Chapter 1

Introduction

1.1 General Introduction

The rapid development of ultrasonic techniques and the introduction of new materials for producing powerful ultrasonic vibrations have opened up wide fields of research and technical applications in physics, chemistry, biology, medicine and industry. Any elastic material has the tendency to allow propagation of ultrasonic waves and this propagation is through the displacement of adjacent elements of the medium. If the substance is elastic, there is a restoring force that tends to bring each element of the material back to its original position. Ultrasonic waves are of two types-longitudinal waves and transverse or shear waves. Since liquids do not possess shear elasticity, transverse waves cannot exist in liquids. Rectilinear propagation is a characteristic exhibited by ultrasonic waves because of their short wave length [1, 2].
The accurate measurement of the speed of sound is very difficult for sound of audible frequency due to the long wavelength and the consequent large size of the apparatus [3]. However, measurement of frequencies above the audible range (ultrasonic frequencies) can be readily made on liquid samples of volume about 100ml or less. Ultrasonic waves are generated by applying an alternating electric field of suitable frequency to a quartz transducer, which is thereby set into resonant oscillations (inverse piezoelectric effect). The wavelengths of ultrasonic waves generated from the free surface of an oscillating crystal can be measured by setting up standing waves in a liquid between the crystal surface and a parallel reflector.

The study of ultrasonic absorption and velocity in various media such as liquids, liquid mixtures, electrolyte solutions, suspensions, polymers, etc. is now rather an effective means for examining certain physical properties of the media [4-11]. The study included in this thesis was aimed at experimental determination of ultrasonic velocity and absorption in binary liquid mixtures, and theoretical estimation of acoustic non-linearity parameter B/A in such systems. Ultrasonic velocity was measured by pulse echo overlap technique and ultrasonic absorption was measured by pulse method using Matec 7700 ultrasonic pulse echo overlap system. Based on the result of this study, important physio-chemical properties such as nature and types of the intermolecular interactions taking place in the liquid mixtures, the energy exchange between different states, the relaxation processes, the non-linearity parameter and related molecular properties of binary liquid mixtures are explained.
1.2 **Brief Review**

A literature survey shows that ultrasonic studies have been carried out in a variety of binary liquid mixtures. It reveals the fact that ultrasonics has been a subject of active interest during the recent past. Recent literature on ultrasonic studies show that ultrasonics still exists as a potential tool in evaluating intermolecular interactions, energy exchange between various degrees of freedom and non-linear properties in binary liquid mixtures. A large number of studies were carried out in the past few decades on ultrasonic velocity in binary liquid mixtures. But studies of ultrasonic absorption of binary liquid mixtures and non-linearity parameters of liquids and liquid mixtures are limited. Brief review of the reported studies of ultrasonic velocity in liquid mixtures over the last ten years and studies on ultrasonic absorption and non-linearity parameter for the last few decades are included.

1.2.1 **Ultrasonic velocity and intermolecular interactions in binary liquid mixtures**

Intermolecular interactions existing in binary liquid mixtures are clearly explained using excess thermodynamical functions derived from ultrasonic velocity and density measurements [12-21]. Rajaguru and Jeyaraj [22] studied the excess thermodynamic functions of binary mixtures of allyl alcohol with 1,4 dioxane and carbon tetrachloride at two different temperatures and concluded that heteromolecular interactions are exist in the allyl alcohol + 1,4 dioxane system and dispersion forces exist in allyl alcohol + carbon tetrachloride system. Vijayabhaskar Reddy *et al.* [23] studied the volumetric and ultrasonic behaviour of ethylacetate with some chloroethanes and chloroethenes. The experimental data were used to explain the effect
of successive chlorination and unsaturation of ethane molecule. Belsare et al. [24] determined specific acoustic impedance and adiabatic compressibilities in binary mixtures of o-chlorophenol, p-chlorophenol, chlorobenzene and nitrobenzene with benzene. They suggested that only a weak interaction such as dispersion forces should be active in these mixtures.

