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# UV-irradiation of $H_2O$ ice under ultra-high-vacuum conditions: product formation and photodesorption

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## Abstract

Water ($H_2O$) is often the most abundant molecule in iterstellar and circumstellar ice mantles covering dust grains. We report some preliminary results on UV-irradiation experiments of solid $H_2O$. In particular, we revisit the formation of photo-products and the photo-desorption of species from the ice under ultra-high-vacuum conditions.

## 1. Introduction

$H_2O$ is the dominant ice component in dense clouds. At present, five interstellar features have been detected which fit reasonably well with laboratory $H_2O$ ice spectra (OH stretching in solid $H_2O$), [4], [5]. The absorption near 3277 $cm^{-1}$ is typically one of the most intense in interstellar spectra, tracing icy dust grains. The $H_2O$ molecule has been identified in many regions in space. In our solar system it can be found in Mars, Europe, Titan and Ceres in the solid phase and in Enceladus in the gas phase.
The InterStellar Astrochemistry Chamber (ISAC) is an ultra-high-vacuum (UHV) set up (base pressure of $3 \times 10^{-11}$ mbar) where an ice layer is deposited at 8 K and later UV-irradiated or warmed up, see [2] for a description of ISAC. The UV source is a microwave stimulated hydrogen flow discharge lamp (flux of $\sim$ 2.5 $\times 10^{14}$ photons $cm^{-2}$ $s^{-1}$, $E_{photon} = 7.3 - 10.5$ eV).
The solid $H_2O$ sample was deposited at 8 K. Its evolution during UV-irradiation and subsequent warm up was monitored using transmittance Fourier transform infrared (FTIR) spectroscopy, and quadrupole mass spectroscopy (QMS).

## 2. Water UV-irradiation

Several experiments were performed in order to have samples with different thicknesses: 50, 100, 170, and 200 monolayers. The mass spectrum of $H_2O$ was measured with the QMS of ISAC. The main mass fragment of $H_2O$ is m/z=18 followed by m/z=17 and m/z=16. After deposition of the ice the sample was warmed up with a 2 K/min heating ramp. An IR spectrum was collected every 5 minutes. The 3277 $cm^{-1}$ feature changes its profile while the temperature rises up indicating the transition from an amorphous state to a crystalline one up to 160 K. The 3277 $cm^{-1}$ (O-H stretching) and 750 $cm^{-1}$ (libration) features became narrower while the 1660 $cm^{-1}$ (O-H bending) and 2200 $cm^{-1}$ (libration + O-H bending) features became broader.

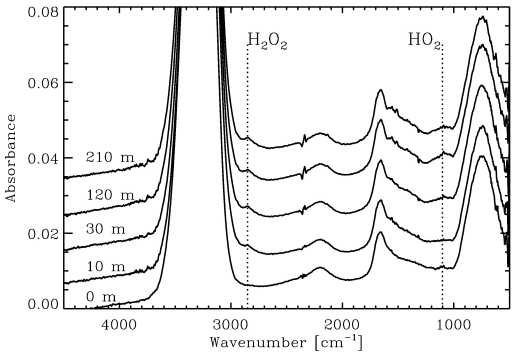


Figure 1: Evolution of the IR spectrum of $H_2O$ during irradiation. The photo-products are indicated. Spectra were offset for clarity. The bottom spectrum corresponds to the non irradiated sample, the irradiation time is indicated on top of each spectrum.

We observed the formation of $H_2O_2$ at 2850 $cm^{-1}$ after 4 minutes of irradiation while $HO_2$ at 1101 $cm^{-1}$ was detected after 30 minutes. A band of molecular hydrogen at 4143 $cm^{-1}$ cited by Ref. [1] and reported by Ref. [6], was not clearly detected, Fig. 1. Gerakines *etal*. (1996) mentioned two OH features at 3428 $cm^{-1}$ and 3453 $cm^{-1}$. These bands were not observed in our

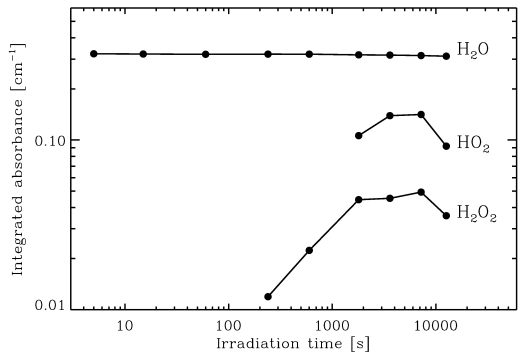


Figure 2: Evolution of the integrated infrared absorbance as a function of total irradiation time for $H_2O$ and the different photo-products. $H_2O$ abundances correspond to the integration of the 3277 cm$^{-1}$ feature.

experiment because they overlap with the main band of water ice (3270 cm$^{-1}$), they were not strong enough to allow the infrared detection.

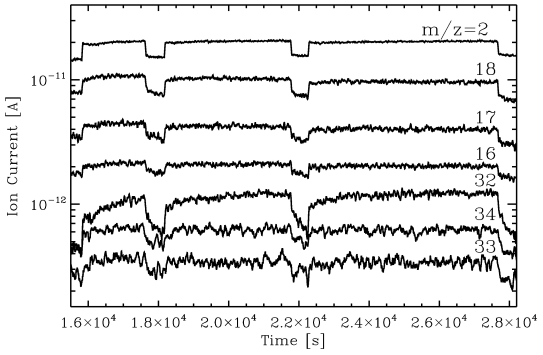


Figure 3: Photo-desorption of $H_2O$ and its photo-products. The shape follows the turn on and turn off of the UV-lamp. The curves were offset for clarity.

Thanks to the QMS technique for the observation of molecules in the gas phase we were able to detect the photo-desorption of $H_2O$, $H_2$, $O_2$, $H_2O_2$,and $HO_2$. The possible photo-desorption of O and OH, and the direct products of $H_2O$ dissociation, will be discussed in our presentation. Fig. 2. shows the integrated infrared absorption bands of $H_2O$, and the $HO_2$ and $H_2O_2$ products as a function of the irradiation time. Here the main feature of $H_2O$ decreases whereas it increases in Ref. [1] experiment. This is an effect of the poor vacuum conditions in previous experiments. Fig. 3 shows how, when the UV-lamp is turned on, the partial pressures of the species rise up and when it is turned off they decrease back to the initial value. This is an indication of photo-desorption of these species.

# 3. Summary and Conclusions

This work is an improvement of previous experiments reported in the literature dedicated to UV-irradiation of solid $H_2O$, e. g. Ref. [1], under poor vacuum conditions. Thanks to our vacuum level in the $10^{-11}$ mbar range, we were able to observe the decrase of the $H_2O$ ice column density during irradiation, Fig. 2., and made a better quantification of the photo-products. The UHV conditions and an optimum use of the FTIR and QMS techbiques allowed such a quantification and the detection of species photo-desorbing from the ice.

# References

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