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Volumetric and Ultrasonic Study of Mixtures of Benzyl Alcohol with 1-Propanol, 2-Propanol, and 1,2-Propandiol, 1,3-Propandiol and T-butanol

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Abstract: Densities and speeds of sound for five binary mixtures of benzylalcohol with 1,3-propandiol, 1- propanol, 2-propanol, 1,2-propandiol and phenylethnol were measured over the entire range of composition and at five temperatures from 298.15K to 323.15K at 5K interval and atmospheric pressure using a vibrating u-tube densimeter (DSA 5000). Besides, the densities for pure compounds in the above-mentioned temperature range were measured. The experimental densities were used to calculate the excess molar volumes, isentropic compressibility changes, the excess thermal expansion coefficients, and the excess partial molar volumes at infinite dilution, The results have been used to discuss the nature and strength of intermolecular interactions in these mixtures. The calculated excess and deviations quantities are correlated with the third-order Redlich–Kister equation. As a final work we modeled the experiment results by using TM and PR EOSs. This is clear that the results with TM EOS are more acceptable than PR EOS. TM and PR EOS can successfully predict density and excess molar volume. And are unable to predict speed of sound.

Keywords: Alcohols, Binary Mixtures, Excess Properties, Density, Modeling, Speed of Sound

1. Introduction

Thermodynamic properties for pure and mixtures of liquids especially alcohols have both practical and theoretical interest; They have to be known to design industrial processes properly. They can be used to develop models that allow us to predict other properties. Finally, they can also reveal the existence of specific molecular interactions. In recent years, measurements of thermodynamic and transport properties have been adequately employed in understanding the nature of molecular systems and physicochemical behavior in liquid mixtures Despite the extensive studies on binary mixtures of alcohols [1–7], so far relatively less attention has been given to the mixtures containing an aromatic alcohol [8]. The mixtures of benzyl alcohol with aliphatic alcohols are interesting to study because of the possibility of weak π…H bonding, in addition to the hydrogen bonding between unlike molecules. The weak π…H bonding of aromatic rings with proton donors appears to play an important role in the structure of certain bimolecular [9]. Yeh et al. [10] reported thermophysical properties of the binary mixtures 2-phenylethanol+2-propanol, 2-phenylethanol+benzylalcohol, at T = (298.15, 308.15, and 318.15) K. Huang et al. [11]. Sastry et al reported Densities, excess molar and partial molar volumes for water + 1-butyl- or, 1-hexyl- or, 1-octyl-3-methylimidazolium halide room temperature ionic liquids at T = (298.15 and 308.15) K [12]. Gyan parkesh et al investigated thermodynamic, thermophysical and partial molar properties of liquid mixtures of diethylenediamine with alcohols at 293.15 to 313.15 K [13] and Sk. Md Nayeem et al investigated thermoacoustic, Volumetric, and Viscometric in Binary Liquid System of Cyclohexanone with Benzyl Benzoate at T = 308.15, 313.15, and 318.15 K [14].

In another search we use butanol and investigated thire thermodynamic properties [15-17] and in continues in present study, we report densities (ρ) and speeds of sound (u) for the binary mixtures of benzylalcohol with 1-propanol, 2-propanol, 1,2-propandiol, and 1,3-propandiol and t-butanol at T= (298.15, 303.15, 308.15, 313.15 and 318.15) K and in the entire composition range and atmospheric pressure using a vibrating u-tube densimeter (DSA 5000). The experimental values of ρ and u were used to calculate the excess molar volumes (V_m^E), deviation in isentropic compressibility ($\Delta\kappa_S$), excess thermal expansion coefficient (α_P^E), infinite partial molar volumes ($\bar{V}_i^{\infty}$), and excess partial molar volume ($\bar{V}_i^{E,\infty}$) of the components at infinite dilution. The variation of these parameters with the composition and temperature of the mixtures have been discussed in terms of molecular interactions. Additionally, the density and excess molar volumes of the studied alcohols (pure and mixtures) were modeled with Tao-Mason (TM) and Peng-Robinson (PR) equations of state.

2. Experimental

1-propanol, 2-propanol, 1,3-propandiol (mass fraction > 98%, Merck), 1,2-propandiol (mass fraction > 98%, Merck) benzyl alcohol (mass fraction ≥ 99.5%, Merck) and t-butanol (mass fraction ≥ 99%, Merck) were used without further purification.

Densities and speeds of sound for pure liquids and their binary mixtures were measured using an Anton Paar DSA 5000 vibrating u-tube densimeter and sound analyzer, with a certified precision of $\pm 1 \cdot 10^{-6}$ g cm^{-3} and ± 0.1 m s^{-1}, respectively. This analyzer automatically corrects the influence of viscosity on the measured density. The DSA 5000 simultaneously determines two physically independent properties within one sample. The instrument is equipped with a density cell and a sound speed cell combining the known oscillating u-tube method with a highly accurate measurement of sound speed. Two integrated Pt 100 platinum thermometers together with Peltier elements provide a good precision in temperature control internally ($T \pm 0.001$ K). The apparatus was checked once a day and calibration was carried out with double distilled water and dry air under atmospheric pressure. Before the measurements, all the components were partially degassed (20 min) using an ultrasound (MISONIX Ultrasonic Liquid Processors). Solutions were prepared by mass using an analytical balance with a precision of $\pm 1 \cdot 10^{-4}$ g and kept in sealed flasks. The experimental uncertainties in the density and speed of sound are estimated to be better than $\pm 5 \times 10^{-6}$ g cm^{-3} and ± 0.05 m s^{-1}, respectively. Precautions were taken in order to minimize evaporation losses during storage and preparation of the solutions.

3. Results and Discussion

The experimental densities and speeds of sound of pure liquids of this work appear in Table (1). Our results agree well with those reported in literature [7]. This agreement gives a verification of the results obtained by the densimeter. After preparation of solutions, the densities and speeds of sound for all five binary mixtures of benzyl alcohol with 1-propanol, 2-propanol, 1,3-propandiol, 1,2-propandiol and phenylethanol over the entire composition range and at five different temperatures were measured using u-tube vibrating densimeter. The results are presented in Tables (2) - (6).

Table 1. *Densities,ρ, and speeds of sound, u, for the pure components.*

T/K	ρ/(g · cm^{-3})	u/(m · s^{-1})
benzylalcohol		
298.15	1.04129	
303.15	1.03743	1509.43
308.15	1.03355	1493.7
313.15	1.02966	1478.25
318.15	1.02575	1462.82
1-propanol		
298.15	0.79973	1205.88
303.15	0.79570	1189.02
308.15	0.79163	1172.04
313.15	0.78755	1155.16
318.15	0.78336	1138.34
2-propanol		
298.15	0.78128	1139.36
303.15	0.77701	1121.96
308.15	0.77265	1104.33
313.15	0.76821	1086.63
318.15	0.76367	1068.84
1,2-propandiol		
298.15	1.03250	1508.82
303.15	1.02879	1494.95
308.15	1.02504	1480.89
313.15	1.02125	1466.77
318.15	1.01743	1452.62
1, 3propandiol		
298.15	1.05206	1625.97
303.15	1.04889	1614.65
308.15	1.04571	1603.23
313.15	1.04250	1591.95
318.15	1.03928	1580.78
phenylethanol		
298.15	1.01615	1526.09
303.15	1.01239	1510.48
308.15	1.00861	1494.66
313.15	1.00475	1479.17
318.15	1.00093	1463.25

3.1. Excess Molar Volume

Excess molar volumes,V_m^E, were calculated from density data according to the following equation:

$$V_m^E = \sum_{i=1}^{2} x_i M_i (\rho^{-1} - \rho_i^{-1}) \quad (1)$$

where x_i, M_i, and ρ_i are the mole fraction, the molar mass and the density of the pure component i respectively, ρ is the density of the mixtures, The outcome of the computations has been listed in Table (2) - (6). Figures (1) (a) – (5) (a) shows these results for the excess molar volumes for the given binary mixtures versus the mole fraction at different temperatures. Considering V_m^Es shown in Tables (2) - (6) as well as Figures (1) (a)–(5) (a), it is evident that V_m^E is negative for the all binary systems of benzyl alcohol + 1, 3propandiol, 1, 2propandiol, 1-propanol, 2-propnol and t-butanol over the entire composition range and all temperatures. Moreover, a close inspection of the V_m^Es curves

indicates that the curve skew occurs toward x_1=1 at the sequence of mixtures of benzyl alcohol with1-propanol, 2-propanol, 1, 2 propandiol, 1,3-propandioldiol, and t-butanol. It means that for the mixture benzylalcohol with 1-propanol minimum occurs at x_1=0.6 while for the other mixtures benzylalcohol with the other alcohol the minimum occurs between x_1=0.4 and 0.6, respectively. This behavior may be related to the difference in size and shape of the mixture partners. The negative minus of V_m^E indicates a decrease in the overall volume of the mixture with respect to pure ones. The contraction of the volume can be attributed to strong interactions (mainly due to H-bonding) between unlike molecules. On the other hand, the positive V_m^E s values demonstrate a loose packing of molecules in the mixture, that is, a dilatation.

