Study of Non-Linearity Thermo Acoustic Parameters in Binary Mixtures of Methyl Iso-Butyl Ketone(MIBK) With Apolar Diluents .

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Abstract:

The ultrasonic velocity(u) and density (ρ) has been measured in the binary mixtures of MIBK with apolar diluents such as carbon tetrachloride and benzene at 303K , 308K, 313K and 318K.The data is used to compute the thermoacoustic parameters viz., isentropic compressibility(β_S) , isothermal compressibility(β_T), Grüneisen parameters (Γ' and $\overline{\Gamma}$) , Beyer's non-linearity parameter (B/A) , intermolecular free length (L_f) and thermoacoustic impedance (Z) by using the standard relations . The magnitude as well as trend of deviations of such parameters shows the existence of dipole-induced dipole and solute-solvent type of interaction among the component molecules with the degree of molecular interaction being maximum in carbon tetrachloride medium.

Keywords:
MIBK , ultrasonic velocity, density , B/A parameter , isothermal compressibility, isentropic compressibility , Grüneisen parameters , acoustic impedance , intermolecular free length , dipole-induced dipole , solute-solvent interaction .

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1. Introduction

The non-linear behavior of the ultrasonic velocity is characterised by Beyer's non-linearity parameter(*B/A*) that can be derived from the knowledge of compressibility , thermal expansion coefficient and heat capacity of the liquid system. Furthermore, it is the ratio of the coefficients of the quadratic to linear terms of a Taylor series led to an equation of state of the medium in terms of pressure and density and can provide information about the process of molecular association and complex formation. Though evaluation of such non-linear parameter in pure organic liquids using thermodynamic method have been reported by several workers [1,2] and such studies are sparse in case of liquid mixtures involving nuclear extractants. Methyl iso-butyl ketone(MIBK) is one of the extratant used for extraction of uranium and protactinium-233 from hydrochloric acid solutions containing neutron–irradiated thorium nitrate at a neutron flux of 10^{12} $ncm^{-2}s^{-1}$[3]. Furthermore, MIBK is also used as solvent for extraction of niobium (Nb) , hafnium(Hf) and zirconium (Zr) [3]. It is used with polar and non-polar diluents to achieve greater separation efficacy and more rapid phase disengagement . As such the level of molecular interaction between MIBK and its apolar diluents play a major role in selecting an effective diluent for solvent extraction process. In our earlier investigation[4] we have studied the non-linear thermoacoustic properties in binary mixture of the nuclear extractant acetyl acetone(HAA) , in polar medium through ultrasonic route . As such in the present report, we extend our ongoing investigation for another extractant MIBK in two apolar diluents such as benzene and CCl_4 . We have studied the Beyer's parameter (*B/A*) , isentropic compressibility(β_S) , isothermal compressibility(β_T), Grüneisen parameters(Γ' and $\bar{\Gamma}$), intermolecular free length (L_f), thermoacoustic impedance (*Z*) and Sharma constant(S_o) from the measurement of ultrasonic velocity (*u*) and density (ρ) in the binary mixture involving MIBK in benzene and CCl_4 medium separately at four different temperatures and constant atmospheric pressure.

2. Experimental

Methyl isobutyl ketone (MIBK), benzene and carbon tetrachloride used were of AR grade and were purified by standard procedures[5].The purity of the sample was checked by comparing the measured densities as reported in the literature[6]. The binary mixtures of apolar diluents involving MIBK were prepared by weight using a digital top loading balance (Simadzu BL-220) with a precision of ± 0.001g. Densities were measured by calibrated pycnometer of 25 ml capacity . The accuracy of measurement of density (ρ) of pure liquids and binary mixtures was found to be ± 0.0001 gcm^{-3} . The ultrasonic velocity(u) was measured by a single crystal variable path ultrasonic interferometer at 3 MHz with an accuracy of ± 0.5 ms^{-1} . The temperature of the sample was maintained with an accuracy of ± 0.1K in an electronically controlled thermostatic water bath in all measurements.

3. Theory

3.1 *Compressibility*

Isentropic compressibility β_S , is given by the relation [7]:

$$\beta_S = \frac{1}{u^2 \rho} \tag{1}$$

Isothermal compressibility β_T , obtained from Flory's relation [7] is given by

$$\beta_T = \beta_S + \frac{\alpha^2 T \overline{M}}{c_P \rho} \tag{2}$$

where, $\alpha = -\frac{1}{\rho}\frac{d\rho}{dT}$, $c_p = \frac{4}{3}\tilde{v}^{1/3} - 1$, T and $\overline{M}$ are the volume expansivity , the heat capacity at constant pressure ,the temperature and average molecular mass of the liquid mixture respectively with $\tilde{v} = \left[1 + \frac{\alpha T}{3(1+\alpha T)}\right]^3$ as reduced molar volume.

3.2 *Grüneisen parameters*

The macroscopic Grüneisen parameter $(\overline{\Gamma})$ is given by [8]

$$\overline{\Gamma} = \frac{\gamma - 1}{\alpha T} \tag{3}$$

where, $\gamma = \frac{c_p}{c_v}$ is the ratio of two specific heats.

Microscopic isothermal Grüneisen parameter [8] is given by

$$\Gamma' = \frac{2}{3}(\alpha T) + \left[2 - F + \frac{9}{2}(\alpha T)(2\alpha T)^{-1} \right] \tag{4}$$

where,

$$F = 2 - S^* + \frac{S_o(S_o^* - 1)}{\alpha T} \tag{5}$$

is the Huggin's parameter , with

$$S_0 = \frac{(1 + 2\alpha t)(3 + 4\alpha T)}{\tilde{\beta}} \tag{6}$$

,

$$S^* = 1 + \tfrac{4}{3}\alpha T \tag{7}$$

and

$$S_0^* = \frac{1 + 2\alpha T}{S^*} \tag{8}$$

with Sharma constant, $(\tilde{\beta} = \tilde{V}^{C_1})$

3.3 *Intermolecular free length*

The intermolecular free length L_f , is related with β_S by the relation[9]

$$L_f = k\beta_S^{1/2} \tag{9}$$

where $k = (93.875 + 0.375\ T) \times 10^{-8}$ is the Jacobson temperature dependent constant .

3.4 *Acoustic impedance*

The acoustic impedance depends upon density and ultrasonic velocity as [10]

$$Z = \rho u \tag{10}$$

3.5 *Beyer's non-linearity parameter*

The Beyer's non-linearity parameter (*B/A*) is a particular combination of the temperature and pressure derivatives of the sound velocity [11] and is given by

$$\frac{B}{A} = 2\rho u\left(\frac{\partial u}{\partial P}\right) + \frac{2u\alpha T}{c_p}\left(\frac{\partial u}{\partial T}\right) \tag{11}$$

which can be written as

$$\frac{B}{A} = 2K' + \frac{(\gamma - 1)^2}{\alpha T} \tag{12}$$

where (K') is the isothermal acoustic parameter related with isobaric acoustic parameter (K) and isochoric acoustic parameter (K'') [12] as

$$K' = K + K'' \tag{13}$$

The parameters such as K and K'' are obtained from the relations [13,14]

$$K = \frac{1}{2}\left[1 + \frac{S^*(1 + \alpha T)}{\tilde{V}^{C_1}}\right] \tag{14}$$

$$K'' = -\frac{[(2\alpha T)^{-1} - \tilde{V}^{C_1} + 1]}{\tilde{V}^{C_1}} \tag{15}$$

where , $C_1 = \frac{13}{3} + \frac{1}{\alpha T} + \frac{4}{3}\alpha T$ is Molelwyn-Hughes parameter[15] .

