Cloud droplet activity of soot particles after long-term exposure to ozone and α-pinene

Franz Friebel and Amewu A. Mensah
Cloud Condensation Nuclei Activity
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Continous-flow Stirred Tank Reactor (CSTR)

- 100 nm soot particles
- 16 h aging time
- miniCAST brown / black

VOCs
Yes/No

Ozone
0 - 200 ppb

RH
5-80%

Temperature
5 - 35 °C

The minion
Setup 1

Aerosol Chamber 2.78 m³
- CSTR – mode
- stainless steel

O₂-Generator

200 ppb O₂-Monitor
5% / 75% Relative Humidity

Temperature

Exhaust

miniCAST

Charcoal Denuder

pre-mix chamber 0.125 m³

Humidifier

Dilution air

DMA

CPC

SMPS

AMS

CPMA

HINC
Activation time ($t_{\text{act}}$)

$t_{\text{act}}$ … activation time

CCN-inactive  CCN-active
### miniCAST Soot + 200 ppb O₃

<table>
<thead>
<tr>
<th></th>
<th>CBw</th>
<th>CBk</th>
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<tbody>
<tr>
<td>fuel / air - ratio</td>
<td>1.03</td>
<td>0.95</td>
</tr>
<tr>
<td>organic carbon content</td>
<td>30 – 60%</td>
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$O_3$ - heterogeneous oxidation

$O_3$ - adsorption

CCN-activity vs. Time
Soot + O$_3$ + volatile organic compounds (VOCs)

α-pinene

Pine tree
Idea: α-Pinene coating and oxidation

\[ \text{+ O}_3 \]

CCN-activity vs. Time
Setup 2

- Aerosol Chamber 2.78 m³
  - CSTR – mode
  - stainless steel

Components:
- O₂-Generator
- Humidifier
- Dilution air

Measurements:
- 200 ppb
- O₂-Monitor
- 5% / 75%
- Relative Humidity
- Temperature

Analysis:
- CCNC
- OPC
- SMPS
- DMA
- CPC
- AMS
- CPMA
- HINC

Chemical:
- CH₃
- H₃C
- H₃C
### miniCAST Soot + 200 ppb O₃ + α-pinene

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References:

[1]
unaged

\[ \text{CBw} \]

\[ \text{O}_3 + \text{pinene} + 16 \text{ h} \]

\[ d = 100 \text{ nm} \]
\[ m = 0.25 \text{ fg} \]

\[ d = 115 \text{ nm} \]
\[ m > 0.50 \text{ fg} \]
α-Pinene; homogenous oxidation

+ O₃

CCN-activity

Time
What do learn from that?

- CBw becomes CCN-active **faster** than CBk **upon** exposure to O$_3$

- CCN-activity ↑ with α-pinene + O$_3$
- **no difference** between CBk and CBw

- Gas phase oxidation of α-pinene and condensation
Stages of the experiment

- filling & steady state
- fresh soot
- flushing

AF (CCNC) vs. super saturation /%

Ozone / ppb
Stages of the experiment

**AF (CCNC)**

- Particle conc. / #/cm³
- Super saturation / %

**Ozone / ppb**

- t↓act

Date and Time:
- 05.08.2016
- 06.08.2016

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Residence Time Distribution (CSTR)

- Steady state
- 1.4 % $\text{SS}_{\text{act}}$
- $\text{AF} = 0.22$

$t/l_{\text{act}} = 168$ min

Particle age - residence time / min

RTD / min$^{-1}$
vs $O_3$ at 25°C

Zurich
Lugano
Mexico City

activation time $t_{act}$ / min

Ozone / ppb

super saturation
- 0.8 %
- 1.0 %
- 1.2 %
- 1.4 %
vs O₃ at 25°C

- Zurich
- Lugano
- Mexico City

activation time $t_{\text{act}}$ / min

Ozone / ppb

super saturation
- • 0.8 %
- □ 1.0 %
- ⊙ 1.2 %
- ● 1.4 %
Temperature dependency at 200 ppb O₃

Moscow

Zurich

Phoenix

[Graph showing temperature dependency with data points for Moscow, Zurich, and Phoenix at different temperatures.]
\[ \tau_{act} = \text{aging rate} \approx \text{constant} \cdot \theta \quad \theta = K_{eq} \cdot C_{ozone} / (1 + K_{eq} \cdot C_{ozone}) \]
What is soot?

- Soot aggregate: 50-500 nm
- Soot primary particle: 5-50 nm
- Soot crystallite: 0.5-5 nm
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Soot surface chemistry. [5]
Size distribution of soot (Karjalainen et al., 2014)

- Gasoline engine exhaust
Sharing is caring

http://tiny.cc/NPC2019
mass and diameter – $\text{O}_3$ / $\text{O}_3 + \text{pinene}$

CBw

CBk