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Electron Releasing Effect on the Thermodynamic and Transport Properties of Liquid Mixtures at Various Temperatures

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Abstract: *Densities (ρ), speeds of sound (u), and viscosities (η) are reported for binary mixtures of N,N-diethyl aniline with 1-alkanols (1-hexanol, 1-heptanol and 1-octanol) over the entire composition range of mole fraction at T = (303.15 - 318.15) K and at atmospheric pressure 0.1 MPa. The excess properties such as excess molar volume, excess isentropic compressibility and deviations in viscosity are calculated from the density, speed of sound and viscosity. Excess properties are correlated using the Redlich – Kister equation. The excess partial molar volumes and excess partial molar isentropic compressibilities are calculated for all the binary systems throughout the composition range and also at infinity dilutions. The results are analyzed in terms of ruptureofhydrogenbonded chainofthedipolar interaction betweensoluteand1- alkanolexceedstheintermolecular interactionthroughdipole-dipoleandhydrogenbonding betweenN, N-diethyl anilineand1-alkanolmolecules.The* V^E *results are analyzed in the light of Prigogine-Flory-Patterson theory. Analysis of each of the three contributions viz. interactional, free volume and P* to* V^E *has shown that interactional contribution are positive for all systems, both the free volume effect and P* contribution are negative for all the mixtures.*

Keywords*: Density, speed of sound, viscosity, N, N-diethyl aniline, 1-alkanols, PFP theory*

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I. Introduction

Thestudyofthermodynamicpropertiesofbinarymixturescontributesto an understanding of the behaviorofdifferentliquidsandtheirfunctionalgroups. This information is very useful in the design of industrialprocessandinthedevelopment oftheoriesfortheliquidstateandpredictivemethods.Excess thermodynamicparametersofdifferentmixturesareusefulinthe studyofmolecularinteractionsand arrangements[1].Forengineeringapplications,liquidmixtures,ratherthan single componentliquidsystemsare usedin processingandproductformulations.The thermodynamicparametersderivedfromthemeasurementof density,speed of soundandviscosityare usefulinunderstandingthenatureandtypeofintermolecular interactionsbetweenthecompoundmolecules

The variations in densities, speeds of sound and other properties derived using them, pertainingto binary mixtures of alcohols with divergent organic liquids which differ in molecular size, shape, chain length and degree of molecular association than that of normal alcohols, is one of the interesting aspect of research in molecular interactions [2]. In the present work, the liquid components selected for the study of molecular interactions are N, N-diethyl aniline and 1-alkanols: 1-hexanol, 1-heptanol and 1-octanol.These solvents are well known organic liquids with a wide range of applications in various fields of chemistry in addition to their use in industries and routine analytical work. N, N-diethyl aniline is used as a solvent and also in preparation of dyes and various organic products. Alcohols are interesting as they are biologically and industrially important amphiphilic materials and also versatile solvents used in chemical and technological processes and further, they are inexpensive and easily available at high purity [3].

The aim of the present work is to know the effect of carbon chain length and the influence of polarity of the 1-alkanols in the binary blends of N, N-diethyl aniline with 1-alkanols on the excess volume, excess isentropic compressibility and deviation in viscosity values. The present investigation is a continuation of our earlier research [4] on thermodynamic properties of binary liquid mixtures.

A review of the literature has shown that the thermodynamic properties of binary mixtures of O-chlorophenol with aniline and N-alkylanilines [5], 2-methoxyethanol with diethylamine and triethylamine [6**],** m-cresol with substituted anilines [7] and 2-(2-butoxyethoxy) ethanol with aniline and N-alkylanilines [8] have been investigated. There are no information accessible indicating itemized physical properties such as density, speed of sound and viscosity for the binary mixtures of N, N-diethyl aniline with 1-alkanols. Hence, this research work is undertaken pertaining to these binary blends. The data found in this work may be helpful in various industrial processes such as formulation of PVC cements. In this paper we report densities *(ρ),* speeds of sound *(u)* and viscosities *(η)* of the binary mixtures of N, N-diethyl aniline with 1-alkanols (including pure liquids) at different temperatures over the entire composition range. By using these data, various physicochemical parameters, *viz.*, V^E (excess molar volume), $\kappa_s{}^E$ (excess isentropic compressibility), deviation in viscosity *($\Delta\eta$),* excess Gibbs energy of activation of viscous flow *(G^{*E})*, $\overline{V}{}^{\circ E}_{m,1}$, $\overline{V}{}^{\circ E}_{m,2}$ $\overline{K}{}^{\circ E}_{s,m,1}$ and $\overline{K}{}^{\circ E}_{s,m,2}$ have been calculated.

II. Experimental

2.1 Materials

Chemicals used in the present study were N, N-diethyl aniline, 1-hexanol, 1-heptanol and 1-octanol. All the chemicals were purchased from S.D. Fine Chemicals Ltd. N, N- diethyl aniline was dried over potassium hydroxide pellets for several days [9]. All the chemicals were further purified by distillation and fractional distillation under reduced pressure, and only the middle fractions were collected [9,10]. Before use, the chemicals were stored over 0.4 nm molecular sieves for about 72 h to remove water and degassed. The purity of the liquid samples was checked by gas chromatography. The water contents were determined by Karl-Fischer method. The details of the chemicals and pertaining purification methods were presented in Table 1.

2.2 Apparatus and procedure

All the binary liquid mixtures were prepared by weighing an amount of pure liquids in an electric balance (ER-120A, Afoset) with a precision of ± 0.1 mg by syringing each component into air-tight stopper bottles to minimize evaporation losses. The uncertainty of the mole fraction was $\pm\ 1\times10^{-4}$. The densities of pure liquids and their binary mixtures were measured by using a single-capillary pycnometer (made of Borosil glass) having a bulb capacity of ~10 cm^3. The capillary with graduated marks had uniform bore and could be closed with a well-fitted cap. The marks on the capillary were calibrated by using triply distilled water. The uncertainty in density measurement was found within $\pm0.2\times10^{-3}$ $g\cdot cm^{-3}$. The speed of sound measurements was performed using a commercially available single crystal ultrasonic in terferometer (model F-05) from Mittal Enterprises, New Delhi, India, at 2 MHz frequency at various temperatures. The uncertainty in the measured speed of sound is ±0.5%. The temperature of the test liquids during the measurements was maintained within an uncertainty of ±0.01 K in an electronically controlled thermostatic water bath. The interferometer function was tested by obtaining measurements for pure samples of benzene, toluene, chloroform, chlorobenzene and acetone and the measured speeds of sound of these liquids were in good agreement with those reported in the literature [11].The viscosities of pure liquids and their mixtures were determined at atmospheric pressure at T = (303.15 - 318.15) K by using an Ubbelohde viscometer, which was calibrated with benzene, carbon tetrachloride, acetonitrile and doubly distilled water [12]. The Ubbelohde viscometer bulb capacity was 15 ml and the capillary tube had a length of about 90 mm with 0.5 mm internal diameter. The viscometer was thoroughly cleaned and perfectly dried, filled with the sample liquid by fitting the viscometer to about 30°from the vertical and its limbs were closed with Teflon caps to avoid the evaporation. The viscometer was kept in a transparent walled bath with a thermal stability of ± 0.1 K for about 20 min to obtain thermal equilibrium. An electronic digital stopwatch with an uncertainty of ± 0.01 s was used for flow time measurements. The experimental uncertainty of viscosity was estimated as ±1.03% and the uncertainty of temperature ± 0.1 K. The purity of all these solvents were compared with the measured densities, speeds of sound and viscosities of the pure liquids with the literature [13-21] and these were enlisted in Table 2.

Experimental datagraphically compared [22-33] and in the givensupplementarymaterial Figs. from 1S to 9S and also third-order polynomial was used to fit viscosity and speed of sound as a function of concentration, for pure substances and its binary mixture of N,N-diethyl aniline with 1-heptanol, + 1-octanol, were listed in Tables and Figs. 1S, 2S. 10S, 11S and 12S respectively (*Supplementary material*).

The analysis of 1-hexanol indicated that the literatureρ data [23] are more scattered as compared to our data. It may arise due to experimental procedure because viscosity ‘η’ was well correlated with our experimental values.The AAD values for ‘*u*’ were found to be less than 0.28% (Jerie et al [27])to our experimental values may be experimental procedure or chemical purity. The 1-heptanol and 1-octanol speed of sound ‘u’ values varies with 0.4% and 0.35% (Average Absolute Deviation) with Dzida et al [32] at 303.15K. The deviations may be arising due to experimental procedure.

III. Results And Discussion:

The experimental densities and viscosities for all the binary systems at various compositions were used to calculate the excess thermodynamic functions using following equations:

$$V^E / \mathrm{cm^3.mol^{-1}} = [x_1M_1 + x_2M_2] / \rho - [x_1M_1/\rho_1 + x_2M_2/\rho_2] \quad (1)$$

$$\Delta\eta / mPa\cdot s = \eta - (x_1\eta_1 + x_2\eta_2) \quad (2)$$

$$G^{*E} / J\cdot mol^{-1} = RT [\ln \eta V - (x_1 \ln \eta_1 V_1 + x_2 \ln \eta_2 V_2)] \quad (3)$$

where ρ , $\eta$and V are density, viscosity and molar volume of the binary mixture. x_1, M_1, ρ_1, η_1,V_1 and x_2, M_2, ρ_2,η_2,$V_2$are the mole fraction, molar mass, density, viscosity and molar volume of pure components 1 and 2 respectively. R is the gas constant and T is the absolute temperature

The experimental data were used to compute isentropic compressibility (κ_s) by using the following relation:

$$\kappa_s = (u^2\rho)^{-1}$$
(4)

The method used for calculating κ_s^E (Benson - Kiyohara approach) was outlined previously [34].

