Supplementary Information for

A Unified Approach to Decarboxylative Halogenation of (Hetero)aryl Carboxylic Acids

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Supplementary Information

1) General information

All purchased reagents were used without additional purification unless otherwise indicated. A Penn PhD Integrated Photoreactor was generally used as the preferred method of irradiation for photochemical reactions and can be purchased through Sigma Aldrich.[1] All solvents were purified and handled according to the method of Grubbs.[2] Liquid reagents were transferred via syringe under N_2 atmosphere. Purification of products was typically performed via chromatography on an automated Biotage Isolera™ Spektra System with Silicycle SiliaSep™ cartridges (or SiliaSep™ C18 cartridges in the case of reverse phase chromatography). In certain instances, forced-flow chromatography according to the method of Still[3] using silica gel (Fluka, 230–400 mesh), or preparative thin-layer chromatography (PTLC) on Analtech 1 mm silica gel GF plates, were employed as purification methods. Thin-layer chromatography (TLC) was performed on Silicycle 0.25 mm or Supelco 0.20 mm silica gel F-254 plates, with resulting chromatograms visualized by fluorescence quenching or $KMnO_4$ stain. ^1H and ^{13}C NMR spectroscopy was performed on a Bruker Avance III NMR 500 MHz, and the resulting spectra were internally referenced to the residual proteo-solvent signals (7.26 ppm and 77.16 ppm, respectively, for $CDCl_3$; 2.50 ppm and 39.52 ppm, respectively, for DMSO-d_6). ^{19}F NMR spectroscopy was performed on a Bruker NanoBay Avance III HD NMR 400 MHz, and the resulting spectra are unreferenced. Data for ^{13}C NMR are reported in terms of chemical shift (multiplicity and coupling constants are included in select cases of coupling with ^2H or ^{19}F nuclei). Data for ^1H and ^{19}F NMR are reported in terms of chemical shift (δ ppm), multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad), coupling constant (Hz), and integration. Liquid chromatography (LC) analysis was performed on an Agilent 1290 Infinity II LC system. IR spectroscopy was performed on a Perkin Elmer Spectrum 100 FTIR spectrometer, and the resulting spectra are reported in wavenumbers (cm^{-1}). High Resolution Mass Spectra were obtained from the Princeton University Mass Spectral Facility.

5-(5-chloro-3-(4-(methylsulfonyl)phenyl)-2-pyridyl)picolinic acid (Etoricoxib–CO_2H) was prepared according to procedures reported in literature.[5]

All ground state absorption spectra were acquired on a Cary 60 UV-Vis spectrophotometer. Samples were prepared in a dry, nitrogen-filled glovebox and were 0.01 M in both 4-fluorobenzoic acid and N-fluorobenzenesulfonimide and 0.002 M in $[Cu(MeCN)_4]BF_4$. These concentrations were selected so as to closely match the reaction concentrations while observing relevant absorption features. Samples were illuminated with a 370 nm Kessil lamp at a distance of 4 cm. Non-illuminated samples were maintained in a laboratory drawer except during measurements.

Nanosecond transient absorption (nsTA) experiments were performed using a LP920 laser flash photolysis system (Edinburgh Instruments). The 355 nm laser pulses (5−7 ns at fwhm) used for excitation were generated using the third harmonic of a 1 Hz Nd:YAG pulsed laser (Surelite I) and data acquisition was controlled by the L900 software program (Edinburgh Instruments).

Ultrafast transient absorption (UFTA) measurements were performed at the NCSU Imaging and Kinetic Spectroscopy Laboratory (IMAKS) using a mode-locked Ti:sapphire laser amplifier (4 W, 1 kHz, Coherent Libra). The pump beam was directed into an optical parametric amplifier (Coherent OPerA Solo) to generate the 350 nm excitation. The 800 nm probe beam was delayed in a 6 ns optical delay stage and focused onto a calcium fluoride crystal to generate a white light continuum between 350 and 775 nm.

TA spectra were acquired while circulating the solutions using a peristaltic pump into flow-type 10 mm or 2 mm cuvettes for nsTA and UFTA, respectively. Stoichiometric amounts of $[Cu(MeCN)_4]BF_4$ were used in these samples.

2) Typical reaction setup

1: **Photoreactor setup** – The Integrated Photoreactor (IPR) is used for reaction irradiation.[1] For most experiments, 365 nm LED modules are used. LED intensity for irradiation is generally 100%, with 1000 rpm stir rate and 5200 rpm fan speed. The reaction temperature is kept near room temperature (~25–30° C) under this setting.

Figure S1. Typical components of Integrated Photoreactor setup.

2: **Kessil lamp setup** – Alternatively, Kessil LED lamps of wavelengths between 350–450 nm can be employed, generally providing lower efficiencies and greater variation between trials (see Figure **S4**). 1000 rpm stirring is maintained under this setup. Reaction temperatures are generally maintained at ~35 °C when using fans for cooling (see Figure **S2**).

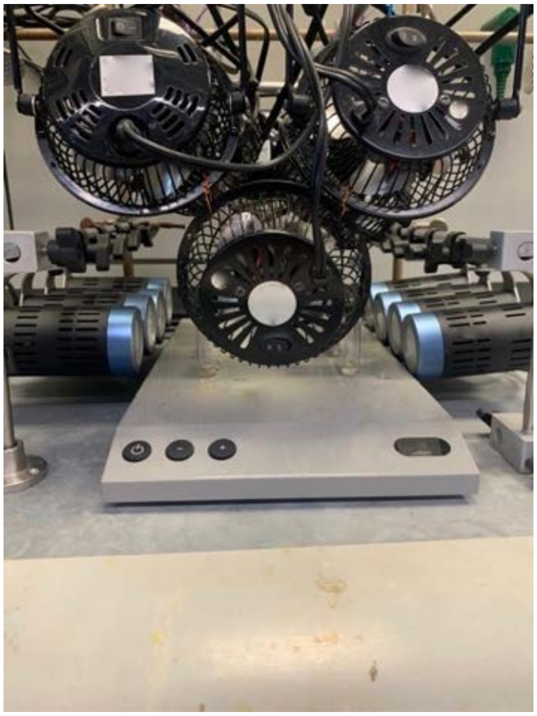
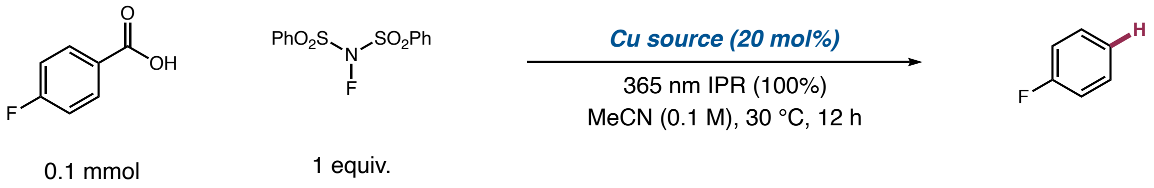


Figure S2. Typical Kessil lamp setup for non-IPR reaction irradiation.

3: **General reaction setup** – All reactions are set up under ambient conditions. All reagents are stored and weighed on the bench-top, and copper catalysts stored in a bench-top desiccator, unless otherwise specified in the experimental procedures.

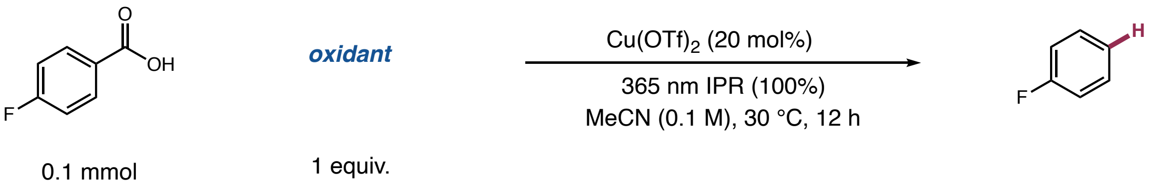
3) Optimization studies for hydrodecarboxylation

General procedure: To an oven-dried 4-mL vial equipped with a stir bar was added copper source (20 mol%, 0.02 mmol), oxidant (1 equiv., 0.1 mmol), and aryl carboxylic acid substrate (1 equiv., 0.1 mmol). Anhydrous acetonitrile (1 mL) was added via syringe, and the reaction mixture was sparged with nitrogen while stirring (200 rpm) for 15 minutes before the reaction vial was sealed under nitrogen with melted parafilm to exclude oxygen. The reaction vial was irradiated in the Integrated Photoreactor (IPR) with 365 nm LEDs (100% LED intensity, 1000 rpm stir rate, 5200 rpm fan rate) for 12 h. Internal standard (3,5-bis(trifluoromethyl)bromobenzene, 1.0 equiv.) was added, and an aliquot was taken for ^{1}H NMR and ^{19}F NMR analysis in DMSO-d_6. Formation of the desired product was confirmed by comparing the NMR and GC-MS data with those of a sample of the authentic product.



copper source	yield
CuF_2	36%
$CuCl_2$	31% (11% ArCl)
$CuBr_2$	31% (18% ArBr)
$Cu(acac)_2$	19%
$Cu(OTf)_2$	51%
Cu_2O	8%
$[Cu(MeCN)_4]BF_4$	27%
Cu(OTf)	29%

Table S1. Evaluation of copper catalysts for aromatic hydrodecarboxylation.



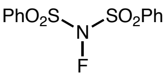
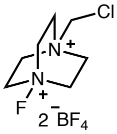
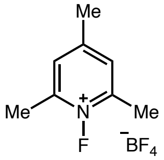
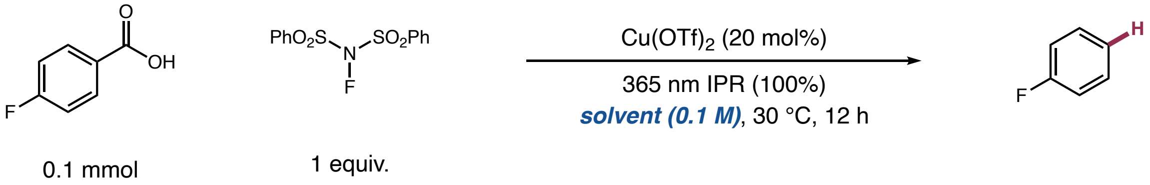
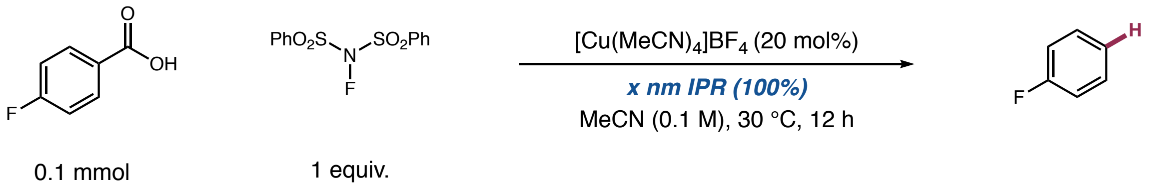
oxidant				$K_2S_2O_8$
yield	51%	48%	24%	0%

Table S2. Oxidant evaluation for aromatic hydrodecarboxylation.



solvent	yield
MeCN	66%
acetone	0%
THF	0%
MeOH	0%
DMF	0%
DCM	0%
DCM/MeCN (1:1)	0%
acetone/MeCN (1:1)	0%
MeOH/MeCN (1:1)	0%

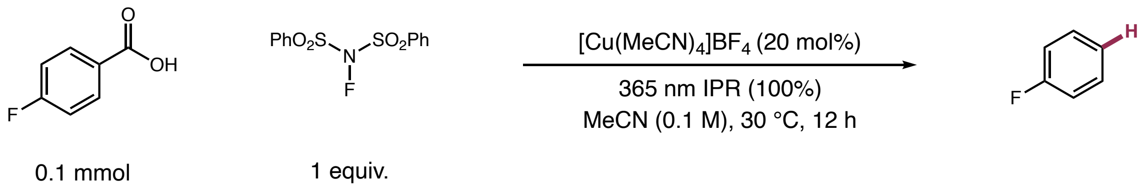
Table S3. Solvent evaluation for aromatic hydrodecarboxylation.



wavelength	yield
365 nm	51%
390 nm Kessil Lamps	42%
395 nm	45%
450 nm	31%

Table S4. Evaluation of LED wavelengths and sources for hydrodecarboxylation.

4) Control experiments



deviations	yield
none	42%
without oxidant	0%
without copper	0%
without light	0%
with 450 nm IPR	31%

Table S5. Control experiments for aromatic hydrodecarboxylation.

<u>*5) Aromatic hydrodecarboxylation*</u>

General procedure: To an oven-dried 4-mL vial equipped with a stir bar was added $Cu(OTf)_2$ (0.02 mmol, 7.2 mg, 20 mol%), NFSI (1 equiv., 31.5 mg, 0.1 mmol), and 4-*tert*-butylbenzoic acid (1 equiv., 17.8 mg, 0.1 mmol). Anhydrous acetonitrile (1 mL) was added via syringe, and the reaction mixture was sparged with nitrogen while stirring (200 rpm) for 15 minutes before the reaction vial was sealed with melted parafilm to exclude oxygen. The reaction vial was irradiated in the Integrated Photoreactor (IPR) with 365 nm LEDs (100% LED intensity, 1000 rpm stir rate, 5200 rpm fan rate) for 12 h. Internal standard (3,5-bis(trifluoromethyl)bromobenzene, 1.0 equiv.) was added, and an aliquot was taken for ^{1}H NMR analysis in DMSO-d_6. Formation of the desired arene product was confirmed and quantified via NMR analysis.

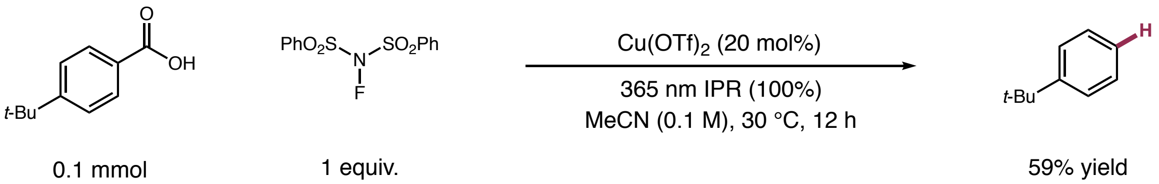


Table S6. Aromatic hydrodecarboxylation.

Spectral assignments used for analysis were based on those reported in literature: Crockett, M. P.; Tyrol, C. C.; Wong, A. S.; Li, B.; Byers, J. A. *Org. Lett.* **2018**, *20*, 5233–5237.

6) Aromatic deuterodecarboxylation

Procedure for deuterodecarboxylation of 4-tert-butylbenzoic acid: To an oven-dried 4-mL vial equipped with a stir bar was added Cu(OTf)$_2$ (0.02 mmol, 7.2 mg, 20 mol%), NFSI (1 equiv., 31.5 mg, 0.1 mmol), and 4-*tert*-butylbenzoic acid (1 equiv., 17.8 mg, 0.1 mmol). CD$_3$CN-*d*$_3$ (0.5 mL) was added via syringe, and the reaction mixture was sparged with nitrogen while stirring (200 rpm) for 15 minutes before the reaction vial was sealed with melted parafilm to exclude oxygen. The reaction vial was irradiated in the Integrated Photoreactor (IPR) with 365 nm LEDs (100% LED intensity, 1000 rpm stir rate, 5200 rpm fan rate) for 12 h. Internal standard (3,5-bis(trifluoromethyl)bromobenzene, 1.0 equiv.) was added, and an aliquot was taken for ^{1}H NMR analysis in DMSO-d$_6$. Formation of the desired arene product was confirmed and quantified via NMR analysis. Substantial deuterium incorporation in the sample was subsequently observed by GC-MS analysis of the crude reaction mixture, consistent with an atom transfer process from CD$_3$CN-*d*$_3$ to an acid-derived aryl radical intermediate.

Procedure for deuterodecarboxylation of 4-F-benzoic acid: To an oven-dried 4-mL vial equipped with a stir bar was added Cu(MeCN)$_4$BF$_4$ (0.02 mmol, 6.3 mg, 20 mol%), NFTPT (1 equiv., 34.2 mg, 0.1 mmol), and 4-fluorobenzoic acid (1 equiv., 14.0 mg, 0.1 mmol). CD$_3$CN-*d*$_3$ (0.5 mL) was added via syringe, and the reaction mixture was sparged with nitrogen while stirring (200 rpm) for 15 minutes before the reaction vial was sealed with melted parafilm to exclude oxygen. The reaction vial was irradiated in the Integrated Photoreactor (IPR) with 365 nm LEDs (100% LED intensity, 1000 rpm stir rate, 5200 rpm fan rate) for 6 h. Internal standard (3,5-bis(trifluoromethyl)bromobenzene, 1.0 equiv.) was added, and an aliquot was taken for ^{19}F NMR analysis in DMSO-d$_6$. Formation of the desired arene product was confirmed and quantified via NMR analysis. Substantial deuterium incorporation in the sample was subsequently observed by GC-MS analysis of the crude reaction mixture, consistent with an atom transfer process from CD$_3$CN-*d*$_3$ to an acid-derived aryl radical intermediate.

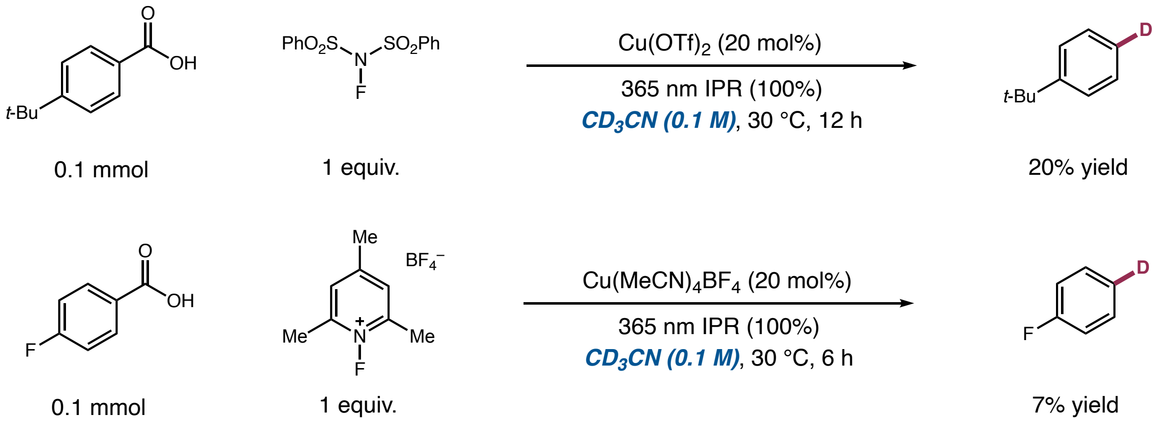
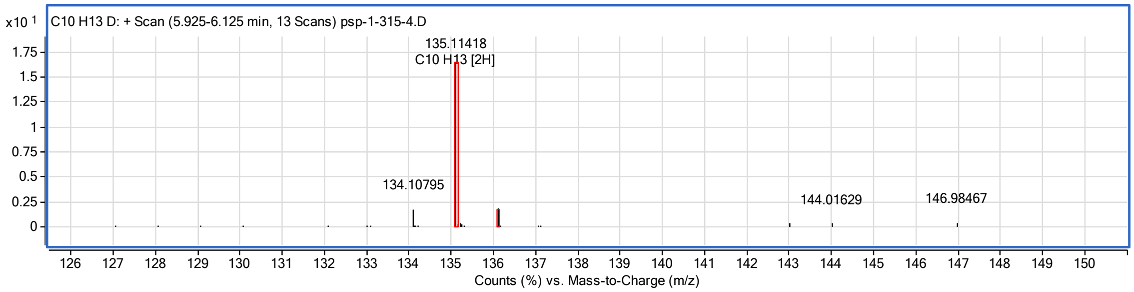
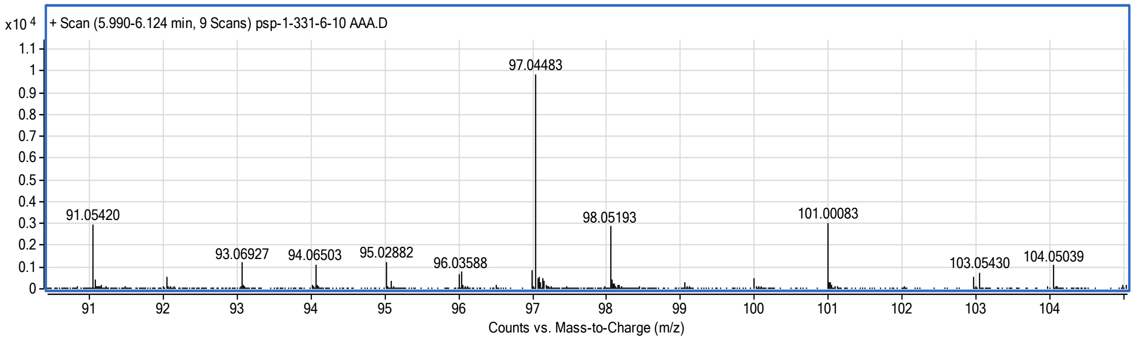


Table S7. Aromatic deuterodecarboxylation.



HRMS (GC-EI-TOF) m/z calcd. for $C_{10}H_{13}D$ ([M*]+) 135.11583, found 135.11418.



HRMS (GC-EI-TOF) m/z calcd. For C_6H_4FD ([M*]+) 97.04381, found 97.04483.

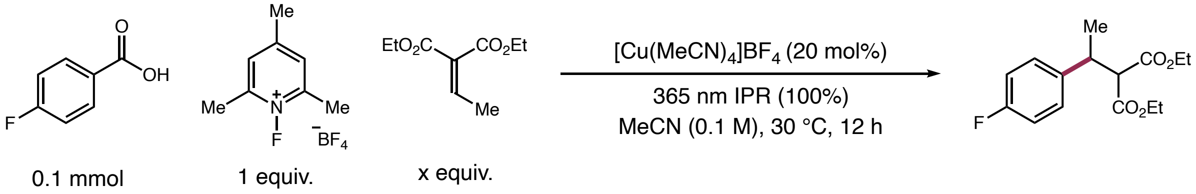
Spectral assignments used for analysis of reactions of 4-tert-butylbenzoic acid were based on those reported in literature:

Patra, T.; Mukherjee, S.; Ma, J.; Strieth-Kalthoff, F.; Glorius, F. *Angew. Chem., Int. Ed.* **2019**, *58*, 10514–10520.

Spectral assignments used for analysis of 4-fluorobenzoic acid were based on comparison to NMRs of commercial fluorobenzene.

7) Aromatic decarboxylative C–C bond formation: Giese reaction

General procedure: To an oven-dried 4-mL vial equipped with a stir bar was added $[Cu(MeCN)_4]BF_4$ (20 mol%, 6.3 mg, 0.02 mmol), 1-fluoro-2,4,6-trimethylpyridinium BF_4 (1 equiv., 22.7 mg, 0.1 mmol), diethyl 2-ethylidenepropanedioate (1 to 2 equiv.), and 4-fluorobenzoic acid (1 equiv., 14.0 mg, 0.1 mmol). Anhydrous acetonitrile (1 mL) was added via syringe, and the reaction mixture was sparged with nitrogen while stirring (200 rpm) for 15 minutes before the reaction vial was sealed under nitrogen with melted parafilm to exclude oxygen. The reaction vial was irradiated in the Integrated Photoreactor (IPR) with 365 nm LEDs (100% LED intensity, 1000 rpm stir rate, 5200 rpm fan rate) for 12 h. Internal standard (3,5-bis(trifluoromethyl)bromobenzene, 1.0 equiv.) was added, and an aliquot was taken for ^{1}H NMR and ^{19}F NMR analysis in DMSO-d_6. Product was isolated via preparatory thin layer chromatography and confirmed via ^{1}H NMR, ^{19}F NMR, and GC-MS characterization.



Michael acceptor equivs.	yield
1 equiv.	6%
2 equiv.	23%

Table S8. Aromatic decarboxylative C–C bond formation: Giese reaction.

^{1}H NMR (500 MHz, CDCl$_3$) δ 7.22 (dd, *J* = 8.7 Hz, 5.3 Hz, 2H), 6.99 (dd, *J* = 8.7 Hz, 5.3 Hz, 2H), 4.25 (q, *J* = 7.1 Hz, 2H), 3.95 (dd, *J* = 7.1, 1.7 Hz, 2H), 3.59-3.48 (m, 2H), 1.35-1.28 (m, 6H), 1.01 (t, *J* = 7.1 Hz, 3H).

^{13}C NMR (125 MHz, CDCl$_3$) δ 168.3, 168.0, 129.1 (d, *J* = 8.2 Hz), 119.4, 115.3 (d, *J* = 21.7 Hz), 100.0, 61.6, 61.3, 59.5, 39.4, 29.8, 20.4, 14.2, 13.9.

^{19}F NMR (282 MHz, CDCl$_3$) δ –116.12 (m, 1F).

Data are consistent with those reported in the literature: Chilamari, M.; Immel, J. R.; Bloom, S. *ACS Catal.*, **2020**, *10*, 12727.

8) Decarboxylative C(sp^2)–C(sp^2) bond formation via aryl radical addition

General procedure: To an oven-dried 4-mL vial equipped with a stir bar was added $[Cu(MeCN)_4]BF_4$ (0.02 mmol, 20 mol%), 1-fluoro-2,4,6-trimethylpyridinium BF_4 (1 equiv., 0.1 mmol), and 4-fluorobenzoic acid (1 equiv., 0.1 mmol). Benzene (0.5 mL) and acetonitrile (0.5 mL) were added via syringe, and the reaction mixture was sparged with nitrogen while stirring (200 rpm) for 15 minutes before the reaction vial was sealed with melted parafilm to exclude oxygen. The reaction vial was irradiated in an integrated photoreactor (IPR) with 365 nm LEDs (100% LED intensity, 1000 rpm stir rate, 5200 rpm fan rate) for 9 h. Internal standard (3,5-bis(trifluoromethyl)bromobenzene, 1.0 equiv.) was added, and an aliquot was taken for ^{1}H NMR and ^{19}F NMR analysis in DMSO-d_6. Formation of the desired product was confirmed and quantified via NMR and GC-MS analysis.

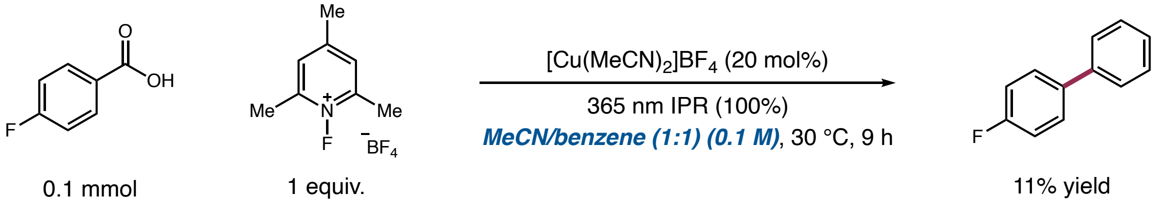


Table S9. Decarboxylative C(sp^2)–C(sp^2) bond formation via aryl radical addition

Spectral assignments used for analysis were based on those reported in literature:
Sather, A. C.; Lee, H. G.; De La Rosa, V. Y.; Yang, Y.; Müller, P.; Buchwald, S. L. *J. Am. Chem. Soc.* **2015**, *137*, 13433–13438.

9) Optimization conditions for bromodecarboxylation

General procedure for optimization studies: To an oven-dried 4-mL vial equipped with a stir bar was added copper source (20 mol%, 0.02 mmol), oxidant (1 equiv., 0.1 mmol), electrophilic bromination reagent, and aryl carboxylic acid substrate (1 equiv., 0.1 mmol). Anhydrous acetonitrile (1 mL) was added via syringe, and the reaction mixture was sparged with nitrogen while stirring (200 rpm) for 15 minutes before the reaction vial was sealed with melted parafilm to exclude oxygen. The reaction vial was irradiated in the Integrated Photoreactor (IPR) with 365 nm LEDs (100% LED intensity, 1000 rpm stir rate, 5200 rpm fan rate) for 12 h. Internal standard (3,5-bis(trifluoromethyl)bromobenzene, 1.0 equiv.) was added and an aliquot was taken for ^{1}H NMR and ^{19}F NMR analysis in DMSO-d_6. Formation of the desired product was confirmed by comparing the NMR & GC-MS data with sample of authentic product.

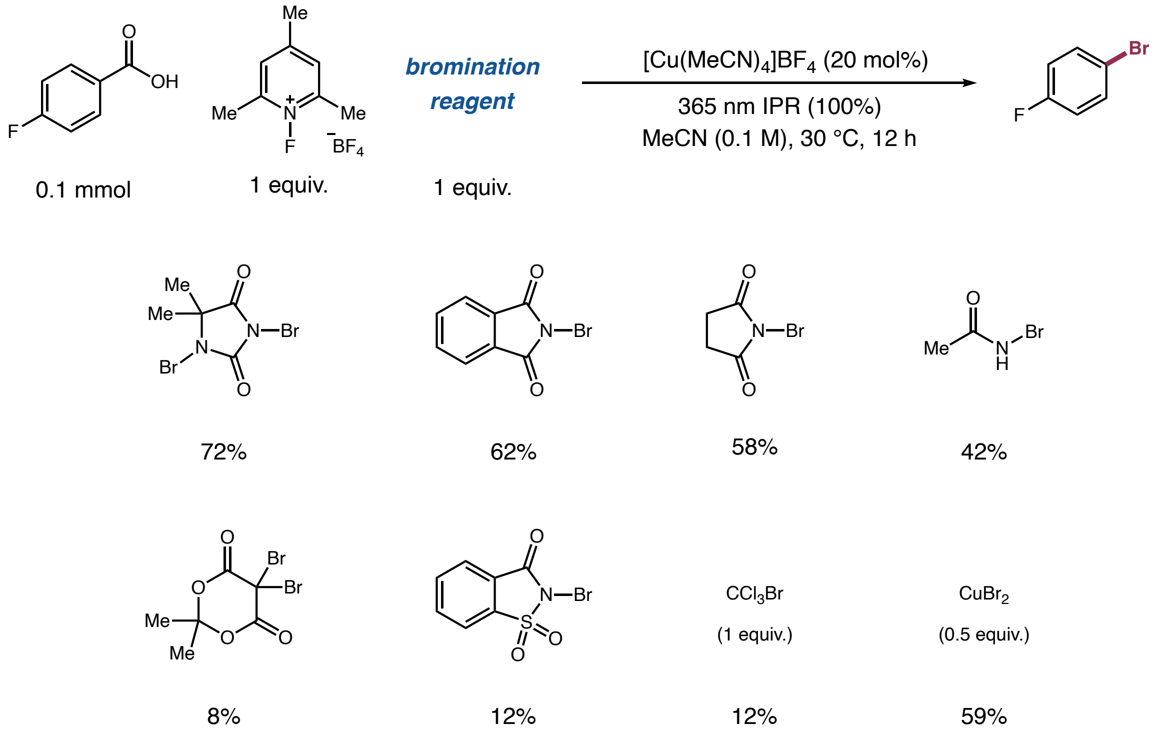
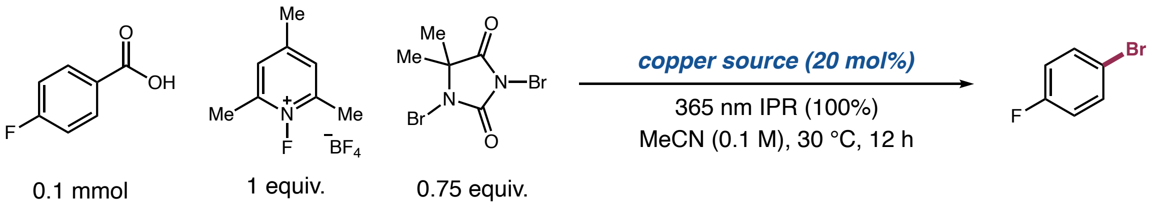
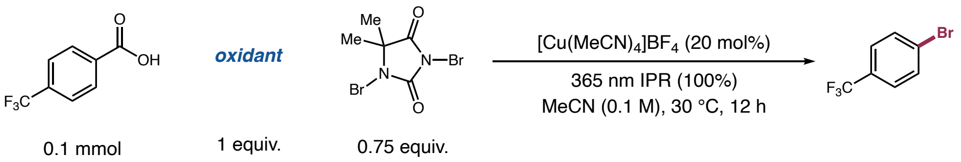


Table S10. Evaluation of bromination reagents for aromatic bromodecarboxylation.



copper source	yield	copper source	yield
$[Cu(MeCN)_4]BF_4$	72%	$Cu(OTf)_2$	28%
CuBr	54%	$Cu(BF_4)_2$	20%
Cu(OAc)	68%	$Cu(CO_3)$	36%
$CuBr_2$	62%	$Cu(TMHD)_2$	64%
$Cu(OAc)_2$	66%	$Cu(CO_2CF_3)_2$	47%

Table S11. Evaluation of copper sources for aromatic bromodecarboxylation.



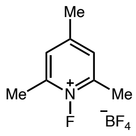
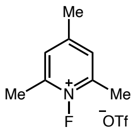
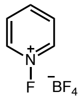
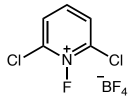
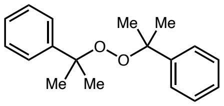
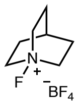
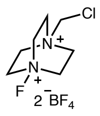
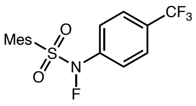
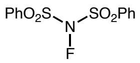
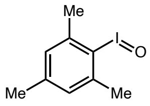
oxidant					
yield	85%	83%	28%	0%	57%
oxidant					
yield	78%	68%	32%	81%	25%

Table S12. Evaluation of oxidants for aromatic bromodecarboxylation.

10) Optimization conditions for iododecarboxylation

General procedure for optimization studies: To an oven-dried 8-mL vial equipped with a stir bar was added copper source (20 mol%, 0.02 mmol), oxidant (1 equiv., 0.1 mmol), electrophilic iodination reagent, and aryl carboxylic acid substrate (1 equiv., 0.1 mmol). Anhydrous acetonitrile (1 mL) was added via syringe, and the reaction mixture was sparged with nitrogen while stirring (200 rpm) for 15 minutes before the reaction vial was sealed with melted parafilm to exclude oxygen. The reaction vial was irradiated in the Integrated Photoreactor (IPR) with 365 nm LEDs (100% LED intensity, 1000 rpm stir rate, 5200 rpm fan rate) for 4 h. Internal standard (mesitylene, 1.0 equiv.) was added and an aliquot was taken for ^{1}H NMR and ^{19}F NMR analysis. Formation of the desired product was confirmed by comparing the NMR & GC-MS data to literature reports.

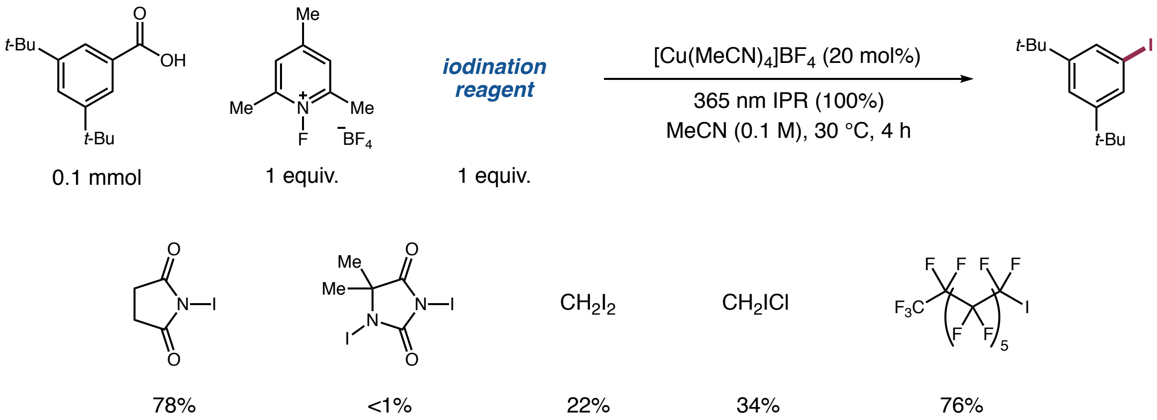
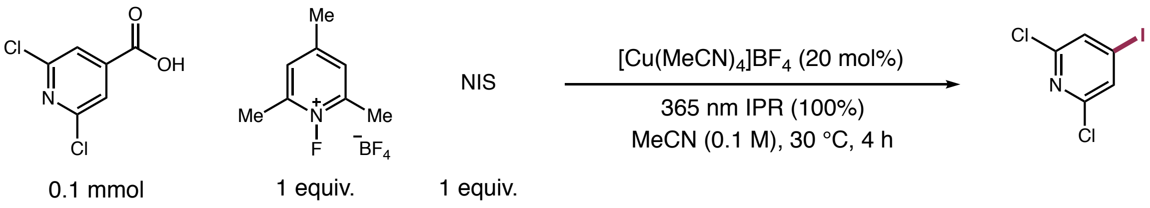


Table S13. Evaluation of iodination reagents for aromatic iododecarboxylation.



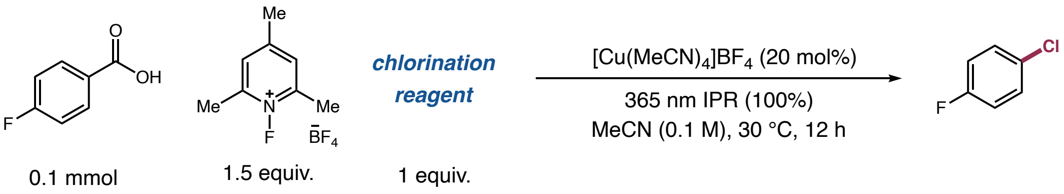
deviations	yield
none	57%
no copper	25%
no oxidant	27%
450 nm LEDs	2%
ambient light only	0%

Table S14. Control reactions for aromatic iododecarboxylation.

Although iodinated product is obtained in the absence of copper catalysts required for LMCT activation, the yields of product obtained are substantially higher when utilizing LMCT conditions analogous to those employed for aromatic bromodecarboxylation.

11) Optimization conditions for chlorodecarboxylation

General procedure for optimization studies: To an oven-dried 4-mL vial equipped with a stir bar was added copper source (20 mol%, 0.02 mmol), oxidant (1.5 equiv., 0.15 mmol, chloride source (1 equiv., 0.05 mmol), and aryl carboxylic acid substrate (1 equiv., 0.1 mmol). Anhydrous acetonitrile (1 mL) was added via syringe, and the reaction mixture was sparged with nitrogen while stirring (200 rpm) for 15 minutes before the reaction vial was sealed with melted parafilm to exclude oxygen. The reaction vial was irradiated in the Integrated Photoreactor (IPR) with 365 nm LEDs (100% LED intensity, 1000 rpm stir rate, 5200 rpm fan rate) for 12 h. Internal standard (3,5-bis(trifluoromethyl)bromobenzene, 1.0 equiv.) was added and an aliquot was taken for ^{1}H NMR and ^{19}F NMR analysis in DMSO-d_6. Formation of the desired product was confirmed by comparing the NMR & GC-MS data with sample of authentic product.



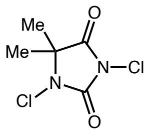
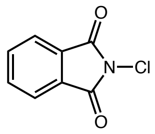
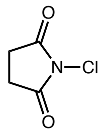
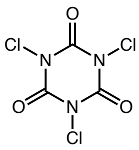
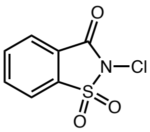
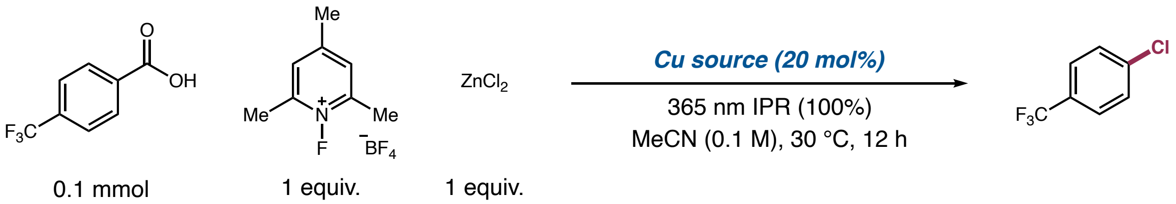
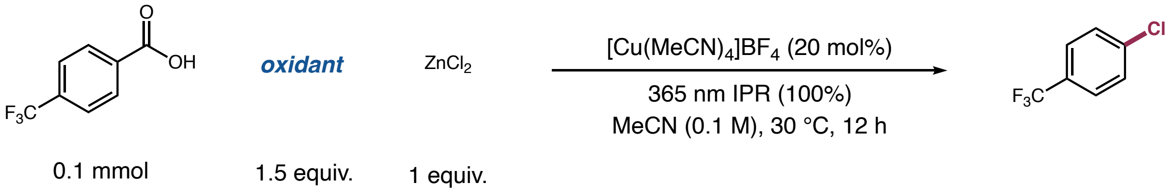
ZnCl$_2$			
53%	7%	19%	15%
		CuCl$_2$	FeCl$_2$
13%	5%	13%	27%
LiCl	NaCl	CuCl (1 equiv)	CuCl$_2$ (1 equiv)
10%^{a,c}	19%^{a,c}	13%^{b,c}	16%^{b,c}

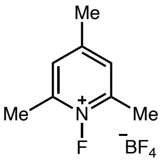
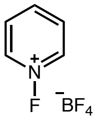
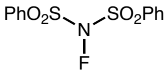
Table S15. Evaluation of chlorination reagents for aromatic chlorodecarboxylation. ^{a}With 1 equiv. [Cu(MeCN)$_4$]BF$_4$. ^{b}Without [Cu(MeCN)$_4$]BF$_4$. ^{c}Reactions performed on 4-trifluoromethylbenzoic acid as the aryl carboxylic acid



copper source	yield
CuCl	69%
$CuCl_2$	53%
$Cu(OTf)_2$	51%
CuBr	16%
CuTC	69%
Cu(OAc)	51%
$[Cu(MeCN)_4]BF_4$	66%

Table S16. Evaluation of copper sources for aromatic chlorodecarboxylation.



oxidant			
yield	78%	61%	55%

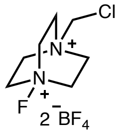
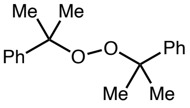
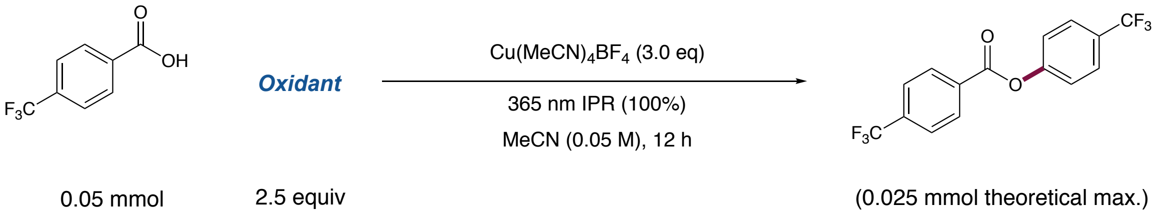
oxidant		
yield	49%	71%

Table S17. Evaluation of oxidants for aromatic chlorodecarboxylation.

12) Optimization conditions for decarboxylative C(sp^2)–O bond formation

General procedure for optimization studies: To an oven-dried 4-mL vial equipped with a stir bar was added copper source (20 mol%, 0.02 mmol), oxidant (1 equiv., 0.1 mmol), and aryl carboxylic acid substrate (1 equiv., 0.1 mmol). Anhydrous acetonitrile (1 mL) was added via syringe, and the reaction mixture was sparged with nitrogen while stirring (200 rpm) for 15 minutes before the reaction vial was sealed with melted parafilm to exclude oxygen. The reaction vial was irradiated in the Integrated Photoreactor (IPR) with 365 nm LEDs (100% LED intensity, 1000 rpm stir rate, 5200 rpm fan rate) for 12 h. Internal standard (3,5-bis(trifluoromethyl)bromobenzene, 1.0 equiv.) was added and an aliquot was taken for ^{1}H NMR and ^{19}F NMR analysis in DMSO-*d$_6$*. Formation of the desired product was confirmed by comparing the NMR & GC-MS data with sample of authentic product. (*note:* maximum yield for this decarboxylative homodimerization of the acid substrate is 0.025 mmol, which is used as theoretical max. to determine % yield).



Oxidant	yield	***Oxidant***	yield
MesIO	73%	ferrocenium BF$_4$	0%
PhI(OAc)$_2$	0%	benzoyl peroxide	0%
$K_2S_2O_8$	5%	lauroyl peroxide	0%
Togni's Reagent	0%	*tert*-butyl peroxide	93%
benzoquinone	0%	cumyl peroxide	98%

Table S18. Evaluation of oxidants for decarboxylative C(sp^2)–O bond formation.

13) Optimization conditions for fluorodecarboxylation

General procedure for optimization studies: To an oven-dried 8-mL vial equipped with a stir bar was added copper source (300 mol%, 0.15 mmol), oxidant (2 equiv., 1.0 mmol), and aryl carboxylic acid substrate (1 equiv., 0.05 mmol). Anhydrous acetonitrile (1.0 mL) was added via syringe, and the reaction mixture was sparged with nitrogen while stirring (200 rpm) for 15 minutes before the reaction vial was sealed with melted parafilm to exclude oxygen. The reaction vial was irradiated in the Integrated Photoreactor (IPR) with 365 nm LEDs (100% LED intensity, 1000 rpm stir rate, 5200 rpm fan rate) for 12 h. Internal standard (3,5-bis(trifluoromethyl)bromobenzene, 1.0 equiv.) was added and an aliquot was taken for ^{1}H NMR and ^{19}F NMR analysis in DMSO-*d*$_6$. Formation of the desired product was confirmed by comparing the NMR & GC-MS data with sample of authentic product.

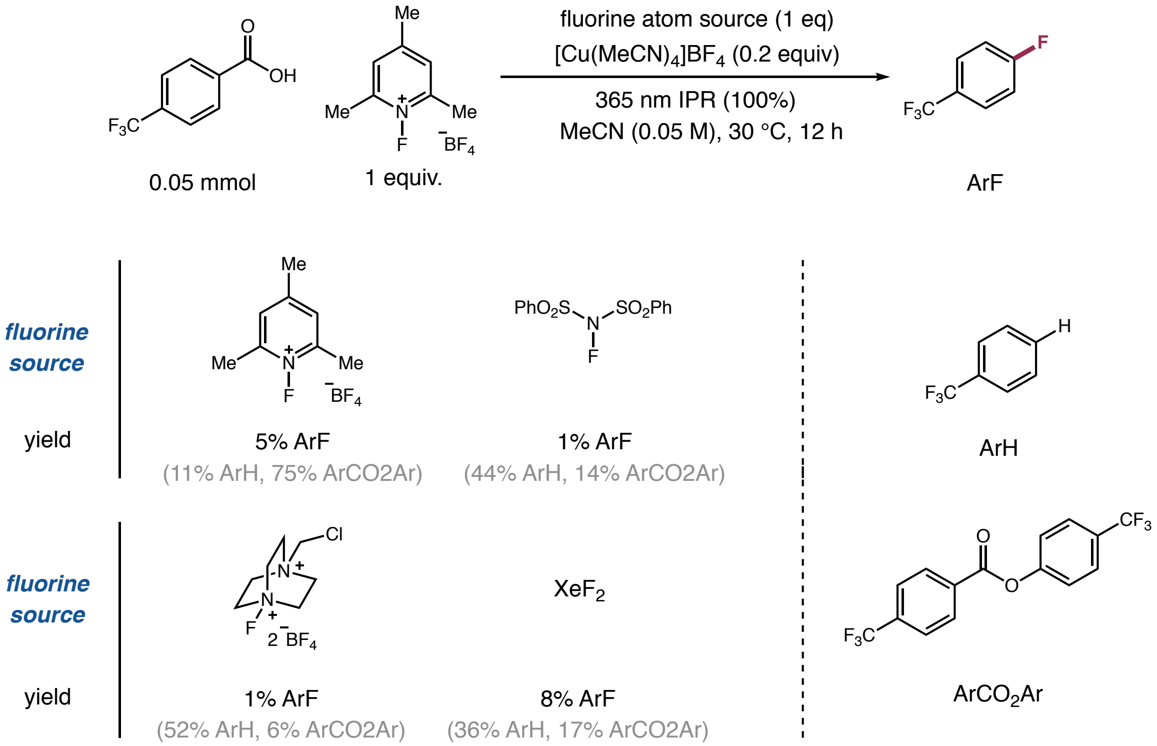
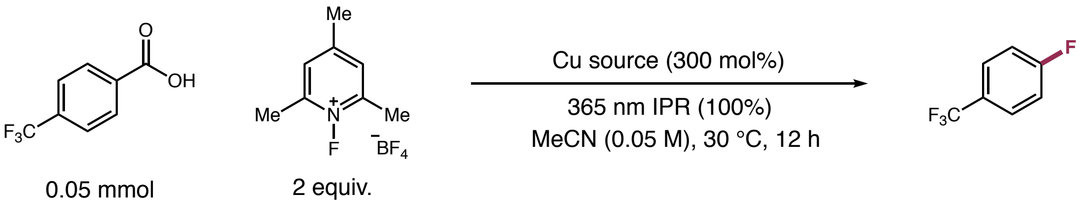
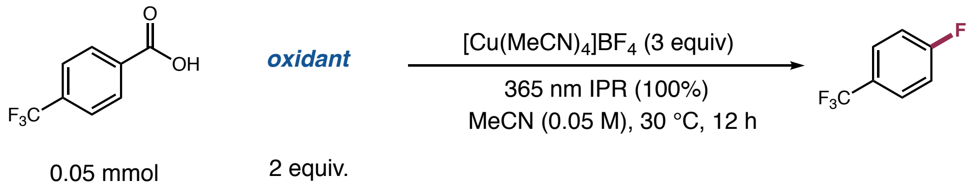


Table S19. Evaluation of fluorine atom transfer reagents for catalytic fluorodecarboxylation.



