FVP of *n*-Butyl 2,4,6-Tri-*tert*-butylphenyl Sulfoxide (10e). Preparative TLC, on elution first with *n*-pentane, gave the fraction consisting of **23**, **26**, and **27**, which were further analyzed by GLC and GLC/MS. The fraction consisting of these compounds had the following properties: IR (film) 3080 (s, =CH), 1650 (s, C=C), 880 (s, CH=C) cm^{-1}; 220-MHz NMR ($CDCl_3$) δ 81.3 (s, CMe_3) 1.7 (s, 3 H, Me), 1.86 (s, 3 H, Me), 1.9 (s, 3 H, Me), 3.3 (s, 2 H, CH_2), 4.75 and 4.8 (d, 2 H, $=CH_2$), 6.3 (s, 1 H, CH=C), 7.0-7.3 (m). The mass spectrum of the compound proposed as **1-(3,5-di-*tert*-butylphenyl)-2-methylpropene (26)** was as follows: *m/z* (relative intensity) 244 (4, M) 229 (8), 131 (6), 115 (5), 91 (7), 77 (4), 57 (100), 55 (15), 41 (50). The mass spectrum of the compound proposed as **3-(3,5-di-*tert*-butylphenyl)-2-methylpropene (27)** was as follows: *m/z* (relative intensity) 224 (7, M), 229 (19), 131 (6), 115 (6), 91 (6), 77 (5), 57 (100), 41 (47).

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Registry No. 7a, 107-47-1; **7b**, 3019-19-0; **7c**, 16463-11-9; **7d**, 78089-43-7; **8d**, 78089-44-8; **8e**, 78089-45-9; **9a**, 2211-92-9; **9b**, 4170-71-2; **9c**, 66713-28-8; **9d**, 78089-46-0; **10d**, 78089-47-1; **10e**, 78089-48-2; **13a**, 31562-40-0; **13b**, 1208-20-4; **13c**, 66713-32-4; **13d**, 989-39-9; **14a**, 110-06-5; **14b**, 882-33-7; **14c**, 2905-17-1; **14d**, 20875-34-7; **14e**, 19715-27-6; **15b**, 1212-08-4; **15c**, 66713-33-5; **15d**, 1062-30-2; **16a**, 66713-31-3; **16c**, 66713-30-2; **16d**, 78089-49-3; **19**, 66741-04-6; **21**, 732-26-3; **23**, 1460-02-2; **26**, 72215-86-2; **27**, 72215-85-1; 1,2,3-tri-*tert*-butylbenzene, 40782-34-1; 2,4,6-tri-*tert*-butylphenyl bromide, 3975-77-7; 2,4,6-tri-*tert*-butylbenzenethiol, 961-39-7; 2,4,6-triisopropylbenzenethiol, 22693-41-0.

Synthesis, Conformation, and Complexation Behavior of 2,9,18,25-Tetraoxa[8,8](1,4)naphthalenophane†

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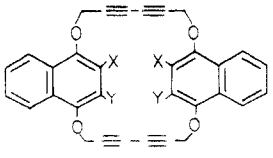
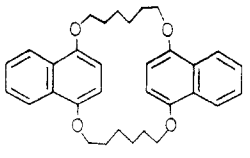
The synthesis of the title compound is described. Evidence is presented for its preferential "face-edge" conformation. Charge-transfer complexation proves to be a classical $\pi-\pi$ interaction with the "face-edge" conformation. There is no evidence for inclusion complexation. Attempted synthesis of substituted analogues of the title compound is described, including novel transformations in the 1,2,4-trisubstituted and 1,2,3,4-tetrasubstituted naphthalene series.

Introduction

We report the preparation and charge-transfer complexation behavior of (1,4)naphthalenophanes **1** and **2**. We have previously shown[3] that the analogous (1,4)-benzenophane **9**, approximating a 3.5 × 4 Å box, is too narrow to accommodate intracavity hosts. Rather it forms π complexes via a flattened conformation wherein the two aromatic rings are coplanar. It seemed to us that fusion of benzo lips onto **9**, forming (1,4)naphthalenophanes such as **1** and **2**, with their increased bite could circumvent these difficulties. A number of interesting transformations were encountered in the development of routes to functionalized derivatives of **1** such as **1a** and **1b**. These are reported here as is the charge-transfer complexation behavior of **2**.



1 X=Y=H
1a X=COOCH$_3$, Y=H
1b X=Y=-CH$_2$OAc
1c X=CH$_2$OAc, Y=H



2

Results and Discussion

Preparation of (1,4)Naphthalenophanes 1 and 2. Our initial plan was to prepare the naked phane **1** and to functionalize it or its hydrogenated derivatives at the 2 and 2′ positions. Linking these functionalities would then enforce a syn conformation upon the molecule. Cupric acetate oxidation of 1,4-bis(propynyloxy)naphthalene[2] afforded a difficultly soluble mixture of products. Peaks due to **1** (35% yield) could be identified in the mixture by their characteristic upfield shifts[3] but separation of **1** from the mixture was thwarted by its insolubility. Catalytic reduction of the crude mixture afforded cyclophane **2** in 28% overall yield, thus confirming the assignments made above.

