**Pd(II)-Catalyzed Coupling Cyclization of 2,3-Allenic Acids with
Allylic Halides. An Efficient Methodology for the Synthesis of
 β -Allylic Butenolides**

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Supporting Information

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4-Allyl-3-methyl-5-phenyl-2(5H)-furanone (3b): A mixture of **1b** (87 mg, 0.5 mmol), allyl bromide (**2a**) (0.22 mL, 306 mg, 2.5 mmol) and PdCl₂ (4 mg, 0.023 mmol) in DMA (3 mL) was stirred for 17.5 hours to afford 89 mg (83%) of **3b** (petroleum ether/ethyl acetate = 20 : 1). Oil; ¹H NMR (300 MHz, CDCl₃) δ 7.15-7.44 (m, 5 H), 5.71 (s, 1 H), 5.53-5.71 (m, 1 H), 5.09 (d, *J* = 11.61 Hz, 1 H), 5.01 (d, *J* = 17.11 Hz, 1 H), 3.13 (dd, *J* = 5.49, 15.28 Hz, 1 H), 2.73 (dd, *J* = 7.33, 15.28 Hz, 1 H), 1.94 (s, 3 H); ¹³C NMR (75.4 MHz, CDCl₃) δ 8.7, 30.8, 83.9, 118.1, 123.7, 127.0, 128.8, 129.2, 131.8, 134.5, 160.2, 174.7; EIMS *m/z* 215 (*M*⁺+1, 24.80), 173 (100); IR(neat) 1704, 1631, 1594 cm⁻¹; Anal. Calcd for C₁₄H₁₄O₂: (%) C 78.48, H 6.59. Found: C 78.23, H 6.36.

4-Allyl-5-(1'-naphthyl)-3-propyl-2(5H)-furanone (3c): A mixture of **1c** (126 mg, 0.5 mmol), allyl bromide (**2a**) (0.22 mL, 306 mg, 2.5 mmol) and PdCl₂ (4 mg, 0.023 mmol) in DMA (3 mL) was stirred for 21 hours to afford 114 mg (78%) of **3c** (petroleum ether/ethyl acetate = 30 : 1). Oil; ¹H NMR (300 MHz, CDCl₃) δ 8.06 (d, *J* = 1.98 Hz, 1 H), 7.80-7.92 (m, 2 H), 7.42-7.58 (m, 3 H), 7.26 (d, *J* = 6.67 Hz, 1 H), 6.55 (s, 1 H), 5.55-5.68 (m, 1 H), 5.04 (d, *J* = 10.05 Hz, 1 H), 4.93 (d, *J* = 17.04 Hz, 1 H), 3.21 (dd, *J* = 5.71, 15.39 Hz, 1 H), 2.74 (dd, *J* = 7.32, 15.40 Hz, 1 H), 2.40 (t, *J* = 7.39 Hz, 2 H), 1.59-1.74 (m, 2 H), 1.01 (t, *J* = 7.39 Hz, 3 H); ¹³C NMR (75.4 MHz, CDCl₃) δ 14.0, 21.5, 25.7, 31.1, 80.0, 118.1, 122.5, 125.2, 125.3, 126.0, 126.7, 128.7, 129.0, 129.9, 130.4, 131.6, 132.3, 133.9, 161.1, 174.4; EIMS *m/z* 293 (*M*⁺+1, 10.81), 292 (*M*⁺, 74.01), 155 (100); IR(neat) 1704, 1625, 1593, 1557, 1473 cm⁻¹; HRMS. Calcd for C₂₀H₂₀O₂: 292.14633. Found: 292.14726.

4-Allyl-3-methyl-5-(1'-naphthyl)-2(5H)-furanone (3d): A mixture of **1d** (112 mg, 0.5 mmol), allyl bromide (**2a**) (0.22 mL, 306 mg, 2.5 mmol) and PdCl₂ (4 mg, 0.023 mmol) in DMA (3 mL) was stirred for 16 hours to afford 107 mg (81%) of **3d**

(petroleum ether/ethyl acetate = 30 : 1). Solid, M.P. 74-75 °C; ^1H NMR (300 MHz, CDCl_3) δ 8.05 (d, J = 1.50 Hz, 1 H), 7.90 (t, J = 8.43 Hz, 2 H), 7.42-7.59 (m, 3 H), 7.27 (d, J = 6.85 Hz, 1 H), 6.56 (s, 1 H), 5.70-5.52 (m, 1 H), 5.04 (d, J = 10.07 Hz, 1 H), 4.93 (d, J = 16.35 Hz, 1 H), 3.18 (dd, J = 5.68, 15.52 Hz, 1 H), 2.77 (dd, J = 7.15, 15.52 Hz, 1 H), 1.99 (s, 3 H); ^{13}C NMR (75.4 MHz, CDCl_3) δ 8.8, 31.1, 80.2, 117.9, 122.5, 124.7, 125.16, 125.20, 126.0, 126.8, 129.0, 129.8, 130.2, 131.5, 131.8, 133.8, 160.7, 174.7; EIMS m/z 265 ($\text{M}^+ + 1$, 13.20), 264 (M^+ , 100); IR(KBr) 1760, 1675, 1641, 1596, 1511 cm^{-1} ; Anal. Calcd for $\text{C}_{18}\text{H}_{16}\text{O}_2$: (%) C 81.79, H 6.10. Found: C 81.79, H 6.09.

