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Author: Mr. Berin Šeta
Universitat Rovira i Virgili (URV), Spain

Dr. Diana Dubert
Universitat Rovira i Virgili (URV), Spain

Dr. Josefina Gavaldà
Universitat Rovira i Virgili, Spain
Prof. Mohammed Mounir Bou-Ali Saidi
Spain

Dr. Xavier Ruiz
Universitat Rovira i Virgili, Spain

GRAVITATIONAL STABILITY ANALYSIS ON DOUBLE DIFFUSION CONVECTION IN TERNARY MIXTURES

Abstract

In binary mixtures with gradient of concentration in isothermal conditions, it is possible to have two potential situations: either heavier component is more concentrated on the top or on the bottom, respectively. First case will generate convective motion because of adverse gradient of mixture [1], while in the second case, mixing process will be pure diffusive, governed by second Fick law [2]. Up to now, many different experiments were run for binary mixtures, by using techniques such as SST (Sliding Symmetric Tubes) and OEC (Open Ended Capillary), in order to obtain molecular diffusion coefficients. In multicomponent mixtures, depending on initial concentrations, it is possible to have convective motion even when top concentration is lighter than the bottom one. This behaviour, called double diffusion, destroys boundary interface and affects diffusion processes. In this work, DCMIX1 ternary mixtures [3], conducted on the International Space Station and Earth laboratories, will be analysed and different conditions for which two possible instabilities, fingers and over-stable regime, are generated. Experimental setup with an initial gradient in one component and a uniform distribution of concentration in the other one is considered. Solving this specific setup from analytical point of view, by using self-similar solution, will be easier to isolate and explain the effects of cross diffusion terms from the main diffusion ones. In fact, depending on the initial concentration gradient of the non-uniform component, instability occurs in form of fingers or over-stable regime causing convection, which in the end affects the determination of diffusion coefficients. In addition, due to this peculiar experimental setup, was proved that the sign of the cross diffusion coefficients of the component without gradient is directly related with the diffusion direction of the uniformly distributed component. Confidence in determined diffusion coefficients is significantly greater if sign of cross diffusion is known. Finally, the detected instabilities have been carefully analysed using 3D numerical simulations of the flow established in SST. For this purpose, a specific solver in the open source software OpenFOAM is created.

[1] J.S. Turner, Buoyancy Effects in Fluids (1973), Cambridge University Press

[2] Adolf Fick, Ueber Diffusion (1855), Annalen der Physik, vol. 170, 59-86

[3] M. Mounir Bou-Ali et al., Benchmark values for the Soret, thermodiffusion and molecular diffusion coefficients of the ternary mixture tetralin+isobutylbenzene+n-dodecane with 0.8-0.1-0.1 mass fraction (2015), Eur. Phys. J. E, 38, 4, 30