The Intermolecular Interaction Studies of Pyrrolidinium Based Ionic Liquid with Water and Propanol Isomers at Different Temperatures

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ABSTRACT

In this experimental investigation, the thermo physical features of density (ρ), and speed of sound(U) were calibrated for aqueous solution/alcoholic(1-propanol/2-propanol) solutions of pyrrolidinium based ionic liquids alike 1-Butyl-1-methylpyrrolidinium tetra fluoroborate ([BMPyy]BF$_4$) in various concentrations within temperatures from 303.15 to 313.15K. From these experimental determined values, various thermodynamic acoustic parameters of excess molar isentropic compressibility($K^E_{s,m}$)and excess molar volume (V^E_m)are expressed in specific and non-specific molecular interactions. Moreover, calibration of the partial molar volume's and partial isentropic compressibility's of both components shows strong interaction in [BMPyy]BF$_4$ + 2-proponol combination than any other executed binary fluids. Further, the FTIR characteristic spectrum of all combinations at different concentrations gives the more promising features such as interaction behavior that helps our analysis to guide the interactions of individual bonds.

Key words: FTIR analysis, Ionic Liquid, Partial isentropic compressibilites, Partial molar volumes.

1. INTRODUCTION

The monumental features of Ionic Liquids (ILs) have great plausible utilization in contemporary epoch[1]. Remarkably, the thermo physical distinctive features of ILs at ambient temperatures play a juggernaut role in many sectors such as industrial engineering, pharmaceutical manufacturing and waste management treatment[2]. With inventiveness, the binary fluids which contain IL accompanied by any organic solvent portrays versatile thermo physical features of these fluids. Noteworthy, the molecular interactions at particular point of concentration of binary fluids are worthwhile and that leads to designer solvents of ILs at that point[3]. In this ambience, several peer groups of brainchildren uplift the binary fluid combination of ILs into high-yield ionic liquid applications in foregoing sectors[4]-[7]. In this investigation research, the authors appraised the binary fluid which includes

IL of 1-butyl, 1-methylpyrrolidinium tetrafluoroborate ([BMPyrr]BF$_4$)[8]with any one of the sample aqueous, 1-propanol and 2-propanol at subsequent interval of temperature ranges fromof temperature ranges from 303.15K to 313.15K throughout an ambient atmospheric pressure. This protic IL commonly engineered in electrochemical energy applications for lithium batteries and super capacitors[9]-[12]. Due to the hydroxyl group attachment to the main group of 1-propanol, 2-propanol and water, they are greatly used as solvents in many physical and chemical fields. Consequently, the study of the binary combinations of pyrrolidinium group with -OH group provides much more attention[13]. The thermodynamic excess features such as excess molar volume(V^E_m)and excess molar isentropic compressibility($K^E_{s,m}$) of binary fluids are extracted from fundamental features of density(ρ) and speed of sound(U)[14]. These fundamental features help to understand the geometrical configurations and that develops the structure property correlations.

2. MATERIAL AND METHODS

Table 1: Specification of Source, CAS Number, Mass Fraction Purity and Further Purification

Name of the chemical	Source	CAS Number	Mass fraction purity	Further purification methods
Water (W)	Double Distillation Method	7732-18-5	>99.99%	----
1-propanol (1P)	HiMedia Laboratories, India	71-23-8	>98.00%	*GLPC
2-propanol (2P)	HiMedia Laboratories, India	67-63-0	>98.00%	*GLPC
[BMPyrr]BF$_4$ (IL)	HiMedia Laboratories, India	345984-11-4	>99.70%	**Millipore

*Gas-Liquid partition chromatography carried through inert gas Ar.
**Impurities separation by filtration.

2.1 Specimen information

The structural isomers of 1-propanol and 2-propanol have

been subjected to glass chromatography. And these inventories of propanol isomers and ([BMPyrr]BF₄)(IL) have been catalogued in Table 1. Additionally, the Table 2 illustrated the density and speed of sound of pure fluids such as water, 1-propanol and 2-propanol with references. Furthermore, the uncharted density (ρ) and speed of sound(U) of the [BMPyrr]BF$_4$ were represented in the Table 2.The specimens were correlated with standard articles[15]-[19].

