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## SPECTROSCOPY OF PHYSISORBED MOLECULES

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Ro-vibrational energy levels of H<sub>2</sub> molecules physisorbed on a metallic surface (Ag (111) or Cu(100)) are calculated, using a 5D or 2D potential energy function determined at different levels of approximation: periodic or cluster representation of the system, DFT or highly correlated wavefunction description.

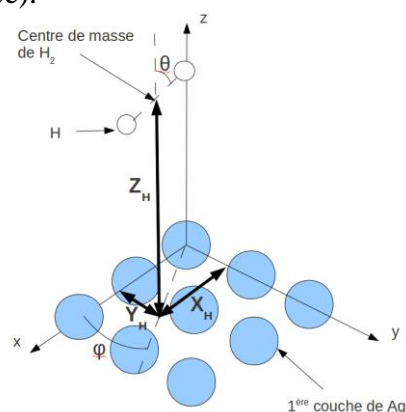
In the physisorption domain, the weak interactions between the H<sub>2</sub> molecules and the metallic surface are governed by van der Waals (vdW) forces and it is well known that standard exchange-correlation functionals provide a poor description of such dispersion interactions. However, recent studies have shown that sophisticated DFT approaches can give promising outcomes for such difficult cases and some data for physisorption energy can be used, as recently shown, to adjust new DFT functionals.

In recent theoretical studies on the H<sub>2</sub>/Cu system [1] using an embedding approach of a cluster model consisting of 22 Cu atoms, it has been shown that the chemisorption of H<sub>2</sub> can be satisfactorily reproduced. On the contrary, the description of the physisorption domain is more delicate. A good test of the accuracy of the potential energy function in this domain is the comparison with ro-vibrational spectroscopic data with EELS experiments [2]. The large rotational constant of H<sub>2</sub> associated with the anharmonic and anisotropic van der Waals potentials, results in a coupling between the rotation of H<sub>2</sub> and the stretching along the physisorption well. Such data exist for H<sub>2</sub> on Cu(100) and on Ag(111).

Highly correlated electronic calculations on the cluster model have been performed with the 2012.1 version of the MOLPRO code using the coupled cluster CCSD(T) method. The embedding method has been applied within the ONIOM approach. The periodic calculations have been performed with DFT approach within the VASP code and various functionals.

In our calculations, the center of mass of the H<sub>2</sub> molecule has been moved on the surface in the periodic approach, otherwise it was kept on the Z axis on top of the central Cu/Ag atom and the interatomic distance H-H was kept at the equilibrium geometry of the H<sub>2</sub> molecule, 0.74 Å. The 2D potential energy cuts were obtained by varying only the Z distance and the  $\theta$  angle between 0 and 90 degree. The 5D potential energy cuts include the X and Y coordinates on the surface and the  $\phi$  angle

(helicopter rotation of H<sub>2</sub> parallel to the surface).



### REFERENCES

1. F. Göttl, C. Houriez, M. Guitou, G. Chambaud and Ph. Sautet, J. Phys. Chem. C, 118, 5374-5382 (2014)
2. K. Svensson, J. Bellman, A. Hellman and S. Andersson, Phys. Rev. B **71**, 245402 (2005)