SF2A 2009
M. Heydari-Malayeri, C. Reylé and R. Samadi (eds)

ORTHO/PARA SPIN CONVERSION OF D_2 ON A POROUS WATER ICE SURFACE AT 10K IN THE PRESENCE OF O_2 TRACES

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1 Introduction

Molecular hydrogen is the most abundant molecule in the universe. It is at the center of several fundamental questions in astrophysics, and in particular the physics and chemistry of the interstellar medium (ISM). As an example, the relative proportions of ortho- and para-populations of H_2 (Fig. 1 left) are valuable data for establishing the nature of interstellar shocks (Kristensen et al 2007) and may contain information on the history of the grains and the emitting molecular clouds.

We present results on the nuclear spin conversion of D_2 adsorbed on a porous water ice surface at 10 K. Such a surface mimics ice covered interstellar grains as they are assumed to exist in cold dark clouds, H_2O being the main constituent of the ice.

2 Experimental

Experiments have been performed with the FORMOLISM (FORmation of MOLecules in the ISM, Fig. 1 right) setup available at the LAMAp/LERMA laboratory and partly described in Lemaire et al (2007). Main experimental conditions (ultra high vacuum $\sim 10^{-10}$ mbar and very low temperature $\sim$8 K) are close to those encountered in some regions of the ISM. Using laser multi-photon ionization (REMPI) and time of flight (TOF) mass spectrometry, it is possible to achieve TPD experiments (Thermally Programmed Desorption) with rovibrational quantum states resolution. REMPI (2+1) ionization is obtained using a laser combination (doubled Nd:YAG + Dye Laser) tuned around 201 nm. As demonstrated previously (Amiaud et al 2008) the E,F (v'=0,J) - X (v " =0,J) transitions can be selected to detect separately the molecules in the ortho state (J=0) or in the para state (J=1). Our results derive from relative population measurements of the molecules during desorption from the cold surface after different latency periods.

3 Preliminary results

According to the Boltzmann statistics, at LTE at 10K, 33% of the molecules are in the para state and 66% in the ortho one (Fig. 1 center). Our results show that a very small amount of molecular oxygen deposited on the ice surface induces a conversion from the para to the ortho state. The conversion times have been measured at several O_2 and D_2 coverage. They are found to exceed few hours in the non oxygen-doped limit, on the contrary to previous study (Hixon et al 992).

4 Discussion

These results can be easily interpreted considering the mobility of the D_2 molecules on the surface at 10K. The conversion is due to the paramagnetic property of the O_2 molecules but, as already demonstrated for D_2

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(Motizuki 1957) (and Motizuki & Nagamiya 1956, for H_2), the conversion only occurs if D_2 goes across an O_2 interaction sphere of 3.8 Å in diameter. At 10K O_2 molecules are frozen on the surface or in the pores, the only possibility for D_2 molecules to encounter an O_2 molecule is then residing in their mobility.

5 Conclusions

The general trend of these experimental results can be understood considering the mobility of D_2 molecules on the surface at 10 K together with the catalytic role of paramagnetic O_2, which is well known from cryogenics matrices studies. Such an experimental diagnostic is, at our knowledge, used here for the first time to measure nuclear spin conversion occurring on a surface at very low temperatures. These conditions are particularly relevant to the interstellar medium.

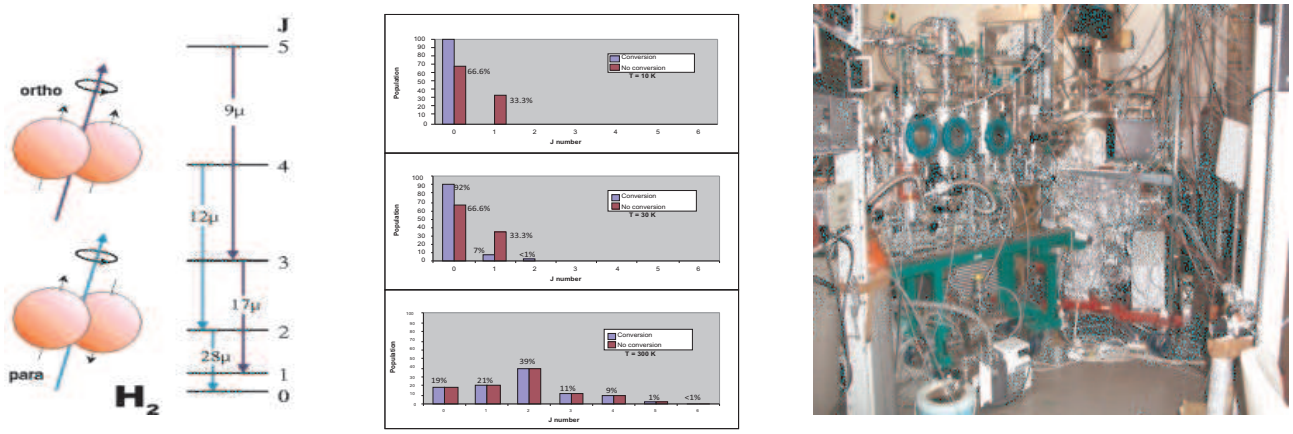

Fig. 1. Left: Ortho and Para states of H_2. Center: Ortho and Para populations ratios of D_2 at 10, 30 and 300K, at LTE. Right: FORMOLISM setup

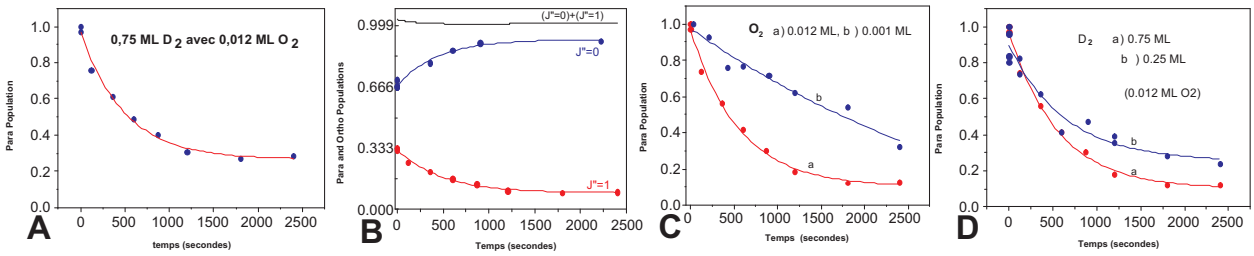

Fig. 2. A: Para population versus delay time after D_2 deposition. B: Para and Ortho populations vs. delay time. C: Para population for different O_2 depositions vs. delay time. D: Para population for different D_2 depositions vs. delay time

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