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# Anthracene Capped Isobenzofuran: A Synthon for the Preparations of Iptycenes and Iptycene Quinones

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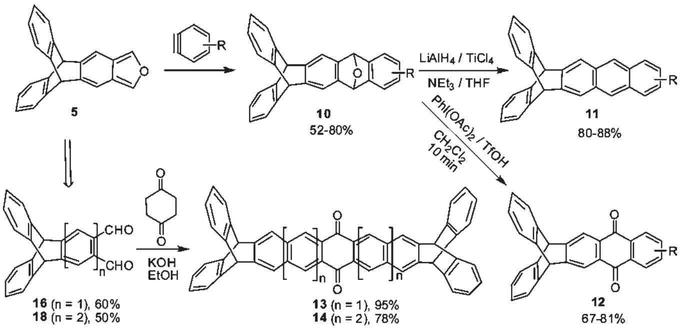
## ABSTRACT



**Anthracene capped isobenzofuran 5 (5,6-(9,10-dihydroanthracen-9,10-yl)isobenzofuran) was synthesized for the first time. It is a highly reactive and versatile synthon for the synthesis of iptycene derivatives *via* Diels–Alder reactions. Cycloadducts 10 could be readily deoxygenated to iptycenes 11. Two new reactions of $PhI(OAc)_2$/TfOH have been explored. Endoxides 10 were directly oxidized to iptycene quinones 12, and isobenzofuran 5 was conveniently converted to triptycene dialdehyde 16. H-shaped centrally extended pentiptycene quinones 13 and 14 were also synthesized.**

The term "iptycene" was coined by Hart to refer to a family of molecules wherein a number of arene units are joined together to form a bridge of a [2.2.2] bicyclic ring system.[1] A prefix is added to indicate the number of independent arenes such as triptycene, pentiptycene, and heptiptycene. Triptycene **1** (tribenzobicyclo[2.2.2]-octatriene) is the basic unit of this family. It is named after "the triptych of antiquity" which is a book with three leaves hinged on a common axis.[2] Iptycenes have unique geometrical, structural, and electronic characters such as rigidity, bulkiness, nonplanarity, and $\pi$-electron richness. A variety of iptycene molecules have been applied for the investigations in a range of fields, including intramolecular charge transfer, atropisomerism studies, ligand design, host–guest chemistry, supramolecular chemistry, and molecular gear devices.[3]

The preparation of iptycenes has attracted much attention. Among the known methods to synthesize iptycenes, Diels–Alder cycloaddition is the most widely used approach (Scheme 1). The triptycene skeleton can be directly formed from Diels–Alder cycloadditions between anthracene or its derivatives and an appropriate dienophile (such as quinone, aryne, or endoxide).[4] Iptycene derivatives **2** can also be obtained from triptycyne **4**.[5] Recently, we reported a new procedure for the preparation of triptycyne **4** from the oxadisilole fused triptycene precursor **4a**.[5c]

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(1) Hart, H.; Shamouilian, S.; Takehira, Y. *J. Org. Chem.* **1981**, *46*, 4427.

(2) Bartlett, P. D.; Ryan, M. J.; Cohen, S. G. *J. Am. Chem. Soc.* **1942**, *64*, 2649.

(3) For recent reviews, see: (a) Zhao, L.-W.; Li, Z.; Wirth, T. *Chem. Lett.* **2010**, *39*, 658–667. (b) Chong, J. H.; MacLachlan, M. J. *Chem. Soc. Rev.* **2009**, *38*, 3301. (c) Yang, J. S.; Yan, J. L. *Chem. Commun.* **2008**, 1501. For some selected studies:(a) Oki, M. *Acc. Chem. Res.* **1990**, *23*, 351. (b) Yamamoto, G. *Chem. Lett.* **1990**, *19*, 1373. (c) Azerraf, C.; Gelman, D. *Organometallics* **2009**, *28*, 6578. (d) Peng, X.-X.; Lu, H.-Y.; Han, T.; Chen, C.-F. *Org. Lett.* **2007**, *9*, 895. (e) Swager, T. M. *Acc. Chem. Res.* **2008**, *41*, 1181. (f) Kelly, T. R. *Acc. Chem. Res.* **2001**, *34*, 514.

