Measurement of energy partitioning in hydrogen molecule produced in the photolysis of amorphous water and methanol ices

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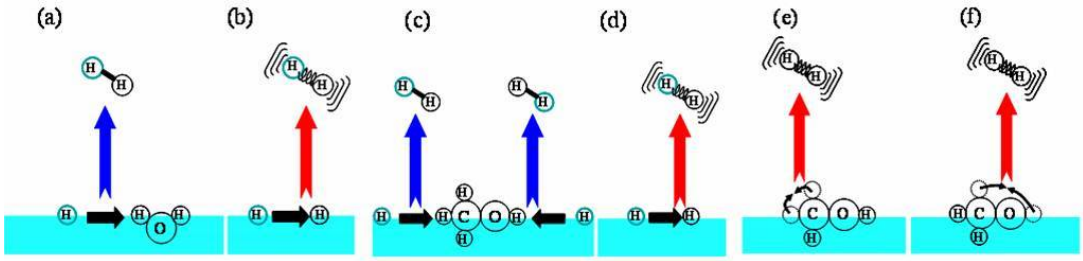
One of the most fundamental processes in the water and methanol ice photochemistry is photodissociation and the subsequent formation of hydrogen molecules. Methanol is typically observed within water rich interstellar ices and its abundance in some grain mantles varies between 0.05 and 0.50 relative to water. Watanabe et al. have estimated the efficiency of H_2 formation. (Reference: N. Watanabe, T. Horii, and A. Kouchi, Astrophys. J. 541 (2), 772 (2000).)

This work reports the details of the H_2 formation reaction mechanisms and the energy partitioning of the products from the 157 nm photodissociation of amorphous solid water (ASW) and amorphous solid methanol (ASM) at 90 K. Direct measurements of $H_2(v,J)$ were performed with resonance-enhanced multiphoton ionization (REMPI) technique.

H_2 are produced by two distinct mechanisms for ASW, i.e., a) hydrogen atom abstraction (HAB) from hydroxyl group leading to cold $H_2(v$=0 and 1), b) recombination of H-atoms (HR) leading to a vibrationally excited $H_2(v$=2-5). For ASM, e) and f) unimolecular elimination (UME) of H_2 from methanol were confirmed as additional H_2 formation mechanisms as well as c) HAB reaction and d) HR reaction. UME reactions lead to even more highly excited $H_2(v$=2-5).

In warmer (T = 20 K) and stronger UV radiation regions, the rate of H_2 formation from photolysis of ASW would exceed that from recombination of adsorbed H atoms because the recombination efficiency drops significantly at elevated temperatures. On the other hand, since UME reactions from ASM are single photon absorption processes, they can yield hydrogen molecule in quiescent clouds despite the cosmic ray induced UV flux inside quiescent clouds is small.



(a) and (b): Schematic illustrations for H_2 formation mechanisms following vacuum ultraviolet irradiation of amorphous solid water. (a) $H_2(v$=0 and 1) from hydrogen abstraction reaction (b) $H_2(v\geq2)$ from H-atom recombination.

(c), (d), (e) and (f): H_2 from amorphous solid methanol. (c) $H_2(v$=0 and 1) from hydrogen abstraction reaction (d) $H_2(v\geq2)$ from H-atom recombination. (e) and (f) $H_2(v\geq2)$ from unimolecular elimination.