Au(I)-Catalyzed Synthesis of Trisubstituted Indolizines from 2-Propargyloxypyridines and Methyl Ketones

Matthew D. Rossler,‡ Colin T. Hartgerink,‡ Emily E. Zerull,‡ Benjamin L. Boss, Abigail K. Frndak, Miles M. Mason, Leslie A. Nickerson,† Evan O. Romero, Jaimie E. Van de Burg, Richard J. Staples, Carolyn E. Anderson*

Department of Chemistry and Biochemistry, Calvin College, 1726 Knollcrest Circle SE, Grand Rapids, MI 49546.

Supporting Information

Representative experimental procedures and tabulated characterization data for all new compounds, details of further optimization studies, CIF file and solid-state packing diagrams for **4**, isotope study spectral data, and copies of ^{1}H and ^{13}C NMR spectra for new compounds.

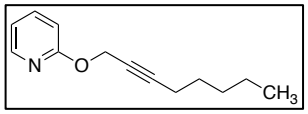
(71 Pages)

General experimental details	S3
Experimental details for newly synthesized compounds	S3-S22
Optimization Studies	S23
Experimental details and solid state packing diagrams for the X-ray crystal structure of Compound **4**	S24-S25
Isotope study spectral data	S26-S27
^{1}H and ^{13}C NMR Spectra of Compound **8a**	S28
^{1}H and ^{13}C NMR Spectra of Compound **8g**	S29
^{1}H and ^{13}C NMR Spectra of Compound **10a**	S30
^{1}H and ^{13}C NMR Spectra of Compound **10c**	S31
^{1}H and ^{13}C NMR Spectra of Compound **22**	S32
^{1}H and ^{13}C NMR Spectra of Compound **10d**	S33
^{1}H and ^{13}C NMR Spectra of Compound **4**	S34
^{1}H and ^{13}C NMR Spectra of Compound **7a**	S35
^{1}H and ^{13}C NMR Spectra of Compound **7b**	S36
^{1}H and ^{13}C NMR Spectra of Compound **7c**	S37
^{1}H and ^{13}C NMR Spectra of Compound **7d**	S38
^{1}H and ^{13}C NMR Spectra of Compound **7e**	S39
^{1}H and ^{13}C NMR Spectra of Compound **7f**	S40
^{1}H and ^{13}C NMR Spectra of Compound **7g**	S41

^{1}H and ^{13}C NMR Spectra of Compound **7h** S42
^{1}H and ^{13}C NMR Spectra of Compound **7i** S43
^{1}H and ^{13}C NMR Spectra of Compound **7j** S44
^{1}H and ^{13}C NMR Spectra of Compound **7k** S45
^{1}H and ^{13}C NMR Spectra of Compound **7l** S46
^{1}H and ^{13}C NMR Spectra of Compound **7m** S47
^{1}H and ^{13}C NMR Spectra of Compound **7n** S48
^{1}H and ^{13}C NMR Spectra of Compound **9a** S49
^{1}H and ^{13}C NMR Spectra of Compound **9aa** S50
^{1}H and ^{13}C NMR Spectra of Compound **9b** S51
^{1}H and ^{13}C NMR Spectra of Compound **9bb** S52
^{1}H and ^{13}C NMR Spectra of Compound **9c** S53
^{1}H and ^{13}C NMR Spectra of Compound **9cc** S54
^{1}H and ^{13}C NMR Spectra of Compound **9ccc** S55
^{1}H and ^{13}C NMR Spectra of Compound **9d** S56
^{1}H and ^{13}C NMR Spectra of Compound **9dd** S57
^{1}H and ^{13}C NMR Spectra of Compound **9e** S58
^{1}H and ^{13}C NMR Spectra of Compound **9f** S59
^{1}H and ^{13}C NMR Spectra of Compound **9ff** S60
^{1}H and ^{13}C NMR Spectra of Compound **9g** S61
^{1}H and ^{13}C NMR Spectra of Compound **11c** S62
^{1}H and ^{13}C NMR Spectra of Compound **11cc** S63
^{1}H and ^{13}C NMR Spectra of Compound **11ccc** S64
^{1}H and ^{13}C NMR Spectra of Compound **11d** S65
^{1}H and ^{13}C NMR Spectra of Compound **11dd** S66
^{1}H and ^{13}C NMR Spectra of Compound **11e** S67
^{1}H and ^{13}C NMR Spectra of Compound **11ee** S68
^{1}H and ^{13}C NMR Spectra of Compound **13** S69
^{1}H and ^{13}C NMR Spectra of Compound **13a** S70
^{1}H and ^{13}C NMR Spectra of Compound **16** S71

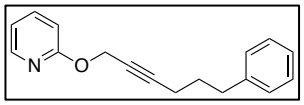
A. Experimental Procedures

General experimental details. All reagents were purchased from commercial venders. Solvents, including 1-phenylethanol and all acetophenone derivatives, were sparged with argon prior to use. All other reagents were used as received, unless noted otherwise. ^{1}H and ^{13}C NMR spectra were obtained on a 400 MHz NMR spectrometer. Chemical shifts are reported in ppm relative to $CDCl_3$. Multiplicity is indicated as follows: s (singlet); d (doublet); t (triplet); q (quartet); m (multiplet); dd (doublet of doublets); dt (doublet of triplets); app (apparent).



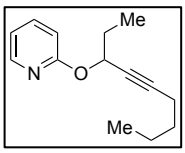
General experimental procedure for the synthesis of 2-propargyloxypyridines. 2-(2-octynyloxy)pyridine (1). To 2-chloropyridine (0.88 mL, 8.0 mmol) in 1,4-dioxane (24 mL) was added 2-octyn-1-ol (2.29 mL, 16.0 mmol). Potassium *tert*-butoxide (1.35 g, 12.0 mmol) was added, and the flask was rinsed with 1,4-dioxane (12 mL). The reaction was equipped with an air condenser and heated to 98 °C, open to air, for 18 hours. After cooling to room temperature, ethyl acetate (30 mL) and H_2O (30 mL) were added. The layers were separated and the aqueous layer was extracted with ethyl acetate (30 mL x 2). The combined organic layers were washed with 1:1 brine/H_2O (30 mL) and brine (30 mL) and dried ($MgSO_4$). After filtration, the reaction mixture was concentrated *in vacuo*. Purification by column chromatography (SiO_2, 19:1 hexanes/ethyl acetate) provided 1.55 g (95% yield) of **1** as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.15 (dd, J = 2.0, 4.8 Hz, 1H), 7.56 (ddd, J = 2.0, 6.8, 8.4 Hz, 1H), 6.88 (ddd, J = 0.8, 4.8, 7.2 Hz, 1H), 6.79 (d, J = 7.6 Hz, 1H), 4.95 (t, J = 2.0 Hz, 2H), 2.23 (tt, J = 2.0, 7.2 Hz, 2H), 1.52 (quintet, J = 7.2 Hz, 2H), 1.24-1.38 (m, 4H), 0.88 (t, J = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 162.9, 147.0, 138.8, 117.3, 111.5, 87.4, 75.5, 54.4, 31.2, 28.4, 22.4, 19.1, 14.2; IR (neat): 2932, 2237, 1749, 1594, 1570, 1472, 1432, 1272 cm^{-1}; HRMS (ESI) m/z 226.1201 [226.1208 calcd for $C_{13}H_{17}NONa$ $(M+Na)^+$].

2-(6-Phenyl-2-pentynyloxy)pyridine (8a). Following the general procedure outlined above for the synthesis of compound **1**, potassium *tert*-butoxide (993 mg, 8.9 mmol) was added to 2-chloropyridine (0.55 mL, 5.40 mmol) and 6-phenyl-2-pentyn-1-ol[1] (1.28 g, 7.4 mmol) in 1,4-dioxane (27 mL). After 22 hours, the reaction was worked up and purified by column chromatography (SiO_2, 97:3 hexanes/ethyl acetate) to afford 1.07 g (72% yield) of **8a** as a yellow

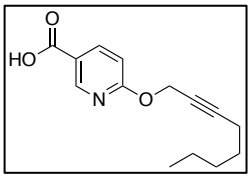


(1) Larionov, O. V.; Corey, E. J. *J. Am. Chem. Soc.* **2008**, *130*, 2954–2955.

oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.18 (d, *J* = 2.9 Hz, 1H), 7.57 (t, *J* = 7.7 Hz, 1H), 7.25-7.29 (m, 2H), 7.15-7.20 (m, 3H), 6.88 (t, *J* = 6.0 Hz, 1H), 6.81 (d, *J* = 8.4 Hz, 1H), 4.99 (s, 2H), 2.70 (t, *J* = 7.5 Hz, 2H), 2.25 (t, *J* = 6.9 Hz, 2H), 1.84 (quintet, *J* = 7.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 162.7, 146.8, 141.5, 138.6, 128.5, 128.3, 125.9, 117.2, 111.3, 86.5, 76.0, 54.1, 34.7, 30.0, 18.3; IR (neat): 3024, 2933, 2238, 1495, 1270, 1141 cm^{-1}; HRMS (ESI) m/z 252.1388 [252.1383 calcd for $C_{17}H_{18}NO$ $(M+H)^+$].

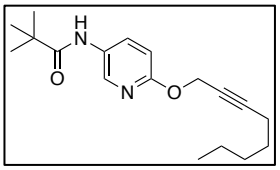


2-(4-Nonynyloxy)pyridine (8g). Following the general procedure outlined above for the synthesis of compound **1**, potassium *tert*-butoxide (329 mg, 2.9 mmol) was added to 2-chloropyridine (0.22 mL, 2.35 mmol) and 4-nonyn-3-ol[1] (412 mg, 2.9 mmol) in 1,4-dioxane (11 mL). After 22 hours, the reaction was worked up and purified by column chromatography (SiO_2,19:1 hexanes/ethyl acetate) to afford 149 mg (29% yield) of **8g** as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.15 (d, *J* = 4.4 Hz, 1H), 7.54 (t, *J* = 7.7 Hz, 1H), 6.83 (t, *J* = 6.0 Hz, 1H), 6.74 (d, *J* = 8.3 Hz, 1H), 5.59 (t, *J* = 5.4 Hz, 1H), 2.17 (t, *J* = 7.0 Hz, 2H), 1.84-1.90 (m, 2H), 1.44 (quintet, *J* = 7.0 Hz, 2H), 1.33 (sextet, *J* = 7.2 Hz, 2H), 1.05 (t, *J* = 7.4 Hz, 3H), 0.84 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 162.8, 146.8, 138.5, 116.8, 111.4, 85.6, 78.6, 66.5, 30.6, 28.6, 21.8, 18.4, 13.5, 9.5; IR (neat): 2958, 1593, 1468, 1430, 1307 cm^{-1}; HRMS (ESI) m/z 218.1530 [218.1539 calcd for $C_{14}H_{20}NO$ $(M+H)^+$].



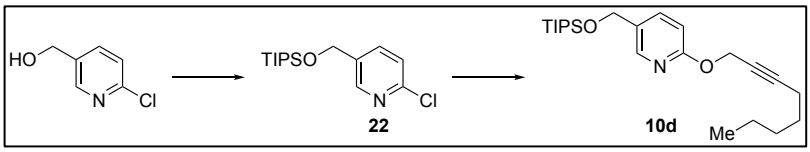
4-Carboxy-2-(2-octynyloxy)pyridine (10a). Following the general procedure outlined above for the synthesis of compound **1**, potassium *tert*-butoxide (2.80 g, 25 mmol) was added to 6-chloropyridine carboxylic acid (1.57 g, 10 mmol) and 2-octyn-1-ol (2.16 mL, 15 mmol) in 1,4-dioxane (46 mL). After 22 hours, ethyl acetate (30 mL) and 1M HCl (30 mL) were added. The layers were separated and the aqueous layer was extracted with ethyl acetate (30 mL x 2). The combined organic layers were washed with 1M Hcl (30 mL), 1:1 brine/H_2O (30 mL), and brine (30 mL) and dried ($MgSO_4$). After filtration, the reaction mixture was concentrated *in vacuo*. Recrystallization from 1:1 ethanol:H_2O afforded 1.12 g (45% yield) of **10a** as a white solid. mp: 146-147 °C, ^{1}H NMR (400 MHz, acetone-d_6): δ 8.79 (s, 1H), 8.22 (d, *J* = 8.6 Hz, 1H), 6.90 (d, *J* = 8.6 Hz, 1H), 5.03 (s, 2H), 2.21 (t, *J* = 6.6 Hz, 2H), 1.47 (q, *J* = 6.9 Hz, 2H), 1.38-1.22 (m, 4H), 0.85 (t, *J* = 6.7Hz, 3H); ^{13}C NMR (100 MHz, acetone-d_6): δ 165.41, 165.38, 149.6, 140.0, 120.5, 110.7, 86.7, 75.1, 54.3, 30.7, 28.0, 21.9, 18.1, 13.3; IR (neat): 2927, 2538, 2238, 1682, 1603, 1281, 1138 cm^{-1}; HRMS (ESI) m/z 248.1278 [248.1281 calcd for $C_{14}H_{18}NO$ $(M+H)^+$].

4-(2,2-Dimethylpropanamide)-2-(2-octynyloxy)pyridine (10c). Following the general procedure



outlined above for the synthesis of compound **1**, potassium *tert*-butoxide (1.25 g, 11 mmol) was added to *N*-(6-chloropyridin-3-yl)-2,2-dimethylpropanamide (1.60 g, 7.4 mmol) and 2-octyn-1-ol (1.60 mL, 11 mmol) in 1,4-dioxane (34 mL). After 22 hours, the reaction was worked up and purified by column chromatography (SiO_2, 9:1 to 3:1 hexanes/ethyl acetate) to afford 1.65 g (73% yield) of **10c** as a yellow powder. mp: 62-65 °C, ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.10 (s, 1H), 7.90 (d, *J* = 8.8 Hz, 1H), 7.37 (s, 1H), 6.71 (d, *J* = 8.9 Hz, 1H), 4.87 (s, 2H), 2.17 (t, *J* = 7.0 Hz, 2H), 1.47 (t, *J* = 6.9 Hz, 2H), 1.26 (s, 13H), 0.84 (t, *J* = 6.7, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 177.1, 159.4, 138.8, 132.8, 129.0, 110.7, 87.2, 75.1, 54.4, 39.4, 34.9, 31.0, 28.1, 27.5, 22.1, 18.8, 13.9; IR (neat): 3275, 2928, 2239, 1649, 1483, 1399, 1275, 1254 cm^{-1}; HRMS (ESI) m/z 303.2058 [303.2067 calcd for $C_{18}H_{27}N_2O_2$ $(M+H)^+$].

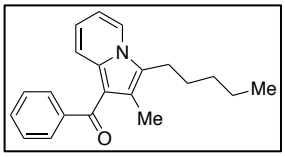
4-(triisopropylsiloxymethyl)-2-(2-octynyloxy)pyridine (10d). To 6-chloro-3-pyridine methanol



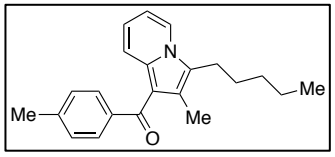
(718mg, 5.0 mmol) in dichloromethane (22 mL) was added imidazole (408 mg, 6.0 mmol). Tris(isopropyl)silyl chloride (1.28 mL, 6.0 mmol) was added, and the flask was rinsed with dichloromethane (22 mL). After 16 hours, H_2O (30 mL) was added, and the layers were separated. The aqueous layer was then extracted with dichloromethane (30 mL x 2). The combined organic layers were washed with saturated aqueous $NaCO_3$ (30 mL) and brine (30 mL) and dried ($MgSO_4$). After filtration, the reaction was concentrated *in vacuo*. Purification by column chromatography (SiO_2, 19:1 hexanes/ethyl acetate) provided 1.37 g (91% yield) of TIPS-protected 6-chloro-3-pyridine methanol **22** as a colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.34 (s, 1H), 7.65 (dd, *J* = 2.0, 7.6 Hz, 1H), 7.28 (d, *J* = 8.0 Hz, 1H), 4.81 (s, 2H), 1.10-1.21 (m, 3H), 1.06 (d, *J* = 7.2 Hz, 18H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 149.9, 147.4, 136.6, 135.9, 123.8, 72.2, 17.9, 11.9; IR (neat): 2942, 2890, 2865, 1568, 1456, 1098 cm^{-1}.

Following the general procedure outlined above for the synthesis of compound **1**, potassium *tert*-butoxide (589 mg, 11 mmol) was added to compound **22** (1.05 g, 3.5 mmol) and 2-octyn-1-ol (0.75 mL, 5.3 mmol) in 1,4-dioxane (16 mL). After 22 hours, the reaction was worked up and purified by column chromatography (SiO_2, 98:2 hexanes/ethyl acetate) to afford 838 mg (61% yield) of **10d** as a clear oil. ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.06 (s, 1H), 7.52 (d, *J* = 8.4 Hz, 1H), 6.71 (d, *J* = 8.4 Hz, 1H), 4.89 (s, 2H), 4.69 (s, 2H), 2.16 (t, *J* = 6.7 Hz, 2H), 1.45 (pentet, *J* = 6.8 Hz, 2H), 1.32-1.15 (m, 4H), 1.15-1.05

(m, 3H), 1.02 (d, *J* = 6.6 Hz, 18H), 0.81 (t, *J* = 7.6 Hz, 6.3 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 161.9, 144.2, 137.1, 129.9, 110.7, 86.8, 75.3, 62.6, 54.1, 31.0, 28.2, 22.1, 18.8, 17.9, 13.9, 11.9; IR (neat): 2939, 2864, 2238, 1486, 1306 cm^{-1}; HRMS (ESI) m/z 390.2815 [390.2823 calcd for $C_{23}H_{40}NO_2Si$ $(M+H)^+$].

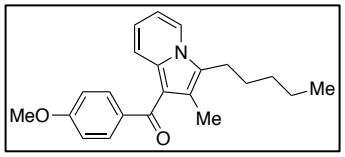


General experimental procedure for the Au(I)-catalyzed formation of trisubstituted indolizines. 1-benzoyl-2-methyl-3-pentylindolizine (4). To 2-(2-octynoxy)pyridine (**1**, 234 mg, 1.15 mmol) in a G10 microwave vial in an inert atmosphere glovebox was added bis(trifluoromethanesulfonyl)imide (2-dicyclohexylphosphino-2',6'-dimethoxy-1,1'-biphenyl)gold(I) (catalyst **5c**, 45 mg, 0.051 mmol), 1-phenylethanol (0.60 mL) and acetophenone (3.9 mL). After closing the vial and removing it from the glovebox, the vial was heated at 100 °C for 18 hours. After cooling to room temperature, the reaction was filtered through a cotton plug, rinsing with ethyl acetate. The volatiles were removed *in vacuo* followed by removal of the remainder of the acetophenone by Kugelrohr distillation. The residual was purified by column chromatography (19:1 to 9:1 hexanes/ethyl acetate) to afford 190 mg (54% yield) of **4** as a yellow solid. mp: 91-92 °C; ^{1}H NMR (400 MHz, *CDCl$_3$*): δ 7.83 (d, *J* = 4.0 Hz, 1H), 7.66 (d, *J* = 7.8 Hz, 2H), 7.47 (t, *J* = 6.6 Hz, 1H), 7.41 (t, *J* = 7.8 Hz, 2H), 6.83 (t, *J* = 7.8 Hz, 1H), 6.68 (t, *J* = 6.4 Hz, 1H), 2.83 (t, *J* = 7.8 Hz, 2H), 2.23 (s, 3H), 1.57 (pentet, *J* = 8.0 Hz, 2H), 1.28-1.37 (m, 4H), 0.87 (t, *J* = 6.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 192.1, 142.3, 136.1, 130.8, 128.7, 128.2, 124.5, 124.3, 122.3, 121.1, 119.4, 112.3, 112.2, 31.6, 26.9, 23.4, 22.5, 14.0, 11.8; IR (neat): 3058, 2927, 2859, 1612, 1497, 1393, 1241 cm^{-1}; HRMS (ESI) m/z 306.1842 [306.1852 calcd for $C_{21}H_{24}NO$ $(M+H)^+$].

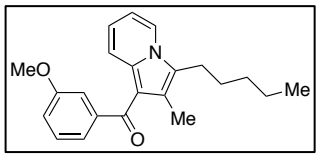


1-(4-Methylbenzoyl)-2-methyl-3-pentylindolizine (7a). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (24 mg, 0.027 mmol), 1-phenylethanol (0.30 mL) and 4'-methylacetophenone (2.0 mL) were added to 2-(2-octynoxy)pyridine (**1**, 103 mg, 0.51 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 19:1 hexanes/ethyl acetate) to afford 64 mg (40% yield) of **7a** as a yellow solid. mp: 81-83 °C; ^{1}H NMR (400 MHz, *CDCl$_3$*): δ 7.82 (d, *J* = 6.8 Hz, 1H), 7.59 (d, *J* = 8.0 Hz, 2H), 7.42 (d, *J* = 8.8 Hz, 1H), 7.22 (d, *J* = 8.0 Hz, 2H), 6.83 (ddd, *J* = 0.8, 6.6, 9.0 Hz, 1H), 6.67 (td, *J* = 1.2, 6.8 Hz, 1H), 2.84 (t, *J* = 7.6 Hz, 2H), 2.41 (s, 3H), 2.25 (s, 3H), 1.53-1.63 (m, 2H), 1.30-1.38 (m, 4H), 0.89 (t, *J* = 7.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 192.0, 141.3, 139.4, 135.8, 129.1, 128.8, 124.3, 124.2, 122.3, 120.8, 119.4, 112.5, 112.0, 31.6,

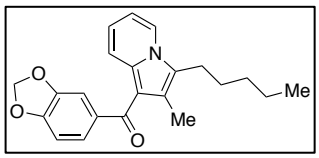
26.9, 23.4, 22.5, 21.6, 14.0, 11.8; IR (neat): 3024, 2922, 2856, 1600, 1492, 1389 cm^{-1}; HRMS (ESI) m/z 320.2009 [320.2011 calcd for $C_{22}H_{26}NO$ $(M+H)^+$].



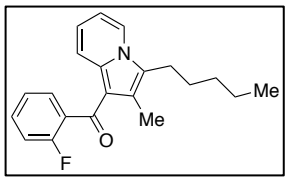
1-(4-Methyloxybenzoyl)-2-methyl-3-pentylindolizine (7b). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (25 mg, 0.028 mmol), 1-phenylethanol (0.30 mL) and 4'-methoxyacetophenone (2.56 g, 17.0 mmol) were added to 2-(2-octynoxy)pyridine (**1**, 61 mg, 0.30 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 97:3 to 19:1 to 9:1 hexanes/ethyl acetate) to afford 66 mg (40% yield) of **7b** as a thick yellow oil. ^{1}H NMR (400 MHz, *CDCl₃*): δ 7.82 (d, *J* = 6.8 Hz, 1H), 7.70 (dt, *J* = 2.4, 9.4 Hz, 2H), 7.42 (d, *J* = 8.8 Hz, 1H), 6.92 (dt, *J* = 2.2, 9.4 Hz, 2H), 6.82 (ddd, *J* = 1.0, 6.8, 9.0 Hz, 1H), 6.66 (td, *J* = 1.2, 6.8 Hz, 1H), 3.86 (s, 3H), 2.85 (t, *J* = 7.6 Hz, 2H), 2.27 (s, 3H), 1.52-1.63 (m, 2H), 1.30-1.39 (m, 4H), 0.89 (t, *J* = 7.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 191.1, 162.1, 135.5, 134.6, 131.3, 124.2, 124.0, 122.2, 120.5, 119.3, 113.3, 112.5, 111.9, 55.4, 31.6, 27.0, 23.5, 22.5, 14.0, 11.7; IR (neat): 3069, 2924, 2855, 1596, 1494, 1389, 1241, 1029 cm^{-1}; HRMS (ESI) m/z 336.1951 [336.1958 calcd for $C_{22}H_{26}NO_2$ $(M+H)^+$].



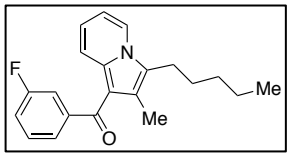
1-(3-Methyloxybenzoyl)-2-methyl-3-pentylindolizine (7c). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (23 mg, 0.026 mmol), 1-phenylethanol (0.30 mL) and 3'-methoxyacetophenone (2.0 mL) were added to 2-(2-octynoxy)pyridine (**1**, 120 mg, 0.59 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 97:3 hexanes/ethyl acetate) to afford 75 mg (38% yield) of **7c** as a thick yellow oil. ^{1}H NMR (400 MHz, *CDCl₃*): δ 7.83 (d, *J* = 6.8 Hz, 1H), 7.43 (d, *J* = 9.2 Hz, 1H), 7.32 (t, *J* = 8.0 Hz, 1H), 7.23 (dd, *J* = 1.6, 8.4 Hz, 2H), 7.02-7.06 (m, 1H), 6.85 (ddd, *J* = 1.2, 6.8, 9.0 Hz, 1H), 6.69 (td, *J* = 1.2, 6.8 Hz, 1H), 3.82 (s, 3H), 2.84 (t, *J* = 7.6 Hz, 2H), 2.25 (s, 3H), 1.52-1.63 (m, 2H), 1.29-1.39 (m, 4H), 0.89 (t, *J* = 7.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 191.7, 159.5, 143.7, 136.1, 129.2, 124.5, 124.3, 122.4, 121.3, 121.2, 119.4, 117.2, 113.0, 112.3, 112.2, 55.4, 31.6, 26.9, 23.4, 22.5, 14.0, 11.8; IR (neat): 3066, 2925, 2856, 1519, 1493, 1252, 1043 cm^{-1}; HRMS (ESI) m/z 336.1974 [336.1958 calcd for $C_{22}H_{26}NO_2$ $(M+H)^+$].



1-(2H-1,3-benzodioxole-5-carbonyl)-2-methyl-3-pentylindolizine (7d). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (23 mg, 0.026 mmol), 1-phenylethanol (0.30 mL) and 2H-1,3-benzodioxole methyl ketone (2.80 g, 17.0) were added to 2-(2-octynoxy)pyridine (**1**, 100 mg, 0.49 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 19:1 to 9:1 hexanes/ethyl acetate) to afford 65 mg (38% yield) of **7d** as a thick yellow oil. ^{1}H NMR (400 MHz, *CDCl₃*): δ 7.82 (d, *J* = 6.8 Hz, 1H), 7.46 (d, *J* = 9.0 Hz, 1H), 7.20-7.29 (m, 2H), 6.78-6.89 (m, 2H), 6.67 (t, *J* = 6.7 Hz, 1H), 6.03 (s, 2H), 2.84 (t, *J* = 7.5 Hz, 2H), 2.26 (s, 3H), 1.52-1.64 (m, 2H), 1.28-1.40 (m, 4H), 0.89 (app t, *J* = 6.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 190.6, 150.2, 147.6, 136.3, 135.6, 124.8, 124.3, 124.0, 122.3, 120.7, 119.3, 112.3, 112.0, 109.3, 107.7, 101.5, 31.6, 26.9, 23.4, 22.5, 14.0, 11.7; IR (neat): 2925, 2857, 1594, 1485, 1437, 1246 cm^{-1}; HRMS (ESI) m/z 350.1730 [350.1751 calcd for $C_{22}H_{24}NO_3$ $(M+H)^+$].

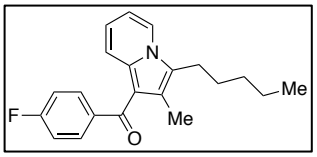


1-(2-Fluorobenzoyl)-2-methyl-3-pentylindolizine (7e). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (23 mg, 0.026 mmol), 1-butanol (0.23 mL) and 2'-fluoroacetophenone (2.0 mL) were added to 2-(2-octynoxy)pyridine (**1**, 103 mg, 0.51 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 19:1 to 9:1 hexanes/ethyl acetate) to afford 68 mg (41% yield) of **7e** as a thick yellow oil. ^{1}H NMR (400 MHz, *CDCl₃*): δ 7.86 (d, *J* = 6.7 Hz, 1H), 7.66 (d, *J* = 9.1 Hz, 1H), 7.39-7.47 (m, 2H), 7.18-7.26 (m, 1H), 7.12 (t, *J* = 8.8 Hz, 1H), 6.97 (t, *J* = 7.8 Hz, 1H), 6.76 (t, *J* = 6.8 Hz, 1H), 2.82 (t, *J* = 7.5 Hz, 2H), 2.15 (s, 3H), 1.50-1.60 (m, 2H), 1.27-1.38 (m, 4H), 0.88 (t, *J* = 5.9 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 186.7, 159.2 (d, *J* = 247 Hz), 136.8, 131.6 (d, *J* = 17 Hz), 131.2 (d, *J* = 7.9 Hz), 129.4 (d, *J* = 3.7 Hz), 124.8, 124.4 (d, *J* = 3.4 Hz), 124.3, 122.9, 122.7, 119.3, 116.0 (d, *J* = 21.7 Hz), 113.0, 112.6, 31.5, 26.9, 23.3, 22.5, 14.0, 11.4; IR (neat): 3059, 2926, 2857, 1602, 1490, 1393 cm^{-1}; HRMS (ESI) m/z 324.1747 [324.1758 calcd for $C_{21}H_{23}FNO$ $(M+H)^+$].

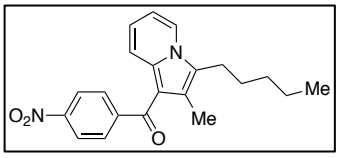


1-(3-Fluorobenzoyl)-2-methyl-3-pentylindolizine (7f). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (22 mg, 0.026 mmol), 1-phenylethanol (0.30 mL) and 3'-fluoroacetophenone (2.0 mL) were added to 2-(2-octynoxy)pyridine (**1**, 103 mg, 0.51 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 97:3 to 19:1 hexanes/ethyl acetate) to afford 109 mg

(66% yield) of **7f** as a thick yellow oil. ^{1}H NMR (400 MHz, *CDCl$_3$*): δ 7.85 (d, *J* = 6.8 Hz, 1H), 7.32-7.49 (m, 4H), 7.19 (t, *J* = 8.2 Hz, 1H), 6.90 (t, *J* = 7.9 Hz, 1H), 6.73 (t, *J* = 6.8 Hz, 1H), 2.84 (t, *J* = 7.5 Hz, 2H), 2.22 (s, 3H), 1.53-1.64 (m, 2H), 1.29-1.40 (m, 4H), 0.89 (t, *J* = 6.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 190.3 (d, *J* = 1.9 Hz), 162.6 (d, *J* = 246 Hz), 144.5 (d, *J* = 6.1 Hz), 136.3, 129.9 (d, *J* = 7.7 Hz), 124.8, 124.4 (d, *J* = 3.0 Hz), 124.2, 122.5, 121.7, 119.3, 117.6 (d, *J* = 21 Hz), 115.5 (d, *J* = 22 Hz), 112.5, 11.8, 31.5, 26.9, 23.4, 22.5, 14.0, 11.8; IR (neat): 3067, 2926, 2857, 1580, 1492, 1391, 1250 cm^{-1}; HRMS (ESI) m/z 324.1739 [324.1758 calcd for $C_{21}H_{23}FNO$ $(M+H)^+$].

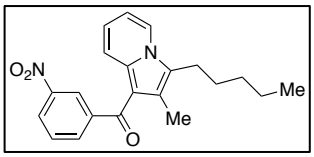


1-(4-Fluorobenzoyl)-2-methyl-3-pentylindolizine (7g). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (23 mg, 0.026 mmol), 1-phenylethanol (0.30 mL) and 4'-fluoroacetophenone (2.0 mL) were added to 2-(2-octynoxy)pyridine (**1**, 110 mg, 0.54 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 97:3 to 19:1 hexanes/ethyl acetate) to afford 89 mg (51% yield) of **7g** as a yellow solid. mp: 66-68 °C; ^{1}H NMR (400 MHz, *CDCl$_3$*): δ 7.84 (d, *J* = 6.8 Hz, 1H), 7.70 (t, *J* = 6.9 Hz, 2H), 7.42 (d, *J* = 9.0 Hz, 1H), 7.10 (t, *J* = 8.4 Hz, 2H), 6.87 (t, *J* = 7.9 Hz, 1H), 6.70 (t, *J* = 6.8 Hz, 1H), 2.85 (t, *J* = 7.5 Hz, 2H), 2.23 (s, 3H), 1.52-1.63 (m, 2H), 1.29-1.40 (m, 4H), 0.89 (app t, *J* = 6.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 190.6, 164.5 (d, *J* = 250 Hz), 138.4 (d, *J* = 2.8 Hz), 136.0, 131.3 (d, *J* = 8.7 Hz), 124.6, 124.1, 122.4, 121.3, 119.2, 115.2 (d, *J* = 21.5 Hz), 112.3, 112.1, 31.6, 26.9, 23.4, 22.5, 14.0, 11.8; IR (neat): 3066, 2926, 2857, 1597, 1492, 1390, 1235 cm^{-1}; HRMS (ESI) m/z 324.1727 [324.1758 calcd for $C_{21}H_{23}FNO$ $(M+H)^+$].



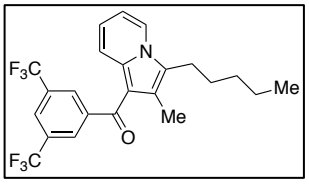
1-(4-Nitrobenzoyl)-2-methyl-3-pentylindolizine (7h). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (23 mg, 0.026 mmol), 1-butanol (0.3 mL) and 4'-nitroacetophenone (1.41 g, 8.5 mmol) were added to 2-(2-octynoxy)pyridine (**1**, 116 mg, 0.57 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 19:1 hexanes/ethyl acetate) to afford 147 mg (73% yield) of **7h** as a bright red solid. mp: 93-95 °C; ^{1}H NMR (400 MHz, *CDCl$_3$*): δ 8.29 (dt, *J* = 2.4, 8.8 Hz, 2H), 7.89 (d, *J* = 6.8 Hz, 1H), 7.78 (dt, *J* = 2.4, 8.8 Hz, 2H), 7.49 (dt, *J* = 1.2, 8.8 Hz, 1H), 6.97 (ddd, *J* = 1.0, 6.8, 9.0 Hz, 1H), 6.78 (dt, *J* = 1.2, 6.8 Hz, 1H), 2.84 (t, *J* = 7.6 Hz, 2H), 2.16 (s, 3H), 1.51-1.63 (m, 2H), 1.36 (heptet, *J* = 6.0 Hz, 4H), 0.89 (t, *J* = 7.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 189.3, 148.8, 148.2, 136.7, 129.3, 125.3, 124.1, 123.6, 122.8, 122.7, 119.2, 113.0, 111.5, 31.5, 26.9,

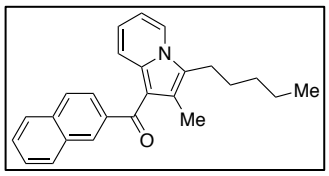
23.4, 22.5, 14.0, 12.1; IR (neat): 3104, 2926, 2857, 1519, 1491, 1344 cm^{-1}; HRMS (ESI) m/z 351.1697 [351.1703 calcd for $C_{21}H_{23}N_2O_3$ $(M+H)^+$].



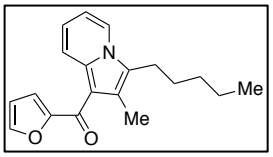
1-(3-Nitrobenzoyl)-2-methyl-3-pentylindolizine (7i). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (22 mg, 0.026 mmol), 1-phenylethanol (0.3 mL) and 3'-nitroacetophenone (2.80 g, 17.0 mmol) were added to 2-(2-octynoxy)pyridine (**1**, 116 mg, 0.57 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 9:1 to 85:15 to 3:1 hexanes/ethyl acetate) to afford 152 mg (76% yield) of **7i** as a thick amber oil. ^{1}H NMR (400 MHz, *CDCl₃*): δ 8.48 (s, 1H), 8.35 (d, *J* = 8.2 Hz, 1H), 8.01 (d, *J* = 6.8 Hz, 1H), 7.89 (d, *J* = 6.8 Hz, 1H), 7.64 (t, *J* = 7.8 Hz, 1H), 7.53 (d, *J* = 9.0 Hz, 1H), 6.96 (t, *J* = 7.8 Hz, 1H), 6.78 (t, *J* = 6.8 Hz, 1H), 2.85 (t, *J* = 7.5 Hz, 2H), 2.217 (s, 3H), 1.53-1.65 (m, 2H), 1.29-1.41 (m, 4H), 0.89 (t, *J* = 6.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 188.7, 148.0, 143.8, 136.7, 134.5, 129.5, 125.22, 125.18, 123.9, 123.7, 122.8, 122.6, 119.1, 113.0, 11.4, 31.5, 26.9, 23.4, 22.5, 14.0, 12.1; IR (neat): 3082, 2925, 2857, 1604, 1528, 1491, 1391, 1345 cm^{-1}; HRMS (ESI) m/z 351.1712 [351.1703 calcd for $C_{21}H_{23}N_2O_3$ $(M+H)^+$].

1-(3,5-Ditrifluoromethylbenzoyl)-2-methyl-3-pentylindolizine (7j). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (44 mg, 0.050 mmol), 1-phenylethanol (0.6 mL) and 3',5'-ditrifluoromethylacetophenone (4.0 mL) were added to 2-(2-octynoxy)pyridine (**1**, 204 mg, 1.0 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 97:3 hexanes/ethyl acetate) to afford 353 mg (80% yield) of **7j** as a thick yellow oil. ^{1}H NMR (400 MHz, *CDCl₃*): δ 8.12 (s, 2H), 8.00 (s, 1H), 7.91 (d, *J* = 6.9 Hz, 1H), 7.61 (d, *J* = 9.0 Hz, 1H),7.02 (t, *J* = 7.7 Hz, 1H), 6.81 (t, *J* = 6.7 Hz, 1H), 2.86 (t, *J* = 7.5 Hz, 2H), 2.12 (s, 3H), 1.53-1.66 (m, 2H), 1.29-1.41 (m, 4H), 0.89 (t, *J* = 6.5 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 187.8, 144.0, 136.8, 131.6 (q, *J* = 34 Hz), 129.0 (q, *J* = 3.5 Hz), 125.4, 123.9 (pentet, *J* = 4.0 Hz), 123.7, 123.1 (q, *J* = 271 Hz), 123.0, 122.9, 119.0, 113.2, 111.1, 31.5, 26.9, 23.4, 22.5, 13.9, 12.1; IR (neat): 2928, 2860, 1626, 1493, 1368, 1275, 1129 cm^{-1}; HRMS (ESI) m/z 442.1625 [442.1600 calcd for $C_{23}H_{22}F_6NO$ $(M+H)^+$].

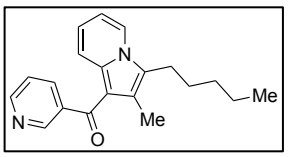




1-naphthoyl-2-methyl-3-pentylindolizine (7k). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (23 mg, 0.026 mmol), 1-phenylethanol (0.3 mL) and naphthyl methyl ketone (2.95 g, 17.0 mmol) were added to 2-(2-octynoxy)pyridine (**1**, 104 mg, 0.51 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 97:3 to 19:1 to 9:1 hexanes/ethyl acetate) to afford 113 mg (62% yield) of **7k** as a thick yellow oil. ^{1}H NMR (400 MHz, *CDCl₃*): δ 8.17 (s, 1H), 7.84-7.93 (m, 4H), 7.82 (d, *J* = 8.4 Hz, 1H), 7.56 (t, *J* = 7.4 Hz, 1H), 7.51 (t, *J* = 7.3 Hz, 1H), 7.44 (d, *J* = 9.1 Hz, 1H), 6.82 (t, *J* = 7.8 Hz, 1H), 6.70 (t, *J* = 6.8 Hz, 1H), 2.87 (t, *J* = 7.5 Hz, 2H), 2.26 (s, 3H), 1.54-1.68 (m, 2H), 1.30-1.42 (m, 4H), 0.90 (t, *J* = 6.3 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 192.0, 139.5, 136.1, 134.7, 132.7, 129.6, 129.1, 128.0, 127.8, 127.3, 126.4, 125.7, 124.5, 124.3, 122.4, 121.2, 119.4, 112.5, 112.3, 31.6, 27.0, 23.5, 22.5, 14.1, 11.9; IR (neat): 3056, 2925, 2856, 1602, 1492, 1392 cm^{-1}; HRMS (ESI) m/z 356.2017 [356.2009 calcd for $C_{25}H_{26}NO$ $(M+H)^+$].

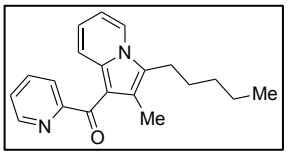


1-(2-furyl)-2-methyl-3-pentylindolizine (7l). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (25 mg, 0.029 mmol), 1-phenylethanol (0.3 mL) and 2-furyl methyl ketone (1.90 g, 17.0 mmol) were added to 2-(2-octynoxy)pyridine (**1**, 104 mg, 0.51 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 85:15 hexanes/ethyl acetate) to afford 107 mg (71% yield) of **7l** as a thick yellow oil. ^{1}H NMR (400 MHz, *CDCl₃*): δ 7.82 (d, *J* = 6.8 Hz, 1H), 7.63 (dt, *J* = 1.2, 9.0 Hz, 1H), 7.58 (q, *J* = 0.8 Hz, 1H), 7.08 (dd, *J* = 0.8, 3.6 Hz, 1H), 6.90 (ddd, *J* = 1.0, 6.6, 9.0 Hz, 1H), 6.69 (td, *J* = 1.2, 6.8 Hz, 1H), 6.54 (t, *J* = 1.8, 3.4 Hz, 1H), 2.84 (t, *J* = 7.6 Hz, 2H), 2.33 (s, 3H), 1.52-1.63 (m, 2H), 1.30-1.39 (m, 4H), 0.89 (t, *J* = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 178.5, 154.4, 145.0, 135.4, 124.5, 123.6, 122.4, 120.9, 119.1, 116.8, 112.2, 111.9, 31.6, 29.7, 26.9, 23.5, 22.5, 14.0, 11.3; IR (neat): 3112, 2924, 2855, 1735, 1599, 1495, 1392, 1248 cm^{-1}; HRMS (ESI) m/z 296.1641 [296.1645 calcd for $C_{19}H_{22}NO_2$ $(M+H)^+$].

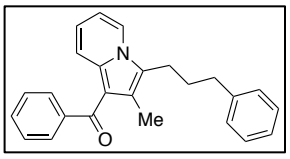


1-(3-pyridinyl)-2-methyl-3-pentylindolizine (7m). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (23 mg, 0.026 mmol), 1-phenylethanol (0.3 mL) and 2-acetyl pyridine (2.0 mL) were added to 2-(2-octynoxy)pyridine (**1**, 110 mg, 0.54 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 7:3 hexanes/ethyl acetate) to afford 84 mg (51% yield) of **7m** as a thick yellow powder. mp: 104-105 °C; ^{1}H NMR (400 MHz, *CDCl₃*): δ 8.83 (s, 1H), 8.71 (d,

J = 4.8 Hz, 1H), 7.96 (d, *J* = 8.4 Hz, 1H), 7.86 (d, *J* = 6.8 Hz, 1H), 7.53 (d, *J* = 9.2 Hz, 1H), 7.38 (dd, *J* = 5.2, 8.0 Hz, 1H), 6.94 (dd, *J* = 6.8, 8.8 Hz, 1H), 6.75 (t, *J* = 6.8 Hz, 1H), 2.83 (t, *J* = 7.6 Hz, 2H), 2.19 (s, 3H), 1.57 (pentet, *J* = 6.8 Hz, 2H), 1.29-1.37 (m, 4H), 0.88 (t, *J* = 6.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 189.3, 151.4, 149.9, 137.7, 136.5, 136.0, 125.0, 124.1, 123.4, 122.7, 122.4, 119.2, 112.8, 112.0, 31.5, 26.9, 23.4, 22.5, 14.0, 12.1; IR (neat): 3089, 2917, 2852, 1589, 1486 cm^{-1}; HRMS (ESI) m/z 307.1805 [307.1805 calcd for $C_{20}H_{23}N_2O$ $(M+H)^+$].

