

Comparative study of theoretical ultrasonic velocities of binary liquid mixture containing Dimethyl Acetamide (DMAc) and Chloroform(CF) at different temperatures $T = (300, 303) \text{ K}$

Tarun Pant¹, Hema², Dr. Tara Bhatt³, Dr. Charu Chandra Dhondiyal⁴

Research Scholar^{1,2}, Assistant Professor³, Associate Professor⁴

Department of Physics, M.B. Government P.G. College Haldwani, Nainital, India

Corresponding author email-tpant7@gmail.com*

Abstract: Ultrasonic velocities and densities of binary liquid mixture containing Dimethyl Acetamide (DMAc) and Chloroform(CF) have been measured at temperatures $T = (300, 303) \text{ K}$ over the entire mole fraction range of Chloroform(CF) under frequency of 2 MHz . Theoretical velocities have been evaluated by using several empirical models of liquid mixtures viz. Nomoto's relation (U_{NOM}), Impedance dependence relation (U_{IDR}), Schaaff's collision factor theory (U_{CFT}), Jacobson's free length theory (U_{FLT}), Ideal mixing relation (U_{IMR}), Zhang-Junjie relation (U_{JR}), Danusso model (U_{DM}) and Rao's specific velocity (U_{R}) models. Chi-square tests for the goodness of the fit, percentage deviation along with their average and average percentage errors (APE) are applied to investigate the relative applicability of these theories to the present binary mixture. A good agreement has been found between experimental and theoretical values. $U^2_{\text{Exp}}/U^2_{\text{Ideal}}$ along with molecular interaction parameter (χ) has also been evaluated for non-ideality in the liquid mixture at two different temperatures viz. (300 and 303K). The results are discussed in terms of intermolecular interactions between the component molecules of the binary liquid mixture.

Keywords: Binary mixture, Ultrasonic velocity, Dimethyl Acetamide (DMAc), Chloroform(CF), Chi-square test, average percentage error(APE), Molecular interactions.

Introduction: Ultrasonic velocity, which is the best tool to measure the mechanical stability of liquids, gives information on the physico-chemical behavior and thermodynamic properties of the complexes of the binary mixtures [1-7]. Ultrasonic velocity and its theoretical evaluation in pure and liquid mixtures and its comparison with experimental data show the behavior of molecular interactions and used to develop theoretical models for liquids. Lageman and Dunbar (1945) initiated using the sound velocity approach for the qualitative estimation of the interactions in liquids. The combined study of ultrasonic velocity and density of solution gives more understanding on the behavior of ideal and non-ideal nature, elastic properties and other co-related parameters of the liquid mixtures. A number of mathematical theories on speed of sound measurements give positive implications to industry and chemical processes. Apparently no study has been reported on comparing the computed values of ultrasonic velocity from

various velocity theories such as Nomato's relation, Van Dael and Vangeel ideal mixing relation, Junjie's relation, impedance dependence relation, Rao's specific velocity relation, Jacobson's free length theory. Schaaff's collision factor theory and Danusso relation for speed of sound with the experimental values of ultrasonic velocity of sound of the N,N dimethylacetamide (DMAc) with Chloroform(CF) binary mixtures at temperatures 300 K and 303 K and to understand the behavior of intermolecular interactions between the molecules. Comparison of theoretical values of ultrasonic velocities with those obtained experimentally in the present binary mixture is expected to reveal the nature of interaction between the component molecules in the mixture. Such theoretical study is useful in obtaining the comprehensive model for liquid mixtures. Hence, this study has such importance and it is useful for the chemical and industrial processes. The present regarding the study of molecular interaction in binary liquid mixture with N,N dimethyl acetamide(DMAc) with chloroform(CF) as constituents is of particular interest ,because DMAc is a dipolar aprotic solvent with high boiling point along with high thermal and chemical stability.It has large dipole moment and dielectric constant($\mu=3.7\text{D}$ and $\epsilon=37.8$).DMAc is an excellent proton donor as well as proton acceptor and hence it is strongly associated through intermolecular hydrogen bond. It is highly soluble in a variety of polar and non-polar solvents and readily suitable to explore solvent-solvent interactions. It is used as a solvent in the production of acrylic and elastane fibres, pharmaceuticals, antibiotics and polyimide resins.Chloroform is considered as non polar solvent.It has small dipole moment and dielectric constant($\mu=1.15\text{D}$ and $\epsilon=4.81$).Chloroform is a common solvent in the laboratory because it is relatively non-reactive, miscible with most organic liquids, and conveniently volatile. Chloroform is used as a solvent in the pharmaceutical industry and for producing dyes and pesticides. It is useful for extracting alkaloids (such as morphine) of pharmaceutical importance from plant materials (such as poppies). Chloroform has myriad uses as a reagent and a solvent. The experimental data of ultrasonic velocities were compared with the values of velocity theories; further, the deviation in molecular interaction parameter (χ) values to understand the non-ideal behavior of the liquid mixtures, relative percentage error and Chi-square test values for the goodness of fit were computed.

