

less coordinates; R_0 , minimum cross section of the region of integration; R , coordinates of the lateral boundary of the region over the r axis; L , length of the region of integration over the x axis.

LITERATURE CITED

1. D. B. Vafin, A. F. Dregalin, and A. B. Shigapov, "Calculation of radiation of two-phase media in axisymmetric volumes," Thirteenth All-Union Conference on Problems of Vaporization, Combustion, and Gas-dynamic Systems, Abstracts of Papers [in Russian], Odessa Univ. (1979), p. 68.
2. V. Ya. Klabukov, E. I. Maratkanova, V. A. Kuz'min, and L. T. Greben'shchikov, "Investigation of the transfer of radiative energy of heterogeneous combustion products in volumes of finite cylindrical geometry," Fifth All-Union Conference on Heat and Mass Transfer, V [in Russian], Vol. 8, Inst. of Heat and Mass Transfer, Minsk (1976), pp. 215-224.
3. K. S. Adzerikho, V. I. Antsulevich, V. P. Nekrasov, and V. P. Trofimov, "Modeling of problems in luminescent heat transfer in media of nonplanar geometry," *Inzh.-Fiz. Zh.*, **36**, No. 2, 231-243 (1979).
4. G. I. Marchuk and V. I. Lebedev, Numerical Methods for Nuclear Reactor Calculations, Plenum Publ. (1959).
5. A. A. Samarskii and E. S. Nikolaev, Methods for Solving Difference Equations [in Russian], Nauka (1978).
6. H. C. Hulst, Scattering of Light by Small Particles [Russian translation], IL, Moscow (1961).
7. D. B. Vafin and A. F. Dregalin, "Expression for the expansion coefficients of scattering indices for Legendre polynomials using Mie Coefficients," *Inzh.-Fiz. Zh.*, **35**, No. 4, 648-650 (1978).

DIFFUSION SLIP OF A GAS

II. APPLICATION OF THE METHOD OF THE THERMODYNAMICS OF IRREVERSIBLE PROCESSES

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A method is proposed for thermodynamic calculation of the diffusion slip coefficient.

A system of equations was obtained in [1] to determine small complements to equilibrium (Maxwell) distribution functions for the components of a binary gas mixture flowing slowly in a plane-parallel channel when the temperature and pressure of the gas are held constant. This system was then solved on the assumption that the concentration of one of the components was trivial. This approximation made it possible to convert the system of eight equations into two systems of four equations each, complete the analytical solution to the problem, and calculate the diffusion slip coefficient K_{DS} by directly computing the mean mass velocity of the gas resulting from concentration gradients of the mixture components.

Also of interest is another method of calculating the slip coefficients, based on the use of the methods of the thermodynamics of irreversible processes [2, 3]. Correct realization of this method — apart from a purely formal proof of the directly obtained result — makes it possible to extract important information on the physical nature of the phenomenon and opens up possibilities for experimental measurement of the effect on a new basis.

1. We will examine the problem of the flow of a binary mixture of gases in a plane-parallel channel with a distance $2d$ between the plates. Let the plates forming the channel be brought into relative motion of a velocity V by a force F . Given constant pressure and temperature in the channel, if we create a gradient in the concentration of the components of the mixture in the channel, then the total entropy produced in such a system may be written in the form

$$\Delta S = \frac{F \cdot V}{T} + k \langle u_1 - u_2 \rangle \nabla n_1, \quad (1)$$

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where $\langle \mathbf{u}_1 - \mathbf{u}_2 \rangle$ is the difference in the velocities of the mixture components integrated over the channel cross section; $\mathbf{V} = \mathbf{V}_1 - \mathbf{V}_2$, relative velocity of the plates; \mathbf{F} , force acting on a unit area of the surface of the plate 1; n_1 , number of molecules the first type in a unit of the volume.

Proceeding on the basis of Eq. (1), we can write the following phenomenological equations of motion:

$$\begin{aligned} \mathbf{V} &= L_{11} \frac{\mathbf{F}}{T} + L_{12} \nabla n_1, \\ k \langle \mathbf{u}_1 - \mathbf{u}_2 \rangle &= L_{21} \frac{\mathbf{F}}{T} + L_{22} \nabla n_1, \end{aligned} \quad (2)$$

Meanwhile, in accordance with the Onsager principle, the relation between the kinetic coefficients $L_{12} = L_{21}$ should be satisfied.