Table 2: Physical properties of pure component water, 1-propanol, 2-propanol and IL with literature at specific temperatures

Sample	Parameter	Expt. /Lit.	Temperatures		
			303.15K	308.15K	313.15K
2P	ρ(kg.m^{-3})	Expt.	782.00	772.50	760.20
	ρ(kg.m^{-3})	Lit.	781.50[a]	772.00[a]	760.10[a]
	ρ(kg.m^{-3})	Lit.	776.85[e]	772.49[e]	768.05[e]
	U (m.s^{-1})	Expt.	1122.40	1106.00	1088.64
	U (m.s^{-1})	Lit.	1122.20[a]	1106.20[a]	1088.80[a]
	U (m.s^{-1})	Lit.	1121.43[e]	1103.94[e]	1086.62[e]
1P	ρ(kg.m^{-3})	Expt.	798.52	793.30	787.02
	ρ(kg.m^{-3})	Lit.	798.50[d]	793.30[d]	786.90[d]
	ρ(kg.m^{-3})	Lit.	775.97[e]	791.89[e]	787.77[e]
	U (m.s^{-1})	Expt.	1189.24	1171.74	1150.10
	U (m.s^{-1})	Lit.	1189.20[d]	1171.80[d]	1150.00[d]
	U (m.s^{-1})	Lit.	1189.26[e]	1172.37[e]	1155.53[e]
W	ρ(kg.m^{-3})	Expt.	995.64	994.04	992.21
	ρ(kg.m^{-3})	Lit.	995.67[b]	994.04[b]	992.23[b]
	ρ(kg.m^{-3})	Lit.	995.70[c]	994.03[c]	992.16[c]
	U (m.s^{-1})	Expt.	1509.12	1519.82	1528.90
	U (m.s^{-1})	Lit.	1509.25[b]	1519.82[b]	1528.89[b]
	U (m.s^{-1})	Lit.	1509.25[c]	1519.82[c]	1528.89[c]
IL	ρ(kg.m^{-3})	Expt.	1410.54	1392.24	1374.56
	U (m.s^{-1})	Expt.	1484.22	1462.12	1443.22

Here [a][15], [b][16],[c][17], [d][18],[e][19]

2.2 Evaluation Approach

The prepared binary fluids and pure fluids were fountained in to glass vials with the help of mass analytical balance (Mettler Toledo) which having an accuracy $\pm10^{-11}$kg. These vials were covered with air tight lids to prevent evaporation and adsorption of atmospheric moisture. The measured final molefraction for binary fluids are having uncertainty less than ±0.0001.The binary fluids of systems such as IL+W, IL+1P and IL+2P were prepared at specified concentrations, i.e., molefractions of these systems carried out 12 subsequent values from 0 to 1. The temperature dependent thermophysical features alike density (ρ) and speed of sound (U) of IL binary fluids were simultaneously calibrated through an instrument vibrating-tube digital density and speed of sound analyser in the temperatures 303.15K, 308.15K and 313.15K. The entire instrument contains temperature bath which has been controlled through incorporated Peltier thermostat with an accuracy of ±0.01K. So the uncertainty

values of experimental density (ρ) and speed of sound (U) were below of 0.01kg.m^{-3} and 0.5m.s^{-1} respectively.

3. DATA VALUE AND VALIDATION

The thermo physical fundamental features ρ and U were experimentally calibrated for binary fluids of IL+W, IL+1P and IL+2P with temperature ranges 303.15K, 308.15K, 313.15K. These were graphically portrayed in Figure 1(a) &(b) respectively. The observed features of non-linear increasing trend suggest that fluids have molecular interactions exists between them[19].
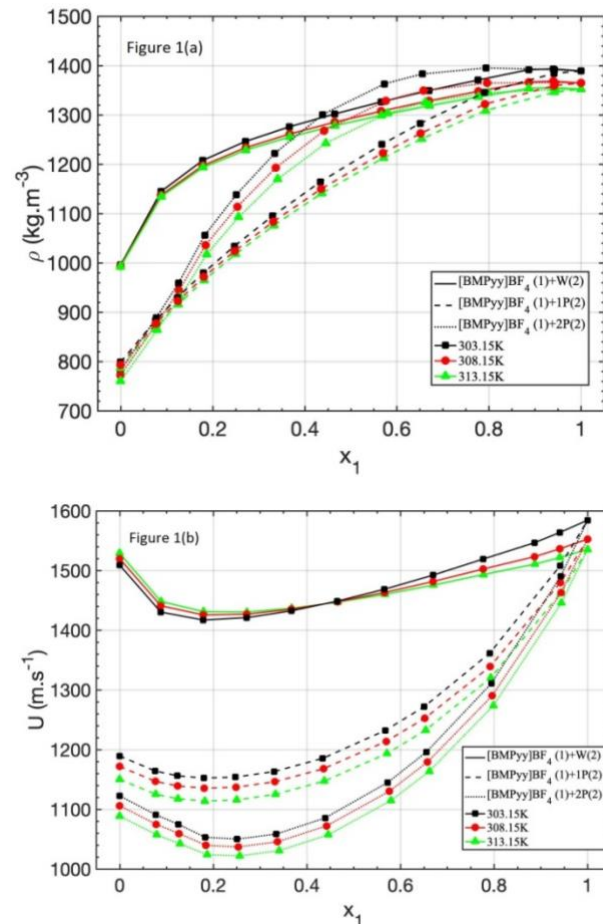

