

## MO 2: Precision Experiments on Small Molecules

Time: Monday 14:30–16:30

Location: N 25

MO 2.1 Mon 14:30 N 25

**Doppler-limited precision spectroscopy of cold formaldehyde in an electric trap** — ●MARTIN IBRÜGGER, ALEXANDER PREHN, MARTIN ZEPPENFELD, and GERHARD REMPE — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

Besides cooling, trapping has proven to be a key ingredient for high precision spectroscopy of many atomic species as can be seen in e.g. various optical clock experiments around the world. For molecules however, in particular polyatomic molecules, there are few to none experiments in a trap employing cooling to cold temperatures to increase control and reduce linewidths.

Here, we present microwave spectroscopy on a magic transition between rotational levels of trapped formaldehyde. The molecules are stored in an electric trap [1] and cooled via optoelectrical Sisyphus cooling [2] to temperatures ranging from 60 mK to 2 mK. We achieve Doppler-limited linewidths down to 3.8 kHz corresponding to an accuracy of  $10^{-8}$ . The lineshapes are in excellent agreement with theory taking into account the energy distribution of the molecules and the electric field distribution of the trap. These results show the feasibility of high precision spectroscopy in our experiment and open up the way to measurements with unprecedented precision for polyatomic molecules once applied to even colder ensembles.

[1] B.G.U. Englert *et al.*, *Phys. Rev. Lett.* **107**, 263003 (2011).

[2] A. Prehn *et al.*, *Phys. Rev. Lett.* **116**, 063005 (2016).

MO 2.2 Mon 14:45 N 25

**Photodetachment study of  $\text{NH}_2^-$  ions in the 22 pole trap** — ●OLGA LAKHMANSKAYA<sup>1</sup>, MALCOLM SIMPSON<sup>1</sup>, SIMON MURAUER<sup>1</sup>, VIATCHESLAV KOKOULINE<sup>2</sup>, and ROLAND WESTER<sup>1</sup> — <sup>1</sup>Universität Innsbruck, Innsbruck, Austria — <sup>2</sup>University of Central Florida, Orlando, US

We present a near-threshold photodetachment spectrum of the amide anion  $\text{NH}_2^-$  performed in a cold (10 K) 22-pole ion trap. The spectrum shows steps in the relative cross section that are associated with the transitions between rotational levels of the vibrational ground states of  $\text{NH}_2^-$  ( $X^1A_1$  electronic state) and  $\text{NH}_2$  ( $X^2B_1$  electronic state). With this data we can significantly improve the determination of the electron affinity of amidogen  $\text{NH}_2$ .

MO 2.3 Mon 15:00 N 25

**Crossed-beam velocity-map-imaging of the  $\text{Ar}^+ + \text{H}_2$  charge-transfer reaction** — ●TIM MICHAELSEN<sup>1</sup>, BJÖRN BASTIAN<sup>1</sup>, JENNIFER MEYER<sup>1</sup>, EDUARDO CARRASCOSA<sup>2</sup>, DAVE PARKER<sup>3</sup>, and ROLAND WESTER<sup>1</sup> — <sup>1</sup>Universität Innsbruck, Austria — <sup>2</sup>University of Melbourne, Australia — <sup>3</sup>Radboud University, Nijmegen, Netherlands

The Reaction of  $\text{Ar}^+ + \text{H}_2$  can proceed via atomic re-arrangement resulting in  $\text{ArH}^+ + \text{H}$  or via charge transfer resulting in  $\text{Ar} + \text{H}_2^+$ . Here we will focus on the charge transfer pathway. Previous studies on this pathway predict a strong dependence of the reaction rate on the spin-orbit state of the  $\text{Ar}^+$  [1] and previous crossed-beam studies predict forward scattering with a large backward scattered fraction at low collision energies [2]. Additionally, theory and experiments predict a quasi-resonant behavior towards the product ion vibrational state  $\text{H}_2^+(v=2)$ [3].

