CHAPTER-2
REVIEW
Densities, speeds of sound, and electrical conductances were measured by Shekaari et al., 2008 for aqueous solutions of room temperature ionic liquid, 1-hexyl-3-methyl-imidazolium bromide, [hmim][Br] at $T = (283.15$ to $308.15)$ K and atmospheric pressure followed by the calculation of apparent molar volumes, $V_\phi$, isentropic compressibilities, $\kappa_\psi$, apparent molar isentropic compressibilities, $\kappa_\psi$, and molar conductivities, $\Lambda$. Redlich-Mayer equation was used for limiting apparent molar quantities which dictated that (ion + solvent) interactions were prevailing in the studied system. Limiting apparent molar expansibility $E_\phi^0$ values for aqueous solutions of this ionic liquid were found to have positive values. Also, small and negative value of $(\partial^2 V_\phi^0 / \partial T^2)_P$ were found which indicated the ionic liquid to be a structure breaker. Structural interactions and clathrate formation might be occurring into the systems indicated by isentropic compressibility isotherms which intersected approximately at a concentration $m = 1.5825$ mol kg$^{-1}$. The ion association constant, $K_a$ values increased upon increasing temperature depicted the extent of increasing ion association with increasing temperature. Similar treatment was given to the amino acid + ionic Liquid [bmim][Br] + water mixtures at 298.15 K by the author (Shekari and Jebali, 2010). The authors had also studied densities and electrical conductances of amino acids, glycine, L-alanine and L-valine in aqueous ionic liquid, 1-hexyl-3-methylimidazolium bromide [hmim][Br] solutions have been measured at 298.15 K (Shekari and Jebali, 2010b). The apparent molar volumes, $V_\phi$, infinite dilution apparent molar volumes, $V_\phi^0$ and the standard partial molar volumes of transfer, $\Delta_\phi V_\phi^0$ of the amino acids from water to the aqueous ionic liquid solutions were calculated. The results had shown that both $V_\phi^0$ and $\Delta_\phi V_\phi^0$ in the glycine + [hmim][Br] + H$_2$O system increased with increasing ionic liquid concentrations and decreased in the cases L-alanine and L-valine systems. The $V_\phi^0$ values were used to estimate the contribution of the charged end groups ($\text{NH}_3^+$, COO$^-$), CH$_2$ group and other alkyl chain of the amino acids. Then, association constant, $K_a$, limiting molar conductivities, $\Lambda_0$ were determined using the molar conductivities of [hmim][Br] in aqueous amino acids solutions. Shekari and Jebali, 2010c reported the densities, viscosities, and refractive indices of glycine, L-alanine, and L-valine in aqueous solutions of an ionic liquid, 1-propyl-3-methylimidazolium bromide [pmim][Br] at 298.15 K. Then, apparent molar volumes, $V_\phi$, viscosity $B$-coefficients, and molar refractions of these mixtures. The standard partial molar
volumes, $V^0_\phi$ and standard partial molar volumes of transfer, $\Delta_\phi V^0_\phi$ were determined and had been interpreted in terms of solute + solvent interactions. The hydrophobic interactions were found to predominate in L-alanine and L-valine solutions. Linear correlation for both $V^0_\phi$ and the viscosity $B$-coefficient with the number of carbon atoms in the alkyl chain of the amino acids were computed which helped to estimate contribution of the charged end groups ($\text{NH}_3^+$, $\text{COO}^-$), the $\text{CH}_2$ group, and other alkyl chains of the amino acids. The viscosity and molar refractivity results were used to confirm the conclusions obtained from volumetric properties.

Shekari and Jebali, 2011 reported apparent molar volumes, $V_\phi$, standard partial molar volumes, $V^0_\phi$, transfer partial molar volumes, $\Delta_\phi V^0_\phi$ and hydration number, $n_H$ calculated from the measured densities of amino acids (glycine, L-alanine and L-valine) in aqueous ionic liquid, 1-hexyl-3-methylimidazolium chloride, $[\text{hmim}]\text{Cl}$ solutions at $T = 298.15$ K. The molar conductivities were reported. With the help of cosphere model, the trend of $\Delta_\phi V^0_\phi$ was interpreted in terms of solute-solvent interactions. For glycine, the hydration number was found to be decreasing with an increase in $[\text{hmim}]\text{Cl}$ concentrations owing to the dehydrating effect of $[\text{hmim}]\text{Cl}$ with the charged centre of the zwitterions of the glycine. The limiting molar conductivity, $\Lambda_0$ and ion association constants, $K_a$ for the mixtures studied, decreased with the molality of amino acid. It was attributed to the interaction of $[\text{hmim}]\text{Cl}$ with the amino acids and increasing viscosity of the binary mixture.

Fang and Ren, 2013 measured densities for the mixtures containing glycine, L-arginine, and L-phenylalanine with 1-ethyl-3-methylimidazolium bromide, $[\text{emim}]\text{[Br]}$ at $T = (298.15$ and $308.15)$ K. Using the experimental data, apparent molar volume, $V_\phi$ and standard partial molar volume, $V^0_\phi$, standard partial molar volume of transfer, $\Delta_\phi V^0_\phi$ were computed. The $\Delta_\phi V^0_\phi$ values were found negative for glycine, L-alanine, and L-phenylalanine but positive for L-arginine. Also, the standard partial molar volume of transfer values increased linearly with increase in temperature and concentration of ionic liquid. The results proved beneficial in understanding the biological processes between head and side chain groups of amino acids and aqueous ionic liquid solution.