It can be seen from the first equation of (2) that relative motion of the plates may also occur in the absence of external forces if there is a gradient in the number of particles of the mixture components directed along the channel. The velocity associated with the relative motion can be determined by assigning a gradient for the concentration of the components and finding the molecule distribution function from the Boltzmann equation. Here, in the case where the mean free path of the molecules is much shorter than the distance between the plates, \mathbf{V} is associated with the difference in the velocities of diffusion slip of the gas relative to the first and second plate.

We can also take an indirect approach - use the symmetry properties $L_{12} = L_{21}$. In the last case, it is necessary to determine the value of $\langle \mathbf{u}_1 - \mathbf{u}_2 \rangle$, resulting from the relative motion of the plates under the influence of the force \mathbf{F} . This approach will also be used below to calculate the diffusion slip velocity.

2. Finding the relative velocity of the components in the given formulation reduces to solving the Couett problem for a homogeneous gas mixture. We will place the origin in the middle between the plates in such a way that the top plate moves in the positive direction of the z axis, directed along the channel, at a velocity $V/2$ and the bottom plate moves at the same velocity in the opposite direction.

Again, as in [1], we will limit ourselves to the case of a small addition of the second component, i.e., we will assume that the inequality $n_2/n \ll 1$ is satisfied. Let us represent the corrections $\varphi_i(x, \mathbf{c}_i)$ to the equilibrium functions $f_i^{(0)}$ in the form of expansions [1] (\mathbf{c}_i is the dimensionless velocity of molecules of type i ; the x axis is directed across the channel):

$$\varphi_i(x, \mathbf{c}_i) = \frac{1}{2} \sum_k a_k^{(i)} P_k(\mathbf{c}_i), \quad (3)$$

where $P_k(\mathbf{c}_i)$ are certain velocity polynomials; $a_k^{(i)}$ are functions which must be determined. In accordance with the assumption of a trivial number of molecules of the second type, we set $a_k^{(1)} = a_{k0}^{(1)} + (n_2/n) \xi_k$. Then system (4) from [1] reduces to two systems. The first (corresponding to $n_2/n = 0$) has the form

$$\sum_{h=0}^3 \left(N_{lh} \frac{\partial}{\partial x} - \mathcal{L}_{lh}^{(1)} \right) a_{h0}^{(1)}(x) = 0, \quad l = 0 - 3. \quad (4)$$

This system of equations will contain functions describing the behavior of only the first component and, in the approximation being examined, it coincides with the corresponding system for the flow of a simple gas [4]. The second system, obtained for $a_k^{(2)}$ with allowance for the first nonzero approximation of n_2/n , is as follows:

$$\sum_{\kappa=0}^3 \left[\left(K_2 N_{l\kappa} \frac{\partial}{\partial x} - M_{l\kappa}^{(22)} \right) a_{\kappa}^{(2)}(x) - a_{h0}^{(1)}(x) M_{l\kappa}^{(21)} \right] = 0, \quad l = 0 - 3. \quad (5)$$

The boundary conditions have the form

$$a_1^{(i)}(d) = \frac{\varepsilon_i}{2 - \varepsilon_i} [a_0^{(i)}(d) + 2 u_{0i}], \quad (6)$$

$$a_3^{(i)}(d) = \frac{\varepsilon_i}{2 - \varepsilon_i} a_2^{(i)}(d),$$

where ε_i is the fraction of molecules of type i diffusely reflected by the channel wall, $u_{0i} = 1/2 \sqrt{2kT/m_i}$. It is easy to see that the boundary conditions for each of the components are independent.

The solution of system (4) with boundary conditions (6) is known. We present the result obtained in [4] below:

$$a_{k0}^{(1)} = \begin{cases} A_k x + \beta_k \operatorname{sh} \alpha_0 x, & k = 0, 2, \\ A_k + \beta_k \operatorname{ch} \alpha_0 x, & k = 1, 3, \end{cases} \quad (7)$$

