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Enrichment of surfactant from its aqueous solution using ultrasonic atomization

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Abstract

Dilute aqueous solutions of dodecyl-benzenesulfonic acid sodium salt (DBS-Na) and polyoxyethylenenonylphenyl ethers (PON-PEs) were ultrasonically atomized. The surfactants were concentrated in collected mist droplets. The enrichment ratio increased with decreasing surfactant concentration. Depending on the surfactant's molecular weight and affinity to water, different enrichment ratio was observed in the range of low feed concentrations. For anionic surfactant, DBS-Na, the enrichment ratio was significantly improved by KCl addition and a peak appeared on the plot of the ratio against KCl concentration. Addition of NaCl or $CaCl_2 \cdot 2H_2O$ to the surfactant solution also enhanced the enrichment ratio; however, the effect was relatively small. Such behaviors of the ratio were interpreted as enhanced interfacial adsorption of the surfactant and a lack of supply of surfactant monomers from liquid bulk because of slow breaking of surfactant micelles. Time required for collecting an amount of mist was also observed. Among the three salt systems, the time for KCl system was twice as long as others. This fact suggested that the formation of smaller droplets in KCl system.

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1. Introduction

Ultrasonic atomization is a highly useful technique to produce very fine liquid particles whose diameter range is less than 10 μm. Because of growing needs for fine liquid particles in fields of combustion, humidification, medical-inhalation, ink-jet printing and materials processing, studies have been carried out from various aspects such as mechanism of droplets formation [1–3], equipments [4], correlations of droplet diameter [5,6] and so on. In most studies, thin liquid films are subjected to vibrate to convert a certain amount of liquid into a number of droplets. Under this situation, composition of liquid mist produced is unchanged from the liquid applied.

A unique application was reported on ethanol separation from ethanol–water solutions using ultrasonic atomization [7]. A 2.4 MHz oscillator was driven under a liquid depth of a few centimeters, and liquid mist was generated. They found that mist of highly concentrated in ethanol was produced from a solution cooled at 283 K, and even at ambient temperature relatively high enrichment was achieved. This fact suggests that preferential distribution of a solute to mist droplets from liquid bulk. Some possible mechanisms were suggested [7,8], however clear explanation was not presented so far. Even if the mechanism is unclear, the technique provides a concept of novel separation and a possibility of practical application has been studied [9]. Unlike distillation, much less heat is required because phase-change

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is less significant. Because of this advantage, ultrasonic atomization equipments can replace distillation columns which has been most extensively applied for separation. In addition, the method is highly potentially applied to separation of compounds readily degradable with heating.

To argue the separation mechanism of ultrasonic atomization, a simpler system was chosen and some effects of interfacial properties on surfactant enrichment behaviors were discussed in the present study. Since most of liquid particles are formed at highly disturbed gas–liquid interface, interfacial adsorption of a solute from liquid bulk should play an important role. Enrichment ratio of a surfactant is examined under various conditions such as surfactant type, its concentration and a salt addition to the surfactant solution.

2. Experimental

Three surfactants were used in the present study. One is a typical anionic surfactant, dodecyl-benzenesulfonic acid sodium salt (DBS-Na) for investigating the effect of salt addition on the concentration behaviors. Others are polyoxyethylene nonylphenylethers (PONPEs) of nonionic surfactants whose number of oxyethylene unit was 10 and 20, respectively. They are represented as PONPE10 and PONPE20, which have different molecular weights and size of hydrophilic parts. Predetermined amount of a surfactant was dissolved into deionized water to obtain a stock solution. To examine effects of salt addition to the surfactant solution, KCl, NaCl or $CaCl_2 \cdot 2H_2O$ was dissolved into the solution. Schematic diagram of the experimental setup is shown in Fig. 1. The size of atomization column was 100 mm in inner diameter and 130 mm in height. The column was made of transparent acrylic resin. A 2.4 MHz ultrasonic oscillator (HM-2412, Honda electronics Co. Ltd., Japan) whose diameter was 18 mm was mounted at the bottom of the column. Applied power to the oscillator was DC 12 W. Feed solution was circulated between the column and a reservoir through a cooler whose temperature was kept at 295 ± 1 K. Liquid temperature in the column was monitored with a thermometer and the temperature was kept constant using the cooler. Total amount of the solution was 600 and 200 cm^3 of the solution was kept inside the column under ultrasonic irradiation. Generated mist was collected at the outlet of a tube mounted at the column wall. Time for collecting a predetermined amount of the mist was observed. Surfactant concentration was determined from absorption at 261 nm by UV spectrophotometer (UV-1600 Shimadzu Co. Ltd., Japan). Surface tension of the solution was measured with Wilhelmy method by use of a surface tension meter (CBVP-A3, Kyowa Interface Science. Co. Ltd., Japan).

