The reaction of 2-chloro-1-methoxynaphthalene and 2-anthraceneforming conditions: convenient synthesis of annular polycyclic aromatic compounds

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Abstract

2-Bromobiphenylene and 2-chloro-1-methoxynaphthalene react with 3-cyanophthalides in the presence of LDA or LiTMP to give functionalized benzo[3,4]cyclobuta[1,2-*b*]anthracene-6,11-diones and naphthacene-5,12-diones, respectively.

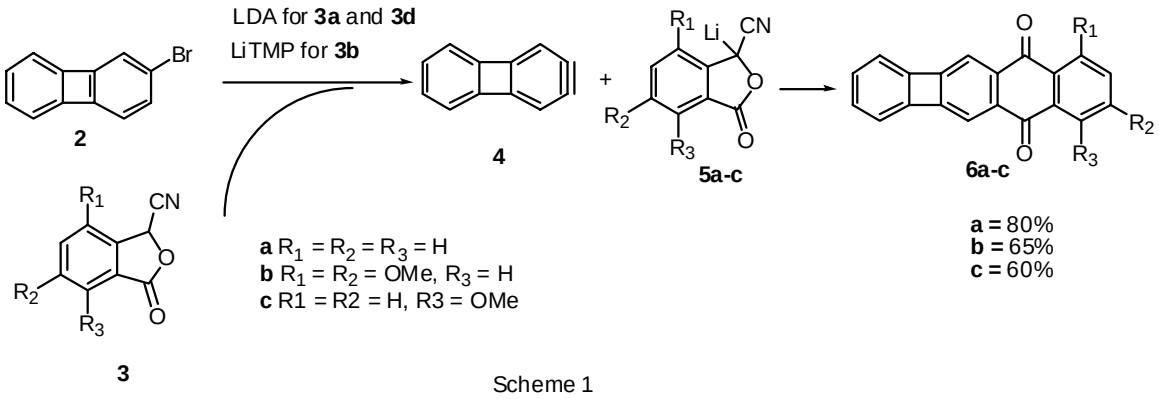
Keywords: 2,3-Dehydronaphthalene, benzo[3,4]cyclobuta[1,2-*b*]anthracene-6,11-dione, LDA, LiTMP, cycloadditions

Introduction

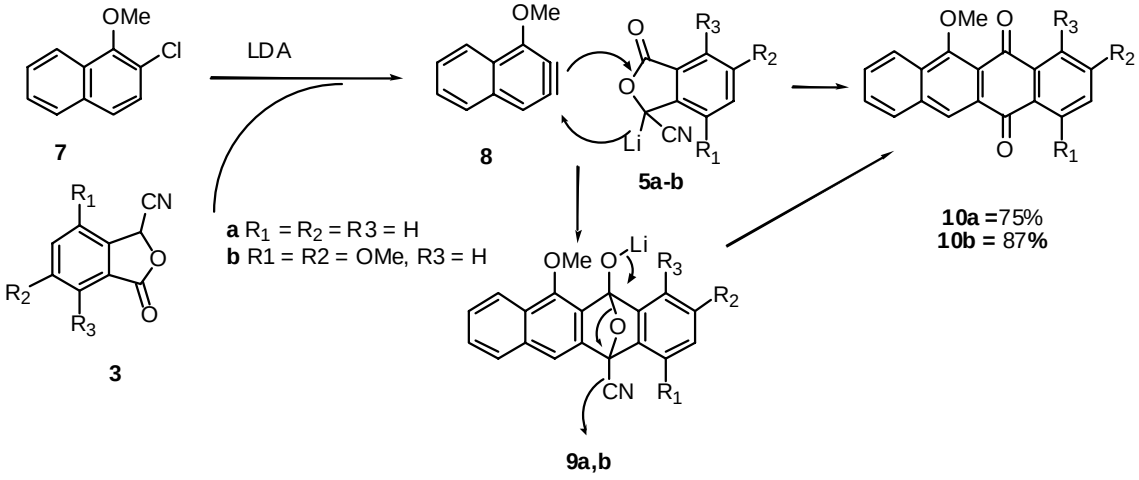
Biphenylenes have recently been studied extensively because they can serve as a unit of new carbon allotropes and can function as spacers and building blocks for functionalized organic materials.[1] One of the more important synthesis of functionalized biphenyls involves the intramolecular coupling of benzoannulated zincacylopentadiene intermediates prepared from 2,2'-diaryls with $ZnCl_2$.[2] During the course of our studies on the synthetic use of aryne reactions, we[3] have prepared a wide variety of functionalized polycyclic quinones from the reaction of haloarenes with 3-lithiophthalides in the presence of sterically hindered bases such as LDA and LiTMP. It occurred to us that 2-bromobiphenylene might react similarly to give functionalized annulated biphenyls. Although 2-bromobiphenylene can in principal give two benzynes, *i.e.* 1,2-dehydro and 2,3-dehydrobiphenylene, our calculations have shown the 2,3-intermediate to be 4.47 kcal/mol more stable than the 1,2-isomer. The relative stability of 1,2 and 2,3-dehydrobiphenylenes were calculated with complete optimization of all geometric variables using the standard AM1 procedure[4] incorporated in version 3.1 of Spartan Package.[5] Furthermore, the latter being symmetric would give a single aryne product. Along similar lines, we decided to investigate also the reaction of 2-chloro-1-methoxynaphthalene with certain 3-cyanophalides. The well-proven *meta*-directing effect of the methoxy group[6] should also afford a single aryne product.

