Hydrogen Bond Directed Highly Regioselective Palladium-Catalyzed Allylic Substitution

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General Experimental Detail

Tetrahydrofuran (THF) and toluene were distilled from benzophenone/ketyl prior to use. Methylene chloride (CH_2Cl_2), acetonitrile (CH_3CN), and triethylamine (Et_3N) were distilled from calcium hydride. Methanol was distilled from magnesium. All other reagents were purchased from Aldrich or ACROS chemical companies and used without further purification. All glassware was oven dried and cooled in a desiccator prior to use. Reactions with air-sensitive materials were carried out by standard syringe techniques. All reactions were run under an inert atmosphere of nitrogen or argon. Flash chromatography was performed using E. Merck silica gel 60 (230-400 mesh). NMR spectra were recorded on a Varian Inova 500 MHz, 400 MHz, or Varian Mercury 300 MHz spectrometer. ^{13}C NMR was recorded using broad band proton decoupling. Chemical shifts are reported in δ relative to TMS and coupling constants in Hz. Optical rotations were recorded on a JASCO-CIP-370 instrument. Elemental analyses were performed on a Perkin Elmer Series II CHNS/O Analyzer 2400. High-resolution mass spectra (HRMS) [Positive Ion FAB (FAB^+) or Electrospray (ES)] were obtained at the Mass Spectrometry Laboratory, University of South Carolina, Columbia, SC. Melting points were determined without correction.

General Procedure for Palladium-Catalyzed Allylic Substitution of 5-Vinyloxazolidinones

Oxazolidinone (1 eq), $[\pi\text{-C}_3\text{H}_5\text{PdCl}]_2$ (1 mol%), chiral ligand (4 mol%), nucleophile (1.1 eq), and potassium phthalimide (2.5 mol%) or NaH (60% dispersion in mineral oil, 20 mol%) were placed in a 5 mL 1-neck flask that was sealed with a rubber septum. The flask was evacuated and flushed with nitrogen 3 times (about 15 min). Solvent was added, and the reaction was stirred at room temperature until the reaction was complete (by TLC analysis). The solution was filtered through a small plug of silica gel, washed with ethyl acetate/dichloromethane (1/1), and concentrated to afford the crude product. The ratios of (1,2)/(1,4) regioisomers, *E/Z* stereoisomers of (1,4) product, and *syn/anti* diastereoisomers of (1,2) product were determined by ^1H NMR of the crude product. The regioisomers were separated on silica gel (200-400 mesh) using a mixture of ethyl acetate and hexanes. If NaH was used as the base in the reaction, 100 mL of hexane

N-[1(*S*)-Benzyl-2(*S*)-(1,3-dioxo-1,3-dihydro-isoindol-2-yl)-but-3-enyl]-4-nitrobenzamide (**6b**)

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (20→40% (v/v) ethyl acetate in hexanes as eluent) afforded the branched product as a white solid (mp 226-228 °C); $[\alpha]_D^{25}$ -218.9 (*c* 1.0, CH_2Cl_2); R_f 0.30 (30:70-ethyl acetate/hexanes); ^1H NMR (400 MHz, CDCl_3) δ 8.49 (d, J = 9.2 Hz, 1H), 8.29-8.34 (m, 2H), 7.99-8.04 (m, 2H), 7.90-7.94 (m, 2H), 7.80-7.84 (m, 2H), 7.21-7.27 (m, 2H), 7.15-7.21 (m, 3H), 6.04 (ddd, J = 15.6 Hz, 10.4 Hz, 5.2 Hz, 1H), 5.21 (dd, J = 10.4 Hz, 1.2 Hz, 1H), 5.13 (dd, J = 15.6 Hz, 1.2 Hz, 1H), 5.01-5.13 (m, 2H), 2.94 (dd, J = 14.0 Hz, 6.4 Hz, 1H), 2.82 (dd, J = 14.0 Hz, 7.2 Hz, 1H); ^{13}C NMR (500 MHz, CDCl_3) δ 169.2, 165.0, 149.8, 140.1, 136.8, 135.0, 132.4, 131.6, 129.3, 128.8, 128.4,

127.1, 124.0, 118.2, 105.6, 55.7, 53.2, 38.8; Anal. Calcd for C₂₆H₂₁N₃O₅: C, 68.56; H, 4.65; N, 9.23; Found: C, 68.74; H, 4.67; N, 9.18.

N-[1(S)-Benzyl-4-(1,3-dioxo-1,3-dihydro-isoindol-2-yl)-(E)-but-2-enyl]-4-nitro-benzamide (7b)

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (15→30% (v/v) ethyl acetate in hexanes as eluent) afforded the linear product as a white solid (mp 184-185 °C); $[\alpha]_D^{25} +0.7$ (c 0.72, CH₂Cl₂); R_f 0.20 (30:70-ethyl acetate/hexanes); ¹H NMR (500 MHz, CDCl₃) δ 8.23-8.27 (m, 2H), 7.84-7.88 (m, 2H), 7.77-7.82 (m, 2H), 7.72-7.77 (m, 2H), 7.19-7.25 (m, 2H), 7.13-7.19 (m, 3H), 6.03 (d, J = 8.5 Hz, 1H), 5.83 (dd, J = 15.5 Hz, 6.0 Hz, 1H), 5.66 (ddt, J = 15.5 Hz, 1.5 Hz, 6.0 Hz, 1H), 4.96-5.03 (m, 1H), 4.23-4.32 (m, 2H), 3.02 (dd, J = 13.5 Hz, 6.5 Hz, 1H), 2.97 (dd, J = 13.5 Hz, 6.0 Hz, 1H); ¹³C NMR (500 MHz, CDCl₃) δ 168.0, 164.8, 149.8, 140.2, 136.5, 134.3, 133.1, 132.2, 129.8, 128.7, 128.3, 127.1, 125.4, 124.1, 123.5, 51.9, 41.1, 39.1; Anal. Calcd for C₂₆H₂₁N₃O₅: C, 68.58; H, 4.65; N, 9.23; Found: C, 68.42; H, 4.56; N, 9.09.

N-[1(S)-Benzyl-2(S)-(1,3-dioxo-1,3-dihydro-isoindol-2-yl)-but-3-enyl]-4-methoxy-benzamide (6c)

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (15→30% (v/v) ethyl acetate in hexanes as eluent) afforded the branched product as a white solid (mp 162-163 °C); $[\alpha]_D^{25} -198.5$ (c, 1.0, CH₂Cl₂); R_f 0.18 (30:70-ethyl acetate/hexanes); ¹H NMR (500 MHz, CDCl₃) δ 8.10 (d, J = 8.5 Hz, 1H), 7.87-7.92 (m, 2H), 7.82-7.86 (m, 2H), 7.77-7.81 (m, 2H), 7.20-7.25 (m, 2H), 7.14-7.20 (m, 3H), 6.93-6.98 (m, 2H), 6.08 (ddd, J = 17.0 Hz, 10.5 Hz, 5.5 Hz, 1H), 5.18 (d, J = 10.5 Hz, 1H), 5.11 (d, J = 17.0 Hz, 1H), 5.02-5.11 (m, 2H), 3.86 (s, 1H), 2.97 (dd, J = 14.0 Hz, 6.0 Hz, 1H), 2.80 (dd, J = 14.0 Hz, 7.5 Hz, 1H); ¹³C NMR (500 MHz, CDCl₃) δ 169.1, 166.6, 162.3, 137.2, 134.7, 132.8, 131.7, 129.4, 129.0, 128.6, 126.9, 126.8, 123.9, 118.0, 113.9, 55.8, 55.6, 52.7, 38.9; Anal. Calcd for C₂₇H₂₄N₂O₄: C, 73.62; H, 5.49; N, 6.36; Found: C, 73.75; H, 5.34; N, 6.38.

N-[1(S)-Benzyl-4-(1,3-dioxo-1,3-dihydro-isoindol-2-yl)-(E and Z)-but-2-enyl]-4-methoxy-benzamide (7c)

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (15→30% (v/v) ethyl acetate in hexanes as eluent) afforded the linear product as a white solid (mp 189-190 °C); (E/Z = 5:1); ¹H NMR (500 MHz, CDCl₃) δ for E isomer: 7.84-7.87 (m, 1H), 7.70-7.75 (m, 2H), 7.62-7.66 (m, 2H), 7.29-7.33 (m, 1H), 7.17-7.22 (m, 2H), 7.11-7.17 (m, 3H), 6.87-6.92 (m, 2H), 5.90 (d, J = 8.5 Hz, 1H), 5.82 (dd, J = 15.5 Hz, 5.5 Hz, 1H), 5.56-5.65 (m, 1H), 4.95-5.03 (m, 1H), 4.26 (d, J = 6.5 Hz, 2H), 3.83 (s, 3H), 2.92-2.99 (m, 2H); Characteristic δ for Z isomer: 6.30 (d, J = 7.5 Hz, 1H), 5.32-5.39 (m, 1H), 4.46 (dd, J = 15.0 Hz, 7.5 Hz, 1H), 4.33 (dd, J = 15.0 Hz, 6.5 Hz, 1H), 3.84 (s, 3H), 3.11 (dd, J = 13.5 Hz, 6.3 Hz, 1H), 3.05 (dd, J = 13.5 Hz, 6.5 Hz, 1H); ¹³C NMR (500 MHz, CDCl₃) δ for E isomer: 168.0, 166.3, 162.3, 136.9, 134.2, 133.9, 132.2, 129.8, 128.8, 128.5, 126.8, 126.7, 124.6, 123.5, 113.9, 55.6, 51.2, 41.2, 39.1; δ for Z isomer: 168.1, 166.4, 162.2, 137.4, 134.1, 133.0, 132.3, 129.9, 128.9, 128.7, 127.0, 125.9, 124.6, 123.4, 113.8, 60.6, 48.6, 41.1, 35.2; HRMS (FAB⁺) Calcd for C₂₇H₂₄N₂O₄ (M+H)⁺: 441.1814; Found: 441.1827.

