§21. A Scaling Law of Cross Sections for Multiple Electron Transfer in Slow Collisions between Highly Charged Ions and Atoms

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We propose a scaling law of cross sections for multiple electron transfer collisions of highly charged ions, which are the important processes in edge and divertor plasma diagnostics.

In a single collision between slow, highly charged ions A^{q+} and multi-electron target atoms B a number of electrons are transferred into excited levels of A. The product ions are stabilized by emission of photon(s) or electron (s). These processes are expressed as follows:

$$A^{q+} + B \rightarrow A^{(q-j)+*} + B^{j+}$$
$$\rightarrow A^{(q-i)+} + B^{j+} + (j-i)e^- + n(h\nu).$$

Since multiple-electron transfer processes are so complicated that sophisticated theoretical treatments are very difficult. It is thus useful to find a simple scaling law which can be used to estimate the cross sections for multiple electron transfer processes.

In the present work we focus on a scaling law which can be applied to the cross sections (σ^j_q) for the formation of intermediate excited states of projectiles. As a guiding principle we use the extended classical over-barrier model (ECBM) proposed by Niehaus[1], which has been proved to account satisfactorily for some features of multiple electron transfer processes for all its simplicity.

The larger the ionization potential energy P_j of the j-th electron on B, the smaller the nuclear separation R_j where the potential barrier ceases to be effective for transferring the electron. R_j is expressed as follows in atomic units:

$$R_j = \{q(1/\alpha_j - 1)+j/(1-\alpha_j)\}/P_j \qquad (1)$$

where $\alpha_j=1/\{1+(j/q)^{1/2}\}$.

When j is much smaller than q the distance R_j in (1) can be further approximated as follows,

$$R_j = 2(jq)^{1/2}/P_j \qquad (2)$$

and the cross section Q_j for multiple electron transfer processes where more than j-electrons transferred is finally obtained:

$$Q_j= \pi R_j^2 = \sigma^j_q + \sigma^{j+1}_q + \sigma^{j+2}_q + ... \qquad (3)$$
$$= 4\pi jq / P_j^2. \qquad (4)$$

When Q_j is expressed in $Å^2$ and P_j in eV units,

$$Q_j=2.6\times 10^3 jq / P_j^2 \qquad (5)$$

In Fig.1, we have shown that our scaling law satisfactorily reproduces our data[2] and other data[3)-5] presently available.

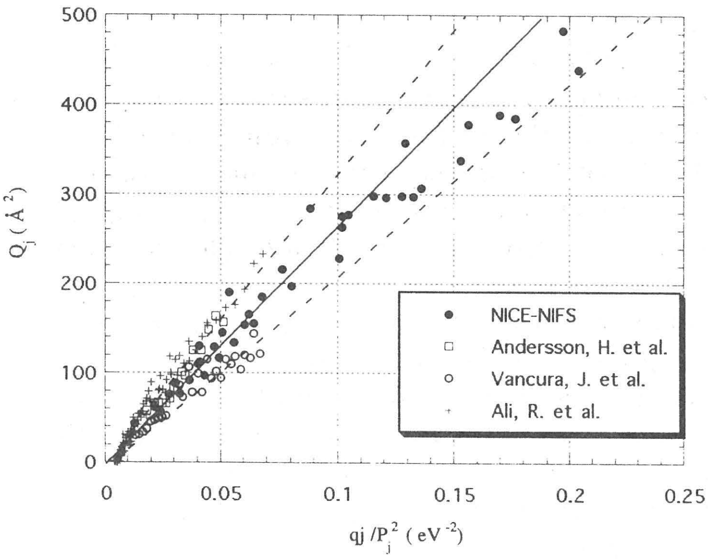

Fig. 1. Reduced cross sections for electron transfer processes. The solid line represents the relation (5), while the dotted lines correspond to the gradients larger and smaller than that of the solid line by 20%.

References

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