Conformation of 2. The syn face-face conformation of **2** is not consistent with its NMR spectra. The data suggest that both the anti and edge-face conformations play an important role in defining the structure of **2**. The marked upfield shift of protons of C2 and C3, δ 5.84 as compared with δ 6.67 in 1,4-bis(1-propyloxy)naphthalene, defines a "cyclization shift" Δ_{cyc}[3] of 0.83 ppm. This may be compared with Δ_{cyc} for the analogous benzenophanes[3] of 0.3–0.5 ppm. Yoshino et al.[28] have studiked several [3.3](1,4)naphthalenophanes. An ArH Δ_{cyc} of 1.5 ppm was observed for a [3.3](1,4)naphthaleno(9,10)-anthracenophane.[28] *syn*-[3.3](1,4)Naphthalenophane is reported to have a Δ_{cyc} of 0.23 ppm; the anti conformer has a Δ_{cyc} of 1.15 ppm.[29] Otsubo et al.[4] have described the preparation of a series of [3.3] mixed arenophanes. The

† *Chemical Abstracts* name: 2,9,18,25-tetraoxapentacyclo[24.6.2.2^{10,12}.0^{11,16}.0^{27,32}]tetratriacontadeca-(10,12,14,16,26,28,30,32,33,35)-ene.

(1) Homeyer, A. H.; Wallingford, V. H. *J. Am. Chem. Soc.* **1942**, *64*, 798.
(2) Sacher, R. M.; Metcalf, R. L.; Fukuto, T. R. *J. Agric. Food Chem.* **1968**, *16*, 779.
(3) Jarvi, E. T.; Whitlock, H. W. *J. Am. Chem. Soc.* **1980**, *102*, 657.
(4) Otsubo, T.; Kitisawa, M.; Misumi, S. *Chem. Lett.* **1977**, 977.

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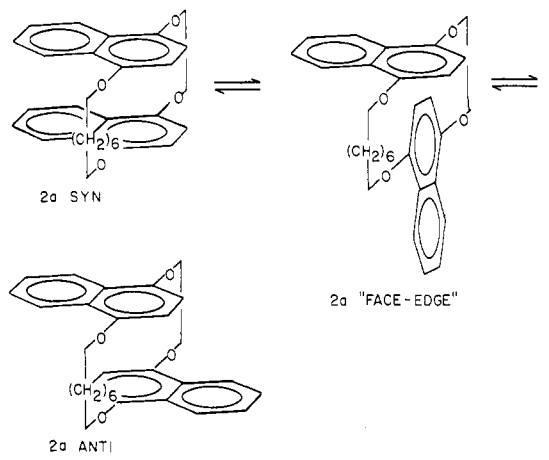
Chart I



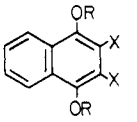
[3.3](1,4)benzo(1,4)naphthalenophane **10** exhibits a Δ_{cyc} of 1.02 for the inside but only 0.22 ppm for the outside phenylene protons. The two conformational isomers of [3.3](2,6)naphthalenophane have been prepared by Blank and Haenel.[5] Both of these [3.3]phanes exhibit ArH Δ_{cyc}'s of 0.3 to 0.5 ppm. Data on larger phanes is sparse: Nishido et al.[26] have reported Δ_{cyc} for several [*n.n*]biphenylophanes, ranging from 0.25 (n = 7) to 0.43 (n = 5); Murakami et al.[27] found a Δ_{cyc} of ~0 for a [10.10]benzenophane.

It would thus seem unreasonable to expect the syn conformation of **2a** to exhibit a Δ_{cyc} of 0.8 ppm; more realistic would be a range of 0 to 0.2 ppm. If **2** in fact possesses the anti conformation pictured, the above data would certainly require that it exist in a compact collapsed conformation. The approximately 18% hypochromicity of **2** agrees with this.

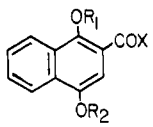
The "face-edge" conformation (Chart I) must be considered as an alternative to the anti conformation for **2**. Two pieces of evidence may be cited in support of this conformation. First is the large upfield shift of the C2–C3 protons. Only the C2,C3 protons of the much smaller bridged *anti*-[3.3](1,4)naphthalenophane possess Δ_{cyc}'s as large. All other phanes, even those with appreciably smaller bridges than in **2**, show considerably smaller Δ_{cyc} values. One is thus left with the feeling that Δ_{cyc} for **2** is "too large" to be accounted for by the anti conformation. Secondly, the proton NMR of **2** shows the protons of the central methylene group ($ArOCH_2CH_2CH_2$) of the bridge to be a multiplet at δ 1.8. Normally in this class of compounds these protons appear at ca. δ 1.2–1.4, slightly upfield from the $ArOCH_2CH_2CH_2$ protons at δ 1.7–1.8. This is true of the (2,6)naphthalenophanes,[7] (1,4)-benzenophanes,[3] a series of 2,3-*bis*(acyloxymethyl)(1,4)-naphthalenophane analogues of **2**[8] (for example **1c**), and simple derivatives of 1,6-hexanediol. The downfield shift of these protons on **2** is reasonably interpreted in terms of deshielding by an in-plane aromatic ring.[9] We note that this structure is consistent with the face-edge arrangement suggested for other hydrocarbon dimers.[6,10]

Functionalized Naphthalenophanes. The original plan was to effect functionalization of **1a** and **2** so that a third bridge might be constructed, thus enforcing a syn conformation upon the molecule. We have been uniformly unsuccessful in attempting a variety of electrophilic and transmetalation[12] reactions on these molecules, principally due to an interplay between poor solubility and electrophilic cleavage of the alkyl ethers.[13]

A stepwise synthesis of functionalized naphthalenophanes by oxidative coupling of **4c** was attempted. Under

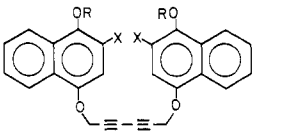


3a R=$CH_2C{\equiv}CH$, X=H
3b R=n-C_3H_7, X=H
3c R=H, X=COOEt
3d R=$CH_2C{\equiv}CH$ & H, X=COOEt
3e R=$CH_2C{\equiv}CH$ & H, X=CH_2OH
3f R=$CH_2C{\equiv}CH$ & MEN, X=COOEt
3g R=$CH_2C{\equiv}CH$ & MEM, X=CH_2OAc
3h R=$CH_2C{\equiv}CH$ & Ac, X=CH_2OAc
3i R=$CH_2C{\equiv}CH$, X=CH_2OAc

