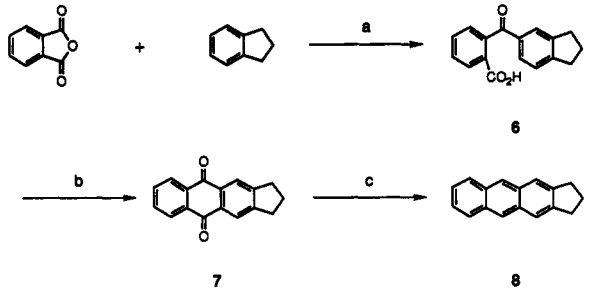
Scheme I[a]



[a] (a) $AlCl_3$, CH_2Cl_2; (b) fuming H_2SO_4; (c) aluminum cyclohexoxide, cyclohexanol.

(0.222 mol) of $KMnO_4$ in portions (*caution*-frothing may occur) during a 40-min period, and the reaction mixture was refluxed for 3 h. The reaction mixture was allowed to cool somewhat and was filtered. The collected solid (MnO_2) was refluxed in water for 6 h and filtered while hot. The combined filtrates were evaporated in vacuo to one-half volume, cooled, and acidified slowly with concentrated HCl. The resulting solid was filtered and air-dried to give 12.20 g (70%) of white crystals with mp 281–283 °C (lit.[25] mp 275 °C): IR (Nujol) 3312 (OH), 1743, 1707, 1687, 1655 (C=O) cm^{-1}; ^1H NMR (CD_3COCD_3) δ 7.45–7.85 (m, 6 H), 9.47 (s, 1 H).

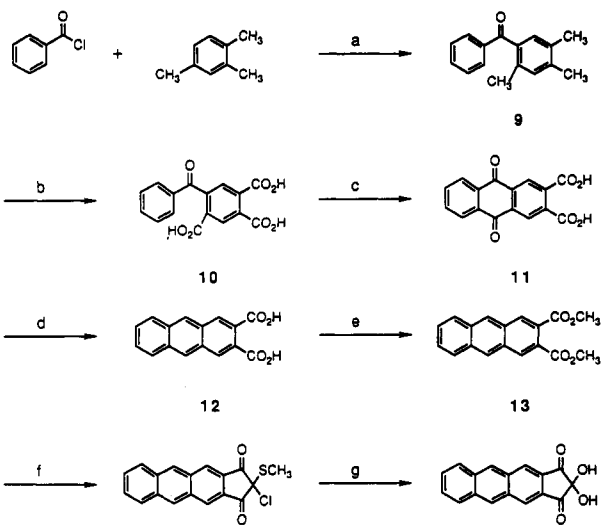
Anthraquinone-2,3-dicarboxylic Acid (11). A solution of triacid 10 (2.10 g, 6.69 mmol) in 21 g of concentrated H_2SO_4 was stirred and heated at 120 °C for 3 h and then poured onto 30 g of ice. The precipitate was filtered, washed with water, and air-dried to give 1.36 g (72%) of a pale yellow solid with mp >310 °C (lit.[31] mp 342 °C): IR (Nujol) 3166 (OH), 1638, 1618 (C=O) cm^{-1}; ^1H NMR (CD_3SOCD_3) δ 7.93–8.03 (m, 2 H), 8.20–8.30 (m, 2 H), 8.56 (s, 2 H).

Anthracene-2,3-dicarboxylic Acid (12). To 50 mL of 20% NH_4OH were added sequencially 1.00 g (3.38 mmol) of diacid 11 and then 3.75 g of activated zinc dust, and the blood-red mixture was refluxed. As soon as the color was discharged, the mixture was filtered while hot and the filtered material was refluxed with 50 mL of 20% NH_4OH for 2 h. This mixture was filtered while hot and the combined filtrates were cooled to 0 °C and acidified to pH 1 with 6 N HCl. The mixture was allowed to stand at room temperature for 1 day and then filtered to give 0.70 g (77%) of a bright yellow solid with mp >310 °C (lit.[19] mp 345 °C): IR (Nujol) 3135 (OH), 1701, 1674 (C=O) cm^{-1}; ^1H NMR (CD_3SOCD_3) δ 7.55–7.70 (m, 2 H), 8.06–8.25 (m, 2 H), 8.49 (s, 2 H), 8.79 (s, 2 H).