V^E, κ_s^E and $\Delta\eta$ values were fitted to a Redlich - Kister [35] polynomial equation,

$$Y^E = x_1 x_2 \sum_{i=0}^{j} A_i (1 - 2x_1)^i \quad (5)$$

where Y^E is the V^E , κ_s^E and $\Delta\eta$. Values of the coefficients $A_i$were determined by using the method of least - squares. The standard deviations σ (Y^E) were calculated by using the formula

$$\sigma (Y^E) = [\Sigma(Y^E_{exp} - Y^E_{cal})^2/(m-n)]^{1/2} \quad (6)$$

where m is the total number of experimental points and n is the number of parameters. The coefficients, A_i and corresponding standard deviation values (σ) were presented in Table 5.

The densities, speeds of sound and viscosities for mixtures of various mole fractions of N, N-diethyl aniline in 1-alkanols were presented in Tables 3.The excess molar volumes, excess isentropic compressibility, viscosity deviation and excess Gibbs energy of activation of viscous flow at various temperatures were presented in Tables 4. Figs. 1, 2, 3 and 4 show values of V^E, κ_s^E, $\Delta\eta$and G^{*E} as a function of the molar fraction of N, N-diethyl aniline, respectively.

The volume changes arising due to addition of N, N-diethyl aniline to an alkanol results from several opposing effects [36]. The main volume effects accompanying the addition of N, N-diethyl aniline to an alkanol result from changes of free volume,disruption of the alkanol structure, and the so-called condensation effect[37] due to restriction of the rotational motion of the alkanol molecule[38]. A perusal of Table 4shows that theexcess molar volume data for the mixtures N,N-diethyl aniline with 1-alkanols are positive over the entire composition range at all temperatures. In the present mixtures, considerable amounts of positive contributions are expected due todissociation of intermolecular interactions between like molecules is dominant over the heteroassociation interactions between unlike molecules. Similar results have also been reported for N,N-dimethylformamide with n-alkanols [39] and toluene with n-alkanols mixtures [40].

The V^E values at equimolar concentration of mixtures follow the order:

1-octanol>1-heptanol >1-hexanol

It indicates thatclustering decreases with increase of chain length of alkanols owing to less proton-donating tendency of higher alkanols. Therefore, heteroassociation effects decrease in the binary mixtures with an increase of chain length of linear alkanols. Hence above order is justified.

The increase of V^E with increase of temperature suggests the breaking of interactions and aggregates of alkanols and N,N-diethyl aniline at elevated temperature [36].An examination of data in the Table 4 shows that the excess isentropic compressibility data for all the binary systems are positive over the entire composition range at T= (303.15 to 318.15) K.

The observed values of κ_s^E can be qualitatively explained by considering the factors (i) declustering and breaking of H-bonds in 1-alkanols (ii) repulsive forces due to the electric charge of components, (iii) size and shape of both component molecules along with the effect of the alkyl chain of the 1-alkanols because the hydrophobic character of the 1-alkanol is amplified by an increase in chain length, and consequently, the molecular interactions between 1-alkanols and N,N-diethyl aniline molecules are weaken. It also suggests that the physical dipole-dipole interactions between 1- alkanol monomers and multimers contribute to increase in free-spaces and these results in decrease in sound velocity and it is reflected in the positive deviation in isentropic compressibilities [41]

Fromthe Fig.2, it is inferred that the positive κ_s^E values increases from 1-octanol to 1-heptanol in their binary blends with N, N-diethyl aniline. This fact signifies decreasing dipole-dipole interaction due to decreasing proton donating ability with increasing chain length of 1-alkanols. It also suggests the rupture of hydrogen bonded chain of the dipolar interactions between N,N-diethyl aniline and 1-alkanol exceed the intermolecular interaction through dipole-dipole and hydrogen bonding between N,N-diethyl aniline and 1-alkanol molecules.

The positive κ_s^E values for binary systems follow the order:

1-octanol >1-heptanol>1-hexanol

The order indicates that the strength of interactions between component molecules decreases due to decrease in polarizability of 1-alkanol molecules [42, 43] as the carbon chain increases and also decreases in proper dipole alignment of the components.

According to Kauzman and Eyring [44], the viscosity of a mixture strongly depends on the entropy of mixture, which is related to liquid structure and enthalpy and consequently, to the molecular interactions between the components of the mixture. Vogel and Weiss [45] affirm that mixtures with strong interactions between different molecules ($H^E < 0$) and negative deviations from Raoult's law present positive viscosity deviations ($\Delta\eta > 0$), whereas for mixtures with positive deviations of Raoult's law and without strong specific interactions, the viscosity deviations are negative ($\Delta\eta < 0$).

An examination of curves in Figs.3 and 4 suggests that the deviation in viscosity ($\Delta\eta$) and excess Gibbs energy of activation of viscous flow (G^{*E}) for all the binary systems is negative over the entire composition range at different temperatures. The negative values of deviation in viscosity and excess Gibbs free energy of activation of viscous flow for the binary systems investigated suggest that the breaking of the self-associated molecules and weak interactions between unlike molecules, decrease systematically with an increasein chain length of alkanol. With increasing in chain length of alkanol, hydrogen bonding interaction of N,N-diethylaniline with 1-hexanol, 1-heptanol and 1-octanol is weaker due to decreased polarizabilityas suggested by Mecke [38].The viscosity deviation values are found to be opposite to the sign of excess molar volumes for all binary mixtures, which is in agreement with the view proposed by Brocos et al [46, 47]

IV. Partial Molar Properties

The interpretation of excess partial molar properties ($\overline{V}^{E}_{m,1}, \overline{V}^{E}_{m,2}$, $\overline{K}^{E}_{s,m,1}$ and $\overline{K}^{E}_{s,m,2}$) and excess partial molar properties at infinite dilution($\overline{V}^{\circ E}_{m,1}$, $\overline{V}^{\circ E}_{m,2}$ $\overline{K}^{\circ E}_{s,m,1}$ and $\overline{K}^{\circ E}_{s,m,2}$) of components 2 have previously been described [48].

In general, the negative values of excess partial molar volume component 1 and excess partial molar volume component 2 ($\overline{V}^{E}_{m,1}, \overline{V}^{E}_{m,2}, \overline{K}^{E}_{s,m,1}$ and $\overline{K}^{E}_{s,m,2}$) values, indicate the presence of significant solute-solvent interactions between unlike molecules, whereas the positive excess partial molar volume component 1 and excess partial molar volume component 2 data indicate presence of solute-solute / solvent-solvent interactions between like molecules in the mixtures [49,50].

A close perusal of Table 6 indicates that the values of $\overline{V}^{E}_{m,1}$ and $\overline{V}^{E}_{m,2}$ are positive for all the binary mixtures over the whole composition range. Positive values may be attributed to the 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

From the Table 6 it may be inferred that the values of $\overline{K}^{E}_{s,m,1}$ and $\overline{K}^{E}_{s,m,2}$ are positive for all the binary mixtures over the whole composition range. The positive values indicate thattheruptureofhydrogen bondedchainofthedipolarinteraction betweensolute,N, N-diethyl anilineand1-alkanolexceedtheintermolecularinteractionthroughdipole-dipoleandhydrogenbondingbetweenN, N-diethyl aniline and 1-alkanolmolecules.

From the Table 7, it can be seen that the values of $\overline{V}^{\circ E}_{m,1}$ and $\overline{V}^{\circ E}_{m,2}$ are positive for all the binary mixtures over the whole composition range. The positive $\overline{V}^{\circ E}_{m,1}$ and $\overline{V}^{\circ E}_{m,2}$ values indicate that the rupture of three-dimensional hydrogen-bonded networkof 1-alkanol duetotheadditionofsolute,N,N-diethyl anilineisnotcompensatedbytheweakinteractionsbetweenunlike molecules.

It is seen from the Table 7 that the values of $\overline{K}^{\circ E}_{s,m,1}$ and $\overline{K}^{\circ E}_{s,m,2}$ are positive for all the binary systems at each investigated temperature. The positive values may be due to interruption of dipolar association in the binary mixtures of N, N-diethyl aniline with 1-alkanols or attributed to weak dipole-dipole interactions between unlike molecules in the mixtures [51, 52].

Prigogine-Flory-Patterson Theory:

The Prigogine-Flory-Patterson theory considers excess thermodynamic properties of binary mixtures to be the sum of different contributions [53-55]. The excess molar volume can be expressed as: an interactional term which is proportional to the interaction parameter, χ_{12}, a free volume contribution which arises from the dependence of the reduced volume upon the reduced temperature as a result of the differences between the degrees of thermal expansion of the components and an internal pressures and of the reduced volumes of the components

$$\frac{V^{E}}{x_1V_1^{*}+x_2V_2^{*}} = .\frac{(\tilde{V}^{1/3}-1)\tilde{V}^{2/3}}{[(4/3)\tilde{V}^{-1/3}-1]}\Psi_1\theta_2\left(\frac{\chi_{12}}{P_1^{*}}\right)\text{ int.contribution) - }\frac{(V_1-V_2)^2[(14/9)\tilde{V}^{-1/3}-1]\Psi_1\Psi_2}{[(4/3)\tilde{V}^{-1/3}-1)\tilde{V}}.$$

$$\text{(fv.contribution) + }\frac{(\tilde{V}_1-\tilde{V}_2)(P_1^{*}-P_2^{*})}{P_1^{*}\Psi_2+P_2^{*}\Psi_1}\Psi_1\Psi_2\ \ (P^{*}\text{contribution}) \qquad (7)$$

The reduced volume of pure component $\tilde{V}_i$ was calculated from the isobaric thermal expansively α_i by equation:

$$\tilde{V}_i = \left(\frac{1+\left(\frac{4}{3}\right)\alpha_i T}{1+\alpha_i T}\right) \qquad (8)$$

The $\tilde{V}$ of mixture was approximated in equation (8) by

$$\tilde{V} = \Psi_1\tilde{V}_1 + \Psi_2\tilde{V}_2 \qquad (9)$$

The molecular contact energy fraction of components$\Psi_1$is given by

$$\Psi_1 = 1-\Psi_2 = \frac{\phi_1 P_1^{*}}{\phi_1 P_1^{*}+\phi_2 P_2^{*}} \qquad (10)$$

The characteristic volume is $V_i^{*} = V_i^{*} / \tilde{V}_i$ and the characteristic pressure is given by

$$P_i^{*} = \frac{T\tilde{V}_i^2\alpha_i}{\kappa_{Ti}} \qquad (11)$$

where κ_{Ti} is the isothermal compressibility of pure component *i*.

