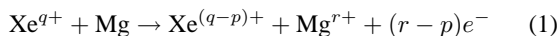# Charge transfer in collisions between highly charged Xe ions and Mg atom

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In this report, we study the charge transfer process between slow, highly charged xenon ions and magnesium vapor. In general the process can be described as

$$\mathrm{Xe}^{q+} + \mathrm{Mg} \rightarrow \mathrm{Xe}^{(q-p)+} + \mathrm{Mg}^{r+} + (r-p)e^- \quad (1)$$

The cross section for that process is $\sigma_r^{q,q-p}$. Within the main process we can distinguish three different sub processes, electron capture ($r - p = 0$), ionization transfer ($r - p > 0$) and ionization ($p = 0$, and $r > 0$). The latter is negligible for the here studied velocity regime..

The setup is shown schematically in Fig. 1. Highly charged xenon ions ($^{132}\mathrm{Xe}^{q+}$) were extracted from an electron beam ion trap at GSI [1] with an energy of $5.5\,q$ keV continuously. After charge to mass selective bending, the ion beam collided with the magnesium vapor produced by an oven. Finally, the projectiles were dispersed by another bending magnet to separate primary ions and ions with one or more captured electrons, recorded by a position sensitive multi-channel plate (MCP) detector. The recoiled Mg^{r+} were accelerated by an electric field perpendicular to the beam axis towards a second MCP detector. The signals of both detectors were measured in coincidence to get the time of flight (TOF) of the recoiled magnesium ion from the reaction zone to the detector. The detected position of the projectiles and the TOF of the recoiled magnesium ions allows one to separate the above mentioned sub processes and, hence, to measure the differential charge exchange cross sections. A typical position spectrum at the projectile detector and a TOF spectrum from the recoil detector are shown in Fig. 2. Unexpectedly, almost no Mg^{3+} ions were produced in the collision.

Figure 2: Left: charge-state distribution of projectile ions after collision with the magnesium target. The primary beam of Xe^{q+} is attenuated by a dense mesh on front of the PSD. Right: TOF spectrum from the recoil detector with the projectile as trigger.
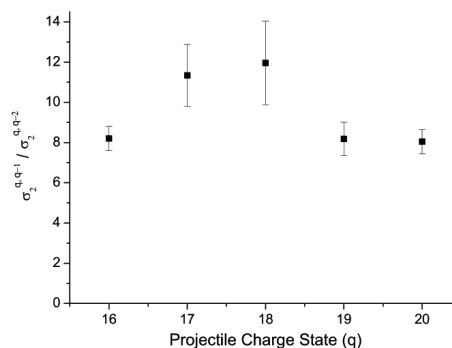
Figure 3: The cross section ratio of transfer ionization to pure two electron capture as a function of the projectile charge state.
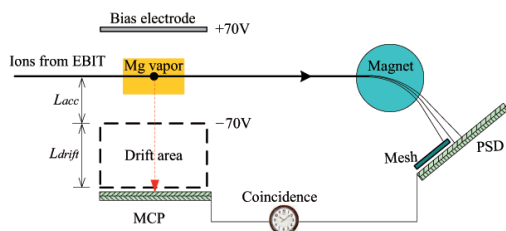

Figure 1: Schematic setup as explained in the text.

After appropriate background subtraction, the peak areas are proportional to the corresponding cross section. The cross section ratio $\sigma_2^{q,q-1}/\sigma_2^{q,q-2}$ as a function of projectile charge state is shown in Fig. 3. It shows that for the system we studied, transfer ionization dominates the two-electron removal process.

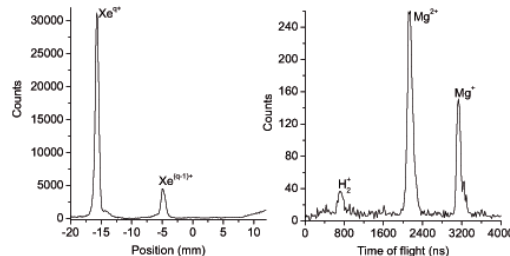Theoretically, the charge transfer process is described in a two-step picture. First the projectile ion and target atom form a quasi-molecule, while the projectile captures two electrons from the target to Rydberg orbitals, forming a doubly-excited state. Then the doubly excited ions release their excess energy by radiative decay or by the Auger process. Especially for highly charged ions with large potential and metal targets with loosely bound electrons, the Auger process dominates the relaxation. This situation is studied for the first time, and shows large deviation from theoretical calculations based on a classic overbarrier model or semiempirical calculations [2].

References

[1] A Sokolov et al., "SPARC EBIT — a charge breeder for the HITRAP project", J. Instrum. **5** (2010), C11001.

[2] N. Selberg, C. Biedermann and H. Cederquist, Phys. Rev. A 56 (1997) 4623.