Chapter 2
Review of previous work
This chapter presents a brief review of binary mixtures containing alkoxy alkanols and alcohols.

2.1 REVIEW OF PREVIOUS WORK

Firstly, it was suggested by van der Waal around 1887, that shape of the liquid molecules determine the molecular interactions. A considerable improvement has been made in the prediction of thermodynamic properties of molecular liquids. However, complete knowledge about the liquid state chemistry is still lacking. In the studies of liquid mixtures, attractive forces like dipole-dipole interactions, hydrogen bond type forces and dipole-induced-dipole interactions leads to non-ideal effects (Candler, 1978). However, quantitative estimation of such interactions is important in order to achieve a fundamental understanding about the liquid state properties which are useful in many specific disciplines like chemistry, physics, engineering, biology, etc. Several noteworthy contributions have been made in this area by many scientists, but still it is not complete. A number of theories have been proposed to compute the useful thermodynamic properties of liquids and liquid mixtures. Parallel to this, many experimental techniques have also been developed.

In the field of solution chemistry, an extensive literature survey reveals that considerable data have been accumulated on thermodynamic, transport, acoustic and spectroscopic studies of liquid-liquid mixtures. In the last two decades, much work has been devoted to the study of density, speed of sound and viscosity in the binary liquid mixtures containing alkoxy alkanols or alcohol as one of the components. There are number of scientific reports on mixture containing alkoxy alkanols or alcohols with other organic solvents but it is beyond the scope of this thesis to give an entire coverage of the published literature. Only the representative papers dealing with binary mixtures of alkoxy alkanols with alcohols will be cited. However, in the present thesis, emphasis will be given on the measurement of different properties, viz. densities, speeds of sound, viscosities and spectroscopic techniques (FT-IR, $^1$H NMR) of the binary liquid mixtures of alkoxy alkanols with alcohols. Using the data observed from these properties, the mixing quantities have been evaluated to investigate their effect in terms of the binary interactions. To best of our knowledge, not much work has been reported on the study of binary mixtures of alkoxy alkanols and alcohols at several temperatures using a wide variety of techniques as in the present study. These considerations led us to undertake the investigation of the effect of alkyl chain length at different temperatures.
Recently, there exists a substantial and growing literature dealing with the physicochemical properties of the aqueous or non-aqueous mixtures of alkoxy alkanols, normal and branched alcohols. However, the numbers of scientific reports on mixtures containing alkoxy alkanols, polyethers or branched ethers as one of the components are not many as compared with the number of papers on other types of mixtures.

Knowledge of the thermophysical properties of these liquids is of high interest on account of their wide usage in science and industrial processes. These properties are crucial for the design of chemical processes as well as for progress in the thermodynamic theories of the liquid state. The densities and viscosities as functions of temperature and pressure, and their derivatives render some insight in the molecular structure of liquids and provide information on intermolecular interactions.

Shindo and Kusano, 1979 evaluated the densities and refractive indices of aqueous mixture of 2-isopropoxy ethanol as a function of composition at 298.15 K. the data obtained were utilized to test refractive index mixture rules. Results show that intramolecular hydrogen bonding ability of molecules seems to have great influence on intermolecular interaction between unlike molecules.

Measurements of excess molar volumes for binary mixtures of 1-propanol, 1-butanol, 1-hexanol, 1-octanol and 1-decanol + hexane were reported by Heintz et al., 1985. The results have been determined with a vibrating tube densitometer. The accuracy to be possibly achieved with such an apparatus is investigated including corrections for evaporation losses into the vapour space during the preparation of the mixtures.

