

CHAPTER-V

Study of the Solution Properties of Ternary Mixtures of 1,3-Dioxolane (1), Diethyl Ether (2), and *n*-Amyl Alcohol (3) and the Corresponding Binary Mixtures by Density, Viscosity, Refractivity, and Ultrasonic Speed Measurements at 298.15 K

5.1. Introduction

Knowledge of densities, excess volumes and viscosities of fluids and fluid mixtures is essential to understand the molecular interactions between unlike molecules, to develop new theoretical models and also for engineering applications in the process industry. Ultrasonic methods find extensive applications owing to their ability of characterizing the physico-chemical behaviour of liquid systems from absorption and velocity data. It is also possible to investigate molecular packing, molecular motion, various types and extent of intermolecular interaction influenced by the size, shape and chemical nature of component molecules and microscopic structure of liquids.

The amyl alcohols are used fundamentally for the perfumes composition and the synthesis of fruit essences. They are also used as solvents for surfaces and lacquer baths, inks for print and dyes for wool as well as in the chemical production of photographic and pharmaceutical substances. Furthermore, they are an intermediate in the production of amyl acetate and other amyl esters. 1, 3-dioxolane is a versatile solvent used in the separation of saturated and unsaturated hydrocarbons, in pharmaceutical synthesis, and serve as solvents for many polymers ^{1,2}.

Ethers such as diethyl ether are regarded as ideal potential fuel alternatives or additives, which have good combustion characteristics. The investigation on the thermophysical properties is very important for the increased applications of oxygenated fuels or fuel additives. Considering all of these aspects we undertook investigations on the thermodynamic and transport

properties of binary and ternary mixtures involving 1, 3 dioxolane (1, 3 D.O), diethylether (D.E.E) and n-amyl alcohol (A.L).

In this paper we have reported excess molar volume (V^E), viscosity deviations ($\Delta\eta$), deviations in isentropic compressibility (ΔK_s) and excess molar refraction (ΔR) for three binary mixtures of 1,3 D.O (1) and D.E.E (2), 1,3 D.O (1) and A.L (3), D.E.E (2) and A.L (3) and their corresponding ternary mixtures at 298.15 K over the entire range of composition. The excess or deviation properties of binary mixtures were fitted to Redilch-Kister polynomial equation to obtain their coefficients and have been interpreted in terms of molecular interactions and structural effects.

5.2. Experimental Section

5.2.1. Chemicals

1, 3 dioxolane (CAS: 646-06-0), n-amyl alcohol (CAS: 71-41-0) and diethylether (CAS: 60-29-7) with minimum mass fraction purities of 0.99 used in this study were purchased from S.d.fine-Chem Limited, Mumbai, India. The pure chemicals were stored over activated 4 Å molecular sieves to reduce water content before use. The purity of each substance was evaluated by comparing experimental values of density, viscosity, sound speed and refractive index with those reported in the literature whenever available, as presented in Table 1.

5.2.2. Apparatus and procedure

Densities (ρ) were measured with an Ostwald-Sprengel type pycnometer having a bulb volume of about 25 cm³ and an internal diameter of the capillary of about 0.1 cm. The measurements were done in a thermostat bath controlled to ± 0.01 K. Viscosity (η) was measured by means of suspended Ubbelohde type viscometer, calibrated at 298.15 K with triply distilled water and purified methanol using density and viscosity values from literature. The flow times were accurate to ± 0.1 s, and the uncertainty in the viscosity measurements was $\pm 2 \times 10^{-4}$ mPa-s. The mixtures were prepared by mixing known volume of pure liquids in airtight-stopper bottles and each solution thus prepared was distributed into three recipients to perform all the measurements in triplicate, with the aim of

determining possible dispersion of the results obtained. Adequate precautions were taken to minimize evaporation losses during the actual measurements. The reproducibility in mole fractions was within ± 0.0002 . The mass measurements were done on a Mettler AG-285 electronic balance with a precision of ± 0.01 mg. The precision of density measurements was $\pm 3 \times 10^{-4} \text{ g}\cdot\text{cm}^{-3}$.

