Sequential Transformations of 1,3-Dibora Butadienes to Enones or Tetrasubstituted 1,3-Butadienes

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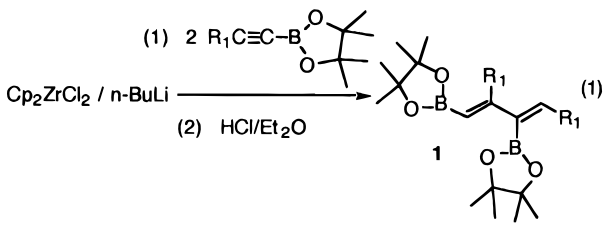
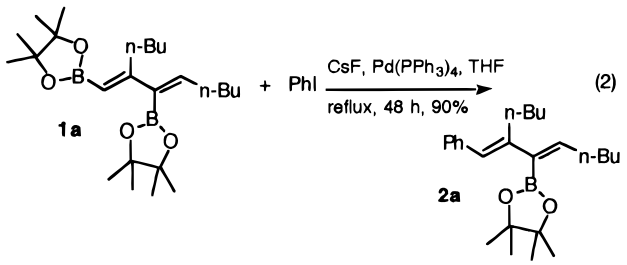
α,β-Unsaturated ketones are ubiquitous and useful compounds whose synthesis and reactions have been actively investigated.[1] Their synthesis by boron-related chemistry includes hydroboration/oxidation of enamines followed by *N*-oxide decomposition and oxidation of the allylic alcohols,[2] hydroboration of 1-halo alkynes with thexylborane followed by coupling and oxidation,[3] oxidation of 1,2-oxaboracyclopent-4-enes,[4] intramolecular transfer reactions with α-halo-α-carbonyl carbanions,[5] by palladium-catalyzed coupling of 1-alkenylboronates with haloenones[6] or palladium-induced coupling of α-iodoenones with 9-alkyl-9-BBN,[7] and carbonylative cross-coupling.[8] We have very recently prepared a series of 1,3-dibora-1,3-butadienes by zirconocene-mediated reductive cyclization of 1-alkynyl boronates (eq 1).[9]



This class of dibora compounds had not been reported prior to our synthesis. The boron atoms in **1** are in different chemical environments, one being terminal and the other internal. This suggested to us the possibility of preferential reactions at the less hindered terminal B−C bond followed by subsequent reaction at the internal B−C bond.[10] The palladium-catalyzed cross-coupling reaction of vinyl and aryl boronic acids and esters with vinyl or aryl halides, the Suzuki−Miyaura reaction, is being intensely investigated.[11] The purpose of the present study was to assess selectivity in Suzuki−Miyaura coupling of the 1,3-dibora butadienes to give **2** and then to demonstrate further transformation of the remaining boron group by oxidation to ketones **3**. Additional coupling of **2** is possible to give **4** (*vide infra*), but the yields of the second coupling are low.

Suzuki and Miyaura discovered that base is required for the cross-coupling of organoboranes with aryl or vinyl halides.[12] Recently CsF has been found to be an effective additive in the cross-coupling reaction.[13] In conjunction with our synthesis of chokol precursors, we have found the use of CsF to be a mild alternative to other bases.[14] Thus when **1a** was reacted with phenyl iodide in the presence of CsF and Pd $(PPh_3)_4$ in refluxing THF, **2a** was isolated in 90% yield (eq 2).[15]



The assignment of structure **2a** is based on the fact that Suzuki−Miyaura coupling proceeds with retention of stereochemistry of the migrating alkenyl group[11] and on our previous assignments of the chemical shifts of 1,3-, 1,4-, and 2,3-dibora-1,3-butadienes.[9] Along with **2a,** a small quantity (<10%) of the diphenylated product was detected by GCMS. However, it was not further characterized. We found that the best protocol for obtaining complete conversion of starting aryl iodide was to add CsF and $Pd(PPh_3)_4$ in two portions, the second being added 24 h after the first. In this manner good yields of **2** were realized (Table 1). As was the case with **2a**, small amounts of diarylated product (<10%) were detected by GCMS. Compounds **2** were obtained as pure isomers except for **2g ,** which was obtained as ∼1:1 mixture of stereoisomers with respect to the double bond containing the boron group. Oxidation of this mixture provided only one ketone, **3g**. The reason for obtaining **2g** as a mixture of isomers is unclear. In principal a second Suzuki−Miyaura coupling of **2** would lead to unsymmetrically alkylated 1,3-butadienes, and substituting the order of

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(1) (a) Thebtaranoth, C.; Thebtaranoth, Y. In *The Chemistry of Enones*; Patai, S., Rappoport, Z., Eds.; Wiley: Chichester, 1989; Part 1, p 199. (b) Boyd, G. V. *Ibid.* p 281.

