Density, ultrasonic velocity, viscosity and their excess parameters of the binary mixtures of

N,N- diethyl aniline with 1-Alkanols (C₃-C₅), + 2-Alkanols (C₃-C₄)   at 303.15 K

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Abstract

The density ρ, ultrasonic   sound velocity u and viscosity η of binary mixtures of N,N-diethylaniline (N, N-DEA) with 1-propanol, + 1-butanol, + 1-pentanol, 1-hexanol, 1-heptanol 1-octanol,1-nonanol, 1-decanol + 2-propanol, and 2-butanol were measured at 303.15 K. The experimental data have been used to calculate excess volume V^E, deviation in ultrasonic velocity Δu, deviation in isentropic compressibility $\Delta\kappa_s$, deviation in intermolecular free length ΔL_f, deviation in acoustic impedance ΔZ, deviation in viscosity $\Delta\eta$ and excess Gibbs free energy of activation of viscous flow (G^{*E}). For all the binary mixtures ΔL_f and $\Delta\kappa_s$ the values are opposite values of ΔZ over the wide range of composition. These results have been used to understand the nature of interaction between unlike molecules in terms of hydrogen bonding, dipole-dipole interaction, proton donor-acceptor interactions and dispersive forces. The experimental viscosity data have been correlated using three equations; Grunberg and Nissan, Katti & Chaudhri and Hind et al. The excess / deviation properties have been fitted by a Redlich-Kister equation and the results were analyzed in terms of specific interactions present in these mixtures.

Keywords: ultrasonic velocity, viscosity, density, excess thermodynamic parameters.

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1. **Introduction**

In recent years, there has been considerable advancement in the experimental investigation of excess thermodynamic properties of liquid mixtures. These properties have been adequately employed in understanding the nature of molecular interactions in binary liquid mixtures. In chemical industry, knowledge of the thermodynamic properties of non-electrolyte solutions is essential in the design involving chemical separation, heat transfer, mass transfer and fluid flow. Furthermore, thermodynamic properties of binary mixtures containing components capable of undergoing specific interactions exhibit significant deviations from ideality arising not only from differences in molecular size and shape but also due to structural changes. In addition, alcohols and amines are widely used in a variety of industrial and consumer applications and hence, knowledge of their physical properties is also of great importance from a practical point of view. The liquids were chosen in the present investigation are having many industrial applications. The liquids were chosen in the present investigation on the basis of their industrial importance. Alcohols are used as hydraulic fluids in pharmaceutical and cosmetics, in medications for animals, in manufacturing of perfumes, paint removers, flavors and dyestuffs, as defrosting and as an antiseptic agent. N,N-diethylaniline is used as a solvent, preparation of dyes and various organic products.

    As a part of ongoing our research program in measurement of thermodynamic properties of binary liquid mixtures [1-5], we report here the excess volume V^E, deviation in ultrasonic sound velocity Δu, deviation in isentropic compressibility $\Delta\kappa_s$,   deviation in intermolecular free

length ΔL_f, deviation in acoustic impedance ΔZ, deviation in viscosity $\Delta\eta$ and excess Gibbs free energy of activation of viscous flow (G^{*E}) of the binary systems: N,N-diethylaniline with homologous series of aliphatic alcohols (1-propanol, + 1-butanol, + 1-pentanol, 1-hexanol, 1-heptanol 1-octanol,1-nonanol, 1-decanol + 2-propanol, + 2-butanol). The experimental results have been used to discuss the nature of interaction between unlike molecules in terms of hydrogen bonding, dipole-dipole interaction, proton-acceptor interaction and dispersive forces. The main intention of present work is chain length of alcohol to analyze the effect of branching in the alcohol and position of the hydroxyl group that may influence both the sign and magnitude of excess functions when mixed with N,N-diethylaniline. A survey of literature reveals that experimental data on above said systems are not reported in the literature. It is well known that amines interact with alcohols by dipole-dipole interactions, formation of new hydrogen bonds or hetero-associates and dispersion forces [6-8]. The purpose of this is work to gain some understanding about the type and magnitude of the molecular interactions in the binary mixtures of N,N-diethylaniline and their effects on the excess thermodynamic properties. A survey of the literature has shown that experimental data on thermodynamic property for binary mixtures of methylcyclohexane with ethanol, 1-propanol, 2-propanol, 1-butanol, 2-methyl-1-propanol, 3-methyl-1-butanol [9], 2-methoxyethanol with diethyl aniline and triethylaniline [10], m-cresol with substituted anilines [11], 2-(2-butoxyethoxy) ethanol with aniline and N-alkylanilines [12] while that on N,N-diethylaniline with alcohols is relatively rare. Results have been used to explain the nature of interaction between unlike molecules in terms of hydrogen bonding, dipole-dipole interaction, proton donor-acceptor interaction and dispersive forces.

