Supporting Information

Template Catalysis by Manganese Pincer Complexes: Oxa- and Aza-Michael Additions to Unsaturated Nitriles

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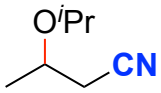
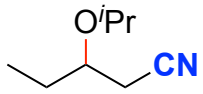
General information

All of the reactions were performed in an atmosphere of purified nitrogen in a Braun glovebox or using standard Schlenk techniques, unless otherwise noted. All of the solvents were reagent grade or better. All non-deuterated solvents were purified according to standard procedures under argon atmosphere. All of the commercially available reagents were used as received. Complexes **[Mn]-1**[1], **[Mn]-2**[2] and **[Mn]-3**[3], compound **1f**[4] were synthesized according to reported procedures. GC analysis was performed on HP 6890 with Hp-5 column, flame ionization detector, and helium as carrier gas. NMR spectra were recorded using Bruker Advance III 300 MHz, Advance III 400 MHz, or Advance 500 MHz spectrometers at 298 K. Chemical shifts were referenced to the residual solvent peaks (^{1}H, ^{13}C) or an external standard of phosphoric acid (85% solution in D_2O) at 0.0 ppm (^{31}P). Chemical shifts are reported in parts per million, and coupling constants (*J)* are reported in hertz. NMR assignments of complex **A** were assisted by ^{13}C-DEPTQ, ^{1}H−13C HSQC, and ^{1}H−^{13}C HMBC data. In the ^{13}C-DEPTQ NMR spectrum, primary and tertiary carbon signals are phased down (d) and secondary and quaternary carbon signals are phased up (u). IR spectra were recorded on a Thermo Scientific Nicolet 6700 FT-IR spectrophotometer as thin films on KBr disks. Electrospray ionization mass spectrometry (ESI-MS) spectra were recorded on a Micromass ZQ V4.1 spectrometer by the Chemical Research Support Unit of the Weizmann Institute of Science.

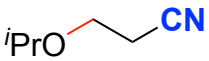
Detailed description of products



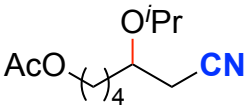
3-Isopropoxybutanenitrile (3a):[4] In a glove box, complex **[Mn]-2** (0.9 mg, 0.0020 mmol) was added to a mixture of crotononitrile (163 µL, 2.0 mmol) or allyl cyanide (161 µL, 2.0 mmol) and isopropanol (2.0 mL, 26.2 mmol). The reaction mixture was stirred at room temperature for 24 h. After quenching by exposure to air, the mixture was analyzed by ^{1}H NMR using mesitylene as an internal standard (96% with crotononitrile, 92% with allyl cyanide). ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.87 – 3.74 (m, 1H), 3.74 – 3.60 (m, 1H), 2.53 – 2.36 (m, 2H), 1.26 (d, J = 6.2 Hz, 3H), 1.19 – 1.12 (m, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 117.68, 70.13, 68.46, 25.54, 22.61, 22.32, 20.69.



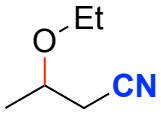
3-Isopropoxypentanenitrile (3b):[4] In a glove box, complex **[Mn]-2** (0.9 mg, 0.0020 mmol) was added to a mixture of 2-pentenenitrile (282 µL of 70% solution, 2.0 mmol) and 3-pentenenitrile (194 µL, 2.0 mmol) and isopropanol (2.0 mL, 26.2 mmol). The reaction mixture was stirred at room temperature for 24 h. After quenching by exposure to air, the mixture was analyzed by ^{1}H NMR using mesitylene as an internal standard (83% with 2-pentenenitrile, 66% with 3-pentenenitrile). ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.70 (hept, J = 6.1 Hz, 1H, OC**H**$(CH_3)_2$), 3.55 (p, J = 6.0 Hz, 1H), 2.46 (dd, J = 5.8, 1.7 Hz, 2H), 1.65 – 1.55 (m, 2H), 1.19 (d, J = 6.1 Hz, 3H), 1.15 (d, J = 6.1 Hz, 3H), 0.94 (t, J = 7.4 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 117.88, 73.80, 70.80, 27.78, 23.36, 22.73, 22.32, 9.47.



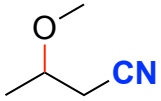
3-Isopropoxypropanenitrile (3c):[4] In a glove box, complex **[Mn]-2** (0.9 mg, 0.0020 mmol) was added to a mixture of 3-pentenenitrile (131 µL, 2.0 mmol) and isopropanol (2.0 mL, 26.2 mmol). The reaction mixture was stirred at room temperature for 24 h. After quenching by exposure to air, the mixture was analyzed by ^{1}H NMR using mesitylene as an internal standard (quantitative). ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.79 – 3.48 (m, 3H), 2.56 (t, J = 6.4 Hz, 2H), 1.17 (d, J = 6.1 Hz, 6H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 117.98, 72.28, 62.67, 21.84, 19.21.



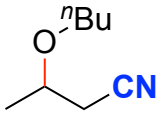
6-Cyano-5-isopropoxyhexyl acetate (3d): In a glove box, complex **[Mn]-2** (2.2 mg, 0.0050 mmol) was added to a mixture of 3-pentenenitrile (167 mg, 1.0 mmol) and isopropanol (2.0 mL, 26.2 mmol). The reaction mixture was stirred at room temperature for 24 h. After quenching by exposure to air, the mixture was analyzed by ^{1}H NMR using mesitylene as an internal standard (71%). ^{1}H NMR (300 MHz, $CDCl_3$) δ 4.06 (t, J = 6.4 Hz, 2H), 3.76 – 3.51 (m, 2H), 2.53 – 2.44 (m, 2H), 2.04 (s, 3H), 1.71 – 1.45 (m, 7H), 1.19 (d, J = 6.2 Hz, 3H), 1.14 (d, J = 6.0 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ 171.06, 117.65, 72.35, 70.83, 64.10, 34.59, 28.39, 23.65, 22.84, 22.18, 21.68. The isolated product contains some starting material. HRMS (ESI) calculated for $C_{12}H_{21}NO_3$ $[M+K]^+$: 266.1159; found: 266.1170.



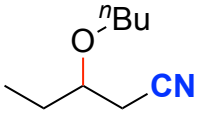
3-Ethoxybutanenitrile (3e):[5] In a glove box, complex **[Mn]-2** (0.9 mg, 0.0020 mmol) was added to a mixture of crotononitrile (163 μL, 2.0 mmol) and ethanol (2.0 mL, 34 mmol). The reaction mixture was stirred at room temperature for 24 h. After quenching by exposure to air, the mixture was analyzed by ^{1}H NMR using mesitylene as an internal standard (quantitative). ^{1}H NMR (500 MHz, $CDCl_3$) δ 3.80 – 3.62 (m, 1H), 3.62 – 3.41 (m, 2H), 2.48 (d, J = 5.7 Hz, 2H), 1.27 (d, J = 6.2 Hz, 3H), 1.23 – 1.13 (m, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 117.60, 70.79, 64.43, 24.92, 19.78, 15.29.



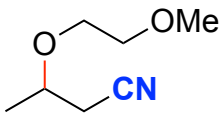
3-Methoxybutanenitrile (3p):[5] In a glove box, complex **[Mn]-2** (0.9 mg, 0.0020 mmol) was added to a mixture of crotononitrile (163 μL, 2.0 mmol) and methanol (2.0 mL, 49 mmol). The reaction mixture was stirred at room temperature for 24 h. After quenching by exposure to air, the mixture was analyzed by ^{1}H NMR using mesitylene as an internal standard (84%). ^{1}H NMR (300 MHz, $CDCl_3$) δ 3.72 – 3.52 (m, 1H), 3.36 (s, 3H), 2.50 (d, J = 5.6 Hz, 2H), 1.29 (d, J = 5.9 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ 117.53, 72.63, 56.73, 24.73, 19.23.



3-Butoxybutanenitrile (3f):[5] In a glove box, complex **[Mn]-2** (0.9 mg, 0.0020 mmol) was added to a mixture of crotononitrile (163 µL, 2.0 mmol) and *n*-butanol (2.0 mL, 22 mmol). The reaction mixture was stirred at room temperature for 24 h. After quenching by exposure to air, the mixture was analyzed by ^{1}H NMR using mesitylene as an internal standard (quantitative). ^{1}H NMR (500 MHz, $CDCl_3$) δ 3.82 – 3.59 (m, 1H), 3.59 – 3.31 (m, 2H), 2.59 – 2.40 (m, 2H), 1.65 – 1.46 (m, 2H), 1.46 – 1.21 (m, 5H), 1.05 – 0.77 (m, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 117.62, 71.10, 69.00, 31.90, 24.95, 19.80, 19.26, 13.84.

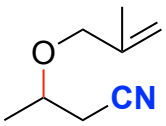


3-Butoxypentanenitrile (3g): In a glove box, complex **[Mn]-2** (0.9 mg, 0.0020 mmol) was added to a mixture of 2-pentenenitrile (282 µL of 70% solution, 2.0 mmol) and *n*-butanol (2.0 mL, 22 mmol). The reaction mixture was stirred at room temperature for 24 h. After quenching by exposure to air, all volatile compounds were removed under vaccum to yield the final product as a pale-yellow oil (284.8 mg, 92%). **Gram scale reaction:** In a glove box, complex **[Mn]-2** (4.3 mg, 0.010 mmol) was added to a mixture of 2-pentenenitrile (1.4 mL of 70% solution, 10 mmol) and *n*-butanol (5.0 mL, 55 mmol). The reaction mixture was stirred at room temperature for 48 h. After quenching by exposure to air, all volatile components were removed under vaccum to yield the final product as a pale-yellow oil (1.34 g, 86%). ^{1}H NMR (300 MHz, $CDCl_3$) δ 3.63 – 3.37 (m, 3H), 2.50 (d, J = 5.7 Hz, 2H), 1.71 – 1.49 (m, 4H), 1.48 – 1.30 (m, 2H), 1.05 – 0.82 (m, 6H). ^{13}C NMR (75 MHz, $CDCl_3$) δ 117.74, 76.33, 69.69, 31.92, 27.06, 22.45, 19.23, 13.78, 9.27. HRMS (ESI) calculated for $C_9H_{17}NO$ $[M+H]^+$: 156.1388; found: 156.1382.

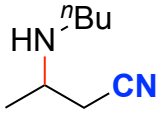


3-(2-Methoxyethoxy)butanenitrile (3h): In a glove box, complex **[Mn]-2** (0.9 mg, 0.0020 mmol) was added to a mixture of crotononitrile (163 µL, 2.0 mmol) and *n*-

butanol (2.0 mL, 25 mmol). The reaction mixture was stirred at room temperature for 24 h. After quenching by exposure to air, the mixture was analyzed by ^{1}H NMR using mesitylene as an internal standard (85%). ^{1}H NMR (500 MHz, $CDCl_3$) δ 3.81 – 3.69 (m, 1H), 3.63 (ddd, J = 9.9, 5.6, 4.0 Hz, 1H), 3.58 – 3.52 (m, 1H), 3.52 – 3.44 (m, 2H), 3.33 (s, 2H), 2.55 – 2.43 (m, 2H), 1.27 (d, J = 6.2 Hz, 3H). ^{13}C NMR (126 MHz, $CDCl_3$) δ 117.53, 71.99, 71.73, 68.48, 59.03, 24.88, 19.65. HRMS (ESI) calculated for $C_7H_{13}NO_2$ $[M+H]^+$: 144.1025; found: 144.1030.

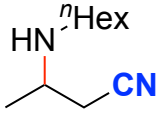


3-((2-Methylallyl)oxy)butanenitrile (3i): In a glove box, complex **[Mn]-2** (4.3 mg, 0.010 mmol) was added to a mixture of crotononitrile (163 µL, 2.0 mmol) and *n*-butanol (2.0 mL, 22 mmol). The reaction mixture was stirred at room temperature for 24 h. After quenching by exposure to air, the mixture was analyzed by ^{1}H NMR using mesitylene as an internal standard (97%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 5.15 – 4.82 (m, 2H), 4.11 – 3.58 (m, 3H), 2.68 – 2.38 (m, 2H), 1.90 – 1.61 (m, 3H), 1.46 – 1.17 (m, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 141.77, 117.52, 112.79, 73.01, 70.30, 25.01, 19.65, 19.46. HRMS (ESI) calculated for $C_8H_{13}NO$ $[M+H]^+$: 140.1075; found: 140.1079.

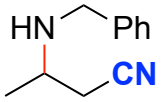


3-(Butylamino)butanenitrile (3j): In a glove box, complex **[Mn]-2** (0.9 mg, 0.0020 mmol) was added to a mixture of crotononitrile (163 µL, 2.0 mmol) and *n*-butylamine (2.0 mL, 20 mmol). The reaction mixture was stirred at room temperature for 24 h. After quenching by exposure to air, all volatile components were removed under vacuum to yield the final product as a colorless oil (214.0 mg, 76%). **Gram Scale reaction:** In a glove box, complex **[Mn]-2** (4.3 mg, 0.010 mmol) was added to a mixture of crotononitrile (0.82 mL, 10 mmol) and *n*-butylamine (5.0 mL, 50 mmol). The reaction mixture was stirred at room temperature for 48 h. After quenching by exposure to air, all volatile components were removed under vacuum to yield 0.87 g (62%) the final product. ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.07 – 2.93 (m, 1H), 2.58 (t, J = 7.0 Hz, 2H), 2.42 (d, J = 5.5 Hz, 2H), 1.51 – 1.40 (m, 2H), 1.39 – 1.27 (m, 2H), 1.21 (d, J = 6.3 Hz, 3H), 0.98 (bs, 1H), 0.89 (t, J = 7.2 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$)

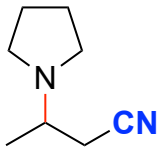
δ 118.09, 50.10, 46.83, 32.35, 24.94, 20.66, 20.37, 13.92. HRMS (ESI) calculated for $C_8H_{16}N_2$ $[M+H]^+$: 141.1392; found: 141.1388.



3-(Hexylamino)butanenitrile (3k): In a glove box, complex **[Mn]-2** (0.9 mg, 0.002 mmol) was added to a mixture of crotononitrile (163 µL, 2.0 mmol) and *n*-butylamine (2.0 mL, 15 mmol). The reaction mixture was stirred at room temperature for 24 h. After quenching by exposure to air, all volatile components were removed under vacuum to yield the final product as a colorless oil (210.0 mg, 63%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.07 – 2.95 (m, 1H), 2.63 – 2.53 (m, 2H), 2.43 (d, J = 5.6 Hz, 2H), 1.51 – 1.40 (m, 2H), 1.36 – 1.25 (m, 6H), 1.22 (d, J = 6.4 Hz, 3H), 0.98 – 0.91 (m, 1H), 0.87 (t, J = 6.6 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 118.03, 50.05, 47.14, 31.64, 30.17, 26.88, 24.88, 22.52, 20.61, 13.96. HRMS (ESI) calculated for $C_{10}H_{20}N_2$ $[M+H]^+$: 169.1705; found: 169.1704.

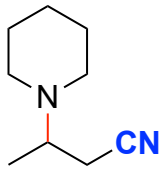


3-(Benzylamino)butanenitrile (3l):[4] In a glove box, complex **[Mn]-2** (0.9 mg, 0.0020 mmol) was added to a mixture of crotononitrile (163 µL, 2.0 mmol) and benzylamine (1.0 mL, 9.2 mmol). The reaction mixture was stirred at room temperature for 24 h. After quenching by exposure to air, the mixture was analyzed by ^{1}H NMR using mesitylene as an internal standard (91%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28 – 7.23 (m, 4H), 7.21 – 7.15 (m, 1H), 3.73 (s, 2H), 3.04 – 2.93 (m, 1H), 2.44 – 2.30 (m, 2H), 1.40 (bs, 1H), 1.18 (d, J = 6.4 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 139.59, 128.46, 127.92, 127.14, 117.95, 51.05, 49.22, 24.96, 20.48.

