1	0.77940	0	1117.8	1026.9	0
303.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.79373	0	1169.1	921.8	0
0.0521	0.79404	−0.084	1169.5	920.8	−5.5
0.1036	0.79355	−0.072	1167.8	924.0	−6.8
0.1551	0.79300	−0.056	1166.2	927.2	−8.1
0.2064	0.79248	−0.046	1165.0	929.8	−10.0
0.2575	0.79186	−0.026	1162.6	934.3	−9.9
0.3084	0.79131	−0.018	1160.8	937.9	−10.7

(*continued*)

Table 1 (*continued*)

Ethanol + 2-Methyl-1-propanol					
303.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0.3591	0.79071	−0.006	1159.0	941.4	−11.6
0.4096	0.79017	−0.004	1157.2	945.0	−12.4
0.4598	0.78955	0.004	1154.6	950.1	−11.7
0.5099	0.78894	0.010	1152.3	954.6	−11.5
0.5598	0.78778	0.064	1148.6	962.3	−8.2
0.6095	0.78704	0.074	1146.3	967.0	−7.8
0.6590	0.78640	0.071	1143.7	972.1	−6.9
0.7083	0.78570	0.071	1141.5	976.8	−6.6
0.7574	0.78496	0.071	1138.6	982.7	−4.9
0.8063	0.78415	0.074	1136.0	988.2	−3.7
0.8550	0.78343	0.067	1133.3	993.9	−2.2
0.9035	0.78253	0.070	1130.6	999.7	−0.6
0.9519	0.78181	0.056	1127.9	1005.5	1.0
1	0.78159	0	1126.2	1008.7	0
300.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.79567	0	1177.3	906.7	0
0.0521	0.79600	−0.085	1177.7	905.7	−5.4
0.1036	0.79551	−0.074	1176.1	908.8	−6.6
0.1551	0.79496	−0.055	1174.5	911.9	−7.9
0.2064	0.79445	−0.046	1173.2	914.5	−9.6
0.2575	0.79382	−0.025	1170.9	918.8	−9.6
0.3084	0.79330	−0.018	1169.1	922.3	−10.5
0.3591	0.79269	−0.005	1167.3	925.8	−11.2
0.4096	0.79218	−0.005	1165.7	929.0	−12.3
0.4598	0.79155	0.005	1162.9	934.2	−11.3
0.5099	0.79095	0.010	1160.6	938.6	−11.2
0.5598	0.78980	0.064	1156.8	946.1	−7.9
0.6095	0.78907	0.074	1154.6	950.7	−7.5
0.6590	0.78845	0.071	1152.0	955.7	−6.6
0.7083	0.78776	0.071	1149.9	960.1	−6.4
0.7574	0.78703	0.071	1146.9	965.9	−4.8
0.8063	0.78623	0.075	1144.4	971.3	−3.5
0.8550	0.78553	0.066	1141.6	976.7	−2.1
0.9035	0.78465	0.069	1139.0	982.4	−0.6
0.9519	0.78394	0.055	1136.2	988.1	1.0
1	0.78373	0	1134.6	991.1	0
298.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.79761	0	1185.6	891.9	0
0.0521	0.79796	−0.087	1186.1	890.8	−5.3
0.1036	0.79748	−0.074	1184.4	893.9	−6.5
0.1551	0.79693	−0.056	1182.9	896.8	−7.8
0.2064	0.79643	−0.046	1181.5	899.5	−9.3
0.2575	0.79580	−0.025	1179.3	903.6	−9.4
0.3084	0.79530	−0.020	1177.5	906.9	−10.2
0.3591	0.79469	−0.005	1175.6	910.5	−10.8
0.4096	0.79419	−0.005	1174.1	913.3	−12.1
0.4598	0.79356	0.006	1171.3	918.6	−11.0
0.5099	0.79297	0.010	1169.0	922.8	−10.8

(*continued*)

Table 1 (*continued*)

Ethanol + 2-Methyl-1-propanol					
298.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0.5598	0.79183	0.065	1165.2	930.2	−7.6
0.6095	0.79110	0.075	1163.0	934.6	−7.2
0.6590	0.79051	0.070	1160.4	939.4	−6.4
0.7083	0.78981	0.072	1158.2	943.8	−6.1
0.7574	0.78911	0.071	1155.3	949.4	−4.5
0.8063	0.78832	0.075	1152.8	954.5	−3.4
0.8550	0.78764	0.066	1150.1	959.8	−2.1
0.9035	0.78677	0.069	1147.4	965.5	−0.4
0.9519	0.78609	0.054	1144.7	970.9	1.0
1	0.78589	0	1143.1	973.8	0
295.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.79953	0	1194.1	877.2	0
0.0521	0.79989	−0.086	1194.5	876.2	−5.2
0.1036	0.79942	−0.075	1192.9	879.1	−6.3
0.1551	0.79887	−0.055	1191.3	882.0	−7.6
0.2064	0.79839	−0.047	1189.8	884.7	−8.9
0.2575	0.79776	−0.024	1187.7	888.6	−9.1
0.3084	0.79726	−0.018	1185.9	891.9	−9.9
0.3591	0.79665	−0.003	1184.0	895.4	−10.4
0.4096	0.79617	−0.004	1182.7	897.9	−11.9
0.4598	0.79555	0.007	1179.7	903.2	−10.6
0.5099	0.79497	0.011	1177.5	907.3	−10.5
0.5598	0.79384	0.065	1173.7	914.5	−7.3
0.6095	0.79312	0.076	1171.4	918.8	−6.9
0.6590	0.79254	0.071	1168.9	923.5	−6.1
0.7083	0.79185	0.073	1166.7	927.7	−5.9
0.7574	0.79117	0.071	1163.8	933.1	−4.4
0.8063	0.79039	0.075	1161.3	938.1	−3.2
0.8550	0.78973	0.066	1158.7	943.2	−2.0
0.9035	0.78888	0.069	1156.0	948.7	−0.5
0.9519	0.78822	0.053	1153.2	954.0	1.0
1	0.78803	0	1151.6	956.8	0
293.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.80145	0	1202.7	862.6	0
0.0521	0.80183	−0.087	1203.2	861.5	−5.1
0.1036	0.80137	−0.076	1201.5	864.4	−6.3
0.1551	0.80080	−0.054	1200.0	867.2	−7.3
0.2064	0.80034	−0.047	1198.4	870.0	−8.5
0.2575	0.79971	−0.023	1196.3	873.7	−8.8
0.3084	0.79923	−0.019	1194.5	876.9	−9.6
0.3591	0.79863	−0.004	1192.6	880.3	−10.0
0.4096	0.79816	−0.005	1191.4	882.6	−11.7
0.4598	0.79753	0.008	1188.4	887.8	−10.3
0.5099	0.79697	0.011	1186.1	891.9	−10.2
0.5598	0.79585	0.065	1182.4	898.8	−7.1
0.6095	0.79513	0.077	1180.0	903.2	−6.6

(*continued*)

Table 1 (*continued*)

Ethanol + 2-Methyl-1-propanol					
293.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0.6590	0.79456	0.072	1177.5	907.8	−5.8
0.7083	0.79388	0.074	1175.4	911.8	−5.6
0.7574	0.79323	0.071	1172.5	917.0	−4.2
0.8063	0.79245	0.076	1170.0	921.9	−3.1
0.8550	0.79181	0.066	1167.3	926.8	−1.9
0.9035	0.79099	0.067	1164.6	932.2	−0.3
0.9519	0.79034	0.052	1161.9	937.3	1.1
1	0.79016	0	1160.3	940.0	0
290.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.80335	0	1211.3	848.4	0
0.0521	0.80375	−0.088	1211.8	847.2	−5.1
0.1036	0.80330	−0.077	1210.2	850.0	−6.1
0.1551	0.80274	−0.056	1208.6	852.8	−7.2
0.2064	0.80228	−0.048	1206.9	855.7	−8.2
0.2575	0.80164	−0.023	1205.0	859.1	−8.5
0.3084	0.80118	−0.019	1203.2	862.2	−9.3
0.3591	0.80058	−0.003	1201.2	865.7	−9.6
0.4096	0.80014	−0.006	1199.9	868.1	−11.0
0.4598	0.79951	0.008	1197.0	872.9	−9.9
0.5099	0.79896	0.012	1194.8	876.7	−9.9
0.5598	0.79784	0.066	1191.0	883.6	−6.8
0.6095	0.79714	0.077	1188.8	887.7	−6.4
0.6590	0.79658	0.072	1186.2	892.2	−5.6
0.7083	0.79590	0.076	1184.1	896.2	−5.4
0.7574	0.79527	0.072	1181.2	901.3	−3.9
0.8063	0.79451	0.077	1178.7	905.9	−2.9
0.8550	0.79389	0.067	1176.1	910.7	−1.8
0.9035	0.79310	0.067	1173.3	915.9	−0.3
0.9519	0.79246	0.053	1170.6	920.9	1.1
1	0.79231	0	1169.1	923.4	0
288.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.80517	0	1220.0	834.4	0
0.0521	0.80561	−0.092	1220.5	833.3	−4.9
0.1036	0.80518	−0.081	1218.9	836.0	−5.9
0.1551	0.80462	−0.058	1217.3	838.7	−6.9
0.2064	0.80416	−0.049	1215.6	841.5	−7.9
0.2575	0.80353	−0.024	1213.7	844.9	−8.2
0.3084	0.80307	−0.020	1211.8	848.0	−8.7
0.3591	0.80246	−0.001	1209.9	851.3	−9.1
0.4096	0.80204	−0.004	1208.3	854.0	−10.1
0.4598	0.80142	0.010	1205.7	858.3	−9.4
0.5099	0.80089	0.013	1203.5	862.0	−9.3
0.5598	0.79977	0.068	1199.8	868.6	−6.3
0.6095	0.79906	0.082	1197.4	872.8	−5.7
0.6590	0.79854	0.075	1194.9	877.1	−5.0
0.7083	0.79785	0.081	1192.7	881.0	−4.6

(*continued*)

Table 1 (*continued*)

Ethanol + 2-Methyl-1-propanol					
288.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0.7574	0.79726	0.076	1189.9	885.9	−3.3
0.8063	0.79648	0.083	1187.4	890.5	−2.2
0.8550	0.79587	0.073	1184.7	895.2	−1.1
0.9035	0.79513	0.071	1182.0	900.2	0.4
0.9519	0.79450	0.058	1179.3	905.0	1.7
1	0.79444	0	1178.2	906.8	0
Ethanol + 2-Methyl-1-butanol					
323.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.79551	0	1166.9	923.3	0.0
0.0487	0.79470	−0.006	1161.1	933.4	−1.7
0.1007	0.79380	−0.013	1160.6	935.2	−12.7
0.1517	0.79289	−0.022	1157.3	941.7	−18.6
0.1995	0.79187	−0.016	1153.7	948.8	−23.2
0.2495	0.79082	−0.016	1149.8	956.5	−27.7
0.3001	0.78969	−0.017	1145.7	964.7	−31.9
0.3491	0.78854	−0.017	1141.6	973.2	−35.3
0.3998	0.78725	−0.014	1137.3	982.0	−38.8
0.4502	0.78586	−0.006	1132.3	992.5	−40.7
0.5005	0.78440	0.000	1126.9	1003.9	−41.5
0.5496	0.78289	0.006	1121.8	1015.0	−42.5
0.5997	0.78120	0.017	1115.8	1028.1	−41.6
0.6503	0.77940	0.027	1109.6	1042.1	−40.0
0.7003	0.77755	0.032	1103.3	1056.5	−37.7
0.8011	0.77339	0.046	1089.4	1089.5	−29.3
0.8495	0.77124	0.045	1082.4	1106.7	−24.0
0.9001	0.76874	0.052	1074.4	1127.0	−16.1
0.9501	0.76615	0.053	1066.2	1148.1	−7.1
1	0.76402	0	1058.8	1167.5	0
320.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.79741	0	1175.4	907.7	0.0
0.0487	0.79661	−0.006	1169.9	917.1	−2.1
0.1007	0.79570	−0.010	1169.3	919.2	−12.4
0.1517	0.79481	−0.021	1165.9	925.6	−18.1
0.1995	0.79380	−0.014	1162.3	932.5	−22.6
0.2495	0.79273	−0.012	1158.3	940.1	−26.9
0.3001	0.79163	−0.014	1154.3	948.1	−30.9
0.3491	0.79047	−0.013	1150.1	956.4	−34.3
0.3998	0.78919	−0.009	1145.8	965.2	−37.5
0.4502	0.78782	−0.003	1140.8	975.3	−39.4
0.5005	0.78637	0.004	1135.4	986.5	−40.2
0.5496	0.78487	0.009	1130.3	997.3	−41.1
0.5997	0.78319	0.021	1124.3	1010.2	−40.1
0.6503	0.78140	0.032	1118.1	1023.7	−38.6
0.7003	0.77957	0.036	1111.8	1037.8	−36.4
0.8011	0.77545	0.048	1097.9	1069.9	−28.2

