

Studies of Hydrogen Formation on Interstellar Grain Analogues

Susan C. Creighan¹ and Stephen D. Price¹

¹Department of Chemistry, University College London,
20 Gordon Street, London, WC1H 0AJ

Abstract. Molecular hydrogen is the dominant molecule in the interstellar medium (ISM) and plays an important role in all the gas phase chemistry that occurs in this region. For example, hydrogen plays a key role in the formation of water and OH molecules which are important coolants of interstellar clouds. The abundance of H₂ in the ISM cannot be explained by gas phase reactions alone, since radiative association reactions of H atoms are extremely slow in the ISM and 3-body reactions are highly unlikely to occur due to the extremely low pressures. The widely accepted model to account for the abundance of H₂ in interstellar clouds is that it forms *via* recombination of H atoms on the surfaces of interstellar dust grains. These dust grains account for around 1% of the mass of the ISM and have a range of sizes, from nanometres to microns. The grains are thought to be composed mainly of carbon or silicates. The temperatures of bare grains in diffuse clouds range between 10-20 K.

Recently, there has been increased laboratory interest in studying the formation of H₂ under conditions approaching those of the ISM. These experiments, on a variety of surfaces, use temperature programmed desorption (TPD) to detect the HD molecules formed when H and D atoms are dosed onto a cold (4 K) surface and allowed to recombine as the temperature of the surface is raised Pirronello *et al.* (1999), Roser *et al.* (2002), Hornekaer *et al.* (2003). These TPD experiments do not investigate the ro-vibrational distribution of the molecules which are formed.

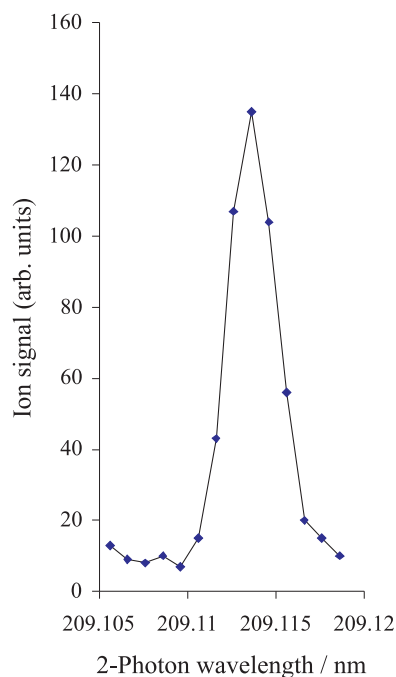


Figure 1. REMPI signal from HD in $v = 1, J = 1$ formed on an HOPG surface.

The UCL 'cosmic dust experiment' has been designed to investigate the internal energy distribution of H₂ and HD molecules that have formed through recombination on the surfaces of interstellar grain analogues Perry *et al.* (2002), Perry & Price (2003). Currently HOPG (graphite) is used as the target surface. In our experiments, atomic hydrogen and atomic deuterium, formed by microwave dissociation of the corresponding molecular gases, are directed onto a HOPG surface held at 15 K. The HD molecules formed are then state-selectively ionised (Figure 1) using the laser spectroscopic technique of resonance enhanced multi-photon ionisation (REMPI) and then detected by a time-of-flight mass spectrometer (TOF-MS). Similar experiments have also been carried out with a single beam of H atoms. We have so far observed H₂ and HD formed ro-vibrationally excited in states $v=1, J=0-3$ and $v=2, J=0-3$. Further experiments will look for higher ro-vibrational levels and we are also planning to study hydrogen formation on other model grain surfaces, such as silicates.

The formation of internally excited hydrogen in the ISM may have a number of astrophysical implications. For example, reactions with hydrogen molecules in states $v > 0$ may be very fast and H₂⁺ may be easier to form from H₂($v > 0$) *via* direct ionisation, or through charge transfer with H⁺, leading to new routes for H₃⁺ formation. In addition, large amounts of translational excitation in the nascent H₂ may result in the heating of interstellar clouds by inelastic scattering.

Keywords. ISM: dust, extinction, ISM: molecules, ISM: clouds, astrochemistry, atomic processes, molecular processes

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