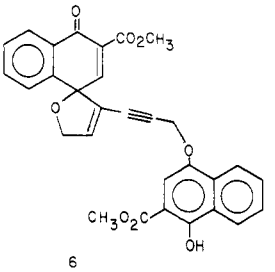


4a R_1=R_2=H, X=OH
4b R_1=R_2=H, X=OCH_3
4c R_1=H, R_2=$CH_2C{\equiv}CH$, X=OCH_3
4d R_1=R_2=$CH_2C{\equiv}CH$, X=OCH_3

carefully controlled conditions (pot temperature <45 °C) **4c** may be dimerized via cupric acetate in pyridine to the desired diyne **5a**, whereas at higher temperatures spiro enone **6** is formed instead. Although **6** is formally the result of an acid-catalyzed cyclization of **5a** we have been unable to convert **5a** to **6** under any of these conditions:



5a X= CO_2CH_3, R=H
5b X= CO_2CH_3, R= $CH_2C{\equiv}CH$



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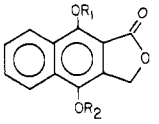
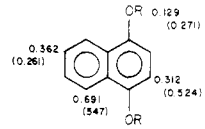
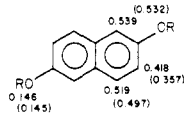


8a R_1= $CH_2C{\equiv}CH$, R_2= H
8b R_1= $CH_2C{\equiv}CH$, R_2= Ac
8c R_1= H, R_2= Ac

pyridinium toluene sulfonate in hot pyridine, cupric acetate or cuprous chloride in hot pyridine, or simply hot pyridine itself. It thus seems likely that the **5a** → **6** conversion occurs at some intermediate stage of the oxidative dimerization. Propargylation of **5a** to **5b** proceeded smoothly, but cyclization of **5b** under various conditions was unsuccessful, resulting in very low yields of the desired naphthalenophane **1b**. Simple electrophilic catalysis via chelation of nucleophilic displacement of the *o*-propynyloxy group seems the likely culprit; no indication of oxidative dealkylation processes was found. This result is somewhat surprising considering the success we have had in cyclizations in the related 2-(alkoxycarbonyl)(1,4)-benzenophane[3] and 3-(alkoxycarbonyl)-2,6-naphthalenophane[11] series.

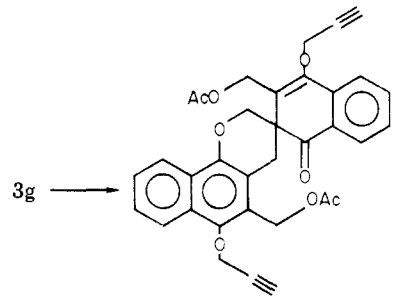
(5) Blank, N. H.; Haenel, M. W. *Tetrahedron Lett.* **1978**, 1425.
(6) (a) Chandross, E. A.; Ferguson, J.; McRae, E. G. *J. Chem. Phys.* **1966**, *45*, 3546. (b) Katal, J. A.; Zahlan, A. B. *Ibid.* **1967**, *47*, 1012.
(7) Whitlock, B. J.; Jarvi, E. T.; Whitlock, H. W., submitted to *J. Org. Chem.*
(8) Adams, S. P., to be published.
(9) Haigh, C. W.; Mallion, R. B. *Org. Magn. Reson.* **1972**, *4*, 203.
(10) Chandra, A. K. *Chem. Phys. Lett.* **1970**, *5*, 229.
(11) Jarvi, E. T. Ph.D. Thesis, University of Wisconsin, 1980.
(12) Shirley, D. A.; Cheng, C. F. *J. Organomet. Chem.* **1969**, *20*, 251.
(13) Metalation–carbonation of 1,4-dipropoxynaphthalene affords the 2-carboxylic acid in high yield. The reaction fails on **2a**.
(14) Corey, E. J.; Gras, J.-L.; Ulrich, P. *Tetrahedron Lett.* **1976**, 4701.
(15) Blocking of the phenolic hydroxyl as an acetate is similarly unsuccessful.
(16) The 1,4-benzenophane,[7] having no benzo lips, cannot accommodate an aromatic quest within its cavity.

Table I. Spectral and Association Constant Data for Cyclophanes 2 and 10 and Their Dimethyl and/or Dipropyl Ether Models

R[a]	1,4-OMe	1,4-OPr	2a	2,6-OPr	11
UV, λ_{max}[b]	321	320 (6420) 332 (6170)	322 (5270) 333 (5180)	334 (3300) 346 (3700)	334 (2000) 346 (2000)
CT-vis, λ_{max}[c]	476	486	497	452	464
K_{assoc}[d]	74	116	274	56	76
complexation shifts (Δ)[e]					

[a] 1,4-OMe, 1,4-dimethoxynaphthalene; 1,4-OPr, 1,4-dipropoxynaphthalene; 2,6-OPr, 2,6-dipropoxynaphthalene. [b] 1,4-series, 1×10^5 M $CHCl_3$ solutions; 2,6-series, methanol solutions. [c] 0.2 M $CHCl_3$ solutions of 1:1 donor/1,3,5-trinitrobenbene. [d] 8-20 mM $CDCl_3$ solutions of donor with 20-fold excess of acceptor, 1,3,5-TNB. K_{assoc} is average of K_a's determined for each proton resonance examined by the Benesi-Hildebrand method. Range: 1,4-OMe, 65-81; 1,4-OPr, 105-132; 2a, 232-317; 2,6-OPr, 29-81; 11, 66-85. [e] Shift of proton in pure donor-acceptor complex minus shift of pure donor. All shifts are upfield. Shifts for 1,4-series are for 1,4-OMe; numbers in parentheses are for 2. In 2,6-series numbers are for 2,6-OPr; those in parentheses are for 11.