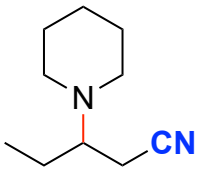


3-(Pyrrolidin-1-yl)butanenitrile (3m):[6] In a glove box, complex **[Mn]-2** (0.9 mg, 0.0020 mmol) was added to a mixture of crotononitrile (163 µL, 2.0 mmol) and pyrrolidine (2.0 mL, 24 mmol). The reaction mixture was stirred at room temperature for 24 h. After quenching by exposure to air, all volatile components were removed under vacuum to yield the final product as a pale-yellow oil (210.0 mg, ~ 100%). ^{1}H

NMR (400 MHz, $CDCl_3$) δ 2.69 – 2.59 (m, 1H), 2.58 – 2.49 (m, 5H), 2.39 (dd, J = 16.7, 7.6 Hz, 1H), 1.80 – 1.69 (m, 4H), 1.24 (d, J = 6.4 Hz, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 118.39, 55.43, 51.09, 23.90, 23.49, 18.89.



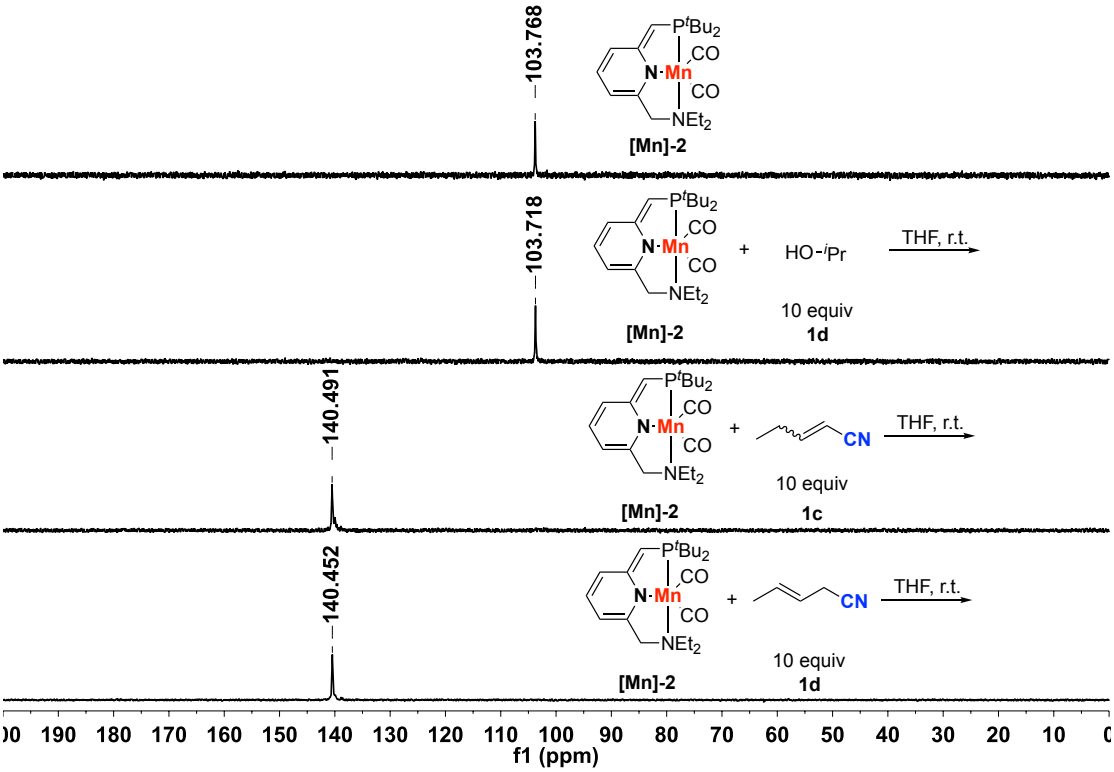
3-(Piperidin-1-yl)butanenitrile (3n):[7] In a glove box, complex **[Mn]-2** (0.9 mg, 0.0020 mmol) was added to a mixture of crotononitrile (163 μL, 2.0 mmol) or allyl cyamide (161 μL, 2.0 mmol) and piperidine (2.0 mL, 20 mmol). The reaction mixture was stirred at room temperature for 24 h. After quenching by exposure to air, all volatile components were removed under vacuum to yield the final product as a pale-yellow oil (310.0 mg, ~ 100%). ^{1}H NMR (300 MHz, $CDCl_3$) δ 3.05 – 2.88 (m, 1H), 2.57 – 2.21 (m, 6H), 1.62 – 1.47 (m, 4H), 1.47 – 1.35 (m, 2H), 1.17 (d, J = 6.7 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ 119.07, 56.73, 49.37, 26.15, 24.53, 20.51, 15.40.



3-(Piperidin-1-yl)pentanenitrile (3o): In a glove box, complex **[Mn]-2** (0.9 mg, 0.0020 mmol) was added to a mixture of 2-pentenenitrile (282 μL of 70% solution, 2.0 mmol) and piperidine (2.0 mL, 20 mmol). The reaction mixture was stirred at room temperature for 24 h. After quenching by exposure to air, all volatile components were removed under vacuum to yield the final product as a pale-yellow oil (332.4 mg, ~ 100%). ^{1}H NMR (300 MHz, $CDCl_3$) δ 2.73 (p, J = 6.7 Hz, 1H), 2.61 – 2.24 (m, 6H), 1.62 – 1.47 (m, 6H), 1.47 – 1.35 (m, 2H), 0.94 (t, J = 7.4 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ 119.53, 63.09, 49.34, 26.28, 24.68, 24.02, 16.94, 11.17. HRMS (ESI) calculated for $C_{10}H_{18}N_2$ $[M+H]^+$: 167.1548; found: 167.1550.

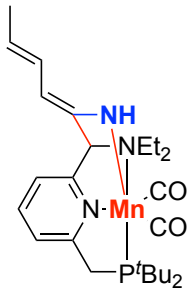
Figure S1

$^{31}P\{^{1}H\}$ NMR spectra of the reactions between [Mn]-2 and substrates



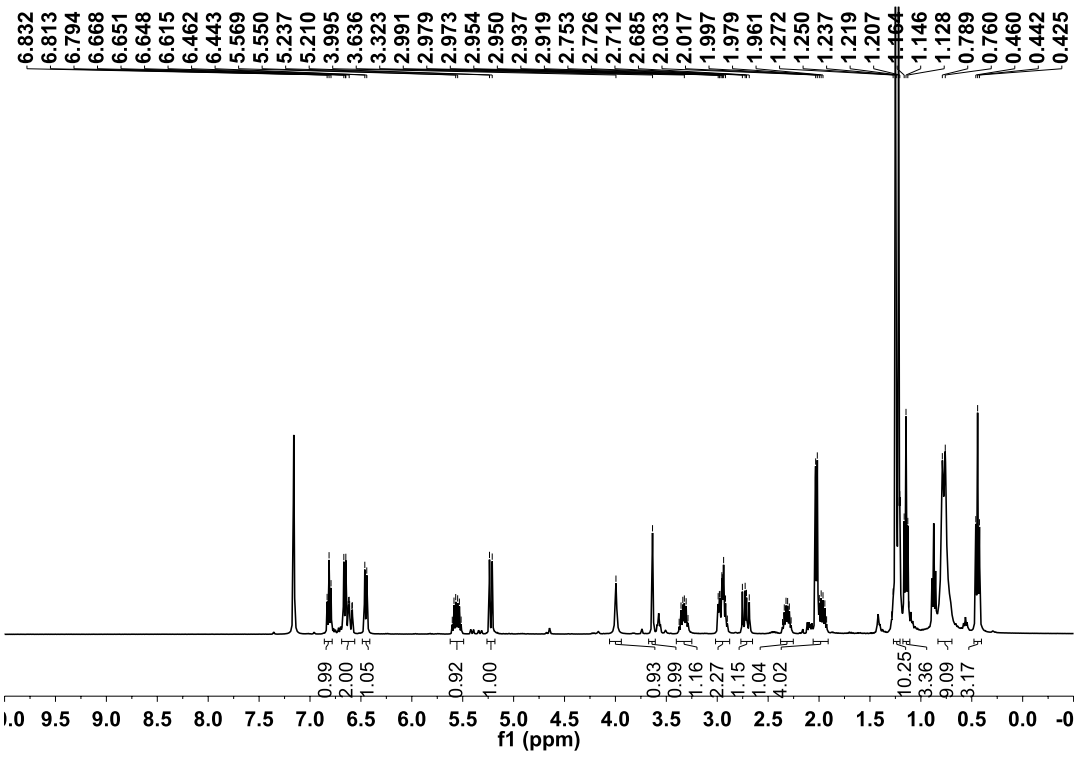
Reaction conditions: **[Mn]-2** (0.010 mmol), substrate (0.10 mmol), THF (0.50 mL), r.t., 5 h.

Synthesis and characterization of complex A

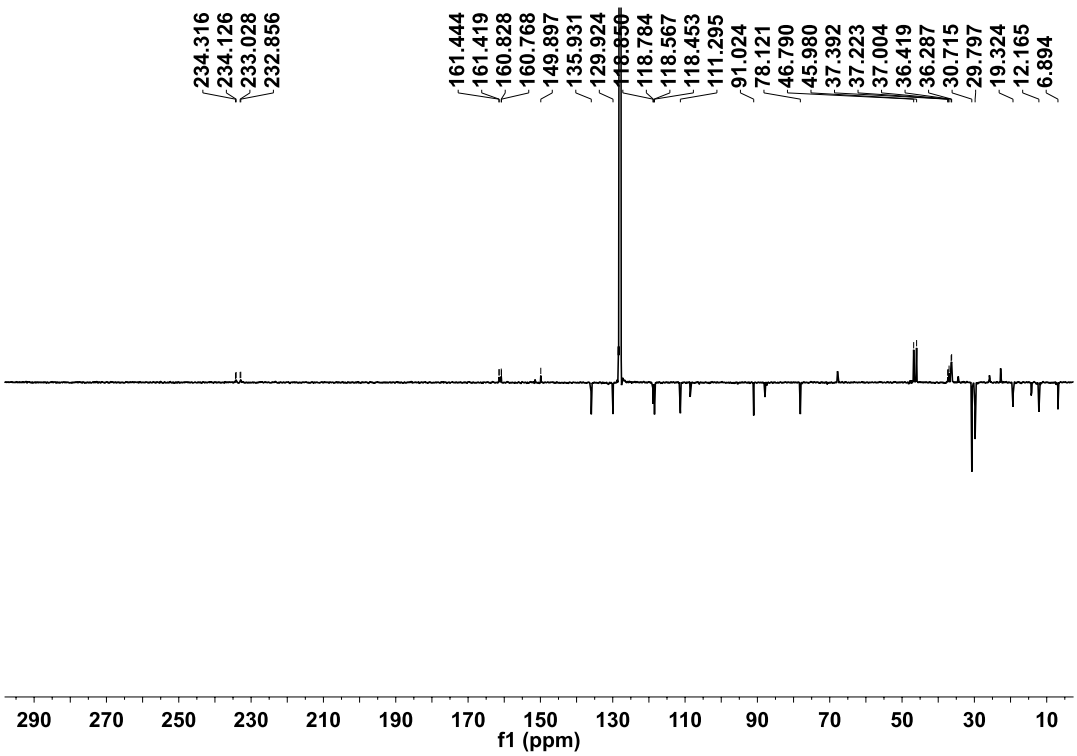


***cis*-[Mn(PNN-NH-C=CH-CH=CH-CH$_3$)(CO)$_2$] (Complex A):** In a glove box, 3-pentenenitrile (48 µL, 0.50 mmol) was added to a solution of complex **[Mn]-2** (21.6 mg, 0.050 mmol) in THF (1.0 mL). The reaction mixture was allowed to stir at room temperature for 5 h. Then 5.0 mL of pentane was added and the solution was kept at -38 °C in a freezer overnight to form orange crystals. The crystals were isolated by decantation and dried under vacuum. (14.4 mg, 56% yield). ^{31}P{^{1}H} NMR (162 MHz, C_6D_6) δ 140.49. ^{1}H NMR (400 MHz, C_6D_6) δ 6.81 (t, $^{3}J_{HH}$ = 7.7 Hz, 1H, pyridyl C**H**), 6.69 – 6.56 (m, 2H, pyridyl C**H** & NH-C=CH-C**H**=CH), 6.45 (d, $^{3}J_{HH}$ = 7.7 Hz, 1H, pyridyl C**H**), 5.56 (dq, $^{3}J_{HH}$ = 13.5, 6.6 Hz, 1H, NH-C=CH-CH=C**H**), 5.22 (d, $^{3}J_{HH}$ = 10.7 Hz, 1H, NH-C=**C**H-CH=CH), 3.99 (s, 1H, N**H**-C=CH-CH=CH), 3.64 (s, 1H, C**H**NEt$_2$), 3.33 (dq, $^{1}J_{HH}$ = 14.3 Hz, $^{3}J_{HH}$ = 7.3 Hz, 1H, N(C**H**$_2$CH$_3$)$_2$), 3.02 – 2.88 (m, 2H, C**H**$_2$P & N(C**H**$_2$CH$_3$)$_2$), 2.72 (dd, $^{1}J_{HH}$ = 16.2 Hz, $^{2}J_{PH}$ = 10.8 Hz, 1H, C**H**$_2$P), 2.32 (dq, $^{1}J_{HH}$ = 13.7 Hz, $^{3}J_{HH}$ = 6.9 Hz, 1H, N(C**H**$_2$CH$_3$)$_2$), 2.06 – 1.91 (m, 4H, NH-C=CH-CH=CH-C**H**$_3$ & N(C**H**$_2$CH$_3$)$_2$), 1.27 – 1.20 (m, 9H, C(C**H**$_3$)$_3$), 1.15 (t, $^{3}J_{HH}$ = 7.2 Hz, 3H, N(CH$_2$C**H**$_3$)$_2$), 0.83 – 0.69 (m, 9H, C(C**H**$_3$)$_3$), 0.44 (t, $^{3}J_{HH}$ = 7.1 Hz, 3H, N(CH$_2$C**H**$_3$)$_2$). ^{13}C{^{1}H} NMR (101 MHz, C_6D_6) δ 234.22 (d, $^{2}J_{P\text{-}C}$ = 19.2 Hz, **C**O), 232.94 (d, $^{2}J_{P\text{-}C}$ = 17.4 Hz, **C**O), 161.43 (d, $^{4}J_{P\text{-}C}$ = 2.5 Hz, pyridyl **C**), 160.80 d, $^{2}J_{P\text{-}C}$ = 6.1 Hz, pyridyl **C**), 149.90 (s, NH-**C**=CH-CH=CH), 135.93 (s, pyridyl **C**H), 129.92 (s, NH-C=CH-**C**H=CH), 118.82 (d, $^{3}J_{P\text{-}C}$ = 6.7 Hz, pyridyl **C**H), 118.45 (s, pyridyl **C**H), 111.30 (s, NH-C=CH-CH=**C**H), 91.02 (s, NH-C=**C**H-CH=CH), 78.12 (s, **C**HNEt$_2$), 46.79 (s, N(**C**H$_2$CH$_3$)$_2$), 45.98 (s, N(**C**H$_2$CH$_3$)$_2$), 37.31 (d, $^{1}J_{P\text{-}C}$ = 17.1 Hz, **C**(CH$_3$)$_3$), 37.00 (s, **C**(CH$_3$)$_3$), 36.35 (d, $^{1}J_{P\text{-}C}$ = 13.3 Hz, **C**H$_2$P), 30.71 (s, C(**C**H$_3$)$_3$), 29.80 (s, C(**C**H$_3$)$_3$), 19.32 (s, NH-C=CH-CH=CH-**C**H$_3$), 12.17 (s, N(CH$_2$**C**H$_3$)$_2$), 6.89 (s, N(CH$_2$**C**H$_3$)$_2$). Decomposition of complex **A** was observed during the measurement process. IR (KBr): ν_{CO} = 1904 cm^{-1}, 1825 cm^{-1} (1:1 ratio). HRMS (ESI) calculated for $C_{26}H_{41}N_3O_2PMn$ $[M+H]^+$: 514.2395; found: 514.2389.