Dimethyl Anthracene-2,3-dicarboxylate (13). Into a refluxing mixture of diacid 12 (6.32 g, 23.8 mmol) in 80 mL of dry methanol was slowly passed HCl gas for 36 h. The mixture was cooled to 0 °C and filtered, and the collected solid was dissolved in CH_2Cl_2. The solution was washed with 5% $NaHCO_3$, dried over $MgSO_4$, and evaporated in vacuo to give 5.94 g (85%) of yellow solid with mp 149–151 °C (lit.[22] mp 151 °C): IR (deposit) 1717 (C=O) cm^{-1}; ^1H NMR ($CDCl_3$) δ 3.99 (s, 6 H), 7.53–7.63 (m, 2 H), 8.00–8.10 (m, 2 H), 8.44 (s, 2 H), 8.51 (s, 2 H).

Chloro Thioether 14. Under nitrogen, a solution of diester 13 (0.85 g, 2.89 mmol) in 4 mL of dry DMSO and 5 mL of THF was added dropwise during a 15-min period to a stirred mixture of 0.35 g (8.75 mmol) of sodium hydride (60% dispersion in mineral oil) in 4 mL of dry DMSO and 2 mL of dry THF, and the mixture was stirred at room temperature for 12 h. The THF was removed in vacuo and the residual DMSO by a simple high vacuum distillation. The dark orange solid residue was dissolved in water (25 mL) and extracted with CH_2Cl_2 (25 mL). The aqueous layer was added dropwise to 25 mL of 6 N HCl during a 45-min period. The orange precipitate was filtered and stirred for 3 h in 200 mL of CH_2Cl_2. The mixture was filtered and the filtrate was washed with water (2 × 100 mL), dried over $MgSO_4$, and evaporated in vacuo. The residue was chromatographed on silica gel with CH_2Cl_2 as eluent to give 0.30 g (33%) of a yellow-orange solid with mp 212 °C (dec): IR (deposit) 1736, 1714 (C=O) cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.51 (s, 3 H), 7.61–7.74 (m, 2 H), 8.05–8.18 (m, 2 H), 8.76 (s, 2 H), 8.81 (s, 2 H). Anal. Calcd for $C_{18}H_{11}ClO_2S$: C, 66.16; H, 3.39. Found: C, 66.40; H, 3.14.

Scheme II[a]



[a] (a) $AlCl_3$, CH_2Cl_2; (b) HNO_3; then $KMnO_4$, aqueous NaOH; (c) concd H_2SO_4; (d) Zn, 20% NH_4OH; (e) CH_3OH, HCl; (f) NaH, DMSO, THF; then HCl, H_2O; (g) aqueous dioxane.

Naphtho[*f*]ninhydrin (3).[34] Chloro thioether 14 (0.100 g, 0.30 mmol) was added in small portions during a 2-h period to a stirred solution of 9 mL of peroxide-free dioxane and 4 mL of distilled water at 95 °C. Heating was continued for 36 h and the reaction mixture was filtered while hot. Dioxane was evaporated from the filtrate in vacuo, and 10 mL of water was added. The mixture was filtered and the collected solid was air-dried to give 0.068 g (80%) of orange-red solid with mp 245 °C (dec): IR (Nujol) 3331 (OH), 1741, 1718 (C=O) cm^{-1}; ^1H NMR (CD_3SOCD_3) δ 7.59 (s, 2 H, O*H*), 7.70–7.80 (m, 2 H), 8.20–8.30 (m, 2 H), 8.90 (s, 2 H), 9.05 (s, 2 H). Anal. Calcd[37] for $C_{17}H_8O_3 \cdot 0.4H_2O$: C, 76.34; H, 3.32. Found: C, 76.26; H, 3.66.

