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Volumetric Studies of Alanine in the Pre-Micellar Regions of Sodium Dodecyl Sulphate (SDS) in Aqueous Solution

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ABSTRACT

Interactions between amino acid (alanine) and surfactant (Sodium dodecyl sulphate) was investigated using density and density data was utilized to calculate apparent molar volume (ϕ_v), and partial molar volume also known as limiting molar volume (ϕ^0_v) to find out solute- solvent interactions between amino acid and surfactant.

Key words: Amino acids, Surfactant, Biomolecules, Solute-solvent interaction, Aqueous medium.

INTRODUCTION

Surfactants are surface-active agents that promote wetting by reducing the surface tension of liquids and decreasing the interfacial tension between immiscible phases [1–7]. The term *surfactant* was first introduced in 1950 by Antara Products. Owing to their versatility, surfactants are among the most widely used materials in the chemical industry and are present in numerous applications, including automotive lubricants, pharmaceutical formulations, household and laundry detergents, drilling fluids for petroleum exploration, and flotation agents in mineral processing. In aqueous systems, surfactant molecules typically consist of a hydrophilic head group and a hydrophobic tail [8-13]. Amino acid are the building blocks of proteins [14-16]. Alanine is an essential amino acid and a fundamental building block of proteins. It is commonly found in protein-rich foods and is associated with improved alertness, mood, and cognitive function [17-19]. Knowledge of the thermodynamic and transport properties of amino acids in aqueous media mainly in surfactant solution [20-27], is crucial for the design and optimization of existing and emerging industrial bioprocesses. However, experimental data on the thermodynamic behavior of amino acids in aqueous surfactant solutions are limited and only a few volumetric studies on alanine in aqueous systems have been reported. In this context, the present work reports density (ρ) measurements of alanine at molalities of 0.00, 0.02, 0.04, 0.06, and 0.08 m in 0.0002 m (mol.kg^{-1}) aqueous sodium dodecyl sulfate (SDS). The obtained results were analyzed to elucidate solute–solute and solute–solvent interactions. The experimentally measured values of density, of 0.02, 0.04, 0.06 and 0.08 m, alanine in 0.0002 m aqueous SDS at 298.15, 303.15,

308.15, and 313.15K are given in the table 1.

Volumetric Study

Volumetric property has been regarded as a sensitive tool to probe molecular interactions in solutions [28-31]. The density data is required for the determination of volumetric properties. Density measurements have been carried out by using single stem pycnometer. Apparent molar volume, ϕ_v, of amino acids were calculated from the solution densities, ρ, using the relation,

$$\phi_v = \frac{M}{\rho} - \frac{1000(\rho-\rho_0)}{m\rho\rho_0} \qquad (1)$$

Where m is the molality of solute (amino acid) having molar mass, M and ρ_0 is the density of solvent. Apparent molar volume is an elegant tool to elucidate the ion – ion, ion – solvent and solvent - solvent interactions. This information is of fundamental importance for understanding the reaction rates equilibria involving dissolved electrolytes.

The calculated apparent molar volume data was utilized for the computation of apparent molar volume at infinite dilution, ϕ^0_v. In case of negligible concentration dependence of ϕ_v, ϕ^0_v was determined by taking the average of all the data points. However, where finite concentration dependence was observed, ϕ_v, were evaluated by least – squares fitting of the data into the equation as follows

$$\phi_v = \phi^0_v + S^*_v m \qquad (2)$$

where S^*_v is the experimental slope. As $m \to 0$, $\phi_v \approx \phi^0_v$ The partial molar volume reflects the true volume of the solute and the volume change arising from the solute – solvent interactions. While, S^*_v gives quantitative estimates of solute – solute interactions and sometimes also considered as volumetric pair wise interaction coefficient.

To study surfactant solutions in monomeric form, the well - known equations of Redlich and Rosenfeld [32] were applied. At a given concentration the apparent molar volumes may be described in the premicellar region by the equation

$$\phi_v = \phi^0_v + A_v\, m^{1/2} + B_v m \qquad (3)$$

where A_v is the Debye-Hückel limiting law coefficient and the values for the 1:1 electrolytes are 1.868, 1.955, 2.046 and 2.138 $cm^3\ kg^{1/2}\ mol^{-3/2}$ at 298.15, 303.15, 308.15 and 313.15 K respectively, and B_v is an adjustable parameter related to a pair of interaction and is equivalent to the second viral coefficient, which measures the deviation from the limiting law due to non - electrostatic solute - solute interactions. This coefficient is usually negative except for hydrogen - bonding interactions.

Table 1. Values of density, ρ, of alanine in 0.0002m aqueous SDS at different temperatures.

m (mol kg^{-1})	T (K)			
	298.15	303.15	308.15	313.15
dl-phenylalanine + 0.0002 m aq. SDS				
ρ (kg m^{-3})				
0.000	1.0007	0.9999	0.9975	0.9957
0.02	1.0011	1.0005	0.9977	0.9961
0.04	1.0022	1.0011	0.9982	0.9966
0.06	1.0031	1.0023	0.9993	0.9978
0.08	1.0043	1.0033	1.0006	0.9983

Table 2. Values of apparent molar volumes of alanine in 0.0002m aqueous SDS at different temperatures.

m (mol kg^{-1})	T (K)			
	298.15	303.15	308.15	313.15
	Apparent molar volumes (10^{-5} m^3 mol^{-1})			
alanine + 0.0002 m aq. SDS				
0.015	11.1730	12.5120	13.8750	14.5670
0.020	9.0046	10.0060	11.5240	12.5450
0.025	6.9040	7.7019	9.3075	10.5220
0.030	4.8395	5.5003	6.8254	8.1644

RESULT AND DISCUSSION

It is found from the table that the value of density increases with increase in the concentration of amino acids (aniline). And value of density decreases with increase in temperature. As the critical micelle concentration of SDS [33-36] is 8.1 × 10^{-1} mol. dm^{-3}, the surfactant molecules in this study are present as monomers behaving as electrolyte in the pre-micellar region. Because of the presence of SDS which is anionic in nature, the interaction of the amino acids (alanine) and SDS is stronger enough, and also the number of hydrogen bonds between amino acid molecules and water molecules increases.

Declaration by Authors

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