CHAPTER-VII

STUDY OF DIVERSE INTERFACES OF BIOLOGICALLY ACTIVE SOLUTES IN H_2O + IONIC LIQUID SYSTEMS BY PHYSICOCHEMICAL APPROACH

Solute-Solvent interactions prevailing in α-amino acids (glycine, L-alanine, L-valine) and aqueous solution of 1-butylpyridinium bromide([BPy]Br) have been reported by physicochemical properties. The apparent molar volume (ϕ_V), viscosity B-coefficient, molal refraction (R_M) and adiabatic compressibility (ϕ_K) of glycine, L-alanine, and L-valine have been studied in 0.001, 0.003, 0.005 mol dm^{-3} aqueous 1-butylpyridinium bromide([BPy]Br) solutions at 298.15 K from the values of densities (ρ), viscosities(η), refractive index (n_D) and speed of sound (u) respectively. The limiting apparent molar volumes (ϕ_V^0), experimental slopes (S_V^*) obtained from the Masson equation have been interpreted in terms of solute-solvent and solute-solute interactions, respectively. The viscosity data were analyzed using the Jones-Dole equation, and the derived parameters A and B have also been interpreted in terms of solute-solvent and solute-solute interactions, respectively in the mixed solutions. Molal refractions (R_M) have been calculated using the Lorentz-Lorenz equation and discussed. The role of the solvent (aqueous ionic liquid solution) and the contribution of solute–solute and solute–solvent interactions to the solution complexes have also been analyzed through the derived properties.

VII.1. INTRODUCTION

Amino acids, particularly important in biochemistry are critical to life, and have many functions in metabolism. One particularly important function is to serve as the

building blocks of proteins. Due to their central role in biochemistry; amino acids are important in nutrition and are commonly used in food technology and industry. Methanoic acid is an essential chemical industry material. It is widely used in the textile industry, tanning industry, rubber processing industry, and pharmaceutical industry. In addition, methanoic acid is used as a preservative and antibacterial agent in livestock feed.[VII.1-VII.2] In this work, we attempted to ascertain the nature of solute solvent interactions of amino acids (glycine, L-alanine, and L-valine) in0.001, 0.003, 0.005 mass fraction of aqueous ionic liquid binary mixtures at 298.15K.

Ionic liquids (ILs) are very attractive because of their unique properties, such as large liquid range, high thermal stability, negligible vapour pressure, ability of dissolving a variety of chemicals, miscibility with common molecular liquids, large electrochemical window and their potential as "designer solvents" and "green" replacements i.e. alternative solvents to volatile organic solvents [VII.3-VII.5] used in reactions involving inorganic compounds as well as bio-catalysts. They are also used as heat transfer fluids for processing biomass and as electrically conductive liquids in electrochemistry (batteries and solar cells) [VII.6-VII.8]. The volumetric, viscometric and acoustic behavior of solutes is very much useful in elucidating the various interactions occurring in solutions. Studies on the effect of concentration (molality), the apparent molar volumes of solutes have been extensively used to obtain information on solute-solute, solute-solvent, and solvent-solvent interactions [VII.9-VII.13]. In view of the above and in continuation of our study, we have undertaken a systematic study on the density, viscosity, refractive index and ultrasonic speed of some amino acids in aqueous 1-butylpyridinium bromide ([BPy]Br)solutions at 298.15 K and we have attempted to report the limiting apparent molar volumes (ϕ_V^0),

experimental slopes (S_V^*) and viscosity *B*-coefficients, molar refraction (R_M) and limiting apparent molar adiabatic compressibility (ϕ_k^0) in solution.

VII.2. EXPERIMENTAL

VII.2.1 Source and purity of samples

([BPy]Br)of puriss grade was procured from Sigma-Aldrich, Germany andwas used as purchased. The mass fraction purity of ([EPy]Br)was ≥ 0.99.The amino acids Glycine (S.D. Fine Chemicals, >99%), L-Alanine (S.D. FineChemicals, >98.5%), and L-Valine (LobaChemie, India, >99%) were used withoutfurther purification.