Rao and Verrall, 1987 have measured the ultrasonic speeds and densities data of binary systems of water + 2-butoxy ethanol, 2-butoxy ethanol + benzene and 2-butoxy ethanol + decane are reported for temperatures of 298.15, 313.15 and 328.15 K. Adiabatic compressibility coefficients, apparent molar volumes and apparent molar compressibilities were calculated from these data. Excess adiabatic compressibility properties were evaluated using volume fraction weighting of the individual component properties to estimate ideal mixture behavior. These result are compared with the data obtained based on the use of mole fraction weighting of the individual component properties for the ideal behavior value. A sharp ultrasonic speed maximum and compressibility minimum is observed at low 2-butoxy ethanol concentration in mixtures of water + 2-butoxy ethanol at all temperatures. These maxima in ultrasonic
velocities and minima in adiabatic compressibilities are attributed to the formation of “clathrate-like” structures of water and alcohol. A shift of the ultrasonic velocities maximum towards lower concentrations of 2-butoxy ethanol was observed with increase of temperature. A minimum in the ultrasonic velocities and a maximum in adiabatic compressibility coefficients values are observed in systems of 2-butoxy ethanol + benzene and + decane. These results are discussed in terms of the breakdown of associated alcohol structure and the interstitial location of hydrocarbon molecules in alcohol aggregates.

The excess molar volumes and excess molar heat capacities have been determined as functions of mole fraction at atmospheric pressure and 298.15 K for six (alkoxy ethanol + di-n-butylether) mixtures by Cobos et al., 1987. The alkoxy ethanol were 2-methoxy ethanol, 2-ethoxy ethanol, 2-butoxy ethanol, 2-(2-methoxyethoxy) ethanol, 2-(2-ethoxyethoxy) ethanol and 2-(2-butoxy-ethoxy) ethanol. The excess molar volumes decrease in magnitude as the alkyl chain length of the alkoxy ethanol increases for the two homologous series. They are positive except for the mixtures containing 2-butoxy ethanol and 2-(2-butoxyethoxy) ethanol. For these, they are positives only at low mole fractions of alkoxy ethanol.

Molar excess volumes, molar excess enthalpies and molar excess heat capacities of mixtures of 2-methoxy ethanol with 2-ethoxy ethanol, 2-butoxy ethanol and 2-(2-methoxyethoxy) ethanol and molar excess enthalpies of mixtures of 2-methoxy ethanol with 2-(2-ethoxyethoxy) ethanol and 2-(2-butoxyethoxy) ethanol were determined as a function of composition at 298.15 K and atmospheric pressure by Cobos et al., 1989. Owing to the similar chemical nature of the components, the excess functions of these mixtures are relatively small.

Ultrasonic speeds have been measured in 2-butoxy ethanol + water at 298.15 K, across their entire composition range by Douheret et al., 1990. Their values have been combined with those of the molar volumes to obtain estimates of the product of the molar volume and the isentropic compressibility. The values that were obtained for the excess molar quantities are analyzed using a segmented composition model.

Liquid binary mixture containing oxygen (-O-) and hydroxyl (-OH) functional groups have been discussed by Cobos et al., 1990. For mixtures of 3,6,9-trioxaundecane + 1-propanol, 1-butanol 1-pentanol, 1-heptanol and 1-nonanol at 298.15 K. Excess values are positive over whole mole fraction range and magnitude increases as chain length of alcohols increases.
Davis and Chacon, 1991 reported the excess molar volumes at 298.15 K for 2-isopropoxy ethanol + water and 2-isobutoxy ethanol + water across their entire composition range. The data have been compared to those for their normal alkyl analogs in order to assess the effects of both $\alpha$- and $\beta$-chain branching. The results are discussed in terms of the relative abilities of the amphiphiles to form structured aggregates.

Reddy et al., 1994 have measured the excess molar volumes for the mixtures of 2-ethoxy ethanol and 2-butoxy ethanol with alcohols at 308.15 K. Excess volumes are measured for mixtures of 2-butoxy ethanol with aliphatic alcohols as a function of mole fraction at 308.15 K and atmospheric pressure using batch dilatometric technique. The aliphatic alcohols include methanol, n-propanol, n-butanol, isobutanol, tert-butanol and n-pentanol. The measured excess volumes are negative over the entire range of composition in all the systems except for the system, 2-butoxy ethanol + n-pentanol, in which excess molar volumes positive over the entire range of composition. Further, increase in chain length of alcohol results in an increase in magnitude of the excess function. The data are interpreted on the basis of hydrogen bonding interaction between unlike molecules.