2. Experimental

2.1 chemicals

N,N-diethylaniline ≥99.7% of purity, 1-propanol ≥ 99% of purity, 1-butanol ≥ 99% of purity, 1-pentanol ≥ 99%of purity, 1-hexano l≥ 99.2%of purity, 1-heptanol ≥ 99.13%of purity, 1-octanol ≥ 98.9%of purity,1-nonanol ≥ 99%of purity, 1-decanol ≥ 99.6%of purity, 2-propanol ≥ 99% of purity, 2-butanol ≥ 99% of purity, 2-methyl-1-propanol ≥ 99.4% of purity and 2-methyl-2-propanol ≥ 98% of purity were purchased from Merck (S.D. Fine Chemicals Ltd., India). Experimental values densities ρ, Viscosities η and ultrasonic sound velocities u of the pure liquids are compared with literature values [1-8] in Table 3.1 at 298.15 K, and the values are good agreement.

The binary mixtures of N,N-diethyl aniline with 1-propanol, + 1-butanol, + 1-pentanol, 1-hexanol, 1-heptanol 1-octanol,1-nonanol, 1-decanol + 2-propanol, + 2-butanol, were prepared in glass bottles with air tight stoppers and adequate precautions were taken to minimize evaporation losses to weights of solutions are measured using Acculab ALC-210.4 digital electronic balance with a precision of ± 0.1mg.   The uncertainty in solution composition, expressed in mole fraction was found to be less than 1×10^{-4}. After mixing the sample, the bubble-free homogeneous sample was transferred into the U-tube of the densimeter through a syringe. The density measurements were performed with a Rudolph Research Analytical digital densimeter (DDH-2911 Model), equipped with a built- in solid-state thermostat and a resident program with accuracy of temperature of 303.15 K ± 0.02 K. The estimated accuracy in the density measurement is ± 2×10^{-5} gm.cm^{-3}. Proper calibration at 303.15 K temperature was achieved with doubly distilled, deionized water and with air as standard. A multi–frequency ultrasonic interferometer (M-82 Model, Mittal Enterprise, New Delhi, India) operated at 2 MHz, was used to measure the ultrasonic velocities of binary liquid mixtures (with an accuracy of ±0.2%) at 303.15 K. A thermostatically controlled, well-stirred circulated water bath with a

temperature controlled to 303.15 ± 0.02 K was used for all the ultrasonic sound velocity measurements. The estimated uncertainty in viscosity measurements is ± 0.005 mPa.s.

3. Results and discussion

The experimental values of density ρ, viscosity η and ultrasonic velocity u of pure liquids and their mixtures as function of mole fraction of N,N-diethylaniline at(303.15 & 308.15) K were used to calculate the parameters such as V^E , κ_s, $\Delta\kappa_s$ and $\Delta\eta$ were calculated from experimental data using the following expressions:

$$V^E = [x_1 M_1 + x_2 M_2]/\rho_m - [x_1 M_1/\rho_1 + x_2 M_2/\rho_2] \qquad (1)$$

$$\kappa_s = u^{-2}\rho^{-1} \qquad (2)$$

$$\Delta\kappa_s = \kappa_s - [x_1\ \kappa_{s1} + x_2\ \kappa_{s2}] \qquad (3)$$

$$\Delta\eta\ = \eta - [x_1\ \eta_1 + x_2\ \eta_2] \qquad (4)$$

In the above equations, M_1, M_2, κ_{s1}, κ_{s2}, η_1, η_2, u_1, u_2, ρ_1, ρ_2, ρ_m, κ_s, η, and u represent molecular weight, isentropic compressibility, viscosity, ultrasonic sound velocity and density data of component 1, component 2 and mixture respectively.

The data related to excess volume (V^E), deviation in isentropic compressibility ($\Delta\kappa_s$) and deviation in viscosity ($\Delta\eta$) for the binary systems of N,N-diethylaniline with 1-propanol, + 1-butanol, + 1-pentanol, 1-hexanol, 1-heptanol 1-octanol,1-nonanol, 1-decanol + 2-propanol and 2-butanol were graphically represented in figures 1-6 respectively at 303.15 K.

3.1 Excess Volume

The V^E data of all the binary mixtures of N,N-diethylaniline with all alcohols are graphically presented figures 1and 2.

A perusal of curves in figs 1 shows that the values of V^E are negative for N,N-diethylaniline with 1-propanol, +1-butanol, + 2-propanol, + 2-butanol, On other hand, an inversion in sign for the binary mixture containing N,N-diethylaniline with 1-pentanol was observed.

A perusal of curves in figs 2 shows that the values of V^E are positive for N,N-diethylaniline with 1-hexanol, 1-heptanol, 1-octanol, 1-nonanol, 1-decanol over the entire composition range at 303.15 K.

