Air Ions and Aerosol Science

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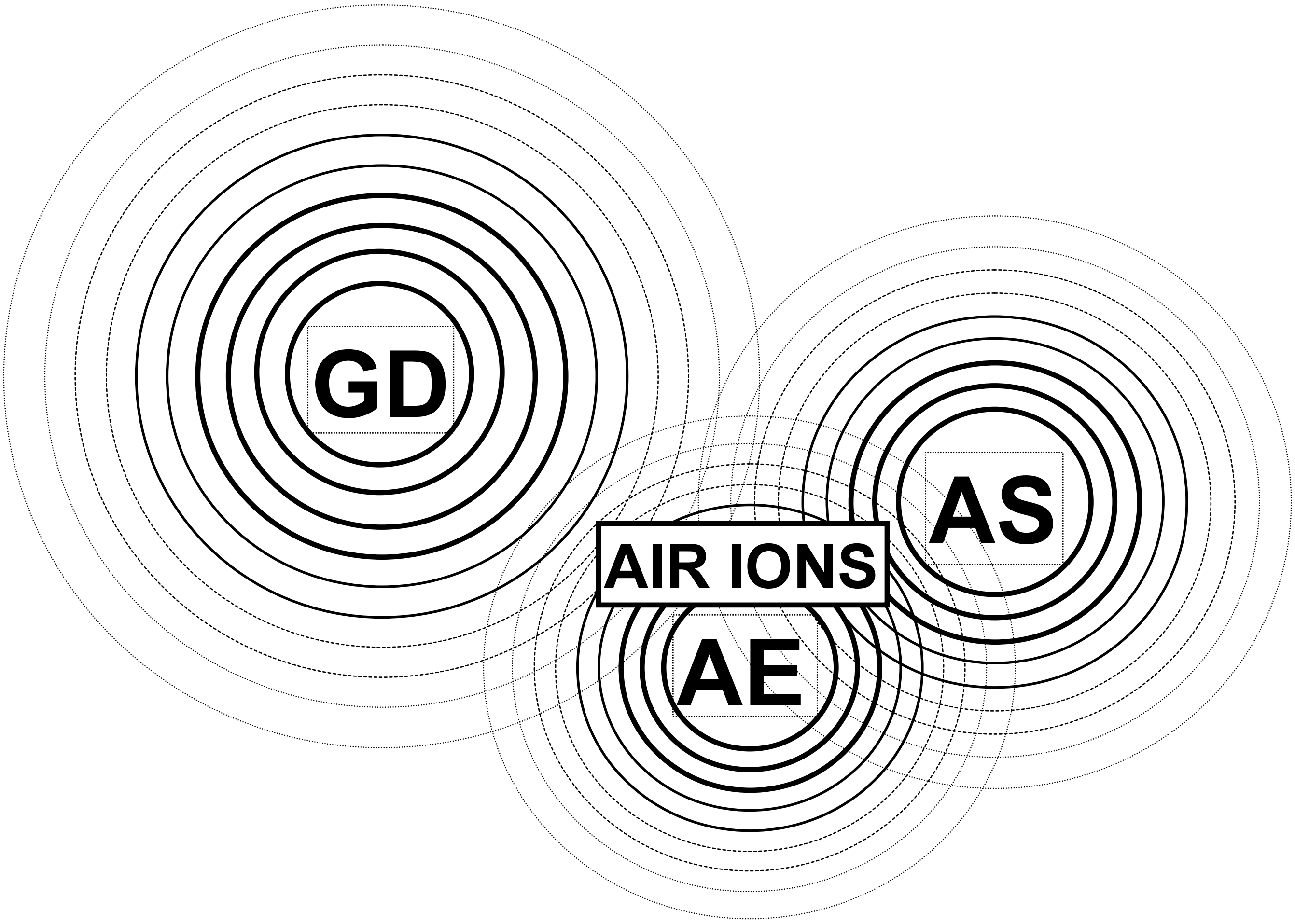
Abstract. Collaboration between Gas Discharge and Plasma Physics, Atmospheric Electricity, and Aerosol Science is a factor of success in the research of air ions. The concept of air ion as of any carrier of electrical current through the air is inherent to Atmospheric Electricity under which a considerable statistical information about the air ion mobility spectrum is collected. A new model of air ion size-mobility correlation has been developed proceeding from Aerosol Science and joining the methods of neighboring research fields. The predicted temperature variation of the mobility disagrees with the commonly used Langevin rule for the reduction of air ion mobilities to the standard conditions. Concurrent errors are too big to be neglected in applications. The critical diameter distinguishing cluster ions and charged aerosol particles has been estimated to be 1.4–1.8 nm.

