1,8,17,24-Tetraoxa[8.8](2,6)naphthalenophane-3,5,19,21-tetrayne-10,30-dicarboxylic Acid Derivatives, Novel Complexors of Aromatic Guests

Esa T. Jarvi and Howard W. Whitlock*

Contribution from the Samuel M. McElvain Laboratories of Organic Chemistry, Department of Chemistry, University of Wisconsin, Madison, Wisconsin 53706. *Received March 5, 1982*

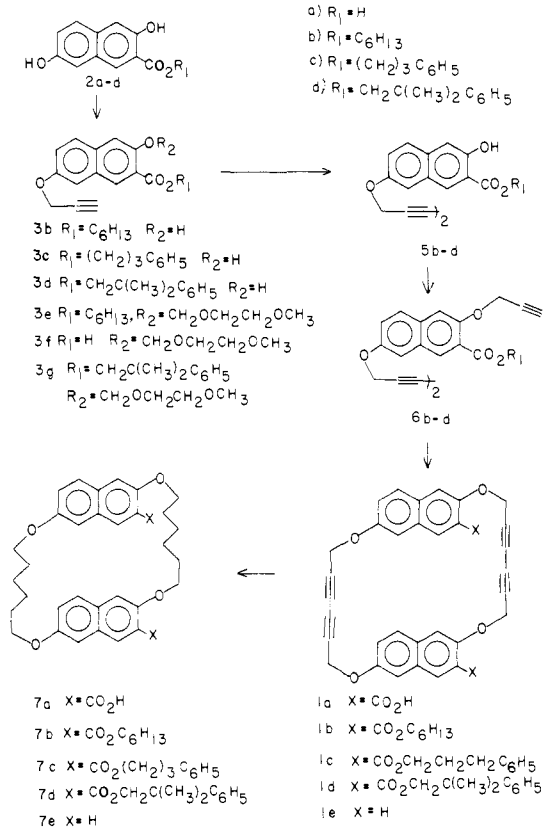
Abstract: Synthesis and complexation behavior of the title molecules are described. Study of the aromatic solvent-induced shifts of these molecules supports the contention that their large cavity can accommodate aromatic rings. The behavior of acid **1a** in water suggests that this effect is enhanced in aqueous medium, as is expected for formation of hydrophobic inclusion complexes. In contrast to the rigid naphthalenophanes (**1**), their saturated derivatives (**7**) exist in a collapsed conformation and do not incorporate aromatic guests.

We report here the synthesis and characterization of [8.8]-(2,6)naphthalenophanes of the general formula **1**. These molecules approximate open-ended boxes having a cavity with lateral dimensions of ca. 6-8 Å and vertical dimensions of 3.4-4.5 Å. We have previously published[1] our work on the related benzenophane **11a**, which has smaller lateral dimensions. It forms open-faced π-π stacking complexes rather than host-guest complexes in aqueous solution. We have reported annelation of the [8.8]-(1,4)benzenophanes to [8.8](1,4)naphthalenophane.[2,3] In this case complexation may be observed to involve classical charge-transfer interactions[2] or host-guest complexation,[3] depending on the degree of flexibility of the eight-atom bridge and solvent system employed for complexation. Of particular importance is the demonstration[3] that the [8.8](1,4)benzenophane cavity may be distended enough to permit ready passage ($\Delta G^{\ddagger} \sim 12$ kcal/mol) of an attached fused benzo substituent through it, even though it does not accommodate an aromatic guest in complexation experiments; host-guest complexation is inherently sensitive to related minor steric features of the partners.

We have reported[4b] the preparation and characterization of unfunctionalized [8.8](2,6)naphthalenophane **1e**. Aromatic solvent effects on the proton NMR spectrum of **1e** suggested host-guest complexation. The work reported herein was carried out with an eye toward clarifying some of the questions emerging from these observations: Can the [8.8](2,6)naphthalenophane system with its 28-membered ring be prepared in reasonable yield? What is the role of the rigid dioxaoctadiyne bridge in maintaining a cavity? Molecular models and experiments on **1e** suggest that host-guest complexation can occur via its cavity. Does it? We described the preparation of diyne-bridged **1a-d** and the flexibly bridged perhydro derivatives **7a-d** and their characterization vis-à-vis conformation and complexation. Our principal conclusion is that in this series the presence of the rigidly bridged cyclophane structure seems to be both a necessary and sufficient condition for host-guest complexation. For convenience, we refer informally to the bis(diyne) series as "rigid", the bis(hexamethylene)-bridged series as "floppy", and those possessing one hexadiyne and one hexamethylene bridge as "half floppy".[4a]

Synthesis. The synthetic route to **1a-d** is given in Scheme I. Starting material 3,7-dihydroxy-2-naphthoic acid (**2a**) was synthesized from 3-hydroxy-2-naphthoic acid by modification of the literature procedure.[5] Fischer esterification[6] with hexanol gave

Scheme I



mainly ether **4i**. The ester **2b** was best prepared with 1-bromohexane in dimethylformamide.[7] From this point the synthesis follows closely the previous benzenophane synthesis.[1] Alkylation of **2b** with propargyl bromide-potassium carbonate[8] in acetone proceeds with good positional selectivity to afford **3b** in 80% yield. Cupric acetate coupling[9] of **3b** in pyridine afforded **5b**, which was propargylated[8] to **6b**. Cyclization of **6b** (ca. 0.05 M) in pyridine with cupric acetate gave naphthalenophane **1b** in 49% yield. By

(1) Jarvi, E. T.; Whitlock, H. W., Jr. *J. Am. Chem. Soc.* **1980**, *102*, 657-662.
(2) Adams, S. P.; Whitlock, H. W. *J. Am. Chem. Soc.* **1982**, *104*, 1602.
(3) Adams, S. P.; Whitlock, H. W. *J. Org. Chem.* **1981**, *46*, 3474-3478.
(4) (a) The term "rigid" means having two dioxadiyne bridges; "floppy" means having two dioxahexamethylene bridges; "half floppy" means having one "rigid" and one "floppy" bridge. (b) Whitlock, B. J.; Jarvi, E. T.; Whitlock, H. W. *J. Org. Chem.* **1981**, *46*, 1832.
(5) (a) Bucherer, H. *Chem. Zentralbl.* **1903**, 42-43. (b) Schmid, J. *Chem. Ber.* **19**, *26*, 1114-1121. (c) Räisänen, K.; Lajunen, L. H. *Org. Magn. Reson.* **1978**, *11*, 12-15.
(6) (a) Liebermann, C.; Hagen, A. *Chem. Ber.* **1882**, *15*, 1427-1431. (b) Fieser, L.; Lathrop, W. *J. Am. Chem. Soc.* **1935**, *57*, 1459-1464.
(7) Alvarez, F. S.; Watt, A. N. *J. Org. Chem.* **1968**, *33*, 2143-2144.
(8) Pomeranz, U. K.; Hanson, H. J.; Schmid, H. *Helv. Chim. Acta* **1973**, *56*, 2981-2989.
(9) Frey, H. M.; Walsh, R. *Chem. Rev.* **1969**, 103-124.

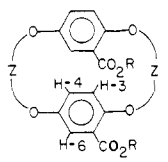
0002-7863/82/1504-7196$01.25/0

Table I. Cyclization Shifts of Naphthalenophanes[f] at Room Temperature

entry	compd	spacer[a]	solvent	proton H-1	H-4	H-5	H-6	H-8	note[b]
1	1b	r	$CDCl_3$	−0.067	−0.137	−0.022	−0.032	−0.048	
2	1b	r	Me_2SO-d_6	−0.061	−0.045	−0.069	−0.017	−0.008	
3	1b	r	$(CD_3)_2CO$	−0.124	−0.104	−0.173	−0.107	−0.083	
4	1b	r	C_6D_6	−0.359	−0.222	−0.514	−0.364	−0.105	
5	1b	r	py-d_5	−0.389	−0.324	−0.621	−0.357	−0.266	
6	6b	r	$CDCl_3$	+0.003	+0.002	+0.004	−0.039	−0.045	
7	6b	r	C_6D_6	−0.057	−0.011	+0.017	−0.082	−0.116	
8	6b	r	py-d_5	−0.026	−0.024	−0.023	−0.037	−0.060	
9	6b	r	$(CD_3)_2CO$	0	+0.002	0	−0.015	0	
10	10	f/r	$CDCl_3$	−0.086	−0.013	−0.348	−0.302	−0.222	
11	10	f/r	C_6D_6	−0.007	+0.230	−0.285	−0.239	−0.126	
12	10	f/r	py-d_5	−0.154	−0.034	−0.226	−0.142	−0.382	
13	7b	f	$CDCl_3$	−0.621	−0.599	−0.501	−0.278	−0.704	
14	7b	f	$(CD_3)_2CO$	−0.563	−0.646	−0.535	−0.253	−0.691	
15	7b	f	C_6D_6	−0.578	−0.190	−0.234	−0.256	−0.613	
16	7b	f	py-d_5	−0.537	−0.410	−0.439	−0.240	−0.680	
17	7a	f	$(CD_3)_2CO$	−0.534	−0.575	−0.524	−0.257	−0.653	
18	7a	f	$CDCl_3$	−0.618	−0.586	−0.390	−0.209	−0.665	
19	7a	f	D_2O	−0.174	−0.507	−0.704	−0.490	−0.413	*c*
20	1c	r	$CDCl_3$	−0.112		−0.074			
21	1c	r	Me_2SO-d_6	−0.096	−0.056	−0.087	0 to −0.2	0 to −0.2	
22	1c	r	py-d_5	−0.408	−0.27 to −0.51	−0.617	−0.367	−0.21 to −0.45	
23	7c	f	$CDCl_3$	−0.601	−0.580	−0.502	−0.284	−0.689	
24	1d	r	$CDCl_3$	−0.101	−0.184	−0.100	−0.120	−0.088	
25	1d	r	Me_2SO-d_6	−0.056		−0.084			
26	7d	f	$CDCl_3$	−0.671	−0.783	−0.749	−0.349	−0.754	
27	7d	f	$(CD_3)_2CO$	−0.650	−0.843	−0.741	−0.313	−0.766	
28	1c	r	$CDCl_3$	−0.132		−0.067			*d*
29	1d	r	$CDCl_3$	−0.162	−0.183	−0.054	−0.111	−0.081	*e*

[a] Spacer r is a diyne bridge; f is a saturated bridge. [b] Blank values were unresolved. [c] Extrapolated to infinite dilution. [d] −31 °C. [e] −54 °C. [f] See 7b in Scheme IV for numbering of protons.

comparison, the analogous reaction to give benzenophane **11b** proceeded[1] in 67% yield.



