

Supporting Information

for

Construction of Quaternary Carbon Centers by KO^tBu-Catalyzed α - Homoallylic Alkylation of Lactams with 1,3-Dienes

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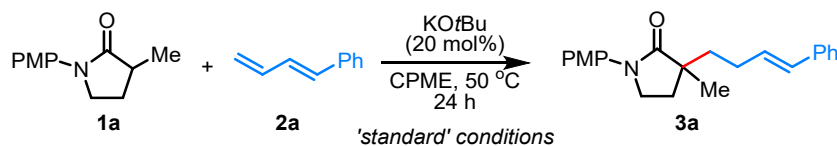
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1. General Information

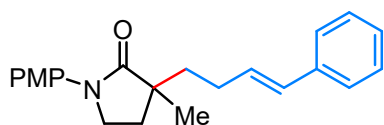
Unless noted otherwise, all ^1H NMR (400 MHz) and ^{13}C NMR (101 MHz) spectra were recorded on Bruker spectrometers in CDCl_3 . Tetramethylsilane (TMS) served as an internal standard ($\delta = 0$) for ^1H NMR, and CDCl_3 was used as internal standard ($\delta = 77.0$) for ^{13}C NMR. Chemical shifts are reported in parts per million as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad). Infrared (IR) spectra were obtained using a Bruker tensor 27 infrared spectrometer. High-resolution mass spectrometry (HRMS (ESI)) was performed on IonSpec FT-ICR or Waters Micromass Q-TOF micro Synapt High Resolution Mass Spectrometer. EPR measurements were performed on a Bruker EMX spectrometer operating at X-band. Unless otherwise noted, solvents used for the key reactions were freshly distilled over calcium hydride or sodium. Cyclopentyl Methyl Ether (CPME) (99.5%, Extra Dry, stabilized) used for the key reactions was purchased from Energy Chemical and degassed with nitrogen before use. All the key reactions were carried out under nitrogen atmosphere with a stir bar in a sealed vial and heated in a pie-block. Reaction temperatures were reported as the temperatures of the bath surrounding the vials. KOtBu was purchased from Strem Chemicals. Lactams¹⁻³ and 1,3-dienes^{4,5} used for the key reactions were synthesized according to literature procedures. All other materials were obtained from commercial sources and were used as received.

2 General Experimental Procedure for the Key Reaction



A 4-mL baked vial charged with a stir bar was transferred into the glove box. To this vial was added compound **1a** (41 mg, 0.2 mmol) and KO t Bu (4.5 mg, 20 mol%) followed by the addition of CPME (0.2 mL). To this mixture was subsequently added compound **2a** (31.2 mg, 0.24 mmol). The vial was tightly capped, removed from glove box and heated at 50 °C for 24 h. After completion of the reaction, the mixture was cooled to room temperature and concentrated in vacuum, the crude mixture was purified by flash column chromatography on silica gel (PE: EA=10:1) to afford **3a** (61.7 mg, 92% yield) as a colorless oil.

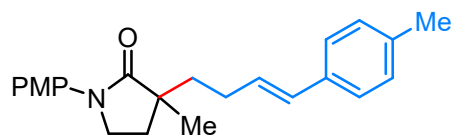
3. Characterization Data of Products



(*E*)-1-(4-methoxyphenyl)-3-methyl-3-(4-phenylbut-3-en-1-yl)pyrrolidin-2-one

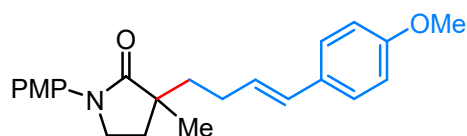
(3a): Synthesized by following general procedure on a 0.2 mmol scale. Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 92% yield. ^1H NMR (400 MHz, CDCl_3) δ 7.47 (d, J = 7.6 Hz, 2H), 7.25-7.18 (m, 4H), 7.12-7.09 (m, 1H), 6.82 (d, J = 8.0 Hz, 2H), 6.33 (d, J = 15.6 Hz, 1H), 6.18-6.10 (m, 1H), 3.72 (s, 3H), 3.69-3.64 (m, 2H), 2.31-2.25 (m, 1H), 2.18-2.04 (m, 2H), 1.90-1.84 (m, 1H), 1.72-1.67 (m, 2H), 1.19 (s, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 177.76, 156.47, 136.16,

132.92, 132.43, 130.99, 128.92, 128.60, 127.15, 121.48, 114.00, 55.50, 45.56, 44.99, 37.39, 30.82, 28.14, 23.24. IR (ν/cm^{-1}): 3732, 3448, 2945, 2830, 2171, 2016, 1121, 1028 cm^{-1} . HRMS (ESI): calcd. $\text{C}_{22}\text{H}_{26}\text{NO}_2$ $[\text{M}+\text{H}]^+$: 336.1964. Found: 336.1959.



(E)-1-(4-methoxyphenyl)-3-methyl-3-(4-(p-tolyl)but-3-en-1-yl)pyrrolidin-2-one

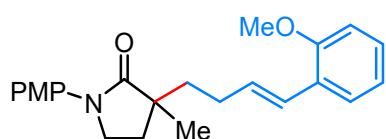
(3b): Synthesized by following general procedure on a 0.2 mmol scale. Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 91% yield. ^1H NMR (400 MHz, CDCl_3) δ 7.54 (d, $J = 9.2$ Hz, 2H), 7.21 (d, $J = 8.0$ Hz, 2H), 7.09 (d, $J = 8.0$ Hz, 2H), 6.89 (d, $J = 9.2$ Hz, 2H), 6.37 (d, $J = 16.0$ Hz, 1H), 6.19-6.12 (m, 1H), 3.80 (s, 3H), 3.75-3.71 (m, 2H), 2.32 (s, 3H), 2.24-2.12 (m, 2H), 1.96-1.90 (m, 1H), 1.79-1.74 (m, 2H), 1.26 (s, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 178.01, 156.54, 136.75, 134.99, 133.08, 130.02, 129.30, 125.95, 121.63, 114.11, 55.61, 45.72, 45.16, 37.65, 30.98, 28.25, 23.29, 21.27. IR (ν/cm^{-1}): 3732, 3448, 2945, 2830, 2171, 2016, 1121, 1023 cm^{-1} . HRMS (ESI): calcd. $\text{C}_{23}\text{H}_{28}\text{NO}_2$ $[\text{M}+\text{H}]^+$: 350.2120. Found: 350.2133.



(E)-1-(4-methoxyphenyl)-3-(4-(4-methoxyphenyl)but-3-en-1-yl)-3-methyl

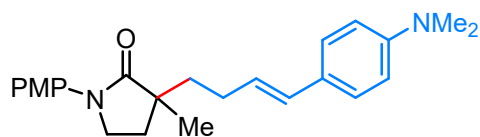
pyrrolidin-2-one (3c): Synthesized by following general procedure on a 0.2 mmol scale. Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 82% yield. ^1H NMR (400 MHz, CDCl_3) δ 7.54 (d, $J = 9.2$ Hz, 2H), 7.24 (d, $J = 8.0$ Hz, 2H), 6.89 (d, $J = 9.2$ Hz, 2H), 6.82 (d, $J = 8.4$ Hz, 2H), 6.35 (d, $J = 16.0$ Hz,

1H), 6.10-6.03 (m, 1H), 3.80 (s, 6H), 3.74 (t, $J = 7.2$ Hz, 2H), 2.36-2.28 (m, 1H), 2.23-2.12 (m, 2H), 1.97-1.90 (m, 1H), 1.81-1.72 (m, 2H), 1.26 (s, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 178.00, 158.84, 156.55, 133.11, 130.65, 129.56, 128.18, 127.14, 121.62, 114.12, 114.04, 55.60, 55.40, 45.70, 45.14, 37.76, 30.97, 28.23, 23.32. IR (V/cm^{-1}): 3749, 3724, 3569, 3376, 2843, 2832, 2339, 1973, 1126, 1022 cm^{-1} . HRMS (ESI): calcd. $\text{C}_{23}\text{H}_{28}\text{NO}_3$ $[\text{M}+\text{H}]^+$: 366.2069. Found: 336.2045.



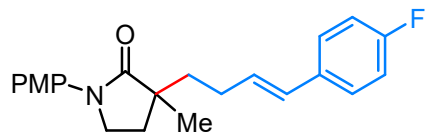
(E)-1-(4-methoxyphenyl)-3-(4-(2-methoxyphenyl)but-3-en-1-yl)-3-methyl

pyrrolidin-2-one (3d): Synthesized by following general procedure on a 0.2 mmol scale. Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 90% yield. ^1H NMR (400 MHz, CDCl_3) δ 7.54 (d, $J = 9.2$ Hz, 2H), 7.37 (dd, $J = 7.6, 1.6$ Hz, 1H), 7.19-7.15 (m, 1H), 6.91-6.87 (m, 3H), 6.83 (d, $J = 8.0$ Hz, 1H), 6.73 (d, $J = 16.0$ Hz, 1H), 6.24-6.16 (m, 1H), 3.81 (s, 3H), 3.79 (s, 3H), 3.73 (t, $J = 7.2$ Hz, 2H), 2.43-2.31 (m, 1H), 2.30-2.20 (m, 1H), 2.21-2.11 (m, 1H), 1.97-1.88 (m, 1H), 1.83-1.74 (m, 2H), 1.26 (s, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 178.04, 156.52, 156.38, 133.11, 131.03, 128.03, 126.84, 126.55, 124.82, 121.63, 120.74, 114.09, 110.85, 55.59, 55.52, 45.71, 45.15, 37.66, 30.92, 28.70, 23.33. IR (V/cm^{-1}): 3749, 3647, 3563, 3376, 2843, 2839, 2027, 1512, 1126, 1022 cm^{-1} . HRMS (ESI): calcd. $\text{C}_{23}\text{H}_{28}\text{NO}_3$ $[\text{M}+\text{H}]^+$: 366.2069. Found: 366.2045.



(E)-3-(4-(4-(dimethylamino)phenyl)but-3-en-1-yl)-1-(4-methoxyphenyl)-3-

methylpyrrolidin-2-one (3e): Synthesized by following general procedure on a 0.2 mmol scale. Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 82% yield. ¹H NMR (400 MHz, CDCl₃) δ 7.54 (d, *J* = 9.2 Hz, 2H), 7.21 (d, *J* = 8.4 Hz, 2H), 6.89 (d, *J* = 9.2 Hz, 2H), 6.66 (d, *J* = 8.8 Hz, 2H), 6.32 (d, *J* = 16.0 Hz, 1H), 6.03-5.96 (m, 1H), 3.80 (s, 3H), 3.73 (t, *J* = 7.2 Hz, 2H), 2.93 (s, 6H), 2.37-2.25 (m, 1H), 2.24-2.12 (m, 2H), 1.98-1.88 (m, 1H), 1.78-1.73(m, 2H), 1.26 (s, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 178.10, 156.51, 149.84, 133.14, 129.93, 126.90, 126.14, 121.62, 114.10, 112.73, 55.60, 45.72, 45.18, 40.75, 37.91, 30.99, 28.28, 23.30. IR (V/cm⁻¹): 3820, 3750, 3446, 2996, 2829, 2108, 1997, 1120, 1022 cm⁻¹. HRMS (ESI): calcd. C₂₄H₃₁N₂O₂ [M+H]⁺: 379.2386. Found: 379.2359.

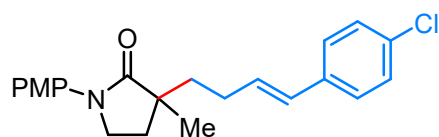


(E)-3-(4-(4-fluorophenyl)but-3-en-1-yl)-1-(4-methoxyphenyl)-3-methyl

pyrrolidin-2-one (3f): Synthesized by following general procedure on a 0.2 mmol scale. Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 89% yield. ¹H NMR (400 MHz, CDCl₃) δ 7.54 (d, *J* = 9.2 Hz, 2H), 7.30-7.22 (m, 2H), 6.96 (t, *J* = 8.4 Hz, 2H), 6.89 (d, *J* = 9.2 Hz, 2H), 6.36 (d, *J* = 16.0 Hz, 1H), 6.15-6.08 (m, 1H), 3.79 (s, 3H), 3.75-3.71 (m, 2H), 2.40-2.28 (m, 1H), 2.27-2.10 (m, 2H), 1.96-1.90 (m, 1H), 1.84-1.74 (m, 2H), 1.26 (s, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 177.91, 163.24, 160.80, 156.56, 133.93, 133.90, 133.03, 130.09, 130.07, 129.01, 127.49, 127.41, 121.60, 115.52, 115.31, 114.10, 55.59, 45.68, 45.10, 37.58, 30.92,

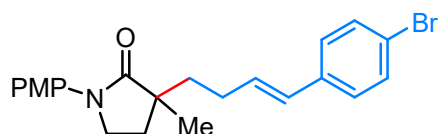
28.19, 23.33. IR (V/cm⁻¹): 3709, 3610, 2941, 2830, 2271, 2046, 1515, 1124, 1023 cm⁻¹.

¹. HRMS (ESI): calcd. C₂₂H₂₅FNO₂ [M+H]⁺: 354.1869. Found: 354.1898.



(E)-3-(4-(4-chlorophenyl)but-3-en-1-yl)-1-(4-methoxyphenyl)-3-methyl

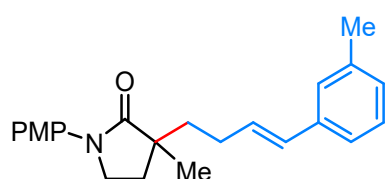
pyrrolidin-2-one (3g): Synthesized by following general procedure on a 0.2 mmol scale. Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 89% yield. ¹H NMR (400 MHz, CDCl₃) δ 7.53 (d, *J* = 9.2 Hz, 2H), 7.27-7.21 (m, 4H), 6.89 (d, *J* = 9.2 Hz, 2H), 6.35 (d, *J* = 15.6 Hz, 1H), 6.23-6.15 (m, 1H), 3.80 (s, 3H), 3.76-3.72 (m, 2H), 2.42-2.29 (m, 1H), 2.29-2.09 (m, 2H), 2.00-1.88 (m, 1H), 1.84-1.70 (m, 2H), 1.26 (s, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 177.87, 156.58, 136.28, 133.04, 132.55, 131.11, 129.04, 128.72, 127.26, 121.60, 114.12, 55.61, 45.68, 45.10, 37.51, 30.94, 28.26, 23.36. IR (V/cm⁻¹): 3751, 3660, 3486, 2941, 2830, 2271, 2046, 1516, 1124, 1022 cm⁻¹. HRMS (ESI): calcd. C₂₂H₂₅ClNO₂ [M+H]⁺: 370.1574. Found: 370.1572.



(E)-3-(4-(4-bromophenyl)but-3-en-1-yl)-1-(4-methoxyphenyl)-3-methyl

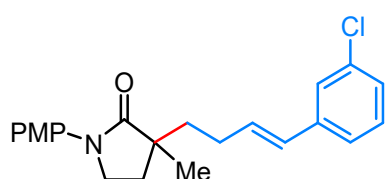
pyrrolidin-2-one (3h): Synthesized by following general procedure on a 0.2 mmol scale. Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 87% yield. ¹H NMR (400 MHz, CDCl₃) δ 7.53 (d, *J* = 9.2 Hz, 2H), 7.38 (d, *J* = 8.4 Hz, 2H), 7.16 (d, *J* = 8.4 Hz, 2H), 6.89 (d, *J* = 9.2 Hz, 2H), 6.34 (d, *J* = 16.0 Hz,

1H), 6.24-6.16 (m, 1H), 3.80 (s, 3H), 3.76-3.71 (m, 2H), 2.40-2.28 (m, 1H), 2.27-2.10 (m, 2H), 1.97-1.90 (m, 1H), 1.80-1.74 (m, 2H), 1.26 (s, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 177.88, 156.61, 136.73, 133.04, 131.66, 131.27, 129.10, 127.62, 121.63, 120.66, 114.14, 55.63, 45.70, 45.10, 37.48, 30.95, 28.28, 23.37. IR (V/cm⁻¹): 3868, 3651, 3552, 2946, 2889, 2169, 1513, 1125, 1022 cm⁻¹. HRMS (ESI): calcd. C₂₂H₂₅BrNO₂ [M+H]⁺: 414.1069. Found: 414.1088.



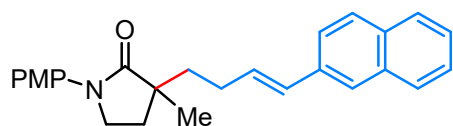
(E)-1-(4-methoxyphenyl)-3-methyl-3-(4-(m-tolyl)but-3-en-1-yl)pyrrolidin-2-one

(3i): Synthesized by following general procedure on a 0.2 mmol scale. Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 91% yield. ¹H NMR (400 MHz, CDCl₃) δ 7.54 (d, *J* = 9.2 Hz, 2H), 7.22-7.08 (m, 3H), 7.00 (d, *J* = 7.2 Hz, 1H), 6.89 (d, *J* = 9.2 Hz, 2H), 6.38 (d, *J* = 15.6 Hz, 1H), 6.23-6.19 (m, 1H), 3.80 (s, 3H), 3.73 (d, *J* = 7.2 Hz, 2H), 2.32 (s, 4H), 2.28-2.10 (m, 2H), 1.99-1.89 (m, 1H), 1.84-1.71 (m, 2H), 1.26 (s, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 177.94, 156.54, 138.10, 137.72, 133.10, 130.26, 130.15, 128.50, 127.82, 126.80, 123.21, 121.65, 121.60, 114.11, 55.60, 45.69, 45.13, 37.63, 30.98, 28.28, 23.31, 21.52. IR (V/cm⁻¹): 3732, 3448, 2945, 2830, 2171, 2016, 1121, 1023 cm⁻¹. HRMS (ESI): calcd. C₂₃H₂₈NO₂ [M+H]⁺: 350.2120. Found: 350.2133.



(E)-3-(4-(3-chlorophenyl)but-3-en-1-yl)-1-(4-methoxyphenyl)-3-methyl

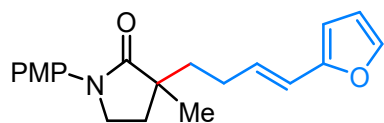
pyrrolidin-2-one (3j): Synthesized by following general procedure on a 0.2 mmol scale. Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 86% yield. ¹H NMR (400 MHz, CDCl₃) δ 7.54 (d, *J* = 9.2 Hz, 2H), 7.28 (s, 1H), 7.21-7.12 (m, 3H), 6.89 (d, *J* = 9.2 Hz, 2H), 6.34 (d, *J* = 16.0 Hz, 1H), 6.26-6.18 (m, 1H), 3.79 (s, 3H), 3.76-3.72 (m, 2H), 2.41-2.30 (m, 1H), 2.29-2.09 (m, 2H), 1.96-1.90 (m, 1H), 1.80-1.74 (m, 2H), 1.26 (s, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 177.82, 156.57, 139.67, 134.51, 133.04, 132.01, 129.80, 128.97, 126.95, 126.00, 124.28, 121.59, 114.12, 55.60, 45.66, 45.09, 37.45, 30.96, 28.24, 23.34. IR (V/cm⁻¹): 3709, 3660, 3486, 2841, 2630, 2170, 2046, 1516, 1124, 1022 cm⁻¹. HRMS (ESI): calcd. C₂₂H₂₅ClNO₂ [M+H]⁺: 370.1574. Found: 370.1572.



(E)-1-(4-methoxyphenyl)-3-methyl-3-(4-(naphthalen-2-yl)but-3-en-1-

yl)pyrrolidin-2-one (3k): Synthesized by following general procedure on a 0.2 mmol scale. Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 83% yield. ¹H NMR (400 MHz, CDCl₃) δ 7.82-7.72 (m, 3H), 7.64 (s, 1H), 7.55 (d, *J* = 9.2 Hz, 3H), 7.48-7.37 (m, 2H), 6.88 (d, *J* = 9.2 Hz, 2H), 6.57 (d, *J* = 16.0 Hz, 1H), 6.38-6.31 (m, 1H), 3.79 (s, 3H), 3.75 (t, *J* = 7.2 Hz, 2H), 2.47-2.36 (m, 1H), 2.34-2.14 (m, 2H), 2.01-1.92 (m, 1H), 1.85-1.79 (m, 2H), 1.29 (s, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 177.95, 156.56, 135.26, 133.80, 133.10, 132.82, 130.87, 130.35, 128.20, 127.97, 127.74, 126.25, 125.62, 125.55, 123.65, 121.62, 114.12, 55.61, 45.71, 45.17,

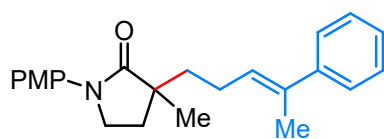
37.65, 31.00, 28.43, 23.39. IR (V/cm^{-1}): 3732, 3448, 2945, 2830, 2171, 2016, 1121, 1022 cm^{-1} . HRMS (ESI): calcd. $\text{C}_{26}\text{H}_{27}\text{NO}_2\text{Na}$ $[\text{M}+\text{Na}]^+$: 408.1939. Found: 408.1938.



(E)-3-(4-(furan-2-yl)but-3-en-1-yl)-1-(4-methoxyphenyl)-3-methylpyrrolidin-2-

one (3l): Synthesized by following general procedure on a 0.2 mmol scale. Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 92% yield.

^1H NMR (400 MHz, CDCl_3) δ 7.54 (d, $J = 9.2$ Hz, 2H), 7.30 (d, $J = 2.0$ Hz, 1H), 6.90 (d, $J = 9.2$ Hz, 2H), 6.33 (dd, $J = 3.6, 2.0$ Hz, 1H), 6.27-6.09 (m, 3H), 3.80 (s, 3H), 3.75-3.71 (m, 2H), 2.37-2.26 (m, 1H), 2.25-2.09 (m, 2H), 1.95-1.91 (m, 1H), 1.80-1.72 (m, 2H), 1.26 (s, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 177.87, 156.57, 153.21, 141.44, 133.06, 129.32, 121.64, 118.93, 114.12, 111.18, 106.31, 55.60, 45.68, 45.08, 37.45, 31.02, 27.97, 23.20. IR (V/cm^{-1}): 3863, 3647, 3252, 2947, 2831, 2215, 2013, 1514, 1120, 1022 cm^{-1} . HRMS (ESI): calcd. $\text{C}_{20}\text{H}_{24}\text{NO}_3$ $[\text{M}+\text{H}]^+$: 326.1756. Found: 326.1746.

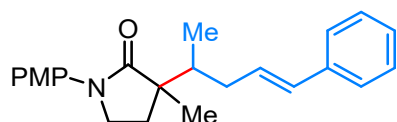


(E)-1-(4-methoxyphenyl)-3-methyl-3-(4-phenylpent-3-en-1-yl)pyrrolidin-2-one

(3m): Synthesized by following general procedure on a 0.2 mmol scale. Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 86% yield.

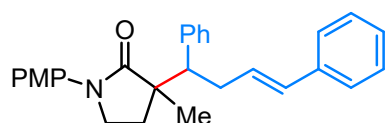
E/Z=10:1. ^1H NMR (400 MHz, CDCl_3) δ 7.59-7.48 (m, 2H), 7.39-7.14 (m, 5H), 6.93-6.86 (m, 2H), 5.79-5.74 (m, 1H), 3.79 (s, 3H), 3.79-3.70 (m, 2H), 2.39-2.26 (m, 1H), 2.27-2.11 (m, 2H), 2.07-1.98 (m, 3H), 1.97-1.90 (m, 1H), 1.78-1.72 (m, 2H), 1.27 (s,

3H). ^{13}C NMR (101 MHz, CDCl_3) δ 178.00, 156.51, 143.83, 135.18, 133.07, 128.25, 127.77, 126.66, 125.68, 121.61, 114.09, 55.58, 45.70, 45.20, 37.66, 30.94, 24.07, 23.20, 15.92. IR (V/cm^{-1}): 3773, 3667, 2947, 2832, 2171, 1515, 1119, 1022 cm^{-1} . HRMS (ESI): calcd. $\text{C}_{23}\text{H}_{28}\text{NO}_2$ $[\text{M}+\text{H}]^+$: 350.2120. Found: 350.2133.



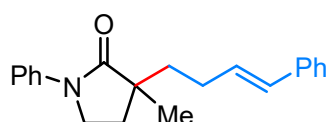
(E)-1-(4-methoxyphenyl)-3-methyl-3-(5-phenylpent-4-en-2-yl)pyrrolidin-2-one

(3n): Synthesized by following general procedure on a 0.2 mmol scale except for the amount of $\text{KO}t\text{Bu}$ (1.2 eq) and the reaction temperature (100 $^\circ\text{C}$). Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 52% yield. 1.4:1 dr. ^1H NMR (400 MHz, CDCl_3) δ 7.54 (d, $J = 8.8$ Hz, 2H), 7.35-7.27 (m, 4H), 7.20 (t, $J = 7.2$ Hz, 1H), 6.89 (dd, $J = 8.8, 5.6$ Hz, 2H), 6.39 (t, $J = 16.0$ Hz, 1H), 6.23-6.16 (m, 1H), 3.80 (s, 3H), 3.77-3.66 (m, 2H), 2.66-2.57 (m, 1H), 2.64-2.59 (m, 0.6H), 2.38-2.33 (m, 0.4H), 2.23-2.15 (m, 1H), 2.09-1.88 (m, 2H), 1.81-1.74 (m, 1H), 1.28 (s, 3H), 0.97 (t, $J = 7.2$ Hz, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 178.15, 178.06, 156.63, 137.82, 133.05, 131.46, 131.40, 129.76, 129.53, 128.65, 128.60, 127.08, 127.01, 126.12, 126.09, 121.80, 121.78, 114.16, 114.14, 55.64, 49.18, 48.82, 45.94, 45.85, 39.10, 38.91, 36.69, 34.95, 27.23, 26.80, 22.91, 22.26, 15.20, 13.86. IR (V/cm^{-1}): 3773, 3667, 2947, 2832, 2146, 1515, 1119, 1022 cm^{-1} . HRMS (ESI): calcd. $\text{C}_{23}\text{H}_{28}\text{NO}_2$ $[\text{M}+\text{H}]^+$: 350.2120. Found: 350.2133.



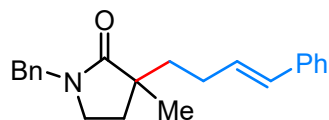
(E)-3-(1,4-diphenylbut-3-en-1-yl)-1-(4-methoxyphenyl)-3-methylpyrrolidin-2-one

(3o): Synthesized by following general procedure on a 0.2 mmol scale except for the amount of KO^tBu (1.2 eq) and the reaction temperature (100 °C). Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 38% yield. 1.4:1 dr. ¹H NMR (400 MHz, Chloroform-*d*) δ 7.49 (d, *J* = 3.6 Hz, 2H), 7.32-6.97 (m, 10H), 6.89 (d, *J* = 8.4 Hz, 2H), 6.29 (d, *J* = 15.6 Hz, 1H), 5.98-5.91 (m, 1H), 3.80 (s, 3H), 3.61 (q, *J* = 8.4 Hz, 1H), 3.49-3.30 (m, 1H), 3.22-3.08 (m, 1H), 2.80-2.72 (m, 1H), 2.69-2.43 (m, 2H), 2.24-1.98 (m, 1H), 1.83-1.75 (m, 1H), 1.41 (s, 1H), 1.13 (s, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 177.39, 176.35, 156.66, 142.50, 141.85, 140.99, 138.83, 137.80, 132.98, 132.90, 131.25, 129.75, 129.25, 128.96, 128.80, 128.41, 128.36, 128.25, 128.07, 127.96, 126.97, 126.90, 126.86, 126.09, 125.82, 121.87, 114.10, 114.09, 55.62, 55.60, 52.46, 51.54, 49.48, 45.80, 45.67, 35.96, 35.18, 32.04, 31.27, 28.33, 24.06, 23.52. IR (V/cm⁻¹): 3691, 3667, 2947, 2832, 2146, 1515, 1119, 1022 cm⁻¹. HRMS (ESI): calcd. C₂₈H₃₀NO₂ [M+H]⁺: 412.2277. Found: 412.2245.



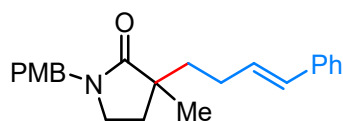
(E)-3-methyl-1-phenyl-3-(4-phenylbut-3-en-1-yl)pyrrolidin-2-one (4a): Synthesized by following general procedure on a 0.2 mmol scale. Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 88% yield. ¹H NMR (400 MHz, CDCl₃) δ 7.66 (d, *J* = 8.0 Hz, 2H), 7.41-7.25 (m, 6H), 7.22-7.10 (m, 2H), 6.41 (d, *J* = 16.0 Hz, 1H), 6.25-6.17 (m, 1H), 3.80-3.76 (m, 2H), 2.41-2.30 (m, 1H), 2.28-2.11 (m, 2H), 1.98-1.92 (m, 1H), 1.81-1.76 (m, 2H), 1.28 (s, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 178.33, 139.81, 137.76, 130.29, 130.25, 128.92, 128.60, 127.04, 126.06,

124.48, 119.84, 45.37, 45.30, 37.55, 30.92, 28.23, 23.23. IR (V/cm⁻¹): 3648, 3463, 2944, 2829, 2167, 1980, 1472, 1118, 1022 cm⁻¹. HRMS (ESI): calcd. C₂₁H₂₄NO [M+H]⁺: 306.1858. Found: 306.1877.



(E)-1-benzyl-3-methyl-3-(4-phenylbut-3-en-1-yl)pyrrolidin-2-one (4b):

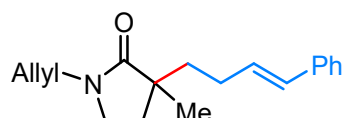
Synthesized by following general procedure on a 0.2 mmol scale. Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 89% yield. ¹H NMR (400 MHz, CDCl₃) δ 7.35-7.26 (m, 7H), 7.25-7.16 (m, 3H), 6.39 (d, *J* = 16.0, 1H), 6.24-6.17 (m, 1H), 4.45 (d, *J* = 3.2 Hz, 2H), 3.15 (t, *J* = 7.2 Hz, 2H), 2.33-2.25 (m, 1H), 2.22-2.12 (m, 1H), 2.05-1.95 (m, 1H), 1.83-1.68 (m, 3H), 1.20 (s, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 178.85, 137.80, 136.83, 130.47, 130.10, 128.78, 128.76, 128.60, 128.20, 127.63, 127.02, 126.04, 46.89, 44.03, 43.44, 37.49, 31.16, 28.26, 23.32. IR (V/cm⁻¹): 3684, 3347, 2943, 2830, 2336, 2043, 1472, 1120, 1022 cm⁻¹. HRMS (ESI): calcd. C₂₂H₂₆NO₂ [M+OH]⁺: 336.1964. Found: 336.1959.



(E)-1-(4-methoxybenzyl)-3-methyl-3-(4-phenylbut-3-en-1-yl)pyrrolidin-2-one (4c):

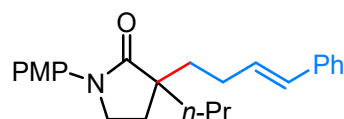
Synthesized by following general procedure on a 0.2 mmol scale. Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 92% yield. ¹H NMR (400 MHz, CDCl₃) δ 7.34-7.26 (m, 4H), 7.21-7.14 (m, 3H), 6.85 (d, *J* = 9.2 Hz, 2H), 6.38 (d, *J* = 16.0 Hz, 1H), 6.24-6.16 (m, 1H), 4.38 (d, *J* = 5.6 Hz, 2H), 3.79 (s, 3H), 3.13 (t, *J* = 6.4 Hz, 2H), 2.34-2.22 (m, 1H), 2.21-2.10 (m, 1H), 2.03-1.93 (m, 1H),

1.79-1.68 (m, 3H), 1.18 (s, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 178.73, 159.14, 137.83, 130.52, 130.09, 129.57, 128.94, 128.62, 127.03, 126.06, 114.15, 55.39, 46.29, 44.11, 43.33, 37.49, 31.15, 28.28, 23.32. IR (V/cm^{-1}): 3690, 3456, 2946, 2830, 2193, 2002, 1516, 1126, 1023 cm^{-1} . HRMS (ESI): calcd. $\text{C}_{23}\text{H}_{28}\text{NO}_2$ $[\text{M}+\text{H}]^+$: 350.2120. Found: 350.2133.



(E)-1-allyl-3-methyl-3-(4-phenylbut-3-en-1-yl)pyrrolidin-2-one (4d):

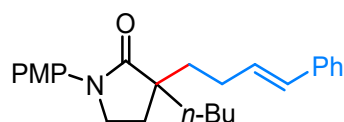
Synthesized by following general procedure on a 0.2 mmol scale. Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 87% yield. ^1H NMR (400 MHz, CDCl_3) δ 7.35-7.24 (m, 5H), 7.22-7.14 (m, 1H), 6.88 (dd, $J = 19.6$, 2.4 Hz, 1H), 6.39 (d, $J = 16.0$ Hz, 1H), 6.22-6.12 (m, 1H), 5.02-4.90 (m, 1H), 3.41 (t, $J = 9.6$ Hz, 2H), 2.36-2.05 (m, 3H), 1.95-1.81 (m, 1H), 1.78-1.66 (m, 5H), 1.20 (s, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 176.68, 137.74, 130.21, 130.18, 128.58, 127.02, 126.04, 124.86, 106.88, 44.67, 42.34, 37.67, 30.96, 28.25, 23.55, 15.33. IR (V/cm^{-1}): 3750, 3464, 3051, 2828, 2196, 1506, 1125, 1023 cm^{-1} . HRMS (ESI): calcd. $\text{C}_{18}\text{H}_{24}\text{NO}$ $[\text{M}+\text{H}]^+$: 270.1858. Found: 270.1855.



(E)-1-(4-methoxyphenyl)-3-(4-phenylbut-3-en-1-yl)-3-propylpyrrolidin-2-one (4e):

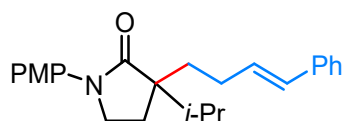
Synthesized by following general procedure on a 0.2 mmol scale. Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 93% yield. ^1H NMR (400 MHz, CDCl_3) δ 7.54 (d, $J = 9.2$ Hz, 2H), 7.35-7.24 (m, 4H), 7.22-7.14 (m,

1H), 6.89 (d, $J = 9.2$ Hz, 2H), 6.39 (d, $J = 16.0$ Hz, 1H), 6.24-6.16 (m, 1H), 3.79 (s, 3H), 3.72 (t, $J = 7.2$ Hz, 2H), 2.37-2.15 (m, 2H), 2.12-2.04 (m, 2H), 1.83-1.71 (m, 2H), 1.65-1.56 (m, 2H), 1.49-1.38 (m, 1H), 1.35-1.24 (m, 1H), 0.93 (t, $J = 7.2$ Hz, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 177.34, 156.57, 137.77, 132.97, 130.39, 130.16, 128.57, 126.99, 126.03, 121.74, 114.10, 55.59, 48.75, 46.13, 39.79, 36.89, 28.13, 17.68, 14.73. IR (V/cm^{-1}): 3711, 3567, 2946, 2828, 2365, 1996, 1669, 1183, 1023 cm^{-1} . HRMS (ESI): calcd. $\text{C}_{24}\text{H}_{30}\text{NO}_2$ $[\text{M}+\text{H}]^+$: 364.2277. Found: 364.2291.



