

I-Q Theoretical Studies on Chemical Reactions and Molecular Dynamics of Polyatomic Molecules in Condensed Systems

In a lot of chemical, biological and environmental phenomena, the chemical reactions and molecular dynamics *in solution* or *across interface* play a very important role, where the microscopic solvation structures of solute molecules offer essential and inevitable information. In this project, to obtain a stationary point on a multi-dimensional free energy surface (FES), *e.g.*, stable state (SS) or transition state (TS) in solution chemical reaction, a new optimization method, *i.e.*, the free energy gradient (FEG) method, has been developed and were applied to obtain the hydrated structure and TS in the ionization process of ammonia molecule in aqueous solution.

I-Q-1 Hydrated Structure of Ammonia-Water Molecule Pair *via* Free Energy Gradient Method: Realization of Zero Gradient and Force Balance on Free Energy Surface

NAGAE, Yukihiro¹; OISHI, Yuki¹; NARUSE, Norihiro¹; NAGAOKA, Masataka²
(¹Nagoya Univ.; ²IMS and Nagoya Univ.)

[*J. Chem. Phys.* **119**, 7972–7978 (2003)]

The hydrated structure of ammonia molecule in aqueous solution was theoretically optimized as an ammonia-water molecule pair ($\text{H}_3\text{N}\cdots\text{H}_2\text{O}$) by the FEG method [*J. Chem. Phys.* **113**, 3516 (2000)]. The interaction between the pair and a solvent water molecule (TIP3P) [*J. Chem. Phys.* **79**, 926 (1983)] was described by a hybrid quantum mechanical and molecular mechanical (QM/MM) method combined with a semi-empirical molecular orbital (MO) method at the PM3 level of theory. It is concluded that the present FEG method works quite well in spite of a simple steepest descent optimization scheme equipped with the adaptive displacement vector. The free energy stabilization was estimated -0.3 kcal/mol from the free energy for the same structure as that of the cluster in gas phase. The optimized structure was found to be almost the same as that in the gas phase except a longer OH bond length of the water molecule. However, its realization in aqueous solution is accomplished by virtue of fulfillment of both “zero gradient” and “force balance” conditions. Finally, we discussed also the effect of microscopic “solvation entropy,” compared with the result by the conductor-like screening model (COSMO) method.

I-Q-2 Structure Optimization of Solute Molecules *via* Free Energy Gradient Method

NAGAOKA, Masataka
(IMS and Nagoya Univ.)

[*Bull. Korean Chem. Soc.* **24**, 805–808 (2004)]

Fundamental ideas of the free energy gradient method are briefly reviewed with three applications: the stable structures of glycine and ammonia-water molecule pair in aqueous solution and the transition state (TS) structure of a Menshutkin reaction $\text{NH}_3 + \text{CH}_3\text{Cl} \rightarrow \text{CH}_3\text{NH}_3^+ + \text{Cl}^-$ in aqueous solution, which is

the first example of full TS optimization of all internal degrees of freedom.

I-Q-3 Slowdown of Water Diffusion around Protein in Aqueous Solution with Ectoine

YU, Isseki¹; NAGAOKA, Masataka²
(¹Nagoya Univ.; ²IMS and Nagoya Univ.)

[*Chem. Phys. Lett.* **388**, 316–321 (2004)]

Ectoine is one of the most common compatible solutes found in halophilic bacteria, and has an effect to introduce a tolerance to high salt concentration or high temperature. By analyzing 1 ns molecular dynamics simulations at 370 K, we have shown that, in the ectoine aqueous solution, the water diffusion slows down around a protein (chymotrypsin inhibitor 2 (CI2)), keeping the protein hydration structure essentially unchanged. It is concluded that the slowdown of water diffusion around the backbone amide protons must be one of the decisive factors in reducing the exchange rate of the backbone amide protons, whose reduction is experimentally believed closely related to the tolerance effect.