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Registry No. 4, 135989-72-9; 6, 6321-58-0; 7, 53933-88-3; 8, 7258-46-0; 9, 52890-52-5; 10, 135989-69-4; 11, 27485-15-0; 12, 10210-28-3; 13, 56306-53-7; 14, 135989-70-7; 15, 135989-71-8; DMSO, 67-68-5; 1,4-cyclopentadienone, 13177-38-3; 2,3-bis(bromoethyl)naphthalene, 38998-33-3; indane, 496-11-7; phthalic anhydride, 85-44-9; benzoyl chloride, 98-88-4; 1,2,4-trimethylbenzene, 95-63-6.

(37) The formula $C_{17}H_8O_3$ is for the triketone formed by dehydration of 3. The elemental analysis sample was dried for an extended period with heating in vacuo before submission for analysis and dried again in vacuo just prior to analysis.

Conjugated Polyene Synthesis via Disilyl Derivatives: A Direct Access to Ostopanic Acid, a Plant Anticancer Agent, and to (6*E*)-LTB$_3$ Leukotriene

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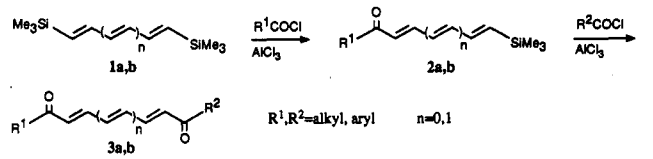
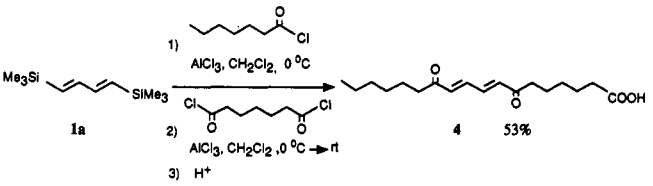
Various classes of natural products such as alcohols,[1] aldehydes,[2] ketones,[3] and acids[4] contain a conjugated

Scheme I



Scheme II

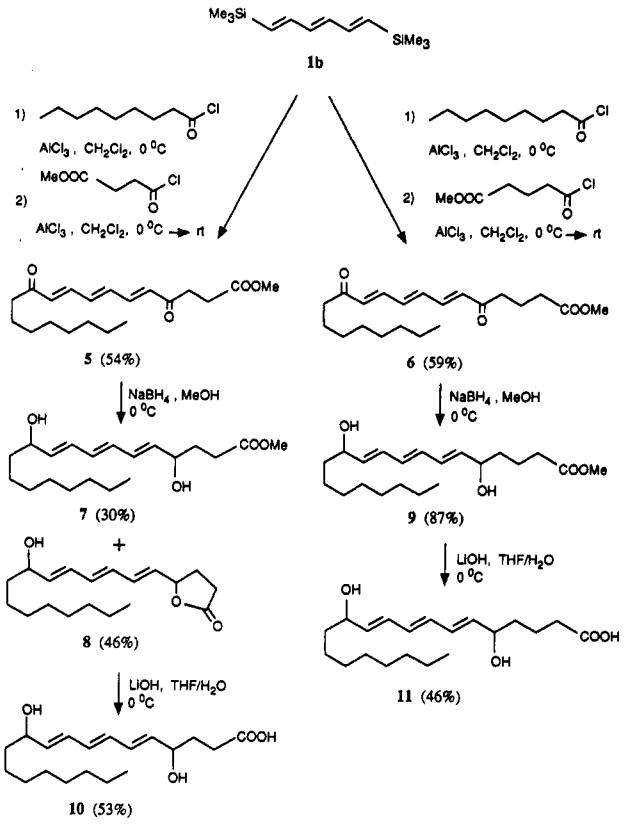


polyene structure, with a specific double-bond geometry being a requirement of primary importance for biological activity. Thus, it is not surprising that considerable effort has been expended in seeking stereoselective methods for the synthesis of such conjugated systems. In continuation of our studies on the synthesis of stereodefined products[5,6] such as alkenes[6a] or monoolefinic insect sex pheromones of *E* or *Z* configuration,[6b] 1-silylated 1,3-dienes with a *E,E* or *E,Z* configuration,[6d] or pheromones with a conjugated (*Z,E* or *E,Z*) diene structure,[6e] we have recently reported a new approach to ketosilanes and dicarbonyl compounds with a conjugated (all *E*) diene or triene structure[7] (Scheme I).

