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Molecular Interaction Studies of Binary Mixtures of Acetophenone with Butylamine, Cyclohexylamine, Dipropylamine, and Dibutylamine at T = (303.15, 308.15 and 313.15) K

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***Abstract*— Measurement of densities (ρ), viscosities (η) and ultrasonic speeds of sound (u) has been carried out for binary mixtures of acetophenone with butylamine, cyclohexylamine, dipropylamine, and dibutylamine at T = (303.15, 308.15 and 313.15) K. The experimental data have been used to calculate the excess molar volumes (VE), deviation in viscosity (Δη,), isentropic compressibility (Ks), deviation in speeds of sound (Δu) and deviation in isentropic compressibilities (ΔKs). These excess properties were correlated with Redlich-kister polynomial equation. Further the predictive ability of some selected viscosity models (Tamura-Kurata, Heric, McAllister (4-body)) was tested. The Speeds of sound data were also correlated using Vandel- Vangeel, and Jouyban- Acree models. The results were interpreted in terms of inter molecular interactions.**

***Index Terms*— Density, Viscosity, Excess molar Volume, Speeds of sound, Iscentropic compressibility.**

I. INTRODUCTION

Thermophysical properties of Keto-amine liquids and their mixtures have found most significant applications in various types of industries. Acetophenone is an organic compound used as an ingredient in perfumes and as a chemical intermediate in manufacturing pharmaceuticals, resins, flavouring agents. Cyclohexylamine is the precursor to sulfonamide based reagents, used as an accelerator for vulcanization. It is a building block for pharmaceuticals (Viz : mucolytics, analgesics, and bronchodilators). Butylamine is used in the manufacture of pesticides, pharmaceuticals and emulsifiers, while dibutylamine is used as a corrosion inhibitor in the manufacture of emulsifiers. Dipropylamine a moderately soluble in water is primarily used to produce pesticides, Zeolites. It occurs naturally in tobacco.

Survey of literature reveals that in recent years there have been some studies on molecular interactions for binary mixtures of (esters + acetophonone) [1- 4], (N,N DMA + P-chloroactophenone) [5] (acetophenone + 2–alkanols) [6], (acetonitrile + acetophenone) [7], (butylamine + alcohols) [8], (butylamine + alkoxy propanols) [9], (cyclohexylamine + butylcarbitol) [10], (butanol + cyclohexylamine) [11], (Chloroform + dipropylamine) [12], (alkylamine + non-electrolyte solvents) [13] and (Ketone + amine) [14]. However there are no reports of ultrasonic velocities for binary mixtures of acetophenone with butylamine, cyclohexylamine, diproplylamine, and dibutylamine in the literature. Therefore in this study we report the density (ρ), viscosity (η), and ultrasonic speeds of sound (u) for binary mixtures of (acetophenone + butylamine), (acetophenone + cyclohexylamine), (acetophenone + dipropylamine) and (acetophenone + dibutylamine) at T = (303-15, 308.15 and 313.15) K. From the experimental data, excess molar volumes (V^E), deviation in viscosities ($\Delta\eta$), isentropic compresibiltiy (Ks), deviation in Speeds of sound (Δu) and deviation in isentropic comprersibiltiy (ΔKs) were evaluated at the respective temperatures. The excess or devialtion results were fitted to the Redlidh-kister [15] polynomial equation. The viscosity- molefraction data pair were used to test the correlating viscosity models, proposed by Tamura-Kurata [16], Heric (two – parameter) [17] and Mc Allister (4-body) [18]. Further the ultrasonic speeds of sound data were used to test the correlating models proposed by Vandel- Vangeel [19] and Jouyban – Acree [20] at all the studied temperatures.

II. EXPERIMENTAL

The liquids acetophenone, butylamine, cyclohexylamine, (Singma, Aldrich) diproplylamine, and dibutylamine (Fluka)of the highest purity of >99.5% were used as such without further purification. The purities of these chemicals were checked by density determination at 303.15 K. The density (ρ) viscosity(η) and speeds of sound (u) of the pure liquids at (303.15, 308.15 and 313.15)K are included in Table 1 along with the available literature values for comparison. The agreement is found to be satisfactory. Binary liquid mixtures of various compositions covering the entire mole fraction range were made on a digitial electronic single pan balance (Mettler, AE 240, Switzerland). The uncertainty in the mole fraction estimated was found to be less than $\pm$ 1 x 10^{-4}. For all the mixtures and pure solvent triplicate measurements were performed and the average of all values were considered in the calculation of molefractions. Densities of pure liquids and the binary mixtures were determined using a Rudulph research analytical densimeter (DDH – 2910 USA). The uncertainty in the density measurement was found to be $\pm$5 x 10^{-4} g.cm^{-3}.Viscosities were determined using an Ubbelhode viscometer. The flow time of each sample was measured by suspending viscometer

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in a low temperature viscometer bath (Cat No : KVB 04/SP Sr No 2 KX – 03-375, Watts 1500, Volts 1-230) supplied by S.Kumar Mumbai, India. The temperature of the viscometer bath was controlled within ± 0.01K. The uncertainty in dynamic viscosities is of order of ± 0.003 mPa.s The ultrasonic velocities were measured at 2 MH_Z with a single crystal variable path interferometer (F-8 Mittal Enterprises, New Delhi). The uncertainty in Speeds of sound was found to be ± 0.6%. The instrument calibration was made by measuring the velocity in standard liquids Viz AR grade benzene, and carbon tetrachloride. The temperature of the measurement was controlled within ± 0.01K using low temperature bath (INSREF [R] 016C India) by circulating water from thermostat.

