

# A Reiterative Approach to 2,3-Disubstituted Naphthalenes and Anthracenes

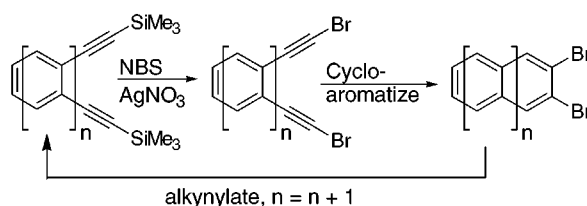
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## ABSTRACT



Simple bis(bromoethynyl)arene diynes are easily prepared by the desilylative halogenation of the corresponding trimethylsilyl derivatives. Cycloaromatization of these halogenated enediynes leads to the otherwise difficult to prepare 2,3-dibromoarenes in good yield. Alkynylation of the resulting haloaromatic compound regenerates the soluble enediyne system, homologated by one aromatic ring. This iterative methodology can be terminated by the cycloaromatization of the unsubstituted enediyne, providing the simple acene hydrocarbon.

Interest in the synthesis of acenes, the simplest class of linearly-fused aromatic hydrocarbons, was initially spurred by several reports that the corresponding polymer could be an organic conductor.<sup>1</sup> In the ensuing years, two distinct routes to acenes have been reported: The first involves the thermal treatment of highly conjugated prepolymers to yield insoluble and difficult to characterize systems with some promising electronic properties.<sup>2</sup> The second route utilizes Diels–Alder methodologies and has been most successful for the preparation of cross-conjugated polyacenequinones and partially saturated acene oligomers.<sup>3</sup> The largest simple acene prepared to date using this methodology is heptacene.

Recent reports that simple oligomeric acenes (such as pentacene) can be used in the preparation of thin-film

transistors<sup>4</sup> has rekindled interest in the synthesis of these fused hydrocarbons, and we report here our initial investigations into an entirely new route to linearly fused aromatic systems which utilizes a Bergman cycloaromatization reaction,<sup>5</sup> rather than Diels–Alder chemistry, in the ring-forming step. Our initial application of this methodology in a reiterative fashion allowed the rapid preparation of 2,3-disubstituted naphthalene and anthracene in good yields.

Beginning with the easily prepared diyne **1**,<sup>6</sup> silver-catalyzed desilylative bromination in acetone<sup>7</sup> provided the dibromide **2** (caution: mild lachrymator) in excellent yield. This bis(bromoalkyne) decomposes rapidly when concentrated but is stable as a solution over a period of several weeks, provided the material is kept in the dark.

Cycloaromatization of this halogenated compound simply required heating a dilute (0.035 M) solution in a 10:1 (v/v)

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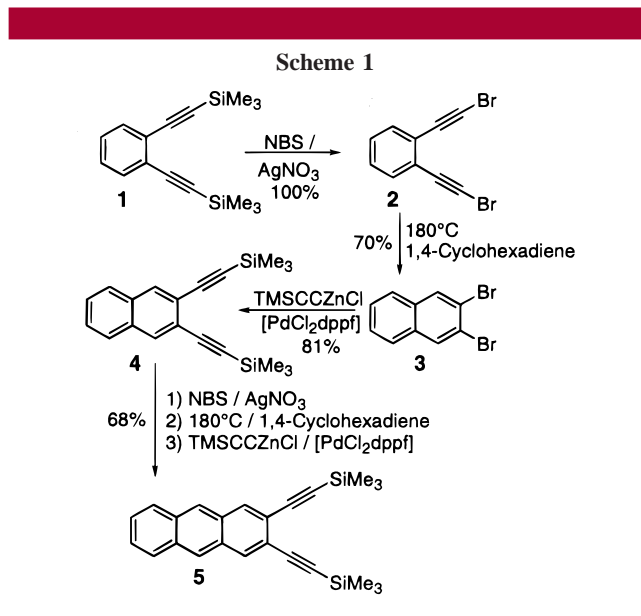
(7) Hofmeister, H.; Annen, K.; Laurent, H.; Wiechert, R. *Angew. Chem., Int. Ed. Engl.* **1974**, *23*, 727.

benzene/1,4-cyclohexadiene (1,4-CHD) mixture to 180 °C in a steel bomb for 2 h.<sup>8</sup> After slow cooling to room temperature, GC/MS analysis of the crude reaction mixture showed 2,3-dibromonaphthalene **3** to be the only significant product, contaminated by a small amount of 2-bromonaphthalene. A single recrystallization of this crude product from heptane provided pure 2,3-dibromonaphthalene in 70% yield. The efficiency with which **2** undergoes cycloaromatization is unusual for an acyclic enediyne and might be explained by the electron-withdrawing effects of the halogens. Electron-withdrawing substituents have been shown to accelerate the rate of other cycloaromatization reactions.<sup>9</sup>