4-Allyl-3-benzyl-5-phenyl-2(5H)-furanone (3e): A mixture of **1e** (125 mg, 0.5 mmol), allyl bromide (**2a**) (0.22 mL, 306 mg, 2.5 mmol) and PdCl_2 (4 mg, 0.023 mmol) in DMA (3 mL) was stirred for 16 hours to afford 103 mg (71%) of **3e** (petroleum ether/ethyl acetate = 30 : 1). Oil; ^1H NMR (300 MHz, CDCl_3) δ 7.07-7.33 (m, 10 H), 5.66 (s, 1 H), 5.38-5.61 (m, 1 H), 5.00 (d, J = 10.02 Hz, 1 H), 4.90 (d, J = 17.81 Hz, 1 H), 3.68 (A(part of AB, J = 14.92 Hz, $\Delta\nu$ = 18.95 Hz, 1 H), 3.62 (B(part of AB, J = 14.92 Hz, $\Delta\nu$ = 18.95 Hz, 1 H), 3.11 (dd, J = 5.70, 15.29 Hz, 1 H), 2.63 (dd, J = 7.58, 15.29 Hz, 1 H); ^{13}C NMR (75.4 MHz, CDCl_3) δ 29.5, 31.0, 83.8, 118.6, 126.6, 126.9, 127.0, 128.5, 128.6, 128.9, 129.3, 131.7, 134.4, 137.9, 161.5, 174.1; EIMS m/z 291 ($\text{M}^+ + 1$, 24.82), 290 (M^+ , 5.03), 91 (100); IR(neat) 1709, 1626, 1593, 1562 cm^{-1} ; HRMS. Calcd for $\text{C}_{20}\text{H}_{18}\text{O}_2$: 290.13068. Found: 290.12871.

5-(1'-Naphthyl)-4-(2'-phenyl-2'-propenyl)-3-propyl-2(5H)-furanone (3f): A mixture of **1c** (126 mg, 0.5 mmol), 3-bromo-2-phenylpropene (**2b**) (498 mg, 2.5 mmol) and PdCl_2 (4 mg, 0.023 mmol) in DMA (3 mL) was stirred for 24 hours to afford 172 mg (93%) of **3f** (petroleum ether/ethyl acetate = 20 : 1). Oil; ^1H NMR (300 MHz, CDCl_3) δ 7.78-7.87 (m, 3 H), 7.30-7.48 (m, 3 H), 7.10-7.25 (m, 6 H), 6.38 (s, 1

H), 5.26 (s, 1 H), 4.79 (s, 1 H), 3.64 (d, $J = 15.82$ Hz, 1 H), 3.04 (d, $J = 15.90$ Hz, 1 H), 2.25-2.40 (m, 2 H), 1.48-1.63 (m, 2 H), 0.94 (t, $J = 7.35$ Hz, 3 H); ^{13}C NMR (75.4 MHz, CDCl_3) δ 14.0, 21.2, 25.8, 32.8, 80.0, 115.2, 122.3, 125.1, 125.69, 125.72, 125.9, 126.6, 127.9, 128.3, 128.8, 129.7, 129.8, 130.4, 131.5, 133.7, 139.6, 143.2, 160.1, 174.1; EIMS m/z 369($\text{M}^+ + 1$, 26.77), 368(M^+ , 96.41), 230 (100); IR(neat) 1704, 1622, 1583 cm^{-1} ; HRMS. Calcd for $\text{C}_{26}\text{H}_{24}\text{O}_2$: 368.17763. Found: 368.18205.

4-(2'-Methyl-2'-propenyl)-5-phenyl-3-propyl-2(5H)-furanone (3g): A mixture of **1a** (101 mg, 0.5 mmol), 3-chloro-2-methylpropene (**2c**) (0.25 mL, 230 mg, 2.5 mmol) and PdCl_2 (4 mg, 0.023 mmol) in DMA (3 mL) was stirred for 24 hours to afford 114 mg (89%) of **3g** (petroleum ether/ethyl acetate = 30 : 1). Oil; ^1H NMR (300 MHz, CDCl_3) δ 7.26-7.34 (m, 3 H), 7.05-7.13 (m, 2 H), 5.61 (s, 1 H), 4.80 (s, 1 H), 4.56 (s, 1 H), 3.04 (d, $J = 15.05$ Hz, 1 H), 2.50 (d, $J = 15.05$ Hz, 1 H), 2.18-2.30 (m, 2 H), 1.49-1.64 (m, 2 H), 1.61 (s, 3 H), 0.89 (t, $J = 7.44$ Hz, 3 H); ^{13}C NMR (75.4 MHz, CDCl_3) δ 13.9, 21.4, 22.5, 25.5, 34.6, 83.6, 113.8, 126.9, 128.4, 128.8, 129.1, 134.9, 140.3, 160.6, 174.3; EIMS m/z 257 ($\text{M}^+ + 1$, 12.46), 256 (M^+ , 65.74), 201 (100); IR(neat) 1709, 1627, 1605, 1419 cm^{-1} ; HRMS. Calcd for $\text{C}_{17}\text{H}_{20}\text{O}_2$: 256.14633. Found: 256.14645.