VII.2.2 Apparatus and Procedure

The density (ρ) was measured by vibrating-tube Anton Paar density-meter (DMA 4500M) with a precision of ± 0.00005 g·cm^{-3}. It was calibrated by double-distilled water and dry air [VII.14]. The temperature was automatically kept constant within ±0.01 K.

Brookfield DV-III Ultra Programmable Rheometer with spindle size-42 was used to measure the viscosity value having an accuracy of ± 1.0% range with displayed test data and fitted to a Brookfield Digital Bath TC-500.

Refractive index was measured with the help of a Digital RefractometerMettler Toledo. The light source was LED, λ=589.3nm. The refractometer was calibrated twice using distilled water and calibration was checked after every few measurements. The uncertainty of refractive index measurement was ± 0.0002 units.

Ultrasonic interferometer (Model M 83) from Mittal enterprises was used to measure the ultrasonic velocities, u (ms-1) measured using an ultrasonic interferometer (Model M 83) from Mittal enterprises. The interferometer working at 2 MHz is based on the same principle as was used by Freyer et al. [VII.15] and Kiyoharo et al. [VII.16-VII.17] The obtained velocities were corrected for diffraction errors as given by Subrahmayan et al. [VII.18]. The maximum uncertainty in the velocity is ±0.5 m s-1. The temperature was controlled within ±0.01 K using a Lauda thermostat for velocity measurements.

VII.3. RESULTS AND DISCUSSIONS

VII.3.1 Density Calculation

The physical properties of different mass fraction of the aqueous Ionic liquid mixture are presented in Table VII.1.The measured experimental values of densities, viscosities, refractive index and ultrasonic speeds of simple three amino acids in different mass fractions (w1 = 0.001, 0.003, 0.005) of aqueous ionic liquid ([BPy]Br) solution at 298.15 K as a function of concentration (molality) are listed in Table VII.2. Apparent molar volume (ϕ_V) was determined from the solution density using the following equation [VII.19].

$$\phi_V = M/\rho - 1000(\rho - \rho_o)/m\rho\rho_o \qquad (1)$$

Where*M* is the molar mass of the solute, *m* is the molality of the solution, ρ_0 and ρ are the densities of the solvent (ascorbic acid solution) and solution (carbohydrate in ascorbic acid solution) respectively. The limiting apparent molar volume ϕ_V^0 was calculated using a least-square treatment to the plots of ϕ_V versus $\sqrt{m}$ using the Masson equation [VII.20].

$$\phi_V = \phi_V^0 + S_V^* \sqrt{m} \qquad (2)$$

where ϕ_V^0 is the limiting apparent molar volume at infinite dilution and S_V^* is the experimental slope. The plots of ϕ_V against square root of molal concentration ($\sqrt{m}$) were found to be linear with slopes. Values of ϕ_V^0 and S_V^* are reported in Table VII.4.

The variation of ϕ_V^0 for these three amino acids with the ionic liquid solution mixture is shown in Figure VII.1.

ϕ_V^0 valuesin Table VII.4 shows that for the studied amino acids are positive and increasewith an increase in concentrations, indicate the presence of strong solute-solvent interactions and these interactions are further enhanced as increases the mass fraction of aqueous IL in the mixture.

The probable point of interaction between the ionic liquid and amino acids are represented in Scheme VII.1, where we see that the point of interaction of ionic liquid is highest in L-Valine (I_3 interaction) than L-Glycine(I_2) and L-Alanine(I_1).

Glycine lacks alkyl group (methyl) whereas Alanine is linked to one and Valine is linked to two methyl groups. It is observed that the methyl group having +I effects increase the electron availability (electron density) on the oxygen atom. As a result, the interfaces (interactions) between nitrogen and oxygen atom in Valine is higher than that Alanine which in turn higher than that in Glycine.

According to the study we can say that the trend in thesolute-solvent interaction is represented bellow

Glycine < L-Alanine < L-Valine

This observation can interpret that with the increase in the number of carbon atoms in the studied amino acids, the solute-solvent interaction also increases, similar results will be found for amino acid in methanoic acid (Formic acid) [VII.21].