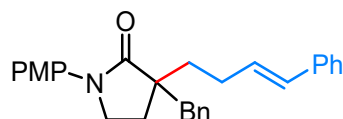
(E)-3-butyl-1-(4-methoxyphenyl)-3-(4-phenylbut-3-en-1-yl)pyrrolidin-2-one (4f):

Synthesized by following general procedure on a 0.2 mmol scale. Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 89% yield. ^1H NMR (400 MHz, CDCl_3) δ 7.55 (d, $J = 9.2$ Hz, 2H), 7.33-7.24 (m, 4H), 7.21-7.14 (m, 1H), 6.89 (d, $J = 9.2$ Hz, 2H), 6.39 (d, $J = 16.0$ Hz, 1H), 6.24-6.16 (m, 1H), 3.79 (s, 3H), 3.72 (t, $J = 7.2$ Hz, 2H), 2.38-2.27 (m, 1H), 2.27-2.16 (m, 1H), 2.11-2.04 (m, 2H), 1.86-1.71 (m, 2H), 1.65-1.60 (m, 2H), 1.42-1.26 (m, 4H), 0.90 (t, $J = 7.2$ Hz, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 177.28, 156.49, 137.69, 132.91, 130.31, 130.07, 128.48, 126.91, 125.95, 121.66, 114.02, 55.51, 48.58, 46.03, 37.12, 36.78, 28.05, 26.45, 23.29, 14.07. IR (V/cm^{-1}): 3751, 3690, 2943, 2830, 2339, 2148, 1514, 1120, 1023 cm^{-1} . HRMS (ESI): calcd. $\text{C}_{25}\text{H}_{32}\text{NO}_2$ $[\text{M}+\text{H}]^+$: 378.2433. Found: 378.2408.



(E)-3-isopropyl-1-(4-methoxyphenyl)-3-(4-phenylbut-3-en-1-yl)pyrrolidin-2-one

(4g): Synthesized by following general procedure on a 0.2 mmol scale except for the amount of KO^tBu (1.2 eq) and the reaction temperature (100 °C). Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 72% yield. ¹H NMR (400 MHz, CDCl₃) δ 7.55 (d, *J* = 9.2 Hz, 2H), 7.33-7.25 (m, 4H), 7.21-7.16 (m, 1H), 6.90 (d, *J* = 9.2 Hz, 2H), 6.38 (d, *J* = 16.0 Hz, 1H), 6.23-6.17 (m, 1H), 3.80 (s, 3H), 3.78-3.64 (m, 2H), 2.35-2.20 (m, 2H), 2.19-2.09 (m, 2H), 1.92-1.69 (m, 3H), 0.93 (t, *J* = 6.8 Hz, 6H). ¹³C NMR (101 MHz, CDCl₃) δ 177.18, 156.68, 137.77, 132.84, 130.43, 130.21, 128.58, 127.00, 126.04, 121.97, 114.15, 114.12, 55.61, 52.49, 46.56, 36.90, 33.55, 28.31, 23.52, 18.42, 16.96. IR (V/cm⁻¹): 3751, 3690, 3417, 2943, 2830, 2389, 1514, 1120, 1024 cm⁻¹. HRMS (ESI): calcd. C₂₄H₃₀NO₂ [M+H]⁺: 364.2277. Found: 364.2291.

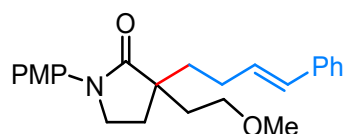


(E)-3-benzyl-1-(4-methoxyphenyl)-3-(4-phenylbut-3-en-1-yl)pyrrolidin-2-one

(4h): Synthesized by following general procedure on a 0.2 mmol scale. Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 89% yield. ¹H NMR (400 MHz, CDCl₃) δ 7.34-7.27 (m, 5H), 7.26-7.15 (m, 7H), 6.84 (d, *J* = 9.2 Hz, 2H), 6.42 (d, *J* = 16.0 Hz, 1H), 6.26-6.19 (m, 1H), 3.77 (s, 3H), 3.40-3.34 (m, 1H), 3.14 (d, *J* = 12.8 Hz, 1H), 2.82-2.78 (m, 1H), 2.71 (d, *J* = 13.6 Hz, 1H), 2.43-2.24 (m, 2H), 2.14-1.92 (m, 3H), 1.79-1.75 (m, 1H). ¹³C NMR (101 MHz, CDCl₃) δ 176.53, 156.72, 137.73, 137.61, 132.61, 130.31, 130.19, 130.15, 128.58, 128.30, 127.03, 126.79, 126.05, 122.19, 114.02, 55.53, 50.33, 46.02, 43.71, 37.98, 28.22, 26.73. IR (V/cm⁻¹):

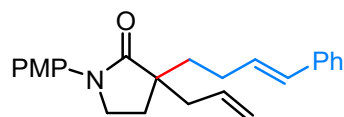
3709, 3647, 3436, 2944, 2832, 2371, 1983, 1558, 1119, 1023 cm⁻¹. HRMS (ESI): calcd.

C₂₈H₃₀NO₂ [M+H]⁺: 412.2277. Found: 412.2245.



(E)-3-(2-methoxyethyl)-1-(4-methoxyphenyl)-3-(4-phenylbut-3-en-1-yl)

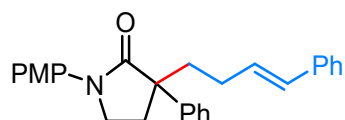
pyrrolidin-2-one (4i): Synthesized by following general procedure on a 0.2 mmol scale. Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 86% yield. ¹H NMR (400 MHz, CDCl₃) δ 7.54 (d, *J* = 9.2 Hz, 2H), 7.33-7.26 (m, 4H), 7.22-7.15 (m, 1H), 6.90 (d, *J* = 9.2 Hz, 2H), 6.40 (d, *J* = 16.0 Hz, 1H), 6.24-6.16 (m, 1H), 3.80 (s, 3H), 3.76-3.72 (m, 2H), 3.54-3.49 (m, 2H), 3.31 (s, 3H), 2.41-2.29 (m, 1H), 2.27-2.16 (m, 2H), 2.14-2.07 (m, 1H), 2.02-1.87 (m, 2H), 1.86-1.74 (m, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 176.86, 156.68, 137.73, 132.94, 130.32, 130.18, 128.61, 127.06, 126.07, 121.86, 114.15, 69.45, 58.85, 55.63, 47.58, 46.13, 36.96, 36.37, 28.52, 28.06. IR (V/cm⁻¹): 3735, 3647, 2944, 2832, 2371, 1983, 1119, 1023 cm⁻¹. HRMS (ESI): calcd. C₂₄H₃₀NO₃ [M+H]⁺: 380.2226. Found: 380.2251.



(E)-3-allyl-1-(4-methoxyphenyl)-3-(4-phenylbut-3-en-1-yl)pyrrolidin-2-one (4j):

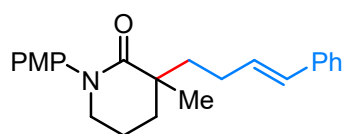
Synthesized by following general procedure on a 0.2 mmol scale. Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 87% yield. ¹H NMR (400 MHz, CDCl₃) δ 7.53 (d, *J* = 9.2 Hz, 2H), 7.33-7.24 (m, 4H), 7.21-7.15 (m, 1H), 6.89 (d, *J* = 9.2 Hz, 2H), 6.39 (d, *J* = 16.0 Hz, 1H), 6.23-6.15 (m, 1H), 5.86-5.75 (m, 1H), 5.20-5.08 (m, 2H), 3.79 (s, 3H), 3.74-3.65 (m, 2H), 2.49-2.43 (m, 1H), 2.38-

2.18 (m, 3H), 2.15-2.01 (m, 2H), 1.88-1.80 (m, 1H), 1.78-1.72 (m, 1H). ¹³C NMR (101 MHz, CDCl₃) δ 176.69, 156.65, 137.71, 133.90, 132.85, 130.28, 130.17, 128.57, 127.02, 126.04, 121.82, 118.78, 114.11, 55.58, 48.70, 46.11, 41.94, 36.89, 28.10, 27.34. IR (V/cm⁻¹): 3608, 3509, 3297, 2944, 2830, 2338, 1115, 1022 cm⁻¹. HRMS (ESI): calcd. C₂₄H₂₈NO₂ [M+H]⁺: 362.2120. Found: 362.2100.



(E)-1-(4-methoxyphenyl)-3-phenyl-3-(4-phenylbut-3-en-1-yl)pyrrolidin-2-one

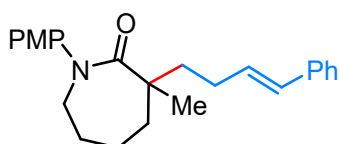
(4k): Synthesized by following general procedure on a 0.2 mmol scale except for the amount of KO^tBu (1.2 eq) and the reaction temperature (100 °C). Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 68% yield. ¹H NMR (400 MHz, CDCl₃) δ 7.54 (d, *J* = 8.4 Hz, 4H), 7.36 (t, *J* = 7.6 Hz, 2H), 7.31-7.26 (m, 5H), 7.19-7.17 (m, 1H), 6.89 (d, *J* = 8.8 Hz, 2H), 6.35 (d, *J* = 16.0 Hz, 1H), 6.20-6.13 (m, 1H), 3.79 (s, 3H), 3.75-3.69 (m, 2H), 2.70-2.65 (m, 1H), 2.43-2.34 (m, 1H), 2.33-2.02 (m, 4H). ¹³C NMR (101 MHz, CDCl₃) δ 175.46, 156.67, 140.89, 137.79, 132.95, 130.26, 130.16, 128.75, 128.60, 127.15, 127.02, 126.71, 126.05, 121.74, 114.13, 55.63, 53.28, 45.89, 38.93, 31.13, 28.48. IR (V/cm⁻¹): 3614, 3466, 3335, 3048, 2950, 2137, 1646, 1224, 952 cm⁻¹. HRMS (ESI): calcd. C₂₇H₂₈NO₂ [M+H]⁺: 398.2120. Found: 398.2148.



(E)-1-(4-methoxyphenyl)-3-methyl-3-(4-phenylbut-3-en-1-yl)piperidin-2-one (4l):

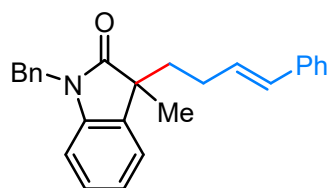
Synthesized by following general procedure on a 0.2 mmol scale. Isolated by flash

column chromatography (PE: EA = 10:1) to afford a colorless oil in 83% yield. ^1H NMR (400 MHz, CDCl_3) δ 7.35-7.26 (m, 4H), 7.21-7.17 (m, 1H), 7.09 (d, $J = 8.8$ Hz, 2H), 6.87 (d, $J = 8.8$ Hz, 2H), 6.42 (d, $J = 16.0$ Hz, 1H), 6.26-6.19 (m, 1H), 3.79 (s, 3H), 3.67-3.59 (m, 1H), 3.59-3.54 (m, 1H), 2.39-2.17 (m, 2H), 2.07-1.93 (m, 4H), 1.73-1.66 (m, 2H), 1.33 (s, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 175.67, 158.02, 137.91, 136.89, 130.94, 129.98, 128.59, 127.53, 126.95, 126.07, 114.42, 55.58, 52.60, 42.11, 39.85, 33.18, 28.35, 26.70, 20.30. IR (V/cm^{-1}): 3712, 3460, 2944, 2826, 2380, 1540, 1199, 1029 cm^{-1} . HRMS (ESI): calcd. $\text{C}_{23}\text{H}_{27}\text{NO}_2\text{Na}$ $[\text{M}+\text{Na}]^+$: 372.1939. Found: 372.1912.



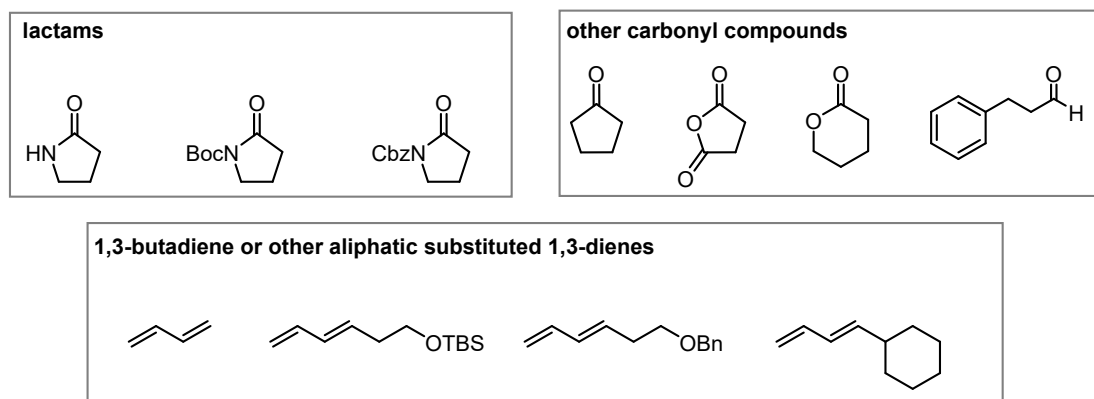
(E)-1-(4-methoxyphenyl)-3-methyl-3-(4-phenylbut-3-en-1-yl)azepan-2-one (4m):

Synthesized by following general procedure on a 0.2 mmol scale. Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 77% yield. ^1H NMR (400 MHz, CDCl_3) δ 7.37-7.27 (m, 4H), 7.22-7.18 (m, 1H), 7.03 (d, $J = 8.8$ Hz, 2H), 6.87 (d, $J = 8.8$ Hz, 2H), 6.43 (d, $J = 16.0$ Hz, 1H), 6.30-6.23 (m, 1H), 3.92-3.83 (m, 1H), 3.79 (s, 3H), 3.64-3.56 (m, 1H), 2.42-2.18 (m, 2H), 2.01-1.93 (m, 1H), 1.91-1.69 (m, 7H), 1.33 (s, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 177.73, 157.83, 140.01, 137.78, 130.86, 129.90, 128.50, 127.63, 126.88, 125.96, 114.43, 55.49, 51.12, 46.31, 35.80, 28.36, 28.24, 26.64, 23.30. IR (V/cm^{-1}): 3566, 3249, 2943, 2899, 2228, 1558, 1123, 1021 cm^{-1} . HRMS (ESI): calcd. $\text{C}_{24}\text{H}_{30}\text{NO}_2$ $[\text{M}+\text{H}]^+$: 364.2277. Found: 364.2291.



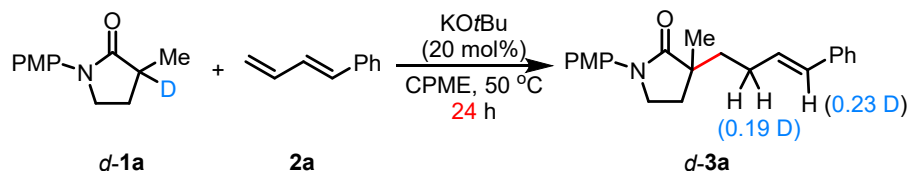
(E)-1-benzyl-3-methyl-3-(4-phenylbut-3-en-1-yl)indolin-2-one (4n): Synthesized by following general procedure on a 0.2 mmol scale except for the amount of KO^tBu (1.2 eq) and the reaction temperature (100 °C). Isolated by flash column chromatography (PE: EA = 10:1) to afford a colorless oil in 58% yield. ¹H NMR (400 MHz, CDCl₃) δ 7.33-7.27 (m, 4H), 7.25-7.12 (m, 8H), 7.09-7.03 (m, 1H), 6.71 (d, *J* = 7.6 Hz, 1H), 6.15 (d, *J* = 16.0 Hz, 1H), 6.17-6.00 (m, 1H), 4.91 (d, *J* = 15.6 Hz, 1H), 4.78 (d, *J* = 15.6 Hz, 1H), 2.24-2.15 (m, 1H), 2.03-1.93 (m, 2H), 1.90-1.80 (m, 1H), 1.44 (s, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 180.75, 142.65, 137.68, 136.30, 133.85, 130.36, 129.65, 128.89, 128.57, 127.84, 127.68, 127.42, 127.07, 126.08, 122.80, 122.67, 109.23, 48.37, 43.82, 37.91, 28.67, 24.67. IR (V/cm⁻¹): 3522, 3419, 2945, 2860, 2143, 1521, 1122, 1020 cm⁻¹. HRMS (ESI): calcd. C₂₆H₂₆NO [M+H]⁺: 368.2014. Found: 368.1994.

Scheme S1: Unreacted Substrates under Standard Conditions (<10% conversion)



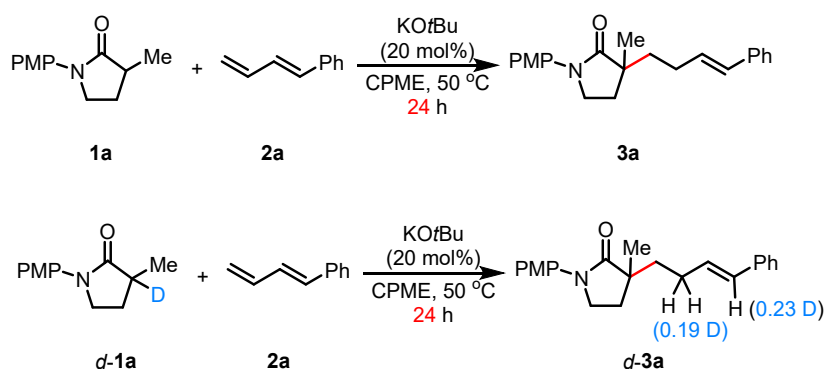
4. Deuterium Experiments

4.1 Deuterium-labelling experiment of *d*-1a and 2a.



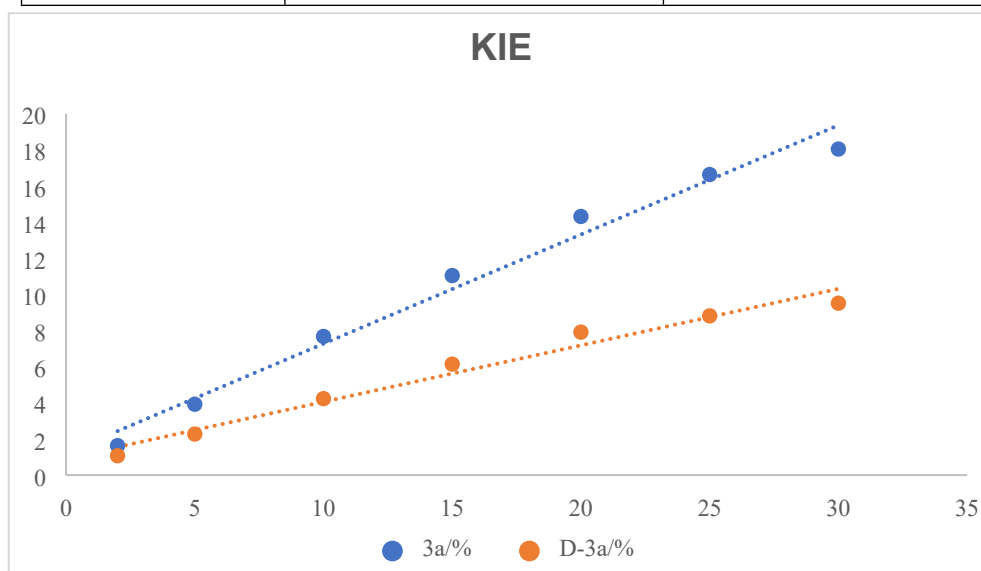
Substrate *d*-1a and 2a were subjected to standard reaction condition, the reaction was stopped after heating at 50 °C for 24 h. The crude reaction mixture was then subjected to column chromatography (PE: EA = 10:1) to isolate the pure products *d*-3a (87%). ¹H NMR (400 MHz, CDCl₃) δ 7.54 (d, *J* = 8.8 Hz, 2H), 7.35-7.24 (m, 4H), 7.18 (t, *J* = 7.2 Hz, 1H), 6.89 (d, *J* = 8.8 Hz, 2H), 6.41 (d, *J* = 16.0 Hz, 0.76H), 6.25-6.18 (m, 1H), 3.80 (s, 3H), 3.75-3.72 (m, 2H), 2.38-2.30 (m, 0.8H), 2.27-2.12 (m, 2H), 1.97-1.90 (m, 1H), 1.80-1.75 (m, 2H), 1.27 (s, 3H).

4.2 KIE study.



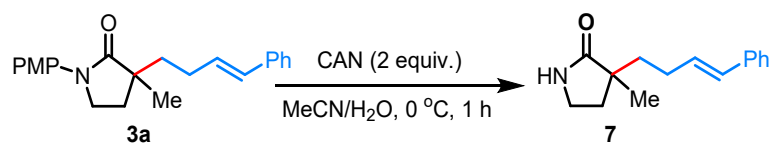
The two parallel experiments starting from either 1a or *d*-1a were conducted under standard reaction conditions. Authentic samples from these two vials were picked at 2 min, 5 min, 10 min, 15 min, 20 min, 25 min, 30 min accordingly. The concentration of the product was determined by GC with *n*-dodecane as the internal standard.

Time (min)	[3a] (%)	[<i>d</i> - 3a] (%)
2	1.63	1.07
5	3.92	2.27
10	7.67	4.23
15	11.04	6.14
20	14.31	7.91
25	16.63	8.81
30	18.04	9.51



5. Synthetic Applications

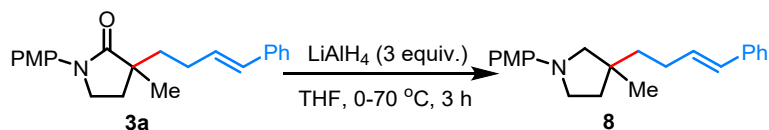
5.1 Synthesis of **7** from **3a**.



(E)-3-methyl-3-(4-phenylbut-3-en-1-yl)pyrrolidin-2-one (7): On the basis of a literature report,⁶ a solution of ceric ammonium nitrate (654 mg, 1.19 mmol) in de-ionized water (4.0 mL) was added dropwise to a stirred solution of compound **3a** (200 mg, 0.59 mmol) in CH₃CN (4.0 mL) at 0 °C. The resulting mixture was stirred at 0 °C for 1 h, at which time the starting material had been consumed. The reaction mixture

was diluted with water (10 mL) and extracted with EtOAc (10 mL × 2). The combined organic layers were dried over anhydrous Na₂SO₄ and then concentrated under reduced pressure. The product was purified by flash column chromatography on silica gel (PE: EA = 1:1), which afforded the desired product as a colorless oil. 70% yield. ¹H NMR (400 MHz, CDCl₃) δ 7.33-7.28 (m, 4H), 7.18 (t, *J* = 7.2 Hz, 1H), 6.41 (d, *J* = 15.2 Hz, 2H), 6.24-6.17 (m, 1H), 3.31 (t, *J* = 7.2 Hz, 2H), 2.35-2.27 (m, 1H), 2.25-2.10 (m, 2H), 1.94-1.87 (m, 1H), 1.69 (t, *J* = 8.4 Hz, 2H), 1.20 (s, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 182.85, 137.83, 130.42, 130.14, 128.61, 127.03, 126.05, 42.93, 38.96, 37.17, 33.74, 28.24, 23.01. IR (V/cm⁻¹): 3711, 3577, 3046, 2829, 2123, 1735, 1513, 1368, 1237, 965, 734 cm⁻¹. HRMS (ESI): calcd. C₁₅H₂₀NO [M+H]⁺: 230.1545. Found: 230.1528.

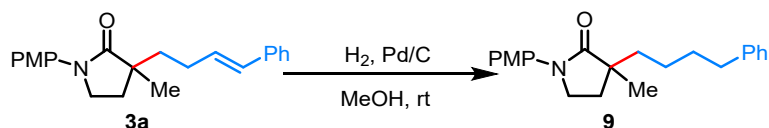
5.2 Synthesis of **8** from **3a**.⁷



(E)-1-(4-methoxyphenyl)-3-methyl-3-(4-phenylbut-3-en-1-yl)pyrrolidine (8): To a solution of LiAlH₄ (68 mg, 1.79 mmol) in 5 mL THF, **3a** (200 mg, 0.59 mmol) in 2 mL THF was added at 0 °C, and then stirred for 3 h at 70 °C. After cooling the mixture to 0 °C, the reaction was quenched by sat. Na₂SO₄ aq. solution, diluted with dichloromethane, and washed with brine, dried, and evaporated to afford the crude product, which was purified by column chromatography on silica gel (PE: EA= 100:1) to give the desired product as a colorless oil. 84% yield. ¹H NMR (400 MHz, CDCl₃) δ 7.37-7.26 (m, 4H), 7.19 (t, *J* = 7.2 Hz, 1H), 6.84 (d, *J* = 8.4 Hz, 2H), 6.48 (d, *J* = 8.4 Hz, 2H), 6.41 (d, *J* = 16.0 Hz, 1H), 6.26-6.19 (m, 1H), 3.75 (s, 3H), 3.36-3.31 (m, 2H),

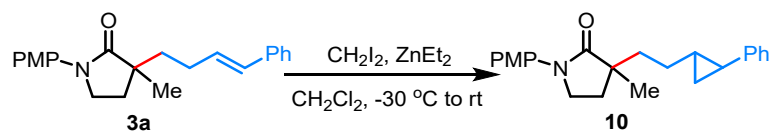
3.10 (d, $J = 8.8$ Hz, 1H), 3.01 (d, $J = 8.8$ Hz, 1H), 2.31-2.24 (m, 2H), 1.88-1.76 (m, 2H), 1.63 (t, $J = 8.4$ Hz, 2H), 1.13 (s, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 150.73, 143.23, 137.88, 131.07, 129.90, 128.63, 127.01, 126.03, 115.22, 112.15, 60.37, 56.19, 47.38, 41.58, 40.21, 38.15, 29.01, 24.31. IR (V/cm^{-1}): 3675, 3463, 2942, 2199, 1732, 1514, 1264, 733 cm^{-1} . HRMS (ESI): calcd. $\text{C}_{22}\text{H}_{28}\text{NO}$ $[\text{M}+\text{H}]^+$: 322.2171. Found: 322.2139.

5.3 Synthesis of **9** from **3a**.



1-(4-methoxyphenyl)-3-methyl-3-(4-phenylbutyl)pyrrolidin-2-one (9): 10% Pd/C(10 mg, 10% w/w) was added to a solution of **3a** (100mg, 0.30 mmol) in 5 mL methanol, the mixture was stirred under an H_2 atmosphere (balloon) at room temperature overnight. The mixture was filtered through a pad of celite, and the filtrate was concentrated in vacuo to give the corresponding product as a colorless oil. 92% yield. ^1H NMR (400 MHz, CDCl_3) δ 7.53 (d, $J = 7.6$ Hz, 2H), 7.27-7.23 (m, 2H), 7.16 (m, 3H), 6.89 (d, $J = 7.2$ Hz, 2H), 3.79 (s, 3H), 3.69 (m, 2H), 2.62 (t, $J = 8.0$ Hz, 2H), 2.06 (m, 1H), 1.87 (m, 1H), 1.68-1.55 (m, 4H), 1.46 (m, 1H), 1.37-1.28 (m, 1H), 1.21 (s, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 178.22, 156.43, 142.58, 133.06, 128.40, 128.29, 125.67, 121.51, 114.02, 55.51, 45.64, 45.15, 37.84, 35.83, 31.97, 30.76, 24.13, 23.18. IR (V/cm^{-1}): 3392, 3259, 2971, 2162, 1964, 1676, 1514, 1249, 1089, 1046, 879 cm^{-1} . HRMS (ESI): calcd. $\text{C}_{22}\text{H}_{27}\text{NO}_2\text{Na}$ $[\text{M}+\text{Na}]^+$: 360.1939. Found: 360.1965.

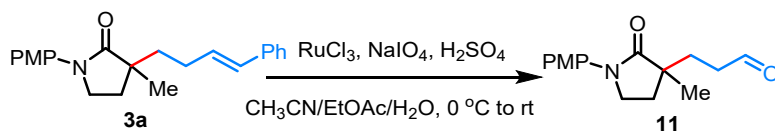
5.4 Synthesis of 10 from 3a.



1-(4-methoxyphenyl)-3-methyl-3-(2-(2-phenylcyclopropyl)ethyl)pyrrolidin-2-one

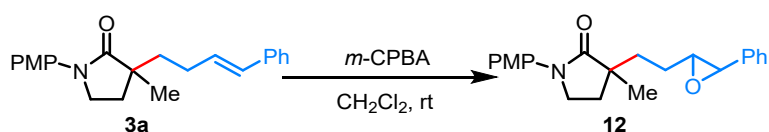
(10): **3a** (200 mg, 0.59 mmol) was dissolved in 7 mL DCM under inert atmosphere, the solution was cooled to $-30\text{ }^\circ\text{C}$, and ZnEt_2 (3 mL, 3 mmol, 1M soln. in hexanes) was added dropwise. The mixture was stirred at $-30\text{ }^\circ\text{C}$ for 5 min. Then CH_2I_2 (0.5 mL, 5.9 mmol) was added slowly, and the reaction was allowed to warm slowly to room temperature. The reaction mixture was stirred at room temperature and quenched with satd. aq. NH_4Cl , extracted with DCM. The combined organic extracts were washed with brine, dried over Na_2SO_4 , filtered and concentrated in vacuo, the crude product was purified by column chromatography on silica gel (PE: EA= 10:1) to give the desired product as a colorless oil. 78% yield. $d_r > 20:1$. ^1H NMR (400 MHz, CDCl_3) δ 7.54 (d, $J = 7.2$ Hz, 2H), 7.23 (t, $J = 7.2$ Hz, 2H), 7.11 (t, $J = 7.2$ Hz, 1H), 7.03 (d, $J = 7.6$ Hz, 2H), 6.90 (d, $J = 8.0$ Hz, 2H), 3.79 (s, 3H), 3.76-3.62 (m, 2H), 2.08 (m, 1H), 1.89 (m, 1H), 1.80-1.70 (m, 2H), 1.61 (m, 1H), 1.50 (m, 1H), 1.43-1.33 (m, 1H), 1.22 (s, 3H), 1.02 (m, 1H), 0.88 (m, 1H), 0.83-0.72 (m, 1H). ^{13}C NMR (101 MHz, CDCl_3) δ 177.99, 156.43, 143.71, 133.03, 128.23, 125.65, 125.64, 125.25, 121.48, 114.03, 55.51, 45.58, 44.92, 44.90, 37.60, 37.58, 30.98, 30.91, 29.37, 29.33, 23.85, 23.81, 23.29, 23.27, 23.14, 23.12, 16.21, 16.18. IR (V/cm^{-1}): 3360, 2970, 2180, 1668, 1513, 1249, 1087, 1049, 879 cm^{-1} . HRMS (ESI): calcd. $\text{C}_{23}\text{H}_{28}\text{NO}_2$ $[\text{M}+\text{H}]^+$: 350.2120. Found: 350.2133.

5.5 Synthesis of 11 from 3a.



2-(1-(4-methoxyphenyl)-3-methyl-2-oxopyrrolidin-3-yl)acetaldehyde (11): A solution of sodium periodate (625.8 mg, 2.93 mmol) in 3 mL CH₃CN and 3 mL H₂O and 96% sulfuric acid (287.4 mg, 2.93 mmol) were added dropwise to a solution of **3a** (200 mg, 0.59 mmol) in 1 mL EtOAc at 0 °C, the mixture was stirred at 0 °C for 5 min, then RuCl₃ was added, the resulting mixture was stirred at room temperature for 30 min. Ethyl acetate was added, the organic layer was separated, and the aqueous layer was extracted with ethyl acetate, the combined organic extracts were washed with brine, dried over Na₂SO₄, filtered and concentrated in vacuo, the crude product was purified by column chromatography on silica gel (PE: EA= 5:1) to give the desired product as a colorless oil. 89% yield. ¹H NMR (400 MHz, CDCl₃) δ 9.79 (s, 1H), 7.52 (d, *J* = 8.0 Hz, 2H), 6.90 (d, *J* = 8.0 Hz, 2H), 3.80 (s, 3H), 3.74 (t, *J* = 6.8 Hz, 2H), 2.72-2.60 (m, 1H), 2.54 (m, 1H), 2.04 (m, 1H), 1.99-1.85 (m, 3H), 1.25 (s, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 201.80, 177.08, 156.62, 132.71, 121.60, 114.07, 55.50, 45.42, 44.20, 39.37, 31.47, 29.61, 22.74. IR (V/cm⁻¹): 3440, 2972, 2888, 2332, 2175, 1379, 1513, 1250, 1087, 1046, 880 cm⁻¹. HRMS (ESI): calcd. C₁₅H₂₀NO₃ [M+H]⁺: 262.1443. Found: 262.1439.

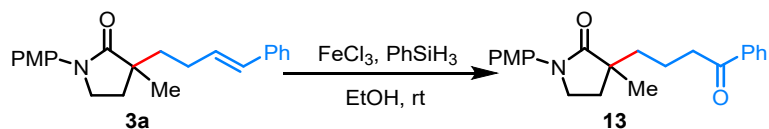
5.6 Synthesis of 12 from 3a.



1-(4-methoxyphenyl)-3-methyl-3-(2-(3-phenyloxiran-2-yl)ethyl)pyrrolidin-2-one

(12): **3a** (200 mg, 0.59 mmol) was dissolved in DCM (5 mL), then *m*-CPBA (152 mg, 0.88 mmol) was added, the mixture was stirred at room temperature overnight. The mixture was quenched with Satd. aq. Na₂S₂O₃ and extracted with EtOAc, the combined organic extracts were washed with brine, dried over Na₂SO₄, filtered and concentrated in vacuo, the crude product was purified by column chromatography on silica gel (PE: EA= 5:1) to give the desired product as a colorless oil. 85% yield. dr=1.4:1. ¹H NMR (400 MHz, CDCl₃) δ 7.53 (d, *J* = 7.6 Hz, 2H), 7.31 (m, 3H), 7.26-7.19 (m, 2H), 6.89 (d, *J*=6.8 Hz, 2H), 3.79 (s, 3H), 3.77-3.68 (m, 2H), 3.64 (s, 1H), 2.98 (s, 1H), 2.10 (m, 1H), 1.99-1.89 (m, 1H), 1.89-1.64 (m, 4H), 1.25 (s, 3H). ¹³C NMR (101 MHz, CDCl₃) δ 177.50, 156.54, 137.58, 137.56, 132.85, 128.46, 128.08, 125.57, 121.58, 121.56, 114.05, 62.90, 62.86, 58.63, 58.51, 55.50, 45.57, 45.55, 44.80, 44.66, 33.92, 33.61, 31.04, 30.75, 27.61, 27.47, 23.27, 22.66. IR (V/cm⁻¹): 3355, 2975, 2888, 1675, 1514, 1456, 1251, 1088, 1047, 879 cm⁻¹. HRMS (ESI): calcd. C₂₂H₂₆NO₃ [M+H]⁺: 352.1913. Found: 352.1918.

