

## CHAPTER- IX

### **Volumetric, Viscometric, Interferometric and Refractometric Properties of 2-Methoxyethanol +Diethylether + Dichloromethane Ternary System and its Corresponding Binaries at 298.15 K**

#### **9.1. Introduction**

The thermodynamics of ternary liquid mixtures has not received much attention as the thermodynamics of binary mixtures as it becomes more difficult and time consuming with the addition of each component beyond a binary mixture. 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 study of alkoxy alkanols is of interest not only because of their wide use as industrial solvents but also from the more theoretical point of investigating the effect of the simultaneous presence of etheric and hydroxyl groups on the interaction of such molecules. Since, ethers are used as oxygenating agents in gasoline technology, the thermodynamics involving ethers and other liquid mixtures have been intensively studied<sup>1-4</sup>. Dichloromethane is a very interesting solvent with appreciable industrial use in pharmaceutical industry, as paint stripping agent, aerosols and as adhesives etc. and also as it is a solvent exhibiting high density and low viscosity.

Considering all of these aspects we undertook investigations on the thermodynamic and transport properties of binary and ternary mixtures involving 2-methoxy ethanol (2-M.E), diethyl ether (D.E.E) and dichloromethane (D.C.M). In this paper are reported excess molar volume ( $V^E$ ), viscosity deviations ( $\Delta\eta$ ), deviations in isentropic compressibility ( $\Delta K_s$ ), excess molar refraction ( $\Delta R$ ) and Gibbs excess free energy of activation for viscous flow ( $\Delta G^*$ ) for three binary mixtures 2-M.E+D.E.E, 2-M.E+D.C.M, D.E.E+D.C.M and their corresponding ternary mixtures at 298.15K 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.

## 9.2. Experimental Section

### 9.2.1. Chemicals

2-Methoxyethanol (S.D. Fine Chemicals, AR, India) were purified as described in the literature<sup>5</sup>. Dichloromethane (Sigma-Aldrich, 99.9%, HPLC Grade), was dried over calcium hydride and distilled. Diethylether (S.D. Fine Chemicals, AR grade, India) was used as purchased. The purity of each substance was evaluated by comparing experimental values of density, viscosity and refractive index with those reported in the literature when available, as presented in Table 1.

### 9.2.2. Apparatus and procedure

Densities ( $\rho$ ) were measured with an Ostwald-Sprengel type pycnometer having a bulb volume of about 25 cm<sup>3</sup> and an internal diameter of the capillary of about 0.1 cm. The measurements were done in a thermostat bath controlled to  $\pm 0.01$  K. Viscosity ( $\eta$ ) 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  $\pm 0.1$ 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  $\pm 0.0002$ . The mass measurements were done on a Mettler AG-285 electronic balance with a precision of  $\pm 0.01$  mg. The precision of density measurements was  $\pm 3 \times 10^{-4}$  g·cm<sup>-3</sup>.

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 303.15K. The precision of ultrasonic speed measurements was  $\pm 0.2 \text{ m}\cdot\text{s}^{-1}$ . The details of the methods and techniques have been described in earlier papers <sup>6-9</sup>. Refractive index was measured with the help of Abbe-Refractometer (U.S.A). The accuracy of refractive index measurement was  $\pm 0.0002$  units. The refractometer was calibrated twice using distilled and deionized water, and calibration was checked after every few measurements.

### 9.3. Results and Discussion

The experimental values of densities and excess molar volumes of binary mixtures 2-M.E + D.E.E, 2-M.E + D.C.M, D.E.E + D.C.M at 298.15K are listed in Table 2.

#### 9.3.1. Excess molar volume

The  $\rho$  values have been used to calculate the excess molar volumes ( $V^E$ ) for binary ( $n=2$ ) and ternary ( $n=3$ ) mixture using the following equation<sup>10</sup>,

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

where  $\rho$  is the density of the mixture and  $M_i$ ,  $x_i$ ,  $\rho_i$  are the molecular weight, mole fraction and viscosity of the  $i^{\text{th}}$  component in the mixture respectively.

Fig. 1 summarizes details of the experimental binary excess molar volume data over the entire range of composition.

