Symposium Molecular Collisions at ultracold temperatures (SYMC)

gemeinsam veranstaltet
vom Fachverband Quantenoptik und Photonik und
vom Fachverband Molekülphysik

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Übersicht der Hauptvorträge und Fachsitzungen

(Hörsäle 5D)

Hauptvorträge

SYMC 1.1	Mo	14:00–14:30	5D	**Towards the study of ultracold ion-molecule reactions** — •Timothy Softley, Martin Bell, David Carty, Alexander Gingell, James Oldham
SYMC 1.2	Mo	14:30–15:00	5D	**Molecular collisions in magnetic fields** — •Jeremy Hutson
SYMC 1.3	Mo	15:00–15:30	5D	**Photodynamics of Atoms in and on Helium Nanodroplets** — •Marcel Drabbels
SYMC 1.4	Mo	15:30–16:00	5D	**Ultracold molecules in an optical lattice** — •Johannes Hecker Denschlag
SYMC 2.1	Mo	16:30–17:00	5D	**Cold Molecular Ions: Single Molecule Studies** — •Michael Drewsen
SYMC 2.2	Mo	17:00–17:30	5D	**Cool anion molecule collisions** — •Jochen Mikosch, Sebastian Trippel, Rico Otto, Christoph Eichhorn, Matthias Weidemüller, Roland Wester
SYMC 2.3	Mo	17:30–18:00	5D	**Controlled Xe-OH collisions and the OH(v=1) radiative lifetime** — •Gerrit Groenenboom
SYMC 2.4	Mo	18:00–18:30	5D	**Molecular collision studies with Stark-decelerated beams** — •Gerard Meijer

Fachsitzungen

SYMC 1.1–1.4	Mo	14:00–16:00	5D	**Molecular collisions at ultracold temperatures I**
SYMC 2.1–2.4	Mo	16:30–18:30	5D	**Molecular collisions at ultracold temperatures II**

SYMC 1: Molecular collisions at ultracold temperatures I

Zeit: Montag 14:00–16:00 Raum: 5D

Hauptvortrag SYMC 1.1 Mo 14:00 5D

Towards the study of ultracold ion-molecule reactions — •Timothy Softley, Martin Bell, David Carty, Alexander Gingell, and James Oldham — Department of Chemistry, University of Oxford, Chemistry Research Laboratory, Mansfield Rd, Oxford, OX1 3TA, United Kingdom

In the sub-Kelvin temperature range, the de Broglie wavelength of colliding species becomes long compared to molecular dimensions and a range of quantum effects will play an important role in determining the dynamics of reactive collisions. However, only reactions with a low activation barrier will have rates that are amenable to study. Ion-molecule reactions are a general category of reactions with negligible activation barriers; free-radical insertion reactions are another suitable category, as are reactions of electronically excited species. In this presentation we describe the development of experiments which are geared towards studying ultracold ion-molecule chemistry. A Coulomb-crystal device has been set up in which calcium ions are laser cooled into the milliKelvin range. The characterization of the temperature of the ions formed in regular arrays, and the possibilities for sympathetic cooling of state-selected molecular ions will be discussed. This device is to be combined with a low-temperature source of neutral dipolar species, which are produced by either a quadrupole guide velocity selector, or by a 130-stage Stark decelerator. We are also developing a decelerator for Rydberg molecules, and a source of ultracold atoms based on photodissociation. Progress towards combining these sources for reactive studies will be discussed.

Hauptvortrag SYMC 1.2 Mo 14:30 5D

Molecular collisions in magnetic fields — •Jeremy Hutson — Department of Chemistry, Durham University, Durham, DH1 3LE, UK

The control of atom-atom interactions using magnetic fields has been crucial to recent advances in atomic physics. Similar control should be possible for atom-molecule and molecule-molecule collisions. We have generalized the BOUND and MOLSCAT packages to allow calculations in magnetic fields, initially for collisions of molecules in multiplet Sigma states with structureless atoms [1]. We have used the new capability to carry out bound-state and scattering calculations on 3He+NH and 4He+NH as a function of magnetic field. Following the bound-state energies to the point where they cross thresholds gives very precise predictions of the magnetic fields at which zero-energy Feshbach resonances occur.