The authors (Heintz et al., 2002) had also reported thermodynamic properties of mixtures of alkanes, alkylbenzenes, alkenes, linear and branched alcohols, acetone, acetonitrile, ethyl acetate, alkyl ethers and chloromethanes in the ionic liquid 1-methyl-3-ethyl-imidazolium bis (trifluoromethyl-sulfonyls) imide and 1,2 dimethyl-3-ethyl-imidazolium bis
(trifluoromethylsulfonyls) imide by gas chromatography from $T = 313-363$ K, keeping the ionic liquid as stationary phase. Later, partial molar excess enthalpies at infinite dilution $H_{i}^{E,\infty}$ of solutes in ionic liquid were derived from the temperature dependence of limiting activity coefficients. Heintz et al., 2005a, Heintz and Verevkin, 2005b, Heintz et al., 2006a measured the activity coefficients at infinite dilution $\gamma_{i}^{\infty}$ for alkanes, alkenes, alkylbenzenes, alkenes and linear and branched C$_{1}$-C$_{6}$ alcohols, esters and aldehydes in the ionic liquids 1-methyl-3-butyl-imidazolium bis(trifluoromethylsulfonyl) imide at $T = 302-385$ K, 1-methyl-3-octyl-imidazolium tetrafluoroborate at $T=302-396$ K and 1-hexyl-3-methylimidazolium bis(trifluoromethylsulfonyl) imide at $T=301-396$ K. The authors had also calculated activity coefficients at infinite dilution, $\gamma_{i}^{\infty}$ for alkanes, alkylbenzenes, alkenes and linear and branched C$_{1}$-C$_{6}$ alcohols, esters and aldehydes in the ionic liquids 1-methyl-3-octyl-imidazolium tetrafluoroborate and 1-methyl-3-butyl-imidazolium bis(trifluoromethyl-sulphonyl) imide by gas chromatography from $T=302-396$ K, keeping the ionic liquid as stationary phase. For all the solutes, data points were obtained. Later, partial molar excess enthalpies at infinite dilution, $H_{i}^{E,\infty}$ of solutes in ionic liquid were derived from the temperature dependence of limiting activity coefficients. In continuation of his studies, activity coefficients for hydrocarbons, alcohols, esters, aldehydes in Trimethylbutylammonium bis(trifluoromethylsulfonyl) imide (Heintz et al., 2006b) were also presented.

Vasiltsova et al., 2006 measured the activity coefficients of aliphatic and aromatic esters and benzylamine in 1-methyl-3-ethylimidazolium bis(trifluoromethylsulfonyl) imide. The Vapor-liquid equilibria of binary mixtures containing the high boiling solutes (dimethyl adipate, ethyl benzoate, and benzylamine) with the ionic liquid 1-methyl-3-ethylimidazolium bis(trifluoromethylsulfonyl) imide [emim][NTf2] were studied using the transpiration method. VLE measurements were carried out over the whole concentration range at temperatures between 298 K and 318 K and activity coefficients ($\gamma_{i}$) of these solvents in the ionic liquid were determined from these data and are correlated by the NRTL equation.

Andreatta et al., 2009b determined the densities, viscosities, and refractive indices for binary and ternary mixtures of ethanol, ethyl acetate, and 1-octyl-3-methyl-imidazolium bis(trifluoromethylsulfonyl)imide at $T = 298.15$ K and atmospheric pressure. Then, excess molar volumes, viscosity and molar refraction changes of mixing were calculated which were later fitted to the Redlich-Kister polynomial equation. The adjustable parameters and the
standard deviations between experimental and calculated values were also reported. The author gave similar treatment to the mixtures, methyl acetate + methanol + 1-octyl-3-methyl-imidazolium bis(trifluoromethylsulfonyl)imide (Andreatta et al., 2009b), ethyl acetate + ethanol + 1-butyl-3-methyl-imidazolium bis(trifluoromethylsulfonyl)imide (Andreatta et al., 2010a), isopropyl acetate + isopropanol + 1-octyl-3-methyl-imidazolium bis(trifluoromethylsulfonyl)imide (Andreatta et al., 2010b), and isopropyl acetate + isopropanol + 1-butyl-3-methyl-imidazolium bis(trifluoromethylsulfonyl)imide (Andreatta et al., 2011).

The density, \( \rho \) and speed of sound, \( u \) for the binary systems were measured at 298.15, 303.15, 308.15, and 313.15 K under atmospheric pressure by Bahadur and Deenadalyalu, 2013. The binary systems contained the ionic liquid (IL): methyltrioctylammoniumbis(trifluoromethylsulfonyl)imide [moa][Tf2N]. The binary systems were [moa][Tf2N] + ethyl acetate or ethanol. The apparent molar volume, \( V_\phi \) and the apparent molar isentropic compressibility, \( \kappa_\phi \) was evaluated from the experimental density and speed of sound data, respectively. A Redlich-Mayer equation was fitted to the apparent molar volume and apparent molar isentropic compressibility data. The partial molar volume, \( V_\phi^0 \) and partial molar isentropic compressibility, \( \kappa_\phi^0 \) of the binary mixtures were also calculated at each temperature. The partial molar volume indicates that the intermolecular interactions for (IL + ethanol) are stronger than for (IL + ethyl acetate) at all temperatures and \( V_\phi^0 \) for both systems increases with an increase in temperature. The values of the infinite dilution apparent molar expansibility, \( E_\phi^0 \), decreases with an increase in temperature. The isentropic compressibilities, \( \kappa_\phi \), increase with an increase in temperature for both binary systems. The positive values of \( \kappa_\phi^0 \) for both binary systems can be attributed to the predominance of solvent intrinsic compressibility over the solute intrinsic effect.

Dohnal et al., 2014 studied two ionic liquids (ILs), namely 1-butyl-1-methylpyrrolidinium dicyanamide [bmpyr][DCA] and 1-ethyl-3-methylimidazolium thiocyanate [emim][SCN] as agents for the separation of the methyl acetate + methanol azeotropic mixture by extractive distillation. The isothermal vapor-liquid equilibria of the ternary systems with the ILs and all the constituting binary subsystems were measured and the effect of IL additives on the separation factor was studied with the help of two HSGC methods. The HSGC methodology developed presented distinct advantages compared to conventional dynamic measurements using recirculation stills. Several activity coefficient models were tested. Both [bmpyr][DCA]
and [emim][SCN] increased considerably the methyl acetate/methanol separation factor, breaking the azeotropic behavior at rather low levels of IL mole fractions (> 0.043 and 0.087, respectively). The ionic liquid used in the study outperformed other ILs for the current purpose.

