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| First Name | |
| Legi-No. | |
| Program of Study | |

# Written Exam
# Supramolecular Chemistry
# Summer 2013


## F. Diederich, Y. Yamakoshi


**Please check:**
This exam paper includes 4 printed pages (4 questions) in addition to the cover.

**Please note:**

- All problems have to be solved.
- Unreadable texts or drawings will not yield any points.
- If you use additional sheets, make sure to mark them with your name and to attach them to this paper.

**Points**

| | |
|---|---|
| Problem 1 | |
| Problem 2 | |
| Problem 3 | |
| Problem 4 | |
| | |
| **Total** | |

**Grades**

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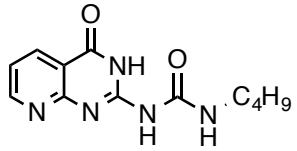
|---|---|
| Written | |
| Oral | |
| **Final** | |

**Problem 1** (15 points). Quadruple hydrogen-bonding arrays.

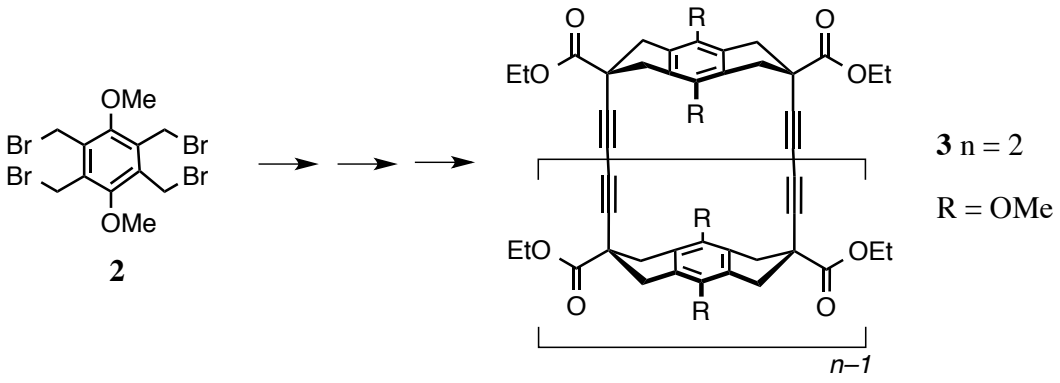



**1**

Compound **1** forms in $CDCl_3$ solution three very stable dimers ($K_{dimer} > 10^7$ $M^{-1}$ in $CDCl_3$) by association of **1** and a second, different tautomer. Each tautomer forms a DDAA···AADD homodimer (D = H-bond donor, A = H-bond acceptor), and the two tautomers form a DDAA···AADD heterodimer. A small amount of a less stable DADA···ADAD homodimer is also present, formed from a third tautomeric form of **1**.

a) Suggest structures for the two additional tautomeric forms of **1** capable of quadruple hydrogen bonding. (2 pts)
b) Suggest the structures of the four dimers. (8 pts)
c) Explain, why three dimers are much more stable than the fourth one. (1 pt)
d) List the rules which determine the stability of H-bonds and hydrogen bonding arrays. (2 pts)
e) By which method could the presence of the four, kinetically stable dimers be studied in solution? (1 pt)
f) Where do strong quadruple hydrogen bonding arrays find application? (1 pt)
(*J. Am. Chem. Soc.* **1998**, *120*, 9710).

**Problem 2** (10 points). Acetylenic Macrocycles

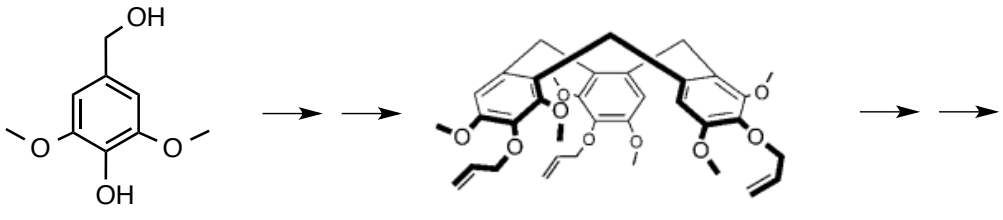



a) Propose the stepwise synthesis of the dimeric macrocycle **3**, starting from **2**. Propose reagents and detailed reaction conditions for each step. (8 pts)