4-(2'-Methyl-2'-propenyl)-5-(1'-naphthyl)-3-propyl-2(5H)-furanone (3h): A mixture of **1c** (126 mg, 0.5 mmol), 3-chloro-2-methylpropene (**2c**) (0.25 mL, 230 mg, 2.5 mmol) and PdCl_2 (4 mg, 0.023 mmol) in DMA (3 mL) was stirred for 15.5 hours to afford 146 mg (95%) of **3h** (petroleum ether/ethyl acetate = 30 : 1). Oil; ^1H NMR (300 MHz, CDCl_3) δ 7.92-7.99 (m, 1 H), 7.77-7.86 (m, 2 H), 7.20-7.51 (m, 3 H), 7.18-7.22 (m, 1 H), 6.49 (s, 1 H), 4.77 (s, 1 H), 4.48 (s, 1 H), 3.09 (d, $J = 15.45$ Hz, 1 H), 2.50 (d, $J = 15.44$ Hz, 1 H), 2.25-2.32 (m, 2 H), 1.51-1.70 (m, 2 H), 1.58 (s, 3 H), 0.93 (t, $J = 7.40$ Hz, 3 H); ^{13}C NMR (75.4 MHz, CDCl_3) δ 14.0, 21.4, 22.7, 25.7, 34.6,

80.0, 113.2, 122.4, 124.8, 125.2, 125.9, 126.6, 128.9, 129.2, 129.6, 130.6, 131.4, 133.8, 140.6, 161.0, 174.4; EIMS m/z 307 ($M^+ + 1$, 15.31), 306 (M^+ , 100); IR(neat) 1703, 1625, 1472, 1417 cm^{-1} ; HRMS. Calcd for $\text{C}_{21}\text{H}_{22}\text{O}_2$: 306.16198. Found: 306.16492.

4-(2'-Bromo-2'-propenyl)-5-phenyl-3-propyl-2(5H)-furanone (3i): A mixture of **1a** (101 mg, 0.5 mmol), 2,3-dibromopropene (**2d**) (500 mg, 2.5 mmol) and PdCl_2 (4 mg, 0.023 mmol) in DMA (3 mL) was stirred for 21 hours to afford 124 mg (77%) of **3i** (petroleum ether/ethyl acetate = 20 : 1). Oil; ^1H NMR (300 MHz, CDCl_3) δ 7.22-7.31 (m, 3 H), 7.04-7.12 (m, 2 H), 5.68 (s, 1 H), 5.44 (s, 1 H), 5.43 (s, 1 H), 3.48 (d, J = 15.28 Hz, 1 H), 2.96 (d, J = 15.28 Hz, 1 H), 2.20-2.31 (m, 2 H), 1.54-1.61 (m, 2 H), 0.88 (t, J = 7.33 Hz, 3 H); ^{13}C NMR (75.4 MHz, CDCl_3) δ 13.9, 21.2, 25.7, 38.3, 83.3, 120.4, 127.0, 127.2, 128.9, 129.4, 130.2, 134.4, 157.2, 173.7; EIMS m/z 322($M(^{81}\text{Br})^+$, 0.64), 320($M(^{79}\text{Br})^+$, 0.60), 201 (100); IR(neat) 1754, 1668, 1623, 1488 cm^{-1} ; HRMS. Calcd for $\text{C}_{16}\text{H}_{17}^{79}\text{BrO}_2$: 320.06119. Found: 320.04192.

4-(2'-Bromo-2'-propenyl)-5-(1'-naphthyl)-3-propyl-2(5H)-furanone (3j): A mixture of **1c** (126 mg, 0.5 mmol), 2,3-dibromopropene (**2d**) (500 mg, 2.5 mmol) and PdCl_2 (4 mg, 0.023 mmol) in DMA (3 mL) was stirred for 23 hours to afford 146 mg (79%) of **3j** (petroleum ether/ethyl acetate = 20 : 1). Oil; ^1H NMR (300 MHz, CDCl_3) δ 8.02-8.10 (m, 1 H), 7.85-7.92 (m, 2 H), 7.30-7.59 (m, 3 H), 7.22-7.28 (m, 1 H), 6.62 (s, 1 H), 5.44 (s, 1 H), 5.33 (s, 1 H), 3.63 (d, J = 15.55 Hz, 1 H), 3.11 (d, J = 15.55 Hz, 1 H), 2.40-2.51 (m, 2 H), 1.61-1.76 (m, 2 H), 1.01 (t, J = 9.39 Hz, 3 H); ^{13}C NMR (75.4 MHz, CDCl_3) δ 14.1, 21.3, 26.0, 38.6, 79.9, 120.3, 122.5, 125.3, 125.4, 126.2, 126.9, 127.1, 129.1, 130.0, 130.1, 131.3, 131.6, 133.9, 157.7, 173.9; EIMS m/z 372($M(^{81}\text{Br})^+$, 66.58), 370($M(^{79}\text{Br})^+$, 67.42), 155 (100); IR(neat) 1750, 1622, 1506 cm^{-1} ; HRMS. Calcd for $\text{C}_{20}\text{H}_{19}^{79}\text{BrO}_2$: 370.07684. Found: 370.05365.

