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Oscillatory regimes of mass transfer between a drop and a solution of surfactant

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The part played by the interfacial tension in liquid/liquid separation, material processing, food production, biotechnology, etc. is great. For instance, the interfacial tension gradients induced by heterogeneities of the surfactant concentration at the surface of a drop in the solution cause an intensive motion (Marangoni convection) in both parts of the liquid system. This motion interacting with buoyancy convection changes the character of mass transfer between the drop and the surrounding liquid. The paper presents the results of experimental investigation of the mass transfer variation under the influence of the Marangoni convection using as an example the process of drop saturation with surfactant from its water solution. Specifically, consideration is given to absorption of isopropyl alcohol by a drop of chlorbenzene. The drop is squeezed in a thin vertical or horizontal layer bounded by parallel walls (Hele-Shaw cell) and has the form of a short broad cylinder with a free lateral surface. Making use of both orientations of the layer allowed us to investigate the development of the mass transfer process at different levels of the gravity interaction with the capillary forces. Investigation into the structure and evolution of the concentration fields inside and around the drop was carried out using the Fizeau interferometer. Visualization of the convective flow was made by means of the opaque emulsion formed at the boundary of the drop during dissolution of the surfactant.

The oscillatory regime of mass transfer was found to occur in the case when the drop was surrounded by a steadily stratified surfactant solution. It was found out that the process of surfactant absorption was reinforced periodically due to the development of solutocapillary motion on the free surface of the drop, giving rise to an intense vortex flow both in the drop and in the surrounding solution. As the outer vortices grew in size they carried to the drop surface the portions of solution with increasingly growing surfactant concentration accelerating thus the surface motion. Simultaneously, average density of the solution in vorticies decreased and they began to float up. Eventually, the vorticies in the vertical layer closed up cutting off the injecting stream, whereas in the horizontal layer these vortices merely draw the flux with higher surfactant concentration away from the drop. As a result the solutocapillary motion stopped until the time when buoyancy convection restored the surfactant gradient near the drop. The main stages of drop saturation and time dependence of the perturbation period were determined for both cases of layer orientation. It was shown that in a vertical layer the oscillatory regime of mass transfer continued until surfactant stratification disappeared, i.e. during several hours. On the contrary, in the horizontal layer the oscillatory regime stopped quickly although vertical concentration still existed. Correlation between average surfactant concentrations in the drop and in the surrounding liquid was established.

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