Combined X-ray Raman Scattering and NEXAFS Analysis of Imidazole in Aqueous Solutions: Structural Evolution during Cooling Crystallisation

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Understanding the structural evolution of crystallizing systems, from molecules in solution through the pre-crystalline state to crystals, enables control of the physical and chemical properties of the final product and hence is essential to the progress of physical and life sciences. For organic systems, the K-edge core level spectra of C, N and O probe local structure and bonding around the absorbing atom and are therefore ideal for characterizing the pre-crystalline state. Over the last decade soft X-ray absorption spectroscopy (XAS) of liquid systems has become a widely available XAS technique, but current experimental setups do not allow precise enough control to perform experiments under metastable supersaturated conditions where pre-crystalline structures are believed to be present. We have therefore developed an *in situ* cell that permits studies of supersaturated solutions by X-ray Raman Scattering (XRS), which utilizes hard X-rays (10 keV) and hence allows studies of supersaturated solutions under ambient conditions. The cell is based on a standard laboratory jacketed flow crystallizer, which facilitates the required level of thermal control and through internal flow minimizes the effects of radiation damage.

We have followed the structural evolution of a 10.3 mol/L aqueous imidazole solution from undersaturation passing through the metastable zone until the onset of crystal nucleation. Results for the undersaturated solutions show that low momentum transfer XRS generates K-edge NEXAFS spectra that are very similar to previously obtained XAS spectra. The variation in the spectral features of the N K-edge XRS spectra in the metastable zone is minor compared to the spectra of the undersaturated solution, but an abrupt change is observed once crystals have formed. This indicates that the local coordination around the imidazole molecules does not change during the cooling crystallization process, suggesting the dominance of solute-solvent interactions over imidazole-imidazole self-association. *In situ* XRS measurements allowed us to follow the structural evolution of supersaturated aqueous imidazole which appears to be best described in terms of secondary interactions between individually hydrated imidazole molecules.

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