4-(2'-Bromo-2'-propenyl)-3-methyl-5-(1'-naphthyl)-2(5H)-furanone (3k): A mixture of **1d** (112 mg, 0.5 mmol), 2,3-dibromopropene (**2d**) (507 mg, 2.5 mmol) and PdCl₂ (4 mg, 0.023 mmol) in DMA (3 mL) was stirred for 23.5 hours to afford 118 mg (69%) of **3k** (petroleum ether/ethyl acetate = 20 : 1). Solid, M.P. 91-93 °C; ¹H NMR (300 MHz, CDCl₃) δ 7.96 (d, *J* = 8.54 Hz, 1 H), 7.74-7.83 (m, 2 H), 7.30-7.50 (m, 3 H), 7.17 (d, *J* = 7.32 Hz, 1 H), 6.53 (s, 1 H), 5.31 (s, 1 H), 5.24 (s, 1 H), 3.48 (d, *J* = 15.56 Hz, 1 H), 3.03 (d, *J* = 15.56 Hz, 1 H), 1.95 (s, 3 H); ¹³C NMR (75.4 MHz, CDCl₃) δ 9.1, 38.7, 80.1, 120.1, 122.4, 125.2, 125.4, 126.1, 126.91, 126.94, 127.2, 129.0, 129.8, 130.1, 131.5, 133.9, 157.4, 174.2; EIMS *m/z* 344(M(⁸¹Br)⁺, 77.41), 342(M(⁷⁹Br)⁺, 77.92), 155 (100); IR(KBr) 1750, 1674, 1622, 1593, 1504 cm⁻¹; HRMS. Calcd for C₁₈H₁₅⁷⁹BrO₂: 342.04554. Found: 342.02806.

3,4-Diallyl-5-phenyl-2(5H)-furanone (3l): A mixture of **1f** (100 mg, 0.5 mmol), allyl bromide (**2a**) (0.22 mL, 306 mg, 2.5 mmol) and PdCl₂ (4 mg, 0.023 mmol) in DMA (3 mL) was stirred for 17 hours to afford 86 mg (72%) of **3l** (petroleum ether/ethyl acetate = 20 : 1). Oil; ¹H NMR (300 MHz, CDCl₃) δ 7.27-7.33 (m, 3 H), 7.08-7.15 (m, 2 H), 5.74-5.89 (m, 1 H), 5.64 (s, 1 H), 5.45-5.58 (m, 1 H), 4.88-5.09 (m, 4 H), 3.02-3.14 (m, 3 H), 2.64 (dd, *J* = 7.53, 15.43 Hz, 1 H); ¹³C NMR (75.4 MHz, CDCl₃) δ 27.6, 30.7, 83.7, 116.5, 118.3, 125.3, 126.9, 128.8, 129.2, 131.8, 133.3, 134.4, 161.6, 173.8; EIMS *m/z* 240 (M⁺, 3.57), 105 (100); IR(neat) 1748, 1670, 1635, 1491, 1428 cm⁻¹; HRMS. Calcd for C₁₆H₁₆O₂: 240.11503. Found: 240.11419.

3-Methyl-4-(2'-methyl-2'-propenyl)-5-(1'-naphthyl)-2(5H)-furanone (3m): A mixture of **1d** (112 mg, 0.5 mmol), 3-chloro-2-methylpropene (**2c**) (0.5 mL, 460 mg, 5 mmol) and PdCl₂ (4 mg, 0.023 mmol) in DMA (3 mL) was stirred for 24 hours to afford 105 mg (76%) of **3m** (petroleum ether/ethyl acetate = 20 : 1). Solid, M.P. 87-88 °C; ¹H NMR (300 MHz, CDCl₃) δ 7.94 (d, *J* = 9.16 Hz, 1 H), 7.74-7.82 (m, 2 H),

7.32-7.49 (m, 3 H), 7.20 (d, $J = 7.33$ Hz, 1 H), 6.48 (s, 1 H), 4.72 (s, 1 H), 4.44 (s, 1 H), 3.03 (d, $J = 15.28$ Hz, 1 H), 2.52 (d, $J = 15.28$ Hz, 1 H), 1.91 (s, 3 H), 1.54 (s, 3 H); ^{13}C NMR (75.4 MHz, CDCl_3) δ 9.00, 22.7, 35.0, 80.4, 113.3, 122.5, 125.1, 125.30, 125.34, 126.1, 126.8, 129.1, 129.8, 130.6, 131.6, 133.9, 140.3, 161.0, 174.9; EIMS m/z 279 ($\text{M}^+ + 1$, 21.07), 278 (M^+ , 100); IR(KBr) 1761, 1675, 1651 cm^{-1} ; Anal. Calcd for $\text{C}_{19}\text{H}_{18}\text{O}_2$: (%) C 81.99, H 6.52. Found: C 82.27, H 6.59.

