

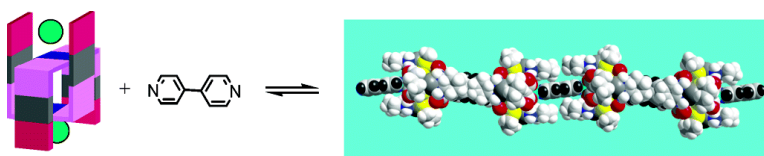
Communication

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J. Am. Chem. Soc., **2003**, 125 (24), 7170-7171 • DOI: 10.1021/ja035126l • Publication Date (Web): 21 May 2003

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A Metal-Centered Hydrophobic Pocket Recognizing Pyridine over Piperidine

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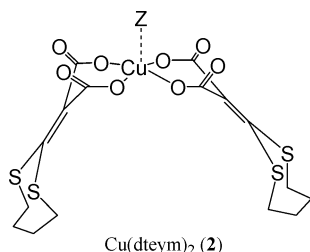
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A metal complex where the metal is settled in a hydrophobic pocket and is coordinatively unsaturated or coordinated by an easily replaceable ligand is of interest.¹ It might mimic an active site of a metalloenzyme when the metal acts as the binding site for a substrate and the hydrophobic pocket recognizes the accessing substrates. Only a very few metal complexes have been reported to have such features.^{2,3} This communication presents a preliminary report on a metal-centered hydrophobic pocket formed by a simple self-assembly working as a recognition site for pyridine, and a novel supramolecular system generated by another self-assembly method using such recognition properties.

The self-assembly of the zwitterionic complex, (dach)Pt(dteym) (where dach = *trans*-(±)-1,2-diaminocyclohexane and dteym = 1,3-dithiepane-2-ylidenemalonate),⁴ together with Cu(triflate)₂ produces a supramolecule, [[[(dach)Pt(dteym)]₂Cu]₂]⁴⁺ (**1**),⁵ whose structural features are quite similar to those⁶ of the inorganic tennis ball encapsulating a tetrafluoroborate anion reported earlier. However, the molecule **1** is different from the previously reported one⁶ in that it has an internal empty cavity because a relatively large triflate anion was used.

There are two identical external spaces in molecule **1**, as shown in Figure 1. The external space between the two (dach) groups facing each other in **1** seems to be suitable for recognizing certain types of molecules such as pyridine compounds for the following reasons. The copper(II) located at the bottom of the space serves as a coordination site for molecules with a metal-binding capability. This is because a copper ion can adopt a square pyramidal five-coordination geometry.⁷ Carbon atoms in one (dach) group are separate from the carbons in the other (dach) group in the space by approximately 8.7–9.5 Å.

When the tennis ball **1** is added respectively to methanol-*d*₄ solutions of pyridine, 2-picoline, and 3-picoline, the signals of the pyridine ring protons in their ¹H NMR spectra shift downfield and are broadened more severely as the protons are closer to the paramagnetic copper(II) ion, as shown in Figure 2. Figure 2 shows that copper(II) binds the pyridines reversibly, and of the above three molecules, it has best the binding affinity for 3-picoline and the poorest binding affinity for 2-picoline. The binding affinity constants (*K*_a) of an external space of **1** for those pyridine compounds were measured by a normal NMR titration method.⁸ The binding affinity constants (*K*_a•'s) of the axial site, Z, of [Cu(dteym)₂]²⁻ (**2**)⁹ for the



same compounds were also investigated to determine the effect of

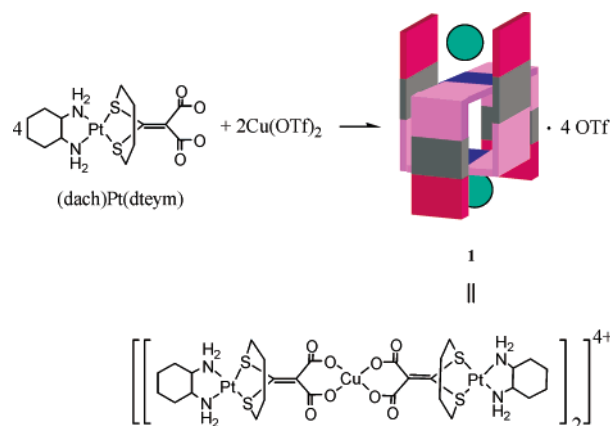


Figure 1. Self-assembly producing the supramolecule **1** with two external spaces. Red box: (dach); pink box: (dteym); blue box: copper(II) coordination plane; gray box: platinum(II) coordination plane; green circle: external space.

