TRANSPORT PHENOMENA IN A MIXTURE OF MONATOMIC AND POLAR GASES

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A solution of the kinetic equation for the case of diffusion and thermodiffusion in a mixture of a monatomic gas and a polar gas with linear molecules is presented. The quadratic approximation with respect to the molecular nonsphericity parameter is used. Expressions are obtained for the diffusion and thermodiffusion coefficient tensors of the mixture in an electric field. It is shown that the change of the magnitude of the corresponding transport coefficients depends on the field strength and the partial pressure of the polar gas via the parameter E^2/P_1.

THE transport coefficients of gases with nonspherical molecules are changed in magnetic and electric fields.[1-3] The variation of these coefficients depends on the ratio between the precession frequency and the collision frequency of the molecules. The thermal conductivity of a polar gas in an electric field was considered by us previously,[3] where we obtained the dependence of the variation of the coefficient of thermal conductivity on the magnitude of the electric field and the pressure. In the present paper we consider diffusion and thermodiffusion in a mixture of a monatomic gas and a polar gas with linear molecules. The calculation is carried out with the aid of the kinetic equation for a gas with rotational degrees of freedom, as was suggested in the work of Kagan and Afanas'ev.[4]

We write down the kinetic equation for the mixture of a polar gas with linear molecules and a monatomic gas in the form

$$\frac{\partial f_1}{\partial t} + \mathbf{v}_1\nabla f_1 + \dot{\mathbf{M}}\frac{\partial f_1}{\partial \mathbf{M}} = \left(\frac{\partial f_1}{\partial t}\right)_{\text{coll}},$$
$$\frac{\partial f_2}{\partial t} + \mathbf{v}_2\nabla f_2 = \left(\frac{\partial f_2}{\partial t}\right)_{\text{coll}}, \tag{1}$$

where f_1, $\mathbf{v}_1$, f_2, $\mathbf{v}_2$ are the distribution functions and the velocities corresponding to the molecules of the polar and monatomic gases, respectively, and $\mathbf{M}$ is the moment of rotation of the polar molecule. The quantity $\dot{\mathbf{M}}$ is determined by the interaction of the dipole moment of the polar molecule with the electric field. As was shown in [3],

$$\dot{\mathbf{M}} = \frac{5}{4}\frac{\mu^2 I}{M^4}(\mathbf{ME})[\mathbf{ME}]. \tag{2*}$$

Here I is the moment of inertia of the molecule.

We shall seek the approximate solution of the set of equations in the form

$$f_1 = f_1^{(0)}(1+\varphi_1), \quad f_2 = f_2^{(0)}(1+\varphi_2), \tag{3}$$

where $f_1^{(0)}$ is the equilibrium distribution function for a gas with linear rotating molecules,[4] and $f_2^{(0)}$ the Maxwell equilibrium distribution function for a monatomic gas.

By using the conservation laws and assuming that the mean moment of rotations of the mixture of gases is equal to zero, we get a set of equations for the unknown functions φ_1 and φ_2:

$$f_1^{(0)}\left[-\frac{\varepsilon_1}{kT}\frac{2}{(5n_{10}+3n_{20})}\frac{\partial c_{0i}}{\partial r_i} - \left(1 - \frac{5}{(5n_{10}+3n_{20})}\right)\frac{\partial c_{0i}}{\partial r_i} + \frac{m_1}{kT}C_{1i}C_{1k}\frac{\partial c_{0i}}{\partial r_k}\right] + f_1^{(0)}\left(\frac{\varepsilon_1}{kT} - \frac{7}{2}\right)\mathbf{C}_1\nabla\ln T + f_1^{(0)}\frac{1}{n_{10}}\mathbf{C}_1\mathbf{d}_{12} + f_1^{(0)}\dot{\mathbf{M}}\frac{\partial\varphi_1}{\partial\mathbf{M}} = J_{11} + J_{12}, \tag{4}$$