Parsad and Venkateswarlu, 1994 have reported measurements of ultrasonic speeds of binary mixtures of 2-butoxy ethanol with benzene, toluene, o-xylene, p-xylene, chlorobenzene and nitrobenzene at 303.15 K.

Krishnaiah et al., 1994 measured the densities, speeds of sound and viscosities for binary mixtures formed from hexadecane with 1-pentanol, 1-hexanol and 1-heptanol at 298.15, 308.15, 318.15 K covering the entire mole fraction range. From the experimental data adiabatic compressibility, intermolecular free length, molar sound speed and acoustic impedance have been computed. These parameters are used to discuss the nature and extent of intermolecular interactions between the component molecules.

Aminabhavi and Gopalakrishna, 1995 have measured densities, viscosities and refractive indices for the mixtures of 2-ethoxy ethanol with alcohols.

Raman et al., 1995 have reported measurements of excess molar volumes, speeds of sound and viscosities of binary liquid mixtures of 2-methoxy ethanol with branched and alicyclic alcohols and some aromatic hydrocarbon at 303.15 K. The sign and magnitude of these quantities have been used to discuss the type and nature of binary interactions. The nature of binary liquid mixtures containing 2-methoxy
ethanol and aliphatic alcohols has also been investigated at 298.15 K by Reddy et al., 1995. All the systems are characterized by endothermic mixing over the entire composition range.

In recent reports, Serna et al., 1995 have calculated excess molar volumes from densities at 298.15 K for 1-propanol and 1-hexanol + butylmethylether, dipropylether and dibutylether. The excess molar volumes are negative over whole mole fraction range. For each monoether, the value of excess molar volume decreases as the chain length of n-alkanols increases. However, for butylmethylether, the excess molar volume is more positive than that of the immediately higher symmetrical dipropylether.

Pal et al., 1997a measured as a function of composition at 298.15 K using a dilution dilatometer, are reported for the binary mixtures of 1-propanol and 2-propanol with propane-1,2-diol, 1-methoxy-2-propanol, 1-ethoxy-2-propanol and 1-tert-butoxy-2-propanol. Excess molar volumes are negative over the whole mole fraction range and rather symmetrical for mixtures with 1-propanol. In another study of Pal and Singh, 1997b; 1997c determined the excess molar volumes, viscosities and ultrasonic studies of binary mixtures of 2-isopropanol with water over the entire composition range and at temperatures 298.15, 308.15, 318.15 K. Excess molar volumes of binary mixture of methanol, 1-propanol, 1-pentanol + 2,5-dioxahexane or 5, 8, 11-trioxaheptadecane or 2-isopropanol at 298.15 K were measured by Pal and Sharma, 1998. The results are discussed on the basis of molecular interactions between the components of the mixtures.

Francesconi et al., 1999 have reported the excess molar enthalpies and excess molar volumes of diethyl carbonate + some alkoxy ethanol mixtures as a function of mole fraction of diethyl carbonate at (298.15 and 313.15)K. The alkoxy ethanol are 2-methoxy ethanol, 2-ethoxy ethanol, 2-butoxy ethanol, 2-(2-methoxyethoxy) ethanol, 2-(2-ethoxyethoxy) ethanol and 2-(2-butoxyethoxy) ethanol, respectively. They have suggested that the values of excess molar enthalpies are increasing with increasing temperature due to hydrogen bonding, although the differences of heat of mixing among various (alkoxyethoxy) ethanol are being very small. The excess molar volumes values are highly positive for 2-alkoxy ethanol with diethyl carbonate, whereas the mixtures 2-(2-alkoxyethoxy) ethanol + diethyl carbonate shows sign inversion.
Densities and viscosities of seven glycol ethers, consisting of 1-methoxy-2-propanol, 3-methoxy-1-butanol, ethylene glycol dimethyl ether, ethylene glycol diethyl ether, diethylene glycol dimethyl ether, ethylene glycol tert-butyl methyl ether, diethylene glycol diethyl ether have been measured from 288.15 to 343.15 K by Ku and Tu, 2000. The data were correlated using simple expression and also used to develop a model for viscosity based on Hildebrand fluidity equation.