4-Allyl-3-benzyl-5-methyl-2(5H)-furanone (3n): A mixture of **1g** (94 mg, 0.5 mmol), allyl bromide (**2a**) (0.44 mL, 612 mg, 5 mmol) and PdCl_2 (4 mg, 0.023 mmol) in DMA (3 mL) was stirred for 17.5 hours to afford 83 mg (73%) of **3n** (petroleum ether/ethyl acetate = 10 : 1). Oil; ^1H NMR (300 MHz, CDCl_3) δ 7.04-7.21 (m, 5 H), 5.48-5.63 (m, 1 H), 4.96-5.07 (m, 2 H), 4.80 (q, $J = 6.42$ Hz, 1 H), 3.52 (s, 2 H), 3.16 (dd, $J = 5.5$, 15.43 Hz, 1 H), 2.91 (dd, $J = 7.34$, 15.43 Hz, 1 H), 1.30 (d, $J = 6.42$ Hz, 3 H); ^{13}C NMR (75.4 MHz, CDCl_3) δ 18.2, 29.4, 30.9, 78.5, 118.6, 126.4, 126.8, 128.4, 128.5, 131.7, 138.0, 162.7, 173.6; EIMS m/z 229 ($\text{M}^+ + 1$, 9.00), 228 (M^+ , 100); IR(neat) 1748, 1670, 1634, 1600 cm^{-1} ; Anal. Calcd for $\text{C}_{15}\text{H}_{16}\text{O}_2$: (%) C 78.92, H 7.06. Found: C 78.71, H 6.87.

4-Allyl-5-ethyl-3-methyl-5-phenyl-2-furanone (3o): A mixture of **1h** (101 mg, 0.5 mmol), allyl bromide (**2a**) (0.22 mL, 306 mg, 2.5 mmol) and PdCl_2 (4 mg, 0.023 mmol) in DMA (3 mL) was stirred for 19 hours to afford 100 mg (83%) of **3o** (petroleum ether/ethyl acetate = 20 : 1). Oil; ^1H NMR (300 MHz, CDCl_3) δ 7.22-7.41 (m, 5 H), 5.38-5.53 (m, 1 H), 4.91-5.04 (m, 2 H), 2.84-3.03 (m, 2 H), 2.30-2.44 (m, 1 H), 2.01-2.16 (m, 1 H), 1.86 (s, 3 H), 0.88 (t, $J = 7.33$ Hz, 3 H); ^{13}C NMR (75.4 MHz, CDCl_3) δ 7.9, 9.1, 28.6, 30.9, 91.1, 118.0, 123.9, 125.7, 128.4, 128.9, 131.8, 138.1, 163.5, 174.8; EIMS m/z 242 (M^+ , 2.58), 213 (100); IR(neat) 1748, 1668, 1634, 1493, 1445 cm^{-1} ; Anal. Calcd for $\text{C}_{16}\text{H}_{18}\text{O}_2$: (%) C 79.31, H 7.49. Found: C 79.33, H 7.70.

4-Allyl-5-(4'-bromo-phenyl)-3-propyl-2(5H)-furanone (3p): A mixture of **1i** (70 mg, 0.25 mmol), allyl bromide (**2a**) (0.11 mL, 153 mg, 1.25 mmol) and PdCl₂ (2 mg, 0.011 mmol) in DMA (1.5 mL) was stirred for 11.5 hours to afford 60 mg (75%) of **3p** (petroleum ether/ethyl acetate = 10 : 1). Oil; ¹H NMR (300 MHz, CDCl₃) δ 7.49 (d, *J* = 8.40 Hz, 2 H), 7.05 (d, *J* = 8.40 Hz, 2 H), 5.52-5.71 (m, 1 H), 5.64 (s, 1 H), 5.09 (d, *J* = 9.90 Hz, 1 H), 4.99 (d, *J* = 17.10 Hz, 1 H), 3.14 (dd, *J* = 5.40, 15.40 Hz, 1 H), 2.65 (dd, *J* = 7.80, 15.40 Hz, 1 H), 2.30 (t, *J* = 8.1 Hz, 2 H), 1.50-1.65 (m, 2 H), 0.93 (t, *J* = 7.20 Hz, 3 H); ¹³C NMR (75.4 MHz, CDCl₃) δ 13.9, 21.5, 25.5, 30.7, 82.7, 118.5, 123.3, 128.0, 128.6, 132.1, 133.8, 160.1, 174.0; EIMS *m/z* 323(M(⁸¹Br)⁺+1, 5.90), 322(M(⁸¹Br)⁺, 31.95), 321(M(⁷⁹Br)⁺+1, 6.68), 320(M(⁷⁹Br)⁺, 33.37), 279 (100); IR(neat) 1759, 1671, 1637, 1488 cm⁻¹; Anal. Calcd for C₁₆H₁₇BrO₂: (%) C 59.83, H 5.33, Found: C 59.96, H 5.42.