The highly chemoselective substitution of one trimethylsilyl group of **1a** (n = 0), (1*E*,3*E*)-1,4-bis(trimethylsilyl)-1,3-butadiene, or **1b** (n = 1), (1*E*,3*E*,5*E*)-1,6-bis(trimethylsilyl)-1,3,5-hexatriene, with acyl chlorides in the presence of $AlCl_3$ afforded silylated ketones **2**. Subsequent substitution of the second silyl group with another acyl chloride in the same reaction flask led to the diketone derivatives **3**.

Both compounds **2** and **3** present several interesting features owing to the possibility of elaborating the silicon and/or the carbonyl functionality for further transformations. Indeed, with this procedure, one may envisage a number of syntheses of natural compounds with a polyene structure. With the aim of illustrating the versatility of our approach and the highly efficient synthetic potential of the disilyl derivatives **1a** and **1b**, we now report their successful use in the synthesis of a series of polyunsaturated fatty acids of special interest.

Scheme III



Ostopanic acid (**4**), a cytotoxic fatty acid, recently[8] isolated in minute quantity (0.009%) from the stem and fruits of *Ostodes paniculata* Blume (Euphorbiaceae), has been shown to inhibit the growth of P-388 lymphocytic leukemia test system in vitro. To date, only one report[9] has described the total synthesis, in low yield and in several steps, of this natural product. The interesting biological activity and the *E,E*-dienyl diketone structure of this compound led us to devise a simple synthetic strategy based upon our procedure. Indeed, as outlined in Scheme II, the synthesis of ostopanic acid was conveniently achieved by a *one-pot* procedure by adding, in the first step, a dichloromethane solution of the heptanoyl chloride–$AlCl_3$ complex to an equimolar amount of **1a**. After completion of the first step and without isolation of the monosubstitution product, a solution of the pimeloyl dichloride–$AlCl_3$ complex was added, leading to compound **4** with an overall 53% yield.

Furthermore, in view of the ease of preparation of 1,6-diacylhexatrienes, illustrated above in Scheme I, the synthetic route appeared to be suited ideally to the construction of the 6*E* isomer[10] and structural analogues[11] of leukotriene B_3, which, in recent years, for its chemotactic activity, has attracted a great deal of attention from the synthetic point of view.[12-14] As depicted in Scheme III,

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(15) Separation of these diastereomers has been reported in ref 10.

the 1,6-diacyl 1,3,5-triene systems **5** and **6**[11] were accessible by the same one-pot procedure, starting from compound **1b** and employing the appropriate acyl chlorides in the two steps. Finally, completion of the synthesis required borohydride reduction of diketo esters **5** or **6** to give the intermediate dihydroxy esters **7** or **9**, whose mild alkaline hydrolysis led to (6*E*)-leukotriene B_3 (**11**)[10] or to structurally related **10**, both as a diastereomeric mixture. It is worth noting that the reduction of compound **5** led to the intermediate dihydroxy ester **7** and to the related γ-lactone **8**, whose hydrolysis gave the same product **10**.

In conclusion, we believe that the present method, providing an easy and direct access to polyunsaturated fatty acids of special interest, compares very favorably with alternative procedures. Further extension of our methodology to the synthesis of natural products possessing a tetraene or pentaene structure is currently in progress.

Experimental Section

All the acyl chlorides were commercially available (Aldrich). Merck silica gel (60, particle size 0.040–0.063 mm) was used for flash column chromatography. High performance liquid chromatography (HPLC) was performed on a Partisil-10 PAC (Whatman) column (4.6 mm × 25 cm). GC analyses were performed with a SPB-1 (methylsilicone, 30 m × 0.25 mm i.d.) capillary column. ^{1}H NMR data were measured at 200 MHz and ^{13}C NMR data at 50.3 MHz on a Varian XL 200 spectrometer. NMR spectral data taken in $CDCl_3$ used the residual $CHCl_3$ singlet at δ 7.26 as the standard for ^{1}H data and the triplet centered at δ 77.0 as the standard for ^{13}C spectra. In cases where the sample did not dissolve completely in deuteriochloroform, a few drops of deuterated dimethyl sulfoxide were added to achieve a homogeneous solution.