3.6 *Deviation in Thermodynamic Properties*

The deviation in isentropic compressibility, isothermal compressibility, Beyer's non-linearity parameter, intermolecular free length and acoustic impedance parameter can be calculated by using the equation

$$\Delta Y = Y_m - (x_1 Y_1 + x_2 Y_2) \quad (16)$$

where, Y_1 , Y_2 and Y_m represent the computed thermoacoustic parameter of MIBK , apolar diluent and binary mixture respectively x_1 and x_2 are the molefractions of MIBK and diluent respectively .

The values of $\Delta\beta_S$, $\Delta\beta_T$, $\Delta(B/A)$, ΔL_f and ΔZ have been fitted to the Redlich-Kister type[16] polynomial equation

$$\Delta Y = x_1 (1 - x_1) \sum_{i=1}^{4} A_i (1 - 2x_1)^{i-1} \quad (17)$$

The values of coefficients A_i and corresponding standard deviations σ are computed using the relation[17]

$$\sigma = \left[\sum (\Delta Y_{expt} - \Delta Y_{cal})^2 / (m - n)\right]^{1/2} \quad (18)$$

where m is the number of experimental data points and n is the number of coefficients considered (n =4 in the present computation) (enlisted in Tables 5-6)has been obtained from Equation (17) using the best–fit values of A_i .

4. Results and Discussion

The ultrasonic velocity (u) and density (ρ)for binary mixtures of MIBK with benzene and carbon tetrachloride were measured at four temperatures *viz*. 303.15K , 308.15K , 313.15K and 318.15K . The experimental data is used for calculation of thermoacoustic non linearity parameters such as isentropic compressibility (β_S), isothermal compressibility(β_T), intermolecular free length (L_f) , acoustic impedance (Z) , microscopic isothermal Grüneisen parameter (Γ') macroscopic Grüneisen parameter ($\bar{\Gamma}$)

and Beyer's parameter (B/A) for the entire range of composition of MIBK in all the binary mixtures. Furthermore , the deviation parameters viz., $\Delta\beta_S$, $\Delta\beta_T$, ΔL_f , ΔZ and $\Delta(B/A)$ were computed for all these mixtures by using Equation (16). Some of the relevant data is presented in Table 1-6 and displayed graphically in Figures (1-10). A close perusal of Table(1-4) , shows that in both the binary mixtures involving MIBK, the values of ultrasonic velocities decreases non-linearly with increase in temperature and molefraction of MIBK. The pronounced non linear increase or decrease in the experimentally measured values of ultrasonic velocity with molefraction of MIBK indicates the presence of molecular interactions between the components of molecules in the binary mixtures .Same trend also marked for the density of liquid mixture. At a fixed temperature it is observed (Table 1-6) that values of B/A increases non-linearily with increase in molefraction of MIBK in both the mixtures . The B/A values for liquids has been interpreted as the quantity representing the magnitude of hardness of the liquid[20] which can be considered for all liquid mixtures .The increasing trend of B/A value indicates the decrease in the degree of hardness in the system[21]. As MIBK is added with benzene and CCl_4 , the density and ultrasonic velocity decreases which leads to the increase in the value of *B/A* parameter.

However, in the present investigation (Figures1-10)the molecular interaction becomes weak with increase in temperature may be due to thermal agitation of component molecules which is indicated by the decreasing trend in ultrasonic velocity. The values of β_S , β_T and L_f increases while Z decreases non linearly with increase in molefraction of MIBK and temperature in all the mixtures . On the basis of the model on sound propagation in liquid mixture as proposed by Eyring and Kincaid[18] , the increase in intermolecular free length L_f , results in decrease of ultrasonic velocity and vice-versa . Our findings are also in agreement with the above model for both the binary mixtures and are in conformity with general trend of sound speed variation in several liquid mixtures [19].Furthermore, the increasing trend of β_S , β_T and L_f and decreasing trend of Z

values may be due to loose packing through structural arrangement of component molecules[22].

From the close observations of Figures 1-6 , it is evident that the deviation parameters $\Delta\beta_S$, $\Delta\beta_T$ and ΔL_f for MIBK + benzene mixture are positive, while it is negative for MIBK + carbon tetrachloride mixture. The value of $\Delta\beta_S$ and $\Delta\beta_T$ increases with the increase in the molefraction of MIBK and shows positive maxima in benzene and a negative maxima in CCl_4 at nearly equimolar concentration region in both the mixtures for all the temperatures. According to Fort and Moore [23] the deviation in isentropic compressibility becomes increasingly negative with increasing strength of interaction in the polar-apolar binary mixture. The negative values of $\Delta\beta_S$, $\Delta\beta_T$ and ΔL_f for MIBK + carbon tetrachloride system indicates stronger dipole-induced dipole type of molecular interaction between MIBK and highly polarizable carbon tetrachloride molecules. Furthermore , at mid concentration range of CCl_4 , $O^{\delta-}$ of carbonyl group of MIBK could possibly interact with $Cl^{\delta-}$ of carbon tetrachloride due to difference in their elecronegativity values. It is attributed by the positive values of ΔZ (Figures 8) , in the entire range of composition in CCl_4 mixture. However , the magnitude of $\Delta\beta_S$, $\Delta\beta_T$, ΔL_f in CCl_4 medium decreases with rise in temperature may be due to reduction in close packing between unlike molecules. MIBK is an equilibrium mixture of two tautomers ,the keto and enol form , and there is a possibility of self-association in the pure MIBK molecules through head-tail arrangement [24]. Besides dipole-dipole type of interaction among the like molecules of MIBK , the dipole-induced dipole type of interaction between unlike molecules also plays a significant role in deciding the extent of interaction in these binary mixtures . In MIBK + benzene mixture , the π-electron cloud of benzene ring likely to interact with $O^{\delta-}$ of carbonyl group of MIBK results in positive values of $\Delta\beta_S$, $\Delta\beta_T$, ΔL_f and negative value of ΔZ . At very low MIBK concentration few MIBK molecules are enclosed by predominantly benzene surrounding where the dipolar interactions of MIBK molecules likely to be weakened may be due to solute-solvent interaction.

At MIBK rich region the dipolar interaction among the like molecules might be reinforced by the head-tail arrangement of MIBK results in lower magnitudes of *B/A* parameter. But it is likely that for MIBK concentration tending to zero , the nearly spherical CCl_4 molecules completely fill in the voids of MIBK structure , thereby isolating MIBK molecules result in negligible interaction. The plot of $\Delta(B/A)$ versus molefraction of MIBK in both the binary mixtures is shown in the Figures 5-6. It is observed that $\Delta(B/A)$ values are all negative in both the binary mixtures and shows minima at about 0.5 molefraction of MIBK. However, its magnitude is higher in CCl_4 than benzene , may be due to stronger dipole-induced dipole type molecular interaction as well as the solute–solvent interaction through interstial accommodation between MIBK and CCl_4 molecules. Furthermore , it is observed that the magnitude of $\Delta(B/A)$ values in CCl_4 medium increases with decrease in temperature of the mixture. It is corroborated by the increasing magnitude of $\Delta\beta_S$, $\Delta\beta_T$ and ΔL_f may be due to increasing order of degree of hardness through stronger molecular interaction between MIBK and CCl_4 molecules.

