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Volumetric, ultrasonic, and viscometric behaviour of *l*-histidine in aqueous-glucose solutions at different temperatures

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Densities, ρ, ultrasonic speeds, u, and viscosities, η, of aqueous-glucose (5%, 10%, 15%, and 20% of glucose, w/w in water) and of solutions of *l*-histidine in aqueous-glucose solvents were measured at T = (293.15, 298.15, 303.15, 308.15, 313.15, and 318.15) K. From these experimental data, apparent molar volume, V_ϕ, limiting apparent molar volume, V_ϕ° and the slope, S_v, apparent molar compressibility, $K_{s,\phi}$, limiting apparent molar compressibility, $K_{s,\phi}^\circ$ and the slope, S_k, transfer volume, $V_{\phi,tr}^\circ$, transfer compressibility, $K_{s,\phi,tr}^\circ$, Falkenhagen coefficient, A, Jones–Dole coefficient, B, and temperature derivative of B-coefficient, dB/dT were calculated. The results are interpreted in terms of solute–solute and solute–solvent interactions in these systems. It has been observed that there exist strong solute–solvent interactions in these systems, which increase with increase in glucose concentration. It has also been observed that *l*-histidine act as structure-maker in aqueous-glucose solvents.

1. Introduction

It is well known that various substances cause changes in the conformation of proteins when present in aqueous-protein solutions. The complex conformational and configurational factors affecting the structure of proteins in solution make the direct study of protein interactions difficult. Therefore, one useful approach is to investigate interactions of the model compounds of proteins, *i.e.*, amino acids in aqueous and mixed-aqueous solutions [1–5]. The physicochemical properties of amino acids in aqueous solutions provide valuable information on solute–solute and solute–solvent interactions that are important in understanding the stability of proteins, and are implicated in several biochemical and physiological processes in a living cell [6]. Water is chosen for preparing mixed solvent because its presence gives rise to hydrophobic forces [7], which are of prime importance in stabilizing the native globular structure of protein [8].

It is known [9,10] that polyhydroxy compounds helps in stabilizing the native globular structure of protein and reduce the extent of their denaturation by other substances. Carbohydrates located at cell surfaces, are important as receptors for the bioactive structures of enzymes, hormones, viruses, antibodies, *etc.* [11]. The protein–carbohydrate interactions are important for immunology, biosynthesis, pharmacology, medicine, and cosmetic industry [12,13]. Thus, the properties of amino acids in aqueous-carbohydrate solutions are essential for understanding the chemistry of biological systems [14,15]. There have been a number of physicochemical studies of amino acids in aqueous-carbohydrate solutions [1–5,14–17], but most of these studies involved amino acids with non-polar, polar, and uncharged R group. To the best of our knowledge, no volumetric, ultrasonic, and viscometric studies have been reported on amino acids with positively charged side chain in aqueous-carbohydrate solutions, except the study by Zhao *et al.* [4], who investigated volumetric and viscometric properties of arginine in aqueous-carbohydrate solutions. These considerations led us to undertake the study of *l*-histidine (with positively charged R group) in aqueous-glucose solutions.

In continuation to our earlier studies [3,17–20] on amino acids in mixed-aqueous solutions, we report here the densities, ρ, ultrasonic speeds, u, and viscosities, η of *l*-histidine in aqueous-glucose (5%, 10%, 15%, and 20% of glucose, w/w) at T = (293.15, 298.15, 303.15, 308.15, 313.15, and 318.15) K. These experimental data have been used to calculate the apparent molar volume, apparent molar volume, V_ϕ, limiting apparent molar volume, V_ϕ° and the slope, S_v, apparent molar compressibility, $K_{s,\phi}$, limiting apparent molar compressibility, $K_{s,\phi}^\circ$ and the slope, S_k; transfer volume, $V_{\phi,tr}^\circ$, transfer compressibility, $K_{s,\phi,tr}^\circ$, Falkenhagen coefficient, A, Jones–Dole coefficient, B, and temperature derivative of B-coefficient, dB/dT. These parameters have been used to discuss the solute–solute and solute–solvent interactions in these systems.

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TABLE 1
Densities, ρ, ultrasonic speeds, u, and viscosities, η of solutions of *l*-histidine in water and (glucose + water) (5%, 10%, 15% and 20% glucose, w/w) solutions as functions of molality, m of *l*-histidine and temperature.

