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Volumetric, compressibility and conductometric studies of L-histidine in aqueous poly ethylene glycol solutions at different temperatures

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Abstract

Polymers are a versatile class of materials that have a wide range of applications, due to their unique physical and chemical properties. In this study, the effect of molar mass of PEG and temperature on the thermodynamic properties of aqueous solutions of L-histidine, has been studied. For this purpose, density, sound velocity and specific conductivity for solutions of L-histidine in pure water and in aqueous solutions of 0.02 w/w of PEG400, PEG2000 and PEG6000 have been measured at T = (298.15, 308.15 and 318.15) K. From the values of experimental density and sound velocity, the apparent molar volume, ϕ_v and apparent molar isentropic compressibility, ϕ_K were calculated and extrapolated to infinite dilution. The transfer apparent molar volume at infinite dilution, $\Delta\phi^{0}_{\vartheta,tr}$ and the transfer apparent molar isentropic compressibility, $\Delta\phi^{0}_{k,tr}$ of L-histidine from water to aqueous PEG solutions have been studied. Also, by using of the measured specific conductivity for the investigated solutions in this work, molar conductivity Λ was calculated. The results show that the values of Λ for all the examined systems decrease with the increase in the concentration of amino acid.

Keywords: L-histidine, Poly ethylene glycol, Volumetric, Molar Conductivity, Aqueous Solutions

1. Introduction

Amino acids have attained much attention in the industrial and biological processes [1]. Also, considering this fact the most of biochemical processes are carried out in aqueous media [2], studies of physicochemical properties of amino acids, building stones of proteins, in aqueous solutions are paramount of importance. Furthermore, such studies can be very useful to obtain a deep knowledge about the nature of exciting interactions in solutions [2-6]. The study of polymers is of immense importance in modern scientific research and technology. The study of polymers involves understanding their molecular structure, properties and behavior, and how they can be synthesized and processed into useful materials. For many years, different polymer or macromolecular solutions have been considered colloidal systems. The reason for this is the similarity between the macromolecule sizes in polymer solutions and the sizes of the dispersed particles in the low molecular weight dispersed colloidal systems. For this goal, we performed the volumetric, compressibility and electrical conductivity studies of amino acid – PEG – water systems. Although these systems are very important, there is a few studies in the literature about the volumetric and compressibility properties of aqueous amino acid – PEG solutions [7-10]. However, Unlike amino acid–IL–water [11-13] and amino acid–salt–water [14,15] systems, the electrical conductivity behavior of amino acid– PEG – water systems has not been studied in literatures. To our knowledge is the first time study of these systems from conductivity point of view. In a continuation of our previous works on the volumetric properties [16-20] and in order to obtain further evidence about the existing interactions in aqueous amino acid–PEG solutions, here, we studied the volumetric, compressibility and conductivity properties at three different temperatures for the solutions of L-histidine in pure water and in aqueous solutions of 0.02 w/w of the PEG400, PEG2000 and PEG600.

2. Experimental section

2.1. Materials.

PEGS and L-histidine were produced from Merck and used without further purification. Double distilled and deionized water was used for the preparation of the solutions. Specifications of used materials was reported in Table 1 and the chemical structure of the L-histidine and PEG showed in Scheme 1.

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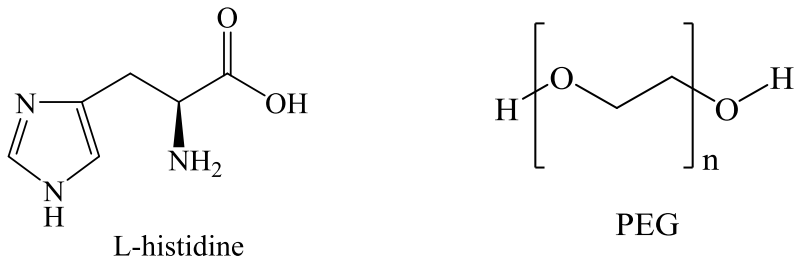

Schem1. Chemical structures of the chemicals studied.

Table 1. Compound description, formula, CAS number and supplier of the materials.

Chemical name	Formula	Supplier
Poly Ethylene Glycol	$H(OCH_2CH_2)_nOH$	Merck
L-Histidine	$C_6H_9N_3O_2$	Merck

2.2. Method

All the solutions were prepared by mass on an electronic balance (Sartorius AG.GK 1203, Germany) accurate to within $\pm$ 10^{-4}g. Anton Paar oscillating U-tube densimeter (DSA 5000 model), automatically regulated within ± 0.01 K and working at frequency of 3 MHz was used to measure the density and speed of sound of pure components and their mixtures. Before each series of measurement, the calibration of the instrument was made with degassed and double distilled water and dry air at atmospheric pressure. All measurement were done at ambient pressure (81.5 kPa) with uncertainty of ± 0.05 MPa. The experimental uncertainties of density and sound velocity measurements were $\pm 3\times10^{-6}$ g.cm^{-3} and $\pm 3\times10^{-1}$ m.s^{-1}, respectively. The experimental specific conductivity, k, were measured using a conductivity meter (model 86503), with an uncertainty of ±0.5 µs.cm^{-1}. The instrument was calibrated with a 1413 solution. The cell temperature was controlled using a thermostatic water bath (Pharmacia Biotech Multitemp III) within an uncertainty of ± 0.1 K.

