The effect of sodium chloride on the nanoparticles observed in a laminar methane diffusion flame

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Introduction

- Soot formation and evolution have been extensively investigated in different experimental and theoretical studies.
- One less-investigated area of research is regarding the effect of alkali metals on the process of soot formation.
- Extractive sampling is a method which has been employed in studies related to soot formation and emission from combustion sources.
- In this method, a probe is being used to extract a sample which is subsequently sent to particle measurement instruments.

Experimental setup

- Co-flow burner: Santoro burner [1] with methane and co-flow air flow rates of 0.35 and 70.0 SLPM, respectively.
- NaCl injection system: A 25% NaCl solution was nebulized (Aerogen Solo) and carried with methane to a diffusion dryer (TSI, Model 3062).
- Dilution system: Based on a modified system of Zhao et al. [2] and Kazemimanesh et al. [3]. Sampling tube had OD of 3.17 mm and wall thickness of 0.125 mm with a pinhole of 0.2 mm.
- Scanning mobility particle sizer (SMPS): Tandem of nano-DMA (TSI, Model 3085) and CPC (TSI, Model 3076).
- TEM thermophoretic sampler: Custom-built as in Dastanpour et al. [4]. Images obtained using JEOL TEM (Model JEM 2100).
- Temperature measurement system: Based on the method of McEnally et al. [5] using a 75 µm R-type thermocouple (Pt/13%Rh-Pt, Omega).

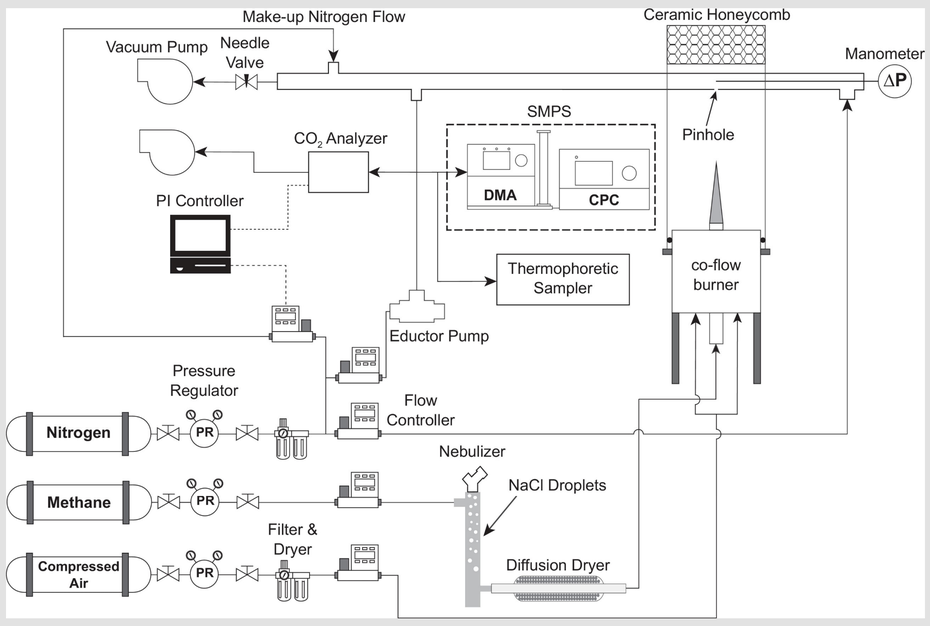

Fig. 1. Schematic of the experimental setup

Results and Discussion

- Sufficiently diluting the sample immediately after extraction prevents particle–particle coagulation and quenches the chemical reactions.
- After a critical dilution ratio, typically on the order of thousands of times, the particle size distribution became independent of the dilution ratio.

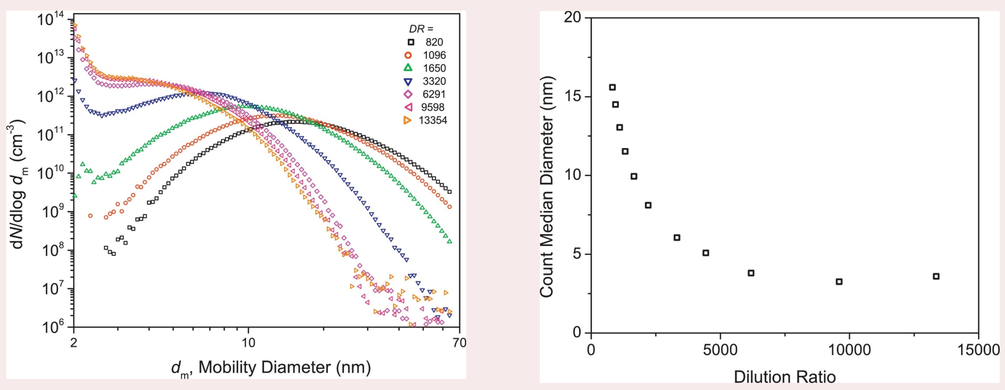

Fig. 2. Variations of particle size distribution and particle median diameter as a function of dilution ratio for HAB = 38 mm

