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Synthesis of 1-(2-ethynyl-6-methylphenyl)- and 1-(2-ethynyl-6-methoxyphenyl)-naphthalene and their cyclization

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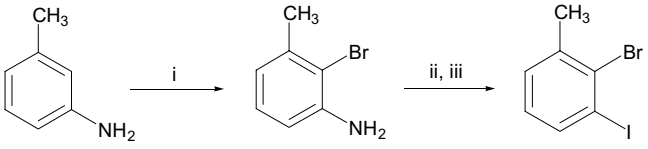
Abstract—A Suzuki cross-coupling reaction of hindered 2-bromo-1-trimethylsilylethynylbenzenes with 1-naphthaleneboronic acid yielding (2-ethynylphenyl)naphthalenes has been achieved. Their subsequent cyclization was carried out, giving benzo[*c*]phenanthrenes, without the use of photochemical procedures.

Interest in the preparation of polycyclic aromatic hydrocarbons (PAHs), which are widely distributed in the environment, has been stimulated by the desire to understand their involvement in the mechanisms of carcinogenesis and also by the discovery of sophisticated systems such as fullerenes or nanotubes having extraordinary properties. Numerous synthetic procedures for the construction of large polycyclic aromatic systems have been described in the literature.[1] However, there are not many studies that deal with the preparation of differently monosubstituted benzo[*c*]phenanthrenes. Efforts have been devoted to the synthesis of compounds such as 3-hydroxy-,[2] 4-hydroxy[3] and 6-methoxybenzo[*c*]phenanthrene.[4] An article concerning only non-photochemical procedures for the synthesis of 1-hydroxybenzo[*c*]phenanthrene was published by Newman in 1964.[5] Herein we report a metal-induced carbocyclization[6] of alkynylated phenyl-naphthalenes for the preparation of 1-hydroxybenzo[*c*]phenanthrenes.

2-Bromo-1-iodobenzenes **5a** and **5c** were prepared according to literature[7] procedures. 2-Bromo-1-iodo-3-methylbenzene **5b** was prepared starting from *m*-toluidine, according to Scheme 1. Selective bromination in the presence of SiO_2[8] gave 2-bromo-*m*-toluidine in high yield, which was then converted into the corresponding iodide by means of the diazonium salt.



Scheme 1. Reagents and conditions: (i) Br_2, SiO_2, $CHCl_3$; (ii) $NaNO_2$, H_2SO_4, 10 °C, (iii) KI, 10 °C → 80 °C, (**5b**): 61%.

2-Bromo-1-trimethylsilylethynylbenzenes **1** (Scheme 2), to be used in the Suzuki coupling reactions with naphthaleneboronic acid, were prepared by Sonogashira coupling with trimethylsilylacetylene and compounds **5a–c** under standard conditions.

The key step in the synthesis of benzo[*c*]phenanthrenes was the Suzuki coupling of an appropriate bromobenzene **1** with 1-naphthaleneboronic acid under palladium/2-(2′,6′-dimethoxybiphenyl)dicyclohexylphosphine (**L**) catalysis under conditions described recently.[9] The reaction led to phenyl-naphthalenes **2** in high yields. Their carbocyclization catalyzed by $PtCl_2$ followed a 6-*endo* pathway with concomitant cleavage of the trimethylsilyl group to give benzo[*c*]phenanthrenes **3**.[10] The electrophilic cleavage of the silicon–carbon bond during the reaction is probably due to the H^+/H_2O system. Traces of acid (HCl) were probably derived from $PtCl_2$ prepared from H_2PtCl_6, and water may have originated from undried toluene. The reaction did not occur with methyl substituted phenylnaphthalene **2b**. 1-Methoxybenzo[*c*]phenanthrene **3c** was demethylated using BBr_3 to afford 1-hydroxybenzo[*c*]phenanthrene **3d**.[11]