[1(S)-Benzyl-2(S)-(1,3-dioxo-1,3-dihydro-isoindol-2-yl)-but-3-enyl]-carbamic acid tert-butyl ester (6d)

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (20→40% (v/v) ethyl acetate in hexanes as eluent) afforded the branched product as a white solid (mp 126-128 °C); $[\alpha]_D^{25} -44.7$ (c = 0.6, CHCl₃); ¹H NMR (400 MHz, CDCl₃, 50°C): δ 7.86-7.64 (m, 4H), 7.26-7.11 (m, 5H), 6.34 (m, 1H), 5.38-5.1 (m, 3H), 4.8 (bs, 1H), 4.53 (bs, 1H), 2.91 (m, 1H), 2.72 (m, 1H), 1.17 (s, 9H); ¹³C NMR (100.5 MHz, CDCl₃): δ

168.40, 155.52, 137.36, 134.15, 133.21, 131.86, 129.27, 128.47, 126.55, 123.40, 119.74, 79.08, 57.50, 52.61, 38.25, 28.08; IR (neat film): 3362, 1773, 1711, 1364 cm^{-1} . Anal. Calcd for $\text{C}_{24}\text{H}_{26}\text{N}_2\text{O}_4$: C, 70.92; H, 6.45; N, 6.89. Found: C, 70.97; H, 6.22; N, 6.97.

[1(S)-Benzyl-4-(1,3-dioxo-1,3-dihydro-isoindol-2-yl)-(E)-but-2-enyl]-carbamic acid *tert*-butyl ester (7d)

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (20→40% (v/v) ethyl acetate in hexanes as eluent) afforded the linear product as a white solid (mp 117 °C); $[\alpha]_D^{25} = +2.6$ ($c = 1.5$, CHCl_3); ^1H NMR (400 MHz, CDCl_3): δ 7.88-7.81 (m, 2H), 7.76-7.69 (m, 2H), 7.21-7.06 (m, 5H), 5.68 (dd, $J = 15.3, 3.9$ Hz, 1H), 5.54 (dt, $J = 15.3, 6.1$ Hz, 1H), 4.40 (br, 2H), 4.22 (d, $J = 5.9$ Hz, 2H), 2.88-2.70 (m, 2H), 1.36 (s, 9H); ^{13}C NMR (100.5 MHz, CDCl_3): δ 167.83, 155.09, 137.14, 134.29, 134.04, 132.18, 129.71, 128.26, 126.46, 123.99, 123.31, 79.50, 52.54, 41.61, 38.98, 28.39; IR (neat film): 3358, 1769, 1709, 1688, 1523 cm^{-1} . Anal. Calcd for $\text{C}_{24}\text{H}_{26}\text{N}_2\text{O}_4$: C, 70.92; H, 6.45; N, 6.89. Found: C, 70.76; H, 6.52; N, 7.15.

[1(S)-Benzyl-2(S)-(1,3-dioxo-1,3-dihydro-isoindol-2-yl)-but-3-enyl]-carbamic acid benzyl ester (6e)

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (20→40% (v/v) ethyl acetate in hexanes as eluent) afforded the branched product; $[\alpha]_D^{25} = -70.0$ ($c = 0.3$, CHCl_3); ^1H NMR (400 MHz, CDCl_3 , 50 °C): δ (7.88 – 7.76 (m, 2H), 7.75 – 7.66 (m, 2H), 7.3 – 7.08 (m, 10H), 6.25 (m, 1H), 5.74 (br, 1H), 5.33 – 5.17 (m, 2H), 5.0 – 4.77 (m, 3H), 4.59 (m, 1H), 2.89 (dd, $J = 14.1, 5.5$ Hz, 1H), 2.78 (m, 1H); ^{13}C NMR (100.5 MHz, CDCl_3 , 50 °C): δ 168.30, 156.0, 137.17, 134.15, 132.94, 131.84, 129.30, 128.48, 127.80, 127.76, 126.63, 123.48, 119.2, 66.4, 57.0, 53.8, 38.5; IR (neat film): 3345, 1770, 1711, 1516, 1385 cm^{-1} . Anal. Calcd for $\text{C}_{27}\text{H}_{24}\text{N}_2\text{O}_4$: C, 73.62; H, 5.49; N, 6.36. Found: C, 74.00; H, 5.55; N, 6.41.

[1(S)-Benzyl-4-(1,3-dioxo-1,3-dihydro-isoindol-2-yl)-(E)-but-2-enyl]-carbamic acid benzyl ester (7e)

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (20→40% (v/v) ethyl acetate in hexanes as eluent) afforded the linear product as a white solid (mp 106 °C); $[\alpha]_D^{25} = +0.2$ ($c = 0.8$, CHCl_3); ^1H NMR (400 MHz, CDCl_3): δ 7.84 (m, 2H), 7.73 (m, 2H), 7.38 – 7.24 (m, 5H), 7.19 – 7.06 (m, 5H), 5.70 (dd, $J = 15.6, 5.3$ Hz, 1H), 5.55 (ddt, $J = 15.6, 5.9, 1.3$ Hz, 1H), 5.04 (ABq, $J = 12.2$ Hz, 2H), 4.67 (br, 1H), 4.48 (br, 1H), 4.22 (d, $J = 5.9$ Hz, 2H), 2.81 (m, 2H); ^{13}C NMR (100.5 MHz, CDCl_3): δ 167.87, 155.60, 136.78, 136.49, 134.08, 133.88, 132.17, 129.70, 128.58, 128.38, 128.17, 128.10, 126.64, 124.39, 123.37, 66.78, 53.0, 41.44, 38.96; IR (neat film): 3329, 1771, 1705, 1612, 1497 cm^{-1} . Anal. Calcd for $\text{C}_{27}\text{H}_{24}\text{N}_2\text{O}_4$: C, 73.62; H, 5.49; N, 6.36. Found: C, 73.50; H, 5.40; N, 6.29.

N-[1(S)-Benzyl-2(S)-(1,3-dioxo-1,3-dihydro-benzo[f]isoindol-2-yl)-but-3-enyl]benzamide (35a)

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (10→20% (v/v) ethyl acetate in hexanes as eluent) afforded the branched product as a white solid (mp 207-209 °C); $[\alpha]_D^{25} = -184.4$ ($c = 1.0$, CH_2Cl_2); R_f 0.20 (30:70-ethyl acetate/hexanes); ^1H NMR (500 MHz, CDCl_3) δ 8.40 (s, 2H), 8.32 (d, $J = 8.0$ Hz, 1H), 8.07-8.13 (m, 2H), 7.86-7.92 (m, 2H), 7.71-7.78 (m, 2H), 7.43-7.53 (m, 3H), 7.15-7.26 (m, 5H), 6.15 (ddd, $J = 16.5$ Hz, 10.5 Hz, 5.8 Hz, 1H), 5.11-5.25 (m, 4H), 3.01 (dd, $J = 14.0$ Hz, 6.0 Hz, 1H), 2.84 (dd, $J = 14.0$ Hz, 7.0 Hz, 1H); ^{13}C NMR (500 MHz, CDCl_3) δ 168.8, 167.1, 137.3, 135.9, 134.7, 132.8, 131.6, 130.6, 129.8, 129.5, 128.8, 128.7, 127.4, 127.3, 126.9, 125.6, 118.2, 56.2, 52.8, 39.0; Anal. Calcd for $\text{C}_{30}\text{H}_{24}\text{N}_2\text{O}_3$: C, 78.24; H, 5.25; N, 6.08; Found: C, 78.31; H, 4.86; N, 5.95.

