Probing the transition from solution electrolyte to liquid metal

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Few metals have the same allure as a clean surface of liquid mercury. Another liquid metal, metallic liquid ammonia, can built from the ‘ground up’ starting from an electronically insulating hydrogen-bonded liquid very similar to water. This system has been known since the early 1800’s and is frequently used as an organic reagent, but here we use it to explore what nanoscale phenomena cause metallic behavior. At low concentrations of a dissolved alkali metal like lithium, dilute solvated electrons (and alkali cations) are formed which give the electrolyte solution a characteristic blue color. As the concentration is increased, the solution first turns inky black and then develops a bronze metallic sheen. When blue, the excess solvated electrons exist as localized entities in the gaps between ammonia molecules; as the number of excess electrons is increased, electrons combine to form di-electrons (two electrons spin pair inside a solvent cavity) and then finally become fully percolated throughout the hydrogen bonded liquid – a delocalized sea that changes ammonia into a metal.

Our research used synchrotron X-ray light to eject electrons from microjets of the liquid solutions to discover how bound electrons are bound within the solvent. The photoelectron spectra map out how the electron binding-to-the-solvent changes from dilute localized species (bottom, blue) to delocalized metallic species (top, bronze).

A close up of a map

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