The primary steps of ion solvation in helium nanodroplets

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Recently, we have obtained experimental results on the solvation dynamics of a single alkali cation in liquid helium, measured with atomic resolution and with femtosecond time resolution [1].

A single Na, K or Li atom sitting in its equilibrium position on the surface of a He nanodroplet is ionized by a 50 fs laser pulse. Thereby, an alkali ion, Ak^+, is introduced instantly to the liquid helium solvent from the gas phase. Hereafter, the Ak^+ ion will gradually pick up helium atoms to form a solvation complex, Ak^+He_n. After a time delay, a Xe atom, residing in the interior of the droplet, is ionized by a 50 fs probe pulse. The created Xe^+ ion pushes the Ak^+He_n complex away from the droplet, due to the internal Coulomb repulsion. The mass and velocity of all Ak^+He_n complexes are recorded by the combination of a Velocity Map Imaging (VMI) spectrometer and a Tpx3CAM detector.

We find that the distribution of attached helium atoms is Poissonian for the first few helium atoms. The first 3 helium atoms for Li^+, the first 5 atoms for Na^+ and the first 11 atoms for K^+ all attach at a constant rate of 1.8 He/ps, in droplets containing 5200 helium atoms on average. This is in good agreement with TDDFT simulations of the process. The time-dependent mean dissipated energy from the complexes to the droplet have also been extracted from the same measurement. Finally, a novel analysis of the detected Ak^+He_n kinetic energies provide droplet size resolution of the above results.

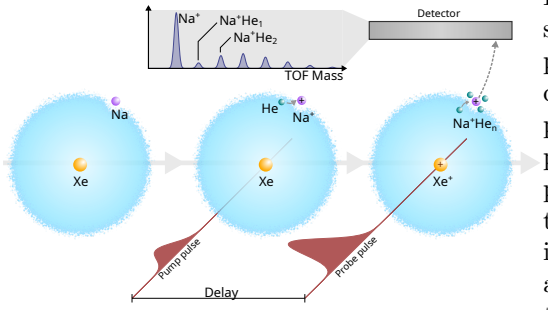

Figure 1: Schematic figure showing the principle of the experiment. Solvation of the Na cation is started by the pump pulse, and the solvation complex is ejected when the probe pulse ionizes the Xe atom in the interior. The time dynamics of the number of He atoms attached to the Na^+ ion can thereby be measured.

[1] Albrechtsen et. al., *Nature*, 2023, doi:10.1038/s41586-023-06593-5