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Volumetric and Transport Properties Of L-Isoleucine In Aqueous Ethanol

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ABSTRACT

Densities and viscosities of L- isoleucine have been measured at 298.15, 303.15, 308.15, 310.15 and 313.15 K in aqueous ethanol mixtures (wt.) % mass of ethanol. The viscosity data have been analyzed using the Jone-Dole equation. Apparent molar volumes, limiting partial molar volumes and relative viscosity have been evaluated from the density and viscosity data. Transfer volumes, limiting partial molar volumes and hydration numbers have also been calculated. The results have been discussed in terms of solute-solute and solute- solvent interactions and the structural changes of the solutes in solutions.

Key words: L-isoleucine, Molar volume, Molecular interaction, Density, Viscosity.

1. INTRODUCTION

The physicochemical properties of amino acids in aqueous solutions provide valuable information on solute-solute and solute-solvent interactions [1-6]. These interactions are important in understanding the stability of proteins, and are implicated in several biochemical and physiological processes in a living cell [7-9]. R. Srivastava, A.R. Saksena and Arti Gupta [10] measured the density and viscosity for ternary systems containing L- isoleucine for several concentrations of amino acids at 303, 313 and 323^{o} K. Densities and volumetric heat capacities had been measured by Duke et al.[11] for aqueous solutions of L- valene, L- leucine and L- isoleucine at 288.15, 298.15, 313.15, and 328.15 K.

In the present article, we report the densities, ρ, viscosities, η, of

l-isoleucine in aqueous ethanol (1 to 10 wt. % of ethanol, w/w in water) at 298.15, 303.15, 308.15, 310.15, and 313.15 K. Experimental data have been used to calculate, apparent molar volume, $V_{\Phi,}$ limiting apparent molar volume, V_{Φ}^{0} and the slopes, S_v, transfer volumes, $V_{\Phi\ tr}^{0}$, Falkenhagen Coefficient, A and Jones – Dole coefficient, B. These parameters have been used to discuss the solute-solute and solute-solvent interactions in these systems.

2. Experimental

Analytical grade L- isoleucine (Research Lab.) was used as it is without further purification. Ethanol (Research Lab) was distilled using quick fit glass assembly. The aqueous ethanol solutions (1 to 10 wt % of ethanol, w/w in water) were prepared using triple distilled water (conductivity less than

1 x 10^{-6} S cm^{-1}) and they were used as solvents to prepare L- isoleucine solutions of eight different molar concentrations (ranging from 0.0154 to 0.0518 M). The weightings were done on an electric one pan balance (Model Dhona 200, India) with a precision of ±0.01 mg .The solutions were prepared with care and stored in special airtight bottles to avoid contamination and evaporation.

The densities of the sample solutions were measured by using a bicapillary pycnometer (made of borosil glass) having a bulb capacity of~ 15 mL. The graduated marks on the capillary were calibrated by using triply distilled water. The accuracy of density measurements was estimated to be ±0.09x1**0**$^{-6}$kg m^{-3}. The viscosities of the solutions were measured by using Ubbelohde type suspended level viscometer in similar manner as reported by Nikam et al [12]. The viscometer containing the test liquid was allowed to stand for about 20 minutes in a thermostatic water bath so that the thermal fluctuations in viscometer were minimized. The time of flow was recorded in triplicate with a digital stopwatch with an accuracy of ±0.01 s. The accuracy of viscosity measurements was found to be ±1.7 x 10^{-6} N.s.m^{-2}. The temperature of the test solution during the measurements was maintained to an accuracy of ±0.01K in an electronically controlled thermostatic water bath.

3. Results and Discussion

The experimental values of density, ρ, and viscosity, η of L- isoleucine solutions in aqueous ethanol solvents as a function of molar concentration and at various temperatures are listed in Table 1 and Table 2 respectively.

3.1Partial molar volume

The partial molar volume, V_Φ of this solute V_Φ^0 of L- isoleucine in aqueous ethanol solutions were calculated by using the relations

$$V_\Phi = \frac{1000(\rho_0 - \rho)}{C\rho_0\rho} + \frac{M}{\rho} \qquad (1)$$

where C is the molar concentration of L-isoleucine, ρ and ρ_0 are the densities of the solution and the solvent (aqueous - ethanol) respectively is the molar mass of l -isoleucine.

The partial molar volumes, V_Φ, as functions of square root of concentration at various temperatures are shown graphically in Fig.1. It is observed that, for L- isoleucine in all the ten aqueous-ethanol solvents, V_Φ was almost linear in the studied concentration range and at each investigated temperature.