where

$$\begin{aligned} \alpha_0 &= \frac{4}{\pi(4-\pi)} \sqrt{2V\pi \mathcal{L}_{22}^{(1)} \left(\frac{V\pi}{2} \mathcal{L}_{11}^{(1)} - \mathcal{L}_{13}^{(1)} \right)}; \\ A_0 &= \frac{2}{\pi} \mathcal{L}_{13}^{(1)} A_3; \quad A_1 = A_2 = 0; \\ \beta_1 &= -\frac{V\pi}{2} \beta_3; \quad \beta_2 = -\frac{V\pi}{2} \beta_0 = -\frac{\beta_3}{\alpha_0} \frac{4V\pi}{\pi(4-\pi)} \left(\mathcal{L}_{13}^{(1)} - \frac{V\pi}{2} \mathcal{L}_{11}^{(1)} \right); \\ \beta_3 &= -\frac{4}{\pi} \frac{\varepsilon_1}{2-\varepsilon_1} \frac{u_{01}}{D}; \quad A_3 = -\beta_3 \operatorname{ch} \alpha_0 d + \frac{\varepsilon_1}{2-\varepsilon_1} \beta_2 \operatorname{sh} \alpha_0 d; \\ D &= -\frac{\varepsilon_1}{2-\varepsilon_1} \frac{4 \mathcal{L}_{13}^{(1)} d}{\pi^2} \left(\operatorname{ch} \alpha_0 d - \frac{\varepsilon_1}{2-\varepsilon_1} \frac{\beta_2}{\beta_3} \operatorname{sh} \alpha_0 d \right) + \frac{1}{V\pi} \left(\operatorname{ch} \alpha_0 d - \frac{\varepsilon_1}{2-\varepsilon_1} \frac{\beta_2}{\beta_3} \frac{4}{V\pi} \operatorname{sh} \alpha_0 d \right). \end{aligned}$$

The solution to system (5) is the superposition of the general solution of the homogeneous system and the particular solution of the inhomogeneous system. For the first we have

$$a_k^{(2)} = \sum_{j=1}^2 C_j \gamma_{kj} \begin{cases} \operatorname{sh} \alpha_j x, & k = 0, 2, \\ \operatorname{ch} \alpha_j x, & k = 1, 3, \end{cases} \quad (8)$$

where α_1 and α_2 are roots of the characteristic equation of system (5). It should be noted that the roots α_j and coefficients γ_{kj} coincide with the corresponding values in [1].

The particular solution of the inhomogeneous system is the sum of the distribution functions in the gas volume and in the Knudsen layer, and the complete solution of system (5) is therefore written in the form

$$a_k^{(2)} = \begin{cases} B_k x + f_k \operatorname{sh} \alpha_0 x + \sum_j C_j \gamma_{kj} \operatorname{sh} \alpha_j x, & k = 0, 2, \\ B_k + f_k \operatorname{ch} \alpha_0 x + \sum_j C_j \gamma_{kj} \operatorname{ch} \alpha_j x, & k = 1, 3, \end{cases} \quad (9)$$

where the coefficients f_k are the solution of the system

$$\sum_{k=0}^3 (K_2 N_{ik} \alpha_0 - M_{ik}^{(22)}) f_k = G_i,$$

and the constants C_j are found from boundary conditions (6).

The quantities B_k and G_l have the form

$$\begin{aligned} B_0 &= \sqrt{\frac{m_1}{m_2}} A_0, \quad B_3 = A_3 \left[\frac{K_2 \mathcal{L}_{13}^{(1)}}{n M_{13}^{(22)}} \sqrt{\frac{m_2}{m_1}} - \frac{M_{31}^{(12)}}{M_{13}^{(22)}} \right], \\ B_1 = B_2 = G_3 &= 0, \quad G_0 = -\frac{1}{2} \frac{K_2}{n} \beta_2 \left(\frac{4}{V\pi} M_{00}^{(12)} - 2 M_{22}^{(12)} \right), \\ G_1 &= \frac{1}{2} \beta_3 \frac{K_2}{n} (2 M_{31}^{(12)} - \sqrt{\pi} M_{11}^{(12)}), \\ G_2 &= -\frac{1}{2} \frac{K_2 \beta_2}{n} \left(\frac{4}{V\pi} M_{02}^{(12)} - 2 M_{22}^{(12)} \right). \end{aligned}$$

It should be noted that the solution to (9) was obtained at different values of α_0 , α_1 , and α_2 . Agreement of α_0 with α_1 or α_2 is a special case of little interest, while $\alpha_1 = \alpha_2$ is possible only under the condition that the mass of the molecules of the first component be equal to zero.