Pereiro et al., 2006 presented the densities and refractive indices of the pure ionic liquid (IL) [hmim][PF₆] at temperature range from \( T = (278.15 \text{ to } 318.15) \) K for density and from \( T = (288.15 \text{ to } 318.15) \) K for refractive index. Using the experimental density data, the coefficient of thermal expansion of IL was calculated. The densities and refractive indices of binary mixtures involving dimethyl carbonate (DMC), diethyl carbonate (DEC), acetone, 2-butanol, 2-pentanone, methylacetate, ethylacetate, and butylacetate + [hmim][PF₆] were measured at \( T = 298.15 \) K and atmospheric pressure. Later, excess molar volumes, changes of refractive index on mixing were calculated. Also, the miscibility of IL with different organic solvents and (liquid + liquid) equilibrium (LLE) data of binary mixture IL + DEC was determined experimentally. The authors also published similar work on (liquid + liquid) equilibria involving ionic liquids \{1,3-dimethylimidazolium methyl sulfate [mim][MeSO₄], \{2-propanol + ethyl acetate + 1-butyl-3-methylimidazolium hexafluorophosphate [bmim][PF₆] and \{2-propanol + ethyl acetate + 1-hexyl-3-methylimidazolium hexafluorophosphate [hmim][PF₆] to separate the azeotropic mixture ethyl acetate and 2-propanol (Pereiro and Rodriguez, 2007a), [hmim][PF₆] (1-butyl-3-methyl imidazolium hexafluorophosphate), [hmim][PF₆] (1-hexyl-3-methylimidazolium hexafluorophosphate), [moim][PF₆] (1-methyl-3-octylimidazolium hexafluorophosphate), and [mmim][CH₃SO₄] (1,3-dimethylimidazolium methyl sulfate) with 2-butanol, ethyl acetate, and 2-propanol (Pereiro et al., 2007b). Pereiro and Rodriguez, 2008 reported the results of study on the use of the two ionic liquids as an extraction solvent in the separation of the azeotropic mixture of hexane with ethyl acetate. Experimental densities, speeds of sound, and refractive indices of the binary mixtures of ethyl acetate + hexane or + 1-hexyl-3-methylimidazolium hexafluorophosphate [hmim][PF₆] from \( T = (293.15 \text{ to } 303.15) \) K. Then, excess molar volume, changes of refractive index on mixing, and deviations in isentropic compressibility were calculated. Liquid-liquid equilibria (LLE) were determined for the ternary systems hexane + ethyl acetate + IL at 298.15 K and atmospheric pressure. From the tie-line data, the values of selectivity and distribution ratio were derived. Experimental liquid-liquid equilibria data was accurately correlated with the NRTL and UNIQUAC equations.
In the work performed by Zhu et al., 2011 the excess molar volume, $V_m^E$ and excess logarithmic viscosity, $(\ln \eta)^E$ for the binary mixtures of 1-hexyl-3-methylimidazolium tetrafluoroborate ([C₆mim][BF₄]) with butanone, ethyl acetate, butylamine, and tetrahydrofuran were determined from density and viscosity measurements in the whole composition range at $T = 298.15$ K. The excess molar volume, $V_m^E$ were found to have negative values but those of $(\ln \eta)^E$ were positive over the whole range of concentration. The $V_m^E$ values exhibited their minimum at the ionic liquid mole fraction of 0.3, and $(\ln \eta)^E$ values exhibited a maximum at the same composition. The excess molar volume values followed the order: tetrahydrofuran > butanone > ethyl acetate > butylamine for the binary systems, whereas the values of $(\ln \eta)^E$ decreased in the order: tetrahydrofuran > butylamine > ethyl acetate > butanone. The results were interpreted in terms of ion-dipole interaction, packing efficiency, hydrogen bonding, and the ion-pairs existing among ionic liquid.

Wang et al., 2005 reported the experimental data of densities and viscosities for the mixtures of the ionic liquid 1-butyl-3-methylimidazolium hexafluorophosphate, [C₄mim][PF₆], with acetone, 2-butanone, 3-pentanone, cyclopentanone and ethyl acetate at 298.15 K followed by the computation of excess molar volumes, $V_m^E$, and excess logarithm viscosities, $(\ln \eta)^E$. The excess molar volume values were found negative but those of $(\ln \eta)^E$ were positive. Also, a minimum in $V_m^E$ and a maximum in $(\ln \eta)^E$ were observed at about the same mole fraction of the ionic liquid ($x = 0.3$) for all the mixture investigated. Combined with the $V_m^E$ data reported in literature, the effects of the [PF₆]⁻ and [BF₄]⁻ anions were compared and discussed in terms of the ion-dipole interactions of the cations of the ionic liquids with the organic compounds as well as their influence on the association of [C₄mim]⁺ and [PF₆]⁻ in the ionic liquid.

Naydenov and Bart, 2009 presented the ternary liquid-liquid equilibria for four systems containing an alcohol (1-propanol or 1-butanol) or acetic acid + ester + the ionic liquid 1-ethyl-3-methylimidazolium hydrogen sulfate at $(313.2 \pm 0.5)$ K headspace gas chromatography. The effect of the alkyl chain on the alcohol and ester on the phase equilibria for these systems containing reactants and products of esterification reactions was investigated. Except the system ester and IL, all were of type I. The effect of alkyl chain length on alcohol and ester immiscibilities regions was discussed. The author (Naydenov and
Bart, 2007) also reported LLE measurements on systems containing acidic ionic liquid (IL) + ethyl acetate + ethanol or acetic acid and discussed the effect of alkyl chain length.

Li et al., 2012 reported the vapor-liquid equilibrium (VLE) and liquid-liquid equilibrium (LLE) of the ternary system of ethyl acetate + ethanol + 1-ethyl-3-methylimidazolium acetate, together with the vapor-liquid-liquid equilibrium (VLLE) for the binary system of ethyl acetate + IL. The experimental VLE, LLE, and VLLE data were correlated by the nonrandom two-liquid (NRTL) equation and the calculated results agreed with the experimental results satisfactorily.

Zhang et al., 2013 reported the isobaric vapor-liquid equilibrium (VLE) data for the binary mixtures containing (propyl acetate + n-pentanol), (propyl acetate + 1-methyl-1-butanol), and (propyl acetate + 3-methyl-1-butanol) at 101.3 kPa using an equilibrium still. The semiempirical methods of Herington were used to test the thermodynamic consistency of the experimental data. The NRTL, Wilson, and UNIQUAC models were used to correlate the activity coefficients.

Cai et al., 2011a presented the vapor-liquid equilibrium (VLE) data for methanol + methyl acetate + 1-octyl-3-methylimidazolium hexafluorophosphate at 101.3 kPa. The experimental VLE data was correlated by the non-random two-liquid (NRTL) activity coefficient model and the binary parameters were obtained. The ionic liquid [moim][PF₆] produced a notable salting-out effect which enhanced the relative volatility of methanol to methyl acetate. The effect of IL on methanol + methyl acetate system was compared with that of o-xylene. The author (Cai et al., 2011b) also measured the (VLE) and (LLE) data for the ternary system of methyl acetate + methanol + 1-ethyl-3-methylimidazolium acetate and treated the data similarly.