3.2 Limiting partial molar volume

The values of limiting partial molar volume, V_Φ^0 and the slope, S_v, have been obtained using method of linear regression of V_Φ vs. molar concentration (C) of L- isoleucine in ethanol- water solvents from the following relation [13].

$$V_\Phi = V_\Phi^0 + S_v C \qquad (2)$$

Where the intercepts, V_Φ^0 by definition are free from solute-solute interactions and therefore provide a measure of solute-solvent interactions, whereas the experimental slope, S_v, provides information regarding solute-solute interaction. The values of V_Φ^0, and S_v for L- isoleucine in aqueous – ethanol solutions at different temperatures are listed in Table 3.

A close perusal of Table 3 reveals that the V_{Φ}^{0} and S_v values are positive for L- isoleucine in aqueous-ethanol solutions indicating the presence of strong solute – solvent interactions and strong solute – solute interactions respectively in the solvent systems under investigation. The trends observed in V_{Φ}^{0} values can be due to their hydration behavior [14-18], which comprises of the following interactions in the present solvent: (a) The terminal groups of zwitterions of amino acids, NH^{+}_{3} and COO^{-} are hydrated in an electrostatic manner whereas, hydration of R group depends on its nature, which may be hydrophilic, hydrophobic or amphiphilic; and (b) the overlap of hydration co-spheres of terminal NH^{+}_{3} and COO^{-} groups and of adjacent groups results in volume change. The V_{Φ}^{0} values increase due to reduction in the electrostriction at terminals, whereas it decreases due to disruption of side group hydration by that of the charged end.

The increase in V_{Φ}^{0} values with increase in temperature for L- isoleucine in aqueous- ethanol solutions can be explained by considering the size of primary and secondary solvation layers around the zwitterions. At higher temperatures the solvent from the secondary solvation layer of L- isoleucine zwitterions is released into the bulk of the solvent, resulting in the expansion of the solution, as inferred from larger V_{Φ}^{0} values at higher temperatures [19, 20]. Similar trends in V_{Φ}^{0} values were obtained by Michele M. Duke et al. [11] on interactions of L- isoleucine in aqueous solutions.

3.3 Transfer volume

Limiting apparent molar properties of transfer volume V^{0}_{Φ} provide qualitative as well as quantitative information regarding solute-solvent interactions without taking into account the effects of solute – solute interactions [21]. The transfer volumes, $V_{\Phi\,tr}^{0}$ of L- isoleucine from water to aqueous – ethanol solutions were calculated by using the relation

$$V_{\Phi\,tr}^{0} = V_{\Phi aq.ethanol}^{0} - V_{\Phi,water}^{0} \qquad (3)$$

Where, $V_{\varphi,water}^{0}$, is the limiting apparent molar volume of L- isoleucine in water. The $V_{\Phi,tr}^{0}$ values for L- isoleucine from water to aqueous ethanol solutions are included in Table 4. Transfer volumes, $V_{\Phi\,tr}^{0}$ values of L- isoleucine are positive as well as negative. In general, the types of interactions occurring between L- isoleucine and ethanol can be classified as follows [11, 22, and 23]:

(a) The hydrophilic – ionic interaction between OH groups of ethanol and zwitterions of L- isoleucine.

(b) Hydrophilic – hydrophilic interaction the OH groups of ethanol and NH groups in the side chain of acid L- isoleucine through hydrogen bonding.

(c) Hydrophilic – hydrophobic interaction between the OH groups of ethanol molecule and non- polar ($-CH_2$) in the side chain of L- isoleucine molecule.

(d) Hydrophobic – hydrophobic group interactions between the non- polar groups of ethanol and non – polar ($-CH_2$) in the side chain of L- isoleucine molecule.

The $V^0_{\Phi tr}$ values decrease due to disruption of side group hydration by that of the charged end by negative contribution from the interactions of type (c) and (d) mentioned earlier. The observed positive $V^0_{\Phi tr}$ values upto 0.0119 mole fraction of ethanol suggest that the hydrophilic – ionic group and hydrophilic – hydrophilic group interactions dominate in these systems. The $V^0_{\Phi tr}$ values decrease with increase in ethanol concentration in the solutions. This may be due to greater Hydrophilic – hydrophobic groups and Hydrophobic – hydrophobic group interactions with increased concentrations of ethanol. The similar trends in V^0_{Φ} and $V^0_{\Phi tr}$ with sucrose concentration were also observed by Zhao et al. [4] from volumetric properties of arginine in aqueous-carbohydrate solutions at 298.15K.

4. Analysis of viscosity data

The viscosity data were analysed by using Jones – Dole [24] equation of the form

$$\eta_r = \frac{\eta}{\eta_0} = 1 + AC^{1/2} + BC \qquad (4)$$

Where η_r is the relative viscosity of the solution, η and η_0 are the viscosities of solution and the solvent (ethanol + water), respectively, C is the molar concentration of L- isoleucine in ethanol + water solvent, A and B are the Falkenhagen [25, 26] and Jones – Dole [24] coefficients, respectively.