***N*-[1(*S*)-Benzyl-4-(1,3-dioxo-1,3-dihydro-benzo[*f*]isoindol-2-yl)-(*E*)-but-2-enyl]-benzamide (36a)**

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (10→20% (v/v) ethyl acetate in hexanes as eluent) afforded the linear product as a white solid (mp 210-213 °C); $[\alpha]_D^{25}$ -9.9 (*c* 1.0, CH₂Cl₂); *R_f* 0.12 (30:70-ethyl acetate/hexanes); ¹H NMR (400 MHz, CDCl₃) δ 8.34 (s, 2H), 8.04-8.10 (m, 2H), 7.69-7.75 (m, 2H), 7.64-7.69 (m, 2H), 7.44-7.51 (m, 1H), 7.36-7.43 (m, 2H), 7.15-7.23 (m, 4H), 7.08-7.15 (m, 1H), 6.02 (d, *J* = 8.8 Hz, 1H), 5.87 (dd, *J* = 15.6 Hz, 5.6 Hz, 1H), 5.66 (dt, *J* = 15.6 Hz, 6.0 Hz, 1H), 4.98-5.07 (m, 1H), 4.33 (d, *J* = 6.0 Hz, 2H), 2.99 (d, *J* = 6.4 Hz, 2H); ¹³C NMR (500 MHz, CDCl₃) δ 167.8, 166.9, 136.9, 135.7, 134.7, 133.9, 131.7, 130.6, 129.9, 129.5, 128.8, 128.6, 128.0, 127.1, 126.9, 125.0, 124.7, 51.4, 41.2, 39.4; Anal. Calcd for C₃₀H₂₄N₂O₃: C, 78.24; H, 5.25; N, 6.08; Found: C, 78.03; H, 5.01; N, 6.04.

***N*-[1(*S*)-Benzyl-2(*S*)-(2,5-dioxo-pyrrolidin-1-yl)-but-3-enyl]-benzamide (35b)**

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (20→40% (v/v) ethyl acetate in hexanes as eluent) afforded the branched product as a white solid (mp 186-189 °C); $[\alpha]_D^{25}$ -120.3 (*c* 1.0, CH₂Cl₂); *R_f* 0.20 (40:60-ethyl acetate/hexanes); ¹H NMR (500 MHz, CDCl₃) δ 7.71-7.76 (m, 2H), 7.61 (d, *J* = 9.0 Hz, 1H), 7.45-7.50 (m, 1H), 7.38-7.44 (m, 2H), 7.24-7.30 (m, 2H), 7.17-7.24 (m, 3H), 6.21 (ddd, *J* = 17.0 Hz, 10.0 Hz, 7.5 Hz, 1H), 5.24 (d, *J* = 10.0 Hz, 1H), 5.20 (d, *J* = 17.0 Hz, 1H), 4.98-5.05 (m, 1H), 4.86 (t, *J* = 7.5 Hz, 1H), 2.95 (dd, *J* = 14.5 Hz, 6.0 Hz, 1H), 2.83 (dd, *J* = 14.5 Hz, 7.0 Hz, 1H), 2.55-2.69 (m, 4H); ¹³C NMR (500 MHz, CDCl₃) δ 178.0, 167.2, 137.1, 134.5, 132.3, 131.7, 129.4, 128.8, 128.7, 127.1, 127.0, 119.6, 57.8, 51.7, 38.4, 28.3; Anal. Calcd for C₂₂H₂₂N₂O₃: C, 72.91; H, 6.12; N, 7.73; Found: C, 73.11; H, 6.01; N, 7.57.

***N*-[1(*S*)-Benzyl-4-(2,5-dioxo-pyrrolidin-1-yl)-(*E* and *Z*)-but-2-enyl]-benzamide (36b)**

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (10→20% (v/v) ethyl acetate in hexanes as eluent) afforded the linear product as a white solid (mp 192-194 °C (*E/Z* = 6:1)); *R_f* 0.1 (40:60-ethyl acetate/hexanes); ¹H NMR (500 MHz, CDCl₃) δ for *E* isomer: 7.65-7.70 (m, 2H), 7.47-7.52 (m, 1H), 7.38-7.44 (m, 2H), 7.26-7.32 (m, 2H), 7.21-7.26 (m, 1H), 7.17-7.21 (m, 2H), 6.01 (d, *J* = 8.5 Hz, 1H), 5.80 (dd, *J* = 15.8 Hz, 5.8 Hz, 1H), 5.53 (dt, *J* = 15.8 Hz, 6.0 Hz, 1H), 4.96-5.04 (m, 1H), 4.07 (d, *J* = 6.0 Hz, 2H), 2.97 (d, *J* = 6.0 Hz, 2H), 2.68 (s, 4H); Characteristic peaks for the *Z* isomer: δ 7.69-7.72 (m, 2H), 6.36 (d, *J* = 7.0 Hz, 1H), 5.58-5.64 (m, 1H), 5.22-5.30 (m, 1H), 4.22 (dd, *J* = 15.4 Hz, 7.8 Hz, 1H), 4.16 (dd, *J* = 15.4 Hz, 7.3 Hz, 1H), 3.06 (dd, *J* = 13.5 Hz, 6.5 Hz, 1H), 3.02 (dd, *J* = 13.5 Hz, 6.7 Hz, 1H); ¹³C NMR (500 MHz, CDCl₃) δ for *E* isomer: 176.8, 166.8, 136.9, 134.6, 134.5, 131.8, 129.9, 128.8, 128.6, 127.0, 126.9, 123.8, 51.3, 41.2, 40.0, 28.5; Characteristic peaks for the *Z* isomer: δ 177.1, 168.3, 48.8, 41.1, 36.0, 28.5; Anal. Calcd for C₂₂H₂₂N₂O₃: C, 72.91; H, 6.12; N, 7.73; Found: C, 72.80; H, 5.89; N, 7.61.

***N*-[1(*S*)-Benzyl-2(*S*)-(2,6-dioxo-piperidin-1-yl)-but-3-enyl]-benzamide (35c)**

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (10→40% (v/v) ethyl acetate in hexanes as eluent) afforded the branched product as a white solid (mp 169-171 °C); $[\alpha]_D^{25}$ -39.7° (*c* 0.6, CH₂Cl₂); ¹H NMR (500 MHz, CDCl₃) δ 7.55-7.61 (m, 2 H), 7.43-7.48 (m, 1 H), 7.34-7.41 (m, 2 H), 7.17-7.30 (m, 5 H), 6.50 (d, *J* = 9.5 Hz, 1 H), 6.43 (ddd, *J* = 18.0, 9.5, 2.0 Hz, 1 H), 5.39 (t, *J* = 9.0 Hz, 1 H), 5.29 (d, *J* = 18.0 Hz, 1H), 5.26 (d, *J* = 9.5 Hz, 1H), 5.13-5.22 (m, 1 H), 3.04 (dd, *J* = 14.5, 5.0 Hz, 1H), 2.25 (dd, *J* = 14.5, 8.5, Hz, 1 H), 2.57-2.66 (m, 2H), 2.45-2.55 (m, 2H), 1.77-1.84 (m, 2 H); ¹³C NMR (100.5 MHz, CDCl₃) δ 173.3, 167.2, 137.2, 134.7, 134.5, 131.6, 129.4, 128.8, 128.7, 126.9, 120.2, 58.5, 50.6, 38.3, 33.6, 17.2 (one overlapping peak); HRMS (ES, *m/z*): calcd for C₂₃H₂₅N₂O₃ (*M*+*H*), 377.1865; found: 377.1862.

***N*-[1(*S*)-Benzyl-4-(2,6-dioxo-piperidin-1-yl)-(*E* and *Z*)-but-2-enyl]-benzamide (36c)**

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (10→40% (v/v) ethyl acetate in hexanes as eluent) afforded the linear product as a mixture of *E* and *Z* isomers (2.8:1); ¹H NMR (500 MHz, CDCl₃) (*E* isomer) δ 7.60 (d, *J* = 8.0, 2 H), 7.37-7.44 (m, 1 H), 7.30-7.36 (m, 2 H), 7.09-7.25 (m, 5 H), 5.94 (d, *J* = 8.5, 1 H), 5.68 (ddd, *J* = 15.5, 5.5, 1.0 Hz, 1 H), 5.42-5.52 (m, 1 H), 4.87-4.96 (m, 1 H), 4.26 (d, *J* = 6.5 Hz, 2 H), 2.89 (d, *J* = 6.0 Hz, 2 H), 2.52-2.58 (m, 4 H), 1.80-1.87 (m, 2 H); (characteristic peaks for the *Z* isomer) δ 7.65 (m, 2 H), 7.15 (m, 2 H), 6.35 (d, *J* = 7.0 Hz, 1 H), 5.42-5.52 (m, 2 H), 5.21 (m, 1 H), 4.36 (d, *J* = 7.0 Hz, 2 H), 3.01 (dd, *J* = 6.5, 13.5 Hz, 1 H), 2.94 (dd, *J* = 7.0, 13.5 Hz, 1 H), 2.50-2.55 (m, 4 H), 1.90-1.96 (m, 2 H); ¹³C NMR (100.5 MHz, CDCl₃) (*E* isomer) δ 172.3, 166.8, 137.1, 134.8, 133.6, 131.7, 130.0, 128.8, 128.6, 127.1, 126.9, 125.3, 51.4, 41.3, 40.7, 33.0, 17.3; (*Z* isomer) δ 172.5, 166.8, 137.6, 134.9, 132.2, 131.6, 129.9, 128.7, 128.6, 127.2, 127.0, 126.8, 49.0, 41.2, 37.2, 31.9, 18.1; HRMS (ES, *m/z*): calcd for C₂₃H₂₄NaN₂O₃ (M+Na), 399.1685; found: 399.1677.