Govindappa et al. [25] measured sound velocities in binary mixtures of 1-chlorobutane with benzene, toluene, o-xylene, m-xylene, p-xylene, chlorobenzene, bromobenzene and nitrobenzene. From the sound velocity and density data, excess compressibilities were derived and it was concluded that weak dipole-induced dipole interactions and dipole-dipole interactions were present in those systems. Rao et al. [26] estimated several excess functions like excess enthalpy, excess viscosity and excess Gibb’s free energy from ultrasonic velocity and viscosity determinations in binary liquid mixtures of toluene with different alcohols. They observed that as the concentration of toluene increased, there was a possibility of breaking of the hydrogen bonds, which associates the alcohol molecule. Srinivasulu et al. [27] evaluated the compressibility and excess compressibility from ultrasonic velocity and density measurements in binary mixtures of 1,1,1,-trichloroethane with different alcohols and observed that excess compressibilities were positive in all these binary systems which indicated that weak interactions were present and that was due to the structure breaking effects of 1,1,1-trichloroethane. Chennarayappa et al. [28] determined the excess compressibility values in binary mixtures of methyl cyclohexylamine with several alcohols. From the magnitude and sign of the excess compressibilities they found that strong hydrogen bond interactions exists in these systems.
Singh and Kalsh [29] studied various thermoacoustical parameters and excess thermodynamical functions in binary mixtures of tetrabutyltin, tributyltin chloride and dibutyltin dichloride with tetrahydrofuran. They concluded that complex formations are absent in these liquid mixtures and molecules interact weakly through dispersion forces. Dewan et al. [30] determined the experimental values of ultrasonic velocities in binary mixtures of ethylbenzene with acetonitrile, butyronitrile, nitromethene and nitroethane at 303.15K. The experimental velocities were compared with the theoretical values calculated by Flory, Jacobson and Schaaff’s theories. They observed that the velocity values computed using Schaaff’s theory agreed well with the experimental values of ultrasonic velocity in these binary mixtures.

Rajandran and Benny [31] measured the ultrasonic velocity in the binary mixtures of triethylamine with different alcohols and evaluated the compressibility and its excess value. From the magnitude and sign of excess compressibility values they suggest that strong hydrogen bond interactions between NH$_2$ group of triethylamine and OH group of alcohols were present in these binary systems. Ramanjappa et al. [32] evaluated excess sound velocity and excess specific acoustic impedance in binary mixtures of di-n-propylether + n-heptane, 3,6-dioxaoctane + n-heptane and 2,5,8-trioxanonane + n-heptane. In these studies they concluded that due to inductive effect several oxygen atoms weakens the C-H bonds and enhance the hydrogen bonding and this leads to self association of molecules. Rao et al. [33] studied ultrasonic speed and isentropic compressibilities of binary mixtures of acetonitrile with some amines of n-butylamine, sec-butylamine, tert-butylamine, n-pentylamine, n-hexylamine, n-heptylamine, n-octylamine, and cyclohexylamine at 303.15K. In these studies the
excess isentropic compressibility were found to be negative for the binary mixtures of n-butaline, sec-butylamine and tert-butalamine with acetonitrile while positive excess compressibilities were found in the mixtures of hexylamine, octylamine, pentyamine and heptylamine with acetonitrile. From these observations they suggested that positive excess compressibility is an indication of weak interaction (due to loss of dipolar association), which contributes to increase in the interspace between molecules in the mixture and negative excess compressibility is an indication of strong interaction between electrostatic forces of dipoles.

Padmasree and Prasad [34] studied ultrasonic behaviour in binary mixture of ethylacetate + n-butanol at 303.15K, 313.15K and 323.15K. Jacobson and Schaaff's theories were successfully applied to these binary mixtures. From the characteristics of excess functions, they found that interaction between unlike molecules are predominant in the binary mixtures besides interstitial occupation which dominates other types of interactions. Reddy et al. [35] evaluated the excess thermodynamic functions of three binary mixtures of acetophenone, 4-chloro acetophenone and 2-hydroxy acetophenone with isopropanol as the common component by measuring ultrasonic velocity, density and viscosity. They observed that there was no complex formation but a strong molecular interaction was present in those binary systems which was due to the interstitial accommodation of acetophenone molecule in the H-bonded alcohol structures and orientational ordering leading to more compact structures. Sivaprasad and Venkateswarlu [36] determined ultrasonic velocity in the binary mixtures of 2-butoxyethanol with benzene, toluene, o-xylene, m-xylene, p-xylene, chlorobenzene, bromobenzene and nitrobenzene at 303.15K. The excess compressibility curve showed a positive
deviation for the binary mixture of 2-butoxyethanol with three xylene and a negative deviation for other mixtures. The positive deviation of excess compressibility revealed that structural effects predominated over the effects of complex formation between π electrons of benzene ring and oxygen in 2-butoxyethanol and the negative deviation was attributed to the decrease in free length due to complex formation through charge transfer and dipolar association between the component molecules.