Amino acid solution given in Table VII.4, the S_V^* values decrease with the increase in the number of carbon atoms of the studied amino acids and also with the increase in the mass fraction of ([BPy]Br)in the solvent mixture interpreting minimum solute-solute interaction in the higher correspondents.

VII.3.2 Viscosity Calculation

These viscositydata wereutilized to calculate the viscosity *B*-coefficient using Jones-Dole equation [VII.22]

$$(\eta/\eta_0 - 1)/\sqrt{c} = A + B\sqrt{c} \qquad (3)$$

where$\eta_0$and$\eta$are the viscosities of the solvent and solution respectively. *A*and*B*are the viscosity co-efficient estimated by a least squares method and are reported in Table VII.4. The values of the A coefficient are found to decrease from glycine to valineand with the increase in mass fraction of aquous ionic liquid mixture. The results indicate the presence of very weak solute–solute interactions. These results are in excellent agreement with those obtained from S_V^* values discuss earlier.

The extent of solute-solvent interactions on the solution viscosity can be estimated from the *B*-coefficient [VII.23-VII.24]. The viscosity *B*-coefficient is a valuable tool to provide information regarding the solvation of the solutes and their effects on the structure of the

solvent. From Table VII.4 and Figure VII.2 it is evident that the values of the *B*-coefficient are positive, and much higher than *A*-coefficient, thereby suggesting the solute-solvent interactions are dominant over the solute-solute interactions. The higher *B*-coefficient values for higher viscosity values is due to the solvated solutes molecule associated by the solvent molecules all round to the formation of associated molecule by solute-solvent interaction, would present greater resistance, and this type of interactions are strengthened with increase of mass fraction (w1) of aqueous ionic liquid solution, are in agreement with the results obtained from ϕ_V^0 values discussed earlier.

VII.3.3 Refractive Index Calculation

The refractive index measurement is also a convenient method for investigating the ion-solvent interaction of salts in solution. The values of n_D are reported in Table VII.2. The molar refraction, R_M can be evaluated from the Lorentz-Lorenz relation[25]

$$R_M = \left\{(n_D^2\text{-}1)/(n_D^2 + 2)\right\}(M/\rho) \qquad (4)$$

Where R_M, n_D, M and ρ are the molar refraction, refractive index, molar mass and density of solution respectively. The refractive index of a substance is defined as the ratio c_0/c, where c is the speed of light in the medium and c_0 the speed of light in vacuum. Stated more simply, the refractive index of a compound describes its ability to refract light as it moves from one medium to another and thus, the higher the refractive index of a compound, the more the light is refracted [VII.26]. As stated by Deetlefs et al. [VII.27].the refractive index of a substance is higher when its molecules are more tightly packed or in general when the

compound is denser. Table VII.2 and Table VII.3 shows that the refractive indices (n_D) and the molar refractions (R_M)increases with the increase of mass fraction of aquous ionic liquid mixture.

Hence the values of Tables VII.2 and Table VII.3, we found that the refractive index and the molar refraction values respectively are higher for L-Valine than L-Glycine and L-Alanine, indicating the fact that the molecules are more tightly packed in the mixture. The interaction in the solution is basically solute–solvent interaction and a small amount of solute–solute interaction. This is also in good agreement with the results obtained from density and viscosity parameters discussed above. The trend in the package of the studied amino acid in aqueous mixture of ionic liquid is

Glycine < L-Alanine < L-Valine

VII.3.4 Ultrasonic Speed Calculation

The adiabatic compressibility (β) was evaluated from the following equation:

$$\beta = 1 / u^2 \rho \quad (5)$$

Where ρ is the density of the solution and *u* is the speed of sound in the solution.

