Supplementary Material (ESI) for Organic and Biomolecular Chemistry

Supporting Information for:

Scope and Limitations of a Three-Component Synthesis of Highly Functionalised β-Alkoxy-β-Ketoenamides – Flexible Precursors for Cyclisations to 4-Hydroxypyridine Derivatives and their Palladium-Catalysed Coupling Reactions

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Contents

General Remarks:

Reactions were generally performed under argon in flame-dried flasks. Solvents and reagents were added by syringes. Solvents were dried using standard procedures. Reagents were purchased and were used as received without further purification unless otherwise stated. Unless otherwise stated, products were purified by flash chromatography on silica gel (230-400 mesh, Merck or Fluka) or HPLC (Nucleosil 50-5). Unless otherwise stated, yields refer to analytical pure samples. NMR spectra were recorded on Bruker (AC 500) and JOEL (Eclipse 500 and ECX 400) instruments. Chemical shifts are reported relative to TMS (^{1}H: δ = 0.00 ppm), $CDCl_3$ (^{1}H: δ = 7.25 ppm, ^{13}C: δ = 77.0 ppm) or CF_3CO_2D (δ = 11.50 ppm, ^{13}C: δ = 116.6 ppm). Integrals are in accordance with assignments; coupling constants are given in Hz. All ^{13}C-NMR spectra are proton–decoupled. Multiplicity is indicated as follows: s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet), m_c (centered multiplet), dd (doublet of doublet), s_{br} (broad singlet). For detailed peak assignments 2D spectra were measured (COSY, HMBC and HMQC). IR spectra were measured with an FT-IRD spectrometer Nicolet 5 SXC. UV/Vis spectra were measured with a UV-Vis spectrophotometer Scinco S-3150 PDA. Fluorescence spectra were measured with a spectrofluorometer Jasco FP-6500. For both techniques a concentration of 10^{-6} M in degassed CH_3CN (1 cm cuvette) at 25 °C was used. MS and HRMS analyses were performed with Finnigan MAT 711 (EI, 80 eV, 8 kV), MAT CH7A (EI, 80 eV, 3 kV), CH5DF (FAB, 3 kV), Varian Ionspec QFT-7 (ESI-FT ICRMS) and Agilent 6210 (ESI-TOF) instruments. Elemental analyses were carried out with Perkin Elmer CHN-Analyzer 2400 and Vario EL Elemental Analyzer. Melting points were measured with a Reichert apparatus Thermovar and are uncorrected. The pyridine derivatives **15a**[2d] and **15b**[2b] were prepared using our previously reported procedure.

General Procedures:

General Procedure for Enamide Synthesis (Method A [or B]):

Alkoxyallene (3.0 [1.0] equiv.) was dissolved in Et_2O (2.5 mL/mmol) and *n*-BuLi (2.7 [1.1] equiv., 2.5 M in hexanes) was added at -40 °C. After 25 min at -50 to -40 °C the solution was cooled to -78 °C and a nitrile (1.0 [3.0] equiv.) was added. After stirring for 4 h at this temperature carboxylic acid* (5.4 [6.0] equiv.) was added and the mixture was warmed up over night to room temperature. Then the reaction mixture was quenched with satd. aq.

$NaHCO_3$ solution and extracted three times with Et_2O. The combined organic phases were dried with Na_2SO_4 and then evaporated. The crude product was purified by column chromatography on silica gel (hexane/ethyl acetate, 10:1).

*Before adding to the reaction mixture the solid (het-)aromatic carboxylic acids have to be dissolved in solvent as follows: 2-thiophene carboxylic acid or benzoic acid in THF or Et_2O and picolinic acid in DMF (0.6-1.0 mL/mmol).

General Procedure for 4-Hydroxypyridine Synthesis:

The enamide (1.0 equiv.) was dissolved in CH_2Cl_2 and treated at 0 °C with Et_3N (3.0 equiv) and TMSOTf (3.0 equiv.). The mixture was heated under reflux for 3 d and then quenched at room temperature with satd. aq. NH_4Cl solution, extracted with CH_2Cl_2 and the combined organic phases were evaporated to provide the crude product. The resulting crude product was dissolved again in CH_2Cl_2 and treated first with TFA or acetic acid and then with water. It was extracted three times with CH_2Cl_2 and the combined organic extracts were dried with Na_2SO_4 and concentrated to dryness. The crude product was purified by column chromatography on silica gel (hexane/ethyl acetate, 8:1).

General Procedure for Three-Step 4-Pyridinyl Nonaflate Synthesis:

Alkoxyallene (3.0 equiv.) was dissolved in Et_2O (2.5 mL/mmol) and *n*-BuLi (2.7 equiv., 2.5 M in hexanes) was added at -40 °C. After 25 min at -50 to -40 °C the solution was cooled to -78 °C and a nitrile (1.0 equiv.) was added. After stirring for 4 h at this temperature carboxylic acid (5.4 equiv.) was added and the mixture was warmed up over night to room temperature. Then the reaction mixture was quenched with satd. aq. $NaHCO_3$ solution and extracted three times with Et_2O. The combined organic phases were dried with Na_2SO_4 and then evaporated. The residue was dissolved in CH_2Cl_2 and treated at 0 °C with Et_3N (3.0 equiv) and TMSOTf (3.0 equiv.). The mixture was heated under reflux for 3 d and then quenched at room temperature with satd. aq. NH_4Cl solution, extracted three times with CH_2Cl_2 and the combined organic phases were dried with Na_2SO_4 and evaporated to provide the crude product. The residue was dissolved in THF (2.0 mL/mmol) and NaH (3.0 equiv., 60% in mineral oil) was added under an argon atmosphere. Nonafluorobutanesulfonyl fluoride (3.0 equiv.) was added dropwise at room temperature. The mixture was stirred at room temperature over night and quenched by slow addition of methanol and water. It was extracted three times with ethyl acetate, dried with Na_2SO_4 and concentrated to dryness. The crude product was purified by column chromatography on silica gel (hexane/ethyl acetate, 40:1).

General Procedure for Suzuki Coupling Reaction of 4-Pyridinyl Nonaflates:

A mixture of 4-pyridyl nonaflate (1.0 equiv.), aryl boronic acid (1.2 equiv.), $Pd(OAc)_2$ (5 mol%), PPh_3 (20 mol%) and K_2CO_3 (1.0 equiv.) in DMF (4.6 mL/mmol) was heated to 70-80 ^oC for 2-7 h under an argon atmosphere. The mixture was allowed to cool to room temperature and diluted with water and extracted three times with Et_2O. The combined organic phase was dried with Na_2SO_4 and concentrated to dryness. The residue was purified by column chromatography on silica gel (hexane/ethyl acetate, 20:1).

General Procedure for Sonogashira Coupling Reaction of 4-Pyridinyl Nonaflates:

A mixture of 4-pyridyl nonaflate (1.0 equiv.), phenyl acetylene (1.2 equiv.), $Pd(OAc)_2$ (5 mol%), PPh_3 (20 mol%) and CuI (5 mol%) in DMF (4.6 mL/mmol) and *i*-Pr_2NH (2.3 mL/mmol) was heated to 70 ^oC for 3-5 h under an argon atmosphere. The mixture was allowed to cool to room temperature, diluted with water and extracted three times with Et_2O. The combined organic phase was dried with Na_2SO_4 and concentrated to dryness. The residue was purified by column chromatography on silica gel (hexane/ethyl acetate, 20:1).

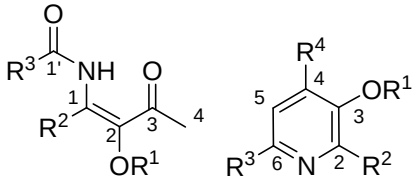
General Procedure for Furopyridine Cyclisation (method a):

A mixture of Sonogashira coupled pyridine (1.0 equiv.) and sodium thioethanolate (8.0 equiv.) in DMF (6.2 mL/mmol) was heated in an ACE-sealed tube to 80 °C for 1 h. The reaction mixture was allowed to cool to room temperature, quenched with brine and extracted three times with Et_2O. The combined organic phases were dried with Na_2SO_4 and concentrated to dryness. The residue was purified by column chromatography on silica gel (hexane/ethyl acetate, 10:1).

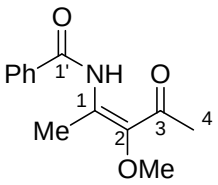
General Procedure for Furopyridine Cyclisation (method b):

To a solution of Sonogashira coupled pyridine (1.0 equiv.) in CH_2Cl_2 (10 mL/mmol) under argon atmosphere BBr_3 (1.0 mL/mmol, 1 M in CH_2Cl_2) was added dropwise at 0 °C and warmed up to room temperature. The reaction mixture was monitored by TLC; upon completion, ice-water was added and the mixture was extracted three times with CH_2Cl_2. The combined organic layers were washed with water and brine, dried with Na_2SO_4 and evaporated under reduced pressure. The residue was dissolved in DMF (8.0 mL/mmol) and K_2CO_3 (3.0 equiv.) and water (1.7 mL/mmol) were added. After stirring at 80 °C for 12 h, the mixture was diluted with water and extracted three times with Et_2O. The combined organic phases were dried with Na_2SO_4 and concentrated to dryness. The residue was purified by column chromatography on silica gel (hexane/ethyl acetate, 10:1).

To facilitate comparison of the data we are using generally this numbering of compounds:

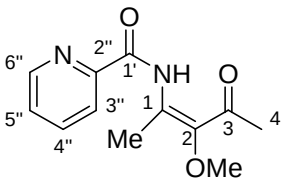


Characterization of All Compounds:



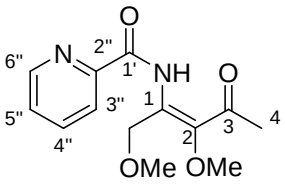
(*E*)-*N*-(2-Methoxy-1-methyl-3-oxobut-1-en-1-yl)benzamide (2a)

light yellow oil: 13%; ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 2.32 (s, 3 H, 4-H), 2.59 (s, 3 H, Me), 3.59 (s, 3 H, OMe), 7.45-7.55, 7.95-7.97 (2 m, 3 H, 2 H, Ph) ppm; NH-signal could not be detected. ^{13}C NMR ($CDCl_3$, 101 MHz): δ = 14.6, 26.9, 61.3, 127.7, 128.8, 132.3, 134.1, 138.5, 146.3, 166.3, 200.7 ppm. IR (film): ν = 3360-3210 (N-H), 3115-2835 (=C-H, C-H), 1725-1585 (C=O, C=C) cm^{-1}. Calcd for $C_{13}H_{15}NO_3$ (233.3): C 66.94; H 6.48; N 6.00%; found: C 66.74; H 6.10; N 5.76%. HRMS (ESI-TOF): Calcd. for $C_{13}H_{15}NO_3$ $[M+Na]^+$: 256.0944; found 256.0956.



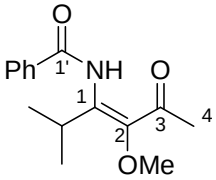
(*E*)-*N*-(2-Methoxy-1-methyl-3-oxobut-1-en-1-yl)picolinamide (2b)

Colourless solid: 22%; mp 88-90 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 2.27 (s, 3 H, 4-H), 2.55 (s, 3 H, Me), 3.54 (s, 3 H, OMe), 7.41 (ddd, 1 H, *J* = 7.6, 4.8, 1.1 Hz, 5''-H), 7.79 (td, 1 H, *J* = 7.8, 1.7 Hz, 4''-H), 8.10 (dt, 1 H, *J* = 7.8, 1.1 Hz, 3''-H), 8.67 (ddd, 1 H, *J* = 4.8, 1.6, 0.8 Hz, 6''-H), 13.47 (s_{br}, 1 H, NH) ppm. ^{13}C NMR ($CDCl_3$, 126 MHz): δ = 14.5, 27.0, 61.2, 122.8, 126.6, 137.4, 139.2, 143.6, 148.7, 150.1, 164.5, 200.0 ppm. IR (KBr): ν = 3350 (N-H), 3060-3000 (=C-H), 2960-2850 (C-H), 1690 (C=O), 1620- 1570 (C=C) cm^{-1}. MS (EI): *m/z* (%) = 234 (11) $[M]^+$, 191 (100), 176 (23), 107 (17), 106 (18), 79 (34), 78 (67). Calcd for $C_{12}H_{14}N_2O_3$ (234.3): C 61.53; H 6.02; N 11.96%; found: C 61.89; H 5.97; N 11.89%.



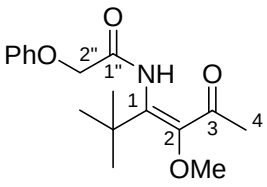
(*E*)-*N*-[2-Methoxy-1-(methoxymethyl)-3-oxobut-1-en-1-yl]picolinamide (2c)

light yellow oil: 33%; ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 2.35 (s, 3 H, 4-H), 3.44, 3.67 (2 s, 3 H each, OMe), 4.82 (s, 2 H, CH_2), 7.43 (ddd, 1 H, *J* = 7.6, 4.8, 1.1 Hz, 5''-H), 7.83 (td, 1 H, *J* = 7.8, 1.7 Hz, 4''-H), 8.17 (dt, 1 H, *J* = 7.8, 1.1 Hz, 3''-H), 8.70 (ddd, 1 H, *J* = 4.8, 1.8, 1.0 Hz, 6''-H), 13.08 (s_{br}, 1 H, NH) ppm. ^{13}C NMR ($CDCl_3$, 126 MHz): δ = 27.3, 58.8, 63.0, 64.6, 122.9, 126.6, 137.4, 139.5, 140.4, 148.7, 149.9, 163.6, 201.0 ppm. IR (film): ν = 3330 (N-H), 3060 (=C-H), 2930-2850 (C-H), 1700-1660 (C=O), 1585-1460 (C=C) cm^{-1}. MS (EI): *m/z* (%) = 264 (5) $[M]^+$, 222 (58), 106 (34), 79 (36), 78 (100), 43 (48). HRMS (EI): Calcd. for $C_{13}H_{16}N_2O_4$ $[M]^+$: 264.11099; found 264.11044.



(*E*)-*N*-(1-Isopropyl-2-methoxy-3-oxobut-1-en-1-yl)benzamide (2d)

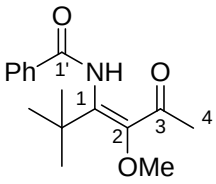
Colourless oil: 53%; ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 1.41 (d, *J* = 7.2 Hz, 6 H, *i*-Pr), 2.34 (s, 3 H, 4-H), 3.63 (s, 3 H, OMe), 3.73 (hept, *J* = 7.2 Hz, 1 H, *i*-Pr), 7.45-7.54, 7.97-8.00 (2 m, 3 H, 2 H, Ph) ppm; NH-signal could not be detected. ^{13}C NMR ($CDCl_3$, 101 MHz): δ = 19.7, 27.7, 27.1, 62.1, 127.8, 128.7, 132.1, 134.6, 139.9, 153.3, 165.5, 201.6 ppm. IR (film): ν = 3300 (N-H), 3065-2830 (=C-H, C-H), 1690-1575 (C=O, C=C) cm^{-1}. Calcd for $C_{15}H_{19}NO_3$ (261.3): C 68.94; H 7.33; N 5.36%; found: C 68.60; H 7.27; N 5.33%.



(*E*)-*N*-(1-*tert*-Butyl-2-methoxy-3-oxobut-1-enyl)-2-phenoxyacetamide (2f)

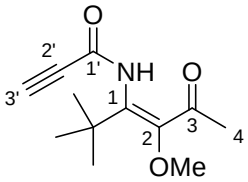
Colourless solid: 63%; mp 76-78 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 1.18 (s, 9 H, *t*-Bu), 2.30 (s, 3 H, 4-H), 3.52 (s, 3 H, OMe), 4.47 (s, 2 H, CH_2), 6.90-6.92, 7.00-7.03, 7.29-7.33 (3 m, 1 H, 2 H, 2 H, Ph), 7.66 (s_{br}, 1H, NH) ppm. ^{13}C NMR ($CDCl_3$, 126 MHz): δ = 27.4, 28.4, 36.4, 59.1, 67.8, 114.8, 122.4, 129.9, 130.0, 150.6, 157.2, 167.2, 200.5 ppm. IR (KBr): ν =

3380 (N-H), 3060-3040 (=C-H), 2960-2870 (C-H), 1670 (C=O), 1630-1500 (C=C) cm^{-1}. MS (EI): *m/z* (%) = 305 (7) $[M]^+$, 262 (100), 77 (49), 57 (27), 43 (41). HRMS (EI): Calcd. for $C_{17}H_{23}NO_4$ $[M]^+$: 305.16272; found 305.16322.



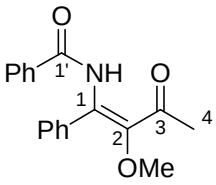
(*E*)-*N*-(1-*tert*-Butyl-2-methoxy-3-oxobut-1-enyl)benzamide (2g)

Colourless solid: 76%; mp 115-117 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 1.31 (s, 9 H, *t*-Bu), 2.29 (s, 3 H, 4-H), 3.55 (s, 3 H, OMe), 7.38-7.44, 7.46-7.51, 7.76-7.80 (3 m, 2 H, 2 H, 1 H, Ph), 7.90 (s_{br}, 1 H, NH) ppm. ^{13}C NMR ($CDCl_3$, 126 MHz): δ = 27.9, 28.5, 36.8, 58.8, 127.3, 128.5, 131.6, 134.4, 135.0, 150.4, 167.5, 200.4 ppm. IR (KBr): ν = 3390-3295 (N-H), 3065-3000 (=C-H), 2970-2840 (C-H), 1700-1650 (C=O), 1600-1480 (C=C) cm^{-1}. Calcd for $C_{16}H_{21}NO_3$ (275.2): C 69.79; H 7.69; N 5.09%; found C 69.93; H 7.71; N 4.70%. MS (EI): *m/z* (%) = 275 (1) $[M]^+$, 232 (100), 77 (52), 43 (13). HRMS (EI): Calcd. for $C_{16}H_{21}NO_3$ $[M]^+$: 275.15213; found 275.15322.



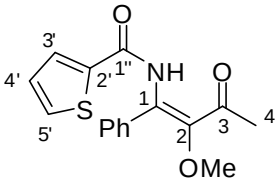
(*E*)-*N*-(1-*tert*-Butyl-2-methoxy-3-oxobut-1-enyl)prop-2-inamide (2h)

colourless solid: 72%; mp 135 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 1.20 (s, 9 H, *t*-Bu), 2.30 (s, 3 H, 4-H), 2.89 (s, 1 H, 3'-H), 3.51 (s, 3 H, OMe), 7.35 (s_{br}, 1 H, NH) ppm. ^{13}C NMR ($CDCl_3$, 126 MHz): δ = 28.0, 28.5, 36.6, 58.9, 75.3, 131.6, 151.9, 171.3, 199.9 ppm; C-3'-signal could not be detected. IR (KBr): ν = 3270 (N-H), 3195 (≡C-H), 2995-2835 (C-H), 2105 (C≡C), 1700-1620 (C=O, C=C) cm^{-1}. Calcd for $C_{12}H_{17}NO_3$ (223.3): C 64.55; H 7.67; N 6.27%; found: C 64.78; H 7.79; N 6.23%.



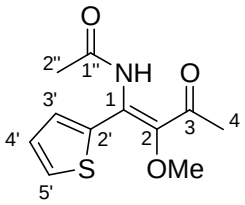
(*E*)-*N*-(2-Methoxy-3-oxo-1-phenylbut-1-enyl)benzamide (2i)

Colourless solid: 45%; mp 74-77 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 2.40 (s, 3 H, 4-H), 3.22 (s, 3 H, OMe), 7.41-7.56, 7.94-7.98 (2 m, 8 H, 2 H, Ph), 12.35 (s_{br}, 1 H, NH) ppm. ^{13}C NMR ($CDCl_3$, 126 MHz): δ = 27.4, 60.6, 127.8, 128.9, 128.3, 128.7, 128.9, 132.4, 133.7, 138.6, 138.7, 143.5, 165.3, 202.4 ppm. IR (KBr): ν = 3135 (N-H), 3055-3005 (=C-H), 2960-2835 (C-H), 1695-1635 (C=O, C=C) cm^{-1}. Calcd for $C_{18}H_{17}NO_3$ (295.3): C 73.20; H 5.80; N 4.74%; found: C 73.37; H 5.92; N 4.76%.



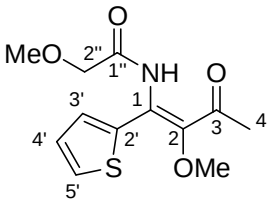
(*E*)-*N*-(2-Methoxy-3-oxo-1-phenylbut-1-enyl)thiophen-2-carboxamide (2j)

light yellow solid: 43%; mp 118 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 2.40 (s, 3 H, 4-H), 3.22 (s, 3 H, OMe), 7.12 (dd, *J* = 5.0, 3.8 Hz, 1 H, 4'-H), 7.39-7.44, 7.46-7.49 (2 m, 5 H, Ph), 7.53 (dd, *J* = 5.0, 1.1 Hz, 1 H, 3'-H), 7.77 (dd, *J* = 3.8, 1.1 Hz, 1 H, 5'-H), 12.39 (s_{br}, 1 H, NH) ppm. ^{13}C NMR ($CDCl_3$, 101 MHz): δ = 27.3, 60.7, 127.86, 127.93, 128.3, 129.0, 129.8, 131.9, 132.0, 139.3, 138.3, 143.4, 159.9, 202.5 ppm. IR (KBr): ν = 3335-3250 (N-H), 3110-2935 (=C-H, C-H), 1680-1635 (C=O, C=C) cm^{-1}. Calcd for $C_{16}H_{15}NO_3S$ (301.4): C 63.77; H 5.02; N 4.65%; found: C 63.88; H 5.00; N 4.66%.



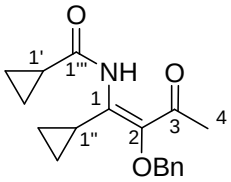
(*E*)-*N*-(2-Methoxy-3-oxo-1-(thiophen-2-yl)but-1-enyl)acetamide (2k)

brown solid: 72%; mp 98-100 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 2.13 (s, 3 H, 2''-H), 2.36 (s, 3 H, 4-H), 3.50 (s, 3 H, OMe), 7.04 (dd, 1 H, *J* = 5.1, 3.7 Hz, 3'-H), 7.37 (dd, 1 H, *J* = 3.7, 1.1 Hz, 2'-H), 7.49 (dd, 1 H, *J* = 5.1, 1.2 Hz, 4'-H), 9.78 (s_{br}, 1 H, NH) ppm. ^{13}C NMR ($CDCl_3$, 126 MHz): δ = 24.6, 27.8, 60.1, 126.9, 130.2, 131.2, 132.5, 133.6, 141.5, 170.5, 200.4 ppm. IR (KBr): ν = 3260 (N-H), 3100-3000 (=C-H), 2935-2835 (C-H), 1600 (C=O), 1620-1435 (C=C) cm^{-1}. MS (EI): *m/z* (%) = 239 (23) $[M]^+$, 196 (71), 43 (100). HRMS (EI): Calcd. for $C_{11}H_{13}NO_3S$ $[M]^+$: 239.06161; found 239.06244.



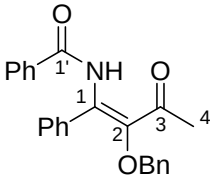
(*E*)-*N*-[2-Methoxy-3-oxo-1-(thiophen-2-yl)but-1-enyl]-2-methoxyacetamide (2l)

yellow oil: 47%; ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 2.30 (s, 3 H, 4-H), 3.48, 3.46 (2 s, 3 H each, OMe), 3.91 (s, 2 H, CH_2), 6.97 (dd, 1 H, *J* = 5.1, 3.7 Hz, 3'-H), 7.27 (dd, 1 H, *J* = 3.7, 1.2 Hz, 2'-H), 7.42 (dd, 1 H, *J* = 5.1, 1.2 Hz, 4'-H), 9.94 (s_{br}, 1 H, NH) ppm. ^{13}C NMR ($CDCl_3$, 126 MHz): δ = 27.7, 59.7, 59.9, 72.6, 126.7, 129.3, 129.9, 130.5, 133.9, 142.9, 169.6, 199.3 ppm. IR (film): ν = 3290 (N-H), 3100 (=C-H), 2935-2830 (C-H), 1700-1670 (C=O), 1580-1450 (C=C) cm^{-1}. MS (EI): *m/z* (%) = 269 (21) $[M]^+$, 226 (37), 45 (100), 43 (41). HRMS (EI): Calcd. for $C_{12}H_{15}NO_4S$ $[M]^+$: 269.07217; found 269.07322.



(*E*)-*N*-(2-(Benzyloxy)-1-cyclopropyl-3-oxobut-1-enyl)cyclopropanecarboxamide (2m)

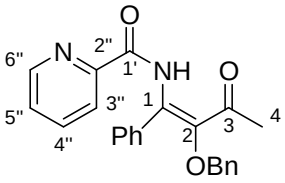
light yellow solid: 56%; mp 51-53 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 0.81-0.88, 0.97-1.04 (2 m, 8 H, *c*-Pr), 1.56 (m_c, 1 H, 1'-H), 2.19 (m_c, 1 H, 1''-H), 2.21 (s, 3 H, 4-H), 4.79 (s, 2 H, CH_2Ph), 7.29-7.42 (m, 5 H, Ph), 11.86 (s_{br}, 1 H, NH) ppm. ^{13}C NMR ($CDCl_3$, 101 MHz): δ = 8.4, 8.9, 11.8, 16.5, 27.3, 76.2, 128.0, 128.1, 128.5, 136.6, 138.7, 147.0, 172.6, 201.1 ppm. IR (KBr): ν = 3300-3205 (N-H), 3090-3000 (=C-H), 2955-2870 (C-H), 1730-1630 (C=O, C=C) cm^{-1}. Calcd for $C_{18}H_{21}NO_3$ (299.4): C 72.22; H 7.07; N 4.68%; found: C 72.35; H 7.10; N 4.62%.



(*E*)-*N*-[2-(Benzyloxy)-3-oxo-1-phenylbut-1-enyl]benzamide (2n)

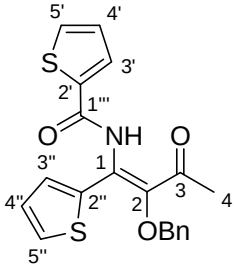
light yellow solid: 54%; mp 142-144 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 2.39 (s, 3 H, 4-H), 4.27 (s, 2 H, CH_2Ph), 6.94-6.96, 7.25-7.27, 7.43-7.55, 7.96-7.99 (4 m, 2 H, 3 H, 8 H, 2 H, Ph), 12.44 (s_{br}, 1 H, NH) ppm. ^{13}C NMR ($CDCl_3$, 101 MHz): δ = 27.5, 75.5, 127.80, 127.84,

128.0, 128.3, 128.4, 128.6, 128.8, 129.0, 132.4, 132.5, 133.7, 135.9, 137.2, 144.1, 165.3, 202.5 ppm. IR (KBr): ν = 3225-3205 (N-H), 3060-3030 (=C-H), 2920-2875 (C-H), 1685-1570 (C=O, C=C) cm^{-1}. Calcd for $C_{24}H_{21}NO_3$ (371.4): C 77.61; H 5.70; N 3.77%; found: C 77.45; H 5.84; N 3.43%.



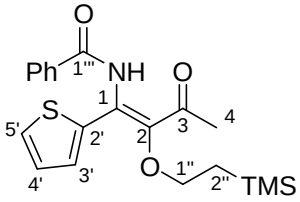
(*E*)-*N*-[2-(Benzyloxy)-3-oxo-1-phenylbut-1-enyl]picolinamide (2o)

light yellow solid: 27%; mp 135-137 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 2.41 (s, 3 H, 4-H), 4.30 (s, 2 H, CH_2Ph), 6.93-7.49 (m, 10 H, Ph), 7.48 (ddd, *J* = 7.6, 4.8, 0.9 Hz, 1 H, 5''-H), 7.80 (td, *J* = 7.6, 1.8 Hz, 1 H, 4''-H), 8.08 (dt, *J* = 7.6, 0.9 Hz, 1 H, 3''-H), 8.77 (ddd, *J* = 4.8, 1.8, 0.9 Hz, 1 H, 6''-H), 13.16 (s_{br}, 1 H, NH) ppm. ^{13}C NMR ($CDCl_3$, 101 MHz): δ = 27.5, 75.4, 122.8, 126.6, 127.9, 128.2, 128.31, 128.32, 128.7, 128.8, 132.6, 135.9, 137.3, 138.0, 141.6, 148.6, 149.7, 163.2, 201.4 ppm. IR (KBr): ν = 3180-3165 (N-H), 3110-3000 (=C-H), 2950-2865 (C-H), 1705-1640 (C=O, C=C) cm^{-1}. Calcd for $C_{23}H_{20}N_2O_3$ (372.4): C 74.18; H 5.41; N 7.52%; found: C 73.93; H 5.05; N 7.47%. HRMS (ESI-TOF): Calcd. for $C_{23}H_{20}N_2O_3$ $[M+H]^+$: 373.1547; found 373.1557.



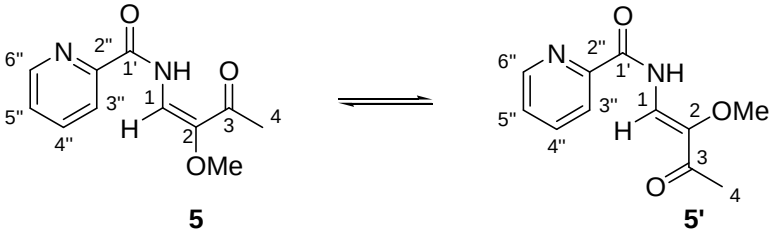
(*E*)-*N*-[2-(Benzyloxy)-3-oxo-1-(thiophen-2-yl)but-1-enyl]thiophen-2-carboxamide (2p)

light yellow solid: 32%; mp 110-114 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 2.35 (s, 3 H, 4-H), 4.54 (s, 2 H, CH_2Ph), 7.08, 7.14 (2 dd, *J* = 5.0, 3.8 Hz, 1 H each, 4'-H, 4''-H), 7.26-7.37 (m, 5 H, Ph), 7.46 (dd, *J* = 3.8, 1.1 Hz, 1 H, 5''-H), 7.52, 7.56 (2 dd, *J* = 5.0, 1.1 Hz, 1 H each, 3'-H, 3''-H), 7.79 (dd, *J* = 3.8, 1.1 Hz, 1 H, 5'-H), 11.58 (s_{br}, 1 H, NH) ppm. ^{13}C NMR ($CDCl_3$, 101 MHz): δ = 27.6, 76.7, 126.8, 128.0, 128.2, 128.4, 128.5, 129.6, 129.9, 131.2, 131.9, 132.6,* 135.5, 136.0, 138.6, 139.1, 160.9, 201.7 ppm; *overlapping of phenyl signals. IR (KBr): ν = 3300-3240 (N-H), 3105-2875 (=C-H, C-H), 1670-1570 (C=O, C=C) cm^{-1}. HRMS (ESI-TOF): Calcd. for $C_{20}H_{17}NO_3S_2$ $[M+H]^+$: 384.0723; found 384.0717.



(*E*)-*N*-{3-Oxo-1-thien-2-yl-2-[2-(trimethylsilyl)ethoxy]but-1-enyl}benzamide (2q)

light yellow solid: 71%; mp 50-52 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ = -0.03 (s, 9 H, TMS), 1.07 (m_c, 2 H, 2''-H), 2.38 (s, 3 H, 4-H), 3.63 (m_c, 2 H, 1''-H), 7.07 (dd, *J* = 5.0, 3.8 Hz, 1 H, 4'-H), 7.41 (dd, *J* = 3.8, 1.1 Hz, 1 H, 5'-H), 7.51 (dd, *J* = 5.0, 1.1 Hz, 1 H, 3'-H), 7.45-7.57, 7.96-7.98 (2 m, 5 H, Ph), 11.24 (s_{br}, 1 H, NH) ppm. ^{13}C NMR ($CDCl_3$, 126 MHz): δ = -1.6, 19.1, 27.6, 71.1, 126.6, 127.7, 128.7, 129.4, 130.8, 132.3, 133.3, 133.8, 134.4, 139.5, 166.5, 201.6 ppm. IR (KBr): ν = 3340 (N-H), 3075-3020 (=C-H), 2955-2890 (C-H), 1680-1560 (C=O, C=C) cm^{-1}. Calcd for $C_{20}H_{25}NO_3SSi$ (387.6): C 61.98; H 6.50; N 3.61%; found: C 61.70; H 6.58; N 3.54%.