$V^E$  is the resultant of contributions from several opposing effects. These may be divided arbitrarily into three types, namely, chemical, physical and structural. Physical contributions, which are nonspecific interactions between the real species present in the mixture, contribute a positive term to  $V^E$ . The negative values to  $V^E$  are contributed by the chemical or specific intermolecular interactions which results in a volume decrease. The structural contributions are mostly negative and arise from several effects, especially from interstitial accommodation and changes of free volume <sup>11</sup>.

From Table 2 and Fig. 1 it is evident that  $V^E$  values are negative for binary mixtures of 2-M.E + D.E.E, 2-M.E + D.C.M and D.E.E + D.C.M. These phenomena

are the results of difference in energies of interaction between molecules being in solutions and packing effects.

The negative values of  $V^E$  indicate that the packing degree is enhanced in these mixed liquids with respect to the pure species and to their ideal mixtures suggesting that specific intermolecular interactions such as hydrogen bonding and dipolar interactions of any kind between the component molecules are more effective and operative. Therefore, the attractive interactions (which are generally responsible for structure-making effects) seems to be the prevailing forces in the liquid structure <sup>12</sup> of these solutions with respect to repulsive phenomena due to sterical hindrances and unfavorable interactions between polar and apolar groups (structure breaking effects). Another negative contribution to  $V^E$  comes from the geometrical fitting of unlike molecules in to each other's structure due to differences in shape and size of the component molecules.

Table 5 lists experimental values of densities ( $\rho$ ) and viscosities ( $\eta$ ) of ternary mixture of 2-M.E+D.E.E+D.C.M at 298.15K. The excess molar volume depend on the balance between two opposing contribution (a) a positive term from the rupture of hydrogen bond and physical dipole-dipole interaction between components in solution (b) a negative term from formation of hydrogen bonded complex and packing effect between solvents. The experimental data in the present investigation suggests that factors (b) which are responsible for negative excess volume dominate over the entire range of composition. From Table 5 it is evident that the magnitude of negative deviation of  $V^E$  values of ternary mixture is more than that of their corresponding binary mixtures suggesting that specific intermolecular interactions between the component molecules are more prominent and operative.

### 9.3.2. Viscosity deviation

The measured  $\eta$  values for binary systems at 298.15K are listed in Table2. The viscosity deviations ( $\Delta\eta$ ) <sup>13</sup> from linear dependence for binary ( $n=2$ ) and ternary ( $n=3$ ) mixtures can be calculated as

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

Where,  $\eta$  is the viscosity of the mixture and  $x_i, \eta_i$  is the mole fraction and viscosity of Pure component  $i$  respectively. The values of  $\Delta\eta$  are negative over entire range of mole fraction for 2-M.E + D.E.E, 2-M.E + D.C.M and D.E.E + D.C.M systems. It is observed in many systems that there is no simple correlation between the strength of the interactions and the observed properties. Rastogi et al. <sup>14</sup> therefore, suggested that the observed excess property is a combination of an interaction and a non-interaction part. The non-interaction part in the form of size effect can be comparable to the interaction part and may be sufficient to reverse the trend set by the latter.

The values of viscosity deviations ( $\Delta\eta$ ) for the ternary mixture are listed in Table 5. 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.

### 9.3.3. Deviation in isentropic compressibility

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

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

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

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  $i^{\text{th}}$  component in the mixture respectively. It is evident from Table 3 and Fig. 3 that, for the binary mixtures, the  $\Delta K_s$  values are negative over all composition range. These results can be explained in terms of molecular interactions <sup>15, 16</sup> between unlike molecules. It appears from the sign and magnitude of  $\Delta K_s$  that specific interaction exist between mixing components. These results are in excellent agreement with those of  $V^E$  discussed earlier.

The values of  $\Delta K_s$  for the ternary mixture are negative over all composition range and are given in Table 6 which suggests that specific interactions exist between mixing components <sup>17</sup>.

### 9.3.4. Deviation in molar refraction

The molar refraction,  $[R]$  can be evaluated from Lorentz-Lorenz relation<sup>18</sup> and gives more information than  $n_D$  about the mixture phenomenon because it 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, correspondingly, the molar refraction, the refractive index and the molar mass of the mixture respectively. Deviation from molar refraction for binary ( $n=2$ ) and ternary ( $n=3$ ) was calculated from the following relation;

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

where  $x_i$  and  $[R]_i$  are mole fraction and molar refraction for the pure components respectively. The values of  $\Delta R$  for binary mixtures (Table 3 and Fig.4) and ternary mixture (Table 5) were found to negative over the entire range of composition.

