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Total Cross Section Measurements for Charge Exchange of He^{++} Ions with He and Ar Atoms

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Abstract. Total charge exchange cross sections were measured for He^{++} in He and Ar gas in the energy range from 50 to 540 eV using a single beam apparatus. For He^{++} in He the measured cross section is in agreement with calculations for symmetric resonant charge exchange. For He^{++} in Ar the cross section for charge exchange decreases with decreasing energy below 300 eV. The measured cross section suggests the formation of Ar^{+} ions to be more important at lower energies and the production of Ar^{++} to be dominant at higher energies.

1. Introduction

Total charge transfer cross sections of a symmetric resonant and a non-resonant system of doubly charged He ions with the target gases He and Ar were measured by a single beam apparatus. As earlier investigations [1, 2] were restricted to energies greater than 400 eV, we attempted to measure the cross sections at lower collision energies down to values below 100 eV and to get information about the dominant reaction channel. We obtained total cross sections for the energy range from 50 to 540 eV which are presented in the following.

A schematic diagram of the experimental setup is given in Fig. 1. The primary ions are produced in a water cooled low voltage arc discharge with heated cathode. They are extracted through the anode and brought into focus on the entrance aperture of a 180° magnetic mass selector. After q/m-separation they are collimated by different electrostatic lenses, before entering an equipotential interaction region. The ion energy is defined by the difference between the plasma potential in the ion source and the variable space potential in the collision chamber. The collision chamber is formed by an inner grid, the ion collector and the entrance aperture, all maintained at the same potential.

Slow ions created by charge exchange processes within the collision chamber are drawn out by an outer grid, which is biased negatively (-2 V ... -4 V) with respect to the collision chamber. Charge transfer ions possessing small energies are collected effectively. The influence of primary ions elastically scattered under large angles can be eliminated by biasing a second outer shielding cylinder positively (4 V ... 10 V) with respect to the potential of the inner grid. A detailed discussion of the working conditions of this electrode configuration is given in Ref. 3 and 4. The proper operation of the whole system was tested by taking current – potential characteristics of the different electrodes.

2. Results and Discussion

2.1. He^{++} – He System

In Fig. 2 we compare our results for the total cross section of ion production by He^{++} ions in He gas with a theoretical calculation of Ferguson and Moiseiwitsch [5] and experiments done by Latypov *et al.* [1] at higher energies.

The energy dependence of our cross section values agrees well with the energy dependence of the cross

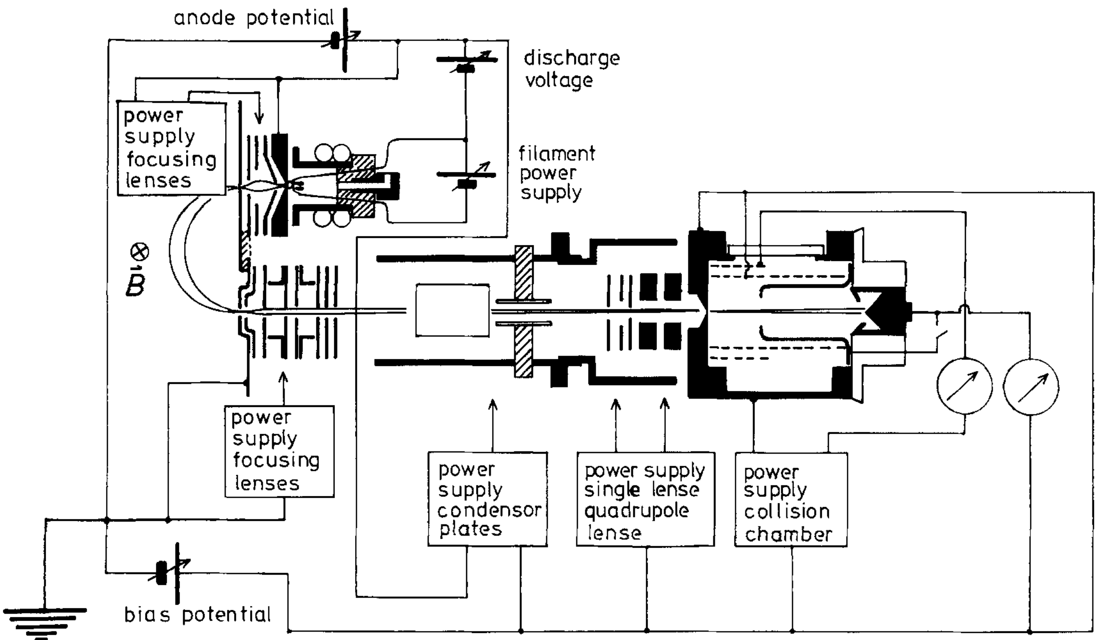

Fig. 1. Schematic diagram of the apparatus

section calculated for the symmetric resonant charge transfer:

$He^{++} + He \rightarrow He + He^{++}$.