3. Results and Discussion

The aim of this work is investigate the effect of molar mass of PEG and temperature on the thermodynamic properties of aqueous solutions of L-histidine and also achieve to a better knowledge about the nature of interactions exciting in solutions. For this purpose, density, sound velocity and specific conductivity measurement for solutions of L-histidine in pure water and in aqueous solutions of 0.02 w/w of PEG400, PEG2000 and PEG6000 were made at T = (298.15, 308.15 and 318.15) K.

3.1. Volumetric and compressibility measurement

The experimental density, d, and sound velocity, u, data for the investigated systems are reported in Table 2. The apparent molar volume, ϕ_v, and apparent molar isentropic compressibility, ϕ_k, were calculated for the L-histidine in the investigated solvents (pure water and in aqueous solutions of 0.02 w/w of PEG400, PEG2000 and PEG6000) by using the equations [10]:

$$\phi_v = \frac{1000}{mdd_o}(d_o - d) + \frac{M}{d} \quad (1)$$

$$\phi_k = -(\frac{\partial \phi_v}{\partial P})_s = \frac{1000\,(k_s d_o - k_{so} d)}{mdd_o} + \frac{Mk_s}{d} \quad (2)$$

Isentropic compressibility, k_s, is given by the following equation:

$$k_s = \frac{1}{du^2} \quad (3)$$

In the above equations, M and m are the molar mass and the molality of amino acid, d_0 and d are densities of solvent and solution, respectively. k_{s0} and k_s are isentropic compressibilities of solvent and solution, respectively.

Table 2. Experimental density d/(g.cm^{-3})and sound velocity u (m.s^{-1}) of L-histidine in water and in aqueous solutions of 0.02 w/w of PEG400, PEG2000 and PEG6000 at different temperatures.

