

Experimental study of charge transfer reactions between noble gas ions and metal atoms

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The aim of this project is to experimentally determine rate coefficients of asymmetric charge transfer (ACT) reactions between noble gas ions and metal atoms. These ACT reactions play an important role in numerous glow discharges. Unfortunately, there are very few rate coefficients available in the literature for analytically important metals, like Cu, Fe, Ti, Ni etc., which have much higher melting temperatures. Cross section data (from which rate coefficients can be calculated) have only been measured for the reactions with Xe⁺ ions at relatively high energies (> 1 eV). Another motivation is that the accuracy of glow-discharge modelling calculations always depends on the correctness of the input parameters. To date, the lack of ACT rate coefficients has prevented the experimental verification of predictions on GD-MS sensitivity factors and limited the accuracy of modelling predictions for emission spectra.

The new apparatus for the experimental determination of the rate coefficients of the ACT reactions between noble gas ions and metal atoms has been designed and built.

The idea of the experiment consists of creating a constant vapour pressure of the studied metal inside a discharge cell using hollow cathode and plane cathode discharges. The rate coefficients can be determined from the characteristic decay time of noble gas ions in the afterglow period of the pulsed discharge. The density of the sputtered metal atoms is determined using atomic absorption spectroscopy. In order to better understand processes taking place in the discharge cell, a tungsten Langmuir Probe ($l = 2.5\text{mm}$; $d = 20\ \mu\text{m}$) was installed at fixed position inside the cell. The probe technique can also help to determine the purity of the apparatus and gases, which can be estimated from the exponential electron density decay in Ar⁺ dominated He-Ar afterglow plasma. A numerical kinetic model has been also developed. The actual experimental conditions (temperature, gas pressure, etc.), diffusion and recombination loss processes are included in this model

During the measurements, it turned out that there is no charge transfer between Ar⁺ and Cu in thermal plasmas (~300 K). In case of neon gas it was evident that during the late afterglow there is a quite strong emission of charge transfer line (270.3 nm). In the future the rate coefficient for Ne⁺-Cu is planned to be determined using Ne-1%Ar mixture using neon gas with higher purity (Ne 5.0 or better). Several experiments were dedicated to Ar⁺-Zn and Ar⁺-Fe systems. The ACT rate coefficient $\sim 8(\pm 3) \times 10^{-9}\ \text{cm}^3\text{s}^{-1}$ was obtained for the Ar⁺-Fe system.

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