Integrative Self-Sorting: Towards High Level Self-Assembly

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I. Introduction

Background: Most of synthetic self-assembled architectures repetitively use *ever the same* building blocks thus severely restricting the implementation of functions. Complexity is achieved more in the sense that large assemblies are built from multiple identical building blocks. However, different components are needed to cooperate with each other for the achievements of complex functions.

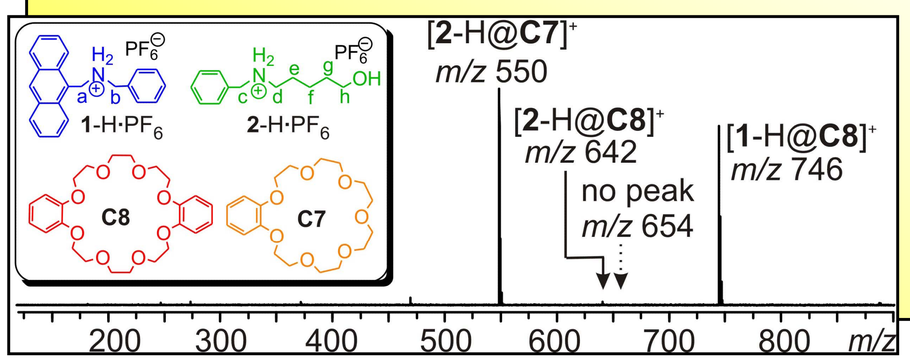
Question: How can we incorporate many *different* building blocks into one assembly with precies positional control to create a higher level of complexity and thus functions?

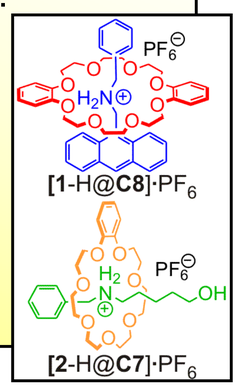
Possible Solution: Nature's functional assemblies, such as DNA and ATP synthase, are often constructed by integrating many different building blocks via self-assembly together with self-sorting to obtain not only the structural complexity but also the resulting functions through the cooperation among their subunits. We very recently coined this strategy, integrative self-sorting [1,2], and are convinced that it will not only enrich the world of supramolecular architectures from the point of view of structural variability but will also form the basis for the implementation of high-level functions in future assemblies.

II. Self-Sorting

Self-sorting has been used to describe the property that only one or a few complexes out of a larger number of potentially possible assemblies are formed in a mixture of the components.

A four-component self-sorting system consisting of C7, C8, 1-H·PF_6, and 2-H·PF_6 has been constructed. In their equimolar mixture, only two pseudorotaxanes out of four possible ones are predominant, which was proved by ESI-FTICR-MS and ^{1}H NMR experiments.





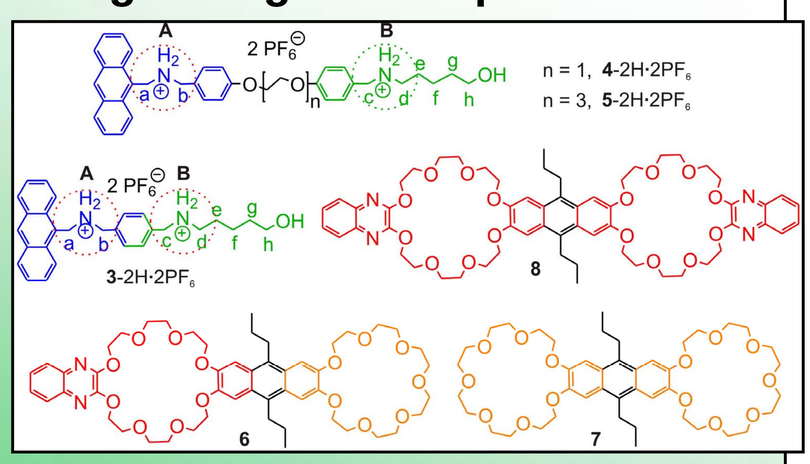
III. Integrative Self-Sorting: Design Concept

Characteristics of *integrative self-sorting* can be summarized as follows:

(a) Only one complex, in which more than two *different* subunits are bound in two or more recognition events with positional control, is formed in a multi-component mixture.

