Knudsen cell: Investigations about the uptake of important traces gases on ambient airborne mineral dust

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Introduction

Why Mineral dust?

Mineral dust is one of the largest mass fractions of the natural aerosol concentration. The emission is estimated at 1300-2000 Tg/a [Cwiertny, D. M., M. A. Young, und V. H. Grassian, 2008].
Therefore mineral dust properties are significant for climate:

- Absorption and scattering of solar radiation → influence of the radiation budget
- Dust deposition → deliver of nutrients
- Act as cloud condensation nuclei → influence cloud properties
- Long range transport → global influence
  → adsorption of trace gases and atmospheric species
  → heterogeneous reaction on the surface

→ **Can act as a sink or source for many atmospheric compounds**

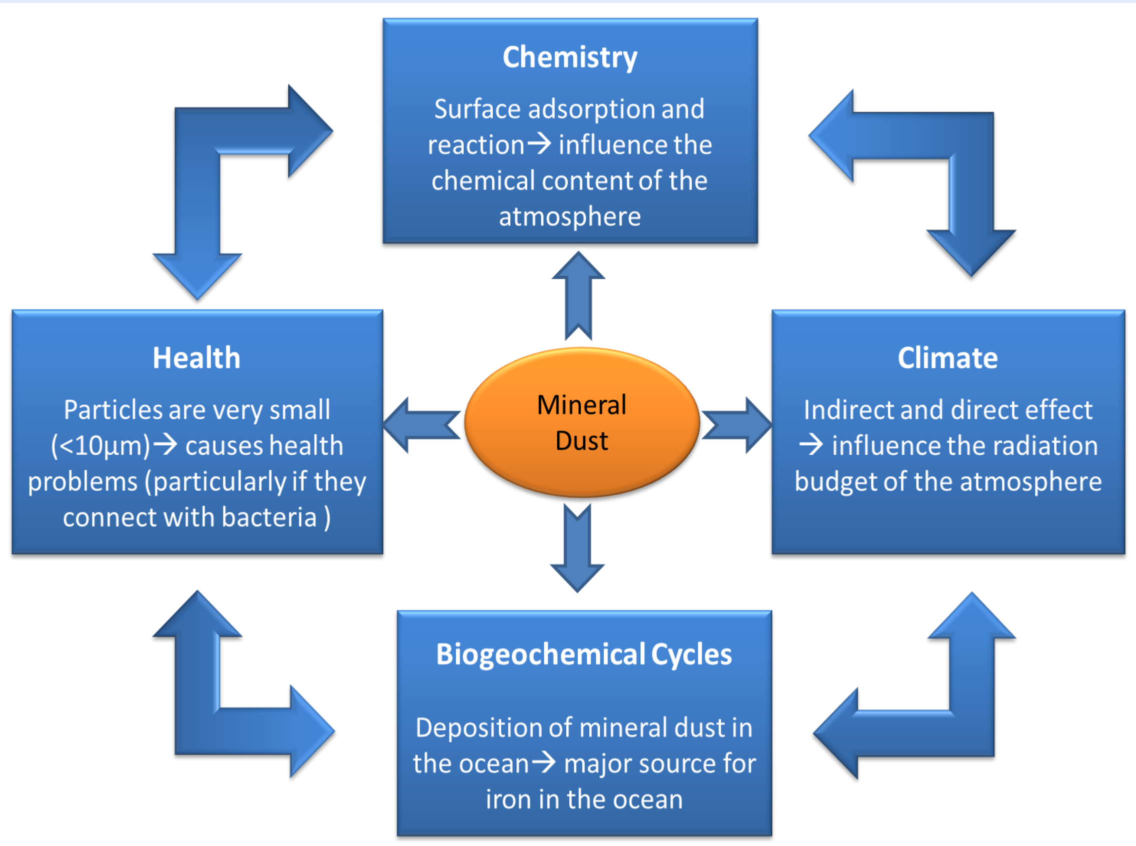

Fig. 1: Mineral dust interactions.

Why trace gases?

Trace gas uptake can play an role in the transformation and/or formation of many atmospheric compounds.

Via heterogeneous uptake, on the mineral dust surface, the following parameter can be changed:

Gas phase concentration of:
- photochemical oxidants,
- acid gases,
- free radicals,
- soluble and/or semi-volatile species

Physical properties of mineral dust:
- size
- optical properties
- ability to nucleate cloud droplets

