Laboratory simulation of Martian atmospheric chemistry

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Introduction

Recently there has been a great deal of interest in understanding the concentration and distribution of gases within the Martian atmosphere due to the observation of trace species such as methane [1,2] that could hold clues to previously unobserved processes such as volcanism or perhaps even life.

Mars Global Circulation Models (MGCMs) can predict both the seasonal and spatial variability of trace gases on Mars. Current models are very effective at predicting the variability due to transport (dynamical) processes [3] but they do not have any gas species that form from the gas phase. The maxima occur when the concentration of water vapour in the atmosphere is lowest. This is because species that form from the gas phase are much more important on Mars than on Earth but not on Earth so it is possible that some reaction mechanisms haven’t yet been observed.

To improve the accuracy of these models more must be learnt about the mechanisms and rates of these reactions under Martian environmental conditions.

The Laboratory Set-up

Figure 1. Shows a photo of the current laboratory set-up. Figure 2. is a schematic diagram of the apparatus.

A: Environmental simulation chamber

A stainless steel vacuum chamber is evacuated and then filled with a Mars mix gas (95% CO₂ + 5% N₂) at a pressure of 0.1 bar to approximate a “standard” Mars atmosphere.

B: FTIR spectrometer

The FTIR measures the IR spectrum of the gases within the chamber. The spectra are analysed to calculate the concentrations of the gases being produced. Spectra are taken at 1 minute intervals to examine the evolution of the gases with time and to ascertain if an equilibrium has been reached.

C: Heating/cooling plate

The chamber is cooled to a standard Mars temperature of -59°C by flowing liquid nitrogen through a compartment at the base of the chamber. A heating element can heat the chamber to simulate diurnal heating effects.

D: Gas inlet

A gas inlet pipe is used to add trace gases such as HCl, H₂O, SO₂ into the chamber in small concentrations. A sample container can be attached to sample the gases in the chamber to perform mass spectrometry on.

E: Deuterium UV lamp

The UV light emits a spectrum similar to the UV output of the Sun. The UV photons are what drive the photochemical reactions within the chamber.

F: Regolith

A basalt powder can be added at the base of the chamber to simulate possible effects of basalt regolith on the reactions occurring in the atmosphere.

The Problem

The reaction rates and mechanisms used are assumed to be the same as those for reactions occurring in the Earth’s atmosphere but this might not be the case. Important differences between Earth and Mars:

• The average temperature of Mars is much lower and so reaction rates will be extrapolated to these lower temperatures.

• The bulk constituent on Mars is CO₂ experiments using CO₂ rather than N₂ or O₂ have been shown to increase the efficiency of certain three-body reactions by ~2.5 times [10].

• Basalt dust is an important constituent in the Martian atmosphere but not on Earth so it is possible that some reaction mechanisms haven’t yet been observed.

To characterise these effects on rates and mechanisms we must measure reactions under Martian conditions.

Summary

The study of trace gas chemistry on Mars is interesting as it offers clues into underlying active processes such as volcanism.

To understand observations of trace gases they must be modelled by MGCMs that are capable of predicting their seasonal and spatial distribution because of both transport and chemical processes.

Laboratory simulations of chemistry under Martian environmental conditions are needed both to improve the accuracy of current MGCM reaction schemes but also to identify possible new reactions of interest such as ones occurring on the surface of basalt dust particles.

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References