Copper Source	yield	***Copper Source***	yield
$Cu(MeCN)_4BF_4$	63%	$Cu(OAc)_2$	0%
CuCl	0%	$Cu(OTf)_2$	0%
CuTC	0%	$CuF_2•H_2O$	10%
CuOAc	0%	2.5 eq $Cu(MeCN)_4BF_4$ and 2.5 eq $Cu(OTf)_2$	8%
$CuCl_2$	0%		

Table S20. Evaluation of copper source for aromatic decarboxylative fluorination.



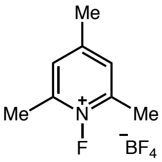
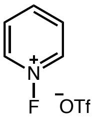
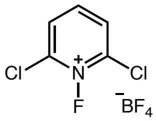
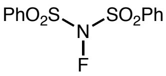
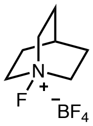
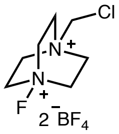
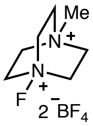
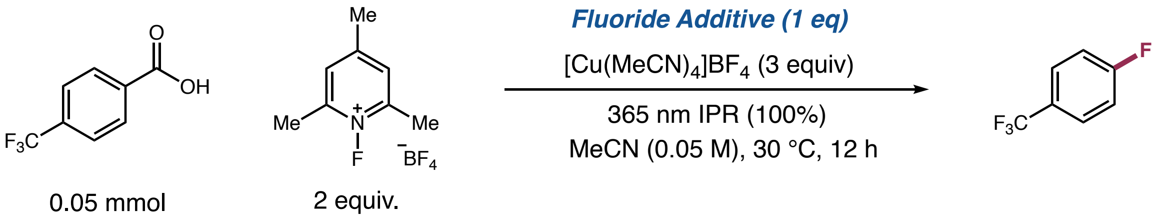
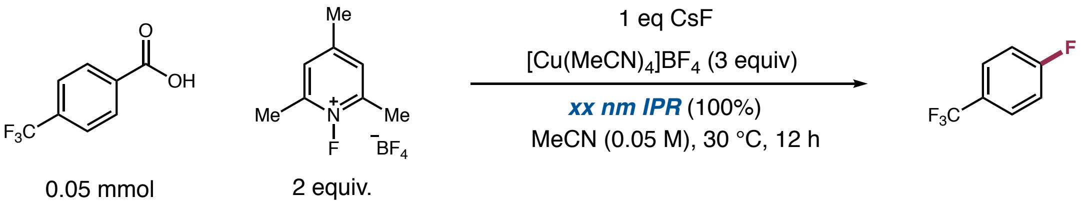
oxidant				
yield	63%	27%	0%	13%
oxidant				
yield		64%	43%	47%

Table S21. Evaluation of oxidant/fluorine source for decarboxylative fluorination.



fluoride additive	yield
None	60%
LiF	60%
NaF	64%
KF	64%
CsF	70%

Table S22. Evaluation of fluoride source for aromatic decarboxylative fluorination.



wavelength	yield
365 nm	68%
395 nm	68%
420 nm	61%
450 nm	30%

Table S23. Evaluation of LED wavelengths for aromatic decarboxylative fluorination.

14) Stoichiometric, oxidant-free conditions for decarboxylative bromination

Procedure for stoichiometric decarboxylative bromination with 2,2,6,6-tetramethylpiperidine (TMP) as base: To an oven-dried 8-mL vial equipped with a stir bar was added Cu(OTf)$_2$ (1.0 equiv., 0.1 mmol), DBDMH (0.75 equiv., 0.075 mmol), and aryl carboxylic acid substrate (1 equiv., 0.1 mmol). Anhydrous acetonitrile (1.0 mL) was added via syringe and if necessary TMP was added (1.0 equiv., 0.1 mmol) before the reaction mixture was sparged with nitrogen while stirring (200 rpm) for 10 minutes. The reaction vial was sealed with melted parafilm to exclude oxygen before being irradiated in the Integrated Photoreactor (IPR) with 365 nm LEDs (100% LED intensity, 1000 rpm stir rate, 5200 rpm fan rate) for 12 h. Internal standard (1,4-difluorobenzene, 1.0 equiv.) was added and an aliquot was taken for ^{1}H NMR and ^{19}F NMR analysis in DMSO-*d*$_6$.

Procedure for stoichiometric decarboxylative bromination with sodium fluoride as base: To an oven-dried 4-mL vial equipped with a stir bar was added Cu(OTf)$_2$ (1.0 equiv., 0.05 mmol), NaF (1.0 equiv., 0.05 mmol), DBDMH (0.75 equiv., 0.038 mmol), and aryl carboxylic acid substrate (1 equiv., 0.05 mmol). Anhydrous acetonitrile (0.5 mL) was added via syringe, and the reaction mixture was sparged with nitrogen while stirring (200 rpm) for 15 minutes before the reaction vial was sealed with melted parafilm to exclude oxygen. The reaction vial was irradiated in the Integrated Photoreactor (IPR) with 365 nm LEDs (100% LED intensity, 1000 rpm stir rate, 5200 rpm fan rate) for 12 h. Internal standard (3,5-bis(trifluoromethyl)bromobenzene, 1.0 equiv.) was added and an aliquot was taken for ^{1}H NMR and ^{19}F NMR analysis in DMSO-*d*$_6$.

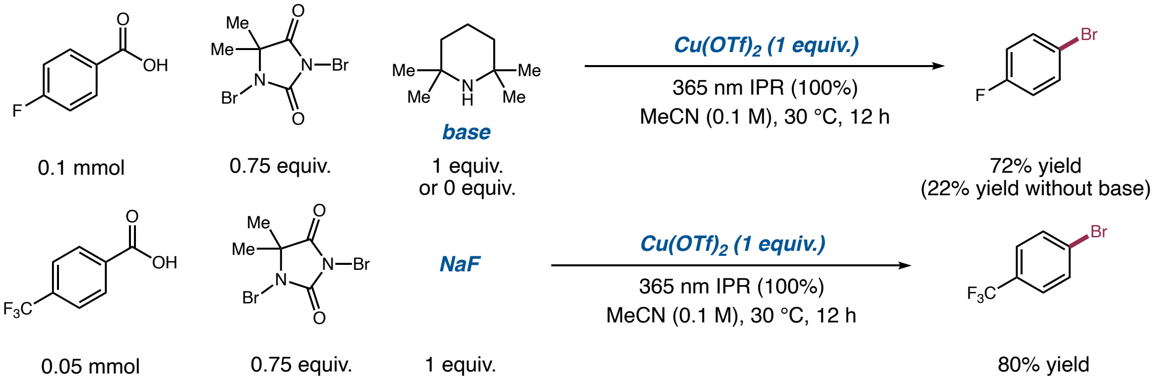
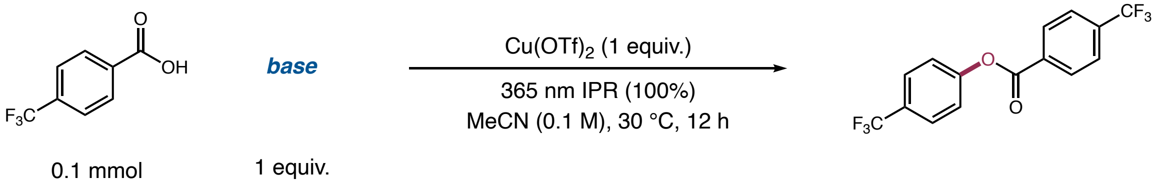


Table S24. Decarboxylative bromination: *oxidant-free* stoichiometric conditions.

15) Stoichiometric, oxidant-free conditions for decarboxylative C(sp^2)–O bond formation

General procedure: To an oven-dried 8-mL vial equipped with a stir bar was added copper source (3.0 equiv., 0.3 mmol), base (1.0 equiv., 0.1 mmol), and aryl carboxylic acid substrate (1 equiv., 0.1 mmol). Anhydrous acetonitrile (1 mL) was added via syringe, and the reaction mixture was sparged with nitrogen while stirring (200 rpm) for 15 minutes before the reaction vial was sealed with melted parafilm to exclude oxygen. The reaction vial was irradiated in the Integrated Photoreactor (IPR) with 365 nm LEDs (100% LED intensity, 1000 rpm stir rate, 5200 rpm fan rate) for 12 h. Internal standard (3,5-bis(trifluoromethyl)bromobenzene, 1.0 equiv.) was added and an aliquot was taken for ^{1}H NMR and ^{19}F NMR analysis in DMSO-d_6. (*note:* maximum yield for this decarboxylative homodimerization of the acid substrate is 0.05 mmol, which is used as theoretical max. to determine % yield).



base	yield
DABCO	31%
DBU	27%
quinuclidine	24%
K_3PO_4	42%
KO*t*-Bu	24%
NaOH	18%
NaF	>49%

Table S25. Decarboxylative C(sp^2)–O bond-formation: *oxidant-free* stoichiometric conditions.

16) Additional examples of bromodecarboxylation using $BrCCl_3$ as a halogenating reagent

As discussed in **Figure 3**, electron-rich substrates subject to Cu-LMCT bromodecarboxylation can display unwanted overbromination side reactivity from electrophilic aromatic substitution (S_EAr) pathways enabled by brominating agents such as DBDMH. Alternative halogenating reagents, such as $BrCCl_3$, can selectively afford the desired halodecarboxylation product while suppressing formation of S_EAr-based byproducts. Beyond the examples displayed in **Figure 3**, **Table S26** displays the application of these alternative conditions to a variety of substrates bearing electron-rich substituents or arene cores, following the general procedure described below:

General procedure: To an oven-dried 8-mL vial equipped with a Teflon stir bar was added (hetero)aryl acid substrate (0.1 mmol, 1 equiv.), *N*-fluoro-2,4,6-trimethylpyridinium tetrafluoroborate (NFTPT) (22.7 mg, 0.1 mmol. 1 equiv.) and $[Cu(MeCN)_4]BF_4$ (6.3 mg, 0.02 mmol, 0.2 equiv.). Anhydrous MeCN (1 mL, 0.1 M) was added via syringe, followed by $BrCCl_3$ (29.6 µL, 0.3 mmol, 3 equiv.). The reaction mixture was sparged with nitrogen while stirring for 10 minutes before the reaction vial was sealed with Parafilm. The reaction vial was irradiated in the Integrated Photoreactor (IPR) with 365 nm LEDs (100% LED intensity, 1000 rpm stir rate, 5200 rpm fan rate) for 6 h. Yields for each reaction were then obtained via ^1H NMR analysis (internal standard: methyl 4-fluorobenzoate) via comparison of the crude reaction spectra to characterization data of the desired product previously reported in literature.

As exhibited in **Table S26**, bromination of S_EAr-sensitive (hetero)aryl acids with $BrCCl_3$ is a generally applicable strategy across a range of structurally diverse acid substrates. However, certain electron-rich heteroaromatic frameworks, such as furans or benzothiophenes, are still unreactive under these conditions and have currently not been incorporated within Cu-LMCT halogenation protocols. The preclusion of certain acids derived from highly electron-rich heteroarenes in Cu-LMCT bromination is most likely not caused by the selection of halogenation agent; in particular, this trend is instead consistent with the established slower rate of decarboxylation of aroyloxyl radicals generated from such substrates.[4]

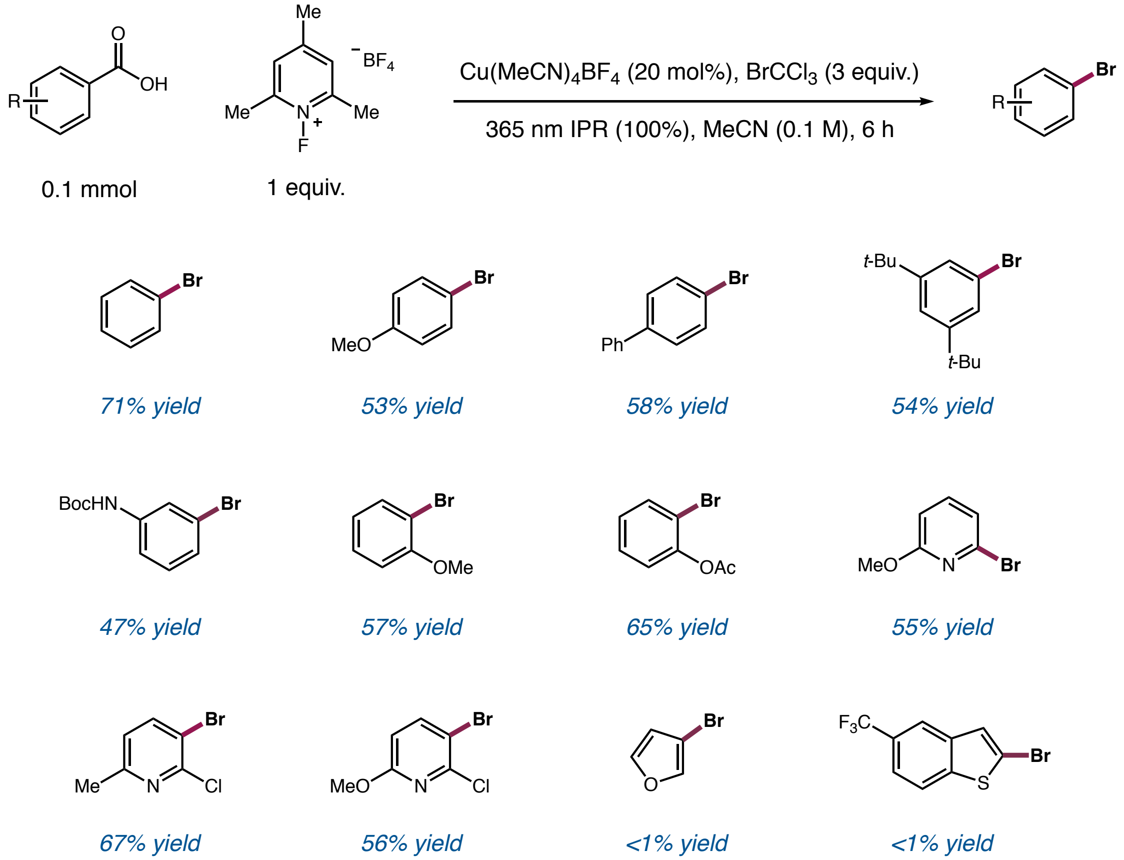
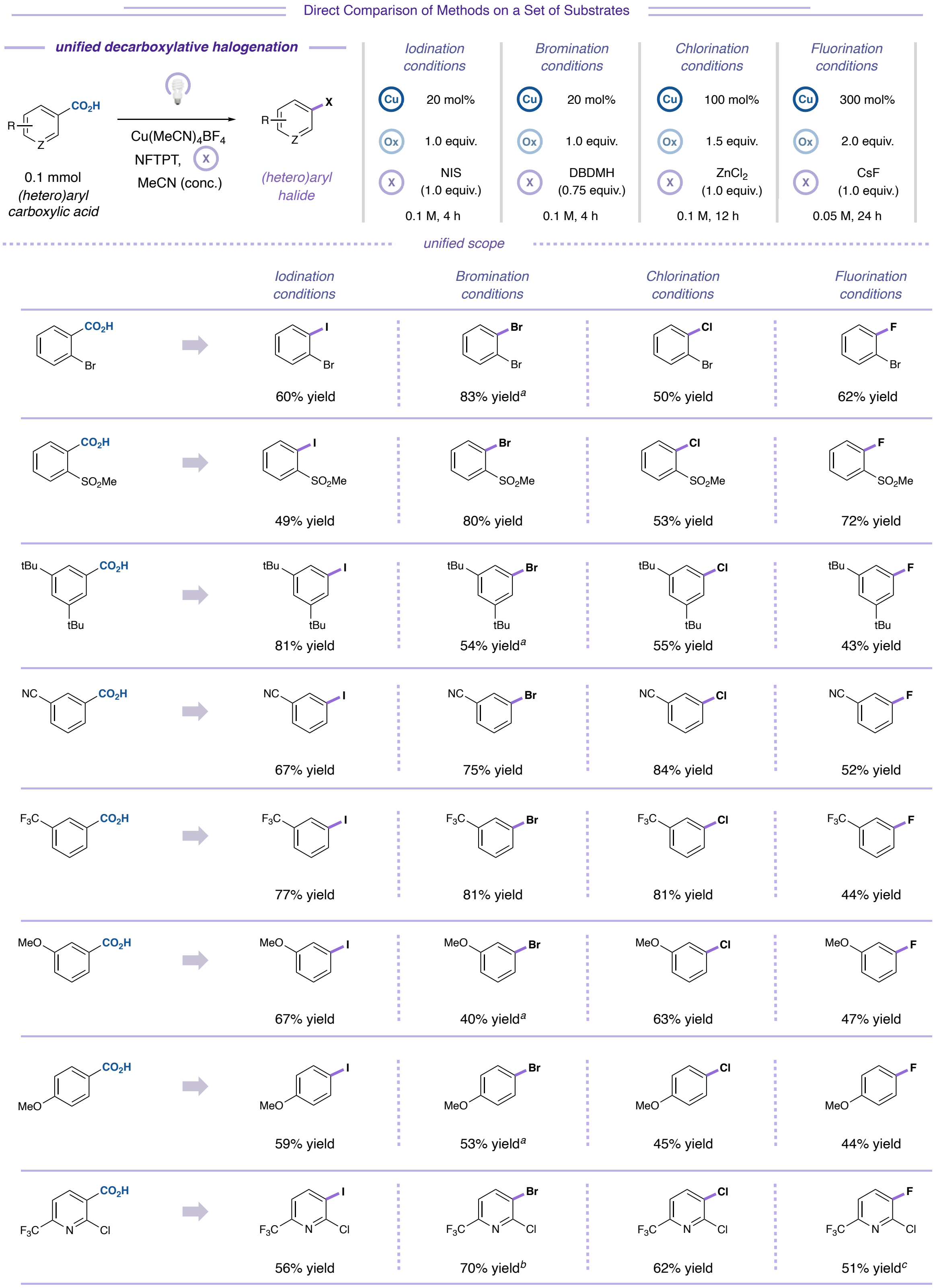


Table S26. Expanded substrate scope for bromodecarboxylation of electron-rich substrates.

17) Unified decarboxylative halogenations on a set of substrates

As introduced in **Figure 7**, the unified nature of this LMCT halogenation method has been demonstrated via additional studies of substrate scope, with 11 examples chosen for displaying the on-demand synthesis of all four halides from a given substrate. The following reactions were performed primarily according to the general 0.1 mmol scale procedures for decarboxylative iodination, bromination, chlorination and fluorination outlined in **Sections S9–11, S13**. For additional details regarding the synthesis and isolation of 3-bromo-2-chloro-6-(trifluoromethyl)pyridine on 0.5 mmol scale, see **Figure 3**, as well as the discussion of product **13** found in **Section S19**. *With the exception of 3-bromo-2-chloro-6-(trifluoromethyl)pyridine, all yields displayed in this table were obtained via ^{1}H or ^{19}F NMR analysis.*

As demonstrated by the following examples, Cu-LMCT decarboxylation enabled by the combination of $Cu(MeCN)_4BF_4$ and NFTPT can be easily applied to the synthesis of (hetero)aryl halides (iodide, bromide, chloride or fluoride) through the judicious selection of halogenating conditions (either atom-transfer reagents or Cu-halide coupling conditions). This unified $Cu(MeCN)_4BF_4$/NFTPT decarboxylation system permits facile access to all four halides in a substrate-independent fashion, as electron-deficient benzoic acids, electron-rich benzoic acids and a variety of (hetero)aryl acids were found to deliver the corresponding iodide/bromide/chloride/fluoride products in useful to excellent efficiencies under the standard conditions for each reported transformation.



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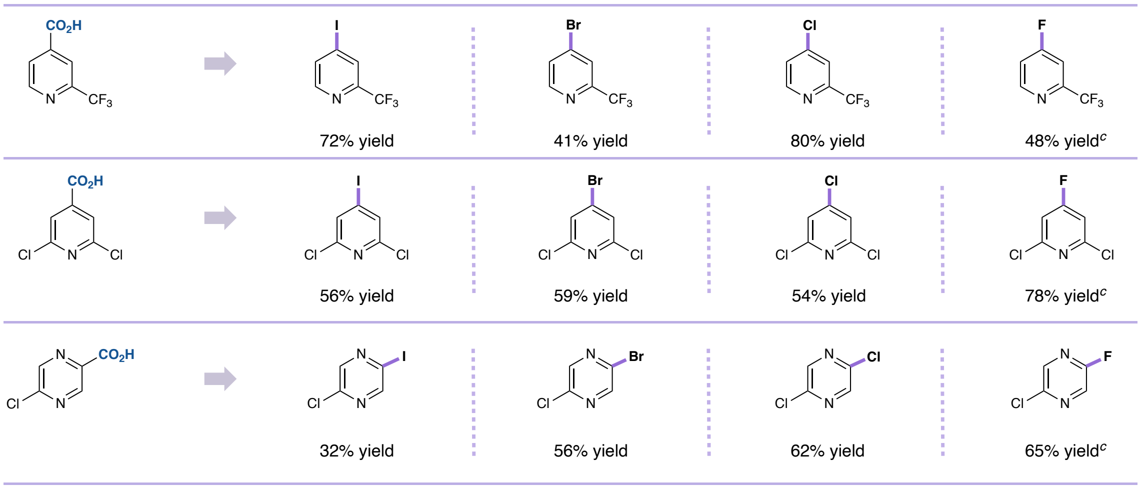
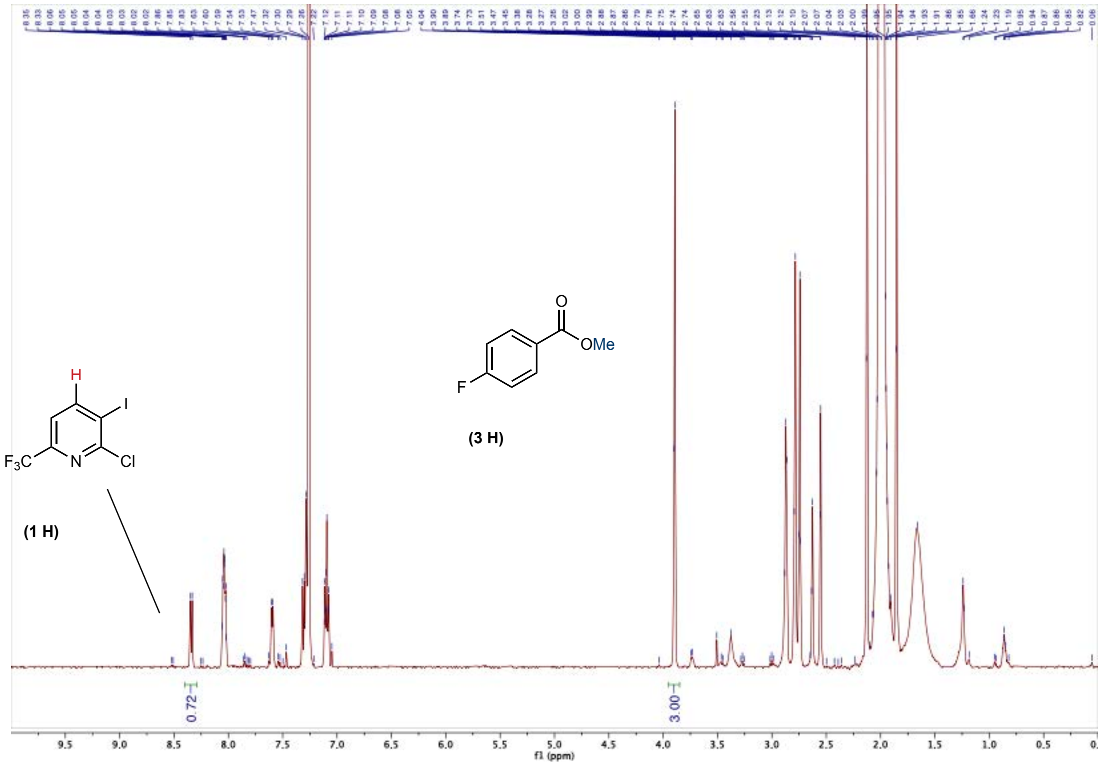


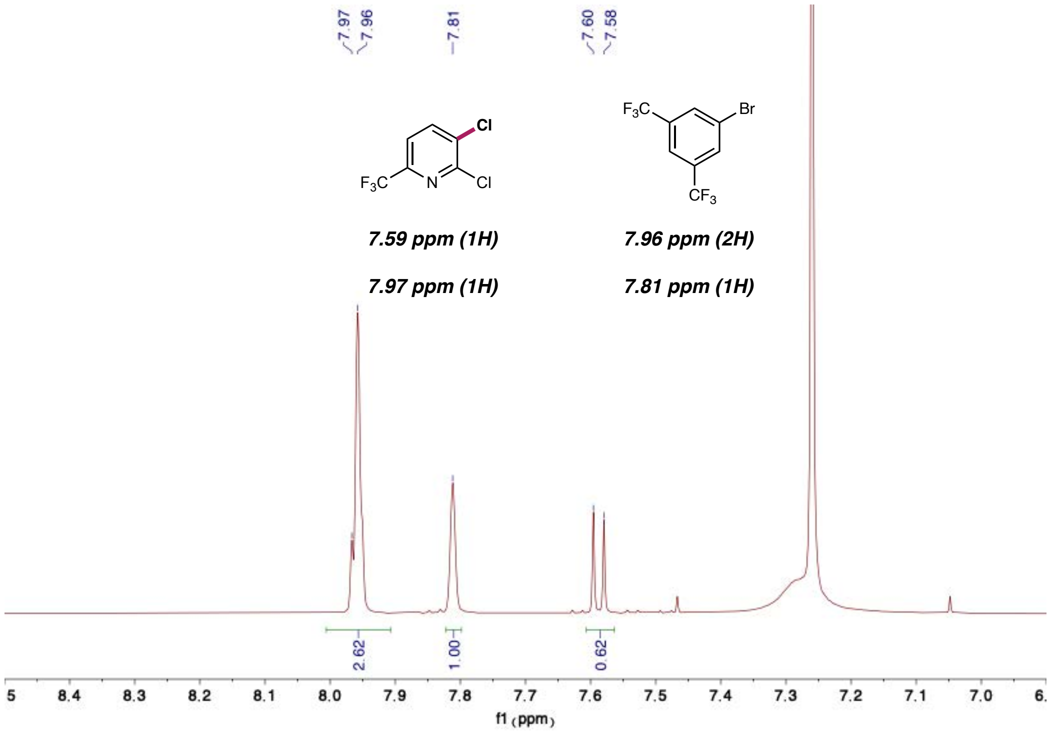
[a]Bromination performed using $BrCCl_3$ (3 equiv.) as brominating agent in place of DBDMH. [b]Isolated yield on 0.5 mmol scale (see **Figure 3**). [c]Fluorination performed in absence of CsF.

Table S27. Unified scope table for on-demand generation of all four halides from a single (hetero)aryl acid.

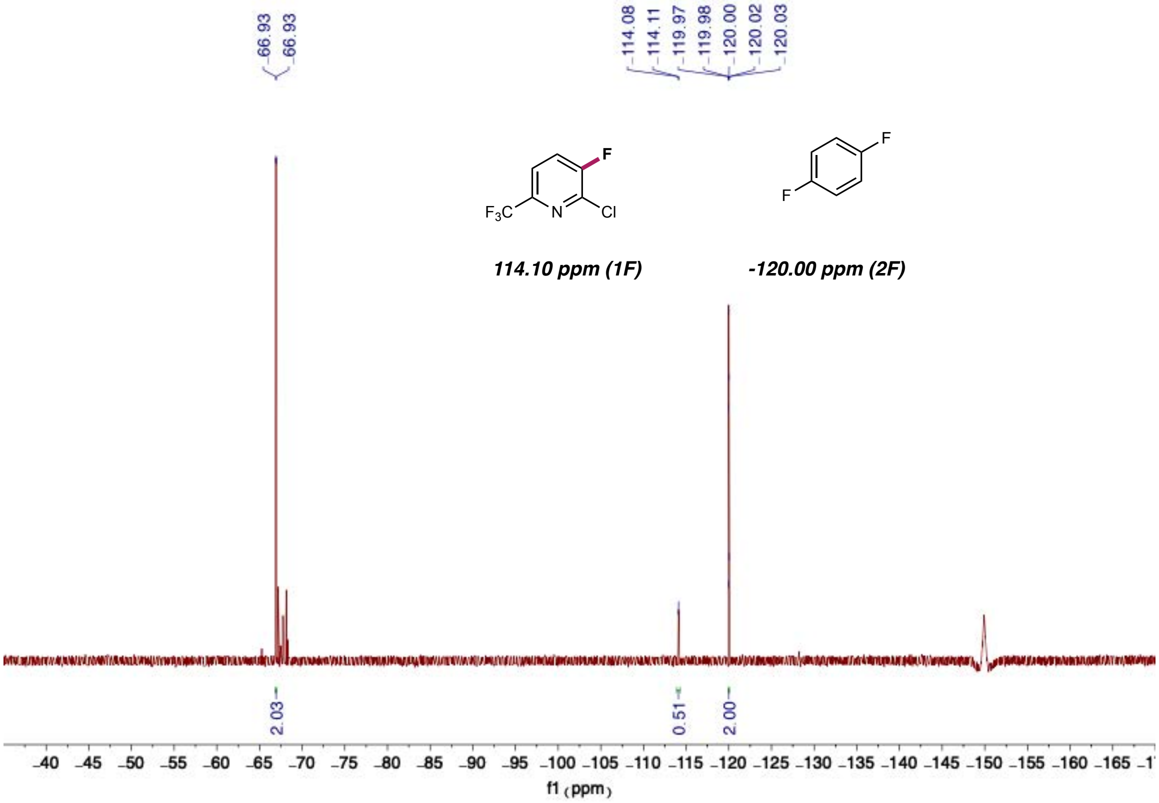
Included below are the assay spectrum from which the yields were determined for the halogenation reactions on 2-chloro-6-trifluoromethyl nicotinic acid that appear in Figure 7. The bromination product yield given is an isolated yield on 0.5 mmol scale, detailed in Section S19.



[(0.72 mmol pdt/mmol std) * 0.0773 mmol std]/0.1 mmol pdt (theoretical) = *56% assay yield*



1-bromo-3-5-bis(trifluoromethyl)benzene (17.3 μL, 0.1 mmol 1.0 equiv.) was added as the internal standard for ^{1}H NMR analysis ($CDCl_3$) (62% yield)



1,4-difluorobenzene (10.3 μL, 0.1 mmol 1.0 equiv.) was added as the internal standard for ^{19}F NMR analysis (CDCl$_3$) (51% yield)

18) Expanded mechanism figure

Based on the observed reactivity, a proposed mechanism for the catalytic decarboxylative functionalization manifold is described in Figure S3. Upon combination of a copper(I) catalyst with an oxidant and the aryl carboxylic acid substrate, an aryl carboxylate-copper(II) complex could be formed. Photoexcitation of this complex followed by LMCT would induce homolysis of the copper–oxygen bond, generating reduced Cu(I) and an aroyloxy radical. Subsequent decarboxylation of the aroyloxy radical could occur to yield an aryl radical and extrude CO_2. The aryl radical could then react with a radical trapping reagent to furnish the functionalized product (X = I, Br, H, D), or another copper equivalent followed by bond formation (X = Cl, F, OR). Reformation of the copper carboxylate complex and single-electron oxidation of Cu(I) would close the copper catalytic cycle. Under conditions for chlorodecarboxylation or conditions for fluorodecarboxylation, aryl radical capture by a putative copper(II)–halide complex could generate high-valent copper(III), and subsequent $C(sp^2)$–X reductive elimination would deliver the desired aryl halide.

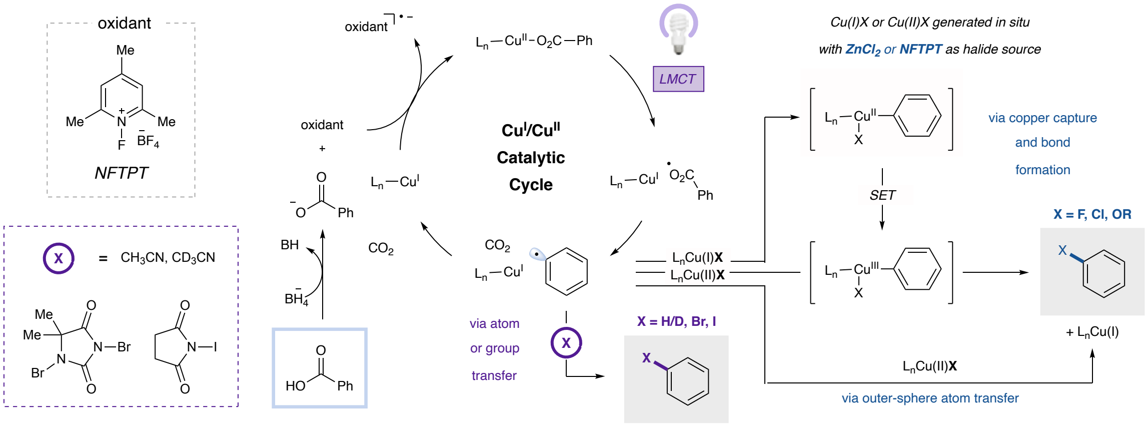
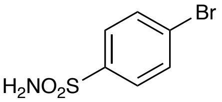


Figure S3. Expanded mechanism of LMCT halogention reactions.

19) Decarboxylative bromination of aryl & heteroaryl acids

General procedure: To an oven-dried 8-mL vial equipped with a Teflon stir bar (or 40-mL vial for 1.0 mmol-scale reactions) was added (hetero)aryl acid substrate, *N*-fluoro-2,4,6-trimethylpyridinium tetrafluoroborate (NFTPT), $[Cu(MeCN)_4]BF_4$ and bromination reagent (if 1,3-dibromo-5,5-dimethylhydantoin (DBDMH) used). Anhydrous MeCN was added via syringe (followed by bromination reagent, if CCl_3Br used), and the mixture was sparged with nitrogen while stirring for 10 minutes before the reaction vial was sealed with Parafilm. The reaction vial was irradiated in the Integrated Photoreactor (IPR) with 365 nm LEDs (100% LED intensity, 1000 rpm stir rate, 5200 rpm fan rate) for 6–12 h.

Once the reaction was complete, the reaction mixture was diluted with deionized water (3 mL) and pentane/Et_2O (10:1, 5 mL), and tetrasodium EDTA was added (200 mg). The reaction mixture was stirred for 15 min. The organic layer was separated, and the aqueous layer was extracted with 10:1 pentane/Et_2O (5 x 10 mL). The organic layers were collected, dried over $MgSO_4$, filtered, and concentrated. The pure product was obtained following isolation by silica gel column chromatography.



4-bromobenzenesulfonamide (1)

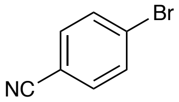
Prepared following the general procedure outlined above using 4-sulfamoylbenzoic acid (100.6 mg, 0.5 mmol, 1.0 equiv.), NFTPT (113 mg, 0.5 mmol, 1.0 equiv.), $[Cu(MeCN)_4]BF_4$ (31.5 mg, 0.1 mmol, 0.2 equiv.), DBDMH (107 mg, 0.375 mmol, 0.75 equiv.) and MeCN (5 mL, 0.1 M) (reaction time: 6 h). Purification by flash chromatography (gradient 20–50% EtOAc in hexanes) afforded the title compound (0.42 mmol, 104.4 mg, 84% yield) as an off-white solid.

^{1}H NMR (500 MHz, $(CD_3)_2SO$) δ 8.27 – 7.68 (m, 4H), 7.48 (s, 1H).

^{13}C NMR (125 MHz, $(CD_3)_2SO$) δ 143.42, 132.06, 127.77, 125.48.

Spectral data is consistent with those reported in literature:

Hayashi, E.; Yamaguchi, Y.; Kita, Y.; Kamata, K.; Hara, M. *Chem. Commun.* **2020**, *56*, 2095–2098.



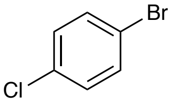
4-bromobenzonitrile (2)

Prepared following the general procedure outlined above using 4-cyanobenzoic acid (73.6 mg, 0.5 mmol, 1.0 equiv.), NFTPT (113 mg, 0.5 mmol, 1.0 equiv.), $[Cu(MeCN)_4]BF_4$ (31.5 mg, 0.1 mmol, 0.2 equiv.), DBDMH (107 mg, 0.375 mmol, 0.75 equiv.) and MeCN (5 mL, 0.1 M) (reaction time: 12 h). Purification by flash chromatography (20:1 pentane/Et_2O) afforded the title compound (0.40 mmol, 72.8 mg, 80% yield) as a white solid.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.66 (d, *J* = 8.2 Hz, 2H), 7.55 (d, *J* = 8.2 Hz, 2H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 133.4, 132.7, 128.0, 118.1, 111.3.

Spectral data is consistent with those reported in literature:
Quibell, J. M.; Perry, G. J. P.; Cannas, D. M.; Larrosa, I. *Chem. Sci.* **2018**, *9*, 3860.



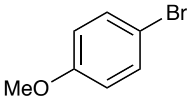
1-bromo-4-chlorobenzene (3)

Prepared following the general procedure outlined above using 4-chlorobenzoic acid (78.3 mg, 0.5 mmol, 1.0 equiv.), NFTPT (113 mg, 0.5 mmol, 1.0 equiv.), $[Cu(MeCN)_4]BF_4$ (31.5 mg, 0.1 mmol, 0.2 equiv.), DBDMH (107 mg, 0.375 mmol, 0.75 equiv.) and MeCN (5 mL, 0.1 M) (reaction time: 12 h). Purification by flash chromatography (gradient) afforded the title compound (0.35 mmol, 67.8 mg, 71% yield) as a white solid.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.46 (s, 1H), 7.40 (s, 1H), 3.92 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 139.7, 130.0, 92.9, 39.5.

Spectral data is consistent with those reported in literature:
Fricke, C.; Deckers, K.; Schoenebeck, F. *Angew. Chem. Int. Ed.,* **2020**, *59*, 18717.



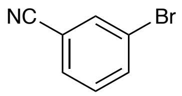
4-bromoanisole (4)

Prepared following the general procedure outlined above using *p*-Anisic acid (76.1 mg, 0.5 mmol, 1.0 equiv.), NFTPT (113 mg, 0.5 mmol, 1.0 equiv.), [Cu(MeCN)$_4$]BF$_4$ (31.5 mg, 0.1 mmol, 0.2 equiv.), CCl$_3$Br (148 µL, 1.5 mmol, 3.0 equiv.) and MeCN (5 mL, 0.1 M) (reaction time: 8 h). Purification by flash chromatography (10:1 pentane/Et$_2$O) afforded the title compound (0.35 mmol, 66.0 mg, 71% yield) as a white solid.

^{1}H NMR (500 MHz, CDCl$_3$) δ 7.41 (d, 2H, *J* = 8.0 Hz), 6.81 (d, 2H, *J* = 8.0 Hz), 3.81 (s, 3H).

^{13}C NMR (125 MHz, CDCl$_3$) δ 158.7, 132.2, 115.7, 112.8, 55.5.

Spectral data is consistent with those reported in literature:
Quibell, J. M.; Perry, G. J. P.; Cannas, D. M.; Larrosa, I. *Chem. Sci.* **2018**, *9*, 3860.



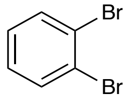
3-bromobenzonitrile (5)

Prepared following the general procedure outlined above using 3-cyanobenzoic acid (73.6 mg, 0.5 mmol, 1.0 equiv.), NFTPT (113 mg, 0.5 mmol, 1.0 equiv.), [Cu(MeCN)4]BF4 (31.5 mg, 0.1 mmol, 0.2 equiv.), DBDMH (107 mg, 0.375 mmol, 0.75 equiv.) and MeCN (5 mL, 0.1 M) (reaction time: 6 h). Purification by flash chromatography (gradient 0–40% Et_2O in pentane) afforded the title compound (0.35 mmol, 63.0 mg, 69% yield) as an off-white solid.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.81 (t, *J* = 1.7 Hz, 1H), 7.76 (ddd, *J* = 8.2, 1.9, 1.0 Hz, 1H), 7.62 (dt, *J* = 7.8, 1.2 Hz, 1H), 7.38 (t, *J* = 8.0 Hz, 1H).

^{13}C NMR (126 MHz, $CDCl_3$) δ 136.17, 134.78, 130.75, 130.66, 122.94, 117.34, 114.21.

Spectral data is consistent with those reported in literature: Movassagh, B.; Fazeli, A. *Synth. Commun.* **2007**, *37*, 623-628.



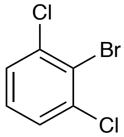
1,2-dibromobenzene (6)

Prepared following the general procedure outlined above using 2-bromobenzoic acid (100.5 mg, 0.5 mmol, 1.0 equiv.), NFTPT (113 mg, 0.5 mmol, 1.0 equiv.), $[Cu(MeCN)_4]BF_4$ (31.5 mg, 0.1 mmol, 0.2 equiv.), CCl_3Br (148 μL, 1.5 mmol, 3.0 equiv.) and MeCN (5 mL, 0.1 M) (reaction time: 6 h). Purification by flash chromatography (gradient 0–15% Et_2O in pentane) afforded the title compound (0.37 mmol, 86.2 mg, 73% yield) as a colorless oil.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.62 (ddd, *J* = 6.1, 3.6, 1.0 Hz, 2H), 7.17 (ddd, *J* = 6.2, 3.5, 1.0 Hz, 2H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 133.88, 128.63, 124.96.

Spectral data is consistent with those reported in literature:
Diemer, V.; Leroux, F. R.; Colobert, F. *Eur. J. Org. Chem.* **2011**, *2*, 327–340.



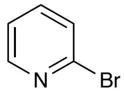
2-bromo-1,3-dichlorobenzene (7)

Prepared following the general procedure outlined above using 2,6-dichlorobenzoic acid (95.5 mg, 0.5 mmol, 1.0 equiv.), NFTPT (113 mg, 0.5 mmol, 1.0 equiv.), $[Cu(MeCN)_4]BF_4$ (31.5 mg, 0.1 mmol, 0.2 equiv.), DBDMH (107 mg, 0.375 mmol, 0.75 equiv.) and MeCN (5 mL, 0.1 M) (reaction time: 12 h). Purification by flash chromatography (10:1 pentane/Et_2O) afforded the title compound (0.30 mmol, 67.8 mg, 60% yield) as a white solid.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.40 (d, *J* = 8.0 Hz, 2H), 7.21 (t, *J* = 8.0 Hz, 1H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 136.4, 128.5, 128.4, 123.5.

Spectral data is consistent with those reported in literature:
Barbero, M.; Degani, I.; Diulgheroff, N.; Dughera, S.; Fochi, R. *Synthesis* **2001**, *14*, 2180.



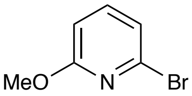
2-bromopyridine (8)

Prepared following the general procedure outlined above using picolinic acid (61.6 mg, 0.5 mmol, 1.0 equiv.), NFTPT (113 mg, 0.5 mmol, 1.0 equiv.), $[Cu(MeCN)_4]BF_4$ (31.5 mg, 0.1 mmol, 0.2 equiv.), DBDMH (107 mg, 0.375 mmol, 0.75 equiv.) and MeCN (5 mL, 0.1 M) (reaction time: 6 h). Purification by flash chromatography (gradient 0–15% Et_2O in pentane) afforded the title compound (0.29 mmol, 45.2 mg, 57% yield) as a colorless oil.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.35 (dd, *J* = 5.0, 1.8 Hz, 1H), 7.53 (td, *J* = 7.7, 2.1 Hz, 1H), 7.47 (dt, *J* = 8.0, 1.0 Hz, 1H), 7.24 (ddd, *J* = 7.3, 4.8, 1.1 Hz, 1H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 150.35, 142.37, 138.57, 128.36, 122.72.

Spectral data is consistent with those reported in literature:
Maloney, K. M.; Nwakpuda, E.; Kuethe, J. T.; Yin, J. *J. Org. Chem.* **2009**, *74*, 5111–5114.



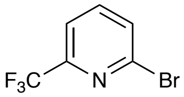
2-bromo-6-methoxypyridine (9)

Prepared following the general procedure outlined above using 6-methoxypicolinic acid (61.6 mg, 0.5 mmol, 1.0 equiv.), NFTPT (113 mg, 0.5 mmol, 1.0 equiv.), $[Cu(MeCN)_4]BF_4$ (31.5 mg, 0.1 mmol, 0.2 equiv.), CCl_3Br (148 μL, 1.5 mmol, 3.0 equiv.) and MeCN (5 mL, 0.1 M) (reaction time: 6 h). Purification by flash chromatography (gradient 0–20% Et_2O in pentane) afforded the title compound (0.27 mmol, 63.1 mg, 53% yield) as a colorless oil.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.41 (ddd, *J* = 8.2, 7.5, 0.8 Hz, 1H), 7.05 (dt, *J* = 7.4, 0.7 Hz, 1H), 6.68 (dd, *J* = 8.2, 0.7 Hz, 1H), 3.93 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 163.89, 140.49, 138.75, 120.34, 109.56, 54.23.

Spectral data is consistent with those reported in literature:
Agarwal, P. K.; Saifuddin, M.; Kundu, B. *Tetrahedron* **2010**, *66*, 862–870.



2-bromo-6-(trifluoromethyl)pyridine (10)

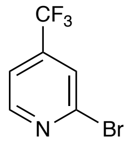
Prepared following the general procedure outlined above using 6-(trifluoromethyl)picolinic acid (95.6 mg, 0.5 mmol, 1.0 equiv.), NFTPT (113 mg, 0.5 mmol, 1.0 equiv.), [Cu(MeCN)$_4$]BF$_4$ (31.5 mg, 0.1 mmol, 0.2 equiv.), DBDMH (107 mg, 0.375 mmol, 0.75 equiv.) and MeCN (5 mL, 0.1 M) (reaction time: 6 h). Purification by flash chromatography (gradient 0–15% Et$_2$O in pentane) afforded the title compound (0.36 mmol, 80.7 mg, 71% yield) as a yellow solid.

^{1}H NMR (500 MHz, CDCl$_3$) δ 7.76 – 7.73 (m, 1H), 7.69 (d, *J* = 7.9 Hz, 1H), 7.65 (dd, *J* = 7.5, 1.1 Hz, 1H).

^{13}C NMR (125 MHz, CDCl$_3$) δ 148.93 (q, *J* = 35.9 Hz), 142.56, 139.68, 131.53 120.67 (q, *J* = 275.0 Hz), 119.54 (q, *J* = 3.0 Hz).

^{19}F NMR (376 MHz, CDCl$_3$) δ –68.09 (s, 3F).

Spectral data is consistent with those reported in literature:
Cottet, F.; Schlosser, M. *Eur. J. Org. Chem.* **2002**, *2*, 327–330.



2-bromo-4-(trifluoromethyl)pyridine (11)

Prepared following the general procedure outlined above using 4-(trifluoromethyl)picolinic acid (95.6 mg, 0.5 mmol, 1.0 equiv.), NFTPT (113 mg, 0.5 mmol, 1.0 equiv.), $[Cu(MeCN)_4]BF_4$ (31.5 mg, 0.1 mmol, 0.2 equiv.), DBDMH (107 mg, 0.375 mmol, 0.75 equiv.) and MeCN (5 mL, 0.1 M) (reaction time: 12 h). Purification by flash chromatography (10:1 pentane/Et_2O) afforded the title compound (0.38 mmol, 86.3 mg, 76% yield) as a colorless oil.

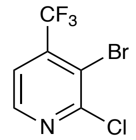
^{1}H NMR (500 MHz, $CDCl_3$) δ 8.61 (s, 1H), 7.77 (s, 1H), 7.51 (s, 1H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 151.2, 142.9, 140.6 (q, *J* = 34.6 Hz), 124.3, 121.9 (q, *J* = 273.8 Hz), 118.5.

^{19}F NMR (376 MHz, $CDCl_3$) δ –64.8 (s, 3F).

Spectral data is consistent with those reported in literature:

Cottet, F.; Marull, M.; Lefebvre, O.; Schlosser, M. *Eur. J. Org. Chem.,* **2003**, *8*, 1559.



3-bromo-2-chloro-4-(trifluoromethyl)pyridine (12)

Prepared following the general procedure outlined above using 2-chloro-4-(trifluoromethyl)nicotinic acid (112.8 mg, 0.5 mmol, 1.0 equiv.), NFTPT (113 mg, 0.5 mmol, 1.0 equiv.), $[Cu(MeCN)_4]BF_4$ (31.5 mg, 0.1 mmol, 0.2 equiv.), DBDMH (107 mg, 0.375 mmol, 0.75 equiv.) and MeCN (5 mL, 0.1 M) (reaction time: 6 h). Purification by flash chromatography (gradient 0–15% Et_2O in pentane) afforded the title compound (0.38 mmol, 97.1 mg, 75% yield) as a pale yellow oil.

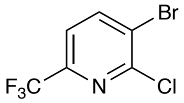
^{1}H NMR (500 MHz, CDCl$_3$) δ 8.48 (d, *J* = 4.6 Hz, 1H), 7.51 – 7.49 (m, 1H).

^{13}C NMR (125 MHz, CDCl$_3$) δ 154.15, 148.44, 141.00 (q, *J* = 32.7 Hz), 121.43 (q, *J* = 273.7 Hz), 120.33 (q, *J* = 5.1 Hz), 118.23.

^{19}F NMR (376 MHz, CDCl$_3$) δ –64.90 (s, 3F).