Ultrasonic speeds of sound (u) were determined by a multifrequency ultrasonic interferometer (Mittal enterprise, New Delhi, M-81) working at 1MHz, calibrated with triply distilled and purified water, methanol and benzene at 303.15 K. The precision of ultrasonic speed measurements was $\pm 0.2 \text{ ms}^{-1}$. The details of the methods and techniques have been described in earlier papers^{3, 4, 5}. Refractive index was measured with the help of Abbe-Refractometer (U.S.A). The accuracy of refractive index measurement was ± 0.0002 units. The refractometer was calibrated twice using distilled and deionized water, and calibration was checked after every few measurements.

5.3. Results and Discussion

We have calculated excess molar volume (V^E), viscosity deviations ($\Delta\eta$), and deviations in isentropic compressibility (ΔK_S), excess molar refraction (ΔR) at 298.15 K for the binary mixtures of diethylether (1), dichloromethane (2) and n-amyl alcohol (3) over the whole composition range. The variations of the excess properties over the entire range of composition for the binary mixtures are depicted in Figures 1-4.

5.3.1. Excess molar volume

The density (ρ) values have been used to calculate the excess molar volumes (V^E) for binary ($n=2$) and ternary ($n=3$) mixture using the following equation⁶,

$$V^E = \sum_{i=1}^n x_i M_i \left(\frac{1}{\rho} - \frac{1}{\rho_i} \right) \quad (1)$$

where ρ is the density of the mixture and M_i , x_i , ρ_i are the molecular weight, mole fraction and density of the i^{th} component in the mixture respectively.

(1) and D.E.E (2) causes a decrease in intermolecular interaction between the mixing components.

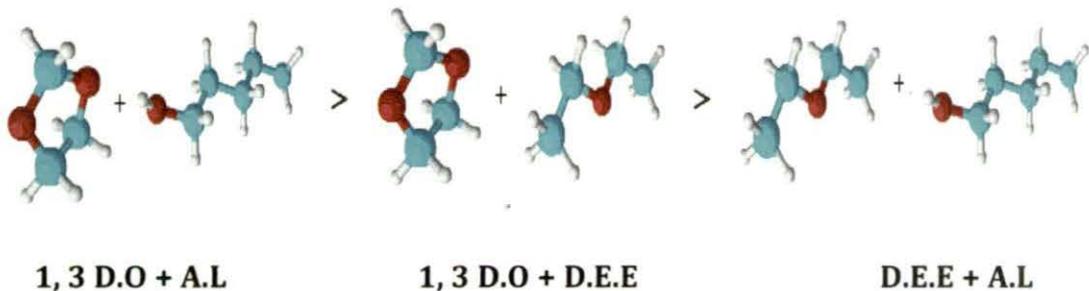
5.3.2. Viscosity deviation

The measured η values for binary systems are listed in Table 2 and depicted graphically in Figure 2. The viscosity deviations ($\Delta\eta$) from linear dependence for binary ($n=2$) and ternary ($n=3$) mixtures can be calculated as ¹³

$$\Delta\eta = \eta - \sum_{i=1}^n (x_i \eta_i) \tag{2}$$

where, η is the viscosity of the mixture and x_i, η_i is the mole fraction and viscosity of pure component i respectively.

The values of $\Delta\eta$ over entire range of mole fraction for the binary mixtures follow the trend which is schematically shown below.



The trend in deviations of $\Delta\eta$ values are found to be opposite with excess molar volumes V^E for all three binary mixtures, which is in agreement with the view proposed by Brocos et al.⁸. The values of viscosity deviations ($\Delta\eta$) for the ternary mixture are listed in Table 3. For the ternary mixture the viscosity deviations are negative over the entire range of composition. These can be interpreted qualitatively by considering the effect of intermolecular interaction and shape of components.