III. RESULTS AND DISCUSSION:

The experimentally measured densities (ρ), viscosities (η), speeds of sound (u) and the calculated excess molar volumes (V^E), isentropic compresibilities (Ks) for the binary mixtures of (Acetophenone + butylamine), (acetophenone + cyclohexylamine) (acetophenone + dipropylamine) and (acetophenone + dibutlylamine) at T = (303.15, 308.15 and 313.15) K are reported in Table 2. The excess molar volumes (V^E) were calculated from density data using the following relation.

$$V^E = \sum_{i=1}^{2} x_i M_i(\rho^{-1} - \rho_i^{-1}) \qquad (1)$$

Where Mi, ρi and ρ are the molar mass, density of the i^{th} component and density of the mixture respectively.

The deviation in viscosity ($\Delta\eta$) from a linear dependence on mole fraction were calculated by

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

Where η is the viscosity of the mixture and $x_i\eta_i$ are the mole fraction and viscosity of pure component i, respectively.

The deviation of the speeds of sound (Δu) were calculated using the following relation.

$$\Delta u = u - \sum_{i=1}^{2} x_i \; u_I \qquad (3)$$

$$K_s = (\rho\, u^2)^{-1} \qquad (4)$$

$$\Delta K_s = K_s - \sum_{i=1}^{2} (x_i (Ks)_i) \qquad (5)$$

where $(Ks)_i$ is the isentropic compressibility for the ith component of the mixture. The results of excess volumes and the deviation properties were fitted to the Redlich-Kister [15] polynomial equation

$$Y = x_1 x_2 \sum_{i=1}^{m} A_i (x_1 - x_2)^{i-1} \qquad (6)$$

Where m is the number of estimated parameters and polynomial coefficients A_i^{15} were obtained by fitting the equation to the experimental results.with least square regression method. The standard deviations (σ) are defined as

$$\sigma(y) = \{(\sum (Y_{exp} - Y_{cal})^2/(n-m))\}^{1/2} \qquad (7)$$

Where y is the property concerned, n and m represent the number of experimental data points and that of estimated parameters used in equation (6. The value of coefficients A_i^{15} of equation (6) and the corresponding standard deviation obtained by equation (7) are given in Table 3. The values of $V^E, \Delta n, \Delta u$ and Δk at T = (303.15, 308.15 and 313.15) K were graphically represented in figs 1-4. Figure1 shows the variation of V^E against mole fraction (x_1) of acetophenone . It is observed that the values of V^E are found to be positive for (acetophenone + cyclohexylamine), while for the remaining studied systems the V^E values are negative through out the entire range of composition at all the studied temperature stated behavior of V^E may be attributed to the resulting contribution of several opposing effects [28] viz : Chemical, Physical and Structural. The chemical or specific interactions results in volume contraction leading to negative V^E. These type of interactions mainly signify the charge transfer complexes, dipole-dipole and dipole-induced dipole effects in the mixture. As observed in figure 1 the positive V^E value, of acetophen- one + cyclohexylamine mixtures may be due to differences in polarizability making the dominance of repulsive forces leading to structural effects arising from interstitial accommodation. While in case of other studied systems the negative V^E may be attributed to the dipole – dipole interactions resulting in the formation of electron transfer complexes. As amines with nitrogen atoms are the best donors [29] possessing lone pairs of electrons on them. This type of similar trend is also observed in N, N-dimethly formamide with ketones [30] The deviation of $\Delta\eta$ with mole fraction ($x_{1)}$ of acetophenone mixtures at (303.15, 308.15 and 313.15) K is shown in figure 2. It is observed that the $\Delta\eta$values show completely positive trend for (acetophenone + cyclohexylamine) mixtures., while for the remaining systems the $\Delta\eta$ values show negative deviation over the entire composition range of acetophenone. These negative $\Delta\eta$ values suggest that dispersion forces are dominant in mixtures of (acetophenone + butylamine), (acetophenone + dipropylamine) and (acetophenone + dibutylamine). The existence of dispersion forces indicate that the component molecules have different molecular sizes and shapes [31]. According to Fort and Moore [32] the deviation in viscosity tends to become more positive as the strength of the interaction between component molecules increases.

Fig 3 represents the deviation in $\Delta\mu$ against mole-fraction of acetophenone (x_1). The $\Delta\mu$ values exhibit negative deviations for all the binary systems studied at T = (303.15, 308.15 and 313.15)K. over the whole composition range. These negative deviation in $\Delta\mu$ may be attributed to structure breaking factor in the mixing components resulting to the expansion [32]. Fig 4 shows the deviation in isentropic compressibility (ΔK_s) against mole fraction of acetophenone (x_1). It is found that the ΔK_s values in our present study may be attributed to the differences in size and shape and the mask

of unlike component in mixtures, while are negative $\boldsymbol{\Delta K_s}$ values indicate the strong molecular dipole-dipole typeinsteractions, enterstite accommodation and corealted using the following empirical equations. entational ordering.

