Supplementary Material (ESI) for Chemical Communications

Supporting Information

Palladium-Catalyzed Direct Arylations of Electron-Deficient Heteroaryl *N*-Oxides with Moisture-Stable Aryl Tosylates and Mesylates

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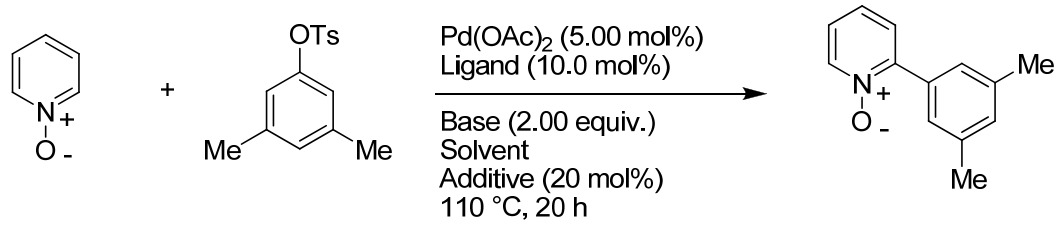
General remarks:

Catalytic reactions were carried out on a 0.5 mmol scale under a N_2 atmosphere using pre-dried glassware. The following starting materials were synthesized according to previously described methods: sulfonates **2**[1] and azine *N*-oxides **1**.[2] Other chemicals were obtained from commercial sources, and were used without further purification. Toluene was dried over sodium or with a SPS solvent purification system MBraun. *t*BuOH was first degassed then dried over sodium and distilled under N_2. Yields refer to isolated compounds, estimated to be > 95 % pure as determined by ^{1}H-NMR analysis. Flash chromatography: Merck silica gel 60 (230-400 mesh). NMR: Spectra were recorded on Varian-NMR *Mercury 300*, *Unity 300* and Varian-NMR *Inova 500* in the solvent indicated; chemical shifts (δ) are given in ppm.

Table 1: Palladium-Catalyzed Direct Arylations of Electron-Deficient Pyridine-*N*-Oxide **1a** with Aryl Tosylates **2a**: Optimization Studies[a]



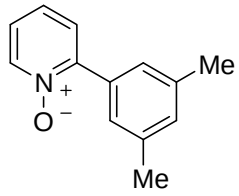
Entry	Ligand	Additive	Base	Solvent	Isolated Yield [%]
1	P(*t*-Bu)$_3$·HBF$_4$	-	K_2CO_3	PhMe	-[b]
2	P(*t*-Bu)$_3$·HBF$_4$	-	K_2CO_3	Dioxane	-[b]
3	Dave-Phos	-	K_2CO_3	PhMe	< 5[b]
4	X-Phos	-	K_2CO_3	PhMe	11
5	S-Phos	-	K_2CO_3	PhMe	< 5
6	X-Phos	-	K_2CO_3	PhMe/*t*-BuOH (2:1)	33
7	X-Phos	-	K_2CO_3	DMF/*t*-BuOH (2:1)	9[c]
8	X-Phos	*t*-BuCO$_2$H	K_2CO_3	PhMe /*t*-BuOH (2:1)	26
9	X-Phos	-	K_2CO_3	PhMe /*t*-BuOH (2:1)	<[d]
10	X-Phos	-	K_2CO_3	Dioxane/t-BuOH (2:1)	<[e]
11	X-Phos	-	K_2CO_3	*o*-Xylene/*t*-BuOH (2:1)	<
12	X-Phos	-	K_2CO_3	DMA/*t*-BuOH (2:1)	<
13	X-Phos	-	K_2CO_3	NMP/*t*-BuOH (2:1)	<
14	X-Phos	-	K_2CO_3	DMSO/*t*-BuOH (2:1)	<
15	X-Phos	-	Na_2CO_3	PhMe/*t*-BuOH (2:1)	<
16	X-Phos	-	K_3PO_4	PhMe/*t*-BuOH (2:1)	19
17	X-Phos	-	Cs_2CO_3	PhMe/*t*-BuOH (2:1)	51
18	X-Phos		Rb_2CO_3	PhMe/*t*-BuOH (2:1)	62

Entry	Ligand	Additive	Base	Solvent	Isolated Yield [%]
19	X-Phos	-	KO*t*-Bu	PhMe/*t*-BuOH (2:1)	11
20	X-Phos	-	NaO*t*-Bu	PhMe/*t*-BuOH (2:1)	63
21	X-Phos	-	NaO*t*-Bu	*o*-xylene/*t*-BuOH (2:1)	18
22	X-Phos	-	CsF	PhMe/*t*-BuOH (2:1)	64
23	X-Phos	-	EtN(*i*Pr)$_2$	PhMe/*t*-BuOH (2:1)	<
24	X-Phos	-	LiO*t*-Bu	PhMe/*t*-BuOH (2:1)	41
25	X-Phos	-	NaO*t*-Bu	DMF/*t*BuOH (2:1)	<
26	X-Phos	*t*-BuCO$_2$H	Rb$_2$CO$_3$	PhMe/*t*-BuOH (2:1)	68
27	X-Phos	*t*-BuCO$_2$H	CsF	PhMe/*t*-BuOH (2:1)	62
28	X-Phos	-	CsF	PhMe/*t*-BuOH (2:1)	<[f]
29	PPh$_3$	-	CsF	PhMe/*t*-BuOH (2:1)	-
30	HIPrCl	-	CsF	PhMe/*t*-BuOH (2:1)	-
31	X-Phos	-	CsF	PhMe/*t*-BuOH (2:1)	56[g]
32	X-Phos	-	CsF	*o*-xylene/*t*-BuOH (2:1)	30[h]
33	PCy$_3$	-	CsF	PhMe/*t*-BuOH (2:1)	-
34	Dave-Phos	-	CsF	PhMe/*t*-BuOH (2:1)	< 5
35	S-Phos	-	CsF	PhMe/*t*-BuOH (2:1)	< 5

[a] Reaction conditions: **1a** (2.00 mmol), **2a** (0.50 mmol), Pd(OAc)$_2$ (5.00 mol%), ligand (10.0 mol%), base (1.00 mmol), *t*-BuCO$_2$H (20 mol%), solvent (3.00 mL), 110 °C, 20 h; [b] Ligand (15 mol%); [c] 130 °C; [d] 30 h; [e] 100 °C; [f] 80 °C; [g] **1** (2.00 Äq); [h] Reaction under microwave irradiation (170 °C, 20 min.).

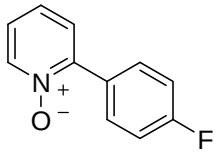
Representative Procedure A: Palladium-Catalyzed Direct Arylations of Electron-Deficient Heteroaryl *N*-Oxides 1 with Moisture-Stable Aryl Tosylates 2 or Mesylates 5.

2-(3,5-Dimethylphenyl)pyridine-1-oxide 3aa (Scheme 1): $Pd(OAc)_2$ (5.60 mg, 0.025 mmol, 5.00 mol%), X-Phos (**4**) (23.8 mg, 0.05 mmol, 10.0 mol%), CsF (152 mg, 1.00 mmol,) 3,5-dimethyl-phenyl-4-methylbenzenesulfonate (**2a**) (138 mg, 0.50 mmol) and pyridine-*N*-oxide (**1a**) (190 mg, 2.00 mmol) in dry toluene (2.0 mL) and dry *t*-BuOH (1.0 mL) were stirred at 110 °C for 20 h and then allowed to cool to ambient temperature. The reaction mixture was diluted with CH_2Cl_2, filtered over Celite and concentrated *in vacuo*. The remaining residue was purified by column chromatography on silica gel (CH_2Cl_2/acetone = 1/1 → CH_2Cl_2/acetone/MeOH = 86/86/1) to yield **3aa** (64 mg, 64 %) as a yellow oil.



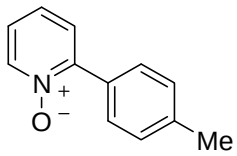
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.30 (ddd, *J* = 6.3, 1.4, 0.5 Hz, 1H), 7.41 – 7.32 (m, 3H), 7.25 (td, *J* = 7.7, 1.4 Hz, 1H), 7.18 (ddd, *J* = 7.5, 6.4, 2.3 Hz, 1H), 7.09 – 7.04 (m, 1H), 2.35 (s, 6H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ = 149.6 (C_q), 140.3 (CH), 137.7 (C_q), 132.5 (C_q), 131.2 (CH), 127.3 (CH), 126.8 (CH), 125.4 (CH), 124.2 (CH), 21.4 (CH_3). IR (film): 3395, 3074, 2947, 2361, 1602, 1406, 1257, 875, 697 cm^{-1}. MS (EI) *m/z* (relative intensity) 199 ([M^+] 63), 170 (100), 130 (39), 78 (51), 58 (47). HR-MS (EI) *m/z* calcd for $C_{13}H_{13}NO$ 199.0997, found 199.0991.

The spectral data were in accordance with those reported in the literature.[3]



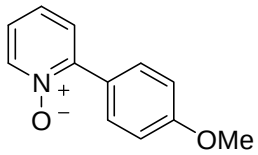
2-(4-Fluorophenyl)pyridine-1-oxide (3ab) (Scheme 2): The representative procedure was followed, using 4-fluoro-phenyl-4-methylbenzenesulfonate (133 mg, 0.50 mmol) and pyridine-1-oxide (**1a**) (195 mg, 2.05 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 1/1 → CH_2Cl_2/acetone/MeOH = 86/86/1) yielded **3ab** (57 mg, 60 %) as a light yellow solid.

m.p. = 161-163 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.32 (dd, J = 6.5, 1.2 Hz, 1H), 7.90 – 7.78 (m, 2H), 7.41 (dd, J = 7.8, 2.2 Hz, 1H), 7.36 – 7.08 (m, 4H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ =163.5 (C_q, J = 250 Hz), 148.5 (C_q), 140.8 (CH), 131.6 (CH, J = 9 Hz), 128.8 (C_q, J = 4 Hz), 127.4 (CH), 125.9 (CH), 124.8 (CH), 115.6 (CH, J = 22 Hz). ^{19}F-NMR (125 MHz, $CDCl_3$): δ = -110.7 (tt, J = 9, 6 Hz). IR (KBr): 3064, 3041, 2463, 1916, 1595, 1247, 1018, 760, 572 cm^{-1}. MS (EI) *m/z* (relative intensity) 189 ([M$^+$] 71), 188 (100), 160 (18), 133 (13), 78 (4). HR-MS (EI) *m/z* calcd for $C_{11}H_8FNO$ 189.0590, found 189.0583.



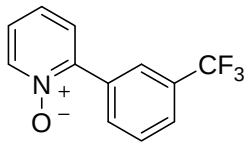
2-(4-Methylphenyl)pyridine-1-oxide (3ac) (Scheme 2): The representative procedure was followed, using 4-methyl-phenyl-4-methylbenzenesulfonate (131 mg, 0.50 mmol) and pyridine-1-oxide (**1a**) (200 mg, 2.10 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 1/1 → CH_2Cl_2/acetone/MeOH = 68/68/1) yielded **3ac** (54 mg, 58%) as a pale yellow solid.

m.p. = 132-133 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.32 (dd, J = 6.4, 0.9 Hz, 1H), 7.71 (d, J = 8.2 Hz, 2H), 7.41 (dd, J = 7.8, 2.0 Hz, 1H), 7.34 – 7.24 (m, 3H), 7.19 (m, 1H), 2.40 (s, 3H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 149.3 (C_q), 140.4 (CH), 139.7 (C_q), 129.7 (C_q), 129.1 (CH), 128.9 (CH), 127.2 (CH), 125.6 (CH), 124.2 (CH), 21.4 (CH_3). IR (KBr): 3066, 3043, 2915, 1614, 1430, 1240, 1010, 816, 760 cm^{-1}. MS (EI) *m/z* (relative intensity) 185 ([M^+] 71), 184 (100), 156 (45), 117 (20), 78 (16). HR-MS (EI) *m/z* calcd for $C_{12}H_{11}NO$ 185.0841, found 185.0835.
The spectral data were in accordance with those reported in the literature.[3]

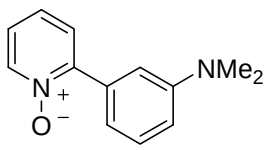


2-(4-Methoxyphenyl)pyridine-1-oxide (3ad) (Scheme 2): The representative procedure was followed, using 4-methoxy-phenyl-4-methylbenzenesulfonate (139 mg, 0.50 mmol) and pyridine-1-oxide (**1a**) (190 mg, 2.00 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 1/1 → CH_2Cl_2/acetone/MeOH = 86/86/1) yielded **3ad** (52 mg, 52 %) as a yellow solid.
m.p. = 136-137 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.29 (ddd, J = 6.4, 1.3, 0.5 Hz, 1H), 7.85 – 7.75 (m, 2H), 7.40 (m, 1H), 7.25 (td, J = 7.7, 1.4 Hz, 1H), 7.15 (ddd, J = 7.5, 6.5, 2.2 Hz, 1H), 7.02 – 6.93 (m, 2H), 3.83 (s, 3H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 160.4 (C_q), 148.8 (C_q), 140.4 (CH), 130.7 (CH), 126.8 (CH), 125.5 (CH), 124.7 (C_q), 123.8 (CH), 113.6 (CH), 55.4 (CH_3). IR (KBr): 3102, 3057, 2935, 2841, 1608, 1435, 1243, 830, 761 cm^{-1}. MS (EI) *m/z* (relative intensity) 201 ([M^+] 100), 200 (92), 185 (38), 158 (25), 130 (24), 78 (15). HR-MS (EI) *m/z* calcd for $C_{12}H_{11}NO_2$ 201.0790, found 201.0783.

The spectral data were in accordance with those reported in the literature.[3]



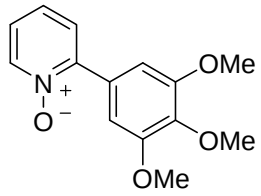
2-{3-(Trifluoromethyl)phenyl}pyridine-1-oxide (3ae) (Scheme 2): The representative procedure was followed, using 3-(trifluoromethyl)phenyl-4-methylbenzenesulfonate (158 mg, 0.50 mmol) and pyridine-1-oxide (**1a**) (189 mg, 2.00 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 2/1 → 1/1) yielded **3ae** (61 mg, 51 %) as a light brown oil. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.34 (m, 1H), 8.10 – 8.01 (m, 2H), 7.71 (m, 1H), 7.61 (m, 1H), 7.45 (dd, J = 7.8, 2.2 Hz, 1H), 7.38 – 7.24 (m, 2H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 147.7 (C_q), 140.5 (CH), 133.2 (C_q), 132.6 (CH), 130.7 (C_q, J = 33 Hz), 128.7 (CH), 127.2 (CH), 126.2 (CH, J = 4 Hz), 126.1 (CH, J = 4 Hz), 126.0 (C_q, J = 275 Hz), 125.1 (CH), 124.9 (CH). ^{19}F-NMR (125 MHz, $CDCl_3$): δ = - 62.7 (s). IR (film): 3402, 3076, 1482, 1337, 1241, 1126, 855, 770, 658 cm^{-1}. MS (EI) *m/z* (relative intensity) 239 ([M$^+$] 70), 238 (100), 190 (13), 117 (17), 78 (12). HR–MS (EI) *m/z* calcd for $C_{12}H_8F_3NO$ 239.0558, found 239.0550.



2-{3-(*N,N*-Dimethylamino)phenyl}pyridine-1-oxide (3af) (Scheme 2): The representative procedure was followed, using 3-(*N,N*-dimethylamino)phenyl-4-methylbenzenesulfonate (154 mg, 0.55

mmol) and pyridine-1-oxide (**1a**) (192 mg, 2.02 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 1/1 → CH_2Cl_2/acetone/MeOH = 70/70/1) yielded **3af** (59 mg, 50 %) as a brown oil.

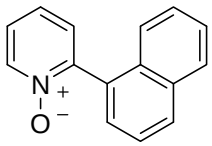
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.31 (dd, J = 6.4, 1.0 Hz, 1H), 7.41 (dd, J = 7.8, 2.1 Hz, 1H), 7.37 – 7.13 (m, 4H), 7.02 (m, 1H), 6.81 (ddd, J = 8.4, 2.7, 0.8 Hz, 1H), 2.97 (s, 6H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 150.3 (C_q), 150.2 (C_q), 140.4 (CH), 133.3 (C_q), 129.0 (CH), 127.5 (CH), 125.5 (CH), 124.2 (CH), 117.3 (CH), 113.8 (CH), 113.2 (CH), 40.6 (CH_3). IR (film): 3389, 3076, 2886, 2804, 1601, 1488, 1229, 850, 772 cm^{-1}. MS (EI) *m/z* (relative intensity) 214 ([M$^+$] 100), 199 (54), 171 (24), 117 (14), 78 (9). HR–MS (EI) *m/z* calcd for $C_{13}H_{14}N_2O$ 214.1106, 214.1098.



2-(3,4,5-Trimethoxyphenyl)pyridine-1-oxide (3ag) (Scheme 2): The representative procedure was followed, using 3,4,5-trimethoxyphenyl-4-methylbenzenesulfonate (169 mg, 0.50 mmol) and pyridine-1-oxide (**1a**) (195 mg, 2.05 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 1/1 → CH_2Cl_2/acetone/MeOH = 86/86/1) yielded **3ag** (88 mg, 67 %) as a light yellow solid.

m.p. = 142-144 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.31 (dd, J = 6.4, 1.3 Hz, 1H), 7.42 (dd, J = 7.8, 2.2 Hz, 1H), 7.29 (td, J = 7.7, 1.4 Hz, 1H), 7.21 (m, 1H), 7.05 (s, 2H), 3.89 (s, 9H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 153.0 (C_q), 149.1 (C_q), 140.5 (CH), 139.1 (C_q), 127.8 (C_q), 127.3 (CH), 125.7 (CH), 124.4 (CH), 106.7 (CH), 60.8 (CH_3), 56.2 (CH_3). IR (KBr): 3336, 3112, 2936, 2832, 2596, 1991, 1583, 1397, 1126, 772 cm^{-1}. MS (EI) *m/z*

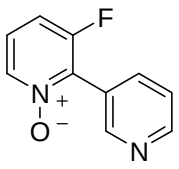
(relative intensity) 261 ([M^+] 83), 172 (66), 104 (90), 78 (100), 51 (50). HR-MS (EI) *m/z* calcd for $C_{14}H_{15}NO_4$ 261.1001, found 261.0999.



2-(Naphthalen-1-yl)pyridine-1-oxide (3ah) (Scheme 2): The representative procedure was followed, using naphthalen-1-yl-4-methylbenzenesulfonate (149 mg, 0.50 mmol) and pyridine-1-oxide (**1a**) (191 mg, 2.00 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 1/1 → CH_2Cl_2/acetone/MeOH = 86/86/1) yielded **3ah** (66 mg, 60 %) as a beige solid.

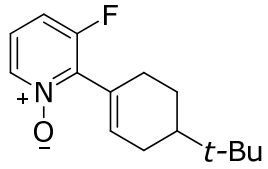
m.p. = 161-162 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.43 (m, 1H), 7.97 (dd, *J* = 8.0, 1.3 Hz, 1H), 7.91 (m, 1H), 7.63 – 7.31 (m, 8H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 149.7 (C_q), 140.3 (CH), 133.4 (C_q), 131.1 (C_q), 130.8 (C_q), 130.1 (CH), 128.8 (CH), 128.5 (CH), 127.7 (CH), 126.8 (CH), 126.2 (CH), 125.3 (CH), 125.2 (CH). IR (KBr): 3418, 3059, 2473, 1977, 1550, 1423, 1243, 966, 778, 494 cm^{-1}. MS (EI) *m/z* (relative intensity) 221 ([M^+] 71), 204 (100), 193 (89), 115 (58), 83 (72). HR-MS (EI) *m/z* calcd for $C_{15}H_{11}NO$ 221.0841, found 221.0834.

The spectral data were in accordance with those reported in the literature.[3]



3-Fluoro-2-(pyrid-3-yl)pyridine-1-oxide (3ai) (Scheme 2): The representative procedure was followed, using pyridin-3-yl-4-methylbenzenesulfonate (124 mg, 0.50 mmol) and 3-fluoropyridine-*N*-oxide (**1b**) (226 mg, 2.00 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 1/1 → acetone/MeOH = 10/1) yielded **3ai** (61 mg, 64 %) as an orange solid.

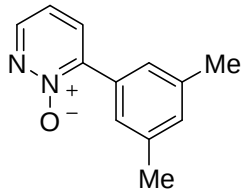
m.p. = 139-142 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.83 (s, 1H), 8.69 (dd, J = 4.9, 1.6 Hz, 1H), 8.23 (dt, J = 6.5, 1.1 Hz, 1H), 8.07 (m, 1H), 7.45 (ddd, J = 8.0, 4.9, 0.8 Hz, 1H), 7.33 – 7.12 (m, 2H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 158.3 (C_q, J = 253 Hz), 150.6 (CH), 150.5 (CH, J = 4 Hz), 137.9 (CH, J = 2 Hz), 137.6 (C_q, J = 25 Hz), 136.7 (CH), 124.3 (CH, J = 11 Hz), 123.0 (CH), 122.9 (C_q, J = 3 Hz), 113.5 (CH, J = 23 Hz). ^{19}F-NMR (282 MHz, $CDCl_3$): δ = - 116.5 (m). IR (KBr): 3045, 2855, 1570, 1408, 1235, 1035, 786, 622 cm^{-1}. MS (EI) *m/z* (relative intensity) 190 ([M^+] 8), 174 (100), 148 (39), 122 (11), 97 (12), 51 (12). HR-MS (EI) *m/z* calcd for $C_{10}H_7FN_2O+H^+$ 191.0615, found 191.0623.



2-(4-*t*-Butylcyclohex-1-enyl)-3-fluoropyridine-1-oxide (3aj) (Scheme 2): The representative procedure was followed, using 4-*t*-butylcyclohex-1-enyl-4-methylbenzene-sulfonate (154 mg, 0.50 mmol) and 3-fluoropyridine-*N*-oxide (**1b**) (226 mg, 2.00 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 1/1) yielded **3aj** (97 mg, 78 %) as a light yellow solid.

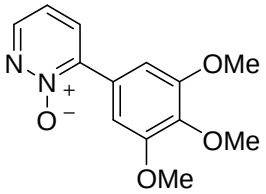
m.p. = 144-145 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.06 (m, 1H), 7.16 – 6.89 (m, 2H), 5.96 (d, J = 2.7 Hz, 1H), 2.47 – 2.36 (m, 2H), 2.25 (m, 1H), 2.11 – 1.83 (m, 2H), 1.59 – 1.29 (m, 2H),

0.89 (s, 9H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 157.9 (C_q, J = 249 Hz), 143.0 (C_q, J = 27 Hz), 136.2 (CH, J = 4 Hz), 133.8 (CH, J = 3 Hz), 125.8 (C_q, J = 2 Hz), 122.5 (CH, J = 10 Hz), 113.1 (CH, J = 23 Hz), 43.2 (CH), 32.3 (C_q), 27.1 (CH_2), 27.0 (CH_3), 26.6 (CH_2), 23.5 (CH_2). ^{19}F-NMR (282 MHz, $CDCl_3$): δ = -117.4 (t, J = 8 Hz). IR (KBr): 3045, 2869, 1550, 1479, 1366, 1228, 1031, 787 cm^{-1}. MS (EI) *m/z* (relative intensity) 249 ([M^+] 4), 176 (100), 148 (67), 111 (20), 57 (54). HR-MS (EI) *m/z* calcd for $C_{15}H_{20}FNO+H^+$ 250.1602, found 250.1604.



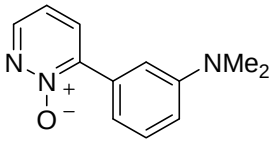
6-(3,5-Dimethylphenyl)pyridazine-1-oxide (3ak) (Scheme 3): The representative procedure was followed, using 3,5-methylphenyl-4-methylbenzenesulfonate (138 mg, 0.50 mmol) and pyridazine-1-oxide (96.5 mg, 1.00 mmol). After 20 h, purification by column chromatography (CH_2Cl_2 → CH_2Cl_2/acetone = 5/1) yielded **3ak** (74 mg, 74 %) as a light yellow solid.

m.p. = 141-142 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.40 (dd, J = 5.2, 2.4 Hz, 1H), 7.70 (dd, J = 7.9, 2.5 Hz, 1H), 7.36 (s, 2H), 7.08 (m, 2H), 2.35 (s, 6H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 148.9 (CH), 144.9 (C_q), 138.2 (C_q), 134.7 (CH), 131.8 (CH), 131.3 (C_q), 126.6 (CH), 116.1 (CH), 21.3 (CH_3). IR (KBr): 3105, 3062, 2918, 2858, 1600, 1360, 1135, 980, 813 cm^{-1}. MS (EI) *m/z* (relative intensity) 200 ([M^+] 100), 172 (57), 157 (32), 128 (33), 77 (12). HR-MS (EI) *m/z* calcd for $C_{12}H_{12}N_2O$ 200.0950, found 200.0942.



6-(3,4,5-Trimethylphenyl)pyridazine-1-oxide (3al) (Scheme 3): The representative procedure was followed, using 3,4,5-trimethoxyphenyl-4-methylbenzenesulfonate (169 mg, 0.50 mmol) and pyridazine-1-oxide (104 mg, 1.08 mmol). After 20 h, purification by column chromatography (CH_2Cl_2 → CH_2Cl_2/acetone = 10/1) yielded **3al** (90 mg, 69 %) as a white solid.

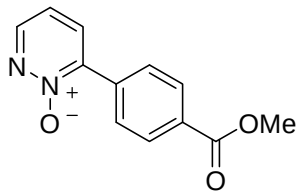
m.p. = 161-163°C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.41 (dd, J = 5.2, 2.5 Hz, 1H), 7.74 (dd, J = 8.0, 2.5 Hz, 1H), 7.11 (dd, J = 8.0, 5.2 Hz, 1H), 7.02 (s, 2H), 3.87 (s, 3H), 3.87 (s, 6H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 153.2 (C_q), 149.0 (CH), 144.3 (C_q), 139.7 (C_q), 134.6 (CH), 126.5 (C_q), 116.2 (CH), 106.5 (CH), 60.9 (CH_3), 56.3 (CH_3). IR (KBr): 3096, 2934, 2836, 1962, 1584, 1344, 1131, 908, 776 cm^{-1}. MS (EI) *m/z* (relative intensity) 262 ([M^+] 100), 247 (27), 215 (53), 204 (6), 173 (2). HR-MS (EI) *m/z* calcd for $C_{13}H_{14}N_2O_4$ 262.0954, found 262.0946.



6-(3-*N,N*-Dimethylphenyl)pyridazine-1-oxide (3am) (Scheme 3): The representative procedure was followed, using 3-(*N,N*-dimethylamino)phenyl-4-methylbenzenesulfonate (145 mg, 0.50 mmol) and pyridazine-1-oxide (95.1 mg, 0.99 mmol). After 20 h, purification by column chromatography (CH_2Cl_2 → CH_2Cl_2/acetone = 40/1 → 20/1 → 15/1) yielded **3am** (64 mg, 60 %) as a brown solid.

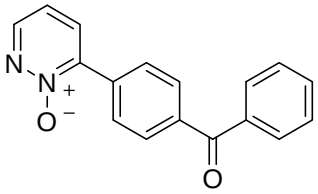
m.p. = 75-78 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.40 (dd, J = 5.2, 2.5 Hz, 1H), 7.73 (dd, J = 7.9, 2.5 Hz, 1H), 7.37 – 7.27

(m, 1H), 7.14 (dd, *J* = 2.5, 1.7 Hz, 1H), 7.08 (dd, *J* = 7.9, 5.2 Hz, 1H), 6.98 (ddd, *J* = 7.6, 1.6, 0.9 Hz, 1H), 6.81 (ddd, *J* = 8.4, 2.7, 0.8 Hz, 1H), 2.97 (s, 6H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 150.3 (C_q), 148.8 (CH), 145.3 (C_q), 134.7 (CH), 132.1 (C_q), 129.2 (CH), 116.8 (CH), 116.0 (CH), 114.1 (CH), 112.6 (CH), 40.6 (CH_3). IR (KBr): 3097, 3053, 2860, 2803, 2669, 1963, 1609, 1447, 868 cm^{-1}. MS (EI) *m/z* (relative intensity) 215 ([M$^+$] 100), 200 (58), 172 (20), 118 (20), 63 (9). HR-MS (EI) *m/z* calcd for $C_{12}H_{13}N_3O$ 215.1059, found 215.1052.



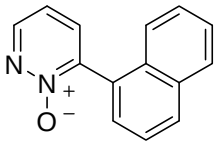
6-(4-Methoxycarbonylphenyl)pyridazine-1-oxide (3an) (Scheme 3): The representative procedure was followed, using methyl-4-(tosyloxy)benzoate (153 mg, 0.50 mmol) and pyridazine-1-oxide (95.1 mg, 0.99 mmol). After 20 h, purification by column chromatography (CH_2Cl_2) yielded **3an** (67 mg, 58 %) as a light yellow solid.

m.p. = 207-209 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.46 (dd, *J* = 5.2, 2.4 Hz, 1H), 8.19 – 8.06 (m, 2H), 7.91 – 7.82 (m, 2H), 7.77 (dd, *J* = 8.0, 2.5 Hz, 1H), 7.14 (dd, *J* = 8.0, 5.3 Hz, 1H), 3.93 (s, 3H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 166.2 (C_q), 149.7 (CH), 143.5 (C_q), 135.6 (C_q), 134.7 (CH), 131.5 (C_q), 129.7 (CH), 129.0 (CH), 116.2 (CH), 52.3 (CH_3). IR (film): 3064, 1725, 1545, 1377, 1278, 1113, 863, 773, 698 cm^{-1}. MS (EI) *m/z* (relative intensity) 230 ([M$^+$] 83), 229 (100), 199 (13), 142 (15), 63 (10). HR-MS (EI) *m/z* calcd for $C_{12}H_{10}N_2O_3$ 230.0691, found 230.0684.