TABLE 1. Diffusion Slip Coefficients at $\varepsilon_1 = \varepsilon_2 = 1$

$\frac{m_1}{m_1+m_2}$	σ_1/σ_{12}								
	0,2	0,4	0,6	0,8	1,0	1,2	1,4	1,6	1,8
0,1	6,45	6,56	6,35	5,80	5,00	3,97	2,73	1,29	-0,347
0,2	2,84	2,72	2,50	2,17	1,74	1,22	0,606	-0,101	-0,900
0,3	1,49	1,39	1,22	1,00	0,718	0,378	-0,0189	-0,474	-0,988
0,4	0,828	0,746	0,620	0,454	0,248	0,00275	-0,283	-0,609	-0,977
0,5	0,456	0,388	0,288	0,158	0,00	-0,187	-0,403	-0,650	-0,927
0,6	0,207	0,158	0,0802	-0,0194	-0,141	-0,285	-0,452	-0,642	-0,856
0,7	0,0540	0,0162	-0,0421	-0,118	-0,212	-0,323	-0,452	-0,598	-0,762
0,8	-0,0433	-0,0689	-0,110	-0,165	-0,233	-0,315	-0,410	-0,519	-0,461
0,9	-0,120	-0,127	-0,143	-0,171	-0,210	-0,261	-0,321	-0,391	-0,470

3. Let us now proceed to the calculation of the velocity of diffusion slip. The relative velocity of the components of the mixture

$$\langle \mathbf{u}_1 - \mathbf{u}_2 \rangle = \int_{-d}^d dx \left[\frac{1}{n_1} \int f_1^{(0)} \varphi_1 \mathbf{v}_1 d\mathbf{v}_1 - \frac{1}{n_2} \int f_2^{(0)} \varphi_2 \mathbf{v}_2 d\mathbf{v}_2 \right] \quad (10)$$

after substitution of the expansions (3) of the functions φ_i in (10) may be expressed through the coefficients $a_k^{(i)}$ in the following manner:

$$\begin{aligned} \langle \mathbf{u}_1 - \mathbf{u}_2 \rangle |_{\nabla n_i=0} &= \sqrt{\frac{kT}{8\pi m_1}} \int_{-d}^d dx \left[\sqrt{\pi} a_{00}^{(1)} + a_{20}^{(1)} - \sqrt{\frac{m_1}{m_2}} (\sqrt{\pi} a_0^{(2)} + a_2^{(2)}) \right] \\ &= \sqrt{\frac{kT}{8\pi m_1}} \frac{\pi \sqrt{\pi}}{2} \frac{K_2}{nM_{00}^{(12)}} \left(a_1^{(2)} + \frac{\sqrt{\pi}}{2} a_3^{(2)} \right) \Big|_{-d}^d. \end{aligned} \quad (11)$$

In obtaining the last equation, we used the first equation of system (5) and Eqs. (7) and (10) from [1]. The following expression is obtained for F:

$$F = \int v_{1x} v_{1z} f_1^{(0)} \varphi_1 d\mathbf{v}_1 = \frac{nkT}{4} A_3 \quad (12)$$

(the small complement proportional to n_2/n is discarded). From this and Eq. (2) we have

$$L_{21} = \sqrt{\frac{kT}{8\pi m_1}} \frac{\pi^2 K_2}{n^2 M_{00}^{(12)}} \left(a_1^{(2)} + \frac{\sqrt{\pi}}{2} a_3^{(2)} \right) \Big|_{-d}^d, \quad (13)$$

while the relative velocity of the plates resulting from the concentration gradient in the absence of an external force is equal to

$$\mathbf{V} = \frac{\pi}{2} \sqrt{\frac{2kT}{m_1}} \frac{\nabla n_1 K_2}{A_3 n^2 M_{00}^{(12)}} \times \left\{ a_1^{(2)}(d) + \frac{\sqrt{\pi}}{2} a_3^{(2)}(d) - \left[a_1^{(2)}(-d) + \frac{\sqrt{\pi}}{2} a_3^{(2)}(-d) \right] \right\}, \quad (14)$$

i. e., it is the difference of certain velocities calculated on the surfaces of the first and second plates, respectively.

It is apparent from (14) that if the accommodation coefficients of the molecules on both surfaces are the same, then no relative motion of the latter under the influence of a concentration gradient will occur.