### 9.3.5. Excess Gibb's free energy of activation

On the basis of the theories of absolute reaction rates<sup>19</sup>, the excess Gibbs energy of activation for viscous flow was calculated from the equation<sup>20</sup> for binary ( $n=2$ ) and ternary ( $n=3$ ) systems.

$$\Delta G^E = RT \left[ \ln \eta V - \sum_{i=1}^n x_i \ln \eta_i V_i \right] \quad (7)$$

where  $R$ ,  $T$ ,  $V_i$  and  $V$  are the universal gas constant, experimental temperature in absolute scale, and the molar volumes of the pure component and the mixtures, respectively. The calculated values of  $\Delta G^E$  for binary and ternary mixtures are reported in Table 2 and 5 respectively.

The excess properties ( $V^E$ ,  $\Delta \eta$ ,  $\Delta K_s$ ,  $\Delta R$ ,  $\Delta G^E$ ) for the binary mixtures were fitted to the Redlich-Kister polynomial equation<sup>21</sup>,

$$Y_{ij}^E = x_1 x_2 \sum_{i=1}^2 a_i (x_1 - x_2)^i \quad (8)$$

where  $Y^E$  refer to an excess property,  $x_1$  is the mole fraction of I.A.A and  $x_2$  is that of the other component.

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 4. The standard deviation was calculated using the equation

$$\sigma = \left[ \frac{(Y_{exp}^E - Y_{cal}^E)^2}{(n-m)} \right]^{\frac{1}{2}} \quad (9)$$

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

#### 9.4. Conclusion

It can be concluded that the specific intermolecular interactions are more prominent in binary liquid mixtures than in the pure species and that of ternary mixtures are more operative as compared to the binary mixtures.

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**Table 1**

 Density ( $\rho$ ), viscosity ( $\eta$ ), sound speed ( $u$ ) and refractive index ( $n_D$ ) of pure liquids at 298.15K.

Pure Components	$\rho \times 10^{-3} / \text{kg}\cdot\text{m}^{-3}$		$\eta / \text{mPa}\cdot\text{s}$		$u / \text{m}\cdot\text{s}^{-1}$		$n_D$	
	This work	Lit	This work	Lit	This work	Lit	This work	Lit
2-methoxyethanol	0.9608	0.9601 <sup>22</sup>	1.5470	1.573 <sup>25</sup>	1339.40	1341 <sup>22</sup>	1.4005	1.3996 <sup>25</sup>
Dichloromethane	1.3162	1.3163 <sup>23</sup>	0.4652	0.406 <sup>26</sup>	1071.30	1035 <sup>23</sup>	1.4210	1.4228 <sup>23</sup>
Diethylether	0.7091	0.7083 <sup>24</sup>	0.2337	-	982.00	983 <sup>24</sup>	1.3515	-

**Table 2**

Densities ( $\rho$ ), viscosities ( $\eta$ ), excess molar volumes ( $V^E$ ), viscosity deviations ( $\Delta\eta$ ) and excess Gibbs energy of activation ( $\Delta G^{\ddagger}$ ) for binary mixtures of 2-methoxyethanol, dichloromethane and diethylether at 298.15K.