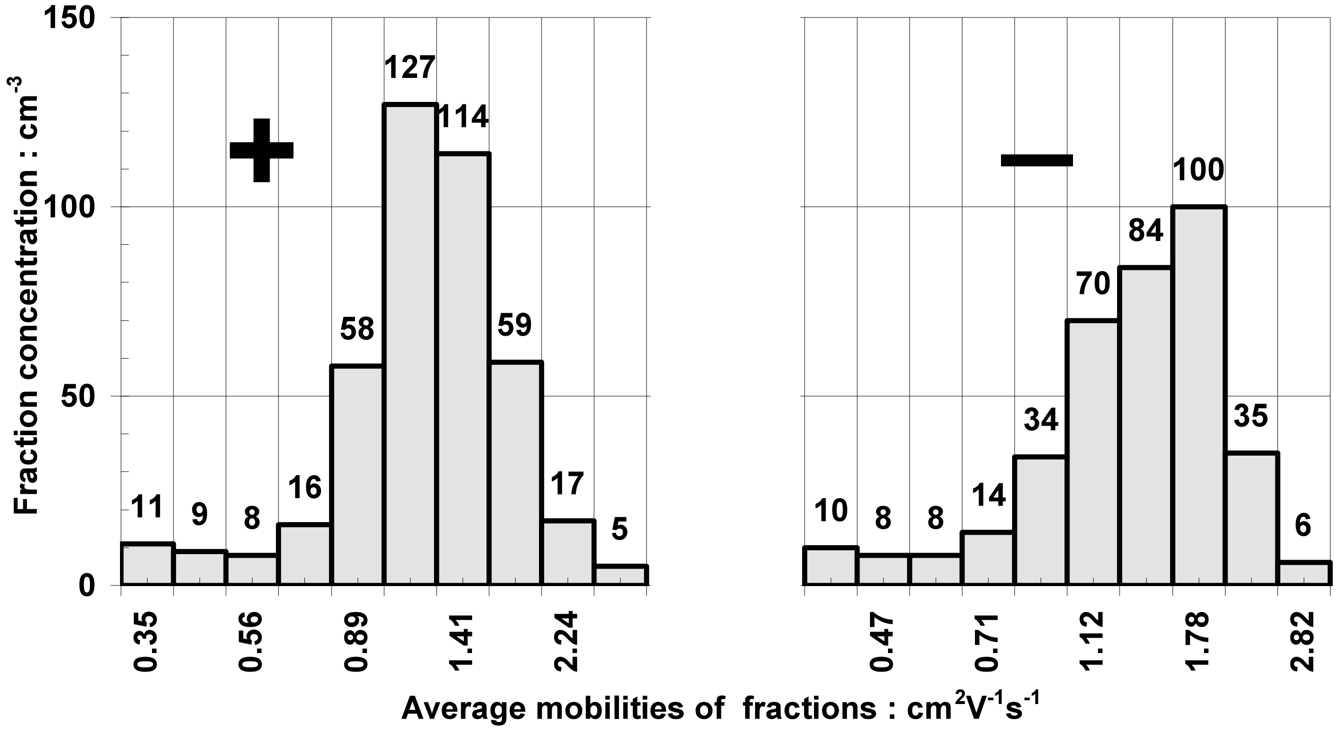


An illustration of the expanding research fields
and of the position of air ions as a common research subject.

