

## **CHAPTER X**

### **Excess Molar Volume and Viscosity Deviations of Binary Liquid Mixtures of 1,3-Dioxolane and 1,4-Dioxane with Butyl acetate, Butyric Acid, Butylamine and 2-Butanol at 298.15 K\***

#### **10.1. Introduction**

Studies on thermodynamic and transport properties are important in understanding the nature of molecular interactions in binary liquid mixtures. Properties of the mixtures are useful for the designing many types of transport and process equipment in chemical industries.<sup>1-5</sup> 1,4-dioxane, 1,3-dioxolane and their binary liquid mixtures are important solvents widely used in various industries. 1,4-dioxane and 1,3-dioxolane are cyclic diethers differing in one methylene group, thus they differs in quadrupolar and dipolar order.<sup>6</sup>

In this chapter we report density and viscosity for {1,4-dioxane or 1,3-dioxolane + butyl acetate, butyric acid, butylamine, 2-butanone} mixtures at 298.15 K. From density and viscosity data, the values of excess molar volume ( $V^E$ ) and viscosity deviation ( $\Delta\eta$ ) have been determined. These results were fitted to Redlich-Kister type polynomial equations. The density and viscosity data have been analyzed for in term of some semi empirical viscosity models.

#### **10.2. Experimental Section**

##### **10.2.1. Materials**

1,4-dioxane (Merck, India) was kept several days over potassium hydroxide (KOH), refluxed for 24 h, and distilled over lithium aluminium hydride ( $\text{LiAlH}_4$ ). Details have been described earlier.<sup>1</sup> 1,3-dioxolane (Merck, India) was purified by standard methods.<sup>7</sup> It was refluxed with  $\text{PbO}_2$ , fractionally distilled after addition of xylene. Butyl acetate, butyric acid, butylamine, 2-butanone (SD Fine Chemicals, Analytical Reagent, Purity > 99%) were used without further purification. The purity of the solvents was ascertained by GLC and also by comparing experimental values of densities and viscosities with those reported in the literature<sup>8-13</sup> as listed in Table 1.

### 10.2.2. Apparatus and procedures

The densities ( $\rho$ ) were measured with an Ostwald-Sprengel type pycnometer having a bulb volume of 25 cm<sup>3</sup> and an internal diameter of the capillary of about 0.1 cm. The pycnometer was calibrated at 298.15 K with doubly distilled water and benzene. The pycnometer with the test solution was equilibrated in a water bath maintained at  $\pm 0.01$  K of the desired temperature by means of a mercury in glass thermoregulator, and the absolute temperature was determined by a calibrated platinum resistant thermometer and Muller bridge. The pycnometer was then removed from the thermostatic bath, properly dried, and weighed. The evaporation losses remained insignificant during the time of actual measurements. An average of triplicate measurements was taken into account. The mixtures were prepared by mixing known volume of pure liquids in airtight-stoppered bottles. The reproducibility in mole fraction was within  $\pm 0.0002$  units. The mass measurements accurate to  $\pm 0.01$ mg were made on a digital electronic analytical balance (Mettler, AG 285, Switzerland). The total uncertainty of density is  $\pm 0.0001$  g.cm<sup>-3</sup> and that of the temperature is  $\pm 0.01$  K.

The viscosity was measured by means of a suspended Ubbelohde type viscometer, which was calibrated at 298.15 K with triply distilled water and purified methanol using density and viscosity values from the literature. The flow times were accurate to  $\pm 0.1$ s, and the uncertainty in the viscosity measurements, based on our work on several pure liquids, was within  $\pm 0.03\%$  of the reported value. Details of the methods and techniques of density and viscosity measurements have been described earlier.<sup>4, 14</sup>

### 10.3. Results and Discussion

The experimental viscosities, densities, excess volumes ( $V^E$ ) and viscosity deviations ( $\Delta\eta$ ) for the binary mixtures studied at 298.15 K are listed in Table 2.

#### 10.3.1. Excess molar volume ( $V^E$ )

The excess molar volumes ( $V^E$ ) were calculated using the equation,

$$V^E = \sum_{i=1}^J x_i M_i (1/\rho - 1/\rho_i) \quad (1)$$

where  $\rho$  is the density of the mixture and  $M_i$ ,  $x_i$  and  $\rho_i$  are the molecular weight, mole fraction and density of  $i^{\text{th}}$  component in the mixture, respectively. The values of excess molar volume ( $V^E$ ) have been presented in Table 2. The estimated uncertainty for excess molar volumes ( $V^E$ ) is  $\pm 0.005 \text{ cm}^3 \cdot \text{mol}^{-1}$ .