Coefficient 'A' accounts for the solute – solute interactions and B is a measure of structural modifications induced by the solute – solvent interactions [27, 28]. The values of A and B have been obtained as the intercept and slope from linear regression of $[(\eta_r - 1)/ C^{1/2}]$ Vs. $C^{1/2}$ curves, which were found almost linear for this systems. The values of A and B are listed in Table 5. The values of A-coefficients are negative while that of B-coefficients are positive. The A- coefficients are much smaller in magnitude as compared to B-coefficients, suggesting weak solute- solute and solute- solvent interactions in these solutions. Positive B-coefficients values, which increase with increasing concentration of ethanol, also indicate a structure to allow the co – solute (ethanol) to act on solvent [1].

B - Coefficients increase when the water is replaced by ethanol, i.e., ethanol acts as water structure – maker by H-bonding. B-coefficients increases with increasing concentration of ethanol, the reason may be that the friction increases to prevent water flow at increased ethanol concentration.

5. Hydration number

The value of hydration numbers (N_h) reflects the electrostriction effect of the charge centre of the amino acids on the nearby water molecules. The hydration numbers of amino acids in aqueous ethanol solutions were estimated using the method reported by Shahidi et al [29] and are included in Table 6.

$$V^{0}_{\Phi\,tr} = [N_h \text{ (in water)} - N_h \text{ (in ethanol solution)}] \times 3 \qquad (5)$$

According to Millero et al [30], the hydration number of amino acid in water can be evaluated by the following equation,

$$N_h \text{ (in water)} = \frac{V_{elect}}{V^{0}_{e} - V^{0}_{b}} \qquad (6)$$

where V_{elect} is the molar mass of electrostricted water and V^{0}_{b} is the molar volume of bulk water. The value of $V^{0}_{e} - V^{0}_{b}$ is approximately 3.3 cm^3 mol^{-1}. The electrostriction partial molar volume (V_{elect}) can be estimated from the measured V^{0}_{Φ} value of the amino acid using the following equation.

$$V_{elect} = V^{0}_{\Phi} - V^{0}_{inter} \qquad (7)$$

The intrinsic molar volume V^{0}_{inter} of the amino acid can be estimated from the crystal volume (V^{0}_{cryst}) and the crystal volume can be calculated from the density of the dry-state amino acid [9].

$$V^{0}_{int} = \frac{0.7}{0.634} V^{0}_{cryst} \quad (8)$$

The hydration numbers decrease with the increasing ethanol concentration, which again indicates that the increase in solute-co solute interactions reduces the electrostriction effect of the amino acids. It also suggests that ethanol has a dehydration effect on the L- isoleucine under investigation. On comparison with the N_h values for the amino acids in ethanol solutions, it can be concluded that ethanol has a little large dehydration effect on the L- isoleucine.

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Table. 1

C Mol kg^{-1}	Density, ρ, kg. m^{-3}					Density, ρ, $kg.m^{-3}$				
	Temperature, K					Temperature, K				
	298.15	303.15	308.15	310.15	313.15	298.15	303.15	308.15	310.15	313.15
	1% ethanol					2% ethanol				
0.0154	995.27	993.99	992.48	992.07	990.63	993.28	991.85	988.52	987.84	987.52
0.0179	995.30	994.02	992.51	992.10	990.66	993.31	991.88	988.55	987.87	987.55
0.0208	995.34	994.06	992.55	992.14	990.70	993.35	991.92	988.59	987.91	987.59
0.0240	995.38	994.10	992.60	992.18	990.74	993.39	991.96	988.63	987.95	987.63
0.0257	995.40	994.12	992.62	992.21	990.77	993.43	991.98	988.65	987.97	987.65
0.0320	995.49	994.20	992.70	992.29	990.85	993.50	992.06	988.73	988.05	987.74
0.0399	995.59	994.31	992.80	992.39	990.95	993.60	992.17	988.84	988.16	987.84
0.0518	995.75	994.47	992.96	992.55	991.11	993.76	992.33	989.00	988.32	988.00
	3% ethanol					4% ethanol				
0.0154	991.73	990.36	988.82	988.18	987.08	989.99	988.62	987.04	986.32	985.36
0.0179	991.76	990.40	988.86	988.21	987.12	990.02	988.65	987.07	986.36	985.40
0.0208	991.80	990.43	988.89	988.24	987.15	990.06	988.69	987.11	983.39	985.43
0.0240	991.84	990.47	988.93	988.28	987.19	990.10	988.73	987.15	986.43	985.47
0.0257	991.86	990.50	988.96	988.31	987.22	990.12	988.75	987.17	986.45	985.49
0.0320	991.95	990.58	989.04	988.39	987.30	990.20	988.83	987.25	986.54	985.58
0.0399	992.05	990.68	989.14	988.49	987.40	990.31	988.94	987.36	986.64	985.68
0.0518	992.21	990.84	989.30	988.65	987.56	990.47	989.10	987.52	986.80	985.84
	5% ethanol					6% ethanol				
0.0154	988.46	987.00	985.00	984.75	983.59	985.49	983.93	982.80	981.91	981.05
0.0179	988.49	987.03	985.03	984.79	983.63	985.52	983.96	982.83	981.94	981.08
0.0208	988.53	987.07	985.07	984.82	983.66	985.55	983.97	982.87	981.98	981.12
0.0240	988.57	987.11	985.11	984.86	983.70	985.60	984.04	982.91	982.02	981.16
0.0257	988.59	987.13	985.13	984.88	983.72	985.62	984.06	982.93	982.04	981.18
0.0320	988.67	987.21	985.21	984.96	983.80	985.70	984.14	983.01	982.12	981.26
0.0399	988.78	987.32	985.32	985.07	983.91	985.80	984.25	983.11	982.22	981.36
0.0518	988.98	987.48	985.47	985.23	984.07	985.96	984.40	983.27	982.38	981.52

