

MO 10: Collisions (joint session MO/Q)

Time: Wednesday 14:30–16:15

Location: F142

MO 10.1 Wed 14:30 F142

Gas phase investigations on dynamics of the reaction of tantalum cation Ta^+ with carbon dioxide CO_2 — ●MARCEL META¹, MAXIMILIAN HUBER¹, MAURICE BIRK¹, ATILAY AYASLI², TIM MICHAELSEN², ROLAND WESTER², and JENNIFER MEYER¹ — ¹RPTU Kaiserslautern-Landau, Fachbereich Chemie, Kaiserslautern, Germany — ²Universität Innsbruck, Institut für Ionenphysik und Angewandte Physik, Innsbruck, Austria

The dynamics of the *oxygen atom transfer* (OAT) reaction $Ta^+ + CO_2 \rightarrow TaO^+ + CO$ in gas phase could be investigated under single collision conditions. The measured energy and angle differential cross sections allow us to probe the rearrangement of atoms during reaction, i.e. the atomistic dynamics [1]. The present results were measured with our new 3D velocity map imaging setup in Kaiserslautern. The reaction is exothermic and spin forbidden in the ground state but takes place due to an efficient crossing from the quintet surface over to the triplet surface. Hence, it was found that the reaction almost proceeds with collision rate at room temperature [2-4]. The TaO^+ velocity map images shows dominant indirect dynamics even at high collision energies with most of the additional collision energy partitioned into internal excitation.

[1] J. Meyer, R. Wester, *Annu. Rev. Phys. Chem.* 2017, 68, 333; [2] R. Wesendrup, H. Schwarz, *Angew. Chem. Int. Ed.* 1995, 34, 2033; [3] G. K. Koyanagi, D. K. Bohme, *J. Phys. Chem. A* 2006, 110, 1232; [4] N. Levin, J. T. Margraf, J. Lengyel, K. Reuter, M. Tschurl, U. Heiz, *Phys. Chem. Phys.* 2022, 24, 2623

MO 10.2 Wed 14:45 F142

Dissociative recombination of ArH^+ at the Cryogenic Storage Ring — ●ÁBEL KÁLOSI^{1,2}, MANFRED GRIESER², LEONARD W. ISBERNER^{3,2}, DANIEL PAUL^{1,2}, DANIEL W. SAVIN¹, STEFAN SCHIPPERS³, VIVIANE C. SCHMIDT², ANDREAS WOLF², and OLDRICH NOVOTNY² — ¹Columbia Astrophysics Laboratory, Columbia University, New York, NY 10027, USA — ²Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany — ³I. Physikalisches Institut, Justus-Liebig-Universität Gießen, 35392 Gießen, Germany

ArH^+ is an important probe of the cosmic ray flux in interstellar space. Cosmic rays are the dominant ionization source for H and H_2 in the cold interstellar medium (ISM). This ionization initiates astrochemistry in the cold phases of the ISM. The cosmic ray ionization rate (CRIR) is thus an important parameter for both chemical and dynamical models of the ISM. ArH^+ forms via cosmic ray ionization of Ar, but can be destroyed via dissociative recombination (DR) with free electrons. Astronomical observations of ArH^+ , combined with chemical models, enable one to quantitatively estimate the CRIR. Such models require reliable rate coefficients that take into account the low internal excitation of the ArH^+ , as occurs in the cold ISM. To this end, we have performed merged-beams DR experiments with ArH^+ in the Cryogenic Storage Ring where, at an ambient temperature of ~ 10 K, the ions relaxed to their lowest rotational states.

MO 10.3 Wed 15:00 F142

Laser induced forced evaporative cooling of molecular anions — ●ERIC ENDRES¹, JONAS TAUCH², SABA HASSAN², MARKUS NÖTZOLD¹, ROLAND WESTER¹, and MATTHIAS WEIDEMÜLLER² — ¹Institut für Ionenphysik und Angewandte Physik, Universität Innsbruck, Austria — ²Physikalisches Institut, Universität Heidelberg, Germany

Cooling molecular anions is key for the production of cold antihydrogen and the creation of anionic coulomb crystals and would open up new fundamental research areas in modern physics and chemistry. An established technique to store and cool anions are collisions with buffer gas in multipole radio frequency ion traps. However, the temperature is limited by the temperature of the used cryogenic cooling medium.

In this contribution we present forced evaporative cooling down to 2.2(8) K by means of photodetachment of an anionic OH^- ensemble, confined in a multipole wire trap. [1] This enables a phase space density approaching the near-strong Coulomb coupling regime. The anion cooling dynamics are described by a quantitative analysis of the experimental results with a full thermodynamic model [2] without any fitting parameters. In principle, this technique can be used for cooling basically any anionic species below the temperature of liquid helium.

[1] J. Tauch, et al. arXiv preprint arXiv:2211.11264 (2022).

[2] A. Crubellier. *J. Phys. B*, 23(20), 3585 (1990).