The excess molar volumes ( $V^E$ ) for all the 1,3-dioxolane systems, except for the system involving butylamine, are negative over the entire range of composition. The negative values of excess volumes ( $V^E$ ) for the three systems are in the order:

1,3-dioxolane + Butyric acid > 1,3-dioxolane + 2-Butanone > 1,3-dioxolane + Butyl acetate

The excess molar volumes ( $V^E$ ) for the two 1,4-dioxane systems involving butylamine and butyl acetate are positive, while for the other two 1,4-dioxane systems involving 2-butanone and butyric acid are negative. The order  $V^E$  values for the 1,4-dioxane systems irrespective of their sign is as follows:

1,4-dioxane + Butylamine > 1,4-dioxane + Butyl acetate > 1,4-dioxane + 2-butabnone > 1,4-dioxane + Butyric acid

The negative values of excess molar volume ( $V^E$ ) suggest specific interactions<sup>15</sup> between the mixing components in the mixtures while its positive values suggest dominance of dispersion forces<sup>16,13</sup> between them. The negative  $V^E$  values indicate the specific interactions such as intermolecular hydrogen bonding between the mixing components and also the interstitial accommodation of the mixing components because of the difference in molar volume. The negative  $V^E$  values may also be due to the difference in the dielectric constants of the liquid components of the binary mixture.<sup>15</sup> The negative  $V^E$  values for all the systems studied may be attributed to dipole-induced dipole interactions between the components liquids of the mixtures resulting in the formation of electron donor-acceptor complexes.<sup>17</sup> The plots of excess molar volume ( $V^E$ ) versus mole fraction ( $x_1$ ) of 1,3-dioxolane or 1,4-dioxane are presented in Figures 1 and 2.

### 10.3.2. Viscosity deviation ( $\Delta\eta$ )

The deviation in viscosities ( $\Delta\eta$ ) was computed using the relationship,<sup>18</sup>

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

where  $\eta$  is the dynamic viscosities of the mixture and  $x_i$ ,  $\eta_i$  are the mole fraction and viscosity of  $i^{\text{th}}$  component in the mixture, respectively.

A perusal of Table 2 shows that the values of viscosity deviation ( $\Delta\eta$ ) are negative over the entire composition range for all the binary liquid mixtures studied except for the mixtures involving butyric acid. The estimated uncertainty for viscosity deviation ( $\Delta\eta$ ) is  $\pm 0.004$  mPa.s. The negative values imply the presence of dispersion forces<sup>18</sup> between the mixing components in these mixtures, while positive values may be attributed to the presence of specific interactions<sup>18</sup> between them. The plots of viscosity deviation ( $\Delta\eta$ ) versus mole fraction ( $x_1$ ) for the different binary mixtures have been presented in Figures 3 and 4.

### 10.3.3. Viscosity models and Interaction parameters

Several semi-empirical models have been proposed to estimate the dynamic viscosity ( $\eta$ ) of the binary liquid mixtures in terms of pure-component data.<sup>19, 20</sup> Some of them we examined are as follows:

a) Grunberg and Nissan<sup>21</sup> have suggested the following logarithmic relation between the viscosity of the binary mixtures and the pure components:

$$\eta = \exp\left[\sum_{i=1}^j (x_i \ln \eta_i) + d_{12} \prod_{i=1}^j x_i\right] \quad (3)$$

where  $d_{12}$  is a constant proportional to the interchange energy. It may be regarded as an approximate measure of the strength of molecular interactions between the mixing components. The values of the interchange parameter ( $d_{12}$ ) have been calculated as a function of the composition of the binary liquid mixtures of 1,3-dioxolane and 1,4-dioxane with butyl acetate, butyric acid, butylamine and 2-butanone were listed in Table 2.

It has been found that the values of  $d_{12}$  are negative for all the binary systems studied, except the systems involving butyric acid. The negative

values of  $d_{12}$  indicate the presence of dispersion forces<sup>18</sup> between the mixing components in the mixtures while its positive values indicate the presence of specific interactions<sup>18</sup> between them.

b) Tamura-Kurata<sup>22</sup> put forward the following equation for the viscosity of the binary liquid mixtures:

$$\eta = \sum_{i=1}^j x_i \phi_i \eta_i + 2T_{12} \prod_{i=1}^j [x_i \phi_i]^{1/2} \quad (4)$$

where  $T_{12}$  is the interaction parameter and  $\phi_i$  is the volume fraction of  $i^{\text{th}}$  pure component in the mixture.

c) Molecular interactions may also be interpreted by the following viscosity model of Hind et al:<sup>23</sup>

$$\eta = \sum_{i=1}^j x_i^2 \eta_i + 2H_{12} \prod_{i=1}^j x_i \quad (5)$$

where  $H_{12}$  is Hind interaction parameter, which may be attributed to unlike pair interaction.<sup>24</sup> In the present study, the values of interaction parameter  $T_{12}$  and  $H_{12}$  have been calculated from equation (4) and (5), respectively and were listed in Table 2. It has been observed that for a given binary mixture  $T_{12}$  and  $H_{12}$  do not differ appreciably from each other, this is in agreement with the view put forward by Fort and Moore<sup>18</sup> in regard to the nature of parameter  $T_{12}$  and  $H_{12}$ . It is also significant to note that the values of  $T_{12}$  and  $H_{12}$  are larger for the binary mixtures of butyric acid with both the cyclic ethers, which involve specific molecular interactions as revealed by the positive values of  $\Delta\eta$  and  $d_{12}$ .<sup>25</sup>