Ostopanic Acid (4). A CH_2Cl_2 solution (10 mL) of freshly distilled heptanoyl chloride (0.83 g, 5.6 mmol) was added, under nitrogen, to a cold (0 °C) stirred suspension of anhydrous $AlCl_3$ (0.74 g, 5.6 mmol) in 10 mL of CH_2Cl_2. The resulting mixture was allowed to stir at 0 °C for 10 min. The obtained clear solution was transferred via syringe to the addition funnel of a three-necked flask, equipped with a magnetic stirrer, and cooled at 0 °C, under nitrogen, which contained a CH_2Cl_2 solution (10 mL) of **1a** (1 g, 5 mmol). After complete addition at 0 °C, the mixture was stirred at the same temperature and the reaction was monitored by capillary GC analysis. After reaction completion (4 h), a solution (20 mL) of the pimeloyl dichloride–$AlCl_3$ complex, prepared as described above from 1.42 g (7.2 mmol) of pimeloyl dichloride and 2 g (15 mmol) of $AlCl_3$, was dropped at 0 °C under nitrogen. After the addition, the reaction mixture was slowly brought at room temperature, stirred for 1.5 h, the time required for completion, quenched with saturated aqueous NH_4Cl, and extracted with ether. The organic extracts were washed with water, dried over Na_2SO_4, and concentrated to give a solid product. Recrystallization from ether gave 0.82 g (53% overall yield) of ostopanic acid (**4**): mp 132–133 °C (lit.[9] mp 132–133 °C). The ^{1}H and ^{13}C NMR spectral data were in agreement with those reported.[8,9]

Methyl 4,11-Dioxo-5(*E*),7(*E*),9(*E*)-nonadecatrienoate (5). Following the same procedure described for the synthesis of ostopanic acid, compound **5** was prepared starting from **1b** (1 g, 4.5 mmol) and using 4.9 mmol of the nonanoyl chloride–$AlCl_3$ complex (nonanoyl chloride 0.87 g, $AlCl_3$ 0.65 g) (1 h, reaction time) in the first step and the complex deriving from methyl succinyl chloride (1 g, 6.7 mmol) and $AlCl_3$ (1.8 g, 13.5 mmol) (1.5 h, reaction time) in the second step. After the usual workup, flash chromatography on silica gel of the residue (elution with 9.5:0.5 methylene chloride–diethyl ether) afforded 0.81 g (54%) of **5**: mp 112–113 °C (from EtOH) (lit.[11] mp 108.5–109 °C). The ^{1}H NMR spectrum was in agreement with that reported.[11]

Methyl 4,11-Dihydroxy-5(*E*),7(*E*),9(*E*)-nonadecatrienoate (7) and γ-Lactone 8. A mixture of diketo ester **5** (0.8 g, 2.4 mmol) and $NaBH_4$ (0.2 g, 5.3 mmol) in 40 mL of MeOH was stirred at 0 °C. After reaction completion (2 h), the solvent was evaporated and dilute aqueous hydrochloric acid was added. Then the mixture was extracted with methylene chloride, dried, and evaporated. Flash chromatography of the residue (elution with 7:3 methylene chloride–diethyl ether) yielded 0.34 g (46%) of γ-lactone **8** as a 1:1 mixture of diastereomers (HPLC, hexane–ethyl acetate 6:4, t_R 15.1, 16.6 min, flow rate = 1 mL/min), mp 65–69 °C (from Et_2O/hexane): IR (KBr) 3344, 1772, 1648, 999 cm^{-1}; ^{1}H NMR ($CDCl_3$ + D_2O) δ 0.84 (t, *J* = 6.4 Hz, 3 H), 1.10–1.62 (m, 14 H), 1.86–2.08 (m, 1 H), 2.28–2.60 (m, 3 H), 4.06–4.22 (m, 1 H), 4.90–5.04 (m, 1 H), 5.58–5.84 (m, 2 H), 6.08–6.42 (m, 4 H); ^{13}C NMR ($CDCl_3$) δ 14.1, 22.6, 25.3, 28.5, 28.8, 29.2, 29.5, 31.8, 37.2, 72.5, 80.4, 129.7, 130.8, 132.9, 134.2, 138.0, 176.9.