Here, we present differential cross-sections obtained with a crossed-beam VMI-spectrometer for charge transfer reactions of  $\text{Ar}^+$  with  $\text{H}_2$  at energies below 1eV. We observe predominantly forward scattering, a dependence on the  $\text{Ar}^+$  spin-orbit state as well as dominant excitation of the  $\text{H}_2^+(v=2)$  state. Additionally, we compare these results to the charge-transfer reaction with  $\text{D}_2$ ,  $\text{N}_2$  [4] and  $\text{O}_2$ .

[1] Tanaka K., *et al.* *J. Chem. Phys.* **75**.10 (1981): 4941-4945. [2] Hierl P., *et al.* *J. Chem. Phys.* **67**.6 (1977): 2678-2686. [3] Baer M., *et al.* *J. Chem. Phys.* **93**.7 (1990): 4845-4857. [4] Trippel S., *et al.* *PRL* **110**.16 (2013): 163201.

MO 2.4 Mon 15:15 N 25

**Experimental studies of the ion-molecule reactions  $\text{H}_2^+ + \text{H}_2$  and  $\text{H}_2^+ + \text{D}_2$  at low collision energies with a merged beam apparatus** — ●KATHARINA HÖVELER, PITT ALLMENDINGER, JOHANNES DEIGLMAYR, OTTO SCHULLIAN, and FRÉDÉRIC MERKT — Laboratorium für Physikalische Chemie, ETH Zürich, CH-8093 Zurich, Switzerland

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The exothermic, barrierless  $\text{H}_2^+ + \text{H}_2 \rightarrow \text{H}_3^+ + \text{H}$  reaction has been studied in the collision-energy range  $E_{\text{coll}}/k_b = 300 \text{ mK} - 50 \text{ K}$ . To reach such low collision energies, we use a merged-beam approach and substitute the  $\text{H}_2^+$  reactants by the ionic cores of  $\text{H}_2$  molecules in high- $n$  Rydberg-Stark states. The Rydberg electron does not influence the reaction but shields the ion from heating by space-charge effects and stray electric fields. Merging of the two pulsed reactant supersonic beams is achieved by photoexcitation of the molecules of one beam to high- $n$  Rydberg-Stark states followed by Rydberg-Stark deceleration and deflection using a curved chip-based surface-electrode device. The collision energy is tuned by varying the temperature of the valve generating the  $\text{H}_2$  ground-state beam for selected velocities of the  $\text{H}_2$  Rydberg beam. The reaction cross section is found to follow the classical Langevin capture model down to  $E_{\text{coll}}/k_b = 5 \text{ K}$ . At lower temperatures, a deviation is observed and attributed to ion-quadrupole long-range interactions. Investigation of the reaction  $\text{H}_2^+ + \text{D}_2$  enables us to distinguish between charge transfer, D atom transfer and  $\text{H}^+$  ion transfer.

MO 2.5 Mon 15:30 N 25

**Towards Reactive Scattering between Metastable Helium and Magneto-Optically Trapped Lithium** — ●JONAS GRZESIAK, KATRIN DULITZ, ANDRIY ACHKASOV, FRANK STIENKEMEIER, and MARCEL MUDRICH — Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg i. Br.

The experimental study of Penning ionization reactions, i.e., the reactive scattering of metastable rare gas atoms with neutral species, has recently attracted a lot of attention through the observation of orbiting resonances at low collision energies [1]. We present first results leading to a detailed study of reactive scattering between supersonically expanded metastable helium atoms and ultracold lithium atoms confined in a magneto-optical trap. We also show that our cryogenically cooled source provides intense, velocity-tunable and cold supersonic beams of metastable helium atoms, and we discuss the efficiency of metastable atom production using two conceptually different, home-made discharge units.

[1] A. B. Henson, S. Gersten, Y. Shagam, J. Narevicius, E. Narevicius, *Science* **338**, 234 (2012).