Cupric acetate dimerization of bis(propynyloxy) ether **3i** affords directly the desired cyclophane **1c** in 1.9% yield. The conformation of this will be reported elsewhere, but in anticipation of improving the yield we have attempted a stepwise synthesis as in eq 1. The plan was to oxida-

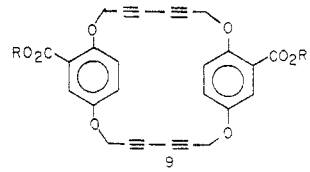


(1)

7

tively couple the monopropynyloxy monoMEM[31] ether **3g** and then operate on the liberated phenol as in our previous work.[3,11] Unfortunately we have been unable to liberate the *o*-(acetoxymethyl)phenol from the MEM ether. Only spiroquinone methide **7** is isolated under a variety of conditions from attempted hydrolysis of **3g**. Currently the best preparation of **1b** related phanes is by direct dimerization.

Complexation Behavior. The electron donor–acceptor (EDA) complexes between 1,3,5-trinitrobenzene (TNB) and cyclophanes **2** and **11**[7] and their appropriate models,



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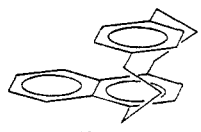

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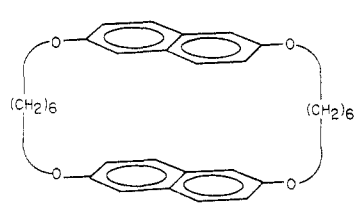


11

methyl and propyl diethers, were investigated, using UV–visible and NMR spectroscopy.[24] The results of our experiments are summarized in Table I. It can be seen that the visible charge-transfer (CT) band experiences a bathochromic shift in the cyclophanes but that a corresponding increase in the association constant K_a is apparent only for the (1,4)naphthalenophane **2**. Under such circumstances it is tempting to invoke intercalation phenomena[17] of the type depicted in **12**, a result we had considered possible due to increased cavity dimensions associated with the lips of **2**.[16] Such a consideration must be ruled out for the following reasons. (1) The complexation shifts (Δ) in the NMR,[18] i.e., the difference between the chemical shift of a proton in pure donor and the chemical shift for the same proton in pure EDA complex, are not in agreement with this idea. As can be seen in the complexation shifts for the model compounds, TNB is centered over the naphthalene ring. If intercalation had occurred in **2**, TNB for steric reasons would have been centered over the fused rings inducing increased shielding of the protons at C5,6 relative to those on the substituted ring. This is not the case; rather the *opposite* is observed; i.e., TNB seems to sit on the more substituted (with electron donating) rings. (2) Intercalation implies an enforced syn conformation of **2** with attendant downfield complexation shift of H2 and H3, but this is not observed. Rather the cyclization shift is upfield and large. (3) As noted above the chemical shift of the central methylene protons of **2**'s bridges are shifted downfield from what is expected. This is also observed in the EDA complex of **2**, which is in conflict with the shift expected for intercalation.

Recent work shows that the π-base strength of aromatic donor compounds is enhanced upon stacking rings such that their π systems overlap.[20] Substantial charge-transfer interactions have also been observed in nominally orthogonal systems such as **14** and **15**[19] which strongly resemble their stacked analogues in EDA interactions. A similar insensitivity to coplanarity has been seen in several

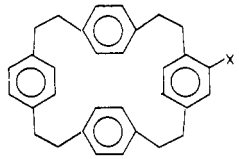
(17) (a) Odashima, K.; Itai, A.; Itaka, Y.; Koga, K. *J. Am. Chem. Soc.* **1980**, *102*, 2504. (b) Tabushi, I.; Kuroda, Y.; Kimura, Y. *Tetrahedron Lett.* **1976**, 3327.

(18) Foster, R. "Organic Charge Transfer Complexes"; Academic Press: New York, 1969.

(19) (a) Yamamura, K.; Nakazawa, T.; Murata, I. *Angew. Chem.* **1980**, *92*, 565. (b) Nakazawa, T.; Murata, I. *J. Am. Chem. Soc.* **1977**, *99*, 1996. (c) Yamamura, K.; Nakatso, K.; Nakao, K.; Nakazawa, T.; Murata, I. *Tetrahedron Lett.* **1979**, 4995, 4999.

(20) (a) Longore, D. T.; Chow, H. S. *J. Am. Chem. Soc.* **1964**, *86*, 3899; *Ibid.* **1970**, *92*, 994. (b) Hubert, A. J. *J. Chem. Soc. C* **1967**, 13. (c) Otsubo, T.; Mizogami, S.; Otsubo, I., Tozuka, Z.; Sakagami, A.; Sakata, Y.; Misumi, S. *Bull. Chem. Soc. Jpn.* **1973**, *46*, 3519. (d) Yoshida, M.; Tatemistu, H.; Sakata, Y.; Misumi, S.; Masuhara, H.; Mataga, N. *J. Chem. Soc., Chem. Commun.* **1976**, 587. (e) Tatemitsu, H.; Otsubo, T.; Sakata, Y.; Misumi, S. *Tetrahedron Lett.* **1974**, 3509. (f) Sheehan, M.; Cram, D. J. *J. Am. Chem. Soc.* **1969**, *91*, 3553.

metacyclophanes.[21] The preference for an edge-face interaction has been observed in 16[22] and is thought to be related to geometry insensitive EDA polarization effects.