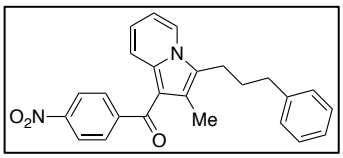


1-(2-pyridinyl)-2-methyl-3-pentylindolizine (7n). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (25 mg, 0.028 mmol), 1-phenylethanol (0.3 mL) and 3-acetyl pyridine (2.0 mL) were added to 2-(2-octynoxy)pyridine (**1**, 111 mg, 0.55 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 7:3 hexanes/ethyl acetate) to afford 99 mg (59% yield) of **7n** as a thick yellow oil. ^{1}H NMR (400 MHz, *CDCl$_3$*): δ 8.61 (d, *J* = 4.4 Hz, 1H), 7.76-7.87 (m, 3H), 7.50 (d, *J* = 9.2 Hz, 1H), 7.38 dd, *J* = 4.8, 7.2 Hz, 1H), 6.91 (t, *J* = 6.8 Hz, 1H), 6.70 (t, *J* = 6.8 Hz, 1H), 2.80 (t, *J* = 7.6 Hz, 2H), 2.13 (s, 3H), 1.48-1.58 (m, 2H), 1.27-1.36 (m, 4H), 0.86 (t, *J* = 6.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 189.9, 159.1, 148.6, 137.01, 136.96, 125.0, 124.9, 124.5, 123.1, 122.6, 122.2, 119.6, 112.7, 111.5, 31.6, 26.9, 23.4, 22.5, 14.0, 11.3; IR (neat): 3049, 2923, 2855, 1602, 1488, 1391 cm^{-1}; HRMS (ESI) m/z 307.1805 [307.1805 calcd for $C_{20}H_{23}N_2O$ $(M+H)^+$].

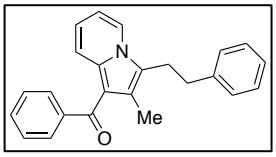


1-benzoyl-2-methyl-3-(3-phenylpropyl)indolizine (9a). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (25 mg, 0.029 mmol), 1-phenylethanol (0.33 mL) and acetophenone (2.16 mL) were added to 2-(6-phenyl-2-hexynoxy)pyridine (**8a**, 136 mg, 0.54 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 85:15 hexanes/ethyl acetate) to afford 94 mg (49% yield) of **9a** as a thick yellow oil. ^{1}H NMR (400 MHz, *CDCl$_3$*): δ 7.68 (app t, *J* = 8.9 Hz, 3H), 7.50 (t, *J* = 7.3 Hz, 1H), 7.42 (app t, *J* = 6.1 Hz, 3H), 7.29 (t, *J* = 7.4 Hz, 2H), 7.20 (app t, *J* = 6.9 Hz, 3H), 6.65 (t, *J* = 7.8 Hz, 1H), 6.66 (t, *J* = 6.8 Hz, 1H), 2.88 (t, *J* = 7.6 Hz, 2H), 2.71 (t, *J* = 7.5 Hz, 2H), 2.22 (s, 3H), 1.92 (pentet, *J* = 7.6 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 192.1, 142.3, 141.4, 136.1, 130.9, 128.7, 128.4, 128.3, 128.2, 126.0, 124.4, 123.9, 122.3, 121.3, 119.4, 112.32, 112.28, 35.4, 28.7, 22.9, 11.8; IR (neat): 3059, 3024, 2926, 2856, 1608, 1495, 1393, 1240 cm^{-1}; HRMS (ESI) m/z 354.1861 [354.1852 calcd for $C_{25}H_{24}NO$ $(M+H)^+$].

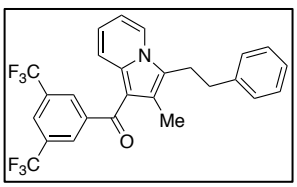
2-methyl-1-(4-nitrobenzoyl)-3-(3-phenylpropyl)indolizine (9aa). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (16 mg, 0.018 mmol), 1-phenylethanol (0.21 mL) and 4'-nitroacetophenone (1.99 g, 12.0 mmol) were added to 2-(6-phenyl-2-hexynoxy)pyridine (**8a**, 88 mg, 0.35 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 85:15 hexanes/ethyl acetate) to afford 100 mg (72% yield) of **9aa** as a thick red oil. ^{1}H NMR (400 MHz, *CDCl₃*): δ 8.29 (d, *J* = 8.0 Hz, 2H), 7.77 (d, *J* = 8.2 Hz, 2H), 7.73 (d, *J* = 6.8 Hz, 1H), 7.50 (d, *J* = 8.9 Hz, 1H), 7.29 (t, *J* = 7.2 Hz, 2H), 7.19 (app t, *J* = 8.9 Hz, 3H), 6.97 (t, *J* = 7.8 Hz, 1H), 6.74 (t, *J* = 6.8 Hz, 1H), 2.88 (t, *J* = 7.6 Hz, 2H), 2.71 (t, *J* = 7.4 Hz, 2H), 2.14 (s, 3H), 1.92 (pentet, *J* = 7.5 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 189.3, 148.9, 148.1, 141.2, 136.8, 129.3, 128.5, 128.3, 126.1, 124.7, 124.3, 123.6, 122.8, 122.7, 119.2, 113.1, 111.5, 35.4, 28.6, 22.8, 12.1; IR (neat): 3025, 2926, 2860, 1595, 1493, 1345 cm^{-1}; HRMS (ESI) m/z 399.1692 [399.1703 calcd for $C_{25}H_{23}N_2O_3$ $(M+H)^+$].



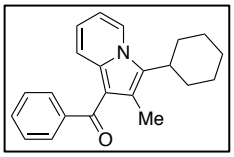
1-benzoyl-2-methyl-3-(2-phenylethyl)indolizine (9b). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (25 mg, 0.028 mmol), 1-phenylethanol (0.31 mL) and acetophenone (2.1 mL) were added to 2-(5-phenyl-2-pentynoxy)pyridine (**8b**, 122 mg, 0.52 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 85:15 hexanes/ethyl acetate) to afford 86 mg (49% yield) of **9b** as a thick yellow oil. ^{1}H NMR (400 MHz, *CDCl₃*): δ 7.79 (d, *J* = 6.9 Hz, 1H), 7.64 (d, *J* = 7.0 Hz, 2H), 7.50 (dd, *J* = 8.8, 13.6 Hz, 2H), 7.41 (t, *J* = 7.4 Hz, 2H), 7.17-7.28 (m, 3H), 7.07 (d, *J* = 7.0 Hz, 2H), 6.88 (t, *J* = 7.8 Hz, 1H), 6.68 (t, *J* = 6.8 Hz, 1H), 3.15 (t, *J* = 7.5 Hz, 2H), 2.87 (t, *J* = 7.4 Hz, 2H), 1.97 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 192.2, 142.1, 140.7, 136.1, 130.9, 128.8, 128.48, 128.46, 128.2, 126.3, 124.8, 123.0, 122.0, 121.4, 119.4, 112.34, 112.28, 33.6, 25.8, 11.5; IR (neat): 3059, 3024, 2922, 2856, 1608, 1494, 1393, 1240 cm^{-1}; HRMS (ESI) m/z 340.1690 [340.1696 calcd for $C_{22}H_{22}NO$ $(M+H)^+$].



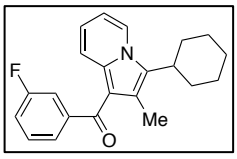
2-methyl-3-(3-phenylethyl)-1-(3,5-bistrifluoromethylbenzoyl)indolizine (9bb). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (18 mg, 0.020 mmol), 1-phenylethanol (0.22 mL) and 3',5'-bistrifluoromethylacetophenone (1.48 mL) were added to 2-(5-phenyl-2-pentynoxy)pyridine (**8b**, 87 mg, 0.37 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 9:1 hexanes/ethyl acetate) to afford 113 mg



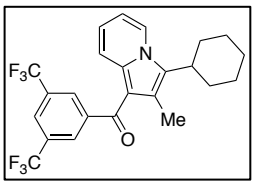
(64% yield) of **9bb** as a yellow powder. mp: 96-97 °C; ^{1}H NMR (400 MHz, *CDCl$_3$*): δ 8.07 (s, 2H), 7.99 (s, 1H), 7.86 (d, *J* = 6.8 Hz, 1H), 7.73 (d, *J* = 9.0 Hz, 1H), 7.23 (app q, *J* = 8.1 Hz, 3H), 7.01-7.08 (m, 3H), 6.80 (t, *J* = 6.8 Hz, 1H), 3.16 (t, *J* = 7.4 Hz, 2H), 2.89 (t, *J* = 7.4 Hz, 2H), 1.83 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 187.9, 143.9, 140.3, 137.0, 131.6 (q, *J* = 34 Hz), 128.9 (q, *J* = 3.0 Hz), 128.5, 128.4, 126.5, 124.4, 124.0 (heptet, *J* = 4.0 Hz), 123.9, 123.2, 123.1 (q, *J* = 271 Hz), 122.5, 119.3, 113.3, 111.1, 33.4, 25.8, 11.8; IR (neat): 3066, 2918, 2851, 1598, 1491, 1368 cm^{-1}; HRMS (ESI) m/z 476.1433 [476.1444 calcd for $C_{26}H_{20}F_6NO$ $(M+H)^+$].



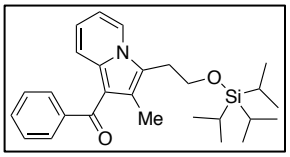
1-benzoyl-3-cyclohexyl-2-methylindolizine (9c). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (23 mg, 0.026 mmol), 1-phenylethanol (0.3 mL) and acetophenone (2.0 mL) were added to 2-(3-cyclohexyl-2-propynoxy)pyridine (**8c**, 107 mg, 0.50 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 19:1 to 9:1 hexanes/ethyl acetate) to afford 63 mg (40% yield) of **9c** as a yellow solid. mp: 120-123 °C; ^{1}H NMR (400 MHz, *CDCl$_3$*): δ 8.03 (d, *J* = 6.8 Hz, 1H), 7.69 (d, *J* = 7.8 Hz, 2H), 7.49 (app t, *J* = 6.8 Hz, 1H), 7.41 (app t, *J* = 7.5 Hz, 2H), 7.36 (d, *J* = 9.0 Hz, 1H), 6.80 (t, *J* = 7.8 Hz, 1H), 6.64 (t, *J* = 6.7 Hz, 1H), 3.01 (t, *J* = 11.4 Hz, 1H), 2.31 (s, 3H), 1.73-1.98 (m, 7H), 1.28-1.50 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 192.3, 142.2, 135.9, 131.0, 129.0, 128.2, 128.0, 123.5, 123.1, 120.6, 119.4, 112.9, 11.8, 36.0, 29.9, 27.2, 26.1, 12.5; IR (neat): 2925, 2851, 1607, 1495, 1392, 1239 cm^{-1}; HRMS (ESI) m/z 318.1851 [318.1852 calcd for $C_{22}H_{24}NO$ $(M+H)^+$].



3-cyclohexyl-1-(3-fluorobenzoyl)-2-methylindolizine (9cc). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (20 mg, 0.023 mmol), 1-phenylethanol (0.28 mL) and 3'-fluoroacetophenone (1.84 mL) were added to 2-(3-cyclohexyl-2-propynoxy)pyridine (**8c**, 100 mg, 0.46 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 19:1 hexanes/ethyl acetate) to afford 88 mg (57% yield) of **9c** as a yellow solid. mp: 95-96 °C; ^{1}H NMR (400 MHz, *CDCl$_3$*): δ 8.04 (d, *J* = 6.7 Hz, 1H), 7.46 (d, *J* = 7.5 Hz, 1H), 7.39 (t, *J* = 8.9 Hz, 3H), 7.19 (t, *J* = 8.2 Hz, 1H), 6.84 (t, *J* = 7.7 Hz, 1H), 6.67 (t, *J* = 6.8 Hz, 1H), 3.01 (t, *J* = 11.9 Hz, 1H), 2.29 (s, 3H), 1.77-1.98 (m, 6H), 1.21-1.51 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 190.5 (d, *J* = 2.0 Hz), 163.8, 161.4, 144.4 (d, *J* = 6.0 Hz), 136.1, 129.8 (d, *J* = 7.7 Hz), 128.3, 124.6 (d, *J* = 2.9 Hz), 123.4 (d, *J* = 19 Hz), 121.2, 119.2, 117.8 (d, *J* = 12 Hz), 115.7 (d, *J* = 22 Hz), 112.5, 112.1, 36.0, 29.8, 27.1, 26.1, 12.5; IR (neat): 3102, 2919, 2850, 1628, 1601, 1494, 1246 cm^{-1}; HRMS (ESI) m/z 336.1743 [336.1758 calcd for $C_{22}H_{23}FNO$ $(M+H)^+$].

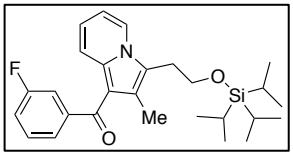


3-cyclohexyl-2-methyl-1-(3,5-bistrifluoromethylbenzoyl)indolizine (9ccc). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (26 mg, 0.029 mmol), 1-phenylethanol (0.33 mL) and 3',5'-bistrifluoromethylacetophenone (2.2 mL) were added to 2-(3-cyclohexyl-2-propynoxy)pyridine (**8c**, 118 mg, 0.55 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 19:1 hexanes/ethyl acetate) to afford 177 mg (71% yield) of **9ccc** as a yellow solid. mp: 134-137 °C; ^{1}H NMR (400 MHz, *CDCl₃*): δ 8.14 (s, 1H), 8.11 (d, *J* = 6.7 Hz, 1H), 8.00 (s, 1H), 7.53 (d, *J* = 8.9 Hz, 1H), 6.95 (t, *J* = 7.8 Hz, 1H), 6.75 (t, *J* = 6.8 Hz, 1H), 3.03 (t, *J* = 10.9 Hz, 1H), 2.22 (s, 3H), 1.76-1.99 (m, 6H), 1.23-1.51 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 188.0, 143.9, 136.7, 131.7 (q, *J* = 34 Hz), 129.2 (q, *J* = 3.6 Hz), 128.9, 124.1 (q, *J* = 3.8 Hz), 123.7, 123.11 (q, *J* = 272 Hz), 123.09, 122.4, 119.0, 112.8, 111.7, 36.1, 29.8, 27.1, 26.0, 12.8; IR (neat): 2930, 2856, 1626, 1494, 1396, 1275, 1127 cm^{-1}; HRMS (ESI) m/z 454.1592 [454.1600 calcd for $C_{24}H_{22}F_6NO$ $(M+H)^+$].

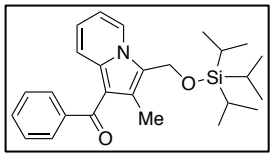


1-benzoyl-2-methyl-3-(2-triisopropylsiloxyethyl)indolizine (9d). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (15 mg, 0.017 mmol), 1-phenylethanol (0.21 mL) and acetophenone (1.4 mL) were added to 2-(5-triisopropylsiloxy-2-pentynoxy)pyridine (**8d**, 117 mg, 0.35 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 19:1 to 9:1 hexanes/ethyl acetate) to afford 68 mg (45% yield) of **9d** as a thick yellow oil. ^{1}H NMR (400 MHz, *CDCl₃*): δ 8.07 (d, *J* = 6.6 Hz, 1H), 7.65 (d, *J* = 7.6 Hz, 2H), 7.49 (t, *J* = 7.2 Hz, 1H), 7.41 (app t, *J* = 9.1 Hz, 3H), 6.84 (t, *J* = 7.9 Hz, 1H), 6.65 (t, *J* = 6.7 Hz, 1H), 3.90 (t, *J* = 6.2 Hz, 2H), 3.12 (t, *J* = 6.1 Hz, 2H), 2.24 (s, 3H), 0.89-1.08 (m, 21H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 192.1, 142.3, 136.3, 130.8, 128.7, 128.2, 125.1, 123.2, 122.1, 121.4, 119.1, 112.3, 112.0, 62.2, 27.3, 17.8, 11.80, 11.76; IR (neat): 2941, 2864, 1611, 1496, 1394, 1138 cm^{-1}; HRMS (ESI) m/z 436.2653 [436.2666 calcd for $C_{27}H_{38}NO_2Si$ $(M+H)^+$].

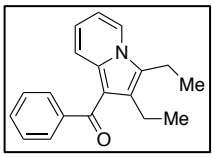
1-(3-fluorobenzoyl)-2-methyl-3-(2-triisopropylsiloxyethyl)indolizine (9dd). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (17 mg, 0.018 mmol), 1-phenylethanol (0.20 mL) and 3'-fluoroacetophenone (1.4 mL) were added to 2-(5-triisopropylsiloxy-2-pentynoxy)pyridine (**8d**, 110 mg, 0.33 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 19:1 to 9:1 hexanes/ethyl acetate) to afford 88 mg (59% yield) of **9dd** as a thick yellow oil. ^{1}H NMR (400 MHz, *CDCl₃*): δ 8.09 (d, *J* = 6.7 Hz, 1H), 7.30-7.47 (m, 4H), 7.18 (t, *J* = 8.1 Hz, 1H), 6.89 (t, *J* = 7.9



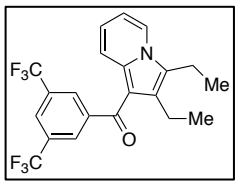
Hz, 1H), 6.68 (t, *J* = 6.7 Hz, 1H), 3.91 (t, *J* = 6.1 Hz, 2H), 3.11 (t, *J* = 6.0 Hz, 2H), 2.22 (s, 3H), 0.87-1.07 (m, 21H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 190.3 (d, *J* = 2 Hz), 162.6 (d, *J* = 246 Hz), 144.5 (d, *J* = 6.0 Hz), 136.5, 129.8 (d, *J* = 7.7 Hz), 125.0, 124.3 (d, *J* = 3.0 Hz), 123.4, 122.5, 122.0, 119.0, 117.6 (d, *J* = 21 Hz), 115.5 (d, *J* = 22 Hz), 112.2, 111.8, 62.3, 27.2, 17.8, 11.8 (2C); IR (neat): 2941, 2864, 1605, 1494, 1393, 1252, 1101 cm^{-1}; HRMS (ESI) m/z 454.2575 [454.2572 calcd for $C_{27}H_{37}FNO_2Si$ $(M+H)^+$].



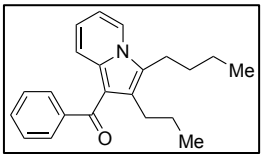
1-benzoyl-2-methyl-3-triisopropylsiloxymethylindolizine (9e). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (16 mg, 0.018 mmol), 1-phenylethanol (0.20 mL) and acetophenone (1.4 mL) were added to 2-(4-triisopropylsiloxy-2-butynoxy)pyridine (**8e**, 108 mg, 0.34 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 19:1 to 9:1 to 85:15 hexanes/ethyl acetate) to afford 8 mg (6% yield) of **9e** as a thick yellow oil. ^{1}H NMR (400 MHz, *$CDCl_3$*): δ 8.26 (d, *J* = 6.9 Hz, 1H), 7.66 (d, *J* = 7.8 Hz, 2H), 7.50 (t, *J* = 6.9 Hz, 1H), 7.36-7.46 (m, 3H), 6.92 (t, *J* = 7.7 Hz, 1H), 6.72 (t, *J* = 6.6 Hz, 1H), 5.02 (s, 2H), 2.27 (s, 3H), 1.15 (heptet, *J* = 7.5 Hz, 3H), 1.05 (app d, *J* = 7.1 Hz, 18H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 192.2, 142.2, 136.8, 130.9, 128.7, 128.2, 125.2, 124.5, 122.9, 122.6, 119.0, 112.2, 112.1, 54.9, 18.0, 12.0, 11.8; IR (neat): 2941, 2864, 1614, 1499, 1393, 1240, 1058 cm^{-1}; HRMS (ESI) m/z 422.2495 [422.2510 calcd for $C_{26}H_{36}NO_2Si$ $(M+H)^+$].



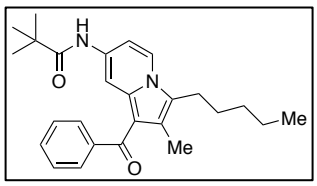
1-benzoyl-2,3-diethylindolizine (9f). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (25 mg, 0.028 mmol), 1-phenylethanol (0.3 mL) and acetophenone (2.0 mL) were added to 2-(3-hexyn-2-oxy)pyridine (**8f**, 91 mg, 0.52 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 9:1 hexanes/ethyl acetate) to afford 53 mg (37% yield) of **9f** as a thick yellow oil. ^{1}H NMR (400 MHz, *$CDCl_3$*): δ 7.84 (d, *J* = 6.7 Hz, 1H), 7.69 (d, *J* = 7.6 Hz, 2H), 7.50 (t, *J* = 6.8 Hz, 1H), 7.42 (t, *J* = 7.5 Hz, 2H), 7.14 (d, *J* = 9.0 Hz, 1H), 6.78 (t, *J* = 7.8 Hz, 1H), 6.67 (t, *J* = 6.7 Hz, 1H), 2.90 (q, *J* = 7.4 Hz, 2H), 2.81 (q, *J* = 7.3 Hz, 2H), 1.23 (t, *J* = 7.3 Hz, 3H), 1.15 (t, *J* = 7.3 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 192.0, 142.2, 136.0, 130.9, 130.8, 128.8, 128.2, 125.3, 122.4, 120.8, 119.4, 112.0, 111.4, 18.6, 16.7, 16.4, 12.3; IR (neat): 3057, 2965, 2871, 1608, 1494, 1389, 1306, 1236 cm^{-1}; HRMS (ESI) m/z 278.1544 [278.1539 calcd for $C_{19}H_{20}NO$ $(M+H)^+$].



2,3-diethyl-1-(3,5-bistrifluoromethylbenzoyl)indolizine (9ff). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (25 mg, 0.028 mmol), 1-phenylethanol (0.32 mL) and 3',5'-bistrifluromethylacetophenone (1.7 mL) were added to 2-(3-hexyn-2-oxy)pyridine (**8f**, 93 mg, 0.53 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 9:1 hexanes/ethyl acetate) to afford 151 mg (69% yield) of **9ff** as a yellow powder. mp: 110-111 °C; ^{1}H NMR (400 MHz, *CDCl$_3$*): δ 8.14 (s, 2H), 8.01 (s, 1H), 7.91 (d, *J* = 6.9 Hz, 1H), 7.22 (d, *J* = 9.0 Hz, 1H), 6.93 (t, *J* = 7.8 Hz, 1H), 6.78 (t, *J* = 6.7 Hz, 1H), 2.92 (q, *J* = 7.5 Hz, 2H), 2.73 (q, *J* = 7.4 Hz, 2H), 1.25 (t, *J* = 7.5 Hz, 3H), 1.12 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 187.7, 143.9, 136.6, 131.7 (q, *J* = 34 Hz), 130.8, 129.0 (q, *J* = 3.0 Hz), 126.2, 124.1 (heptet, *J* = 3.8 Hz), 123.1 (q, *J* = 271 Hz), 122.9, 122.5, 118.8, 112.9, 110.1, 18.7, 16.7, 16.2, 12.2; IR (neat): 3097, 2969, 2872, 1628, 1497, 1276, 1127 cm^{-1}; HRMS (ESI) m/z 414.1278 [414.1287 calcd for $C_{21}H_{18}F_6NO$ $(M+H)^+$].



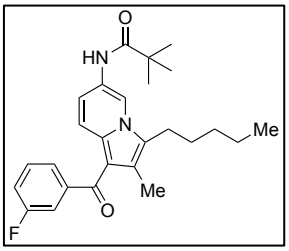
1-benzoyl-3-pentyl-2-propylindolizine (9g). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (21 mg, 0.024 mmol), 1-phenylethanol (0.29 mL) and acetophenone (1.93 mL) were added to 2-(4-nonynyloxy)pyridine (**8g**, 105 mg, 0.48 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 9:1 hexanes/ethyl acetate) to afford 63 mg (41% yield) of **9g** as a thick yellow oil. ^{1}H NMR (400 MHz, *CDCl$_3$*): δ 7.83 (d, *J* = 6.9 Hz, 1H), 7.68 (d, *J* = 7.1 Hz, 2H), 7.50 (t, *J* = 7.4 Hz, 1H), 7.42 (t, *J* = 7.4 Hz, 2H), 7.16 (d, *J* = 9.0 Hz, 1H), 6.78 (t, *J* = 7.6 Hz, 1H), 6.66 (t, *J* = 6.7 Hz, 1H), 2.86 (t, *J* = 7.7 Hz, 2H), 2.74 (t, *J* = 7.8 Hz, 2H), 1.39-1.60 (m, 6H), 0.97 (t, *J* = 7.2 Hz, 3H), 0.85 (t, *J* = 7.3 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 192.2, 142.2, 136.1, 130.9, 129.6, 128.8, 128.2, 124.4, 122.5, 120.7, 119.3, 111.9, 111.6, 29.6, 27.5, 25.0, 23.4, 22.7, 14.3, 13.9; IR (neat): 3059, 2956, 2869, 1612, 1496, 1389, 1241 cm^{-1}; HRMS (ESI) m/z 320.2013 [320.2009 calcd for $22_3H_{26}NO$ $(M+H)^+$].



***N*-(1-benzoyl-2-methyl-3-pentylindolizin-7-yl)-2,2-dimethylpropanamide (11c).** Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (15 mg, 0.017 mmol), 1-phenylethanol (0.20 mL) and acetophenone (1.3 mL) were added to 4-(2,2-dimethylpropanamide)-2-(2-octynyloxy)pyridine (**10c**, 100 mg, 0.33 mmol). After 18 hours, the reaction was worked up and

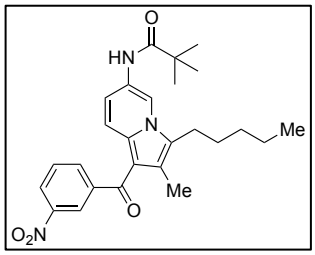
purified by column chromatography (SiO_2, 3:1 hexanes/ethyl acetate) to afford 87 mg (65% yield) of **11c** as a yellow powder. mp: 175-179 °C; ^{1}H NMR (400 MHz, *CDCl$_3$*): δ 8.92 (s, 1H), 7.64 (d, *J* = 7.1 Hz, 2H), 7.49 (t, *J* = 7.4 Hz, 1H), 7.41 (app t, *J* = 7.8 Hz, 3H), 7.25 (s, 1H), 6.56 (dd, *J* = 2.0, 9.5 Hz, 1H), 2.84 (t, *J* = 7.5 Hz, 2H), 2.16 (s, 3H), 1.52-1.63 (m, 4H), 1.32 (s, 11H), 0.87 (app s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 192.0, 176.8, 142.2, 133.5, 130.8, 128.7, 128.2, 125.7, 125.4, 124.6, 119.2, 116.4, 114.2, 112.6, 39.6, 31.4, 27.6, 26.8, 23.4, 22.5, 14.0, 12.0; IR (neat): 3281, 3088, 2951, 2924, 2856, 1670, 1589, 1490 cm^{-1}; HRMS (ESI) m/z 405.2523 [405.2537 calcd for $C_{26}H_{33}N_2O_2$ $(M+H)^+$].

***N*-(1-(3-fluorobenzoyl)-2-methyl-3-pentylindolizin-7-yl)-2,2-dimethylpropanamide (11cc).**



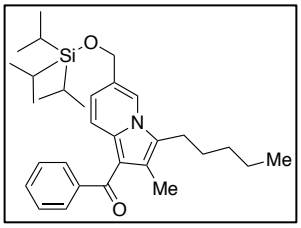
Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (15 mg, 0.017 mmol), 1-phenylethanol (0.21 mL) and 3'-fluoroacetophenone (1.4 mL) were added to 4-(2,2-dimethylpropanamide)-2-(2-octynyloxy)pyridine (**10c**, 105 mg, 0.34 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 85:15 hexanes/ethyl acetate) to afford 81 mg (56% yield) of **11cc** as a yellow powder. mp: 185-188 °C; ^{1}H NMR (400 MHz, *CDCl$_3$*): δ 8.96 (s, 1H), 7.49 (d, *J* = 9.3 Hz, 1H), 7.31-7.44 (m, 3H), 7.25 (s, 1H), 7.14-7.23 (m, 2H), 6.59 (d, *J* = 79.5 Hz, 1H), 2.84 (t, *J* = 7.1 Hz, 2H), 2.16 (s, 3H), 1.53-1.60 (m, 4H), 1.33 (s, 9H), 1.23 (app s, 2H), 0.87 (app s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 190.2, 176.9, 162.5 (d, *J* = 246 Hz), 144.4 (d, *J* = 6.0 Hz), 133.7, 129.8 (d, *J* = 30.8 Hz), 129.2, 125.8, 124.4, 123.8, 119.1, 117.6 (d, *J* = 21.2 Hz), 117.0, 115.5 (d, *J* = 22.0 Hz), 114.3, 112.1, 39.6, 31.4, 27.6, 26.8, 23.4, 22.5, 14.0, 12.0; IR (neat): 3290, 3086, 2927, 2858, 1672, 1565, 1487, 1329 cm^{-1}; HRMS (ESI) m/z 423.2434 [423.2442 calcd for $C_{26}H_{32}FN_2O_2$ $(M+H)^+$].

2,2-dimethyl-*N*-(2-methyl-1-(3-nitrobenzoyl)-3-pentylindolizin-7-yl)-propanamide (11ccc).



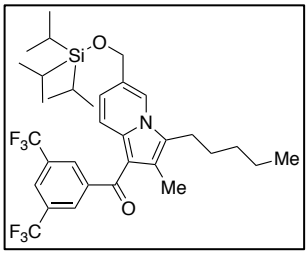
Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (15 mg, 0.017 mmol), 1-phenylethanol (0.20 mL) and 3'nitroacetophenone (2.8 g, 17.0 mmol) were added to 4-(2,2-dimethylpropanamide)-2-(2-octynyloxy)pyridine (**10c**, 100 mg, 0.33 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 3:1 hexanes/ethyl acetate) to afford 96 mg (65% yield) of **11ccc** as an orange powder. mp: 176-179 °C; ^{1}H NMR (400 MHz, *CDCl$_3$*): δ 9.02 (s, 1H), 8.47 (s, 1H), 8.35 (d, *J* = 8.2 Hz, 1H), 8.00 (d, *J* = 7.6 Hz, 1H), 7.53-7.68 (m, 2H), 7.56 (s, 1H), 6.66 (d, *J* = 9.4 Hz, 1H), 2.86 (t, *J* = 7.3

Hz, 2H), 2.11 (s, 3H), 1.51-1.63 (m, 2H), 1.34 (s, 13H), 0.80-0.92 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 188.6, 176.9, 148.0, 143.8, 134.5, 134.0, 129.5, 126.5, 126.1, 125.2, 124.2, 123.8, 119.0, 117.5, 114.5, 111.6, 39.7, 31.4, 27.6, 26.8, 23.4, 22.5, 14.0, 12.3; IR (neat): 3293, 3088, 2924, 2858, 1670, 1529, 1488, 1345, 1171 cm^{-1}; HRMS (ESI) m/z 450.2384 [450.2387 calcd for $C_{26}H_{32}N_3O_4$ $(M+H)^+$].



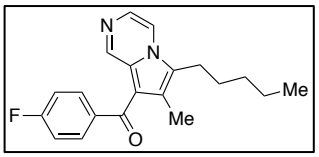
1-benzoyl-2-methyl-3-penty-6-(triisopropylsiloxymethyl)lindolizine (11d). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (24 mg, 0.027 mmol), 1-phenylethanol (0.31 mL) and acetophenone (2.0 mL) were added to 4-(triisopropylsiloxymethyl)-2-(2-octynyloxy)pyridine (**10d**, 199 mg, 0.51 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 19:1 hexanes/ethyl acetate) to afford 155 mg (62% yield) of **11d** as a thick yellow oil. ^{1}H NMR (400 MHz, *CDCl₃*): δ 7.96 (s, 1H), 7.67 (d, *J* = 7.2 Hz, 2H), 7.48 (t, *J* = 7.1 Hz, 1H), 7.41 (t, *J* = 7.3 Hz, 2H), 7.36 (d, *J* = 9.2 Hz, 2H), 6.70 (d, *J* = 9.2 Hz, 1H), 4.81 s, 2H), 2.84 (t, *J* = 7.4 Hz, 2H), 2.23 (s, 3H), 1.52-1.59 (m, 2H), 1.30-1.41 (m, 4H), 1.14-1.27 (m, 3H), 1.10 (d, J = 6.8 Hz, 18H), 0.89 (t, *J* = 5.5 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 192.0, 142.4, 135.5, 130.7, 128.7, 128.1, 126.1, 124.8, 124.1, 120.2, 119.1, 118.8, 112.2, 62.8, 51.7, 27.1, 23.7, 22.6, 18.0, 14.0, 11.9; IR (neat): 2940, 2863, 1613, 1505, 1394, 1241, 1098 cm^{-1}; HRMS (ESI) m/z 492.3285 [492.3292 calcd for $C_{31}H_{46}NO_2Si$ $(M+H)^+$].

1-(3,5-bistrifluoromethylbenzoyl)-2-methyl-3-penty-6-(triisopropylsiloxymethyl)lindolizine



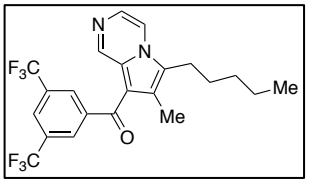
(11dd). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (28 mg, 0.027 mmol), 1-phenylethanol (0.32 mL) and 3',5'-bistrifluoromethylacetophenone (2.0 mL) were added to 4-(triisopropylsiloxymethyl)-2-(2-octynyloxy)pyridine (**10d**, 209 mg, 0.54 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 97:3 hexanes/ethyl acetate) to afford 291 mg (86% yield) of **11dd** as a yellow solid. mp: 85-87 °C; ^{1}H NMR (400 MHz, *CDCl₃*): δ 8.12 (s, 2H), 8.03 (s, 1H), 7.99 (s, 1H), 7.55 (d, *J* = 9.1 Hz, 1H), 6.88 (d, *J* = 9.2 Hz, 1H), 4.86 (s, 2H), 2.85 (t, *J* = 7.4 Hz, 2H), 2.12 (s, 3H), 1.51-1.59 (m, 2H), 1.29-1.39 (m, 4H), 1.15-1.27 (m, 3H), 1.11 (d, *J* = 6.9 Hz, 18H), 0.89 (t, *J* = 4.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 187.7, 144.1, 136.2, 131.6 (q, *J* = 34 Hz), 129.0 (q, *J* = 3.5 Hz), 127.3, 125.7, 124.5, 123.6, 123.1 (q, *J* = 272 Hz), 121.9, 119.6, 118.5, 111.1, 62.7, 31.7, 27.0, 23.7, 22.6, 18.0, 14.0,

12.1, 12.0; IR (neat): 2942, 2866, 1627, 1504, 1367, 1278, 1138 cm^{-1}; HRMS (ESI) m/z 628.3022 [628.3040 calcd for $C_{33}H_{44}F_6NO_2Si$ $(M+H)^+$].

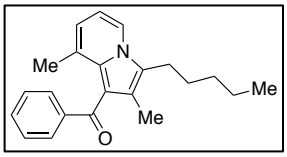


8-(4-fluorobenzoyl)-7-methyl-6-pentylpyrrolo[1,2-a]pyrazine (11e). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (22 mg, 0.025 mmol), 1-phenylethanol (0.30 mL) and 4'-fluoroacetophenone (2.0 mL) were added to 2-(2-octynyloxy)pyrazine (**10e**, 100 mg, 0.49 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 7:3 hexanes/ethyl acetate) to afford 12 mg (8% yield) of **11e** as a yellow oil. ^{1}H NMR (400 MHz, *CDCl₃*): δ 8.60 (s, 1H), 7.77 (t, *J* = 6.3 Hz, 2H), 7.71 (s, 2H), 7.14 (t, *J* = 8.2 Hz, 2H), 2.87 (t, *J* = 7.5 Hz, 2H), 2.31 (s, 3H), 1.55-1.64 (m, 2H), 1.31-1.38 (m, 4H), 0.86-0.92 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 190.4, 178.6, 165.2 (d, *J* = 252 Hz), 144.4, 137.1, 131.6 (d, *J* = 9.0 Hz), 129.2, 129.0, 126.4 (d, *J* = 244 Hz), 115.5 (d, *J* = 21 Hz), 115.2, 114.9, 31.5, 26.8, 23.3, 22.4, 14.0, 11.4; IR (neat): 2954, 2926, 2857, 1629, 1597, 1495, 1384, 1241, 1151 cm^{-1}; HRMS (ESI) m/z 325.1703 [325.1711 calcd for $C_{20}H_{22}FN_2O$ $(M+H)^+$].

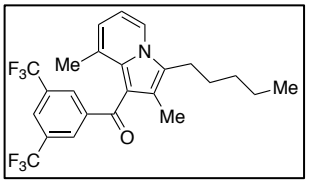
8-(3,5-bistrifluoromethylbenzoyl)-7-methyl-6-pentylpyrrolo[1,2-a]pyrazine (11ee). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (22 mg, 0.025 mmol), 1-phenylethanol (0.30 mL) and 3'5'-bistrifluoromethylacetophenone (2.0 mL) were added to 2-(2-octynyloxy)pyrazine (**10e**, 100 mg, 0.49 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 7:3 hexanes/ethyl acetate) to afford 59 mg (27% yield) of **11ee** as an orange solid. mp: 140-142 °C; ^{1}H NMR (400 MHz, *CDCl₃*): δ 8.80 (s, 1H), 8.18 (s, 2H), 8.07 (s, 1H), 7.86-7.75 (m, 2H), 2.90 (t, *J* = 7.7 Hz, 2H), 2.22 (s, 3H), 1.56-1.69 (m, 2H), 1.33-1.40 (m, 4H), 0.91 (t, *J* = 6.9 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 188.4, 144.3, 142.8, 132.2 (q, *J* = 34 Hz), 130.3, 129.8, 129.3 (q, *J* = 3.9 Hz), 127.4, 126.0, 125.2 (heptet, *J* = 3.8 Hz), 123.1 (q, *J* = 273 Hz), 115.3, 114.1, 31.7, 26.9, 23.4, 22.6, 14.1, 12.0; IR (neat): 2929, 2860, 1634, 1608, 1495, 1174 cm^{-1}; HRMS (ESI) m/z 443.1557 [443.1553 calcd for $C_{22}H_{21}F_6N_2O$ $(M+H)^+$].

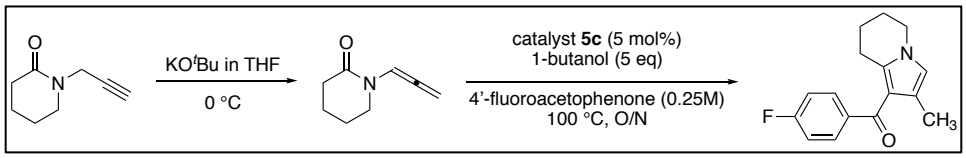


1-benzoyl-2,8-dimethyl-3-pentylindolizine (13). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (25 mg, 0.029 mmol), 1-phenylethanol (0.31 mL) and acetophenone (2.0 mL) were added to 3-methyl-2-(2-octynoxy)pyridine (**12**, 116 mg, 0.53 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 97:3 hexanes/ethyl acetate) to afford 78 mg (46% yield) of **13** as a thick yellow oil. ^{1}H NMR (400 MHz, *CDCl$_3$*): δ 7.82 (d, *J* = 7.6 Hz, 2H), 7.73 (d, *J* = 6.0 Hz, 1H), 7.52 (t, *J* = 7.0 Hz, 1H), 7.41 (t, *J* = 7.3 Hz, 2H), 6.61 (t, *J* = 6.8 Hz, 1H), 2.83 (t, *J* = 7.3 Hz, 2H), 2.16 (s, 3H), 1.98 (s, 3H), 1.51-1.72 (m, 2H), 1.33 (app s, 4H), 0.88 (t, *J* = 5.3 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 194.3, 141.3, 132.8, 132.1, 130.0, 128.8, 128.2, 122.9, 122.1, 120.8, 120.1, 113.6, 111.3, 31.6, 27.1, 23.8, 22.5, 21.0, 14.0, 11.3; IR (neat): 2923, 2856, 1633, 1492, 1389, 1231 cm^{-1}; HRMS (ESI) m/z 320.2003 [320.2009 calcd for $C_{22}H_{26}NO$ $(M+H)^+$].



2,8-dimethyl-3-pentyl-1-(3,5-bistrifluoromethylbenzoyl)indolizine (13a). Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (24 mg, 0.026 mmol), 1-phenylethanol (0.32 mL) and 3',5'-bistrifluoromethylacetophenone (2.0 mL) were added to 3-methyl-2-(2-octynoxy)pyridine (**12**, 114 mg, 0.53 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 98:2 hexanes/ethyl acetate) to afford 110 mg (46% yield) of **13a** as a deep orange solid. mp: 86-87 °C; ^{1}H NMR (400 MHz, *CDCl$_3$*): δ 8.30 (s, 2H), 8.04 (s, 1H), 7.80 (d, *J* = 6.4 Hz, 1H), 6.81 (d, *J* = 6.0 Hz, 1H), 6.71 (t, *J* = 6.6 Hz, 1H), 2.86 (t, *J* = 7.2 Hz, 2H), 2.26 (s, 3H), 1.91 (s, 3H), 1.51-1.60 (m, 3H), 1.33 (app s, 4H), 0.88 (app s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 189.4, 142.8, 134.1, 131.8 (q, *J* = 34 Hz), 130.1, 130.0, 128.9, 125.0 (heptet, *J* = 3.9 Hz), 123.9, 123.1 (q, *J* = 272 Hz), 122.8, 121.8, 120.6, 112.3, 31.5, 26.9, 23.7, 22.5, 21.2, 14.0, 12.0; IR (neat): 2927, 2861, 1639, 1489, 1365, 1278, 1136 cm^{-1}; HRMS (ESI) m/z 456.1758 [456.1757 calcd for $C_{24}H_{24}F_6NO$ $(M+H)^+$].

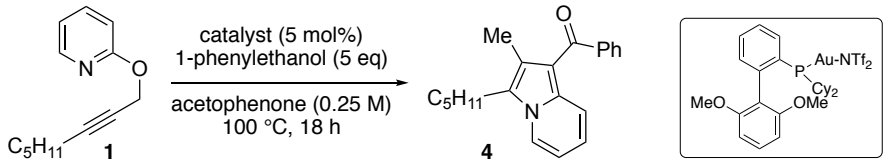




To a solution of *N*-propargylvalerolactam (223 mg, 1.63 mmol) in THF (5 mL) at 0 °C was added potassium *tert*-butoxide (1.0 M in THF, 0.49 mL, 0.49 mmol). After 90 minutes, Et_2O (20 mL) was added and the mixture was filtered through celite. After removing the excess solvent *in vacuo*, the residual was used directly in the Au(I)-catalyzed transformation.

Following the general procedure outlined above for the synthesis of compound **4**, catalyst **5c** (29 mg, 0.033 mmol), 1-butanol (0.30 mL) and 4'-fluoroacetophenone (2.62 mL) were added to *N*-(1,2-propadienyl)valerolactam (**15**, 90 mg, 0.66 mmol). After 18 hours, the reaction was worked up and purified by column chromatography (SiO_2, 85:15 hexanes/ethyl acetate) to afford 7 mg (8% yield) of **16** as a clear oil that decomposes both during purification and upon standing. ^{1}H NMR (400 MHz, *CDCl$_3$*): δ 7.74-7.61 (m, 2H), 7.09 (t, *J* = 8.7 Hz, 2H), 6.30 (s, 1H), 3.88 (t, *J* = 6.8 Hz, 2H), 2.70 (t, *J* = 6.8 Hz, 2H), 1.90-1.97 (m, 5H), 1.68-1.79 (m, 2H); ^{13}C NMR (400 MHz, CDCl3): 192.2, 136.5, 131.0 (d, *J* = 8.6 Hz), 120.2, 119.2, 119.0, 115.0 (d, *J* = 21.6 Hz), 53.4, 45.3, 30.9, 24.3, 22.9, 20.4, 12.2; IR (neat): 3280, 2942, 2850, 1722, 1613, 1471, 1242 cm^{-1}; HRMS (ESI) m/z 258.1262 [258.1289 calcd for $C_{16}H_{17}FNO$ $(M+H)^+$].