(4) (a) Bartlett, P. D.; Ryan, M. J.; Cohen, S. G. *J. Am. Chem. Soc.* **1942**, *64*, 2649. (b) Patney, H. K. *Synthesis* **1991**, 694. (c) Hart, H. *Pure Appl. Chem.* **1993**, *65*, 27. (d) Kitamura, T.; Yamane, M.; Inoue, K.; Todaka, M.; Fukatsu, N.; Meng, Z. H.; Fujiwara, Y. *J. Am. Chem. Soc.* **1999**, *121*, 11674. (e) Thomas, S. W.; Long, T. M.; Pate, B. D.; Kline, S. R.; Thomas, E. L.; Swager, T. M. *J. Am. Chem. Soc.* **2005**, *127*, 17976. (f) Pei, B. J.; Lee, A. W. M. *Tetrahedron Lett.* **2010**, *51*, 4519.

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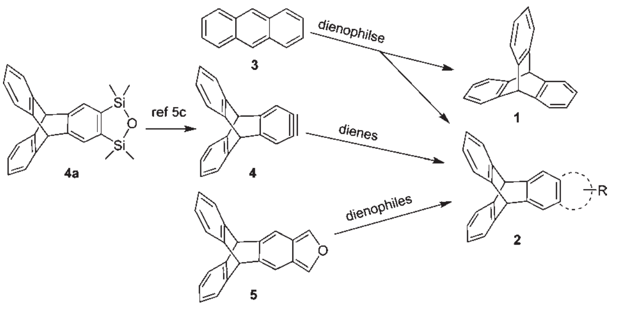
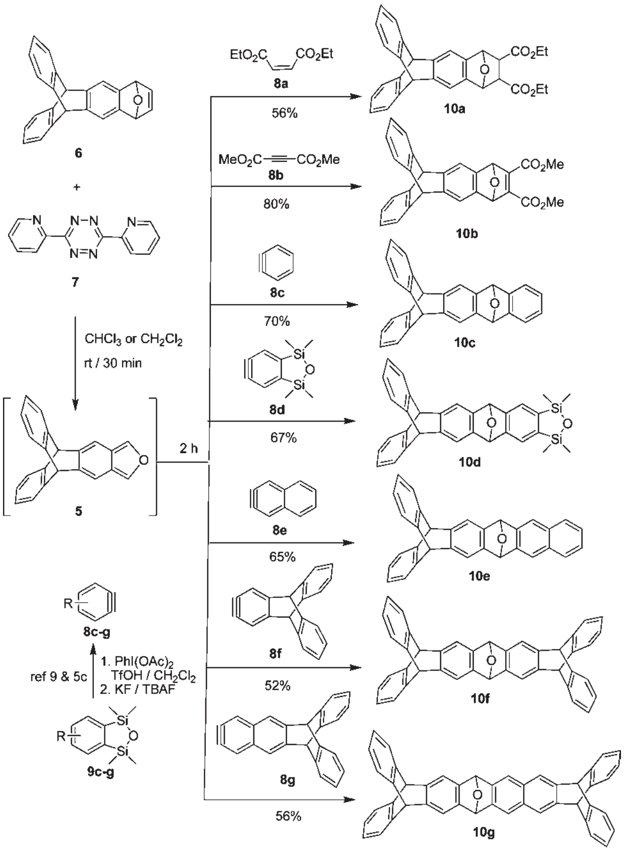
**Scheme 1.** Diels–Alder Cycloaddition Approaches for the Preparations of Iptycenes



When trapped by various dienes, a series of iptycenes **2** could be obtained. In this article, we would like to introduce a new approach to the preparation of iptycenes. A previously unknown anthracene capped isobenzofuran, 5,6-(9,10-dihydroanthracen-9,10-yl)isobenzofuran **5**, is envisioned as a synthon for the preparations of iptycenes and iptycene quinones.