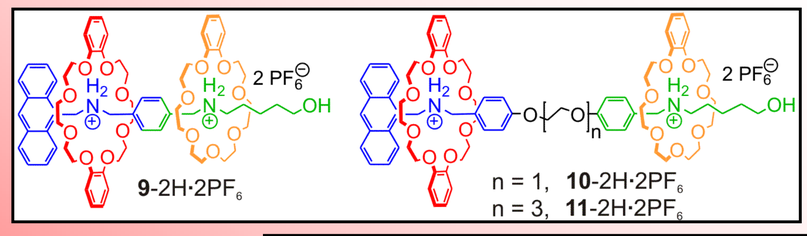
(b) As a prerequisite, more than one binding site must be integrated in at least one of the components

(c) This strategy ensures programmability and correct positioning of all distinct subunits in the final complex



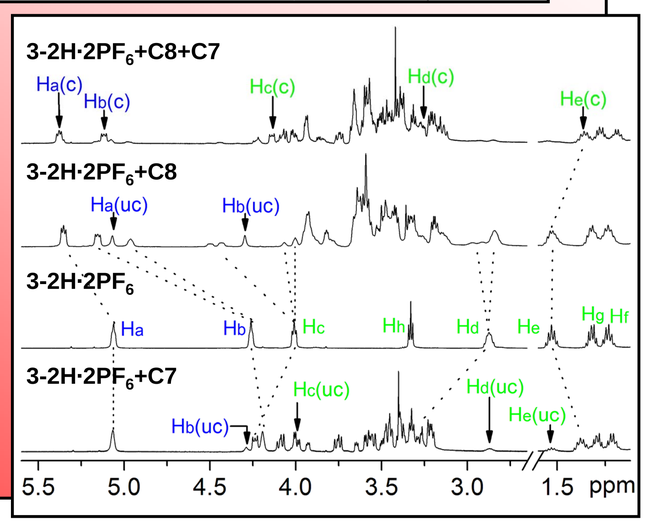
The design of appropriate *integrative components*, which bring all the other subunits into one final complex with positional control, is the key for constructing integrative self-sorting complex. Many different options for the construction of integrative components arise: (i) We can connect the 2 guests ''linearly''. (ii) The 2 crown ether hosts can be incorporated into dimers and—if connected through the anthracene core chosen here—are coplanar with each other. (iii) One of the 2 guests can be cross-connected with the other host. (iv) Several reasonable combinations and repetitions of the first 3 strategies can be realized.

IV. Merging 2 Monotopic Axles into Ditopic Ones

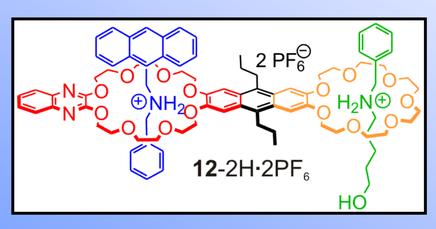


Merging 1-H·PF_6 and 2-H·PF_6 into the sequential divalent guests allow the overwhelming self-assemby of hetero[3]-pseudorotaxanes from the equimolar mixture of the corresponding guest with C8 and C7.

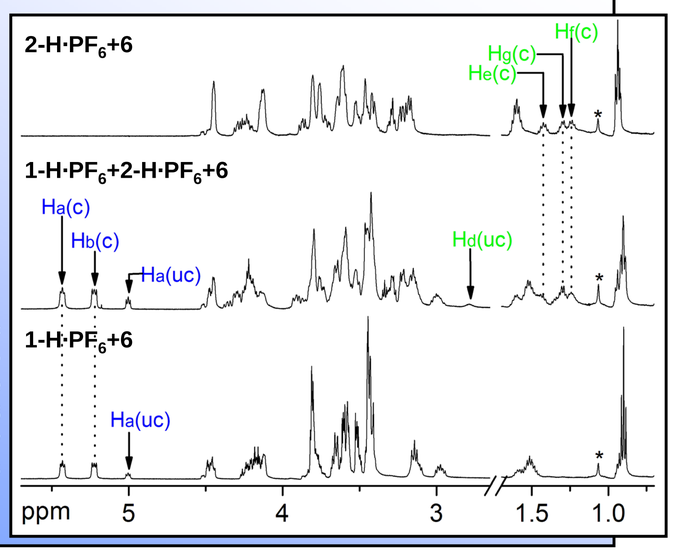
The sequential structures of hetero[3]pseudorotaxanes were confirmed by both ESI-MS and ^{1}H NMR experiments, and especially by tandem MS experiments. The sequential loss of C7, HPF_6 and then C8 with increasing the laser intensity in IRMPD experiments is perfectly in line with the sequential structures of C7 and C8 on the axle in the [3]pseudorotaxanes .



