

Experimental studies of H₂ and D₂ interaction with water ice films

Jean-Hugues Fillion, Lionel Amiaud, François Dulieu, Anouchah Momeni, Saoud Baouche, Jean-Louis Lemaire

Laboratoire pour l'Etude du Rayonnement et de la Matière, UMR 8112 du CNRS,
Observatoire de Paris et Université de Cergy Pontoise, 5 Mail Gay-Lussac, F-95031
Cergy-Pontoise Cedex, France

Abstract. The "FORmation of MOLEcules in the InterStellar Medium" (FORMOLISM) set-up, has been designed to investigate heterogeneous chemistry occurring at the surface of astronomically relevant materials. The main goal is a contribution to the study of molecular hydrogen formation processes on surfaces which mimic interstellar dust grains. For this purpose, two atomic/molecular beams are connected to a main chamber operating under ultra-high vacuum conditions. The samples are deposited on a copper plate attached to a cryo-generator allowing temperature regulation in the 8-800 K range. Desorbed molecules are monitored either with a high sensitive quadrupole mass spectrometer or with a time-of-flight mass spectrometer for REMPI (resonantly enhanced multiphoton ionization) detection, allowing in the latter case quantum state selection. Currently, the surfaces consist of different phases of solid water ice films obtained by vapour deposition at low temperature. Water samples are considered to be good analogues of frozen mantles covering dust-grain particles in cold and dense regions of the interstellar medium.

In a first set of experiments, we have investigated the interaction of molecular hydrogen with porous or non-porous amorphous solid water (ASW) and cubic crystalline water ice (Ic) by using temperature programmed desorption (TPD). A good knowledge of the binding energies of the molecules physisorbed on solid water ice films is essential for the determination of the molecular hydrogen amount which can be frozen on dust grains. This information is also necessary to interpret other experimental investigations of the atomic recombination process using TPD (Roser *et al.* (2002)). As shown by a recent study (Hornekaer *et al.* (2005)), TPD is very sensitive to the ice surface morphology and particularly to surface thickness and porosity. A broad distribution of binding energies for D₂ monolayer on ASW was measured in this study. We have obtained complementary desorption curves as a function of D₂ coverage. We show that the broad energy distribution obtained by the direct inversion of our TPD curves cannot satisfactorily give account of the whole set of experimental results on porous ASW films. The interpretation requires the development of models more correctly adapted to species weakly bound to the surface. We then propose an alternative approach, based on a statistical equilibrium of the molecules over their binding sites, in order to explain our experimental results. The ability of our model to qualitatively describe a strong isotopic segregation effect when both H₂ and D₂ are sequentially deposited on the sample, tends to support this approach (Dulieu *et al.* (2005)).

In another set of experiments, the molecules released in the gas phase are ionized by a tunable UV laser. A (2+1) photons REMPI detection coupled to a time-of-flight mass spectrometer is used to selectively detect the molecules in their individual rovibrational quantum state. This allows the desorption kinetics to be investigated separately for ortho- and para- states of the molecules. Preliminary results will be shown. Further experiments will be also carried out to investigate the internal energy distribution of the molecules (H₂, HD or D₂) that are promptly formed by recombination of hydrogen atoms on the surface. These experiments should complete other investigations of the atomic recombination process which have been previously studied using TPD (Hornekaer *et al.* (2003)), or which have been undertaken on other astrophysical relevant surfaces (Perry *et al.* (2002)).

Keywords. methods: laboratory, astrochemistry, molecular processes, ISM:dust, extinction

References

- Dulieu, F., Amiaud, L., Baouche, S., Momeni A., Fillion, J.-H., & Lemaire, J.L. 2005, *Chem. Phys. Lett.* 404, 187
- Hornekaer, L., Baurichter, A., Petrunin, V. V., Field, D., & Luntz, A. C. 2003, *Science* 302, 1943
- Hornekaer, L., Baurichter, A., Petrunin, V. V., Luntz, A. C., Kay, B. D., & Al-Halabi, A. 2005, *J. Chem. Phys.* 122, 124701.
- Perry, S. A., Gingell, J. M., Newson, K. A., To, J., Watanabe, N., & Price, S. D. 2002, *Meas. Sci. & Tech.* 13, 1414
- Roser, J. E., Manico, G., Pironello, V., & vidali, G. 2002, *Astrophys. J.* 581, 276