

## X-ray observation of a transient hemiaminal trapped in a porous network

Takehide Kawamichi, Tsuyoshi Haneda, Masaki Kawano\*† and Makoto Fujita\*

Department of Applied Chemistry, The University of Tokyo, CREST, Japan Science and Technology Corporation (JST), Bunkyo-ku, Tokyo 113-8656, Japan

### Introduction

The simplified reaction scheme of Schiff base formation from an amine and an aldehyde involves two key steps proceeding through the intermediate tetrahedral hemiaminal. The hemiaminal intermediate is short-lived and typically observed only by spectroscopic methods using low temperature matrices. In an exceptional case, X-ray crystallographic analysis with a low resolution data revealed a hemiaminal intermediate bound by multiple hydrogen bonds in the pocket of an enzyme specifically mutated to prevent reaction completion. The hemiaminal intermediate can be stable by kinetic protection in a pore. As the networks are highly crystalline, any kinetically trapped intermediate should be directly observable by X-ray crystallography, thus providing valuable structural and mechanistic information.

### Results

The platform porous coordination network  $\{[(\text{ZnI}_2)_3(\mathbf{2})_2(\mathbf{3})] \cdot x(\mathbf{G})\}_n$  ( $\mathbf{1}$ ;  $\mathbf{G}$  = nitrobenzene,  $x = 4$ ) was prepared by slowly diffusing layers of  $\text{ZnI}_2$ , 2,4,6-tris(4-pyridyl)-1,3,5-triazine ( $\mathbf{2}$ ), and 1-aminotriphenylene ( $\mathbf{3}$ ) in nitrobenzene (Figure 1a,b). The network structure features two pores with different sizes. To enable further chemical transformations in the pores, nitrobenzene encapsulated in a pore was replaced with a non-aromatic solvent, allowing rapid diffusion of reactants. Thus crystals of  $\mathbf{1}$  were immersed in ethyl acetate for 24 h to give solvent exchanged  $\mathbf{1}$  ( $\mathbf{G}$  = ethyl acetate;  $x = \text{ca. } 4$ ). Crystallinity persisted after solvent exchange and the structure of  $\mathbf{1}$  ( $\mathbf{G}$  = ethyl acetate) was solved by X-ray crystallography.

The condensation of acetaldehyde with the amine groups of embedded  $\mathbf{3}$  was examined at low temperatures. A red single crystal of  $\mathbf{1}$  ( $\mathbf{G}$  = ethyl acetate) was mounted on a diffractometer, covered with a capillary, and cooled to 215 K. An ethyl acetate solution of acetaldehyde was continuously introduced through a capillary at 215 K for 10 min, immersing the crystal in a gentle flow of the acetaldehyde. The crystal was cooled to 90 K to freeze the reaction and diffraction data were collected. After data collection, the crystal was again warmed to 270 K and allowed to stand for 30 min to complete the condensation. The crystal slightly turned from red to yellow at 270 K. The crystal was again cooled to 90 K and the diffraction data were collected.

The X-ray crystal structure after 10 min at 215 K revealed the unstable hemiaminal intermediate along with unreacted amine. Least-square refinement successfully

converged to give yields of 34% of hemiaminal and 66% of unreacted amine. The tetrahedral,  $sp^3$  carbon of the hemiaminal was clearly observed.

The crystal structure after warming (270 K, 30 min) showed complete conversion of the hemiaminal to final imine (Figure 2). The chemical reactions in the pore were monitored by single crystal microscopic IR spectroscopy under the same conditions. The temperature dependent measurement showed excellent agreement with the X-ray results.

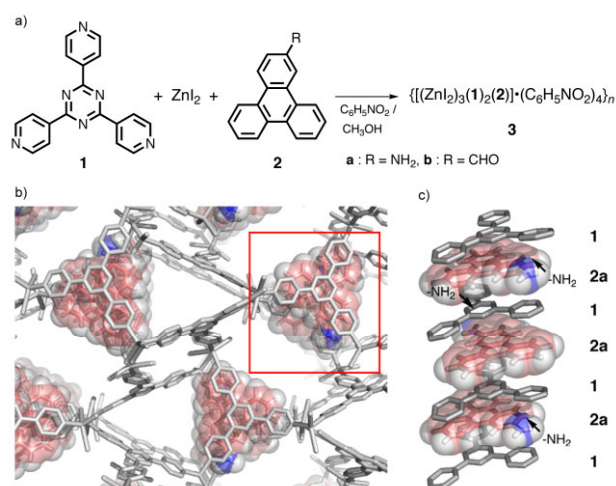


Figure 1. Porous coordination network of  $\mathbf{1}$ .

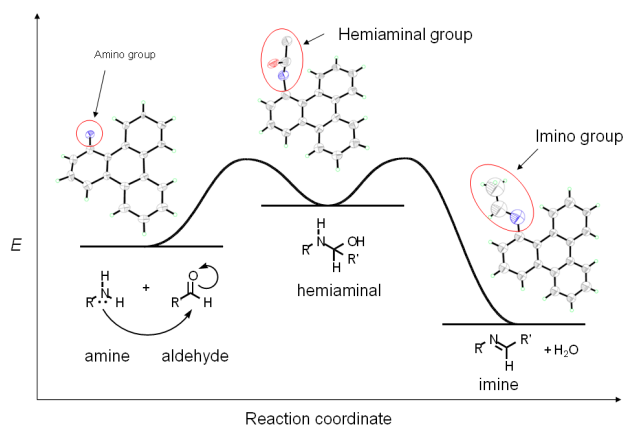


Figure 2. Hemiaminal and imine formation from condensation reaction of amine with aldehyde in a pore of  $\mathbf{1}$ .

### Reference

[1] T. Kawamichi *et al.*, *Nature*, **2009**, 461, 633-635.

\*mkawano@postech.ac.kr

† Present address: POSTECH, Pohang, Korea