The effect of ultraviolet irradiation of mixture ice rich in $CO_2$

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Summary. There are many ways to study material present in space: observation, theory, computational simulation and laboratory works. Since 2001 and astrolaboratory for physical and chemical studies of material in space is building up in Alcoi. Laboratory experiments are crucial in order to simulate situations where it is impossible to carry out direct measurements. Also in the Solar System (SS) it is possible to do experiments in order to simulate situations as for example seasonal changes in temperature. On the other hand we can study chemical changes due to reactions with ultraviolet (UV) photons irradiations in controlled environments. All of these studies can be analyzed with different techniques and electromagnetic wavelengths. In this contribution we want to offer our first experiments in order to analyse the effect of UV irradiation in mixtures reaches of $CO_2$.

1 Introduction

Different targets can be emulated in laboratory: gases, liquids or solid material as silicates, carbonaceous material or ices. We understand ices as the solid phase of molecules that are gases or liquids in standard conditions; for example it is possible to produce ices of water, methane, carbon dioxide, nitrogen, etc. With this purpose, a particular sample prepared in the system, to emulate a particular scenario, is called "analog". It is composed by relevant molecules for a particular astronomical scenario as planets, satellites, comets, trans-neptunian objects in our Solar System and in the interstellar medium (ISM). At the moment more than a hundred interstellar molecular species has been identified: from the simple molecules ($H_2$, $CO$, $H_2O$, $CO_2$) until the complexes polyaromatic hydrocarbons (PAHs). At the 80’s we began to find these molecules using infrared (IR) spectra, as dirty ice mantle taking part of the dust grains forming an onion structure [1]. $CO_2$ ice is an important constituent of these ices in the ISM and also in our SS. On the other hand, the composition of the dust grains can evolve thanks to its exposure to energetic processes as UV photons and ion irradiation. We have performed a number
of preliminary experiments using the capabilities of our astrolaboratory [2]. In these experiments different samples of CO$_2$ ice has been irradiated with a microwave-powered hydrogen lamp in order to study the formation of new molecules using a quadrupole mass spectrometer.

2 Experimental set-up

The experiments have been performed in a vacuum chamber operating at a pressure of 10$^{-7}$ mbar obtained by a turbomolecular pump in a High Vacuum System backed by a root pump (Figure 1). A compressor connected with a closed-cycle He cryostat is used to cool down the sample at 10 K. A resistor and temperature controller allow us increase the temperature until 300 K. When initial conditions are established, the gases (pure or mixture) prepared in a pre-chamber passes trough a needle valve to the chamber. The proportions of a particular mixture are controlled by their partial pressures.

![Fig. 1. Experimental set-up](image)

Our sample holder (placed vertically) is a Quartz Crystal Microbalance (QCMB) which frequency is measured precisely by a frequencymeter. The deposited samples are chemically processed by UV photons to form new molecules which composition is monitored by mass spectroscopy.

UV photons are provided by a microwave-powered (Opthos Instruments) hydrogen lamp similar to that used by other groups [3] [4]. The lamp is mounted directly onto the sample chamber separated by an UV-transmitting MgF$_2$ window, and its spectrum is dominated by these bands: 1220, 1360, 1450 and 2800 A. With this lamp we obtain a flux $10^{15}$ photons cm$^{-2}$s$^{-1}$ with an energy up to 6 eV.
In order to simulate the photon flow, we irradiate the ices during a determined interval of time (Fig. 2). This process is called UV photolysis. The energy of photons is sufficient to destroy the bonds of the atoms of the deposited ices. The resulting pieces are recombined giving new molecules. These molecules are detected by spectroscopy of mass. A quantity of these molecules can be trapped in the matrix ice, so we have to increase the temperature above the sublimation temperature of these new molecules in order to detect them.

3 Results and discussion

The results presented here represent the first experiments of calibration of our, recently acquired, UV lamp by irradiating $CO_2$ ices (Figure 3 and 4). The objective of these experiments has been to verify qualitatively the production of new molecules. We found that initial proportions in mixtures, the irradiation time and the way of deposition (mixed or in layers) are determinant to form new molecules. In all our experiments, the most important chemical species detected have been the carbon monoxide and oxygen. In addition, other compounds have been detected as traces.

The quantitative analysis will be possible when the Bruker Optics IFS 66v/S series FT-IR spectrometer will be operative in our laboratory in the close future. Their analysis will give information about the structure of the ices and the chemical processes to understand the physic present in different astrophysical scenarios.
Fig. 3. Results for a deposit of CO$_2$ (40 K) and an UV photolysis of 2 hours

Fig. 4. Results for a deposit of CO$_2$ (10 K) and an UV photolysis of 2 hours

References