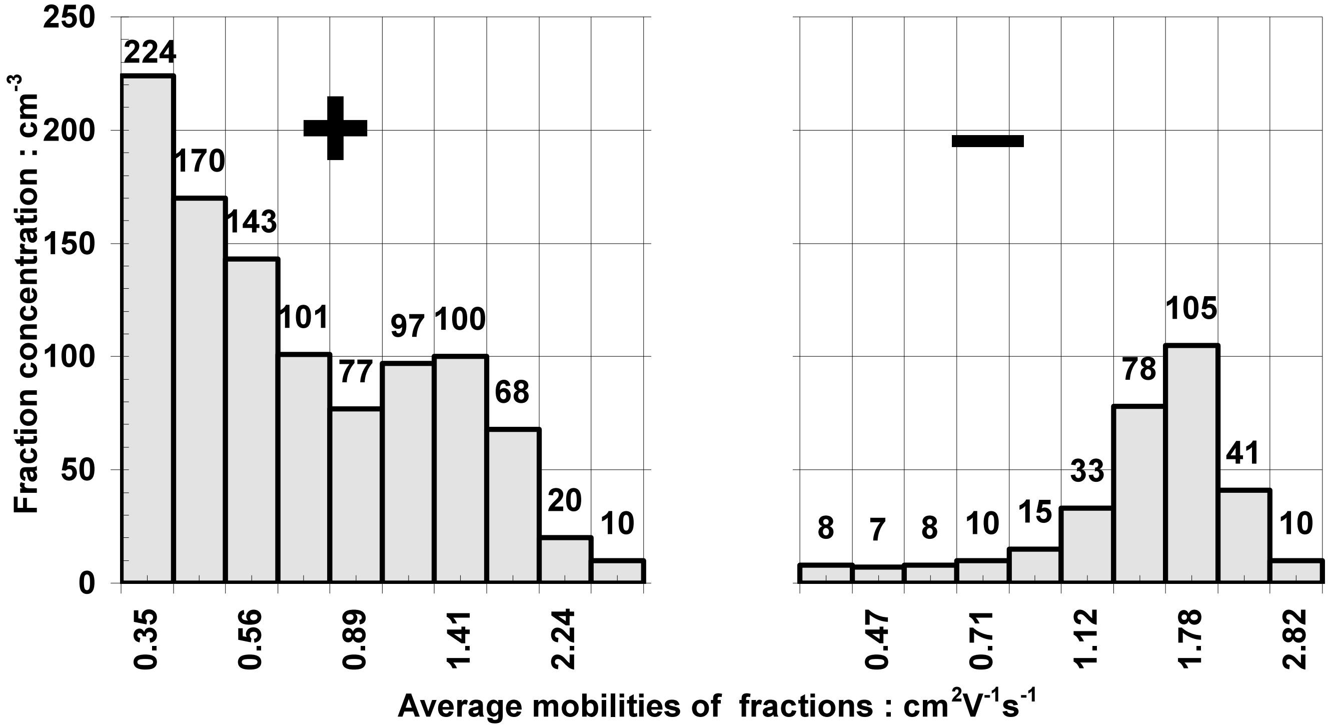
GD – Gas Discharge and Plasma Physics,

AE – Atmospheric Electricity,

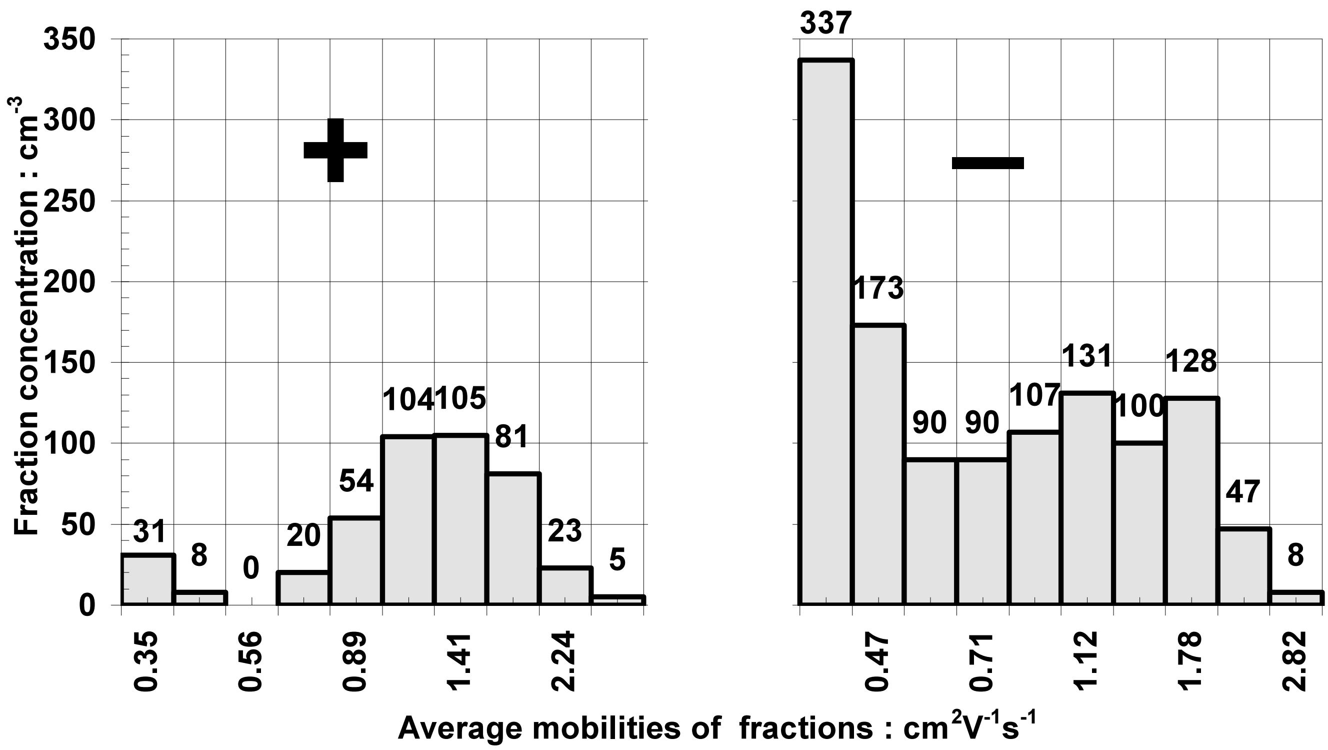
AS – Aerosol Science.