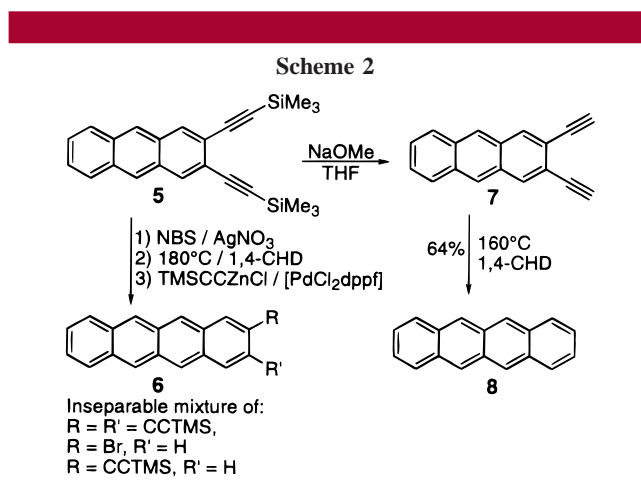
In an attempt to avoid performing these cycloaromatization reactions under pressure, we investigated a number of other reaction conditions which utilized less-volatile hydrogen atom sources. Our best results were obtained using inexpensive  $\gamma$ -terpinene (bp 182 °C), which has been reported to be a higher-boiling replacement for 1,4-cyclohexadiene in cycloaromatization reactions<sup>10</sup>—although for our systems it proved to be significantly less efficient than 1,4-CHD. Thus, when dibromide **2** was added slowly to a refluxing (180 °C) solution of 1,2-dichlorobenzene/ $\gamma$ -terpinene (10:1 v/v) and allowed to react at that temperature overnight, we were able to separate a 35% yield of dibromonaphthalene **3** from the significant amount of oligomerization and addition products formed from this reaction.<sup>11</sup> Increasing the proportion of  $\gamma$ -terpinene did not improve the yield of the desired product, and in fact when  $\gamma$ -terpinene was used as the reaction solvent, the yield of dibromonaphthalene was reduced dramatically. However, the ability to perform the cycloaromatization in simple refluxing solvents, rather than in a sealed pressure apparatus, is a significant advantage for larger-scale reactions.

The alkylation of 2,3-dibromonaphthalene was best performed by palladium-catalyzed coupling with (trimethylsilylethynyl)zinc chloride in refluxing ether, which proceeded in significantly higher yield than any attempted Sonagashira-type couplings.<sup>12</sup> The overall yield for the first full iteration (**1** to **4**) was 57%.

The second iteration was performed in a similar manner: Desilylative bromination to form 2,3-bis(bromoethynyl)naphthalene and cycloaromatization at 180 °C followed by alkylation to give the desired bis(trimethylsilylethynyl)anthracene **5** in a 68% overall yield from **4** (Scheme 1). In this case, we did not purify the intermediate dibromonaphthalene before performing the acetylenic coupling, since the very soluble **5** was significantly easier to separate from the reaction byproducts.



A single attempt at performing a third iteration was plagued with problems caused by the insolubility of the intermediates (Scheme 2). The dibromide prepared by



desilylative halogenation of **5** was only sparingly soluble in hot benzene, and the cycloaromatization of this material produced a significant amount of black char. The palladium-catalyzed coupling of (trimethylsilylethynyl)zinc chloride to this crude material led to the recovery of approximately 20% by mass of soluble material, which was a chromatographically inseparable mixture of products shown by GC/MS analysis to include the desired diethynyl compound, the monoethynyl compound, and several dehalogenated products. It is obvious that the success of this iterative scheme depends on the solubility of the intermediate dibromoenediyne.

The iterative process can be terminated in a number of ways. For example, the dibromoarenes formed by cycloaromatization can be substituted with alkyl, aryl, or alkynyl functional groups by well-known coupling chemistry.<sup>13</sup> More simply, the iterative process can be ended by the cycloaromatization of the unsubstituted enediyne to yield the

(8) Lower temperature cycloaromatization runs were attempted, but led to slow decomposition of starting material. All of the high-temperature reactions performed in sealed systems were carried out behind protective shielding.

(9) (a) Semmelhack, M. F.; Neu, T.; Foubelo, F. *J. Org. Chem.* **1994**, *59*, 5038. (b) Maier, M. E.; Greiner, B. *Liebigs Ann. Chem.* **1992**, 855. (c) Schmittl, M.; Kiau, S. *Chem. Lett.* **1995**, 953.

(10) Grissom, J. W.; Calkins, T. L.; Egan, M. *J. Am. Chem. Soc.* **1993**, *115*, 11744.

(11) Addition of *p*-benzyne diradical to the hydrogen atom source is a common byproduct of cycloaromatization reactions. See, e.g., ref 8a.

(12) (a) Negishi, E.; Kotora, M.; Xu, C. D. *J. Org. Chem.* **1997**, *62*, 8957. (b) John, J. A.; Tour, J. M. *Tetrahedron* **1997**, *53*, 15515.

parent acene. Thus, anthracene **5** was desilylated with sodium methoxide in THF to give the sparingly soluble diyne **7**, which was immediately subjected to cycloaromatization conditions at 160 °C. Because of the moderate solubility of free diyne **7** in hot benzene, the cycloaromatization reaction proceeded with significantly less charring, producing a single major compound. Recrystallization of the resulting crude material three times from methylene chloride provided naphthacene **8** in 64% yield.

In conclusion, we have demonstrated a simple cycloaromatization-based methodology which was used in the preparation of 2,3-dihalo- and 2,3-diethynynaphthalene and -anthracene. The yields for the process are good, and purification is typically possible by simple recrystallization. We have also shown that the terminal alkynes can undergo cycloaromatization to give parent acenes, also in good yield. Because the success of our iterative methodology appears

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(13) For example, nickel-catalyzed coupling with a Grignard reagent: Tamao, K.; Sumitani, K.; Kumada, M. *J. Am. Chem. Soc.* **1972**, *94*, 4374–4376.

highly dependent on solubility of the intermediate dibromoenediyne, we are currently investigating the effect of solubilizing groups on the cycloaromatization reaction. To maximize the efficiency of the high-dilution cycloaromatization reactions, we are also preparing systems with multiple enediyne units to form large polycyclic systems in a single step. The results of these investigations will be reported in due course.

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**Supporting Information Available:** Text giving experimental procedures for the iterative process and spectroscopic data for compounds **3**, **4**, **5**, and **8**. This material is available free of charge via the Internet at <http://pubs.acs.org>.

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