#### 10.3.4. Redlich-Kister polynomial equation

The excess properties ( $V^E$  and  $\Delta\eta$ ) were fitted to the Redlich-Kister polynomial equation,<sup>26</sup>

$$Y^E = x_1 x_2 \sum_{i=1}^k a_i (x_1 - x_2)^i \quad (6)$$

where  $Y^E$  refers to excess properties and  $x_1$  and  $x_2$  are the mole fraction 1,3-dioxolane or 1,4-dioxane and other component, respectively. The coefficients  $a_i$  were obtained by fitting equation (6) 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 ( $\sigma$ ). The calculated values of  $a_i$  along with the tabulated standard deviations ( $\sigma$ ) are listed in Table 3. The standard deviation ( $\sigma$ ) was calculated using,

$$\sigma = [(Y_{\text{exp}}^E - Y_{\text{cal}}^E)^2 / (n - m)]^{1/2} \quad (7)$$

where  $n$  is the number of data points and  $m$  is the number of coefficients. The  $\sigma$  values lie between  $0.013 \text{ m}^3\cdot\text{mol}^{-1}$  and  $0.001 \text{ m}^3\cdot\text{mol}^{-1}$  for  $V^E$  and between  $0.006 \text{ mPa}\cdot\text{s}$  and  $0.001 \text{ mPa}\cdot\text{s}$  for  $\Delta\eta$ , respectively. The largest  $\sigma$  values corresponds to the 1,3-dioxolane + 2-butanone system for  $V^E$  and the 1,4-dioxane + butyric acid for  $\Delta\eta$ , respectively. In the present study both  $V^E$  and  $\Delta\eta$  are quite systematic and functions of the composition of the binary mixtures.

#### **10.4. Conclusion**

In general, for both the cyclic diether binary systems the order of specific or chemical interaction has been found to be: Butyric acid > 2-Butanone > Butyl acetate > Butylamine. More extensive studies are, however, required to arrive at a concrete conclusion about the above order and nature of solvent-solvent interactions.

#### **References**

- [1] M. N. Roy, A. Jha, R. Dey, *J. Chem. Eng. Data.*, 46 (2001) 1247.
- [2] C. G. Janz, R. P. T. Tomkins, *Non-aqueous Electrolytes Handbook*, Academic Press, New York, Vol. 2 (1973).
- [3] R. Jasinski, *High Energy Batteries*, Plenum Press, New York, (1967).
- [4] M. N. Roy, D. K. Hazra, *Indian J. Chem. Technol.*, 1 (1994) 93.
- [5] F. J. Millero, *Structure and Transport Process in Water and Aqueous Solutions*, R. A. Horne, New York, (1972).
- [6] P. Brocos, E. Calvo, A. Pineiro, R. Bravo, A. Amigo, *J. Chem. Eng. Data.*, 48 (1999) 1341.
- [7] J. Riddick, W. B. Bunger, T. K. Sakano, *Organic solvents. Physical Properties and Methods of Purification*, 4<sup>th</sup> ed., Wiley, New York, Vol-2 (1986).
- [8] S. Martin Contreras, *J. Chem. Eng. Data.*, 46 (2001) 1149.
- [9] R. Francesconi, F. Comelli, *J. Chem. Eng. Data.*, 40 (1995) 31.

- [10] N. V. Sastry, M. C. Patel, J. Chem. Eng. Data., 48 (2003) 1019.
- [11] C. M. Kinart, W. J. Kinart, D. Checinska-Majak, J. Chem. Eng. Data., 48 (2003) 1037.
- [12] A. Pal, R. K. Bhardwaj, Z. Phys. Chem., 216 (2002) 1033.
- [13] K. Hsu-Chen, T. Chein-Hsiun, J. Chem. Eng. Data., 50 (2005) 608.
- [14] P. S. Nikam, M. Hosan, J. Chem. Eng. Data., 33 (1988) 165.
- [15] J. N. Nayak, M. I. Aralaguppi, T. M. Aminabhavi, J. Chem. Eng. Data., 48 (2003) 1489.
- [16] M. N. Roy, A. Sinha, B. Sinha, J. Soln. Chem., 34 (2005) 1311.
- [17] P. Jain, M. Singh, J. Chem. Eng. Data., 49 (2004) 1214.
- [18] R. J. Fort, W. R. Moore, Trans. Faraday. Soc., 62 (1966) 1112.
- [19] R. C. Reid, J. M. Prausnitz, B. E. Poling, *The properties of Gases and Liquids*, 4<sup>th</sup> ed., McGraw-Hill International, (1987).
- [20] J. B. Irving, *Viscosities of Liquid Mixtures*, NEL Report No 630 and 631, National Engineering Laboratory, East Kilbride, Glassgow, (1977).
- [21] L. Grunberg, A. H. Nissan, Nature., 164 (1949) 799.
- [22] M. Tamura, M. Kurata, Bull. Chem. Soc. Jpn., 25 (1952) 32.
- [23] R. K. Hind, E. McLaughlin, A. R. Ubbelohde, Trans. Faraday. Soc., 56 (1960) 328.
- [24] S. L. Oswal, H. S. Desai, Fluid Phase Equilibr., 186 (2001) 81.
- [25] P. Jain, M. Singh, J. Indian. Chem. Soc., 82 (2005) 225.
- [26] O. Redlich, A. T. Kister, Ind. Eng. Chem., 40 (1948) 345.