The hard-core volume fractions of the components 1and 2 ($\phi_1$andϕ_2) are defined by

$$\phi_1 = 1-\phi_2 = \frac{x_1V_1^{*}}{x_1V_1^{*}+x_2V_2^{*}} \qquad (12)$$

The $\kappa_T$values were calculated from the following expression,

$$\kappa_T = \kappa_S + \frac{TV\alpha^2}{C_P} \qquad (13)$$

The χ_{12} parameter required for the calculation of V^E using Flory-Patterson theory was derived by fitting the V^E expression to the experimental equimolar value of V^E for each system investigated. The calculated equimolar values of the three contributions together with the χ_{12} parameter for each system were listed in Table 8.An analysis of each of the three contributions to V^E showed that the interactional contribution was positive for all systems, the free volume contribution was negative for all the mixtures and P* contribution was positive for all the mixtures except 1-octanol which had a negative internal pressure term. It is clear from Table 8 that the dominant role is played by the interactional contribution and this is the main parameter for deciding the sign and magnitude of excess volumes for N,N-diethyl aniline + 1-alkanols.

V. Conclusion

This paper reports experimental data of densities, speeds of sound and viscosities of binary blends of N,N-diethyl aniline with 1-alkanols (1-hexanol,1-heptanol and1-octanol) binary mixtures over the entire composition range at T= (303.15 - 318.15) K with 5 K intervals. From the experimental data, various physicochemical parameters, *viz.*, V_m^E , κ_s^E and$\Delta\eta$ of the mixtures, the excess partial molar properties at infinite dilution($\overline{V}^{\circ E}_{m,1}$, $\overline{V}^{\circ E}_{m,2}$ $\overline{K}^{\circ E}_{s,m,1}$ and $\overline{K}^{\circ E}_{s,m,2}$) of components were calculated. The results are analyzed in terms of rupture ofhydrogenbonded chainofthedipolar interaction betweensoluteand1-alkanolexceedtheintermolecular interactionthroughdipole-dipoleandhydrogenbonding betweenN,N-diethyl anilineand1-alkanolmolecules.Thisbehaviorischaracteristicfor systemscontaininganassociated component. Moreover, the V^E values have been analyzed with Prigogine- Flory-Patterson theory and shown that the interactional contribution is the main factor for positive values of excess molar quantities.

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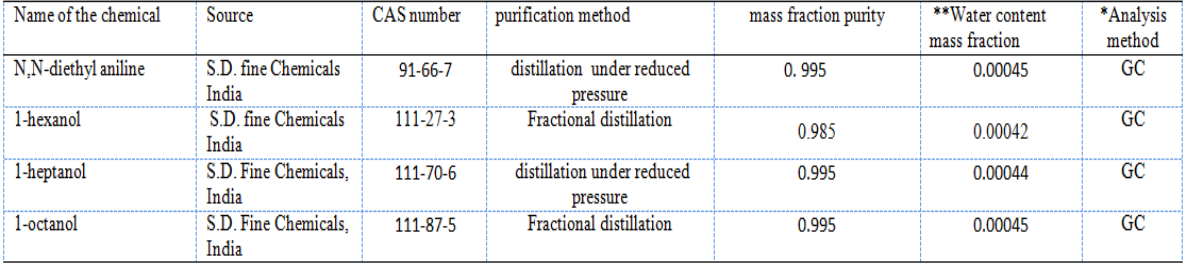
Table 1 List of chemicals with details of supplier, CAS number, Purity and water content



Name of the chemical	Source	CAS number	purification method	mass fraction purity	**Water content mass fraction	*Analysis method
N,N-diethyl aniline	S.D. fine Chemicals India	91-66-7	distillation under reduced pressure	0. 995	0.00045	GC
1-hexanol	S.D. fine Chemicals India	111-27-3	Fractional distillation	0.985	0.00042	GC
1-heptanol	S.D. Fine Chemicals, India	111-70-6	distillation under reduced pressure	0.995	0.00044	GC
1-octanol	S.D. Fine Chemicals, India	111-87-5	Fractional distillation	0.995	0.00045	GC

*Gas Chromatography

** Karl-Fischer method

Table 2 Densities, viscosity and speeds of sounds data of pure components at different temperatures and 0.1MPa pressure

component	density (ρ /g·cm^{-3})		speed of sound, (u / m·s^{-1})		viscosity (mPa·s)		C_p (J· K^{-1} · mol^{-1})
	experimental	literature	experimental	literature	experimental	literature	
N,N-diethyl aniline							
303.15 K	0.9258[4]	0.9259[13]	1432.8[4]	1434.0[15]	1.711[4]	1.709[13]	291.0[16]
		0.9260[14]					
		0.9261[15]					
308.15 K	0.9218[4]	0.9219[13]	1415.2[4]		1.537[4]	1.534[13]	
313.15 K	0.9179[4]	0.9180[13]	1397.2[4]	1396.0[15]	1.400[4]	1.402[13]	296.0[16]
		0.9177[14]					
		0.9175[15]					
318.15 K	0.9138[4]	0.9139[13]	1378.8[4]		1.276[4]	1.279[13]	
1-hexanol							
303.15 K	0.8122	0.81212[17]	1283.4	1287.90[20]	3.883	3.885[20]	246.52[20]
308.15 K	0.8081	0.80780[19]	1270.2	1271.14[20]	3.355	3.359[20]	251.47[20]
313.15 K	0.8043	0.80451[17]	1256.9	1254.45[20]	2.911	2.914[20]	256.48[20]
318.15 K	0.8002	0.80018[18]	1244.2		2.656	2.655[18]	
1-heptanol							
303.15 K	0.8153	0.81529[21]	1315.5	1313.58[20]	5.065	5.069[20]	275.37[20]
308.15 K	0.8117	0.81174[21]	1298.4	1293.86[20]	4.329	4.333[20]	289.83[20]
313.15 K	0.8081	0.80816[21]	1280.5	1277.15[20]	3.723	3.726[20]	295.35[20]
318.15 K	0.8044	0.80439[18]	1261.5		3.446	3.447[18]	
1-octanol							
303.15 K	0.8183	0.81823[21]	1334.9	1338.02[20]	6.405	6.402[20]	313.60[20]
308.15 K	0.8147	0.81474[21]	1318.7	1314.27[20]	5.422	5.425[20]	320.12[20]
313.15 K	0.8101	0.81009[21]	1300.0	1297.60[20]	4.625	4.628[20]	325.98[20]
318.15 K	0.8055	0.80555[18]	1284.9		4.051	4.051[18]	

The standard uncertainties are u (ρ) = ± 0.2×10^{-3} g·cm^{-3}, u (u) = 0.5%, u (η) = ±1.03%, u (T) = 0.01 K for density and speed of sound, u (T) = 0.1 K for viscosity and u (p) = 1 kPa

Table3; Density (ρ), Viscosity (η) and speed of sound (u) of binary liquid mixtures of N,N-diethylaniline with 1-hexanol,1-heptanol and 1-octanol at T= (303.15 to 318.15) K and 0.1MPa pressure