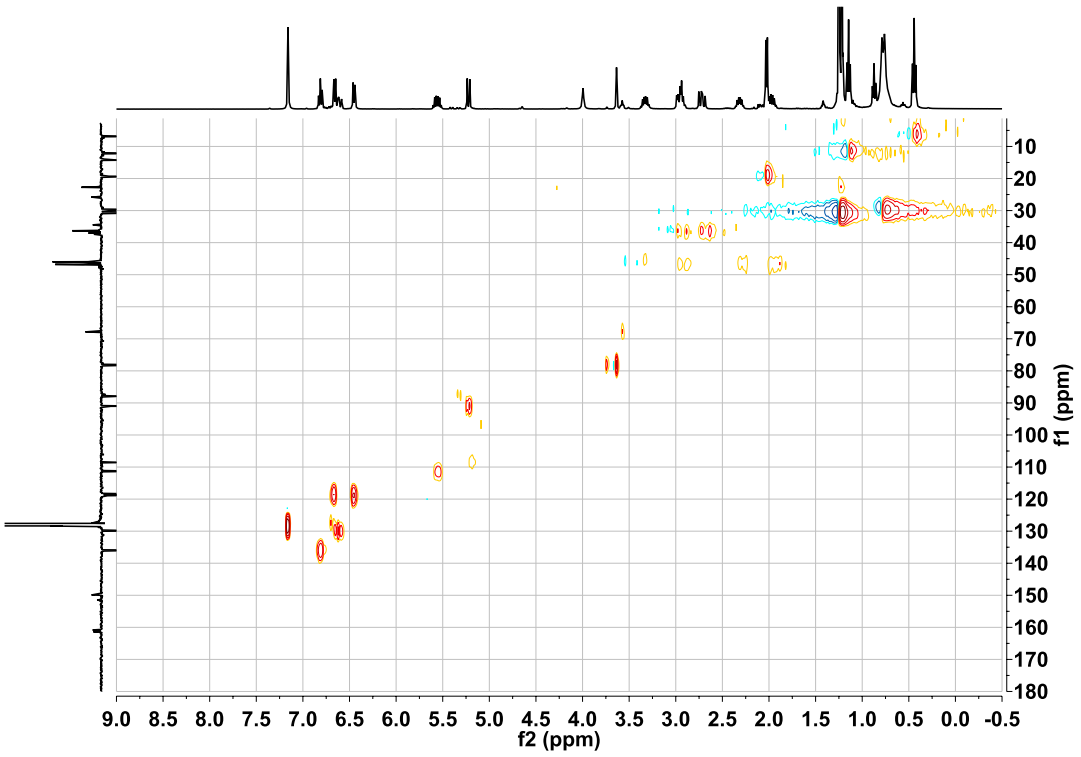
^{1}H NMR



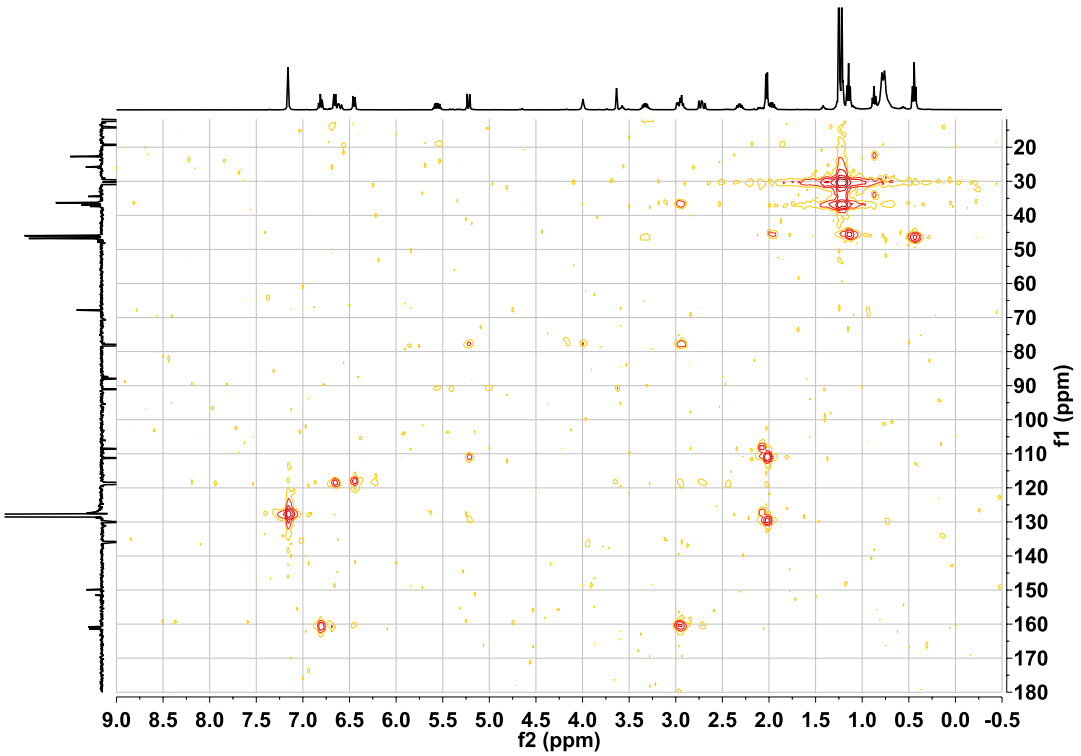
^{13}C-DEPTQ NMR



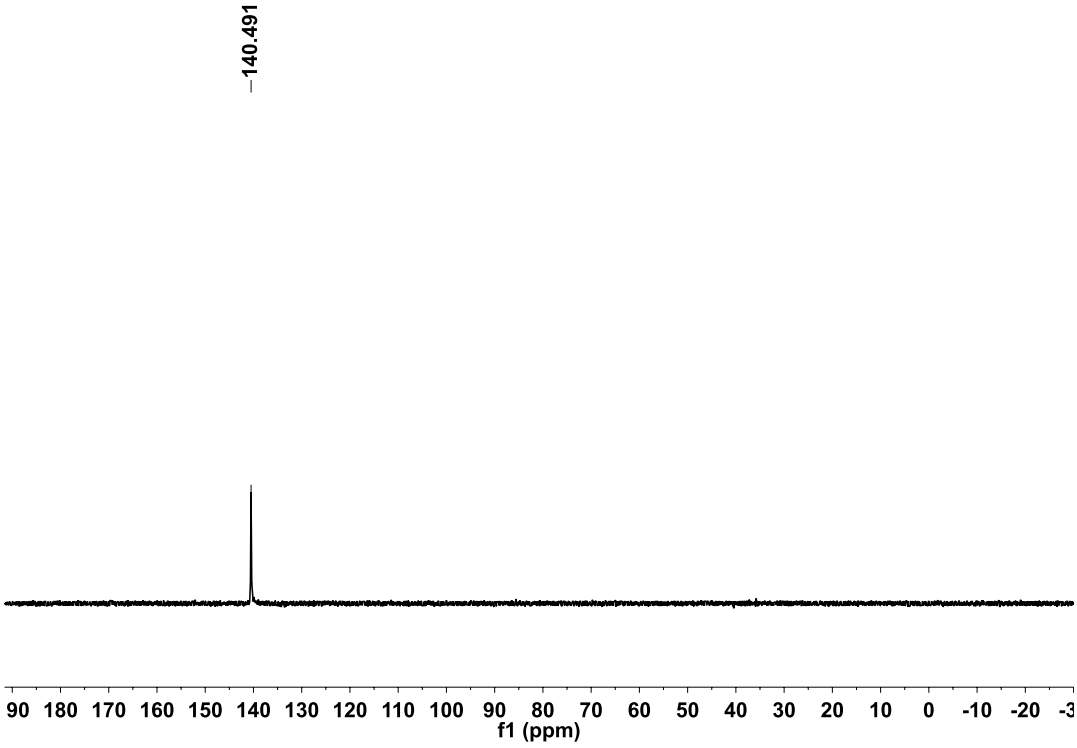
^{1}H-^{13}C HSQC



^{1}H-^{13}C HMBC



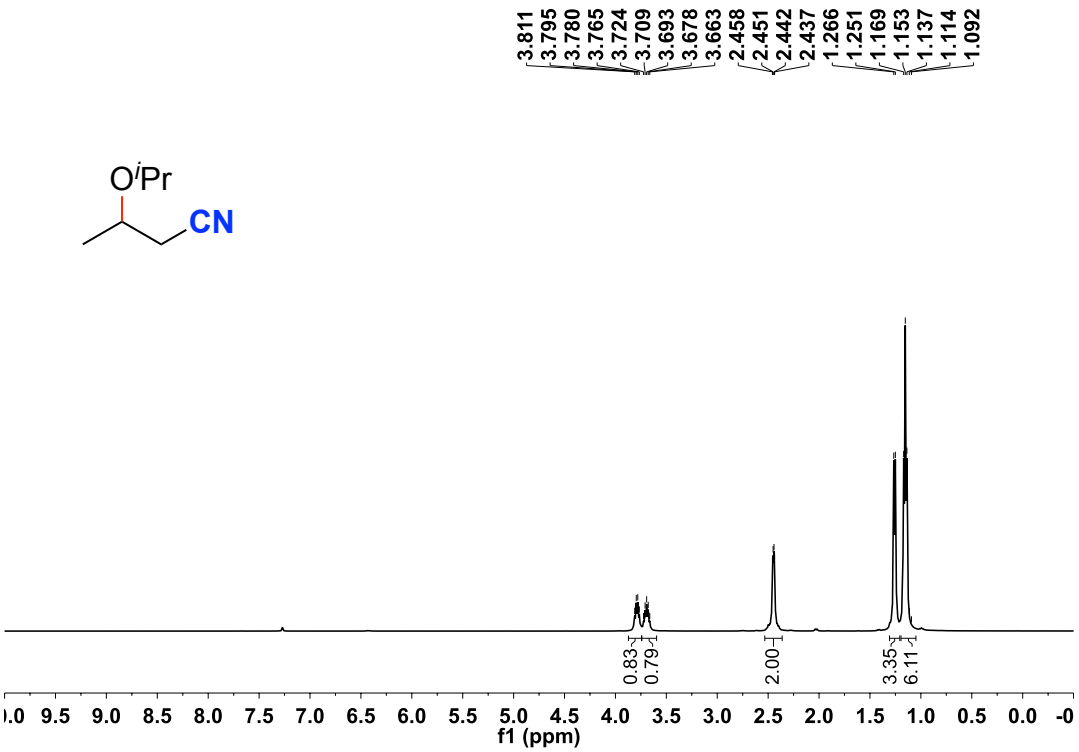
$^{31}P\{^{1}H\}$ NMR


140.491
90 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20 -3
f1 (ppm)

