Surface Tension of Aqueous Solutions of Sodium Dodecyl Sulfate from 20 °C to 50 °C and pH between 4 and 12

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The surface tension of aqueous solutions of sodium dodecyl sulfate were measured in the range of sodium dodecyl sulfate concentration between 7.3×10^{-6} mol·L^{-1} and 1.4×10^{-4} mol·L^{-1} at temperatures of (20 °C to 50 °C) and pH values between 4 and 12.

Introduction

The study of variation in surface tension in a flotation bath, due to the presence of the surface agent and the modification of pH, is of great importance with regard to the wetting phenomenon, owing to the influence both exert on the flotability of solid particles during flotation (Somasundaran, 1975; Pugn and Stenius, 1985). Owing to their hydrophilic structure, surfactant molecules spread in solvents such as water in such a way that their concentration at the liquid−gas interface is greater than that in the bulk of the solution. At the interface, the molecules are arranged with their polar groups pointing toward the polar phase, while their nonpolar, or hydrophobic, groups point away from it. Excessive molecule adsorption at the liquid−air interface causes a gradual decrease in the solvent surface tension, which may be quite considerable, even at very low surfactant concentrations. Such surface activity depends mainly on the agent and solvent structures, as well as temperature and pH. Finally, the concentration range of the surfactant applied in this study is that generally used for the surfactant as a flotation agent (Cyanamid Co., 1989).

Experimental Section

For this research, surface tension measurements were performed using the Wilhelmy plate principle, (Hernáinz and Gálvez, 1995; Hines, 1996), considered as one of the most appropriate, since no hydrostatic correction is required as in the ring method. Measurements of surface tension were performed with a KRUSS K10 digital tensiometer, with an accuracy of ±0.1 mN·m^{-1} and a platinum plate measuring (20 × 10 × 0.1) mm

The solution whose surface tension is to be measured is placed in a thermostated flask at the temperature, using a thermostat that allows consistent temperature regulation to ±0.1 °C. In general, 11 determinations of surface tension were carried out for each case, with the average value being recorded.

The sodium dodecyl sulfate (SDS) was dissolved in Milli-Q quality distilled water; the solute supplied by Merck (with a guaranteed minimun purity of 99%) was weighed on a METTLER AJ-150 scale with an accuracy of ±0.1 mg, and the desired solution volume was obtained by successive dilutions since the concentrations of the agent used are very small. In all cases, the solutions were prepared very shortly before the experiments were carried out to avoid possible alterations in the surface agents and hence changes in their properties over time.

NaOH and HCl, supplied by Merck and Probus, respectively, were used as pH modifiers; in both cases a concentration of 4 mol·L^{-1} was used to reach the desired pH easily, and pH measurements were performed with a CRISON 2001 pH-meter.

Table 1. Surface Tension of Aqueous Solutions of Sodium Dodecyl Sulfate of Concentration *C*