$$f_2^{(0)}\left[-\frac{\varepsilon_2}{kT}\frac{2}{(5n_{10}+3n_{20})}\frac{\partial c_{0i}}{\partial r_i} - \left(1 - \frac{3}{(5n_{10}+3n_{20})}\right)\frac{\partial c_{0i}}{\partial r_i} + \frac{m_2}{kT}C_{2i}C_{2k}\frac{\partial c_{0i}}{\partial r_k}\right] + f_2^{(0)}\left(\frac{\varepsilon_2}{kT} - \frac{5}{2}\right)\mathbf{C}_2\nabla\ln T - f_2^{(0)}\frac{1}{n_{20}}\mathbf{C}_2\mathbf{d}_{12} = J_{22} + J_{21}.$$

Here $\epsilon_1 = m_1C_1^2/2 + M^2/2I$, $\epsilon_2 = m_2C_2^2/2$; $\mathbf{C} = \mathbf{v} - \mathbf{c}_0$ ($\mathbf{c}_0$ is the macroscopic velocity of the mixture of gases); n_1 and n_2 are the number of polar and nonpolar molecules per unit volume; $n_{10} = n_1/n$, $n_{20} = n_2/n$, $n = n_1 + n_2$;

$$\mathbf{d}_{12} = \nabla n_{10} + \frac{n_1n_2(m_2-m_1)}{(m_1n_1+m_2n_2)}\nabla\ln P. \tag{5}$$

J_{pq} are the collision integrals of molecules with indices p and q, having the form

$$J_{pq} = \int f_p^{(0)}f_q^{(0)}(\varphi_p' + \varphi_q' - \varphi_p - \varphi_q)g_{pq}w_{pq}d\sigma_{pq}d\mathbf{\Gamma}_q, \tag{6}$$

where $\mathbf{g}_{pq}$ are the relative velocities of the col-

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*$[\mathbf{ME}] \equiv \mathbf{M}\times\mathbf{E}$.

liding molecules; $d\sigma_{pq}$ is the differential cross section without account of nonsphericity; $d\mathbf{\Gamma}_q$ is the phase volume, $d\mathbf{\Gamma}_1 = C_1^2 dC_1 d\Omega_C M dM d\Omega_M$, $d\mathbf{\Gamma}_2 = C_2^2 dC_2 d\Omega_C$;

$$w_{11} = 1 + \beta_{11}[P_2(\cos \widehat{\mathbf{g}_{11}\mathbf{M}}) + P_2(\cos \widehat{\mathbf{g}_{11}\mathbf{M}_1}) + P_2(\cos \widehat{\mathbf{g}'_{11}\mathbf{M}}) + P_2(\cos \widehat{\mathbf{g}'_{11}\mathbf{M}_1})],$$
$$w_{12} = 1 + \beta_{12}[P_2(\cos \widehat{\mathbf{g}_{12}\mathbf{M}}) + P_2(\cos \widehat{\mathbf{g}'_{12}\mathbf{M}})], \qquad w_{22} = 1; \tag{7}$$

β_{11} and β_{12} are small parameters which take into account the nonsphericity of the interaction of the polar molecules with one another and the nonsphericity of the interaction of the polar molecules with the nonpolar; P_2 is the Legendre polynomial.

The conditions attached to the functions f_1 and f_2,

$$\int f_1 d\mathbf{\Gamma}_1 = n_1, \quad \int f_2 d\mathbf{\Gamma}_2 = n_2, \quad \int f_1 \mathbf{M} d\mathbf{\Gamma}_1 = 0,$$
$$\int f_1 m_1 \mathbf{C}_1 d\mathbf{\Gamma}_1 + \int f_2 m_2 \mathbf{C}_2 d\mathbf{\Gamma}_2 = \rho \mathbf{c}_0,$$
$$\int f_1 \varepsilon_1 d\mathbf{\Gamma}_1 + \int f_2 \varepsilon_2 d\mathbf{\Gamma}_2 = \frac{5}{2} n_1 kT + \frac{3}{2} n_2 kT, \tag{8}$$