Table.1 continued….

C Mol kg^{-1}	Density, ρ, kg. m^{-3}					Density, ρ, kg. m^{-3}				
	Temperature, K					Temperature, K				
	298.15	303.15	308.15	310.15	313.15	298.15	303.15	308.15	310.15	313.15
7% ethanol						8% ethanol				
0.0154	985.18	983.77	982.04	981.28	980.12	982.57	981.14	979.30	978.52	977.69
0.0179	985.22	983.80	982.07	981.31	980.15	982.60	981.18	979.33	978.55	977.72
0.0208	985.23	983.83	982.10	981.35	980.19	982.64	981.21	979.37	978.58	977.75
0.0240	985.29	983.87	982.14	981.38	980.22	982.68	981.25	979.41	978.62	977.79
0.0257	985.31	983.89	982.16	981.41	980.25	982.70	981.27	979.43	978.64	977.81
0.0320	985.39	983.97	982.24	981.49	980.33	982.78	981.35	979.51	978.72	977.89
0.0399	985.50	984.08	982.35	981.59	980.43	982.88	981.45	979.62	978.83	978.00
0.0518	985.66	984.24	982.51	981.75	980.59	983.04	981.61	979.78	978.99	978.16
9% ethanol						10% ethanol				
0.0154	982.22	980.84	979.02	978.26	977.05	979.48	978.26	976.74	976.13	974.74
0.0179	982.25	980.87	979.06	978.29	977.08	979.51	978.29	976.77	976.17	974.77
0.0208	982.29	980.91	979.09	978.32	977.11	979.54	978.33	976.81	976.20	974.80
0.0240	982.33	980.95	979.13	978.36	977.15	979.58	978.37	976.85	976.24	974.84
0.0257	982.35	980.97	979.15	978.38	977.17	979.60	978.39	976.87	976.26	974.86
0.0320	982.43	981.05	979.23	978.46	977.25	979.68	978.47	976.95	976.34	974.94
0.0399	982.53	981.15	979.33	978.56	977.36	979.78	978.57	977.05	976.44	975.04
0.0518	982.69	981.31	979.50	978.73	977.52	979.94	978.72	977.21	976.60	975.21

Table.2.