Figure 1: Plot of thermo physical features (a) density (b) speed of sound versus molefraction

This gives a first observable fact that as the temperature increases the interactions of molecules decreases. The eventual general expression was

$$Y^E = Y^r - Y^{id} \quad (1)$$

HereY^E=V_m^E,$K^E_{s,m}$and $Y\{=V_m$(molar volume), $K_{s,m}$ (molarisentropic compressibility)}are the real value of fluids. And, the ideal component of thermodynamic acoustic parameters for molar volume stands for

$$V^{id} = x_1V_1 + (1 - x_1)V_2 \quad (2)$$

Here, $x_1$is the molefraction of component IL(1) with respect to W/1P/2P(2). V_1 and V_2 are the pure acoustic molar values of IL(1)and W/1P/2P(2) respectively. The molar isentropic compressibility $K_{s,m}$ was calculated from the equation

$$K_{s,m} = V_m K_s = \frac{V_m}{\rho U^2} \quad (3)$$

And the ideal component of molar isentropic compressibility can be calculated as follows

$$K_{s,m}^{id} = \Sigma_{i=1}^2 x_i \left[K_{s,m,i} + \frac{TV_i(\alpha_i)^2}{C_{p,m,i}} \right] - \left[\frac{T(\Sigma_{i=1}^2 x_i V_i)(\Sigma_{i=1}^2 x_i \alpha_i)^2}{(\Sigma_{i=1}^2 x_i C_{p,m,i})} \right] \quad (4)$$

Where $K_{s,m,i}$, V_i, x_i, α_i and $C_{p,m,i}$ are the molar heat capacity, molar volume, molefraction, isobaric coefficient of thermal expansion and molar heat capacity of pure components in binary fluids. The isobaric thermal expansion coefficients of pure components were calculated as follows.

$$\alpha = -\frac{1}{\rho}\left(\frac{\partial \rho}{\partial T}\right) \quad (5)$$

The molar heat capacity $C_{p,m,i}$ and isobaric thermal coefficient for pure samples IL calculated from group contribution method of estimation of heat capacity[20]. The formula for group contribution method are

$$C_{p,m} = R\left[A + B\left(\frac{T}{100}\right) + D\left(\frac{T}{100}\right)^2 \right] \quad (6)$$

R is a universal gas constant. T is the temperature measured in kelvins. A,B and D are group contribution parameters can be calculated from as follows.

$$A = \Sigma_i^k n_i a_i, B = \Sigma_i^k n_i b_i, D = \Sigma_i^k n_i d_i \quad (7)$$

Whereas the heat capacity of structural isomers of propanol, water were pulled from the standard article[21]. These were catalogued in Table 3.

3.1 Redlich-Kister Polynomial Analysis

The conventional non-lineal curve fitting strategy for attributes of binary fluids pertains Redlich-Kister polynomial regression[22]-[24] which contains legendre coefficients.

$$Y_{RK}^E = x_1(1 - x_1)\Sigma_{p=0}^{p=N} A_{p,T} L_p(2x_i - 1) \quad (8)$$

Here, Y_{RK}^E means excess thermo dynamic feature which contain any value (i.e., V_m^E, $K_{s,m}^E$) has been taken. The standard deviation was also calibrated for the consequence.

$$\sigma(Y_{RK}^E) = \sqrt{\sum_{i=1}^{i=N} \frac{(Y_{i,exp} - Y_{i,cal})^2}{M - N}} \quad (9)$$

Where M stands for the number of experimental values and N stands for the adjustable parameter. These excess values are examined with Redlich-Kister polynomial non-linear regression with legendre coefficients. And these values of $A_{i,T}$(i=0,1,2,3) are determined along with standard deviation for the experimental values. Table 4 catalogued the whole values of all composites. The abnormality of thermodynamic acoustic excess parameters of V_m^E, $K_{s,m}^E$ are portrayed in Figure 2(a) & 2(b) respectively. Due to thermal agitations of all fluids, temperature rise ushers to descend the excess parameters [25]. The values of V_m^E are attributes positive or small negative for high concentrations of W, 1P&2P and the trend turns to negative during the increasing concentration of [BMPyy]BF₄ in the respective composites.
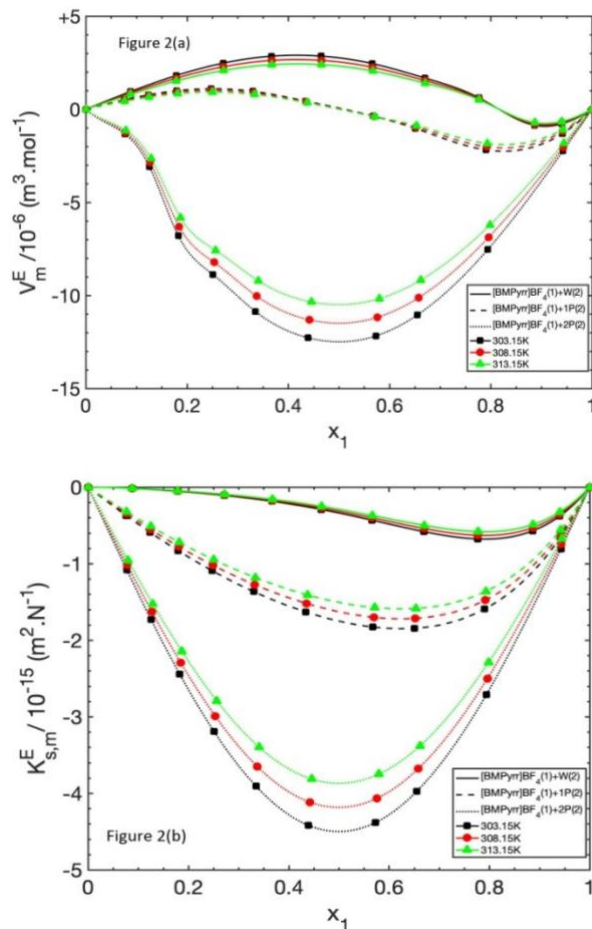