5.3.3. Deviation in Isentropic Compressibility

Isentropic compressibility, K_s and deviation in isentropic compressibility ΔK_s , for binary ($n=2$) and ternary ($n=3$) mixtures were calculated using the following relations:

$$K_s = \frac{1}{(u^2 \rho)} \quad (3)$$

$$\Delta K_s = K_s - \sum_{i=1}^n x_i K_{s,i} \quad (4)$$

where u and K_s are the speed of sound and isentropic compressibility of the mixture and $K_{s,i}$, the isentropic compressibility of the i^{th} component in the mixture.

It is evident from Table 4 and Figure 3 that, for the binary mixtures, the ΔK_s values are negative over all composition range and order of negative deviation is as follows, D.E.E (2) and A.L (3) > 1,3 D.O (1) and D.E.E (2) > 1,3 D.O (1) and A.L (3).

These results can be explained in terms of molecular interactions^{9, 10} between unlike molecules. It appears from the sign and magnitude of ΔK_s that specific interaction exist between mixing components. These results are in excellent agreement with those of V^E discussed earlier.

The values of ΔK_s for the ternary mixture are negative over all composition range and are given in Table 5 which suggests that specific interactions exist between mixing components¹¹.

5.3.4. Deviation in Molar Refraction

The molar refraction, $[R]$ can be evaluated from Lorentz-Lorenz relation¹² and gives more information than n_D about the mixture phenomenon because takes into account the electronic perturbation of molecular orbital during the liquid mixture process and $[R]$ is also directly related to the dispersion forces

$$[R] = \left(\frac{n_D^2 - 1}{n_D^2 + 2} \right) \cdot \left(\frac{M}{\rho} \right) \quad (5)$$

Where $[R]$, n_D^2 , and M are the molar refraction, the refractive index and the molar mass of the mixture respectively. Deviation in molar refraction was calculated from the following relation;

$$\Delta R = [R] - \sum_{i=1}^n x_i [R]_i \quad (6)$$

The values of refractive indices and deviation in molar refraction (ΔR) for the binary mixtures are presented in Table 4 and depicted graphically in Figure 4. The data for ternary mixture are reported in Table 5.

The excess properties (V^E , $\Delta\eta$, ΔK_s , ΔR) for the binary mixtures were fitted to the Redlich–Kister polynomial equation¹³,

$$Y^E = x_1 x_2 \sum_{n=0}^k a_n (x_1 - x_2)^n \quad (7)$$

where Y^E refer to excess property.

The coefficients (a_i) were obtained by fitting Eq. (8) to experimental results using a least-squares regression method. In each case, the optimal number of coefficients was ascertained from an approximation of the variation in the standard deviation. The estimated values of along with the standard deviations are summarized for all mixtures in Table 6. The standard deviation was calculated using the equation

$$\sigma = [\sum (Y_{exp}^E - Y_{calcd}^E)^2 / (n - m)]^{1/2} \quad (8)$$

where n is the number of data points and m is the number of coefficients.

5.4. Conclusion

In the binary mixtures intermolecular interaction occurs and the interaction follows the order D.E.E + A.L > D.O + D.E.E > D.O + A.L. In case of ternary mixtures the extent of intermolecular interaction decreases as concentration of amyl alcohol increases.