***N*-[1(*S*)-Benzyl-2(*S*)-(1,3-dioxo-1*H*,3*H*-benzo[*de*]isoquinolin-2-yl)-but-3-enyl]-benzamide (35d)**

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (10→40% (v/v) ethyl acetate in hexanes as eluent) afforded the branched product as a white solid (mp 143-145 °C); [α]_D²⁵ -74.0 (*c* 1.0, CH₂Cl₂); R_f 0.2 (30:70-ethyl acetate/hexanes); ¹H NMR (500 MHz, CDCl₃) δ 8.52-8.66 (m, 2H), 8.21 (d, *J* = 8.5 Hz, 2H), 7.71-7.79 (m, 2H), 7.61-7.67 (m, 2H), 7.50 (d, *J* = 9.5 Hz, 1H), 7.38-7.44 (m, 1H), 7.30-7.37 (m, 2H), 7.13-7.24 (m, 5H), 6.52 (ddd, *J* = 17.0 Hz, 10.5 Hz, 7.0 Hz, 1H), 5.98 (apparent t, *J* = 7.9 Hz, 1H), 5.36-5.44 (m, 1H), 5.36 (d, *J* = 17.0 Hz, 1H), 5.29 (d, *J* = 10.5 Hz, 1H), 3.05 (dd, *J* = 14.1 Hz, 6.0 Hz, 1H), 2.93 (dd, *J* = 14.1 Hz, 7.3 Hz, 1H); ¹³C NMR (500 MHz, CDCl₃) δ 167.1, 165.2, 137.3, 134.9, 134.4, 133.9, 131.9, 131.6, 131.3, 129.5, 128.6, 128.5, 128.4, 127.2, 127.0, 126.7, 122.7, 119.5, 57.9, 51.5, 38.5; Anal. Calcd for C₃₀H₂₄N₂O₃: C, 78.24; H, 5.25; N, 6.08; Found: C, 78.32; H, 5.56; N, 5.88.

***N*-[1(*S*)-Benzyl-4-(1,3-dioxo-1*H*,3*H*-benzo[*de*]isoquinolin-2-yl)-(*E*)-but-2-enyl]-benzamide (36d)**

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (10→40% (v/v) ethyl acetate in hexanes as eluent) afforded the linear *E* product as a white solid (mp 189-190 °C); [α]_D²⁵ +2.0 (*c* 1.0, CH₂Cl₂); R_f 0.15 (30:70-ethyl acetate/hexanes); ¹H NMR (500 MHz, CDCl₃) δ for *E* isomer: 8.57-8.62 (m, 2H), 8.19-8.25 (m, 2H), 7.72-7.79 (m, 2H), 7.62-7.68 (m, 2H), 7.42-7.48 (m, 1H), 7.34-7.40 (m, 2H), 7.13-7.18 (m, 2H), 7.08-7.13 (m, 2H), 7.02-7.08 (m, 1H), 6.03 (d, *J* = 8.5 Hz, 1H), 5.95 (dd, *J* = 15.5 Hz, 6.0 Hz, 1H), 5.75 (dt, 15.5 Hz, 6.5 Hz, 1H), 4.99-5.07 (m, 1H), 4.77 (d, *J* = 6.5 Hz, 2H), 2.98 (d, *J* = 6.0 Hz, 2H); Characteristic peaks for the *Z* isomer: δ 6.68 (d, *J* = 7.0 Hz, 1H), 5.66-5.70 (m, 2H), 5.44-5.50 (m, 1H), 3.20 (dd, *J* = 13.6 Hz, 6.0 Hz, 1H), 3.12 (dd, *J* = 13.6 Hz, 6.8 Hz, 1H); ¹³C NMR (500 MHz, CDCl₃) δ for *E* isomer: 166.8, 164.0, 137.0, 134.7, 134.3, 133.9, 131.8, 131.6, 131.5, 130.0, 128.7, 128.5, 128.4, 127.2, 127.0, 126.7, 125.3, 122.8, 51.4, 41.4, 41.3; Anal. Calcd for C₃₀H₂₄N₂O₃: C, 78.24; H, 5.25; N, 6.08; Found: C, 77.92; H, 5.47; N, 5.79.

***N*-[1(*S*)-Benzyl-2(*S*)-(3-methyl-2,5-dioxo-imidazolidin-1-yl)-but-3-enyl]-benzamide (35e)**

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (10→40% (v/v) ethyl acetate in hexanes as eluent) afforded the branched product as a white solid (mp 165.5-167 °C); [α]_D²⁵ -144.9° (*c* 0.7, CH₂Cl₂); ¹H NMR (500 MHz, CDCl₃) δ 8.30 (d, *J* = 9.0, Hz, 1 H), 7.81-7.86 (m, 2 H), 7.41-7.52 (m, 3

H), 7.18-7.30 (m, 5 H), 6.07 (ddd, $J = 6.5, 10.5, 17.0$ Hz, 1 H), 5.20 (d, $J = 10.5$ Hz, 1 H), 5.16 (d, $J = 17.5$ Hz, 1 H), 4.91-4.98 (m, 1 H), 4.86 (t, $J = 6.0$ Hz, 1 H), 3.84 (d, $J = 17.5$ Hz, 1 H), 3.78 (d, $J = 17.5$ Hz, 1 H), 2.98 (s, 3 H), 2.93 (dd, $J = 7.0, 14.0$ Hz, 1 H), 2.88 (dd, $J = 6.0, 14.0$ Hz, 1 H); ^{13}C NMR (100.5 MHz, CDCl_3) δ 170.6, 167.0, 157.1, 137.4, 134.5, 132.5, 131.7, 129.5, 128.8, 128.6, 127.2, 126.9, 118.7, 57.1, 52.7, 51.8, 38.6, 30.0; HRMS (ES, m/z): calcd for $\text{C}_{22}\text{H}_{24}\text{N}_3\text{O}_3$ ($M+H$), 378.1823; found: 378.1818.

***N*-[1(*S*)-Benzyl-4-(3-methyl-2,5-dioxo-imidazolidin-1-yl)-(E)-but-2-enyl]-benzamide (36e)**

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (10→40% (v/v) ethyl acetate in hexanes as eluent) afforded the linear *E* product as a white solid (mp 143.5-144.5°C); $[\alpha]_D^{25} +17.2^\circ$ (c 0.4, CH_2Cl_2); ^1H NMR (500 MHz, CDCl_3) δ 7.66 (d, $J = 8.5$ Hz, 2 H), 7.48 (t, $J = 7.5$ Hz, 1 H), 7.40 (t, $J = 8.0$ Hz, 2 H), 7.17-7.31 (m, 5 H), 6.0 (d, $J = 9.0$ Hz, 1 H), 5.81 (dd, $J = 6.0, 15.5$ Hz, 1 H), 5.57 (dt, $J = 6.0, 15.5$ Hz, 1 H), 4.97-5.04 (m, 1 H), 4.07 (d, $J = 6.0$ Hz, 2 H), 3.83 (s, 2 H), 3.01-2.94 (m, 2 H), 2.98 (s, 3 H); ^{13}C NMR (100.5 MHz, CDCl_3) δ 169.6, 166.9, 156.6, 136.9, 134.6, 134.2, 131.8, 129.9, 128.8, 128.7, 127.1, 126.9, 124.3, 51.9, 51.3, 41.2, 40.2, 29.9; HRMS (ES, m/z): calcd for $\text{C}_{22}\text{H}_{24}\text{N}_3\text{O}_3$ ($M+H$), 378.1823; found: 378.1818.

***N*-[1(*S*)-Benzyl-2(*S*)-(1-oxo-1*H*-phthalazin-2-yl)-but-3-enyl]-benzamide (35f)**

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (10→40% (v/v) ethyl acetate in hexanes as eluent) afforded the branched product as a white solid (mp 135-137°C); $[\alpha]_D^{25} -204.9^\circ$ (c 0.7, CH_2Cl_2); ^1H NMR (500 MHz, CDCl_3) δ 8.40 (d, $J = 8.0$ Hz, 1 H), 8.27 (s, 1 H), 7.81 (dt, $J = 1.5, 7.5$ Hz, 1 H), 7.76 (dt, $J = 1.5, 8.0$ Hz, 1 H), 7.6607.72 (m, 4 H), 7.43 (tt, $J = 1.5, 7.0$ Hz, 1 H), 7.35 (tt, $J = 1.5, 8.0$ Hz, 2 H), 7.15-7.26 (m, 4 H), 6.19 (ddd, $J = 7.0, 10.5, 17.0$ Hz, 1 H), 5.82 (t, $J = 7.0$ Hz, 1 H), 5.31 (dt, $J = 10.5, 1.0$, 1 H), 5.23 (dt, $J = 17.0, 1.0$, 1 H), 5.05 (m, 1 H), 3.00 (dd, $J = 7.0, 14.0$ Hz, 1 H), 2.94 (dd, $J = 6.5, 14.0$ Hz, 1 H); ^{13}C NMR (100.5 MHz, CDCl_3) δ 167.1, 160.0, 138.7, 137.5, 134.9, 134.7, 133.8, 132.3, 131.5, 129.7, 129.3, 128.7, 128.6, 127.9, 127.2, 127.1, 126.8, 126.5, 119.5, 61.3, 54.1, 38.7; HRMS (ES, m/z): calcd for $\text{C}_{26}\text{H}_{24}\text{N}_3\text{O}_2$ ($M+H$), 410.1857; found: 410.1869.