4-(2'-butenyl)-5-phenyl-3-propyl-2(5H)-furanone (3q): A mixture of **1a** (101 mg, 0.5 mmol), 3-chloro-1-butene (**2e**) (228 mg, 2.5 mmol) and PdCl₂ (4 mg, 0.023 mmol) in DMA (3 mL) was stirred for 16 hours to afford 116 mg (91%) of **3q** (petroleum ether/ethyl acetate = 15 : 1). Oil; ¹H NMR (300 MHz, CDCl₃) δ 7.23-7.37 (m, 3 H), 7.02-7.21 (m, 2 H), [5.61 (s), 5.59 (s), 1 H], [5.40-5.53 (m), 5.25-5.37 (m), 1 H], 5.10-5.24 (m, 1 H), 2.93-3.10 (m, 1 H), [2.65-2.75 (m), 2.49-2.63 (m), 1 H], 2.20-2.33 (m, 2 H), 1.30-1.71 (m, 5 H), 0.89 (t, *J* = 7.38 Hz, 3 H); EIMS *m/z* 257 (M⁺+1, 2.38), 256 (M⁺, 12.28), 77 (100); IR(neat) 1748, 1668, 1601, 1537, 1489, 1449 cm⁻¹; Anal. Calcd for C₁₇H₂₀O₂: (%) C 79.65, H 7.86. Found: C 79.36, H 7.77.

(-)-4-Allyl-5-phenyl-3-propyl-2(5H)-furanone (3a): A mixture of (-)-**1a** (50 mg, >97% ee, 0.25 mmol), allyl bromide (**2a**) (0.11 mL, 153 mg, 1.25 mmol) and PdCl₂ (2 mg, 0.011 mmol) in DMA (2 mL) was stirred at 25 °C for 36.5 hours to afford 49 mg (82%, 99% ee) of **3a**. (HPLC condition: AS Column; rate: 0.7 mL/min; eluent:

hexane/*i*-PrOH = 85/15), $[\alpha]_{\text{D}}^{20} = -188.1$ (C 2.10, EtOH).

(+)-4-Allyl-3-methyl-5-(1'-naphthyl)-2(5H)-furanone (3d): A mixture of (+)-**1d** (56 mg, >98% ee, 0.25 mmol), allyl bromide (**2a**) (0.11 mL, 153 mg, 1.25 mmol) and PdCl₂ (2 mg, 0.011 mmol) in DMA (2 mL) was stirred at 25 °C for 40 hours to afford 60 mg (91%, 90% ee) of **3d**. (HPLC condition: AS Column; rate: 0.7 mL/min; eluent:

hexane/*i*-PrOH = 85/25), $[\alpha]_{\text{D}}^{20} = +120.4$ (C 1.08, EtOH).

(-)-4-Allyl-3-methyl-5-(1'-naphthyl)-2(5H)-furanone (3d): A mixture of (-)-**1d** (56 mg, >97% ee, 0.25 mmol), allyl bromide (**2a**) (0.11 mL, 153 mg, 1.25 mmol) and PdCl₂ (2 mg, 0.011 mmol) in DMA (2 mL) was stirred at 25 °C for 40 hours to afford 56 mg (85%, 92% ee) of **3d**. (HPLC condition: AS Column; rate: 0.7 mL/min; eluent:

hexane/*i*-PrOH = 85/25), $[\alpha]_{\text{D}}^{20} = -116.8$ (C 1.04, EtOH).

Allyl 4-phenyl-2-propyl-2,3-butadienoate 6: A mixture of **1a** (50 mg, 0.248 mmol), allyl bromide (**2a**) (0.11 mL, 153 mg, 1.25 mmol), K₂CO₃ (37 mg, 0.268 mmol) and PdCl₂ (2 mg, 0.011 mmol) in DMA (2 mL) was stirred at room temperature for 24 hours to afford the product (57 mg, 95%) (petroleum ether/ethyl acetate = 8 : 1). Oil; ¹H NMR (300 MHz, CDCl₃) δ 7.21-7.38 (m, 5 H), 6.56 (t, *J* = 2.85 Hz, 1 H), 5.84-5.97 (m, 1 H), 5.29 (d, *J* = 17.40 Hz, 1 H), 5.19 (d, *J* = 10.50 Hz, 1 H), 4.67 (d, *J* = 5.70 Hz, 2 H), 2.28-2.43 (m, 2 H), 1.48-1.62 (m, 2 H), 0.96 (t, *J* = 7.35 Hz, 3 H); ¹³C NMR (75.4 MHz, CDCl₃) δ 13.7, 21.3, 30.9, 65.4, 98.3, 104.1, 117.7, 127.2, 127.6, 128.7, 132.1, 132.4, 166.4, 212.2; EIMS *m/z* 242 (*M*⁺, 11.74), 41 (100); IR(neat) 1944, 1715 cm⁻¹; Anal. Calcd for C₁₆H₁₈O₂: (%) C 79.31, H 7.49. Found: C 79.14, H 7.52.

ppm

Hz

Solvent: cdc13
 Ambient temperature
 Mercury-300BB "MERCURYvx300"

Relax. delay 1.000 sec
 Pulse 22.5 degrees
 Acq. time 1.997 sec
 Width 10010.0 Hz
 16 repetitions
 OBSERVE H1, 300.0332279 MHz
 DATA PROCESSING
 FT size 32768
 Total time 0 min, 51 sec

ppm

Hz

ppm

Hz

2410.20
2377.04
2369.48
2367.72
2360.18
2272.83
2271.04
2267.83
2265.48
2262.86
2260.06
2258.52
2244.21
2236.77
2228.78
2185.46
2184.47
2178.61
2177.26
1967.16
1690.60
1684.43
1674.85
1674.36
1673.53
1517.75
1516.59
1507.68
1506.53
1488.82
1487.45
1486.11
1471.79
1470.42
963.99
958.31
948.53
942.73
843.09
835.94
827.54
820.45
598.10
597.56
596.97
497.16

ppm

Integral

Hz

ppm

Hz

2390.11
2386.08
2380.82
2354.44
2348.92
2345.21
2337.24
2249.05
2244.09
2243.08
2239.25
2235.45
2234.55
2224.81
2217.44
2209.41
2165.47
2158.33
2157.82
1945.86

