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Volumetric and viscometric studies of l-proline in aqueous solution of alcohols at different temperatures

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Abstract

Volumetric and viscometric properties of L-Proline have been measured as a function of molar concentration (0.02M-0.1M) of L-Proline in aqueous alcohols (Methanol, Ethanol and Propanol) at different temperatures (293.15K, 303.15K, 308.15K, 313.15K and 323.15K). The apparent molar volumes (φ_v), limiting apparent molar volume (φ_v^0), viscosity B-coefficient by employing the Jones-Dole equation, dB/dT values, change of free energy ($\Delta G^\#$), enthalpy ($\Delta H^\neq$), entropy ($\Delta S^\neq$) have been calculated by using experimental density(ρ) and viscosity(η) data. The limiting transfer apparent molar volume $(\Delta\varphi_v^0)_{tra}$, limiting apparent molar volume expansibilities (E_φ^0), the values of $(\delta E_\varphi^0/\delta T)_p$ and (dB/dT) have also been computed. The experimental and computed parameters have been discussed on the basis of structure making and structure breaking mechanism of L-Proline in aqueous alcohols under experimental conditions.

Keywords: L-Proline; jones-dole equation; masson equation; molecular interactions

1. Introduction

Proteins are natural substances, which are the polymer of one or more long chains of amino acids and are the main constituents of cell screen and cytoplasm. The straight study of proteins in aqueous solution is very much challenging because of a combination of several specific interactions in solutions. To study the molecular interactions of proteins in systems, one should approaches to study amino acids as it is the basic units of proteins and also it will reduces the complexity and requires less complex measurement techniques [1, 5]. Amino acids play a momentous role in metabolism and many neurochemical response mechanisms, such as memory, appetite control, and pain transmission [6]. The stability of protein structure in biological conditions may decide the activity of enzymes and four main types of non-covalent interacting forces that could play a major role in alcohols-protein binding, like hydrogen bonds, van der Waals forces, electrostatic, and hydrophobic interactions. Physical factors like temperature, pressure, mechanical shear force, ultrasonic vibration and ionizing radiation are the main reasons for which protein loses its biological activity. The thermodynamic parameters of binding reaction are the main evidence for confirming acting forces [4, 5, 7]. Consequently, the thermodynamic parameters (e.g. Gibb's free energy, Enthalpy, Entropy) depend on temperature and concentration are analysed in order to characterize the active forces between aqueous alcohols solution and amino acid.

Nain *et al.* [8, 12] have studied solute – solute and solute – solvent interactions of L- threonine, L- serine, L- arginine, L- phenyl alanine and L- histidine in aqueous arabinose, glucose and sucrose solutions by means of volumetric and viscometric measurements. Riyazudden and Usmani *et al.* [13] have measured the densities, viscosities and speed of sound of L-Proline in aqueous glucose and sucrose solutions. Palani and Geetha [14] have measured the density, viscosity and ultrasonic velocity of L-serine, L-glutamine and L-asparagine in aqueous glucose solutions. Ali *et al.* [15] have evaluated the density, viscosity and refractive index of glycine, DL-alanine, L-serine and DL-valine in aqueous glucose solution.

As far as our knowledge, no volumetric and viscometric studies have been reported on amino acids in aqueous alcohols solution. This consideration leads us to undertake the study of L-Proline in aqueous alcohols solutions. To understand the nature of interactions of alcohols with amino acids in aqueous solutions, the values of density (ρ) and viscosity (η) of L-Proline aqueous alcohols as a function of molar concentrations of L-Proline at temperatures: (298.15, 303.15, 308.15, 313.15, 318.15, and 323.15) K have been measured. Using the experimentally measured ρ and η data, apparent molar volumes (φ_v), limiting apparent molar volume (φ_v^0), limiting transfer apparent molar volume $(\Delta\varphi_v^0)_{tra}$, limiting apparent molar volume expansibilities (E_φ^0), the values of $(\delta E_\varphi^0/\delta T)_p$, viscosity B-coefficient by employing the Jones-Dole equation, and dB/dT values for L-Proline in aqueous alcohols solutions have been evaluated. The measured and calculated parameters have been discussed in terms of structure making and structure breaking mechanism of L-Proline in aqueous alcohols solution.