Anal. Calcd for $C_{19}H_{30}O_3$: C, 74.47; H, 9.87. Found: C, 74.65; H, 9.93.

Further elution gave 0.24 g (30%) of compound **7** as a mixture (1:1) of the two diastereomers (HPLC, hexane–ethyl acetate 7:3, t_R 19.8, 22.9 min, flow rate = 1 mL/min), mp 68–71 °C (from Et_2O/hexane): IR (KBr) 3305, 1737, 1639, 989 cm^{-1}; ^{1}H NMR ($CDCl_3$ + D_2O) δ 0.84 (t, *J* = 6.3 Hz, 3 H), 1.10–1.60 (m, 14 H), 1.74–1.92 (m, 2 H), 2.39 (t, *J* = 7.3 Hz, 2 H), 3.63 (s, 3 H), 4.02–4.30 (m, 2 H), 5.55–5.80 (m, 2 H), 6.05–6.35 (m, 4 H); ^{13}C NMR ($CDCl_3$) δ 14.1, 22.6, 25.4, 29.2, 29.5, 30.0, 31.8, 37.3, 51.7, 71.6, 72.6, 130.1, 130.7, 131.9, 132.6, 135.4, 136.9, 174.3.

Anal. Calcd for $C_{20}H_{34}O_4$: C, 70.97; H, 10.12. Found: C, 71.10; H, 10.28.

4,11-Dihydroxy-5(*E*),7(*E*),9(*E*)-nonadecatrienoic Acid (10). Compounds **7** and **8** were separately hydrolyzed as follows: 2 mL of a 0.36 M lithium hydroxide aqueous solution (0.72 mmol) was added to a THF solution (5 mL) of the dihydroxy ester **7** (0.24 g, 0.71 mmol) and the mixture was stirred at 0 °C for 1 h, neutralized with dilute aqueous hydrochloric acid, and extracted with CH_2Cl_2. The extract was washed with water and dried over Na_2SO_4. Evaporation of the extract followed by crystallization yielded 0.11 g of compound **10**: mp 102–104 °C (from CH_2Cl_2/Et_2O); IR (Nujol) 3301, 3222, 1709, 1680, 988 cm^{-1}; ^{1}H NMR ($CDCl_3$ + D_2O, trace DMSO-d_6) δ 0.69 (t, *J* = 6.4 Hz, 3 H), 0.95–1.50 (m, 14 H), 1.55–1.75 (m, 2 H), 2.21 (t, *J* = 7.4 Hz, 2 H), 3.87 (q, *J* = 6.3 Hz, 1 H), 3.99 (q, *J* = 6.3 Hz, 1 H), 5.40–5.65 (m, 2 H), 5.92–6.20 (m, 4 H), ^{13}C NMR ($CDCl_3$, trace DMSO-d_6) δ 13.6, 22.0, 24.9, 28.6, 28.9, 29.0, 29.7, 31.2, 31.6, 36.9, 70.3, 71.3, 128.92, 128.95 (diastereomer), 129.38, 129.41 (diastereomer), 131.1, 131.7, 135.8, 137.1, 175.3.

Anal. Calcd for $C_{19}H_{32}O_4$: C, 70.33; H, 9.94. Found: C, 70.08; H, 10.06.

The hydrolysis of compound **8** was performed in a similar manner, starting from 0.34 g (1.11 mmol) of **8** and 1.11 mmol of LiOH solution (3 mL, 0.37 M), leading, after crystallization, to 0.20 g of **10**. Taking also into account the amount (0.11 g) of compound **10** deriving from the hydrolysis of compound **7**, the overall yield was 53%.