(*continued*)

Table 1 (*continued*)

Ethanol + 2-Methyl-1-butanol					
320.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0.8495	0.77330	0.049	1090.8	1086.7	−22.9
0.9001	0.77085	0.053	1082.9	1106.2	−15.4
0.9501	0.76828	0.054	1074.7	1126.9	−6.6
1	0.76620	0	1067.5	1145.4	0
318.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.79945	0	1184.0	892.2	0.0
0.0487	0.79865	−0.006	1178.9	901.0	−2.6
0.1007	0.79773	−0.007	1177.7	903.8	−11.8
0.1517	0.79683	−0.016	1174.3	910.0	−17.4
0.1995	0.79586	−0.013	1170.8	916.7	−21.8
0.2495	0.79478	−0.009	1166.7	924.3	−25.8
0.3001	0.79368	−0.010	1162.7	932.0	−29.9
0.3491	0.79253	−0.008	1158.5	940.2	−33.0
0.3998	0.79126	−0.005	1154.2	948.7	−36.3
0.4502	0.78990	0.001	1149.2	958.5	−38.1
0.5005	0.78847	0.007	1143.8	969.4	−38.9
0.5496	0.78697	0.014	1138.7	980.0	−39.7
0.5997	0.78531	0.024	1132.6	992.6	−38.7
0.6503	0.78352	0.035	1126.5	1005.8	−37.3
0.7003	0.78172	0.039	1120.2	1019.5	−35.2
0.8011	0.77763	0.051	1106.3	1050.8	−27.2
0.8495	0.77551	0.051	1099.2	1067.2	−22.0
0.9001	0.77308	0.055	1091.3	1086.1	−14.9
0.9501	0.77054	0.055	1083.1	1106.3	−6.3
1	0.76848	0	1075.9	1124.1	0
315.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.80133	0	1192.5	877.6	0.0
0.0487	0.80054	−0.006	1187.5	885.8	−2.8
0.1007	0.79963	−0.008	1186.2	888.7	−11.6
0.1517	0.79873	−0.015	1182.9	894.8	−17.0
0.1995	0.79773	−0.008	1179.1	901.6	−21.1
0.2495	0.79668	−0.006	1175.2	908.9	−25.1
0.3001	0.79558	−0.006	1171.2	916.4	−29.0
0.3491	0.79445	−0.005	1167.0	924.3	−32.2
0.3998	0.79318	−0.001	1162.6	932.8	−35.2
0.4502	0.79184	0.004	1157.7	942.3	−37.0
0.5005	0.79040	0.011	1152.2	953.1	−37.6
0.5496	0.78892	0.017	1147.1	963.3	−38.6
0.5997	0.78728	0.028	1141.1	975.5	−37.6
0.6503	0.78550	0.039	1134.9	988.4	−36.2
0.7003	0.78373	0.040	1128.7	1001.6	−34.3
0.8011	0.77967	0.053	1114.6	1032.4	−26.3
0.8495	0.77756	0.053	1107.6	1048.4	−21.2
0.9001	0.77515	0.057	1099.7	1066.8	−14.3
0.9501	0.77264	0.055	1091.5	1086.3	−6.1
1	0.77063	0	1084.3	1103.6	0

(*continued*)

Table 1 (*continued*)

Ethanol + 2-Methyl-1-butanol					
313.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.80330	0	1200.9	863.2	0.0
0.0487	0.80251	−0.004	1195.9	871.2	−2.7
0.1007	0.80160	−0.006	1194.6	874.1	−11.3
0.1517	0.80069	−0.011	1191.1	880.3	−16.4
0.1995	0.79973	−0.007	1187.5	886.8	−20.4
0.2495	0.79866	−0.002	1183.6	893.8	−24.4
0.3001	0.79757	−0.002	1179.5	901.2	−28.1
0.3491	0.79645	−0.002	1175.3	909.0	−31.2
0.3998	0.79518	0.003	1171.0	917.2	−34.2
0.4502	0.79386	0.007	1166.0	926.6	−35.9
0.5005	0.79243	0.015	1160.4	937.1	−36.4
0.5496	0.79096	0.021	1155.4	947.1	−37.3
0.5997	0.78934	0.030	1149.4	959.0	−36.5
0.6503	0.78757	0.042	1143.2	971.6	−35.0
0.7003	0.78580	0.044	1136.9	984.6	−33.0
0.8011	0.78178	0.055	1122.9	1014.5	−25.3
0.8495	0.77971	0.053	1116.0	1029.8	−20.7
0.9001	0.77730	0.059	1108.0	1048.0	−13.7
0.9501	0.77483	0.056	1099.8	1067.0	−5.6
1	0.77285	0	1092.7	1083.7	0
310.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.80525	0	1209.3	849.2	0.0
0.0487	0.80447	−0.004	1204.6	856.7	−3.0
0.1007	0.80356	−0.006	1203.0	860.0	−10.9
0.1517	0.80267	−0.011	1199.6	865.8	−16.0
0.1995	0.80167	−0.003	1195.7	872.4	−19.7
0.2495	0.80064	−0.001	1191.8	879.3	−23.6
0.3001	0.79954	0.001	1187.9	886.4	−27.4
0.3491	0.79843	0.001	1183.5	894.2	−30.1
0.3998	0.79718	0.006	1179.2	902.1	−33.1
0.4502	0.79585	0.012	1174.2	911.3	−34.8
0.5005	0.79446	0.017	1168.8	921.4	−35.4
0.5496	0.79298	0.024	1163.7	931.2	−36.3
0.5997	0.79137	0.033	1157.6	943.0	−35.3
0.6503	0.78960	0.047	1151.5	955.2	−33.9
0.7003	0.78788	0.046	1145.1	967.9	−32.0
0.8011	0.78389	0.056	1131.2	997.0	−24.6
0.8495	0.78183	0.056	1124.2	1012.1	−19.9
0.9001	0.77945	0.061	1116.3	1029.6	−13.2
0.9501	0.77701	0.056	1108.2	1048.0	−5.6
1	0.77505	0	1101.0	1064.4	0
308.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.80717	0	1217.7	835.5	0.0
0.0487	0.80639	−0.004	1213.2	842.5	−3.3
0.1007	0.80549	−0.004	1211.3	846.1	−10.6
0.1517	0.80458	−0.007	1207.8	851.9	−15.4

(*continued*)

Table 1 (*continued*)

Ethanol + 2-Methyl-1-butanol					
308.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0.1995	0.80363	−0.002	1204.2	858.2	−19.2
0.2495	0.80259	0.001	1200.2	865.0	−22.9
0.3001	0.80149	0.003	1196.1	872.1	−26.4
0.3491	0.80039	0.004	1191.9	879.5	−29.3
0.3998	0.79914	0.010	1187.6	887.2	−32.2
0.4502	0.79783	0.014	1182.6	896.3	−33.7
0.5005	0.79644	0.020	1177.1	906.2	−34.3
0.5496	0.79498	0.027	1172.1	915.6	−35.2
0.5997	0.79339	0.035	1166.0	927.1	−34.3
0.6503	0.79163	0.049	1159.8	939.1	−32.9
0.7003	0.78991	0.049	1153.4	951.6	−30.9
0.8011	0.78598	0.058	1139.5	979.8	−23.8
0.8495	0.78393	0.058	1132.5	994.6	−19.2
0.9001	0.78157	0.062	1124.6	1011.6	−12.8
0.9501	0.77918	0.055	1116.6	1029.4	−5.5
1	0.77724	0	1109.4	1045.4	0
305.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.80907	0	1226.1	822.2	0.0
0.0487	0.80829	−0.003	1221.8	828.8	−3.3
0.1007	0.80740	−0.003	1219.7	832.5	−10.2
0.1517	0.80650	−0.006	1216.2	838.3	−14.9
0.1995	0.80555	−0.002	1212.5	844.4	−18.6
0.2495	0.80451	0.003	1208.5	851.1	−22.2
0.3001	0.80342	0.006	1204.5	858.0	−25.6
0.3491	0.80232	0.007	1200.2	865.3	−28.4
0.3998	0.80108	0.014	1195.9	872.9	−31.1
0.4502	0.79979	0.017	1190.9	881.6	−32.7
0.5005	0.79842	0.022	1185.4	891.3	−33.3
0.5496	0.79695	0.031	1180.4	900.6	−34.1
0.5997	0.79539	0.038	1174.3	911.7	−33.2
0.6503	0.79363	0.053	1168.1	923.5	−31.8
0.7003	0.79194	0.051	1161.7	935.6	−30.0
0.8011	0.78804	0.059	1147.9	963.0	−23.1
0.8495	0.78600	0.060	1140.8	977.5	−18.6
0.9001	0.78366	0.064	1133.0	994.1	−12.3
0.9501	0.78131	0.056	1124.9	1011.4	−5.3
1	0.77940	0	1117.8	1026.9	0
303.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.81100	0	1234.6	809.0	0.0
0.0487	0.81023	−0.003	1230.4	815.3	−3.5
0.1007	0.80933	−0.002	1228.2	819.1	−10.0
0.1517	0.80843	−0.004	1224.6	824.8	−14.5
0.1995	0.80750	−0.001	1221.0	830.7	−18.1
0.2495	0.80646	0.005	1216.9	837.3	−21.5
0.3001	0.80538	0.009	1212.9	844.1	−24.9
0.3491	0.80429	0.010	1208.6	851.2	−27.5
0.3998	0.80304	0.017	1204.3	858.7	−30.2
0.4502	0.80178	0.019	1199.3	867.2	−31.7

(*continued*)

Table 1 (*continued*)

Ethanol + 2-Methyl-1-butanol					
303.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0.5005	0.80041	0.024	1193.8	876.7	−32.2
0.5496	0.79895	0.034	1188.7	885.7	−33.0
0.5997	0.79741	0.040	1182.7	896.6	−32.2
0.6503	0.79566	0.055	1176.4	908.1	−30.8
0.7003	0.79399	0.053	1170.1	919.8	−29.0
0.8011	0.79013	0.060	1156.3	946.7	−22.3
0.8495	0.78811	0.061	1149.3	960.7	−18.0
0.9001	0.78580	0.064	1141.4	976.8	−11.9
0.9501	0.78348	0.056	1133.3	993.7	−5.1
1	0.78159	0	1126.2	1008.7	0
300.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.81289	0	1243.0	796.3	0.0
0.0487	0.81211	−0.001	1239.0	802.1	−3.6
0.1007	0.81122	0.000	1236.6	806.2	−9.7
0.1517	0.81032	−0.001	1233.0	811.8	−14.0
0.1995	0.80940	0.002	1229.3	817.6	−17.5
0.2495	0.80837	0.008	1225.3	824.0	−20.9
0.3001	0.80728	0.013	1221.2	830.7	−24.1
0.3491	0.80621	0.013	1216.9	837.6	−26.7
0.3998	0.80497	0.020	1212.5	845.0	−29.2
0.4502	0.80373	0.021	1207.6	853.3	−30.7
0.5005	0.80237	0.027	1202.1	862.5	−31.3
0.5496	0.80092	0.036	1197.0	871.4	−32.0
0.5997	0.79940	0.041	1191.0	881.9	−31.2
0.6503	0.79765	0.057	1184.8	893.2	−29.8
0.7003	0.79602	0.053	1178.5	904.5	−28.2
0.8011	0.79219	0.061	1164.6	930.7	−21.7
0.8495	0.79018	0.062	1157.6	944.4	−17.4
0.9001	0.78788	0.065	1149.8	960.1	−11.5
0.9501	0.78560	0.055	1141.7	976.5	−4.9
1	0.78373	0	1134.6	991.1	0
298.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.81478	0	1251.4	783.7	0.0
0.0487	0.81400	0.000	1247.7	789.1	−3.9
0.1007	0.81311	0.002	1245.0	793.5	−9.4
0.1517	0.81222	0.002	1241.4	798.9	−13.6
0.1995	0.81131	0.005	1237.6	804.7	−17.0
0.2495	0.81028	0.011	1233.6	811.0	−20.2
0.3001	0.80920	0.016	1229.6	817.4	−23.4
0.3491	0.80814	0.015	1225.3	824.2	−25.9
0.3998	0.80692	0.022	1221.0	831.3	−28.4
0.4502	0.80568	0.023	1215.9	839.5	−29.8
0.5005	0.80434	0.029	1210.5	848.5	−30.3
0.5496	0.80289	0.040	1205.4	857.2	−31.0
0.5997	0.80139	0.044	1199.4	867.5	−30.2
0.6503	0.79965	0.060	1193.1	878.4	−28.9