Materials and methods:

Experimental Details:

The liquid mixtures of various concentrations in mole fraction were prepared by taking N,N dimethyl acetamide and Chloroform with minimum assay(>99.9) of analytical grade (ARgrade), manufactured by Sisco Research Laboratory ,Mumbai,India. which were used as such without further purification.

Velocity Measurement

The velocity of ultrasonic waves in the liquid mixture have been measured by using a single crystal variable frequency ultrasonic interferometer supplied by Mittal Enterprises, New Delhi (M-81) working at four different frequencies (2,4,6 & 8MHz) with a tolerance of $\pm 0.005\%$. The

measuring cell is a specially designed double walled vessel with provision for temperature constancy. The high frequency generator excites a quartz crystal fixed at the bottom of the measuring cell, at its resonant frequency. The capacity of the measuring cell is 10cc. A fine micrometer screw, with a least count of 0.01mm at the top of the cell, can be raised (or) lowered the reflector plate in the liquid through a known distance. The measuring cell is connected to the output terminals of the high frequency generator through a shielded co-axial cable. Ultrasonic waves, normal to quartz crystal, is reflected from the reflector plate. Stationary waves are formed in the region between reflector plate and the quartz crystal. The micrometer is slowly moved till a number of maximum or minimum readings (n) of the anode current is passed. The total distance moved by the micrometer is noted (d). The wavelength of the ultrasonic waves in the liquid is $\lambda = 2d/n$. The velocity of ultrasonic waves in the concerned liquid can be determined by the following relation,

$$U = \lambda f \quad (1)$$

Where f is the frequency of the generator which is 2MHz as assumed.

Density Measurement

The density of pure liquids and mixtures are measured using a 10ml specific gravity bottle. The weight of the pure liquids and liquid mixtures are determined by using single pan electronic balance supplied by Aczet Pvt.Ltd.India (Model CY 132) with least accuracy up to 1 mg. The specific gravity bottle with the experimental liquid is immersed in a double walled or jacketed cylindrical borosilicate glass beaker supplied by Saber Scientific ,Ahmedabad , Gujrat, India, connected via inlet and outlet pipes with temperature controlled water bath Supplied by Mittal enterprises, New Delhi with $\pm 0.1^{\circ}\text{C}$ accuracy to maintain desired temperature for density measurement . An average of triple measurements was taken into account to reduce the possible experimental error. Sufficient care was taken to avoid any air bubble entrapment. The densities of pure liquids thus obtained are found to be in good agreement with standard values. The measured density was measured using the formula,

$$\rho_2 = \left(\frac{W_2}{W_1} \right) \rho_1 \quad (2)$$

Where, W_1 , is the weight of the distilled water.

W_2 , that of weight of the experimental liquid.

ρ_1 , is the density of distilled water.

ρ_2 , that of the experimental liquid.

Theory:-The following empirical and semi-empirical relations were used for theoretical estimation of speed of sound in the studied binary mixture.

1)Schaaff's collision factor theory (CFT):-Schaaff's and Nutsch-Kuhnlies^[8] developed the Collision factor theory for the determination of ultrasonic velocity of binary liquid mixtures, which is expressed using following formula as,

$$U_{CFT} = U_{\infty} \left[\frac{(x_1 S_1 + x_2 S_2)(x_1 B_1 + x_2 B_2)}{V_m} \right] \quad (3)$$

Where $U_{\infty} = 1600 \text{ms}^{-1}$, $V_m = \left[\left(\frac{x_1 M_1 + x_2 M_2}{\rho} \right) \right]$, $S = \left(\frac{UV}{BU_{\infty}} \right)$ Actual Volume(B) = $\left(\frac{4}{3} \pi r^3 N \right)$, $r = \left(\frac{3b}{16\pi N} \right)^{\frac{1}{3}}$, b is the Vander Waal's constant and N is the Avogadro number.

2)Jacobson's free length theory(FLT):-Free length theory was established by Jacobson^[9] for ultrasonic velocity and which is calculated using the following formula as,

$$U_{FLT} = \left(\frac{K}{L_{f \text{ mix}} \rho_{\text{mix}}^{1/2}} \right) \quad (4)$$

Where K is Jacobson's constant. Its value can be calculated by the following equation as

$K = (93.875 + 0.375) \cdot 10^{-8}$, T is absolute temperature.

$$L_{f \text{ mix}} = 2 \left[\frac{V_m - (x_1 V_{01} + x_2 V_{02})}{x_1 Y_1 + x_2 Y_2} \right]$$

Where $U_{\infty} = 1600 \text{ms}^{-1}$

Molar Volume at absolute zero, $V_{01} = V_1 \frac{U_1}{U_{\infty}}$ & $V_{02} = V_2 \frac{U_2}{U_{\infty}}$

Surface area per mole, $Y_1 = \frac{2(V_1 - V_{01})}{L_{f1}}$ & $Y_2 = \frac{2(V_2 - V_{02})}{L_{f2}}$

$L_{f \text{ mix}}$ and ρ_{mix} are the intermolecular free length and density of the mixtures respectively.