2. Experimental

The L-Proline and the alcohols (Methanol, Ethanol and Propanol) of highly pure (mass fraction ≥ 99%), used in the present studies, were purchased from E. Merck (India). Ethanol and water mixtures were used for recrystallizing of L-Proline. The recrystallized L-Proline was dried at 383.15K, and kept in a vacuum desiccator over P_2O_5 for at least 72 h before use. The aqueous alcohols solutions were prepared by using doubly distilled water (conductivity less than 1×10^{-6} S. cm^{-1}) and these were used as solvents to prepare L-Proline solutions of different molar concentrations ranging from 0.0 to 0.1M. 25mL density bottles were to measure the densities. For calibration of volumes of the density bottles distilled water was used and calibrate at different temperatures. The densities of the solutions were determined from the mass of the solution in the density bottle after reaching thermal equilibrium with a water bath at the studied temperatures (298.15to 323.15) K. For the mass determination, a HR-200 electronic balance with an accuracy of ±0.0001g was used. The viscosity measurements were carried out using a calibrated U-type Ostwald viscometer of the British standard at six temperatures (298.15 to 323.15) K. The test solution filled in a clean and dried viscometer and the viscometer was placed vertically in the water bath maintained at a desired temperature. Efflux times of flow were recorded with an electronic watch with the resolution of 0.01s after the attainment of thermal equilibrium. The final efflux time was taken from the average of at least three readings reproducible within 0.1s and the viscosity (η) was calculated by using the following equation,

$$\eta = A\rho t \qquad (1)$$

Where, $A = \frac{\pi r^4 hg}{8lv}$ is the viscometer constant at a particular temperature determined by measuring the efflux time of water, ρ is density and t is the final efflux time. For calibration purposes, the viscosity values of water at different temperatures were taken from the literature [16].

3. Results and Discussion

The density data measured for L-Proline in water and aqueous alcohols solution at T = (293.15, 303.15, 308.15, and 313.15) K are listed in Table 1. The densities of L-Proline in solutions increase with the increase in the concentration but decreases with the rise of temperature. The apparent molar volumes (φ_v) of L-Proline in aqueous alcohols solution were calculated from density data by using the following equation [17],

$$\varphi_v = \left[\frac{M_2}{\rho_0} - \frac{1000(\rho - \rho_0)}{C\rho_0}\right] \qquad (2)$$

Where, ρ_0 and ρ are the densities of solvent and solution respectively, C is the molar concentration and M_2 is molecular weight of solute.

For each system φ_v with √C were found to be linear thus the data are fitted to Masson equation [18]. Limiting partial molar volume (φ_v^0) and experimental slope (S_v) were calculated by this equation.

$$\varphi_v = \varphi_v^0 + S_v\sqrt{c} \qquad (3)$$

In these S_v is the experimental slope or volumetric pair wise interaction coefficient [18, 20], which provides information regarding solute-solute interaction and limiting apparent molar volume (φ_v^0) provides information regarding solute–solvent interaction. The values of φ_v^0 and S_v for L-Proline in aqueous alcohols solution at different temperatures are presented in Table 2. For all systems, S_v values are positive that indicates the very strong ion-ion interactions.

Limiting transfer apparent molar volume $(\Delta\varphi_v^0)_{tra}$ of L-Proline from water to aqueous alcohols solution was calculated by using given relation at different temperatures and is listed in Table 2.

$$(\Delta\varphi_v^0)_{tra} = \varphi_v^0 \text{ (L-Proline in aqueous alcohols)} - \varphi_v^0 \text{ (L-Proline in pure water)} \qquad (4)$$

Limiting transfer apparent molar volume $(\Delta\varphi_v^0)_{tra}$ provides information about solute-solvent interactions which are free from the effect of solvent-solvent interactions [21].

Four types of possible interactions in the studied ternary systems containing L-Proline in aqueous alcohol solutions are as following [12, 22, 24]:

a. The hydrophilic-ionic interactions between -OH group of alcohols and zwitterions of L-Proline
b. The hydrophilic-hydrophilic interactions between -OH groups of alcohols and the -NH groups in the side chain of L-Proline via hydrogen bonding
c. The hydrophilic-hydrophobic interactions between -OH group alcohols and non-polar groups of L-Proline
d. The hydrophobic-hydrophobic interactions between the non-polar groups of alcohols and amino acid (L-Proline).