5.7 Synthesis of 13 from 3a.

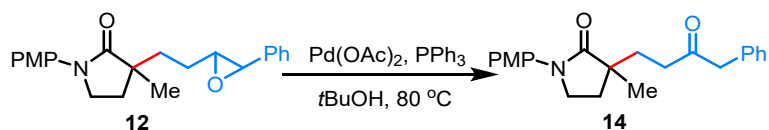


1-(4-methoxyphenyl)-3-methyl-3-(4-oxo-4-phenylbutyl)pyrrolidin-2-one (13):

Phenylsilane (128 mg, 1.2 mmol) was added to a solution of **3a** (200 mg, 0.59 mmol) in EtOH (5 mL), then FeCl₃ (2.8 mg, 3 mol%) was added. The mixture was stirred at room temperature under air overnight and concentrated in vacuo, the crude product was

purified by column chromatography on silica gel (PE: EA= 5:1) to give the desired product as a colorless oil. 83% yield. ^1H NMR (400 MHz, CDCl_3) δ 7.95 (d, J = 7.6 Hz, 2H), 7.62-7.50 (m, 3H), 7.46 (t, J = 7.6 Hz, 2H), 6.89 (d, J = 8.4 Hz, 2H), 3.80 (s, 3H), 3.78-3.69 (m, 2H), 3.01 (t, J = 6.5 Hz, 2H), 2.21 (m, 1H), 1.92 (m, 2H), 1.78-1.64 (m, 3H), 1.25 (s, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 200.01, 178.01, 156.47, 137.00, 133.03, 132.98, 128.61, 128.01, 121.56, 114.02, 55.50, 45.68, 45.23, 38.65, 37.45, 30.47, 23.06, 19.08. IR (V/cm^{-1}): 3687, 2993, 2209, 1738, 1514, 1372, 1236, 1095, 1045, 879 cm^{-1} . HRMS (ESI): calcd. $\text{C}_{22}\text{H}_{26}\text{NO}_3$ $[\text{M}+\text{H}]^+$: 352.1913. Found: 352.1918.

5.8 Synthesis of 14 from 12.



1-(4-methoxyphenyl)-3-methyl-3-(3-oxo-4-phenylbutyl)pyrrolidin-2-one (14):

12(100 mg, 0.28 mmol) was dissolved in 2mL *t*BuOH, then $\text{Pd}(\text{OAc})_2$ (3.2 mg, 0.014mmol) and PPh_3 (11.2 mg, 0.042 mmol) were added to the mixture successively, the reaction mixture was stirred at 80 °C under N_2 overnight and concentrated in vacuo, the crude product was purified by column chromatography on silica gel (PE: EA= 5:1) to give the desired product as a colorless oil. 80% yield. ^1H NMR (400 MHz, CDCl_3) δ 7.48 (d, J = 6.8 Hz, 2H), 7.30 (m, 2H), 7.26-7.14 (m, 3H), 6.89 (d, J = 7.2 Hz, 2H), 3.80 (s, 3H), 3.69 (m, 4H), 2.74-2.61 (m, 1H), 2.61-2.49 (m, 1H), 1.89 (m, 4H), 1.19 (s, 3H). ^{13}C NMR (101 MHz, CDCl_3) δ 207.90, 177.27, 156.58, 134.21, 132.78, 129.47, 128.69, 126.99, 121.67, 114.04, 55.51, 50.08, 45.45, 44.22, 37.23, 31.72, 31.13, 22.72. IR (V/cm^{-1}): 3589, 2987, 2213, 1759, 1514, 1368, 1252, 1098, 1047, 879 cm^{-1} . HRMS

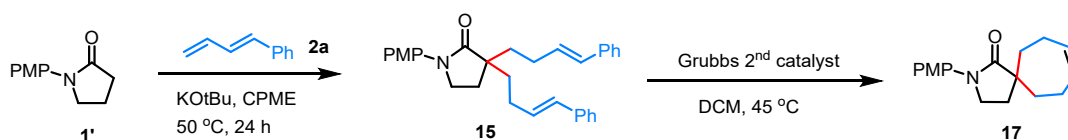
(ESI): calcd. $C_{22}H_{25}NO_3Na$ $[M+H]^+$: 374.1732. Found: 374.1739.

5.9 Synthesis of 16 from 4j.



2-(4-methoxyphenyl)-2-azaspiro[4.5]dec-7-en-1-one (16): To a round-bottomed flask equipped with a reflux condenser was added **4j** (100 mg, 0.49 mmol) followed by addition of 2 mL DCM. Grubbs 2nd generation catalyst (41.6 mg, 0.05 mmol) was added. The reaction mixture was allowed to reflux at 45 °C for 3 hours. The solvent was concentrated under reduced pressure. The product was purified by flash column chromatography on silica gel (PE: EA = 5:1), which afforded the desired product as a colorless oil. 73% yield. ¹H NMR (400 MHz, CDCl₃) δ 7.56 (d, *J* = 6.8 Hz, 2H), 6.90 (d, *J* = 6.8 Hz, 2H), 5.73 (m, 2H), 3.84-3.79 (m, 3H), 3.79-3.70 (m, 2H), 2.45 (d, *J* = 18.0 Hz, 1H), 2.27-2.06 (m, 2H), 2.05-1.87 (m, 4H), 1.66-1.56 (m, 1H). ¹³C NMR (101 MHz, CDCl₃) δ 178.00, 156.39, 133.07, 126.33, 124.56, 121.37, 114.01, 55.50, 45.56, 44.16, 32.29, 29.38, 28.54, 22.04. IR (V/cm⁻¹): 3343, 2899, 2340, 1939, 1686, 1513, 1396, 1249, 1046, 879 cm⁻¹. HRMS (ESI): calcd. $C_{16}H_{20}NO_2$ $[M+H]^+$: 258.1494. Found: 258.1508.

5.10 Synthesis of 17 from 15.

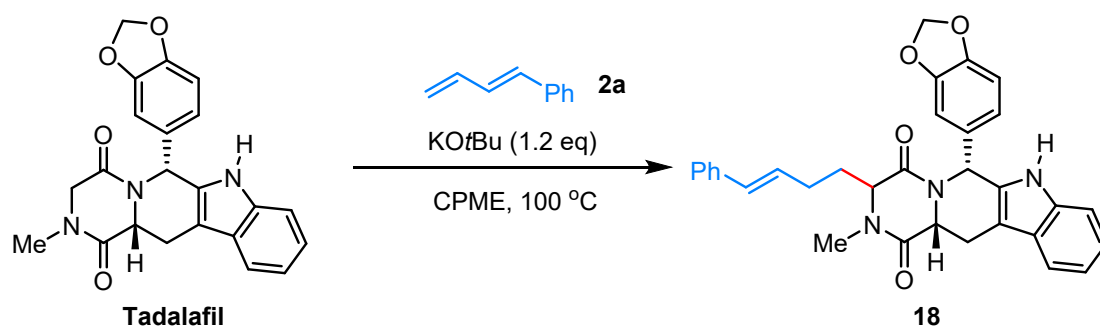


2-(4-methoxyphenyl)-2-azaspiro[4.6]undec-8-en-1-one (17): A 4-mL baked vial charged with a stir bar was transferred into the glove box. To this vial was added

compound **1'** (191 mg, 1 mmol) and KO t Bu (24.4 mg, 20 mol%) followed by the addition of CPME (1 mL). To this mixture was subsequently added compound **2a** (260 mg, 2 mmol). The vial was tightly capped, removed from glove box and heated at 50 °C for 24 h. After completion of the reaction, the mixture was cooled to room temperature and concentrated in vacuum, the crude mixture was silica gel chromatography (PE: EA=10:1) to afford **15** (284 mg, 63% yield) as a colorless oil.

To a round-bottomed flask equipped with a reflux condenser was added **15** (200 mg, 0.44 mmol) followed by addition of 2 mL DCM. Grubbs 2nd generation catalyst (41.6 mg, 0.05 mmol) was added. The reaction mixture was allowed to reflux at 45 °C for 3 hours. The solvent was concentrated under reduced pressure. The product was purified by flash column chromatography on silica gel (PE: EA = 5:1), which afforded the desired product as a colorless oil. 67% yield. ¹H NMR (400 MHz, CDCl₃) δ 7.47 (d, J = 8.8 Hz, 2H), 6.82 (d, J = 8.8 Hz, 2H), 5.69-5.67 (m, 2H), 3.73 (s, 3H), 3.65 (t, J = 6.8 Hz, 2H), 2.38-2.30 (m, 2H), 2.09 (dd, J = 16.4, 11.2 Hz, 2H), 2.03-1.89 (m, 4H), 1.59 (dd, J = 14.0, 7.6 Hz, 2H). ¹³C NMR (101 MHz, CDCl₃) δ 178.67, 156.45, 133.14, 131.52, 121.55, 114.09, 55.61, 48.82, 45.46, 34.28, 30.88, 24.46. IR (V/cm⁻¹): 3564, 3400, 3048, 2950, 2197, 1646, 1224, 952 cm⁻¹. HRMS (ESI): calcd. C₁₇H₂₂NO₂ [M+H]⁺: 272.1651. Found: 272.1664.

5.11 Synthesis of 18 from tadalafil.



(6*R*,12*aR*)-6-(benzo[*d*][1,3]dioxol-5-yl)-2-methyl-3-((*E*)-4-phenylbut-3-en-1-yl)-

2,3,6,7,12,12*a*-hexahydropyrazino[1',2':1,6]pyrido[3,4-*b*]indole-1,4-dione (18):

Synthesized by following general procedure on a 0.2 mmol scale. Isolated by flash column chromatography (PE: EA = 1:1) to afford a colorless oil in 45% yield. ¹H NMR (400 MHz, CDCl₃) δ 7.86 (d, *J* = 7.1 Hz, 1H), 7.55 (d, *J* = 7.8 Hz, 1H), 7.31 (d, *J* = 8.1 Hz, 1H), 7.24-7.14 (m, 6H), 6.94 (s, 1H), 6.85 (s, 1H), 6.76-6.66 (m, 2H), 6.38 (d, *J* = 15.8 Hz, 1H), 6.12 (dt, *J* = 14.5, 6.3 Hz, 1H), 5.93 (s, 2H), 4.47-4.33 (m, 1H), 4.07 (d, *J* = 6.4 Hz, 1H), 3.61 (d, *J* = 16.0 Hz, 1H), 3.00 (s, 4H), 2.25 (d, *J* = 14.6 Hz, 3H), 2.03 (d, *J* = 15.2 Hz, 1H). ¹³C NMR (101 MHz, CDCl₃) δ 165.87, 164.06, 148.15, 148.04, 137.11, 136.37, 132.13, 131.59, 129.94, 128.47, 127.86, 127.16, 126.25, 125.96, 122.80, 122.55, 120.12, 118.50, 111.22, 109.25, 109.00, 108.28, 101.35, 61.61, 52.24, 52.02, 32.37, 32.20, 28.02, 27.89. IR (V/cm⁻¹): 3674, 3392, 2970, 2885, 2017, 1948, 1633, 1450, 1382, 1086, 1047, 880 cm⁻¹. HRMS (ESI): calcd. C₃₂H₃₀N₃O₄ [M+H]⁺: 520.2236. Found: 520.2240.

6. EPR experiments

A 4-mL baked vial charged with a stir bar was transferred into the glove box. To this vial was added compound **1a** and KO t Bu followed by the addition of CPME (0.2 mL). The vial was tightly capped, removed from glove box and heated at 50 °C for 0.5 h. The solution sample was taken out into a small tube which placed in a nuclear magnetic tube and then analyzed by EPR. CW X-band EPR spectra for radicals were acquired on Bruker EMX instrument EMXPLUS-10/12. EPR spectra simulation was conducted on the Bruker SpinFit and Anisotropic SpinFit software.

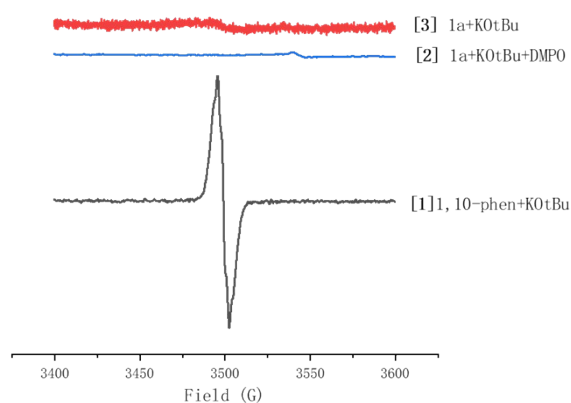
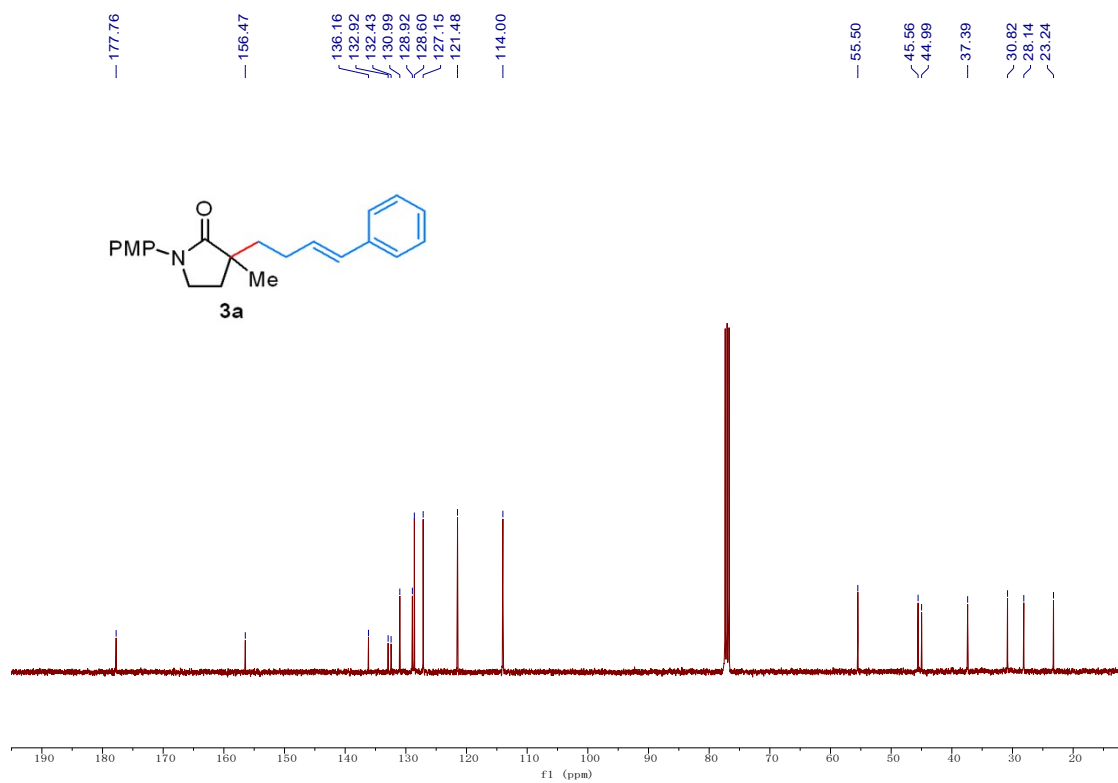
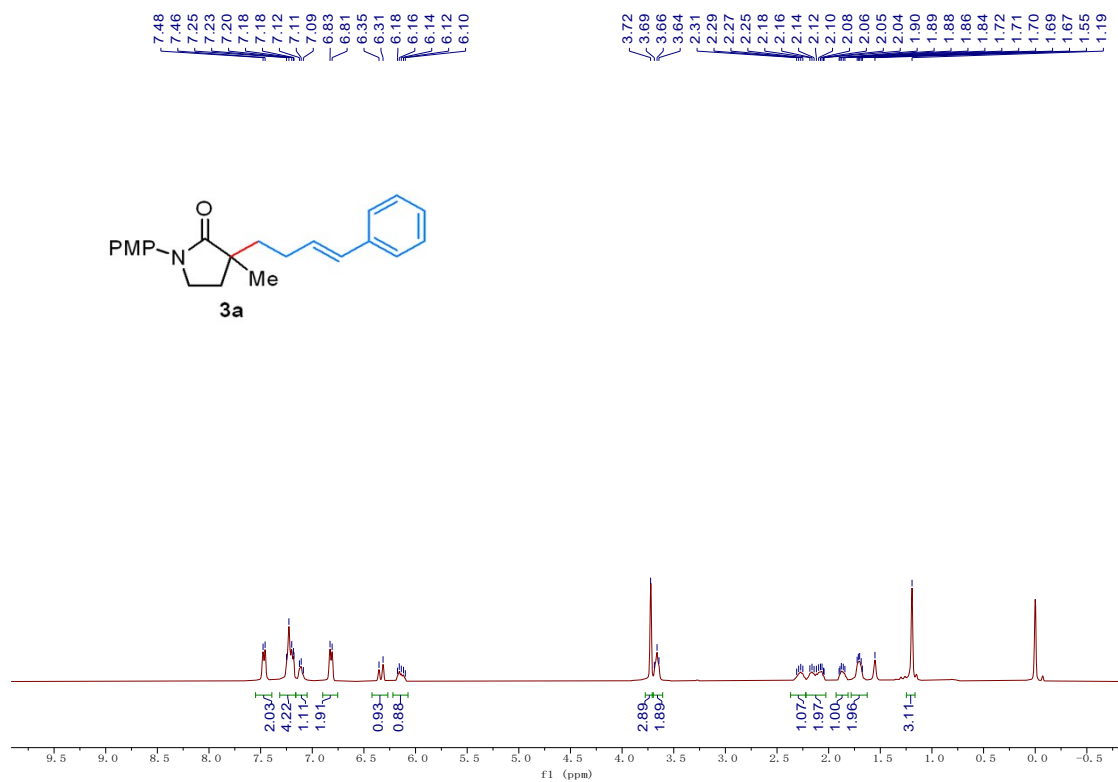


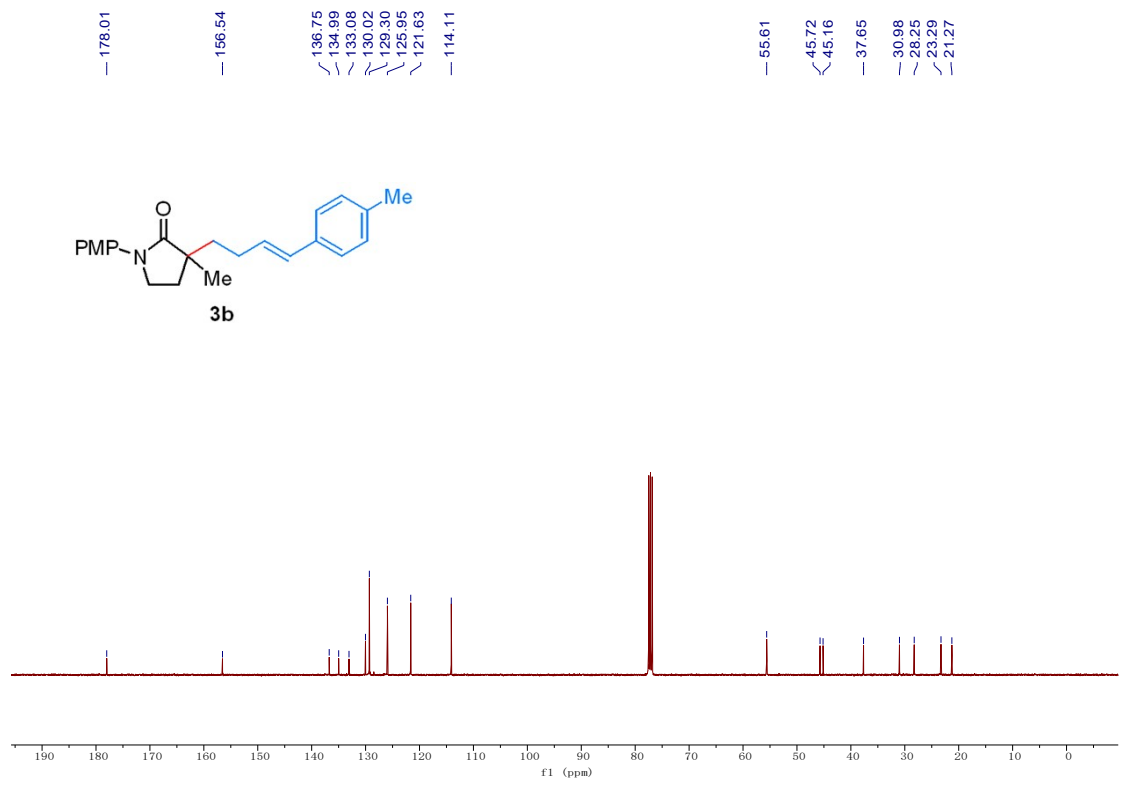
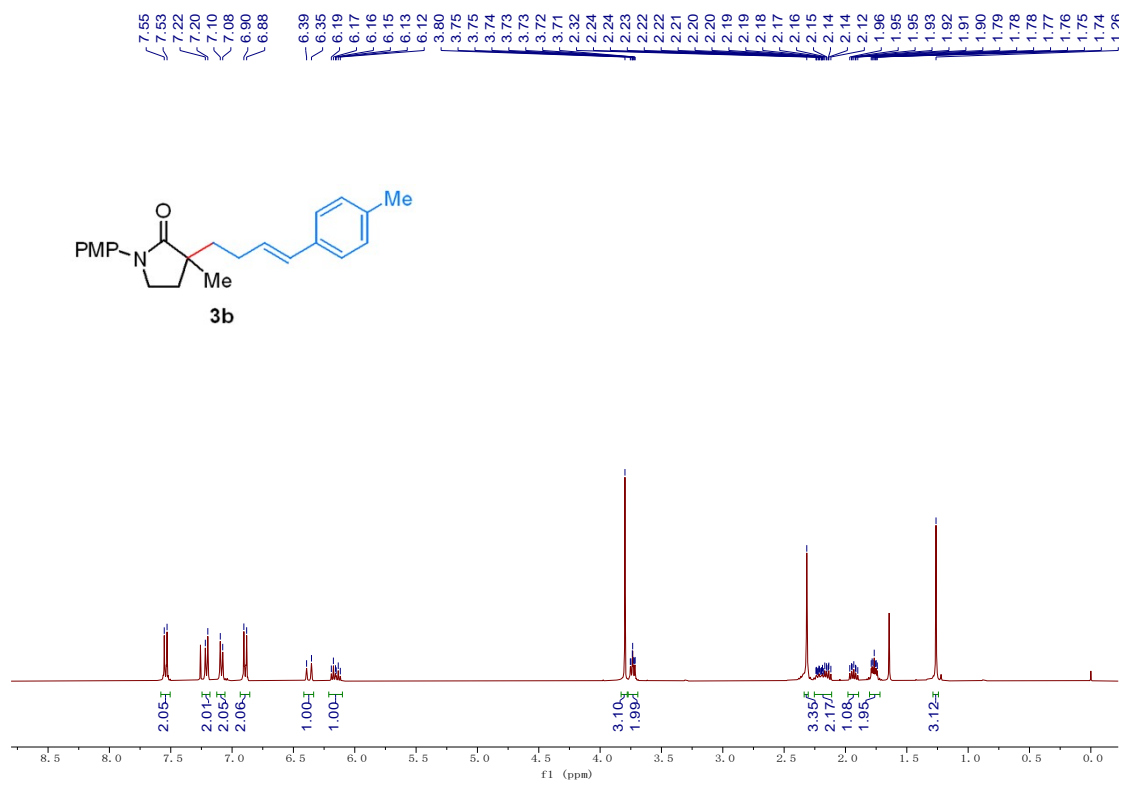
Fig S1. Electron paramagnetic resonance (EPR) spectra. [1] 1,10-phenanthroline (0.1 mmol) and KO t Bu (0.4 mmol) in CPME (2 mL) at 50 °C, the black line; [2] **1a** (0.1 mmol) and KO t Bu (0.4 mmol) in CPME (2 mL) at 50 °C, the blue line; [3] **1a** (0.1 mmol) and KO t Bu (0.4 mmol) and DMPO (5,5-Dimethyl-1-pyrroline N-oxide, 0.01 mmol) in CPME (2 mL) at 50 °C, the red line.

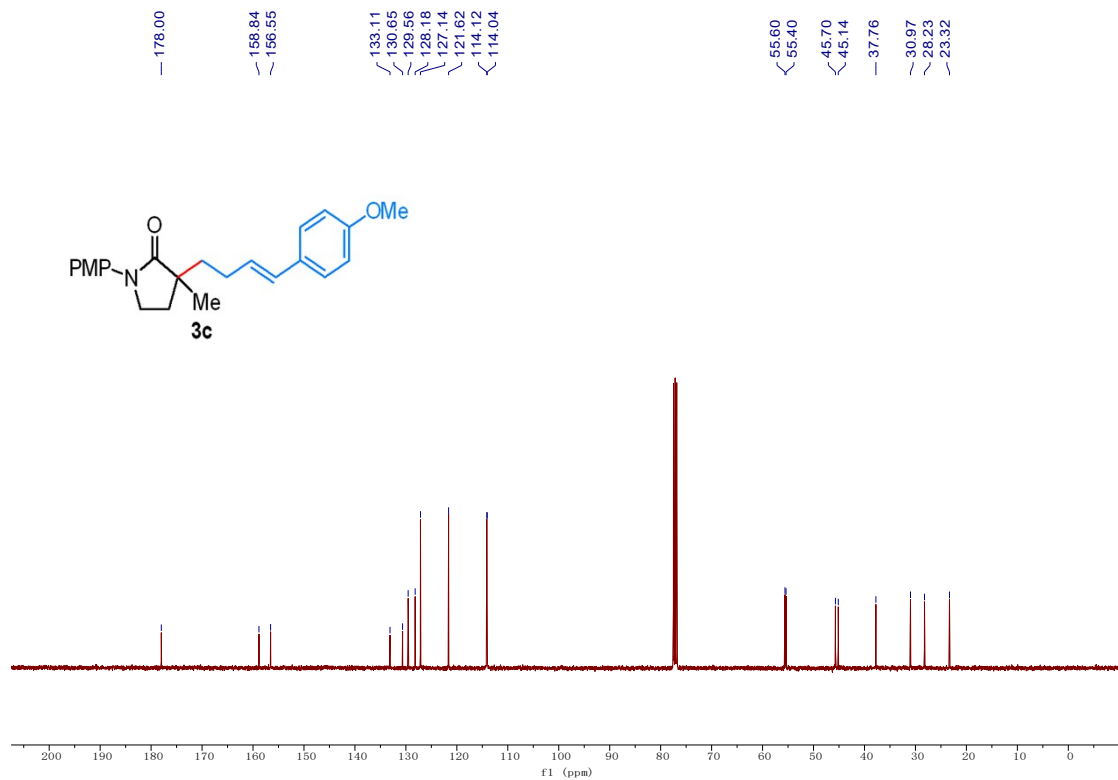
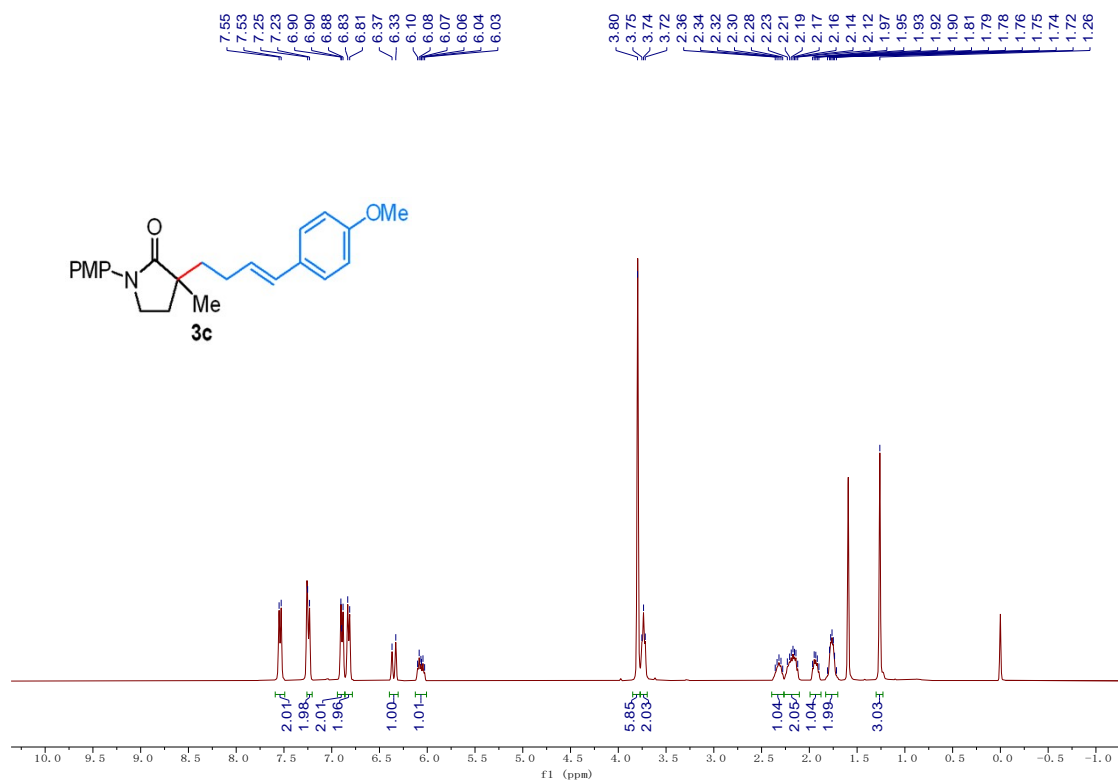
7. References:

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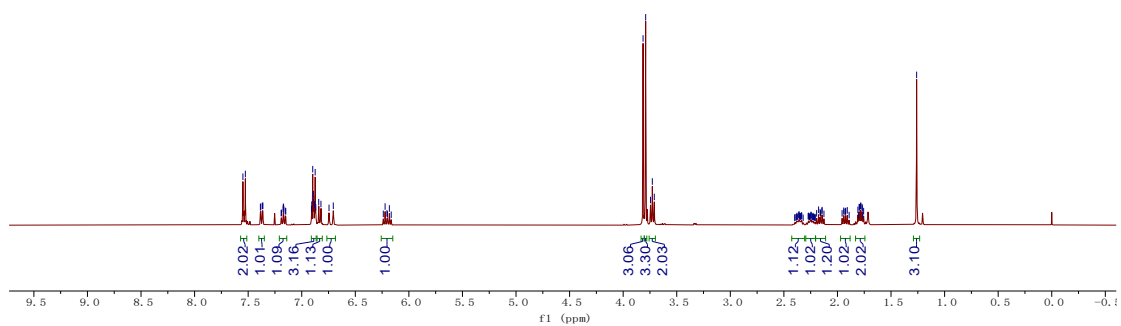
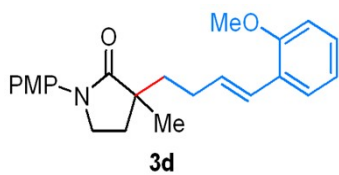
8. NMR Spectra





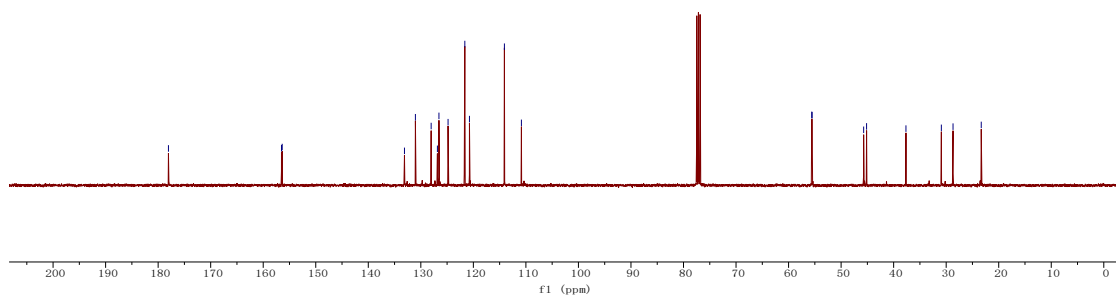
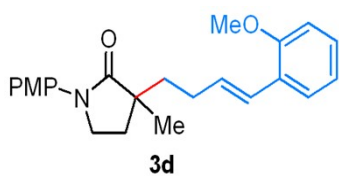