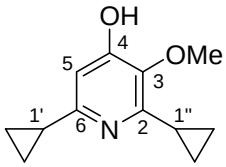
5 **5'**

(*E*)-*N*-(2-Methoxy-3-oxobut-1-enyl)picolinamide (5) and (*Z*)-*N*-(2-Methoxy-3-oxobut-1-enyl)picolinamide (5')

light yellow solid: 5%; mp 124-125 °C. **5**: ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 2.28 (s, 3 H, 4-H), 3.64 (s, 3 H, OMe), 7.07 (d, 1 H, *J* = 10.0 Hz, 1-H), 7.41 (ddd, 1 H, *J* = 7.7, 4.7, 1.7 Hz, 5''-H), 7.81 (td, 1 H, *J* = 7.8, 1.7 Hz, 4''-H), 8.14 (dt, 1 H, *J* = 7.8, 1.1 Hz, 3''-H), 8.64 (ddd, 1 H, *J* = 4.8, 1.5, 0.9 Hz, 6''-H), 12.39 (d, 1 H, *J* = 10.0 Hz, NH) ppm. ^{13}C NMR ($CDCl_3$, 126 MHz): δ = 27.0, 56.4, 112.9, 122.8, 126.7, 137.3, 141.2, 148.9, 163.1, 200.0 ppm; C-2'' could not be unambiguously detected. IR (KBr): ν = 3270 (N-H), 3085-3010 (=C-H), 2955-2840 (C-H), 1675 (C=O), 1600-1480 (C=C) cm^{-1}. MS (EI): *m/z* (%) = 220 (17) $[M]^+$, 177 (100), 106 (21), 79 (33), 78 (76), 43 (22). HRMS (EI): Calcd. for $C_{11}H_{12}N_2O_3$ $[M]^+$: 220.08479; found 220.08538.

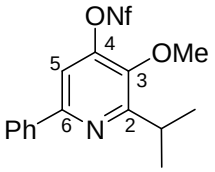
5': ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 2.26 (s, 3 H, 4-H), 3.51 (s, 3 H, OMe), 5.19 (d, 1 H, *J* = 8.5 Hz, 1-H), 7.44 (ddd, 1 H, *J* = 7.7, 4.7, 1.6 Hz, 5''-H), 7.83 (td, 1 H, *J* = 7.7, 1.6 Hz, 4''-H), 8.14 (dt, 1 H, *J* = 7.8, 1.0 Hz, 3''-H), 8.65 (ddd, 1 H, *J* = 4.8, 1.5, 0.9 Hz, 6''-H), 9.28 (d,

1H, *J* = 8.5 Hz, NH) ppm. ^{13}C NMR ($CDCl_3$, 126 MHz): δ = 26.3, 54.3, 85.2, 122.4, 126.5, 137.3, 148.7, 149.3, 164.3, 208.8 ppm; C-2'' could not be unambiguously detected.



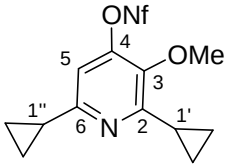
2,6-Dicyclopropyl-3-methoxypyridin-4-ol (6a)

colourless solid: 97%; mp 158 °C. ^{1}H NMR (CF_3CO_2D, 500 MHz): δ = 0.83-0.88, 0.99-1.09 (2 m, 2 H, 6 H, *c*-Pr), 1.97 (m_c, 1 H, 1'-H), 2.21 (m_c, 1 H, 1''-H), 3.90 (s, 3 H, OMe), 6.49 (s, 1 H, 5-H) ppm. ^{13}C NMR (CF_3CO_2D, 101 MHz): δ = 7.6, 9.9, 9.5, 12.7, 61.5, 105.5, 142.8, 150.3, 157.2, 164.5 ppm. IR (KBr): ν = 3270 (O-H), 3090-2865 (=C-H, C-H), 1635-1595 (C=C) cm^{-1}. Calcd for $C_{12}H_{15}NO_2$ (205.3): C 70.22; H 7.37; N 6.82%; found: C 69.89; H 7.26; N 6.78%. HRMS (ESI-TOF): Calcd. for $C_{12}H_{15}NO_2$ $[M+H]^+$: 206.1176; found 206.1183.



2-Isopropyl-3-methoxy-6-phenylpyridin-4-yl nonaflate (9a)

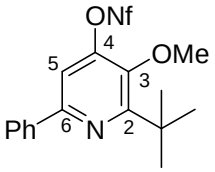
colourless oil: 52%; ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 1.38 (d, 6 H, *J* = 6.8 Hz, *i*-Pr), 3.54 (hept, 1 H, *J* = 6.8 Hz, *i*-Pr), 3.94 (s, 3 H, OMe), 7.46-7.49, 8.00-8.03 (2 m, 4 H, 2 H, 5-H, Ph) ppm. ^{13}C NMR ($CDCl_3$, 101 MHz): δ = 22.0, 29.8, 61.3, 110.9, 126.8, 128.9, 129.4, 138.0, 143.9, 149.6, 153.8, 163.8 ppm. IR (film): ν = 3090-2835 (=C-H, C-H), 1565-1425 (C=C) cm^{-1}. HRMS (ESI-TOF): Calcd. for $C_{19}H_{16}F_9NO_4S$ $[M+H]^+$: 526.0735; found 526.0725.



2,6-Dicyclopropyl-3-methoxypyridin-4-yl nonaflate (9b)

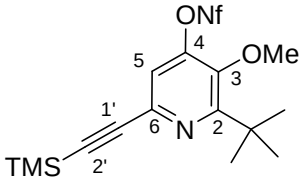
colourless oil: 38%; ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 0.90-0.97, 1.01-1.05 (2 m, 4 H, 4 H, *c*-Pr), 1.88 (m_c, 1 H, 1''-H), 2.34 (m_c, 1 H, 1'-H), 3.87 (s, 3 H, OMe), 6.78 (s, 1 H, 5-H) ppm. ^{13}C NMR ($CDCl_3$, 101 MHz): δ = 9.9*, 11.3, 16.8, 61.9, 110.8, 143.2, 148.5, 158.8, 159.1

ppm; overlapping of *c*-Pr signals. IR (film): ν = 3095-3005 (=C-H), 2945-2835 (C-H), 1575 (C=C) cm^{-1}. HRMS (ESI-TOF): Calcd. for $C_{16}H_{14}F_9NO_4S$ $[M+H]^+$: 488.0573; found 488.0590.



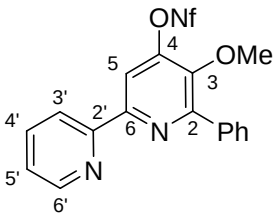
2-*tert*-Butyl-3-methoxy-6-phenyl-pyridin-4-yl nonaflate (9d)

colourless oil: 38%; ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 1.49 (s, 9 H, *t*-Bu), 3.94 (s, 3 H, OMe), 7.39-7.42, 7.44-7.48 (2 m, 1 H, 2 H, Ph), 7.50 (s, 1 H, 5-H), 7.98-8.00 (m, 2 H, Ph) ppm. ^{13}C NMR ($CDCl_3$, 126 MHz): δ = 29.3, 39.1, 61.8, 111.9, 126.6, 128.7, 129.3, 137.9, 146.0, 150.4, 151.5, 164.2 ppm. IR (film): ν = 3090-3065 (=C-H), 2960-2870 (C-H), 1590-1460 (C=C) cm^{-1}. MS (EI): *m/z* (%) = 538 (100) $[M]^+$, 524 (82), 57 (38). HRMS (EI): Calcd. for $C_{20}H_{18}F_9NSO_4$ $[M]^+$: 539.08130; found 539.08222.



2-*tert*-Butyl-3-methoxy-6-[(trimethylsilyl)ethynyl]pyridin-4-yl nonaflate (9e)

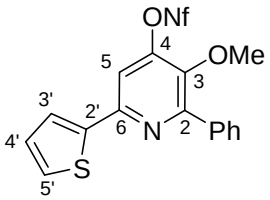
colourless oil: 22%; ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 0.26 (s, 9 H, TMS), 1.39 (s, 9 H, *t*-Bu), 3.91 (s, 3 H, OMe), 7.23 (s, 1 H, 5-H) ppm. ^{13}C NMR ($CDCl_3$, 101 MHz): δ = -0.3, 29.1, 38.8, 61.9, 94.9, 102.7, 119.1, 137.2, 147.1, 149.0, 165.4 ppm. IR (film): ν = 3010-2835 (=C-H, C-H), 2165 (C≡C), 1740-1575 (C=C) cm^{-1}. HRMS (ESI-TOF): Calcd. for $C_{19}H_{22}NO_4SSi$ $[M+H]^+$: 560.0968; found 560.0983.



3-Methoxy-2-phenyl-[6,2']bipyridinyl-4-yl nonaflate (9f)

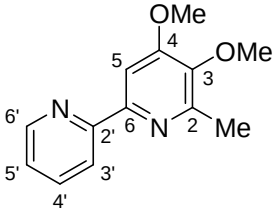
colourless solid: 55%; mp 58-59 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 3.70 (s, 3 H, OMe), 7.33 (ddd, 1 H, *J* = 7.6, 4.8, 1.1 Hz, 5'-H), 7.48-7.55 (m, 3 H, Ph),7.81 (td, 1 H, *J* = 7.6, 1.6

Hz, 4'-H), 8.08-8.09 (m, 2 H, Ph), 8.35 (s, 1 H, 5-H), 8.50 (dt, 1 H, *J* = 7.8, 1.0 Hz, 3'-H), 8.68 (ddd, 1 H, *J* = 4.8, 1.8, 0.9 Hz, 6'-H) ppm. ^{13}C NMR ($CDCl_3$, 126 MHz): δ = 61.9, 113.0, 121.2, 124.2, 128.6, 129.1, 129.6, 136.9, 137.0, 146.8, 149.3, 153.1, 153.3, 154.4, 157.5 ppm. IR (KBr): ν = 3090 (=C-H), 2980-2840 (C-H), 1590-1500 (C=C) cm^{-1}. MS (EI): *m/z* (%) = 561 (21) $[M + H]^+$, 560 (100) $[M]^+$, 545 (12), 277 (90), 262 (13), 249 (74), 69 (22). HRMS (EI): Calcd. for $C_{21}H_{13}F_9N_2O_4S$ $[M]^+$: 560.04523; found 560.04622.



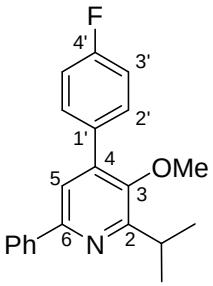
3-Methoxy-2-phenyl-6-(thiophen-2-yl)pyridin-4-yl nonaflate (9g)

colourless solid: 23%; mp 89 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 3.66 (s, 3 H, OMe), 7.11 (dd, *J* = 5.0, 3.8 Hz, 1 H, 4'-H), 7.41-7.52, 8.06-8.08 (2 m, 6 H, 3'-H, Ph), 7.43 (s, 1 H, 5-H), 7.56 (dd, *J* = 3.8, 1.0 Hz, 1 H, 5'-H) ppm. ^{13}C NMR ($CDCl_3$, 101 MHz): δ = 61.5, 110.2, 125.3, 128.1, 128.5, 128.7, 129.1, 129.6, 136.1, 143.3, 145.0, 149.3, 150.3, 153.6 ppm. IR (KBr): ν = 3100-3025 (=C-H), 2955-2865 (C-H), 1595-1560 (C=C) cm^{-1}. Calcd for $C_{20}H_{12}F_9NO_4S_2$ (556.4): C 42.48; H 2.14; N 2.48%; found: C 42.44; H 1.85; N 2.47%.



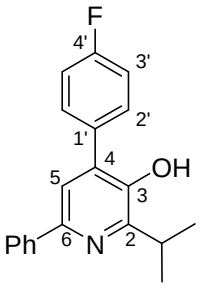
3,4-Dimethoxy-2-methyl-6,2'-bipyridine (10a)

colourless solid: 53%; mp 84-85 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 2.54 (s, 3 H, Me), 3.84, 4.00 (2 s, 3 H each, OMe) 7.15 (ddd, 1 H, *J* = 7.6, 4.8, 1.1 Hz, 5'-H), 7.78 (td, 1 H, *J* = 7.8, 1.6 Hz, 4'-H), 7.87 (s, 1 H, 3-H), 8.38 (dt, 1 H, *J* = 7.8, 0.9 Hz, 3'-H), 8.62 (ddd, 1 H, *J* = 4.8, 1.8, 0.9 Hz, 6'-H) ppm. ^{13}C NMR ($CDCl_3$, 126 MHz): δ = 19.3, 55.9, 60.5, 103.3, 121.1, 123.8, 136.9, 143.8, 148.9, 152.05, 152.08, 156.2, 158.9 ppm. IR (KBr): ν = 3050-3000 (=C-H), 2920-2850 (C-H), 1580-1460 (C=C) cm^{-1}. MS (EI): *m/z* (%) = 231 (21), 230 (100) $[M]^+$, 229 (24), 215 (49). HRMS (EI): Calcd. for $C_{13}H_{14}N_2O_2$ $[M]^+$: 230.10553; found 230.10482.



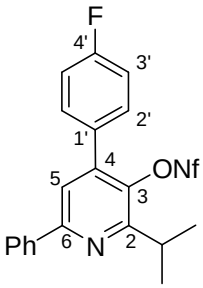
4-(4-Fluorophenyl)-2-isopropyl-3-methoxy-6-phenylpyridine (11)

light yellow oil: 92%; ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 1.40 (d, 6 H, *J* = 6.9 Hz, *i*-Pr), 3.43 (s, 3 H, OMe), 3.58 (hept., 1 H, *J* = 6.9 Hz, *i*-Pr), 7.16-7.20, 7.37-7.40, 7.45-7.48 (3 m, 2 H, 1 H, 2 H, Ar), 7.53 (s, 1 H, 5-H), 7.65-7.68, 8.07-8.09 (2 m, 2 H, 2 H, Ar) ppm. ^{13}C NMR ($CDCl_3$, 101 MHz): δ = 22.3, 29.4, 61.0, 115.8 (d, $^{2}J_{CF}$ = 21.6 Hz), 119.3, 126.8, 128.5, 128.7, 130.7 (d, $^{3}J_{CF}$ = 8.1 Hz), 133.0 (d, $^{4}J_{CF}$ = 3.1 Hz), 139.5, 140.9, 149.9, 152.0, 161.1, 164.1 (d, $^{1}J_{CF}$ = 249 Hz) ppm. IR (film): ν = 3065 (=C-H), 2960-2850 (C-H), 1605-1465 (C=C) cm^{-1}. HRMS (ESI-TOF): Calcd. for $C_{21}H_{20}FNO$ $[M+H]^+$: 322.1602; found 322.1592.



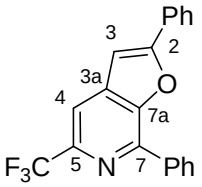
4-(4-Fluorophenyl)-2-isopropyl-6-phenylpyridin-3-ol (12)

light yellow oil: 73%; ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 1.39 (d, 6 H, *J* = 6.8 Hz, *i*-Pr), 3.49 (hept., 1 H, *J* = 6.8 Hz, *i*-Pr), 5.19 (s_{br}, 1 H, OH), 7.21-7.25, 7.33-7.35, 7.41-7.45, 7.49-7.52, 8.02-8.04 (5 m, 2 H, 1 H, 3 H, 2 H, 2 H, 5-H, Ar) ppm. ^{13}C NMR ($CDCl_3$, 101 MHz): δ = 21.2, 29.8, 116.5 (d, $^{2}J_{CF}$ = 21.6 Hz), 118.5, 126.3, 128.0, 128.6, 130.7 (d, $^{3}J_{CF}$ = 8.1 Hz), 131.5 (d, $^{4}J_{CF}$ = 3.5 Hz), 134.0, 139.5, 144.8, 148.5, 154.2, 164.2 (d, $^{1}J_{CF}$ = 250.1 Hz) ppm. IR (film): ν = 3300-3100 (O-H), 2965 (=C-H, C-H), 1695-1435 (C=C) cm^{-1}. HRMS (ESI-TOF): Calcd. for $C_{20}H_{18}FNO$ $[M+H]^+$: 308.1445; found 308.1449.



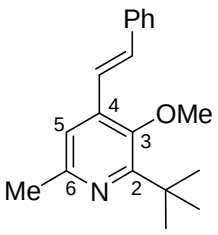
4-(4-Fluorophenyl)-2-isopropyl-6-phenylpyridin-3-yl nonaflate (13)

colourless oil: 55%; ^{1}H NMR ($CDCl_3$, 400 MHz): δ = 1.42 (d, *J* = 6.6 Hz, 6 H, *i*-Pr), 3.54 (hept., *J* = 6.6 Hz, 1 H, *i*-Pr), 7.09-7.19, 7.42-7.50 (2 m, 3 H, 4 H, Ar), 7.57 (s, 1 H, 5-H), 8.07-8.09 (m, 2 H, Ar) ppm. ^{13}C NMR ($CDCl_3$, 101 MHz): δ = 22.1, 30.1, 116.0 (d, $^{2}J_{CF}$ = 22.0 Hz), 120.4, 126.4, 127.2, 128.3, 128.9, 131.2 (d, $^{3}J_{CF}$ = 8.5 Hz), 132.9, 137.9, 143.6, 156.1, 160.7, 165.7 (d, $^{1}J_{CF}$ = 250 Hz) ppm; C-1' could not be detected. ^{19}F NMR (470 MHz, $CDCl_3$): δ = -80.6 (s, CF), -109.9, -111.7, -120.7, -125.8 (4 m_c, ONf) ppm. IR (film): ν = 3065-2855 (=C-H, C-H), 1610-1510 (C=C) cm^{-1}. HRMS (ESI-TOF): Calcd. for $C_{24}H_{17}F_{10}NO_3S$ $[M+H]^+$: 590.0848; found 590.0855.



2,7-Diphenyl-5-(trifluoromethyl)furo[2,3-*c*]pyridine (16b)

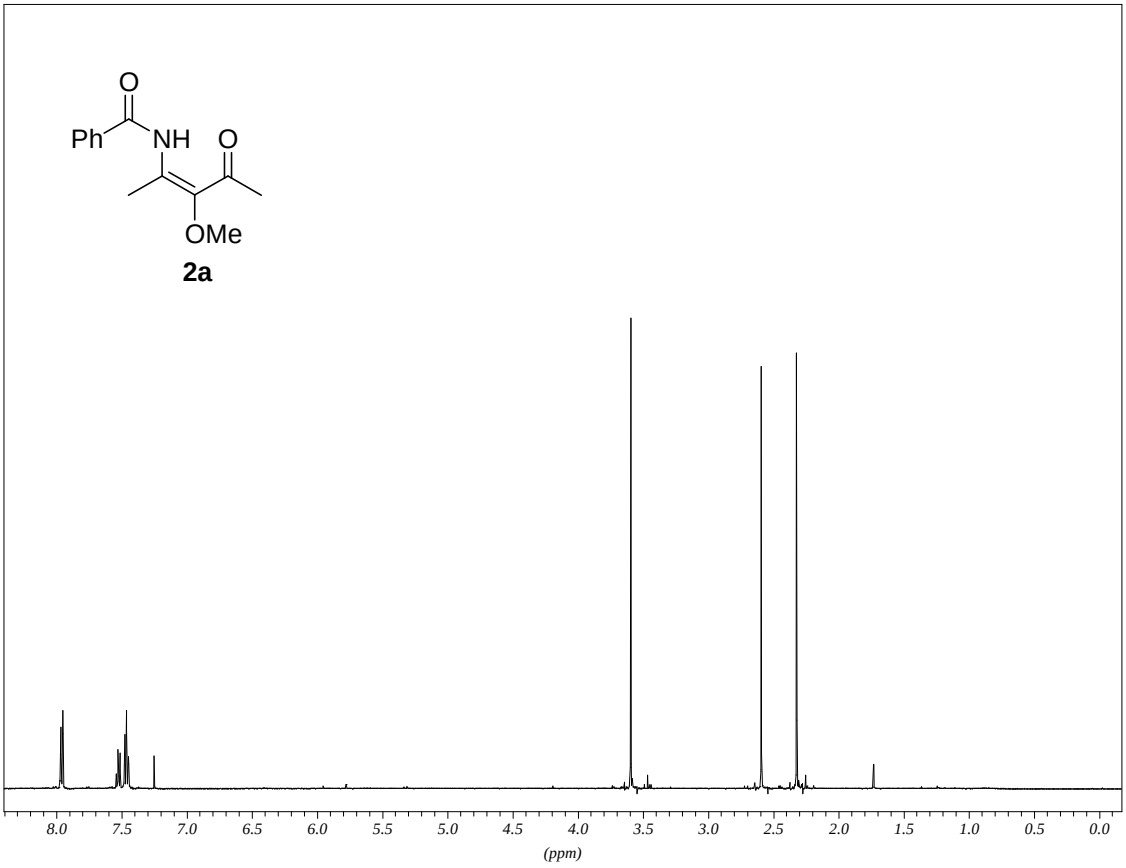
colourless solid: 40%; mp 96-99 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 7.16 (s, 1 H, 3-H), 7.46-7.61, 7.95-7.96, 8.49-8.51 (3 m, 6 H, 2 H, 2 H, Ph), 7.87 (s, 1 H, 4-H) ppm. ^{13}C NMR ($CDCl_3$, 126 MHz): δ = 100.9, 112.0 (q, $^{3}J_{CF}$ = 3.1 Hz), 122.1 (q, $^{1}J_{CF}$ = 274 Hz), 125.8, 128.74, 128.78, 128.8, 129.1, 130.3, 135.1,* 137.4, 141.5 (q, $^{2}J_{CF}$ = 34.4 Hz), 141.9, 150.1, 160.3 ppm; *overlapping of phenyl signals. ^{19}F NMR ($CDCl_3$, 470 MHz): δ = -66.4 (s, CF_3) ppm. IR (KBr): ν = 3115-2850 (=C-H, C-H), 1605-1560 (C=C) cm^{-1}. Calcd for $C_{20}H_{12}F_3NO$ (339.3): C 70.79; H 3.56; N 4.13%; found: C 71.17; H 3.86; N 4.07%. HRMS (ESI-TOF): Calcd. for $C_{20}H_{12}F_3NO$ $[M+H]^+$: 340.0944; found 340.0945.



(E)-2-*tert*-Butyl-3-methoxy-6-methyl-4-styrylpyridine (17a)

colourless solid: 92%; mp 120-121 °C. ^{1}H NMR ($CDCl_3$, 500 MHz): δ = 1.43 (s, 9 H, *t*-Bu), 2.64 (s, 3 H, Me), 3.76 (s, 3 H, OMe), 7.18 (d, 1 H, *J* = 16.4 Hz, HC=C), 7.19 (s, 1 H, 5-H), 7.29 (d, 1 H, *J* = 16.4 Hz, HC=C), 7.33-7.37, 7.38-7.41, 7.57-7.55 (3 m, 1 H, 2 H, 2 H, Ph) ppm. ^{13}C NMR ($CDCl_3$, 126 MHz): δ = 24.2, 30.0, 37.9, 62.5, 118.0, 122.6, 126.9, 128.4, 128.9, 132.2, 136.9, 138.3, 151.2, 151.3, 160.7 ppm. IR (KBr): ν = 3080-3000 (=C-H), 2980-2860 (C-H), 1595-1450 (C=C) cm^{-1}. MS (EI): *m/z* (%) = 281 (100) $[M]^+$, 280 (55), 266 (99), 250 (44), 57 (57), 43 (91). HRMS (EI): Calcd. for $C_{19}H_{23}NO$ $[M]^+$: 281.17798; found 281.17844.

NMR-Spectra of All Compounds:



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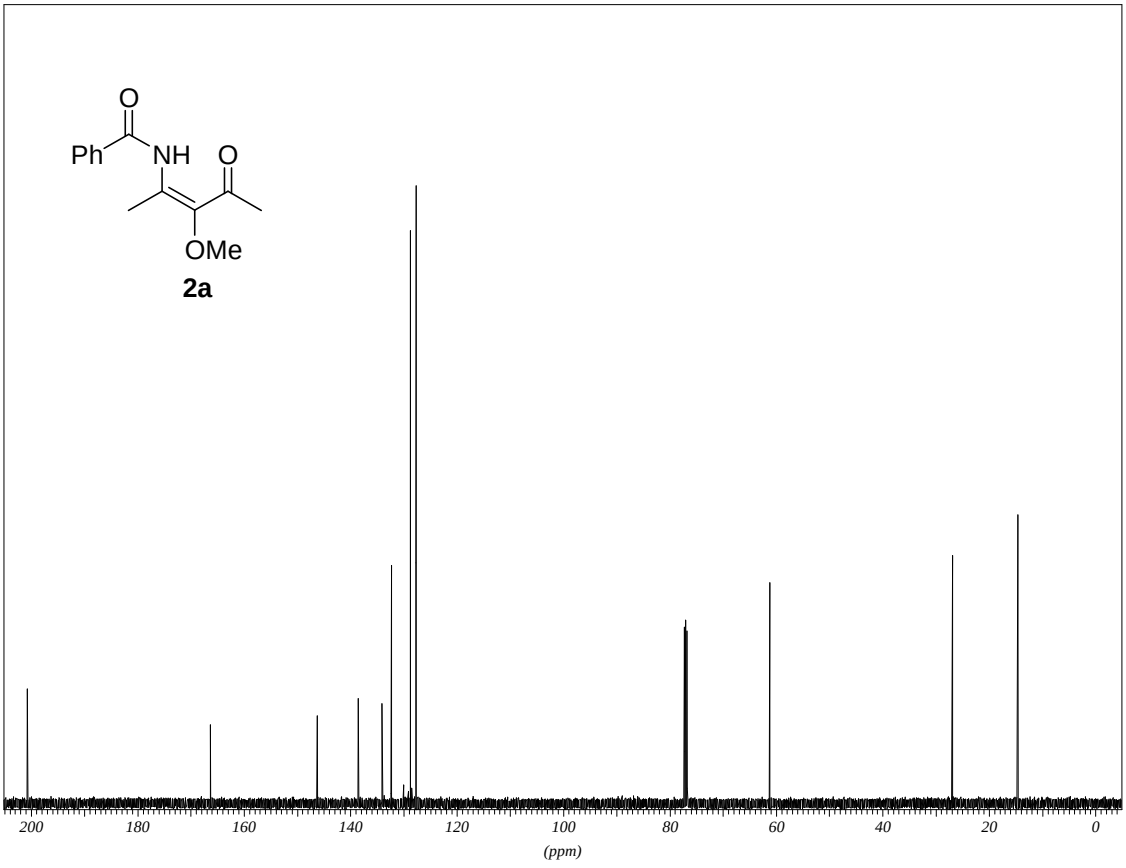

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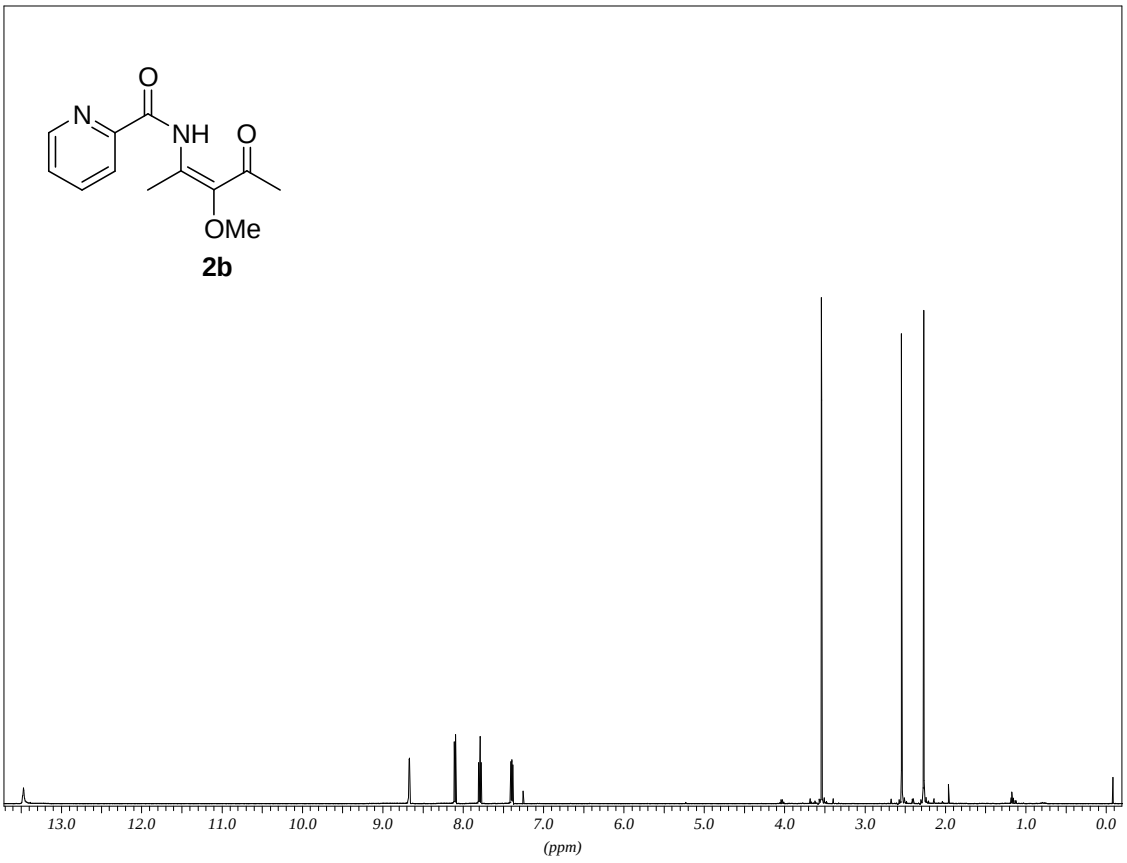

