acta phys. slov. 32 (1982), No. 3—4

NUMERICAL SOLUTION OF THE DIFFUSION MODEL OF THE ELECTRIC SHEATH[1])

K. TEPLANOVÁ[2]), I. KOŠINÁR[2]), V. MARTIŠOVITŠ[3]), Bratislava

A solution of a model of the electric sheat formed by contact of an infinite electric non-conducting plane with unlimited plasma is presented. It is assumed that electrons are distributed according to the Boltzmann law and ions are accelerated in the electric field towards the wall. Heating of ions and variation of their mobility are neglected.

ЧИСЛЕННОЕ РЕШЕНИЕ ОДНОЙ ДИФФУЗИОННОЙ МОДЕЛИ ЭЛЕКТРИЧЕСКОГО СЛОЯ

В работе приводится решение одной модели электрического слоя, образованного токонепроводящей бесконечной плоскостью и неограниченным пространством с плазмой. Предполагается, что распределение электронов подчиняется закону Больцмана и ионы ускоряются электрическим полем по направлению к стенке. При этом нагревом ионов и изменением их подвижности пренебрегается.

I. INTRODUCTION

As shown in [1], the problem can be formulated by using planar geometry. The model is based on the Poisson and momentum equation for ions, when neglecting pressure effects of ions:

$$\frac{d^2\varphi}{dz^2} = -\frac{e}{\varepsilon_0}(n_+ - n_-), \tag{1}$$

$$n_+ v_+ \frac{dv_+}{dz} = -\frac{n_+}{m_+} e \frac{d\varphi}{dz} - n_+ v_+ \nu_+ - v_+ n_-(\alpha - \beta n_+), \tag{2}$$

where φ is the electric potential; z the coordinate normal to the wall; e the elementary charge; n_+, n_- the concentration of ions and electrons; ε_0 the

[1]) Contribution presented at the 3rd Symposium on Elementary Processes and Chemical Reactions in Low Temperature Plasma in Krpáčovo, September 22—26, 1980.

[2]) Department of Experimental Physics, Mathematical and Physical Faculty Comenius University, Mlynská dolina, 842 15 BRATISLAVA, Czechoslovakia.

[3]) Institute of Physics and Biophysics, Comenius University, Mlynská dolina, 842 15 BRATISLAVA, Czechoslovakia.

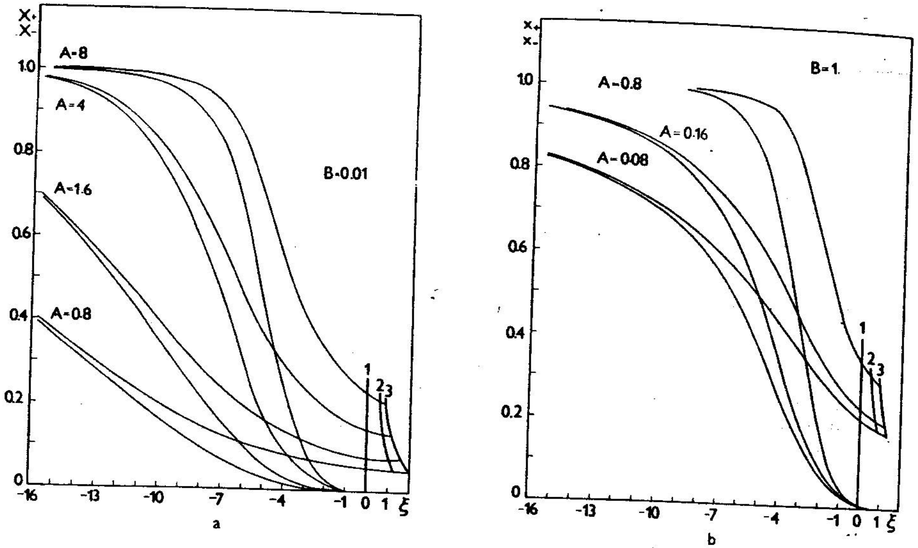

Fig. 1a, b: The normalized concentrations of ions x_+ and electrons x_- as a function of the normalized distance ξ for the following parameters a) $B=0.01$; $A=0.8, 1.6, 4, 8$; b) $B=1$; $A=0.08, 0.16, 0.8$. Curves 1, 2, 3 illustrate the location of the wall, where the boundary condition (5) is fulfilled: 1 — for He, 2 — for Ar, 3 — for Hg.

permitivity of free space; v_+ and m_+ the drift velocity and mass of an ion; ν_+ the frequency of collisions of ions with gas atoms; α the frequency for single-stage ionization; β the recombination coefficient.

The concentration of ions can be estimated by the solution of the continuity equation in ambipolar approximation [1]:

$$n_+v_+ = n_0\left(\frac{\alpha D_a}{3}\right)^{1/2}\left(1-\frac{n_-}{n_0}\right)\left(2\frac{n_-}{n_0}+1\right)^{1/2}, \qquad (3)$$

where n_0 is the charge particles concentration in the plasma.

The concentration of electrons is assumed to be given by the Boltzmann law:

$$n_- = n_0 \exp\left(\frac{e\varphi}{kT_-}\right), \qquad (4)$$

k is the Boltzmann constant and T_- the electron temperature.

