Controlling Chemical Reactions of a Single Particle

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The full control over all quantum mechanical degrees of freedom in binary collisions allows for the identification of fundamental interaction processes and for steering chemical reactions. Focussing on the best-controlled experimental conditions, such as using state-selected single particles and low temperatures, is crucial for the investigation of chemical processes at the most elementary level.
The hybrid system of trapped atoms and ions offers key advantages in this undertaking: ion traps have a large potential well depth in order to trap the reaction products, while the absence of a Coulomb-barrier allows the particles to collide at short internuclear distance.
Here, we report on the experimental tuning of the exchange reaction rates of a single trapped ion with ultracold neutral atoms by exerting control over both their quantum states. We observe the influence of the hyperfine state on chemical reaction rates and branching ratios and monitor the kinematics of the reaction products. These investigations advance chemistry with single trapped particles towards achieving quantum-limited control of chemical reactions and pave the way to the study of the coherence properties of a single trapped ion in an ultracold buffer gas.