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Induced Absorption and Annihilation in Hadronic Hydrogen Atoms

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The lightest hadronic atoms (π^-p, K^-p, etc.) are of particular interest among the exotic atoms due to their simplest structure and unique possibility to give access to the fundamental properties of hadron-nucleon interaction at threshold energy. The essential distinction of hadronic atoms as compared with muonic hydrogen is a complex energy shift in the low angular-momentum states due to strong hadron-nucleon interaction. The corresponding states of hadronic atoms are unstable (non-stationary) and cannot be treated as normal asymptotic states of the scattering problem. The strong coupling between stable and unstable states leads to the induced absorption in the collisions of hadronic atoms with ordinary ones.

In this paper, we study the elastic scattering, Stark transitions, Coulomb de-excitation, and induced absorption or annihilation in the collisions of the hadronic hydrogen atoms in the excited states with ordinary hydrogen in the ground state. These processes have been described in a self-consistent manner in the framework of the close-coupling approach. The approach was generalized to include both the open (for pionic hydrogen) and closed (for kaonic and antiprotonic hydrogen) channels corresponding to non-stationary states. We have investigated the dependence of the collisional cross sections on the width of the non-stationary states in a wide range of its values.

For the first time the integral cross sections of the induced absorption, elastic scattering, and Stark transitions have been calculated for the excited states of pionic, kaonic and antiprotonic hydrogen atoms with the values of the principal quantum number $n = 2 - 8$ in a wide energy range including the cross sections of the induced absorption in kaonic and antiprotonic hydrogen below the corresponding ns thresholds. The present results are very important for the kinetics of atomic cascade in hadronic atoms.

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