Figure 2: Plot of thermo physical features versus molefraction (a) Excess molar volume (b) Excess molar isentropic compressibility.

Table 3: Pure component isobaric expansivity and heat capacity at different temperatures

Sample	Parameter	Temperatures		
		303.15K	308.15 K	313.15K
2P	$C_{p,m}$(JK⁻¹.mol⁻¹)	157.5400	164.0100	167.8700
	α (x10⁻³K⁻¹)	2.10	2.80	3.60
1P	$C_{p,m}$(JK⁻¹.mol⁻¹)	147.8000	150.0500	153.5800
	α (x10⁻³K⁻¹)	1.20	1.40	1.70
W	$C_{p,m}$(JK⁻¹.mol⁻¹)	75.3176	75.2815	75.2640
	α (x10⁻³K⁻¹)	0.30	0.35	0.39
IL	$C_{p,m}$(JK⁻¹.mol⁻¹)	349.4563	349.4516	349.4470
	α (x10⁻³K⁻¹)	4.40	2.70	0.93

The flipping sharpness of V_m^E from positive to negative was greater in [BMPyy]BF₄ +2P than compared to the other fluids of [BMPyy]BF₄ +1P & [BMPyy]BF₄ +W respectively. This is clearly visible in Figure 2(a), for the replicated sequence $V_m^E V_m^E$. This clearly distinguishes the formation of H-bond, which is stronger at higher concentration and weaker in lower concentrations of composites. In addition to that, formation of

H-bond is very weak at high concentrations of W,1P and 2P[26].The abnormality of excess isentropic compressibility at all temperatures has been illustrated in Figure 2(b) over an entire concentration for all composites. The $K_{s,m}^E$ values are negative at all investigated temperatures for all composites. The sign of $K_{s,m}^E$ plays a vital role in assessing the compactness due to molecular interactions in multi-component mixtures suggests interstitial accommodation and oriental ordering leading to more compact structure.
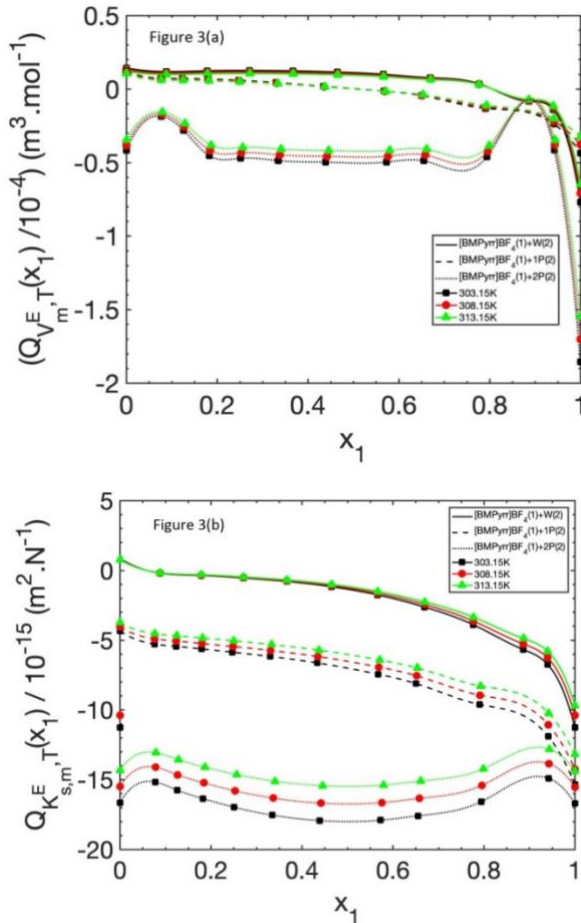

Figure 3: Plot of thermo physical features versus molefraction (a) Excess molar volume (b) Excess molar isentropic compressibility.