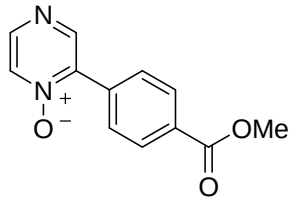
6-(4-Benzoylphenyl)pyridazine-1-oxide (3ao) (Scheme 3): The representative procedure was followed, using 4-benzoylphenyl-4-methylbenzenesulfonate (176 mg, 0.50 mmol) and pyridazine-1-oxide (94.6 mg, 0.98 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 20/1) yielded **3ao** (68 mg, 50 %) as a white solid.

m.p. = 149-151 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.48 (dd, J = 5.3, 2.5 Hz, 1H), 7.99 – 7.86 (m, 4H), 7.86 – 7.77 (m, 3H), 7.65 – 7.55 (m, 1H), 7.49 (ddt, J = 8.2, 6.6, 1.1 Hz, 2H), 7.17 (dd, J = 8.0, 5.3 Hz, 1H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 196.1 (C_q), 150.0 (CH), 143.8 (C_q), 139.1 (C_q), 137.3 (C_q), 135.2 (C_q), 135.0 (CH), 133.1 (CH), 130.3 (CH), 130.3 (CH), 129.2 (CH), 128.7 (CH), 116.6 (CH). IR (KBr): 3369, 3058, 2857, 2329, 1648, 1369, 1283, 988, 690 cm^{-1}. MS (EI) *m/z* (relative intensity) 276 ([M$^+$] 100), 219 (10), 143 (9), 105 (43), 77 (34). HR-MS (EI) *m/z* calcd for $C_{17}H_{12}N_2O_2$ 276.0899, found 276.0891.



6-(Naphtahalen-1-yl)pyridazine-1-oxide (3ap) (Scheme 3): The representative procedure was followed, using naphthalen-1-yl-4-methylbenzenesulfonate (149 mg, 0.50 mmol) and pyridazine-1-oxide (99.6 mg, 1.04 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 30/1 → 20/1) yielded **3ap** (80 mg, 71 %) as a brown solid.

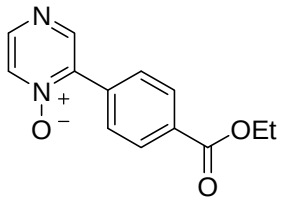
m.p. = 177-179 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.55 (dd, J = 5.2, 2.4 Hz, 1H), 7.97 (d, J = 8.1 Hz, 1H), 7.90 (dd, J = 7.0, 1.8 Hz, 1H), 7.73 (dd, J = 7.8, 2.5 Hz, 1H), 7.61 – 7.37 (m, 5H), 7.15 (dd, J = 7.8, 5.3 Hz, 1H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 150.0 (CH), 144.8 (C_q), 136.3 (CH), 133.4 (C_q), 130.7 (CH), 130.3 (C_q), 129.7 (C_q), 128.7 (CH), 127.8 (CH), 127.1 (CH), 126.5 (CH), 125.2 (CH), 124.7 (CH), 115.5 (CH). IR (KBr): 3097, 3054, 2674, 2165, 1948, 1586, 1370, 1047, 789 cm^{-1}. MS (EI) *m/z* (relative intensity) 222 ([M$^+$] 100), 205 (31), 194 (43), 140 (29), 63 (10). HR-MS (EI) *m/z* calcd for $C_{14}H_{10}N_2O$ 222.0793, found 222.0785.



2-(4-Methoxycarbonylphenyl)pyrazine-1-oxide (3aq) (Scheme 3): The representative procedure was followed, using methyl-4-(tosyloxy)benzoate (153 mg, 0.50 mmol) and pyrazine-1-oxide (96.5 mg, 1.00 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 6/1) yielded **3aq** (61 mg, 53 %) as a pale yellow solid.

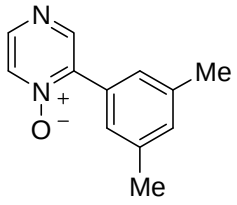
m.p. = 218-222 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.65 (s, 1H), 8.42 (d, J = 4.1 Hz, 1H), 8.24 – 8.14 (m, 3H), 7.93 – 7.86 (m, 2H), 3.95 (s, 3H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 166.2 (C_q), 148.3 (CH), 146.2 (CH), 143.7 (C_q), 134.5 (CH), 133.1 (C_q), 131.7 (C_q), 129.7 (CH), 129.2 (CH), 52.4 (CH_3). IR (KBr): 3070, 3013, 2576, 1922, 1719, 1454, 1286, 1108, 861 cm^{-1}. MS (EI) *m/z* (relative intensity) 230 ([M$^+$] 100), 202 (78), 183 (74), 143 (77), 75 (34). HR-MS (EI) *m/z* calcd for $C_{12}H_{10}N_2O_3$ 230.0691, found 230.0694.

The spectral data were in accordance with those reported in the literature.[2]



2-(4-Ethoxycarbonylphenyl)pyrazine-1-oxide (3ar) (Scheme 3): The representative procedure was followed, using ethyl-4-(tosyloxy)benzoate (160 mg, 0.50 mmol) and pyrazine-1-oxide (96.4 mg, 1.00 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 7/1) yielded **3ar** (69 mg, 57 %) as a pale yellow solid.

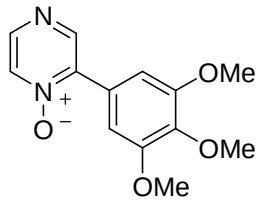
m.p. = 160-162 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.65 (s, 1H), 8.42 (d, J = 4.1 Hz, 1H), 8.26 – 8.10 (m, 3H), 7.93 – 7.85 (m, 2H), 4.41 (q, J = 7.1 Hz, 2H), 1.41 (t, J = 7.1 Hz, 3H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 165.8 (C_q), 148.3 (CH), 146.2 (CH), 143.8 (C_q), 134.5 (CH), 133.0 (C_q), 132.1 (C_q), 129.7 (CH), 129.1 (CH), 61.3 (CH_2), 14.3 (CH_3). IR (KBr): 3413, 3103, 2992, 1716, 1459, 1289, 1111, 1017, 863 cm^{-1}. MS (EI) *m/z* (relative intensity) 244 ([M$^+$] 100), 216 (31), 199 (53), 171 (59), 143 (36), 89 (14). HR-MS (EI) *m/z* calcd for $C_{13}H_{12}N_2O_3$ 244.0848, found 244.0840.



2-(3,5-Dimethylphenyl)pyrazine-1-oxide (3as) (Scheme 3): The representative procedure was followed, using 3,5-

dimethylphenyl-4-methylbenzenesulfonate (138 mg, 0.50 mmol) and pyrazine-1-oxide (96.9 mg, 1.01 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 1/2) yielded **3as** (52 mg, 51 %) as a yellow oil.

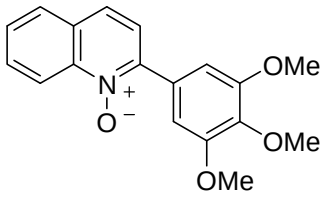
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.56 (s, 1H), 8.33 (d, J = 4.1 Hz, 1H), 8.17 (dd, J = 4.1, 0.7 Hz, 1H), 7.40 – 7.31 (m, 2H), 7.12 (ddd, J = 2.2, 1.5, 0.7 Hz, 1H), 2.37 (d, J = 0.6 Hz, 6H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 148.4 (CH), 145.3 (CH), 145.0 (C_q), 138.3 (C_q), 134.4 (CH), 132.1 (CH), 128.7 (C_q), 126.7 (CH), 21.3 (CH_3). IR (KBr): 3012, 2918, 1603, 1456, 1390, 1296, 888, 696 cm^{-1}. MS (EI) *m/z* (relative intensity) 200 ([M$^+$] 100), 171 (75), 132 (33), 88 (33), 47 (51). HR–MS (EI) *m/z* calcd for $C_{12}H_{12}N_2O$ 200.0950, found 200.0942.



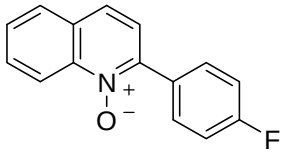
2-(3,4,5-Trimethoxyphenyl)pyrazine-1-oxide (3at) (Scheme 3): The representative procedure was followed, using 3,4,5-trimethoxyphenyl-4-methylbenzenesulfonate (169 mg, 0.50 mmol) and pyrazine-1-oxide (96.3 mg, 1.00 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 1/2) yielded **3at** (81 mg, 62 %) as an orange solid.

m.p. = 117-120 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.61 (s, 1H), 8.35 (d, J = 4.1 Hz, 1H), 8.17 (d, J = 4.1 Hz, 1H), 7.02 (s, 2H), 3.88 (s, 9H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 153.3 (C_q), 148.3 (CH), 145.3 (CH), 144.4 (C_q), 139.9 (C_q), 134.5 (CH), 124.0 (C_q), 106.6 (CH), 60.9 (CH_3), 56.3 (CH_3). IR (KBr): 3416, 3108, 2949, 2841, 2146, 1576, 1298, 1121, 837, 640 cm^{-1}. MS (EI) *m/z* (relative intensity) 262 ([M$^+$] 71), 247 (30), 215

(100), 173 (35), 105 (16). HR-MS (EI) *m/z* calcd for $C_{13}H_{14}N_2O_4$ 262.0954, found 262.0948.



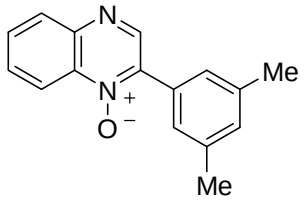
2-(3,4,5-Trimethoxyphenyl)quinoline-1-oxide (3au) (Scheme 3): The representative procedure was followed, using 3,4,5-trimethoxyphenyl-4-methylbenzenesulfonate (169 mg, 0.50 mmol) and quinoline-1-oxide (148 mg, 1.02 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 5/1) yielded **3au** (107 mg, 69 %) as an orange solid.
m.p. = 137-139 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.83 (d, J = 8.7 Hz, 1H), 7.91 – 7.67 (m, 3H), 7.63 (ddd, J = 8.1, 7.0, 1.2 Hz, 1H), 7.49 (d, J = 8.7 Hz, 1H), 7.23 (s, 2H), 3.90 (s, 9H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 153.0 (C_q), 144.8 (C_q), 142.3 (C_q), 139.2 (C_q), 130.6 (CH), 129.4 (C_q), 128.7 (C_q), 128.4 (CH), 127.9 (CH), 125.2 (CH), 123.3 (CH), 120.2 (CH), 107.2 (CH), 60.9 (CH_3), 56.3 (CH_3). IR (KBr): 2931, 1585, 1499, 1335, 1127, 999, 823, 728 cm^{-1}. MS (EI) *m/z* (relative intensity) 311 (14), 268 (11), 168 (100), 157 (78), 118 (42), 51 (31). HR-MS (EI) *m/z* calcd for $C_{18}H_{17}NO_4$+H^+ 312.1230, found 312.1242.



2-(4-Fluorophenyl)quinoline-1-oxide (3av) (Scheme 3): The representative procedure was followed, using 4-fluoro-phenyl-4-methylbenzenesulfonate (133 mg, 0.50 mmol) and quinoline-1-

oxide (145 mg, 1.00 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 10/1) yielded **3av** (60 mg, 50 %) as a light yellow solid.

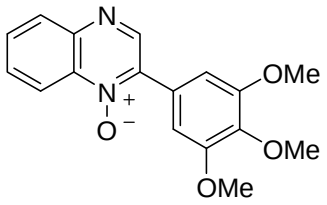
m.p. = 162-164 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.84 (d, J = 8.6 Hz, 1H), 8.06 – 7.95 (m, 2H), 7.91 – 7.72 (m, 3H), 7.65 (ddd, J = 8.1, 7.0, 1.2 Hz, 1H), 7.49 (d, J = 8.7 Hz, 1H), 7.29 – 7.13 (m, 2H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 163.1 (C_q, J = 250 Hz), 143.9 (C_q), 142.2 (C_q), 131.6 (CH, J = 9 Hz), 130.6 (CH), 129.5 (C_q), 129.3 (C_q, J = 4 Hz), 128.4 (CH), 127.9 (CH), 125.2 (CH), 122.9 (CH), 120.2 (CH), 115.3 (CH, J = 22 Hz). ^{19}F-NMR (282 MHz, $CDCl_3$): δ = - 110.6 (tt, J = 9, 6 Hz). IR (KBr): 3066, 3034, 2361, 1599, 1501, 1327, 1234, 1096, 889, 740 cm^{-1}. MS (EI) *m/z* (relative intensity) 239 ([M$^+$] 74), 210 (21), 183 (11), 128 (17), 75 (12). HR-MS (EI) *m/z* calcd for $C_{15}H_{10}FNO+H^+$ 240.0819, found 240.0819.



2-(3,5-Dimethylphenyl)quinoxaline-1-oxide (3aw) (Scheme 3): The representative procedure was followed, using 3,5-dimethylphenyl-4-methylbenzenesulfonate (138 mg, 0.50 mmol) and quinoxaline-1-oxide (146 mg, 1.00 mmol). After 20 h, purification by column chromatography (CH_2Cl_2) yielded **3aw** (64 mg, 51 %) as a light orange solid.

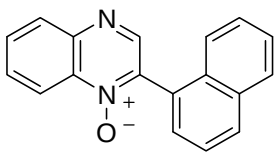
m.p. = 107-109 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.87 (s, 1H), 8.69 (m, 1H), 8.13 (m, 1H), 7.89 – 7.66 (m, 2H), 7.64 – 7.48 (m, 2H), 7.16 (dd, J = 1.4, 0.7 Hz, 1H), 2.42 (d, J = 0.6 Hz, 6H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 147.5 (CH), 144.3 (C_q), 139.6 (C_q), 138.2 (C_q), 137.4 (C_q), 132.0 (CH), 130.9 (CH), 130.3 (CH), 129.9 (CH), 129.7 (C_q), 126.9 (CH), 119.3 (CH), 21.5

(CH_3). IR (KBr): 3058, 2911, 2856, 1926, 1601, 1348, 1087, 854, 756 cm^{-1}. MS (EI) *m/z* (relative intensity) 250 ([M^+] 100), 221 (64), 207 (34), 129 (10), 77 (11). HR-MS (EI) *m/z* calcd for $C_{16}H_{14}N_2O$ 250.1106, found 250.1098.



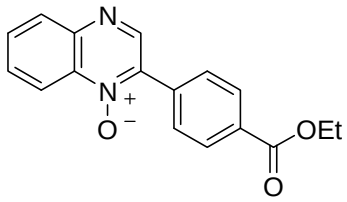
2-(3,4,5-Trimethoxyphenyl)quinoxaline-1-oxide (3ax) (Scheme 3): The representative procedure was followed, using 3,4,5-trimethoxyphenyl-4-methylbenzenesulfonate (169 mg, 0.50 mmol) and quinoxaline-1-oxide (146 mg, 1.00 mmol). After 20 h, purification by column chromatography (CH_2Cl_2 → CH_2Cl_2/acetone = 40/1 → 30/1) yielded **3ax** (120 mg, 77 %) as a pale yellow solid.

m.p. = 124-126 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.90 (s, 1H), 8.67 (m, 1H), 8.14 (m, 1H), 7.89 – 7.69 (m, 2H), 7.25 (s, 2H), 3.93 (s, 9H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 153.3 (C_q), 147.3 (CH), 144.3 (C_q), 140.0 (C_q), 139.1 (C_q), 137.4 (C_q), 131.1 (CH), 130.5 (CH), 130.0 (CH), 125.0 (C_q), 119.3 (CH), 107.0 (CH), 60.9 (CH_3), 56.4 (CH_3). IR (KBr): 3116, 2931, 2834, 2361, 1960, 1586, 1348, 1138, 845 cm^{-1}. MS (EI) *m/z* (relative intensity) 312 ([M^+] 67), 265 (100), 223 (27), 155 (27), 49 (23). HR-MS (EI) *m/z* calcd for $C_{17}H_{16}N_2O_4$ 312.1110, found 312.1102.



2-(Naphthalen-1-yl)quinoxaline-1-oxide (3ay) (Scheme 3): The representative procedure was followed, using naphthalen-1-yl-4-methylbenzenesulfonate (149 mg, 0.50 mmol) and quinoxaline-1-oxide (220 mg, 1.50 mmol). After 20 h, purification by column chromatography (CH_2Cl_2 → CH_2Cl_2/acetone = 100/1) yielded **3ay** (99 mg, 73 %) as a light yellow solid.

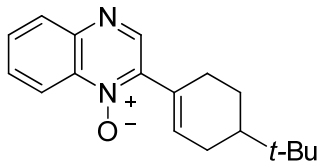
m.p. = 139-140 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.86 (s, 1H), 8.71 (m, 1H), 8.22 (m, 1H), 8.04 (dd, J = 6.6, 2.9 Hz, 1H), 7.95 (d, J = 7.4 Hz, 1H), 7.92 – 7.75 (m, 2H), 7.70 – 7.38 (m, 5H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ = 148.3 (CH), 145.1 (C_q), 140.1 (C_q), 137.4 (C_q), 133.4 (C_q), 131.4 (CH), 130.8 (CH), 130.7 (C_q), 130.3 (CH), 130.1 (CH), 128.7 (CH), 128.5 (CH), 128.1 (C_q), 127.1 (CH), 126.4 (CH), 125.3 (CH), 125.0 (CH), 119.4 (CH). IR (KBr): 3054, 2927, 1575, 1487, 1350, 1327, 1099, 899, 778 cm^{-1}. MS (EI) *m/z* (relative intensity) 272 ([M$^+$] 99), 244 (100), 217(10), 115 (21), 76 (9). HR-MS (EI) *m/z* calcd for $C_{18}H_{12}N_2O$+H$^+$ 273.1022, found 273.1025.



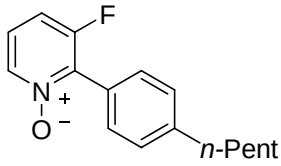
2-(4-Ethoxycarbonylphenyl)quinoxaline-1-oxide (3az) (Scheme 3): The representative procedure was followed, using ethyl-4-(tosyloxy)benzoate (160 mg, 0.50 mmol) and quinoxaline-1-oxide (146 mg, 1.00 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 40/1) yielded **3az** (100 mg, 68 %) as a shiny yellow solid.

m.p. = 215-217 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.89 (s, 1H), 8.67 (m, 1H), 8.26 – 8.17 (m, 2H), 8.13 (m, 1H), 8.09 – 8.00 (m, 2H), 7.88 – 7.72 (m, 2H), 4.41 (q, J = 7.1 Hz, 2H), 1.41 (t, J = 7.1 Hz, 3H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ = 165.7 (C_q),

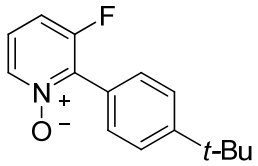
147.0 (CH), 144.6 (C_q), 138.4 (C_q), 137.3 (C_q), 134.0 (C_q), 131.8 (C_q), 131.4 (CH), 130.6 (CH), 130.0 (CH), 129.6 (CH), 129.3 (CH), 119.3 (CH), 61.3 (CH_2), 14.4 (CH_3). IR (KBr): 3044, 2978, 1717, 1489, 1280, 1128, 901, 774, 703 cm^{-1}. MS (EI) *m/z* (relative intensity) 294 ([M^+] 100), 265 (32), 221 (26); 193 (27), 168 (8), 102 (8). HR–MS (EI) *m/z* calcd for $C_{17}H_{14}N_2O_3$+ Na^+ 317.0897, found 317.0904.



2-(4-*t*-Butylcyclohexene-1-yl)quinoxaline-1-oxide (3ba) (Scheme 3): The representative procedure was followed, using 4-*t*-butylcyclohexene-2-yl-4-methylbenzenesulfonate (155 mg, 0.50 mmol) and quinoxaline-1-oxide (220 mg, 1.50 mmol). After 20 h, purification by column chromatography (CH_2Cl_2 → CH_2Cl_2/acetone = 100/1 → 50/1) yielded **3ba** (69 mg, 51 %) as an orange solid. m.p. = 153–155 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.67 (s, 1H), 8.65 – 8.56 (m, 1H), 8.15 – 8.02 (m, 1H), 7.81 – 7.68 (m, 2H), 6.49 (dd, *J* = 4.9, 2.4 Hz, 1H), 2.81 – 2.54 (m, 2H), 2.36 (dt, *J* = 18.8, 5.2 Hz, 1H), 2.20 – 1.92 (m, 2H), 1.60 – 1.22 (m, 2H), 0.93 (s, 9H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 146.8 (CH), 144.2 (C_q), 141.9 (C_q), 137.2 (C_q), 134.9 (CH), 130.6 (C_q), 130.5 (CH), 130.1 (CH), 129.7 (CH), 118.9 (CH), 43.5 (CH), 32.4 (C_q), 27.8 (CH_2), 27.2 (CH_3), 27.1 (CH_2), 23.8 (CH_2). IR (KBr): 3123, 2959, 2361, 1574, 1487, 1343, 1124, 918, 765 cm^{-1}. MS (EI) *m/z* (relative intensity) 282 ([M^+] 69), 225 (33), 197 (100), 169 (46), 129 (21), 57 (23). HR–MS (EI) *m/z* calcd for $C_{18}H_{22}N_2O$+H^+ 283.1805, found 283.1805.



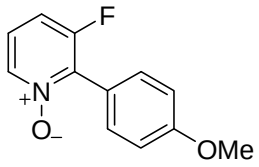
2-(4-*n*-Pentylphenyl)-3-fluoropyridine-1-oxide (3bb) (Scheme 4): The representative procedure was followed, using 4-*n*-pentylphenylmethanesulfonate (127 mg, 0.52 mmol) and 3-fluoropyridine-*N*-oxide (**1b**) (226 mg, 2.00 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 4/1 → 3/1 → 2/1) yielded **3bb** (90 mg, 66 %) as a yellow solid.
m.p. = 88-90 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.19 (dt, J = 6.2, 1.2 Hz, 1H), 7.52 (dd, J = 8.2, 1.5 Hz, 2H), 7.30 (d, J = 8.2 Hz, 2H), 7.21 – 7.03 (m, 2H), 2.72 – 2.54 (m, 2H), 1.73 – 1.53 (m, 2H), 1.33 (m, 4H), 0.88 (t, J = 6.9 Hz 3H). ^{13}C-NMR (75 MHz, $CDCl_3$) δ = 158.3 (C_q, J = 251 Hz), 145.1 (C_q), 140.8 (C_q, J = 25 Hz), 136.7 (CH, J = 4 Hz), 129.9 (CH, J = 3 Hz), 128.3 (CH), 123.4 (C_q, J = 2 Hz), 123.2 (CH, J = 11 Hz), 113.3 (CH, J = 23 Hz), 35.9 (CH_2), 31.5 (CH_2), 30.8 (CH_2), 22.5 (CH_2), 14.0 (CH_3). ^{19}F-NMR (282 MHz, $CDCl_3$): δ = - 116.5 (m). IR (KBr): 3042, 2930, 2859, 1910, 1472, 1033, 787, 723 cm^{-1}. MS (EI) *m/z* (relative intensity) 259 ([M$^+$] 3), 243 (25), 186 (100), 135 (7), 93 (2). HR-MS (EI) *m/z* calcd for $C_{16}H_{18}FNO+H^+$ 260.1445, found 260.1442.



2-(4-*t*-Butylphenyl)-fluoropyridine-1-oxide (3bc) (Scheme 4): The representative procedure was followed, using 4-*t*-butylphenylmethanesulfonate (111 mg, 0.49 mmol) and 3-fluoropyridine-*N*-oxide (**1b**) (226 mg, 2.00 mmol). After 20 h,

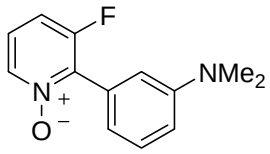
purification by column chromatography (CH_2Cl_2/acetone = 2/1) yielded **3bc** (83 mg, 69 %) as a yellow solid.

m.p. = 118-120 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.20 (m, 1H), 7.62 – 7.46 (m, 4H), 7.21 – 7.04 (m, 2H), 1.33 (s, 9H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ = 158.3 (C_q, J = 251 Hz), 153.0 (C_q), 140.6 (C_q, J = 25 Hz), 136.6 (CH, J = 4 Hz), 129.7 (CH, J = 3 Hz), 125.2 (CH), 123.2 (C_q, J = 2 Hz), 123.1 (CH, J = 11 Hz), 113.3 (CH, J = 23 Hz), 34.9 (C_q), 31.2 (CH_3). ^{19}F-NMR (282 MHz, $CDCl_3$): δ = - 120.4 (mt, J = 7 Hz). IR (KBr): 3047, 2965, 1912, 1468, 1234, 1033, 836, 789, 695 cm^{-1}. MS (EI) *m/z* (relative intensity) 245 ([M$^+$] 2), 214 (100), 185 (21), 93 (15). HR-MS (EI) *m/z* calcd for $C_{15}H_{16}FNO$-H$^+$ 244.1143, found 244.1140.



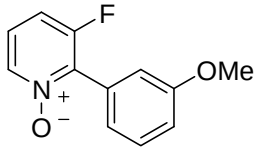
3-Fluoro-2-(4-methoxyphenyl)pyridine-1-oxide (3bd) (Scheme 4): The representative procedure was followed, using 4-methoxyphenylmethanesulfonate (98.6 mg, 0.52 mmol) and 3-fluoropyridine-*N*-oxide (**1b**) (226 mg, 2.00 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 1/1) yielded **3bd** (68 mg, 62 %) as a pale yellow solid.

m.p. = 138-140 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.19 (m, 1H), 7.65 – 7.54 (m, 2H), 7.20 – 6.94 (m, 4H), 3.85 (s, 3H).^{13}C-NMR (125 MHz, $CDCl_3$): δ = 160.6 (C_q), 158.2 (C_q, J = 250 Hz), 140.4 (C_q, J = 25 Hz), 136.6 (CH, J = 3 Hz), 131.6 (CH, J = 2 Hz), 122.8 (CH, J = 11 Hz), 118.2 (C_q, J = 2 Hz),114.4 (CH), 113.2 (CH, J = 23 Hz), 55.4 (CH_3). ^{19}F-NMR (282 MHz, $CDCl_3$): δ = - 116.6 (mt, J = 7 Hz). IR (KBr): 3009, 2971, 2551, 1577, 1234, 1129, 833, 725 cm^{-1}. MS (EI) *m/z* (relative intensity) 219 ([M$^+$] 6), 203 (100), 188 (33), 159 (36), 107 (9), 63 (7). HR-MS (EI) *m/z* calcd for $C_{12}H_{10}FNO_2$-H$^+$ 218.0623, found 218.0623.



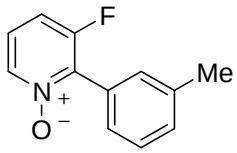
2-{3-(*N*,*N*-Dimethylamino)phenyl}-3-fluoropyridine-1-oxide (3be) (Scheme 4): The representative procedure was followed, using 3-(*N*,*N*-dimethylamino)phenylmethanesulfonate (108 mg, 0.50 mmol) and 3-fluoropyridine-*N*-oxide (**1b**) (226 mg, 2.00 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 1/2) yielded **3be** (95 mg, 82 %) as a yellow solid.

m.p. = 89-91 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.21 (dt, J = 6.3, 1.2 Hz, 1H), 7.37 (t, J = 7.9 Hz, 1H), 7.23–7.07 (m, 2H), 6.93–6.80 (m, 3H), 2.97 (s, 6H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 158.4 (C_q, J = 251 Hz), 150.4 (C_q), 141.5 (C_q, J = 86 Hz), 136.7 (CH, J = 3 Hz), 129.1 (CH), 127.0 (C_q, J = 2 Hz), 123.3 (CH, J = 10 Hz), 117.7 (CH, J = 2 Hz), 114.1 (CH), 113.5 (CH, J = 2 Hz), 113.3 (CH, J = 23 Hz), 40.5 (CH_3). ^{19}F-NMR (282 MHz, $CDCl_3$): δ = - (115.7-115.8) (m). IR (KBr): 3078, 2887, 2806, 1604, 1355, 1233, 1031, 788, 688 cm^{-1}. MS (EI) *m/z* (relative intensity) 232 ([M$^+$] 9), 216 (100), 200 (43), 172 (34), 93 (16). HR–MS (EI), *m/z* calcd for $C_{13}H_{13}FN_2O$+H$^+$ 233.1085, found 233.1087.



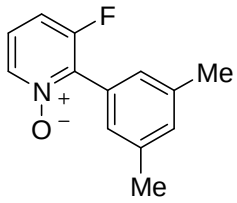
3-Fluoro-2-(3-methoxyphenyl)pyridine-1-oxide (3bf) (Scheme 4): The representative procedure was followed, using 3-methoxyphenylmethanesulfonate (125 mg, 0.62 mmol) and 3-fluoropyridine-*N*-oxide (**1b**) (226 mg, 2.00 mmol). After 20 h,

purification by column chromatography (CH_2Cl_2/acetone = 4/1 → 3/1) yielded **3bf** (95 mg, 70 %) as a yellow oil.
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.19 (dt, J = 6.4, 1.2 Hz, 1H), 7.41 (m, 1H), 7.23 – 7.06 (m, 4H), 7.00 (ddd, J = 8.4, 2.5, 1.2 Hz, 1H), 3.81 (s, 3H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ = 159.3 (C_q), 158.2 (C_q, J = 251 Hz), 140.5 (C_q, J = 26 Hz), 136.6 (CH, J = 4 Hz), 129.4 (CH), 127.4 (C_q, J = 2 Hz), 123.5 (CH, J = 11 Hz), 122.3 (CH, J = 3 Hz), 116.0 (CH), 115.3 (CH, J = 2 Hz), 113.3 (CH, J = 23 Hz), 55.4 (CH_3). ^{19}F-NMR (282 MHz, $CDCl_3$): δ = - 120.0 (m). IR (film): 3112, 3071, 2837, 2322, 1924, 1584, 1418, 1030, 791 cm^{-1}. MS (EI) *m/z* (relative intensity) 219 ([M$^+$] 50), 204 (94), 176 (76), 148 (100), 96 (14). HR-MS (EI) *m/z* calcd for $C_{12}H_{10}FNO_2$+Na$^+$ 242.0588, found 242.0590.



