Ions colliding with weakly bound clusters of fullerenes

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We report on the ionization and fragmentation of weakly bound clusters of C_{60} molecules following collisions with 12-13 keV Ar^{2+}, 22.5 keV He^{2+} and 300 keV Xe^{20+} projectile ions. C_{60}^+ is the dominant reaction product in all three cases.

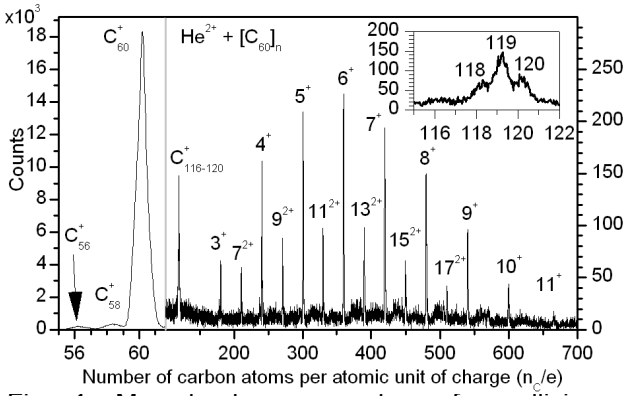

Fig. 1: Mass-to-charge spectrum for collisions between 22.5 keV He^{2+} ions and small clusters of C_{60} molecules. The inset shows the spectrum in the dimer region (n_C/e = 120).

For Ar^{2+} and He^{2+} ions this can most often be explained by an evaporation process in which neutral molecules are sequentially ejected until a single, cold, C_{60}^+ remains. Using an Arrhenius-type evaporation model [1] we estimate that only 1.2 eV per C_{60} molecule in a $[C_{60}]_{55}^+$ cluster indeed is sufficient to evaporate it completely. This value is substantially lower than the median energy deposited according to our stopping calculations. Only few intact charged clusters are observed, as can be seen in Figure 1, and these correspond to the most distant of the ionizing collisions. The observation of C_{119}^+ may be explained by the prompt knock-out of carbon atoms from a C_{60} in the cluster and the subsequent formation of dumb-bell shaped molecules in $C_{59}^+ + C_{60}$ collisions. This picture is strongly supported by Molecular Dynamics simulations of such collisions which show that only very small kinetic energies - in the range of a few eV - are needed to form C_{119}^+ [2]. The C_{118}^+ ion may also be formed at similarly low energies in $C_{58}^+ + C_{60}$ collisions while the $C_{60}^+ + C_{60}$ fusion reaction requires energies larger than 50 eV.

For the Xe^{20+} projectiles the clusters are often multiply charged leading to rapid Coulomb explosions and complete disintegration leaving internally rather hot C_{60}^+ ions which may fragment further.

Weakly bound clusters do not sustain keV ion impact and decay in two different modes depending on the projectile ion charge state and mass. Still, ion collisions may induce very efficient, specific, molecular growth processes different from those obtained with photoabsorption. This may be of interest for astrophysics.

References:

[1] H. A. B. Johansson et al., Phys. Rev. A **84**, 043201 (2011).
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