The excess volume (V^E) may be explained in terms of the following effects. (a) dipole-dipole interaction between unlike molecules (b) hydrogen bonding between nitrogen atom of amino group of N,N-diethylaniline and hydrogen atom of –OH group of alkanol molecules (c) dispersion forces. The first two effects contribute contraction in volume and the latter effect contributes to expansion of volume.

It is observed that in the case of branched monoalcohols from figure -1. V^E values are higher than the respective normal alcohols. This may be attributed due to the, in 2-alkanols the presence of two alkyl groups (–CH_3 groups) at the α-carbon atom increases the electron density at the oxygen atom of hydroxyl group to a greater extent than in 1-alkanols, which has one alkyl group on the α-carbon atom, resulting in stronger interaction (H-bonding) in former.

From fig 2 shows that the increase in V^E with increasing chain length of alkanols implies that dipole-dipole interactions are weak in higher alkanols owing to their decrease in polarizability, strength and extent of H-bonds with increasing chain length of 1-alkanols [12].

From experimental results suggest that the negative excess volume can be attributed to the dipole –dipole interactions between unlike molecules through hydrogen bonding and positive values indicate that the effect due to breaking up of self-associated structures of the components

of the mixtures is dominant over the effect of H-bonding and dipole-dipole interaction between unlike molecules

The algebraic V^E values of N,N-diethyl aniline with alcohols fall in the order:

1-decanol < 1-nonanol <1-octanol< 1-heptanol < 1-hexanol < 1-pentanol < 1-butanol < 1-propanol < 2-butanol < 2-propanol

The order suggests that dipole-dipole interactions between unlike molecules decrease with increasing in chain length of alcohols as a consequence of the decreases the degree of polymerization in the pure sate.

3.2 Excess isentropic compressibility ($\Delta\kappa_s$)

The deviation in isentropic compressibility ($\Delta\kappa_s$) data of all the binary mixtures of N,N-diethylaniline with all alcohols are graphically presented figures 3 and 4..

An examination of curves in figs.3 shows that the values of deviation in isentropic compressibility ($\Delta\kappa_s$) are negative for N,N-diethylaniline with 1- alkanols (C_3-C_5), + 2-alkanols (C_3-C_4)) over the entire composition range at 303.15 K.

An examination of curves in figs. 4 shows that the values of deviation in isentropic compressibility ($\Delta\kappa_s$) are negative for N,N-diethylaniline with 1- alkanols (C_6-C_{10}) over the entire composition range at 303.15 K.

The $\Delta\kappa_s$ values were ascribed according to Sri Devi et al [37] the negative excess values have been due to the closely packed molecules which account for existence of strong molecular interaction where as positive excess values are due to prevailing of dispersion forces between unlike molecules. The sign of deviation in isentropic compressibility ($\Delta\kappa_s$) and deviation in intermolecular free length (ΔL_f) play a vital role in assessing the compactness due to molecular interaction in liquid mixtures through hydrogen-bonding, charge-transfer complex formation and

dipole-dipole interactions and dipole-induced dipole interactions, interstitial accommodation and orientational ordering [38] leading to more compact structure making negative excess isentropic compressibility and excess intermolecular free length values. Hence negative values of deviation in isentropic compressibility ($\Delta\kappa_s$) and deviation in intermolecular free length (ΔL_f) in the present investigation suggests that, specific interactions are prevailing between unlike molecules in the liquid mixtures. The positive $\Delta\kappa_s$ values for N,N-diethylaniline with cyclohexanone, 2-methyl cyclohexanone suggests that free length increases due to the loss of dipolar association and cyclic nature of two components that leads to decrease in sound velocity and increase in isentropic compressibility. This behavior is qualitatively similar to that of excess molar volumes.

A perusal of curves in fig 3 shows that the ($\Delta\kappa_s$) negative values decreases may be attributed to hetero association and homo association of molecules decreases with increasing chain length, probably due to less proton-donating ability of higher alcohols.

An examination curves in fig 4 shows that the ($\Delta\kappa_s$) positive values increases suggest that the rupture of hydrogen bonded chain of the dipolar interaction between solute and alcohol exceed the intermolecular interaction through dipole-dipole and hydrogen bonding between solute and alcohol.

From experimental results suggest that the negative values of deviation in isentropic compressibility ($\Delta\kappa_s$) and deviation intermolecular free length (ΔL_f) for binary mixtures suggest that the dipole-dipole interactions through formation of complexes between the molecules of mixing components[16] and the positive values of deviation in isentropic compressibility ($\Delta\kappa_s$) and deviation intermolecular free length (ΔL_f) for binary mixtures may be dispersion forces dominates over formation of complexes between unlike molecules.