The experimental measurements of density in the temperature interval, $T = (293.15$ to $313.15) \text{ K}$, the speed of sound and osmotic coefficients at 298.15 K for aqueous solution of 1-ethyl-3-methylimidazolium bromide [emim][Br], and osmotic coefficients at 298.15 K for aqueous solutions of 1-butyl-3-methylimidazolium chloride [bmim][Cl] in the dilute concentration region were carried out by Gardas et al., 2008. Then compressibilities, expansivity, apparent and limiting molar properties, internal pressure, activity, and activity coefficients for [emim][Br] in aqueous solutions were computed. Hydration number and the osmotic second virial coefficients of ionic liquids were calculated from the activity data which was also compared with that obtained from Debye-Hückel and Pitzer models. Partial molar entropies of [bmim][Cl] have been calculated and the distance of the closest approach of ions is estimated using the activity data for ILs in aqueous solutions and is compared with that of
X-ray data analysis in the solid phase. It was interpreted that the concentration dependence for aqueous solutions of IL can be accounted for hydrophobic hydration of ions and that the IL exhibited coulombic interactions as well as hydrophobic hydration for both the cations and anions.

An attempt was made by Tomé et al., 2009 to understand the intermolecular interactions existing among aqueous ILs and biomolecules. The liquid liquid equilibria was studied for aqueous 1-butyl-3-methylimidazolium tricynomethane and amino acids. Various factors such as polarity, size, and charge distribution of amino acids were found to influence solubility effects and have been explained in terms of refined models. The salting in and salting out phenomenon resulted by the most prominent interaction among water-amino acid side chain, IL-amino acid side chain and water-IL interactions which is further decided by the relative affinities of biomolecules towards water, or IL cation and anion.

Classical molecular dynamics simulation studies were carried out upon amino acids (glycine, alanine, valine, isoleucine, and glutamic acid) and ionic liquid {1-butyl-3-methylimidazolium bis(trifluoromethyl) sulfonyl imide} in aqueous media to understand the underlying molecular level mechanisms by Tomé et al., 2012. The results provided a comprehensive coverage of factors involved in solubility phenomenon observed in [IL + amino acid+ water] systems such as magnitude, direction and strength of interaction which finally depends upon interactions of IL cation, IL anion, and water with amino acids.

The density, $\rho$ and speed of sound, $u$ for the binary systems (methanol + ethyl acetate) and (ethanol + methyl acetate or ethyl acetate) were measured at 298.15, 303.15, 308.15 and 313.15 K and at atmospheric pressure by Bahadur et al., 2014 in this work whereas the system (methanol + methyl acetate) had been studied in literature. Then, apparent molar volume, $V_{\phi}^*$, isentropic compressibility, $\kappa_s^*$, and apparent molar isentropic compressibility, $\kappa_{\phi}^*$ were calculated using density and speed of sound data respectively. The limiting apparent molar volume, $V_{\phi}^{0*}$, and limiting apparent molar isentropic compressibility, $\kappa_{\phi}^{0*}$, were found by extrapolation to infinite dilution using the Redlich-Mayer equation. The limiting apparent molar volume was used to obtain information about interactions among solute-solvent and solute-solute. Finally, apparent molar expansibility, $E_{\phi}^{0*}$ and Hepler's constant, $(\partial^2 V_{\phi}^0 / \partial T^2)_{p}$, isobaric thermal expansion coefficient, $\alpha_p$ were also calculated. Positive $\kappa_{\phi}^{0*}$ values for all binary systems could be attributed to the predominance of solvent intrinsic compressibility over the solute intrinsic effect.
Sastry et al., 2003 reported new experimental data of densities at \( T = (298.15 \text{ to } 313.15 \text{ K}) \), viscosities, speeds of sound, relative permittivities at \( T = (298.15 \text{ and } 308.15 \text{ K}) \) for the binary mixtures of alkyl (methyl, ethyl, butyl, and isoamyl) acetates + glycols (ethylene, diethylene, triethylene, and propylene) as a function of composition. The deviations in excess molar volumes and excess isentropic compressibilities were calculated and fitted to Redlich-Kister type equation. Grunberg-Nissan McAllister, and Auslander equations correlated the mixture viscosities efficiently. A qualitative analysis of the deviation and excess functions was made to evaluate the nature and type of bulk state interactions.

The \( V_m^E \) at 298.15 K for binary mixtures of \( n \)-alkanols \( \text{C}_n\text{H}_{2n+1}\text{OH} \) (from \( n = 2 \) to \( n = 10 \)) with ethyl and propyl acetates were reported by Ortega et al., 1986. All the excess volumes were found positive over the entire concentration range, with \( V_m^E \) increasing linearly with the length of the alkanol chain. Suitable equations were fitted to the data for each mixture.

Densities and viscosities were measured by Nikam et al., 1996 for the binary mixtures of ethyl acetate with linear and branched alkanols (C1-C4) at \( T = (298.15, 303.15, \text{ and } 308.15) \text{ K} \). The experimental density, \( \rho \) and viscosity, \( \eta \) values were used to calculate the excess molar volume, \( V_m^E \) and viscosity deviation, \( \Delta \eta \). Later, the \( V_m^E \) and \( \Delta \eta \) values were fitted to a Redlich-Kister polynomial equation.

In a study performed by Canosa et al., 1998 the viscosities were measured for the binary mixtures of methyl acetate + (methanol, or ethanol, or propanol, or 2-propanol, or 1-butanol), and methanol + (ethanol, or 1-propanol, or 2-propanol, or 2-butanol) and their viscosity deviations were evaluated at \( T = 298.15 \text{ K} \) and atmospheric pressure over the entire range of composition. Several semi-empirical relations were proposed to estimate the dynamic viscosity of mixtures, and results are compared with the experimental data. The UNIFAC-VISCO group contribution method, Lobe’s volume fraction exponential model, and the group contribution thermodynamic viscosity model (GC-UNIMOD) were used to predict the dynamic viscosity of the binary mixtures under investigation.