V. Meging 2 Monotopic Wheels into a Heteroditopic one



Merging C7 and C8 affords a heteroditopic host 6 which could self-assemby with 1-H·PF_6 and 2-H·PF_6 into 12-2H·$2PF_6$. The structure of 12-2H·$2PF_6$ with blue axle in C8 and green axle in C7 was thoroughly characterized by ^{1}H NMR and Tandem Mass spectrometry

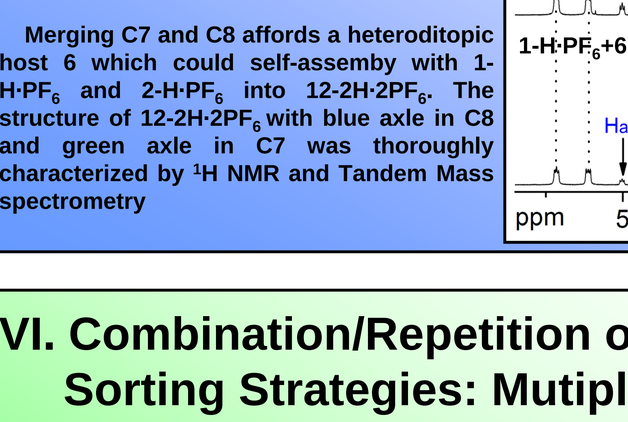


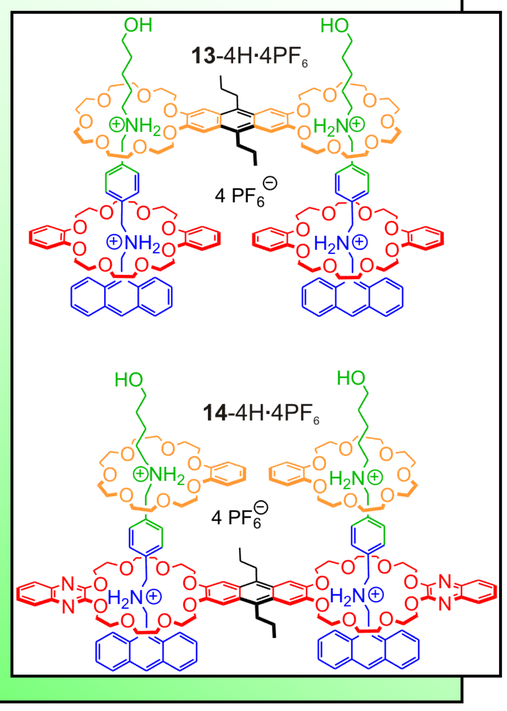
VI. Combination/Repetition of Integrative Self-Sorting Strategies: Mutiple Pseudorotaxanes

Combining integrative self-sorting with other self-assembly strategies could lead to more complex topological structures.

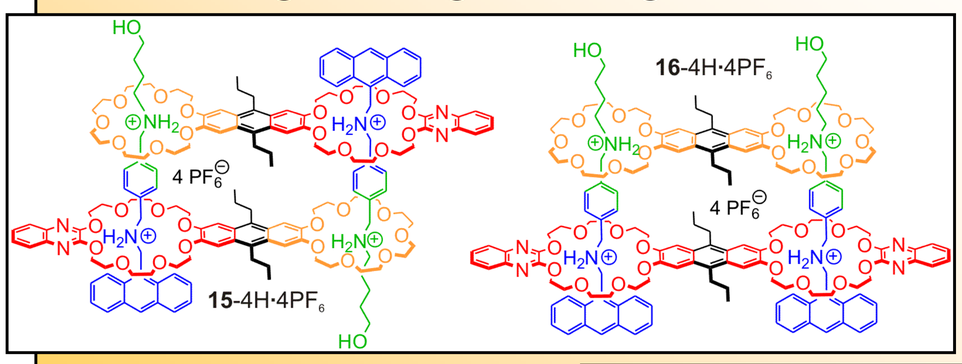
Symmetrical homomultivalent compounds, which are often used to assemble symmetrical structures, can further improve the complexity of integrative self-sorting assemblies, such as in 13-4H·$4PF_6$ and 14-4H·$4PF_6$.

