Universität Basel

Research Project

Hybrid trapping of cold molecules and cold ions: state-controlled ion-molecule interactions, collisions and reactions in the millikelvin regime

Third-party funded project

Project title Hybrid trapping of cold molecules and cold ions: state-controlled ion-molecule interactions, collisions and reactions in the millikelvin regime
Principal Investigator(s) Willitsch, Stefan ;
Project Members von Planta, Claudio ; Mangeng, Christian ; Haas, Dominik ;
Organisation / Research unit
Departement Chemie / Chemische Physik (Willitsch)
Department
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Enabled by the recent development of experimental techniques for the simultaneous trapping of cold ions and atoms, the study of interactions between these species at temperatures down to the millikelvin range has emerged as a new scientific field at the interface between chemistry and physics over the past few years. These ”hybrid” systems of cold ions and atoms have formed the basis of exciting new avenues of research. These include studies of the dynamics of ion-neutral collisions at very low energies, the elucidation of exotic ultralow-temperature ion chemistry, the investigation of many-body physics in a regime of intermediate interaction strengths, precise characterizations of intermolecular interactions and the development of new cooling techniques for ions.One major drawback of previous experiments, however, was their technological restriction to laser- coolable atoms, mostly alkalis, which were confined in suitable atom traps and superimposed with trapped ions. This experimental limitation severely constrained the scope of systems and phenomena which could be studied. As the main objective of our current SNSF project over the past two years, we have been developing a new experimental approach for the simultaneous trapping of cold neutral molecules and molecular ions which substantially enhances the chemical and scientific scope of hybrid trapping experiments. Our new method is based on the magnetic trapping of Stark-decelerated cold neu- tral molecules which are superimposed with sympathetically cooled molecular ions in a radiofrequency ion trap under cryogenic conditions. This new experimental setup opens the dorr for probing interactions, collisions and chemical reactions between ions and molecules in the millikelvin regime for the first time.Following the experimental development of this new method during the first phase of the project, we now apply for a continuation of this project grant to harvest its full scientific potential by (i) implementing internal quantum-state preparation of both the trapped neutrals and the trapped ions in order to realize fully state-controlled studies, (ii) further extending its chemical scope by trapping a wider range of neutral molecules and molecular ions, and (iii) apply these developments to investigations of cold collisions and chemical reactions in a range of prototypical and fundamental ion-molecule hybrid systems consisting of the combination of N2+ , O2+ and H2O+ with OH and NH.The present project combines experimental methods established in the domains of quantum optics and atomic and molecular physics in a new and original fashion in order to address pertinent problems in chemistry and chemical physics. It will introduce new experimental techniques into studies of the collisional and chemical dynamics of ionic processes which enable an unprecedented level of control over collision parameters such as collision energies and molecular quantum states. In this way, it will provide new insights into fundamental principles of molecular energy transfer, chemical reactivity and collision dynamics of interest to a wider chemistry and physics community

Keywords cold ions; cold molecules; ion trapping; ion-neutral hybrid systems; chemical dynamics; ion-molecule reactions; cold chemistry
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