3-Fluoro-2-(3-methylphenyl)pyridine-1-oxide (3bg) (Scheme 4): The representative procedure was followed, using 3-methylphenylmethanesulfonate (95.5 mg, 0.51 mmol) and 3-fluoropyridine-*N*-oxide (**1b**) (226 mg, 2.00 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 4/1) yielded **3bg** (72 mg, 69 %) as a yellow oil.
^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.19 (dt, J = 6.3, 1.2 Hz, 1H), 7.46 – 7.01 (m, 6H), 2.39 (s, 3H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ = 158.2 (C_q, J = 251 Hz), 140.8 (C_q, J = 25 Hz), 137.9 (C_q), 136.6 (CH, J = 4 Hz), 130.7 (CH), 130.4 (CH, J = 2 Hz), 128.2 (CH), 127.0 (CH, J = 3 Hz), 126.2 (C_q, J = 2 Hz), 123.3 (CH, J = 11 Hz), 113.3 (CH, J = 23 Hz), 21.5 (CH_3). ^{19}F-NMR (282 MHz, $CDCl_3$): δ = - 120.2 (m). IR (film): 3113, 3064, 1616, 1588, 1430, 1279, 1237, 1031, 793 cm^{-1}. MS (EI) *m/z* (relative

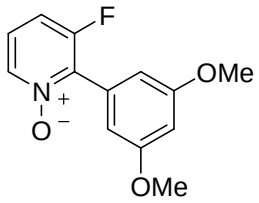
intensity) 203 ([M^+] 63), 174 (100), 135 (39), 96 (9), 51 (11). HR–MS (EI) *m/z* calcd for $C_{13}H_{10}FNO-H^+$ 202.0674, found 202.0669.



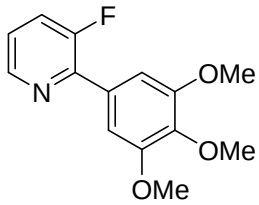
2-(3,5-Dimethylphenyl)3-fluoropyridine-1-oxide (3bh) (Scheme 4): The representative procedure was followed, using 3,5-dimethylphenylmethanesulfonate (100 mg, 0.50 mmol) and 3-fluoropyridine-*N*-oxide (**1b**) (226 mg, 2.00 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 2/1) yielded **3bh** (78 mg, 72 %) as a yellow solid.

m.p. = 84–85 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.18 (dd, J = 6.3, 1.1 Hz, 1H), 7.23 – 7.02 (m, 5H), 2.35 (s, 6H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ = 158.2 (C_q, J = 251 Hz), 141.1 (C_q, J = 25 Hz), 137.9 (C_q), 136.6 (CH, J = 4 Hz), 131.7 (CH), 127.4 (CH, J = 2 Hz), 126.1 (C_q, J = 2 Hz), 123.2 (CH, J = 10 Hz), 113.2 (CH, J = 23 Hz), 21.4 (CH_3). ^{19}F-NMR (282 MHz, $CDCl_3$): δ = - 116.2 (dd, J = 10, 4 Hz). IR (KBr) 3111, 2862, 1609, 1419, 1290, 1238, 1033, 790, 724 cm^{-1}. MS (EI) *m/z* (relative intensity) 217 ([M^+] 7), 201 (100), 184 (50), 148 (6), 105 (7), 77 (7). HR–MS (EI) *m/z* calcd for $C_{13}H_{12}FNO+H^+$ 218.0976, found 218.0983.

The spectral data were in accordance with those reported in the literature.[4]



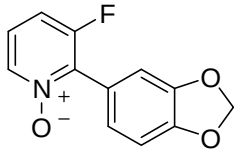
2-(3,5-Dimethoxyphenyl)-3-fluoropyridine-1-oxide (3bi) (Scheme 4): The representative procedure was followed, using 3,5-dimethoxyphenylmethanesulfonate (116 mg, 0.50 mmol) and 3-fluoropyridine-*N*-oxide (**1b**) (225 mg, 1.99 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 1/1) yielded **3bi** (97 mg, 78 %) as a pale yellow solid.
m.p. = 111-113 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.18 (dt, J = 6.4, 1.1 Hz, 1H), 7.23 – 7.06 (m, 2H), 6.69 (dd, J = 2.3, 1.0 Hz, 2H), 6.55 (dd, J = 2.3 Hz, 1H), 3.79 (s, 6H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 160.7 (C_q), 158.3 (C_q, J = 252 Hz), 140.7 (C_q, J = 24 Hz), 136.7 (CH, J = 4 Hz), 127.9 (C_q, J = 2 Hz), 123.6 (CH, J = 10 Hz), 113.3 (CH, J = 23 Hz), 107.9 (CH, J = 2 Hz), 102.5 (CH), 55.4 (CH_3). ^{19}F-NMR (282 MHz, $CDCl_3$): δ = - (115.7-115.8) (m). IR (KBr): 3050, 1597, 1421, 1345, 1157, 1033, 843, 788 cm^{-1}. MS (EI) *m/z* (relative intensity) 233 (100), 203 (18), 173 (15), 147 (18), 87 (15). HR-MS (EI) *m/z* calcd for $C_{13}H_{12}FNO_3$+H$^+$ 250.0874, found 250.0879.



3-Fluoro-2-(3,4,5-trimethoxyphenyl)pyridine (3bj) (Scheme 4): The representative procedure was followed, using 3,4,5-trimethoxyphenylmethanesulfonate (131 mg, 0.50 mmol) and 3-fluoropyridine-*N*-oxide (**1b**) (226 mg, 2.00 mmol). After 20 h the reaction mixture was allowed to cool to ambient

temperature, diluted with CH_2Cl_2, filtered over Celite and concentrated *in vacuo*. The remaining residue was stirred in acetic acid (15.0 mL) with iron powder (10 equiv.) for 20 h at 50 °C.[4] After extraction with ethyl acetate purification by column chromatography (*n*-pentane/ethyl acetate = 4/1 → 3/1) yielded the reduced product **3bj** (104 mg, 79 %) as a colorless solid.

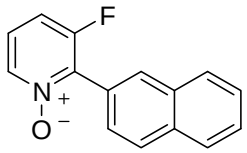
m.p. = 111-113 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.55-8.43 (m, 1H), 7.56 – 7.39 (m, 1H), 7.31 – 7.16 (m, 3H), 3.93 (s, 6H), 3.90 (s, 3H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 157.4 (C_q, J = 260 Hz), 153.1 (C_q), 145.6 (C_q, J = 10 Hz), 145.2 (CH, J = 5 Hz), 139.6 (C_q), 130.7 (C_q, J = 6 Hz), 124.1 (CH, J = 21 Hz), 123.3 (CH, J = 4 Hz), 106.1 (CH, J = 7 Hz), 60.9 (CH_3), 56.2 (CH_3). ^{19}F-NMR (282 MHz, $CDCl_3$): δ = - 122.3 (ddd, J = 11, 3, 2 Hz). IR (KBr) 3055, 2940, 2307, 1590, 1267, 1129, 753, 717 cm^{-1}. MS (EI) *m/z* (relative intensity) 263([M$^+$] 100), 248 (59), 220 (38), 190 (36), 134 (33). HR–MS (EI) *m/z* calcd for $C_{14}H_{14}FNO_3$+H$^+$ 264.1030, found 264.1033.



2-(Benzo[d]-[1,3]dioxol-5'-yl)-3-fluoropyridine-1-oxide (3bk) (Scheme 4): The representative procedure was followed, using benzo[d]-[1,3]dioxol-5'-ylmethanesulfonate (113 mg, 0.52 mmol) and 3-fluoropyridine-*N*-oxide (**1b**) (226 mg, 2.00 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 4/1) yielded **3bk** (78 mg, 64 %) as an orange solid.

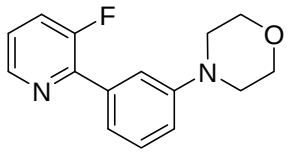
m.p. = 156-158 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.18 (m, 1H), 7.20 – 7.01 (m, 4H), 6.91 (d, J = 8.1 Hz, 1H), 6.00 (s, 2H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ = 158.2 (C_q, J = 251 Hz), 148.9

(C_q), 147.5 (C_q), 140.2 (C_q, J = 25 Hz), 136.6 (CH, J = 3 Hz), 124.6 (CH, J = 3 Hz), 123.1 (CH, J = 11 Hz), 119.3 (C_q, J = 2 Hz), 113.3 (CH, J = 23 Hz), 110.4 (CH), 108.3 (CH), 101.4 (CH_2). ^{19}F-NMR (282 MHz, $CDCl_3$): δ = - 120.1 (ddd, J = 9, 3, 1 Hz). IR (KBr): 3050, 2899, 2507, 1861, 1472, 1234, 1037, 816, 636 cm^{-1}. MS (EI) *m/z* (relative intensity) 233 ([M^+] 84), 217 (100), 147 (85), 122 (29), 63 (16). HR-MS (EI) *m/z* calcd for $C_{12}H_8FNO_2$+Na^+ 256.0380, found 256.0381.

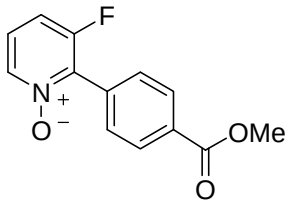


3-Fluoro-2-(naphthalen-2-yl)pyridine-1-oxide (3bl) (Scheme 4): The representative procedure was followed, using naphthalen-2-ylmethanesulfonate (111 mg, 0.50 mmol) and 3-fluoropyridine-*N*-oxide (**1b**) (226 mg, 2.00 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 2/1) yielded **3bl** (85 mg, 71 %) as a pale yellow solid.

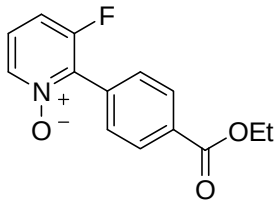
m.p. = 179-181 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.24 (dt, J = 6.2, 1.2 Hz, 1H), 8.09 (s, 1H), 7.95 (d, J = 8.6 Hz, 1H), 7.92 – 7.82 (m, 2H), 7.75 – 7.67 (m, 1H), 7.59 – 7.46 (m, 2H), 7.18 (tdd, J = 8.7, 7.5, 3.6 Hz, 2H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ = 158.4 (C_q, J = 251 Hz), 140.6 (C_q, J = 25 Hz), 136.7 (CH, J = 4 Hz), 133.7 (C_q), 132.7 (C_q), 130.4 (CH, J = 3 Hz), 128.4 (CH), 127.8 (CH), 127.6 (CH), 127.2 (CH), 126.5 (CH, J = 2 Hz), 126.2 (CH), 123.7 (C_q, J = 2 Hz), 123.5 (CH, J = 11 Hz), 113.4 (CH, J = 23 Hz). ^{19}F-NMR (282 MHz, $CDCl_3$): δ = - 116.4 (m). IR (KBr): 3052, 1548, 1423, 1267, 1228, 1029, 753, 705 cm^{-1}. MS (EI) *m/z* (relative intensity) 223 (100), 194(5), 175 (6), 111 (36), 97 (7). HR-MS (EI) *m/z* calcd for $C_{15}H_{10}FNO$+H^+ 240.0819, found 240.0823.



3-Fluoro-2-(3-morpholinophenyl)pyridine (3bm) (Scheme 4): The representative procedure was followed, using 3-morpholinophenylmethanesulfonate (114 mg, 0.45 mmol) and 3-fluoropyridine-*N*-oxide (**1b**) (226 mg, 2.00 mmol). After 20 h the reaction mixture was allowed to cool to ambient temperature, diluted with CH_2Cl_2, filtered over Celite and concentrated *in vacuo*. The remaining residue was stirred in acetic acid (15.0 mL) with iron powder (10 equiv.) for 20 h at 50 °C.[4] After extraction with ethyl acetate purification by column chromatography (*n*-pentane/ethyl acetate = 5/1 → 2/1) yielded the reduced product **3bm** (74 mg, 65 %) as a yellow oil. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.49 (dt, J = 4.5, 1.6 Hz, 1H), 7.64 – 7.10 (m, 5H), 6.98 (ddd, J = 8.1, 2.5, 1.0 Hz, 1H), 3.95 – 3.75 (m, 4H), 3.34 – 3.04 (m, 4H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 157.4 (C_q, J = 260 Hz), 151.3 (C_q), 146.4 (C_q, J = 11 Hz), 145.1 (CH, J = 5 Hz), 136.1 (C_q, J = 5 Hz), 129.1, (CH), 124.0 (CH, J = 21 Hz), 123.3 (CH, J = 4 Hz), 120.6 (CH, J = 7 Hz), 116.6 (CH), 115.9 (CH, J = 5 Hz), 67.0 (CH_2), 49.4 (CH_2). ^{19}F-NMR (282 MHz, $CDCl_3$): δ = - (122.4-122.5) (m). IR (film): 3067, 2962, 2854, 2572, 1937, 1729, 1599, 1376, 1065, 801 cm^{-1}. MS (EI) *m/z* (relative intensity) 258 ([M^+] 100), 227 (12), 200 (78), 173 (61), 145 (9). HR-MS (EI) *m/z* calcd for $C_{15}H_{15}FN_2O$ 258.1168, found 258.1165.

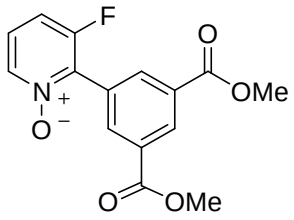


2-(4-Methoxycarbonylphenyl)-3-fluoropyridine-1-oxide (3bn) (Scheme 4): The representative procedure was followed, using methyl-4-(methylsulfonyloxy)benzoate (115 mg, 0.50 mmol) and 3-fluoropyridine-*N*-oxide (**1b**) (226 mg, 2.00 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 2/1) yielded **3bn** (70.6 mg, 57 %) as a light yellow solid.
m.p. = 164-166 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.20 (dt, J = 6.5, 1.1 Hz, 1H), 8.18 – 8.11 (m, 2H), 7.74 – 7.66 (m, 2H), 7.28 – 7.08 (m, 2H), 3.92 (s, 3H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ = 166.3 (C_q), 158.2 (C_q, J = 252 Hz), 139.6 (C_q, J = 25 Hz), 136.7 (CH, J = 4 Hz), 131.3 (C_q), 130.7 (C_q, J = 2 Hz), 130.2 (CH, J = 3 Hz), 129.3 (CH), 124.0 (CH, J = 11 Hz), 113.4 (CH, J = 23 Hz), 52.3 (CH_3). ^{19}F-NMR (282 MHz, $CDCl_3$): δ = - (116.2-116.3) (m). IR (KBr): 2954, 1724, 1516, 1436, 1282, 1113, 827, 724 cm^{-1}. MS (EI) *m/z* (relative intensity) 247 ([M^+] 2), 231 (60), 200 (100), 172 (56), 86 (19). HR-MS (EI) *m/z* calcd for $C_{13}H_{10}FNO_3$+H^+ 248.0717, found 248.0723.



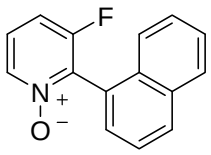
2-(4-Ethoxycarbonylphenyl)-3-fluoropyridine-1-oxide (3bo) (Scheme 4): The representative procedure was followed, using Ethyl-4-(methylsulfonyloxy)benzoate (122 mg, 0.50 mmol) and 3-fluoropyridine-*N*-oxide (**1b**) (226 mg, 2.00 mmol). After 20 h,

purification by column chromatography (CH_2Cl_2/acetone = 3/1) yielded **3bo** (78 mg, 59 %) as a pale yellow solid.
m.p. = 141-143 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.31 – 8.06 (m, 3H), 7.81 – 7.62 (m, 2H), 7.27 – 7.09 (m, 2H), 4.38 (q, J = 7.1 Hz, 2H), 1.38 (t, J = 7.1 Hz, 3H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 165.7 (C_q), 158.2 (C_q, J = 252 Hz), 139.6 (C_q, J = 25 Hz), 136.7 (CH, J = 4 Hz), 131.6 (C_q), 130.6 (C_q, J = 2 Hz), 130.1 (CH, J = 3 Hz), 129.3 (CH), 124.0 (CH, J = 11 Hz), 113.3 (CH, J = 23 Hz), 61.2 (CH_2), 14.4 (CH_3). ^{19}F-NMR (282 MHz, $CDCl_3$): δ = - 120.1 (m). IR (KBr): 2983, 1716, 1551, 1432, 1279, 1109, 1034, 857, 724 cm^{-1}. MS (EI) *m/z* (relative intensity) 261 ([M$^+$] 24), 245 (42), 200 (100), 172 (50), 43 (10). HR-MS (EI) *m/z* calcd for $C_{14}H_{12}FNO_3$-H$^+$ 260.0728, found 260.0722.



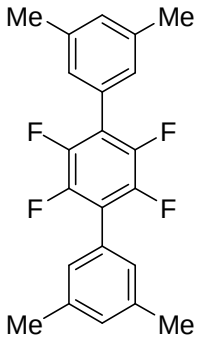
2-{3,5-Dimethoxycarbonyl)phenyl}-3-fluoropyridine-1-oxide (3bp) (Scheme 4): The representative procedure was followed, using dimethyl-5-(methylsulfonyloxy)isophthalate (145 mg, 0.50 mmol) and 3-fluoropyridine-*N*-oxide (**1b**) (226 mg, 2.00 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 2/1) yielded **3bp** (71 mg, 46 %) as a light yellow solid.
m.p. = 212-213 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.77 (t, J = 1.6 Hz, 1H), 8.48 (dd, J = 1.4 Hz, 2H), 8.22 (dt, J = 6.5, 1.0 Hz, 1H), 7.38 – 7.06 (m, 2H), 3.94 (s, 6H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 165.5 (C_q), 158.3 (C_q, J = 253 Hz), 138.7 (C_q, J = 23 Hz), 136.8 (CH, J = 4 Hz), 135.6 (CH, J = 3 Hz), 132.1 (CH), 130.9 (C_q), 127.2 (C_q, J = 2 Hz), 124.4 (CH, J = 11 Hz), 113.6 (CH, J = 22 Hz), 52.5 (CH_3). ^{19}F-NMR (282 MHz,

$CDCl_3$): δ = - 116.3 (td, J = 7, 1 Hz). IR (KBr): 3084, 3016, 2961, 1934, 1728, 1421, 1253, 989, 790 cm^{-1}. MS (EI) *m/z* (relative intensity) 289 (27), 258 (54), 231 (100), 171 (19), 100 (14). HR-MS (EI) *m/z* calcd for $C_{15}H_{12}FNO_5+Na^+$ 328.0592, found 328.0593.



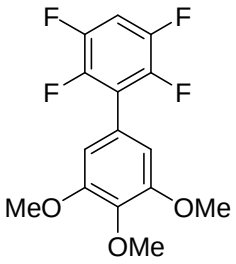
3-Fluoro-2-(naphthalen-1-yl)pyridine-1-oxide (3bq) (Scheme 4): The representative procedure was followed, using naphthalen-1-ylmethanesulfonate (132 mg, 0.59 mmol) and 3-fluoropyridine-*N*-oxide (**1b**) (226 mg, 2.00 mmol). After 20 h, purification by column chromatography (CH_2Cl_2/acetone = 4/1 → 3/1 →2/1) yielded **3bq** (93 mg, 66 %) as a yellow solid.

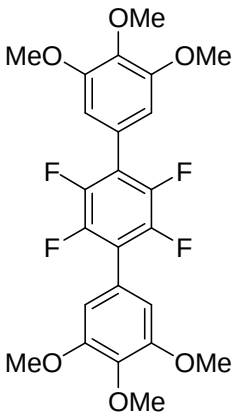
m.p. = 159-160 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 8.31 (dt, J = 6.5, 1.0 Hz, 1H), 8.02 (d, J = 8.0 Hz, 1H), 7.93 (dd, J = 7.2, 1.9 Hz, 1H), 7.66 – 7.39 (m, 5H), 7.39 – 7.17 (m, 2H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 159.1 (C_q, J = 252 Hz), 140.3 (C_q, 27 Hz), 136.8 (CH, J = 4 Hz), 133.6 (C_q), 130.9 (C_q), 130.7 (CH), 128.7 (CH), 128.6 (CH, J = 2 Hz), 127.0 (CH), 126.3 (CH), 125.3 (CH), 124.5 (CH), 124.4 (C_q, J = 2 Hz), 124.2 (CH, J = 11 Hz), 113.0 (CH, J = 23 Hz). ^{19}F-NMR (282 MHz, $CDCl_3$): δ = - 114.3 (t, J = 7 Hz). IR (KBr): 3051, 1925, 1552, 1428, 1241, 1033, 783, 730 cm^{-1}. MS (EI) *m/z* (relative intensity) 239 ([M^+] 6), 222 (100), 175 (6), 110 (20). HR-MS (EI) *m/z* calcd for $C_{15}H_{10}FNO+H^+$ 240.0819, found 240.0825.



The representative procedure was followed, using 3,5-dimethylphenyl-4-methylbenzenesulfonate (138 mg, 0.50 mmol), 1,2,4,5-tetrafluorobenzene (**6**) (121 mg, 0.80 mmol) and Cs_2CO_3 (180 mg, 0.55 mmol). After 16 h, H_2O (50.0 mL) was added to the reaction mixture at ambient temperature and the aqueous phase was extracted with ethyl acetate (2 × 50.0 mL). The combined organic layers were washed with brine (50.0 mL), dried over Na_2SO_4 and concentrated *in vacuo*. Purification by column chromatography (*n*-pentane) yielded **8a** (15 mg, 16%) as a white solid.

1,4-Bis-(3,5-dimethylphenyl)-2,3,5,6-tetrafluorobenzene (8a): m.p. = 215-217 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.10 (s, 6H), 2.38 (s, 12H). ^{13}C-NMR (75 MHz, $CDCl_3$): δ = 144.0 (C_q, J = 249 Hz), 138.1 (C_q), 130.8 (CH), 127.8 (CH), 127.3 (C_q), 119.6 (C_q), 21.3 (CH_3). ^{19}F-NMR (282 MHz, $CDCl_3$): δ = - 144.3 (s). IR (KBr): 2956, 2862, 1744, 1602, 1479, 1423, 1254, 983, 846, 708 cm^{-1}. MS (EI) *m/z* (relative intensity) 358 ([M^+] 100), 343 (13), 237 (2), 164 (7), 77 (3). HR-MS (EI) *m/z* calcd for $C_{22}H_{18}F_4$ 358.1345, found 358.1347.



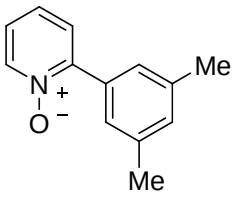


The representative procedure was followed, using 3,4,5-trimethoxyphenyl-4-methylbenzenesulfonate (169 mg, 0.50 mmol), 1,2,4,5-tetrafluorobenzene (**6**) (121 mg, 0.80 mmol) and Cs_2CO_3 (180 mg, 0.55 mmol). After 16 h, H_2O (50.0 mL) was added to the reaction mixture at ambient temperature and the aqueous phase was extracted with ethyl acetate (2 × 50.0 mL). The combined organic layers were washed with brine (50.0 mL), dried over Na_2SO_4 and concentrated *in vacuo*. Purification by column chromatography (*n*-pentane/ethyl acetate = 50/1 → 30/1 → 20/1 → 10/1 → 7/1 → 4/1) yielded **7b** (71 mg, 45%) and **8b** (49 mg, 40%) as white solids.

2,3,5,6-Tetrafluoro-3,4,5-trimethoxy-biphenyl (7b): m.p. = 112-113 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 7.12 - 6.97 (m, 1H), 6.68 - 6.61 (m, 2H), 3.90 (s, 3H), 3.86 (s, 6H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ = 153.3 (C_q), 146.2 (C_q, J = 249 Hz), 143.7 (C_q, J = 249 Hz), 138.8 (C_q), 122.5 (C_q), 121.4 (C_q, J = 17 Hz), 107.5 (CH), 104.7 (CH), 60.9 (CH_3), 56.2 (CH_3). ^{19}F-NMR (282 MHz, $CDCl_3$): δ = - (139.0-139.2) (m), - (143.2-143.4) (m). IR (KBr): 3188, 3008, 2941, 1970, 1585, 1502, 1245, 1131, 942, 842 cm^{-1}. MS (EI) *m/z* (relative intensity) 316 ([M^+] 100), 301 (61), 273 (42), 213 (19), 187 (49). HR-MS (EI) *m/z* calcd for $C_{15}H_{12}F_4O_3$ 316.0723, found 316.0712.

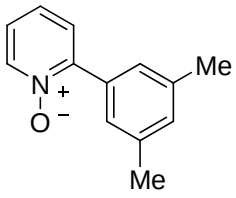
1,4-Bis-(3,4,5-trimethoxyphenyl)-2,3,5,6-tetrafluorobenzene (8b): m.p. = 196-198 °C. ^{1}H-NMR (300 MHz, $CDCl_3$): δ = 6.69 (s,

4H), 3.91 (s, 6H), 3.88 (s, 12H). ^{13}C-NMR (125 MHz, $CDCl_3$): δ = 153.3 (C_q), 144.0 (C_q, J = 250 Hz), 138.8 (C_q), 120.5 (C_q), 119.5 (C_q), 107.5 (CH), 60.9 (CH_3), 56.2 (CH_3). ^{19}F-NMR (282 MHz, $CDCl_3$): δ = - 143.7 (s). IR (KBr): 3008, 2937, 1654, 1516, 1128, 1001, 822, 742 cm^{-1}. MS (EI) *m/z* (relative intensity) 482 ([M^+] 100), 467 (35), 439 (14), 407 (16). HR-MS (EI) *m/z* calcd for $C_{24}H_{22}F_4O_6$ 482.1353, found 482.1358.



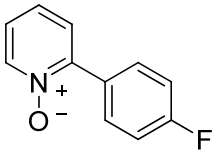
3aa

($CDCl_3$, 300 MHz)



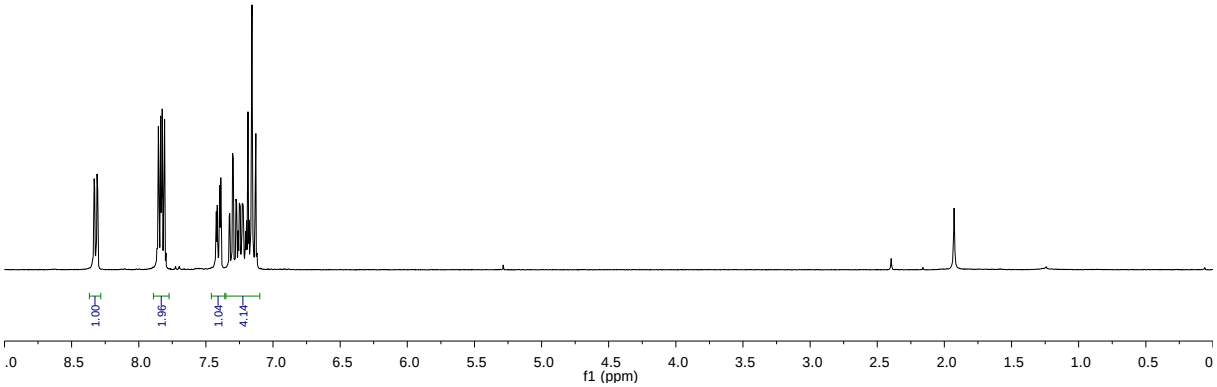
3aa

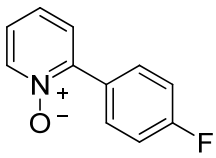
($CDCl_3$, 125 MHz)



3ab

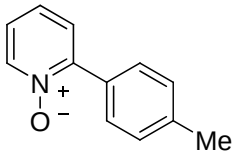
($CDCl_3$, 300 MHz)





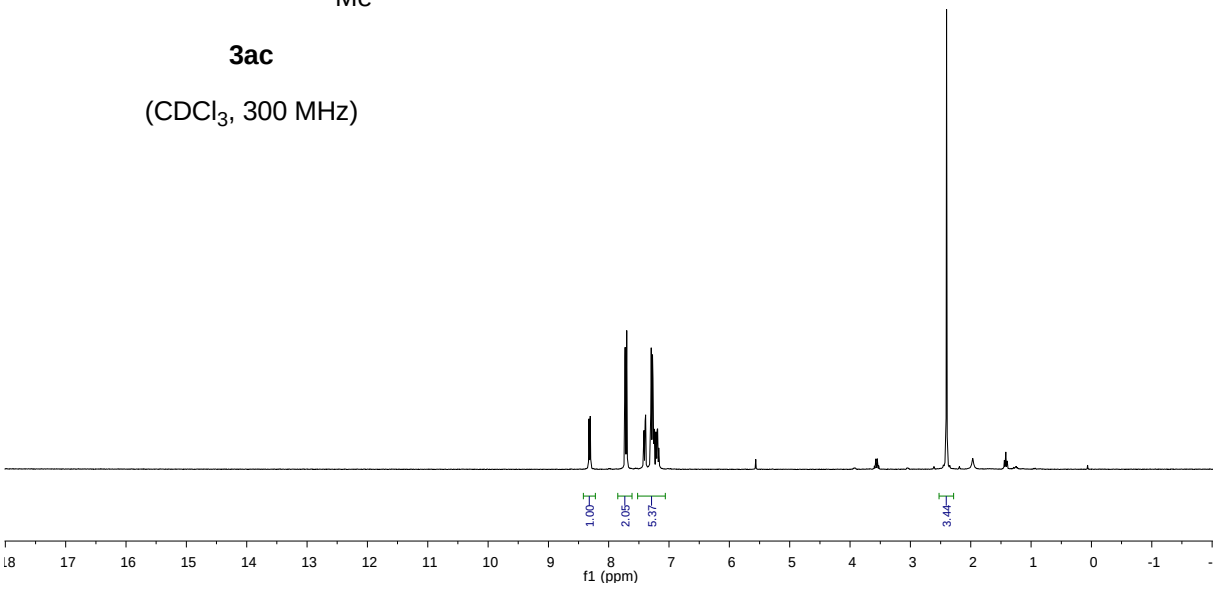
3ab

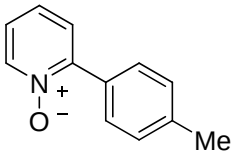
($CDCl_3$, 75 MHz)



3ac

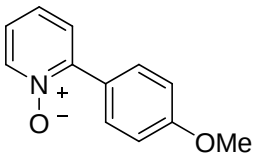
($CDCl_3$, 300 MHz)





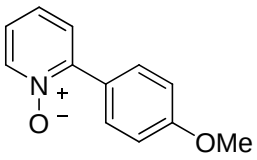
3ac

($CDCl_3$, 75 MHz)



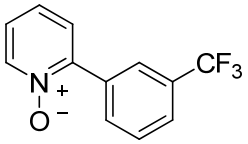
3ad

($CDCl_3$, 300 MHz)



