Journal of Molecular Liquids 159 (2011) 180–188

Contents lists available at ScienceDirect

Journal of Molecular Liquids

journal homepage: www.elsevier.com/locate/molliq

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

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ARTICLE INFO

Article history:
Received 18 October 2010
Received in revised form 8 January 2011
Accepted 20 January 2011
Available online 26 January 2011

Keywords:
Density
Ultrasonic speed
Viscosity
L-Methionine

ABSTRACT

Densities, ρ, ultrasonic speeds, u, and viscosities, η, of aqueous-glucose (2.5, 5, 10, 15 and 20% of glucose, w/w in water) and of solutions of L-methionine in four aqueous-glucose solvents were measured at 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 compressibiliity, $K_{s,\phi}$, 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, free energy of activation of viscous flow per mole of solvent, $\Delta\mu_1^{\circ\#}$ and per mole of solute, $\Delta\mu_2^{\circ\#}$ were calculated. The results are interpreted in terms of solute–solvent and solute–solute interactions in these systems. It is observed that there exist strong solute–solvent interactions in these systems, which increase with increase in glucose concentration. It is observed that L-methionine act as structure-breaker in aqueous-glucose solvents. The thermodynamics of viscous flow has also been discussed.

1. Introduction

The physicochemical and thermodynamic properties of amino acids are of considerable interest, as these biomolecules are the building blocks of all living organisms, and are found to provide valuable information that leads to a better understanding of proteins [1–5]. Since proteins are large complex molecules, the direct study of protein interactions is difficult. Therefore, one useful approach is to investigate interactions of the model compounds of proteins, *e.g.*, amino acids, in aqueous and mixed-aqueous solutions [1–5]. It has also been recognized that in the absence of experimental thermodynamic data of proteins, amino acids can serve as useful models in estimating their properties [6]. The choice of water for preparing mixed solvent stems from its important and unique role in determining the structure and stability of protein since its presence give rise to hydrophobic forces [7], which are of prime importance in stabilizing native globular structure of protein [8].

It is known [9,10] that polyhydroxy compounds (carbohydrates) 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], however, these are not components of living organisms, but they act as a vehicle for pharmaceuticals or cosmetics when introduced into living organisms [13]. Thus, the properties of amino acids in aqueous-carbohydrate solutions are important for understanding the chemistry of biological systems [14,15]. There have been a number of physico-chemical studies of some amino acids in aqueous-carbohydrate solutions [1–5,14–20]. To the best of our knowledge, no volumetric, ultrasonic and viscometric studies have been reported on L-methionine in aqueous-glucose solutions.

In the present paper, we report the densities, ρ, ultrasonic speeds, u, and viscosities, η of solutions of L-methionine in water and in aqueous-glucose solvents (2.5, 5, 10, 15 and 20% of glucose, w/w in water) at 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, 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. These parameters have been used to discuss the solute–solute and solute–solvent interactions in these systems. Furthermore, the free energies of activation of viscous flow per mole of solvent, $\Delta\mu_1^{\circ\#}$ and per mole of solute, $\Delta\mu_2^{\circ\#}$ for L-methionine in aqueous-glucose solutions were also calculated. The thermodynamics of viscous flow has also been discussed.

2. Experimental

L-Methionine (SRL India, purity > 99%) was used after recrystallization from ethanol–water mixture and dried in vacuum over P_2O_5 at room temperature for 72 h. Glucose (E. Merck, Germany, purity > 99.9%) was used as such without further purification, except drying in oven for 24 h. The aqueous-glucose solutions (2.5, 5, 10, 15 and 20% of glucose, w/w in water) were prepared using triple distilled

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doi:10.1016/j.molliq.2011.01.010

Table 1
Densities, ρ, ultrasonic speeds, u, and viscosities, η of solutions of L-methionine in water and glucose + water (2.5, 5, 10, 15 and 20% glucose, w/w) solutions at different temperatures.