M/(mol · kg^{-1})	T/K					
	293.15	298.15	303.15	308.15	313.15	318.15
			l-Histidine in water			
			ρ/(kg · m^{-3})			
0.0000	1072.41	1070.56	1068.72	1066.87	1065.01	1063.17
0.0200	1073.26	1071.42	1069.58	1067.74	1065.88	1064.05
0.0400	1074.11	1072.27	1070.45	1068.61	1066.76	1064.93
0.0599	1074.96	1073.13	1071.30	1069.47	1067.63	1065.81
0.0799	1075.81	1073.99	1072.17	1070.34	1068.51	1066.69
0.0999	1076.67	1074.85	1073.03	1071.21	1069.38	1067.57
0.1199	1077.52	1075.70	1073.90	1072.09	1070.26	1068.46
0.1400	1078.38	1076.57	1074.77	1072.96	1071.14	1069.34
0.1600	1079.23	1077.43	1075.64	1073.83	1072.01	1070.22
			u/(m · s^{-1})			
0.0000	1543.2	1553.3	1563.1	1573.5	1582.2	1591.2
0.0200	1546.8	1556.9	1566.7	1577.1	1585.8	1594.8
0.0400	1550.1	1560.2	1570.0	1580.3	1589.0	1597.9
0.0599	1553.1	1563.2	1572.9	1583.2	1591.8	1600.7
0.0799	1555.8	1565.8	1575.5	1585.8	1594.3	1603.1
0.0999	1558.2	1568.2	1577.8	1587.9	1596.4	1605.2
0.1199	1560.3	1570.2	1579.7	1589.8	1598.1	1606.7
0.1400	1562.1	1572.0	1581.3	1591.2	1599.4	1608.0
0.1600	1563.6	1573.3	1582.5	1592.4	1600.5	1608.9
			$10^3 \cdot \eta$/(N · s · m^{-2})			
0.0000	1.8768	1.6696	1.4911	1.3452	1.2098	1.1122
0.0200	1.9120	1.6986	1.5152	1.3654	1.2266	1.1268
0.0400	1.9398	1.7215	1.5342	1.3808	1.2393	1.1368
0.0599	1.9675	1.7434	1.5522	1.3956	1.2512	1.1467
0.0799	1.9950	1.7658	1.5705	1.4101	1.2627	1.1558
0.0999	2.0230	1.7883	1.5888	1.4250	1.2748	1.1654
0.1199	2.0500	1.8103	1.6066	1.4392	1.2860	1.1742
0.1400	2.0770	1.8322	1.6240	1.4536	1.2972	1.1836
0.1600	2.1042	1.8533	1.6412	1.4675	1.3089	1.1928
			l-Histidine in 5% aqueous-glucose			
			ρ/(kg · m^{-3})			
0.0000	1016.28	1014.69	1013.08	1011.47	1009.85	1008.21
0.0200	1017.33	1015.74	1014.14	1012.53	1010.91	1009.28
0.0400	1018.38	1016.79	1015.19	1013.59	1011.98	1010.35
0.0599	1019.42	1017.84	1016.24	1014.65	1013.04	1011.41
0.0799	1020.47	1018.89	1017.30	1015.71	1014.10	1012.48
0.1000	1021.53	1019.95	1018.36	1016.77	1015.16	1013.55
0.1200	1022.58	1021.01	1019.42	1017.83	1016.23	1014.62
0.1400	1023.63	1022.06	1020.47	1018.89	1017.29	1015.68
0.1600	1024.68	1023.11	1021.52	1019.95	1018.35	1016.74
			u/(m · s^{-1})			
0.0000	1499.7	1514.3	1525.1	1535.7	1545.6	1554.5
0.0200	1503.9	1518.4	1529.0	1539.4	1549.1	1557.8
0.0400	1507.5	1521.8	1532.1	1542.3	1551.7	1560.2
0.0599	1510.5	1524.6	1534.5	1544.4	1553.5	1561.8
0.0799	1512.9	1526.7	1536.3	1545.9	1554.5	1562.4
0.1000	1514.6	1528.1	1537.3	1546.5	1554.8	1562.4
0.1200	1515.6	1529.1	1538.1	1546.8	1554.5	1561.8
0.1400	1515.9	1529.1	1537.5	1546.2	1553.5	1560.6
0.1600	1515.6	1528.4	1536.9	1545.0	1552.1	1559.0
			$10^3 \cdot \eta$/(N · s · m^{-2})			
0.0000	1.1757	0.9767	0.8605	0.7697	0.6945	0.6334
0.0200	1.1918	0.9894	0.8711	0.7787	0.7023	0.6403
0.0400	1.2048	0.9995	0.8794	0.7856	0.7080	0.6450
0.0599	1.2181	1.0095	0.8874	0.7923	0.7134	0.6492
0.0799	1.2314	1.0194	0.8955	0.7986	0.7186	0.6534
0.1000	1.2448	1.0293	0.9033	0.8051	0.7236	0.6574
0.1200	1.2580	1.0392	0.9112	0.8115	0.7284	0.6611
0.1400	1.2715	1.0496	0.9192	0.8175	0.7335	0.6650
0.1600	1.2850	1.0597	0.9271	0.8237	0.7383	0.6687
			ρ/(kg · m^{-3})			
0.0000	1034.79	1033.15	1031.50	1029.84	1028.17	1026.48
0.0200	1035.74	1034.10	1032.46	1030.80	1029.14	1027.45
0.0399	1036.69	1035.06	1033.41	1031.76	1030.10	1028.42
0.0600	1037.65	1036.02	1034.38	1032.74	1031.08	1029.41
0.0799	1038.60	1036.98	1035.34	1033.70	1032.05	1030.38