Table 2. *Densities, ρ, speeds of sound, u, excess molar volumes, V_m^E, deviation in isentropic compressibility's, $\Delta\kappa_s$, and excess thermal expansion coefficients α_P^E as functions of mole fraction, x_1 of glycerol for {benzyl alcohol (1) + 1,2-propanol (2)} mixtures at the temperatures (298.15 to 318.15) K.*

x_1	ρ/g*cm^{-3}	u/m*s^{-1}	V_m^E/cm^{3*}mol^{-1}	$\Delta\kappa_S$/TPa^{-1}	$10^4 \cdot \alpha_P^E$/K^{-1}
$T = 298.15$ K					
0.0000	1.03272	1505.88	0.000	0.00	0.000
0.1034	1.044602	1550.43	-0.206	-22.42	-0.025
0.2049	1.065623	1589.17	-0.369	-32.60	-0.880
0.3051	1.07363	1626.96	-0.492	-37.30	-0.423
0.4062	1.09827	1661.86	-0.557	-39.02	-0.453
0.5042	1.105712	1694.5	-0.577	-39.90	-0.463
0.6032	1.138194	1722.94	-0.592	-40.63	-0.297
0.7048	1.188879	1752.99	-0.527	-40.82	-0.252
0.8057	1.207981	177940	-0.547	-37.36	-0.098
0.9034	1.225682	1703.72	-0.253	-27.55	-0.232
1.0000	1.34129	1725.13	0.000	0.00	0.000
$T = 303.15$ K					
0.0000	1.035697	1371.68	0.000	0.00	0.000
0.1034	1.04057	1507.83	-0.205	-24.35	-0.062
0.2049	1.051161	1543.3	-0.489	-36.01	-0.645
0.3051	1.070618	1581.84	-0.600	-42.29	-0.371
0.4062	1.097272	1626.76	-0.600	-44.25	-0.481
0.5042	1.10676	1680.88	-0.625	-45.46	-0.490
0.6032	1.144239	1748.99	-0.651	-44.03	-0.352
0.7048	1.15486	1739.41	-0.575	-43.54	-0.136
0.8057	1.204066	1861.34	-0.455	-42.16	-0.118
0.9034	1.261794	1992.34	-0.280	-29.79	-0.180
1.0000	1.33743	2002.17	0.000	0.00	0.000
$T = 308.15$ K					
0.0000	1.038626	1372.04	0.000	0.00	0.000
0.1034	1.056496	1416.78	-0.254	-26.59	-0.095
0.2049	1.07562	1456.1	-0.501	-39.99	-0.426
0.3051	1.086574	1493.98	-0.557	-46.33	-0.315
0.4062	1.093243	1528.95	-0.683	-49.36	-0.510
0.5042	1.237751	1561.92	-0.634	-50.45	-0.506
0.6032	1.310249	1592.53	-0.665	-49.69	-0.399
0.7048	1.390896	1620.82	-0.583	-47.89	-0.160
0.8057	1.50129	1647.37	-0.454	-44.43	-0.129
0.9034	1.597885	1672.07	-0.327	-31.61	-0.125
1.0000	1.7355	1693.7	0.000	0.00	0.000

Table 2. *Continued.*

x_1	ρ/g*cm^{-3}	u/m*s^{-1}	V_m^E/cm^{3*}mol^{-1}	$\Delta\kappa_S$/ TPa^{-1}	$10^4 \cdot \alpha_P^E$/K^{-1}
$T = 313.15$ K					
0.0000	1.047518	1355.16	0.000	0.00	0.000
0.1034	1.052387	1400.05	-0.250	-29.40	-0.139
0.2049	1.06347	1439.52	-0.434	-45.02	-0.210
0.3051	1.082496	1477.55	-0.564	-52.16	-0.263
0.4062	1. 09183	1512.59	-0.657	-55.01	-0.526
0.5042	1.99372	1545.68	-0.684	-56.23	-0.511
0.6032	1.136238	1576.43	-0.593	-55.01	-0.449
0.7048	1.20691	1604.84	-0.505	-52.51	-0.110
0.8057	1.36174	1631.58	-0.387	-47.83	-0.146
0.9034	1.413963	1656.39	-0.251	-33.12	-0.079
1.0000	1.62966	1678.25	0.000	0.00	0.000
$T = 318.15$ K					
0.0000	1.03359	1338.34	0.000	0.00	0.000
0.1034	1.048231	1383.4	-0.226	-32.39	-0.180
0.2049	1.069338	1423.04	-0.450	-49.11	0.018
0.3051	1.078383	1461.2	-0.565	-57.30	-0.206
0.4062	1.085093	1496.33	-0.653	-61.07	-0.549
0.5042	1.09649	1529.59	-0.673	-62.85	-0.517
0.6032	1.19199	1560.45	-0.628	-60.36	-0.503

x_1	ρ/g*cm^{-3}	u/m*s^{-1}	V_m^E/cm^{3*}mol^{-1}	$\Delta\kappa_S$/ TPa^{-1}	$10^4 \cdot \alpha_P^E$/K^{-1}
0.7048	1.3029	1588.99	-0.505	-57.16	-0.055
0.8057	1.52199	1615.93	-0.391	-51.35	-0.158
0.9034	1.6002	1640.85	-0.254	-35.00	-0.039
1.0000	1.72575	1662.82	0.000	0.00	0.000

Table 3. *Densities, ρ, speeds of sound, u, excess molar volumes, V_m^E, deviation in isentropic compressibility, $\Delta\kappa_s$, and excess thermal expansion coefficients α_P^E as functions of mole fraction, x_1 of glycerol for {benzyl alcohol (1) + 1-propanol (2)} mixtures at the temperatures (298.15 to 318.15) K.*

x_1	ρ/g*cm^{-3}	u/m*s^{-1}	V_m^E/cm^{3*}mol^{-1}	$\Delta\kappa_S$/TPa^{-1}	$10^4 \cdot \alpha_P^E$/K^{-1}
$T = 298.15$ K					
0.0000	0.79972	1205.88	0.000	0.00	0.000
0.1034	0.834602	1250.43	-0.196	-21.50	-0.016
0.2049	0.865623	1289.17	-0.339	-31.62	-0.863
0.3051	0.89463	1326.96	-0.482	-37.00	-0.403
0.4062	0.921272	1361.86	-0.537	-38.55	-0.446
0.5042	0.945712	1394.5	-0.567	-39.51	-0.473
0.6032	0.968194	1422.94	-0.532	-39.66	-0.289
0.7048	0.988798	1452.99	-0.467	-39.85	-0.242
0.8057	1.007981	147940	-0.347	-36.69	-0.088
0.9034	1.025682	1503.72	-0.213	-26.97	-0.212
1.0000	1.04129	1525.13	0.000	0.00	0.000
$T = 303.15$ K					
0.0000	0.795697	1171.68	0.000	0.00	0.000
0.1034	0.83057	1207.83	-0.195	-23.38	-0.055
0.2049	0.861618	1243.3	-0.389	-35.51	-0.638
0.3051	0.890618	1281.84	-0.500	-41.29	-0.361
0.4062	0.917272	1326.76	-0.560	-43.30	-0.479
0.5042	0.94176	1380.88	-0.595	-44.49	-0.488
0.6032	0.964239	1448.99	-0.551	-44.03	-0.343
0.7048	0.98486	1539.41	-0.475	-42.77	-0.129
0.8057	1.004066	1661.34	-0.355	-41.06	-0.108
0.9034	1.021794	1792.34	-0.220	-28.80	-0.170
1.0000	1.03743	1902.17	0.000	0.00	0.000
$T = 308.15$ K					
0.0000	0.791626	1172.04	0.000	0.00	0.000
0.1034	0.826496	1216.78	-0.204	-25.61	-0.092
0.2049	0.857562	1256.1	-0.401	-39.39	-0.419
0.3051	0.886574	1293.98	-0.517	-45.87	-0.309
0.4062	0.913243	1328.95	-0.583	-48.39	-0.500
0.5042	0.937751	1361.92	-0.614	-49.49	-0.499
0.6032	0.960249	1392.53	-0.565	-48.71	-0.398
0.7048	0.980896	1420.82	-0.483	-46.89	-0.150
0.8057	1.000129	1447.37	-0.354	-43.48	-0.121
0.9034	1.017885	1472.07	-0.227	-30.61	-0.122
1.0000	1.03355	1493.7	0.000	0.00	0.000