(2) (a) Gore, J.; Drouet, J. P.; Barieux, J. J. *Tetrahedron Lett.* **1969**, 9. (b) Barieux, J. J.; Gore, J. *Bull. Soc. Chim. Fr.* **1971**, 1649.

(3) Negishi, E. I.; Yoshida, T. *Chem. Commun.* **1973**, 606.

(4) Binger, P. *Angew. Chem.* **1968**, *80*, 288.

(5) Campbell, J. B., Jr. Ph.D. Dissertation, Purdue University, 1978.

(6) Satoh, N.; Ishiyama. T.; Miyaura, N. Suzuki, A. *Bull. Chem. Soc. Jpn.* **1987**, *60*, 3471.

(7) Johnson, C. R.; Braun, M. P. *J. Am. Chem. Soc.* **1993**, *115*, 11014.

(8) (a) Ishiyama, T.; Miyaura, N.; Suzuki, A. *Bull. Chem. Soc. Jpn.* **1991**, *64*, 1999. (b) Ishiyama, T.; Kizaki, H.; Miyaura, N.; Suzuki. A. *Tetrahedron Lett.* **1993**, *34*, 7595. (c) Ishikura, M.; Terashima, M. J. *J. Org. Chem.* **1994**, *59*, 2634.

(9) Desurmont, G.; Klein, R.; Uhlenbrock, S.; Laloë, E.; Deloux, L.; Giolando, D. M.; Kim, Y. W.; Pereira, P.; Srebnik, M. *Organometallics* **1996**, in press. The 1,4-dibora regioisomers are also obtained.

(10) Several examples of selective transformations of B−C bonds are the following: oxidation with amine oxides (a) Zweifel, G.; Polston, N. L.; Whitney, C. C. *J. Am. Chem. Soc.* **1968**, *90*, 6243. (b) Soderquist, J. A.; Najafi, M. R. *J. Org. Chem.* **1986**, *51*, 1330. (c) Miyaura, N.; Suzuki, A. *Chem. Lett.* **1981**, 879; protonolysis: (d) Mikhailov, B. M.; Bubnov, Yu. N. *Organoboron Compounds in Synthesis*; Harwood: New York, 1984; p 255, for a discussion with many references; carbonylation: (e) Brown, H. C.; Rathke, M. W. *J. Am. Chem. Soc.* **1967**, *89*, 4528. (f) Brown, H. C.; Kabalka, G. W.; Rathke, M. W. *J. Am. Chem. Soc.* **1967**, *89*, 4530. (g) Danheiser, R. L.; Savoca, A. C. *J. Org. Chem.* **1985**, *50*, 2401. (h) Kabalka, G. W.: Shoup, T. M.; Gougaon, N. M. *Tetrahedron Lett.* **1989**, *30*, 1483; cyanidation: (i) Pelter, A.; Smith, K.; Hutchings, M.; Rowe, K. *J. Chem. Soc. Perkin Trans. 1* **1975**, 129; reaction with diazo compounds: (j) Hooz, J.; Bridson, J. N. *Can. J. Chem.* **1972**, *50*, 2387; selective oxidation of alkyl groups: (k) Brown, H. C.; Midland. M. M.; Kabalka, G. W. *Tetrahedron* **1986**, *42*, 5523; β-elimination of (β-iodovinyl)boranes: (l) Pelter, A.; Drake, R. A. *Tetrahedron Lett.* **1988**, *29*, 4181. (m) Negishi, E. I.; Yoshida, T.; Abramovitch, A.; Lew, G.; Williams, R. W. *Tetrahedron* **1991**, *47*, 343.

(11) Miyaura, N.; Suzuki, A. *Chem. Rev.* **1995**, *95*, 2457.

(12) (a) Miyaura, N.; Yanagi, T.; Suzuki, A. *Synth. Commun.* **1981**, *11*, 513. (b) Miyaura, N.; Yamada, K.; Suginome, H.; Suzuki, A. *J. Am. Chem. Soc.* **1985**, *107*, 972.

(13) Wright, S. W.; Hageman, D. L.; McClure, L. D. *J. Org. Chem.* **1994**, *59*, 6095.