x_1 N,N-diethylaniline	density (ρ /g.cm^{-3})				viscosity (η/ mPa·s)				speed of sound (u/ m.s^{-1})			
	303.15K	308.15K	313.15K	318.15K	303.15K	308.15K	313.15K	318.15K	303.15K	308.15K	313.15K	318.15K
N,N-diethylaniline (1) + 1-hexanol (2)												
0.0000	0.8122	0.8081	0.8043	0.8002	3.883	3.355	2.911	2.656	1283.4	1270.2	1256.9	1244.2
0.1057	0.8245	0.8202	0.8167	0.8124	3.391	2.850	2.403	2.105	1293.7	1278.4	1265.1	1252.4
0.1952	0.8348	0.8306	0.8270	0.8227	3.041	2.524	2.096	1.801	1302.6	1287.2	1273.6	1260.3
0.3004	0.8469	0.8427	0.8391	0.8348	2.695	2.226	1.835	1.569	1314.3	1298.8	1284.7	1270.8
0.4021	0.8585	0.8543	0.8507	0.8464	2.423	1.997	1.652	1.421	1326.8	1311.2	1296.7	1282.1
0.5011	0.8698	0.8656	0.8619	0.8577	2.207	1.814	1.518	1.314	1340.3	1324.6	1309.5	1294.1
0.6117	0.8823	0.8782	0.8744	0.8702	2.014	1.667	1.405	1.218	1356.8	1340.9	1325.3	1308.9
0.7135	0.8938	0.8897	0.8859	0.8817	1.879	1.577	1.332	1.151	1373.7	1357.7	1341.3	1324.0
0.8163	0.9053	0.9012	0.8974	0.8932	1.780	1.525	1.297	1.119	1392.6	1376.4	1359.3	1341.0
0.9045	0.9152	0.9111	0.9073	0.9031	1.725	1.501	1.313	1.148	1410.5	1394.2	1376.7	1357.5
1.0000	0.9258	0.9218	0.9179	0.9138	1.711	1.537	1.400	1.276	1432.8	1415.2	1397.2	1378.8
N,N-diethylaniline (1) + 1-heptanol (2)												
0.0000	0.8153	0.8117	0.8081	0.8044	5.054	4.337	3.735	3.407	1315.5	1298.4	1280.5	1261.5
0.1216	0.8276	0.8240	0.8203	0.8165	4.250	3.658	3.122	2.671	1322.4	1305.9	1286.1	1267.9
0.2426	0.8401	0.8364	0.8327	0.8289	3.593	3.095	2.622	2.129	1330.9	1314.5	1294.8	1276.5
0.3349	0.8498	0.8461	0.8424	0.8385	3.178	2.735	2.308	1.826	1338.6	1322.2	1302.7	1284.2
0.4641	0.8638	0.8600	0.8563	0.8523	2.706	2.323	1.960	1.535	1351.1	1334.7	1315.4	1296.6
0.5612	0.8745	0.8707	0.8669	0.8629	2.425	2.079	1.760	1.398	1361.9	1345.5	1326.3	1307.2
0.6524	0.8848	0.8809	0.8771	0.8731	2.210	1.895	1.617	1.319	1373.2	1356.6	1337.6	1318.4
0.7356	0.8943	0.8904	0.8866	0.8826	2.049	1.763	1.520	1.278	1384.8	1368.4	1349.4	1329.9
0.8144	0.9035	0.8996	0.8957	0.8917	1.923	1.665	1.455	1.257	1397.1	1380.6	1361.8	1342.0
0.9141	0.9154	0.9114	0.9075	0.9034	1.792	1.577	1.405	1.243	1414.5	1398.1	1379.6	1359.6
1.0000	0.9258]	0.9218]	0.9179]	0.9138	5.065	4.329	3.723	3.446	1432.8	1415.2	1397.2	1378.8
N,N-diethylaniline (1) + 1-octanol (2)												
0.0000	0.8183	0.8147	0.8101	0.8055	6.392	5.388	4.585	4.011	1334.7	1318.0	1298.8	1284.3
0.1141	0.8284	0.8248	0.8202	0.8157	5.389	4.420	3.684	3.135	1339.5	1321.5	1301.4	1288.6
0.2548	0.8415	0.8379	0.8334	0.8289	4.382	3.490	2.854	2.356	1346.4	1328.0	1307.3	1295.0
0.3537	0.8512	0.8476	0.8431	0.8386	3.806	2.987	2.428	1.976	1352.5	1334.0	1313.3	1300.5
0.4726	0.8634	0.8597	0.8553	0.8509	3.235	2.519	2.056	1.667	1361.3	1343.3	1322.8	1308.8
0.5725	0.8742	0.8704	0.8661	0.8617	2.842	2.221	1.837	1.503	1370.4	1352.8	1332.7	1317.5
0.6945	0.8879	0.8840	0.8798	0.8755	2.446	1.947	1.653	1.386	1383.9	1366.8	1347.2	1330.5
0.7795	0.8979	0.8940	0.8899	0.8856	2.212	1.800	1.560	1.339	1395.2	1378.2	1359.1	1341.4
0.8584	0.9076	0.9036	0.8996	0.8953	2.016	1.684	1.487	1.305	1407.0	1390.1	1371.3	1353.0
0.9317	0.9168	0.9129	0.9089	0.9047	1.847	1.587	1.421	1.271	1419.5	1402.3	1383.9	1365.2
1.0000	0.9258	0.9218	0.9179	0.9138	6.405	5.422	4.625	4.051	1432.3	1414.8	1396.5	1377.9

The standard uncertainties are (x_1) = 1×10^{-4}, u (ρ) = ± 0.54×10^{-3} g·cm^{-3}, u (u) = 0.3%, u (η) = 1.03%, u (T) = 0.01 K for density and speed of sound, u (T) = 0.1 K for viscosity and u (p) = 1 kPa

Table 4 Excess molar volume (V^E), excess isentropic compressibility (κ_s^E), deviation in viscosity ($\Delta\eta$) and excess Gibbs free energy of activation of viscous flow (G^{*E}) of liquid mixtures of N,N-diethylaniline with 1-hexanol,1-heptanol and1-octanol at T= (303.15 to 318.15) K

					N,N-diethylaniline (1) + 1-hexanol (2)							
	V^E / cm³· mol⁻¹				$\Delta\eta$ / mPa·s				κ_s^E / TPa⁻¹			
x_1	303.15 K	308.15K	313.15K	318.15K	303.15 K	308.15K	313.15K	318.15K	303.15 K	308.15K	313.15K	318.15K
0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.1057	0.0216	0.0247	0.0279	0.0307	-0.262	-0.312	-0.348	-0.405	2.226	2.549	2.877	3.207
0.1952	0.0384	0.0429	0.0483	0.0530	-0.418	-0.476	-0.520	-0.585	3.689	4.020	4.462	4.877
0.3004	0.0546	0.0583	0.0631	0.0675	-0.535	-0.583	-0.623	-0.672	4.876	5.310	5.764	6.168
0.4021	0.0647	0.0684	0.0721	0.0762	-0.587	-0.627	-0.651	-0.680	5.560	5.979	6.453	6.887
0.5011	0.0677	0.0725	0.0759	0.0796	-0.588	-0.630	-0.635	-0.650	5.792	6.224	6.749	7.198
0.6117	0.0643	0.0685	0.0725	0.0768	-0.541	-0.576	-0.582	-0.594	5.631	6.125	6.608	7.160
0.7135	0.0546	0.0591	0.0634	0.0681	-0.454	-0.480	-0.501	-0.521	4.926	5.369	5.990	6.535
0.8163	0.0385	0.0433	0.0479	0.0521	-0.330	-0.346	-0.380	-0.410	3.750	4.203	4.780	5.264
0.9045	0.0216	0.0249	0.0268	0.0312	-0.193	-0.210	-0.231	-0.260	2.264	2.597	2.942	3.363
1.0000	0.0000	0.0000	0.0000	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
					N,N-diethylaniline (1) + 1-heptanol (2)							
0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.1216	0.0289	0.0316	0.0353	0.0390	-0.396	-0.338	-0.328	-0.471	2.741	3.103	3.479	3.789
0.2426	0.0505	0.0546	0.0586	0.0637	-0.647	-0.561	-0.544	-0.750	4.586	5.008	5.450	5.833
0.3349	0.0626	0.0664	0.0704	0.0754	-0.752	-0.662	-0.640	-0.852	5.442	5.841	6.256	6.739
0.4641	0.0702	0.0748	0.0781	0.0824	-0.790	-0.710	-0.686	-0.863	6.029	6.491	6.983	7.445
0.5612	0.0704	0.0753	0.0779	0.0821	-0.745	-0.682	-0.657	-0.788	6.040	6.527	7.014	7.582
0.6524	0.0651	0.0701	0.0737	0.0778	-0.655	-0.609	-0.587	-0.669	5.790	6.407	6.856	7.343
0.7356	0.0566	0.0604	0.0647	0.0701	-0.536	-0.508	-0.488	-0.529	5.124	5.630	6.191	6.746
0.8144	0.0429	0.0489	0.0517	0.0560	-0.398	-0.384	-0.369	-0.378	4.060	4.644	5.110	5.635
0.9141	0.0238	0.0271	0.0281	0.0320	-0.195	-0.193	-0.184	-0.175	2.347	2.733	3.100	3.466
1.0000	0.0000	0.0000	0.0000	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
					N,N-diethylaniline (1) + 1-octanol (2)							
0.0000	0.0000	0.0000	0.0000	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.1141	0.0311	0.0336	0.0370	0.0410	-0.467	-0.525	-0.533	-0.559	2.112	3.413	4.731	2.608
0.2548	0.0563	0.0609	0.0650	0.0685	-0.814	-0.907	-0.908	-0.946	4.465	6.337	8.417	5.505
0.3537	0.0678	0.0719	0.0755	0.0796	-0.925	-1.025	-1.014	-1.051	5.729	7.500	9.682	7.070
0.4726	0.0738	0.0784	0.0817	0.0857	-0.937	-1.031	-1.002	-1.030	6.610	7.940	9.913	8.183
0.5725	0.0733	0.0774	0.0807	0.0849	-0.861	-0.941	-0.898	-0.916	6.707	7.540	9.152	8.329
0.6945	0.0653	0.0698	0.0741	0.0782	-0.685	-0.739	-0.688	-0.693	5.949	6.205	7.279	7.429
0.7795	0.0554	0.0595	0.0639	0.0677	-0.519	-0.556	-0.506	-0.505	4.846	4.809	5.506	6.076
0.8584	0.0396	0.0443	0.0473	0.0514	-0.344	-0.365	-0.324	-0.319	3.410	3.241	3.621	4.302
0.9317	0.0228	0.0261	0.0269	0.0286	-0.169	-0.177	-0.154	-0.149	1.771	1.618	1.762	2.238
1.0000	0.0000	0.0000	0.0000	0.0000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