Fort and Moore [27] indicated that the binary fluids having distinct molecular sizes and shapes mix well there by reducing the volume which causes values of $K_{s,m}^E$ to be negative. The $K_{s,m}^E$ value of negative was greater in [BMPyy]BF$_4$ + 2P than compared to the other composites of [BMPyy]BF$_4$ +1P & [BMPyy]BF$_4$ +W respectively. This is clearly visible in Figure 2(b). This also clearly distinguishes a greater steric hindrance to the formation of hydrogen bonds in the respective composites. The order of V_m^E and $K_{s,m}^E$ values are IL(1)+2P(2)>IL(1)+1P(2) >IL(1)+ W(2).

3.2 Reduced Redlich-Kister Polynomial Analysis
The ineluctable Redlich Kister approach sporadically misguides the dissimilar composites. In conjunction to that it deceives interactions of molecules at low concentration regions in composites. Consequently, desnoyers[28]

suggested a contemporary befitted Reduced Redlich-Kister (RRK)[29] polynomial analysis to address more specific features in composites. So the equation becomes

$$Q_{Y_{RRK}^E}(x_1) = \frac{Y_{RK}^E(x_1)}{x_1(1-x_1)} \qquad (10)$$

Table 4: Coefficients of redlich-kister equation parameters and standard deviations at different temperatures.

Combination	T/K	Redlich-kister equation coefficients				error
		$A_{0,T}$	$A_{1,T}$	$A_{2,T}$	$A_{3,T}$	$\sigma(Y_{RK}^E)$
		V_m^E (10^{-6} m^3.mol^{-1})				
IL(1)+W(2)	303.15	-20.78	-28.16	-10.4	-17.32	0.11
	308.15	-19.15	-25.91	-9.56	-15.94	0.1
	313.15	-17.54	-23.67	-8.71	-14.57	0.09
		$K_{s,m}^E$ (10^{-15} m^2 .N^{-1})				
IL(1)+W(2)	303.15	-2.74	-0.08	0.02	-0.02	7.08E-07
	308.15	-0.93	-0.01	0	0	3.45E-08
	313.15	-0.05	-0.01	0	0	4.01E-07
		V_m^E (10^{-6} m^3.mol^{-1})				
IL(1)+1P(2)	303.15	0.97	-15.7	-5.41	-0.97	0.18
	308.15	-5.68	-18.78	-5.93	-4.09	0.03
	313.15	-4.88	-17.1	-5.39	-3.56	0.01
		$K_{s,m}^E$ (10^{-15} m^2 .N^{-1})				
IL(1)+1P(2)	303.15	-1.41	0.01	0	0	3.73E-08
	308.15	-0.22	0	0	0	4.78E-09
	313.15	-0.11	0.01	0	0	5.35E-08
		V_m^E (10^{-6} m^3.mol^{-1})				
IL(1)+2P(2)	303.15	-134.09	-39.19	20.8	-32.37	0.03
	308.15	-122.58	-35.89	19.16	-29.44	0.05
	313.15	-111.24	-32.55	17.68	-26.5	0.03
		$K_{s,m}^E$ (10^{-15} m^2 .N^{-1})				
IL(1)+2P(2)	303.15	-0.75	0	0	0	5.20E-09
	308.15	0.01	-0.01	0	0	2.79E-07
	313.15	-1.02	-0.05	0.01	-0.01	2.79E-07

The above specification is equivalent to apparent molar quantity of respective excess parameters in entire concentration range. Excess thermodynamic quantities have

