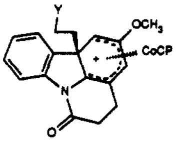
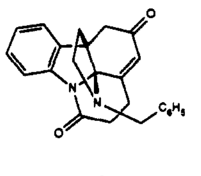
of the oxidative cyclization becomes evident through a control experiment in which the free diene ligand derived from **2d** is degraded by aged MnO_2 (CH_2Cl_2, 25 °C, 2 days) into a complex mixture of products containing only traces of **6d**. (5) It is tempting to propose that the complexes **5** (and eventually compounds **6** and **7**) arise through the intermediacy of CpCo-stabilized cations of the type **9**,[8] perhaps via **3**.[3e,9] Consistent with these notions, **9d**[6] [from **5d**: CF_3CO_2H (2.2 equiv), $CDCl_3$, <1 min] regenerates **5d** on kinetic deprotonation,[9] with regioselectivity similar to that found in analogous $Fe(CO)_3$ systems,[3,10] and **9g** (84% from **2a** via **5a**[3b–e]) results in the acetate of **2a** when attacked by hydride [$NaBH_4$, CH_3OH–THF or $(CH_3CH_2CH_2CH_2)_4NBH_4$, CH_2Cl_2)].



9d [Y = $C_6H_5CH_2NH_2^+(CF_3CO_2^-)_2$]

9g [Y = $O\overset{O}{\overset{\|}{C}}CH_3(PF_6)^-$]



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Most remarkable is, however, that standard oxidative demetalation [$CuCl_2 \cdot H_2O$, 5 equiv, $(CH_3CH_2)_3N$, 2 equiv, 1,2-dimethoxyethane–H_2O, 0 °C][11] of **5d** provides not only the expected **6d** (27%) *but also the originally desired framework of spirofusion in* ***4d*** (51%)![12] That neither is the precursor to the other can be shown by control experiments. Thus, when reexposed to the conditions employed for their generation, **6d** slowly hydrolyzes to **10**, while **4d** is stable. Judging from these observations, it appears that an intermediate (perhaps the radical cation derived from **5** by one-electron transfer)[13] is present in the form of two equilibrating species, one bearing the propellane and the other the spirofused ligand; in such a case, selective interception of either one through manipulation of the reaction conditions might be possible. Indeed, upon switching to a non-nucleophilic medium (CH_2Cl_2), with $Cp_2Fe^+PF_6^-$ as the oxidant (1.1 equiv, 25 °C, 0.2–2 h), a mixture of **4d** and **6d** in ratios near 20:1 (yield of **4d**: 74–82%) is obtained. In 1,2-dimethoxyethane, this ratio drops to 8:1, and in CH_3CN it reverses to 1:4 (yield of **6d**: 55%). Unsaturated N-functionality does not perturb the regiochemical course of the rearrangement (**5e** → **4e**, 55%; **5f** → **4f**, 37%; ratio of **4**:**6** in the crude products ca. 20:1). The potential for direct regiocontrolled conversions of **2** is indicated by the preliminary finding that **2d** undergoes $CuCl_2$ decomplexation[11] to **4d** and **6d**, in addition to its free ligand **8**.

Clearly, the reported chemistry is of relevance not only to the systems under investigation on the way to strychnine **1**, but also more generally to the problem of biasing the equilibrium between complex structural isomers of this type in favor of a desired product.

Acknowledgment. This work was supported by NIH Grant GM22479. D.B.G. thanks the Monsanto Chemical Company for the sponsorship of an ACS Organic Division Fellowship (1986–1987).

Supplementary Material Available: Experimental, spectral, and analytical data for all new compounds (32 pages). Ordering information is given on any current masthead page.

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[8] Sternberg, E. D.; Vollhardt, K. P. C. *J. Org. Chem.* **1984**, *49*, 1564–1573.

[9] Pearson, A. J.; Ham, P.; Rees, D. C. *J. Chem. Soc., Perkin Trans. I* **1982**, 489–497.

[10] Birch, A. J.; Stephenson, G. R. *J. Organomet. Chem.* **1981**, *218*, 91–104.

[11] Vollhardt, K. P. C. *Angew. Chem., Int. Ed. Engl.* **1984**, *23*, 539–556.