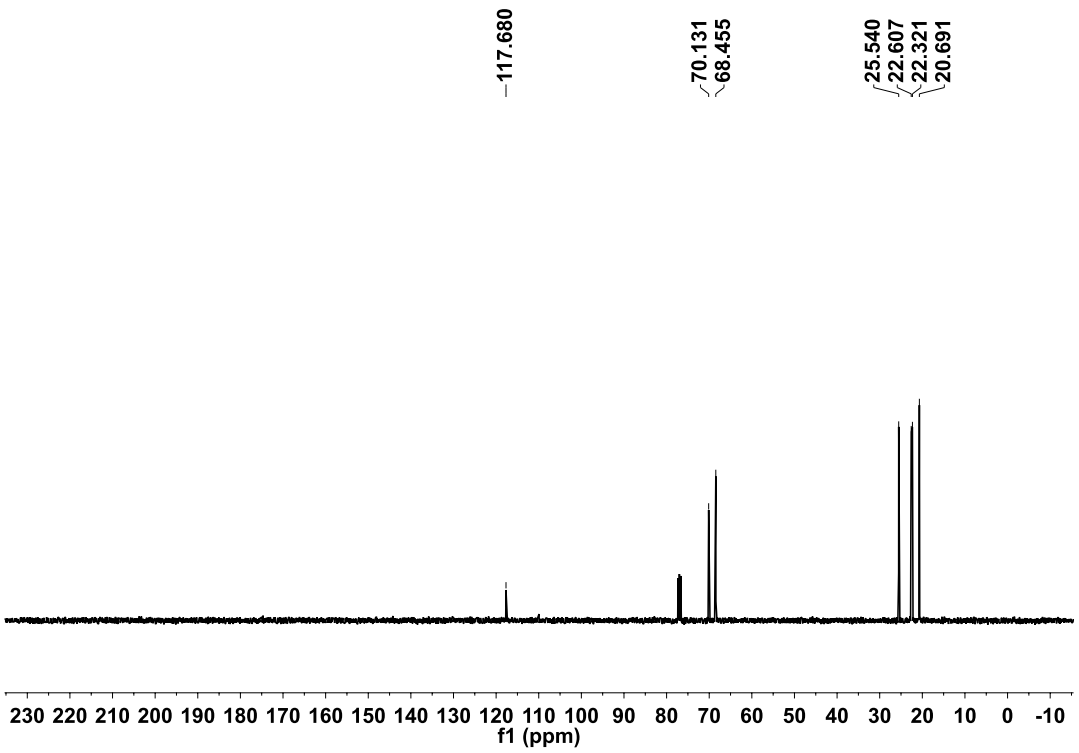
Copies of NMR Spectra

3a

^{1}H NMR

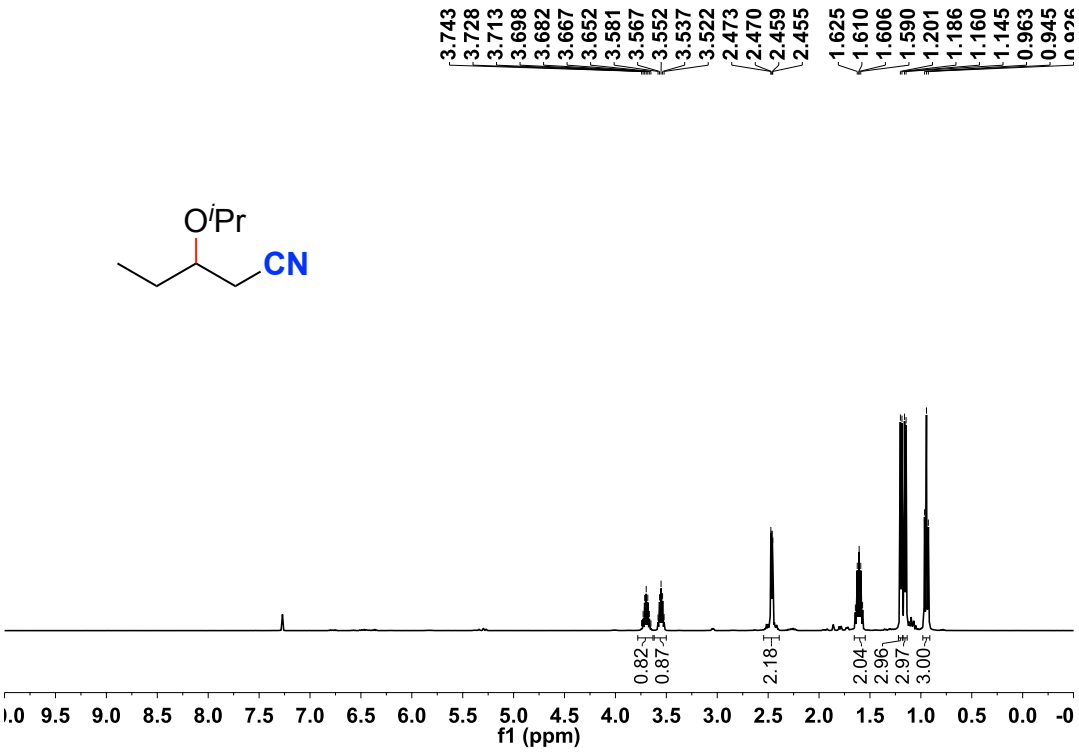


^{13}C NMR

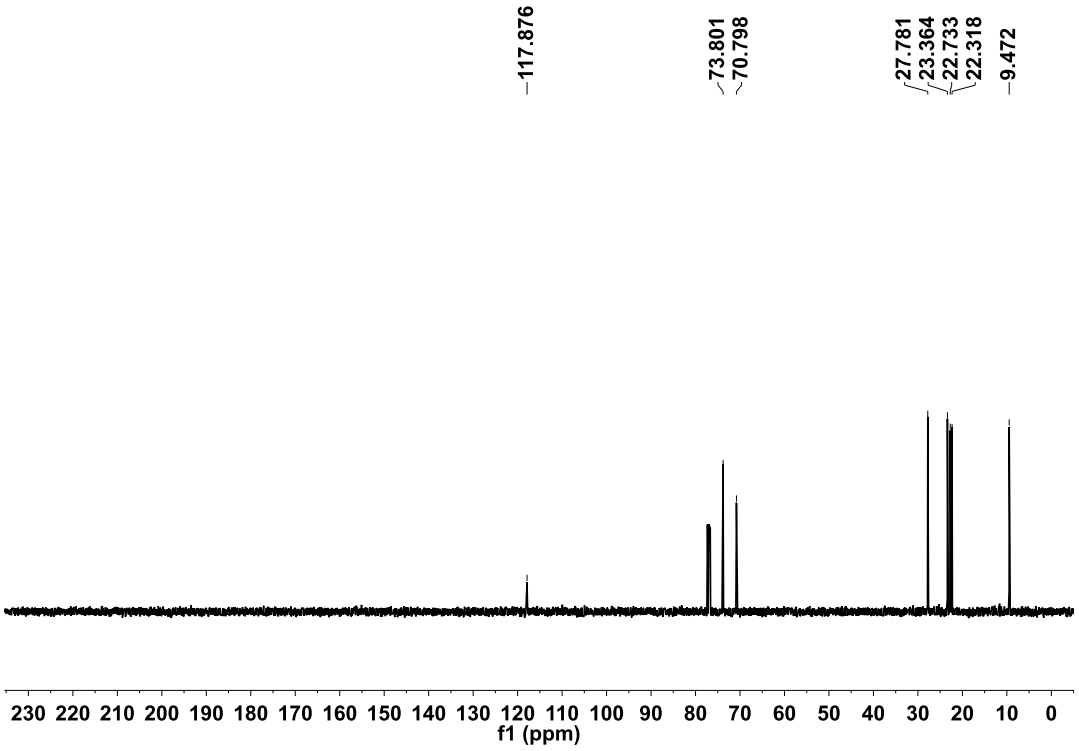


3b

^{1}H NMR

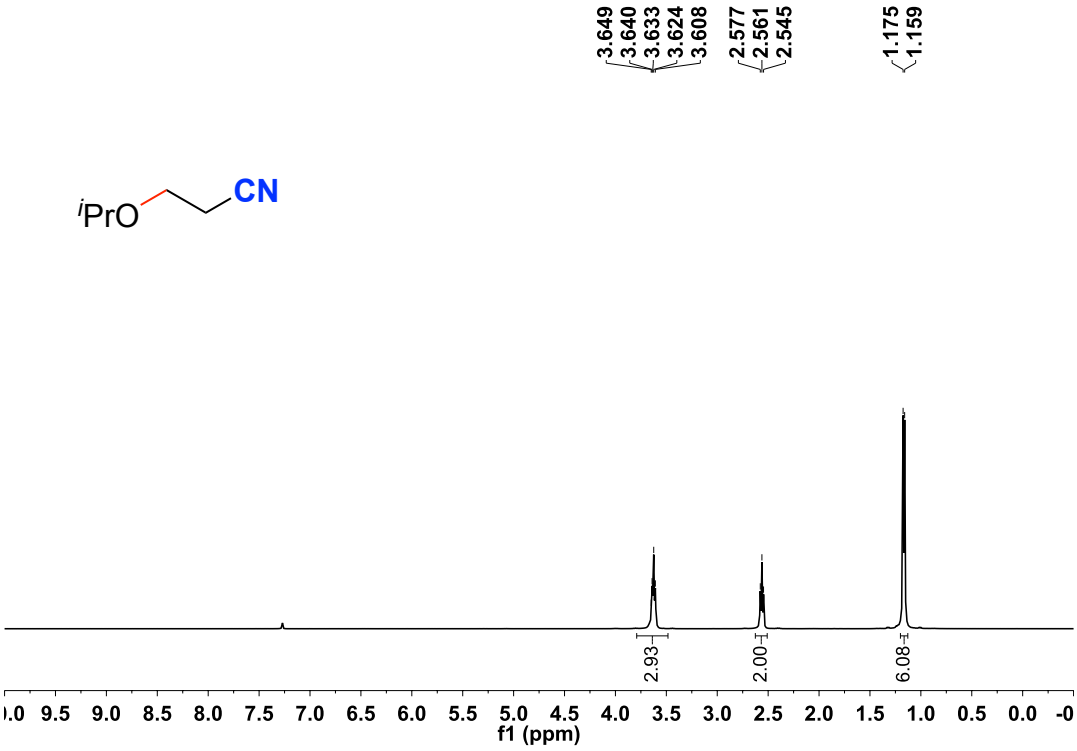


^{13}C NMR

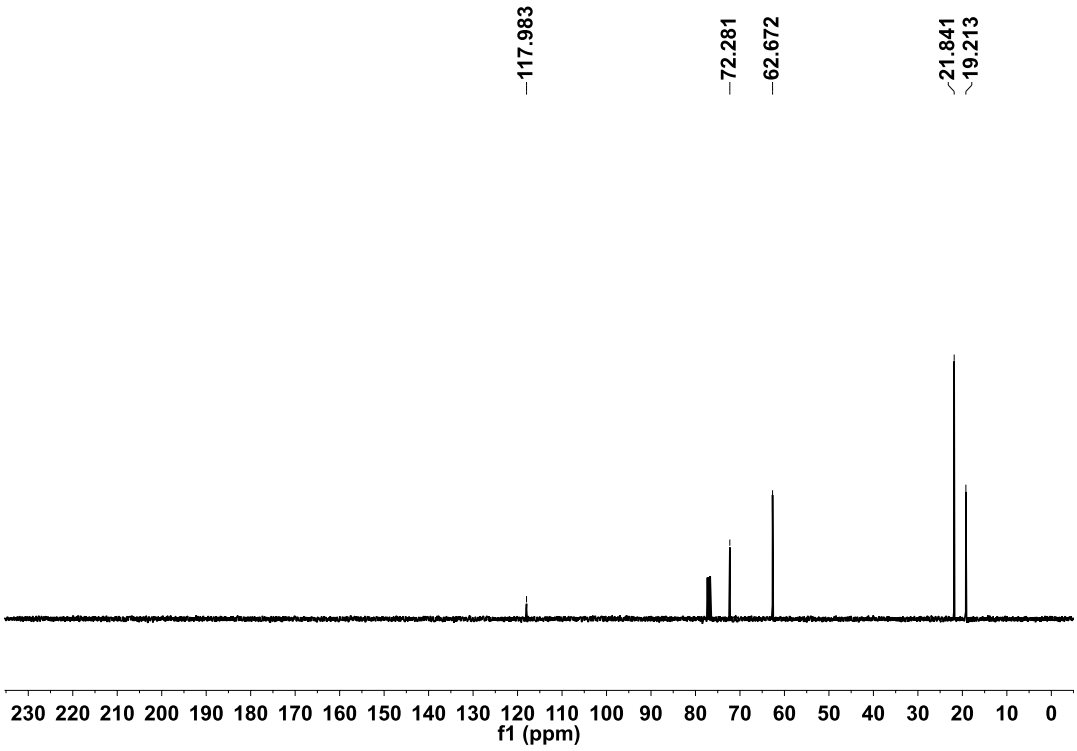


3c

^{1}H NMR

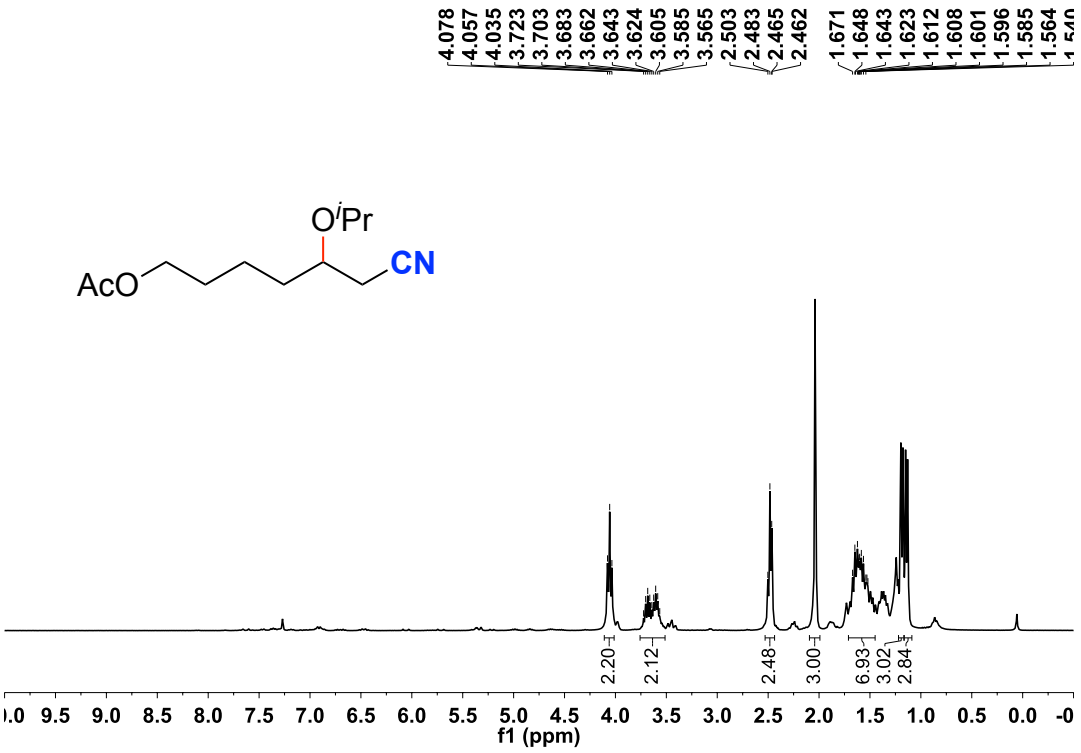


^{13}C NMR

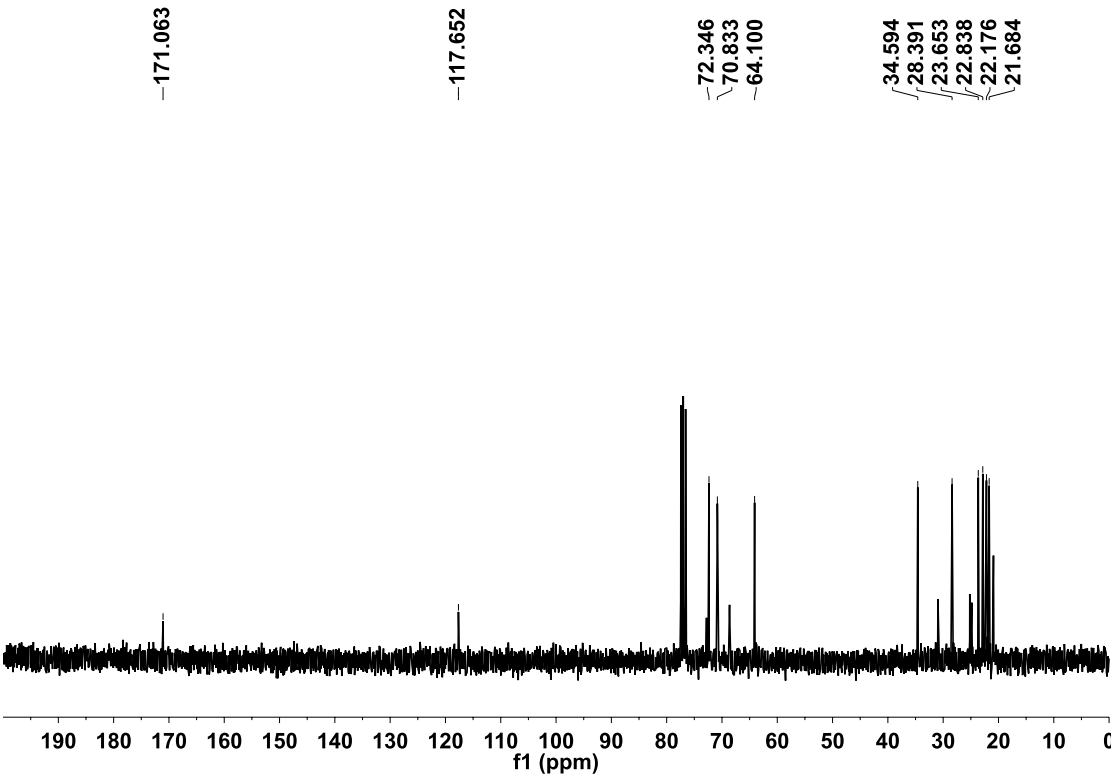


3d

^{1}H NMR



^{13}C NMR



3e

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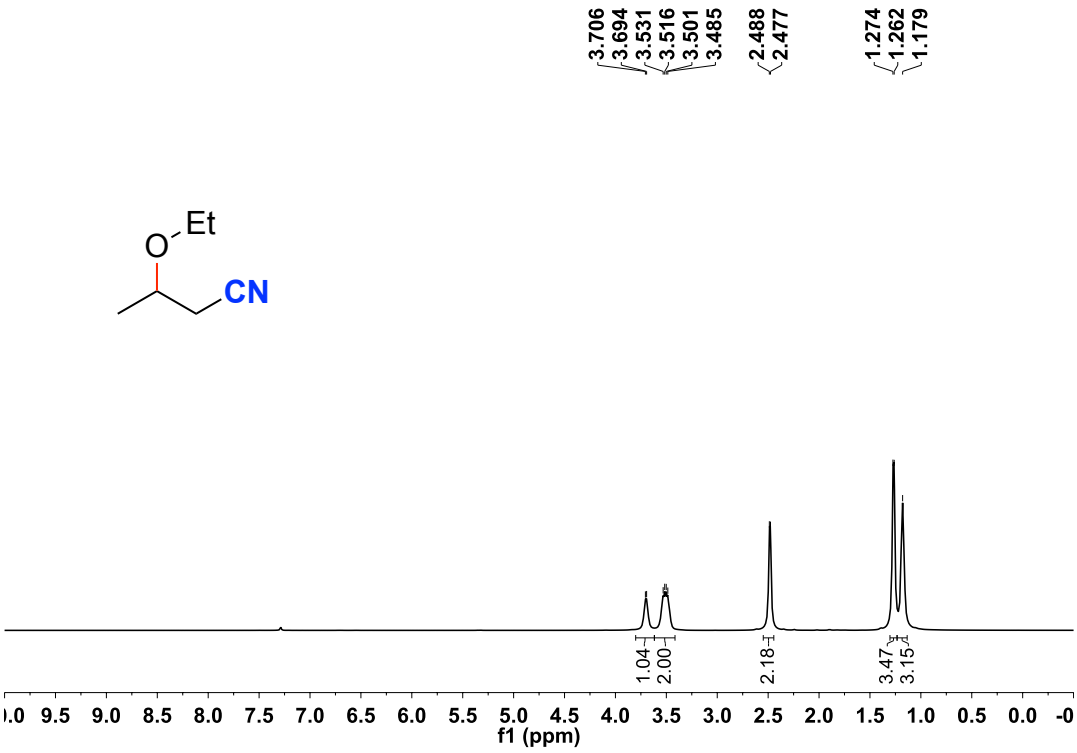
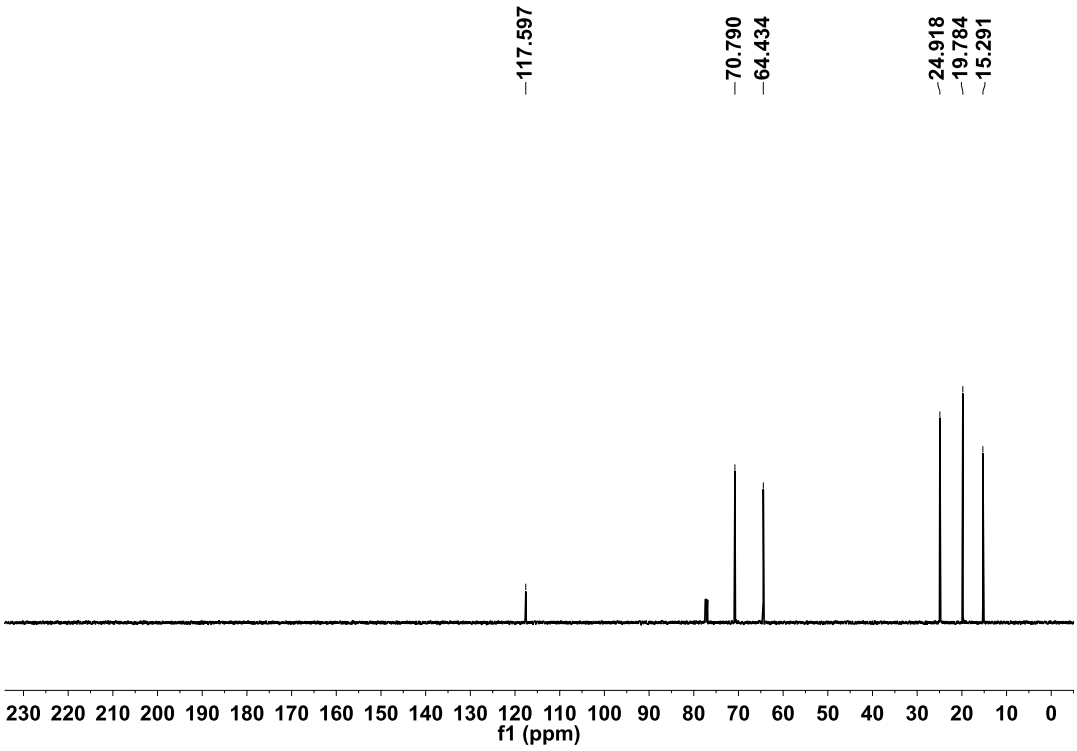
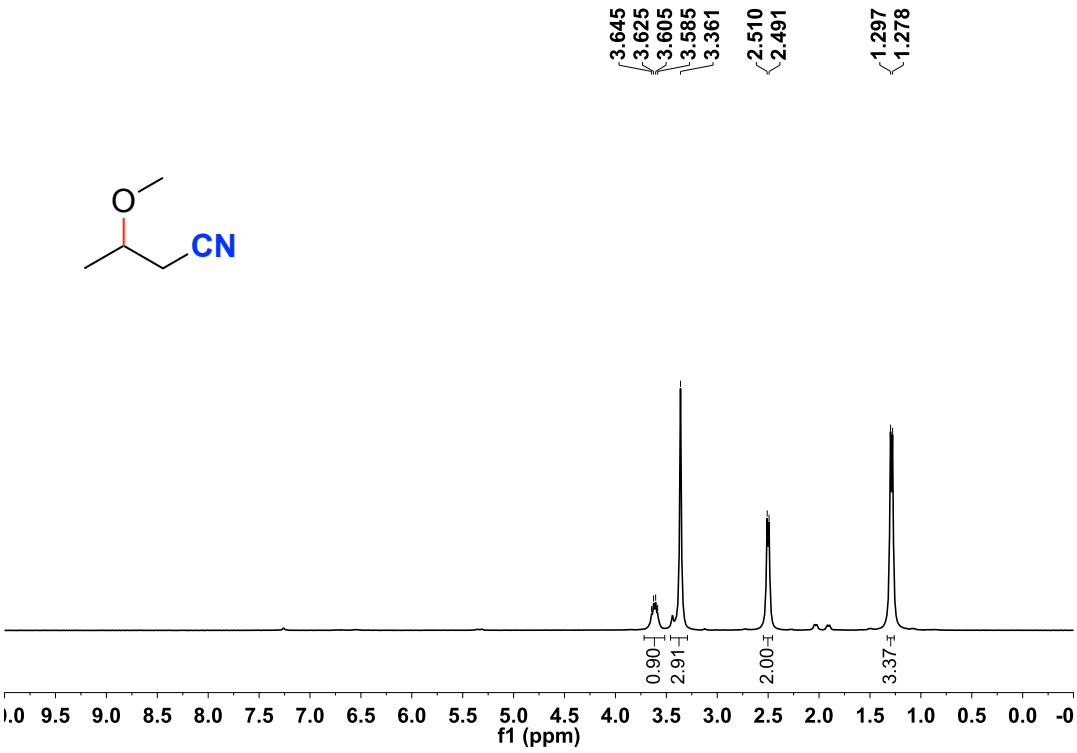


