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Self-assembly of a new series of quadruply hydrogen bonded heterotrimers driven by the donor–acceptor interaction

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Abstract—This paper describes the self-assembly of a new series of heterotrimers in chloroform-*d* by utilizing the cooperative interaction of hydrogen bonding and donor–acceptor interaction. Compounds **1** and **11**, in which an 2-ureido-4[1*H*]-pyrimidinone unit is connected to 34-crown-10 or 36-crown-10, were used as donor monomer, and **2** and **19**, in which an 2-ureido-4[1*H*]-pyrimidinone unit is connected to NDI, were used as acceptor monomer, while linear compound **4**, which contains two diamido-1,8-naphthyridines, was used as template. A large tri-*p*-(*t*-butyl)phenylmethoxyl group was introduced to **19** in order to compare its assembling behavior with that of **2**. Mixing **4** with dimer **1**·**2** caused **1**·**2** to fully decompose and to afford 55% of 'in–in'-oriented heterotrimer **1**·**4**·**2**. Adding **4** to the solution of **2**·**11** or **11**·**19** in chloroform-*d* also led to full dissociation of the dimers. However, in these systems the 'in–in'-arranged heterotrimer **2**·**4**·**11** or **11**·**4**·**19** could be produced exclusively.

1. Introduction

Cooperative interaction of different non-covalent forces play a critical role in the formation of biological structures and functions.[1] For example, the DNA double helixes are stabilized mainly by intermolecular hydrogen bonds between the complementary bases and stacking interactions between adjacent base pairs, whereas the secondary and tertiary structures of proteins are generated as a result of the cooperative behavior of specifically located hydrogen bonds, hydrophobic interaction, and Van der Waals force. One of the challenges in supramoleulcar chemistry is the construction of new molecular assemblies with defined structures or functions in a strong, selective, and directional way.[2] In the past decade, a large number of artificial supramolecular architecture have been constructed based on single non-covalent force including transition metal–ligand interaction,[3] hydrophobic interaction,[4] hydrogen bonding,[5] and electrostatic interaction.[6] In principle, the combination of two or more different non-covalent interactions may also function well or even more efficiently in constructing new supramolecular species. Nevertheless, only recently have examples of supramolecular assemblies of this kind been reported.[7]

Due to their remarkable stability and directionality, the self-complimentary 2-ureido-4[1*H*]-pyrimidinone-based quadruply hydrogen bonded AADD (A, hydrogen bonding acceptor; D, hydrogen bonding donor) homodimers have recently found extensive applications in self-assembly of discrete supramolecular systems.[8–10] Previously, we had reported that AADD-featured homodimers of **1** and **2** could dissociate to generate more stable quadruply hydrogen bonded heterodimer **1**·**2**,[11,12] as a result of the additional intermolecular donor–acceptor interaction between the electron-rich bis(*p*-phenylene)-34-crown-10 moiety of **1** and the electron-deficient naphthalene diimide (NDI) of **2**.[13] Moreover, the addition of **3** to the solution of **1**·**2** in chloroform-*d* led to the formation of heterodimers **1**·**3** and **2**·**3**, both of which possess a new ADDA–DAAD binding motif.[11a] The formation of the hydrogen bonded heterodimers from hydrogen bonded homodimers driven by additional donor–acceptor interaction represents a new and useful assembling strategy. In this paper we report that linear compounds incorporating two diamido-1,8-naphthyridine moieties have been successfully utilized to

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Keywords: Hydrogen bonding; Donor–acceptor interaction; Self-assembly; Heterocycle; Supramolecular chemistry.

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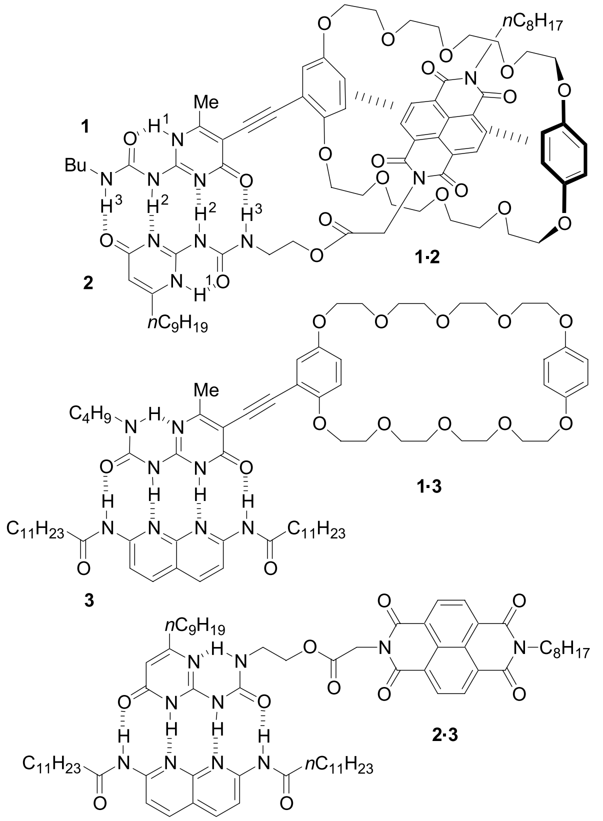
template the selective self-assembly of a new series of hydrogen bonded heterotrimers whose structures are regulated by additional donor–acceptor interaction.[14]