(acetophenone + butylamine) and (acetophonone + diproplyamine) mixtures, while for (acetophenone + cyclohexylamine) and for (acetophenone + dibutylamine) mixture, the ΔK_s values are positive over the entire composition range at all the studied temperatures. The positive ΔK_s values in our present study may be attributed to the differences in Tamura and Kurata [16] proposed the one parameter relation for the viscocity of binary liquid mixtures.

$$\boldsymbol{\eta_{mix}) = x_1 \phi_1 \eta_{i+} x_2 \phi_{2\eta 2} + 2(x_1 x_2 \phi_1 \phi_2) 1/2.C}$$

Where C = $\eta_{12}, \phi_1 \phi_2$ are volume fractions

Heric [17] proposed a two – parameter relation

$$\boldsymbol{\ln(\eta_{mix}) = x_1 \ln\eta_1 + x_2 \ln\eta_2 + x_1 \ln M_1 + x_2 \ln M_2 - \ln(x_1 M_1 + x_2 M_2) + x_1 x_2 [y_{12} + y_{21}(x_1 - x_2)]} \quad \textbf{(9)}$$

Where y_{12} and y_{21} are the adjustable parameters, M_1 and M_2 are the molar masses of pure components.

McAllister [18] proposed a four-body equation which is a quadratic education having three interaction parameters. This model approaches more nearly a three dimensional treatment and the molecular diameter is greater than 1.5. The equitation of this model applied to kinematic viscosity as

$$\begin{aligned}\boldsymbol{\ln \nu_{mix}} &= \boldsymbol{x_1^4 \ln \nu_1 + 4x_1^3 x_2 \ln \nu_{1112} + 6x_1^2 x_2^2 \ln \nu_{1122}} \\ &+ \boldsymbol{4x_1 x_2^3 \ln \nu_{2221} + x_2^4 \ln \nu_2 - \ln[x_1 + (x_2 M_2/M_1)]} \\ &+ \boldsymbol{4x_1^3 x_2 \ln[\{3 + (M_2/M_1)\}/4]} \\ &+ \boldsymbol{6x_1^2 x_2^2 \ln[\{1 + (M_2/M_1)\}/2]} \\ &+ \boldsymbol{4x_1 x_2^3 \ln[\{1 + (3M_2/M_1)\}/4]} \\ &+ \boldsymbol{x_2^4 \ln(M_2/M_1)} \quad \textbf{(10)}\end{aligned}$$

Where ν_{mix}, ν_1, ν_2 are the kinematic viscosities.

The speeds of sound (u) data were correlated by using the following empirical equations.

Vandel–Vangeel [19] Proposed

$$u = [(x_1/M_1\, u_1^2 + x_2/M_2\, u_2^2 (x_1 M_1 + x_2 M_2)^{1/2} \quad \textbf{(11)}$$

Where u_1 and u_2 are the speeds of sound of pure components 1 and 2 respectively, M_1 and M_2 are the molecular weights of pure components

Jouyban –Acree [20] proposed the following relation

$$\begin{aligned}\boldsymbol{\ln u} &= \boldsymbol{x_1 \ln u_1 + x_2 \ln u_2 + A_0 [x_1 x_2/T]} \\ &+ \boldsymbol{A_1 [x_1 x_2 (x_1 - x_2)/T] + A_2 [x_1 x_2 (x_1 - x_2)^2/T]} \quad \textbf{(12)}\end{aligned}$$

Where A_0, A_1 and A_2 are the model constants

The predictive ability of eqs [8-12] was tested by calculating the standard percentage deviation (σ between the experimental and calculated property values as.

$$\boldsymbol{\sigma\% = [1/(n-k) \sum \{100(Y_{exp} - Y_{cal})/Y_{exp}\}^2]^{1/2}} \quad \textbf{(13)}$$

Where 'n' represents the number of data points in each set and 'K' the number of numerical coefficients. y is the concerned Property.

The values of coefficients obtained by eqs. (8-10) along with the value of $\sigma\%$ are included in Table 4. while the coefficients obtained by eqn (11-12) of speeds of sound are included in Table 5 along with the $\sigma\%$ values.

Esamanition of $\sigma\%$ values of Table 4 shows that for one parameter Tamura - Kurata equation the $\sigma\%$ values lie in the range of (0.01 – 0.14). Heric two-Parameter (0.01- 0.09) and McAllister (four-body) three parameter (0.00 – 0.01). These $\sigma\%$ values clearely indicate the McAllister models predicts very low values as compared to Tamura-Kurata and Heric modeles. From this it is apparent that as the number of parameter increases in a models equation the predictive abilitie of that equitation also increases.

The $\sigma(\sigma\%)$ values for speeds of sound in Table 5 indicate that for Vandel –Vangeel relation these values are in the range (0.004 – 0.557) and for Jouyban – Acree (0.001 – 0.014). The low $\sigma(\sigma\%)$ values Jouyban-Acree confirm once again our earlier arguments that Jouyban – Acree model with three paramenters provided the best results as compared to Vandeal-Vangel equation.

