NONSTEADY THERMODIFFUSIONAL SEPARATION OF BINARY MIXTURES IN A REGIME WITH SAMPLING. II

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The dynamics of the thermodiffusional separation of two-component mixtures in a regime with sampling is investigated with allowance for nonlinear effects.

The nonlinear nonsteady problem of the thermodiffusional separation of binary mixtures in a regime with sampling is solved in [1]. Explicit functions are given only for the concentrations at the end of the thermodiffusion column, however, and no detailed analysis is made of the solutions obtained. The dynamic characteristics of the process of separation in a regime with sampling are studied in the present paper with allowance for the finite concentration.

The general solution for the concentration has the form (see [1] for notation):

$$c(\xi, \tau) = \frac{1}{2b}\left\{b + \varkappa + \right.$$
$$\left. + \frac{\sum_{n=0}^{\infty} \frac{\sqrt{p_n}\,\mathrm{sh}\,\sqrt{p_n}\xi + B\,\mathrm{ch}\,\sqrt{p_n}\xi}{(p_n - B^2)\,\Delta_n\,\mathrm{ch}\,\sqrt{p_n}} R_n\left(\frac{\varkappa}{B^2} p_n\right) \exp\left[(p_n - p_0)\,\tau\right]}{\sum_{n=0}^{\infty} \frac{\sqrt{p_n}\,\mathrm{ch}\,\sqrt{p_n}\xi + B\,\mathrm{sh}\,\sqrt{p_n}\xi}{\sqrt{p_n}\,(p_n - B^2)\,\Delta_n\,\mathrm{ch}\,\sqrt{p_n}} R_n\left(\frac{\varkappa}{B^2} p_n\right) \exp\left[(p_n - p_0)\,\tau\right]}\right\}, \quad (1)$$

where p_0 is determined from the transcendental equation

$$\lim_{\tau\to\infty} c(1, \tau) = c(1, \infty) = c_0 \frac{1 + \frac{b+\varkappa}{\sqrt{p_0}}\,\mathrm{th}\,\sqrt{p_0}}{1 + \frac{2bc_0 + \varkappa - b}{\sqrt{p_0}}\,\mathrm{th}\,\sqrt{p_0}}; \quad (2)$$

$$p_0 = (\varkappa + b)^2 - 4b\varkappa c(1, \infty) > 0, \quad (3)$$

while p_n ($n = 1, 2, \ldots$) are roots of the equation

$$\frac{\mathrm{th}\,\sqrt{p_n}}{\sqrt{p_n}} = -\frac{R(\varkappa)}{BR\left(\frac{\varkappa}{B^2} p_n\right)}, \quad n = 1, 2, \ldots \quad (4)$$

It must be noted that this equation, along with the purely imaginary roots, can have one real root, depending on the values of the parameters c_0, b, and κ.

To establish the limiting characteristics, we give the solution of the original problem for a column of infinite length:

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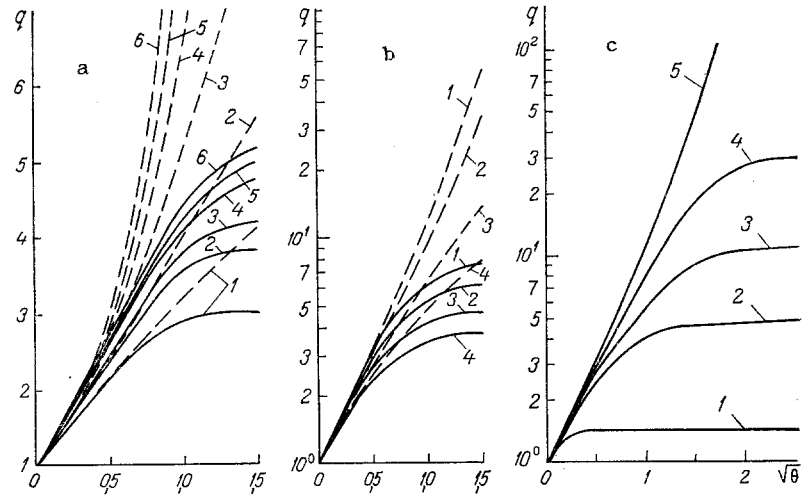

Fig. 1. Separation coefficient q as a function of $\sqrt{\theta}$: a) $\kappa = 0.3$, b = 1 (solid curves), b = ∞ (dashed curves), and 1) $c_0 = 0.0$; 2) 0.1; 3) 0.3; 4) 0.5; 5) 0.7; 6) 0.9; b) $c_0 = 0.5$, b = 1 (solid curves), b = ∞ (dashed curves), and 1) $\kappa = 0.0$; 2) 0.1; 3) 0.3; 4) 0.5; c) $c_0 = 0.5$, $\kappa = 0.3$, and 1) b = 0.25; 2) 1.0; 3) 1.5; 4) 2.0; 5) ∞.