MO 10.4 Wed 15:15 F142

Product spin and binding energy propensities for three-body recombination of ultracold atoms — ●JINGLUN LI¹, SHINSUKE HAZE¹, JOSÉ P. D'INCAO^{1,2}, DOMINIK DORER¹, MARKUS DEISS¹, EBERHARD TIEMANN³, PAUL S. JULIENNE⁴, and JOHANNES HECKER DENSCHLAG¹ — ¹Institut für Quantenmaterie, Universität Ulm, Germany — ²JILA, University of Colorado, USA — ³Institut für Quantenoptik, Leibniz Universität Hannover, Germany — ⁴JQI, University of Maryland, USA

Three-body recombination (TBR) is an elementary chemical reaction process, in which free atoms collide to form a molecule and release the binding energy E_b into the translational movement of the molecule and the third atom. Knowing favored molecular products in TBR is crucial for various fields such as astrophysics, atmospheric physics, and physical chemistry. In recent years we have been working experimentally and theoretically on TBR of ultracold atoms and have achieved great progress in identifying the molecular product distribution on a full quantum state resolution level. In particular, for ultracold Rb atoms we find that TBR intends to produce a molecule preserving the initial spins of two atoms that form it and that the state-to-state reaction rate follows roughly a power-law scaling $L_3 \propto 1/E_b$. Our numerical simulations predict that the $1/E_b$ propensity even holds, with a different prefactor, for two specific groups of molecular products disfavored by the spin propensity. We further elaborate a more comprehensive theoretical investigation on different alkali-metal species to explore the modifications and breakdowns of these propensities.

MO 10.5 Wed 15:30 F142

Two-photon optical shielding of collisions between ultracold polar molecules. — ●CHARBEL KARAM¹, MARA MEYER ZUM ALTEN BORGLOH³, ROMAIN VEXIAU¹, MAXENCE LEPERS², SILKE OSPELKAUS³, NADIA BOULOUBA-MAAFA¹, LEON KARPA³, and OLIVIER DULIEU¹ — ¹Université Paris-Saclay, CNRS, Laboratoire Aimé Cotton, Orsay 91400, France — ²Laboratoire interdisciplinaire Carnot de Bourgogne, Cedex F-21075 Dijon, France — ³Institut für Quantenoptik, Leibniz Universität Hannover, 30167 Hannover, Germany

We propose a method to engineer repulsive long-range interactions between ultracold ground-state molecules using optical fields, thus preventing short-range collisional losses. It maps the microwave coupling recently used for collisional shielding onto a two-photon transition, and takes advantage of optical control techniques. In contrast to one-photon optical shielding [*Phys. Rev. Lett.* 125, 153202 (2020)], this scheme avoids heating of the molecular gas due to photon scattering. The proposed protocol, exemplified for $23Na39K$, should be applicable to a large class of polar diatomic molecules.

MO 10.6 Wed 15:45 F142

Light controlled engineering of long-range molecular states — ●PATRICK MISCHKE, JANA BENDER, TANITA KLAS, FLORIAN BINOTH, THOMAS NIEDERPRÜM, and HERWIG OTT — Department of Physics and Research center OPTIMAS, RPTU Kaiserslautern-Landau

We experimentally engineer the deformation of the 5S-6P potential of Rubidium atoms at large interatomic distances on the order of several hundred Bohr radii. This deformation leads to a potential shape that supports bound molecular states.

To achieve this, we couple off-resonantly to an ultra-long range Rydberg molecule potential using strong laser driving. Properties that are commonly associated with Rydberg molecules, usually formed by an Rydberg atom and a ground state atom, are optically admixed to the 5S-6P pair state.

We spectroscopically observe the photoassociated 5S-6P molecules. The change in binding energy for different experimental coupling parameters is in qualitative agreement with a simple theoretical model.

MO 10.7 Wed 16:00 F142

Electric-field-controlled dipolar collisions between trapped polyatomic molecules — ●FLORIAN JUNG, MANUEL KOLLER, JINDARATSAMEE PHROMPAO, MARTIN ZEPPENFELD, ISABEL M. RABEY,

and GERHARD REMPE — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching, Germany

Polar symmetric top molecules exhibit a permanent electric dipole moment which creates strong anisotropic interactions, and allows them to be manipulated with moderate electric fields. This, together with their multitude of internal states, renders them promising for applications in e.g. quantum information processing or cold chemistry. For these applications reaching high-density low-temperature ensembles is imperative. This requires the capability to control collisional losses, which is a challenging task.

By combining a cryogenic buffer-gas cell with a centrifuge decelerator

and an electrostatic trap, we can now confine up to 2×10^7 CH₃F molecules at a temperature of ~ 350 mK for several seconds, achieving densities of up to $10^7/\text{cm}^3$, which allows for the observation of collisions [1]. We employ a homogeneous control field, covering a large fraction of our trap to mitigate collisional losses and obtain inelastic loss coefficients below $4 \times 10^{-8} \text{cm}^3/\text{s}$. An ab-initio theory shows excellent agreement with our experiment and highlights dipolar relaxation as the major loss mechanism. These findings are immediately relevant for cold molecular collision studies and an important step towards the observation of re-thermalisation between polyatomic molecules.

[1] M. Koller *et al.*, Phys. Rev. Lett. **128**, 203401 (2022).