IR (film) ν_{max} 2925, 1546, 1359, 1308, 1233, 1199, 1151, 1095, 1026, 846, 818, 757 cm^{-1}.

HRMS (GC-EI-TOF) m/z calcd. for $C_6H_2BrClF_3N$ ($[M^*]^+$) 258.90112, found 258.90289.



3-bromo-2-chloro-6-(trifluoromethyl)pyridine (13)

Prepared following the general procedure outlined above using 2-chloro-6-(trifluoromethyl)nicotinic acid (112.8 mg, 0.5 mmol, 1.0 equiv.), NFTPT (113 mg, 0.5 mmol, 1.0 equiv.), $[Cu(MeCN)_4]BF_4$ (31.5 mg, 0.1 mmol, 0.2 equiv.), DBDMH (107 mg, 0.375 mmol, 0.75 equiv.) and MeCN (5 mL, 0.1 M) (reaction time: 6 h). Purification by flash chromatography (gradient 0–15% Et_2O in pentane) afforded the title compound (0.35 mmol, 90.6 mg, 70% yield) as a yellow oil.

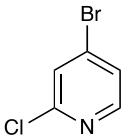
^{1}H NMR (500 MHz, $CDCl_3$) δ 8.13 (d, *J* = 8.1 Hz, 1H), 7.49 (d, *J* = 8.1 Hz, 1H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 151.68, 146.77 (q, *J* = 36.5 Hz), 143.65, 124.36 (q, *J* = 1.2 Hz), 120.61 (q, *J* = 274.4 Hz), 120.20 (q, *J* = 2.7 Hz).

^{19}F NMR (376 MHz, $CDCl_3$) δ –68.24 (s, 3F).

IR (film) ν_{max} 2930, 2845, 1564, 1440, 1337, 1242, 1148, 1106, 1021, 837, 726 cm^{-1}.

HRMS (GC-EI-TOF) m/z calcd. for $C_6H_2BrClF_3N$ ($[M^*]^+$) 258.90112, found 258.90343.



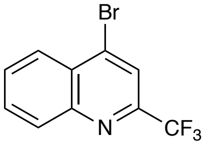
4-bromo-2-chloropyridine (14)

Prepared following the general procedure outlined above using 2-chloroisonicotinic acid (78.8 mg, 0.5 mmol, 1.0 equiv.), NFTPT (113 mg, 0.5 mmol, 1.0 equiv.), $[Cu(MeCN)_4]BF_4$ (31.5 mg, 0.1 mmol, 0.2 equiv.), DBDMH (107 mg, 0.375 mmol, 0.75 equiv.) and MeCN (5 mL, 0.1 M) (reaction time: 12 h). Purification by flash chromatography (10:1 pentane/Et_2O) afforded the title compound (0.30 mmol, 56.8 mg, 59% yield) as a colorless oil.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.17 (d, 1H), 7.48 (d, 1H), 7.34 (dd, *J* = 5.3, 1.7 Hz, 1H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 152.2, 150.1, 134.3, 127.4, 125.9.

Spectral data is consistent with those reported in literature:
Zhang, X.; Feng, X.; Yamamoto, Y.; Bao, M. *Green Chem.*, **2019**, *21*, 5565.



4-bromo-2-(trifluoromethyl)quinoline (15)

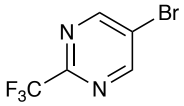
Prepared following the general procedure outlined above using 2-(trifluoromethyl)quinoline-4-carboxylic acid (120.6 mg, 0.5 mmol, 1.0 equiv.), NFTPT (113 mg, 0.5 mmol, 1.0 equiv.), $[Cu(MeCN)_4]BF_4$ (31.5 mg, 0.1 mmol, 0.2 equiv.), DBDMH (107 mg, 0.375 mmol, 0.75 equiv.) and MeCN (5 mL, 0.1 M) (reaction time: 6 h). Purification by flash chromatography (gradient 0–15% Et_2O in pentane) afforded the title compound (0.28 mmol, 108.1 mg, 56% yield) as a yellow oil.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.25 (ddd, *J* = 17.7, 8.7, 1.2 Hz, 2H), 8.03 (s, 1H), 7.90 – 7.87 (m, 1H), 7.79 (ddd, *J* = 8.4, 6.9, 1.3 Hz, 1H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 147.73, 147.69 (q, *J* = 35.3 Hz), 136.00, 131.79, 130.74, 130.04, 128.62, 126.90, 121.06 (q, *J* = 2.4 Hz), 120.94 (q, *J* = 275.6 Hz).

^{19}F NMR (376 MHz, $CDCl_3$) δ –67.45 (s, 3F).

Spectral data is consistent with those reported in literature:
Marull, M.; Schlosser, M. *Eur. J. Org. Chem.* **2003**, *8*, 1576–1588.



5-bromo-2-(trifluoromethyl)pyrimidine (16)

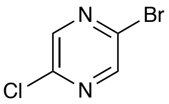
Prepared following the general procedure outlined above using 2-(trifluoromethyl)pyrimidine-5-carboxylic acid (96.1 mg, 0.5 mmol, 1.0 equiv.), NFTPT (113 mg, 0.5 mmol, 1.0 equiv.), $[Cu(MeCN)_4]BF_4$ (31.5 mg, 0.1 mmol, 0.2 equiv.), DBDMH (107 mg, 0.375 mmol, 0.75 equiv.) and MeCN (5 mL, 0.1 M) (reaction time: 12 h). Purification by flash chromatography (10:1 pentane/Et_2O) afforded the title compound (0.30 mmol, 67.8 mg, 60% yield) as a colorless oil.

^{1}H NMR (500 MHz, $CDCl_3$) δ 9.00 (s, 2H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 158.8, 154.9 (q, $J_{C\text{–}F}$ = 37.8 Hz), 123.0, 119.4 (q, $J_{C\text{–}F}$ = 275.6 Hz).

^{19}F NMR (376 MHz, $CDCl_3$) δ –70.1 (s, 3F).

Spectral data is consistent with those reported in literature:
Zhang, X.; Feng, X.; Yamamoto, Y.; Bao, M. *Green Chem.*, **2019**, *21*, 5565.



2-bromo-5-chloropyrazine (17)

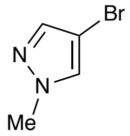
Prepared following the general procedure outlined above using 5-chloropyrazine-2-carboxylic acid (79.3 mg, 0.5 mmol, 1.0 equiv.), NFTPT (113 mg, 0.5 mmol, 1.0 equiv.), [Cu(MeCN)$_4$]BF$_4$ (31.5 mg, 0.1 mmol, 0.2 equiv.), DBDMH (107 mg, 0.375 mmol, 0.75 equiv.) and MeCN (5 mL, 0.1 M) (reaction time: 6 h). Purification by flash chromatography (gradient 15–40% Et$_2$O in pentane) afforded the title compound (0.26 mmol, 49.0 mg, 51% yield) as a colorless oil.

^{1}H NMR (500 MHz, CDCl$_3$) δ 8.48 – 8.47 (m, 1H), 8.39 – 8.38 (m, 1H).

^{13}C NMR (125 MHz, CDCl$_3$) δ 148.45, 146.84, 144.78, 138.60.

IR (film) ν_{max} 2923, 2854, 1523, 1458, 1373, 1260, 1132, 1096, 1039, 961, 802, 701 cm^{-1}.

HRMS (GC-EI-TOF) m/z calcd. for $C_4H_2BrClN_2$ ([M*]$^+$) 191.90899, found 191.90981.



4-bromo-1-methyl-1*H*-pyrazole (18)

Prepared following the general procedure outlined above (in an oven-dried 40 mL vial) using 1-methyl-1*H*-pyrazole-4-carboxylic acid (126.1 mg, 1.0 mmol, 1.0 equiv.), NFTPT (227 mg, 1.0 mmol, 1.0 equiv.), $[Cu(MeCN)_4]BF_4$ (62.9 mg, 0.2 mmol, 0.2 equiv.), DBDMH (214 mg, 0.75 mmol, 0.75 equiv.) and MeCN (10 mL, 0.1 M) (reaction time: 12 h). Purification by flash chromatography (10% EtOAc/hexane) afforded the title compound (0.70 mmol, 112.7 mg, 70% yield) as a colorless oil.

^{1}H NMR (500 MHz, CDCl$_3$) δ 7.46 (s, 1H), 7.40 (s, 1H), 3.92 (s, 3H).

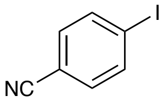
^{13}C NMR (125 MHz, CDCl$_3$) δ 139.7, 130.0, 92.9, 39.5.

Spectral data is consistent with those reported in literature:
Quibell, J. M.; Perry, G. J. P.; Cannas, D. M.; Larrosa, I. *Chem. Sci.,* **2018**, *9*, 3860.

20) Decarboxylative iodination of aryl & heteroaryl acids

General procedure: To an oven-dried 8-mL vial equipped with a Teflon stir bar was added (hetero)aryl acid substrate, NFTPT, $[Cu(MeCN)_4]BF_4$ and *N*-iodosuccinimide (NIS). Anhydrous MeCN was added via syringe, and the mixture was sparged with nitrogen while stirring for 10 minutes before the reaction vial was sealed with Parafilm. The reaction vial was irradiated in the Integrated Photoreactor (IPR) with 365 nm LEDs (100% LED intensity, 1000 rpm stir rate, 5200 rpm fan rate) for 6 h.

Following irradiation, the crude mixture was transferred to a round-bottom flask and carefully concentrated *in vacuo.* The resulting residue was redissolved in CH_2Cl_2 (10 mL) and transferred (with two additional 10 mL CH_2Cl_2 washes) to a separatory funnel containing a 1:1 mixture of saturated NH_4Cl and brine (10 mL). The layers were separated, and the aqueous layer was extracted with additional CH_2Cl_2 (3 x 10 mL). The combined organics were collected, dried over $MgSO_4$, filtered and concentrated *in vacuo*. The remaining residue was then purified via flash chromatography on silica gel to obtain the desired iodoarene product.



4-iodobenzonitrile (19)

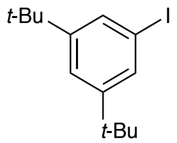
Prepared following the general procedure outlined above using 4-cyanobenzoic acid (73.6 mg, 0.5 mmol, 1.0 equiv.), NFTPT (113 mg, 0.5 mmol, 1.0 equiv.), $[Cu(MeCN)_4]BF_4$ (31.5 mg, 0.1 mmol, 0.2 equiv.), NIS (112 mg, 0.5 mmol, 1.0 equiv.) and MeCN (5 mL, 0.1 M). Purification by flash chromatography (gradient 0–15% Et_2O in pentane) afforded the title compound (0.31 mmol, 71.0 mg, 62% yield) as a yellow solid.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.84 (dd, *J* = 8.5, 2.6 Hz, 2H), 7.36 (dd, *J* = 8.6, 2.0 Hz, 2H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 138.62, 133.28, 118.34, 111.84, 100.44.

Spectral data is consistent with those reported in literature:

Boehm, P.; Cacherat, B.; Lee, Y. H.; Martini, T.; Morandi, B. *Angew. Chem. Int. Ed.* **2021**, *133*, 17348–17355.



1-iodo-3,5-di-*tert*-butylbenzene (20)

Prepared following the general procedure outlined above using 3,5-di-*tert*-butylbenzoic acid (117.2 mg, 0.5 mmol, 1.0 equiv.), NFTPT (113 mg, 0.5 mmol, 1.0 equiv.), $[Cu(MeCN)_4]BF_4$ (31.5 mg, 0.1 mmol, 0.2 equiv.), NIS (112 mg, 0.5 mmol, 1.0 equiv.) and MeCN (5 mL, 0.1 M). Purification by flash chromatography (gradient 0–15% Et_2O in pentane) afforded the title compound (0.36 mmol, 111.7 mg, 71% yield) as a white solid.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.53 (d, J = 1.7 Hz, 2H), 7.37 (t, J = 1.7 Hz, 1H), 1.30 (s, 18H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 153.25, 131.94, 121.97, 94.91, 35.03, 31.42.

Spectral data is consistent with those reported in literature:
Li, L.; Liu, W.; Zeng, H.; Mu, X.; Cosa, G.; Mi, Z.; Li, C.-J. *J. Am. Chem. Soc.* **2015**, *137*, 8328–8331.

Gram scale decarboxylative iodination: To an oven-dried 40-mL vial equipped with a Teflon stir bar was added 3,5-di-*tert*-butylbenzoic acid (1.41 g, 6.0 mmol, 1.0 equiv.), NFTPT (1.37 g, 6.0 mmol, 1.0 equiv.), $[Cu(MeCN)_4]BF_4$ (0.377 g, 1.2 mmol, 0.2 equiv.) and *N*-iodosuccinimide (1.35 g, 6.0 mmol, 1.0 equiv.). Anhydrous MeCN (30 mL, 0.2 M) was added via syringe, and the mixture was sparged with nitrogen while stirring for 10 minutes before the reaction vial was sealed with Parafilm. The reaction vial was placed directly on the LEDs of an Integrated Photoreactor (IPR, 365 nm LEDs) and secured in place with tape (vida infra) before irradiating (100% LED intensity, 2000 rpm stir rate, 5200 rpm fan rate) for 16 hours.

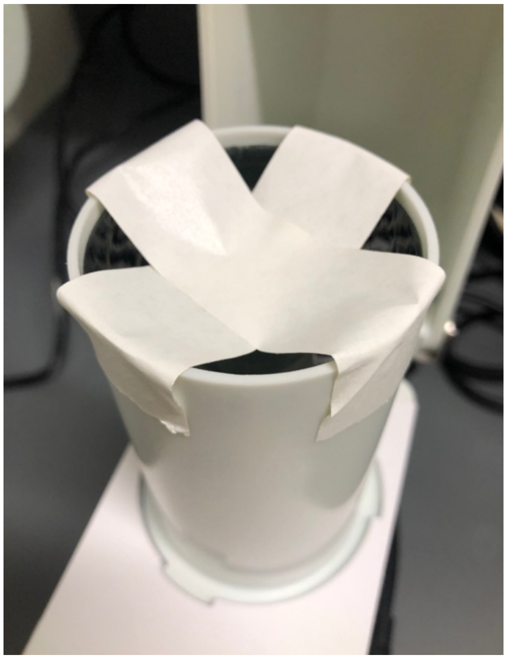
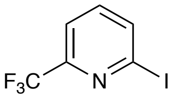


Figure S4. Integrated Photoreactor setup for gram-scale decarboxylative iodination.

Following irradiation, the crude mixture was transferred to a round-bottom flask and carefully concentrated *in vacuo.* The resulting residue was redissolved in CH_2Cl_2 (30 mL) and transferred (with two additional 10 mL CH_2Cl_2 washes) to a separatory funnel containing a 1:1 mixture of saturated NH_4Cl and brine (50 mL). The layers were separated, and the aqueous layer was extracted with additional CH_2Cl_2 (3 x 50 mL). The combined organics were collected, dried over $MgSO_4$, filtered, and concentrated *in vacuo*. The remaining residue was then purified via flash chromatography (gradient 0–15% Et_2O in pentane) on silica gel to obtain 1-iodo-3,5-di-*tert*-butylbenzene (3.96 mmol, 1.25 g, 66% yield) as a light pink solid. Characterization data (^{1}H NMR and ^{13}C NMR) were identical to those obtained for product **20** and are consistent with those reported in literature:

Li, L.; Liu, W.; Zeng, H.; Mu, X.; Cosa, G.; Mi, Z.; Li, C.-J. *J. Am. Chem. Soc.* **2015**, *137*, 8328–8331.



2-iodo-6-(trifluoromethyl)pyridine (21)

Prepared following the general procedure outlined above using 6-(trifluoromethyl)picolinic acid (95.6 mg, 0.5 mmol, 1.0 equiv.), NFTPT (113 mg, 0.5 mmol, 1.0 equiv.), $[Cu(MeCN)_4]BF_4$ (31.5 mg, 0.1 mmol, 0.2 equiv.), NIS (112 mg, 0.5 mmol, 1.0 equiv.) and MeCN (5 mL, 0.1 M). Purification by flash chromatography (gradient 0–15% Et_2O in pentane) afforded the title compound (0.26 mmol, 70.2 mg, 52% yield) as a yellow solid.

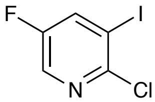
^{1}H NMR (500 MHz, $CDCl_3$) δ 7.92 (d, *J* = 7.9 Hz, 1H), 7.65 (dd, *J* = 7.7, 0.9 Hz, 1H), 7.51 (td, *J* = 7.8, 0.8 Hz, 1H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 149.34 (q, *J* = 35.7 Hz), 138.53, 138.11, 120.62 (q, *J* = 274.6 Hz), 119.82 (q, *J* = 3.0 Hz), 117.77.

^{19}F NMR (376 MHz, $CDCl_3$) δ –68.06 (s, 3F).

Spectral data is consistent with those reported in literature:

Newkome, G. R.; Moorfield, C. N.; Sabbaghian, B. *J. Org. Chem.* **1986**, *51*, 953–954.



3-iodo-2-chloro-5-fluoropyridine (22)

Prepared following the general procedure outlined above using 2-chloro-5-fluoronicotinic acid (87.8 mg, 0.5 mmol, 1.0 equiv.), NFTPT (113 mg, 0.5 mmol, 1.0 equiv.), [Cu(MeCN)$_4$]BF$_4$ (31.5 mg, 0.1 mmol, 0.2 equiv.), NIS (112 mg, 0.5 mmol, 1.0 equiv.) and MeCN (5 mL, 0.1 M). Purification by flash chromatography (gradient 0–15% Et$_2$O in pentane) afforded the title compound (0.29 mmol, 73.1 mg, 57% yield) as a yellow oil.

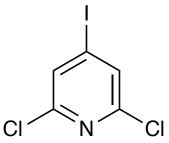
^{1}H NMR (500 MHz, CDCl$_3$) δ 8.25 (d, *J* = 2.3 Hz, 1H), 7.91 (dd, *J* = 7.0, 2.7 Hz, 1H).

^{13}C NMR (125 MHz, CDCl$_3$) δ 157.01 (d, *J* = 262.6 Hz), 149.72 (d, *J* = 2.6 Hz), 136.89 (d, *J* = 24.8 Hz), 136.03 (d, *J* = 21.2 Hz), 94.12 (d, *J* = 3.1 Hz).

^{19}F NMR (376 MHz, CDCl$_3$) δ –127.46 (d, *J* = 7.0 Hz).

IR (film) ν_{max} 3062, 2924, 1571, 1401, 1371, 1245, 1220, 1130, 1025, 876, 713 cm^{-1}.

HRMS (GC-EI-TOF) m/z calcd. for C_5H_2ClFIN ([M*]$^+$) 256.89045, found 256.89154.



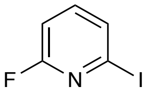
4-iodo-2,6-dichloropyridine (23)

Prepared following the general procedure outlined above using 2,6-dichloroisonicotinic acid (96.0 mg, 0.5 mmol, 1.0 equiv.), NFTPT (113 mg, 0.5 mmol, 1.0 equiv.), $[Cu(MeCN)_4]BF_4$ (31.5 mg, 0.1 mmol, 0.2 equiv.), NIS (112 mg, 0.5 mmol, 1.0 equiv.) and MeCN (5 mL, 0.1 M). Purification by flash chromatography (gradient 0–20% Et_2O in pentane) afforded the title compound (0.25 mmol, 68.9 mg, 50% yield) as a white solid.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.65 (s, 2H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 150.76, 131.61, 107.74.

Spectral data is consistent with those reported in literature:
Rohbogner, C. J.; Wunderlich, S. H.; Clososki, G. C.; Knochel, P. *Eur. J. Org. Chem.* **2009**, *11*, 1781–1795.



2-iodo-6-fluoropyridine (24)

Prepared following the general procedure outlined above using 6-fluoropicolinic acid (95.6 mg, 0.5 mmol, 1.0 equiv.), NFTPT (113 mg, 0.5 mmol, 1.0 equiv.), $[Cu(MeCN)_4]BF_4$ (31.5 mg, 0.1 mmol, 0.2 equiv.), NIS (112 mg, 0.5 mmol, 1.0 equiv.) and MeCN (5 mL, 0.1 M). Purification by flash chromatography (gradient 0–15% Et_2O in pentane) afforded the title compound (0.31 mmol, 68.0 mg, 61% yield) as a yellow solid.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.66 – 7.61 (m, 1H), 7.43 (qd, *J* = 8.0, 1.4 Hz, 1H), 6.93 – 6.90 (m, 1H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 161.76 (dd, *J* = 246.5, 1.4 Hz), 142.06 (dd, *J* = 7.4, 3.7 Hz), 132.67 (dd, *J* = 4.7, 0.8 Hz), 113.08 (dd, *J* = 13.6, 0.8 Hz), 108.78 (d, *J* = 35.1 Hz).

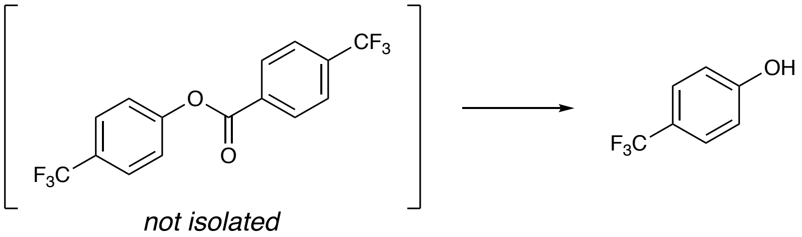
^{19}F NMR (376 MHz, $CDCl_3$) δ –64.09 (s, 1F).

IR (film) ν_{max} 3080, 1575, 1426, 1326, 1253, 1155, 1127, 1068, 986, 857, 786, 719 cm^{-1}.

HRMS (GC-EI-TOF) m/z calcd. for C_5H_3FIN ($[M^*]^+$) 222.92942, found 222.93041.

21) Phenol synthesis via decarboxylative esterification & hydrolysis

General procedure: To an oven-dried 8-mL vial equipped with a Teflon stir bar was added (hetero)aryl acid substrate, dicumyl peroxide and $[Cu(MeCN)_4]BF_4$. The contents of the vial were dissolved in anhydrous MeCN, and the mixture was sonicated until homogeneous. The reaction mixture was then sparged with nitrogen for 10 minutes. After 10 minutes, the vial cap was sealed with Parafilm, and the mixture was subsequently irradiated in the Integrated Photoreactor for 6 hours using a 365 nm LED module (standard settings: 100% LED intensity, 5200 rpm fan speed, 1000 rpm stirring speed). Following irradiation, the crude mixture was transferred to a round-bottom flask and concentrated *in vacuo.* To the round-bottom flask was added a Teflon stir bar, NaOH (aq.) and THF, and the resulting mixture was stirred at room temperature under air for 16 hours. After 16 hours, 1N HCl was added until obtaining a solution of pH ~1–3, and the contents of the round-bottom flask were then transferred to a separatory funnel using Et_2O rinses (~20 mL total). The layers were separated, and the aqueous layer was extracted with additional Et_2O (3 x 10 mL). The combined organics were collected, dried over $MgSO_4$, filtered and concentrated *in vacuo*. The remaining residue was then purified via flash chromatography on silica gel to obtain the desired phenol product (*note:* maximum theoretical yields for this transformation are 50% yield).



4-(trifluoromethyl)phenol (S1)

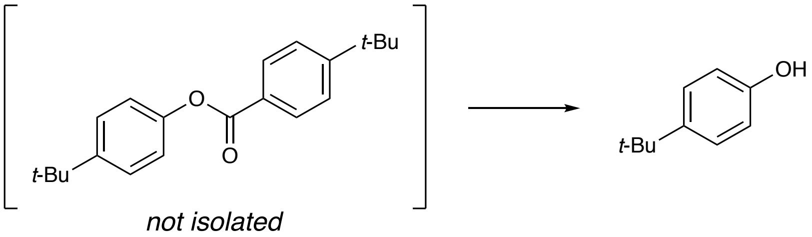
Prepared following the general procedure outlined above using 4-(trifluoromethyl)benzoic acid (95.1 mg, 0.5 mmol, 1.0 equiv.), dicumyl peroxide (338 mg, 1.5 mmol, 2.5 equiv.), $[Cu(MeCN)_4]BF_4$ (472 mg, 1.5 mmol, 3.0 equiv.) and MeCN (5 mL, 0.1 M). Following hydrolysis of the crude aryl ester according to the general procedure using 2M aqueous NaOH (2.5 mL, 5.0 mmol, 10 equiv.) and THF (2.5 mL), purification by flash chromatography (gradient 0–35% Et_2O in pentane) afforded the title compound (0.21 mmol, 33.8 mg, 42% yield) as a white solid.

^{1}H NMR (500 MHz, CDCl$_3$) δ 7.51 (d, *J* = 8.3 Hz, 2H), 6.90 (d, *J* = 8.3 Hz, 2H), 5.34 (s, 1H).

^{13}C NMR (125 MHz, CDCl$_3$) δ 158.26, 127.35 (q, *J* = 3.8 Hz), 124.49 (q, *J* = 271.0 Hz), 123.35 (q, *J* = 32.8 Hz), 115.59.

^{19}F NMR (376 MHz, CDCl$_3$) δ –61.54 (s, 3F).

Spectral data is consistent with those reported in literature:
Samant, B. S.; Kabalka, G. W. *Chem. Commun.* **2011**, *47*, 7236–7238.



4-*tert*-butylphenol (S2)

Prepared following the general procedure outlined above using 4-*tert*-butylbenzoic acid (89.1 mg, 0.5 mmol, 1.0 equiv.), dicumyl peroxide (338 mg, 1.5 mmol, 2.5 equiv.), $[Cu(MeCN)_4]BF_4$ (472 mg, 1.5 mmol, 3.0 equiv.) and MeCN (5 mL, 0.1 M). Following hydrolysis of the crude aryl ester according to the general procedure using 2M aqueous NaOH (2.5 mL, 5.0 mmol, 10 equiv.) and THF (2.5 mL), purification by flash chromatography (gradient 0–35% Et_2O in pentane) afforded the title compound (0.23 mmol, 33.7 mg, 45% yield) as a white solid.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.29 – 7.27 (m, 2H), 6.81 – 6.79 (m, 2H), 1.32 (s, 9H).

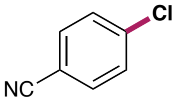
note – phenolic proton not observed.

^{13}C NMR (125 MHz, $CDCl_3$) δ 153.38, 143.57, 126.57, 114.89, 34.21, 31.68.

Spectral data is consistent with those reported in literature:
Zhu, C.; Wang, R.; Falck, J. R. *Org. Lett.* **2012**, *14*, 3494–3497.

22) Decarboxylative chlorination of aryl & heteroaryl acids

General procedure: An oven dried 8-mL vial with a Teflon-coated stir bar was charged with $ZnCl_2$ (anhydrous, stored in glovebox), (hetero)aryl carboxylic acid, NFTPT and $[Cu(MeCN)_4]BF_4$ (0.2–1.0 equiv.). Anhydrous MeCN (5 mL, 0.1 M) was then added, and the suspension was sparged for 10 minutes with nitrogen while stirring. The vial was then Parafilmed to protect from air during the course of the reaction. The reaction vial was then irradiated with 365 nm light in the Integrated Photoreactor (100% light intensity, 1000 rpm stir rate, 5200 rpm fan speed) for 12 hours. Once the reaction was complete, the vial was quenched by exposure to air. Work up and purification for each substrate are described below.



4-chlorobenzonitrile (25)

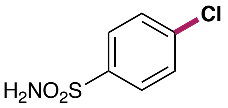
Prepared according to the general procedure outlined above using $[Cu(MeCN)_4]BF_4$ (31.5 mg, 0.1 mmol, 0.2 equiv.), $ZnCl_2$ (68 mg, 0.5 mmol, 1 equiv.), NFTPT (170 mg, 0.75 mmol, 1.5 equiv.), and 4-cyanobenzoic acid (73.6 mg, 0.5 mmol, 1 equiv) in MeCN (5 mL, 0.1 M). Irradiation time: 12 h.

The final reaction mixture was stirred with tetrasodium EDTA (50 mg) and water (3 mL) for 30 minutes. The mixture was then transferred to a separatory funnel and water (15 mL) was added before extracting with 9:1 pentane:ether (5x20 mL). The combined organic layers were then dried over magnesium sulfate, filtered, and concentrated. The product was then purified via silica gel column chromatography to yield the pure product (48 mg, 0.35 mmol, 70%) as a white solid.

^{1}H NMR (500 MHz, $CDCl_3$) δ 7.62 (d, *J* = 8.5 Hz, 1H), 7.49 (d, *J* = 8.6 Hz, 1H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 139.58, 133.41, 129.72, 118.01, 110.78.

Spectral data are consistent with those reported in the literature: Hatsuda, M.; Seki, M. *Tetrahedron,* **61**, 9908 – 9917 (2005).



4-chlorobenzenesulfonamide (26)

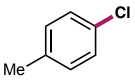
Prepared according to the general procedure outlined above using [Cu(MeCN)$_4$]BF$_4$ (31.5 mg, 0.1 mmol, 0.2 equiv.), ZnCl$_2$ (68 mg, 0.5 mmol, 1 equiv.), NFTPT (170 mg, 0.75 mmol, 1.5 equiv.), and 4-sulfamoylbenzoic acid (73.6 mg, 0.5 mmol, 1 equiv) in MeCN (5 mL, 0.1 M). Irradiation time: 12 h.

The final reaction mixture was stirred with tetrasodium EDTA (50 mg) and water (3 mL) for 30 minutes. The mixture was then transferred to a separatory funnel and water (15 mL) was added before extracting with ethyl acetate (3x20 mL). The combined organic layers were then dried over magnesium sulfate, filtered, and concentrated down to ~5 mL. diethyl ether (10 mL) was added, and the resulting precipitate was filtered off over a pad of celite. The filtrate was then concentrated and purified via silica gel column chromatography to yield the pure product (59 mg, 0.31 mmol, 62%) as a white solid.

^{1}H NMR (500 MHz, DMSO) δ 7.86 – 7.80 (m, 1H), 7.70 – 7.63 (m, 1H), 7.48 (s, 1H).

^{13}C NMR (125 MHz, CDCl$_3$) δ 140.38, 139.35, 129.46, 128.00.

Spectral data are consistent with those reported in the literature: F. Carta et al. *Chem. Biol. Drug Des.*, **74**, 196 – 202 (2009).



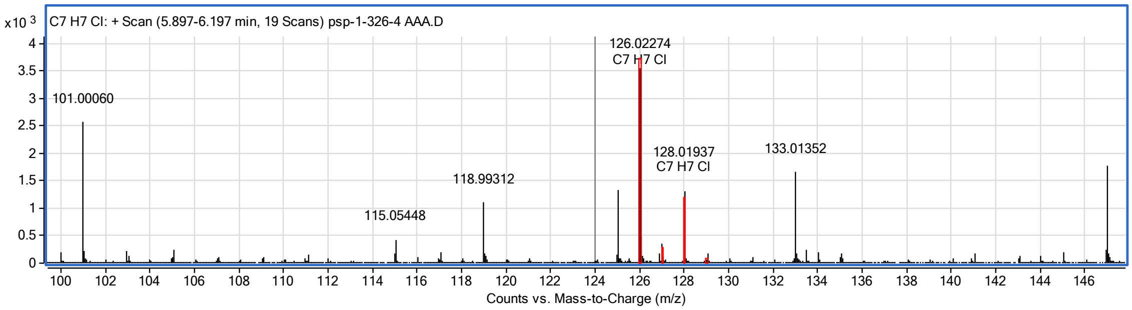
4-chloro-toluene (27)

Prepared according to the general procedure outlined above using $[Cu(MeCN)_4]BF_4$ (157.3 mg, 0.5 mmol, 1.0 equiv.), $ZnCl_2$ (68 mg, 0.5 mmol, 1.0 equiv.), NFTPT (170 mg, 0.75 mmol, 1.5 equiv.), and 4-methyl benzoic acid (68.1 mg, 0.5 mmol, 1.0 equiv) in MeCN (5 mL, 0.1 M). Irradiation time: 12 h.

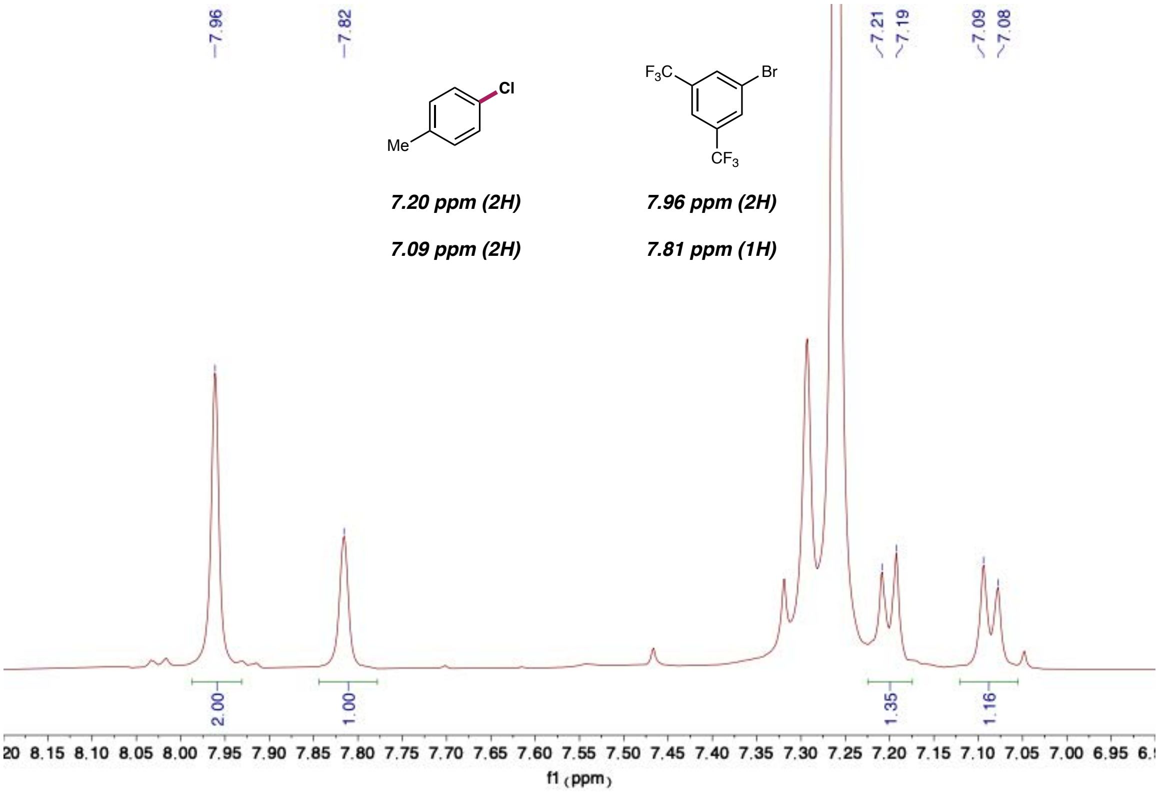
Yield was determined by ^1H NMR in triplicate due to volatility of the desired product.

1-bromo-3-5-bis(trifluoromethyl)benzene (87 µL, 0.5 mmol 1.0 equiv.) was added as the internal standard for ^1H NMR analysis ($CDCl_3$) (58% yield – average of three trials: 58%, 57%, and 58%).

Spectral data are consistent with those obtained from a commercial sample of 4-chloro toluene.



HRMS (GC-EI-TOF) m/z calcd. for C_7H_7Cl ($[M^*]^+$) 126.02363, found 126.02274.

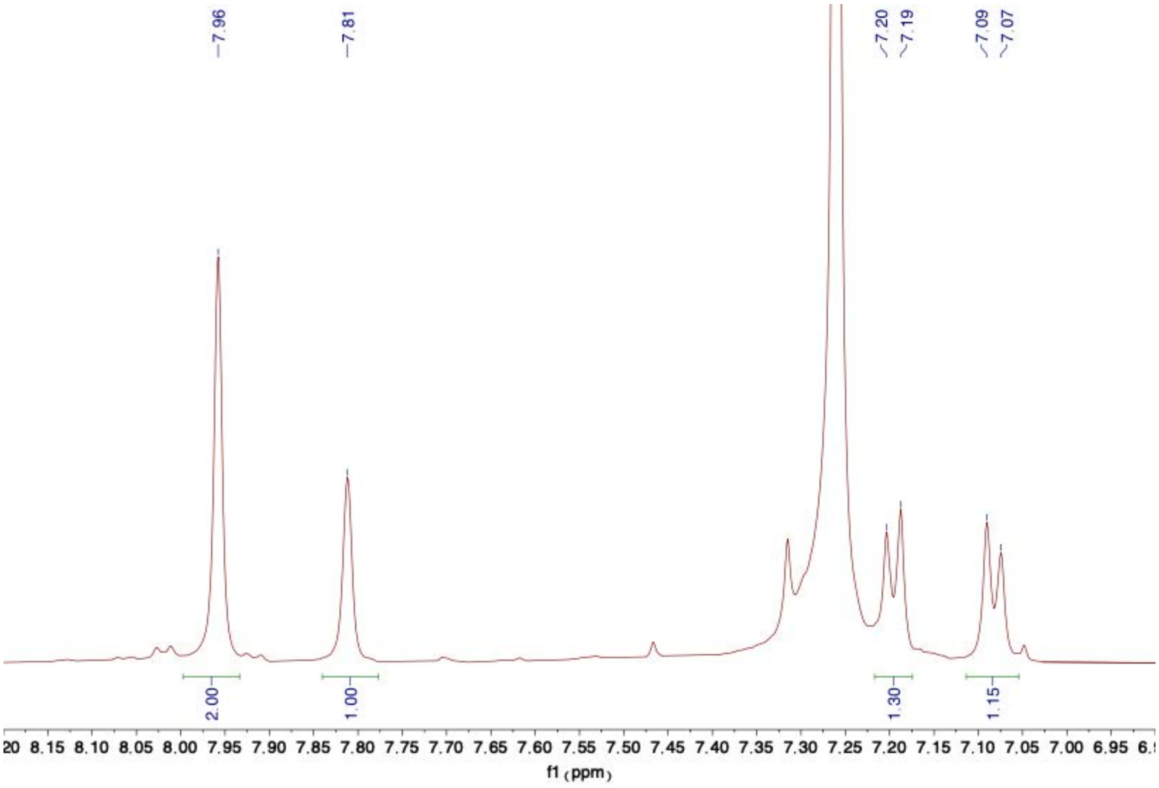


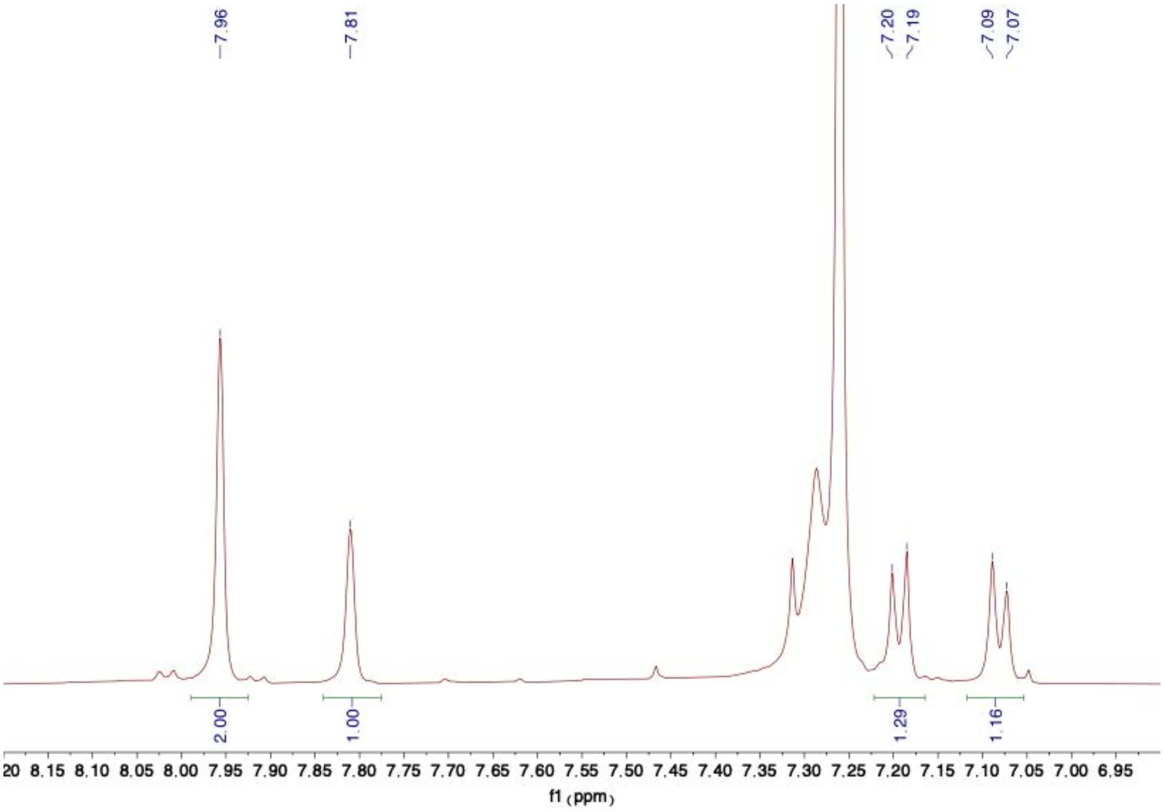
7.20 ppm (2H)

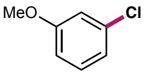
7.09 ppm (2H)

7.96 ppm (2H)

7.81 ppm (1H)




7.96
7.81
7.20
7.19
7.09
7.07
2.00
1.00
1.29
1.16
20 8.15 8.10 8.05 8.00 7.95 7.90 7.85 7.80 7.75 7.70 7.65 7.60 7.55 7.50 7.45 7.40 7.35 7.30 7.25 7.20 7.15 7.10 7.05 7.00 6.95
f1 (ppm)



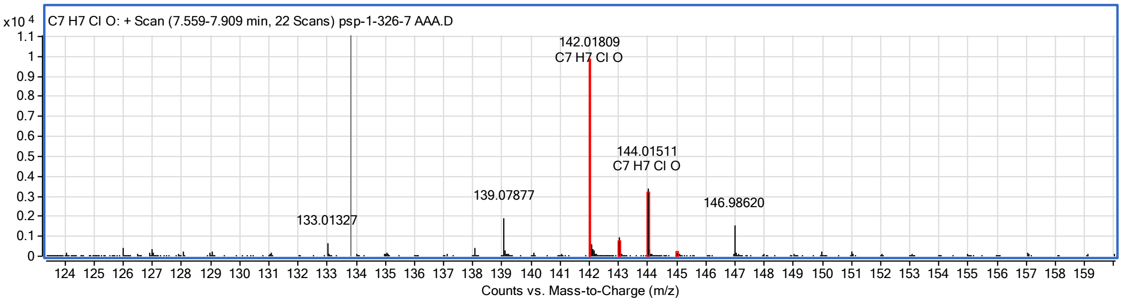
3-chloro-anisole (28)

Prepared according to the general procedure outlined above using [Cu(MeCN)$_4$]BF$_4$ (157.3 mg, 0.5 mmol, 1.0 equiv.), ZnCl$_2$ (68 mg, 0.5 mmol, 1.0 equiv.), NFTPT (170 mg, 0.75 mmol, 1.5 equiv.), and 4-methyl benzoic acid (68.1 mg, 0.5 mmol, 1.0 equiv) in MeCN (5 mL, 0.1 M). Irradiation time: 12 h.

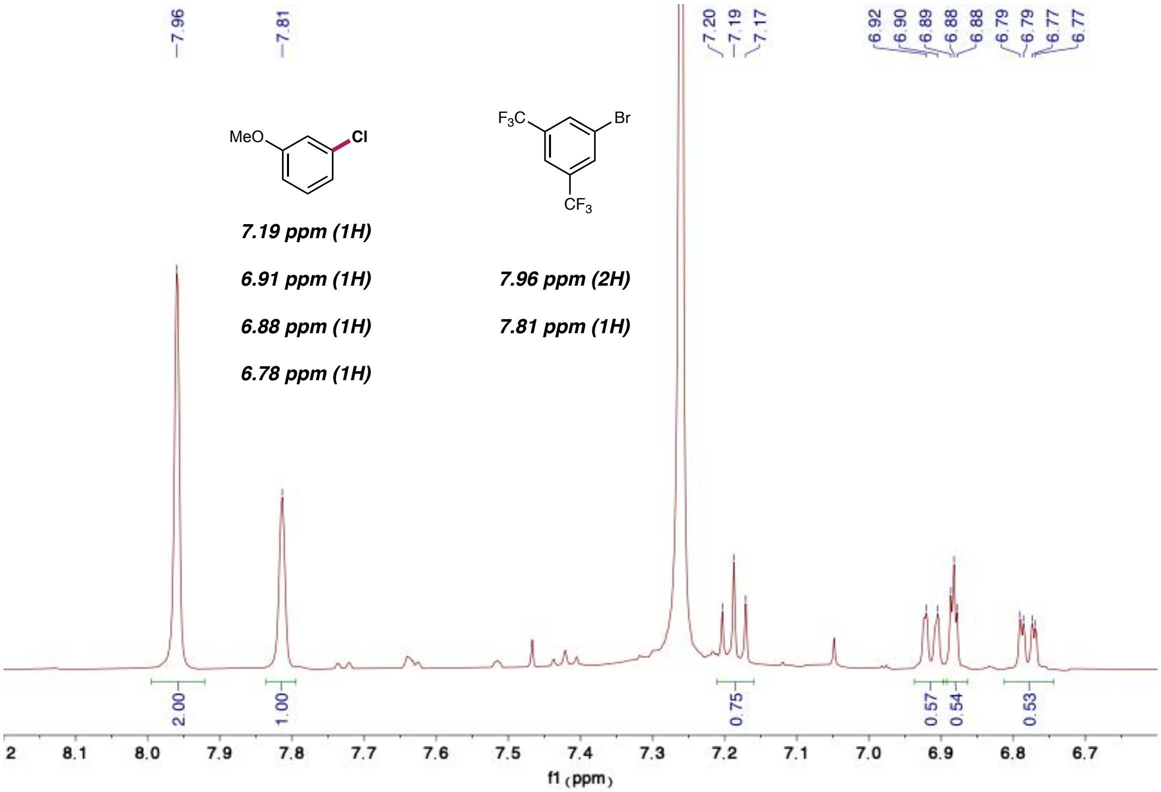
Yield was determined by ^{1}H NMR in triplicate due to volatility of the desired product.

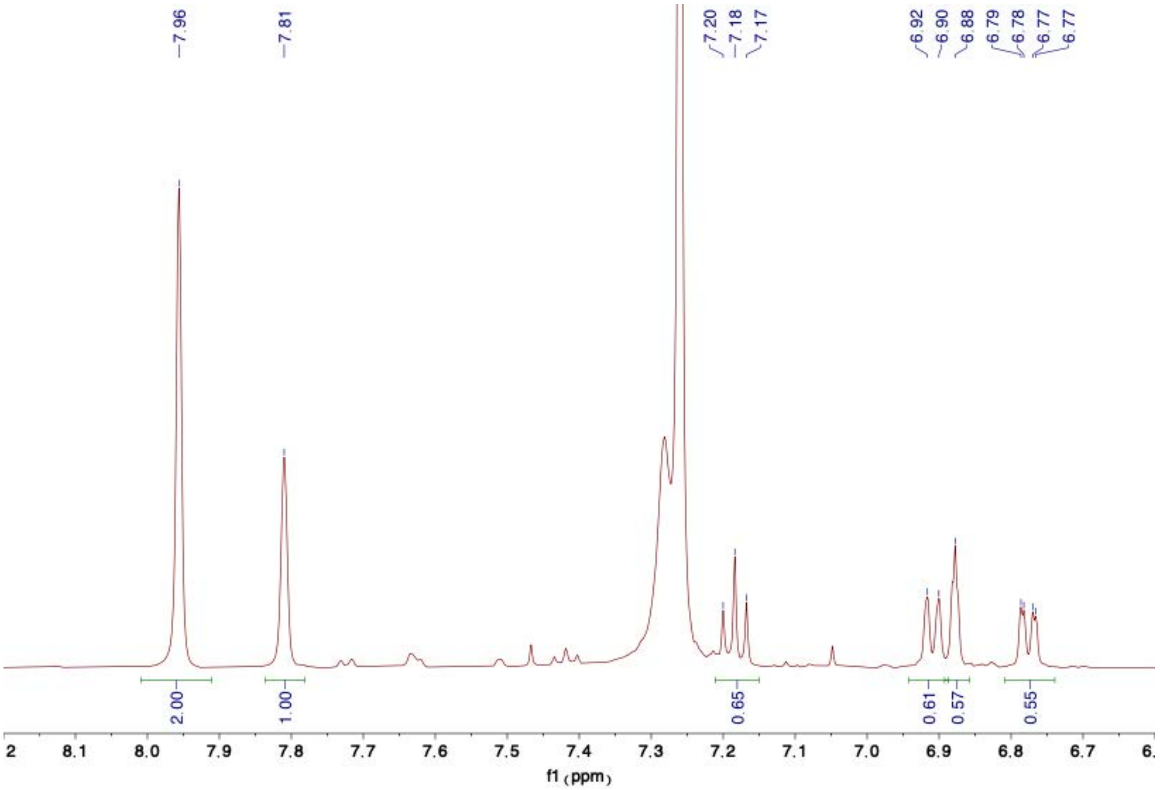
1-bromo-3-5-bis(trifluoromethyl)benzene (87 µL, 0.5 mmol 1.0 equiv.) was added as the internal standard for ^{1}H NMR analysis (CDCl$_3$) (53% yield – average of three trials: 53%, 55%, and 51%).