The negative $\Delta\kappa_s$ values of N,N-diethylaniline with alcohol fall in the order:

1-decanol < 1-nonanol <1-octanol< 1-heptanol < 1-hexanol < 1-pentanol < 1-butanol <

2-butanol < 1- propanol < 2- propanol

The order suggests that proton donor-acceptor interaction decrease with increase in chain length of alcohols as a consequence of the decrease the proton donating ability.

IV. 4 Viscosity

An examination of curves in figs. 5 -6 suggests that the values of $\Delta\eta$ are negative for N,N-diethylaniline with 1-propanol, + 1-hexanol, + 1-heptanol, + 1-octanol, +1-nonanol, +1-decanol and 2-propanol over the entire composition range at 303.15 K. On other hand, the property is positive for reaming mixtures.

According to Fort and Moore[17,] deviation in viscosity tends to become more positive as the strength of the interaction between component molecules increases. The deviation in viscosity gives a qualitative estimation of the strength of the intermolecular interactions. It may be generally explained by considering the following factors. The deviation in viscosity is influenced by[18] (j) The difference in size and shape of the component molecules and the loss of dipolar association to a decrease in viscosity (ii) Specific interactions between unlike molecules such as H-bonding formation and charge transfer complexes may cause for the increase in viscosity in mixture rather than in pure component. The former effect produces negative in excess viscosity and latter effect produces positive in excess viscosity. Positive values of $\Delta\eta$ are indicating of strong interactions whereas negative values indicate weaker interactions [19].

An examination of curves in figs. 5 shows that the positive $\Delta\eta$ values are indicative of specific interactions between component molecules while the negative $\Delta\eta$ values suggest that dispersion forces are dominant mixtures. The existence of dispersion forces indicates that the component molecules have different molecular sizes and shapes.

A perusal of curves in fig. 6 shows negative deviation in viscosity increases systematically with an increased in chain length of alcohols implies that hydrogen bond between unlike molecules weaker due to decreased polarizability.

From experimental results suggest that the positive values of $\Delta\eta$ may be attributed to the formation of hydrogen bonding (O-H….N) resulting in the formation of complexes between the component molecules and negatives values suggesting that the rupture of hydrogen bonded chain of the dipolar interaction between solute and alcohol exceed the intermolecular interaction through dipole-dipole and hydrogen bonding between solute and alcohol.

The algebraic values deviation in viscosity for molecules of N,N-diethylaniline + alkanols fall in the order:

1-decanol <1-nonanol < 1-octanol <1-heptanol < 1-hexanol <2-propanol < 1-propanol< 2-butanol< < 1-butanol < 1-pentanol

. According to Reed et al[21], the positive values of $G*^E$ may be attributed to specific interactions between unlike molecules, such as hydrogen bonding, dipole-dipole interaction, charge-transfer complex and dispersion forces, which generally are responsible for negative deviations in the property. From experimental results suggests that the values of $G*^E$ are positive for all binary mixtures. In the present work the positive values of $G*^E$ may be attributed to specific interactions through of hydrogen bonding (O-H….N) resulting in the formation of complexes between the component molecules.

Viscosity Models and Interaction Parameters: With a view towards correlations the viscosities of binary liquid mixtures with those of component liquids and interpreting the molecular interactions in these mixtures. Several equations have been put forward from time to time. These are given in the following text.

Grunberg and Nissan[22] values ($d_{12)}$) of the binary mixtures suggest that the values of d_{12} are positive for all binary mixtures over the entire composition range at 303.15 K.

Fort and Moore[17] and Ramamoorthy[23] reported that for any binary liquid mixture, a positive value of d_{12} indicates the presence of specific interactions and a negative value of d_{12} indicates the presence of weak interactions between the unlike molecules. In the present work the positive values of d_{12} may be attributed to the specific interactions between unlike molecules and negatives values suggesting breaking of the self-associated alcohols and weak interactions between unlike molecules. A similar observation was made by Subba et al[24] from the d_{12} values of the binary liquid mixtures of propionic acid with alcohols.

Katti and Chaudhri[25] values (W_{vis}/RT) of the binary mixtures suggest that the values of W_{vis}/RT are positive for all binary mixtures over the entire composition range at 303.15 K

Hind et al.[26] values (H_{12}) of binary mixtures shows that interaction parameter are positive for all binary mixtures over the entire range of composition, suggesting strong dipole-dipole interactions in lower alcohols and weak dipole-dipole interactions in high alcohols. In the present study, the value of H_{12} increases with increase of alkyl chain length in N,N-diethylaniline $_{+}$ of alcohols implies that dipole-dipole interaction is weaker in higher alcohols[27].

