Stripping of Fast Heavy Low-Charged Ions in Gases

V. Shevelko (GSI and P.N. Lebedev Institute, Moscow),
T. Stöhlker (GSI)

Electron loss and capture processes arising in collisions of heavy low-charged ions with atoms and ions are the main charge-changing reactions in heavy-ion driven inertial fusion (HIDIF) [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

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

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. The 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.

For the case of ionization of Pb-like ions (Xe^{0+}, Bi^{1+}, ..., U^{10+}) and the energy range considered, a scaling law for stripping cross sections was obtained in the form:

$$\tilde{\sigma} = \sigma \cdot (I_\mathrm{P}/Z_\mathrm{T})^{1.4}, \;\; \tilde{E} = E/I_\mathrm{P}, \qquad (1)$$

where I_P is the *first* ionization potential of the projectile in eV, E is the beam energy in eV/u, and Z_T denotes the target nuclear charge. The scaled cross sections for Pb-like ions are displayed in Fig. 1 in comparison with available experimental data and other calculations (see [2] in detail); 1 Ry = 13.606 eV.

Ion-beam lifetimes τ have been calculated with account for electron capture processes using the CAPTURE computer code. The values of τ are shown in Fig. 2. A small minimum for U^{28+} ions around 2 MeV/u is related to the influence of electron capture which for these ions prevails at energies $E < 10$ MeV/u.

A comparison of the present calculations with experimental data [3]–[5], classical-trajectory Monte-Carlo (CTMC) calculations [6] and $Z_\mathrm{T}^2 + Z_\mathrm{T}$ scaling [7] 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, in calculations, one has to account for 6–8 inner subshells,

2) at high energies, the stripping cross sections fall off approximately as $\sigma \sim E^{-1}$,

3) multiple-ionization processes seem to play a very important role and, according to [6], their contribution can reach up to 50 % to the total stripping cross section.

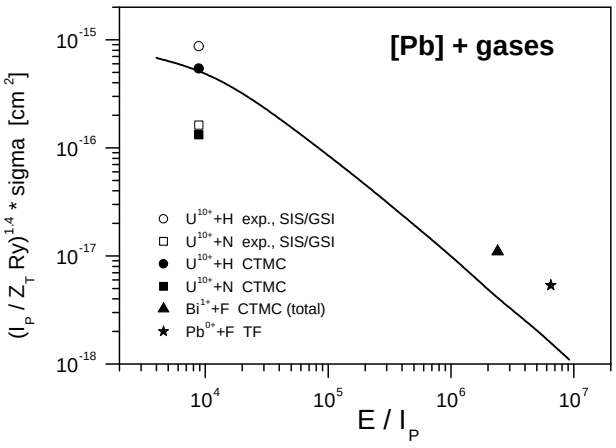

Figure 1: Scaled ionization cross sections of Pb-like ions colliding with neutral atoms, eq. (1). Solid curve – present result, symbols – experimental and theoretical data (see [2] in detail).

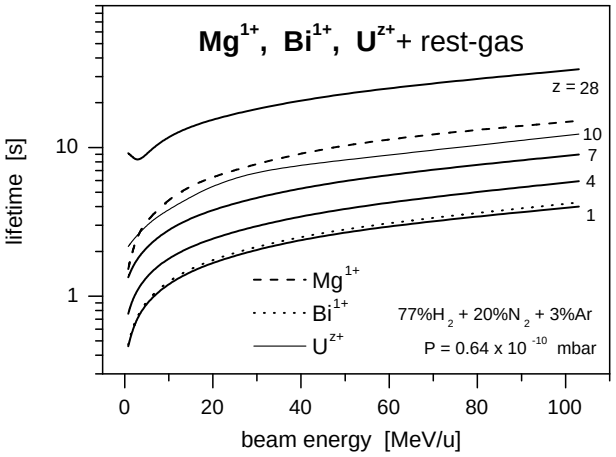

Figure 2: Beam lifetimes of ions colliding with a residual gas mixture and a gas pressure indicated in the figure – present result.

References

[1] I. Hofmann, G. Plass (eds.): *The HIDIF-Study*, Report GSI-98-06, Darmstadt (1998)

[2] I.Yu. Tolstikhina, V.P. Shevelko, Th. Stöhlker: Preprint GSI-2000-54, Darmstadt (2000)

[3] W. Erb: Report GSI-P-78, Darmstadt (1978)

[4] B. Franzke: IEEE, NS-**28**, 2116 (1981)

[5] K. Blasche et al.: GSI Scientific Report 1996, Darmstadt (1997), p. 159

[6] R. Olson: Proc. HIF-2000, San Diego (Febr. 2000) (in press)

[7] V.P. Shevelko et al.: Hyp. Int. **114**, 289 (1998); V.P. Shevelko et al.: NIM A **415**, 609 (1998)