IV. CONCLUSION

Density (ρ), Viscositie (η) and Speeds of sound (u) properties were experimentally determined for binary mixtures of acetophenone with butyl amine, cyclohexylamine, dipropylamine, and dibutylamine at T = (303.15, 308.15, and 313.15) K over the entire range of composition. Excess molar volumes (V^E), deviation in viscosity (Δn), deviation in speed of sound, deviation in isentropic compressibility (ΔK_s) were evaluated from the experimental data. These excess properties were found to exhibit both positive and negative deviations. It in concluded that the magnitude of various contributions depends on the relative size and shapes of the components and also the existence of diploe -dipole interactions. From the analysis of $\sigma\sigma\%$ values as obtained for viscosities and speeds of sound data, it can be concluded that the model equation with more number of adjustable parameters has the best predicative ability as compared to the equation with no adjustable parameters.

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APPENDIX

Table: 1 Experimental and Literature values of densities (ρ), Viscosities (η) and Ultrasonic Speeds of sound (u) of pure liquids.

Component	Temp T/K	Density (ρ) g.cm^{-3}		Viscosity (η) m Pa.s		Ultrasonic Speeds of sound (u) m.s^{-1}	
		Expt.	Lit	Expt.	Lit	Expt.	Lit
Acetophenone [C_8H_8O]	303.15	1.0194	1.0199[1] 1.0194[26] 1.0205[27]	1.511	1.511 [27] 1.518[1]	1459	
	308.15	1.0164	1.01619[1] 1.0172[27]	1.378	1.378 [1]	1442	
	313.15	1.0134	1.0135[1] 1.0139[27]	1.291	1.291 [1]	1425	
Butylamine ($C_4H_{11}N$]	303.15	0.7322	0.7321[8] 0.7325[21]	0.501	0.501 [27]	1332	1228.9 [9]
	308.15	0.7223	07322[27]	0.431	0.4248 [10]	1316	1205.7[9]
	313.15	0.7130	0.7239[23 0.7241[10] 0.7246[27] 0.71917[22] 0.7229[8] 0.7232[21]	0.397	0.4249 [23]	1304	
Cyclohexylamine	303.15	0.8578	0.85767[11] 0.85782[27]	1.698		1424	
	308.15	0.8520	0.85314[11]	1.563		1408	
	313.15	0.8462	0.84861[11]	1.403		1393	
Dipropylamine ($C_6H_{15}N$)	303.15	0.7285	0.73019[25] 0.7281[27]	0.512		1293	
	308.15	0.7239	0.7233[27]	0.460		1277	
	313.15	0.7188	0.7185[27]	0.434		1261	
Dibutylamine [$C_8H_{19}N$]	303.15	0.7535	0.75228 [9] 0.7535 [27]	0.838	0.830[27]	1220	1226.7[9] 1227[24]
	308.15	0.7490	0.74817[9] 0.7493 [27]	0.812		1204	1206.9[9] 1206[24]
	313.15	0.7448	0.7451 [27]	0.760		1189	

Table 2 Densities (ρ) Excess molar volumes (V^E), Viscosities (η) Speeds of sound (u) and isentropic compressibility (Ks) for the binary mixtures at different temperatures.