(*continued*)

Table 1 (*continued*)

Ethanol + 2-Methyl-1-butanol					
298.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0.7003	0.79803	0.056	1186.9	889.6	−27.3
0.8011	0.79424	0.063	1173.0	915.0	−20.9
0.8495	0.79225	0.063	1166.0	928.3	−16.8
0.9001	0.78998	0.066	1158.2	943.6	−11.2
0.9501	0.78774	0.055	1150.2	959.5	−4.8
1	0.78589	0	1143.1	973.8	0
295.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.81664	0	1260.0	771.4	0.0
0.0487	0.81587	0.000	1256.5	776.3	−4.1
0.1007	0.81498	0.003	1253.5	780.9	−9.1
0.1517	0.81409	0.003	1249.9	786.3	−13.2
0.1995	0.81320	0.005	1246.2	791.8	−16.5
0.2495	0.81217	0.012	1242.2	798.0	−19.7
0.3001	0.81109	0.018	1238.1	804.3	−22.7
0.3491	0.81005	0.017	1233.8	811.0	−25.1
0.3998	0.80883	0.024	1229.4	818.0	−27.5
0.4502	0.80761	0.025	1224.4	825.9	−28.9
0.5005	0.80628	0.031	1218.9	834.7	−29.4
0.5496	0.80483	0.042	1213.9	843.2	−30.1
0.5997	0.80336	0.045	1207.8	853.2	−29.3
0.6503	0.80162	0.063	1201.6	863.9	−28.0
0.7003	0.80004	0.056	1195.3	874.8	−26.4
0.8011	0.79628	0.064	1181.5	899.6	−20.3
0.8495	0.79431	0.064	1174.6	912.5	−16.4
0.9001	0.79205	0.067	1166.7	927.5	−10.8
0.9501	0.78985	0.054	1158.8	942.9	−4.7
1	0.78803	0	1151.6	956.8	0
293.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.81851	0	1268.8	759.0	0.0
0.0487	0.81773	0.002	1265.5	763.6	−4.2
0.1007	0.81686	0.004	1262.2	768.4	−8.8
0.1517	0.81597	0.005	1258.7	773.6	−12.8
0.1995	0.81509	0.006	1254.9	779.1	−15.9
0.2495	0.81407	0.014	1250.8	785.1	−19.0
0.3001	0.81299	0.020	1246.8	791.3	−22.0
0.3491	0.81195	0.020	1242.5	797.8	−24.3
0.3998	0.81075	0.027	1238.0	804.8	−26.6
0.4502	0.80954	0.027	1233.1	812.5	−28.0
0.5005	0.80822	0.033	1227.6	821.0	−28.6
0.5496	0.80679	0.044	1222.6	829.3	−29.2
0.5997	0.80534	0.046	1216.5	839.1	−28.4
0.6503	0.80361	0.064	1210.3	849.5	−27.2
0.7003	0.80205	0.057	1204.0	860.1	−25.7
0.8011	0.79832	0.065	1190.2	884.2	−19.7
0.8495	0.79636	0.065	1183.3	896.9	−15.9

(*continued*)

Table 1 (*continued*)

Ethanol + 2-Methyl-1-butanol					
293.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0.9001	0.79414	0.067	1175.5	911.4	−10.5
0.9501	0.79196	0.054	1167.5	926.4	−4.6
1	0.79016	0	1160.3	940.0	0
290.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.82035	0	1277.5	746.9	0.0
0.0487	0.81958	0.002	1274.3	751.3	−4.1
0.1007	0.81871	0.005	1271.0	756.1	−8.5
0.1517	0.81783	0.006	1267.4	761.3	−12.4
0.1995	0.81696	0.007	1263.6	766.6	−15.5
0.2495	0.81593	0.017	1259.6	772.5	−18.5
0.3001	0.81489	0.021	1255.5	778.5	−21.3
0.3491	0.81385	0.022	1251.1	785.0	−23.5
0.3998	0.81265	0.029	1246.7	791.8	−25.7
0.4502	0.81147	0.029	1241.7	799.2	−27.1
0.5005	0.81016	0.033	1236.4	807.4	−27.8
0.5496	0.80873	0.046	1231.2	815.7	−28.3
0.5997	0.80729	0.048	1225.2	825.2	−27.5
0.6503	0.80558	0.066	1219.0	835.4	−26.3
0.7003	0.80404	0.059	1212.8	845.6	−24.9
0.8011	0.80035	0.066	1199.0	869.1	−19.1
0.8495	0.79843	0.065	1192.0	881.4	−15.4
0.9001	0.79621	0.069	1184.2	895.7	−10.1
0.9501	0.79407	0.054	1176.3	910.1	−4.5
1	0.79231	0	1169.1	923.4	0
288.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.82214	0	1286.3	735.1	0.0
0.0487	0.82137	0.004	1283.2	739.4	−4.0
0.1007	0.82050	0.007	1279.7	744.2	−8.2
0.1517	0.81962	0.009	1276.2	749.2	−12.0
0.1995	0.81878	0.009	1272.5	754.3	−15.1
0.2495	0.81776	0.019	1268.3	760.2	−17.8
0.3001	0.81670	0.027	1264.2	766.1	−20.5
0.3491	0.81567	0.027	1259.9	772.3	−22.7
0.3998	0.81449	0.034	1255.4	779.1	−24.7
0.4502	0.81331	0.035	1250.4	786.4	−26.0
0.5005	0.81202	0.040	1245.0	794.5	−26.5
0.5496	0.81060	0.052	1239.9	802.4	−27.1
0.5997	0.80919	0.054	1233.9	811.7	−26.4
0.6503	0.80747	0.073	1227.7	821.6	−25.1
0.7003	0.80595	0.066	1221.5	831.6	−23.8
0.8011	0.80231	0.072	1207.7	854.5	−18.1
0.8495	0.80040	0.071	1200.7	866.5	−14.4
0.9001	0.79821	0.075	1193.0	880.2	−9.4
0.9501	0.79611	0.060	1185.1	894.4	−3.8
1	0.79444	0	1178.2	906.8	0

(*continued*)

Table 1 (*continued*)

Ethanol + 3-Methyl-1-butanol					
323.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.78731	0	1149.1	962.0	0.0
0.0510	0.78656	0.002	1146.0	968.0	−4.5
0.0988	0.78597	0.005	1143.7	972.7	−9.6
0.1992	0.78442	0.018	1137.5	985.3	−17.6
0.3003	0.78275	0.023	1130.7	999.3	−24.4
0.3997	0.78089	0.031	1123.3	1014.8	−29.3
0.4998	0.77886	0.034	1115.1	1032.5	−32.1
0.5998	0.77648	0.045	1105.8	1053.2	−32.0
0.7004	0.77379	0.053	1095.5	1076.8	−29.1
0.8002	0.77078	0.056	1084.1	1104.0	−22.4
0.8998	0.76734	0.057	1071.3	1135.5	−11.4
0.9500	0.76538	0.058	1064.4	1153.2	−4.0
1.0000	0.76402	0	1058.8	1167.5	0.0
320.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.78918	0	1157.4	945.9	0.0
0.0510	0.78843	0.003	1154.5	951.5	−4.5
0.0988	0.78784	0.008	1152.1	956.3	−9.3
0.1992	0.78631	0.020	1145.9	968.5	−17.1
0.3003	0.78467	0.024	1139.2	982.1	−23.7
0.3997	0.78282	0.034	1131.7	997.4	−28.3
0.4998	0.78083	0.035	1123.7	1014.3	−31.3
0.5998	0.77846	0.047	1114.3	1034.6	−31.0
0.7004	0.77581	0.055	1103.9	1057.8	−27.9
0.8002	0.77282	0.060	1092.4	1084.3	−21.2
0.8998	0.76945	0.058	1079.8	1114.6	−10.8
0.9500	0.76751	0.060	1072.9	1131.9	−3.6
1.0000	0.76620	0	1067.5	1145.4	0.0
318.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.79116	0	1165.8	930.0	0.0
0.0510	0.79042	0.004	1162.8	935.6	−4.3
0.0988	0.78984	0.008	1160.5	940.1	−9.1
0.1992	0.78832	0.021	1154.2	952.2	−16.5
0.3003	0.78670	0.026	1147.5	965.4	−22.9
0.3997	0.78487	0.035	1140.1	980.3	−27.3
0.4998	0.78289	0.038	1131.9	997.0	−30.0
0.5998	0.78056	0.049	1122.6	1016.7	−29.8
0.7004	0.77794	0.056	1112.2	1039.1	−26.9
0.8002	0.77500	0.060	1100.8	1064.8	−20.6
0.8998	0.77167	0.059	1088.2	1094.3	−10.4
0.9500	0.76976	0.060	1081.2	1111.2	−3.2
1.0000	0.76848	0	1075.9	1124.1	0.0
315.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.79300	0	1174.3	914.5	0.0
0.0510	0.79227	0.004	1171.4	919.9	−4.2

(*continued*)

Table 1 (*continued*)

Ethanol + 3-Methyl-1-butanol					
315.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0.0988	0.79169	0.009	1168.8	924.6	−8.6
0.1992	0.79019	0.023	1162.6	936.2	−15.9
0.3003	0.78858	0.027	1155.8	949.2	−22.1
0.3997	0.78679	0.036	1148.5	963.6	−26.5
0.4998	0.78482	0.039	1140.2	980.0	−29.0
0.5998	0.78251	0.051	1130.9	999.2	−28.8
0.7004	0.77994	0.057	1120.6	1021.1	−25.9
0.8002	0.77704	0.061	1109.2	1046.0	−19.9
0.8998	0.77376	0.059	1096.6	1074.7	−10.0
0.9500	0.77187	0.060	1089.6	1091.2	−3.0
1.0000	0.77063	0	1084.3	1103.6	0.0
313.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\delta\kappa_S$/T Pa^{-1}
0	0.79494	0	1182.5	899.7	0.0
0.0510	0.79421	0.004	1179.6	904.9	−4.1
0.0988	0.79364	0.009	1177.1	909.4	−8.4
0.1992	0.79214	0.024	1170.8	920.9	−15.4
0.3003	0.79056	0.028	1164.1	933.4	−21.5
0.3997	0.78879	0.037	1156.7	947.6	−25.6
0.4998	0.78682	0.043	1148.5	963.6	−28.0
0.5998	0.78456	0.053	1139.2	982.2	−27.8
0.7004	0.78202	0.059	1128.8	1003.5	−25.0
0.8002	0.77916	0.062	1117.5	1027.7	−19.2
0.8998	0.77592	0.059	1105.0	1055.6	−9.7
0.9500	0.77407	0.060	1098.0	1071.6	−2.9
1.0000	0.77285	0	1092.7	1083.7	0.0
310.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\delta\kappa_S$/T Pa^{-1}
0	0.79687	0	1190.7	882.0	0.0
0.0510	0.79612	0.008	1187.7	887.3	−3.8
0.0988	0.79557	0.012	1185.3	891.5	−8.1
0.1992	0.79409	0.026	1179.1	902.6	−14.9
0.3003	0.79252	0.031	1172.3	914.9	−20.7
0.3997	0.79076	0.041	1164.9	928.7	−24.7
0.4998	0.78881	0.047	1156.7	944.2	−27.0
0.5998	0.78660	0.054	1147.5	962.1	−27.0
0.7004	0.78409	0.060	1137.1	982.9	−24.2
0.8002	0.78127	0.063	1125.7	1006.4	−18.5
0.8998	0.77808	0.060	1113.2	1033.4	−9.3
0.9500	0.77624	0.061	1106.2	1049.0	−2.7
1.0000	0.77505	0	1101.0	1060.6	0.0
308.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.79877	0	1199.1	870.7	0.0
0.0510	0.79802	0.008	1196.1	875.9	−3.7

