

# **Comparative Study of Mass Transfer in Oil–Water–Oil Multiple Emulsions Stabilized by Conventional and Gemini Surfactants by Differential Scanning Calorimetry**

Muhammad Nadeem<sup>C, S</sup> and I.B. Tan

*Chemical Engineering Department, Universiti Teknologi PETRONAS, Perak, Malaysia  
nadeem\_waterchemist@yahoo.com*

Multiple emulsions of the type O1/W/O2 stabilized by conventional (poly quaternary amines) and gemini surfactant have been studied experimentally by means of differential scanning calorimetry (DSC). The objectives of this work were to characterize and measure the time-dependent changes within the emulsions. Particularly the interest was focused to quantify the concentration changes in the internal and external phases of the O1/W/O2 multiple emulsions as a function of surfactant concentration. In order to accomplish the objectives, the measurement and analysis carried out by DSC were based on the phase separation of the emulsions. Periodically, some volume of the emulsions was removed from the bulk O1/W/O2 multiple emulsions. The samples were submitted to steady cooling and the crystallization thermograms were recorded. The obtained experimental data by the crystallization thermograms was utilized to quantify the crystallized mass for both phases i.e. the internal and the external. Furthermore, the composition in each phase was also deduced from the obtained thermograms respectively. To deduce the exact composition, diagrams of crystallization temperatures were elaborated, employing several mixtures of known composition. In addition, the influence of formulation parameters such as mixing time, temperature, agitation speed, surfactant concentration in the aqueous phase and the mass ratio of the internal and external phases were also analyzed. The experimental results revealed mass transfer took place from the internal phase toward the external phase which is influenced by the composition difference on both sides of the aqueous membrane. The most likely mechanism of mass transfer through the aqueous membrane is a solution–diffusion of tetradecane enhanced by the micelles of the gemini surfactant as compared to the conventional one. It was also concluded that an increment of surfactant concentration in the aqueous phase enhances the kinetics of the tetradecane transfer.

**Keywords:** Gemini surfactant; Multiple emulsion; Mass transfer; Liquid membrane; Micelles; Differential scanning calorimetry