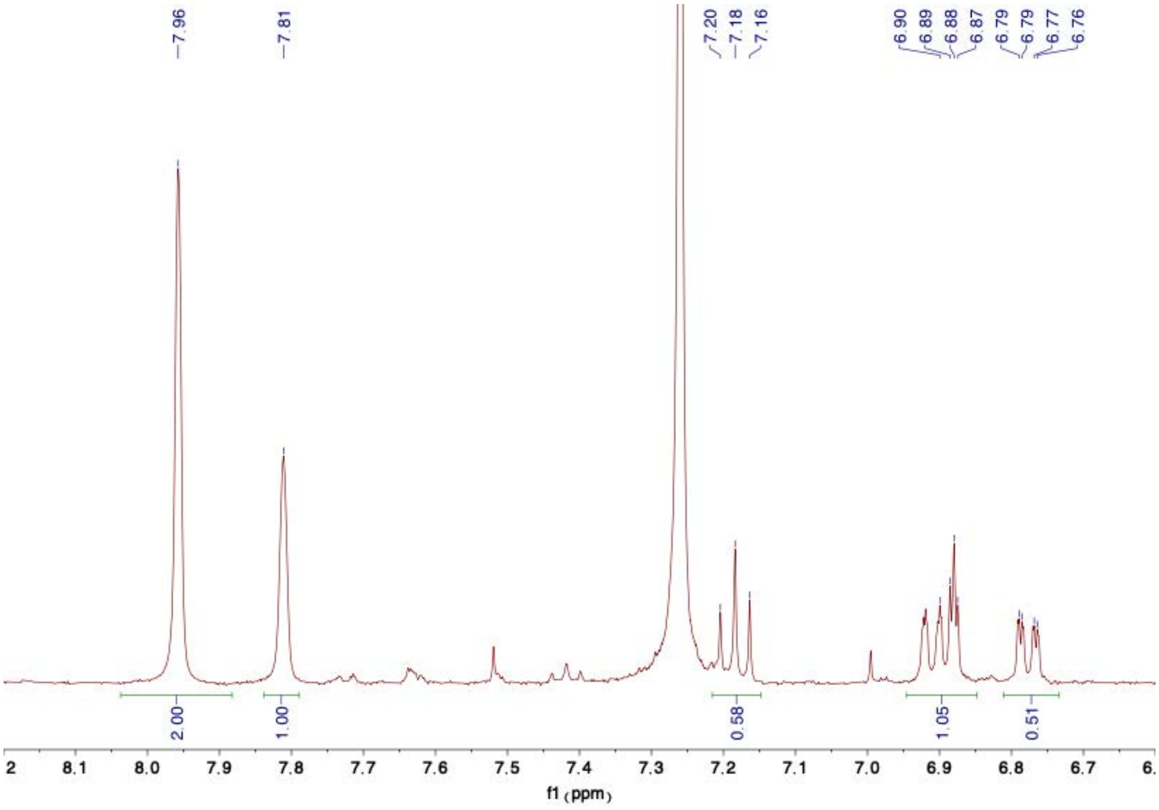
Spectral data are consistent with those reported in the literature: J. Zilberman. *Org. Process Res. Dev.*, **7**, 303 – 305 (2003).

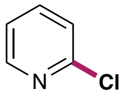


HRMS (GC-EI-TOF) m/z calcd. for C$_7$H$_7$ClO ([M*]$^+$) 142.01854, found 142.01809.


7.96
7.81
7.20
7.19
7.17
6.92
6.90
6.89
6.88
6.88
6.79
6.79
6.77
6.77
MeO
Cl
F_3C
Br
CF_3
7.19 ppm (1H)
6.91 ppm (1H)
6.88 ppm (1H)
6.78 ppm (1H)
7.96 ppm (2H)
7.81 ppm (1H)
2.00
1.00
0.75
0.57
0.54
0.53
2
8.1
8.0
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7.0
6.9
6.8
6.7
f1 (ppm)


7.96
7.81
7.20
7.18
7.17
6.92
6.90
6.88
6.79
6.78
6.77
6.77
2.00
1.00
0.65
0.61
0.57
0.55
2
8.1
8.0
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7.0
6.9
6.8
6.7
6.
f1 (ppm)


7.96
7.81
7.20
7.18
7.16
6.90
6.89
6.88
6.87
6.79
6.79
6.77
6.76
2.00
1.00
0.58
1.05
0.51
2
8.1
8.0
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7.0
6.9
6.8
6.7
6.
f1 (ppm)



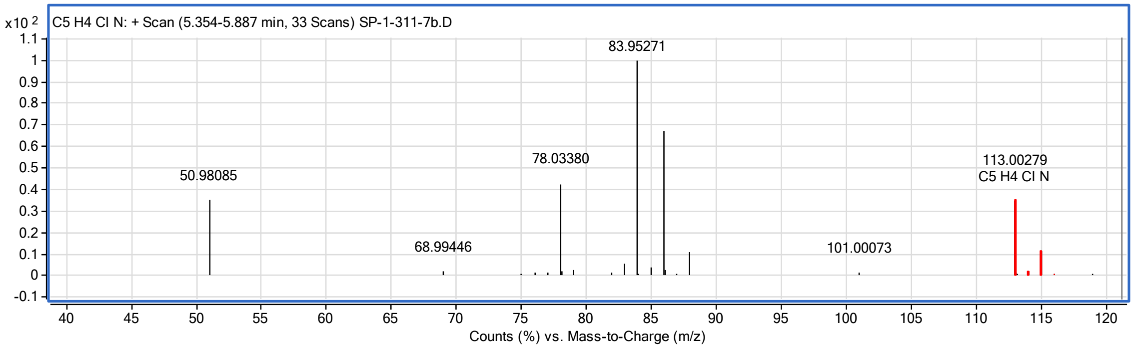
2-chloropyridine (29)

Prepared according to the general procedure outlined above using [Cu(MeCN)$_4$]BF$_4$ (78.6 mg, 0.25 mmol, 0.5 equiv.), ZnCl$_2$ (68 mg, 0.5 mmol, 1 equiv.), NFTPT (170 mg, 0.75 mmol, 1.5 equiv.), and picolinic acid (61.6 mg, 0.5 mmol, 1 equiv) in MeCN (5 mL, 0.1 M). Irradiation time: 12 h.

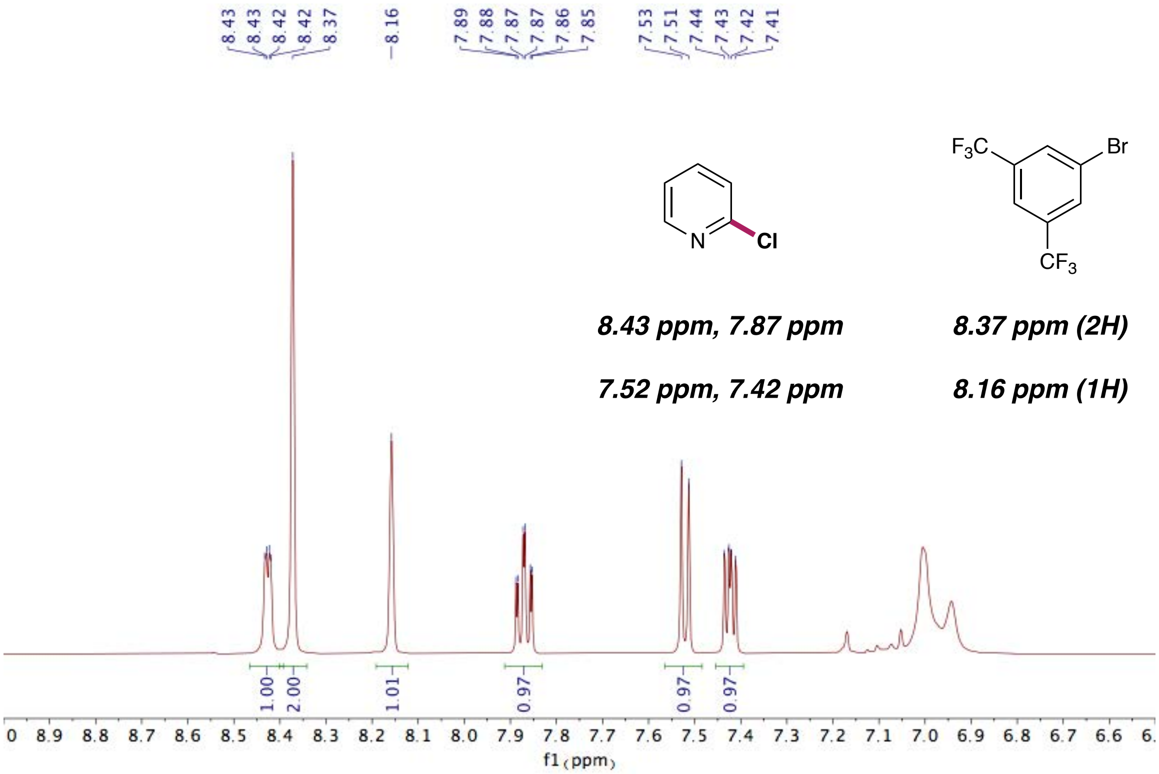
Yield was determined by ^{1}H NMR in triplicate due to the high volatility of the desired product.

1-bromo-3-5-bis(trifluoromethyl)benzene (87 µL, 0.5 mmol 1.0 equiv.) was added as the internal standard for ^{19}F NMR analysis (*d*$_6$-DMSO) (97% yield – average of three trials: 97%, 99%, and 95%).

Spectral data are consistent with those reported in the literature: P. Narendar et al. *Synth. Commun*. **34**, 1097–1103 (2004).



HRMS (GC-EI-TOF) m/z calcd. for C$_5$H$_4$ClN ([M*]$^+$) 113.00323, found 113.00279.

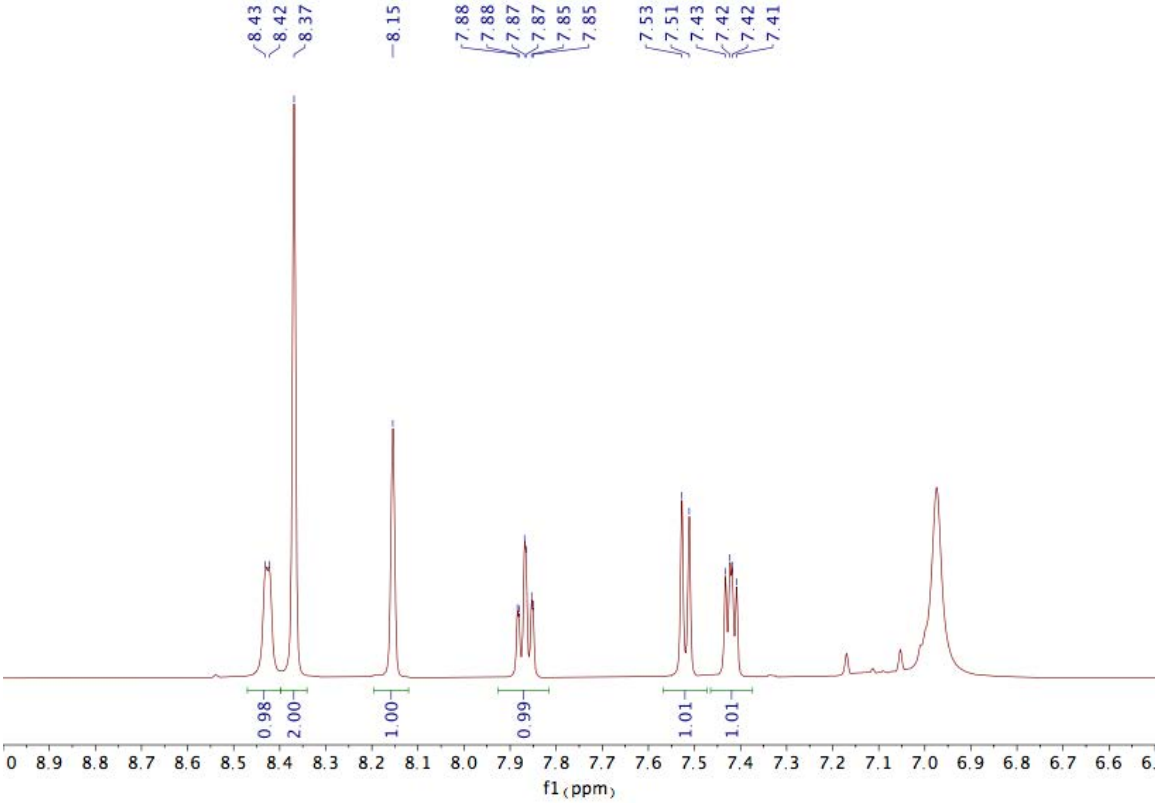


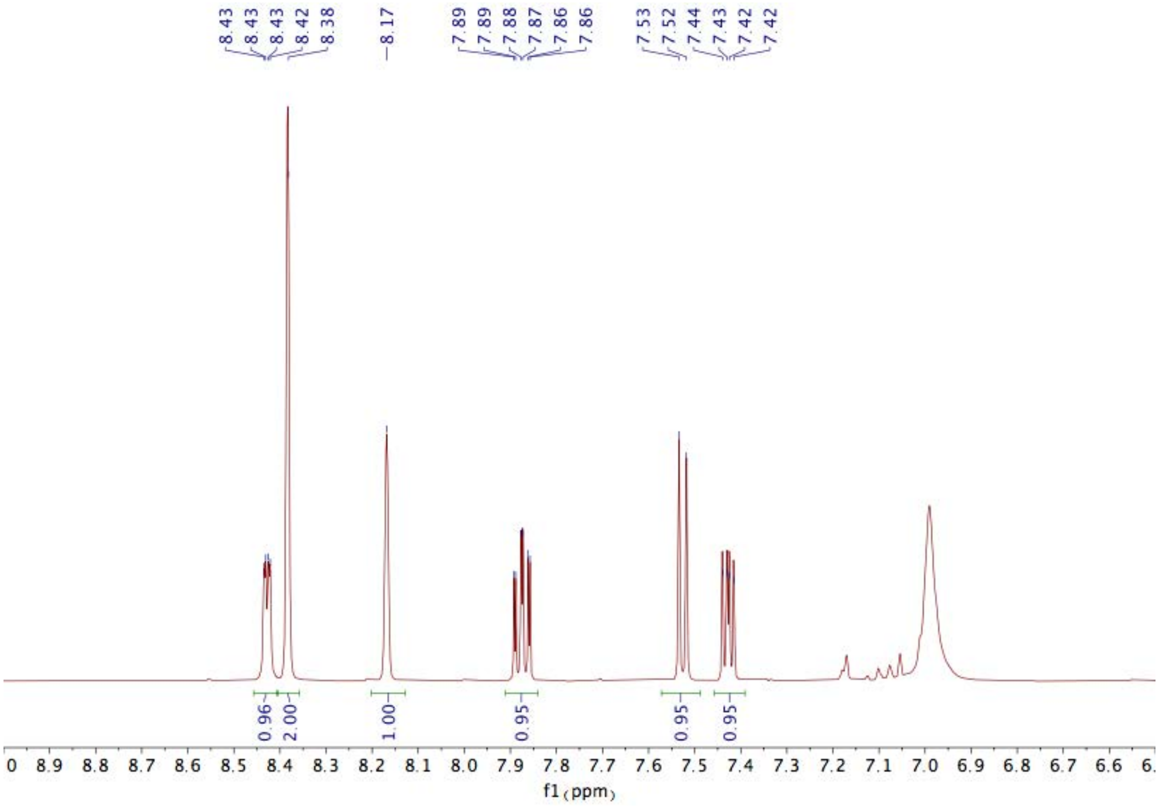
8.43 ppm, 7.87 ppm

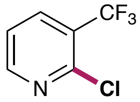
7.52 ppm, 7.42 ppm

8.37 ppm (2H)

8.16 ppm (1H)




8.43
8.43
8.43
8.42
8.38
8.17
7.89
7.89
7.88
7.87
7.86
7.86
7.53
7.52
7.44
7.43
7.42
7.42
0.96
2.00
1.00
0.95
0.95
0.95
0
8.9
8.8
8.7
8.6
8.5
8.4
8.3
8.2
8.1
8.0
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7.0
6.9
6.8
6.7
6.6
6.
f1 (ppm)



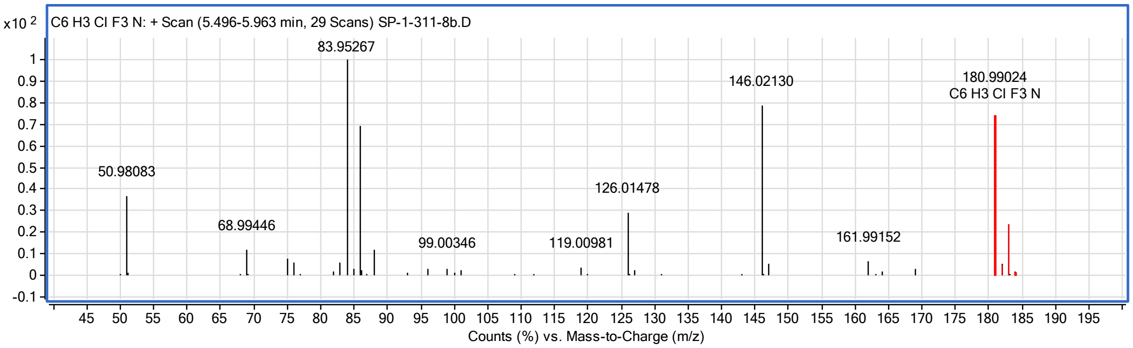
2-chloro-3-(trifluoromethyl)pyridine (30)

Prepared according to the general procedure outlined above using $[Cu(MeCN)_4]BF_4$ (78.6 mg, 0.25 mmol, 0.5 equiv.), $ZnCl_2$ (68 mg, 0.5 mmol, 1 equiv.), NFTPT (170 mg, 0.75 mmol, 1.5 equiv.), and 3-(trifluoromethyl)picolinic acid (96.5 mg, 0.5 mmol, 1 equiv) in MeCN (5 mL, 0.1 M). Irradiation time: 12 h.

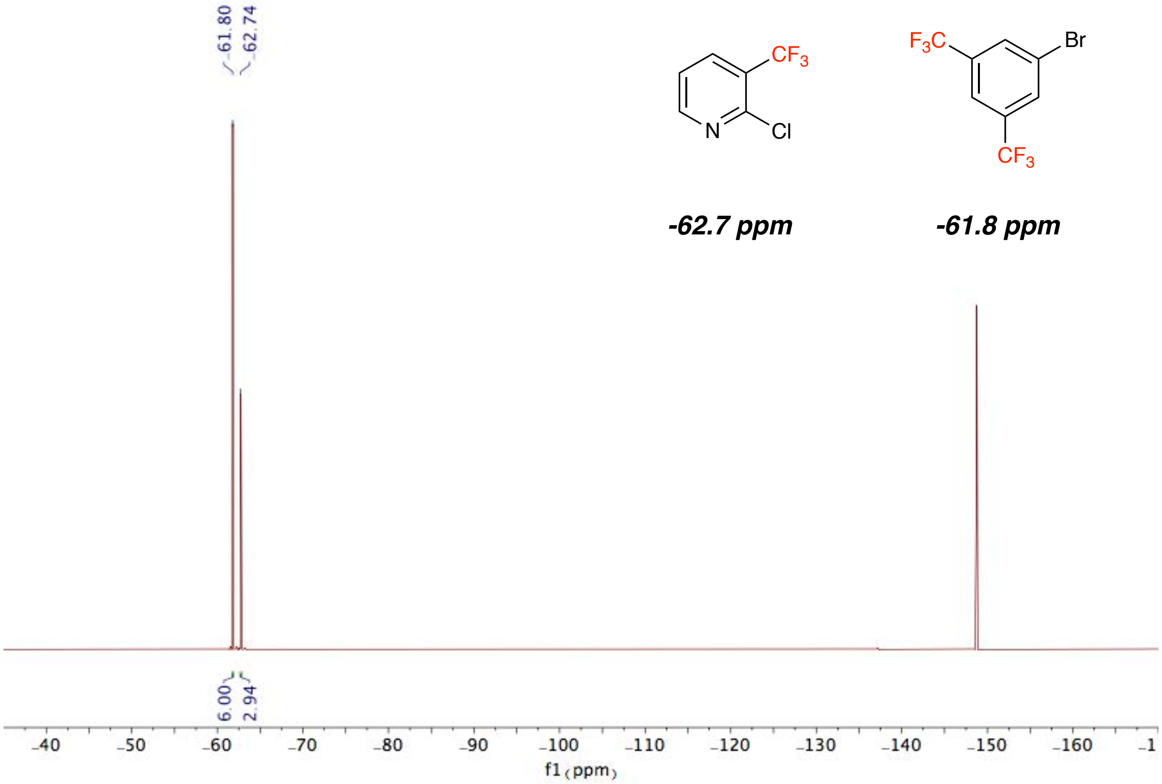
Yield was determined by ^{19}F NMR in triplicate due to instability of the desired product.

1-bromo-3-5-bis(trifluoromethyl)benzene (87 µL, 0.5 mmol 1.0 equiv.) was added as the internal standard for ^{19}F NMR analysis (d_6-DMSO) (98% yield – average of three trials: 98%, 98%, and 98%).

Spectral data are consistent with those reported in the literature: J. H. Clark. *J. Fluor. Chem.,* **50**, 411 – 426 (1990).

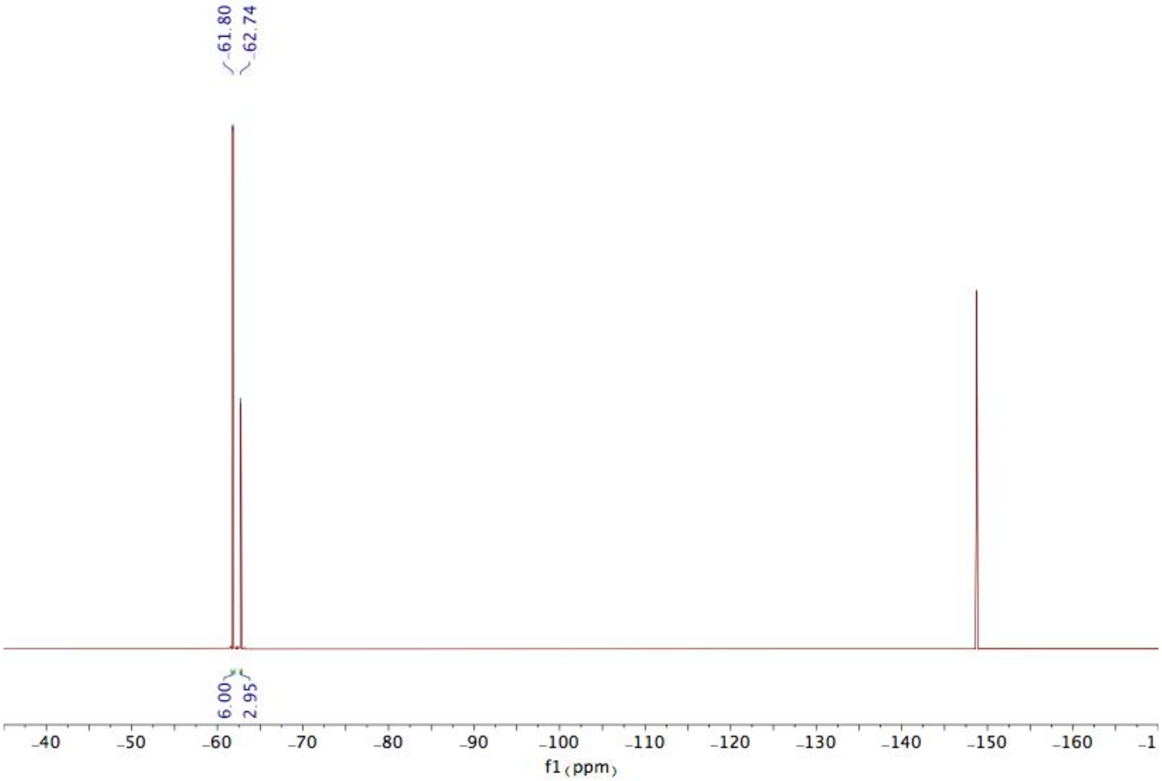


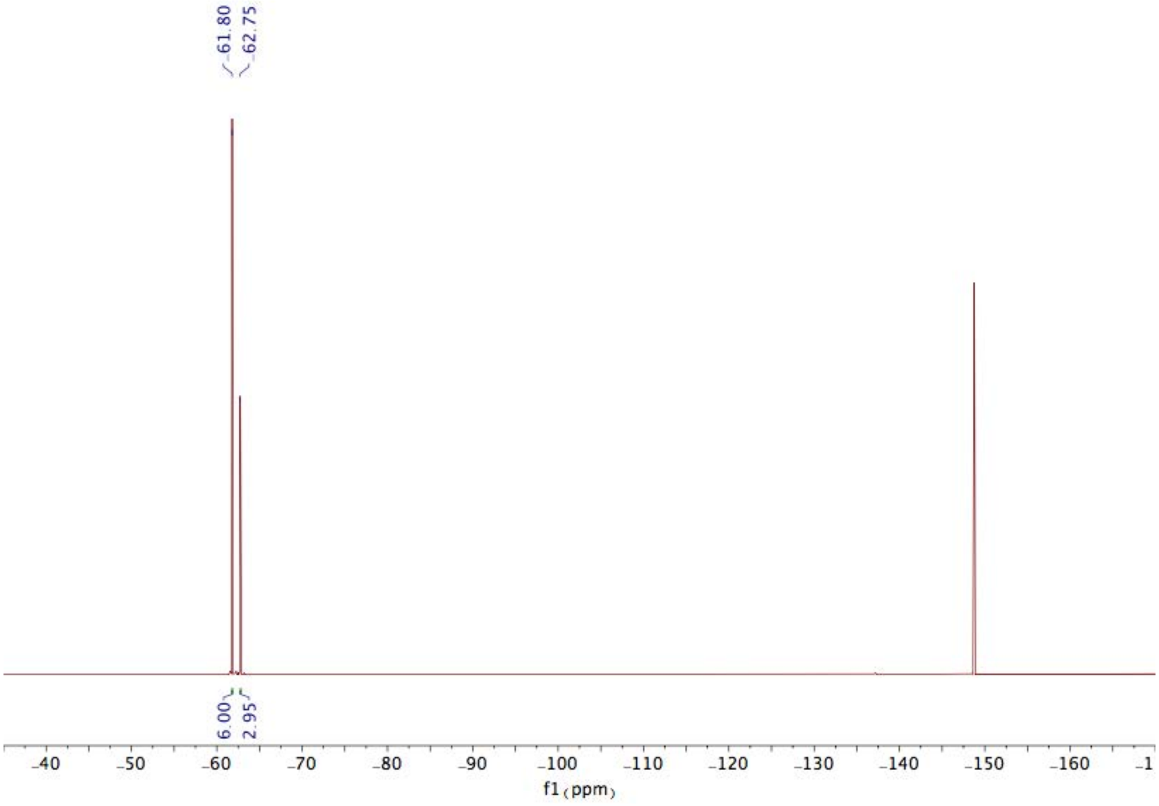
HRMS (GC-EI-TOF) m/z calcd. for $C_6H_3ClF_3N$ ($[M^*]^+$) 180.99061, found 180.99024.

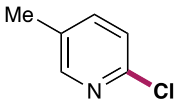


-62.7 ppm

-61.8 ppm




-61.80
-62.75
6.00
2.95
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-1
f1 (ppm)



2-chloro-5-methylpyridine (31)

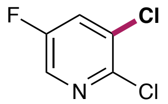
Prepared according to the general procedure outlined above using [Cu(MeCN)$_4$]BF$_4$ (157.3 mg, 0.5 mmol, 1.0 equiv.), ZnCl$_2$ (68 mg, 0.5 mmol, 1 equiv.), NFTPT (170 mg, 0.75 mmol, 1.5 equiv.), and 5-methylpicolinic acid (68.6 mg, 0.5 mmol, 1 equiv) in MeCN (5 mL, 0.1 M). Irradiation time: 12 h.

The final reaction mixture was stirred with tetrasodium EDTA (200 mg) and water (3 mL) for 30 minutes. The mixture was then filtered through celite and transferred to a separatory funnel before water (15 mL) was added. The aqueous layer was then extracted with 9:1 pentane:ether (3x20 mL). The combined pentane/ether layers were then dried over magnesium sulfate, filtered, concentrated, and carefully purified by silica column chromatography (pipette column, 5% ether in pentane) to yield the pure product (29 mg, 0.23 mmol, 46%) as a clear oil.

^{1}H NMR (500 MHz, CDCl$_3$) δ 8.14 (d, *J* = 2.5 Hz, 1H), 7.39 (dd, *J* = 8.2, 2.5 Hz, 1H), 7.15 (d, *J* = 8.1 Hz, 1H), 2.25 (s, 3H).

^{13}C NMR (125 MHz, CDCl$_3$) δ 149.90, 148.66, 139.45, 132.04, 123.73, 17.74.

Spectral data are consistent with those reported in the literature: C. L. Bell. *J. Heterocycl. Chem*, **2**, 420 – 429 (1965).

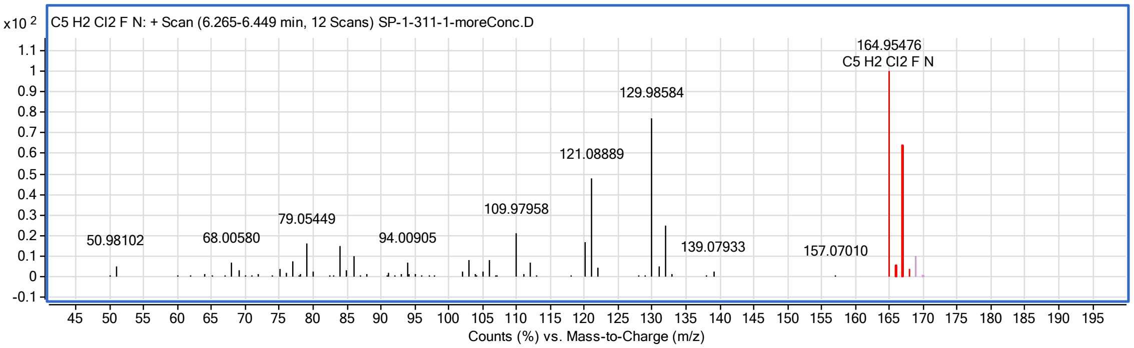


2,3-dichloro-5-fluoropyridine (32)

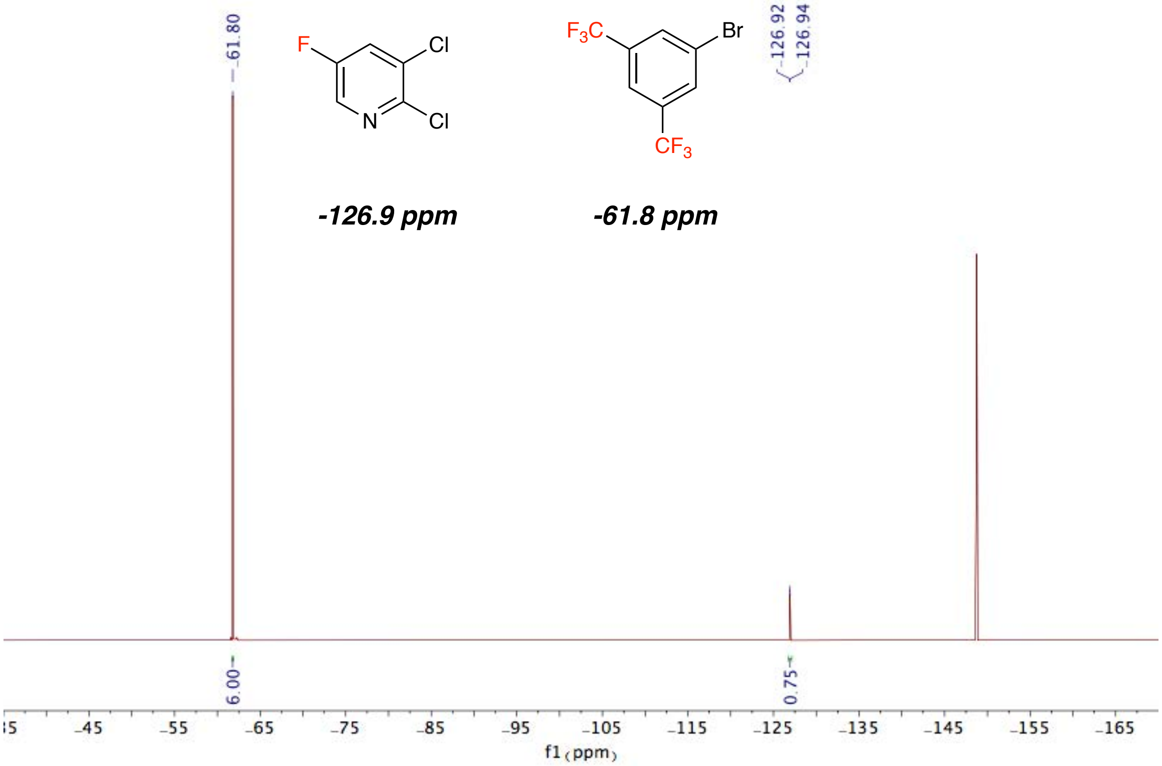
Prepared according to the general procedure outlined above using [Cu(MeCN)$_4$]BF$_4$ (78.6 mg, 0.25 mmol, 0.5 equiv.), ZnCl$_2$ (68 mg, 0.5 mmol, 1 equiv.), NFTPT (170 mg, 0.75 mmol, 1.5 equiv.), and 2-chloro-5-fluoronicotinic acid (87.8 mg, 0.5 mmol, 1 equiv) in MeCN (5 mL, 0.1 M). Irradiation time: 12 h.

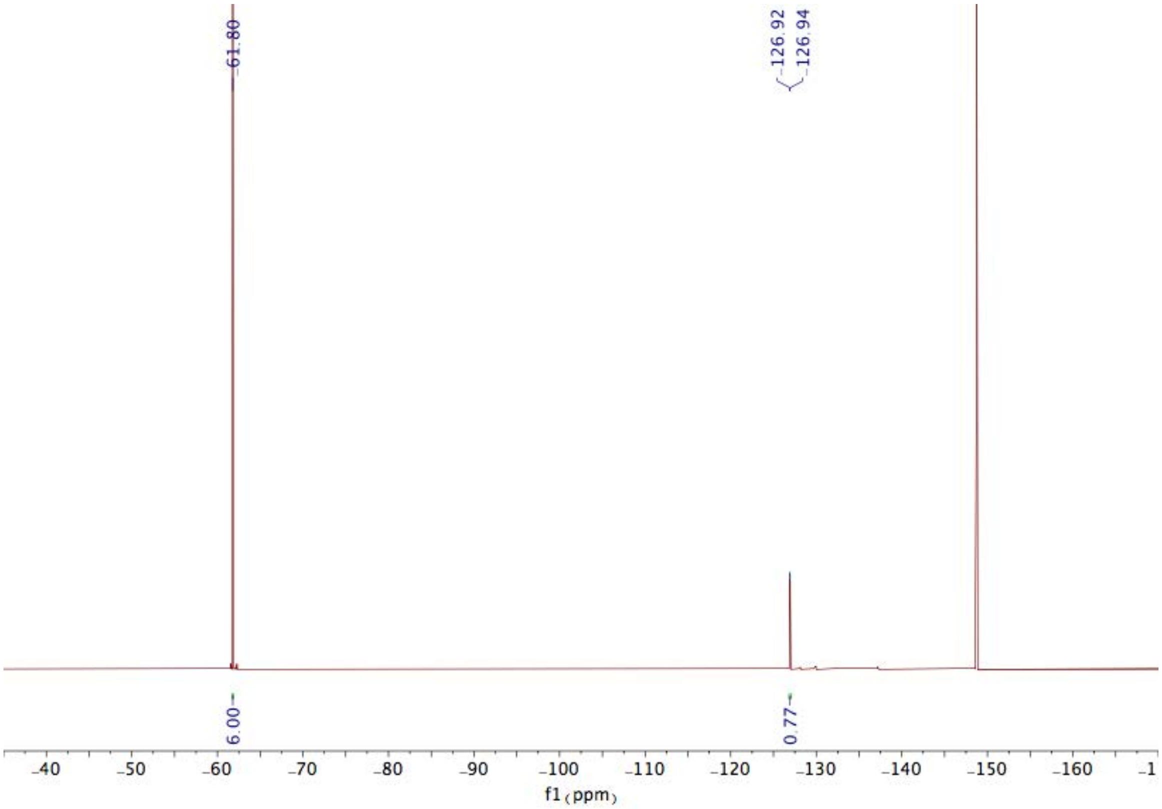
Yield was determined by ^{19}F NMR in triplicate due to instability of the desired product.

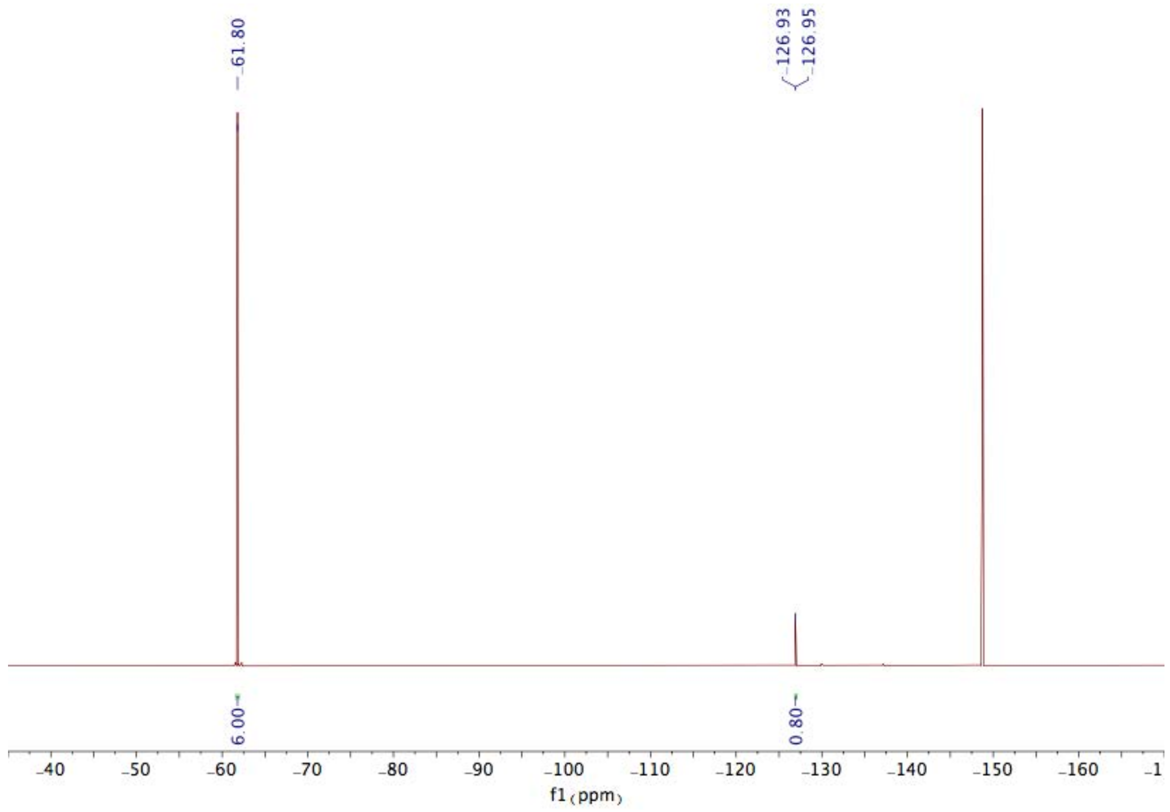
1-bromo-3-5-bis(trifluoromethyl)benzene (87 µL, 0.5 mmol 1.0 equiv.) was added as the internal standard for ^{19}F NMR analysis (d_6-DMSO) (77% yield – average of three trials: 75%, 77%, and 80%).



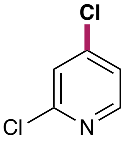
HRMS (GC-EI-TOF) m/z calcd. for $C_5H_2Cl_2FN$ ([M*]$^+$) 164.95483, found 164.95476.


-61.80
F
Cl
N
Cl
F3C
Br
CF3
-126.92
-126.94
-126.9 ppm
-61.8 ppm
6.00
0.75
-45
-55
-65
-75
-85
-95
-105
-115
-125
-135
-145
-155
-165
f1 (ppm)


-61.80
-126.92
-126.94
6.00
0.77
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
f1 (ppm)



-61.80
-126.93
-126.95
6.00
0.80
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-1
f1 (ppm)



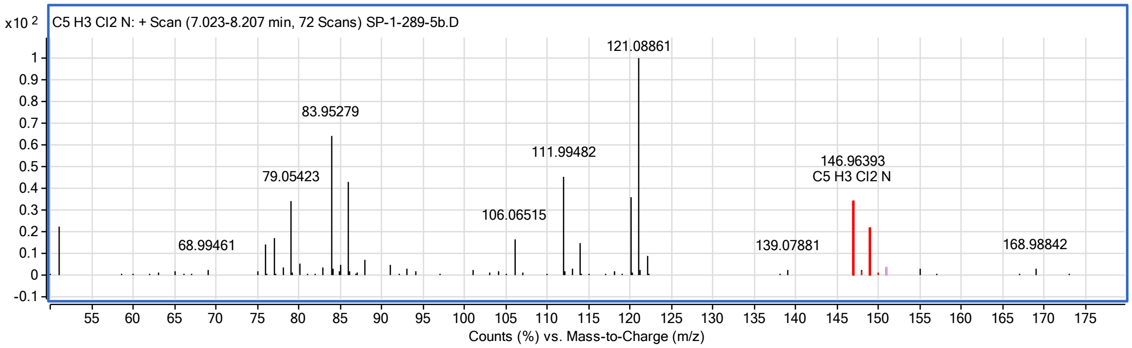
2,4-dichloropyridine (33)

Prepared according to the general procedure outlined above using [Cu(MeCN)$_4$]BF$_4$ (157.3 mg, 0.5 mmol, 1.0 equiv.), ZnCl$_2$ (68 mg, 0.5 mmol, 1 equiv.), NFTPT (170 mg, 0.75 mmol, 1.5 equiv.), and 2-chloroisonicotinic acid (61.6 mg, 0.5 mmol, 1 equiv) in MeCN (5 mL, 0.1 M). Irradiation time: 12 h.

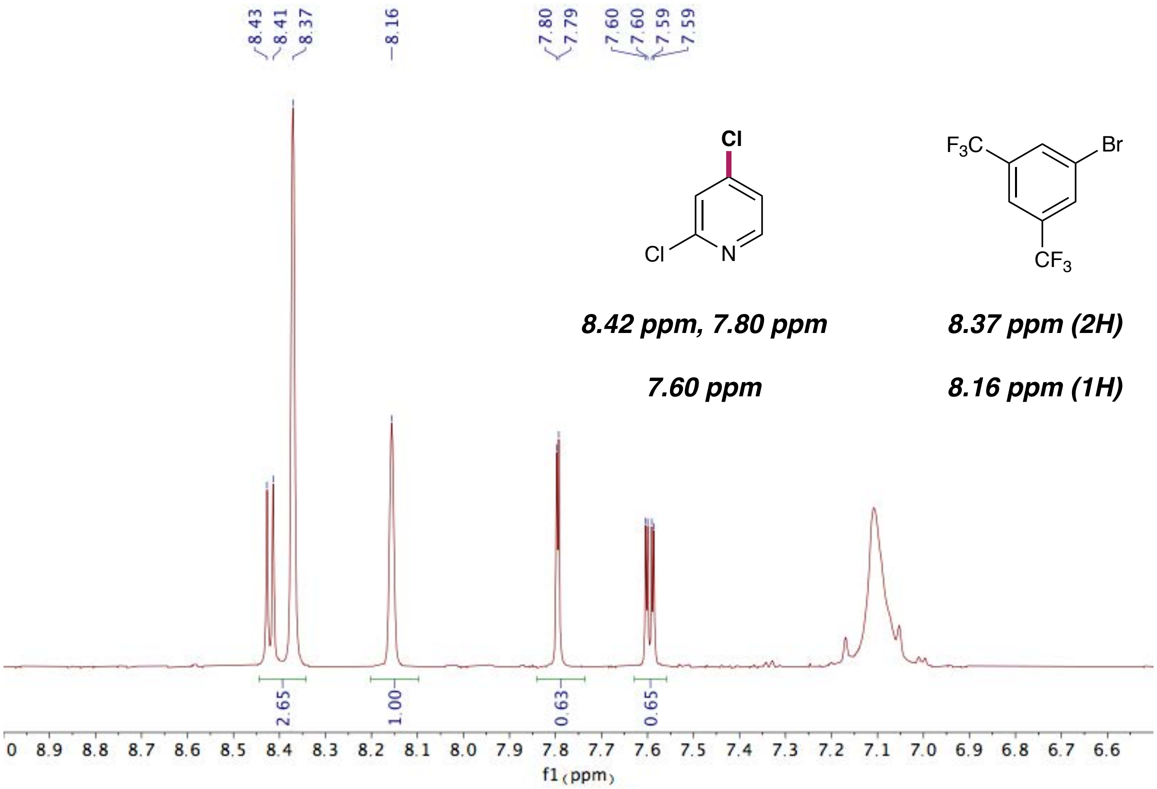
Yield was determined by ^{1}H NMR in triplicate.

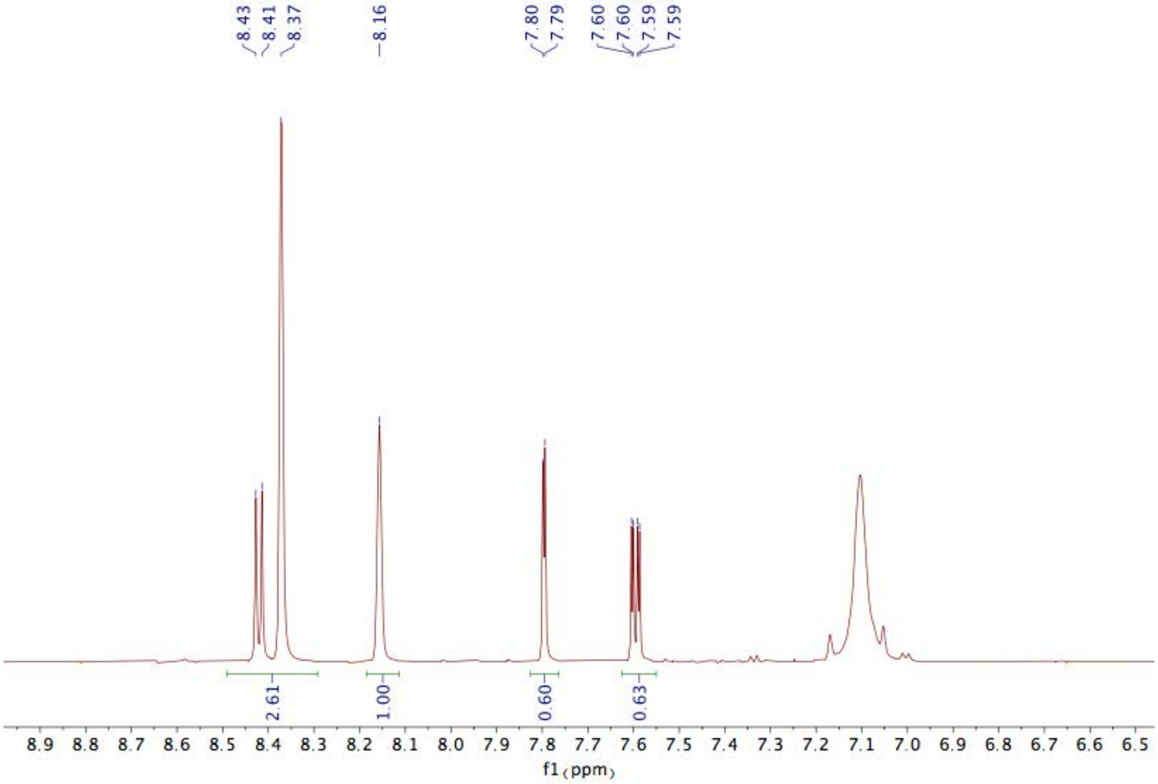
1-bromo-3-5-bis(trifluoromethyl)benzene (87 µL, 0.5 mmol 1.0 equiv.) was added as the internal standard for ^{1}H NMR analysis (*d*$_6$-DMSO) (61% yield – average of three trials: 64%, 61%, and 59%).