Densities, viscosities and speeds of sound of binary mixtures of ethanol, propan-1-ol, butan-1-ol and pentane-1-ol with \( n \)-butyl acetate were measured over the entire range of composition in the temperature interval \( T = (298.15-313.15) \text{ K} \) and atmospheric pressure by Hasan et al., 2011. From the experimental densities, viscosities and speeds of sound, the excess molar volumes, \( V_m^E \), deviations in viscosity, \( \Delta \eta \) and deviations in isentropic compressibility, \( \Delta \kappa \), were calculated. The excess molar volumes and deviations in isentropic
compressibility were found to be positive for all the binary systems, while deviations in viscosities were negative for all of the binary mixtures. The excess molar volumes, deviations in viscosity, and deviations in isentropic compressibility were fitted to Redlich-Kister type polynomial equation. FTIR and $^1$H-NMR studies of these mixtures were also reported into the study.

Qin et al., 1993 calculated excess molar volumes from the measured densities of binary mixtures of five alkanols (methanol, ethanol, 1-propanol, 1-butanol, and 1-pentanol) with $n$-alkyl acetates (methyl, ethyl, propyl, butyl, and pentyl acetates) and with two ketones (acetone and 2-butane) at 20 °C over the whole composition range. For a particular alcohol, the $\Delta V/\phi_2$ value decreased upon increasing the size of carbonyl compound and for a given carbonyl compound, it increased with the length of alkanol. The $\Delta V/\phi_2$ values were found somehow for systems containing methyl acetate component. The systems containing methanol were found to display different compositional dependency as compared to other alcohols.

Lladosa et al., 2010 reported the vapor-liquid equilibrium (VLE) data for the ternary systems ethanol + 2-butanone + butyl propionate and 2-propanol + 2-butanone + butyl propionate and some of their constituent binary systems: ethanol + butyl propionate and 2-butanone + butyl propionate at 101.3 kPa. Positive deviations from Raoult’s law for ethanol + butyl propionate system were observed. However, the system 2-butanone + butyl propionate didn’t show any deviation from ideal behavior. Using Wilson, nonrandom two-liquids, and universal quasichemical models, the activity coefficients of the solutions were correlated as a function of mole fraction. Various thermodynamic consistency tests were performed and the binary VLE data measured in the present study passed the tests. It was concluded that Butyl propionate could be considered an effective agent for the separation of the azeotropic mixtures ethanol + 2-butanone and 2-propanol + 2-butanone by extractive distillation.

Wang et al., 2014 determined the isobaric (vapor + liquid) equilibrium (VLE) data for the binary system methanol + 2-butyl alcohol and the quaternary system methyl acetate + methanol + 2-butyl alcohol + 2-butyl acetate at $P = 101.33$ kPa in a modified Rose still. The VLE data was found thermodynamic consistent using the Herrington method. It was correlated by the Wilson and NRTL equations respectively, which were used to predict the VLE data of the quaternary system. Wilson and NRTL models matched well with the (vapor + liquid) phase equilibrium data.
Xiao et al., 2013 reported the isobaric vapor-liquid equilibrium (VLE) data for the quaternary system methyl acetate + methanol + isopropanol + isopropyl acetate and the constituent binary system methyl acetate + isopropyl acetate at 101.3 kPa. The rest of binary systems VLE data was obtained from the literature. According to Herington analysis, the measured experimental data were found to be thermodynamically consistent. Various models like Wilson, NRTL and UNIQUAC activity coefficient models were used to correlate the experimental binary data. The three models with their best-fitted parameters were used for the prediction of quaternary vapor–liquid equilibrium. Later, a comparison of performances was made. The NRTL model yielded a good prediction for the quaternary system from the parameters of the correlated binary systems.

Wang et al., 2005b used imidazolium based ionic liquids [bmim][PF₆], [hmim][PF₆], [hmim][BF₄] and [moim][BF₄] used as alternative solvents for the recovery of some amino acids (L-tryptophan, L-phenylalanine, L-tyrosine, L-leucine and D-valine) from aqueous media. The logarithm of partition coefficients, log (P_{IL/W}), of the amino acids correlated well with the hydrophobicity of the amino acids. It indicated the importance of the amino acid’s hydrophobic effect as a driving force for their partition into a particular ionic liquid. The partition coefficients decreased with increasing pH in the range of pH < pK₁, but increased with increasing solubility of water in ionic liquid phases. Strong electrostatic interactions between cationic form of the amino acids and anion of the ionic liquids were accounted for the higher extraction degree at low pHs. The ionic liquid with BF₄⁻ anion had much higher extraction efficiency for the amino acids than those with PF₆⁻ anion because of the stronger effective charge in BF₄⁻. Preliminary results indicated that [hmim][BF₄] and [moim][BF₄] ionic liquids might be adapted to liquid-liquid recovery process of some amino acids from aqueous media. Also, L-tryptophan could be effectively separated from fermentation broth in a multiple step process using Ionic liquid, [hmim][BF₄] as an extractant.

Domínguez-Pérez et al., 2010 studied aqueous biphasic systems (ABS) composed by hydrophilic ILs and aminoacids to obtain new evidences regarding their ABS formation ability and their capacity for the extraction of specific biomolecules. On the basis of the IL cation 1-butyl-3-methylimidazolium, the IL anion influence on ABS formation was assessed through its combination with tetrafluoroborate, triflate, and dicyanamide anions, with different amino acids. Ternary phase diagrams alongwith tie-lines formed by these aqueous solutions were measured at T = 298 K and atmospheric pressure. The ability of amino acids to form ABS followed the order: l-lysine ≈ d,l-lysine HCl > l-proline. Later, the extraction
capability of the studied ABS was evaluated through their application to the extraction of biomolecules. Cheng et al., 2006 measured the vapor-liquid equilibrium (VLE) data for the ternary mixture of carbon dioxide, 1-propanol and propyl acetate at \( T = 308.2, 313.2, \) and \( 318.2 \) K, and at pressures ranging from 4 to 10 MPa using a static type phase equilibrium apparatus with visual sapphire windows. New VLE data for CO\(_2\) in the mixed solvent was presented. These ternary VLE data at elevated pressures were also correlated using either the modified Soave-Redlich-Kwong or Peng-Robinson equation of state (EOS), and by employing either the van der Waals one-fluid or Huron-Vidal mixing model which correlated satisfactorily. The results showed that at \( T = 318.2 \) K and 10 MPa, 1-propanol might be separated from propyl acetate into the vapor phase at the entire concentration range in the presence of high pressure CO\(_2\).