3. Results and discussion

To discuss a degree of surfactant enrichment from liquid bulk to mist droplets, enrichment ratio of the surfactant is defined as ratio of the concentration in collected mist and that of initial solution, C_m/C_0. Because the volume of initial solution is much larger than the collected mist, C_0 is regarded as the bulk concentration. Thus, the ratio becomes a distribution ratio of the solute between droplet and liquid bulk. Fig. 2 represents a typical result of enrichment ratio against a surfactant concentration in feed. For most runs, time required for collecting about 1.4 cm^3 of mist was 30 min. A large enrichment was obtained at lower surfactant concentra-

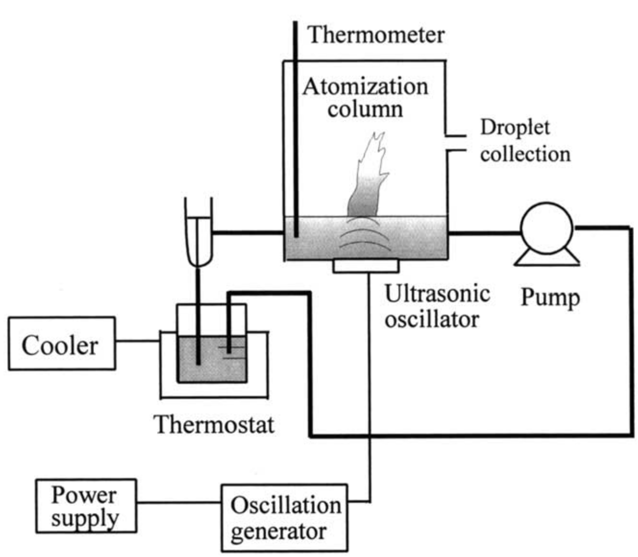

Fig. 1. Schematic diagram of experimental setup.

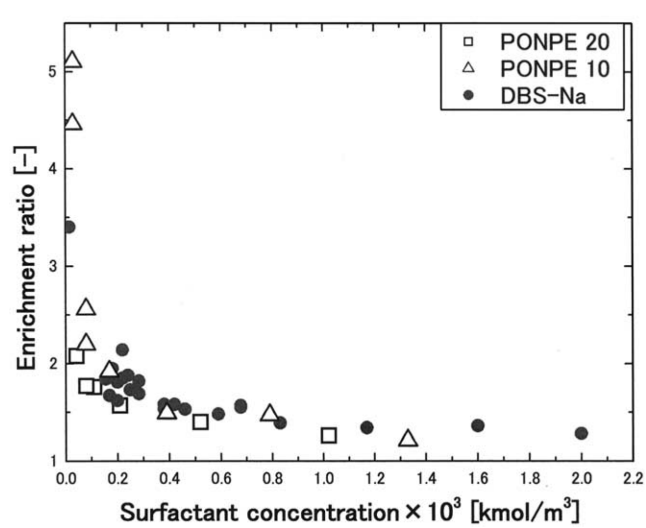

Fig. 2. Enrichment ratio of surfactant.