

Charge exchange in slow collisions of ions with Hydrogen isotopes. Adiabatic approach.

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In low-temperature plasmas (near-wall plasma and plasma in a divertor of tokamaks and stellarators), charge exchange is the dominant process in the population of excited states of plasma ions and, therefore, plays an important role in ion charge distribution, radiative cooling, and the transport of particles.

Recently, the strong isotope effect was predicted for $\text{He}^{2+} + \text{H}, \text{D}, \text{T}$ charge exchange processes [1], which are of considerable interest for plasma modeling in a fusion reactor. This effect is due to the rotational mixing of electronic states at small internuclear separations R and results in a significant difference in the charge exchange cross sections in collisions of He^{2+} ions with H, D, and T atoms – the heavier the isotope the larger the cross section – at low collision energies (1–500 eV/amu). These findings motivated a series of studies where the results of [1] were confirmed and extended to other collision systems. In particular, in [2,3,4], using the adiabatic approach developed by Solov'ev [5], the strong isotope effect was shown to exist also for heavier projectiles. These results, apart from their general interest for collision physics, have important implications for diagnostics and simulation of elementary processes in fusion edge plasmas.

In the theory of atomic collisions, the adiabatic approximation is used to describe electronic transitions when the collision velocity is small and the nuclear motion can be treated classically. In this theory, there are no assumptions on the specific form of the electronic Hamiltonian, and only the smallness of the relative nuclear velocity is used. It results in a deeper understanding of the nature of nonadiabatic transitions. Since the isotope effect occurs at collision energies where the adiabatic theory applies, the adiabatic approximation is a natural theoretical framework for studying the effect.

The electron-nuclei interaction affects the internuclear motion in slow ion-atom collisions, which in turn affects theoretical results for the cross sections of various collision processes. The results are especially sensitive to the details of the internuclear dynamics in the presence of a strong isotope effect on the cross sections, as is the case, e.g., for the charge transfer in low-energy collisions of He^{2+} with H, D, and T. It was shown in [6] that internuclear trajectories defined by the Born-Oppenheimer (BO) potential in the entrance collision channel, which effectively accounts for the electron-nuclei interaction, are in much better agreement with trajectories obtained in the *ab initio* electron-nuclear dynamics approach [7] than the corresponding Coulomb trajectories. It was also shown that the use of the BO trajectory instead of the Coulomb trajectory in the calculations of the charge-transfer cross sections within the adiabatic approach improves the agreement of the results with *ab initio* calculations.

- [1] N. Stolterfoht *et al.*, Phys. Rev. Lett. **99**, 103201 (2007).
- [2] I.Y. Tolstikhina *et al.*, Phys. Rev. A **84**, 012706 (2011).
- [3] I.Y. Tolstikhina *et al.*, J. Phys. B **45**, 145201 (2012).
- [4] I.Y. Tolstikhina *et al.*, J. Phys. B **47**, 035206 (2014).
- [5] E. A. Solov'ev, Usp. Phys. Nauk **157**, 437 (1989) [Sov. Phys. Usp. **32**, 228 (1989)].
- [6] I.Y. Tolstikhina *et al.*, Phys. Rev. A **92**, 042707 (2015).
- [7] R. Cabrera-Trujillo *et al.*, Phys. Rev. A **83**, 012715 (2011).