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Surface Tension of Aqueous Solutions of Sodium 1-Dodecanesulfonate from 20 °C to 50 °C and pH between 4 and 12

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The surface tension of aqueous solutions of sodium 1-dodecanesulfonate were measured in the range of sodium 1-dodecanesulfonate concentration between 7.3×10^{-6} mol·L^{-1} and 6.2×10^{-4} mol·L^{-1} at temperature (20 °C to 50 °C) and pH between 4 and 12.

Introduction

Surface tension in aqueous solutions of surfactants is a property of vital importance to the design of flotation equiment, given that it affects the wetting phenomena largely responsible for the flotation of solids (Hernáinz and Gálvez, 1995). The modification of surface tension in surfactant solutions has been examined more systematically over the past two decades, with greater attention being given to reagent purity (Motomura et al., 1981; Mysels, 1986; Hines, 1996). Currently, the development of new surfactants for use in flotation technique operations has opened up new horizons for further applications. Along these lines, sodium 1-dodecanesulfonate has recently been used as a collector agent in flotation concentration operations (Hernáinz et al., 1997).

This paper studies the modification of surface tension of aqueous sodium 1-dodecanesulfonate solutions, with varying temperature, pH, and concentration within the ranges generally used for flotation reagents (Cyanamid Co., 1989).

Experimental Section

Surface tension measurements were performed using the Wilhelmy plate principle (Hines, 1996; Hernáinz et al., 1998), considered as one of the most appropriate, since no hydrostatic correction are required as in the ring method. Measurements of surface tension were performed with a KRUSS K10 digital tensiometer, with a platinum plate measuring (20 × 10 × 0.1) mm. The accuracy was ±0.1 mN·m^{-1}.

Solutions were placed in a thermostated flask at the requered temperature, obtained using a thermostat that allowed consistent temperature regulation to ±0.1 °C. In general, 10 determinations of surface tension were carried out for each solution, with the average value being recorded.

Table 1. Surface Tension, σ/mN·m^{-1}, of Aqueous Solutions of Sodium 1-Dodecanesulfonate

		pH								
c/mol·L^{-1}	t/°C	4	5	6	7	8	9	10	11	12
7.3×10^{-6}	20	72.2	72.2	72.1	71.8	71.6	71.5	71.3	71.1	71.0
	25	71.7	71.6	71.2	71.0	70.5	70.4	70.0	69.8	69.2
	30	71.1	71.0	70.7	70.1	69.8	69.8	68.8	68.6	68.4
	40	69.7	69.5	69.2	68.7	67.5	67.3	66.7	66.0	66.2
	50	68.5	68.3	68.2	67.4	65.8	65.7	64.2	64.0	63.3
1.4×10^{-5}	20	71.4	71.9	71.0	70.8	70.8	69.2	69.0	68.8	69.4
	25	70.8	71.3	70.4	70.2	69.6	68.4	68.2	68.1	68.4
	30	70.3	70.6	69.8	69.4	68.8	67.6	67.4	67.1	67.4
	40	69.5	69.1	68.4	68.0	66.6	66.1	65.8	65.7	65.2
	50	68.0	67.8	67.1	66.4	65.0	64.8	64.0	63.8	63.1
4.5×10^{-5}	20	70.4	70.8	69.3	69.0	69.4	68.8	67.8	68.7	68.1
	25	69.9	70.1	68.5	68.2	68.2	67.8	66.9	67.7	66.6
	30	69.4	69.5	67.8	67.3	67.1	67.1	66.3	66.9	65.4
	40	68.6	67.9	66.2	65.7	65.2	65.2	64.7	65.1	63.7
	50	67.6	66.4	64.5	64.0	63.3	63.3	63.1	63.5	61.0
7.3×10^{-5}	20	69.0	69.5	68.6	68.3	67.9	67.8	67.2	67.5	66.8
	25	68.3	68.8	67.8	67.4	67.1	66.8	66.4	66.9	65.3
	30	67.7	68.0	67.2	66.5	66.1	65.8	65.8	65.9	64.3
	40	66.5	66.3	65.5	65.1	64.5	64.2	64.0	64.2	62.5
	50	65.1	64.4	63.9	63.4	62.7	62.4	62.2	61.9	60.4
1.4×10^{-4}	20	67.5	67.9	68.0	67.5	66.9	66.6	66.6	66.2	66.0
	25	66.8	67.0	67.2	66.7	66.0	65.8	66.1	65.5	64.6
	30	65.7	65.8	66.5	65.6	65.3	65.0	65.0	64.8	63.2
	40	64.1	63.8	64.9	64.3	63.4	63.4	63.4	63.1	60.2
	50	62.2	61.3	63.2	62.4	62.0	62.0	61.8	61.1	57.8
6.2×10^{-4}	20	66.1	66.2	66.1	66.5	66.2	65.4	65.4	64.5	58.5
	25	65.4	64.9	65.0	65.7	65.4	65.0	64.8	63.8	56.8
	30	64.3	63.8	64.3	64.8	64.6	64.1	64.1	62.9	55.5
	40	62.7	61.9	62.6	63.2	62.8	62.3	62.2	61.4	53.4
	50	60.8	59.6	61.2	61.5	61.4	61.0	60.9	60.0	51.1

The sodium 1-dodecanesulfonate was dissolved in milli-Q quality distilled water, the solute supplied by Merck (with a guaranteed minimun purity of 99%, solubility in water of 9.3×10^{-3} mol·L^{-1} and cmc of 7×10^{-3} mol·L^{-1}, obtained experimentally) was weighed on a METTLER AJ-150 balance 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 before the experiments were carried out to avoid possible alterations in the surface agents and hence changes in their properties over time. Surface tension was measured 15 min after the preparation of the solutions, thus ensuring that values obtained for surface tension were steady-state values, in accordance with Loznetsova et al. (1980) and Hynes (1996).