***N*-[1(*S*)-Benzyl-2(*S*)-(2-oxo-2*H*-benzo[*cd*]indol-1-yl)-but-3-enyl]-benzamide (35g)**

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (10→40% (v/v) ethyl acetate in hexanes as eluent) afforded the branched product as a yellow solid (mp 133-135 °C); $[\alpha]_D^{25} -267.7^\circ$ (c 1.0, CH_2Cl_2); R_f 0.30 (30:70-ethyl acetate/hexanes); ^1H NMR (500 MHz, CDCl_3) δ 9.09 (d, $J = 7.5$ Hz, 1H), 8.18 (d, $J = 7.0$ Hz, 1H), 8.13 (d, $J = 8.0$ Hz, 1H), 7.93-7.99 (m, 2H), 7.79-7.84 (m, 1H), 7.61 (d, $J = 8.0$ Hz, 1H), 7.45-7.54 (m, 3H), 7.38-7.42 (m, 1H), 7.13-7.20 (m, 3H), 7.06-7.11 (m, 2H), 6.50 (d, $J = 7.5$ Hz, 1H), 6.10 (ddd, $J = 17.3$ Hz, 10.8 Hz, 5.0 Hz, 1H), 5.15-5.24 (m, 1H), 5.16 (dd, $J = 10.5$ Hz, 1.5 Hz, 1H), 5.06 (dd, $J = 17.0$ Hz, 1.5 Hz, 1H), 4.78-4.83 (m, 1H), 3.20 (dd, $J = 14.0$ Hz, 5.5 Hz, 1H), 2.83 (dd, $J = 14.0$ Hz, 9.5 Hz, 1H); ^{13}C NMR (500 MHz, CDCl_3) δ 170.0, 167.0, 139.6, 137.6, 134.7, 132.8, 131.9, 131.5, 129.6, 129.4, 129.0, 128.8, 128.7, 128.6, 127.3, 126.8, 126.2, 125.4, 125.0, 121.3, 117.6, 106.9, 58.1, 53.7, 38.9; Anal. Calcd for $\text{C}_{29}\text{H}_{24}\text{N}_2\text{O}_2$: C, 80.53; H, 5.59; N, 6.48; Found: C, 80.30; H, 5.65; N, 6.55.

***N*-[1(*S*)-Benzyl-4-(2-oxo-2*H*-benzo[*cd*]indol-1-yl)-(E)-but-2-enyl]-benzamide (36g)**

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (10→40% (v/v) ethyl acetate in hexanes as eluent) afforded the linear *E* product as a yellow solid (mp 139-140 °C); $[\alpha]_D^{25} -6.8^\circ$ (c 1.0, CH_2Cl_2); R_f 0.15 (30:70-ethyl acetate/hexanes); ^1H NMR (500 MHz, CDCl_3) δ 8.08 (d, $J = 7.0$ Hz, 1H), 8.04 (d, $J = 8.0$ Hz, 1H), 7.71-7.76 (m, 1H), 7.63-7.69 (m, 2H), 7.56 (d, J

= 8.5 Hz, 1H), 7.36-7.50 (m, 4H), 7.15-7.21 (m, 3H), 7.09-7.14 (m, 2H), 6.81 (d, J = 7.0 Hz, 1H), 6.02 (d, J = 8.5 Hz, 1H), 5.71-5.80 (m, 2H), 4.98-5.05 (m, 1H), 4.53-4.59 (m, 1H), 4.47-4.53 (m, 1H), 2.97 (dd, J = 13.5 Hz, 6.0 Hz, 1H), 2.93 (dd, J = 13.5 Hz, 7.0 Hz, 1H); ^{13}C NMR (500 MHz, CDCl_3) δ 167.8, 166.8, 139.1, 137.0, 134.6, 132.3, 131.7, 131.1, 129.7, 129.2, 128.8, 128.7, 128.5, 127.0, 126.8, 126.5, 126.0, 125.3, 124.5, 120.5, 105.9, 51.6, 41.5, 41.2 (one overlapping peak); Anal. Calcd for $\text{C}_{29}\text{H}_{24}\text{N}_2\text{O}_2$: C, 80.53; H, 5.59; N, 6.48; Found: C, 80.42; H, 5.75; N, 6.57.

***N*-[1(*S*)-Benzyl-4-(1,1-dioxo-1*H*-1 λ ⁶-naphtho[1,8-*cd*]isothiazol-2-yl)-(*E*)-but-2-enyl]-benzamide (36h)**

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (20→50% (v/v) ethyl acetate in hexanes as eluent) afforded the linear *E* product as a light brown solid (mp 151-152 °C) and a trace of the *Z* isomer; $[\alpha]^{25}_{\text{D}}$ -5.3 (c 1.0, CH_2Cl_2); R_f 0.12 (30:70-ethyl acetate/hexanes); (*E* isomer) ^1H NMR (500 MHz, CDCl_3) δ 8.07 (d, J = 7.5 Hz, 1H), 7.96 (d, J = 7.5 Hz, 1H), 7.73-7.78 (m, 1H), 7.68 (d, J = 7.5 Hz, 2H), 7.44-7.51 (m, 3H), 7.36-7.42 (m, 2H), 7.23-7.28 (m, 2H), 7.16-7.23 (m, 3H), 6.62 (d, J = 7.0 Hz, 1H), 6.18 (d, J = 8.0 Hz, 1H), 5.98 (dd, J = 15.5 Hz, 5.8 Hz, 1H), 5.81 (dt, J = 15.5 Hz, 5.5 Hz, 1H), 5.00-5.07 (m, 1H), 4.42 (dd, J = 17.0 Hz, 5.0 Hz, 1H), 4.37 (dd, J = 17.0 Hz, 5.0 Hz, 1H), 3.02 (dd, J = 13.5 Hz, 6.3 Hz, 1H), 2.96 (dd, J = 13.5 Hz, 7.0 Hz, 1H); (*Z* isomer) ^1H NMR (500 MHz, CDCl_3) δ 8.03-8.07 (m, 1H), 7.92-7.95 (m, 1H), 7.71-7.77 (m, 3H), 7.50-7.55 (m, 1H), 7.35-7.47 (m, 6H), 7.29-7.35 (m, 3H), 6.68 (d, J = 7.0 Hz, 1H), 6.24 (d, J = 7.5 Hz, 1H), 5.73-5.79 (m, 1H), 5.64-5.70 (m, 1H), 5.28-5.36 (m, 1H), 4.55 (dd, J = 17.0 Hz, 7.0 Hz, 1H), 4.33 (dd, J = 17.0 Hz, 5.8 Hz, 1H), 3.18 (dd, J = 13.0 Hz, 5.5 Hz, 1H), 2.99 (dd, J = 13.0 Hz, 7.8 Hz, 1H). (*E* isomer) ^{13}C NMR (500 MHz, CDCl_3) δ 166.9, 137.0, 136.3, 134.6, 134.0, 131.6, 131.4, 130.8, 130.5, 129.7, 129.6, 128.7, 128.6, 128.2, 127.0, 126.9, 124.8, 119.9, 119.4, 118.5, 104.1, 51.7, 43.1, 41.1; Anal. Calcd for $\text{C}_{28}\text{H}_{24}\text{N}_2\text{O}_3\text{S}$: C, 71.77; H, 5.16; N, 5.98; Found: C, 71.96; H, 5.21; N, 5.96.

***N*-{1(*S*)-Benzyl-4[benzyl-(toluene-4-sulfonyl)-amino]-(*E* and *Z*)-but-2-enyl}-benzamide (36i)**

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (20→50% (v/v) ethyl acetate in hexanes as eluent) afforded the linear product as a white solid (mp 140-142 °C); R_f 0.20 (30:70-ethyl acetate/hexanes); ^1H NMR (500 MHz, CDCl_3) *E* isomer: δ 7.66-7.71 (m, 2H), 7.58-7.63 (m, 2H), 7.49-7.55 (m, 1H), 7.40-7.46 (m, 2H), 7.17-7.33 (m, 10H), 7.12-7.17 (m, 2H), 5.72 (d, J = 8.5 Hz, 1H), 5.46 (dd, J = 15.5 Hz, 5.5 Hz, 1H), 5.22 (dt, J = 15.5 Hz, 6.5 Hz, 1H), 4.76-4.86 (m, 1H), 4.29 (d, J = 14.8 Hz, 1H), 4.18 (d, J = 14.8 Hz, 1H), 3.66-3.77 (m, 2H), 2.77-2.87 (m, 2H), 2.37 (s, 3H); Characteristic peaks for the *Z* isomer: δ 5.97 (d, J = 7.5 Hz, 1H), 5.27-5.35 (m, 2H), 2.45 (s, 3H); ^{13}C NMR (500 MHz, CDCl_3) *E* isomer: δ 166.7, 143.4, 137.2, 137.1, 136.3, 134.4, 134.2, 131.6, 129.8, 129.4, 128.7, 128.6, 128.5, 128.4, 127.7, 127.1, 126.9, 126.8, 125.3, 51.4, 50.6, 48.9, 40.8, 21.5; Characteristic peaks for the *Z* isomer: δ 51.9, 48.4, 45.3, 41.1, 29.8; Anal. Calcd for $\text{C}_{32}\text{H}_{32}\text{N}_2\text{O}_3\text{S}$: C, 73.25; H, 6.15; N, 5.34; Found: C, 73.42; H, 6.14; N, 5.30.