The average spectrum of positive and negative air ions with the mobility of 0.32–3.2 $cm^2V^{-1}s^{-1}$ in a rural observatory Tahkuse, Estonia during June–September 1985.



Hourly average 13 June 1985 at 03 a.m.



Hourly average 05 September 1985 at 05 p.m.

Tammet, H., "Size and mobility of nanometer particles, clusters and ions", *J. Aerosol Sci.* **26**, 459–475 (1995)

The basic features of the size-mobility correlation model:

◊ The interaction between an air ion and ambient gas molecule is described by the (∞ – 4) potential, where the collision distance is written as a sum of three addends: the collision radius of the gas molecule, the mass radius of the air ion and an extra distance that is completing the mass radius to fit the collision radius of the air ion.

◊ The collision radius of the gas molecule is considered to depend on the temperature as in the Chapman-Hainsworth model, and on the energy of the polarization interaction.

◊ The extra distance is regarded as an empirical parameter that should be estimated fitting the model to the experimental data.

◊ The transition from the elastic collisions specific of molecules to the inelastic collisions specific of macroscopic particles is described using the Einstein factor of "melting" of the particle internal energy levels.

◊ The model is written as Millikan equation completed by additional factors describing the transition to the Chapman-Enskog equation in the microscopic limit.

$$K \approx \left(\sqrt[3]{\frac{1210\mathrm{u}}{m}} - 0.21 \right) \mathrm{cm^2V^{-1}s^{-1}}$$

$$d_m = \sqrt[3]{\frac{6m}{\pi\rho}}$$

$$K_{\mathrm{reduced}} = K_{\mathrm{measured}} \frac{273.15\mathrm{K}}{T} \frac{p}{101325\mathrm{Pa}}$$

$$K_{\mathrm{measured}} \rightarrow d \rightarrow K_{\mathrm{reduced}}$$

$$\left.\begin{aligned} x &= \frac{\Delta E}{kT} = \frac{273\mathrm{K}}{T}\left(\frac{r_{\mathrm{cr}}}{r_{\mathrm{m}}}\right)^3 \\ s &= 1 + (s_\infty - 1)x^2\mathrm{e}^x \big/ (\mathrm{e}^x - 1)^2 \end{aligned}\right\}$$

$$\Omega_{\infty-4}^{(1,1)*} = \begin{cases} \text{if} \quad T^* \le 1 \\ \text{then} \quad 1.4691 \times T^{*-1/2} - 0.341 \times T^{*-1/4} + 0.185 \times T^{*5/4} + 0.059 \\ \\ \text{if} \quad T^* \ge 1 \\ \text{then} \quad 1 + 0.106 \times T^{*-1} + 0.263 \times T^{*-4/3} \end{cases}$$

