Investigation of radiative cooling of small metal cluster anions by laser-induced electron detachment

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Radiative cooling is a fundamental process that determines the internal temperature of vibrationally excited ions as a function of time, eventually bringing them into thermal equilibrium with their environment. We have investigated the cooling of Cu\textsuperscript{n} (n=4,5,6,7) and Co\textsuperscript{3-} anions.

The cluster ions were produced in a Cs sputter ion source, with a vibrational excitation corresponding to temperatures of several thousand Kelvins. They were then size-selected and transferred to the Cryogenic Trap for Fast ion beams (CTF) within 120 µs, where they were stored at a kinetic energy of 6 keV. This electrostatic ion beam trap can be kept at a temperature below 15 K by a closed-cycle helium refrigeration system. The extremely low pressure (few 10\textsuperscript{-12} mbar) achieved by cryopumping resulted in a very low background of collision-induced ion loss and thus a beam lifetime of several minutes.

We have studied vibrational autodetachment (also called delayed detachment) by recording the rate of neutral particles escaping from the trap, as a function of the delay after the pulses from a laser emitting at a wavelength of 1064 nm. The rate for this process persists up to 3 ms after each laser pulse and approximately follows a power law in time. As the slope of the decay curve depends on the population of rotational and vibrational levels in the beam just before excitation, it can be used to probe the population of the stored ions.

For Co\textsubscript{3-} we have studied the rate of delayed detachment as a function of storage time and photon energy in the wavelength region of 500 to 1500 nm. Again the number of clusters which undergo vibrational autodetachment depends on their internal energy and thus can be used to probe the vibrational population of the stored ions. For short wavelength no delayed detachment rate is observed. For increased wavelengths the detected rate increases with time in the period immediately after injection of the clusters into the CTF, before decreasing again or staying constant. For even longer wavelengths only a fast decrease of autodetachment rate is observed.

References