m /(mol.kg^{-1})	T=298.15K		T=308.15K		T=318.15K	
	d /(g.cm^{-3})	u /(m.s^{-1})	d /(g.cm^{-3})	u /(m.s^{-1})	d /(g.cm^{-3})	u /(m.s^{-1})
L- histidine in water						
0.0000	0.997045	1497.14	0.994038	1520.05	0.990220	1536.62
0.0256	0.998518	1499.28	0.995483	1522.04	0.991646	1538.47
0.0517	0.999955	1501.54	0.996896	1524.10	0.993042	1540.36
0.0644	1.000656	1502.62	0.997587	1525.06	0.993726	1541.25
0.0845	1.001780	1504.34	0.998691	1526.66	0.994814	1542.72
0.1404	1.004840	1508.99	1.001701	1530.91	0.997785	1546.63
0.1693	1.006398	1511.31	1.003233	1533.09	0.999302	1548.66
0.1971	1.007898	1513.68	1.004709	1535.21	1.000761	1550.61
0.2277	1.009503	1516.25	1.006289	1537.58	1.002312	1552.83
0.2659	1.011520	1519.25	1.008274	1540.31	1.004254	1555.32
L-histidine in aqueous solution of 2 % w/w PEG400						
0.0000	0.997036	1496.94	0.994022	1519.96	0.990188	1536.56
0.0096	1.000540	1508.28	0.997426	1529.60	0.993315	1544.78
0.0129	1.000715	1508.74	0.997597	1530.01	0.993648	1545.18
0.0161	1.000878	1508.88	0.997759	1530.09	0.993836	1545.20
0.0226	1.001269	1509.62	0.998143	1530.79	0.994158	1545.90
0.0291	1.001620	1510.03	0.998492	1531.15	0.994547	1546.18
0.0393	1.002173	1510.88	0.999033	1531.92	0.995076	1546.90
0.0524	1.002927	1512.19	0.999773	1533.16	0.995709	1548.09
0.0643	1.003549	1513.01	1.000382	1533.86	0.996090	1548.71
0.0858	1.004774	1514.81	1.001588	1535.52	0.997524	1550.23
0.1176	1.006520	1517.49	1.003308	1537.98	0.999290	1552.49
0.1448	1.007926	1519.72	1.004616	1540.03	1.000339	1554.42
0.1713	1.009440	1522.23	1.006179	1542.35	1.002163	1556.55
0.1998	1.010927	1524.22	1.007641	1544.14	1.003604	1558.22
0.2353	1.012881	1527.29	1.009566	1546.94	1.005181	1560.77
0.2691	1.014640	1530.10	1.011298	1549.55	1.007220	1563.24
L-histidine in aqueous solution of 2 % w/w PEG2000						
0.0000	0.997041	1497.07	0.994034	1519.97	0.990211	1536.56
0.0096	1.000853	1509.28	0.997665	1530.58	0.993657	1545.89
0.0129	1.001057	1509.04	0.997913	1530.24	0.993735	1545.34
0.0162	1.001226	1509.28	0.998079	1530.46	0.993884	1545.51
0.0225	1.001578	1509.97	0.998423	1531.11	0.994471	1546.17
0.0291	1.001955	1510.39	0.998795	1531.48	0.994843	1546.46
0.0384	1.002455	1511.17	0.999287	1532.18	0.995328	1547.10
0.0516	1.003190	1512.27	1.000012	1533.20	0.996046	1548.05
0.0648	1.003950	1513.46	1.000759	1534.29	0.996781	1549.03
0.0849	1.005064	1515.19	1.001852	1535.86	0.997863	1550.48
0.1164	1.006798	1517.96	1.003560	1538.42	0.999547	1552.89
0.1450	1.008344	1520.23	1.005079	1540.48	1.001052	1554.74
0.1735	1.009883	1522.58	1.006593	1542.62	1.002437	1556.72
0.2029	1.011455	1525.00	1.008141	1544.84	1.004072	1558.78
0.2236	1.012519	1526.64	1.009188	1546.34	1.005116	1560.17
0.2639	1.014692	1530.06	1.011327	1549.48	1.007132	1563.09
L-histidine in aqueous solution of 2 % w/w PEG6000						
0.0000	0.997066	0.997066	0.994057	1519.99	0.988974	1536.65
0.0129	1.001065	1.001065	0.997915	1530.19	0.992440	1545.31
0.0145	1.001173	1.001173	0.998017	1530.34	0.993079	1545.44
0.0163	1.001260	1.001260	0.998101	1530.47	0.992814	1545.57
0.0226	1.001637	1.001637	0.998485	1530.99	0.993726	1546.09
0.0291	1.001996	1.001996	0.998835	1531.57	0.993273	1546.56
0.0506	1.003191	1.003191	0.999965	1533.08	0.994426	1547.93
0.0842	1.005036	1.005036	1.001804	1535.65	0.996869	1550.30
0.1177	1.006892	1.006892	1.003649	1538.25	0.998927	1552.71
0.1453	1.008439	1.008439	1.005171	1540.46	1.000332	1554.72
0.1722	1.009838	1.009838	1.006547	1542.69	1.002491	1556.82
0.1985	1.011230	1.011230	1.007920	1544.35	1.003219	1558.34
0.2305	1.012964	1.012964	1.009624	1546.83	1.004837	1560.62
0.2663	1.014859	1.014859	1.011489	1549.49	1.007366	1563.0
L-histidine in aqueous solution of 2 % w/w PEG6000						

0.0000	0.997066	0.997066	0.994057	1519.99	0.988974	1536.65
0.0129	1.001065	1.001065	0.997915	1530.19	0.992440	1545.31
0.0145	1.001173	1.001173	0.998017	1530.34	0.993079	1545.44
0.0163	1.001260	1.001260	0.998101	1530.47	0.992814	1545.57
0.0226	1.001637	1.001637	0.998485	1530.99	0.993726	1546.09
0.0291	1.001996	1.001996	0.998835	1531.57	0.993273	1546.56
0.0506	1.003191	1.003191	0.999965	1533.08	0.994426	1547.93
0.0842	1.005036	1.005036	1.001804	1535.65	0.996869	1550.30
0.1177	1.006892	1.006892	1.003649	1538.25	0.998927	1552.71
0.1453	1.008439	1.008439	1.005171	1540.46	1.000332	1554.72
0.1722	1.009838	1.009838	1.006547	1542.69	1.002491	1556.82
0.1985	1.011230	1.011230	1.007920	1544.35	1.003219	1558.34
0.2305	1.012964	1.012964	1.009624	1546.83	1.004837	1560.62
0.2663	1.014859	1.014859	1.011489	1549.49	1.007366	1563.0

Fig. 1 (a) the temperature and concentration dependence of ϕ_v for L-histidine in aqueous solutions of 0.02 w/w of PEG2000 have been given. This Fig shows that the apparent molar volume of L-histidine increases with an increase in the amino acid molality.