^{13}C NMR

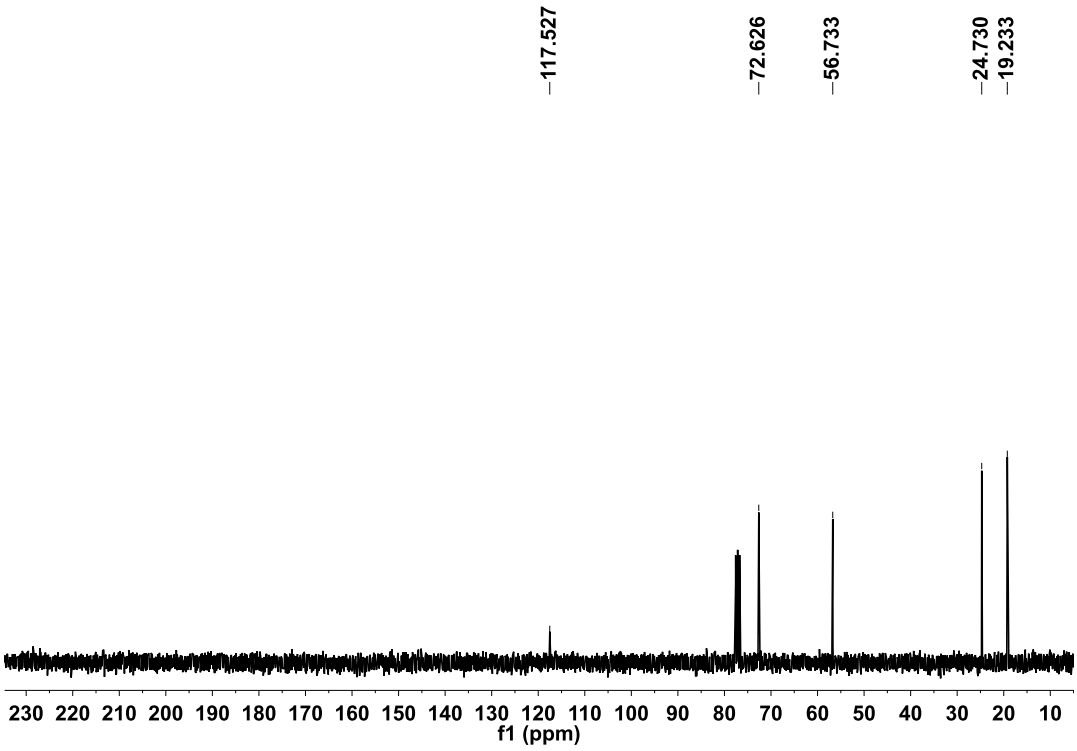


3p

^{1}H NMR

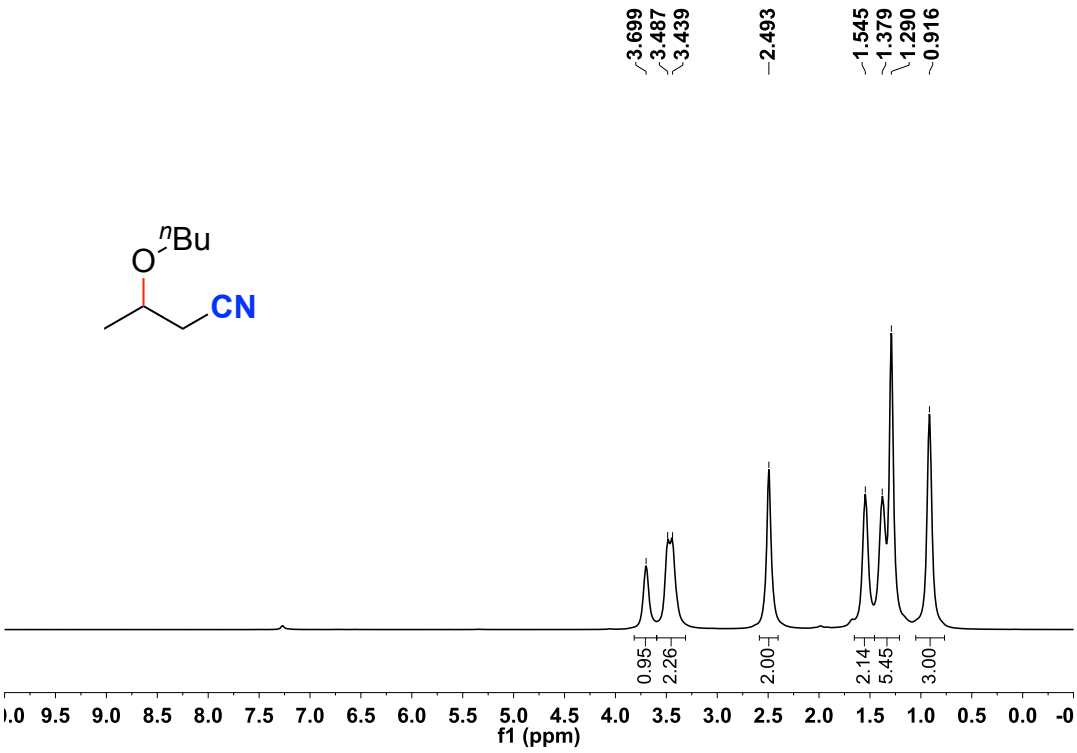


^{13}C NMR

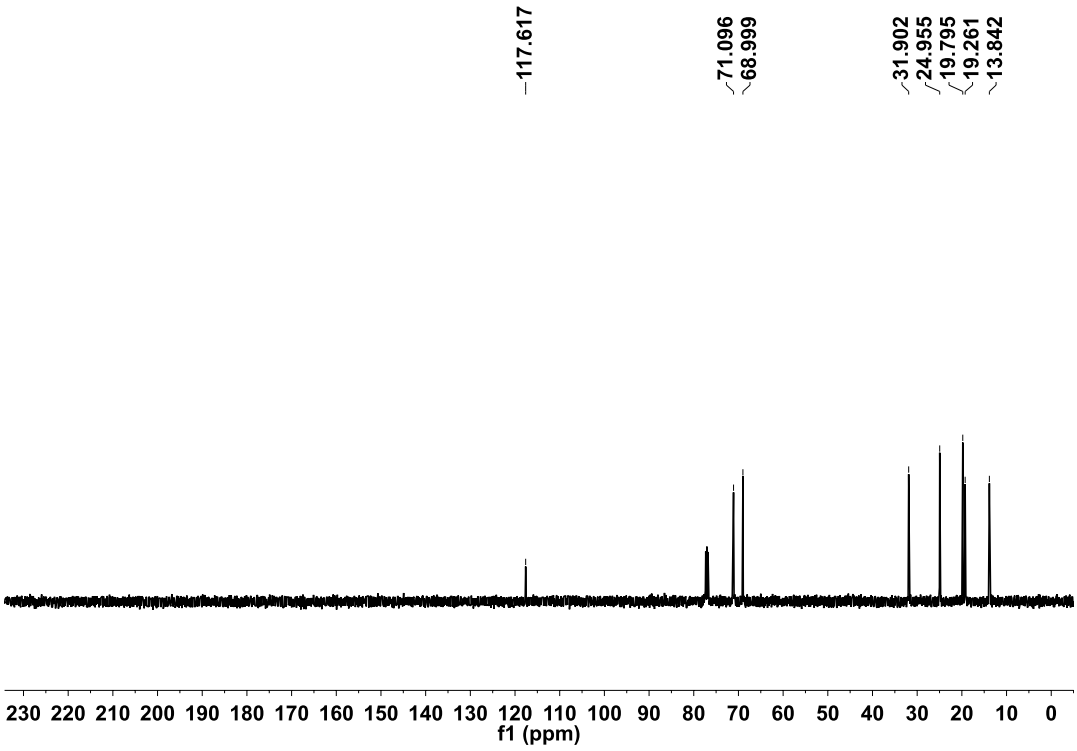


3f

^{1}H NMR

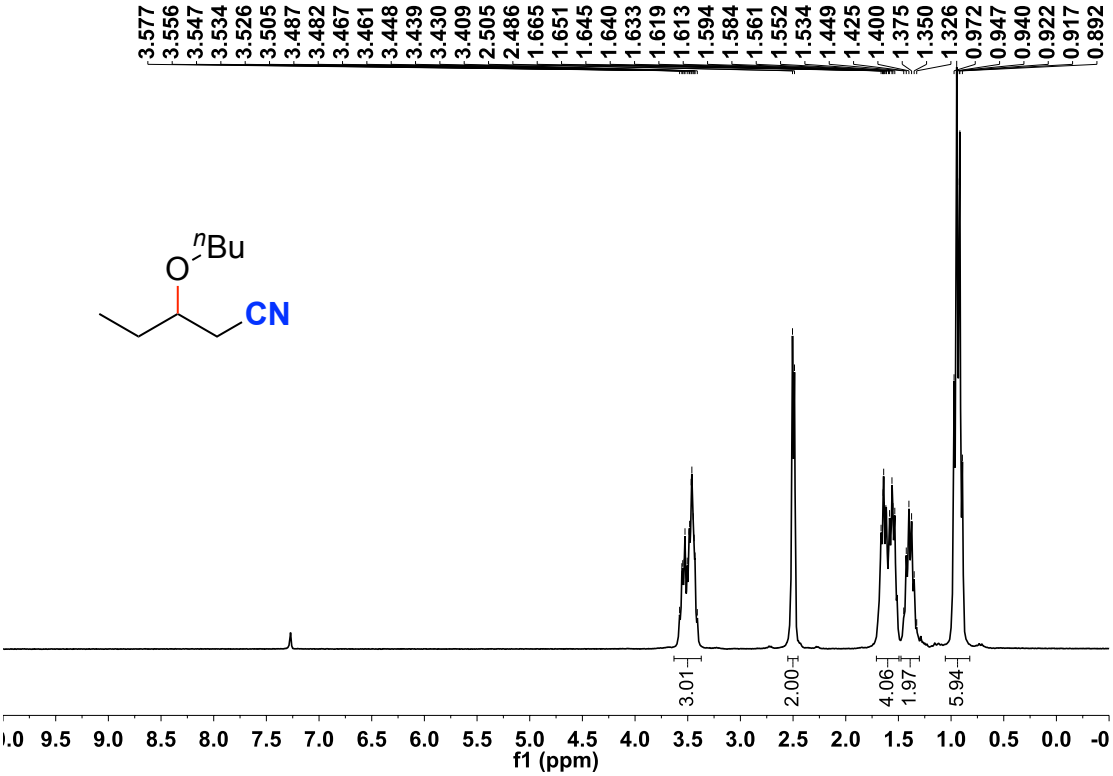


^{13}C NMR

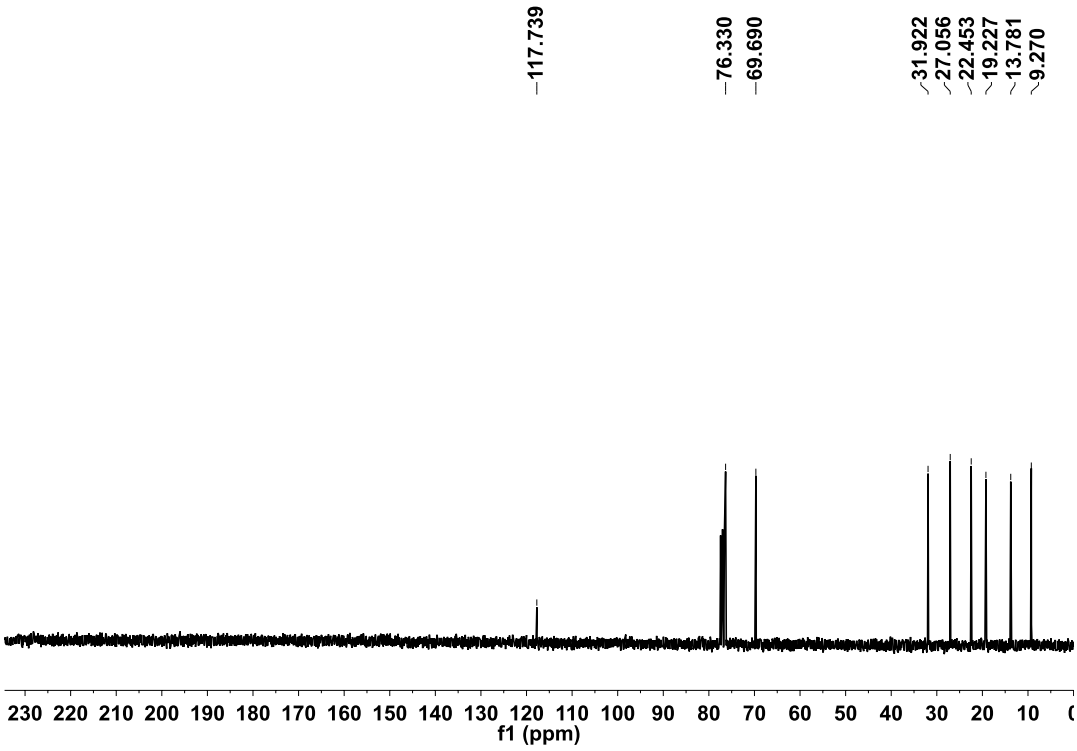


3g

^{1}H NMR



^{13}C NMR



3h