(14) Laurent, D.; Srebnik, M. *Tetrahedron Lett.* **1996**, *37*, 2735.

(15) For a preliminary account of this work see reference 9.

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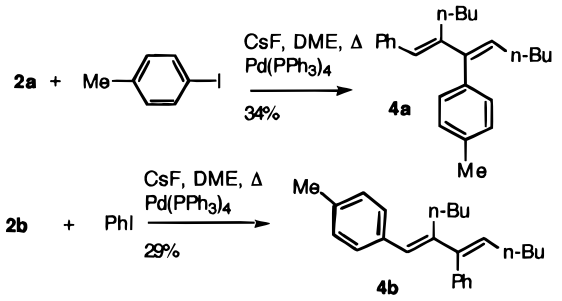
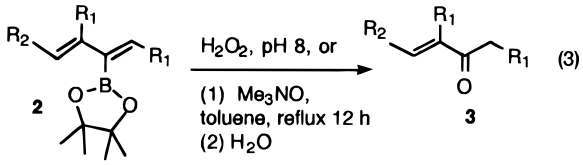
Scheme 1. Sequential Suzuki−Miyaura Coupling



addition of aryl iodides would furnish regioisomeric 1,3-butadienes. In practice, the second coupling step proved difficult and the desired products were obtained in rather low yield (Scheme 1). Refluxing in DME was required. Thus **4a** and **4b** were obtained as pure isomers, but in low yield, from a complex reaction mixture.[16] Optimization at this point was not attempted.

In 1971 Negishi and Yoshida prepared monosubstituted α,β-unsaturated ketones from mixed thexyl bis(divinyl) boranes by hydrogen peroxide oxidation in buffered solution.[3] Compounds **2** would be suitable candidates for conversion to ketones in a similar manner (and would complement those obtained by the Negishi−Yoshida protocol) to provide stereochemically pure α,β-disubstituted enones **3**.[17] In the process sequential transformations of the two boron groups in **1** would be demonstrated. We selected both phosphate buffered H_2O_2 and anhydrous trimethylamine *N*-oxide (TMANO) as suitable oxidizing reagents (eq 3). Results are tabulated in Table 1. In all cases excellent yields of the ketones were obtained. TMANO oxidation of **2a** provided the enol borate (^{11}B NMR, 18 ppm) which was not isolated but hydrolyzed to ketone **3a**. In principal the enol borate could be reacted with aldehydes to provide aldol products.[18] But this was not pursued. Ketones **3** were obtained as isomerically pure compounds in which the *E* stereochemistry of the double bond was retained. Assignment of *E* configuration is consistent with known compounds in the literature.[17] In addition, it is well known that the *E* isomers of α,β-unsaturated ketones are thermodynamically more stabile than the *Z* isomers.[19]



In conclusion, we have developed a highly stereoselective procedure that converts 1,3-dibora-1,3-butadienes, **1**, to *(E)*-α,β-unsaturated ketones, **3**, and in the process also demonstrated preferential Suzuki−Miyaura coupling at the terminal boron group to give **2**. A second coupling can be performed on **2** to provide tetrasubstituted 1,3-butadienes, **4**, but the yield in the second coupling step is low.

Experimental Section

Glassware, syringes, and needles were oven dried at 120 °C, assembled while hot, and cooled under a flow of Ar. All reactions were done under a positive pressure of Ar. Solvents were distilled from sodium benzophenone ketyl and used immediately. ^{11}B, ^{13}C, and ^{1}H NMR spectra were recorded at 128.3, 100.6, and 400 MHz, respectively. Compounds **1** were synthesized according to the literature.[9]

