Numerical investigation of the onset of evaporative of convection for binary fluids

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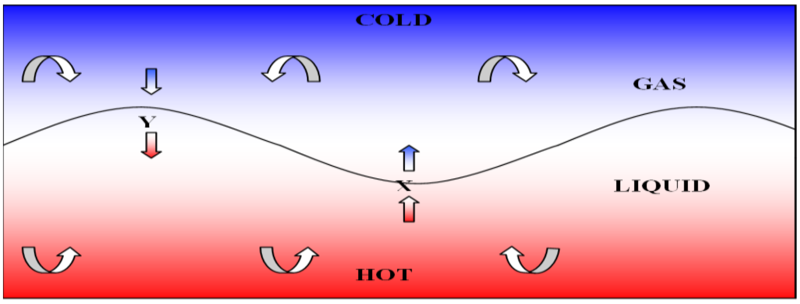
ABSTRACT

There are several applications in chemical engineering in which convection phenomena play a very important role, ranging from crystal growth and the coating of films to the casting of alloys and the space processing of glasses and semiconductors and most of those applications involve mixtures of fluids. Common to, many of these problems is the occurrence of an interface such as a fluid-fluid or fluid-solid interface and when there is an interface there often occurs a form of interfacial instability wherein a sudden change in interfacial pattern occurs as a system control variable crosses a critical value.

In this study, evaporative convection accompanies the classical Rayleigh and Marangoni convection phenomena. Having two or more fluids introduces solutal effects into the system such as the concentration dependence of density and concentration dependence of surface tension. Due to these new effects binary mixtures behave different than pure ones. Pure evaporative instability manifested by convective flow, in the absence of gravity and surface tension, can occur if the system is bounded by impermeable walls and a temperature gradient is imposed across the layers. The closed system guarantees a zero total evaporation rate. However perturbations can cause sustained evaporation at local troughs and sustained condensation at local crests. This is depicted in Fig. 1. Due to the vast density difference between vapor and liquid, the vapor flow is much greater than the liquid flow. This vapor flow is stabilizing taking hot vapors from troughs making them less hot while condensing the vapors on crests making them less cold.



In this work the effect of mass fraction, vapor dynamics and heating arrangement (heating from below or above) are investigated.

The results show that the deeper the liquid layer, the more unstable the system becomes. However, a similar statement does not hold for the vapor layer height. For the vapor layer height, there is a trade off between the buoyancy-driven convection and the stabilizing effect of vapor flow of phase change even when buoyancy is ignored. Thus there is a turning point of stability for the vapor height where the destabilizing effect of the buoyancy overcomes the stabilizing role of vapor flow arising from phase change itself.