# Evaporation and growth dynamics of layered droplets: Theory and experiments

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Many physical and commercial processes involve evaporation and growth of two phase layered droplets of partially miscible components. In many cases, a volatile droplet is coated with an immiscible layer to create a diffusional barrier in order to retard evaporation of the core droplet. The presence of a layer, however, brings about a number of rate-controlling mechanisms for the transfer of species from the core droplet to the surrounding gas phase and induces markedly different effects on the evaporation rate of the core droplet, including enhancement of the rate (Ray et al., 1991). To understand evaporation and growth dynamics of layered droplets we have experimentally studied droplets of a number of immiscible systems to determine the determine evaporation characteristics of volatile core droplets coated with layers of nonvolatile components and developed a pseudo steady state model for evaporation and growth kinetics of a two phase droplet of two partially miscible components, exposed to a stagnant gas phase.

The theoretical analysis show the rate of evaporation or growth of a core droplet may increase, decrease or show a maximum with increasing layer thickness, depending the physical properties (e.g., vapour pressure, diffusion coefficients and miscibility limits) of the binary system. Criteria for various scenarios that arise during the evaporation or growth of a layered droplet have been developed in terms of analytical expressions. We have also examined evaporation of single layered droplets suspended in an electrodynamic balance (EDB) under vapour-free atmospheres. Droplets were generated from a homogeneous solution that was prepared by dissolving two immiscible components in a highly volatile common solvent. With the evaporation of the volatile solvent two phases in a suspended droplet separated to form a layered droplet. Droplets of di-ethylene glycol (DEG), tri-ethylene glycol (TEG), diethyl phthalate (DEP), and dimethyl phthalate (DMP) coated, respectively, with dioctyl phthalate (DOP), dibutyl phthalate (DBP), and squalane were studied. A suspended droplet was illuminated by a polarized laser beam, and scattered light from the droplet was by monitored by two photomultiplier tubes (PMTs). Resonances (i.e., peaks) observed in the elastic scattering intensity versus time spectra from a suspended droplet were interpreted using elastic light scattering theory to obtain outer and core radii of the droplet as functions of time ( Ray and Nandakumar, 1995; Tu and Ray, 2006). The results obtained from core droplets of DEG and TEG coated with DOP as well as DBP layers show that the core evaporation rate monotonically increases as the layer thickness increases, and the evaporation rate of a core droplet can exceed the rate of an uncoated droplet of the same size. The results from DEP droplets coated with squalane layers show the core evaporation rate increases to a maximum, and then decreases as the layer thickness increases. The experimental results are highly reproducible and agree well with the model predictions. Because of the relatively low volatility of the core compounds involved in the study, a monotonic decrease in the core evaporation rate with increasing layer thickness, one of the scenarios indicated by the model, was not observed. In this study, we show that miscibility limits of nearly of immiscible binary systems, and the unknown parameters of a binary activity coefficient model can be evaluated from the evaporation data on layered droplets such binary systems.

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