Pandey et al. [37] measured sound velocity and density in six binary mixtures namely n-heptane + toluene, n-heptane + n-hexane, toluene + n-hexane, cyclohexane + n-heptane, cyclohexane + n-hexane and n-decane + n-hexane at 298.15K. The calculated isothermal compressibility was compared with the theoretically calculated values using hard sphere equation of state and Flory’s statistical theory and a satisfactory agreement was found. Kalra et al. [38] studied the molecular interactions in mixtures of quinoline with some aromatic hydrocarbons using ultrasonic, dielectric and viscometric methods. From the study they concluded that strong specific interactions resulting from H-bond formation, closer molecular arrangement, donor acceptor interaction and self association of quinoline exists between unlike molecules. Chauhan et al. [39] studied ultrasonic velocity and viscosity in a binary mixture of acetonitrile with propylene carbonate. The excess compressibility was evaluated and the negative nature of excess compressibility revealed that strong dipole-dipole interaction existed in the binary mixture.

Rout and Chakravortty [40] studied the molecular interaction existing in binary mixtures of acetylacetone with isoamyl alcohol, benzene and carbon
tetrachloride at four temperatures. The excess thermodynamical functions were evaluated from ultrasonic velocity, viscosity and density measurements. The nature and sign of excess functions indicated that strong dipole-induced dipole interactions were present in acetylacetone + carbon tetrachloride mixture while the interactions present in the other two systems were weak. Rajendran and Marikani [41] measured ultrasonic velocities in liquid mixtures of aniline with methanol, ethanol and phenol at 303.15K. From nature of excess compressibility and excess internal pressure they found that hydrogen bond interaction was present in aniline-methanol and aniline-ethanol binary systems while a 2:1 complex formation was predominant in aniline-phenol mixture. Lafuente et al. [42] studied the excess compressibilities of binary mixtures of several isomers of chlorobutane with isomers of butanol. From these observations they found that negative excess compressibility values might be due to better packing of the molecules in the mixture that could lead to a smaller compressibility than that of the ideal mixture.

Chauhan et al. [43] calculated several acoustical parameters in the binary mixture of acetonitrile + propylene carbonate by measuring ultrasonic velocity and density. The nature and behaviour of acoustical parameter like Rao’s constant, Wada’s constant etc. revealed the absence of any complex formation and the presence dipole-dipole interactions in this system. Nikam et al. [44] studied the acoustical properties of nitrobenzene with several alcohols at 303.15K. The excess functions like excess compressibility and excess intermolecular freelength were found to be negative in all these systems, which showed the presence of strong dipole-dipole type molecular interactions between nitrobenzene and alcohols. Chauhan et al. [45] measured ultrasonic velocity, density and viscosities in the binary mixtures of
methanol with dimethyl sulfoxide and dimethyl formamide, and dimethyl sulfoxide with dimethyl formamide at 25, 35 and 45°C. The excess functions revealed that hydrogen bond interactions were present in methanol + dimethyl sulfoxide and methanol + dimethyl formamide systems where as both dipolar and hydrogen bonding interactions were present in dimethyl sulfoxide + dimethyl formamide systems.

Gupta and Shukla [46] studied molecular association in binary mixtures of dioxan with formic acid, salicylic acid and benzoic acid using ultrasonic velocity data. The non-linear variations of velocity, intermolecular frelength, specific acoustic impedance and Rao's constant supported the existence of complex formation in these binary systems. Rajendran [47] carried out volumetric, viscometric and ultrasonic behaviour of binary mixtures of n-heptane with some isomeric alcohols at 298.15K. In these measurements they found that the strength of intermolecular interactions decreased with increase in size of alcohol molecules and complex formation was absent in these systems.