3)Nomoto's relation(NOM):-Nomoto^[10] establish the relation for ultrasonic velocity in binary liquid mixtures on the assumption of additivity of molar sound velocity with concentration of molar fraction as,

$$U_{NOM} = \left[\frac{x_1 R_1 + x_2 R_2}{x_1 V_1 + x_2 V_2} \right]^3 \quad (5)$$

Where $R_1 = \frac{M_1 U_1^{1/3}}{\rho_1}$, $R_2 = \frac{M_2 U_2^{1/3}}{\rho_2}$, $V_1 = \frac{M_1}{\rho_1}$, $V_2 = \frac{M_2}{\rho_2}$

In the above equations x_1 and x_2 are the mole fraction of component of liquids, M_1 and M_2 are molecular weight, U_1 and U_2 are the ultrasonic velocity and V_1 and V_2 are the molar volume of components of binary liquid mixtures.

4)Van Dael ideal mixing relation(IMR):-This theory was advanced by Van Dael and Vangeel^[11] in the light of assumptions made by Blandamer and Waddington, yield the following relation for the velocity of sound in binary liquid mixtures as,

$$U_{IMR} = \left[\left(\frac{x_1}{M_1 U_1^2} + \frac{x_2}{M_2 U_2^2} \right) \right]^{-1/2} [(x_1 M_1 + x_2 M_2)]^{-1/2} \quad (6)$$

In the above equations x_1 and x_2 are the mole fraction of component of liquids, M_1 and M_2 are molecular weight, U_1 and U_2 are the ultrasonic velocity of components of binary liquid mixtures.

5)Impedance dependence(IR)relation:-The ultrasonic velocity of liquid mixtures can be calculated by using impedance dependence relation^[12] as follows:

$$U_{IDR} = \left(\frac{\sum x_i Z_i}{\sum x_i \rho_i} \right) \quad (7)$$

Where x_i, ρ_i and Z_i are the mole fraction, density and acoustic impedance of the pure components respectively.

6)Rao's Relation(R):-The Rao's relation^[13] is also called as specific sound velocity and can be expressed as,

$$U_R = (\sum x_i r_i \rho_i)^3 \quad (8)$$

Where r_i is the Rao's specific sound velocity which is given by,

$$r_i = \left(\frac{U^{1/3}}{\rho_i} \right)$$

7)Zhang-Junjie relation(JR):-The Junjie's relation^[14] for determination of ultrasonic velocity in binary liquid mixture is,

$$U_{JR} = \frac{x_1 V_1 + x_2 V_2}{\sqrt{(x_1 M_1 + x_2 M_2) \left(\frac{x_1 V_1}{\rho_1 U_1^2} + \frac{x_2 V_2}{\rho_2 U_2^2} \right)}} \quad (9)$$

8)Danusso Model(DM):- Danusso model^[15] of velocity of ultrasonic waves is given by

$$U_{DM} = \left(\frac{1}{\rho_{mix}} \right) \left[\frac{1}{M_{eff}} \left(\frac{x_1 M_1}{\rho_1^2 U_1^2} + \frac{x_2 M_2}{\rho_2^2 U_2^2} \right) \right] \quad (10)$$

Where $\rho_{mix} = (x_1 \rho_1 + x_2 \rho_2)$ and $M_{eff} = \frac{x_1 M_1 + x_2 M_2}{\rho_{mix}}$ and other terms have their usual meaning.

9)Chi-Square Test for Goodness of Fit:- According to Karl Pearson Chi-square value is evaluated for the binary liquid mixtures under study using the formula,

$$\chi^2 = \sum_{i=1}^n \frac{(U_{mix(obs)} - U_{mix(cal)})^2}{U_{mix(cal)}} \quad (11)$$

Where n is the number of data used.

10)Average Percentage Error (APE):- The Average percentage error calculated using the relation,

$$APE = \frac{1}{N} \sum \left[\frac{U_{mix(obs)} - U_{mix(cal)}}{U_{mix(obs)}} \right] \times 100\% \quad (12)$$

Where n is the number of data used.

$U_{mix(obs)}$ = Experimental values of ultrasonic velocities.
Computed values of ultrasonic velocities.

$U_{mix(cal)}$ =

11)Intermolecular interaction(molecular association)(χ):-The degree of intermolecular interaction is given by,

$$\chi = \left[\left(\frac{U_{Exp}}{U_{Ideal}} \right)^2 - 1 \right] \quad (13)$$

Where $U_{Ideal} = x_1 U_1 + x_2 U_2$ is the ideal mixing velocity.