Table 1.  
Comparison of density ( $\rho$ ), viscosity ( $\eta$ ) of the Pure Liquids with  
Literature Data at 298.15 K.

Pure Liquid	$\rho / (\text{g}\cdot\text{cm}^{-3})$		$\eta / (\text{mPa}\cdot\text{s})$	
	Expt.	Lit.	Expt.	Lit.
1,4-Dioxane	1.0265	1.0278 <sup>8</sup>	1.1956	1.196 <sup>8</sup>
1,3-Dioxolane	1.0571	1.0587 <sup>9</sup>	0.5307	-
Butyl acetate	0.8744	0.8761 <sup>10</sup>	0.6684	0.674 <sup>10</sup>
Butyric acid	0.9528	-	1.3962	-
Butylamine	0.7319	0.7331 <sup>11</sup>	0.4934	0.496 <sup>12</sup>
2-Butanone	0.7981	0.7996 <sup>13</sup>	0.3728	0.378 <sup>13</sup>



**Excess Molar Volume and Viscosity Deviations ... .. at 298.15 K**

Table 2.

Values of density ( $\rho$ ), viscosity ( $\eta$ ), excess molar volume ( $V^E$ ), viscosity deviation ( $\Delta\eta$ ) and different interaction parameters for the binary mixtures of 1,4-dioxane or 1,3-dioxolane at 298.15 K.

$x_1$	$\rho$ /(g.cm <sup>-3</sup> )	$\eta$ /(mPa.s)	$V^E \times 10^6$ /(m <sup>3</sup> .mol <sup>-1</sup> )	$\Delta\eta$ /(mPa.s)	$d_{12}$	$T_{12}$	$H_{12}$
1,3-dioxolane (1) + 2-Butanone (2)							
0	0.7981	0.3728	0	0	-	-	-
0.0976	0.8189	0.3843	-0.084	-0.004	-0.0479	0.4405	0.4293
0.1957	0.8405	0.3972	-0.133	-0.006	-0.0368	0.4430	0.4311
0.2944	0.8631	0.4113	-0.164	-0.008	-0.0276	0.4451	0.4325
0.3935	0.8868	0.4258	-0.185	-0.009	-0.0260	0.4455	0.4325
0.4933	0.9118	0.4408	-0.201	-0.010	-0.0273	0.4454	0.4319
0.5935	0.9381	0.4564	-0.207	-0.010	-0.0311	0.4447	0.4306
0.6943	0.9655	0.4731	-0.173	-0.009	-0.0330	0.4444	0.4297
0.7956	0.9942	0.4910	-0.113	-0.007	-0.0352	0.4440	0.4298
0.8975	1.0245	0.5102	-0.045	-0.004	-0.0366	0.4438	0.4279
1	1.0571	0.5307	0	0	-	-	-
1,3-dioxolane (1) + Butyric acid (2)							
0	0.9528	1.3962	0	0	-	-	-
0.1167	0.9631	1.2966	-0.067	0.001	0.3771	0.9201	0.9703
0.2292	0.9737	1.2017	-0.150	0.004	0.4054	0.9243	0.9743
0.3376	0.9843	1.1107	-0.209	0.007	0.4372	0.9283	0.9784
0.4422	0.9953	1.0231	-0.276	0.010	0.4735	0.9325	0.9829
0.5432	1.0061	0.9379	-0.302	0.012	0.5140	0.9363	0.9873
0.6408	1.0169	0.8541	-0.317	0.012	0.5576	0.9389	0.9906
0.7351	1.0272	0.7702	-0.270	0.010	0.5965	0.9373	0.9897
0.8263	1.0374	0.6882	-0.206	0.007	0.6393	0.9353	0.9882
0.9146	1.0473	0.6077	-0.113	0.003	0.6751	0.9297	0.9827
1	1.0571	0.5307	0	0	-	-	-
1,3-dioxolane (1) + Butyl acetate (2)							
0	0.8744	0.6684	0	0	-	-	-
0.1484	0.8907	0.6213	-0.128	-0.027	-0.3078	0.4728	0.4939
0.2816	0.9069	0.5986	-0.149	-0.031	-0.2239	0.5167	0.5230
0.4019	0.9233	0.5876	-0.129	-0.025	-0.1506	0.5490	0.5465
0.5111	0.9403	0.5828	-0.103	-0.015	-0.0771	0.5761	0.5690
0.6106	0.9578	0.5774	-0.072	-0.007	-0.0230	0.5939	0.5851
0.7017	0.9761	0.5712	-0.050	-0.001	0.0224	0.6068	0.5981
0.7853	0.9952	0.5651	-0.034	0.005	0.0783	0.6204	0.6138
0.8625	1.0150	0.5558	-0.023	0.006	0.1211	0.6291	0.6253
0.9338	1.0356	0.5442	-0.012	0.004	0.1568	0.6349	0.6344
1	1.0571	0.5307	0	0	-	-	-
1,3-dioxolane (1)+ Butylamine (2)							
0	0.7319	0.4934	0	0	-	-	-
0.1001	0.7551	0.4767	0.013	-0.020	-0.4626	0.3922	0.3988
0.2001	0.7796	0.4629	0.038	-0.038	-0.0489	0.3907	0.3937
0.3002	0.8058	0.4576	0.065	-0.047	-0.4628	0.4022	0.4001
0.4002	0.8338	0.4546	0.082	-0.054	-0.4630	0.4062	0.4002
0.5002	0.8641	0.4561	0.085	-0.056	-0.4606	0.4103	0.4003
0.6002	0.8968	0.464	0.077	-0.052	-0.4384	0.4185	0.4041
0.7002	0.9321	0.4784	0.058	-0.041	-0.3899	0.4319	0.4142