MO 2.6 Mon 15:45 N 25

**Nondestructive Detection of Polar Molecules via Rydberg Atoms** — ●MARTIN ZEPPENFELD and FERDINAND JARISH — MPI für Quantenoptik, Hans Kopfermann Str. 1, 85748 Garching

Research on cold and ultracold molecules is impeded by the difficulty in many cases to efficiently detect molecules, with the choice of molecule species often influenced by the need for a suitable detection scheme. We demonstrate the possibility to efficiently and nondestructively detect basically any polar molecule species using Rydberg atoms [1]. A Rydberg atom senses the presence of a molecule based on Förster resonance energy transfer. We show that huge interaction cross sections of more than  $10^{-6} \text{ cm}^2$  exist for low collision energies, allowing for efficient detection [1]. First results on detection of room temperature ammonia molecules with Rubidium Rydberg atoms will be presented.

[1] M. Zeppenfeld, arXiv:1611.08893 [physics.atom-ph] (2016).

MO 2.7 Mon 16:00 N 25

**Laser cooling of molecular anions** — ●SEBASTIAN GERBER<sup>1</sup>, JULIAN FESEL<sup>1</sup>, CHRISTIAN ZIMMER<sup>1</sup>, INGMARI TIETJE<sup>1</sup>, ALEXANDER HINTERBERGER<sup>1</sup>, DANIEL COMPARAT<sup>2</sup>, and MICHAEL DOSER<sup>1</sup> — <sup>1</sup>CERN, 127 Rute de Meyrin, Switzerland — <sup>2</sup>Laboratoire Aime Cotton, CNRS, 91405 Orsay, France

Molecular anions play a central role in a wide range of fields: from atmospheric and interstellar science, anionic superhalogens to the chemistry of highly correlated systems. However, up to now the synthesis of negative ions in a controlled manner at ultracold temperatures relevant for the processes in which they are involved is currently limited to a few kelvin by supersonic beam expansion followed by resistive, buffer gas or electron cooling in cryogenic environments. We present a realistic scheme for laser cooling of  $\text{C}_2^-$  molecules to subkelvin temperatures, which has been only achieved for a few neutral diatomics. The generation of a pulsed source of  $\text{C}_2^-$  and the subsequent laser cooling

techniques of  $C_2^-$  confined in a Penning trap are reviewed. Further, laser cooling one anions species would allow to sympathetically cool other molecular anions, electrons and antiprotons that are confined in the same trapping potential. In this presentation the status of the experiment and the feasibility of  $C_2^-$  sympathetic Doppler laser cooling, photo-detachment cooling and AC Stark Sisyphus cooling will be reviewed.

MO 2.8 Mon 16:15 N 25

**Trapping and Cooling of Polar Molecules: YO and OH** —  
•TIM LANGEN<sup>1,2</sup>, DAVID REENS<sup>1</sup>, HAO WU<sup>1</sup>, ALEJANDRA COLLOPY<sup>1</sup>,  
YEWEI WU<sup>1</sup>, SHIQIAN DING<sup>1</sup>, and JUN YE<sup>1</sup> — <sup>1</sup>JILA, NIST and Uni-  
versity of Colorado, Boulder, USA — <sup>2</sup>5. Physikalisches Institut and  
IQST, Universität Stuttgart, Germany

We present two experiments progressing towards directly trapping and cooling polar molecular gases to the millikelvin regime and below.

First, using microwave mixing of rotational states and two vibrational repump lasers, we implement a cycling transition in the yttrium (II) monoxide (YO) molecule that is closed to the  $10^6$  level [1]. With this cycling transition, a beam of YO from a two-stage cryogenic buffer gas cell is decelerated to less than 5 m/s, slow enough to be loaded into a three-dimensional magneto-optical trap. We plan to implement a second stage of narrow-line cooling to reach below 100 microkelvin [2]. Second, we present our progress in the magnetic trapping and cooling of a gas of the dipolar hydroxyl (OH) radical [3]. Using detailed studies of electric-field-induced losses, we identify a novel Majorana-like loss mechanism that is inherently connected to the dipolar nature of the molecules. We discuss a newly developed trap design that will mitigate this loss to enable further evaporative cooling.

- [1] M. Yeo et al., Phys. Rev. Lett. **114**, 223003 (2015).
- [2] A. L. Collopy et al., New J. Phys. **17**, 055008 (2015).
- [3] B. K. Stuhl et al., Nature **492**, 396 (2012).