. The variation of V^E, $\Delta\kappa_s$, and $\Delta\eta$ with mole fraction were fitted to the Redlich-Kister polynomial equation [16] of the type,

$$Y^E = x_1 x_2 [a_0 + a_1(x_1-x_2) + a_2(x_1-x_2)^2]$$

(10)

where Y^E is V^E or $\Delta\kappa_s$ or $\Delta\eta$. The values of a_0, a_1 and a_2 are the coefficients of the polynomial equation and the corresponding standard deviations, σ obtained by the method of least –

squareswith equal weights assigned to each point are calculated. The standard deviation (σ) and

are defined as:

$$\sigma\,(Y^E) = [\textstyle\sum(Y^E{}_{obs} - Y^E{}_{cal})^2/(n\text{-}m)]^{1/2} \tag{11}$$

where n is the total number of experimental points and m is the number of coefficients. The

values of a_0, a_1 and a_2 are the coefficients is determined by a multiple-regression analysis on the

least square method and summarized along with the standard deviations between the

experimental and fitted values of V^E, Δu, $\Delta \kappa_s$, $\Delta \eta$ are presented in Table 2. Finally, it can be

concluded that the expressions used for interpolating the experimental data measured in this

work good results, as can be seen by inspecting the σ values obtained.

IV .5 Conclusion

System	V^E /cm^3.mol^{-1}	$\Delta \kappa_s$ /TPa^{-1}	$\Delta \eta$ / mPa.s	G^{*E} / J.mol^{-1}
equimolar values (0.5)				
N,N-diethylaniline				
1-propanol	-0.1917	-8.735	-0.008	+0.071
1-butanol	-0.1506	-5.254	+0.064	+0.085
1-pentanol	+0.0038	-3.547	+0.070	+0.089
1-hexanol	+0.1589	+4.471	-0.367	+0.059
1-heptanol	+0.1851	+6.445	-0.435	+0.018
1-octanol	+0.1991	+7.702	-0.505	+0.085
1-nonanol	+0.2359	+9.797	-0.552	+0.125
1-decanol	+0.2858	+9.461	-0.608	+0.206
2-propanol	-0.2090	-9.206	-0.013	+0.063
2-butanol	-0.1638	-8.469	+0.048	+0.094
2-methyl-1-propanol	-0.2432	-9.237	+0.197	+0.165
2-methyl-2-propanol	-0.2826	-10.34	+0.227	+0.193

1. From experimental results, negative V^E and $\Delta \kappa_s$ values can be attributed to the dipole –dipole

interactions between unlike molecules through hydrogen bonding and positive values indicate

that the effect due to breaking up of self-associated structures of the components of the mixtures

is dominant over the effect of H-bonding and dipole-dipole interaction between unlike molecules

2. The positive values of $\Delta\eta$ and G^{*E} may be attributed to the formation of hydrogen bonding

(O-H….N) resulting in the formation of complexes between the component molecules and

negatives values suggesting breaking of the self-associated alcohols and weak interactions

between unlike molecules.

3. From these data, several thermodynamic excess functions have been calculated and correlated

using the Redlich – Kister type polynomial equation. The sign and magnitude of these quantities

have been discussed in terms of hydrogen bond, electron-transfer complexes and dipole-dipole

interactions between the component molecules.

4.1 Acknowledgment

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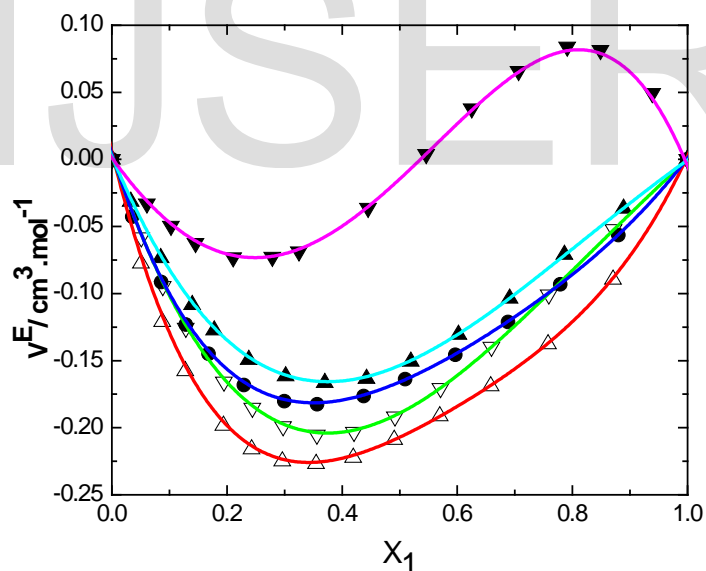
Mole fraction of N, N-DEA (x_1)

Figure 1 Variation of excess molar volume (V^E) with mole fraction (x_1) of N, N-

DEA in the binary liquid mixtures of N,N-DEA with 2-propanol (Δ), 1- propanol(∇), 2-butanol