the convenience of showing the flipping sign, sharpness and magnitude of the dissimilarity composites, but the RRK polynomial specification elucidates promising features to lift the origin of the dissimilarity solutions.The abnormality of $Q_{V_m^E,T}(x_1)$ at all temperatures has been illustrated in Figure 3(a) over an entire concentration for all composites. The values $Q_{V_m^E,T}(x_1)$ are attributes higher values for high concentrations of W,1P & 2P and the trend turns to lower values during the increasing concentration of IL in the respective fluids. The decreasing trend of value from higher to lower was greater in IL+2P than compared to the other fluids of IL+1P &IL+W respectively.
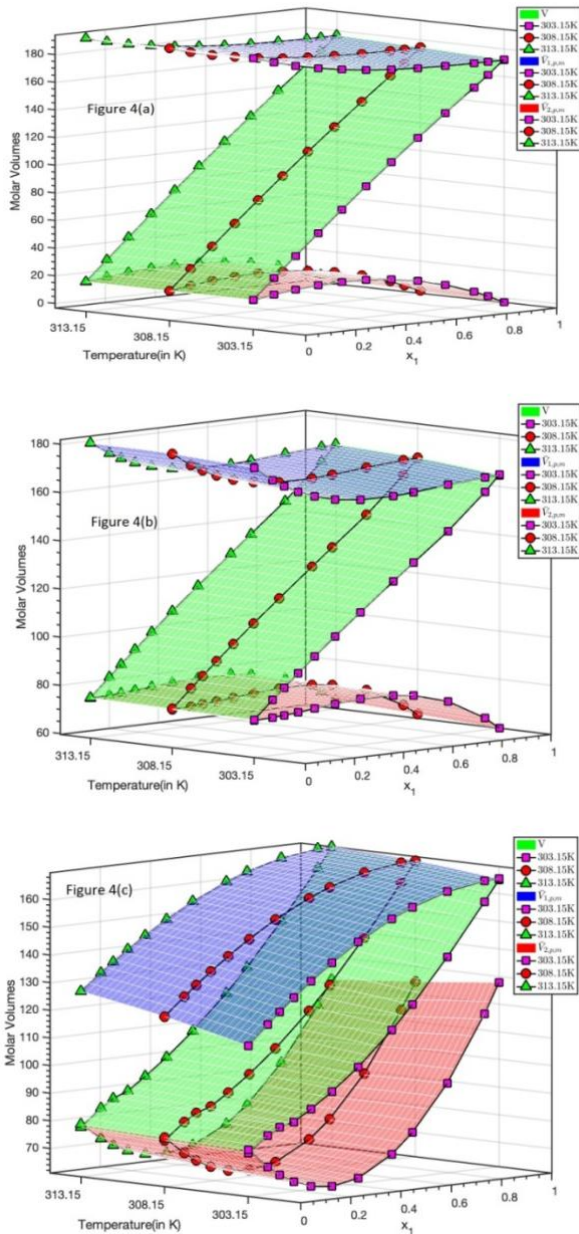
Figure 4: Plot of partial molar volumes/10^{-6} against molefraction and temperature for the solution (a)[BMPyy]BF$_4$(1)+W(2) (b)[BMPyy]BF$_4$(1)+1P(2) (c)[BMPyy]BF$_4$(1)+2P(2).

This evidently distinguishes the hydrophobic interactions are present and stronger in the region of higher concentrations of

ILs. In addition to that, Hydrophobic interactions are very weak at high concentrations of W, 1P & 2P. For the present scenario, the reduced functions values $Q_{K_{s,m}^E,T}(x_1)$ are higher value on W/1P/2P side and lower value on IL side. This clearly visible in Figure 3(b), for the replicated sequence of $Q_{K_{s,m}^E,T}(x_1)$.
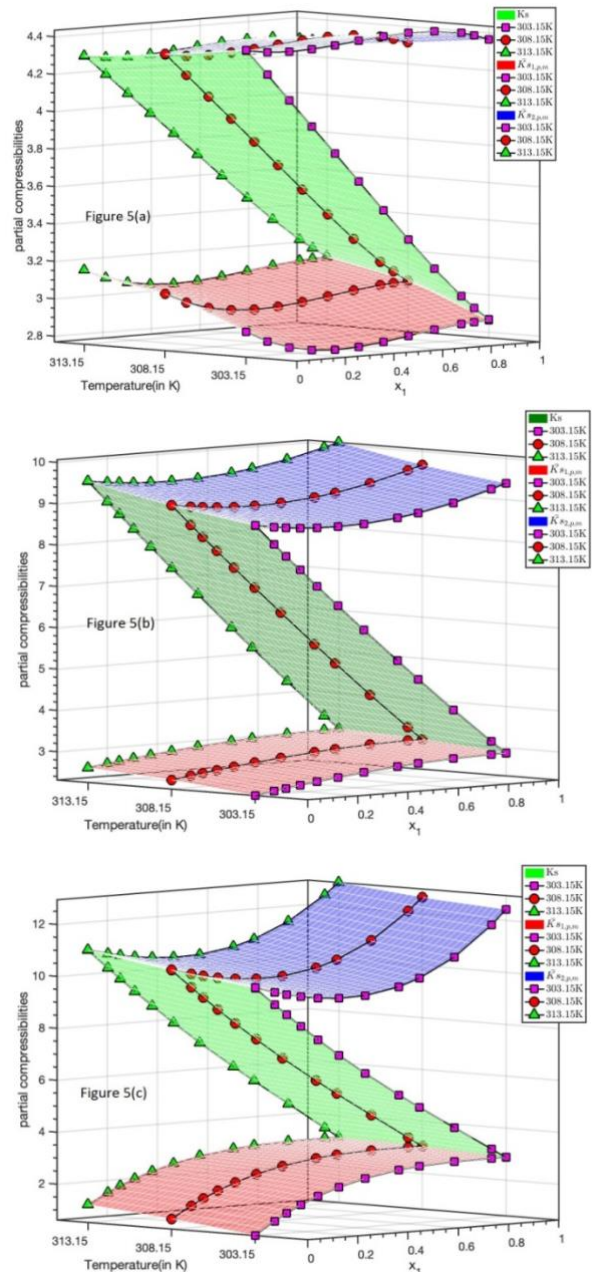

