

CHAPTER X

Studies on Solution Properties of Ternary Mixture of Acetophenone + Amyl alcohol + Dichloromethane and its Corresponding Binaries at 298.15 K.

10.1. Introduction

In recent years, measurements of thermodynamic and transport properties of binary and ternary liquid mixtures have been adequately employed in understanding the nature of molecular systems and physico-chemical behaviour in liquid mixtures [1]. 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.

Acetophenone, a typical ketone is used in perfumery and as a hypotonic under the name "hypone". It is also used as a solvent for cellulose ethers. 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 acetophenone (A.P), amyl alcohol (A.L) and dichloromethane (D.C.M).

In this paper are reported excess molar volume (V^E), viscosity deviations ($\Delta\eta$), deviations in isentropic compressibility (ΔK_S), excess molar refraction (ΔR) and Gibbs excess free energy of activation for viscous flow (ΔG^E) for three binary mixtures of A.P + A.L, A.P + D.C.M, A.L + D.C.M and

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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.

10.2. Experimental

10.2.1 *Experimental materials*

Acetophenone, amyl alcohol and dichloromethane were procured from S.d.fine-Chem Limited, Mumbai, India. Acetophenone was dried over anhydrous potassium carbonate for 3 days, filtered, and then distilled. The middle fraction of the distillate was retained [2]. Dichloromethane was dried over calcium hydride and distilled. Amyl alcohol was used as purchased. 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

10.2.2 *Measurements*

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 $\pm 2 \times 10^{-4}$ mPas. 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 $\pm 3 \times 10^{-4}$ g 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 303.15K. The precision of ultrasonic speed measurements was ± 0.2 ms⁻¹. The details of the methods and techniques have been described in earlier papers [3-6]. 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.

10.3. Results and discussion

We have calculated excess molar volume (V^E), viscosity deviations ($\Delta\eta$), deviations in isentropic compressibility (ΔK_s), excess molar refraction (ΔR) and Gibbs excess free energy of activation for viscous flow (ΔG^E) at 298.15K for the binary mixtures of acetophenone, dichloromethane and amyl alcohol over all composition range. The variations of the excess properties over the entire range of composition for the binary mixtures are depicted in Figs. 1-5.

10.3.1 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 equation [7]

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

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

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 chemical or specific intermolecular interactions result in a volume decrease, thereby contributing negative V^E values. The structural contributions are mostly negative and arise from several effects, especially from interstitial accommodation and changes of free volume [8].

The values of excess molar volume (V^E) are found to be negative for binary mixtures of A.P+A.L and A.L+D.C.M over the entire range of compositions but for A.P+D.C.M the V^E values are positive.

These phenomena are the results of difference in energies of interaction between molecules being in solutions and packing effects. Disruption of the ordered structure of pure component during formation of the mixture leads to a positive effect observed on excess volume while an order formation in the mixture leads to negative contribution. The carbonyl group is highly polar and has a high percentage of ionic character [9]. There is a negative charge on the carbonyl oxygen atom of acetophenone. The weaker interactions in binary mixture of A.P and D.C.M may be attributed to the internal interaction between the π -electrons of C=O bond and the π electrons of benzene ring [10]. The positive V^E values may also be due to repulsion between the highly electronegative chlorine atom of D.C.M and π electrons of benzene ring of acetophenone. Thus, for this binary mixture the factors which are responsible for expansion in volume are dominant over the entire composition range. The negative V^E values indicate the specific interactions such as intermolecular hydrogen bonding between the (-OH group of amyl alcohol and π electrons of C=O bond of acetophenone and also between -OH group of amyl alcohol and electronegative chlorine atom of dichloromethane) mixing components and also interstitial accommodation of the mixing components because of the difference in molar volumes. The negative V^E values may also be due to the

difference in the dielectric constants of the liquid components of the binary mixtures [11]. The negative V^E values for all the systems studied may be attributed to dipole-induced dipole interactions between the component liquids of the mixtures resulting in the formation of electron donor-acceptor complexes [12].