($\bullet$), 1-butanol ($\blacktriangle$), 1-pentanol ($\blacktriangledown$) at 303.15 K.
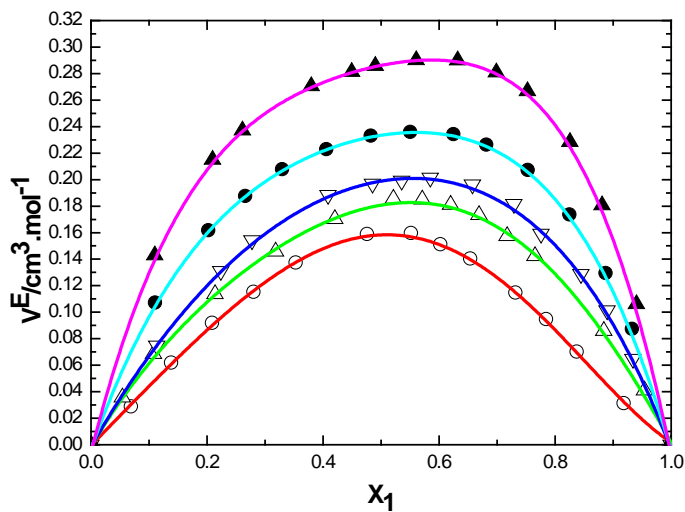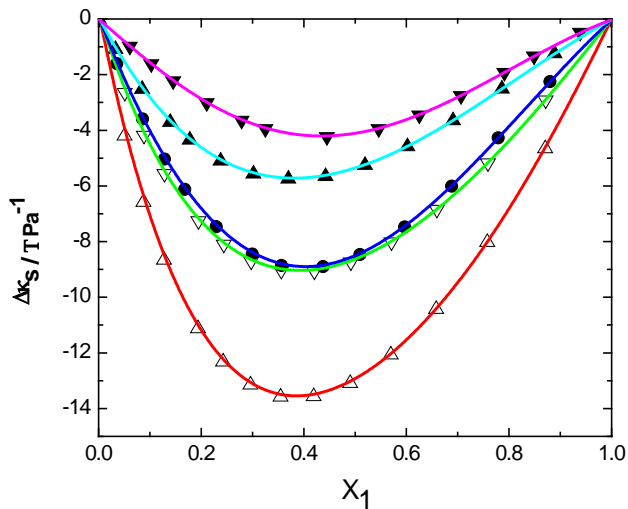
Mole fraction of N, N-DEA (X_1)

Figure 2 Variation of excess molar volume (V^E) with mole fraction (x_1) of N,N-DEA in the

binary liquid mixtures of N,N-DEA with 1-hexanol (O), 1-heptanol (Δ), 1 –octanol (∇),

1-nonanol   (●)   and 1-decanol (▲) at 303.15 K

Mole fraction of N, N-DEA (x_1)

Figure 3 Deviation in isentropic compressibility $(\Delta\kappa_s)$ with mole fraction (x_1) of N,N-

DEA in the binary liquid mixtures of N, N-DEA with 2-propanol (Δ), 1-propanol (∇),

2- butanol (●), 1-butanol (▲), 1-pentanol (▼) at 303.15K.

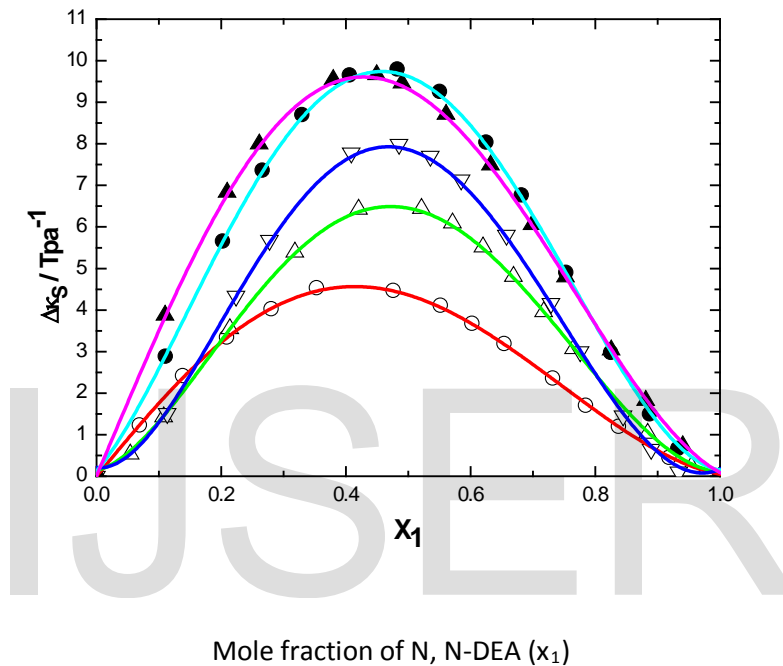Mole fraction of N, N-DEA (x_1)