	N,N-diethylaniline (1) + 1-hexanol (2)				N,N-diethylaniline (1) + 1-heptanol (2)					N,N-diethylaniline (1) + 1-octanol (2)				
x_1	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	x_1	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	x_1	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**
0.0000	0.000	0.000	0.000	0.000	0.0000	0.000	0.000	0.000	0.000	0.0000	0.000	0.000	0.000	0.000
0.1057	-1.207	-2.029	-2.929	-4.043	0.1216	-0.997	-1.085	-1.499	-3.108	0.1141	-0.430	-1.266	-1.999	-2.863
0.1952	-2.093	-3.335	-4.761	-6.390	0.2426	-1.880	-2.110	-2.894	-5.797	0.2548	-0.886	-2.638	-4.098	-5.925
0.3004	-2.944	-4.426	-6.200	-7.979	0.3349	-2.425	-2.797	-3.811	-7.348	0.3537	-1.106	-3.354	-5.126	-7.440
0.4021	-3.517	-5.172	-6.975	-8.623	0.4641	-2.912	-3.507	-4.729	-8.456	0.4726	-1.210	-3.804	-5.660	-8.212
0.5011	-3.827	-5.647	-7.282	-8.764	0.5612	-3.006	-3.756	-5.016	-8.312	0.5725	-1.138	-3.757	-5.424	-7.830
0.6117	-3.850	-5.592	-7.195	-8.625	0.6524	-2.845	-3.693	-4.879	-7.410	0.6945	-0.858	-3.145	-4.328	-6.183
0.7135	-3.494	-4.985	-6.652	-8.170	0.7356	-2.473	-3.335	-4.358	-6.030	0.7795	-0.574	-2.404	-3.170	-4.496
0.8163	-2.754	-3.822	-5.402	-6.925	0.8144	-1.927	-2.701	-3.488	-4.369	0.8584	-0.297	-1.560	-1.958	-2.765
0.9045	-1.733	-2.484	-3.438	-4.581	0.9141	-0.988	-1.461	-1.856	-2.015	0.9317	-0.086	-0.727	-0.859	-1.215
1.0000	0.000	0.000	0.000	0.000	1.0000	0.000	0.000	0.000	0.000	1.0000	0.000	0.000	0.000	0.000

Table 5 Coefficients of Redlich – Kister equation and standard deviation (σ) values for liquid mixtures of N, N-diethyl aniline with 1-alkanols at T= (303.15 - 318.15) K

Binary mixtures	Functions	A_0	A_1	A_2	σ
	303.15 K				
N,N-diethylaniline+ 1-hexanol	V^E/ cm³·mol⁻¹	0.272	0.013	-0.051	0.001
	$\Delta\eta$/ mPa· s	-2.351	0.362	-0.237	0.003
	κ_s^E/ TPa⁻¹	23.23	1.382	2.565	0.026
N,N-diethylaniline+ 1-heptanol	V^E/ cm³·mol⁻¹	0.283	0.015	0.002	0.001
	$\Delta\eta$/ mPa· s	-3.118	0.774	-0.435	0.001
	κ_s^E/ TPa⁻¹	24.32	1.857	5.201	0.054
N,N-diethylaniline+ 1-octanol	V^E/ cm³·mol⁻¹	0.295	0.020	0.051	0.001
	$\Delta\eta$/ mPa· s	-3.694	1.227	-0.495	0.001
	κ_s^E/ TPa⁻¹	26.08	1.758	6.656	0.023
	308.15 K				
N,N-diethylaniline+ 1-hexanol	V^E/ cm³·mol⁻¹	0.288	0.015	-0.020	0.001
	$\Delta\eta$/ mPa· s	-2.489	0.561	-0.563	0.006
	κ_s^E/ TPa⁻¹	24.90	1.734	5.416	0.047
N,N-diethylaniline+ 1-heptanol	V^E/ cm³·mol⁻¹	0.300	0.024	0.029	0.001
	$\Delta\eta$/ mPa· s	-3.162	0.978	-0.787	0.001
	κ_s^E/ TPa⁻¹	26.14	2.636	8.807	0.069
N,N-diethylaniline+ 1-octanol	V^E/ cm³·mol⁻¹	0.311	0.028	0.083	0.001
	$\Delta\eta$/ mPa· s	-3.742	1.523	-1.282	0.001
	κ_s^E/ TPa⁻¹	27.51	2.011	10.18	0.052
	313.15 K				
N,N-diethylaniline+ 1-hexanol	V^E/ cm³·mol⁻¹	0.305	0.009	0.003	0.001
	$\Delta\eta$/ mPa· s	-2.543	0.649	-1.005	0.009
	κ_s^E/ TPa⁻¹	26.94	2.249	8.256	0.024
N,N-diethylaniline+ 1-heptanol	V^E/ cm³·mol⁻¹	0.315	0.015	0.045	0.001
	$\Delta\eta$/ mPa· s	-3.212	1.214	-1.125	0.001
	κ_s^E/ TPa⁻¹	27.89	3.034	12.35	0.075
N,N-diethylaniline+ 1-octanol	V^E/ cm³·mol⁻¹	0.327	0.022	0.098	0.001
	$\Delta\eta$/ mPa· s	-3.916	1.813	-1.506	0.001
	κ_s^E/ TPa⁻¹	29.44	2.173	11.99	0.049
	318.15 K				
N,N-diethylaniline+ 1-hexanol	V^E/ cm³·mol⁻¹	0.319	0.016	0.042	0.001
	$\Delta\eta$/ mPa· s	-2.603	0.835	-1.649	0.001
	κ_s^E/ TPa⁻¹	28.70	2.929	11.82	0.034
N,N-diethylaniline+ 1-heptanol	V^E/ cm³·mol⁻¹	0.332	0.017	0.085	0.001
	$\Delta\eta$/ mPa· s	-3.355	1.390	-1.541	0.001
	κ_s^E/ TPa⁻¹	29.79	3.849	15.18	0.081
N,N-diethylaniline+ 1-octanol	V^E/ cm³·mol⁻¹	0.343	0.018	0.126	0.001
	$\Delta\eta$/ mPa· s	-4.018	2.018	-1.519	0.001
	κ_s^E/ TPa⁻¹	31.12	4.120	15.39	0.063

Table 6: The values $\bar{V}^E_{m,1}$, $\bar{V}^E_{m,2}$, $\bar{K}^E_{s,m,1}$, $\bar{K}^E_{s,m,2}$ of liquid mixtures of N,N-diethyl aniline with 1-alkanols at T= (303.15 - 318.15) K

	303.15K		308.15K		313.15K		318.15K		303.15K		308.15K		313.15K		318.15K	
x_1	$\bar{V}^E_{m,1}$	$\bar{V}^E_{m,2}$	$\bar{V}^E_{m,1}$	$\bar{V}^E_{m,2}$	$\bar{V}^E_{m,1}$	$\bar{V}^E_{m,2}$	$\bar{V}^E_{m,1}$	$\bar{V}^E_{m,2}$	$\bar{K}^E_{s,m,1}$	$\bar{K}^E_{s,m,2}$	$\bar{K}^E_{s,m,1}$	$\bar{K}^E_{s,m,2}$	$\bar{K}^E_{s,m,1}$	$\bar{K}^E_{s,m,2}$	$\bar{K}^E_{s,m,1}$	$\bar{K}^E_{s,m,2}$
N,N-diethylaniline(1) + 1-hexanol(2)																
0.0000	0.234	0.000	0.283	0.000	0.318	0.000	0.377	0.000	36.65	0.000	43.52	0.000	50.77	0.000	59.07	0.000
0.1057	0.205	0.001	0.230	0.003	0.249	0.004	0.278	0.006	26.86	0.530	29.97	0.722	36.77	0.921	36.82	1.166
0.1952	0.173	0.007	0.187	0.010	0.199	0.013	0.213	0.017	20.48	1.651	21.89	2.134	27.64	2.640	24.80	3.254
0.3004	0.134	0.021	0.140	0.026	0.148	0.029	0.153	0.036	14.70	3.541	15.26	4.295	19.42	5.096	16.17	6.040
0.4021	0.096	0.043	0.100	0.048	0.107	0.052	0.109	0.059	10.46	5.827	10.86	6.660	13.47	7.566	11.42	8.576
0.5011	0.064	0.071	0.068	0.076	0.073	0.079	0.076	0.084	7.275	8.45	7.772	9.189	9.106	10.03	8.617	10.87
0.6117	0.036	0.110	0.039	0.113	0.044	0.116	0.047	0.118	4.526	11.89	5.141	12.49	5.483	13.20	6.329	13.74
0.7135	0.017	0.147	0.020	0.151	0.024	0.155	0.027	0.158	2.587	15.71	3.163	16.40	3.045	17.20	4.336	17.71
0.8163	0.006	0.181	0.008	0.190	0.010	0.201	0.012	0.209	1.140	20.43	1.510	21.83	1.307	23.32	2.286	24.51
0.9045	0.001	0.201	0.002	0.222	0.003	0.245	0.003	0.265	0.331	25.45	0.469	28.32	0.373	31.25	0.764	34.10
1.0000	0.000	0.208	0.000	0.252	0.000	0.298	0.000	0.346	0.000	32.21	0.000	38.09	0.000	43.93	0.000	50.28
N,N-diethylaniline (1) + 1-heptanol(2)																
0.0000	0.300	0.000	0.353	0.000	0.405	0.000	0.434	0.000	42.73	0.000	51.52	0.000	59.49	0.000	67.54	0.000
0.1216	0.225	0.005	0.250	0.007	0.278	0.008	0.288	0.010	28.42	0.878	31.76	1.195	39.92	1.485	38.03	1.762
0.2426	0.162	0.019	0.173	0.024	0.183	0.027	0.191	0.031	19.16	2.901	20.12	3.717	26.41	4.446	22.14	5.179
0.3349	0.123	0.035	0.128	0.041	0.123	0.049	0.140	0.050	14.34	4.845	14.71	5.888	19.03	6.795	15.67	7.760
0.4641	0.077	0.065	0.080	0.071	0.084	0.072	0.090	0.078	9.593	7.979	10.00	8.981	11.70	9.795	10.99	10.80
0.5612	0.051	0.093	0.053	0.098	0.057	0.095	0.062	0.103	6.926	10.78	7.541	11.57	7.802	12.16	8.857	13.05
0.6524	0.031	0.123	0.033	0.128	0.038	0.122	0.042	0.132	4.809	14.06	5.522	14.70	5.012	15.18	6.962	16.00
0.7356	0.018	0.153	0.020	0.159	0.024	0.152	0.026	0.167	3.111	17.93	3.758	18.73	3.031	19.44	5.027	20.45
0.8144	0.009	0.185	0.010	0.194	0.011	0.201	0.014	0.213	1.723	22.74	2.178	24.23	1.584	25.72	3.055	27.33
0.9141	0.002	0.228	0.002	0.248	0.004	0.260	0.003	0.296	0.431	31.11	0.574	34.68	0.373	38.46	0.844	41.84
1.0000	0.000	0.269	0.000	0.305	0.000	0.361	0.000	0.400	0.000	41.08	0.000	48.09	0.000	55.53	0.000	61.75
N,N-diethylaniline (1) + 1-octanol(2)																
0.0000	0.366	0.000	0.422	0.000	0.447	0.000	0.487	0.000	47.43	0.000	54.98	0.000	60.13	0.000	69.65	0.000
0.1141	0.257	0.007	0.283	0.009	0.298	0.009	0.318	0.011	32.20	0.871	35.00	1.129	41.99	1.274	41.26	1.591
0.2548	0.163	0.027	0.172	0.033	0.181	0.035	0.190	0.038	20.67	3.403	21.20	4.130	26.57	4.570	22.88	5.555
0.3537	0.117	0.046	0.121	0.053	0.128	0.056	0.134	0.060	15.56	5.620	15.81	6.455	19.03	7.018	16.54	8.279
0.4726	0.076	0.072	0.078	0.079	0.084	0.081	0.089	0.084	11.19	8.681	11.70	9.323	12.41	9.912	12.42	11.13
0.5725	0.051	0.098	0.053	0.102	0.058	0.105	0.063	0.107	8.266	11.89	9.048	12.24	8.288	12.83	10.01	13.78
0.6945	0.027	0.136	0.030	0.140	0.033	0.145	0.037	0.148	5.079	17.46	5.916	17.74	4.495	18.56	6.950	19.19
0.7795	0.015	0.172	0.017	0.178	0.019	0.186	0.022	0.193	3.055	23.17	3.704	24.01	2.498	25.36	4.518	26.10
0.8584	0.007	0.215	0.008	0.227	0.009	0.242	0.010	0.257	1.446	30.52	1.812	32.68	1.108	35.00	2.277	36.40
0.9317	0.002	0.266	0.002	0.289	0.002	0.313	0.003	0.342	0.383	39.71	0.492	44.11	0.278	47.92	0.633	50.68
1.0000	0.000	0.325	0.000	0.366	0.000	0.403	0.000	0.450	0.000	50.88	0.000	58.56	0.000	64.42	0.000	69.37