1430.95
1429.70
1344.37

934.93
919.48
757.47
742.03
703.84
696.40
691.16
688.85
683.70
490.98
483.55
473.54
468.43
461.56
286.37
279.06
271.66

1.000

2.918

1.051

0.929

0.964

0.962

0.974

1.000

1.987

5.554

2.953

2186.16
2182.49
2180.66
2179.44
2131.78
2129.33
2125.06
2123.22

1704.08
1631.37
1627.70

1050.92
1035.64

894.50
879.23

687.37
682.49
679.43
674.54
672.10

479.02
471.69
464.36
456.42

271.89
264.56
257.23

3i

ppm

Integral

Hz

Pulse Sequence: s2p1
 Solvent: CDCl3
 Ambient temperature
 Mercury-300BB "MERCURYvx300"

Relax. delay 1.000 sec
 Pulse 27.7 degrees
 Acq. time 0.998 sec
 Width 18797.0 Hz
 1168 repetitions
 OBSERVE C13, 75.4H34155 MHz
 DECOUPLE H1, 300.0346884 MHz
 Power 45 dB
 on during acquisition
 off during delay
 WALTZ-16 modulated
 DATA PROCESSING
 FT size 65536
 Total time 0 min, 0 sec

—34.962

—22.682

—8.965

Solvent: CDCl₃
Ambient temperature
Mercury-300BB "MERCURYvx300"

Relax. delay 1.000 sec
Pulse 34.6 degrees
Acq. time 3.405 sec
Width 18797.0 Hz
36 repetitions
OBSERVE C13, 75.4433982 MHz
DECOUPLE H1, 300.0346884 MHz
Power 45 dB
on during acquisition
off during delay
WALTZ-16 modulated
DATA PROCESSING
FT size 131072
Total time 176 hr, 57 min, 44 sec

138.140
131.788
128.879
128.396
125.667
123.861
117.991

91.100

77.771
77.353
76.927

30.906
28.571

9.045
7.893

ppm

Hz

3q : 3qA = 98 : 2

Injection Date : 9/12/2002 4:02:32 AM

Sample Name : YZQ-mix

Acq. Operator :

Vial : 1

Inj : 1

Inj Volume : Manually

Acq. Method : C:\HPCHEM\CORE\TEST.M

Last changed : 9/12/2002 2:27:53 AM
(modified after loading)

Analysis Method : C:\HPCHEM\CORE\TEST.M

Last changed : 9/12/2002 8:54:11 PM
(modified after loading)

Area Percent Report

Sorted By : Signal
Multiplier : 1.0000
Dilution : 1.0000

Signal 1: FID1 A,

Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	2.622	VV	0.0431	302.00620	95.07925	0.12399
2	4.432	BB	0.0693	461.83835	102.94131	0.18960
3	5.101	BB S	0.0680	1.22871e5	2.81099e4	50.44310
4	7.303	PB S	0.0706	1.18076e5	2.43490e4	48.47489
5	8.984	BV	0.0511	146.80029	44.91988	0.06027
6	9.680	BB	0.0461	160.55519	53.33584	0.06591
7	11.300	VB	0.0354	214.15775	91.13419	0.08792
8	13.633	VV	0.0240	434.27737	280.84637	0.17829
9	13.730	VB	0.0390	165.92458	69.13519	0.06812
10	15.092	VV	0.0573	167.04102	37.98257	0.06858
11	15.175	VV	0.0847	255.56442	39.38997	0.10492
12	16.736	VB	0.1341	327.42444	31.53204	0.13442

Totals : 2.43583e5 5.33052e4

Results obtained with enhanced integrator!

*** End of Report ***

The main component was the more stable isomer **2f** by monitoring the reaction with gas chromatography.

```

=====
Injection Date   : 9/12/2002 3:34:17 AM
Sample Name     : YZQ-12-77
Acq. Operator   :
Vial            : 1
Inj             : 1
Inj Volume      : Manually

Acq. Method     : C:\HPCHEM\CORE\TEST.M
Last changed    : 9/12/2002 2:27:53 AM
                  (modified after loading)
Analysis Method  : C:\HPCHEM\CORE\TEST.M
Last changed    : 9/12/2002 8:56:09 PM
                  (modified after loading)
=====
  
```

Area Percent Report

```

Sorted By      : Signal
Multiplier     : 1.0000
Dilution       : 1.0000
  
```

Signal 1: FID1 A,

Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	5.087	BB	0.0684	3414.76172	775.77557	2.62104
2	7.260	BB	0.0593	9616.27051	2423.09082	7.38107
3	13.140	BB S	0.0353	1.15406e5	5.32902e4	88.58151
4	13.336	PB	0.0241	113.14590	73.08990	0.08685
5	14.113	BB	0.0231	140.87653	96.10023	0.10813
6	15.663	PV	0.0822	802.90118	123.00509	0.61628
7	15.691	VB	0.0851	788.36603	120.80119	0.60512

Totals : 1.30283e5 5.69021e4

Results obtained with enhanced integrator!