$x_1$	$\rho \times 10^{-3}/\text{kg} \cdot \text{m}^{-3}$	$\eta/\text{mPa} \cdot \text{s}$	$V^E \times 10^6 / \text{m}^3 \cdot \text{mol}^{-1}$	$\Delta\eta/ \text{mPa} \cdot \text{s}$	$\Delta G^{\ddagger} \times 10^{-3}/\text{J} \cdot \text{mol}^{-1}$
<b>(<math>x_1</math>) 2-methoxyethanol+(1-<math>x_1</math>)diethylether</b>					
0.0000	0.7091	0.2337	0.0000	0.0000	0.00
0.0976	0.7321	0.2661	-0.5400	-0.0958	-167.00
0.1958	0.7562	0.3070	-1.0400	-0.1838	-280.00
0.2944	0.7824	0.3630	-1.5900	-0.2574	-309.82
0.3936	0.8083	0.4399	-1.9000	-0.3107	-276.00
0.4933	0.8360	0.5713	-2.2000	-0.3103	-175.00
0.5936	0.8650	0.6782	-2.4500	-0.3351	-96.00
0.6944	0.8927	0.8546	-2.3700	-0.2910	31.00
0.7957	0.9201	1.0645	-2.1100	-0.2142	80.00
0.8976	0.9445	1.3300	-1.4400	-0.0825	70.60
1.0000	0.9608	1.5470	0.0000	0.0000	0.00
<b>(<math>x_1</math>)2-methoxyethanol+(1-<math>x_1</math>)dichloromethane</b>					
0.0000	1.3162	0.4652	0.0000	0.0000	0.00
0.1103	1.2779	0.5177	-0.4500	-0.0668	-75.08
0.2181	1.2419	0.5832	-0.8942	-0.1180	-113.11
0.3235	1.2056	0.6707	-1.2004	-0.1445	-88.49
0.4266	1.1702	0.7669	-1.4324	-0.1598	-53.00
0.5274	1.1359	0.8908	-1.5990	-0.1450	-3.13
0.6260	1.1013	1.0294	-1.6165	-0.1130	48.00
0.7225	1.0671	1.1678	-1.5248	-0.0790	77.00
0.8170	1.0331	1.2950	-1.2940	-0.0540	80.00
0.9095	0.9977	1.4276	-0.8000	-0.0214	49.05
1.0000	0.9608	1.5470	0.0000	0.0000	0.00
<b>(<math>x_1</math>)diethylether+(1-<math>x_1</math>) dichloromethane</b>					
0.0000	1.3162	0.4652	0.0000	0.0000	0.00
0.1130	1.2193	0.4351	-0.3915	-0.0039	50.00
0.2227	1.1347	0.4106	-0.7090	-0.0031	91.00
0.3294	1.0592	0.3839	-0.8800	-0.0050	124.40
0.4331	0.9934	0.3585	-1.0670	-0.0064	134.44
0.5341	0.9343	0.3342	-1.1633	-0.0074	127.97
0.6322	0.8806	0.3106	-1.1290	-0.0083	113.09
0.7278	0.8313	0.2890	-0.9383	-0.0077	89.81
0.8209	0.7842	0.2687	-0.6520	-0.0065	63.00
0.9116	0.7471	0.2496	-0.5070	-0.0046	20.24
1.0000	0.7091	0.2337	0.0000	0.0000	0.00

**Table 3**

 Ultrasonic speed ( $u$ ), isentropic compressibility ( $K_s$ ) deviation in isentropic compressibility ( $\Delta K_s$ ), refractive indices ( $n_D$ ) excess molar refraction ( $\Delta R$ ) for binary mixtures of 2-methoxyethanol, dichloromethane and diethylether at 298.15K.