The velocity of the plates relative to the gas can be obtained from the following reasoning. In the case $\alpha_{jd} \gg 1$ (no overlapping of the Knudsen layers), as already noted, the relative velocity of the plates \mathbf{V} is the difference between the velocities of slip of each of them relative to the gas: $\mathbf{V} = \mathbf{u}_{ck}^{(2)} - \mathbf{u}_{ck}^{(1)}$. From this and Eq. (14), the diffusion slip velocity \mathbf{u}_{DS} is equal to

$$\mathbf{u}_{DS} = \mathbf{u}_{ck}^{(1)} = -\frac{\pi}{2} \sqrt{\frac{2kT}{m_1}} \frac{\nabla n_1 K_2}{A_3 n^2 M_{00}^{(12)}} \left(a_1^{(2)}(d) + \frac{\sqrt{\pi}}{2} a_3^{(2)}(d) \right) + C_0, \quad (15)$$

where C_0 is a constant independent of the character of the interaction of the gas with the surface of the solid. It is therefore the same for each surface. To determine its value, we will use the result from [5]. At $\varepsilon_i \rightarrow 0$, the slip velocity is equal to

$$u_{DS}(\varepsilon_i \rightarrow 0) = \frac{nm_2}{\rho n_1} D_{12} \frac{1 - \sqrt{\frac{m_1}{m_2} \frac{\varepsilon_2}{\varepsilon_1}}}{1 + \frac{n_2}{n_1} \sqrt{\frac{m_2}{m_1} \frac{\varepsilon_2}{\varepsilon_1}}} \nabla n_1. \quad (16)$$

Or, considering the condition $n_2/n_1 \ll 1$ and assuming $\rho_1 \gg \rho_2$, we have

$$u_{DS}(\varepsilon_i \rightarrow 0) = D_{12} \left(\frac{m_2}{m_1} - \frac{\varepsilon_2}{\varepsilon_1} \sqrt{\frac{m_2}{m_1}} \right) \nabla \ln n_1. \quad (17)$$

Under the same conditions, Eq. (15) takes the form

$$u_{DS} = -D_{12} \sqrt{\frac{m_2}{m_1}} \frac{\varepsilon_2}{\varepsilon_1} \nabla \ln n_1 + C_0, \quad (18)$$

where, in accordance with the first approximation of Chapman-Enskog, we have introduced the diffusion coefficient D_{12} (see [1]).

Comparison of (17) and (18) gives us the constant in Eq. (15). Finally, we have

$$u_{DS} = K_{DS} D_{12} \nabla \ln n_1 = D_{12} \nabla \ln n_1 \left\{ \frac{m_2}{m_1} - \sqrt{\frac{m_2}{m_1}} \frac{\varepsilon_2}{\varepsilon_1} \frac{2 - \varepsilon_1}{2 - \varepsilon_2} \times \right. \\ \left. \times \frac{F_0 + \frac{\varepsilon_1}{2 - \varepsilon_1} H_1^* + \left(\frac{\varepsilon_1}{2 - \varepsilon_1} \right)^2 H_2^* + \frac{\varepsilon_2}{2 - \varepsilon_2} \left[Q_0 + \frac{\varepsilon_1}{2 - \varepsilon_1} Q_1^* + \left(\frac{\varepsilon_1}{2 - \varepsilon_1} \right)^2 Q_2 \right]}{\left(1 - \frac{\varepsilon_1}{2 - \varepsilon_1} \frac{\beta_2}{\beta_3} \right) \left(F_0 + \frac{\varepsilon_2}{2 - \varepsilon_2} F_1 + \left(\frac{\varepsilon_2}{2 - \varepsilon_2} \right)^2 F_2 \right)} \right\}$$

It is readily seen that the coefficients of diffusion slip obtained by direct [1] and thermodynamic calculations are of the same form. Meanwhile, the coefficients F_1 , Q_0 , and Q_2 in these calculations are expressed in the same manner through the parameters γ_{kj} . Agreement of the coefficients H_1^* , H_2^* , and Q_1^* with H_1 , H_2 , and Q_1 obtained in [1] was established by calculating them numerically at different values of mass and cross section for the gas-phase molecules.

The final result confirms the conclusion reached in [6] concerning the method of constructing a system of moment equations, making it possible to exactly satisfy the Onsager reciprocal relations even using an approximate solution.

Table 1 presents values of K_{DS} for different ratios of molecule mass and diameter.

NOTATION

V_1 , V_2 , velocities of first and second plates; k , Boltzmann constant; T , gas temperature; D_{12} , inter-diffusion coefficient of the gas mixture; $\mathcal{J}_{km}^{(i)}$, $M_{km}^{(ij)}$, moments of the Boltzmann collision integral; K_{DS} and u_{DS} , coefficient and velocity of diffusion slip; n_i , number of particles per unit volume; m_i , mass; σ_i , diameters; ε_i , accommodation coefficients of the type i molecules.