The density (ρ) values and excess molar volume (V^E) for the ternary mixture (A.P+A.L+D.C.M) are reported in Table 5. From Table 5 it is evident that the V^E values are negative in the low mole fraction region of D.C.M suggesting specific intermolecular interaction between the two components (A.P+A.L), but as the mole fraction of D.C.M in the ternary mixture increases the magnitude of V^E decreases suggesting that dispersion forces now begins to operate. Thus, it can be said that the addition of D.C.M to binary mixture of A.L+A.P causes a decrease in intermolecular interaction between the mixing components. This is in agreement with our earlier discussion of binary mixtures.

10.3.2 Viscosity deviation

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

$$\Delta\eta = \eta - \sum_{i=1}^3 (x_i\eta_i) \quad (2)$$

where, η is the viscosity of the mixture and x_i , η_i are the mole fraction and viscosity of pure component i respectively. The values of $\Delta\eta$ are positive for A.P+A.L and A.L+D.C.M and negative for A.P+D.C.M over the entire range of compositions. Also, the deviations in $\Delta\eta$ values are found to be opposite to the sign of excess molar volumes V^E or all three binary mixtures, which is in agreement with the view proposed by Brocos et al. [14, 15]. This further

reinforces our earlier conclusions regarding the intermolecular interactions from the variations of V^E values of these mixtures.

A correlation between the sign of $\Delta\eta$ and V^E (Table 2) has been observed for a number of binary solvent systems [16, 17] i.e., $\Delta\eta$ is positive when V^E is negative and vice-versa. In general, for systems where dispersion and dipolar interactions are operating, $\Delta\eta$ values are found to be negative, whereas charge-transfer and hydrogen-bonding interactions lead to the formation of complex species between unlike molecules, thereby resulting in positive $\Delta\eta$ values [18].

10.3.3 Viscosity model and interaction parameter

Several semi empirical models have been proposed to estimate the dynamic viscosity, η of the binary liquid mixtures in terms of pure component data [19, 20] one of which is discussed below.

Grunberg and Nissan [21] have suggested the following logarithmic relation between the viscosity of binary liquid mixtures and of pure components

$$\ln\eta = x_1\ln\eta_1 + x_2\ln\eta_2 + x_1x_2d_{12} \quad (3)$$

where d_{12} is a constant, proportional to interchange energy, and the other symbols have their usual significance. It may be regarded as an approximate measure of the strength of molecular interactions between the mixing components. The calculated d_{12} values of the binary mixtures at different temperatures are listed in Table 2. Table 2 shows that the values of d_{12} are negative for all the binary liquid mixtures except that of acetophenone with dichloromethane over the entire range of compositions. The positive values of d_{12} may be attributed to the presence of specific interactions [22, 23] between the mixing components in the mixtures, whereas the negative values of d_{12} indicate the presence of dispersion forces [23] between them.

The viscosity (η) values and deviation in viscosity ($\Delta\eta$) values are reported in Table 5. It is seen from Table 5 that $\Delta\eta$ values are positive in the low mole fraction region of D.C.M but as the mole fraction of D.C.M in the ternary mixture increases the values of $\Delta\eta$ gradually decreases and becomes negative in higher mole fraction region of D.C.M. This in accordance with the inference of V^E values of ternary mixture.

10.3.4 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:

$$K_S = \frac{1}{(u^2\rho)} \tag{4}$$

$$\Delta K_S = K_S - \sum_{i=1}^3 x_i K_{S,i} \tag{5}$$

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 respectively.

An examination of deviation in isentropic compressibility (ΔK_S) data in Table 3 and Fig.3 suggest that the quantity is positive for binary mixture of A.P+D.C.M and negative for A.P+A.L, D.C.M+A.L binary mixtures. These may be attributed to the relative strength of effects which influenced the free space between component molecules. The negative ΔK_S values arise from changes of "free volume" and polar interactions in the real mixture and positive ΔK_S values are due to the dispersion interactions between unlike molecules. These results support our earlier discussion arising from excess molar volumes.