B. Optimization Studies



entry	modification or additive	Compound 4 (% yield)
1	–	54
2	$MgSO_4$	54
3	Na_2SO_4	55
4	$CaSO_4$	53
5	molecular sieves	58
6	K_2CO_3	53
7	pyridine	38
8	morpholine	16
9	TsOH	42
10	160 °C	42

C. Experimental Details for the X-ray Crystal Structure of Compound 4

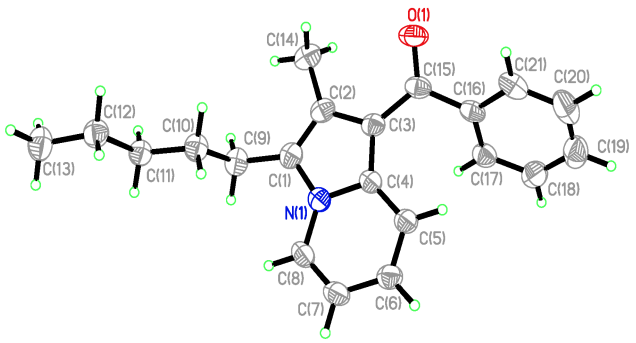


Figure 1. ORTEP of Indolizine **4** Solved at 0.72 Å Resolution

A colorless chunk-shaped crystal with dimensions 0.27×0.27×0.15 mm^3 was mounted on a nylon loop with paratone oil. Data were collected using a Bruker APEX-II CCD diffractometer equipped with an Oxford Cryosystems low-temperature device, operating at T = 173(2) K.

Data were measured using ϕ and ω scans of 1.00° per frame for 20.00 s using CuK□ radiation (sealed tube, 40 kV, 30 mA). The total number of runs and images was based on the strategy calculation from the program COSMO.[1] The actually achieved resolution was Θ= 71.969. Cell parameters were retrieved using the SAINT software[2] and refined using SAINT on 8646 reflections, 76 % of the observed reflections. Data reduction was performed using the SAINT software which corrects for Lorentz polarization. The final completeness is 98.80 out to 71.969 in Θ. The absorption coefficient μ of this material is 0.563 at this wavelength (λ = 1.54178) and the minimum and maximum transmissions are 0.6895 and 0.7535.

The structure was solved in the space group $P2_12_12_1$ (# 19) by Direct Methods using the **ShelXS** structure solution program.[3] The structure was refined by Least Squares using version 2014/6 of XL incorporated in Olex2.[4] All non-hydrogen atoms were refined anisotropically. Hydrogen atom positions were calculated geometrically and refined using the riding model. There is a single molecule in the asymmetric unit, which is represented by the reported sum formula. In other words: Z is 4 and Z' is 1. The Flack parameter was refined to 0.05(11). Determination of absolute structure using Bayesian statistics on Bijvoet differences using the Olex2 results in 0.07(11). Note: The Flack parameter is used to determine chirality of the crystal studied, the value should be near 0, a value of 1 means that the stereochemistry is wrong and the model should be inverted. A value of 0.5 means that the crystal consists of a racemic mixture of the two enantiomers.

---

[1] COSMO-V1.61, *Software for the CCD Detector Systems for Determining Data Collection Parameters*. Bruker Analytical X-ray Systems, Madison, WI (2009).

[2] SAINT-8.34A-2013. *Software for the Integration of CCD Detector System*. Bruker Analytical X-ray Systems, Madison, WI (2013).

[3] Sheldrick, G. M. "A short history of ShelX" *Acta Cryst.*, **2008**, *A64*, 339-341.

[4] Dolomanov, O. V.; Bourhis, L. J.; Gildea, R. J.; Howard, J. A. K.; Puschmann, H. "Olex2: A complete structure solution, refinement and analysis program" *J. Appl. Cryst.*, **2009**, *42*, 339-341.

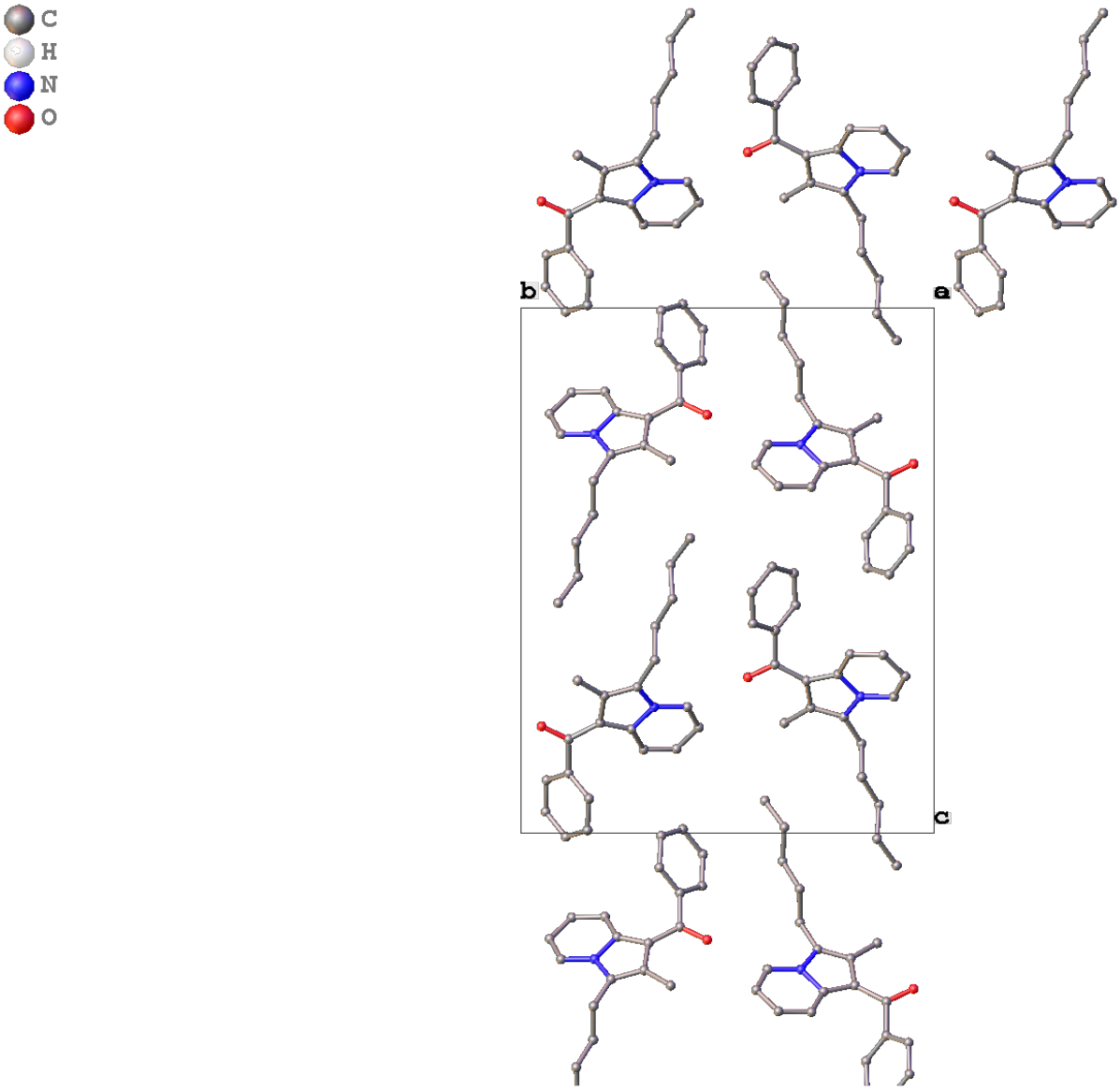
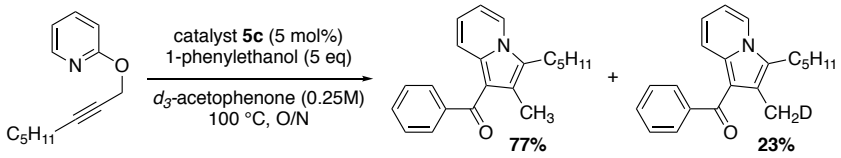
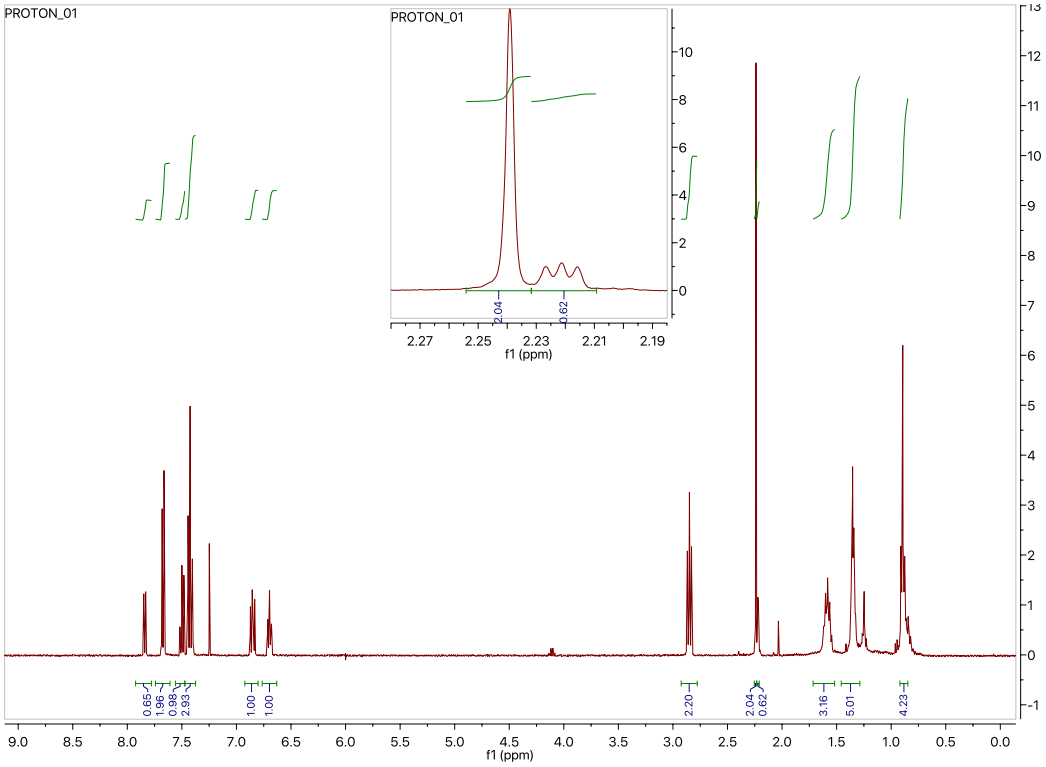
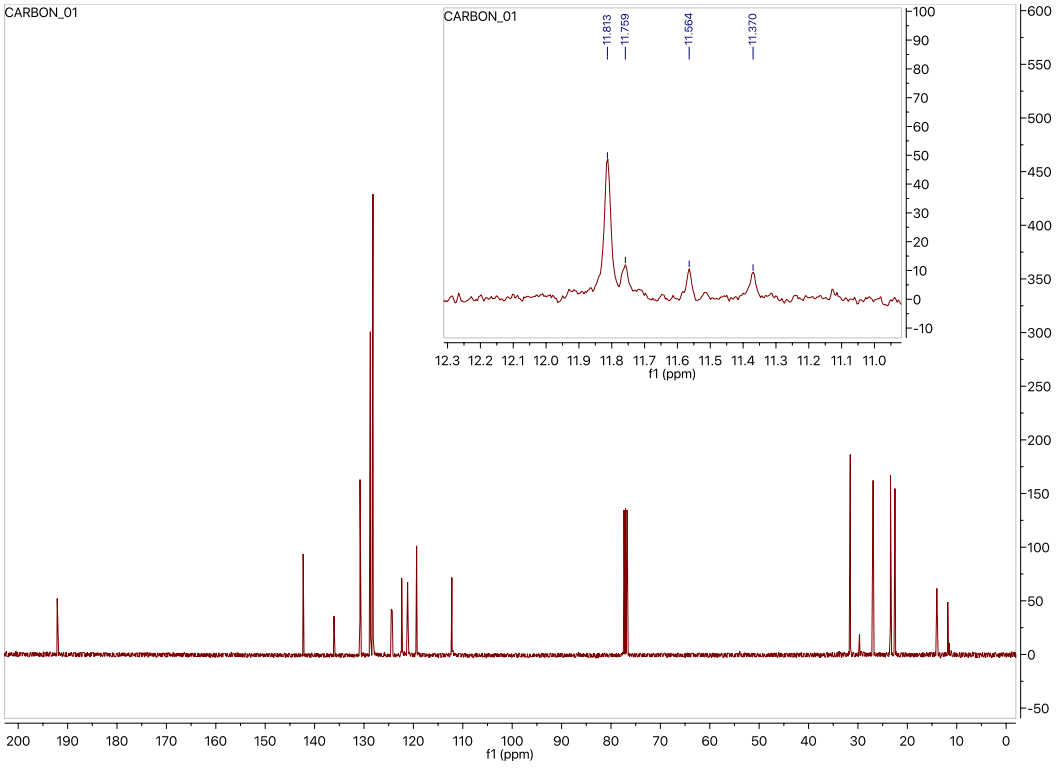


Figure 2. Solid state packing diagram for compound **4**.

D. ^{1}H, ^{13}C NMR, and HRMS of Isotopically Labelled Indolizine 4/4'







Mass Spectrometry & Proteomics Facility

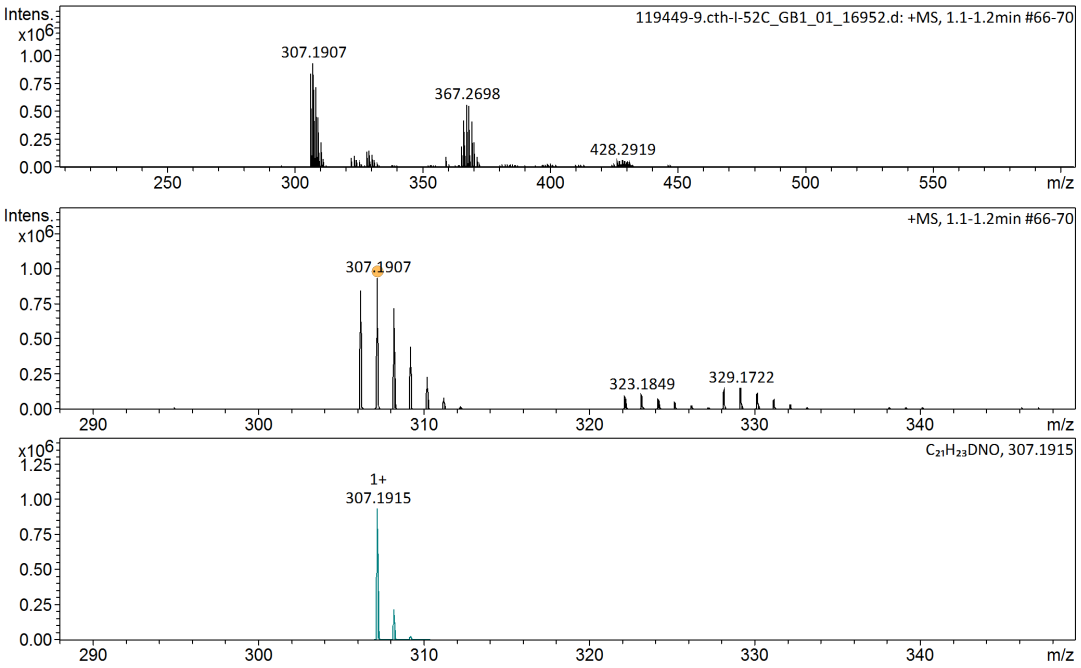
Mass Spectrum SmartFormula Report

Analysis Info

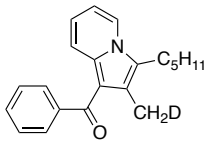
Analysis Name	D:\Data\Nonka\2019 Data\May'19\CAnderson_0517\119449-9.cth-I-52C_GB1_01_16952.d	Acquisition Date	5/17/2019 3:27:08 PM
Method	lc_tune_low_pos_031519.m	Operator	BDAL@DE
Sample Name	119449-9.cth-I-52C	Instrument / Ser#	micrOTOF-Q 228888.10195
Comment			

Acquisition Parameter

Source Type	ESI	Ion Polarity	Positive	Set Nebulizer	4.0 Bar
Focus	Not active	Set Capillary	4500 V	Set Dry Heater	180 °C
Scan Begin	100 m/z	Set End Plate Offset	-500 V	Set Dry Gas	8.0 l/min
Scan End	3000 m/z	Set Collision Cell RF	160.0 Vpp	Set Divert Valve	Source



Meas. m/z	#	Ion Formula	m/z	err [ppm]	mSigma	# mSigma	Score	rdb	e⁻ Conf	N-Rule
307.1907	1	C21H23DNO	307.1915	2.5	402.9	1	100.00	10.5	even	ok

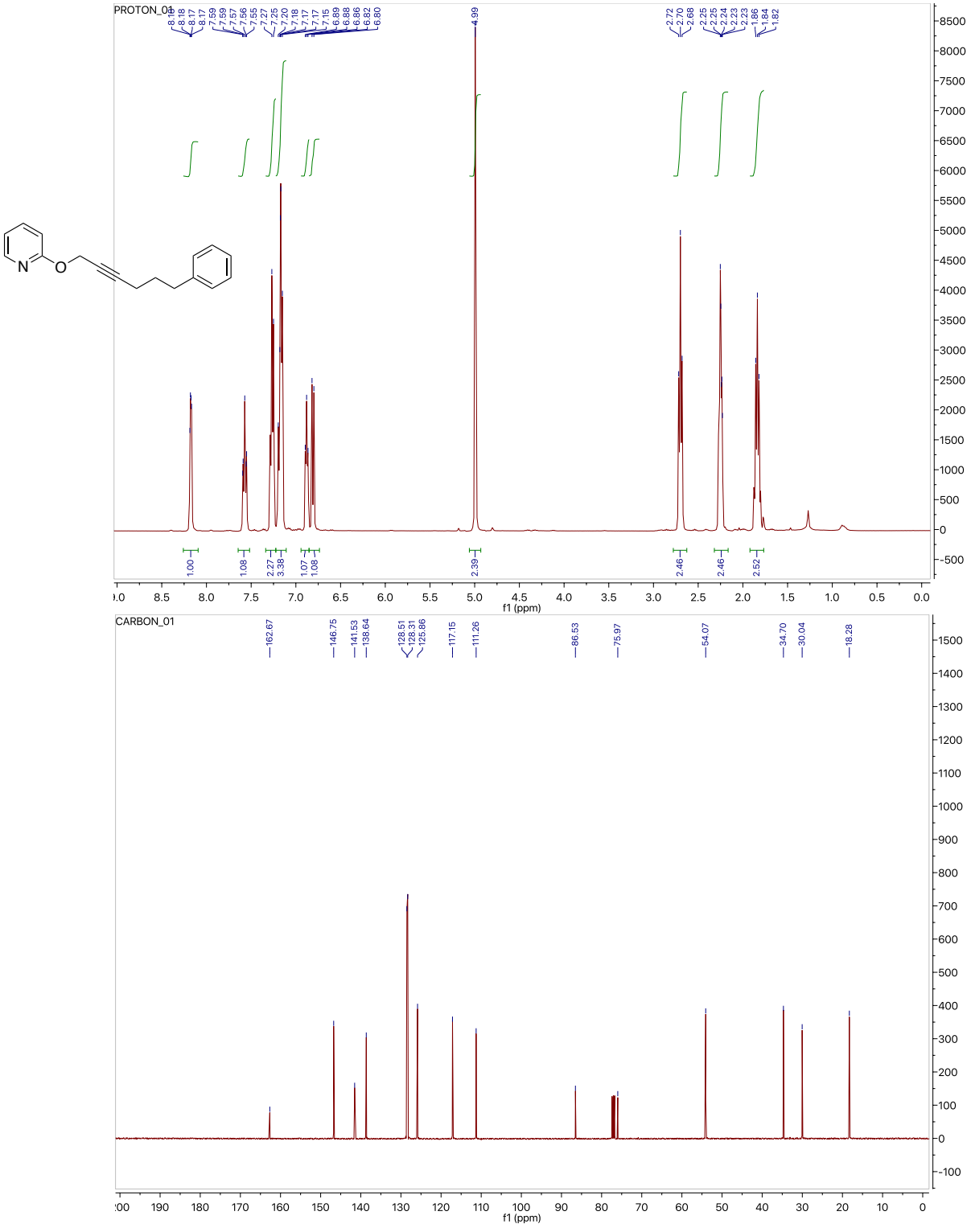


Chemical Formula: $C_{21}H_{22}DNO$
Exact Mass $[M+H]^+$: 307.1915

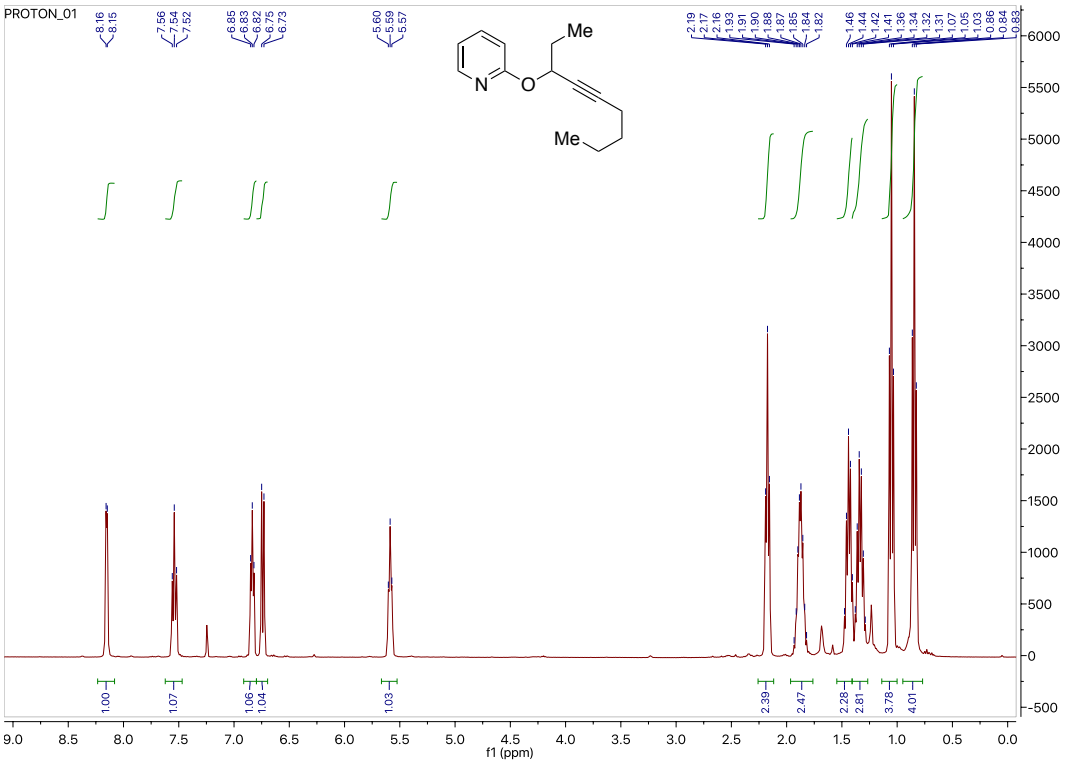
This material is based upon work supported by the National Science Foundation under CHE-0741793

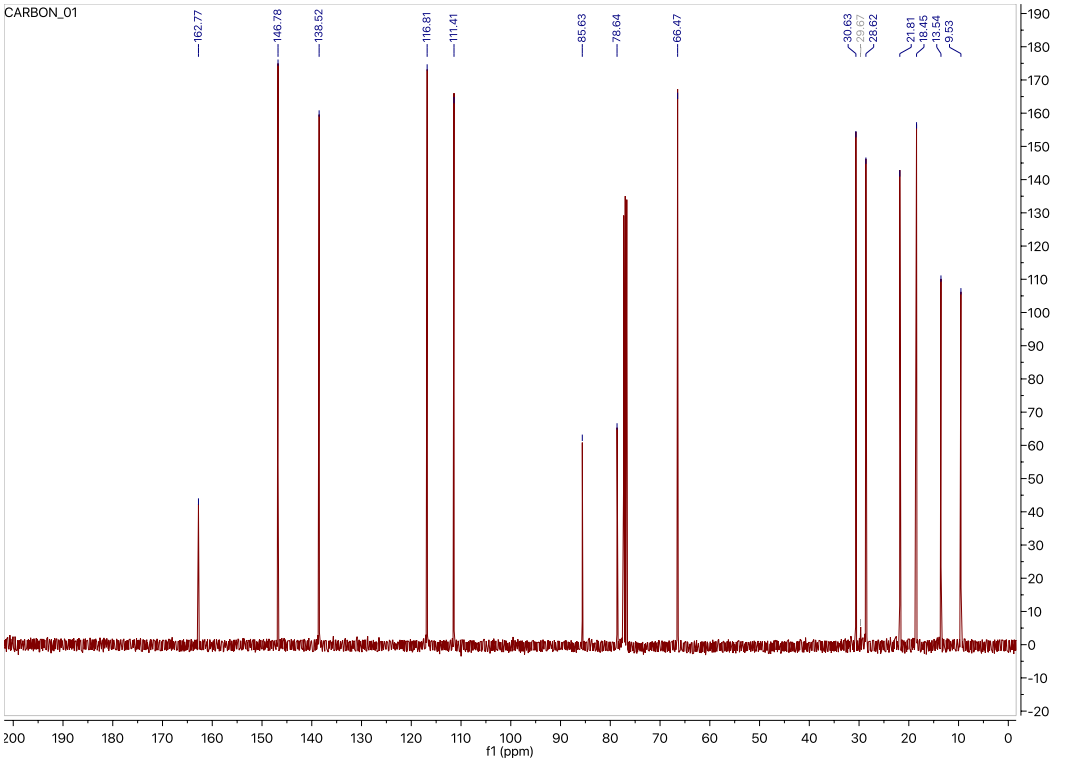
E. ^{1}H and ^{13}C NMR Spectra of New Compounds

Compound 8a



Compound 8g


PROTON_01
8.16
8.15
7.56
7.54
7.52
6.85
6.83
6.82
6.75
6.73
5.60
5.59
5.57
2.19
2.17
2.16
1.93
1.91
1.90
1.88
1.87
1.85
1.84
1.82
1.46
1.44
1.42
1.41
1.36
1.34
1.32
1.31
1.07
1.05
1.03
0.86
0.84
0.83
Me
N
O
Me
1.00
1.07
1.06
1.04
1.03
2.39
2.47
2.28
2.81
3.78
4.01
f1 (ppm)


CARBON_01
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146.78
138.52
116.81
111.41
85.63
78.64
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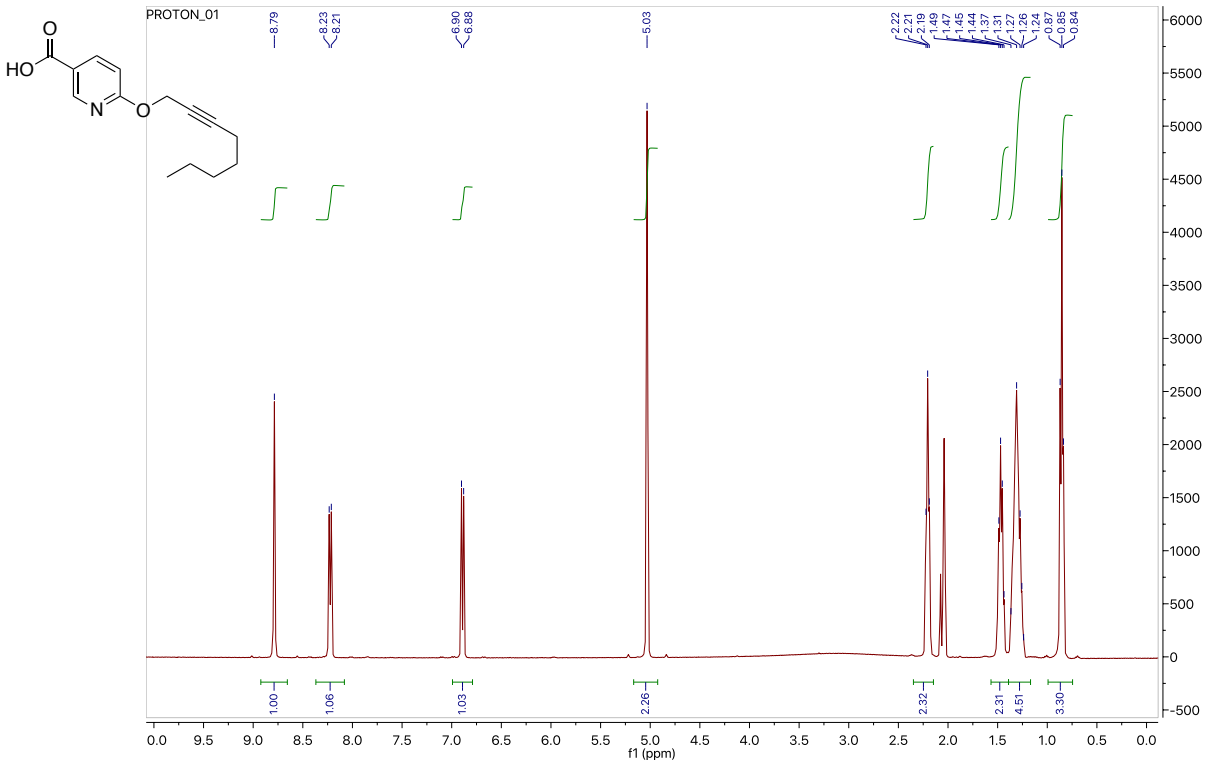
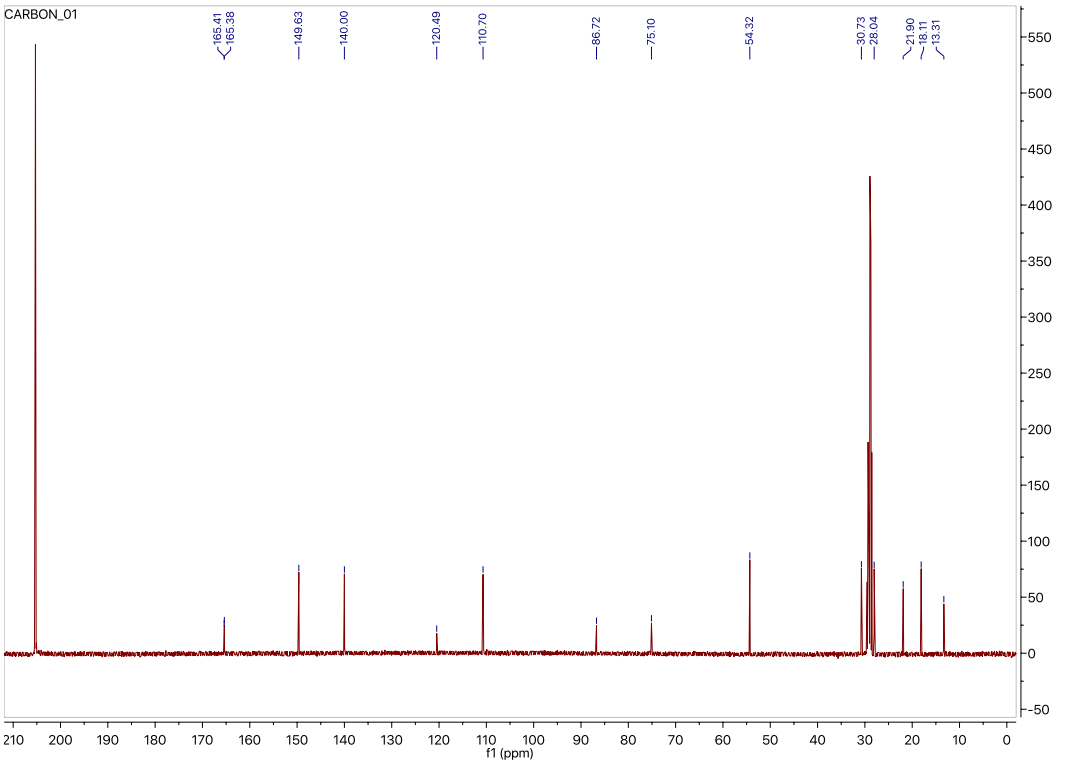
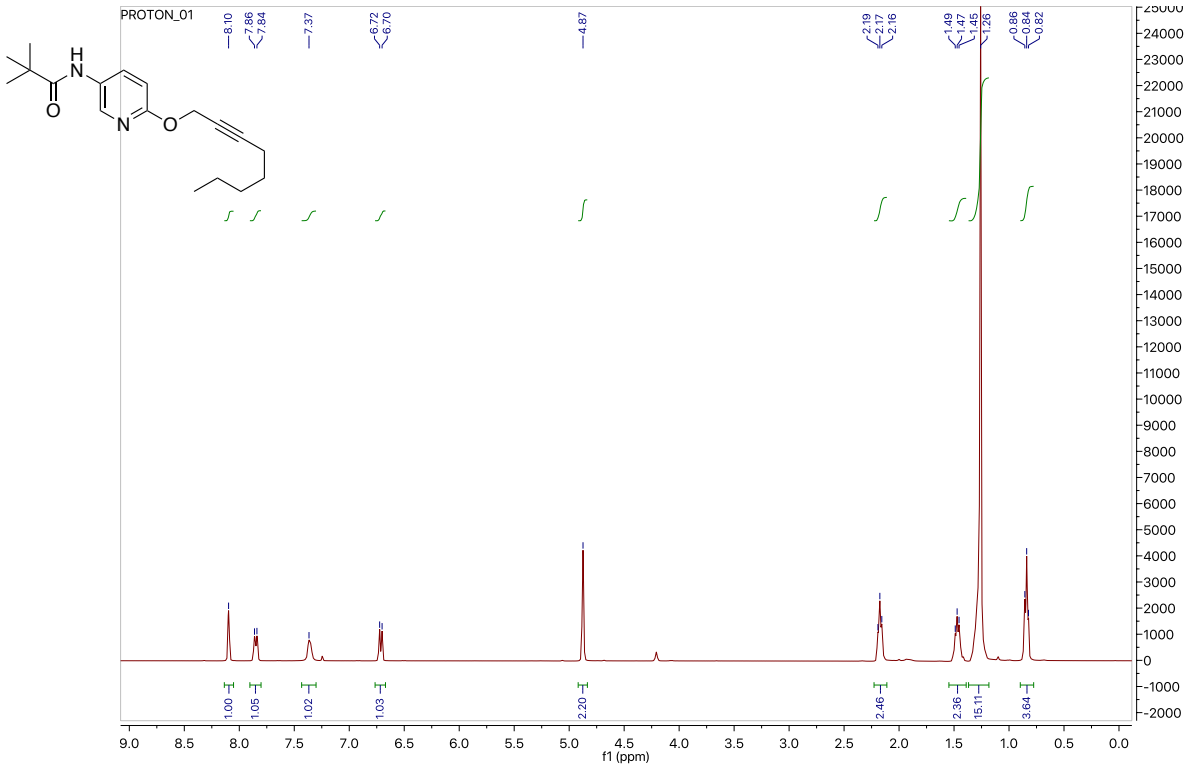
30.63
29.67
28.62
21.81
18.45
13.54
9.53
f1 (ppm)