11a R=H Z=$CH_2C{\equiv}C\text{-}C{\equiv}C\text{-}CH_2$
11b R=C_6H_{13} Z=$CH_2\text{-}C{\equiv}C\text{-}C{\equiv}C\text{-}CH_2$
11c R=CH_3 Z=$CH_2C{\equiv}C\text{-}C{\equiv}C\text{-}CH_2$
11d R=H Z=$(CH_2)_6$
11e R=C_6H_{13} Z=$(CH_2)_6$
11f R=CH_3 Z=$(CH_2)_6$

Considering the sizes of the rings involved, 28 and 24 for the 2,6-naphthalenophanes and 1,4-benzenophanes, respectively, these cyclizations are remarkably successful at the concentrations employed. This can be at least partially ascribed to the relatively few degrees of conformational freedom associated with the rigid dioxaoctadiyne spacers. Cyclization of the flexibly bridged **9** to "half-floppy"[4a] naphthalenophane **10** proceeded in only 18% yield. The better yield for **1b** can partly be ascribed[9] to the rigidity of the precursor **6b**, compared to **9**. The naphthalenophane **1b** was subjected to isopiestic[10] molecular weight determination. All evidence supports the fact that **1b** is the cyclic monomer of **6b**. Hydrogenation of **1b** gave floppy[4a] naphthalenophane **7b**, which was saponified to **7a**. All the other naphthalenophanes, **1c**, **1d**, and **10**, have been converted to diacid **7a**, establishing that they have a common cyclic monomer structure. The saponification of benzenophane **11b** to **11a** presented problems due to solubility. The same was observed for **1b**. It was saponified to **1a**, but **1a** could not be obtained in an analytically pure form, although its 270-MHz ^1H NMR spectrum (Me_2SO-d_6) was consistent with the structure.

(10) Clark, E. P. *Ind. Eng. Chem.* **1941**, *13*, 820–822.

Conformation of Naphthalenophanes[4b]

(1) Flexibly Bridged Naphthalenophanes Exist in a Collapsed Conformation. For purposes of discussion we consider two limiting conformations of these cyclophanes: an "open" conformation characterized by a cavity and exhibiting little interaction between the opposed naphthalene rings and a "collapsed" conformation where the two naphthalene rings are in contact and there is no cavity associated with the cyclophane. Consideration of proton NMR spectra of this series of compounds in conjunction with those of the half-molecules (e.g., **4a**) and uncyclized precursors (e.g., **6b**) shows two things clearly.

The fully hydrogenated floppy naphthalenophanes exist in a collapsed conformation; each ring proton exhibits pronounced upfield shifts arising from the other aromatic ring. This is uniformly true regardless of whether one is observing esters (**7b–d**) in organic solvents, carboxylic acid (**7a**) in organic solvent or aqueous solution, or unfunctionalized naphthalenophane **7e**.[4b]

The parameter used to argue for collapsing of benzenophane **11d** is the cyclization shift, Δ_{cyc}. This was defined[1] for a given proton as $\delta_{cyclophane} - \delta_{model}$, where the model if the "half-molecule" corresponding to the cyclophane. Relevant values for naphthalenophanes **1** and **7** are contained in Table I. As a limiting example [4.4]paracyclophane has $\Delta_{cyc} = -0.30$ ppm[14] relative to *p*-xylene. (A negative Δ_{cyc} corresponds to an upfield shift on cyclization.) The slightly strained [3.3]paracyclophane[14] has $\Delta_{cyc} = -0.30$. The aromatic rings are certainly close in these examples. The Δ_{cyc} values of floppy benzenophane **11f** ranged from 0.30 to −0.17 ppm in $CDCl_3$, while inspection of Table I shows that Δ_{cyc} values for the floppy naphthalenophanes range from ca. −0.2 to −0.7 ppm. There are few literature examples of macrocyclic

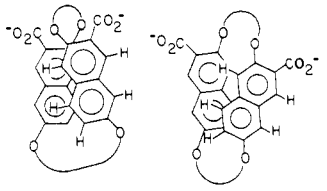
(11) (a) Murakami, Y.; Aoyama, Y.; Kida, M.; Nakano, A.; Dobashi, K.; Tran, C. D.; Matsuda, Y. *J. Chem. Soc., Perkin Trans. 1* **1979**, 1569–1567. (b) Nishikido, J.; Inazu, T.; Yoshino, T. *Bull. Chem. Soc. Jpn.* **1973**, 263–265.
(12) Kemp, D. S.; Garnst, M. E.; Harper, R. W.; Cox, D. D.; Carlson, D.; Denmark, S. *J. Org. Chem.* **1979**, *44*, 4469–4473.
(13) Odashima, K.; Itai, A.; Iitaka, Y.; Koga, K. *J. Am. Chem. Soc.* **1980**, *102*, 2504–2505.
(14) Cram, D. J.; Helgeson, R. C. *J. Am. Chem. Soc.* **1966**, *88*, 3515.

Table II. Δ_{cyc} of Naked [n.n](2,6)Naphthalenophanes

entry	compd	[n.n]	spacer	solvent	proton H-1	proton H-3	proton H-4	note
1	1e	[8.8]	rigid	$CDCl_3$	−0.046	−0.054	−0.041	*a*
2	1e	[8.8]	rigid	Me_2SO-d_6	−0.046	−0.027	−0.055	*a*
3	1e	[8.8]	rigid	py-d_5	−0.248	−0.276	−0.517	*a*
4	7e	[8.8]	floppy	$CDCl_3$	−0.339	−0.290	−0.483	*a*
5	7e	[8.8]	floppy	py-d_5	−0.288	−0.264	−0.440	*a*
6	7e	[8.8]	floppy	C_6D_6	−0.304	−0.278	−0.420	*a*
7	chiral	[3.3]	floppy	$CDCl_3$	−0.77	−0.28	−0.49	*b*
8	achiral	[2.2]	floppy	$CDCl_3$	−0.46	−0.42	−0.52	*c*
9	chiral	[2.2]	floppy	$CDCl_3$	−1.08	−0.34	−0.52	*c*

[a] From ref 4. [b] From ref 15. [c] From ref 16.

Chart I



arenophanes possessing flexible bridges with which to compare these results. It is interesting to note several [10.10]cyclophanes whose Δ_{cyc}'s are low (0 to −0.1 ppm),[11a] while several closely related [5.5]-, [6.6]-, and [7.7]biphenylophanes show Δ_{cyc}'s of −0.43, −0.36, and −0.25 ppm, respectively.[11b] It is striking that our floppy [8.8]cyclophanes have Δ_{cyc} values comparable to the two isomers of [3.3](2,6)naphthalenophane[15] wherein the rings are clearly jammed together.

In the absence of X-ray structure determinations we can only speculate as to the origin of the collapse of floppy [8.8]-naphthalenophanes. Models show, as do dynamic NMR studies of related [8.8](1,4)naphthalenophanes,[2] that at maximum distension the length of a 1,8-dioxaocta-3,5-diynyl segment is appreciably greater than that of a 1,8-dioxahexa-3,5-diynyl segment (8.7_2 Å vs. 7.6_8 Å), so it seems that the floppy naphthalenophanes do *not* exist in an all-anti extended conformation in a time-average sense.

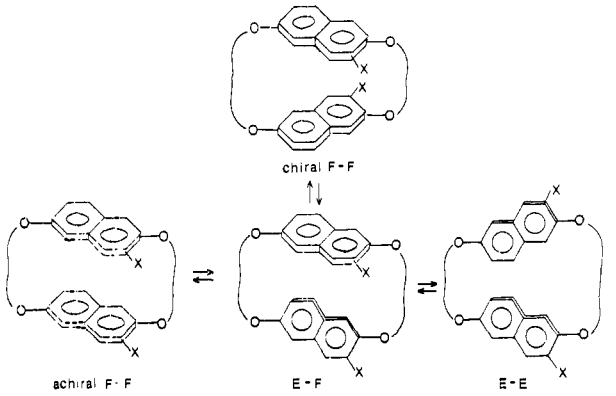
The simplest, but speculative, interpretation of this ascribes the required kink in the spacer to the planarity required for lone-pair delocalization by the oxygens into the naphthalene ring, although we cannot evaluate the contribution of this relative to (for example) simple attractive dispersion forces between the two naphthalene rings.

(2) [8.8]Naphthalenophanes Are Conformationally Mobile. None of the naphthalenophanes reported here, floppy or rigid, show indication of restricted rotation about the naphthalene 2,6 axis, at temperatures down to −60 °C in their 270-MHz proton spectra. This is consistent with our findings that one must substitute *both* sides of the 2,6-2′,6′ plane to restrict rotation about the 2,6 axis.[2] Thus the two limiting F–F conformations of Scheme II which are separately isolable in the case of [3.3]-naphthalenophanes,[15] are merely contributors to the weighted average conformation in the case of **1** and **7**.

Since the molecules **1** and **7** allow for skewing, it is possible for either the achiral or chiral F–F conformation to have the rings stacked in the skewed arrangement as in the chiral [3.3](2,6)-naphthalenophane, where two of the protons (H-1, Chart I) experience large shieldings above the other ring. It is also possible that the E–F conformers play a role in generating the high Δ_{cyc}'s of the floppy series.

(3) Rigid [8.8]Naphthalenophanes (1) Have Cavities. First, the rigid naphthalenophane **1b** in nonaromatic solvents (Table I, entries 1–3) shows rather small cyclization shifts. There is some variation in different solvents, but none of the protons of **1b** have Δ_{cyc} greater in magnitude than −0.1 ppm in *all* solvents. Models

Scheme II[a]



[a] F-F, face to face; E-E, edge to edge.

indicate a 7-Å ring–ring distance which effectively keeps the rings apart. There is probably no one preferred conformation, ust as there were none for benzenophane **11b**.

(4) Conformations of Floppy Naphthalenophanes. On hydrogenation **1b** gives **7b**. In **7b** H-8, H-6 and H-5 have Δ_{cyc} of −0.70, −0.28, and −0.50, respectively (Table I, entry 13). These are close to those of H-1, H-3, and H-4 of chiral [3.3](2,6)-naphthalenophane (entry 7, Table II): −0.77, −0.28, −0.49, respectively. This suggests that **7b** is in the collapsed F–F conformation with a ring–ring distance of 4 Å and skewed so that H-8 is above the other naphthalene ring. The skewing may relieve some strain in the bridges. The naked naphthalene **7e** (Table II, entry 4) has the aromatic rings stacked, but there seems to be little skewing, since the Δ_{cyc} values resemble the Δ_{cyc} of achiral [3.3](2,6)naphthalenophane (Table II, entry 8) more than those of the chiral one.

