PHYSICAL ADSORPTION MECHANISMS OVER NON-POLAR ICY SURFACES

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Abstract:
In the present work, we analyze the possibilities of our laboratory to study the capacity of non-polar ices of astrophysical interest to retain molecules of some gases relevant in astrophysical environments.

The most abundant molecule in solid state in the Universe is water (H_2O) followed in many scenarios by carbon dioxide (CO_2). Therefore the study of the adsorption properties of their ices can be relevant in understanding the physical and chemical processes in those environments in which they are present in significant quantities.

Our laboratory setup is designed to perform experiments of desorption of volatiles trapped in CO_2 or H_2O with increasing temperature. In this work we focus on CO_2 as H_2O has been widely studied. Two lasers and a quartz crystal microbalance used together, allow us to study the adsorption and desorption mechanisms of volatile molecules in ices.

Keywords: Laboratory – Ices – ISM – Adsorption.

1 Introduction

There exist different astrophysical environments where ices of simple molecules are know to be present [1]. Molecules such as for example CO_2 or H_2O play a relevant role in several astrophysical scenarios. Studies of water's capacity to retain other molecules in its own structure have been already (and widely) performed by the scientific community [1]. However the same is not true for CO_2.

CO_2 ice's capacity for retaining molecules at temperatures higher than their characteristic sublimation one, might play a relevant role in some astrophysical scenarios and in the kinetics of reaction taking place within their structure. The physical conditions, in which ices could be present, vary from a place to another one. Temperature ranges from 10 K in the inner parts of molecular clouds to more than 200 K on the surface of some planets or satellites. Concerning the pressure, this can vary from some millibars in some planets or satellites to less than 10^4 particles cm^{-3} (roughly 10^{-13} mbar) in the diffuse interstellar medium.

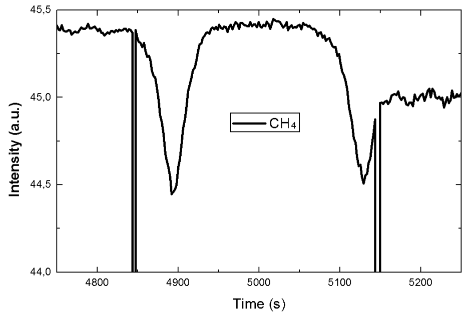

Figure 1: Interferometric pattern obtained during deposition of CH_4 on the balance.

The scientific aim would be to reproduce in the laboratory the same type of physical conditions (as much as it would be possible) present in those scenarios, however, whereas in the laboratory it is possible to reproduce the interval of temperatures quoted above, nowadays the lowest pressure that it is possible to obtain is around 10^{-11} mbar, thus far away from the pressure present in the ISM. Therefore, in the analysis of this kind of experiments it must be always taken into account that the parameter or the characteristics that we are studying are not pressure dependant as is the case of the interactions of volatiles with CO_2.

2 Method

To study the adsorption capacity of ices we have analyzed the desorption process of several simple gases such as CH_4, N_2 and CO_2 and the following binary mixtures CH_4:CO_2 and N_2:CO_2.

2.1 Experimental setup

The experimental equipment used in our laboratory is described in detail in Satorre et al. 2006 [2]. Mainly it is composed of a high vacuum chamber (around 10^{-8} mbar) a quartz crystal microbalance (QCMB), a mass spectrometer, two lasers, a prechamber where the mixture of gases to deposit is prepared, and a system to register the data obtained during the experiments.

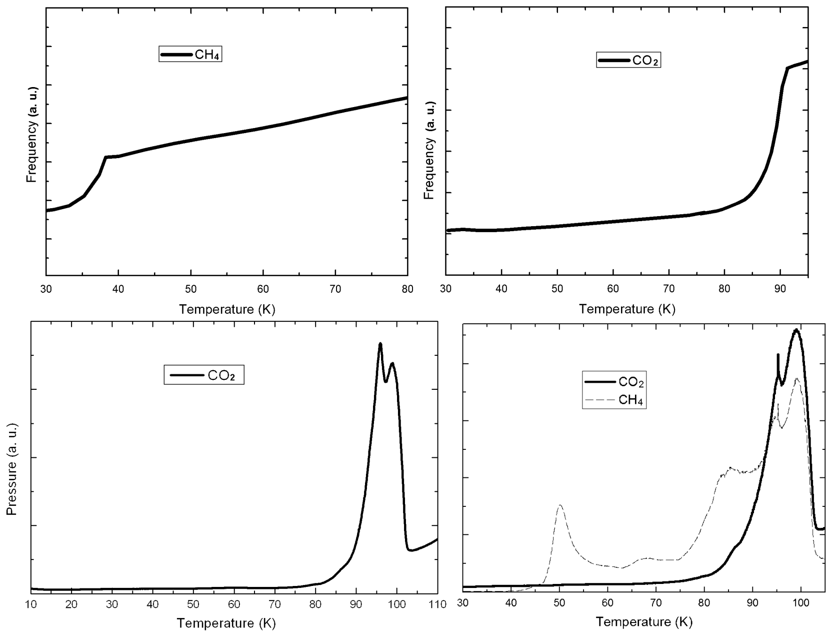

Figure 2: Upper panels: Frequency evolution of the QCMB with increasing temperature, when deposited gas is CH_4 (left panel) or CO_2 (right panel). Lower panels: signal recorded by the mass spectrometer during the desorption experiment. Left: pure CO_2. Right: mixture of CO_2 and CH_4 (95:5).

2.2 Procedure

A cryostat and a turbomolecular pump, both of them connected to the chamber, allow the system to reach a temperature of 10 K and a pressure of 10^{-8} mbar. Under these conditions, pure or a mixture of gases are injected to the chamber from a prechamber. This way a gas deposits onto the sample holder.

Once the deposit is finished, a resistor located in the sample holder is turned on and the sample is warmed at fixed rate of 1 K min^{-1}. Temperature and QCMB frequency data during experiments are registered.

The lasers allow us to monitor the growth of ices using interferometry (Figure 1). The mass spectrometer is used to control the proportion of gases during injection into the chamber at a fixed flow and to monitor the species present in the chamber during all the experiment.

3 Results and conclusions

To analyze the behavior of pure and mixed gases we have performed experiments for both types of samples. As an example, we can see in Figure 2 (upper panels) the evolution in frequency of QCMB with temperature when pure CH_4 (left panel) or pure CO_2 (right panel) are warmed up in the sample holder. Both graphs show a linear behavior in frequency with increasing temperature except in one interval of temperature where an abrupt increase in frequency occurs.

This zone allows us to determine the desorption temperature for each of the species studied (but only) under our experimental conditions. In this case the desorption of CH_4 occurs in the interval of temperatures corresponding to 35-40 K whereas the desorption of CO_2 takes place between 85 and 90 K.

When the analyzed sample is a mixture of gases it is necessary that the mass spectrometer differentiate throughout the experiment every molecule desorbing from the balance, especially in the temperature intervals in which both molecules could leave together the surface of the balance (Figure 2, lower panels).

The results of these experiments may be of interest for environments where the presence of CO_2 ices could be responsible for retaining other simple molecules up to temperatures above their characteristic sublimation point (see Luna et al. [3]) and in this way they remain available to react with other species [4] or to interact with the incident radiation leading to other species whose presence is difficult to explain if we do not take into account this retaining mechanism.

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References

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