A Quantum–Classical Approach for the Study of Cascade Processes in Exotic Hydrogen Atoms

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The theoretical study of cascade processes in exotic ($p\mu^-$, pK^-, $p\bar{p}$, etc.) hydrogen atoms is of great interest both for the description of processes with negative muons in hydrogen [1], including the precise determination of muon catalyzed fusion parameters, and for the detailed analysis of experimental data investigating the strong interaction [2]. In the present work a quantum–classical Monte Carlo cascade model has been developed and applied to the calculation of the various characteristics of cascade processes in muonic and kaonic hydrogen atoms.

The main problem of cascade research by quantum mechanical methods is the lack of a complete set of data on total and differential cross-sections. Therefore we use an approach based on a purely classical description of the exotic atom collision with the hydrogen atom whereas radiative transitions are taken into account within the framework of quantum mechanics and Auger processes are treated in a semi-classical way. Such a calculation scheme is a compromise which provides a way for *ab initio* calculation of the physical parameters with an accuracy of $\sim 20\%$.

The effect of exotic atoms acceleration due to Auger capture of them by hydrogen with subsequent decay of the formed molecular complex has been considered. "Heavy" kaonic atoms become fast due to multi-quantum Coulomb transitions [3] just after formation and therefore cannot be captured in Auger processes, consequently kaonic molecule formation by the Auger mechanism are not essential in the cascade [4]. The results of the calculations have shown that in the case of "light" muonic atoms, also due to Coulomb acceleration, only a small part of $p\mu$ atoms can be captured in Auger processes, and their contribution to the values of the cascade characteristics has been estimated at about $\sim 1\%$.

The yields for the K-series X-rays in kaonic and muonic hydrogen, the kinetic energy distribution functions for exotic atoms in excited states as well as other cascade characteristics have been calculated and compared with the experimental data at different hydrogen target densities.

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