Table 3. *Continued.*

x_1	ρ/g*cm^{-3}	u/m*s^{-1}	V_m^E/cm^{3*}mol^{-1}	$\Delta\kappa_S$/ TPa^{-1}	$10^4 \cdot \alpha_P^E$/K^{-1}
$T = 313.15$ K					
0.0000	0.787518	1155.16	0.000	0.00	0.000
0.1034	0.822387	1200.05	-0.210	-28.44	-0.131
0.2049	0.85347	1239.52	-0.414	-44.00	-0.202
0.3051	0.882496	1277.55	-0.534	-51.36	-0.255
0.4062	0.909183	1312.59	-0.607	-54.21	-0.519
0.5042	0.93372	1345.68	-0.634	-55.29	-0.501
0.6032	0.956238	1376.43	-0.583	-54.01	-0.449
0.7048	0.97691	1404.84	-0.495	-51.55	-0.100
0.8057	0.996174	1431.58	-0.367	-46.83	-0.141
0.9034	1.013963	1456.39	-0.231	-32.14	-0.072
1.0000	1.02966	1478.25	0.000	0.00	0.000
$T = 318.15$ K					
0.0000	0.783359	1138.34	0.000	0.00	0.000
0.1034	0.818231	1183.4	-0.216	-31.41	-0.173
0.2049	0.849338	1223.04	-0.430	-48.41	0.011
0.3051	0.878383	1261.2	-0.545	-56.77	-0.202
0.4062	0.905093	1296.33	-0.633	-60.07	-0.546
0.5042	0.929649	1329.59	-0.663	-60.88	-0.513
0.6032	0.952199	1360.45	-0.608	-59.38	-0.501
0.7048	0.9729	1388.99	-0.495	-56.16	-0.051
0.8057	0.992199	1415.93	-0.371	-50.39	-0.155
0.9034	1.01002	1440.85	-0.234	-34.00	-0.032
1.0000	1.02575	1462.82	0.000	0.00	0.000

Table 4. *Densities, ρ, speeds of sound, u, excess molar volumes, V_m^E, deviation in isentropic compressibility, $\Delta\kappa_s$, and excess thermal expansion coefficients α_P^E as functions of mole fraction, x_1 of glycerol for {benzyl alcohol (1) + 2-propanol (2)} mixtures at the temperatures (298.15 to 318.15) K.*

x_1	ρ/g*cm^{-3}	u/m*s^{-1}	V_m^E/cm^{3*}mol^{-1}	$\Delta\kappa_S$/TPa^{-1}	$10^4 \cdot \alpha_P^E$/K^{-1}
$T = 298.15$ K					
0.0000	0.781279	1139.36	0.000	0.00	0.000
0.1034	0.817946	1193.67	-0.099	-17.51	-0.228
0.2049	0.852029	1243.89	-0.265	-29.80	-0.435
0.3051	0.882397	1290.16	-0.398	-36.69	-0.155
0.4062	0.911462	1332.39	-0.522	-41.01	-0.676
0.5042	0.937684	1371.74	-0.551	-42.49	-0.680
0.6032	0.961894	1408.05	-0.589	-43.38	-0.751
0.7048	0.98388	1440.92	-0.533	-42.35	-0.771
0.8057	1.005465	1473.06	-0.483	-38.09	-0.455
0.9034	1.024805	1501.16	-0.302	-25.71	-0.180
1.0000	1.04129	1525.13	0.000	0.00	0.000
$T = 303.15$ K					
0.0000	0.777005	1121.96	0.000	0.00	0.000
0.1034	0.813696	1176.35	-0.112	-19.83	-0.298
0.2049	0.847815	1226.98	-0.288	-33.88	-0.504
0.3051	0.877727	1273.37	-0.418	-41.29	-0.471
0.4062	0.907328	1315.64	-0.542	-46.01	-0.711
0.5042	0.933566	1355.17	-0.584	-47.48	-0.706
0.6032	0.957838	1391.61	-0.621	-47.86	-0.725
0.7048	0.979869	1424.67	-0.569	-46.29	-0.601
0.8057	1.001501	1456.9	-0.501	-41.08	-0.339
0.9034	1.020897	1485.53	-0.310	-27.03	-0.058
1.0000	1.03743	1509.43	0.000	0.00	0.000
$T = 308.15$ K					
0.0000	0.77265	1104.33	0.000	0.00	0.000
0.1034	0.809377	1158.99	-0.127	-22.61	-0.355
0.2049	0.843536	1209.79	-0.314	-38.39	-0.588
0.3051	0.872984	1256.37	-0.437	-46.49	-0.801
0.4062	0.90314	1298.78	-0.587	-51.70	-0.742
0.5042	0.929446	1338.45	-0.615	-53.08	-0.731
0.6032	0.953748	1375.1	-0.653	-53.05	-0.719
0.7048	0.975833	1408.33	-0.583	-50.16	-0.441
0.8057	0.997516	1440.79	-0.512	-44.18	-0.220
0.9034	1.016965	1469.59	-0.308	-28.89	0.065
1.0000	1.03355	1493.7	0.000	0.00	0.000

Table 4. *continued.*

x_1	ρ/g*cm^{-3}	u/m*s^{-1}	V_m^E/cm^{3*}mol^{-1}	$\Delta\kappa_S$/ TPa^{-1}	$10^4 \cdot \alpha_P^E$/K^{-1}
$T = 313.15$ K					
0.0000	0.768208	1086.63	0.000	0.00	0.000
0.1034	0.804985	1141.59	-0.146	-25.72	-0.422
0.2049	0.839199	1192.6	-0.343	-43.38	-0.668
0.3051	0.856654	1238.99	-0.494	-52.55	-1.122
0.4062	0.898909	1281.95	-0.622	-58.01	-0.781
0.5042	0.925273	1321.81	-0.648	-59.07	-0.761
0.6032	0.949619	1358.65	-0.685	-58.71	-0.700
0.7048	0.97177	1392.08	-0.603	-55.00	-0.272
0.8057	0.993509	1424.77	-0.520	-47.63	-0.101
0.9034	1.013014	1453.78	-0.304	-30.88	0.191
1.0000	1.02966	1478.25	0.000	0.00	0.000
$T = 318.15$ K					
0.0000	0.76367	1086.84	0.000	0.00	0.000
0.1034	0.800051	1124.13	-0.168	-29.23	-0.490
0.2049	0.834793	1175.37	-0.377	-48.40	-0.745
0.3051	0.848137	1221.97	-0.545	-59.22	-1.459
0.4062	0.894635	1265.15	-0.654	-64.83	-0.822
0.5042	0.921059	1305.24	-0.685	-65.59	-0.791
0.6032	0.945482	1342.26	-0.716	-64.86	-0.683
0.7048	0.967664	1375.9	-0.613	-60.13	-0.102
0.8057	0.989477	1408.88	-0.524	-51.51	0.012
0.9034	1.009043	1438.08	-0.297	-32.91	0.318
1.0000	1.02575	1462.82	0.000	0.00	0.000