The interactions (a) and (b) lead to positive sign for $(\Delta\varphi_v^0)_{tra}$ values since the electrostriction effect is reduce trough hydrophilic-ionic interactions and then the water molecules can release to the bulk state, as a consequence, the transfer volumes for studied amino acid are positive, but the interactions types (c) and (d) lead to negative $(\Delta\varphi_v^0)_{tra}$ due to increase in electrostriction effect [25]. In the study, we found that $(\Delta\varphi_v^0)_{tra}$ values are negative for L-Proline in aqueous methanol system and the interaction type is (c) and (d). Similar trends are found for $(\Delta\varphi_v^0)_{tra}$ values by F. Salini *et al*. [26] from volumetric properties of DL-alanine/+ D (-)-fructose + water at different temperatures. We also found positive $(\Delta\varphi_v^0)_{tra}$ values for L-Proline in aq. ethanol and L-Proline in aq. propanol systems which means that the interaction type is (a) and (b). Similar trends are also found for $(\Delta\varphi_v^0)_{tra}$ values by Nain *et al*. [12] from volumetric properties of l-histidine in aqueous glucose solutions at different temperatures.

Table 1: Densities ρ ($g.L^{-1}$) and Apparent Molar Volume $\varphi_V (cm^3.mol^{-1})$ as functions of molar concentration of L-Proline in water and aq. alcohols at at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively

Conc. (*mol.L*$^{-1}$)	**ρ (g.L^{-1})**						**φ_V (cm^3. mol^{-1})**					
	298.15 K	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**	**298.15 K**	**303.15 K**	**308.15 K**	**313.15 K**	**318.15 K**	**323.15 K**
	L-Proline in Water											
0.0201	0.99450	0.99277	0.99175	0.99020	0.98900	0.98771	40.22	43.32	46.91	50.53	55.67	61.34
0.0401	0.99742	0.99577	0.99480	0.99330	0.99215	0.99095	35.68	39.28	42.36	45.47	49.35	54.48
0.0599	1.00019	0.99863	0.99770	0.99624	0.99514	0.99405	31.64	35.57	38.31	41.07	44.51	49.82
0.0799	1.00290	1.00134	1.00050	0.99907	0.99795	0.99699	28.87	31.83	35.02	37.49	39.82	45.46
0.0998	1.00550	1.00400	1.00310	1.00170	1.00070	0.99980	26.09	29.07	31.03	33.31	36.39	41.53
L-Proline in aq. Methanol												

0.0201	0.93721	0.93484	0.93298	0.93103	0.92853	0.92616	30.76	25.96	22.25	19.35	14.98	9.50
0.0401	0.93874	0.93645	0.93469	0.93280	0.93036	0.92804	36.09	31.61	26.84	24.08	20.48	16.30
0.0599	0.94017	0.93802	0.93636	0.93449	0.93204	0.92981	39.50	34.11	29.28	26.96	24.87	20.42
0.0799	0.94154	0.93949	0.93789	0.93610	0.93361	0.93142	42.12	36.68	32.37	29.58	28.49	24.66
0.0998	0.94292	0.94101	0.93941	0.93760	0.93518	0.93294	43.57	37.80	34.28	32.31	30.70	28.18
L-Proline in aq. Ethanol												
0.0201	0.92919	0.92572	0.92146	0.91518	0.91243	0.90930	0.62	2.52	4.60	6.77	8.49	11.17
0.0401	0.93120	0.92768	0.92336	0.91704	0.91420	0.91100	8.20	10.54	13.28	15.61	18.81	22.19
0.0599	0.93301	0.92942	0.92504	0.91860	0.91570	0.91243	14.33	17.25	20.16	23.82	27.23	30.86
0.0799	0.93454	0.93095	0.92651	0.92002	0.91695	0.9136	21.16	23.37	26.43	29.99	34.88	38.78
0.0998	0.93607	0.9324	0.92781	0.92120	0.91807	0.91453	25.30	27.87	32.06	36.34	40.90	46.15
L-Proline in aq. Propanol												
0.0201	0.92876	0.92561	0.92295	0.91924	0.91644	0.91398	56.23	49.63	42.84	36.39	27.48	20.92
0.0401	0.92986	0.92679	0.92424	0.92068	0.91797	0.91568	60.50	55.51	49.09	41.71	34.91	27.09
0.0599	0.93086	0.92786	0.92539	0.92197	0.91936	0.91719	63.79	59.07	53.54	46.24	39.92	32.59
0.0799	0.93171	0.92879	0.92639	0.92313	0.92063	0.91862	67.39	62.91	57.74	50.20	44.00	36.40
0.0998	0.93232	0.92953	0.92731	0.92423	0.92191	0.91987	72.17	67.24	61.21	53.22	46.39	40.59