(*continued*)

Table 1 (*continued*)

Ethanol + 3-Methyl-1-butanol					
308.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0.0988	0.79748	0.012	1193.6	880.1	−7.9
0.1992	0.79602	0.026	1187.4	891.0	−14.5
0.3003	0.79446	0.032	1180.6	903.0	−20.2
0.3997	0.79273	0.041	1173.2	916.5	−24.1
0.4998	0.79080	0.048	1165.0	931.7	−26.3
0.5998	0.78862	0.055	1155.7	949.3	−26.1
0.7004	0.78614	0.061	1145.4	969.6	−23.4
0.8002	0.78336	0.063	1134.1	992.5	−17.9
0.8998	0.78021	0.060	1121.6	1018.9	−8.9
0.9500	0.77840	0.060	1114.6	1034.1	−2.6
1.0000	0.77724	0	1109.4	1045.4	0.0
305.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.80066	0	1207.4	856.8	0.0
0.0510	0.79991	0.010	1204.4	861.8	−3.6
0.0988	0.79938	0.013	1201.9	866.0	−7.7
0.1992	0.79793	0.027	1195.7	876.6	−14.0
0.3003	0.79639	0.034	1188.9	888.4	−19.5
0.3997	0.79467	0.044	1181.4	901.6	−23.2
0.4998	0.79275	0.052	1173.3	916.3	−25.5
0.5998	0.79062	0.056	1164.0	933.5	−25.3
0.7004	0.78816	0.062	1153.7	953.3	−22.7
0.8002	0.78542	0.064	1142.4	975.6	−17.3
0.8998	0.78232	0.060	1129.9	1001.2	−8.7
0.9500	0.78053	0.060	1122.9	1016.0	−2.4
1.0000	0.77940	0	1117.8	1026.9	0.0
303.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\delta\kappa_S$/T Pa^{-1}
0	0.80256	0	1215.8	843.0	0.0
0.0510	0.80182	0.010	1212.7	848.0	−3.4
0.0988	0.80129	0.014	1210.3	852.0	−7.4
0.1992	0.79987	0.028	1204.0	862.4	−13.6
0.3003	0.79834	0.035	1197.3	873.9	−18.9
0.3997	0.79664	0.045	1189.8	886.8	−22.5
0.4998	0.79473	0.055	1181.6	901.2	−24.6
0.5998	0.79264	0.058	1172.4	917.9	−24.5
0.7004	0.79020	0.065	1162.0	937.2	−21.8
0.8002	0.78751	0.065	1150.8	958.9	−16.7
0.8998	0.78444	0.061	1138.3	983.8	−8.3
0.9500	0.78270	0.060	1131.4	998.2	−2.3
1.0000	0.78159	0	1126.2	1008.7	0.0
300.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\delta\kappa_S$/T Pa^{-1}
0	0.80443	0	1224.1	829.6	0.0
0.0510	0.80369	0.011	1221.1	834.5	−3.4
0.0988	0.80315	0.017	1218.6	838.5	−7.1

(*continued*)

Table 1 (*continued*)

Ethanol + 3-Methyl-1-butanol					
300.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\delta\kappa_S$/T Pa^{-1}
0.1992	0.80175	0.030	1212.3	848.7	−13.1
0.3003	0.80024	0.038	1205.5	859.9	−18.3
0.3997	0.79857	0.046	1198.1	872.4	−21.8
0.4998	0.79667	0.056	1189.9	886.5	−23.9
0.5998	0.79461	0.059	1180.7	902.8	−23.7
0.7004	0.79221	0.065	1170.4	921.6	−21.2
0.8002	0.78956	0.065	1159.1	942.7	−16.2
0.8998	0.78654	0.061	1146.7	967.0	−8.0
0.9500	0.78482	0.059	1139.7	980.9	−2.2
1.0000	0.78373	0	1134.6	991.1	0.0
298.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.80631	0	1232.5	816.5	0.0
0.0510	0.80557	0.012	1229.5	821.2	−3.3
0.0988	0.80504	0.018	1227.0	825.1	−6.9
0.1992	0.80365	0.032	1220.7	835.1	−12.7
0.3003	0.80216	0.039	1213.9	846.0	−17.7
0.3997	0.80051	0.047	1206.4	858.3	−21.1
0.4998	0.79863	0.058	1198.3	872.0	−23.1
0.5998	0.79660	0.060	1189.1	887.9	−22.9
0.7004	0.79424	0.066	1178.8	906.1	−20.5
0.8002	0.79162	0.066	1167.5	926.7	−15.6
0.8998	0.78865	0.060	1155.1	950.3	−7.7
0.9500	0.78695	0.059	1148.2	963.9	−2.0
1.0000	0.78589	0	1143.1	973.8	0.0
295.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.80816	0	1241.0	803.5	0.0
0.0510	0.80743	0.012	1238.0	808.1	−3.2
0.0988	0.80690	0.018	1235.5	811.9	−6.7
0.1992	0.80553	0.032	1229.2	821.7	−12.3
0.3003	0.80406	0.039	1222.4	832.3	−17.2
0.3997	0.80243	0.049	1214.9	844.4	−20.4
0.4998	0.80057	0.060	1206.8	857.7	−22.4
0.5998	0.79858	0.061	1197.6	873.2	−22.3
0.7004	0.79624	0.067	1187.3	891.0	−19.9
0.8002	0.79366	0.066	1176.0	911.0	−15.1
0.8998	0.79073	0.061	1163.7	933.9	−7.5
0.9500	0.78906	0.060	1156.7	947.2	−2.0
1.0000	0.78803	0	1151.6	956.8	0.0
293.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.81003	0	1249.8	790.4	0.0
0.0510	0.80929	0.013	1246.6	795.1	−2.9
0.0988	0.80878	0.019	1244.2	798.7	−6.5
0.1992	0.80742	0.033	1237.9	808.2	−12.0

(*continued*)

Table 1 (*continued*)

Ethanol + 3-Methyl-1-butanol					
293.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0.3003	0.80596	0.042	1231.0	818.8	−16.5
0.3997	0.80435	0.050	1223.6	830.4	−19.8
0.4998	0.80251	0.061	1215.4	843.5	−21.6
0.5998	0.80054	0.062	1206.2	858.6	−21.5
0.7004	0.79823	0.068	1195.9	875.9	−19.2
0.8002	0.79569	0.067	1184.8	895.4	−14.7
0.8998	0.79282	0.061	1172.4	917.6	−7.4
0.9500	0.79117	0.059	1165.6	930.4	−2.1
1.0000	0.79016	0	1160.3	940.0	0.0
290.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.81188	0	1258.5	777.7	0.0
0.0510	0.81114	0.015	1255.5	782.1	−3.0
0.0988	0.81063	0.021	1252.9	785.8	−6.3
0.1992	0.80928	0.036	1246.6	795.2	−11.5
0.3003	0.80784	0.044	1239.8	805.4	−16.1
0.3997	0.80625	0.053	1232.3	816.8	−19.1
0.4998	0.80444	0.064	1224.1	829.6	−20.9
0.5998	0.80251	0.064	1215.0	844.2	−20.9
0.7004	0.80021	0.072	1204.6	861.3	−18.5
0.8002	0.79772	0.069	1193.4	880.2	−14.1
0.8998	0.79489	0.063	1181.2	901.7	−7.1
0.9500	0.79327	0.060	1174.3	914.1	−2.0
1.0000	0.79231	0	1169.1	923.4	0.0
288.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.81367	0	1267.1	765.5	0.0
0.0510	0.81296	0.011	1264.2	769.7	−3.0
0.0988	0.81242	0.023	1261.6	773.4	−6.0
0.1992	0.81110	0.037	1255.1	782.6	−11.0
0.3003	0.80968	0.046	1248.4	792.4	−15.5
0.3997	0.80810	0.056	1240.9	803.7	−18.3
0.4998	0.80638	0.061	1233.1	815.6	−20.5
0.5998	0.80439	0.070	1223.4	830.6	−19.7
0.7004	0.80216	0.074	1213.3	846.9	−17.6
0.8002	0.79968	0.074	1202.2	865.3	−13.3
0.8998	0.79690	0.067	1189.8	886.5	−6.1
0.9500	0.79530	0.065	1183.0	898.5	−1.2
1.0000	0.79444	0	1178.2	906.8	0.0
Ethanol + 1-Pentanol					
323.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.79225	0	1190.1	891.2	0.0
0.0536	0.79127	0.024	1184.8	900.3	−5.7

(*continued*)

Table 1 (*continued*)

Ethanol + 1-Pentanol					
323.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0.1039	0.79046	0.026	1179.4	909.5	−10.4
0.2080	0.78865	0.028	1172.7	922.1	−26.6
0.3101	0.78661	0.037	1163.1	939.8	−37.1
0.4103	0.78439	0.043	1152.4	960.0	−44.6
0.5116	0.78188	0.046	1140.5	983.3	−49.3
0.6108	0.77900	0.052	1127.5	1009.8	−50.1
0.7091	0.77582	0.065	1112.9	1040.6	−46.5
0.8071	0.77218	0.065	1096.4	1077.2	−36.9
0.9037	0.76807	0.062	1080.1	1116.0	−24.9
0.9515	0.76578	0.060	1071.9	1136.5	−17.6
1	0.76402	0	1058.8	1167.5	0.0
320.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.79407	0	1198.5	876.7	0.0
0.0536	0.79311	0.023	1193.4	885.4	−5.7
0.1039	0.79230	0.025	1187.9	894.5	−10.1
0.2080	0.79051	0.028	1181.2	906.6	−25.9
0.3101	0.78849	0.037	1171.4	924.2	−35.8
0.4103	0.78629	0.044	1160.9	943.7	−43.2
0.5116	0.78382	0.047	1149.0	966.4	−47.7
0.6108	0.78097	0.053	1135.9	992.4	−48.4
0.7091	0.77782	0.067	1121.3	1022.6	−44.6
0.8071	0.77423	0.067	1104.9	1058.0	−35.6
0.9037	0.77017	0.064	1088.6	1095.7	−23.8
0.9515	0.76791	0.062	1080.5	1115.5	−16.9
1	0.76620	0	1067.5	1145.4	0.0
318.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.79604	0	1206.8	862.5	0.0
0.0536	0.79506	0.025	1201.7	871.0	−5.6
0.1039	0.79427	0.027	1196.2	879.8	−9.9
0.2080	0.79251	0.029	1189.5	891.8	−25.2
0.3101	0.79051	0.038	1179.8	908.8	−34.9
0.4103	0.78832	0.047	1169.2	928.0	−41.9
0.5116	0.78588	0.050	1157.3	950.1	−46.3
0.6108	0.78306	0.054	1144.3	975.3	−47.0
0.7091	0.77995	0.068	1129.7	1004.7	−43.3
0.8071	0.77640	0.068	1113.3	1039.2	−34.5
0.9037	0.77239	0.064	1097.0	1075.8	−23.1
0.9515	0.77016	0.061	1088.9	1095.0	−16.4
1	0.76848	0	1075.9	1124.1	0.0
315.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.79785	0	1215.2	848.7	0.0
0.0536	0.79688	0.026	1210.1	857.0	−5.4

(*continued*)

Table 1 (*continued*)