$x_1$	$u/\text{m}\cdot\text{s}^{-1}$	$K_s \times 10^{12}/\text{Pa}^{-1}$	$\Delta K_s \times 10^{12}/\text{Pa}^{-1}$	$n_D$	$\Delta R \times 10^{-6} (\text{m}^3 \cdot \text{mol}^{-1})$
<b><i>(x<sub>1</sub>) 2-methoxyethanol+(1-x<sub>1</sub>)diethylether</i></b>					
0.0000	982.30	1461.52	0.00	1.3515	0.0000
0.0976	1017.70	1318.92	-56.55	1.3562	-0.0570
0.1958	1053.40	1191.72	-97.26	1.3616	-0.0890
0.2944	1089.10	1077.55	-124.47	1.3674	-0.1280
0.3936	1124.80	977.80	-136.79	1.3727	-0.1640
0.4933	1160.50	888.22	-138.49	1.3786	-0.1840
0.5936	1196.20	807.91	-130.44	1.3846	-0.2070
0.6944	1231.90	738.17	-111.35	1.3897	-0.2140
0.7957	1267.60	676.38	-83.84	1.3948	-0.1920
0.8976	1303.30	623.32	-47.11	1.3990	-0.1284
1.0000	1339.40	580.16	0.00	1.4005	0.0000
<b><i>(x<sub>1</sub>)2-methoxyethanol+(1-x<sub>1</sub>)dichloromethane</i></b>					
0.0000	1071.30	662.00	0.00	1.4210	0.0000
0.1103	1104.91	640.97	-12.00	1.4190	-0.0883
0.2181	1137.46	622.34	-21.80	1.4157	-0.2260
0.3235	1166.54	609.52	-26.00	1.4130	-0.3134
0.4266	1196.12	597.28	-29.80	1.4105	-0.3808
0.5274	1222.20	589.35	-29.48	1.4080	-0.4373
0.6260	1247.93	583.06	-27.70	1.4062	-0.4360
0.7225	1270.90	580.17	-22.70	1.4050	-0.3881
0.8170	1292.52	579.39	-15.74	1.4033	-0.3310
0.9095	1315.96	578.77	-8.79	1.4020	-0.1960
1.0000	1339.40	580.16	0.00	1.4005	0.0000
<b><i>(x<sub>1</sub>)diethylether+(1-x<sub>1</sub>) dichloromethane</i></b>					
0.0000	1.4210	662.00	0.00	1.4210	0.0000
0.1130	1.4106	575.31	-177.00	1.4106	-0.0320
0.2227	1.4015	575.07	-265.00	1.4015	-0.0586
0.3294	1.3930	621.73	-303.63	1.3930	-0.0758
0.4331	1.3859	686.30	-322.00	1.3859	-0.0827
0.5341	1.3794	775.98	-313.00	1.3794	-0.0840
0.6322	1.3732	897.03	-270.46	1.3732	-0.0782
0.7278	1.3671	1013.53	-230.39	1.3671	-0.0647
0.8209	1.3603	1148.43	-169.92	1.3603	-0.0452
0.9116	1018.01	1291.50	-99.36	1.3568	-0.0272
1.0000	982.30	1461.52	0.00	1.3515	0.0000

**Table 4**

 Redlich-Kister coefficients and standard deviations ( $\sigma$ ) for the binary mixtures at 298.15K.

Excess property	$A_0$	$A_1$	$A_2$	$A_3$	$A_4$	$A_5$	$\Sigma$
<b><i>(x<sub>1</sub>) 2-methoxyethanol+(1-x<sub>1</sub>)diethylether</i></b>							
$V^E \times 10^6 / \text{m}^3 \cdot \text{mol}^{-1}$	-8.9561	-4.5284	-2.8712	-2.1783			0.0361
$\Delta\eta / \text{mPa} \cdot \text{s}$	-1.4062	-0.2284	0.5879	-0.1309	-1.4100	0.9561	0.0039
$\Delta G^* \times 10^{-3} / \text{J} \cdot \text{mol}^{-1}$	-726.6322	2050.1837	260.3553	529.6563			8.1111
$\Delta K_s \times 10^{12} / \text{Pa}^{-1}$	-554.1238	90.0715	-35.7869	-13.8799			0.3714
$\Delta R \times 10^{-6} / \text{m}^3 \cdot \text{mol}^{-1}$	-0.7534	-0.4545	-0.4509	-0.1894	0.2568		0.0019
<b><i>(x<sub>1</sub>)2-methoxyethanol+(1-x<sub>1</sub>)dichloromethane</i></b>							
$V^E \times 10^6 / \text{m}^3 \cdot \text{mol}^{-1}$	-6.2185	-2.3247	-1.4405	-1.2546			0.0124
$\Delta\eta / \text{mPa} \cdot \text{s}$	-0.5735	0.4051	0.1382	-0.2725			0.0025
$\Delta G^* \times 10^{-3} / \text{J} \cdot \text{mol}^{-1}$	-58.5601	1071.7461	-56.7858	-292.8441			3.6397
$\Delta K_s \times 10^{12} / \text{Pa}^{-1}$	-118.1758	3.3582	-20.3350				0.4595
$\Delta R \times 10^{-6} / \text{m}^3 \cdot \text{mol}^{-1}$	-1.6550	-0.9392					0.0108
<b><i>(x<sub>1</sub>)diethylether+(1-x<sub>1</sub>) dichloromethane</i></b>							
$V^E \times 10^6 / \text{m}^3 \cdot \text{mol}^{-1}$	-4.51045	-1.01182					0.0364
$\Delta\eta / \text{mPa} \cdot \text{s}$	-0.03317	-0.00694	-0.00822				0.0002
$\Delta G^* \times 10^{-3} / \text{J} \cdot \text{mol}^{-1}$	417.5670	88.7335	-12.3521	-92.0735	82.5724		1.3980
$\Delta K_s \times 10^{12} / \text{Pa}^{-1}$	-1249.4508	340.0011	-336.8316				4.6221
$\Delta R \times 10^{-6} / \text{m}^3 \cdot \text{mol}^{-1}$	-0.33878	0.01127	0.02961				0.0012