[12] Under these conditions **5b** and **5c** gave only unrearranged **6b** (84%) and **6c** (78%), respectively.

[13] Brammer, L.; Connelly, N. G.; Edwin, J.; Geiger, W. E.; Orpen, A. G.; Sheridan, J. B. *Organometallics* **1988**, *7*, 1259–1265 and the references therein.

First Synthesis of Aromatic Compounds Carrying Two 1-Adamantyls on Adjacent Positions: 3,4-Di-1-adamantylthiophene, *o*-Di-1-adamantylbenzene, and 4,5-Di-1-adamantylpyridazine

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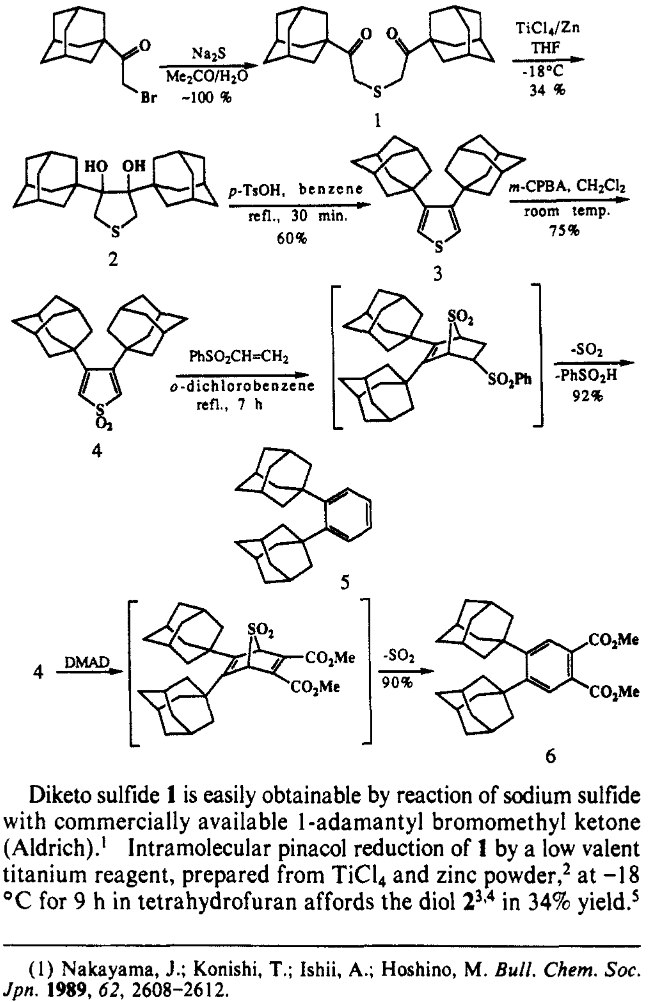
1-Adamantyl is a very bulky substituent similar to *tert*-butyl. It can be considered a kind of "tied-back" *tert*-butyl group but is far less flexible and thus might behave as a bulkier substituent than *tert*-butyl. To our knowledge, no report has appeared on the successful synthesis of five- or six-membered aromatic rings carrying two 1-adamantyl groups on adjacent positions. These would be sterically more strained than the corresponding di-*tert*-butyl-substituted compounds. Here we report the first synthesis of such molecules, 3,4-di-1-adamantylthiophene (**3**), *o*-di-1-adamantylbenzene (**5**), and 4,5-di-1-adamantylpyridazine (**8**).



Diketo sulfide **1** is easily obtainable by reaction of sodium sulfide with commercially available 1-adamantyl bromomethyl ketone (Aldrich).[1] Intramolecular pinacol reduction of **1** by a low valent titanium reagent, prepared from $TiCl_4$ and zinc powder,[2] at −18 °C for 9 h in tetrahydrofuran affords the diol **2**[3,4] in 34% yield.[5]

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[1] Nakayama, J.; Konishi, T.; Ishii, A.; Hoshino, M. *Bull. Chem. Soc. Jpn.* **1989**, *62*, 2608–2612.

