Vapor Pressure of Aqueous Solutions of Polyacrylamide + Sodium Dodecyl Sulfate with and without NaOH

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The vapor pressure of aqueous solutions of sodium dodecyl sulfate (SDS) + 0.1 mass % polyacrylamide (PAM) and SDS + 0.1 mass % PAM + 0.1 M NaOH were measured at 298.15 K, 308.15 K, and 318.15 K, and the concentration of SDS (m_{SDS}) was up to 50 mmol/kg. The activity coefficient of water in the solution was calculated. The surface tension of the solutions was also determined. The results show that the effect of the solutes on the vapor pressure of water is very limited under the experimental conditions although the surface tension changes significantly with SDS concentration.

Introduction

Vapor pressure data are of great importance to some chemical processes and theoretical studies. However, measurement of the vapor pressures of systems containing surfactants and surfactant−polymer has received comparatively little attention. In a previous paper (Li et al., 1996), the vapor pressure of aqueous solution of sodium dodecyl sulfate (SDS) was measured. Recently, attention was paid to the study of the different properties of surfactant−polymer solutions because of their widespread applications in industry. In this work, the vapor pressures of the aqueous solutions of SDS + 0.1 mass % polyacrylamide (PAM) and SDS + 0.1 mass % PAM + 0.1 M NaOH were determined at different conditions.

Experimental Section

The SDS was ultrapure supplied by Bethesda Research Laboratory, and the purity was 99.5%. The PAM was obtained from Aldrich Chemical Co. with a average molecular weight of 5 000 000 (1.5 mass % acrylic acid).The NaOH was A.R. grade.

The experimental apparatus and procedures for the vapor pressure measurement were described in detail previously (Li et al., 1996; Han et al., 1993). Very briefly, the experiment was conducted in a thermostat that was maintained within ±0.02 K of the desired temperature. The vapor pressure of the solution was determined on the basis of the height difference of the two mercury levels of a U-shaped mercury manometer. An altimeter (height-measuring equipment) with a resolution of 0.01 mm was used to measure the height difference of the two mercury levels. The reliability of the apparatus was checked again by measuring the vapor pressure of pure water at 298.15 K, 308.15 K, and 318.15 K, and the maximum deviation between these data and those reported (Weast et al., 1989−1990) is ±0.2%. The maximum uncertainty of the vapor pressure data determined in this work is estimated to be ±0.3%. The surface tension was measured by drop-volume method (Tornberg, 1977). It was estimated that the accuracy of the data is better than ± 2%.

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Table 1. Surface Tension σ (mN·m^{-1}) of Aqueous Solutions of SDS + 0.1 mass % PAM at Different Temperatures

	T/K		
m_{SDS}/mmol·kg^{-1}	298.15	308.15	318.15
0.000	69.0	68.4	67.0
2.634	43.5	42.5	42.3
4.684	38.5	38.0	37.2
5.025	35.9	35.3	35.0
5.501	35.3	35.3	35.2
5.613	36.0	35.1	34.8
5.924	35.9	35.5	35.3
6.968	36.5	35.2	35.1
9.045	36.0	35.4	35.0
10.90	37.5	37.1	37.8
13.27	39.0	37.8	38.6
15.51	39.3	38.6	38.7
16.37	39.2	38.0	36.9
17.48	36.4	37.6	37.8
17.90	38.4	38.5	38.3
18.22	38.7	38.6	38.5
21.70	37.3	36.3	36.7
26.24	37.6	36.9	36.8
34.60	37.6	36.3	33.8
42.99	35.4	36.3	32.5

DT-100 and Mettler MP1200 balances were used to determine the mass of the solid chemicals and the solutions, respectively, and their sensitivities were respectively 0.000 05 and 0.001 g. It is certain that for all the solutions the accuracy in the reported concentrations is better than ±0.1%.

Results and Discussions

The vapor pressure and surface tension of the aqueous solutions of sodium dodecyl sulfate (SDS) + 0.1 mass % polyacrylamide (PAM) and SDS + 0.1 mass % PAM + 0.1 M NaOH are listed in Tables 1−4, and Figures 1−4 show the dependence of the surface tension and vapor pressure on temperature and the concentration of SDS.