**Table 5**

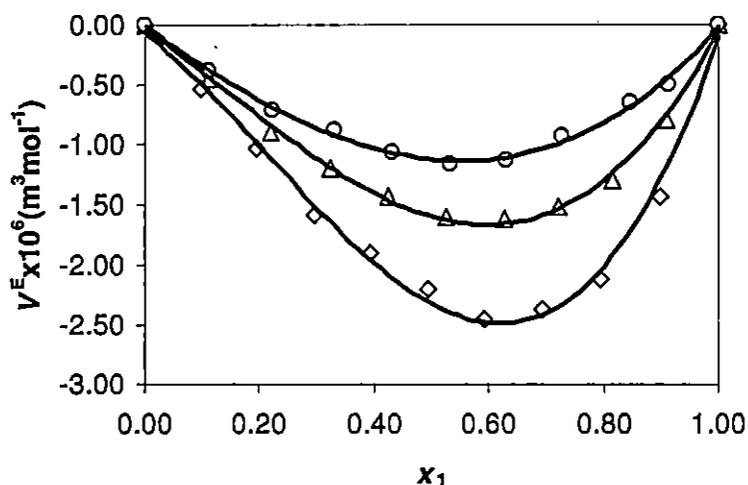
Densities ( $\rho$ ), viscosities ( $\eta$ ), excess molar volumes ( $V^E$ ), viscosity deviations ( $\Delta\eta$ ) and excess Gibbs energy of activation ( $\Delta G^*$ ) for ternary mixtures of 2-methoxyethanol, diethylether and dichloromethane at 298.15K.

$(1-x_1-x_2)$	$\rho \times 10^{-3}$ /kg·m <sup>-3</sup>	$\eta$ /mPa·s	$V^E \times 10^6$ /m <sup>3</sup> ·mol <sup>-1</sup>	$\Delta\eta$ / mPa·s	$\Delta G^* \times 10^{-3}$ /J·mol <sup>-1</sup>
<b><i>(x<sub>1</sub>)2-methoxyethanol+(x<sub>2</sub>)diethylether +(1-x<sub>1</sub>-x<sub>2</sub>)dichloromethane</i></b>					
0.0000	0.8338	0.5713	-1.9657	-0.3103	-35.00
0.0468	0.8723	0.5616	-4.0630	-0.3005	-62.34
0.0995	0.9084	0.5541	-5.4352	-0.2861	-97.18
0.1593	0.9434	0.5476	-6.2341	-0.2677	-146.79
0.2276	0.9832	0.5306	-6.9236	-0.2562	-193.65
0.3065	1.0266	0.5158	-7.3003	-0.2382	-260.69
0.3987	1.0741	0.5026	-7.2811	-0.2130	-298.59
0.5077	1.1256	0.4926	-6.7043	-0.1776	-316.29
0.6388	1.1842	0.4857	-5.5657	-0.1299	-285.48
0.7991	1.2493	0.4799	-3.5475	-0.0689	-158.19
1.0000	1.3241	0.4652	-0.4003	0.0000	-0.12