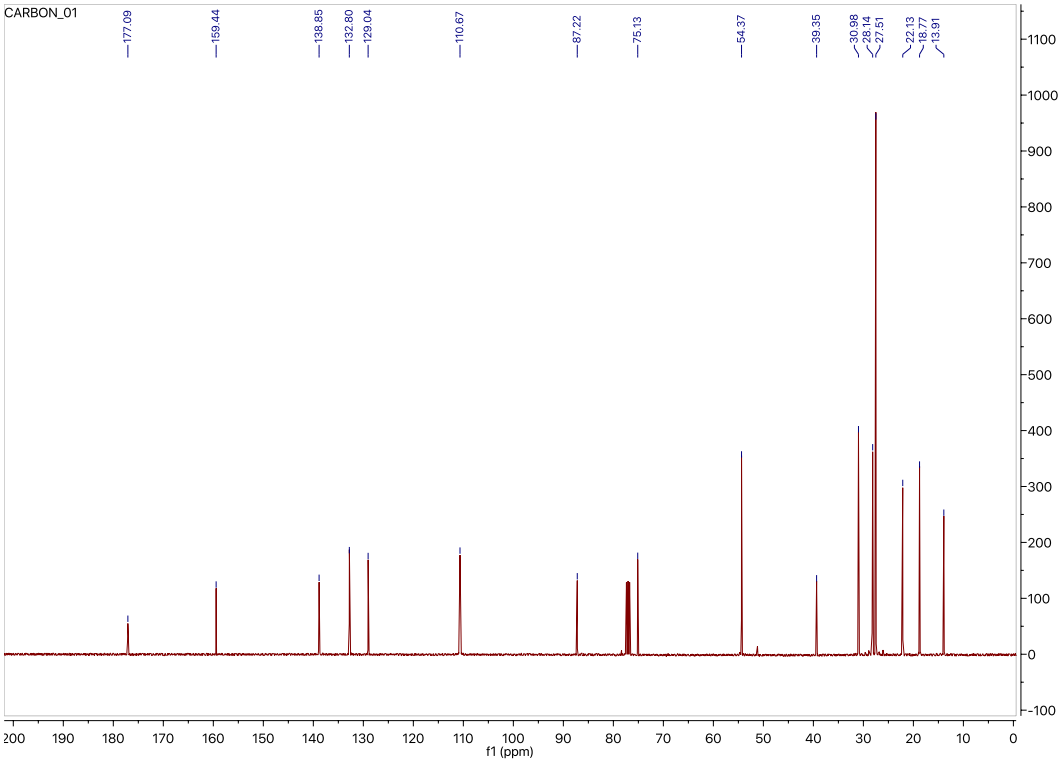
Compound 10a



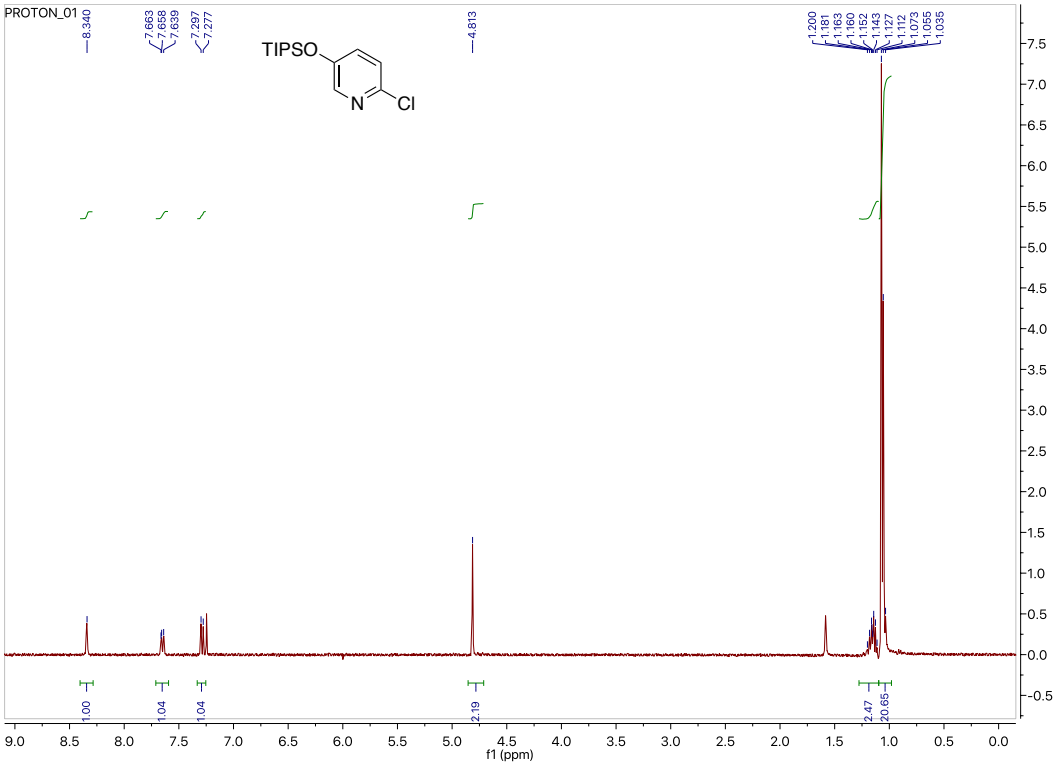


Compound 10c





Compound 22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7.639
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7.277
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1.200
1.181
1.163
1.160
1.152
1.143
1.127
1.112
1.073
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TIPSO
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Cl
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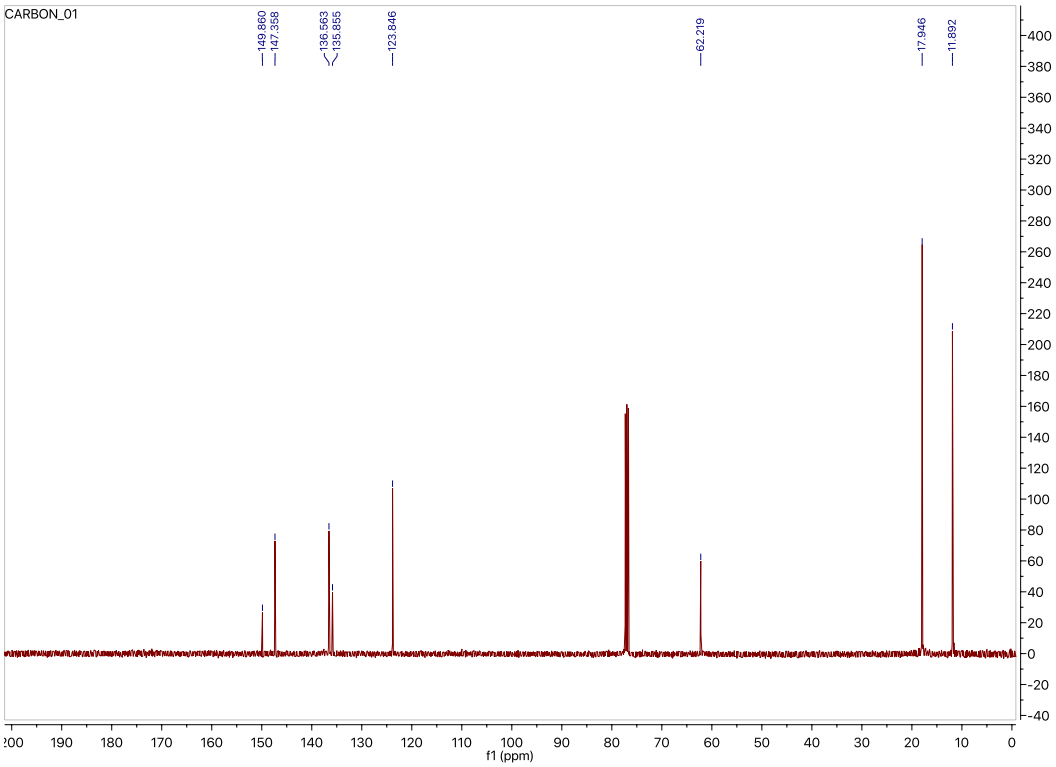
1.04
2.19
2.47
20.65
f1 (ppm)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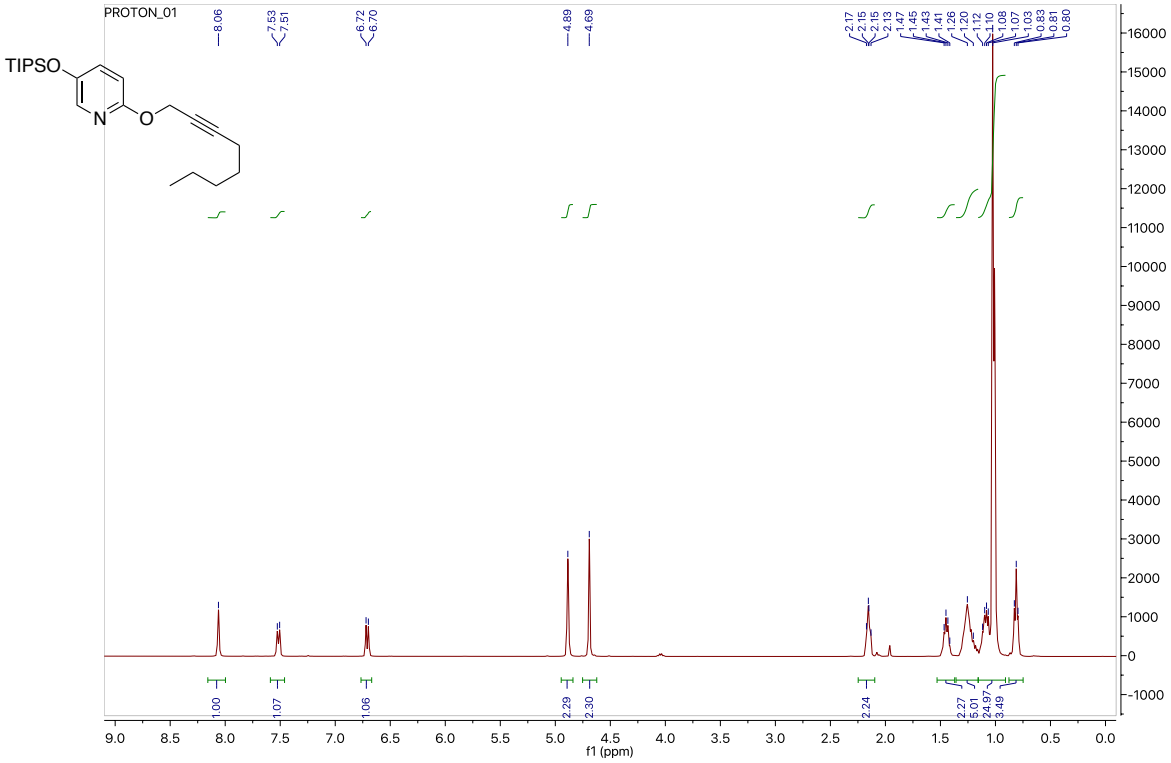
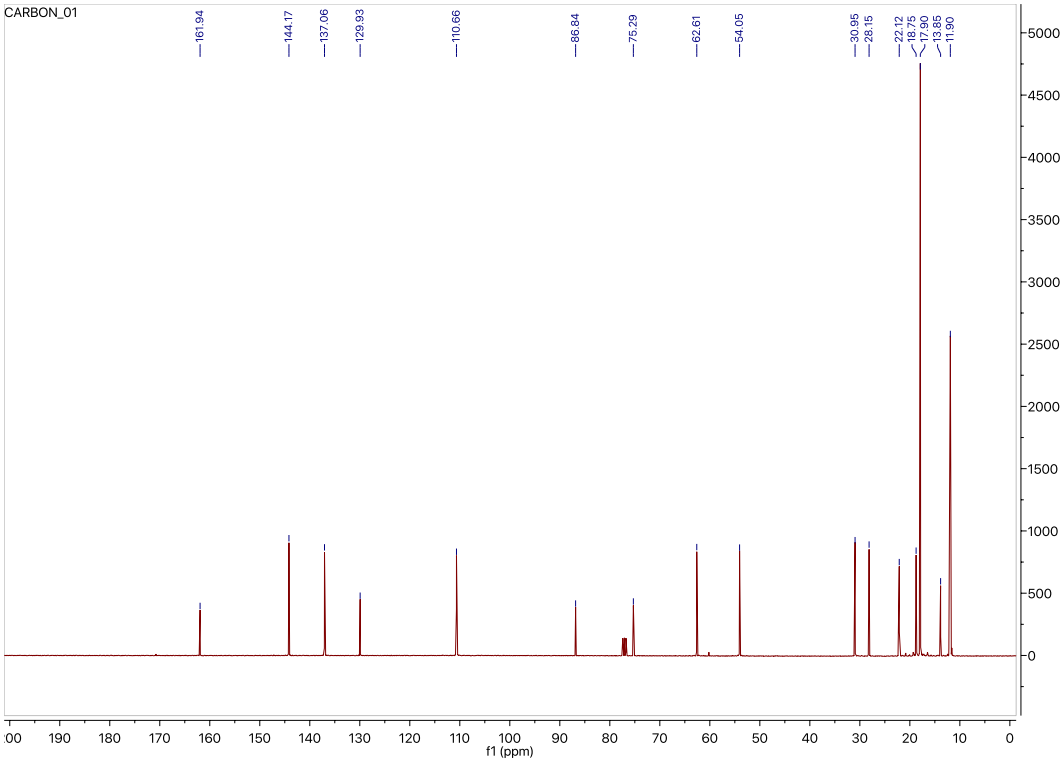
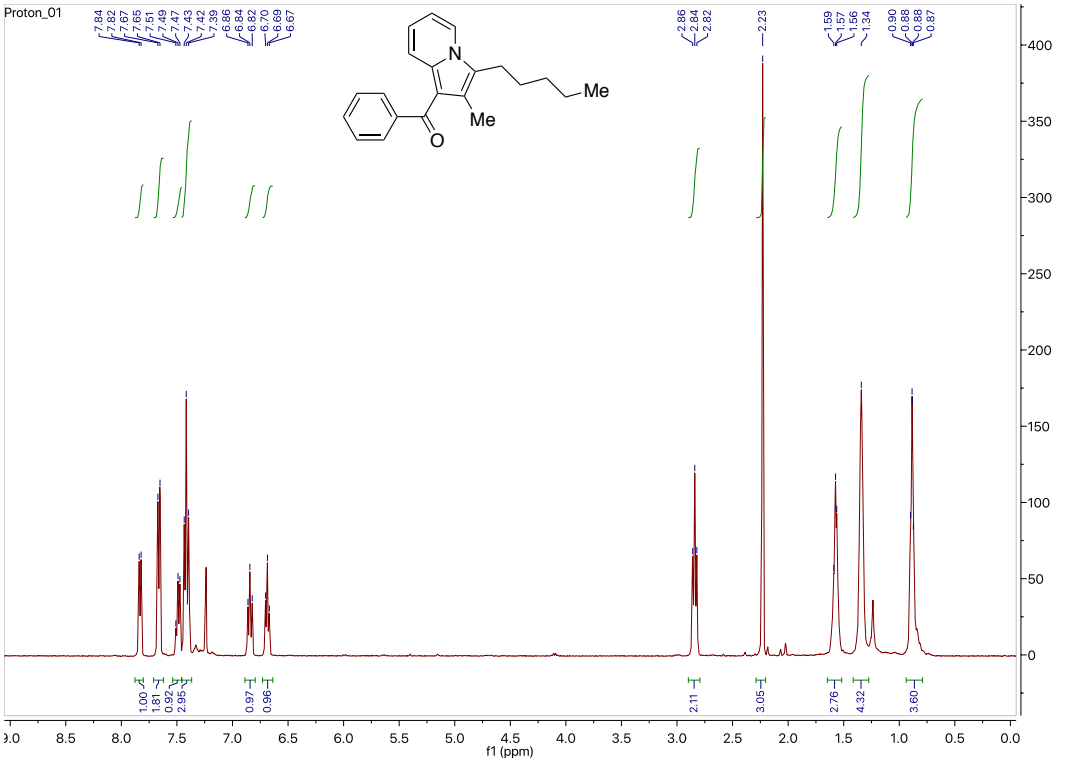
17.946
11.892
f1 (ppm)

Compound 10d





Compound 4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7.51
7.49
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7.42
7.39
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6.82
6.70
6.69
6.67
2.86
2.84
2.82
2.23
1.59
1.57
1.56
1.34
0.90
0.88
0.88
0.87
N
Me
Me
O
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0.97
0.96
2.11
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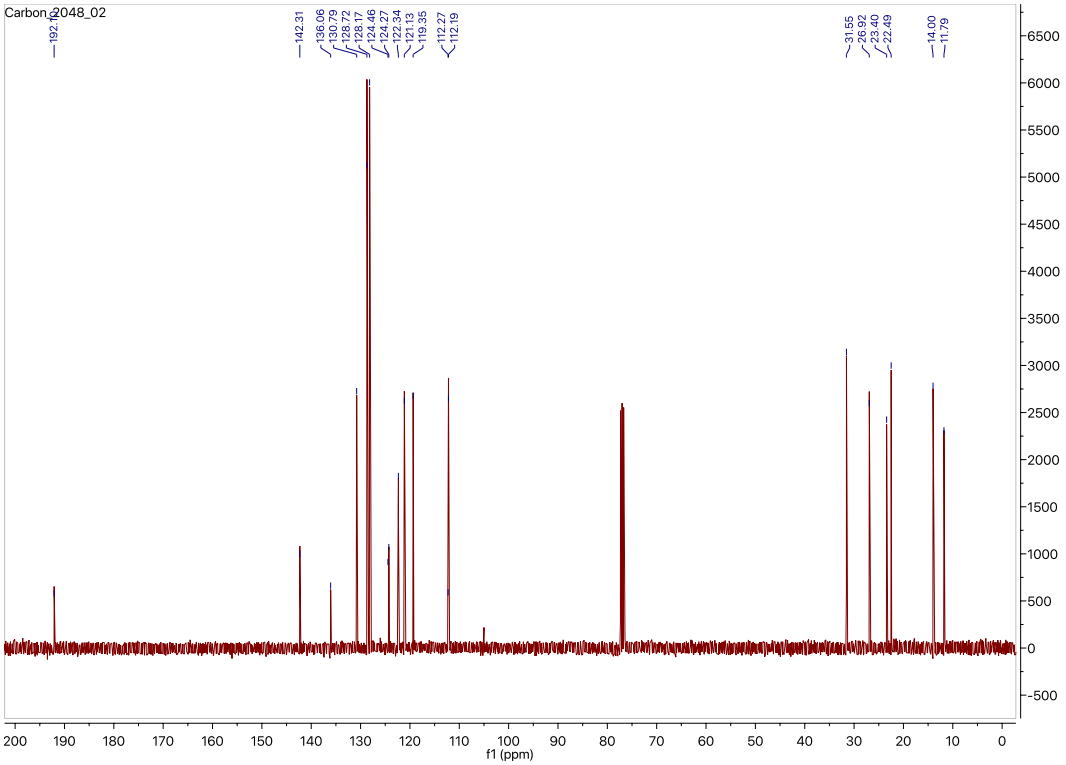
2.76
4.32
3.60
f1 (ppm)


Carbon_2048_02
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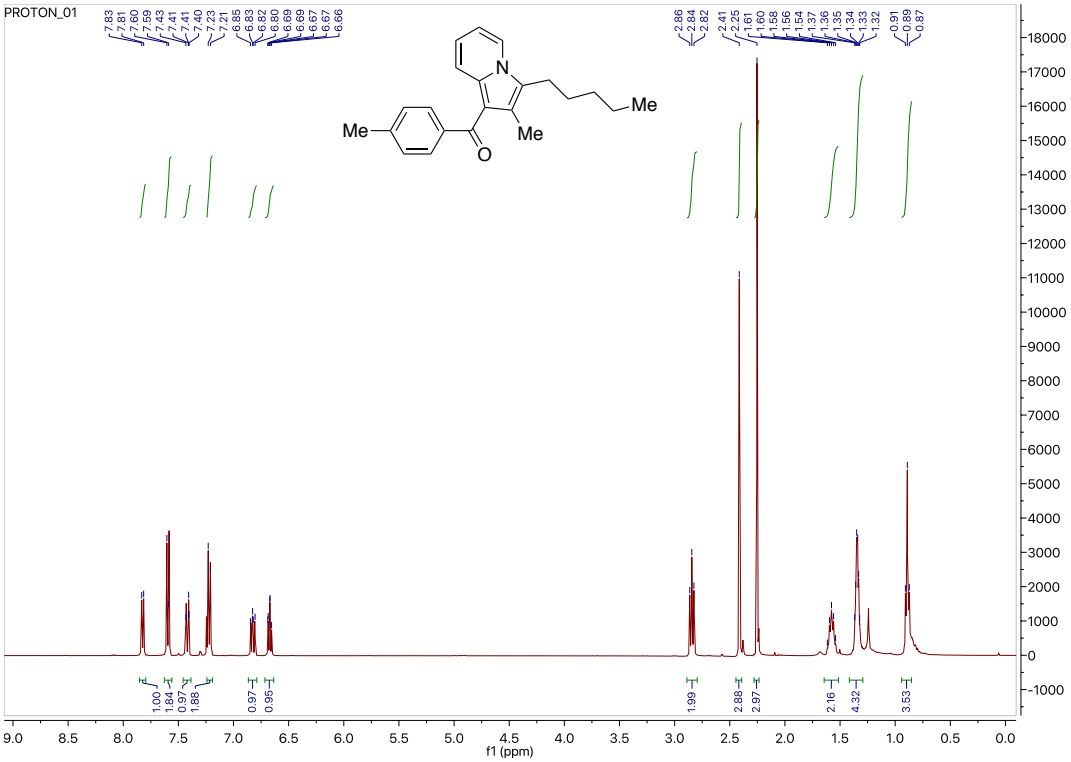
142.31
136.96
130.79
128.72
128.17
124.46
124.27
122.34
121.13
119.35
112.27
112.19
31.55
26.92
23.40
22.49
14.00
11.79
f1 (ppm)

Compound 7a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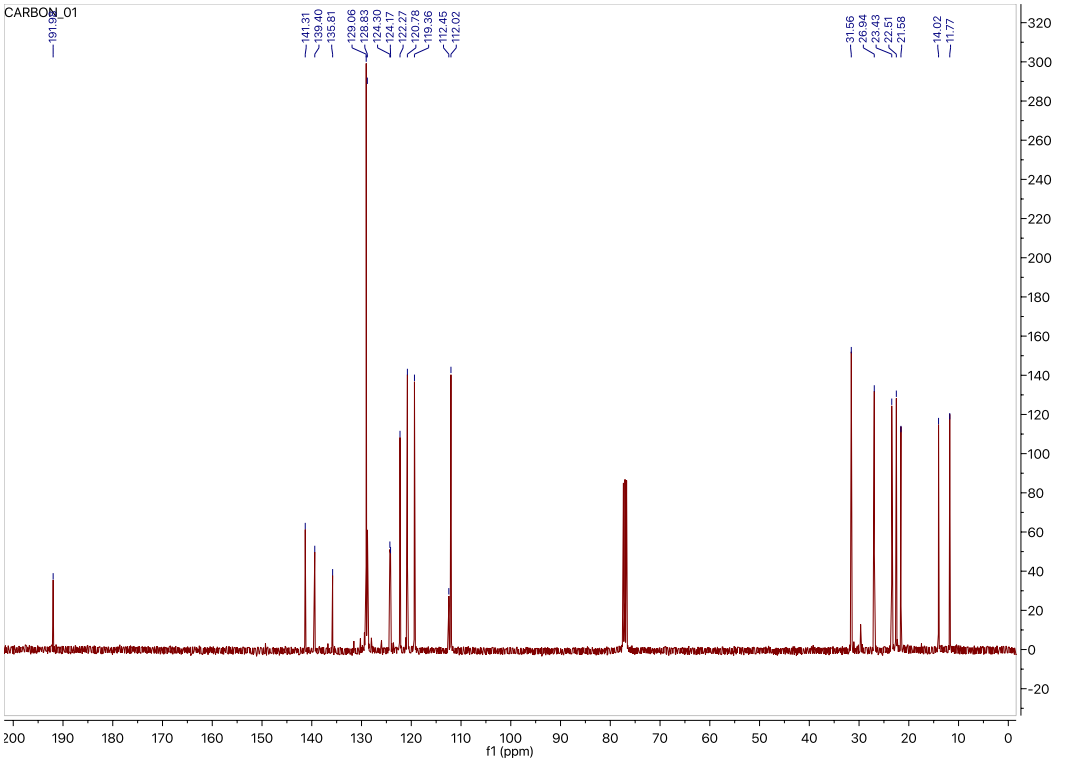
6.82
6.80
6.69
6.69
6.67
6.67
6.66
2.86
2.84
2.82
2.41
2.25
1.61
1.60
1.58
1.56
1.54
1.37
1.36
1.35
1.34
1.33
1.32
0.91
0.89
0.87
N
Me
Me
Me
O
1.00
1.84
0.97
1.88
0.97
0.95
1.99
2.88
2.97
2.16
4.32
3.53
f1 (ppm)


CARBON_01
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135.81
129.06
128.83
124.30
124.17
122.27
120.78
119.36
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31.56
26.94
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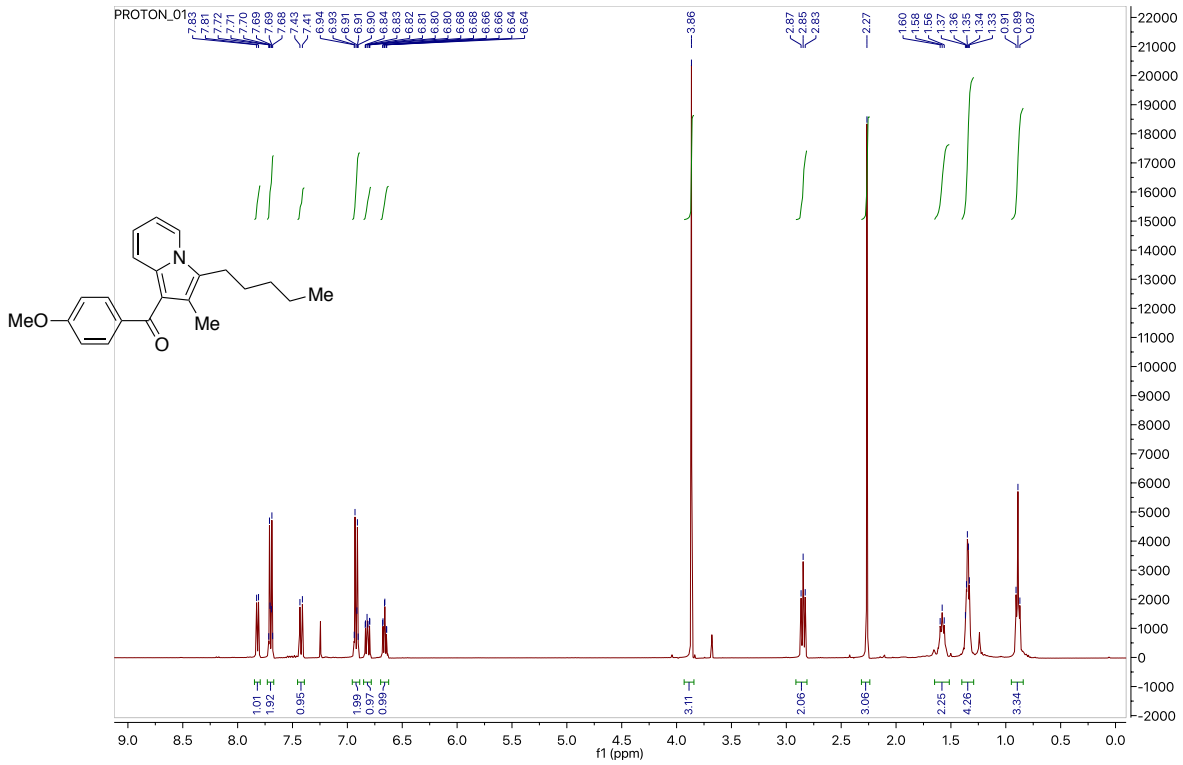
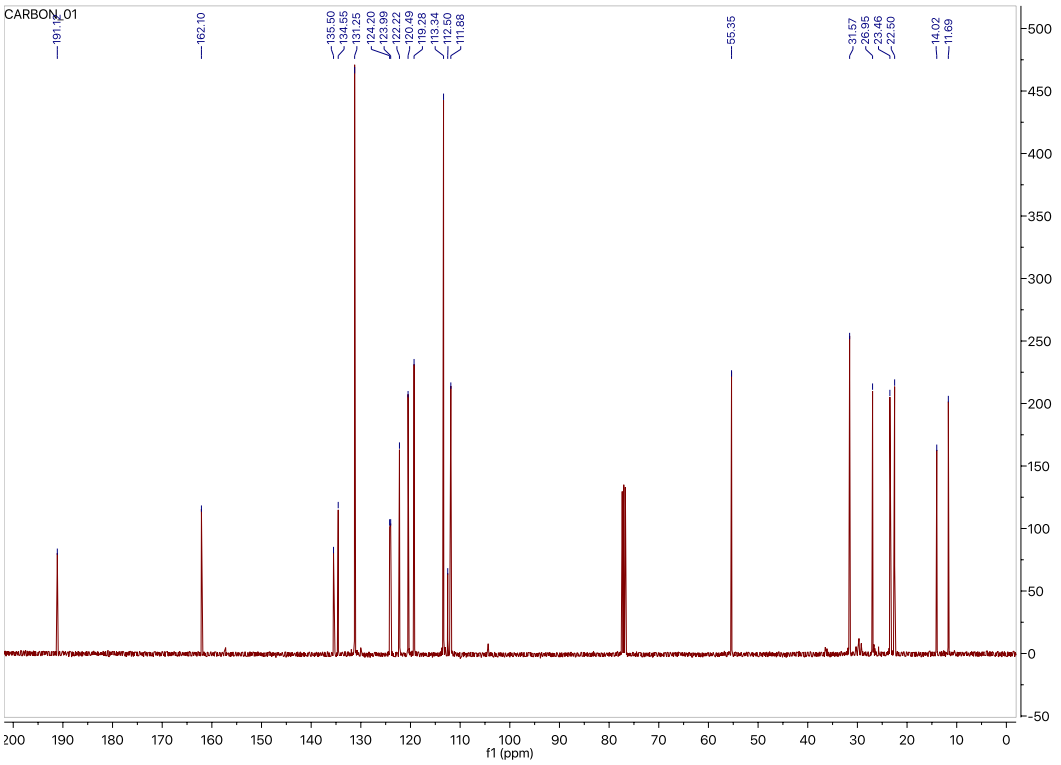
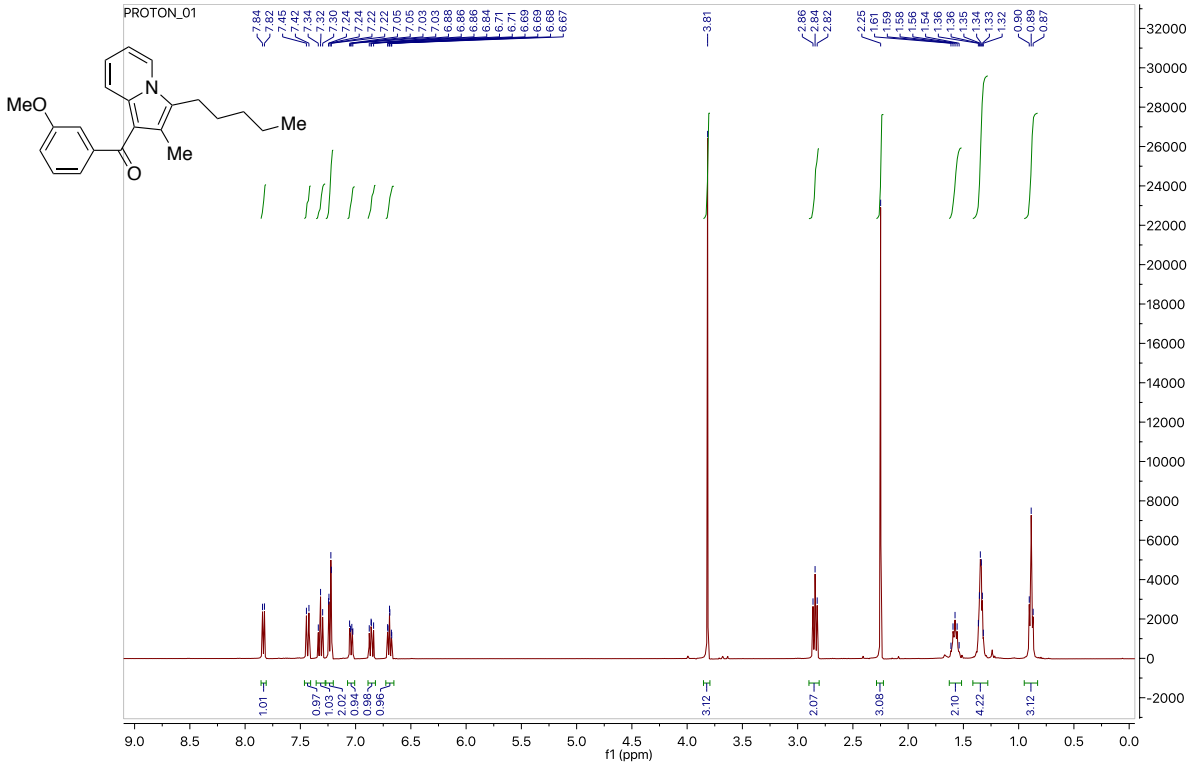
22.51
21.58
14.02
11.77
f1 (ppm)

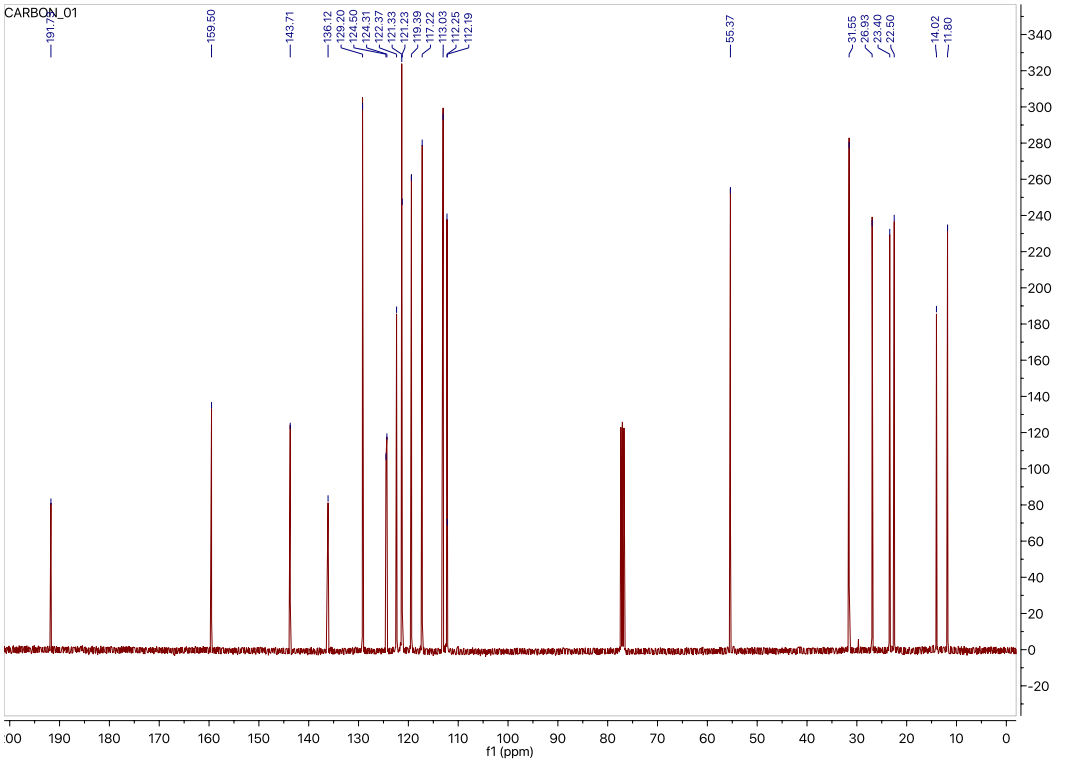
Compound 7b



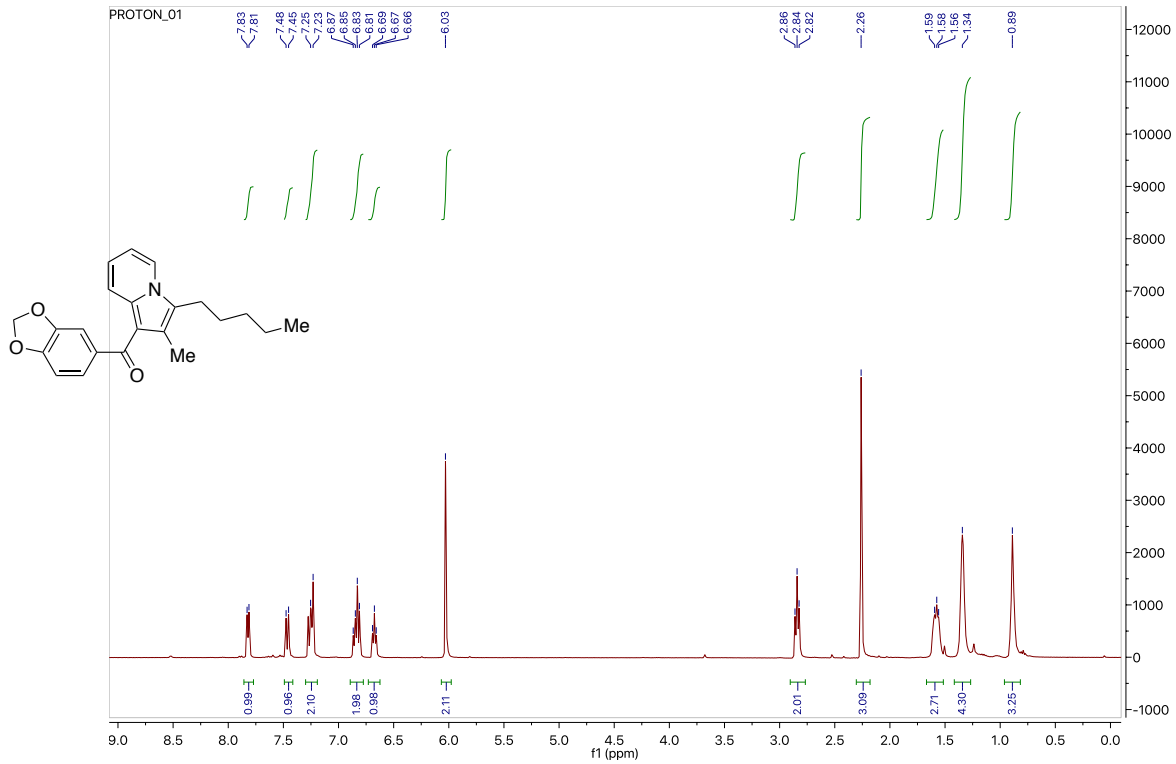


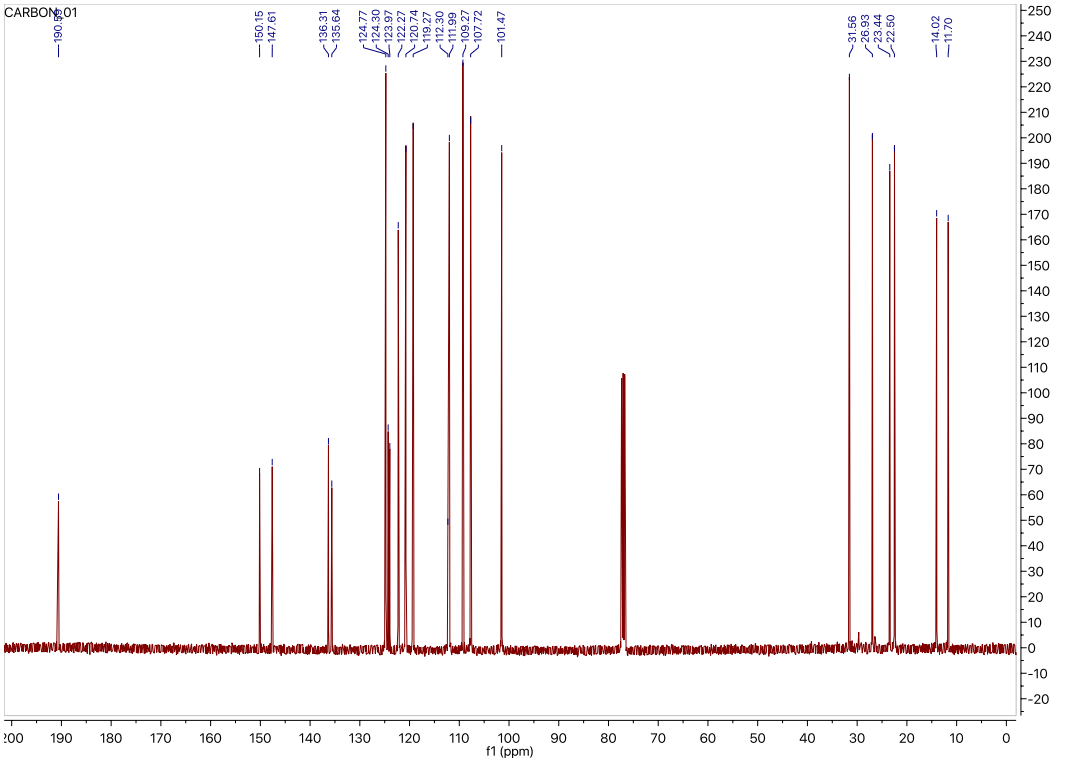
Compound 7c



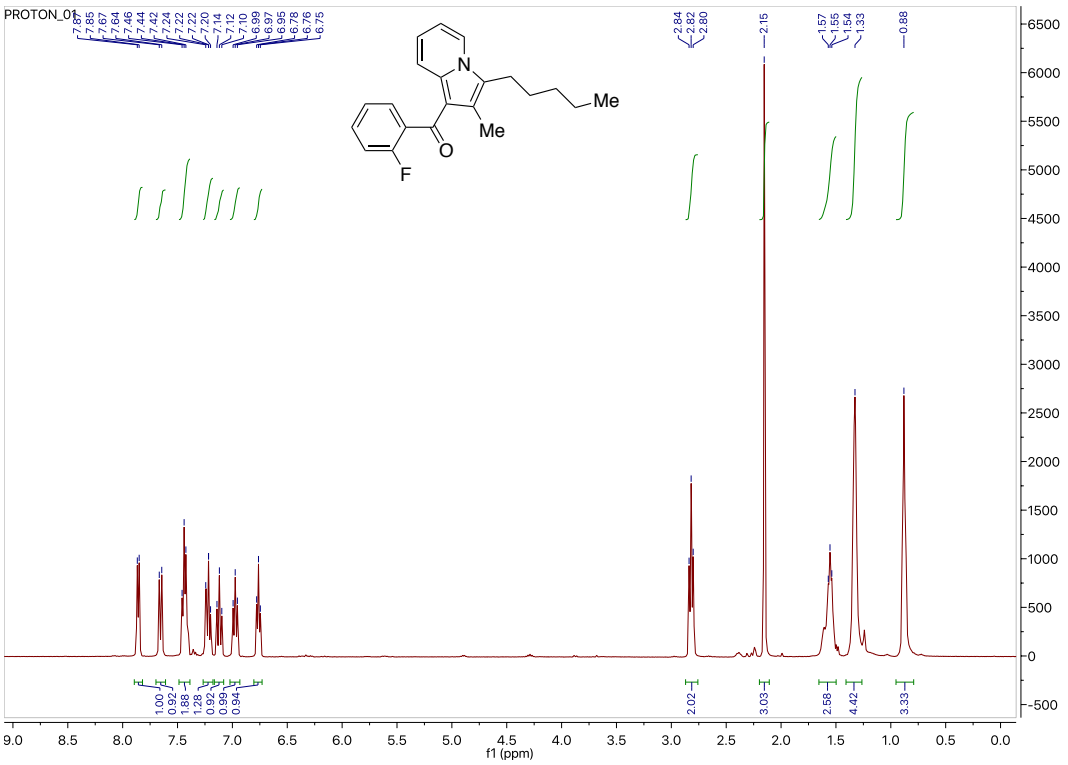


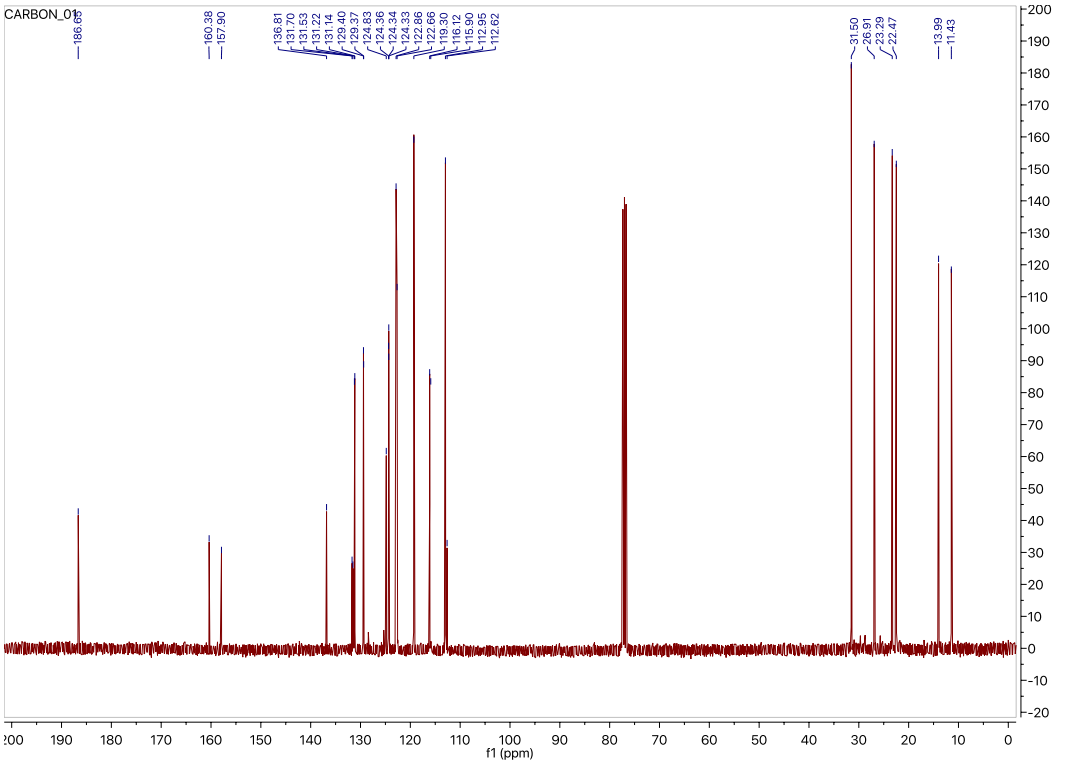
Compound 7d


PROTON_01
7.83
7.81
7.48
7.45
7.25
7.23
6.87
6.85
6.83
6.81
6.69
6.67
6.66
6.03
2.86
2.84
2.82
2.26
1.59
1.58
1.56
1.34
0.89
N
O
O
O
Me
Me
0.99
0.96
2.10
1.98
0.98
2.11
2.01
3.09
2.71
4.30
3.25
f1 (ppm)

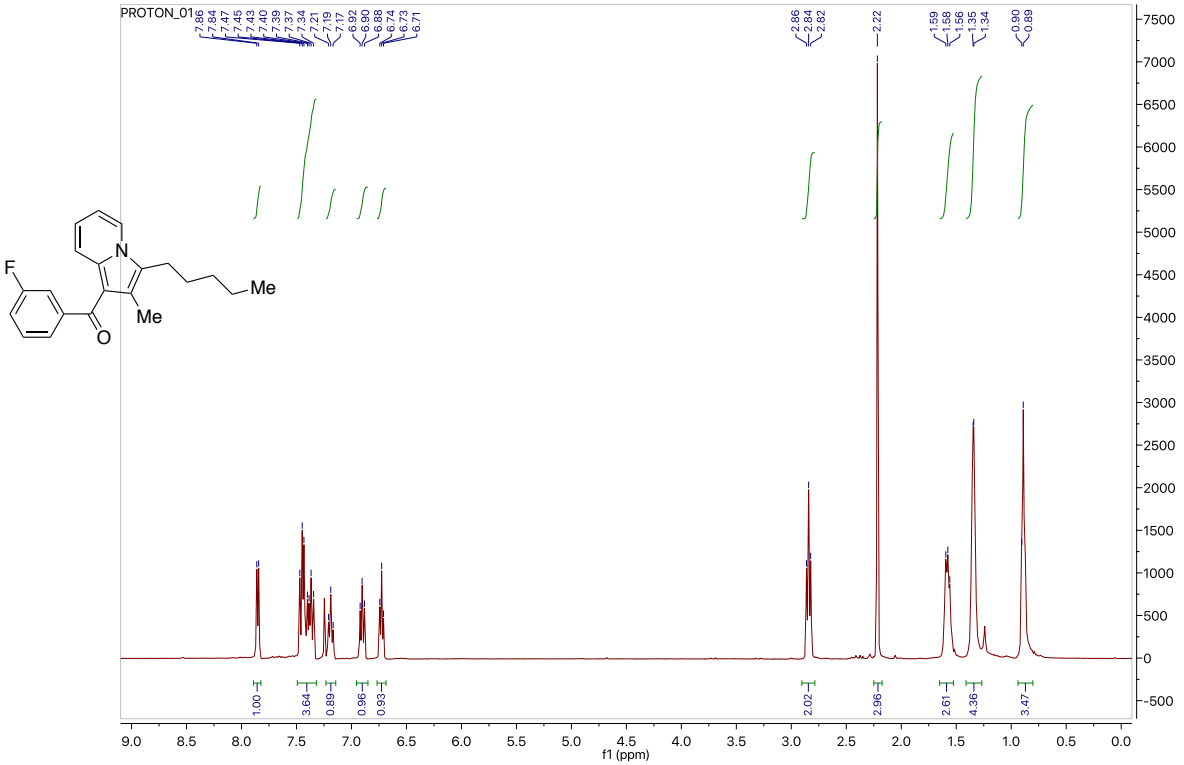

CARBON_01
190.09
150.15
147.61
136.31
135.64
124.77
124.30
123.97
122.27
120.74
119.27
112.30
111.99
109.27
107.72
101.47
31.56
29.93
28.44
22.50
14.02
11.70
f1 (ppm)