Acid **7a** (Table I, entry 18) derived from **7b** shows skewing in D_2O to hold the carboxyls away from each other in the collapsed F–F conformation. This skewing is in the direction opposite that seen for **7b**, so that H-5 and H-6 experience the largest upfield shifts (Chart I). The acid **7a** and hexyl ester **7b** have similar Δ_{cyc} value in $CDCl_3$ (Table I, entries 18, 13) but not identical, so the hexyl group exerts a slight perturbation on the system.

Without tables of isoshielding contours such as were available for benzenophanes,[1] it is hard to say how exact the above conclusions are. It is rather certain that the floppy [8.8](2,6)-naphthalenophanes are appreciably collapsed, and the ring–ring distance is on the order of 4 Å, although as mentioned above the interplay between F–F and F–E conformations cannot be evaluated exactly.

The half-floppy naphthalenophane **10** represents an intermediate case between **1b** and **7b**. It was synthesized in order to see whether just one rigid spacer can hold the rings apart. The Δ_{cyc} values (Table I, entry 10) indicate just what was expected: the molecule is collapsed at the "floppy" end so that only H-5, H-6, and H-8 show appreciable Δ_{cyc} values.

(15) Blank, N. E.; Haenel, M. W. *Tetrahedron Lett.* **1978**, 1425–1428.

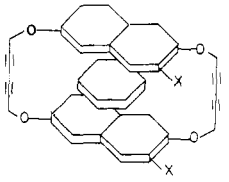
(16) Haenel, M.; Staab, H. A. *Tetrahedron Lett.* **1970**, *41*, 3585–3588.

Table III. Δ_{cyc} of Benzenophane[c,d]

entry	compd	spacer	solvent	proton H-3	proton H-4	proton H-6	note
1	11b	rigid	$CDCl_3$	−0.065	−0.002	−0.044	*a*
2	11b	rigid	py-d_5	−0.110	−0.027	−0.096	
3	11b	rigid	C_6D_6	−0.075	−0.109	−0.016	
4	11b	floppy	$CDCl_3$	−0.290	−0.320	−0.150	*a*
5	11d	floppy	D_2O	−0.203	−0.231	−0.003	*a, b*
6	11d	rigid	D_2O	−0.087	−0.026	−0.056	*a, c*

[a] From ref 1. [b] As K salt. [c] As Na salt. [d] See 11b,d in text diagram for numbering of protons.

(5) Rigid [8.8]Naphthalenophanes Effect Inclusion of Aromatic Solvents. So far, Δ_{cyc} values in nonaromatic solvents only have been discussed. The values in C_6D_6 and pyridine-d_5 (py-d_5) require a separate explanation. First, we point out that the rigid benzenophanes (Table III) have slightly larger Δ_{cyc} in py-d_5 and C_6D_6 than in $CDCl_3$, but they are not nearly as large as the Δ_{cyc} values of the floppy benzenophanes. When one looks at Δ_{cyc} for rigid naphthalenophane **1b** in C_6D_6 and py-d_5 (Table I, entries 4 and 5), they are unusually large. Some values are larger than those for the floppy **7b**. Since it is physically impossible for **1b** to collapse, we must explain these cyclization shifts in terms of some interaction with the aromatic solvent. Moreover, the interaction is *different* for the cyclophane and the model; otherwise there would not be an appreciable Δ_{cyc}. The naked naphthalenophane **1e** also shows large Δ_{cyc} values in py-d_5 (Table II, entry 3). We feel these are best explained in terms of an inclusion complex with the aromatic solvent:



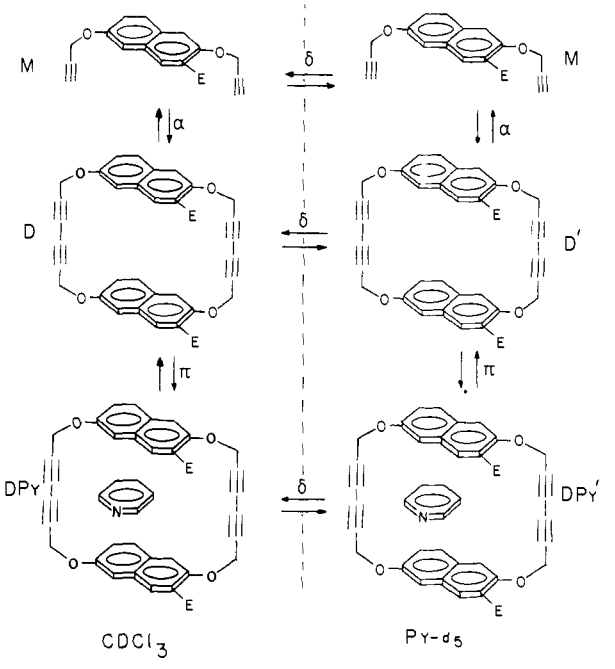
in **1b**, H-5 experiences the strongest shielding, so the pyridine is pictured in that area of the molecule. An important test of this idea lies in the behavior of the uncyclized dimeric naphthalenophane precursor **6b**, as the well-recognized complexity[17,18,34] of aromatic solvent–solute interactions prevents one from simply equating upfield shifts with inclusion complex formation. Precyclophane **6b** does not show large Δ_{cyc} (Table I, entries 7 and 8) in aromatic solvents. It has only one bridge and is not held in a rigid conformation. Also, as pointed out, the rigid benzenophanes do not have large Δ_{cyc} values in aromatic solvents. The simple explanation is that the cavity is not large enough to include aromatic solvents. It is the cooperative interaction between the two rings of the naphthalenophane in the form of the rather commodious cavity that distinguishes them from all other closely related structures we have investigated. We have already reported[1] on the failure of the benzenophane **11a** to form an inclusion complex in D_2O.

Collision complexes of aromatic solvents with steroids are well-known.[17] These are thought to be weak dipole–dipole interactions with small association constants (<10 M^{-1}).[18] They are usually studied by aromatic solvent-induced shifts (ASIS).[34]

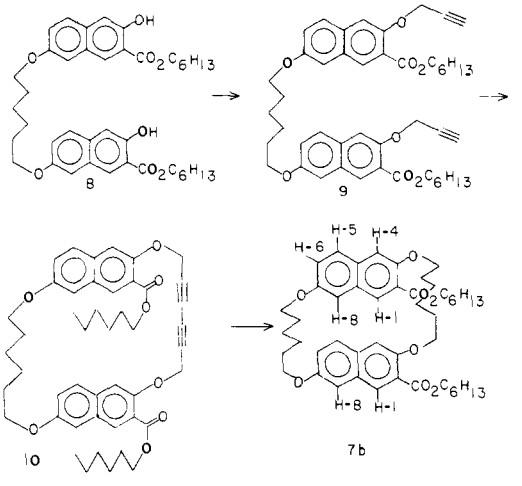
ASIS

An ASIS value for a particular proton is the difference of the chemical shift of the proton in an inert solvent ($CDCl_3$ here) and an aromatic solvent.[19] With simple molecules, the aromatic solvent forms collision complexes with one or two functional groups, and the effects are often additive. However, for **1b** or naphthalene **4b**, the ether oxygens[20] and carbonyls[17] are all potential complexation sites, and one expects observed ASIS values to be a complicated function of the molecular structure. One may, however, factor out the cavity effect on ASIS by comparison of the cyclophanes with their "half-molecule" naphthalene analogues. Substantial residual ASIS effects may then be (judiciously) interpreted as arising from host–guest complexation within the cavity, by the mechanism charge transfer[21] or other weak $\pi-\pi$ interactions.[22] The complexation model resulting from this factoring process is summarized in Scheme III.

Scheme III

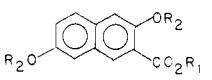


Scheme IV



The ASIS values for the naphthalenophanes are given in Table IV. A positive ASIS means an upfield shift on going to aromatic solvent. The first observation is that the aromatic solvent complexes with all compounds including the models [4]. There are probably several complexation sites, since all protons have significant ASIS values, and indeed this is expected for molecules of this complexity. The fact that some are positive and some negative is consistent with previous work[17-20] but leads to no useful interpretation. The ASIS of **1b** and **4b** in py-d_5 are of particular interest, since the model behaves quite differently from the rigid

(17) Laszlo, P. *Prog. Nucl. Magn. Reson.* **1967**, *3*.
(18) Laszlo, P.; Williams, D. H. *J. Am. Chem. Soc.* **1966**, *88*, 2799–2803.
(19) Williams, D. H. *Tetrahedron Lett.* **1965**, 2305–2311.
(20) Bowie, J. H.; Ronayne, J.; Williams, D. H. *J. Chem. Soc. B* **1967**, 535.
(21) Hanna, M. W.; Ashbaughn, A. L. *J. Phys. Chem.* **1964**, *68*, 811–816.
(22) Ewing, D. F. *Org. Magn. Reson.* **1973**, *6*, 321–325.



4a R_1=H R_2=$CH_2C{\equiv}CH$
4b R_1=C_6H_{13} R_2=$CH_2C{\equiv}CH$
4c R_1=$(CH_2)_3C_6H_5$ R_2=$CH_2C{\equiv}CH$
4d R_1=$CH_2C(CH_3)_2C_6H_5$ R_2=$CH_2C{\equiv}CH$
4e R_1=H R_2=$CH_2CH_2CH_3$
4f R_1=C_6H_{13} R_2=$CH_2CH_2CH_3$
4g R_1=$(CH_2)_3C_6H_5$ R_2=$CH_2CH_2CH_3$
4h R_1=$CH_2C(CH_3)_2C_6H_5$ R_2=$CH_2CH_2CH_3$
4i R_1=C_6H_{13} R_2=H, C_6H_{13}

naphthalenophane. All the ASIS values of **4b** are negative whereas H-5 and H-6 of **1b** have considerable positive values. H-1 of rigid cyclophane **1b** was found to have ASIS values ranging from −0.083 (at −38 °C) to +0.075 (at 82 °C) in pyridine relative to $CDCl_3$. This is not consistent with the traditional collision complex, which has ASIS values of the same sign at all temperatures. We propose that there are two effects: traditional collision complex with negative ASIS and an inclusion complex with positive ASIS values.