10.3.5 Deviation in Molar Refraction.

The molar refraction, $[R]$ can be evaluated from Lorentz-Lorenz relation [24] 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

$$[R] = \left(\frac{n_D^2 - 1}{n_D^2 + 2} \right) \cdot \left(\frac{M}{\rho} \right) \quad (6)$$

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 was calculated from the following relation;

$$\Delta R = [R] - \sum_{i=1}^3 x_i [R]_i \quad (7)$$

The values of refractive indices and excess molar refraction (ΔR) for the binary mixtures are presented in Table 3 and depicted graphically in Fig.4 and the data for ternary mixture are reported in Table 6.

10.3.6 Excess Gibb's free energy of activation

On the basis of the theories of absolute reaction rates [25], the excess Gibbs energy of activation for viscous flow was calculated from the equation [26] for binary ($n=2$) and ternary ($n=3$) systems.

$$\Delta G^E = RT \left[\ln \eta V - \sum_{i=1}^3 x_i \ln \eta_i V_i \right] \quad (8)$$

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. From Table 3 and Fig. 5 it is evident that the ΔG^E

values are positive for A.P + D.C.M and negative for A.P + A.L and A.L + D.C.M binary mixtures over entire range of mole fraction. The positive values indicate the specific interaction between unlike molecules compared to like molecules, while the negative values of ΔG^E indicate the dominance of dispersion forces in these mixtures.

The ΔG^E values of ternary mixture are reported in Table 5. The ΔG^E values decreases in the low mole fraction region of D.C.M and becomes negative but as the mole fraction of D.C.M increases, the magnitude of ΔG^E begins to increase and becomes positive in higher mole fraction region of D.C.M. Thus, it can be said that specific interaction between unlike molecules increases with the increase of D.C.M in the ternary mixture.

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 [27],

$$Y_{ij}^E = x_1 x_2 \sum_{i=1}^2 a_i (x_1 - x_2)^i \quad (9)$$

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

$$\sigma = \left[\frac{(Y_{exp}^E - Y_{cal}^E)^2}{(n - m)} \right]^{\frac{1}{2}} \quad (10)$$

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

10.4. Conclusion

It may be concluded that in the low mole fraction region of D.C.M, intermolecular interaction between the two components (A.P+A.L), but as the mole fraction of D.C.M in the ternary mixture increases dispersion forces begins to operate. Thus, it can be said that the addition of D.C.M to binary mixture of A.L+A.P causes a decrease in intermolecular interaction between the mixing components.

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TABLE 1: Density (ρ), viscosity (η), sound speed (u) and refractive index (n_D) of the pure component liquids at different temperatures.

Pure components	$\rho \times 10^{-3} \text{kg m}^{-3}$		η/mPas		u/ms^{-1}		n_D	
	This work	Lit	This work	Lit	This work	Lit	This work	Lit
	Acetophenone	1.0291	1.0241[28]	1.6663	1.680[28]	1519.4	-	1.5340
amyl alcohol	0.8164	0.8110[30]	3.1858	3.056[31]	1271.6	1256[32]	1.4100	1.4078[30]
dichloromethane	1.3162	1.3163[33]	0.4652	0.406[34]	1071.3	1035[33]	1.4210	1.4228[33]

[29]^a Value reported at 293.15K

TABLE 2: Densities (ρ), viscosities(η), excess molar volumes (V^E), viscosity deviations ($\Delta\eta$), interaction parameter (d_{12}) and excess Gibbs energy of activation (ΔG^E) for binary mixtures of acetophenone, dichloromethane amyl alcohol.