Table 7: The values of $\bar{V}^{\circ}_{m,1}$, $V^*_{m,1}$, $\bar{V}^{\circ E}_{m,1}$, $\bar{V}^{\circ}_{m,2}$, $V^*_{m,2}$, $\bar{V}^{\circ E}_{m,2}$ $\bar{K}^{\circ}_{s,m,1}$, $K^*_{s,m,1}$, $\bar{K}^{\circ E}_{s,m,1}$, $\bar{K}^{\circ}_{s,m,2}$, $K^*_{s,m,2}$ and $\bar{K}^{\circ E}_{s,m,2}$ of the components for N,N-diethyl aniline with 1-alkanols of binary mixtures at T= (303.15 - 318.15) K

T/K	$\bar{V}^{\circ}_{m,1}$	$V^*_{m,1}$	$\bar{V}^{\circ E}_{m,1}$	$\bar{V}^{\circ}_{m,2}$	V^*_{m2}	$\bar{V}^{\circ E}_{m,2}$	$\bar{K}^{\circ}_{s,m,1}$	$K^*_{s,m,1}$	$\bar{K}^{\circ E}_{s,m,1}$	$\bar{K}^{\circ}_{s,m,2}$	$K^*_{s,m,2}$	$\bar{K}^{\circ E}_{s,m,2}$
	$(cm^3 \cdot mol^{-1})$						TPa^{-1}					
N,N-diethylaniline (1) +1-hexanol (2)												
303.15	131.14	130.90	0.234	126.01	125.80	0.208	43.54	6.895	36.65	41.60	9.392	32.21
308.15	131.75	131.47	0.283	126.72	126.47	0.252	50.63	7.113	43.52	47.81	9.718	38.09
313.15	132.35	132.03	0.318	127.30	127.00	0.298	58.13	7.360	50.77	53.93	10.00	43.93
318.15	133.00	132.62	0.377	128.03	127.69	0.346	66.72	7.643	59.07	60.58	10.30	50.28
N,N-diethylaniline (1) +1-heptanol (2)												
303.15	131.20	130.90	0.300	142.80	142.53	0.269	49.63	6.895	42.73	51.18	10.10	41.08
308.15	131.82	131.47	0.353	143.46	143.15	0.306	58.63	7.113	51.52	58.53	10.45	48.09
313.15	132.40	132.03	0.375	144.13	143.79	0.346	66.85	7.360	59.49	66.40	10.87	55.53
318.15	133.06	132.62	0.434	144.86	144.46	0.400	75.19	7.643	67.54	73.04	11.29	61.75
N,N-diethylaniline (1) +1-octanol (2)												
303.15	131.27	130.90	0.366	159.48	159.16	0.325	54.33	6.895	47.43	61.79	10.91	50.88
308.15	131.89	131.47	0.422	160.21	159.85	0.366	62.09	7.113	54.98	69.88	11.32	58.56
313.15	132.48	132.03	0.447	161.17	160.76	0.403	67.49	7.360	60.13	76.25	11.83	64.42
318.15	133.11	132.62	0.487	162.12	161.67	0.450	77.29	7.643	69.65	81.53	12.16	69.37

Table 8: PFP interaction parameter, χ_{12} and calculated values of the three contributions from the PFP theory with experimental excess molar volumes at x_1= 0.5 at 303.15K

Binary mixtures	χ_{12} (10^6)	Calculated contributions			V^E_m $(x=0.5)$ $cm^3.mol^{-1}$		
		Interactional(10^{-8})	Free volume	P* effect	EXP	PFP	δ / $cm^3.mol^{-1}$
N,N-diethylaniline+1-hexanol	13.70	1.585	-0.0274	-0.1219	0.0679	0.0679	0.0000
N,N-diethylaniline+1-heptanol	6.948	1.617	-0.0014	-0.0403	0.0710	0.0707	0.0003
N,N-diethylaniline+1-octanol	6.406	1.639	-0.0010	-0.0303	0.0741	0.0737	0.0004

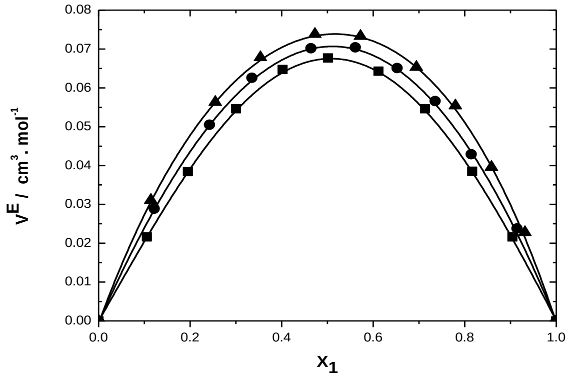


Figure 1 Variation of excess molar volume (V^E) with mole fraction (x_1) of N, N-diethyl aniline in the binary liquid mixtures of N,N-diethyl aniline with 1-hexanol (■), 1-heptanol (●) and 1-octanol (▲) at 303.15 K

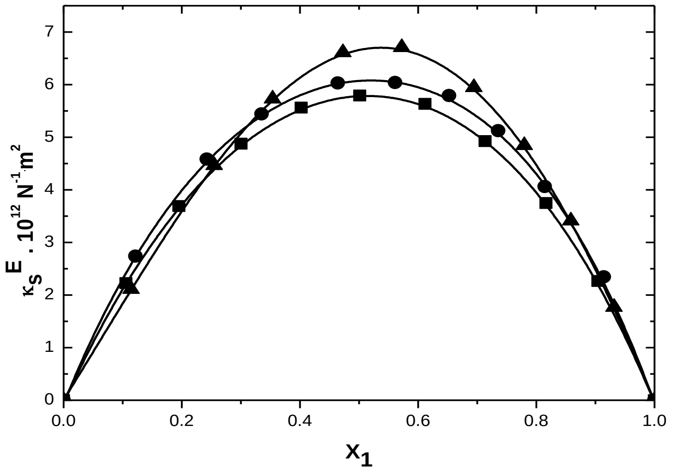


Figure 2 Excess isentropic compressibility (κ_s^E)with mole fraction (x_1) of N, N-diethyl aniline in the binary liquid mixtures of N,N-diethyl aniline with 1-hexanol (■), 1-heptanol (●) and 1-octanol (▲) at 303.15 K

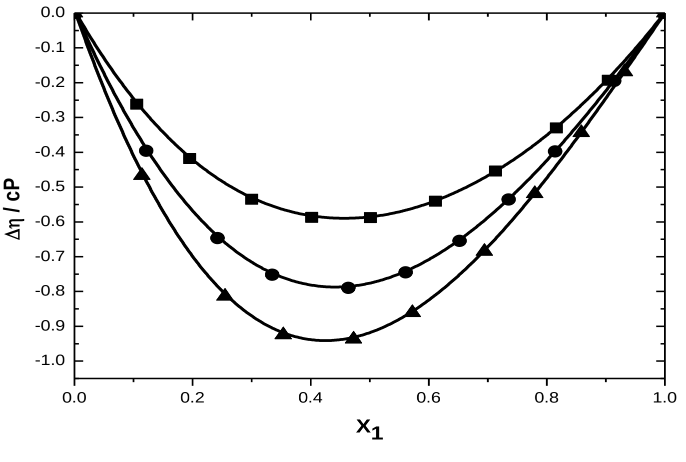


Figure 3 Variation of deviation viscosity (Δη) with mole fraction (x_1) of N, N-diethyl aniline in the binary liquid mixtures of N,N-diethyl aniline with 1-hexanol (■), 1- heptanol (●) and 1-octanol (▲) at 303.15 K