We have located and characterized two very narrow zero-energy Feshbach resonances in 4He+NH. One resonance shows a pole in the scattering length as usually observed for atomic collisions, but for the second resonance the pole in the scattering length is dramatically suppressed and the cross sections show relatively small peaks.

The suppression of the pole in the scattering length is due to inelastic scattering. This is a general result, applicable to both atomic and molecular collisions [2]. In general, poles will be strongly suppressed whenever the resonant state is coupled with comparable strength to the elastic and inelastic channels.

[1] M. L. Gonzalez-Martinez and J. M. Hutson, arXiv:physics/0610214 (2006). [2] J. M. Hutson, arXiv:physics/0610210 (2006).

Hauptvortrag SYMC 1.3 Mo 15:00 5D

Photodynamics of Atoms in and on Helium Nanodroplets — •Marcel Drabbels — Swiss Federal Institute of Technology (EPFL), Lausanne, Switzerland

The photodynamics of excited silver atoms dissolved in, and sodium atoms attached to helium nanodroplets has been investigated. Embedded silver atoms are excited from the 5s $^2S_{1/2}$ state to either the 5p $^2P_{1/2}$ or $^2P_{3/2}$ state. The excited species are subsequently ionized by a second photon to provide time-of-flight mass spectra, photoelectron and ZEKE spectra. The experiments indicate that the helium environment induces non-adiabatic transitions between the different electronic states before the silver atoms are being ejected from the droplets. Ion imaging experiments demonstrate that the speed distributions of ejected Ag atoms depends on the excited state and consequently are not related to the critical Landau velocity, *i.e.* the velocity below which no energy and momentum can be transferred from a moving object to the helium environment.

Sodium atoms attached to the surface of the droplets are electronically excited and subsequently ionized. The excitation spectrum has been recorded up to the ionization threshold and indicates that the sodium atoms desorb from the droplets independent of the electronic state excited. Photoelectron spectroscopy and ion imaging experiments indicate that the helium environment induces a fast relaxation of the excited sodium atoms before they desorb from the droplets.

Hauptvortrag SYMC 1.4 Mo 15:30 5D

Ultracold molecules in an optical lattice — •Johannes Hecker Denschlag — Institut für Experimentalphysik, Universität Innsbruck, 6020 Innsbruck, Austria

An optical lattice is an excellent environment to produce, manipulate and study ultracold molecules. We describe recent experiments where we have created a pure ultracold ensemble of Rb_2 dimers in various well defined quantum states in the electronic ground state. Starting from an atomic ^{87}Rb condensate which is adiabatically loaded into a 3D optical lattice we first create Feshbach molecules by ramping over a Feshbach resonance. A purification scheme based on a combined laser and radiofrequency pulse removes all unbound atoms. Using optical STIRAP (stimulated Raman adiabatic passage) or a radio frequency sweep, we can efficiently transfer these Feshbach molecules to a more deeply bound vibrational level. In this way we create well defined mixtures and coherent superpositions of molecular states which can later be used to invesigate molecular interactions and collisions. Besides studying chemically bound molecules, optical lattices also allow forming a novel kind of stable bound state of two atoms which is based on repulsion rather than attraction between the particles. We will explain how these lattice-induced repulsively bound atom pairs come about and discuss their interesting properties.

SYMC 2: Molecular collisions at ultracold temperatures II

Zeit: Montag 16:30–18:30 Raum: 5D

Hauptvortrag SYMC 2.1 Mo 16:30 5D

Cold Molecular Ions: Single Molecule Studies — •Michael Drewsen — Department of Physics and Astronomy, University of Aarhus, Ny Munkegade, Build. 1520, DK-8000, Aarhus C, Denmark

In ion traps, the translational motion of molecular ions can effectively be sympathetically cooled to temperature in the mK range through the Coulomb interaction with laser cooled atomic ions. At such low temperatures the molecular ions typically become part of spatial ordered structures (Coulomb crystals) in which the individual molecules can be localized within a few μm^3. The extreme situation of having only a single laser-cooled atomic ion interacting with a single molecular ion is an ideal starting point for single molecule studies. A few years back, we have demonstrated a rather simple non-destructive technique for the identification of the single molecular ion in such a situations relying on an in-situ mass measurement of the molecule. In the talk, I will focus on two recent single molecule studies using this technique, namely, photofragmentation of singly changed Aniline ions ($C_6H_7N^+$) and isotope effects in the reaction of $^{26}Mg^+$ atomic ions with a H_2, HD, and D_2 molecules.