Table 5. *Densities, ρ, speeds of sound, u, excess molar volumes, V_m^E, deviation in isentropic compressibility, $\Delta\kappa_s$, and excess thermal expansion coefficients α_P^E as functions of mole fraction, x_1 of glycerol for {{benzyl alcohol (1) +1,3-propanol (2)} mixtures at the temperatures (298.15 to 318.15) K.*

x_1	ρ/g*cm^{-3}	u/m*s^{-1}	V_m^E/cm^{3*}mol^{-1}	$\Delta\kappa_S$/TPa^{-1}	$10^4 \cdot \alpha_P^E$/K^{-1}
$T = 298.15$ K					
0.0000	1.04129	1525.13	0.000	0.00	0.000
0.1043	1.05728	1543.09	0.041	4.72	0.052
0.2038	1.07409	1562.03	0.027	8.61	0.111
0.3053	1.09245	1584.55	0.004	11.50	0.113
0.4087	1.11251	1612.10	-0.024	13.02	0.120
0.5045	1.13247	1642.75	-0.056	13.12	0.184
0.6037	1.15432	1680.15	-0.068	12.25	0.101
0.7059	1.17848	1727.55	-0.078	9.71	0.072
0.8039	1.20330	1783.84	-0.077	5.79	0.030
0.9069	1.23127	1851.74	-0.063	1.63	0.059
1.0000	1.25777	1914.44	0.000	0.00	0.000
$T = 303.15$ K					
0.0000	1.03743	1509.43	0.000	0.00	0.000
0.1043	1.05343	1527.76	0.044	4.73	0.061
0.2038	1.07025	1547.04	0.032	8.62	0.111
0.3053	1.08865	1570.02	0.010	11.47	0.120
0.4087	1.10876	1597.69	-0.019	13.11	0.123
0.5045	1.12876	1628.77	-0.050	13.16	0.182
0.6037	1.15071	1666.50	-0.065	12.22	0.108
0.7059	1.17497	1714.34	-0.076	9.64	0.101
0.8039	1.19991	1770.93	-0.078	5.62	0.090
0.9069	1.22798	1839.23	-0.062	1.52	0.105
1.0000	1.25461	1902.17	0.000	0.00	0.000
$T = 308.15$ K					
0.0000	1.03355	1493.70	0.000	0.00	0.000
0.1043	1.04955	1512.33	0.048	4.81	0.069
0.2038	1.06639	1531.86	0.038	8.73	0.108
0.3053	1.08483	1555.20	0.016	11.58	0.121
0.4087	1.10499	1583.27	-0.012	13.20	0.122
0.5045	1.12501	1614.62	-0.040	13.22	0.181
0.6037	1.14708	1652.86	-0.060	12.26	0.120
0.7059	1.17141	1701.05	-0.070	9.63	0.132
0.8039	1.19644	1758.22	-0.071	5.51	0.150
0.9069	1.22462	1827.15	-0.055	1.42	0.163
1.0000	1.25150	1890.42	0.000	0.00	0.000

Table 5. *Continued.*

x_1	ρ/g*cm^{-3}	u/m*s^{-1}	V_m^E/cm^{3*}mol^{-1}	$\Delta\kappa_S$/ TPa^{-1}	$10^4 \cdot \alpha_P^E$/K^{-1}
$T = 313.15$ K					
0.0000	1.02966	1478.25	0.000	0.00	0.000
0.1043	1.04566	1497.01	0.052	4.95	0.075
0.2038	1.06252	1516.79	0.044	8.93	0.102
0.3053	1.08100	1540.52	0.022	11.74	0.128
0.4087	1.10122	1568.94	-0.006	13.34	0.130
0.5045	1.12125	1600.59	-0.031	13.43	0.178
0.6037	1.14343	1639.24	-0.053	12.36	0.131
0.7059	1.16784	1687.96	-0.063	9.65	0.163
0.8039	1.19294	1745.76	-0.063	5.50	0.210
0.9069	1.22123	1815.05	-0.046	1.42	0.218
1.0000	1.24838	1879.08	0.000	0.00	0.000
$T = 318.15$ K					
0.0000	1.02575	1462.82	0.000	0.00	0.000
0.1043	1.04175	1481.8	0.056	5.08	0.081
0.2038	1.05864	1501.85	0.049	9.12	0.100
0.3053	1.07715	1525.86	0.028	11.92	0.132
0.4087	1.09742	1554.65	0.000	13.50	0.131
0.5045	1.11751	1586.66	-0.025	13.53	0.173
0.6037	1.13977	1625.72	-0.049	12.41	0.142
0.7059	1.16424	1674.9	-0.057	9.69	0.193
0.8039	1.18941	1733.17	-0.055	5.49	0.271
0.9069	1.21782	1803.06	-0.039	1.38	0.272
1.0000	1.24521	1867.86	0.000	0.00	0.000

Table 6. *Densities, ρ, speeds of sound, u, excess molar volumes, V_m^E, deviation in isentropic compressibilities, $\Delta\kappa_s$, and excess thermal expansion coefficients α_P^E as functions of mole fraction, x_1 of glycerol for {{benzilalcohol (1) +phenylethanol (2)} mixtures at the temperatures (298.15 to 318.15) K.*

x_1	ρ/g*cm^{-3}	u/m*s^{-1}	V_m^E/cm^{3*}mol^{-1}	$\Delta\kappa_S$/TPa^{-1}	$10^4 \cdot \alpha_P^E$/K^{-1}
$T = 298.15$ K					
0.0000	1.04129	1525.13	0.000	0.00	0.000
0.1043	1.05728	1543.09	0.041	4.77	0.057
0.2038	1.07409	1562.03	0.027	8.63	0.115
0.3053	1.09245	1584.55	0.004	11.50	0.116
0.4087	1.11251	1612.10	-0.024	13.01	0.122
0.5045	1.13247	1642.75	-0.056	13.19	0.189
0.6037	1.15432	1680.15	-0.068	12.31	0.101
0.7059	1.17848	1727.55	-0.078	9.75	0.075
0.8039	1.20330	1783.84	-0.077	5.81	0.033
0.9069	1.23127	1851.74	-0.063	1.66	0.061
1.0000	1.25777	1914.44	0.000	0.00	0.000
$T = 303.15$ K					
0.0000	1.03743	1509.43	0.000	0.00	0.000
0.1043	1.05343	1527.76	0.044	4.76	0.065
0.2038	1.07025	1547.04	0.032	8.63	0.113
0.3053	1.08865	1570.02	0.010	11.45	0.122
0.4087	1.10876	1597.69	-0.019	13.14	0.125
0.5045	1.12876	1628.77	-0.050	13.18	0.183
0.6037	1.15071	1666.50	-0.065	12.26	0.111
0.7059	1.17497	1714.34	-0.076	9.66	0.107
0.8039	1.19991	1770.93	-0.078	5.65	0.092
0.9069	1.22798	1839.23	-0.062	1.56	0.113
1.0000	1.25461	1902.17	0.000	0.00	0.000
$T = 308.15$ K					
0.0000	1.03355	1493.70	0.000	0.00	0.000
0.1043	1.04955	1512.33	0.048	4.84	0.070
0.2038	1.06639	1531.86	0.038	8.73	0.110
0.3053	1.08483	1555.20	0.016	11.60	0.126
0.4087	1.10499	1583.27	-0.012	13.20	0.125
0.5045	1.12501	1614.62	-0.040	13.28	0.183
0.6037	1.14708	1652.86	-0.060	12.27	0.122
0.7059	1.17141	1701.05	-0.070	9.61	0.133
0.8039	1.19644	1758.22	-0.071	5.59	0.153
0.9069	1.22462	1827.15	-0.055	1.45	0.167
1.0000	1.25150	1890.42	0.000	0.00	0.000

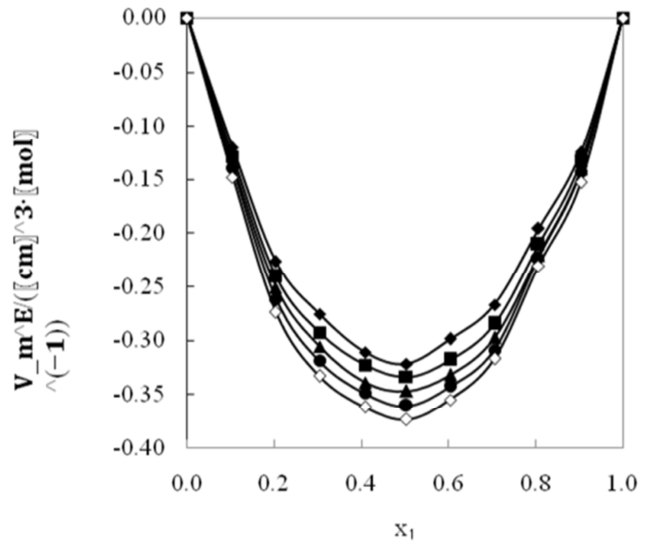

Figure 1. *Plot of: (a) excess molar volumes against mole fraction for {benzylalcohol (1) + 1,2-propandiol (2)} at the temperatures 298.15 K; ◆, 303.15 K; ■, 308.15 K; ▲, 313.15 K; ●, 318.15 K; ◊.*