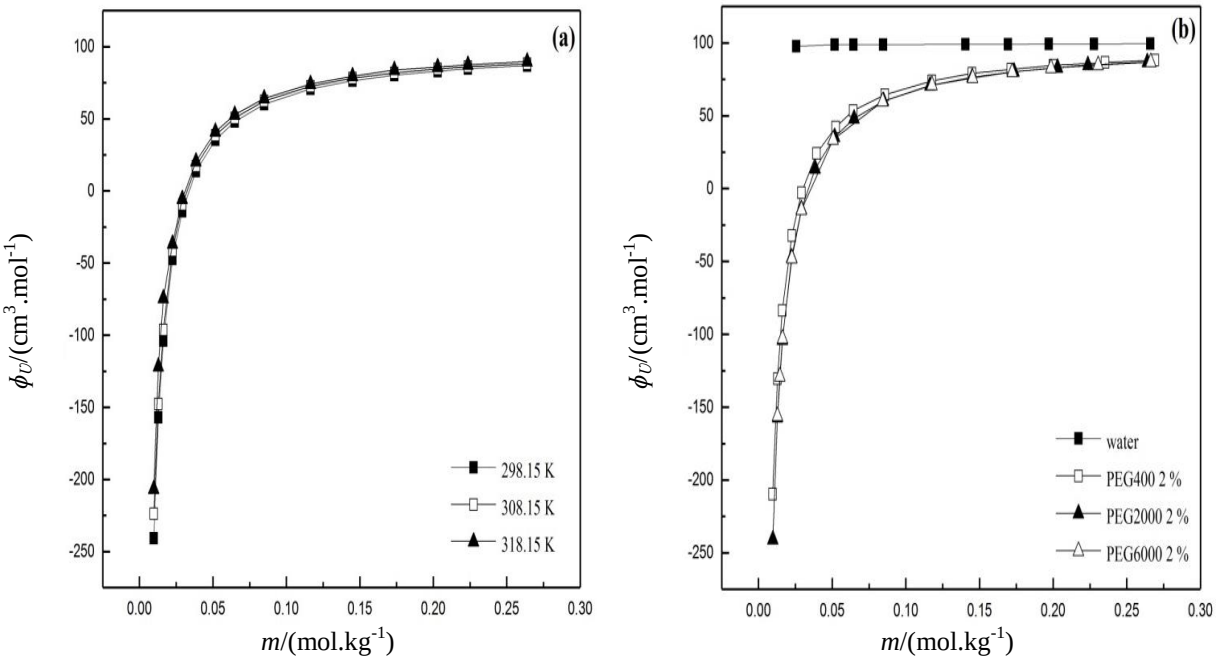

Fig. 1. Plot of apparent molar volume (ϕ_v) against molality (m) L-histidine. (a): in aqueous solution of 0.02 w/w of PEG2000 at different temperatures, (b): in water and in aqueous solutions of 0.02 w/w of PEG400, PEG2000 and PEG6000 at 298.15 K.

However, temperature changes don't effect on the values of ϕ_v of L-histidine in aqueous PEG2000 solutions. Similar behavior was observed for other L-histidine + PEG + water systems. In Fig .1 (b), the apparent molar volume for L-histidine in pure water and in aqueous solutions of 0.02 w/w of PEG400, PEG2000 and PEG6000 have been shown at 298.15 K. In this Fig, the values of ϕ_v of L-histidine in pure water are larger than those in aqueous PEG solutions.Furthermore, this Fig shows that the molar mass of PEG doesn't effect on the values of ϕ_v. In Fig. 2 (a), the temperature and concentration dependence of apparent molar isentropic compressibility are presented for L-histidine in aqueous solutions of 0.02 w/w of PEG2000. The values of ϕ_k of L-histidine in the all temperatures and amino acid concentrations have negative and increases by increasing temperature and amino acid molality. The other investigated L-histidine + PEG + water systems show the similar behavior. In Fig. 2 (b),

the apparent molar isentropic compressibility for L- histidine in pure water and in aqueous solutions of 0.02 w/w of PEG400, PEG2000 and PEG6000 have been shown at 298.15 K. The values of ϕ_k of L-histidine in pure water is larger than those in aqueous PEG solutions. This behavior shows that the hydrating of L-histidine (groups of zwitterionic of L-histidine $NH_3^+$and COO^-) in aqueous PEG solutions is larger than that of pure water, as result of, in the presence of PEG, the values of ϕ_k for the L-histidine decreased.