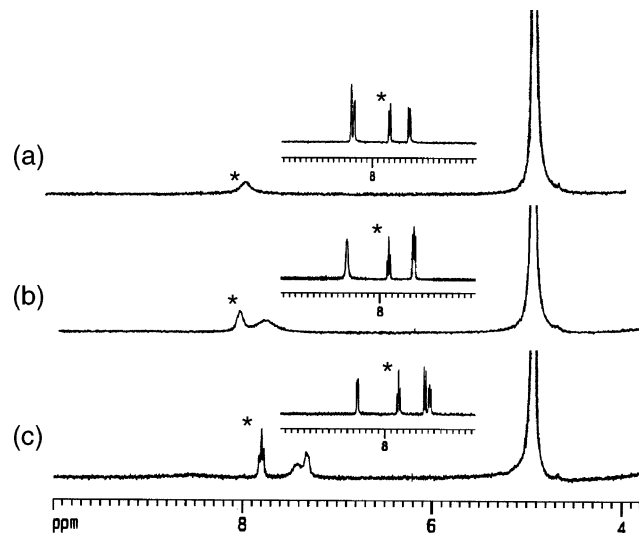





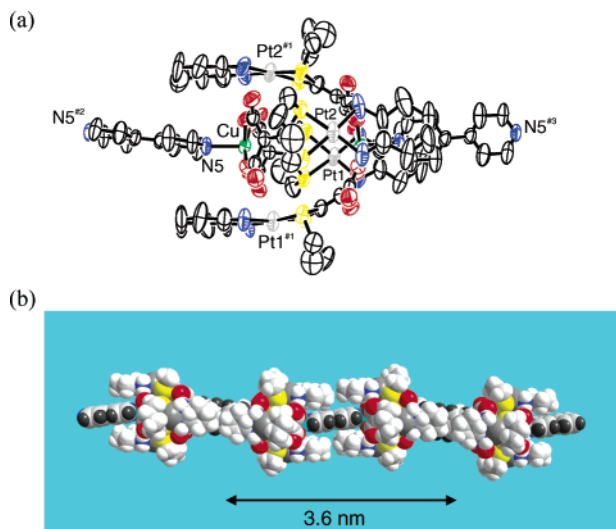
Figure 2. ¹H NMR spectra of the CD₃OD solutions containing **1** and 3-picoline (a), pyridine (b), and 2-picoline (c), respectively. ¹H NMR spectra for the corresponding free compounds are shown at the upper sites. The signals corresponding to **1** appear broadly in the range of 1–3.5 ppm and are omitted in the figure. All the concentrations of the components are equivalent to 6.13 mM. The signal marked by an asterisk corresponds to the para proton of each pyridine.

the (dach) groups on the binding affinity. The *K*_a and *K*_a• for relatively bulky piperidine were also investigated.¹⁰ All of the results are tabulated in Table 1 except for those corresponding to 2-picoline which shows low binding affinity for both **1** and **2** presumably due to steric repulsion between the methyl group and the copper coordination plane.

The *K*_a for pyridine is smaller than the corresponding *K*_a•, while the *K*_a for 3-picoline is larger than *K*_a•. The latter may be due to a

Table 1. Binding Affinity Constants of an External Space of **1** (K_a) and an Axial Site of **2** ($K_{a\bullet}$) for Some Representative Compounds

| Compounds | K_a/M^{-1} | $K_{a\bullet}/M^{-1}$ |
|---|--------------|-----------------------|
| Pyridine,  | 50 ± 9 | 94 ± 7 |
| 3-Picoline,  | 155 ± 10 | 56 ± 9 |
| Piperidine,  | <10 | 101 ± 1 |