The apparent molar adiabatic compressibility ϕ_K of the solution was determined from the relation. [VII.28]

$$\phi_K = M\beta / \rho + 1000\left(\beta \rho_o - \beta_o \rho\right) / m \rho \rho_o \quad (6)$$

where β_0, β are the adiabatic compressibility of the solvent and solution respectively and m is the molality of the solution. Limiting molar adiabatic compressibilities (ϕ_K^0) and experimental slopes (S_K^*) were obtained by fitting ϕ_K against the square root of molality ($\sqrt{m}$) using the least squares method.

$$\phi_K = \phi_K^0 + S_K^* \cdot \sqrt{m} \qquad (7)$$

The values of β and ϕ_K are reported in Table VII.3 and the values of ϕ_K^0 and S_K^* are presented in Table VII.4. The values of ϕ_K^0 and S_K^* are important parameter provided information about the extent of solute-solvent and solute-solute interaction respectively. The behavior is useful in characteristic of solvation and electrostriction (the contraction of the solvent around the solute) of salt in solutions.

From Table VII.4 and Fig. VII.3, it is observed that the value of limiting apparent molar compressibility ϕ_K^0 are positive and increases with the increase in concentration (w_1) of ionic liquid solution for all the studied solution, and shows the stronger solute-solvent interaction. The result is good agreement with the ϕ_V^0 value discussed earlier. It is also observed that the values of ϕ_K^0 for the studied amino acids follow the order:

Glycine < L-Alanine < L-Valine

Since the contribution of methylene group to the apparent compressibility is positive, it implies that the ions having the larger hydrophobic group may have more positive values for the molal expansibilities. Hence, L-Valine may have largest hydrophobic group resulting higher values of ϕ_K^0.

VII.4. CONCLUSION

The values of the limiting apparent molar volume (ϕ_V^0) and viscosity *B*-coefficients of simple amino acids in aqueous 1-butylpyridinium bromide([BPy]Br)solution at 298.15 K indicate the presence of strong solute-solvent interactions. It is evident that in the association of the investigated amino acids, the L-Valine is greater than L-Alanine which is, in turn, greater than that Glycine. The refractive index and the molar refraction values suggest that the molecules of L-Valine are more tightly packed in the solution leading to higher solute-solvent interaction than L-Glycine and L-Alanine. The thorough study of amino acids in Ionic Liquid solution indicates that the solute-solvent interaction dominants over the solute-solute interaction. Above all, this study demands a novelty of some amino acids prevailing in the aqueous solutions of 1-butylpyridinium bromide ([BPy]Br).

TABLES

Table VII.1: The values of Density (ρ), Viscosity (η), Refractive index (n_D), and Speed of sound (u) in different mass fraction of 1-butylpyridinium bromide solution at 298.15K

Mass-fraction of 1-butylpyridinium bromide	ρ x 10^{-3} (kg m^{-3})	η (mPa s)	n_D	U (ms^{-1})
w_1 = 0.001	0.99705	0.909	1.3326	1489.4
w_1 = 0.003	0.99816	0.914	1.3333	1495.9
w_1 = 0.005	0.99923	0.919	1.3341	1505.3

Table VII.2: Experimental values of Densities (ρ), Viscosities (η), Refractive Index (n_D) and Ultrasonic Speed (u)of L-Glycine, L-Alanine and L-Valine in different mass fraction of 1-butylpyridinium bromide at 298.15K

molality (mol kg^{-1}	P x 10^{-3} (kgm^{-3})	η (mPas)	n_D	u (ms^{-1})	molality (mol kg^{-1}	P x 10^{-3} (kgm^{-3})	H (mPas)	n_D	u (ms^{-1})
w_1 = 0.001					w_1 = 0.003				
L-Glycine					L-Glycine				
0.1002	0.99733	0.916	1.3328	1485.1	0.1001	0.99836	0.917	1.3335	1489.2
0.1584	0.99779	0.922	1.3332	1490.4	0.1584	0.99873	0.921	1.3337	1492.3
0.2005	0.99824	0.927	1.3335	1501.6	0.2005	0.99932	0.925	1.3340	1513.7
0.2351	0.99874	0.932	1.3338	1514.8	0.2350	0.99986	0.929	1.3343	1528.3
0.2654	0.99927	0.937	1.3341	1532.6	0.2652	1.00037	0.933	1.3345	1559.3
0.2925	0.99983	0.942	1.3344	1546.9	0.2924	1.00079	0.937	1.3347	1578.0
L-Alanine					L-Alanine				
0.1002	0.99728	0.918	1.3330	1481.2	0.1001	0.99834	0.921	1.3338	1487.4
0.1584	0.99771	0.928	1.3334	1487.4	0.1584	0.99874	0.930	1.3342	1497.5
0.2005	0.99814	0.937	1.3337	1495.5	0.2004	0.99921	0.939	1.3346	1510.4
0.2351	0.99857	0.946	1.334	1513.2	0.2350	0.99962	0.948	1.3349	1554.5
0.2654	0.9990	0.956	1.3343	1528.2	0.2652	1.00011	0.957	1.3352	1574.9
0.2925	0.99943	0.964	1.3346	1541.0	0.2924	1.00061	0.966	1.3355	1618.8
L-Valine					L-Valine				
0.1002	0.99725	0.916	1.3334	1479.3	0.1001	0.99831	0.922	1.3341	1484.5

