XXIX International Conference on Photonic, Electronic, and Atomic Collisions (ICPEAC2015) IOP Publishing
Journal of Physics: Conference Series **635** (2015) 112124 doi:10.1088/1742-6596/635/11/112124

Radiative cooling of hot C_n^- and C_nH^- molecules

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Synopsis We have measured the rates of neutrals produced from 10 keV C_n^- or C_nH^- (n=2, 4, 6, 8, and 10) ion beams stored in one of DESIREE's 14 K storage rings. For n=4, 6, and 8 we observe marked differences between C_n^- and C_nH^- cooling rates as inverse internal conversion [cf. S. Martin *et al* (2013) *Phys. Rev. Lett.* **110**, 063003] processes are effective for the C_n^- ions only. Knowledge of the cooling rates of these ions are important for estimates of their formation and destruction rates in cold interstellar environments.

We investigate the cooling of internally hot C_n^- and C_nH^- ions with n=2, 4, 6, 8, and 10 stored in the electrostatic ion storage ring DESIREE [1, 2] operating at 14 K. We record the signal of neutrals detected after a straight section of the ring as a function of time, t, after producing internally hot C_n^- or C_nH^- ions in a sputter ion source. This production method gives wide internal temperature distributions. If the ions do not stabilize radiatively very fast, the hottest ones will decay first giving overall rates of neutrals following t^{-p} power laws [3].

In Fig. 1 we show data for n=4 (the results for n=6 and n=8 are qualitatively similar). While the C_4^--signal is small and disappears rapidly (sub-milliseconds), the C_4H^-- signal follows a power law for tens of milliseconds. Similar to C_6^- [4, 5], C_4^- and C_8^- are open-shell systems that cool very rapidly as they can convert (part of) their internal vibrational energies to low-lying electronically excited states, which decay through fast radiative transitions. The C_nH^- ions, on the other hand, are closed shell systems and have much higher HOMO-LUMO gaps. This means that inverse internal conversions to electronically excited states become highly unlikely [4, 5] and internal cooling must proceed through much slower vibrational transitions. While C_2H^- and $C_{10}H^-$ have similar decay behaviors as C_4H^-, C_6H^- and C_8H^-, the decays for C_2^- and C_{10}^- are much slower than those for C_4^-, C_6^- and C_8^-. The C_{10}^- decay is also more complex possibly reflecting the presence of linear and ring isomers in the stored beam. For C_n^- and C_nH^- anions, knowledge of their cooling rates are considered to be very important for estimates of their interstellar abundances [6].

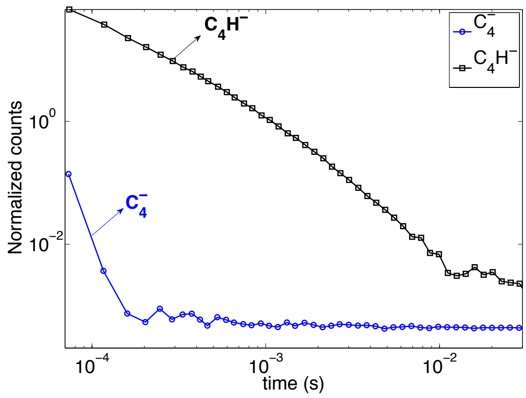

Figure 1. Rates of detected neutral particles normalized to the injected ion currents for the two molecular ions C_4^- and C_4H^-. The rapid disappearance of the signal for C_4^- is due to fast cooling through inverse internal conversion [4, 5, 7].

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