Naphthalene **4b** can only form traditional collision complexes, so it was studied first to see if an association constant could be obtained by known methods.[18] Williams[23] has shown that if there are several complexation sites, variable temperature curves will give average association constants (K_A) for the various complexes. The experimentally observed ASIS values ($\delta_{CDCl_3} - \delta_{py\text{-}d_5}$) of **4b** are given in Table V and Figure 1. They were used to calculate K_A by using eq 1 and 2[18] where P is the fraction of **4b** complexed,

$$P = \frac{\delta_{py\text{-}d_5}{}^T - \delta_0}{(\delta_c - \delta_0)} \quad (1)$$

$$K_A{}^T = P/(1-P) \quad (2)$$

δ_c is the chemical shift in the complex δ_0 is the chemical shift in $CDCl_3$, and $\delta_{py\text{-}d_5}{}^T$ is the chemical shift in pyridine at a particular temperature. Extrapolation of the ASIS values to 0 °K gives $\delta_c - \delta_0$. The term $\delta_c - \delta_0$ is labeled γ in Scheme III.

Scheme III has been formulated as an aid in dissecting the observed data. Naphthalene **4b** is designated by M. The symbols above the arrows (α, γ, π) designate changes in chemical shift of a given proton associated with the indicated processes: α, Δ_{cyc}, the chemical shift effect arising from cyclophane formation; γ, ASIS effects not involving the cavity; π, π-complexation effects peculiar to the cavity. Thus when **4b** is taken from chloroform (M) into pyridine (M′), a change of γ in a proton's chemical shift is observed. The cyclization shift in $CDCl_3$ is an approximation of α. The cyclization shift in py-d_5 is some combination of α and π, since both D′ and D′·py are present. But if the $\Delta_{cyc}{}^{py\text{-}d_5}$ is extrapolated to 0 °K, this should equal $\alpha + \pi$.

One observes that $\Delta_{cyc}{}^{CDCl_3}$ is temperature dependent (Table VI). This could arise from temperature-dependent conformational equilibria that can be quite impressive in cyclophanes of this type or from complexation with $CDCl_3$.[24] Extrapolation of $\Delta_{cyc}{}^{py\text{-}d_5} - \Delta_{cyc}{}^{CDCl_3}$ to 0 °K permits, with use of eq 1 and 2 calculation of a K_{assoc} of 2.2 M^{-1} for H-5 at 23 °C. The errors and assumptions built into this procedure are such that one can only meaningfully use the term "small but nonzero" to describe the interaction. The data do not justify obtaining thermodynamic parameters. The proton that experiences highest shielding by pyridine solvent is H-5, so we think pyridine is complexed in that part of the molecule. We feel these complexes form for the same reason that the floppy cyclophanes collapse.

Phenylpropyl and Neophyl Naphthalenophanes

Since **1b** is thought to form weak inclusion complexes with benzene and pyridine, the synthesis of **1c** and **1d** was undertaken

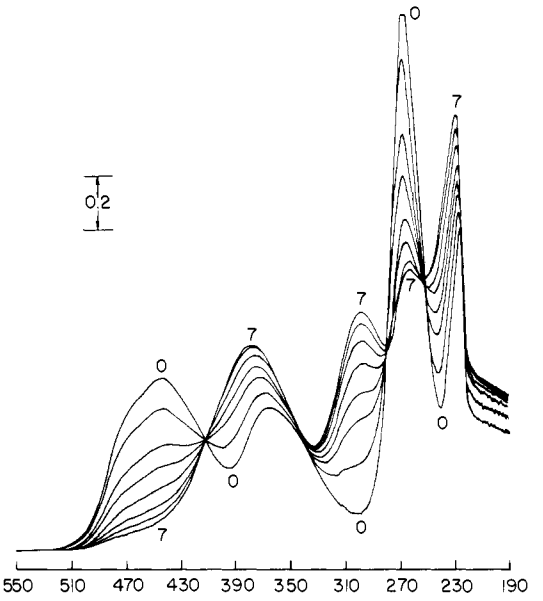
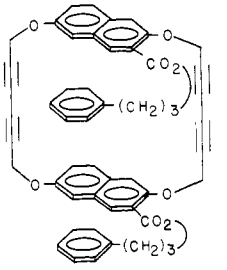


Figure 1. Differential chemical shifts ($\delta_{CDCl_3} - \delta_{py\text{-}d_5}$) vs. temperature (see Table V) for **4b**.

with the idea in mind of forming stronger intramolecular inclusion "complexes".



The synthesis of **1c** follows that of **1b** (Scheme I), but a slightly different scheme was required for **1d**. The sequence **3b** → **3e** → **3f** → **3g** → **3d** → **5d** → **6d** → **1d** → **7d** (Scheme I) was followed. The principal problem was introduction of the neophyl ester group. Due to the limited quantities of neophyl alcohol[25] available and the well-known problem of esterification of hydroxy acids,[26] esterification at the stage of **2a** was not possible. Therefore, **3c** was protected as the MEM derivative[27] **3e**, saponified to **3f**, and esterified with DCC[28] to **3g**, which was deprotected to the desired **3d**. From this point the synthesis proceeded in the usual manner. The model **4d** was prepared by esterification of **4a**.

The cyclization shifts of **1c** and **1d** (Table I, entries 20–22, 24–25) are much like those of **1b**, and there is no inclusion at room temperature of the phenyl into the cavity. It was hoped that on cooling, this might be observed. No dramatic change was observed at −31 °C (Table I, entry 28) for **1c** or at −54 °C (Table I, entry 29) for **1d**. The geminal methyl groups of **1d** apparently do not aid the molecule in reaching the conformation of the ester side chain required for insertion of the phenyl into the cavity.

The floppy naphthalenophanes **7b**, **7c**, and **7d** all show large cyclization shifts (Table I, Table VII). The largest Δ_{cyc} are seen for **7d** (entries 26, 27 Table I). This is thought to be due to four aromatic rings being in close proximity. The phenylpropyl naphthalenophane **7c** shows some temperature dependence (Table VII), but the same is seen for the hexyl ester **7b**. This may be explained by accordion-like stretching apart of the two rings at high temperatures.

(23) Ronayne, J.; Williams, D. H. *J. Chem. Soc. B* **1967**, 540–546.
(24) (a) $CHCl_3$ complexes THF: Creswell, J. A.; Allred, A. L. *J. Am. Chem. Soc.* **1963**, *85*, 1723. (b) $CHCl_3$ self-associates: Kaiser, R. *Can. J. Chem.* **1963**, *41*, 430.
(25) See Experimental Section for synthesis.
(26) Neelakantan, S.; Padmasani, R.; Seshadari, T. R. *Tetrahedron* **1965**, *21*, 3531–3536 and references therein.
(27) Corey, E. J.; Gras, J.-L.; Ulrich, P. *Tetrahedron Lett.* **1976**, 809–812.
(28) Hassner, A.; Alexanian, V. *Tetrahedron Lett.* **1978**, 4475–4478.

Table IV. ASIS ($\delta_{CDCl_3} - \delta_{Ar}$) in ppm

compd	bridge[c]	aromatic solvent	proton H-1	H-4	H-5	H-6	H-8	note
1b	r	C_6D_6	0.204	0.373	0.878	0.432	0.382	
4b	m	C_6D_6	−0.088	0.288	0.386	0.100	0.325	
7b	f	C_6D_6	−0.322	−0.216	−0.099	−0.108	0.105	
4f	m	C_6D_6	−0.279	0.193	0.168	−0.086	0.196	
1b	r	py-d_5	0.049	−0.189	0.463	0.156	−0.157	
4b	m	py-d_5	−0.273	−0.376	−0.136	−0.168	−0.375	
7b	f	py-d_5	−0.449	−0.412	−0.295	−0.261	−0.309	
4f	m	py-d_5	−0.365	−0.223	−0.233	−0.219	−0.285	
1e	r	py-d_5	−0.131	0.033	−0.350			*a*
7e	f	py-d_5	−0.322	−0.282	−0.303			*a*
7e	f	C_6D_6	0.033	−0.175	0.004			*a*
11b	r	C_6D_6	0.391	0.394	−0.218			*b*
11b	r	py-d_5	−0.174	−0.151	−0.291			*b*

[a] For protons H-1, H-3, and H-4 in that order. [b] For protons H-3, H-4, and H-6 in that order. [c] Bridge: r = rigid, f = floppy, m = model compd (no bridge).

Table V. ASIS ($\delta_{CDCl_3} - \delta_{py\text{-}d_5}$) of 4b in ppm, Internal Me_4Si Reference

T, °C	proton H-1	H-4	H-5	H-6	H-8
98	−0.187	−0.217	−0.063	−0.078	−0.209
82	−0.195	−0.230	−0.063	−0.100	−0.225
23	−0.279	−0.361	−0.115	−0.164	−0.369
−4.6	−0.303	−0.417	−0.128	−0.183	−0.432
−38	−0.378	−0.545	−0.181	−0.246	−0.573
		$\delta_c - \delta_o$			
0 (K)	−0.78	−1.32	−0.50	−0.58	−1.44
		K_A, M^{-1}			
23	0.56	0.37	0.30	0.39	0.34

Table VI. Cyclization Shifts ($\delta_{1b} - \delta_{4b}$) at Different Temperatures

T, °C	solvent	proton H-1	H-4	H-5	H-6	H-8	note
98	$CDCl_3$	−0.057	−0.105	−0.068	−0.024	−0.060	*a*
55	$CDCl_3$	−0.068	−0.131	−0.057	−0.038	−0.059	
23	$CDCl_3$	−0.083	−0.147	−0.048	−0.050	−0.057	
−4.6	$CDCl_3$	−0.095	−0.162	−0.050	−0.065	−0.065	
−38	$CDCl_3$	−0.114	−0.174	−0.044	−0.080	−0.082	
−57	$CDCl_3$	−0.149	−0.202	−0.071	−0.118	−0.085	
98	py-d_5	−0.308	−0.249	−0.466	−0.250	−0.213	
82	py-d_5	−0.304	−0.261	−0.492	−0.268	−0.221	
23	py-d_5	−0.399	−0.321	−0.619	−0.364	−0.268	
−4.6	py-d_5	−0.403	−0.325	−0.645	−0.386	−0.269	
−38	py-d_5	−0.409	−0.335	−0.664	−0.416	−0.275	
		$\Delta_{cyc}^{py\text{-}d_5} - \Delta_{cyc}^{CDCl_3}$ (= *Z*)					
98		−0.251	−0.144	−0.398	−0.226	−0.153	
82		−0.270	−0.146	−0.430	−0.243	−0.161	
23		−0.316	−0.174	−0.571	−0.314	−0.211	
−4.6		−0.304	−0.163	−0.595	−0.321	−0.203	
38		−0.295	−0.161	−0.620	−0.336	−0.193	
(0 K)				−0.83	−0.47		*a*

[a] Extrapolated.