References

- [1] G.G. Janz, R.P.T. Tomkins, *Nonaqueous Electrolytes Handbook*, Academic Press, New York (1973).
- [2] R. Jasinski, *High Energy Batteries*, Plenum Press, New York (1967).
- [3] D.K. Hazra, M.N. Roy, B. Das, *Ind. J. Chem. Technol.*, 1 (1994) 93.
- [4] M.N. Roy, A. Jha, R. Dey, *J. Chem. Eng. Data*, 46 (2001) 1327.
- [5] M.N. Roy, A. Sinha, B. Sinha, *J. Sol. Chem.*, 34 (2005) 1311.
- [6] P.S. Nikam, A.B. Sawant, *J. Ind. Chem. Soc.*, 77 (2000) 197.
- [7] S.J. Kharat, P.S. Nikam, *J. Mol. Liq.*, 131- 132 (2007) 81.
- [8] P. Brocos, A. Pineiro, R. Bravo, A. Amigo, *Phys. Chem. Chem. Phys.*, 5 (2003), 550.
- [9] M.J.W. Povey, S.A. Hindle, J.D. Kennedy, Z. Stec, R.G. Taylor, *Phys. Chem. Chem. Phys.*, 5 (2003) 73.
- [10] C. Lafuente, B. Giner, A. Villares, I. Gascon, P. Cea, *Int. J. Thermo Phys.*, 25 (2004) 1735.
- [11] T.M. Aminbhavi, H.T.S. Phyade, M.I. Aralaguppi, R.S. Khinnavar, *J. Chem. Eng. Data*, 38 (1993) 540.
- [12] V. Minkin, O. Osipov, Y. Zhdanov, *Dipole Moments in Organic Chemistry*, Plenum Press, New York (1970).
- [13] D.S. Gill, T. Kaur, H. Kaur, *J. Chem. Soc. Faraday Trans.*, 89 (1993) 1737.
- [14] I. Gascon, A.M. Mainar, F.M. Royo, J.S.J. Urieta, *Chem. Eng. Data*, 45 (2000) 751.
- [15] B. Giner, A. Villares, P. Gascon, P. Cea, C. Lafuente, *Int. J. Thermophys.*, 25 (6) (2004) 1735.
- [16] S. Ottani, D. Vitalini, F. Comelli, C. J. Castellari, *Chem. Eng. Data*, 47 (2002) 1197.
- [17] B. Orge, M. Iglesias, G. Marino, L.M. Casas, J. Tojo, *J. Phys. Chem. Liq.*, 43 (2005) 551.
- [18] N.V. Sastry, M.K. Valand, *J. Chem. Eng. Data*, 41 (1996) 1426.
- [19] R. Mehra, *Proc. Indian Acad. Sci. (Chem. Sci.)*, 115 (2003) 147.
- [20] A.F. Ribeiro, E. Langa, A.M. Mainar, J.I. Pardo, J.S. Urieta, *J. Chem. Eng. Data*, 51 (2006) 1846.
- [21] G. Savaroglu, E. Aral, *Pramana J. Phys.*, 66 (2006) 435.

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Table 1

Density (ρ), viscosity (η), sound speed (u) and refractive index (n_D) of pure liquids at T= 298.15 K.

Pure solvent	$\rho \times 10^{-3} / \text{kg} \cdot \text{m}^{-3}$		$\eta / \text{m} \cdot \text{Pas}$		$u / \text{m} \cdot \text{s}^{-1}$		n_D	
	exptl	lit	exptl	lit	exptl	lit	exptl	lit
1,3 dioxolane	1.0587	1.0586 ¹⁴	0.589	0.5886 ¹⁴	1339.4	1338.8 ¹⁵	1.3985	1.398 ¹⁶
n-amyl alcohol	0.8112	0.8110 ¹⁷	3.504	3.510 ¹⁸	1271.6	1274.1 ¹⁹	1.4100	1.409 ²⁰
diethylether	0.7083	0.7083 ²¹	0.247	-	982.3	983 ²¹	1.3515	-

Table 2

Densities (ρ), viscosities (η), excess molar volumes (V^E), viscosity deviations ($\Delta\eta$) for binary mixtures of 1, 3 dioxolane (1), diethylether (2) and n-amyl alcohol (3) at T=298.15 K.