0.1584	0.99764	0.922	1.3337	1483.4	0.1584	0.99868	0.935	1.3345	1495.7
0.2005	0.99804	0.927	1.334	1492.9	0.2004	0.99906	0.948	1.3349	1506.8
0.2351	0.99846	0.932	1.3343	1508.7	0.2350	0.99956	0.962	1.3353	1550.6
0.2654	0.99886	0.937	1.3346	1523.6	0.2652	0.99995	0.975	1.3356	1570.7
0.2925	0.99928	0.942	1.3349	1536.5	0.2924	1.00037	0.997	1.3369	1614.7
$w_1 = 0.005$									
L-Glycine									
0.1001	0.99941	0.924	1.3343	1505.6					
0.1583	0.99986	0.930	1.3347	1531.3					
0.2002	1.00041	0.935	1.3351	1543.7					
0.2349	1.00079	0.940	1.3354	1572.3					
0.2651	1.00129	0.945	1.3357	1606.3					
0.2922	1.00179	0.950	1.336	1648.4					
L-Alanine									
0.1001	0.99941	0.926	1.3345	1502.8					
0.1583	0.99986	0.936	1.3349	1517.5					
0.2002	1.00041	0.945	1.3353	1538.4					
0.2349	1.00079	0.954	1.3356	1566.0					
0.2651	1.00129	0.964	1.3359	1599.4					
0.2922	1.00179	0.973	1.3362	1640.7					
L-Valine									
0.1001	0.99933	0.927	1.3347	1501.8					
0.1583	0.99968	0.939	1.3351	1515.0					
0.2002	1.00018	0.953	1.3355	1534.8					

0.2349	1.00059	0.967	1.3359	1560.9					
0.2651	1.00102	0.981	1.3362	1592.8					
0.2922	1.00158	0.996	1.3365	1631.6					

Table VII.3: Molality, apparent molar volume (ϕ_V),$(\eta/\eta_0-1)/m^{1/2}$, molar refraction (R), adiabatic compressibility (β) and apparent molal adiabatic compressibility (ϕ_K) of L-Glycine,L- Alanine, and L-Valine in 1-butylpyridinium bromide 298.15 K

molality (mol kg^{-1})	ϕ_V x 10^6 (m^{3}mol^{-1})	$(\eta/\eta_0-1)/m^{1/2}$ (kg$^{1/2}$ mol$^{-1/2}$)	R (cm^3 mol^{-1})	β x 10^{10} (Pa^{-1})	ϕ_K x 10^{10} (m^3 mol^{-1} Pa^{-1})
w_1 = 0.001					
L-Glycine					
0.1002	48.22	0.077	**15.4745**	4.0257	-2.2563
0.1584	46.62	0.090	**15.4842**	4.1522	-3.6040
0.2005	45.45	0.099	**15.4899**	4.0533	-4.5768
0.2351	44.47	0.108	**15.4947**	3.9308	-5.4517
0.2654	43.48	0.116	**15.4992**	3.7951	-6.1420
0.2925	42.80	0.124	**15.5031**	3.6395	-6.6241
L-Alanine					
0.1002	66.2789	0.098	**18.3745**	4.2312	-1.6191
0.1584	62.8692	0.131	**18.3842**	4.1641	-3.0530
0.2005	62.0167	0.152	**18.3909**	4.0710	-4.0610
0.2352	61.6293	0.171	**18.3967**	3.9560	-4.9164
0.2655	61.4079	0.193	**18.4019**	3.8185	-5.7282

