Investigations of the decay of fullerene ions in a storage ring, and of delayed ionization of neutral fullerenes measured by time of flight.

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Highly excited finite systems like fullerenes can relax in a variety of ways such as by photon emission, by electron emission or by neutral particle emission. We have demonstrated that when hot fullerene ions are injected and stored in the ELectrostatic Ion Storage ring in Aarhus ELISA [1] their decay by electron or C_2 emission follows a $1/t$ dependence when the initial energy of the ions is conserved, i.e. when photon emission can be ignored. Deviations from a $1/t$ distribution therefore gives information about the radiative cooling of the stored fullerene. By the use of the cooling rate for positively charged fullerene ions we have by comparing with calculated values extracted dissociation energies for C_2 loss from several fullerene cations as shown in Figure 1 [2]. Hot fullerene anions have been produced in the ring after absorption of photons. Their decay by electron emission follows a 1/t distribution which again is perturbed by cooling at longer times and information on cooling rates for a given excitation energy is determined directly by the experimental parameters [3].
We have also studied delayed ionization of neutral C_{60} molecules in a time of flight (TOF) spectrometer. The molecules were produced in an effusive source filled with pure C_{60} which was heated until it produces a low density molecular beam. The C_{60} molecules in this beam were excited by a collinear laser beam and TOF spectra like the one shown in Figure 2 were obtained. At times larger than 20 µs this spectrum contains information on delayed ionization of C_{60}. This part of the spectrum is shown in Figure 3 as a log log plot. The straight line fitted to the short time delay part of the spectrum has a time dependence which can be expressed as $t^{-0.72}$. The exponent contains information on the ratio between the ionization energy and the dissociation energy for C_2 emission from C_{60} as discussed by Hansen and Echt [5]. The deviation from the straight line dependence at times larger than 100 µs is caused by the influence of radiative cooling. The experimental data are compared with a curve obtained from a numerical calculation including radiative cooling (see ref 4 and references herein).

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References

1. S. Pape Møller, Nucl. Instrum. Metmods Phys. Res. A **394**, 281 (1997)
2. 2. S. Tomita, et al. Phys. Rev. Lett. **87**, 073401 (2001)
3. J. U. Andersen et al. Phys. Rev. A **65**, 053202 (2002)
4. J. U. Andersen et al. Eur. Phys. J. D (to be published)
5. K. Hansen and O. Echt, Phys Rev. Lett. **78**, 2337 (1997)
6. P.E. Barran, S. Firth, A. J. Stace, H. W. Kroto, K. Hansen, and E. E. B. Campbell, Int. J. Mass Spectr. And Ion proc. **167/168**, 127 (1997)

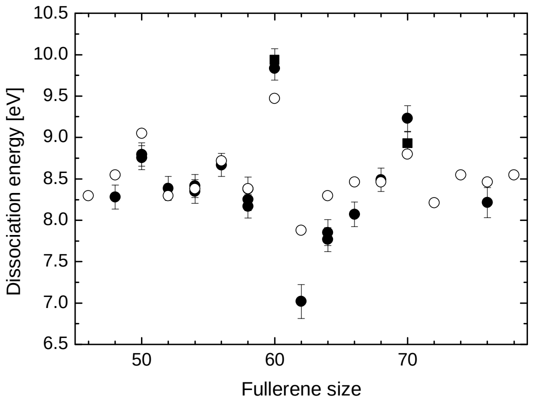

FIG. 1. Dissociation energies of fullerene cations. The values obtained in the present work are indicated by filled circles for singly charged ions and filled squares for doubly charged ions. Results from Ref. [6] (open circles) are shown for comparison.

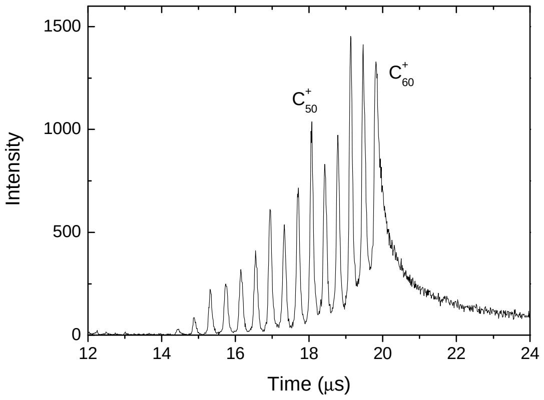

FIG. 2. Yield of fullerene cations as a function of time after multi-photon excitation of C_{60} with a pulse of third-order-harmonic radiation from a Nd:YAG laser

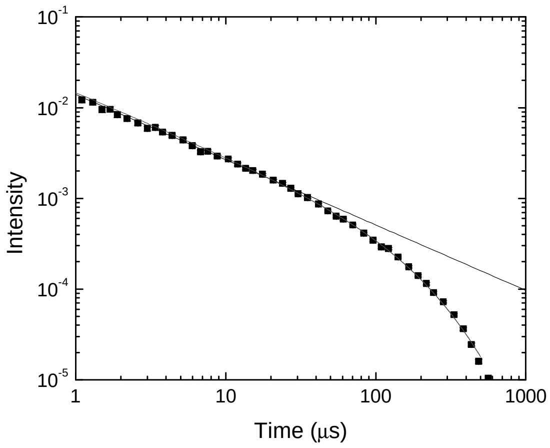

FIG.3. Yield of C_{60}^+ as a function of time after excitation. The linear part contains information about activation energies (see text). The curve through the ecperimental data is obtained is obtained from a numerical calculation including radiative cooling. [4]