***N*-[1(*S*)-Benzyl-4-dibenzylamino-(*E*)-but-2-enyl]-benzamide (36j)**

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (20→50% (v/v) ethyl acetate in hexanes as eluent) afforded the linear product as a white solid (mp 102-104 °C); $[\alpha]^{25}_{\text{D}}$ +10.4 (c 1.0, CH_2Cl_2); R_f 0.40 (30:70-ethyl acetate/hexanes); ^1H NMR (500 MHz, CDCl_3) δ 7.68 (d, J = 7.5 Hz, 2H), 7.47-7.52 (m, 1H), 7.39-7.45 (m, 2H), 7.15-7.37 (m, 15H), 5.94 (d, J = 7.5 Hz, 1H), 5.59-5.72 (m, 2H), 4.94-5.01 (m, 1H), 3.44-3.55 (m, 4H), 3.04 (bs, 2H), 2.99 (dd, J = 13.8 Hz, 6.0 Hz, 1H), 2.93 (dd, J = 13.8 Hz, 7.0 Hz, 1H); ^{13}C NMR (300 MHz, CDCl_3) δ 166.8, 139.8, 137.4, 134.8, 131.9, 131.6, 129.7, 129.5, 128.9, 128.7, 128.6, 128.3, 127.0, 126.9, 126.8, 58.2, 55.4, 51.9, 41.4; Anal. Calcd for $\text{C}_{32}\text{H}_{32}\text{N}_2\text{O}$: C, 83.44; H, 7.00; N, 6.08; Found: C, 83.30; H, 6.81; N, 6.12.

***N*-(1(*S*)-Benzyl-4-pyrrolidin-1-yl-(*E*)-but-2-enyl)-benzamide (36k)**

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (5% (v/v) methanol in dichloromethane as eluent) afforded the linear *E* product as a white solid (mp 137-138°C); $[\alpha]_D^{25} +5.7^\circ$ (c 0.6, CH₂Cl₂); ¹H NMR (300 MHz, CDCl₃) δ 7.67 (d, *J* = 9.5, Hz, 2 H), 7.10-7.40 (m, 8 H), 6.50 (d, *J* = 14.0, Hz, 1 H), 5.50-5.74 (m, 2 H), 4.82-4.98 (m, 1 H), 2.80-3.10 (m, 4 H), 2.30-2.50 (m, 4 H), 1.55-1.7 (m, 2 H); ¹³C NMR (75 MHz, CDCl₃) δ 167.0, 137.6, 134.8, 132.7, 131.6, 129.7, 128.7, 128.6, 128.3, 127.2, 126.8, 57.6, 53.9, 52.1, 41.3, 23.6; HRMS (ES, *m/z*): calcd for C₂₂H₂₇N₂O (*M*+*H*), 335.2127; found: 335.2123.

***N,N* Bis[1(*S*)-Benzyl-4-benzyloxyamino-(*E*)-but-2-enyl]-benzamide (37)**

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (5→35% (v/v) ethyl acetate in hexanes as eluent) afforded the linear product as a white solid (mp 203-205°C); $[\alpha]_D^{25} +10.0^\circ$ (c 0.3, CH₂Cl₂); ¹H NMR (500 MHz, CDCl₃) δ 7.66 (d, *J* = 8.5, Hz, 4 H), 7.48 (tt, *J* = 2.0, 6.0, 2 H), 7.39 (t, *J* = 7.5 Hz, 4 H), 7.25-7.29 (m, 7 H), 7.10-7.23 (m, 8 H), 6.02 (d, *J* = 7.5, 2 H), 5.63-5.73 (m, 4 H), 4.92-5.01 (m, 2 H), 4.55 (brs, 2 H), 3.24-3.33 (m, 4 H), 2.93-3.01 (m, 4 H); ¹³C NMR (100.5 MHz, CDCl₃) δ 167.0, 137.4, 137.3, 134.7, 133.8, 131.8, 129.8, 129.7, 128.8, 128.7, 128.6, 127.7, 127.4, 127.1, 127.0, 64.2, 61.7, 52.1, 41.3; HRMS (ES, *m/z*): calcd for C₄₃H₄₅N₃O₃ (*M*+*H*), 650.3394; found: 650.3383.

***N*-[1(*S*)-Benzyl-4-(benzyl-hydroxy-amino)-(*E*)-but-2-enyl]-benzamide (36l)**

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (5→35% (v/v) ethyl acetate in hexanes as eluent) afforded the linear *E* product as a white solid (mp 153-155°C); $[\alpha]_D^{25} +11.1^\circ$ (c 1.4, CH₂Cl₂); ¹H NMR (500 MHz, CDCl₃) δ 7.68 (d, *J* = 9.0 Hz, 2 H), 7.48 (t, *J* = 7.0 Hz, 1 H), 7.40 (t, *J* = 8.0 Hz, 2 H), 7.18-7.33 (m, 10 H), 6.05 (d, *J* = 8.0 Hz, 1 H), 5.76 (dd, *J* = 5.0, 16.0 Hz, 1 H), 5.70 (dt, *J* = 16.0, 5.5 Hz, 1 H), 4.96-5.02 (m, 1 H), 3.75 (s, 2 H), 3.45 (d, *J* = 5.5 Hz, 2 H), 3.03 (dd, *J* = 6.0, 13.5 Hz, 1 H), 2.98 (dd, *J* = 6.5, 13.5 Hz, 1 H); ¹³C NMR (100.5 MHz, CDCl₃) δ 167.0, 137.4, 137.3, 134.7, 133.8, 131.8, 129.7, 128.8, 128.7, 128.5, 127.7, 127.3, 127.1, 127.0, 64.2, 61.7, 52.1, 41.3 (one overlapping peak); HRMS (ES, *m/z*): calcd for C₂₅H₂₇N₂O₃ (*M*+*H*), 387.2066; found: 387.2073.

2-[4(*S*)-Benzoylamino-5-phenyl-(*E*)-pent-2-enyl]-malonic acid dimethyl ester (36m)

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (10→40% (v/v) ethyl acetate in hexanes as eluent) afforded the linear product as a white solid (mp 87-89 °C); $[\alpha]_D^{25} +4.1$ (c 1.0, CH₂Cl₂); *R_f* 0.18 (30:70-ethyl acetate/hexanes); ¹H NMR (400 MHz, CDCl₃) δ 7.64-7.71 (m, 2H), 7.45-7.51 (m, 1H), 7.36-7.44 (m, 2H), 7.26-7.33 (m, 2H), 7.16-7.26 (m, 3H), 6.11 (d, *J* = 8.0 Hz, 1H), 5.63 (dd, *J* = 15.4 Hz, 5.6 Hz, 1H), 5.55 (dt, *J* = 15.4 Hz, 6.8 Hz, 1H), 4.86-4.96 (m, 1H), 3.69 (s, 3H), 3.66 (s, 3H), 3.39 (t, *J* = 7.6 Hz, 1H), 2.95 (d, *J* = 6.8 Hz, 2H), 2.61 (dd, *J* = 7.6 Hz, 6.8 Hz, 2H); ¹³C NMR (300 MHz, CDCl₃) δ 169.3, 166.7, 137.2, 134.7, 132.8, 131.6, 129.7, 128.7, 128.6, 127.3, 127.0, 126.8, 52.8, 52.7, 51.9, 51.5, 41.3, 31.6; Anal. Calcd for C₂₃H₂₅NO₅: C, 69.86; H, 6.37; N, 3.54; Found: C, 70.04; H, 6.24; N, 3.48.

2,2-Bis-[4(*S*)-benzoylamino-5-phenyl-(*E*)-pent-2-enyl]-malonic acid dimethyl ester (38)

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (10→40% (v/v) ethyl acetate in hexanes as eluent) afforded the bis-allylated linear product: *R_f* 0.08 (30:70-ethyl

acetate/hexanes); ^1H NMR (400 MHz, CDCl_3) δ 7.66-7.70 (m, 4H), 7.46-7.51 (m, 2H), 7.37-7.43 (m, 4H), 7.16-7.31 (m, 10H), 6.17 (d, J = 8.0 Hz, 2H), 5.57 (dd, J = 15.4 Hz, 6.6 Hz, 2H), 5.41 (td, J = 15.4 Hz, 7.2 Hz, 2H), 4.80-4.89 (m, 2H), 3.63 (s, 6H), 2.96 (dd, J = 13.7 Hz, 6.7 Hz, 2H), 2.88 (dd, J = 13.7 Hz, 7.0 Hz, 2H), 2.50 (d, J = 7.2 Hz, 4H); ^{13}C NMR (300 MHz, CDCl_3) δ 171.2, 166.8, 137.5, 134.8, 134.3, 131.7, 129.6, 128.8, 128.7, 127.0, 126.9, 126.0, 57.7, 52.7, 52.5, 41.3, 35.7.