1.2.2 Ultrasonic absorption in binary liquid mixtures

Willis [48] measured ultrasonic absorption and velocity in the binary mixtures of water-acetone, water-ethyl alcohol, acetone-ethyl alcohol and glycerol-water systems in the frequency range of 3.8 to 19.2MHz using optical method. In these mixtures, $\alpha / f^2$ ($\alpha$-absorption coefficient and $f$ the frequency) was found to be independent of frequency and no measurable dispersion of acoustic velocity was observed. Also, absorption peaks were observed in acetone-water and ethyl alcohol-water systems at intermediate concentrations and
absorption peaks did not shift with frequency. Absorption peaks were absent in acetone-ethyl alcohol and glycerol-water systems. Burton [49] studied the absorption and velocity of sound in binary mixtures of water with alcohols, glycols and glycol ethers in the frequency range of 5-25MHz using optical diffraction method. They observed absorption peaks at intermediate concentration of water and that the magnitude of absorption increased as one progresses from ethyl to butyl derivative. Sette [50] studied the ultrasonic absorption in binary mixtures of nitrobenzene with benzene, chloroform, chlorobenzene, toluene, acetone, methyl alcohol and ethyl alcohol. They observed that the value of $\alpha/f^2$ decreased quickly when a small quantity of nitrobenzene was added to highly absorbing liquids such as benzene, carbon tetrachloride, chloroform, etc. Also they observed that in the binary mixtures of chlorobenzene and toluene with nitrobenzene $\alpha/f^2$ was running between two pure component values. In the binary systems of nitrobenzene with alcohols, the plot of $\alpha/f^2$ vs mole fraction of nitrobenzene had a maximum at an intermediate concentration. In the light of these observations Sette [50] concluded that in the case of unassociated liquid mixtures, energy loss was mainly due to collision between two dissimilar molecules and when associated liquid like alcohol was added to nitrobenzene, the nitrobenzene molecules altered the molecular structure of alcohol. Storey's [51] detailed study of ultrasonic absorption in water-ethyl alcohol mixture at 0 and 10$^\circ$C at three different frequencies of 22.5, 37.5 and 52.5MHz showed that the absorption peak at intermediate concentration is due to the interaction between molecules of the two components leading to the partial development of a structure or complex in the liquid with a composition of four molecules of water to one of alcohol. He also
pointed out that the magnitude of absorption increased rapidly as the temperature was lowered and decreased as frequency increased.

Romanov and Solov’ev [52] developed a theory to estimate the absorption of sound waves in binary associated liquid mixtures. They calculated the absorption due to concentration fluctuations, which were treated as regions of variable concentration in a continuous medium. The agreement between theoretical values and experimental absorption of water-alcohol mixtures was found good. Thamsen [53] evaluated ultrasonic absorption in the binary mixture of water with 2-chloro-ethanol in the temperature range of 0 to 25°C and over a frequency range of 12 to 92MHz by pulse method. Absorption peaks were also observed in this system at intermediate concentrations as observed in water-alcohol systems [49]. The results were explained on the basis of the relaxation phenomena involved in the molecular association and the relaxation parameters were calculated using single relaxation theory. On the basis of relaxation mechanism, Thamsen [53] pointed that the excess absorption is due to complex formation and molecular association. Andreae et al. [54] studied ultrasonic absorption in binary mixtures of aqueous solutions of several amines, alcohols, ketones and ether. Four theoretical models were used to discuss the experimental results. On the basis of these models, Andreae et al. [54] concluded that as the concentration of solute increases from zero, there is a rapid breakdown of water structure appearing as a sharp rise in sound velocity. As the concentration of the solute increases the equilibrium between free water and water in complexes begins to give rise to ultrasonic absorption. Solovyev et al. [55] carried out ultrasonic studies in binary mixtures of ethanol with various ethyl halides over a frequency range at 15-165MHz. The results showed that a single relaxation exists in ethanol-
ethyl chloride mixture in this frequency range. Also, an absorption peak was observed at intermediate concentration of ethyl chloride. They explained the excess sound absorption based on the disruption of the local order in one of the component by the presence of the molecule of the other component.

Blandamer et al. [56-60] studied ultrasonic absorption in binary mixtures of various alcohols and amines with water in the frequency range of 1.5 to 230MHz. Binary mixtures of water and alcohol in these studies showed an absorption peak at intermediate concentration of alcohol. The absorption of a given mixture at a fixed temperature decreased with increase in frequency. The sudden increase in sound absorption due to the addition of alcohol was attributed to the inability of water to accommodate all the alcohol molecules. In the case of amine-water mixture, an absorption peak was observed at low amine concentration, which shifted to lower amine concentration with increase in the size and chain branching of the alkyl group. The relaxation mechanism in these mixtures was due to rotational isomerism. Hunter et al. [61] studied that relaxation process in binary mixtures of Kenser liquids like carbon disulphide, methyl chloride, methyl bromide, benzene, and carbon tetrachloride over a frequency range of 40 to 800MHz. They observed vibrational relaxations in these systems and average relaxation frequency was calculated for each binary system. This average relaxation frequency was an indication of the overall efficiency of various collisions occurring in the liquid mixture. The collision between two unlike molecules are always more efficient than collision between molecules of the same species for de-exciting a molecule. Samal et al. [62] determined the ultrasonic absorption in binary mixtures of benzene, carbon tetrachloride, methyl iodide,
chlorobenzene, nitrobenzene and ethyl iodide with carbon disulphide as a common component. Hunter et al. [63] studied the absorption in binary mixtures of Kenser liquids and explained the concentration fluctuations of absorption. They also concluded that if there were no molecular interaction between two unlike molecules, in a binary mixture the plot of $\alpha/f^2$ vs concentration of one component could be a straight line running between the absorption of the two liquids in their pure state.

