Stripping of Fast Heavy Low-Charged Ions in Gases

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Electron loss and capture processes arising in collisions of heavy low-charged ions with atoms and ions belong to the main charge-changing reactions in heavy-ion driven inertial fusion (HIDIF) (see, e.g., [1]). However, at present time, virtually no experimental and theoretical data are available for removal processes involving fast heavy low-charged ions.

In this work, the projectile-ionization (stripping) cross sections and beam lifetimes in reactions

$$X^{z+} + A \to X^{(z+1)+} + e^- + ...$$

have been calculated for ions X = Xe, Pb, Bi, U ($z < 10$) colliding with neutral atoms A =H, He, Be, C, F, N, Ar, Xe in the $E = 1-100$ MeV/u energy range. Calculations have been performed for *single*-electron stripping in the first-order perturbation theory using the LOSS computer code. Atomic structure of the target was taken into account in the form of its atomic form-factor $F(q)$ depending on the momentum transfer q.

In the case of ionization of Pb-like ions (Xe^{0+}, Bi^{1+}, ..., U^{10+}) in the energy range considered, the doubly scaling law of the stripping cross sections on the projectile charge and the target nuclear charge Z_T was obtained in the form:

$$\tilde{\sigma} = \sigma \cdot (I_P/Z_T)^{1.4}, \quad \tilde{E} = E/I_P, \qquad (1)$$

where I_P is the *first* ionization potential of the projectile in eV and E is the projectile energy in eV/amu. The scaled cross section for Pb-like ions is displayed in Fig. 1 in comparison with experiment and other calculations (see [7] in detail); here 1 Ry = 13.606 eV.

Beam lifetimes for some ions calculated with account for electron capture processes are shown in Fig. 2; here 1 Ry = 13.606 eV. A small minimum for U^{28+} ions around 2 MeV/amu is related with influence of electron capture which prevails at energies $E < 10$ MeV/u.

A comparison of the present calculations with experimental data [2]–[4], classical-trajectory Monte-Carlo (CTMC) calculations [5] and $Z_T^2 + Z_T$ scaling [6] shows the following peculiarities for the stripping processes of heavy low-charged ions in neutral targets:

1) the contribution from ionization of the projectile inner-shell electrons is very significant, and one has to account for 6–8 inner subshells,

2) at high energies, the stripping cross sections fall off approximately as $\sigma \sim E^{-1}$, i.e. without logarithmic (Bethe) term due to the screening caused by the target electrons and nucleus,

3) multiple-ionization processes seem to play very important role and, according to [5], their contribution can reach up to 50 % to the total stripping cross section.

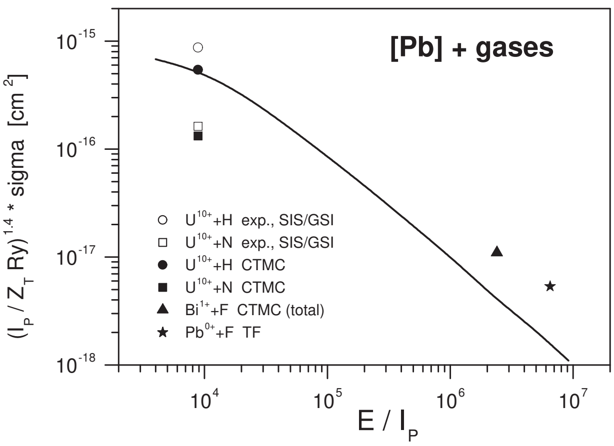

Figure 1: Scaled ionization cross section of Pb-like ions colliding with neutral atoms, eq. (1). Solid curve – present result, symbols – experimental and theoretical data (see [7] in detail).

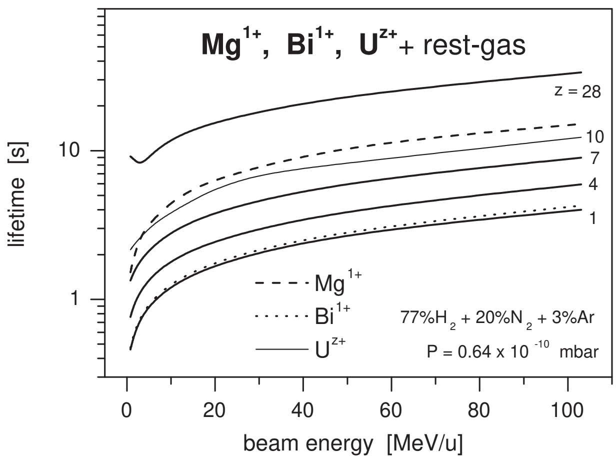

Figure 2: Beam lifetimes of ions colliding with a residual gas mixture and a gas pressure indicated in the figure – present result.

References

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