Ethanol + 1-Pentanol					
315.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0.1039	0.79610	0.027	1204.7	865.6	−9.6
0.2080	0.79435	0.030	1197.9	877.3	−24.5
0.3101	0.79237	0.040	1188.1	894.0	−33.8
0.4103	0.79021	0.049	1177.5	912.6	−40.7
0.5116	0.78779	0.051	1165.6	934.2	−44.9
0.6108	0.78501	0.056	1152.6	958.8	−45.6
0.7091	0.78194	0.069	1138.0	987.5	−42.0
0.8071	0.77842	0.070	1121.7	1021.0	−33.4
0.9037	0.77446	0.065	1105.5	1056.6	−22.5
0.9515	0.77226	0.062	1097.3	1075.4	−15.9
1	0.77063	0	1084.3	1103.6	0.0
313.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.79974	0	1223.4	835.4	0.0
0.0536	0.79879	0.025	1218.4	843.3	−5.4
0.1039	0.79802	0.026	1212.9	851.7	−9.5
0.2080	0.79629	0.030	1206.1	863.3	−23.8
0.3101	0.79433	0.040	1196.3	879.6	−32.8
0.4103	0.79218	0.049	1185.8	897.8	−39.5
0.5116	0.78979	0.052	1173.9	918.9	−43.6
0.6108	0.78705	0.056	1161.0	942.7	−44.4
0.7091	0.78401	0.069	1146.3	970.7	−40.8
0.8071	0.78053	0.070	1130.0	1003.4	−32.4
0.9037	0.77663	0.065	1113.8	1038.0	−21.8
0.9515	0.77445	0.062	1105.8	1056.0	−15.6
1	0.77285	0	1092.7	1083.7	0.0
310.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.80164	0	1231.7	822.3	0.0
0.0536	0.80068	0.026	1226.6	830.1	−5.2
0.1039	0.79991	0.029	1221.3	838.2	−9.3
0.2080	0.79819	0.033	1214.3	849.6	−23.0
0.3101	0.79627	0.042	1204.6	865.5	−31.9
0.4103	0.79415	0.050	1194.0	883.3	−38.3
0.5116	0.79179	0.053	1182.1	903.9	−42.3
0.6108	0.78906	0.058	1169.2	927.0	−43.1
0.7091	0.78607	0.070	1154.6	954.3	−39.6
0.8071	0.78263	0.071	1138.3	986.1	−31.5
0.9037	0.77877	0.066	1122.0	1020.0	−21.1
0.9515	0.77663	0.062	1114.1	1037.5	−15.2
1	0.77505	0	1101.0	1064.4	0.0
308.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.80352	0	1240.0	809.4	0.0
0.0536	0.80256	0.028	1235.0	816.9	−5.1

(*continued*)

Table 1 (*continued*)

Ethanol + 1-Pentanol					
308.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0.1039	0.80180	0.030	1229.8	824.7	−9.2
0.2080	0.80010	0.034	1222.7	836.1	−22.4
0.3101	0.79819	0.044	1212.9	851.7	−30.9
0.4103	0.79609	0.052	1202.3	869.0	−37.2
0.5116	0.79378	0.053	1190.4	889.0	−41.1
0.6108	0.79105	0.060	1177.5	911.8	−41.7
0.7091	0.78811	0.071	1162.9	938.3	−38.4
0.8071	0.78469	0.073	1146.6	969.4	−30.4
0.9037	0.78090	0.066	1130.4	1002.2	−20.5
0.9515	0.77878	0.062	1122.5	1019.1	−14.8
1	0.77724	0	1109.4	1045.4	0.0
305.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.80537	0	1248.3	796.8	0.0
0.0536	0.80441	0.029	1243.3	804.2	−5.0
0.1039	0.80366	0.031	1238.1	811.8	−9.0
0.2080	0.80198	0.035	1230.9	823.0	−21.7
0.3101	0.80010	0.043	1221.2	838.1	−30.1
0.4103	0.79803	0.052	1210.6	855.0	−36.2
0.5116	0.79572	0.054	1198.7	874.6	−39.9
0.6108	0.79303	0.062	1185.8	896.8	−40.5
0.7091	0.79013	0.071	1171.2	922.7	−37.3
0.8071	0.78674	0.074	1154.9	953.0	−29.6
0.9037	0.78299	0.067	1138.7	984.9	−19.8
0.9515	0.78092	0.062	1130.8	1001.4	−14.4
1	0.77940	0	1117.8	1026.9	0.0
303.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.80723	0	1256.6	784.5	0.0
0.0536	0.80629	0.028	1251.8	791.5	−5.0
0.1039	0.80554	0.031	1246.5	799.0	−8.8
0.2080	0.80389	0.035	1239.2	810.0	−21.1
0.3101	0.80202	0.044	1229.5	824.8	−29.2
0.4103	0.79998	0.052	1218.9	841.3	−35.2
0.5116	0.79768	0.056	1207.0	860.5	−38.7
0.6108	0.79502	0.064	1194.1	882.1	−39.3
0.7091	0.79217	0.072	1179.5	907.3	−36.2
0.8071	0.78881	0.075	1163.2	936.9	−28.6
0.9037	0.78513	0.067	1147.2	967.8	−19.3
0.9515	0.78308	0.061	1139.3	983.8	−14.0
1	0.78159	0	1126.2	1008.7	0.0
300.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.80907	0	1264.9	772.5	0.0
0.0536	0.80814	0.027	1260.2	779.2	−5.0

(*continued*)

Table 1 (*continued*)

Ethanol + 1-Pentanol					
300.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0.1039	0.80740	0.030	1254.8	786.6	−8.6
0.2080	0.80576	0.034	1247.5	797.4	−20.5
0.3101	0.80391	0.044	1237.8	811.8	−28.5
0.4103	0.80188	0.053	1227.2	828.1	−34.1
0.5116	0.79963	0.056	1215.3	846.7	−37.6
0.6108	0.79698	0.065	1202.4	867.9	−38.1
0.7091	0.79417	0.072	1187.8	892.4	−35.1
0.8071	0.79086	0.075	1171.6	921.1	−27.8
0.9037	0.78722	0.066	1155.4	951.5	−18.6
0.9515	0.78521	0.060	1147.7	966.9	−13.7
1	0.78373	0	1134.6	991.1	0.0
298.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.81091	0	1273.3	760.6	0.0
0.0536	0.81000	0.026	1268.6	767.1	−5.0
0.1039	0.80928	0.028	1263.3	774.2	−8.5
0.2080	0.80764	0.034	1255.9	785.0	−19.9
0.3101	0.80582	0.044	1246.2	799.1	−27.7
0.4103	0.80380	0.054	1235.6	814.9	−33.1
0.5116	0.80157	0.057	1223.7	833.2	−36.5
0.6108	0.79896	0.065	1210.8	853.8	−37.0
0.7091	0.79618	0.072	1196.2	877.8	−34.0
0.8071	0.79290	0.076	1180.0	905.8	−26.9
0.9037	0.78933	0.066	1163.8	935.4	−17.9
0.9515	0.78735	0.059	1156.1	950.3	−13.1
1	0.78589	0	1143.1	973.8	0.0
295.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.81273	0	1281.8	748.9	0.0
0.0536	0.81182	0.028	1277.3	755.1	−5.0
0.1039	0.81112	0.028	1272.0	762.0	−8.5
0.2080	0.80949	0.036	1264.4	772.7	−19.4
0.3101	0.80769	0.046	1254.6	786.5	−26.8
0.4103	0.80569	0.056	1244.0	802.0	−32.2
0.5116	0.80349	0.059	1232.2	819.7	−35.5
0.6108	0.80090	0.067	1219.2	839.9	−35.9
0.7091	0.79817	0.073	1204.7	863.2	−33.1
0.8071	0.79493	0.077	1188.5	890.6	−26.1
0.9037	0.79139	0.067	1172.2	919.5	−17.2
0.9515	0.78945	0.059	1164.6	934.0	−12.7
1	0.78803	0	1151.6	956.8	0.0
293.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.81456	0	1290.4	737.3	0.0
0.0536	0.81364	0.029	1286.0	743.1	−5.0

(*continued*)

Table 1 (*continued*)

Ethanol + 1-Pentanol					
293.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0.1039	0.81294	0.030	1280.7	750.0	−8.4
0.2080	0.81136	0.035	1273.2	760.3	−19.1
0.3101	0.80956	0.046	1263.4	773.9	−26.2
0.4103	0.80759	0.057	1252.7	789.1	−31.4
0.5116	0.80542	0.059	1240.9	806.3	−34.6
0.6108	0.80285	0.068	1227.9	826.2	−34.9
0.7091	0.80017	0.072	1213.4	848.8	−32.2
0.8071	0.79695	0.078	1197.1	875.6	−25.3
0.9037	0.79346	0.067	1180.9	903.8	−16.6
0.9515	0.79155	0.059	1173.2	917.8	−12.3
1	0.79016	0	1160.3	940.0	0.0
290.65 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.81637	0	1299.1	725.8	0.0
0.0536	0.81548	0.027	1294.8	731.5	−4.9
0.1039	0.81478	0.029	1289.7	737.9	−8.4
0.2080	0.81319	0.037	1281.9	748.4	−18.5
0.3101	0.81143	0.047	1272.1	761.6	−25.4
0.4103	0.80948	0.058	1261.5	776.3	−30.5
0.5116	0.80732	0.062	1249.5	793.4	−33.5
0.6108	0.80481	0.068	1236.6	812.6	−33.9
0.7091	0.80215	0.074	1222.1	834.7	−31.2
0.8071	0.79897	0.079	1205.8	860.8	−24.5
0.9037	0.79552	0.069	1189.3	888.7	−15.7
0.9515	0.79364	0.061	1181.9	902.1	−11.7
1	0.79231	0	1169.1	923.4	0.0
288.15 K					
x_1	ρ/g cm^{-3}	V^E/cm^3 mol^{-1}	u/m s^{-1}	κ_S/T Pa^{-1}	$\kappa_S{}^E$/T Pa^{-1}
0	0.81813	0	1307.8	714.7	0.0
0.0536	0.81723	0.028	1303.4	720.3	−4.7
0.1039	0.81655	0.030	1298.4	726.4	−8.2
0.2080	0.81498	0.038	1290.4	736.9	−17.8
0.3101	0.81323	0.050	1280.5	749.9	−24.4
0.4103	0.81132	0.060	1270.0	764.1	−29.4
0.5116	0.80918	0.065	1258.1	780.8	−32.2
0.6108	0.80668	0.073	1245.3	799.4	−32.6
0.7091	0.80408	0.078	1230.9	820.9	−30.0
0.8071	0.80092	0.085	1214.6	846.4	−23.3
0.9037	0.79752	0.075	1197.9	873.8	−14.5
0.9515	0.79568	0.065	1190.6	886.6	−10.8
1	0.79444	0	1178.2	906.8	0.0

Physical Properties Estimation

The prediction of different thermodynamic properties of multicomponent mixtures has been the subject of study in recent years. Different empirical or semiempirical models were applied. In this paper, the measured experimental properties were compared with those estimated by applying several relations [7]. The density of the mixtures were estimated

Table 2. Refractive index and change of refractive index on mixing as a function of composition and temperature (288.15–318.15 K) for the binary systems