Contd...

Excess Molar Volume and Viscosity Deviations ... .. at 298.15 K

0.8001	0.9703	0.4963	0.039	-0.027	-0.3285	0.4478	0.4277
0.9001	1.0118	0.5135	0.021	-0.013	-0.2860	0.4590	0.4370
1	1.0571	0.5307	0	0	-	-	-
1,4-Dioxane (1) +2-Butanone (2)							
0	0.7981	0.3728	0	0	-	-	-
0.0833	0.8170	0.3915	-0.077	-0.050	-0.632	0.4613	0.4576
0.1698	0.8365	0.4109	-0.124	-0.102	-0.7139	0.4283	0.4237
0.2597	0.8568	0.4364	-0.160	-0.150	-0.7555	0.3997	0.3938
0.3530	0.8779	0.4636	-0.186	-0.200	-0.8467	0.3545	0.3472
0.4501	0.9001	0.5124	-0.202	-0.231	-0.8346	0.3275	0.3180
0.5511	0.9233	0.5763	-0.205	-0.250	-0.8356	0.2909	0.2789
0.6563	0.9472	0.6497	-0.167	-0.263	-0.9285	0.2162	0.2009
0.7660	0.9722	0.7514	-0.111	-0.252	-1.0713	0.1022	0.0821
0.8805	0.9985	0.9006	-0.044	-0.197	-1.3692	-0.1215	-0.1502
1	1.0265	1.1956	0	0	-	-	-
1,4-Dioxane (1) + Butyric acid (2)							
0	0.9528	1.3962	0	0	-	-	-
0.1000	0.9617	1.5042	-0.183	0.128	0.9998	2.0259	2.0071
0.2000	0.9703	1.5699	-0.332	0.214	0.9268	1.9767	1.9642
0.3000	0.9784	1.5872	-0.420	0.251	0.8320	1.9004	1.8939
0.4000	0.9861	1.5722	-0.467	0.256	0.7531	1.8312	1.8297
0.5000	0.9934	1.5073	-0.456	0.211	0.6163	1.7161	1.7186
0.6000	1.0002	1.4428	-0.395	0.167	0.5245	1.6385	1.6437
0.7000	1.0068	1.3617	-0.307	0.106	0.3978	1.5416	1.5481
0.8000	1.0131	1.2926	-0.184	0.057	0.2938	1.4670	1.4737
0.9000	1.0194	1.2415	-0.065	0.026	0.2459	1.4322	1.4392
1	1.0265	1.1956	0	0	-	-	-
1,4-Dioxane (1) + Butyl acetate (2)							
0	0.8744	0.6684	0	0	-	-	-
0.1278	0.8875	0.6821	0.005	-0.054	-0.4852	0.7261	0.6911
0.2479	0.9010	0.6918	0.014	-0.107	-0.5890	0.6856	0.6441
0.3610	0.9149	0.7076	0.023	-0.151	-0.6628	0.6570	0.6045
0.4678	0.9292	0.7394	0.032	-0.176	-0.6871	0.6462	0.5794
0.5687	0.9441	0.7788	0.036	-0.189	-0.7249	0.6287	0.5459
0.6641	0.9594	0.8222	0.036	-0.196	-0.8028	0.5936	0.4920
0.7547	0.9753	0.8657	0.032	-0.201	-0.9734	0.5184	0.3903
0.8406	0.9918	0.9394	0.022	-0.172	-1.1077	0.4510	0.2898
0.9223	1.0089	1.0355	0.011	-0.119	-1.3746	0.3162	0.1013
1	1.0265	1.1956	0	0	-	-	-
1,4-Dioxane (1) + Butylamine (2)							
0	0.7319	0.4933	0	0	-	-	-
0.0855	0.7534	0.5087	0.020	-0.045	-0.5766	0.5699	0.5586
0.1738	0.7761	0.5242	0.052	-0.091	-0.6484	0.5408	0.5271
0.2650	0.8001	0.5408	0.089	-0.139	-0.7327	0.5055	0.4886
0.3594	0.8258	0.5601	0.117	-0.186	-0.8304	0.4626	0.4414
0.4569	0.8533	0.5901	0.141	-0.224	-0.9088	0.4199	0.3927
0.5579	0.8828	0.6369	0.147	-0.248	-0.9672	0.3762	0.3411
0.6625	0.9147	0.6994	0.127	-0.259	-1.0620	0.3105	0.2648
0.7709	0.9492	0.7919	0.080	-0.243	-1.1845	0.2176	0.1570
0.8834	0.9864	0.9412	0.039	-0.172	-1.3201	0.0898	0.0074
1	1.0265	1.1956	0	0	-	-	-

**Excess Molar Volume and Viscosity Deviations ... .. at 298.15 K**

Table 3.