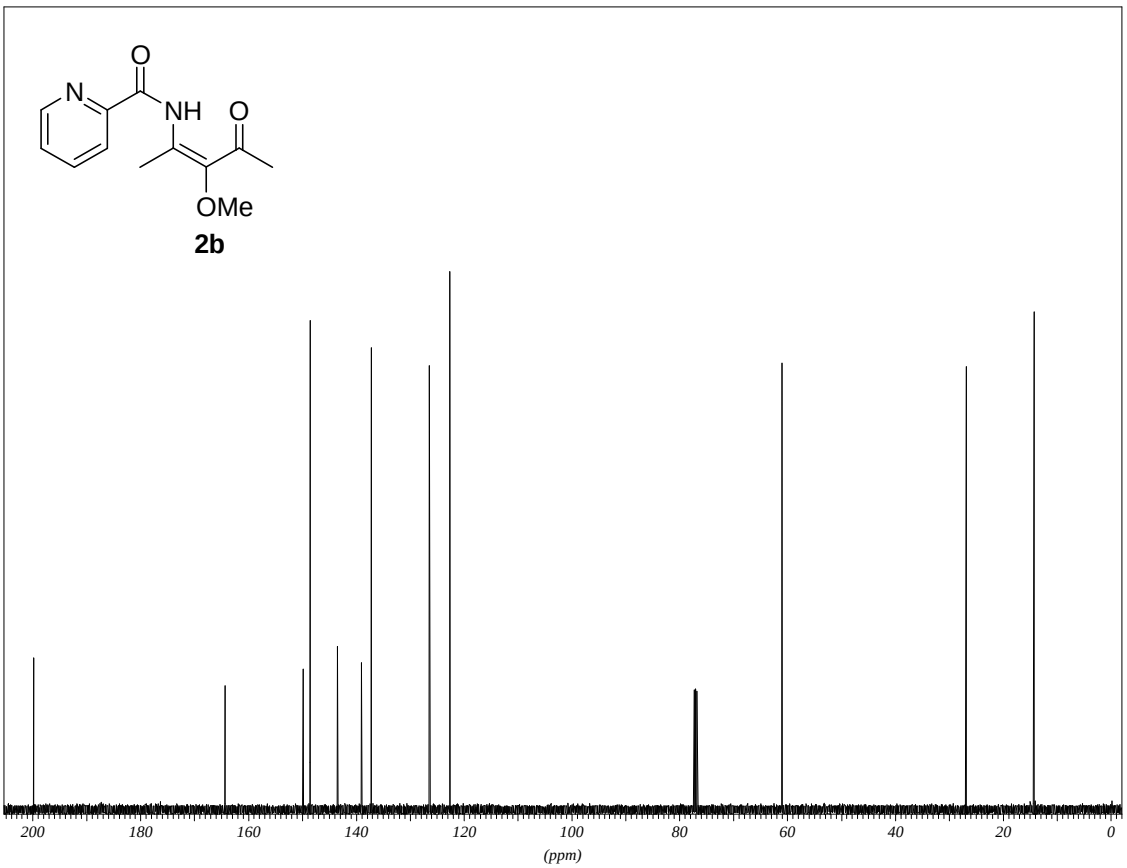

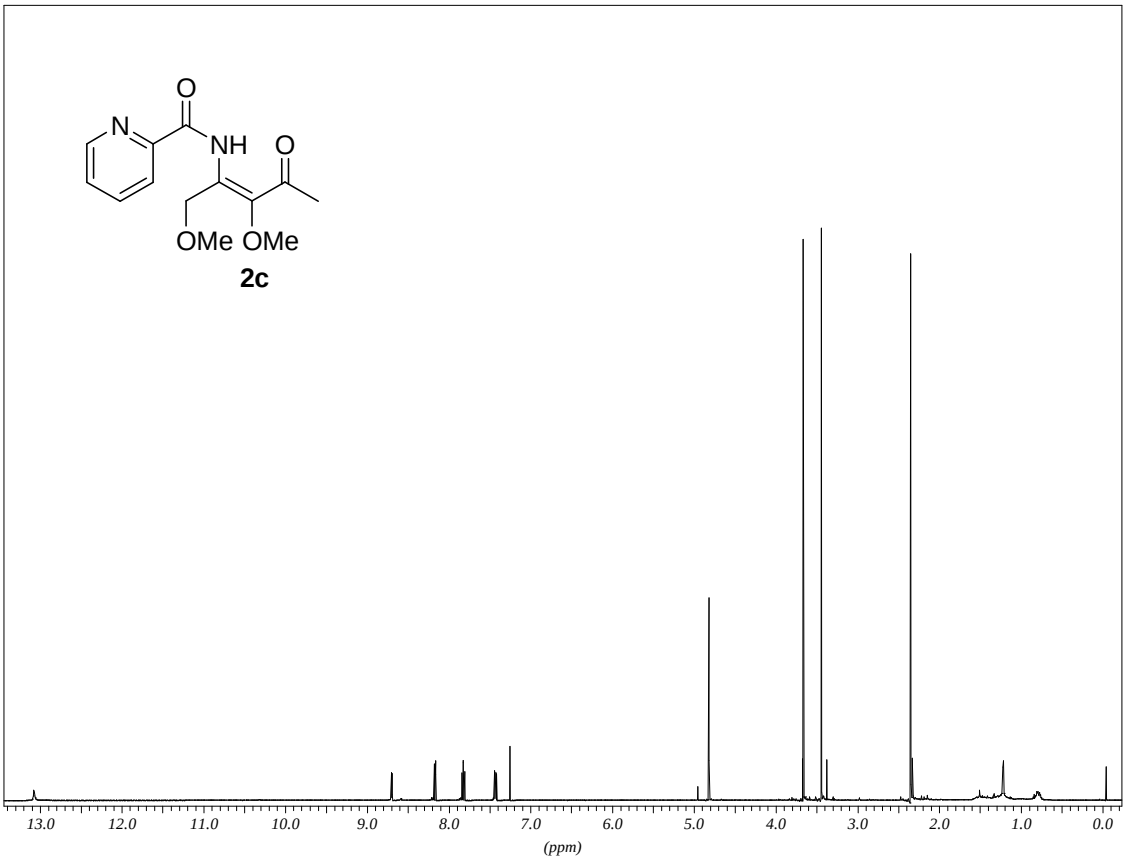

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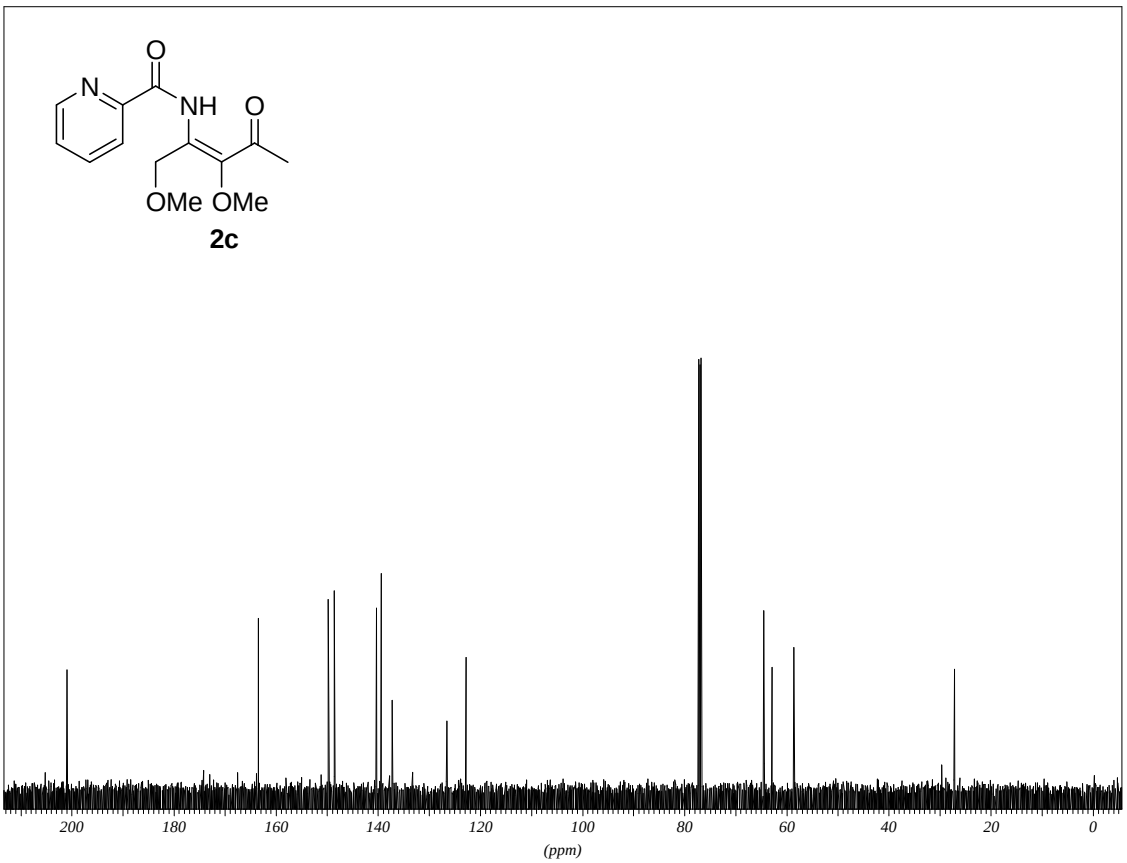

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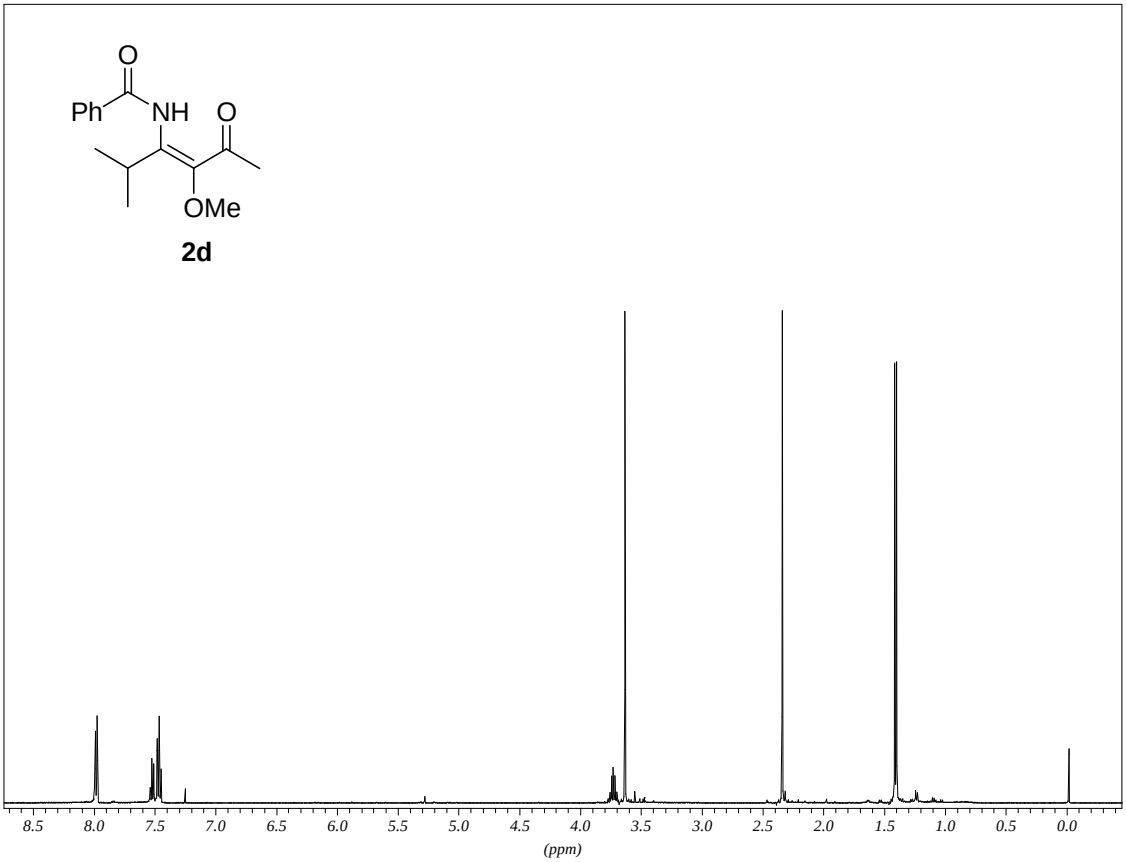

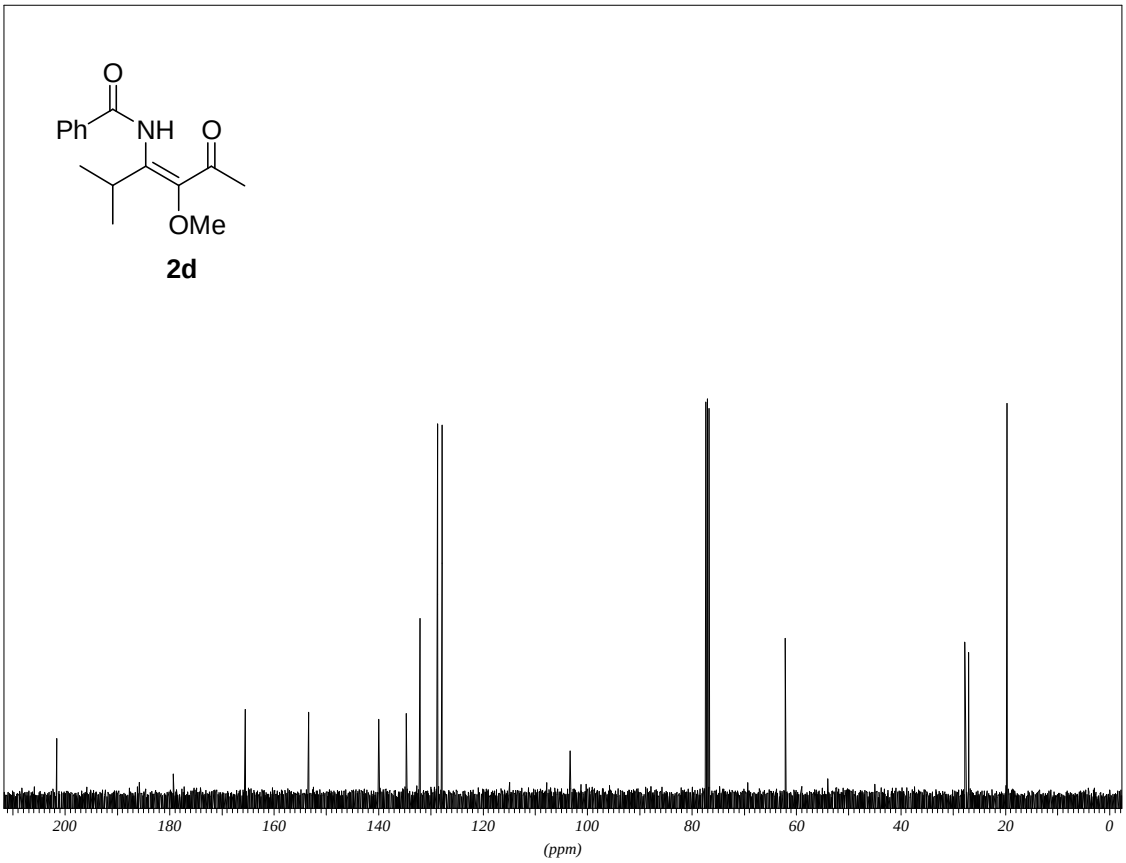

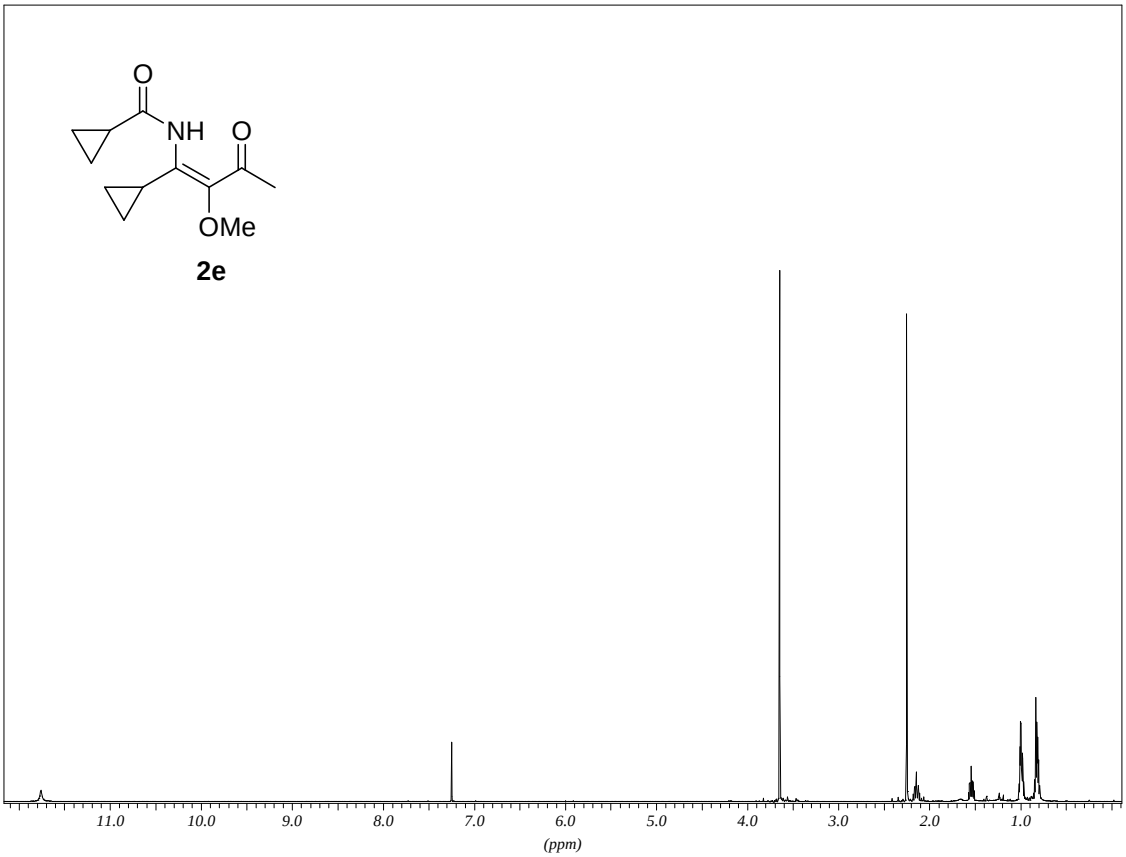

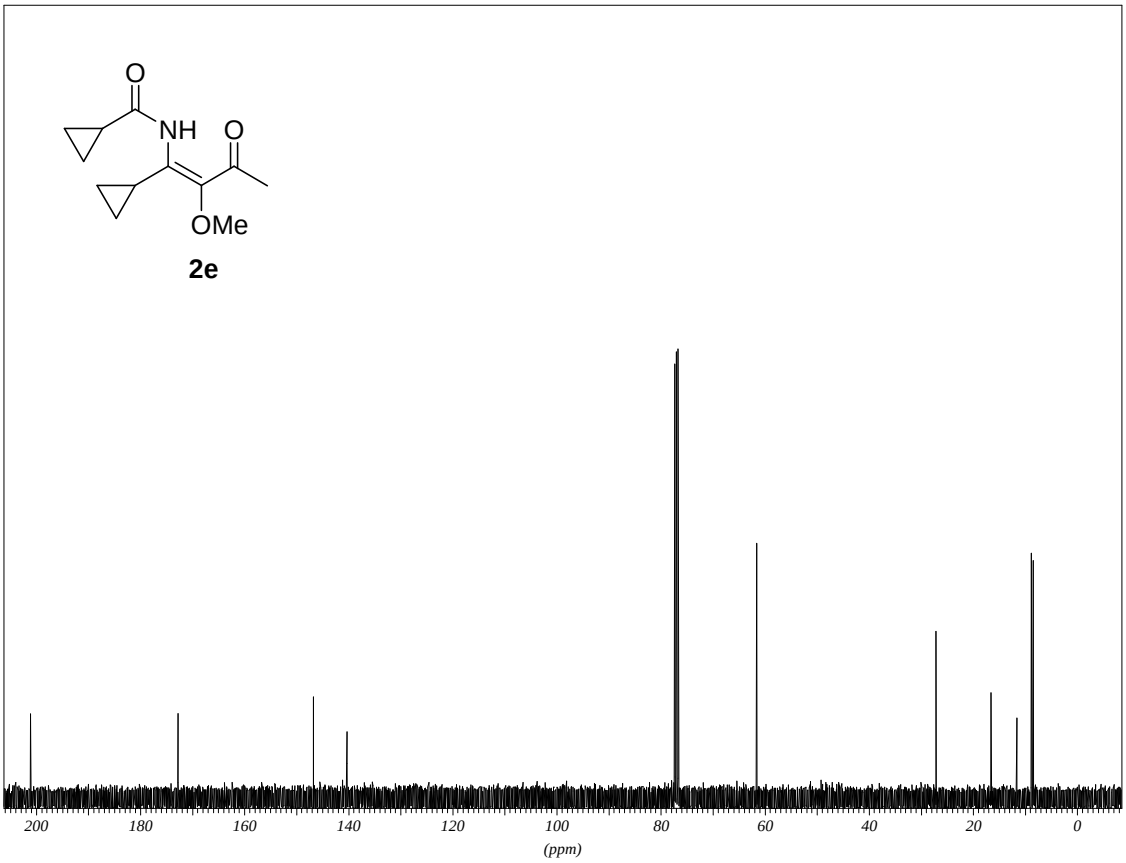

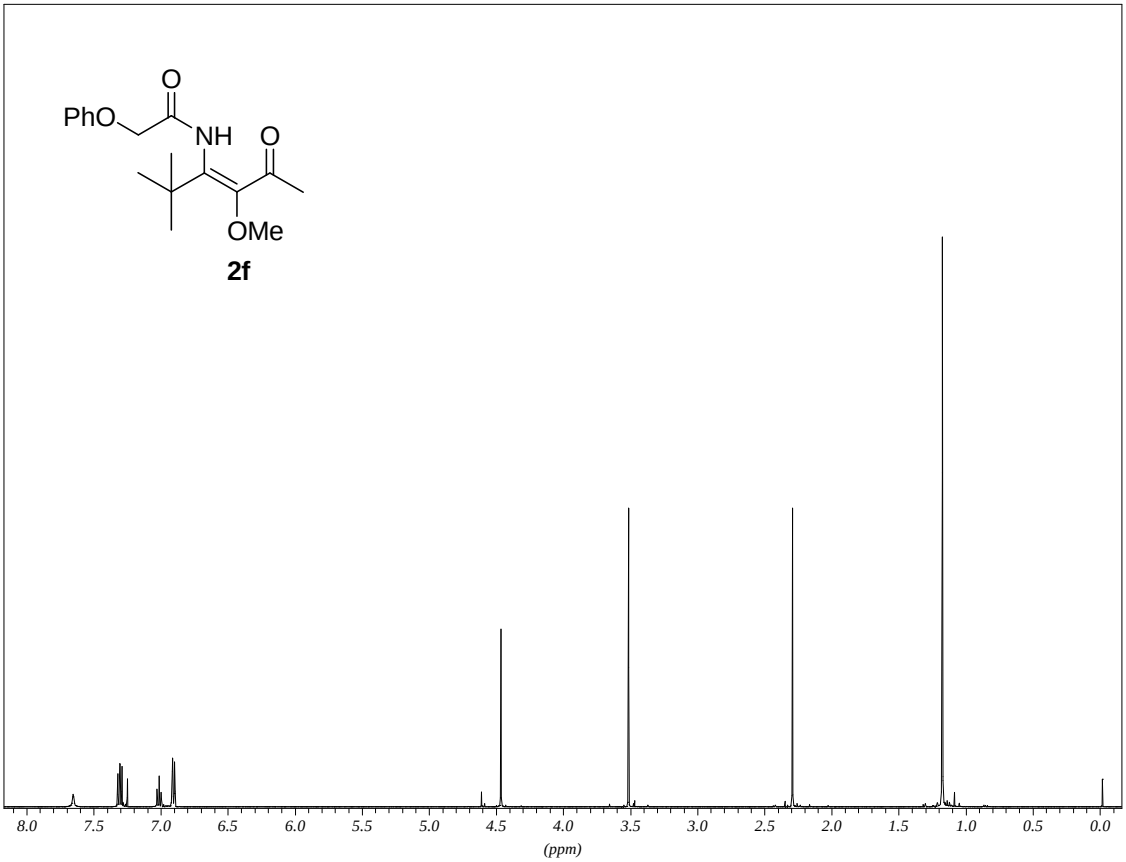

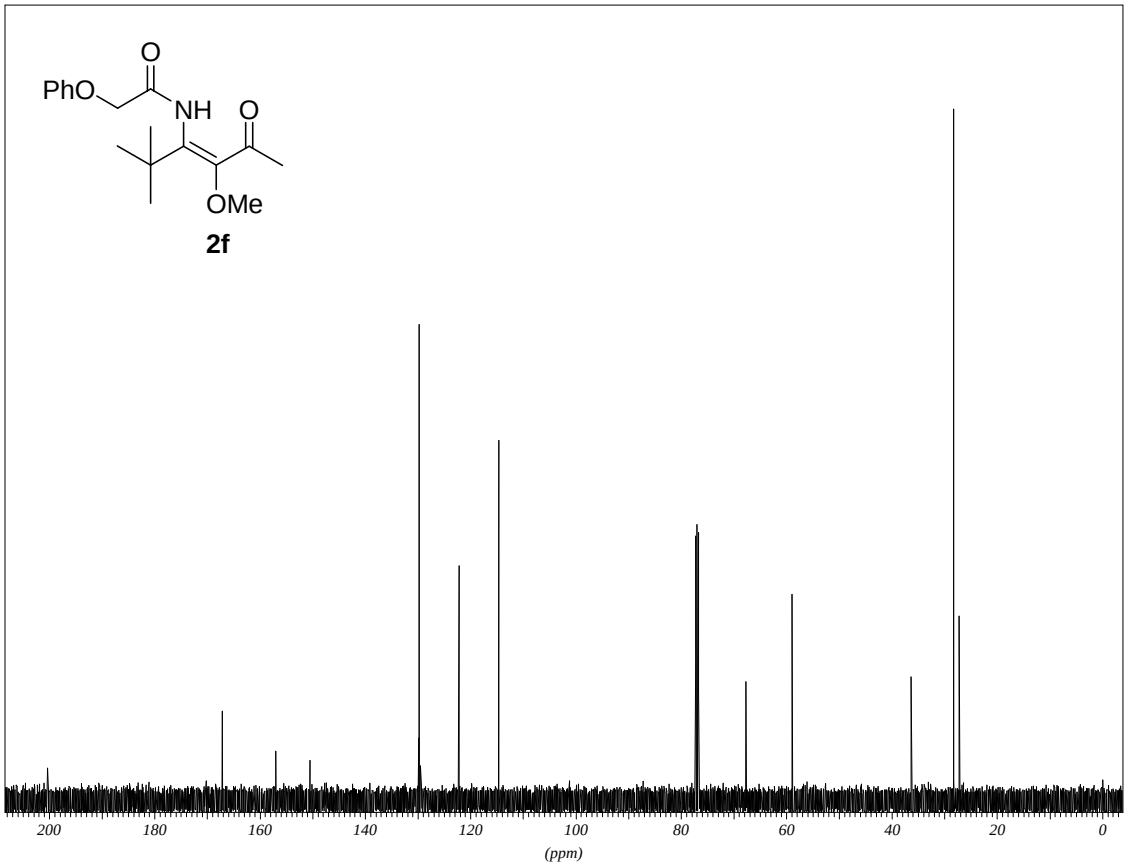

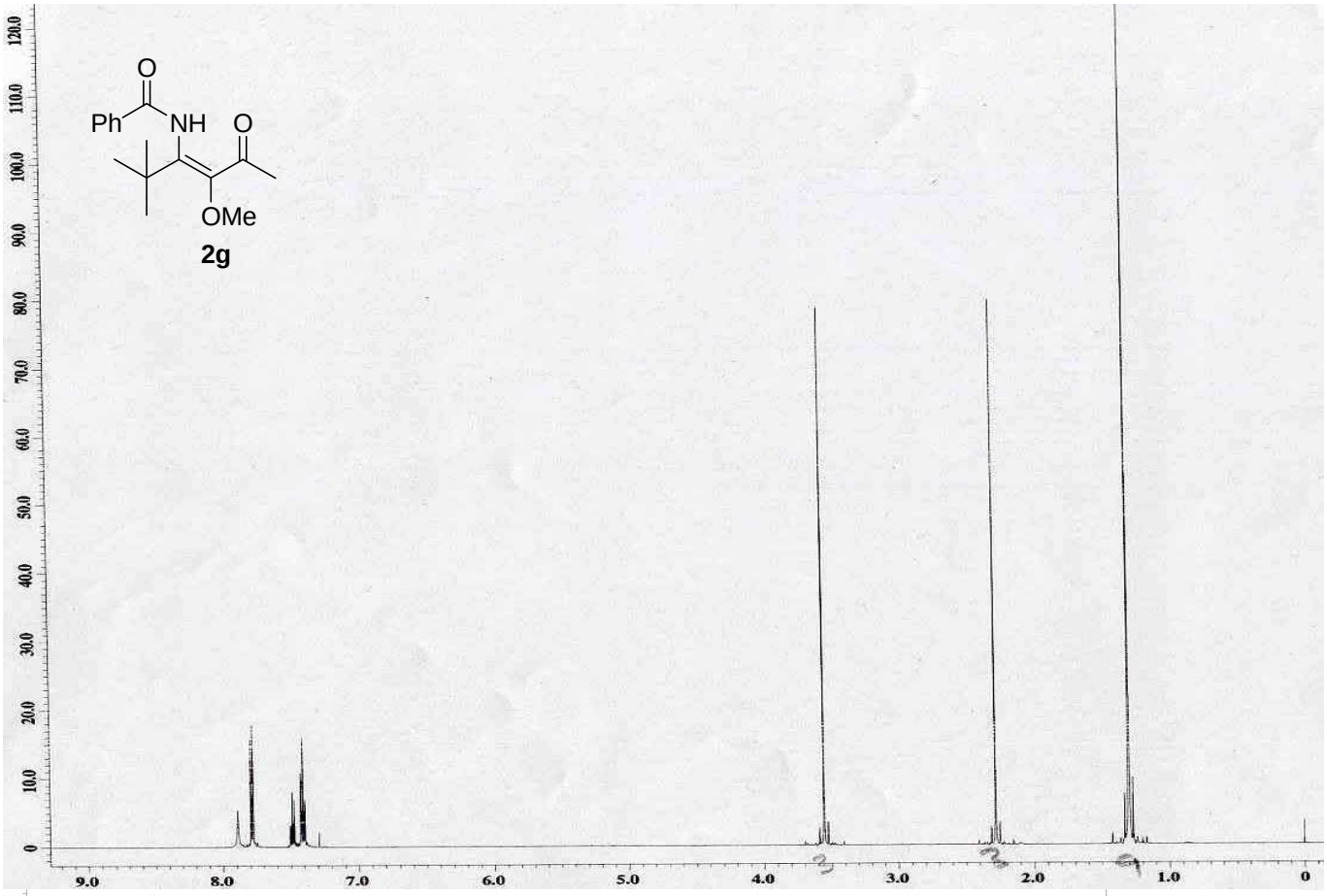

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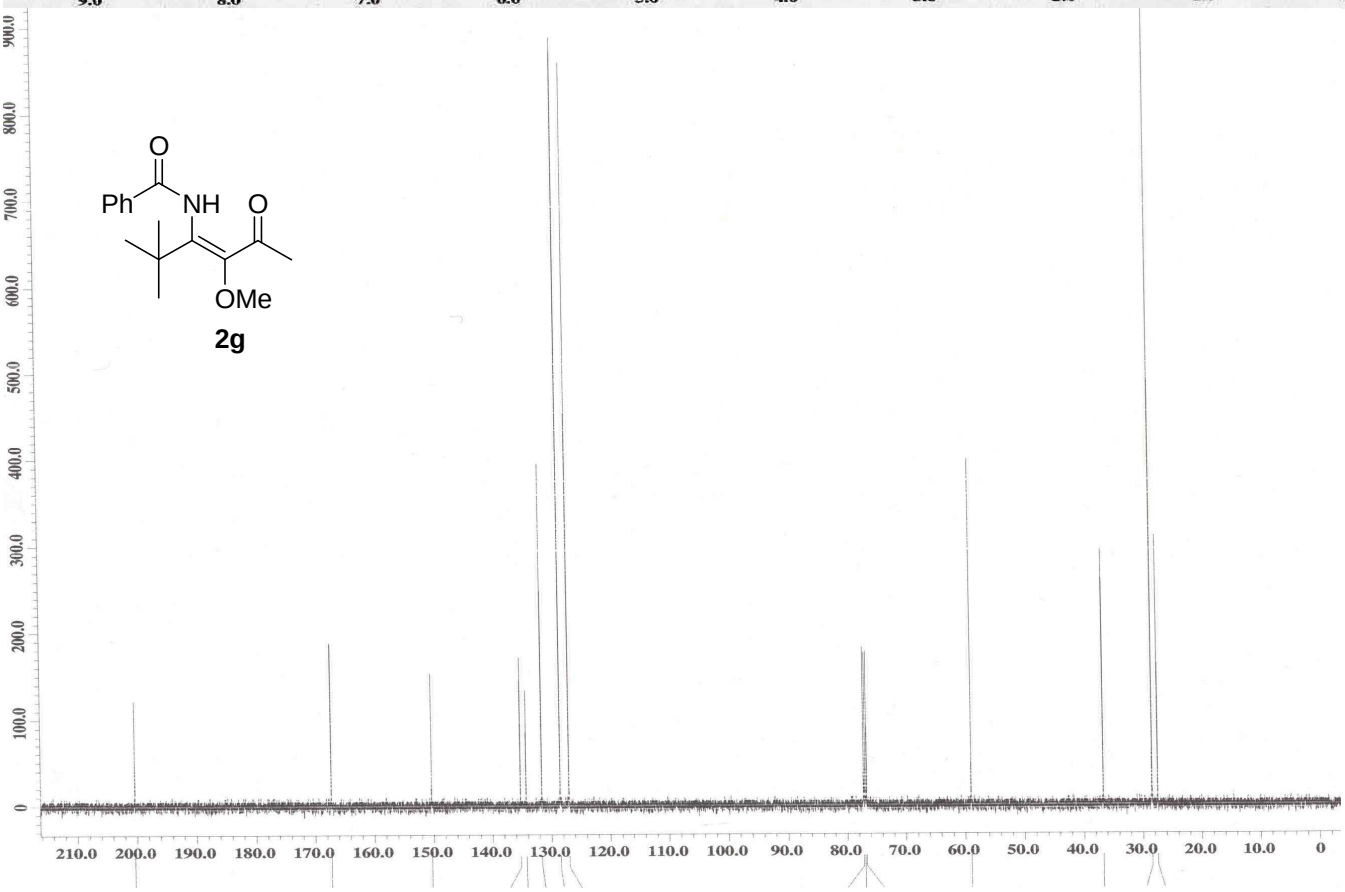