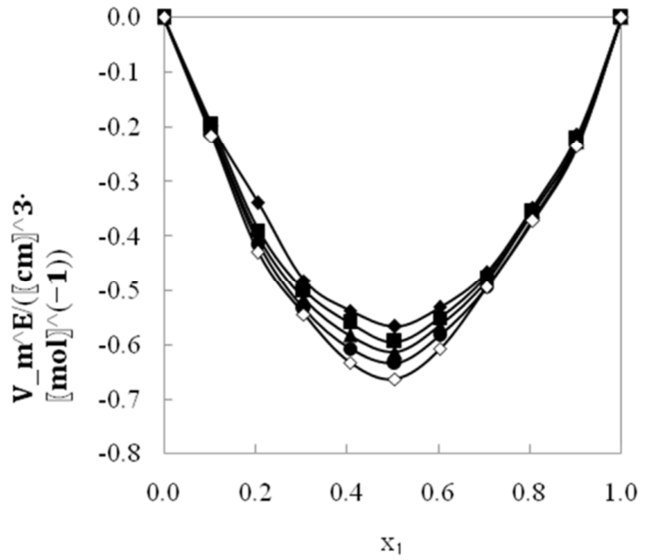

Figure 2. *Plot of: (a) excess molar volumes against mole fraction for {benzylalcohol (1) + 1-propanol (2)} at the temperatures 298.15 K; ◆, 303.15 K; ■, 308.15 K; ▲, 313.15 K; ●, 318.15 K; ◊.*

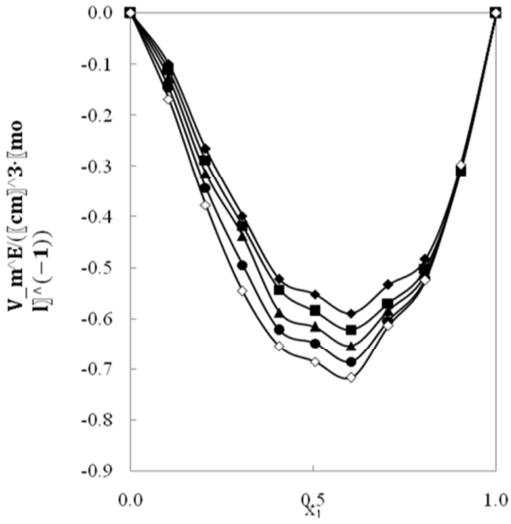

Figure 3. *Plot of: (a) excess molar volumes against mole fraction for {benzylalcohol (1) + 2-propanol (2)} at the temperatures 298.15 K; ◆, 303.15 K; ■, 308.15 K; ▲, 313.15 K; ●, 318.15 K; ◊.*

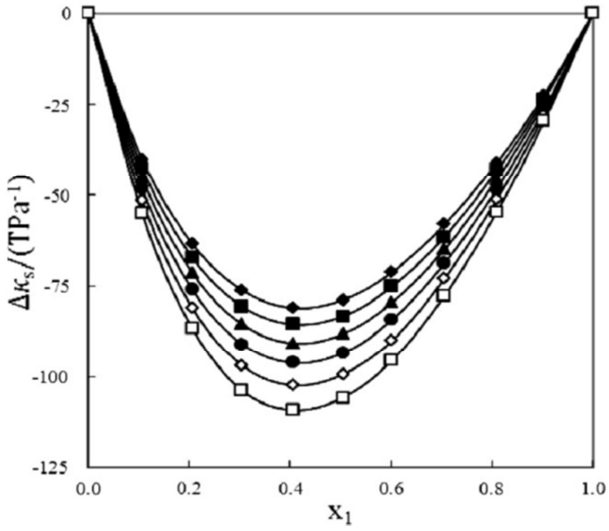

Figure 4. *Plot of: (a) excess molar volumes against mole fraction for { benzylalcohol (1) + 1,3-propandiol (2) } at the temperatures 298.15 K; ◆, 303.15 K; ■, 308.15 K; ▲, 313.15 K; ●, 318.15 K; ◊.*

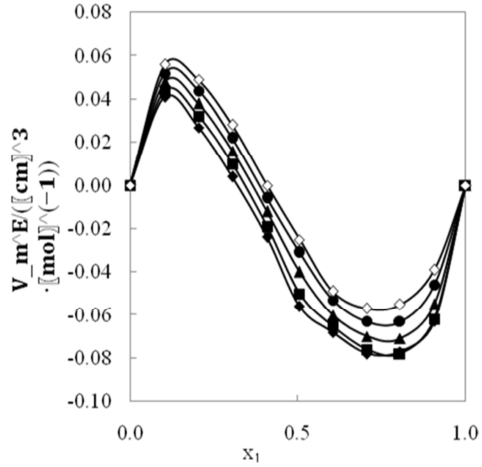

Figure 5. *Plot of: (a) excess molar volumes, against mole fraction for {benzylalcohol (1) + phenylethanol (2)} at the temperatures 298.15 K; ◆, 303.15 K; ■, 308.15 K; ▲, 313.15 K; ●, 318.15 K; ◊.*

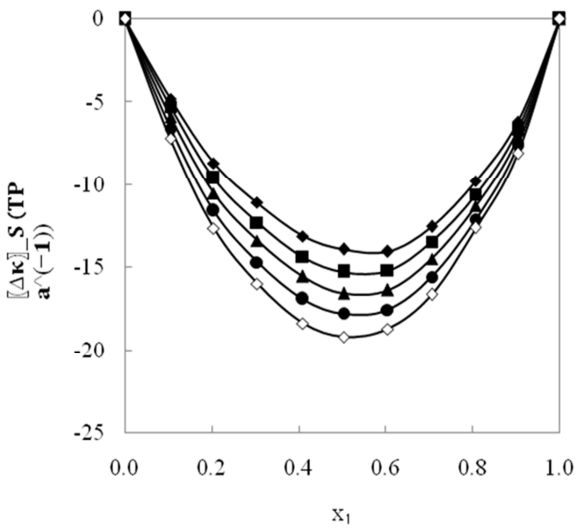

Figure 6. *Plot of (b) deviations in isentropic compressibility against mole fraction for {benzylalcohol (1) + 1,2-propandiol (2)} at the temperatures 298.15 K; ◆, 303.15 K; ■, 308.15 K; ▲, 313.15 K; ●, 318.15 K; ◊.*

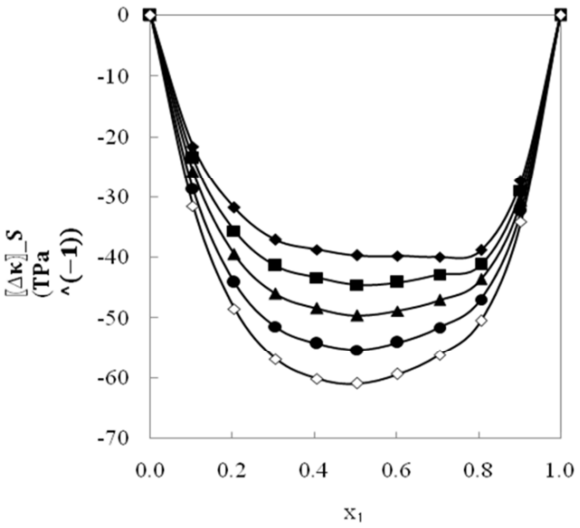

Figure 7. *Plot of: (b) deviations in isentropic compressibility against mole fraction for {benzylalcohol (1) + 1-propanol (2)} at the temperatures 298.15 K; ◆, 303.15 K; ■, 308.15 K; ▲, 313.15 K; ●, 318.15 K; ◊.*