5,5-Bis-[4(S)-benzoylamino-5-phenyl-(E)-pent-2-enyl]-2,2-dimethyl-4,6-dioxo-[1,3]dioxane (39)

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (10→40% (v/v) ethyl acetate in hexanes as eluent) afforded the bis-allylated linear product as a white solid (mp 172-173 °C); $[\alpha]_D^{25} +21.0$ (c 1.0, CH_2Cl_2); R_f 0.10 (30:70-ethyl acetate/hexanes); ^1H NMR (400 MHz, CDCl_3) δ 7.61-7.65 (m, 4H), 7.47-7.51 (m, 2H), 7.38-7.43 (m, 4H), 7.28-7.33 (m, 4H), 7.21-7.26 (m, 2H), 7.16-7.21 (m, 4H), 6.00 (d, J = 8.5 Hz, 2H), 5.69 (dd, J = 15.3 Hz, 6.3 Hz, 2H), 5.48 (dt, 15.3 Hz, 7.5 Hz, 2H), 4.92-5.01 (m, 2H), 2.96 (dd, J = 13.3 Hz, 6.3 Hz, 2H), 2.92 (dd, J = 13.5 Hz, 6.0 Hz, 2H), 2.66 (d, J = 7.5 Hz, 4H), 1.49 (s, 6H); ^{13}C NMR (300 MHz, CDCl_3) δ 168.6, 166.6, 137.1, 136.5, 134.7, 131.5, 129.5, 128.6, 128.5, 127.0, 126.7, 123.8, 106.0, 55.4, 51.8, 41.5, 41.2, 29.7; HRMS (FAB $^+$) Calcd for $\text{C}_{42}\text{H}_{42}\text{N}_2\text{O}_6$ (M+H) $^+$: 671.3116; Found: 671.3121.

2,2-Bis-[4(S)-benzoylamino-5-phenyl-(E)-pent-2-enyl]-1,3-indandione (40)

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (15→40% (v/v) ethyl acetate in hexanes as eluent) afforded the bis-allylated linear product as a white solid (mp 159-161 °C); $[\alpha]_D^{25} +5.6$ (c 1.0, CH_2Cl_2); R_f 0.18 (40:60-ethyl acetate/hexanes); ^1H NMR (500 MHz, CDCl_3) δ 7.77-7.81 (m, 2H), 7.64-7.68 (m, 2H), 7.49-7.54 (m, 4H), 7.44-7.49 (m, 2H), 7.34-7.40 (m, 4H), 7.22-7.27 (m, 4H), 7.16-7.21 (m, 2H), 7.06-7.11 (m, 4H), 5.80 (d, J = 6.8 Hz, 2H), 5.50 (dd, J = 15.5 Hz, 6.5 Hz, 2H), 5.29 (dt, J = 15.5 Hz, 7.5 Hz, 2H), 4.64-4.71 (m, 2H), 2.70-2.78 (m, 4H), 2.44 (d, J = 7.5 Hz, 4H); ^{13}C NMR (500 MHz, CDCl_3) δ 203.3, 166.4, 142.2, 137.0, 135.9, 134.6, 134.5, 131.6, 129.6, 128.7, 128.6, 126.9, 126.8, 125.1, 123.1, 58.6, 51.6, 41.1, 37.2; Anal. Calcd for $\text{C}_{45}\text{H}_{40}\text{N}_2\text{O}_4$: C, 80.33; H, 5.99; N, 4.16; Found: C, 80.65; H, 6.12; N, 4.13.

N-[1(S)-Benzyl-4-(phthalazin-1-yloxy)-(E)-but-2-enyl]-benzamide (43a)

To a 10-mL, 1-neck, round-bottom flask, allylic alcohol (**41a**) (0.068 g, 0.243 mmol) and NaH (60% in mineral oil, 0.021 g, 0.535 mmol) were added, followed by THF (2.5 mL). The reaction mixture was stirred at room temperature for 10 min. Then, 1-chlorophthalazine (0.044 g, 0.268 mmol) was added. The reaction was allowed to continue at room temperature overnight. To the reaction mixture, 1.5 mL of water and 1.5 mL of EtOAc were added, and the two layers were separated. The water layer was extracted with EtOAc (3×5 mL). The combined organic layers were washed with water and brine, dried with MgSO_4 , filtered, and concentrated. Flash column chromatography (1 → 4% methanol in CH_2Cl_2 as eluent) to afford **43a** (0.092g, 92%). White solid (mp 147-148 °C) $[\alpha]_D^{25} +5.4$ (c 1.1, CH_2Cl_2); R_f 0.10 (50:50-ethyl acetate/hexanes); ^1H NMR (500 MHz, CDCl_3) δ 9.17 (d, J = 1.0 Hz, 1H), 8.17-8.22 (m, 1H), 7.82-7.90 (m, 3H), 7.68-7.73 (m, 2H), 7.45-7.51 (m, 1H), 7.37-7.44 (m, 2H), 7.23-7.28 (m, 2H), 7.16-7.23 (m, 3H), 6.15 (d, J = 8.0 Hz, 1H), 6.05 (dd, J = 15.5 Hz, 5.0 Hz, 1H), 6.00 (ddt, J = 15.5 Hz, 1.0 Hz, 4.5 Hz, 1H), 5.17 (d, J = 4.5 Hz, 2H), 5.07-5.14 (m, 1H), 3.04 (d, J = 7.0 Hz, 2H); ^{13}C NMR (500 MHz, CDCl_3) δ 166.9, 160.1, 148.2, 137.1, 134.7, 133.8, 132.5, 132.3, 131.7, 129.8, 129.0, 128.8, 128.6, 127.1, 126.9, 126.0, 125.9, 123.2, 120.0, 67.1, 51.6, 41.3; Anal. Calcd for $\text{C}_{26}\text{H}_{23}\text{N}_3\text{O}_2$: C, 76.26; H, 5.66; N, 10.26; Found: C, 76.15; H, 5.88; N, 10.10.

[1(*S*)-Benzyl-4-(phthalazin-1-yloxy)-(E)-but-2-enyl]-carbamic acid *tert*-butyl ester (**43b**)

To a 50-mL, 1-neck, round-bottom flask, allylic alcohol (**41b**) (0.515 g, 1.86 mmol) and NaH (60% in mineral oil, 0.164 g, 4.09 mmol) were added, followed by THF (19 mL). The reaction mixture was stirred at room temperature for 10 min. Then, 1-chlorophthalazine (0.336 g, 2.04 mmol) was added. The reaction was allowed to continue at room temperature overnight. To the reaction mixture, 20 mL of water and 20 mL of EtOAc were added, and the two layers were separated. The water layer was extracted with EtOAc (3×40 mL). Combined organic layers were washed with water and brine, dried with MgSO₄, filtered, and concentrated. Flash column chromatography (30 → 70 % EtOAc in hexanes as eluent) afforded **43b** (0.529 g, 70%). Brown oil; $[\alpha]_D^{25} +0.2$ (c 0.8, CH₂Cl₂); R_f 0.20 (50:50-ethyl acetate/hexanes); ¹H NMR (500 MHz, CDCl₃) δ 9.19 (d, *J* = 1.0 Hz, 1H), 8.18–8.22 (m, 1H), 7.85–7.92 (m, 3H), 7.23–7.28 (m, 2H), 7.19–7.23 (m, 1H), 7.15–7.19 (m, 2H), 5.97 (dd, *J* = 15.5 Hz, 4.5 Hz, 1H), 5.90–5.95 (m, 1H), 5.12–5.22 (m, 2H), 4.44–4.64 (bs, 2H), 2.89 (d, *J* = 6.0 Hz, 2H), 1.41 (s, 9H); ¹³C NMR (500 MHz, CDCl₃) δ 160.2, 155.3, 148.2, 137.4, 134.6, 132.5, 132.3, 129.8, 129.0, 128.5, 126.7, 126.0, 125.3, 123.2, 120.1, 67.2, 41.8, 31.8, 28.5, 14.3; Anal. Calcd for C₂₄H₂₇N₃O₃: C, 71.09; H, 6.71; N, 10.36; Found: C, 71.10; H, 6.78; N, 10.21.