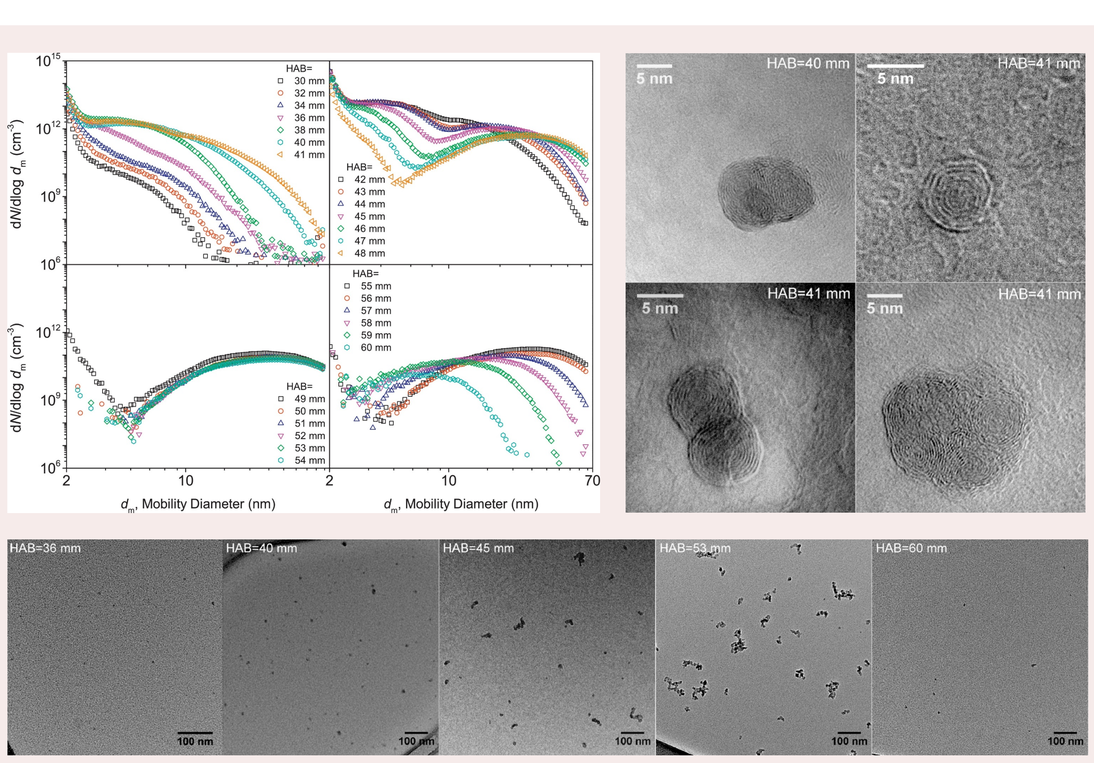

Fig. 3. Size distribution and TEM images of particles from HAB = 30 to 60 mm

- Particle size distributions show the evolution of soot particles from nucleation and surface growth to coagulation, aggregation, and oxidation.
- High resolution TEM iamges show that incipient soot particles have single or mutliple core-shell structure.

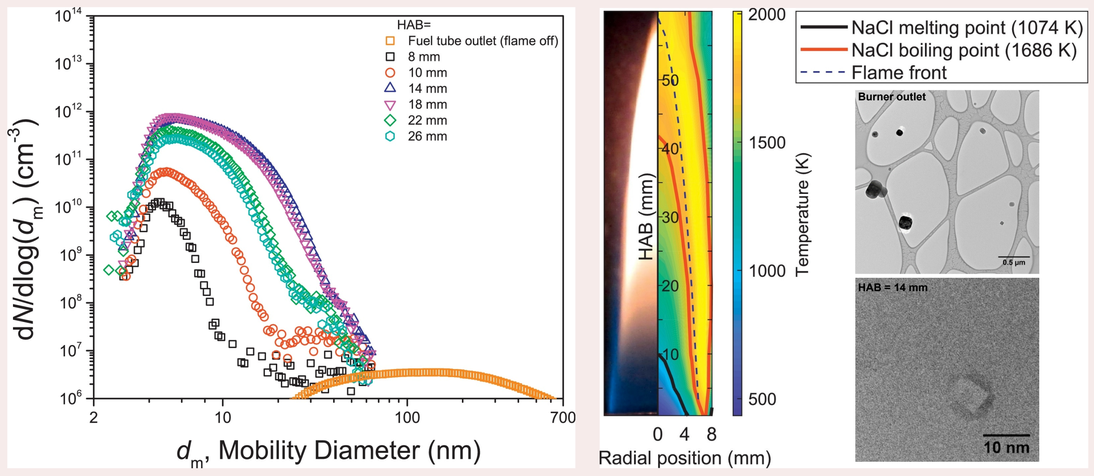

Fig. 4. Size distribution and TEM images of particles from methane-NaCl flame from burner outlet to HAB = 14 mm. The contour plot shows the temperature of the methane-NaCl flame.

- The NaCl particles seen at HAB = 8 to 26 mm have been formed by nucleation of condensed NaCl vapour that may have diffused from the flame front where the temperature is above the boiling point of NaCl.
- At HABs from 46 to 56 mm, where coagulation is the dominant process, the addition of NaCl to the flame leads to smaller particles with greater number concentration. Thus, the coagulation between soot particles is decreased in this region.
- This is presumably due to the increase in the concentration of neutral soot particles based on the following interaction:

$$Soot^{+} + Na \rightarrow Soot + Na^{+}$$

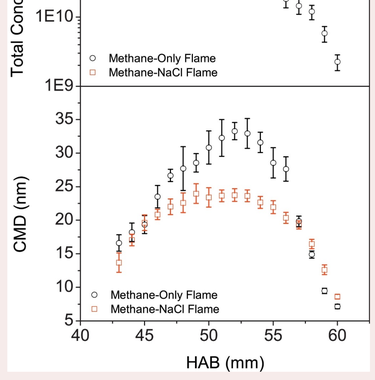

Fig. 5. Variation of count median diameter (CMD) and total number concentration of particles for HAB = 43–60 mm for methane-only and methane–NaCl flames.

References

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