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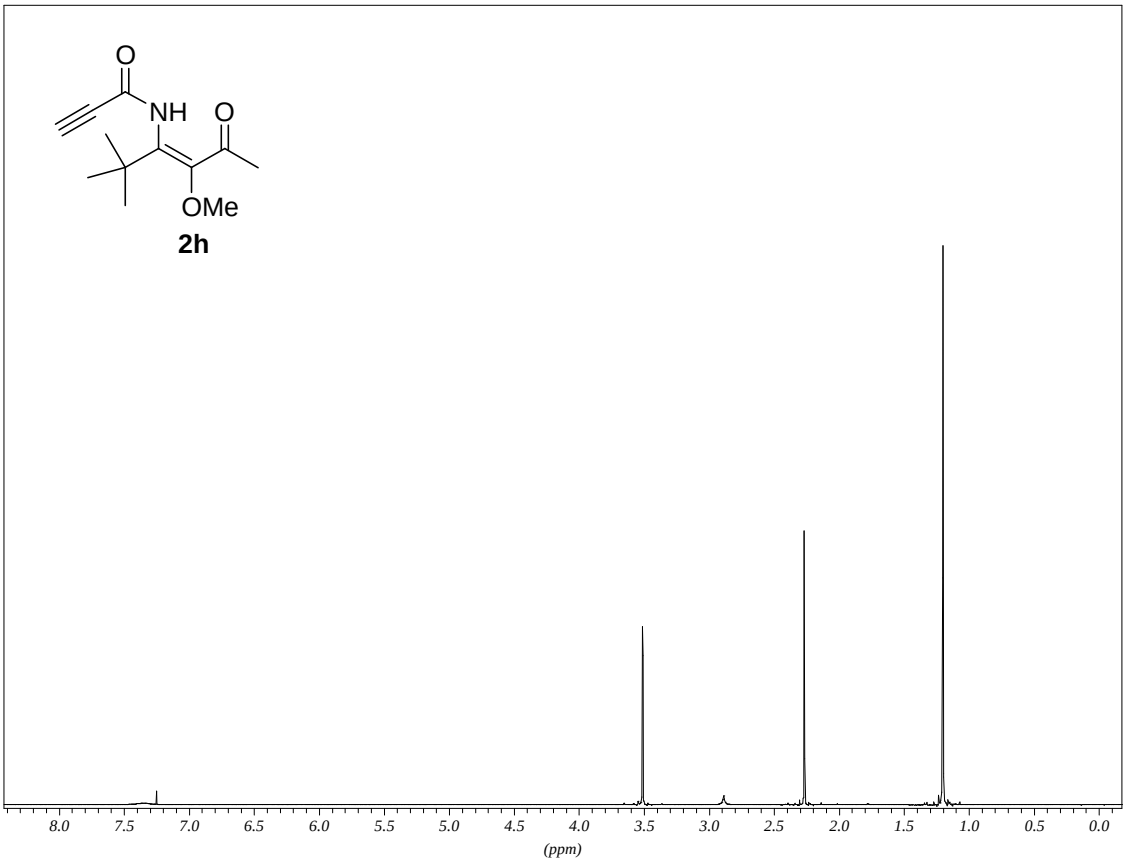
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6.0
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4.0
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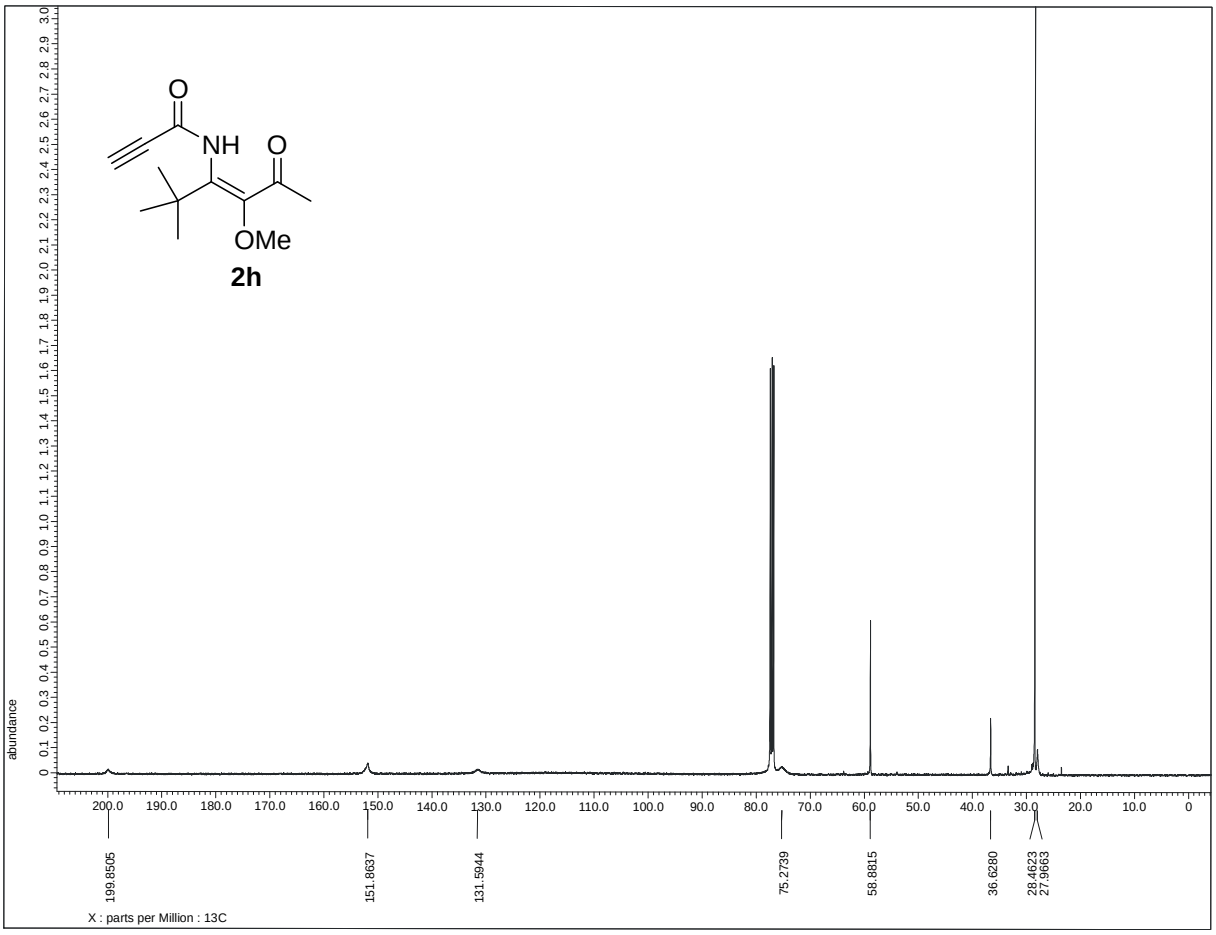
2.5
2.0
1.5
1.0
0.5
0.0
(ppm)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O
OMe
2h
abundance
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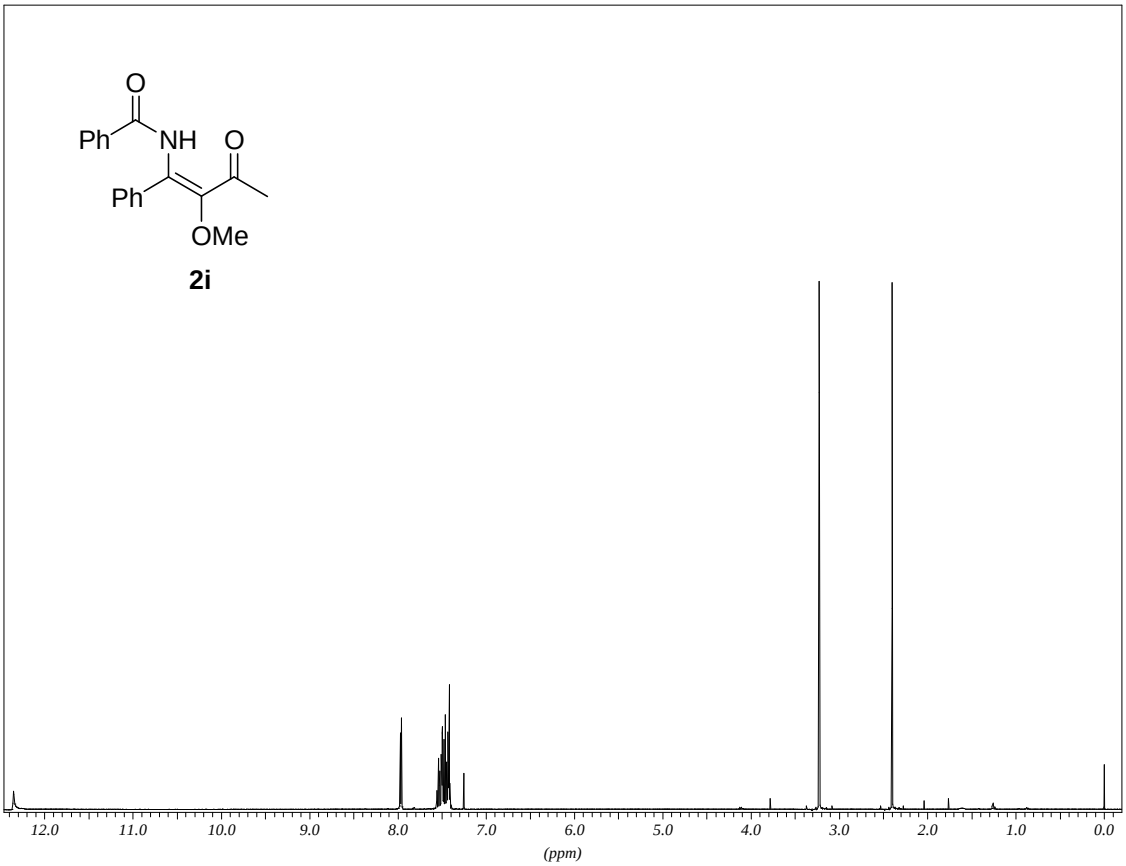
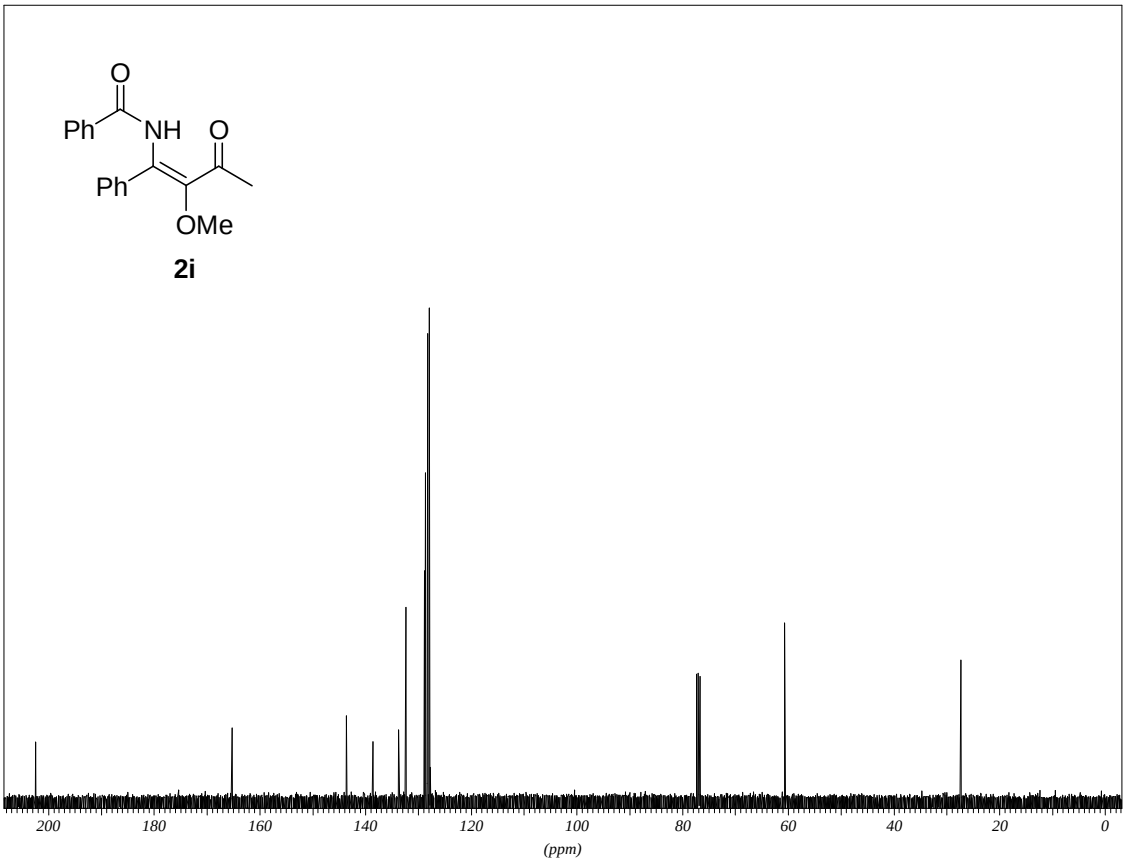
28.4623
27.9663
X : parts per Million : 13C



2i



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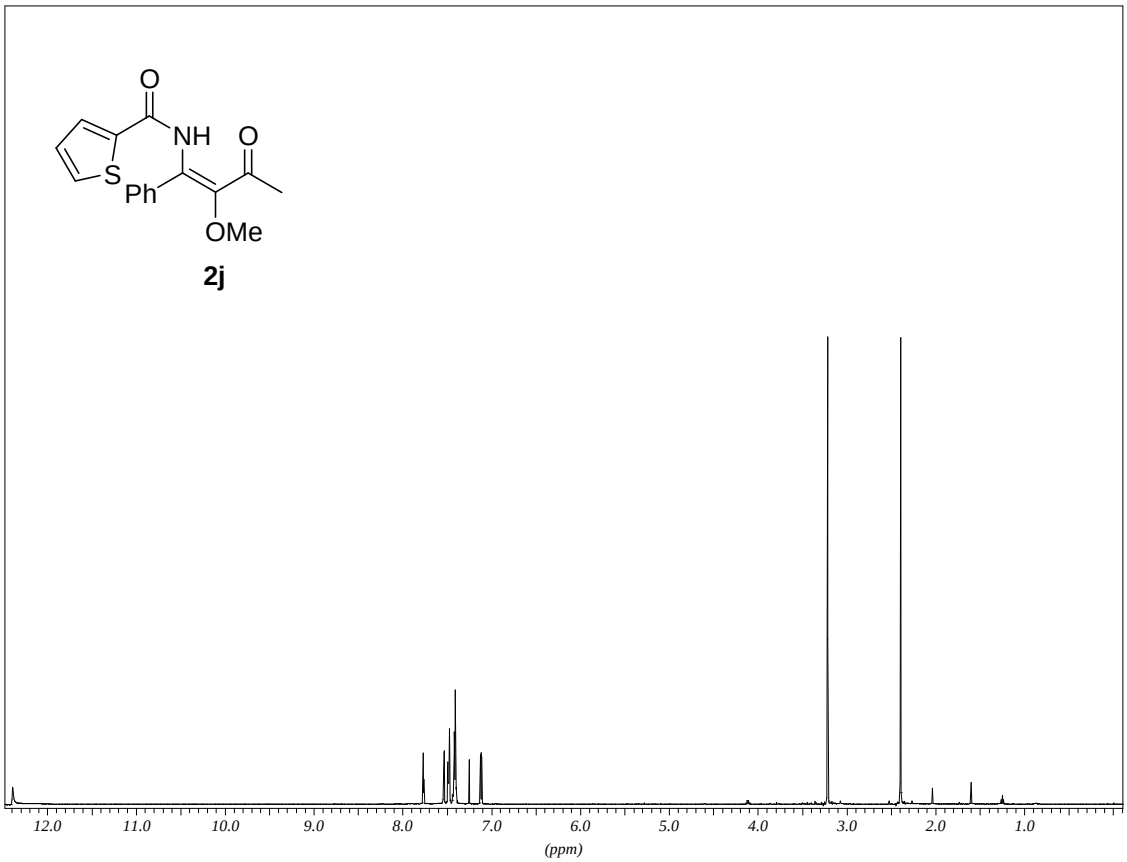