The temperature dependency of the limiting apparent molar volumes can be defined as following relation:

$$\phi^{o}_{v}=a_0+a_1T+a_2T \qquad (5)$$

Where, a_0, a_1 and a_2 are empirical parameters. By using the first derivative of Eq. (5) with respect to temperature, we can calculate the limiting apparent molar expansibility E_φ^0 as:

$$E_\varphi^0=a_1+2a_2T \qquad (6)$$

The calculated values of empirical parameters of Eq. (6) and the E_φ^0 values are summarized in Table 2. According to this table, we observe that at each temperature, the E_φ^0 values for L-Proline in aqueous alcohol solutions are negative (except L-Proline in aq. Ethanol system; but, small).

According to Hepler theory [27] the second derivative of limiting apparent molar volume with respect to temperature or the sign of$(\delta E_\varphi^0/\delta T)_p$ demonstrate the structure making or breaking tendency of solutes in mixtures. The thermodynamic term is applied as following:

$$(\delta E_\varphi^0/\delta T)_p = 2a_2 \qquad (7)$$

The $(\delta E_\varphi^0/\delta T)_p$ values are positive for structure-making solutes, whereas they are negative for structure-breaking solutes. According to this description and Eq. (7), it is concluded that small positive and negative values of $(\delta E_\varphi^0/\delta T)_p$ indicate the weak interaction between solute and solvents [28].

Table 2: Limiting apparent molar volume(φ_V^0) limiting transfer apparent molar volume $(\Delta\varphi_v^0)_{tra}$, experimental slope ($S_V$), limiting apparent molar volume expansibilities (E_φ^0) and $(\delta E_\varphi^0/\delta T)_p$ of L-Proline in Water and aq. alcohols at 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Systems	T (K)	φ_V^0 (cm^3.mol^{-1})	$(\Delta\varphi_V^0)_{tra}$ (cm^3.mol^{-1})	S_v	E_φ^0 (cm^3·mol^{-1}K^{-1})	$(\delta E_\varphi^0/\delta T)_p$
L-Proline in Water	298.15K	81.40	-	51.79	0.98	0.04
	303.15K	82.93	-	55.47	1.16	
	308.15K	90.09	-	60.08	1.35	
	313.15K	97.88	-	64.77	1.53	
	318.15K	111.55	-	71.59	1.71	
	323.15K	112.93	-	77.29	1.89	
L-Proline in aq. Methanol	298.15K	74.43	6.97	20.77	-1.79	0.25
	303.15K	67.98	14.95	17.12	-0.54	
	308.15K	68.93	21.16	12.67	0.72	
	313.15K	73.06	24.82	9.14	1.98	
	318.15K	91.98	19.57	2.10	3.23	
	323.15K	106.34	6.59	5.39	4.49	
L-Proline in aq. Ethanol	298.15K	147.89	6.97	10.09	0.20	-0.09
	303.15K	148.72	65.79	13.27	-0.28	
	308.15K	150.03	59.94	15.92	-0.75	
	313.15K	137.15	39.27	15.05	-1.22	
	318.15K	133.55	22.00	16.14	-1.70	
	323.15K	125.06	12.13	18.17	-2.17	
L-Proline in aq. Propanol	298.15K	88.69	7.29	42.99	1.35	-0.04
	303.15K	98.48	15.54	35.53	1.15	
	308.15K	105.36	15.27	27.91	0.96	
	313.15K	101.22	3.34	21.82	0.76	
	318.15K	109.95	1.60	12.48	0.57	
	323.15K	112.79	0.14	4.79	0.37	

The viscosities of L–Proline in Water, L-Proline in aq. Methanol, in aq. Ethanol and in aq. Propanol systems are determined at temperatures ranging from (298.15K to 323.15K) with the interval of 5K are shown in Table 3.