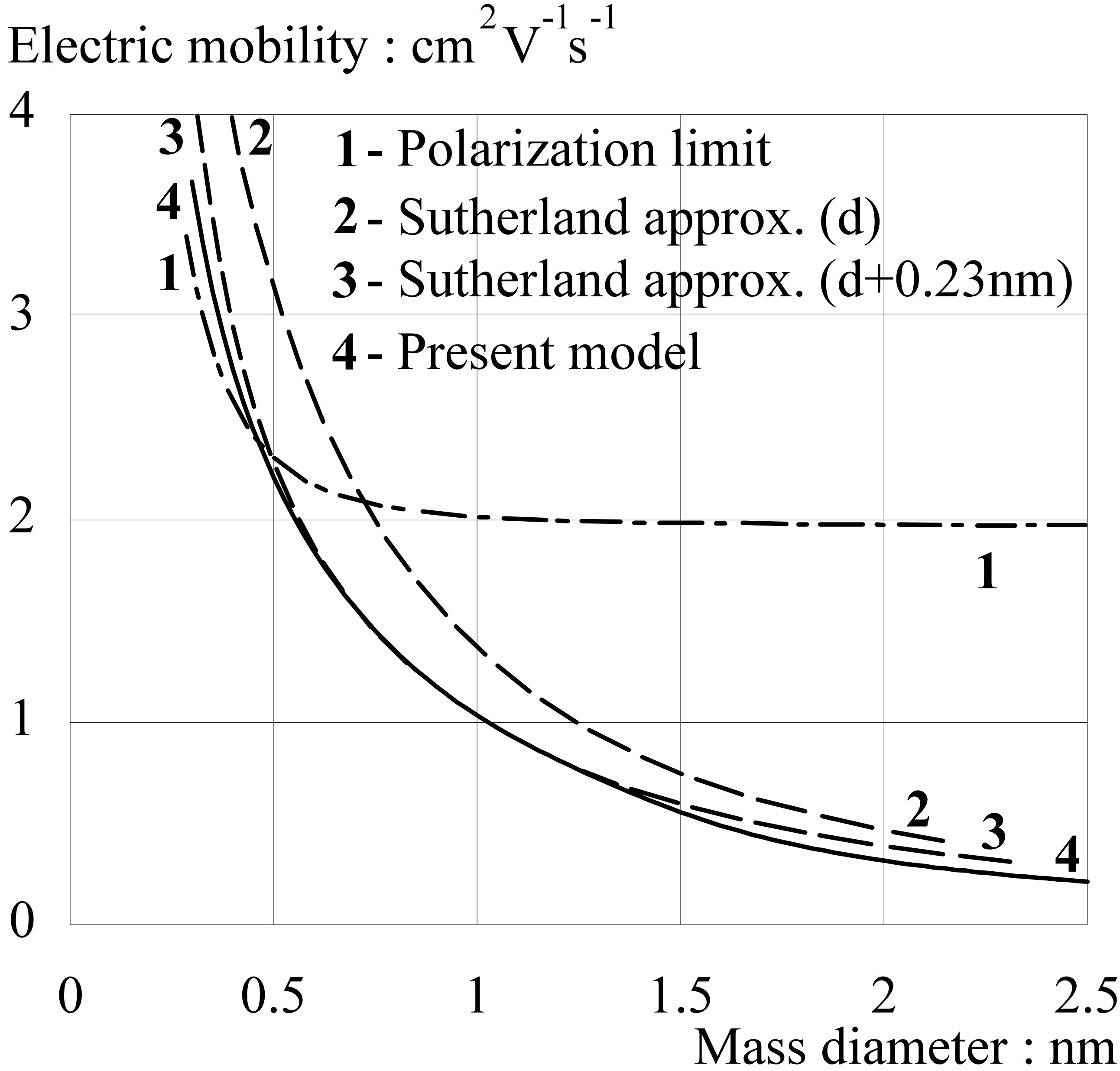
$$B = f_1 f_2 \frac{1 + \frac{l}{\delta}\left[a + b\exp\left(-c\frac{\delta}{l}\right)\right]}{6\pi\eta\delta}$$