Hydrophobic Complexation

So far we have shown that the cavity of **1** is large enough to include aromatic solvents. Diacid **1a** was not soluble enough in water to study complexation by NMR. We therefore applied Murakami's[11] technique of using a 4-cyanopyridinium iodide to study complexation. In the presence of a water-soluble [10.10]paracyclophane, they found a λ_{max} of 330 nm for the pyridinium salt charge-transfer band, indicating an environment intermediate between water and methanol. The implication was that the pyridinium salt was complexed to the cyclophane. From molecular models it is not certain whether the pyridinium iodide will fit inside **1a**, and there are the usual experimental difficulties

Table VII. Temperature Dependence of Δ_{cyc} of Floppy Naphthalenophanes in $CDCl_3$

compd	*T*, °C	proton H-1	H-4	H-5	H-6	H-8
7b	52	−0.566	−0.544	−0.495	−0.290	−0.639
7b	23	−0.621	−0.599	−0.501	−0.278	−0.704
7b	−31	−0.672	−0.656	−0.510	−0.266	−0.758
7c	52	−0.547	−0.527	−0.499	−0.291	−0.622
7c	23	−0.601	−0.615	−0.502	−0.284	−0.689
7c	−31	−0.652	−0.647	−0.515	−0.272	−0.746

associated with different spectroscopy involving compounds with large extinction coefficients. We chose 4-cyano-1-ethylpyridinium iodide,[29] which is known to have a CT band at λ_{max} 361 nm (ϵ 130) in methanol and λ_{max} 491 nm (ϵ 992) in chloroform. It has no CT band in water. In the presence of 7.8×10^{-5} M **1a**, a 7.9×10^{-5} M solution of 4-cyano-1-ethylpyridinium iodide had a λ_{max} of 357 nm (ϵ 75). The extinction coefficient of 75 is more than half of that in methanol. Assuming the pyridinium salt is 50% complexed requires a K_A of 2.5×10^4.

Furthermore, the floppy naphthalenophane **7a**, which is collapsed and is not expected to form strong inclusion complexes, produces no maximum in the spectrum of the pyridinium salt. The benzenophane **11a**, whose cavity is too small, has no effect either.

We feel the charge-transfer band observed with **1a** is real, and the microenvironment of the pyridinium salt in the complex is roughly as polar as in methanol.

Hydrophobic Complexation by ^1H NMR Spectroscopy. Since the floppy naphthalenophane **7a** is expected to form only weak complexes, these are better observed by NMR spectroscopy. It is quite soluble in water as its potassium salt.

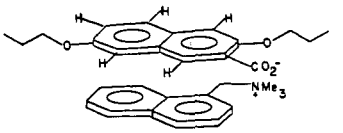
Proton NMR is a useful tool for measuring association constants.[30] However, we have experienced problems in using TSP (sodium 3-(trimethylsilyl)propionate-*2,2,3,3-d*$_4$) as an internal reference. Others[31] have expressed concern over the problem of what reference to use. The problem arises when the self-association in D_2O of trimethyl(α-methylnaphthyl)ammonium chloride (TMNAC), the guest chosen for **7a** is studied. With internal TSP as a reference, the chemical shifts of TMNAC move upfield with increasing concentration, but eventually move downfield again. This does not fit the mathematical treatment[32] usually applied

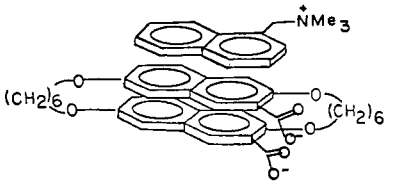
(29) Kosower, E. M. *J. Am. Chem. Soc.* **1958**, *80*, 3253–3260.
(30) Examples of the use of NMR spectroscopy for complexation studies: (a) Bergeron, R. J.; Channing, M. A.; McGovern, K. A. *J. Am. Chem. Soc.* **1978**, *100*, 2878–2883. (b) Granot, J. *J. Am. Chem. Soc.* **1978**, *100*, 1539–1548.
(31) (a) Blackburn, B. J.; Hruska, F. E.; Smith, I. C. P. *Can. J. Chem.* **1969**, *47*, 4491–4493. (b) Jones, R. A. Y.; Katritzky, A. R.; Murrell, J. N.; Sheppard, N. *J. Chem. Soc.* **1962**, 2576–2578. (c) Reference 17.
(32) (a) Barthelemy-Clovey, V.; Maurizot, J. C.; Dimicah, J. L; Sicard P. *FEBS Lett.* **1974**, *46*, 5–10. (b) Bangerter, B. W.; Chan, S. K. *J. Am. Chem. Soc.* **1969**, *91*, 3910–3921.

Table VIII. Association Constants with TMNAC

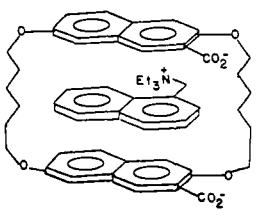
compd, data	H-4	H-5	H-6	H-8	OCH_2	OCH_2
4e, Δ, ppm	0.78	0.67	0.83	0.632	0.41	0.92
4e, *T*, K	31 ± 6	37 ± 6	28 ± 6	31 ± 8	50 ± 5	16 ± 9
7a, Δ, ppm	0.42	0.60	0.49	0.59	0.33	0.33
7a, *T*, K	195 ± 20	138 ± 10	71 ± 4	74 ± 8	160 ± 20	110 ± 10

Chart II





A



B

to self-association. With external TSP as reference, the chemical shifts of TMNAC only move upfield with increasing concentration. The magnetic susceptibility of TMNAC is not known, but its maximum effect could only account for 5% of the effect seen: over a range of 0–0.5 M TMNAC, internal TSP moves from +0.04 ppm to −0.26 ppm referenced to external TSP. Using external TSP, one obtains K_A = 0.3–1.2 M^{-1}, depending on the proton used. The self-association data of **7b** could not be calculated from the anomalous data that did not fit usual formulas[32] due to changes in curvature. A possible explanation is micellization. Application of the pinacyanol[33] diagnostic for micellization gave results consistent with some self-association of **7b** at concentrations of $\sim 10^{-2}$ M in water.

The model **4e** self-associates with K = 1–6 M^{-1}. Its association with TMNAC has association constants of 40–150 M^{-1} (Chart II and Table VIII) calculated by the equation[21] $1/\Delta_{obsd} = 1/(K\Delta C) + 1/\Delta$, where Δ_{obsd} is δ(uncomplexed) − δ(obsd) at concentration C and Δ is δ(uncomplexed) − δ(complexed). C is the concentration of **4e**.

The association constants for **7a** and TMNAC are somewhat larger (Chart II) than for the model, but this is easily explained by the increased surface area. Normally Δ gives information about the geometry of the complex, but since **7a** has significant cyclization shifts, the change on complexation (Δ) is not predictable and one cannot support arrangement A or B of Chart II or any other arrangement.

Conclusions

Ultraviolet spectra indicate that **1a** can form a stable complex with a pyridinium salt. The cyclization shifts in aromatic solvents are best interpreted in terms of inclusion of the aromatic solvents. The rigid naphthalenophane framework of **1** is suited for hydrophobic inclusion complexes. The problem of solubilizing groups has not been solved to our complete satisfaction, but when the framework of **1** is obtained in a water-soluble form, it should be an ideal candidate for NMR complexation studies, since it does not have the problems encountered with **7a**.

Experimental Section

Methodology. All ^1H NMR spectra were determined at 270 MHz on a Bruker FT WH-270 spectrometer with a memory size of 16K. Data reported in tables were obtained at concentrations of 0.05 M or lower. Chemical shifts in D_2O were extrapolated to infinite dilution. UV–visible spectra were recorded on a Cary 113 instrument. Elemental analyses were performed by Galbraith Laboratories, Knoxville, TN.

NMR Complexation Studies. A stock solution of **7a** potassium salt or **4e** potassium salt was used to dilute samples of TMNAC to volume. The concentration of TMNAC was thus varied while the other component (whose chemical shift is observed) was held constant. External sodium 3-(trimethylsilyl)propionate in an inserted capillary served as reference. Coupling constants are given in hertz.

4-Cyano-1-ethylpyridinium Iodide Complex. The compounds **1** and **7** have strong UV maxima in the 340–360-nm range. To look at the pyridinium salt, we adopted the following procedure: A solution (solution 1) 1.59×10^{-4} M in 4-cyano-1-ethylpyridinium iodide was prepared by diluting 6.36 mg of the salt to 250 mL with pH 8.0 phosphate buffer. Then a solution (solution 2) was prepared from 8.35 mg of **1a** in 0.4 mL of Me_2SO, diluted to 100 mL with pH 8.0 phosphate buffer (λ_{max} 340 nm (ε 4330)).

A sample solution 7.95×10^{-5} M in 4-cyano-1-ethylpyridinium iodide and 7.85×10^{-5} M in **1a** was prepared by mixing 5 mL of solution 1 with 5 mL of solution 2. This was run against a reference solution containing 5 mL of solution 2 and 5 mL of buffer. The absorbance of **1a** is thus subtracted out. The spectrum had λ_{max} 357 nm (ε 75).

The procedure above was repeated for **7a** (8.75×10^{-5} M in the sample and reference cell) and for **11a** itself, and in neither case was a maximum observed.

Synthesis. 3,7-Dihydroxy-2-naphthoic Acid (2a). The literature[5] procedure was followed and 3-hydroxy-2-naphthoic acid (Aldrich) was sulfonated in concentrated sulfuric acid, affording sodium 2-carboxy-3-hydroxy-7-naphthalenesulfonate (40% yield).

Anal. Calcd for $C_{11}H_7O_6SNa \cdot H_2O$: C, 42.86; H, 2.94. Found: C, 42.09; H, 3.02.

To a melt of 400 g of KOH at 200 °C in a steel beaker was added 110 g of the above sodium sulfonate. The mixture was stirred at 250–300 °C for 1.5 h. It was then poured into water and acidified with hydrochloric acid. Ethyl acetate extraction afforded 63 g (81%) of **2a** contaminated by 5% of 3-hydroxy-2-naphthoic acid (by ^2H NMR spectroscopy). This was used as such.

***n*-Hexyl 3,7-Dihydroxy-2-naphthoate (2b).** *p*-Toluenesulfonic acid catalyzed esterification of **2a** (hexanol, benzene, azetropic removal of water) produced the desired **2b** (23% yield), but the hexyl ether of **2b** was the major product (40% yield).