Table 3: Viscosity (η) of L-Proline in Water and aq. alcohols at temperatures 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L-1)	**298.15K**	**303.15K**	**308.15K**	**313.15K**	**318.15K**	**323.15K**
	η (m Pa. s)					
L-Proline in Water						
0.0201	0.8841	0.7862	0.6933	0.6215	0.5741	0.5225
0.0401	0.9008	0.7977	0.7088	0.6351	0.5875	0.5332
0.0599	0.9124	0.8105	0.7188	0.6459	0.5962	0.5424
0.0799	0.9273	0.8208	0.7283	0.6586	0.6096	0.5577
0.0998	0.9446	0.8298	0.7415	0.6706	0.6227	0.5664
L-Proline in aq. Methanol						
0.0201	1.4084	1.2542	1.1325	0.9772	0.9019	0.7824
0.0401	1.4352	1.2848	1.1723	0.9991	0.9496	0.8069
0.0599	1.4650	1.3248	1.2091	1.0492	0.9690	0.8491
0.0799	1.5016	1.3696	1.2578	1.0869	1.0018	0.8918
0.0998	1.5208	1.3967	1.2867	1.1178	1.0269	0.9449
L-Proline in aq. Ethanol						
0.0201	1.4457	1.2974	1.2091	1.0547	0.9322	0.8463
0.0401	1.4870	1.3302	1.2589	1.0896	0.9599	0.8928
0.0599	1.5430	1.3714	1.2984	1.1308	0.9872	0.9456
0.0799	1.6090	1.4203	1.3407	1.1644	1.0205	0.9759
0.0998	1.6745	1.4753	1.3741	1.2058	1.0577	0.9981
L-Proline in aq. Propanol						
0.0201	2.5255	2.2191	1.9676	1.7311	1.5393	1.3895
0.0401	2.5862	2.3050	2.0273	1.7739	1.5861	1.4238
0.0599	2.6702	2.3922	2.0966	1.8306	1.6489	1.4700
0.0799	2.7207	2.4583	2.1600	1.8752	1.6951	1.5378
0.0998	2.7851	2.5313	2.2201	1.9585	1.7545	1.5837

From the above data it is seem that viscosities increases rapidly with the increasing concentration of L–Proline. This trend leads to the hydrophilic-ionic and hydrophilic-hydrophobic interactions. The viscosity values decreases with increasing temperature in all the systems. The reason is due to the fact that the increasing temperature may increase the kinetic energy of the molecules. The viscosity data is putted in the Jones-Dole equation [29, 30] to calculate viscosity A and B coefficients by the following equation:

$$\frac{\eta_r - 1}{\sqrt{C}} = A + B\sqrt{C} \qquad (8)$$

Where, η_r= the relative viscosity of the solution and the viscosity A and B coefficients were obtained from the intercepts and slopes and are listed in Table 4.

A (Falkenhagen coefficient) represents the solute-solute interactions associated with the size and shape of solute and B or Jones-Dole coefficient is a constant which is used to determine solute-solvent interactions [31, 32].

The positive values of B-coefficient in the present systems (except for L-Proline in water system) points out the strong solute-solvent interactions and also the solute's structure making ability [33].

The temperature derivatives of B-coefficient (dB/dT) have also been calculated. The sign of dB/dT values is found to provide important information regarding structure making or structure breaking ability of the solute in solvent media [34, 36]. In general, the dB/dT is negative for structure maker and positive for structure breaker solutes in solutions. The small positive values of dB/dT for L-Proline indicates weak structure making ability of L-Proline in aqueous alcohols solutions.

Table 4: Viscosity Coefficient B and A of L-Proline in Water and aq. alcohols at temperatures 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively

Viscosity Coefficient-B						**Viscosity Coefficient-A**					
298.15K	303.15K	308.15K	313.15K	318.15K	323.15K	298.15K	303.15K	308.15K	313.15K	318.15K	323.15K
L-Proline in Water											
-0.0073	-0.1533	-0.0082	-0.0079	0.0403	0.0176	0.8650	1.0588	0.8886	1.0249	0.9733	1.0571
L-Proline in aq. Methanol											
0.8016	1.5046	1.9923	1.8186	1.8893	2.9271	0.1220	0.0074	-0.085	0.0628	-0.042	-0.129
L-Proline in aq. Ethanol											
2.3962	1.8235	1.4131	1.9445	1.7684	2.4205	-0.176	-0.045	0.1911	-0.044	-0.032	0.0471
L-Proline in aq. Propanol											
0.9664	1.9315	1.9073	1.7987	1.7628	2.1635	0.1799	-0.038	-0.108	-0.088	0.025	-0.162

The Gibb's free energy (ΔG#) are calculated for all the systems and listed in the Table 5 and evaluated by the Erying viscosity relation [37, 38]:

$$\Delta G^{\#} = RT\ln\left(\frac{\eta V_m}{Nh}\right) \qquad (9)$$

Where, h is the Plank constant, N is the Avogadro number; η is the viscosity of the solution and ΔG# is the contribution per mole of the solute to the free energy of activation for viscous flow of the solution at infinite dilution, Vm is the Molar volume [39] of solution.