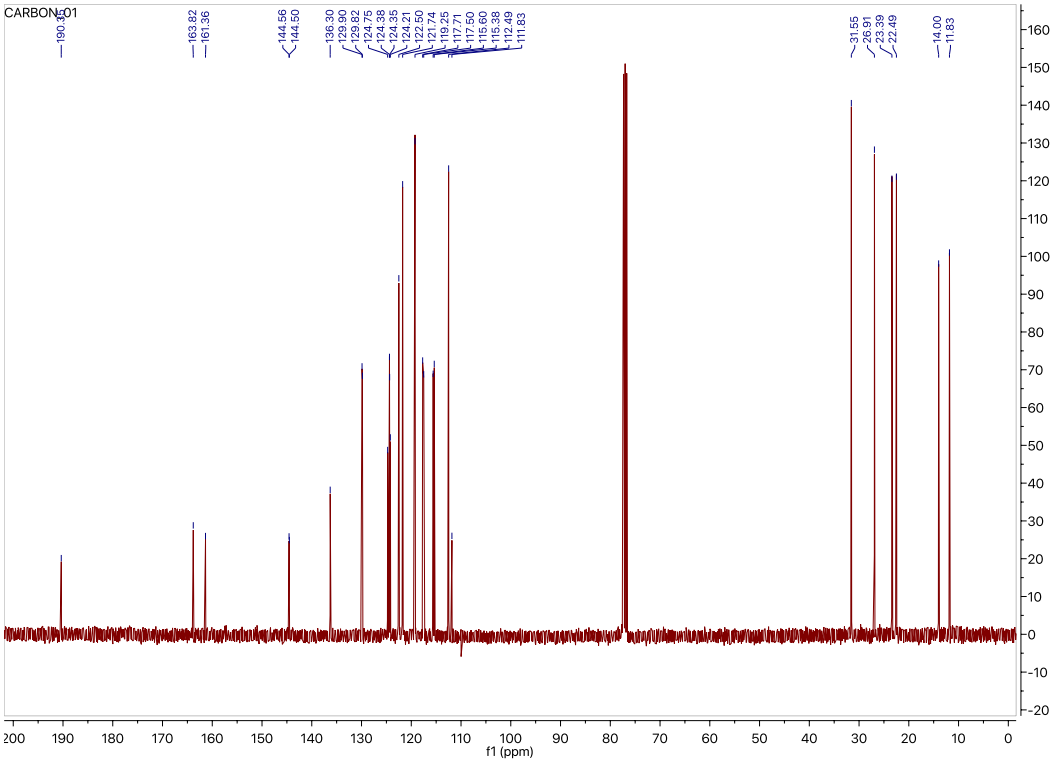
Compound 7e


PROTON_01
7.86
7.85
7.67
7.64
7.46
7.44
7.42
7.24
7.22
7.20
7.14
7.12
7.10
6.99
6.97
6.95
6.78
6.76
6.75
2.84
2.82
2.80
2.15
1.57
1.55
1.54
1.33
0.88
N
Me
Me
O
F
1.00
0.92
1.88
1.28
0.92
0.99
0.94
2.02
3.03
2.58
4.42
3.33
f1 (ppm)

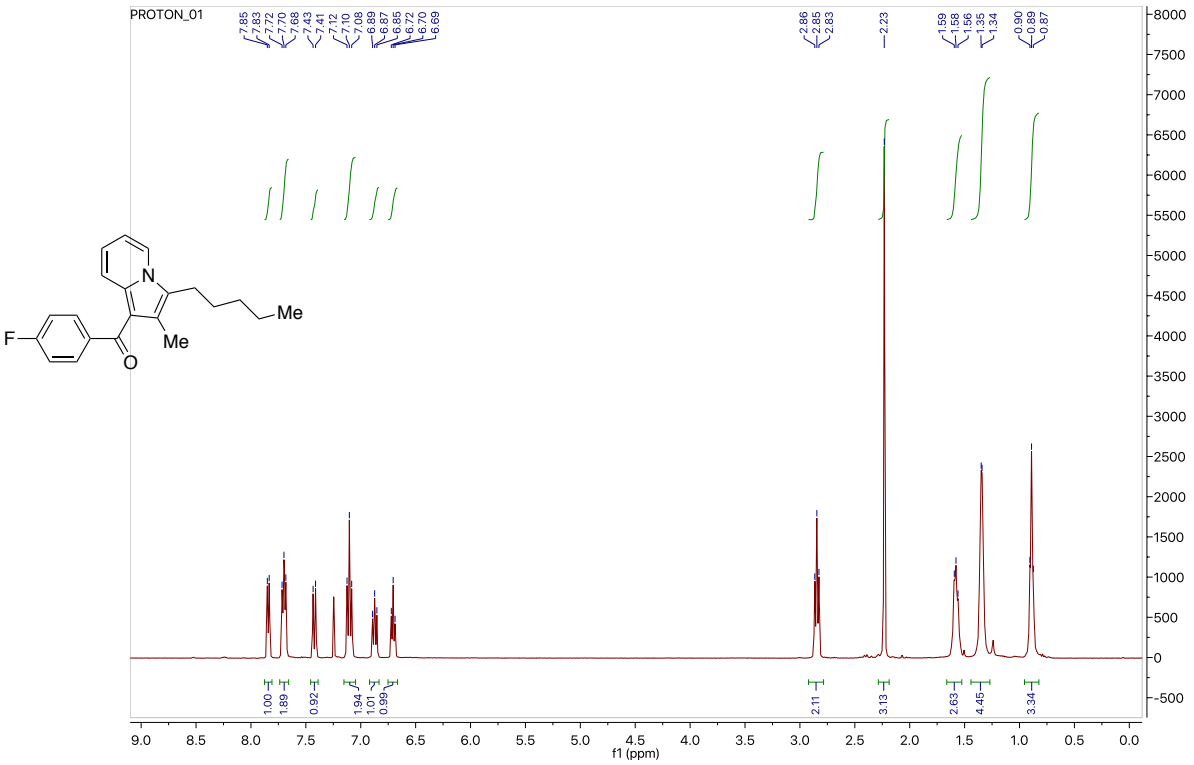

CARBON_01
186.65
160.38
157.90
136.81
131.70
131.53
131.22
131.14
129.40
129.37
124.83
124.36
124.34
124.33
122.86
122.66
119.30
116.12
115.90
112.95
112.62
31.50
26.91
23.29
22.47
13.99
11.43
f1 (ppm)

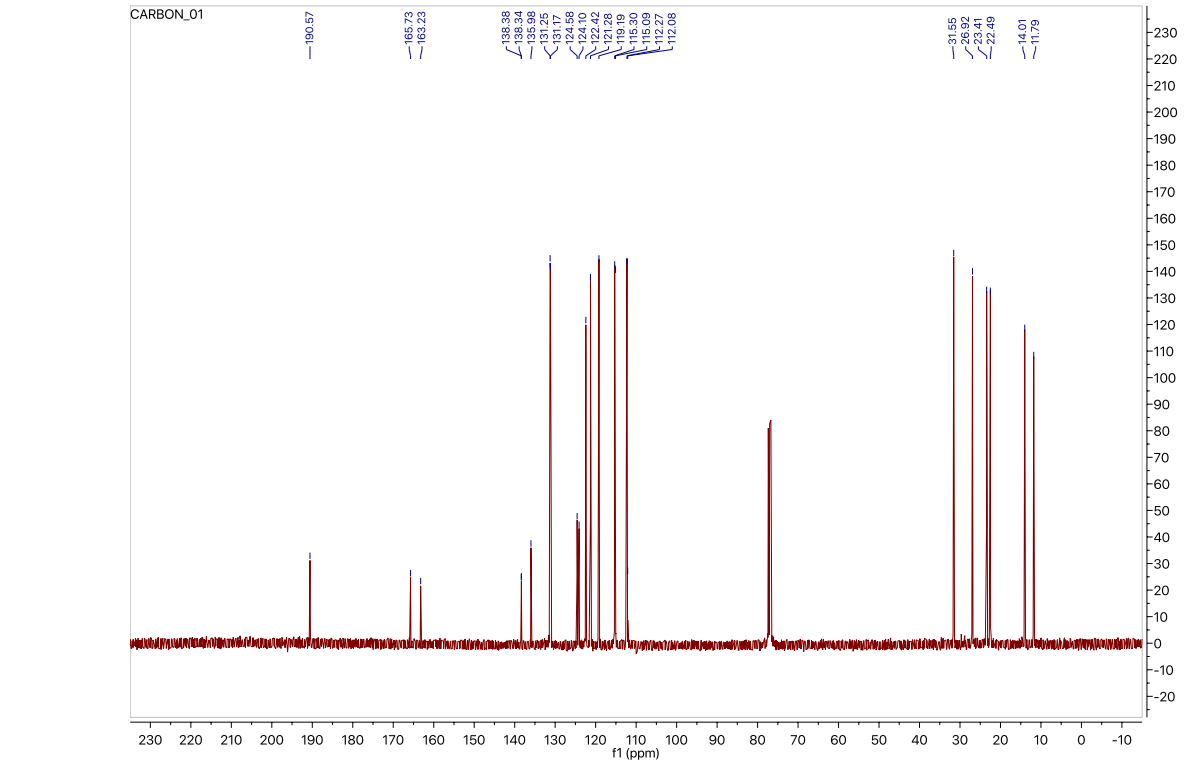
Compound 7f



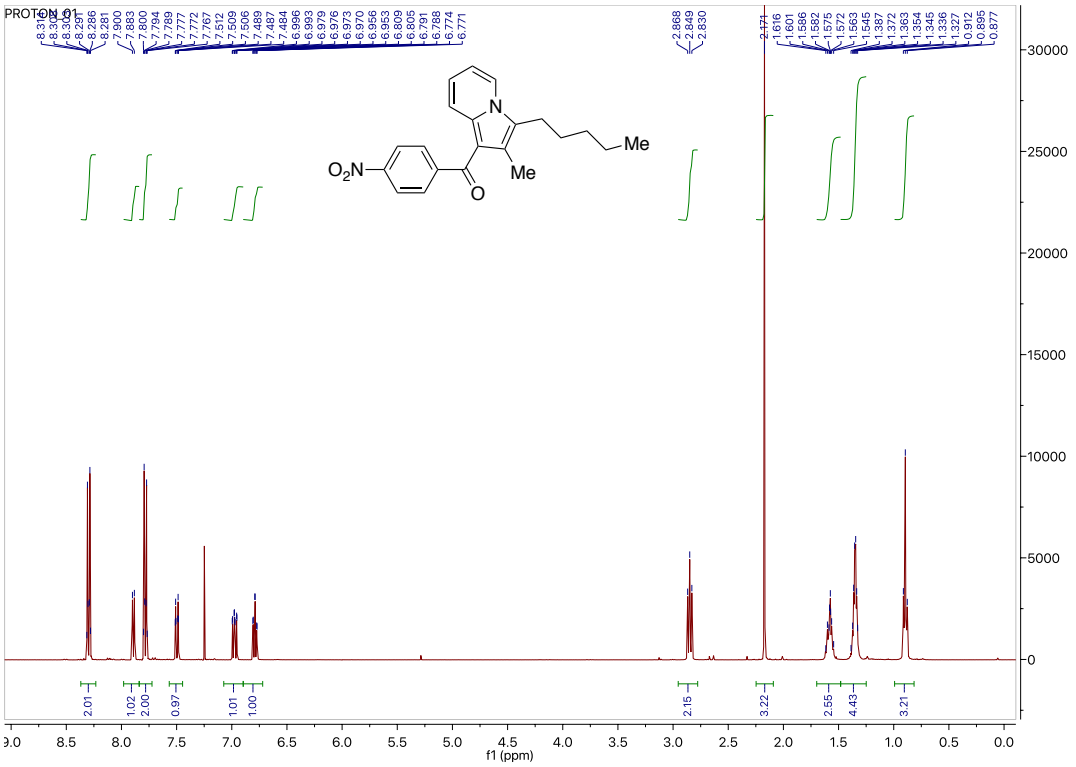


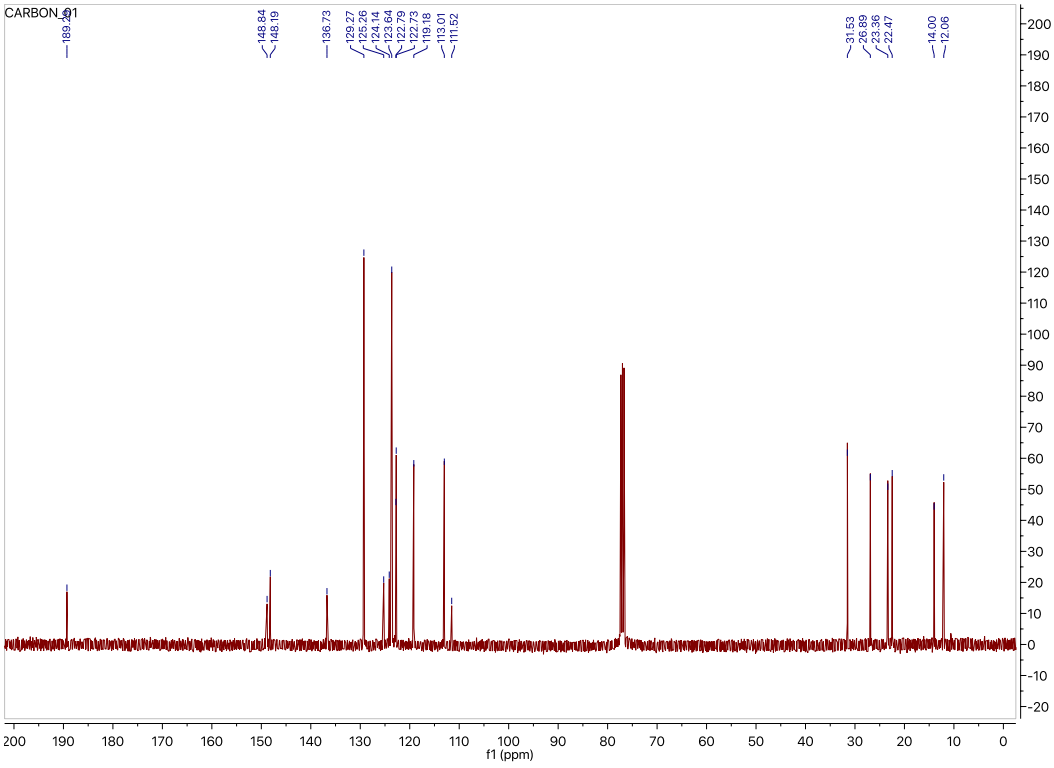
Compound 7g


PROTON_01
7.85
7.83
7.72
7.70
7.68
7.43
7.41
7.12
7.10
7.08
6.89
6.87
6.85
6.72
6.70
6.69
2.86
2.85
2.83
2.23
1.59
1.58
1.56
1.35
1.34
0.90
0.89
0.87
1.00
1.89
0.92
1.94
1.01
0.99
2.11
3.13
2.63
4.45
3.34
f1 (ppm)
N
Me
Me
F
O

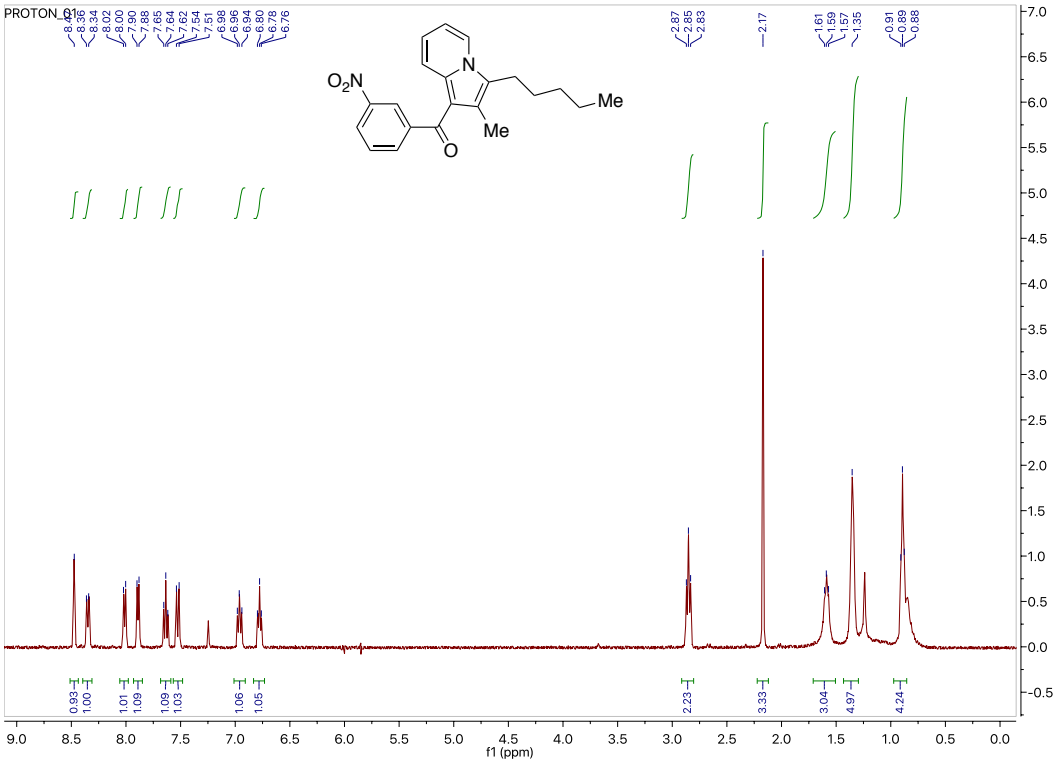

CARBON_01
190.57
165.73
163.23
138.38
138.34
135.98
131.25
131.17
124.58
124.10
122.42
121.28
119.19
115.30
115.09
112.27
112.08
31.55
26.92
23.41
22.49
14.01
11.79
f1 (ppm)

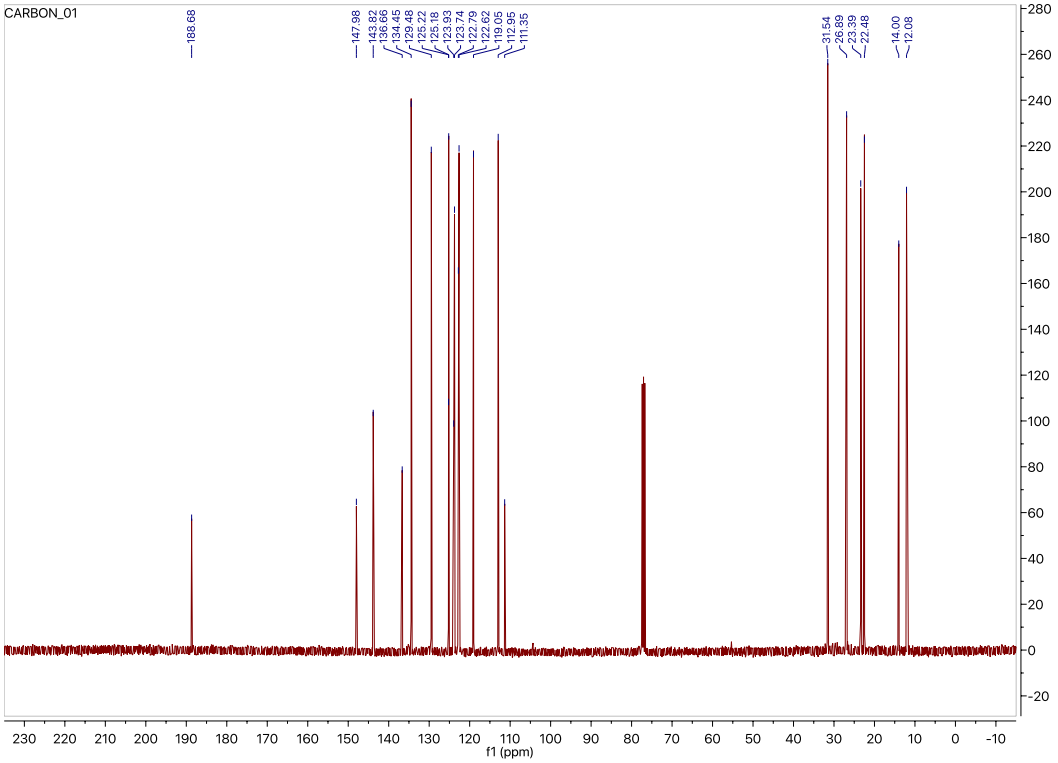
Compound 7h



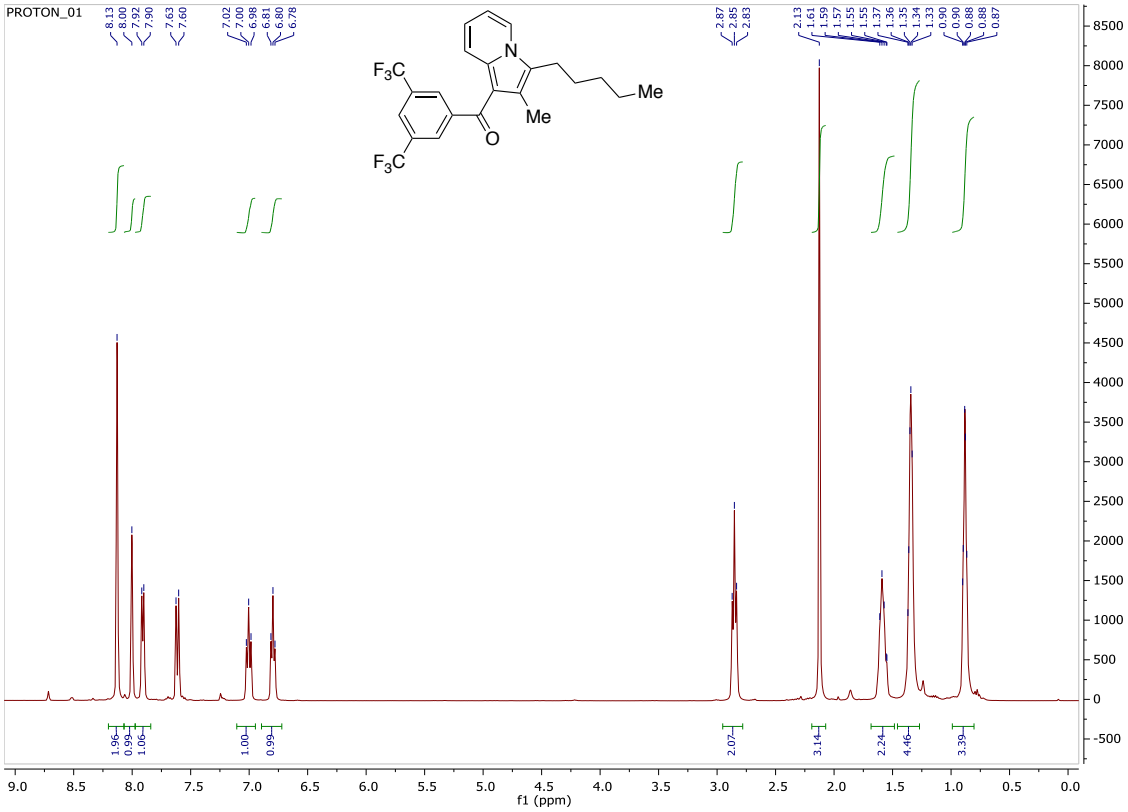


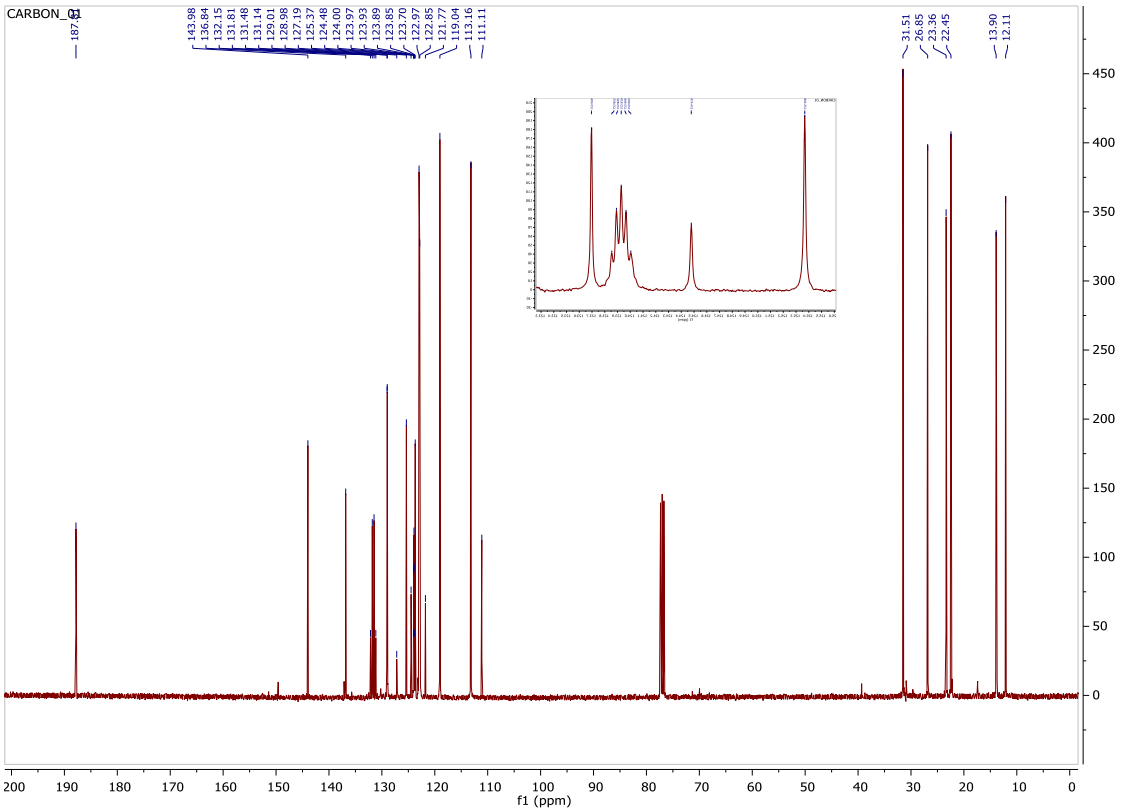
Compound 7i


PROTON_01
8.36
8.35
8.34
8.02
8.00
7.90
7.88
7.65
7.64
7.62
7.54
7.51
6.98
6.96
6.94
6.80
6.78
6.76
2.87
2.85
2.83
2.17
1.61
1.59
1.57
1.35
0.91
0.89
0.88
O2N
N
Me
Me
O
0.93
1.00
1.01
1.09
1.09
1.03
1.06
1.05
2.23
3.33
3.04
4.97
4.24
f1 (ppm)

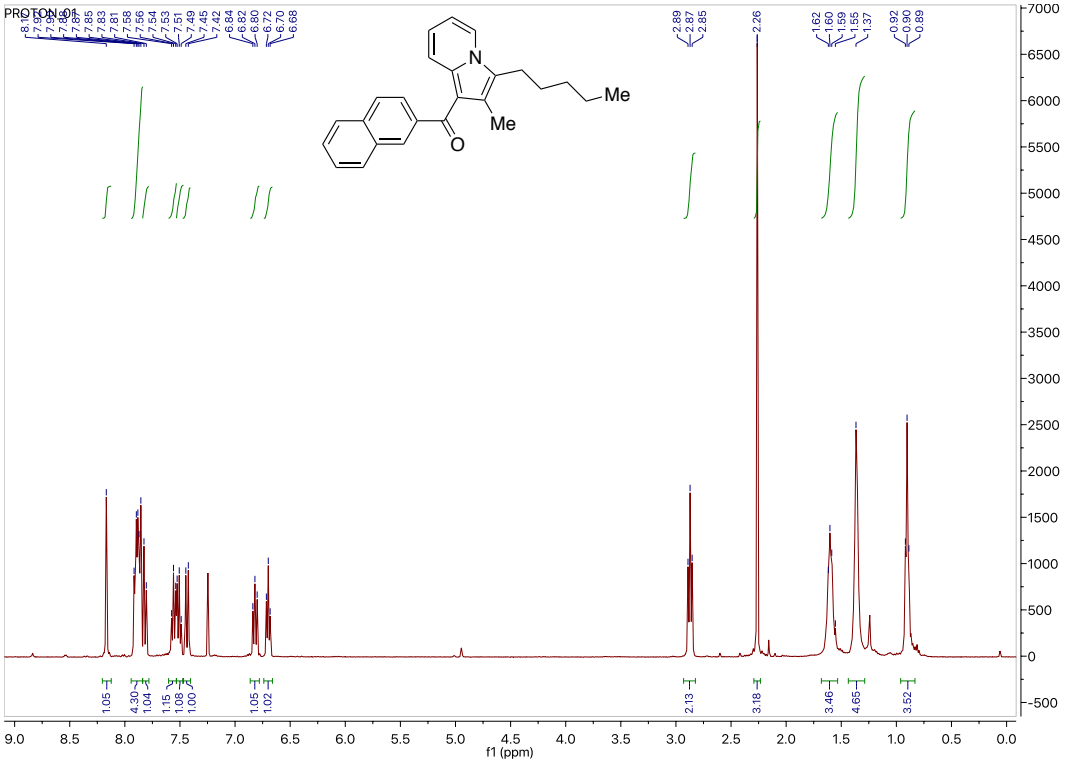

CARBON_01
188.68
147.98
143.82
136.66
134.45
129.48
125.22
125.18
123.93
123.74
122.79
122.62
119.05
112.95
111.35
31.54
26.89
23.39
22.48
14.00
12.08
f1 (ppm)

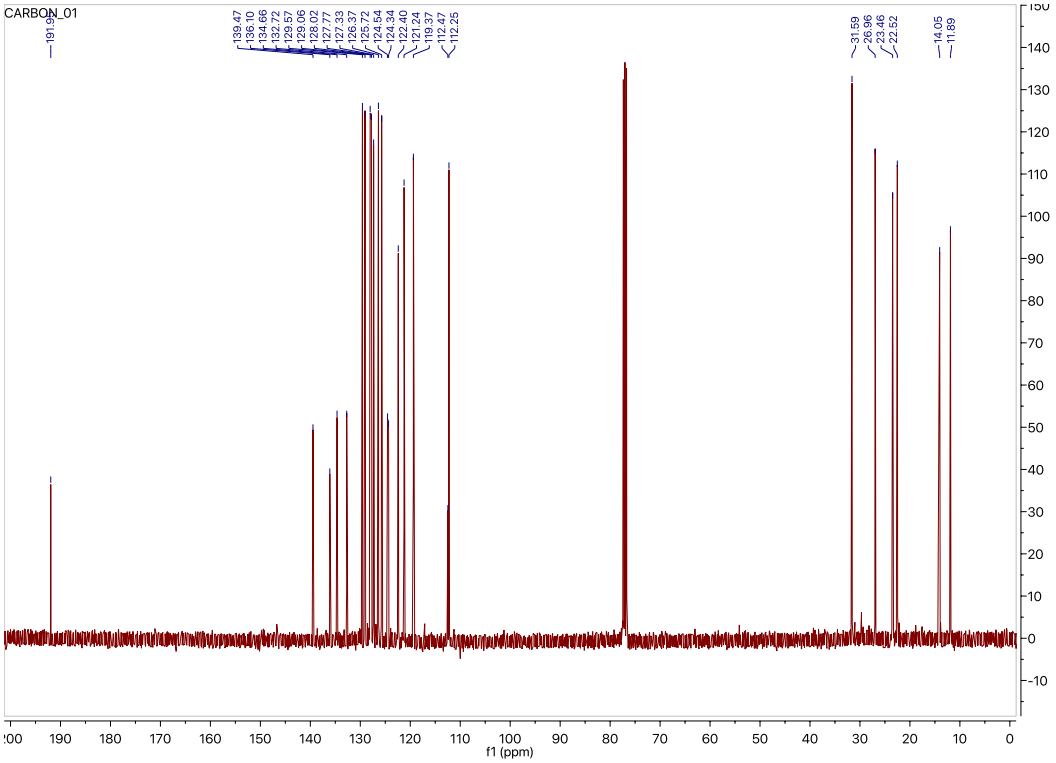
Compound 7j



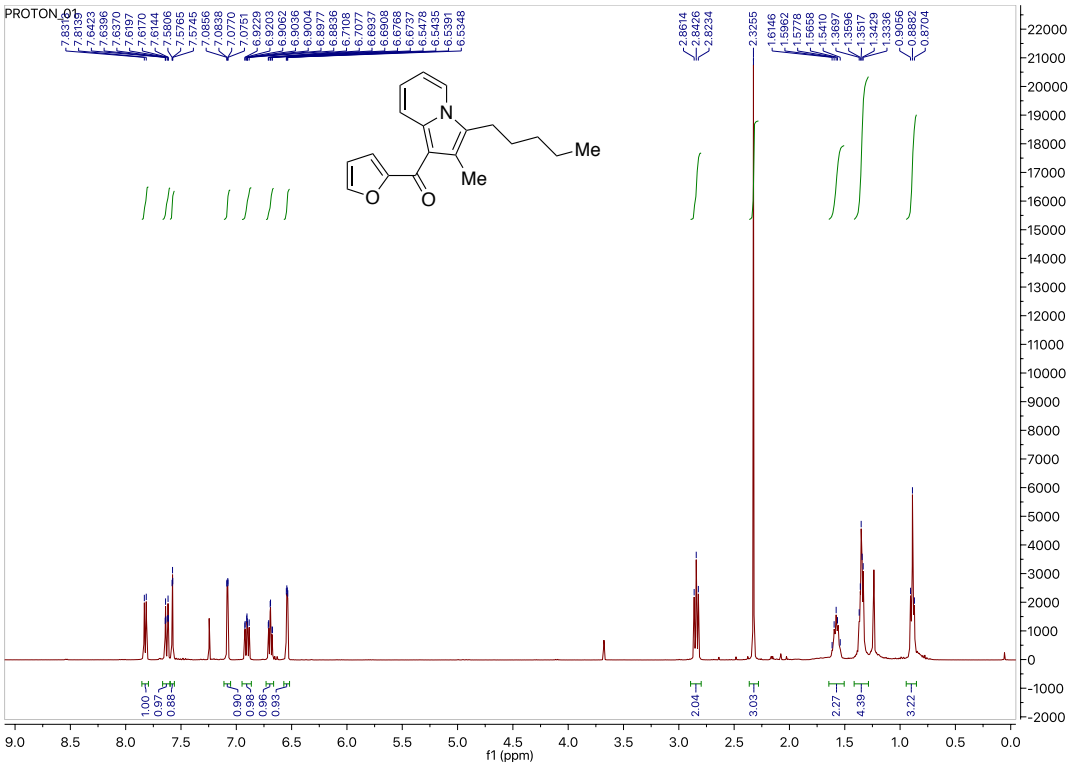


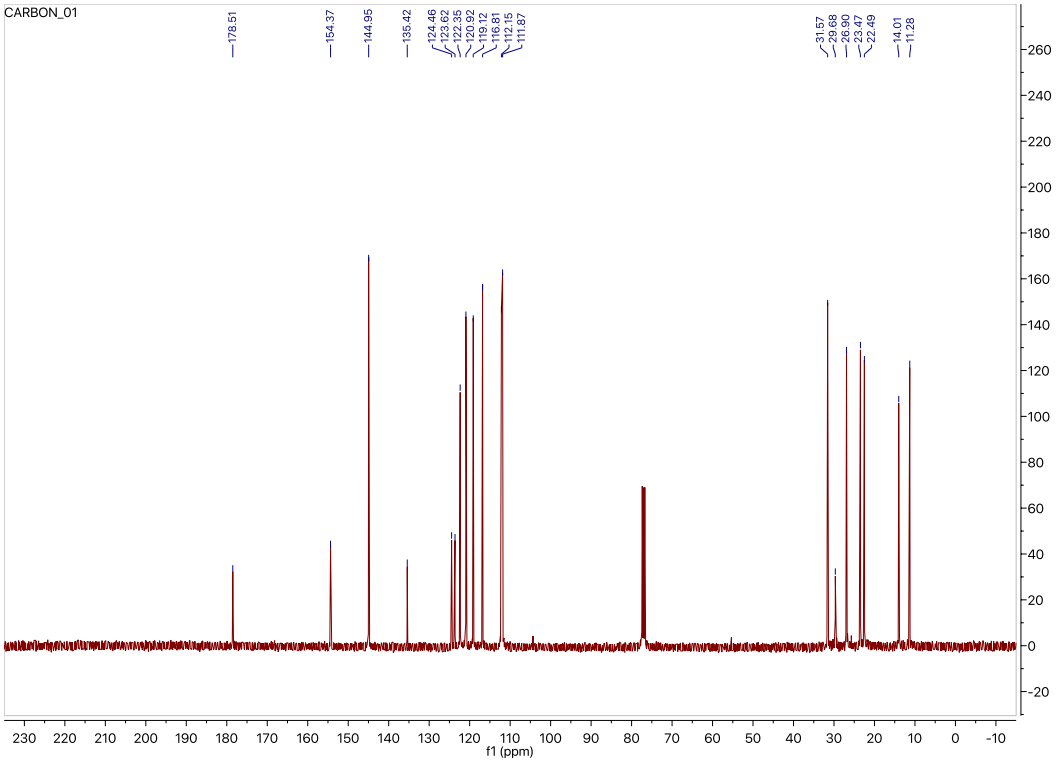
Compound 7k



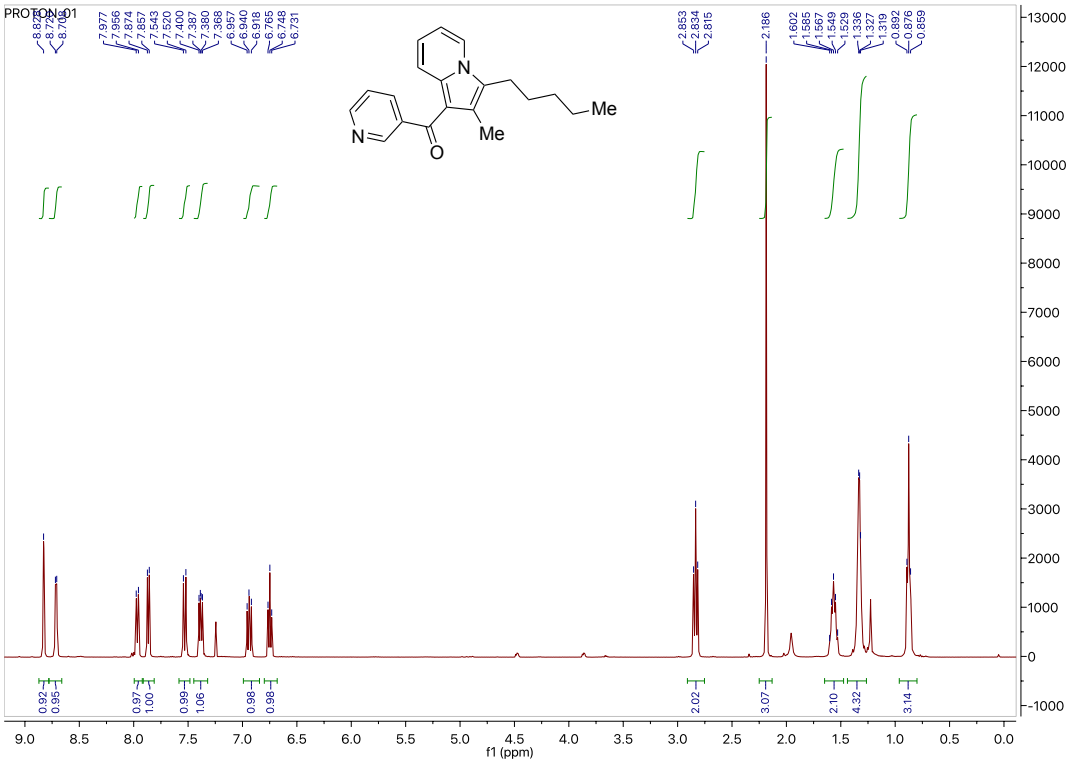


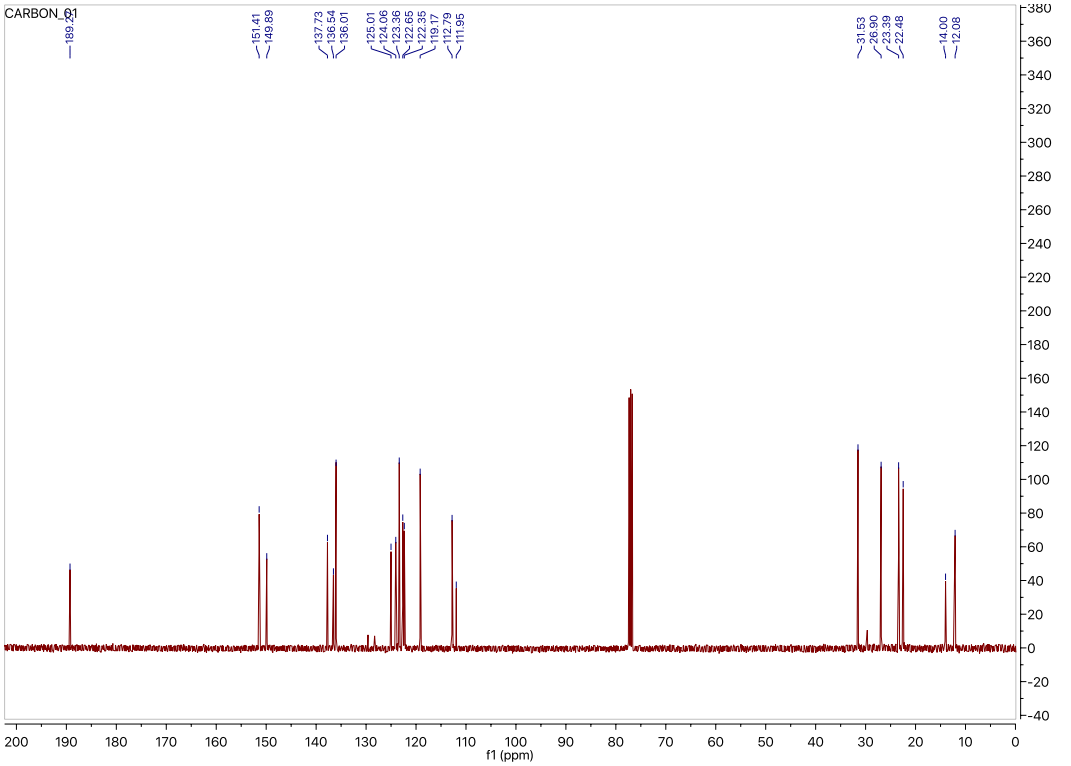
Compound 7l



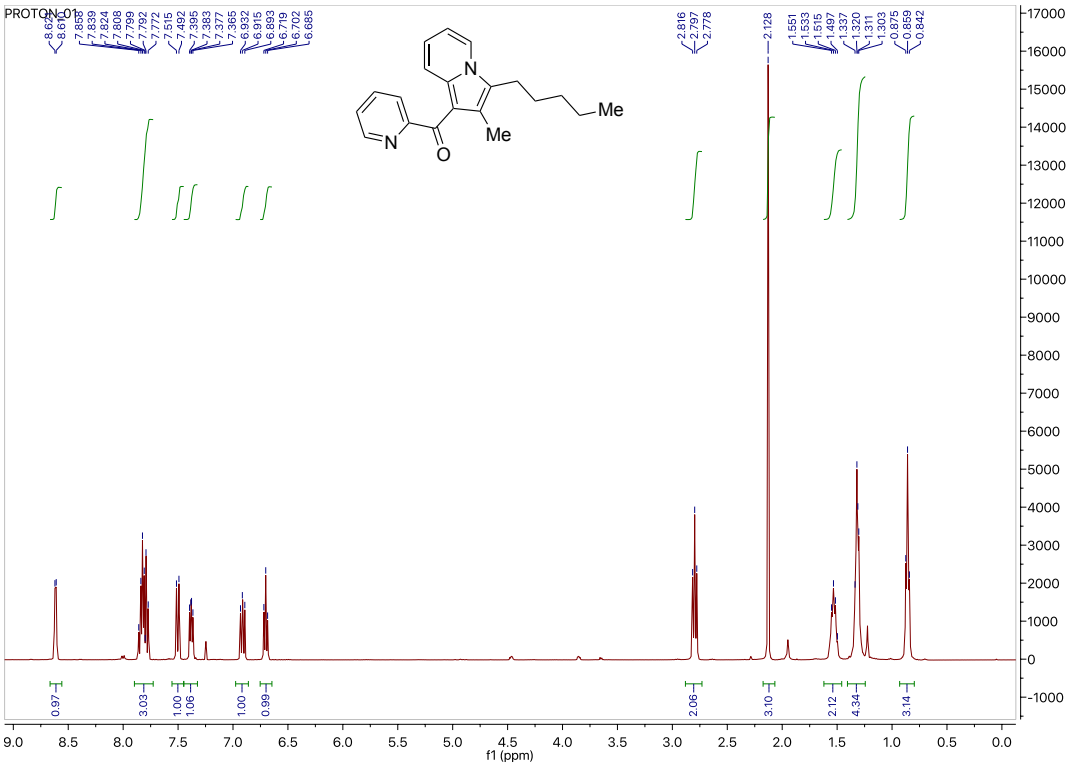


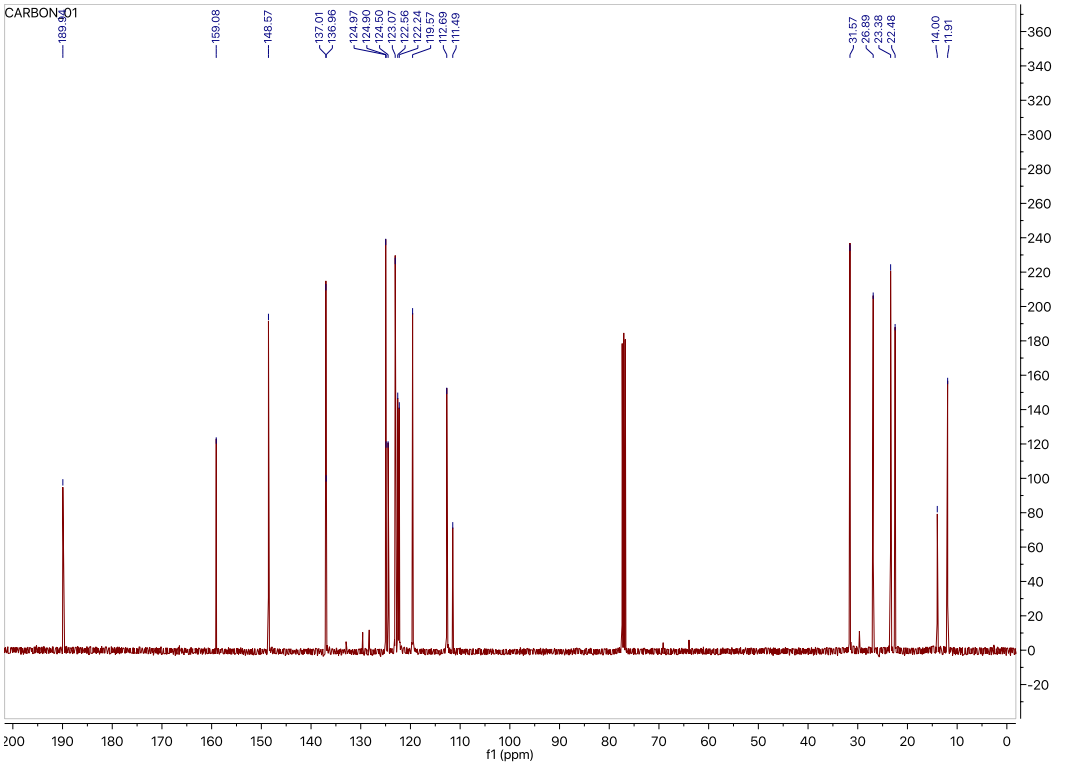
Compound 7m


PROTON_01
8.827
8.723
8.705
7.977
7.956
7.874
7.857
7.543
7.520
7.400
7.387
7.380
7.368
6.957
6.940
6.918
6.765
6.748
6.731
2.853
2.834
2.815
2.186
1.602
1.585
1.567
1.549
1.529
1.336
1.327
1.319
0.892
0.876
0.859
N
N
O
Me
Me
0.92
0.95
0.97
1.00
0.99
1.06
0.98
0.98
2.02
3.07
2.10
4.32
3.14
f1 (ppm)