Results and discussion: The comparison of experimental values of densities (ρ) and ultrasonic velocities (U) with the literature values is given in **Table -1& Table-2**.

Generally study of thermo-acoustical and excess thermo-acoustical parameters [18], [19] are useful to explain strength of the interactions between the component molecules of liquid mixtures in most of the cases. But in some cases where there is no possibility for the calculation of acoustical and excess acoustical parameters, these theoretical ultrasonic velocity studies play the major role. The experimental values of ultrasonic velocities along with the theoretically evaluated values by using various theories in the binary liquid mixtures containing N,N dimethylacetamide and Chloroform at temperatures $T = (300 \text{ and } 303) \text{ K}$ are given in **Table-3** and **Table-4**. The average percentage error (APE) and chi-square test values for all the theoretical velocity models are also calculated at temperatures $T = (300 \text{ and } 303) \text{ K}$. The percentage deviations along with their average are also calculated at temperatures $T = (300 \text{ and } 303 \text{ K})$ and tabulated in **Table-5** and **Table-6**. The values of U_{Exp}^2/U_{Ideal}^2 , molecular interaction parameter (α) and average molecular interaction parameter (χ_{avg}) are given in **Table-7**. It can be seen from **Table-3** and **Table-4** that, the theoretical values of ultrasonic velocity evaluated by various theories show deviations from experimental values. The limitations and approximations incorporated in these theories are responsible for it [20]. It is assumed that all the molecules are spherical in shape, which is not true every time. In Nomoto's theory, it is supposed that the volume does not change on mixing. Therefore, no interaction between the components of liquid

mixtures has been taken into account. The assumption for the formation of ideal mixing relation is that the ratio of specific heats of ideal mixtures and the volumes are also equal. Again, no molecular interaction is taken into account. Similarly as per the assumption for the collision factor theory, the molecules are treated as real non elastic substances, which is not really the case. But on mixing two liquids, the interaction between the molecules of the two liquids takes place because of presence of various types of forces such as dispersion forces, charge transfer, hydrogen bonding, dipole-dipole and dipole-induced dipole interactions.. The deviations of experimental values from theoretical values calculated using VanDael and Vangeel equation might be due to the compressibility of the component liquids in the present mixtures. The deviations of experimental values and calculated values from impedance relation and Rao's relation simply non-additively of acoustic impedance and Rao's velocity in the liquid mixtures. Thus, the observed deviation of theoretical values of ultrasonic velocity from the experimental values shows that the molecular interaction is taking place between the unlike molecules in the liquid mixtures [21]. From **Table-5** and **Table-6**, it is observed that the percentage deviations of the ultrasonic velocity are both negative and positive. Such deviations indicate the non-ideal behavior of liquid mixtures. The ratio of $U^2_{\text{Exp}}/U^2_{\text{Ideal}}$ is used as an important tool to measure the non-ideality in the mixtures, especially in these cases where the properties other than sound velocity are not known. The variations of the ratio of $U^2_{\text{Exp}}/U^2_{\text{Ideal}}$ with the mole fraction of chloroform at two different temperatures are represented in **fig(3)**.

In general, the predictive ability of various ultrasonic theories depends upon the strength of interactions that exist in a binary system. In case strong interactions exist between the molecules of the mixtures, there is much deviation in theoretical prediction of velocity than the molecules of the mixture where less interactions are present. **Fig.1** and **2** shows that there is a deviation between experimental and theoretical values which confirms the existence of molecular interactions. Higher variation is observed at some intermediate concentrations suggesting the existence of strong tendency of association between component molecules as a result of hydrogen bonding. The perusal of the figures reveal good agreement between the experimental and calculated sound velocities, owing to the several assumptions and approximations made in the respective theories. It is observed from the **Table-3** and **Table-4**, that Junjie's relation predicts a good agreement of sound velocity with the experimental values in binary mixtures of N,N dimethylacetamide(DMAc) with chloroform(CF). Thus from the comparison of experimental velocity values with theoretical models, it is clear that the Free length theory is not best suited for the estimation of ultrasonic velocity at both temperatures. Theoretical results of ultrasonic velocities in liquid mixtures are showed, it is observed that out of all eight theories Junjie's theory gives best results in all the systems studied. Thus the observed deviation of theoretical values of velocity from the experimental values shows that the molecular interaction is taking place between the unlike molecules in the liquid mixtures. Similar kinds of results were obtained by earlier workers[22-23]. Statistical analysis done by using average percentage error and

chi-square test. These theories are tested considering percentage deviation and chi square test for goodness of fit. The chi-square value determines the overall validity of the theory.