x_1	(ρ) (gcm^{-3})	V^E $cm^3\ mol^{-1}$	η mPa.S	u $m.s^{-1}$	Ks Tpa^{-1}
Acetophenone + Butyl amine					
T = 303.15K					
0.1001	0.7672	-0.222	0.506	1335	731.4
0.1813	0.7943	-0.338	0.529	1339	702.2
0.2629	0.8205	-0.412	0.565	1345	673.7
0.3443	0.8457	-0.455	0.617	1352	646.9
0.4259	0.8700	-0.463	0.677	1361	620.5
0.5073	0.8934	-0.447	0.758	1371	595.5
0.5889	0.9160	-0.405	0.850	1383	570.8
0.6701	0.9378	-0.352	0.954	1396	547.2
0.7517	0.9589	-0.274	1.068	1410	524.6
T= 308.15K					
0.1001	0.7579	-0.244	0.447	1318	759.6
0.1813	0.7855	-0.370	0.470	1321	729.5
0.2629	0.8123	-0.461	0.507	1326	700.2
0.3443	0.8378	-0.477	0.552	1333	671.7
0.4259	0.8627	-0.491	0.609	1341	644.6
0.5073	0.8866	-0.466	0.686	1351	618.0
0.5889	0.9098	-0.422	0.769	1363	591.6
0.6701	0.9322	-0.367	0.864	1376	566.6
0.7517	0.9541	-0.306	0.974	1390	542.5
T= 313.15 K					
0.1001	0.7491	-0.261	0.419	1304	785.1
0.1813	0.7771	-0.391	0.441	1307	753.3
0.2629	0.8043	-0.479	0.477	1311	723.4
0.3443	0.8303	-0.500	0.521	1317	694.4
0.4259	0.8557	-0.515	0.577	1325	665.7
0.5073	0.8801	-0.486	0.647	1335	637.5
0.5889	0.9039	-0.448	0.724	1346	610.6
0.6701	0.9269	-0.395	0.818	1358	585.0
0.7517	0.9493	-0.322	0.919	1372	559.6
Acetophenone + cyclohexylamine					
T = 303.15K					
0.1001	0.8732	0.140	1.6987	1424	564.8
0.2113	0.8905	0.257	1.7019	1425	553.0
0.2970	0.9040	0.315	1.7046	1426	544.0
0.3985	0.9201	0.360	1.7036	1428	533.0
0.5004	0.9366	0.354	1.6901	1431	521.4
0.6056	0.9540	0.295	1.6605	1435	509.0
0.7015	0.9698	0.243	1.6301	1440	497.3
0.8010	0.9863	0.171	1.5905	1446	484.9
0.8958	1.0021	0.088	1.5497	1452	473.3
			T= 308.15K		
0.1001	0.8674	0.173	1.5579	1409	580.7
0.2113	0.8850	0.285	1.5589	1410	568.4
0.2970	0.8988	0.333	1.5598	1411	558.8
0.3985	0.9151	0.387	1.5544	1413	547.3
0.5004	0.9320	0.365	1.5387	1416	535.1
0.6056	0.9496	0.317	1.5142	1419	523.0
0.7015	0.9657	0.263	1.4813	1424	510.7
0.8010	0.9825	0.190	1.4432	1430	497.7
0.8958	0.9985	0.119	1.4083	1435	486.3
			T= 313.15 K		
0.1001	0.8617	0.192	1.4028	1394	597.2
0.2113	0.8794	0.328	1.4072	1395	584.3
0.297	0.8933	0.390	1.4103	1396	574.4
0.3985	0.9101	0.413	1.4076	1398	562.2
0.5004	0.9272	0.400	1.4002	1401	549.5
0.6056	0.9450	0.364	1.3806	1404	536.8
0.7015	0.9614	0.307	1.3592	1409	523.9
0.8010	0.9786	0.222	1.3353	1414	511.1
0.8958	0.9950	0.138	1.3108	1419	499.1
Acetophenone + dipropylamine					
T = 303.15K					
0.1011	0.7561	-0.408	0.5354	1299	783.8
0.2006	0.7830	-0.590	0.5796	1307	747.6
0.2991	0.8102	-0.715	0.6394	1317	711.6
0.3960	0.8375	-0.782	0.7146	1329	676.0
0.4993	0.8670	-0.766	0.8119	1344	638.5

0.5971	0.8955	-0.699	0.9207	1361	602.9
0.6956	0.9253	-0.655	1.0421	1380	567.5
0.7946	0.9555	-0.515	1.1740	1402	532.4
0.8981	0.9878	-0.329	1.3316	1429	495.8
T= 308.15K					
0.1011	0.7518	-0.457	0.4805	1283	808.1
0.2006	0.7788	-0.643	0.5180	1292	769.2
0.2991	0.8061	-0.767	0.5763	1302	731.8
0.3960	0.8334	-0.814	0.6446	1314	695.0
0.4993	0.8632	-0.820	0.7312	1329	655.9
0.5971	0.892	-0.770	0.8291	1346	618.8
0.6956	0.9217	-0.683	0.9386	1365	582.3
0.7946	0.9525	-0.589	1.0649	1387	545.7
0.8981	0.9850	-0.391	1.2100	1413	508.5
T= 313.15 K					
0.1011	0.7469	-0.484	0.4432	1268	832.7
0.2006	0.7741	-0.687	0.4792	1277	792.2
0.2991	0.8014	-0.789	0.5322	1288	752.2
0.3960	0.8290	-0.860	0.5984	1299	714.9
0.4993	0.8591	-0.879	0.6791	1314	674.2
0.5971	0.8881	-0.824	0.7686	1331	635.6
0.6956	0.9181	-0.742	0.8712	1350	597.6
0.7946	0.9490	-0.621	0.9920	1371	560.6
0.8981	0.9820	-0.440	1.1317	1397	521.8
Acetophenone + dibutylamine					
T = 303.15K					
0.1034	0.7743	-0.273	0.8803	1224	862.0
0.2004	0.7950	-0.492	0.9242	1228	834.1
0.2968	0.8164	-0.594	0.9717	1232	807.0
0.4016	0.8412	-0.673	1.0281	1236	778.2
0.4968	0.8651	-0.690	1.0850	1250	739.8
0.5974	0.8917	-0.619	1.1526	1276	688.8
0.6958	0.9195	-0.510	1.2278	1308	635.7
0.7988	0.9510	-0.395	1.3145	1350	577.0
0.8968	0.9831	-0.231	1.4050	1400	519.0
T= 308.15K					
0.1034	0.7702	-0.351	0.8410	1206	892.7
0.2004	0.7910	-0.575	0.8706	1208	866.3
0.2968	0.8125	-0.678	0.9048	1212	837.9
0.4016	0.8374	-0.752	0.9507	1217	806.3
0.4968	0.8615	-0.779	0.9967	1230	767.2
0.5974	0.8888	-0.788	1.0533	1254	715.5
0.6958	0.9168	-0.671	1.1203	1284	661.6
0.7988	0.9484	-0.529	1.1959	1329	597.0
0.8968	0.9807	-0.348	1.2791	1378	537.0
T= 313.15 K					
0.1034	0.7663	-0.412	0.7814	1189	923.1
0.2004	0.7872	-0.646	0.8077	1190	897.1
0.2968	0.8088	-0.754	0.8385	1192	870.2
0.4016	0.8339	-0.845	0.8789	1195	839.8
0.4968	0.8582	-0.886	0.9192	1204	803.8
0.5974	0.8853	-0.838	0.9672	1225	752.7
0.6958	0.9139	-0.785	1.0258	1254	695.8
0.7988	0.9458	-0.651	1.0981	1300	625.6
0.8968	0.9783	-0.459	1.1819	1350	560.9