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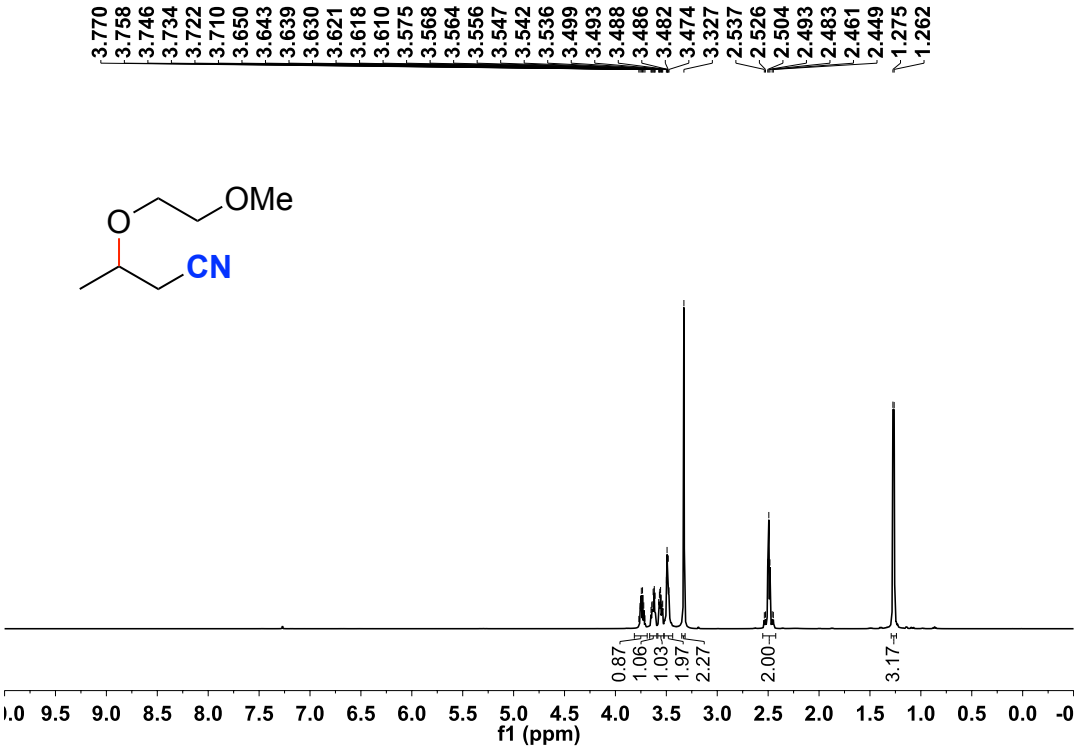
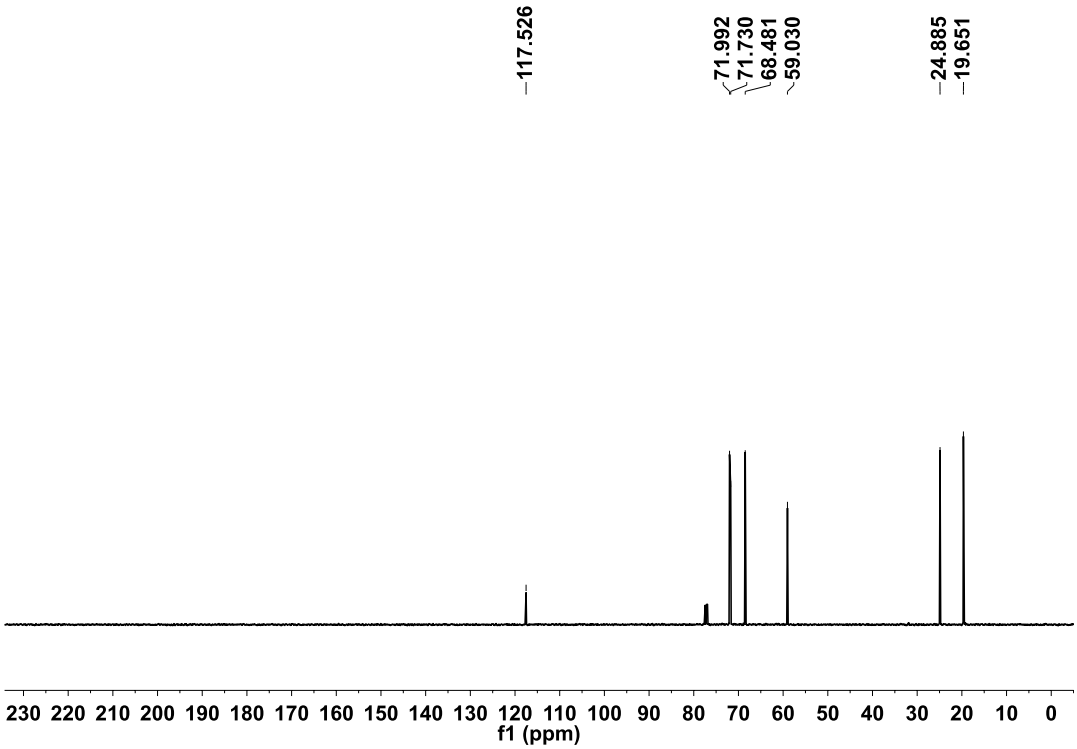
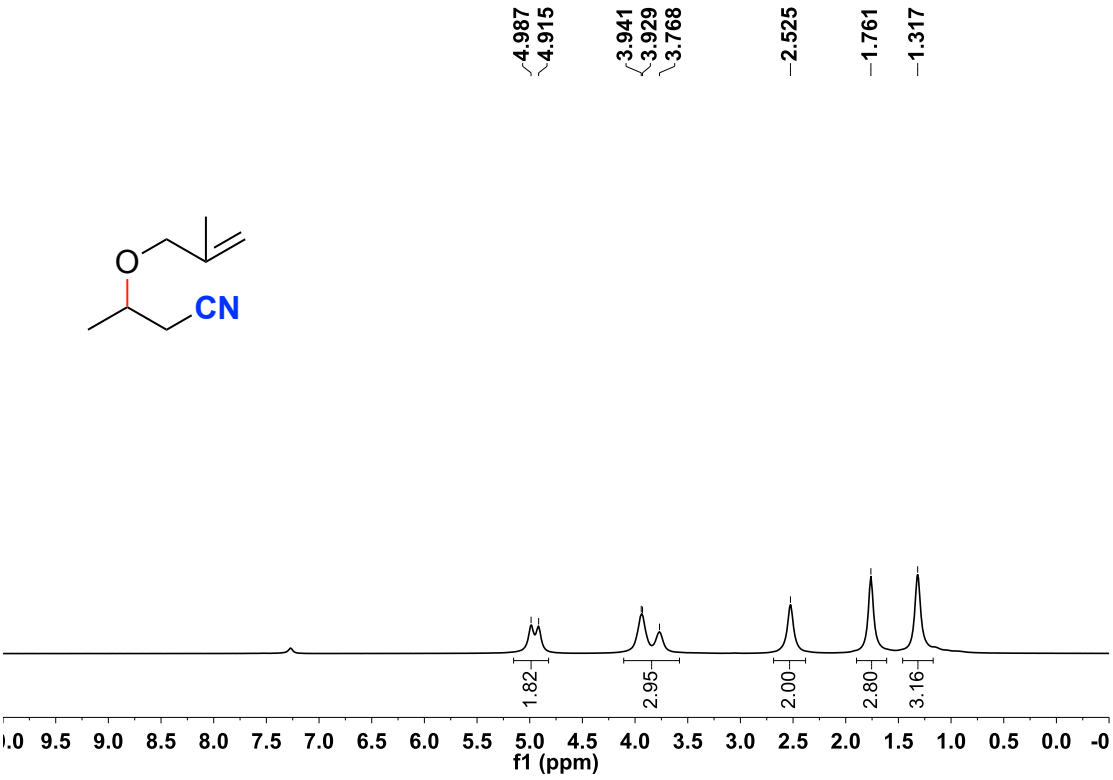


^{13}C NMR

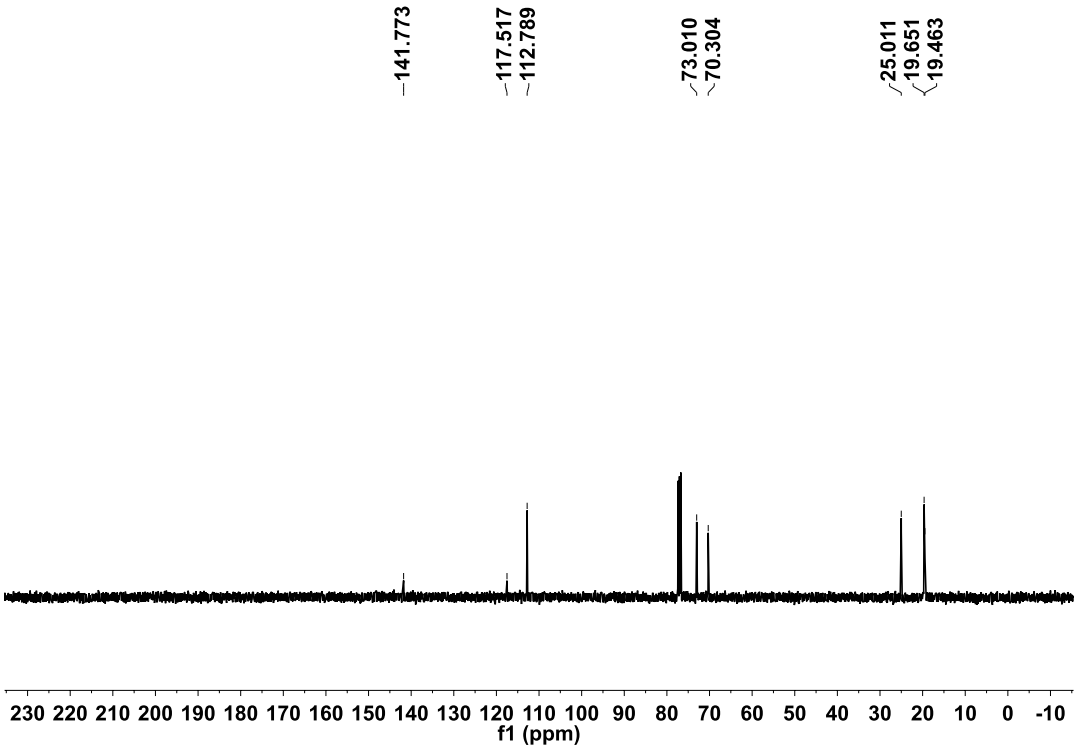


3i

^{1}H NMR



^{13}C NMR



3j

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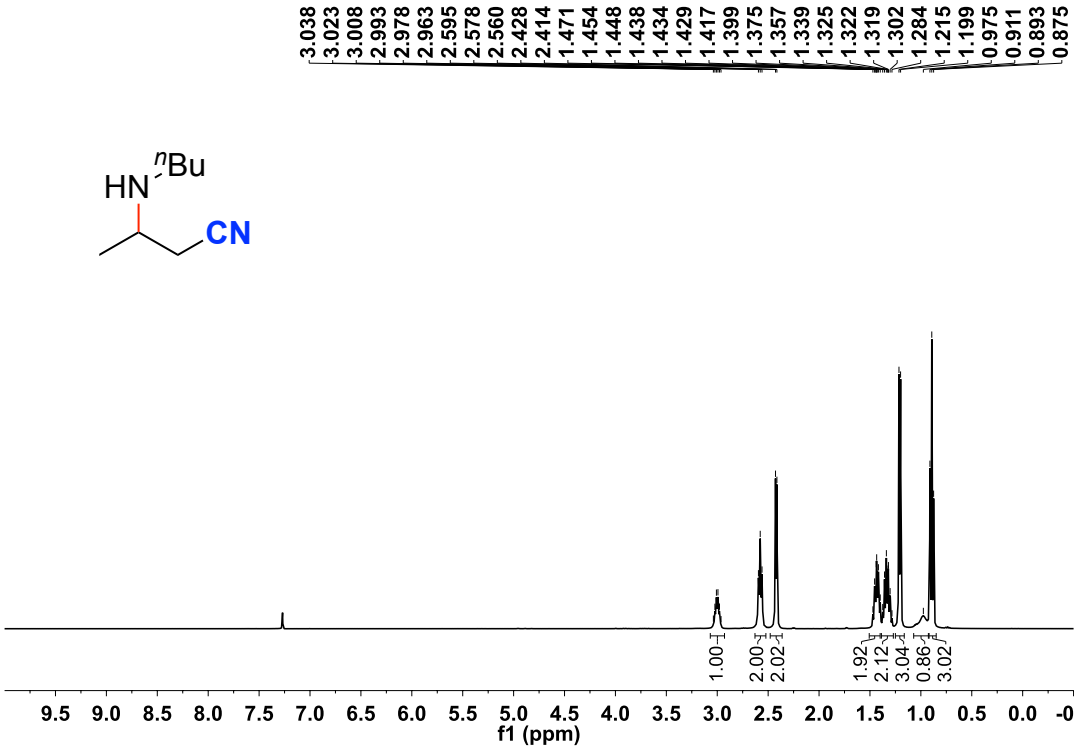