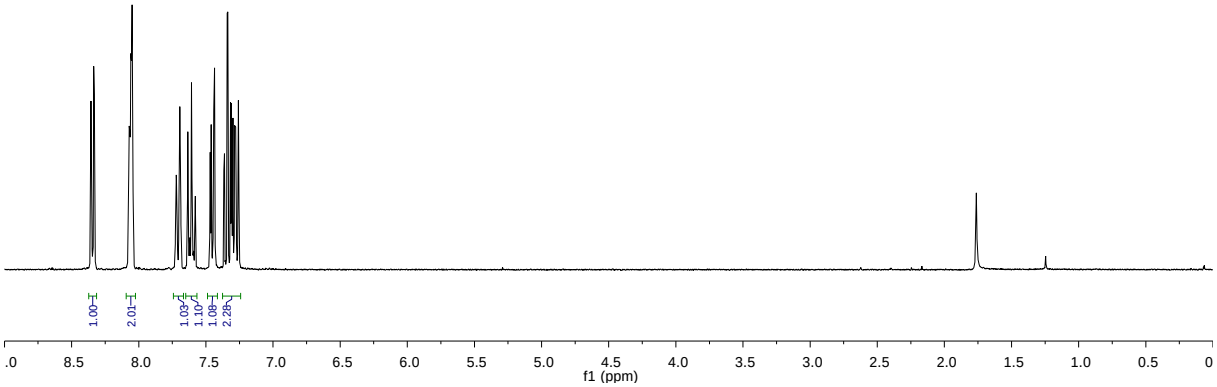
3ad

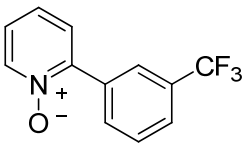
($CDCl_3$, 125 MHz)



3ae

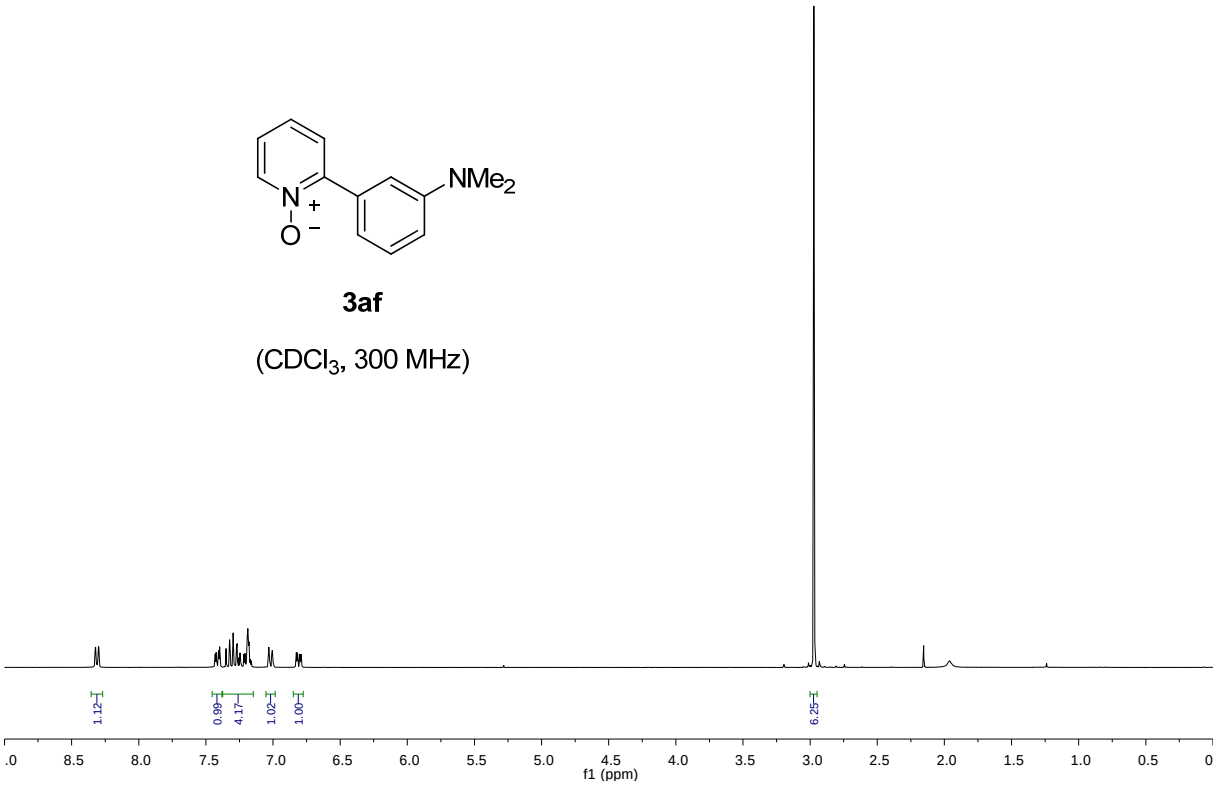
($CDCl_3$, 300 MHz)





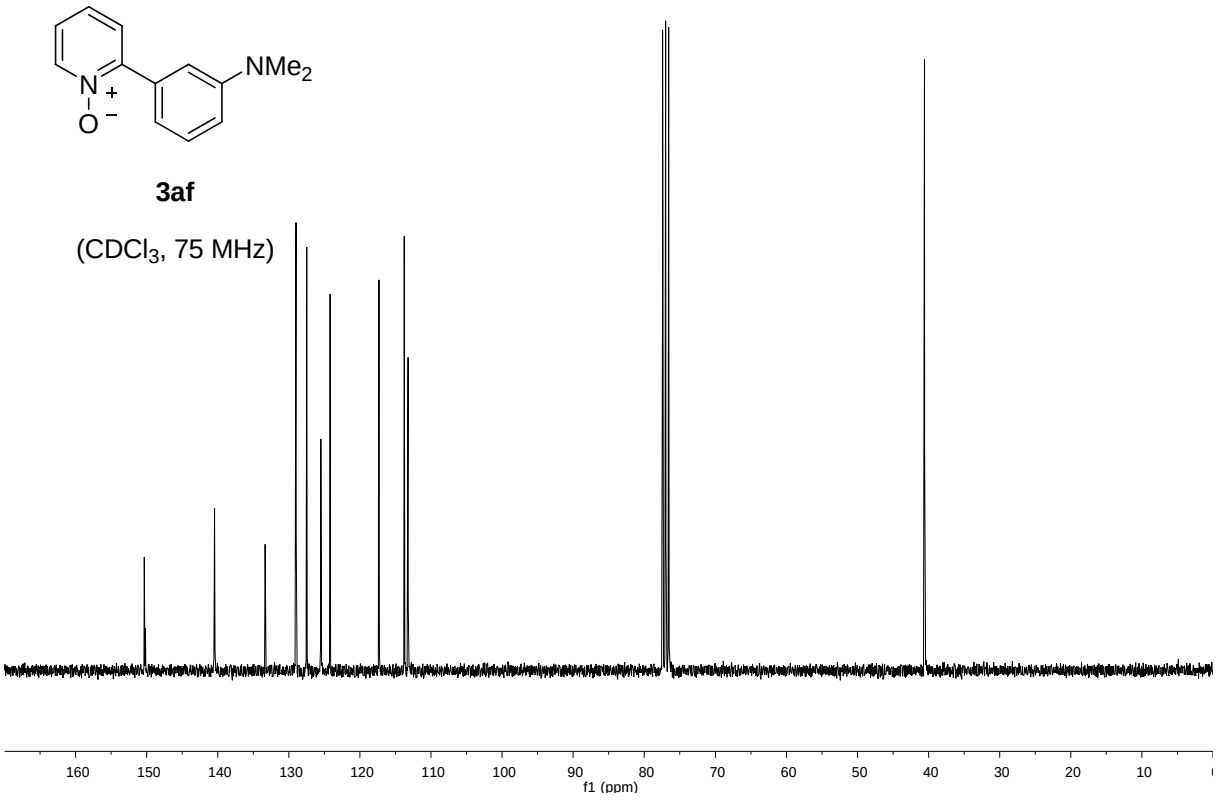
3ae

($CDCl_3$, 125 MHz)



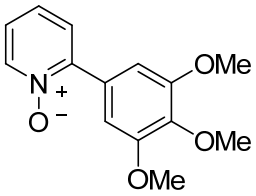
3af

($CDCl_3$, 300 MHz)



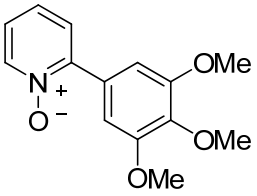
3af

($CDCl_3$, 75 MHz)



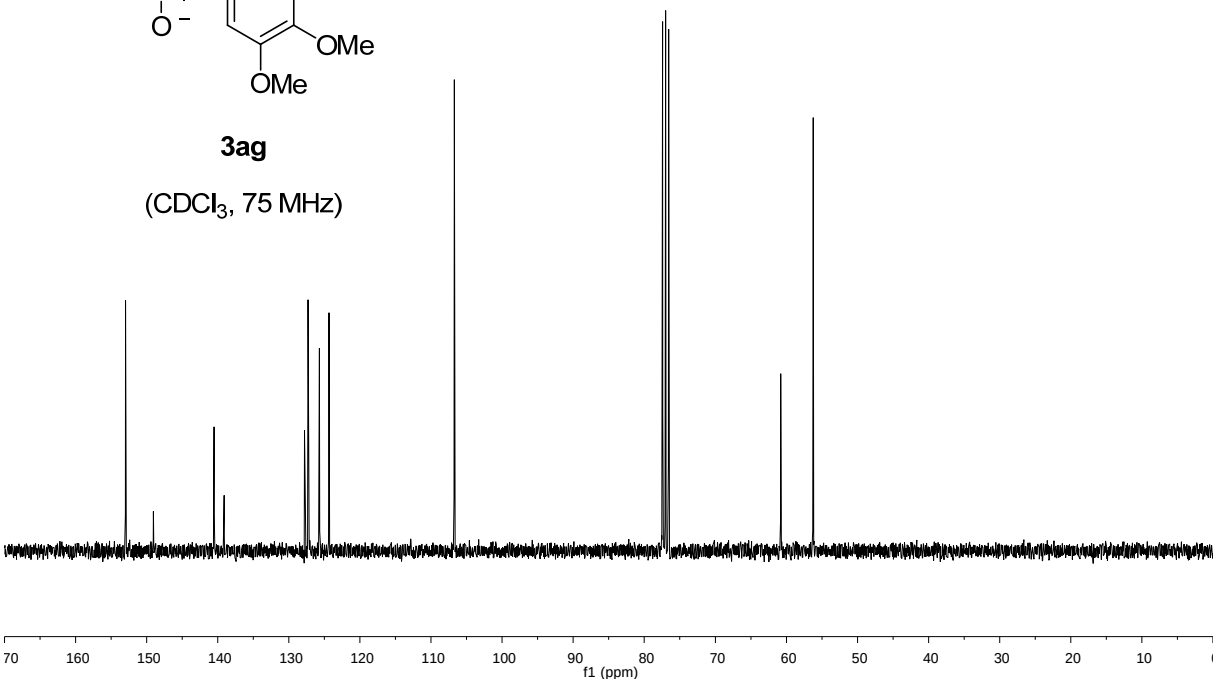
3ag

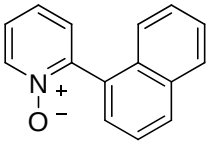
($CDCl_3$, 300 MHz)



3ag

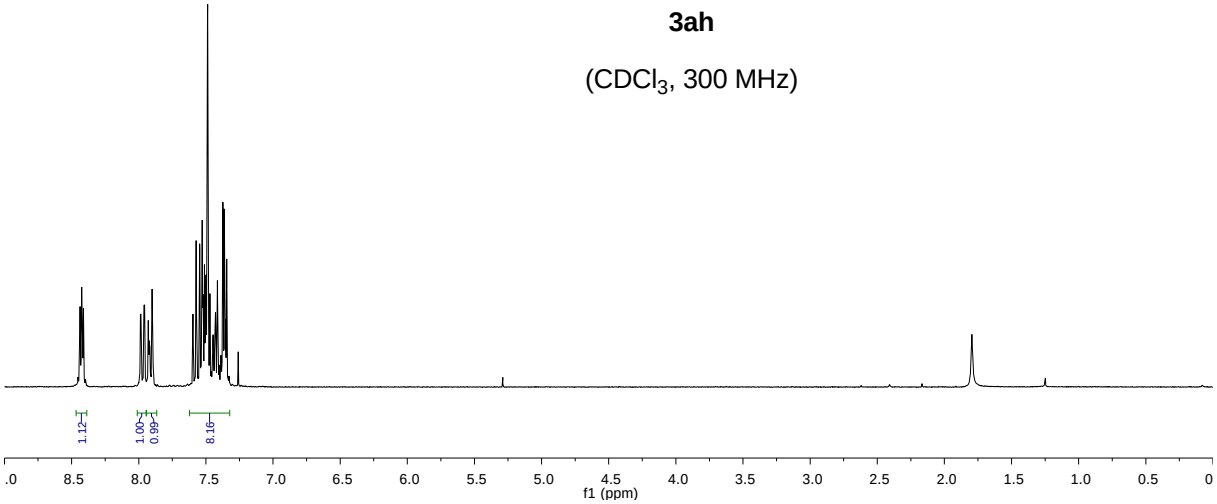
($CDCl_3$, 75 MHz)

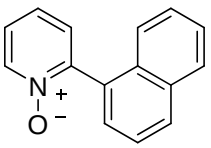




3ah

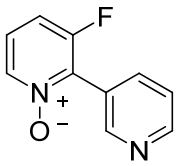
($CDCl_3$, 300 MHz)





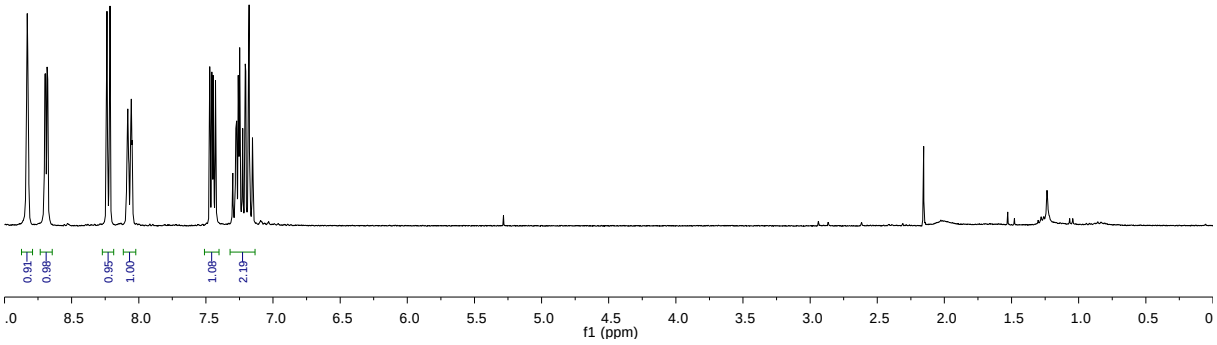
3ah

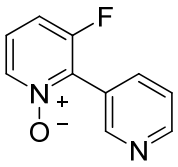
($CDCl_3$, 75 MHz)



3ai

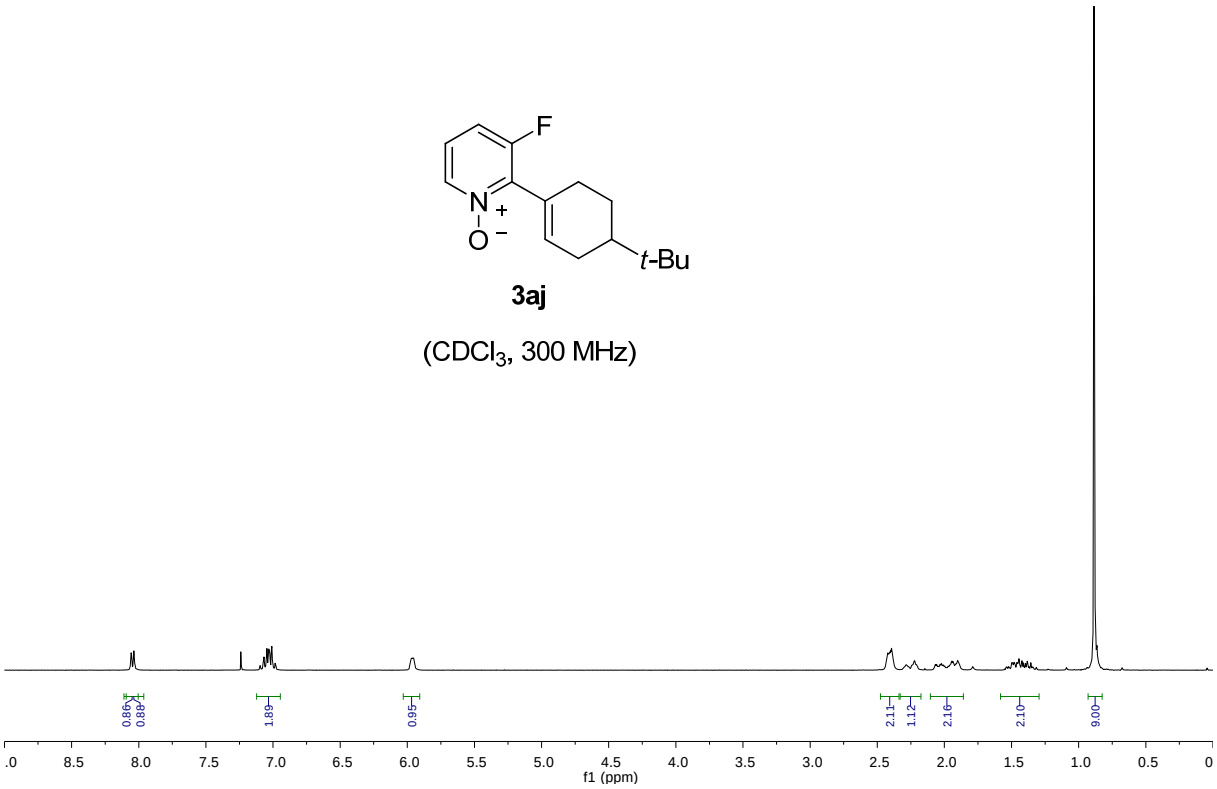
($CDCl_3$, 300 MHz)





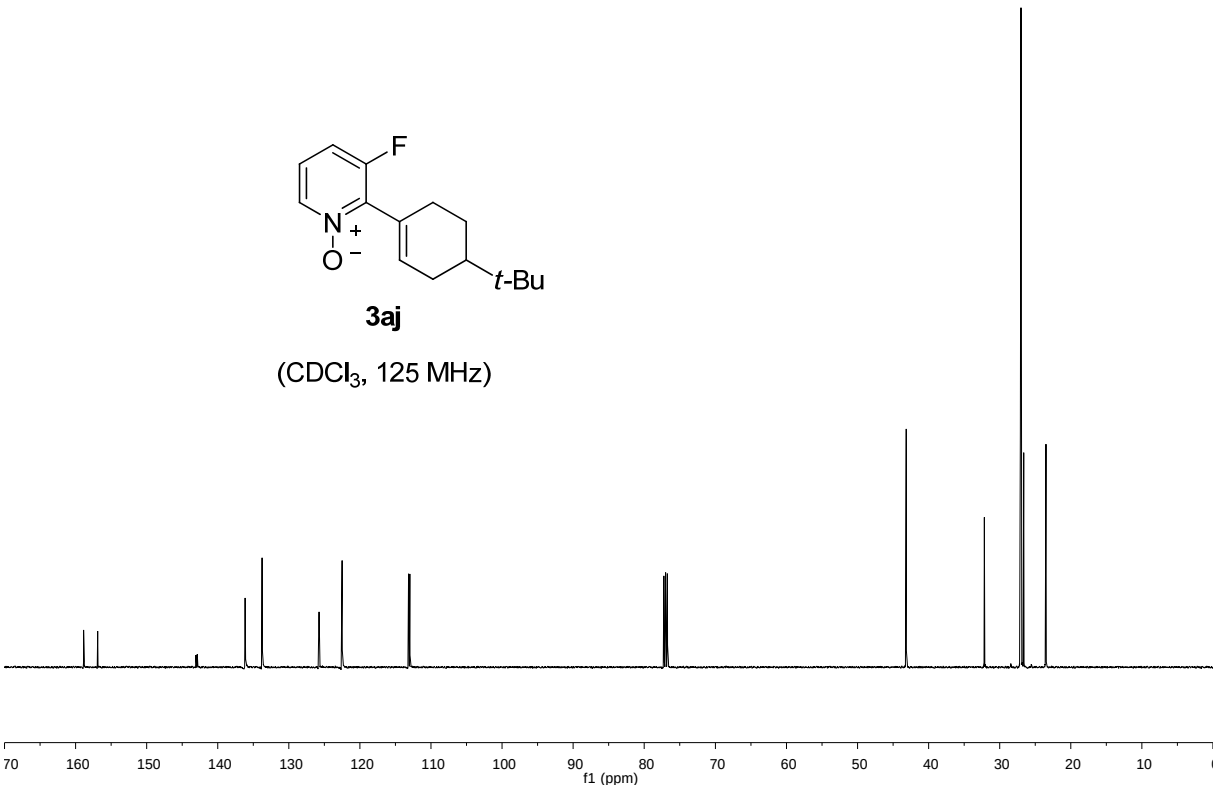
3ai

($CDCl_3$, 125 MHz)



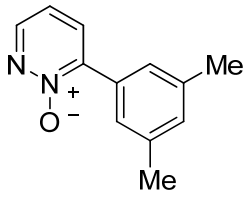
3aj

($CDCl_3$, 300 MHz)



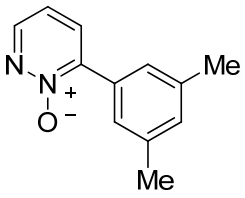
3aj

($CDCl_3$, 125 MHz)



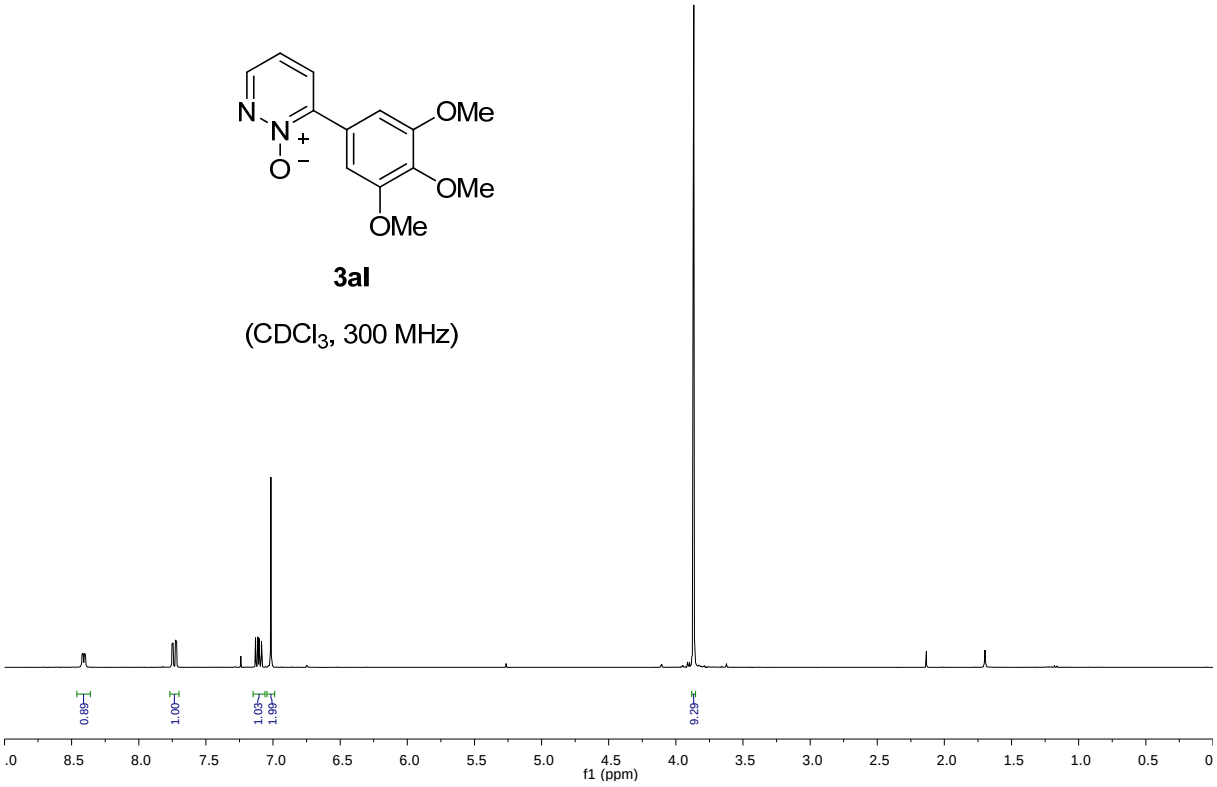
3ak

($CDCl_3$, 300 MHz)



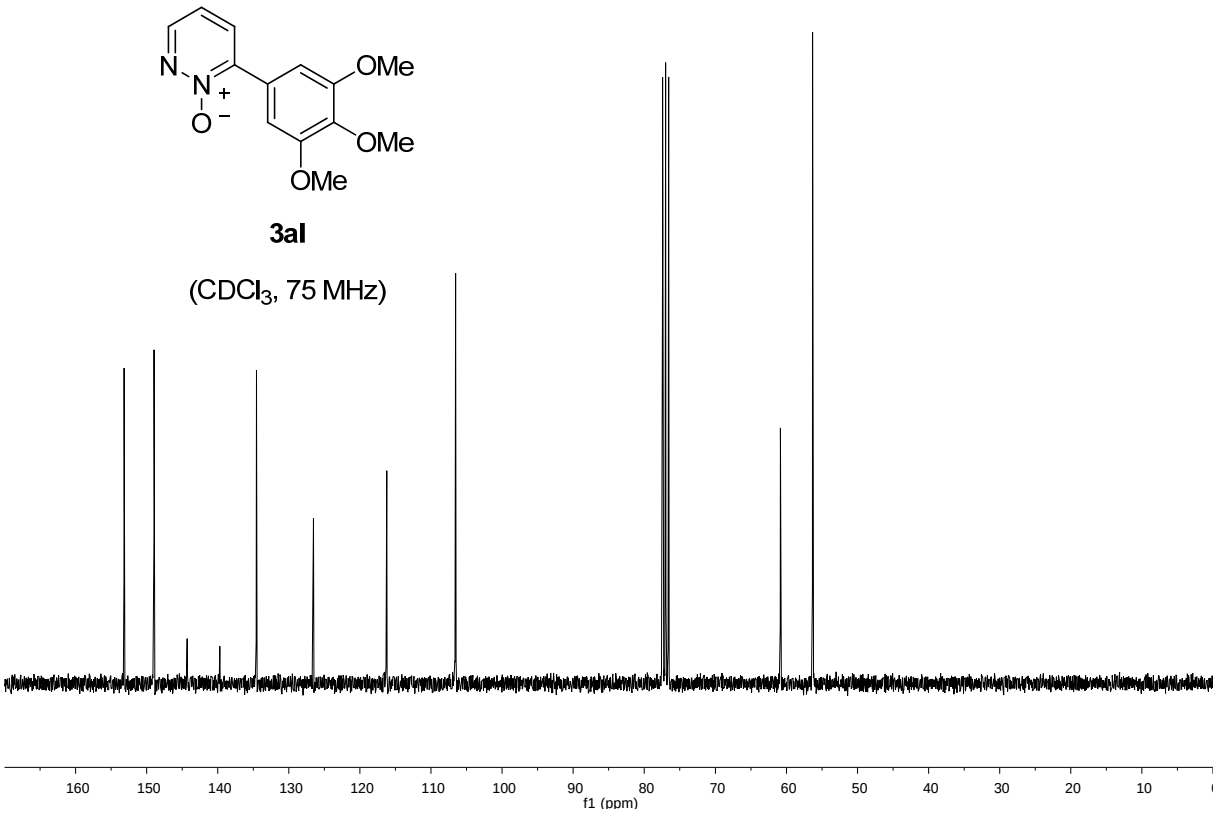
3ak

($CDCl_3$, 75 MHz)



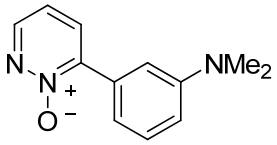
3al

($CDCl_3$, 300 MHz)



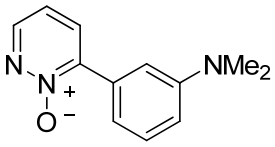
3al

($CDCl_3$, 75 MHz)



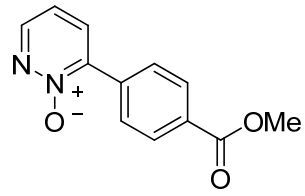
3am

($CDCl_3$, 300 MHz)



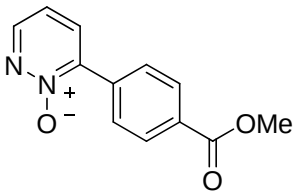
3am

($CDCl_3$, 125 MHz)



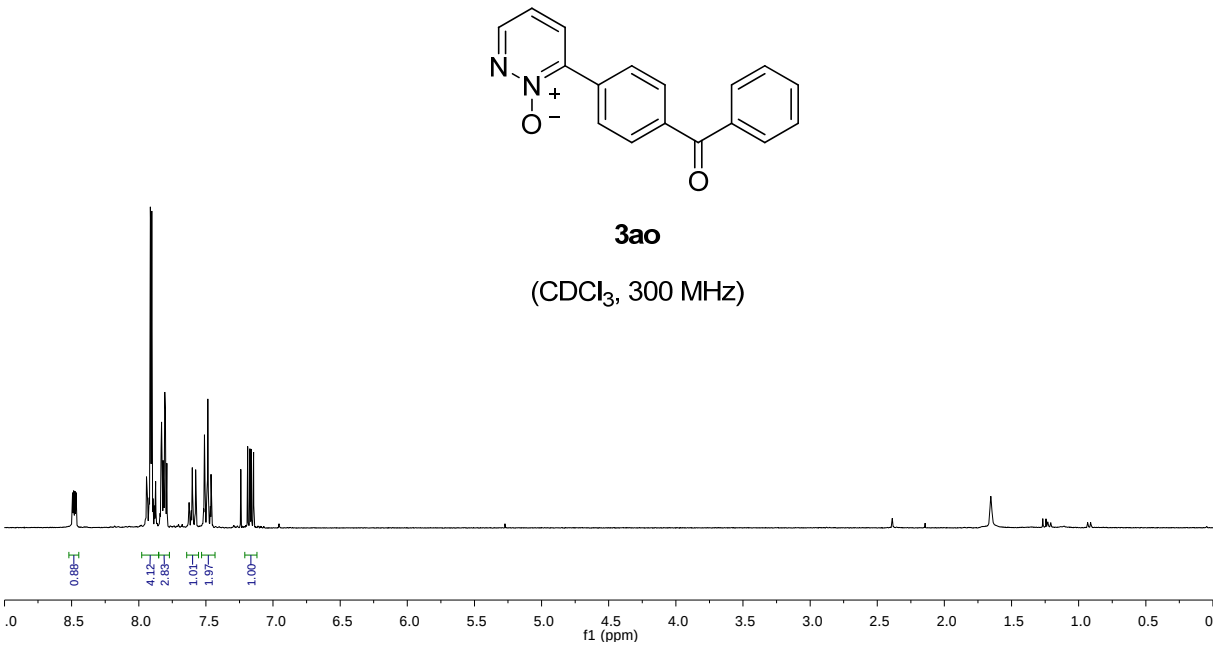
3an

($CDCl_3$, 300 MHz)