Sastry et al., 2000a have measured the excess molar volumes, excess enthalpies and dielectric constants of the binary mixtures of alkanols with alkoxy ethanols at 298.15 K.

Excess molar volumes and viscosities for 2-propoxy ethanol and of 2-isoproxy ethanol with methanol, 1-propanol, 2-propanol and 1-pentanol at 298.15 K have been reported by Pal and Dass, 2000. The systems exhibit negative and positive excess molar volumes. The viscosity data have been correlated with the equations of Kendall and Monroe, Grunberg and Nissan, Tamura and Kurata, Hind, Katti and Chaudhary and McAllister.

The densities, viscosities and speeds of sound were measured for binary mixtures of methyl methacrylate + 2-methoxy ethanol, + 2-butoxy ethanol, + 1-butanol at 298.15 and 308.15 K by Sastry and Patel, 2000b. The mixture viscosities were correlated by Grunberg-Nissan, McAllister and Auslander equations. The sound speeds were predicted by using free length and collision factor theoretical formulations and Junjie and Nomoto equations. The excess viscosities and excess isentropic compressibility were also calculated.

Densities and viscosities have been reported by Weng, 2000 for the binary mixtures of butylamine with 1-butanol, 1-pentanol, 1-hexanol, 1-heptanol and 1-octanol at 303.15 K, 313.15 K and 323.15 K over the entire composition range. Excess molar volumes and viscosities deviations were calculated at various temperatures. Both excess molar volumes and viscosity deviations were negative for all investigated systems. A Redlich-Kister type equation was applied to fit the isothermal excess volumes and viscosity deviations and McAllister’s three-body and four-body interaction models were also used to correlate the kinematic viscosities.

Rao et al., 2000, have reported measurements of excess molar volumes, speeds of sound of 2-methoxy ethanol, 2-ethoxy ethanol and 2-butoxy ethanol with ethyl acetate and butyl acetate at 298.15 K.
Excess molar volumes and viscosities have been reported by Ku *et al.*, 2001 for the binary mixtures of 1-methoxy-2-propanol, 1-propoxy-2-propanol, 1-butoxy-2-propanol, dipropylene glycol monopropyl ether and dipropylene glycol monobutyl ether with ethanol at 298.15, 308.15 and 318.15 K over the whole concentration range. Deviations in viscosity for the mixtures have been derived from viscosity data. McAllister’s multibody interaction model is used to correlate the binary kinematic viscosities. For each of the mixture studied, the values of excess molar volume are negative over the whole mole fraction range, symmetrical for mixtures with monoethers and slightly skewed towards the region of high mole fraction of ethanol for mixtures with diethers. There is obvious increase in the magnitude of deviations in viscosity with alkyl chain length of the increase in the number of -OC$_3$H$_6$ group in the glycol molecules.

In another study by Cobos *et al.*, 2001; 2002 excess molar volumes for binary mixtures of methanol, ethanol, 1-propanol, 1-butanol, 1-pentanol, 1-hexanol, 1-heptanol and 1-octanol with dipropylamine over the entire composition range at 298.15 K have been reported. All the excess volumes have large negative deviation over the whole mole fraction range, indicating strong interactions between unlike molecules, which are more important for the system involving lower alkanols, characterized by the most negative excess molar volume. The excess molar volume curves are nearly symmetrical and excess molar enthalpies of the mixtures studied are consistently described by the ERAS model. The strongest interactions between unlike molecules are encountered which are confirmed by ERAS parameters.

