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The effect of temperature on the interfacial tension between crude oil and gemini surfactant solution

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ABSTRACT

The effect of temperature on the interfacial tension between gemini surfactant solution and crude oil is investigated in this paper. The interfacial tension is measured by the spinning drop interfacial tensionmeter of Texas-500c. For surfactants 14-4-14 and 16-4-16, the interfacial tensions are very sensitive to temperature and undergo minima with the increase of the temperature. Temperature has also an effect on the dynamic interfacial tension, i.e. increasing the temperature can shorten the time needed for an interfacial tension to reach equilibrium. However, for a mixing surfactant system, the effect of temperature on the interfacial tension between oil and surfactant solution is not remarkable because of synergism.

1. Introduction

Gemini surfactants are presently attracting considerable interest in the academic and industrial communities working on surfactants for their essential properties of very low critical micelle concentration and high efficiency in reducing the surface tension of water compared with conventional single-chain surfactants [1–5]. Although a large amount of studies on the aqueous solution of gemini surfactant have been reported, the research of liquid–liquid interface properties influenced by gemini surfactant is relatively few [6]. For an oil/water system, the interfacial tension is determined by the natures of the surfactant and oil, concentration, and other environmental factors, such as electrolyte, temperature, or additives [7–10]. In a given surfactant and oil system, temperature is an important factor influencing the interface property of an oil/water system. So in this paper, two gemini surfactants, the butyl-α, ω-bis(tetradecyldimethylammonium bromide) and the butyl-α, ω-bis(hexadecyldimethylammonium bromide), referred to below as 14-4-14 and 16-4-16, are prepared, and the effects of temperature on the interfacial tension between gemini surfactant solution and crude oil have been investigated.

2. Materials and methods

2.1. Materials

Gemini surfactants investigated in this study were synthesized according to procedures previously reported in the literature [11]. The purification of the gemini surfactant is essential, particularly in the study of its interface property, as the surface tension is very sensitive to the impurity of samples. If there is a very little impurity in the surfactant solution, a minimum value of surface tension will appear at the vicinity of the critical micelle concentration (cmc) in the plot of surface tension *vs.* surfactant concentration. Based on this phenomenon, the surface tension method can be used for the purification of samples and the absence of a minimum is sometimes taken as an indication of the purity of a surfactant. The samples used in this paper were carefully purified by recrystallization of the products in the mixture of ethyl acetate and chloroform for several times until a minimum in the surface tension–concentration curve was no longer observed.

Gemini surfactant solution is prepared by weighing the surfactant in doubly distilled water and stirred using a magnetic stirrer at a temperature above its Krafft temperature (T_K) until the compound totally dissolved into the solvent, and then cooled to room temperature.

The crude oil used in this study is obtained from the Shengli oil field of China, which have been dehydrated and the density

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of the oil is 0.85 g cm^{-3}, and is used without further disposal.

2.2. Methods

The surface tension of gemini surfactant solution and the interfacial tension between oil and gemini surfactant solution are measured by the spinning drop interfacial tension-meter of Texas-500c, which has a wide range of measurement, 10^{-5} mN m^{-1} to 10^{2} mN m^{-1}. Experiments are carried out with special care to avoid water evaporation.

3. Results and discussion

The surface tension or the interfacial tension of a surfactant system is greatly related to the adsorption of the surfactant at the interface. There are many factors that will affect the adsorption of the surfactant, such as the nature of the surfactant, ionic strength of the solution, temperature, and so on [12,13]. In this study, the effect of temperature on the interfacial properties of gemini surfactant solution is primarily investigated.

The surface/interfacial tension *vs.* gemini surfactant concentration plots for 14-4-14 and 16-4-16 are illustrated in Figs. 1 and 2. These experiments are carried out at a temperature of 35 °C, which is higher than the T_K of both 14-4-14 and 16-4-16 [1]. It can be seen that gemini surfactant is very efficient in decreasing the surface tension of water or interfacial tension of oil and water. In both Figs. 1 and 2, there are no minimum values of tension at the vicinity of their cmc's, which shows that the surfactant samples used in this paper have been well purified. However, the cmc's determined by interfacial tension method is larger than what determined by surface tension method, which may probably be that some polarity material contained in oil phase affect the results of cmc's.

