1 Variables

Variable	Description	Value	Unit
π	Ratio of circle circumference to diameter	3.1416	–
k_B	Boltzmann's Constant	$1.38066 \cdot 10^{-23}$	JK^{-1}
m_e	Electron mass	$9.11{\cdot}10^{-13}$	kg
h	Planck's constant	$6.62618{\cdot}10^{-34}$	J s
k_{ion}	Ionization rate		m^3s^{-1}
E_{ion}	Ionization energy		J
T_e	Electron temperature		K
T_h	Heavy particle temperature		K
m_h	Particle mass		kg
σ_{aa}	Heavy-heavy collision cross section		m^2
σ_{ia}	Ion-heavy collision cross section		m^2
λ_h	Heavy particle heat conductivity		$JK^{-1}m^{-1}s^{-1}$
q	Exponent in Arrhenius		–
k_{rate}	Arrhenius reaction rate coefficient		m^3s^{-1}
k_{rec}	Recombination rate		m^3s^{-1}
k_{heat}	Heat transfer		$J\ m^{-3}s^{-1}$
G	Ratio of degeneracy of ion and ground state		–
n_a	Heavy particle density		m^{-3}
n_e	Electron density		m^{-3}
τ_{ia}	Ion-atom collision time		s
ν_{ea}	Volumetric electron-atom collision frequency		m^3s^{-1}
D_i	Ion diffusion coefficient		m^2s^{-1}
D_{amb}	Ambipolar diffusion coefficient		m^2s^{-1}
c_p	Isobaric heat capacity per cubic meter		$J\ K^{-1}m^{-3}$
c_v	Isochoric heat capacity per cubic meter		$J\ K^{-1}m^{-3}$

2 Equations

2.1 Low to moderate ionization (<1%)

Heat conductivity (Heavy particles)

$$\sqrt{\frac{8k_BT_h}{\pi m_h}}\frac{\sqrt{2}}{\sigma_{aa}}k_B \tag{1}$$

Ionization rate (Arrhenius, single-step; Mind the normalization of T_e in T_e^q)

$$k_{ion} = k_{rate}T_e^q \exp\left(\frac{-E_{ion}}{k_BT_e}\right) \tag{2}$$

Recombination rate

$$k_{rec} = (\frac{h}{\sqrt{2\pi m_e k_B T_e}})^3 \frac{k_{rate}}{2G}T_e^q \tag{3}$$

Atom collision time for one ion

$$\tau_{ia} = \sqrt{\frac{\pi m_a}{8k_BT_h}}\frac{1}{\sigma_{ai}n_a} \tag{4}$$

Diffusion coefficient

$$D_i = \frac{k_B T_h}{M} \tau_{ia} \tag{5}$$

Ambipolar diffusion

$$D_{amb} = D_i (1 + \frac{Te}{Th}) \tag{6}$$

Collision frequency

$$\nu_{ea} = n_e n_a \sigma_{ea} \sqrt{\frac{8 k_B T_e}{\pi m_e}} \tag{7}$$

Electron-heavy particle heat transfer

$$k_{heat} = \nu_{ea} \frac{3 m_e}{m_a} k_B (T_e - T_h) \tag{8}$$

Isobaric heat capacity of a single type of particle n:

$$c_p = \frac{5}{2} k_B n \tag{9}$$

Isochoric heat capacity of a single type of particle n:

$$c_v = \frac{3}{2} k_B n \tag{10}$$

warning:

The equations in this document are only approximately valid, and only for a limited parameter range, while containing undocumented assumptions. If you are looking for formulas for scientific use, it is suggested you look elsewhere.