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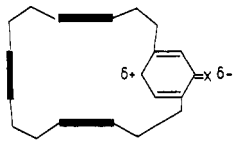

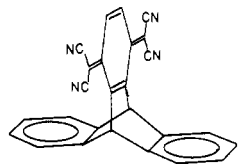

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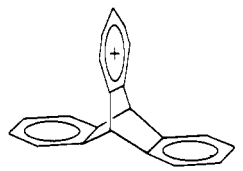

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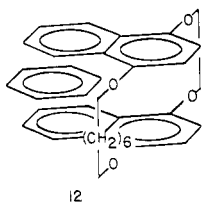
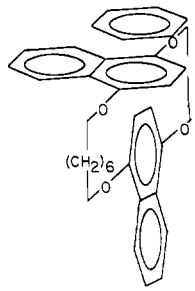
That 2 exhibits both longer wavelength and larger K_{assoc} than model compounds is consistent with the known relationship between K_{assoc} and λ in EDA complexes.[23]

The above considerations lead us to the conclusion that 2 forms a traditional π-π EDA complex with TNB as depicted in 13. The increase in K_a and hence in the π-base strength of **2a** may be interpreted as arising from a polarization interaction between the two naphthalene rings upon complexation of one with TNB.[25]



12



13

Experimental Section[31]

Naphthalenophanes 1 and 2. (a) 1,4-Bis(propynyloxy)naphthalene (**3a**) was prepared. A solution of 10.0 g (0.0625 mol) of naphthohydroquinone, 30.0 g (0.25 mol) of propargyl bromide, and 50 g of anhydrous potassium carbonate in 50 mL of anhydrous acetone was refluxed under nitrogen for 4 h. Workup afforded 9.3 g (63%) of **3a**: mp 87–89.5 °C (absolute EtOH) (lit.[2] mp 90.5–92 °C); NMR ($CDCl_3$) δ 8.21 (dd, J = 3.3, 6.3 Hz, 2 H), 7.51 (dd, J = 3.3, 6.3 Hz, 2 H), 6.83 (s, 2 H), 4.83 (d, J = 2.6 Hz, 4 H), 2.52 (t, J = 2.6 Hz, 2 H); mass spectrum, m/e 236.0842 (calcd for $C_{16}H_{12}O_2$ 236.0834).

Catalytic hydrogenation of **3a** afforded 1,4-bis(propyloxy)naphthalene, **3b**: mp 28–29 °C; NMR ($CDCl_3$) δ 8.24 (dd, J = 3, 6.6 Hz, 2 H), 7.48 (dd, J = 3, 6.6 Hz, 2 H), 6.67 (s, 2 H), 4.03 (t, J = 7 Hz, 4 H), 1.92 (sextent, 4 H), 1.12 (t, 6 H).

(b) To a suspension of 21.25 g (0.108 mol) of cupric acetate monohydrate in 200 mL of pyridine which was being stirred at 45 °C was added 5.0 g (0.021 mol) of **3a** in 50 mL of pyridine over 30 min. The mixture was stirred at 45 °C for 6 h and then poured into a concentrated hydrochloric acid/ice mixture and filtered. The resulting moist solid was triturated with acetone to afford 4.7 g (96%) of an infusible solid.

The NMR spectrum of this material in Me_2SO-d_6 showed, in addition to poorly defined bands ascribed to linear oligomers and polymers, a set of peaks (ca. 35% of total) at slightly higher field assigned to 1: (Me_2SO-d_6) δ 8.07 (dd, J = 3.2, 6.2 Hz, 1 H), 7.55 (dd, J = 3.2, 6.6 Hz, 1 H), 6.90 (s, 1 H), 5.16 (s, 2 H). The extreme insolubility of this material defeated all attempts at its isolation.

A mixture of the crude product from above (4.5 g) and 1.0 g of 10% Pd/C in 100 mL of ethyl acetate was hydrogenated (1 atm) for 10 h. The reaction mixture was diluted with 250 mL of boiling chloroform and filtered hot to afford after evaporation and trituration with boiling acetone 1.37 g (28%) of **2**: mp 203–205 °C (dichloroethane); UV ($CHCl_3$) λ_{max} 322 (ϵ 5270), 333 (5180); NMR ($CDCl_3$) δ 8.14 (dd, J = 3.3, 6.4 Hz, 4 H), 7.44 (dd, J = 3.3, 6.4 Hz, 4 H), 5.84 (s, 4 H), 3.94 (t, J = 8 Hz, 8 H), 1.75 (br m, 16 H).

Anal. Calcd for $C_{32}H_{36}O_4$: C, 79.31; H, 7.49; m/e 484.2618. Found: C, 79.29; H, 7.25; m/e 484.2603.

Diethyl 1,4-Dihydroxynaphthalene-2,3-dicarboxylate (3c). A modification of the procedure of Homeyer and Wallingford[1] was used. Diethyl phthalate (400 mL, 2.0 mol) was added to a solution of 24 g (1 mol) of sodium in 200 mL of ethanol. The mixture was stirred at 120 °C (oil bath) and 85 mL (0.5 mol) of diethyl succinate was added over 1.5 h. The mixture was then heated an additional hour, distilling 150 mL of ethanol from the reaction. The reaction mixture was cooled, acidified, and worked up to afford 79.3 g (52% yield) of **3c**: mp 58–62 °C (lit.[1] mp 62–63 °C); NMR ($CDCl_3$) δ 10.3 (br s, 2 H), 8.26 (dd, J = 8, 4 Hz, 2 H), 7.58 (dd, J = 8, 4 Hz, 2 H), 4.32 (q, J = 11 Hz, 4 H), 1.32 (t, J = 11 Hz, 6 H).