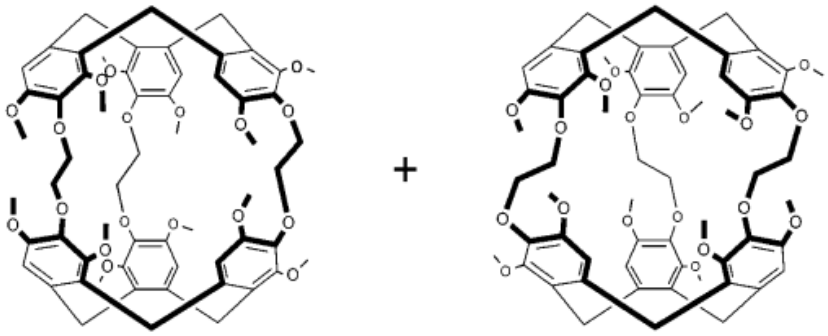
b) Compound **3** is a "shape-persistent" macrocycle as revealed by several X-ray crystal structures of derivatives. What does "shape-persistent" mean? (1 pt)

c) In addition to the dimer **3**, a "preorganized" macrocyclic trimer (not shown) is obtained with a cavity large enough to include organic solutes. What does "preorganized" mean? (1 pt)
(*Chem. Eur. J.* **2013**, *19*, 4513-4524)

**Problem 3** (15 points). Macrocyclic Receptors




**4** **5**



**6** **7**

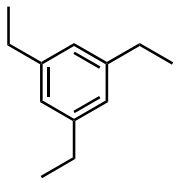
a) Propose the stepwise synthesis of the cryptophane macrocycles **6** and **7**, starting from **4** and passing via cyclotriveratrylene (CTV) **5**. Propose reagents and detailed reaction conditions for each step. Note that the allyl group is simply used as a protecting group and not for any subsequent RCM. Please also note that one CTV has to act as "templating" scaffold for the construction of the second CTV moiety in **6** and **7**; simple bridging of two deprotected moieties of **5** was not successful. (11 pts)

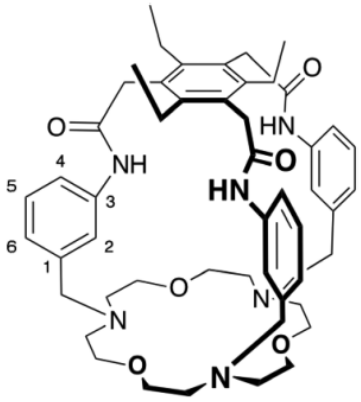
b) What are the symmetries (point groups) of **6** and **7**? Please draw conclusions about chirality. (2 pts)

c) What guests can be included into the cavities of **6** and **7** and how is inclusion complexation demonstrated in solution study? (2 pts)
(*J. Org. Chem.* **2013**, *78*, 6143-6153)

**Problem 4** (20 points). Macrocyclic Receptors II

4,10,16-triaza-18-crown-6 ⟶ ⟶





**8**

a) Propose the synthesis of macrocycle **8** starting from the triazacrown ether and triethylbenzene (which needs to be further modified to provide the hexasubstituted benzene in the cap of the receptor). Suggest reagents and conditions for year step. (10 pts)

b) In DMSO-$d_6$, various anions are bound by **8**, such as $NO_3^-$ ($K_a$ = 280 $M^{-1}$). Which counterion in the added nitrate salt is suitable to evaluate pure anion binding by **8**? (1 pt) Propose how the nitrate anion binds. (1 pt)

c) When 1 equivalent of alkali metal ions of $NH_4^+$ is added, the binding of nitrate by **8** is strenghtened and in the presence of $NH_4^+PF_6^-$, $K_a$ = 1050 $M^{-1}$ is measured. Suggest why the binding becomes strenghtened and propose a binding mode. Which species is now recognized by **8**? (4 pts)

d) Binding investigations involved extensive $^1H$ NMR studies at fast host-guest exchange kinetics. Which characteristic signal is specifically monitored to monitor the anion binding? (1 pt)

e) Show in one diagram the binding titration curves recorded for (a) the complexation of nitrate alone and (b) in the presence of $NH_4^+PF_6^-$. Please label abscissa and ordinate and propose a suitable concentration range. Briefly describe the titration experiment. (3 pts)
(*J. Org. Chem.* **2013**, *78*, 4341-4347)