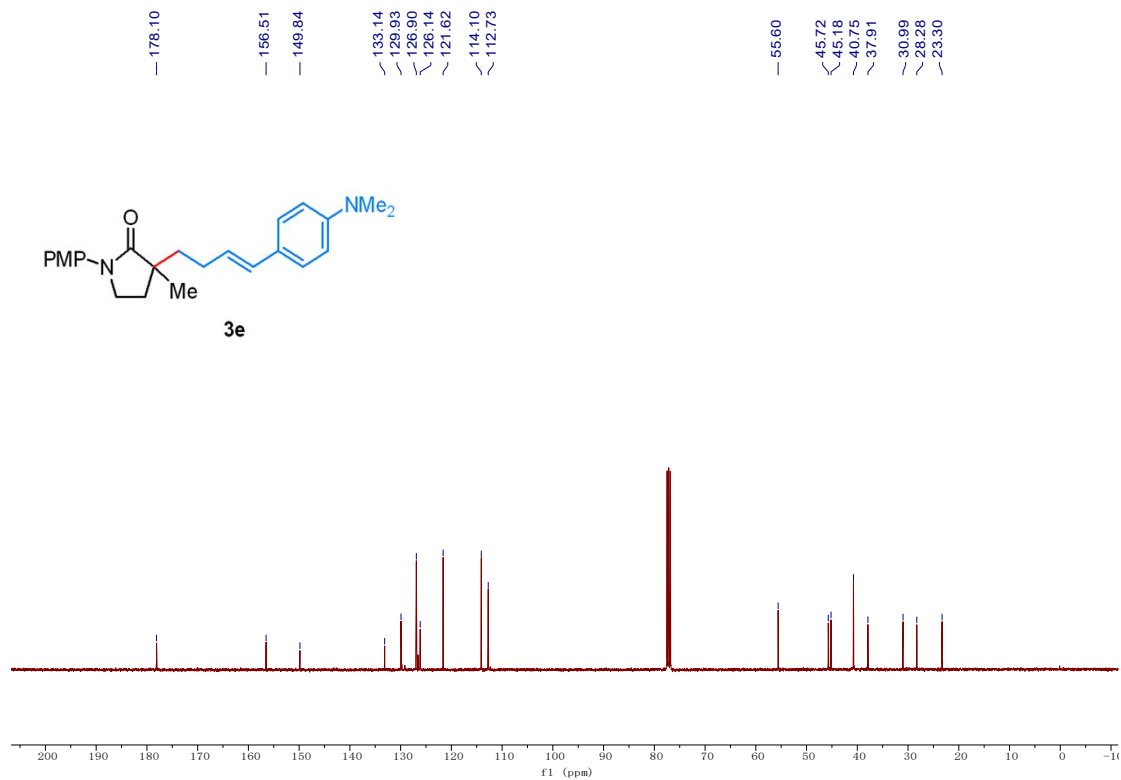
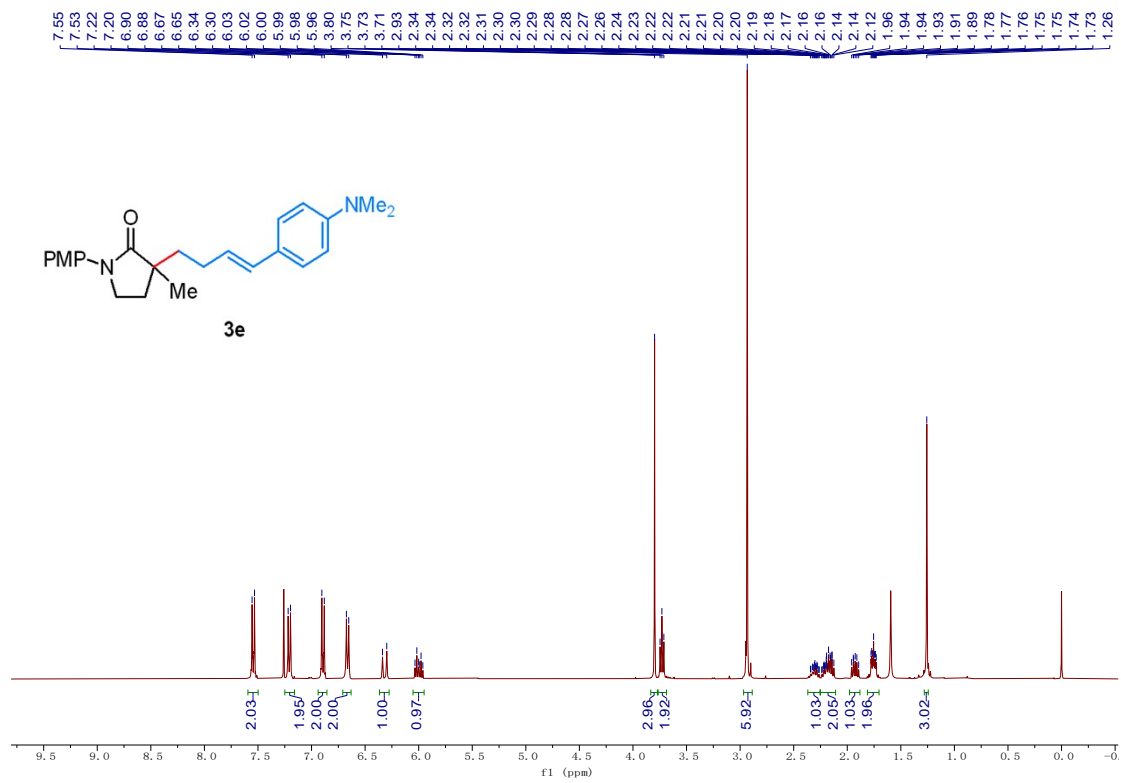
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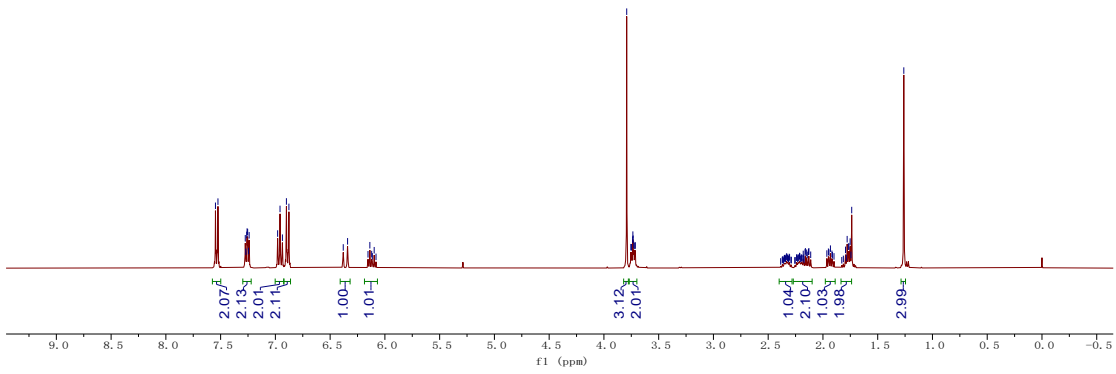
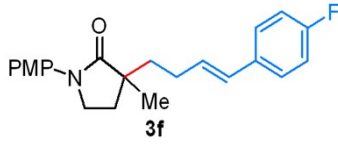
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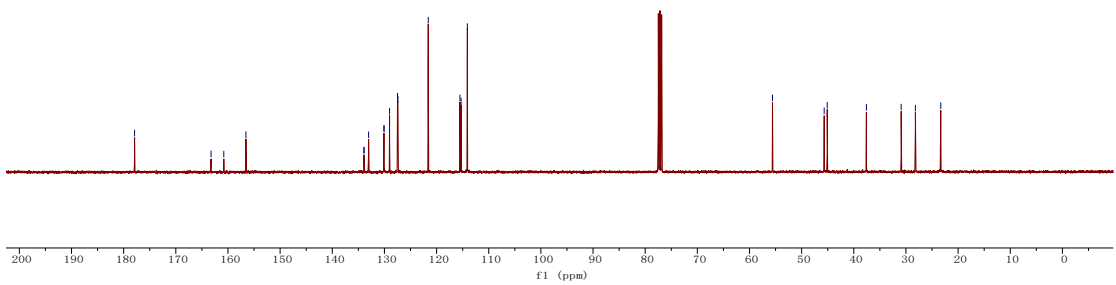
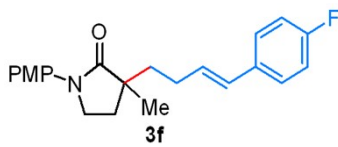


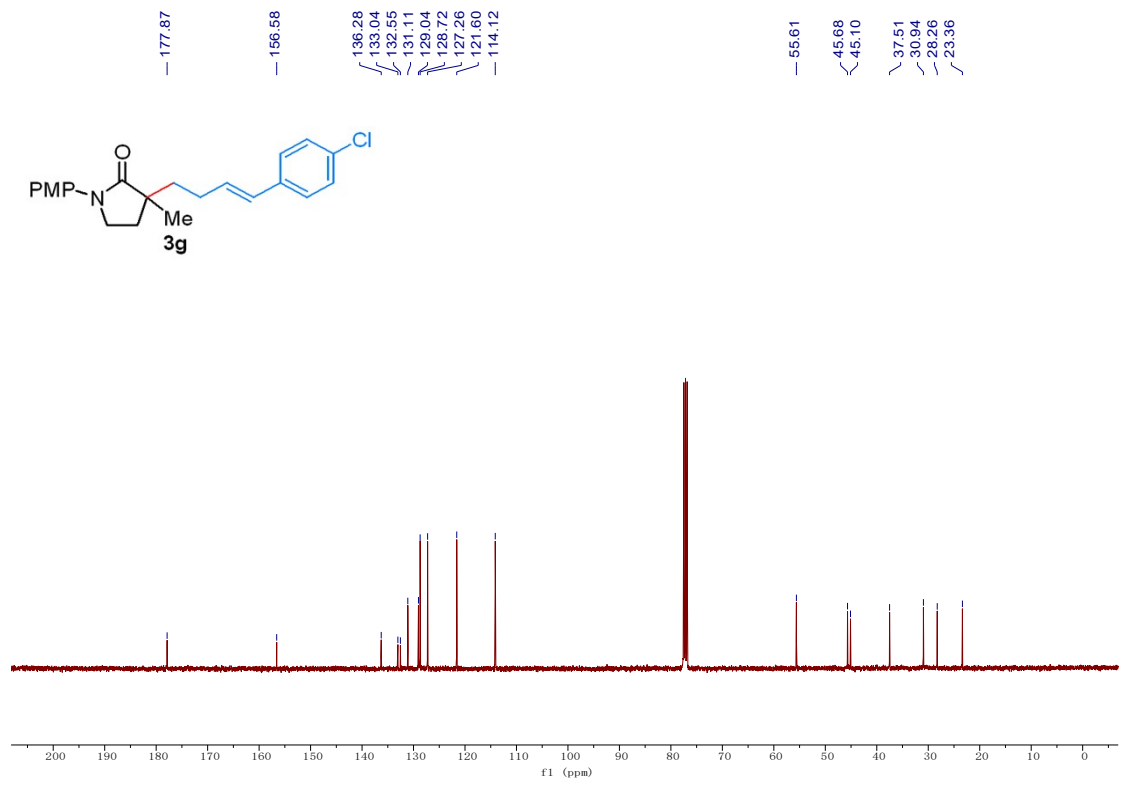
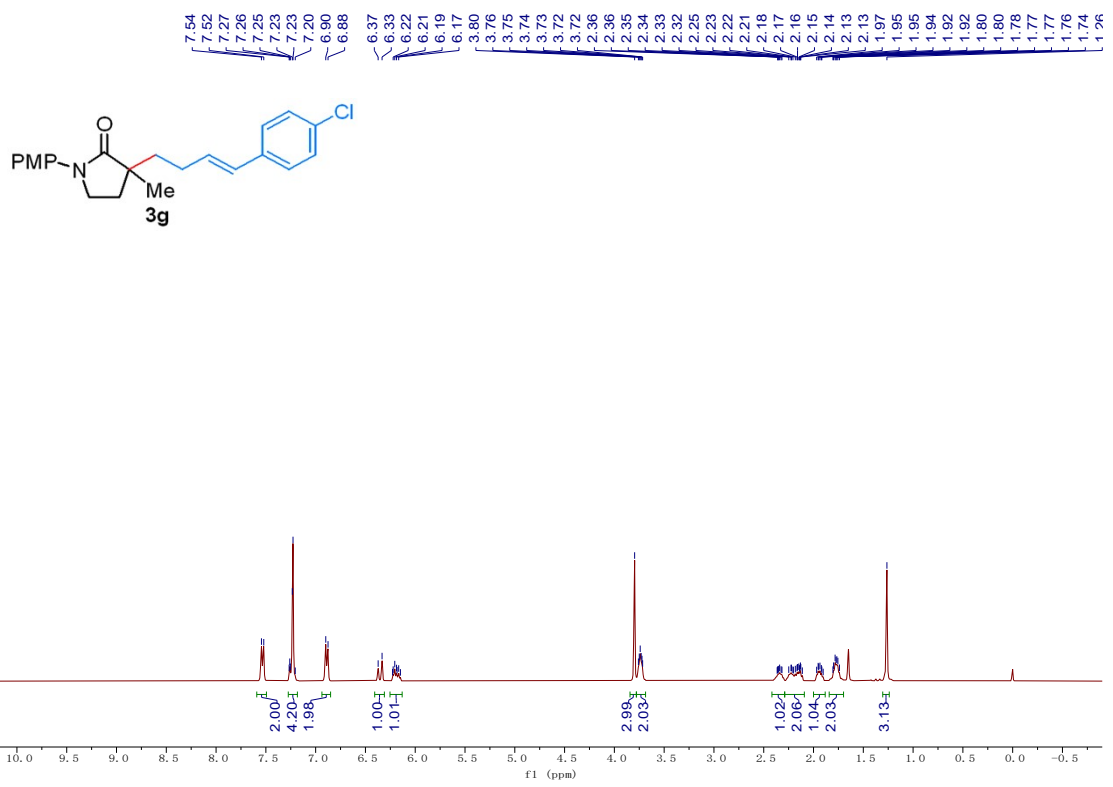


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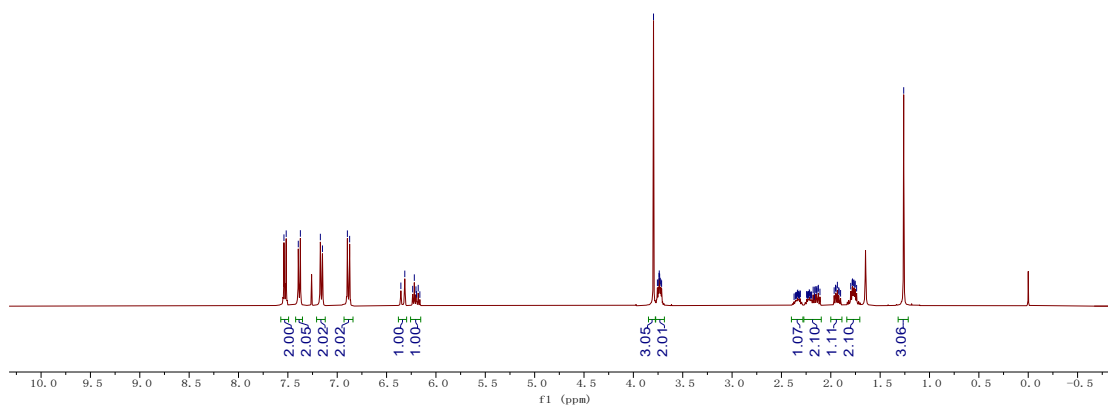
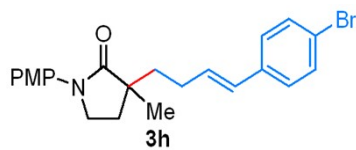


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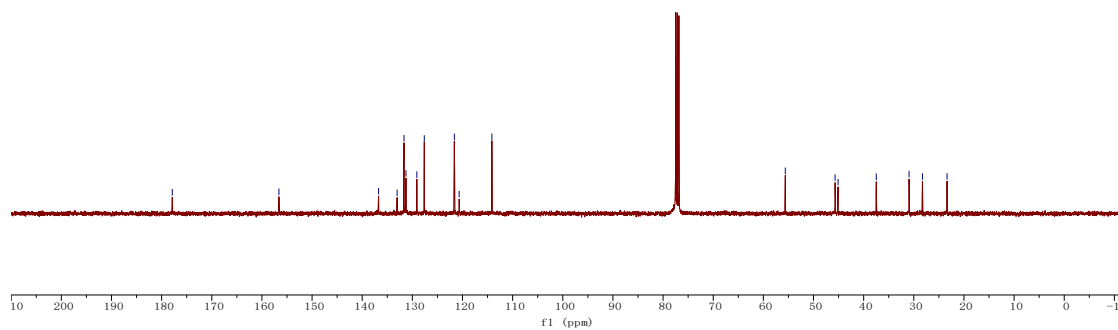
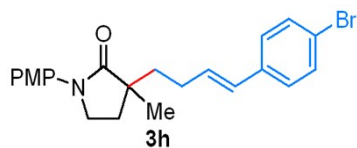


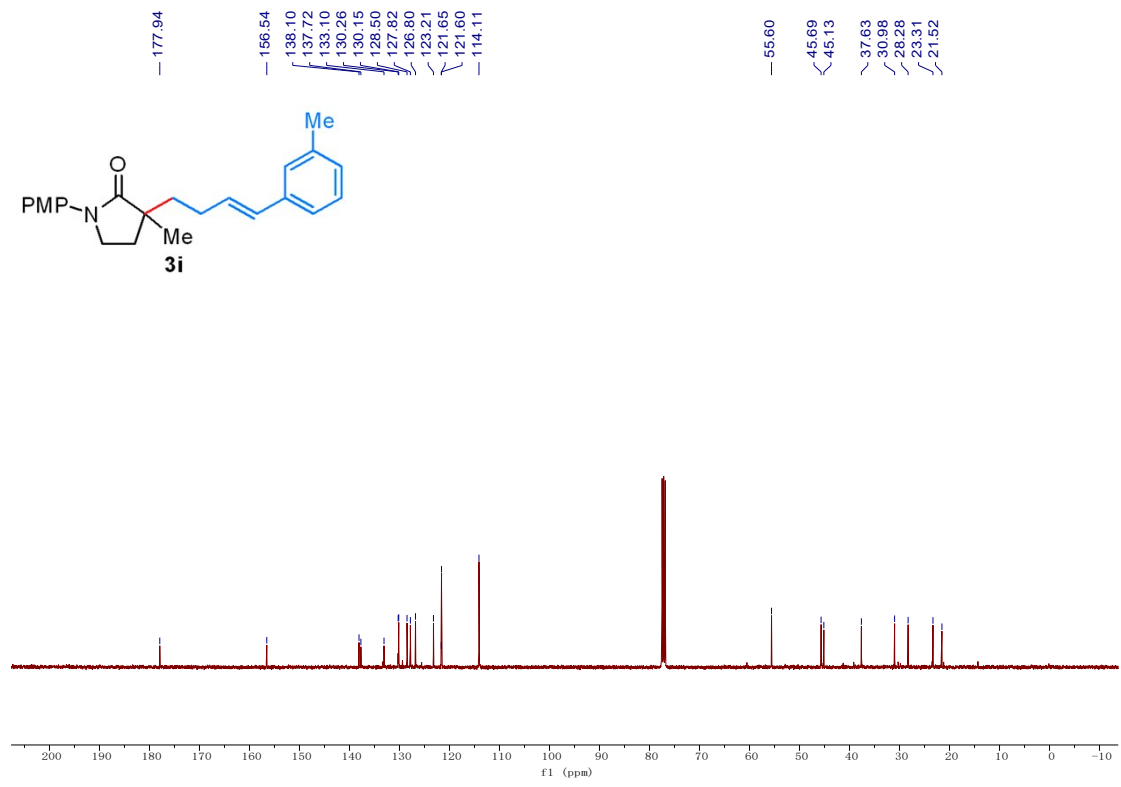
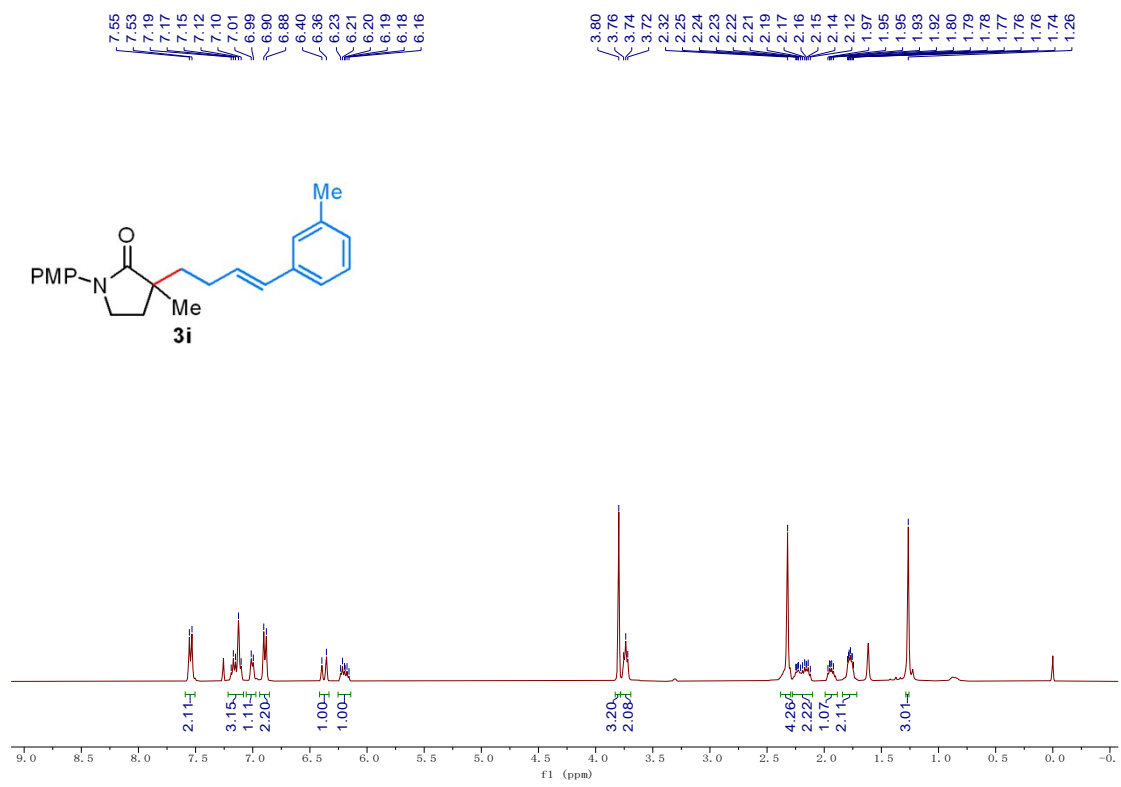


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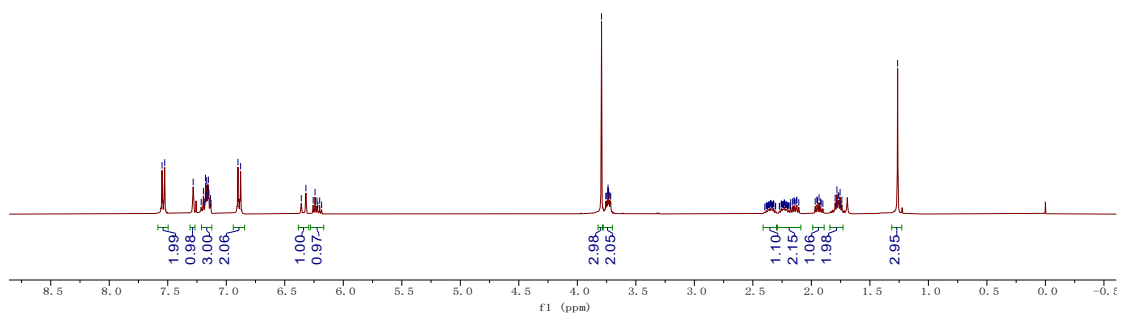
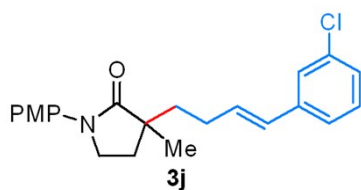


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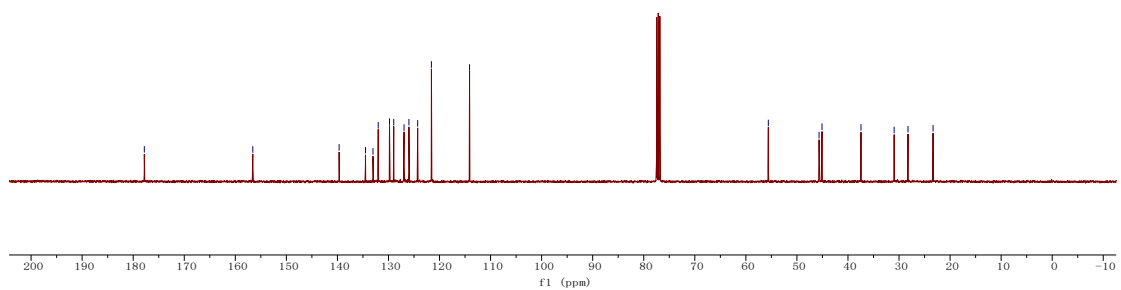
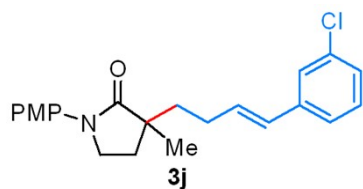




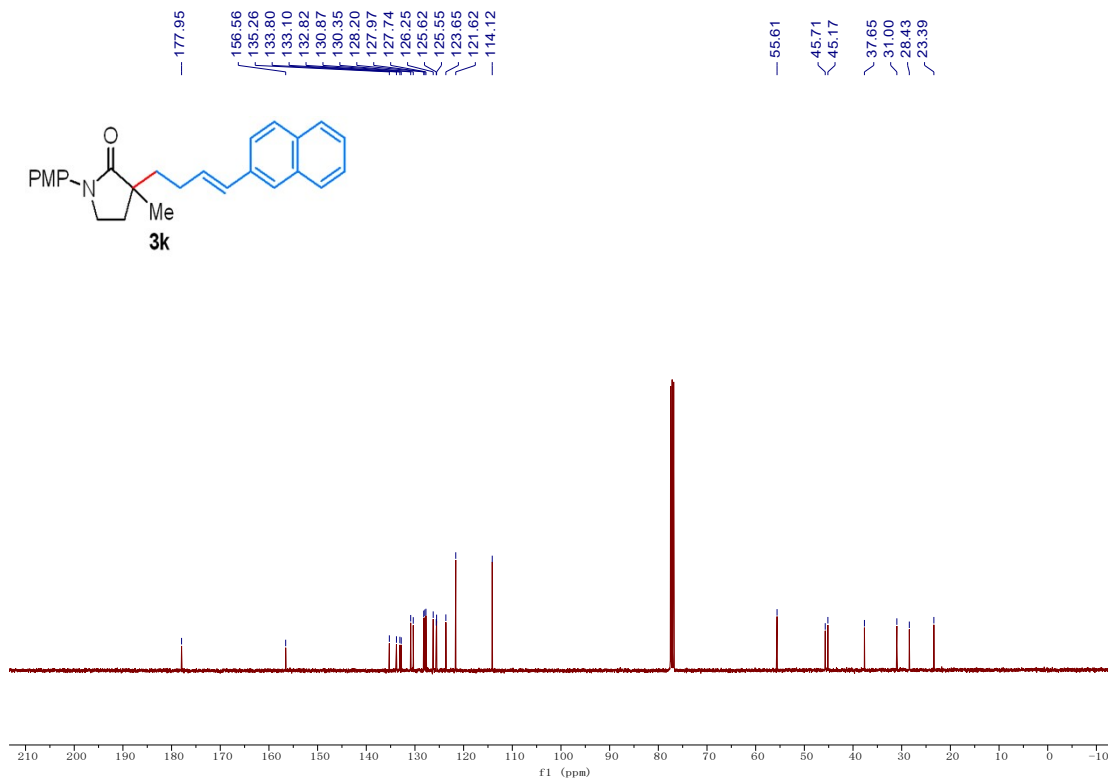
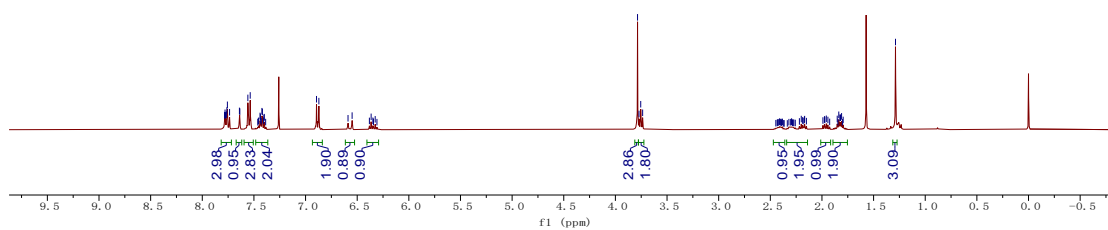
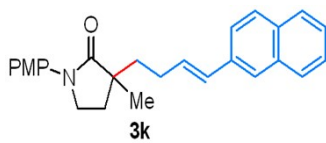
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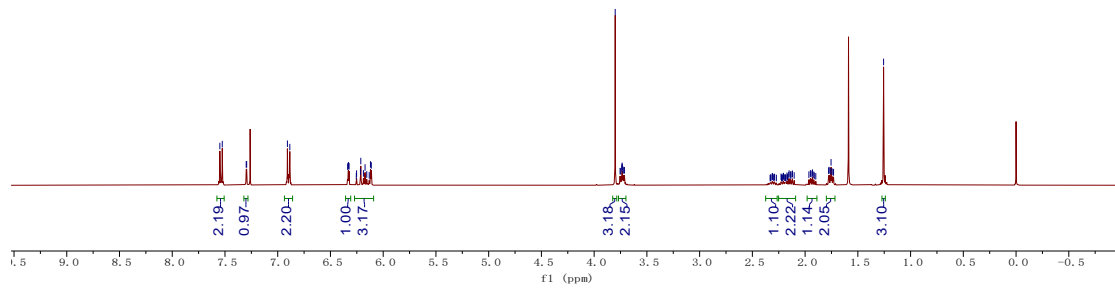
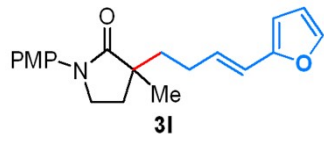
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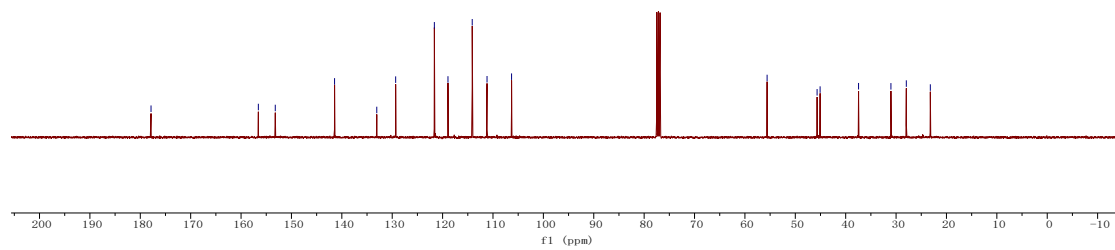
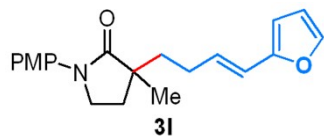
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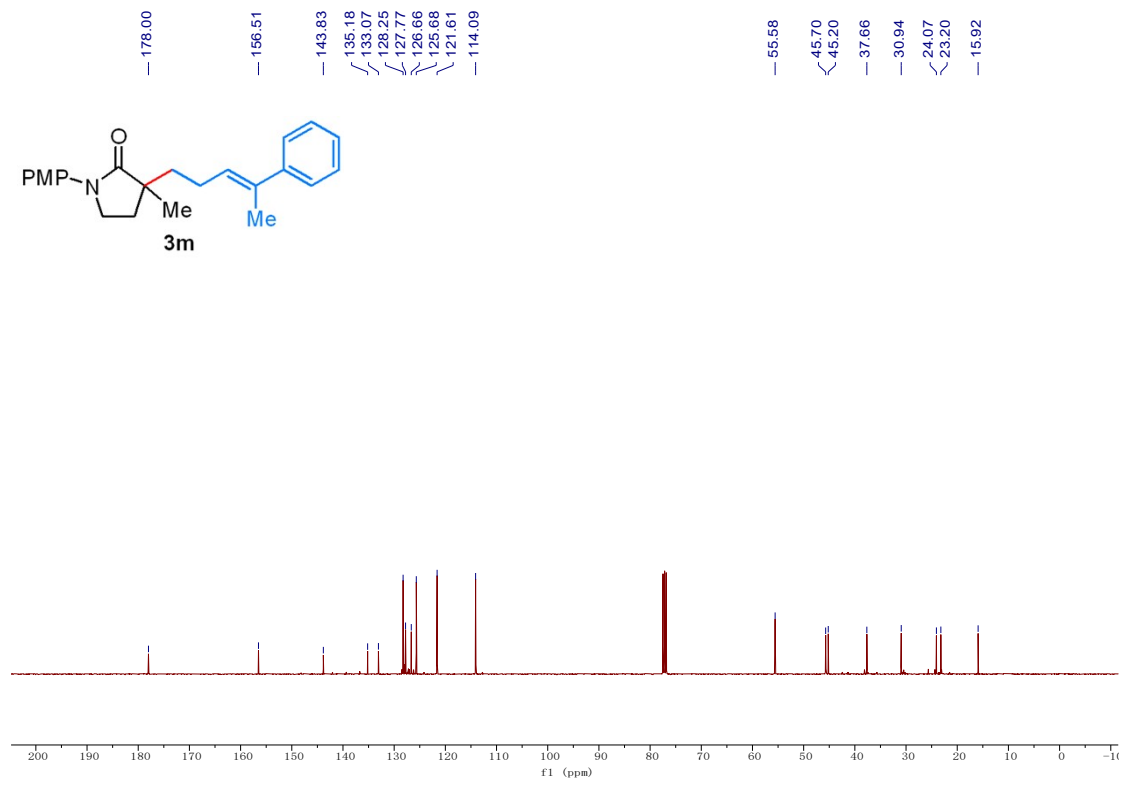
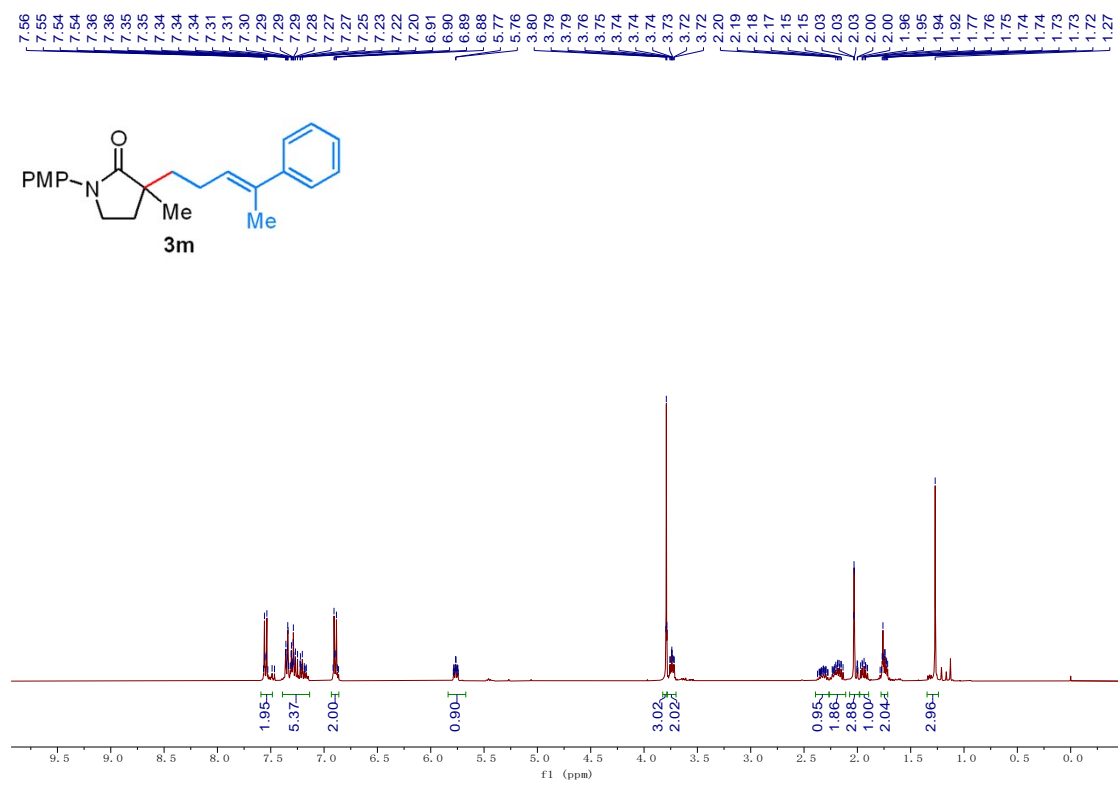