In the table we see that the values of ΔG# are positive for all the systems. This can be described by the fourth model [40] by whom it can be said that the kinetic species involved in forming cavities or holes in the medium is given by the Work required in forming the hole against surface tension of these systems. The slow increase in ΔG#-values for aqueous L-Proline solutions indicates that the structure–destroying property is decreased with increasing solute concentration.

Table 5: Gibb's free energy (ΔG#), enthalpy of activation (ΔH#) and entropy of activation (ΔS#) for L-Proline in Water, L-Proline in aqueous Methanol, L- in aqueous Ethanol and L-Proline in aqueous Propanol systems at temperatures 298.15K, 303.15K, 308.15K, 313.15K, 318.15K and 323.15K respectively.

Conc. (mol.L^{-1})	**ΔG$^{\#}$ (kJ.mol^{-1})**						**ΔH$^{\#}$ (kJ.mol^{-1})**	**ΔS$^{\#}$ (kJ.mol^{-1})**
	298.15K	**303.15K**	**308.15K**	**313.15K**	**318.15K**	**323.15K**	-	
L-Proline in Water								
0.0201	13.75	13.69	13.60	13.54	13.55	13.51	15.51	3.58
0.0401	13.79	13.72	13.64	13.58	13.60	13.55	13.88	-1.91
0.0599	13.81	13.75	13.67	13.62	13.63	13.59	14.40	-0.29
0.0799	13.85	13.78	13.70	13.66	13.68	13.66	15.05	1.73
0.0998	13.89	13.80	13.74	13.70	13.73	13.69	13.34	-3.93
L-Proline in aq. Methanol								
0.0201	15.05	15.02	15.01	14.87	14.91	14.77	18.25	10.65
0.0401	15.09	15.07	15.09	14.93	15.04	14.85	17.63	8.43
0.0599	15.14	15.14	15.17	15.05	15.09	14.98	16.97	6.04
0.0799	15.19	15.22	15.26	15.14	15.17	15.11	16.41	3.93
0.0998	15.22	15.27	15.32	15.21	15.24	15.26	15.28	0.08
L-Proline in aq. Ethanol								
0.0201	15.14	15.13	15.21	15.12	15.05	15.03	16.68	5.03
0.0401	15.21	15.20	15.32	15.21	15.12	15.18	16.08	2.83
0.0599	15.30	15.27	15.40	15.31	15.20	15.33	15.63	1.06
0.0799	15.41	15.36	15.48	15.38	15.29	15.42	15.91	1.69
0.0998	15.51	15.46	15.54	15.47	15.38	15.48	16.29	2.64
L-Proline in aq. Propanol								
0.0201	16.52	16.48	16.45	16.40	16.36	16.34	18.77	7.55
0.0401	16.58	16.57	16.52	16.46	16.43	16.40	18.91	7.78
0.0599	16.65	16.66	16.61	16.53	16.53	16.49	18.91	7.51
0.0799	16.70	16.73	16.68	16.59	16.60	16.60	18.36	5.49
0.0998	16.75	16.80	16.75	16.70	16.69	16.68	18.09	4.39

The changes of entropy of activation (ΔS≠) with the concentration of the studied systems are noted in Table 5. It is seen that ΔS≠ values for the flow process are positive in all systems but do not follow any specific pattern. The positive values of ΔH≠ for all the systems indicate the positive work has to be done to overcome the energy barrier for the flow process. So, it may be decided that the viscous flow is not thermodynamically favoured for the studied systems.

4. Conclusions

The densities and viscosities of L-Proline in water and in aqueous alcohols solution were measured at different temperatures. By using these experimental results, various parameters were calculated. The higher (Δφv0) tra values of L-Proline in aqueous alcohols solution is due to the stronger hydrophilic-ionic interactions between -OH groups of alcohols molecules and zwitterionic centre of L-Proline. It can be concluded that the ionic-hydrophilic interactions have been found to dominate over hydrophobic-hydrophilic interactions and the L-Proline acts as a structure-maker properties in aqueous alcohols solutions.

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