		σ/mN·m^{-1}								
C/mol·L^{-1}	t/°C	pH = 4	pH = 5	pH = 6	pH = 7	pH = 8	pH = 9	pH = 10	pH = 11	pH = 12
7.3×10^{-6}	20	73.0	73.0	72.3	72.7	72.4	72.7	72.6	72.6	72.8
	25	71.9	71.8	71.4	71.2	71.7	70.8	72.0	71.3	71.5
	30	70.2	69.2	70.1	69.6	71.0	71.2	71.2	70.6	69.5
	40	68.3	67.6	69.4	67.8	69.5	68.8	69.6	69.3	67.3
	50	66.4	64.5	66.7	65.0	68.3	67.4	67.6	68.2	64.7
1.4×10^{-5}	20	69.9	69.3	70.0	71.0	70.5	72.7	71.0	72.1	71.9
	25	68.7	68.7	69.2	69.7	69.4	70.8	70.1	70.3	70.3
	30	67.2	67.7	68.5	69.0	69.3	71.0	69.5	68.6	68.2
	40	66.7	65.3	67.0	66.3	68.0	68.8	68.2	66.2	65.3
	50	65.2	64.0	64.7	64.8	66.9	66.9	66.8	64.1	63.1
4.5×10^{-5}	20	68.4	67.8	68.9	69.0	68.4	67.0	68.5	70.2	66.9
	25	67.6	67.3	68.0	68.0	67.8	66.5	67.8	68.3	64.9
	30	66.6	66.8	67.0	67.5	66.8	65.9	66.9	67.1	63.5
	40	63.6	64.3	65.6	65.6	66.1	65.4	65.7	64.8	60.5
	50	62.4	63.5	63.1	64.5	65.3	64.7	65.2	62.8	57.0
7.3×10^{-5}	20	66.8	66.9	67.5	68.5	67.4	66.4	66.9	66.9	65.8
	25	65.7	66.6	67.2	67.7	66.7	66.3	66.3	66.0	63.7
	30	64.4	66.2	66.2	66.8	66.1	65.8	66.0	65.2	62.2
	40	62.9	63.9	64.4	65.3	64.8	65.1	65.0	63.7	59.1
	50	59.6	62.8	62.3	64.3	64.1	64.5	63.7	62.2	56.4
1.4×10^{-4}	20	64.6	64.2	65.7	65.0	64.8	64.8	63.1	63.3	62.0
	25	61.5	62.8	65.2	64.9	64.4	64.7	63.0	63.0	60.1
	30	60.7	61.2	64.4	64.7	64.0	64.6	62.9	62.5	59.5
	40	58.8	58.4	62.5	64.3	63.6	64.5	62.7	62.0	57.3
	50	55.7	55.8	61.2	64.1	63.2	64.4	62.2	60.9	55.9

Results and Discussion

Surface tension for aqueous solutions of sodium dodecyl sulfate (SDS) are shown in Table 1, according to pH at temperatures ranging between 20 °C and 50 °C and at surfactant concentrations of between 7.3×10^{-6} mol·L^{-1} and 1.4×10^{-4} mol·L^{-1}. The values show that surface

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S0021-9568(98)00014-4 CCC: $15.00
Published on Web 07/15/1998

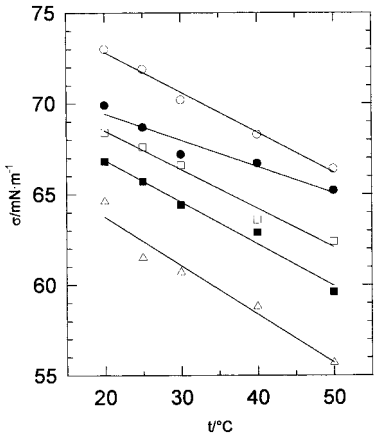

Figure 1. Surface tension of aqueous solutions of sodium dodecyl sulfate as a function of temperature at pH = 4 and different sodium dodecyl sulfate concentrations: (○) 7.3×10^{-6} mol·L^{-1}; (●) 1.4×10^{-5} mol·L^{-1}; (□) 4.5×10^{-5} mol·L^{-1}; (■) 7.3×10^{-5} mol·L^{-1}; (△) 1.4×10^{-4} mol·L^{-1}.

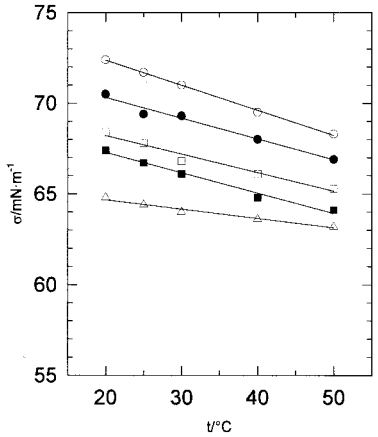

Figure 2. Surface tension of aqueous solutions of sodium dodecyl sulfate as a function of temperature at pH = 8 and different sodium dodecyl sulfate concentrations: (○) 7.3×10^{-6} mol·L^{-1}; (●) 1.4×10^{-5} mol·L^{-1}; (□) 4.5×10^{-5} mol·L^{-1}; (■) 7.3×10^{-5} mol·L^{-1}; (△) 1.4×10^{-4} mol·L^{-1}.