Table: 3 Coefficients Ai of equation (σ) and corresponding Standard deviations (σ)

Binary mixture	T/K	Excess property	A_o	A_1	A_2	A_3	σ
Acetophenone+ butylamine	303.15	V^E (cm^3. mol^{-1})	-1.7961	0.6346	-0.0758	0.1992	0.137
		$\Delta\eta$(mPa.s)	-1.0202	0.0288	-0.0549	-0.0440	0.057
		Δu($m.s^{-1}$)	-101.11	13.358	5.337	-0.9512	5.819
		ΔKs (TPa^{-1})	-7.0957	0.4938	-0.8363	0.5043	0.373
	308.15	V^E (cm^3. mol^{-1})	-1.8673	0.7912	-0.5222	-0.2572	0.139
		$\Delta\eta$(mPa.s)	-0.9109	0.0034	0.0319	-0.0351	0.053
		Δu($m.s^{-1}$)	-114.90	11.879	0.2192	-11.643	6.516
		ΔKs (TPa^{-1})	-6.4625	0.3645	-0.7650	1.2870	0.330
	313.15	V^E (cm^3. mol^{-1})	-1.9653	0.7395	-0.5440	-0.0119	0.142
		$\Delta\eta$(mPa.s)	-0.8191	0.0079	0.0687	-0.0360	0.048
		Δu($m.s^{-1}$)	-122.52	8.8152	-13.478	-13.805	6.741
		ΔKs (TPa^{-1})	-6.0755	0.4213	0.4105	1.3362	0.333
Acetophenone+ cyclohexylamine	303.15	V^E (cm^3. mol^{-1})	1.3891	-0.5116	-0.2446	0.2579	0.176
		$\Delta\eta$(mPa.s)	0.3371	-0.0059	-0.0212	0.0121	0.035
		Δu($m.s^{-1}$)	-42.192	-2.3372	9.5266	7.0601	4.051
		ΔKs (TPa^{-1})	1.4246	-0.2815	-0.7848	-0.3200	0.193
	308.15	V^E (cm^3. mol^{-1})	1.4474	-0.5257	0.0966	0.2294	0.177
		$\Delta\eta$(mPa.s)	0.2751	-0.0210	-0.2253	-0.0081	0.033
		Δu($m.s^{-1}$)	-37.415	-5.2161	11.5124	2.1885	3.200
		ΔKs (TPa^{-1})	1.1270	-0.0362	-0.8546	0.0107	0.128
	313.15	V^E (cm^3. mol^{-1})	1.6102	-0.5219	0.2752	0.1464	0.192
		$\Delta\eta$(mPa.s)	0.2065	-0.0329	-0.1601	0.0199	0.025
		Δu($m.s^{-1}$)	-33.221	-1.3601	11.5968	-0.0355	3.121
		ΔKs (TPa^{-1})	0.9153	-0.309	-0.7813	0.1575	0.130
Acetophenone + dipropylamine	303.15	V^E (cm^3. mol^{-1})	-3.0315	0.5084	-1.3487	-0.0569	0.359
		$\Delta\eta$(mPa.s)	-0.7898	0.0577	-0.0873	-0.0955	0.089
		Δu($m.s^{-1}$)	-127.127	-14.945	-7.5818	-2.2032	0.173
		ΔKs (TPa^{-1})	-1.0921	-0.7436	-0.2802	0.2079	0.016
	308.15	V^E (cm^3. mol^{-1})	-3.2048	0.4718	-1.9301	-0.1306	0.351
		$\Delta\eta$(mPa.s)	-0.7437	0.009	-0.0868	-0.0173	0.083
		Δu($m.s^{-1}$)	-120.747	-13.600	-4.1402	3.6372	0.235
		ΔKs (TPa^{-1})	-1.8452	-0.6703	-0.7607	-0.3970	0.019
	313.15	V^E (cm^3. mol^{-1})	-3.4010	0.3602	-2.1249	-0.0378	0.361
		$\Delta\eta$(mPa.s)	-0.7149	-0.0196	-0.0894	0.0396	0.079
		Δu($m.s^{-1}$)	-114.194	-15.700	0.9134	3.8240	0.443
		ΔKs (TPa^{-1})	-2.7002	-0.3232	-1.4520	-0.1815	0.041
Acetophenone + dibutylamine	303.15	V^E (cm^3. mol^{-1})	-2.6901	0.6505	-0.0477	-0.5247	0.351
		$\Delta\eta$(mPa.s)	-0.3469	-0.0658	0.0093	0.0012	0.034
		Δu($m.s^{-1}$)	-349.722	-101.19	98.58	-0.6959	34.426
		ΔKs (TPa^{-1})	24.157	-1.6817	-16.162	3.0452	3.383
	308.15	V^E (cm^3. mol^{-1})	-3.1243	0.0046	-0.0908	0.2543	0.336
		$\Delta\eta$(mPa.s)	-0.3865	-0.0634	0.0159	-0.0137	0.038
		Δuu($m.s^{-1}$)	-365.975	-119.86	64.83	10.791	33.821
		ΔKs (TPa^{-1})	26.962	-0.7055	-14.296	0.8148	3.622
	313.15	V^E (cm^3. mol^{-1})	-3.4452	0.0388	-1.7623	-0.4665	0.318
		$\Delta\eta$(mPa.s)	-0.4213	-0.1532	-0.0862	0.0316	0.033
		Δu($m.s^{-1}$)	-404.025	-174.95	27.78	5.6772	33.092
		ΔKs (TPa^{-1})	33.036	4.899	-14.449	-2.4105	3.908