3.2. Speed of Sound Excess Isentropic Compressibility

By employing the experimental values of ρ and u, deviations in isentropic compressibility, $\Delta\kappa_s$ were obtained from the equation:

$$\Delta\kappa_s = \kappa_s - \sum_{i=1} x_i \kappa_{s,i} \quad (2)$$

Where $\kappa_{s,I}$ and κ_s are the isentropic compressibilities of the pure component i and mixtures, respectively. The isentropic compressibility, κ_s, was calculated using the Newton–Laplace equation:

$$\kappa_s = 1/\rho u^2 \quad (3)$$

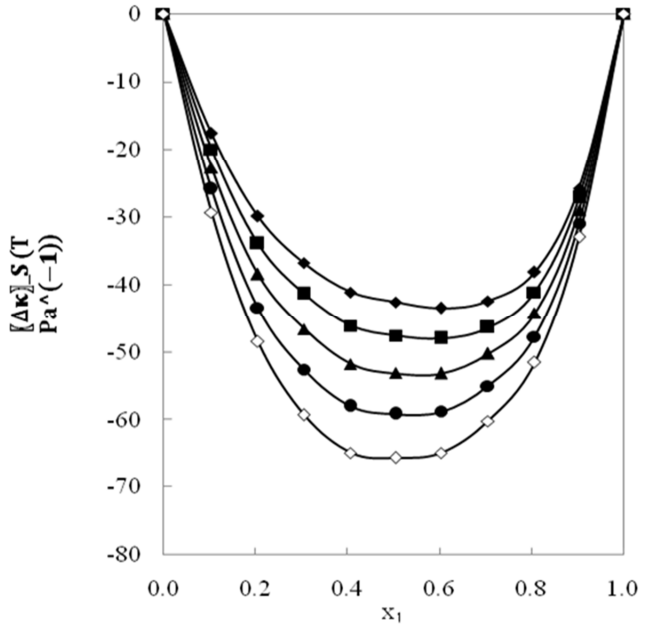

Figure 8. *Plot of: (b) deviations in isentropic compressibility against mole fraction for {benzylalcohol (1) + 2-propanol (2)} at the temperatures 298.15 K; ◆, 303.15 K; ■, 308.15 K; ▲, 313.15 K; ●, 318.15 K; ◊.*

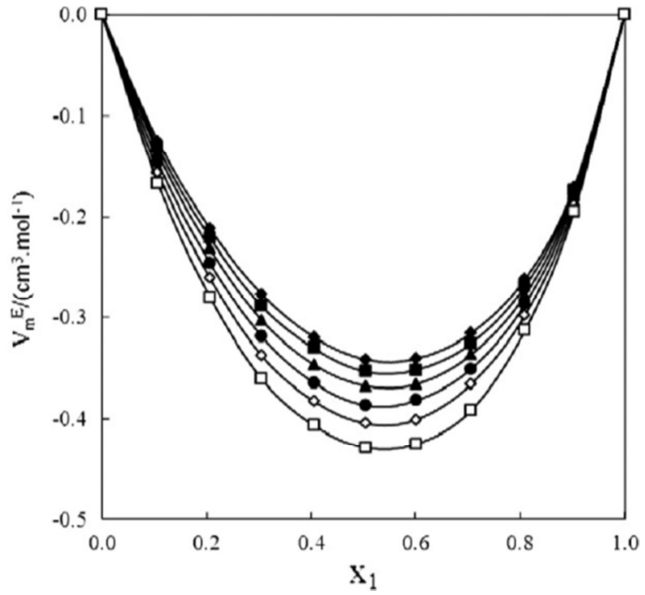

Figure 9. *Plot of: (b) deviations in isentropic compressibility against mole fraction for { benzylalcohol (1) + 1,3-propandiol (2) } at the temperatures 298.15 K; ◆, 303.15 K; ■, 308.15 K; ▲, 313.15 K; ●, 318.15 K; ◊.*

The calculated Δκs values for the selected binary mixtures are listed in Tables (2) - (6). The change of this property has been shown in Figures (1-5) (b). It is evident from Figure 1-5) (b) and Tables (2) - (6) that the Δκs values are negative over the entire mole fraction range and become more negative with increasing temperature for all binary mixtures. Thus, the mixtures are less compressible than the pure components, i.e., the greater resistance to compression (enhanced rigidity) is observed. The most of the systems show both enhanced rigidity (Δκs < 0) and contraction (V_m^E < 0) over the entire composition range. In other words, the volume decreases (more compact packing of molecules), and simultaneously the whole system becomes more rigid (less compressible). Interpretation of the Δκs data is generally not simple because the Δκs values are affected by both the molecular packing and the patterns of molecular aggregation induced by the molecular interactions. However, in these three binary systems it seems that interpretation of negative Δκs values is the same as negative V_m^E values.

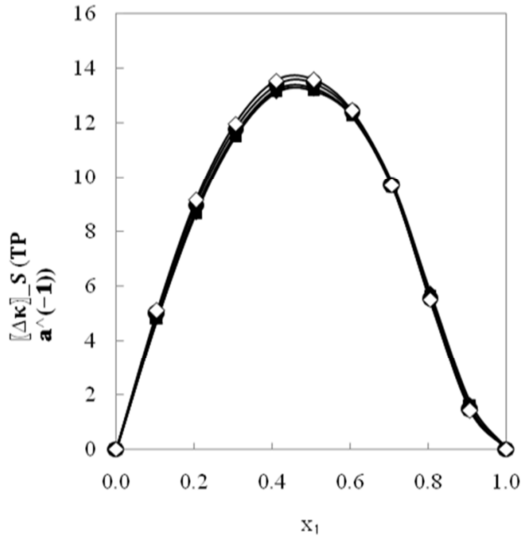

Figure 10. *Plot of: (b) deviations in isentropic compressibility against mole fraction for {benzylalcohol (1) + phenylethanol (2)} at the temperatures 298.15 K; ◆, 303.15 K; ■, 308.15 K; ▲, 313.15 K; ●, 318.15 K; ◊.*

3.3. Excess Thermal Expansion Coefficient

The excess thermal expansion coefficient, α_P^E, were determined using the following equation:

$$\alpha_P^E = \alpha_P - \sum_{i=1}^{2} \varphi_i \alpha_{P,i} \quad (4)$$

where α_P and $\alpha_{P,i}$ are thermal expansion coefficients of the mixture and pure component i, respectively;$\varphi_i$represents the volume fraction of component i obtained through the relation:

$$\varphi_i = \frac{x_i V_i^*}{\sum_{i=1}^{2} x_i V_i^*} \quad (5)$$

Where V_i^* is the molar volume of the pure component i. The thermal expansion coefficient, α_P, was calculated from:

$$\alpha_P = -\frac{1}{\rho}\left(\frac{\partial \rho}{\partial T}\right)_P \quad (6)$$

The measured densities for all components were fitted with temperature by the following simple polynomial equation:

$$\rho(T) = \sum_{i=0}^{2} a_i (T/\mathrm{K})^i \quad (7)$$

Where a_i refer to the fitting coefficients.

By employing Esq. (4) - (7) the numerical values of α_P^E were calculated for the selected binary mixtures. The numerical results have been tabulated in Tables (2) – (6). From Tables (2) - (6) and Figures (1) - (5) (c) it is obvious that the values of excess thermal expansion coefficients α_p^E are negative over the whole composition range for the

considered mixtures In general, negative α_p^E values indicate the presence of strong interaction between the components in the mixtures.

The composition dependence of V_m^E, $\Delta\kappa_s$ and α_P^E of all binary mixtures, were fitted to a Redlich–Kister type polynomial equation:

$$Y^E = x_1 x_2 \sum_{i=0}^{3} A_i (1 - 2x_1)^i \quad (8)$$

Where Y^E stands for V_m^E, $\Delta\kappa_s$ and α_P^E. A_i are the polynomial coefficients and x is the mole fraction. The coefficients A_i in Eq. 8) were allowed to vary using a non-linear least squares method and are listed in Table (7). To ascertain the validity of the polynomial coefficients, the standard deviations $\sigma(Y^E)$ are also calculated from the following expression and included in Table (7).

$$\sigma(Y^E) = \left[\sum_{i=1}^{n} \frac{(Y_i - Y_i(calc.))^2}{n-p}\right]^{1/2} \quad (9)$$

Where n is the number of experimental data and p is the number of parameters.

