Experiments on small $(H_2)_N$ clusters

S. Montero, J. H. Morilla, G. Tejeda, J. M. Fernández

Laboratory of Molecular Fuid Dynamics
Instituto de Estructura de la Materia, CSIC, Spain

emsalvador@iem.cfmac.csic.es

Theoreticians and experimentalists are showing in recent times growing interest on small (para-$H_2)_N$ clusters for a number of good reasons: low temperature $(pH_2)_N$ clusters are non-rigid spinless bosons which have been predicted to show superfluid behavior for $N < 30$ [1]; $(pH_2)_N$ clusters are ideal reference systems for quantum Monte Carlo methods; $(pH_2)_N$ clusters show magic numbers [2]; spectroscopic data on small $(H_2)_N$ clusters provide fundamental information for high-quality H_2-H_2 (6-dim) potential energy surface [3]; $(pH_2)_N$ clusters are likely to be the best suited system to understand molecular nucleation in depth; etc, etc.
The formation process of small $(pH_2)_N$ clusters has been observed in great detail in a recent experimental survey with space, time, and number size N resolution [4] on the basis of supersonic expansions of the gas through cryogenic axisymmetric nozzles. The diagnostic of the jet medium is based on high-sensitivity (few photon/sec) Raman spectroscopy with very high spatial resolution ($\approx$2 μm) enabling for quantitative time of flight measurements in the domain of nanoseconds. Temperatures of up to 0.1 K have been attained in the jet at a collisional rate low enough to avoid sudden freezing of the gas. This way clusters between two and eight units appear size resolved, while the gradual transition of larger clusters into the liquid and eventually into the solid has been observed in the experiment.
Exhaustive investigation on nozzle temperature and pressure, and on time scale (position along the jet) have lead us to optimize the sequential formation of clusters from the very beginning of the nucleation process: the formation of dimers, and only dimers, in a bath of monomers. The data obtained from a number of supersonic H_2 jet experiments conducted along well-defined isentropic paths have lead to map the dimer-existing region in the phase diagram. The reaction rate for the three-body collisional process underlying the H_2-dimer formation has been determined for the first time. Similar experiments have been conducted on mixed H_2+He jets.

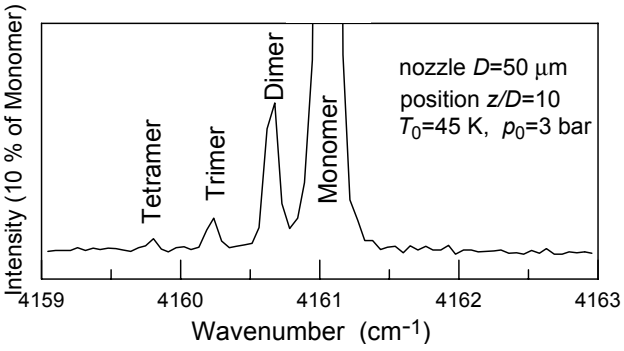

Figure 1: Raman spectrum of small para-H_2 clusters in a $pH_2(10\%)$+He(90%) supersonic jet.

[1] F. Mezzacapo and M. Boninsegni, Phys. Rev. Lett., **97**, 045301 (2006).
[2] R. Guardiola and J. Navarro, C. Europ. J. Phys., **6**, 33 (2007).
[3] R. J. Hinde, J. Chem. Phys., **128**, 154308 (2008).
[4] G. Tejeda et al., Phys. Rev. Lett., **92**, 223401 (2004).