However, parallel and antiparallel isomers coexist in these systems due to one-point connection between all subunits.





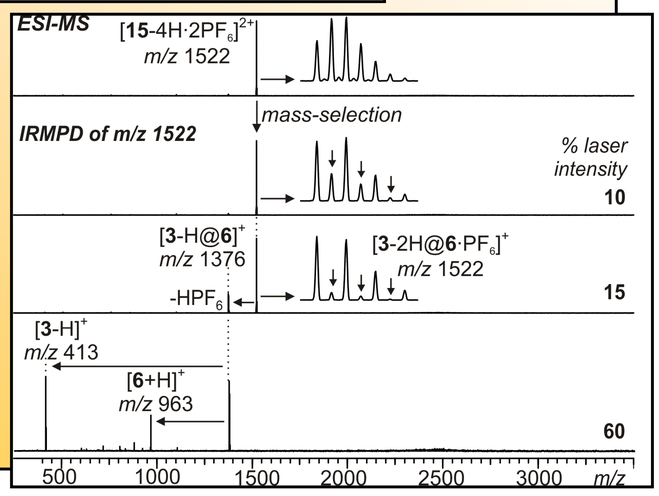
VII. Combination/Repetition of Integrative Self-Sorting Strategies: Allignment of the Axles



To achieve full control over the allignments of the axles relative to each other, two-point connection between all subunits is required.

The structures of 15-4H·$4PF_6$ and 16-4H·$4PF_6$ can be unambiguously proved by tandem MS experiments. For example, [15-4H·$2PF_6$]$^{2+}$ dissociates into two identical halves, suggesting its highly symmetrical structures.

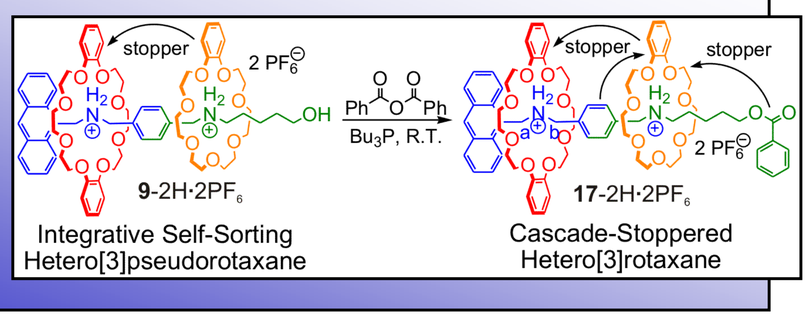
To further confirm the closed structures, 15-4H·$4PF_6$ and 16-4H·$4PF_6$ are mixed with 2 equiv. 9-4H·$4PF_6$. Self-sorting between 9-4H·$4PF_6$ and them is observed from ESI-MS experiments, providing evidences for them to be closed structrues. Otherwise, the free binding sites in 15-4H·$4PF_6$ or 16-4H·$4PF_6$ could interfere with 9-4H·$4PF_6$.



VIII. A Cascade-Stoppered Hetero[3]Rotaxane

The reversibly self-assembled complexes by using integrative self-sorting can be further frozen into interlocked structures through attaching suitable stoppers.

In 17-2H·$2PF_6$, the phenyl groups trap C7, and then C7 and anthracenyl group trap C8, which could be considered as a "stopper cascade"



Reference:

[1] W. Jiang, H. D. F. Winkler, C. A. Schalley, *J. Am. Chem. Soc.* **2008**, *130*, 13852-13853.
[2] W. Jiang, C. A. Schalley, *Proc. Natl. Acad. Sci. USA*, **2009**, DOI:10.1073/pnas.0809512106.

Acknowledgement. We thank Henrik D. F. Winkler and Dr. Andreas Springer for help with the ESI-FTICR experiments. This work was supported by Deutsche Forschungsgemeinschaft (SFB 765 "multivalency"). C.A.S. acknowledges the Fonds der Chemischen Industrie for a Dozentenstipendium and the DFG and FCI for financial support.