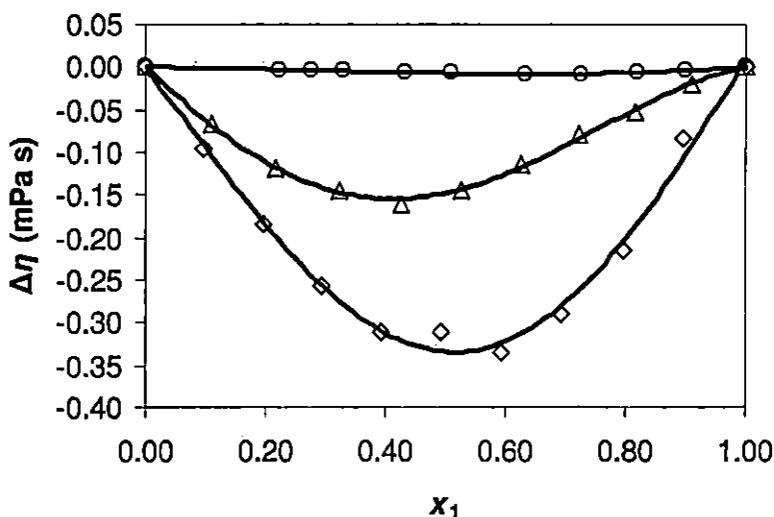
**Table 6**

Ultrasonic speed ( $u$ ), isentropic compressibility ( $K_s$ ) deviation in isentropic compressibility ( $\Delta K_s$ ), refractive indices ( $n_D$ ) excess molar refraction ( $\Delta R$ ) for ternary mixtures of 2-methoxyethanol, diethylether and dichloromethane at 298.15K.

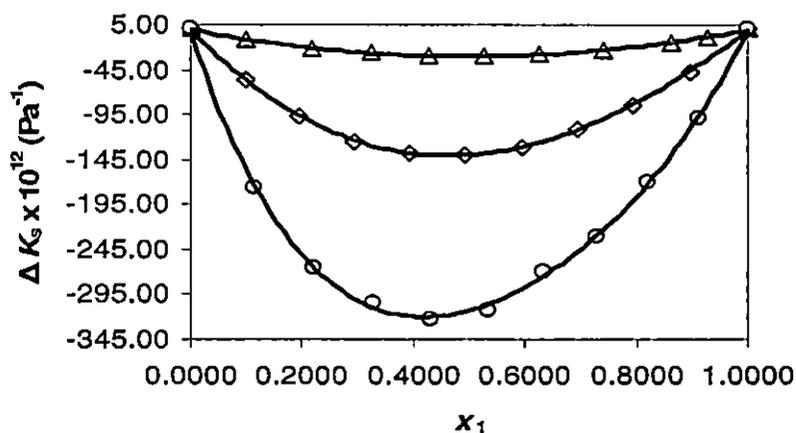
$(1-x_1-x_2)$	$u/m \cdot s^{-1}$	$K_s$ $10^{12}/Pa^{-1}$	$x \Delta K_s$ $10^{12}/Pa^{-1}$	$x n_D$	$\Delta R \times 10^{-6}$ $/m^3 \cdot mol^{-1}$
<i>(x<sub>1</sub>)2-methoxyethanol+(x<sub>2</sub>)diethylether +(1-x<sub>1</sub>-x<sub>2</sub>)dichloromethane</i>					
0.0000	1260.90	890.5	-136.17	1.4668	0.0000
0.0468	1293.77	834.9	-150.00	1.4475	-0.4136
0.0995	1296.88	806.5	-152.00	1.4294	-0.7550
0.1593	1249.41	826.0	-147.00	1.4139	-0.9582
0.2276	1208.62	830.3	-134.00	1.3986	-1.1149
0.3065	1171.32	827.0	-117.00	1.3835	-1.2055
0.3987	1148.04	806.4	-100.00	1.3668	-1.2957
0.5077	1125.02	785.9	-84.00	1.3525	-1.1946
0.6388	1109.57	746.9	-61.00	1.3377	-0.9935
0.7991	1090.98	706.5	-34.00	1.3244	-0.5604
1.0000	1071.30	658.0	0.00	1.3090	0.0000