x_1	$\rho \times 10^3$ kg m ³	$\eta_{exp}/$ mPas	$V^E \times 10^6$ m ³ mol ⁻¹	$\Delta\eta$ /mPas	d_{12}	$\Delta G^E \times 10^{-3}$ (Jmol ⁻¹)
(x_1) acetophenone + (1- x_1)dichloromethane						
0.0000	1.3162	0.4652	0.0000	0.0000		0.0000
0.0728	1.2899	0.5046	0.1321	-0.0480	-0.171	9.3000
0.1501	1.2608	0.5598	0.3706	-0.0857	-0.051	19.7945
0.2324	1.2299	0.6209	0.6697	-0.1234	-0.044	28.0000
0.3201	1.2005	0.6967	0.8474	-0.1530	-0.021	45.0000
0.4139	1.1704	0.7804	1.0167	-0.1820	-0.045	60.0000
0.5144	1.1419	0.8931	1.0240	-0.1900	-0.017	74.3000
0.6224	1.1145	1.0357	0.8800	-0.1770	0.027	82.3386
0.7386	1.0867	1.2123	0.6684	-0.1400	0.080	80.0000
0.8641	1.0594	1.4220	0.2992	-0.0810	0.127	54.3000
1.0000	1.0291	1.6663	0.0000	0.0000		0.0000
(x_1)acetophenone + (1- x_1) amyl alcohol						
0.0000	0.8164	3.1858	0.0000	0.0000		0.0000
0.0754	0.8388	3.1043	-0.4083	0.0330	0.329	42.1548
0.1550	0.8495	3.0163	-0.5623	0.0660	0.349	120.6803
0.2392	0.8672	2.9183	-0.7467	0.0960	0.370	177.2188
0.3285	0.8859	2.8007	-0.8582	0.1140	0.381	221.3045
0.4232	0.9062	2.6567	-0.9433	0.1140	0.379	243.2884
0.5240	0.9280	2.4976	-0.9796	0.1080	0.386	250.8472
0.6313	0.9508	2.3096	-0.8895	0.0830	0.376	228.1293
0.7459	0.9745	2.1024	-0.6520	0.0500	0.358	178.6798
0.8685	1.0008	1.8981	-0.3810	0.0320	0.394	117.9123
1.0000	1.0291	1.6663	0.0000	0.0000		0.0000
(x_1)amyl alcohol + (1- x_1) dichloromethane						
0.0000	1.3162	0.4652	0.0000	0.0000		0.0000
0.0966	1.2400	0.7741	-0.3062	0.0460	3.704	773.7460
0.1940	1.1722	1.0969	-0.5479	0.1040	3.099	1144.5033
0.2921	1.1110	1.3908	-0.6950	0.1310	2.579	1275.3330
0.3909	1.0558	1.6686	-0.7650	0.1400	2.206	1261.3701

Studies on Solution..... Binaries at 298.15 K.

0.4905	1.0056	1.9296	-0.7434	0.1300	1.916	1156.8684
0.5908	0.9603	2.1816	-0.6768	0.1090	1.690	991.2391
0.6919	0.9197	2.4367	-0.6050	0.0890	1.523	783.5470
0.7938	0.8820	2.6879	-0.4269	0.0630	1.385	545.4065
0.8965	0.8481	2.9273	-0.2730	0.0230	1.234	272.8385
1.0000	0.8164	3.1858	0.0000	0.0000		0.0000

TABLE 3: Ultrasonic speed (u), isentropic compressibility (K_S), deviation in isentropic compressibility (ΔK_S), refractive indices (n_D) and excess molar refraction (ΔR) for binary for binary mixtures of acetophenone, dichloromethane and amyl alcohol at 298.15K.