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 and pH measurements were performed with a CRISON 2001 pH-meter.

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Table 2. Surface Tension Parameters K_1 and K_2 (Eq 1) for Aqueous Solutions of Sodium 1-Dodecanesulfonate

	c/mol·L^{-1}											
	7.3×10^{-6}		1.4×10^{-5}		4.5×10^{-5}		7.3×10^{-5}		1.4×10^{-4}		6.2×10^{-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	$-K_2 \cdot 10^2$	K_1	$-K_2 \cdot 10^2$
4	74.80	12.60	73.35	10.00	72.21	9.17	71.55	12.81	71.11	17.74	69.71	17.74
5	74.89	13.24	74.73	13.90	73.81	14.76	73.03	17.07	72.41	21.97	70.37	21.49
6	74.56	12.97	73.67	13.12	72.52	15.93	71.78	15.69	71.22	15.93	69.17	16.14
7	74.64	14.66	73.82	14.72	72.34	16.66	71.44	16.05	70.82	16.72	69.84	16.66
8	75.48	19.50	74.56	19.38	73.27	20.10	71.37	17.31	70.17	16.52	69.44	16.24
9	75.43	19.67	72.07	14.71	72.45	18.20	71.26	17.76	69.65	15.41	68.65	15.41
10	75.88	23.28	72.35	16.59	70.89	15.50	70.63	16.69	70.00	16.41	68.61	15.55
11	75.78	23.88	72.16	16.55	72.08	17.28	71.46	18.74	69.75	17.00	67.52	15.14
12	75.72	24.53	73.67	21.12	72.44	22.66	70.65	20.59	71.49	27.65	62.96	23.95

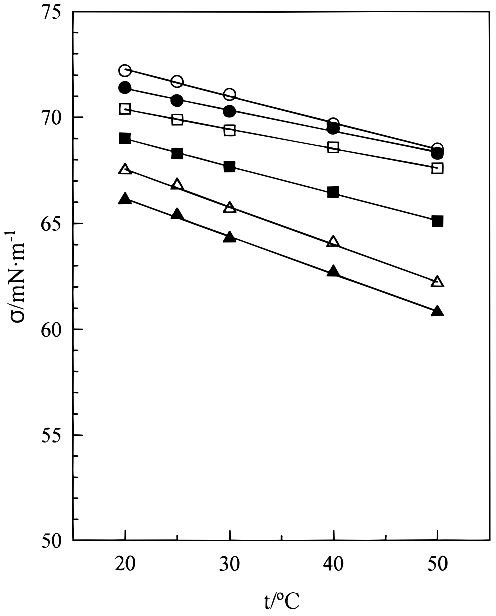

Figure 1. Surface tension of aqueous solutions of sodium 1-dodecanesulfonate as a function of temperature at pH = 4 and different sodium 1-dodecanesulfonate concentration: (○) 7.3×10^{-6} mol·L^{-1}; (●) 1.4×10^{-5} mol·L^{-1}; (□) 4.5×10^{-5} mol·L^{-1}; (■) 7.3×10^{-5} mol·L^{-1}; (△) 1.4×10^{-4} mol·L^{-1}; (▲) 6.2×10^{-4} mol·L^{-1}.

Results and Discussion

Surface tension for aqueous solutions of sodium 1-dodecanesulfonate are shown in Table 1, as a function of pH at temperatures ranging between 20 °C and 50 °C and at surfactant concentrations of between 7.3×10^{-6} mol·L^{-1} and 6.2×10^{-4} mol·L^{-1}. The values show that surface tension varied slightly when the pH in the medium was modified, with the most marked effect occurring as the concentration of the surfactant was increased, especially at high temperatures and at either end of the pH interval studied. Thus, when the temperature was raised from 20 °C to 50 °C, at a sodium 1-dodecanesulfonate concentration of 6.2×10^{-4} mol·L^{-1} and pH = 4, the surface tension varies from 71.0 to 63.3 mN·m^{-1}. At pH = 12, surface tension values fall from 58.5 to 51.1 mN·m^{-1}. The increase in concentration of the surfactant assayed reduces the surface tension of the aqueous solutions, regardless of temperature and pH. This finding may give rise to a decrease in the wetting ability of certain solid bodies in these solutions, which in turn would lead to the possibility of their flotation.

The surface tensions 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 (Álvarez et al., 1997; Vázquez et al., 1997; Hernáinz et al., 1998).

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

Equation 1 also fit the data of Table 1, with a maximun absolute deviation of less than ±0.6%, and average absolute deviation of ±0.2%. Figure 1 is shown as an example. The values of K_1 and K_2 are listed in Table 2. The results show that the concentration of sodium 1-dodecanesulfonate greatly influences the relationship between surface tension and temperature.

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