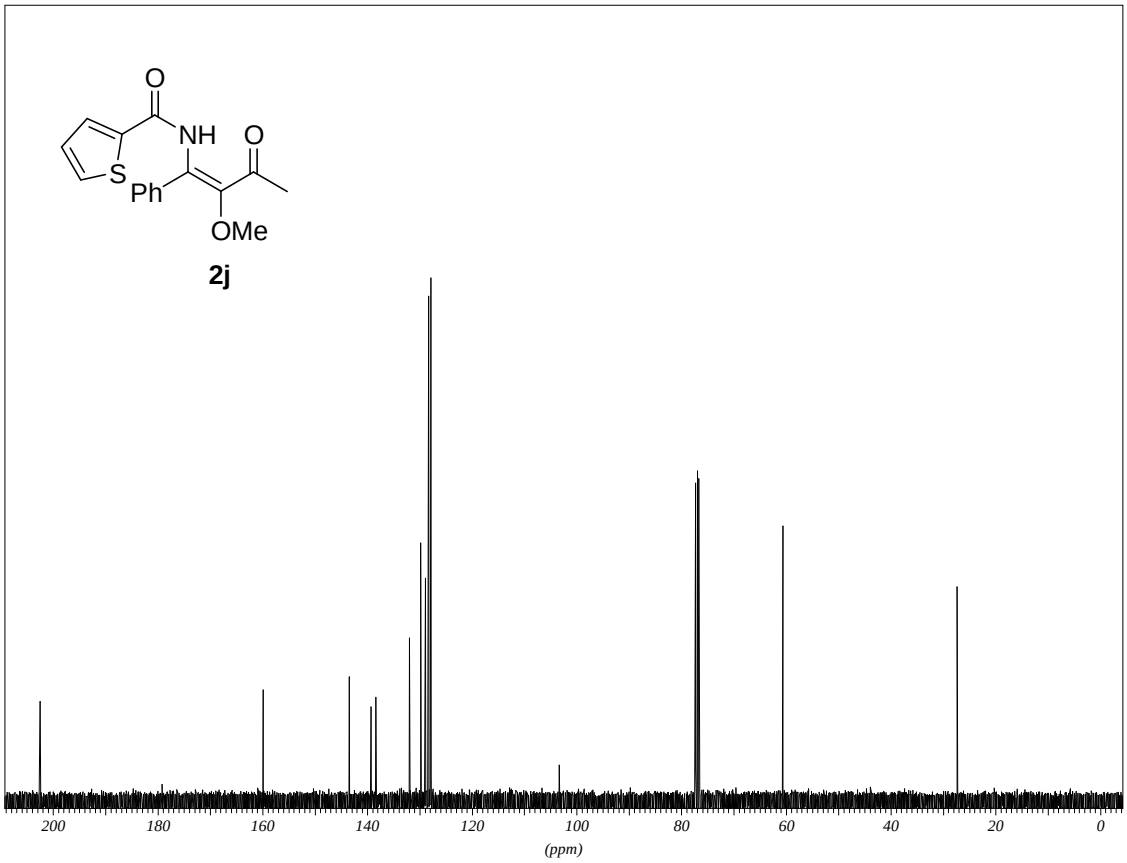

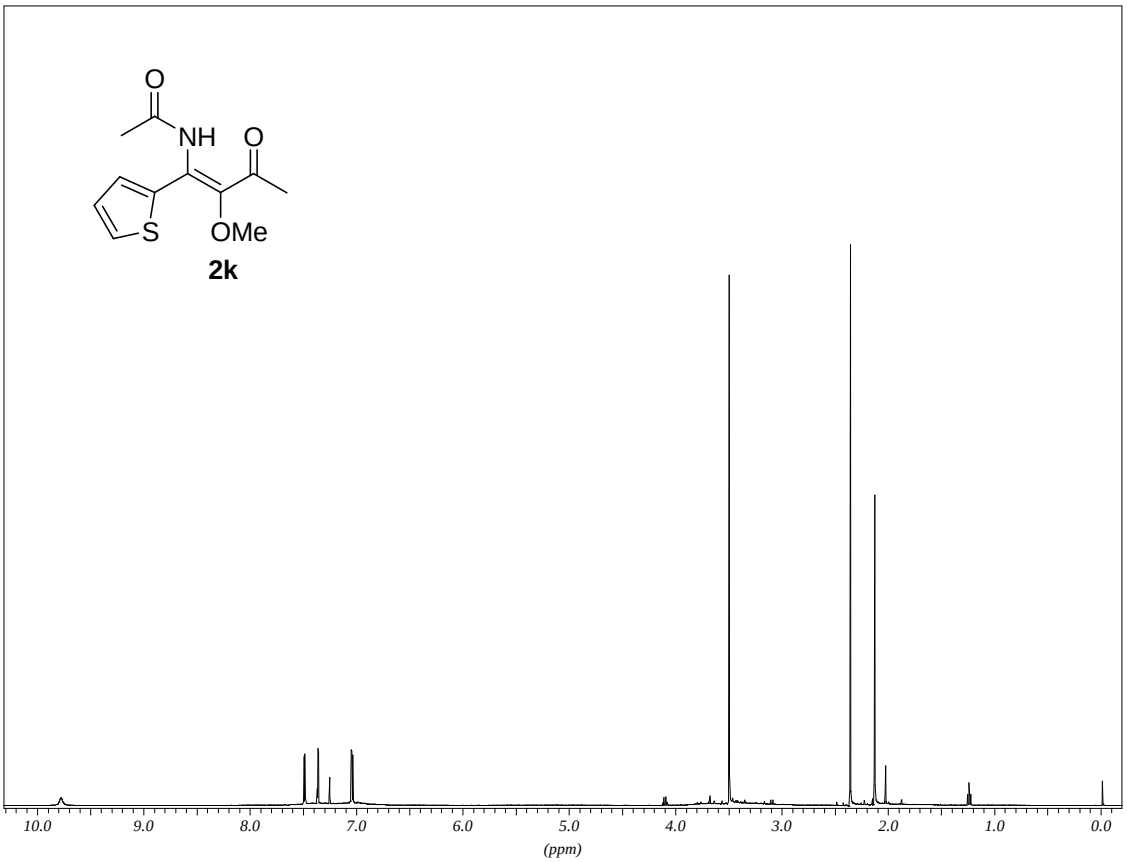

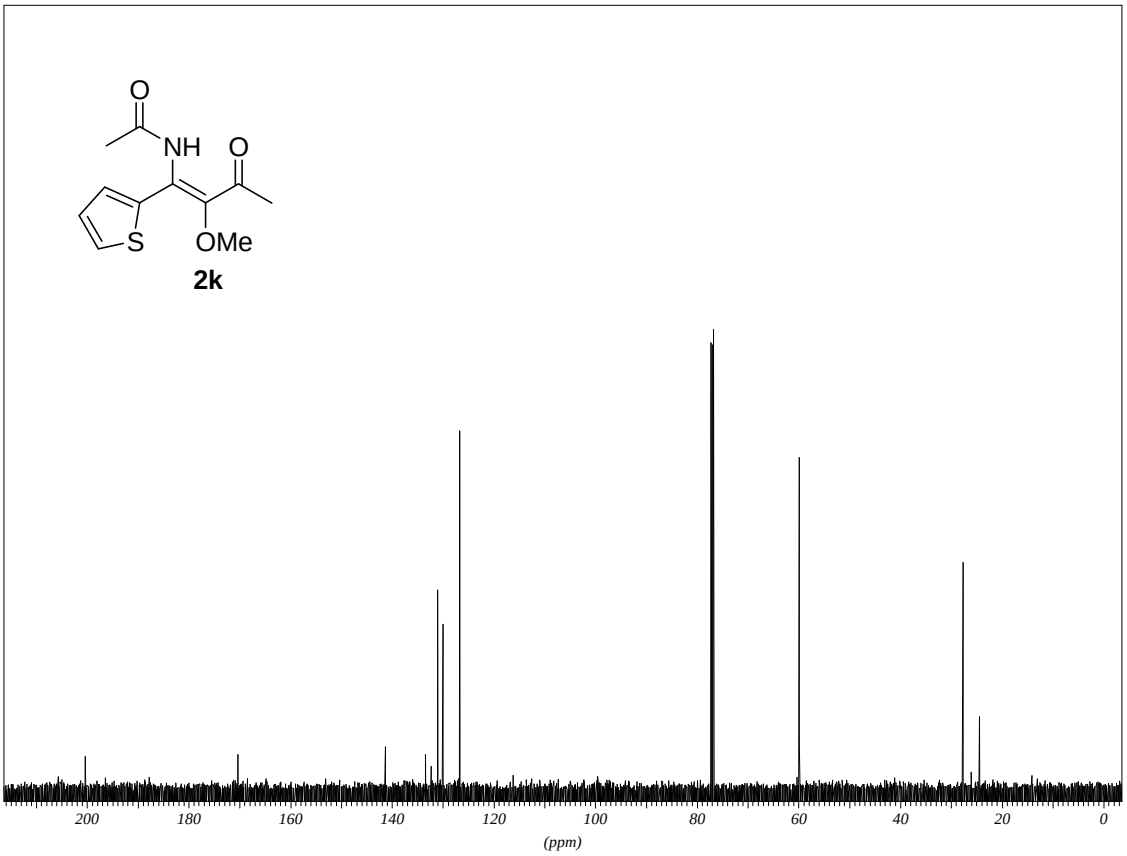

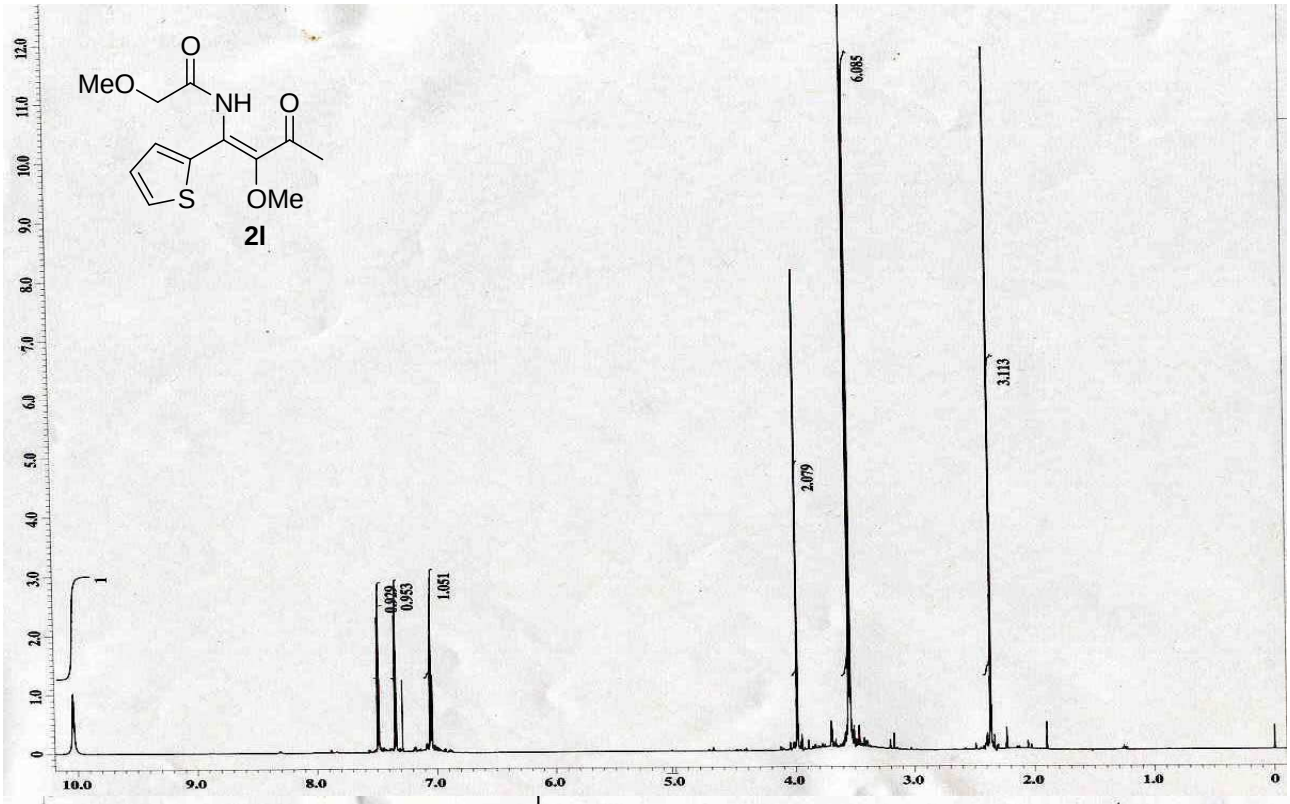

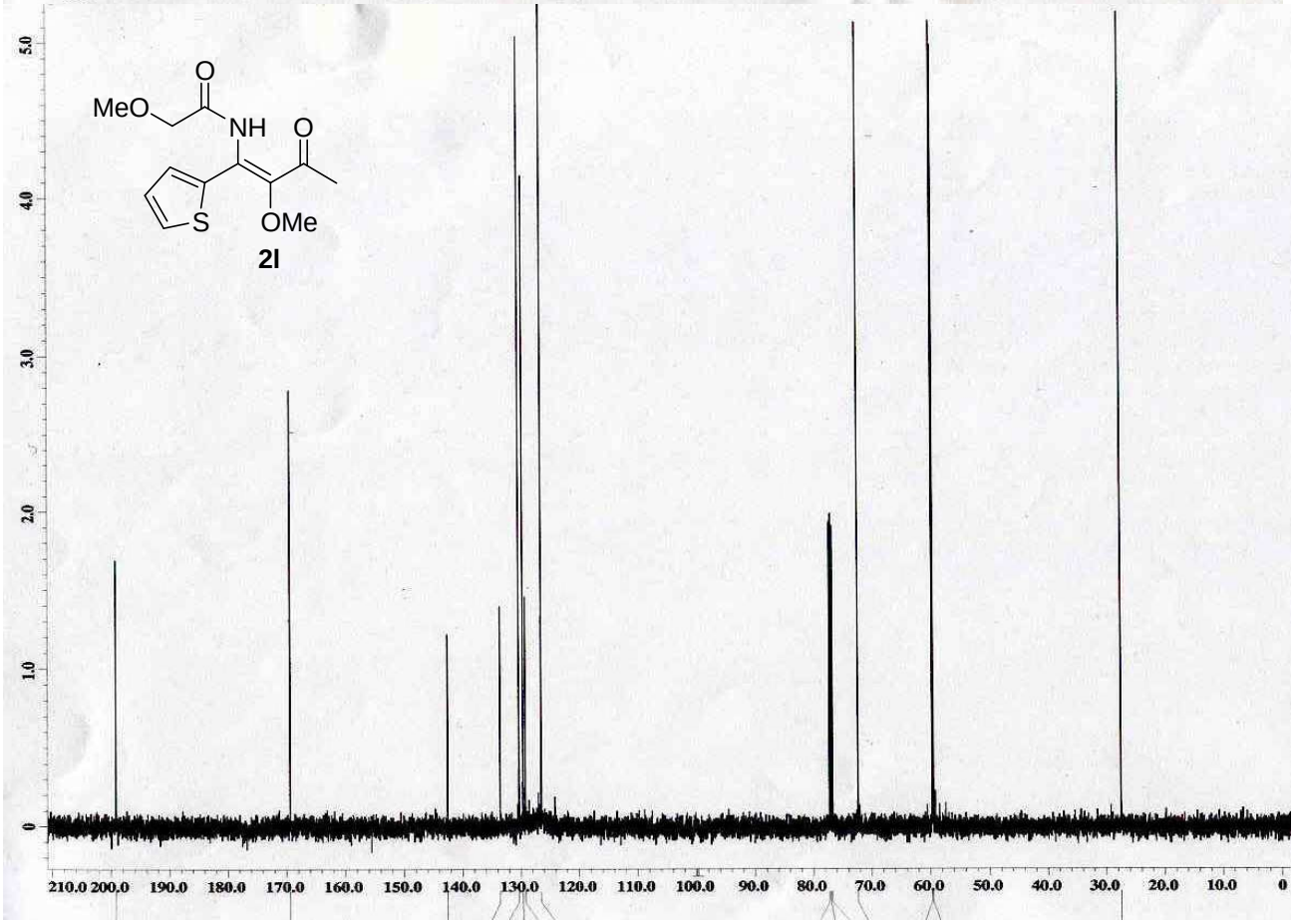

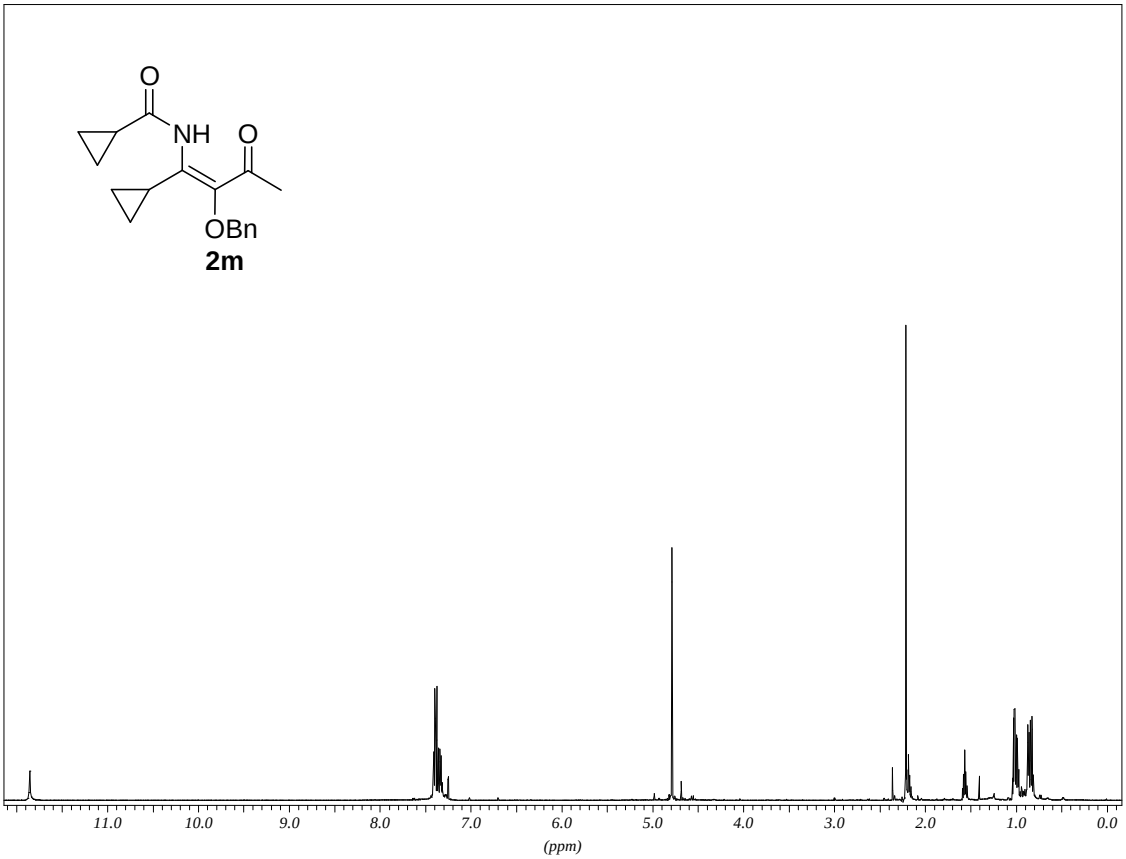

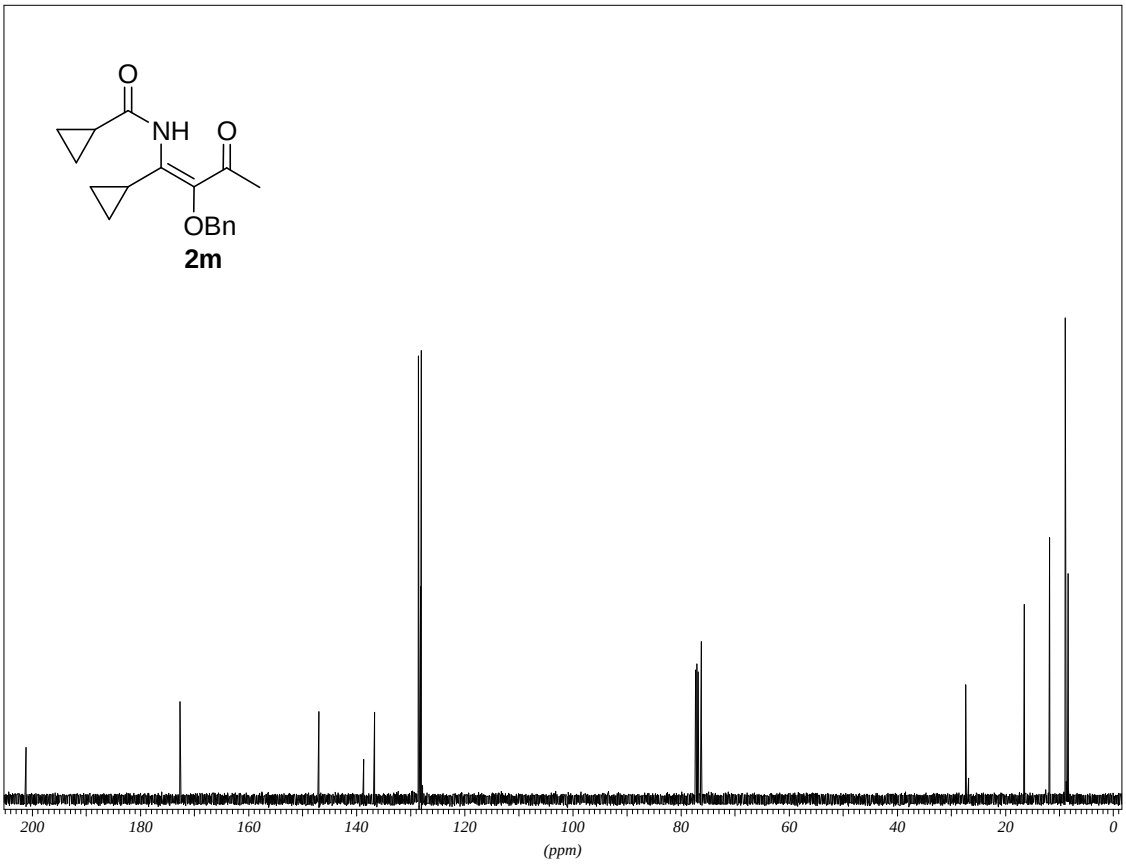

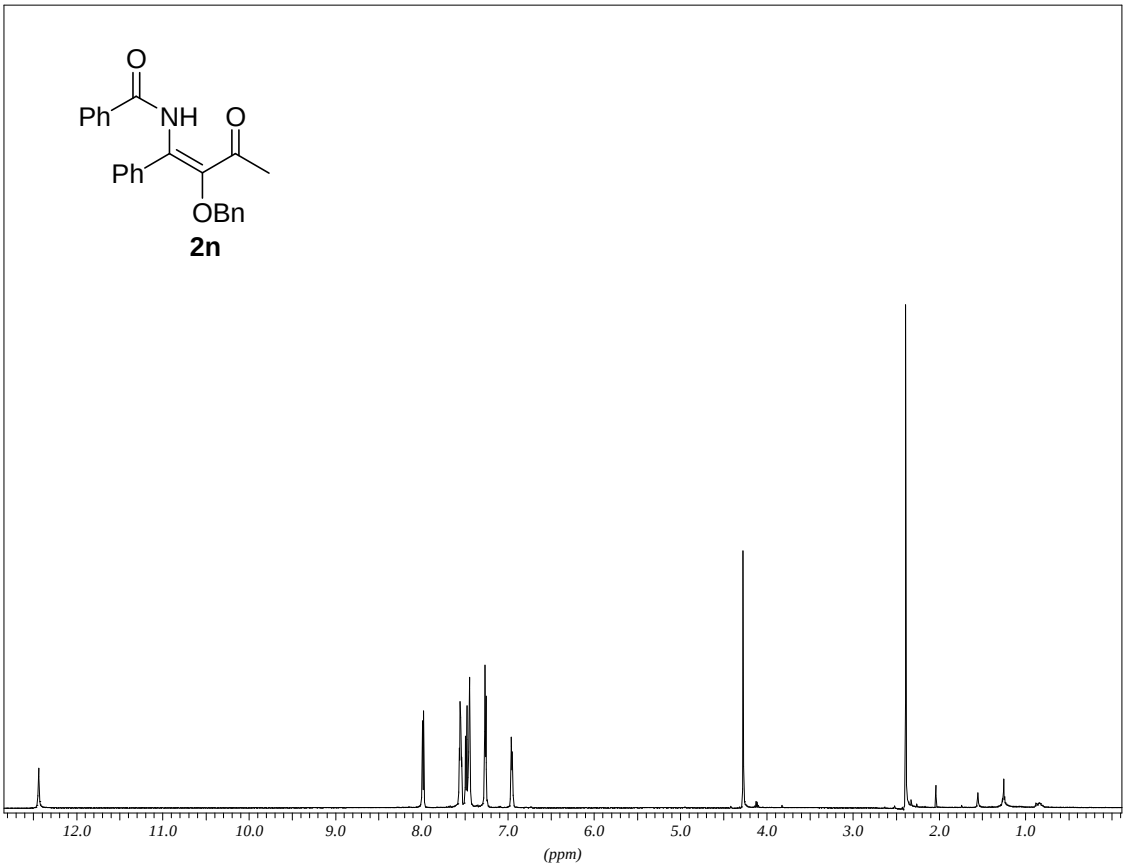

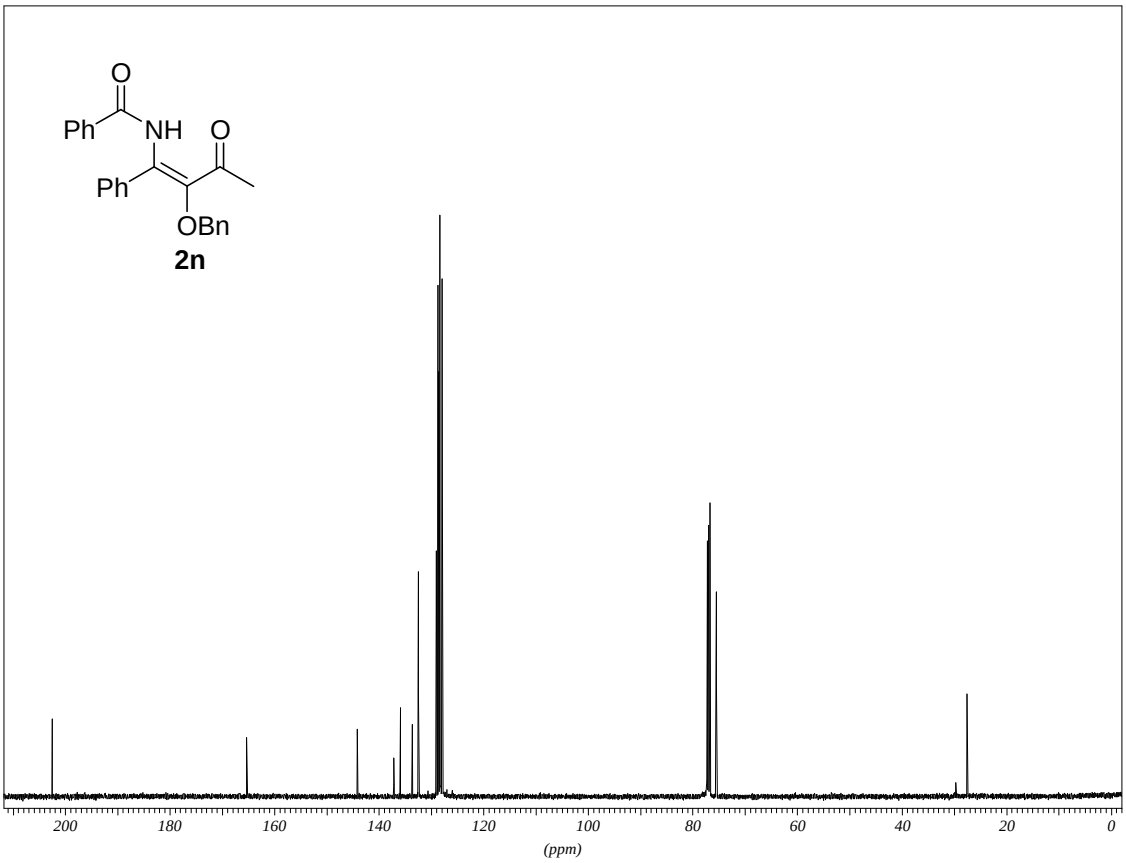

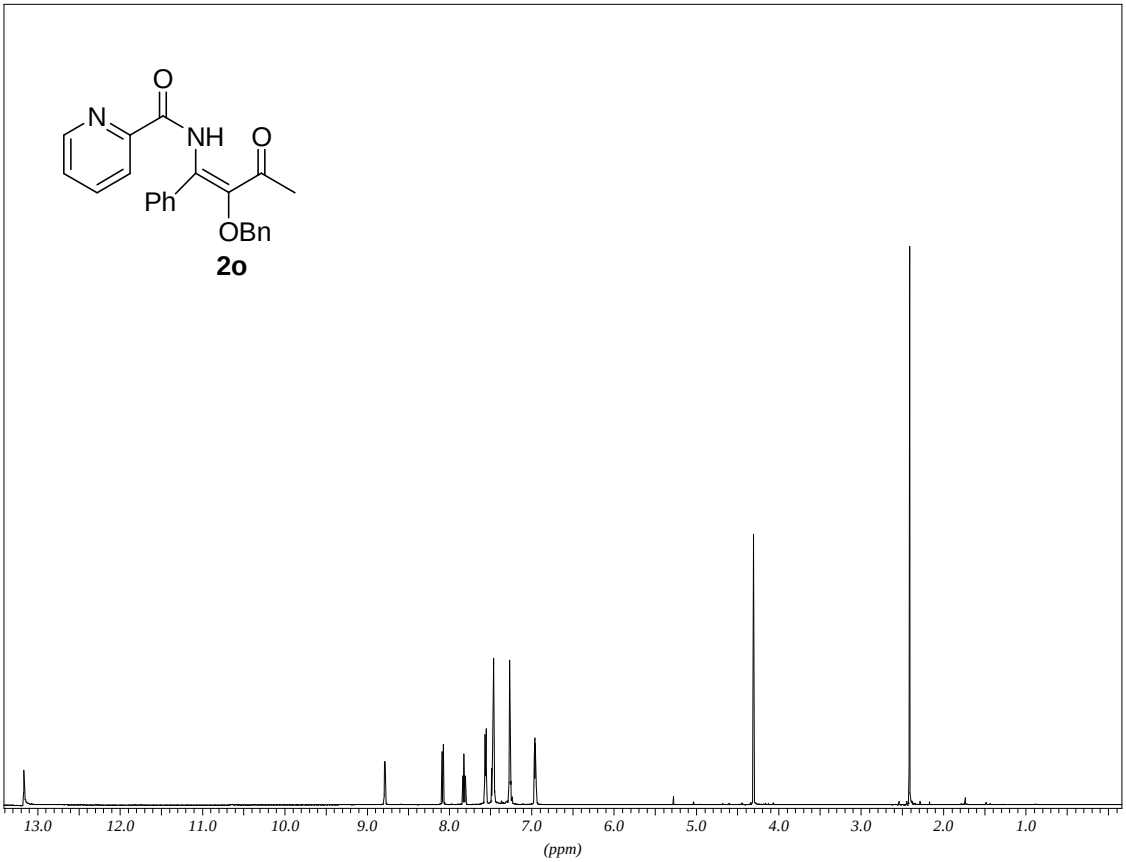

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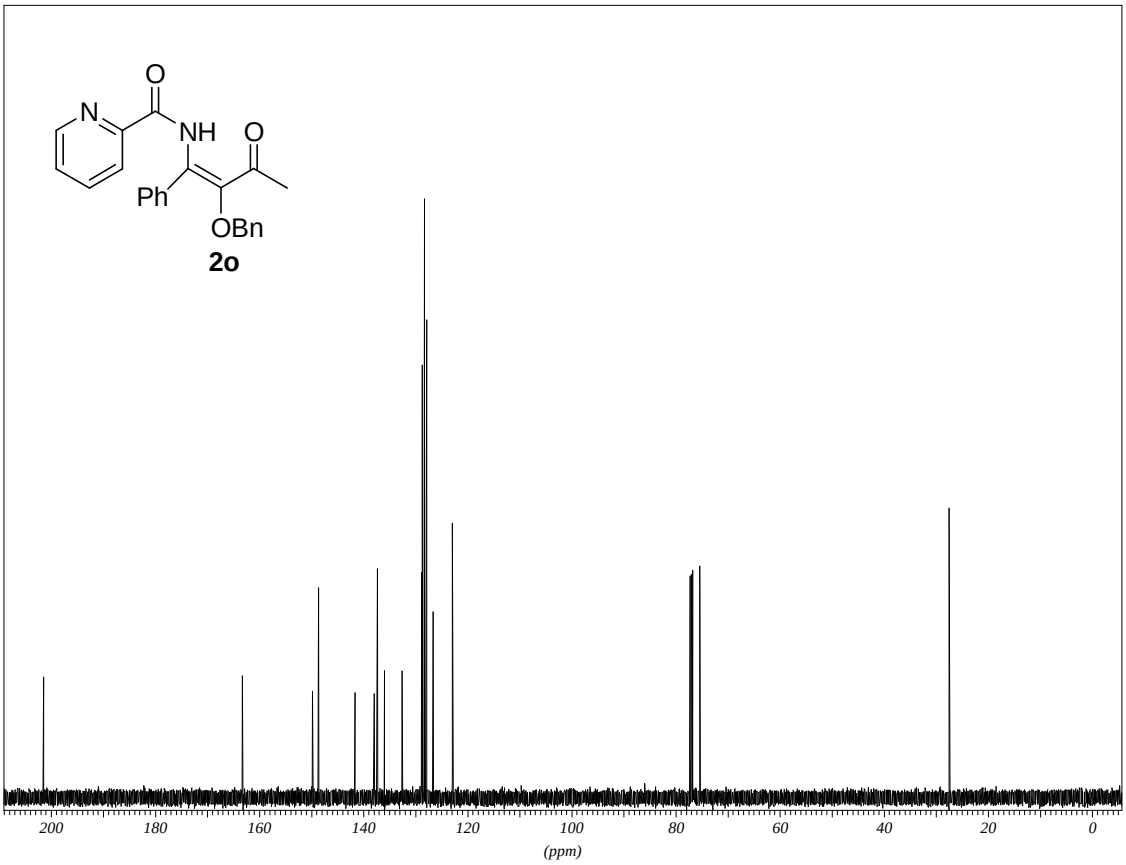

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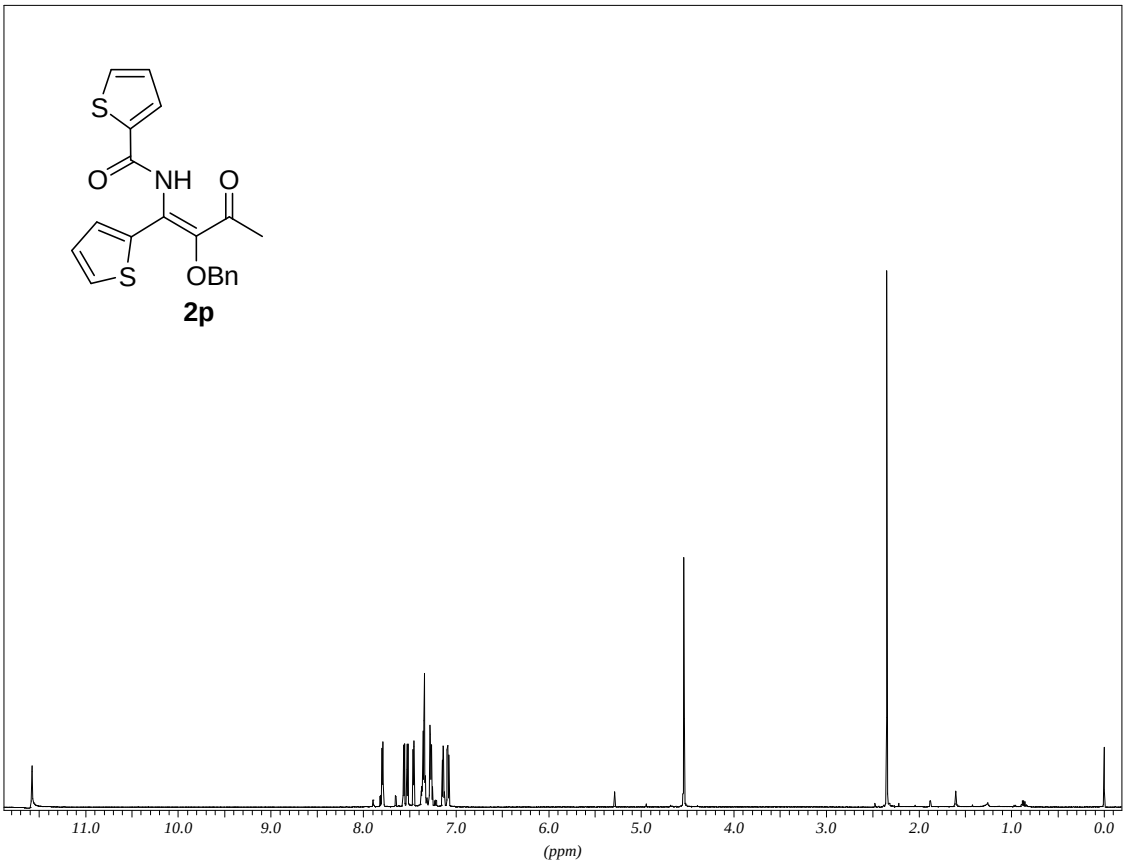

