

Quasiclassical Description of Physics with Antiprotons

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Quasiclassical methods like classical-trajectory Monte Carlo (CTMC) and fermion molecular dynamics (FMD) have been found to be very useful for getting approximate cross sections for exotic atoms. Antiprotonic (\bar{p}) atoms are formed in low-energy collisions between antiprotons and normal atoms or molecules. The FMD method has enabled us to go beyond the atomic hydrogen target and study electron-correlation effects with noble-gas targets (He, Ne, Ar, Kr, and Xe) and molecular effects with isotopic hydrogen targets (H_2 , D_2 , and HD). Multiple ionization and ro-vibrational excitation are found to greatly increase the maximum energy of capture, with the latter also leading to a significant dependence on the projectile mass and target isotope. The kinetic energies of the ionized electrons are found to increase somewhat with the target nuclear charge. Atomic capture of \bar{p} is mechanistically very similar to capture of the lighter negative particles μ^- and π^- . Recent calculations of π^- capture by molecular hydrogen clear up the long-standing anomaly of pion transfer from p to d being apparently very different in HD and in H_2/D_2 mixtures. Calculations on the noble-gas atoms yield capture ratios in agreement with a number of experiments with muons and pions. They demonstrate the role of multiple electrons and suggest what features will be important in a future completely quantum-mechanical treatment. The agreement with experiments done with μ^- and π^- lends support to the theoretical results for \bar{p} capture, which will soon be observed experimentally for the first time.

Some results may also be given for rearrangement in hydrogen-antihydrogen collisions and for field-assisted formation of antihydrogen, although quasiclassical methods are less justified in these cases.