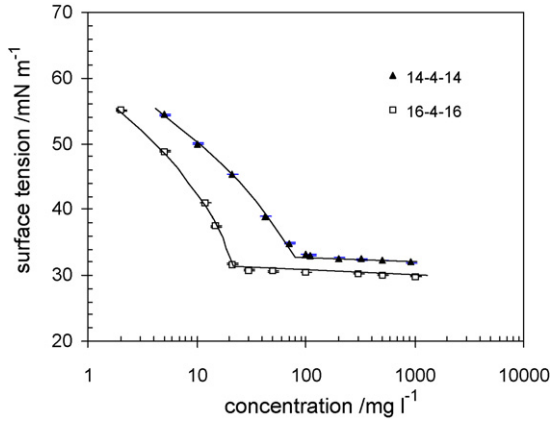

Fig. 1. The surface tension as a function of surfactant concentration, at 35 °C.

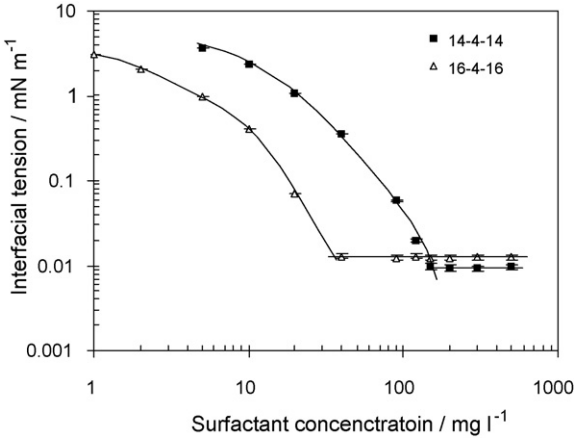

Fig. 2. The interfacial tension as function of surfactant concentration, at 35 °C.

3.1. The equilibrium interfacial tension

It is well known that the surface tension of a pure liquid decreases nearly linearly with temperature, so temperature is a chief factor affecting the surface tension between air and liquid. For a liquid–liquid interface, temperature is also an important factor that affects the interfacial tension between oil and solution [14].

The plot of the interfacial tension between oil and solution against temperature is illustrated in Fig. 3. In this experiment, the concentration of the surfactant is 1 g l^{-1} and the temperature is ranging between 30 °C and 80 °C. The effect of temperature on the interfacial tension between pure water and crude oil is also investigated. From Fig. 3, it can be seen that in the case without additives the gemini surfactant 14-4-14 or 16-4-16 can reduce the interfacial tension between crude oil and solution to an ultralow interfacial tension, however, the interfacial tensions are very sensitive to the temperature and undergo minima with the increase of temperature. The minimal values appear almost at a same temperature for two gemini surfactants investigated in this paper, which is approximate 70 °C. When the temperature is below 70 °C, the interfacial tension decreases with the increase of temperature until the temperature reaches 70 °C, and then the interfacial tension increases by increasing the temperature. As the surfactants have been well purified before experiment, so the minimum of interfacial tension between crude oil and solution caused by the impurities of sample can be excluded and the phenomenon should be attributed to other factors. However, in pure water, the interfacial tension decreases linearly with temperature, which means that increasing temperature modifies the mutual solubility of the solvents (oil and water) and favors the reduction of interfacial tension.

It is also found that the oil/water interfacial tension passing through a minimum by increasing the temperature when studying the interfacial tension between oil and sugar surfactants (decyl β-D-glucoside)[15], in much the same way as for this system with gemini surfactant. It was considered that the phenomenon was attributed to the variation of the distribution of the surfactants between oil and water and the emulsions inverting from oil-in-water (at low temperature) to water-in-oil with the increasing of

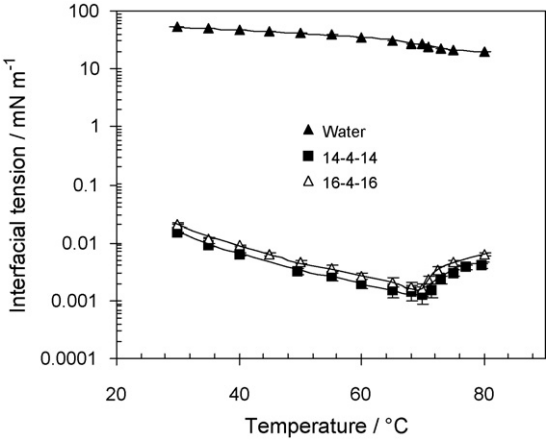

Fig. 3. The interfacial tension as function of temperature, the concentration of 14-4-14 or 16-4-16 is 1 g l^{-1}.