The activity coefficient of water, γ_1, can be calculated from the vapor pressure using the following equation

$$\gamma_1 = P_1/(P_1^0 x_1) \quad (1)$$

where P_1^0 and P_1 stand, respectively, for the vapor pressure

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Table 2. Surface Tension σ (mN·m^{-1}) of Aqueous Solutions of SDS + 0.1 mass % PAM + 0.1 M NaOH at Different Temperatures

	T/K		
m_{SDS}/mmol·kg^{-1}	298.15	308.15	318.15
0.000	68.9	68.0	66.6
2.179	36.0	36.0	35.6
4.653	35.4	34.9	34.6
5.025	35.2	35.0	34.8
5.545	35.4	34.9	34.7
6.135	34.7	34.4	34.3
6.476	34.7	34.2	34.2
7.140	35.6	34.9	34.7
8.689	35.3	34.8	34.6
10.35	35.1	34.4	34.3
13.23	34.9	34.6	34.0
17.60	35.3	34.3	33.8
21.80	34.7	34.6	34.6
25.91	35.1	34.7	34.9
28.70	35.2	34.8	34.7
29.42	35.3	35.2	35.1
30.17	34.0	33.9	33.6
30.33	34.8	34.6	34.5
31.40	34.8	34.5	34.4
34.87	34.7	34.5	34.4
43.24	34.9	35.2	34.0
51.57	34.1	34.1	33.9

Table 3. Vapor Pressure of the SDS + 0.1 mass % PAM + Water System and the Activity Coefficient of Water γ_1

	T = 298.15 K		T = 308.15 K		T = 318.15 K	
m_{SDS}/mmol·kg^{-1}	P/kPa	γ_1	P/kPa	γ_1	P/kPa	γ_1
0.000	3.049	1.008	5.520	1.003	9.373	0.989
1.521	2.993	0.989	5.504	1.000	9.350	0.987
3.723	2.939	0.972	5.499	0.999	9.333	0.985
5.118	2.956	0.977	5.533	1.005	9.291	0.980
5.749	3.069	1.014	5.563	1.011	9.294	0.981
6.509	2.939	0.972	5.440	0.988	9.289	0.980
9.359	2.924	0.967	5.399	0.979	9.290	0.980
14.86	2.981	0.986	5.483	0.996	9.367	0.988
18.39	2.949	0.975	5.427	0.986	9.312	0.983
24.43	2.903	0.960	5.326	0.968	9.271	0.978
28.02	2.820	0.932	5.311	0.965	9.227	0.974
36.24	2.772	0.916	5.388	0.979	9.239	0.975
45.60	2.743	0.907	5.330	0.968	9.267	0.978

Table 4. Vapor Pressure of the SDS + 0.1 mass % PAM + 0.1 M NaOH + Water System and the Activity Coefficient of Water γ_1

	T = 298.15 K		T = 308. K		T = 318.15 K	
m_{SDS}/mmol·kg^{-1}	P/kPa	γ_1	P/kPa	γ_1	P/kPa	γ_1
0.000	2.869	0.949	5.485	0.997	9.308	0.982
1.665	2.898	0.958	5.471	0.994	9.263	0.977
3.879	2.875	0.950	5.445	0.990	9.330	0.984
4.836	2.898	0.958	5.464	0.993	9.374	0.989
5.344	2.976	0.984	5.438	0.988	9.450	0.997
6.943	3.075	1.017	5.536	1.006	9.482	1.000
7.464	2.968	0.981	5.512	1.002	9.458	0.998
9.000	2.863	0.947	5.435	0.988	9.423	0.994
13.51	2.867	0.948	5.485	0.997	9.401	0.992
18.30	2.861	0.946	5.494	0.999	9.407	0.992
22.48	2.879	0.952	5.526	1.004	9.394	0.991
27.29	2.861	0.946	5.475	0.995	9.329	0.984
30.97	2.874	0.961	5.484	0.997	9.320	0.983
37.22	2.884	0.953	5.458	0.992	9.325	0.984
46.93	2.879	0.952	5.467	0.994	9.337	0.985
53.86	2.890	0.956	5.438	0.992	9.331	0.984

of pure water and the partial pressure of water. x_1 is the mole fraction of water. The vapor pressures of SDS and PAM are extremely low under the experimental conditions. Thus, it can be assumed that the total vapor pressure of a solution is equal to the partial pressure of water. The calculated activity coefficients of water in these systems are also listed in Tables 3 and 4.

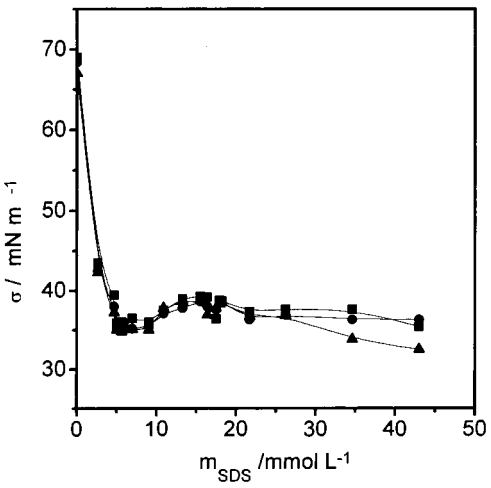

Figure 1. Surface tension of SDS + 0.1 mass % PAM solution: −■−, 298.15 K; −●−, 308.15 K; −▲−, 318.15 K.