Figure 5: Plot of partial molar isentropic compressibilities/10^{-15} against molefraction and temperature for the solution (a)[BMPyy]BF$_4$(1)+W(2)(b)[BMPyy]BF$_4$(1)+1P(2) (c)[BMPyy]BF$_4$(1)+2P(2).

This result indicates composites are less compressible than the ideal mixtures. This strongly reveals strong interactions occur in these composites. It also clearly indicates that the 2P molecules are more sterically hindered in IL molecules.

3.3 Partial molar volumes and partial molar isentropic compressibilities

The RRK functions of $Q_{V_m^E,T}(x_1)$ and $Q_{K_{s,m},T}^E(x_1)$ at infinite dilution over a constant temperature and pressure was an addition tool to represents partial molar volumes[30] and partial isentropic compressibilities. The above extrapolation expression (8) has modified as

$$Q_{V_m^E}(x_1 = 0) = A_{0,T} - A_{1,T} + A_{2,T} - A_{3,T}$$
$$= \bar{V}_{1,p,m}^{E,\infty} = \bar{V}_{1,p,m}^{\infty} - V_{1,m} \quad (11)$$
$$Q_{V_m^E}(x_1 = 1) = A_{0,T} + A_{1,T} + A_{2,T} + A_{3,T}$$
$$= \bar{V}_{2,p,m}^{E,\infty} = \bar{V}_{2,p,m}^{\infty} - V_{2,m} \quad (12)$$

$\bar{V}_{1,p,m}^{E,\infty}$ and $\bar{V}_{2,p,m}^{E,\infty}$ are excess partial molar volumes two pure components at infinite dilutions. $\bar{V}_{1,p,m}^{\infty}$ and $\bar{V}_{2,p,m}^{\infty}$ are partial molar volumes at infinite dilutions. $V_{1,m}$ and $V_{2,m}$ are pure molar volumes of two components IL and W,1P & 2P. Similarly, the equation analogy is also true for partial isentropic compressibilities. But, the real partial molar volumes and partial isentropic compressibilities with respect to a molefraction at constant pressure and temperatures can be evaluated from the following differential equation

$$\bar{V}_{i,p,m} = V_m(x_i) - x_j \left(\frac{\partial V_m(x_j)}{\partial x_j} \right)_{T,P} \quad (13)$$

$$\bar{K}_{i,p,s} = K_s(x_i) - x_j \left(\frac{\partial K_s(x_j)}{\partial x_j} \right)_{T,P} \quad (14)$$

Here x_i and x_j are the mole fractions of two components in the composite ($i=1,2$ & $j=i-1$).The intermolecular interactions in the composites can be interpreted in terms of packing efficiency of molecules with the help of partial molar volumes and partial isentropic compressibilities. The partial molar volumes of two components $\bar{V}_{1,p,m}$ and $\bar{V}_{2,p,m}$ are play vital role in binary fluids. Because the domain influence of the components in the mixtures would changes with respect to the composition concentrations and as well as temperature. In thisscenario, the partial molar volumes of all components has been shelled in Figure 4(a),4(b) & 4(c) respectively.

In each of the figure, the scaffold Z symbol graph contains three colored meshes, which are concerned to red ($\bar{V}_{1,p,m}$), green (total molar volume, V) and blue ($\bar{V}_{2,p,m}$). For all combinations, the partial molar volumes of both components $\bar{V}_{1,p,m}$ and $\bar{V}_{2,p,m}$ are lower than of their individual values in the pure state, which reveals the domain influence of the individual components decreasing with their respective lower concentration regions. The abnormality is examined for all constant intervals of temperatures. This clearly suggests presence of solute-solvent interactions in between unlike molecules. Hence, from the representation of Figure 4(a), 4(b) & 4(c) the effect of domain influence of volume is low for [BMPyy]BF₄+2P than compared to the other composites of [BMPyy]BF₄+1P & [BMPyy]BF₄+W respectively. The partial isentropic compressibilities of two components $\bar{K}_{1,p,s}$ and $\bar{K}_{2,p,s}$ are also play crucial role in binary mixture. Because the geometrical influence of the components in the mixture changes with respect to the composition concentration and