1·2

1·3

2·3

2. Results and discussion

Previous investigation has revealed that ADDA–DAAD-typed heterodimers such as **1**·**3** and **2**·**3** are remarkably more stable than the corresponding AADD–DDAA homodimers.[11a] In principle, linear molecules (A, Fig. 1) incorporating two 2,7-diamido-1,8-naphthyridine moieties connected by a flexible linker of proper length might also induce the dissociation of heterodimers of monomers B and C to generate a new generation of heterotrimers (Fig. 1). To explore this possibility, compound **4** was prepared. The four *n*-octyl groups were expected to provide solubility in common organic solvents. Molecular modeling for a system of **1**, **2**, and **4** revealed that the length of the linker between the two binding moieties of **4** is suitable for the formation of a potential heterotrimer **1**·**4**·**2**.

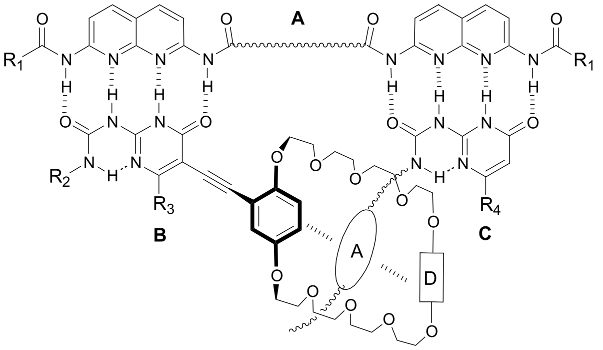
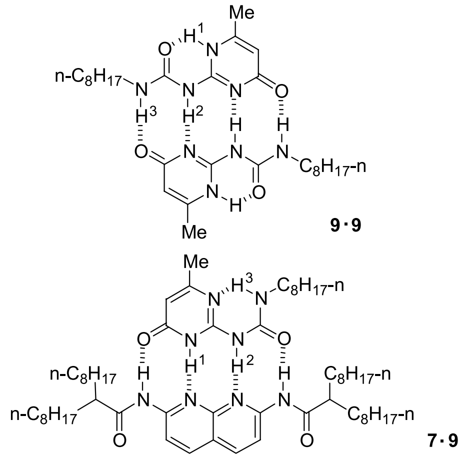
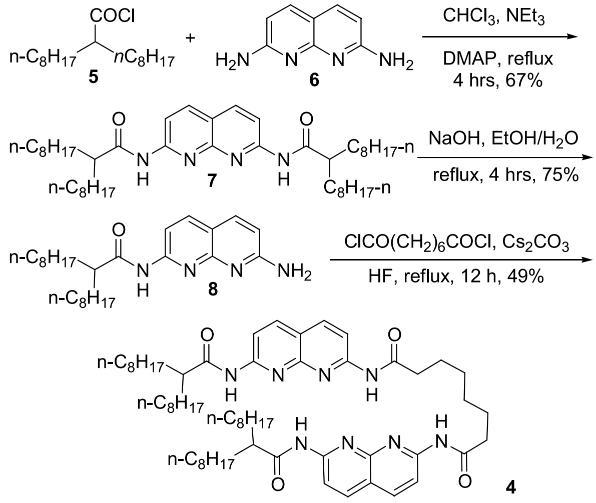


Figure 1. The underlying assembling strategy for the new generation of heterotrimers driven by cooperative hydrogen bonding and donor–acceptor interactions.

The synthetic route for **4** is shown in Scheme 1. Thus, diamide **7** was first produced from the reaction of **5** and **6** and then hydrolyzed with sodium hydroxide to yield **8**.[15] Subsequent treatment of **8** with suberoyl chloride in refluxed THF produced **4**, which is of good solubility in organic solvents such as chloroform and dichloromethane.





Scheme 1.

Prior to binding studies with **4**, the ability of **7** to induce the dissociation of homodimer **9**·**9** in chloroform-*d* were investigated by ^{1}H NMR spectroscopy.[16,17] Adding 1 equiv of **7** to the solution of **9** in chloroform-*d* induced the homodimer of the latter to fully dissociate and to afford heterodimer **7**·**9** exclusively (Fig. 2). The structure of **7**·**9** has been characterized by using the methods for the characterization of other similar heterodimers.[11a]

The binding behaviors of **4** with homodimers **1**·**1** and **2**·**2** were then investigated. As revealed by Figure 3b and d, adding 1 equiv of **4** to the solution of **1** or **2** in $CDCl_3$ also led to complete dissociation of the latter's homodimer due to the formation of new heterotrimers $\mathbf{1}_2\cdot\mathbf{4}$ and $\mathbf{2}_2\cdot\mathbf{4}$, respectively. In principle, the two molecules of **1** or **2** in the