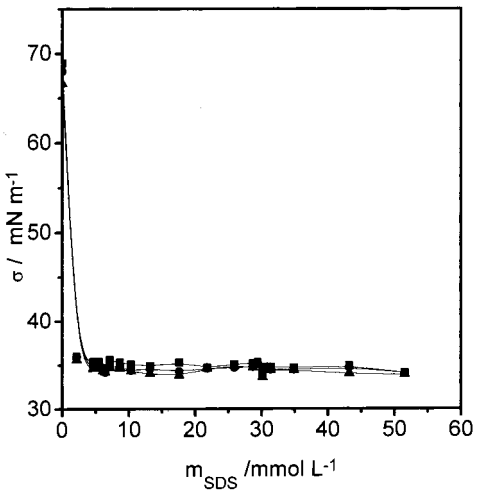

Figure 2. Surface tension of SDS + 0.1 mass % PAM + 0.1 M NaOH solution: −■−, 298.15 K; −●−, 308.15 K; −▲−, 318.15 K.

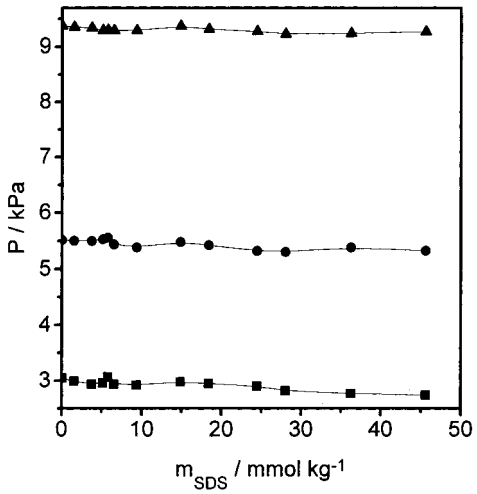

Figure 3. Vapor pressure of SDS + 0.1 mass % PAM solution: −■−, 298.15 K; −●−, 308.15 K; −▲−, 318.15 K.

Surface Tension. Each surface tension vs m_{SDS} curve exhibits two break points, as shown in Figures 1 and 2. The surface tensions of a number of surfactant−polymer solutions have been determined by other authors (Bahadur

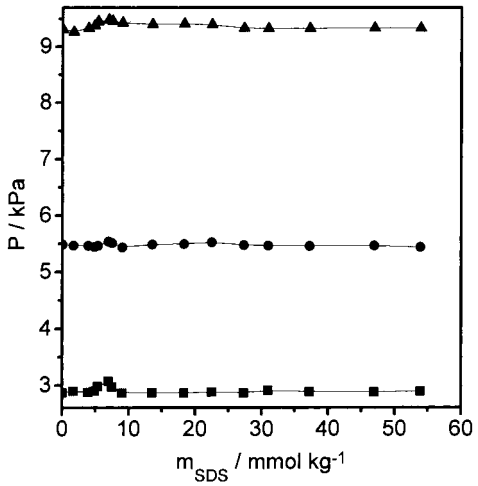

Figure 4. Vapor pressure of SDS + 0.1 mass % PAM + 0.1 M NaOH solution: −■−, 298.15 K; −●−, 308.15 K; −▲−, 318.15 K.

et al., 1995; Minatti and Zanette, 1996; Jones, 1967), and the break points were also found. The authors pointed out that the first break point corresponds to the critical aggregation concentration (CAC) where the micelles bound to PAM begin to form. The second point is the polymer saturation point (PSP), where the polymer chains are saturated by surfactant and the ordinary free micelles are formed. It can be concluded that the break point at lower SDS concentration and that at higher SDS concentration are the CAC and PSP, respectively.

Vapor Pressure. From the data in Tables 3 and 4 or Figures 3 and 4, it can be concluded that the effect of the solutes (SDS, PAM, and NaOH) on the vapor pressure of water is not significant under the experimental conditions, and as expected, the vapor pressure increases with temperature.

There is also a break point at the CAC in each vapor pressure curve, as can be known from Figures 3 and 4. However, the break point at the PSP is not obvious.

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