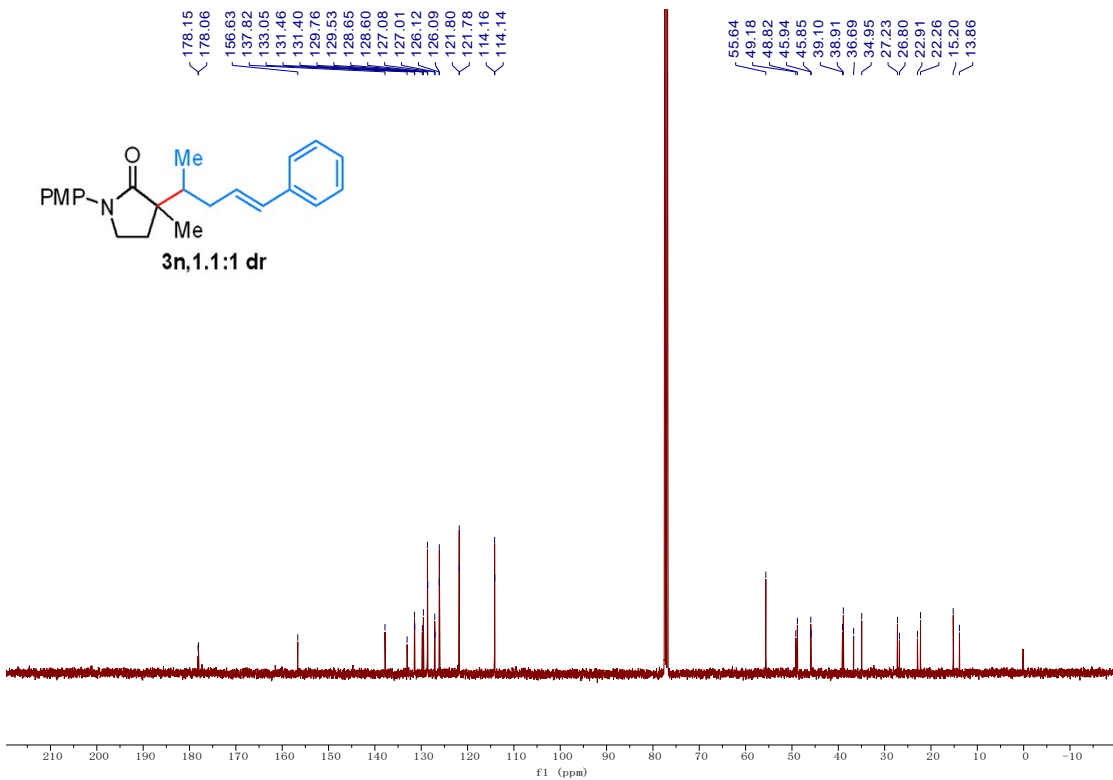
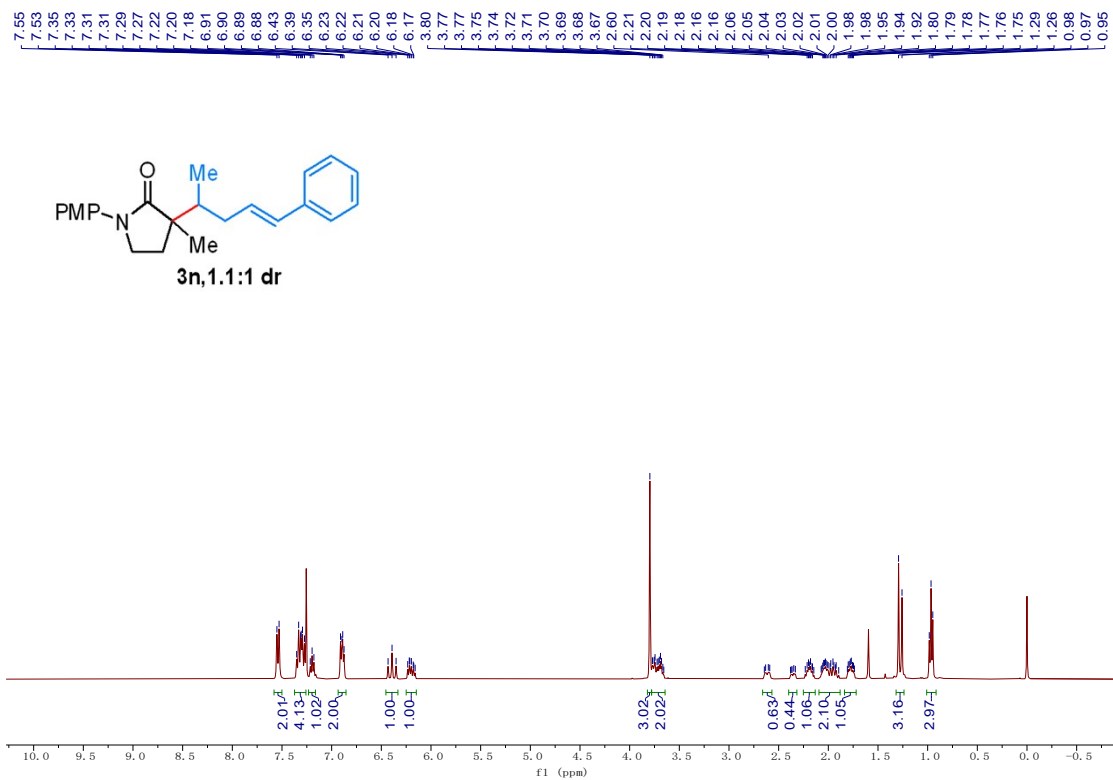
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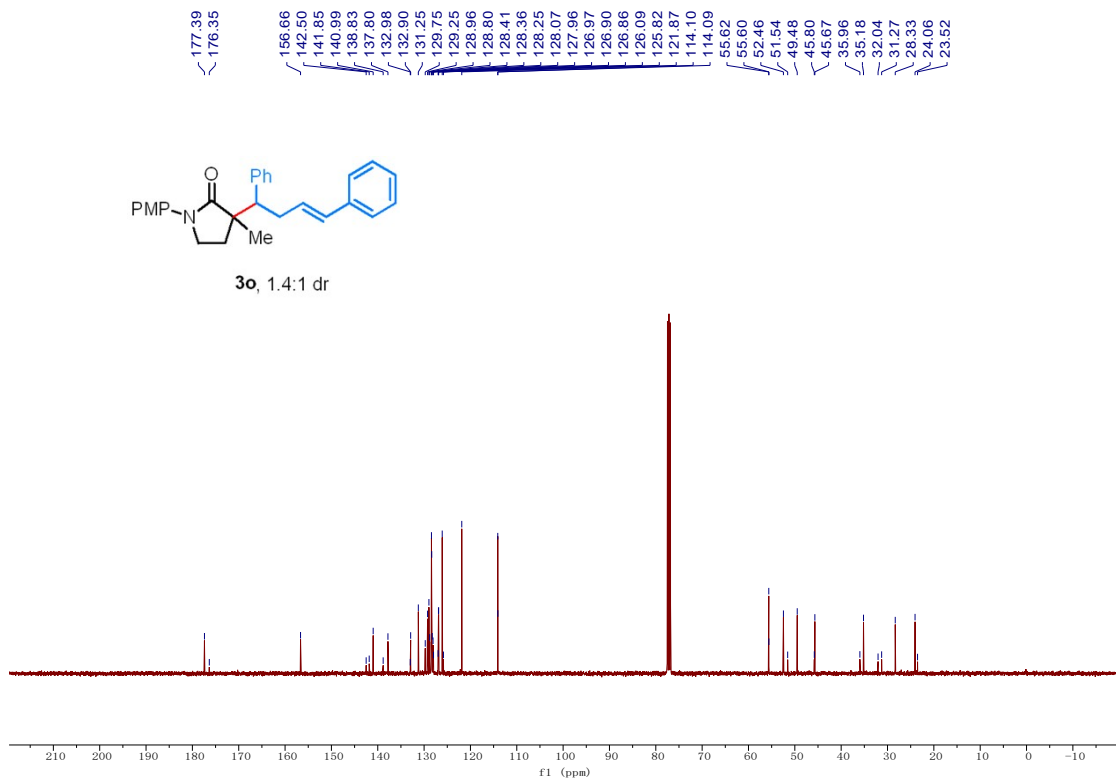
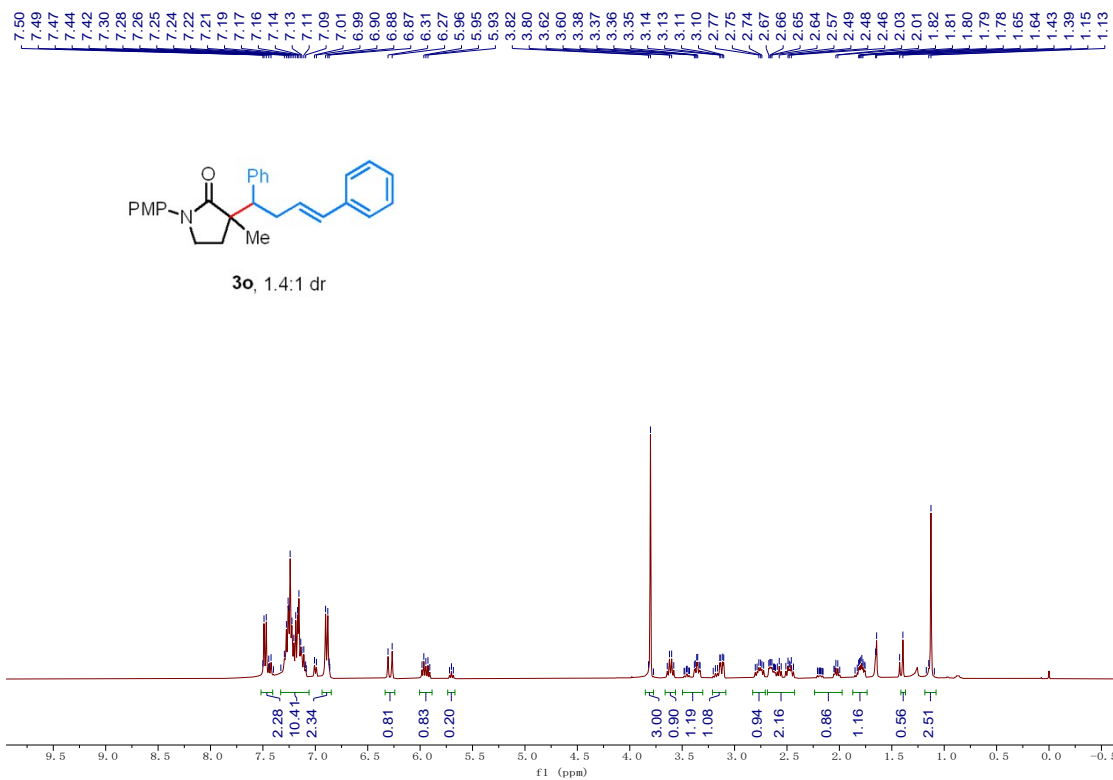


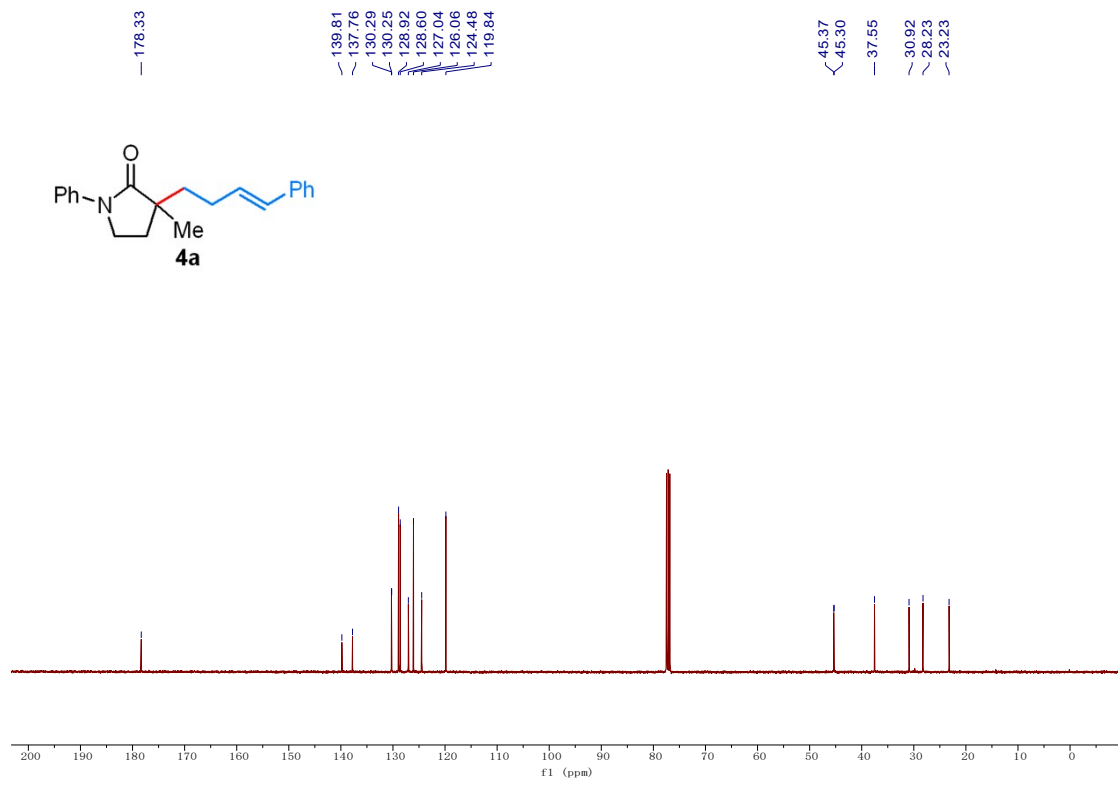
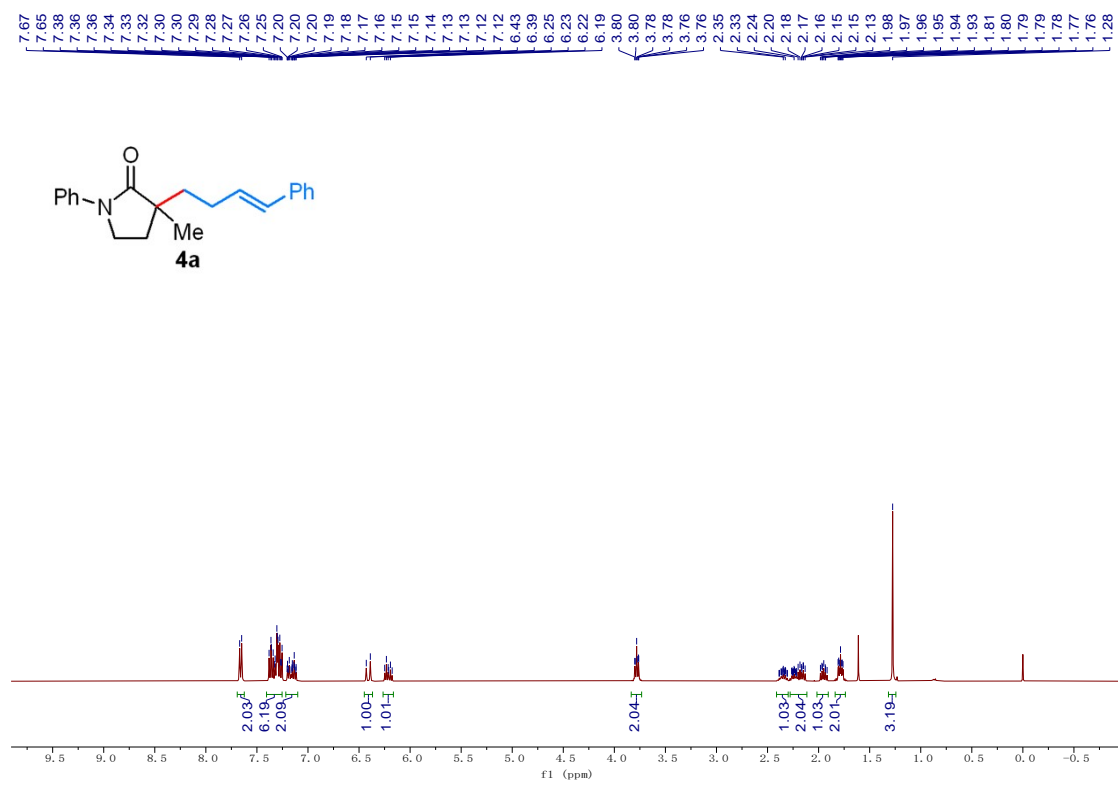
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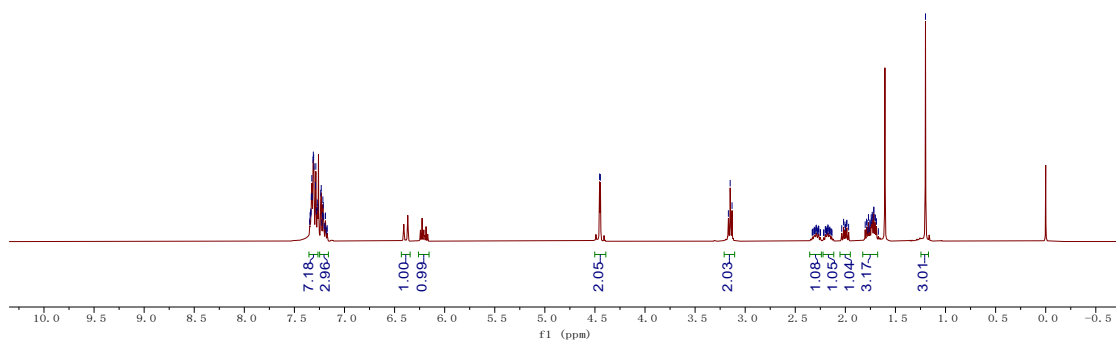
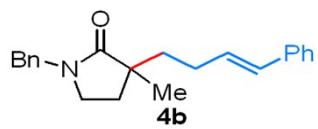








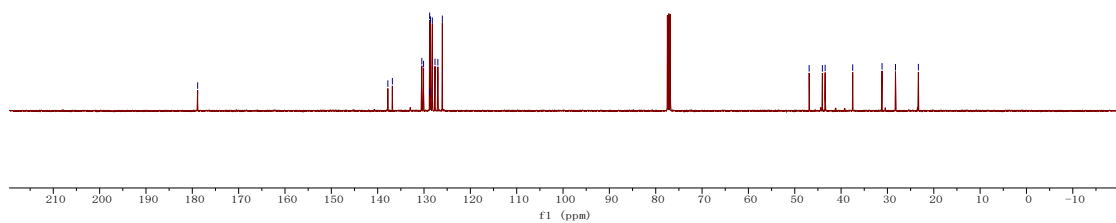
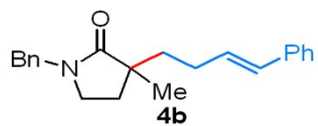
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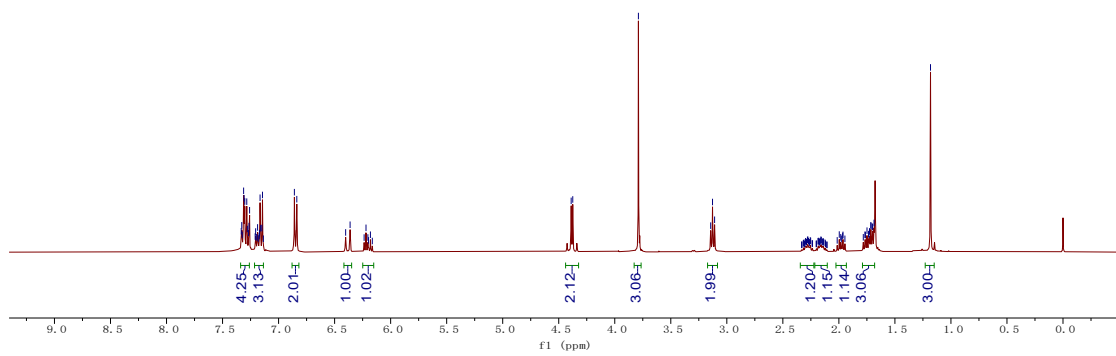
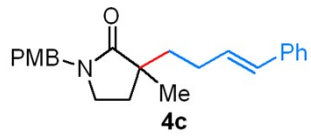
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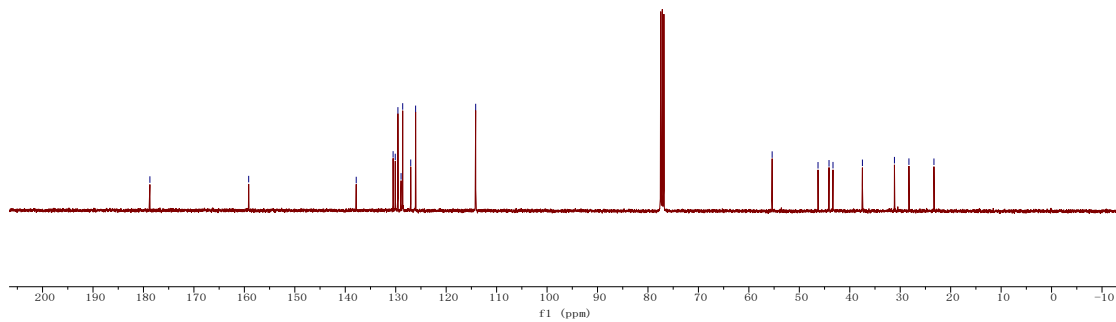
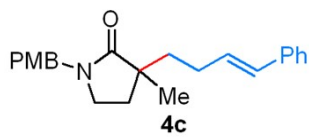
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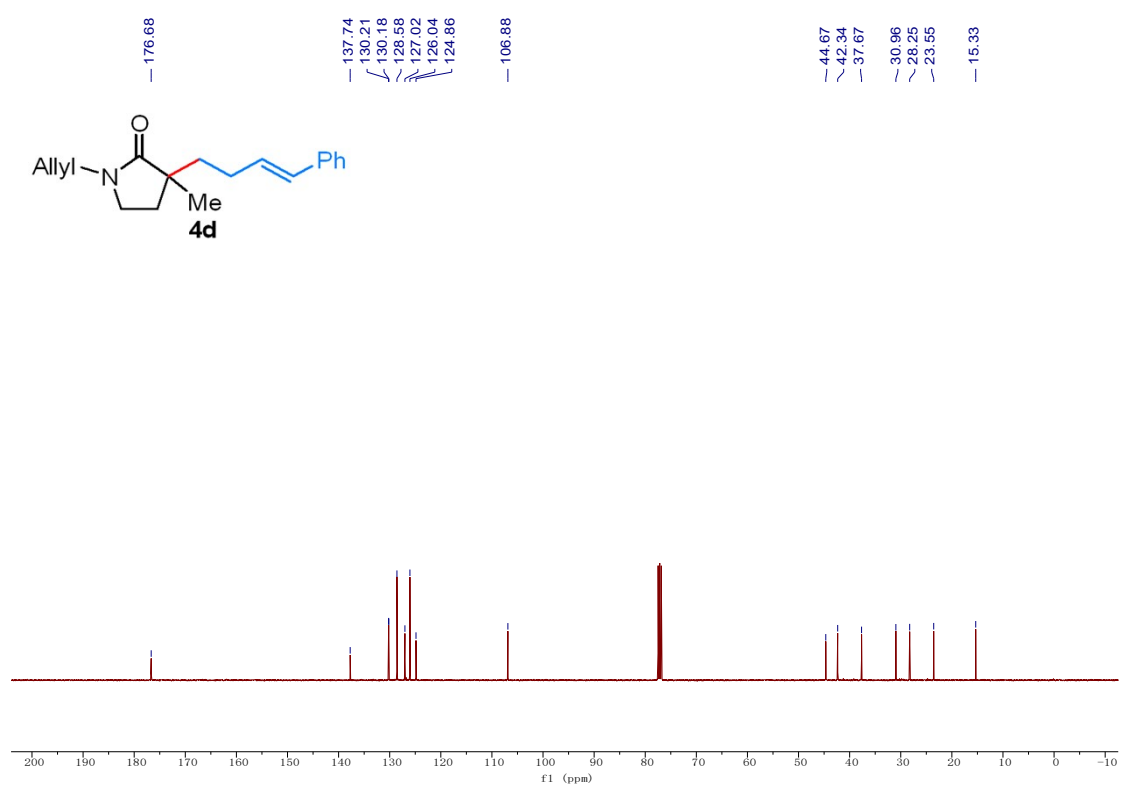
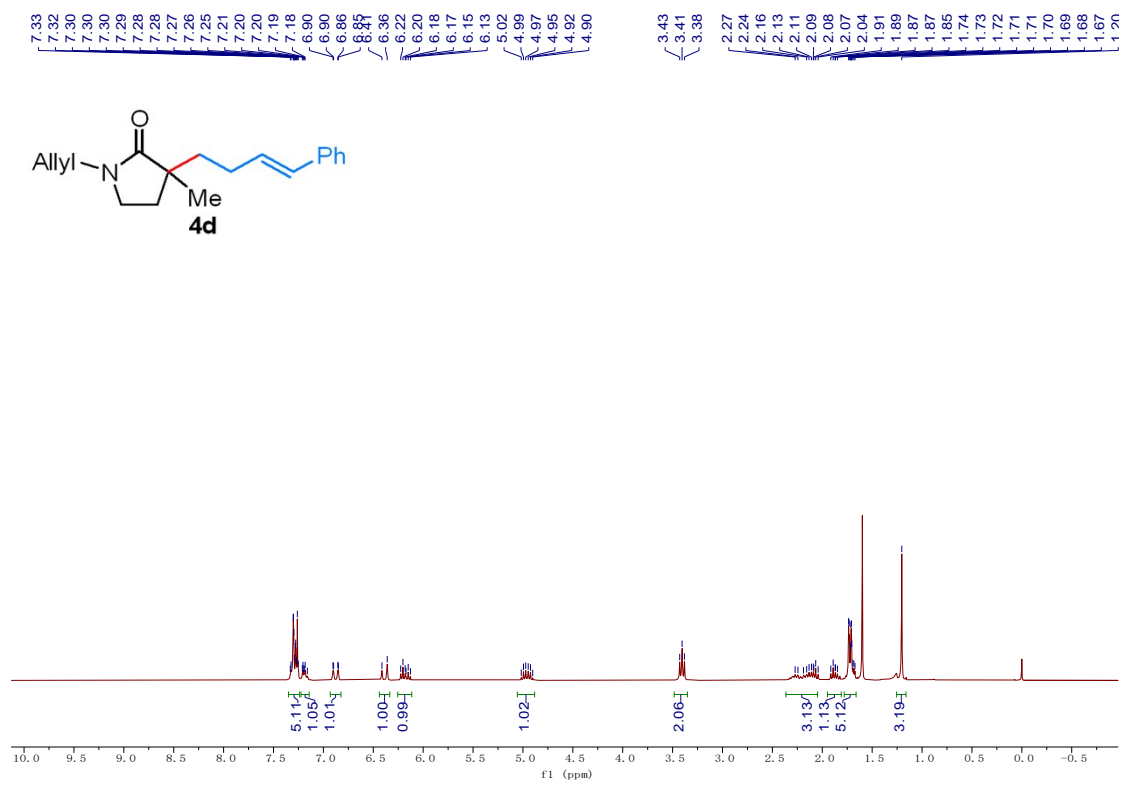


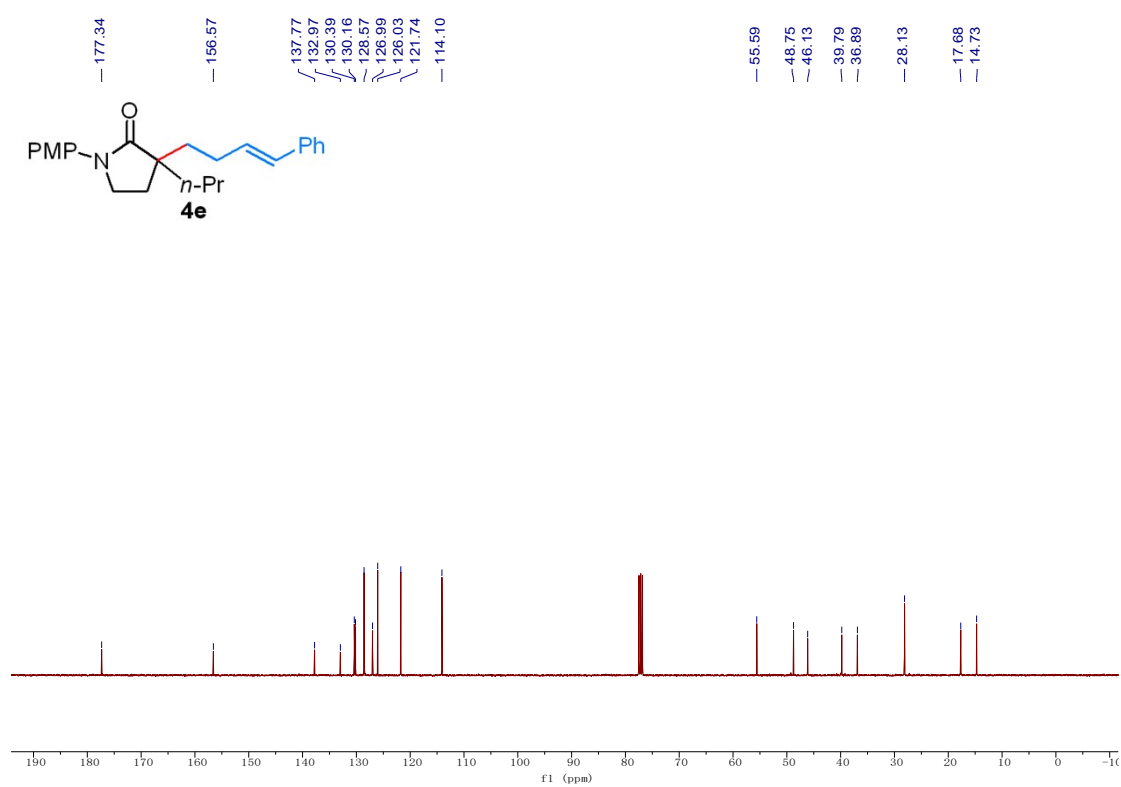
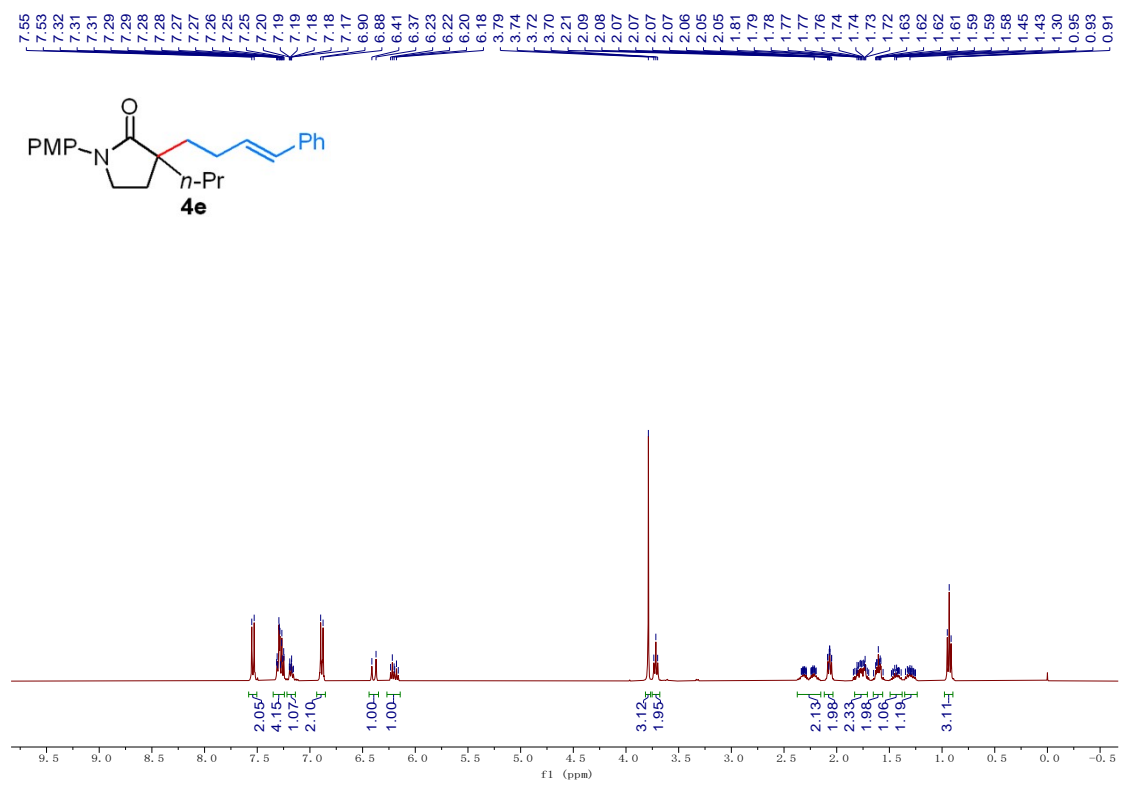
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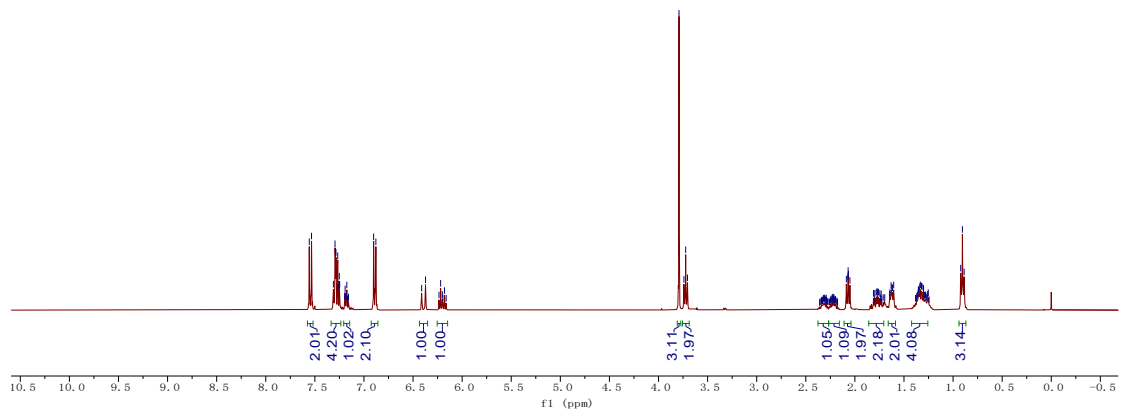
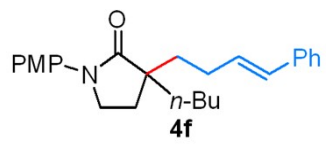
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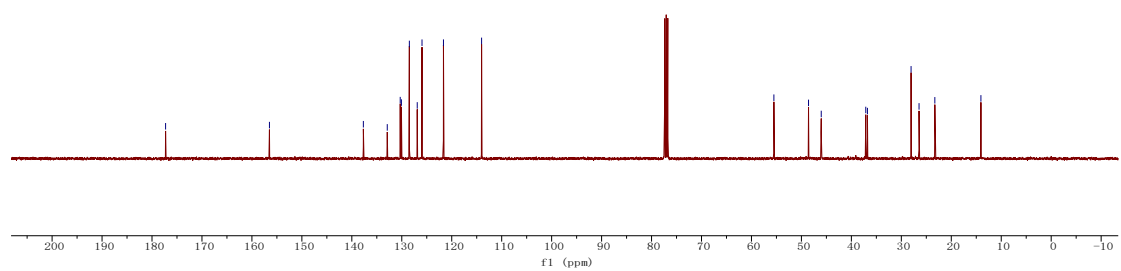
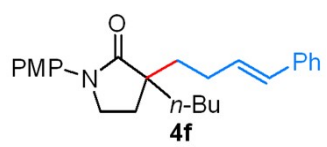