[1-Benzyl-2-(1-oxo-1*H*-phthalazin-2-yl)-but-3-enyl]-carbamic acid *tert*-butyl ester (**44**)

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (10→40% (v/v) ethyl acetate in hexanes as eluent) afforded the branched product as a yellow solid (mp 65–67°C); $[\alpha]_D^{25} -2.6^\circ$ (c 0.5, CH₂Cl₂); ¹H NMR (500 MHz, CDCl₃) δ 8.42 (d, *J* = 7.5 Hz, 1 H), 8.24 (s, 1 H), 7.73–7.84 (m, 2 H), 7.69 (d, *J* = 7.0 Hz, 1 H), 7.03–7.38 (m, 5 H), 6.16 (ddd, *J* = 7.0, 10.5, 17.5 Hz, 1 H), 5.70 (t, *J* = 7.0 Hz, 1 H), 5.40 (d, *J* = 10.0 Hz, 1 H), 5.29 (d, *J* = 10.5 Hz, 1 H), 5.23 (d, *J* = 17.5 Hz, 1 H), 4.40–4.52 (m, 1 H), 2.89 (dd, *J* = 6.0, 14.0 Hz, 1 H), 2.72 (dd, *J* = 7.5, 14.0 Hz, 1 H), 1.19 (s, 9 H); ¹³C NMR (100.5 MHz, CDCl₃) δ 159.8, 155.6, 138.3, 134.9, 133.6, 132.1, 129.6, 128.5, 128.0, 127.3, 126.6, 126.3, 119.5, 79.1, 61.3, 54.7, 38.9, 28.4; HRMS (ES, *m/z*): calcd for C₂₄H₂₈N₃O₃ (M+H), 406.2131; found: 406.2122.

[1(*S*)-Benzyl-4-(1-oxo-1*H*-phthalazin-2-yl)-(E)-but-2-enyl]-carbamic acid *tert*-butyl ester (**45**)

Following the general procedure for Pd-catalyzed allylic substitution of 5-vinyloxazolidinone flash column chromatography (10→40% (v/v) ethyl acetate in hexanes as eluent) afforded the bis-allylated linear product as a white solid (mp 128–130°); $[\alpha]_D^{25} 2.2^\circ$ (c 0.2, CH₂Cl₂); ¹H NMR (500 MHz, CDCl₃) δ 8.46 (d, *J* = 8.0 Hz, 1 H), 8.18 (s, 1 H), 7.78–7.88 (m, 2 H), 7.72 (d, *J* = 7.0 Hz, 1 H), 7.10–7.23 (m, 5 H), 5.72–5.84 (m, 2 H), 4.82 (d, *J* = 4.5, 2 H), 4.48 (bs, 1 H), 4.20–4.50 (m, 1 H), 2.84 (bs, 2 H), 1.4 (s, 9 H); ¹³C NMR (100.5 MHz, CDCl₃) δ 159.3, 155.3, 138.1, 137.4, 134.5, 133.4, 131.9, 129.9, 129.8, 128.4, 128.2, 126.9, 126.6, 126.2, 124.9, 79.9, 52.7, 41.8, 40.7, 28.5; HRMS (ES, *m/z*): calcd for C₂₄H₂₈N₃O₃ (M+H), 406.2131; found: 406.2122.

N-[1-Benzyl-4-(1,3-dioxo-1,3-dihydro-isoindol-2-yl)-but-2-enyl]-*N*-methylbenzamide (**47**)

A 10 ml Schlenk flask was charged with the carbonate **46** (88 mg, 0.25 mmol) which is an inseparable mixture of the allylic carbonate and the corresponding saturated alkyl carbonate, phthalimide (41 mg, 0.27 mmol), sodium hydride (20 mol%), [(π-C₃H₅)PdCl]₂ (0.9 mg, 1 mol%) and (*R*)-tol-BINAP (4 mol%) and sealed with a rubber septum. The tube was evacuated and flushed with nitrogen three times. THF (2 ml) was added and the reaction was stirred at ambient temperature for 24h. The product was chromatographed using 10–40% v/v ethylacetate/hexane as eluent to afford an inseparable mixture of **47** and the saturated alkyl carbonate. Spectral characterization is complicated by the presence of this impurity and amide rotational isomers. Only the linear product of the allylic substitution was obtained. The ¹H NMR data lacks any resonances characteristic of a terminal olefin

of the branched product and only contains a trans internal olefin. Characteristic peaks (major rotational isomer): ^1H NMR (500 MHz, CDCl_3) δ 7.90 (m, 2 H), 7.78 (m, 2 H) 7.1-7.4 (m, 8 H), 7.00 (d, $J = 7.5$ Hz, 1 H), 6.92 (bs, 1 H), 6.8 (d, $J = 9.0$ Hz, 1 H), 5.81 (dd, $J = 5.0, 18.0$ Hz, 1 H), 5.66 (dt, $J = 18.0, 7.0$ Hz, 1 H), 4.46 (m, 1 H), 4.3 (d, $J = 4.5$ Hz, 2 H); Compound **47** was confirmed by Mass Spectrometry: HRMS (ES, m/z): calcd for $\text{C}_{27}\text{H}_{25}\text{N}_2\text{O}_3$ ($\text{M}+\text{H}$), 425.1865; found: 425.1863.

hy-1-96-c-400

Pulse Sequence: s2pu1

hy-i-96-c-500-13C

Pulse Sequence: s2pu1

S13

hy-111-91-d2-500

Pulse Sequence: s2pu1

hy-iii-91-d2-500-13C

Pulse Sequence: s2pul

hy-111-89-a-500

Pulse Sequence: s2pu1

hy-111-89-a-500-13C

Pulse Sequence: s2pu1

~~Pulse Sequence: s2pu1~~

$$E/Z = 5:1$$

S18

hy-111-89-b-500-13C
Pulse Sequence: s2pul

PSS-II-236AH.7

PSS-II-234A_C13.5

(Billions)

X : parts per Million : ^{13}C

hy-11-22-a-500

Pulse Sequence: s2pu1

hy-11-22-a-500-13C
Pulse Sequence: s2pul

ny-ii-147-b-b-400
Pulse_Sequence: s2pu1

hy-11-147-b-b-13C
Pulse Sequence: s2pu1

Pulse Sequence: s2pu1

S32

Pulse Sequence: s2pu1

S33

hy-11-145-b-500
Pulse Sequence: s2pu1

trans : cis = 6.0 : 1

hy-11-145-b-500-13C

Pulse Sequence: s2pu1

trans major

cis minor

ssn-1-288a-300

Pulse Sequence: s2pul

ssn-1-287-1-500

Pulse Sequence: s2pu1

ssn-1-271b-1-500

Pulse Sequence: s2pu1

ssn-1-271b-c13-500

Pulse Sequence: s2pu1

hy-11-57-a-500

Pulse Sequence: s2pu1

hy-11-57-a-500-13C

Pulse Sequence: s2pu1

~~Pulse Sequence: s2pu1~~

hy-11-72-c-500-13C
Pulse Sequence: s2pu1

ssn-2-148a- 500

Pulse Sequence: s2pu1

ssn-2-148-500

Pulse Sequence: s2pu1

ssn-3-14b-etoH- 500

Pulse Sequence: s2pu1

ssn-3-14b-500

Pulse Sequence: s2pu1

ssn-1-273-1-500

Pulse Sequence: s2pu1

ssn-1-273-1-500

Pulse Sequence: s2pu1

hy-1-181-de-a-500

Pulse Sequence: s2pu1

hy-1-181-de-a-500-13C

Pulse Sequence: s2pu1

hy-11-294-e-2-500

Pulse Sequence: s2pu1

hy-ii-294-500-130

Pulse Sequence: s2pu1

S53

hy-11-28-b-500

Pulse Sequence: s2pul

hy-11-26-b-500

Pulse Sequence: s2pu1

S55

hy-1-170-b-500

Pulse Sequence: s2pu1

E/Z = 9:1

hy-i-170-b-13C-500

Pulse Sequence: s2pu1

✓ hy-1-249-b-500
Pulse Sequence: s2pu1

hy-1-249-b-300-13C
Pulse Sequence: s2pul

ssn-1-266-300

Pulse Sequence: s2pul

ssn-1-266-300

Pulse Sequence: s2pu1

ssn-2-obn-223- 500
Pulse Sequence: s2pu1

223

ssn-2-223-500

Pulse Sequence: s2pu1

225
 ssn-2-225-500
 Pulse Sequence: s2pu1

Spectrum integrated except for
 (diethylated product)

ssn-2-225-500

Pulse Sequence: s2pu1

hy-11-35-a-400

Pulse Sequence: s2pu1

hy-11-35-a-300-13C

Pulse Sequence: s2pul

hy-ii-35-b-400

Pulse Sequence: s2pu1

hy-fi-35-b-300-13C
Pulse Sequence: s2pu1

hy-11-85-c-500

Pulse Sequence: s2pu1

hy-ii-49-b-300-13C
Pulse Sequence: s2pul

CDCl_3 + 1 drop $\text{DMSO}-d_6$

hy-11-98-d-500

Pulse Sequence: s2pu1

hy-11-98-d-500-13C
Pulse Sequence: s2pu1

hy-111-71-a-500

Pulse Sequence: s2pu1

hy-iii-51-500-13C
Pulse Sequence: s2pul

hy-111-73-a-2-500

Pulse Sequence: s2pu1

hy-111-73-a-500-13C
Pulse Sequence: s2pu1

ssn-2-213a-500

Pulse Sequence: s2pu1

ssn-2-213a-500

Pulse Sequence: s2pu1

ssn-2-213b-500

Pulse Sequence: s2pul1

ssn-2-213b-500

Pulse Sequence: s2pu1

S81

ssn-2-280b-400

Pulse Sequence: s2pul