Supplement of Atmos. Chem. Phys., 21, 14631–14648, 2021
https://doi.org/10.5194/acp-21-14631-2021-supplement

Atmospheric Chemistry and Physics
Open Access
EGU

Supplement of

The effect of $(NH_4)_2SO_4$ on the freezing properties of non-mineral dust ice-nucleating substances of atmospheric relevance

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Supplementary Information

Table 1. Comparison of studies on the effect of dilute (≤ 0.1 M) $(NH_4)_2SO_4$ on the freezing properties of non-mineral INS. In this table, ΔT_{50} is the change in median freezing temperature with addition of $(NH_4)_2SO_4$, ΔT_{90} is the change in the temperature at which 90% of the sample droplets were frozen with addition of $(NH_4)_2SO_4$, ΔT_{onset} is the change in the onset freezing temperature with addition of $(NH_4)_2SO_4$, and n_m is the number of ice nucleating active sites per gram of material.

Material	Study	Freezing temperature range	$[(NH_4)_2SO_4]$	Weight % of material	Estimated mass of material per droplet	Observations
Snomax	This study	-5 to 0 °C	0.05 M	0.05 wt %	1 x 10^{-6} g	$\Delta T_{50} \approx 0$ °C No significant change in n_m
	Koop and Zobrist, (2009)	-15 to -5 °C	0 to 0.1 M	~ 0.4 wt%	~ 2 x 10^{-14} g[a]	$\Delta T_{onset} \approx 0$ °C
Humic acid	This study	-25 to -15 °C	0.05 M	0.05 wt %	1 x 10^{-6} g	$\Delta T_{50} \approx 0$ °C No significant change in n_m
	Whale et al., (2018)	-25 to -10 °C	0.015 M	1 wt %	1 x 10^{-5} g	$\Delta T_{50} \approx 0$ °C
Leaf derived nuclei	Reischel and Vali, (1975)	-10 to -5 °C	0.01 to 1 M	0.05 wt%	1 x 10^{-5} g	$\Delta T_{90} \approx 0$ °C

[a]Calculated using the reported median droplet diameter of 2.4 μm (Koop and Zobrist, 2009)

Table 2. Comparison of studies on the effect of dilute (≤ 0.1 M) $(NH_4)_2SO_4$ on the freezing properties of mineral dust INS. In this table, ΔT_{50} is the change in median freezing temperature with addition of $(NH_4)_2SO_4$, ΔT_{onset} is the change in the onset freezing temperature with addition of $(NH_4)_2SO_4$, n_m is the number of ice nucleating active sites per gram of material, and n_s is the number of ice nucleating active sites per surface area of material.

Material	Study	Freezing temperature range	$[(NH_4)_2SO_4]$	Weight % of material	Estimated mass of material per droplet	Observations
K-feldspar	This study	-15 to -5 °C	0.05 M	0.05 wt %	1 x 10^{-6} g	$\Delta T_{50} \approx +3$ °C n_m increased by a factor of ~10
	Whale et al., (2018)	-20 to -5°C	1.5 x 10^{-4} to 0.015 M	0.1 wt %	1 x 10^{-6} g	$\Delta T_{50} \approx +1.5$ to +3 °C n_s increased by a factor of ~5 to ~15
	Kumar et al., (2018)	-35 to -20 °C	~9x10^{-6} to ~0.1 M	2 wt %	~ 2 x 10^{-11} g[a]	$\Delta T_{onset} \approx +1$ to +4.5 °C
ATD	This study	-20 to -10 °C	0.05 M	0.05 wt %	1 x 10^{-6} g	$\Delta T_{50} \approx +5.5$ °C n_m increased by a factor of ~20
	Whale et al., (2018)	-20 to -5 °C	0.015 M	0.1 wt %	1 x 10^{-6} g	$\Delta T_{50} \approx 0$ °C No significant change in n_s
Kaolinite	This study	-25 to -10 °C	0.05 M	0.5 wt %	1 x 10^{-5} g	$\Delta T_{50} \approx +8$ °C n_m increased by a factor of ~30
	Kumar et al., (2019b)	-35 to -25 °C	~8 x 10^{-4} to ~0.08 M	5 wt %	~ 4.5 x 10^{-11} g[a]	$\Delta T_{onset} \approx +2$ to +3 °C
Montmorillonite	This study	-20 to -5 °C	0.05 M	0.5 wt %	1 x 10^{-5} g	$\Delta T_{50} \approx +5.5$ °C n_m increased by a factor of ~10

[a]Calculated using an estimated droplet diameter of 12 μm (Kumar et al., 2018, 2019b)