George and Sastry, 2003 have reported measurements on densities, speeds of sound, viscosities and relative permittivities for binary mixtures of alkoxy ethanols (2-methoxy ethanol, 2-ethoxy ethanol and 2-butoxy ethanol) + benzene, + toluene, +(o-, m-, and p-) xylenes, + ethylbenzene, and + cyclohexane at different temperatures. The excess molar volumes, excess isentropic compressibilities, deviations in dynamic viscosity, speeds of sound and relative permittivities have been calculated across the entire range of mole fraction.

Densities, viscosities and refractive indices of the binary mixtures of diethylene glycol dimethyl ether with 1-propanol, 1-butanol, 2-methyl-1-propanol and 2-methyl-2-propanol have been measured at different temperatures 298.15, 303.15 and 308.15 K by Aminabhavi *et al.*, 2003. From the measured values, deviations in
viscosity, molar refraction and isentropic compressibilities have been calculated. These data have been used to discuss the mixing behavior of the components.

Densities and ultrasonic speeds of binary mixtures of tetrahydrofuran with alkanols (1-hexanol, 1-octanol and 1-decanol) have been measured over the whole composition range at 308.15 K by Ali et al., 2004.

Roy et al., 2004 have measured the densities and ultrasonic velocities of binary mixtures of 2-butoxy ethanol with n-butylamine, sec-butylamine, tert-butylamine, n-hexylamine, n-octylamine and cyclohexylamine at 308.15 K. From the measured values of densities and ultrasonic velocities, various acoustical parameters like acoustical impedance, isentropic compressibility, intermolecular free length, relative association have been computed. The results have been discussed in terms of various interactions present in these mixtures and self-association in the components.

Kinart et al., 2005a have reported measurements of relative permittivities and densities of numerous binary mixtures of dipropylene glycol monomethyl ether with 2-methoxy ethanol, propylene glycol monobutyl ether and dipropylene glycol monobutyl ether at five temperatures between 293.15 and 313.15 K. The excess molar volumes and the deviations in relative permittivity were calculated from these experimental data. The results are discussed in terms of molecular interactions in the bulk of studied binary mixtures.

Viscosities and densities of binary mixtures of tert-butyl ethyl ether at different temperatures with propylene glycol monomethyl ether, dipropylene glycol monomethyl ether, tripropylene glycol monomethyl ether, 2-methoxy ethanol, 2-(2-methoxyethoxy) ethanol, 2-{2-(2-methoxyethoxy)ethoxy} ethanol and with 2-ethoxy ethanol, 2-(2-ethoxyethoxy) ethanol, 2-{2-(2-ethoxyethoxy)ethoxy} ethanol have been measured as a function of composition (Kinart et al., 2005b; 2006a; 2006b). The viscosity data were correlated with equations of Grunberg-Nissan, Auslaender and McAllister. Also, densities at 293.15, 298.15, 303.15, 308.15 and 313.15 K of the binary liquid mixtures made of tert-butyl ethyl ether with either 2-ethoxy ethanol, or 2-(2-ethoxy)ethoxy ethanol, or 2-[2-(2-ethoxy)ethoxy]ethoxy ethanol have been measured over the whole mixture composition (Kinart et al., 2006c).

Das and Roy, 2006 have determined densities, viscosities and speeds of sound of binary mixtures of 2-ethoxy ethanol with methanol, ethanol, 1-propanol, 1-butanol, 1-pentanol, 1-hexanol, 1-heptanol and 1-octanol over the entire range of mole fractions at 298.15 K. The excess molar volumes, deviations in viscosity and excess
energy of activation for viscous flow have been investigated from these experimental
densities and viscosities values. The viscosity data have been correlated by Grunberg-
Nissan, Tamura-Kurata and Hind correlation equations. The deviations in isentropic
compressibility were also calculated using the measured densities and speeds of
sound. The results are discussed and interpreted in terms of molecular package,
structural effects and specific interaction predominated by hydrogen bonding. The
speeds of sound were predicted by using Nomoto equation, Van Dael and Vangeel
ideal mixing relations, free length and collision factor theoretical formulations and the
impedence dependence relation. The excess properties are found to be either
negative or positive depending on the molecular interactions and the nature of liquid
mixtures.