Figure 4 Deviation of deviation in isentropic compressibility $(\Delta\kappa_s)$ with mole fraction (x_1) of

N,N-DEA in the binary liquid mixtures of N,N-DEA with 1-hexanol (O), 1-heptanol (Δ),

1 –octanol (∇), 1-nonanol   (●)   and 1-decanol (▲) at 303.15 K
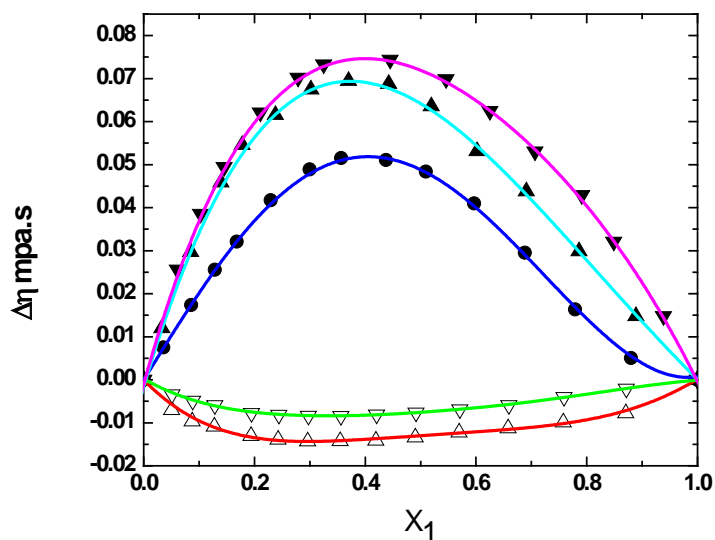
Mole fraction of N, N-DEA (x$_1$)

Figure 5 Deviation in viscosity (Δη) with mole fraction (x$_1$) of N, N-DEA in the binary liquid

mixtures of N,N-DEA with 2-propanol (Δ), 1-propanol (∇), 2- butanol (●), 1-butanol

(▲), 1-pentanol (▼) at 303.15K.
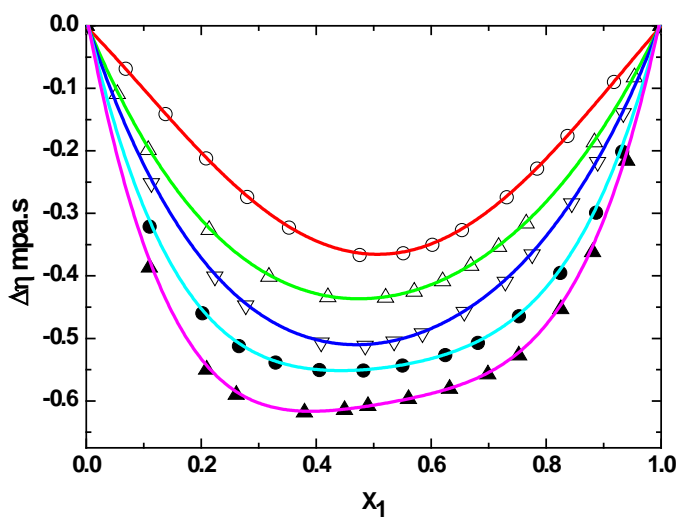
Mole fraction of N, N-DEA (x$_1$)

Figure 6 Deviation in viscosity Δη with mole fraction (x_1) of N,N-DEA in the binary liquid

mixtures of N,N-DEA with 1-hexanol (O), 1-heptanol (Δ), 1 –octanol (∇), 1-nonanol

(●)   and 1-decanol (▲) at 303.15 K

Table 4.1: **Comparison of Experimental and Literature values of density (ρ), ultrasonic**

velocity (u) and Viscosity (η)   for pure components at 298.15 K

	density ρ / g.cm^{-3}		Velocity u /m.sec^{-1}		viscosity η / mPa.s	
Pure components	Experimental	Literature	Experimental	Literature	Experimental	Literature
N,Ndiethylaniline	0.92992	0.92990 [1]	1411.0	1434.0 [5]	1.917	1.919 [1]
1-propanol	0.79961	0.79960 [2]	1204.8	1209.9 [8]	1.947	1.943 [2]
1-butanol	0.80573	0.80575 [2]	1235.6	1222.0* [6]	2.568	2.571 [2]
1-pentanol	0.81112	0.81110 [3]	1245.2	1258.6* [6]	3.351	3.350 [3]
1-hexanol	0.81521	0.81523 [4]	1304.8	1304.72 [4]	4.591	4.593 [4]
1-heptanol	0.81870	0.818732 [4]	1326.1	1327.32 [4]	5.945	5.944 [4]
1-octanol	0.82171	0.821722 [4]	1347.2	1347.82 [4]	7.663	7.661 [4]
1-nonanol	0.82445	0.824478 [4]	1365.9	1365.48 [4]	9.714	9.715 [4]
1-decanol	0.82673	0.826762 [4]	1379.5	1380.01 [4]	11..825	11.825 [4]
2-propanol	0.78124	0.78126 [2]	1125.4	1128.2 [8]	2.044	2.043 [2]
2-butanol	0.80239	0.80241 [2]	1152.2	1157.5* [7]	2.996	2.998 [2]
2-methyl-1propanol	0.79978	0.79980 [2]	1210.9	1211.4 [8]	3.334	3.333 [2]
2-methyl-2propanol	0.78119	0.78120 [2]	1122.5	1123.5 [8]	4.437	4.438 [2]