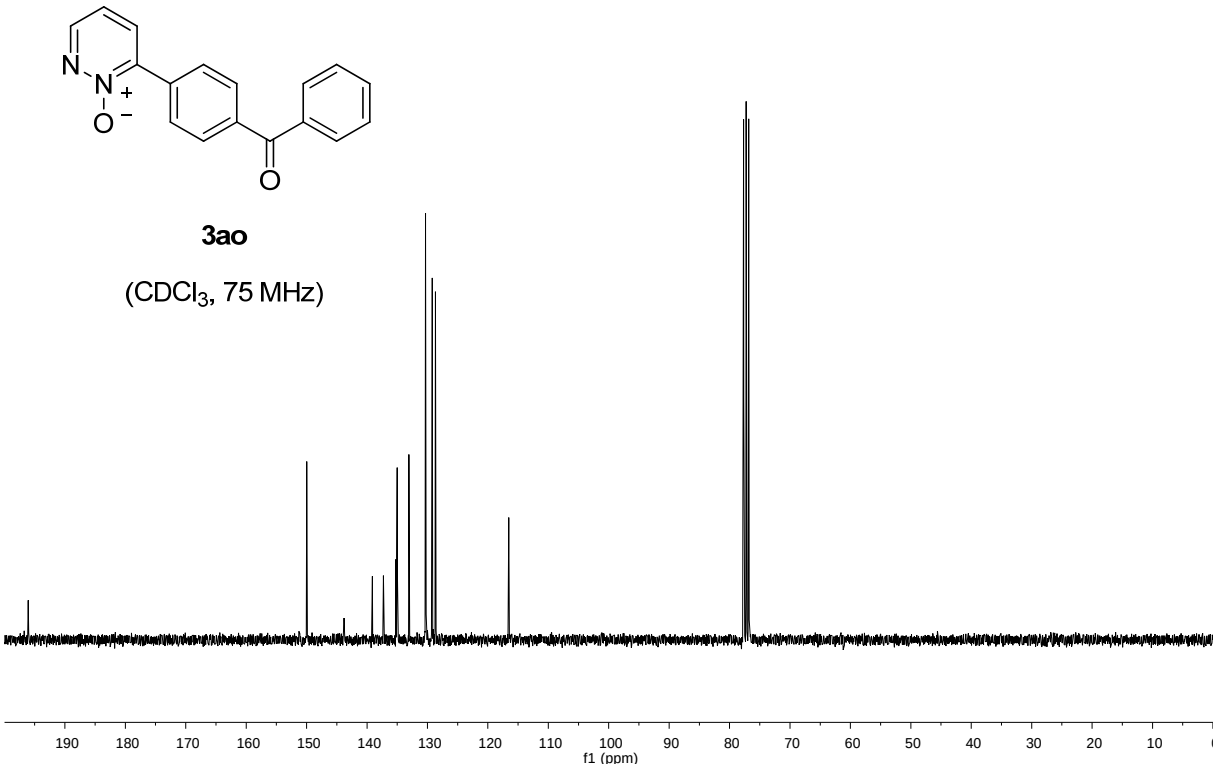
3an

($CDCl_3$, 75 MHz)



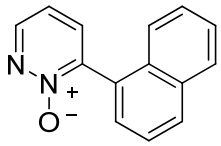
3ao

($CDCl_3$, 300 MHz)



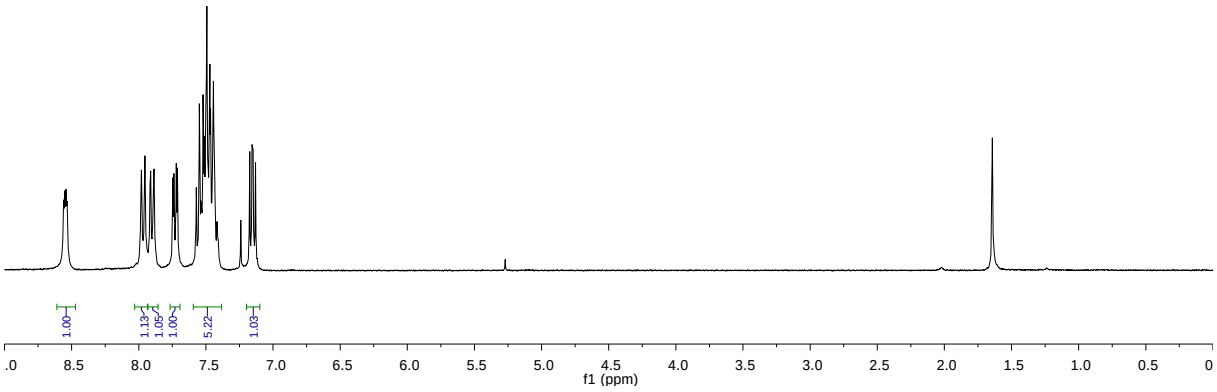
3ao

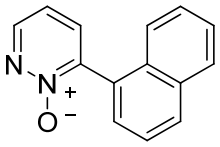
($CDCl_3$, 75 MHz)



3ap

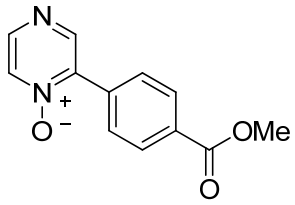
($CDCl_3$, 300 MHz)





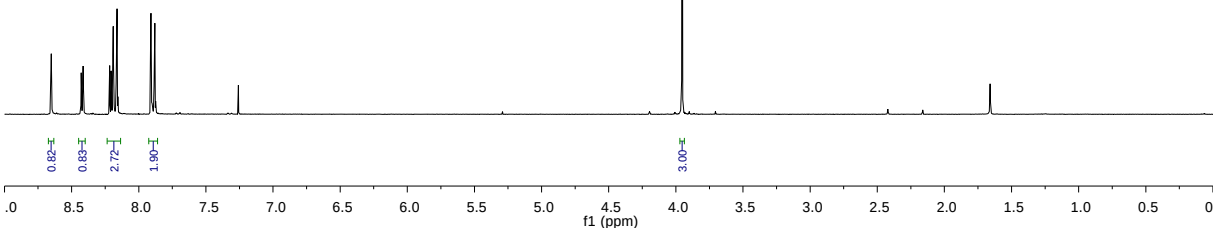
3ap

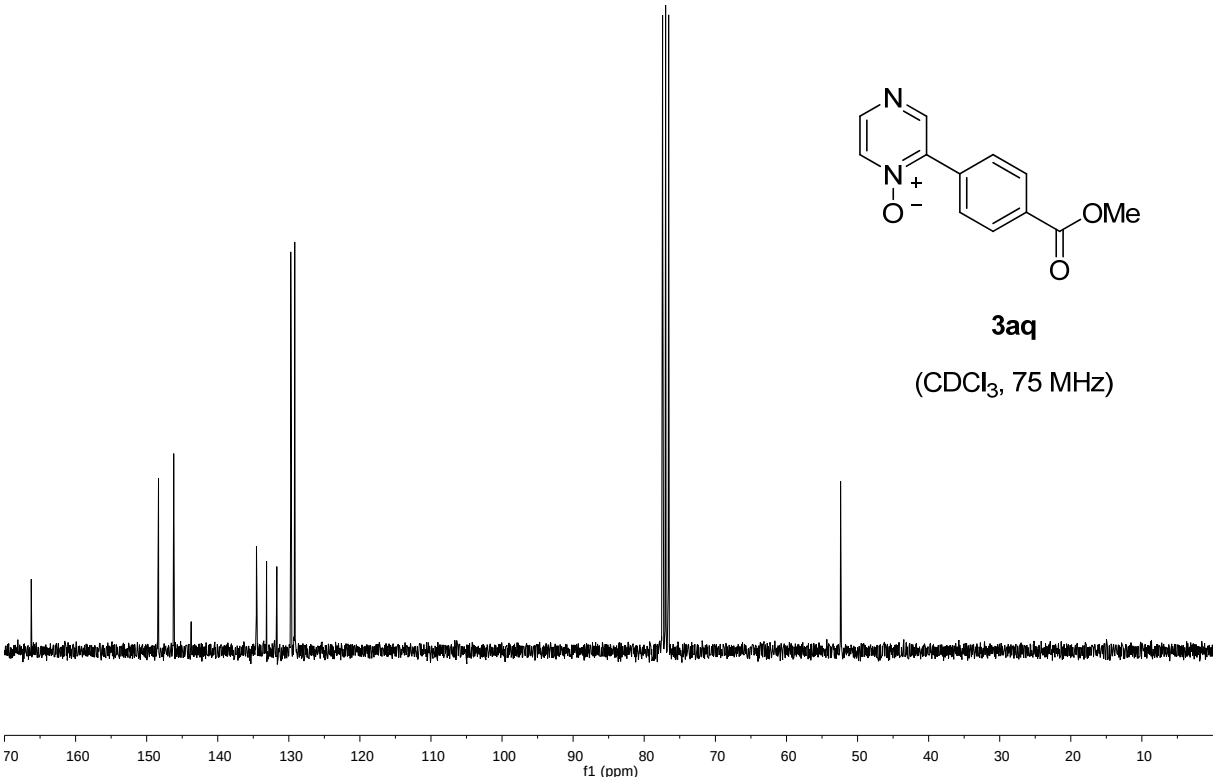
($CDCl_3$, 75 MHz)



3aq

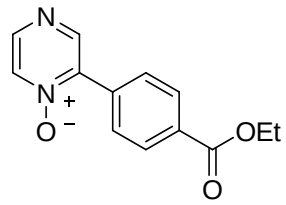
($CDCl_3$, 300 MHz)





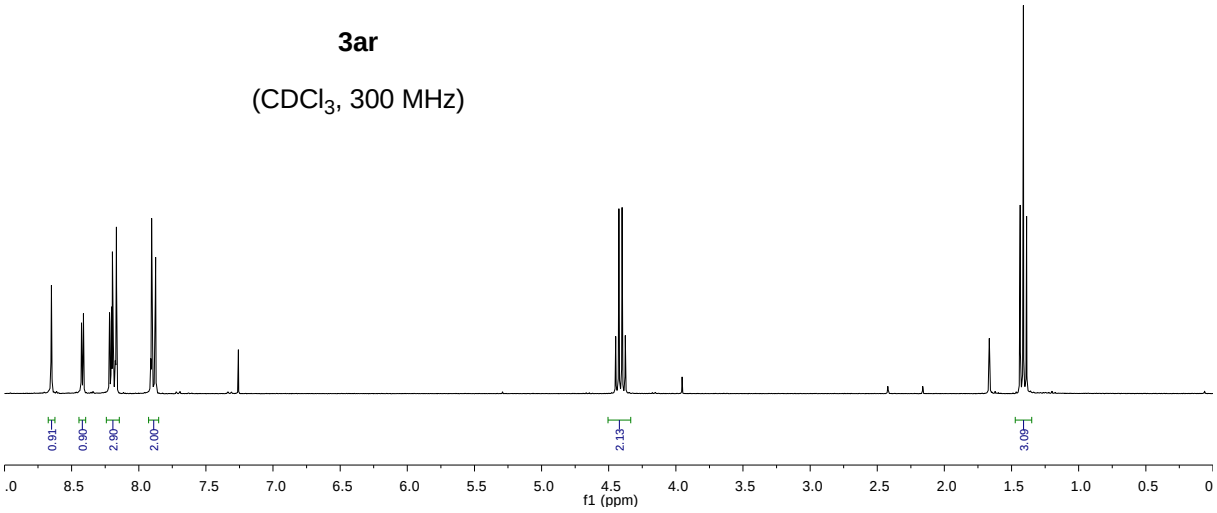
3aq

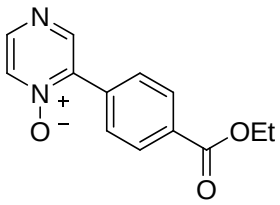
($CDCl_3$, 75 MHz)



3ar

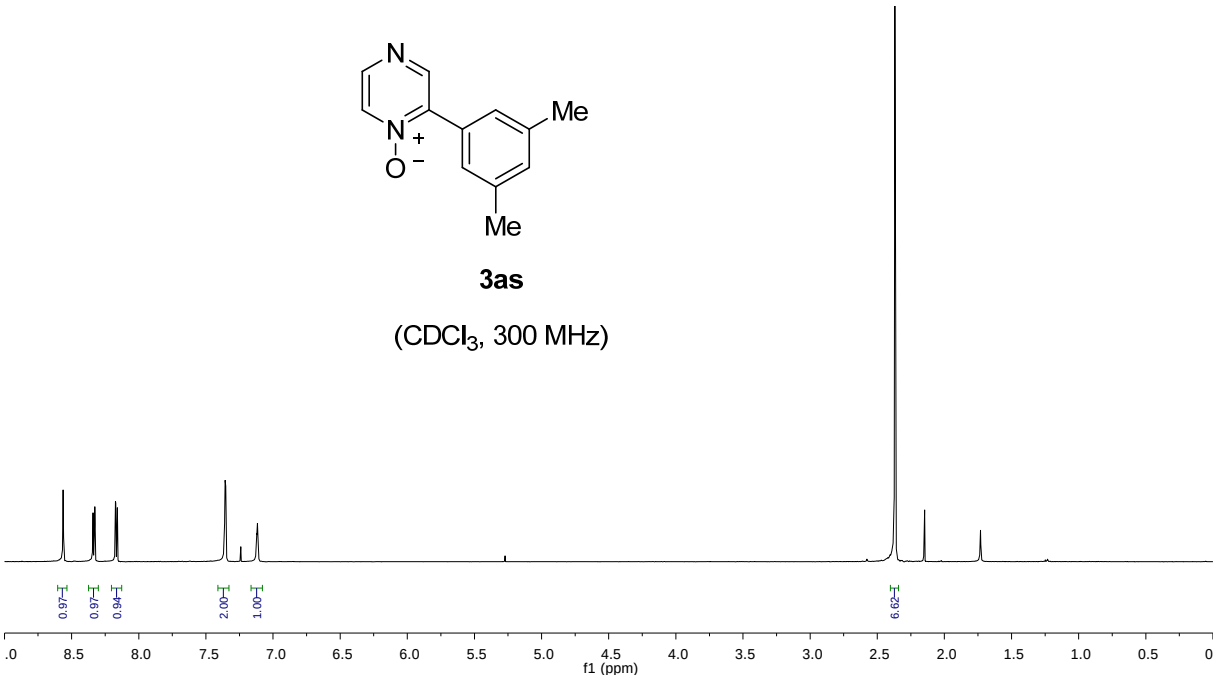
($CDCl_3$, 300 MHz)





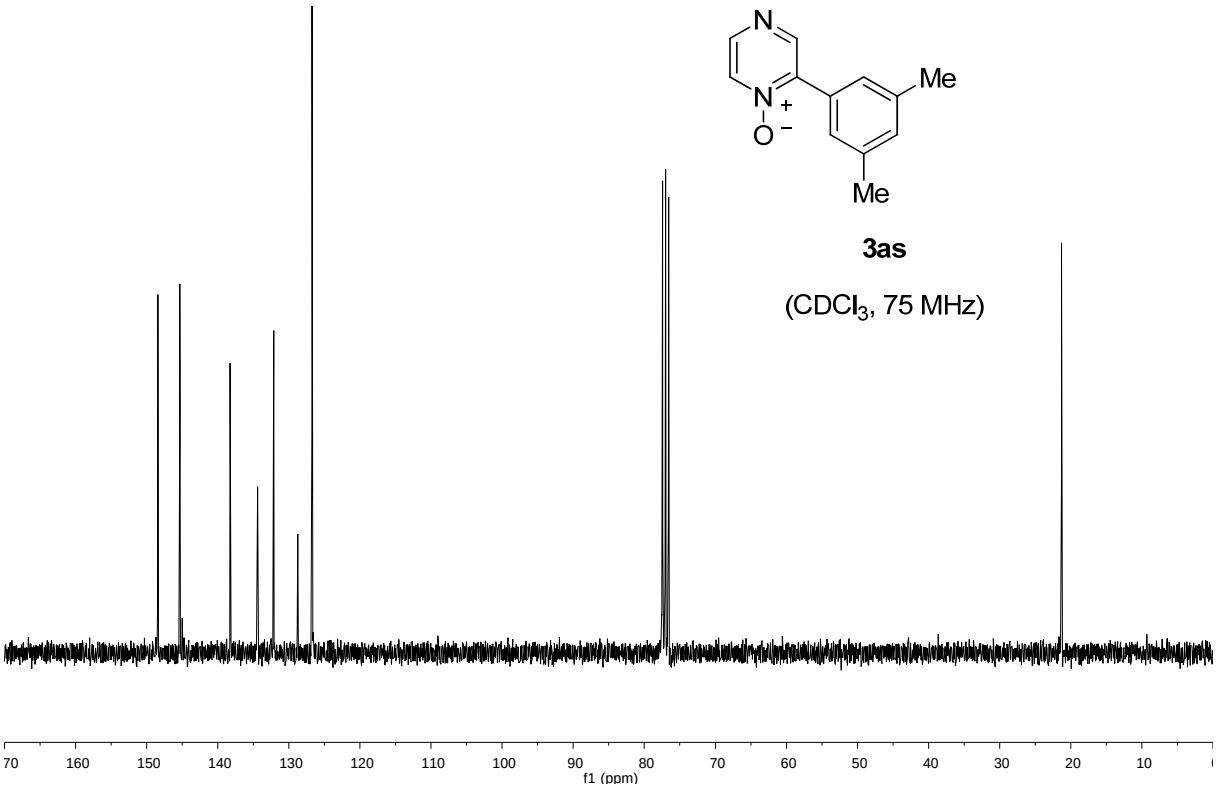
3ar

($CDCl_3$, 75 MHz)



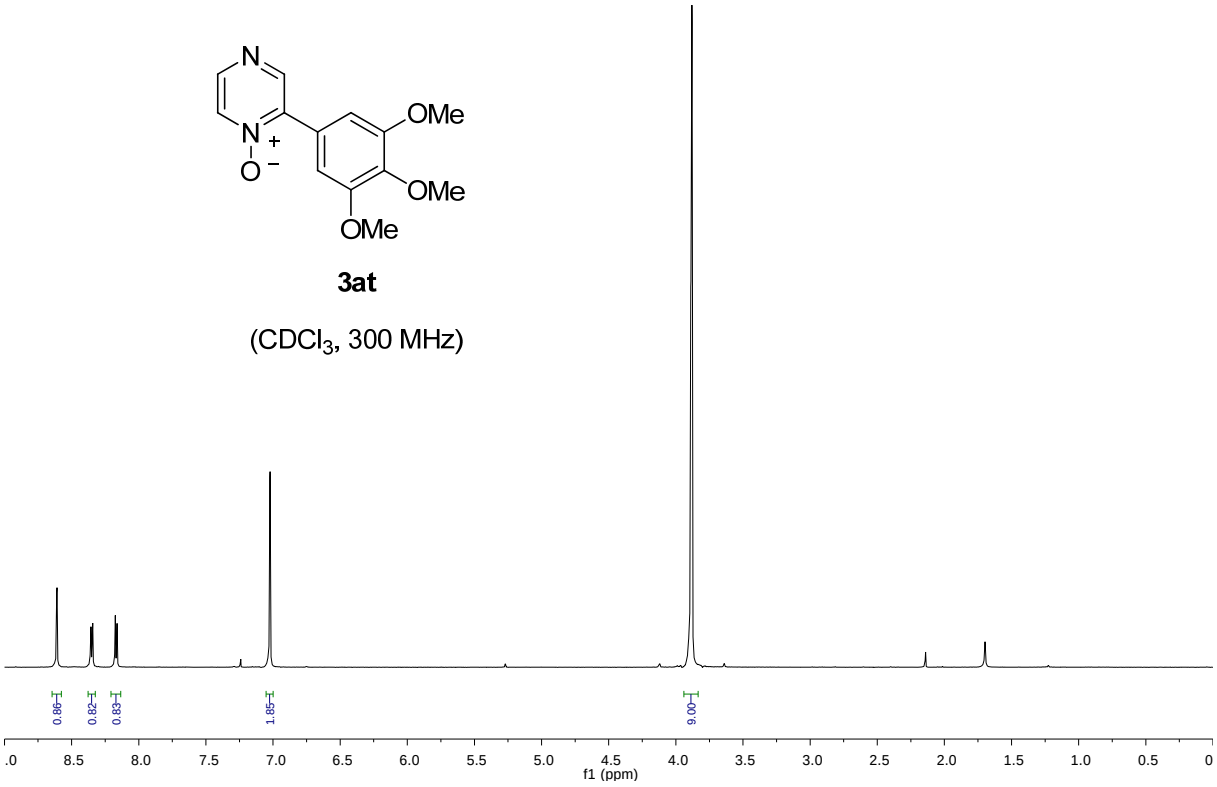
3as

($CDCl_3$, 300 MHz)



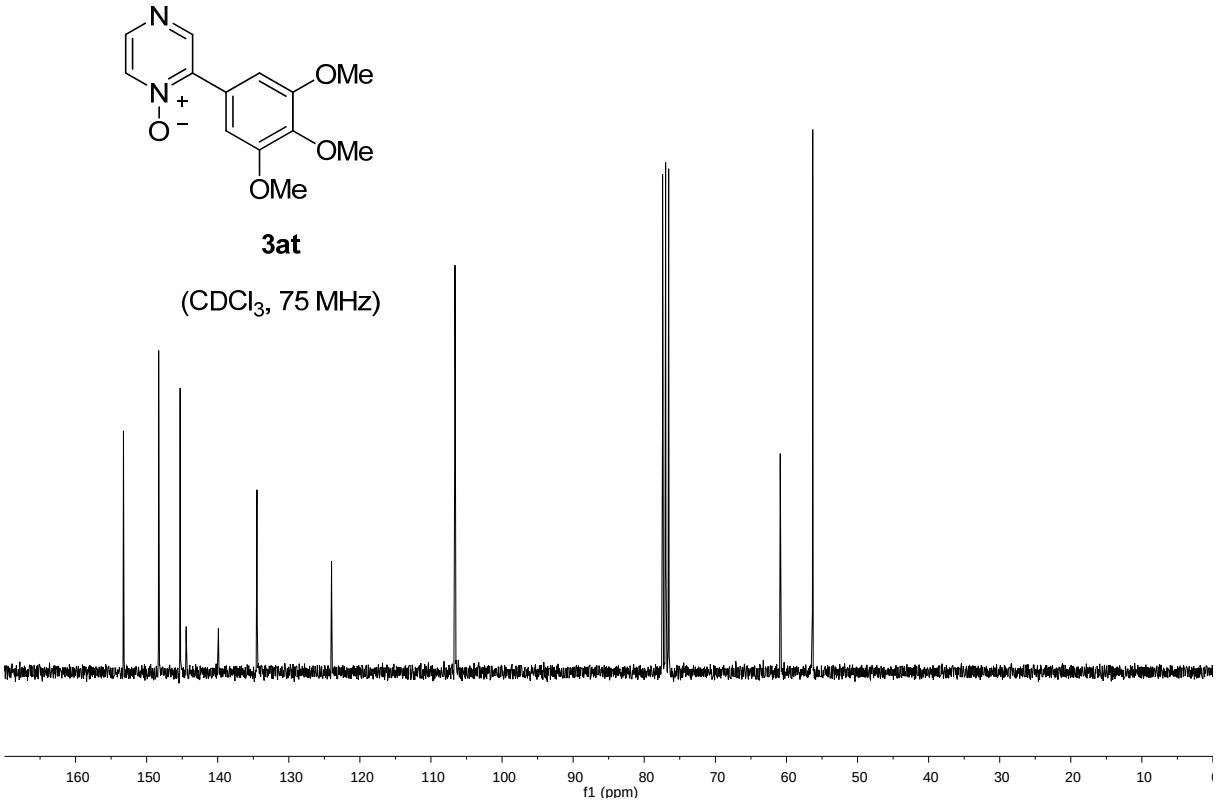
3as

($CDCl_3$, 75 MHz)



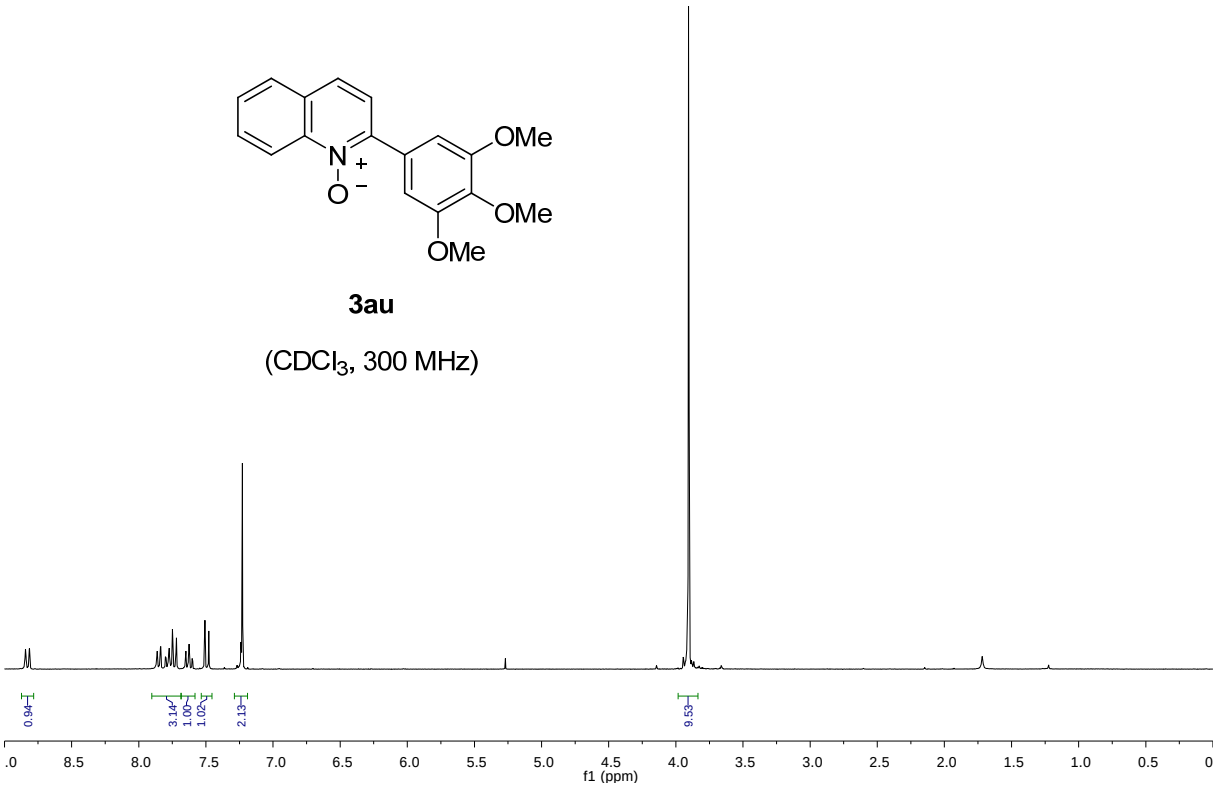
3at

($CDCl_3$, 300 MHz)



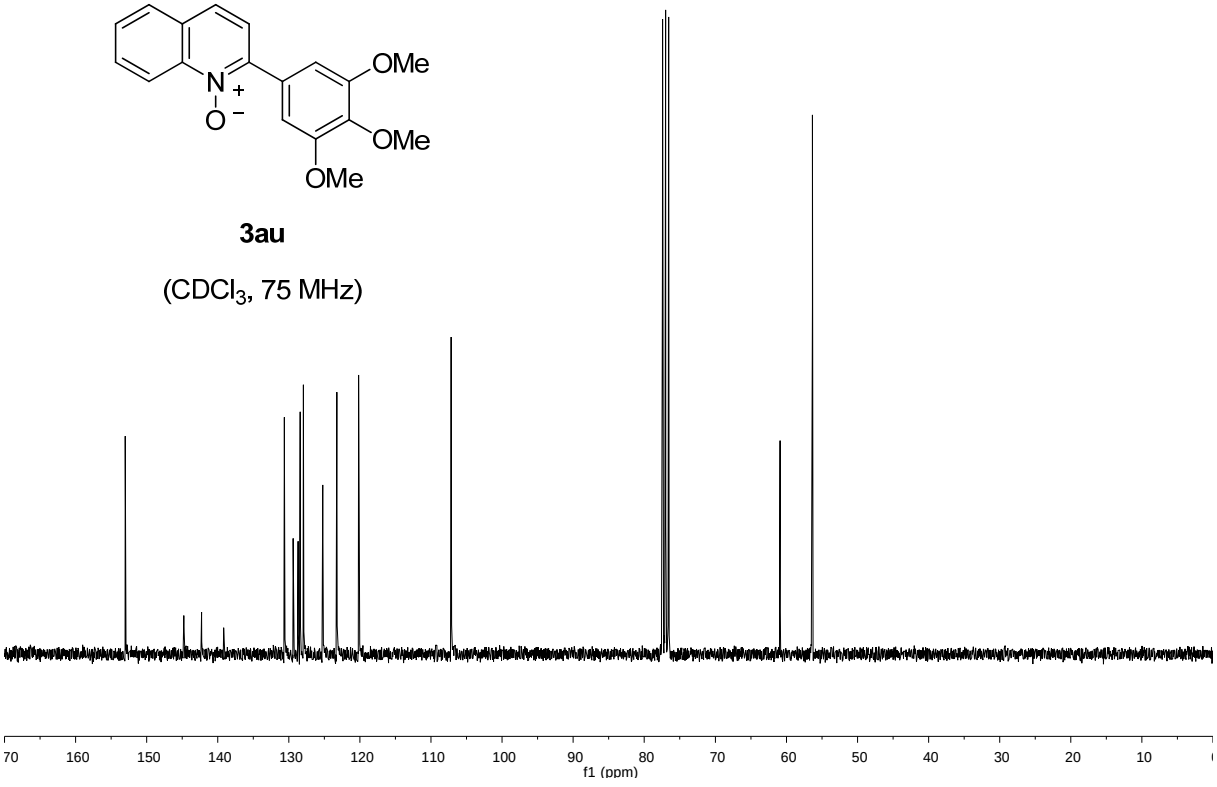
3at

($CDCl_3$, 75 MHz)