The calculated values of Γ' and $\bar{\Gamma}$ for above liquid mixtures at various temperature are shown in Table 1-4 . It is observed that the value of $\bar{\Gamma}$ lies between 0.5 to 1 whereas Γ' is around 4 for both the liquid mixtures. These values decreases with rise in temperature. The difference between Γ' and $\bar{\Gamma}$ reveals that the isochoric temperature derivative of compressibility and specific heat ratio are the dominating factors that influence the thermo-acoustic non linear properties of quasi-spherical molecular liquids[25]. Such studies may be useful for explaining the non-linearity effects in sound propagation data and anharmonic effects in structural studies with regard to molecular order and interaction. Our findings betokens that in both the liquid mixtures $\Gamma' > \bar{\Gamma}$ and attributes similar behavior as observed by many workers [26 , 27] .

5. Conclusion

From the measured values of density and ultrasonic velocity the thermoacoustic parameters such as β_S, β_T, B/A, L_f and Z were computed in binary mixtures of benzene and CCl_4 separately involving MIBK at four temperatures .The trend of variation of these parameters shows that the molecular interaction among the MIBK molecules is decreased due to solvent effect in both the mixtures. However , the negative deviation in isentropic compressibility $\Delta\beta_S$, isothermal compressibility $\Delta\beta_T$, intermolecular free length ΔL_f and Beyer's non-linearity parameter $\Delta(B/A)$ indicates the molecular interaction between heterogeneous molecules is stronger in CCl_4 medium at about equimolar concentration range of MIBK probably due to dipole-induced dipole as well as solute-solvent interactions. Furthermore, the negative magnitude of $\Delta(B/A)$, $\Delta\beta_S$, $\Delta\beta_T$, ΔL_f in CCl_4 mixture is found to increase with decrease in temperature may be due to increasing order of hardness . The microscopic Grüneisen parameter Γ' , is observed to be higher than the macroscopic Grüneisen parameter $\bar{\Gamma}$ in both the mixtures. As such CCl_4 may be used as an effective diluents in MIBK medium in solvent extraction process.

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References

[1] B .K. Sharma and R. R. Reddy , Pramana **28 ,** 197 (1987).

[2] A . J . Clement Lourduraj and I . Johnson , *Proceedings of National Symposium on Acoustic , Jhansi , Indian Shree Publishers and Distributers* , New Delhi 51 (2011).

[3] A .K. Dey, S. M. Khopkar & R .A. Chalmers, *Solvent extraction of metals* (Van Nostrand-Reinhold , London) 1970.

[4] P.R.Dash , S. K. Dash, L Moharana, M. D. Swain and B.B.Swain, Orissa Journal of Phy.**19**, 147 (2011).

[5] A .Weisberger ,*Techniques of organic chemistry, organic solvents* (Interscience Publishers, New York) **7** (1959) **.**

[6] *Hand Book of Chemistry and Physics* (*CRC Press*) ,60th ed.CRC Press Inc.Ohio (1979-80).

[7] R.K .Shukla, A. Kumar , K. Srivastava and S. Yadav , *Indian J. of pure and Applied Physics* **45**, 726(2007).

[8] B. K. Sharma,*Acustica* **77,** 74 (1992).

[9] A. N .Kannapan , V. Rajendra, *Indian J. pure and Applied Phy*. **3**, 240 (1992).

[10] R. Thiyagarajan and L. Palaniappan , *Indian J. pure and Applied Phy*. **46**, 852 (2008).

[11] P.Kuchhal, R. Kumar & N .Dass , Pramana **52** , 321 (1999) .

[12] B. K. Sharma, *Pramana* **20**, 91 (1983).

[13] E. H. Carnevale and T.A. Litovitz , J.Acoust. soc. Am. **27**, 547(1955).

[14] M. R. Rao, J .Chem. Phys. **9** , 682 (1941).

[15] B. K. Sharma , J. Phys. D**15** , 1273 , 1735 (1982) and **16** , 1959 (1983).

[16] O. Redlich and A . T. Kister , *Ind. Eng. Chem.* **40**, 345(1948).

[17] S.K.Dash, S. K.Pradhan , B . Dalai , L . Moharana and B.B.Swain , Phys. Chem.Liq. **50**, 735(2012).

[18] H .Eyring and J. F. Kincaid, J Chem. Phys. **6**, 620(1938).

[19] K . Rajgopal and S . Chenthilnath, J . Mol. Liq. **160**, 72(2011).

[20] H . Enda , J. Acoust. Soc. Am. **83** , 2043(1988).

[21] M . Rastogi , A . Awasthi and J . P. Shukla , Phys. Chem. Liq. **42**, 117 (2004).

[22] A . Ali, A. K . Nain, N. Kumar and M. Ibrahim , Chin . J . Chem. **21** , 253(2003).

[23] R. J.Fort and W. H. Moore: *Trans. Faraday soc.* **61** , 2102 (1965).

[24] J . K . Dash , S K. Dash , N . Swain and B . B. Swain , J. Mol. Liq. **81** , 163 (1999).

[25] E. Soczkiewilc , Acustica **39**, 189 (1978).

[26] A . B . Coppens , R. T. Beyer , M. B. Seiden , J . Donohue , F . Guepin , R . H. Hodson and C. J . Townsend , J . Acoust .Soc. Am. **38** , 79(1956).

[27] B . K. Sharma , Acustica **67** , 52 (1988).

Figure caption:

Fig.1 Variation of deviation of isentropic compressibility $\Delta\beta_S$ with molefraction x_1 of Methyl iso-butyl ketone(MIBK) in benzene.

Fig.2 . Variation of deviation of isentropic compressibility $\Delta\beta_S$ with molefraction x_1 of Methyl iso-butyl ketone(MIBK) in carbon tetrachloride .

Fig.3 Variation of deviation of isothermal compressibility $\Delta\beta_T$ with molefraction x_1 of Methyl iso-butyl ketone(MIBK) in benzene.

Fig.4 Variation of deviation of isothermal compressibility $\Delta\beta_T$ with molefraction x_1 of Methyl iso-butyl ketone(MIBK) in carbon tetrachloride.

Fig.5 Variation of deviation of intermolecular free length ΔL_f with molefraction x_1 of Methyl iso-butyl ketone(MIBK) in benzene.

Fig.6 Variation of deviation of intermolecular free length ΔL_f with molefraction x_1 of Methyl iso-butyl ketone(MIBK) in carbon tetrachloride.

Fig.7 Variation of deviation of Beyer's nonlinearity parameter $\Delta(B/A)$ with molefraction x_1 of Methyl iso-butyl ketone(MIBK) in benzene.

Fig.8 Variation of deviation of Beyer's nonlinearity parameter $\Delta(B/A)$ with molefraction x_1 of Methyl iso-butyl ketone(MIBK) in carbon tetrachloride.

Fig.9 Variation of deviation of acoustic impedance ΔZ with molefraction x_1 of Methyl iso-butyl ketone(MIBK) in benzene.

Fig.10 Variation of deviation of acoustic impedance ΔZ with molefraction x_1 of Methyl iso-butyl ketone(MIBK) in carbon tetrachloride.