x_1	u/ms^{-1}	$K_S \times 10^{12}$ /Pa $^{-1}$	$\Delta K_S \times 10^{12}$ /Pa $^{-1}$	n_D	$\Delta R \times 10^6$ (m 3 mol $^{-1}$)
(x_1) acetophenone + (1- x_1)dichloromethane					
0.0000	1071.30	662.00	0.00	1.4210	0.0000
0.0728	1091.31	650.95	6.50	1.4400	0.0626
0.1501	1116.37	636.42	10.60	1.4566	0.1200
0.2324	1146.94	618.08	12.10	1.4695	0.1084
0.3201	1180.31	597.92	13.10	1.4820	0.1020
0.4139	1219.21	574.80	12.60	1.4918	0.0450
0.5144	1262.78	549.18	11.20	1.5011	-0.0250
0.6224	1312.85	520.56	8.60	1.5097	-0.1100
0.7386	1371.47	489.24	5.30	1.5179	-0.1500
0.8641	1439.73	455.39	1.70	1.5263	-0.1450
1.0000	1519.40	420.92	0.00	1.5340	0.0000
(x_1)acetophenone + (1- x_1)amyl alcohol					
0.0000	1271.60	757.53	0.00	1.4100	0.0000
0.0754	1286.95	719.86	-12.30	1.4232	0.0330
0.1550	1321.15	674.45	-30.90	1.4300	0.0842
0.2392	1348.82	633.80	-43.20	1.4409	0.1340
0.3285	1368.40	602.80	-44.15	1.4519	0.1510
0.4232	1384.17	575.97	-39.10	1.4637	0.1610
0.5240	1402.94	547.46	-33.70	1.4760	0.1357
0.6313	1426.23	517.03	-28.00	1.4890	0.1142
0.7459	1451.80	486.86	-19.60	1.5020	0.0540
0.8685	1483.20	454.22	-10.97	1.5171	0.0200
1.0000	1519.40	420.92	0.00	1.5340	0.0000
(x_1)amyl alcohol + (1- x_1) dichloromethane					
0.0000	1071.30	662.00	0.00	1.4210	0.0000
0.0966	1098.30	668.58	-3.30	1.4190	-0.0490
0.1940	1123.57	675.79	-5.90	1.4170	-0.1400
0.2921	1148.71	682.13	-9.30	1.4155	-0.1800
0.3909	1172.21	689.28	-11.81	1.4140	-0.2300

Studies on Solution..... Binaries at 298.15 K.

0.4905	1193.17	698.47	-12.20	1.4130	-0.2373
0.5908	1212.41	708.39	-11.80	1.4120	-0.2209
0.6919	1228.46	720.53	-9.10	1.4115	-0.1820
0.7938	1243.96	732.70	-6.30	1.4110	-0.1240
0.8965	1258.21	744.80	-3.50	1.4105	-0.0400
1.0000	1271.60	757.53	0.00	1.4100	0.0000

TABLE 4: Redlich-Kister coefficients and standard deviations (σ) for binary liquid mixtures at 298.15K.

Excess property	A_0	A_1	A_2	A_3	A_4	A_5	σ
(x_1) acetophenone + (1- x_1) dichloromethane							
$V^E \times 10^6$ $m^3 mol^{-1}$	4.0824	-0.6338	-1.7676	0.9017	-	1.5929	0.018
$\Delta\eta$ (mPa s)	-0.7056	-0.3702	-	-	-	-	0.004
$\Delta G^E \times 10^{-3}$ (Jmol $^{-1}$)	289.402	262.168	26.544	-81.231	-	-	1.073
$\Delta K_S \times 10^{12}$ /Pa $^{-1}$	45.7807	-34.9423	-0.2823	-23.9907	-	-	0.146
$\Delta R \times 10^6$ ($m^3 mol^{-1}$)	-0.0635	-1.4624	-0.1939	-	-	-	0.007
(x_1) acetophenone + (1- x_1) amyl alcohol							
$V^E \times 10^6$ $m^3 mol^{-1}$	-3.8344	0.5163	-	-	-	-	0.020
$\Delta\eta$ (mPa s)	0.4557	-0.0921	-0.1845	-	-	-	0.003
$\Delta G^E \times 10^{-3}$ (Jmol $^{-1}$)	1001.28 5	-132.586	-136.136	485.046	-	-	4.958
$\Delta K_S \times 10^{12}$ /Pa $^{-1}$	- 144.016 4	125.208 4	-83.6329	-	-	-	1.951
$\Delta R \times 10^6$ ($m^3 mol^{-1}$)	0.6373	-0.1529	-0.5202	-	-	-	0.005
(x_1) amylalcohol + (1- x_1) dichloromethane							
$V^E \times 10^6$ $m^3 mol^{-1}$	-2.9834	0.9074	-0.33454	-0.7695	-	-	0.013
$\Delta\eta$ (mPa s)	0.5065	-0.3149	0.2584	0.2111	-0.6720	-	0.002

Studies on Solution..... Binaries at 298.15 K.