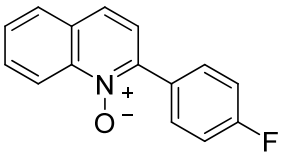
3au

($CDCl_3$, 300 MHz)



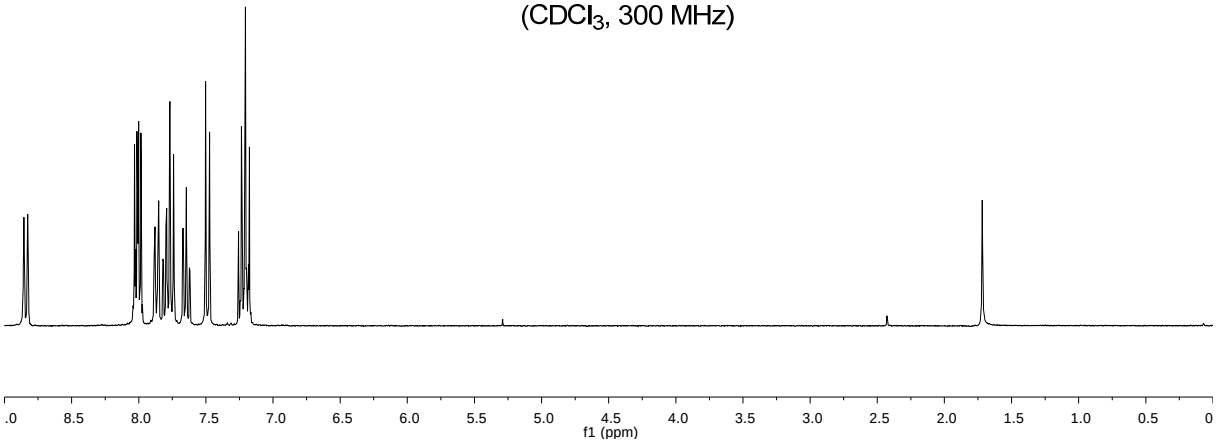
3au

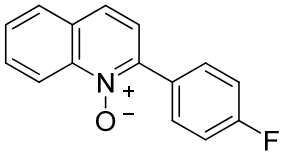
($CDCl_3$, 75 MHz)



3av

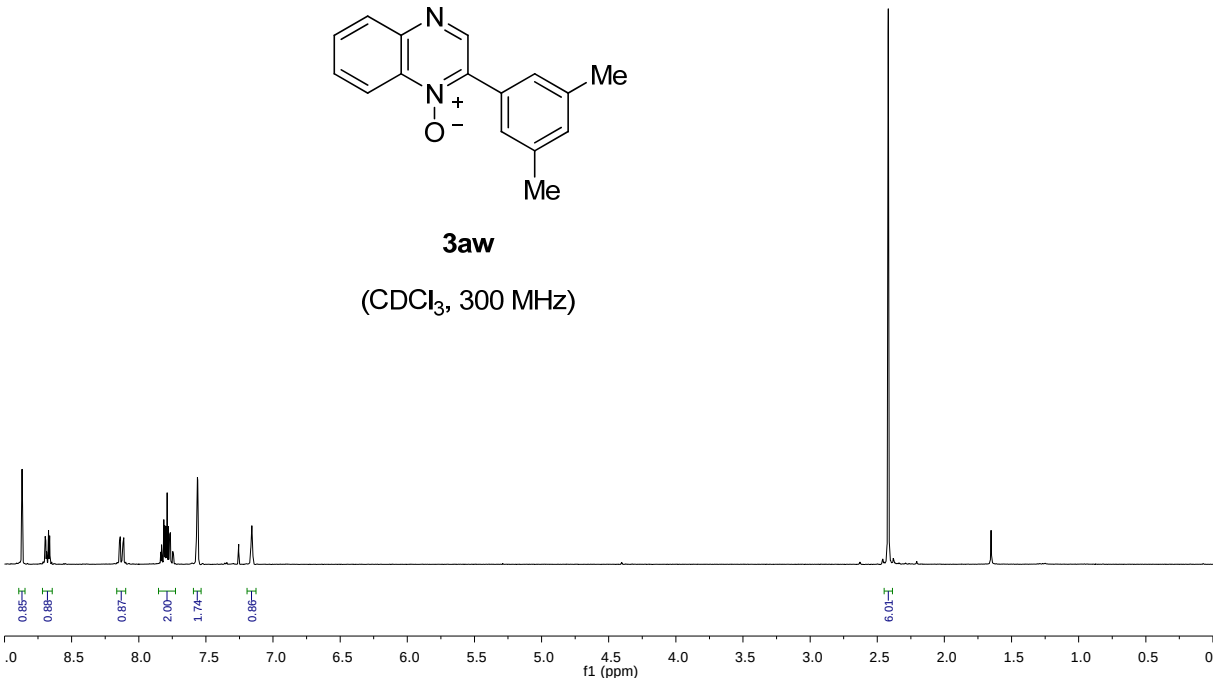
($CDCl_3$, 300 MHz)





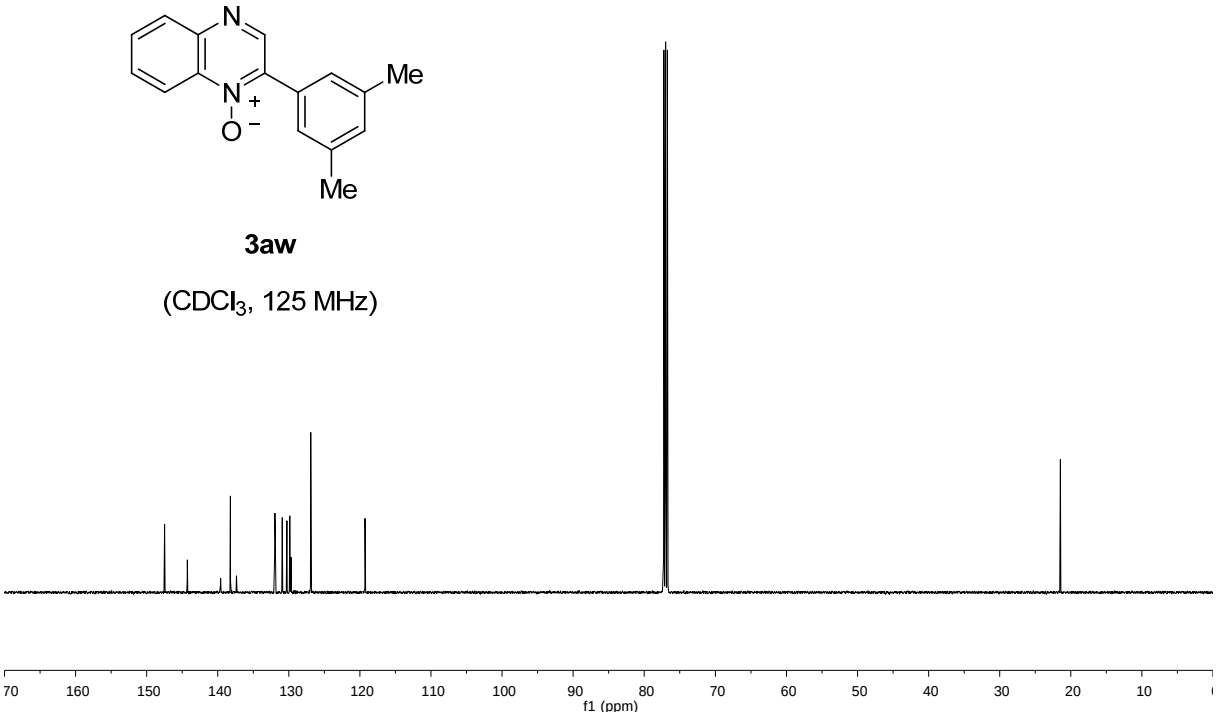
3av

($CDCl_3$, 125 MHz)



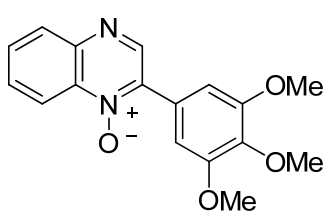
3aw

($CDCl_3$, 300 MHz)



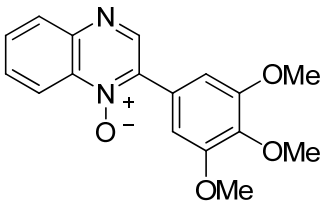
3aw

($CDCl_3$, 125 MHz)



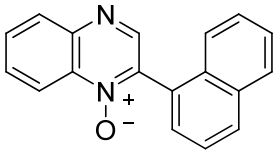
3ax

($CDCl_3$, 300 MHz)



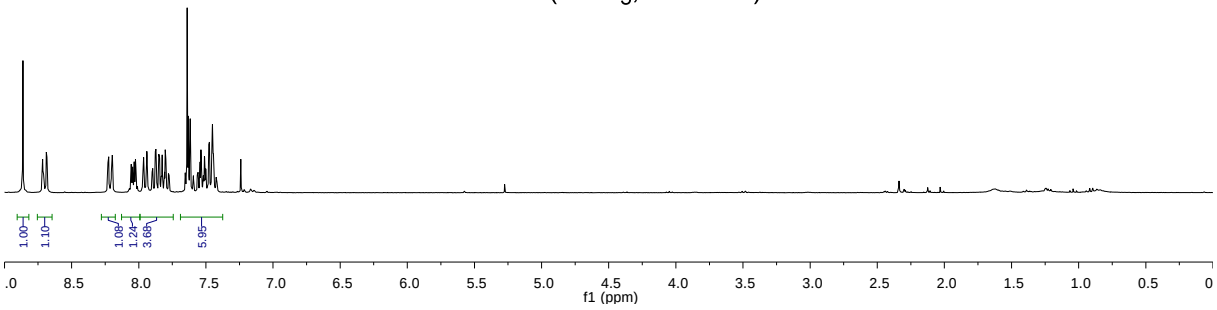
3ax

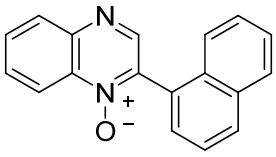
($CDCl_3$, 75 MHz)



3ay

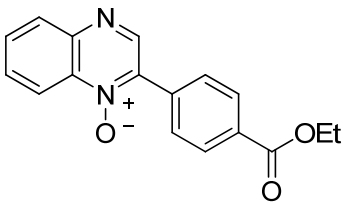
($CDCl_3$, 300 MHz)





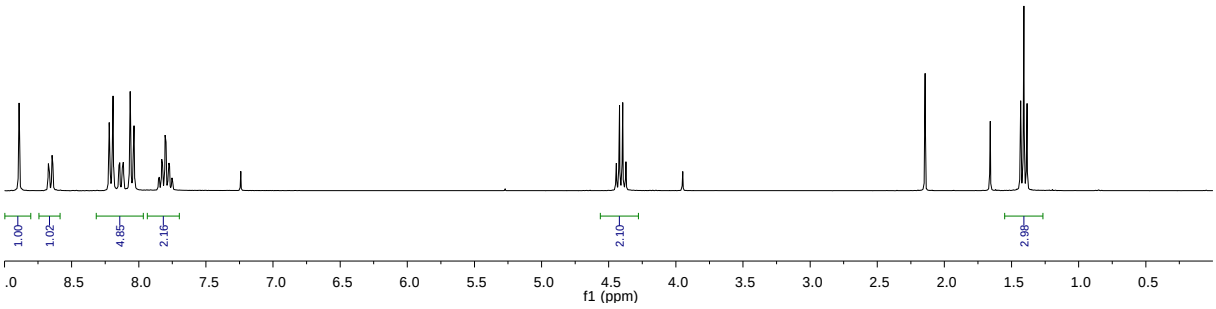
3ay

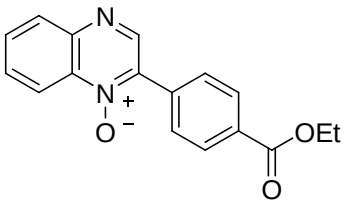
($CDCl_3$, 125 MHz)



3az

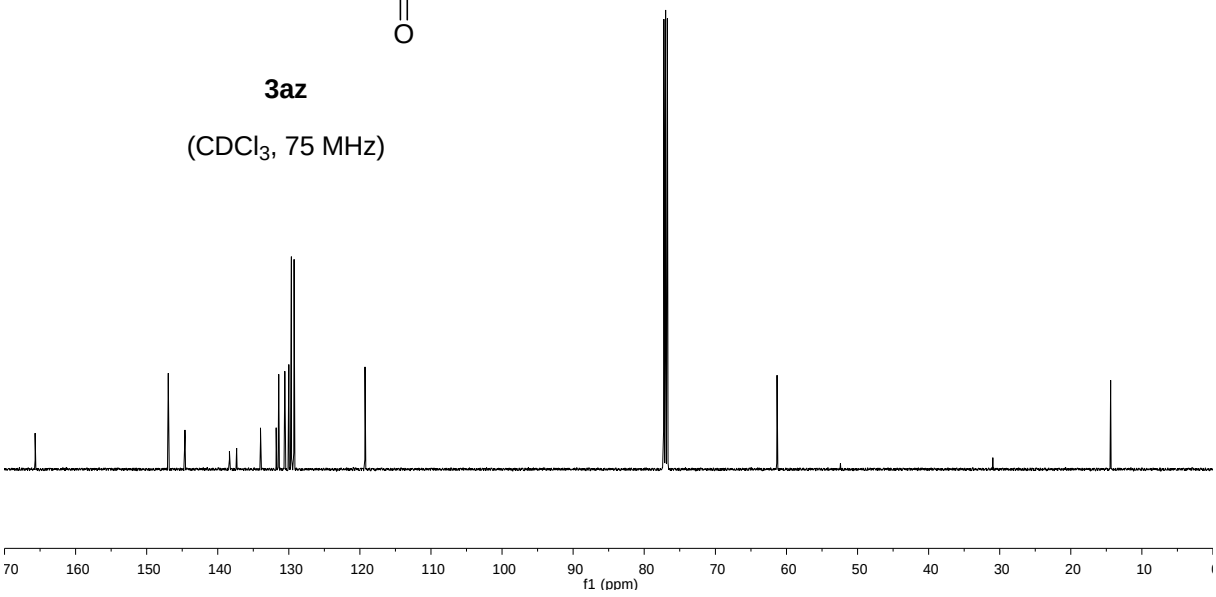
($CDCl_3$, 300 MHz)

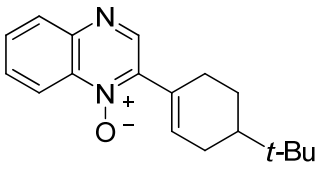




3az

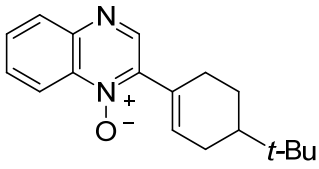
($CDCl_3$, 75 MHz)





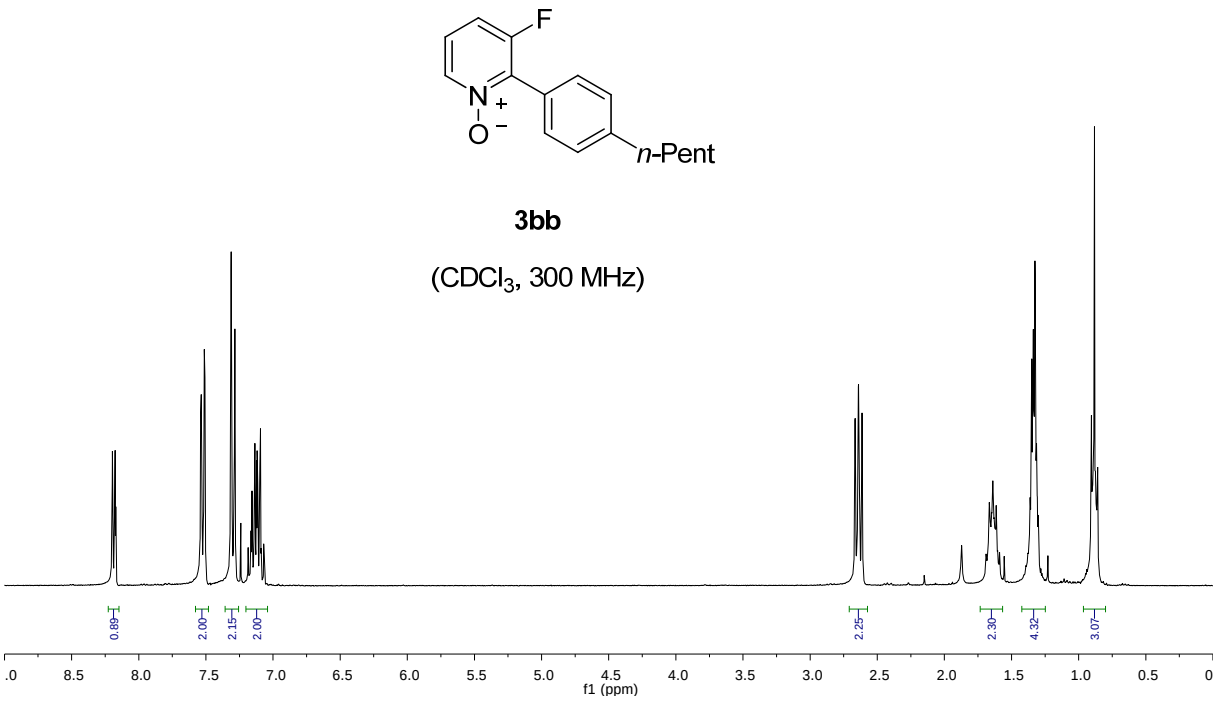
3ba

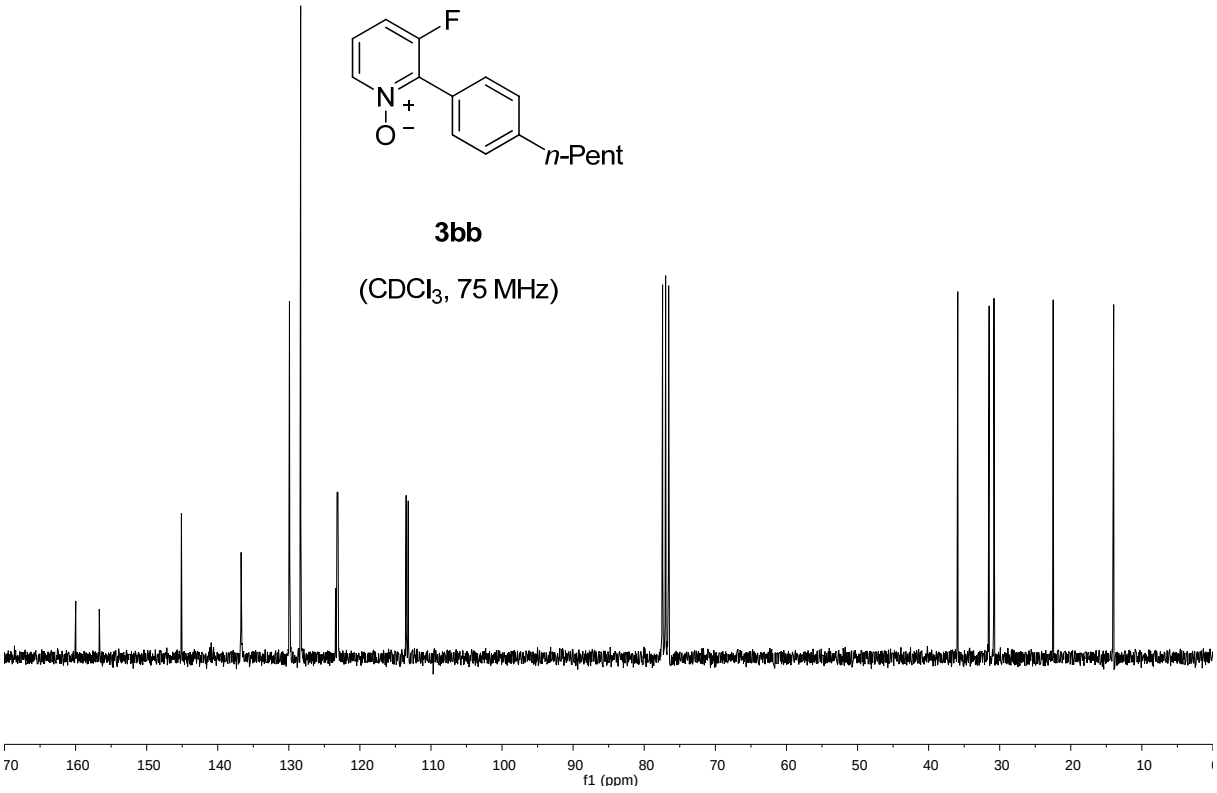
($CDCl_3$, 300 MHz)

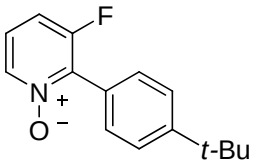


3ba

($CDCl_3$, 125 MHz)

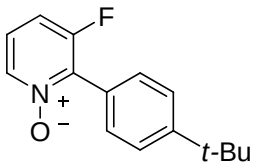

F
N +
O −
n-Pent
3bb
(CDCl3, 300 MHz)
0.89
2.00
2.15
2.00
2.25
2.30
4.32
3.07
f1 (ppm)


F
N +
O −
n-Pent
3bb
(CDCl3, 75 MHz)
f1 (ppm)



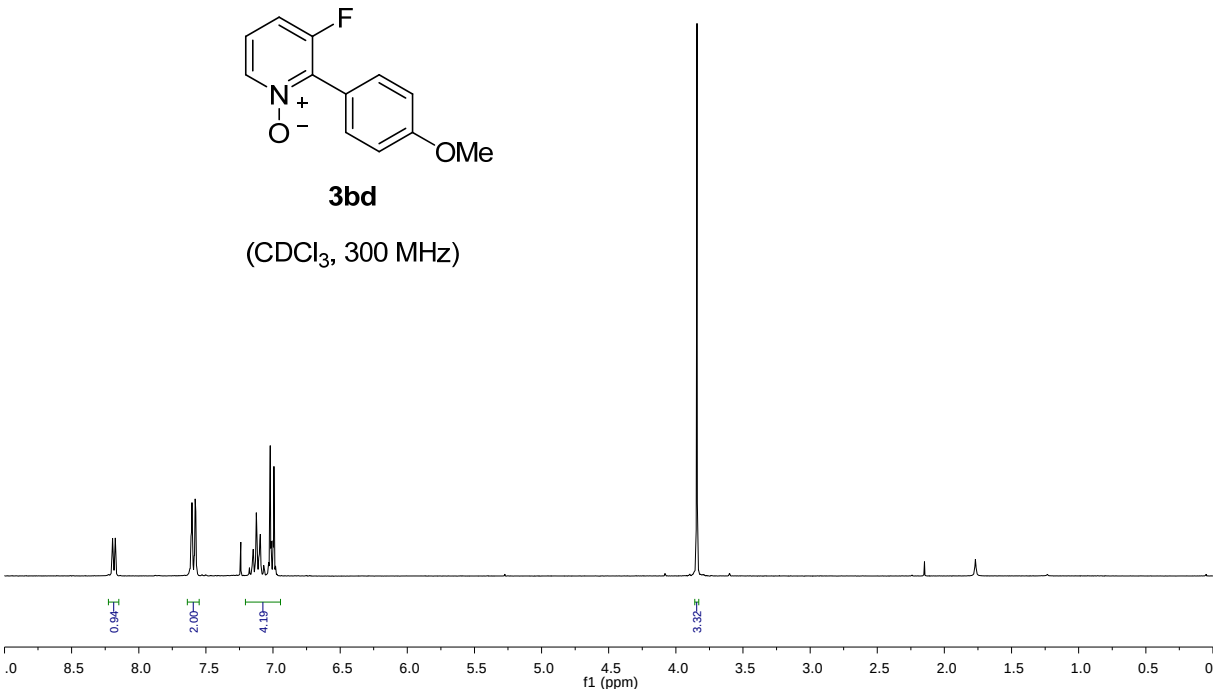
3bc

($CDCl_3$, 300 MHz)



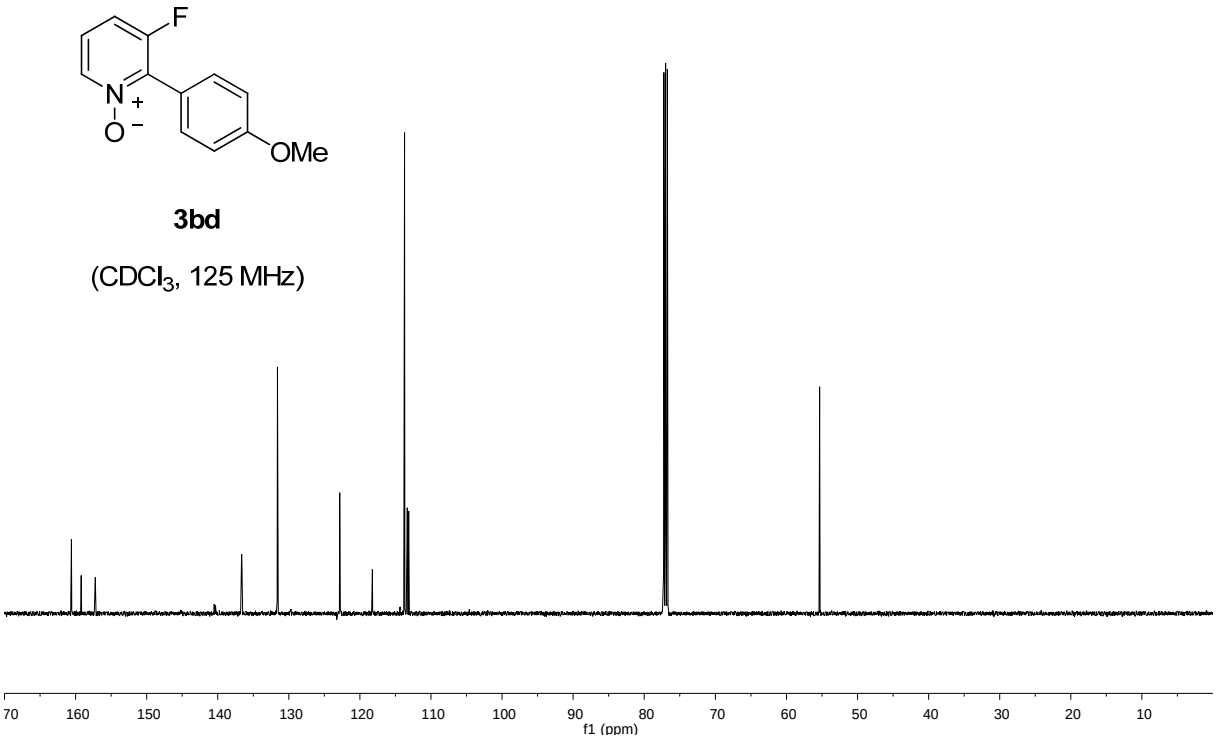
3bc

($CDCl_3$, 125 MHz)



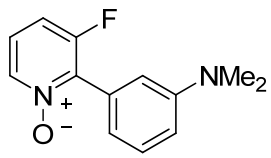
3bd

($CDCl_3$, 300 MHz)



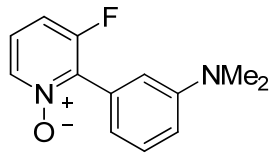
3bd

($CDCl_3$, 125 MHz)



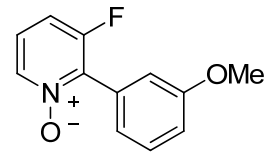
3be

($CDCl_3$, 300 MHz)



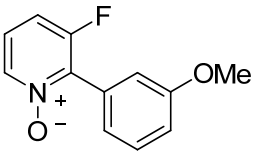
3be

($CDCl_3$, 125 MHz)



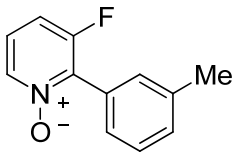
3bf

($CDCl_3$, 300 MHz)



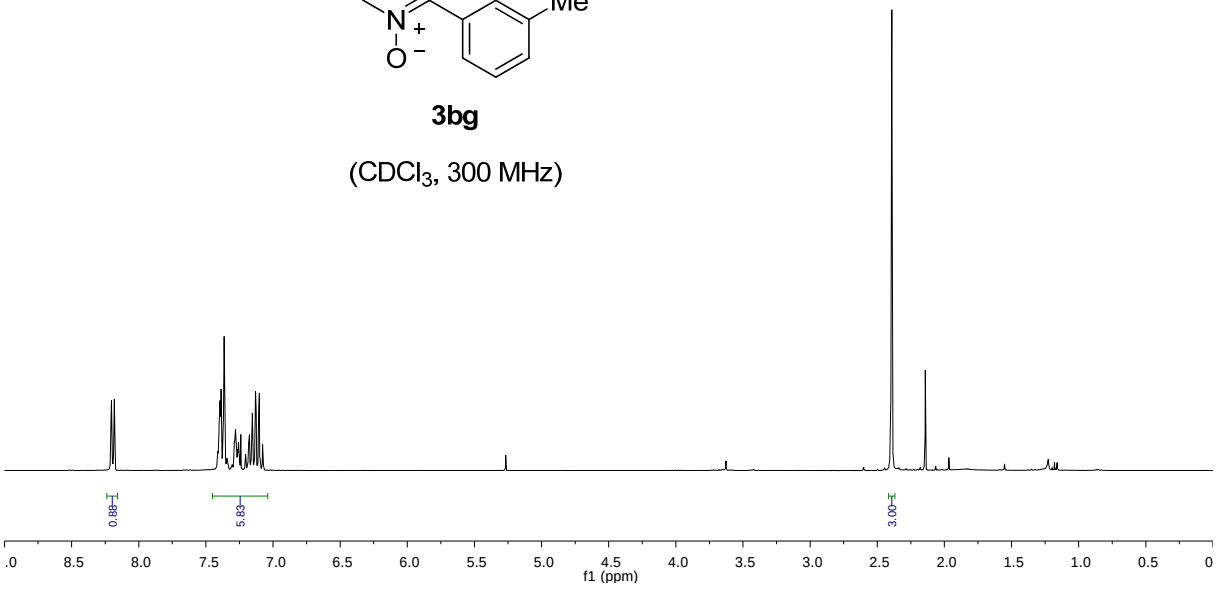
3bf

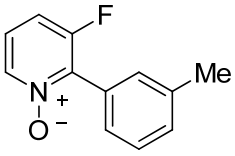
($CDCl_3$, 125 MHz)