Table 1 : Variation of ρ, u, L_f, Z ,, β_s, β_T, C_p, Γ', $\bar{\Gamma}$ and B/A in the binary mixtures of MIBK with benzene and CCl_4 at 303.15K.

x_1	ρ kgm^{-3}	u ms^{-1}	$Z\times10^{-5}$ kg m^{-2}s^{-1}	$L_f\times10^{10}$ m	$\beta_S\times10^{12}$ m^{2}N^{-1}	$\beta_T\times10^{12}$ m^{2}N^{-1}	C_p Jmol^{-1} K^{-1}	$\bar{\Gamma}$	Γ'	B/A
benzene										
0.0000	862.2	1275	11.069	0.5525	708.0	1013.17	150.13	1.096	3.833	8.256
0.1037	861.5	1264	10.889	0.5594	726.5	1014.65	153.50	1.046	3.838	8.241
0.2054	849.7	1251	10.630	0.5692	752.0	1025.44	156.66	0.905	3.845	8.235
0.4025	833.3	1226	10.216	0.5865	798.4	1039.53	162.44	0.895	3.863	8.257
0.6016	820.8	1206	9.899	0.6007	837.7	1040.90	168.13	0.811	3.884	8.320
0.8053	807.3	1192	9.623	0.6128	871.8	1051.73	173.38	0.732	3.915	8.443
0.9087	799.9	1186	9.487	0.6188	888.8	1054.70	176.91	0.695	3.932	8.521
1.0000	791.3	1180	9.337	0.6253	907.6	1060.72	178.10	0.660	3.953	8.608
carbon tetrachloride										
0.0000	1584.8	908	14.390	0.5759	770.0	1131.69	303.10	0.777	3.819	7.831
0.1061	1473.8	932	13.736	0.5802	781.4	1119.44	306.11	0.774	3.813	7.832
0.2075	1378.7	959	13.222	0.5829	788.7	1102.65	290.13	0.776	3.812	7.849
0.4031	1213.3	1010	12.254	0.5900	808.0	1086.32	261.33	0.764	3.817	7.909
0.6069	1058.8	1064	10.946	0.5995	834.3	1073.85	231.55	0.752	3.840	8.059
0.8021	922.2	1120	10.329	0.6103	864.5	1064.62	205.23	0.721	3.874	8.222
0.9070	855.3	1152	9.853	0.6161	881.0	1058.55	191.04	0.706	3.902	8.363
1.0000	791.3	1180	9.337	0.6253	907.6	1060.72	178.10	0.660	3.953	8.608

Table 2 : Variation of ρ, u, L_f, Z, β_s, β_T, C_p, Γ', $\bar{\Gamma}$ and B/A in the binary mixtures of MIBK with benzene and CCl_4 at 308.15K.

x_1	ρ kgm^{-3}	u ms^{-1}	$Z\times10^{-5}$ Kg m^{-2}s^{-1}	$L_f\times10^{10}$ m	$\beta_S\times10^{12}$ m^{2}N^{-1}	$\beta_T\times10^{12}$ m^{2}N^{-1}	C_p Jmol^{-1}K^{-1}	$\bar{\Gamma}$	Γ'	B/A
benzene										
0.0000	862.9	1260	10.873	0.5659	730.0	1044.1	150.77	1.071	3.830	8.219
0.1037	857.5	1250	10.719	0.5722	746.4	1042.2	154.10	1.023	3.835	8.207
0.2054	846.0	1238	10.473	0.5816	771.2	1052.0	157.31	0.975	3.841	8.201
0.4025	830.0	1214	10.076	0.5988	817.5	1068.8	163.09	0.778	3.858	8.221
0.6016	817.9	1195	9.774	0.6128	856.2	1072.9	168.79	0.797	3.878	8.282
0.8053	803.1	1183	9501.	0.6247	889.7	1074.9	174.05	0.721	3.908	8.401
0.9087	797.4	1177	9.385	0.6301	905.3	1075.7	176.66	0.686	3.925	8.475
1.0000	787.7	1170	9.216	0.6377	927.4	1082.1	178.73	0.639	3.944	8.558
carbon tetrachloride										
0.0000	1568.4	893	14.006	0.5922	799.5	1112.0	317.87	0.700	3.817	7.771
0.1061	1467.5	920	13.501	0.5942	805.1	1093.9	301.03	0.696	3.812	7.792
0.2075	1372.7	948	13.013	0.5963	810.6	1083.9	285.96	0.701	3.813	7.825
0.4031	1207.8	1000	12.078	0.6026	828.0	1076.6	258.39	0.705	3.822	7.910
0.6069	1054.7	1054	11.117	0.6118	853.5	1075.1	230.64	0.701	3.843	8.040
0.8021	919.0	1111	10.211	0.6218	881.6	1173.8	204.66	0.687	3.879	8.234
0.9070	853.1	1142	9.742	0.6378	898.8	1175.1	191.16	0.676	3.906	8.371
1.0000	787.7	1170	9.216	0.6377	927.4	1082.1	178.73	0.639	3.944	8.561

Table 3 : Variation of ρ, u, L_f, Z, β_s, β_T, C_p, Γ', $\overline{\Gamma}$ and B/A in the binary mixtures of MIBK with benzene and CCl_4 at 313.15K.

x_1	ρ kgm^{-3}	u ms^{-1}	$Z\times10^{-5}$ Kg m^{-2}s^{-1}	$L_f\times10^{10}$ m	$\beta_S\times10^{12}$ m^{2}N^{-1}	$\beta_T\times10^{12}$ m^{2}N^{-1}	C_p Jmol^{-1}K^{-1}	$\overline{\Gamma}$	Γ'	B/A
benzene										
0.0000	856.0	1248	10.683	0.5787	750.1	1075.34	151.48	1.054	3.826	8.189
0.1037	854.0	1238	10.573	0.5841	764.0	1067.56	154.73	1.005	3.831	8.175
0.2054	842.6	1228	10.347	0.5928	787.0	1075.17	157.95	0.960	3.838	8.171
0.4025	826.8	1205	9.963	0.6099	833.0	1086.95	163.75	0.866	3.848	8.189
0.6016	814.7	1187	9.670	0.6237	871.2	1093.54	169.44	0.787	3.871	8.248
0.8053	799.7	1175	9.396	0.6359	905.7	1095.94	174.72	0.713	3.901	8.361
0.9087	794.4	1169	9.287	0.6413	921.2	1096.28	177.33	0.678	3.917	8.432
1.0000	784.5	1162	9.116	0.6492	944.1	1105.10	179.34	0.641	3.937	8.519
carbon tetrachloride										
0.0000	1562.2	883	13.794	0.6055	821.0	1141.57	319.26	0.684	3.811	7.754
0.1061	1462.3	912	13.336	0.6059	822.2	1118.30	302.33	0.685	3.832	7.776
0.2075	1367.4	939	12.890	0.6086	829.4	1109.52	287.16	0.687	3.814	7.806
0.4031	1202.7	992	11.931	0.6142	844.9	1100.08	259.59	0.695	3.820	7.887
0.6069	1050.9	1046	10.992	0.6232	869.7	1096.66	231.54	0.691	3.839	8.012
0.8021	913.0	1103	10.030	0.6340	900.3	1098.21	205.45	0.678	3.873	8.199
0.9070	850.4	1134	9.644	0.6389	914.4	1094.89	191.86	0.667	3.809	8.333
1.0000	784.5	1162	9.116	0.6492	944.1	1105.10	179.34	0.641	3.937	8.519

Table 4 : Variation of ρ, u, L_f, Z, β_s, β_T, C_p, Γ', $\overline{\Gamma}$ and B/A in the binary mixtures of MIBK with benzene and CCl_4 at 318.15K.