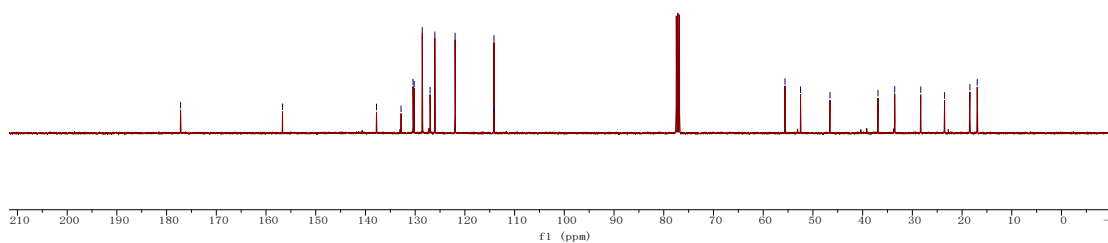
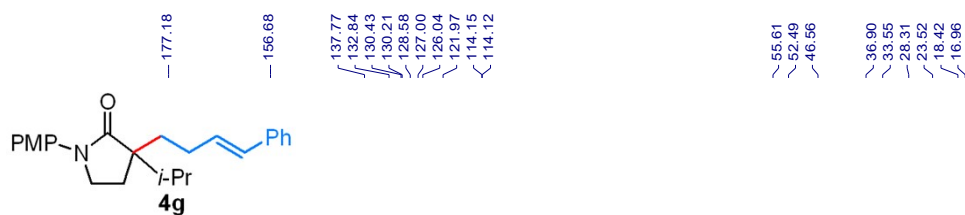
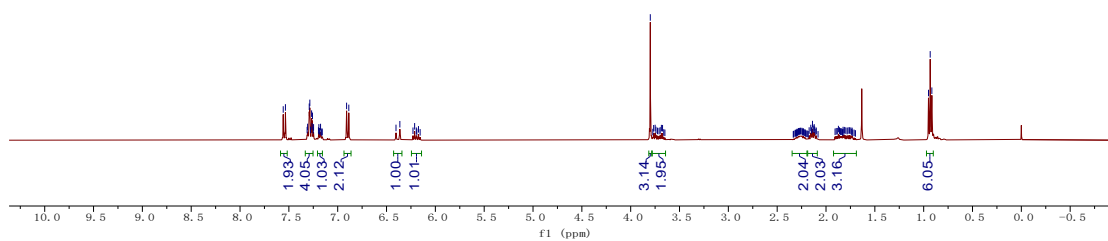
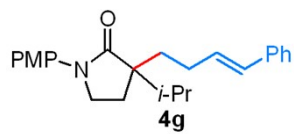
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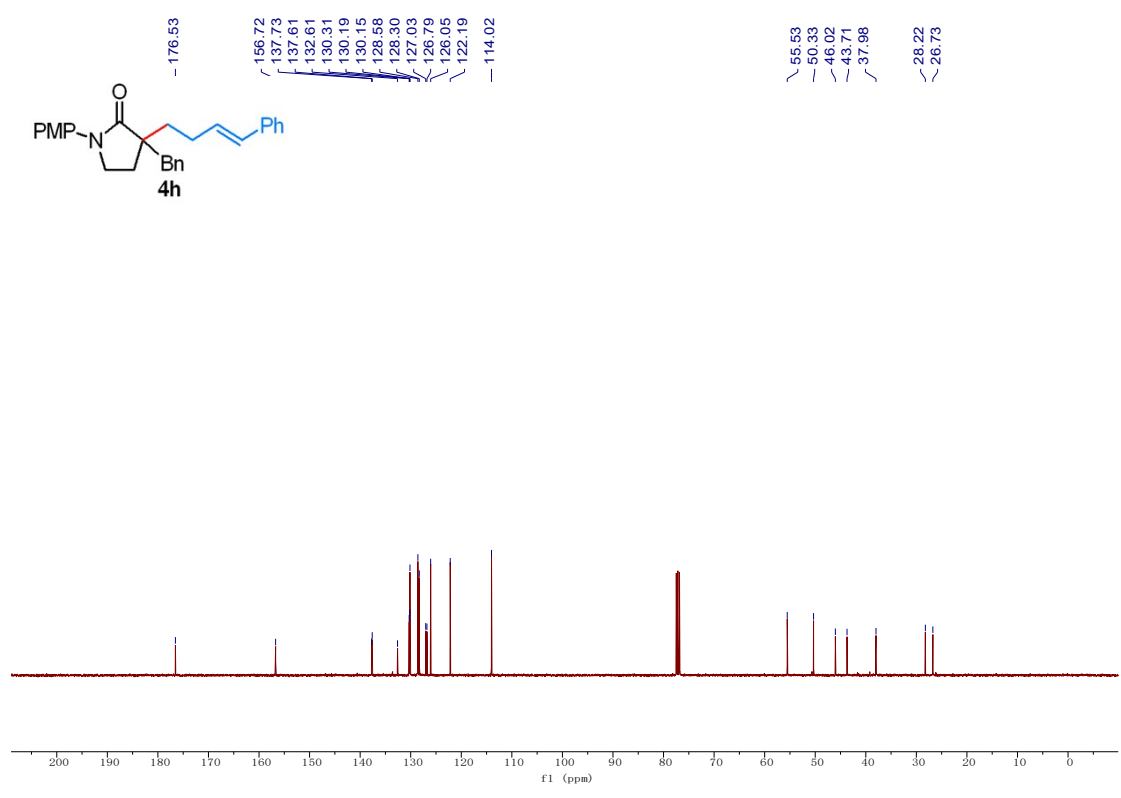
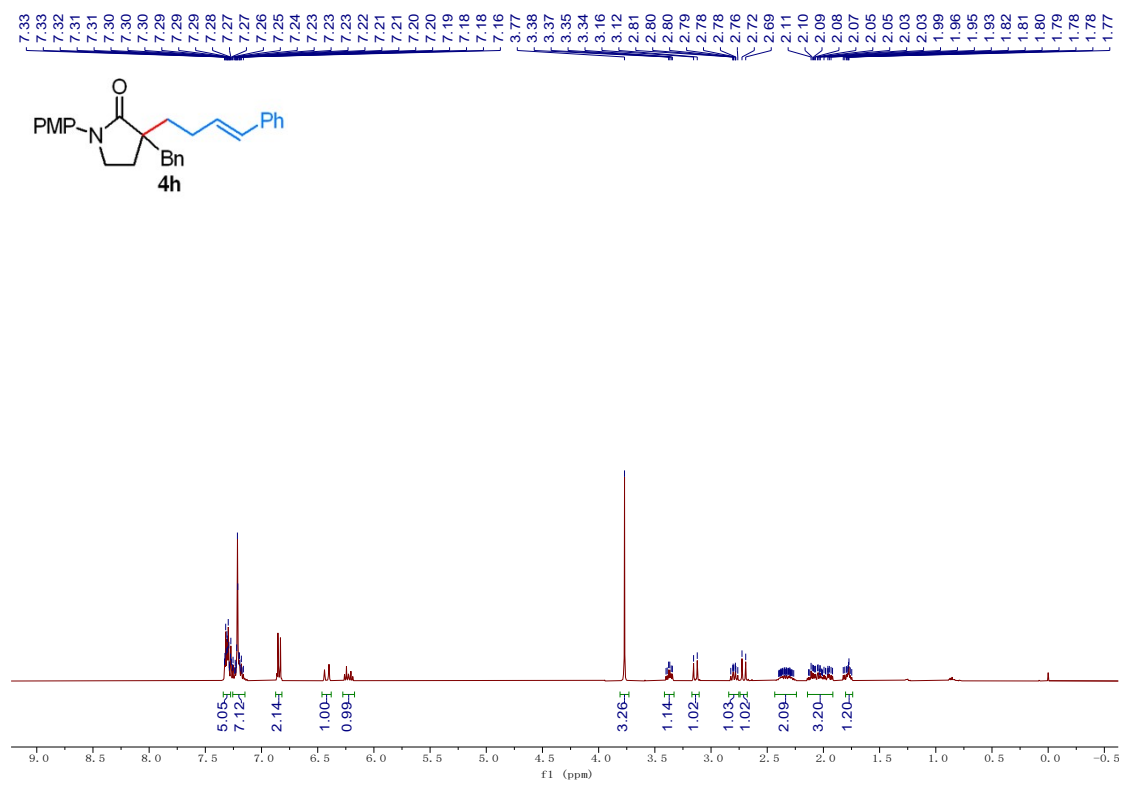


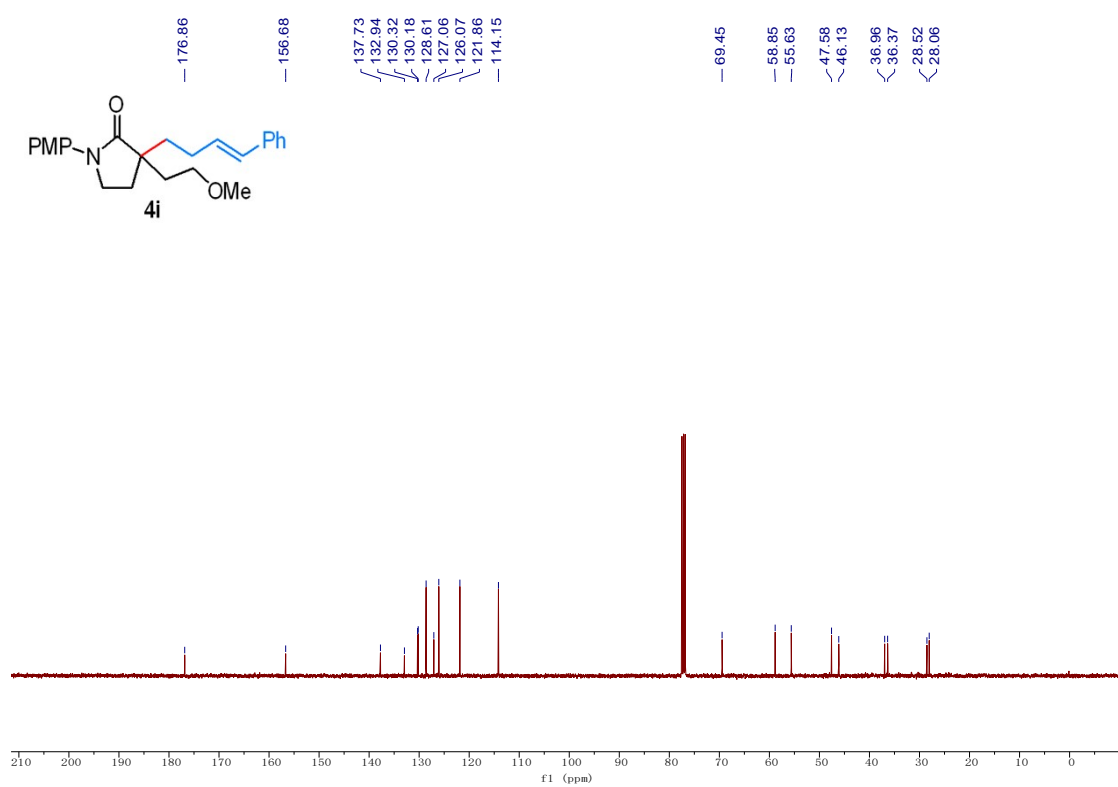
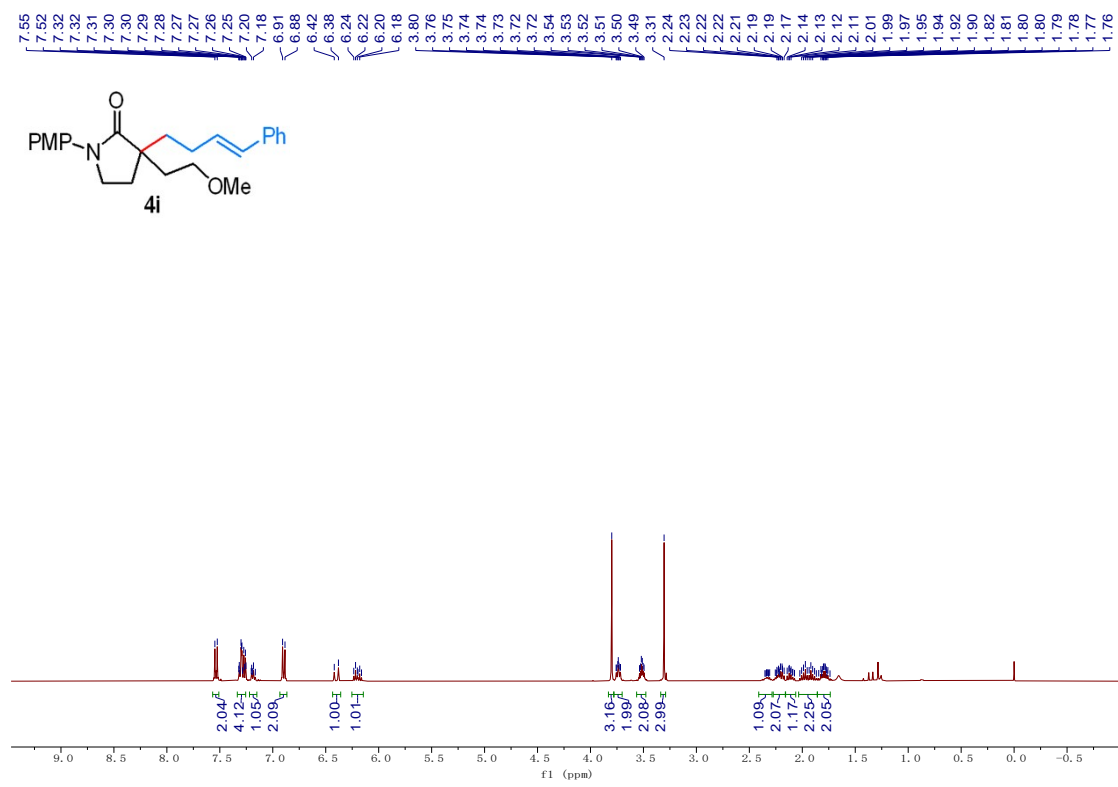
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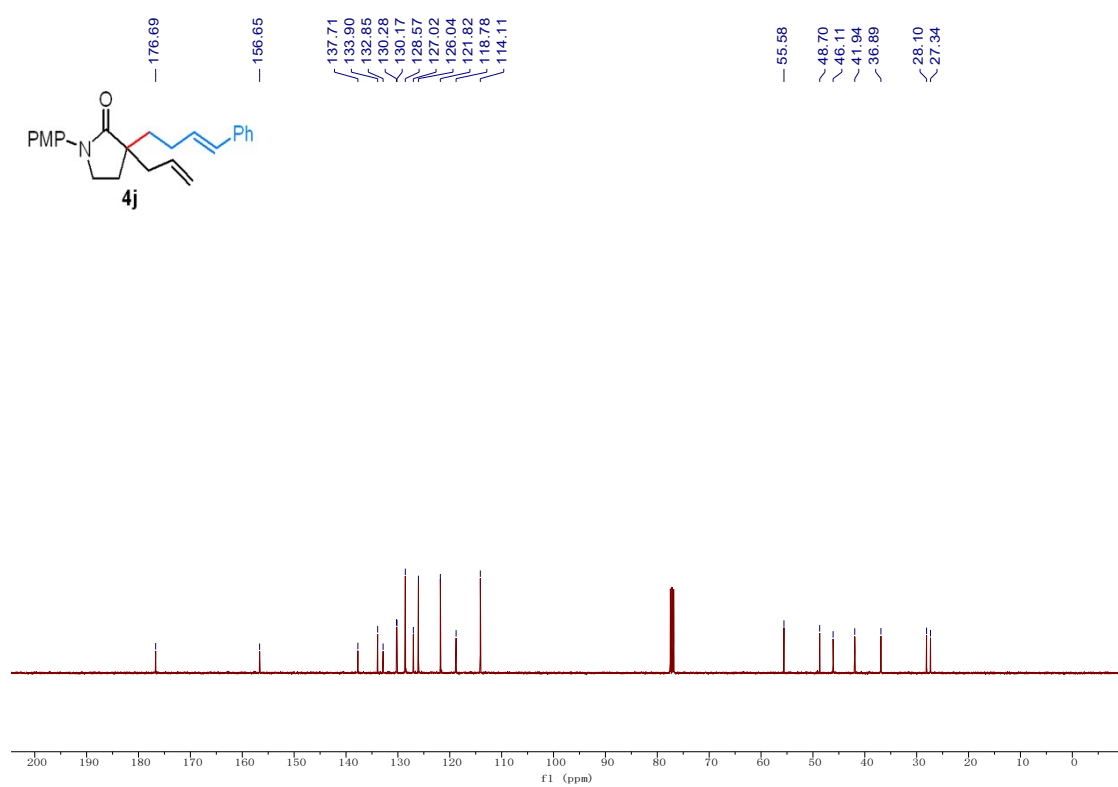
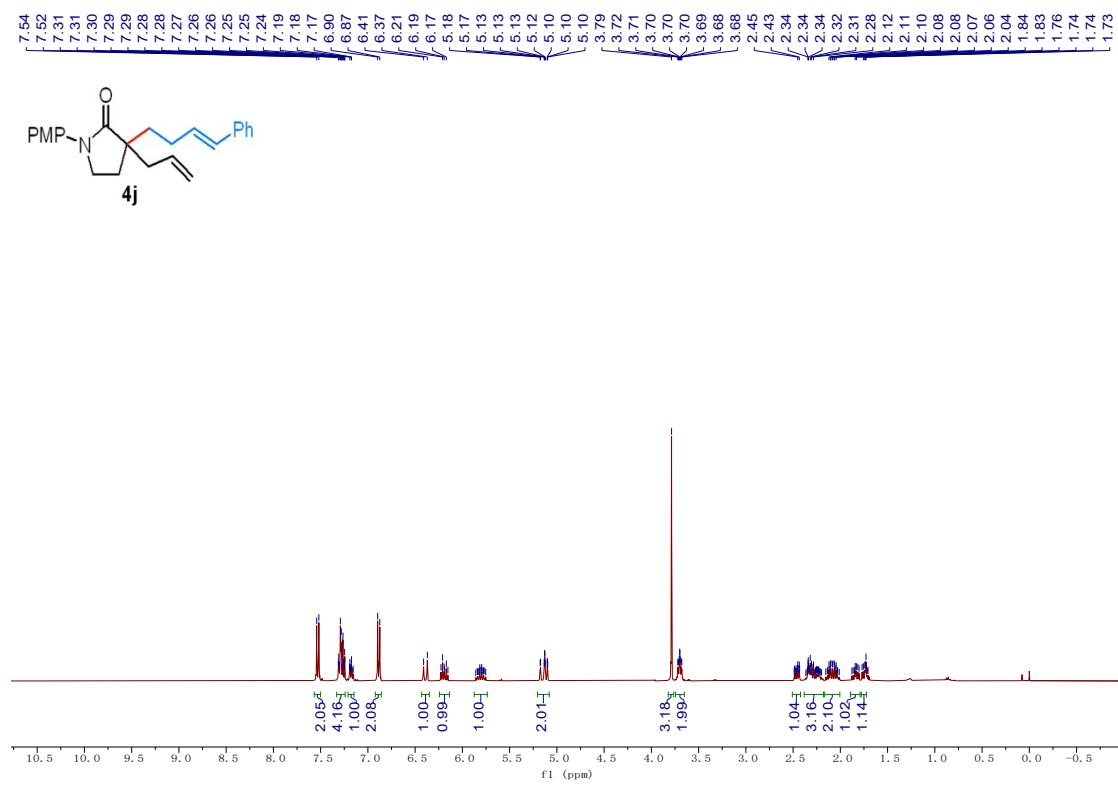


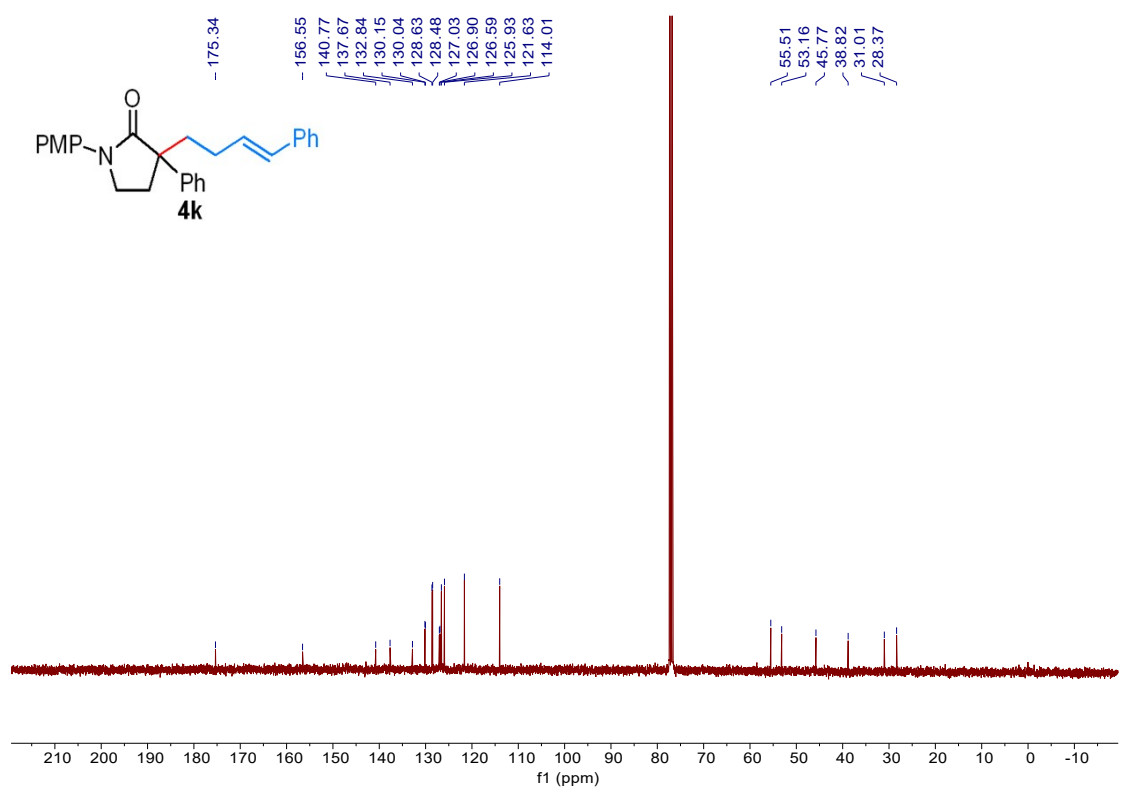
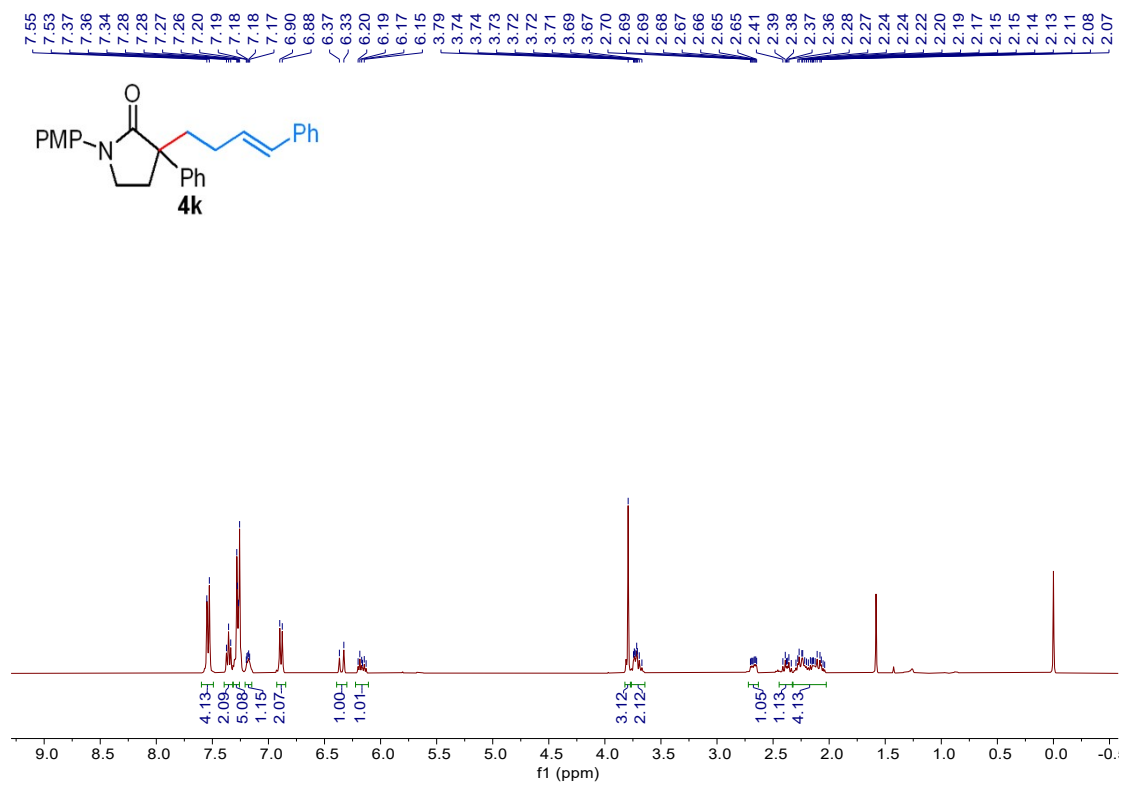
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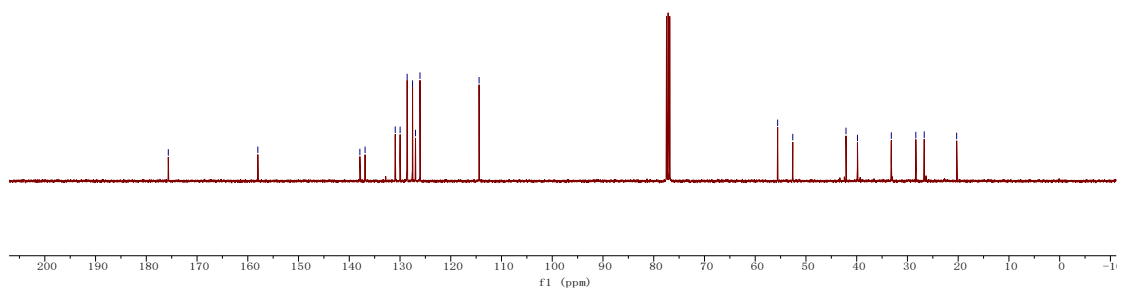
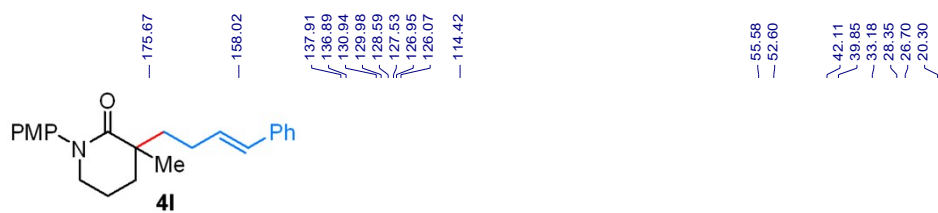
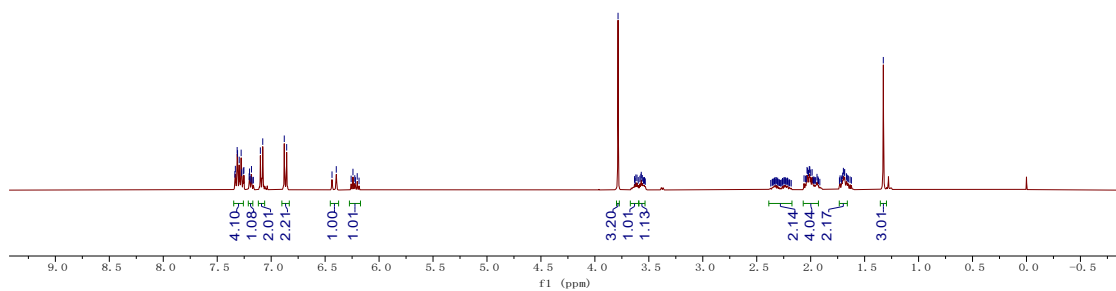
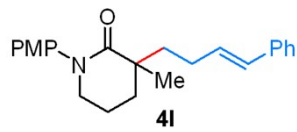




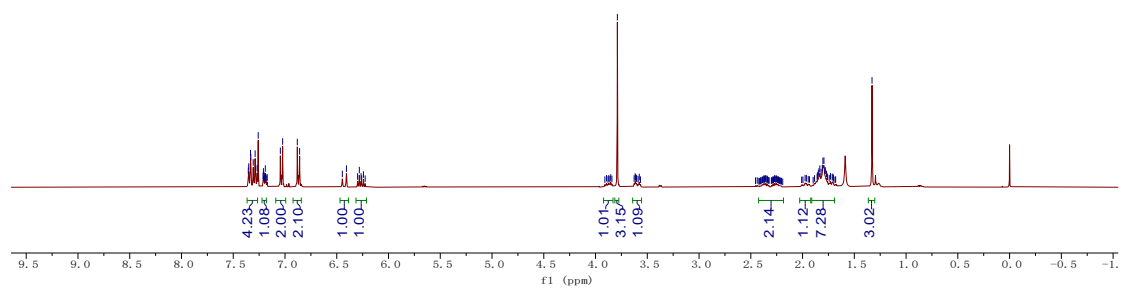
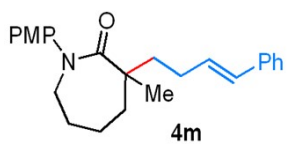