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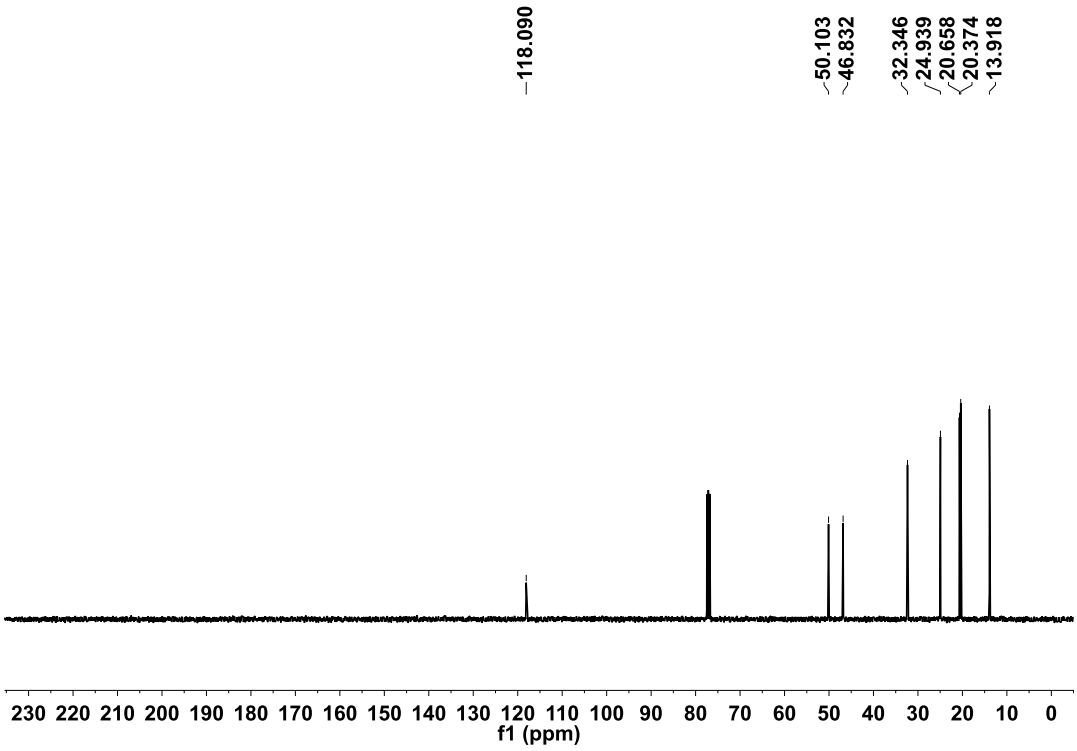

3k

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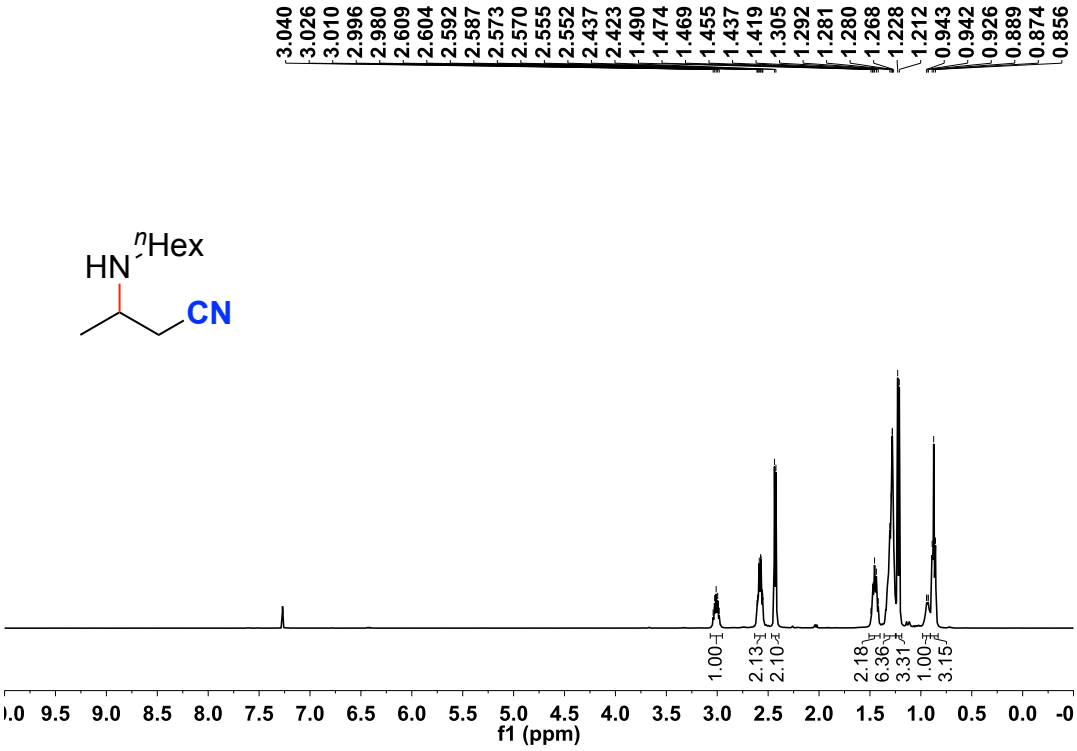
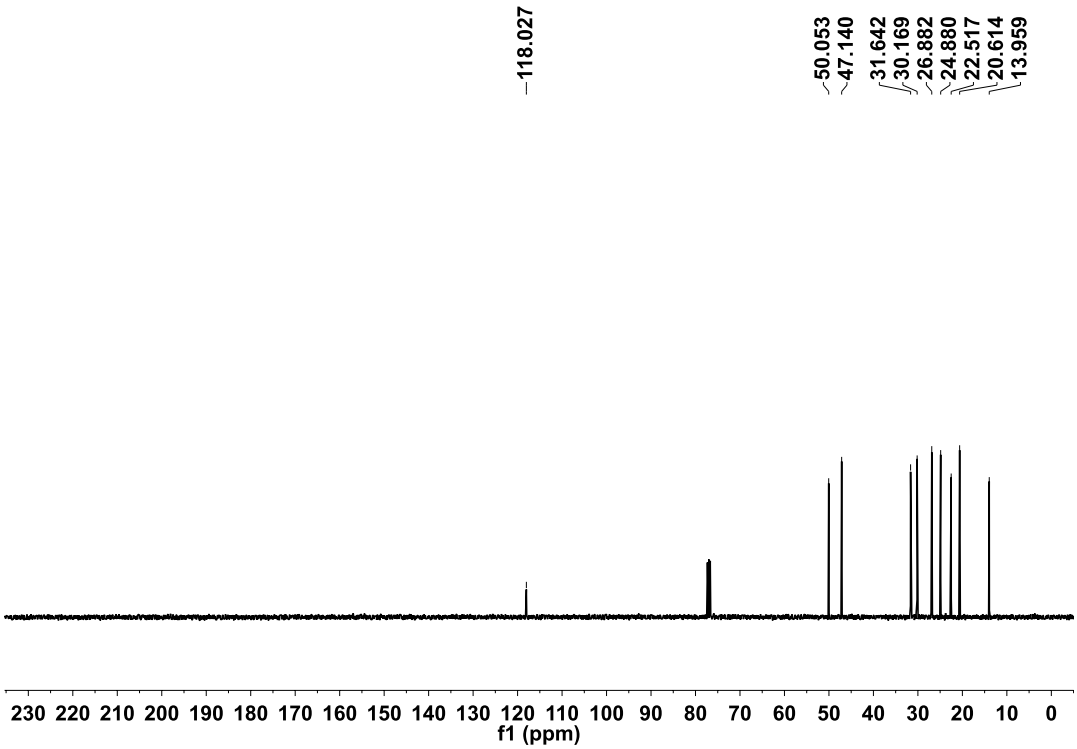
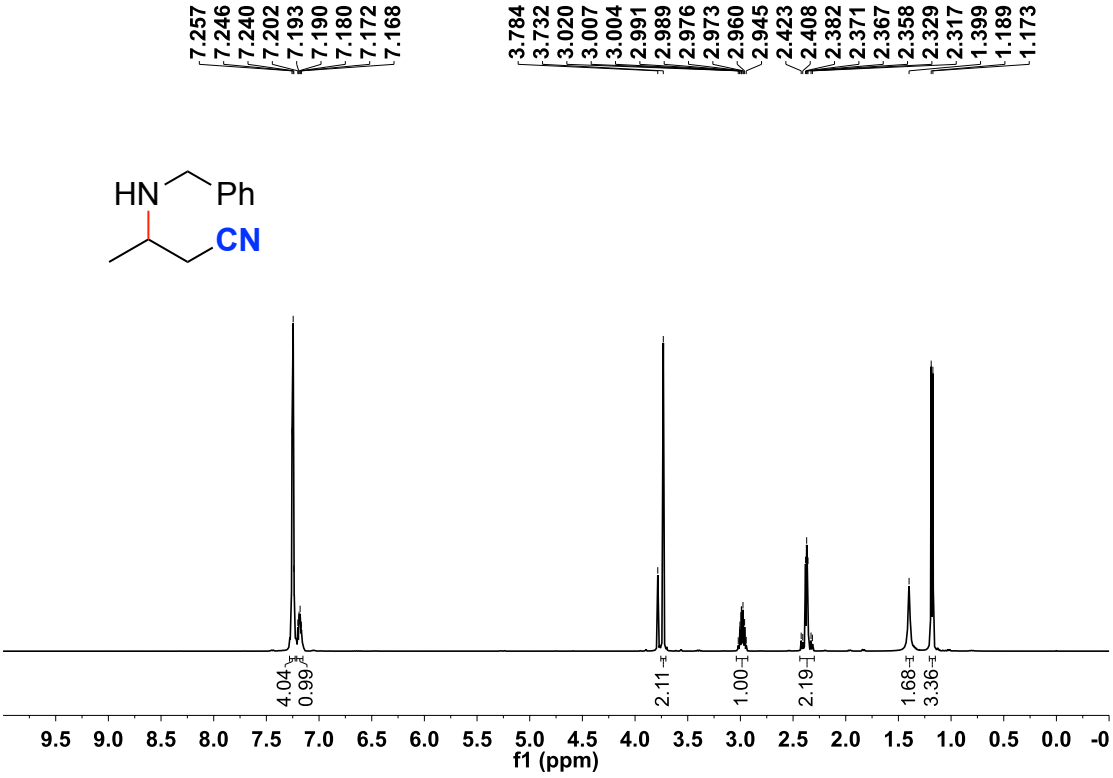


