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Abstract

Full Text

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PHYSICS

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On the Question of the Existence of a “Negative” Enrichment Effect in the Thermal Diffusion of Gases in Porous Media

(Presented by Academician I. K. Kikoin on 25 VII 1962)

In work (1), in studying thermal diffusion in capillaries in the transitional pressure region ($\lambda \sim d$, where λ is the mean free path of the molecules and d is the diameter of the capillary), a “negative” enrichment effect was observed, consisting in an increase in the concentration of the light component at the cold end of the capillary. The authors of (1) suggested the possibility of detecting this effect also when porous media are used instead of a capillary.

We investigated the effect of separation of the gas mixtures H_2—Ar, H_2—Kr, He—Kr, arising when they move through a porous medium in the presence of a temperature gradient (the layout of the apparatus is shown in Fig. 1).

As is known (2), in the molecular and transitional pressure regions, owing to the phenomenon of thermal transpiration, in two volumes V_1 and V_2, separated by a porous partition and maintained at different temperatures T_1 and T_2, a pressure difference is established. One may imagine that in this case there simultaneously exist two kinds of flow of the gas mixture as a whole: one caused by the temperature gradient, the other, oppositely directed, by the pressure gradient.

Fig. 1. Schematic of the experimental apparatus. 1 —working chamber; 2 —porous medium; 3 —heating jacket; 4 —cooling jacket.

Fig. 2

Figure 2: Fig. 2

Measurements of the separation effect were carried out by us both in this case (this corresponded to the conditions under which the "negative" enrichment effect was observed in work (^{1})) and in the case where the pressure gradient was reduced to zero by means of a special "return" tube connecting the volumes V_1 and V_2 and possessing a sufficiently large diffusion resistance and a small "hydraulic"resistance. In the latter case, in work (^{1}), the so-called "positive"effect was observed (enrichment of the mixture with the light component occurred in the "hot" vessel).

The principal qualitative difference of our experimental apparatus from that described in work (^{1}) was the careful thermostating of both working volumes V_1 and V_2, in such a way that their temperature did not differ from the temperature of the corresponding outer surface of the porous specimen; i.e., in the working volumes there were no temperature drops of any kind.

The porous specimen was connected to the volumes directly, without any transitional communications whatsoever.

Barium ferrite ($BaO \cdot 6Fe_2O_3$) was used as one of the specimens. The effective pore radius was determined from the ratio of viscous and molecular fluxes, measured experimentally (3). The initial concentrations of the mixtures were chosen equal to $C_0 = 50\%$. The composition of the mixture was analyzed with a thermal detector based on measurement of thermal conductivity. The accuracy of the analysis was ±0.15% (absolute). In Fig. 2, as an example, the dependence is given of the separation effect $\Delta C = C_{\text{hot}} - C_{\text{cold}}$ on the ratio d/λ for an H_2 –Ar mixture when a pressure gradient and a temperature gradient simultaneously exist along the porous specimen; in Fig. 3 the same dependence is shown when only a temperature gradient is present. It is seen that in the first case the effect is "positive" over the entire pressure range and goes to zero at $P_0 = 0$. In the second case the effect decreases monotonically with increasing pressure from its maximum value at $P_0 = 0$, although even at relatively high pressures it remains greater than the effect corresponding to ordinary thermal diffusion in free space (4). Results obtained for H_2–Kr and He–Kr mixtures and for other porous specimens do not differ from those shown in Figs. 2 and 3.

Fig. 2. Dependence of separation on the value of the ratio d/λ for an H_2–Ar mixture (50% H_2). Along the porous medium there simultaneously exist a temperature gradient and a pressure gradient. $T_1 = 473$°K, $T_2 = 298$°K. Curve **1**–the gas temperature in the working chambers coincides with the temperature of the corresponding end surfaces of the porous medium; **2**–reverse temperature differences exist in the working volumes.

The "negative" effect in thermal diffusion in a porous medium is not observed. Most likely, this effect, described in (1) and also observed in (5), was caused by

Fig. 3

Figure 3: Fig. 3

the presence of "parasitic" reverse temperature differences in the experimental setups used in those works. We carried out direct experiments confirming this supposition (curve 2 in Fig. 2). It is not excluded, however, that the possibility also exists that a partially "negative" effect is associated with the specific motion of a gas mixture in long capillaries.

Fig. 3. Dependence of separation on the value of the ratio d/λ for an H_2–Ar mixture (50% H_2). Along the porous medium there exists only a temperature gradient. $T = 477°K$, $T_2 = 295°K$.

Our experimental results agree well with the theory developed earlier by Yu. M. Kagan, to whom the initiative in setting up these experiments belongs.

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