C Mol kg^{-1}	Viscosity, η ,N.s.m^{-2}					Viscosity, η ,N.s.m^{-2}				
	Temperature, K					Temperature, K				
	298.15	303.15	308.15	310.15	313.15	298.15	303.15	308.15	310.15	313.15
	1% ethanol					2% ethanol				
0.0154	0.9200	0.8280	0.7462	0.7169	0.6790	0.9571	0.8459	0.7651	0.7326	0.6948
0.0179	0.9230	0.8309	0.7491	0.7199	0.6816	0.9601	0.8489	0.7680	0.7355	0.6977
0.0208	0.9262	0.8340	0.7523	0.7230	0.6848	0.9633	0.8521	0.7712	0.7387	0.7009
0.0240	0.9297	0.8370	0.7557	0.7264	0.6882	0.9667	0.8555	0.7746	0.7421	0.7044
0.0257	0.9314	0.8387	0.7577	0.7283	0.6902	0.9685	0.8576	0.7766	0.7440	0.7065
0.0320	0.9375	0.8448	0.7638	0.7344	0.6963	0.9746	0.8640	0.7827	0.7501	0.7127
0.0399	0.9457	0.8529	0.7719	0.7425	0.7045	0.9821	0.8725	0.7908	0.7582	0.7208
0.0518	0.9557	0.8630	0.7824	0.7541	0.7153	0.9919	0.8862	0.8012	0.7680	0.7317
	3% ethanol					4% ethanol				
0.0154	0.9903	0.8695	0.7616	0.7521	0.7180	1.0335	0.9052	0.8125	0.7738	0.7368
0.0179	0.9933	0.8724	0.7645	0.7550	0.7210	1.0364	0.9082	0.8154	0.7767	0.7399
0.0208	0.9965	0.8756	0.7676	0.7581	0.7243	1.0397	0.9114	0.8187	0.7798	0.7431
0.0240	1.0000	0.8791	0.7711	0.7615	0.7277	1.0431	0.9148	0.8223	0.7832	0.7466
0.0257	1.0017	0.8809	0.7730	0.7636	0.7298	1.0449	0.9166	0.8242	0.7853	0.7487
0.0320	1.0075	0.8869	0.7791	0.7696	0.7360	1.0510	0.9226	0.8303	0.7914	0.7548
0.0399	1.0142	0.8954	0.7872	0.7778	0.7443	1.0585	0.9307	0.8385	0.7996	0.7632
0.0518	1.0234	0.9062	0.7976	0.7885	0.7551	1.0685	0.9406	0.8495	0.8103	0.7739
	5% ethanol					6% ethanol				
0.0154	1.0777	0.9491	0.8611	0.8050	0.7534	1.1198	0.9773	0.8651	0.8189	0.7670
0.0179	1.0815	0.9520	0.8641	0.8077	0.7547	1.1244	0.9803	0.8681	0.8217	0.7700
0.0208	1.0856	0.9552	0.8674	0.8109	0.7578	1.1289	0.9835	0.8712	0.8246	0.7735
0.0240	1.0899	0.9586	0.8708	0.8144	0.7613	1.1336	0.9869	0.8746	0.8280	0.7773
0.0257	1.0921	0.9606	0.8728	0.8164	0.7633	1.1363	0.9888	0.8766	0.8300	0.7793
0.0320	1.0997	0.9666	0.8789	0.8226	0.7694	1.1445	0.9949	0.8827	0.8360	0.7858
0.0399	1.1084	0.9744	0.8870	0.8309	0.7776	1.1534	1.0026	0.8909	0.8441	0.7943
0.0518	1.1202	0.9844	0.8982	0.8468	0.7896	1.1659	1.0127	0.9016	0.8547	0.8050

Table.2: Continued……..

C Mol kg^{-1}	Viscosity, η ,N.s.m^{-2}					Viscosity, η ,N.s.m^{-2}				
	Temperature, K					Temperature, K				
	298.15	303.15	308.15	310.15	313.15	298.15	303.15	308.15	310.15	313.15
	7 % ethanol					8 % ethanol				
0.0154	1.1641	0.9733	0.8911	0.8342	0.7879	1.2026	1.0444	0.9191	0.8687	0.8177
0.0179	1.1692	0.9764	0.8940	0.8377	0.7907	1.2076	1.0474	0.9221	0.8717	0.8206
0.0208	1.1747	0.9798	0.8972	0.8411	0.7939	1.2130	1.0505	0.9252	0.8749	0.8237
0.0240	1.1808	0.9834	0.9006	0.8446	0.7974	1.2190	1.0539	0.9287	0.8783	0.8271
0.0257	1.1840	0.9854	0.9025	0.8466	0.7994	1.2221	1.0563	0.9307	0.8804	0.8290
0.0320	1.1946	0.9917	0.9087	0.8538	0.8057	1.2327	1.0628	0.9368	0.8866	0.8350
0.0399	1.2074	0.9993	0.9168	0.8618	0.8141	1.2449	1.0678	0.9450	0.8951	0.8431
0.0518	1.2250	1.0097	0.9275	0.8734	0.8287	1.2619	1.0799	0.9558	0.9059	0.8537
	9 % ethanol					10 % ethanol				
0.0154	1.2491	1.0805	0.9535	0.8983	0.8362	1.3070	1.1101	1.0516	0.9693	0.8614
0.0179	1.2534	1.0846	0.9566	0.9026	0.8386	1.3124	1.1133	1.0549	0.9724	0.8644
0.0208	1.2580	1.0891	0.9600	0.9072	0.8413	1.3195	1.1166	1.0584	0.9756	0.8676
0.0240	1.2628	1.0938	0.9635	0.9121	0.8447	1.3270	1.1202	1.0622	0.9790	0.8711
0.0257	1.2652	1.0963	0.9653	0.9155	0.8467	1.3303	1.1220	1.0642	0.9811	0.8731
0.0320	1.2736	1.1047	0.9717	0.9269	0.8527	1.3438	1.1282	1.0707	0.9873	0.8793
0.0399	1.2842	1.1164	0.9790	0.9372	0.8610	1.3612	1.1354	1.0785	0.9951	0.8860
0.0518	1.2988	1.1299	0.9888	0.9543	0.8719	1.3868	1.1452	1.0890	1.0057	0.8952