**Figure 3.** Structures of **3**. (a) ORTEP drawing showing (bpy) bound to the external spaces of **1**. Blue: nitrogen; red: oxygen; yellow: sulfur; green: copper; gray: platinum. Symmetry code. No. 1: $-x, y, 1.5 - z$; no. 2: $-0.5 - x, 1.5 - y, -z$; no. 3: $0.5 + x, y, 0.5 + z$. The bond distance of Cu–N(5) is 2.251(10) Å. (b) Space filling diagram of its extended structure. The hydrogens attached to (bpy) are dark gray.

hydrophobic interaction between the methyl and (dach) groups. In the case of the relatively bulky piperidine, the difference between K_a and $K_{a\bullet}$ is very large compared to those of the pyridine compounds by more than an order of magnitude. This result certainly indicates that the (dach) groups play a role in recognizing the molecules approaching the space.

On the basis of the recognition properties of the tennis ball **1** for pyridine compounds, this study tried to obtain a novel supramolecule by linking the supramolecules of **1** with 4,4'-bipyridyl (bpy). Single crystals were obtained by self-assembly from a methanol solution of $1 \cdot (\text{OTf})_4$ and excess (bpy) and were revealed as $[[[(\text{dach})\text{Pt}(\text{dteym})]_2\text{Cu}(\text{bpy})_{0.5}]_2]_n$ (**3**) by X-ray crystallographic study.¹¹ Figure 3 shows the structure as an ORTEP (a) and space filling (b) drawings. The tennis balls were successfully linked by (bpy). One pyridine ring of (bpy) is immersed in the space between the two (dach) groups. The bond distance between the copper and pyridine nitrogen (Cu–N(5)) is 2.251(10) Å. The atoms of the (dach) groups are separate from the pyridine plane by approximately 3.8–4.6 Å. The distance between the two (dach) groups is somewhere between 8.5 and 8.9 Å, which is similar to that (8.7–9.5 Å) of **1**. In this space, if a bulkier piperidine is bound to the copper, then it may be imagined that steric repulsion will occur between the piperidine and the (dach) groups.

When the crystals of **3** were dissolved in methanol and recrystallized by adding ethyl ether, crystals of **1** were obtained in

significant quantities, which was certainly due to the reversible property of the Cu–(bpy) binding. Such reversible binding property may produce supramolecules of various sizes in solution. If one (bpy) links two tennis balls, then its size becomes 3.6 nm long, and if two (bpy)s link three tennis balls, then its size increases to 5.4 nm. Another interesting aspect of the supramolecule **3** is that the hydrophobic (dach) groups cover the linking unit (bpy). Such coverings may alter rigidity and electronic properties of (bpy) which is used in many supramolecular architectures as a linking unit.¹²

In conclusion, this study has shown the reversible recognition properties of the external space of **1** where two (dach) groups stand perpendicularly to and around the metal coordination plane. Such a metal-centered hydrophobic pocket was not known in the molecular recognition study before. The method establishing a hydrophobic pocket as shown in the preparation of **1** may be exploited in the construction of new receptors with various recognition properties. This study also showed that a novel supramolecular system is generated via a double self-assembly using the pyridine recognition property.

Acknowledgment. This work was financially supported by KIST and by a basic research program of the Korea Science and Engineering Foundation (R03-2000-0000-0008-02).

Supporting Information Available: Details of X-ray data of **1** and **3** in CIF format. This material is available free of charge via the Internet at <http://pubs.acs.org>.

