J. Chem. Thermodynamics 71 (2014) 6–13

Contents lists available at ScienceDirect

J. Chem. Thermodynamics

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

Studies on sodium dodecylsulfate in aqueous and in aqueous amino acid solutions: Volumetric and viscometric approaches

Muhammad Sarwar Hossain [b], Tapan Kumar Biswas [a], Dulal Chandra Kabiraz [a], Md. Nazrul Islam [a], Muhammad Entazul Huque [a,*]

[a] Department of Chemistry, University of Rajshahi, Rajshahi 6205, Bangladesh
[b] Department of Chemistry, Khulna University, Khulna 9208, Bangladesh

ARTICLE INFO

Article history:
Received 16 May 2013
Received in revised form 15 November 2013
Accepted 16 November 2013
Available online 23 November 2013

Keywords:
Apparent molar volume
Free energy
Isentropic compressibility
Viscosity coefficient
Critical micelle concentration

ABSTRACT

Physicochemical properties like density, ultrasound velocity and viscosity of aqueous solutions of glycine and SDS (sodium dodecylsulfate) in 0.1 m aqueous glycine solution as a function of concentration at different temperatures ranging from 293.15 K to 313.15 K have been determined. These data have been used to calculate apparent molar volume, isentropic compressibility and viscosity *B*-coefficient values of the studied solutions. The viscosity coefficients A and B have been determined from the Jones–Dole equation. The limiting apparent molar volumes (ϕ_v^0) and experimental slopes (S_v) derived from the Masson equations have been interpreted in terms of solute–solute and solute–solvent interactions. From the volumetric and viscometric data, the structural effect of SDS in glycine solution has been discussed. The change in free energy, enthalpy and entropy of activation were calculated using the Nightingale and Benck, and Eyring equations. Glycine in aqueous solution exhibits structure-breaking behaviour. The results were explained in terms of structure making and structure breaking properties.

1. Introduction

In recent years, there has been growing interest in the interactions between protein and surfactant due to its many applications in biosciences, foods, cosmetics, drug delivery, detergency and biotechnological processes [1,2]. Commonly used surfactant, sodium dodecylsulfate (SDS) is reported to act as a potent protein denaturant than urea and guanidine hydrochloride [3]. It is commonly used to stabilize biological membranes and to isolate and purify membranes proteins and membrane lipids. In ionic surfactants, the repulsive forces from electrostatic repulsion between the polar head groups [4] and attractive interactions have generally been attributed to hydrophobic interactions [5] between the nonpolar tails of the surfactant monomers. Using various tools and techniques, these interactions have been studied and published in the past few years [6–9]. It has been proposed that hydrophobic and electrostatic interactions are the two main driving forces for the association between surfactants and proteins in aqueous solution. However, the study of protein–surfactant interactions is difficult because of the complexity of interactions in such a large molecule. Details of these interactions are yet to be answered. It will be important to understand the origin and nature of these interactions both qualitatively and quantitatively. To understand fine details, the interactions of the building block molecules of the protein with surfactants should be studied. There have been some investigations on the interaction of surfactants with amino acids [10–13]. Singh *et al.* [10] reported only volumetric properties of some amino acids and two peptides (diglycine and triglycine) in aqueous surfactant solutions at $T = 298.15$ K. Yan *et al.* [13] reported interactions of glycyl dipeptides with sodium dodecylsulfate in aqueous solution by volumetric, conductometric, and fluorescence probe study at $T = 298.15$ K to 313.15 K with 5 K intervals. Both have used aqueous sodium dodecylsulfate as solvent. However, no report is available on the physico-chemical properties of SDS in aqueous amino acid solutions at different temperatures.

The partial molar volume, adiabatic compressibility and viscosity *B*-coefficient are the important physicochemical properties to understand the interactions between molecules in solution. Thus in continuation with our earlier work [14] we report here study of the volumetric, viscometric and ultrasound behaviour of sodium dodecylsulfate in water and in 0.1 m glycine solutions. Using these data, infinite-dilution apparent molar volumes, Hepler constant, viscosity *B*-coefficients, and activation free-energy parameters have been calculated. The results are discussed in terms of the solute–solute, solute– solvent and solvent–solvent interactions.