$$c(\eta, \theta) = A/D;\ A = c_0(c_0 - \chi - 1)[(c_0 - \chi)\Phi(\beta) -$$
$$-(1 - c_0)\Psi(\beta) - (\chi - 1)\Psi(\chi - 1)];$$
$$D = (c_0 - \chi)(c_0 - \chi - 1)\Phi(\beta) + c_0(1 - c_0)\Psi(\beta) -$$
$$-c_0(c_0 - \chi - 1)(\chi - 1)\Psi(\chi - 1) - (1 - c_0)(c_0 - \chi)(\chi + 1)\Psi(\chi + 1), \quad (5)$$

where new dimensionless variables and designations are introduced through the formulas

$$\eta = b\xi = \frac{H}{2K}z,\ \theta = b^2\tau = \frac{H^2}{4\mu K}t,\ \chi = \frac{\varkappa}{b} = \frac{\sigma}{H},$$
$$\Psi(x) = \exp(x\eta + x^2\theta)\operatorname{erfc}\left(x\sqrt{\theta} + \frac{\eta}{2\sqrt{\theta}}\right),$$
$$\Phi(\beta) = \exp(-\beta\eta + \beta^2\theta)\operatorname{erfc}\left(\beta\sqrt{\theta} - \frac{\eta}{2\sqrt{\theta}}\right),$$
$$\beta = \frac{B}{b} = 2c_0 - \chi - 1. \quad (6)$$

It is necessary to expose the indeterminacy in Eq. (5) arising as $\chi \to c_0$.

The separation coefficient

$$q = \frac{c_e}{1 - c_e}\,\frac{1 - c_i}{c_i}$$

as a function of the parameters characterizing the regime of operation of the column is analyzed on the basis of Eqs. (1) and (5).

The influence of the initial concentration on the separation coefficient is shown in Fig. 1. From an analysis of the corresponding curves (a), it follows that the time of arrival at the steady state grows with an increase in c_0. The influence of the amount of sampling on the dynamics of the separation process is presented (b). It is seen that more time is required to reach a given separation level in the presence of sampling than when the column operates in a nonsampling regime. Kinetic curves of the separation process with sampling as a function of the column length are also given (c).

Nonsteady measurement methods are used to study the thermodiffusional characteristics of substances, and so it is important to know the dynamics of the concentration difference at the ends of the separation system at short times [2]. Using the results of [1], we can show that

$$\Delta c \simeq 4c_0(1-c_0)\left[\sqrt{\frac{\theta}{\pi}}-\chi\theta\right]$$

as $\tau \to 0$, from which it follows that the influence of sampling is negligibly small in the initial stage of the separation process.

NOTATION

c, concentration; t, time; z, coordinate; H, K, σ, transfer coefficients; L, column length; μ, mass of the substance per unit length; c_0, initial concentration; c_e, c_i, concentrations at the positive and negative ends of the column; b = HL/2K.

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ABSORPTION OF RADIATION IN A LAYER OF HIGHLY POROUS MATERIAL

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Radiative transfer through a porous layer, modeled by a uniform system of opaque particles fixed in space, is investigated.

Problems of the interaction of radiation with porous solids are important for many fields of modern thermophysics. Depending on the geometry and physical properties of the frame, as well as on the relation between the wavelength of the radiation and the parameters of the porous structure, it is possible to use various models of porous bodies and various approaches to describing the process of propagation and absorption of the radiation. For example, the case of the passage of radiation through a porous body modeled by a system of parallel cylindrical capillaries was considered in [1]. Highly porous bodies with a frame of globular structure are used very often in practice, however. A model of randomly arranged spheres is more adequate in such cases.

As is noted in [2], three models of radiative transfer in loose layers are usually used. The first model is based on the approximation of a heterogeneous mixture of randomly packed solid particles and pores by a certain regular geometrical arrangement of the solid phase and the voids. In the second model, proposed by Rosseland, it is assumed that when the mean free path of a photon in a loose layer is much less than the geometrical size of the absorbing medium, the path of an individual quantum of radiant energy can be taken as random, and the process is diffusional. In the third type of model, the loose layer is treated as a pseudohomogeneous medium, in which radiative heat exchange is described through differential or integrodifferential equations and the corresponding boundary conditions.

The transmission of radiation in layers with both open and dense packing of particles is analyzed in [3, 4]. Here to determine the transmission coefficient in the case of open packing a two-flux approximation is used, while a layer with dense particle packing is

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