



Structure Dependent Yield of the Cyclization of Outside-Templated Bisacetylenes: Catenation or Oligomerization ?

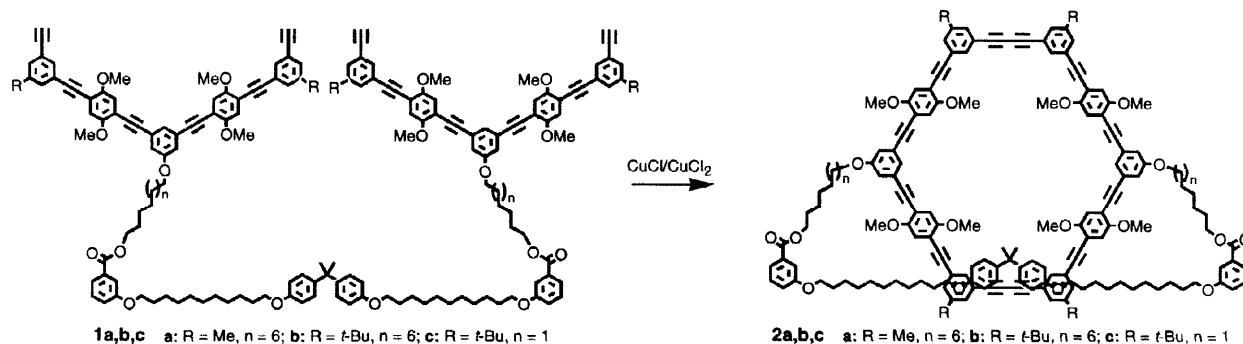
Sigurd Höger,* and Anne-Désirée Meckenstock

Max-Planck-Institut für Polymerforschung, Ackermannweg 10, D-55128 Mainz, Germany

Received 25 November 1997; accepted 30 December 1997

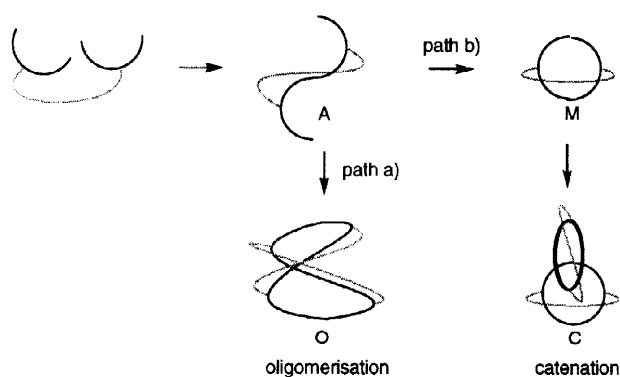
Abstract: Cyclization experiments of the templated bisacetylenes **1a**, **1b** and **1c** have demonstrated that the appearance of higher oligomers was not due to a catenation process, but rather due to the restricted mobility of the intermediate after the first Glaser coupling. It is demonstrated that the geometrical restrictions of the template prevent a fast intramolecular cyclization. © 1998 Elsevier Science Ltd. All rights reserved.

The template directed synthesis of cyclic structures is a well known procedure to improve moderate yield and to simplify the product purification.¹ Although early work of the formation of templates started several decades ago, and has been extensively used in both organic and inorganic chemistry, their use in the synthesis of nanometer scale molecular objects is rather limited.² Recently, we reported that the copper catalysed template directed cyclotrimerization of three rigid bisacetylenes in pyridine yields more than 95 % of the desired product, nearly independent of the template length.³ However, the cyclodimerization of two templated bisacetylenes under the same conditions resulted in a yield of only 86–88 %. This lower than expected yield can be attributed to the template attached to the outside of the final ring (scheme 1), although, the exact reason for the modified yield remained unknown.



Scheme 1

Herein we propose two possible pathways for the formation of the higher oligomers and evaluate their contribution to this process. Based on the assumption that the cyclization of the two bisacetylenes is a stepwise process (scheme 2), the formation of the macrocycle (path b) occurs via the intermediate "A". However, steric restrictions, due to the template, may slow down the intramolecular cyclization and therefore enlarge the concentration of A in the reaction mixture allowing it to oligomerize to "O" via another molecule of A and/or additional starting material (path a) (only the dimer of A is shown). Using this proposed scheme, any change in the length of the spacer should affect the yield of the cyclic dimer "M" (path a). On the other hand, solvophobic interactions may induce a catenation of M by A, or by starting material. In this case, any change in the volume of the torus of the rings should affect the product distribution.



