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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Amines are likely to enhance neutral and ion-induced sulfuric acid-water nucleation in the atmosphere more effectively than ammonia" *by* T. Kurtén et al.

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We thank the reviewer for his or her constructive comments. Answers to specific comments are given below. Changes to the manuscript are also indicated

1. The "varying predictions" for the role of ammonia in enhancing sulfuric acid-water nucleation refer to the contrast between earlier CNT-based studies, which predicted an enhancement of several orders of magnitude, and earlier quantum chemical studies, which predicted no enhancement at all. Later CNT-based studies with more correct thermodynamical parameters (Anttila et al., 2005), as well as more recent higher-level quantum chemical studies, are in agreement with experimental results. The state-of-the art assessment is that ammonia at ppt concentrations enhances sulfuric-acid

water nucleation by around 1-2 orders of magnitude. This issue has been discussed extensively in many of the references given in the manuscript (e.g. Kurtén et al. 2007a, Nadykto and Yu 2007), and also in a recent review paper (Kurtén and Vehkamäki, Advances in Quantum Chemistry 55, 407-427, 2008). We have added a sentence on this topic to the manuscript.

Changes to the manuscript: "Experiments (Ball et al., 1999), updated and corrected classical nucleation theory simulations (Anttila et al., 2005) and quantum chemical calculations are now all in qualitative agreement, and indicate a modest enhancement of sulfuric acid-water nucleation by ammonia in most atmospheric conditions."

2. We have added more references to measurements on amine concentration measurements (Sellegri et al., 2005) in addition to those already given (Rabaud et al., 2003) A reference to an experimental study by Angelino et al. (2001) was also added.

Changes to the manuscript:

"Based on a combination of smog chamber experiments and field measurements, Angelino et al. (2001) suggested that amine chemistry 'may play a significant role in particle formation in regions with high amine concentrations' due to both acid-base and oxidation reactions."

"However, at a boreal forest site in Hyytiälä, Finland, trimethylamine concentrations during a spring measurement campaign (Sellegri et al., 2005) varied between 34 and 80 ppt, indicating that the order-of-magnitude estimate above may be roughly correct."

3. Unfortunately it is not possible to give a quantitative estimate of the composition of the clusters observed in Kulmala et al. 2007, but based on these results it seems that the clusters are more likely to contain amine adducts than ammonia adducts. A sentence on this was added to the manuscript.

Changes to the manuscript: "As vegetation is a also source of amines, a nucleation mechanism involving enhancement of sulfuric acid-water nucleation by biogenic

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amines would provide another link between biogenic vapor emissions from forests and particle formation. The results presented here indicate that the stable pool of 1.5-1.8 nm neutral clusters observed by Kulmala et al. (2007) in boreal forest conditions are likely to contain contributions from amine-sulfuric acid clustering rather than ammonia-sulfuric acid clustering reactions."

New references:

Angelino, A., Suess, D. T. and Prather, K.: Formation of Aerosol Particles from Reactions of Secondary and Tertiary Alkylamines: Characterization by Aerosol Time-of-Flight Mass Spectrometry, Environ. Sci. Technol. 35, 35, 3130-3138, 2001.

Sellegri, K., Hankel, M, Umann, B., Arnold, F. and Kulmala, M.: Measurements of organic gases during aerosol formation events in the boreal forest atmosphere during QUEST, Atmos. Chem. Phys., 5, 373-384, 2005.

Interactive comment on Atmos. Chem. Phys. Discuss., 8, 7455, 2008.