Procedure for Suzuki−Miyaura Coupling of Dibora Butadienes. Preparation of **2a** is typical. To a solution of **1a** (0.5 mmol, 0.209 g) in THF (5 mL) were added $Pd(PPh_3)_4$, (0.013 mmol, 0.015 g), CsF (0.5 mmol, 0.076 g), and phenyl iodide (0.5 mmol, 0.102 g). The order of addition did not affect yields. The reaction mixture was refluxed for 24 h, and then another portion of $Pd(PPh_3)_4$ (0.013 mmol, 0.015 g) and CsF (0.5 mmol, 0.076 g) was added. The solution was then diluted with hexanes, washed with brine, dried over anhydrous Na_2SO_4, and concentrated *in vacuo*. The residue was chromatographed on silica gel to yield **2a** as a colorless oil. GC yield = 97%; isolated yield = 90% (0.166 g); ^{1}H NMR ($CDCl_3$): δ = 7.31−7.14 (m, 5 H), 6.38 (s, 1 H), 6.20 (t, J = 8.4 Hz, 1 H), 2.40 (t, J = 9.2 Hz, 2 H), 2.29 (q, J = 8.0 Hz, 2 H), 1.51−1.25 (m, 8 H), 1.33 (s, 12 H), 0.92 (t, J = 10 Hz, 3 H), 0.87 (t, J = 8.8 Hz, 3 H); ^{13}C NMR ($CDCl_3$): δ = 145.6, 142.0, 138.8, 129.7, 127.95, 126.8, 125.9, 83.4, 32.1, 31.8, 31.3, 28.9, 24.9, 24.8, 22.9, 22.4, 14.0; ^{11}B NMR ($CDCl_3$): δ = 32.17; MS (EI) m/z (relative intensity): 368 (M^+, 0.17).

Preparation of **2b** followed the procedure described above using **1a** (0.209 g, 0.5 mmol) and 4-iodotoluene (0.109 g, 0.5 mmol) to give **2b** in a GC yield of 92%; isolated yield = 78% (0.149 g). ^{1}H NMR ($CDCl_3$): δ = 7.16−7.11 (m, 4 H), 6.40 (s, 1 H), 6.20 (t, J = 7.83 Hz, 1 H), 2.42 (t, J = 7.88 Hz, 2 H), 2.31 (s, 3 H), 2.28 (q, J = 6.59 Hz, 2 H), 1.50−1.25 (m, 20 H), 0.938 (t, J = 7.24 Hz, 3 H), 0.906 (t, J= 7.26, 3H); ^{13}C NMR ($CDCl_3$): δ = 144.90, 141.52, 135.89, 135.56, 128.74, 128.69, 127.99, 126.84, 83.48, 32.21, 31.86, 31.34, 28.94, 24.95, 22.98, 22.42, 21.15, 14.01, 13.96; ^{11}B NMR ($CDCl_3$): δ = 31.63; MS (EI) m/z (relative intensity): 382 (M^+, 0.14).

Preparation of **2c** followed the procedure described above using **1b** (0.229 g, 0.5 mmol) and 2-iodoanisole (0.117 g, 0.5 mmol) to give **2c** in a GC yield of 70%; isolated yield = 63% (0.138 g). ^{1}H NMR ($CDCl_3$): δ = 7.37−7.18 (m, 10 H), 7.12 (s, 1 H), 7.07 (m, 1 H), 6.78 (s, 1 H), 6.77 (m, 1 H), 6.55 (m, 2 H), 3.82 (s, 3 H), 1.27 (s, 12 H); ^{13}C NMR ($CDCl_3$): δ = 157.57, 145.13, 140.32, 139.71, 139.13, 130.33, 130.06, 128.43, 128.26, 127.98, 127.77, 127.25, 127.02, 126.36, 124.28, 119.75, 110.23, 84.09, 55.31, 25.05; ^{11}B NMR ($CDCl_3$): δ = 30.17; MS (EI) m/z (relative intensity): 438 (M^+, 0.24).

Preparation of **2d** followed the procedure described above using **1b** (0.229 g, 0.5 mmol) and 4-iodoanisole (0.117 g, 0.5 mmol) to give **2d** in a GC yield of 91%; isolated yield = 83% (0.182 g). ^{1}H NMR ($CDCl_3$): δ = 7.38−7.12 (m, 10 H), 6.84 (d, J = 8.78 Hz, 2 H), 6.81 (s, 1 H), 6.78 (s, 1 H), 6.65 (d, J = 8.86 Hz, 2 H), 3.74 (s, 3 H), 1.26 (s, 12 H); ^{13}C NMR ($CDCl_3$): δ = 158.34, 143.78, 140.24, 139.87, 139.06, 130.84, 130.33, 130.14, 128.98, 128.70, 128.29, 128.04, 127.33, 127.21, 113.41, 84.08, 55.15, 25.05; ^{11}B NMR ($CDCl_3$): δ = 30.59; MS (EI) m/z (relative intensity): 438 (M^+, 0.31).