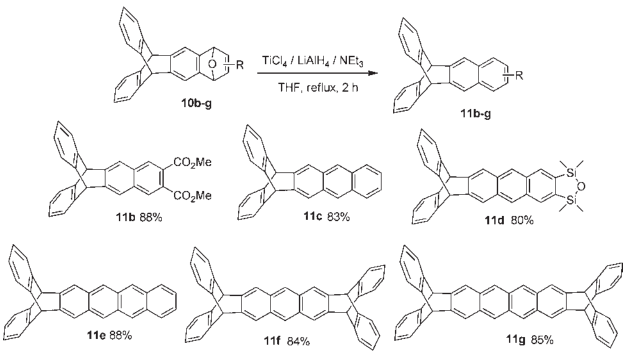
Isobenzofurans (IBFs) are well-known useful intermediates in organic synthesis.[6] Most of them are too unstable to be isolated at ambient conditions and needed to be prepared *in situ*. One of the most efficient methods for the synthesis of IBFs is the Warrener's protocol.[7] We adopted this approach to prepare our synthon anthracene capped isobenzofuran **5**. Reacted with 2,6-bis-2-pyridyl-1,2,4,5-tetrazine **7** in chloroform or dichloromethane at room temperature, endoxide **6**[5c] was completely converted to IBF **5** within 30 min. IBF **5** was quite stable in a chloroform solution under a nitrogen atmosphere. The $^{1}H$ and $^{13}C$ NMR spectra of the reaction mixture kept under nitrogen remained unchanged for 2 weeks.[8] But when the mixture was exposed to air, IBF **5** polymerized completely within 5 h. Freshly generated IBF **5** was reacted with various dienophiles **8a–g**. As depicted in Scheme 2, diethyl maleate **8a**, dimethyl acetylene dicarboxylate **8b**, and arynes **8c–g** reacted with IBF **5** to afford the corresponding iptycene cycloadducts **10a–g** in good isolated yields. In these reactions, oxadisilole fused compounds **9c–g** were the precursors of arynes **8c–g**.[5c,9]

**Scheme 2.** Generation of Anthracene Capped Isobenzofuran **5** and Trapping Experiments



Endoxides derived from isobenzofurans have been demonstrated as the key intermediates for the synthesis of acene derivatives.[10] We found that endoxides **10b–g** could be readily deoxygenated with $TiCl_4/LiAlH_4/Et_3N$. The corresponding extended triptycenes **11b–e** and H-shaped centrally extended pentiptycene **11f** and **11g** were obtained in high yields (81–88%) (Scheme 3).

**Scheme 3.** Synthesis of Extended Triptycenes and H-Shaped Pentiptycenes



Iptycene quinones, in particular pentiptycene quinone, have been used as the precursors for the preparations of

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(5) (a) Skvarchenko, V. R.; Shalaev, V. K. *Dokl. Akad. Nauk SSSR, Ser. Khim.* **1974**, *216*, 110. (b) Hart, H.; Bashir-Hashemi, A.; Luo, J.; Meador, M. A. *Tetrahedron* **1986**, *42*, 1641. (c) Pei, B. J.; Chan, W. H.; Lee, A. W. M. *J. Org. Chem.* **2010**, *75*, 7332.

(6) For reviews, see: (a) Haddadin, M. J. *Heterocycles* **1978**, *9*, 865. (b) Friedrichsen, W. *Adv. Heterocycl. Chem.* **1980**, *26*, 135. (c) Rodrigo, R. *Tetrahedron* **1988**, *44*, 2093. (d) Peters, O.; Friedrichsen, W. *Trends Heterocycl. Chem.* **1995**, *4*, 217. (e) Friedrichsen, W. *Adv. Heterocycl. Chem.* **1999**, *73*, 1–96. (f) Steel, P. G. *Sci. Synth.* **2001**, *10*, 87.