Table: 4 Value of the fitting Parameters and PercentageSstandard Deviations (σ%) of the Viscoity Models for Binary Mixtures.

Binary Mixuture	T/K	Tamura-Karata		Heric			McAllister (4-body)			
		η_1	σ	Y_{12}	Y_{21}	σ%	V_{1112}	V_{1122}	V_{2221}	σ%
Acetophenone +	303.15	0.4546	0.67	-0.4893	0.5163	0.06	0.1137	-0.1611	-0.5345	0.02
Butylamine	308.15	0.4162	0.12	-0.4061	0.4417	0.03	0.0485	-0.2948	-0.5975	0.03
	313.15	0.4053	0.14	-0.3323	0.3918	0.03	0.0117	-0.3681	-0.6183	0.03
Acetophenone+	303.15	1.7585	0.04	0.2123	0.0072	0.04	0.4880	0.6500	0.6303	0.01
Cyclohexylamine	308.15	1.5926	0.05	0.1891	-0.0079	0.05	0.3887	0.5681	0.5439	0.00
	313.15	1.440	0.04	0.1560	-0.016	0.04	0.3136	0.4635	0.4543	0.01
Acetophenone	303.15	0.6548	0.12	-0.326	0.344	0.07	0.1582	-0.0217	-0.3877	0.02
+Dipropylamine	308.15	0.5818	0.11	-0.347	0.340	0.08	0.0545	-0.1151	-0.4955	0.02
	313.15	0.5332	0.10	-0.364	0.341	0.09	-0.0193	-0.1797	-0.5733	0.02
Acetophenone +	303.15	1.0833	0.01	-0.131	-0.0035	0.01	0.3062	0.2134	0.1611	0.01
Dibutylamine	308.15	0.9734	0.01	-0.224	0.0067	0.01	0.2112	0.1246	0.0928	0.01
	313.15	0.8736	0.05	-0.300	-0.053	0.02	0.0959	0.0697	0.0103	0.01

Table|5 Values of the fitting parameters and Percentage Standard Deviations (σ%) for the Uultrasonic Speeds of Sound (u) for Binary Mixtures

Binary mixture	T/K	Vandel-Vangeel	Jouyban-Acree			
		σ%	A_0	A_1	A_2	σ%
Acetophenone +	303.15	0.215	-20.897	3.835	1.324	0.001
Butylamine	308.15	0.193	-24.767	3.305	0.941	0.002
	313.15	0.173	-27.253	2.643	-2.031	0.002
Acetophenone +	303.15	0.009	-8.830	0.145	2.159	0.001
Cyclohexylamine	308.15	0.005	-7.999	-0.964	2.354	0.003
	313.15	0.004	-7.305	-0.195	2.610	0.002
Acetophenone +	303.15	0.071	-25.114	-1.962	-1.241	0.008
Dipropylamine	308.15	0.063	-24.009	-2.869	2.064	0.015
	313.15	0.054	-23.101	-2.224	5.489	0.018
Acetophenone +	303.15	0.437	-76.962	-17.508	27.353	0.013
Dibutylamine	308.15	0.476	-83.323	-21.132	20.626	0.009
	313.15	0.557	-95.637	-35.021	14.046	0.014

Graphical representation for variation of V^E, $\Delta\eta$, Δu and ΔK_S with mole fraction of Acetophenone

Butylamine (□) at 303.15K : (◊) at 308.15K : (Δ) at 313.15K
Cyclohexylamine (x) at 303.15K : (*) at 308.15K : (—) at 313.15K
Dipropylamine (●) at 303.15K : (+) at 308.15K : (■) at 313.15 K
Dibutylamine (♦) at 303.15K : (▲) at 308.15K : (o) at 313.15K