3bg

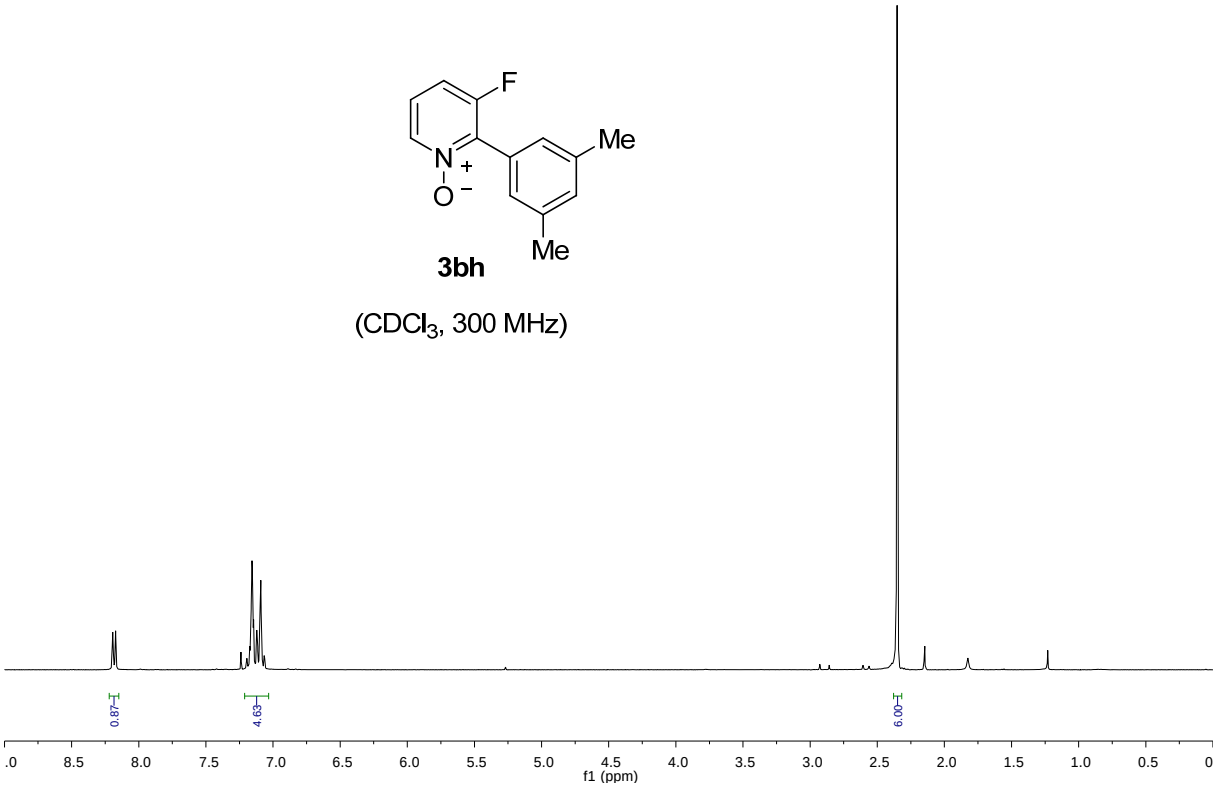
($CDCl_3$, 300 MHz)





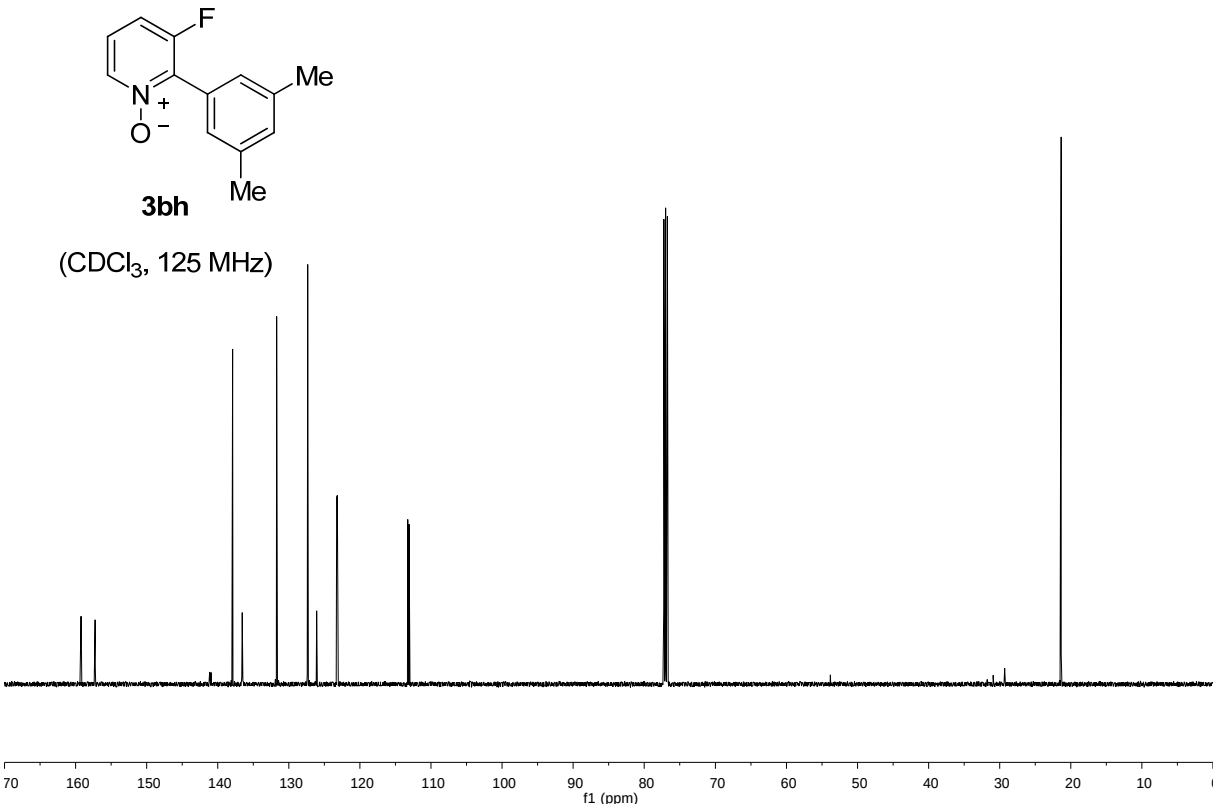
3bg

($CDCl_3$, 125 MHz)



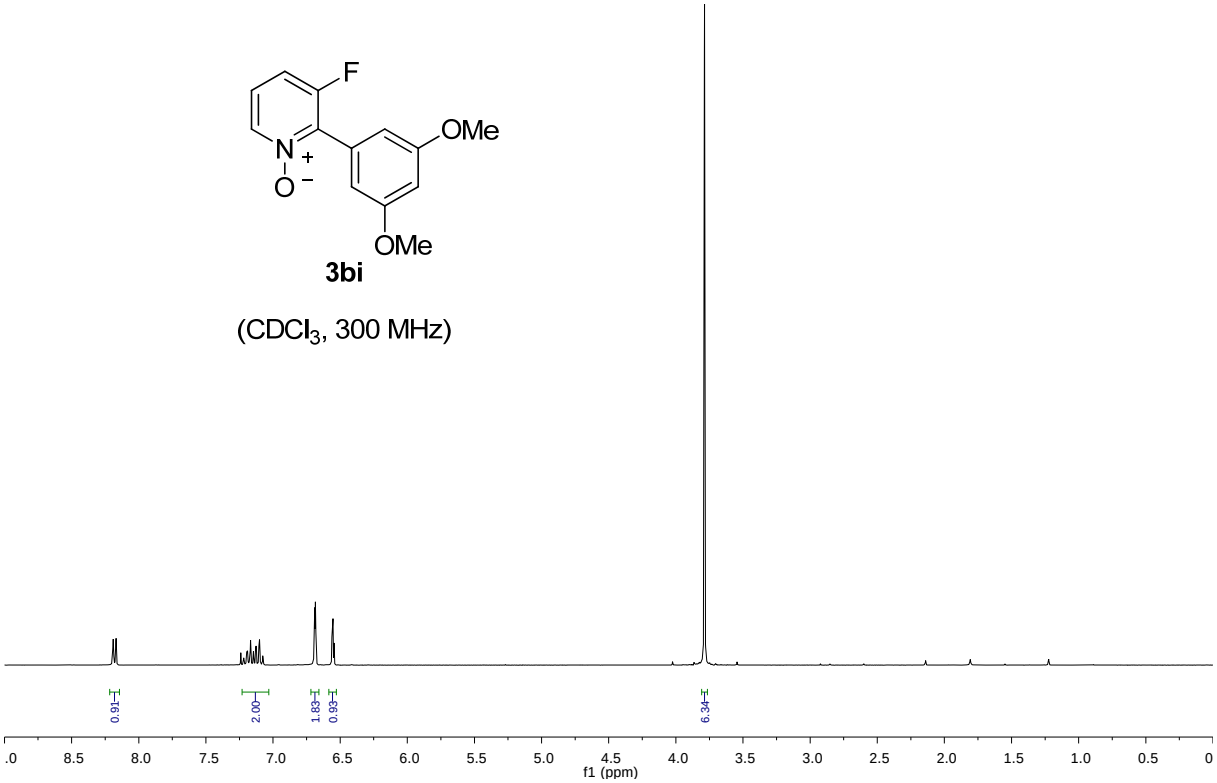
3bh

($CDCl_3$, 300 MHz)



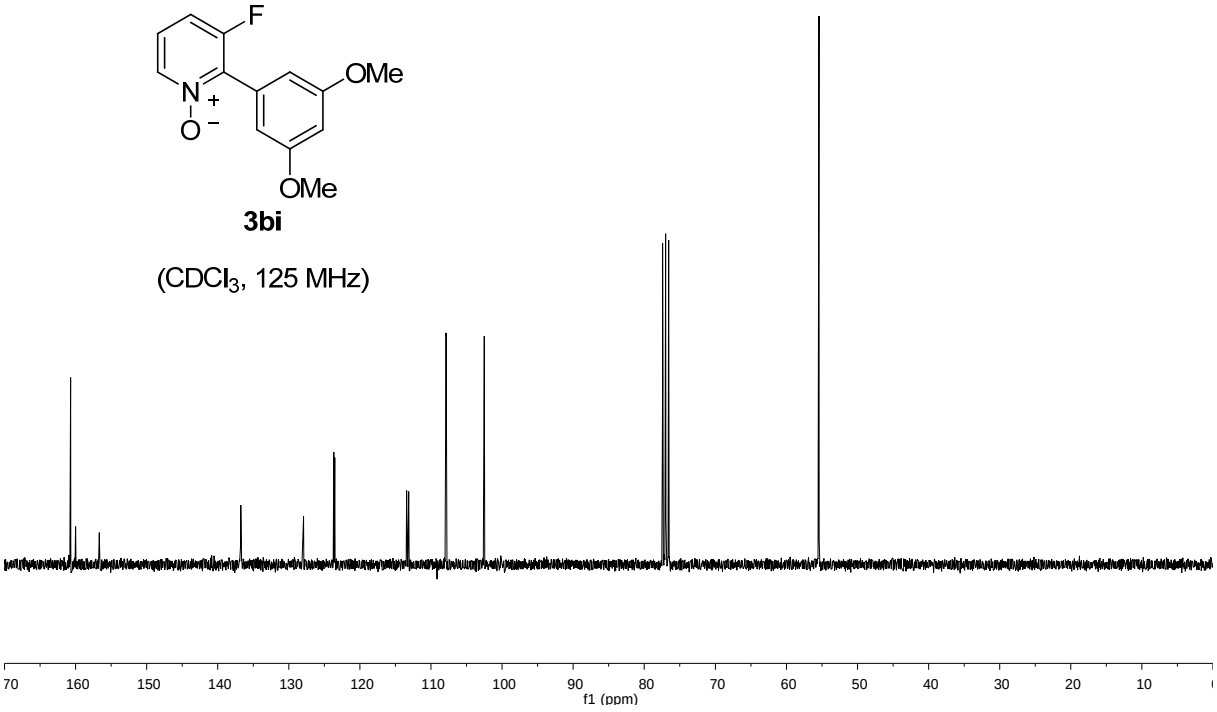
3bh

($CDCl_3$, 125 MHz)



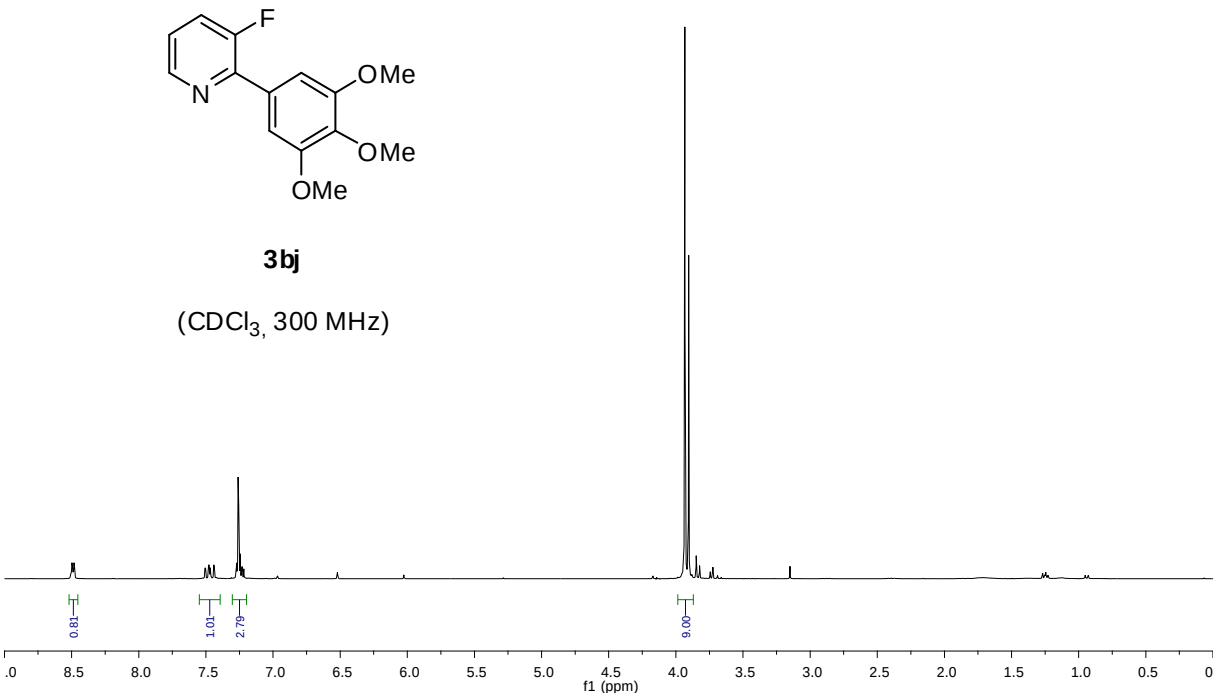
3bi

($CDCl_3$, 300 MHz)



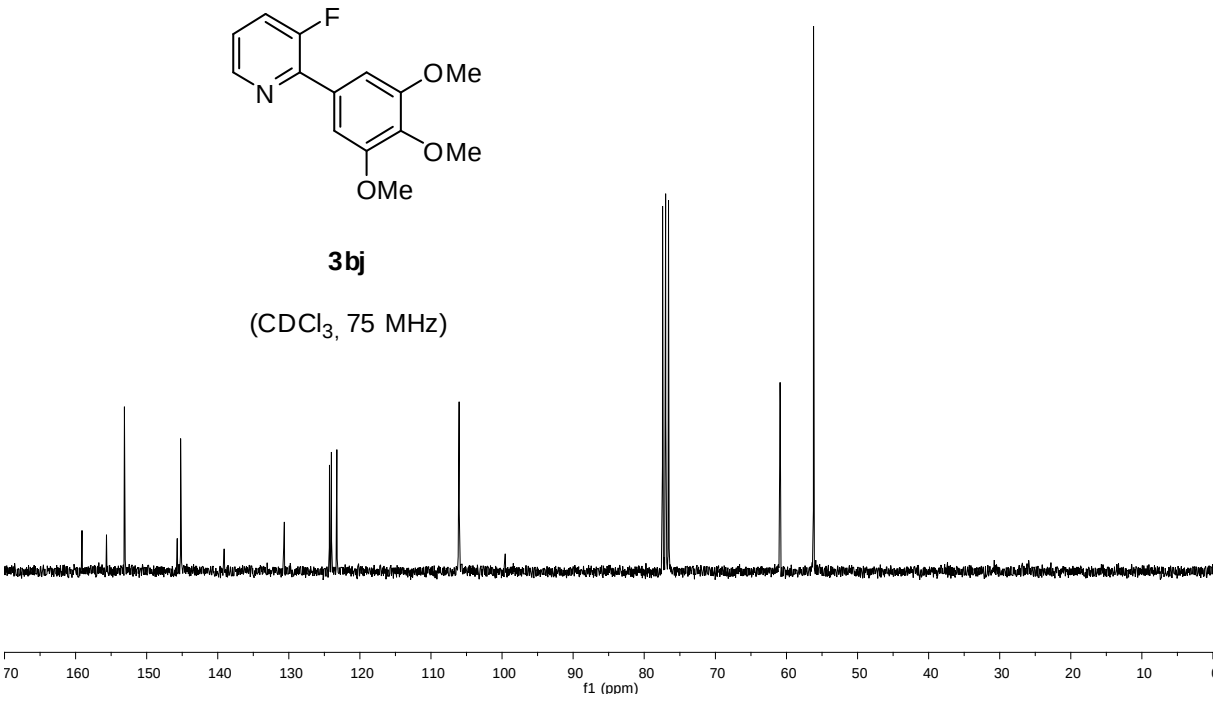
3bi

($CDCl_3$, 125 MHz)



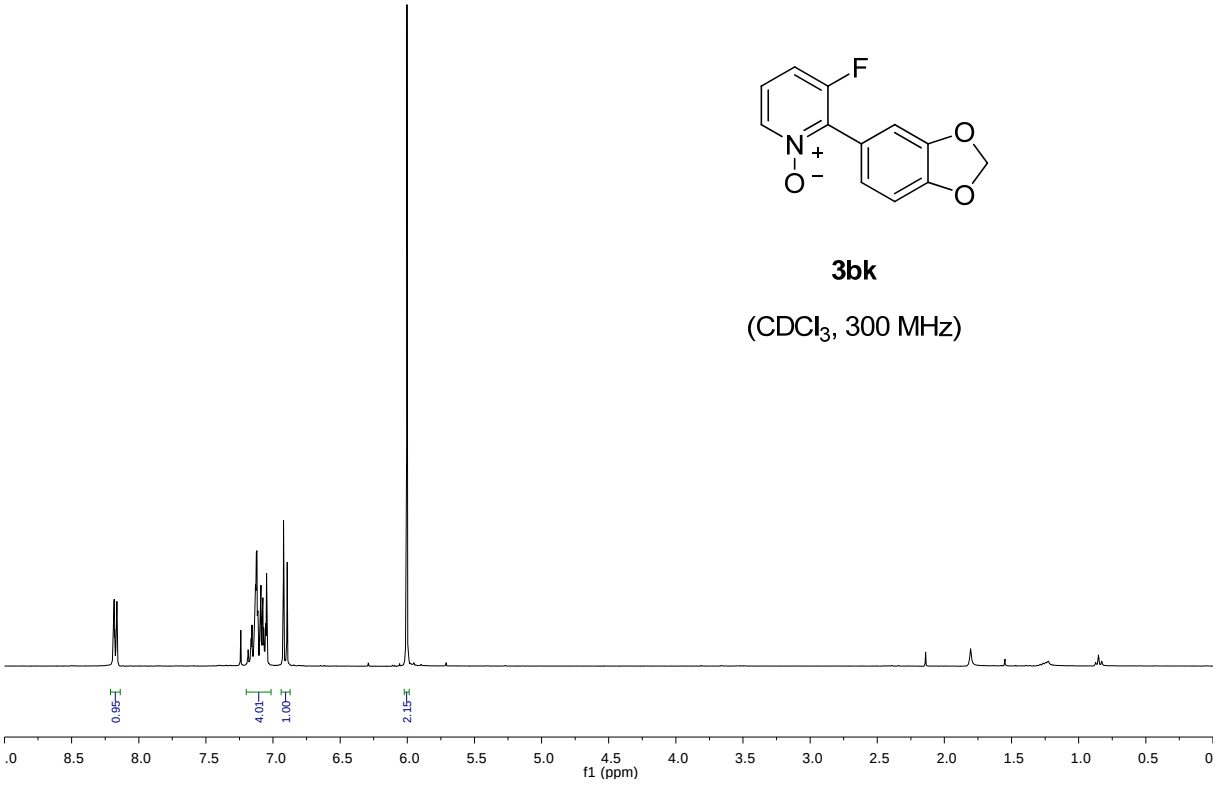
3bj

($CDCl_3$, 300 MHz)



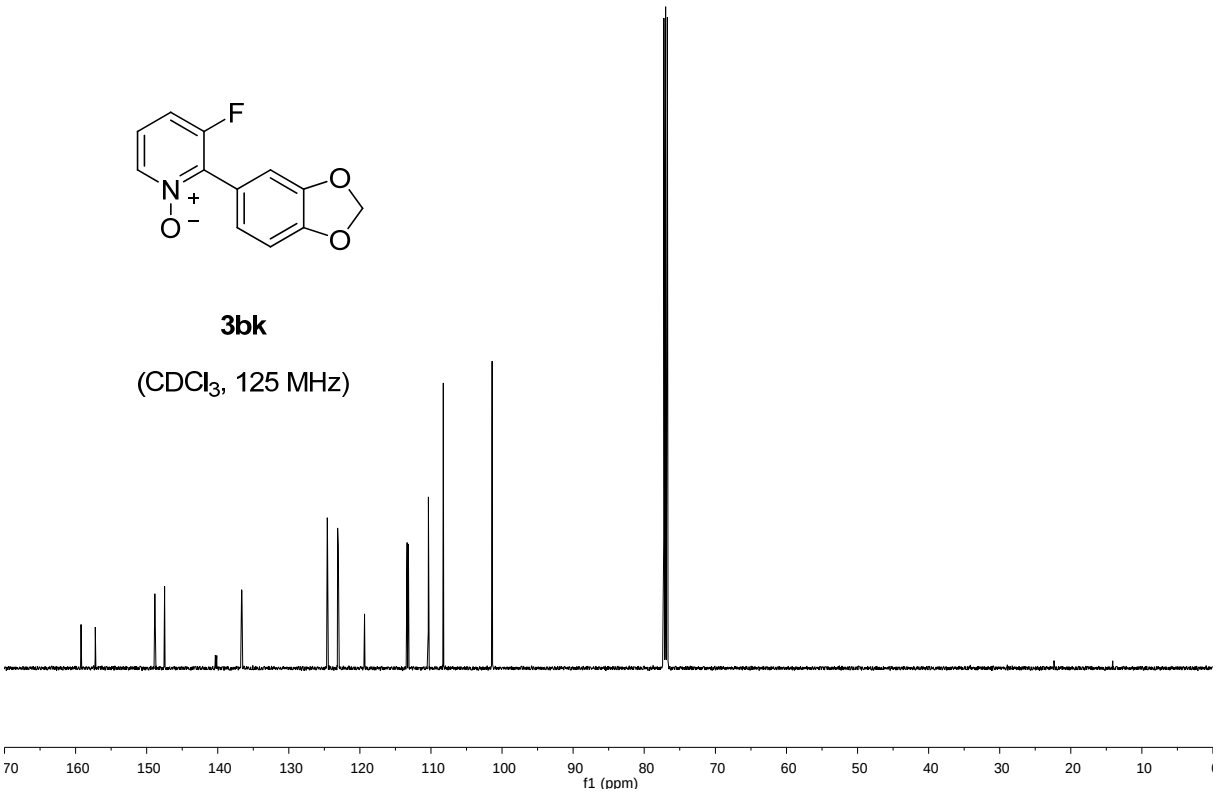
3bj

($CDCl_3$, 75 MHz)



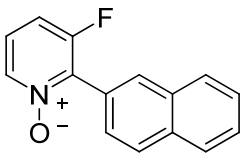
3bk

($CDCl_3$, 300 MHz)



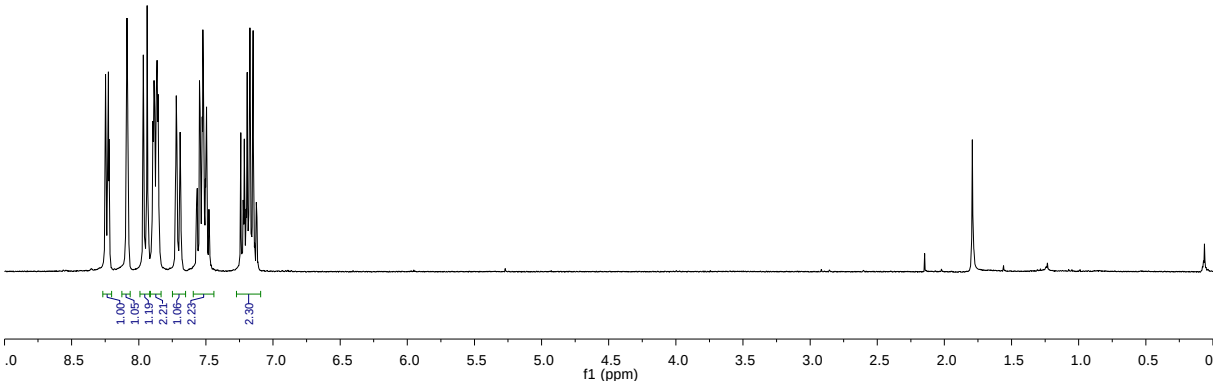
3bk

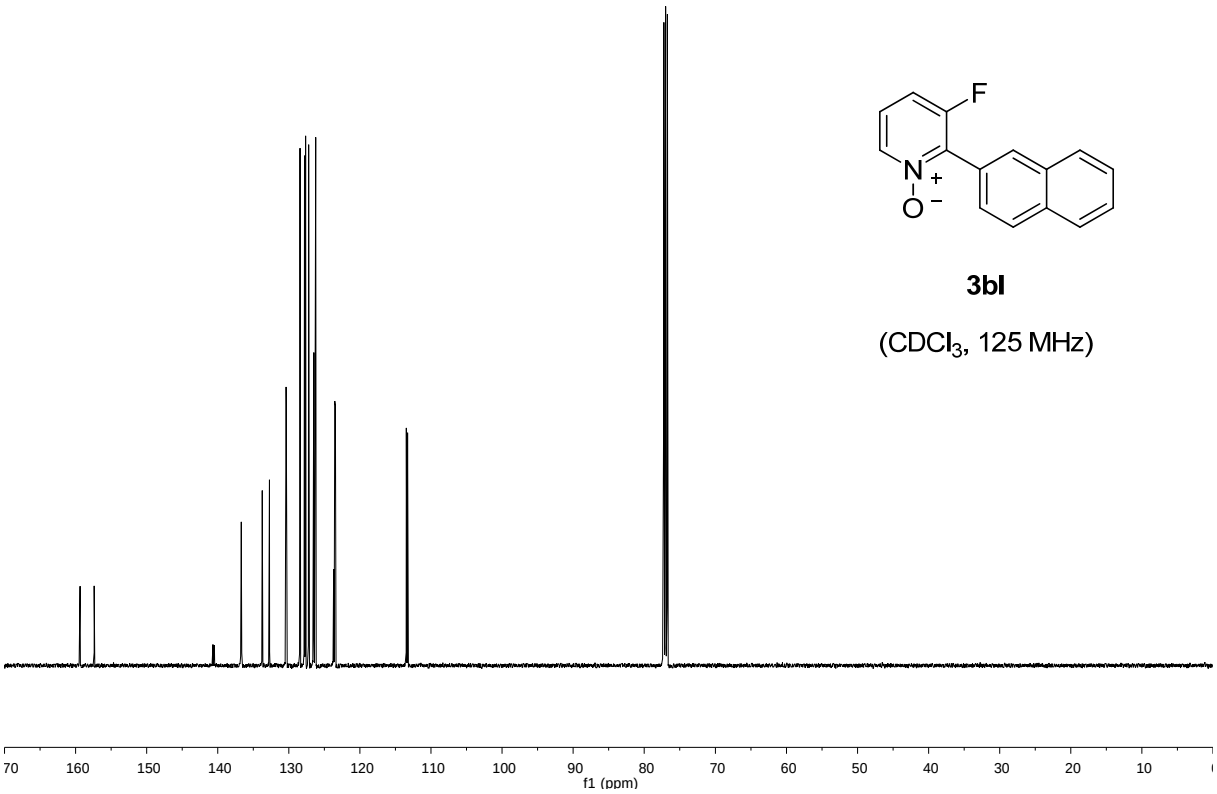
($CDCl_3$, 125 MHz)



3bl

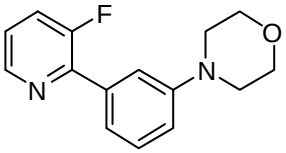
($CDCl_3$, 300 MHz)





