THERMODIFFUSION RATIO IN A TRINARY MIXTURE WITH IONIZATION. HELIUM PLASMA [[1]](#footnote-1)\*)

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Investigations of the arc discharge He plasma at atmospheric pressure in a narrow channel [1] led to the need to calculate the fluxes and diffusion coefficients using the gas kinetic theory [2]. One of the diffusion processes occurring in non-isotropic media with temperature gradients is thermal diffusion. Its properties in ionized helium are investigated in the present work.

Thermal diffusion refers to second-order transport phenomena, but in the first approximation of the Chapman-Enskog theory, the thermal diffusion ratios Ki can be found relatively simply. They are determined by linear combinations of the integral brackets of the Sonin polynomials $Λ\_{ij}^{01}$ and $Λ\_{ij}^{11}$ [2]. To find them in a trinary mixture, it is necessary to solve 3 systems of linear equations with 3 unknowns in each. The task is extremely simplified in an ionized simple gas (indices: 1 - electron, 2 - ion, 3 - atom):

$\frac{2}{5}$K1=-х1$(Λ\_{21}^{01}+Λ\_{31}^{01})/Λ\_{11}^{11}$, (1)

$\frac{2}{5}$K2= х1$\frac{Λ\_{21}^{01}}{Λ\_{11}^{11}}$ + $Λ\_{23}^{01}\frac{x\_{2}(Λ\_{23}^{11}+Λ\_{33}^{11})-x\_{3}(Λ\_{23}^{11}+Λ\_{22}^{11})}{(Λ\_{23}^{11})^{2}-Λ\_{22}^{11}Λ\_{33}^{11}}$ , (2)

$\frac{2}{5}$K3= х1$\frac{Λ\_{31}^{01}}{Λ\_{11}^{11}}$ - $Λ\_{23}^{01}\frac{x\_{2}(Λ\_{23}^{11}+Λ\_{33}^{11})-x\_{3}(Λ\_{23}^{11}+Λ\_{22}^{11})}{(Λ\_{23}^{11})^{2}-Λ\_{22}^{11}Λ\_{33}^{11}}$ . (3)

In contrast to a binary mixture, ions and atoms have electronic components - these are the first terms of the right-hand sides of (2), (3). With strong ionization, the electronic component for atoms is small, and with weak ionization, it is small for ions. The second term of the right-hand sides of (2), (3) is unchanged in the transition to binary mixtures. This is the main component of K2 and K3, let's call it binary Kb, which determines the diffusion fluxes, although in magnitude it is comparable to the electronic component of thermal diffusion K1. The latter accelerates the diffusion of ions and slows it down for electrons, but is not important for the entire electron-ion gas included in the binary mixture with atoms, so that the electronic components do not affect the diffusion fluxes of ions and atoms. For ionized He, the second terms of the right-hand sides of (2), (3) give us[2]:

Kb≈ -0.16(x2+0.03x3)/(x2/x3+0.013x3/x2+0.23). (4)

Small numerical coefficients for atomic components are negligible for strong ionization. The Coulomb cross sections cancel each other out, as in (1). The other cross sections weakly depend on the energy. In a weakly ionized plasma, Coulomb collisions can be neglected altogether, so that the hard sphere model is practically always applicable.

In helium, the binary component has its maximum at x1≈0.2. As x1 increases, the thermal diffusion relations become simpler: Kb≈-x3/6.2→0, K1≈-x1/6.5→-1/13. With complete ionization, the binary component is insignificant, and the electronic component is maximum.

In a weakly ionized plasma (x1<<0.02), all thermal diffusion ratios are small, K2≈-Kb, and terms with small numerical coefficients predominate in (4). In He, the electronic and binary components are almost the same: K1≈Kb≈- x1/2.6, so that K3=Kb-K1≈0 - thermal diffusion of atoms, as in the approximation of strong ionization, stops.

References

1. Korshunov, O.V., Chinnov, V.F. & Kavyrshin, D.I. Highly Ionized Arc He Plasma: Nonequilibrium, Nonideality, and Kinetics. High Temp 57, 147–155 (2019). <https://doi.org/10.1134/S0018151X18060147>
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1. \*) [abstracts of this report in Russian](http://www.fpl.gpi.ru/Zvenigorod/L/Lt/ru/FK-Kavyrshin.docx) [↑](#footnote-ref-1)