lead to a homogeneous relation which φ_1 and φ_2 should satisfy:

$$\int f_1^{(0)} \varphi_1 d\mathbf{\Gamma}_1 = 0, \quad \int f_2^{(0)} \varphi_2 d\mathbf{\Gamma}_2 = 0, \quad \int f_1^{(0)} \varphi_1 \mathbf{M} d\mathbf{\Gamma}_1 = 0,$$
$$\int f_1^{(0)} \varphi_1 m_1 \mathbf{C}_1 d\mathbf{\Gamma}_1 + \int f_2^{(0)} \varphi_2 m_2 \mathbf{C}_2 d\mathbf{\Gamma}_2 = 0,$$
$$\int f_1^{(0)} \varphi_1 \varepsilon_1 d\mathbf{\Gamma}_1 + \int f_2^{(0)} \varphi_2 \varepsilon_2 d\mathbf{\Gamma}_2 = 0. \tag{9}$$

In the consideration of the diffusion, we shall seek the functions φ_1 and φ_2 in the form

$$\varphi_1 = -n\mathbf{D}_1 \mathbf{d}_{12}, \qquad \varphi_2 = -n\mathbf{D}_2 \mathbf{d}_{12}. \tag{10}$$

By substituting (10) in Eq. (4), and taking (22) into account, we get equations which should be satisfied by the unknown functions $\mathbf{D}_1$ and $\mathbf{D}_2$:

$$-\frac{1}{n_1} f_1^{(0)} C_{1i} + \frac{5}{4} \frac{\mu^2 I}{M^4} (\mathbf{ME})[\mathbf{ME}] \frac{\partial D_{1i}}{\partial \mathbf{M}} f_1^{(0)} = J_{11} + J_{12},$$
$$\frac{1}{n_2} f_2^{(0)} C_{2i} = J_{22} + J_{21}. \tag{11}$$

We shall seek an approximate solution of the set of Eqs. (11) in the form[1, 3]

$$D_{1i} = \overset{1}{D}_{1ik} C_{1ik} + \overset{2}{D}_{1ik} C_{1k} \left(C_1^2 - \frac{5}{2} \right) + \overset{3}{D}_{1ik} C_{1k} (M^2 - 1) + \overset{4}{D}_{1ikl} C_{1k} M_l + \overset{5}{D}_{1iklm} C_{1k} \left(M_l M_m - \frac{1}{3} \delta_{lm} M^2 \right),$$
$$D_{2i} = \overset{1}{D}_{2ik} C_{2k} + \overset{2}{D}_{2ik} C_{2k} \left(C_2^2 - \frac{5}{2} \right). \tag{12}$$

(In these expressions, $\mathbf{M}$ and $\mathbf{C}_1$, $\mathbf{C}_2$ are the dimensionless moment and the characteristic velocities of the molecules, which differ from the previous by the factors $\sqrt{1/2IkT}$, $\sqrt{m_1/2kT}$, $\sqrt{m_2/2kT}$, respectively.

We represent the unknown coefficients D_1^p and D_2^q in the form of the following expressions:

$$\overset{p}{D}_{1ik} = D_1{}^p \delta_{ik} + \overset{p}{Y}_{1ik} \qquad (p = 1, 2, 3),$$
$$\overset{4}{D}_{1ikl} = \overset{4}{Y}_{1ikl},$$
$$\overset{5}{D}_{1iklm} = D_1{}^5 (-{}^2/_3 \delta_{ik} \delta_{lm} + \delta_{il} \delta_{km} + \delta_{im} \delta_{kl}) + \overset{5}{Y}_{1iklm},$$
$$\overset{q}{D}_{2ik} = D_2{}^q \delta_{ik} + \overset{q}{Y}_{2ik} \qquad (q = 1, 2), \tag{13}$$

where $\mathrm{Y} = 0$ for $\mathbf{E} = 0$.