^{13}C NMR

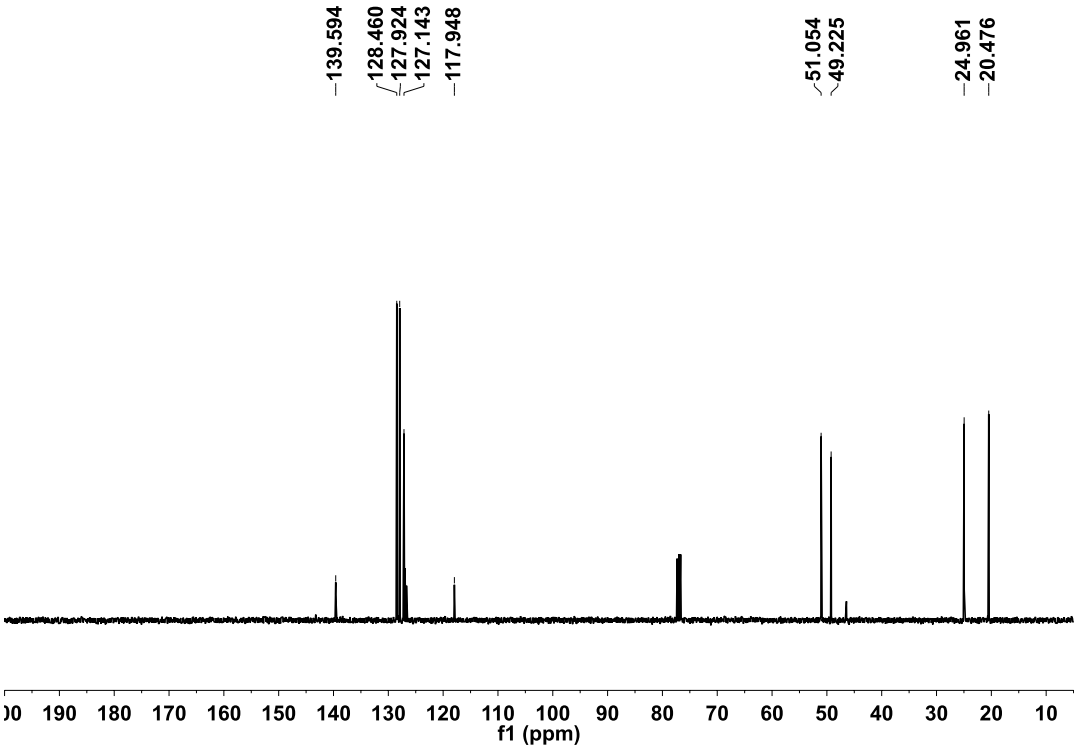


3l

^{1}H NMR

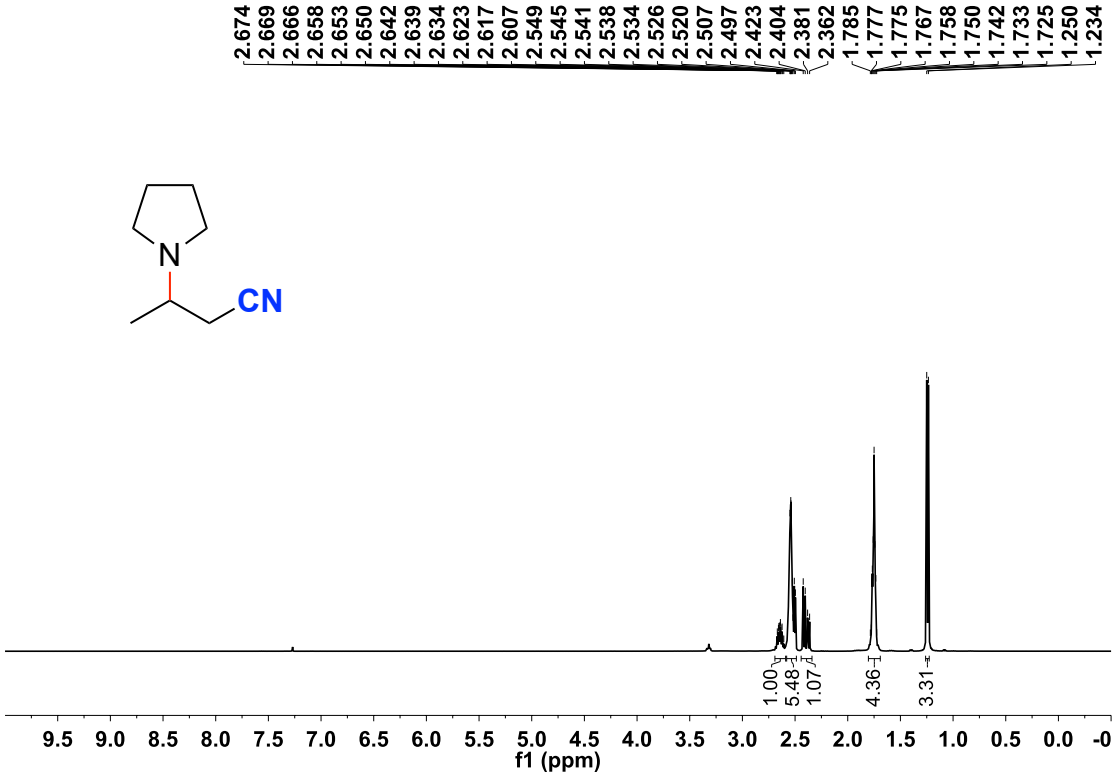


^{13}C NMR



3m

^{1}H NMR



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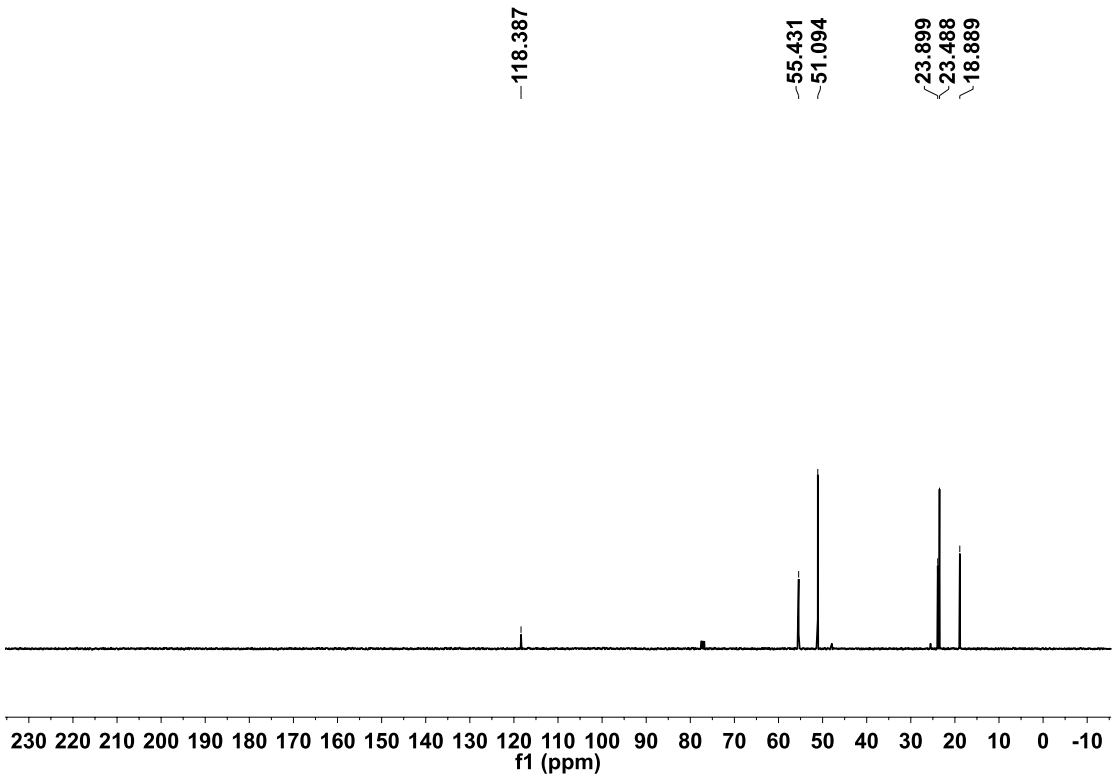

3n

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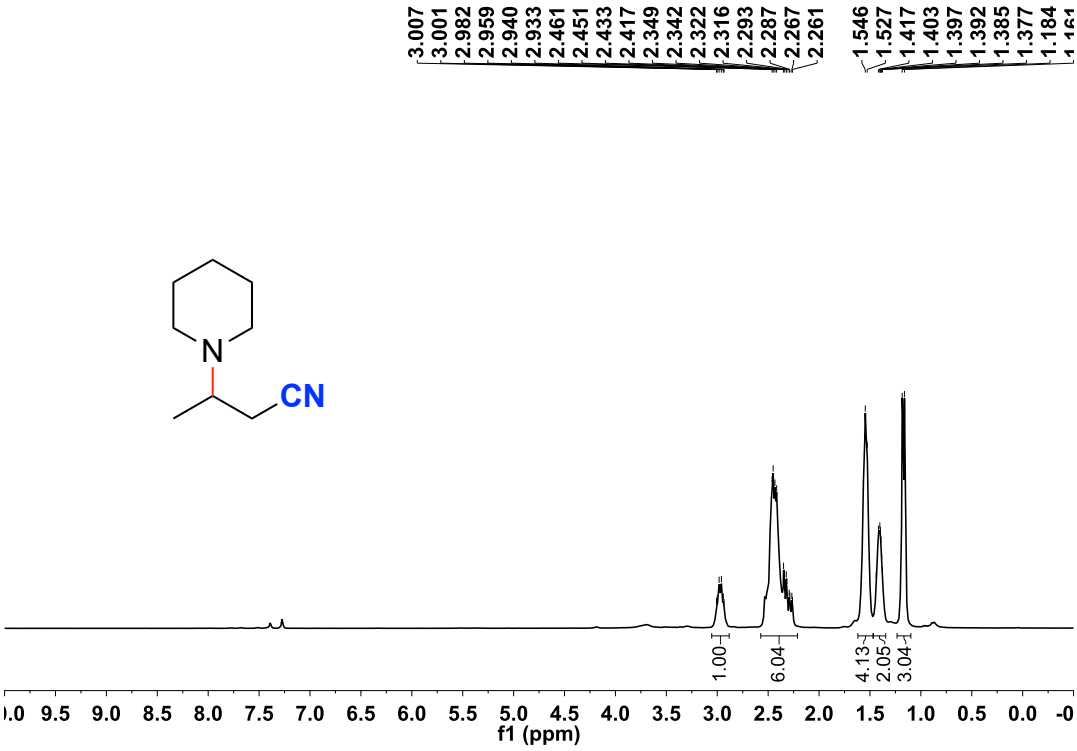

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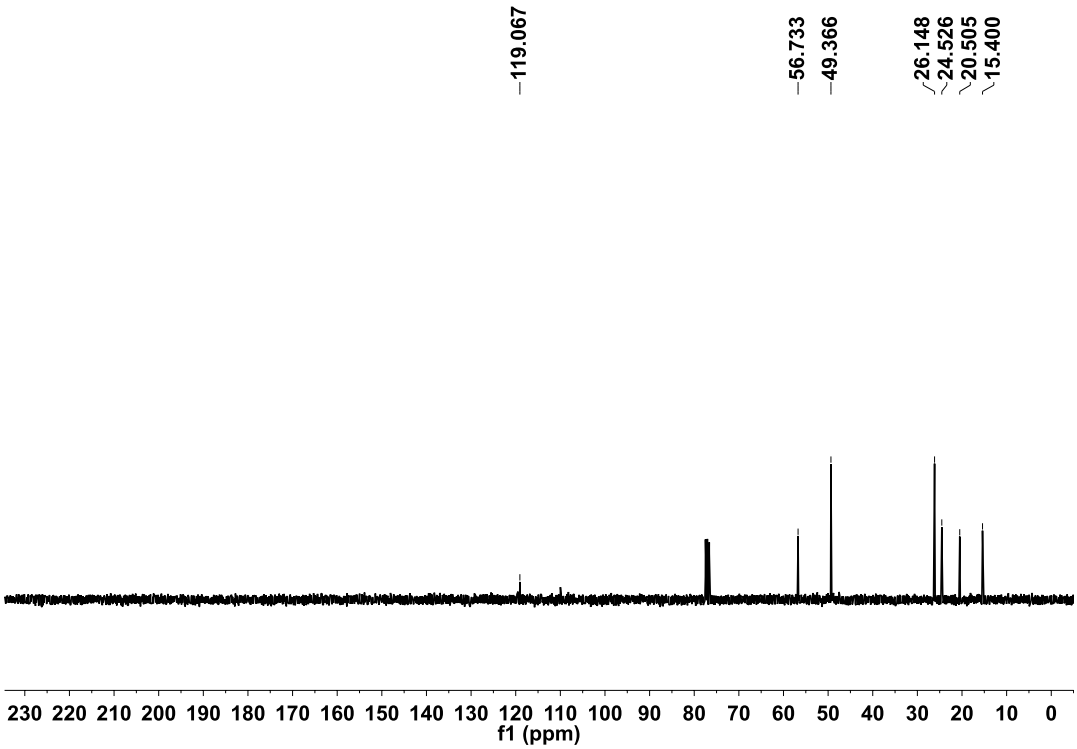
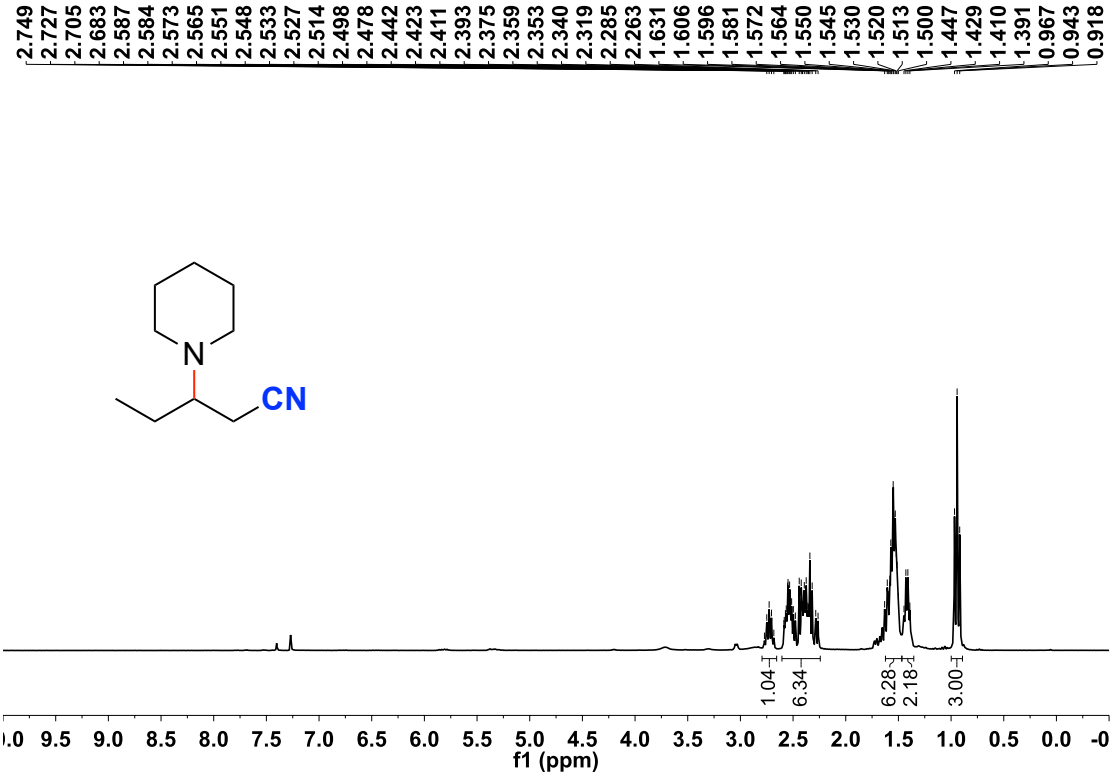


3o

^{1}H NMR



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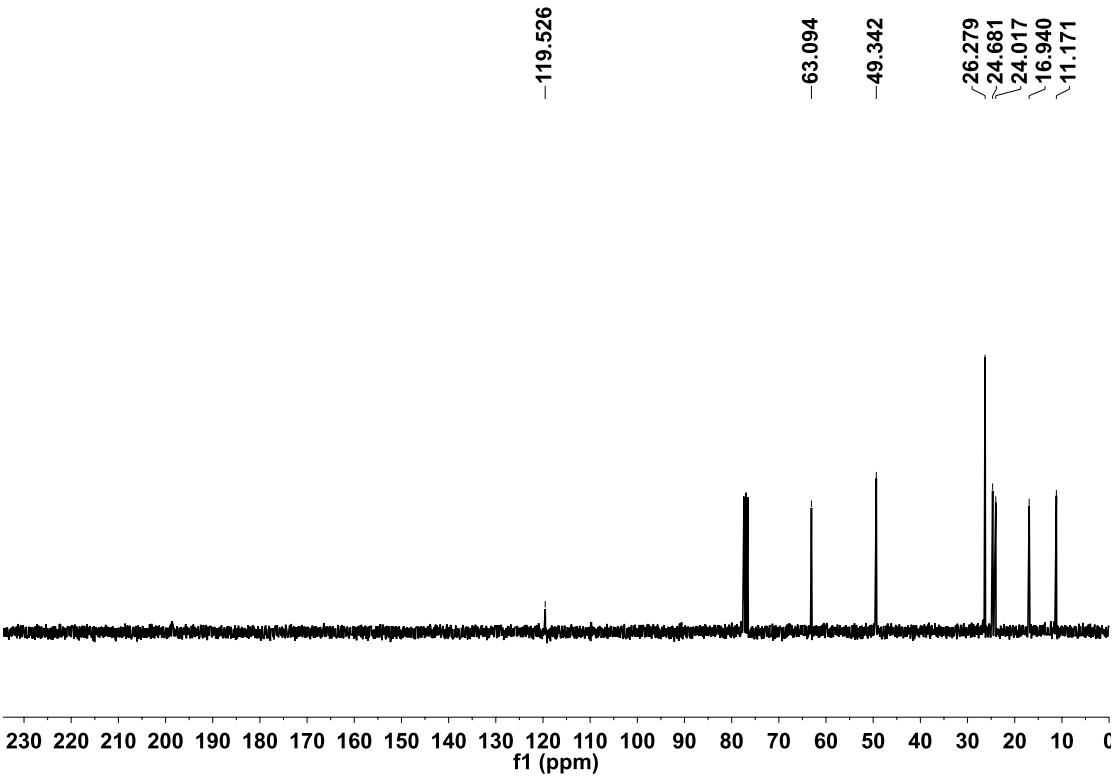

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