Results and Discussion

These expectations were indeed realized and are illustrated in Schemes 1 and 2. As shown in Scheme, 1, 2-bromobiphenylene (**2**) and 3-cyanophthalides (**3a-c**) were treated with LDA and LiTMP to provide 2,3-dehydrobiphenylene (**4**) and the 3-lithio-3-cyanophthalides (**5a-c**), respectively. These intermediates then underwent cycloaddition to give the corresponding benzo[3,4]cyclobuta[1,2-*b*]anthracene-6,11-dione (**6a-c**) in 60-80% yields after usual workup. The benzyne precursor, 2-bromobiphenylene (**2**) was prepared by the bromination of biphenylene (**1**) with 1,8-diazabicyclo[5.4.0]undec-7-ene in the presence of $HgCl_2$ in 75% yield.[7] This method is superior to simple bromination which gives **2** in only 50% along with some polybromides.[8] The 3-cyanophthalides (**3a-c**) were on hand from previous studies and IR spectra were consistent with proposed structures.



Scheme 1

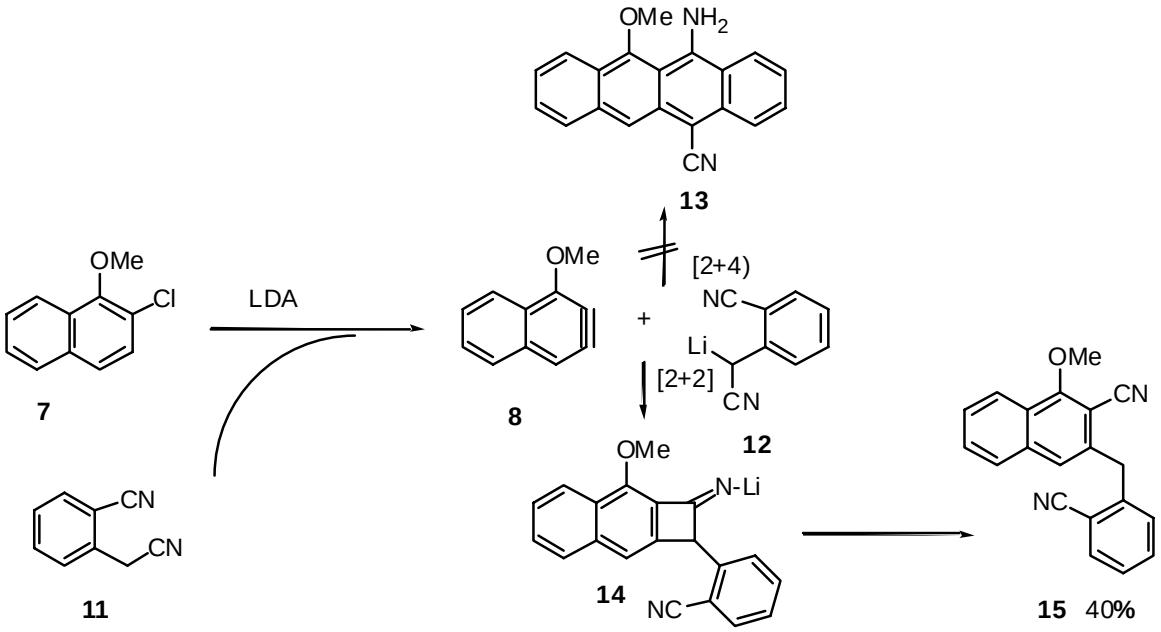


Scheme 2

As shown in Scheme 2, 1-methoxynaphthacene- (**10a**) and 1,3,6, trimethoxynaphthacene-5,12-dione (**10b**) were obtained in 75 and 87% yields, respectively, from the reaction of 2-chloro-1-methoxynaphthalene (**7**) and 3-cyanophthalides (**3a** and **3b**). The regioselective

addition to 1-methoxy-2,3-dehydronaphthalene (**8**) was clearly shown in the case of **5b** to give a single adduct (**9b**). Obviously, no regiochemistry is involved in the case of the unsubstituted lithiated nitrile **5a**. The IR, ^{1}H NMR, ^{13}C NMR, and mass spectra were consistent with proposed structures.

