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Temperature Dependence of Thermal Diffusion Factors in Ne—CO_2 Mixture

Zależność stałej termodyfuzji od temperatury dla mieszaniny Ne—CO_2

Зависимость коэффициента термодиффузии от температуры для смеси Ne—CO_2

Chapman-Enskog kinetic theory of homogenous gases, which also contains the theory of thermal diffusion is strictly valid only for the molecules that do not possess internal degrees of freedom. Monoatomic gases have this kind of molecules, but Chapman-Enskog theory also describes the transmission phenomena in polyatomic gases fairly well, though in some cases the discrepancies between the theory and experimental data become too considerable (e.g. in case of thermal conductivity and thermal diffusion). The discrepancies can be explained by the occurrence of inelastic collisions among molecules [1]. Inelastic collisions were introduced into Chapman-Enskog theory for homogenous gases by Wang-Chang and Uhlenbeck [2] and Taxman [3]. The theory was adapted to the mixtures of gases by Monchik et al. [4, 5, 6]. Their considerations give the definitions of viscosity, diffusion, thermal conductivity and thermal diffusion coefficients in the form required by the first approximation of classical Chapman-Enskog theory. The comparison between the theory including the inelastic collisions and experimental data showed that the influence of these collisions is very small, especially in case of viscosity [7, 8], but in some cases the influence becomes distinct e.g. for thermal diffusion [9, 10]. The fact can be explained by the special sensibility of the phenomenon on intermolecular forces.

Considerable discrepancies between the experimental data and the data obtained from the theoretical calculations taking into consideration the inelastic collisions, can be explained only by the lack of satisfactory theory introducing inelastic collisions into thermal diffusion phenomena.

It is obvious that the influence of inelastic collisions should be shown more distinctly, especially in case of mixtures containing the molecules of the symmetry basically different from the spherical one. For instance, the gaseous mixtures containing carbon dioxide can be used. And thus, the authors of the paper [12] who examined the dependance of thermal diffusion constant on temperature for $Ne-CO_2$ mixture in the presence of helium as a third component, found the distinct discrepancy between the theoretical and experimental data and explained it by the participation of inelastic collisions.

It seemed interesting and useful to examine the above described conclusions in case of pure, two-component $Ne-CO_2$ mixture. The measurements were carried out with the use of the "two-bulb" apparatus described in the paper [11].

The coefficient of thermal diffusion was found for three different temperatures of the heated bulb ($T_1 = 373°K$, 423°K, 453°K). The temperature of the cold bulb was constant and amounted to $T_0 = 293°K$. Thermal diffusion coefficient was calculated according to the formula:

$$\alpha = \frac{\Delta C}{C_1 \cdot C_2 \ln \frac{T_1}{T_0}}$$

where: c_1, c_2 — initial concentrations of both components, $\Delta c = c_2^0 - c_2^1$, c_2^0 — concentration of the heavier component in the cold bulb, c_2^1 — concentration of the heavier component in the hot bulb. The constant α thus calculated is the mean value for the temperature interval $T_1 - T_0$, and the precise value, as it was shown by B r o w n [13], for a determined temperature of the interval, which can be calculated from the formula:

$$\bar{T} = \frac{T_0 \cdot T_1}{T_1 - T_0} \ln \frac{T_1}{T_0}$$

Neon of spectral purity from VEB Technische Gase-Werke Bln.-Niederschöneweide was used in the experiments. Carbon dioxide was produced in Kipps apparatus in which calcium carbonate was treated with hydrochloric acid.

The results of the measurements of the thermal diffusion coefficient α of $Ne-CO_2$ mixture are given in Table 1 and presented diagrammaticaly in Figure 1. The Figure 1 contains also the results from paper [12] for comparison.

Table 1. Thermal difusion constant α v.s. temperature of Ne-CO_2 mixture

Ne—CO_2	$\overline{T}$[°K]		
	329,2	349,3	361,9
α	−0,046	+0,047	+0,095

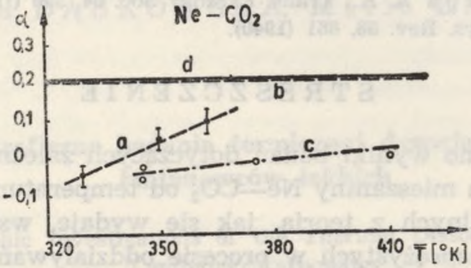

Fig. 1. Dependence of thermal diffusion constant α on temperature for Ne—CO_2; a — experimental data for Ne—CO_2 system, b — Chapman-Enskog theoretical curve for Ne—CO_2, c — experimental data for Ne—CO_2+He system [12], d — Van der Valk theoretical curve for Ne—CO_2+He system

It can be easily seen that the process of thermal diffusion in the described mixture depends significantly on temperature, up to the reversal of sign of the coefficient α inclusively (which means the accumulation of the excess of heavier component in the hot part of the apparatus). Besides, the results obtained for the two-component Ne—CO_2 mixture differ only slightly from those presented in paper [12] for Ne—CO_2+He system. Both experimental curves, however, deviate distinctly from the theoretical ones. This can be explained by the considerable share of inelastic collisions of (1—2) and (2—2) type in the thermal diffusion process, additionally complicated by the quadrupolar momentum of carbon dioxide molecule.

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STRESZCZENIE

W pracy opisano wyniki badań dotyczących zależności współczynnika termodyfuzji α dla mieszaniny Ne—CO_2 od temperatury. Porównanie wyników doświadczalnych z teorią, jak się wydaje, wskazuje na znaczny udział zderzeń niesprężystych w procesie oddziaływań międzycząsteczkowych w badanej mieszaninie.

РЕЗЮМЕ

Исследовали зависимость коэффициента термодиффузии от температуры для смеси Ne—CO_2. Сравнение экспериментальных результатов с теорией указывает на значительное участие неупругих столкновений в процессе межмолекулярных взаимодействий в исследованной смеси.

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