Decarboethoxylation of 3c. 1,4-Dihydroxynaphthalene-2-carboxylic Acid (4a). A solution of 24 g (0.079 mol) of **3c**, 24 g of sodium hydroxide, and 0.5 g of sodium thiosulfate in 100 mL of water was allowed to stand at room temperature for 18 h. With cooling, 70 mL of hydrochloric acid was added and the resulting tan solid was partitioned into ethyl acetate. Workup afforded 14 g (87%) of **4a**: mp 203–205 °C dec (lit.[1] mp 200 °C); NMR ($CDCl_3$) δ 11.9 (br s, 1 H), 8.62 (br s, 1 H), 8.35 (m, 2 H), 7.65 (m, 2 H), 7.28 (s, 1 H).

Methyl 1,4-Dihydroxy-2-naphthoate (4b). A solution of 30 g (0.15 mol) of **4a**, 20.9 g (0.16 mol) of ethyldiisopropylamine, and 20.8 mL (0.22 mol) of dimethyl sulfate in 200 mL of dry DMF was stirred at 85 °C for 1 h. The solution was cooled, poured into aqueous sodium bicarbonate, and worked up to afford 25.2 g (79% yield) of **4b**: mp 192–193 °C ($CHCl_3$); NMR ($CDCl_3$) δ 8.40 (d, J = 8 Hz, 1 H), 8.14 (d, J = 8, 1 H), 7.61 (m, 2 H), 7.11 (s, 1 H), 3.98 (s, 3 H).

Anal. Calcd for $C_{12}H_{10}O_4$: C, 66.05; H, 4.62; m/e 218.0578. Found: C, 65.96; H, 4.61; m/e 218.0579.

Methyl 1-Hydroxy-4-(propynyloxy)naphthalene-2-carboxylate (4c) and Methyl 1,4-Bis(propynyloxy)-naphthalene-2-carboxylate (4d). A solution of 16.85 g (0.08 mol) of **4b**, 11.1 g (0.09 mol) of propargyl bromide, and 50 g of anhydrous potassium carbonate in 200 mL of dry acetone was refluxed for 3 h. The reaction mixture was poured into excess dilute hydrochloric acid and extracted into chloroform. The chloroform solution was concentrated to 80 mL, applied to a silica gel column (5.5 × 45 cm), and eluted rapidly with hexane to provide 13.0 g (66%) of **4c**: mp 126.5–127 °C (ethanol); NMR ($CDCl_3$) δ 11.67 (s, 1 H), 8.38 (d, J = 7 Hz, 1 H), 8.19 (d, J = 7 Hz, 1 H), 7.59 (m, 2 H), 7.15 (s, 1 H), 4.83 (d, J = 2 Hz, 2 H), 3.99

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(s, 3 H), 2.54 (d, J = 2 Hz, 1 H).

Anal. Calcd for $C_{15}H_{12}O_4$: C, 70.30; H, 4.72; m/e 256.0735. Found: C, 70.04; H, 5.12; m/e 256.0736.

Elution with chloroform provided **4d**: mp 94–94.5 °C (EtOH); NMR ($CDCl_3$) δ 8.32 (m, 1 H), 8.27 (m, 1 H), 7.61 (m, 2 H), 7.31 (s, 1 H), 4.91 (d, J = 2.5 Hz, 2 H), 4.81 (d, J = 2.2 Hz, 2 H), 3.99 (s, 3 H), 2.57 (t, J = 2.5 Hz, 1 H), 2.55 (t, J = 2.2 Hz, 1 H).

Anal. Calcd for $C_{18}H_{14}O_4$: C, 73.46; H, 4.79; m/e 294.0888. Found: C, 73.21; H, 4.96; m/e 294.0890.

1,6-Bis[[4-hydroxy-3′-(carbomethoxy)naphthalenyl]oxy]hexa-2,4-diyne (5a). To a 25 °C solution of 20 g (0.10 mol) of cupric acetate monohydrate in 80 mL of pyridine was added in one portion 5.12 g (0.02 mol) of **4c**. No reaction occurred. The reaction mixture was placed in a 40 °C bath and maintained with stirring at this temperature for 4 h. The mixture was cooled, poured into excess 15% aqueous hydrochloric acid, and worked up. Trituration with hot ethanol afforded 2.63 g (52%) of **5a**: mp 198.5–199 °C (dichloroethane); NMR ($CDCl_3$) δ 8.38 (d, J = 7 Hz, 1 H), 8.17 (d, J = 7 Hz, 1 H), 7.59 (m, 2 H), 4.11 (s, 1 H), 4.90 (s, 2 H), 3.96 (s, 3 H).

Anal. Calcd for $C_{30}H_{22}O_8$: C, 70.58; H, 4.34; m/e 510.1314. Found: C, 69.67; H, 4.41; m/e 510.1313.

3-[3-[[4-hydroxy-3-(carbomethoxy)naphthalenyl]oxy]prop-1-ynyl]-3′-(carbomethoxy)-4′-oxospiro[furan-2(5*H*),1′(4′*H*)-naphthalene] (6). To a solution of 13.0 g (0.0508 mol) of **4c** in 200 mL of pyridine which was being stirred at 50 °C was added in one portion 50 g (0.25 mol) of cupric acetate monohydrate. The internal temperature rose to 60–65 °C. The reaction wa stirred at 50 °C for 3.5 h after which it was poured into excess 10% aqueous hydrochloric acid and extracted into chloroform. Concentration of the chloroform solution and elution through a short column afforded 10.4 g (80%) of **6**: mp 189–190 °C (EtOAc); IR ν_{max} ($CHCl_3$) 1730, 1713, 1665, 1660; NMR[30] ($CDCl_3$) δ 11.66 (s, 1 H), 8.36 (dd, J = 2, 7 Hz, 1 H), 8.05 (dd, J = 2, 7 Hz, 1 H), 7.96 (dd, J = 2, 7 Hz, 1 H), 7.65–7.49 (m, 3 H), 7.52 (s, 1 H), 7.44–7.32 (m, 2 H), 6.84 (s, 1 H), 6.44 (X of ABX, J = 1.7 Hz, 1 H), 5.14 (A of ABX, J = 1.7, 15.1 Hz, 1 H), 5.09 (B of ABX, J = 1.7, 15.1 Hz, 1 H), 4.68 (s, 2 H), 3.97 (s, 3 H), 3.84 (s, 3 H).