A mixture of 17.4 g (85 mmol) of acid **2a**, 21 g (210 mmol) of $NaHCO_3$, and 120 mL of dimethylformamide was heated with stirring at 70 °C for 1 h. To the mixture was added 14 mL (99 mmol) of 1-bromohexane, and heating was continued at 70 °C for 2 h. Chloroform workup and recrystallization afforded 12.8 g (52%) of **2b**: mp 119–121 °C (hexane–chloroform); ^1H NMR ($CDCl_3$) δ 0.29 (3 H, t, J = 7.0), 1.37 (4 H, m), 1.48 (2 H, m), 1.84 (2 H, p, J = 6.6), 4.41 (2 H, t, J = 6.6), 5.10 (1 H, s, OH-7), 7.14 (1 H, br s, H-8), 7.17 (1 H, d of d, J = 2.6, 9.4), 7.27 (1 H, s, H-4), 7.60 (1 H, d, J = 8.4), 8.30 (1 H, s, H-1), 10.4 (1 H, s, OH-3).

Anal. Calcd for $C_{17}H_{20}O_4$: C, 70.81; H, 6.99. Found: C, 71.07; H, 7.23.

***n*-Hexyl 3-Hydroxy-7-(propargyloxy)-2-naphthoate (3b).** A mixture of 15.8 g (54 mmol) of **2b**, 10.6 mL (99 mmol) of 80% propargyl bromide (Aldrich), and 8.3 g of K_2CO_3 in 115 mL of acetone was refluxed with stirring for 11 h. Workup afforded 18.7 g, which was percolated through silica gel column (benzene solvent) to afford 14.2 g (80%) of **3b**: mp 80–81 °C (hexane–chloroform); ^1H NMR ($CDCl_3$) δ 0.93 (3 H, t, J = 7), 1.39 (4 H, m), 1.49 (2 H, t, J = 6), 1.84 (2 H, p, J = 6.6), 2.56 (1 H, t, J = 2.6), 4.41 (2 H, t, J = 7.0), 4.78 (2 H, d, J = 2.2), 7.20–7.27

(33) The effect seen was a dip in the curve of dye absorbance vs. [TMNAC] concentration. See: Mukerjee, P.; Mysels, K. J. *J. Am. Chem. Soc.* **1955**, *77*, 2937–2943.

(3 H, m H-4, -6, -8), 7.61 (1 H, d, J = 8.9), 8.37 (1 H, s, H-1), 10.4 (1 H, s, OH-3).

Anal. Calcd for $C_{20}H_{22}O_4$: C, 73.60; H, 6.79. Found: C, 73.64; H, 6.91.

Cupric Acetate Coupling of *n*-Hexyl Ester 3b. Diyne 5b. A mixture of 11.3 g (35 mmol) of **3b**, 15.8 g (79 mmol) of cupric acetate monohydrate, and 180 mL of pyridine was stirred at 45 °C (bath temperature) for 6 h. The reaction mixture was poured into 0.5 L of 6 M hydrochloric acid and worked up to afford 13 g of crude product. This was percolated through a short silica gel column (benzene solvent) to afford 9.7 g (86%) of **5b**: mp 103–104 °C (hexane–chloroform); ^{1}H NMR ($CDCl_3$) δ 0.92 (6 H, t, J = 7.0), 1.38 (8 H, m), 1.48 (4 H, m), 1.83 (4 H, p, J = 7.0), 4.40 (4 H, t, J = 6.6), 4.84 (4 H, s), 7.15 (2 H, d, J = 2.6), 7.19 (2 H, d of d, J = 2.6, 8.8), 7.26 (1 H, s, H-4), 7.60 (2 H, d, J = 8.8), 8.36 (2 H, s, H-1), 10.4 (2 H, s, OH-3).

Anal. Calcd for $C_{40}H_{42}O_8$: C, 73.83; H, 6.50. Found: C, 74.08; H, 6.85.

Alkylation of *n*-Hexyl Diyne 5b to Prenaphthalenophane 6b. A mixture of 7.18 g (11 mmol) of **5b**, 3.8 mL of 80% propargyl bromide (34 mmol), and 11.3 g of K_2CO_3 in 80 mL of acetone was refluxed for 38 h. Workup afforded 8.1 g of crude product. Recrystallization (methanol–chloroform) afforded 6.1 g (74%) of **6b**: mp 120–121 °C; ^{1}H NMR ($CDCl_3$) δ 0.91 (6 H, t, J = 7), 1.36 (8 H, m), 1.48 (4 H, m), 1.80 (4 H, p, J = 7.0), 2.53 (2 H, t, J = 2.6), 4.35 (4 H, t, J = 6.6), 4.84 (4 H, d, J = 2.3), 4.85 (4 H, s), 7.20 (2 H, s, H-8), 7.22 (2 H, d of d, J = 2.6, 8.6), 7.23 (2 H, s, H-4), 7.68 (2 H, d, J = 10.3), 8.21 (2 H, s, H-1).

Anal. Calcd for $C_{46}H_{46}O_8$: C, 76.01; H, 6.38. Found: C, 75.82; H, 6.46.

Oxidative Cyclization of Precyclophane 6b to Rigid Naphthalenophase 1b. To a stirred solution of 2.56 g (13 mmol) of cupric acetate monohydrate in 90 mL of pyridine at 40 °C (bath temperature) was added over 2 h a solution of 2.75 g (3.8 mmol) of **6b** in 75 mL of pyridine. After 3-h further stirring at 40 °C the mixture was poured into 600 mL of 4 M hydrochloric acid and extracted with chloroform, affording 2.6 g of crude product.

The procedure was repeated with another 2.75 g of **6b**, and the combined crude products, 5.6 g, were percolated through a silica gel column (chloroform solvent). The highest R_f component, 2.7 g (49%), was identified as **1b**: mp 187–190 °C (chloroform); ^{1}H NMR ($CDCl_3$) δ 0.92 (6 H, t, J = 7.0), 1.36 (8 H, m), 1.46 (4 H, br t, J = 7), 1.78 (4 H, p, J = 6.6), 4.33 (4 H, t, J = 6.6), 4.87 (4 H, s), 4.95 (4 H, s), 7.188 (2 H, s), 7.197 (2 H, m, J = 2.7), 7.207 (2 H, m, J = 2.7, 9.5), 7.653 (2 H, d, J = 9.5), 8.145 (2 H, s, H-1).

Anal. Calcd for $C_{46}H_{44}O_8$: C, 76.22; H, 6.12. Found: C, 76.44; H, 6.25.

Molecular weight (isopiestic method,[39] azobenzene standard) 650; calcd for $C_{46}H_{44}O_8$, 724.8.

Saponification. A 100-mg sample of **1b** was stirred with 0.5 mL of 1 M KOH and 5 mL of THF for 93 h. Workup afforded 39 mg (51%) of acidic material. Its proton NMR spectrum (Me_2SO-d_6) was consistent with **1a**, but it was not soluble in alkali and could not be recrystallized; ^{1}H NMR (Me_2SO-d_6) δ 5.11 (4 H, s), 5.16 (4 H, s), 7.26 (2 H, d of d, J = 2.6, 9.2), 7.43 (2 H, s), 7.46 (2 H, d, J = 2.6), 7.75 (2 H, d, J = 8.8), 8.08 (2 H, s, H-1).

Hydrogenation of 1b to 1,8,17,24-Tetraoxa[8.8](2,6)-naphthalenophane-10,30-dicarboxylic Acid Di-*n*-hexyl Ester (7b). Hydrogenation (10% Pd/C, ethyl acetate, atmospheric pressure, 2 h) of **1b** afforded **7b**, an oil: ^{1}H NMR ($CDCl_3$) δ 0.93 (6 H, t, J = 7.0), 1.39 (8 H, m), 1.51 (4 H, br t, J = 7.0), 1.66–1.87 (20 H, m), 3.87 (4 H, t, J = 5.1), 4.02 (4 H, m), 4.37 (4 H, t, J = 7.0, $CO2CH_2$), 6.40 (2 H, d, J = 2.2), 6.54 (2 H, s, H-4), 6.90 (2 H, d of d, J = 2.6, 8.8), 7.10 (2 H, d, J = 8.8), 7.51 (2 H, s, H-1); MS, m/e 740.4286 (calcd for $C_{46}H_{60}O_8$, 740.4288).

Anal. Calcd for $C_{46}H_{60}O_8$: C, 74.56; H, 8.16. Found: C, 74.71; H, 8.05.

Saponification of 7b (KOH in methanol–THF) afforded **7a**: mp 176–178 °C (chloroform); ^{1}H NMR ($(CD_3)_2CO$) δ 1.69–1.88 (16 H, m), 4.00 (4 H, t, J = 5.5), 4.21 (4 H, t, J = 5.5), 6.73 (2 H, d, J = 2.6), 6.84 (2 H, s, H-4), 6.99 (2 H, d of d, J = 2.6, 8.8), 7.25 (2 H, d, J = 8.8), 7.86 (2 H, s, H-1); MS, m/e 572.2392 (calcd for $C_{34}H_{36}O_8$, 572.2410).

Anal. Calcd for $C_{34}H_{36}O_8$: C, 71.31; H, 6.34. Found: C, 71.12; H, 6.49.

Hydrogenation of *n*-Hexyl Naphthoate Diyne 5b to 8. Entry into the Semifloppy Series. Hydrogenation (10% Pd/C, C_6H_6, atmospheric pressure, 2 h) of **5b** afforded **8**: mp 114–115 °C (hexane–chloroform); ^{1}H NMR ($CDCl_3$) δ 0.92 (6 H, t J = 6.6), 1.37 (8 H, m), 1.49 (4 H, p, J = 7.3), 1.61 (4 H, m), 1.83 (4 H, p, J = 6.6), 1.87 (4 H, m), 4.07 (4 H, t, J = 6.2), 4.40 (4 H, t, J = 6.6), 7.09 (2 H, d, J = 2.6), 7.19 (2 H, d, J = 2.6, 9.2), 7.26 (2 H, s, H-4), 7.58 (2 H, d, J = 9.2), 8.34 (2 H, s, H-1), 10.4 (2 H, s, OH).

Anal. Calcd for $C_{40}H_{50}O_8$: C, 72.92; H, 7.65. Found: C, 73.11; H, 7.62.