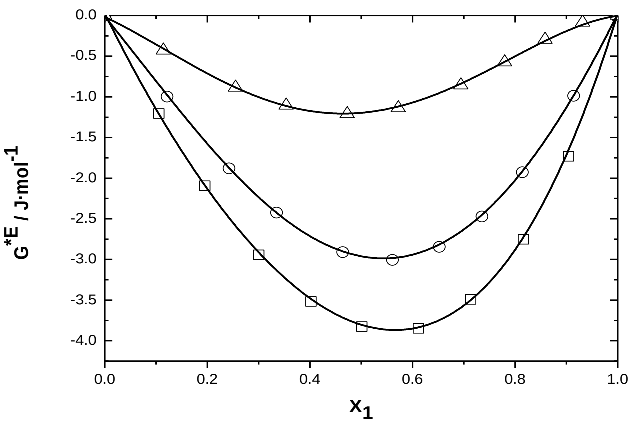


Figure 4 Excess Gibbs energy of activation of viscous flow *(G^{*E})* with mole fraction (x_1) of N, N-diethyl aniline in the binary liquid mixtures of N, N-diethyl aniline with 1-hexanol (∀), 1-heptanol (–) and 1-octanol (Δ) at 303.15 K

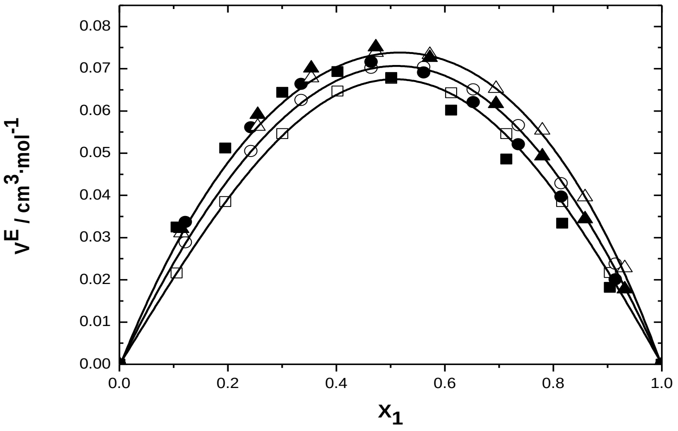


Figure 5 Excess molar volumes of the binary mixtures against mole fraction x_1 at T = 303.15 K for N,N-diethyl aniline + 1-hexanol (∀), N,N-diethyl aniline + 1-heptanol (–), N, N-diethyl aniline + 1-octanol (Δ) and (---) calculated with PFP theory using Parameters