To find the coefficients (13), we multiply Eqs. (11) by the corresponding functions of $\mathbf{C}_1$, $\mathbf{C}_2$, and $\mathbf{M}$ from the expansion (12) and integrate over the corresponding phase spaces. By solving the resultant set of equations by the method described in [3], we find the coefficients (13). As will be shown below, the coefficient of diffusion in the electric field is determined only by the quantities D_1^1, D_1^5 and Y_{1ik}^1, where

$$D_1{}^1 = \frac{\Delta_{D1}}{\Delta}, \quad D_1{}^5 = \frac{\Delta_{D5}}{\Delta}, \quad \overset{1}{Y}_{1ik} = \frac{\Delta_1}{\Delta_4} \frac{\Delta_{D5}}{\Delta} \alpha \left(\delta_{ik} + \frac{E_i E_k}{E^2} \right), \tag{14}$$

with

$$\Delta = \begin{vmatrix} \left(T_1{}^{11} - Q^{11} \frac{n_1}{n_2} \sqrt{\frac{m_1}{m_2}} \right) & T_1{}^{21} & \frac{20}{3} T_1{}^{15} & Q^{12} \\ \left(T_1{}^{21} - Q^{21} \frac{n_1}{n_2} \sqrt{\frac{m_1}{m_2}} \right) & T_1{}^{22} & \frac{20}{3} T_1{}^{25} & Q^{22} \\ \left(T_1{}^{51} - Q^{51} \frac{n_1}{n_2} \sqrt{\frac{m_1}{m_2}} \right) & T_1{}^{52} & \left(2T_1{}^{55} - \frac{20}{3} (T_1{}^{35})^2 / T_1{}^{33} \right) & Q^{52} \\ \left(Q^{12} - T_2{}^{21} \frac{n_1}{n_2} \sqrt{\frac{m_1}{m_2}} \right) & Q^{22} & \frac{20}{3} Q^{52} & T_2{}^{22} \end{vmatrix} \tag{15}$$

$$\Delta_{D1} = \begin{vmatrix} \frac{1}{2}\sqrt{\frac{2kT}{m_1}} & T_1^{12} & \frac{20}{3}T_1^{15} & Q^{12} \\ 0 & T_1^{22} & \frac{20}{3}T_1^{25} & Q^{22} \\ 0 & T_1^{52} & \left(2T_1^{55} - \frac{20}{3}(T_1^{35})^2/T_1^{33}\right) & Q^{52} \\ 0 & Q^{22} & \frac{20}{3}Q^{52} & T_2^{22} \end{vmatrix}$$

$$\alpha = \frac{4\gamma^2}{T_1^{55}T_1^{44} + 2\gamma^2}, \qquad \gamma = \frac{1}{96}\frac{\mu^2 n_1^2}{\sqrt{2IkT}}\frac{E^2}{P_1}, \qquad P_1 = n_1 kT. \tag{16}$$

The determinant Δ_{D5} is obtained from Δ by replacement of the third column by the first column of the determinant Δ_{D1}, the determinant Δ_4 is equal to the minor of the element $(2T_1^{55} - {}^{20}/_3(T_1^{35})^2/T_1^{33})$ of the determinant Δ, and Δ_1 is the minor of the element $(T_1^{51} - Q^{51}(n_1/n_2)\sqrt{m_1/m_2})$, divided by ${}^{20}/_3$. (The coefficients T and Q are easily calculated by the method suggested in [1,3].)

To consider thermodiffusion, we shall seek a solution of the set (4) in the form

$$\varphi_1 = -\mathbf{A}_1 \nabla \ln T, \quad \varphi_2 = -\mathbf{A}_2 \nabla \ln T. \tag{17}$$

The functions $\mathbf{A}_1$ and $\mathbf{A}_2$ must satisfy a set of equations which differ from (11) by the fact that in the left side of the first equation, we have $f_1^{(0)} \times (\epsilon_2/kT - {}^7/_2)C_{1i}$ in place of the first term, and in the second equation on the left will be the term $f_2^{(0)}(\epsilon_2/kT - {}^5/_2)C_{2i}$. By substituting $\mathbf{A}_1$ and $\mathbf{A}_2$ in the form of expressions similar to (12), and solving the corresponding set of equations, we can determine the expansion coefficients for $\mathbf{A}_1$ and $\mathbf{A}_2$.