Table 7. *Coefficients, $A_i$from Eq. (8) for V_m^E, $\Delta\kappa_s$,α_P^E and standard deviations σfor benzilalcohol + 1,3-propandiol, 1,3-propandiol, 1-propanol, 2-propanol and t-butanol mixtures at temperatures from 298.15 to 318.15 K.*

Property	T/K	A_0	A_1	A_2	A_3	σ
Benzylalcohol (1) +1,2-propandiol (2)						
	298.15	-1.2634	-0.1182	-0.1311	0.2138	0.007
	303.15	-1.3238	-0.0913	-0.2209	0.1746	0.008
V_m^E/cm^{3*}mol^{-1}	308.15	-1.3819	-0.1113	-0.2309	0.2054	0.007
	313.15	-1.4535	-0.1211	-0.2131	0.1639	0.009
	318.15	-1.4819	-0.1626	-0.2783	0.2418	0.009
	298.15	-56.67	8.89	-7.12	2.34	0.21
	303.15	-60.70	6.90	-7.43	5.88	0.21
$\Delta\kappa_S$/ TPa^{-1}	308.15	-65.81	6.68	-8.53	4.64	0.25
	313.15	-70.93	5.55	-10.52	5.10	0.23
	318.15	-7.74	2.90	-1.23	6.62	0.30
	298.15	-1.51261	2.15325	-4.9845	1.0875	0.333
	303.15	-1.37009	0.75108	-1.7968	0.0426	0.079
$10^4 \cdot \alpha_P^E$/K^{-1}	308.15	-1.29502	-0.69357	1.41682	-0.9885	0.194
	313.15	-1.22523	-2.14394	4.65273	-2.0256	0.460
	318.15	-1.16061	-3.58215	7.94834	-3.0804	0.732
Benzylalcohol (1) + 1-propanol (2)						
	298.15	-2.2051	-0.0895	0.0700	0.4465	0.010
	303.15	-2.3400	-0.2116	0.0638	0.6038	0.010
V_m^E/cm^{3*}mol^{-1}	308.15	-2.4013	-0.2938	0.1108	0.6850	0.011
	313.15	-2.4957	-0.3288	0.1442	0.7581	0.010
	318.15	-2.5920	-0.3860	0.2760	0.7797	0.016
	298.15	-156.57	11.19	-176.55	63.93	0.58
	303.15	-174.97	3.145	-177.23	71.26	0.69
$\Delta\kappa_S$/ TPa^{-1}	308.15	-195.38	-1.05	-178.09	71.10	0.57
	313.15	-219.44	-4.96	-182.10	64.65	0.52
	318.15	-241.58	-8.91	-187.08	62.21	0.49
	298.15	-1.71563	-3.03623	-0.98801	4.11638	0.222
$10^4 \cdot \alpha_P^E$/K^{-1}	303.15	-1.72135	-2.59565	0.07873	3.58621	0.153
	308.15	-1.90504	-1.63241	1.09382	1.95767	0.097

Table 7. *continued.*

Benzylalcohol (1) + phenylethanol (2)						
	298.15	-0.2181	0.4245	0.1289	0.4684	0.004
	303.15	-0.1886	0.4628	0.1207	0.4547	0.003
V_m^E/cm^{3-}mol^{-1}	308.15	-0.1710	0.4567	0.1581	0.3972	0.003
	313.15	-0.1342	0.4597	0.2115	0.3433	0.002
	318.15	-0.2041	0.4714	0.2603	0.2710	0.004
	298.15	54.86	5.5	-24.78	20.99	0.20
	303.15	53.95	6.12	-25.94	21.56	0.19
$\Delta\kappa_S$/ TPa^{-1}	308.15	54.37	6.77	-26.72	22.37	0.20
	313.15	54.88	7.63	-26.92	23.10	0.18
	318.15	55.39	8.44	-27.02	23.01	0.18
	298.15	0.56027	0.39127	-0.13909	-0.44829	0.033
	303.15	0.55041	0.28840	0.37896	-0.85222	0.030
$10^4 \cdot \alpha_P^E$/ K^{-1}	308.15	0.54939	0.17739	0.91041	-1.31337	0.028
	313.15	0.54454	0.06993	1.42560	-1.74029	0.027
	318.15	0.54077	-0.03574	1.95118	-2.18964	0.026

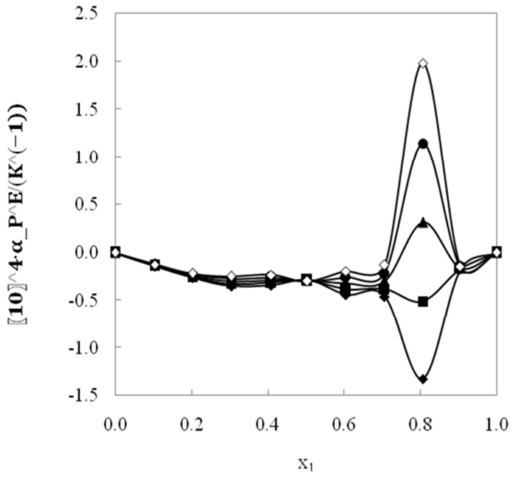

Figure 11. *Plot of: (c) excess thermal expansion coefficients against mole fraction for {benzylalcohol (1) + 1,2-propandiol (2)} at the temperatures 298.15 K; ◆, 303.15 K; ■, 308.15 K; ▲, 313.15 K; ●, 318.15 K; ◊.*

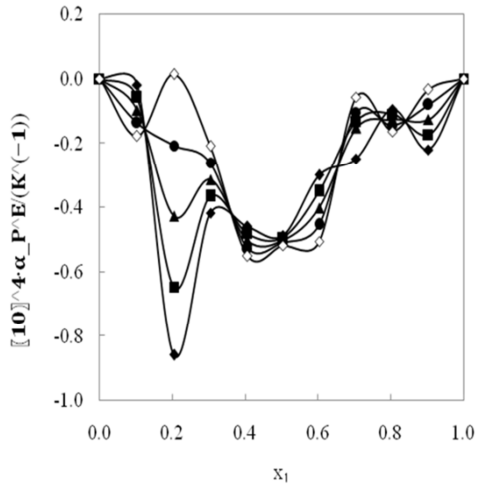

Figure 12. *Plot of: (c) excess thermal expansion coefficients against mole fraction for {benzylalcohol (1) + 1-propanol (2)} at the temperatures 298.15 K; ◆, 303.15 K; ■, 308.15 K; ▲, 313.15 K; ●, 318.15 K; ◊.*

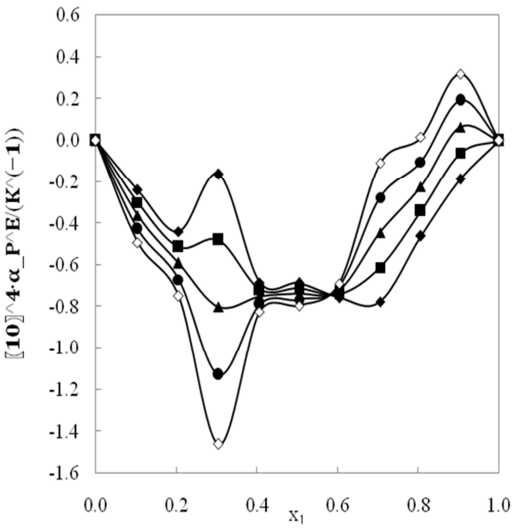

Figure 13. *Plot of (c) excess thermal expansion coefficients against mole fraction for {benzylalcohol (1) + 2-propanol (2)} at the temperatures 298.15 K; ◆, 303.15 K; ■, 308.15 K; ▲, 313.15 K; ●, 318.15 K; ◊.*

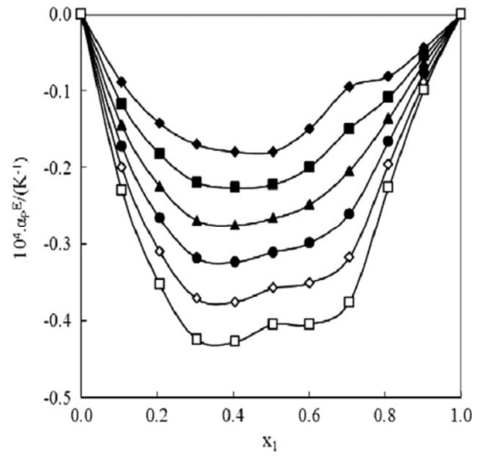

Figure 14. *Plot of: (c) excess thermal expansion coefficients against mole fraction for {benzylalcohol (1) + 1,3-propandiol (2)} at the temperatures 298.15 K; ◆, 303.15 K; ■, 308.15 K; ▲, 313.15 K; ●, 318.15 K; ◊.*