m ($mol \cdot kg^{-1}$)	T/(K)					
	293.15	298.15	303.15	308.15	313.15	318.15
L-Methionine in water						
$\rho/(kg \cdot m^{-3})$						
0.0000	998.24	997.07	995.68	994.07	992.25	990.24
0.0250	998.90	997.72	996.33	994.71	992.88	990.87
0.0500	999.55	998.36	996.96	995.34	993.51	991.49
0.0750	1000.19	998.99	997.58	995.95	994.11	992.09
0.1000	1000.81	999.61	998.20	996.55	994.71	992.68
0.1250	1001.42	1000.21	998.79	997.14	995.29	993.26
0.1499	1002.02	1000.80	999.38	997.72	995.86	993.82
0.1750	1002.61	1001.38	999.95	998.29	996.42	994.38
0.1999	1003.18	1001.95	1000.50	998.84	996.97	994.91
$u/(m \cdot s^{-1})$						
0.0000	1483.6	1496.9	1508.4	1519.8	1526.8	1533.0
0.0250	1484.6	1497.8	1509.1	1520.3	1527.1	1533.1
0.0500	1486.0	1499.0	1510.2	1521.2	1527.9	1533.7
0.0750	1487.7	1500.7	1511.7	1522.6	1529.1	1534.8
0.1000	1489.8	1502.7	1513.6	1524.3	1530.6	1536.2
0.1250	1492.1	1505.1	1515.9	1526.5	1532.8	1538.1
0.1499	1495.0	1507.8	1518.6	1529.0	1535.1	1540.5
0.1750	1498.1	1510.8	1521.6	1531.9	1538.1	1543.2
0.1999	1501.5	1514.4	1524.9	1535.2	1541.1	1546.2
$\eta/(10^{-3}\ N \cdot s \cdot m^{-2})$						
0.0000	1.0019	0.8903	0.7973	0.7190	0.6526	0.5972
0.0250	1.0115	0.8992	0.8057	0.7270	0.6602	0.6044
0.0500	1.0189	0.9063	0.8126	0.7340	0.6671	0.6110
0.0750	1.0258	0.9131	0.8195	0.7408	0.6735	0.6178
0.1000	1.0325	0.9198	0.8264	0.7475	0.6803	0.6244
0.1250	1.0394	0.9266	0.8330	0.7540	0.6870	0.6310
0.1499	1.0464	0.9335	0.8396	0.7607	0.6936	0.6373
0.1750	1.0532	0.9403	0.8465	0.7675	0.6999	0.6436
0.1999	1.0600	0.9474	0.8535	0.7743	0.7063	0.6495
L-Methionine in 2.5% aqueous-glucose						
$\rho/(kg \cdot m^{-3})$						
0.0000	1007.26	1005.91	1004.61	1003.21	1001.61	999.76
0.0249	1007.87	1006.52	1005.21	1003.80	1002.19	1000.34
0.0500	1008.48	1007.12	1005.80	1004.38	1002.77	1000.91
0.0750	1009.08	1007.70	1006.37	1004.95	1003.33	1001.47
0.1000	1009.66	1008.27	1006.93	1005.50	1003.88	1002.01
0.1249	1010.23	1008.83	1007.48	1006.04	1004.42	1002.55
0.1500	1010.79	1009.38	1008.02	1006.57	1004.95	1003.08
0.1750	1011.34	1009.91	1008.54	1007.09	1005.46	1003.59
0.2000	1011.87	1010.44	1009.05	1007.59	1005.96	1004.09
$u/(m \cdot s^{-1})$						
0.0000	1492.9	1506.2	1517.4	1528.3	1536.9	1544.5
0.0249	1493.9	1507.1	1518.2	1529.0	1537.5	1544.9
0.0500	1495.2	1508.4	1519.3	1530.0	1538.4	1545.8
0.0750	1496.7	1509.9	1520.8	1531.3	1539.6	1546.8
0.1000	1498.7	1511.8	1522.6	1533.1	1541.3	1548.4
0.1249	1500.9	1514.0	1524.7	1535.1	1543.3	1550.4
0.1500	1503.5	1516.5	1527.3	1537.7	1545.8	1552.8
0.1750	1506.3	1519.4	1530.2	1540.5	1548.6	1555.6
0.2000	1509.4	1522.4	1533.3	1543.7	1551.7	1558.6
$\eta/(10^{-3}\ N \cdot s \cdot m^{-2})$						
0.0000	1.0790	0.9202	0.8167	0.7324	0.6610	0.6035
0.0249	1.0891	0.9294	0.8254	0.7408	0.6690	0.6113
0.0500	1.0971	0.9369	0.8330	0.7481	0.6762	0.6183
0.0750	1.1050	0.9444	0.8405	0.7553	0.6833	0.6252
0.1000	1.1127	0.9519	0.8480	0.7627	0.6906	0.6322
0.1249	1.1204	0.9593	0.8552	0.7700	0.6976	0.6392
0.1500	1.1282	0.9670	0.8628	0.7773	0.7047	0.6462
0.1750	1.1359	0.9746	0.8704	0.7848	0.7119	0.6534
0.2000	1.1437	0.9820	0.8778	0.7920	0.7190	0.6607
L-Methionine in 5% aqueous-glucose						
$\rho/(kg \cdot m^{-3})$						
0.0000	1016.28	1014.69	1013.08	1011.47	1009.85	1008.21
0.0249	1016.85	1015.26	1013.64	1012.02	1010.39	1008.75
0.0500	1017.42	1015.81	1014.19	1012.56	1010.93	1009.28
0.0750	1017.97	1016.36	1014.72	1013.09	1011.45	1009.79
0.1000	1018.51	1016.89	1015.24	1013.60	1011.96	1010.29
0.1249	1019.04	1017.42	1015.75	1014.10	1012.45	1010.78
0.1500	1019.56	1017.93	1016.25	1014.59	1012.94	1011.26
0.1750	1020.07	1018.43	1016.74	1015.07	1013.41	1011.73
0.2000	1020.57	1018.92	1017.22	1015.54	1013.88	1012.19

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