Costa et al., 2009 reported the liquid-liquid equilibrium (LLE) data for the system water + \( n\)-butyl acetate + 1-propanol at \( T = 323.15 \) K and atmospheric pressure. The densities, viscosities, and surface tensions were measured. Also, the liquid interfacial tensions of the conjugate phases located in the isothermal binodal curve were determined. The UNIFAC method was used to predict the experimental tie-line data and it was correlated using the empirical method of Othmer and Tobias, and the method of Pick et al. was applied for binodal data correlation. The molar volumes, \( V_m^E \), dynamic viscosity, \( \eta \) and the surface tension, \( \gamma \) of the binary systems were correlated in terms of composition using rational functions. Later, binary pair additivity and a rational function were considered for the ternary contributions to describe the ternary system.

Dong et al., 2005 determined the excess molar enthalpies of five binary systems for methyl acetate and (1-propanol, 2-propanol, 1-butanol, 2-butanol, and 1-pentanol) at \( T = (298.15 \) and \( 308.15) \) K and \( p = (5.0 \) and \( 10.0) \) MPa using a high-pressure flow-mixing isothermal calorimeter. The smooth values of \( H_m^E \) calculated by Redlich-Kister equation were compared with the experimental results.

Ortega et al., 1990a reported the vapor-liquid equilibrium data at 101.32±0.02 kPa for (methyl acetate (1) + ethanol (2) or + 1-propanol (2). The results were compared with those predicted by UNIFAC and ASOG methods. Then, the formation of azeotrope was reported. Both methods predicted the vapor phase composition well. The author (Ortega et al., 1990b) also reported isobaric vapor-liquid equilibrium of methyl butanoate with ethanol and 1-propanol binary systems. In succession, he reported the VLE data for isobutylalkanol and an alkyl (ethyl to butyl) alkanoate (methanoate to butanoate) (Ortega et al., 1999),
isobaric vapor-liquid equilibria and excess quantities for binary mixtures of an ethyl ester + tert-butanol (Ortega et al., 2003), methyl esters + tert-butanol (Ortega et al., 2004), butyl esters + tert-butyl alcohol (Ortega et al., 2005), and alkyl esters + tert-butyl alcohol: (Ortega et al., 2006).

Susial et al., 1989 reported the isobaric vapor-liquid equilibrium measurements for the binary mixtures of methyl propanoate-ethanol and methyl propanoate-propan-1-ol at 101.32 kPa. The systems were found to deviate from the ideality and thermodynamically consistent and the mixture was found to form azeptrope at \( x = y = 0.483 \) and \( T = 345.58 \) K. Later, suitable equations were used to fit the data compared with the values predicted by UNIFAC and ASOS models. The author also treated the data of methyl propanoate + isobutyl alcohol (Susial et al., 1993\textsuperscript{a}) and propanoate + n-butyl alcohol (Susial et al., 1993\textsuperscript{b}) similarly. Susial et al., 2010 also determined vapor-liquid equilibrium (VLE) data for ethyl acetate + methanol binary system at (0.1, 0.5, and 0.7) MPa using a stainless-steel ebulliometer in which both phases were recirculated. The operating procedure was based on the Cottrell pump principle. The liquid mixture was placed in an inverted double-walled vessel and heated. Using the data previously studied by various authors, the equipment performance was verified. The experimental data was tested with the point-to-point test of Van Ness, employing the program of Fredenslund. The results were consistent. Similarly, the author studied the (VLE) data for isobutyl Acetate + methanol and isobutyl acetate + 1-propanol (Susial et al., 2012\textsuperscript{a}), propyl Acetate and isobutyl acetate with ethanol or 2-propanol (Susial et al., 2012\textsuperscript{b}), isobutyl acetate + ethanol, + 1-propanol or + 2-propanol (Susial et al., 2012\textsuperscript{c}) and binary Systems of methyl acetate, ethyl acetate, and propyl acetate with 1-propanol (Susial et al., 2013)

Blanco and Ortega, 1996 reported the isobaric vapor-liquid equilibrium data at 141.3 kPa for the binary systems methanol + methyl ethanoate, +methyl propanoate, and +methyl butanoate. All mixtures showed positive deviations from ideality but methanol + methyl ethanoate and methanol + methyl propanoate showed a minimum temperature azeotrope. Later, the results were tested for thermodynamic consistency and correlated with several equations. The results were compared with the predictions of the ASOG and UNIFAC methods. The author (Blanco and Ortega, 1998) also treated the binary mixtures of methanol and ethyl esters similarly.

Dhanalakshmi et al., 2013 investigated the separation of the nonaqueous azeotropic systems methyl acetate-methanol and ethyl acetate-ethanol with 13 cations and 27 anions as entrainers to identify suitable ionic liquids using the COSMO-RS model. It is observed that the cations best suited are imidazolium > pyridinium > methyl pyrrolidinium > octyl quinolinium. The
lengthening of the alkyl chain of cations was also studied as well as whether the shorter the alkyl chain, the better is the separation. It was also noticed that the efficacy of the anions is in the order [OAc] > [Cl] > [DHP]. It was seen that the influence of anions is more significant on the behavior of ionic liquid solvation in alcohols. The effects of polarity, excess free energy, and excess enthalpy are addressed on nonaqueous systems containing ionic liquids. It is suggested that [emim][OAc], [emim][Cl], and [emim][DHP] can be used as promising entrainers for practical applications of ester-alcohol separation.

Bermúdez-Salguero et al., 2011 measured the densities, \( \rho \), refractive indices, \( n_D \), speeds of sound, \( u \) and surface tensions, \( \sigma \) for the aqueous binary solutions of partially miscible 2-methyl-1-propanol, cyclopentanone, cyclohexanone, cyclohexanol, and ethyl acetoacetate at the temperature of 298.15 K and atmospheric pressure over the mole fraction range reaching the solubility limit in the aqueous phase. Isentropic compressibilities, determined by means of the Laplace equation, have been calculated from the measured experimental data. To analyze the behavior of surface tensions, the extended Langmuir (EL) model was used.

Gao et al., 2009 presented the data on excess molar enthalpies of five binary systems for ethyl acetoacetate + (1-butanol, + 2-butanol, + 1-pentanol, + water, and + ethyl acetate) at \( T = (298.15, 313.15, 328.15, 338.15, \text{ and } 348.15) \) K and \( p = 0.1 \) MPa using a flow-mixing isothermal microcalorimeter. Upon increasing the temperature and the molecular size of the alcohols, excess molar enthalpies increased. The Redlich-Kister equation was used to correlate the experimental data. Similarly, the author (Gao et al., 2011) reported the excess molar enthalpies for four binary systems of methyl acetoacetate + (methanol, + ethanol, + 1-propanol, and + 2-propanol) at \( T = (288.2, 298.2, 313.2, \text{ and } 328.2) \) K and \( p = 101.3 \) kPa.