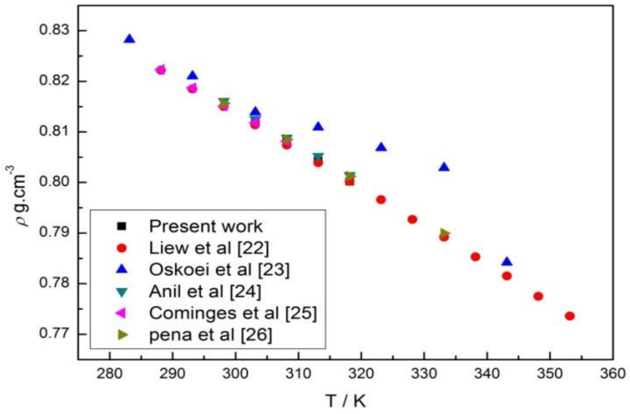


Figure1sdensity of 1-hexanol

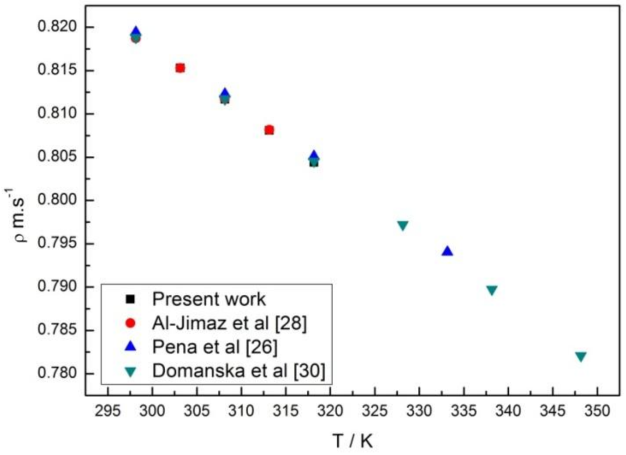


Figure2sdensity of 1-heptanol

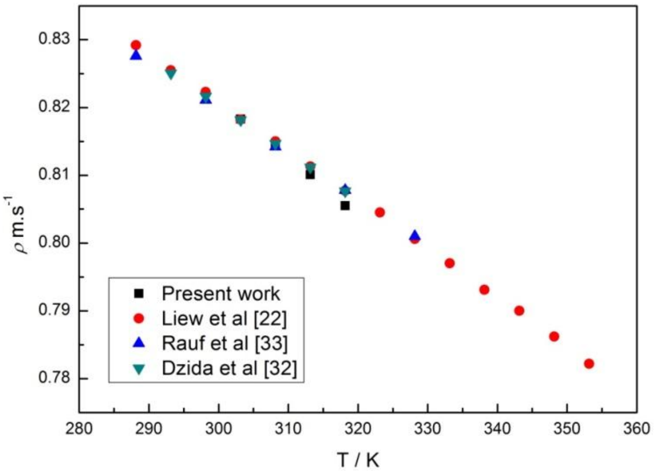


Figure 3sdensity of 1-octanol

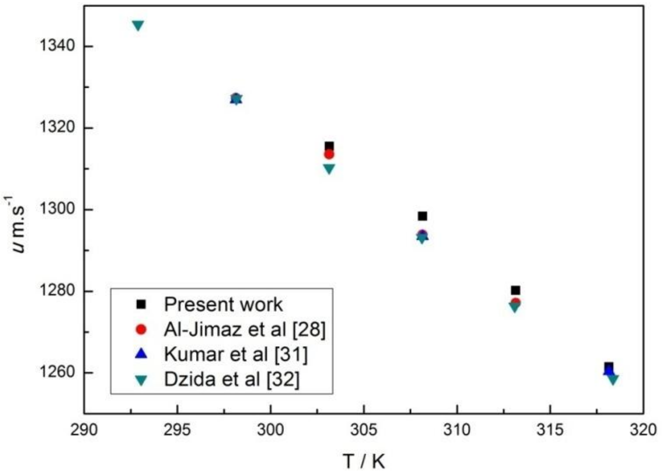


Figure 4s Speed of sound of 1-hexanol

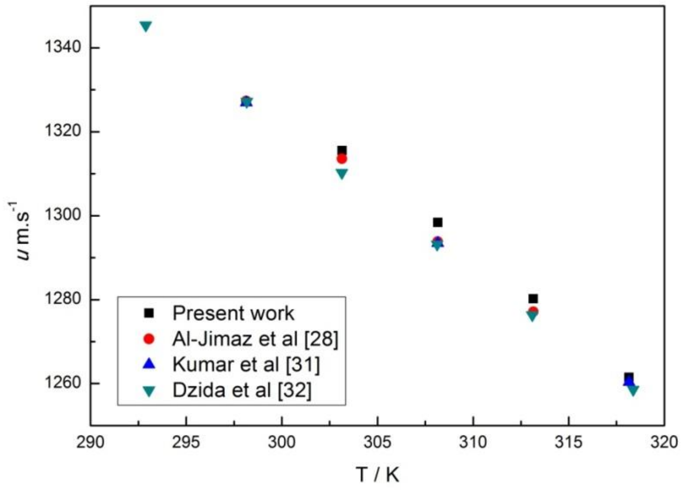


Figure 5s Speed of sound of 1-heptanol

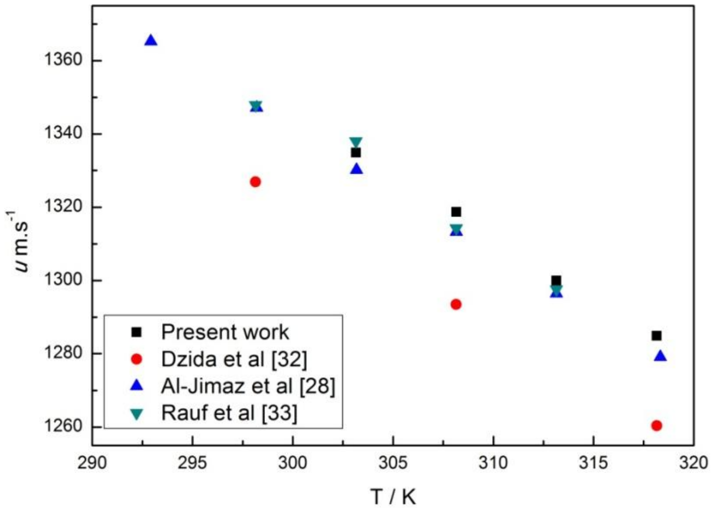


Figure6s Speed of sound of 1-octanol

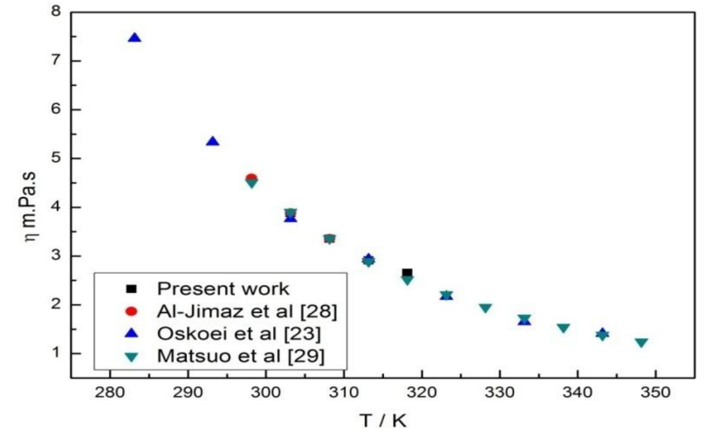


Figure 7s Viscosity of 1-hexanol

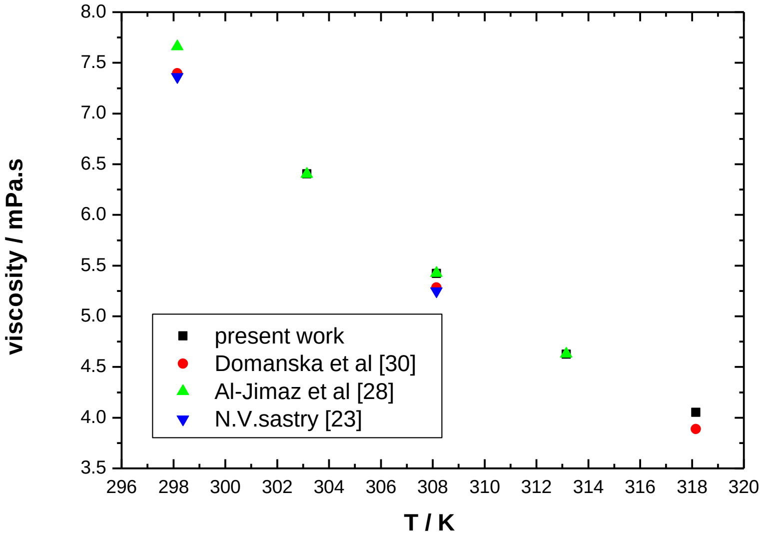


Figure 8s Viscosity of 1-heptanol

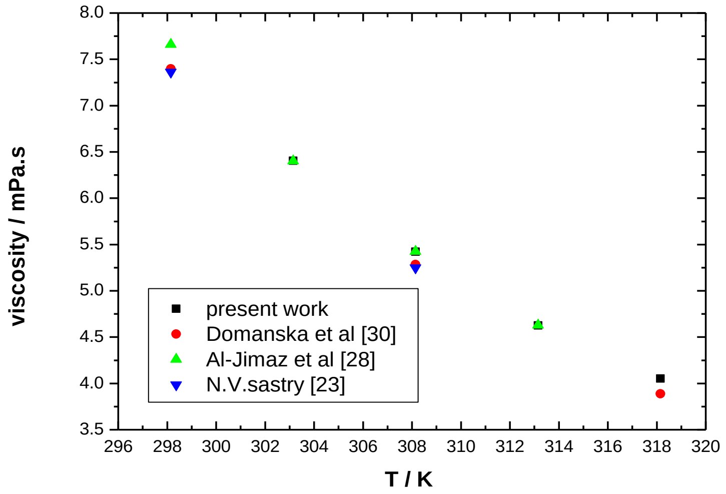


Figure 9s Viscosity of 1-octanol

Table 1S: Coefficients of the polynomial for the correlation of the viscosity as a function of concentration at different temperatures for the N,N-diethylaniline (1) +1-heptanol (2), N,N-diethylaniline (1) +1-octanol (2) binary system

T / (K)	b_0 / (mPa·s)	b_1 / (mPa·s)	b_2 / (mPa·s)	b_3 /(mPa·s)	σ
		N,N-diethylaniline (1) +1-heptanol(2)			
303.15	5.054	-7.250	5.439	-1.545	0.013
308.15	4.337	-6.079	4.163	-0.894	0.016
313.15	3.735	-5.528	4.089	-0.910	0.023
318.15	3.407	-6.925	7.510	-2.760	0.046
		N,N-diethylaniline (1) +1-octanol(2)			
303.15	6.392	-9.593	7.304	-2.406	0.015
308.15	5.388	-9.414	8.461	-2.936	0.038
313.15	4.585	-8.905	9.174	-3.500	0.045
318.15	4.011	-8.760	9.882	-3.903	0.045
303.15	6.392	-9.593	7.304	-2.406	0.015

Parameters of the equation $u = b_3 x_1^3 + b_2 x_1^2 + b_1 x_1 + b_0$

Table 2S: Coefficients of the polynomial for the correlation of the speed of sound as a function of concentration at different temperatures for the N,N-diethylaniline (1) +1-octanol (2) binary system

T / (K)	b_0 / (m·s^{-1})	b_1 / (m·s^{-1})	b_2 / (m·s^{-1})	b_3 /(m·s^{-1})	σ
303.15	1334.73	38.91	17.13	41.55	0.471
308.15	1318.02	24.70	50.51	21.56	0.642
313.15	1298.85	13.90	72.33	11.47	1.072
318.15	1284.31	35.19	14.71	43.68	0.741

Parameters of the equation $u = b_3 x_1^3 + b_2 x_1^2 + b_1 x_1 + b_0$

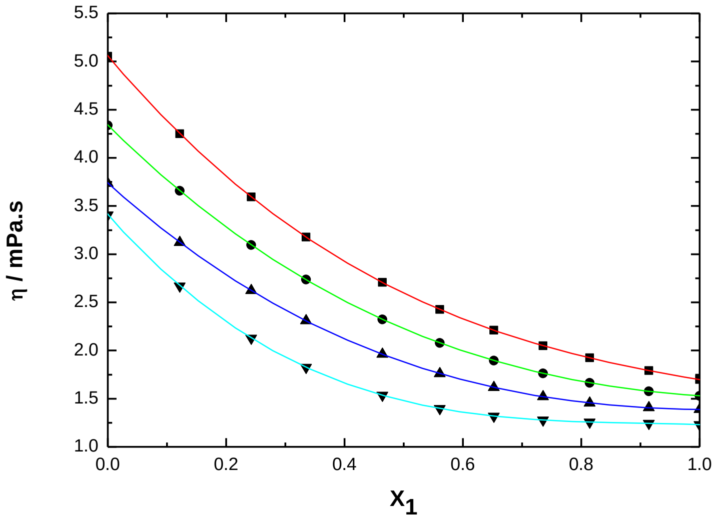


Figure10s: viscosity of binary mixture of N,N-diethylaniline+1-heptanol following the third-order polynomial equation

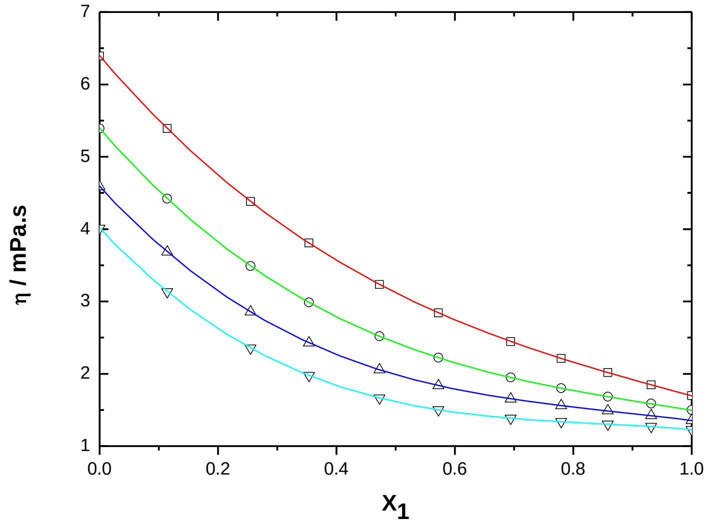


Figure11s: viscosity of binary mixture of N,N-diethylaniline+1-octanol following the third-order polynomial equation

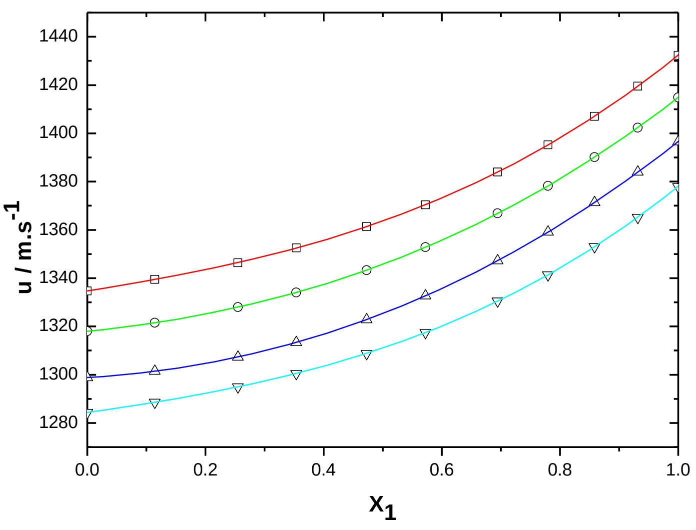


Figure12s: speed of sound of binary mixture of N,N-diethylaniline+1-octanol following the third-order polynomial equation

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Muvva Raghavendra. "Electron Releasing Effect on the Thermodynamic and Transport Properties of Liquid Mixtures at Various Temperatures." IOSR Journal of Applied Chemistry (IOSR-JAC) 10.7 (2017): 12-27.