For the system DMAc + CF, CFT, NOM, IDR, IMR, R, DR and JR relations are applicable for theoretical evaluation of ultrasonic velocity. FLT is not applicable for theoretical evaluation of ultrasonic velocity. Also having high value of APE and χ^2 value in Free length theory as compared to other theories. The variations of the ratio of $U_{\text{Exp}}^2/U_{\text{Ideal}}^2$ with the mole fraction of chloroform at two temperatures are represented in **Fig-3**. The deviation of the ratio $U_{\text{Exp}}^2/U_{\text{Ideal}}^2$ from unity is a direct measure of non-ideality of the system as a consequence of association or other type of interactions which is called as molecular interaction parameter (χ). A perusal of **Tables-7** indicate small deviations from ideality, which may be due to the existence of weak tendency for the formation of association in liquid mixtures.

The interaction parameter characterizing a system varies with the composition, molar mass, and temperature. It is employed to account for the contribution of non-combinatorial entropy of mixing and the enthalpy of mixing to the Gibbs energy of mixing. When the values of interaction parameters show positive sign, it represents strong interaction between the mixing molecules. In systems studied, we observed that the interaction parameters are negative for all the given mixtures, indicating weaker interactions. Further the interaction parameter(χ) shows irregular trend with the change in temperature. Negative value of interaction parameter(χ) indicates the dominance of dispersion forces arising from the breakage of hydrogen bonds in the associates [23].

The deviations between theoretical and experimental value of ultrasonic velocities decrease with increase of temperature due to breaking of hetero- and homomolecular clusters at higher temperatures. On increasing the temperature, the ultrasonic velocity values decrease in the three binary liquid mixtures. This is probably due to the fact that the thermal energy activates the molecule, which would increase the rate of association of unlike molecules.

Conclusions:- We evaluated theoretical ultrasonic velocities in binary liquid mixture containing N,N dimethylacetamide(DMAc) with chloroform(CF) by using Nomoto (U_{NOM}), impedance dependence relation (U_{IDR}), Ideal mixing relation (U_{IMR}), Junjie relation (U_{JR}), Rao's specific velocity (U_{R}) and Danusso relation (U_{DR}), Collision factor theory(U_{CFT}) and Free length theory(U_{FLT}) and compared with the experimentally measured ultrasonic velocities at temperatures 300&303 K. As per the average percentage error(APE) values, Junjie's relations, Ideal mixing relation and Danusso model are best suited with the experimental values in all the binary systems. Junjie's relation for speed of sound appears to have an edge over the other relations in comparison. Overall, the goodness of fit (Chi-square values) is in good agreement for the models U_{JR} , U_{IMR} , U_{DR} and U_{IDR} comparatively to other four models in all the binary mixtures. The observed deviation of theoretical values of velocity from the experimental values is attributed to the presence of molecular interactions in the system studied. Further the negative values of α and also from the magnitude of the ratio of $U_{\text{Exp}}^2/U_{\text{Ideal}}^2$ in the present system at all

the temperatures clearly indicate the existence of weak tendency for the formation of association in liquid mixtures. and also the strength of interaction between the component molecules in a liquid mixture decreases with the increase of temperature. As the temperature increases interaction becomes weak, due to the thermal agitation of the liquid components.

References:

- 1-M. V. Rathnam, Kavita R. Bhanushali, Reema T. Sayed and M. S. S. Kumar, *J. Mol. Liq.*, 173, 35 (2012).
- 2-M. Sahin and E. Ayranci, *J. Chem. Thermodyn.*, 177, 43 (2011).
- 3-V. Kannappan, J. R. S. Xavier and R. J. Shanthi, *Indian J. Pure. Appl. Phys.*, 41, 690 (2003).
- 4- Amalendu, Sureshkumar, *J. Ind. Chem. Soc.*, 81, 101 (2004).
- 5- M. S. Chauhan, A. Kumar and S. Chauhan, *Acoust. Lett.*, 21, 228 (1998).
- 6-K. Samatha, V. V. Hari Babu and J. Sreeramamurthy, *Acustica*, 84, 169 (1998).
- 7- M. Rita and Meenakshi, *J. Ind. Chem. Soc.*, 82, 791 (2005)
- 8- W. von Schaaffs, *Acustica*, 30 (1974) 275.
- 9- Jacobson B, *Acta Chem Scand.*, (Denmark), 1952, 6, 1485-1487
- 10- Nomoto O, *J Phys Soc Japan*, 1958, 13(12), 1528-1532; DOI:10.1143/JPSJ.13.1528
- 11- VanDael W and Vangeel, in *Proceedings International Conference on Calorimetry and Thermodynamics*, 1955, 555, Warsaw, Poland.
- 12- Kalidass M and Srinivasamoorthy R, *J Pure Appl Ultrasonics*, 1997, 19, 9-15.
- 13- R. Rao *J. Chem. Phys.*, 9 (1941), p. 682
- 14-Z. Junjie, *J. Chem. Univ. Sci. Tech.*, 14 (1984) 298.
- 15- Danusso, F., "Ultrasonic velocity and adiabatic compressibility of liquid mixtures", *Atti della academia nazionale di linnei*, 10 (1951) 235 .
- 16- Dash Ashok Kumar and Paikaray Rita, *Research Journal of Physical Sciences* Vol. 1(3), 12-20, April (2013).
- 17- V. Vanathi , S. Mullainathan, and S. Nithiyanantham, *Asian Journal of Chemistry*; Vol. 25, Supplementary Issue (2013),