x_1	$\rho \times 10^{-3} / \text{kg} \cdot \text{m}^{-3}$	$\eta / \text{m} \cdot \text{Pas}$	$V^E \times 10^6 / \text{m}^3 \cdot \text{mol}^{-1}$	$\Delta\eta / \text{m} \cdot \text{Pas}$
(x_1) 1,3 dioxolane + (x_2) diethylether				
0.0000	0.7083	0.247	0.000	0.000
0.1000	0.7364	0.266	-0.533	-0.016
0.2000	0.7656	0.284	-0.905	-0.031
0.3001	0.7963	0.306	-1.176	-0.044
0.4001	0.8290	0.331	-1.381	-0.053
0.5001	0.8634	0.360	-1.480	-0.058
0.6001	0.8997	0.394	-1.480	-0.058
0.7001	0.9382	0.435	-1.400	-0.052
0.8000	0.9770	0.478	-1.072	-0.043
0.9000	1.0184	0.531	-0.694	-0.025
1.0000	1.0587	0.589	0.000	0.002
(x_1) 1,3 dioxolane + (x_3) n-amyl alcohol				
0.0000	0.8112	3.504	0.000	0.000
0.1168	0.8329	2.505	-0.287	-0.659
0.2293	0.8545	1.885	-0.414	-0.951
0.3377	0.8766	1.440	-0.460	-1.080
0.4424	0.8992	1.063	-0.440	-1.152
0.5434	0.9225	0.906	-0.377	-1.014
0.6409	0.9468	0.756	-0.290	-0.880
0.7352	0.9725	0.647	-0.213	-0.714
0.8264	0.9993	0.570	-0.117	-0.525
0.9146	1.0282	0.541	-0.058	-0.297
1.0000	1.0587	0.589	0.000	0.000
(x_2) diethylether + (x_3) n-amyl alcohol				
0.0000	0.8112	3.504	0.000	0.000
0.1167	0.8052	2.651	-0.750	-0.384
0.2292	0.7975	1.966	-1.250	-0.714
0.3377	0.7889	1.491	-1.575	-0.847
0.4423	0.7797	1.123	-1.788	-0.884
0.5433	0.7704	0.829	-1.950	-0.859
0.6409	0.7595	0.620	-1.860	-0.761
0.7352	0.7479	0.481	-1.638	-0.602
0.8263	0.7361	0.382	-1.345	-0.413
0.9146	0.7230	0.314	-0.820	-0.203
1.0000	0.7083	0.247	0.000	0.000

Table 3

Densities (ρ), viscosities (η), excess molar volumes (V^E), viscosity deviations ($\Delta\eta$) for ternary mixtures of 1, 3 dioxolane (1), diethylether (2) and n-amyl alcohol (3) at T=298.15 K.

x_1	x_2	$\rho \times 10^{-3} / \text{kg} \cdot \text{m}^{-3}$	$\eta / \text{m} \cdot \text{Pas}$	$V^E \times 10^6$ $/\text{m}^3 \cdot \text{mol}^{-1}$	$\Delta\eta / \text{m} \cdot \text{Pas}$
(x ₁)1,3 dioxolane + (x ₂) diethylether + (x ₃) n-amyl alcohol					
0.5001	0.4999	0.8634	0.360	-1.480	-0.058
0.4574	0.4572	0.8602	0.431	-1.595	-0.121
0.4132	0.4131	0.8567	0.480	-1.668	-0.222
0.3676	0.3675	0.8525	0.552	-1.680	-0.322
0.3205	0.3204	0.8477	0.651	-1.608	-0.421
0.2717	0.2716	0.8424	0.759	-1.476	-0.543
0.2212	0.2211	0.8367	0.966	-1.293	-0.607
0.1689	0.1688	0.8307	1.243	-1.046	-0.654
0.1146	0.1146	0.8246	1.682	-0.770	-0.609
0.0584	0.0584	0.8181	2.304	-0.424	-0.476
0.0000	0.0000	0.8112	3.404	0.000	0.000

Table 4

Ultrasonic speed (u), isentropic compressibility (K_s), deviation in isentropic compressibility (ΔK_s), refractive indices (n_D) and excess molar refraction (ΔR) for binary mixtures of 1, 3 dioxolane (1), diethylether (2) and n-amyl alcohol (3) at T=298.15 K.