Bhadra and Basu [64] evaluated ultrasonic absorption in water-alcohol mixture by the method of streaming. These results were compared with those obtained by other methods. They observed absorption peaks at intermediate concentration of alcohols. The absorption peaks were explained in terms of dipole moment and dielectric constant. They pointed out that absorption decreases as the dipole moment increases. Also stronger the dipole moment stronger the force of attraction between water and alcohol molecules since they are all polar in nature. When alcohol is gradually added to water, the strength of attractive forces among the water molecules gradually decreases. This is due to different orientations of the dipole belonging to the two groups causes a reduction of intermolecular coupling strength and consequently higher the absorption. At a particular molar percentage, the resultant attractive force attains a minimum value, which means that the dipole moment and dielectric constant also reach a minimum and hence absorption attains a maximum value. As the alcohol concentration is increased, the dielectric constant increases and hence absorption decreases. From these findings, Bhadra and Basu [64] concluded that higher the dielectric constant lower the ultrasonic energy absorption.
Atkinson et al. [65] studied ultrasonic absorption in binary mixtures of tetrahydrofuran and water at 25°C over a frequency range of 0.3 to 630MHz. Frequency dependence of absorption was quantitatively explained by the fluctuation theory of Romanov and Solov'yev [52]. Two relaxation frequencies were calculated and it was found that the above theory correctly predicted the low frequency limit of excess absorption.

Gupta and Stumpf [66] determined ultrasonic absorption and velocity in binary mixtures of heavy water, butyl alcohol and phenol with pyridine. In these experiments, they observed that an associated complex of pyridine with heavy water was formed and hence an absorption peak was observed. In pyridine-butyl alcohol system an absorption minimum was present in the region of 0.5-mole fraction of pyridine. In pyridine-phenol system the absorption dropped rapidly as phenol was added to pure pyridine. Kaul et al. [67] studied ultrasonic relaxation in binary mixtures of benzyl amine with o-chlorophenol in the frequency range of 3 to 15MHz. They detected a single relaxation process and the absorption peak in this system was attributed to a hydrogen bonded complex formation. Madigosky and Warfield [68] measured ultrasonic absorption in a mixture of dimethyl sulfoxide and water over the temperature from -80 to 25°C and in the frequency range of 5 to 200MHz. No complex formation was found and a single relaxation time was calculated with activation energy of 7.3 kcal/mol. At low temperatures they observed shear and volume relaxation which was explained on the basis of single relaxation time. Miecznik [69] studied absorption of ultrasonic waves in aqueous solutions of n-ethylacetamide in the frequency range of 10 to 1000MHz. A single relaxation time was observed in this frequency range and it was attributed to the
formation and disintegration of molecular complexes. The value of the activation
enthalpy indicated that molecular complexes were formed as a result of interaction
through hydrogen bond. A peak in the $\alpha / f^2$ vs concentration plots supported
complex formation and the peak value of the absorption decreased with increase in
frequency. Subrahmanyan and Sarma [70] measured ultrasonic absorption in binary
mixtures of p-cresol and m-cresol with ethanolamine over the temperature range of
40 to 50°C and frequency between 3 and 21 MHz. Absorption peaks were observed in
these systems and the value of peak absorption decreased with increase in temperature
and was found to be independent of frequency. They explained the existence of
the absorption peak on the basis of molecular association due to hydrogen
bonding between protons of ethanolamine and line pair electrons of donor atoms
in p-cresol and m-cresol.