x_1	ρ kgm^{-3}	u ms^{-1}	$Z\times10^{-5}$ Kg m^{-2}s^{-1}	$L_f\times10^{10}$ m	$\beta_S\times10^{12}$ m^{2}N^{-1}	$\beta_T\times10^{12}$ m^{2}N^{-1}	C_p Jmol^{-1}K^{-1}	$\overline{\Gamma}$	Γ'	B/A
benzene										
0.0000	851.5	1240	10.614	0.5892	763.8	1098.12	152.12	1.041	3.824	8.166
0.1037	850.2	1231	10.513	0.5939	776.2	1088.10	155.40	0.995	3.829	8.152
0.2054	839.5	1221	10.288	0.6026	799.0	1094.55	158.60	0.950	3.834	8.146
0.4025	823.8	1199	9.913	0.6195	844.4	1005.10	164.41	0.859	3.849	8.161
0.6016	811.2	1181	9.622	0.6338	883.8	1112.05	170.10	0.780	3.867	8.216
0.8053	796.7	1170	9.356	0.6455	916.9	1112,22	175.39	0.708	3.894	8.324
0.9087	790.2	1163	9.239	0.6521	935.6	1115.82	178.01	0.672	3.910	8.392
1.0000	781.6	1156	9.069	0.6596	957.4	1122.27	179.94	0.634	3.929	8.479
carbon tetrachloride										
0.0000	1556.4	875	13.619	0.6176	839.2	1167.91	320.65	0.672	3.816	7.742
0.1061	1459.1	904	13.190	0.6174	838.6	1141.71	303.62	0.673	3.812	7.761
0.2075	1363.2	932	12.705	0.6195	844.5	1131.32	288.36	0.677	3.813	7.790
0.4031	1197.2	985	11.799	0.6253	860.4	1121.87	260.54	0.687	3.818	7.867
0.6069	1047.9	1040	10.889	0.6335	883.1	1115.50	232.45	0.683	3.836	7.987
0.8021	908.5	1098	9.975	0.6441	913.1	1114.70	206.21	0.672	3.868	8.168
0.9070	847.8	1128	9.554	0.6491	927.0	1112.13	192.59	0.661	3.893	8.297
1.0000	781.6	1156	9.069	0.6596	957.4	1122.27	179.94	0.634	3.929	8.479

Table 5: The values of A_i and corresponding standard deviations σ of $\Delta\beta_S$, $\Delta\beta_T$, ,$\Delta(B/A)$, ΔL_f and ΔZ for carbon tetrachloride .

T ^{0}C	A_0	A_1	A_2	A_3	A_4	σ
			$\Delta\beta_s \times 10^{12}$ (m^2N^{-1})			
30	5.73	-1.95	1.01	4.99	-6.29	0.55
35	5.54	-2.06	-4.04	5.59	-4.41	0.35
40	3.53	-2.01	-2.88	7.35	2.57	0.49
45	1.63	-1.08	-0.29	3.20	-2.51	0.34
			$\Delta\beta_T \times 10^{12}$ (m^2N^{-1})			
30	-6.07	0.64	-3.59	-1.70	7.10	0.57
35	-8.02	0.06	-3.25	-1.25	5.91	0.28
40	-9.86	1.05	-0.71	-1.72	6.01	0.74
45	-10.50	0.72	-3.42	-7.00	3.90	0.64
			$\Delta(B/A)$			
30	-10.00	-0.44	- 0.81	-0.83	0.43	0.34
35	-8.34	-0.94	0.33	-0.86	-1.88	0.25
40	-7.93	-0.84	0.39	0.90	-1.82	0.47
45	-7.78	-0.79	0.46	0.82	-1.85	0.24

Table 5, continued

			$\Delta Z \times 10^{-5}$ (kg $m^{-2}s^{-1}$)			
30	5.33	-1.64	1.01	5.64	-4.90	0.22
35	5.80	-1.48	1.12	5.21	-4.62	0.22
40	5.89	-1.42	2.36	4.56	-6.46	0.22
45	6.38	1.35	1.92	4.25	-5.25	0.24
			$\Delta L_f \times 10^{10}$ (m)			
30	-24.75	-1.53	1.43	-1.04	3.05	1.27
35	-32.22	-0.16	-5.78	-3.60	9.10	1.31
40	-36.82	0.17	-0.64	-2.35	-0.82	1.25
45	-38.67	-1.81	-0.33	3.87	-5.26	1.42

Table 6: The values of A_i and corresponding standard deviations σ of $\Delta\beta_S$, $\Delta\beta_T$, $\Delta(B/A)$, ΔL_f and ΔZ for benzene .

T ^{0}C	A_0	A_1	A_2	A_3	A_4	σ
			$\Delta\beta_s \times 10^{12}$ (m^2N^{-1})			
30	5.73	-1.95	1.01	4.99	-6.29	0.55
35	5.54	-2.06	-4.04	5.59	-4.41	0.35
40	3.53	-2.01	-2.88	7.35	2.57	0.49
45	1.63	-1.08	-2.9	3.20	-2,51	0.34
			$\Delta\beta_T \times 10^{12}$ (m^2N^{-1})			
30	-6.07	6.4	-3.59	-1.70	7.10	0.57
35	-8.02	1.06	-3.25	-1.25	5.91	0.28
40	-9.86	1.05	-3.71	-1.72	6.01	0.47
45	-10.5	0.72	-3.42	-7.00	3.90	0.64
			$\Delta(B/A)$			
30	-10.00	-0..44	- 0.81	-0.83	0.43	0.34
35	-8.34	-0.94	0.33	-0.86	-1.88	0.25
40	-7.93	-0.84	0.39	0.90	-1.82	0.24
45	-7.8 .	-0.79	0.46	0.82	-1.85	0.24

Table 6, continued

	$\Delta Z \times 10^{-5}$ (kg m^{-2}s^{-1})					
30	5.33	-1.64	1.01	5.64	-4.90	0.22
35	5.80	-1.48	1.12	5.21	-4.62	0.22
40	5.89	-1.42	2.36	4.56	-6.46	0.22
45	6.38	1.35	1.92	4.25	-5.25	0.24
	$\Delta L_f \times 10^{10}$ (m)					
30	-24.75	-1.53	1.43	-1.04	3.05	1.27
35	-32.22	-0.16	-5.78	-3.60	9.10	1.31
40	-36.82	0.17	-0.64	-2.35	-0.82	1.25
45	-38.67	-1.81	-0.33	3.87	-5.26	1.42