Densities, viscosities and ultrasonic speeds were measured by Roy et al., 2007
for binary mixtures of 2-butanone, + 2-methoxy ethanol, + 2-ethoxy ethanol + 2-
butoxy ethanol, + isopropylamine, + cyclohexylamine and + diethylamine over the
entire composition range at 298.15 K. From the experimental values of densities,
ultrasonic speeds and viscosities the values of excess molar volumes, deviations in
viscosity and deviations in isentropic compressibility have been calculated. The
excess or deviation properties were fitted to the Redlich-Kister polynomial equation
to obtain their coefficients and standard deviations. To explore the nature of the
interactions, various thermodynamic parameters have also been derived from the
densities and ultrasonic speeds data. McAllister’s multibody interaction model along
with the Heric-Brewer model has been used to correlate kinematic viscosities of the
binary mixtures. The excess or deviation properties were found to be either negative
or positive depending on the molecular interactions and the nature of liquid mixtures
have been discussed in terms of molecular interactions and structural changes.

Pal and Gaba, 2007a have been measured the excess molar volumes and
kinematic viscosities as a function of composition for binary mixtures of 1-methoxy-
2-propanol, 1-ethoxy-2-propanol, 1-propoxy-2-propanol, 1-butoxy-2-propanol and 1-
tert-butoxy-2-propanol with 1-butanol and 2-butanol at 298.15 K and atmospheric
pressure. Excess molar volumes for binary mixtures of (n-alkanol + 1-methoxy-2-
propanol, 1-ethoxy-2-propanol, 1-propoxy-2-propanol, 1-butoxy-2-propanol and 1-
tert-butoxy-2-propanol) have been measured as a function of composition using a
continuous dilution dilatometer at 298.15 K and atmospheric pressure over the full
range of composition. The n-alkanols were methanol, ethanol and 1-propanol. The
excess molar volumes are negative across the entire range of composition for all the systems with 1-butanol, for the system 2-butanol + 1-butoxy-2-propanol and positive for the systems 2-butanol + 1-methoxy-2-propanol and 1-propoxy-2-propanol and changes sign for the systems 2-butanol + 1-ethoxy-2-propanol and 1-tert-butoxy-2-propanol. From the experimental data, the deviations in dynamic viscosity have been calculated. In addition, viscosity of above mixtures have been measured (Pal and Gaba, 2007b; 2007c). The viscosity values for each of the binary mixture studied are positive over the whole composition range. For all the cases, except propylene glycol tert-butyl ether, viscosity increases in a positive direction with increase in chain length of n-alkoxy propanols. Deviations in viscosity are found to be positive for all binary mixtures. The results are discussed in term of molecular interactions.

Viscosities at T = (293.15, 298.15, and 303.15) K in the binary mixtures of ethyl tert-butyl ether with 2-ethoxy ethanol, 2-(2-ethoxyethoxy) ethanol and 2-[2-(2-ethoxyethoxy)ethoxy] ethanol have been measured over the entire range of mixture composition by Cwiklinska et al., 2007. From the experimental data, deviations in the viscosity and excess energies of activation for viscous flow have been calculated. The viscosity data were correlated with equations of Hind et al., Grunberg and Nissan, Auslaender, and McAllister. The results were discussed in terms of intermolecular interactions and structure of studied binary mixtures.

Kinart et al., 2008a; 2008b have reported densities, viscosities and relative permittivities for mixtures of 2-propoxy ethanol and sulpholane with diethylene glycol, triethylene glycol and tetraethylene glycol and sulpholane with 2-methoxy ethanol, 2-ethoxy ethanol, 2-propoxy ethanol and 2-butoxy ethanol.