18- K. Narendra, Ch Srinivasu, Sk Fakruddin, P. Narayanamurthy *J. Chem. Thermodyn.*, 43 (2011), p. 1604

19- K. Narendra, Ch Srinivasu, Ch Kalpana, P. Narayanamurthy *J. Therm. Anal. Calorim.*, 107 (2012), p. 25

20- B. Zareena, P.B. Sandhyasri, C. Rambabu *ISRN Phys. Chem.* (2012), 10.5402/2012/943429

21- G.V. Ramarao, M. Triveni, D. Ramachandran *Int. J. Eng. Res.*, 3 (Special Issue1) (2015)

22- Sumathi T and Abeetha K, *J Chem.*, 2011, 8(1), 252-256;

23- Begum Z, Sandhya Sri P B and Rambabu C, *ISRN Phys Chem.*, 2012, 2012,

Table-1

Liquids	Density(ρ)(kgm ⁻³)		Ultrasonic velocity(U)(ms ⁻¹)	
At temperature 300K				
	Exp	Lit	Exp	Lit
N,N Dimethylacetamide (DMAc)	911.1	902.6 ^[16]	1432	1447 ^[16]
Chloroform(CF)	1425.7	1445 ^[2]	963	952 ^[2]

Table-2

Liquids	Density(ρ)(kgm ⁻³)		Ultrasonic velocity(U)(ms ⁻¹)	
At temperature 303K				
	Exp	Lit	Exp	Lit
N,N Dimethylacetamide (DMAc)	908.6	900.6 ^[16]	1424	1428 ^[16]
Chloroform(CF)	1416.4	1435.2 ^[17]	955.2	950.5 ^[17]

Table-3

X_1	U_{EXP}	U_{CFT}	U_{FLT}	U_{NOM}	U_{IMR}	U_{IDR}	U_{R}	U_{JR}	U_{DR}
0.0	1432	1432	1432	1432	1432	1432	1432	1432	1432
0.1	1378.2	1378.98	1358.73	1385.3	1364.9	1362.5	1354.6	1372.52	1378.18
0.2	1320	1334.2	1248.56	1338.5	1304	1300.1	1287.5	1316.5	1319.69
0.3	1272.4	1285.08	1185.25	1291.6	1269.8	1243.7	1228.8	1263.63	1268.73
0.4	1228.6	1242.94	1159.28	1244.7	1197.5	1192.5	1177.09	1213.66	1213.98
0.5	1159.7	1185.28	1082.2	1197.6	1150.7	1145.9	1131.22	1166.35	1177.13
0.6	1107.5	1142.24	1060.28	1150.6	1107.4	1103.1	1090.28	1121.48	1128.49
0.7	1073.4	1101.55	1045.06	1103.6	1067.3	1063.8	1053.53	1078.87	1079.91
0.8	1035.4	1059.58	1026.12	1056.6	1030.1	1027.6	1020.4	1038.36	1034.82

0.9	998.7	1009.23	988.77	1009.7	995.4	994.09	990.34	999.78	999.97
1.0	963	963	963	963	963	963	963	963	963
APE	.....	-1.3318	3.3384	-1.6239	0.6461	1.0478	1.8128	-0.0142	-0.2338
χ^2	.....	3.4317	23.5248	4.9732	1.2805	2.5864	6.6874	0.5271	0.8764

Table-4

X ₁	U _{EXP}	U _{CFT}	U _{FLT}	U _{NOM}	U _{IMR}	U _{IDR}	U _R	U _{JR}	U _{DR}
0.0	1424	1424	1424	1424	1424	1424	1424	1424	1424
0.1	1364.2	1372.5	1355.54	1377.2	1356.8	1354.8	1346.84	1364.26	1368.4
0.2	1316.6	1321.64	1218.47	1330.2	1295.8	1292.5	1279.86	1308.07	1315.75
0.3	1257.9	1272.13	1157.36	1283.2	1240.2	1236.2	1221.23	1255.11	1265.09
0.4	1206.4	1224	1111.21	1236.2	1189.3	1185.1	1169.55	1205.11	1216.1
0.5	1151.3	1177.13	1074.63	1189.2	1142.4	1138.4	1123.66	1157.82	1168.75
0.6	1100.7	1131.3	1044.35	1142.2	1099.2	1095.6	1082.7	1113.03	1122.93
0.7	1068.2	1086.33	1018.36	1095.3	1059.2	1056.3	1045.9	1070.53	1078.7
0.8	1020.8	1042.07	995.34	1048.4	1022.1	1020	1012.7	1030.17	1036
0.9	984.6	998.38	974.43	1001.7	987.49	986.4	982.6	991.77	994.83
1.0	955.2	955.2	955.2	955.2	955.2	955.2	955.2	955.2	955.2
APE	.....	-1.2532	4.2701	-1.8638	0.5703	0.7815	1.5593	-0.2344	-0.7877
χ^2	.....	2.8030	36.5536	5.8803	1.0304	1.5837	5.0640	0.3786	1.2627