Preparation of **2e** followed the procedure described above using **1c** (0.299 g, 0.5 mmol) and phenyl iodide (0.102 g, 0.5 mmol) to give **2e** in a GC yield of 92%; isolated yield = 80% (0.163 g). ^{1}H NMR ($CDCl_3$): δ = 7.33−7.22 (m, 5 H), 6.47 (s, 1 H), 6.21 (t, J = 7.78 Hz, 1 H), 3.59 (t, J = 6.59 Hz, 2 H), 3.51 (t, J = 6.45 Hz, 2 H), 2.59 (t, J = 7.96 Hz, 2 H), 2.47 (q, J = 11.13 Hz, 2 H), 1.94 (sextet, J = 8.23 Hz, 4 H), 1.35 (s, 12 H); ^{13}C NMR ($CDCl_3$): δ = 143.56, 140.62, 138.17, 136.40, 128.78, 128.35, 128.18, 126.41, 83.75, 45.10, 44.64, 32.81, 31.91, 29.46, 26.79, 24.98; ^{11}B NMR ($CDCl_3$): δ = 29.64; MS (EI) m/z (relative intensity): 408 (M^+, 0.16).

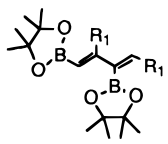
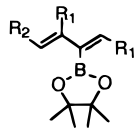
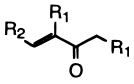
(16) The Suzuki−Miyaura reaction of vinyl boronates can be complicated by Heck and other side-products. (a) Hunt, A. R.; Stewart, S. K.; Whiting, A. *Tetrahedron Lett.* **1993**, *34*, 3599. (b) Stewart, S. K.; Whiting, A. *J. Organomet. Chem.* **1994**, *482*, 293. In our case, reaction of **1** with 2 equiv of aryl iodide in THF provided **2** in almost the same ratio as in the reaction with 1 equiv. In refluxing DME the use of 2 equiv of aryl iodide gave a complex reaction mixture.

(17) Acyclic α,β-disubstituted enones have also been obtained by isomerization of β,γ-enones with aluminum oxide: (a) Reetz, M. T.; Wenderoth, B.; Urz, R. *Chem. Ber.* **1985**, *118*, 348; by Rh(I) catalyzed isomerization of 1,3-diene monoepoxides: (b) Sato, S.; Matsuda, I.; Izumi, Y. *Tetrahedron Lett.* **1985**, *26*, 1527; by alkylation of 1-isocyano-tosylalkenes: (c) Moskal, J.; van Leusen, A. M. *Tetrahedron Lett.* **1984**, *25*, 2585.

(18) Hoffmann, R. W.; Ditrich, K.; Fröch, S. *Liebigs Ann. Chem.* **1987**, 977.

(19) Combant, G.; Giral, L. *Bull. Soc. Chim. Fr.* **1970**, 3715.

Table 1. Coupling Followed by Oxidation of 1,3-Dibora-1,3-butadienes

Entry	 1	 2	Yield,% isolated (GC)	 3 Yield,% isolated (GC)[a]
a	R_1 = n-Bu	R_1 = n-Bu; R_2 = Ph	90 (97)	80 (92,95[b])
b	R_1 = n-Bu	R_1 = n-Bu; R_2 = 4-Me-C_6H_4	78 (92)	79 (90)
c	R_1 = Ph	R_1 = Ph; R_2 =2-MeO-C_6H_4	63 (70)	81 (89)
d	R_1 = Ph	R_1 = Ph; R_2 = 4-MeO-C_6H_4	83 (91)	76 (92)
e	R_1 = 3-Cl-n-Pr	R_1 = 3-Cl-n-Pr; R_2 = Ph	80 (92)	77 (87)
f	R_1 = n-Bu	R_1 = n-Bu; R_2 = 2-Thienyl	71 (90)	76 (88)
g	R_1 = n-Bu	R_1 = n-Bu; R_2 = 3-NO_2-C_6H_4;	67 (87)[c]	78 (86)
h	R_1 = c-C_5H_9	R_1 = c-C_5H_9; R_2 = Ph	80 (89)	--

[a]Oxidation carried out in pH 8 phosphate buffered H_2O_2 for 12 hours at 0 - 25 °C.

[b] Trimethylamine-N-oxide was used in refluxing toluene for 12 h. [c] As a 43:57 mixture of isomers.