Anal. Calcd for $C_{30}H_{22}O_8$: C, 70.58; H, 4.34; m/e 510.1313. Found: C, 70.36; H, 4.60; m/e 510.1294.

1,6-Bis[[4-(propynyloxy)-3-(carbomethoxy)naphthalenyl]oxy]hexa-2,4-diyne (5b). A suspension of 1.44 g (2.82 mmol) of **5a**, 10 g (50 mmol) of propargyl bromide, and 25 g of anhydrous potassium carbonate in 50 mL of anhydrous acetone was refluxed for 5 h. Workup afforded 1.5 g (91%) of **5b**: mp 192.5–193.5 °C (C_6H_6); NMR ($CDCl_3$) δ 8.32 (m, 2 H), 8.24 (m, 2 H), 7.60 (m, 4 H), 7.25 (s, 2 H), 4.97 (s, 4 H), 4.81 (d, J = 2.4 Hz, 4 H), 3.98 (s, 6 H), 2.53 (t, J = 2.4 Hz, 2 H).

Anal. Calcd for $C_{3626}O_8$: C, 73.71; H, 4.47; m/e 586.1262. Found: C, 71.09; H, 7.44; m/e 586.1267.

Diethyl 1-(Propynyloxy)-4-hydroxynaphthalene-2,3-dicarboxylate (3d). A solution of 30.4 g (0.10 mol) of **3c**, 13.1 g (0.112 mol) of propargyl bromide, and 70 g of anhydrous potassium carbonate in 200 mL of anhydrous acetone was refluxed for 2 h to afford, after acidic workup, 2.05 g (61%) of **3d**: mp 102.5–103.5 °C (acetone); NMR ($CDCl_3$) δ 12.35 (s, 1 H), 8.45 (d, J = 8 Hz, 1 H), 8.15 (d, J = 8 Hz, 1 H), 7.65 (m, 2 H), 4.70 (d, J = 3 Hz, 2 H), 4.42 (q, J = 8 Hz, 2 H), 4.40 (q, J = 8 Hz, 2 H), 2.60 (t, J = 3 Hz, 1 H), 1.40 (t, J = 8 Hz, 3 H), 1.38 (t, J = 8 Hz, 3 H).

Anal. Calcd for $C_{19}H_{18}O_6$: C, 66.66; H, 5.30; m/e 342.1111. Found: C, 66.46; H, 5.35; m/e 342.1098.

4-(Propynyloxy)-9-hydroxynaphtho[2,3-*c*]furan-3(1*H*)-one (8a). A solution of 5.0 g (14.6 mmol) of **3d** in 50 mL of THF was added over 15 min to a suspension of 1.2 g (31.6 mmol) of lithium aluminum hydride in 50 mL of THF being stirred at −70 °C. The cooling bath was removed and the temperature was allowed to rise to 0 °C over 15 min at which point the reaction was quenched with ethyl acetate. Acidic workup afforded 3.7 g (99%) of **8a**: mp 208–209.5 °C ($CHCl_4$); IR ν_{max} (KBr) 3380, 3280, 2120, 1730, 1710; NMR (acetone-d_6) δ 9.25 (s, 1 H), 8.44 (m, 1 H), 8.31 (m, 1 H), 7.66 (m, 2 H), 5.44 (s, 2 H), 5.20 (d, J = 2.5 Hz, 2 H), 2.93 (t, J = 2.5 Hz, 1 H).

Anal. Calcd for $C_{15}H_{10}O_4$: C, 70.86; H, 3.96; m/e 254.0573. Found: C, 70.87; H, 4.32; m/e 254.0570.

Acetylation of **8a** (acetic anhydride/pyridine) afforded the acetate **8b**: mp 185–186 °C; NMR ($CDCl_3$) δ 8.55 (d, J = 8 Hz, 1 H), 7.89 (d, J = 8 Hz, 1 H), 7.72 (t, J = 8 Hz, 1 H), 7.63 (t, J = 8 Hz, 1 H), 5.34 (t, J = 2.4 Hz, 2 H), 5.29 (s, 2 H), 2.49 (s, 3 H), 2.45 (t, J = 2.4 Hz, 1 H). Anal. Calcd for $C_{17}H_{12}O_5$: m/e 296.0681; Found: m/e 296.0678.

Attempted coupling of **8b** ($Cu(OAc)_2$, pyridine) afforded instead the depropargylated monoacetate **8c** in 75% yield: mp 197–198.5 °C (dichloromethane/hexane); NMR ($CDCl_3$) δ 8.58 (br s, 1 H), 8.38 (d, J = 8 Hz, 1 H), 7.90 (d, J = 8 Hz, 1 H), 7.71 (td, J = 8.5, 1.5 Hz, 1 H), 7.60 (td, J = 8.5, 1.5 Hz, 1 H), 5.33 (s, 2 H), 2.47 (s, 3 H).

Anal. Calcd for $C_{14}H_{10}O_5$: C, 65.12; H, 3.90; m/e 258.0523. Found: C, 65.21; H, 4.10; m/e 258.0525.

2,3-Bis(hydroxymethyl)-4-(propynyloxy)naphth-1-ol (3e). Reaction of 1.56 g (4.56 mmol) of **3a** with lithium aluminum hydride (0.4 g) in THF (25 mL) at 0 °C followed by room temperature for 3 h afforded 1.03 g (88%) of **3c**: mp 119–120 °C (chloroform); NMR (acetone-d_6) δ 8.23 (m, 1 H), 8.09 (m, 1 H), 7.51 (m, 2 H), 5.23 (s, 2 H), 4.88 (s, 2 H), 4.72 (d, J = 2.6 Hz, 2 H), 3.12 (t, J = 2.6 Hz, 1 H).