Table.3

298.15 K		303.15 K		308.15 K		310.15 K		313.15 K	
V_{Φ}^{0}	S_v	V_{Φ}^{0}	S_v	V_{Φ}^{0}	S_v	V_{Φ}^{0}	S_v	V_{Φ}^{0}	S_v
1% ethanol									
11.70	6.528	11.71	6.311	11.89	5.643	11.88	5.912	11.91	5.555
2% ethanol									
11.60	6.688	11.58	6.617	11.70	6.071	11.75	6.132	11.54	6.926
3% ethanol									
10.89	9.593	11.05	8.956	11.27	7.774	11.40	7.179	11.30	7.775
4% ethanol									
10.56	10.97	10.82	10.095	10.90	9.395	11.29	7.673	11.30	7.744
5% ethanol									
10.50	11.21	10.75	9.78	10.91	9.210	11.22	7.751	11.25	7.532
6% ethanol									
10.41	11.19	10.68	10.03	10.77	9.577	10.96	8.647	11.03	8.319
7% ethanol									
10.20	11.42	10.14	10.03	10.52	10.24	10.81	9.037	10.81	9.173
8% ethanol									
10.20	11.25	10.29	10.70	10.38	10.81	10.69	9.508	10.75	9.400
9% ethanol									
10.16	11.73	10.29	10.72	10.34	10.88	10.47	10.16	10.55	9.733
10% ethanol									
10.22	10.41	10.29	10.12	10.30	10.88	10.47	10.16	10.47	10.45

Table.4

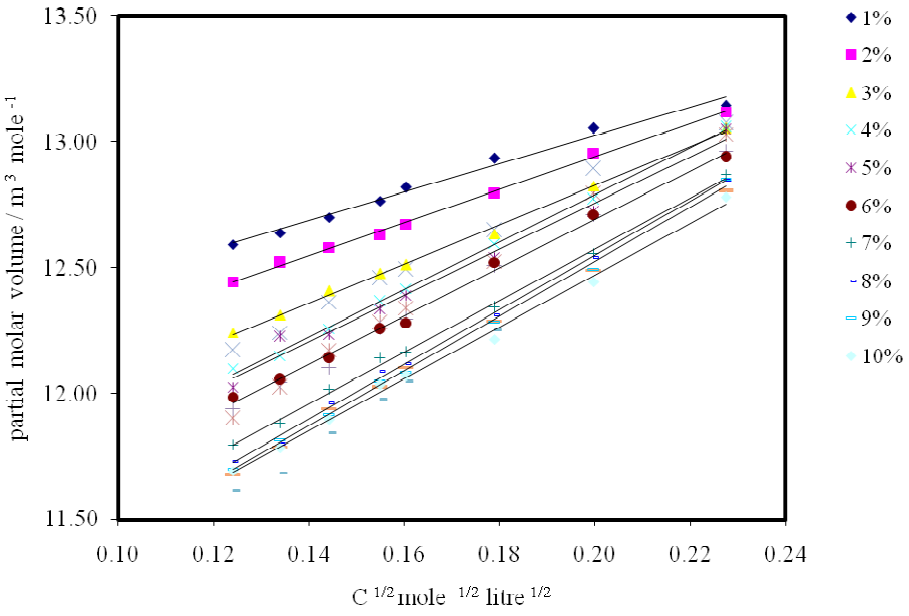
Mole fraction of ethanol	$V^{0}_{\Phi tr}$ / m^3 mol^{-1}				
	Temperature K				
	298.15	303.15	308.15	310.15	313.15
0.0039	0.68	0.58	0.50	0.49	0.43
0.0079	0.59	0.47	0.31	0.39	0.36
0.0119	0.13	0.14	0.05	0.09	0.00
0.016	-0.05	-0.02	-0.13	0.02	-0.04
0.0201	-0.13	-0.11	-0.19	-0.02	-0.07
0.0243	-0.19	-0.16	-0.30	-0.25	-0.20
0.0285	-0.40	-0.34	-0.49	-0.33	-0.40
0.0328	-0.42	-0.41	-0.58	-0.41	-0.50
0.0372	-0.55	-0.48	-0.61	-0.55	-0.50
0.0416	-0.57	-0.49	-0.59	-0.56	-0.63