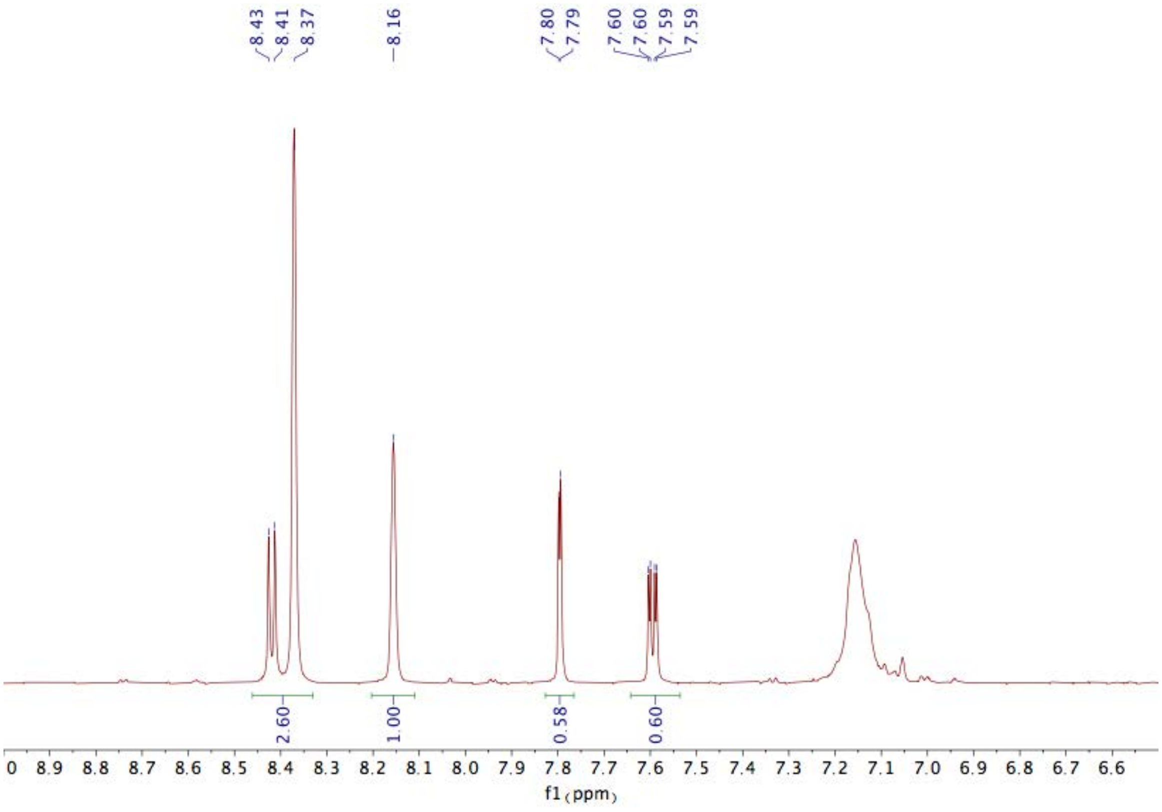
Spectral data are consistent with those reported in the literature: M. Schlosser et al. *Org. Lett*. **7**, 127–129 (2005).

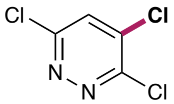


HRMS (GC-EI-TOF) m/z calcd. for $C_5H_3Cl_2N$ ([M*]$^+$) 146.96425, found 146.96393.


8.43
8.41
8.37
8.16
7.80
7.79
7.60
7.60
7.59
7.59
Cl
Cl
N
F3C
Br
CF3
8.42 ppm, 7.80 ppm
7.60 ppm
8.37 ppm (2H)
8.16 ppm (1H)
2.65
1.00
0.63
0.65
0 8.9 8.8 8.7 8.6 8.5 8.4 8.3 8.2 8.1 8.0 7.9 7.8 7.7 7.6 7.5 7.4 7.3 7.2 7.1 7.0 6.9 6.8 6.7 6.6
f1 (ppm)


8.43
8.41
8.37
8.16
7.80
7.79
7.60
7.60
7.59
7.59
2.61
1.00
0.60
0.63
8.9 8.8 8.7 8.6 8.5 8.4 8.3 8.2 8.1 8.0 7.9 7.8 7.7 7.6 7.5 7.4 7.3 7.2 7.1 7.0 6.9 6.8 6.7 6.6 6.5
f1 (ppm)


8.43
8.41
8.37
8.16
7.80
7.79
7.60
7.60
7.59
7.59
2.60
1.00
0.58
0.60
0
8.9
8.8
8.7
8.6
8.5
8.4
8.3
8.2
8.1
8.0
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7.0
6.9
6.8
6.7
6.6
f1 (ppm)



3,4,6-trichloropyridazine (34)

Prepared according to the general procedure outlined above using [Cu(MeCN)$_4$]BF$_4$ (157.3 mg, 0.5 mmol, 1.0 equiv.), ZnCl$_2$ (68 mg, 0.5 mmol, 1 equiv.), NFTPT (170 mg, 0.75 mmol, 1.5 equiv.), and 3,6-dichloropyridazine-4-carboxylic acid (96.5 mg, 0.5 mmol, 1 equiv) in MeCN (5 mL, 0.1 M). Irradiation time: 12 h.

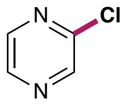
The final reaction mixture was stirred with tetrasodium EDTA (200 mg) and water (3 mL) for 30 minutes. The mixture was then transferred to a separatory funnel before water (15 mL) was added. The aqueous layer was then extracted with 3:1 pentane:ether (3x20 mL). The combined pentane/ether layers were then dried over magnesium sulfate, filtered, concentrated, and purified by silica column chromatography (0-10% acetone in hexane) to yield the pure product (54 mg, 0.29 mmol, 59%) as a white solid.

^{1}H NMR (500 MHz, CDCl$_3$) δ 7.70 (s, 1H).

^{13}C NMR (125 MHz, CDCl$_3$) δ 155.25, 154.89, 138.98, 129.49.

IR (film) ν_{max} 1533, 1497, 1486, 1342, 1316, 1291, 1129, 1083, 910, 855, 580, 464 cm^{-1}.

HRMS (GC-EI-TOF) m/z calcd. for $C_4HN_2Cl_3$ ([M*]$^+$) 182.9278, found 182.9278.



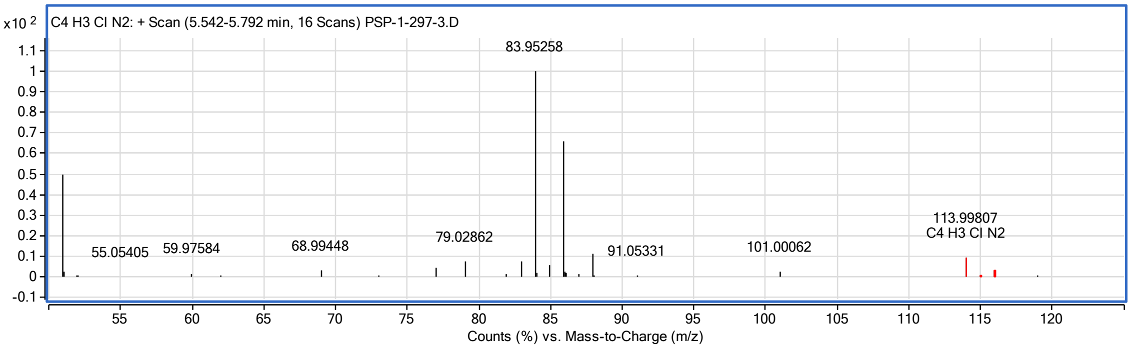
2-chloropyrazine (35)

Prepared according to the general procedure outlined above using [Cu(MeCN)$_4$]BF$_4$ (157.3 mg, 0.5 mmol, 1.0 equiv.), ZnCl$_2$ (68 mg, 0.5 mmol, 1 equiv.), NFTPT (170 mg, 0.75 mmol, 1.5 equiv.), and pyrazine-2-carboxylic acid (62.1 mg, 0.5 mmol, 1 equiv) in MeCN (5 mL, 0.1 M). Irradiation time: 12 h.

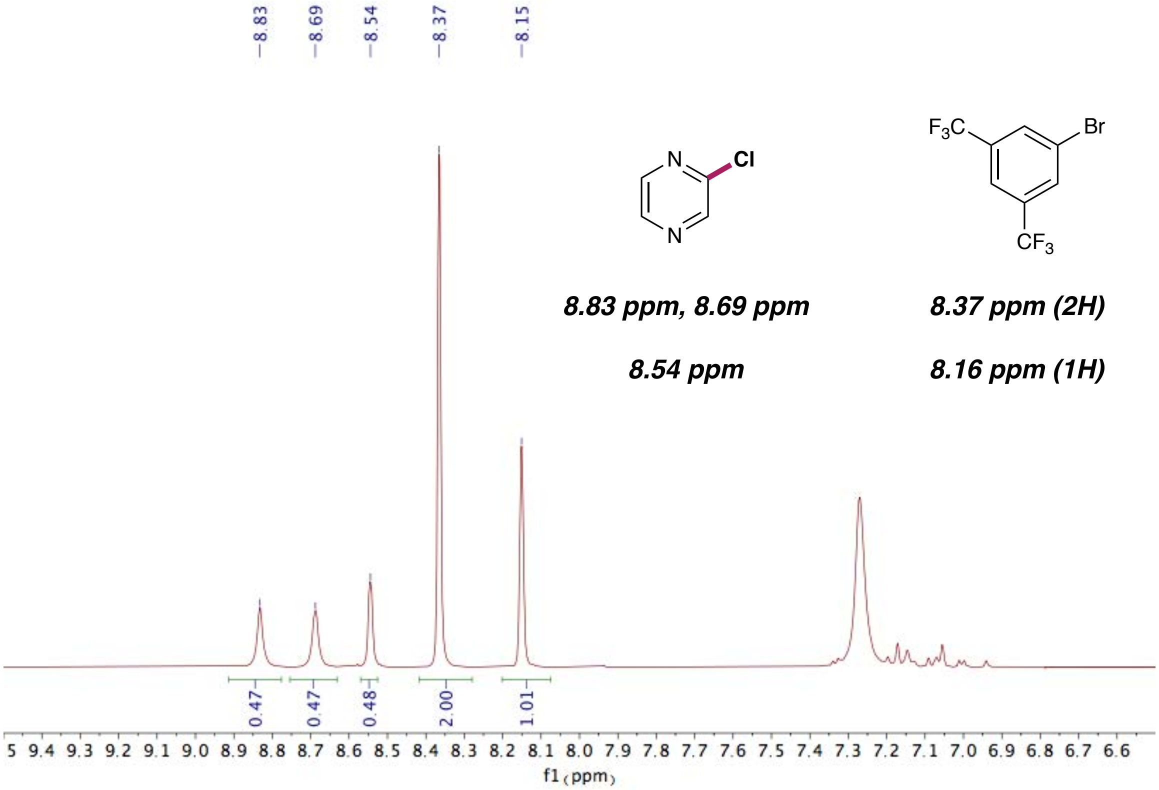
Yield was determined by ^{1}H NMR in triplicate due to the high volatility of the desired product.

1-bromo-3-5-bis(trifluoromethyl)benzene (87 µL, 0.5 mmol 1.0 equiv.) was added as the internal standard for ^{19}F NMR analysis (*d*$_6$-DMSO) (48% yield – average of three trials: 47%, 48%, and 48%).

Spectral data are consistent with those reported in the literature: R. H. Cox, A. A. Bothner-By. *J. Phys. Chem*. **72**, 1646–1649 (1968).



HRMS (GC-EI-TOF) m/z calcd. for C$_4$H$_3$N$_2$Cl ([M*]$^+$) 113.99848, found 113.99807.

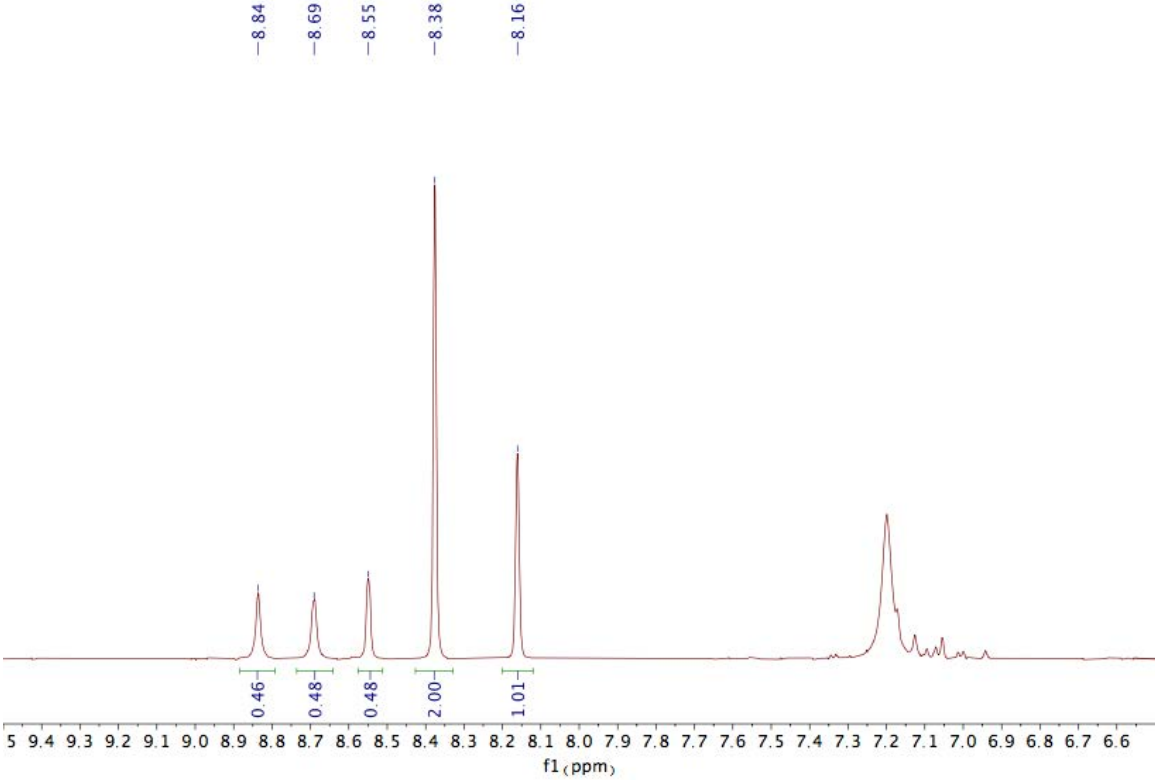


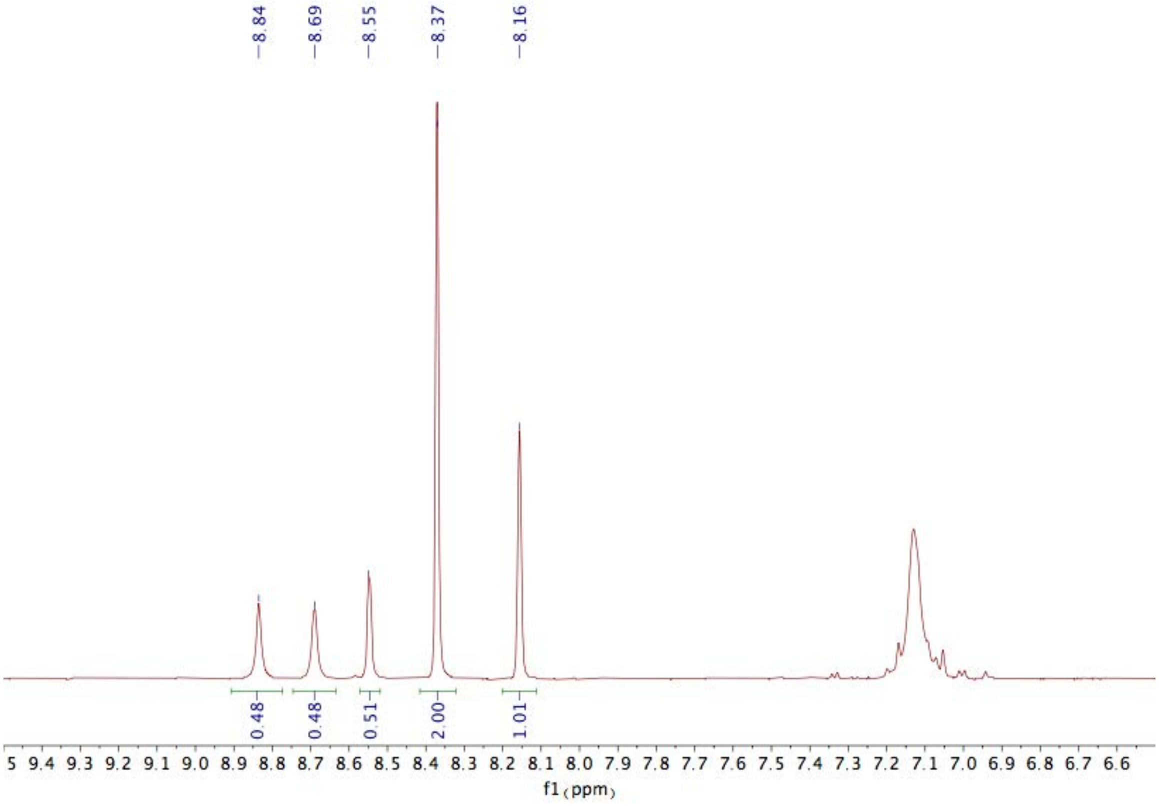
8.83 ppm, 8.69 ppm

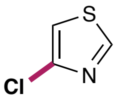
8.54 ppm

8.37 ppm (2H)

8.16 ppm (1H)




8.84
8.69
8.55
8.37
8.16
0.48
0.48
0.51
2.00
1.01
5 9.4 9.3 9.2 9.1 9.0 8.9 8.8 8.7 8.6 8.5 8.4 8.3 8.2 8.1 8.0 7.9 7.8 7.7 7.6 7.5 7.4 7.3 7.2 7.1 7.0 6.9 6.8 6.7 6.6
f1 (ppm)

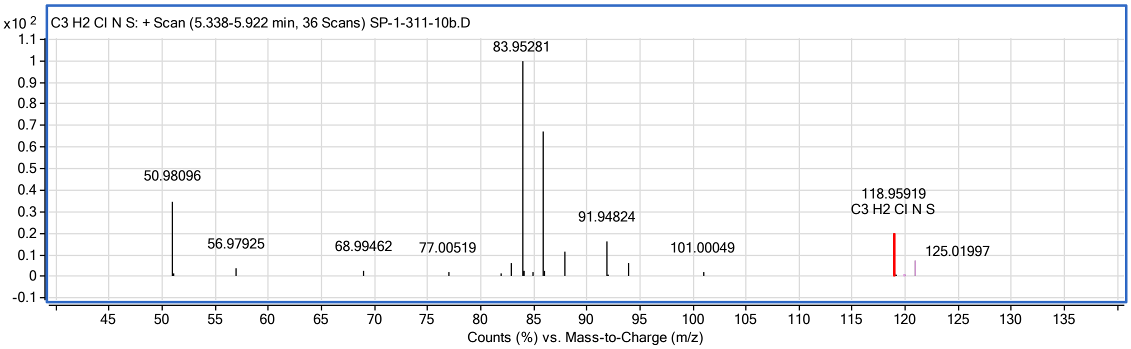


4-chlorothiazole (36)

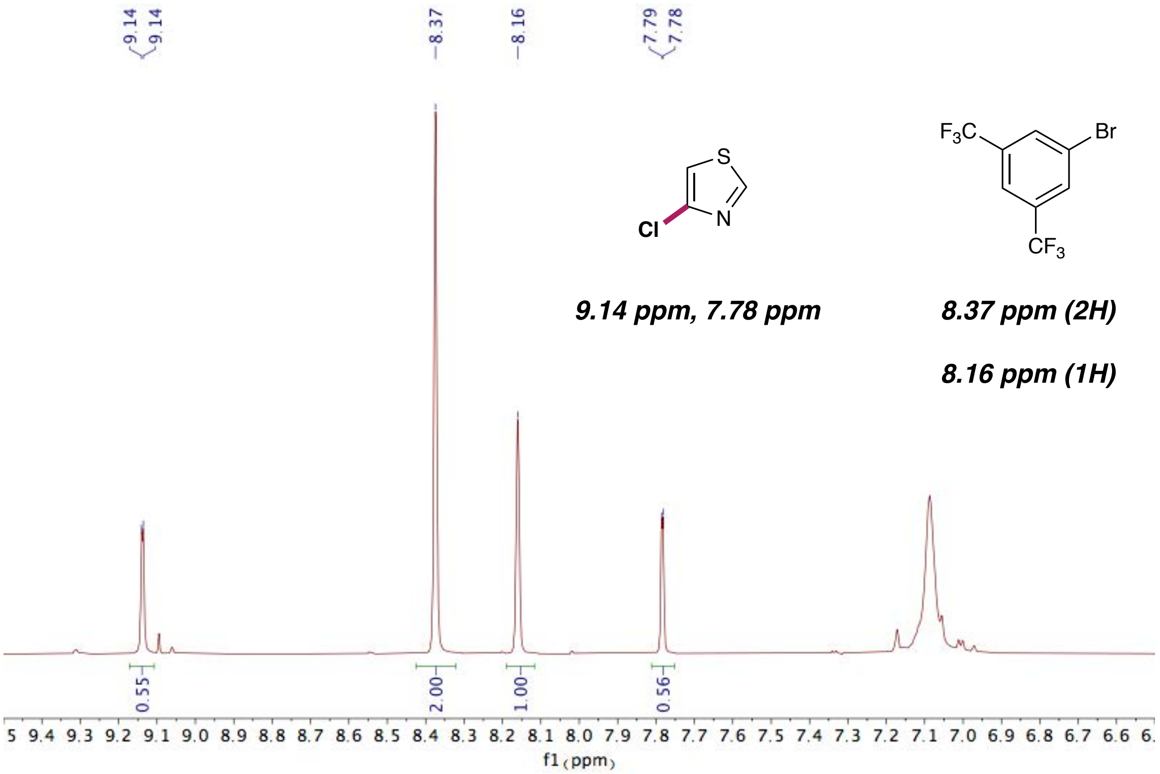
Prepared according to the general procedure outlined above using [Cu(MeCN)$_4$]BF$_4$ (157.3 mg, 0.5 mmol, 1.0 equiv.), ZnCl$_2$ (68 mg, 0.5 mmol, 1 equiv.), NFTPT (170 mg, 0.75 mmol, 1.5 equiv.), and thiazole-4-carboxylic acid (64.6 mg, 0.5 mmol, 1 equiv) in MeCN (5 mL, 0.1 M). Irradiation time: 12 h.

Yield was determined by ^{1}H NMR in triplicate due to the high volatility of the desired product.

1-bromo-3-5-bis(trifluoromethyl)benzene (87 µL, 0.5 mmol 1.0 equiv.) was added as the internal standard for ^{1}H NMR analysis (*d*$_6$-DMSO) (54% yield – average of three trials: 56%, 54%, and 53%).



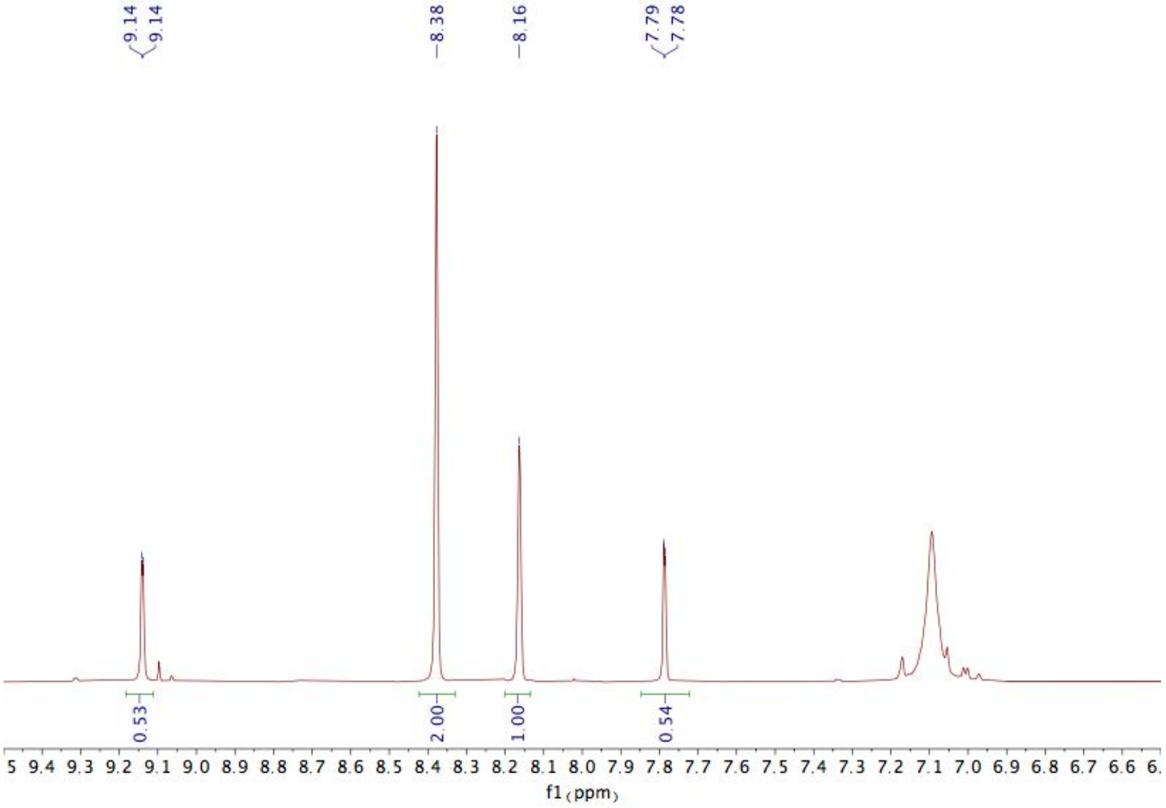
HRMS (GC-EI-TOF) m/z calcd. for C$_3$H$_2$NSCl ([M*]$^+$) 118.95965, found 118.95919.

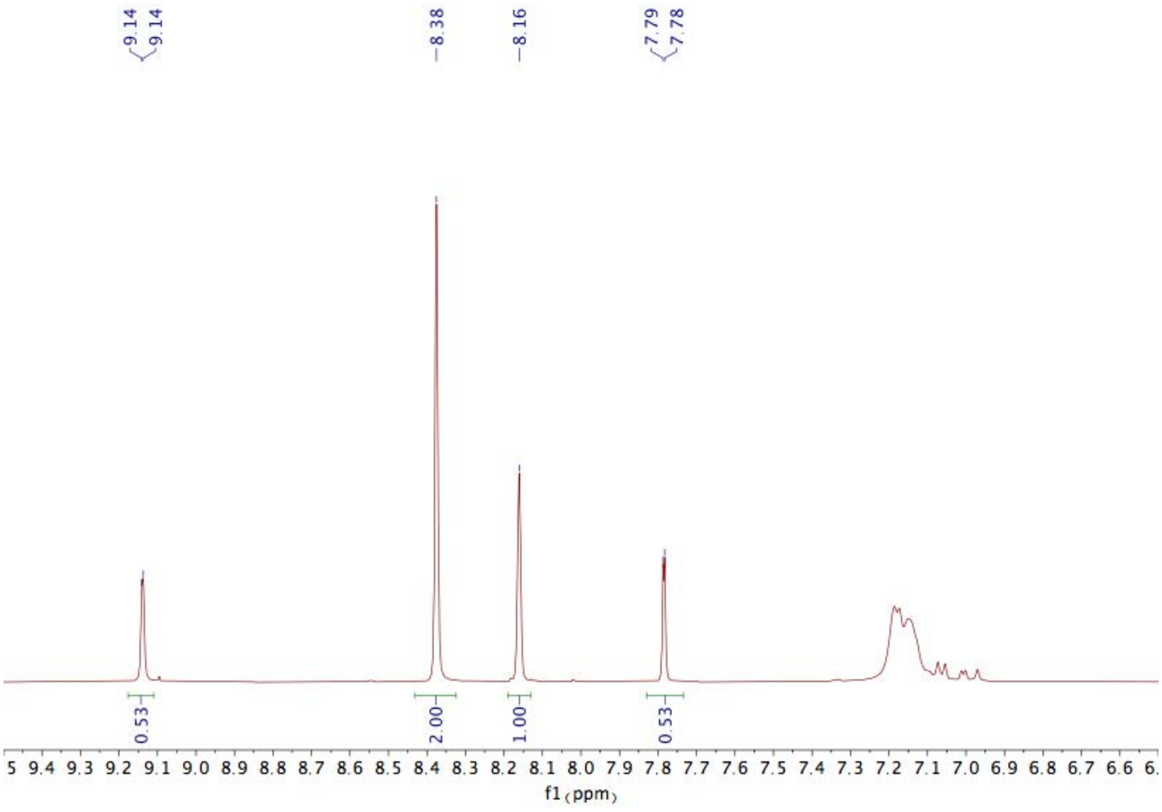


9.14 ppm, 7.78 ppm

8.37 ppm (2H)

8.16 ppm (1H)

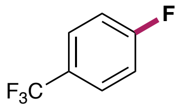



9.14
9.14
8.38
8.16
7.79
7.78
0.53
2.00
1.00
0.53
5 9.4 9.3 9.2 9.1 9.0 8.9 8.8 8.7 8.6 8.5 8.4 8.3 8.2 8.1 8.0 7.9 7.8 7.7 7.6 7.5 7.4 7.3 7.2 7.1 7.0 6.9 6.8 6.7 6.6 6.
f1 (ppm)

23) Decarboxylative fluorination of aryl & heteroaryl acids

General procedure **A**: An oven-dried 40 mL vial with a Teflon-coated stir bar was charged with a (hetero)aryl carboxylic acid substrate. NFTPT (2.0 eq, 228 mg), and [Cu(MeCN)$_4$]BF$_4$ (3.0 eq, 471 mg) were then added sequentially. Anhydrous MeCN (10 mL, 0.05 M) was then added, and the suspension was sparged for 10 minutes with nitrogen while stirring. The vial was then Parafilmed to protect from air during the course of the reaction. The reaction vial was then irradiated with 365 nm light in the Integrated Photoreactor (100% light intensity, 1000 rpm stir rate, 5200 rpm fan speed) for 12–24 hours. Once the reaction was complete, the vial was quenched by exposure to air. Work up and purification for each substrate are described below.

General procedure **B**: To an oven-dried 40 mL vial with a stir bar was added CsF (0.5 mmol, 76 mg) in a glovebox. The vial was capped and removed from the glovebox. (Hetero)aryl carboxylic acid, NFTPT (2.0 eq, 228 mg), and [Cu(MeCN)$_4$]BF$_4$ (3.0 eq, 471 mg) were then added sequentially. Anhydrous MeCN (10 mL, 0.05 M) was then added, and the suspension was sparged for 10 minutes with nitrogen while stirring. The vial was then Parafilmed to protect from air during the course of the reaction. The reaction vial was then irradiated with 365 nm light in the Integrated Photoreactor (100% light intensity, 1000 rpm stir rate, 5200 rpm fan speed) for 12–24 hours. Once the reaction was complete, the vial was quenched by exposure to air. Work up and purification for each substrate are described below.



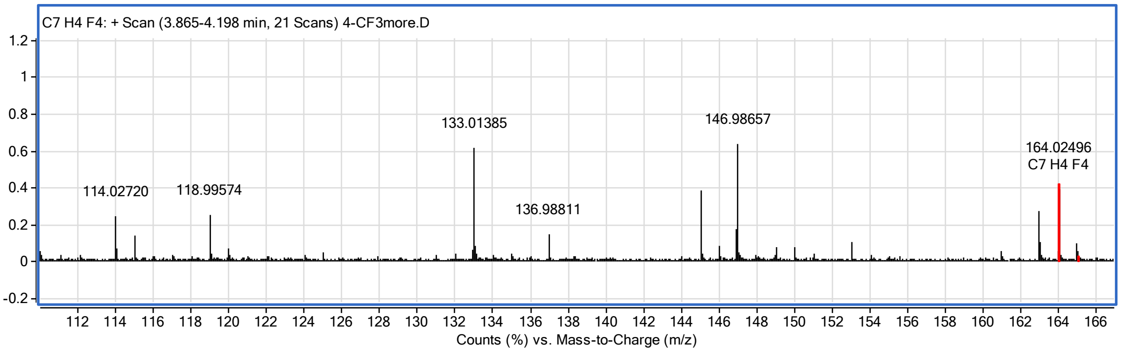
1-fluoro-4-(trifluoromethyl)benzene (37)

Prepared according to the general procedure **B** outlined above using CsF (76.1 mg, 0.5 mmol, 1 equiv.), NFTPT (228 mg, 1.0 mmol, 2 equiv.), [Cu(MeCN)$_4$]BF$_4$ (471 mg, 1.5 mmol, 3 equiv), and 4-(trifluoromethyl)benzoic acid (95.1 mg, 0.5 mmol, 1 equiv) in MeCN (10 mL, 50 mM). Irradiation time: 6 h.

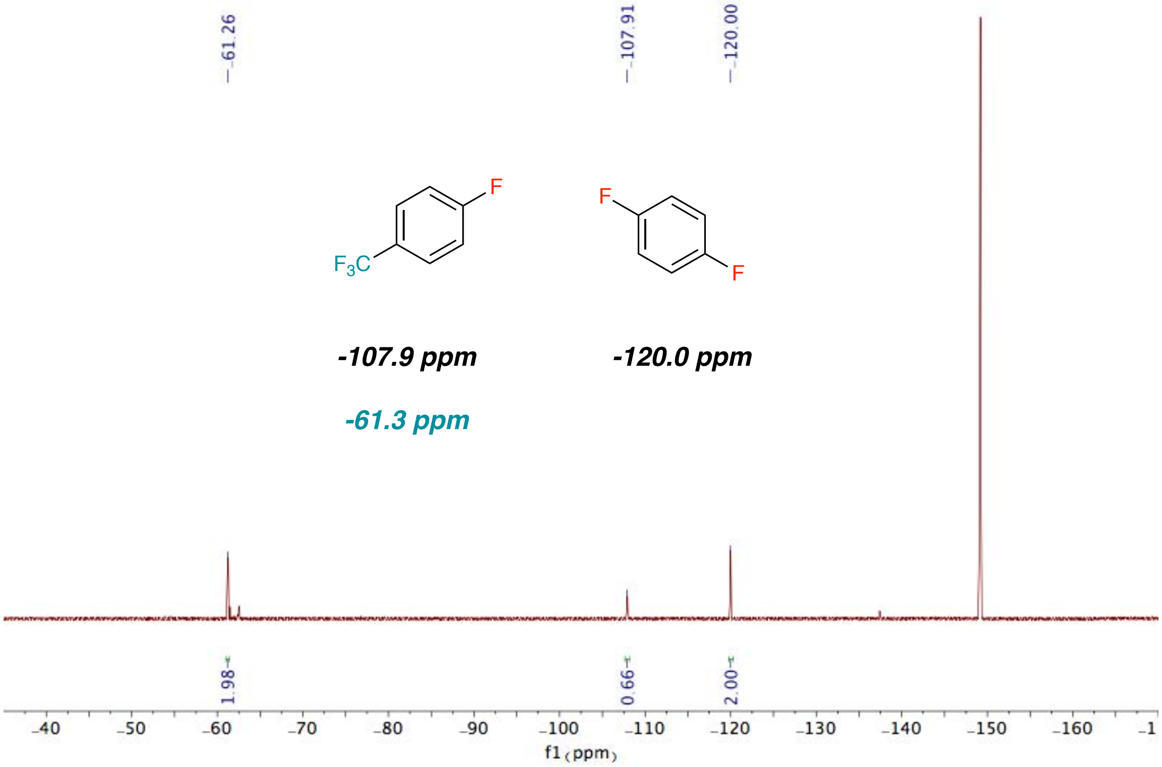
Yield was determined by ^{19}F NMR in triplicate due to the high volatility of the desired product.

1,4-difluorobenzene (52 µL, 0.5 mmol 1.0 equiv.) was added as the internal standard to the crude reaction mixture for ^{19}F NMR analysis (d_6-DMSO) (66% yield- average of three trials: 66% yield, 68% yield, 65% yield).

Spectral data are consistent with those reported in the literature: T. Knauber, F. Arikan, G. V. Rçschenthaler, and L. J. Gooßen. *Chem. Eur. J.* **17**, 2689 – 2697 (2011).



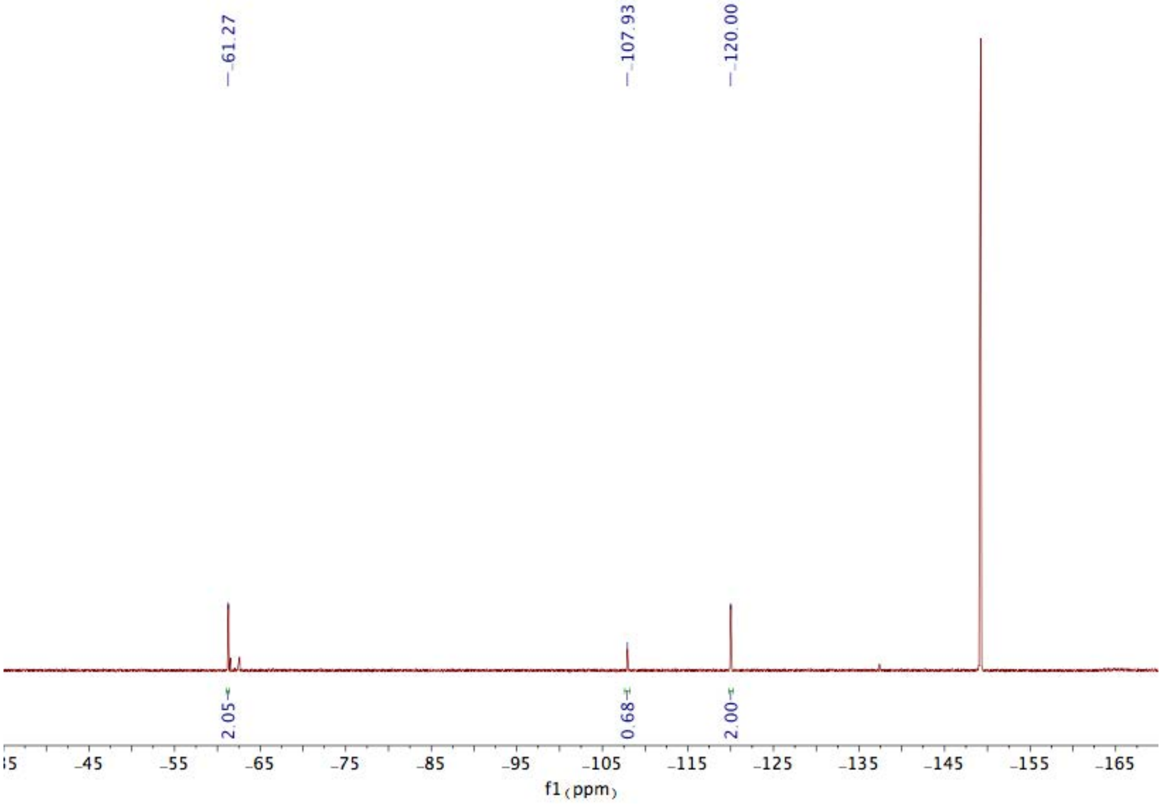
HRMS (GC-EI-TOF) m/z calcd. for $C_7H_4F_4$ ([M*]$^+$) 164.02491, found 164.02496.

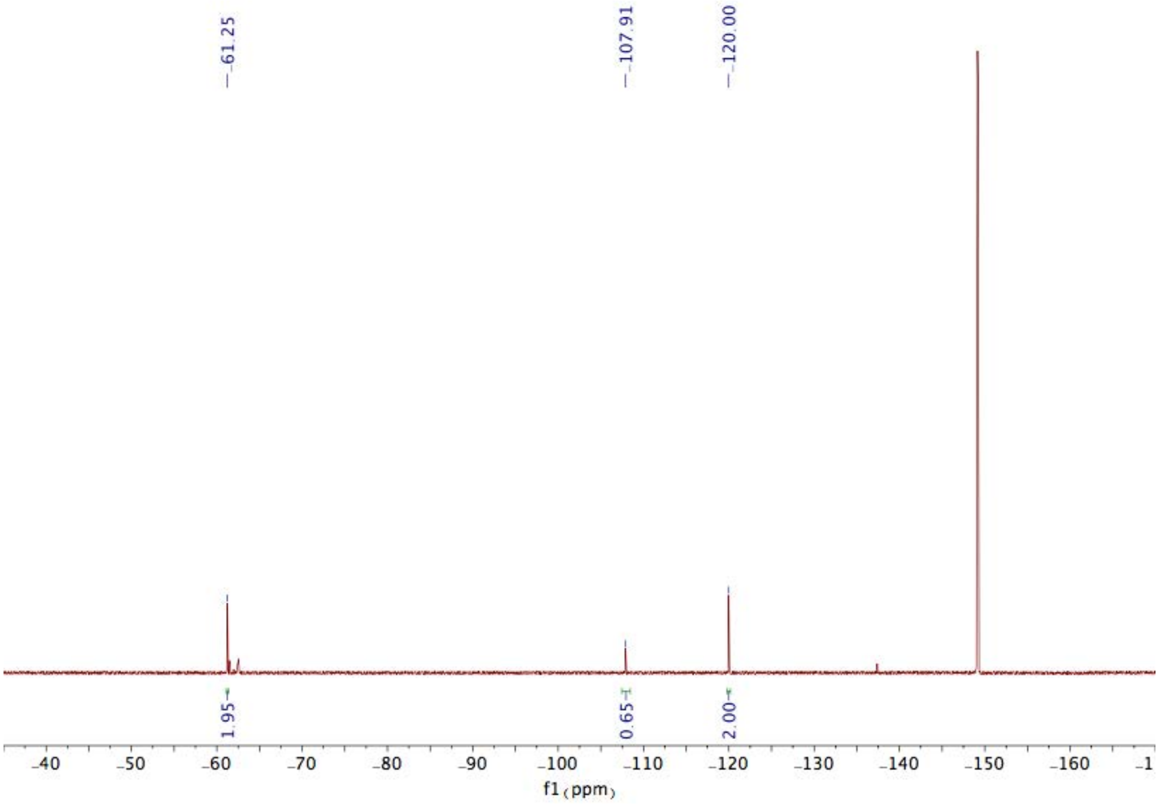


-107.9 ppm

-120.0 ppm

-61.3 ppm





-61.25
-107.91
-120.00
1.95
0.65
2.00
-40
-50
-60
-70
-80
-90
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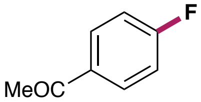
-160
-1
f1 (ppm)



4-fluoroacetophenone (38)

Prepared according to the general procedure **B** outlined above using CsF (76.1 mg, 0.5 mmol, 1 equiv), NFTPT (228 mg, 1.0 mmol, 2 equiv.), $[Cu(MeCN)_4]BF_4$ (471 mg, 1.5 mmol, 3 equiv), and 4-acetylbenzoic acid (94.1 mg, 0.5 mmol, 1 equiv) in MeCN (13 mL, 38 mM). Irradiation time: 24 h. 1-bromo-3-5-bis(trifluoromethyl)benzene (87 µL, 0.5 mmol 1.0 equiv.) was added as the internal standard for ^{19}F NMR analysis (*d*$_6$-DMSO) (64% yield).

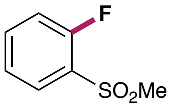
The final reaction mixture was stirred with tetrasodium EDTA (500 mg) and water (10 mL) for 30 minutes. The mixture was then extracted with 9:1 pentane:ether (5x20 mL). The combined organic layers were then dried over magnesium sulfate, filtered, and concentrated. The product was then purified via silica gel column chromatography to yield the pure product (38 mg, 0.28 mmol, 55%) as a clear oil.

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.02 – 7.94 (m, 2H), 7.17 – 7.09 (m, 2H), 2.59 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 196.52, 165.79 (d, *J* = 254.6 Hz), 133.60 (d, *J* = 3.1 Hz), 130.96 (d, *J* = 9.4 Hz), 115.68 (d, *J* = 21.9 Hz), 26.57.

^{19}F NMR (376 MHz, $CDCl_3$) δ -105.36 (tt, *J* = 8.2, 5.5 Hz, 1F).

Spectral data are consistent with those reported in the literature: Murphy, J. A.; Commeureuc, A. G. J.; Snaddon, T. N.; McGuire, T. M.; Khan, T. A.; Hisler, K.; Dewis, M. L.; Carling, R. *Org. Lett.*, *7*, 1427–1429 (2005).



1-fluoro-2-(methylsulfonyl)benzene (39)

Prepared according to the general procedure **B** outlined above using CsF (76.1 mg, 0.5 mmol, 1 equiv), NFTPT (228 mg, 1.0 mmol, 2 equiv.), $[Cu(MeCN)_4]BF_4$ (471 mg, 1.5 mmol, 3 equiv), and 2-(methylsulfonyl)benzoic acid (100.1 mg, 0.5 mmol, 1 equiv) in MeCN (10 mL, 50 mM). Irradiation time: 12 h.

The final reaction mixture was stirred with tetrasodium EDTA (500 mg) and water (10 mL) for 30 minutes. The mixture was then extracted with 3:1 pentane:ether (5x20 mL). The combined organic layers were then dried over magnesium sulfate, filtered, and concentrated. The product was then purified via silica gel column chromatography (25% EtOAc in hexanes) to yield the pure product (62 mg, 0.35 mmol, 71%) as a white solid.

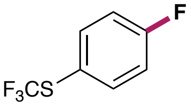
1-bromo-3-5-bis(trifluoromethyl)benzene (87 μL, 0.5 mmol 1.0 equiv.) was added as the internal standard for ^{19}F NMR analysis (d_6-DMSO) (72% yield).

^1H NMR (500 MHz, $(CD_3)_2CO$) δ 7.94 (td, *J* = 7.5, 1.8 Hz, 1H), 7.83 (dddd, *J* = 8.3, 7.2, 5.1, 1.8 Hz, 1H), 7.50 (td, *J* = 7.6, 1.1 Hz, 1H), 7.45 (ddd, *J* = 10.4, 8.3, 1.0 Hz, 1H), 3.29 (s, 3H).

^{13}C NMR (125 MHz, $CDCl_3$) δ 159.50 (d, *J* = 255.2 Hz), 136.19 (d, *J* = 8.5 Hz), 129.71 (s), 128.38 (d, *J* = 14.8 Hz), 124.83 (d, *J* = 3.8 Hz), 117.19 (d, *J* = 21.2 Hz), 43.89 (d, *J* = 3.1 Hz).

^{19}F NMR (376 MHz, $CDCl_3$) δ -109.58 – -109.68 (m, 1F).

Spectral data are consistent with those reported in the literature: M. Peyronneau, M.-T. Boisdon, N. Roques, S. Mazieres, and C. Le Roux. *Eur. J. Org. Chem*, **2004**, 4636-4640.



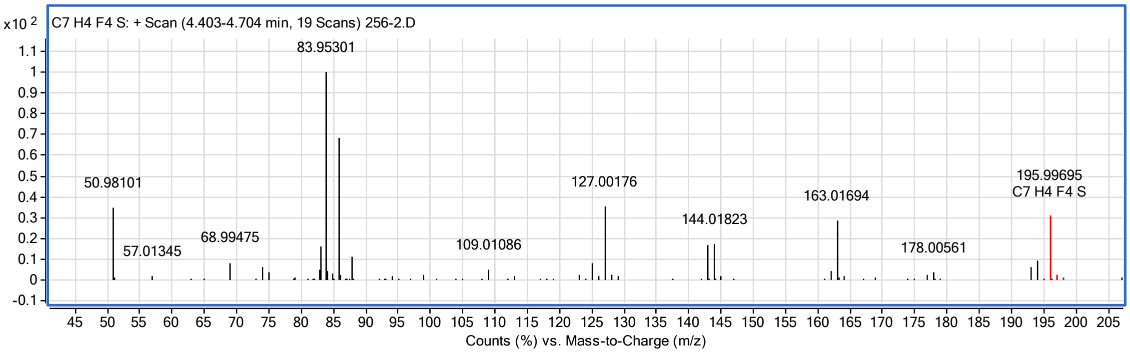
(4-fluorophenyl)(trifluoromethyl)sulfane (40)

Prepared according to the general procedure **B** outlined above using CsF (76.1 mg, 0.5 mmol, 1 equiv.), NFTPT (228 mg, 1.0 mmol, 2 equiv.), [Cu(MeCN)$_4$]BF$_4$ (471 mg, 1.5 mmol, 3 equiv), and 4-((trifluoromethyl)thio)benzoic acid (95.1 mg, 0.5 mmol, 1 equiv) in MeCN (10 mL, 50 mM). Irradiation time: 24 h.

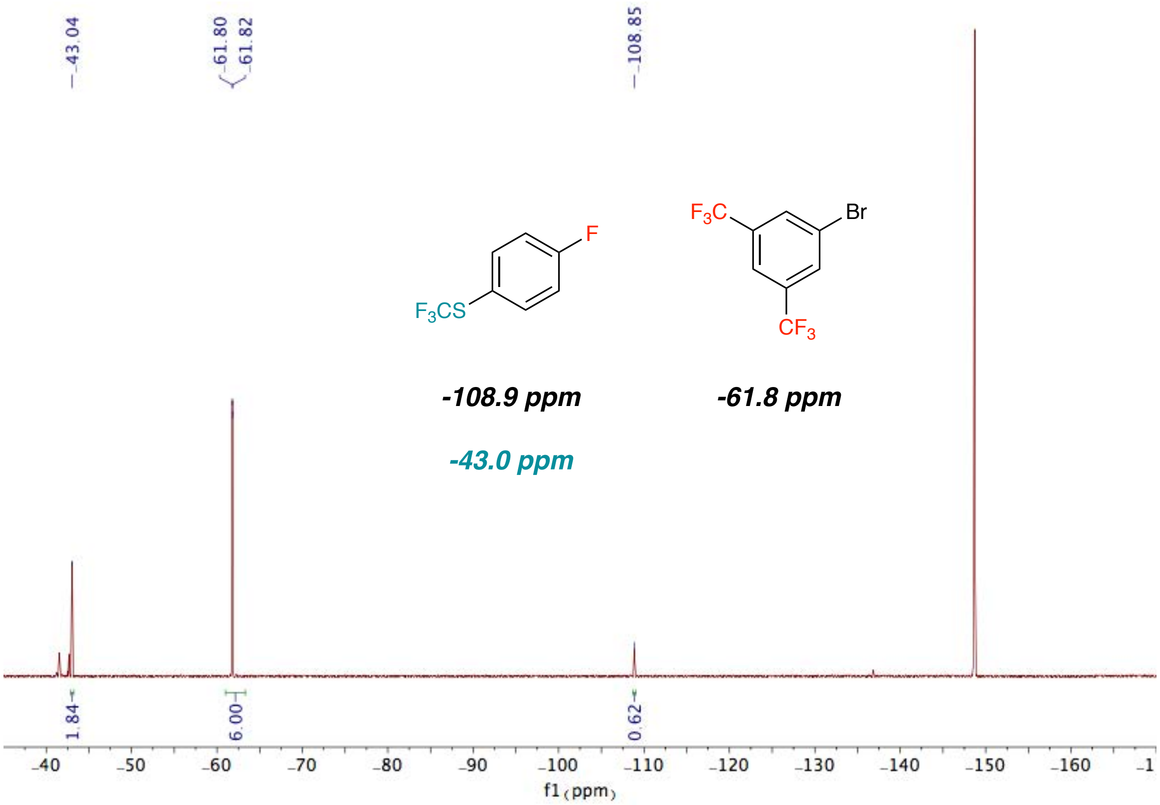
Yield was determined by ^{19}F NMR in triplicate due to the high volatility of the desired product.