Acetylation afforded the triacetate **3i**: mp 96–97.5 °C (hexane/benzene); NMR ($CDCl_3$) δ 8.18 (m, 1 H), 7.75 (m, 1 H), 7.59 (m, 2 H), 5.54 (s, 2 H), 5.30 (br s, 2 H), 4.75 (d, J = 2.5 Hz, 2 H), 2.63 (t, J = 2.5 Hz, 1 H), 2.50 (s, 3 H), 2.08 (s, 3 H), 2.03 (s, 3 H).

Anal. Calcd for $C_{21}H_{20}O_7$: C, 65.62; H, 5.24; m/e 384.1202. Found: C, 65.71; H, 5.39; m/e 384.1203.

Diethyl 4-(Propynyloxy)-1-[(2-methoxyethoxy)methoxy]naphthalene-2,3-dicarboxylate (3f). To a solution of 3.42 g (10 mmol) of **3d** in 10 mL of dichloromethane was added 5.5 mL (60 mmol) of diisopropylethylamine and 2.3 mL (20 mmol) of (2-methoxyethoxy)methyl chloride (MEM chloride). The reaction was allowed to stir for 30 min at room temperature and then worked up to afford 4.21 g (98%) of **3f** as an oil: NMR ($CDCl_3$) δ 8.27 (m, 2 H), 7.62 (m, 2 H), 5.30 (s, 2 H), 4.83 (d, J = 2.2 Hz, 2 H), 4.40 (q, J = 7 Hz, 2 H), 4.37 (q, J = 7 Hz, 2 H), 3.96 (AA′, 2 H), 3.56 (BB′, 2 H), 3.34 (s, 3 H), 2.72 (t, J = 2.2 Hz, 1 H), 1.40 (t, J = 7 Hz, 3 H), 1.38 (t, J = 7 Hz, 3 H).

Reduction of **3f** with LAH (THF, 26 °C) afforded the diol which was directly acetylated (Ac_2O/pyridine, room temperature, 1 h) to afford the diacetate **3g** in 86% yield: mp 95.6–96 °C (hexane/benzene); NMR ($CDCl_3$) δ 8.15 (m, 2 H), 7.59 (m, 2 H), 5.41 (s, 2 H), 5.43 (s, 2 H), 5.25 (s, 2 H), 4.73 (d, J = 2.2 Hz, 2 H), 4.05 (AA′, 2 H), 3.64 (BB′, 2 H), 3.41 (s, 3 H), 2.618 (t, J = 2.2 Hz, 1 H), 2.08 (s, 3 H), 2.07 (s, 3 H).

Anal. Calcd for $C_{23}H_{26}O_8$: C, 64.18; H, 6.09; m/e 430.1620. Found: C, 64.23; H, 6.18; m/e 430.1620.

3,5′-Bis(acetoxymethyl)-4,6′-bis(propynyloxy)spiro(naphthalene-2(1*H*),3′(4′*H*)-[2*H*]naphtho[1,2-*b*]pyran)-1-one (7). To a solution of 215 mg (0.5 mmol) of **3g** in 2 mL of dichloromethane being stirred in an ice bath was added 0.11 mL (1.0 mmol) of titanium tetrachloride. After 30 s, the reaction was quenched with aqueous sodium bicarbonate and partitioned into dichloromethane which was extracted with aqueous bicarbonate and brine to afford, after evaporation and trituration with methanol, 120 mg (85%) of **7**: mp 136.5–137.5 °C (MeOH); NMR ($CDCl_3$) δ 8.21 (m, 1 H), 8.09 (m, 1 H), 7.93 (d, J = 8 Hz, 1 H), 7.71 (t, J = 7 Hz, 1 H), 7.63 (d, J = 7 Hz, 1 H), 7.51 (m, 4 H), 5.38 (A of AB, J = 11.0 Hz, 1 H), 5.37 (B of AB, J = 11.0 Hz, 1 H), 5.16 (A of AB, J = 11.8 Hz, 1 H), 5.11 (B of AB, J = 11.8 Hz, 1 H), 4.70 (d, J = 2.2 Hz, 2 H), 4.67 (A of ABX, J = 15.3, 2.2 Hz, 1 H), 2.84 (m, 1 H), 2.63 (t, J = 2.2 Hz, 1 H), 2.60 (t, J = 2.2 Hz, 1 H), 2.59 (m, 1 H), 2.38 (m, 1 H), 2.20 (m, 1 H), 2.07 (s, 3 H), 2.01 (s, 3 H).

Anal. Calcd for $C_{34}H_{28}O_8$: C, 72.33; H, 5.00; m/e 564.1782. Found: C, 72.16; H, 5.26; m/e 564.1800.

Registry No. **1**, 77060-67-4; **2**, 77060-68-5; **3a**, 1025-10-1; **3b**, 77060-69-6; **3c**, 59883-07-7; **3d**, 77060-70-9; **3e**, 77060-71-0; **3f**, 77070-44-1; **3g**, 77060-72-1; **3h**, 77060-73-2; **4a**, 31519-22-9; **4b**, 77060-74-3; **4c**, 77060-75-4; **4d**, 77060-76-5; **5a**, 77060-77-6; **5b**, 77060-78-7; **6**, 77060-79-8; **7**, 77060-80-1; **8a**, 77070-45-2; **8b**, 77060-81-2; **8c**, 77060-82-3; propargyl bromide, 106-96-7; naphthohydroquinone, 571-60-8; diethyl phthalate, 84-66-2; diethyl succinate, 123-25-1; (2-methoxyethoxy)methyl chloride, 3970-21-6.