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Correspondence

# Response to the letter of Dr. Amiri

Dear Editor,

I would thank Dr. Amiri first for his interest to our paper "The effects of a surfactant on the mass transfer in spray-tower extraction column" [1]. In this paper, we study the variation of overall efficiency ($K_Ra$) with the concentration of SLS. The result showed that the value of $K_Ra$ decreases rapidly with increasing SLS concentration, approaches a minimum at about 10 ppm, and then increases monotonically with further addition of SLS. However, the $K_Ra$ cannot attain a value as high as that of a surfactant free system even at the maximum SLS concentration (400 ppm) used. Based on this result, we concluded that the effect of SLS on the decrease in $K_R$ is more important than that on the increase in the mass transfer area, $a$, and thus, the SLS has a negative effect in the extraction efficiency. By comparing with the results of other researchers, both consistent [2,3] and contrary [4,5] results were found. This discrepancy was taken as the effects of different apparatus, solvent–solute system, and the surfactants used.

In this letter, Dr. Amiri mentions that the discrepancy is due to the lack of good characterization of the system. He also reviews some effects, which are said to be important in evaluating the mass transfer efficiency of an extraction process at the presence of surfactants. These effects did play important roles in the extraction mass transfer and deserved to be studied to make a better understanding of the extraction process. However, being a complex system, it is not easy to take care of these effects simultaneously in one paper. Besides, the contribution of each effect in the mass transfer may vary under various operation conditions, such as the drop formation rate, hydrodynamic behavior of the droplets traveling through the continuous phase, drop size distribution, holdup of the dispersion phase, etc. All of these conditions depend not only on the operation parameters, but also on the extraction apparatus, and on the interfacial properties of the system which controlled by the solvent–solute system and the surfactants. This is why they were taken as the causes of the discrepant results among various researchers.

I agree Dr. Amiri's mention that only when all these related parameters are clearly specified, can one obtain reproducible data for such complex system. I am sorry that some of the parameters were not measured and clearly specified in this paper. However, since increasing extraction efficiency was always the main purpose of a process development, it is more important to find out the principles for that the positive or negative effect of surfactants will be obtained. That is, to predict how the $Ka$ will change for a particular system. For example, the higher efficiency obtained in a mixer-settler apparatus [4] and packed tower [5] seems to suggest that the increase in the interfacial area will become dominant effect of a surfactant when the system was violently agitated. In addition, we had found that the effectiveness of various surfactants in decreasing the mass transfer coefficient, $K_R$, are different [6]. This effectiveness is related to the adsorption rate and the adsorbed surface concentration of a surfactant on the interface. A surfactant with less effectiveness in decreasing the $K_R$ is like to get a higher efficiency ($K_Ra$). Thus, for a solvent–solute system, the mass transfer efficiency can be enhanced by the control of the hydrodynamic behavior of droplets and the selection of the surfactants. However, how to control the hydrodynamic condition and select the surfactants is not concluded now. Only when all the related effects and phenomena are clearly understood, can we answer this question.

The effects of surfactants on the mass transfer had been studied for a long time in the literature. Parts of the effects raised by Dr. Amiri had been studied in our laboratory such as the end effects, the surfactant effect on the hydrodynamic behavior of droplet through the column, effect of surfactant types on the mass transfer, and the mechanism of a surfactant in decreasing the $K_R$ [6,7]. In addition to those effects raised by Dr. Amiri, I think the following two phenomena are also important.

1. *The effect of dynamic adsorption behavior of surfactant on the mass transfer*. Most of the previous studies used the equilibrium surface tension to deal with the effects of surfactant on the mass transfer. However, the time required to establish the equilibrium surface tension is always much longer than the resident time of a droplet in the extraction column. That is, the equilibrium surface tension is always not established in the mass transfer stage. Besides, the moving of dispersed droplets through the continuous phase promotes the surface convection and makes stretching and compressing on the drop sur-

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face. For a surfactant-containing system, the concentration profile of surfactants on the drop surface is a competing result of the surface convection, and the diffusion, adsorption and desorption of the surfactants to and from the drop surface. So, the adsorption kinetics of the surfactants on the mass transfer should be more important than the equilibrium surface tension, and all of the related effects are more reasonable to be considered in terms of the adsorption kinetic [8,9].

2. *Identification of the real mechanisms of surfactants in decreasing the mass transfer coefficient*. The presence of tiny amount of surface active agents in the mass transfer system is known to reduce the mass transfer coefficient markedly. This is the main reason which lead to the decrease of the overall efficiency. The excess mass transfer resistance exerted by the surfactants had been attributed either to the hydrodynamic effect, or to the formation of an interfacial barrier layer. Although many efforts were made to identify the mechanisms of mass transfer at the presence of surfactants, no consistent conclusion had been drawn. A more understanding of this mechanism will help one to control the mass transfer resistance either from the point of hydrodynamic or from the selection of surfactant system.

Due to the complication of this process, many effects and phenomena are not understood yet and are need for further studied. We should thank Dr. Amiri who raised the important aspects which are not considered in this paper and are worthy of further studying.

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