1-bromo-3-5-bis(trifluoromethyl)benzene (87 µL, 0.5 mmol 1.0 equiv.) was added as the internal standard for ^{19}F NMR analysis (*d*$_6$-DMSO) (63% yield – average of three trials: 62%, 65%, and 62%).

Spectral data are consistent with those reported in the literature: Tordeux, M.; Magnier, E.; Guidotti, J.; Diter, P.; Wakselman, C. *Magnetic Resonance in Chemistry* **2004**, *42* (8), 700–703.



HRMS (GC-EI-TOF) m/z calcd. for $C_7H_4F_4S$ ([M*]$^+$) 195.99698, found 195.99695.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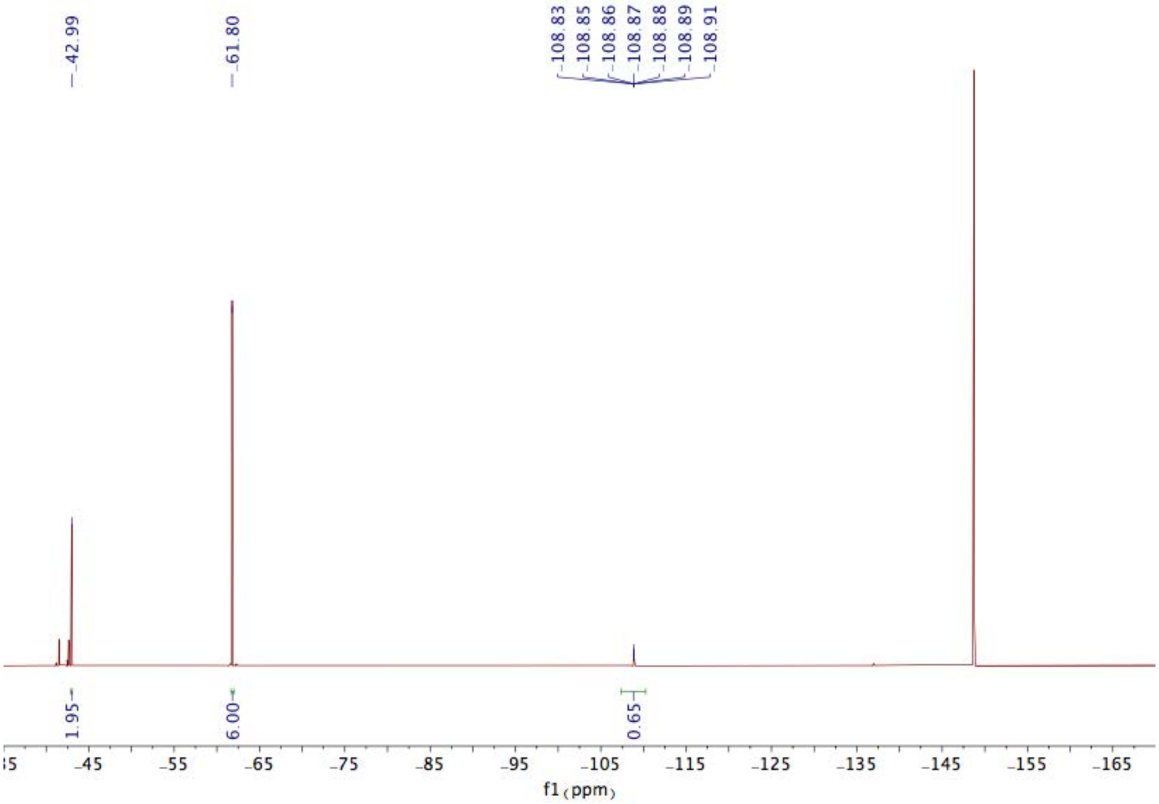
-61.80
-61.82
-108.85
F
F3CS
F3C
Br
CF3
-108.9 ppm
-61.8 ppm
-43.0 ppm
1.84
6.00
0.62
-40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -1
f1 (ppm)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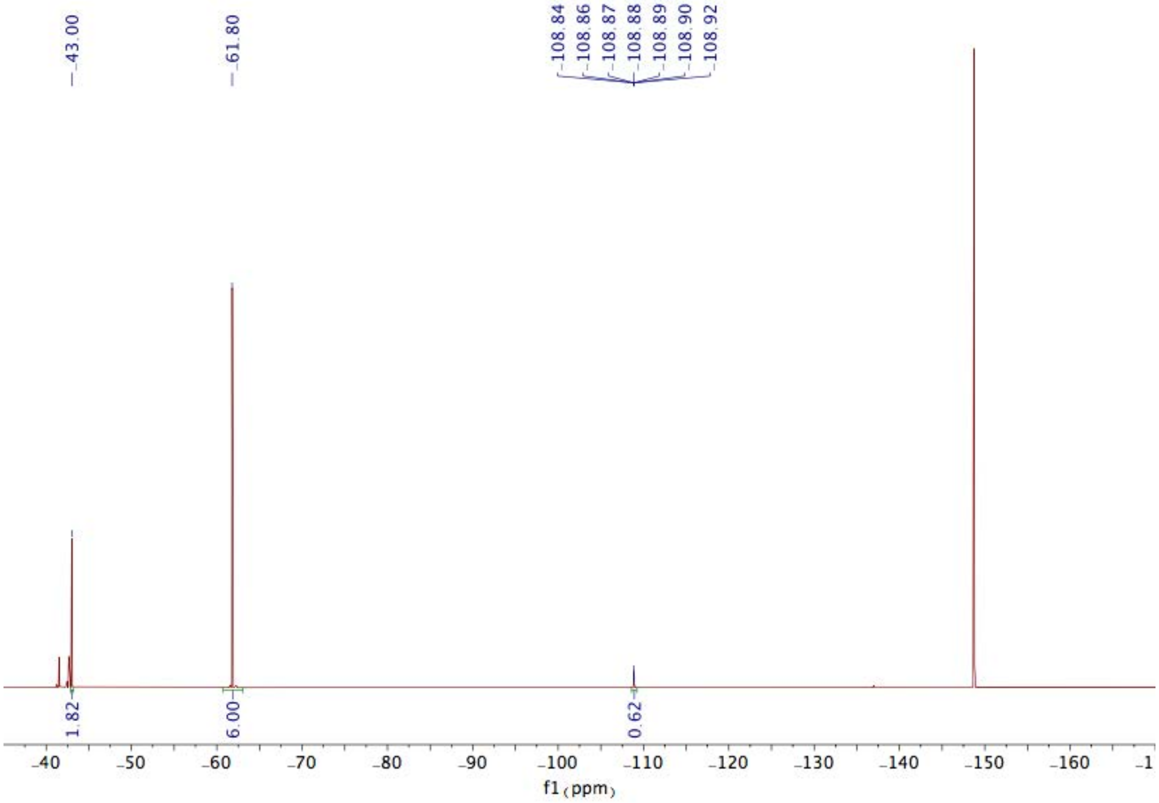
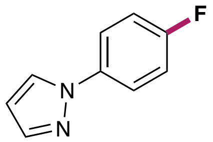
-108.85
-108.86
-108.87
-108.88
-108.89
-108.91
1.95
6.00
0.65
-45 -55 -65 -75 -85 -95 -105 -115 -125 -135 -145 -155 -165
f1 (ppm)


-43.00
-61.80
-108.84
-108.86
-108.87
-108.88
-108.89
-108.90
-108.92
1.82
6.00
0.62
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
f1 (ppm)



1-(4-fluorophenyl)-1*H*-pyrazole (41)

Prepared according to the general procedure **A** outlined above using NFTPT (228 mg, 1.0 mmol, 2 equiv.), $[Cu(MeCN)_4]BF_4$ (471 mg, 1.5 mmol, 3 equiv), and 4-pyrazol-1-ylbenzoic acid (94.1 mg, 0.5 mmol, 1 equiv) in MeCN (15 mL, 33 mM). Irradiation time: 24 h.

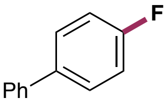
The final reaction mixture was stirred with tetrasodium EDTA (500 mg) and water (10 mL) for 30 minutes. The mixture was then extracted with 9:1 pentane:ether (5x20 mL). The combined organic layers were then dried over magnesium sulfate, filtered, and concentrated. The product was then purified via silica gel column chromatography (10% EtOAc in hexanes) to yield the pure product (42 mg, 0.26 mmol, 52%) as a clear oil.

^{1}H NMR (500 MHz, $(CD_3)_2CO$) δ 8.31 (d, *J* = 2.5 Hz, 1H), 7.93 – 7.86 (m, 2H), 7.70 (d, *J* = 2.1 Hz, 1H), 7.33 – 7.25 (m, 2H), 6.52 (dd, *J* = 2.5, 1.8 Hz, 1H).

^{13}C NMR (125 MHz, $(CD_3)_2CO$) δ 160.82 (d, *J* = 243.1 Hz), 140.79, 136.92, 127.07, 120.50 (d, *J* = 8.4 Hz), 115.98 (d, *J* = 23.1 Hz), 107.59.

^{19}F NMR (376 MHz, $(CD_3)_2CO$) δ -113.31 (m, 1F).

Spectral data are consistent with those reported in the literature: F. Chevallier, Y. S. Halauko, C. Pecceu, I. F. Nassar, T. U. Dam, T. Roisnel, V. E. Matulis, O. A. Ivashkevich, F. Mongin. *Org. Biomol. Chem.*, **9**, 4671 (2011).



4-fluorobiphenyl (42)

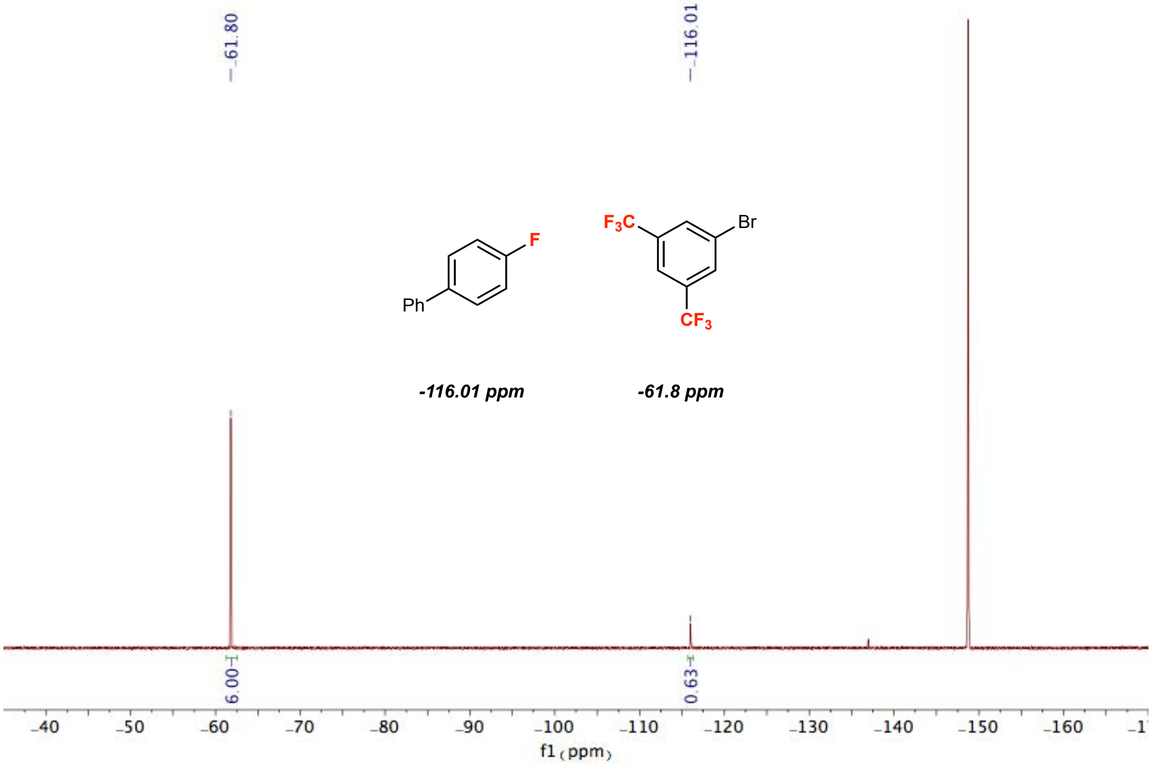
Prepared according to the general procedure **B** outlined above using CsF (76.1 mg, 0.5 mmol, 1 equiv.), 1-Fluoro-2,4,6-trimethylpyridinium tetrafluoroborate (228 mg, 1.0 mmol, 2 equiv.), tetrakis(acetonitrile)copper(I) tetrafluoroborate (471 mg, 1.5 mmol, 3 equiv), and 4-phenylbenzoic acid (99.1 mg, 0.5 mmol, 1 equiv) in MeCN (10 mL, 50 mM). Irradiation time: 24 h.

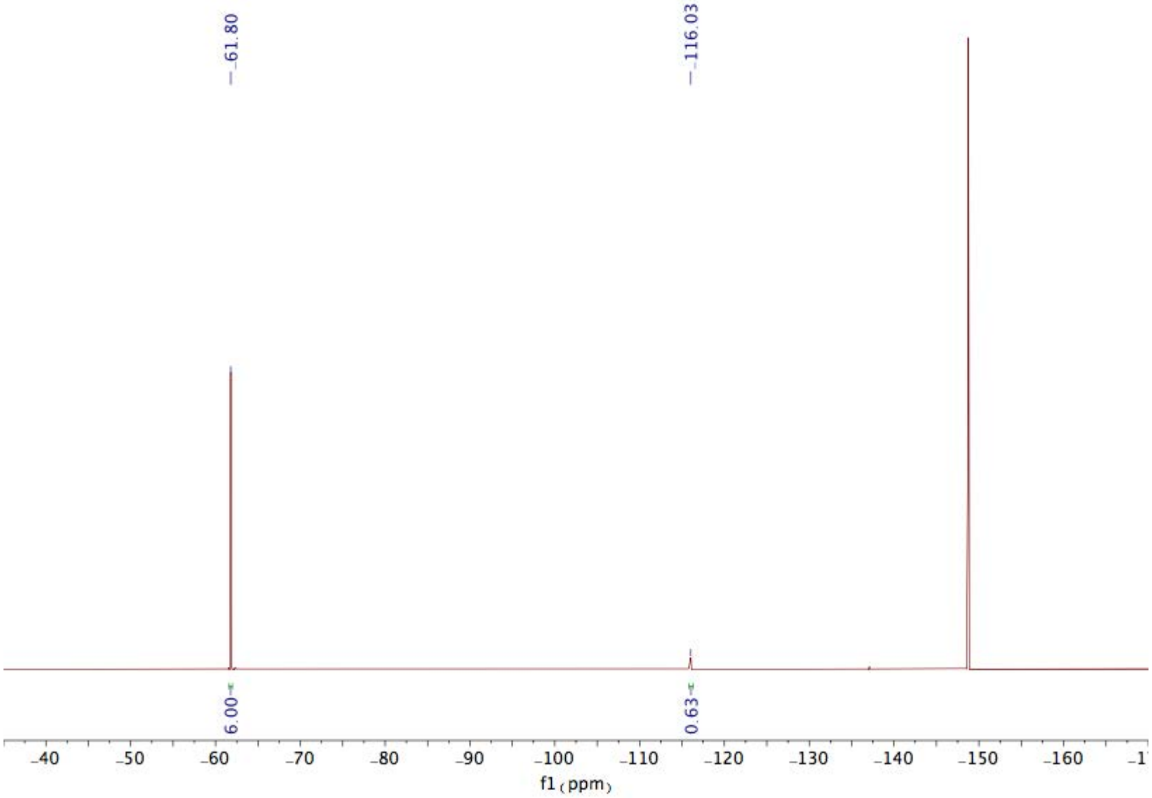
Yield was determined by ^{19}F NMR in triplicate

1-bromo-3-5-bis(trifluoromethyl)benzene (87 µL, 0.5 mmol 1.0 equiv.) was added as the internal standard for ^{19}F NMR analysis (d_6-DMSO) (63% yield- average of three trials: 63% yield, 63% yield, 62% yield).

Spectral data are consistent with those reported in the literature: Bolton, Roger; Sandall, John P. B.; Williams, Gareth H. *J. Fluor. Chem.* **11**, 591–600 (1978).

HRMS (GC-EI-TOF) m/z calcd. for $C_{12}H_9F$ ([M*]+) 172.06938, found 172.06848.


-61.80
-116.01
F
Ph
F_3C
Br
CF_3
-116.01 ppm
-61.8 ppm
6.00
0.63
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
f1 (ppm)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-116.03
6.00
0.63
-40
-50
-60
-70
-80
-90
-100
-110
-120
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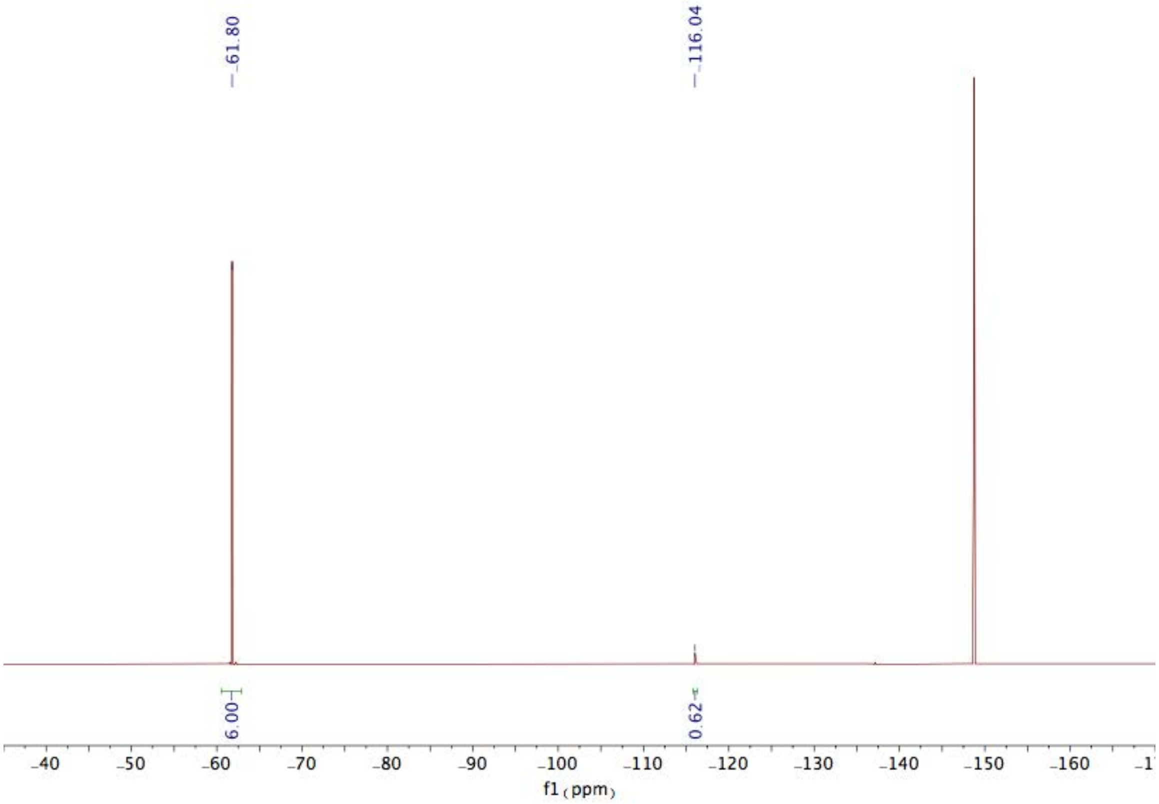
-140
-150
-160
f1 (ppm)



-61.80
-116.04
6.00
0.62
-40
-50
-60
-70
-80
-90
-100
-110
-120
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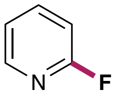
-140
-150
-160
f1 (ppm)

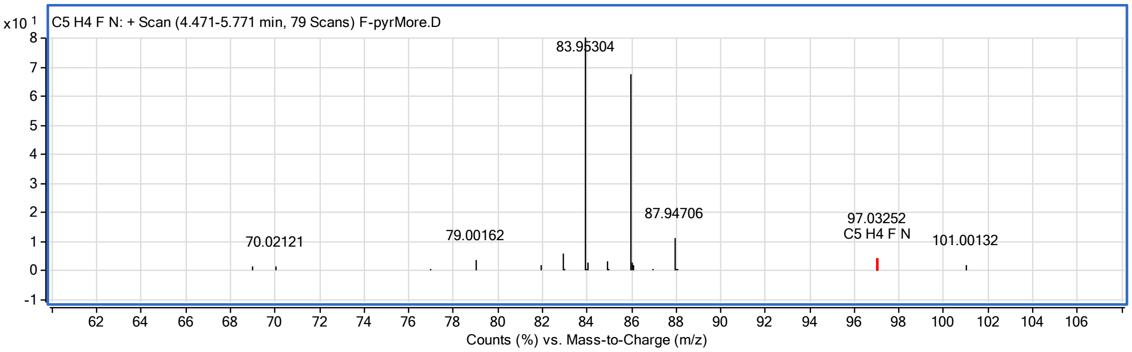


2-fluoropyridine (43)

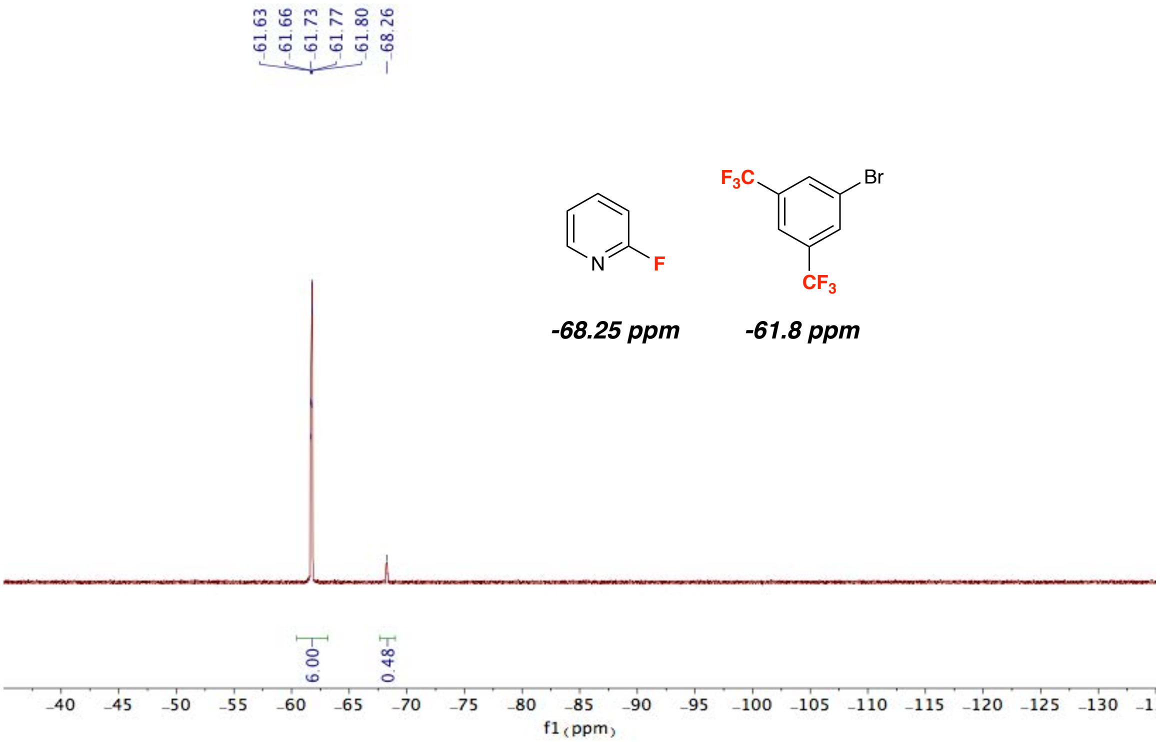
Prepared according to the general procedure **A** outlined above using NFTPT (228 mg, 1.0 mmol, 2 equiv.), $[Cu(MeCN)_4]BF_4$ (471 mg, 1.5 mmol, 3 equiv), and picolinic acid (61.6 mg, 0.5 mmol, 1 equiv) in MeCN (10 mL, 50 mM). Irradiation time: 12 h.

Yield was determined by ^{19}F NMR in triplicate due to the high volatility of the desired product.

1-bromo-3-5-bis(trifluoromethyl)benzene (87 µL, 0.5 mmol 1.0 equiv.) was added as the internal standard for ^{19}F NMR analysis (d_6-DMSO) (49% yield – average of three trials: 48%, 48%, and 52%).



HRMS (GC-EI-TOF) m/z calcd. for C_5H_4FN ([M*]$^+$) 97.03278, found 97.03252.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F_3C
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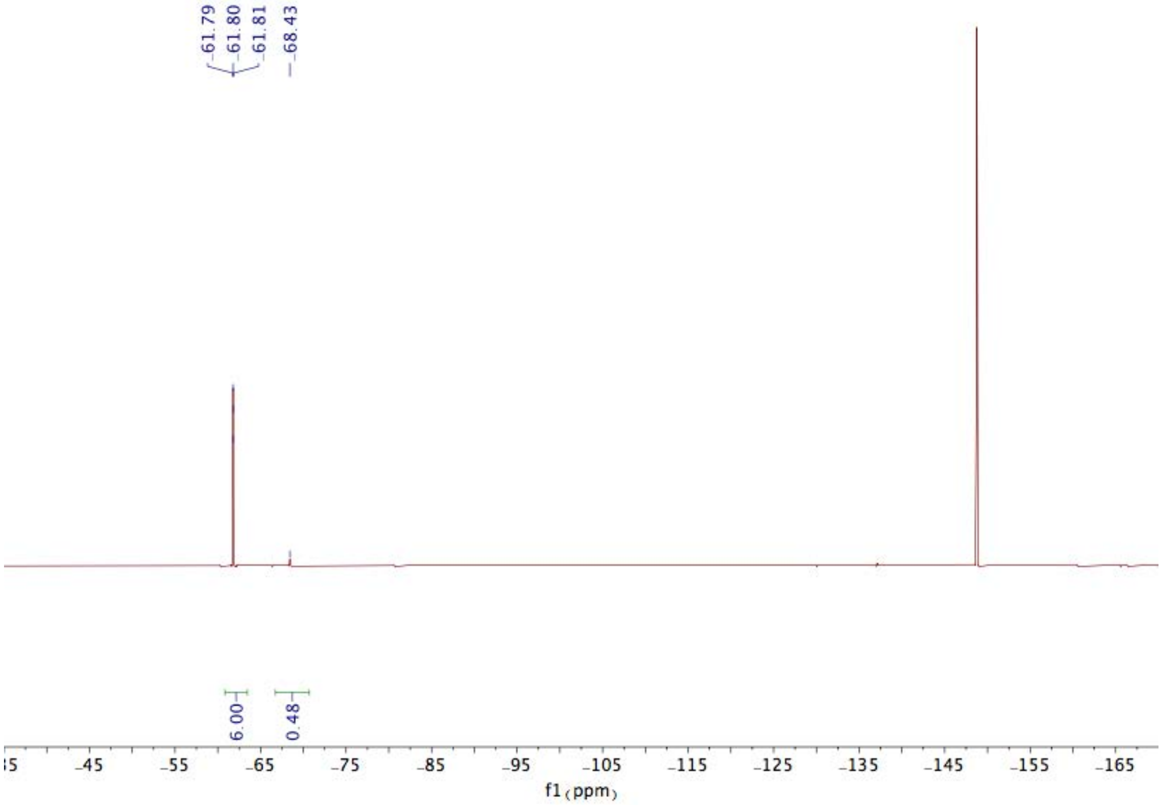
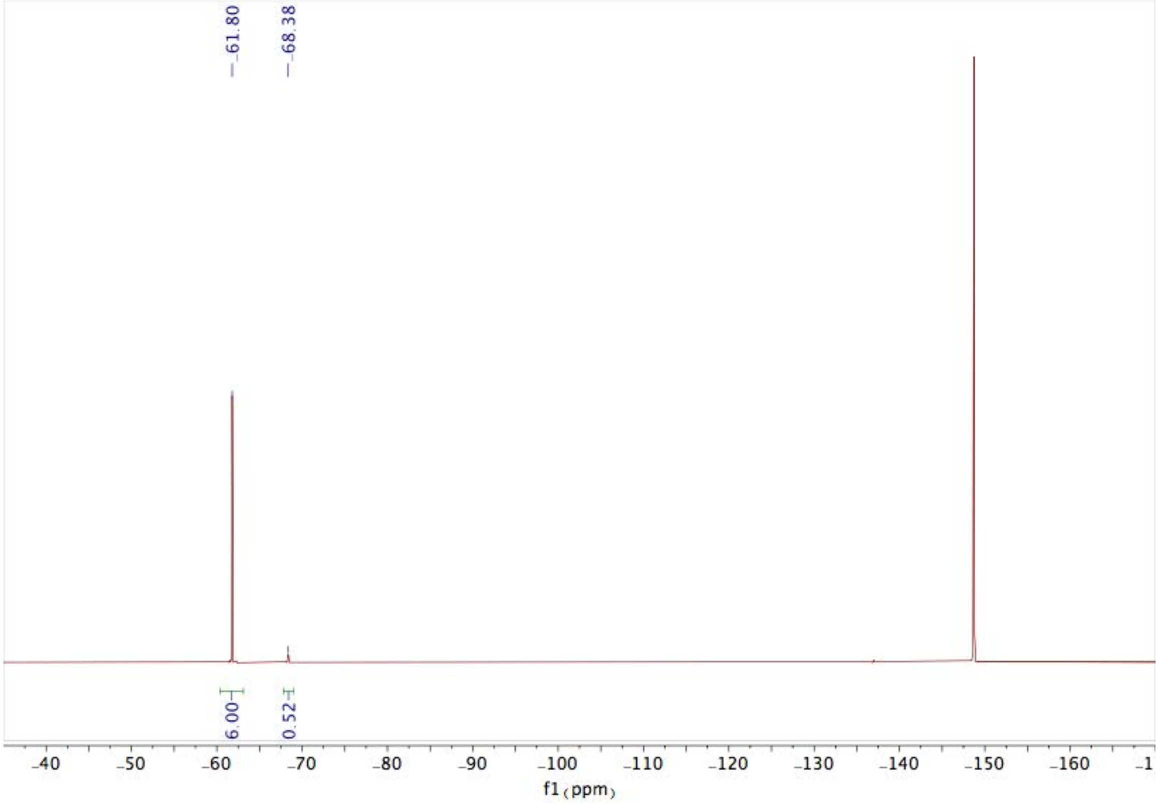
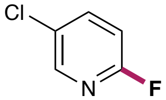
6.00
0.48
-40 -45 -50 -55 -60 -65 -70 -75 -80 -85 -90 -95 -100 -105 -110 -115 -120 -125 -130 -1
f1 (ppm)


-61.79
-61.80
-61.81
-68.43
6.00
0.48
-45 -55 -65 -75 -85 -95 -105 -115 -125 -135 -145 -155 -165
f1 (ppm)



-61.80
-68.38
6.00
0.52
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
f1 (ppm)



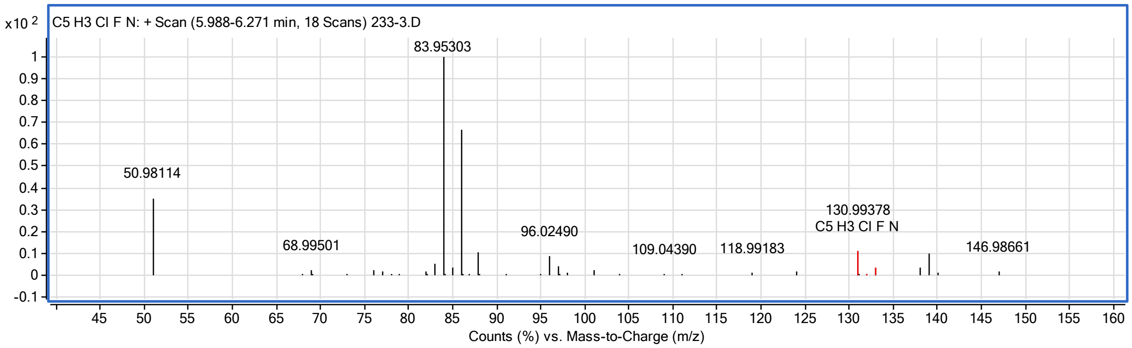
5-chloro-2-fluoropyridine (44)

Prepared according to the general procedure **A** outlined above using NFTPT (228 mg, 1.0 mmol, 2 equiv.), [Cu(MeCN)$_4$]BF$_4$ (471 mg, 1.5 mmol, 3 equiv), and 5-chloropicolinic acid (78.8 mg, 0.5 mmol, 1 equiv) in MeCN (10 mL, 50 mM). Irradiation time: 12 h.

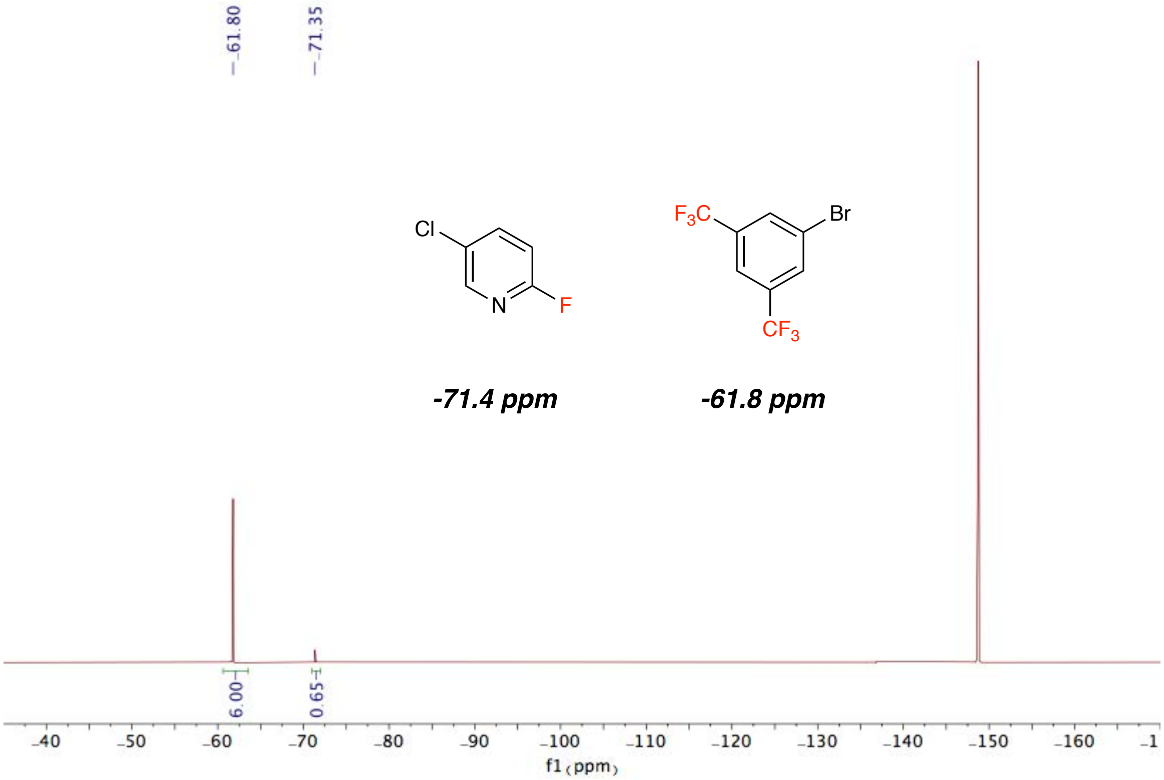
Yield was determined by ^{19}F NMR in triplicate due to the high volatility of the desired product

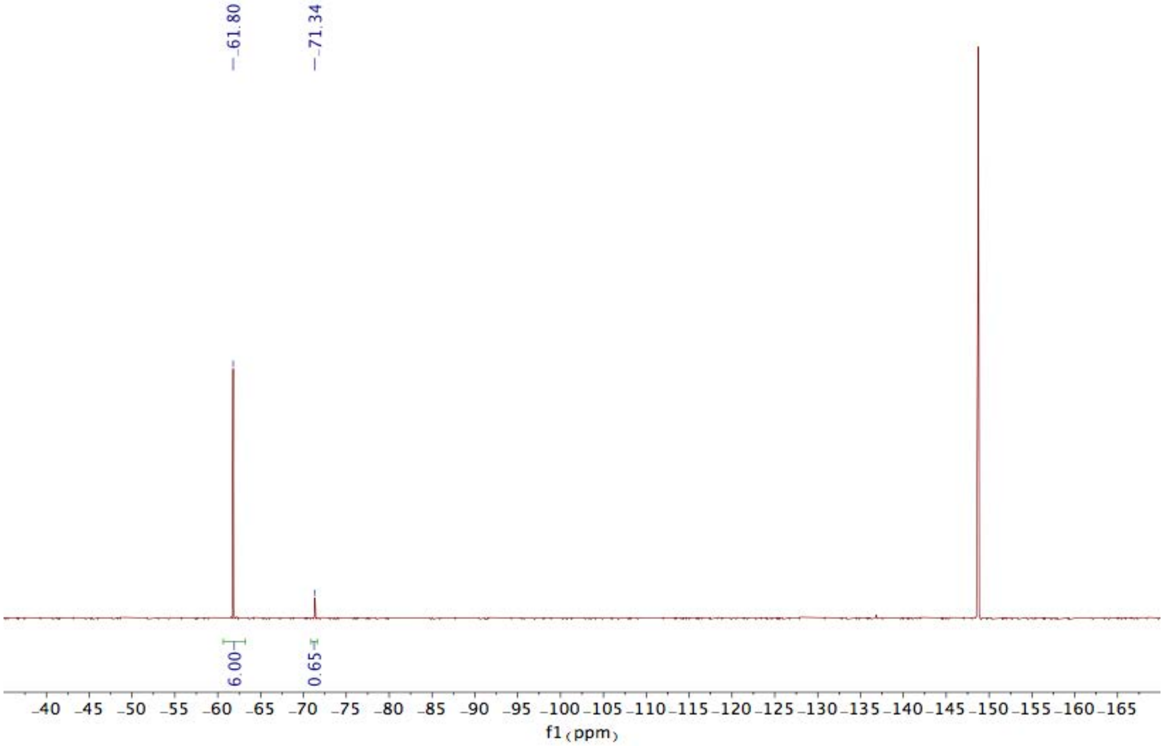
1-bromo-3-5-bis(trifluoromethyl)benzene (87 µL, 0.5 mmol 1.0 equiv.) was added as the internal standard for ^{19}F NMR analysis (d_6-DMSO) (65% yield – average of three trials: 65%, 65% and 66%).

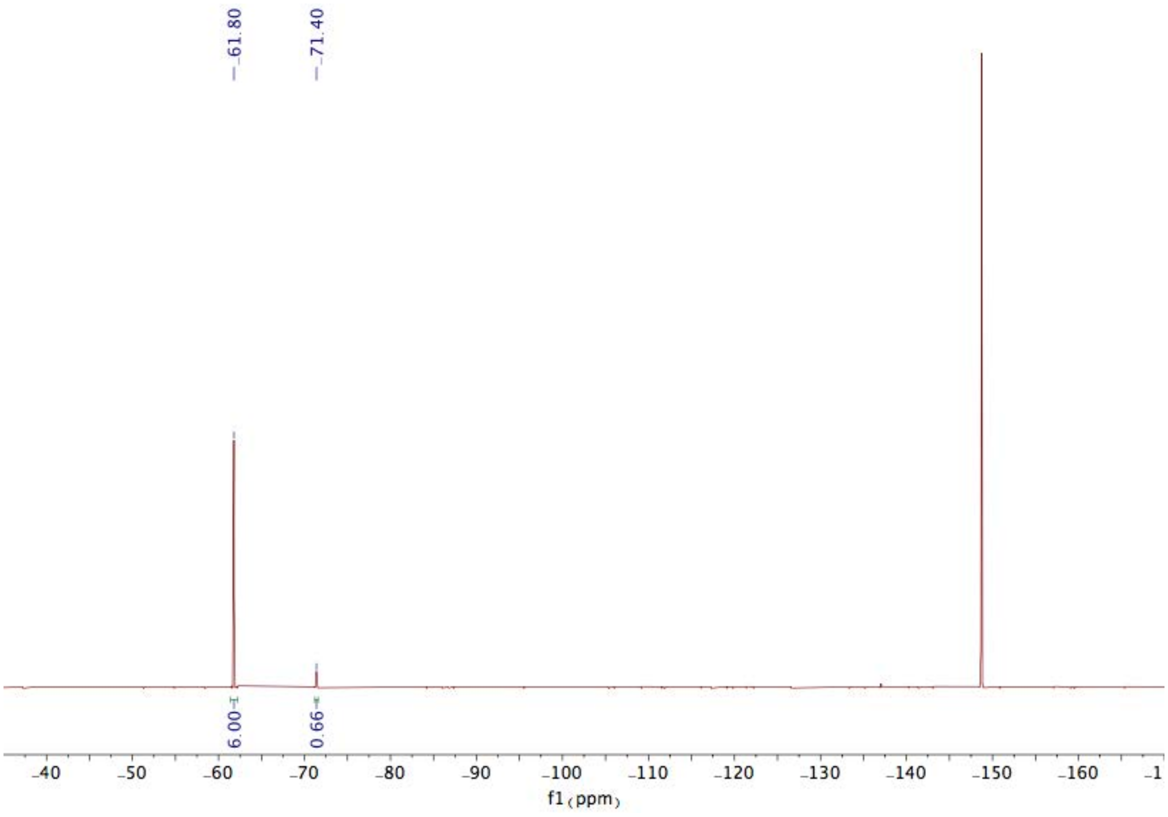
Spectral data are consistent with those reported in the literature: W. A. Thomas, G. E. Griffin. *Org. Magn. Reson.* **2**, 503-510 (1970).

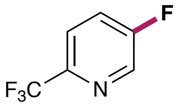


HRMS (GC-EI-TOF) m/z calcd. for C_5H_3ClFN ([M*]$^+$) 130.99381, found 130.99378.


-61.80
-71.35
Cl
N
F
F3C
Br
CF3
-71.4 ppm
-61.8 ppm
6.00
0.65
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-1
f1 (ppm)


-61.80
-71.34
6.00
0.65
-40
-45
-50
-55
-60
-65
-70
-75
-80
-85
-90
-95
-100
-105
-110
-115
-120
-125
-130
-135
-140
-145
-150
-155
-160
-165
f1 (ppm)


-61.80
-71.40
6.00
0.66
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-1
f1 (ppm)



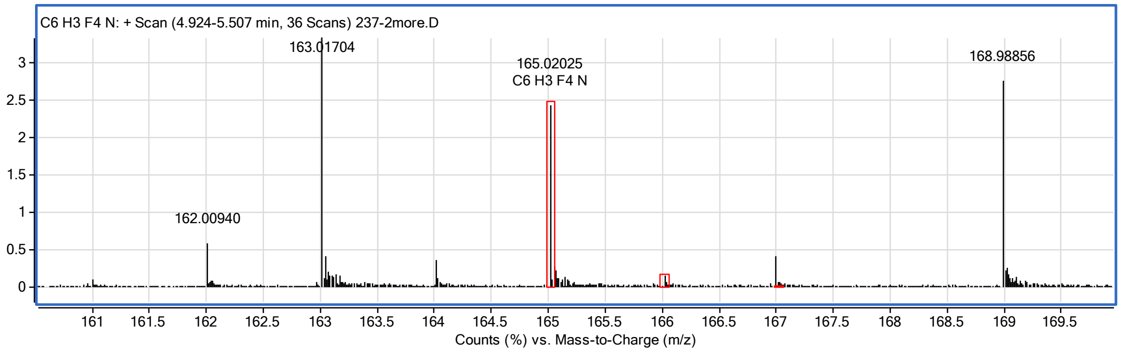
5-fluoro-2-(trifluoromethyl)pyridine (45)

Prepared according to the general procedure **A** outlined above using NFTPT (285 mg, 1.25 mmol, 2.5 equiv.), [Cu(MeCN)$_4$]BF$_4$ (471 mg, 1.5 mmol, 3 equiv), and 6-(trifluoromethyl)nicotinic acid (95.6 mg, 0.5 mmol, 1 equiv) in MeCN (10 mL, 50 mM). Irradiation time: 24 h, fan speed: 1500 rpm.

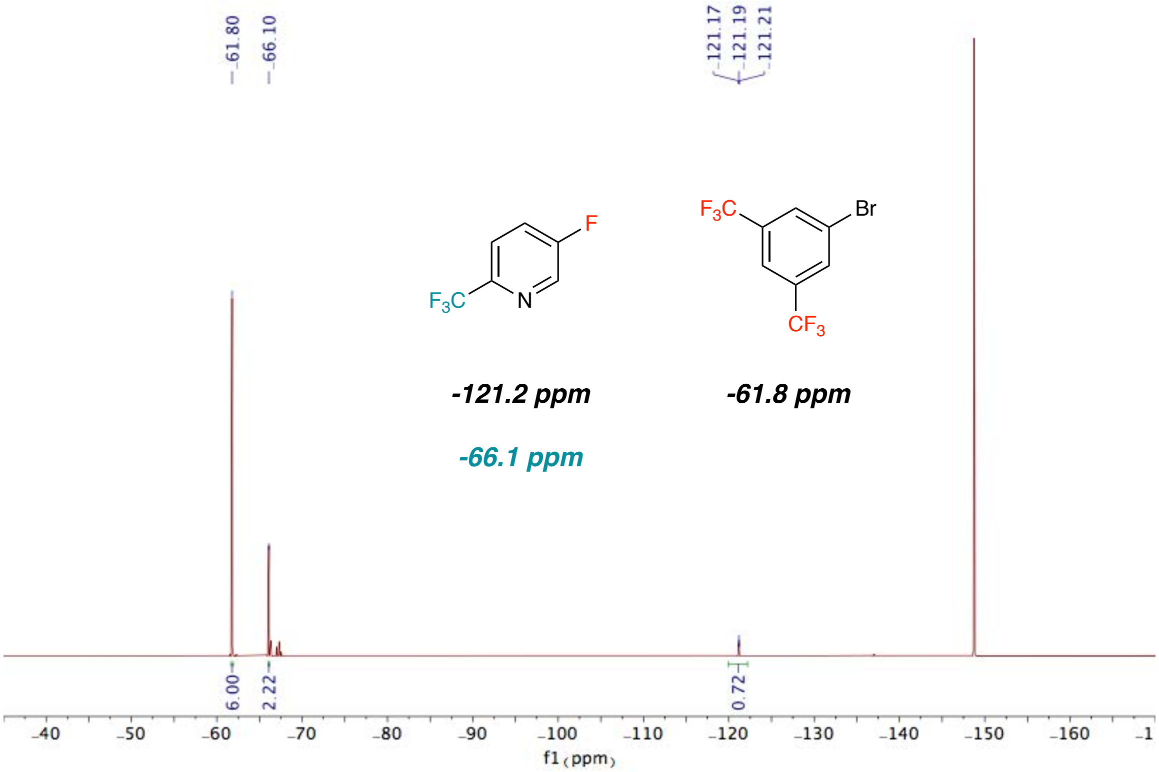
Yield was determined by ^{19}F NMR in triplicate due to the high volatility of the desired product.

1-bromo-3-5-bis(trifluoromethyl)benzene (87 μL, 0.5 mmol 1.0 equiv.) was added as the internal standard for ^{19}F NMR analysis (d_6-DMSO) (71% yield – average of three trials: 68%, 72%, and 72%).

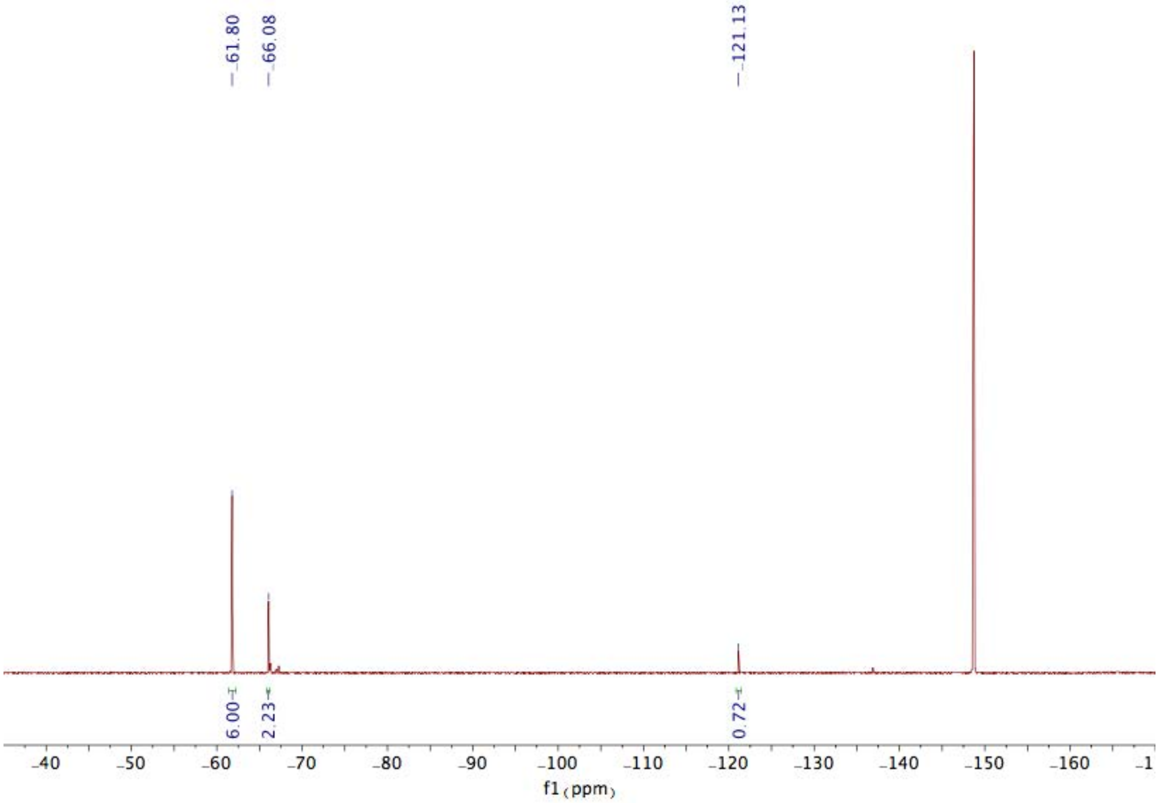
Spectral data are consistent with those reported in the literature: S. Trofymchuk et al. *J. Org. Chem.* **85**, 3110–3124 (2020).