References

- (1) Recent reviews concerning this topic: (a) Rizzarelli, E.; Vecchio, G. *Coord. Chem. Rev.* **1999**, *188*, 343–364. (b) Linton, B.; Hamilton, A. D. *Chem. Rev.* **1997**, *97*, 1669–1680; Sanders, J. K. M. *Chem. Eur. J.* **1998**, *4*, 1378–1383. (c) Feiters, M. C. *Supramolecular Catalysis*. In *Comprehensive Supramolecular Chemistry*; Reinhoudt, D. N., Ed.; Pergamon: New York, 1996; Vol. 10, pp 267–360. (d) Murakami, Y.; Kikuchi, J.-I.; Hisaeda, Y.; Hayashida, O. *Chem. Rev.* **1996**, *96*, 721–758. (e) Feiters, M. C.; Klein Gebbink, R. J. M.; Schenning, A. P. H. J.; van Strijdonck, G. P. F.; Martens, C. F.; Nolte, R. J. M. *Pure Appl. Chem.* **1996**, *68*, 2163–2170.
- (2) (a) Breslow, R.; Zhang, X.; Huang, Y. *J. Am. Chem. Soc.* **1997**, *119*, 4535–4536. (b) Rybak-Akimova, E. V.; Kuczera, K.; Jas, G. S.; Deng, Y.; Busch, D. H. *Inorg. Chem.* **1999**, *38*, 3423–3434. (c) Elemans, J. A. A. W.; Claase, M. B.; Aarts, P. P. M.; Rowan, A. E.; Schenning, A. P. H. J.; Nolte, R. J. M. *J. Org. Chem.* **1999**, *64*, 7009–7013. (d) French, R. R.; Holzer, P.; Leuenberger, M. G.; Woggon, W.-D. *Angew. Chem., Int. Ed.* **2000**, *39*, 1267–1269.
- (3) Calix[6]arene-based metal complexes: Rondelez, Y.; Rager, M.-N.; Duprat, A.; Reinaud, O. *J. Am. Chem. Soc.* **2002**, *124*, 1334–1340 and references therein.
- (4) Sohn, Y. S.; Kim, K. M.; Kang, S.-J.; Jung, O.-S. *Inorg. Chem.* **1996**, *35*, 4274–4276.
- (5) The crystallographic data for **1** is given as Supporting Information.
- (6) Kim, K. M.; Park, J. S.; Kim, Y.-S.; Jun, Y. J.; Kang, T. Y.; Sohn, Y. S.; Jun, M.-J. *Angew. Chem., Int. Ed.* **2001**, *40*, 2458–2460.
- (7) Kokot, E.; Martin, R. L. *Inorg. Chem.* **1964**, *3*, 1306–1312.
- (8) Creswell, C. J.; Allred, A. L. *J. Phys. Chem.* **1962**, *66*, 1469–1472.
- (9) Park, J. S.; Youm, K.-T.; Jun, M.-J. *Polyhedron* **2002**, *21*, 1273–1278.
- (10) The shift and broadening of the signals of piperidine are only slight even in the presence of 2–3 times excess of **1**, while they are dramatic in the presence of even 0.25 equiv of **2**. K_a for piperidine could not be quantified and was assumed to be less than $10 M^{-1}$. $K_{a\bullet}$ for piperidine was calculated on the basis of the shifts of the resonances of the methylene protons in **2**.
- (11) All the X-ray data were collected on an Enraf-Nonius CAD4 system equipped with a Mo X-ray tube at the ambient temperature. Crystal data of **3**: *monoclinic*, *C2/c* (No.15), $Z = 4$, $a = 34.419(9)$ Å, $b = 15.989(3)$ Å, and $c = 26.712(4)$ Å, $\beta = 108.475(18)^\circ$, $V = 13942(5)$ Å³, $\mu = 4.551$ mm⁻¹, $d_{\text{calc}} = 1.486$ g/cm³, $R1 = 7.86$, $wR2 = 17.2\%$ for 12201 unique reflections, 681 variables, and 184 restraints. The structure solution and refinement of the data were handled using the SHELXS-86 and SHELXL-97 programs.
- (12) (a) Schwab, P. F. H.; Levin, M. D.; Michi, J. *Chem. Rev.* **1999**, *99*, 1863–1933. (b) Leininger, S.; Olenyuk, B.; Stang, P. J. *Chem. Rev.* **2000**, *100*, 853–908. (c) Yaghi, O. M.; Li, H.; Groy, T. L. *Inorg. Chem.* **1997**, *36*, 4292–4293. (d) Fujita, M.; Kwon, Y.; Washizu, S.; Ogura, K. *J. Am. Chem. Soc.* **1994**, *116*, 1151–1152.

JA035126L