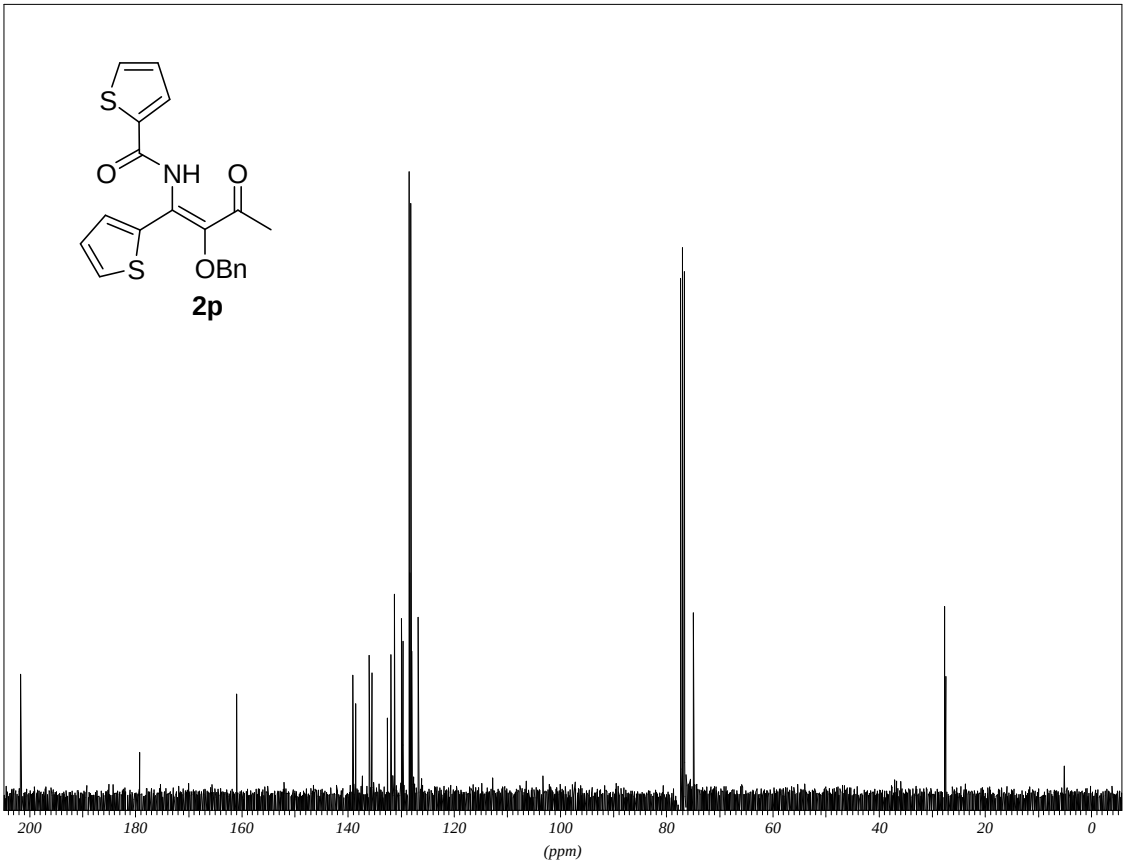

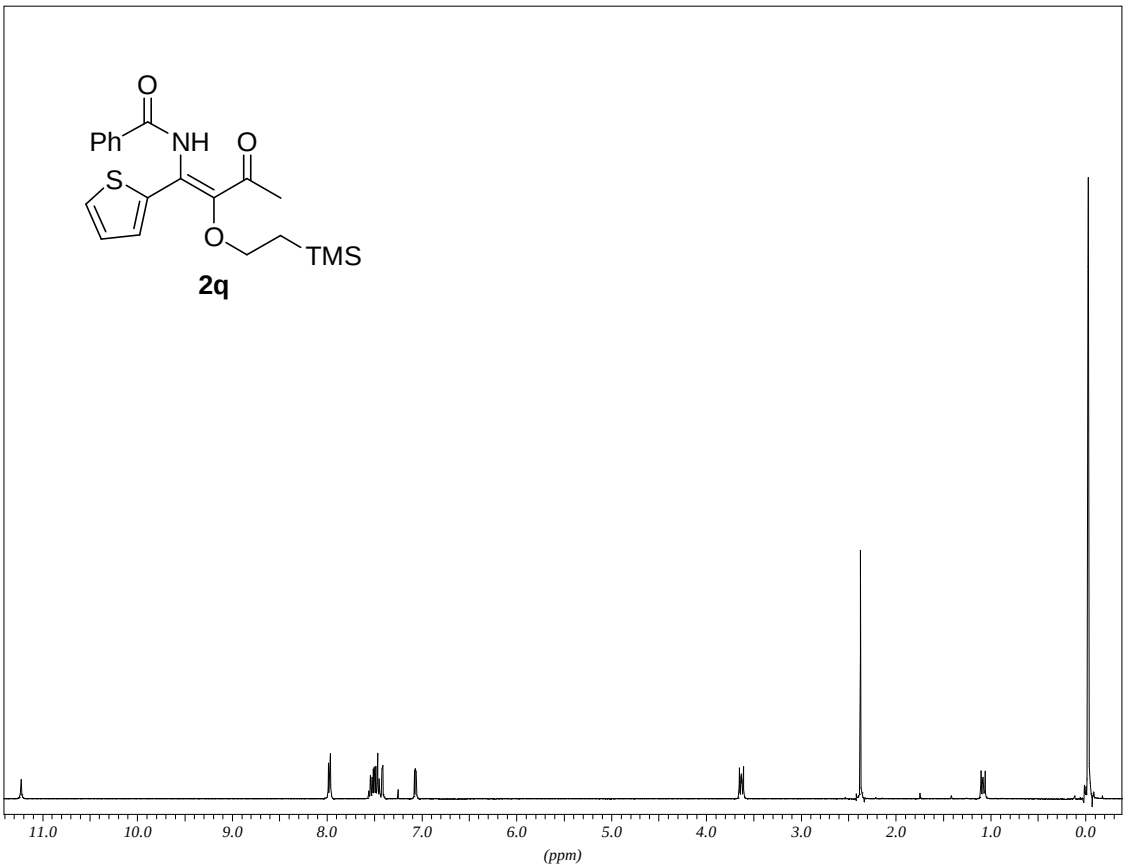
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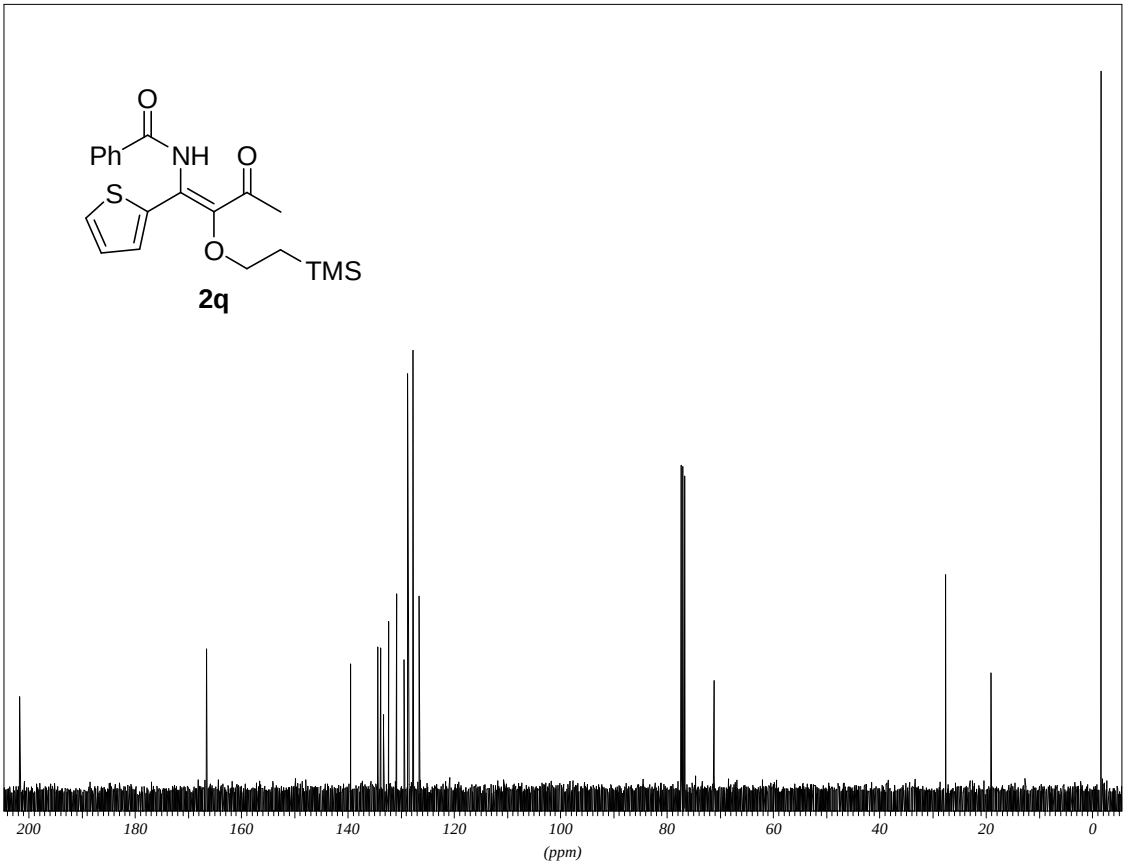
(ppm)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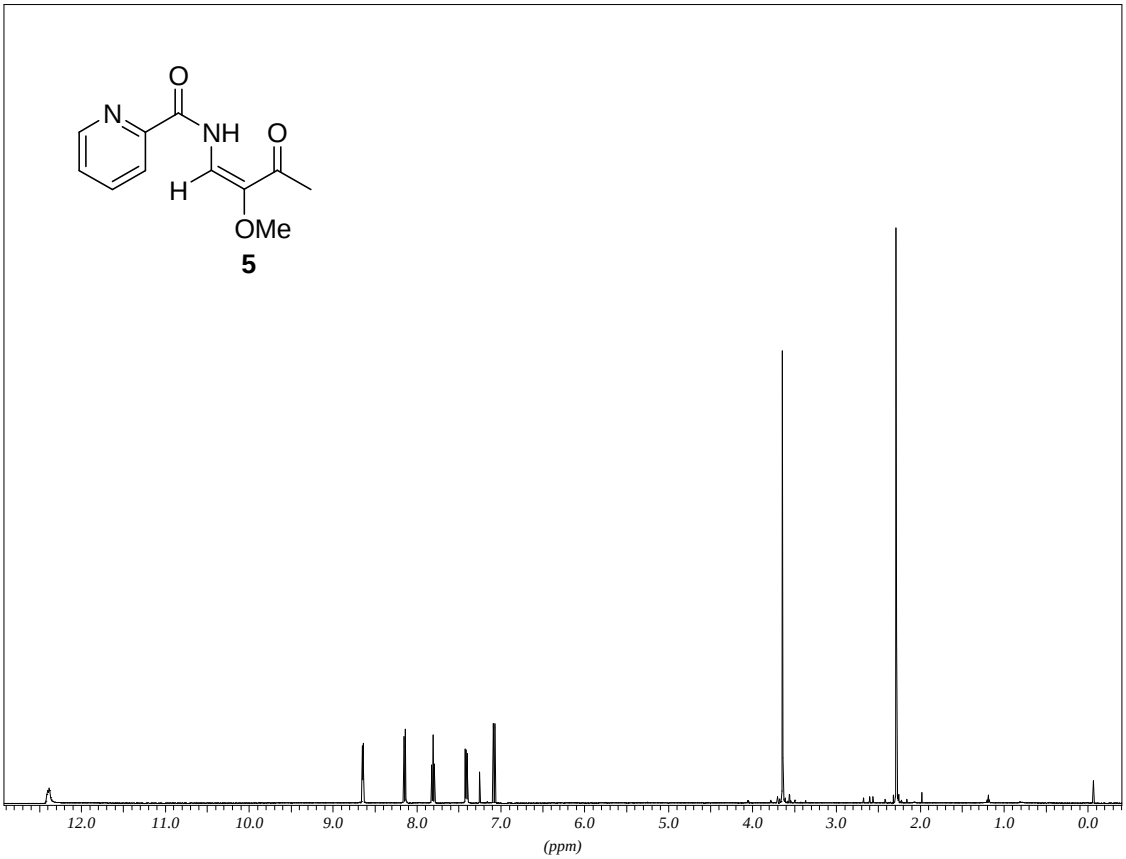
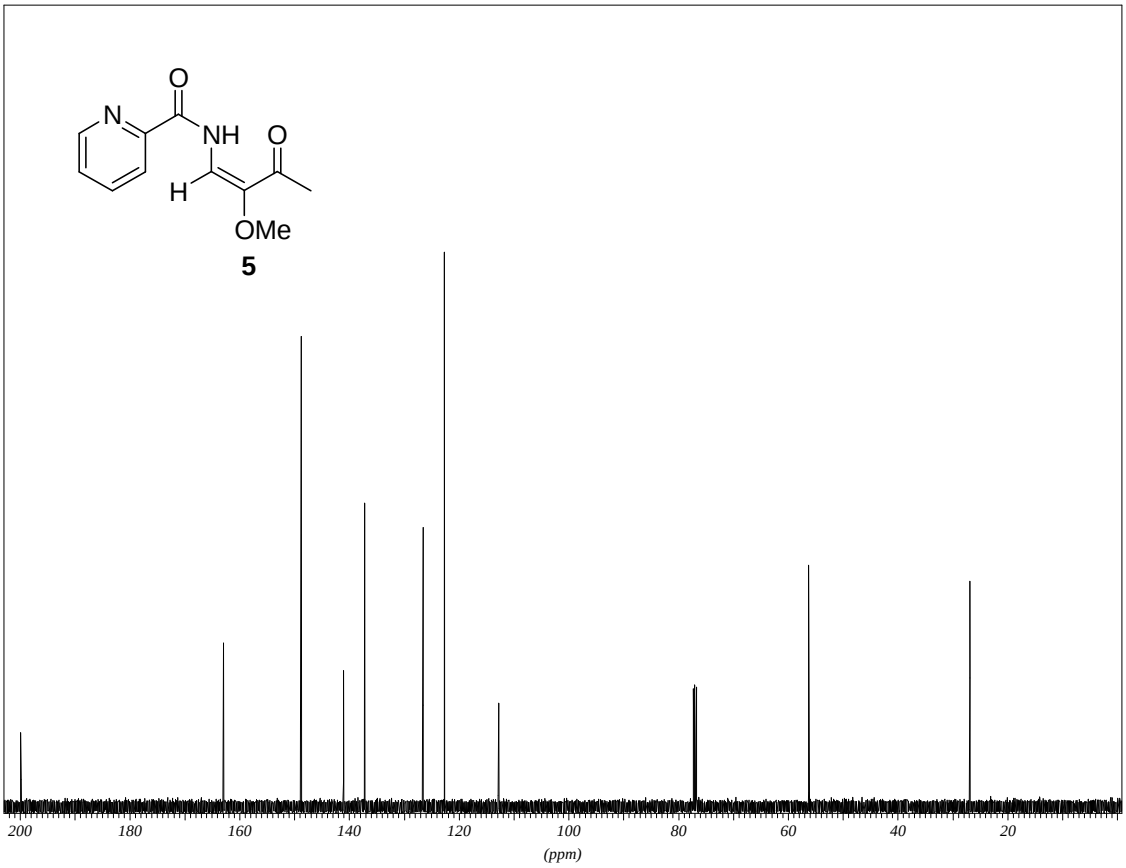
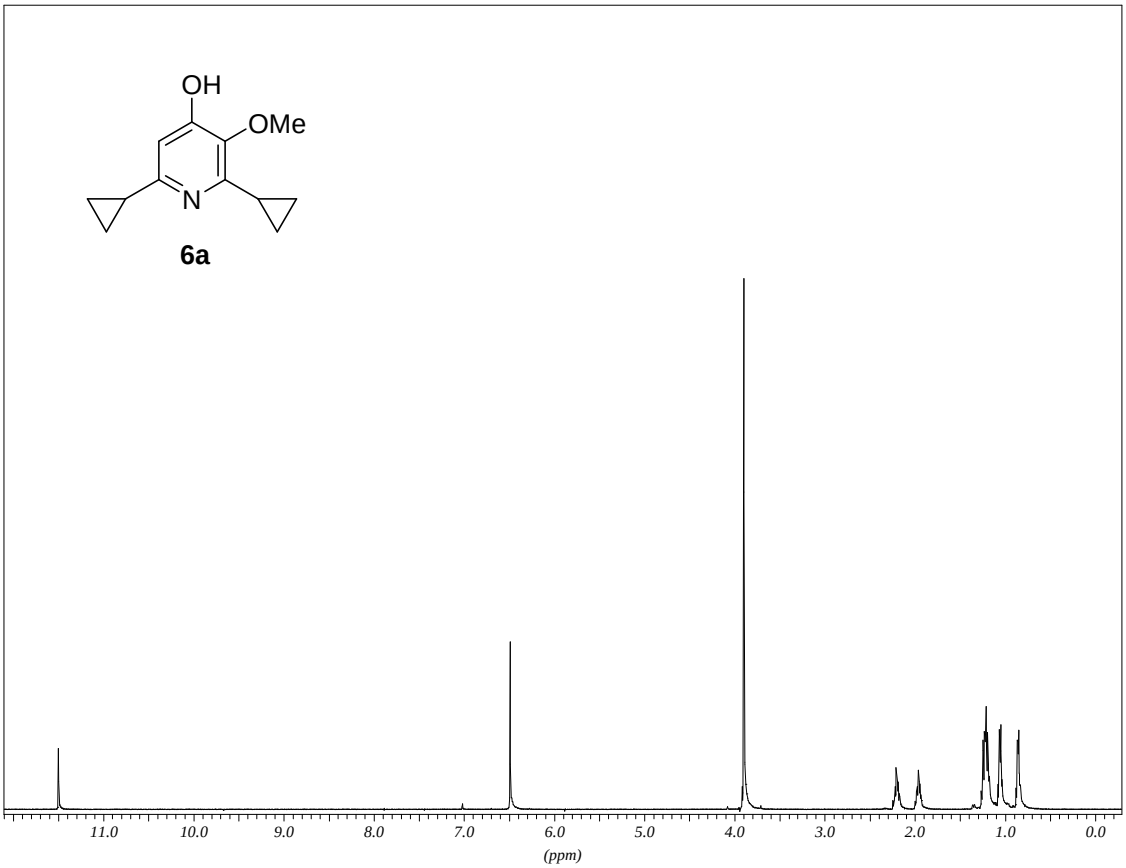
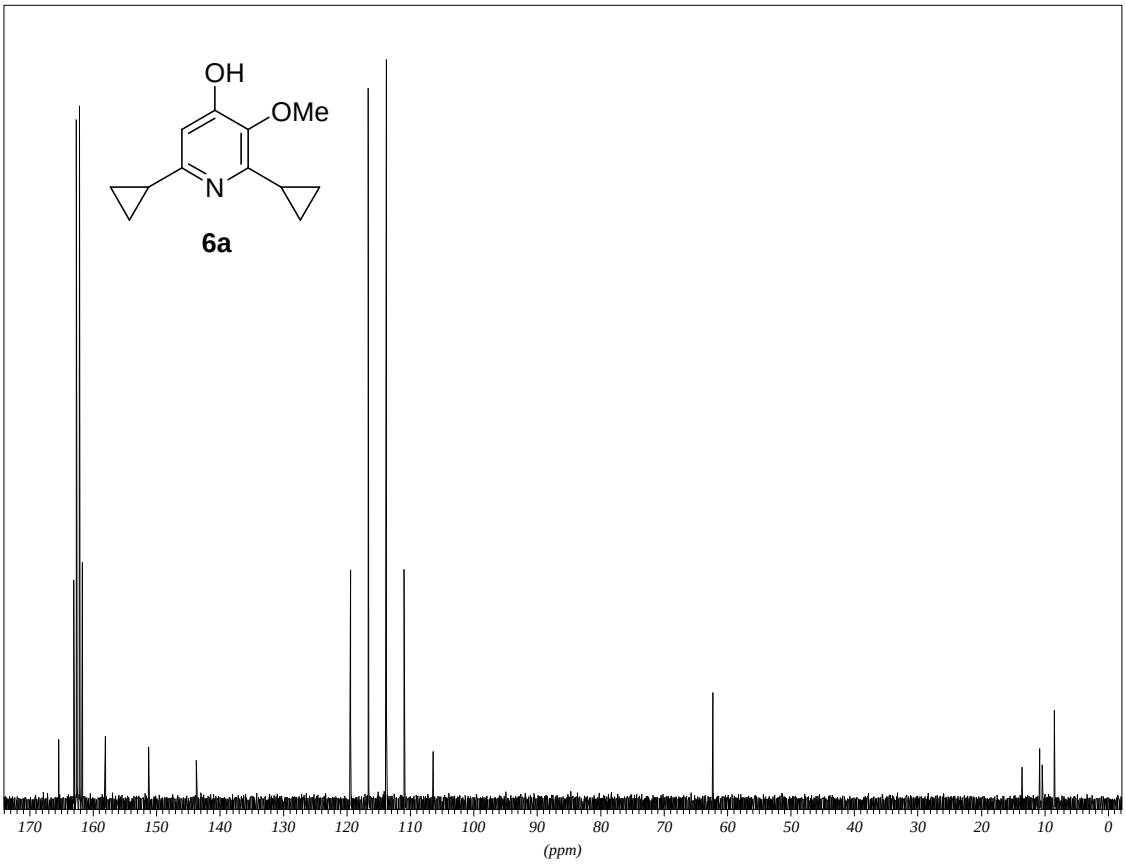
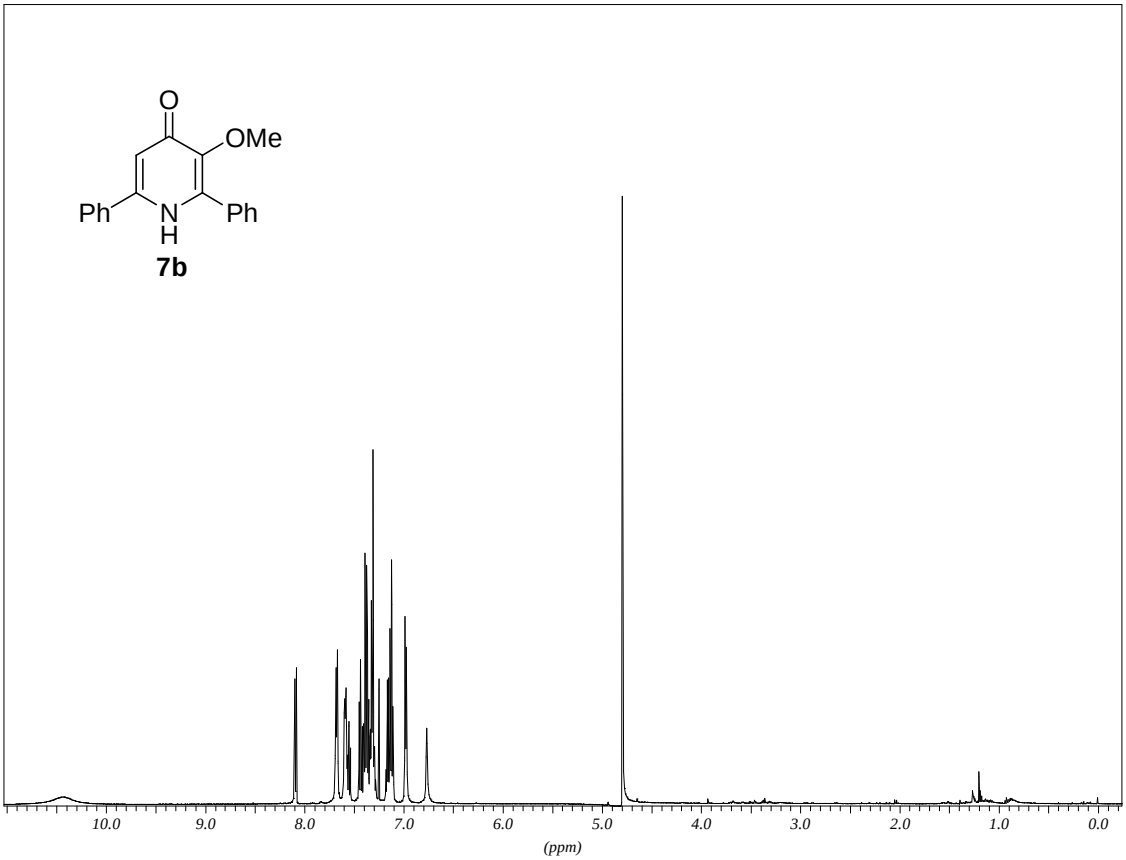
(ppm)

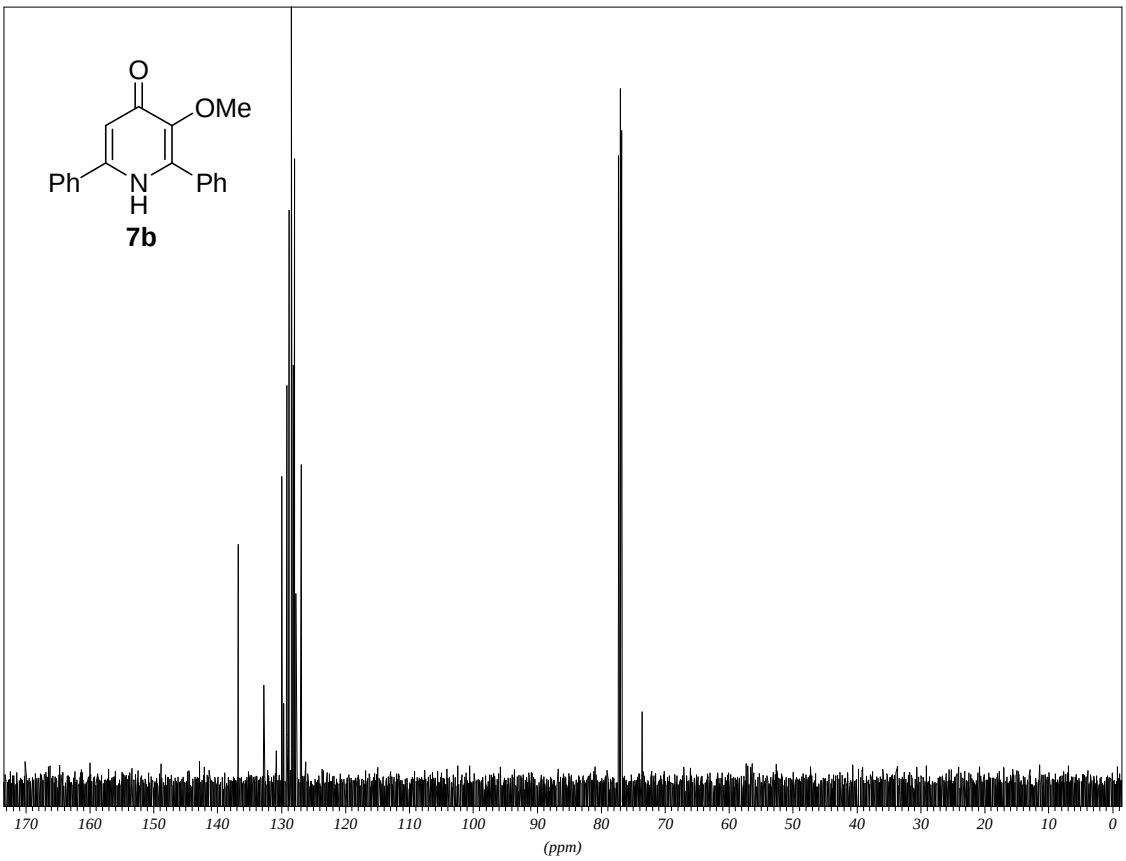


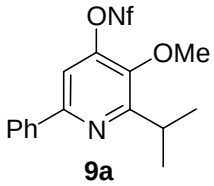




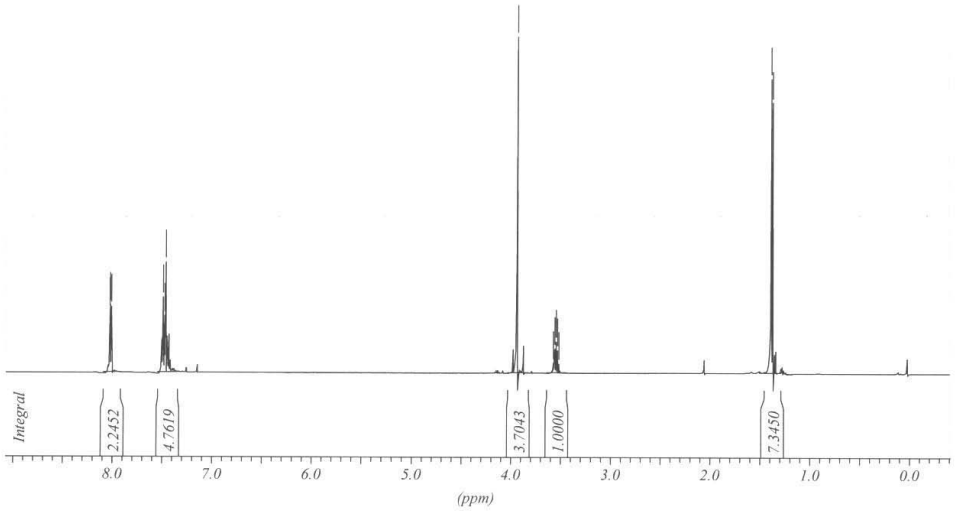


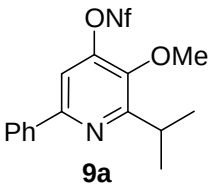

O
OMe
Ph
N
H
Ph
7b
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
(ppm)


O
OMe
Ph
N
H
Ph
7b
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
(ppm)

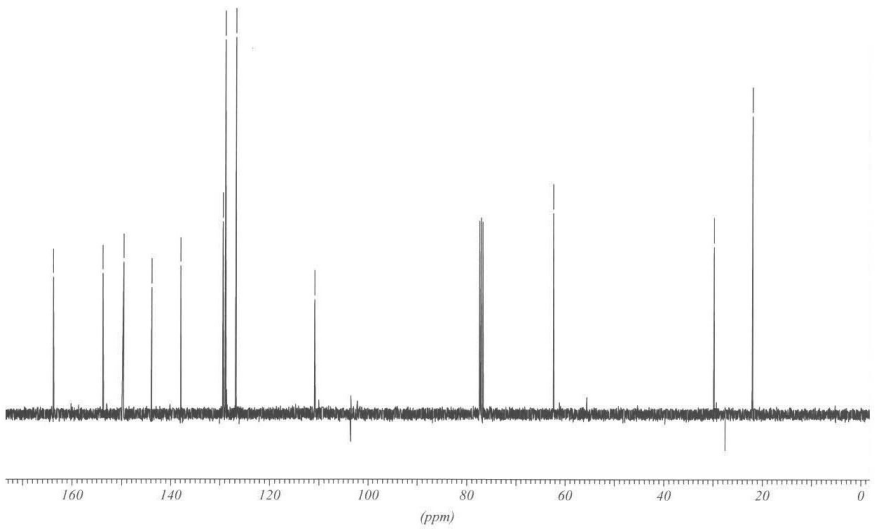

ONf
OMe
Ph
N

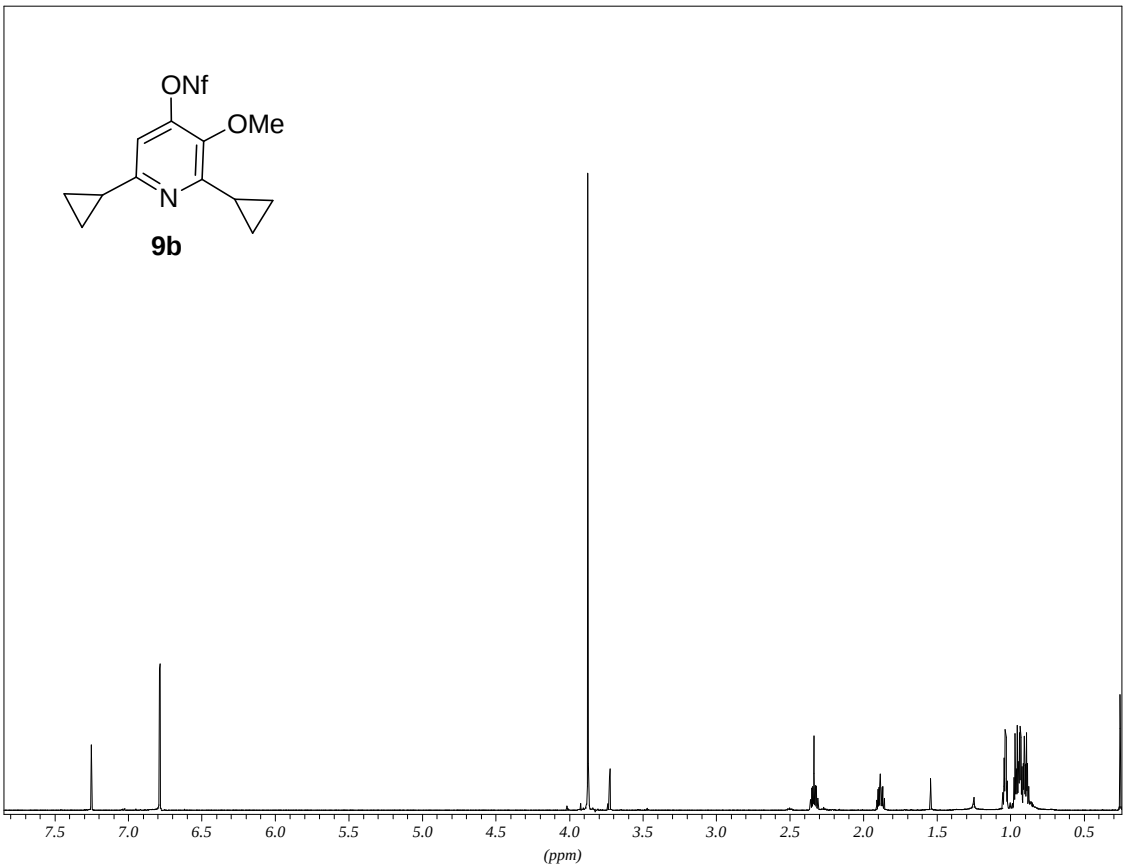
9a

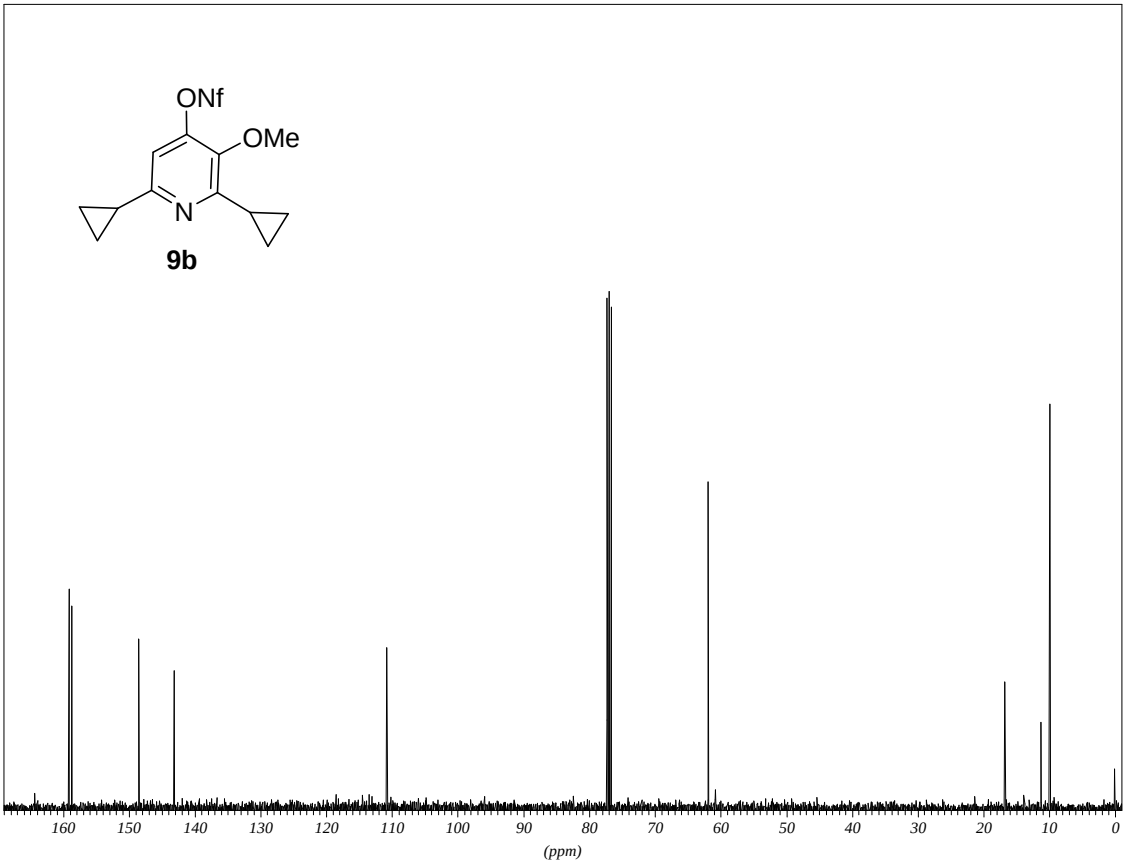

Integral
2.2452
4.7619
3.7043
1.0000
7.3450
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
(ppm)