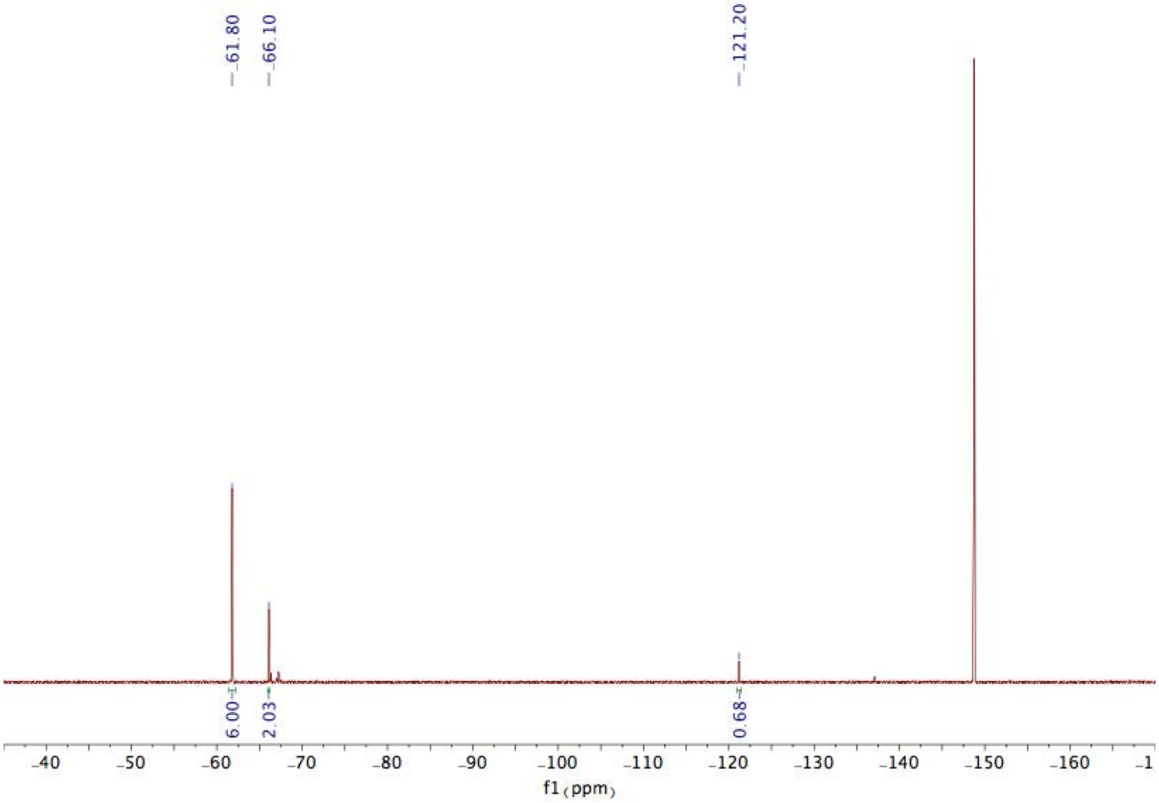
HRMS (GC-EI-TOF) m/z calcd. for $C_6H_3F_4N$ ([M*]$^+$) 165.02016, found 165.02025.

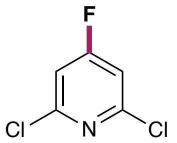


-61.80
-66.10
-121.17
-121.19
-121.21
F3C
F
N
F3C
Br
CF3
-121.2 ppm
-61.8 ppm
-66.1 ppm
6.00
2.22
0.72
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-1
f1 (ppm)



-61.80
-66.08
-121.13
6.00
2.23
0.72
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-1
f1 (ppm)


-61.80
-66.10
-121.20
6.00
2.03
0.68
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-1
f1 (ppm)

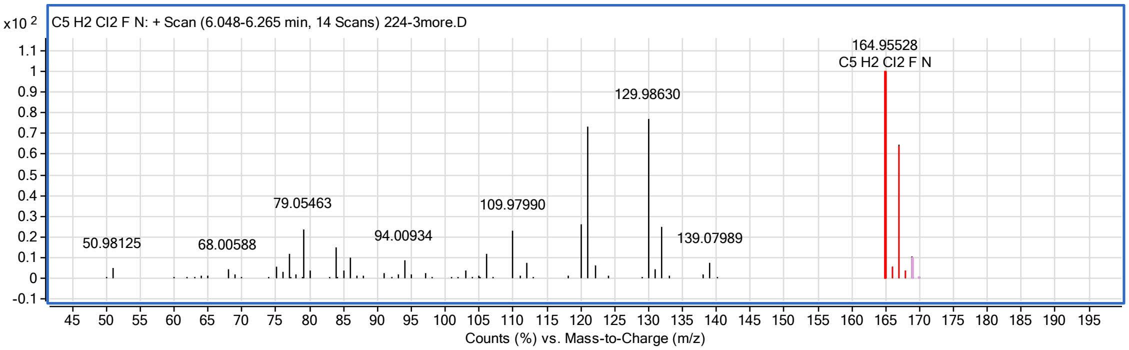


2,6-dichloro-4-fluoropyridine (46)

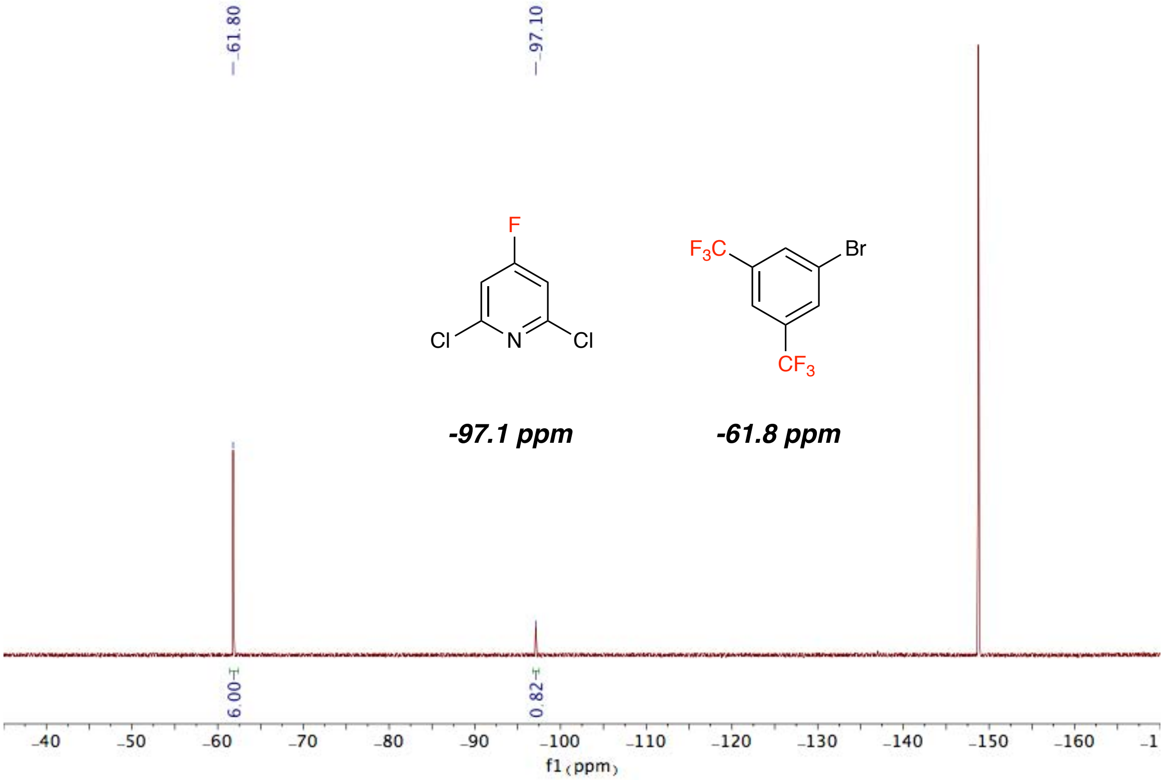
Prepared according to the general procedure **A** outlined above using NFTPT (228 mg, 1.0 mmol, 2.0 equiv.), [Cu(MeCN)$_4$]BF$_4$ (471 mg, 1.5 mmol, 3 equiv), and 2,6-dichloroisonicotinic acid (96.0 mg, 0.5 mmol, 1 equiv) in MeCN (10 mL, 50 mM). Irradiation time: 24 h.

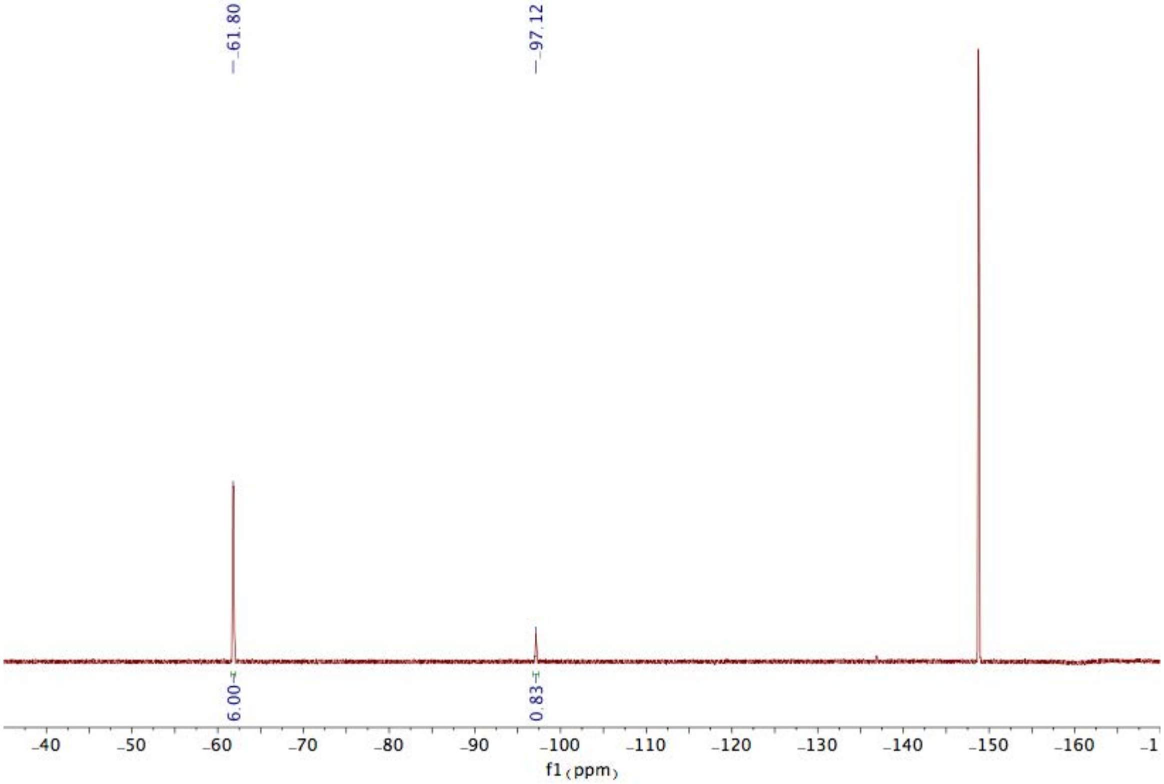
Yield was determined by ^{19}F NMR in triplicate due to instability of product to common isolation techniques

1-bromo-3-5-bis(trifluoromethyl)benzene (87 μL, 0.5 mmol 1.0 equiv.) was added as the internal standard for ^{19}F NMR analysis (d_6-DMSO) (81% yield – average of three trials: 78%, 82%, and 83%).



HRMS (GC-EI-TOF) m/z calcd. for C$_5$H$_2$Cl$_2$FN ([M*]$^+$) 164.95483, found 164.95528.


-61.80
-97.10
F
Cl
N
Cl
F_3C
Br
CF_3
-97.1 ppm
-61.8 ppm
6.00
0.82
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-1
f1 (ppm)


-61.80
-97.12
6.00
0.83
-40
-50
-60
-70
-80
-90
-100
-110
-120
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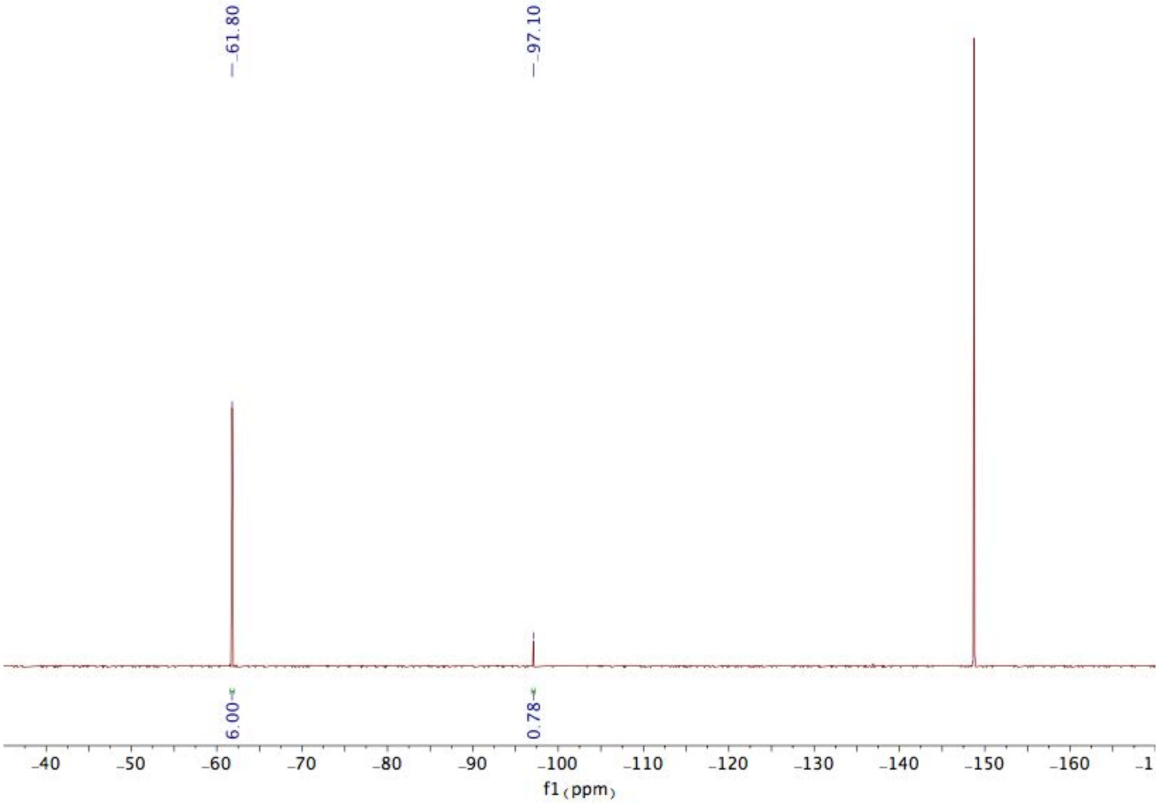
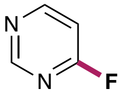
-140
-150
-160
-1
f1 (ppm)


-61.80
-97.10
6.00
0.78
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
f1 (ppm)

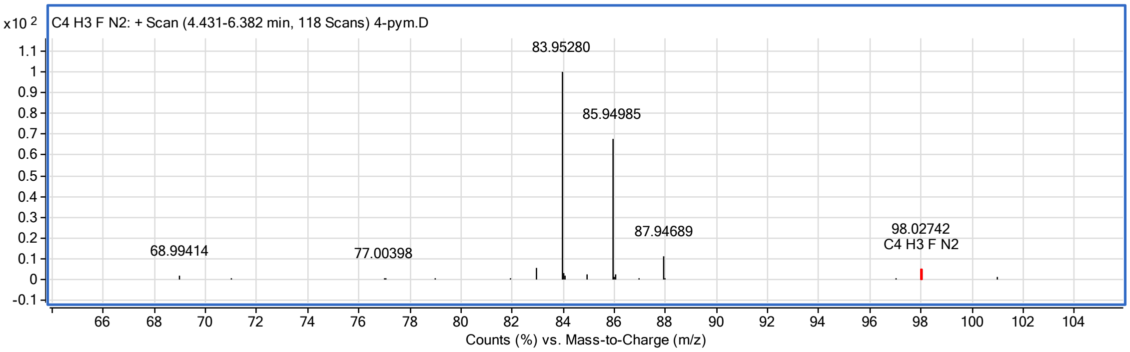


4-fluoropyrimidine (47)

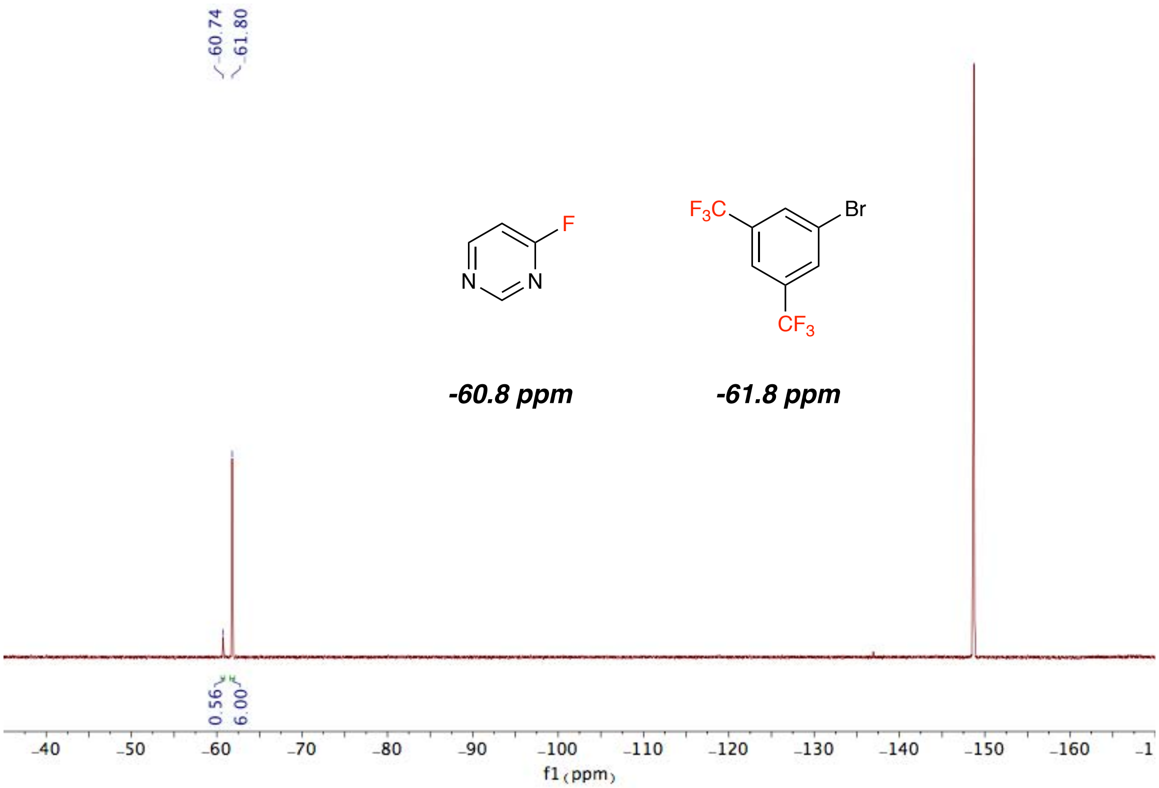
Prepared according to the general procedure **A** outlined above NFTPT (228 mg, 1.0 mmol, 2.0 equiv.), [Cu(MeCN)$_4$]BF$_4$ (471 mg, 1.5 mmol, 3 equiv), and pyrimidine-4-carboxylic acid (96.1 mg, 0.5 mmol, 1 equiv) in MeCN (10 mL, 50 mM). Irradiation time: 24 h.

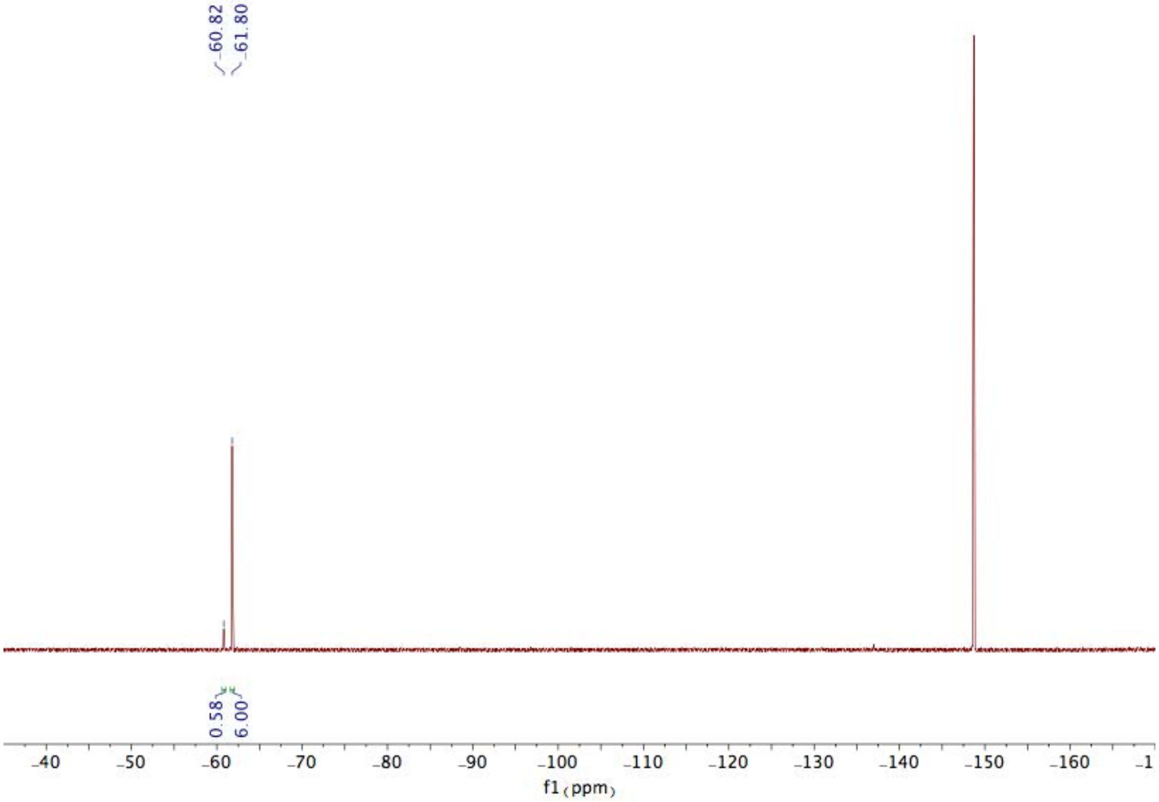
Yield was determined by ^{19}F NMR in triplicate due to the high volatility of the desired product.

1-bromo-3-5-bis(trifluoromethyl)benzene (87 μL, 0.5 mmol 1.0 equiv.) was added as the internal standard for ^{19}F NMR analysis (*d*$_6$-DMSO) (56% yield – average of three trials: 56%, 58%, and 53%).



HRMS (GC-EI-TOF) m/z calcd. for $C_4H_3FN_2$ ([M*]$^+$) 98.02803, found 98.02742.


-60.74
-61.80
F
N
N
F3C
Br
CF3
-60.8 ppm
-61.8 ppm
0.56
6.00
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-1
f1 (ppm)


-60.82
-61.80
0.58
6.00
-40
-50
-60
-70
-80
-90
-100
-110
-120
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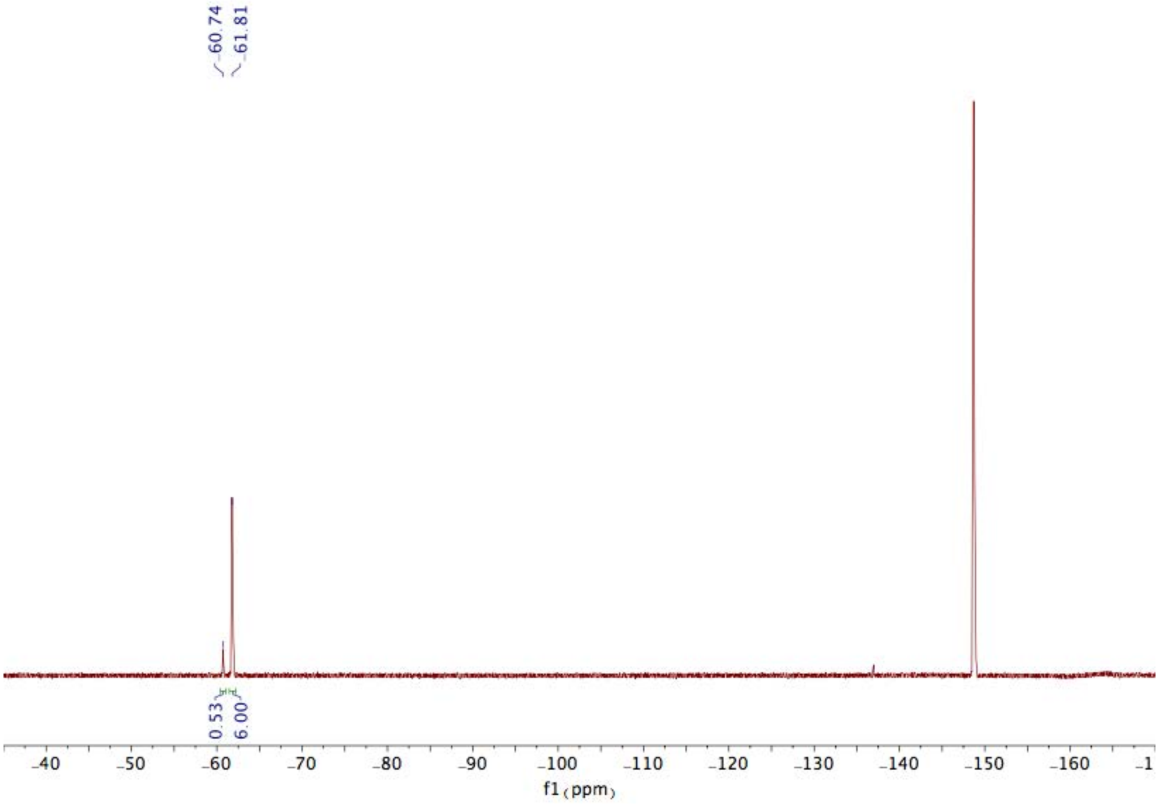
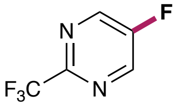
-140
-150
-160
-1
f1 (ppm)



-60.74
-61.81
0.53
6.00
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-1
f1 (ppm)

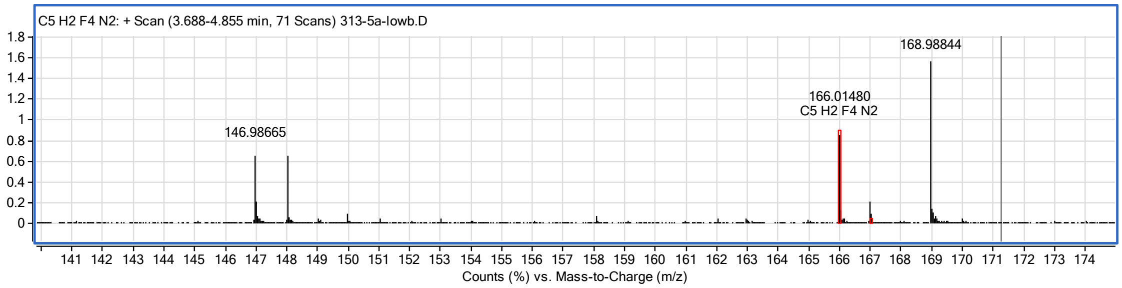


5-fluoro-2-trifluoromethylpyrimidine (48)

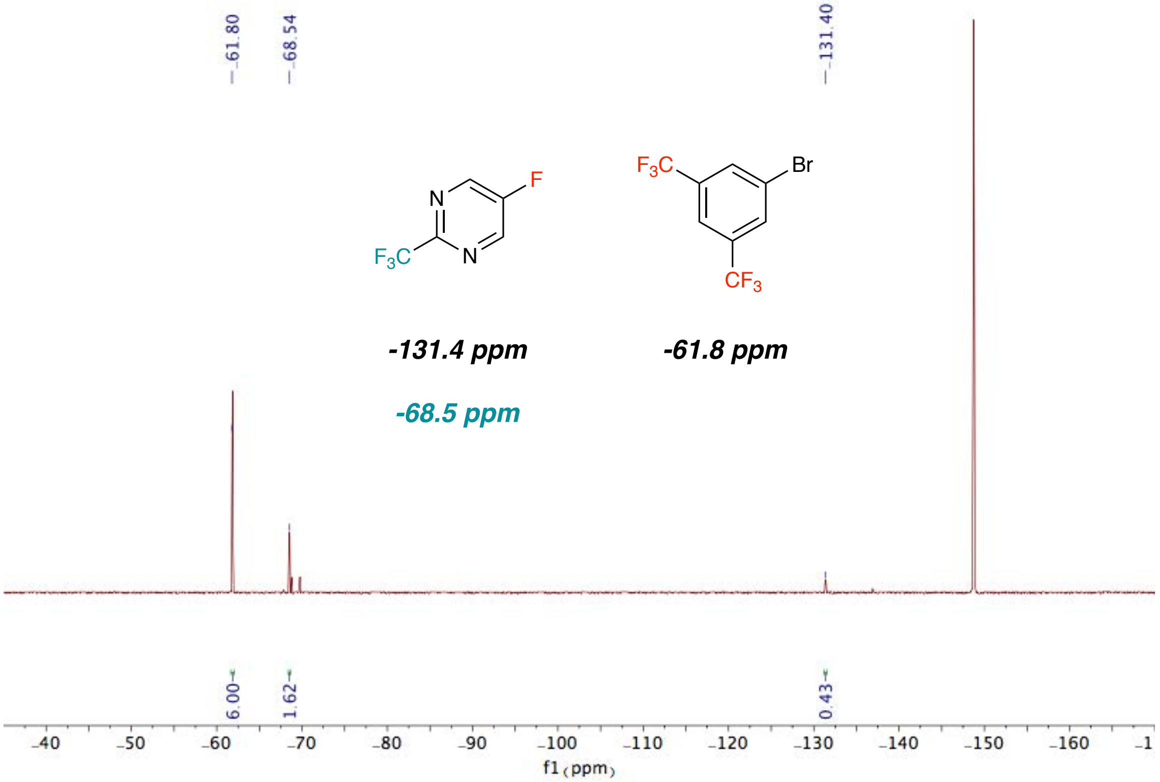
Prepared according to the general procedure **A** outlined above using NFTPT (228 mg, 1.0 mmol, 2.0 equiv.), $[Cu(MeCN)_4]BF_4$ (471 mg, 1.5 mmol, 3 equiv), and 2-(trifluoromethyl)pyrimidine-5-carboxylic acid (96.1 mg, 0.5 mmol, 1 equiv) in MeCN (10 mL, 50 mM). Irradiation time: 24 h.

Yield was determined by ^{19}F NMR in triplicate due to the high volatility of the desired product.

1-bromo-3-5-bis(trifluoromethyl)benzene (87 μL, 0.5 mmol 1.0 equiv.) was added as the internal standard for ^{19}F NMR analysis (d_6-DMSO) (40% yield – average of three trials: 43%, 38%, and 38%).



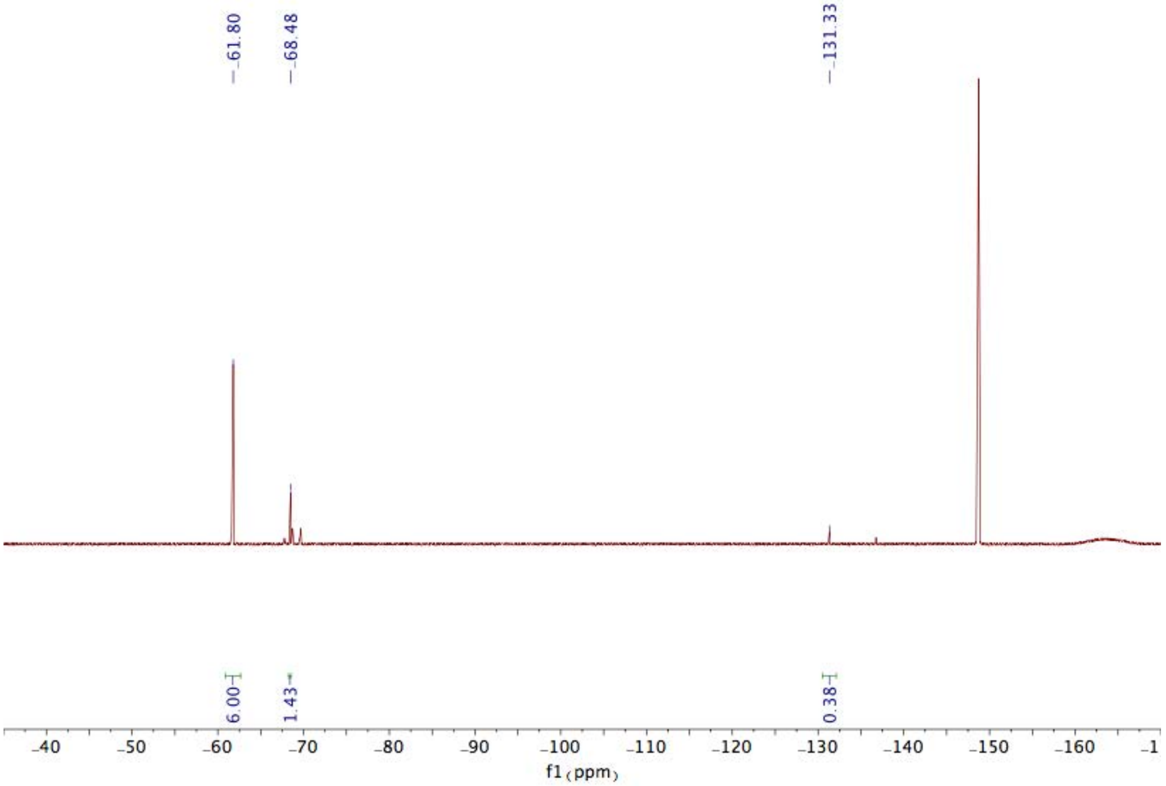
HRMS (GC-EI-TOF) m/z calcd. for $C_5H_2F_4N_2$ ($[M^*]^+$) 166.01541, found 166.01480.

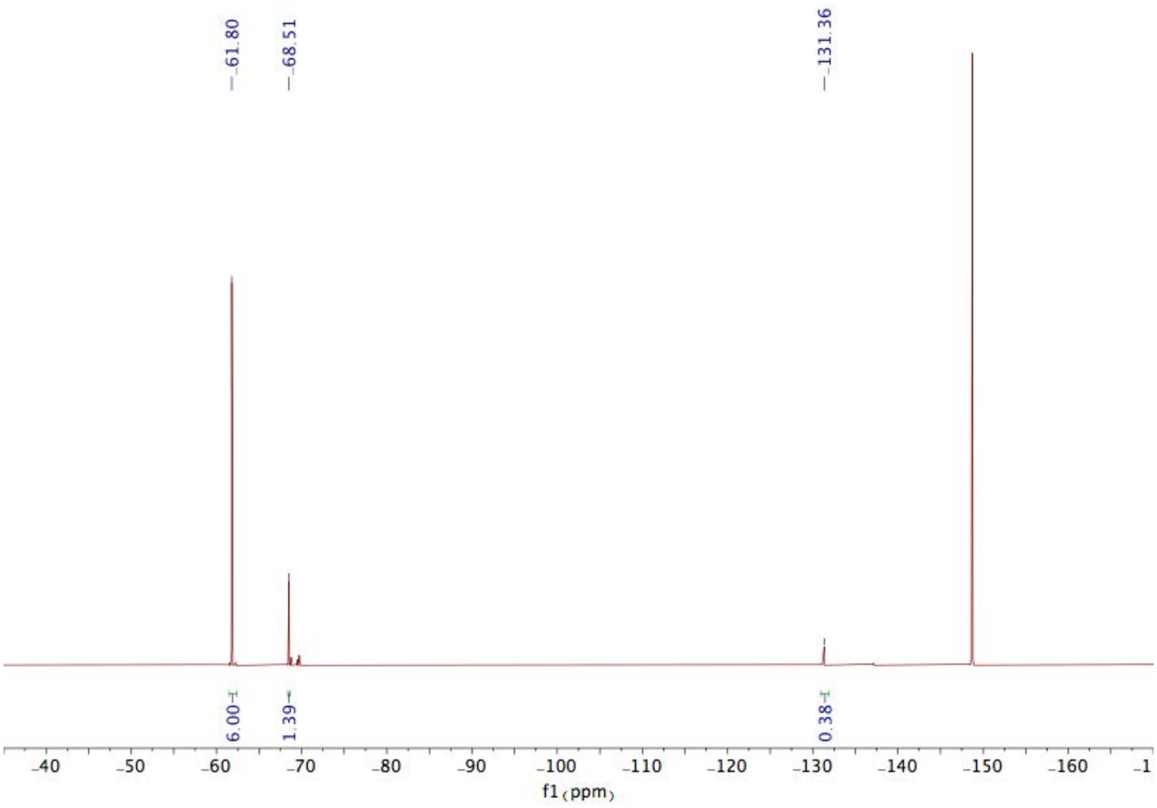


-131.4 ppm

-61.8 ppm

-68.5 ppm




-61.80
-68.51
-131.36
6.00
1.39
0.38
-40
-50
-60
-70
-80
-90
-100
-110
-120
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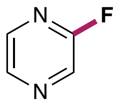
-140
-150
-160
-1
f1 (ppm)



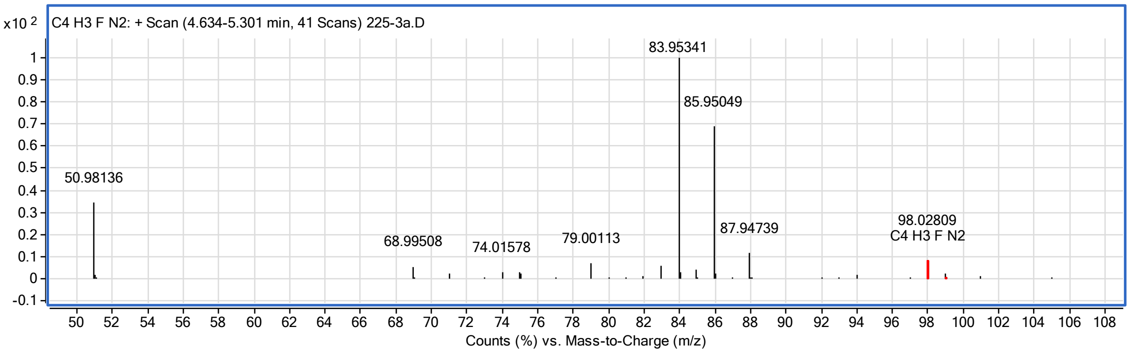
2-fluoropyrazine (49)

Prepared according to the general procedure **A** outlined above using NFTPT (228 mg, 1.0 mmol, 2.0 equiv.), [Cu(MeCN)$_4$]BF$_4$ (471 mg, 1.5 mmol, 3 equiv), and pyrazine-2-carboxylic acid (62.1 mg, 0.5 mmol, 1 equiv) in MeCN (10 mL, 50 mM). Irradiation time: 24 h.

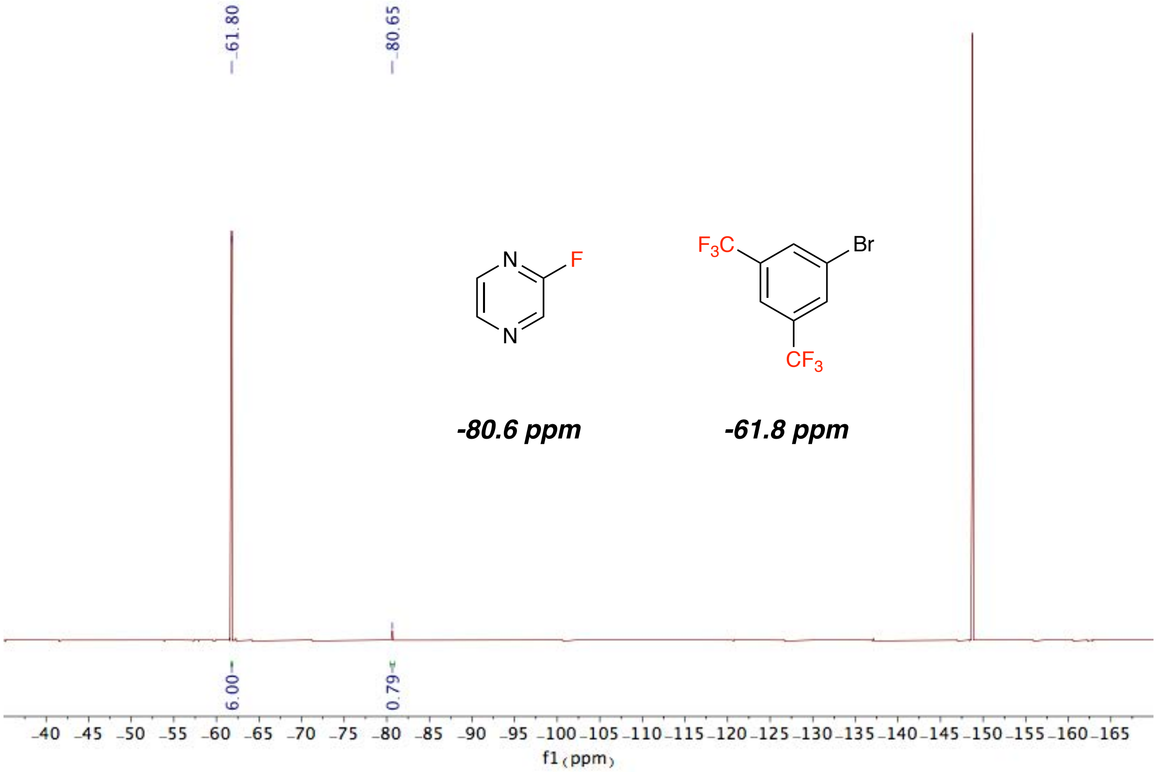
Yield was determined by ^{19}F NMR in triplicate due to the high volatility of the desired product.

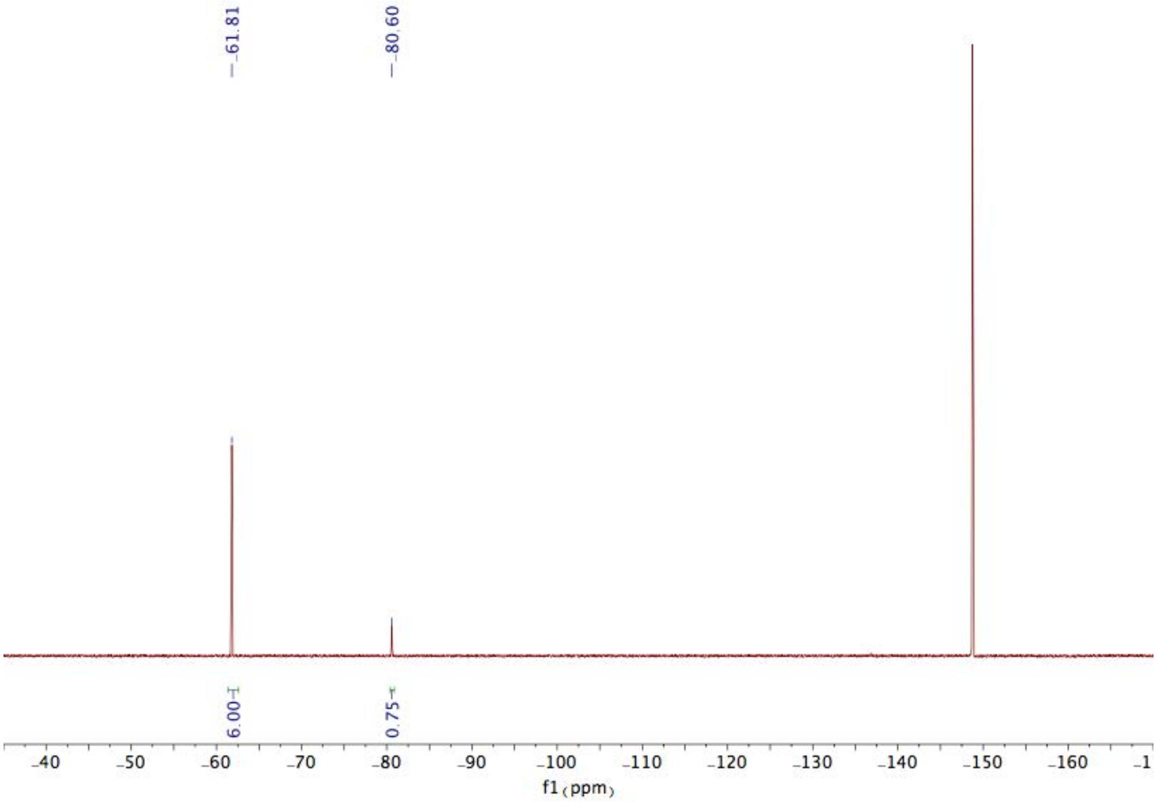
1-bromo-3-5-bis(trifluoromethyl)benzene (87 µL, 0.5 mmol 1.0 equiv.) was added as the internal standard for ^{19}F NMR analysis (*d*$_6$-DMSO) (77% yield – average of three trials: 79%, 75%, and 76%).

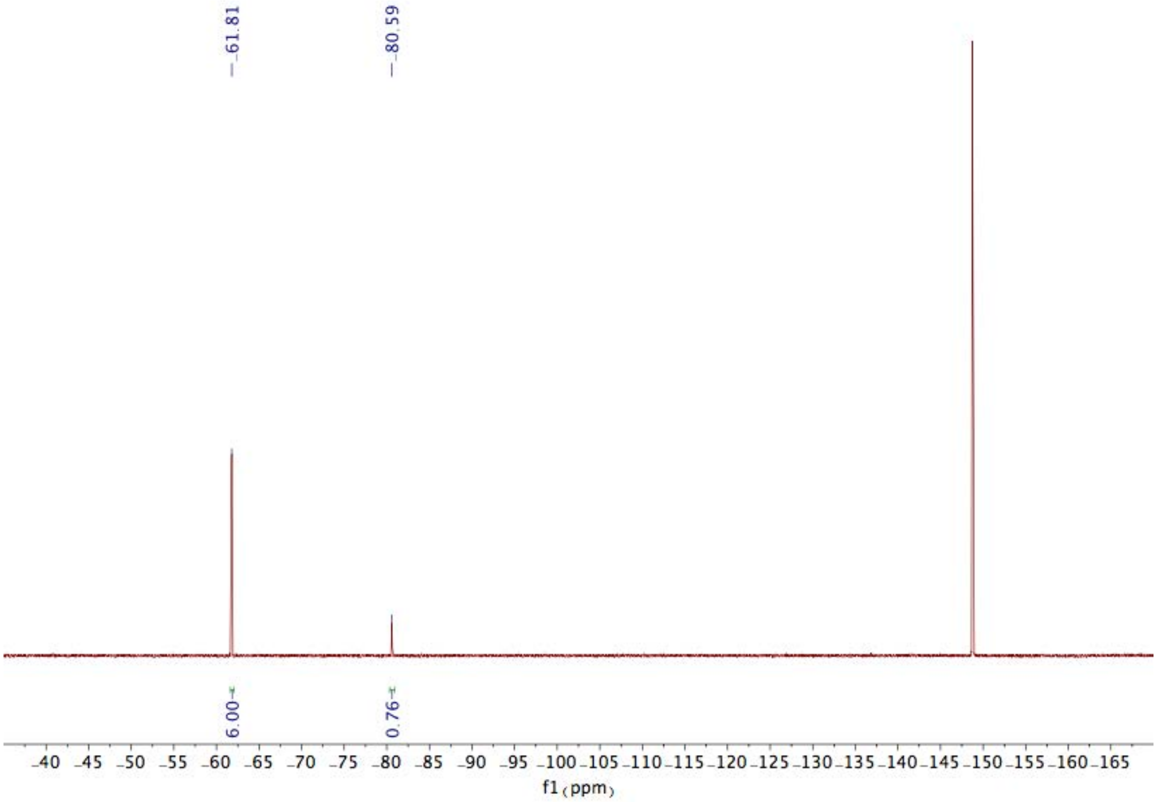
Spectral data are consistent with those reported in the literature: R. H. Cox, A. A. Bothner-By. *J. Phys. Chem.* **72**, 1646–1649 (1968).