*303.15 K

Table-2 Coefficients of Redlich – Kister equation and standard deviation values at 303.15 K

Binary mixtures	Functions	a_0	a_1	a_2	σ
N,N-DEA+1-propanol	V^E (cm^3.mol^{-1})	-0.761	0.444	0.059	0.001
	Δu (msec^{-1})	66.38	-30.13	-6.097	0.047
	$\Delta \kappa_s$ (Pa^{-1})	-34.48	15.73	-6.659	0.056
	$\Delta \eta$ (mPa.s)	-0.029	0.023	-0.017	0.001
N,N-DEA+1-butanol	V^E (cm^3.mol^{-1})	-0.618	0.359	-0.042	0.001
	Δu (msec^{-1})	91.77	-60.92	-26.58	0.032
	$\Delta \kappa_s$ (Pa^{-1})	-21.45	12.19	-1.340	0.018
	$\Delta \eta$ (mPa.s)	0.263	-0.146	-0.008	0.001
N,N-DEA+1-pentanol	V^E m^3.mol^{-1}	-0.059	0.812	0.262	0.001
	Δu m.sec-^{1}	68.62	-17.86	-64.61	0.035
	$\Delta \kappa_s$ TPa^{-1}	-16.55	5.302	5.024	0.031
	$\Delta \eta$ mPa.s	0.288	-0.104	0.078	0.001
N,N-DEA+1-hexanol	V^E (cm^3.mol^{-1})	0.647	-0.001	-0.286	0.003
	Δu (msec^{-1})	-83.54	2.968	5.322	0.029
	$\Delta \kappa_s$ (Pa^{-1})	17.54	-8.481	-6.876	0.046
	$\Delta \eta$ (mPa.s)	-1.472	-0.054	0.467	0.001
N,N-DEA+1-heptanol	V^E (cm^3.mol^{-1})	0.721	0.112	0.102	0.003
	Δu (msec^{-1})	-71.26	-1.036	23.79	0.003
	$\Delta \kappa_s$ (Pa^{-1})	25.85	-3.453	-22.25	0.099
	$\Delta \eta$ (mPa.s)	-1.751	0.153	-0.312	0.001
N,N-DEA+1-octanol	V^E (cm^3.mol^{-1})	0.799	0.169	0.145	0.002
	Δu (msec^{-1})	-61.92	2.327	38.63	0.006
	$\Delta \kappa_s$ (Pa^{-1})	31.54	-6.029	-33.78	0.111
	$\Delta \eta$ (mPa.s)	-2.042	-0.187	-0.532	0.001
N,N-DEA+1-nonanol	V^E (cm^3.mol^{-1})	0.935	0.138	0.432	0.001
	Δu (msec^{-1})	-52.81	7.593	33.68	0.036
	$\Delta \kappa_s$ (Pa^{-1})	38.74	-9.900	-27.11	0.073
	$\Delta \eta$ (mPa.s)	-2.198	0.184	--1.540	0.001
N,N-DEA+1-decanol	V^E (cm^3.mol^{-1})	1.147	0.181	0.750	0.001
	Δu (msec^{-1})	-42.36	14.45	21.84	0.002
	$\Delta \kappa_s$ (Pa^{-1})	37.46	-15.04	-15.01	0.052
	$\Delta \eta$ (mPa.s)	-2.428	0.290	-2.143	0.001
N,N-DEA+2-propanol	V^E (cm^3.mol^{-1})	-0.829	0.414	-0.499	0.001
	Δu (msec^{-1})	55.44	-14.31	39.77	0.042
	$\Delta \kappa_s$ (Pa^{-1})	-36.24	17.44	-13.65	0.118
	$\Delta \eta$ (mPa.s)	-0.048	0.024	-0.076	0.001
N,N-DEA+2-butanol	V^E (cm^3.mol^{-1})	-0.665	0.377	-0.272	0.001
	Δu (msec^{-1})	131.3	-48.77	-71.14	0.063
	$\Delta \kappa_s$ (Pa^{-1})	-34.25	15.68	2.037	0.014
	$\Delta \eta$ (mPa.s)	0.197	-0.120	-0.104	0.001