Ethanol + 2-Methyl-1-propanol								
	n_D				Δn_D			
x_1	318.15 K	308.15 K	298.15 K	288.15 K	318.15 K	308.15 K	298.15 K	288.15 K
0	1.38520	1.38959	1.39370	1.39788	0	0	0	0
0.0521	1.38408	1.38831	1.39253	1.39663	0.00068	0.00052	0.00062	0.00055
0.1036	1.38292	1.38714	1.39136	1.39540	0.00130	0.00113	0.00123	0.00110
0.1551	1.38170	1.38593	1.39012	1.39415	0.00185	0.00170	0.00176	0.00163
0.2064	1.38041	1.38466	1.38890	1.39287	0.00233	0.00221	0.00231	0.00212
0.2575	1.37904	1.38341	1.38753	1.39161	0.00272	0.00272	0.00270	0.00263
0.3084	1.37766	1.38202	1.38611	1.39024	0.00310	0.00309	0.00303	0.00302
0.3591	1.37635	1.38068	1.38470	1.38891	0.00354	0.00350	0.00337	0.00344
0.4096	1.37495	1.37904	1.38330	1.38740	0.00388	0.00361	0.00371	0.00367
0.4598	1.37337	1.37759	1.38169	1.38579	0.00403	0.00390	0.00383	0.00380
0.5099	1.37180	1.37601	1.38014	1.38421	0.00419	0.00405	0.00400	0.00395
0.5598	1.37013	1.37442	1.37847	1.38264	0.00424	0.00418	0.00400	0.00411
0.6095	1.36840	1.37252	1.37674	1.38086	0.00423	0.00400	0.00403	0.00404
0.6590	1.36650	1.37070	1.37500	1.37895	0.00403	0.00389	0.00404	0.00384
0.7083	1.36463	1.36888	1.37301	1.37716	0.00387	0.00377	0.00370	0.00376
0.7574	1.36270	1.36690	1.37111	1.37520	0.00363	0.00349	0.00349	0.00349
0.8063	1.36041	1.36460	1.36884	1.37297	0.00303	0.00288	0.00291	0.00305
0.8550	1.35818	1.36245	1.36675	1.37084	0.00248	0.00242	0.00250	0.00251
0.9035	1.35599	1.36008	1.36431	1.36841	0.00206	0.00172	0.00173	0.00176
0.9519	1.35336	1.35768	1.36189	1.36601	0.00100	0.00100	0.00097	0.00113
1	1.35070	1.35502	1.35926	1.36332	0	0	0	0
Ethanol + 2-Methyl-1-butanol								
	n_D				Δn_D			
x_1	318.15 K	308.15 K	298.15 K	288.15 K	318.15 K	308.15 K	298.15 K	288.15 K
0	1.40000	1.40447	1.40871	1.41265	0	0	0	0
0.0487	1.39899	1.40321	1.40734	1.41133	0.00139	0.00115	0.00104	0.00108
0.1007	1.39765	1.40180	1.40583	1.40985	0.00261	0.00231	0.00210	0.00217
0.1517	1.39601	1.40031	1.40424	1.40827	0.00349	0.00334	0.00303	0.00310
0.1995	1.39450	1.39870	1.40277	1.40679	0.00433	0.00409	0.00392	0.00398
0.2495	1.39287	1.39701	1.40112	1.40509	0.00517	0.00488	0.00475	0.00475
0.3001	1.39115	1.39514	1.39926	1.40332	0.00594	0.00551	0.00539	0.00547
0.3491	1.38924	1.39335	1.39756	1.40165	0.00645	0.00614	0.00611	0.00622
0.3998	1.38724	1.39142	1.39549	1.39953	0.00695	0.00672	0.00655	0.00660
0.4502	1.38523	1.38931	1.39341	1.39766	0.00742	0.00710	0.00696	0.00722
0.5005	1.38298	1.38708	1.39120	1.39525	0.00765	0.00736	0.00724	0.00729
0.5496	1.38068	1.38477	1.38899	1.39304	0.00778	0.00748	0.00746	0.00750
0.5997	1.37803	1.38229	1.38636	1.39047	0.00760	0.00748	0.00731	0.00740
0.6503	1.37542	1.37954	1.38373	1.38782	0.00748	0.00723	0.00718	0.00725
0.7003	1.37259	1.37679	1.38109	1.38513	0.00712	0.00695	0.00701	0.00703
0.8011	1.36625	1.37046	1.37475	1.37882	0.00574	0.00560	0.00565	0.00569
0.8495	1.36305	1.36714	1.37134	1.37547	0.00493	0.00468	0.00464	0.00473
0.9001	1.35915	1.36334	1.36758	1.37180	0.00353	0.00338	0.00338	0.00355
0.9501	1.35533	1.35930	1.36358	1.36780	0.00217	0.00181	0.00185	0.00202
1	1.35070	1.35502	1.35926	1.36332	0	0	0	0

(*continued*)

Table 2 (*continued*)

Ethanol + 3-Methyl-1-butanol								
	n_D				Δn_D			
x_1	318.15 K	308.15 K	298.15 K	288.15 K	318.15 K	308.15 K	298.15 K	288.15 K
0	1.39702	1.40121	1.40519	1.40928	0	0	0	0
0.0510	1.39571	1.39990	1.40393	1.40794	0.00105	0.00104	0.00108	0.00100
0.0988	1.39454	1.39870	1.40282	1.40676	0.00210	0.00206	0.00217	0.00202
0.1992	1.39165	1.39572	1.39979	1.40375	0.00385	0.00371	0.00375	0.00362
0.3003	1.38849	1.39253	1.39662	1.40060	0.00538	0.00519	0.00522	0.00512
0.3997	1.38489	1.38898	1.39307	1.39714	0.00638	0.00623	0.00624	0.00623
0.4998	1.38097	1.38491	1.38913	1.39308	0.00710	0.00678	0.00689	0.00677
0.5998	1.37643	1.38053	1.38465	1.38879	0.00719	0.00702	0.00701	0.00708
0.7004	1.37133	1.37543	1.37945	1.38363	0.00675	0.00657	0.00643	0.00654
0.8002	1.36540	1.36960	1.37373	1.37774	0.00544	0.00535	0.00529	0.00524
0.8998	1.35910	1.36287	1.36715	1.37123	0.00376	0.00322	0.00329	0.00330
0.9500	1.35500	1.35907	1.36329	1.36756	0.00199	0.00174	0.00174	0.00194
1	1.35070	1.35502	1.35926	1.36332	0	0	0	0
Ethanol + 1-Pentanol								
	n_D				Δn_D			
x_1	318.15 K	308.15 K	298.15 K	288.15 K	318.15 K	308.15 K	298.15 K	288.15 K
0	1.39936	1.40363	1.40761	1.41170	0	0	0	0
0.0536	1.39831	1.40233	1.40636	1.41031	0.00156	0.00130	0.00134	0.00120
0.1039	1.39691	1.40102	1.40493	1.40893	0.00261	0.00244	0.00234	0.00226
0.2080	1.39382	1.39797	1.40191	1.40589	0.00458	0.00445	0.00435	0.00425
0.3101	1.39048	1.39449	1.39846	1.40246	0.00621	0.00594	0.00585	0.00576
0.4103	1.38664	1.39090	1.39498	1.39891	0.00725	0.00721	0.00721	0.00706
0.5116	1.38269	1.38654	1.39063	1.39457	0.00823	0.00778	0.00776	0.00762
0.6108	1.37785	1.38181	1.38587	1.38992	0.00821	0.00787	0.00779	0.00777
0.7091	1.37238	1.37649	1.38064	1.38471	0.00753	0.00733	0.00732	0.00732
0.8071	1.36654	1.37040	1.37480	1.37849	0.00645	0.00600	0.00621	0.00584
0.9037	1.35911	1.36330	1.36740	1.37152	0.00372	0.00360	0.00348	0.00354
0.9515	1.35539	1.35927	1.36352	1.36769	0.00233	0.00189	0.00192	0.00203
1	1.35070	1.35502	1.35926	1.36332	0	0	0	0

by application of the *Rackett* (*R*) and *Spencer* and *Danner* modified *Rackett* (*SDR*) equations using expanded mixing rules proposed by those authors and the *Kay* (modified *Prausnitz-Gunn* combination) rule and literature data of the pure components (Table 4). The refractive indices were compared with the results predicted by *Lorentz-Lorenz* (*LL*), *Dale-Gladstone* (*DG*), *Arago-Biot* (*AB*), *Eykman* (*Ey*), *Newton* (*N*), *Oster* (*O*), and *Eyring-John* (*EJ*) mixing rules. The prediction of speed of sound was made by means of *Nomoto*, *Van Dael*, *Jacobson* (Free Length Theory, FLT), and *Schaffs-Nutsch-Kuhnkies* (Collision Factor Theory, CFT) methods. In Tables 5–7 the mean square deviations of the estimations are gathered. Density estimation according to the *Rackett* method leads to smaller deviations for all the mixtures in the range of temperatures studied. The best refractive indices estimation in the binary mixtures are those obtained by the *Dale-Gladstone* equation considering additivity on mixing. The application of the Collision Factor Theory, as well as the empirical equations (*Nomoto* and *Danusso* models) present lower deviation values in predicting the speed of sound in almost all systems. The data of pure liquid components are listed in Table 8.

Results and Discussion

A lot of chemical, food, and other industries produce non-Newtonian and non-ideal fluids and mixtures in their processes. For design and simulation of these processes the respective thermodynamic data are

Table 3. In tables a, b, and c fitting parameters of refractive index, excess volume, and isentropic compressibility are gathered as function of temperature, according to Eqs. (2) and (3), for the binary mixtures ethanol + solvent

Table a	2-*Me*-1-Propanol	2-*Me*-1-Butanol	3-*Me*-1-Butanol	1-Pentanol
B_{00}	0.15771	0.40606	0.24763	0.24185
B_{01}	−0.00096	−0.00253	−0.00148	−0.00145
B_{02}	1.63019×10^{-6}	4.23049×10^{-6}	2.47057×10^{-6}	2.47392×10^{-6}
B_{10}	0.06420	−0.40862	−0.14433	0.16885
B_{11}	−0.00040	0.00278	0.00102	−0.00106
B_{12}	6.70686×10^{-7}	-4.64630×10^{-6}	-1.72113×10^{-6}	1.77937×10^{-6}
B_{20}	−0.82336	−1.18758	−1.07094	−1.28606
B_{21}	0.00552	0.00789	0.00701	0.00856
B_{22}	-9.22344×10^{-7}	-1.30790×10^{-5}	-1.14534×10^{-5}	-1.41735×10^{-5}
B_{30}	0.48199	0.93324	1.56255	0.21624
B_{31}	−0.00313	−0.00608	−0.01041	−0.00138
B_{32}	5.07398×10^{-6}	9.89998×10^{-5}	1.73292×10^{-5}	2.20394×10^{-6}
B_{40}	1.87566	3.20446	2.30850	2.79757
B_{41}	−0.01253	−0.02135	−0.01521	−0.01870
B_{42}	2.08952×10^{-5}	3.55431×10^{-5}	2.50541×10^{-5}	3.12271×10^{-5}
σ	0.00003	0.00007	0.00006	0.00009
Table b	2-*Me*-1-Propanol	2-*Me*-1-Butanol	3-*Me*-1-Butanol	1-Pentanol
B_{00}	−1.325	−1.964	−0.832	1.018
B_{01}	0.011	0.018	0.010	−0.003
B_{02}	-1.957×10^{-5}	-3.740×10^{-5}	-2.129×10^{-5}	2.294×10^{-5}
B_{10}	5.257	1.782	−1.042	−0.473
B_{11}	−0.031	−0.011	0.007	0.005
B_{12}	5.041×10^{-5}	2.055×10^{-5}	-1.201×10^{-5}	-8.855×10^{-6}
B_{20}	3.884	−4.794	20.387	−3.828
B_{21}	−0.021	0.033	−0.137	0.025
B_{22}	2.904×10^{-5}	-5.605×10^{-5}	2.292×10^{-4}	-4.059×10^{-5}
B_{30}	−3.881	−5.045	7.054	12.169
B_{31}	0.034	0.036	−0.047	−0.079
B_{32}	-6.015×10^{-5}	-5.964×10^{-5}	8.163×10^{-5}	1.302×10^{-4}
B_{40}	−10.996	15.139	−22.409	4.791
B_{41}	0.055	−0.097	0.157	−0.025
B_{42}	-7.150×10^{-5}	1.590×10^{-4}	-2.670×10^{-4}	4.174×10^{-5}
σ	0.013	0.005	0.005	0.004
Table c	2-*Me*-1-Propanol	2-*Me*-1-Butanol	3-*Me*-1-Butanol	1-Pentanol
B_{00}	−95.1	−472.7	−632.6	−644.8
B_{01}	0.9	3.9	4.8	5.1
B_{02}	-2.5×10^{-3}	-9.0×10^{-3}	-1.0×10^{-2}	-1.1×10^{-2}
B_{10}	−713.6	−69.8	−372.3	−737.3
B_{11}	4.8	0.5	2.7	5.0
B_{12}	-7.8×10^{-3}	-1.3×10^{-3}	-5.0×10^{-3}	-8.8×10^{-3}
B_{20}	−360.6	−1822.2	922.2	−1265.6
B_{21}	2.7	12.8	−5.9	8.5
B_{22}	-4.8×10^{-3}	-2.3×10^{-2}	9.4×10^{-2}	-1.4×10^{-2}
B_{30}	1451.8	−949.4	343.3	2964.9
B_{31}	−9.5	6.9	−2.3	−18.2
B_{32}	1.6×10^{-2}	-1.2×10^{-2}	4.2×10^{-2}	2.7×10^{-2}
B_{40}	556.0	2704.8	−1410.5	3470.7
B_{41}	−4.1	−19.6	9.2	−23.1
B_{42}	7.3×10^{-3}	3.6×10^{-2}	-1.4×10^{-2}	3.8×10^{-2}
σ	0.7	0.5	0.4	3.5