x_1	$u/\text{m}\cdot\text{s}^{-1}$	$K_s \times 10^{12}/\text{Pa}^{-1}$	$\Delta K_s \times 10^{12}/\text{Pa}^{-1}$	n_D	$\Delta R \times 10^{-6}/\text{m}^3 \cdot \text{mol}^{-1}$
(x_1) 1,3 dioxolane + (x_2) diethylether					
0.0000	982.3	1463.2	0.00	1.3515	0.0000
0.1000	1003.9	1347.5	-22.0	1.3568	-0.0390
0.2000	1033.4	1223.1	-52.7	1.3604	-0.0781
0.3001	1067.4	1102.1	-80.0	1.3649	-0.1054
0.4001	1108.5	981.7	-106.7	1.3696	-0.1268
0.5001	1152.8	871.6	-123.2	1.3743	-0.1460
0.6001	1191.4	783.1	-118.0	1.3791	-0.1520
0.7001	1230.9	703.5	-104.0	1.3842	-0.1320
0.8000	1265.3	639.3	-74.5	1.3893	-0.1000
0.9000	1302.4	578.9	-41.3	1.3956	-0.0530
1.0000	1339.4	526.5	0.0	1.3985	0.0000
(x_1) 1,3 dioxolane + (x_3) n-amyl alcohol					
0.0000	1271.6	762.4	0.0	1.4100	0.0000
0.1168	1278.8	734.2	-0.7	1.4085	-0.1038
0.2293	1287.5	705.9	-2.4	1.4072	-0.1510
0.3377	1296.8	678.3	-4.4	1.4060	-0.1715
0.4424	1305.0	653.0	-5.0	1.4050	-0.1616
0.5434	1313.4	628.4	-5.8	1.4040	-0.1365
0.6409	1321.5	604.8	-6.4	1.4030	-0.1054
0.7352	1327.1	583.9	-5.1	1.4022	-0.0730
0.8264	1332.7	563.4	-4.1	1.4010	-0.0415
0.9146	1337.0	544.1	-2.5	1.4000	-0.0121
1.0000	1339.5	526.5	-0.0	1.3985	0.0000
(x_2) diethylether + (x_3) n-amyl alcohol					
0.0000	1271.6	762.4	0.0	1.4100	0.0000
0.1167	1241.8	803.5	-40.7	1.4043	-0.1830
0.2292	1216.7	846.3	-76.7	1.3977	-0.2680
0.3377	1193.9	889.3	-109.7	1.3922	-0.2740
0.4423	1172.2	933.3	-139.0	1.3874	-0.2480
0.5433	1141.6	996.6	-146.5	1.3825	-0.2054
0.6409	1110.7	1068.2	-143.3	1.3774	-0.1430
0.7352	1077.3	1152.1	-125.5	1.3724	-0.0720
0.8263	1046.3	1240.8	-100.7	1.3664	-0.0350
0.9146	1011.2	1350.8	-52.5	1.3601	-0.0070
1.0000	982.3	1463.2	0.0	1.3515	0.0000

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Table 5

Ultrasonic speed (u), isentropic compressibility (K_s), deviation in isentropic compressibility (ΔK_s), refractive indices (n_D) and excess molar refraction (ΔR) for ternary mixtures of 1, 3 dioxolane (1) , diethylether (2) and n-amyl alcohol (3) at T=298.15 K.

x_1	x_2	$u/\text{m}\cdot\text{s}^{-1}$	$K_s \times 10^{12}/\text{Pa}^{-1}$	$\Delta K_s \times 10^{12}/\text{Pa}^{-1}$	n_D	$\Delta R \times 10^{-6}/$ $\text{m}^3 \cdot \text{mol}^{-1}$
(x ₁)1,3 dioxolane + (x ₂) diethylether + (x ₃) n-amyl alcohol						
0.5001	0.4999	1149.2	877.0	-83.7	1.3750	-0.1081
0.4574	0.4572	1165.9	858.4	-88.7	1.3775	0.0710
0.4132	0.4131	1183.4	843.3	-92.7	1.3805	0.1540
0.3676	0.3675	1196.6	828.9	-89.0	1.3850	0.2608
0.3205	0.3204	1207.6	815.9	-80.5	1.3875	0.3340
0.2717	0.2716	1213.9	805.6	-64.5	1.3925	0.3829
0.2212	0.2211	1224.6	796.9	-53.2	1.3945	0.3600
0.1689	0.1688	1235.8	788.3	-41.1	1.3980	0.3049
0.1146	0.1146	1246.7	780.3	-27.6	1.4005	0.1720
0.0584	0.0584	1258.2	772.2	-13.4	1.4035	0.0140
0.0000	0.0000	1271.6	762.4	0.00	1.4100	0.0000

Table 6

 Redlich-Kister coefficients and standard deviations (σ) for the binary mixtures at T=298.15 K.