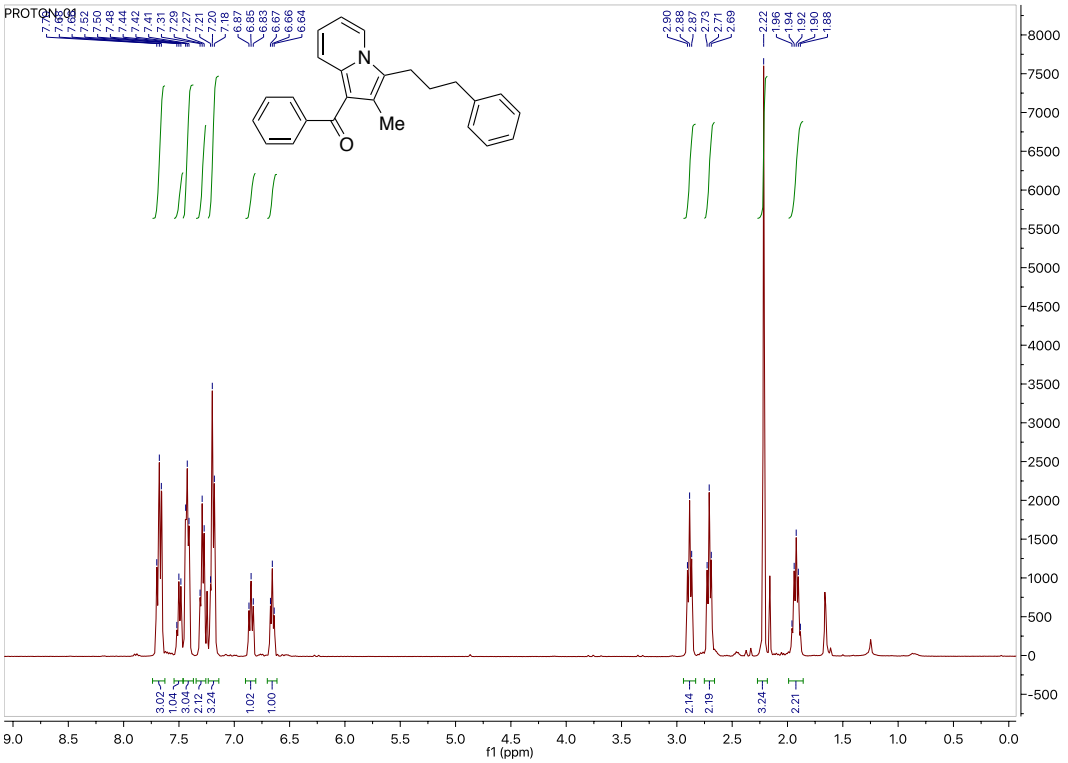

CARBON_01
189.21
151.41
149.89
137.73
136.54
136.01
125.01
124.06
123.36
122.65
122.35
119.17
112.79
111.95
31.53
26.90
23.39
22.48
14.00
12.08
f1 (ppm)

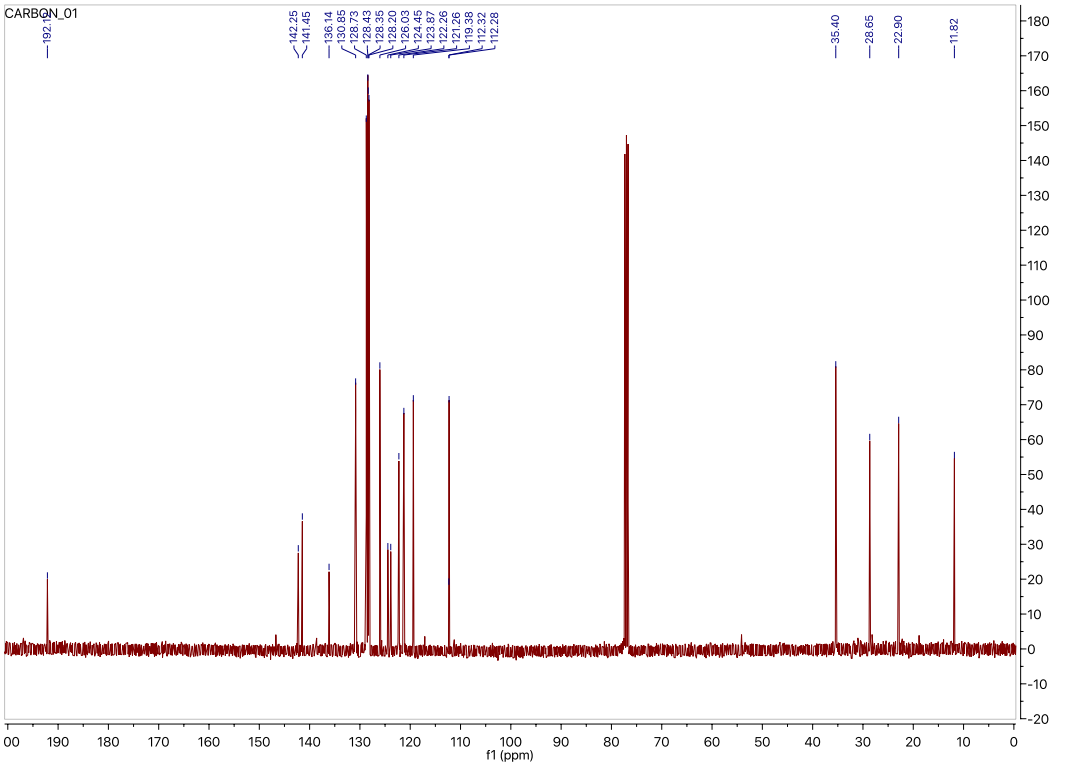
Compound 7n


PROTON_01
8.672
8.617
7.855
7.839
7.824
7.808
7.799
7.792
7.772
7.515
7.492
7.395
7.389
7.377
7.365
6.932
6.915
6.893
6.719
6.702
6.685
2.816
2.797
2.778
2.128
1.551
1.533
1.515
1.497
1.337
1.320
1.311
1.303
0.875
0.859
0.842
N
Me
Me
N
O
0.97
3.03
1.00
1.06
1.00
0.99
2.06
3.10
2.12
4.34
3.14
f1 (ppm)

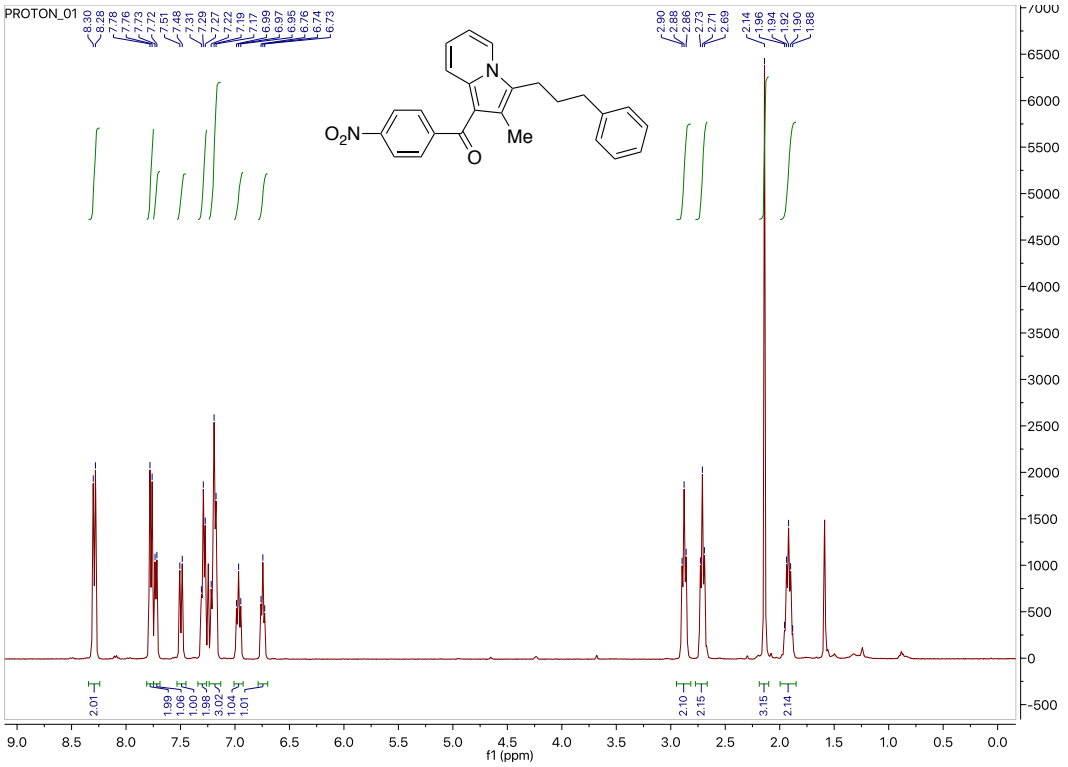

CARBON_01
189.93
159.08
148.57
137.01
136.96
124.97
124.90
124.50
123.07
122.56
122.04
115.57
112.69
111.49
31.57
26.89
23.38
22.48
14.00
11.91
f1 (ppm)

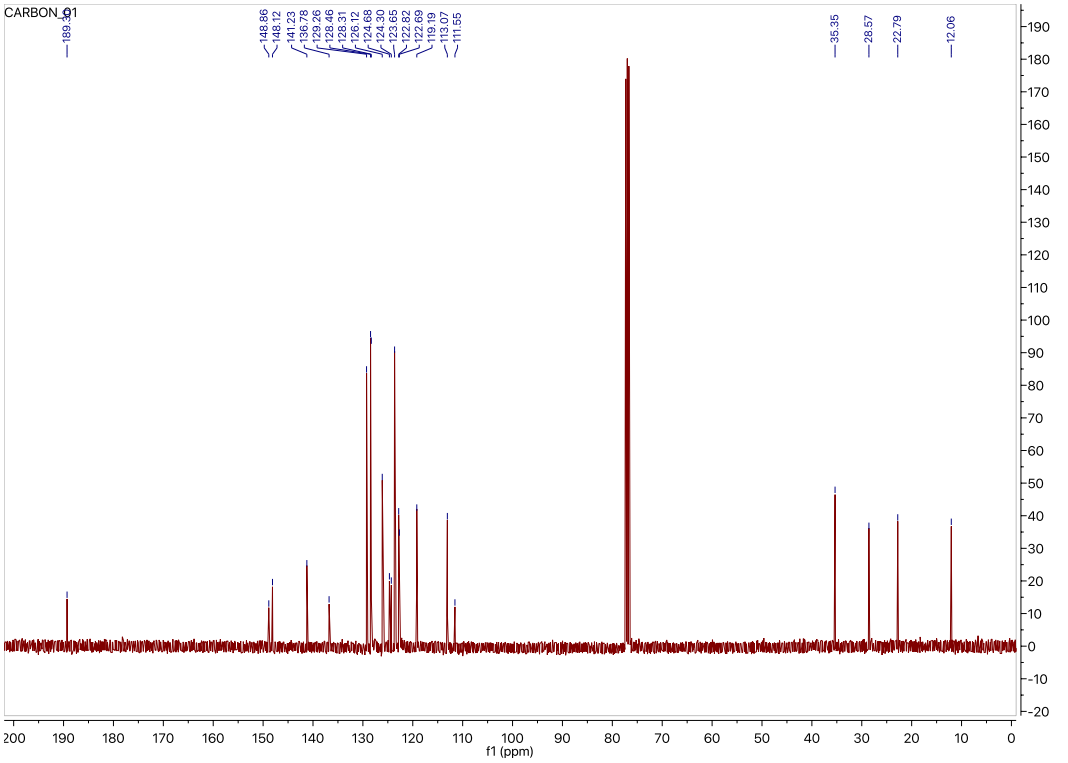
Compound 9a


PROTON_01
7.76
7.68
7.65
7.52
7.50
7.48
7.44
7.42
7.41
7.31
7.29
7.27
7.21
7.20
7.18
6.87
6.85
6.83
6.67
6.66
6.64
2.90
2.88
2.87
2.73
2.71
2.69
2.22
1.96
1.94
1.92
1.90
1.88
N
Me
O
3.02
1.04
3.04
2.12
3.24
1.02
1.00
2.14
2.19
3.24
2.21
f1 (ppm)

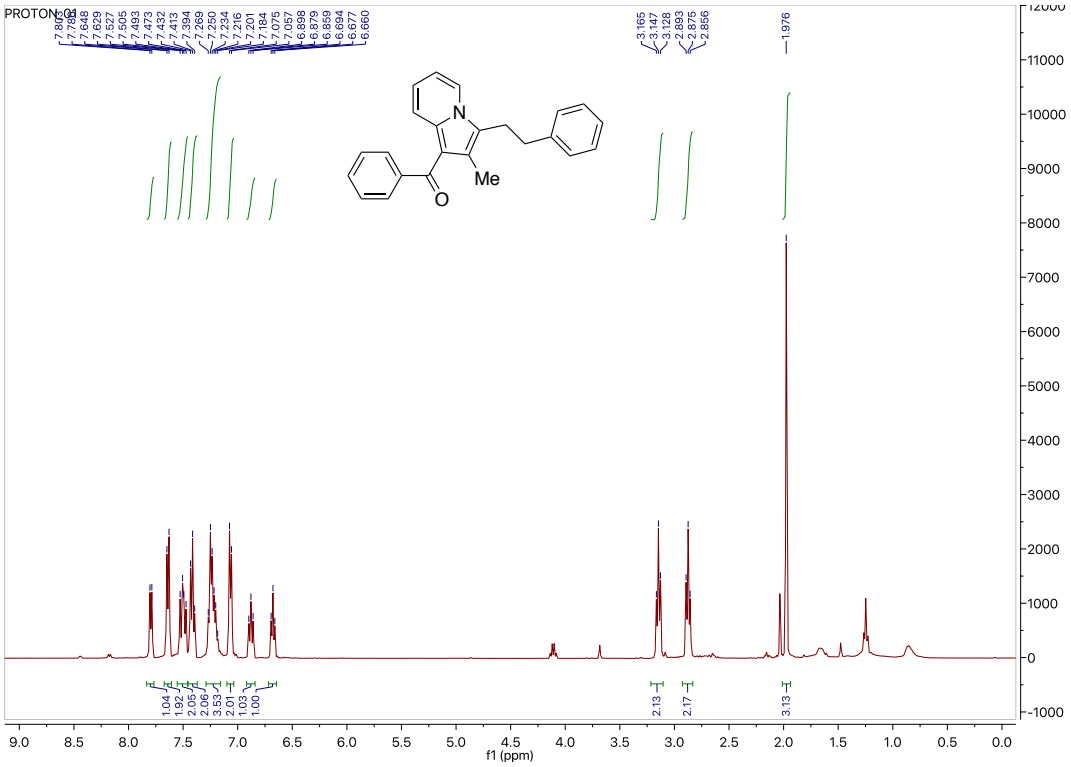

CARBON_01
192.12
142.25
141.45
136.14
130.85
128.73
128.43
128.35
128.20
126.03
124.45
123.37
122.26
121.26
119.38
112.32
112.28
35.40
28.65
22.90
11.82
f1 (ppm)

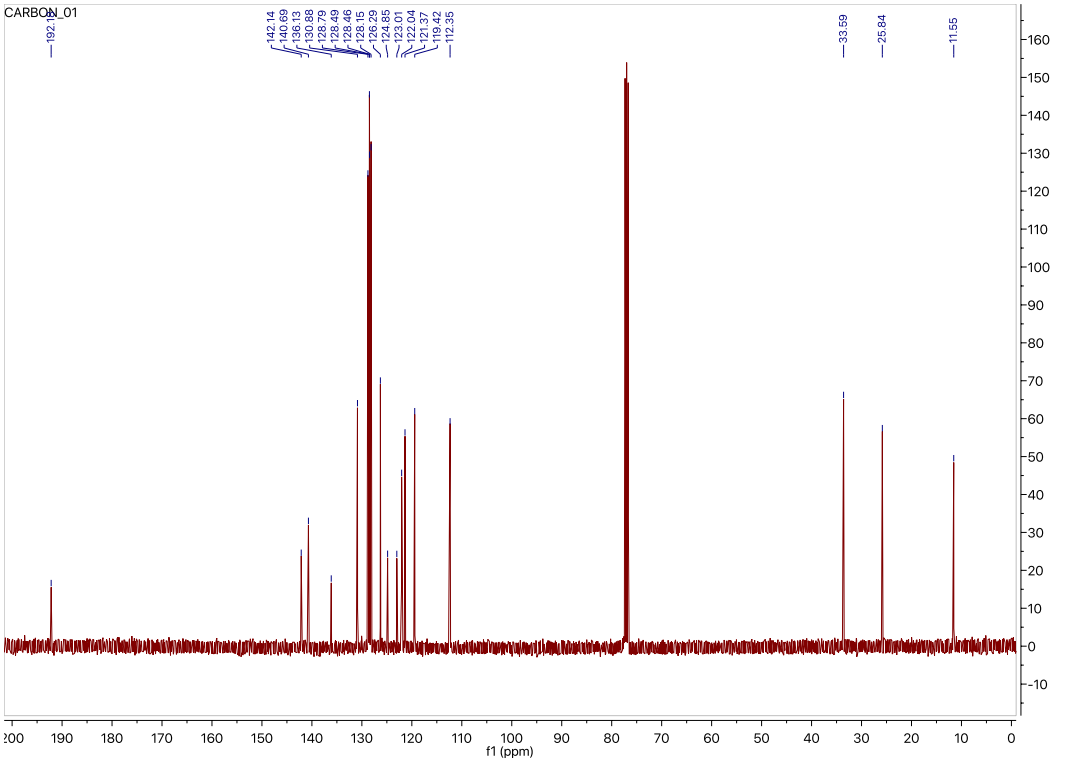
Compound 9aa



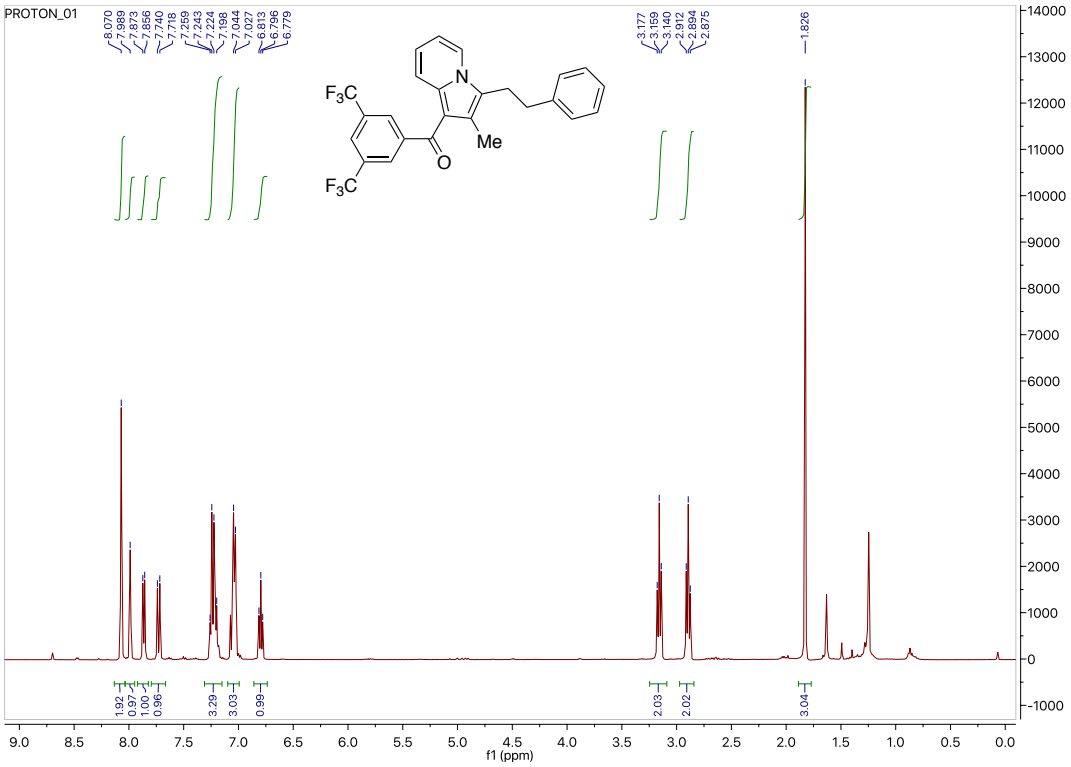


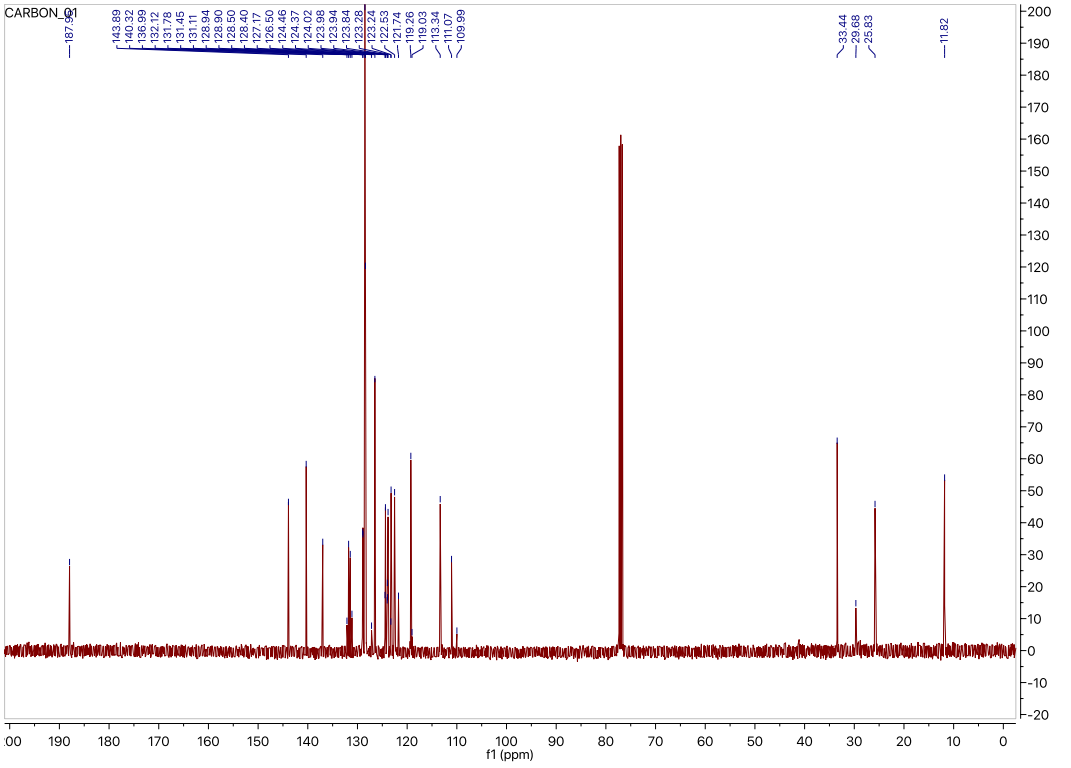
Compound 9b


PROTON_01
7.806
7.788
7.648
7.629
7.527
7.505
7.493
7.473
7.432
7.413
7.394
7.269
7.250
7.234
7.216
7.201
7.194
7.075
7.057
6.898
6.879
6.859
6.694
6.677
6.660
3.165
3.147
3.128
2.893
2.875
2.856
1.976
N
Me
O
1.04
1.92
2.05
2.06
3.53
2.01
1.03
1.00
2.13
2.17
3.13
f1 (ppm)

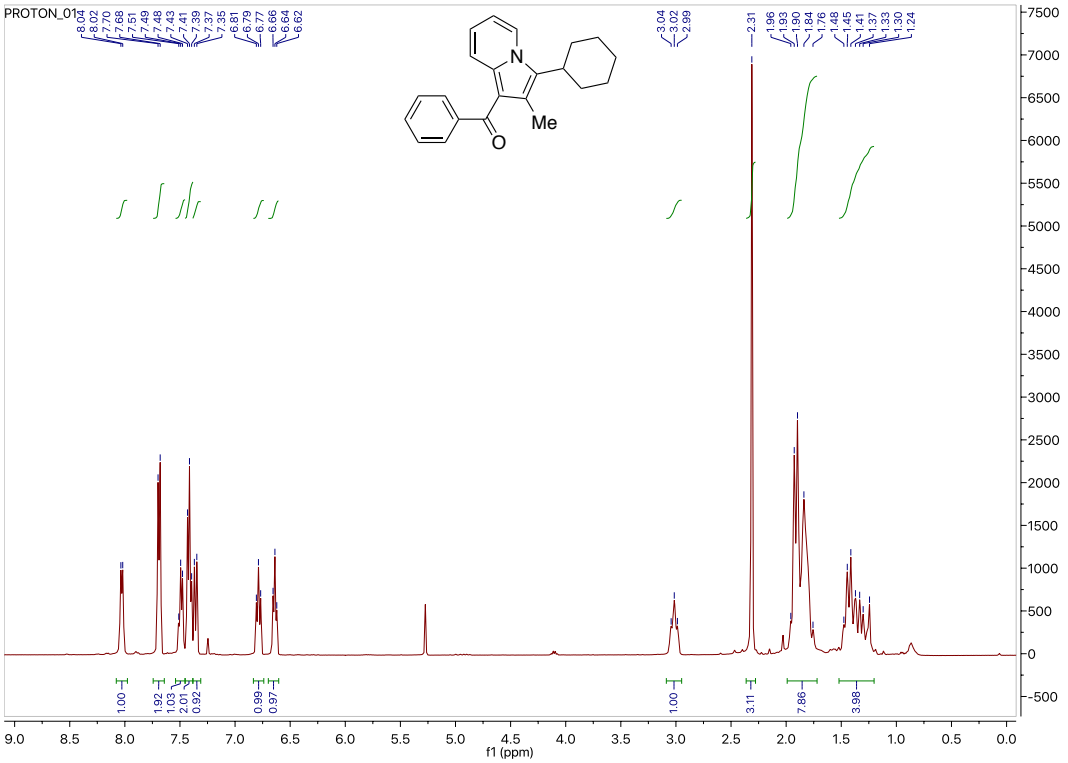

CARBON_01
192.15
142.14
140.69
136.13
130.88
128.79
128.49
128.46
128.15
126.29
124.85
123.01
122.04
121.37
119.42
112.35
33.59
25.84
11.55
f1 (ppm)

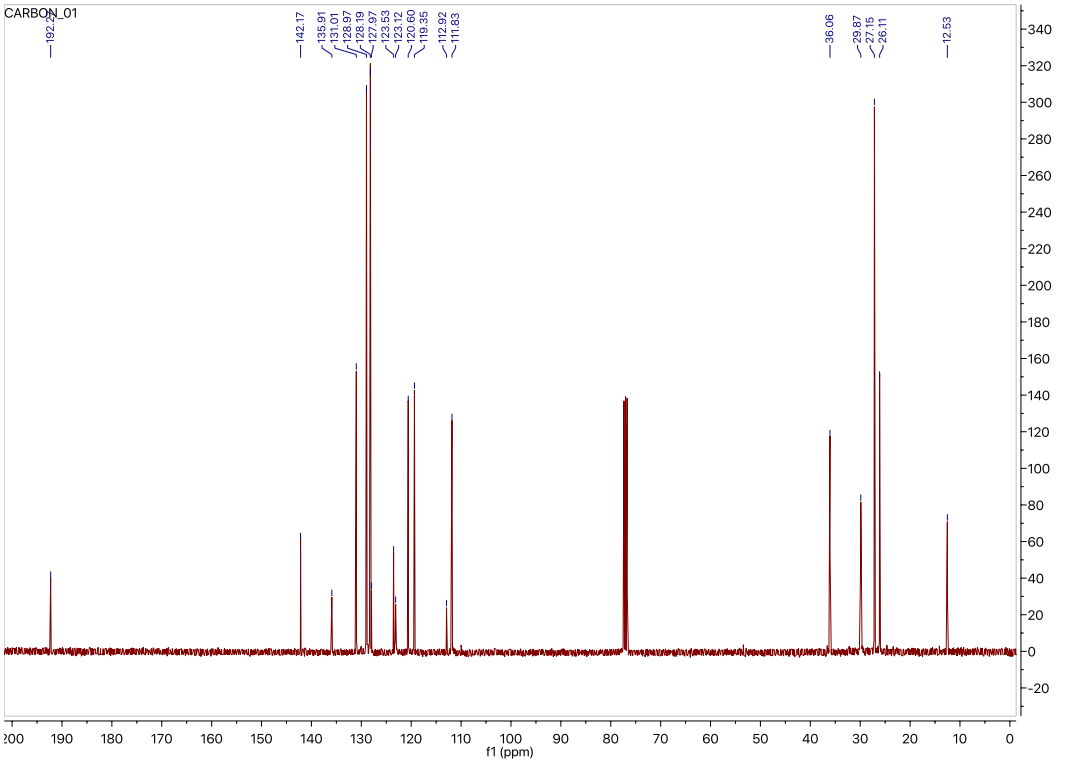
Compound 9bb



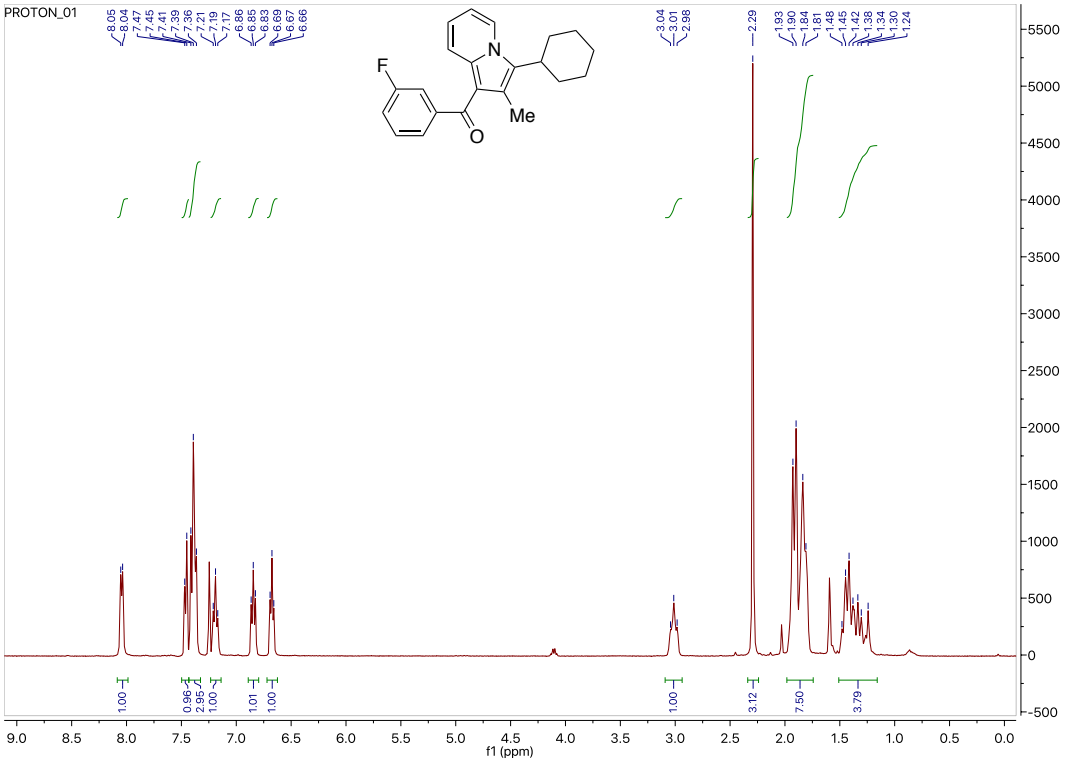


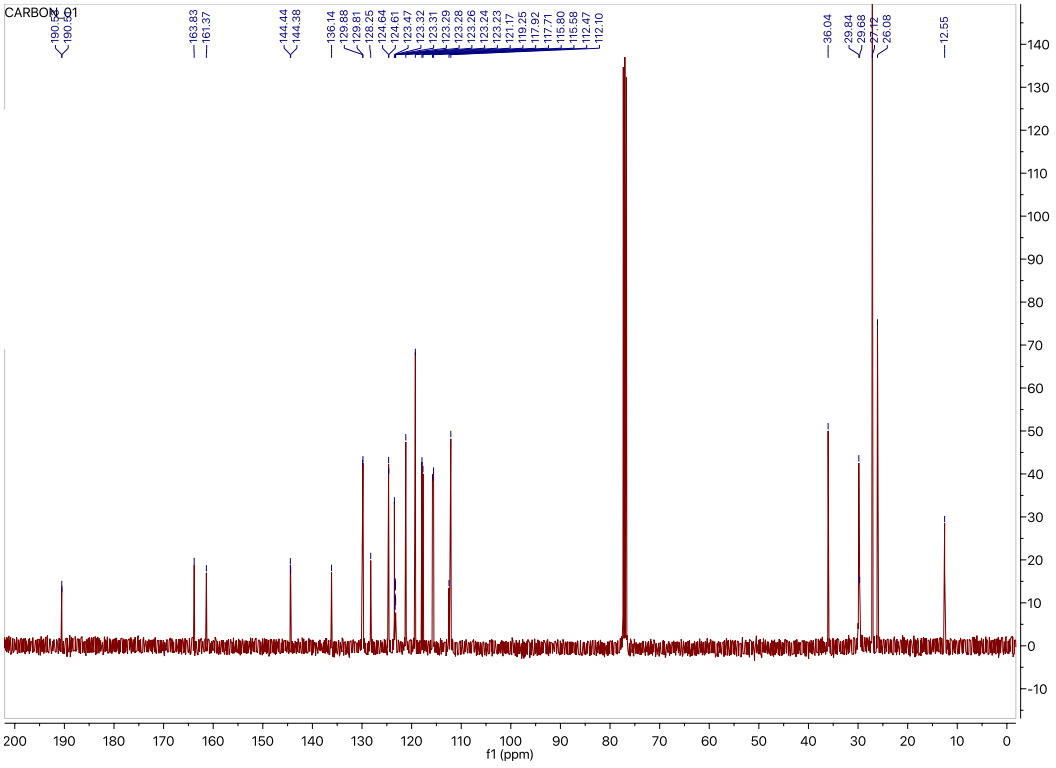
Compound 9c


PROTON_01
8.04
8.02
7.70
7.68
7.51
7.49
7.48
7.43
7.41
7.39
7.37
7.35
6.81
6.79
6.77
6.66
6.64
6.62
3.04
3.02
2.99
2.31
1.96
1.93
1.90
1.84
1.76
1.48
1.45
1.41
1.37
1.33
1.30
1.24
N
Me
O
1.00
1.92
1.03
2.01
0.92
0.99
0.97
1.00
3.11
7.86
3.98
f1 (ppm)

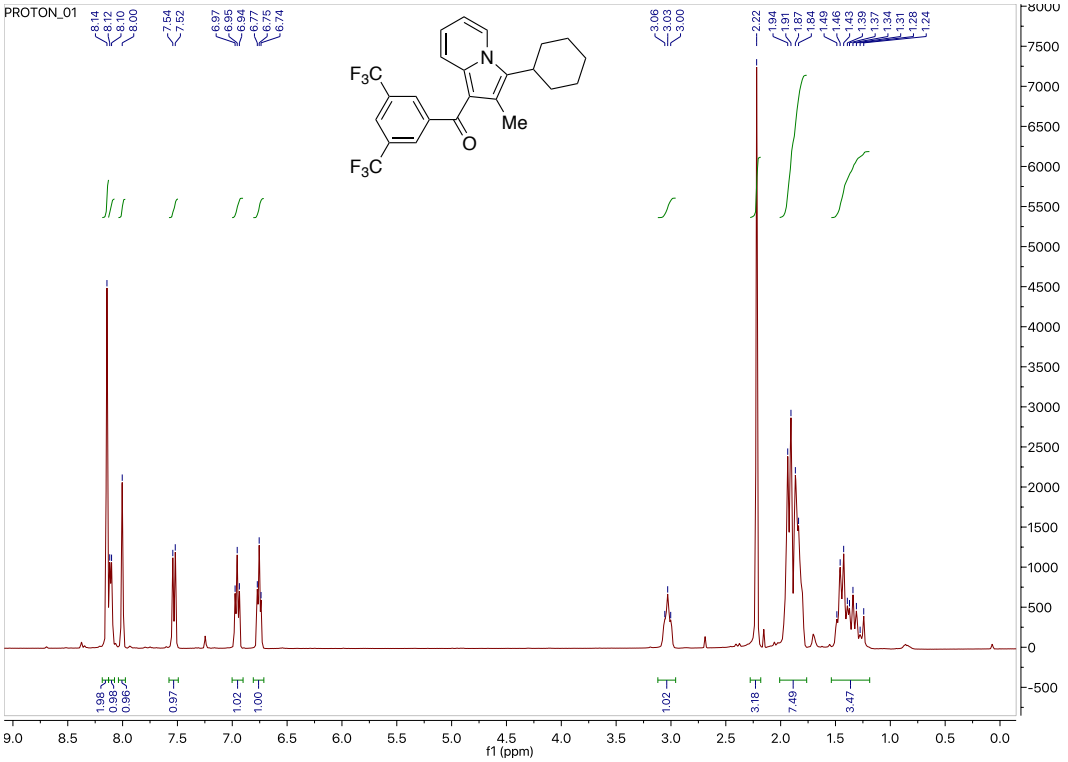

CARBON_01
192.17
142.17
135.91
131.01
128.37
128.19
127.97
123.53
123.12
120.60
119.35
112.92
111.83
36.06
29.87
27.15
26.11
12.53
f1 (ppm)

