Scaling for state-selective charge exchange due to collisions of multicharged ions with hydrogen

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Synopsis State-resolved charge exchange (CX) cross sections for Be^{4+}, C^{6+}, N^{7+} and O^{8+} projectiles colliding with atomic hydrogen are evaluated employing two different methods: the Classical Trajectory Monte Carlo (CTMC) and the eikonal impulse (EI) approximations. These cross sections are used to extend previously derived scaling laws for $n-$, $nl-$, and $nlm-$ distributions to highly excited final levels with $4 \leq n \leq 9$, covering energies in the range 50-2000 keV/amu. Present results are in agreement with available experimental and theoretical data for these collision systems, becoming a useful instrument for plasma research.

As reported in Ref. [1], it is possible to use the prior EI approach to derive a scaling rule for the following reaction:

$$A^{Z_P+} + H(1s) \rightarrow H^+ + A^{(Z_P-1)+}(n,l,m), \quad (1)$$

using that the corresponding CX cross section, σ_{nlm}, nearly satisfies:

$$\sigma^{EI}_{nlm} \simeq \tilde{z_P}^{-7} \, |C(Z_P/v)|^2 \, u_{nlm}(\tilde{W}), \quad (2)$$

where v is the impact velocity, $\tilde{z_P} = Z_P/v$, and $C(Z_P/v)$ is the Coulomb factor coming from the asymptotic conditions. In Eq. (2) the function u_{nlm} can be considered as an universal function of the scaled transferred momentum $\tilde{W} = (\tilde{v}^2 + \tilde{z_T}^2 - 1)/(2\tilde{v})$, with $\tilde{z_T} = Z_T/\tilde{z_P}$ (Z_T =1 for H) and $\tilde{v} = v/\tilde{z_P}$.

Two different approximations, EI [1] and CTMC [2], are used to evaluate state-selective CX cross sections for Be^{4+}, C^{6+}, N^{7+}, and O^{8+} projectiles impinging on H(1s), considering a different velocity range for each method: $v = 1-3$ a.u. for the CTMC approach and $v = 2-10$ a.u. for the EI one. The fact that there is a velocity region where both approaches can be successfully applied allows us to provide reliable scaling rules that cover a wide range of incidence energies.

In Fig. 1 we display scaled CX cross sections into the final level n, $S_n = \tilde{z_P}^7 \sigma_n/|C(Z_P/v)|^2$, as a function of $\tilde{W}$, including CTMC and EI results for $n = 4-9$. The proposed scaling makes it possible to gather all the results in a relatively narrow band. Similar behavior is also obtained for the $nl-$distributions, defined as $P_{nl} = \sigma_{nl}/\sigma_n$, when they are plotted as a function of $\tilde{W}$, as shown in Fig. 2.

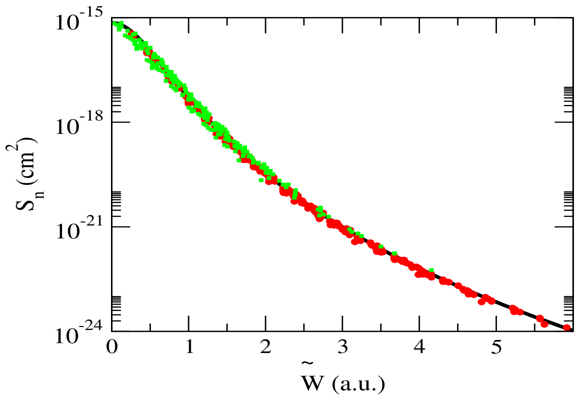

Figure 1. Scaled cross sections S_n in the range $n = 4-9$, evaluated with the considered approaches: ● EI, ■ CTMC.

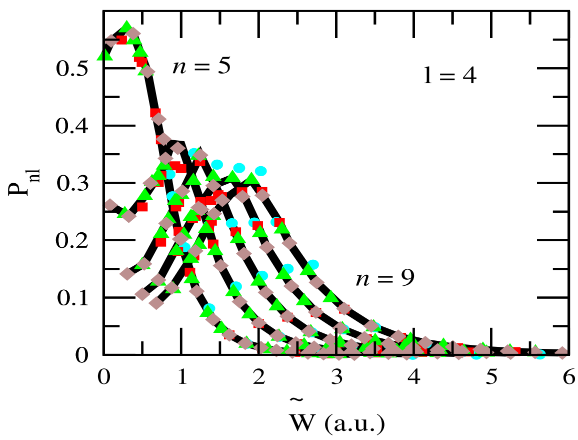

Figure 2. Joined CTMC and EI distributions for $l = 4$, as a function of $\tilde{W}$, considering different projectiles: ● Be^{4+}, ■ C^{6+}, ▲ N^{7+}, ◆ O^{8+}.

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References

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