Excess property	a_0	a_1	a_2	a_3	σ
(x₁) 1,3 dioxolane + (x₂) diethylether					
$V^E \times 10^6 / \text{m}^3 \cdot \text{mol}^{-1}$	-5.915	-1.079	-1.113		0.021
$\Delta \eta / \text{m} \cdot \text{Pa s}$	-0.230	-0.056			0.001
$\Delta K_s \times 10^{12} / \text{Pa}^{-1}$	-480.02	-127.24	222.66		1.81
$\Delta R \times 10^{-6} / \text{m}^3 \cdot \text{mol}^{-1}$	-0.5842	-0.2040	0.0988	0.1994	0.0024
(x₁) 1,3 dioxolane + (x₃) n-amyl alcohol					
$V^E \times 10^6 / \text{m}^3 \cdot \text{mol}^{-1}$	-1.623	1.286	-0.196		0.005
$\Delta \eta / \text{m} \cdot \text{Pa s}$	-3.717	2.154	-0.732	0.356	0.013
$\Delta K_s \times 10^{12} / \text{Pa}^{-1}$	-22.97	-13.39	6.97		0.27
$\Delta R \times 10^{-6} / \text{m}^3 \cdot \text{mol}^{-1}$	-0.5995	0.4953			0.0019
(x₂) diethylether + (x₃) n-amyl alcohol					
$V^E \times 10^6 / \text{m}^3 \cdot \text{mol}^{-1}$	-7.480	-1.698	-1.748		0.029
$\Delta \eta / \text{m} \cdot \text{Pa s}$	-3.548	0.820	0.352		0.014
$\Delta K_s \times 10^{12} / \text{Pa}^{-1}$	-574.02	-204.92	69.38		2.30
$\Delta R \times 10^{-6} / \text{m}^3 \cdot \text{mol}^{-1}$	-0.8943	1.0672	-0.0883		0.0048

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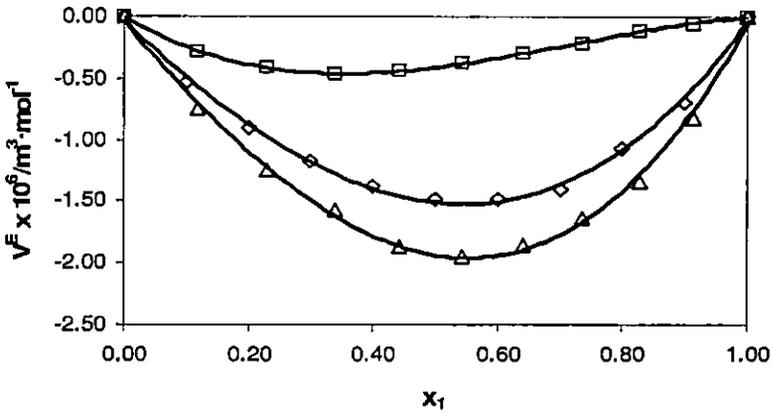


Figure 1. Excess molar volumes $V^E \times 10^6(\text{m}^3 \cdot \text{mol}^{-1})$ versus mole fraction (x_1) for the three binary subsystems at $T= 298.15 \text{ K}$. \square , 1, 3 dioxolane (1) and n-amyl alcohol (3); \diamond , 1, 3 dioxolane (1) and diethylether (2); Δ , diethylether (2) and n-amyl alcohol (3).