tension varies very slightly when the pH in the medium is modified, with the most marked effect occurring as the concentration of the surfactant is increased, especially at high temperatures and at either end of the pH interval studied. Thus, when temperature is raised from 20 °C to 50 °C, at an SDS concentration of 1.4×10^{-4} mol·L^{-1} and pH = 4, the surface tension varies from 64.6 to 55.7 mN·m^{-1}. At pH = 12, surface tension values fall from 62.0 to 55.9 mN·m^{-1}.

The surface tension of binary mixtures were correlated with temperature by the following expression (Jasper, 1972), proposed for pure components. This equation has been used on similar systems to the this work (Álvarez et al., 1997; Vázquez et al., 1997).

$$\sigma/\mathrm{mN\cdot m^{-1}} = K_1 - K_2 t/°\mathrm{C} \qquad (1)$$

The data of Table 1 are also fitted for each concentration, with a maximun absolute deviation of less than ±1.5% and average absolute deviation of ±0.3%. Figures 1 to 3 show the results as an example. The fitted values of K_1 and K_2

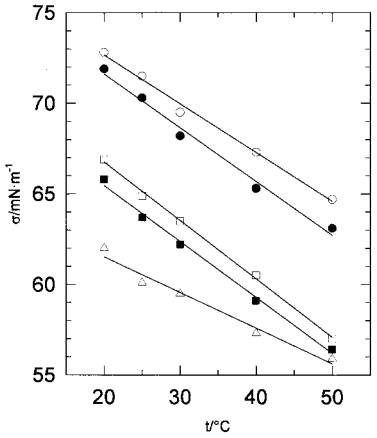

Figure 3. Surface tension of aqueous solutions of sodium dodecyl sulfate as a function of temperature at pH = 12 and different sodium dodecyl sulfate concentrations: (○) 7.3×10^{-6} mol·L^{-1}; (●) 1.4×10^{-5} mol·L^{-1}; (□) 4.5×10^{-5} mol·L^{-1}; (■) 7.3×10^{-5} mol·L^{-1}; (△) 1.4×10^{-4} mol·L^{-1}.

Table 2. Surface Tension Parameters K_1 and K_2 (Eq 1) for Aqueous Solutions of Sodium Dodecyl Sulfate (SDS)

	C/mol·L^{-1}									
	7.3×10^{-6}		1.4×10^{-5}		4.5×10^{-5}		7.3×10^{-5}		1.4×10^{-4}	
pH	K_1	$-K_2 \cdot 10^2$	K_1	$-K_2 \cdot 10^2$	K_1	$-K_2 \cdot 10^2$	K_1	$-K_2 \cdot 10^2$	K_1	$-K_2 \cdot 10^2$
4	77.24	22.05	72.35	14.59	72.76	21.34	71.49	23.05	69.1	26.79
5	78.40	27.81	73.17	18.71	71.09	15.62	70.18	14.86	69.77	28.14
6	75.77	17.53	73.58	17.28	72.71	18.76	71.43	17.90	68.98	15.69
7	77.45	24.81	75.10	21.02	71.92	15.14	71.20	14.19	65.65	3.19
8	75.14	13.83	72.59	11.43	70.25	10.21	69.51	11.17	65.71	5.17
9	75.74	16.84	76.05	18.21	68.35	7.41	67.83	6.69	65.03	1.29
10	76.12	16.72	73.63	13.67	70.54	11.26	69.01	10.38	63.73	2.88
11	75.04	14.05	76.93	26.28	74.55	23.98	69.92	15.52	64.91	7.78
12	78.03	26.88	77.54	29.64	73.19	32.22	71.63	30.88	65.44	19.64

are listed in Table 2. The results obtained show that SDS concentration greatly influences the relationship between surface tension and temperature.

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Received for review January 20, 1998. Accepted May 15, 1998.

JE9800149