Electron Capture in Collisions Between Low Charged Heavy Ions

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Electron capture arising in collisions between heavy low-charged ions is an important charge-changing reaction to be accounted for in many problems related to heavy-ion driven inertial fusion (HIDIF). One of the problems is the limited lifetime of ion beams in accelerators (see, e.g., [1, 2]). However, existing data on the corresponding cross sections are very scarce and little is known experimentally and theoretically (see the review article [3]).

In this work, the first preliminary calculations of electron-capture cross sections in collisions between low-charged ions of Xe, Cs, Ba, Pb, Bi and U atoms at relative collision energies E > 0.1 keV/u are presented. Calculations have been performed with the aid of the computer code CAPTURE using the impact-parameter representation and the relation between the quasi-classical and quantum-mechanical capture probabilities obtained in [4].

Calculated data are presented in Figures 1 and 2 as a function of the relative energy E[keV/u] $\simeq 25v^2$ [a.u.], where v is the relative velocity in atomic units, 1 a.u.$\simeq 2.2{\cdot}10^8$ cm/s. The values for the energy (resonance) defect ΔE are also given.

As seen from the Figures, the cross sections for ion–ion collisions have a maximum at energies around E=8–10 keV/u: $\sigma \approx (0.5-3)\cdot 10^{-15}$ cm^2 for $X^{1+}+X^{1+}$ and $\sigma \approx (5-8)\cdot 10^{-16}$ cm^2 for $X^{4+}+X^{4+}$ collisions, respectively. In the low-energy range E $\approx$ 0.1–0.8 keV/u, which is characterized by intra-beam scattering, all considered ion–ion cross sections increase with the relative energy and strongly depend on the atomic structure of colliding systems.

For comparison, the calculated cross section for $U^{4+}+U^{0+}$ collisions, i.e. for electron capture from neutral atoms, is also given (Fig. 2, curve 1). As expected, the cross section is quite large ($\approx 10^{-14}$ cm^2) and remains nearly constant in a wide energy range. At high enough energies, where the target inner-shell electrons mainly contribute to the capture process, the cross sections for reactions $U^{4+}+U^{0+}$ and $U^{4+}+U^{4+}$ (curve 5) practically coincide.

The electron-capture cross sections, calculated in the present work, are in qualitatively good agreement with available experimental and theoretical data (see [3]), however, a further detailed analysis and comparison is certainly required.

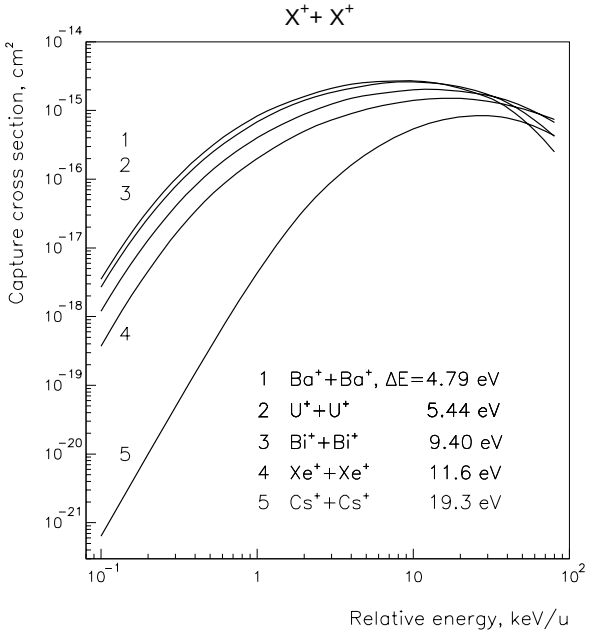

Figure 1: *Calculated cross sections for electron capture* $X^+{+}X^+ \rightarrow X^{0+}{+}X^{2+}$ *as a function of relative energy:* 1: $Ba^+{+}Ba^+$*;* 2: $U^+{+}U^+$*;* 3: $Bi^+{+}Bi^+$*;* 4: $Xe^+{+}Xe^+$*;* 5: $Cs^+{+}Cs^+$.

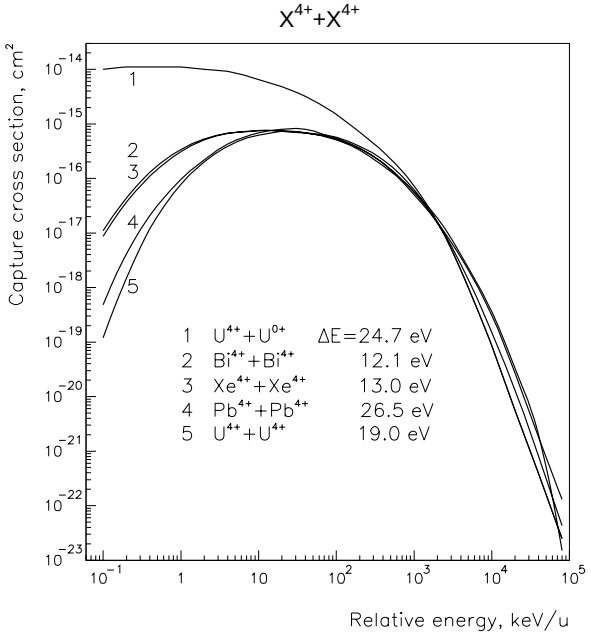

Figure 2: *Calculated cross sections for electron capture* $X^{4+}{+}X^{4+} \rightarrow X^{3+}{+}X^{5+}$ *and* $U^{4+}{+}U^{0+} \rightarrow U^{3+}{+}U^{1+}$ *as a function of relative energy:* 1: $U^{4+}{+}U^{0+}$*;* 2: $Bi^{4+}{+}Bi^{4+}$*;* 3: $Xe^{4+}{+}Xe^{4+}$*;* 4: $Pb^{4+}{+}Pb^{4+}$*;* 5: $U^{4+}{+}U^{4+}$.

References

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