We write down the equation of diffusion[5] in terms of the functions $\mathbf{A}$ and $\mathbf{D}$:

$$C_{1k} - C_{2k} = nd_{12i}\left[\frac{1}{n_1}\int f_1^{(0)}C_{1k}D_{1i}d\Gamma_1 - \frac{1}{n_2}\int f_2^{(0)}C_{2k}D_{2i}d\Gamma_2\right] + \nabla_i \ln T\left[\frac{1}{n_1}\int f_1^{(0)}C_{1k}A_{1i}d\Gamma_1 - \frac{1}{n_2}\int f_2^{(0)}C_{2k}A_{2i}d\Gamma_2\right]. \tag{18}$$

Substituting the expansion (12) in (17), and the corresponding equations for $\mathbf{A}_1$ and $\mathbf{A}_2$, we get

$$C_{1k} - C_{2k} = nd_{12i}\left[\frac{1}{2}\sqrt{\frac{2kT}{m_1}}D_{1ik}^{1} - \frac{1}{2}\sqrt{\frac{2kT}{m_2}}D_{2ik}^{1}\right] + \nabla_i \ln T\left[\frac{1}{2}\sqrt{\frac{2kT}{m_1}}A_{1ik}^{1} - \frac{1}{2}\sqrt{\frac{2kT}{m_2}}A_{2ik}^{1}\right]. \tag{19}$$

We define the diffusion coefficient by means of the relation

$$C_{1k} - C_{2k} = -D_{ik}\frac{n_1 n_2}{n}\nabla_i n_{10}. \tag{20}$$

Since we have $\mathbf{d}_{12} = n^{-1}\nabla n_{10}$, for constant T and P, we obtain, by using (18), an expression for the diffusion coefficient in terms of the expansion

$$D_{ik} = \frac{n_1 n_2}{3n}\left(\frac{1}{2}\sqrt{\frac{2kT}{m_1}}D_{1ik}^{1} - \frac{1}{2}\sqrt{\frac{2kT}{m_2}}D_{2ik}^{1}\right). \tag{21}$$

We define the thermodiffusion coefficient as

$$D_{ik}^{T} = \frac{n_1 n_2}{3n^2}\left(\frac{1}{2}\sqrt{\frac{2kT}{m_1}}A_{1ik}^{1} - \frac{1}{2}\sqrt{\frac{2kT}{m_2}}A_{2ik}^{1}\right). \tag{22}$$

Using these expressions for D_{1ik}^1 and A_{1ik}^1 and the relation (9), we find the value of the coefficients of diffusion and thermodiffusion in the absence of the field, and that part which depends on the field:

$$D_{0ik} = D_0\delta_{ik},$$

$$D_0 = \frac{1}{2}\frac{\Delta_{D1}}{\Delta}\frac{n_1 n_2}{3n}\left(\sqrt{\frac{2kT}{m_1}} + \frac{n_1}{n_2}\sqrt{\frac{m_1}{m_2}}\sqrt{\frac{2kT}{m_2}}\right),$$

$$\frac{(\Delta D)_{ik}}{D_0} = \frac{\Delta_{D5}}{\Delta_{D1}}\frac{\Delta_1}{\Delta_4}\alpha\left(\delta_{ik} + \frac{E_i E_k}{E^2}\right); \tag{23}$$

$$D_{0ik}^{T} = D_0^T\delta_{ik},$$

$$D_0^T = \frac{1}{2}\frac{\Delta_{A1}}{\Delta}\frac{n_1 n_2}{3n^2}\left(\sqrt{\frac{2kT}{m_1}} + \frac{n_1}{n_2}\sqrt{\frac{m_1}{m_2}}\sqrt{\frac{2kT}{m_2}}\right),$$

$$\frac{(\Delta D^T)_{ik}}{D_0^T} = \frac{\Delta_{A5}}{\Delta_{A1}}\frac{\Delta_1}{\Delta_4}\alpha\left(\delta_{ik} + \frac{E_i E_k}{E^2}\right). \tag{24}$$