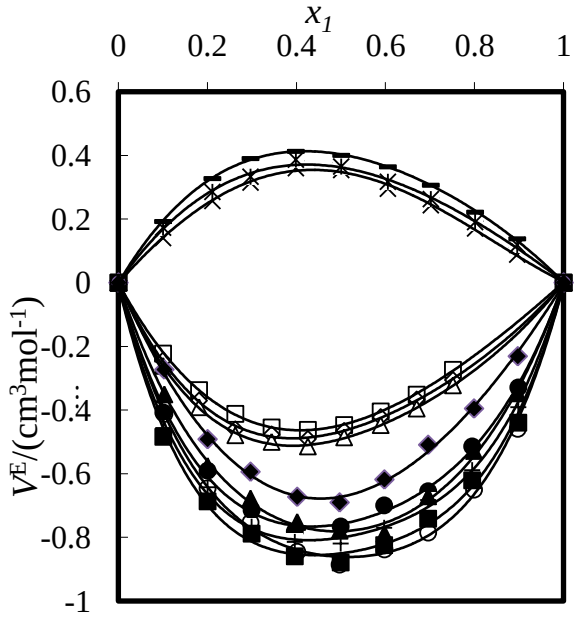


Fig 1

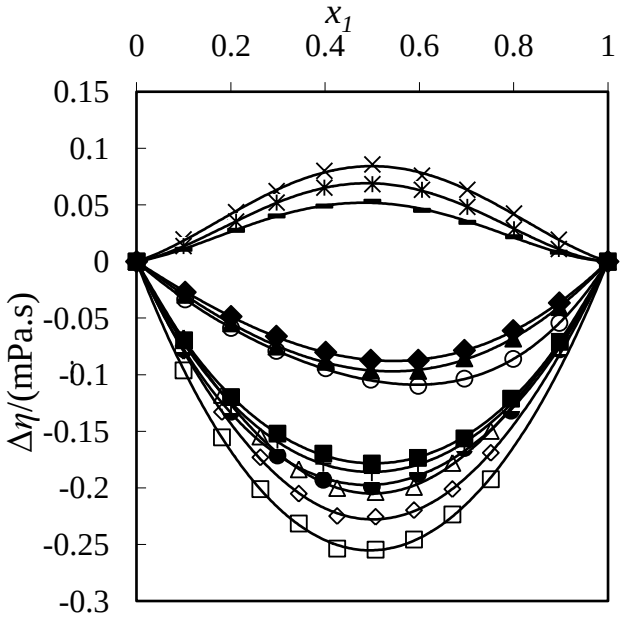


Fig 2

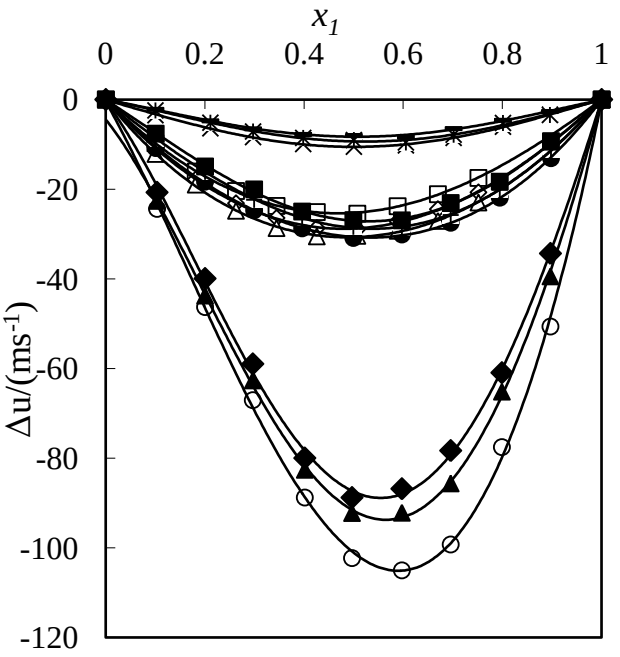
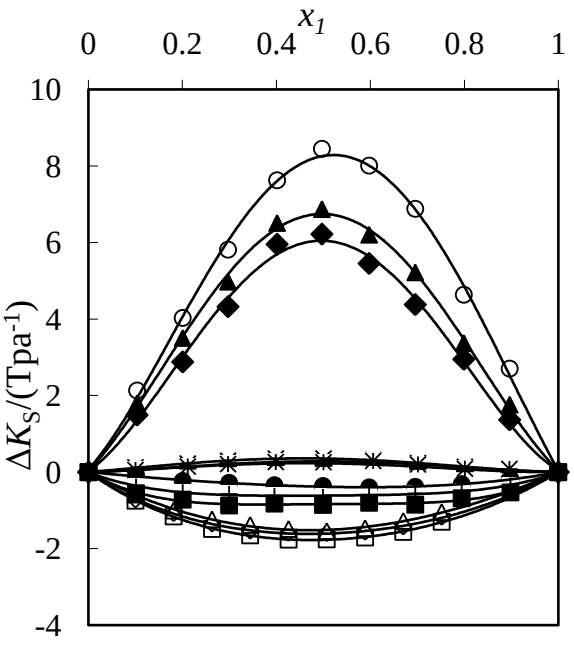

x_1
0
0.2
0.4
0.6
0.8
1
0
-20
-40
-60
-80
-100
-120
$\Delta u/(ms^{-1})$

Fig 3


x_1
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0.2
0.4
0.6
0.8
1
10
8
6
4
2
0
-2
-4
$\Delta K_S/(Tpa^{-1})$

Fig 4