1.2.3 Acoustic non-linearity parameter B/A in liquids and liquid mixtures

Adler and Hiedemann [71] determined the acoustic non-linearity parameter
B/A for water and m-xylene from optical determination of the initial pressure
amplitudes and second harmonic component of a distorted 3 MHz ultrasonic wave at
various distances and initial pressure amplitudes. Hagelberg [72] measured the velocity
of sound in water over a wide range of temperature and pressure, and calculated the
non-linearity parameter B/A in the temperature range from 0 to 80°C and at a
pressure of about 10000 kg/cm². Lisnyanskii et al. [73] studied the relationship
between the structure of aqueous solutions of tertiary butyl alcohol and the non-
linearity parameter. Narayana and Swami [74] studied the non-linear acoustical
properties of n-amyl alcohol. They obtained the B/A values of n-amyl alcohol over
273 to 373K temperature range and 0 to 96.5 MPa pressure range. Sound velocity and B/A in fluorocarbon fluids were studied by Madigosky et al. [75]. Very low sound velocities and very high B/A values were observed in these fluorocarbon fluids. Determination of the non-linearity parameter B/A for some biological media was carried out by Law et al. [76]. Endo [77] derived an empirical relation for non-linearity parameter of liquids using thermodynamical constants. Sharma [78] made an attempt to relate the non-linearity parameter with Rao's constant. Cobb [79] discussed the finite amplitude method for the determination of acoustic non-linearity parameter B/A in liquids. Law et al. [80] compared the finite amplitude and thermodynamical methods of B/A measurements in biological materials. It was found that the agreement achieved between the two methods was within a fraction of a percent for liquid samples and within 10% for the soft tissues studied. Apfel [81] derived a relation which gives the effective non-linearity parameter of a system of immiscible liquids. Cain et al. [82] discussed ultrasonic methods for the measurement of non-linearity parameter in fluid-like media. They suggested several improvements on ultrasonic B/A measurement techniques. Hartmann et al. [83] calculated the B/A values for n-alkane liquids. It was found that alkane chain length dependence of B/A was not linear but B/A decreased as the chain length increased.

Yoshizumi et al. [84] made a physiochemical evaluation of the non-linearity parameter B/A for media predominantly composed of water. Endo [85] derived a relation for the prediction of non-linearity parameter B/A of a liquid from equation of state. It was found that the calculated values of B/A were in fairly good agreement with the experimental values. Sarvazyan et al. [86] studied the parameter B/A of aqueous solutions of some amino acids and proteins. Chalikian et al. [87]
studied the temperature dependence of the non-linearity parameter of aqueous solutions of amino acids. Sehgal [88] developed simple relations that relate acoustic non-linearity parameter to molecular properties, namely, internal pressure, free energy of binding, effective Van der Waal’s constants, translational diffusion coefficient and rotational correlational time.

1.3 Present Study

Ultrasonic velocity in and density and viscosity of the following binary liquid systems were measured at four different temperatures of 30, 40, 50 and 60°C.

1. Methyl Ethyl Ketone (MEK) + Nitrobenzene
2. Methyl Ethyl Ketone (MEK) + Bromobenzene
3. Methyl Ethyl Ketone (MEK) + Chlorobenzene
4. Methyl Ethyl Ketone (MEK) + Toluene
5. Methyl Ethyl Ketone (MEK) + Benzene

Various thermo-acoustical parameters like isentropic compressibility, intermolecular free length, internal pressure, and specific acoustic independence were computed. Also various excess thermodynamical functions were evaluated. The sign and magnitude of the excess functions were used to determine the nature, type and strength of intermolecular interactions present in these binary mixtures. Ultrasonic absorption measurements were carried out in these binary systems at different temperatures. The experimental values were compared with the values predicted using Pinkerton [89], Bauer [90] and Bauer-Sette [91] theories. Theoretical evaluation of acoustic nonlinearity parameter B/A was done in these binary systems
using Tong and Dong theory [92]. Molecular interactions in these systems were explained based on excess isentropic compressibility and excess non-linearity parameter.

Also acoustic non-linearity parameter $B/A$ was calculated in the following binary liquid mixtures making use of high-pressure ultrasonic velocity data of these systems available in the literature [93-97].

1. Benzene + Aniline
2. Benzene + Nitrobenzene
3. Chlorobenzene + Aniline
4. Chlorobenzene + Bromobenzene
5. Benzonitrile + Nitrobenzene
6. Toluene + O-Xylene
7. Toluene + Aniline

Molecular interactions existing these systems were discussed in the light of excess isentropic compressibility and excess non-linearity parameter. Sehgal's relations [88] for evaluating molecular properties like internal pressure, effective Van der Waal's constant, rotational correlation time and diffusion coefficients for pure liquids were extended to these binary mixtures.
References