Sheu and Tu, 2006a measured the refractive indices and surface tensions for binary mixtures of six flavor esters (ethyl acetoacetate, ethyl isovalerate, methyl benzoate, benzyl acetate, ethyl salicylate, and benzyl propionate) with ethanol over the whole composition range at \( T = (288.15, 298.15, 308.15, \text{ and } 318.15) \) K and atmospheric pressure. Refractive indices and surface tensions were measured using a digital Abbe-type refractometer and Wilhelmy-plate method respectively. From the experimental data, deviations in the refractive index \( \Delta n_D \) and deviations in the surface tension \( \Delta \sigma \) from volume fraction average for the binary mixtures were derived. The binary data of \( \Delta n_D \) and \( \Delta \sigma \) was correlated as a function of mole fraction using the Redlich-Kister equation. The author (Sheu and Tu, 2006b) also reported the densities and viscosities for six binary mixtures formed by the flavor esters (ethyl acetoacetate, ethyl isovalerate, methyl benzoate, benzyl acetate, ethyl salicylate, and benzyl
propionate) with ethanol at $T = (288.15, 298.15, 308.15, \text{ and } 318.15)$ K and atmospheric pressure. Then, the excess molar volume, $V_m^E$ and deviations in the viscosity from mole fraction average, $\Delta \eta$ for the binary mixtures were computed and were correlated to Redlich-Kister equation. Later, kinematic viscosities were correlated using the McAllister's multi-body interaction models.

Nikam et al., 1998 reported the densities and viscosities for the binary mixtures of ethyl acetate with linear and branched alkanols (C1-C4) at $T = (298.15, 303.15, \text{ and } 308.15)$ K. Then, the experimental density, $\rho$ and viscosity, $\eta$ values were used to calculate the excess molar volume, $V_m^E$ and viscosity deviation, $\Delta \eta$. The $V_m^E$ and $\Delta \eta$ values were fitted to Redlich-Kister polynomial.

Montón et al., 2005 presented the new consistent vapor-liquid equilibrium data for the binary systems isobutyl alcohol (IBA) + isobutyl acetate (IBAc) and tert-butyl alcohol (TBA) + tert-butyl acetate (TBAc) at 20 and 101.3 kPa. The IBA + IBAc system deviated positively from ideal behavior. It was described as symmetric solution and presented azeotrope at both pressures. The TBA + TBAc system also deviated positively from ideal behavior and presented azeotrope only at 20 kPa. The activity coefficients and boiling points of the solutions were correlated with their composition by the Wilson, UNIQUAC, NRTL and Wisniak-Tamir equations.

Muñoz et al., 2005a determined the consistent vapor-liquid equilibrium (VLE) data at 101.3 kPa for the ternary system isobutyl alcohol (IBA) + isobutyl acetate (IBAc) + butyl propionate (BUP) and two constituent binary systems: IBA + BUP and IBAc + BUP. The positive deviation were found from Raoult's law for IBA + BUP system and no deviation for IBAc + BUP system were exhibited. The activity coefficients of the solutions were correlated with its composition by the Wilson, NRTL, UNIQUAC models. The ternary system was well predicted from binary interaction parameters. IBA-IBAc binary azeotrope was eliminated by BUP. The significant change of phase equilibria behavior was observed which indicated that the solvent was an effective agent for that azeotrope mixture separation. The binary VLE data measured in this study passed the thermodynamic consistency test reported in the literature and phase behavior was well predicted using the parameters obtained from binary data. The author gave similar treatment to the ternary system of isobutyl alcohol + isobutyl acetate + 1-hexanol and the binary systems isobutyl alcohol + 1-hexanol, isobutyl acetate + 1-hexanol at 101.3 kPa (Muñoz et al., 2005b).
Tovar et al., 1997 measured the density for the binary mixtures of ethyl acetate [\(\text{CH}_3\text{COOCH}_2\text{CH}_3\)] and glymes [\(\text{CH}_3\text{O(CH}_2\text{CH}_2\text{O})_n\text{CH}_3\), \(n = 1, 2, 3,\) and 4] and dibutyl ether [\((\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{O})\)] at \(T = (278.15, 288.15,\) and 308.15) K and atmospheric pressure using Kyoto Electronics DA-210 vibrating-tube densimeter. The excess molar volume was calculated using the experimental density values. Also, the excess molar isobaric heat capacities were determined using micro DSC II differential scanning calorimeter for the binary mixtures of ethyl acetate with glymes \((n = 2, 4)\) and dibutyl ether at \(T = 298.15\) K.

Pal and Kumar, 2001 studied the excess molar volumes, \(V^E_m\) and viscosities, \(\eta\) for the binary liquid mixtures of polyether + methyl acetate (\(\text{C}_3\text{H}_6\text{O}_2\)), ethyl acetate (\(\text{C}_4\text{H}_8\text{O}_2\)), and propyl acetate (\(\text{C}_5\text{H}_{10}\text{O}_2\)) as a function of composition at the temperatures of 298.15, 308.15, and 318.15 K and atmospheric pressure over the entire range of composition. The polyethers used in the study were 2,5,8-trioxanonane, and 2,5,8,11-tetraoxadodecane. From these results, the deviations of the viscosity, \(\Delta\eta\) from a mole fraction average and excess free energies of activation of viscous flow, \(\Delta G^E\) were calculated and discussed in terms of molecular interactions between the components of the mixtures. Furthermore, activation enthalpies, \(\Delta H^*\), entropies, \(\Delta S^*\) of viscous flow and their variation with concentration were discussed.

Excess molar volumes, and viscosities for the binary mixtures of tetraethylene glycol dimethyl ether with methyl acetate, ethyl acetate, and propyl acetate at (298.15, 308.15, and 318.15) K and atmospheric pressure were reported by Pal and Kumar, 2000. From the measured data, deviations in viscosity, and excess free energies of activation of viscous flow have been computed and these quantities were used to interpret molecular interactions existing among solution. Furthermore, activation enthalpies, and entropies of viscous flow have been evaluated and their variation with concentration is discussed. A short comparative study with results for mixtures with esters and polyethers was also been furnished.