Table.5

298.15 K		303.15 K		308.15 K		310.15 K		313.15 K	
B	A	B	A	B	A	B	A	B	A
1% ethanol									
0.3670	-0.2218	0.3638	-0,2024	0.3669	-0.0675	0.3382	-0.0464	0.3650	-0.0303
2% ethanol									
0.3636	-0.4176	0.3579	-0.0384	0.3556	-0.1829	0.3552	-0.1311	0.3686	-0.1380
3% ethanol									
0.3543	-1.5017	0.3579	-0.0290	0.3643	-0.3082	0.3626	-0.0982	0.3537	-0.2236
4% ethanol									
0.3543	-0.3980	0.3582	-0.2053	0.3813	-0.2032	0.3600	-0.0625	0.3638	-0.1948
5%Ethanol									
0.3631	-1.5726	0.3648	-0.3904	0.2753	-0.3343	0.3498	-0.0284	0.3739	-0.0355
6% ethanol									
0.3719	-.1.6142	0.3537	-0.6627	0.3851	-0.2343	0.3621	-0.0311	0.3706	-0.4424
7% ethanol									
0.3602	-0.4245	0.4603	-0.6727	0.3537	-0.1561	0.3624	-0.2149	0.3584	0.0568
8% ethanol									
0.3644	-0.4417	0.3581	-0.6513	0.3585	-0.1121	0.4216	-0.0182	0.3997	-0.0474
9% ethanol									
0.4172	-0.6562	0.4767	-0.8664	0.3675	-0.8245	0.3615	0.1654	0.3452	-0.0194
10% ethanol									
0.3723	-0.0927	0.5589	-1.0809	0.3521	-0.8963	0.3743	-0.4002	0.3542	-0.0134

Table.6

Mole fraction of ethanol	298.15 K	303.15 K	308.15 K	310.15 K	313.15 K
0.0039	3.26	3.27	3.32	3.32	3.33
0.0079	3.23	3.23	3.24	3.28	3.31
0.0119	3.01	3.06	3.13	3.15	3.15
0.016	2.93	2.99	3.05	3.12	3.13
0.0201	2.89	2.95	3.01	3.11	3.13
0.0243	2.88	2.94	2.97	3.01	3.09
0.0285	2.80	2.87	2.90	2.98	2.99
0.0328	2.80	2.85	2.85	2.94	2.93
0.0372	2.75	2.82	2.84	2.88	2.94
0.0416	2.74	2.81	2.83	2.87	2.88