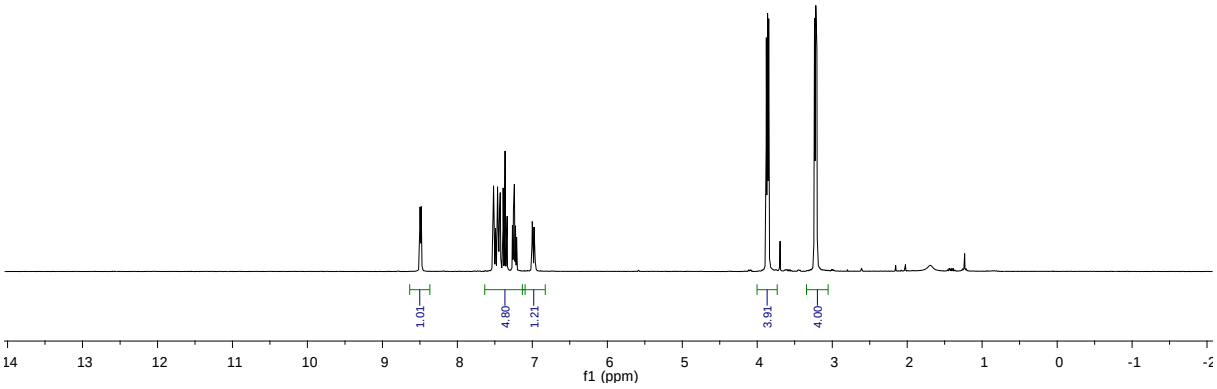
3bl

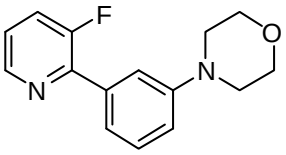
($CDCl_3$, 125 MHz)



3bm

($CDCl_3$, 300 MHz)





3bm

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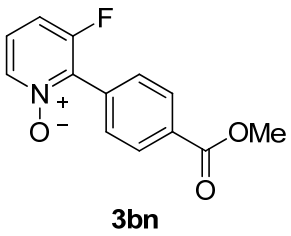
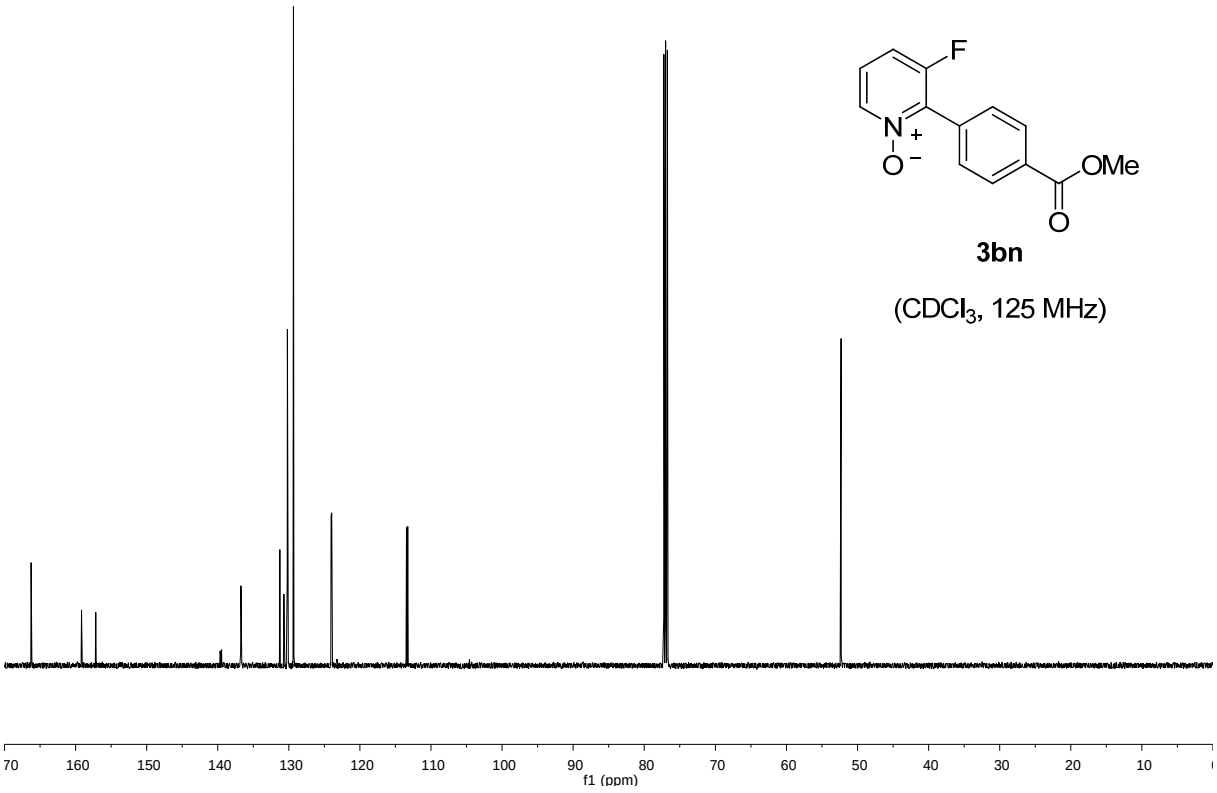


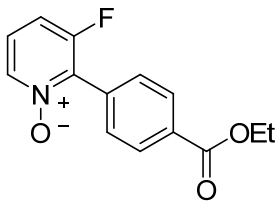
3bn

($CDCl_3$, 300 MHz)



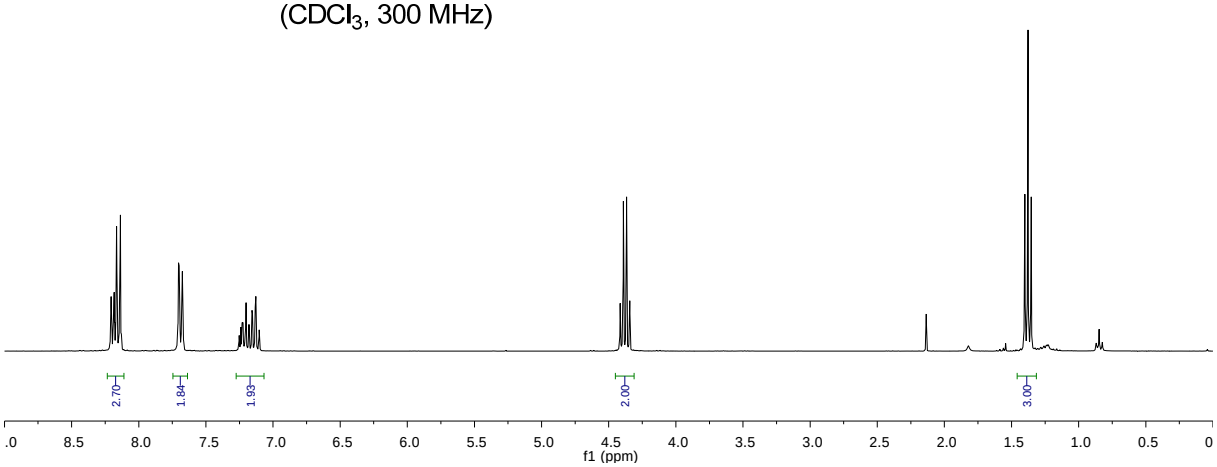
3bn

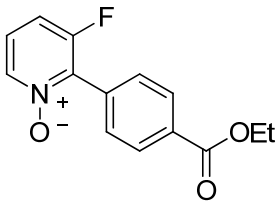
($CDCl_3$, 125 MHz)



3bo

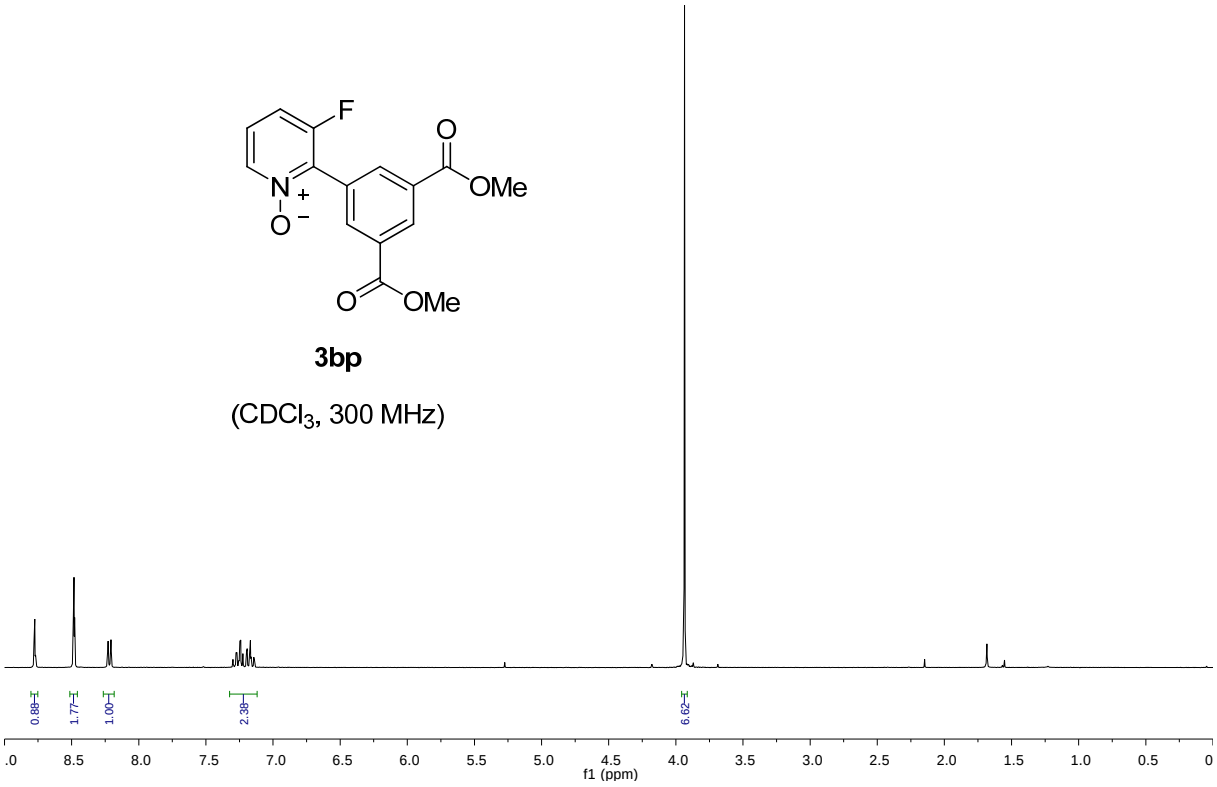
($CDCl_3$, 300 MHz)





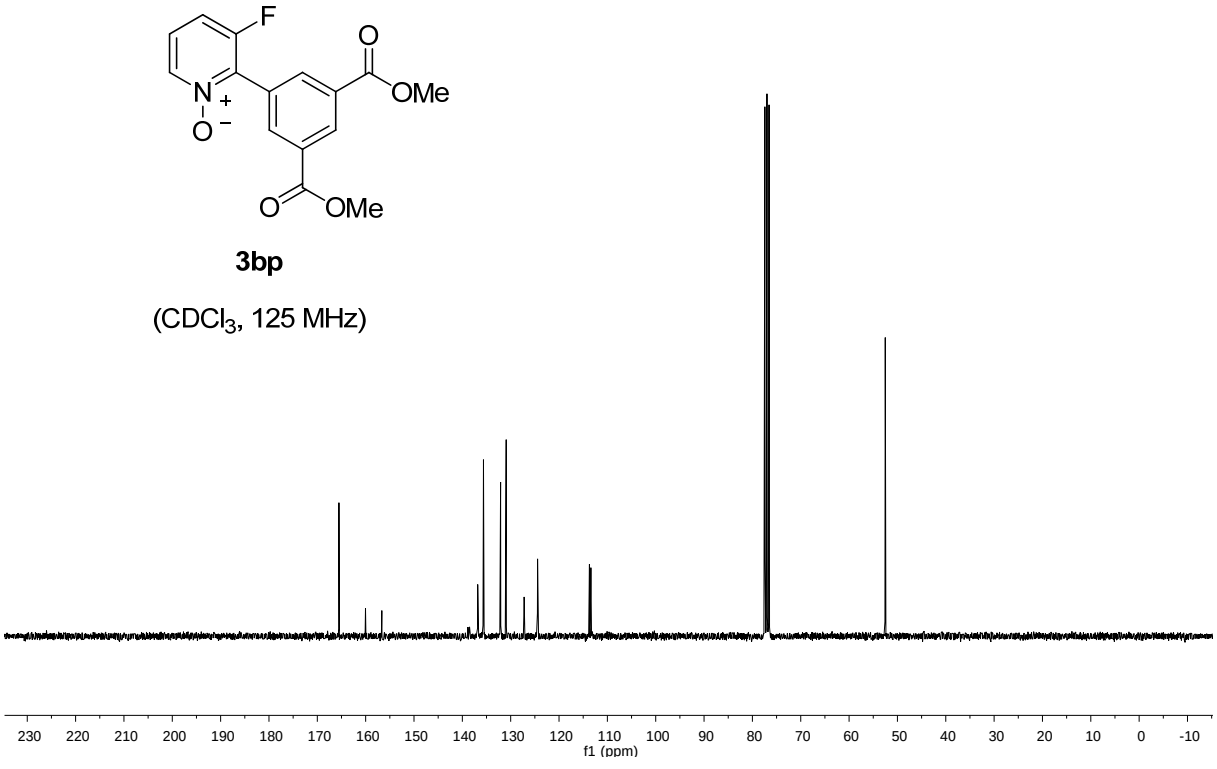
3bo

($CDCl_3$, 125 MHz)



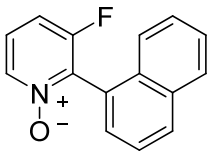
3bp

($CDCl_3$, 300 MHz)



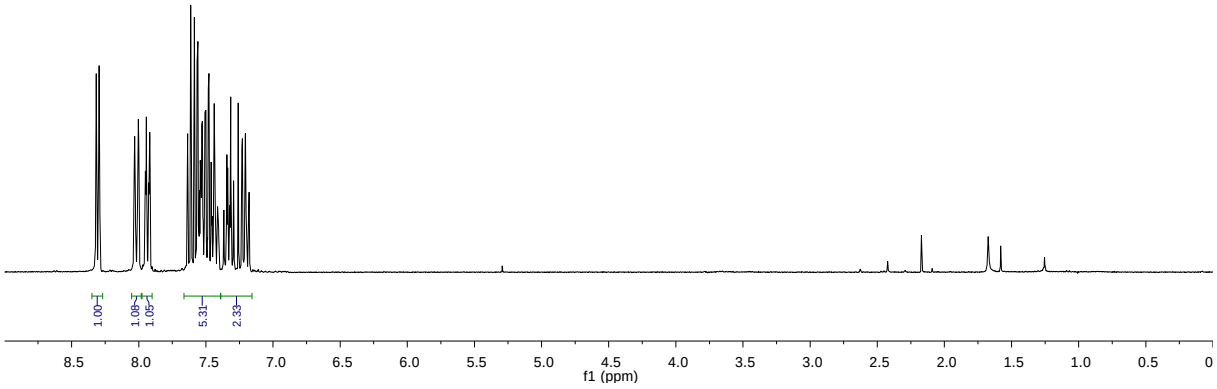
3bp

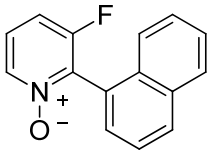
($CDCl_3$, 125 MHz)



3bq

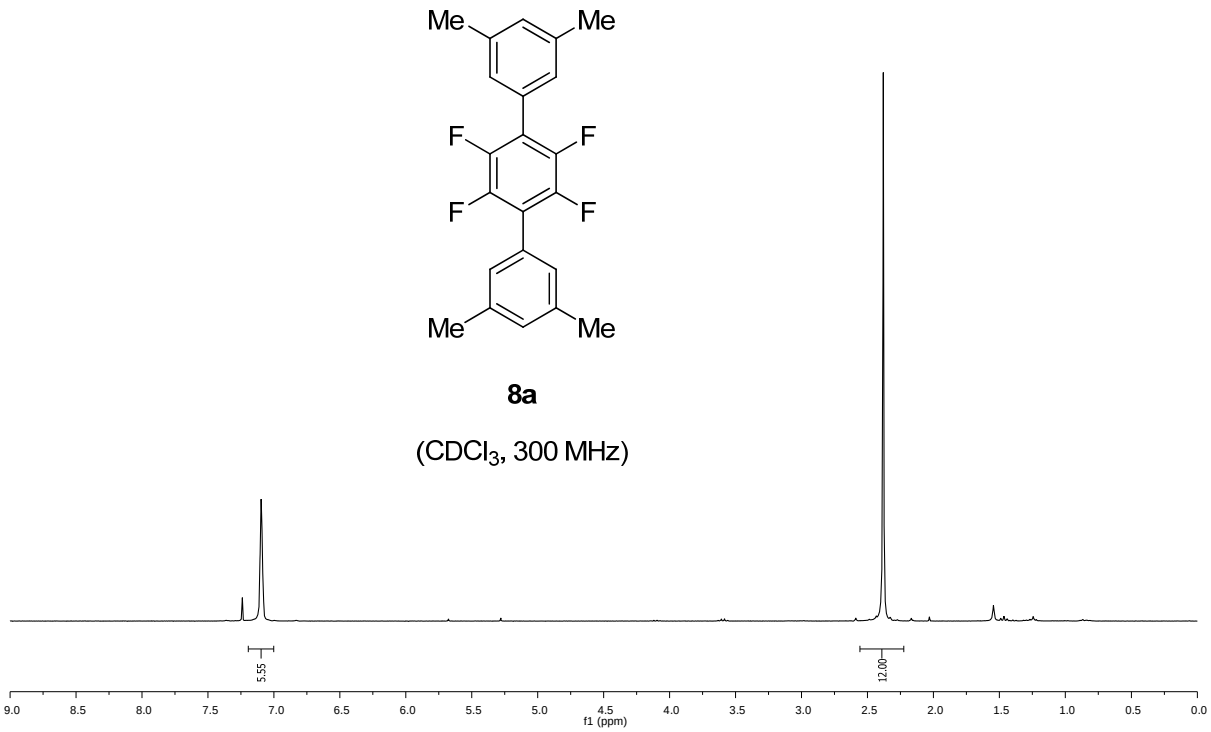
($CDCl_3$, 300 MHz)





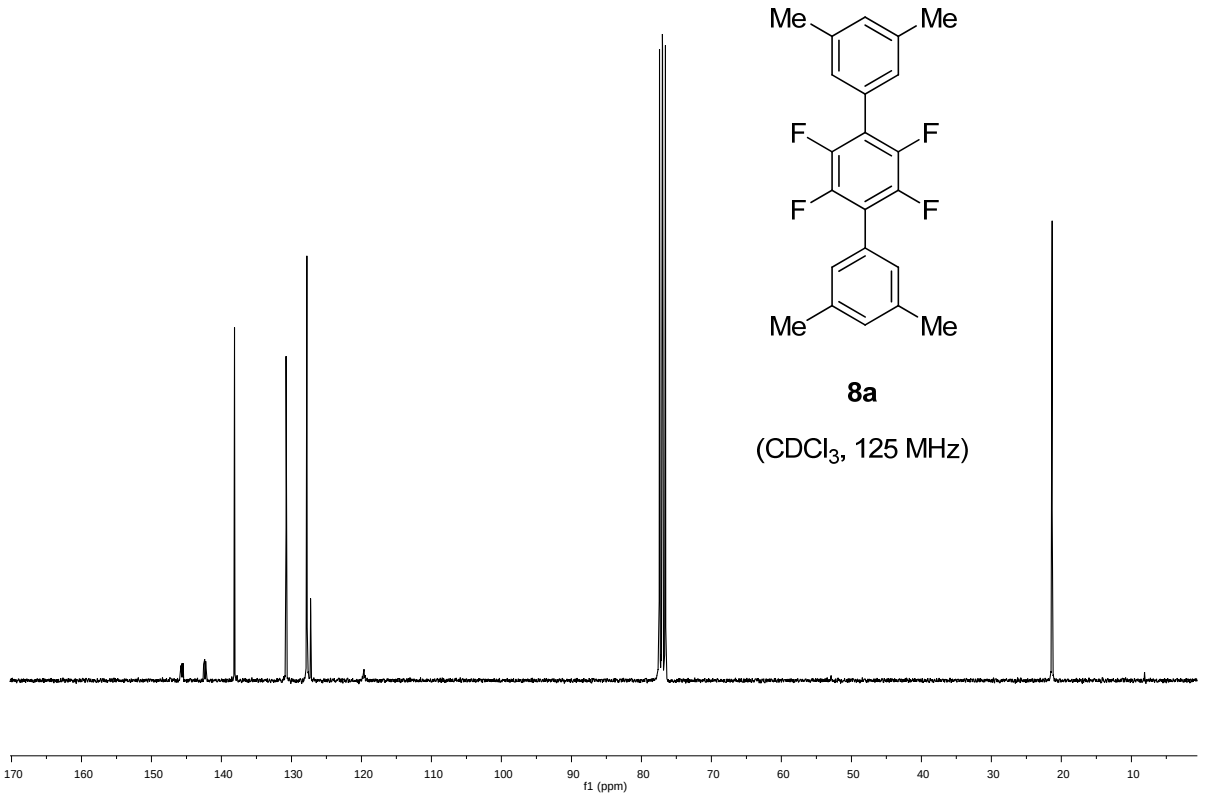
3bq

($CDCl_3$, 125 MHz)



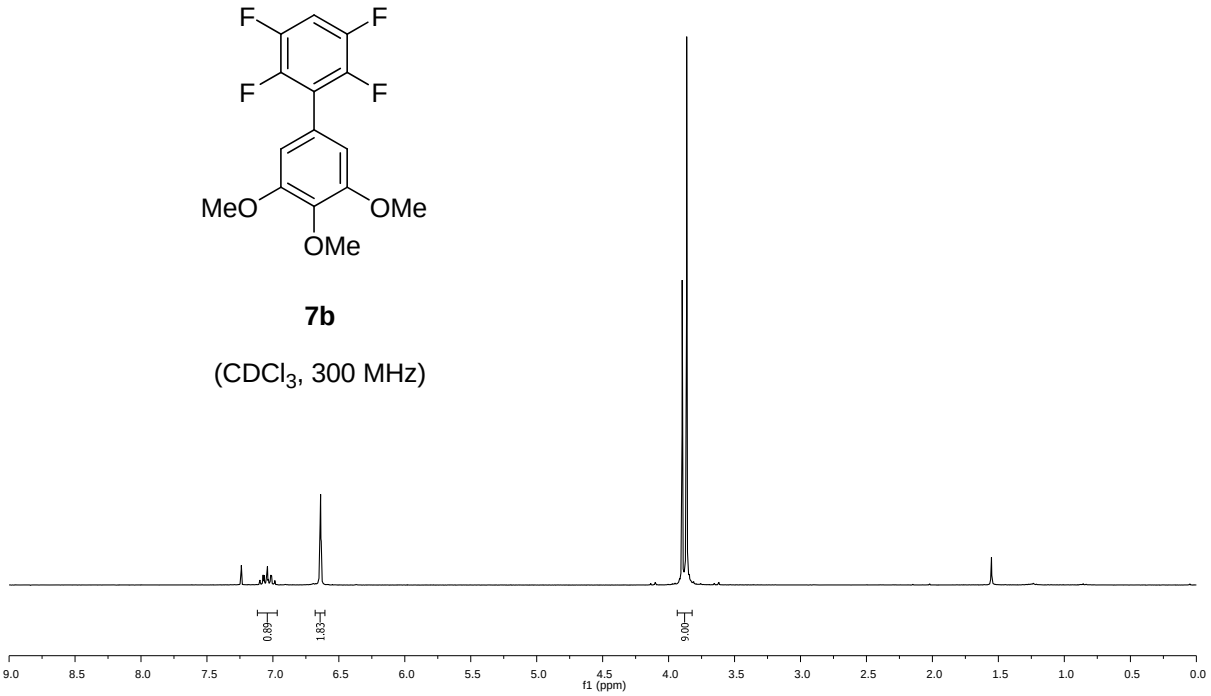
8a

($CDCl_3$, 300 MHz)



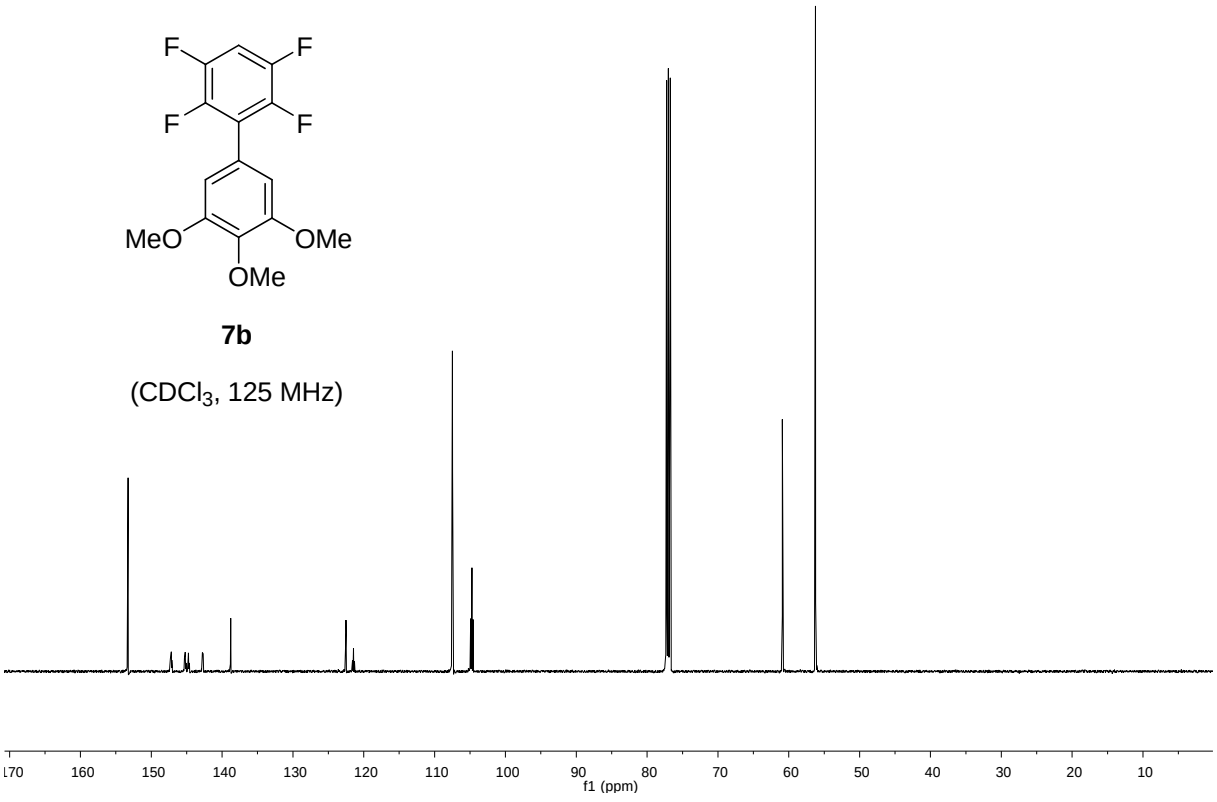
8a

($CDCl_3$, 125 MHz)



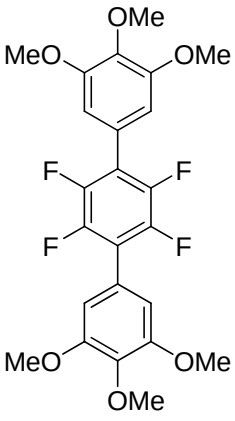
7b

($CDCl_3$, 300 MHz)



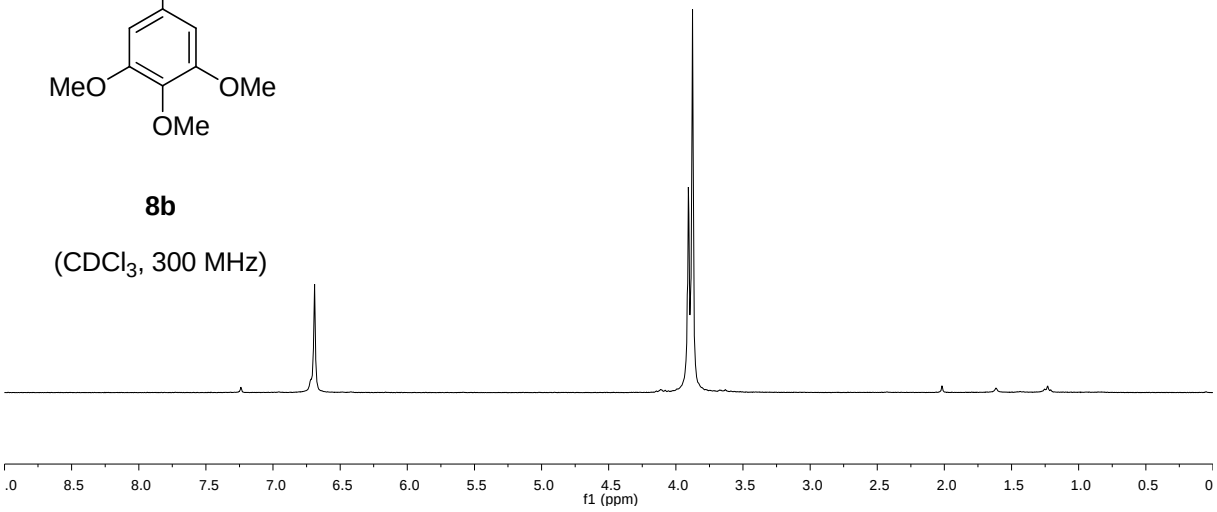
7b

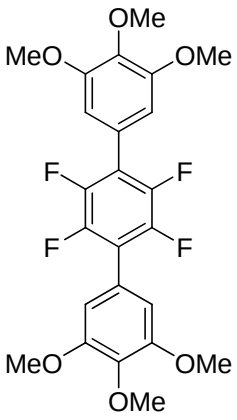
($CDCl_3$, 125 MHz)



8b

($CDCl_3$, 300 MHz)





8b

($CDCl_3$, 300 MHz)

References:

[1] a) Z. Tang, Q. S. Hu, *J. Am. Chem. Soc*. **2004**, *126*, 3058–3055; b) A. Klapars, K. R. Campos, C. Chen, R. P. Volante, *Org. Lett*. **2005**, 7, 1185–1188.

[2] J.-P. Leclerc, K. Fagnou, *Angew. Chem. Int. Ed.* **2006**, *45*, 7781–7786.

[3] L.-C. Campeau, S. Rousseaux, and K. Fagnou, *J. Am. Chem. Soc.* **2005**,*127*, 18020–18021.

[4] L.-C. Campeau, D. R. Stuart, J.-P. Leclerc, M. Bertrand-Laperle, E. Villemure, H.-Y. Sun, S. Lasserre, N. Guimond, M. Lecavallier, K. Fagnou, *J. Am. Chem. Soc.* **2009**, *131*, 3291–3306.