Aminabhavi et al., 1994 reported the densities, speeds of sound, and sheer viscosities for the mixtures of diethylene glycol dimethyl ether with ethyl acetate, methyl acetate, methyl benzoate, or diethyl succinate are measured as a function of mole fraction at temperatures, \(T = (298.15, 303.15, 308.15, 313.15,\) and 318.15) K. Then, the values of these properties were fitted to a power series equation involving both temperature and the mole fraction of the binary mixture. The experimental values of the mixtures and pure liquids were used to calculate excess molar volume, \(V^E_m\), changes in isentropic compressibility, \(\Delta k_s\), changes in refractivity, \(\Delta R\) and changes in viscosity, \(\Delta\eta\) for the mixing process. Later, these results were fitted to the Redlich-Kister polynomial relation to estimate the binary coefficients. The
specific acoustic impedance factor of the liquids was calculated to find a possible match of their values with that of sea water, and the potential applications of these liquids as sonar transducer fill fluids have been investigated. The refractive index and density values of the mixtures were used to test the accuracy of the available refractive index mixing relationships in predicting the binary refractive index data. Viscosity results were also analyzed by using the viscosity equations of MacAllister, Heric, and Auslaender.

Density, viscosity, and refractive index at 298.15, 303.15 and speed of sound at 298.15 K for the binary mixtures of methyl acetate + ethylene glycol or + poly (ethylene glycol) were reported by Aminabhavi et al., 1998. Then, excess molar volume, \( V^E \), deviations in viscosity, \( \Delta \eta \), molar refractivity, \( \Delta R \), speed of sound, \( \Delta u \), and isentropic compressibility, \( \Delta \kappa \), were computed. Finally the results were fitted to Redlich-Kister type equation and binary coefficients and standard errors were calculated.

Aminabhavi et al., 1993 presented the densities, viscosities, refractive indices, and speed of sound at 298.15, 303.15 and 308.15 K for the binary mixtures of methyl acetoacetate with methyl alcohol, ethyl alcohol, 1-propanol, 2-propanol, 2-methyl-1-propanol, 1-butanol, 1-pentanol, 1-hexanol, 1-heptanol and 2-octanol. Excess molar volumes, excess molar refractivities, viscosity deviations and isentropic compressibility deviations were calculated. Later, fitting of results using polynomial relation was performed to estimate the coefficients and standard errors. The experimental and calculated quantities were used to interpret the intermolecular interactions.

The density and sound velocity of the solutions of room temperature ionic liquid 1-butyl-3-methylimidazolium bromide, \([\text{bmim}]\text{[Br]}\) in water, methanol, and ethanol were measured at \( T = (298.15 \text{ to } 318.15) \) K at atmospheric pressure by Zafarani-Moattar and Shekaari, 2005. Apparent molar volume and the apparent molar isentropic compressibility were computed and fitted to a Redlich+Mayer type equation. Then, apparent molar volume and apparent molar isentropic compressibility of the solutions at the infinite dilution were also been calculated at all studied temperatures which indicated ionic liquid + solvent interactions in water were stronger than the alcoholic solutions. An intersection point in isotherms of isentropic compressibility was observed for aqueous solutions which was indicative of structural interactions and clathrate formation.

Tshibangu et al., 2011 synthesized the ionic liquid, 1-butyl-3-methylimidazolium bromide \([\text{bmim}]\text{[Br]}\) and characterized. Density and viscosity measurement for the ionic liquid with water, methanol, ethanol, acetonitrile and acetone were carried out at room temperature. The
density measurements were found to decrease monotonically while viscosity measurement decreased with increase in temperature. Conductivity measurement showed increase in conductivity due to the presence of the ionic liquid in water and ethanol, and decrease in other cosolvents. Conductivity measurement of the ionic liquid and mixture of the ionic liquid in various cosolvents at different concentrations showed increase in conductivity with increase in concentration. High thermal stability of IL was confirmed from thermo gravimetric analysis (TGA) with decomposition starting at about 400°C.

González et al., 2006 determined dynamic viscosities, densities, and speed of sound for the binary mixtures of 1-methyl-3-octylimidazoliumchloride with methanol, ethanol, and 1-propanol at \( T = (298.15, 313.15, \text{ and } 328.15) \) K and refractive index at \( T = 298.15 \) K and \( P = 0.1 \) MPa. From the data, excess molar volumes, isentropic compressibility deviations, and viscosity deviations from 298.15 to 328.15 K were calculated. The results were further fitted to Redlich-Kister type polynomial equation to obtain fitting parameters and root mean square deviations.

González et al., 2007 reported the dynamic viscosities, densities, and speeds of sound of 1-ethyl-3-methylimidazolium ethyl sulfate with methanol, 1-propanol, and 2-propanol at \( T = (298.15, 313.15, \text{ and } 328.15) \) K and refractive indices at \( T = 298.15 \) K and at atmospheric pressure over a wide range of composition. Then, using the experimental data, excess molar volumes, excess molar isentropic compressions, and viscosity deviations for the binary systems from \( T = 298.15 \) K to \( T = 328.15 \) K and refractive deviations at 298.15 K were calculated. The results were fitted to Redlich-Kister equation to obtain the fitting parameters and the root-mean-square deviations.

Arce et al., 2006 determined the densities, refractive indices, speeds of sound and dynamic viscosities of 1-methyl-3-octylimidazolium tetrafluoroborate, \([\text{moim}][\text{BF}_4]\) in binary mixtures with methanol, ethanol, 1-propanol and 2-propanol at 298.15 K and atmospheric pressure. Then, excess molar volumes, molar refraction, isentropic compressibility and dynamic viscosity changes of mixing were calculated. Finally, the results were correlated to Redlich-Kister polynomial equation.

Calvar et al., 2006 reported the densities, refractive indices, speeds of sound and isentropic compressibilities of the ternary mixture of ethanol + water + 1-butyl-3-methylimidazolium chloride \([\text{bmim}][\text{Cl}]\), and of the binary subsystems containing the ionic liquid at 298.15 K and atmospheric pressure.
Gómez et al., 2006 presented the densities and refractive indices of the ternary mixture ethanol + water + 1-hexyl-3-methylimidazolium chloride, [hmim][Cl] and of the binary systems containing the ionic liquids (ILs) at $T=298.15\,\text{K}$ and atmospheric pressure. Experimental data was used to calculate excess molar volumes and changes of refractive indices upon mixing. Finally, the data was correlated using the Redlich-Kister polynomial equation, while the Cibulka equation was applied for the ternary system.
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