Photodetachment thermometry of stored OH^- at the Cryogenic Storage Ring

C. Meyer[*,1], A. Becker[*], K. Blaum[*], C. Breitenfeldt[*,†], S. George[*], J. Göck[*], M. Grieser[*], F. Grussie[*], E. A. Guerin[*], R. von Hahn[*], P. Herwig[*], J. Karthein[*], C. Krantz[*], H. Kreckel[*], J. Lion[*], S. Lohmann[*], P. M. Mishra[*], O. Novotný[*], A. P. O'Connor[*], R. Repnow[*], S. Saurabh[*], D. Schwalm[*,‡], L. Schweikhard[†], K. Spruck[*,§], S. Sunil Kumar[*], S. Vogel[*], and A. Wolf[*]

[*] Max-Planck-Institut für Kernphysik, D-69117 Heidelberg, Germany
[†] Institut für Physik, Ernst-Moritz-Arndt-Universität Greifswald, D-17487 Greifswald, Germany
[‡] Weizmann Institute of Science, Rehovot 76100, Israel
[§] Institut für Atom- und Molekülphysik, Justus-Liebig-Universität Gießen, D-35392 Gießen, Germany

Synopsis We have monitored the radiative cooling of the lowest rotational states of OH^- stored in the cryogenic storage ring CSR for up to 20 minutes, until thermal equilibration. From the data we extract the equilibrium rotational temperature as well as details on the photodetachment process and radiative relaxation.

The Cryogenic Storage Ring (CSR) [1], located at the Max-Planck-Institut für Kernphysik in Heidelberg, is a fully cryogenic, electrostatic ring with a circumference of 35 m. The experimental program aims at investigating ground-state properties and collisions of molecular and cluster ions with neutral particles or electrons in the gas phase. By cooling the experimental chambers down to 6 K, a residual gas density below 140 cm^{-3} (< 10^{-14} mbar room temperature equivalent) can be reached, which enables storage times of fast ion beams of several hours [1]. Under such extreme conditions infrared-active molecules can radiatively cool down to the rovibrational ground state. Rotational relaxation of CH^+ cations stored in the cryogenic environment of the CSR have been recently reported [2]. Here we present measurements of the internal state populations of OH^- by near-threshold photodetachment, similar to previous ion trap studies [3]. For the present measurements, a 60 keV OH^- ion beam was overlapped with a continuous wave HeNe laser (633 nm) and a pulsed, wavelength tunable OPO laser operated between 680 to 709 nm. Neutral OH^- produced by laser-induced photodetachment leave the closed orbit of the ring and are detected by a microchannel-plate detector in the cryogenic zone. The ion-beam lifetime and other ring effects are taken into account by normalizing the OH count rate from the OPO laser to that from the HeNe laser. By changing the wavelength of the OPO laser different combinations of rotational states are probed. The normalized count rates for various wavelengths (see Fig. 1) are fitted by a rate equation model of the rotational cooling folded with relative state-resolved photodetachment cross sections. The exponential decays of the photodetachment signal in Figure 1 are directly linked to the radiative lifetime of the rotational states. The relative state-resolved photodetachment cross sections for the three lowest rotational states at the employed photon energies can be inferred from the data with a precision of about 10%. Hence the equilibrium population distribution of OH^- can be determined almost independent of theoretical calculations. The data are compatible with an effective radiative temperature of 15.3(3) K, which leads to an equilibrium population of more than 90% in the rotational ground state.

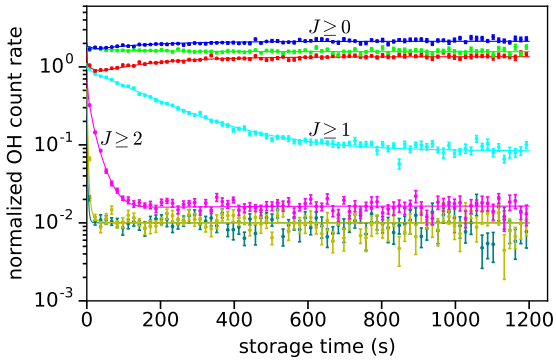

Figure 1. Normalized OH count rate induced by photodetachment of OH^- as a function of the storage time. The colors correspond to different laser frequencies, chosen to address various combinations of rotational states. The solid lines represent a model of rotational relaxation.

References

[1] R. von Hahn *et al.* 2016 *Rev. Sci. Instrum.* **87** 063115

[2] A. P. O'Connor *et al.* 2016 *Phys. Rev. Lett.* **116** 113002

[3] R. Otto *et al.* 2013 *Phys. Chem. Chem. Phys.* **15** 612

[1] E-mail: cmeyer@mpi-hd.mpg.de