Values of coefficients  $a_i$  of equation 6 and standard deviations  $\sigma$  for excess properties of the binary mixtures of 1,3-dioxolane (1) or 1,4-dioxane (1) studied at 298.15 K.

Binary mixture	Excess property	$a_0$	$a_1$	$a_2$	$a_3$	$a_4$	$\sigma$
1,3-dioxolane + 2-Butanone	$V^E \times 10^6$ /( $\text{m}^3 \cdot \text{mol}^{-1}$ )	-0.798	0.084	-	-	-	0.01
	$\Delta\eta$ /( $\text{mPa} \cdot \text{s}$ )	-0.040	-0.009	-0.009	0.129	-	0.00
1,3-dioxolane + Butyric acid	$V^E \times 10^6$ /( $\text{m}^3 \cdot \text{mol}^{-1}$ )	-1.184	-0.640	0.215	0.253	-	0.00
	$\Delta\eta$ /( $\text{mPa} \cdot \text{s}$ )	0.044	0.040	-0.027	-0.037	-	0.00
1,3-dioxolane + Butyl acetate	$V^E \times 10^6$ /( $\text{m}^3 \cdot \text{mol}^{-1}$ )	-0.414	0.580	-0.371	-	-	0.00
	$\Delta\eta$ /( $\text{mPa} \cdot \text{s}$ )	-0.068	0.183	-0.029	-	-	0.00
1,3-dioxolane + Butylamine	$V^E \times 10^6$ /( $\text{m}^3 \cdot \text{mol}^{-1}$ )	0.342	-0.070	-0.321	0.200	0.123	0.00
	$\Delta\eta$ /( $\text{mPa} \cdot \text{s}$ )	-0.222	0.031	0.056	0.040	-	0.00
1,4-Dioxane + 2-Butanone	$V^E \times 10^6$ /( $\text{m}^3 \cdot \text{mol}^{-1}$ )	-0.824	0.063	0.442	0.486	-0.337	0.00
	$\Delta\eta$ /( $\text{mPa} \cdot \text{s}$ )	-0.972	-0.422	-0.315	-0.623	-0.353	0.00
1,4-Dioxane + Butyric acid	$V^E \times 10^6$ /( $\text{m}^3 \cdot \text{mol}^{-1}$ )	-1.816	0.673	0.454	0.234	0.343	0.00
	$\Delta\eta$ /( $\text{mPa} \cdot \text{s}$ )	0.859	-0.819	-	-	-	0.00
1,4-Dioxane + Butyl acetate	$V^E \times 10^6$ /( $\text{m}^3 \cdot \text{mol}^{-1}$ )	0.135	0.112	-0.055	-0.063	-	0.00
	$\Delta\eta$ /( $\text{mPa} \cdot \text{s}$ )	-0.720	-0.319	-0.408	-0.582	-	0.00
1,4-Dioxane + Butylamine	$V^E \times 10^6$ /( $\text{m}^3 \cdot \text{mol}^{-1}$ )	0.579	0.093	-0.443	-0.105	-	0.00
	$\Delta\eta$ /( $\text{mPa} \cdot \text{s}$ )	-0.944	-0.527	-0.247	-0.469	-0.122	0.00

