§4. Charge Exchange Cross Sections in Collisions of Highly Charged Argon Ions with Helium, Neon, and Argon Atoms

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Multiple electron processes occurring in single ion-atom collisions are of important interests not only in pure many body theories, but also in application fields like controlled nuclear fusion research and physics of energetic heavy ions in the Earth's magnetosphere. In low energy, highly charged ion-atom collisions, the dominant process is single electron capture, but other processes such as multi-electron capture and transfer ionization are also of important contributions to the total charge exchange cross section with increasing the projectile charge states. Experiments were performed on the ECR ion source by using argon ions with charge q=8, 9, 11, and 12 in collision with He, Ne, and Ar atoms. In the experiment, the beam energy is from 80keV to 240keV. By using time-of-flight methods and position sensitive technique, the charge states of the ionized target atoms (r) and of the scattered projectiles (q-k) can be determined simultaneously in the experiments. The supersonic gas jet is applied to produce atomic beam as targets. From the measured two-dimensional map [1] various sub-channels for electron transfer were identified. In Ar^{8+} on Ar collisions, taking for example, 12 reaction channels can be ascribed as following:

1: $Ar^{8+} + Ar \rightarrow Ar^{7+} + Ar^{+}$
2: $Ar^{8+} + Ar \rightarrow Ar^{6+} + Ar^{2+}$
3: $Ar^{8+} + Ar \rightarrow Ar^{5+} + Ar^{3+}$
4: $Ar^{8+} + Ar \rightarrow Ar^{4+} + Ar^{4+}$
5: $Ar^{8+} + Ar \rightarrow Ar^{7+} + Ar^{2+} + e\text{-}$
6: $Ar^{8+} + Ar \rightarrow Ar^{6+} + Ar^{3+} + e\text{-}$
7: $Ar^{8+} + Ar \rightarrow Ar^{5+} + Ar^{4+} + e\text{-}$
8: $Ar^{8+} + Ar \rightarrow Ar^{4+} + Ar^{5+} + e\text{-}$
9: $Ar^{8+} + Ar \rightarrow Ar^{6+} + Ar^{4+} + 2e\text{-}$
10: $Ar^{8+} + Ar \rightarrow Ar^{5+} + Ar^{5+} + 2e\text{-}$
11: $Ar^{8+} + Ar \rightarrow Ar^{4+} + Ar^{6+} + 2e\text{-}$
12: $Ar^{8+} + Ar \rightarrow Ar^{6+} + Ar^{5+} + 3e\text{-}$

In Ar^{12+} on Ar collisions, up to 6 electrons were found finally being captured on the projectile. The electrons are not essentially captured into ground states of the projectile, some of them are in excited states, and forming the so-called hollow ions. The decay of the multiply excited states via Auger or radiative processes is sensitive to the electron-electron interactions [2]. The partial cross sections for these charge exchange processes, such as pure electron capture $\sigma^{r}_{q,q-r}$, phenomenological transfer ionization $\sigma^{r}_{q,q-k},(k<r)$, projectile charge changing $\sigma_{q,q-k}$, and target ion production σ^{r}_{q}, were measured experimentally. Figure 1 shows projectile charge changing cross sections measured in Ar^{q+} on Ar collisions. The cross section data will be supplemented into the database.

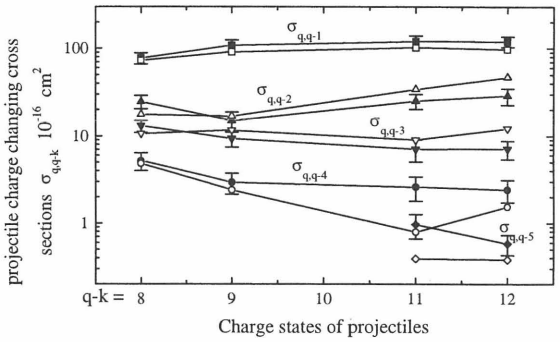

Fig. 1 $\sigma_{q,q-k}$ as a function of projectile charge states q, Solid and open symbols represent experimental results and calculations from classical models.

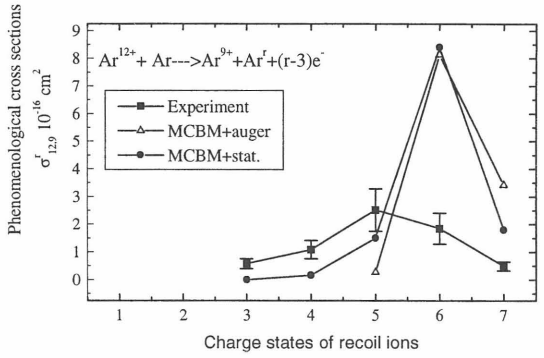

Fig. 2 transfer ionization cross sections $\sigma^{r}_{q,q-3}$ with three electrons stabilized on the projectile in Ar^{12+} on Ar collisions.

[1] Xinwen Ma, et al., Science in China A41 (1998) 296
[2] Xinwen Ma, et al., Physics Scripta, T80, (1999) 375.