

NANO HIGHLIGHT

Nanoscale Processes in the Environment: Atmospheric Nanoparticles

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Atmospheric particles in the size range of 1-100 nm are precursors to the larger particles that affect global climate, atmospheric chemistry, and visibility. A key property in any understanding of atmospheric particles is their interaction with water vapor, which determines whether the particles are in the crystalline or the aqueous form. The objective of this study is to investigate the size effect on the hygroscopic behavior of common atmospheric nanoparticles experimentally by using a tandem Differential Mobility Analyzer (TDMA) and an Environmental Transmission Electron Microscope (ETEM) and theoretically by using Molecular Dynamic (MD) simulations.

Characteristic TDMA measurements of the hygroscopic properties of NaCl nanoparticles are shown in Fig.1.

The deliquescence and the efflorescence relative humidities (DRH and ERH, respectively) increase when the dry mobility diameter decreases below 40 nm. The growth factors steadily decrease for dry sizes below 40 nm. The decrease is quantitatively predicted by a model that includes the Kelvin effect and a size-dependent shape factor. Agreement in DRH, ERH, and growth factors for particles generated by two independent methods (namely, vaporization-condensation and electro spray), as well as observations of prompt deliquescence, indicates the absence of chemical impurities.

The hygroscopicity of several inorganic particles in the size range of 0.1-4 μm at RH values of 0-100% has been monitored using the ETM. The DRH of these particles was independent of their size. In the nanosize regime, the hygroscopic behavior of 30 to 60-nm NaCl particles was also observed. No significant departure from the large-particle DRH was observed, corroborating the TDMA measurements. We are currently working to measure the DRH values of NaCl particles with sizes less than 30 nm.

An MD-based algorithm has been developed to simulate water uptake and dissolution at short (100 ps) timescales. The technique involves a combination of lattice defects and surface defects that lower the crystal lattice energy relative to the solvation energy. The technique has been applied to an infinite, flat surface, which allows for estimation of various surface energies in salt-water-vapor systems, and has been extended to nanoparticles. Simulations of nanoparticle-vapor systems suggest the formation of a liquid-like layer at the particle surface. Studies are now underway to quantify the physical properties of this liquid like layer.

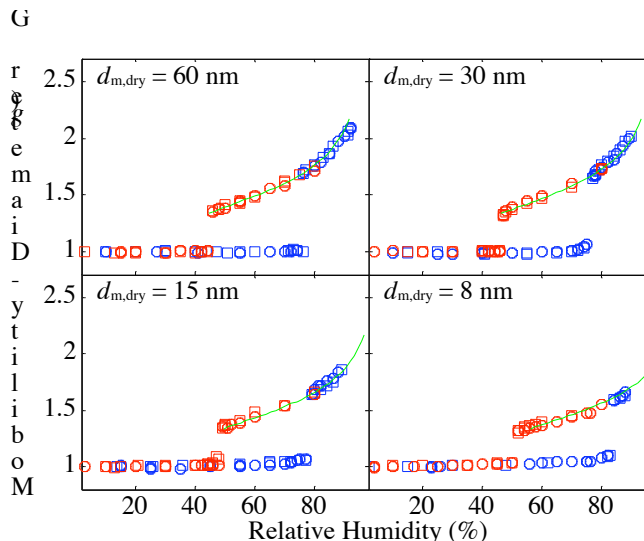


Figure 1. Growth curves of NaCl aerosol particles. (○) electro spray particles and (□) vaporization-condensation particles. Red points represent efflorescence-mode and blue points deliquescence-mode experiments. Lines are calculated growth factors that take into account the Kelvin effect and a size-dependent shaper factor.