XENON PLASMA WITH CAESIUM AS ADDITIVE

S. M. Stojilković¹), N. V. Novaković²), Lj. M. Živković¹)

¹) Electronic Faculty, University of Niš, 18000 Niš, Yugoslavia
²) Philosphic Faculty, University of Niš, 18000 Niš, Yugoslavia

The concentration dependence of xenon plasma with caesium as additive in the temperature region of 2 000 K to 20 000 K has been analysed. Plasma has been considered as weakly nonideal in the complete local thermodynamic equilibrium and the interaction between plasma and vessel walls was not taken into account. The values of some of the parameters for nonideality of plasma with 1% of caesium (γ = 0.01010) and 10% of caesium (γ = 0.11111) are computed, for initial pressure in plasma of p₀ = 13 000 Pa and initial temperature T₀ = 1 000 K. Also the ratio of electrical conductivity of plasma computed by Lorentz's formula and electrical conductivity computed by Spitzer's formula in the same temperature interval has been analysed.

1. INTRODUCTION

The analysis of the plasma composition with caesium as additive under conditions of constant volume has particular interest regarding the application of plasma in the pulsed gas lamps. Since pulsed gas lamps are the components of electronic circuits, knowledge of the dynamic characteristic of this component is required for particular operating conditions.

Since every change in the ionization kinetics affects the composition and thermodynamic properties of a plasma, the plasma state can be determined by some characteristic parameters. The description of plasma state by these parameters could be only approximately depending on appropriate model. From the numerous proposed parameters of plasma, the most commonly used in the literature are listed below: the average distance between particles in plasma r₀, Debye radius of electrostatic screening in plasma r_D and average value for de Broglie wavelengths λ_e.

For λ_e ≪ r₀ plasma behaves as a classical nonideal one, so the Boltzmann statistics distribution function can be applied, and in this case for the movements of particles in plasma the classical laws can be applied [1]. According to the condition λ_e < r₀ a necessary condition for the computation if the limit temperature at which the degenerate Fermi gas of free electrons appears is defined as T > T_F concerning the temperature up to which the plasma behaves as a classical plasma, and T_F is the Fermi temperature [2]. If a number of particles in a Debye sphere N_D is much greater than unity (N_D ≫ 1), the plasma behaves as a weakly nonideal plasma. The Debye sphere is defined as a sphere whose centre is in an individual electron and with a radius which is equal to Debye electrostatic screening radius in plasma.
2. CALCULATION OF PLASMA CONCENTRATION

The composition of plasma in complete local thermodynamic equilibrium can be calculated by Saha formula [3],

\[ \frac{n_z n_{z+1}}{n_z} = K_z(T), \quad z = 0, 1, 2, \ldots, z_m-1, \]

where \( n_z \) is the ion concentration, \( z \) the number of elemental charges of ion (for \( z = 0 \), atom is neutral) and \( z_m \) is the atomic number of element.

The equilibrium constant \( K_z(T) \) is defined by formula [4],

\[ K_z(T) = 2 \left( \frac{2\pi m_e kT}{\hbar^2} \right)^{3/2} \frac{Q_{z+1}}{Q_z} \exp \left( - \frac{W_z - \Delta W_z}{kT} \right), \]

where \( Q_z \) is the partition function [5],

\[ Q_z = \sum_i g_i \exp \left( - \frac{W_i}{kT} \right), \]

\( W_z \) the ionization energy of atom and

\[ \Delta W_z = \frac{e^2}{4\pi\varepsilon_0 r_D} \]

represents the decrease in the ionization energy of atoms due to the electrostatic screening [6].

The system of nonlinear equations (2.1) is completed by the following equations:

- the equation of the gas state [7],

\[ \sum n_i = \frac{P_0}{kT_0}, \]

- the equation for the electroneutrality of plasma

\[ \sum z_i n_i - n_e = 0, \]

- the equation for the initial composition of plasma,

\[ n_{Cs}^0 = \gamma n_{Xe}^0, \]

where \( \gamma \) is the ratio of the initial concentration of a caesium and xenon and

- the equations which define the constant number of particles in plasma

\[ n_{Xe}^0 = n_{Xe} + n_{Xe^+} + n_{Xe^{++}} \]

and

\[ n_{Cs}^0 = n_{Cs} + n_{Cs^+} + n_{Cs^{++}}. \]