temperature. In this scenario, the partial isentropic compressibilities of components [BMPyy]BF₄+W, [BMPyy]BF₄+1P & [BMPyy]BF₄+2P at all temperatures has been shelled in Figure 5(a), 5(b) & 5(c) respectively.In each of the figure, the mirror scaffolded Z symbol graph contains three colored meshes, which are concerned to red ($\bar{K}_{1,p,s}$), green (total isentropic compressibility, K_s) and blue ($\bar{K}_{1,p,s}$ and $\bar{K}_{2,p,s}$). The partial isentropic compressibilities $\bar{K}_{1,p,s}$ and $\bar{K}_{2,p,s}$ are more for the combination [BMPyy]BF₄+2P than compared to [BMPyy]BF₄+1P & [BMPyy]BF₄+W. This clearly suggests the breaking of dipole inclusions in [BMPyy]BF₄+2P has more than compared to the other combinations of [BMPyy]BF₄+1P & [BMPyy]BF₄+W. Hence, from the representation of Figure 5(a), 5(b) & 5(c), the effect of geometrical influence is low for [BMPyy]BF₄+W than compared to the other composites of [BMPyy]BF₄+1P & [BMPyy]BF₄+2P.
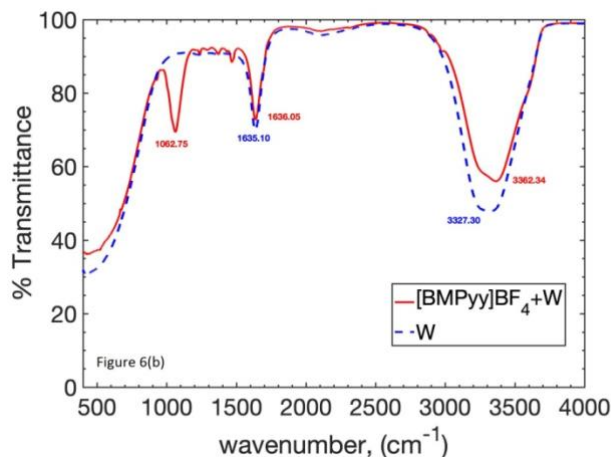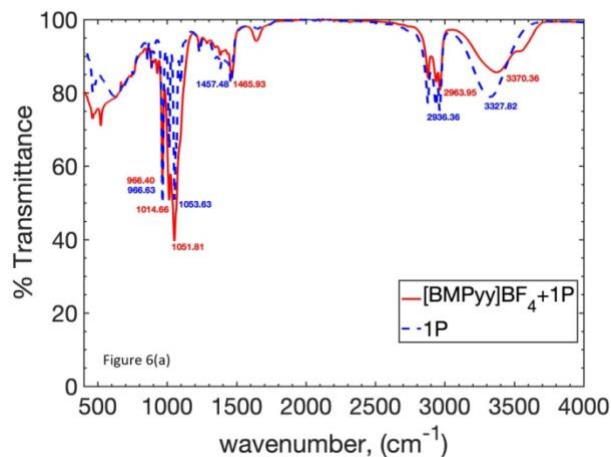
4. FT-IR SPECTRUM ANALYSIS

Figure 6: Normalized FT-IR Spectra analysis for the binary mixtures over the range 400 to 4000 cm⁻¹ for the combination (a)[BMPyy]BF₄(1)+1P(2) (b) [BMPyy]BF₄(1)+W(2).

The FT-IR spectrum of components [BMPyy]BF₄+W & [BMPyy]BF₄+1P & [BMPyy]BF₄+2P and their pure components are carried at room temperature 303.15K. The peaks of intensity N-H strong for secondary amine, C-H medium stretching and C=O strong stretching are shown in the

Figure 6(a) & 6(b) for the combination [BMPyy]BF$_4$+1P and stronger than [BMPyy]BF$_4$+W. This contention was supported by the formation of strong molecular interaction bonds between binary fluids.

5. CONCLUSIONS

In this frame work, the values of excess thermodynamic parameters have been calibrated for an entire composition of IL+W, IL+1P &IL+2P with accustomed levels of temperatures. This is clearly elucidating a strong hydrogen bonding, dipole-inclusion interactions present in the component molecules. Moreover, the reduced excess thermodynamic parameters have been executed by using contemporary RRK polynomial over an entire composition with accustomed levels of temperatures. This reveals more specific features about, smaller molar mass of W, IP& 2P molecules sterically hindered in larger molar mass of ILs in their respective compositions. The reduced excess parameters value decreases for increasing the temperatures in their compositions due to their thermal agitations. The reactive of composites are in the order IL(1)+W(2)<IL(1)+1P(2)<IL(1)+2P(2). And the partial molar volumes,partial molar isentropic compressibilities of all components have been plotted in 3D format. This discloses the intermolecular interactions are strong in IL(1)+2P(2) than compare to IL(1)+1P(2) &IL(1)+2P(2). These results indicate, the intermolecular interaction behaviors were also supported with FT-IR spectroscopy.

ACKNOWLEDGEMENT

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