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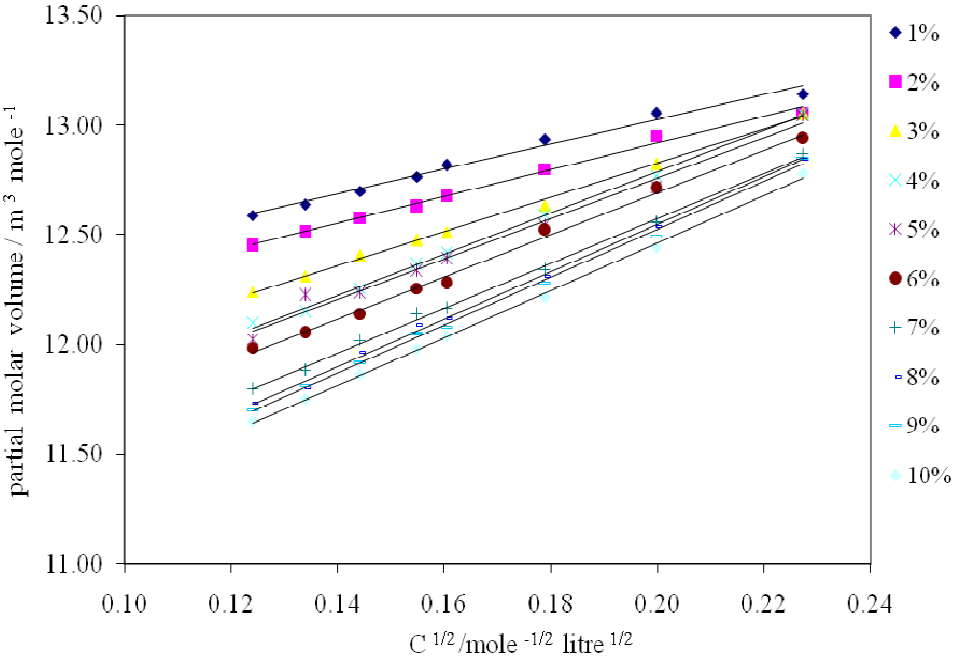
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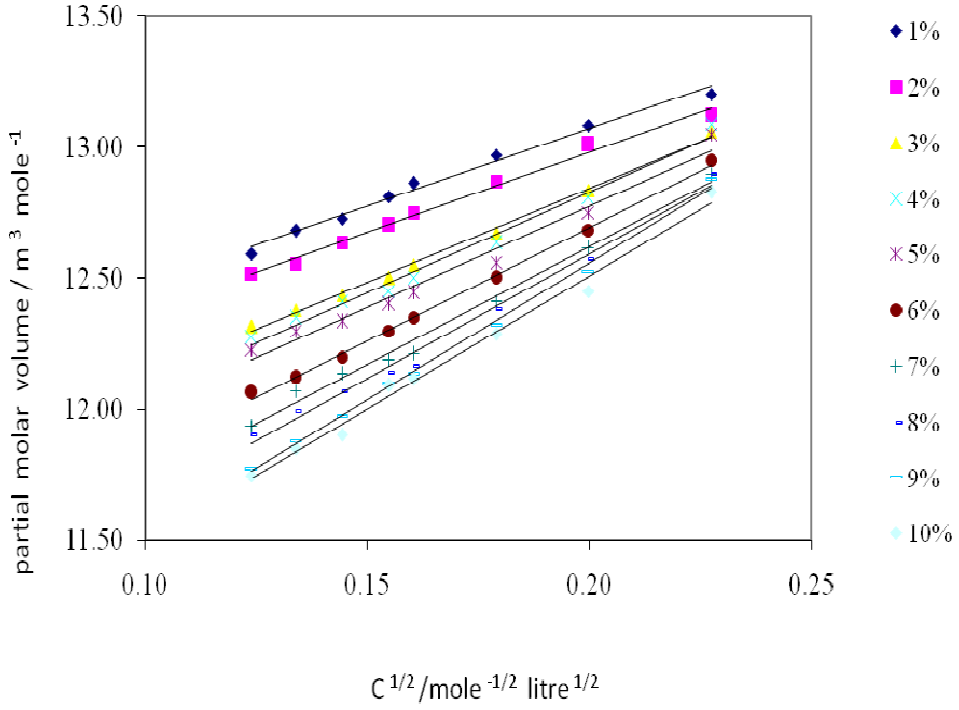
(iii)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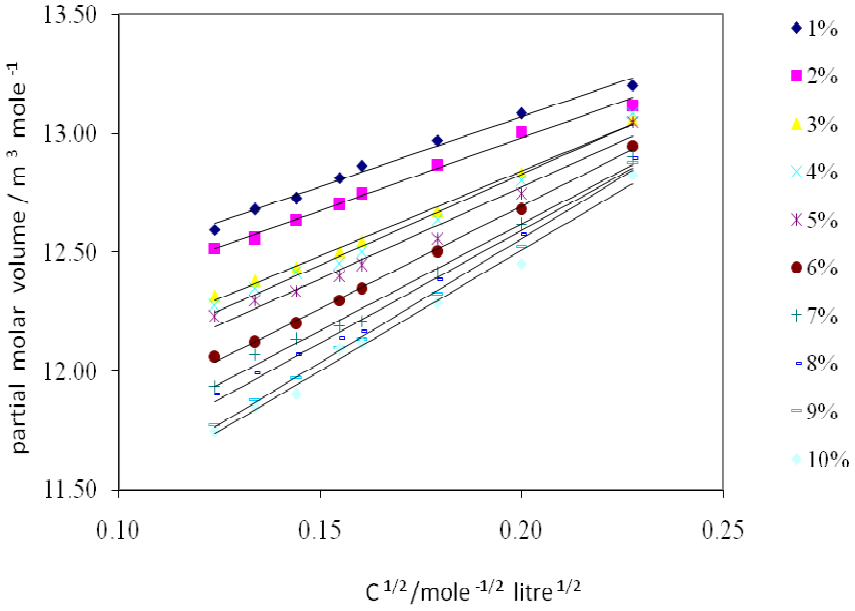
(iv)



(v)

Table captions

Table 1: Densities, ρ, of solutions of L- isoleucinein ethanol + water (1 to 10 % ethanol, w/w in water) solvents as a function of molar concentration of l - isoleucine in ethanol + water at various temperatures.

Table 2: Viscosities, η, of solutions of L- isoleucinein ethanol + water (1 to 10 % ethanol, w/w in water) solvents as a function of molar concentration of l - isoleucine in ethanol + water at various temperatures.

Table 3: Limiting apparent molar volume, $10^5 . V_{\Phi}^{0}$ /m^3 $mole^{-1}$ and slopes, $10^5.S_v$/ m^3 $mole^{-1}$ kg^{-1} in ethanol + water (1 to 10 % ethanol, w/w in water) solvents as a function of concentration, C, of L- isoleucineat various temperatures.

Table 4: Transfer volume, $V_{\Phi tr}^{0}$ for L- isoleucine in ethanol + water (1 to 10 % ethanol, (w/w) in water) solutions at different temperatures.

Table 5: Parameters of Jones – Dole equation, B, dm^3 $mole^{-1}$ and A, dm^3 $mole^{-1/2}$ for L- isoleucine in water + ethanol (1 to 10 % ethanol, (w/w) in water) solutions at different temperatures.

Table 6: Hydration number for L- isoleucine in mole fraction of ethanol at different temperatures.

Graph captions

Fig. 1: Variation of partial molar volumes, V_Φ vs. molar concentration, C of L- isoleucinein ethanol + water (w/w) solutions, at (i) 298.15 K, (ii) 303.15 K, (iii) 308.15 K, (iv) 310.15 K, (v) 313.15 K.

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