ISSN 0040-5795, Theoretical Foundations of Chemical Engineering, 2016, Vol. 50, No. 2, pp. 171–177. © Pleiades Publishing, Ltd., 2016.
Original Russian Text © Yu.I. Zhavrin, V.N. Kosov, O.V. Fedorenko, A.A. Akzholova, 2016, published in Teoreticheskie Osnovy Khimicheskoi Tekhnologii, 2016, Vol. 50, No. 2, pp. 177–183.

Some Features of Isothermal Multicomponent Mass Transfer in the Convective Instability of Gas Mixture

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Received March 2, 2015

Abstract—Isothermal multicomponent diffusion in the H_2 + Ar–N_2 and CH_4 + Ar–N_2 three-component gas mixtures has been experimentally studied at various pressures and certain concentrations of components in binary mixtures. It has been shown that, in systems where diffusion coefficients differ significantly from each other, convective instability occurs with increasing pressure, which significantly intensifies multicomponent mass transfer. The parameters of transition diffusion mixing to convective can be defined in the framework of stability theory. The comparison carried out between experimental and calculated data shows satisfactory agreement between them.

Keywords: isothermal multicomponent diffusion, convective instability, stability theory, multicomponent mass transfer

DOI: 10.1134/S0040579516020135

INTRODUCTION

Research of the process of separating and purifying gas systems is traditionally associated with the description of the kinetics of mass transfer [1, 2]. As a rule, main difficulties in the study of multicomponent mixtures result from the lack of reliable computational models of mass transfer [3] and the lack of experimental data. Therefore, the study of problems of multicomponent mass transfer on both the experimental and computational–theoretical level continues to develop intensively [3–5]. In the study of the diffusion of vapors of liquid binary solutions into receiving gas, it has been found that, in these systems, the appearance of convective instability is possible, which significantly intensifies the overall mass transfer during evaporation [6–8]. The observed convective mechanism is similar to the Rayleigh–Benard problem for an inhomogeneous temperature field and other manifestations of instability, where it is necessary to account for the dependence of medium properties on the composition, temperature, and cross effects [9, 10]. Therefore, the authors of [6–8] used the formalism of stability theory to determine the specific terms and the occurrence of convective flows in the diffusion [9, 11]. However, it should be noted that, if the receiving gas is a multicomponent mixture, then in this system, transition to convective mixing regime is apparently possible, which will be determined not only by the original composition of the mixture, but also by other parameters not discussed in [6–8].

In this study, isothermal diffusion in quasi-stationary mode is studied experimentally at different pressures for three-component gas systems. Test mixtures are analyzed on the stability of mechanical equilibrium in plane vertical channel with mass impenetrable walls.

EXPERIMENTAL RESULTS

For the study of diffusive and convective transfer, method of two flasks was used [12, 13], wherein the analysis of gas mixtures after mixing was performed by chromatography. The experiments were performed in the pressure range from 0.5 to 3.0 MPa at temperature of 295.0 K. The lower limit of pressure complied with the condition of taking several samples for analysis, and the upper—by technical features of experimental devices. The experimental setup is shown in Fig. 1 and includes two parts. First *a* is a gas preparation unit that consists of pressure gauges *12*, which measure the pressure in the flasks, container *13* to equalize pressure in the flasks of diffusion apparatus, as well as taps *1–10* to fill the flasks of setup with corresponding mixtures from balloons *20* and *21*. The gauges were equipped with specially manufactured permeators *11*. The second part of the setup *b*–diffuser with volumes of flasks $V_u = 2.268 \times 10^{-4}$ m^3 and $V_l = 2.145 \times 10^{-4}$ m^3, respectively. The flasks were connected with a slit diffusion