$$\delta = r_{\mathrm{m}} + h + r_{\mathrm{g}}(T_\delta)$$

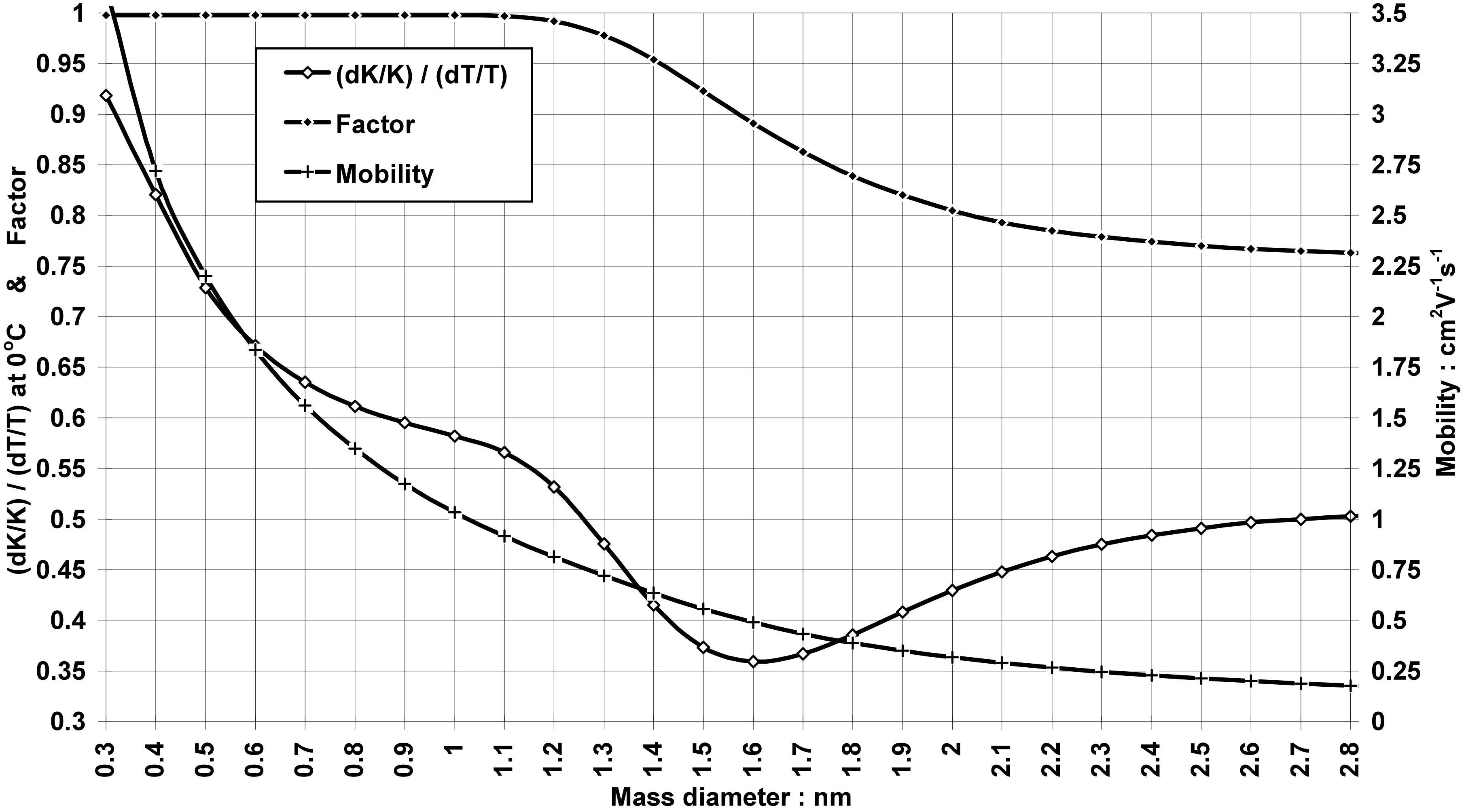
$$f_1 = \sqrt{1 + \frac{m_{\mathrm{g}}}{m_{\mathrm{p}}}}$$

$$f_2 = \frac{2.25}{(a+b)\left(\Omega_{\infty-4}^{(1,1)*}(T^*) + s(r_{\mathrm{m}}, T_\delta) - 1\right)}$$