Here

$$\Delta_{A1} = \begin{vmatrix} 0 & T_1^{12} & \frac{20}{3}T_1^{15} & Q^{12} \\ \frac{5}{4}n_1\sqrt{\frac{2kT}{m_1}} & T_1^{22} & \frac{20}{3}T_1^{25} & Q^{22} \\ \frac{1}{2}n_1\sqrt{\frac{2kT}{m_1}}\frac{T_1^{53}}{T_1^{33}} & T_1^{52} & \left(2T_1^{55} - \frac{20}{3}(T_1^{53})^2/T_1^{33}\right) & Q^{52} \\ \frac{5}{4}n_2\sqrt{\frac{2kT}{m_2}} & Q^{22} & \frac{20}{3}Q^{52} & T_2^{22} \end{vmatrix}.$$

The determinant Δ_{A5} is obtained from Δ (15) by replacement of the third column by the first column of the determinant Δ_{A1}.

Thus the expressions (23) and (24) show that the coefficients of diffusion and thermodiffusion of a mixture of polar and monatomic gases become anisotropic in an electric field. The tensors D_{ik} and D^T_{ik} are identical in form with the thermal conductivity tensor of a polar gas in an electric field.[3] Apparently, there will be a similar tensor dependence in all the transport coefficients of polar gases, computed in the quadratic approximation from the parameter of nonsphericity of the molecular interaction.

The anisotropy of the coefficients of diffusion and thermodiffusion leads to the appearance of diffusion and thermodiffusion currents in directions perpendicular to the directions of the concentration and temperature gradients if the field makes angles with the latter that are different from 0 to 90°. The dependence of the coefficients of diffusion and thermodiffusion on the values of the field and pressure is determined by the values α of (16). As is seen from (16), (23) and (24), for constant temperature and fixed composition, the change in the coefficients of diffusion and thermodiffusion of a mixture of polar and nonpolar gases is determined by the ratio E^2/P_1, where P_1 is the partial pressure of the polar gas. The dependence of α on the composition reflects the fact that the effect is determined by the relation between the precession frequency of the polar molecules and the frequency with which the precessing molecules collide with one another or with the other molecules.

From Eqs. (23) and (24) we find the relative change in the coefficients of diffusion and thermodiffusion in the case in which the field is parallel to the gradients of concentration and temperature:

$$\left(\frac{\Delta D}{D_0}\right)_{\parallel} = 2\alpha\frac{\Delta_{D5}}{\Delta_{D1}}\frac{\Delta_1}{\Delta_4}, \quad \left(\frac{\Delta D^T}{D_0{}^T}\right)_{\parallel} = 2\alpha\frac{\Delta_{A5}}{\Delta_{A1}}\frac{\Delta_1}{\Delta_4}. \tag{25}$$

The relative change of the thermodiffusion ratio in this case is

$$\left(\frac{\Delta k^T}{k_0{}^T}\right)_{\parallel} = 2\alpha\frac{\Delta_1}{\Delta_4}\left(\frac{\Delta_{A5}}{\Delta_{A1}} - \frac{\Delta_{D5}}{\Delta_{D1}}\right). \tag{26}$$

For sufficiently large values of the ratio E^2/P_1, the quantity $\alpha \rightarrow 2$ and the effect reaches saturation.