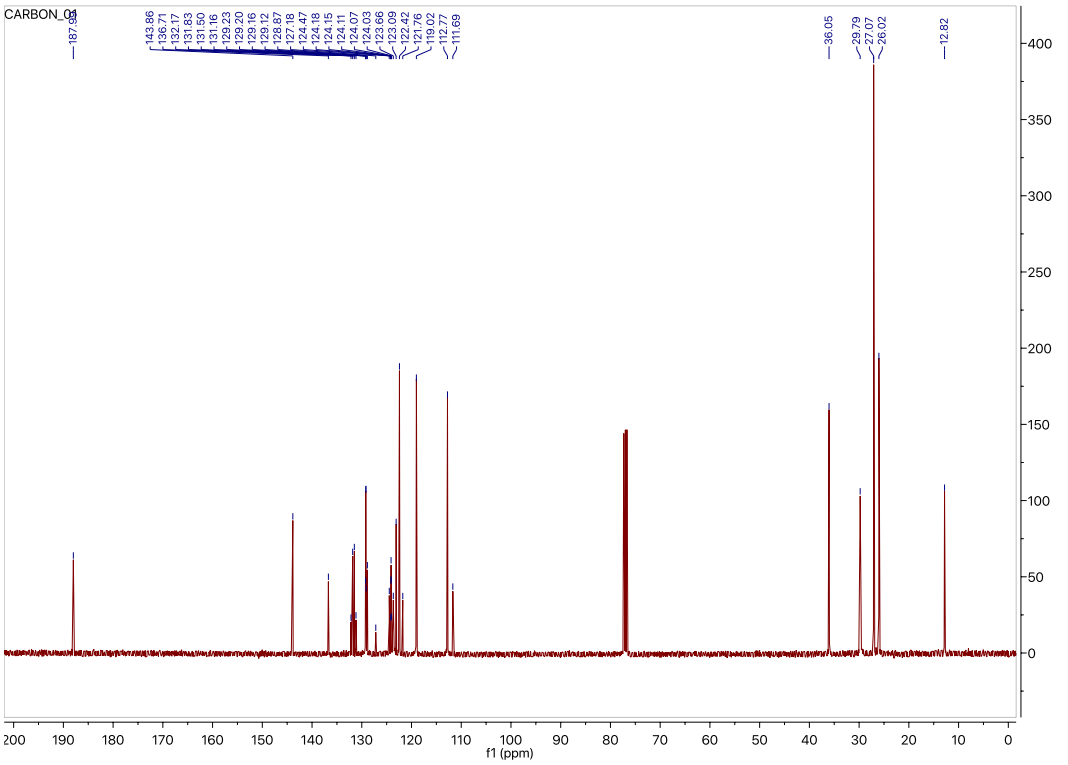
Compound 9cc



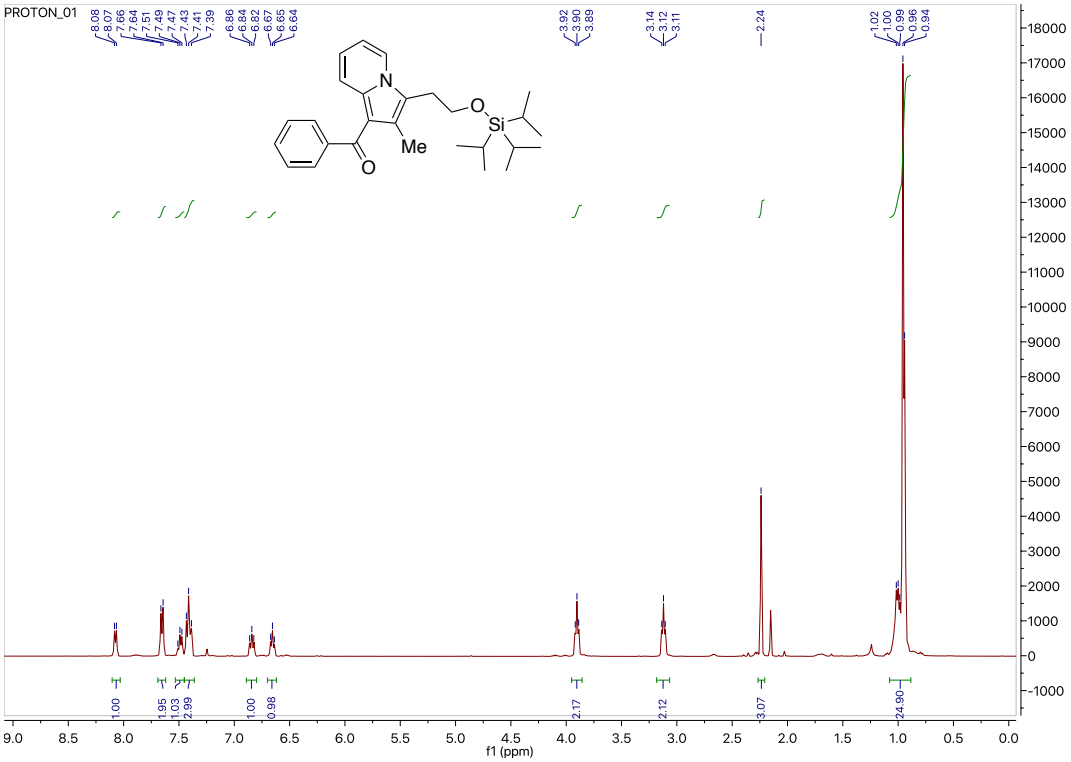


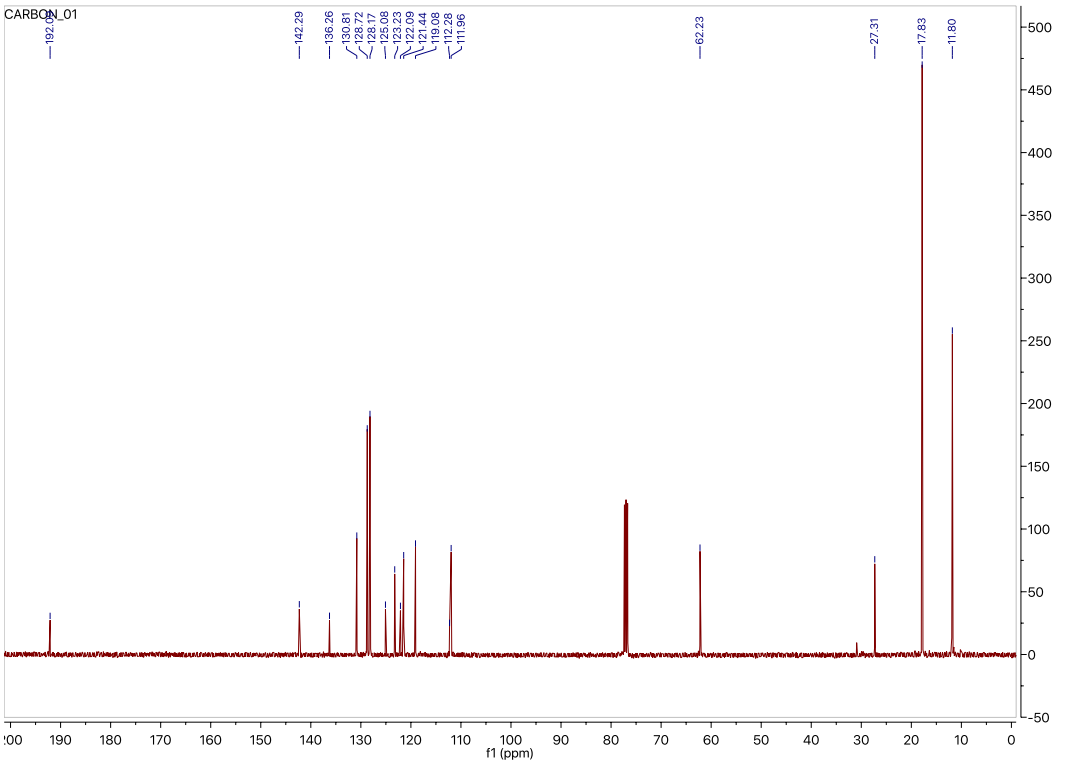
Compound 9ccc



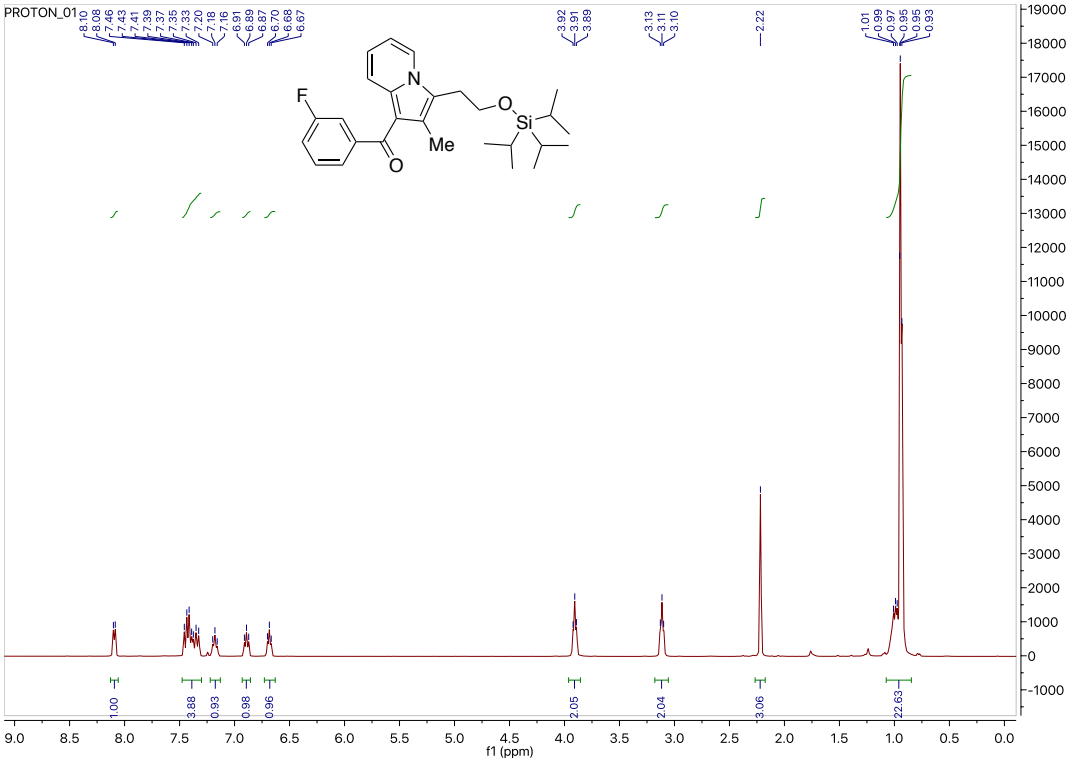


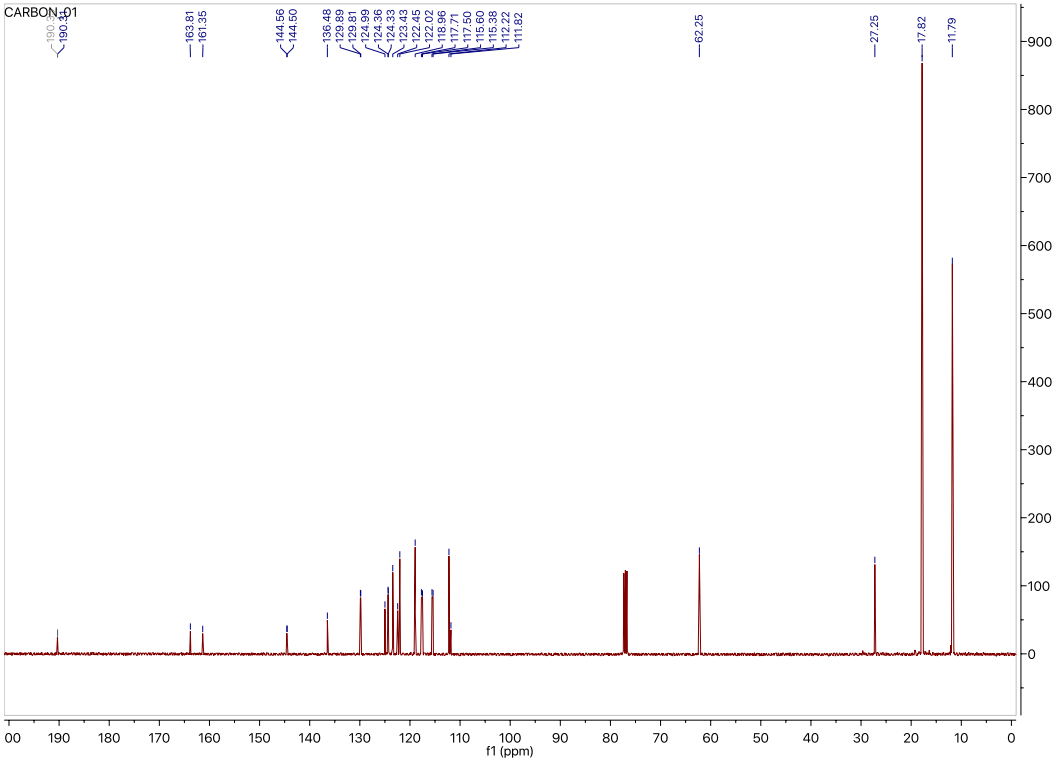
Compound 9d


PROTON_01
8.08
8.07
7.66
7.64
7.51
7.49
7.47
7.43
7.41
7.39
6.86
6.84
6.82
6.67
6.65
6.64
3.92
3.90
3.89
3.14
3.12
3.11
2.24
1.02
1.00
0.99
0.96
0.94
N
O
Si
Me
O
1.00
1.95
1.03
2.99
1.00
0.98
2.17
2.12
3.07
24.90
f1 (ppm)

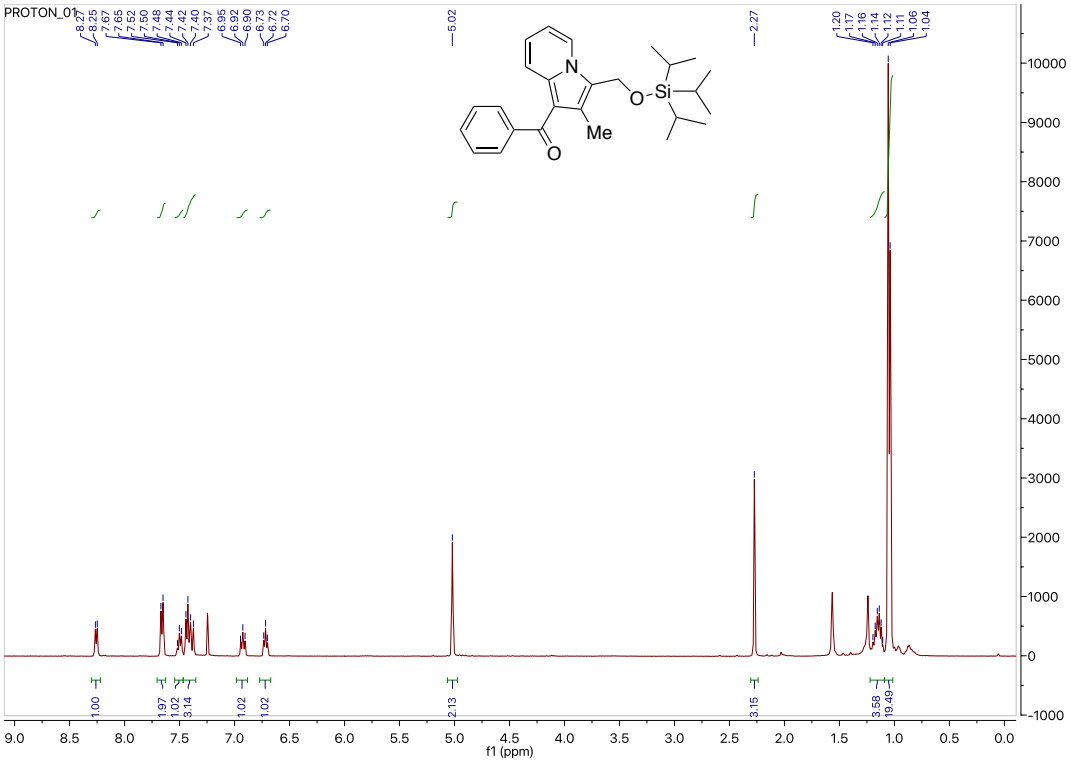

CARBON_01
192.06
142.29
136.26
130.81
128.72
128.17
125.08
123.23
122.09
121.44
119.08
112.28
111.96
62.23
27.31
17.83
11.80
f1 (ppm)

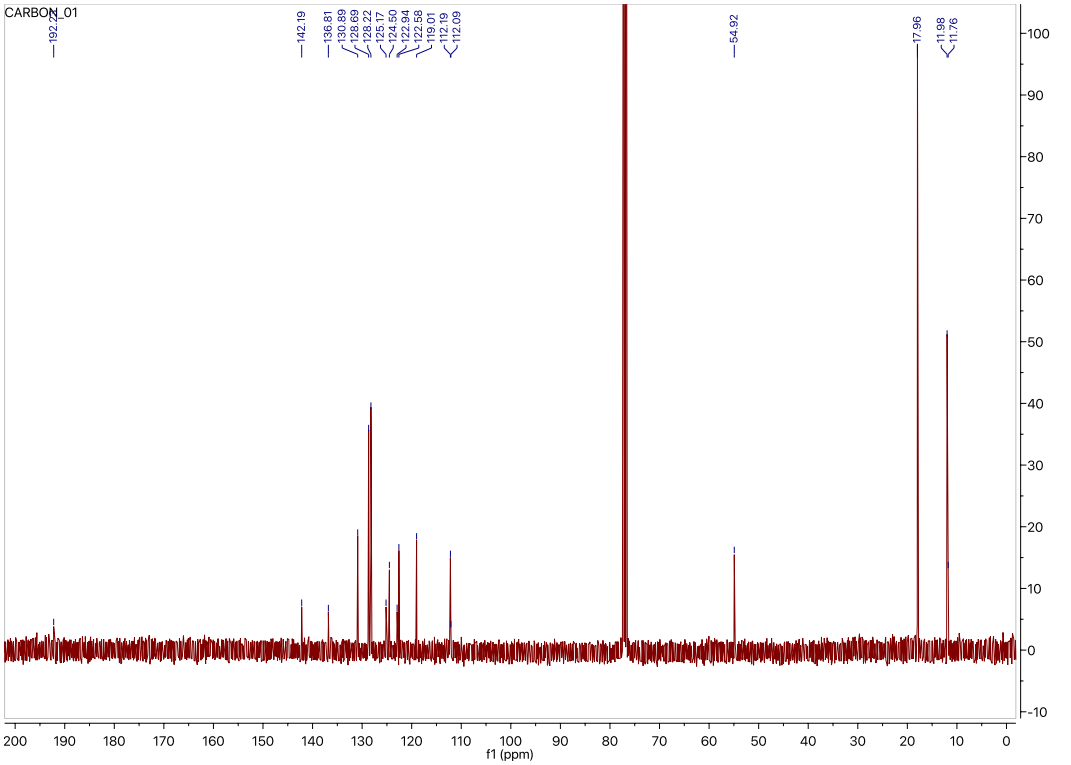
Compound 9dd



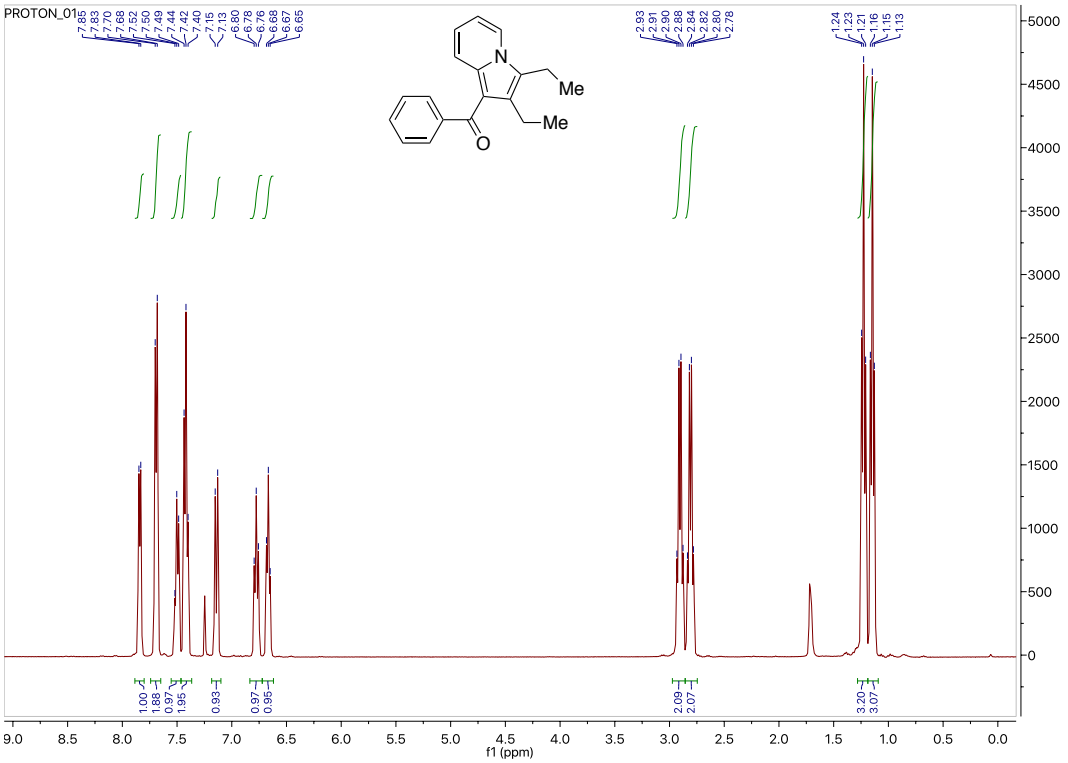


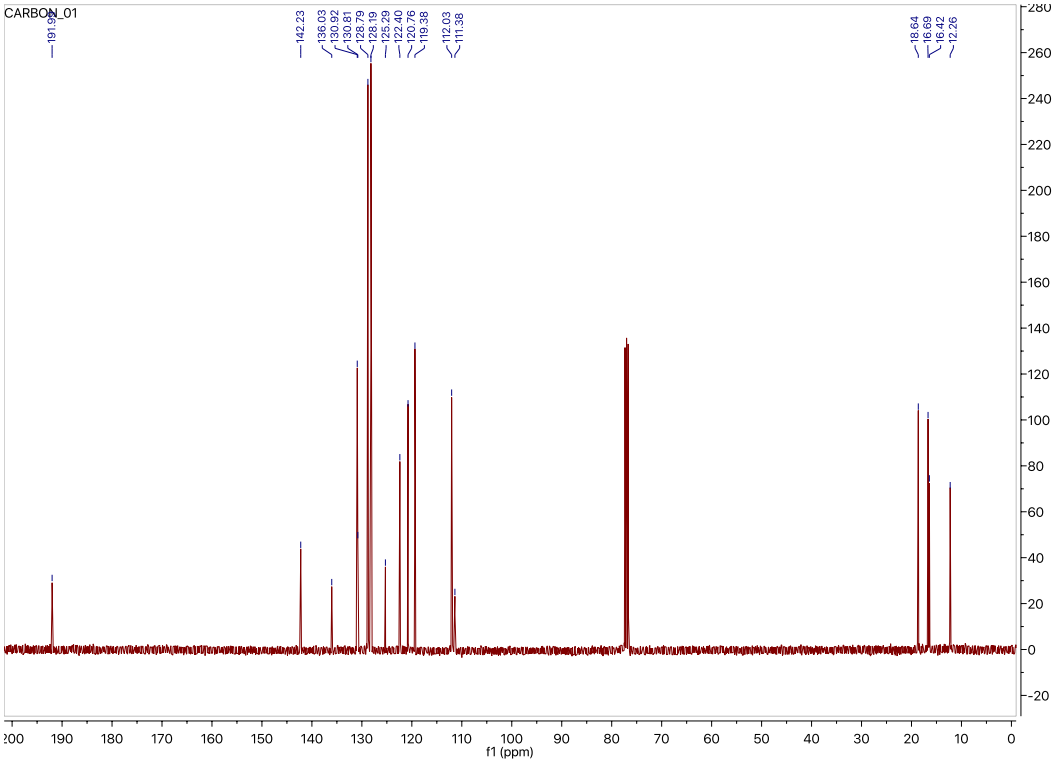
Compound 9e


PROTON_01
8.27
8.25
7.67
7.65
7.52
7.50
7.48
7.44
7.42
7.40
7.37
6.85
6.92
6.90
6.73
6.72
6.70
5.02
2.27
1.20
1.17
1.16
1.14
1.12
1.11
1.06
1.04
N
O
Si
Me
O
1.00
1.97
1.02
3.14
1.02
1.02
2.13
3.15
3.58
19.49
f1 (ppm)

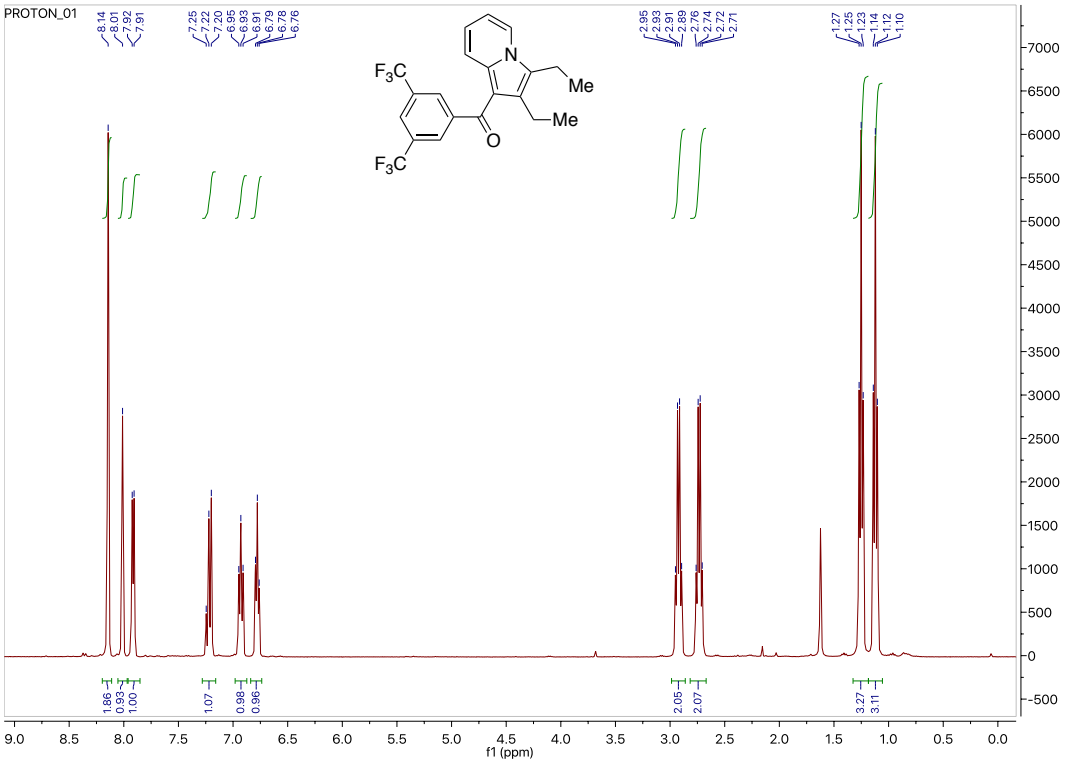

CARBON_01
192.77
142.19
136.81
130.89
128.69
128.22
125.17
124.50
122.94
122.58
119.91
119.19
112.09
54.92
17.96
11.98
11.76
f1 (ppm)

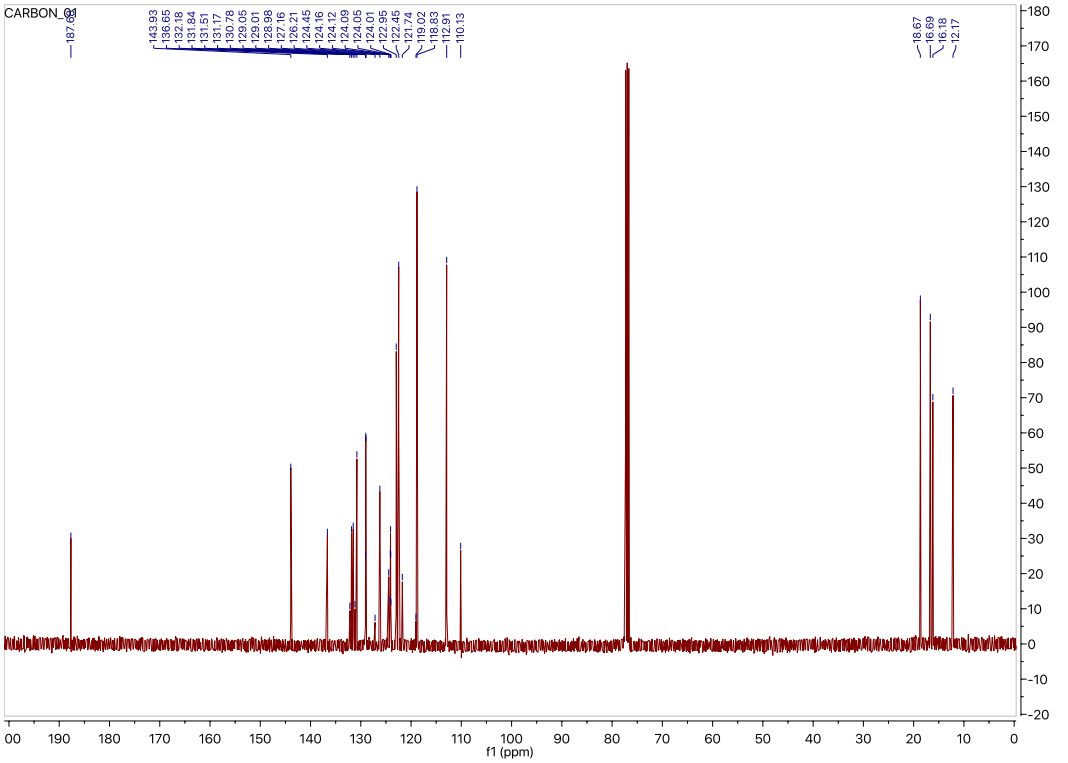
Compound 9f


PROTON_01
7.85
7.83
7.70
7.68
7.52
7.50
7.49
7.44
7.42
7.40
7.15
7.13
6.80
6.78
6.76
6.68
6.67
6.65
2.93
2.91
2.90
2.88
2.84
2.82
2.80
2.78
1.24
1.23
1.21
1.16
1.15
1.13
N
Me
Me
O
1.00
1.88
0.97
1.95
0.93
0.97
0.95
2.09
2.07
3.20
3.07
f1 (ppm)

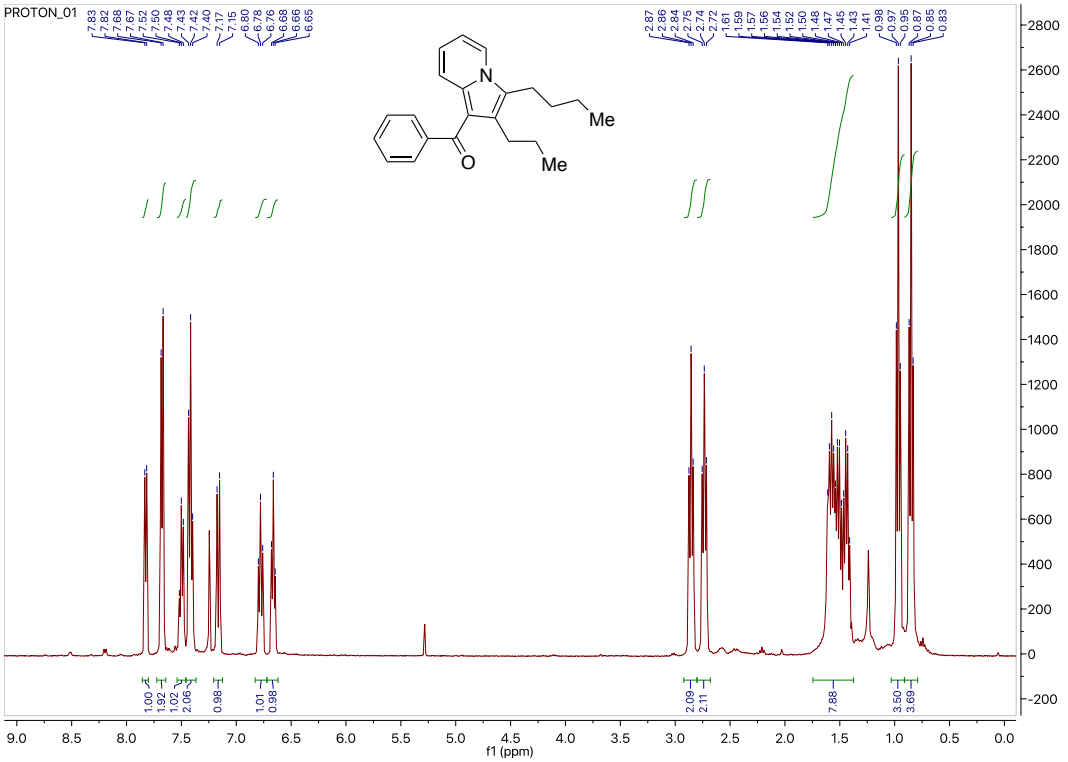

CARBON_01
191.89
142.23
136.03
130.92
130.91
128.79
128.19
125.29
122.40
120.76
119.38
112.03
111.38
18.64
16.69
16.42
12.26
f1 (ppm)