We next treated **7** with α-cyano-*o*-tolunitrile **11** and LDA expecting aryne **8** and α-lithio-α-cyano-*o*-tolunitrile (**12**) to undergo [2+4]cycloaddition[9] to give the aminonaphthacene **13**. However, as shown in Scheme 3, this reaction proceeded by a tandem addition-rearrangement pathway[10] in which **8** and **12** reacted *via* a [2+2] cycloaddition pathway to the benzocyclobutenium adduct (**14**). Intermediate **14** then opened up to give the rearranged product, 2-cyano-3-(cyanobenzyl)-1-methoxynaphthalene (**15**) in 40% yield, after quenching.



Scheme 3

In conclusion, we have shown that 2,3-dehydrobiphenylene and 1-methoxy-2,3-dehydronaphthalene can serve as valuable intermediates in the synthesis of functionalized benzo[3,4]cyclobuta[1,2-b]anthracene-6,11-dione and naphthacene-5,12-dione, respectively.

Experimental Section

General Procedures. Melting points were taken on Fisher-Johns apparatus and are uncorrected. NMR spectra were recorded on a 400 MHz Brucker spectrometer: chemical shifts were related to TMS as internal standard.. Chemicals were purchased from commercial sources. LDA and BuLi were purchased as solutions in hexanes. The glassware heated at 125 ^{o}C in oven overnight prior

to use. Benzyne reactions were done under an atmosphere of dry O_2-free N_2 contained in a balloon possessing a needle protruding through a rubber septum attached to one of the reaction flask necks.

Biphenylene (**1**),[2] 2-bromobiphenylene (**2**)[7] and 2-chloro-1-methoxynaphthalene (**7**)[11] were prepared by literature procedures. The 3-cyanophthalides (**3a-c**) were available from previous studies.

General procedure for the reaction of haloarenes (2 and 7) with 3-cyanophthalides (3a-c)

In a flame-dried flask flushed with N_2. LDA (15 mmol) was prepared by adding 6 mL of *n*-BuLi (2.5 M in hexanes) to a solution containing diisopropylamine (15 mg, 15 mmol) in THF (30 mL) at -70 ^oC. After stirring for 10 min, 5 mmol of the appropriate nitrile (**3a-c**) in 30 mL of THF was added and the temperature was allowed to warm to -40 ^oC. At this point, 5 mmol of the haloarene (**2** or **7**) in 30 mL of THF was added over a period of 20 min while maintaining the temperature between -30 to -40 ^oC. After the addition of the haloarene, the resulting mixture was allowed to warm to rt where it was stirred for an additional 3 h. The resulting dark reddish solution was quenched with 30 mL of saturated NH_4Cl, and the solvent removed by rotary evaporation. The residue was extracted with three 20 mL portions of CH_2Cl_2. The fractions were combined, washed with 25 ml of 5% HCl, dried (Na_2SO_4) and concentrated (rotary evaporation) to provide a dark viscous liquid. The liquid was purified by flash chromatography (silica gel) using hexane/acetone (19:1) as eluent to give a solid product which was further purified by recrystallization from CH_2Cl_2-hexane. The physical properties of the products are given below.

Benzo[3,4]cyclobuta[1,2-*b*]anthracene-6,11-dione (6a). Yellow powder, mp 218-219 ^0C. IR (KBr) ν 1684 $cm^{-1.}$ ^1H NMR ($CDCl_3$) δ 6.81 (d, *J* = 8.0 Hz, 2 H), 6.92 (m, 2 H), 7.32 (d, *J* = 8.0 Hz, 1 H), 7.73 (m, 2 H), 7.79 (d, *J* = 8.1 Hz, 1 H), 8.23 (m, 1 H), 8.32 (m, 1 H). ^{13}C NMR ($CDCl_3$) δ 119.2, 120.1, 121.9, 123.6, 126.8, 127.7, 130.8, 130.9, 131.0, 131.8, 133.7, 133.8, 134.1, 149.3, 151.1, 153.5, 158.2, 181.8, 182.2. Anal. Calcd for $C_{20}H_{10}O_2$: C, 85.09; H, 3.57. Found: 85.15; H, 3 66.