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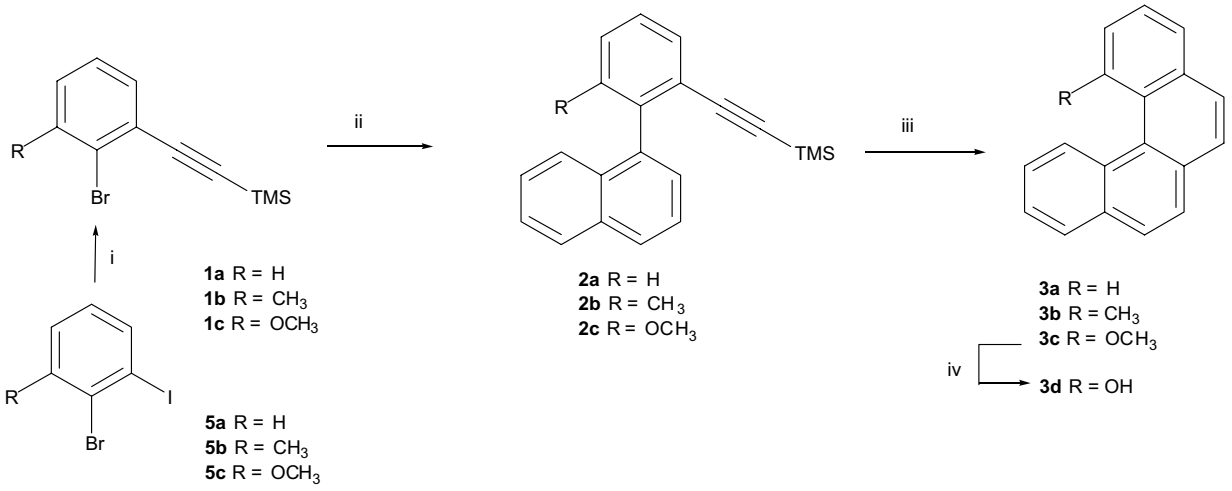
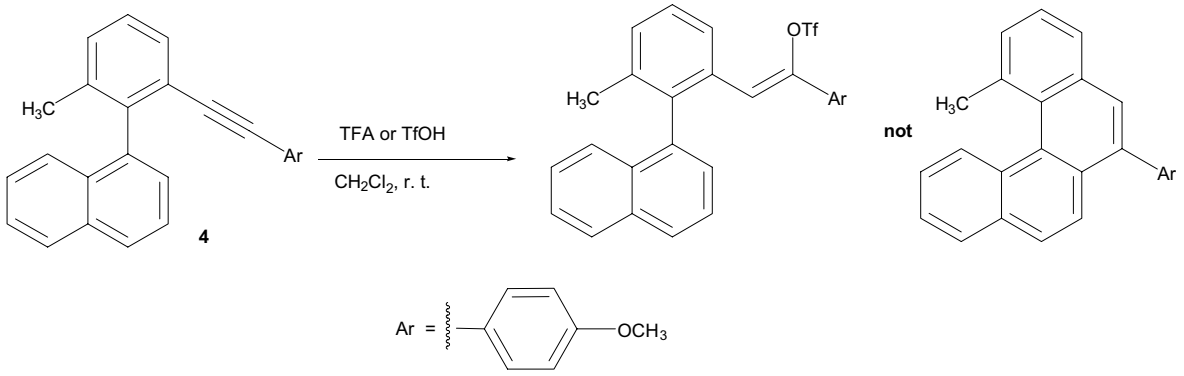


Scheme 2. Reagents and conditions: (i) TMS–C≡CH, $PdCl_2(PPh_3)_2$, CuI, Et_3N, rt, (**1a**): 98%, (**1b**): 89%, (**1c**): 98%; (ii) 1-naphthaleneboronic acid, **L**, $Pd_2(dba)_3{\cdot}CHCl_3$, K_3PO_4, toluene, 90 °C, (**2a**): 95%, (**2b**): 90%, (**2c**): 90%; (iii) $PtCl_2$, toluene, 90 °C, (**3a**): 86%, (**3b**): 0%, (**3c**): 80%; (iv) BBr_3, CH_2Cl_2, rt, (**3d**): 88%.



Scheme 3. Attempts for electrophilic cyclization.

Attempts to catalyze cyclization of **2b** with $InCl_3$[6] or $PdCl_2(PhCN)_2/2AgBF_4$[6] did not provide any detectable amount of the desired product. The reaction failed probably due to steric influences. To support this conclusion, we attempted electrophilic cyclization of compound **4**, where Ar was an electron-rich *p*-methoxyphenyl group (Scheme 3), which provided resonance stabilization of the positive charge at the β-carbon and would thus lead to preferential protonation at the α-carbon.[12] Treatment of **4** with TfOH or TFA produced the corresponding vinyl ester as the only isolable product.

In summary, we have prepared 1-hydroxybenzo[*c*]phenanthrene via an atom economic cyclization method in three simple steps compared to Newman method[5] which involved eight steps starting from diethyl benzhydrylmalonate.