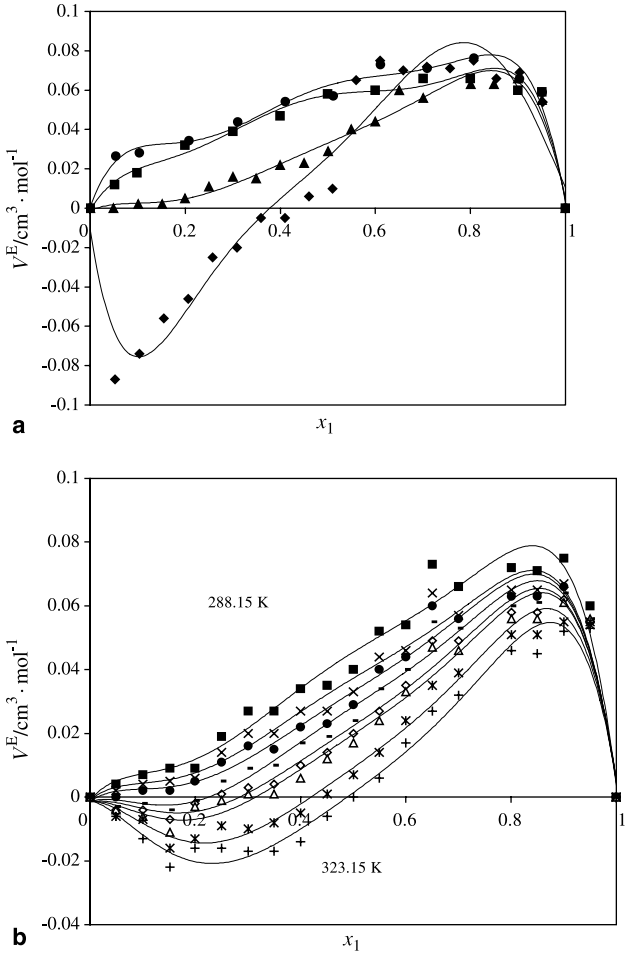

Fig. 1. Curves of (a) excess molar volumes ($cm^3 \cdot mol^{-1}$) for the mixtures ethanol + ((◆) 2-methyl-1-propanol, (▲) 2-methyl-1-butanol, (■) 3-methyl-1-butanol, and (●) 1-pentanol) at 298.15 K and (b) excess molar volumes ($cm^3 \cdot mol^{-1}$) for the systems ethanol + 2-methyl-1-butanol as function of temperature in the range 288.15 –323.15 K (■, 288.15 K; ×, 293.15 K; ◆, 298.15 K; −, 303.15 K; ◇, 308.15 K; Δ, 313.15 K; ∗, 318.15 K; +, 323.15 K). Experimental data was fitted to *Redlich-Kister* polynomias (——)

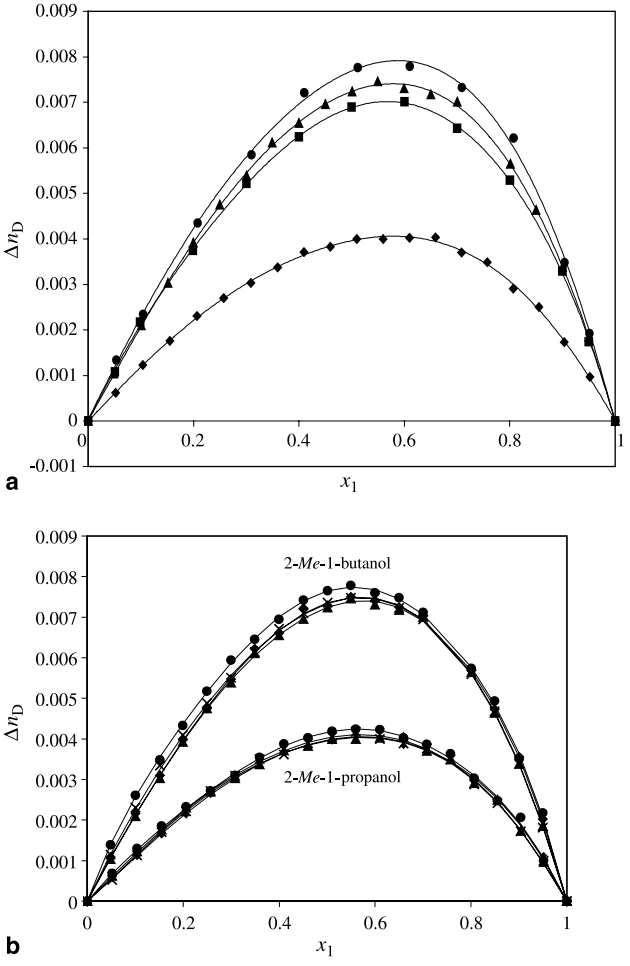

Fig. 2. Curves of (a) changes of refractive index on mixing for the mixtures ethanol + ((◆) 2-methyl-1-propanol, (▲) 2-methyl-1-butanol, (■) 3-methyl-1-butanol, and (●) 1-pentanol) at 298.15 K and (b) changes of refractive index on mixing for the systems ethanol + (2-methyl-1-propanol and 2-methyl-1-butanol) at (■, 288.15 K; ×, 293.15 K; ◆, 298.15 K; −, 303.15 K; ◇, 308.15 K; Δ, 313.15 K; ∗, 318.15 K; +, 323.15 K). Experimental data was fitted to *Redlich-Kister* polynomias (——)

needed. As a continuation of previous works on this scope, this paper is devoted to the study of different thermodynamic properties of chemicals containing hydroxyl groups. To this aim, we present experimental data of speed of sound, refractive index on mixing and density for the binaries ethanol + (2-methyl-1-propanol, 2-methyl-1-butanol, 1-pentanol, or 3-methyl-1-butanol) in the temperature range 288.15 to 323.15 K and at atmospheric pressure. The corresponding derived properties were computed, and correlated by application of a modified temperature dependent *Redlich-Kister* equation. Values of the quantities were compared with those estimated using different procedures. These mixtures show a rising expansive tendency due to increase of steric hindrance. If the interactions between the molecules of two mixed components are weaker than in the pure component, the excess volume will be positive, as occurs for the studied mixtures. This fact is also expressed in terms of change of refractive index on mixing and changes of isentropic compressibility, showing positive and negative values, respectively. This usually occurs when one of the components has polar groups and the other non-polar/weakly polar behaviour, or as in this case, polar molecules highly influenced by a three dimensional structure of

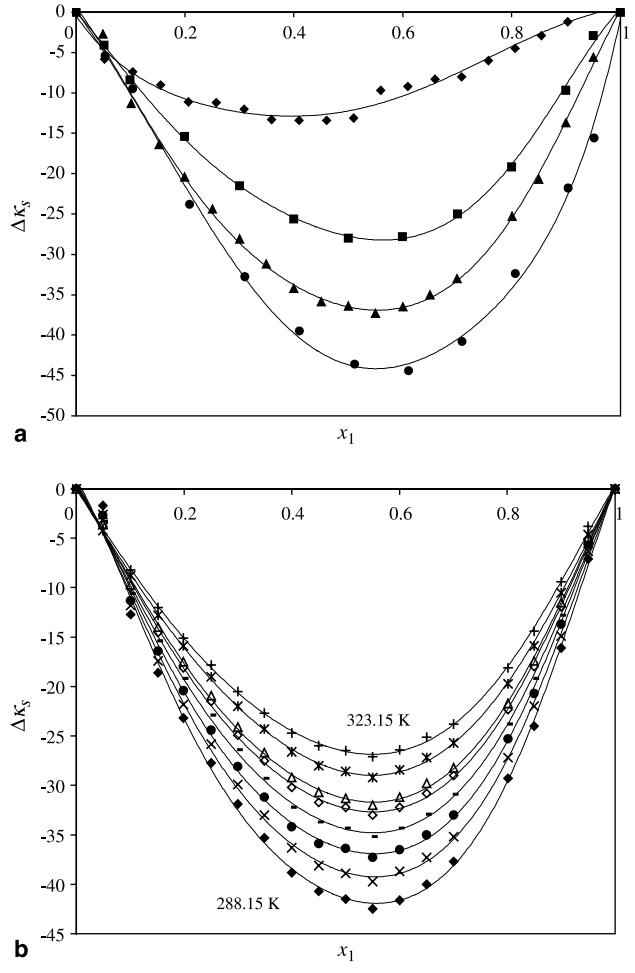

Fig. 3. Curves of (a) changes of isentropic compressibility for the mixtures ethanol ((◆) 2-methyl-1-propanol, (▲) 2-methyl-1-butanol, (■) 3-methyl-1-butanol, and (●) 1-pentanol) at 298.15 K and (b) changes of isentropic compressibility for the systems ethanol + 2-methyl-1-butanol as function of temperature in the range 288.15–323.15 K (■, 288.15 K; ×, 293.15 K; ◆, 298.15 K; −, 303.15 K; ◇, 308.15 K; Δ, 313.15 K; ∗, 318.15 K; +, 323.15 K). Experimental data was fitted to *Redlich-Kister* polynomias (——)

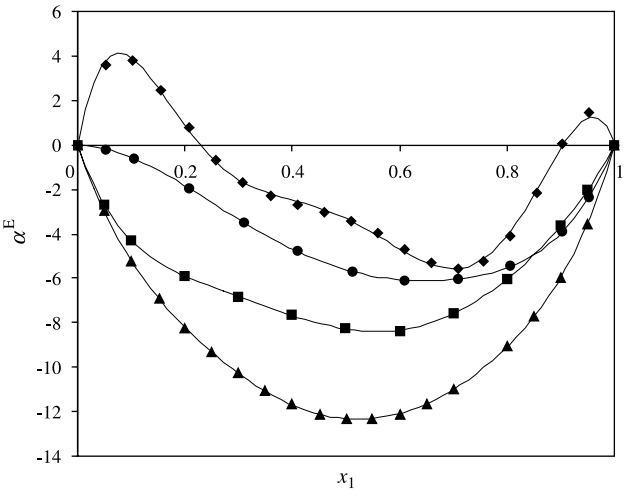

Fig. 4. Curves of constant isobaric expansibility (α/K^{-1}) of the mixtures ethanol + ((◆) 2-methyl-1-propanol, (▲) 2-methyl-1-butanol, (■) 3-methyl-1-butanol, and (●) 1-pentanol) at 298.25 K

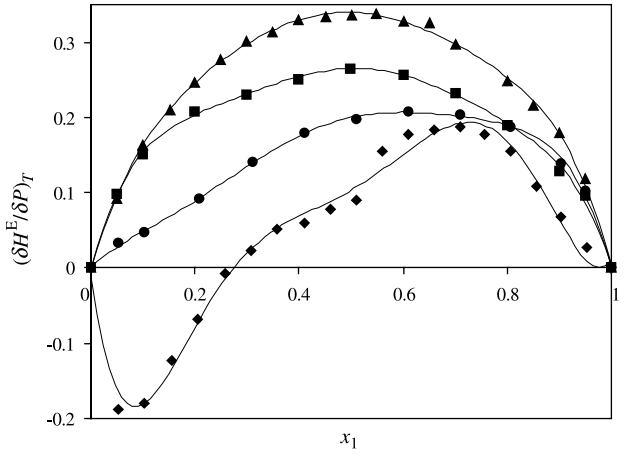

Fig. 5. Curves of constant isothermal coefficient of pressure excess molar enthalpy $\left(\left(\partial H^E/\partial P\right)_T/\mathrm{JMPa^{-1}\,mol^{-1}}\right)$ of the mixtures ethanol + ((◆) 2-methyl-1-propanol, (▲) 2-methyl-1-butanol, (■) 3-methyl-1-butanol, and (●) 1-pentanol) at 298.25 K

compounds. Two tendencies could be observed depending on the molecular structure of the chemicals employed and the temperature range. At first, the shorter aliphatic molecules (2-methyl-1-propanol and 2-methyl-1-butanol) show in ethanolic mixtures a sigmoidal trend in excess molar volumes. Otherwise, the compounds of higher molecular weight show an expansive trend in the whole range of temperatures. All the systems are sensitive to temperature, show a slight expansive effect which increases at lower temperatures. Isothermal coefficient of pressure excess molar enthalpy and partial molar volume at infinite dilution are shown in Figs. 5 and 6, the partial excess molar volume becomes positive (infinite dilution) in almost all cases (with the exception of 2-methyl-1-propanol). This causes the differences of the derived properties from some heavy alcohols to others.

