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Outgassing of H_2O/CO_2 mixtures

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Abstract

Gas diffusion plays an important role in understanding comet activity as the diffusion process directly effects the energy balance within a cometary surface and, therefore, influences processes like surface evolution and dust production. Here, we introduce a novel selection of experiments examining the gas production mechanisms of cometary like porous aggregate layers consistent of H_2O, CO_2 and SiO_2. With our results we provide a set of equations relevant for comet surface evolution and dust activity simulations.

1 Introduction

Models of gas transportation through porous media are used to calculate the production of volatiles of active comets, to resolve the flows of energy in the cometary surface and finally to model dust activity and evolution of the surface layers. Most scientific works consider either the results of numeric gas transport simulations [5] or laboratory measurements with a two layer setups comprised of solid volatile ices with an overlain, relatively compact, dust layer [4].

However, there is strong evidence that the building blocks of comets consists of porous aggregates of mainly H_2O, CO , CO_2, SiO_2, organic components and other volatiles [2, 1, 3]. Hence, describing the processes of gas diffusion through porous layers of pebble like material presents the next step in understanding the processes behind cometary activity and dust production.

To assess the diffusion mechanisms of cometary surfaces, we examine the gas flow of H_2O and CO_2 ices through a porous pebble layer in dependence of the samples temperature, layer height and composition of the pebbles.

2 The experiment setup

Two types of samples are examined within this work. First we analyze a system in which porous pebbles of volatile and inactive components are mixed together. Each aggregate consists of only one constituent. We refer to this system as the separately mixed sample. Inactive components are either SiO_2 or H_2O, depending on temperature. Secondly, we analyze a system in which the volatile and inactive components are intrinsically mixed in each aggregate. We refer to this system as the intrinsically mixed sample. A draft of both systems is shown in figure 1. For both types of samples, we analyze the deviation of the samples gas production rate from that of a solid, barren ice in dependency on the samples temperature as well as on the thickness of the porous layer.

Each experiment consists of the following steps: after production, the sample is handled at liquid nitrogen temperature to ensure the unaltered status and is subsequently transfered into the nitrogen cooled measurement chamber. Directly following, the experiment chamber is evacuated. As soon as a steady background pressure is reached, the sample is heated to a constant temperature and the outgassing rate measured as the volatile boundary retreats into the sample.

To measure the gas production rate, we utilize the fact, that at low sample temperatures, as found on comets, the outgassing rate of H_20 and CO_2 ices is such low that the production rate is proportional to the density of the gas flow emerging from the sample. Therefore the gas production rate is proportional to the pressure above the sample and can be calculated from the latter. In our setup, the pressure above the sample is recorded by a hot cathode pressure sensor or a mass spectrometer (to differentiate the partial pressure of the gas species). A chopper system is used to separate the background pressure from the sample pressure.

Since the pressure produced by the sample must be significantly higher than the background pressure to be measured, the experimental setup comprises a

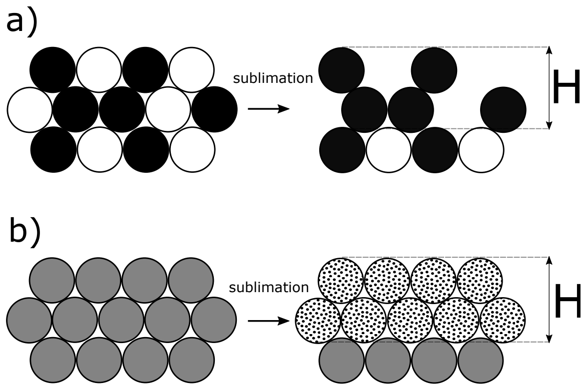

Figure 1: Schematic visualization of the different type of mixtures and the effect of material loss: Separately mixed model with black inactive pebbles and white active pebbles a) and the intrinsically mixed model with gray pebbles consisting of active as well as inactive components while dotted pebbles symbolize pebbles depleted of active constituents b). H is the height of the inactive layer.

two stage rotary vane pump and a turbo molecular pump. A comprehensive explanation of the measurement principle can be found in [4].

3 The diffusion model

At the beginning of each experiment, the outgassing rate equals that of a solid ice sample. However, with beginning loss of material, the boundary of the active volatile component retreats into the sample. The remaining, overlaying layer of inactive material dampens the gas flow. The ratio between the dampened gas flow and the gas flow of a solid sample is described by the so called diffusion coefficient and depends on the thickness of the overlaying layer. The thickness of the layer can be derived by comparing the sublimated mass calculated from the measured production rate. Examples of analytical models and simulations can be found in [5].

4 Results and conclusions

Our experimental setup enables us to measure the production rate of a porous pebble mixture composed of H_20 and CO_2 ices and SiO_2 dust in dependency of the thickness of the inactive layer and the ices temperature. Based on the measured data we develop a diffusion model that depends on the mixing type (intrinsic or separate) of the aggregates, the temperature and the thickness of the inactive layer. These models can be used by comet simulation models to improve the understanding of cometary activity such as subsurface evolution and dust release. The data and model will be presented at the EPSC 2018 in Berlin.

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