$\Delta G^E \times 10^{-3}$ (Jmol ⁻¹)	4679.077	-2656.448	1513.940	-947.285	528.753	632.36	0.008
$\Delta K_S \times 10^{12}$ /Pa ⁻¹	-48.9707	-2.7738	25.1304	-	-	-	0.320
$\Delta R \times 10^6$ (m ³ mol ⁻¹)	-0.9516	-0.0615	0.5962	-	-	-	0.003

TABLE 5: Densities (ρ), viscosities(η), excess molar volumes (V^E), viscosity deviations ($\Delta\eta$), and excess Gibbs energy of activation (ΔG^E) for ternary mixtures of acetophenone, amyl alcohol and dichloromethane at 298.15K.

(1- x_1 - x_2)	$\rho \times 10^3$ kg m ³	$\eta_{exp}/$ mPas	$V^E \times 10^6$ m ³ mol ⁻¹	$\Delta\eta/m$ Pas	$\Delta G^E \times 10^{-3}$ (Jmol ⁻¹)
(x_1)acetophenone+(x_2)amyl alcohol +(1- x_1 - x_2)dichloromethane					
0.0000	0.9116	1.8698	-1.9657	0.8962	624.78
0.0624	0.9392	1.6192	-4.0630	0.6748	450.41
0.1302	0.9716	1.3917	-5.4352	0.4791	269.37
0.2043	1.0039	1.2036	-6.2341	0.3258	131.89
0.2854	1.0385	1.0550	-6.9236	0.2151	53.05
0.3746	1.0763	0.8967	-7.3003	0.0986	-73.97
0.4733	1.1183	0.7779	-7.2811	0.0259	-118.99
0.5829	1.1621	0.6797	-6.7043	-0.0209	-102.19
0.7055	1.2106	0.6032	-5.5657	-0.0400	-1.87
0.8435	1.2655	0.5418	-3.5475	-0.0367	181.02
1.0000	1.3241	0.4652	-0.4003	-0.0400	322.40

 TABLE 6: 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 acetophenone, amyl alcohol and dichloromethane at 298.15K.

(1- x_1 - x_2)	u/ms^{-1}	$K_S \times 10^{12}$ /Pa ⁻¹	$\Delta K_S \times 10^{12}$ /Pa ⁻¹	n_D	$\Delta R \times 10^6$ (m ³ mol ⁻¹)
(x_1)acetophenone+(x_2)amyl alcohol +(1- x_1 - x_2)dichloromethane					
0.0000	1381.81	574.50	-36.88	1.4635	-0.0364
0.0624	1345.86	587.81	-18.00	1.4620	-0.4302
0.1302	1277.42	630.71	8.66	1.4595	-0.8879
0.2043	1243.04	644.67	18.19	1.4560	-1.2357
0.2854	1202.73	665.70	33.85	1.4530	-1.4516
0.3746	1180.89	666.27	38.30	1.4490	-1.6099
0.4733	1152.76	672.90	43.50	1.4445	-1.6728
0.5829	1128.73	675.44	41.30	1.4405	-1.5144
0.7055	1092.76	691.73	32.00	1.4350	-1.2433
0.8435	1084.10	672.38	16.12	1.4300	-0.7490
1.0000	1071.62	657.64	-3.96	1.4210	-0.0978

