Double Diffusive Instabilities of Statically Stable Chemical Fronts

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Gravitational Hele-Shaw fingering of an autocatalytic reaction diffusion interface is investigated theoretically. Dimensional analysis based on reaction diffusion length, time, and velocity scales reveal the dependence on the Lewis number Le, and thermal and concentration Rayleigh numbers R_T and R_c. Linear stability analysis of a planar upward propagating (against the gravitational acceleration) interface results in an eigenvalue problem for each wavenumber k which we solve using a Chebyshev pseudospectral method. Novel light over heavy instabilities were found when $Le > 1$. One instability branch corresponds to an upward endothermic front that is equivalent to a downward propagating exothermic wave. Nonlinear second-order Crank-Nicolson, finite volume simulations are in agreement with linear theory and also show the docile nature of the interface breakup. A displaced particle argument confirms that this unexpected instability is local, that it is subdued by a region of local stability behind the front, and elucidates its dependence on the underlying reaction diffusion mechanism. A second branch of statically stable systems corresponds to an upward exothermic reaction. Displaced particle argument also explains this instability that takes place ahead of the front. This is confirmed by nonlinear computations with interface fingering much larger than that of the former branch.