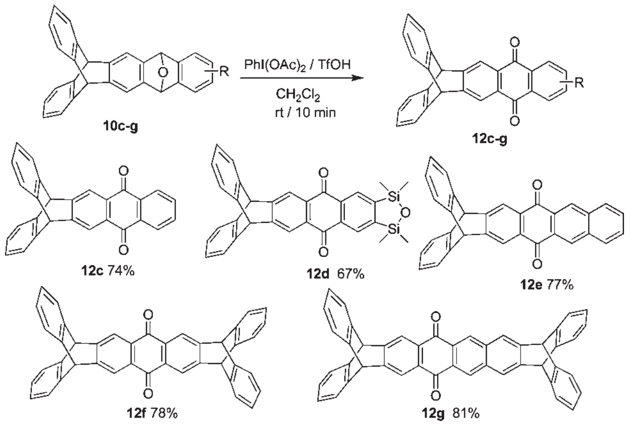
(7) (a) Warrener, R. N. *J. Am. Chem. Soc.* **1971**, *93*, 2346. (b) Warrener, R. N.; Hammer, B. C.; Russell., R. A. *J. Chem. Soc., Chem. Commun.* **1981**, 942.

(8) **IBF 5**. $^{1}H$ NMR ($CDCl_3$, ppm): $\delta$ 5.27 (s, 2H), 7.04 (m, 4H), 7.27 (s, 2H), 7.38 (m, 4H), 7.78 (s, 2H). $^{13}C$ NMR ($CDCl_3$, ppm): $\delta$ 53.4, 111.4, 122.5, 123.5, 125.7, 134.5, 139.5, 143.5. HRMS (MALDI-TOF) for $C_{22}H_{14}O$ $[M]^+$: calcd 294.1039, found 294.1057.

(9) (a) Kitamura, T.; Meng, Z.; Fujiwara, T. *Tetrahedron Lett.* **2000**, *41*, 6611. (b) Chen, Y. L.; Zhang, H.; Wong, W. Y.; Lee, A. W. M. *Tetrahedron Lett.* **2002**, *43*, 2259–2262. (c) Chen, Y. L.; Sun, J. Q.; Wei, X.; Wong, W. Y.; Lee, A. W. M. *J. Org. Chem.* **2004**, *69*, 7190–7197.

functionalized iptycene derivatives.[3,11] Most of the reported iptycene quinones were prepared from Diels–Alder reactions between anthracenes and appropriate quinone compounds. We would like to explore the possibility of transforming endoxides **10c–g** directly to iptycene quinones **12c–g**. In literature, such a transformation was done by cleavage of the ether bridge under basic conditions to afford the corresponding dihydroxy derivatives. Then the dihydroxy compounds were oxidized by $O_2/K_2CO_3$ to give the desired acenequinones.[12,13] However, such a reported procedure did not work well for our endoxides **10c–g**. Only trace amounts of the desired products could be detected.

**Scheme 4.** Synthesis of Iptycene Quinones **12c–g**



Hypervalent iodine compounds have been used as oxidants for oxygenation and oxidative functionalization of various organic substrates.[14] However, to the best of our knowledge, there is no report on the oxidation of endoxide with hypervalent iodine reagents. We explored if such oxidants could transform our endoxides to the corresponding quinones. We first tried $PhI(OAc)_2$ for the oxidation of endoxide **10c**. It worked, but the desired quinone product **12c** could only be obtained in very low yield ( < 5%). It has been reported that the oxidation powder of $PhI(OAc)_2$ could be enhanced by adding various strong acids.[14] Activation of $PhI(OAc)_2$ with TFA only slightly increased the yield of **12c** to 14%. Finally, to our delight, with 2 equiv of TfOH,[9,15] the oxidation reaction went very fast and iptycene quinone **12c** could be isolated in 74% yield in 10 min. Under this $PhI(OAc)_2$/TfOH condition (Scheme 4), all the endoxides **10c–g** could be oxidized directly to the corresponding iptycene quinones **12c–g** in good yields (67–81%).

With $PhI(OAc)_2$/TfOH as the oxidant, we have successfully prepared the previously unknown H-shaped pentiptycene quinones **12f** and **12g**. We then attempted the synthesis of H-shaped centrally extended pentiptycene quinones of larger scales, **13** and **14**. The synthetic approach was summarized in Scheme 5. At first, we anticipated that the double Diels–Alder reaction of *p*-quinone with 2 equiv of IBF **5** would provide the bis-cycloadduct **15**. After dehydration, the target compound **13** could be obtained. However, to our surprise, the Diels–Alder step was complicated and no expected product could be isolated. We then changed our synthetic strategy to base-catalyzed 4-fold aldol condensation.[16] Condensation between 1,4-cyclohexane-dione and 2 equiv of either 2,3-triptycenedialdehyde **16** or 2,3-naphthalenedialdehyde **18** could lead to the targeted iptycene quinones with high efficiency.