→ **Uptake of trace gas influences important processes in the atmosphere**

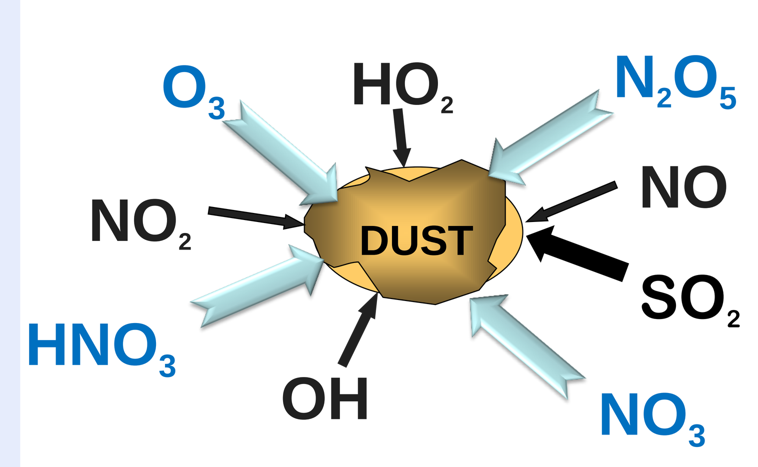

Fig. 2: Trace gas uptake on mineral dust.

Motivation

Mineral dust:
- large flux of dust into the troposphere
- long-range global transport

→ Interaction with atmospheric, terrestrial and oceanic systems

Trace gas uptake:
- heterogeneous reactions may provide missing link for some reactions

→ Influences particle properties and gas phase concentration

→ **Therefore it is important to understand the interaction of trace gas with mineral dust surfaces.**

Method

Knudsen cell

High vacuum flow reactor is operating in a pressure range between 10^{-3} and 10^{-5} mbar. This pressure ensures that the gas entering the cell is under molecular flow conditions. Gas-wall collisions are highly preferred over gas-gas collisions.

The Knudsen cell consists of :

- Gas handling system (GDS) (1)
- Gas inlet (2)
- Reaction chamber (3)
- Detection chamber (4)

(1) Gas handling system (GDS):
Consist of a glass tube with outlets for the pump, for reactor and three stop-cocks.
Pressure inside is regulated by a membrane pump and measured by a absolute pressure gauge.

(2) Gas inlet:
(a) Steady state measurements: constant flow through a capillary.
(b) Pulse measurements: the gas is introduced through an electromagnetic valve.

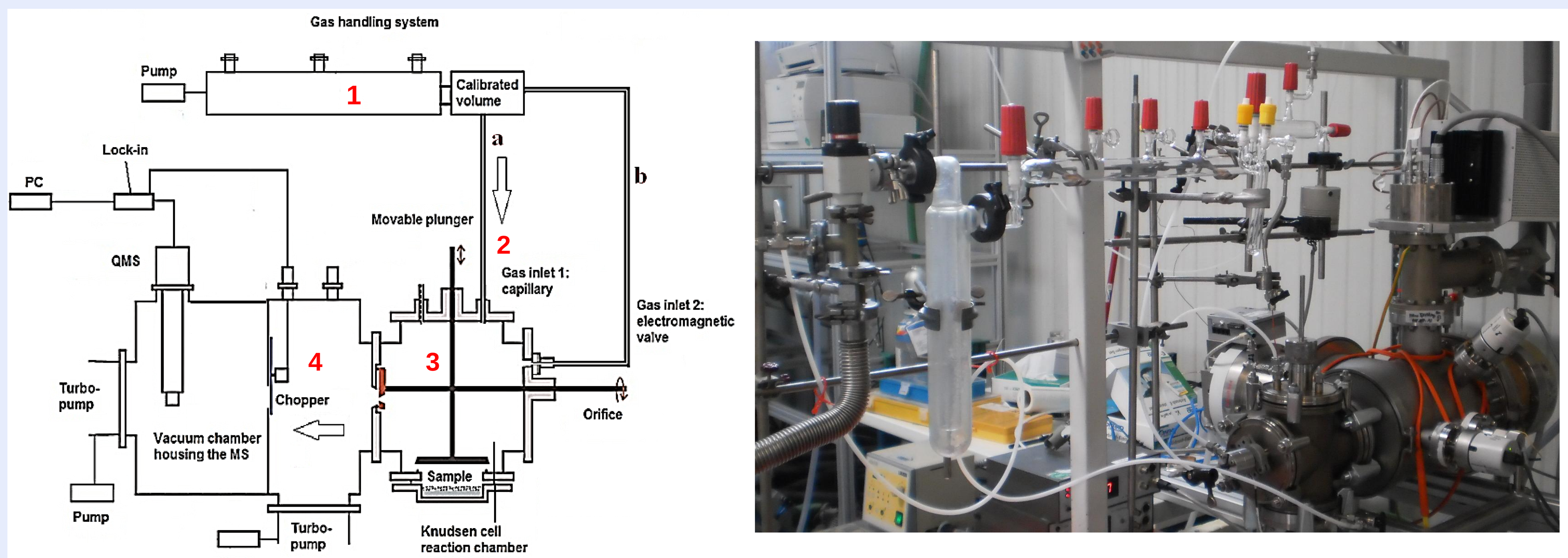

Fig. 3: Left: Scheme of a Knudsen cell, right: Setup Knudsen cell.