Methyl 5,12-Dioxo-6(*E*),8(*E*),10(*E*)-eicosatrienoate (6). Compound **6** was prepared as described for compound **5**, starting from 4.5 mmol of **1b** and using the complex deriving from methyl glutaryl chloride (1.1 g, 6.7 mmol) and $AlCl_3$ (1.8 g, 13.5 mmol) in the second step. Flash chromatography of the residue afforded 0.92 g (59%) of **6**: mp 126–127 °C (from EtOH) (lit.[11] mp 122–122.5 °C). The spectral data (^{1}H and ^{13}C NMR) were in agreement with those reported.[10,11]

Methyl 5,12-Dihydroxy-6(*E*),8(*E*),10(*E*)-eicosatrienoate (9). Sodium borohydride reduction of diketo ester **6** (0.5 g, 1.43 mmol) yielded **9**[10] (0.44 g, 87%) as a waxy residue, sufficiently pure for further reaction, as evidenced by HPLC (99% chemical purity, a mixture 1:1 of diastereomers, ethyl acetate:hexane 1:1 as eluent, t_R 10.9, 12.9 min, flow rate = 1 mL/min).[15] ^{1}H NMR ($CDCl_3$ + D_2O) δ 0.85 (t, *J* = 6.4 Hz, 3 H), 1.12–1.42 (m, 12 H), 1.45–1.82 (m, 6 H), 2.33 (t, *J* = 7 Hz, 2 H), 3.64 (s, 3 H), 4.03–4.20 (m, 2 H), 5.55–5.85 (m, 2 H), 6.10–6.40 (m, 4 H).

(6*E*)-LTB$_3$ (11). After alkaline hydrolysis of compound **9** (0.43 g, 1.22 mmol) with an LiOH solution and usual workup, the residue was purified by crystallization, and 0.19 g of **11**[10] (46%) was obtained: mp 101–103 °C (from CH_2Cl_2/Et_2O); ^{1}H NMR ($CDCl_3$ + D_2O, trace DMSO-d_6) δ 0.80 (t, *J* = 6.3 Hz, 3 H), 1.10–1.35 (m, 12 H), 1.40–1.75 (m, 6 H), 2.25 (t, *J* = 7.3 Hz, 2 H), 3.95–4.15 (m, 2 H), 5.52–5.75 (m, 2 H), 6.03–6.30 (m, 4 H).

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Registry No. **1a**, 22430-47-3; **1b**, 133683-82-6; **4**, 110187-19-4; **5**, 104226-70-2; **6**, 114730-22-2; **7** (isomer 1), 135570-10-4; **7** (isomer 2), 135570-11-5; **8** (isomer 1), 135570-12-6; **8** (isomer 2), 135570-13-7; **9** (isomer 1), 135570-16-0; **9** (isomer 2), 135570-17-1; **10** (isomer 1), 135570-14-8; **10** (isomer 2), 135570-15-9; **11** (isomer 1), 135637-50-2; **11** (isomer 2), 135637-51-3; $H_3C(CH_2)COCl$, 334-19-0; $ClCO(CH_2)_5COCl$, 142-79-0; $H_3C(CH_2)_7COCl$, 764-85-2; $MeO_2CCH_2CH_2COCl$, 1490-25-1; $MeO_2C(CH_2)COCl$, 1501-26-4.

Organic Reactions Catalyzed by Solid Superacids. 10.[1] Perfluorinated Sulfonic Acid Resin (Nafion-H) Catalyzed Ring Closure Reaction of 2,2′-Diaminobiphenyls. A Preparative Route to Carbazoles

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Introduction

The acid-catalyzed ring closure of 2,2′-diaminobiphenyls to corresponding carbazoles has been studied using various acids.[2-4] However, these methods require elevated temperatures (>200 °C), long reaction times, and excess of protic acids. Furthermore, some of these reactions were plagued with undesirable side products during cyclization.[4] Therefore, the scope and selectivity for the preparation of carbazole derivatives have been limited.

Recently, we have found that Nafion-H, a perfluorinated sulfonic acid resin, catalyzes ring closure of 2,2′-dihydroxybiphenyls to dibenzofuran derivatives under relatively mild conditions.[5]