0.2927	61.2646	0.205	**18.4066**	3.6644	-6.4478
L-Valine					
0.1002	97.4277	0.1086	**24.1834**	4.2367	-0.9359
0.1585	93.8174	0.1579	**24.2003**	4.1759	-2.4406
0.2006	92.6641	0.1953	**24.2103**	4.0859	-3.5496
0.2354	91.7752	0.2265	**24.2199**	3.9759	-4.4307
0.2658	91.5538	0.2579	**24.2299**	3.8426	-5.2482
0.2931	91.1746	0.2859	**24.2394**	3.6916	-5.9934
w_1 = 0.003					
L-Glycine					
0.1001	55.17	0.033	**15.4838**	4.1913	-2.3940
0.1583	51.54	0.048	**15.4907**	4.1089	-4.0056
0.2004	48.55	0.060	**15.4942**	3.9988	-5.1233
0.2350	46.34	0.070	**15.4984**	3.8659	-6.0413
0.2653	44.57	0.078	**15.5031**	3.7078	-6.9238
0.2924	43.01	0.086	**15.5050**	3.5374	-7.6350
L-Alanine					
0.1001	70.22	0.077	**18.3959**	4.2077	-1.9565
0.1584	67.02	0.111	**18.4085**	4.1304	-3.5534
0.2004	64.95	0.137	**18.4198**	4.0227	-4.7430
0.2352	62.95	0.158	**18.4273**	3.8919	-5.7006
0.2654	61.54	0.177	**18.4332**	3.7403	-6.5485
0.2926	60.27	0.195	**18.4389**	3.5666	-7.3572
L-Valine					

0.1001	100.11	0.087	**24.2104**	4.2131	-1.1779
0.1585	97.52	0.145	**24.2274**	4.1409	-2.9962
0.2006	95.42	0.186	**24.2447**	4.0377	-4.2277
0.2354	93.82	0.223	**24.2589**	3.9073	-5.2885
0.2657	92.39	0.251	**24.2691**	3.7568	-6.1767
0.2930	91.32	0.273	**24.2785**	3.5866	-6.9844
$w_1 = 0.005$					
L-Glycine					
0.1001	57.11	0.054	**15.5054**	4.1555	-2.6370
0.1583	52.54	0.076	**15.5152**	4.0647	-4.4513
0.2003	49.60	0.087	**15.5235**	3.9404	-5.7550
0.2350	46.89	0.097	**15.5302**	3.7905	-6.7978
0.2652	45.02	0.107	**15.5351**	3.6225	-7.6602
0.2923	42.98	0.115	**15.5399**	3.4291	-8.5166
L-Alanine					
0.1001	72.15	0.076	**18.4125**	4.1720	-2.0626
0.1583	68.23	0.117	**18.4243**	4.0863	-3.9757
0.2004	65.27	0.141	**18.4363**	3.9696	-5.2298
0.2351	63.22	0.162	**18.4421**	3.8228	-6.3508
0.2654	61.11	0.185	**18.4478**	3.6557	-7.2819
0.2926	59.45	0.201	**18.4533**	3.4633	-8.1808
L-Valine					
0.1001	102.23	0.087	**24.2251**	4.1778	-1.3508
0.1584	99.17	0.137	**24.2428**	4.1008	-3.2542

0.2005	96.79	0.185	**24.2569**	3.9892	-4.6126
0.2353	94.49	0.222	**24.2732**	3.8495	-5.7328
0.2657	92.87	0.254	**24.2824**	3.6882	-6.6818
0.2930	91.57	0.286	**24.2885**	3.5045	-7.5651

Table VII.4: Limiting apparent molar volumes (ϕ_V^0), experimental slopes(S_V^*), *A*, *B* coefficients, limiting partial adiabatic compressibility (ϕ_K^0), and experimental slope (S_K^*) of L-Glycine, L-Alanine, and L-Valine in aqueous 1-butylpyridinium bromide 298.15 K

