CCN Activity and Mixing Rules of Isoprene Secondary Organic Aerosol (SOA) and Sulfate

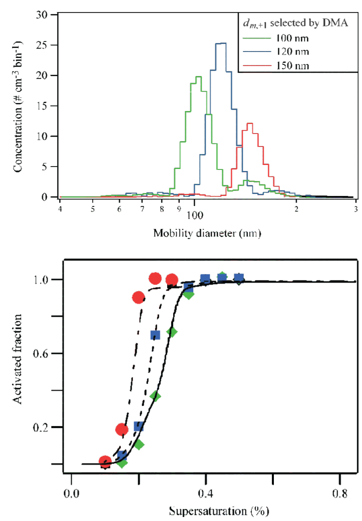
Research Highlight

The growth of atmospheric particles to form cloud droplets influences climate through indirect effects on cloud brightness and lifetime and changes in patterns of precipitation. Predictions of which atmospheric particles act as cloud condensation nuclei (CCN), which are the initial particles on which water condenses to grow into droplets, are complicated by their diverse composition. In particular, the influence of organic material on CCN activity is both important and challenging, given that organic material at times comprises a dominant fraction of the particle mass but consists of myriad possible molecular configurations. Moreover, less CCN-active organic material is often internally mixed with more CCN-active inorganic material (mainly sulfate) within a single particle so that an understanding of the CCN activity of mixed materials is required. In the atmosphere, a significant fraction of this organic material results from the gas-to-particle condensation of the low-volatility oxidation products of volatile organic compounds (VOCs), thereby forming a secondary organic aerosol (SOA). Globally, the dominant contributors to SOA production are biogenic VOCs, such as terpenes and isoprene. Although isoprene is the most abundant non-methane hydrocarbon, the CCN activity of material resulting from the photo-oxidation of isoprene has not been previously studied.

Therefore, experiments to test (1) the CCN activity of isoprene secondary organic aerosol and (2) mixing rules between this organic material with the inorganic species sulfate were conducted in the Harvard Environmental Chamber (HEC).

The CCN properties of ammonium sulfate particles mixed with organic material condensed during the hydroxyl-radical-initiated photo-oxidation of isoprene were investigated in the continuous-flow HEC. CCN activation curves were measured for organic particle mass concentrations of 0.5 to 10.0 µg m^-3, NOx concentrations from under 0.4 ppbv up to 38 ppbv, and particle mobility diameters from 70 to 150 nm. The figure shows an example of data recorded for a particle organic mass concentration of 7.0 µg m^3 and 50-nm sulfate seed particles. Activated fraction (i.e., y-axis of the figure's bottom panel) is the ratio of the activated-droplet concentration to the total-particle concentration. A droplet is operationally defined as activated if it grows to greater than 1 µm optical diameter during the residence time inside the CCN counter.

The CCN activity of mixed particles was successfully described by a volume-based mixing rule of sulfate and secondary organic material produced by isoprene photo-oxidation for the range of studied conditions, including isoprene:NOx ratios spanning 200:0 to 50:38 ppbv:ppbv. A single suite of physicochemical parameters for fully water-soluble secondary organic material was used, indicating minimal change in the organic material with reference to CCN activity for the range of investigated conditions. The effective hygroscopicity parameter kappa describing the CCN activity of the organic material was 0.10+/-0.03. This value is similar to those reported in the literature for organic material produced by the oxidation of other VOC precursor gases, such as monoterpenes and small aromatic molecules. These findings suggest that over regions dominated by high biogenic emissions (e.g., the ecosystem of the Amazon Basin), the CCN activity of particles can be simply and accurately as represented in large-scale atmospheric and climate models by using a multi-component Köhler model that employs a single suite of parameters for biogenic secondary organic components in conjunction with the parameters representing the inorganic species.



CCN activation of mixed particles consisting of secondary organic material produced by isoprene photo-oxidation and ammonium sulfate seed. Top: Size fractions selected by a differential mobility analyzer from aerosol exiting the HEC. Bottom: Observed (points) and modeled (lines) CCN activation curves for low-NOx conditions. The particle mode diameters include 100 (green), 120 (blue), and 150 nm (red).

Reference(s)

King SM, T Rosenoern, JH Shilling, Q Chen, Z Wang, G Biskos, KA McKinney, U Poeschl, and ST Martin. 2010. "Cloud droplet activation of mixed organic-sulfate particles produced by the photooxidation of isoprene." Atmospheric Chemistry and Physics, 10(8), 3953-3964.

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Working Group(s)

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