(3) Reaction chamber:
stainless steel cross
inner walls are coated → elimination of reaction with the walls
Sample is placed on the bottom of the reaction chamber and can be separated by a movable plunger.

(4) Detection chamber:
Gas leave through a small escape orifice with an adjustable diameter. The orifice determine the residence time and concentration of the gas molecules.
Gas species enter the differently pumped vacuum chamber housing the quadrupole mass spectrometer (QMS).
Gas beam is modulated by a chopper operating at 70 to 80 Hz.
Pressure inside the vacuum chamber is regulated by two turbo molecular pumps and measured by two compact full range gauge.

Measurement

Isopropanol on TiO_2 surface

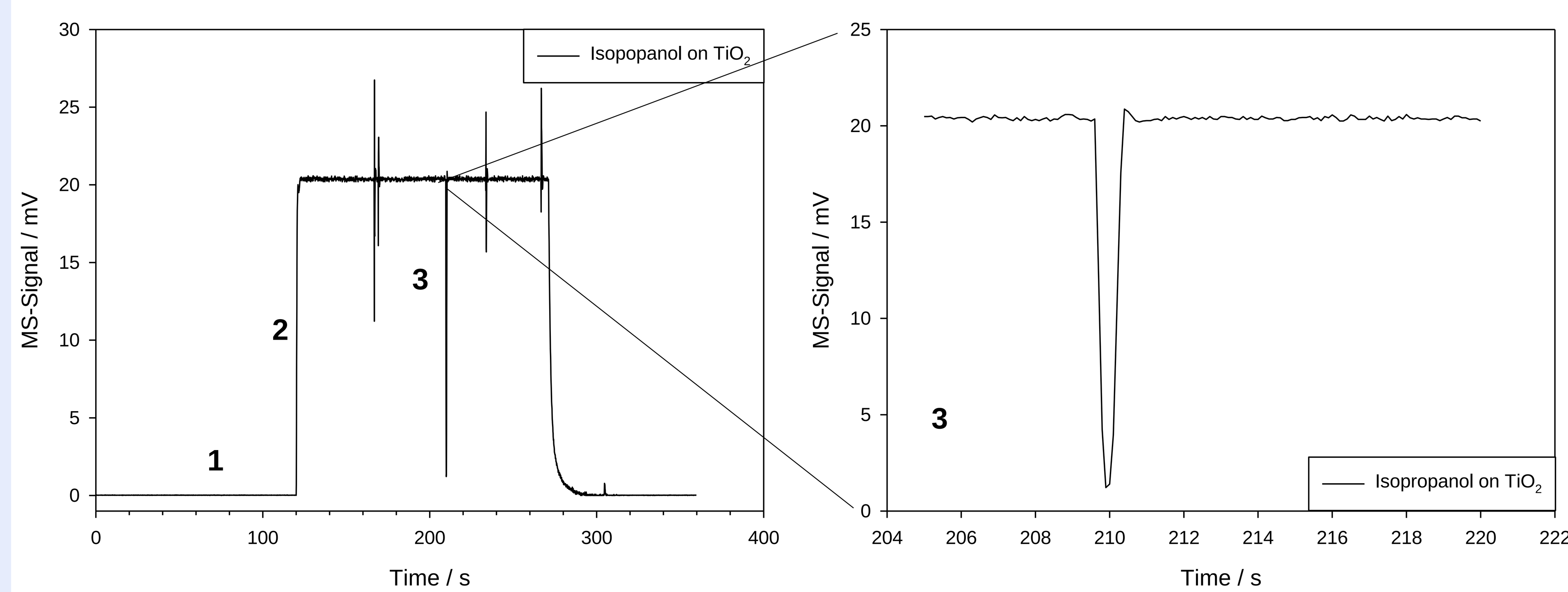

Fig. 4: Left: Knudsen cell measurement, isopropanol on TiO_2, 293 K, right: Magnification of the curve while the plunger is up.

A typically Knudsen cell experiment is shown (in Figure 4). In the beginning of every experiment, the background is measured (1). In the second step the gas of interest is introduced into the cell when the plunger in down (2). After lifting the plunger (3), which separates the sample compartment from the reactor, a steep decrease of the concentration of the gas can be observed.

Summary

- On mineral dust surfaces trace gas uptake/heterogeneous reactions may occur.
- Trace gas uptake influences the particle properties and gas phase concentration.

→ The surface can act as a sink or source for many atmospheric compounds.
→ Significant influence on climate.

→ **Important to understand the interaction between trace gas and mineral dust.**

Outlook

- For trace gas uptake measurements different surfaces will be used:
  TiO_2, Al_2O_3 (α- and γ-phase), FeO_2, Arizona test dust, air collected mineral dust from the Cap Verde islands.
- Trace gas: SO_2, NO_2, HNO_3, isopropanol and acetone will be used.

References

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