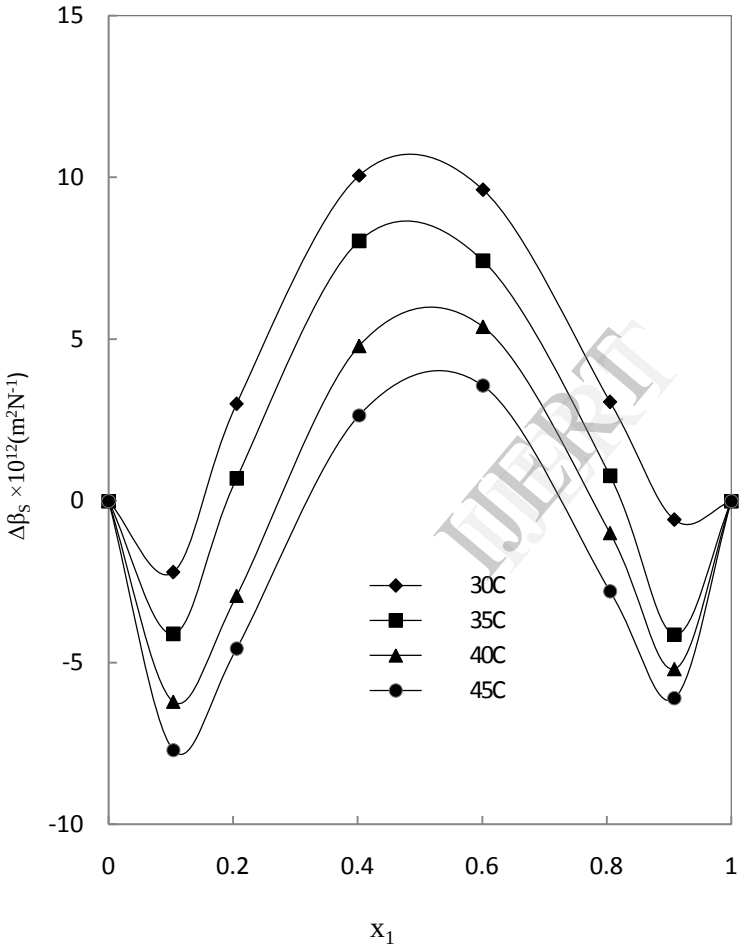


Figure1: Variation of $\Delta\beta_S$ with molefraction of MIBK(x_1) for benzene

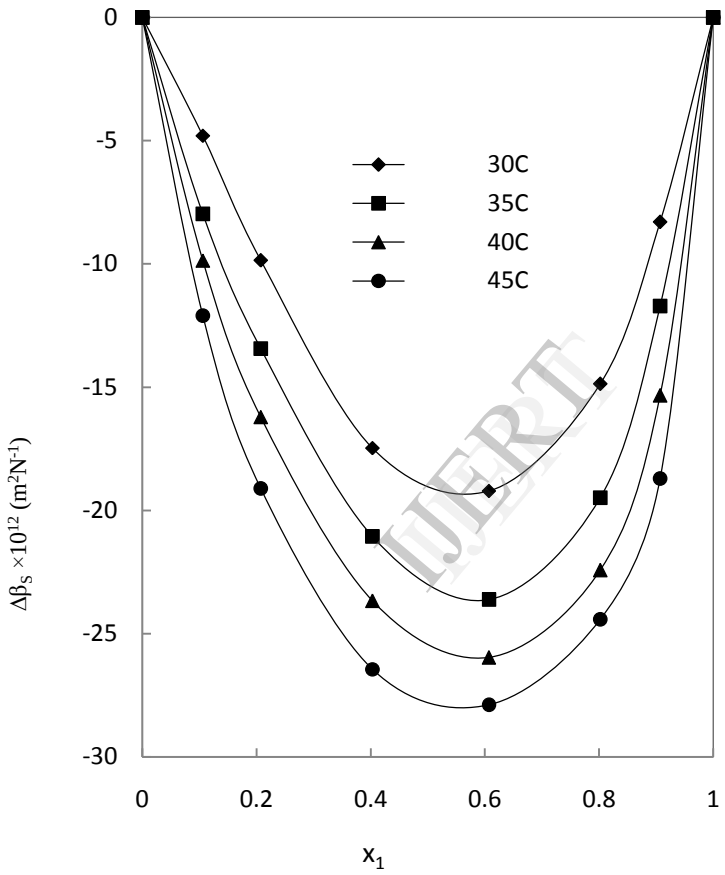


Figure2: Variation of $\Delta\beta_s$ with molefraction of MIBK(x_1) for carbon tetrachloride

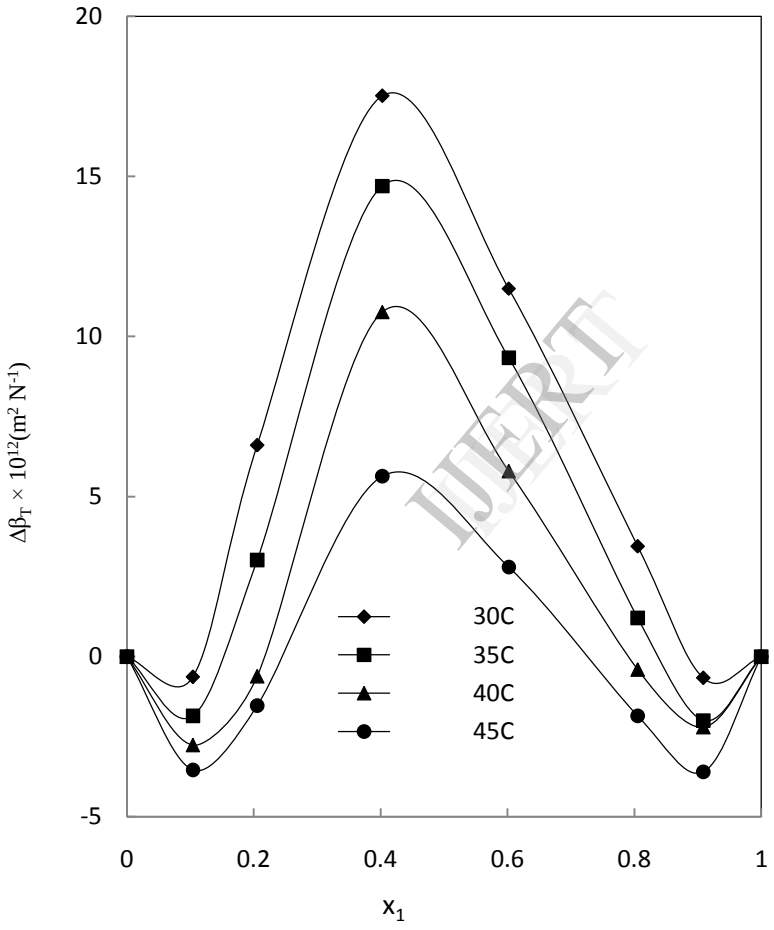


Figure3: Variation of $\Delta\beta_T$ with molefraction of MIBK(x_1) for benzene

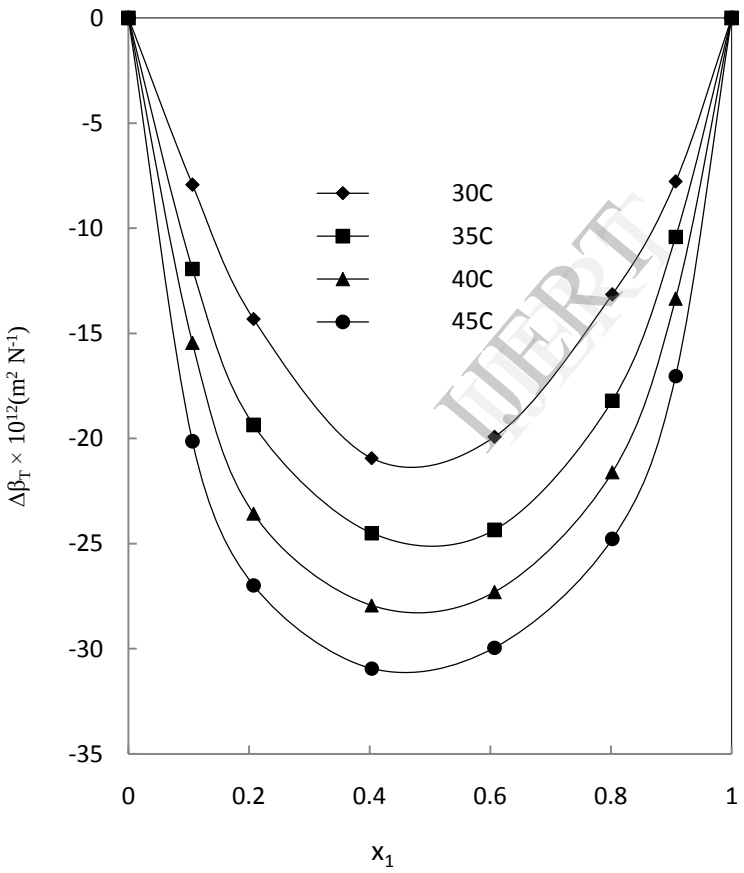


Figure3: Variation of $\Delta\beta_T$ with molefraction of MIBK(x_1) for carbon tetrachloride