Despite a discrepancy by a factor of about 1.5 in the absolute values we thus conclude this process to be dominant in the investigated energy range. This is supported by the results of Latypov *et al.* at collision energies above 400 eV. By comparing electron production (σ_-), He^+ production (σ_{01}) and He^{++} production (σ_{02}) by He^{++} impact they also found the symmetric resonant charge transfer to be the dominant process.

2.2. $He^{++}-Ar$ System

Fig. 3 represents the measured energy dependence of the cross section for the production of positively charged slow ions in the reaction system $He^{++} + Ar$. The cross section has a maximum at about 300 eV and decreases for higher and lower collision energies, increasing again for collision energies exceeding 500 eV. For comparison the results of Latypov *et al.* [2] for the production of Ar^+, Ar^{2+} and Ar^{3+} in $He^{2+}-Ar$ collisions are shown in Fig. 3, too. The sum of these partial cross sections yields total cross section values represented by the dashed line.

As in the energy region below 500 eV the formation of Ar^{3+} ions has a very low probability, our total cross section represents the production of Ar^+ and Ar^{2+} ions. The Ar^{2+} curve decreases more rapidly towards lower energies than the total cross sections, therefore the probability for the production of Ar^+ ions must increase below 400 eV (see dotted line in Fig. 3: difference between the present values and the Ar^{2+} curve). Thus at higher energies the Ar^{2+} formation is the dominant process and at lower energies the main contribution to the total cross section seems to be given by the Ar^+ production.

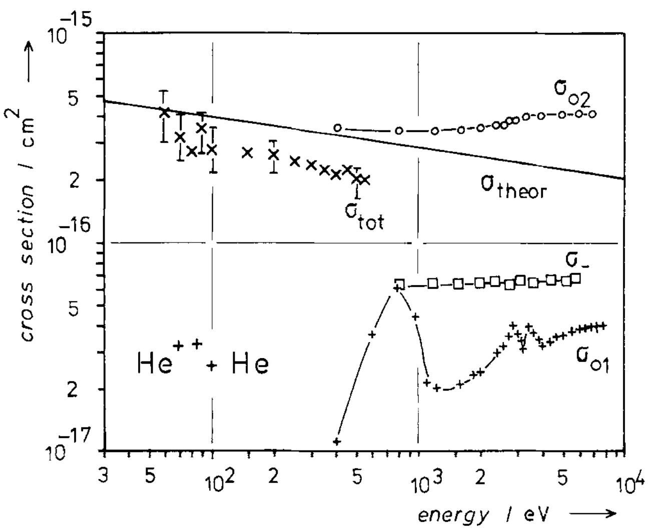

Fig. 2. Total cross sections for charge exchange in the system He^{++} and He. ×: present results (the spread below 100 eV is due to the decrease of the secondary ion current); — · : theoretical curve calculated by Ferguson [5]. Cross section for the production of He^+ (σ_{01}), He^{++} (σ_{02}), free electrons (σ_-) from Latypov *et al.* [1]

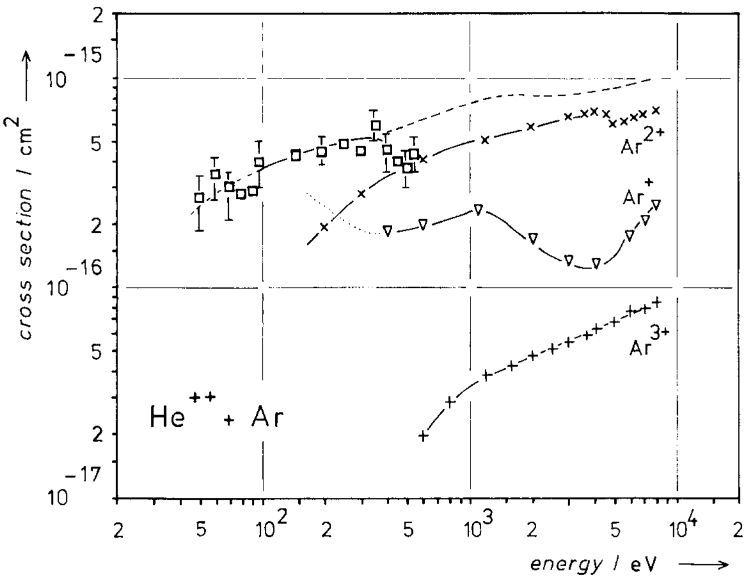

Fig. 3. Total cross sections for charge exchange in the system He^{++} and Ar. □: present results; cross sections for the production of Ar^+ (–▽–); Ar^{++} (–×–); Ar^{3+} (–+–) from Latypov *et al.* [2]. Dashed line: total cross section [2] (sum of the partial cross sections)

Refering to Latypov [2] this formation of Ar^{2+} proceeds essentially via the reaction channel

$$He^{2+} + Ar \rightarrow He^{+} + Ar^{2+} + e,$$

which is less exothermic than the single charge transfer reaction

$$He^{2+} + Ar \rightarrow He^{+} + Ar^{+(*)}.$$

Therefore the assumed energy dependence of the Ar^+ and Ar^{++} formation is in agreement with measurements of differential charge exchange cross sections [6], showing an increasing importance of the endothermic reaction channels with increasing collision energy.

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