Table-5

% U _{NOM}		% U _{IDR}	% U _{IMR}	% U _{JR}	% U _{FLT}	% U _{CFT}	% U _{RAO}	% U _{DR}
0		0	0	0	0	0	0	0
-0.5166		1.1363	0.9621	0.4121	1.4127	-0.0566	1.7124	0.0014
-1.4030		1.5061	1.2091	0.2652	5.4121	-1.0758	2.4621	0.0235
-1.5105		2.2532	0.2043	0.6892	6.8493	-0.9965	3.4266	0.2884
-1.3064		2.935	2.5297	1.216	5.6422	-1.1672	4.1926	1.1899
-3.2698		1.1934	0.7804	-0.573	6.6828	-2.2057	2.4558	-1.5029
-3.8916		0.3955	0.009	-1.262	4.2637	-3.1368	1.5548	-1.8952
-2.8135		0.8916	0.5683	-0.51	2.6402	-2.6225	1.8511	-0.6065
-2.0475		0.7533	0.5138	-0.286	0.8963	-2.3353	1.4487	0.0560
-1.1044		0.4616	0.3304	-0.108	0.9943	-1.0544	0.8370	-0.1272
0		0	0	0	0	0	0	0
APD	-1.9848	1.2807	0.7897	-0.017	3.8659	-1.6279	2.2157	-0.2858

Table-6

%U _{NOM}	%U _{IDR}	%U _{IMR}	%U _{JR}	%U _{FLT}	%U _{CFT}	%U _{RAO}	%U _{DR}
-------------------	-------------------	-------------------	------------------	-------------------	-------------------	-------------------	------------------

0	0	0	0	0	0	0	0
-0.9493	0.689	0.5424	-0.004	0.6348	-0.6084	1.2725	-0.3078
-1.0345	1.8282	1.5798	0.6479	7.4533	-0.3828	2.7905	0.0646
-2.0137	1.7219	1.4071	0.2218	7.9927	-1.1313	2.9152	-0.5716
-2.4701	1.7664	1.4199	0.1069	7.8904	-1.4589	3.0545	-0.8040
-3.2902	1.1205	0.7696	-0.566	6.6594	-2.2436	2.4007	-1.5157
-3.7685	0.4606	0.1336	-1.12	5.1195	-2.78	1.6353	-2.0196
-2.5323	1.114	0.8407	-0.218	4.6658	-1.6972	2.0876	-0.9829
-2.7047	0.0793	-0.1254	-0.918	2.4941	-2.0837	0.7935	-1.4890
-1.7387	-0.1828	-0.2935	-0.728	1.0329	-1.3996	0.2031	-1.0390
0	0	0	0	0	0	0	0
APD	-2.2780	0.9552	0.6971	-0.287	4.8825	-1.5317	1.9059
							-0.9628

Table-7

Mole fraction of Chloroform(X_1)	$(U_{Exp}/U_{Ideal})^2$	Molecular interaction parameter(χ)	$(U_{Exp}/U_{Ideal})^2$	Molecular interaction parameter(χ)
T=300K			T=303K	
0.0	1.0000	0.0000	1.0000	0.0000
0.1	0.9900	-0.0099	0.9813	-0.0187
0.2	0.9729	-0.0271	0.9796	-0.0204
0.3	0.9709	-0.0291	0.9607	-0.0393
0.4	0.9748	-0.0252	0.9519	-0.0481
0.5	0.9379	-0.0621	0.9366	-0.0634
0.6	0.9265	-0.0735	0.9278	-0.0722
0.7	0.9458	-0.0542	0.9502	-0.0498
0.8	0.9599	-0.0401	0.9470	-0.0530
0.9	0.9779	-0.0221	0.9654	-0.0346
1.0	1.0000	0.0000	1.0000	0.0000
Average molecular interaction parameter(χ_{avg})= -0.0312			Average molecular interaction parameter(χ_{avg})= -0.0363	