[2] Mukaiyama, T.; Sato, T.; Hanna, J. *Chem. Lett.* **1973**, 1041–1044. For reviews on the carbonyl-coupling reactions using low valent titanium reagents, see: (a) McMurry, J. E. *Chem. Rev.* **1989**, *89*, 1513–1524. (b) Lenoir, D. *Synthesis* **1989**, 883–897.

[3] **2**: mp 205–220 °C dec; ^1H NMR (CD_2Cl_2) (400 MHz) δ 1.70 (s, 12 H), 2.02 (s, 6 H), 2.14 (br s, 12 H), 2.73 (d, J = 12 Hz, 2 H, thiolane ring), 3.30 (s, 2 H, OH), 3.33 (d, J = 12 Hz, 2 H, thiolane ring). The hydroxy groups of **2** are probably cis to each other.[5]

[4] Satisfactory NMR and IR spectra and combustion analyses (high-resolution mass spectra) were obtained for all new compounds.

[5] (a) Nakayama, J.; Machida, H.; Saito, R.; Hoshino, M. *Tetrahedron Lett.* **1985**, *26*, 1983–1984. (b) Nakayama, J.; Yamaoka, S.; Hoshino, M. *Ibid.* **1987**, *28*, 1799–1802. (c) Nakayama, J.; Yamaoka, S.; Hoshino, M. *Ibid.* **1988**, *29*, 1161–1164.

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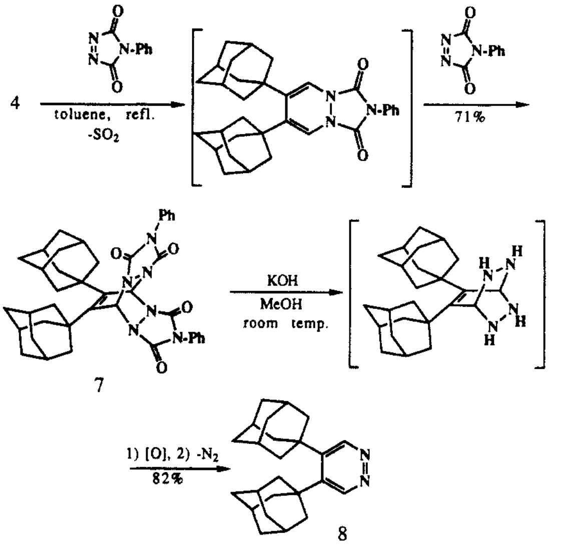
p-Toluenesulfonic acid catalyzed dehydration of **2** in refluxing benzene for 0.5 h produced the expected thiophene **3**[4,6] in 60% yield.[5a,c] Oxidation of **3** with *m*-chloroperbenzoic acid (MCPBA) in CH_2Cl_2 at room temperature gave the corresponding 1,1-dioxide **4**[4] in 75% yield.[5c]

The diels-Alder reaction of dioxide **4** with phenyl vinyl sulfone (3 equiv) in refluxing *o*-dichlorobenzene for 24 h afforded *o*-di-1-adamantylbenzene (**5**)[4,7,8] in 92% yield with cheletropic loss of sulfur dioxide and of benzenesulfonic acid from the initial adduct. Similarly, the reaction of **4** with dimethyl acetylenedicarboxylate (DMAD) in refluxing *o*-dichlorobenzene for 7 h furnishes dimethyl 4,5-di-1-admantylphthalate (**6**)[4,9] in 90% yield with extrusion of sulfur dioxide from the initial adduct.[10]

The reaction of **4** with excess 4-phenyl-1,2,4-triazoline-3,5-dione (7.5 equiv) in refluxing toluene affords the bis adduct (**7**)[4] in 72% yield. Treatment of **7** with KOH/MeOH at room temperature followed by air oxidation and nitrogen extrusion leads directly to 4,5-di-1-adamantylpyridazine (**8**)[4,11] in 82% yield.[12]



The two adamantyl substituents of **3**, **5**, and **8** are equivalent in the ^{1}H NMR spectra, which confirms that rotation about the bond from the aromatic ring to adamantyl is fast on the ^{1}H NMR time scale at room temperature. A similar conclusion is reached from ^{13}C NMR analysis.[13]

Treatment of **3** with $AlCl_3$ in CS_2 at room temperature for 6 days brings about quantitative isomerization to 2,4-di-1-adamantylthiophene.[14] Treatment of **5** under similar conditions results in exhaustive deadamantylation, although the use of benzene as the solvent gives 1-adamantylbenzene[15] in 41% yield.

