Catching proteins in liquid helium droplets

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The isolation of foreign species in liquid helium nano-droplets is of fundamental interest and has found important applications in molecular spectroscopy. Helium clusters have an internal equilibrium temperature of ~0.37 K, which is maintained by evaporative cooling.

Liquid helium is optically transparent from the deep UV to the far IR and superfluid helium droplets can serve as gentle matrices to provide an isothermal environment for embedded molecules at cryogenic temperatures. Further, due to the weak interactions of liquid helium, molecules embedded in helium nanodroplets can rotate freely and their optical spectra show narrow linewidths.

For studying molecules in helium droplets, a prerequisite is the ability to bring the intact molecule into the gas phase. For many interesting species such as most larger biomolecules, this can not be done via evaporation. Pulsed laser desorption is one other possibility, doing so, however, yields low concentrations in the gas phase as well as frequently a mixture of species that additionally contains decomposed molecules and matrix molecules. More promising would be to use established techniques, as for example electrospray ionization followed by mass separation, and to incorporate those mass/charge selected ions into helium droplets.

We here present an experimental approach in which mass/charge selected ions that are stored and accumulated in an ion trap are picked up by helium droplets traversing the trap. The approach is conceptually similar to pickup experiments of neutrals from gas cells, however a crucial difference is that in the case of the ion trap, use is made of the high kinetic energy of the heavy helium droplets, which allows ions only to leave the trap once they are inside a droplet.

It is demonstrated that droplets can be efficiently doped with a mass/charge selected amino acid as well as with the much bigger m ≈ 12 000 amu protein Cytochrome C in selected charge states. The sizes of the ion-doped droplets are determined via electrostatic deflection. Under the experimental conditions employed, the observed droplet sizes are very large and range, dependent on the incorporated ion, from 10^{10} helium atoms for protonated Phenylalanine to 10^{12} helium atoms for Cytochrome C.