II. NUMERICAL SOLUTION

The system of equations (1—4) was solved for suitable initial conditions which were obtained by expanding φ and $d\varphi/dz$ as a power series in v_+. The method of

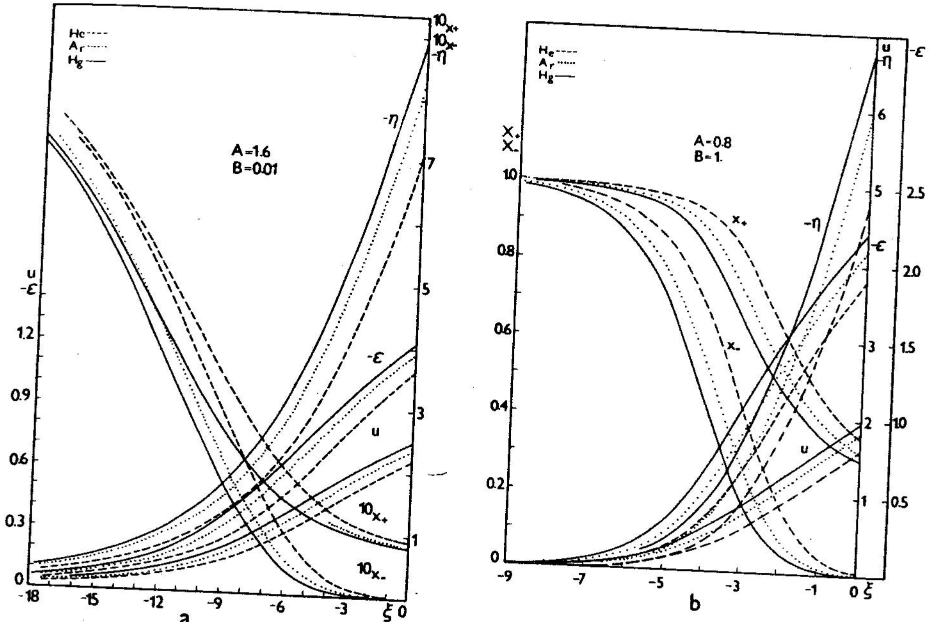

Fig. 2a, b: The normalized ion velocity u, electric field ε, potential η, concentration of ions x_+ and electrons x_- versus the normalized distance ξ for parameters a) $B=0.01$ and $A=1.6$; b) $B=1$ and $A=0.8$ and for various gases.

solution was described in [1]. The equations were solved by introducing the dimensionless variables:

$u=v_+/v_i$, $\eta=e\varphi/kT_-$, $x_-=n_-/n_0$, $x_+=n_+/n_0$, $\xi=z/h$, where $v_i=\sqrt{kT_-/m_+}$ is the ion sound speed and $h=\sqrt{\frac{\varepsilon_0 kT_-}{e^2 n_0}}$ the Debye length.

Appropriate parameters are: $A=h\nu_+/v_i$ and $B=\alpha/\nu_+$. The first parameter is a measure for collisions of ions in the sheath (for $T_+/T_-\approx 10^{-2}$, $A\approx 0.16h/\lambda_+$, where λ_+ is the mean free path of ions) and the second one B describes properties of the plasma.

The solution of equations is independent of the kind of gas. Properties of the gas are included in the boundary condition only:

$$\frac{ux_+}{x_-}=\sqrt{\frac{2m_+}{\pi m_-}}. \qquad (5)$$

The location of the wall is determined by a normalized distance ξ, where the boundary condition is fulfilled. This point is taken to be an origin of the normalized distance ξ.

The results were obtained for $B=0.01$ and 1 and various values of A. The normalized concentrations x_+ and x_- are plotted in Fig. 1. The curves in Fig. 2 demonstrate the influence of the ionic mass on the sheat properties. The respective values for helium and mercury at the wall are shown in Fig. 3 as

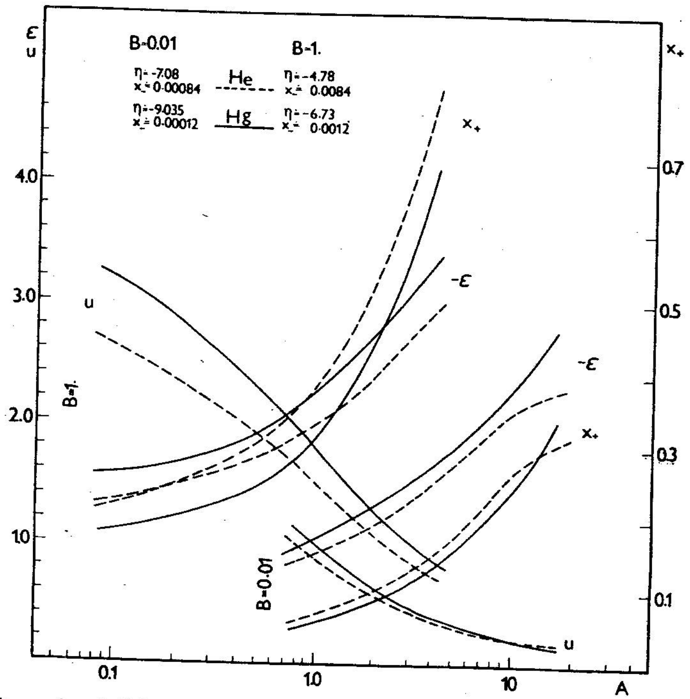

Fig. 3: Ion velocity u, electric field ε and ion concentration x_+ at the wall versus the parameter A for $B=0.01$ and $B=1$. The respective values of normalized potential η and electron concentration x_- are nearly constant.

a function of A and B. It was found that independent on the initial value of u the solutions are numerically stable near the wall. For a normalized concentration x_+ calculated for A higher than as it is shown in Fig. 1 there is an interval of ξ, where x_+ overtops the value unity and the dependences are non-monotonous. The reason of this is probably due to neglecting the thermal term in Eq. (2).

REFERENCES

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Received October 20th, 1980