Hygroscopicity of Sub-6 nm Sodium Chloride Particles

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Some studies suggest that the hygroscopic growth of water soluble salt particles may not follow the Köhler theory with particles below the diameter of 8 nm (Biskos et al., 2006a; Hakala et al., 2013). So far the hygroscopic growth of sodium chloride (NaCl) particles has not been studied below the mobility diameter of 6 nm (Biskos et al., 2006a, 2006b). In this study we present our investigations in hygroscopic growth of NaCl measured with a specially made nano Hygroscopicity Tandem Differential Mobility Analyzer (nHTDMA) from mobility diameter of 2.5 nm to 6 nm and in relative humidities from 10% to 95%.

Methods

The nHTDMA is consisted of a high resolution Herrmann Differential Mobility Analyzer (HDMA) for selecting the initial mobility diameter, a humidifier, and a TSI nano Differential Mobility Analyzer (nDMA, TSI DMA 3085) for measuring the mobility diameter after the humidifying. The nDMA was used in a closed loop arrangement. This way the humidifying is easy to achieve and keep stable with just one humidifier. The particles were produced in a tube furnace by vaporization-condensation method in ultrapure nitrogen carrier gas flow (Kangasluoma et al., 2013). To convert the agglomerates produced by this method (Krämer et al., 2000) into cubical crystals, the sample aerosol flow was humidified with an additional humidifier and cooled to 2°C. The aerosol experienced supersaturated conditions inside the cooling unit undergoing a phase transition into solute droplets. After drying in a silica gel diffusion dryer the NaCl particles were assumed to be cubical crystals.

Results

The Hygroscopic Growth Factors (HGF=diameter of humidified particle/diameter of dry particle) in different RH conditions were measured for NaCl particles with mobility diameters of 2.5 nm, 3 nm, 4 nm, 5 nm and 6 nm. The results showed clearly that the HGFs were lower for smaller particles due the Kelvin effect. Also the Deliquescence Relative Humidities (DRH) were determined for 4 nm, 5 nm and 6 nm NaCl particles. The DRH was higher the smaller the particle was. Particles below the mobility diameter of 4 nm had higher DRH than 95%. In Fig. 1. are the HGF distributions for 2.5 nm and 6 nm NaCl particles at different RHs. 2.5 nm particles have significantly lower HGF in same RH than 6 nm particles. The DRH is between 85% and 90% for 6 nm particles. This is marked by disappearance of the mode near HGF 1.1. The bimodal nature of the distribution for 2.5 nm particles is not as clear as for 6 nm particles at high RHs, but the widening of the distribution at RH of 95% shows that the DRH is not yet reached. The bimodal distribution near DRH is caused by different RH histories the particles have experienced before the size classification in nDMA.

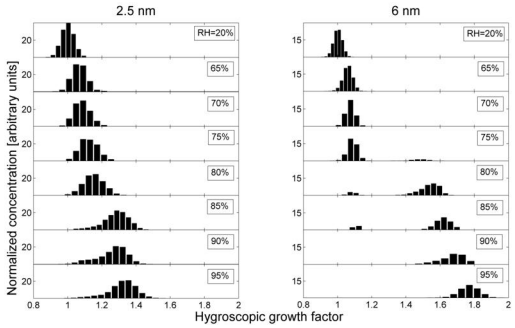

Figure 1. The hygroscopic growth factor distributions for 2.5 nm and 6 nm (mobility diameters) NaCl particles.

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