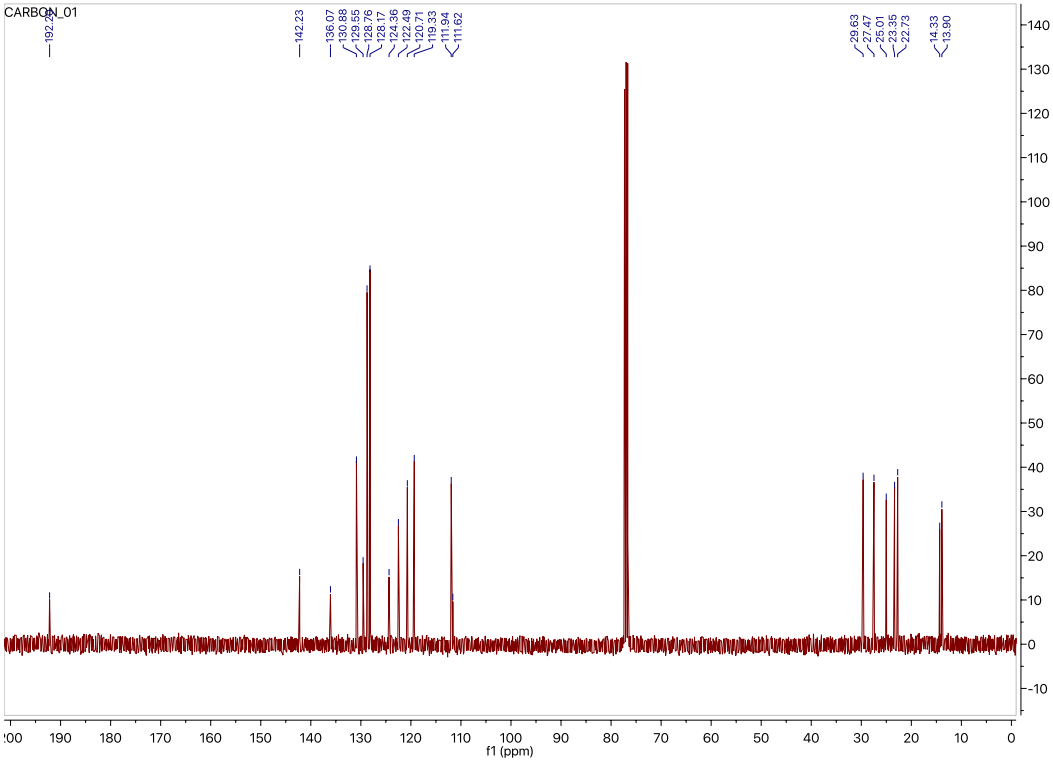
Compound 9ff



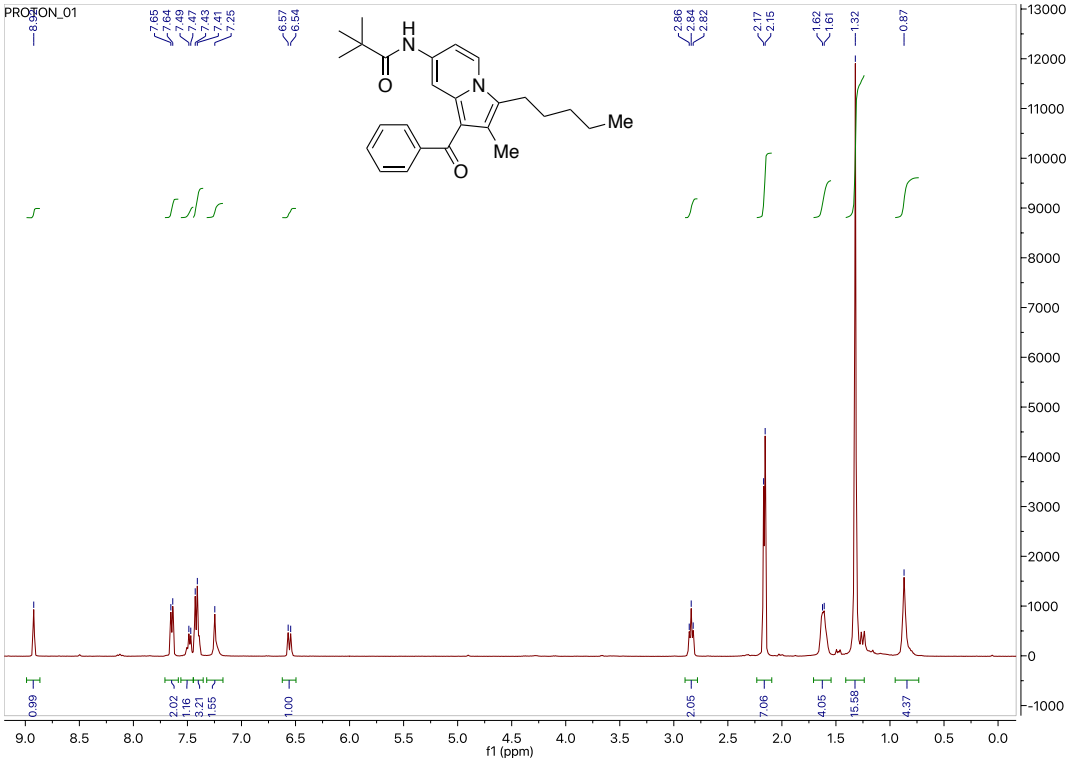


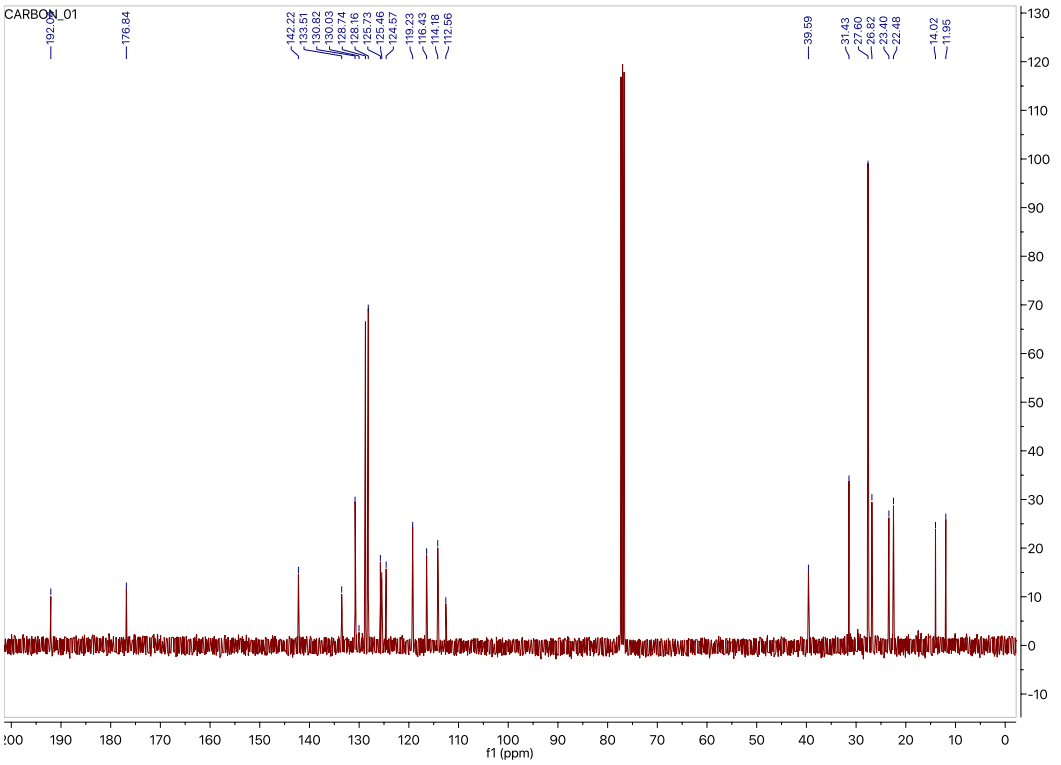
Compound 9g



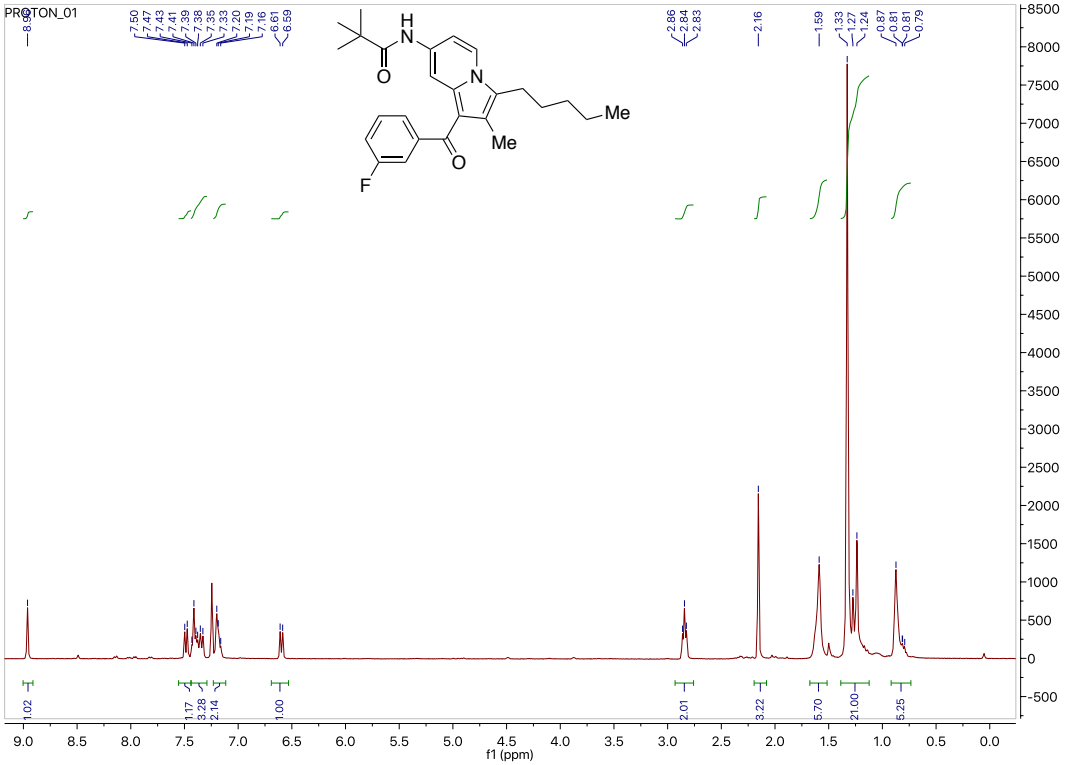


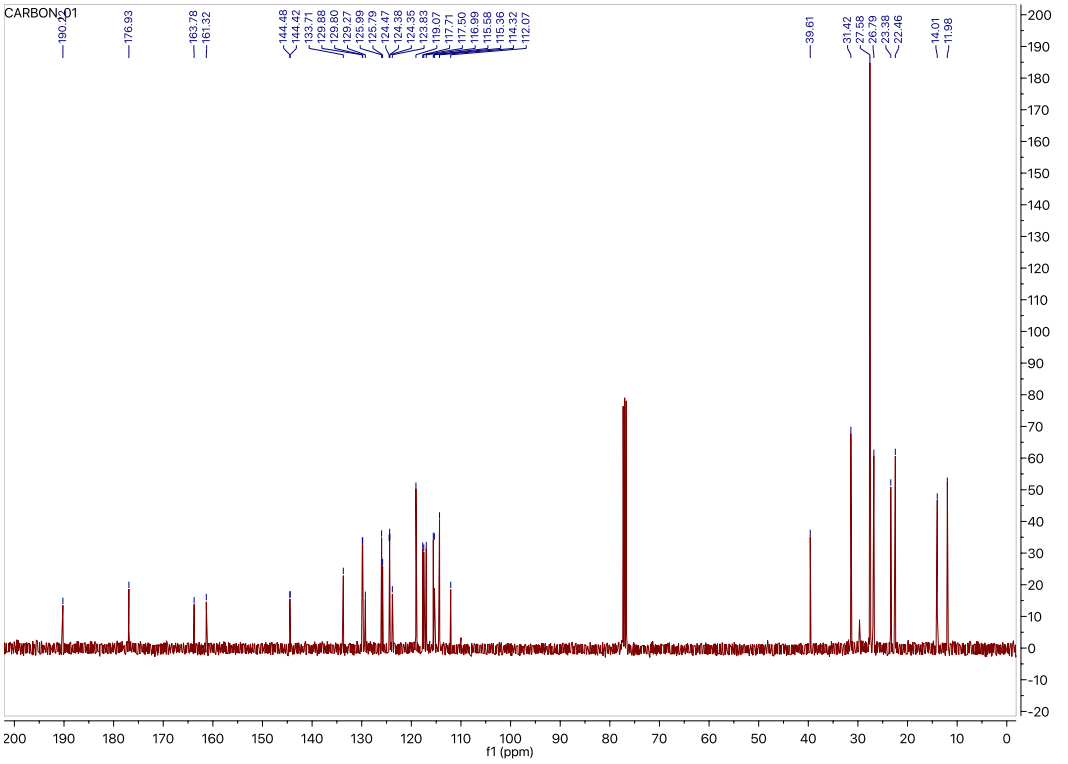
Compound 11c



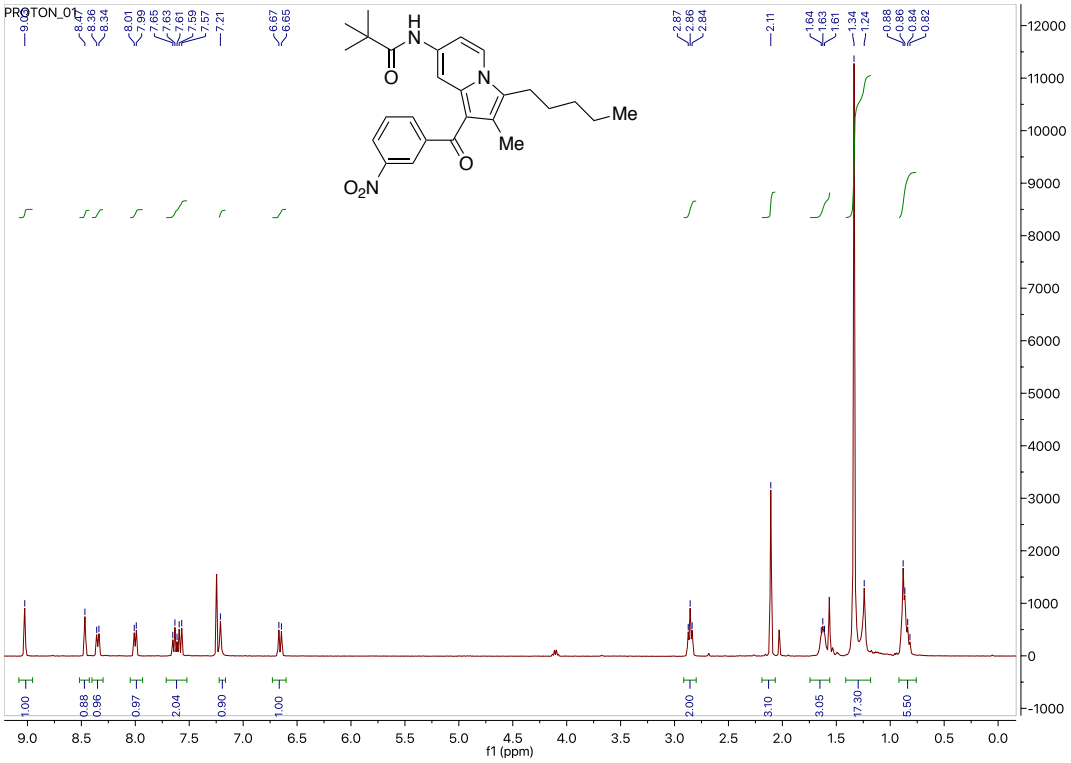


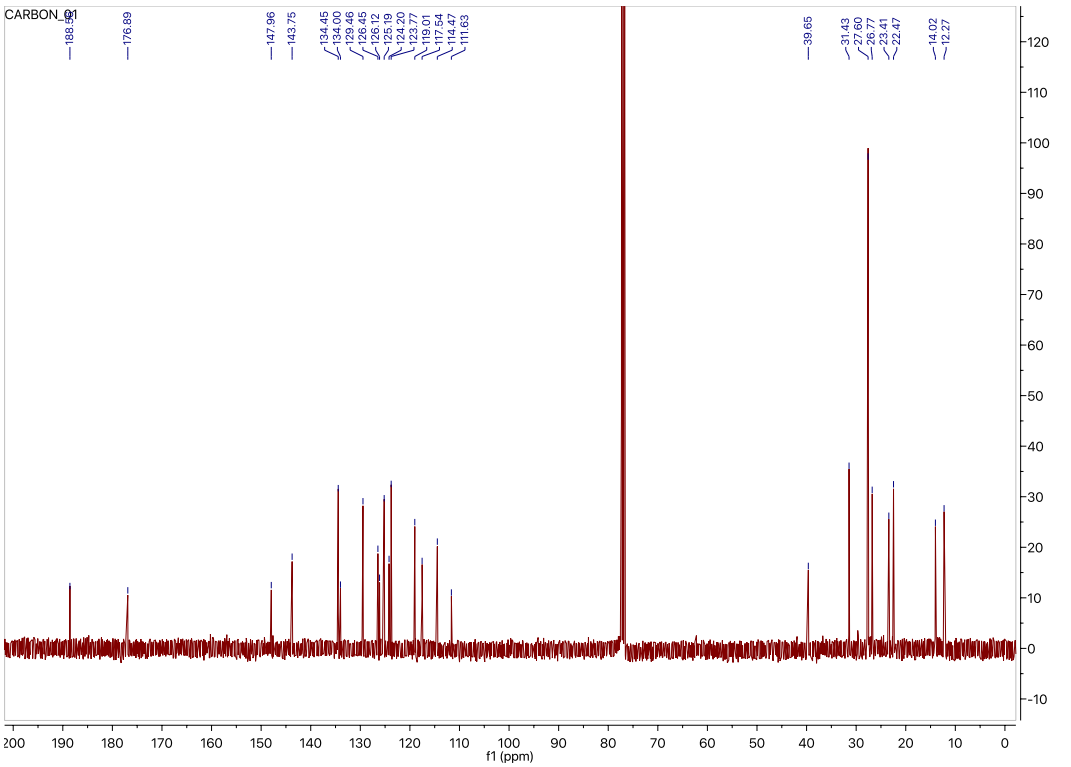
Compound 11cc



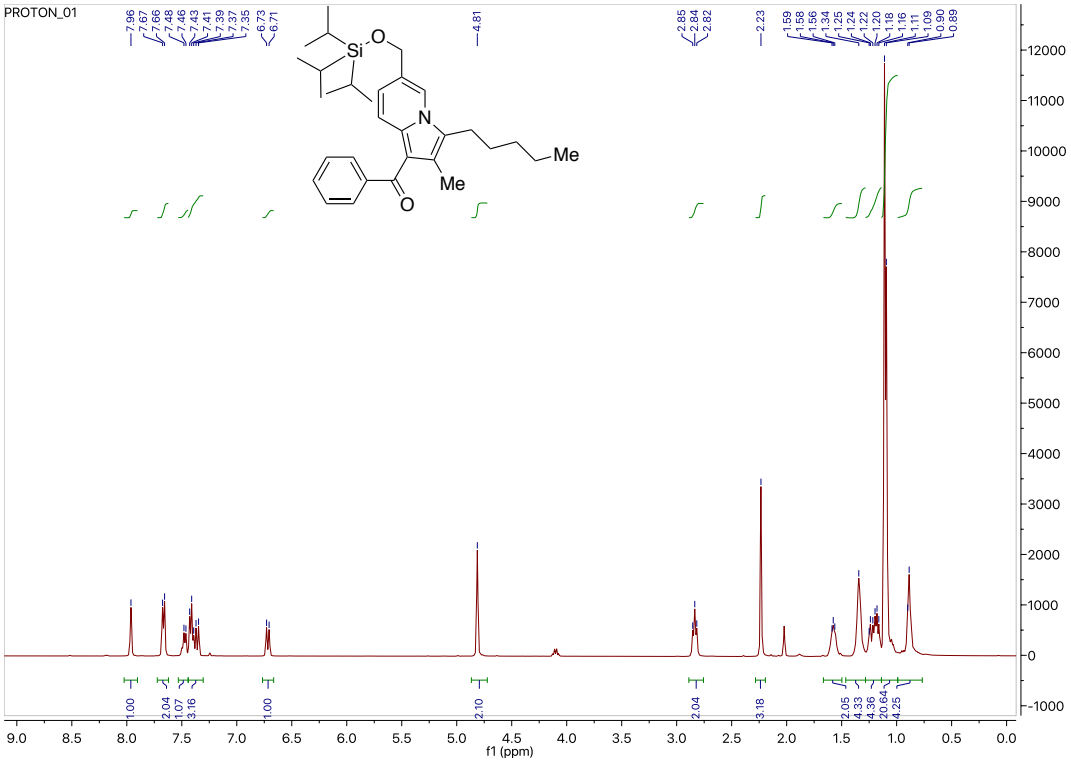


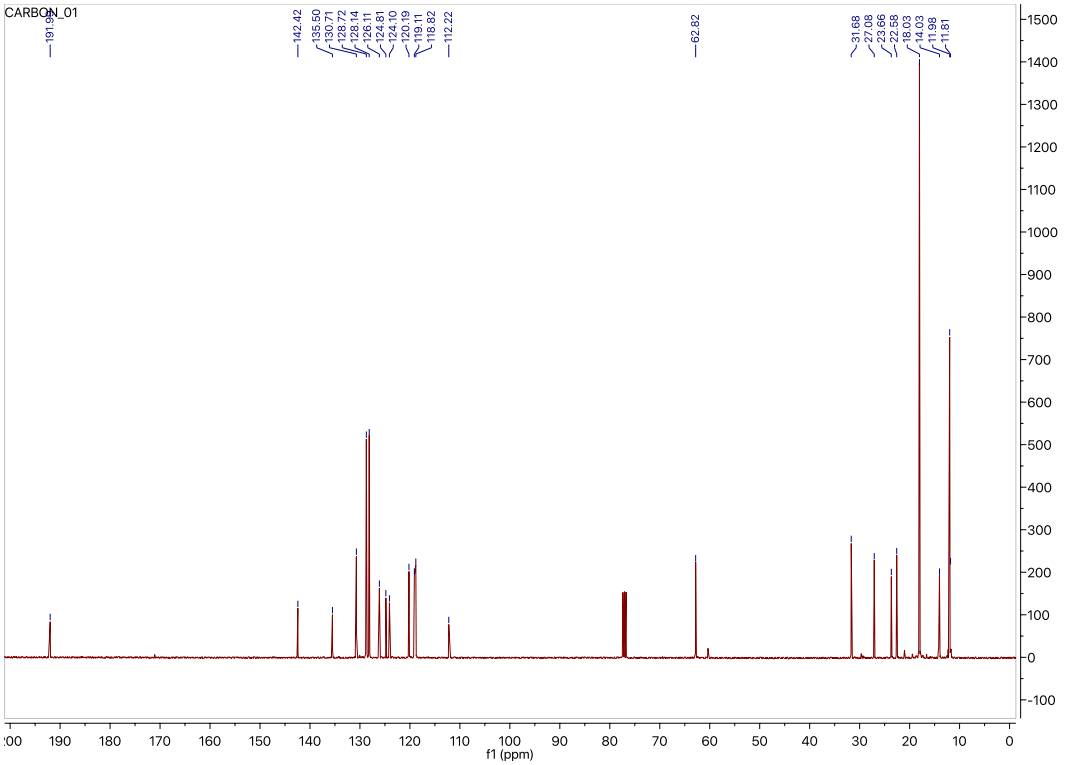
Compound 11ccc



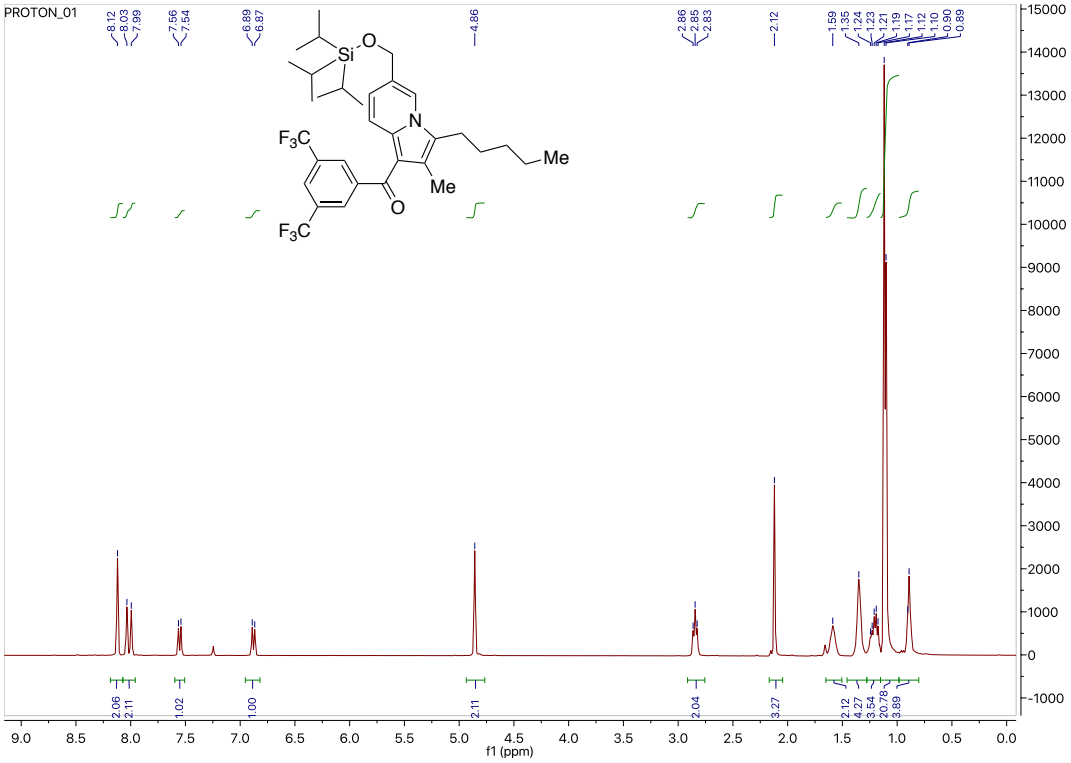


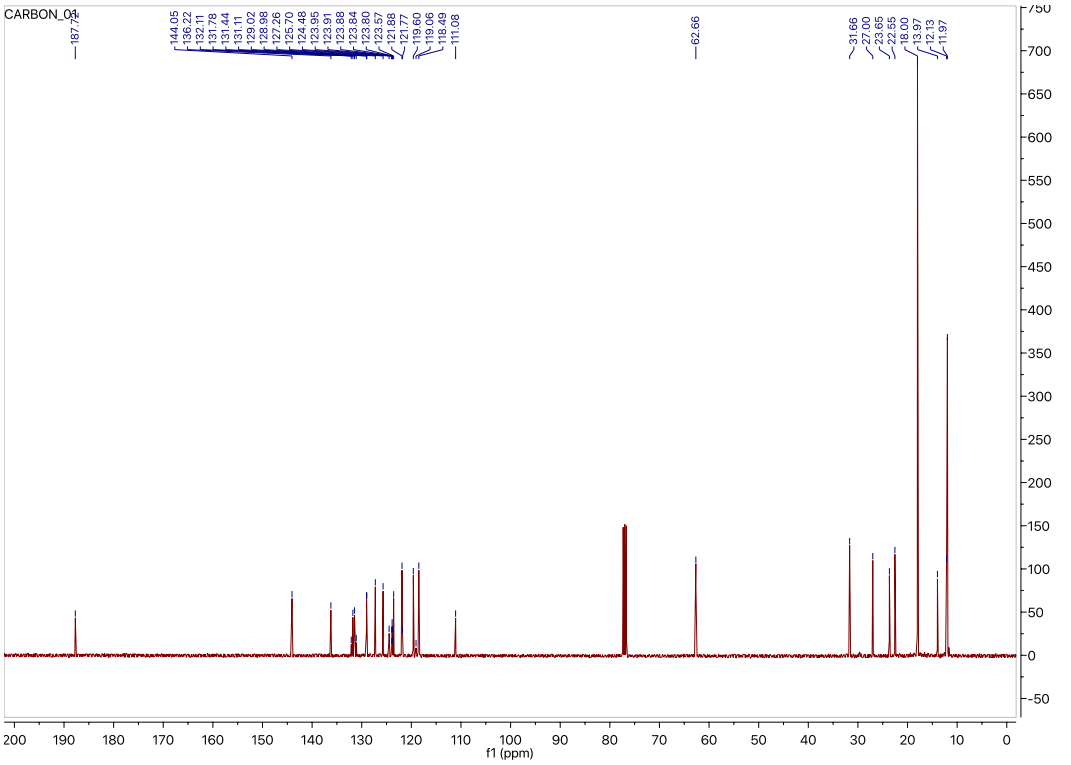
Compound 11d



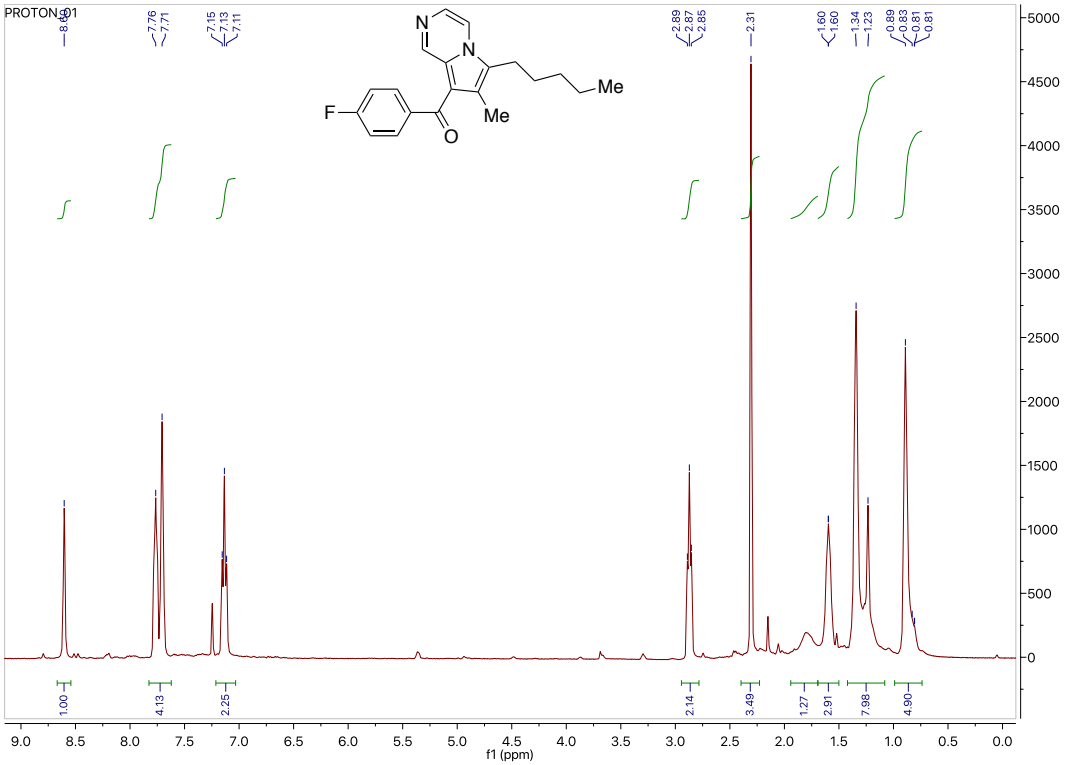


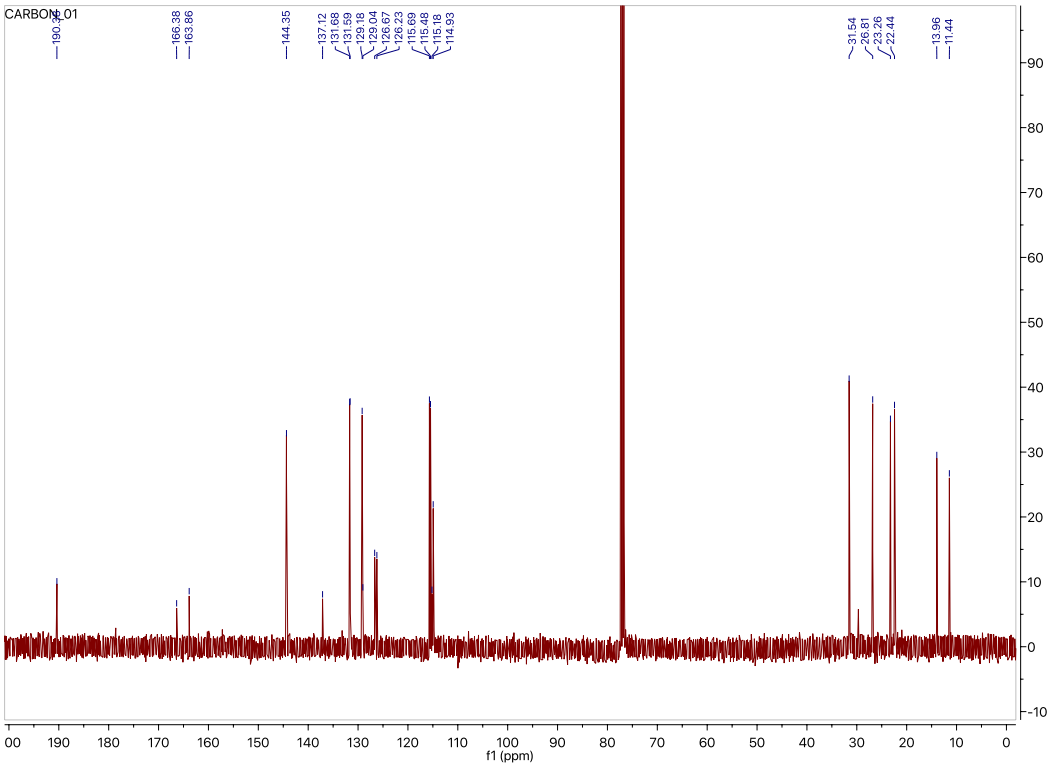
Compound 11dd



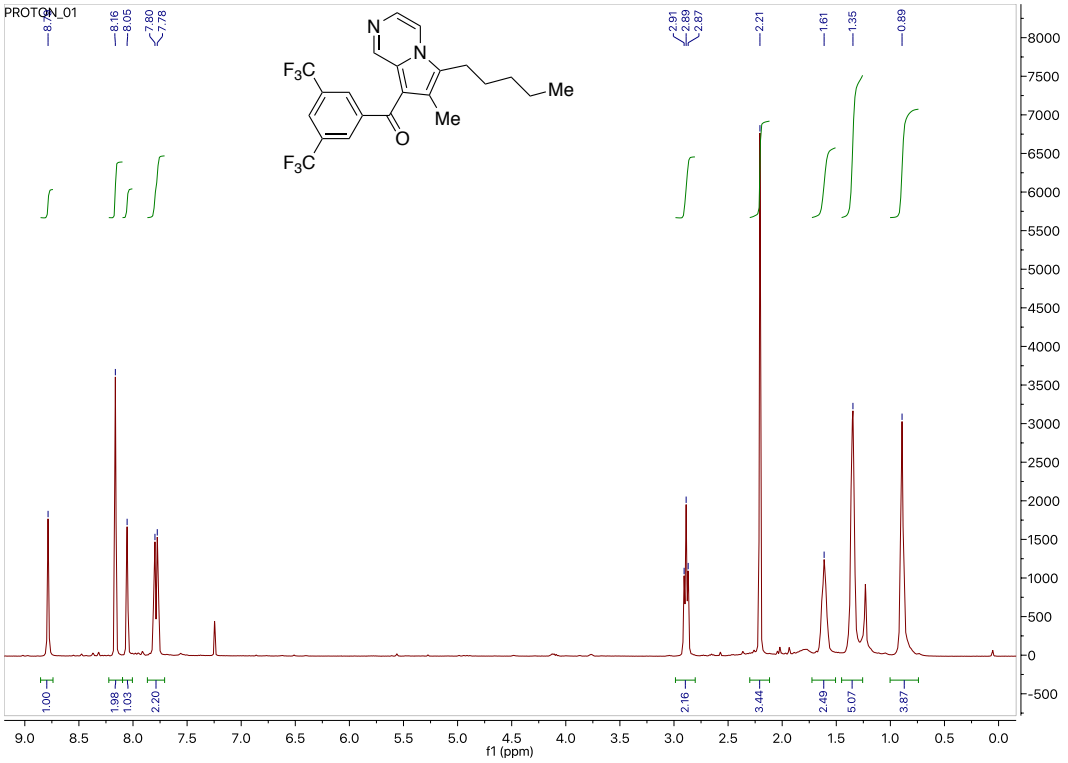


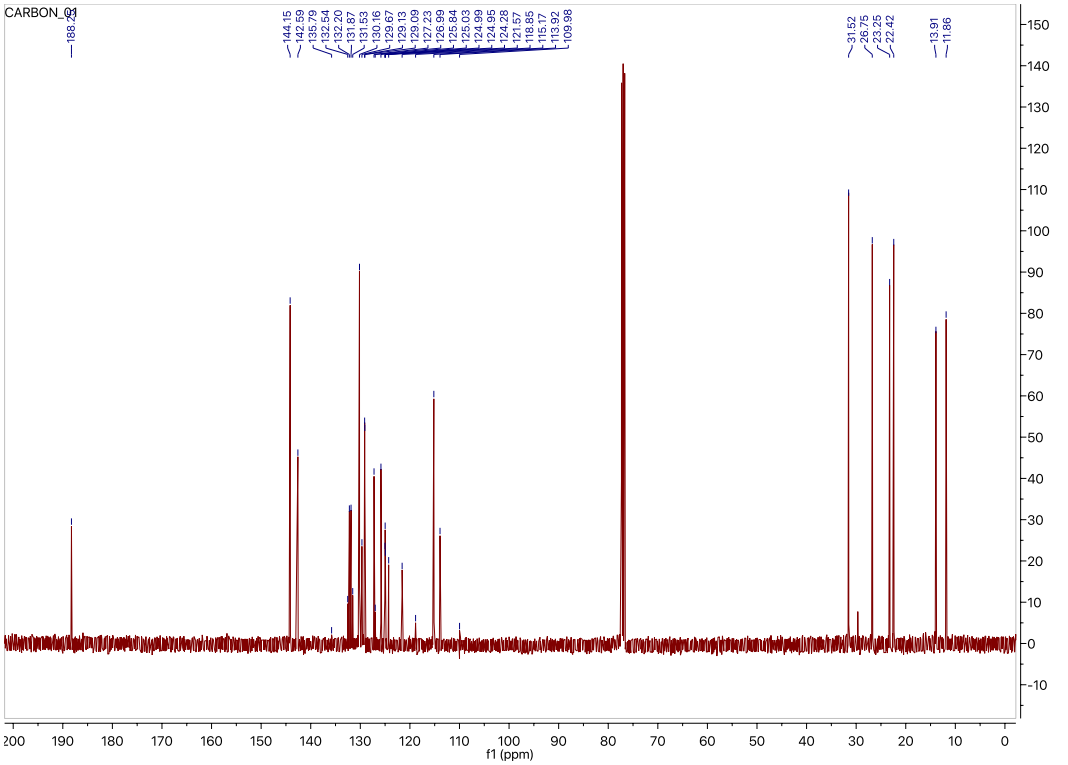
Compound 11e



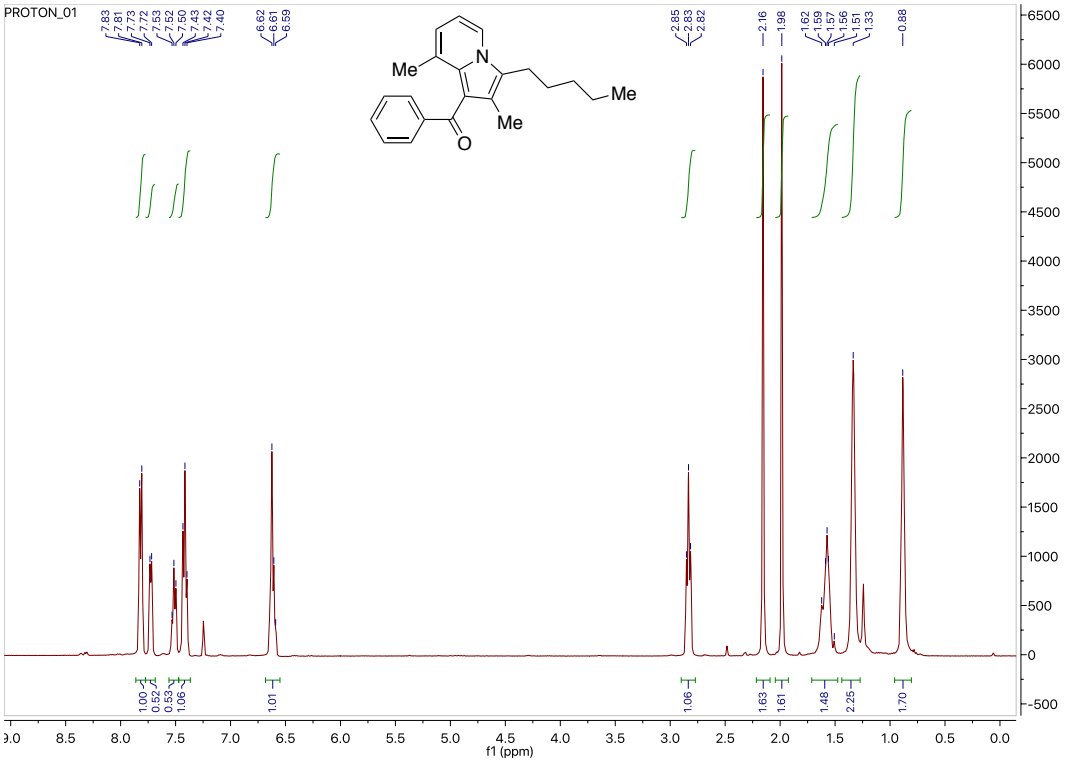


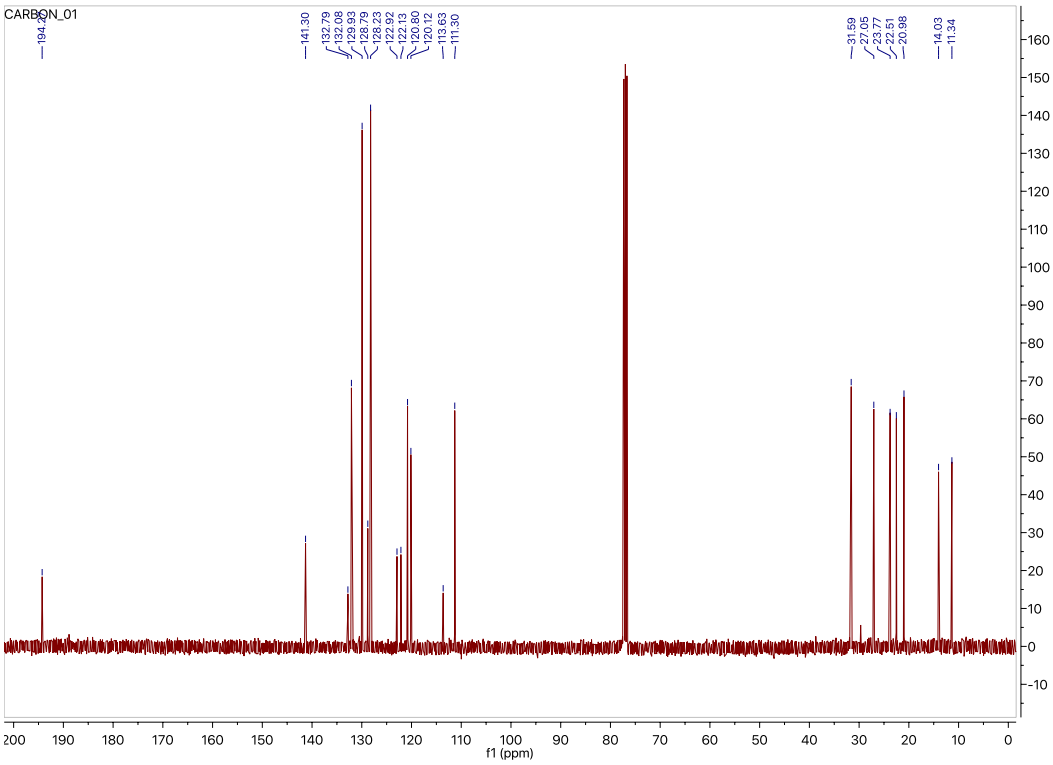
Compound 11ee



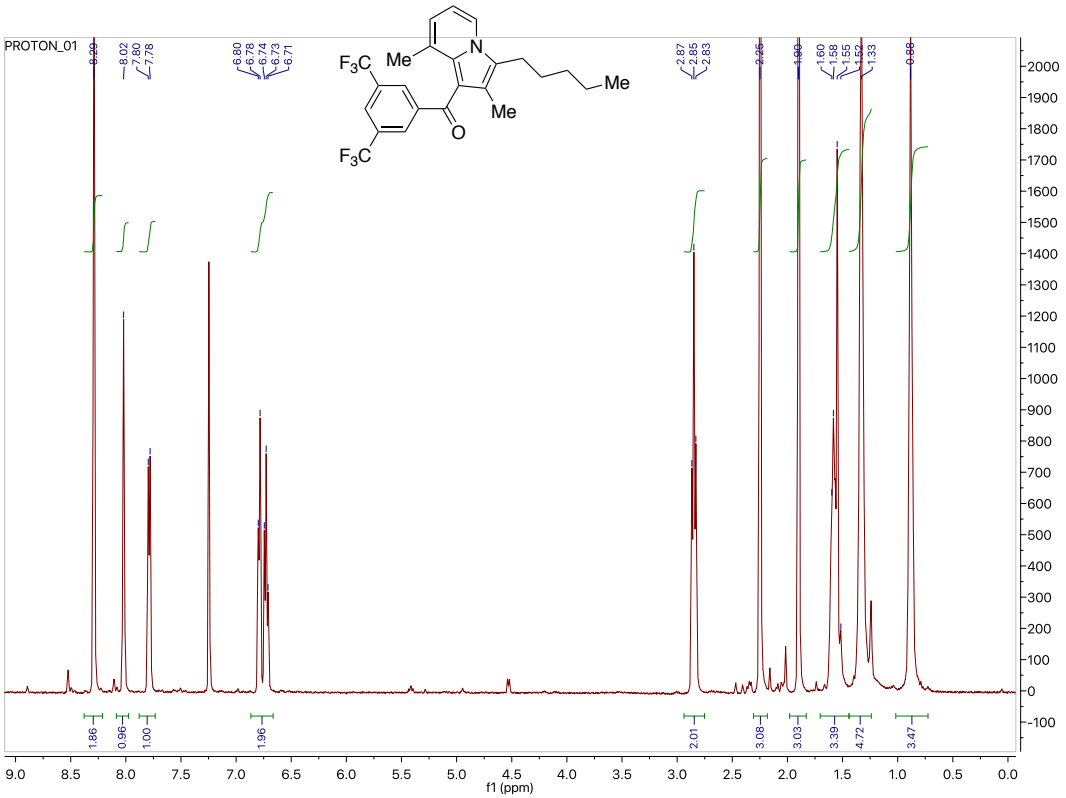


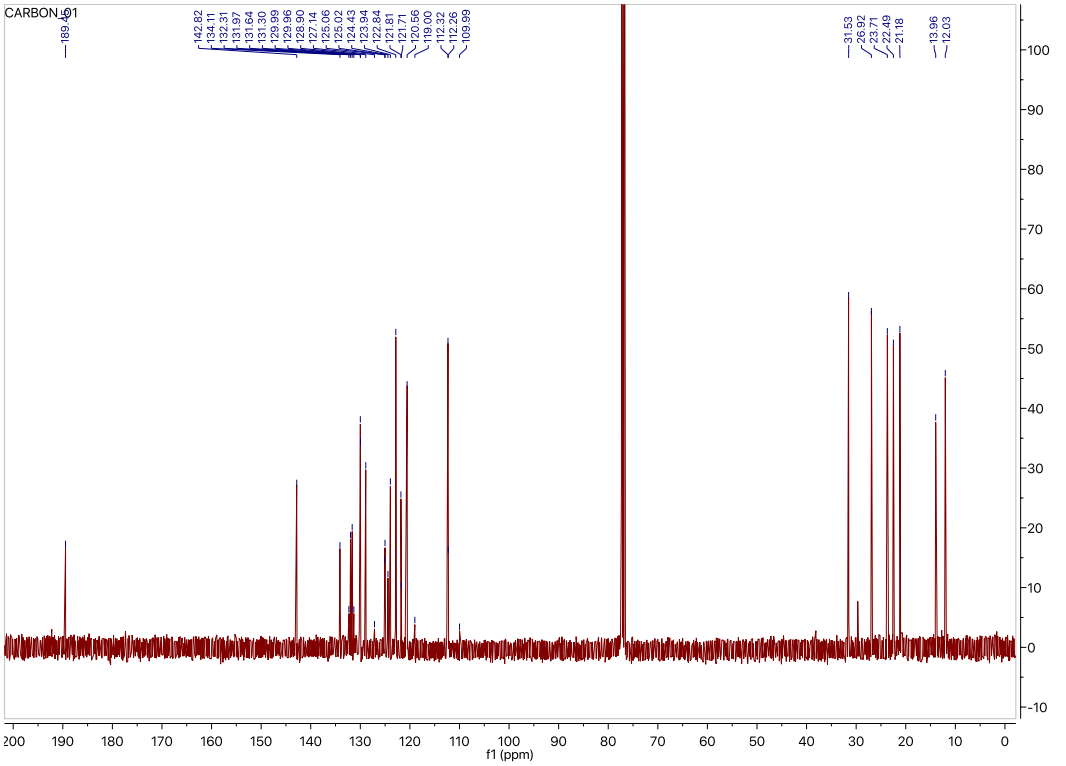
Compound 13


PROTON_01
7.83
7.81
7.73
7.72
7.53
7.52
7.50
7.43
7.42
7.40
6.62
6.61
6.59
2.85
2.83
2.82
2.16
1.98
1.62
1.59
1.57
1.56
1.51
1.33
0.88
Me
N
Me
Me
O
1.00
0.52
0.53
1.06
1.01
1.06
1.63
1.61
1.48
2.25
1.70
f1 (ppm)

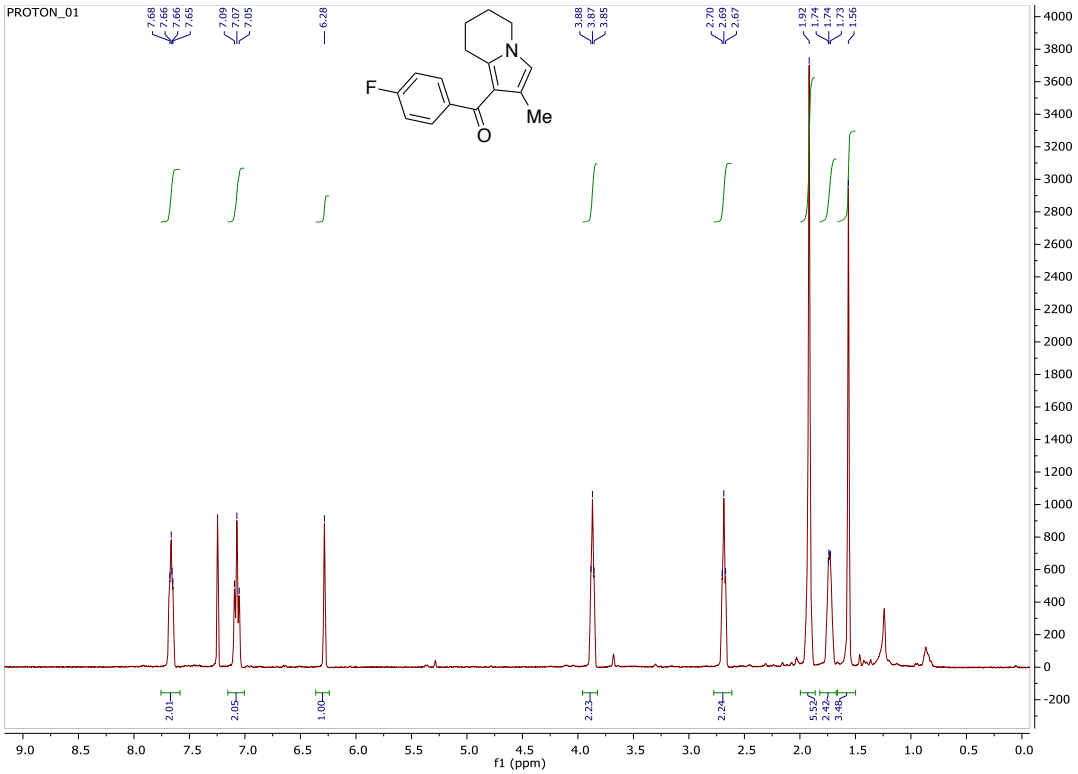

CARBON_01
194.42
141.30
132.79
132.08
129.93
128.79
128.23
122.92
122.73
120.80
120.12
113.63
111.30
31.59
27.05
23.77
22.51
20.98
14.03
11.34
f1 (ppm)

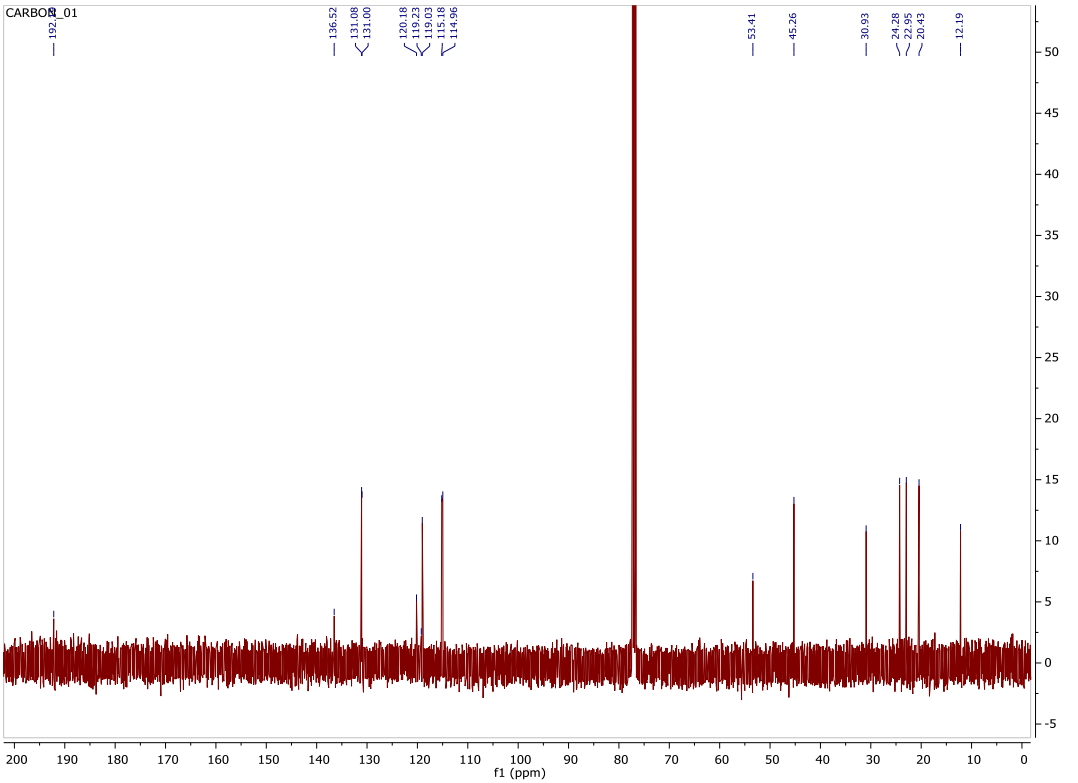
Compound 13a





Compound 16


PROTON_01
7.68
7.66
7.66
7.65
7.09
7.07
7.05
6.28
3.88
3.87
3.85
2.70
2.69
2.67
1.92
1.74
1.74
1.73
1.56
F
N
Me
O
2.01
2.05
1.00
2.23
2.24
5.52
2.42
3.48
f1 (ppm)


CARBON_01
192.1
136.52
131.08
131.00
120.18
119.23
119.03
115.18
114.96
53.41
45.26
30.93
24.28
22.95
20.43
12.19
f1 (ppm)