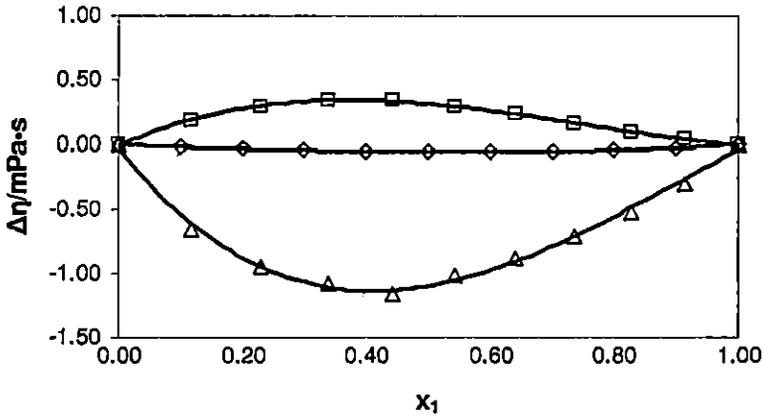


Figure 2. Viscosity deviations, $\Delta\eta$ ($\text{m} \cdot \text{Pa} \cdot \text{s}$) versus mole fraction (x_1) for the three binary subsystems at $T=298.15 \text{ K}$. \square , 1, 3 dioxolane (1) and n-amyl alcohol (3); \diamond , 1, 3 dioxolane (1) and diethylether (2); Δ , diethylether (2) and n-amyl alcohol (3).

Study of the Solution Properties.....at 298.15 K

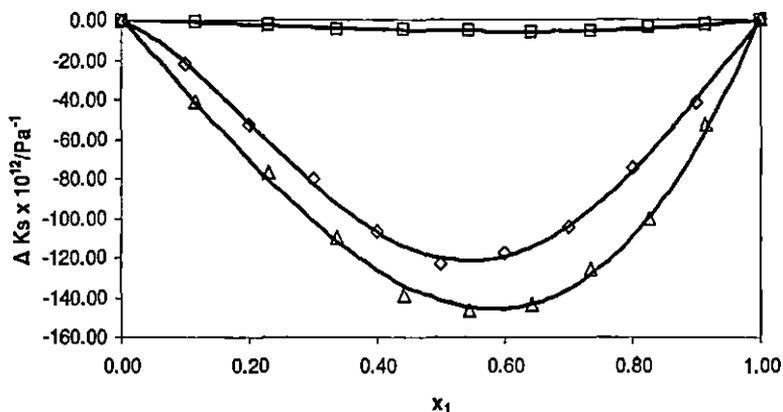


Figure 3. Deviation in isentropic compressibility $\Delta K_s \times 10^{12}$ (Pa^{-1}) versus mole fraction (x_1) for the three binary subsystems at $T=298.15$ K. \square , 1, 3 dioxolane (1) and n-amyl alcohol(3); \diamond , 1, 3 dioxolane (1) and diethylether (2); Δ , diethylether (2) and n-amyl alcohol (3).

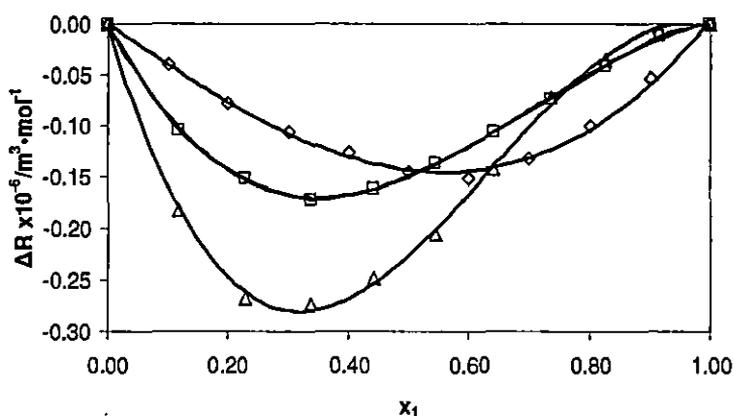


Figure 4. Excess molar refraction $\Delta R \times 10^{-6}$ ($\text{m}^3 \cdot \text{mol}^{-1}$) versus mole fraction (x_1) for the three binary subsystems at $T=298.15$ K. \square , 1, 3 dioxolane (1) and n-amyl alcohol (3); \diamond , 1, 3 dioxolane (1) and diethylether (2); Δ , diethylether (2) and n-amyl alcohol (3).