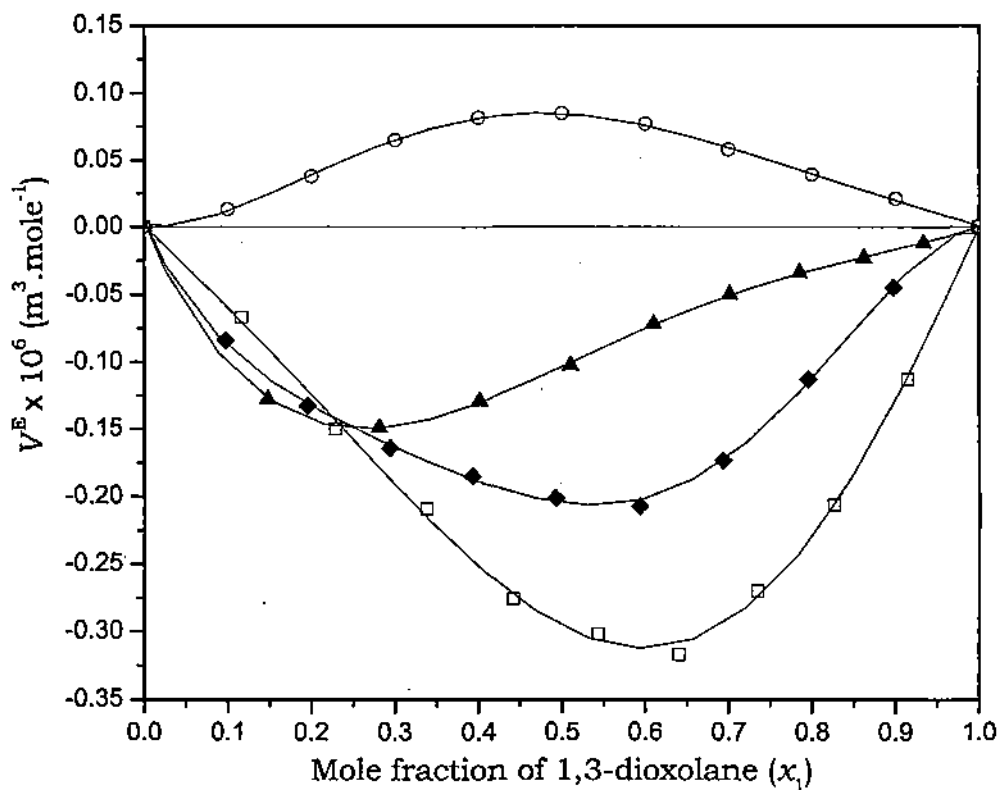


Figure 1. Excess molar volumes ( $V^E$ ) at 298.15 K for binary mixtures of 1,3-dioxolane (1) with Butyric acid (□), 2-Butanone(♦), butyl acetate (▲) and butylamine (O).

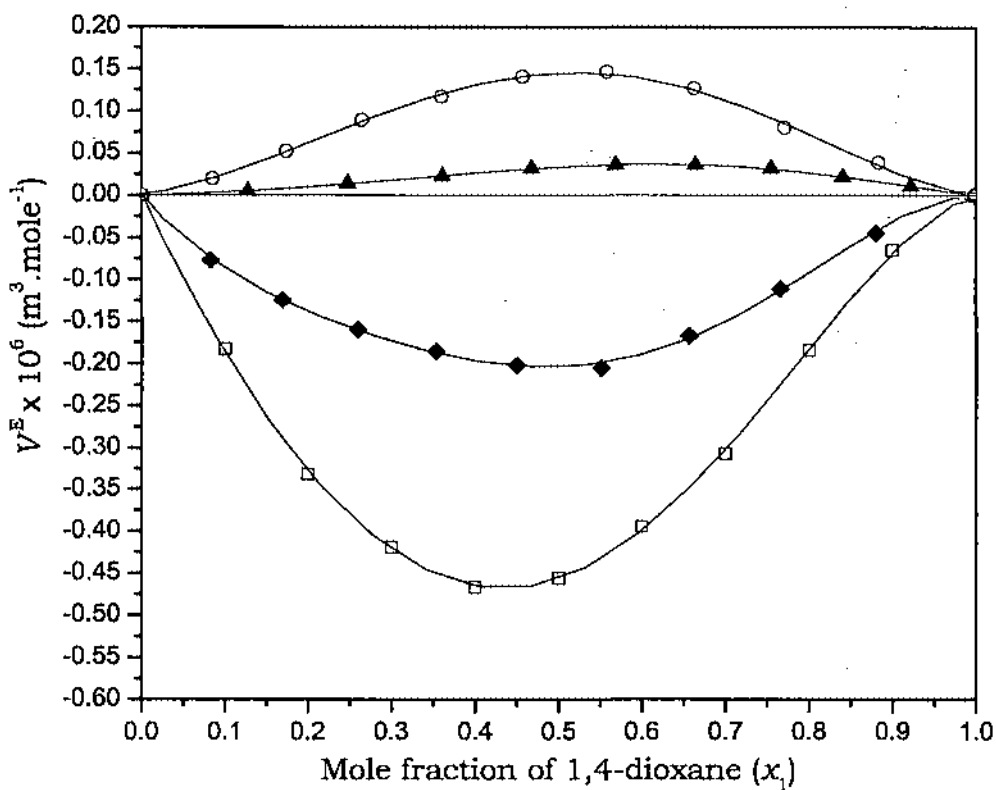


Figure 2.

Excess molar volumes ( $V^E$ ) at 298.15 K for binary mixtures of 1,4-dioxane (1) with Butyric acid ( $\square$ ), 2-Butanone( $\blacklozenge$ ), butyl acetate ( $\blacktriangle$ ) and butylamine (O).