In order to study the signs of the relative changes of the coefficients of diffusion and thermodiffusion , and the dependence of the effects on the composition of the mixture, it is necessary to substitute the values of the coefficients T and Q in the determinants in (25) and (26). Doing this, we get

$$\frac{\Delta_{A5}}{\Delta_{A1}} = \frac{1}{x}\,\frac{a_1x^4 + a_2x^3 + a_3x^2 + a_4x + a_5}{b_1x^3 + b_2x^2 + b_3x + b_4},$$

$$\frac{\Delta_{D5}}{\Delta_{D1}} = \frac{c_1x^4 + c_2x^3 + c_3x^2 + c_4x + c_5}{d_1x^4 + d_2x^3 + d_3x^2 + d_4x + d_5},$$

$$\frac{\Delta_1}{\Delta_4} = \frac{e_1x^3 + e_2x^2 + e_3x}{f_1x^3 + f_2x^2 + f_3x + f_4} \tag{27}$$

where $x = n_2/n_1$.

The coefficients a_i, b_i, c_i, d_i, e_i, f_i are unwieldy expressions that depend on the mass, the diameters of the molecules, the potentials of the intermolecular interaction, and the nonsphericities β_{11} and β_{12}. Using (23), (24), and (27) one can show that the thermodiffusion ratio and the value of its increment Δk^T in the field tend to zero when the concentration of polar or monatomic gases tends to zero.

In the case of limiting values of the concentration ($n_1 = 0$ and $n_2 = 0$), the diffusion coefficient has corresponding zero limiting values. The change in the diffusion coefficient in the field vanishes when the concentration of the monatomic gas vanishes, and takes on a non-zero value when the concentration of the polar gas goes to zero.

Let us consider the case of molecular masses that are close to one another. By substituting the values of the coefficients T and Q in the corresponding determinants and setting $m_1 = m_2$, we find that b_1 and $b_2 < 0$, $b_4 > 0$, while b_3 will be positive or negative depending on the parameters of the molecules. Therefore, the polynomial with the coefficients b_i takes on a zero value for some value n_2/b_1. But, since this polynomial is equal to $\Delta_{A1}(\Omega^{11}_{11} + x\Omega^{11}_{12})$ and $k_0^T \sim \Delta_{A1}$, the zero point corresponds to the inversion of the thermodiffusion ratio of the mixture of gases as a function of the composition. A change in the sign of k^T with change in the composition of the mixture was observed by Clusius and Flubacher in their study of thermodiffusion in the system Ar^{40}-DCl^{37}.[6] Calculation of α_T as a function of the composition of this mixture was carried out by Mason and Monchick[7] under the assumption that the interaction of the polar molecules with one another obeys the Stockmayer potential, while the mutual orientation of the dipoles in the collision is fixed and equally probable; however, the resultant $\alpha_T(n_2/n_1)$ curve did not have a zero point.

If the coefficient of nonsphericity of the interaction of the polar molecules with one another is known (it can be found from the measurement of the thermal conductivity of the pure polar gas in an electric or magnetic field), then the experimentally determined value of n_2/n_1 corresponds to the inversion point, and allows us to compute the coefficient of nonsphericity of the interaction of the polar molecules with the molecules of the monatomic gas from the equation $k_0^T = 0$. Moreover, β_{12} can be found from measurement of the diffusion coefficient and the thermodiffusion constant of the mixture in an electric field. Use of these two independent methods obviously makes it possible to understand the nature of the nonsphericity of the interaction of the polar and nonpolar molecules, and also to make clear the suitability of the considered model of interaction of the molecules for the description of the transport properties of the mixtures of polar and monatomic gases.

In the case $m_1 = m_2$, the coefficients d_i, e_i, $f_i > 0$, while a_i, $c_i < 0$ for arbitrary diameters of the molecules and nonsphericities. From Eqs. (25) and (26) it follows that the diffusion coefficient and the thermodiffusion ratio of the mixture of monatomic and polar gases with masses that are nearly the same are decreased in an electric field. At the inversion point, the thermodiffusion ratio in the electric field is determined completely by the collision-cross-section change due to the nonsphericity of the interactions β_{11} and β_{12}.

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