Supplementary Material Available: Experimental details of the preparation of compounds **2**–**8** and spectroscopic data (^{1}H and ^{13}C NMR, IR, and UV) for these compounds (4 pages). Ordering information is given on any current masthead page.

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(6) **3**: mp 198-199 °C; ^{1}H NMR ($CDCl_3$) (400 MHz) δ 1.76 (s, 12 H), 2.10 (br s, 6 H), 2.18 (d, J = 3 Hz, 12 H), 7.20 (s, 2 H, thiophene ring); ^{13}C NMR ($CDCl_3$) (100.6 MHz) δ 29.32 (d), 36.78 (t), 38.17 (s), 44.14 (t), 122.15 (d, C_2 and C_5 of thiophene ring), 152.20 (s, C_3 and C_4 of thiophene ring); UV (hexane) λ_{max} (ε) 237 (5350), 242 nm (5350).

(7) **5**: mp 184.5-185 °C; ^{1}H NMR ($CDCl_3$) (400 MHz) δ 1.74 (d, J = 12 Hz, 6 H), 1.80 (d, J = 12 Hz, 6 H), 2.13 (s, 6 H), 2.29 (s, 12 H), 7.13 (m, 2 H, benzene ring), 7.64 (m, 2 H, benzene ring); ^{13}C NMR ($CDCl_3$) (100.6 MHz) δ 29.71 (d), 36.84 (t), 40.95 (s), 44.59 (t), 125.47 (d), 128.66 (d), 150.39 (s); UV (hexane) λ_{max} (ε) 264 nm (145).

(8) The only known isomer is the para-substituted one: Rundel, W. *Chem. Ber.* **1966**, *99*, 2707-2708.

(9) **6**: mp 192-193 °C; ^{1}H NMR ($CDCl_3$) (400 MHz) δ 1.75 (d, J = 13 Hz, 6 H), 1.80 (d, J = 13 Hz, 6 H), 2.15 (br s, 6 H), 2.26 (d, J = 2 Hz, 12 H), 3.89 (s, 6 H, CO_2Me), 7.99 (s, 2 H, benzene ring); ^{13}C NMR ($CDCl_3$) (100.6 MHz) δ 29.41 (d), 36.54 (t), 41.39 (s), 44.15 (t), 52.45 (q, Me), 127.95 (s, C_1 and C_2), 129.73 (d, C_3 and C_6), 154.46 (s, C_4 and C_5), 168.53 (s, carbonyl).

(10) For Diels-Alder reactions of thiophene 1,1-dioxides, see: Rajappa, S. in *Comprehensive Heterocyclic Chemistry*; Bird, C. W., Cheeseman, G. W. H., Eds.; Pergamon: New York, Vol. 4, Chapter 3.14.

(11) **8**: mp 257.5-258 °C; ^{1}H NMR ($CDCl_3$) (400 MHz) δ 1.75 (s, 12 H), 2.13 (s, 6 H), 2.21 (s, 12 H), 9.15 (s, 2 H, pyridazine ring); ^{13}C NMR ($CDCl_3$) (100.6 MHz) δ 29.03 (d), 36.34 (t), 39.84 (s), 43.34 (t), 147.77 (s, C_4 and C_5), 150.23 (d, C_3 and C_6).

(12) Nakayama, J.; Hirashima, A. *Heterocycles* **1989**, *29*, 1241-1242.

(13) Single-crystal structure analyses of **3** and **5** are under way by Professor F. Iwasaki of the University of Electro-Communications and will be reported elsewhere in detail. Preliminary results show that the two adamantyls of **5** are twisted with a torsion angle of 16.6° and an adamantyl-C_1-C_2 bond angle of 129.3° (bond angle adamantyl-C_2-C_3, 115.0°), and the C_1-C_2 bond is as long as 1.446 Å, while the C_4-C_5 bond is interestingly as short as 1.333 Å.