* Corresponding author. Tel.: +88 0721 770059; fax: +88 0721 750064.
E-mail addresses: tapankb@ru.ac.bd (T.K. Biswas), emhuque@yahoo.com (M.E. Huque).

0021-9614/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jct.2013.11.022

TABLE 1
Specification of the chemical samples.

Materials	Molar mass	Reported purity (%)	Source	CAS number	Analysis method
SDS (Sodium dodecylsulfate)	288.38	99	Fluka AG, Switzerland	330345/1 893	GC[a]
Glycine	75.07	99	Fluka AG, Switzerland	441845/1 54902100	GC

[a] GC = Gas chromatography.

2. Experimental

Sodium dodecylsulfate (SDS), $C_{12}H_{25}SO_4Na$ (Mass fraction purity $\geqslant 0.99$) and glycine (mass fraction purity $\geqslant 0.99$) were procured from Fluka Chemical Company, Switzerland and were used as such without further purifications. These compounds were dried under vacuum for at least 48 h, to reduce the water content and other compounds to negligible values. The details of the chemical used in the present work are given in table 1. The distilled water was redistilled and deionised by passing through two ion exchange columns. The redistilled and deionised water was distilled again in alkaline $KMnO_4$ medium and were used for preparation of solution. Conductivity of this water was found to be 1.00 μS. The CMC (critical micelle concentration) of the surfactant was determined from the intersection of the molar conductivity data in the premicellar and postmicellar region. The molar conductivity decreases with increasing SDS concentration and showed a sharp break in its value where micelle starts to form. The conductivity measurements were carried out on a Laboratory Conductivity Meter (Model 4310 Jenway). The observed values of critical micelle concentration for SDS are $(8.2 \cdot 10^{-3}, 8.3 \cdot 10^{-3}, 8.7 \cdot 10^{-3}, 9.0 \cdot 10^{-3}, 9.3 \cdot 10^{-3})$ mol · kg^{-1} at $T = (303.15, 308.15, 313.15, 318.15$ and $323.15)$ K respectively. The values obtained almost agreed with the reported values of Umlong *et al. and* Li *et al.* [15].

TABLE 2
Concentration dependence of density (ρ),[a] and apparent molar volumes (ϕ_v) for glycine, SDS and SDS in 0.1 m aqueous glycine solution at $T = (293.15, 298.15, 303.15, 308.15,$ and $313.15)$ K respectively.

