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EXPERIMENTAL EVIDENCE FOR WATER FORMATION VIA O_3 HYDROGENATION ON A WATER ICE COVERED SURFACE UNDER INTERSTELLAR CONDITIONS

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1 Introduction

In dense cold interstellar clouds, dust grains are covered with an ice mantle mainly composed of water H_2O ice (Gibb et al 2000). Solid water ice has been observed in general on the surface of many different astronomical objects, such as outer planets, satellites, comets and interstellar cloud.

The chemical origin of the water is not well understood. Its formation in the gas phase is not efficient to reproduce the observed abundance. Then water ice in dark clouds is likely to be formed directly on grain surfaces.

Several reaction schemes for water formation on cold grain surfaces, predicted by astrochemical models are likely to occur via the hydrogenation of O, O_2 and O_3 (Tielens & Hagen 1982, Cuppen & Herbst 2007). Although O_3 molecules have not so far been detected on interstellar dust grains, their presence is presumed.

2 Experimental

Experiments are performed with the FORMOLISM setup using the Temperature Programmed Desorption (TPD) diagnostics. Ozone (prepared ex-situ by radio frequency electric discharge in O_2 gas in a glass bottle) is first deposited on a non-porous amorphous solid water ice. Then D-atoms are sent onto the sample held at 10K. HDO molecules are detected during the desorption of the whole substrate where isotope mixing takes place, indicating that water synthesis has occurred. The efficiency of water formation via hydrogenation of ozone is of the same order of magnitude than found for reactions involving O atoms or O_2 molecules and exhibits no apparent activation barrier. These experiments validate the assumption made by models using ozone as one of the precursors of water formation via solid-state chemistry on interstellar dust grains.

3 Discussion

There are several possible chemical pathways (Tielens & Hagen 1982, Miyauchi et al 2008, Ioppolo et al 2008) to form D_2O. At T_s= 10K, formation of D_2O on np-ASW ice from O_3 + D may proceeds through the following steps:

$$O_3 + D \rightarrow OD + O_2$$
$$OD + D \rightarrow D_2O$$

and

$$O_2 + D \rightarrow DO_2$$
$$DO_2 + D \rightarrow D_2O_2$$
$$D_2O_2 + D \rightarrow D_2O + OD$$

At $T_s > 120$K and during the heating, an isotopic exchange is occuring between D_2O formed and the H_2O substrate, leading to HDO formation:

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$$D_2O + H_2O \rightarrow 2\ HDO$$

In dense clouds where H_2 and D_2 are abundant, another reaction (Tielens & Hagen 1982) is possible:

$$OD + H_2 \rightarrow HDO + H$$

4 Conclusions

1) The reaction O_3 + D proceeds without activation barrier. **2)** The formation of water from O_3 + D reaction on non-porous ASW is efficient and produces water HDO molecules. **3)** The experimental result confirms the theoretical models considering O_3 as the major actor of water formation in dark clouds (Tielens & Hagen 1982, Cuppen & Herbst 2007).

This work (Mokrane et al 2009) presents the first experimental evidence of water formation from O_3 reaction with D-atoms on non-porous amorphous solid water ice under conditions relevant to interstellar molecular clouds.

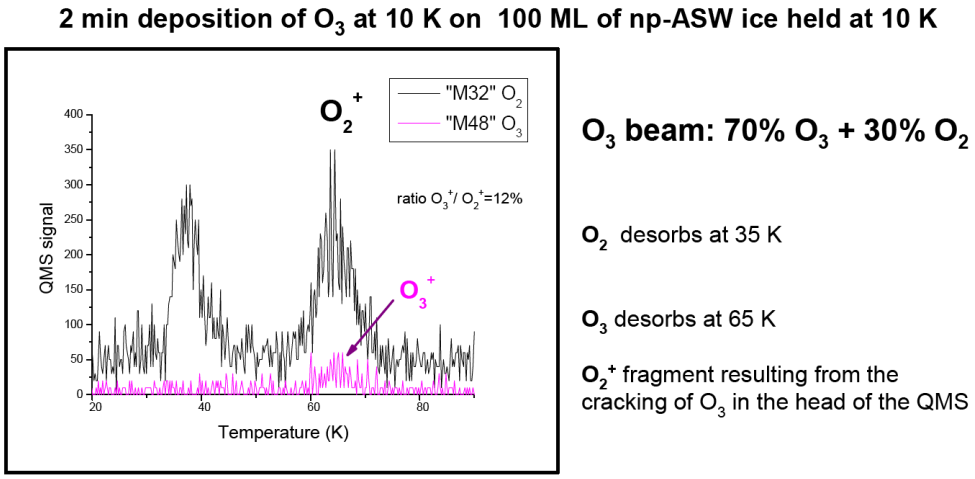

Fig. 1. TPD spectra of O_3 (in red) and O_2 (in black) on np-ASW

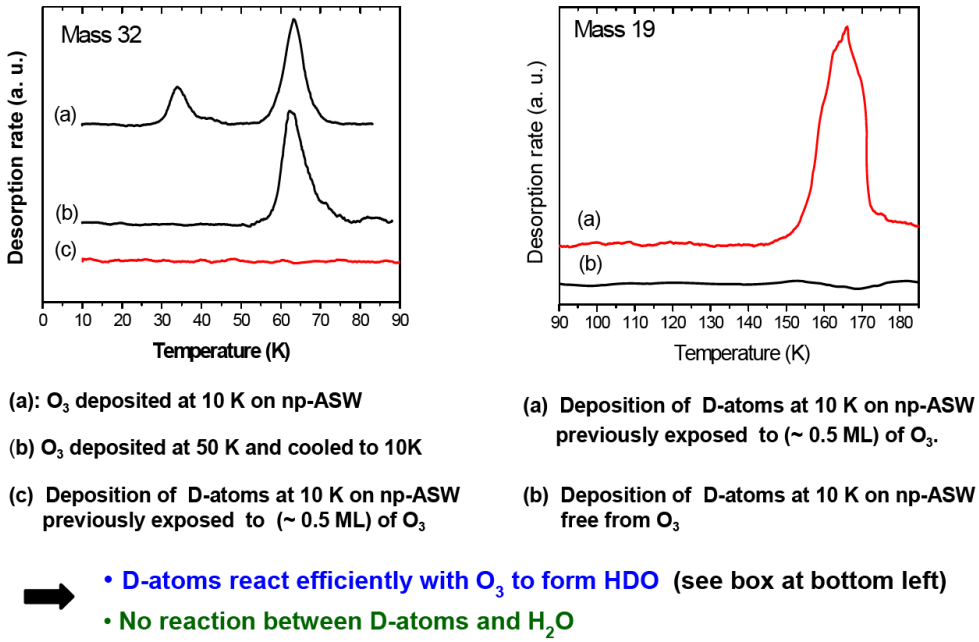

Fig. 2. TPD spectra of O_3 +D on np-ASW, for mass 32 (O_2) and 19 (HDO)

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