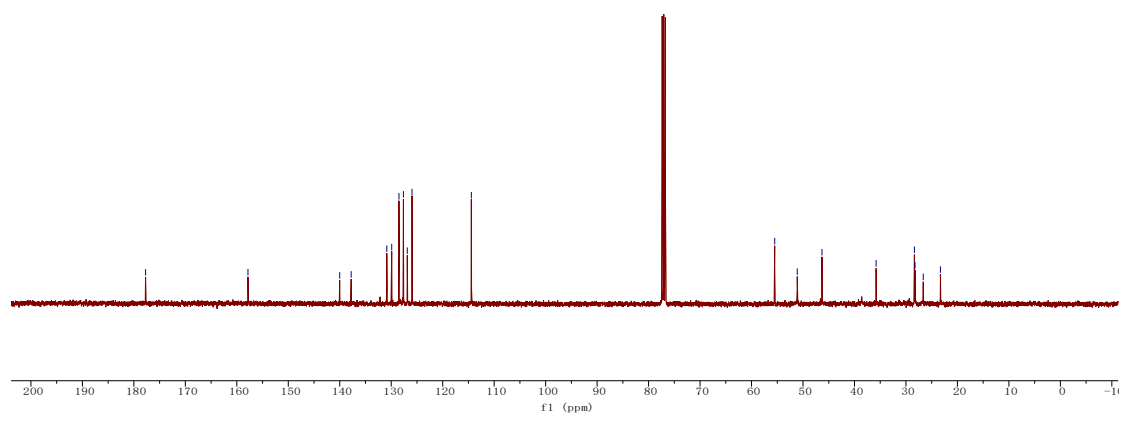
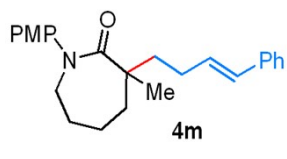
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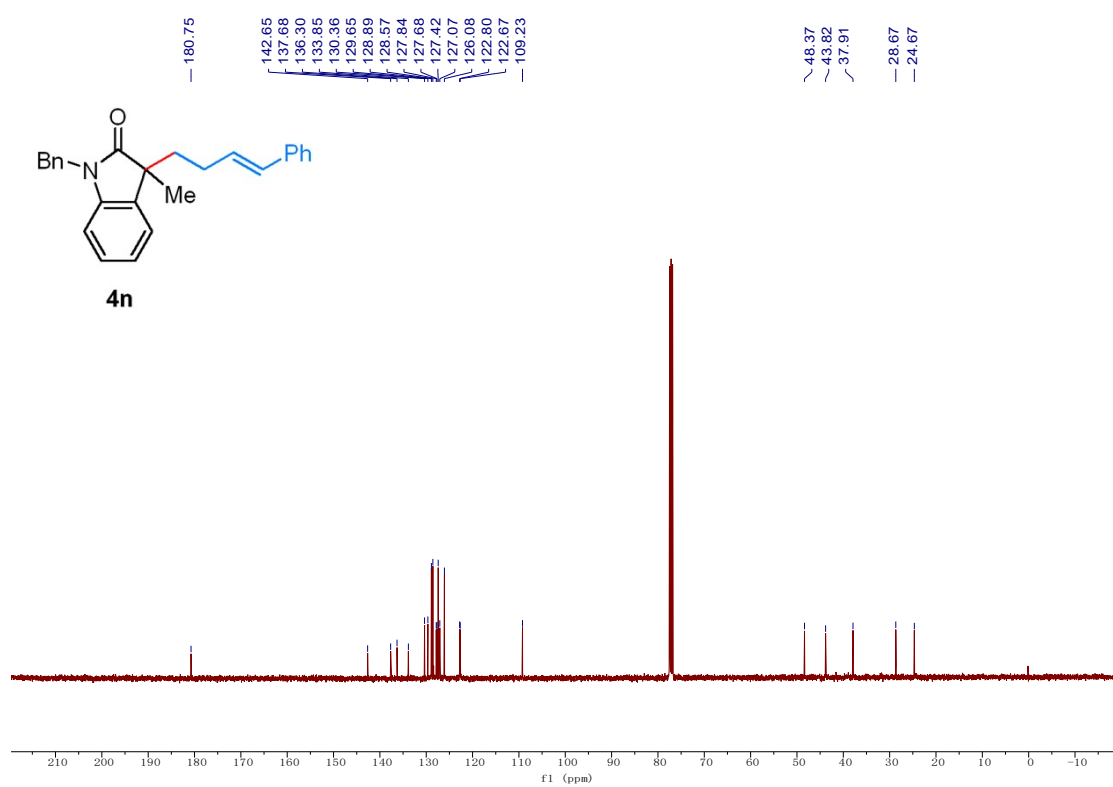
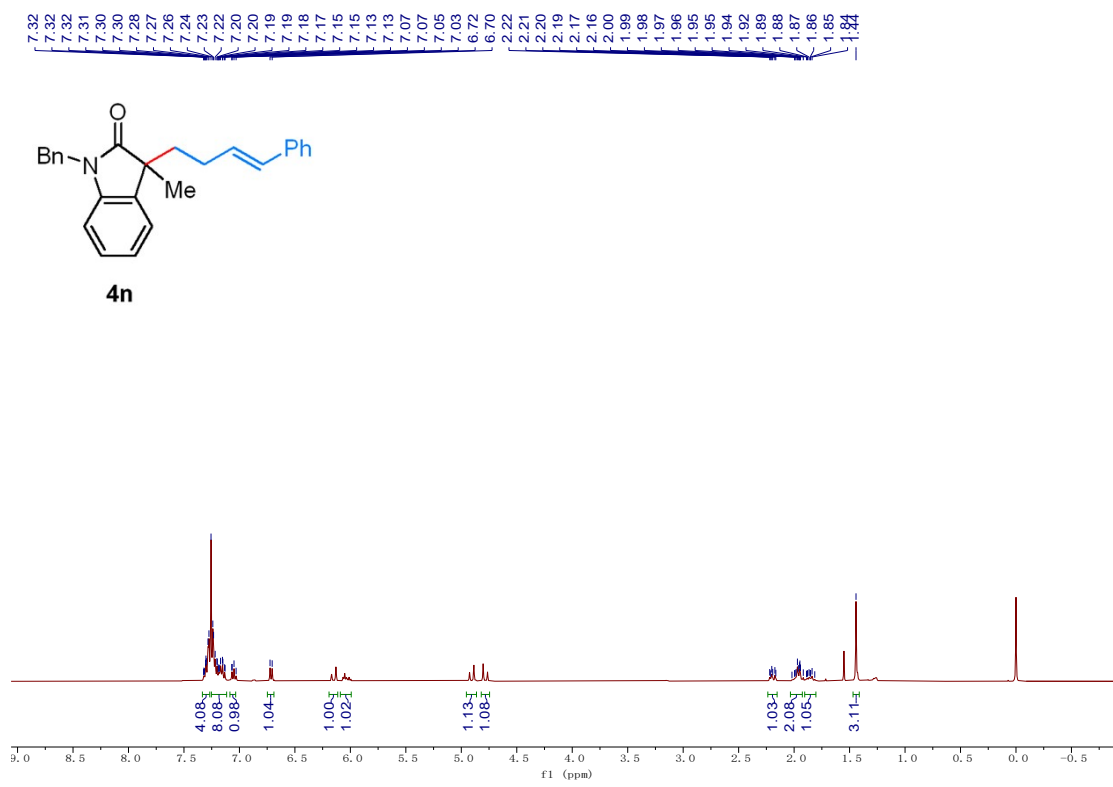


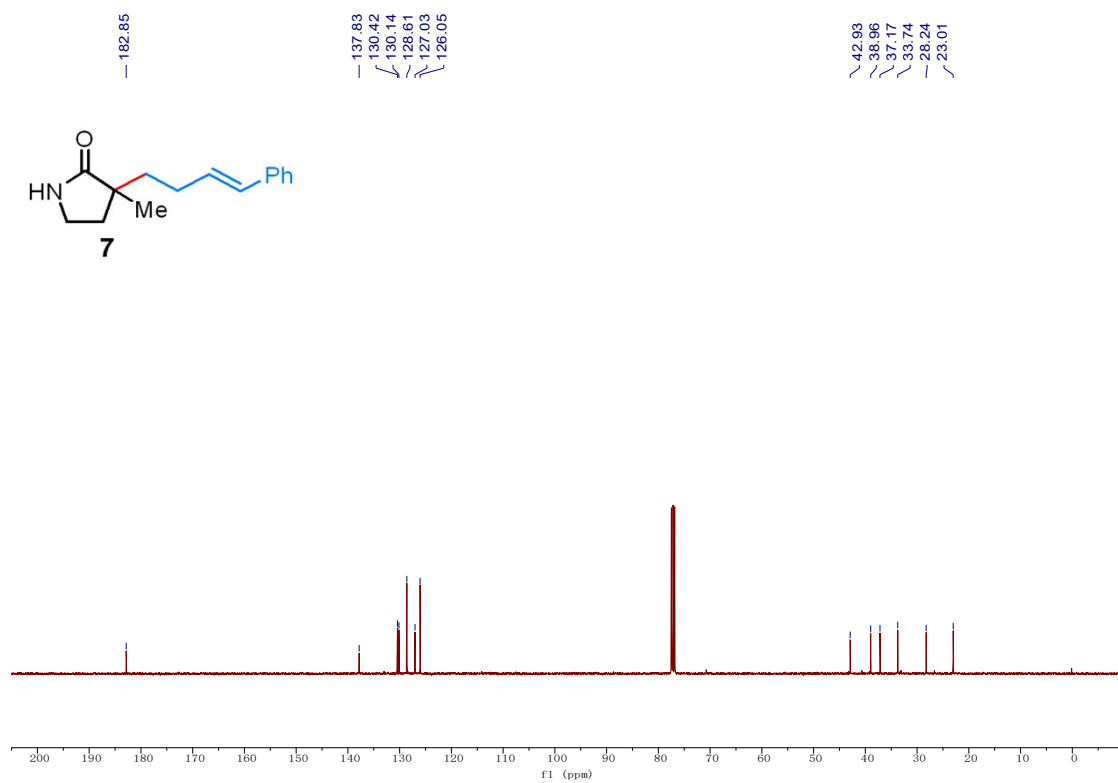
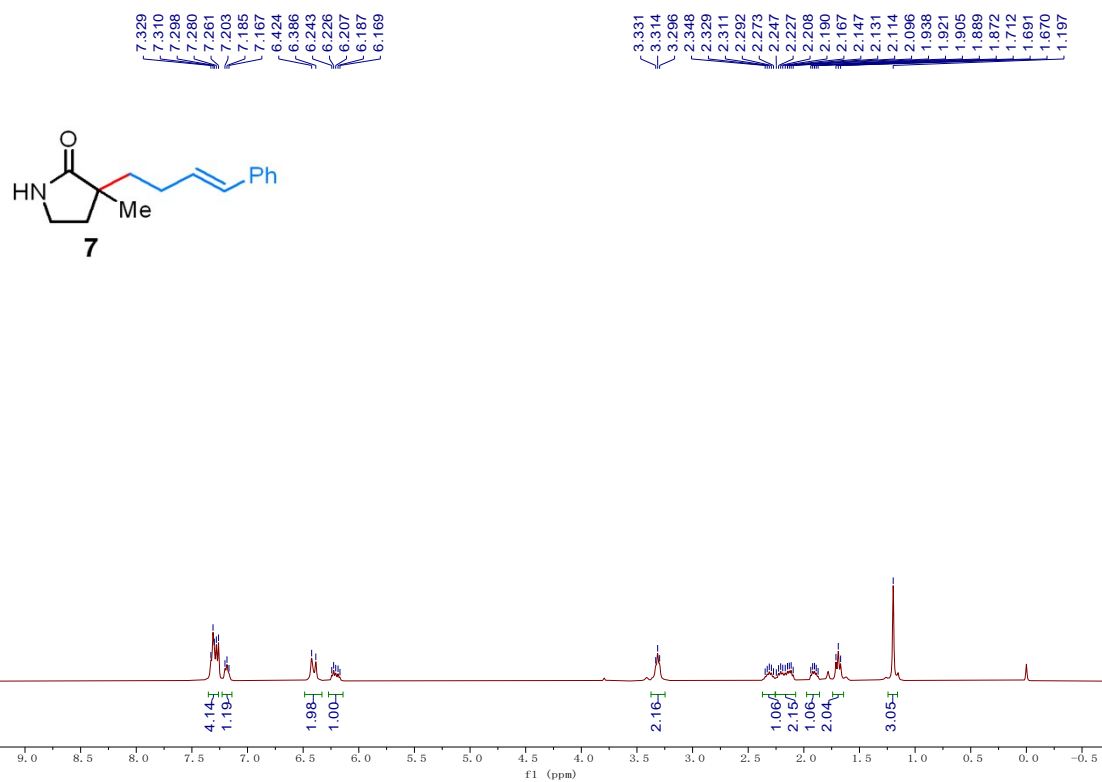
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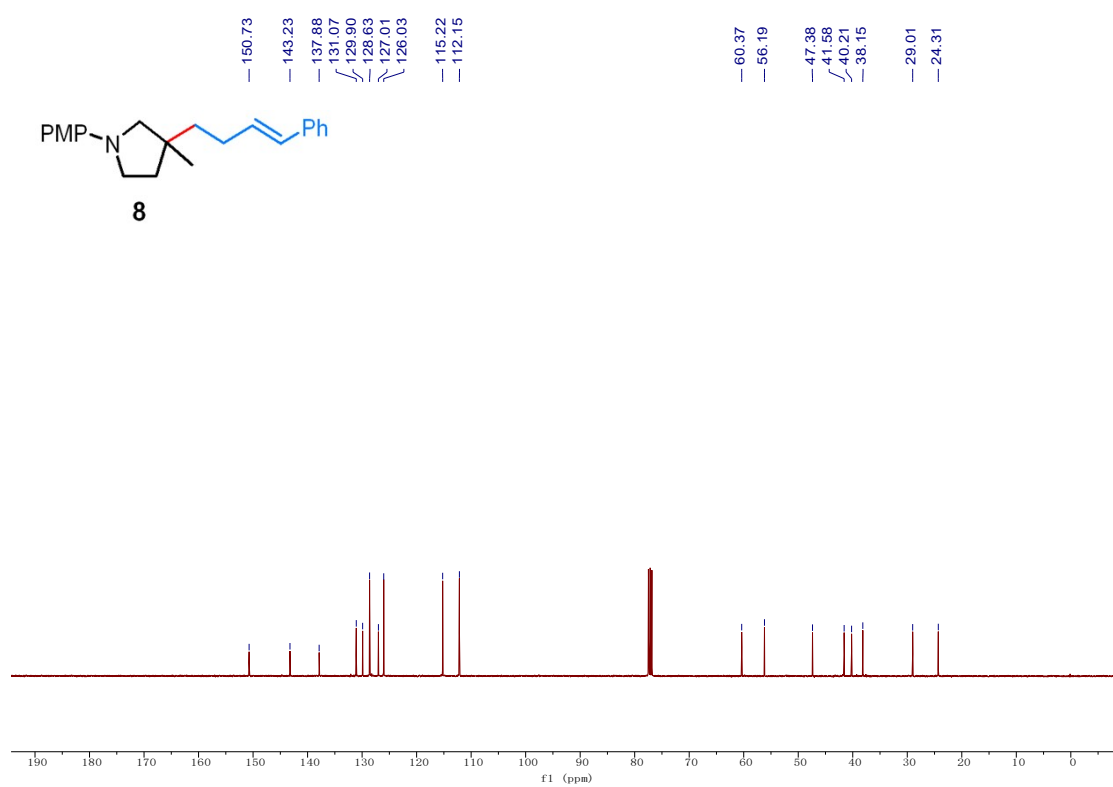
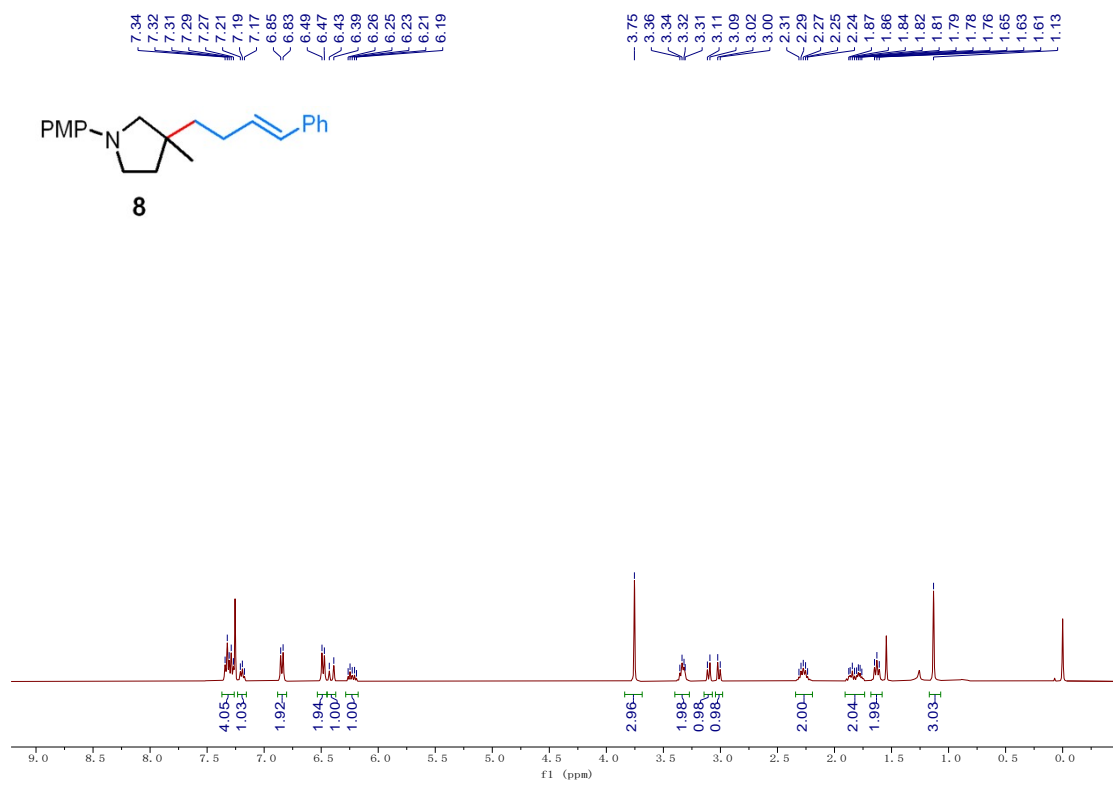


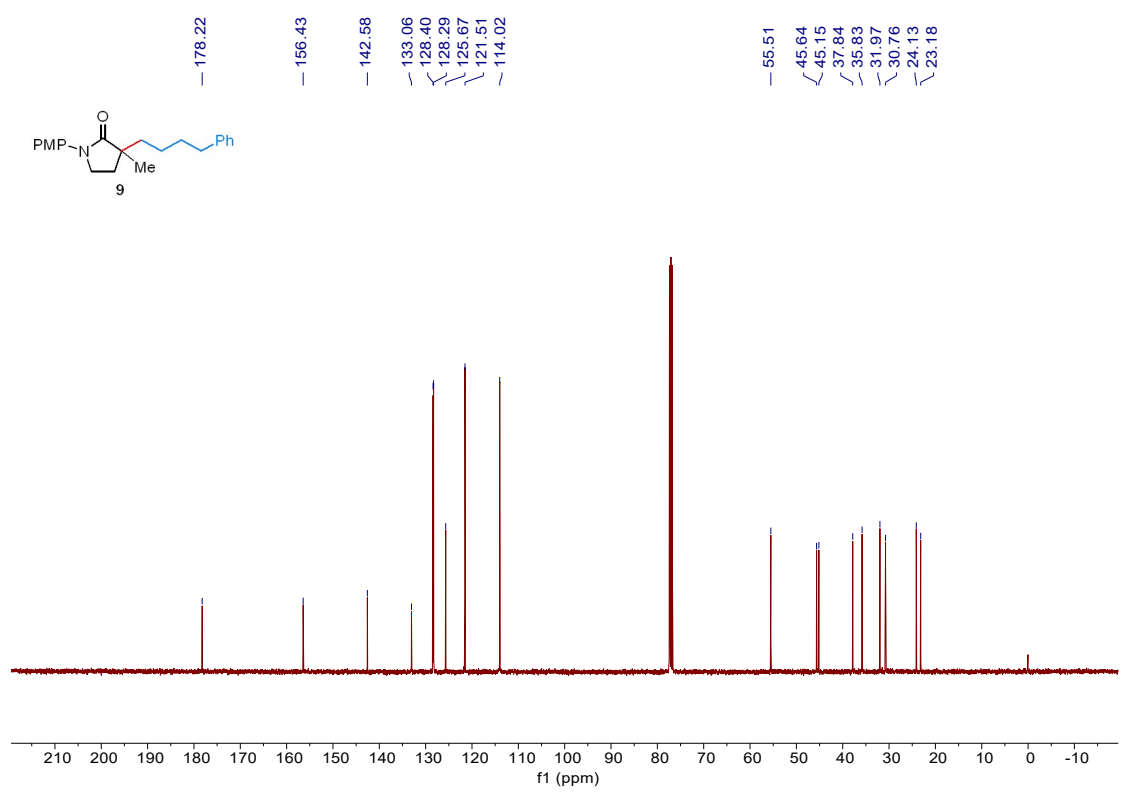
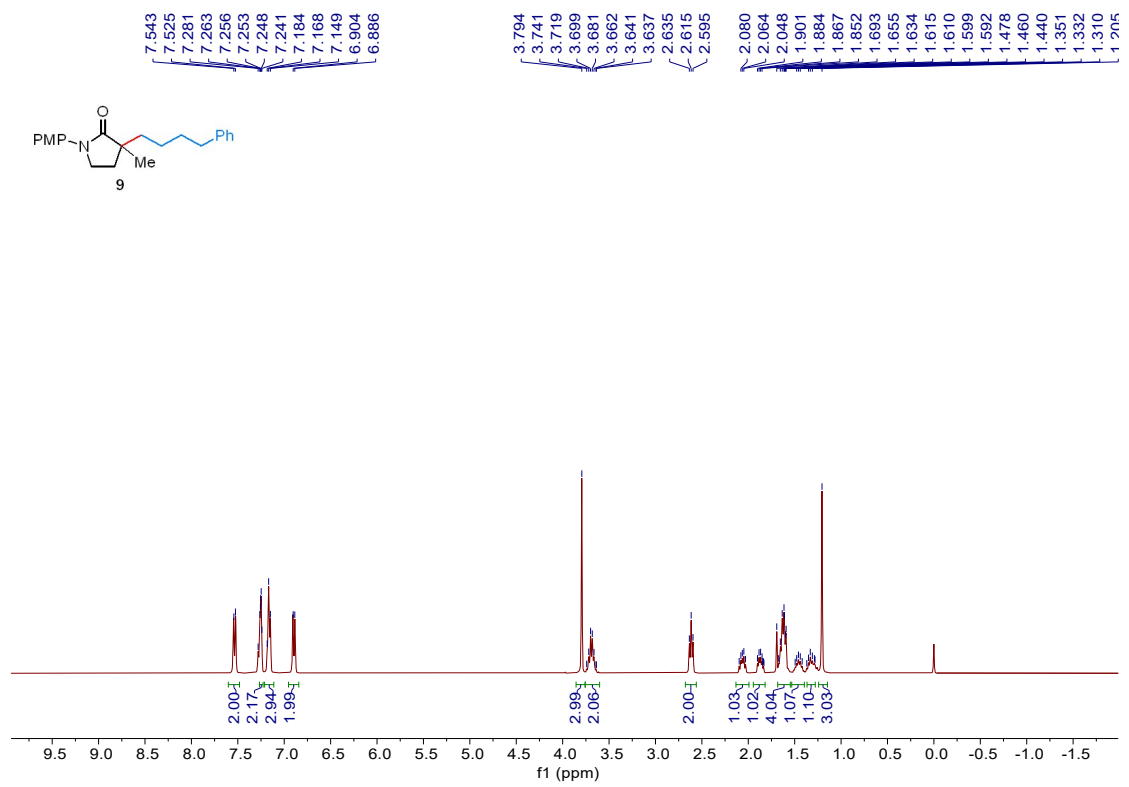
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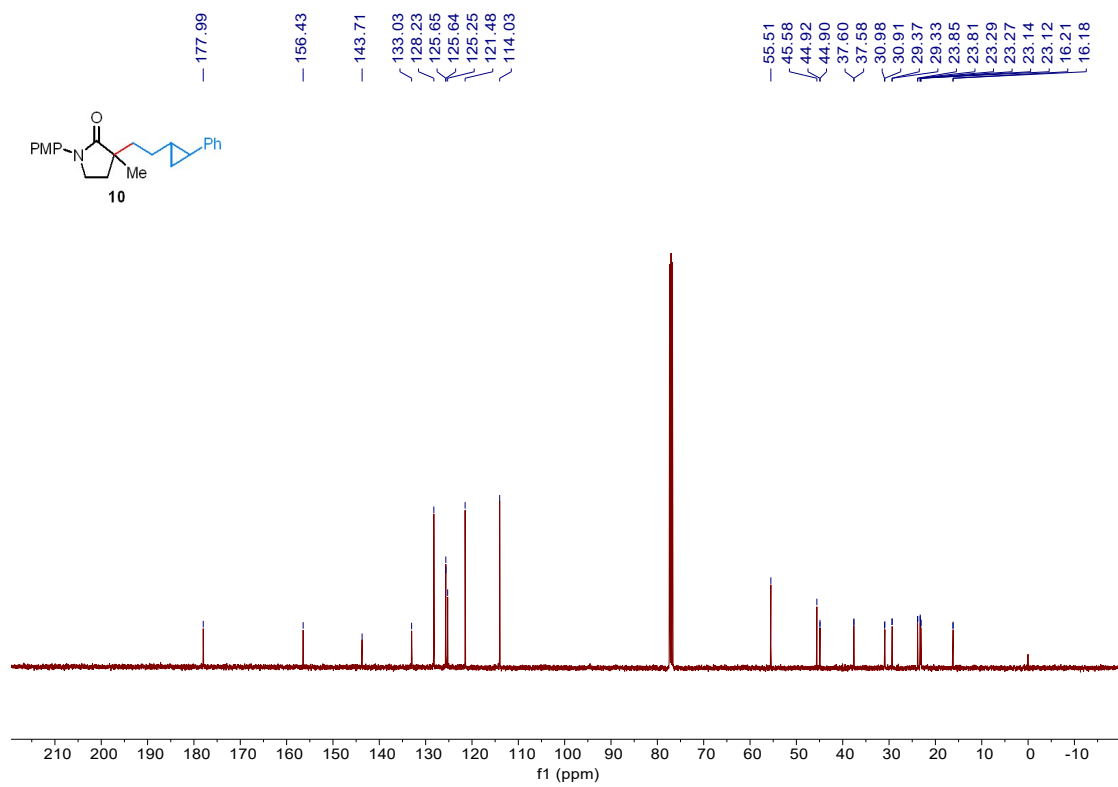
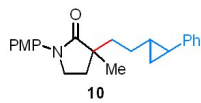
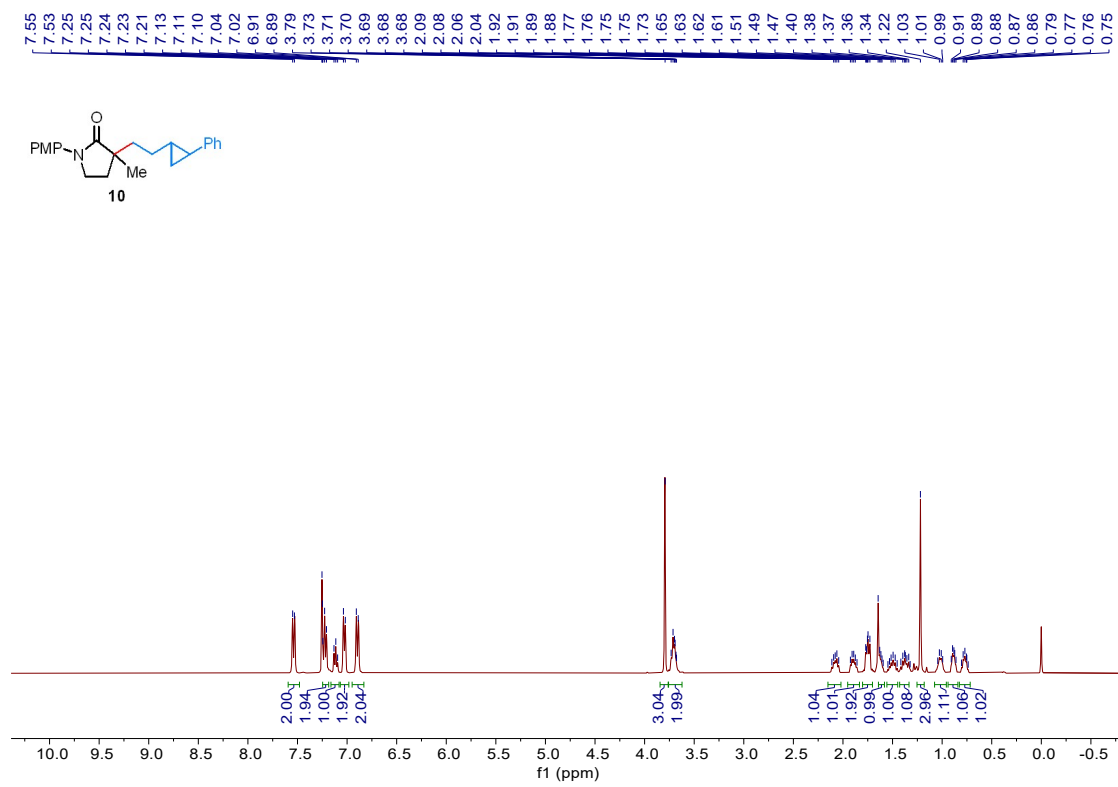


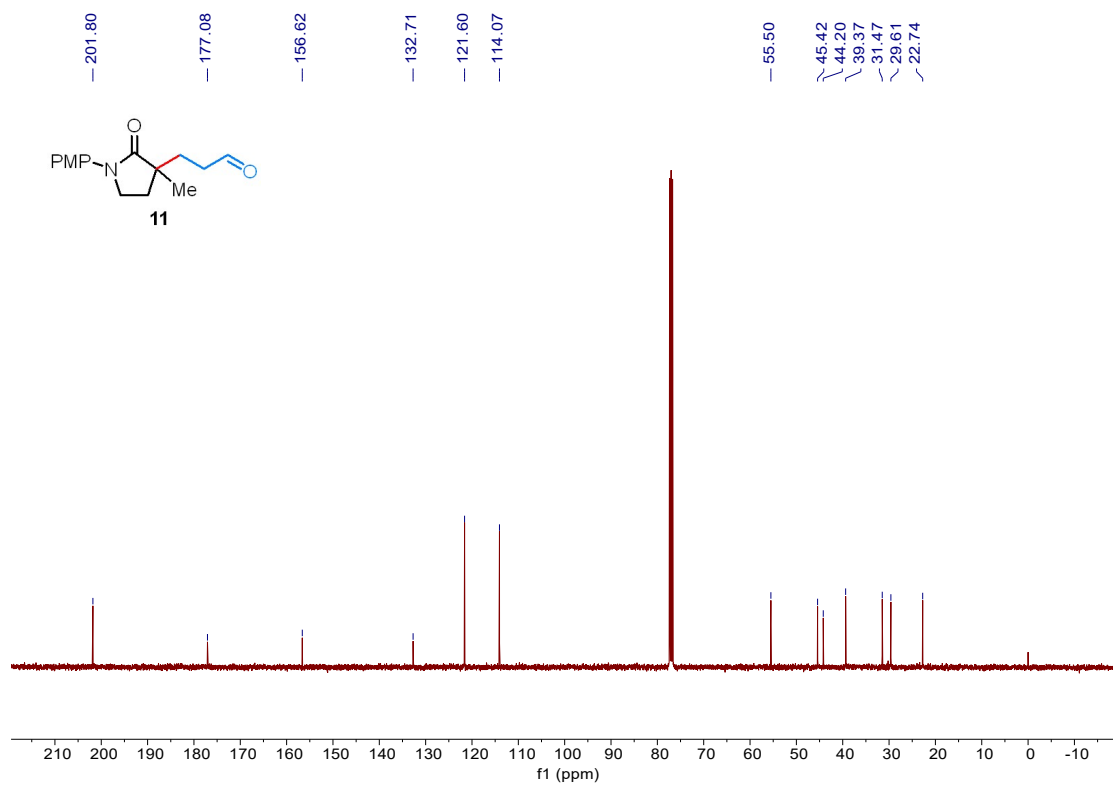
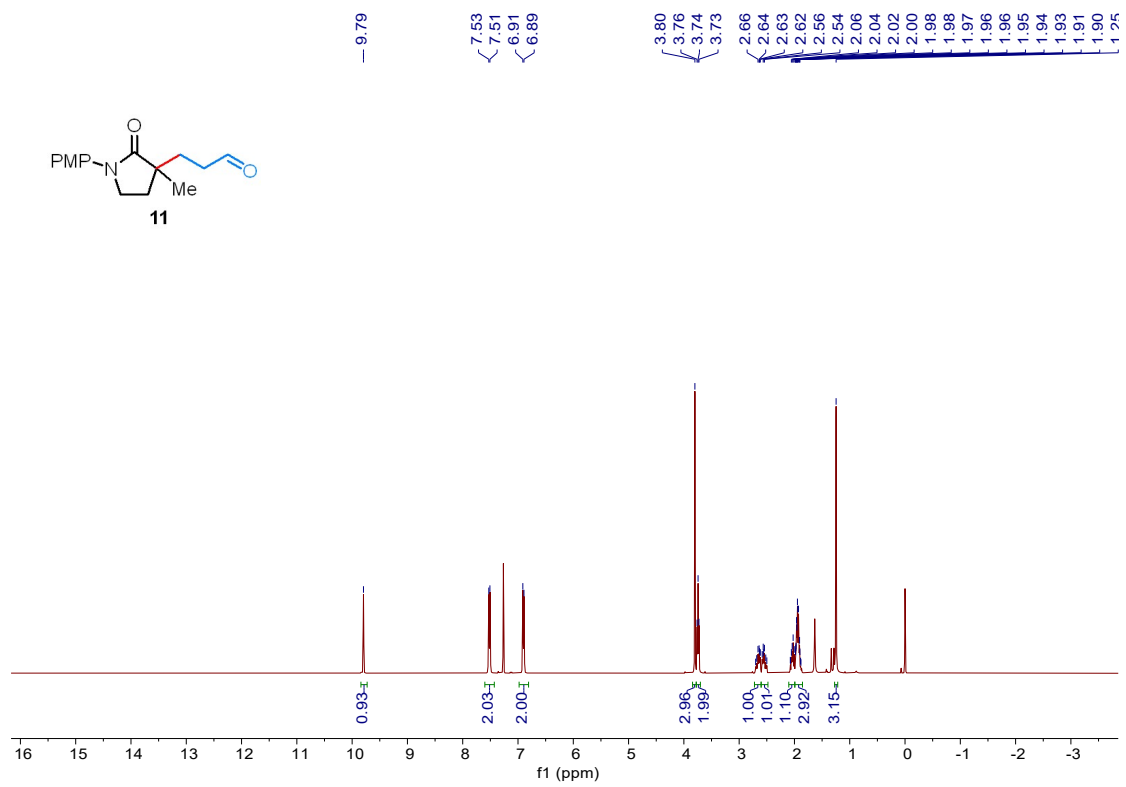