Mozo et al., 2008 have reported the densities and speeds of sound of systems formed by 2-methoxy ethanol, 2-ethoxy ethanol, 2-propoxy ethanol, or 2-butoxy ethanol and 1-butanol at 293.15, 298.15 and 303.15 K and atmospheric pressure using a vibrating tube densimeter and sound analyzer Anton Paar model DSA-5000. The densities and speeds of sound values were used to calculate excess molar volumes at those temperatures and deviations from the ideal behavior of the thermal expansion coefficients or of the isentropic and isothermal compressibilities and at 298.15 K. From the data, it is apparent that the interactional contribution to excess molar volumes are more important for systems with 2-methoxy ethanol or 2-ethoxy ethanol, while structural effects are more relevant in the 2-propoxy ethanol or 2-butoxy ethanol mixtures and that dipolar interactions decrease with the size of the 2-alkoxy
ethanol. Several methods are applied to predict speeds of sound from Jacobson’s free length, collision factor theory (CFT), Nomoto, Junjie and Van Dael equations. CFT and Nomoto’s equation provide the better predictions. Finally, 1-butanol + 2-alkoxy ethanol, or + 2-(2-alkoxyethoxy) ethanol mixtures have been studied using ERAS theory. Poorer results were obtained for systems including 2-(2-alkoxyethoxy) ethanol, which may be due to dipolar interactions and structural effects are more important in such solutions.

Sarkar et al., 2009 have calculated excess molar volumes and deviations in viscosity from experimental densities and viscosities data of the binary mixtures of 1,3-dioxane with 2-methoxy ethanol, 2-ethoxy ethanol, 2-butoxy ethanol, 2-propylamine and cyclohexylamine measured over the entire range of composition at 298.15 K. Moreover, deviations in isentropic compressibility and molar refraction have been calculated from ultrasonic speeds of sound and refractive indices of the mixture.

Densities, ultrasonic speeds and viscosities have been measured by Priya et al., 2010 for binary liquid mixtures containing methyl methacrylate + 2-methoxy ethanol, methyl methacrylate + 2-ethoxy ethanol, methyl methacrylate + 2-butoxy ethanol at 303.15 K. The adiabatic compressibility, free length, free volume, internal pressure, relaxation time, acoustic impedance and Gibbs’s free energy values have been calculated from the experimental data. These parameters are used to discuss the molecular interactions in the mixtures.

Dhondge et al., 2010 have reported the experimental data of densities, speeds of sound and refractive indices of aqueous solutions of different glycol ethers, namely, ethylene glycol iso-propyl ether, ethylene glycol monobutyl ether, diethylene glycol monomethyl ether, diethylene glycol monobutyl ether, propylene glycol monomethyl ether and dipropylene glycol monomethyl ether, over the entire composition range at temperature T = 298.15 K and atmospheric pressure. The derived parameters such as the apparent molar volumes of solute, isentropic compressibilities of solution, apparent molar isentropic compressibilities of solute, excess molar volumes of solution have been computed. The limiting apparent molar volumes of solute, limiting apparent molar isentropic compressibilities of solute and the limiting excess partial molar volumes of solute have also been obtained. The results are interpreted in terms of hydrogen bonding, solute-solute and solute-solvent interactions.
Speeds of sound of butan-1-ol or butan-2-ol (1) + 1,3-dioxolane or 1,4-dioxane (2) were reported over entire composition range at 308.15 K and atmospheric pressure by Kumar et al., 2010. The experimental data have been used to evaluate isentropic and excess isentropic compressibilities values. These values vary from positive to negative with an increase in mole fraction of 1,3-dioxolane. Two methods, Redlich-Kister and Graph theory, were used to compute and correlate isentropic compressibility values. The values were fitted to Redlich-Kister polynomial equation to derive binary coefficients and the standard errors between experimental and calculated quantities. These values were also analyzed by Graph theory, which involves the topology of the components of the mixture, to extract information about the state of components in pure and mixture states. The values calculated by Graph theory are very close to the experimental values. This shows the validity of this theory for the studied mixtures.