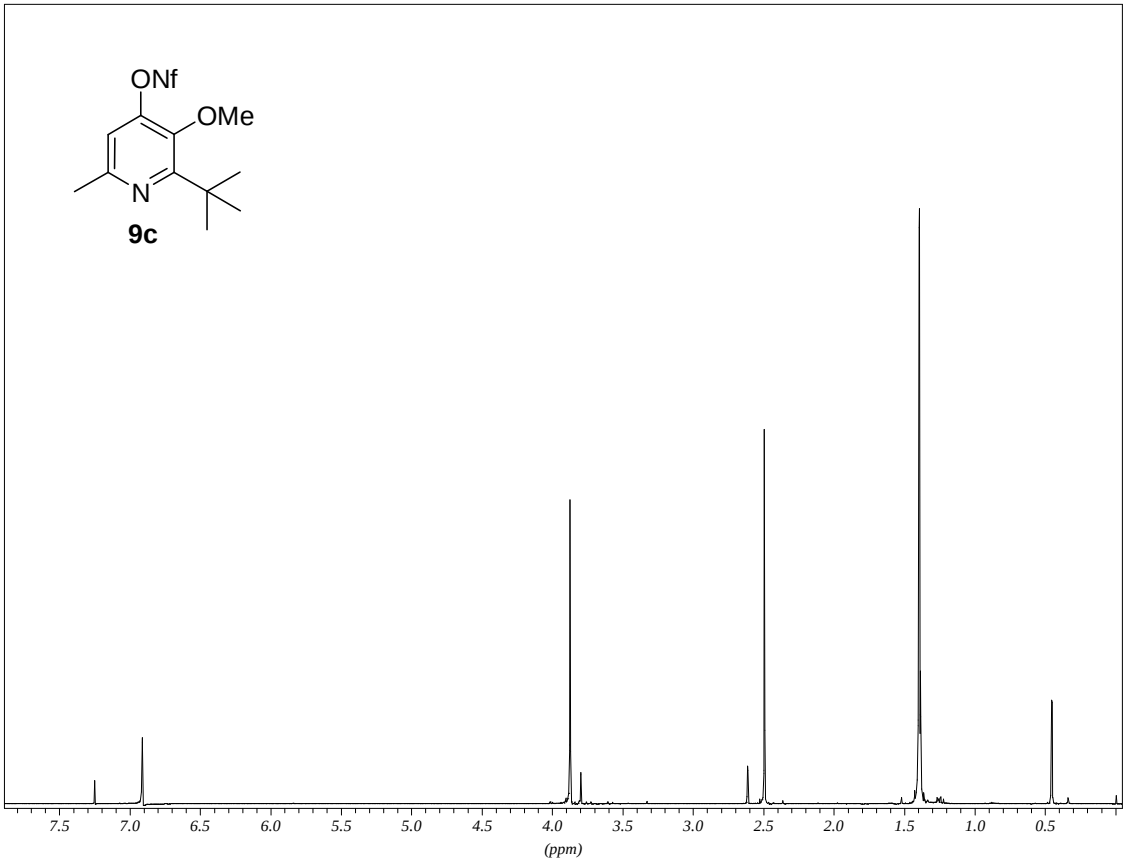

ONf
OMe
Ph
N

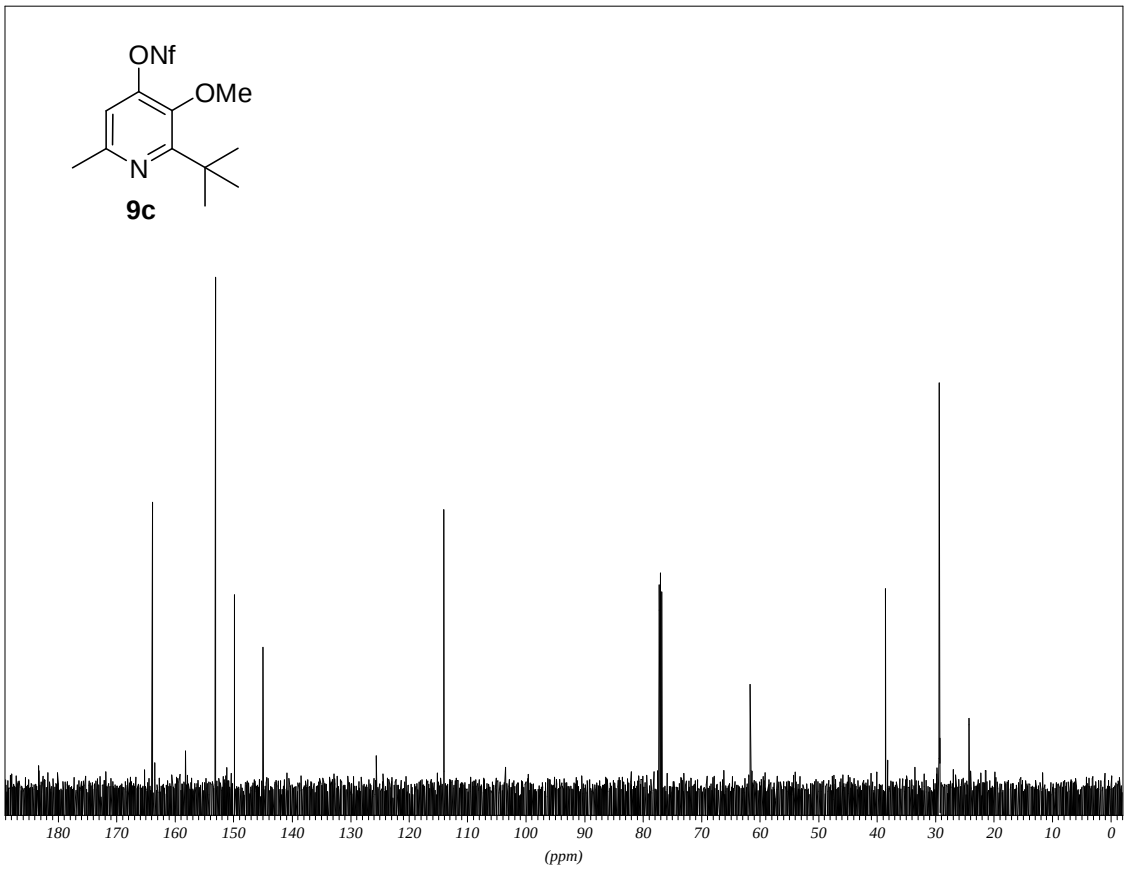
9a

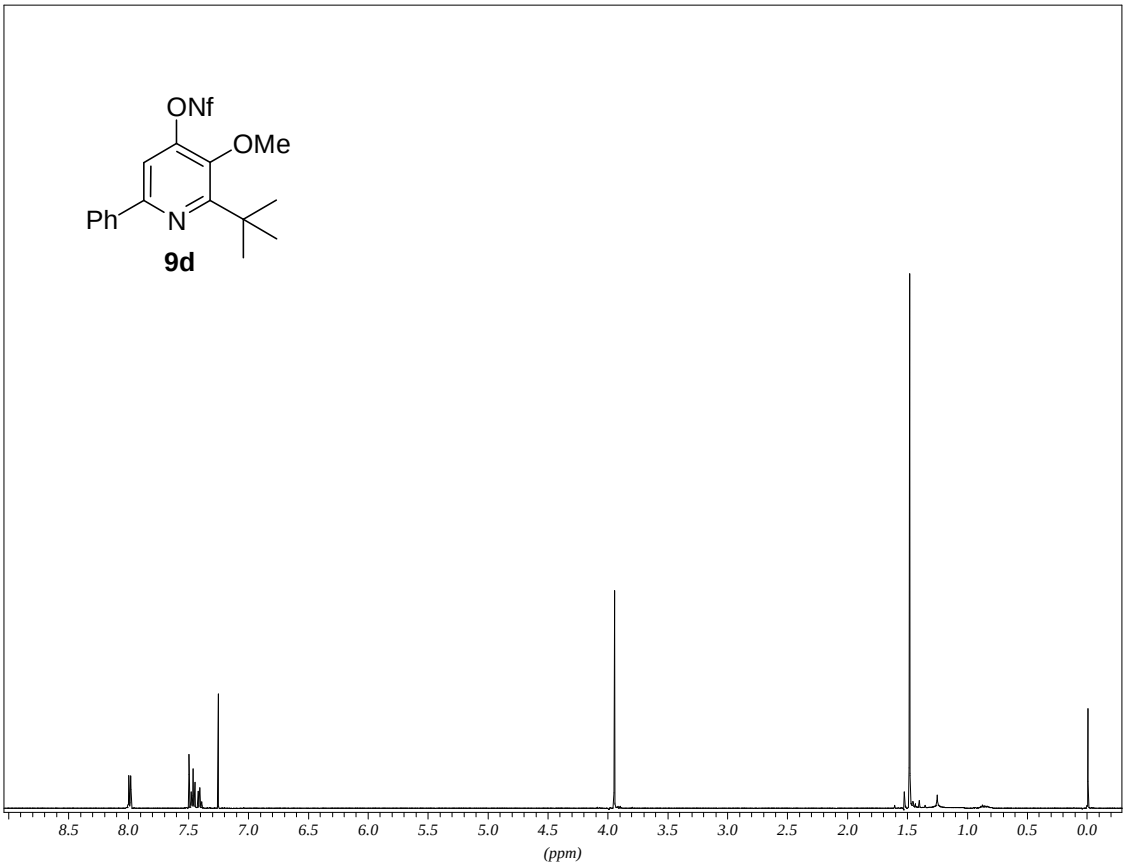

160
140
120
100
80
60
40
20
0
(ppm)

