Thermal radiative cooling of carbon cluster cations C_N^+, N=8-27

K.Hansen[1,2], S.Iida[3], P.Ferrari[4], W.Hu[1], R.Zhang[1], T.Azuma[5], H.Shiromaru[3]

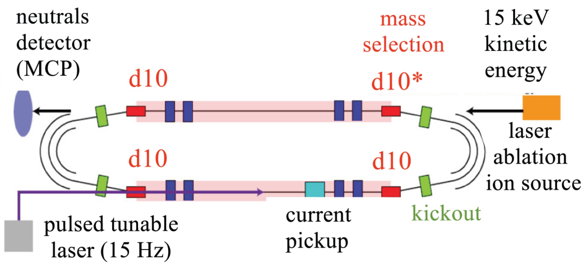
[1]Tianjin University, China, [2]Lanzhou University, China, [3]Tokyo Metropolitan University, Japan, [4]KU Leuven, Belgium, [5]RIKEN, Japan

Introduction

Emission of thermal radiation from molecules have until recently been considered an exclusively vibrational effect. Measurements in both time-of-flight mass spectrometers and storage rings have now demonstrated a number of cases of a very efficient radiative cooling of clusters and molecules by emission of NIR and visible photons from thermally excited electronic states of a range of different molecules and clusters. The emission rate constants exceed typical IR rates by large factors, in some cases by more than four orders of magnitude. We report measurements of radiative cooling rates of C_N^+ clusters, with N=8-27, in a storage ring. The values are on the order of 10^4 s^{-1}.

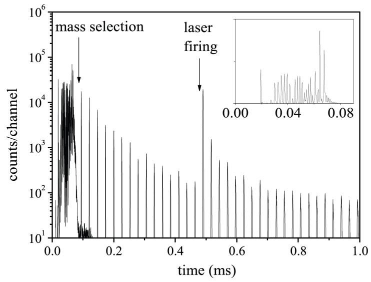
This translates into an efficient radiative stabilization after absorption of photons of energies between 10 eV and 14 eV.

Experiment



A sketch of the electrostatic storage ring used in these studies, the TMU E-ring. The ions were produced in the laser ablation source shown in the upper right corner of the figure, accelerated to 15 keV and injected into the ring. The mass selection was accomplished by pulsing the potential on the ten degree deflection plate d10* and on the kickout electrode. The neutral fragments that were produced during storage by decays in the top straight section were detected with the neutral particle detector at the end of that section on the top left of the figure. For the laser excitation experiments, a light pulse from a tunable Optical Parametric Oscillator (OPO) laser was introduced at the lower left hand corner with the light propagating toward the lower right corner along the straight section of the ring.

Example of spectrum, C_{11}^+



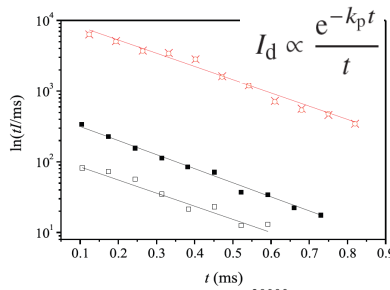
The spontaneous and photo-induced decay rate after absorption of a 520 nm photon at the time indicated by the rightmost arrow.

The clusters were introduced into the ring as bunches and appeared as peaks in the spectrum.

Source performance and the statistical decay assumption were tested by single photon excitation

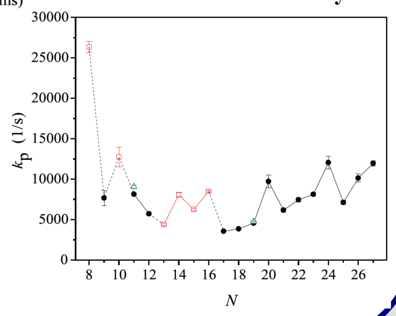
Observed decay rates

The decay rate is a combined exponential and powerlaw:



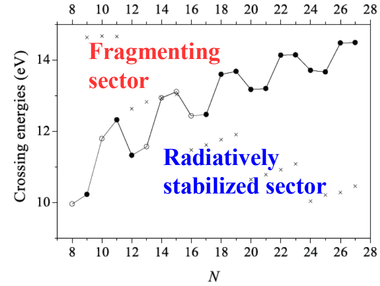
Spontaneous and photo-induced decays of C_{19}^+. The slope is the radiative cooling constant. The parallel curves confirm the statistical decay

Summary of measured radiative decay constants. Red curves are from [3].



Consequences

Photon emission provides a strong stabilizing effect on clusters, and provides a source of above unity quantum efficiency conversion of excitation by XUV photons into visible photons. Both are important effects for the modeling of the interstellar medium.



Stability regions calculated from the measured photon emission constants and theoretical binding energies and fragmentation rate constants

References

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klavshansen@tju.edu.cn hansen@lzu.edu.cn