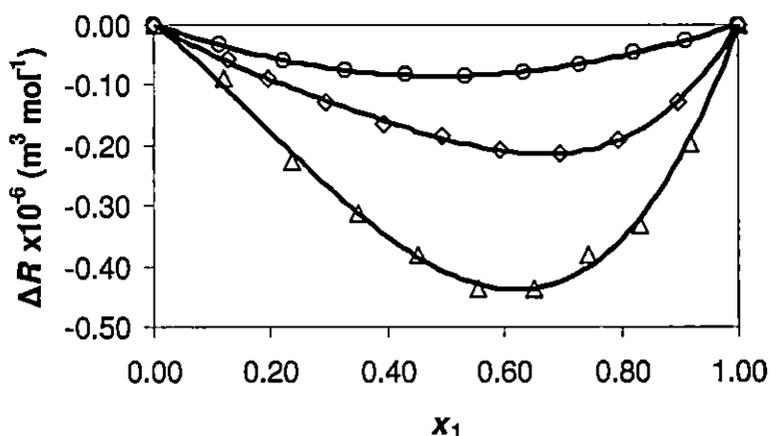
**Figure 1:** Plot of excess molar volumes  $V^E \times 10^6 (\text{m}^3 \cdot \text{mol}^{-1})$  against mole fraction ( $x_1$ ) for the three binary subsystems at 298.15K.  $\diamond$  ( $x_1$ ) 2-M.E + ( $1-x_1$ ) D.E.E;  $\Delta$  ( $x_1$ )2-M.E + ( $1-x_1$ ) D.C.M;  $\circ$  ( $x_1$ ) D.E.E + ( $1-x_1$ ) D.C.M.



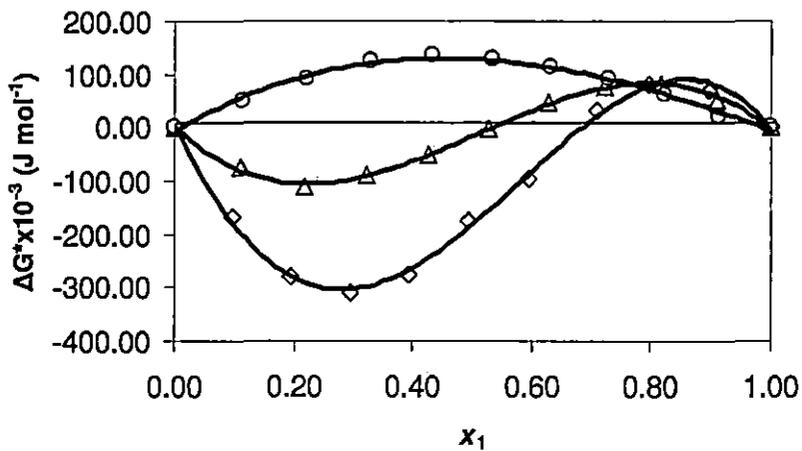
**Figure 2.** Plot of viscosity deviations,  $\Delta\eta$  (mPa·s) against mole fraction ( $x_1$ ) for the three binary subsystems at 298.15K.  $\diamond$  ( $x_1$ ) 2-M.E + ( $1-x_1$ ) D.E.E;  $\Delta$  ( $x_1$ )2-M.E + ( $1-x_1$ ) D.C.M;  $\circ$ ( $x_1$ ) D.E.E + ( $1-x_1$ ) D.C.M.



**Figure 3.** Plot of deviation in isentropic compressibility  $\Delta K_s \times 10^{12}$  ( $\text{Pa}^{-1}$ ) against mole fraction ( $x_1$ ) for the three binary subsystems at 298.15K.  $\diamond(x_1)$  2-M.E +  $(1-x_1)$  D.E.E;  $\Delta(x_1)$  2-M.E +  $(1-x_1)$  D.C.M;  $\circ(x_1)$  D.E.E +  $(1-x_1)$  D.C.M.



**Figure 4.** Plot of molar refraction  $\Delta R \times 10^{-6}$  ( $\text{m}^3 \cdot \text{mol}^{-1}$ ) against mole fraction ( $x_1$ ) for the three binary subsystems at 298.15K.  $\diamond(x_1)$  2-M.E +  $(1-x_1)$  D.E.E;  $\Delta(x_1)$  2-M.E +  $(1-x_1)$  D.C.M;  $\circ(x_1)$  D.E.E +  $(1-x_1)$  D.C.M.



**Figure 5.** Plot of deviation of excess Gibbs energy of activation  $\Delta G^* \times 10^{-3} \text{ (J} \cdot \text{mol}^{-1}\text{)}$  against mole fraction ( $x_1$ ) for the three binary subsystems at 298.15K.  $\diamond(x_1)$  2-M.E + (1-  $x_1$ ) D.E.E;  $\Delta(x_1)$  2-M.E + (1-  $x_1$ ) D.C.M; o ( $x_1$ ) D.E.E + (1-  $x_1$ ) D.C.M.