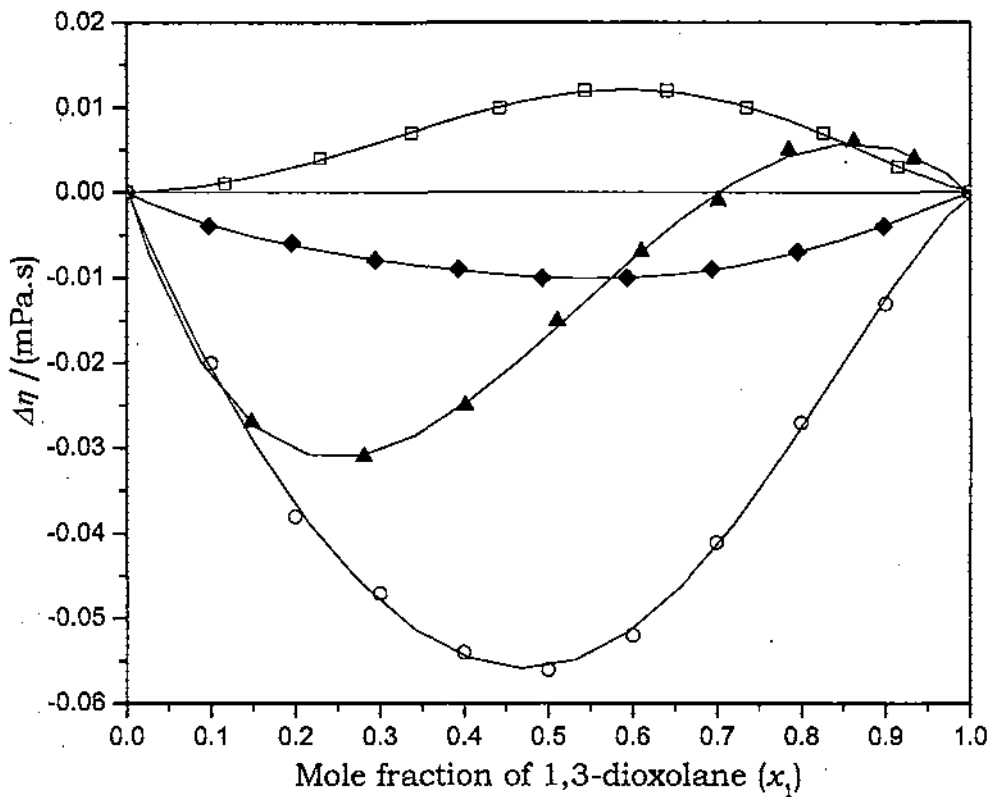


Figure 3.  
 Viscosity deviations ( $\Delta\eta$ ) at 298.15 K for binary mixtures of 1,3-dioxolane  
 (1) with Butyric acid (□), 2-Butanone(◆), butyl acetate (▲) and butylamine  
 (○).

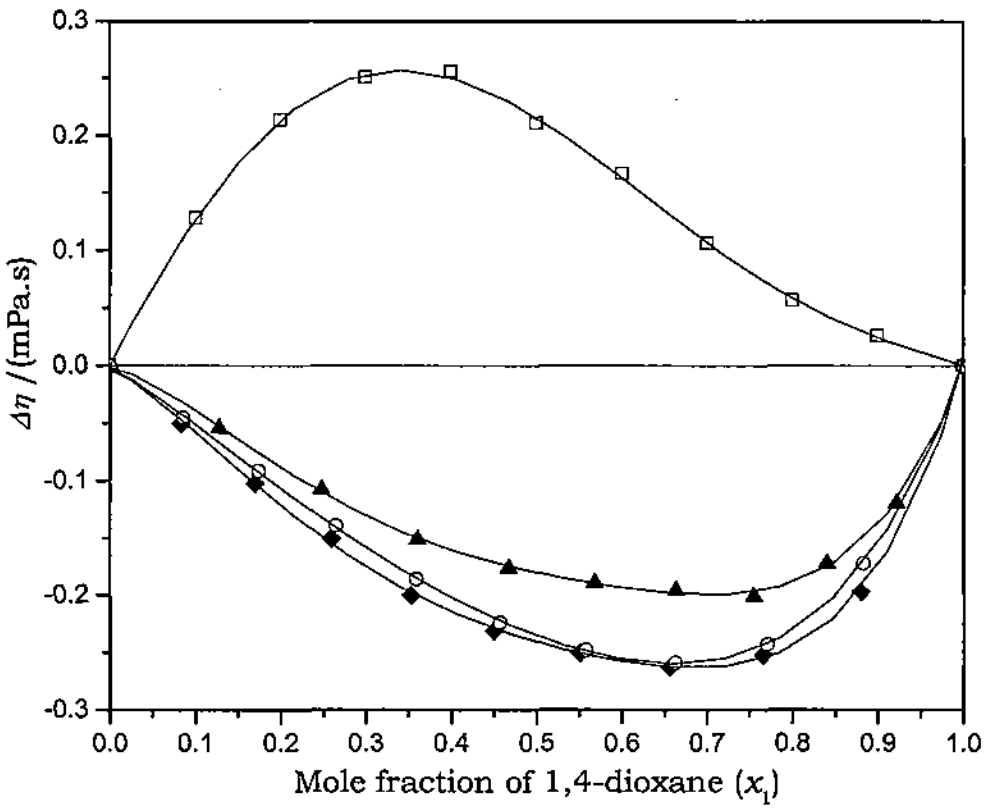


Figure 4. Viscosity deviations ( $\Delta\eta$ ) at 298.15 K for binary mixtures of 1,4-dioxane (1) with Butyric acid ( $\square$ ), 2-Butanone( $\blacklozenge$ ), butyl acetate ( $\blacktriangle$ ) and butylamine (O).