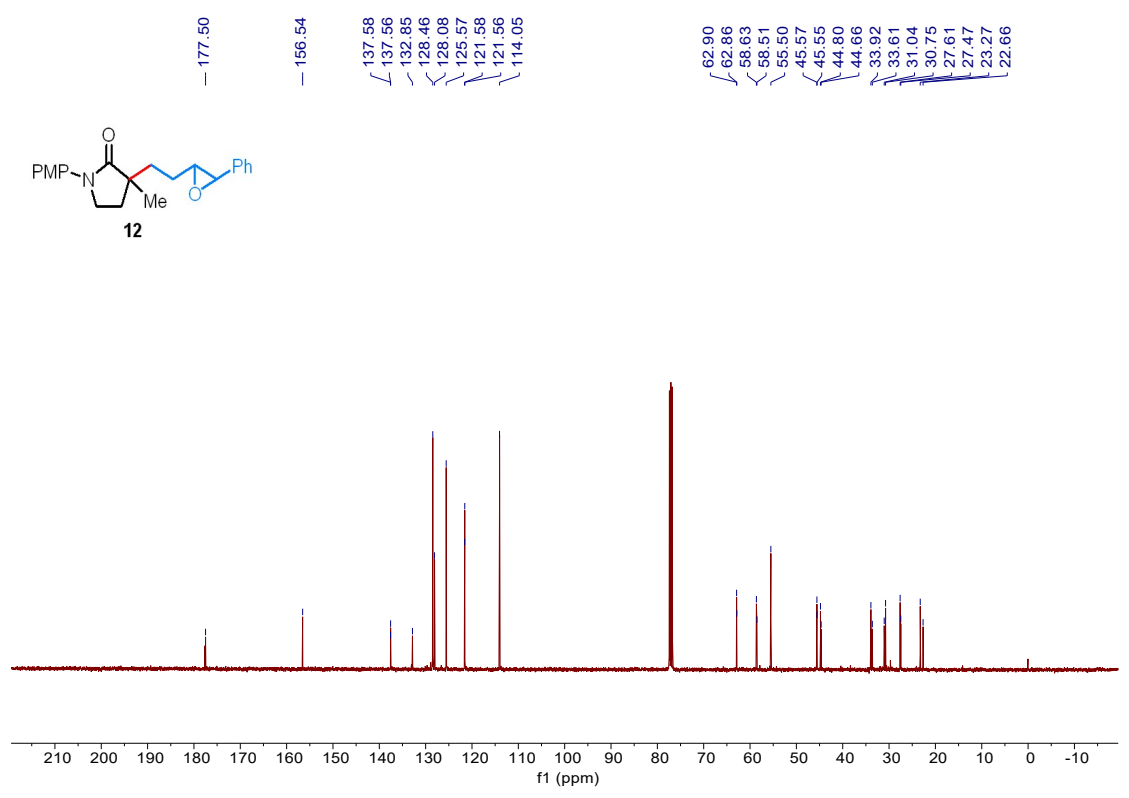
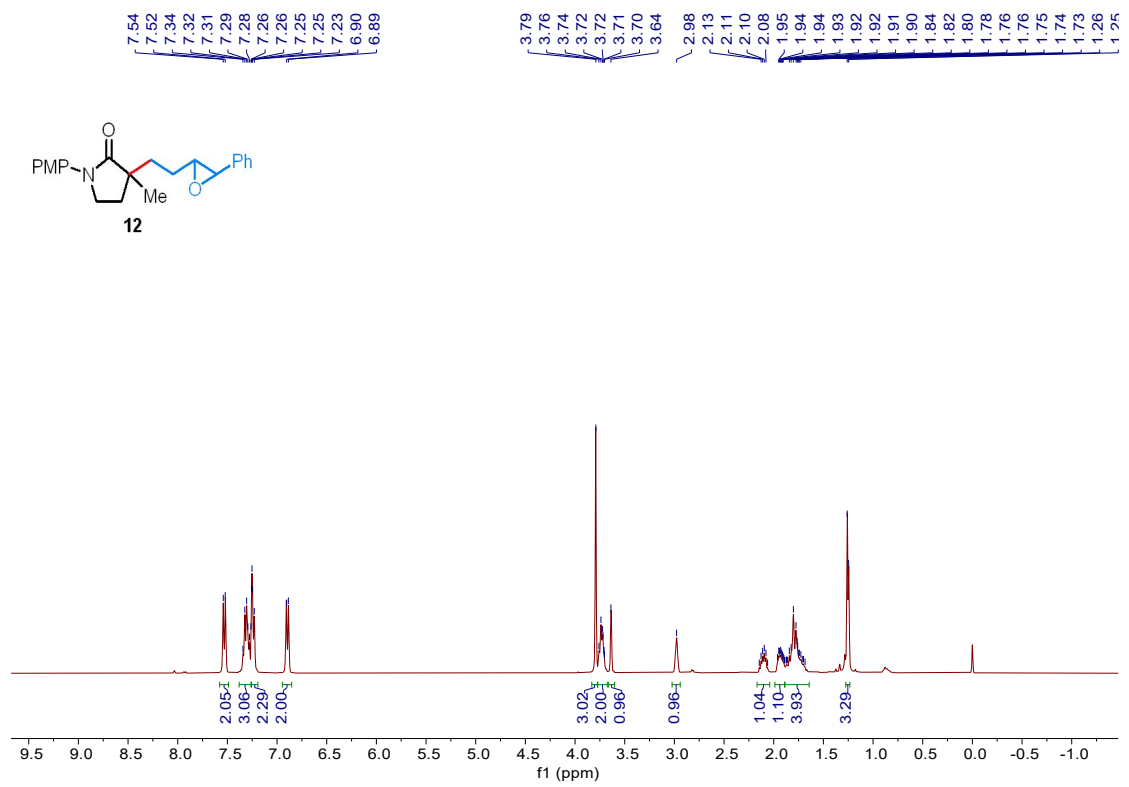


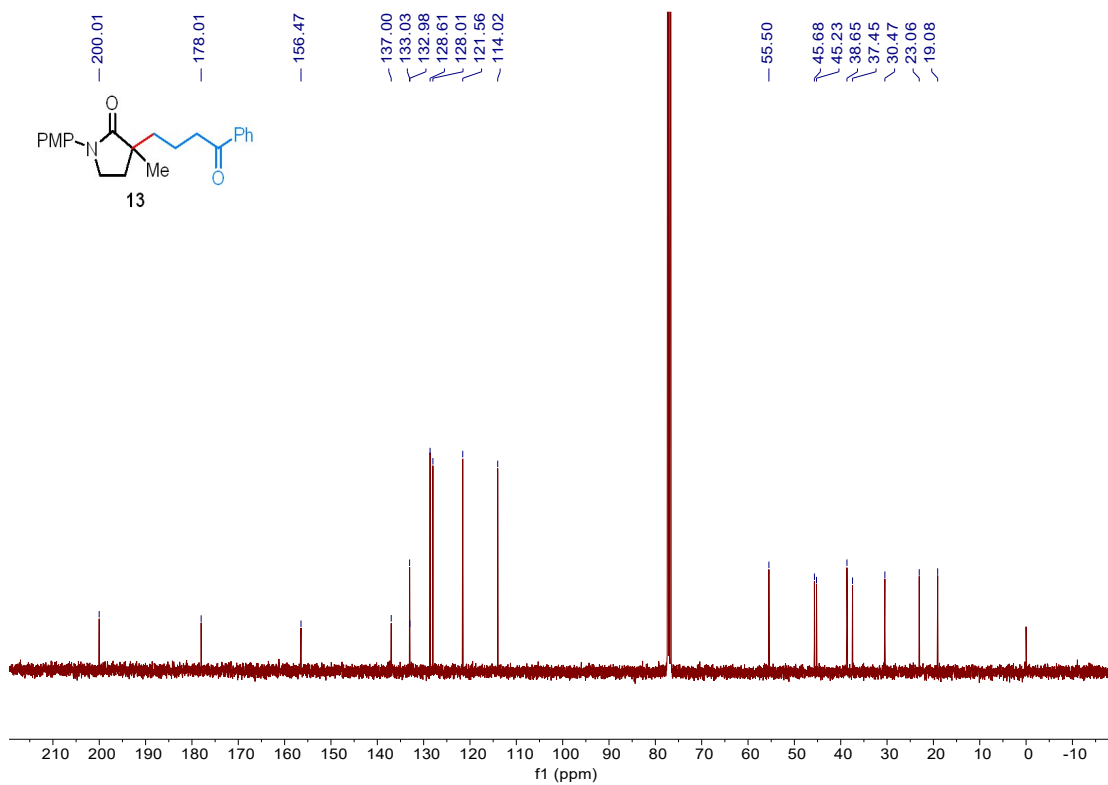
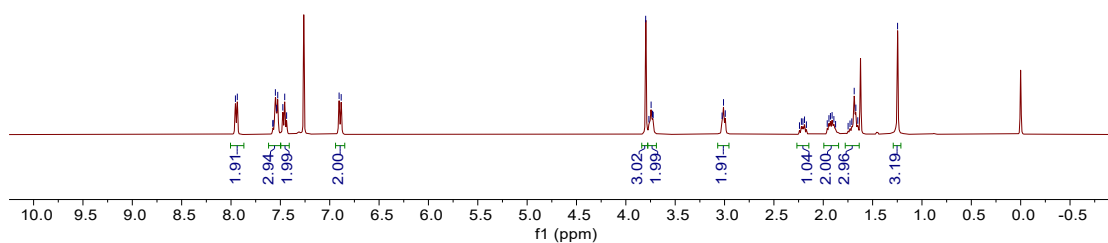




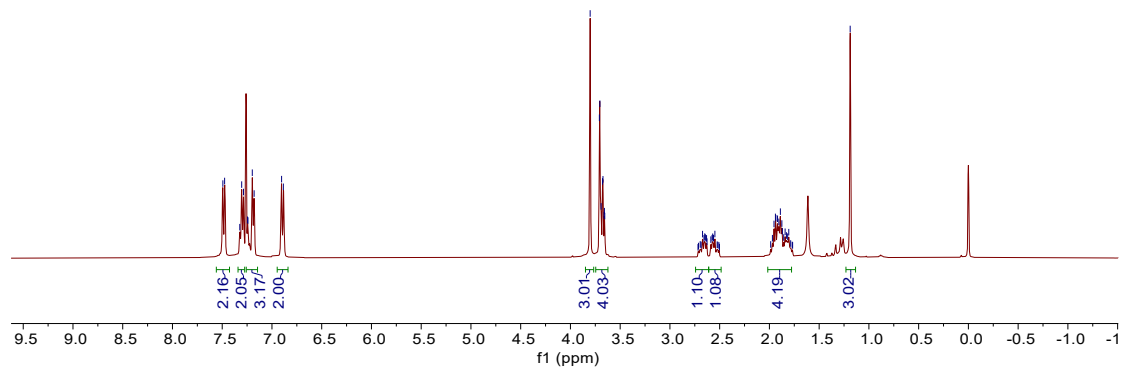
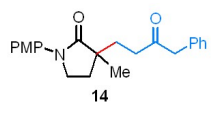




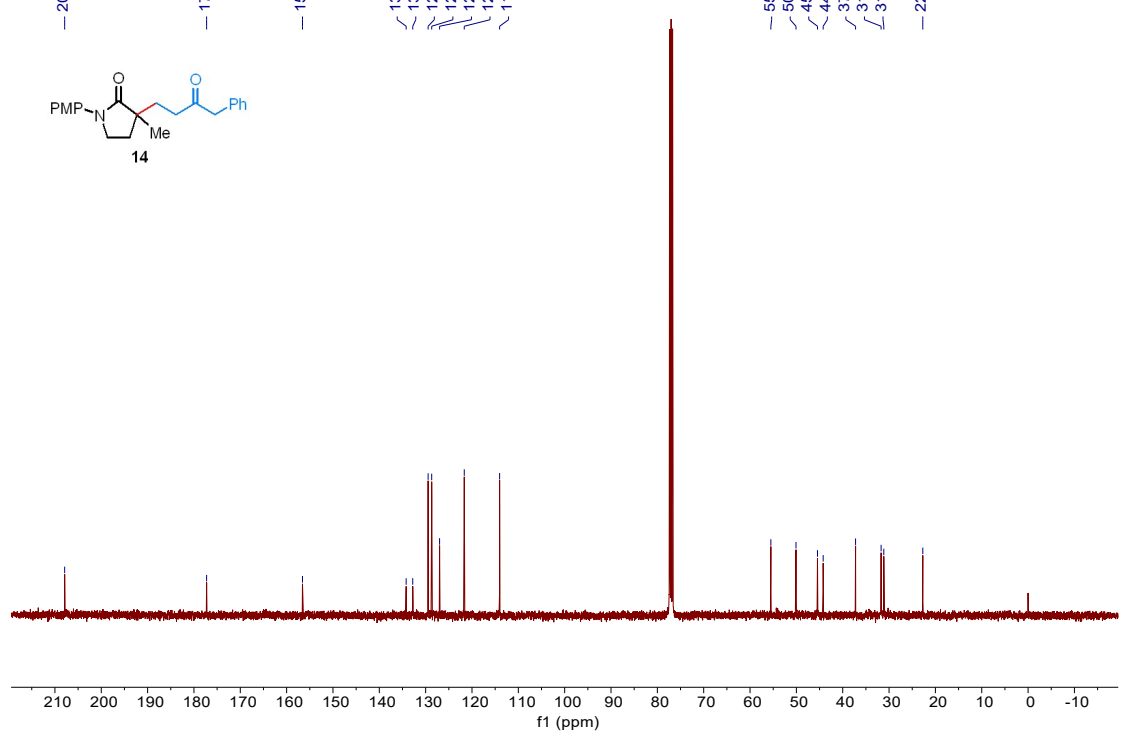
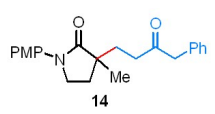


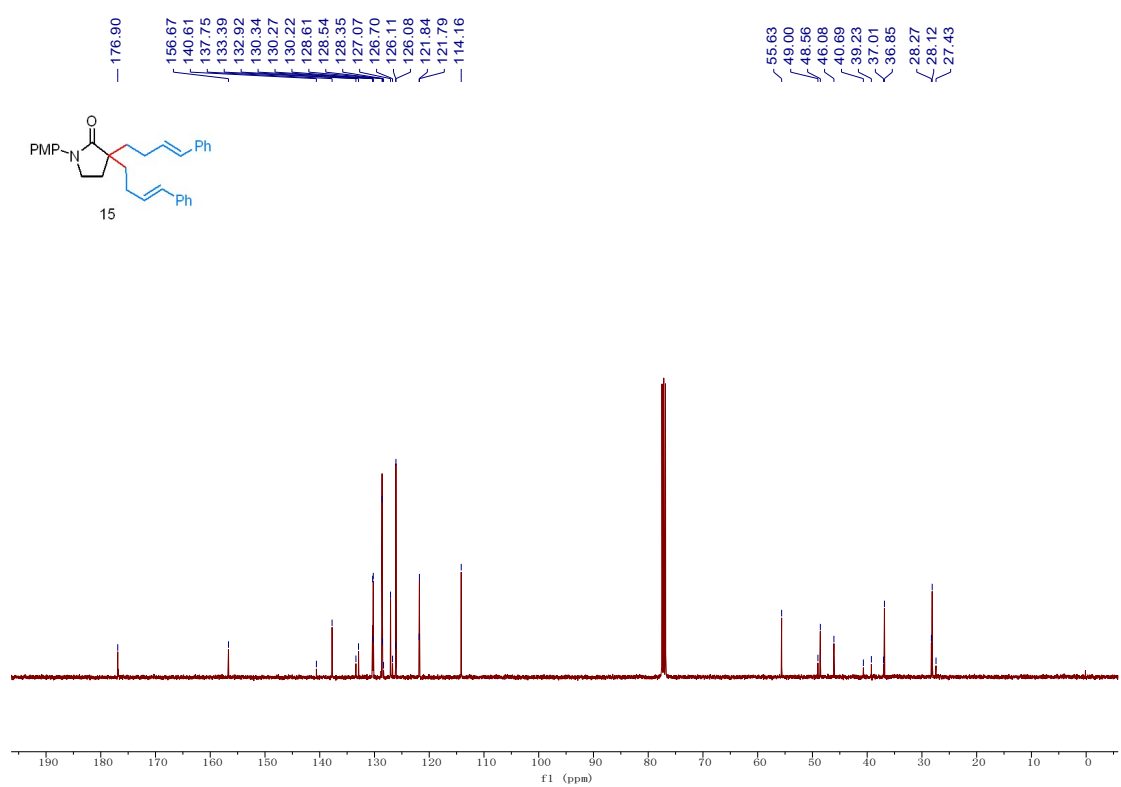
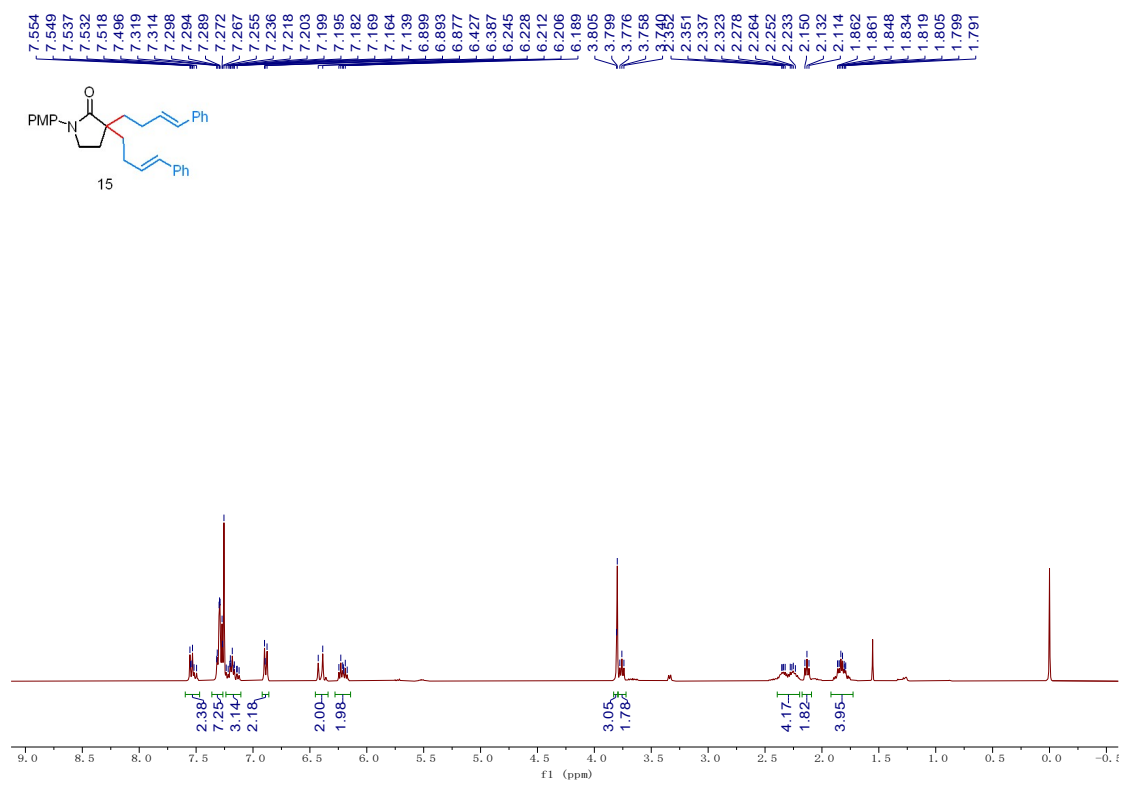


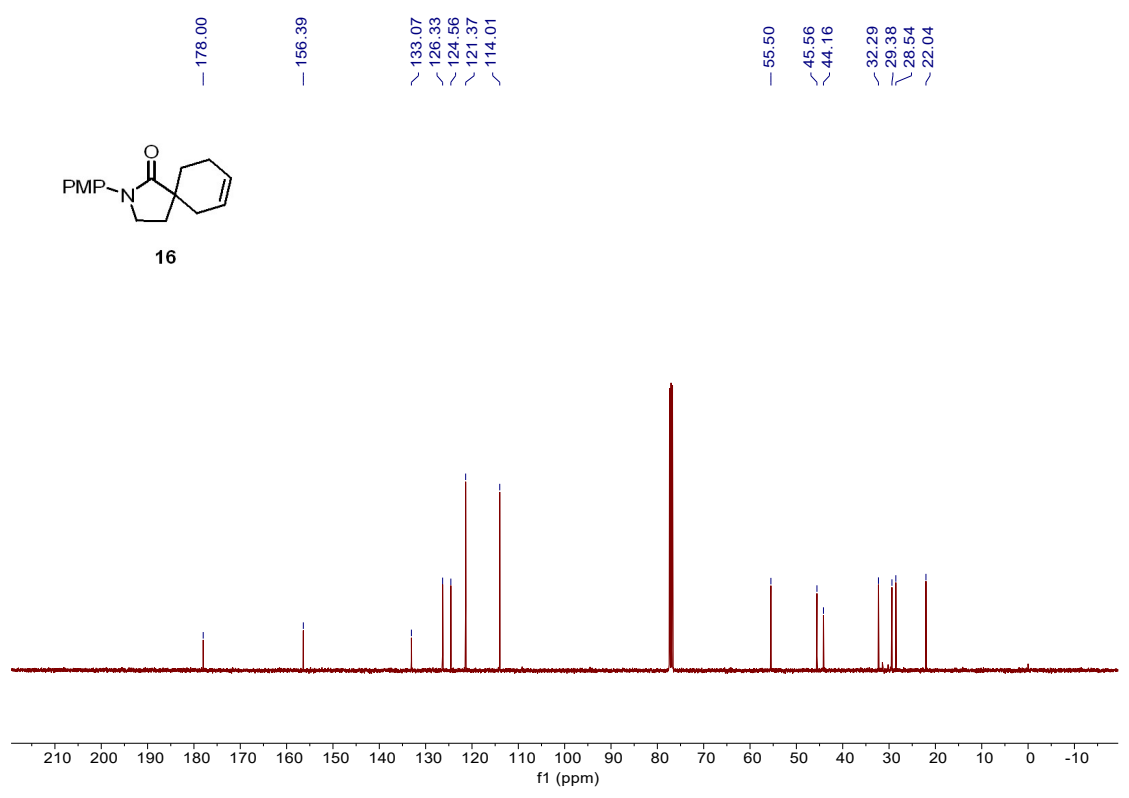
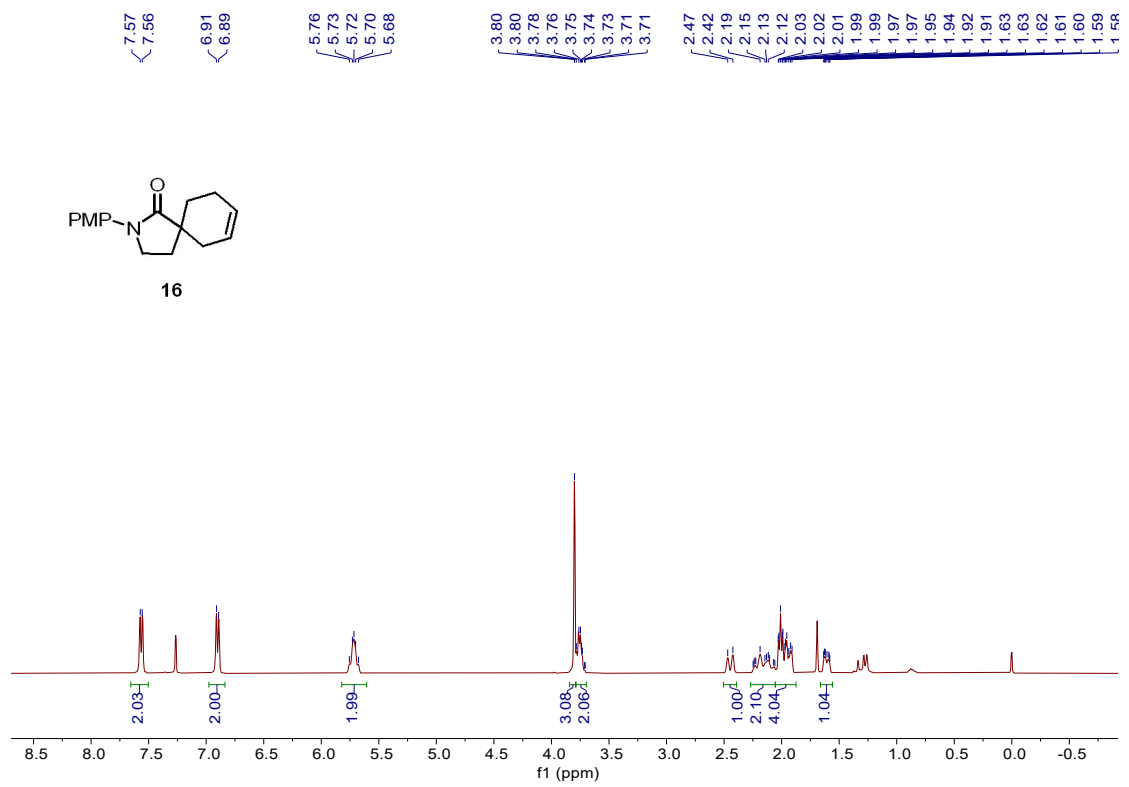
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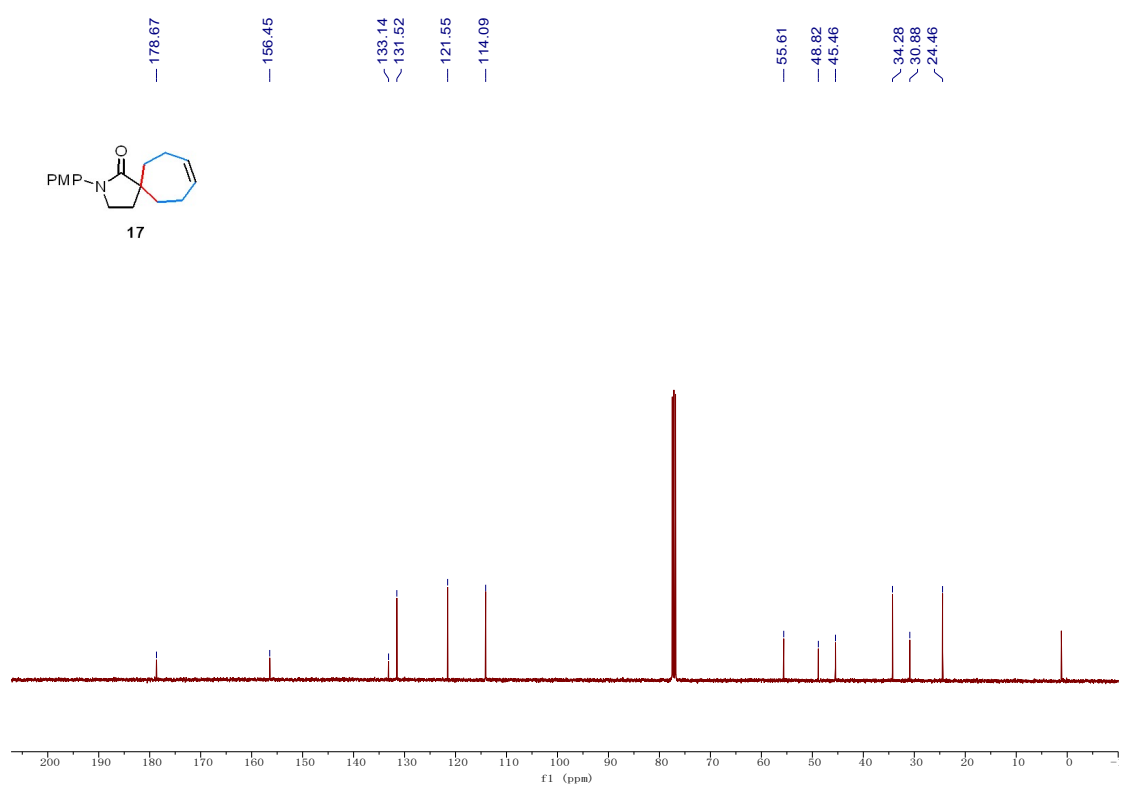
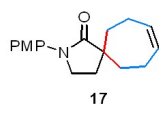
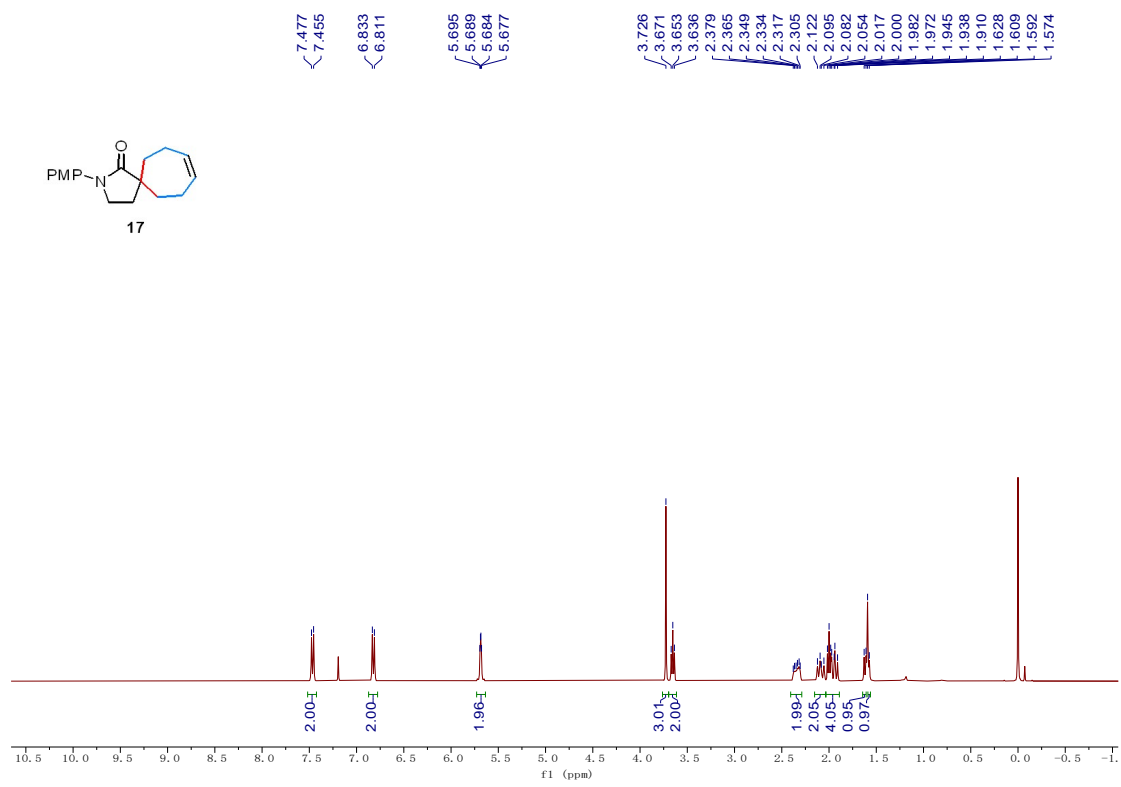
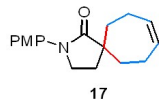


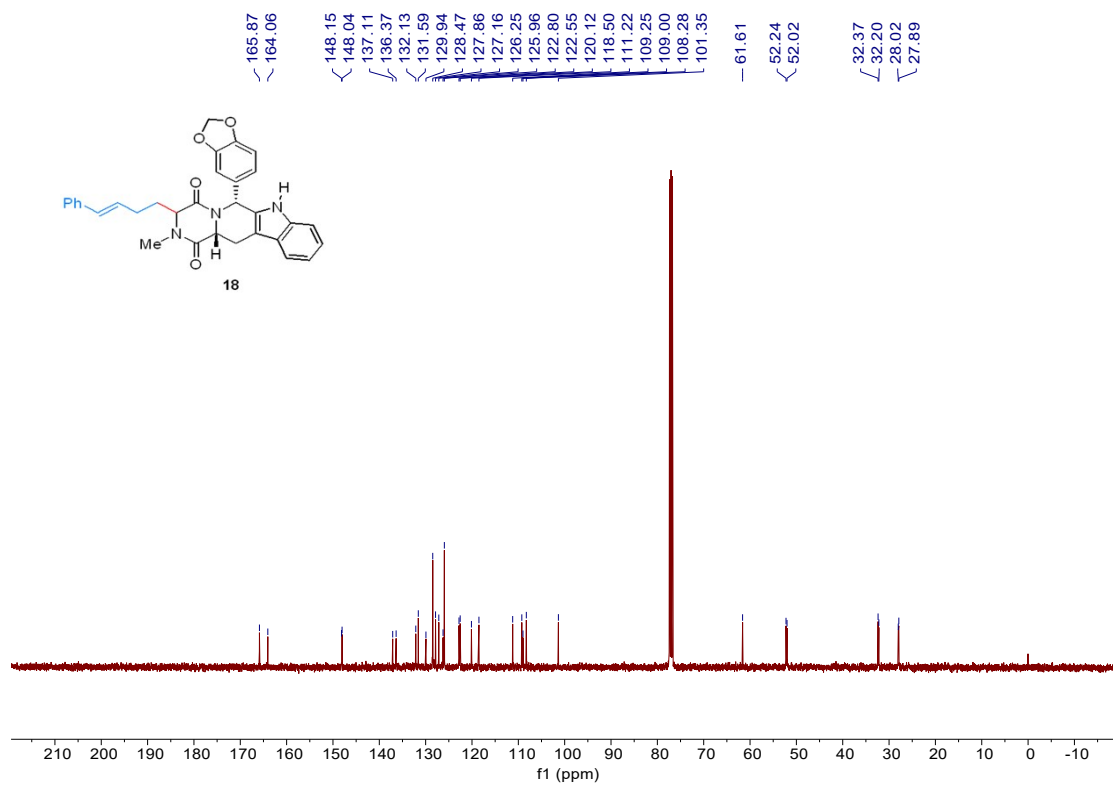
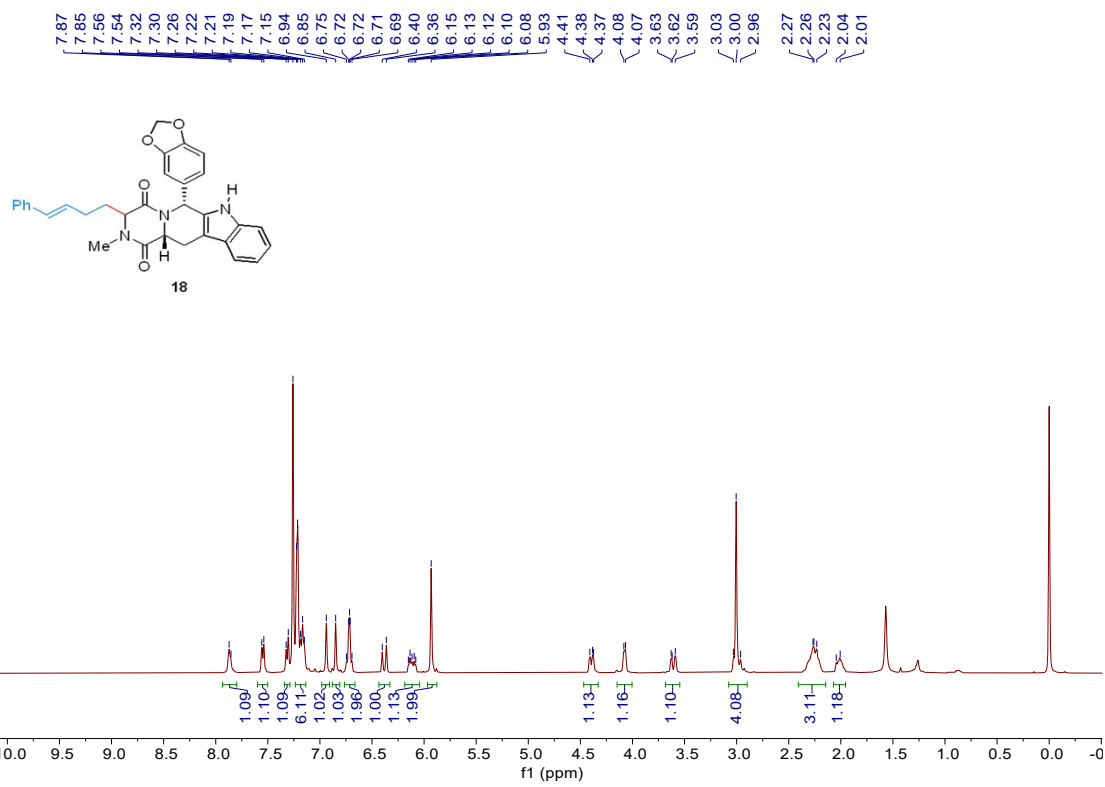
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45.45
44.22
37.23
31.72
31.13
22.72











7.555
7.533
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7.505
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7.277
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7.202
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6.904
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