Comparison of Nonlinear Evaporation and Diffusion Models in a Capillary Tube Geometry

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Abstract

Fick's law for molecular diffusion can be used to describe how water vapor is transported through a gas mixture. The general forms of Fick's law are written using gradients of either mass concentration, mole fraction, or chemical potential of the water vapor as dependent variables. Using concentration as a dependent variable is more natural for the modeling process (as it appears naturally in the conservation of mass equations), but it is difficult to measure and yields nonlinear equations that have no known analytic solution. Using chemical potential is less natural for modeling but yields governing equations that are more mathematically tractable. In this work we consider diffusion of water vapor through the simple geometry of a capillary tube. Depending on the choice of dependent variable we derive different sets of governing equations for the transport of water vapor through the tube. A careful derivation and analysis of each model will be presented, and comparisons of evaporation rate will be made between the models. We apply these equations to an evaporation problem where the liquid-gas interface moves in time and the shape of the capillary tube changes spatially.