The synthesis of 2,3-triptycenedialdehyde **16** from 2,3-dimethyltriptycene through a four-step reaction sequence has been reported.[17] We report here a new synthesis of 2,3-triptycenedialdehyde **16** directly from IBF **5**. IBF **5** freshly prepared from endoxide **6** could be rapidly converted to dialdehyde **16** in the presence of $PhI(OAc)_2$/TfOH in 60% yield (based on **6**). This is the first example of using TfOH activated $PhI(OAc)_2$ in this type of transformation. Dialdehyde **16** reacted with 1,4-cyclohexane-dione in hot ethanol afforded H-shaped centrally extended pentiptycene quinone **13** (bis-anthracene capped pentacenequinone) in 95% yield.

For the synthesis of the next homologue, extended triptycene dialdehyde **18** was prepared from diester **11b** (Scheme 5). Diester **11b** was first reduced by $LiAlH_4$ to provide diol **17** in 95% yield. Subsequent Swern oxidation of **17** successfully gave dialdehyde **18** in 93% yield. KOH catalyzed 4-fold aldol condensation between 1,4-cyclohexane-dione and 2 equiv of **18** afforded H-shaped centrally

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(10) (a) Crump, S. L.; Netka, J.; Rickborn, B. *J. Org. Chem.* **1985**, *50*, 2746. (b) Mikami, K.; Ohmura, H. *Org. Lett.* **2002**, *4*, 3355. (c) Chan, S. H.; Yick, C. Y.; Wong, H. N. C. *Tetrahedron* **2002**, *58*, 9413. (d) Chen, Y. L.; Hau, C. K.; Wang, H.; He, H.; Wong, M. S.; Lee, A. W. M. *J. Org. Chem.* **2006**, *71*, 3512. (e) Rainbolt, J. E.; Miller, G. P. *J. Org. Chem.* **2007**, *72*, 3020. (f) Chun, D.; Cheng, Y.; Wudl, F. *Angew. Chem., Int. Ed.* **2008**, *47*, 8380. (g) Franz, D.; Robbins, S. J.; Boere, R. T.; Dibble, P. W. *J. Org. Chem.* **2009**, *74*, 7544.

(11) (a) Rybacek, J.; Zavada, J.; Holy, P. *Synthesis* **2008**, 3615. (b) Gung, B. W.; Xue, X. W.; Reich, H. J. *J. Org. Chem.* **2005**, *70*, 3641. (c) Satrijo, A.; Swager, T. M. *Macromolecules* **2005**, *38*, 4054. (d) Zhu, X. Z.; Chen, C. F. *J. Org. Chem.* **2005**, *70*, 917.

(12) Barluenga, J.; Martinez, S.; Suarez-Sobrino, A. L.; Tomas, M. *Org. Lett.* **2008**, *10*, 677.

(13) Yamaguchi, M.; Hasabe, K.; Higshi, H.; Uchida, M.; Irie, A.; Minami, T. *J. Org. Chem.* **1990**, *55*, 1611.