Preparation of **2f** followed the procedure described above using **1a** (0.209 g, 0.5 mmol) and 2-iodothiophene (0.105 g, 0.5 mmol) to give **2f** in a GC yield of 80%; isolated yield = 71% (0.132 g). ^{1}H NMR ($CDCl_3$): δ = 7.18 (d, J = 5.05 Hz, 1 H), 6.96 (t, J = 4.40 Hz, 1 H), 6.89 (d, J = 3.29 Hz, 1 H), 6.51 (s, 1 H), 6.17 (t, J = 7.69 Hz, 1 H), 2.55 (t, J = 7.73 Hz, 2 H), 2.25 (q, J = 7.35 Hz, 2 H), 1.58−1.26 (m, 20 H), 0.97−0.81 (m, 6 H); ^{13}C NMR ($CDCl_3$): δ = 143.96, 141.95, 141.52, 126.84, 126.67, 124.38, 120.12, 83.57, 32.18, 31.90, 30.57, 29.89, 24.94, 24.86, 23.14, 22.41, 14.01; ^{11}B NMR ($CDCl_3$): δ = 31.22; MS (EI) m/z (relative intensity): 374 (M^+, 0.41).

Preparation of **2g** followed the procedure described above using **1a** (0.221 g, 0.5 mmol) and 3-nitrophenyl iodide (0.124 g, 0.5 mmol) to give **2g** as a 1:1 mixture of isomers in a GC yield of 87%; isolated yield = 67% (0.138 g). ^{1}H NMR ($CDCl_3$): δ = 8.15−7.94 (m), 7.55−7.38 (m), 6.58 (s), 6.31 (s), 6.21 (t), 5.99 (m), 2.38−2.22 (m), 1.52−1.11 (m), 0.94−0.72 (m).^{11}B NMR ($CDCl_3$): δ = 32.41; MS (EI) m/z (relative intensity): 413 (M^+, 0.22).

Preparation of **2h** followed the procedure described above using **1d** (0.221 g, 0.5 mmol) and phenyl iodide (0.102 g, 0.5 mmol) to give **2h** in a GC yield of 89%, Isolated yield = 80% (0.157 g). ^{1}H NMR ($CDCl_3$): δ = 7.31−7.20 (m, 5 H), 6.27 (s, 1 H), 5.99 (d, J = 9.81 Hz, 1 H), 3.08 (quintet, J = 8.54 Hz, 1 H), 2.97 (quintet, J = 8.42 Hz, 1 H), 1.91−1.88 (m, 4 H), 1.87−1.51 (m, 12 H), 1.37−1.27 (m, 12 H); ^{13}C NMR ($CDCl_3$): δ = 151.41, 149.22, 138.88, 132.60, 128.82, 127.86, 126.50, 125.72, 83.16, 42.06, 41.46, 34.14, 31.67, 25.67, 25.34, 24.84; ^{11}B NMR ($CDCl_3$): δ = 30.84; MS (EI) m/z (relative intensity): 392 (M^+, 0.23).

Two Different Procedures Were Used for the Oxidation of 2 to Ketones 3. Preparation of **3a** is typical. A solution of **2a** (30 mg, 0.082 mmol) in 1 mL of THF and 1 mL of buffer solution (pH = 8) was treated with 1.1 equiv of H_2O_2 (30% w/w, 9.3 μL) at 0 °C. The ice-bath was removed, and the reaction mixture was stirred overnight at 25 °C, extracted with ether, washed with brine, and dried over Na_2SO_4 to give **3a** (GC yield: 92%) as a colorless oil which was purified on two analytical silica gel plates. Isolated yield: 17 mg, 80%.

To a solution of **2a** (30 mg, 0.082 mmol) in 1 mL of toluene was added and 1.1 equiv of trimethylamine *N*-oxide (6.8 mg). The reaction was refluxed for 12 h and then quenched with H_2O to give **3a** (GC yield: 95%) which was worked-up and purified as above. Isolated yield: 17 mg, 80%. ^{1}H NMR ($CDCl_3$): δ = 7.43−7.24 (m, 6 H), 2.75 (t, J = 8.01 Hz, 2 H), 2.48 (m, 2 H), 1.65 (quintet, J = 7.37 Hz, 2 H), 1.38−1.31 (m, 8 H), 0.91−0.86 (m, 6 H); ^{13}C NMR ($CDCl_3$): δ = 202.92, 142.96, 137.92, 136.04, 129.21, 128.51, 128.34, 37.92, 31.63, 31.40, 26.41, 24.74, 23.00, 22.57, 13.99, 13.86; MS (EI) m/z (relative intensity): 258 (M^+, 0.18); IR (NaCl) cm^{-1}: 1669.