Conc. m/mol · kg^{-1}	Density, ρ/kg m^{-3} · 10^3					Apparent molal volume, ϕ_v/m^{-3} · mol^{-1} · 10^6				
	293.15 K	298.15 K	303.15 K	308.15 K	313.15 K	293.15 K	298.15 K	303.15 K	308.15 K	313.15 K
					Glycine in water					
0.0500	0.999804	0.998625	0.997207	0.995577	0.993753	42.74	43.09	43.41	43.65	43.90
0.0999	1.001401	1.000206	0.998773	0.997132	0.995297	42.81	43.15	43.47	43.72	43.96
0.1499	1.002988	1.001777	1.000329	0.998677	0.996832	42.88	43.22	43.54	43.78	44.02
0.2001	1.004568	1.003341	1.001878	1.000216	0.998361	42.94	43.28	43.60	43.84	44.08
0.2504	1.006138	1.004896	1.003418	1.001745	0.999881	43.01	43.34	43.66	43.90	44.13
0.2999	1.007668	1.006411	1.004920	1.003237	1.001364	43.08	43.41	43.73	43.96	44.19
0.3501	1.009207	1.007935	1.006431	1.004737	1.002857	43.15	43.48	43.79	44.03	44.24
0.3998	1.010720	1.009435	1.007917	1.006209	1.004325	43.21	43.53	43.84	44.09	44.29
					SDS in water					
0.0001	0.998198	0.997034	0.995633	0.994016	0.992200	225.21	227.33	231.45	231.73	234.00
0.0003	0.998209	0.997045	0.995644	0.994026	0.992210	227.66	231.26	231.51	235.22	235.55
0.0005	0.998221	0.997057	0.995655	0.994037	0.992220	229.04	231.23	233.48	235.78	238.14
0.0020	0.998310	0.997144	0.995740	0.994120	0.992299	228.95	230.66	232.42	234.23	237.11
0.0040	0.998425	0.997255	0.995848	0.994224	0.992402	230.21	232.17	233.93	235.99	237.84
0.0060	0.998538	0.997365	0.995955	0.994327	0.992500	230.77	232.65	234.41	236.56	238.76
0.0080	0.998647	0.997472	0.996058	0.994429	0.992601	231.55	233.27	235.16	236.98	238.84
0.0100	0.998750	0.997569	0.996155	0.994524	0.992696	232.42	234.45	236.02	237.74	239.31
0.0120	0.998851	0.997670	0.996252	0.994619	0.992789	233.51	235.23	236.92	238.57	240.10
0.0140	0.998949	0.997768	0.996348	0.994715	0.992884	234.42	235.92	237.55	239.01	240.45
0.0160	0.999048	0.997867	0.996441	0.994806	0.992975	234.95	236.30	238.14	239.58	240.88
0.0180	0.999145	0.997957	0.996536	0.994898	0.993061	235.54	237.15	238.53	240.02	241.56
0.0200	0.999237	0.998048	0.996624	0.994988	0.993153	236.16	237.69	239.11	240.39	241.70
0.0220	0.999338	0.998142	0.996718	0.995076	0.993239	236.29	238.02	239.34	240.80	242.13
0.0240	0.999426	0.998232	0.996807	0.995164	0.993323	236.94	238.46	239.74	241.15	242.57
					SDS in 0.1 m aqueous glycine solution					
0.0001	1.001392	1.000197	0.998767	0.997125	0.995289	115.38	86.48	86.31	124.80	115.02
0.0003	1.001409	1.000212	0.998782	0.997142	0.995306	169.54	166.21	166.27	173.17	169.85
0.0005	1.001417	1.000221	0.998789	0.997149	0.995316	202.57	198.73	202.88	207.08	199.26
0.0020	1.001496	1.000296	0.998862	0.997218	0.995381	227.45	228.65	230.88	234.17	234.50
0.0040	1.001646	1.000441	0.999003	0.997357	0.995516	220.19	222.12	224.35	226.62	227.93
0.0060	1.001757	1.000551	0.999110	0.997458	0.995615	224.42	225.94	228.01	230.63	231.95
0.0080	1.001876	1.000665	0.999221	0.997567	0.995722	225.08	226.90	228.90	231.20	232.54
0.0100	1.001968	1.000756	0.999311	0.997658	0.995811	228.63	230.23	231.99	233.78	235.12
0.0120	1.002046	1.000835	0.999389	0.997737	0.995887	231.97	233.30	234.86	236.34	237.77
0.0140	1.002150	1.000936	0.999488	0.997834	0.995983	232.49	233.85	235.40	236.85	238.20
0.0160	1.002252	1.001036	0.999586	0.997930	0.996075	233.06	234.40	235.92	237.35	238.83
0.0179	1.002350	1.001130	0.999679	0.998019	0.996164	233.50	234.94	236.38	237.92	239.28
0.0200	1.002451	1.001228	0.999772	0.998112	0.996253	233.99	235.46	237.03	238.45	239.91
0.0220	1.002547	1.001321	0.999865	0.998200	0.996342	234.56	236.06	237.51	239.05	240.37
0.0240	1.002642	1.001413	0.999951	0.998286	0.996424	235.02	236.53	238.14	239.58	240.99

The experimental pressure is 101.33 kPa.
[a] Standard uncertainty σ are $\sigma(T) = \pm 0.001$ K; $\sigma(m) = \pm 0.0001$ mol · kg^{-1}; $\sigma(\rho) = 1 \cdot 10^{-3}$ kg · m^{-3}.