Acknowledgment

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References and notes

1. Harvey, R. G. *Curr. Org. Chem.* **2004**, *8*, 303–323.
2. (a) Kumar, S. *J. Org. Chem.* **1997**, *62*, 8535–8539; (b) Pataki, J.; Raddo, Di P.; Harvey, R. G. *J. Org. Chem.* **1989**, *54*, 840–844.
3. Bijay, M.; Shantu, A. *J. Org. Chem.* **1990**, *55*, 4478–4480.
4. Mallory, F. B.; Rudolph, M. J.; Oh, S. M. *J. Org. Chem.* **1989**, *54*, 4619–4626.
5. Newman, M. S.; Blum, J. *J. Am. Chem. Soc.* **1964**, *86*, 503–507.
6. Mamane, V.; Hannen, P.; Fürstner, A. *Chem. Eur. J.* **2004**, *10*, 4556–4575.
7. (a) Tunney, S. E.; Stille, J. K. *J. Org. Chem.* **1987**, *52*, 748–753; (b) Ooi, T.; Takahashi, M.; Yamada, M.; Tayama, E.; Omoto, K.; Maruoka, K. *J. Am. Chem. Soc.* **2004**, *126*, 1150–1160.
8. Ghiaci, M.; Asghari, J. *Bull. Chem. Soc. Jpn.* **2001**, *74*, 1151–1152.
9. Barder, T. E.; Walker, S. D.; Martinelli, J. R.; Buchwald, S. L. *J. Am. Chem. Soc.* **2005**, *127*, 4685–4696.
10. A solution of phenyl-naphthalene **2c** (1 g, 3.0 mmol) and $PtCl_2$ (80 mg, 0.3 mmol) in toluene (10 mL) was stirred for 20 h at 90 °C. The solvent was evaporated and the residue

was purified by flash silica gel column chromatography using 20% acetone–hexane as eluent to give 1-methoxybenzo[*c*]phenanthrene **3c** as a yellow solid (0.6 g, 78%). ^{1}H NMR (500 MHz; $CDCl_3$) δ 3.84 (s, 3H), 7.16 (dd, $J = 2.0$, 7.5 Hz, 1H), 7.44–7.63 (m, 4H), 7.79 (AB, $J =$ 8.4 Hz, 1H), 7.82 (AB, $J = 8.5$ Hz, 1H), 7.85 (AB, $J =$ 8.4 Hz, 1H), 7.94 (AB, $J = 8.5$ Hz, 1H), 7.95–7.97 (m, 1H), 8.16–8.18 (m, 1H); ^{13}C NMR (75 MHz; $CDCl_3$) δ 156.6, 135.1, 132.4, 131.6, 131.0, 130.1, 127.6, 127.05, 127.02, 127.0, 126.6, 126.0, 125.8, 125.4, 123.4, 120.7, 120.1, 107.4, 54.6; EI-MS: *m*/*z* 258 (100% M^+), 242, 226, 213, 121, 113, 106, 101, 94. Anal. calcd for $C_{19}H_{14}O$: C, 88.34; H, 5.46; O, 6.19. Found: C, 88.06; H, 5.56; O, 6.23%.

11. *Spectroscopic data for* **3d**: ^{1}H NMR (300 MHz; $CDCl_3$) δ 5.56 (br s, 1H), 7.22 (dd, $J = 2.7$, 6.3 Hz, 1H), 7.60–7.90 (m, 4H), 7.71 (AB, $J = 8.5$ Hz, 1H), 7.83 (AB, $J = 8.5$ Hz, 1H), 7.84 (AB, $J = 8.5$ Hz, 1H), 7.92 (AB, $J = 8.5$ Hz, 1H), 8.00 (m, 1H), 8.17 (m, 1H); ^{13}C NMR (75 MHz; $CDCl_3$) δ 152.6, 135.0, 132.9, 131.8, 128.5, 128.0, 127.8, 127.7, 127.5, 127.4, 126.7, 126.3, 126.2, 126.1, 124.0, 120.4, 118.1, 113.1; EI-MS: *m*/*z* 243 (100%, M^+-H), 213, 121, 106, 94. Anal. calcd for $C_{18}H_{12}O$: C, 88.50; H, 4.95; O, 6.55. Found: C, 88.32; H, 4.99; O, 6.61%.
12. Goldfinger, M. B.; Crawford, K. B.; Swager, T. M. *J. Am. Chem. Soc.* **1997**, *119*, 4578–4593.