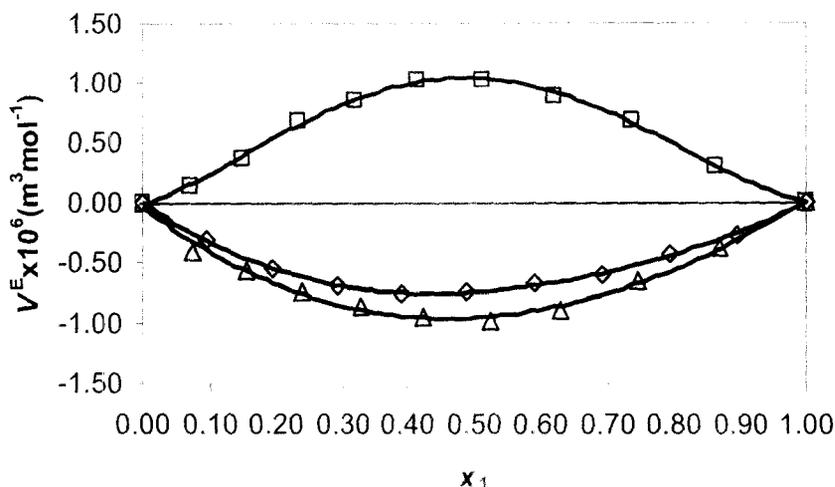


FIGURE 1. Excess molar volumes $V^E \times 10^6$ ($\text{m}^3 \text{mol}^{-1}$) versus mole fraction (x_1) for the three binary subsystems at 298.15K. $\square(x_1)$ A.P + (1- x_1) D.C.M, $\diamond(x_1)$ A.L + (1- x_1) D.C.M, $\triangle(x_1)$ A.P + (1- x_1) A.L.

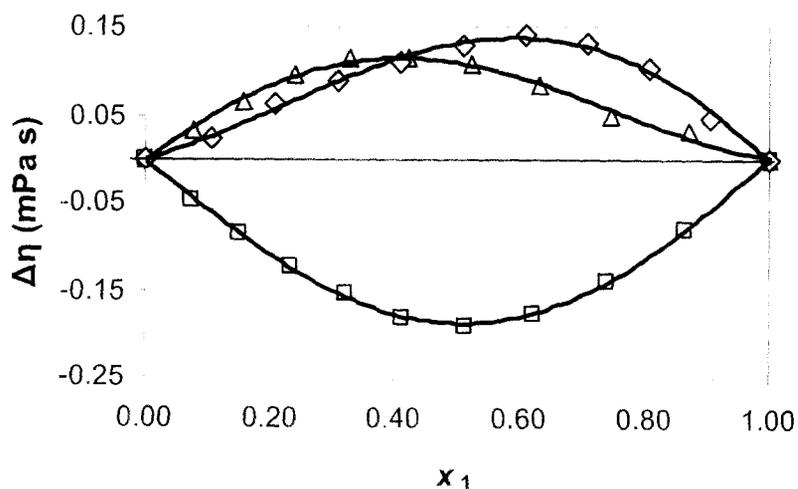


FIGURE 2. Viscosity deviations, $\Delta\eta$ (mPa s) versus mole fraction (x_1) for the three binary subsystems at 298.15K. $\square(x_1)$ A.P + (1- x_1) D.C.M, $\diamond(x_1)$ A.L + (1- x_1) D.C.M, $\triangle(x_1)$ A.P + (1- x_1) A.L.