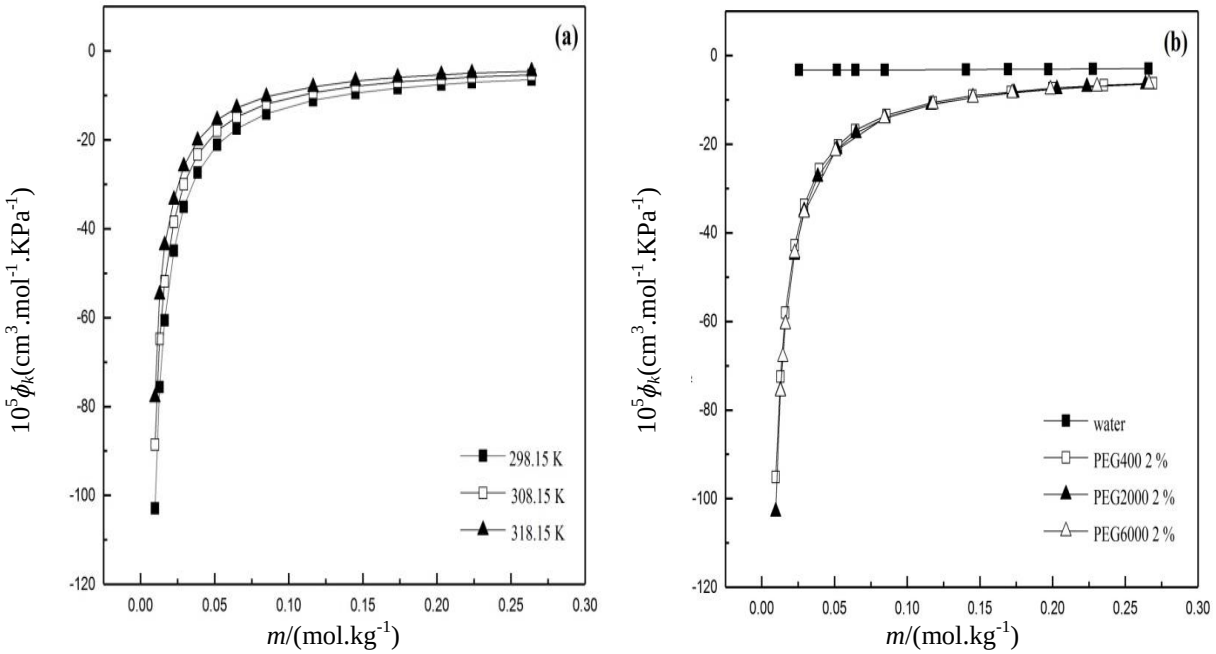

Fig. 2. Plot of apparent molar isentropic compressibility (ϕ_k) against molality (m) L-histidine. (a): in aqueous solution of 0.02 w/w PEG2000 at different temperatures, (b): in water and in aqueous solutions of 0.02 w/w of PEG400, PEG2000 and PEG6000 at 298.15 K.

Also, this Fig shows that the molar mass of PEG doesn't effect on the values of ϕ_K. The values of the infinite dilution apparent molar volume, ϕ_v^0 and infinite dilution apparent molar isentropic compressibility, ϕ_K^0provide useful information about the solute–solvent interactions [21] and can be determined by a least squares analysis of the equations 4 and 5 (Redlich – Mayer equations) [22]:

$$\phi_k = \phi_k^o + A_k m^{0.5} + b_k m \quad (4)$$

$$\phi_v = \phi_v^o + A_v m^{0.5} + b_v m \quad (5)$$

Where A_v and A_k are the Pitzer – Debye –Huckel limiting slope for apparent molar volume and apparent molar isentropic compressibility, respectively [23]. Where b_v and b_k are empirical parameters that determines the deviation from the limiting law as a result of the nonelectrostatic solute – solute interactions [24]. The values of ϕ_v^0 ϕ_k^0, A_v, A_k, b_v and b_k for studied systems are given in Table 3. Also can be seen from Table 3, the values of ϕ_k^o for the examined systems in this work are negative and become less negative by increasing temperature. The negative values of the ϕ_k^o indicated that the water molecules surrounding the solute are less compressible than the water molecules in bulk solutions.

Table 3. Infinite dilution apparent molar properties (ϕ_V^0 and ϕ_K^0), and coefficients of equations (3) and (4), (A_V, A_k, b_V and b_k) for L-histidine in water and in aqueous solutions of 0.02 w/w of PEG400, PEG2000 and PEG6000 at different temperatures.

T/K	ϕ_v^0 / ($cm^3.mol^{-1}$)	A_v / ($cm^3.mol^{-1.5}.kg^{0.5}$)	b_v / ($cm^3.mol^{-2}.kg$)	$10^5\phi_k^0$ / ($cm^3.mol^{-1}.kPa^{-1}$)	$10^5 A_k$ / ($cm^3.mol^{-1.5}.kPa^{-1}.kg^{0.5}$)	$10^5 b_k$ / ($cm^3.mol^{-2}.kPa^{-1}.kg$)
L- histidine in water						
298.15	96.1860	12.9167	-13.4516	-3.2044	-0.4176	1.7131
308.15	97.5872	11.4766	-11.9196	-2.7191	0.3876	0.5168
318.15	98.6890	9.9785	-9.6445	-2.3202	0.7466	-0.0310
L-histidine in aqueous solution of 2 % w/w PEG400						
298.15	-337.4417	2.2455×10^3	-2.8561×10^3	-134.0200	672.6200	-854.2300
308.15	-325.7304	2.1913×10^3	-2.7876×10^3	-114.2300	574.4500	-729.8500
318.15	-302.5640	2.0731×10^3	-2.6333×10^3	-98.3810	495.0400	-628.7200
L-histidine in aqueous solution of 2 % w/w PEG2000						
298.15	-389.2563	2.5348×10^3	-3.2584×10^3	-144.1800	735.6100	-947.6400
308.15	-368.8310	2.4296×10^3	-3.1196×10^3	-123.9200	633.4600	-816.2900
318.15	-331.5139	2.2200×10^3	-2.8348×10^3	-106.9800	547.2400	-705.1200
L-histidine in aqueous solution of 2 % w/w PEG6000						
298.15	-320.1519	2.0239×10^3	-2.4699×10^3	-122.5300	577.5300	-704.9300
308.15	-305.1296	1.9580×10^3	-2.3910×10^3	-104.3100	492.2100	-600.6700
318.15	-289.6180	1.8782×10^3	-2.3054×10^3	-90.3740	426.3700	-521.3800