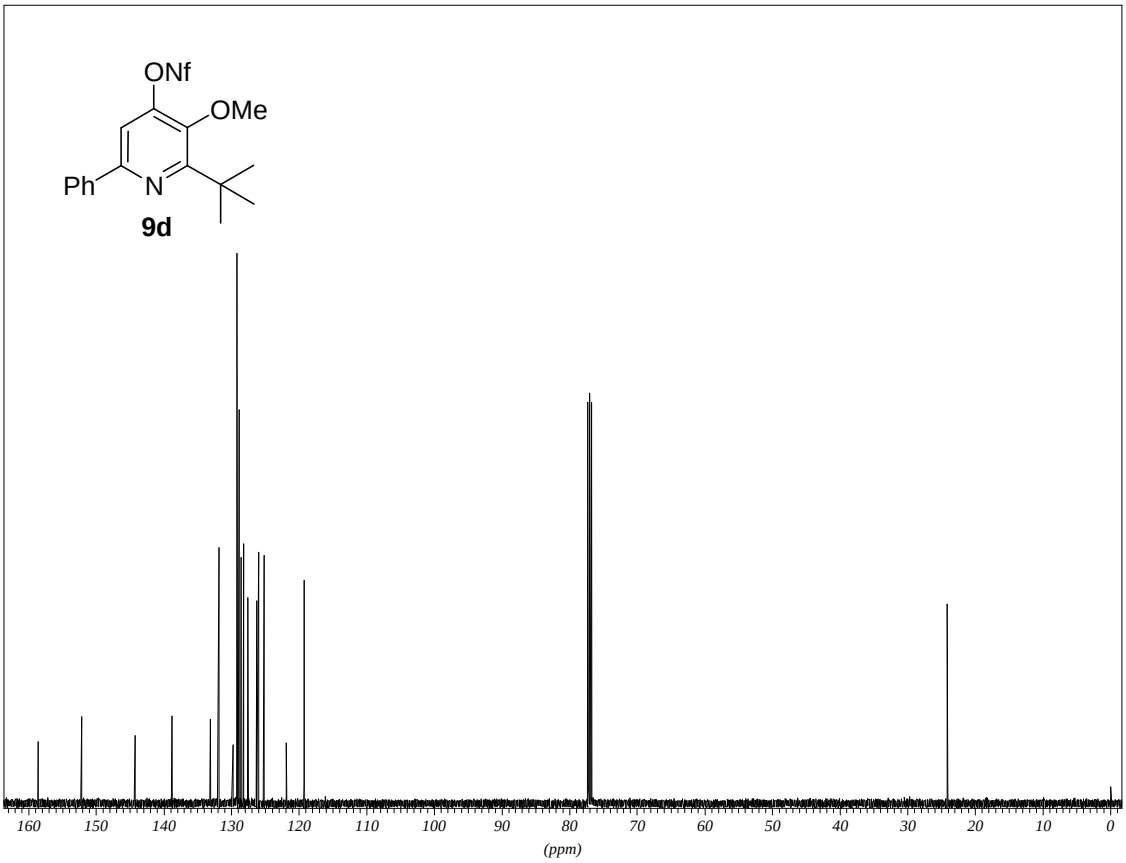


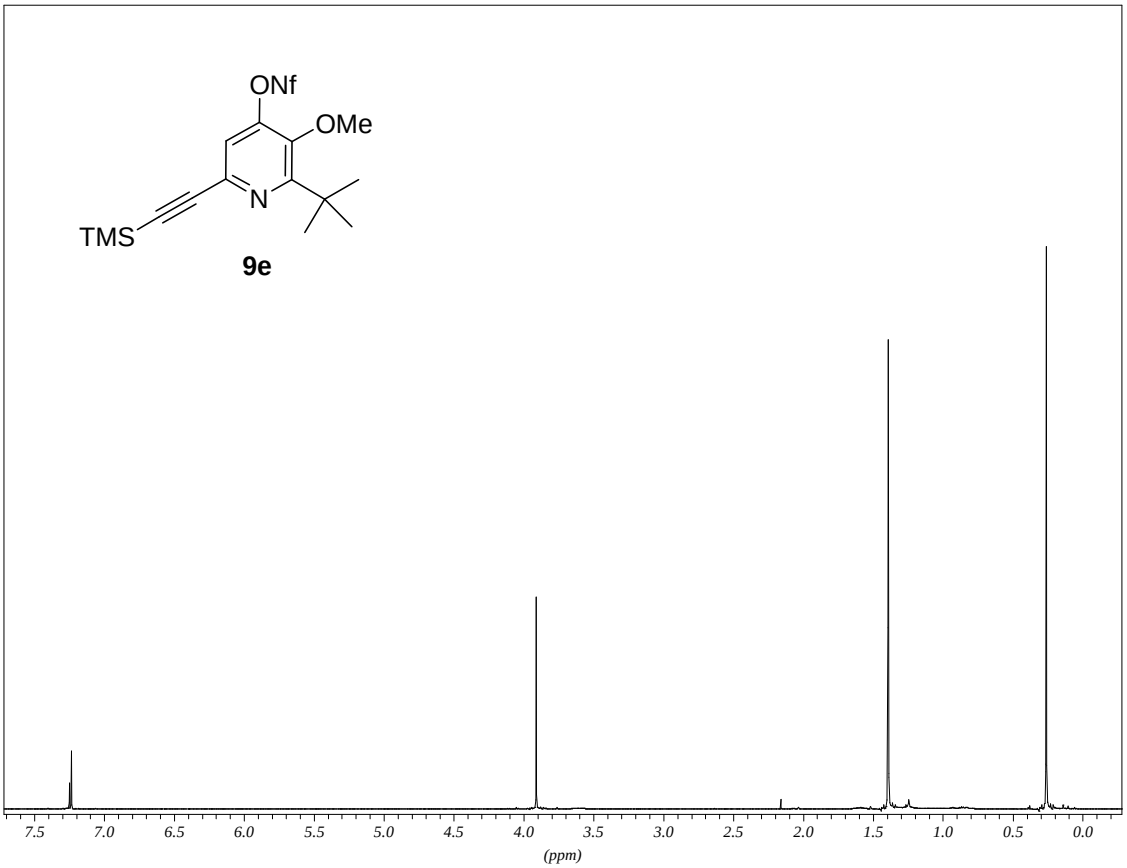


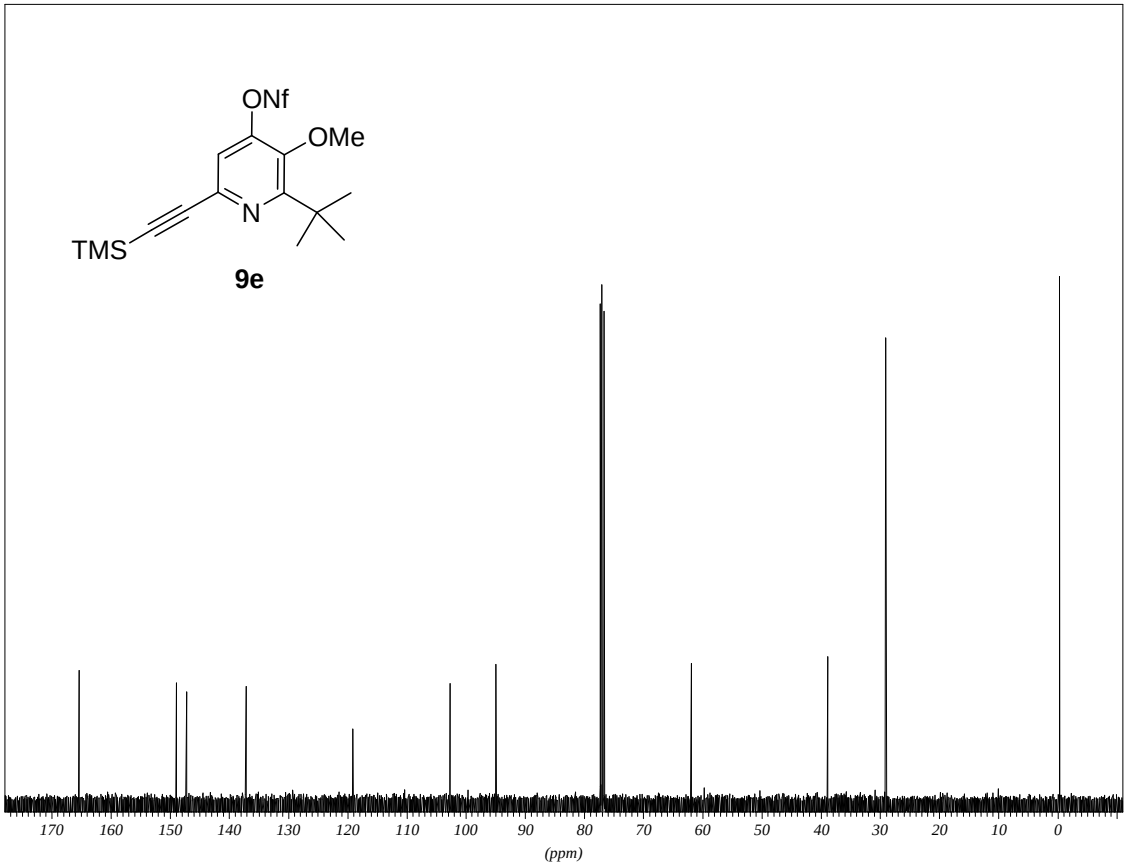


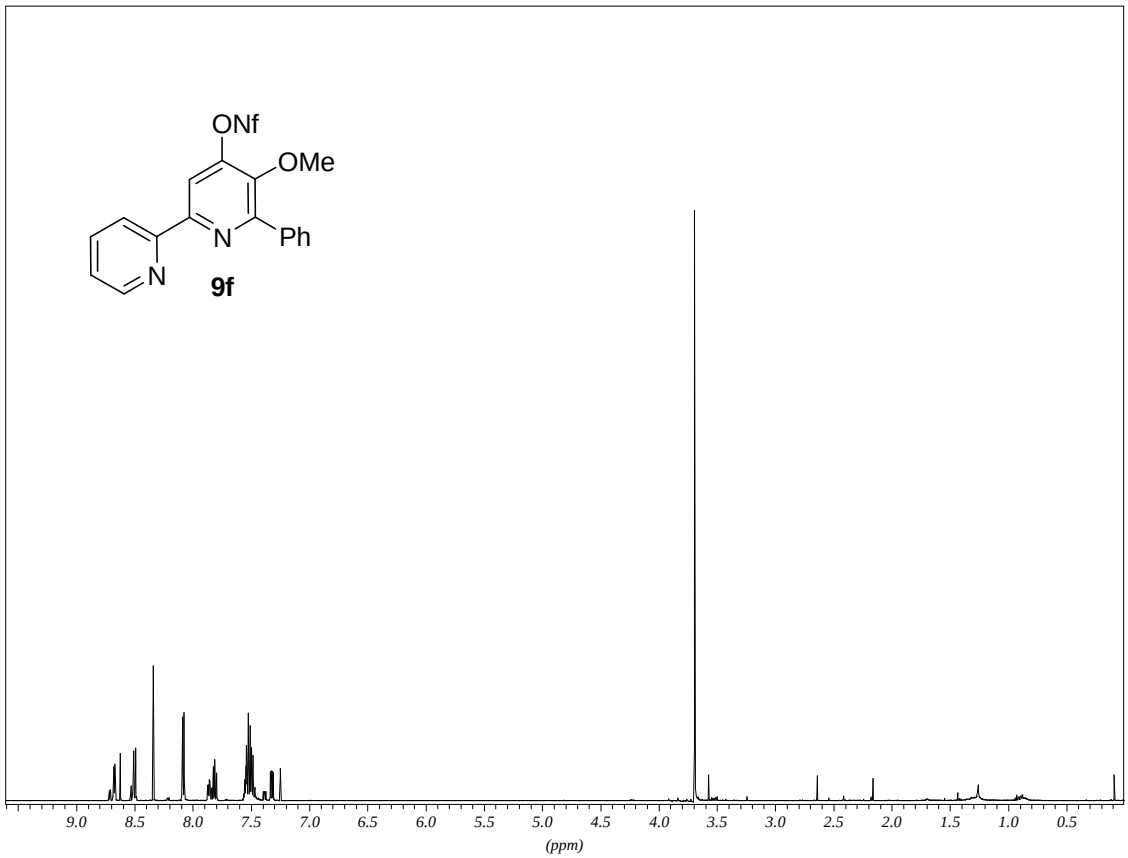


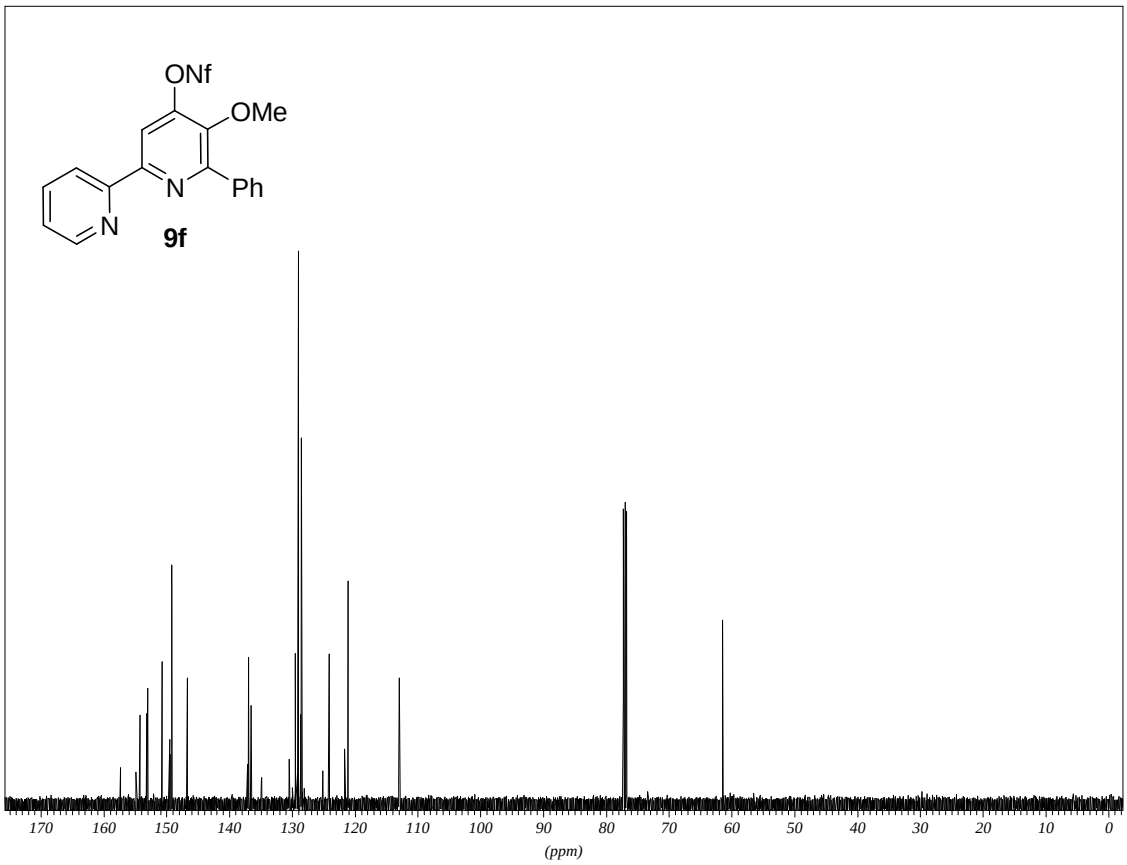


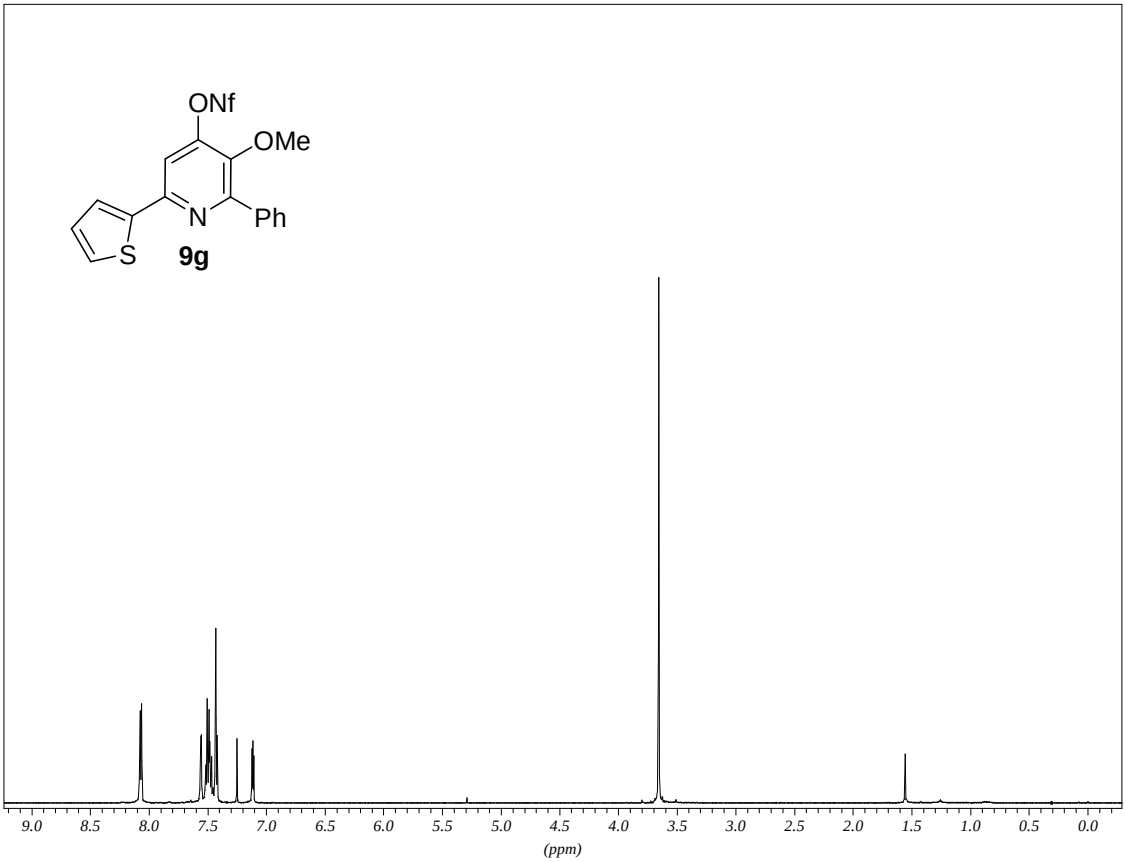


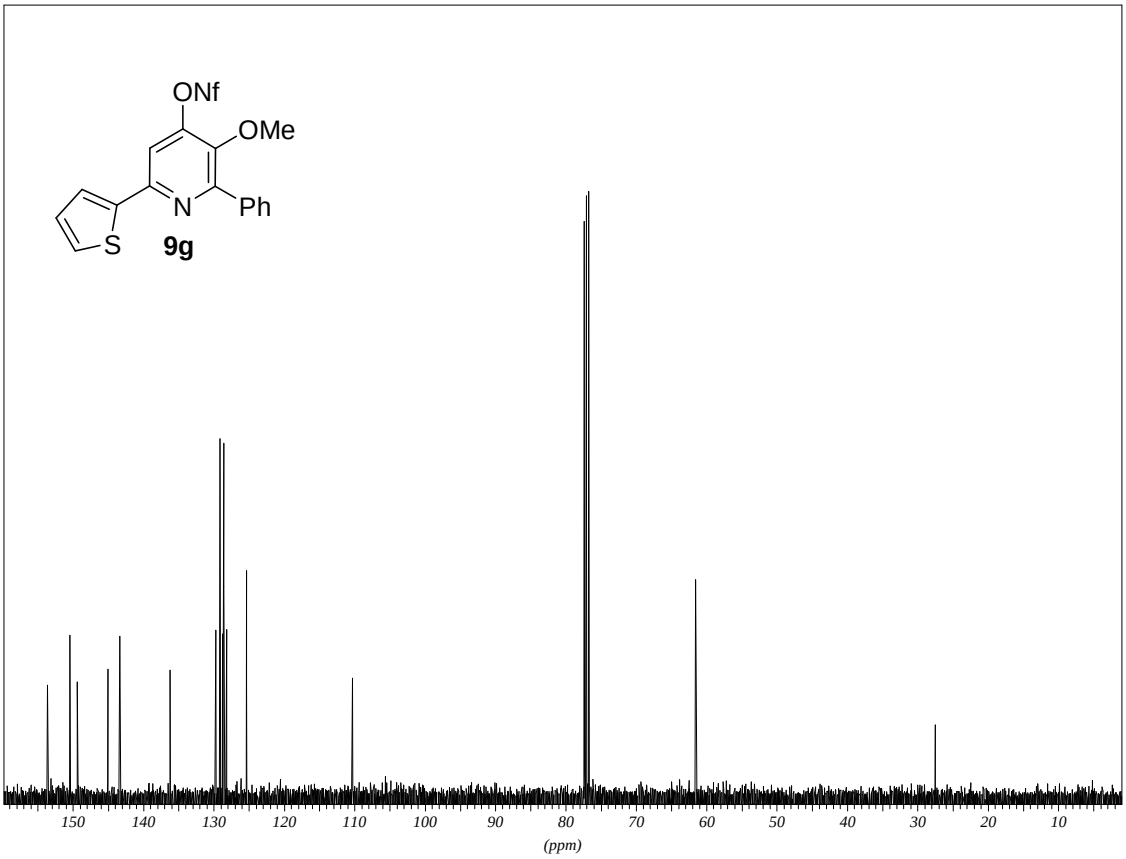


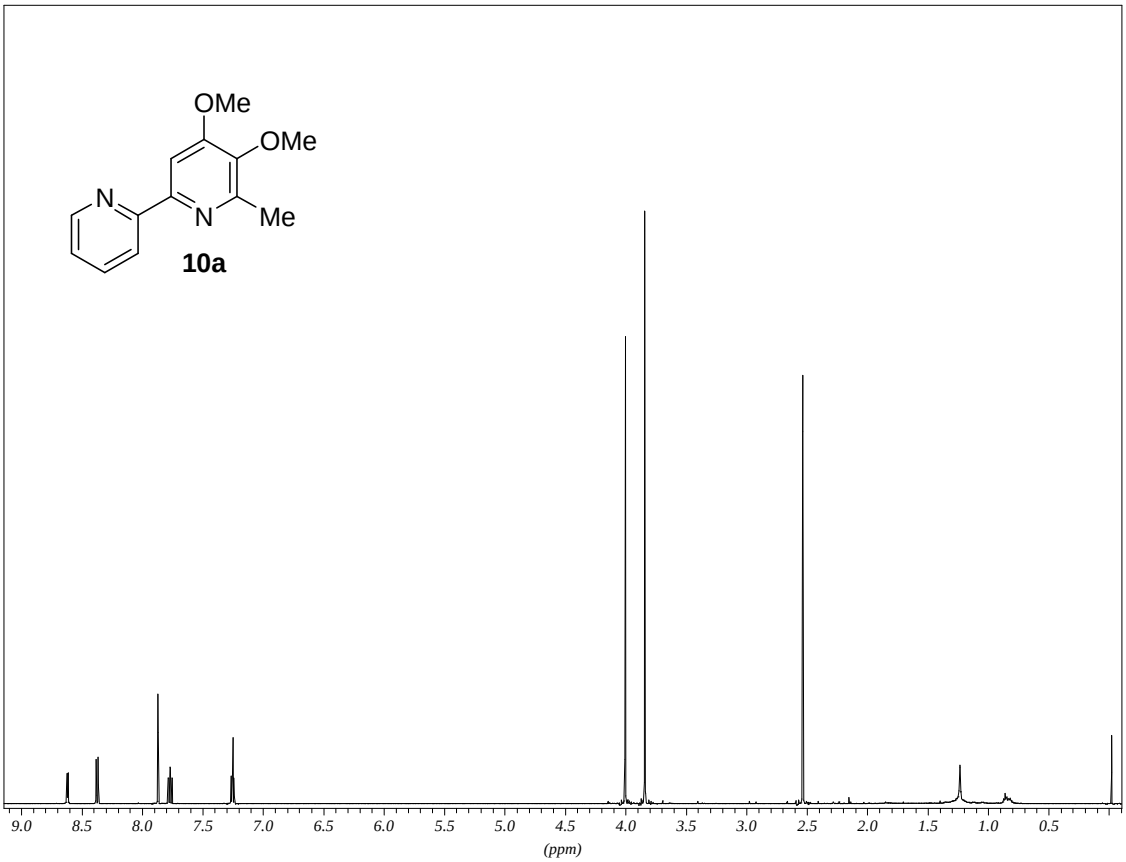


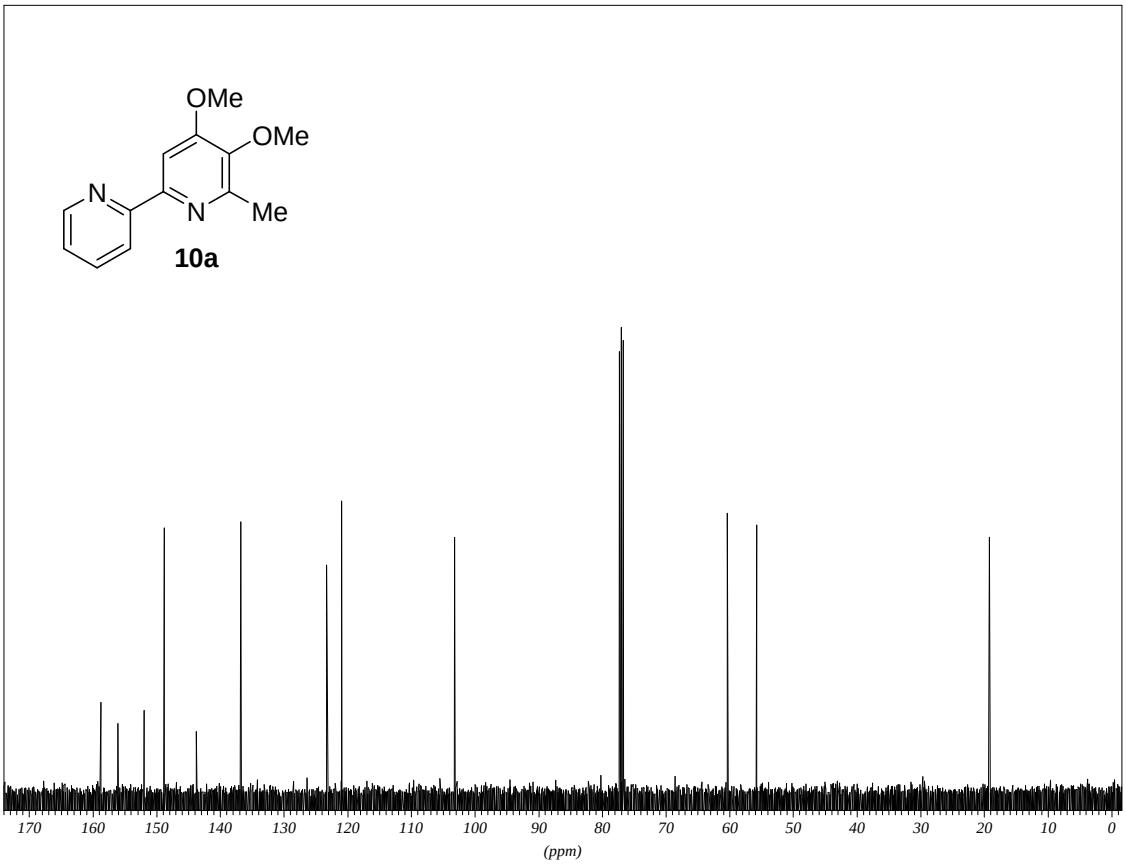


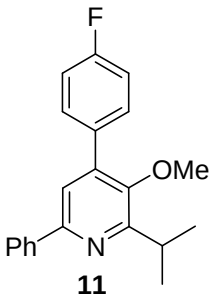




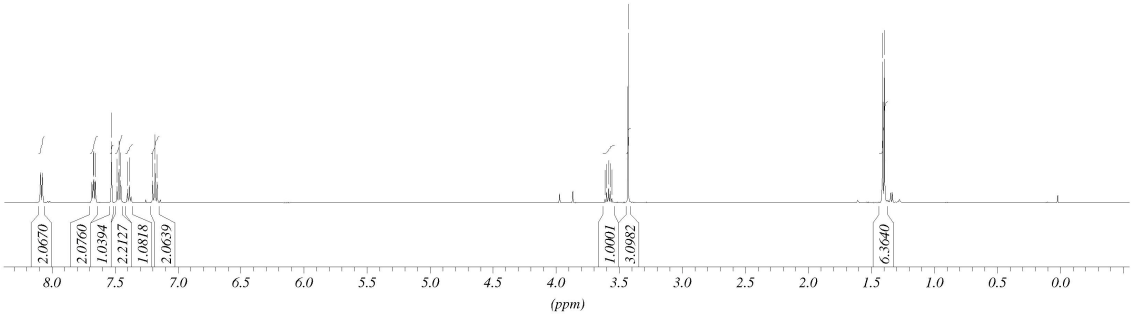


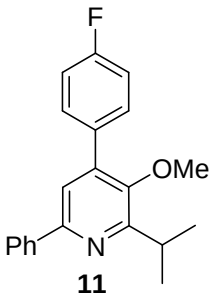




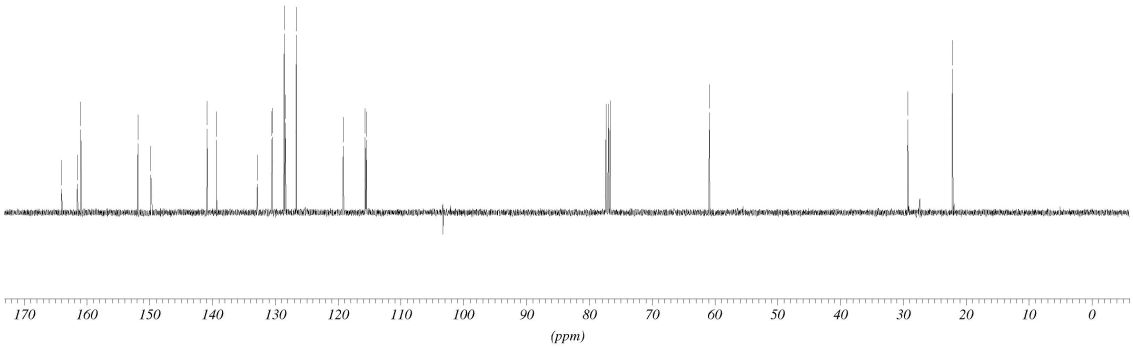

F
OMe
Ph
N

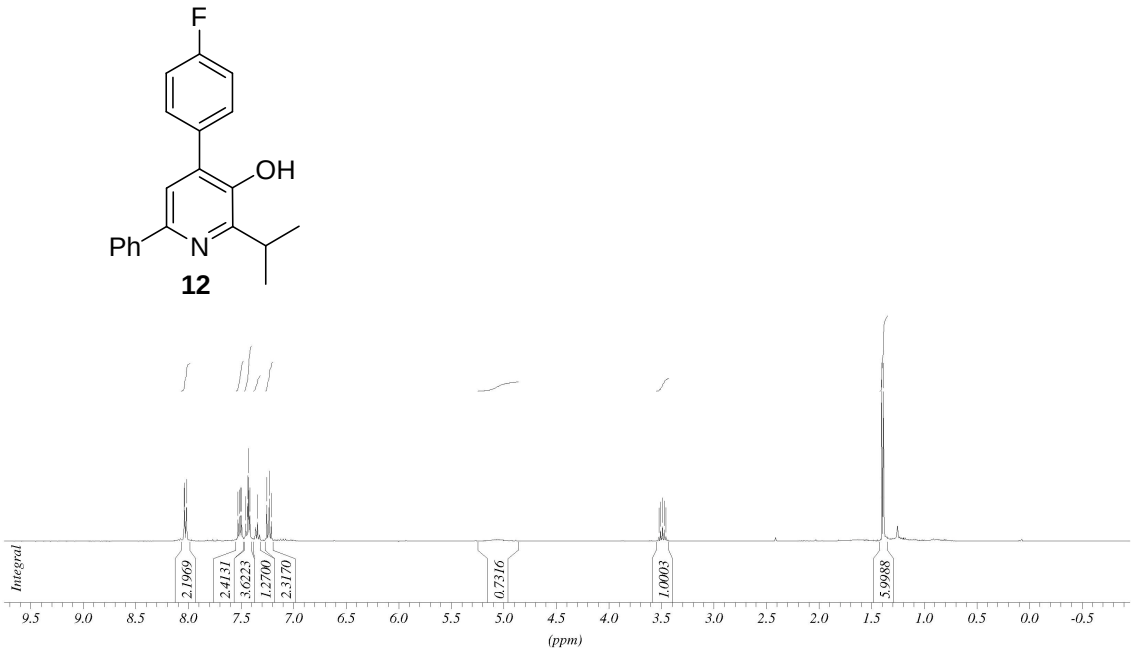
11

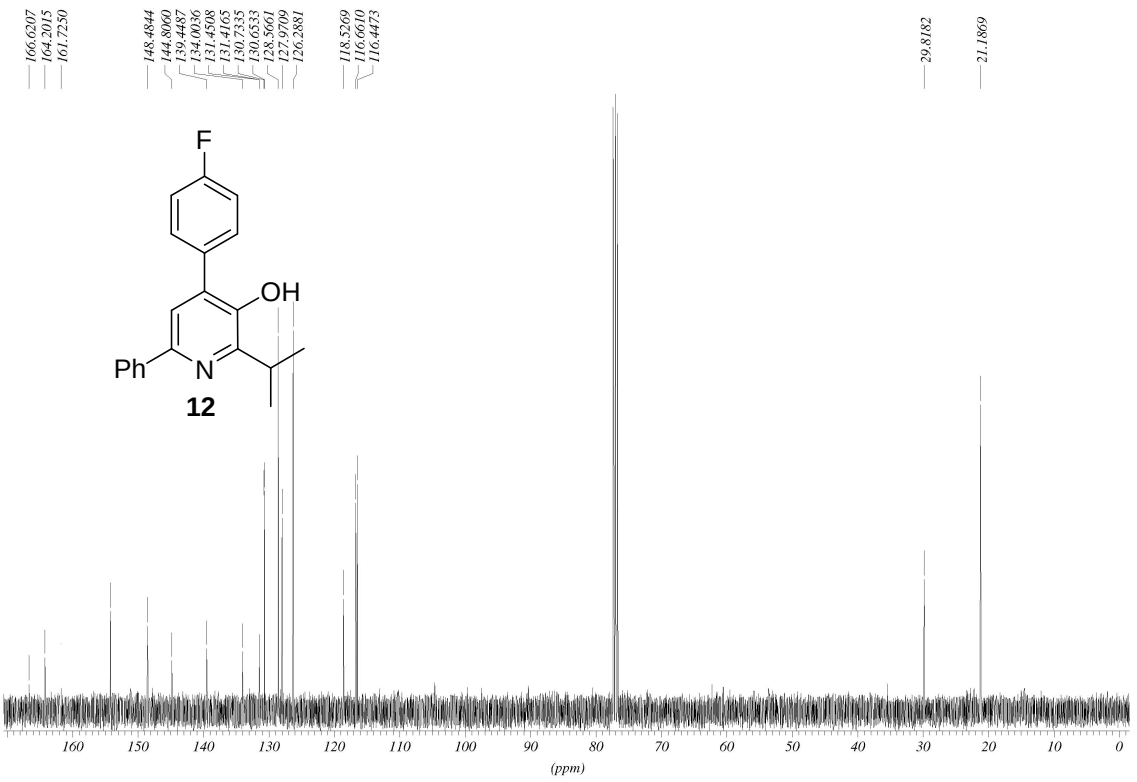

2.0670
2.0760
1.0394
2.2127
1.0818
2.0639
1.0001
3.0982
6.3640
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
(ppm)

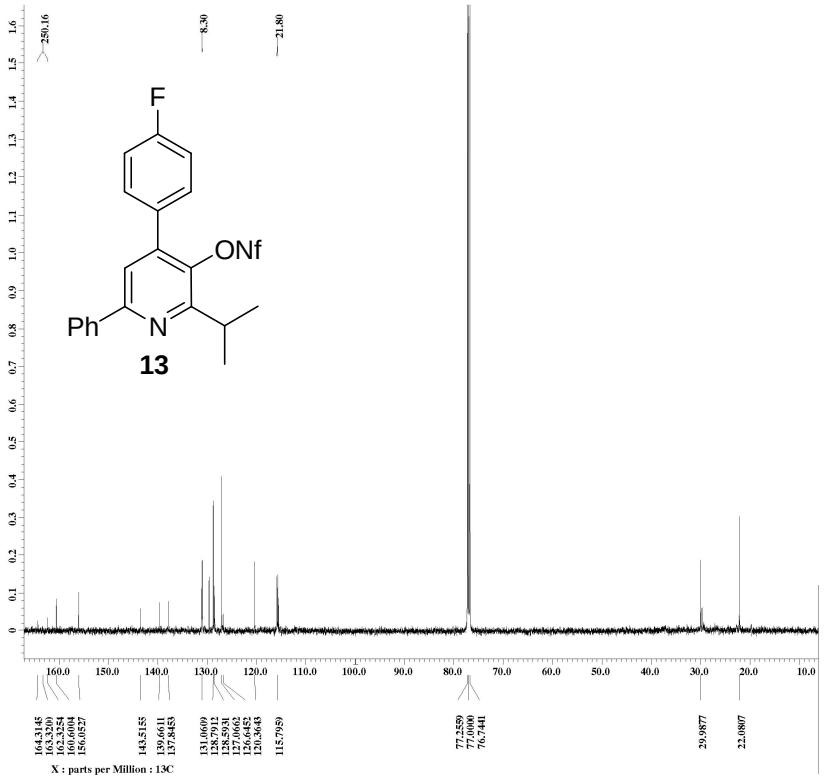

F
OMe
Ph
N

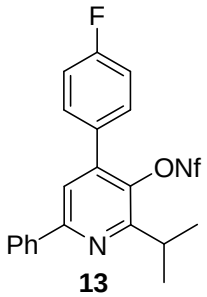
11

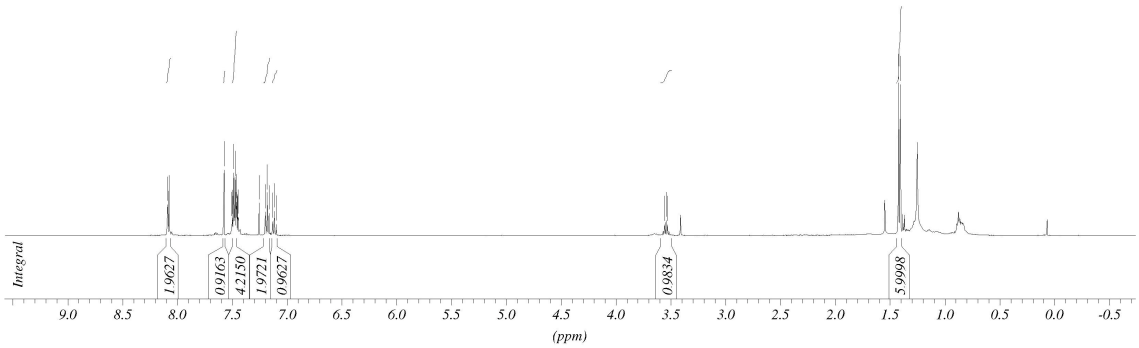

170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
(ppm)

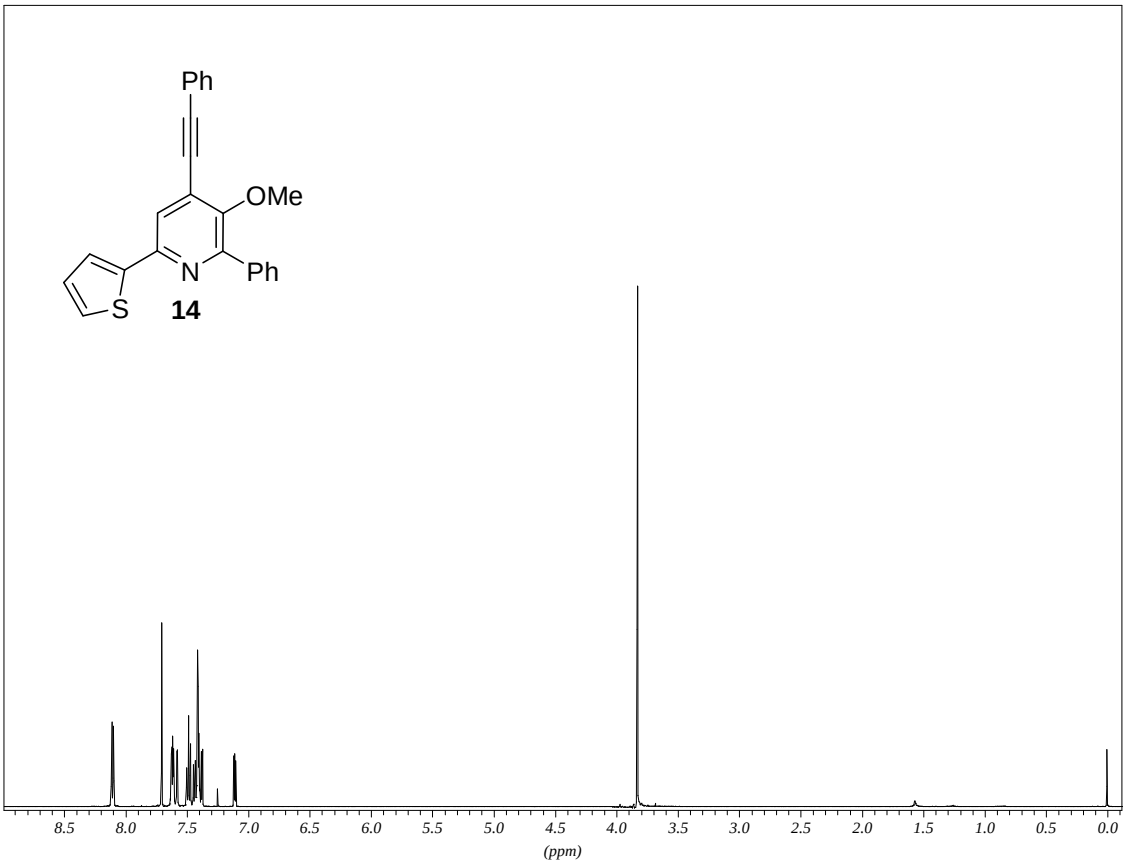

F
OH
Ph
N
12
Integral
2.1969
2.4131
3.6223
1.2700
2.3170
0.7316
1.0003
5.9988
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
(ppm)

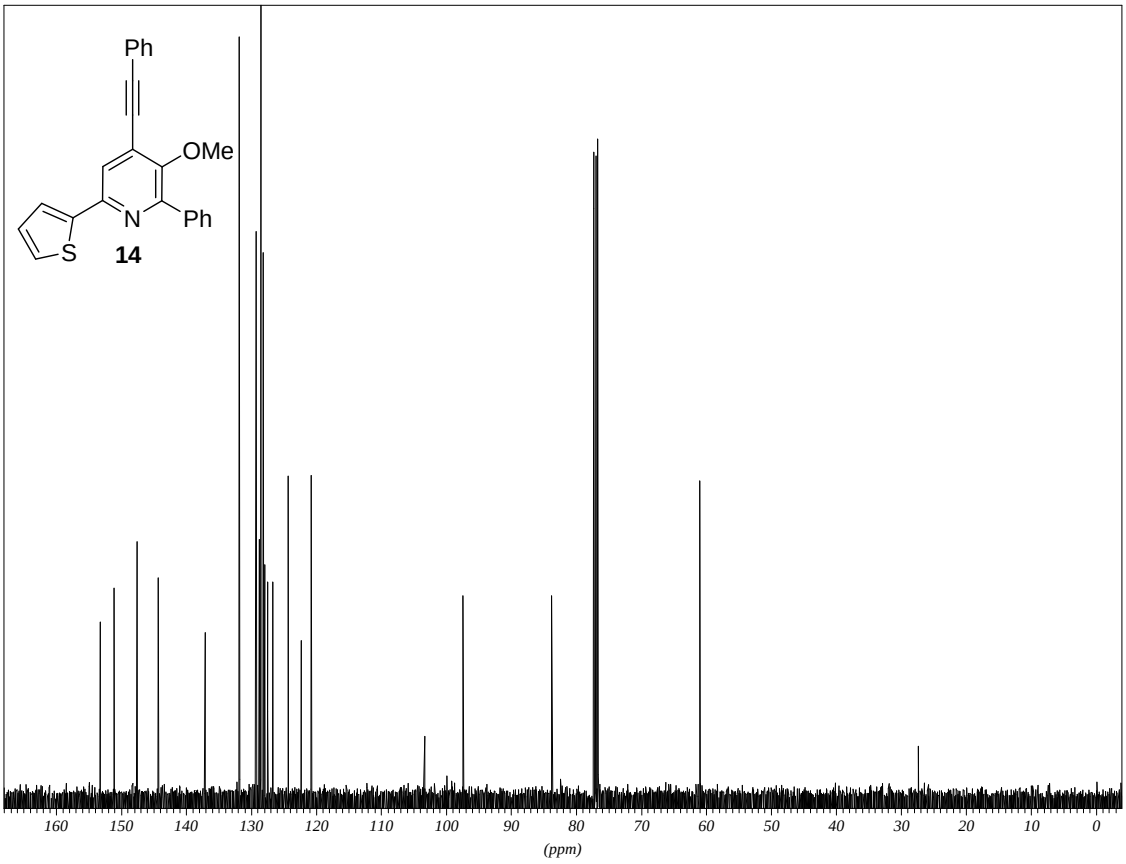

166.6207
164.2015
161.7250
148.4844
144.8060
139.4487
134.0036
131.4308
131.4165
130.7335
130.6533
128.5661
127.9709
126.2881
118.5269
116.6610
116.4473
29.8182
21.1869
F
OH
Ph
N
12
160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
(ppm)

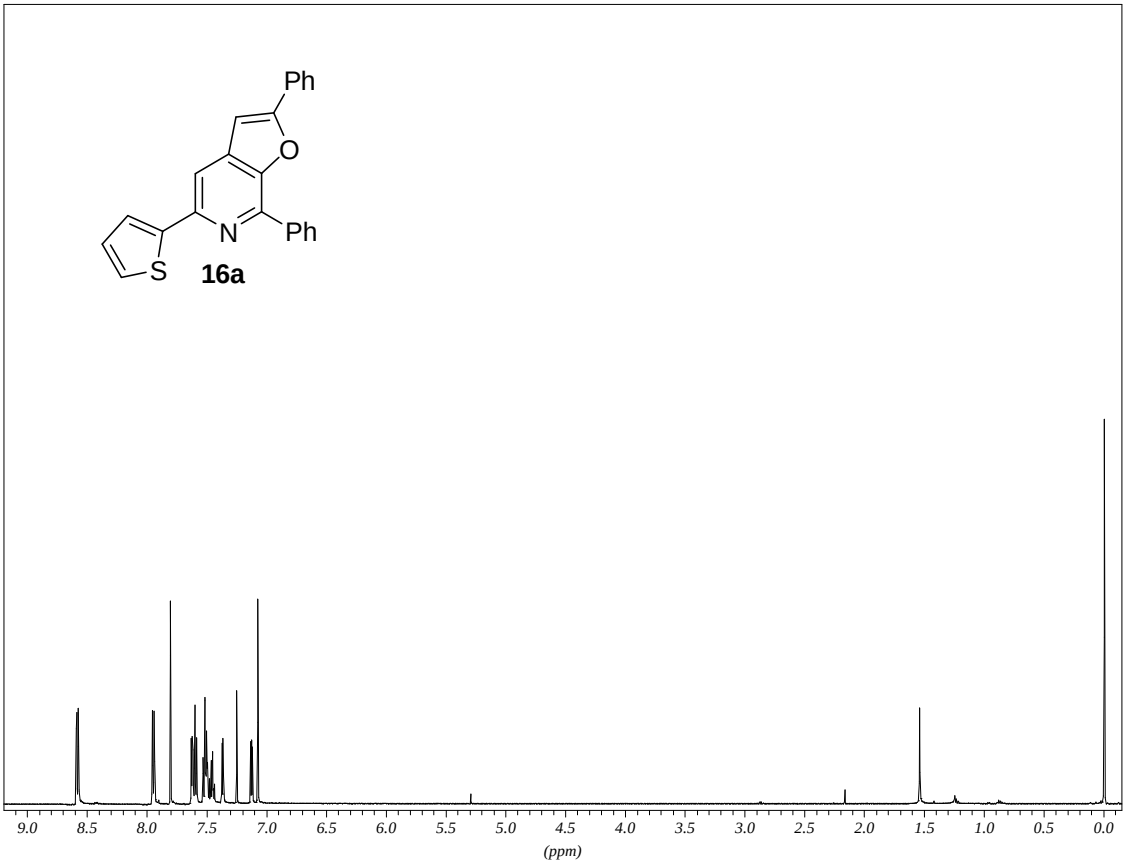

250.16
8.30
21.80
F
ONf
Ph
N
13
X : parts per Million : 13C

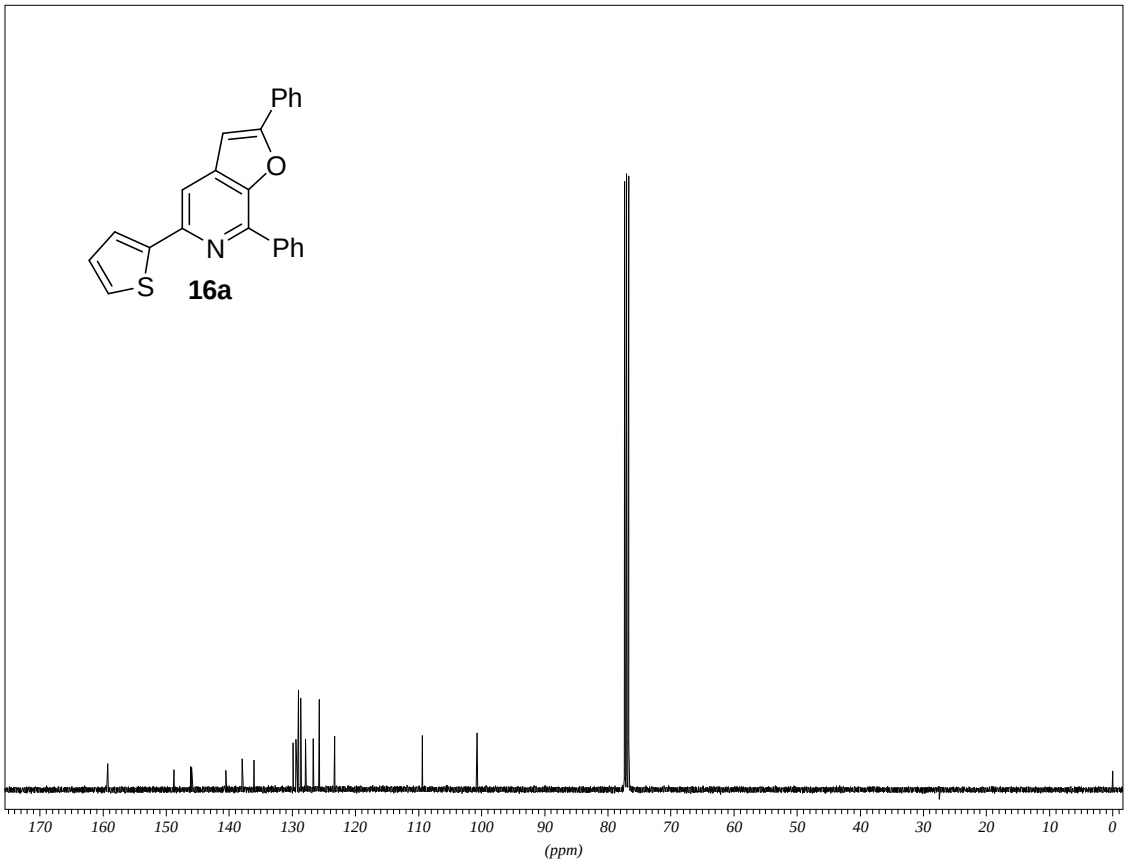

F
ONf
Ph
N
13

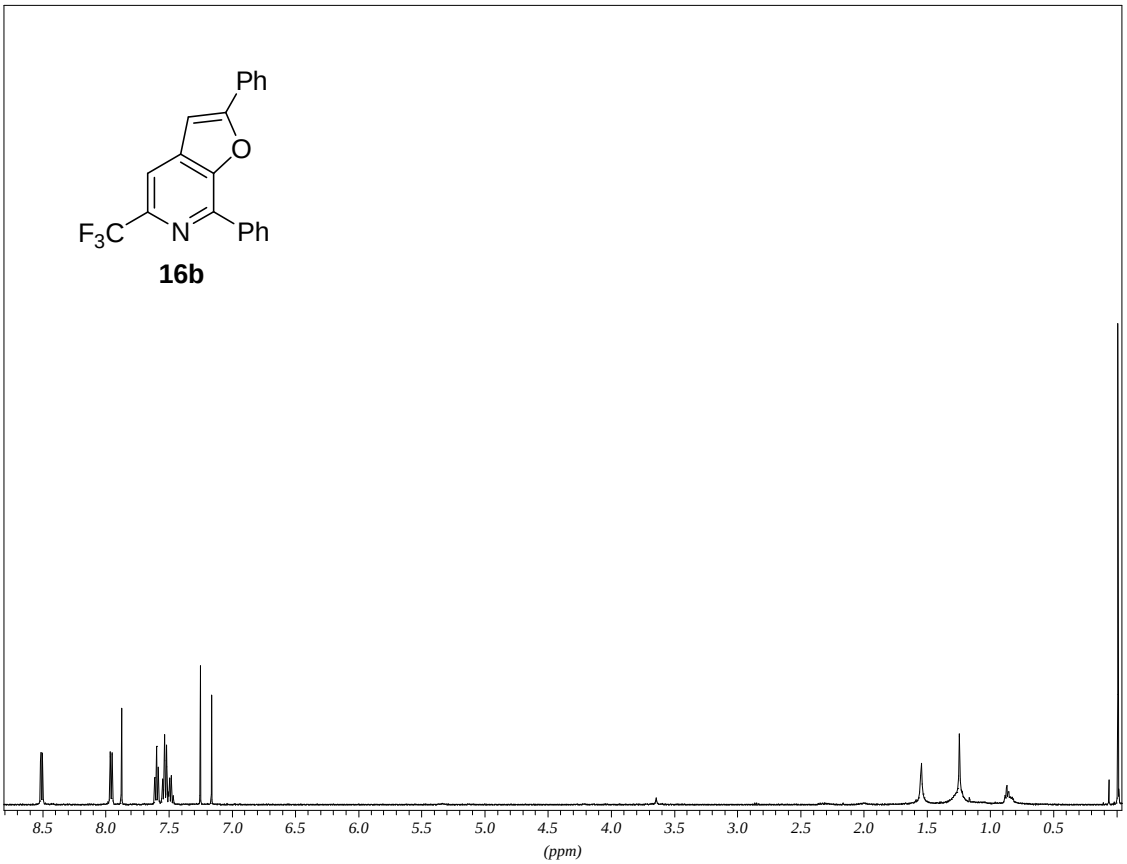

Integral
1.9627
0.9163
4.2150
1.9721
0.9627
0.9834
5.9998
(ppm)

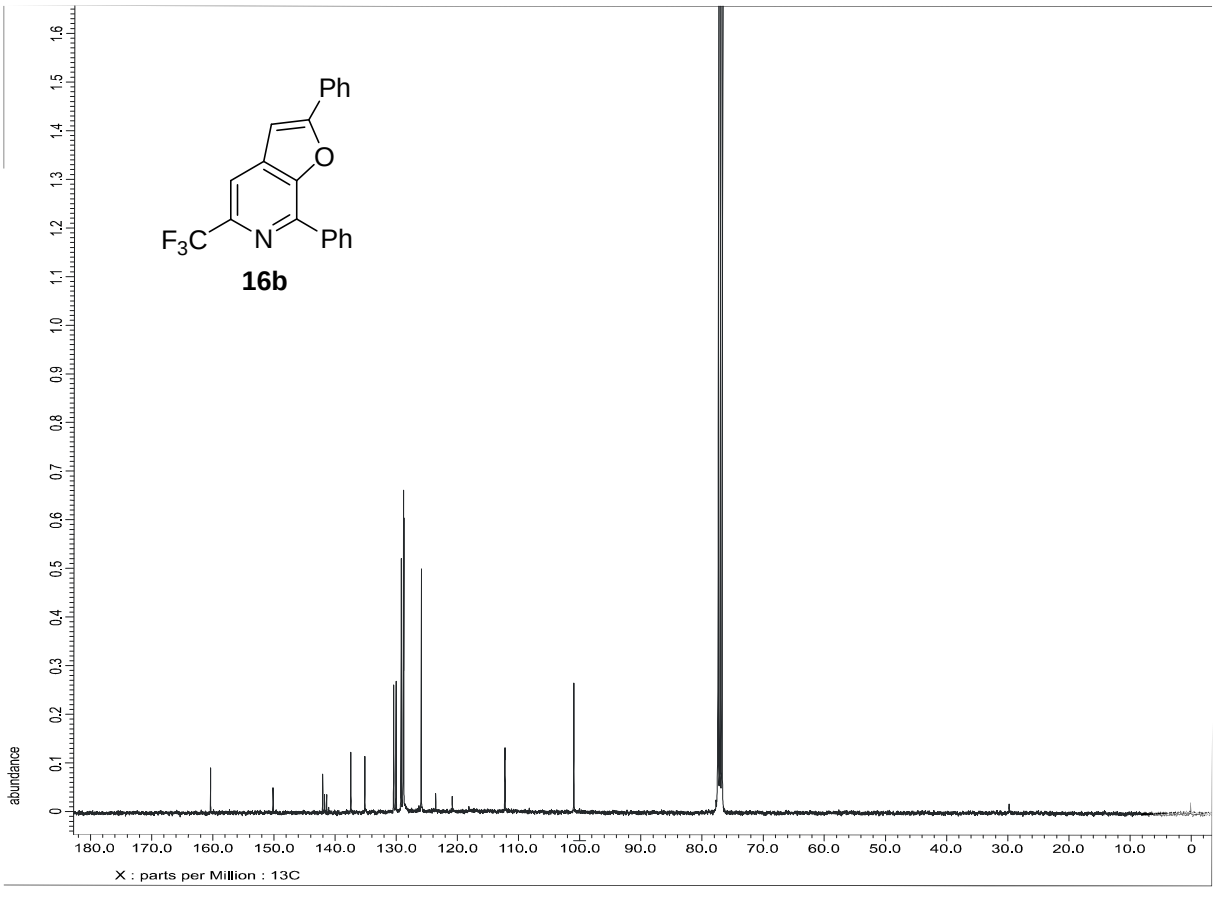









Ph
O
F3C
N
Ph
16b
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
(ppm)


Ph
O
F3C
N
Ph
16b
abundance
180.0
170.0
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0
X : parts per Million : 13C