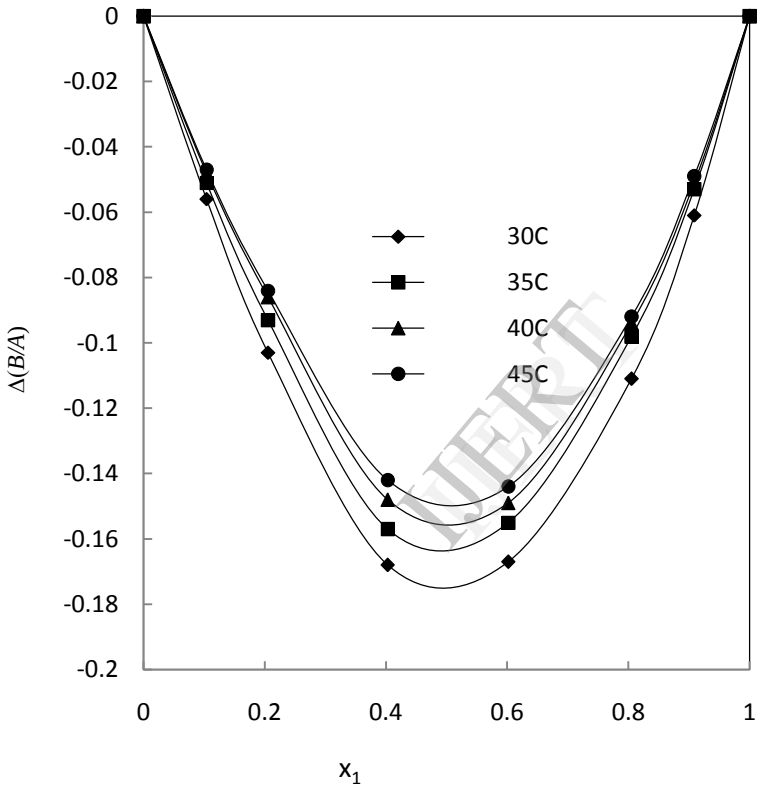


Figure 5: Variation of $\Delta(B/A)$ with molefraction of MIBK(x_1) for benzene

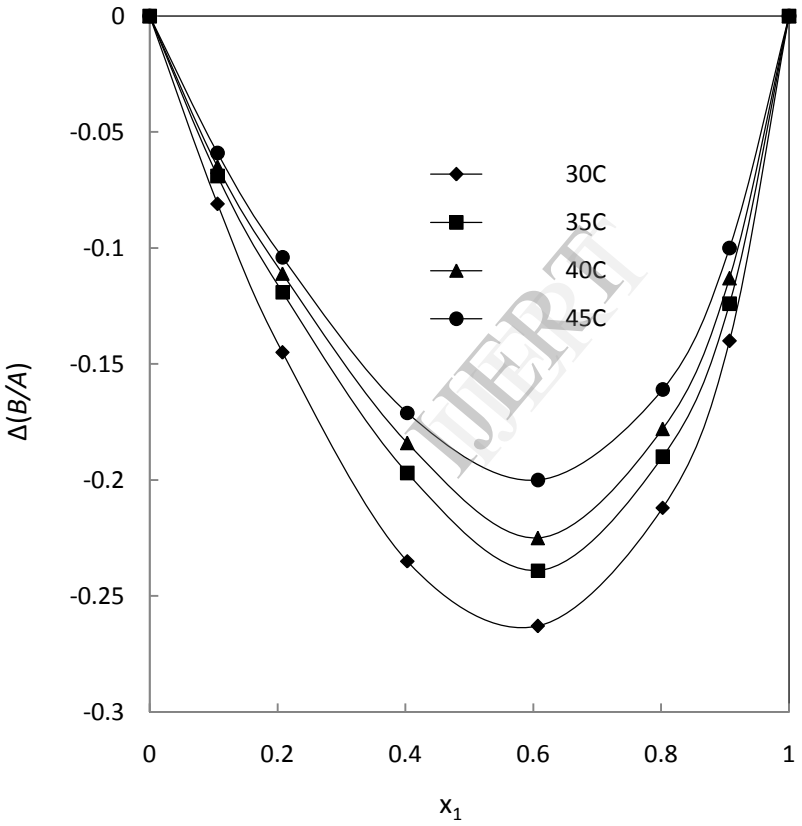


Figure6: Variation of $\Delta(B/A)$ with molefraction of MIBK(x_1) for carbon chloride