the transfer apparent molar isentropic compressibility, $\Delta\phi_{k,tr}^o$ of L-histidine from water to aqueous PEG solutions have been calculated as:

$$\Delta_t\phi_{v,tr}^o = \phi_v^o(\text{in aqueous 0.02 w/w polymer solution}) - \phi_v^o(\text{in water}) \quad (6)$$

$$\Delta_t\phi_{k,tr}^o = \phi_k^o(\text{in aqueous 0.02 w/w polymer solution}) - \phi_k^o(\text{in water}) \quad (7)$$

Table 4 shows that the calculated values of both $\Delta\phi_{v,tr}^o$ and $\Delta\phi_{k,tr}^o$ are negative and increases with increasing temperature. This behavior can be explained by the interactions between amino acid and PEG. As a result of, the ion–dipole interactions between groups of zwitterionic of L-histidine $NH_3^+$and COO^- and the etheric –o– group of PEGS cause a negative value of $\Delta\phi_{v,tr}^o$.

Also, possibility the H– bonding interactions of imidazole ring of L-histidine with hydroxyl group of PEG lead to releasing some hydrophobically hydrate water molecules around PEG400. Hydrophobically hydrated water is known to be in an ice like structure having greater volume than the normal bulk water. Thus, when hydrophobically hydrate water molecules are released in to normal bulk water, their volume decreases [7].

3.2. Conductivity measurement

From the experimental specific conductivity, k, can calculate the molar conductivity of the solutions, Λ, by [11]:

$$\Lambda = \frac{1000k}{C} \quad (8)$$

where, C is the molarity of solution. The values of the experimental specific conductivity of the solutions of L-histidine in pure water and in aqueous PEG solutions at T = (298.15, 308.15 and 318.15) K are listed in Table 4. Fig. 3 shows the plots of molar conductivity Λ as a function of the square root the molarity of amino acid ($\sqrt{C}$) at different temperatures, for the solutions of L-histidine (a): in pure water and (b): in aqueous solutions of 0.02 w/w of PEG2000.

Table 4. Apparent molar volume of transfer, $\Delta\phi_{v,tr}^{0}$ and apparent molar isentropic compressibility of transfer, $\Delta\phi_{k,tr}^{0}$ of L-histidine in aqueous solutions of 0.02 w/w of PEG400, PEG2000 and PEG6000 at different temperatures

Solvent	T /K	$\Delta\phi_{v,tr}^{o}(cm^3.mol^{-1})$	$10^5\Delta\phi_{k,tr}^{o}/(cm^3.mol^{-1}.kPa^{-1})$
Aqueous solution of 2 %w/w of PEG400	298.15	-433.6277	-130.8200
	308.15	-423.3176	-111.5100
	318.15	-401.2530	-96.0610
Aqueous solution of 2 %w/w of PEG2000	298.15	-485.4423	-140.9800
	308.15	-466.4182	-121.2000
	318.15	-430.2029	-104.6600
Aqueous solution of 2 % w/w of PEG6000	298.15	-416.3379	-119.3300
	308.15	-402.7168	-101.5900
	318.15	-388.3070	-88.0540

According to this plots, the molar conductivity increases with increasing temperature and decrease the concentration of amino acid. Increasing the temperature due to increase of the ions mobility, led to increase of the molar conductivity. Also by increasing the concentration of amino acid, due to increasing viscosity of solution, the molar conductivity decreases [25]. A comparison of Fig. 3 (a) and (b) shows that molar conductivity for of L-histidine + water system is more sensitive to the temperature variations than L-histidine + PEG2000 + water system. The other investigated L-histidine + PEG + water systems show the similar behavior. Fig. 4 compares the molar conductivity of the solutions of L-histidine in pure water and in aqueous solutions of 0.02 w/w of different molar mass of polymers at 298.15 K.