Experimental

The standard physical properties of the chemicals, recent literature values, and other relevant information are listed in

Table 4. Open literature critical values for compounds enclosed into binary mixtures[a]

Compound	P_c/bar	T_c/K	V_c/cm$^3 \cdot$ mol^{-1}	ω	Z_c	Z_{RA}
2-Methyl-1-propanol	43.00	547.78	273.00	0.590	0.258	0.239
2-Methyl-1-butanol*	39.40	575.40	328.50	0.605	0.270	0.267
3-Methyl-1-butanol	39.10	579.40	325.00	0.559	0.264	0.241
1-Pentanol	39.09	588.15	326.00	0.579	0.262	0.240
Etanol	61.48	513.92	167.00	0.649	0.240	0.234

[a] Ref. [10]
* V_c and Z_c were estimated by the *Joback* method [22]

Table 5. Root mean square deviations of the experimental density from the estimation results by the *Rackett* (*R*) and modified *Rackett* (m*R*) equations of state at the studied range of temperature

	R	m*R*
Ethanol + 2-Methyl-1-propanol	0.0362	0.1137
Ethanol + 2-Methyl-1-butanol	0.0321	0.0561
Ethanol + 3-Methyl-1-butanol	0.0375	0.1239
Ethanol + 1-Pentanol	0.0368	0.1220

Table 8. The chemicals were supplied by Merck (LichroSolv grade), all of them with a purity better than 99.990. Ultrasonic treatment was used for degassing and molecular sieves were introduced into the bottles to reduce possible water contents in solvents. Solution compositions were determined gravimetrically, special care being taken during solution preparation to avoid evaporation losses. Samples were prepared by mass using a Mettler AT-261 Delta Range balance with an accuracy of $\pm 10^{-4}$ g, covering the whole composition ranges of the mixtures. The accuracy of the mole fractions was estimated to be better than 10^{-4}. The densities and ultrasonic velocities were measured with an Anton Paar DSA-48 device with a precision of $\pm 5\ 10^{-5}$ g $\cdot$ cm^{-3} and ± 1 m $\cdot$ s^{-1}. The refractive indices of the pure liquids and mixtures were measured with the automatic refractometer ABBEMAT-HP Dr. Kernchen with a precision of $\pm 10^{-5}$ and thermostated with a Poly-Science controller bath model 9010 with a temperature stability of $\pm 10^{-2}$ K. Calibration of the apparatus was performed periodically, in accordance with technical specifications, using

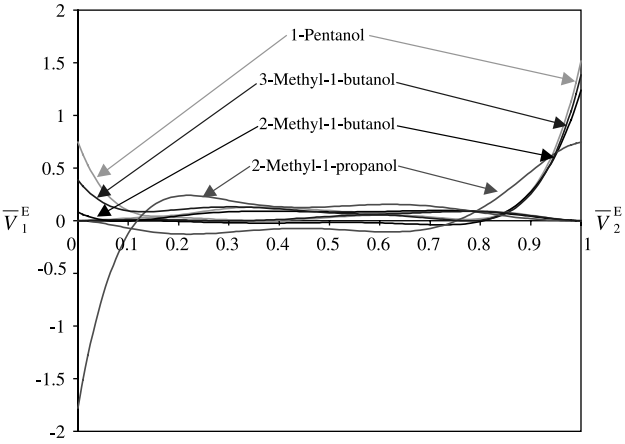

Fig. 6. Partial excess molar volumes (cm$^3 \cdot$ mol^{-1}) ($\overline{V}_1^E$ (left axis) and $\overline{V}_2^E$ (right axis)) of ethanol + (2-methyl-1-propanol, 2-methyl-1-butanol, 3-methyl-1-butanol, and 1-pentanol) at 298.15 K

Millipore quality water (resistivity, 18.2 M$\Omega \cdot$ cm) and ambient air. Maximum deviation in the calculation of the derived quantities for these mixtures has been estimated to be better than $\pm 2 \times 10^{-3}$ cm$^3 \cdot$ mol, $\pm 10^{-4}$, and ± 1 T Pa^{-1} for excess molar volume, change of refractive index, and change of isentropic compressibility. We are not aware of any such data in previous literature of these mixtures, except for the cases indicated above. Further details about technical procedures or manipulation can be found in earlier works.

Table 6. Root mean square deviations of the experimental refractive indices from the estimation results by different rules, considering additive volumes or non-additive volumes (indicated with*)

	LL	*DG*	*AB*	*Ey*	*N*	*O*
Ethanol + 2-Methyl-1-propanol	0.00011	0.00011	0.00018	0.00018	0.00025	0.00025
	0.00033*	0.00029*	0.00103*	0.00031*	0.00028*	0.00029*
Ethanol + 2-Methyl-1-butanol	0.00009	0.00009	0.00009	0.00006	0.00024	0.00017
	0.00030*	0.00016*	0.00071*	0.00021*	0.00014*	0.00012*
Ethanol + 3-Methyl-1-butanol	0.00011	0.00010	0.00010	0.00008	0.00020	0.00014
	0.00036*	0.00022*	0.00090*	0.00027*	0.00010*	0.00016*
Ethanol + 1-Pentanol	0.00053	0.00039	0.00039	0.00044	0.00026	0.00032
	0.00074*	0.00058*	0.00112*	0.00064*	0.00041*	0.00050*

Table 7. Root mean square deviations $\sigma/\mathrm{T\,Pa^{-1}}$ for estimated isentropic compressibilities from experimentally data at 298.15 K

	Nomoto	*Danusso*	CFT	FLT
Ethanol + 2-Methyl-1-propanol	2.40	3.49	1.46	46.09
Ethanol + 2-Methyl-1-butanol	2.97	1.85	6.53	45.91
Ethanol + 3-Methyl-1-butanol	3.43	2.42	3.57	45.99
Ethanol + 1-Pentanol	2.03	2.73	9.64	45.82

Table 8. Comparison of experimental measured data with literature data for pure liquids at 298.15 K

Component	$M/\mathrm{g\,mol^{-1}}$	$\rho/\mathrm{g\,cm^{-3}}$		n_D		$u/\mathrm{m\,s^{-1}}$	
		Exptl.	Ref.[a]	Exptl.	Ref.[a]	Exptl.	Ref.
Ethanol	46.069	0.78589	0.78493	1.35926	1.35941	1143.1	1143.11[b]
2-Methyl-1-propanol	74.122	0.79761	0.7978	1.39370	1.39389	1185.6	1185.6[e]
2-Methyl-1-butanol	88.149	0.81478	0.8150	1.40871	1.4086	1251.4	not available
3-Methyl-1-butanol	88.149	0.80631	0.8071	1.40519	1.4052	1232.5	1230.18[d]
1-Pentanol	88.149	0.81091	0.81080	1.40761	1.4080	1273.3	1273.3[c]

[a] [10], [b] [11], [c] [12], [d] [13], [e] [14]

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Appendix A

The isobaric expansibility for pure chemicals can be expressed as:

$$\alpha = -\left(\frac{\partial \ln \rho}{\partial T}\right)_{P,x} \tag{A1}$$

taking into account the temperature dependence of density. However a more interesting contribution is made to the field of properties in liquid mixtures if this calculation is done taking separately the partial contributions of the thermal expansibilities of each component in the mixture, as well as that due to non-ideality in mixture. To this aim, the basic expression relating the molar volume of a mixture and its excess molar volume will be:

$$V = \sum_{i=1}^{N} x_i V_i + V^\mathrm{E} \tag{A2}$$

where V_i is the molar volume and x_i is the mole fraction of compound i. By differentiating of Eq. (A2)

$$\left(\frac{\partial V}{\partial T}\right)_{P,x_i} = \frac{\partial\left(\sum_{i=1}^{N} x_i V_i\right)}{\partial T} + \left(\frac{\partial V^\mathrm{E}}{\partial T}\right)_{P,x_i} \tag{A3}$$

dividing by V and changing negative signs in two terms of the equation:

$$\alpha = \frac{1}{V}\left[\left(\frac{\partial V^\mathrm{E}}{\partial T}\right)_{P,x_i} + \frac{\partial}{\partial T}\sum_{i=1}^{N}(x_i V_i)\right] \tag{A4}$$

we obtain:

$$\alpha = V^{-1}\left[\left(\frac{\partial V^\mathrm{E}}{\partial T}\right)_{P,x_i} + \sum_{i=1}^{N}(\alpha_i x_i V_i)\right] \tag{A5}$$

α and α_i being the coefficient of thermal expansion of mixture and pure compound, respectively. From this expression, the excess isobaric expansibility would be expressed as:

$$\alpha^\mathrm{E} = \alpha - \sum_{i=1}^{N} \phi_i \alpha_i \tag{A6}$$

where

$$\phi_i = \frac{x_i V_i}{\sum_{i=1}^{N} x_i V_i} \tag{A7}$$

is the volume fraction of the components of the ideal mixture, see Eq. (A2).

Appendix B

According to the *Rackett* model, the density can be described as [15, 16]:

$$\rho = \left(\frac{MP_\mathrm{c}}{RT_\mathrm{c}}\right) \cdot \beta^{-[1+(1-T_r)^{2/7}]} \tag{B1}$$

where T_r is the reduced temperature, T_c and P_c are the critical properties of the mixture, M is the average molecular weight of the mixture, and β is the compressibility factor or an acentric factor dependent parameter which varies depending on a molecular structure parameter [17]. The selected mixing rule

to compute densities was proposed by *Kay* (modified combination of *Prausnitz-Gunn*) [18]. In order to predict this property, the critical values are required for each compound, to this end open literature or estimation methods have been used.

The refractive index was estimated by the following semi-empirical relations [3]:

Lorentz-Lorenz

$$\frac{n_D^2-1}{n_D^2+2}=\sum_{i=1}^{N}\left[\phi_i\left(\frac{n_{Di}^2-1}{n_{Di}^2+2}\right)\right] \tag{B2}$$

Dale-Gladstone

$$n_D-1=\sum_{i=1}^{N}\left[\phi_i\left(n_{Di}-1\right)\right] \tag{B3}$$

Arago-Biot

$$n_D=\sum_{i=1}^{N}\left(\phi_i n_{Di}\right) \tag{B4}$$

Eykman

$$\frac{n_D^2-1}{n_D^2+0.4}=\sum_{i=1}^{N}\left[\phi_i\left(\frac{n_{Di}^2-1}{n_{Di}^2+0.4}\right)\right] \tag{B5}$$

Newton

$$n_D^2-1=\sum_{i=1}^{N}\left[\phi_i\left(n_{Di}^2-1\right)\right] \tag{B6}$$

Oster

$$\frac{(n_D^2-1)-(2n_D^2+1)}{n_D^2}=\sum_{i=1}^{N}\left[\phi_i\left(\frac{(n_{Di}^2-1)-(2n_{Di}^2+1)}{n_{Di}^2}\right)\right] \tag{B7}$$

where the symbols show the same meaning as above.

The models of *Danusso* and *Nomoto* (Eqs. (B8) and (B9)) are in accordance to the following expressions:

$$\kappa_S=\left(\frac{1}{M\cdot\rho}\right)\cdot\left(\sum_{i=1}^{N}\frac{n_iM_i}{\rho_i^2u_i^2}\right) \tag{B8}$$

$$\kappa_S=\left(\frac{1}{\rho}\right)\cdot\left(\frac{\sum_i^N n_iR_i}{\sum_i^N n_iu_i}\right)^{-6} \tag{B9}$$

where $R=u^{1/3}\cdot\sum_i^N n_iV_i$ and the Collision Factor Theory (CFT) and Free Length Theory (FLT) [19, 20] for the isentropic compressibilities were applied:

$$\kappa_S=\left(\frac{1}{\rho^3}\right)\cdot\left(\frac{M}{u_\infty\cdot\sum_i^N x_iS_s\cdot\sum_i^N x_iB_s}\right)^2 \tag{B10}$$

$$\kappa_S=\left(\frac{L_f^2}{K^2}\right) \tag{B11}$$

The CFT is dependent on the collision factors among molecules as a function of temperature in pure solvent or mixture. The pertinent relations in these calculations and its theoretical basis were described in the literature cited. The collision factors (S) and the characteristic molecular volumes (B) of the pure solvents used in the CFT calculations were estimated by using the experimental ultrasonic velocities, enclosed in this paper, and the molar volumes. These values could be also evaluated by means of the group contribution method proposed by *Schaffs* [21], when no experimental data are disposable. The FLT estimates the isentropic compressibility of a mixture assuming the free displacement of molecules as function of temperature.

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