Preparation of **3b** followed the procedure described above using **2b** (30 mg, 0.079 mmol) and H_2O_2 (30% w/w, 8.9 μL) to give **3b** (GC yield of 90%) which was purified as above. Isolated yield: 17 mg, 79%. ^{1}H NMR ($CDCl_3$): δ = 7.43−7.21 (m, 5 H), 2.75 (t, J= 7.4 Hz, 2 H), 2.51−2.49 (m, 2 H), 2.39 (s, 3 H), 1.67 (quintet, J = 7.28 Hz, 2 H), 1.41−1.34 (m, 8 H), 0.94−0.90 (m, 6 H); ^{13}C NMR ($CDCl_3$): δ = 202.81, 142.19, 138.54, 138.08, 133.11, 129.33, 129.21, 37.84, 31.64, 31.35, 26.42, 24.80, 23.04, 22.57, 21.33, 13.99, 13.88; MS (EI) m/z (relative intensity): 272 (M^+, 0.14); IR (NaCl) cm^{-1}: 1669.

Preparation of **3c** followed the procedure described above using **2c** (30 mg, 0.068 mmol) and H_2O_2 (30% w/w, 8.6 μL) to give **3c** (GC yield of 89%) which was purified as described above: Isolated yield: 18 mg, 81%. ^{1}H NMR ($CDCl_3$): δ = 8.08 (s, 1 H), 7.34−7.11 (m, 11 H), 6.86 (m, 1 H), 6.64 (m, 1 H), 6.56 (m, 1 H), 3.99 (s, 2 H), 3.87 (s, 3 H); ^{13}C NMR ($CDCl_3$): δ = 199.16, 158.53, 140.31, 136.73, 135.05, 134.42, 130.61, 130.51, 130.01, 129.53, 128.66, 128.42, 127.68, 126.61, 123.78, 119.94, 110.56, 55.60, 46.44; MS (EI) m/z (relative intensity): 328 (M^+, 0.03); IR (NaCl) cm^{-1}: 1672.

Preparation of **3d** followed the procedure described above using **2d** (30 mg, 0.068 mmol) and H_2O_2 (30% w/w, 8.6 μL) to give **3d** (GC yield of 92%) purified as described above. Isolated yield: 17 mg, 76%. ^{1}H NMR ($CDCl_3$): δ = 7.69 (s, 1 H), 7.42−7.09 (m, 10 H), 6.97 (d, J = 9.10 Hz, 2 H), 6.65 (d, J = 7.69 Hz, 2 H), 3.86 (s, 2 H), 3.75 (s, 3H); ^{13}C NMR ($CDCl_3$): δ = 199.88, 160.51, 139.06, 138.10, 137.31, 134.97, 132.80, 129.89, 129.43, 129.15, 128.42, 127.89, 127.23, 126.61, 113.70, 55.24, 46.57; MS (EI) m/z (relative intensity): 328 (M^+, 0.04); IR (NaCl) cm^{-1}: 1675.

Preparation of **3e** followed the procedure described above using **2e** (30 mg, 0.074 mmol) and H_2O_2 (30% w/w, 8.4 μL) to give **3e** (GC yield of 87%), purified as described above: Isolated yield: 15 mg, 77%. ^{1}H NMR ($CDCl_3$): δ = 7.56 (s, 1 H), 7.44−7.27 (m, 5 H), 3.61−3.56 (m, 4 H), 2.86 (t, J = 6.67 Hz, 2 H), 2.67 (t, J = 7.92 Hz, 2 H), 1.94 (quintet, J = 7.87 Hz, 2 H), 1.88 −1.84 (m, 4 H); ^{13}C NMR ($CDCl_3$): δ = 201.44, 140.83, 139.85, 135.31, 129.24, 128.88, 128.71, 45.11, 44.72, 36.65, 32.11, 31.93, 24.32, 22.12; MS (EI) m/z (relative intensity): 262 (M^+, 0.24); IR (NaCl) cm^{-1}: 1669.

Preparation of **3f** followed the procedure described above using **2f** (30 mg, 0.080 mmol) and H_2O_2 (30% w/w, 9 μL) to give **3f** (GC yield of 88%) purified as described above: Isolated yield: 16 mg, 76%. ^{1}H NMR ($CDCl_3$): δ = 7.54 (s, 1 H), 7.42 (m, 1H), 7.24 (m, 1 H), 7.05 (m, 1 H), 2.69 (t, J = 7.51 Hz, 2 H), 2.59 (t, J = 8.05 Hz, 2 H), 1.59 (quintet, J = 7.29 Hz , 2 H), 1.39−1.25

(m, 6 H), 0.90−0.75 (m, 8 H); ^{13}C NMR ($CDCl_3$): δ = 201.77, 139.24, 138.90, 132.02, 130.82, 129.36, 127.34, 37.55, 31.63, 30.51, 29.72, 24.80, 23.24, 22.57, 13.99, 13.96; MS (EI) *m*/*z* (relative intensity): 264 (M^+, 0.40); IR (NaCl) cm^{-1}: 1654.