Alkylation of 8 to Semifloppy Naphthalenophane Precursor 9. A mixture of 2.07 g (3.1 mmol) of **8**, 1.4 mL of 80% propargyl bromide (12.6 mmol), and 4.2 g of K_2CO_3 was refluxed in 30 mL of acetone for 55 h. Workup afforded 2.1 g (90%) of **9**: mp 127–128 °C (chloroform–methanol); ^{1}H NMR ($CDCl_3$) δ 0.91 (6 H, t, J = 7.0), 1.35 (8 H, m), 1.48 (4 H, m), 1.61 (4 H, m), 1.79 (4 H, p, J = 7.0), 1.90 (4 H, m), 2.53 (2 H, t, J = 2.2), 4.08 (4 H, t, J = 6.2), 4.35 (4 H, t, J = 6.6, CO_2CH_2), 4.84 (4 H, d, J = 2.2), 7.13 (2 H, d, J = 2.6), 7.20 (2 H, d of d, J = 2.6, 8.8), 7.32 (2 H, s, H-4), 7.65 (2 H, d, J = 8.8), 8.18 (2 H, s, H-1).

Anal. Calcd for $C_{46}H_{54}O_8$: C, 75.18; H, 7.41. Found: C, 74.66; H, 7.35.

Cyclization of 9 to Semifloppy Naphthalenophane 10. (1,8,17,24-Tetraoxa[8.8](2,6)naphthalenophane-3,5-diyne-10,30-dicarboxylic Acid Di-*n*-hexyl Ester). A solution of 1.60 g (2.2 mmol) of **9** in 35 mL of pyridine was added over 4 h to 1.60 g (8 mmol) of cupric acetate monohydrate in 60 mL of pyridine at 40 °C. The reaction mixture was stirred 30 min longer at 40 °C. The mixture was poured into 450 mL of 3 M hydrochloric acid and extracted with chloroform to afford 1.90 g of a brown oil. This was percolated through a silica gel column (toluene solvent) and the component of highest R_f, 289 mg (18%), was isolated and identified as **10** by NMR spectroscopy. Trituration (hexane–benzene) afforded 240 mg of **10** as a white powder: mp 82–84 °C (hexane–benzene); ^{1}H NMR ($CDCl_3$) δ 0.90 (6 H, t, J = 7), 1.34 (8 H, m), 1.64 (4 H, m), 1.76 (4 H, p, J = 7.0), 1.85 (4 H, m), 4.08 (4 H, t, J = 5.5), 4.31 (4 H, t, J = 7.0), 4.88 (4 H, s), 6.94 (2 H, d of d, J = 2.6, 8.8), 7.02 (2 H, d, J = 2.2), 7.31 (2 H, s, H-4), 7.33 (2 H, d, J = 8.1), 8.13 (2 H, s, H-1); MS, m/e 732.3642 (calcd for $C_{46}H_{52}O_8$, 732.3662).

Anal. Calcd for $C_{46}H_{52}O_8$): C, 75.38; H, 7.15. Found: C, 75.00; H, 7.14.

Hydrogenation (10% Pd/C, ethyl acetate, atmospheric pressure, 1 h) of **10** afforded **7b**, identical with authentic **7b** by NMR and MS. The new **7b** was saponified as described earlier to afford **7a**: mp 176–178 °C, mmp 176–178 °C with **7a** derived from **1b**.

3-Phenylpropyl Esters 2c to 6c. Syntheses of compounds **2c–6c** were analogous to those of *n*-hexyl esters **2b–6b**.

Reaction of 3,7-Dihydroxy-2-naphthoic acid with 1-bromo-3-phenylpropane (Aldrich) at 90 °C for 12 h afforded **2c**: mp 85–87 °C (hexane–chloroform); ^{1}H NMR ($CDCl_3$) δ 2.19 (2 H, p, J = 6.6), 2.83 (2 H, t, J = 7.3), 4.43 (2 H, t, J = 6.6), 5.00 (1 H, s, OH-3), 7.13 (1 H, d, J = 2.7), 7.14 (1 H, d of d, J = 2.4, 8.3), 7.21–7.32 (6 H, m, H-4, Ph), 7.61 (1 H, d, J = 8.4), 8.25 (1 H, s, H-1), 10.2 (1 H, s, OH-7).

Anal. Calcd for $C_{20}H_{18}O_4$: C, 74.50; H, 5.63. Found: C, 74.51; H, 5.55.

3-Phenylpropyl 3-hydroxy-7-(propargyloxy)-2-naphthoate (3c): mp 91–92 °C (hexane–chloroform); ^{1}H NMR ($CDCl_3$) δ 2.20 (2 H, p, J = 7.7), 2.57 (1 H, d, J = 2.2), 2.85 (2 H, t, J = 7), 4.44 (2 H, t, J = 6.6, CO_2CH_2), 4.79 (2 H, d, J = 2.2), 7.20–7.32 (9 H, m), 7.62 (1 H, d, J = 8.8), 8.29 (1 H, s, H-1), 10.37 (1 H, s, OH).

Anal. Calcd for $C_{23}H_{20}O_4$: C, 76.65; H, 5.59. Found: C, 76.95; H, 5.64.

3-Phenylpropyl Naphthoate Diyne 5c: mp 130–135 °C (hexane–chloroform); ^{1} NMR ($CDCl_3$) δ 2.17 (4 H, p, J = 7.0), 2.83 (4 H, t, J = 7.0), 4.42 (4 H, t, J = 6.2), 7.13 (2 H, d, J = 2.6), 7.18 (2 H, d of d, J = 2.6, 9.2), 7.21–7.33 (12 H, H-4, Ph), 7.59 (2 H, J = 8.8), 8.23 (2 H, s, H-1), 10.2 (2 H, s, OH).

Anal. Calcd for $C_{46}H_{38}O_8$: C, 76.86; H, 5.33. Found: C, 76.40; H, 5.41.

3-Phenylpropyl Ester 6c: mp 129–131 °C; ^{1}H NMR ($CDCl_3$) δ 2.13 (4 H, p, J 7.0), 2.51 (2 H, t, J = 2.5), 2.83 (4 H, t, J = 7.0), 4.38 (4 H, t, J = 6.6), 4.85 (4 H, s), 4.85 (4 H, d, J = 3.3), 7.20–7.32 (18 H, m), 7.68 (2 H, d, J = 9.1), 8.18 (2 H, s, H-1).

Anal. Calcd for $C_{52}H_{42}O_8$: C, 78.57; H, 5.32. Found: C, 78.34; H, 5.42.

1,8,17,24-Tetraoxa[8.8](2,6)naphthalenophane-3,5,19,21-tetrayne-10,30-dicarboxylic Acid Bis(3-phenylpropyl) Ester (1c). To a stirred solution of 450 mg (2.26 mmol) of cupric acetate monohydrate in 16 mL of pyridine at 44 °C was added over 45 min 500 mg (0.63 mmol) of **6c**

(34) Abbreviations used: ASIS, aromatic solvent-induced shift; TMNAC, trimethyl(α-methylnaphthyl)ammonium chloride; TSP, sodium 3-(trimethylsilyl)propionate-*2,2,3,3-d*$_4$; py = pyridine.

(35) Volhard, J. *Liebigs Ann. Chem.* **1892**, *296*, 2.

(36) Keynon, W. G.; Kaiser, E. M.; Hauser, C. R. *J. Org. Chem.* **1965**, *30*, 2937–2942.

(37) (a) Parzens, R.; Levy J. *Hebd. Seances Acad. Sci.* **189**, 1288. (b) Rothstein, E.; Saville, R. W. *J. Chem.* **1949**, 1946.

(38) Wilds, A. L.; Shunk, C. H. *J. Am. Chem. Soc.* **1948**, *70*, 2427–2428.

(39) Clark, E. P. *Ind. Eng. Chem.* **1941**, *13*, 820–822.

in 10 mL of pyridine. The reaction mixture was allowed to stir at 44 °C for 4 h further. Workup afforded 526 mg of brown foam, which was percolated through a silica gel column (chloroform solvent). The component of highest R_f, 330 mg, was identified as **1c**. Recrystallization afforded 234 mg (50%) of pure **1c**: mp 181–183 (chloroform–methanol); ^{1}H NMR δ ($CDCl_3$) 2.10 (4 H, p, J = 7.0), 2.80 (4 H, t, J = 7.0), 4.36 (4 H, t, J = 6.2), 4.88 (4 H, s), 4.95 (4 H, s), 7.18–7.32 (18 H, m), 7.62 (2 H, d, J = 9.5), 8.08 (2 H, s, H-1).

Anal. Calcd for $C_{52}H_{40}O_8$: C, 78.77; H, 5.08. Found: C, 78.72; H, 5.25.

Hydrogenation (10% Pd/C, ethyl acetate, atmospheric pressure, 40 min) of **1c** afforded **7c**, an oil: ^{1}H NMR ($CDCl_3$) δ 1.67–1.80 (16 H, m), 2.18 (4 H, p, J = 6.6), 2.84 (4 H, t, J = 7.3), 3.90 (4 H, t, J = 5.1), 4.03 (4 H, m), 4.40 (4 H, t, J = 6.6), 6.42 (2 H, q, J = 2.6), 6.90 (2 H, d of d, J = 2.6, 8.8), 7.11 (2 H, d, J = 9.2), 7.52 (2 H, s, H-1).

Anal. Calcd for $C_{52}H_{56}O_8$: C, 77.20; H, 6.98. Found: C, 77.14; H, 7.04.

Saponification (KOH, methanol–THF) of **7c** afforded **7a**: mp 174–176 °C; mmp with **7a** from **1b**, 174–176 °C.

Neophyl Ester Series. Neophyl Alcohol. Neophyl alcohol was required for preparation of naphthalenophane **1d**. Methylation[36] of ethyl phenylacetate[35] with 8 equiv of methyl iodide and 4.5 equiv of sodium hydride in DME (3 h reflux) followed by saponification afforded 2-methyl-2-phenylpropionic acid, mp 76–78 °C (lit. mp 77–78 °C),[37] in 25% yield. Borane reduction (room temperature, stirring overnight in THF) gave neophyl alcohol[37] (2-methyl-2-phenylpropanol; bp 114–116 °C (15 mm)) in 80% yield.

Protection of 3-Hydroxy-7-(propargyloxy)-2-naphthoate *n*-Hexyl Ester 3b as Its (β-Methoxyethoxy)methyl Ether[27] and Saponification to 3f. To a solution of 4.6 g (14.1 mmol) of **3b** in 80 mL of dry THF at 0 °C under nitrogen was added 10.0 mL of 1.37 M *n*-butyllithium. Immediately 2.1 mL (18.4 mmol) of distilled MEM chloride (Aldrich) was added. The mixture was stirred at 0 °C for 1 h and room temperature overnight. Workup afforded 7.1 g of an oil. Silica gel column chromatography (toluene solvent) afforded 4.6 g of an oil (mainly **3e**, $R_f^{CHCl_3}$ 0.41–0.68). The oil was saponified with 1.0 g of KOH in 20 mL of methanol for 4 h at reflux. Workup afforded 2.8 g (60% from **3b**) of **3f**, mp 90–92 °C (benzene), as the acidic product. The neutral material is believed to be the carbinol from butyllithium addition to the ester carbonyl: ^{1}H NMR ($CDCl_3$) δ 2.61 (1 H, t, J = 2.6), 3.34 (3 H, s), 3.56–3.62 (2 H, m), 3.92–3.96 (2 H, m), 4.78 (2 H, d, J = 2.6), 5.52 (2 H, s), 7.23–7.27 (2 H, m, H-6, H-8), 7.54 (1 H, s, H-4), 7.68 (1 H, d, J = 9.6), 8.51 (1 H, s, H-1), 9.02 (1 H, OH).