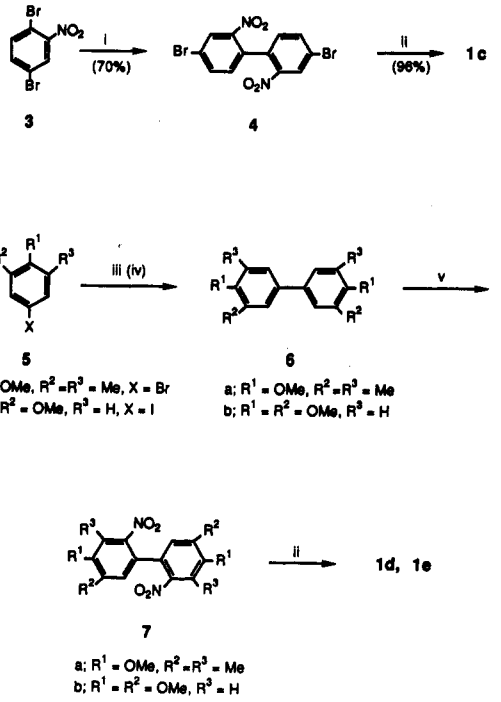
Now we wish to report an efficient and mild procedure for the ring closure of 2,2′-diaminobiphenyls in the presence of the solid superacid, Nafion-H, to afford carbazole derivatives in good to moderate yields.

Results and Discussion

The preparative route for 2,2′-diamino-4,4′-dibromobiphenyl (**1c**), 2,2′-diamino-3,3′,5,5′-tetramethyl-4,4′-dimethoxybiphenyl (**1d**), and 2,2′-diamino-4,4′,5,5′-tetramethoxybiphenyl (**1e**) is shown in Scheme I, and the preparation of other diaminobiaryls **1a** and **1b** was carried out by the reduction of the corresponding dinitrobiaryls with Sn–HCl in ethanol according to the literature.[6-8]

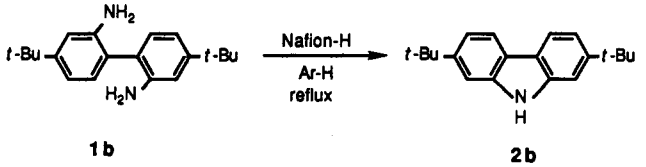
The attempted ring closure reaction of 4,4′-di-*tert*-butyl-2,2′-diaminobiphenyl (**1b**), performed in refluxing *o*-xylene for 36 h in the presence of Nafion-H, failed. Only starting material was recovered. However, when the reaction was carried out in refluxing 4-*tert*-butyltoluene, 4-*tert*-butyl-*o*-xylene, or nitrobenzene, the desired product, 2,7-di-*tert*-butylcarbazole (**2b**), was obtained (Table I). In the case of 4-*tert*-butyltoluene reflux, it takes more than 36 h to complete the reaction, but under 4-*tert*-butyl-*o*-xylene or nitrobenzene reflux only 12 h are required.

Scheme I[a]



[a] Key: (i) Cu/DMF, 120 °C for 1 h; (ii) Sn/HCl/EtOH; (iii) $NiCl_2$/Zn/triphenylphosphine/DMF, 50–60 °C for 12 h; (iv) Cu, 260 °C for 3 h; (v) fuming HNO_3/Ac_2O.

Table I. Nafion-H-Catalyzed Condensation of 4,4′-Di-*tert*-butyl-2,2′-diaminobiphenyls 1b



1b **2b**

run	solvent	amount of Nafion-H (wt %)	reaction time (h)	yields[a] (%) 1b	2b
1	*o*-xylene	50	36	100	0
2	4-*tert*-butyltoluene	50	12	41	54
3	4-*tert*-butyltoluene	100	12	35	61
4	4-*tert*-butyltoluene	100	48	0	98 (88)[b]
5	4-*tert*-butyl-*o*-xylene	50	12	5	90
6	4-*tert*-butyl-*o*-xylene	50	12	4	90 (87)[b]
7	nitrobenzene	50	12	0	95 (93)[b]
8	biphenyl[c]	100	12	0	0[d]

[a] Yields are determined by GLC analyses. [b] Isolated yields are shown in parentheses. [c] Reaction temperature: 250–260 °C. [d] Carbazole **2a** was obtained in quantitative yield.

However, when nitrobenzene was used as a solvent, the highest isolated yield of **2b** (run 7) was obtained, but a remarkable deactivation of catalyst was observed because regeneration of catalyst could not be achieved to the original catalytic activity.

Product **2b** was isolated by simple filteration of the hot reaction mixture followed by distillation of the filtrate.

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