*** End of Report ***

The main component was the more stable isomer **2f** by monitoring the reaction with gas chromatography.

```

=====
Injection Date   : 9/12/2002 3:05:59 AM
Sample Name     : YZQ-12-75
Acq. Operator   :
Vial            : 1
Inj             : 1
Inj Volume      : Manually

Acq. Method     : C:\HPCHEM\CORE\TEST.M
Last changed    : 9/12/2002 2:27:53 AM
                  (modified after loading)
Analysis Method  : C:\HPCHEM\CORE\TEST.M
Last changed    : 9/12/2002 8:56:46 PM
                  (modified after loading)
=====
  
```

Area Percent Report

```

Sorted By      : Signal
Multiplier     : 1.0000
Dilution       : 1.0000
  
```

Signal 1: FID1 A,

Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	2.628	BV	0.0480	126.71148	35.21826	0.10215
2	5.088	BB	0.0691	3736.93335	852.45215	3.01250
3	7.262	BB	0.0594	1.07723e4	2708.77246	8.68402
4	13.140	PB S	0.0336	1.09186e5	5.18192e4	88.01959
5	13.337	PP	0.0252	111.30080	71.33041	0.08972
6	14.693	VV	0.1038	114.15324	13.62340	0.09202

Totals : 1.24048e5 5.55006e4

Results obtained with enhanced integrator!

*** End of Report ***

all graphic windows

Current Chromatogram(s)

2e

```

=====
Injection Date   : 9/12/2002 2:06:55 AM
Sample Name     : YZQ-12-77-b
Acq. Operator   :
Vial            : 1
Inj             : 1
Inj Volume      : Manually

Acq. Method     : C:\HPCHEM\CORE\TEST.M
Last changed    : 9/12/2002 2:23:50 AM
                  (modified after loading)
Analysis Method : C:\HPCHEM\CORE\TEST.M
Last changed    : 9/12/2002 8:59:51 PM
                  (modified after loading)
=====

```

Area Percent Report

```

=====
Sorted By       : Signal
Multiplier     : 1.0000
Dilution       : 1.0000
=====

```

Signal 1: FID1 A,

Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	4.961	BB	0.0640	160.57822	38.99017	0.32021
2	5.550	BB S	0.0621	4.55584e4	1.15219e4	90.84818
3	7.525	BB	0.0563	1089.59937	287.08163	2.17278
4	13.642	VV	0.0248	992.48828	649.71954	1.97913
5	13.739	VV	0.0317	399.14423	174.29976	0.79594
6	14.815	VV	0.0371	118.41897	50.97746	0.23614
7	15.095	VV	0.0770	280.10226	45.36784	0.55855
8	15.308	VB	0.0415	143.50497	48.53473	0.28616
9	16.200	BV	0.0324	131.12303	62.82186	0.26147
10	16.256	VV	0.0314	303.79703	151.57852	0.60580
11	16.329	VV	0.0339	216.63431	101.44622	0.43199
12	16.449	VV	0.0514	252.34938	69.44090	0.50321
13	16.530	VV	0.0518	367.53903	95.63480	0.73291
14	16.740	VV	0.0795	134.15764	25.88116	0.26752

Totals : 5.01478e4 1.33237e4

Results obtained with enhanced integrator!

2f

```

=====
Injection Date   : 9/12/2002 2:36:41 AM
Sample Name     : YZQ-12-75-b
Acq. Operator   :
Vial            : 1
Inj             : 1
Inj Volume      : Manually

Acq. Method     : C:\HPCHEM\CORE\TEST.M
Last changed    : 9/12/2002 2:27:53 AM
                  (modified after loading)
Analysis Method : C:\HPCHEM\CORE\TEST.M
Last changed    : 9/12/2002 8:58:42 PM
                  (modified after loading)
=====

```

Area Percent Report

```

Sorted By      : Signal
Multiplier     : 1.0000
Dilution       : 1.0000

```

Signal 1: FID1 A,

Peak #	RetTime [min]	Type	Width [min]	Area [pA*s]	Height [pA]	Area %
1	2.632	VV	0.0494	212.58928	59.92524	0.08970
2	5.104	BB	0.0679	5226.56836	1197.85718	2.20521
3	7.347	PB S	0.0813	2.29985e5	3.98753e4	97.03628
4	8.999	BV	0.0514	312.27988	94.83775	0.13176
5	9.451	PB	0.0559	196.47980	54.65207	0.08290
6	11.263	VV	0.0279	223.64572	124.80726	0.09436
7	11.308	VB	0.0412	404.54990	156.25478	0.17069
8	11.503	VV	0.0281	142.91049	78.95730	0.06030
9	13.639	BV	0.0239	105.34793	64.98284	0.04445
10	18.901	PB	0.1194	199.93460	21.51345	0.08436

Totals : 2.37010e5 4.17291e4

Results obtained with enhanced integrator!