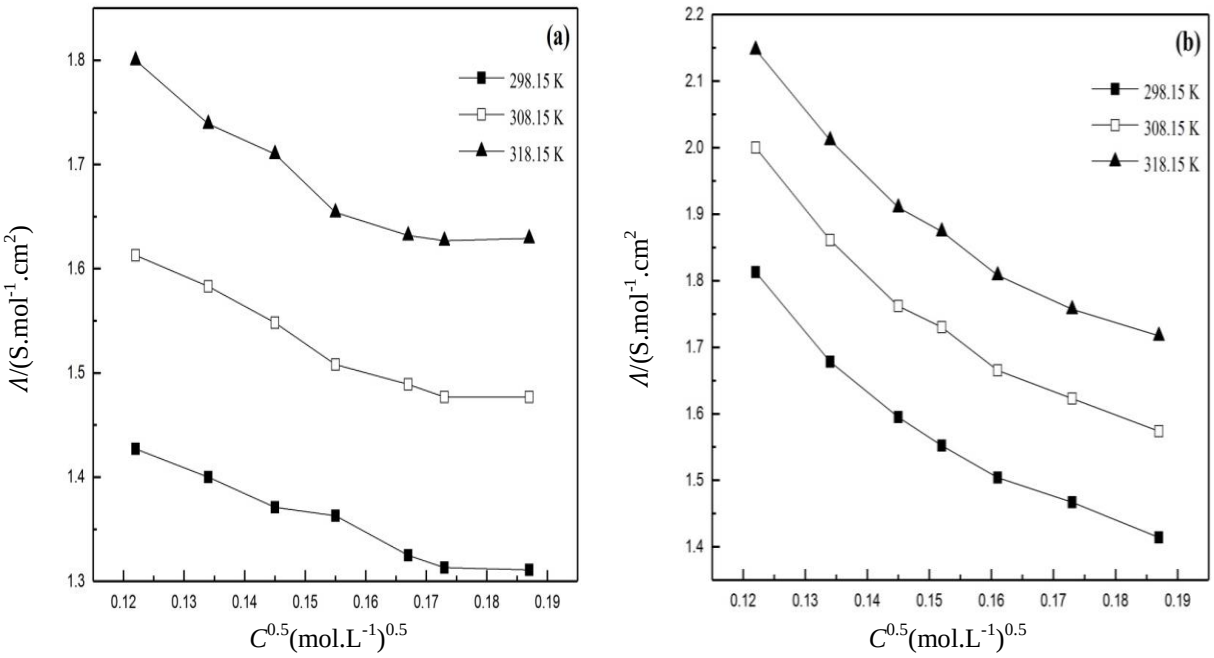

Fig. 3. Plot of Λ against $C^{0.5}$, for solutions of L-histidine, at different temperatures. (a): in pure water, (b): in aqueous solution of 0.02 w/w of PEG2000.

This Fig. shows that the values of Λ for the aqueous solutions of L-histidine follow the order (L-histidine in aqueous PEG400 solutions) > (L-histidine in aqueous PEG2000 solutions) > (L-histidine in aqueous PEG6000 solutions) > (L-histidine in pure water). The difference between the molar conductivity values both L-histidine in aqueous PEG solutions and L-histidine in pure water systems can be attributed by this fact that, in the aqueous

PEG–amino acid systems, transfer of electric charge by the etheric oxygen and oxygen of hydroxyl group of the polyethylene glycol, which has a negative partial charge increases.

By increasing molecular weight PEG in solution, the effect of transfer of electric charge decreases and the effect of viscosity of polymer dominates. So, by increasing molecular weight PEG, the viscosity solution increases whereas the mobility of the ions decreases so that Λ decreases.

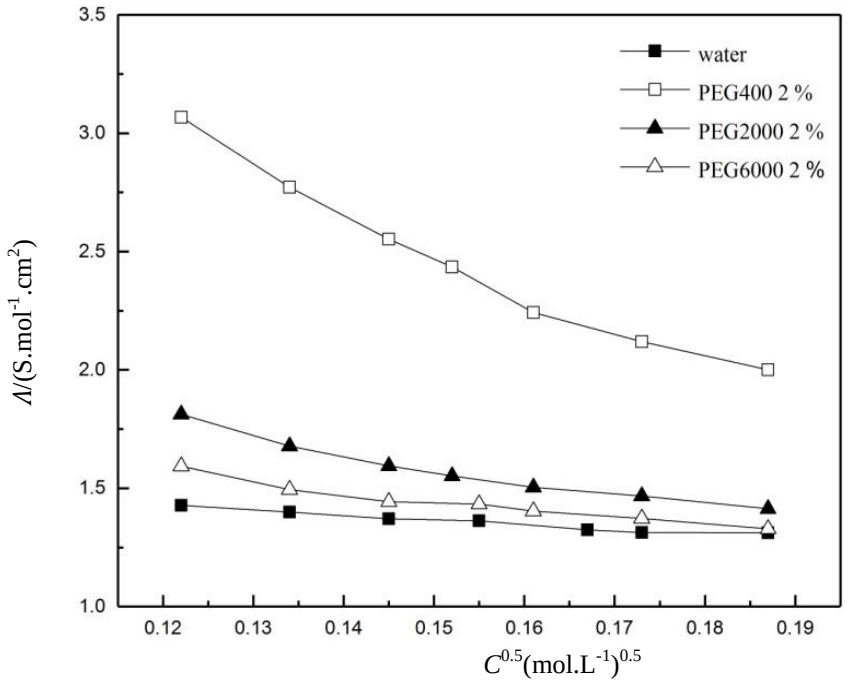

Fig. 4. Plot of Λ against $C^{0.5}$, for solutions of L-histidine, in pure water and in aqueous solutions of 0.02 w/w of PEG400, PEG2000 and PEG6000 at 298.15 K.