Scheme 2

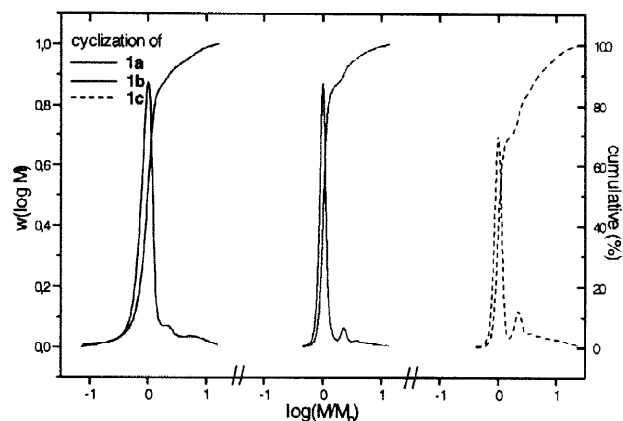


Figure 1

The oxidative coupling of the template bound tetraacetylenes **1a-c** was performed in pyridine via the addition of a solution of the starting materials to a suspension of $\text{CuCl}/\text{CuCl}_2$ over a period of 96 hours.⁴ Figure 1 shows the product distribution of the crude products of the reaction as determined by gel permeation chromatography (GPC).⁵ Comparison of the crude products of **1a** ($R = \text{Me}$; $n = 6$) and **1b** ($R = t\text{-Bu}$; $n = 6$) clearly shows that the size of the torus of the macrocycles has, within the experimental error, only a negligible influence on the product distribution. On the other hand, if the length of the template is changed, as the comparison of the GPC diagrams of **1b** ($R = t\text{-Bu}$; $n = 6$) and **1c** ($R = t\text{-Bu}$; $n = 1$) illustrates, the yield of the cyclic dimer drops from 86–88 % to about 70 %. This clearly indicates that *catenation is not* the predominant process which is responsible for a non quantitative yield of **M** in these reactions. It is more likely, assuming a stepwise cyclization, that the intramolecular Glaser coupling of the intermediate **A** is slowed down as the length of the template is reduced. It is interesting to note, that we have here the first indications that the cyclizations of these templated acetylenes behave analogous to the formation of low molecular weight ansa hydroquinone polymethylene ethers.⁶ The shape of the product profile of these structures, with dimensions in the nanometer region, is therefore caused by the direction of the attachment of the bisacetylene to the template *as well as* the size of the template. Further investigations concerning the template length should demonstrate if this effect tends to vanish when the length of the spacer is increased.

References and Notes

- 1) For recent articles dealing with template reactions see: a) S. Anderson, H.L. Anderson, J.K.M. Sanders, *Acc.Chem. Res.*, **26**, 469, (1993). b) R. Hoss, F. Vögtle, *Angew. Chem. Int. Ed. Engl.*, **33**, 375 (1994); c) B. Dietrich, P. Viout, J.-M. Lehn, *Macrocyclic Chemistry*, VCH, Weinheim, **1993**. Chap. 3.3.
- 2) D.W.J. McCallien, J.K.M. Sanders, *J. Am. Chem. Soc.*, **117**, 6611 (1995).
- 3) S. Höger, A.-D. Meckenstock, H. Pellen, *J. Org. Chem.*, **62**, 4556 (1997).
- 4) D. O'Krongly, S. R. Denmad, M. Y. Chiang, R. Breslow, *J. Am. Chem. Soc.*, **107**, 5544 (1985).
- 5) The GPC diagrams were measured in THF (flow rate 1 ml min^{-1}) at room temperature, using a combination of three styragel columns (porosity 10^3 , 10^5 , and 10^6 \AA) and an UV detector operating at $\lambda = 254 \text{ nm}$. Molecular weights M are given relative to the peak molecular weight M_p . Selected spectroscopic data for **1c**: $^1\text{H-NMR}$ (CD_2Cl_2): 7.62–7.49 (m, 16 H), 7.36–7.30 (m, 4 H), 7.12–7.05 (m, 18 H), 6.77 and 6.74 (part of a AA'BB' pattern, 2 H each), 4.31 (t, $J = 6.60 \text{ Hz}$, 4 H), 4.03 (t, $J = 6.46 \text{ Hz}$, 4 H), 3.99 (t, $J = 6.46 \text{ Hz}$, 4 H), 3.90 (s, 24 H), 3.89 (t, $J = 6.21 \text{ Hz}$, 4 H), 3.15 (s, 4 H), 1.91–1.65 (m, 16 H), 1.60 (s, 6 H), 1.52–1.26 (m, 32 H), 1.24 (s, 36 H). Compounds **2a-c** were not separated from the oligomers. After base catalysed hydrolysis of the crude products the macrocyclic diols **3a-c** were purified by repeated extraction with ethyl acetate and ethyl acetate/toluene. Selected spectroscopic data for **3c**: $^1\text{H-NMR}$ (THF-d_6): 7.63–7.61 (m, 4 H), 7.60–7.58 (m, 4 H), 7.57–7.55 (m, 4 H), 7.29–7.27 (m, 2 H), 7.14 (s, 4 H), 7.13 (s, 4 H), 7.07–7.05 (m, 4 H), 4.04 (t, $J = 6.49 \text{ Hz}$, 4 H), 3.89 (s, 24 H), 3.51 (t, $J = 6.11 \text{ Hz}$, 4 H), 3.37 (s, 2 H, OH), 1.90–1.75 (m, 4 H), 1.60–1.40 (m, 12 H), 1.36 (s, 36 H).
- 6) G. Illuminati, L. Mandolini, *Acc. Chem. Res.*, **14**, 95, (1981).