Preparation of **3g** followed the procedure described above using **2g** (30 mg, 0,076 mmol) and H_2O_2 (30% w/w, 8.55 μL) to give **3g** (GC yield of 86%) purified as described above: Isolated yield: 16 mg, 78%, as a 43:57 mixture of isomers as determined by ^{1}H NMR. ^{1}H NMR ($CDCl_3$): δ = 8.25 (s, 1 H), 8.23 (m, 1 H), 7.64−7.57 (m, 2 H), 7.40 (s, 1 H), 2.76 (t, J = 7.47 Hz, 2 H), 2.46 (t, J = 7.69 Hz, 2 H), 1.67 (q, J = 7.19 Hz, 2 H), 1.42−1.32 (m, 8 H), 0.92−0.87 (m, 6 H); ^{13}C NMR ($CDCl_3$): δ = 202.3, 148.41, 145.33, 137.71, 134.89, 134.52, 129.52, 123.83, 122.93, 38.11, 31.55, 31.30, 26.55, 24.47, 22.91, 22.55, 13.97, 13.77; MS (EI) *m*/*z* (relative intensity): 303 (M^+, 0.17); IR (NaCl) cm^{-1}: 1675.

Procedure for the Suzuki−Miyura Coupling of 2. Preparation of **4a** is typical. A solution of **2a** (0.5 mmol, 0.184 g) in DME (5mL) was treated with $Pd(PPh_3)_4$, (0.013 mmol, 0.015 g), CsF (0.5 mmol, 0.076 g), and 4-iodotoluene (0.5 mmol, 0.108 g). The reaction mixture was refluxed for 24 h, and then $Pd(PPh_3)_4$ (0.013 mmol, 0.015 g) and CsF (0.5 mmol, 0.076 g) were again added, followed by refluxing for another 24 h. The solution was then diluted with hexanes, washed with brine, dried over Na_2SO_4, and concentrated *in vacuo*. **4a** was isolated as an oil after chromatography on silica gel. GC yield: 40%; isolated yield = 29%. ^{1}H NMR ($CDCl_3$): δ = 7.31−7.08 (m, 9 H), 6.21 (s, 1 H), 5.86 (t, J = 7.47 Hz, 1 H), 2.43−2.37 (m, 5 H), 2.05−1.99 (m, 2 H), 1.56−1.29 (m, 8 H), 0.92−0.85 (m, 6 H); ^{13}C NMR ($CDCl_3$): δ = 145.24, 138.73, 136.00, 129.77, 129.63, 129.24, 128.77, 128.74, 128.66, 128.00, 127.95, 126.08, 32.28, 31.43, 29.35, 28.25, 24.50, 22.82, 22.38, 21.25, 14.02; MS (EI) *m*/*z* (relative intensity): 332 (M^+, 0.20).

Preparation of **4b** followed the procedure described above using **2b** (0.5 mmol, 0.191 g) and phenyl iodine (0.5 mmol, 0.102g) to give **4b** in a GC yield of 46%; isolated yield = 34%. ^{1}H NMR ($CDCl_3$): δ = 7.36−7.11 (m, 9 H), 6.15 (s, 1 H), 5.86 (t, J = 7.55 Hz, 1 H), 2.40 (t, J = 8.05, 2 H), 2.34 (s, 3 H), 1.92 (q, J = 7.33 Hz, 2 H), 1.60−1.25 (m, 8 H), 0.93−0.84 (m, 6 H); ^{13}C NMR ($CDCl_3$): δ = 144.41, 143.48, 140.26, 135.76, 129.78, 129.14, 128.88, 128.75, 128.66, 128.02, 127.94, 126.46, 32.25, 31.45, 30.56, 29.32, 28.24, 22.86, 22.36, 21.15, 14.00; MS (EI) *m*/*z* (relative intensity): 332 (M^+, 0.15).

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Supporting Information Available: ^{1}H NMR and ^{13}C NMR spectra of compounds **2**−**4** (33 pages). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.

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