Salt	ϕ_V^0 x 10^6 ($m^3 mol^{-1}$)	S_V^* x 10^6 (m^3 $mol^{-3/2}$ $kg^{1/2}$)	*A* (kg mol^{-1})	*B* ($kg^{1/2}$ $mol^{-1/2}$)	ϕ_K^0 x 10^{10} (m^3 mol^{-1} Pa^{-1})	S_K^* x 10^4 (m^3 $mol^{-3/2}$ Pa^{-1} $kg^{1/2}$)
w_1 = 0.001						
-Glycine	51.11	−26.40	0.0481	0.19	0.04	−21.75
L-Alanine	66.42	−37.14	0.0415	0.52	0.61	−22.98
L-Valine	96.97	−38.21	0.0339	0.88	1.39	−24.15
w_1 = 0.003						
-Glycine	61.53	−27.03	0.0321	0.21	0.09	−25.25
L-Alanine	75.32	−39.91	0.0235	0.56	0.67	−26.43
L-Valine	104.75	−53.71	0.0131	0.91	1.49	−28.05
w_1 = 0.005						
-Glycine	64.27	−29.62	0.0122	0.26	0.15	−28.49
L-Alanine	78.69	−47.19	0.0088	0.58	0.77	−29.60
L-Valine	107.96	−67.23	0.0054	0.98	1.55	−30.20

FIGURES

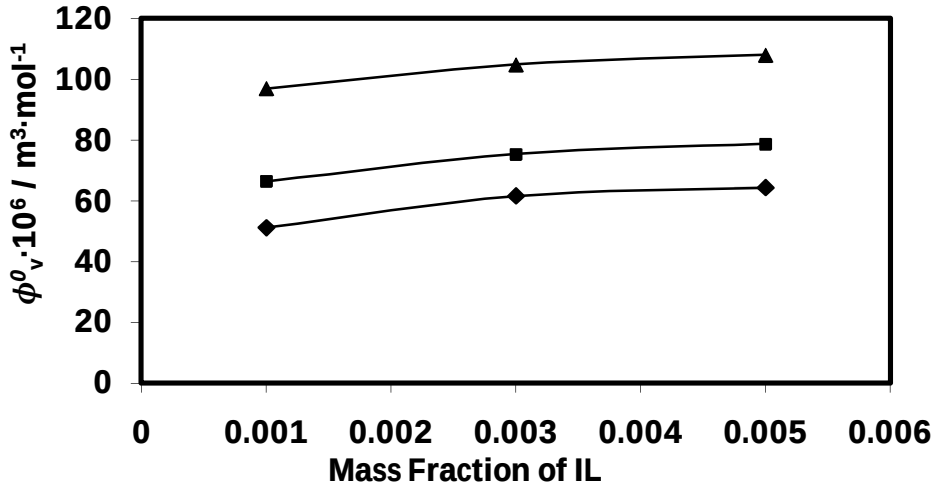


Figure VII.1: Plot of limiting apparent molar volume (ϕ_V^0) for glycine (◊), alanine (□),andvaline (Δ)against mass fraction of aqueous ionic liquid solution.