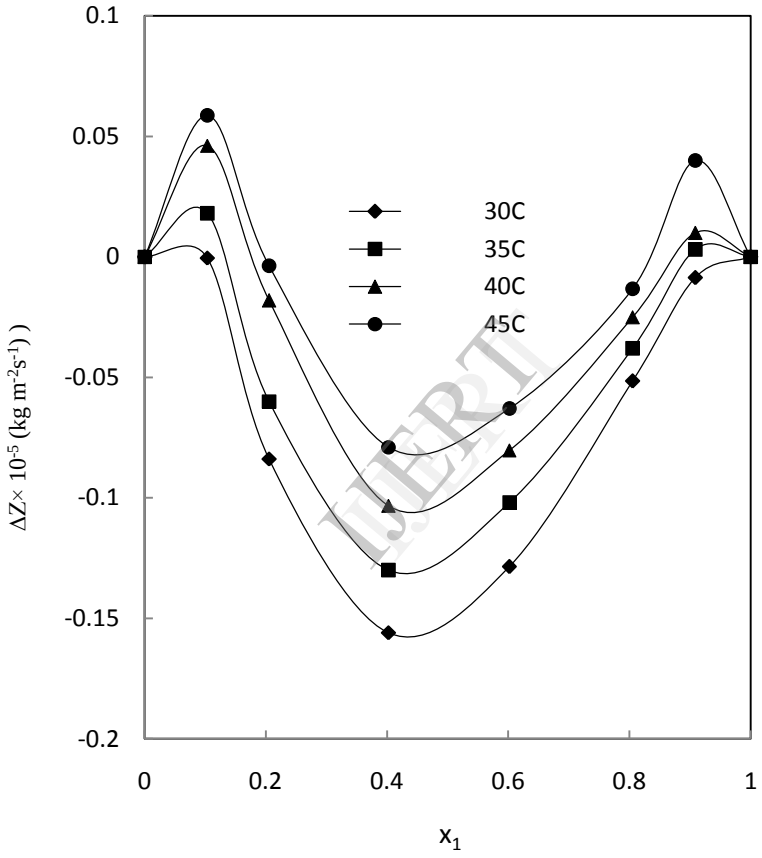


Figure7: Variation of ΔZ with molefraction of MIBK(x_1) for benzene

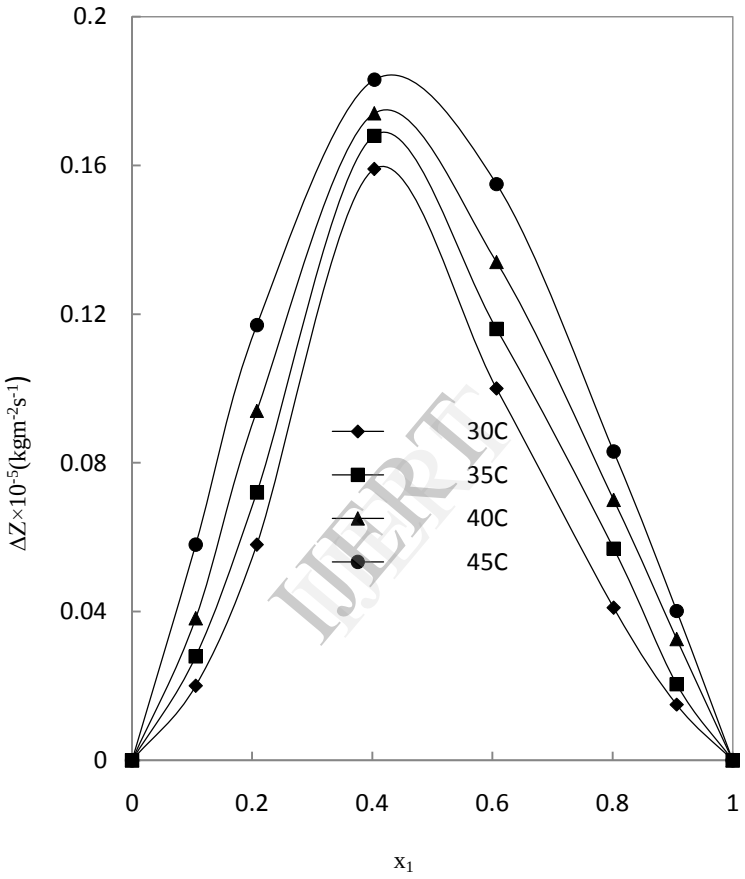


Figure8: Variation of ΔZ with molefraction of MIBK(x_1) for carbon tetrachloreide

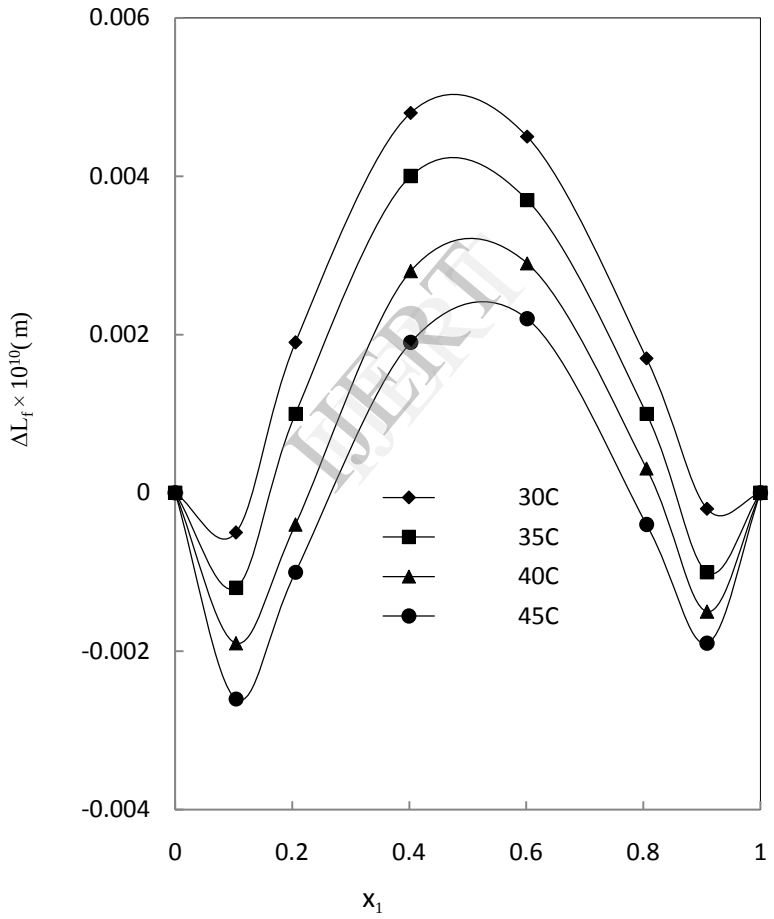
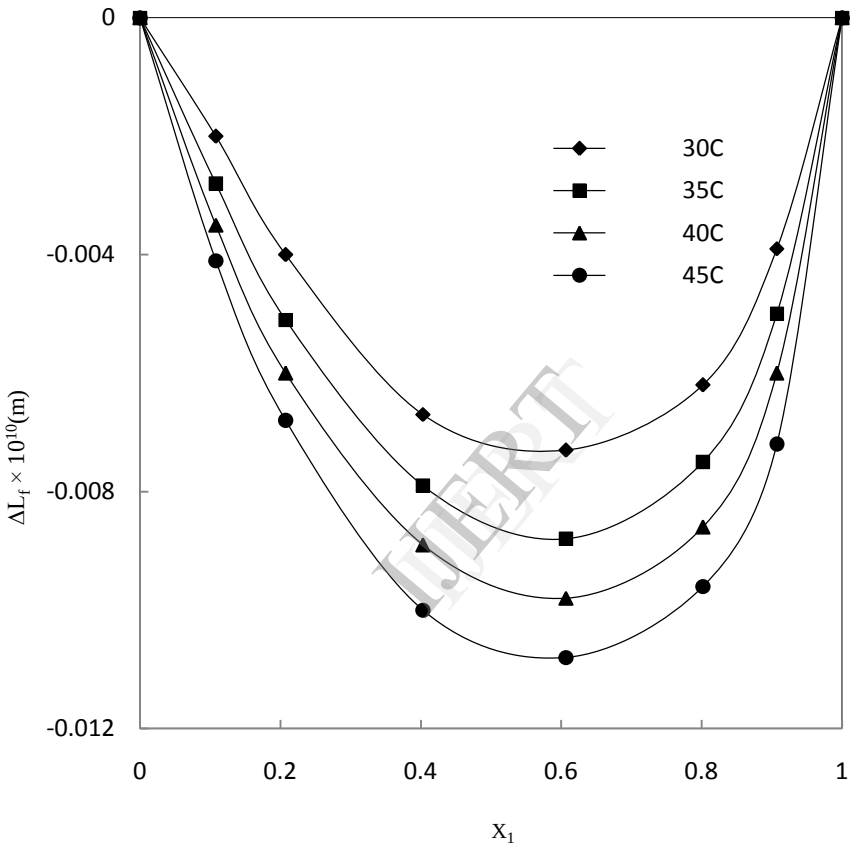


Figure 9: Variation of ΔL_f with molefraction of MIBK(x_1) for benzene



Figuire10: Variation of ΔL_f with molefraction of MIBK(x_1) for carbon tetrachloride