Anal. Calcd for $C_{18}H_{18}O_6$: C, 65.45; H, 5.49. Found: C, 65.28; H, 5.53.

Esterification of 3f to Neophyl 3-(MEMoxy)-7-(propargyloxy)-2-naphthoate (3g). The acid chloride[38] method produced only deprotected **3d** in poor yield. Hassner's[28] method gave the desired **3g**.

To a stirred solution of 2.00 g (6.06 mmol) of **3f**, 900 mg (6.0 mmol) of neophyl alcohol, 113 mg (0.9 mmol) of 4-(dimethylamino)pyridine, and 35 mL of dichloromethane was added 1.35 g (6.5 mmol) of dicyclohexyl carbodiimide in 5 mL of dichloromethane. The mixture was stirred for 3 h at room temperature and filtered and the filtrate evaporated. The residue was triturated with benzene and filtered. The benzene was washed with 1 M hydrochloric acid followed by 5% sodium bicarbonate. Evaporation of the benzene afforded 2.77 g (99%) of **3g**, an oil: ^{1}H NMR ($CDCl_3$) δ 1.48 (6 H, s), 2.56 (1 H, t, J = 2.6), 3.36 (3 H, s), 3.51–3.55 (2 H, m), 3.77–3.81 (2 H, m), 4.42 (2 H, s, CO_2CH_2), 4.78 (2 H, d, J = 2.2), 5.29 (2 H, s), 7.17 (1 H, d, J = 2.6), 7.20–7.51 (7 H, m, Ph, H-4, H-6), 7.65 (1 H, d, J = 8.8), 8.01 (1 H, s, H-1).

Anal. Calcd for $C_{28}H_{30}O_6$: C, 72.71; H, 6.53. Found: C, 72.54; H, 6.54.

Deprotection of MEM Ether 3g to Neophyl 3-Hydroxy-7-(propargyloxy)-2-naphthoate (3d). Dry hydrogen chloride was bubbled through a solution of 140 mg of **3g** in 2 mL of benzene for 4 min. Workup and recrystallization afforded 105 mg (93%) of **3d**: mp 110–112 °C (hexane–chloroform); ^{1}H NMR ($CDCl_3$) δ 1.52 (6 H, s), 2.57 (1 H, t, J = 2.6), 4.44 (2 H, s), 4.76 (2 H, d, J = 2.2), 7.12 (1 H, d, J = 2.6), 7.20 (1 H, d of d, J = 2.6, 8.8), 7.23 (1 H, s, H-4), 7.25–7.49 (5 H, m), 7.57 (1 H, d, J = 9.2), 8.19 (1 H, s, H-1), 10.27 (1 H, s, OH).

Anal. Calcd for $C_{24}H_{22}O_4$: C, 76.99; H, 5.92. Found: C, 76.43; H, 6.04.

Coupling of Neophyl 3-Hydroxy-7-(propargyloxy)-2-naphthoate (3d) to Diyne 5d. A mixture of 3.80 g (10.2 mmol) of **3d**, 5.11 g (25.5 mmol) of cupric acetate monohydrate, and 64 mL of pyridine was stirred at 40 °C for 2.5 h. Workup afforded 5.4 g of crude product, which was percolated through a short silica gel column (toluene solvent) to afford 3.6 g of solid. Recrystallization (hexane–chloroform) gave 3.3 g (87%) of **5d**: mp 161–163 °C; ^{1}H NMR ($CDCl_3$) δ 1.50 (12 H, s), 4.43 (4 H, s), 4.82 (4 H, s), 7.04 (2 H, d, J = 2.3), 7.15 (2 H, d of d, J = 2.3, 9.0), 7.20 (2 H, s, H-4), 7.24–7.47 (10 H, m), 7.54 (2 H, d, J = 9.0), 8.13 (2 H, s, H-1), 10.25 (2 H, s, OH).

Anal. Calcd for $C_{48}H_{42}O_8$: C, 76.99; H, 5.92. Found: C, 76.18; H, 5.74. No parent ion was observed in its mass spectrum.

Alkylation of Diyne 5d to Neophyl Ester 6d. A suspension of 2.62 g (3.52 mmol) of **5d** in 30 mL of acetone was refluxed with 3.1 g of K_2CO_3 and 2.0 mL (6.7 eq) of propargyl bromide (distilled from 80% solution in toluene) for 45 h. Workup afforded 2.7 g. Trituration (chloroform–methanol) gave 1.90 g (66% yield) of **6d**: mp 170–172 °C (benzene); ^{1}H NMR ($CDCl_3$) δ 1.48 (12 H, s), 2.52 (2 H, t, J = 2.2), 4.40 (4 H, s), 4.76 (4 H, d, J = 2.2), 4.85 (4 H, s), 7.13 (2 H, d, J = 2.6), 7.20 (2 H, d of d, J = 2.6, 8.8), 7.24–7.49 (12 H, m, H-4, Ph), 7.66 (2 H, d of d, J = 8.8), 8.01 (2 H, s, H-1).

Anal. Calcd for $C_{54}H_{46}O_8$: C, 78.62; H, 5.86. Found: C, 78.34; H, 5.94.

Cyclization of 6d to 1,8,17,24-Tetraoxa[8.8](2,6)naphthalenophane-3,5,19,21-tetrayne-10,30-dicarboxylic Acid Dineophyl Ester (1d). To a stirred solution of 0.84 g (4.2 mmol) of cupric acetate monohydrate in 35 mL of pyridine at 42 °C was added over 45 min 1.00 g (1.22 mmol) of **6d** in 35 mL of pyridine. The mixture was allowed to stir at 42 °C for 2 h further and then worked up to afford 1.05 g of crude product. Percolation through a silica gel column (toluene followed by 1:1 toluene–chloroform) allowed isolation of 501 mg of the highest R_f component, **1d**: mp 190 °C (chloroform–methanol); ^{1}H NMR ($CDCl_3$) δ 1.46 (12 H, s), 4.38 (4 H, s), 4.83 (4 H, s), 4.87 (4 H, s), 7.124 (2 H, d, J = 2.6), 7.13. (2 H, s, H-4), 7.183 (2 H, d of d, J = 2.2, 9.2), 7.22–7.47 (10 H, m), 7.610 (2 H, d, J = 8.8), 7.943 (2 H, s, H-1).

Anal. Calcd for $C_{54}H_{44}O_8$: C, 78.81; H, 5.63. Found: C, 79.05; H, 5.55.

Hydrogenation (10% Pd/C, ethyl acetate, atmospheric pressure, 1 h) of **1d** afforded **7d** as an oil: ^{1}H NMR ($CDCl_3$) δ 1.51 (12 H, s), 1.70–1.81 (16 H, m), 3.85 (8 H, m), 4.46 (4 H, s), 6.285 (2 H, br s, H-8), 6.366 (2 H, s, H-4), 6.824 (2 H, M, J = 2.4, 9.4), 6.843 (2 H, m, J = 9.4), 7.25–7.54 (10 H, m), 7.29 (2 H, s, H-1).

Anal. Calcd for $C_{54}H_{60}O_8$: C, 77.23; H, 7.45. Found: C, 77.58; H, 7.33.

Saponification (KOH, methanol–THF) of **7d** afforded **7a**: mp 176–178 °C (chloroform); mp 176–178 °C with **7a** derived from **1b**.

The following compounds were prepared for reference purposes (all were obtained in analytically pure form): *n*-hexyl 3,7-bis(propargyloxy)-2-naphthoate (**4b**), mp 54–55 °C; 3,7-bis(propargyloxy)-2-naphthoic acid (**4a**), mp 148–151 °C; *n*-hexyl 3,7-bis(propyloxy)-2-naphthoate (**4f**), mp 48–49 °C; 3,7-bis(propyloxy)-2-naphthoic acid (**4e**), mp 146–147 °C; 3-phenylpropyl 3,7-bis(propargyloxy-2-naphthoate (**4c**), mp 72–74 °C; 3-phenylpropyl 3,7-bis(propyloxy)-2-naphthoate (**4g**), mp 53–58 °C; neophyl 3,7-bis(propargyloxy)-2-naphthoate (**4d**), mp 82–83 °C, prepared as described under **3g**; neophyl 3,7-bis(propyloxy-2-naphthoate (**4h**), an oil.

Registry No. 1a, 83511-09-5; **1b**, 83511-08-4; **1c**, 83487-58-5; **1d**, 83487-66-5; **2a**, 83511-07-3; **2b**, 83487-45-0; **2c**, 83487-54-1; **3b**, 83487-46-1; **3c**, 83487-55-2; **3d**, 83487-63-2; **3e**, 83487-60-9; **3f**, 83487-61-0; **3g**, 83487-62-1; **4a**, 83487-69-8; **4b**, 83487-68-7; **4c**, 83487-72-3; **4d**, 83487-74-5; **4e**, 83487-71-2; **4f**, 83487-70-1; **4g**, 83487-73-4; **4h**, 83511-10-8; **4i**, 83511-06-2; **5b**, 83487-47-2; **5c**, 83487-56-3; **5d**, 83487-64-3; **6b**, 83487-48-3; **6c**, 83487-57-4; **6d**, 83487-65-4; **7a**, 83487-50-7; **7b**, 83487-49-4; **7c**, 83487-59-6; **7d**, 83487-67-6; **8**, 83487-51-8; **9**, 83487-52-9; **10**, 83487-53-0; sodium 2-carboxy-3-hydroxy-2-naphthalenesulfonate, 26513-28-0; 3-hydroxy-2-naphthoic acid, 92-70-6; hexanol, 111-27-3; 1-bromohexane, 111-25-1; propargyl bromide, 106-96-7; 1-bromo-3-phenylpropane, 637-59-2; ethyl phenylacetate, 101-97-3; 2-methyl-2-phenylpropionic acid, 826-55-1; neophyl alcohol, 2173-69-5; (β-methoxyethoxy)methyl chloride, 3970-21-6.