

Dynamics of basic hydrolysis of methyl formate. Effect of micro-hydration

Ivan Černušák and Michal Novotný

Department of Physical and Theoretical Chemistry, Faculty of Natural Sciences, Comenius University, Mlynská dolina, 842 15 Bratislava, Slovakia

Ester hydrolysis is one of the fundamental reactions in chemistry and biochemistry. Experimentally, there are two known reaction channels: **(a)** $B_{AC}2$ (base catalyzed, ACyl-oxygen fission) and **(b)** S_N2 (nucleophilic substitution at methyl carbon). In solution, the mechanism **(a)** prevails.

Hypothesis: Intrinsic reactivity within $B_{AC}2$ channel can include only few water molecules cooperating via hydrogen bonds. Proton transfers in this network usually occur on *ps* scale.

Project: Base catalyzed hydrolysis of methyl formate including one, two and three water molecules.

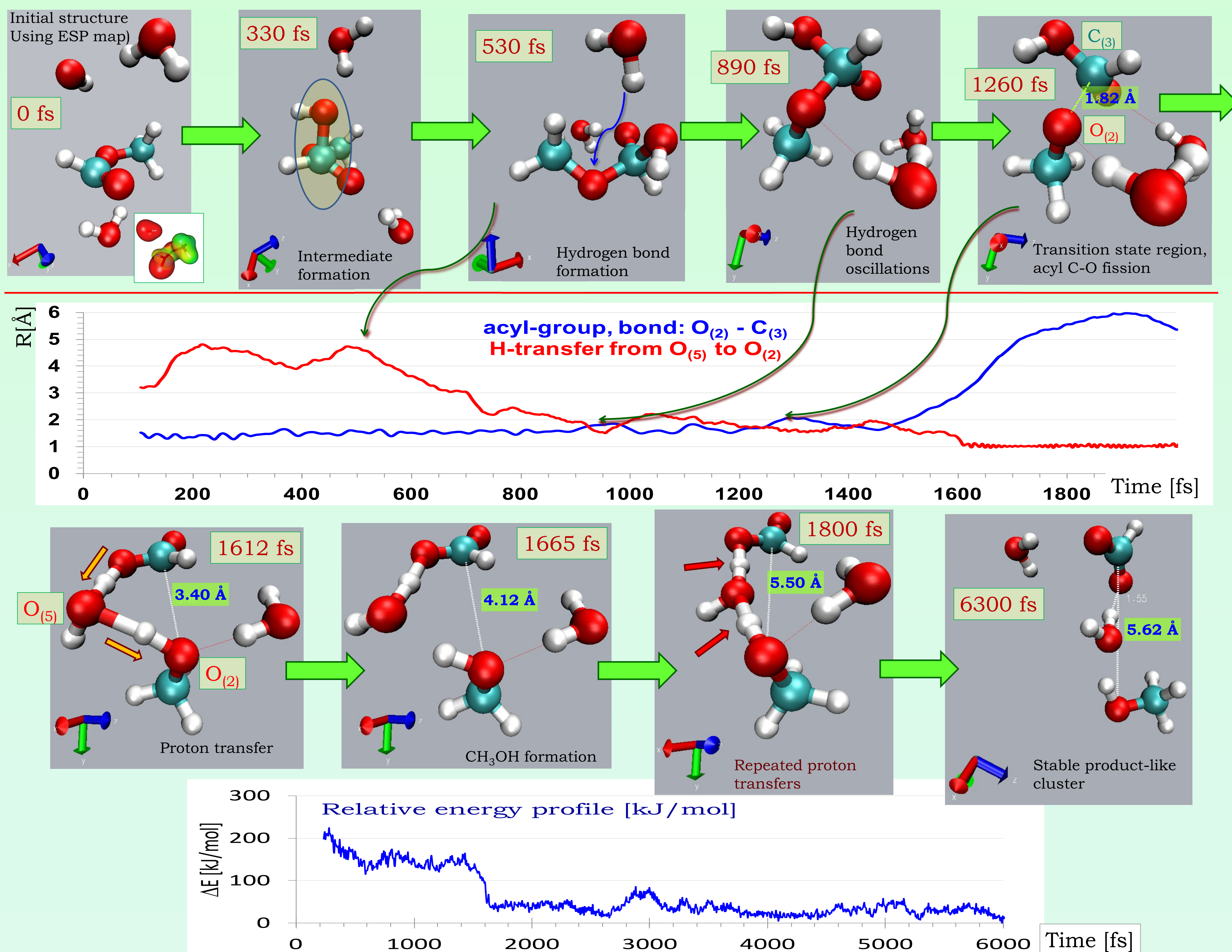
Method: *ab initio* molecular dynamics (www.cp2k.org) – MD-CP2K, using PBE functional (Perdew, Burke and Ernzerhof; PRL **77** (1996) 3865, **78** (1997) 1396) with additional empirical dispersion correction (D3 method) by Grimme et al. (JCP **132** (2010) 154104). Gaussian basis sets of DZ-quality with polarization in combination with the Goedecker, Teter and Hutter pseudo-potentials (PR - B **54**, (1996) 1703) were used. The MD simulations were conducted in NVT ensemble $T = 288$ and 298 K maintained by CSVR thermostat (*canonical sampling through velocity rescaling*) with a time constant of 0.05 ps in the box of size 24 - 30 Å (open boundary conditions). Equilibration

part ranged from 5 to 10 ps. 16 to 32 nodes used, one SCF iteration took 1 - 2 s CPU time, average MD step required 10 - 20 SCF iterations.

Results: Important part of the micro-hydration assisted $B_{AC}2$ mechanism - the OH^- attack on carbon in COH-group - strongly depends on the H-bonded network in the initial cluster. Several trajectories with different initial geometries of the hydrated $CH_3-O-COH...OH^-$ cluster and total length between 20 - 30 ps were analyzed. Only a small fraction of them leads spontaneously to traditional $B_{AC}2$ mechanism, while many others end-up in stable but non-reactive hydrated ion coordinated to methyl formate or OH^- caged in the hydrogen bonded H_2O network. Microhydrated S_N2 mechanism is viable through very specific OH^- approach in narrow channel towards CH_3 -group.

Future tasks:

- Explore convergence characteristics (long MD runs 50 - 100 ps).
- Explore the Potential of Mean Force to determine effect of micro-hydration on the barrier of the both mechanisms.



ACKNOWLEDGEMENT: This work was supported by Slovak agency VEGA (grant 1/0092/14). Computer time was kindly provided by the Computing Centre of the Slovak Academy of Sciences using the supercomputing infrastructure acquired in project ITMS 26230120002 and 26210120002 (Slovak infrastructure for high-performance computing) supported by the Research & Development Operational Programme funded by the ERDF and also in part by the IFERC computing centre in Rokkasho (HELIOS, project AECU_PWI).