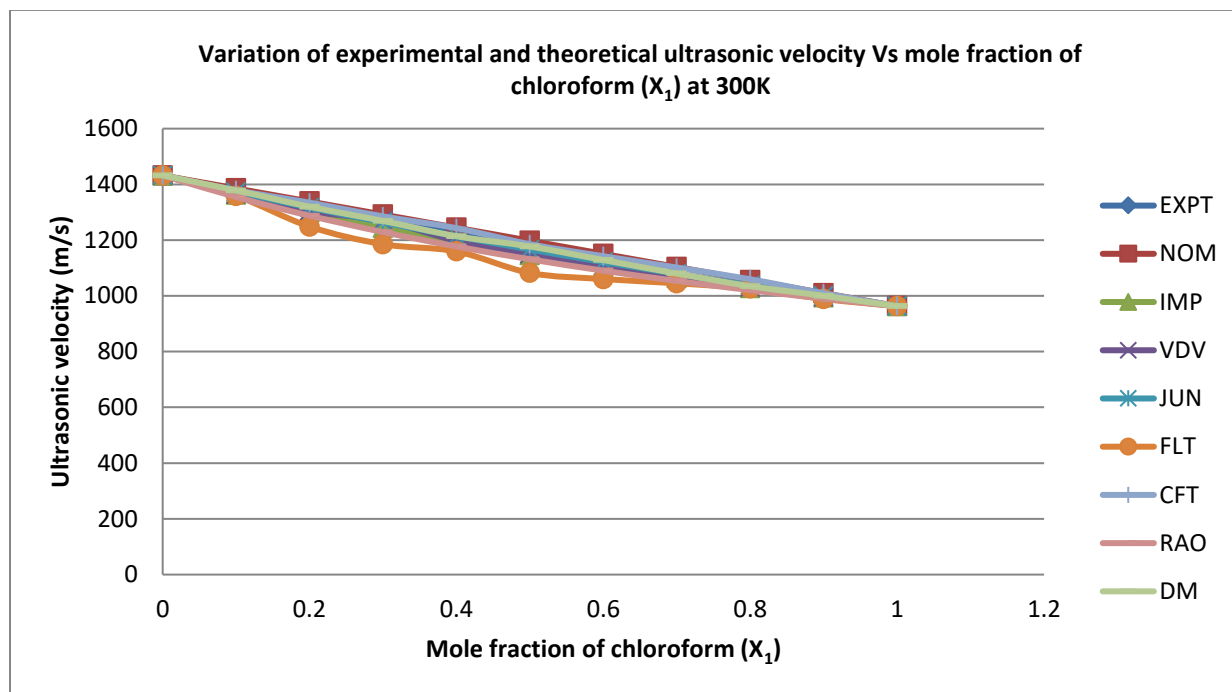
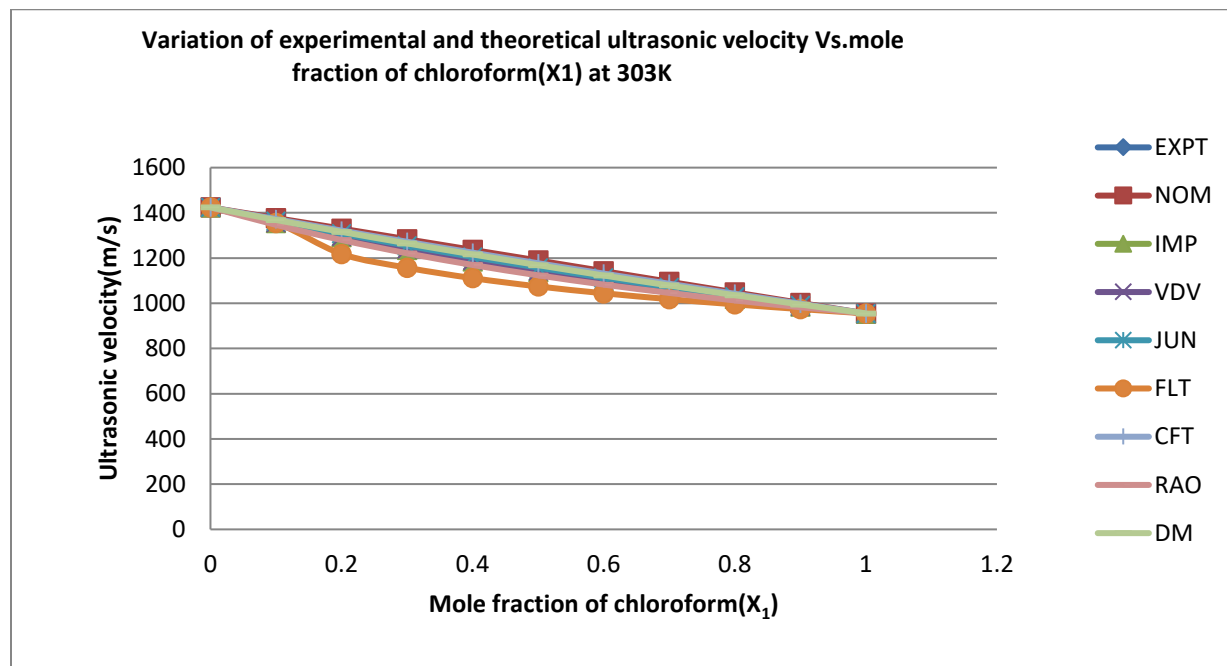
Figure-1**Figure-2**

Figure-3