(14) Such isomerization was also observed with 3,4-di-*tert*-butylthiophene.[5c]

(15) Stetter, H.; Schwarz, M.; Hirschhorn, A. *Chem. Ber.* **1959**, *92*, 1629-1635.

Molecular Clefts. 3. The Crystal Structure of a Chiral Molecular Tweezer and Its Guest

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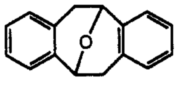
Host-guest chemistry constitutes an important area of research. Many intriguing, structurally diverse hosts have been devised and synthesized for the purpose of studying the nature of the binding interactions between host and guest and exploiting such interactions to some productive end (e.g., catalysis).[1] Molecular clefts represent a structural class of hosts that are currently of great interest, primarily due to the work of Rebek and co-workers.[2] A subset of this class of hosts comprises the molecular tweezers, currently being studied in detail by Zimmerman and co-workers.[3] In the course of our work on the development of analogues of Kagan's ether (**1**) as hosts, it became clear that it would, in principle, be possible to synthesize a new class of chiral molecular tweezers capable of binding to neutral aromatic systems.[4,5] In this paper we report the first example of a crystal structure of an unnatural chiral, but racemic, molecular tweezer and its guest.[6,7]



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(1) For recent reviews, see: (a) Dugas, H. *Bioorganic* Chemistry—*A Chemical Approach to Enzyme Action*, 2nd ed.; Springer-Verlag: New York, 1989. (b) Diederich, F. *Angew. Chem., Int. Ed. Engl.* **1988**, *27*, 362. (c) Pederson, C. J. *Ibid.* **1988**, *27*, 1021. (d) Cram, D. J. *Ibid.* **1988**, *27*, 1009. (e) Lehn, J.-M. *Ibid.* **1988**, *27*, 89. (f) *Host-Guest Complex Chemistry: Macrocycles*; Vögtle, F., Wever, E., Eds.; Springer-Verlag: New York, 1985. (g) *Synthesis of Macrocycles—The Design of Selective Complexing Agents*; Izatt, R. M., Christensen, J. J., Eds.; Progress in Macrocyclic Chemistry, Vol. 3; Wiley: New York, 1987.

(2) For a comprehensive review of the seminal contributions of Rebek and co-workers to the area of molecular clefts, see: Rebek, J., Jr. *Top. Curr. Chem.* **1988**, *149*, 190.

(3) (a) Zimmerman, S. C.; Mrksich, M.; Baloga, M. *J. Am. Chem. Soc.* **1989**, *111*, 8528. (b) Zimmerman, S. C.; Wu, W. *Ibid.* **1989**, *111*, 8054. (c) Zimmerman, S. C.; VanZyl, C. M.; Hamilton, G. S. *Ibid.* **1989**, *111*, 1373. (d) Zimmerman, S. C. *Tetrahedron Lett.* **1988**, 983. (e) Zimmerman, S. C.; VanZyl, C. M. *J. Am. Chem. Soc.* **1987**, *109*, 7894.

(4) Wilcox and co-workers have made significant contributions in their studies of Troeger's base and its analogues. Troeger's base is structurally very similar to **1**. See: (a) Webb, T. H.; Wilcox, C. S. *J. Org. Chem.* **1990**, *55*, 363. (b) Adrian, J. C., Jr.; Wilcox, C. S. *J. Am. Chem. Soc.* **1989**, *111*, 8055. (c) Sucholeiki, I.; Lynch, V.; Phan, L.; Wilcox, C. S. *J. Org. Chem.* **1988**, *53*, 98. (d) Wilcox, C. S.; Greer, L. M.; Lynch, V. *J. Am. Chem. Soc.* **1987**, *109*, 1865. (e) Larson, S. B.; Wilcox, C. S. *Acta Crystallogr., Sect. C: Cryst. Struct. Commun.* **1986**, *C42*, 224. (f) Wilcox, C. S.; Cowart, M. D. *Tetrahedron Lett.* **1986**, 5563. (g) Wilcox, C. S. *Ibid.* **1985**, 5749.

(5) (a) Harmatra, M.; Murray, T. *J. Org. Chem.* **1989**, *54*, 3761. (b) Harmata, M.; Barnes, C. L. *Tetrahedron Lett.* **1990**, 1825.

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