Proceedings of CHT-15
ICHMT International Symposium on Advances in Computational Heat Transfer

May 25-29, 2015, Rutgers University, Piscataway, USA

CHT-15-xxx

OCCURRENCE OF CONVECTIVE FLOWS IN TERNARY LIQUID AND GASEOUS MIXURES UNDER ISOTHERMAL CONDITIONS

Vladimir Kossov [*,§], Yuri Zhavrin[**], Olga Fedorenko[**] and Venera Mukamedenkyzy[**]
[*]Abai Kazakh National Pedagogical University, Almaty, Kazakhstan
[**]Institute of Experimental and Theoretical Physics, al-Farabi Kazakh National University, Almaty, Kazakhstan
[§]Correspondence author. Fax: + 7 727 291 90 12 Email: kosov_vlad_nik@list.ru

INTRODUCTION

Analysis of the onset of instability during the isothermal interdiffusion has shown that when the system has only one constant thermodynamic force ∇c causing convection then the description is completely analogous to the usual thermal convection. In the case of the two forces ∇c and ∇T at the same time there are new effects which essentially comes to and including the fact that the convectively unstable states are possible and the negative direction of the density gradient (mixture is more dense at the bottom). In this case, for the occurrence of thermo concentration convection there are two reasons both the heterogeneity of temperature and concentration. Since isothermal diffusion in ternary mixtures is also characterized by the presence of two independent partial concentration gradients, it seems important to analyze the most characteristic moments that arise in the study of the phenomena of convection class known as "double diffusion".

EXPERIMENTAL DATA

Convective instability in isothermal liquid mixtures has been studied in practice at aqueous solution diffusion of salt and sugar in a vertical plane channel. A set of pictures obtained by Tepler's shadow method are shown in Fig. 1. The lower part of the channel is filled with an aqueous salt solution (ρ = 1.125 g/cm^3), and the upper part with water solution in 3 parts of salt and 1 part of sugar (ρ = 1.057 g/cm^3). Fig. 1a shows the initial mixture in the cell. First, a salt solution is poured, and then along the wall of the cell a lower density of salt and sugar solution is added. At the edges of the cell is clearly observed the boundary of liquids. Diffusion starts, but after 10-15 seconds there can be seen convective instability in the system. Further observation over the system indicates the presence of structured convective flows.

More information is got at the result of experiments on studying the instability of mechanical equilibrium in gases. A vertical flat channel connected two identical flasks. At the top of the flask was a binary mixture of light and heavy components. Average density gas was placed in the lower flask. Concentrations of light and heavy components were chosen so that the mixture in the upper (top) flask was always of lower density of the gas than in the lower (bottom) flask ($\rho < 0$). Pressure is the same in both flasks. The channel connecting the flasks opened. After some time, the channel was blocked and the mixture in both flasks was recorded. Concentrations got at the result of experiments were

normalized to the calculated assuming diffusion. Figure 1d shows the typical dependences thus obtained parameter versus the pressure for the system 0.47He + 0.53Ar - N_2. From Fig. 1d is seen that at a certain critical pressure the parameter exceeds the unit, i.e. mechanical equilibrium of mixture becomes unstable. There occurs gravitational concentration convection. A similar character of mixing was also observed for the $H_2 + N_2 – CH_4$ ternary mixture.

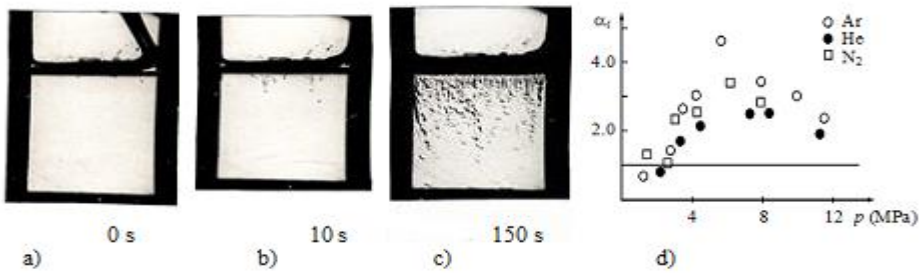

Figure 1. a) – c): Photographs of instabilities formation. d) Parameter α_i versus the pressure for various components of the mixture 0.47 He + 0.53 Ar – N_2.

MATHERMATICAL DISCRIPTION

Mathematical description of the effect is based on the linearization of the system equations of continuous mechanics for isothermal ternary systems in ratio to small perturbations. We have considered the unstable diffusion mixing problem in a plane vertical channel at boundary conditions, assuming the disappearance of the velocity and disturbances of the concentrations of components at the vertical planes that enclose the gas mixture. For the system $H_2 + N_2 – CH_4$ the arrangement of transition boundaries between the diffusion and the concentration gravitation convection subject to the pressure and various concentrations of components was defined in terms of Rayleigh numbers.

CONCLUSION

The main conclusions emerging from this study are follows. (1) Experimental investigations with aqueous solutions of salts and sugars showed that with increasing of the experiment duration a growth of the number of filamentous structures, their mutual interaction and the independent movement to the bottom of the cell happen, i.e. there is a development of convective mass transport. (2) For the three-component gas mixture, appearance of convective flows under the diffusion depends on the specific values of the state parameters: pressure, the initial composition of the gas mixture, etc. The study of the effect of pressure on the occurrence of the unstable regime under diffusion in ternary gas mixtures has shown that the change of regime takes place from a certain pressure, i.e. the occurrence of convective flows is observed.