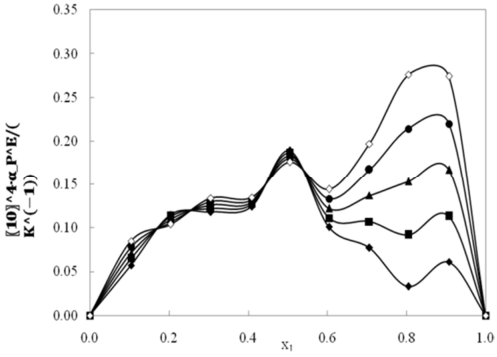

Figure 15. *Plot of: (c) excess thermal expansion coefficients against mole fraction for {benzylalcohol (1) + phenylethanol (2)} at the temperatures 298.15 K; ◆, 303.15 K; ■, 308.15 K; ▲, 313.15 K; ●, 318.15 K; ◊.*

3.4. The Partial Molar Volume

The partial molar volume $\bar{V}_i$ of each component was calculated by using the following reactions:

$$\bar{V}_i = V_m^E + V_i^* + (1 - x_i)\left(\frac{\partial V_m^E}{\partial x_i}\right)_{T,P} \quad (10)$$

where V_i^* is the molar volume of pure component i. By differentiating Eq. (8) and employing Eq. (10). $\bar{V}_1$ and $\bar{V}_2$ were computed according to the following equations:

$$\bar{V}_1 = V_1^* + x_2^2 \sum_{i=0}^{3} A_i(1-2x_1)^i - 2x_1x_2^2 \sum_{i=0}^{3} A_i(i)(1-2x_1)^{i-1} \quad (11)$$

By using Eqs. (11) and (12) the partial molar volumes at infinite dilution were calculated and with the help of Eqs. (13) and (14), the excess partial molar volumes, $\bar{V}_1^{E,\infty}$ and $\bar{V}_2^{E,\infty}$ of each component at infinite dilution were calculated:

$$\bar{V}_2 = V_2^* + x_1^2 \sum_{i=0}^{3} A_i(1-2x_1)^i - 2x_1^2x_2 \sum_{i=0}^{3} A_i(i)(1-2x_1)^{i-1} \quad (12)$$

$$\bar{V}_1^{E,\infty} = \bar{V}_1^{\infty} - V_1^* \quad (13)$$

$$\bar{V}_2^{E,\infty} = \bar{V}_2^{\infty} - V_2^* \quad (14)$$

The values of $V_1^*, V_2^*, \bar{V}_1^{\infty}, \bar{V}_2^{\infty}, \bar{V}_1^{E,\infty}$ and $\bar{V}_2^{E,\infty}$ for all four binary systems at different temperatures are listed in Table 8.

Table 8. *The values of V_1^*,V_2^*,$\bar{V}_1^\infty$, $\bar{V}_2^\infty$,$\bar{V}_1^{E,\infty}$ and $\bar{V}_2^{E,\infty}$ for benzylalcohol + 1,3-propandiol, 1,3-propandiol, 1-propanol, 2-propanol and t-butanol mixtures at the temperatures from 298.15 to 318.15 K.*

T/K	V_1^*	V_2^*	$\bar{V}_1^\infty$	$\bar{V}_2^\infty$	$\bar{V}_1^{E,\infty}$	$\bar{V}_2^{E,\infty}$
	($cm^{3*}mol^{-1}$)					
Benzylalcohol (1) + 1,2-propandiol (2)						
298.15	73.325	90.108	71.925	88.510	-1.320	-1.520
303.15	73.419	90.395	71.956	88.745	-1.465	-1.650
308.15	73.595	90.809	72.083	89.016	-1.520	-1.749
313.15	73.786	91.143	72.181	89.405	-1.605	-1.730
318.15	73.971	91.536	72.295	89.658	-1.671	-1.869
Benzylalcohol (1) + 1-propanol (2)						
298.15	73.257	92.985	71.505	90.523	-1.803	-2.543
303.15	73.415	93.418	71.527	90.690	-1.896	-2.670
308.15	73.602	93.834	71.693	91.321	-1.921	-2.693
313.15	73.786	94.291	71.856	91.491	-1.951	-2.770
318.15	73.973	94.788	72.122	92.071	-1.931	-2.710
Benzylalcohol (1) + 2-propanol (2)						
298.15	73.227	92.276	72.914	87.958	-0.321	-4.337
303.15	73.410	92.800	72.798	88.457	-0.613	-4.313
308.15	73.593	93.262	72.907	89.082	-0.795	-4.189
313.15	73.778	93.791	72.782	89.645	-0.994	-4.238
318.15	73.973	94.318	72.704	90.339	-1.299	-3.989
Benzylalcohol (1) + 1,3-propandiol (2)						
298.15	73.225	103.862	74.028	102.910	0.796	-0.962
303.15	73.410	104.248	74.230	103.293	0.822	-0.952
308.15	73.596	104.640	74.440	103.783	0.843	-0.857
313.15	73.778	105.035	74.646	103.915	0.870	-0.717
318.15	73.965	105.445	74.872	104.839	0.899	-0.586
Benzylalcohol + phenylethanol						
298.15	73.235	103.862	74.118	102.902	0.894	-0.970
303.15	73.419	104.338	74.239	103.283	0.920	-0.969
308.15	73.595	104.633	74.443	103.793	0.941	-0.857
313.15	73.776	105.035	74.746	103.914	0.879	-0.736
318.15	73.973	105.525	74.862	104.844	0.899	-0.686

As it is evident from Table 8, the partial molar volumes of benzyl alcohol at infinite dilution $\bar{V}_1^\infty$, in1,2-propandiol, 1-propanol, 1,3-propandiol and 2-propanol, and the partial molar volumes of 1,2-propandiol, 1-propanol, 1,3-propandio and 2-propanol at infinite dilution, $\bar{V}_2^\infty$ in benzyl alcohol are smaller than the corresponding molar volume V_1^* and V_2^* of benzyl alcohol and four mentioned alcohols, respectively. This observation is consistent with an idea that the molar volume of pure components is a result of the sum of the actual molar volume plus the free or empty volume that arises from the intra-molecular self-association of pure molecules. Thus negative $\bar{V}_1^{E,\infty}$ and $\bar{V}_2^{E,\infty}$ values of benzyl alcohol + 1,2-propandiol, 1-propanol, 1,3-propandiol and, 2-propanol and phenylethanol suggest the contraction in volume of the mixtures on mixing, which may be attributed to the presence of significant interactions between benzyl alcohol and 1,2-propandiol, 1-propanol, 1,3-propandiol, 2-propanol and phenylethanol molecules. As a final work we modeled the experiment results by using TM and PR EOSs and results are gathered in Table 9. This is clear that the results with TM EOS are more acceptable than PR EOS. TM and PR EOS can successfully predict density and excess molar volume. And are unable to predict speed of sound.

Table 9. *Average absolute deviations of the calculated densities, excess molar volumes, and speed of sound using Peng-Robinson (PR) and Tao-Mason (TM) equations of state from the measured ones.*

TM EOS	AAD (density)	AAD (sound velocity)	AAD (excess volume)
Benzylalcohol + 1, 3propandiol	0.98	14.92	1.68
Benzylalcohol + 1, 2propandiol	0.96	13.18	1.51
Benzylalcohol + t-butanol	1.27	14.60	2.74
Benzylalcohol + 1propanol	1.09	16.02	1.41
Benzylalcohol + 2propanol	1.08	15.95	1.52
PR EOS			
Benzylalcohol + 1, 3propandiol	1.79	20.05	2.23
Benzylalcohol + 1, 2propandiol	1.73	21.73	1.91
Benzylalcohol + t-butanol	2.52	19.52	2.638
Benzylalcohol + 1propanol	1.70	17.83	2.25
Benzylalcohol + 2propanol	1.65	17.51	2.65

4. Conclusion

This article reported the densities and speed of sound of six pure (benzyl alcohol, 1-propanol, 2-propanol, 1,2-propandiol, 1, 3propandiol, phenyl ethanol) and mixtures, at T = 298.15 K to 323.15 K at 5 K interval and atmospheric pressure over the entire range of mole fractions using a vibrating tube densimeter. As outlined earlier all systems under study showed non-ideal behavior. This non-ideality can be explained by two factors intermolecular forces in the mixture and enhanced rigidity. The main source of intermolecular interactions comes from hydrogen bonding between the components and also interaction between π electrons of benzene ring and proton of alkanols and instead of experimental work we can calculate thermodynamic properties.

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