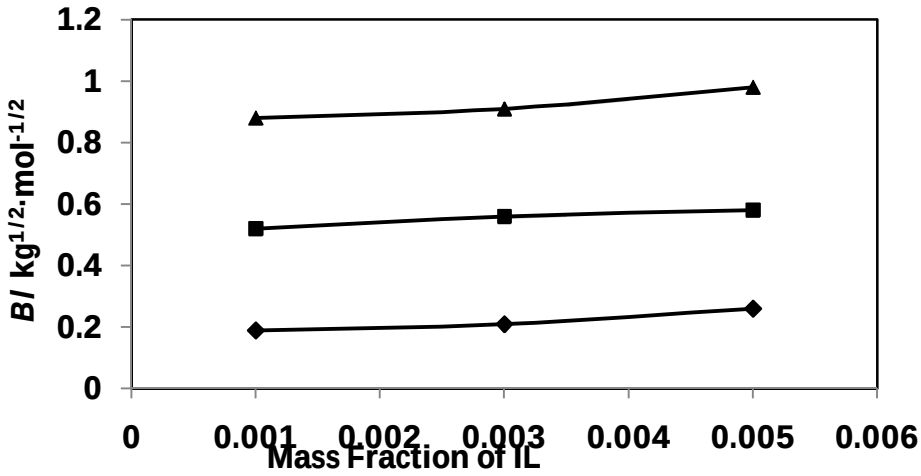


Figure VII.2: Plot of Viscosity *B*-coefficient for glycine (♦), alanine (□)and valine (Δ) against mass fraction of aqueous ionic liquid solution.

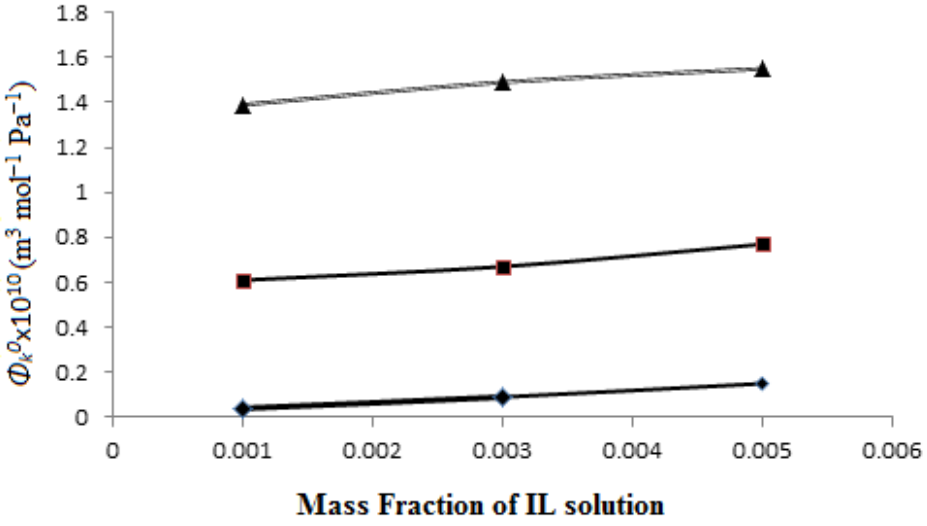
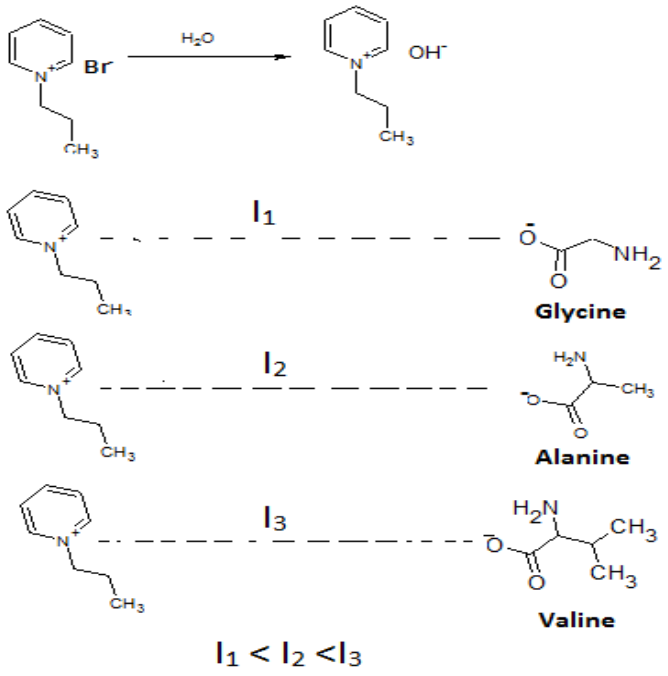


Figure VII.3: Plot of limiting molar compressibility (ϕ_K^0) for glycine (◊), alanine (□), valine (Δ), against mass fraction of aqueous ionic liquid solution

SCHEMES



Scheme VII.1: Interactions between Ionic Liquid and Amino Acids