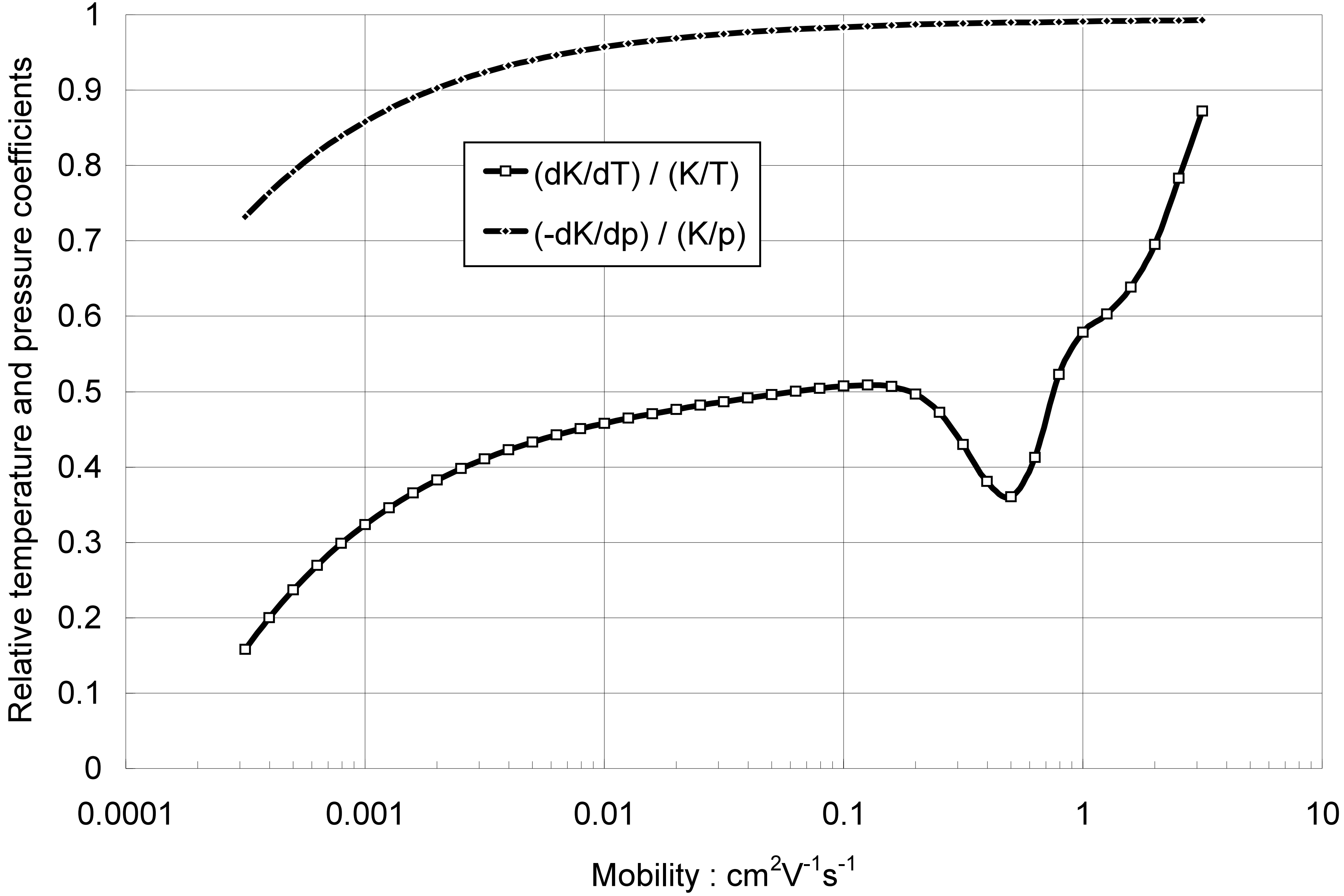
ρ = 2.07 g cm^{-3}, h = 0.115 nm, r_{cr} = 1.24 nm.



Electric mobility : cm^{2}V^{-1}s^{-1}
4
3
2
1
0
0
0.5
1
1.5
2
2.5
Mass diameter : nm
1 - Polarization limit
2 - Sutherland approx. (d)
3 - Sutherland approx. (d+0.23nm)
4 - Present model
3
2
4
1
1
2
3
4



Size-mobility correlation, the mobility factor of inelastic collisions, and relative temperature coefficient of the mobility for air ions in the standard conditions.



(dK/dT) / (K/T)
(-dK/dp) / (K/p)
Relative temperature and pressure coefficients
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0.0001
0.001
0.01
0.1
1
10
Mobility : cm^{2}V^{-1}s^{-1}