7-Methoxybenzo[3,4]cyclobuta[1,2-*b*]anthracene-6,11-dione (6b). Yellow powder, mp 238-240 ^0C. IR (KBr) ν 1667 $cm^{-1.}$ ^1H NMR ($CDCl_3$) δ 4.01 (s, 3 H), 6.91 (m, 4 H), 7.3 1(d, *J* = 8.1, 1 H), 7.41(s,1 H), 7.52 (s, 1 H), 7.7 (t, *J* = 8.1 Hz, 1 H), 7.94 (d, *J* = 8.1 Hz, 1 H), 8.2 (m, 1 H), 8.3 (m, 1 H). ^{13}C NMR ($CDCl_3$) δ 56.6, 113.0, 113.9, 117.8, 119.6, 119.7, 119.8, 1303, 130.4, 134.8, 135.2, 137.0, 137.9, 149.6, 156.2, 157.3, 160.1, 171.2, 182.1, 182.9. Anal. Calcd for $C_{21}H_{12}O_3$: C, 80.76; H, 3.87. Found: 80.87; H, 3 90.

7,9-Dimethoxybenzo[3,4]cyclobuta[1,2-*b*]anthracene-6,11-dione (6c). Yellow powder, mp 208-210 ^0C. IR (KBr) ν 1682 $cm^{-1.}$ ^1H NMR ($CDCl_3$) δ 4.0 (6.8 (d, *J* = Hz, 2 H), 6.9)m, 2 H), 7.3 (d, *J* = 8 Hz, 1 H), 7.7 (m, 2 H), 7.8 (d, *J* = 8 Hz, 1 H), 8.2 (m, 1 H), 8.3 (m, 1 H). ^{13}C NMR ($CDCl_3$) δ 130.9, 131.0, 131.8, 133.7, 133.8, 134.1, 149.3, 151.1, 153.5, 158.2, 181.8, 182.2. Anal. Calcd for $C_{22}H_{14}O_4$: C, 85.09; H, 3.57. Found: 85.15; H, 3 66.

6-Methoxynaphthacene-dione (10a). Colorless prisms, mp 283-284 ^oC. IR (KBr) ν 1677 cm^{-1}. ^1H NMR δ 4.21 (s, 3 H), 7.82 (m, 4 H), 8.10 (m, 1 H), 8.33 (m, 2 H), 8.44 (m, 1 H), 8.70 (s, I H).

^{13}C NMR δ 63.0, 120.0, 124.7, 125.8, 127.0, 127.5, 129.5, 130.0, 130.3, 130.9, 132.0, 133.5, 133.6, 134.3, 135.9, 126.0, 160.0, 182.2, 183.2. Anal. Calcd for $C_{19}H_{12}O_3$: C, 79.16; H, 4.20. Found: C, 79.31; H, 4.26.

1,3,6-Trimethoxynaphthacene-5,12-dione (10b). Light yellow powder, mp 216-217 ^{o}C. IR (KBr) 1667. ^{1}H NMR ($CDCl_3$) δ 3.91 (s, 3 H), 4.01 (s, 3 H), 4.12 (s, 3 H), 6.72 (d, *J* = 4.2 Hz, 1 H), 7.50 (d, *J* = 4.1 Hz, 1 H), 7.72 (m, 2 H), 8.13 (m, 1 H), 8.41 (m, 1 H), 8.58 (m, 1 H). ^{13}C NMR ($CDCl_3$) δ 56.0, 56.6, 63.1, 103.1, 104.4, 116.7, 120.0, 124.5, 125.2, 128.9, 130.1, 131.1, 132.5, 136.3, 140.0, 159.2, 162.3, 164.9, 181.2, 182.4. Anal. Cacld for $C_{21}H_{16}O_3$: C, .72.41; H, 4.63. Found: C, 72.45; H, 4.70.

2-Cyano-3-(2-cynobenzyl)-1-methoxynaphthalene (15). Colorless crystals, mp 142-143 ^{o}C. IR (KBr) ν 2223 cm^{-1}. ^{1}H NMR ($CDCl_3$) δ 4.21 (s, 3 H), 4.51 (s, 2 H), 7.30-7.80 (m, 8 H), 8.21 (8.21 (d, *J* = 8.1 Hz, 1 H). ^{13}C NMR ($CDCl_3$) δ 38.5, 63.0, 101.3, 113.1, 122.8, 124.2, 126.1, 127.0, 127.4, 127.8, 130.0, 130.2, 133.1, 133.2, 136.0, 136.4, 142.5, 162.5. Anal. Calcd for $C_{20}H_{14}N_2O$: C, 80.52, H, 4.73, N, 9.39. Found: C, 80.55; H, 4.74; N, 9.44.

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