LITERATURE CITED

1. S. P. Bakanov and V. I. Roldugin, "On diffusion slip of a gas. I. Calculation of the distribution function of the gas molecules in the Knudsen layer," *Inzh. - Fiz. Zh.*, **40**, No. 5, 807-817 (1981).
2. B. V. Deryagin and S. P. Bakanov, "Toward a theory of gas slip along a solid surface under the influence of a temperature gradient," *Dokl. Akad. Nauk SSSR*, **141**, 384-386 (1961).
3. S. P. Bakanov, B. V. Deryagin, and V. I. Roldugin, "On gas slip along a solid surface under the influence of a temperature gradient," *Dokl. Akad. Nauk SSSR*, **227**, 329-332 (1976).

4. S. P. Bakanov, "On certain integral relations in the kinetic theory of gases," *Zh. Tekh. Fiz.*, **44**, 2625-2629 (1974).
5. H. A. Kramers and J. Kistemaker, "On the slip of a diffusing gas mixture along a wall," *Physica*, **10**, 699-713 (1943).
6. S. P. Bakanov and V. I. Roldugin, "Boundary-value problems of the kinetic theory of gases and irreversible thermodynamics," *Prikl. Mat. Mekh.*, **41**, 651-659 (1977).

THERMODIFFUSIOPHORETIC CAPTURE OF AEROSOL
PARTICLES IN A PLANE CHANNEL WITH NONUNIFORM
TEMPERATURE

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The article theoretically studies the process of capturing aerosol particles from a laminar stream of a binary gas mixture inhomogeneous in temperature and concentration passing through a plane channel with nonuniform temperature.

Aerosol particles are settling in a channel through which passes a stream of a binary gas mixture; its first component consists of molecules of some volatile substance condensing on the lower plate with a temperature T_h that is lower than the temperature of the upper plate T_0 . We examine the case of steady-state motion of the gas stream where we may neglect the influence of the inlet part on the distribution of mass velocity, temperature, and concentration of the components of the gas mixture. The theory of capture is devised for gas mixtures with similar molecular masses where the coefficients of viscosity, thermal conductivity, and diffusion depend only weakly on the concentration of the substances of which the gas mixture is composed. Among such gas mixtures is the steam-air mixture consisting of molecules of air and water vapor.

The aerosol particles entering the channel begin to move toward the surface of the lower plate along a path described by the differential equation of motion of aerosol particles

$$dx/v_x = dz/v_z, \quad (1)$$

where v_x and v_z are the x- and z-components of the velocity of the particles. The velocity of steady-state motion of the particles relative to the channel walls is composed of the velocity of mass motion of the gas \mathbf{u} , the speed of diffusiophoresis due to nonuniform distribution of the concentration \mathbf{v}_D [1, 2], the velocity \mathbf{v}_T due to nonuniform distribution of the temperature T [1, 2], and the gravitational velocity \mathbf{v}_g :

$$\mathbf{v} = \mathbf{u} + \mathbf{v}_D + \mathbf{v}_T + \mathbf{v}_g = \mathbf{u} - \frac{D_{12}f_D}{c_2} \text{grad } c_1 - f_T \frac{\mathbf{v}}{T} \text{grad } T - \frac{2}{9} f_g g \rho_i \frac{R^2}{\rho v} \mathbf{n}_x, \quad (2)$$

where $c_1 = n_1/n$; $c_2 = n_2/n$; $n = n_1 + n_2$; n_1 and n_2 are the concentrations of molecules of the first and second kind, respectively; m_1 and m_2 , molecular masses of the first and second component, respectively; ρ_i , density of the substance of the particle; \mathbf{n}_x , unit vector. The scalar coefficients f_D , f_T , and f_g depend on the geometrical dimensions of the particles, on the phase composition of the substance of the particles, on c_1 , c_2 , T , and on the molecular properties of the gas mixture. We do not present here the explicit form of the expressions for the coefficients f_D , f_T , and f_g because in the general case these expressions have a fairly cumbersome form. The expressions for f_D , f_T , and f_g can be found in [1-4]. In the model of gas flow examined here, the distributions of u_x , u_z , T , and c_1 depend only on the x-coordinate. Therefore $v_z = u_z$, and v_x is described by the expression

$$v_x = u_x + v_{Dx} + v_{Tx} + v_{gx} = u_x + f_D D_{12} \frac{d}{dx} \ln(1 - c_1) - v f_T \frac{d}{dx} \ln T - \frac{2}{9} g f_g \rho_i \frac{R^2}{\rho v}. \quad (3)$$