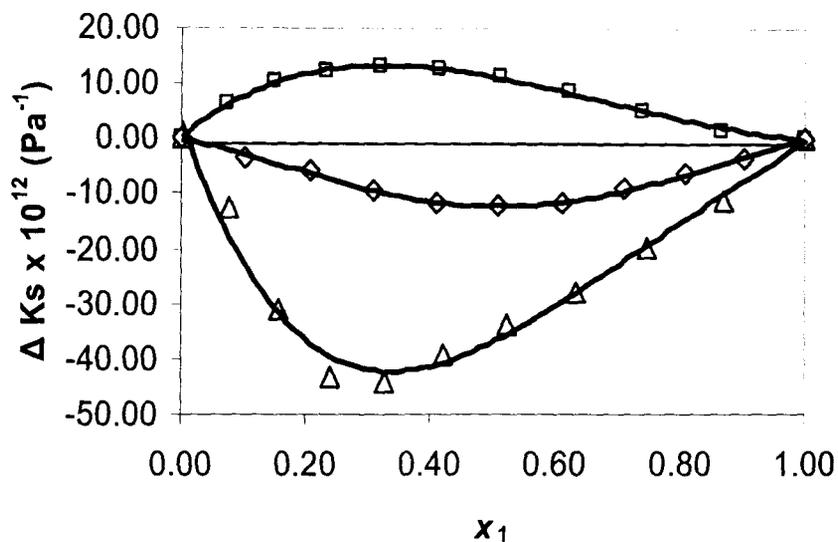


FIGURE 3. Deviation in isentropic compressibility $\Delta K_S \times 10^{12}$ (Pa^{-1}) versus mole fraction (x_1) for the three binary subsystems at 298.15K. $\square(x_1)$ A.P + (1- x_1) D.C.M, $\diamond(x_1)$ A.L + (1- x_1) D.C.M, $\Delta(x_1)$ A.P + (1- x_1) A.L.

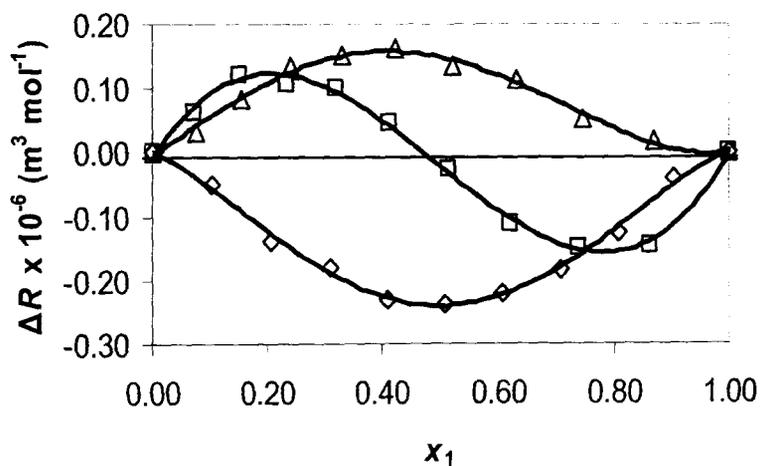


FIGURE 4. Molar refraction $\Delta R \times 10^{-6}$ ($\text{m}^3 \text{mol}^{-1}$) versus mole fraction (x_1) for the three binary subsystems at 298.15K. $\square(x_1)$ A.P + (1- x_1) D.C.M, $\diamond(x_1)$ A.L + (1- x_1) D.C.M, $\Delta(x_1)$ A.P + (1- x_1) A.L.

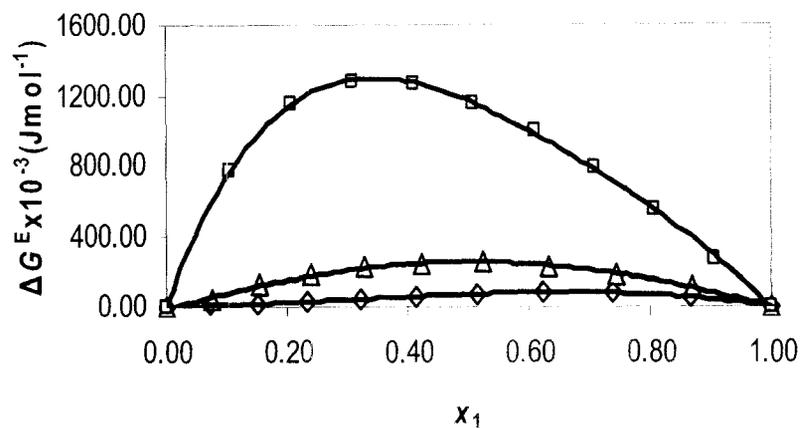


FIGURE 5. Deviation of excess Gibbs energy of activation $\Delta G^E \times 10^{-3} \text{ (J mol}^{-1}\text{)}$ versus mole fraction (x_1) for the three binary subsystems at 298.15K. $\square(x_1)$ A.P + (1- x_1) D.C.M, $\diamond(x_1)$ A.L + (1- x_1) D.C.M, $\Delta(x_1)$ A.P + (1- x_1) A.L.