Hauptvortrag SYMC 2.2 Mo 17:00 5D

Cool anion molecule collisions — •Jochen Mikosch, Sebastian Trippel, Rico Otto, Christoph Eichhorn, Matthias Weidemüller, and Roland Wester — Physikalisches Institut, Universität Freiburg

Collisions of neutral molecules with anions at low relative energy are

strongly affected by long range ion-dipole interactions. On the potential energy surface reactions are steered through deeply bound entrance and exit channel complexes separated by a central barrier. We investigate the quantum dynamics of reactive collisions, in particular rovibrational state dependencies, tunneling, and stereodynamical effects.

For the S_N2 reaction $Cl^- + CH_3Cl$ we were able to stabilize the short lived collision complex in a high order multipole trap by a third impacting particle. The three body association is strongly enhanced for decreasing temperature. On the other hand the proton transfer of H_2 to NH_2^- exhibits a maximal rate coefficient at around 20 K and is strongly suppressed for decreasing temperature. We also investigate slow collisions of anions with cold neutrals at fixed energy rather than temperature. Crossed beam ion imaging gives access to the doubly differential cross section. A detailed study of the S_N2 reaction $Cl^- + CH_3I \longrightarrow ClCH_3 + I^-$ shows the cone of acceptance opening up for increasing collision energy accompanied by excitation of many vibrational quanta in the molecular product.

We will extend our studies to the stereodynamics of ion-molecule reactions using microsolvated anions, which are subject to stereodynamics hindrance, and alignment in strong laser fields.

Hauptvortrag SYMC 2.3 Mo 17:30 5D

Controlled Xe-OH collisions and the OH(v=1) radiative lifetime — •Gerrit Groenenboom — Theoretical Chemistry, Institute for Molecules and Materials, Radboud University Nijmegen, Toernooiveld 1, 6525ED Nijmegen, The Netherlands

Beams of polar molecules can be produced with very well controlled velocities with the Stark deceleration technique developed by Gerard Meijer and coworkers. In a recent proof-of-principle experiment this was used to study collisions of Xe with Stark controlled OH in the 50-400 wavenumber region [1]. Inelastic cross sections were determined for several rotational and spin orbit inelastic transitions. I will present calculated Xe-OH potential energy surfaces, theoretical cross sections, and the comparison with experiment.

In earlier work Stark decelerated OH was loaded into an electrostatic quadrupole trap. The long observation time in the trap made it possible to measure the radiative lifetime, which was found to be 59 +/- 2 ms., in excellent agreement with our calculations [2]. I will present new results for the OH Meinel system [3].

[1] J. J. Gilijamse, S. Hoekstra, S. Y. T. van de Meerakker, G. C. Groenenboom, and G. Meijer, Science, 313, 1617 (2006)

[2] S. Y. T. van de Meerakker, N. Vanhaecke, M. P. J. van der Loo, G. C. Groenenboom, and G. Meijer, Phys. Rev. Lett., 95, 013003 (2005).

[3] Mark P. J. van der Loo and Gerrit C. Groenenboom, J. Chem. Phys., accepted (2007).

Hauptvortrag SYMC 2.4 Mo 18:00 5D

Molecular collision studies with Stark-decelerated beams — •Gerard Meijer — Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, D-14195 Berlin, Germany

Molecular scattering behavior has generally proven difficult to study at low collision energies. We formed a molecular beam of OH radicals with a narrow velocity distribution and a tunable absolute velocity by passing the beam through a Stark decelerator. The transition probabilities for inelastic scattering of the OH radicals with Xe atoms were measured as a function of the collision energy in the range of 50 to 400 wavenumbers, with a high intrinsic energy resolution. The behavior of the cross-sections for inelastic scattering near the energetic thresholds was accurately measured, and excellent agreement was obtained with cross-sections derived from coupled-channels calculations on ab initio computed potential energy surfaces [Science 313, (2006) 1617-1620]. The possibilities to perform collision studies using either two Stark-decelerated beams in a crossed beam configuration or counter-propagating packets of molecules in a molecular synchrotron will be discussed. Time permitting, our experimental approach to the sympathetic cooling of polar molecules with ultra-cold Rb atoms will be presented as well.