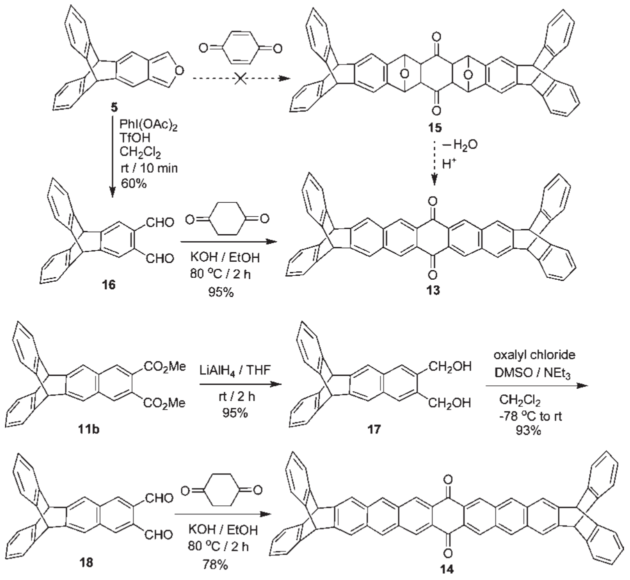
(14) For reviews, see: (a) Wirth, T. *Angew. Chem., Int. Ed.* **2005**, *44*, 3656. (b) Zhdankin, V. V.; Stang, P. J. *Chem. Rev.* **2002**, *102*, 2523. (c) Grushin, V. V. *Chem. Soc. Rev.* **2000**, *29*, 315. (d) Stang, P. J.; Zhdankin, V. V. *Chem. Rev.* **1996**, *96*, 1123. (e) Varvoglis, A. *Hypervalent Iodine in Organic Synthesis*; Academic Press: London, 1997. (f) Varvoglis, A. *The Organic Chemistry of Polycoordinated Iodine*; VCH Publishers: New York, 1992.

(15) (a) Kitamura, T.; Matsuyuki, J.; Taniguchi, H. *Synthesis* **1994**, 147. (b) Kitamura, T.; Yamane, M. *J. Chem. Soc., Chem. Commun.* **1995**, 983. (c) Ye, X. S.; Lee, W. K.; Wong, H. N. C. *J. Am. Chem. Soc.* **1996**, *118*, 2511. (d) Kitamura, T.; Yamane, M.; Inoue, K.; Todaka, M.; Fukatsu, N.; Meng, Z. H.; Fujiwara, Y. *J. Am. Chem. Soc.* **1999**, *121*, 11674.

(16) (a) Chen, Y. L.; Wong, M. S.; Wong, W. Y.; Lee, A. W. M. *Tetrahedron Lett.* **2008**, *49*, 1257. (b) Mondal, R.; Adhikari, R. M.; Shah, B. K.; Neckers, D. C. *Org. Lett.* **2007**, *9*, 2505. (c) Anthony, J. E.; Gierschner, J.; Landis, C. A.; Parkin, S. R.; Shermana, J. B.; Bakus, R. C., II. *Chem. Commun.* **2007**, 4746. (d) Jiang, J.; Kaafarani, B. R.; Neckers, D. C. *J. Org. Chem.* **2006**, *71*, 2155. (e) Payne, M. M.; Delcamp, J. H.; Parkin, S. R.; Anthony, J. E. *Org. Lett.* **2004**, *6*, 1609. (f) Vets, N.; Smet, M.; Dehaen, W. *Tetrahedron Lett.* **2004**, *45*, 7287.

(17) Rybacek, J.; Rybackova, M.; Hoj, M.; Belohradsky, M.; Holy, P.; Kilsa, K.; Nielsen, M. B. *Tetrahedron* **2007**, *63*, 8840.

**Scheme 5.** Synthesis of H-shaped Pentiptycene Quinones **13** and **14**



extended pentiptycene quinone **14** (bis-anthracene capped heptacenequinone) in 78% yield.

In summary, we reported a new strategy for the synthesis of iptycene derivatives. A previously unknown anthracene capped isobenzofuran **5** was prepared. It shows high reactivity and can react with different dienophiles to afford the corresponding iptycene derivatives **8a–g**. Deoxyaromatization of the endoxide adducts **8b–g** provided the extended triptycenes **11b–e** and pentiptycene **11f–g** with high yields. Two new reactions with $PhI(OAc)_2$/TfOH were also developed. First, endoxides **8c–g** could be oxidized by $PhI(OAc)_2$/TfOH to the corresponding iptycene quinones **12c–g**. Second, IBF **5** was conveniently converted to triptycene dialdehyde **16** with $PhI(OAc)_2$/TfOH. Two previously unknown H-shaped centrally extended pentiptycene quinones **13** and **14** were then successfully synthesized through KOH catalyzed 4-fold aldol condensation from triptycene dialdehydes **16** and **18** respectively.

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**Supporting Information Available.** General Methods section, experimental procedures, and characterization data as well as hardcopy NMR ($^1H$ and $^{13}C$) spectra of all new compounds. This material is available free of charge via the Internet at http://pubs.acs.org.