4. Conclusions

The infinite dilution apparent molar isentropic compressibility, ϕ_K^0 and the infinite dilution apparent molar volume, ϕ_v^0, of L-histidine in pure water and in aqueous solutions of 0.02 w/w of PEG400, PEG2000 and PEG6000 at T = (298.15, 308.15 and 318.15) were measured. Also, the infinite dilution apparent molar properties for transfer of L-histidine from water to aqueous PEG solutions have been studied. Our studies indicate that both of $\Delta\phi_{\vartheta,tr}^0$ and $\Delta\phi_{K,tr}^0$ have negative values and increases by increasing the temperature. The results obtained from conductivity measurement show that the value of molar conductivity for all the examined systems increases with increase temperature, and decrease amino acid concentration. Also, the revels Λ for the aqueous solutions of L-histidine follow the order (L-histidine in aqueous PEG400 solutions) > (L-histidine in aqueous PEG2000 solutions) > (L-histidine in aqueous PEG6000 solutions) > (L-histidine in pure water).

Conflicts of Interest

The author declares no conflict of interest.

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References

[1] M.T. Zafarani-Moattar, B. Asadzadeh, 1-Effect of 1-carboxymethyl-3-methylimidazolium chloride ionic liquid on thermodynamic and solubility of l-threonine in water at 298.15 K and atmospheric pressure, Fluid Phase Equilibria. 379 (2014) 86. http://DOI:10.1016/j.fluid.2014.07.001

[2] A. Pal, N. Chauhan, Interactions of amino acids and peptides with the drug pentoxifylline in aqueous solution at various temperatures: a volumetric approach, J. Chem. Thermodyn. 54 (2012) 288. http://DOI:10.1016/j.jct.2012.05.009
[3] Z. Yan, J. Wang, J. Lu, Viscosity behavior of some α-amino acids and their groups in water–sodium acetate mixtures, Biophys. Chem. 99 (2002) 199. http://DOI: 10.1016/s0301-4622(02)00200-4
[4] T.S. Banipal, J. Kaur, P.K. Banipal, A.K. Sood, K. Singh, Volumetric and Viscometric Studies of Some Amino Acids in Aqueous Solutions of Cadmium Chloride at T = (288.15 to 318.15) K and at Atmospheric Pressure, J. Chem. Eng. Data. 56 (2011) 2751. http://DOI:10.1021/je100909b
[5] K. Rajagopal, J. Johnson, Production of biodiesel from waste used cooking oil using two different alkaline catalysts., J. Sci. Res. Pub. 5 (2015) 2. https://www.researchgate.net/publication/305387662
[6] N. Ebrahimi, R. Sadeghi, Volumetric and compressibility behaviour of poly (propylene glycol)–Amino acid aqueous solutions at different temperatures, J. Chem. Thermodyn. 90 (2015) 129. http://DOI:10.1016/j.jct.2015.06.024
[7] M. Sahin, Z. Yesil, M. Gunel, S. Tahiroglu, E. Ayranci, Interactions of glycine with polyethylene glycol studied by measurements of density and ultrasound speed in aqueous solutions at various temperatures, J. Fluid Phase Equilibr. 300 (2011) 155. http://DOI:10.1016/j.fluid.2010.11.005
[8] K. Sasahara, Temperature dependence of volume changes on glycine-PEG and L-alanine-PEG in aqueous solution, Colloid Polym. Sci. 273 (1995) 782. https://doi.org/10.1021/j100052a053
[9] K. Sasahara, Volume and compressibility changes on mixing aqueous solutions of the amino acid and poly (ethylene glycol), Colloid Polym. Sci. 272 (1994) 385. https://doi.org/10.1021/j100412a110
[10] R. Sadeghi, B. Hamidi, N. Ebrahimi, Investigation of amino acid–polymer aqueous biphasic systems, J. Phys. Chem. B. 118 (2014) 10285. https://doi.org/10.1021/jp505383r
[11] H. Shekaari, M.T. Zafarani-Moattar, S. N. Mirheydari, Conductometric analysis of1-butyl-3-methylimidazolium ibuprofenate as an active pharmaceutical ingredient ionic liquid (API-IL) in the aqueous amino acids solutions, J. Chem. Thermodyn. 103 (2016) 165. http://DOI10.1016/j.jct.2016.07.047
[12] H. Shekaari, F. Jebali, Densities, viscosities, electrical conductances, and refractive indices of amino acid+ ionic liquid ([BMIm] Br)+ water mixtures at 298.15 K, J. Chem. Eng. Data. 55 (2010) 2517. https://doi.org/10.1021/je900882r