Densities, speeds of sound and viscosities have been measured by Dubey et al., 2010a over the whole composition range for the binary mixtures of diethylene glycol monomethyl ether with 1-hexanol, 1-octanol and 1-decanol from 293.15 to 308.15 K along with the properties of the pure components. By using, the experimental values of densities, speeds of sound, viscosities the excess molar volumes, deviations in viscosity, isentropic compressibilities, deviations in isentropic compressibility and deviations of the speed of sound have been calculated. The viscosity results have also been analyzed in terms of semi-empirical equations. Also, Dubey and Kumar, 2010b have calculated the densities, speeds of sound and viscosities of ethylene glycol monomethyl ether with 1-hexanol, 1-octanol and 1-decanol at different temperatures over the whole composition range. The results were discussed in terms of molecular interaction between the unlike molecules.

Recently, work has also been done on ethylene glycol monomethyl/diethylene triamine with 2-methyl-1-propanol, 2-propanol and 1-butanol in our laboratory by Dubey and Kumar 2011a; 2011b.

Almasi and Sarkooohaki, 2012 measured the densities and viscosities of mixtures of cyclohexanone with 2-alkanols, namely as 2-propanol, 2-butanol, 2-pentanol, 2-hexanol and 2-heptanol, as a function of composition range at T = (298.15, 303.15, 308.15 and 313.15) K and ambient pressure. Excess molar volumes and viscosity deviations were calculated and correlated by Redlich-Kister type function to derive the coefficients and estimate the standard error. For mixtures of
cyclohexanone with 2-alkanols, excess molar volumes are positive and deviations in viscosity are negative over the entire range of mole fraction. The effect of temperature and chain length of the 2-alkanols on the excess molar volumes and viscosity deviations of its mixtures with cyclohexanone is discussed.

The experimental densities, viscosities and ultrasonic speeds of anisaldehyde and alkoxy ethanol, namely, 2-methoxy ethanol, 2-ethoxy ethanol and 2-butoxy ethanol have been measured over the full range of compositions at atmospheric pressure and at different temperatures by Begum et al., 2013. From these experimental values the molar volumes, adiabatic compressibilities and intermolecular free lengths were computed and their properties along with deviations in viscosity are fitted to Redlich-Kister type equation, a multi parametric nonlinear regression analysis technique to derive the binary coefficients and to estimate the standard deviation between experimental and calculated data. The experimental data of viscosity is also used to test the applicability of empirical relations of Grunberg-Nissan, Katti-Chaudhri, Heric-Brewer and Hind et al. for the systems studied. Further, FT-IR analysis of these binary mixtures at different concentrations confirms the presence of hydrogen bonding and supported the results as observed in thermodynamic analysis with respect to forces of association/dispersion between unlike molecules. The interaction of anisaldehyde with alkoxy ethanol is found to decrease with increase in alkyl chain length of the alkoxy group.

Excess molar volumes, isentropic compressibilities, excess isentropic compressibilities for the binary mixtures of o-chlorotoluene with 1-propanol, 1-butanol, 1-pentanol, 1-hexanol and 1-heptanol over the temperature range from (298.15 to 308.15) K and at atmospheric pressure have been derived from experimental densities and speeds of sound data by Karlapudi et al., 2013. The measured excess properties were correlated with the Redlich-Kister polynomial equation. The calculated excess properties are discussed in terms of molecular interactions between o-chlorotoluene and 1-alkanol molecules and also with Fourier transform infrared (FT-IR) spectroscopy.

Dubey and Kumar, 2013 calculated the densities, speeds of sound and viscosities of ethylenediamine with 2-methyl-1-propanol, 2-propanol and 1-butanol over the whole composition and at different temperatures. Very recently, work has also been done on tetrahydrofuran with 1-hexanol, 1-octanol and 1-decanol in our laboratory by Dubey and Kumar, 2014.