HRMS (GC-EI-TOF) m/z calcd. for $C_4H_3FN_2$ ([M*]$^+$) 98.02803, found 98.02809.


-61.80
-80.65
N
N
F
F3C
Br
CF3
-80.6 ppm
-61.8 ppm
6.00
0.79
-40 -45 -50 -55 -60 -65 -70 -75 -80 -85 -90 -95 -100 -105 -110 -115 -120 -125 -130 -135 -140 -145 -150 -155 -160 -165
f1 (ppm)


-61.81
-80.60
6.00
0.75
-40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -1
f1 (ppm)


-61.81
-80.59
6.00
0.76
-40
-45
-50
-55
-60
-65
-70
-75
-80
-85
-90
-95
-100
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-120
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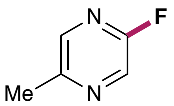
-130
-135
-140
-145
-150
-155
-160
-165
f1 (ppm)



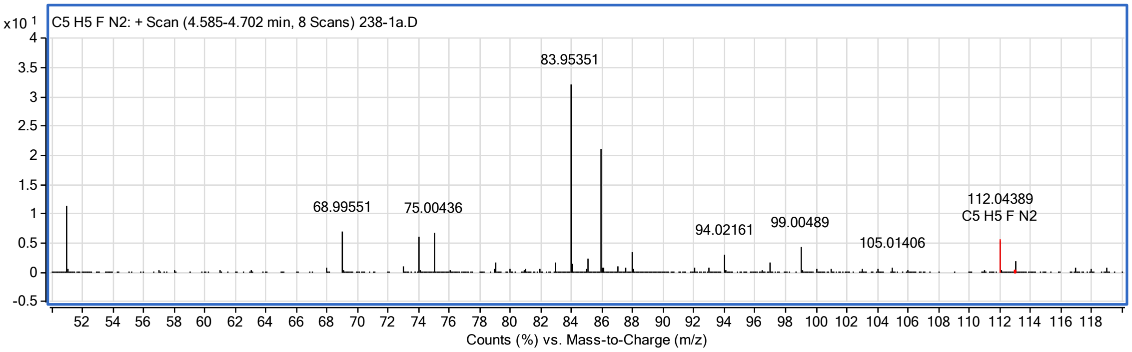
2-fluoro-5-methylpyrazine (50)

Prepared according to the general procedure **A** outlined above using NFTPT (228 mg, 1.0 mmol, 2.0 equiv.), [Cu(MeCN)$_4$]BF$_4$ (471 mg, 1.5 mmol, 3 equiv), and 5-methylpyrazine-2-carboxylic acid (69.1 mg, 0.5 mmol, 1 equiv) in MeCN (10 mL, 50 mM). Irradiation time: 24 h.

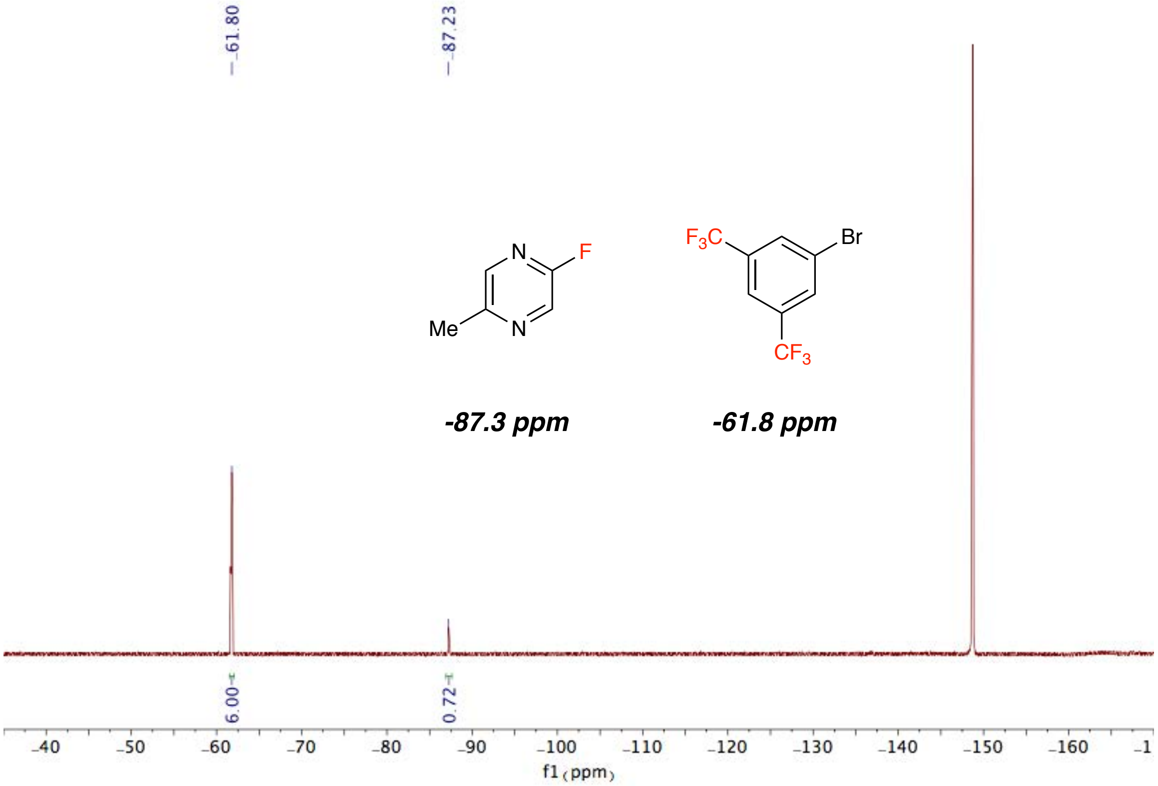
Yield was determined by ^{19}F NMR

1-bromo-3-5-bis(trifluoromethyl)benzene (87 µL, 0.5 mmol 1.0 equiv.) was added as the internal standard for ^{19}F NMR analysis (d_6-DMSO) (72% yield – average of three trials: 72%, 74%, and 69%).

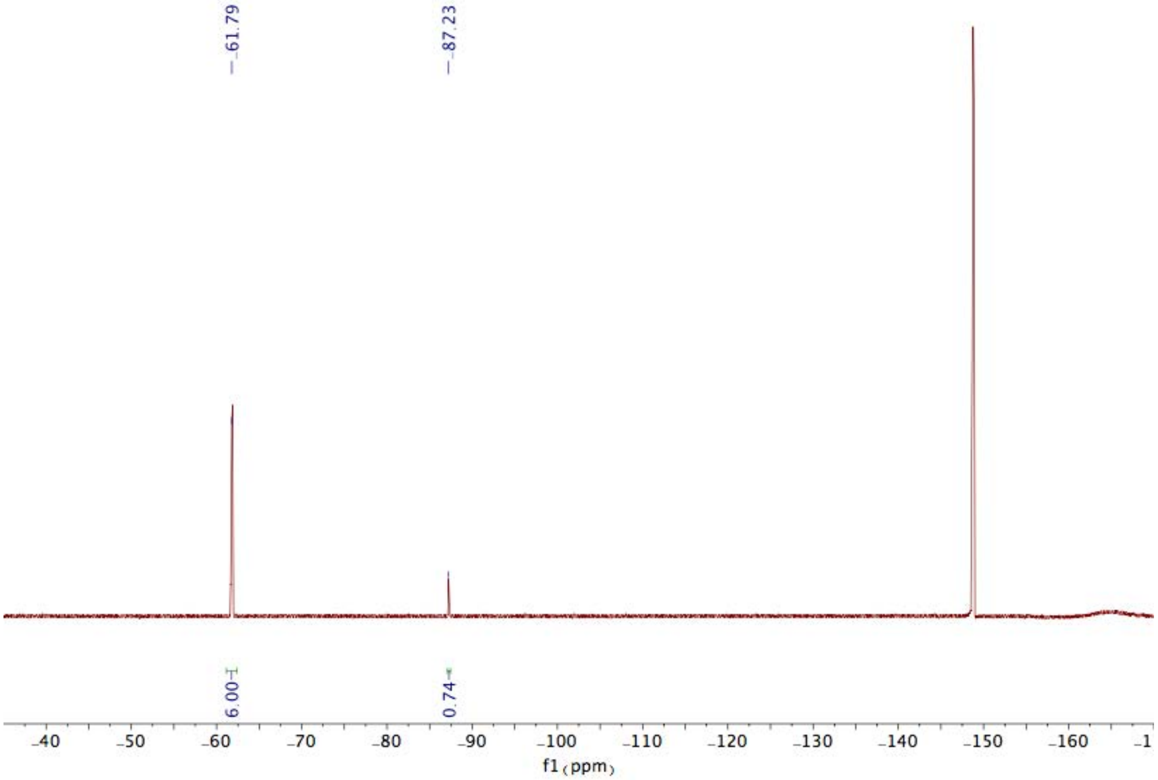
Spectral data are consistent with those reported in the literature: R. H. Cox, A. A. Bothner-By. *J. Phys. Chem.* **72**, 1646–1649 (1968).



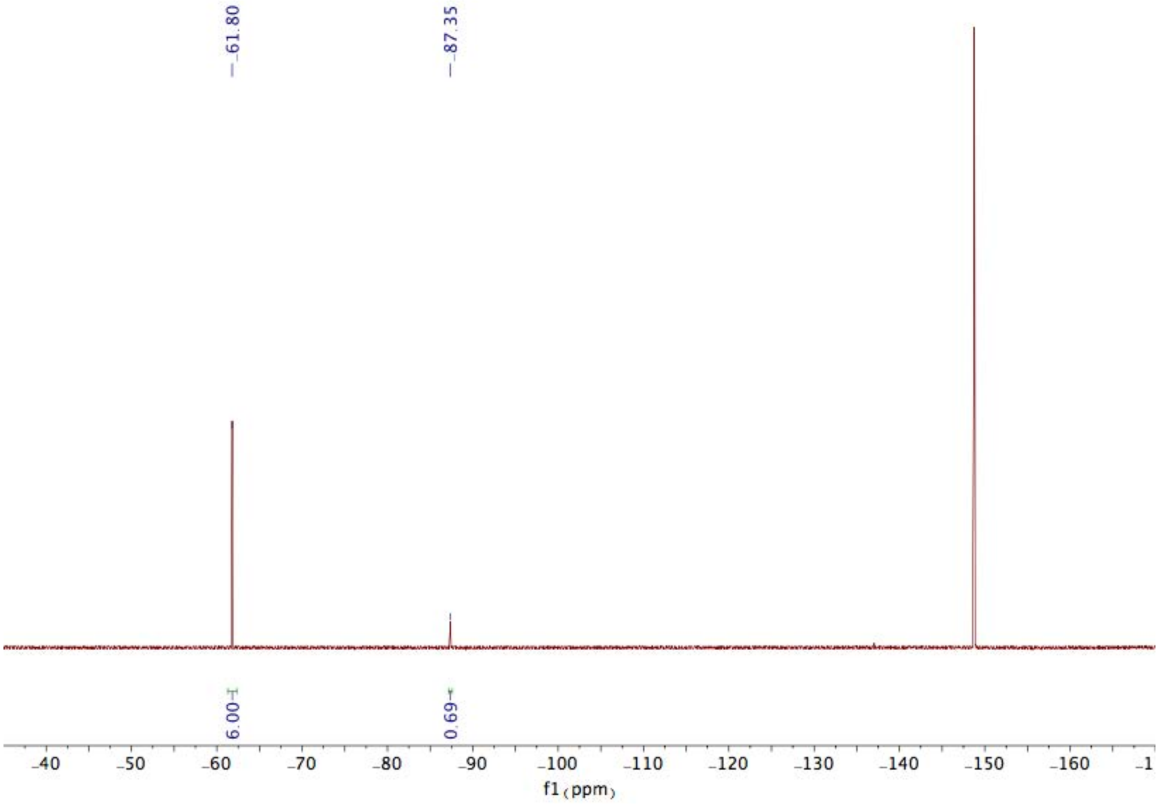
HRMS (GC-EI-TOF) m/z calcd. for $C_5H_5FN_2$ ([M*]$^+$) 112.04368, found 112.04389.



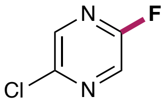
-61.80
-87.23
N
F
Me
N
F3C
Br
CF3
-87.3 ppm
-61.8 ppm
6.00
0.72
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-1
f1 (ppm)



-61.79
-87.23
6.00
0.74
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-1
f1 (ppm)



-61.80
-87.35
6.00
0.69
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
f1 (ppm)

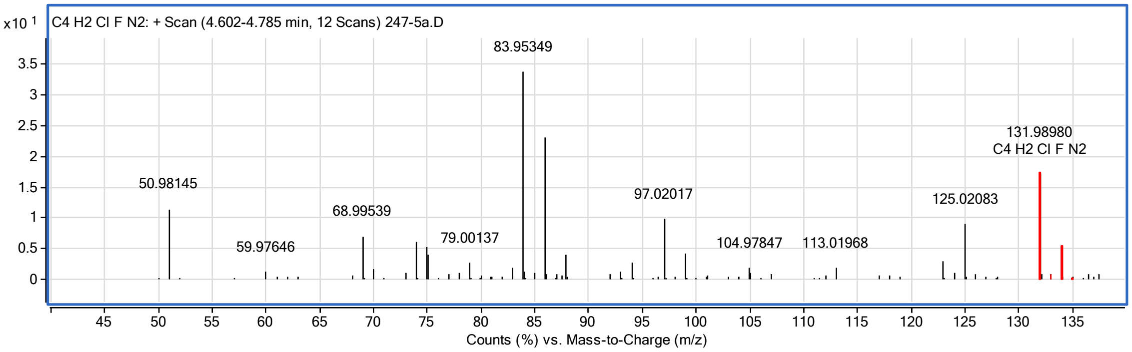


2-fluoro-5-chloropyrazine (51)

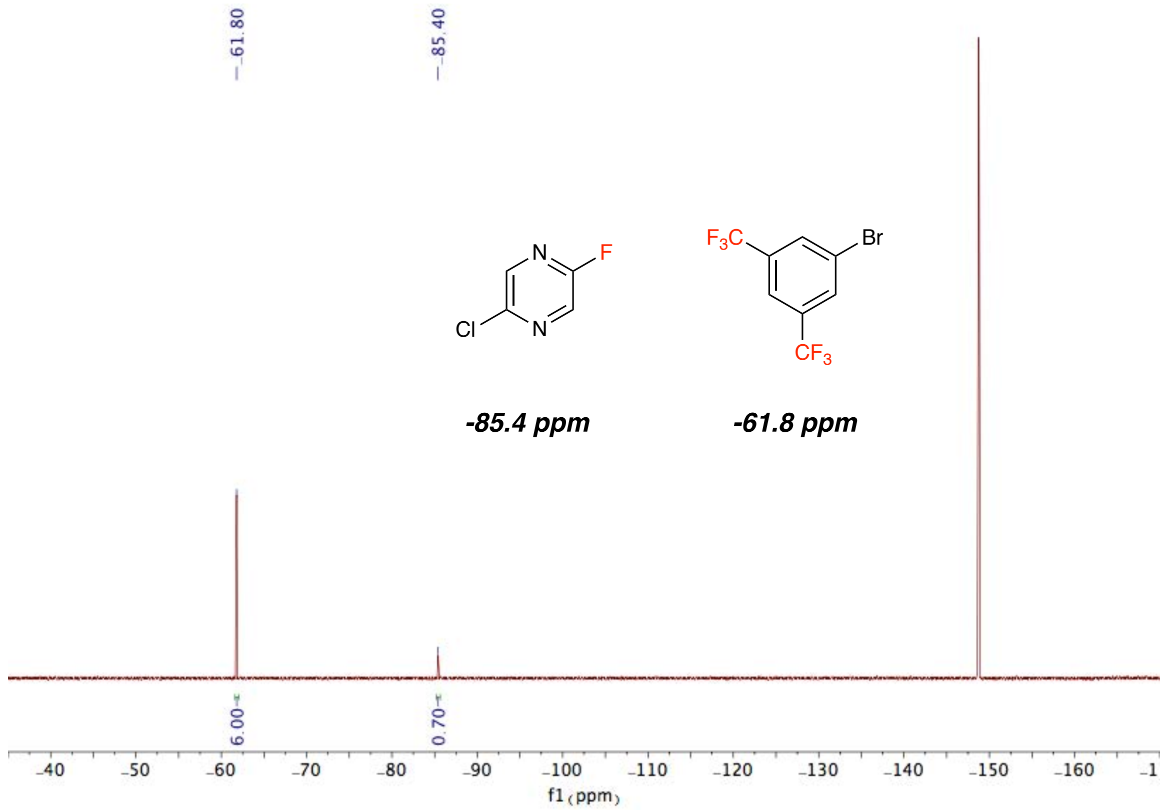
Prepared according to the general procedure **A** outlined above using NFTPT (228 mg, 1.0 mmol, 2.0 equiv.), [Cu(MeCN)$_4$]BF$_4$ (471 mg, 1.5 mmol, 3 equiv), and 5-chloropyrazine-2-carboxylic acid (79.3 mg, 0.5 mmol, 1 equiv) in MeCN (10 mL, 50 mM). Irradiation time: 24 h.

Yield was determined by ^{19}F NMR

1-bromo-3-5-bis(trifluoromethyl)benzene (87 µL, 0.5 mmol 1.0 equiv.) was added as the internal standard for ^{19}F NMR analysis (d_6-DMSO) (73% yield – average of three trials: 70%, 74%, and 75%).



HRMS (GC-EI-TOF) m/z calcd. for C$_4$H$_2$ClFN$_2$ ([M*]$^+$) 131.98905, found 131.98980.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-85.40
N
N
F
Cl
F3C
Br
CF3
-85.4 ppm
-61.8 ppm
6.00
0.70
-40
-50
-60
-70
-80
-90
-100
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-120
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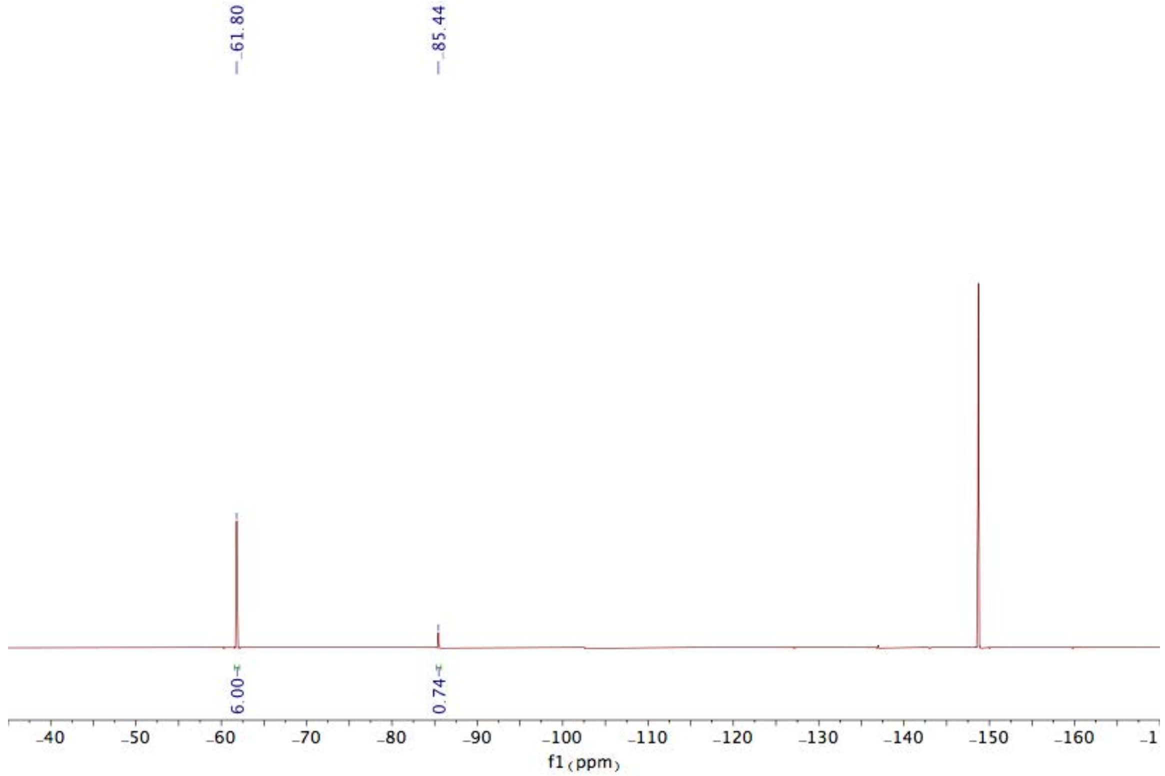
-140
-150
-160
-1
f1 (ppm)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6.00
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-150
-160
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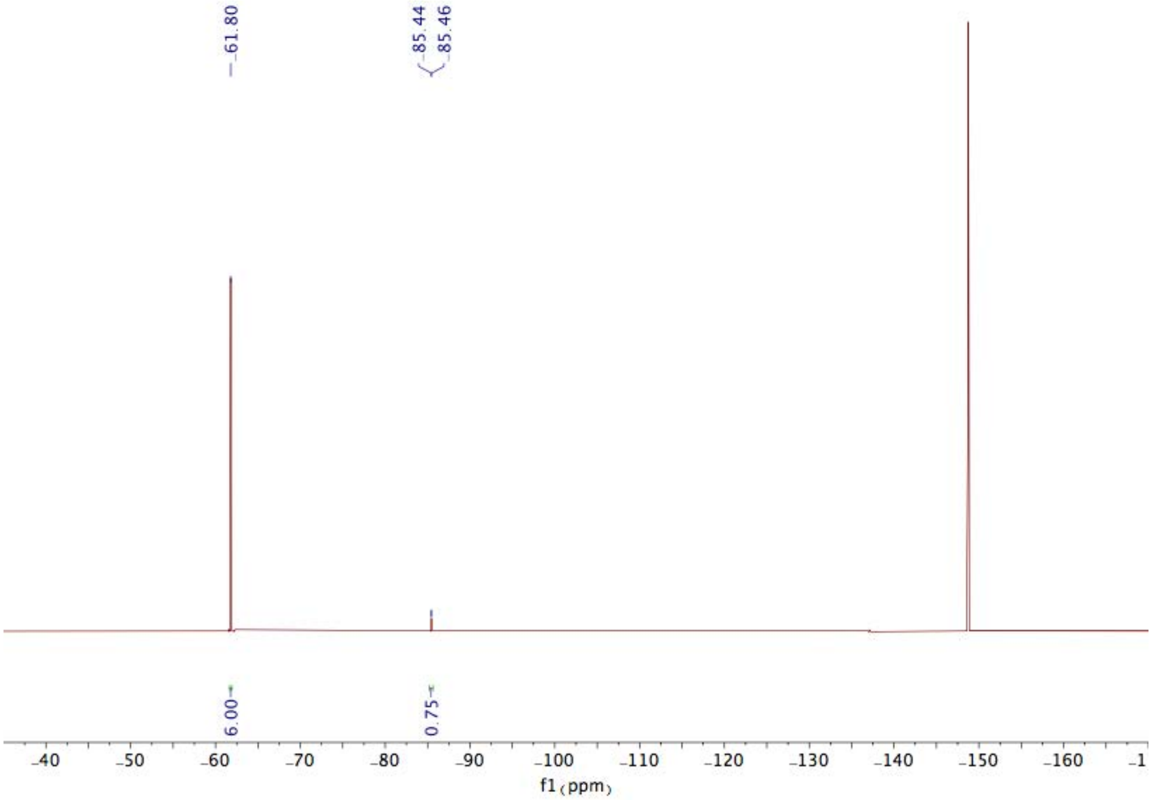
f1 (ppm)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-85.44
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6.00
0.75
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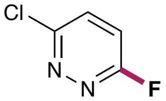
-150
-160
-1
f1 (ppm)



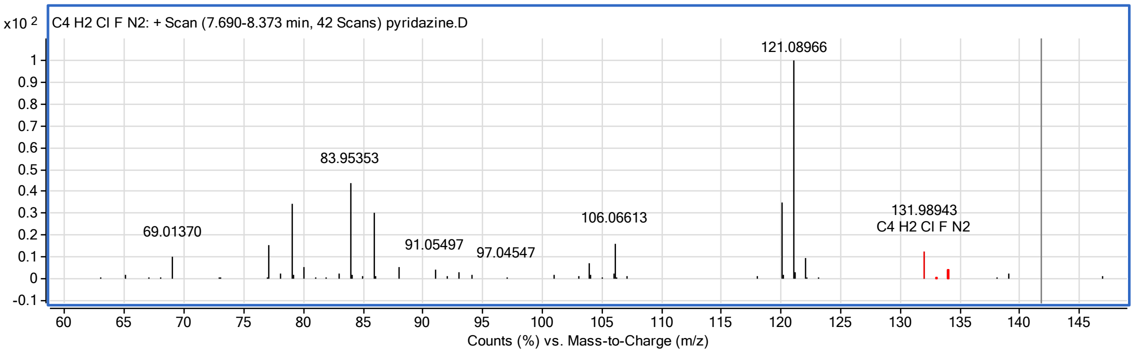
6-chloro-3-fluoropyridazine (52)

Prepared according to the general procedure **A** outlined above using NFTPT (228 mg, 1.0 mmol, 2.0 equiv.), [Cu(MeCN)$_4$]BF$_4$ (471 mg, 1.5 mmol, 3 equiv), and 6-chloropyridazine-3-acid (79.3 mg, 0.5 mmol, 1 equiv) in MeCN (10 mL, 50 mM). Irradiation time: 24 h.

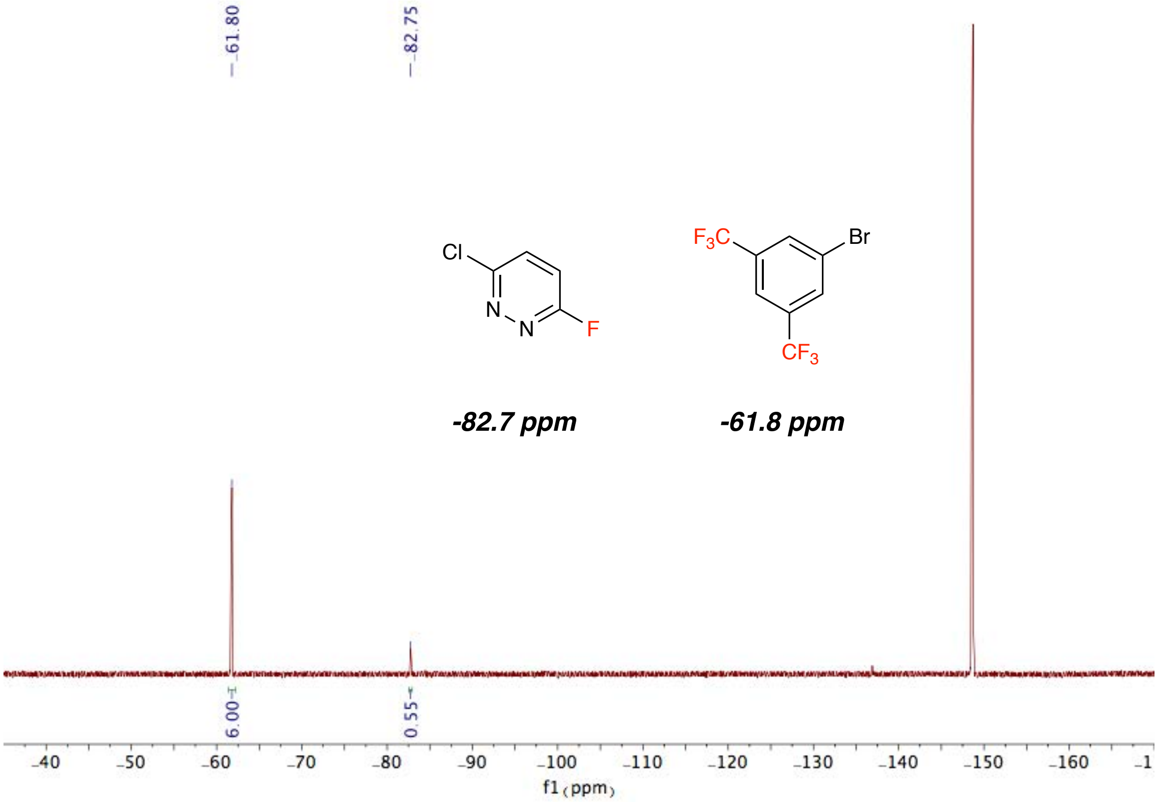
Yield was determined by ^{19}F NMR in triplicate due to instability of the desired product

1-bromo-3-5-bis(trifluoromethyl)benzene (87 µL, 0.5 mmol 1.0 equiv.) was added as the internal standard for ^{19}F NMR analysis (d_6-DMSO) (55% yield – average of three trials: 55% yield, 55% yield, and 55% yield).

Spectral data are consistent with those reported in the literature: M. Darabantu et al. *Tetrahedron.* **57**, 739–750 (2001).



HRMS (GC-EI-TOF) m/z calcd. for $C_4H_2ClFN_2$ ([M*]$^+$) 131.98905, found 131.98943.


-61.80
-82.75
Cl
N
N
F
F_3C
Br
CF_3
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-61.8 ppm
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0.55
-40
-50
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-80
-90
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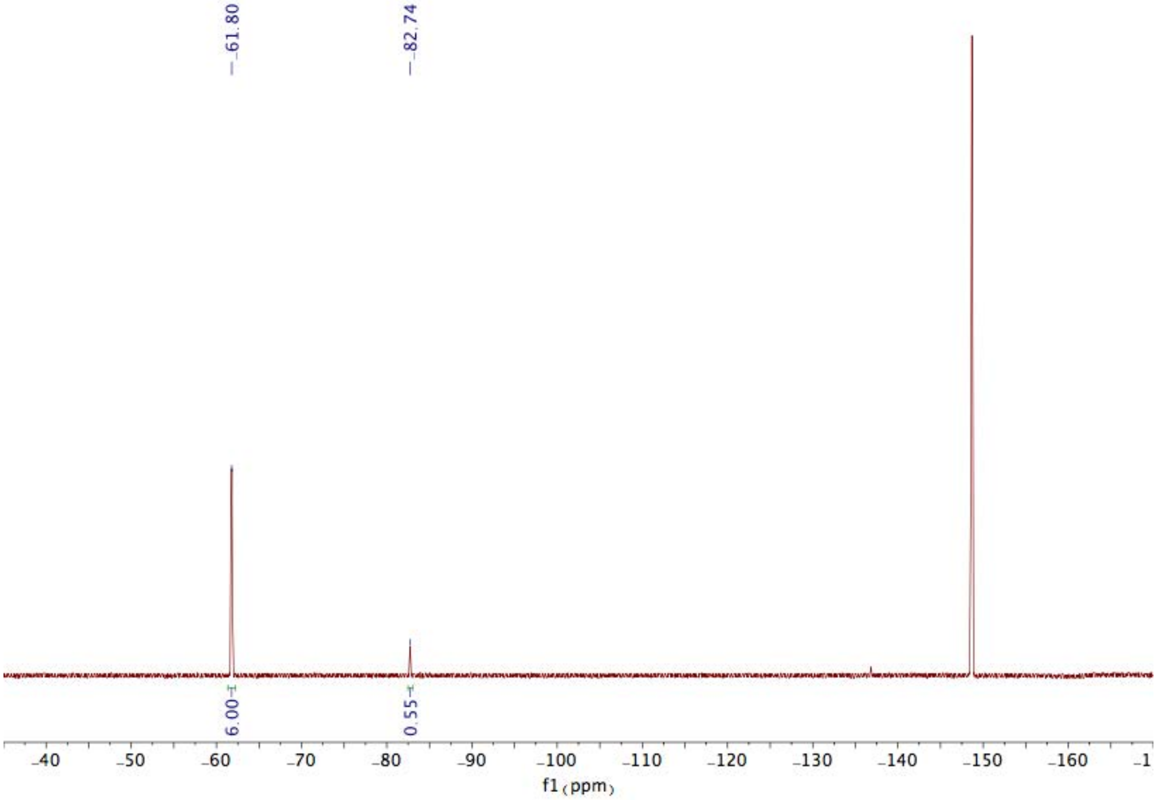
-140
-150
-160
-1
f1 (ppm)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-100
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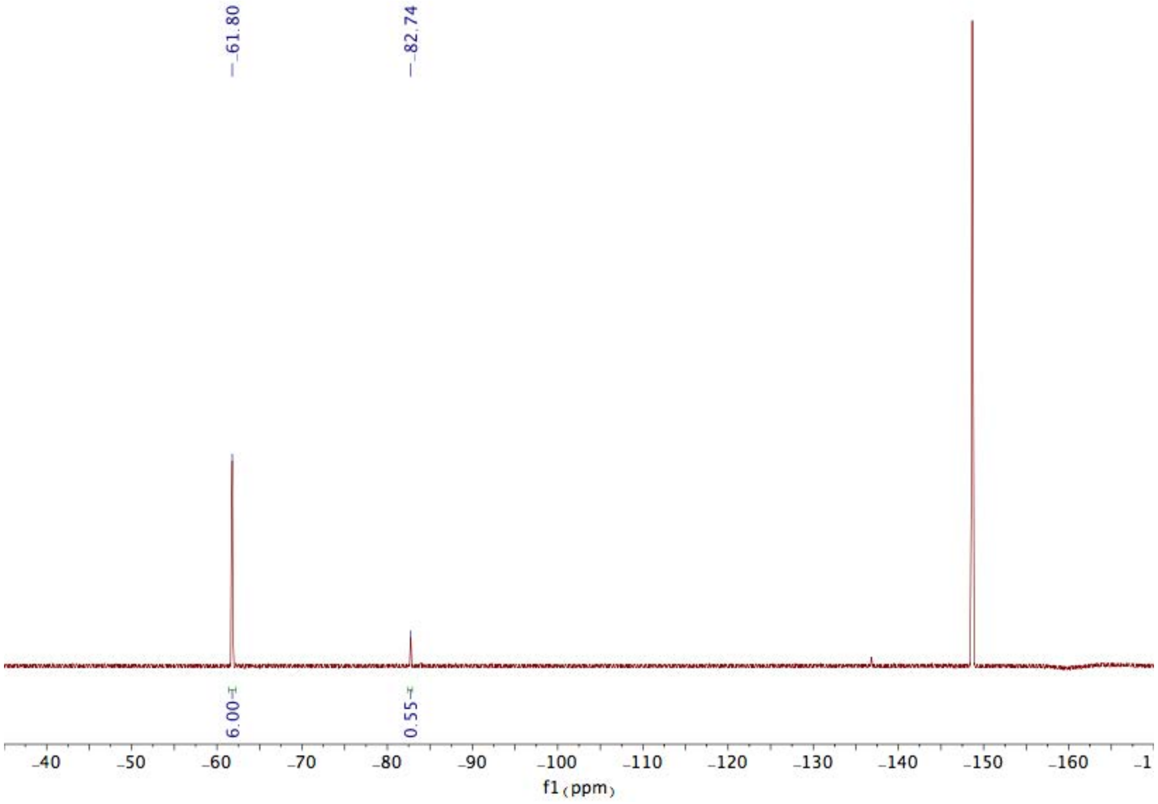
-150
-160
-1
f1 (ppm)



-61.80
-82.74
6.00
0.55
-40
-50
-60
-70
-80
-90
-100
-110
-120
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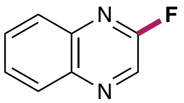
-160
-1
f1 (ppm)



2-fluoroquinoxaline (53)

Prepared according to the general procedure **A** outlined above using NFTPT (228 mg, 1.0 mmol, 2.0 equiv.), $[Cu(MeCN)_4]BF_4$ (471 mg, 1.5 mmol, 3 equiv), and 2-quinoxalinecarboxylic acid (87.1 mg, 0.5 mmol, 1 equiv) in MeCN (10 mL, 50 mM). Irradiation time: 24 h.

1-bromo-3-5-bis(trifluoromethyl)benzene (87 µL, 0.5 mmol 1.0 equiv.) was added as the internal standard for ^{19}F NMR analysis (d_6-DMSO) (75% yield)

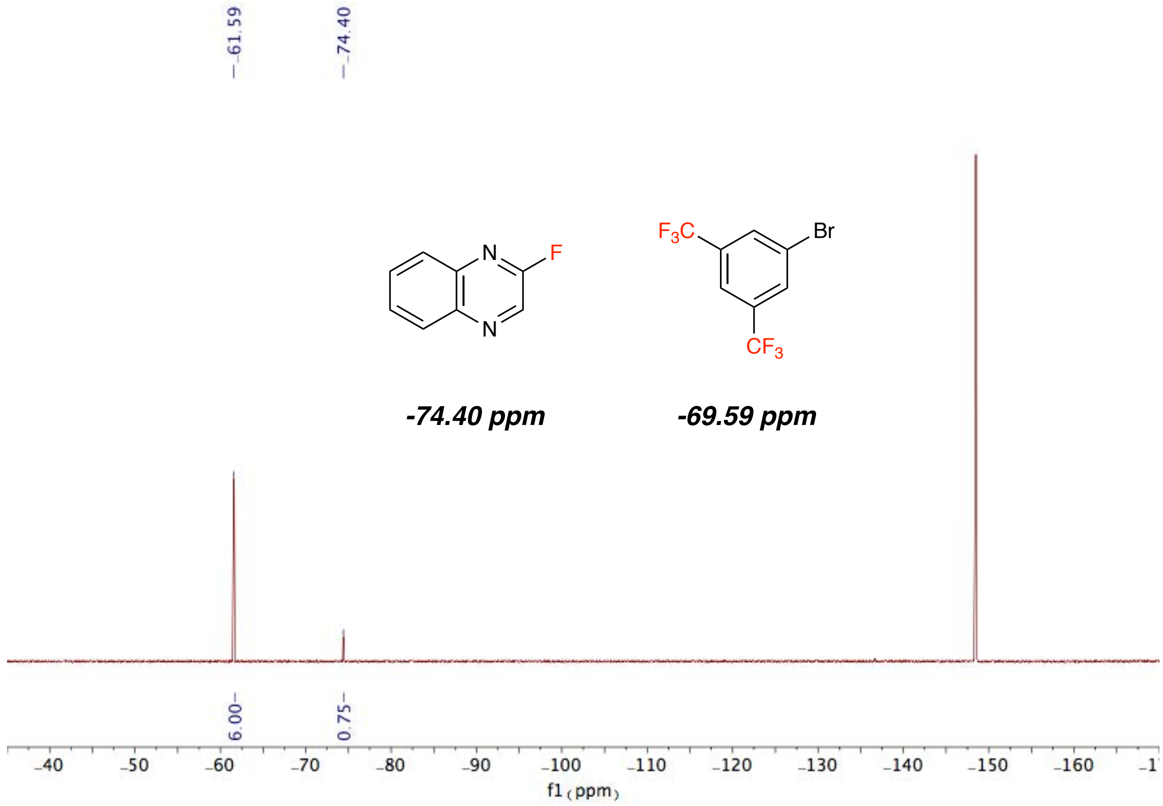
The final reaction mixture was stirred with tetrasodium EDTA (500 mg) and water (10 mL) for 30 minutes. The mixture was then extracted with 9:1 pentane:ether (5x20 mL). The combined organic layers were then dried over magnesium sulfate, filtered, and concentrated. The product was then purified via silica gel column chromatography (10% ether in pentane) to yield the pure product (49 mg, 0.33 mmol, 66% yield) as a clear oil.

^{1}H NMR (400 MHz, CDCl$_3$) δ 8.80 (s, 1H), 8.19 (d, *J* = 7.9 Hz, 1H), 8.00 (d, *J* = 8.0 Hz, 1H), 7.85 – 7.73 (m, 2H).

^{13}C NMR (125 MHz, CDCl$_3$) δ 156.49 (d, *J* = 257.3 Hz), 141.33 (d, *J* = 1.9 Hz), 139.52 (d, *J* = 11.0 Hz), 136.35, 136.01, 131.43, 129.24 (d, *J* = 2.7 Hz), 128.19 (d, *J* = 1.8 Hz).

^{19}F NMR (376 MHz, CDCl$_3$) δ -74.4 (s).

Spectral data are consistent with those reported in the literature: K. Makino, H. Yoshioka. *Heterocycles*, **26**, 1215-1220 (1987).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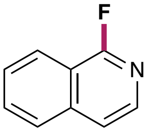
-74.40
N
N
F
F3C
Br
CF3
-74.40 ppm
-69.59 ppm
6.00
0.75
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
f1 (ppm)



1-fluoroisoquinoline (54)

Prepared according to the general procedure **A** outlined above using NFTPT (228 mg, 1.0 mmol, 2.0 equiv.), $[Cu(MeCN)_4]BF_4$ (471 mg, 1.5 mmol, 3 equiv), and 1-isoquinolinecarboxylic acid (86.6 mg, 0.5 mmol, 1 equiv) in MeCN (10 mL, 50 mM). Irradiation time: 12 h.

1-bromo-3-5-bis(trifluoromethyl)benzene (87 μL, 0.5 mmol 1.0 equiv.) was added as the internal standard for ^{19}F NMR analysis (*d*$_6$-DMSO) (58% yield)

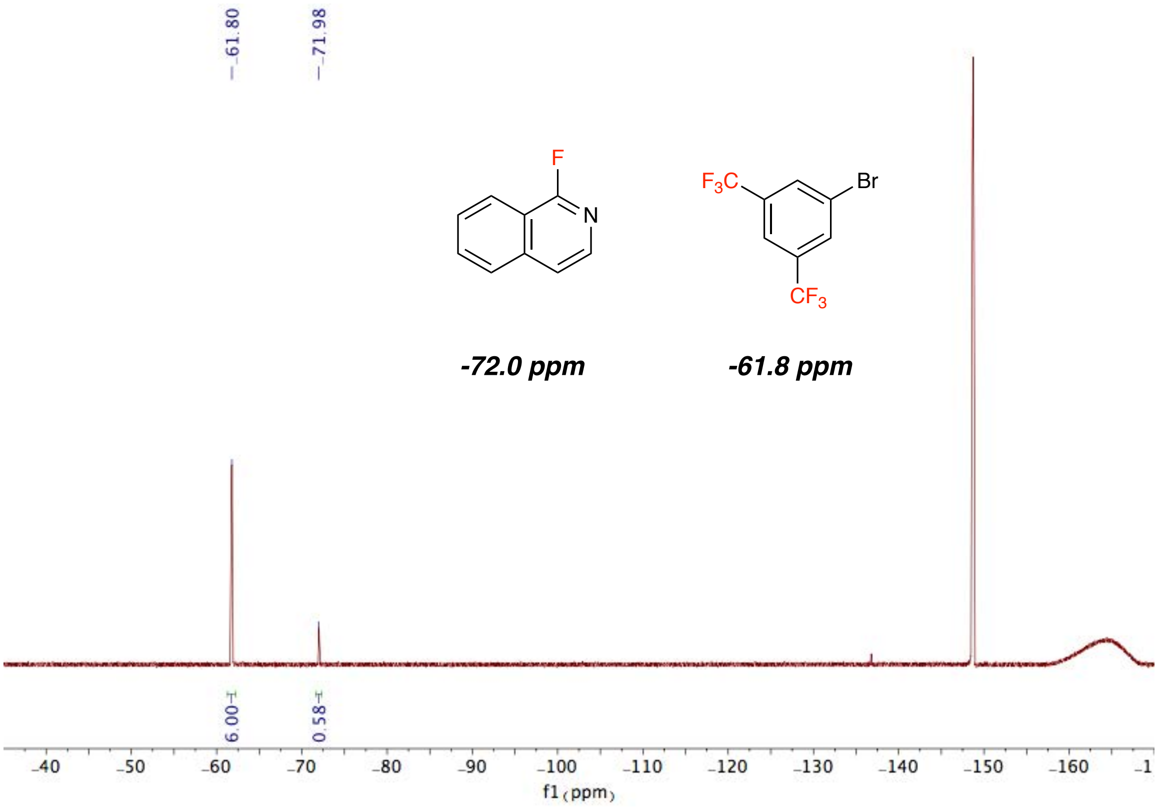
The final reaction mixture was stirred with tetrasodium EDTA (500 mg) and water (10 mL) for 30 minutes. The mixture was then extracted with 9:1 pentane:ether (5x20 mL). The combined organic layers were then dried over magnesium sulfate, filtered, and concentrated. The product was then purified via silica gel column chromatography (10% ether in pentane) to yield the pure product (37 mg, 0.25 mmol, 50%) as a clear oil.

Spectral data are consistent with those reported in the literature: S. Yamada, A. Gavryushin, P. Knochel. *Angew. Chem. Int. Ed.*, **49**, 2215-2218 (2010).

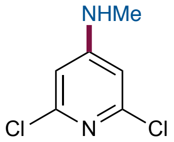
^{1}H NMR (500 MHz, CDCl$_3$) δ 8.20 (d, *J* = 8.3 Hz, 1H), 8.11 – 8.07 (s, 1H), 7.89 (d, *J* = 8.3 Hz, 1H), 7.79 (ddd, *J* = 8.3, 6.9, 1.2 Hz, 1H), 7.69 (ddd, *J* = 8.2, 6.7, 1.1 Hz, 1H), 7.56 (d, *J* = 5.7 Hz, 1H).

^{13}C NMR (125 MHz, CDCl$_3$) δ 159.93 (d, *J* = 246.8 Hz), 139.66 (d, *J* = 5.7 Hz), 139.13, 131.53, 127.98, 126.38 (d, *J* = 3.5 Hz), 123.22, 119.47, 117.87 (d, *J* = 29.6 Hz).

^{19}F NMR (376 MHz, CDCl$_3$) δ -71.12


-61.80
-71.98
F
N
F$_3$C
Br
CF$_3$
-72.0 ppm
-61.8 ppm
6.00
0.58
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-1
f1 (ppm)

24) One-pot functionalization of heteroaryl fluorides via S_NAr



2,6-dichloro-*N*-methylpyridin-4-amine (55)

From **2,6-dichloro-4-fluoropyridine (46)**. After irradiation, a solution of methyl amine in THF (7.5 mmol, 2.0 M, 5 mL) was added directly to the crude reaction. The mixture was stirred for a further 16 hours before being concentrated down to a total volume of ~5 mL. The solution was then stirred while diethyl ether (15 mL) was added. The resulting suspension was filtered through celite. The filtrate was then transferred to a separatory funnel containing an aqueous solution of tetrasodium EDTA (20 mL, 0.1 M). The layers were separated, and the aqueous layer was extracted with ethyl acetate (3x20 mL). The combined organic layers were then washed with brine, dried over magnesium sulfate, filtered, concentrated, and purified by silica gel chromatography (0-20% acetone in hexanes) to yield the pure product (69 mg, 0.39 mmol, 78% yield).

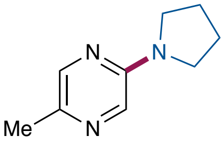
Spectral data are consistent with those found in the literature: M. Malavall et al. *New Journal of Chemistry*, **2016**, *40*, 9194 – 9204.

^{1}H NMR (400 MHz, $(CD_3)_2SO$) δ 7.27 (d, *J* = 5.5 Hz, 1H), 6.52 (s, 2H), 2.73 (d, *J* = 4.9 Hz, 3H).

^{13}C NMR (125 MHz, CD_3OD) δ 158.74, 149.83, 104.39, 27.95.

IR (film) ν_{max} 3253, 3119, 1588, 1441, 1170, 1143, 1100, 975, 835, 819, 807, 454 cm^{-1}.

HRMS (GC-EI-TOF) m/z calcd. for $C_6H_7Cl_2N^+$ ($[M+H]^+$) 176.9986, found 176.9978.



2-methyl-5-(pyrrolidin-1-yl)pyrazine (56)

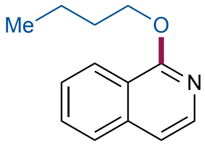
From **2-fluoro-5-methylpyrazine (48)**. After irradiation, pyrrolidine (15 equiv, 616 µL) was added to the crude reaction mixture. The mixture was then stirred at room temperature for 16 hours before volatiles were removed *in vacuo*. The crude oil was then dissolved in 1 M NH_4OH and stirred for 5 minutes before filtering through celite. The filtrate was then extracted with ethyl acetate (3x20 mL). The combined organic layers were then washed with brine (1x20 mL), dried over magnesium sulfate, filtered, concentrated, and purified by silica gel column chromatography (0–40% acetone in hexanes). The desired fractions were pooled and concentrated to yield the desired product (55 mg, 34 mmol, 67%) as a beige solid.

^{1}H NMR (500 MHz, $(CD_3)_2CO$) δ 7.89 (s, 1H), 7.81 (s, 1H), 3.48 – 3.41 (m, 4H), 2.31 (s, 3H), 2.05 – 1.97 (m, 4H).

^{13}C NMR (125 MHz, $(CD_3)_2CO$) δ 151.73, 140.66, 138.92, 129.08, 46.09, 25.11, 19.15.

IR (film) ν_{max} 2916, 2863, 1587, 1514, 1480, 1457, 1408, 1353, 1306, 1194, 1158, 1020 cm^{-1}.

HRMS (GC-EI-TOF) m/z calcd. for $C_9H_{14}N_3^+$ ($[M+H]^+$) 164.1188, found 164.1183.



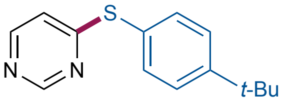
1-butoxyisoquinoline (57)

From **1-fluoroisoquinoline (52)**. After irradiation, 1-butanol (10 equiv, 0.46 mL) and potassium *tert*-butoxide (10 equiv, 5 mmol, 560 mg) were added sequentially to the crude reaction mixture. The resulting suspension was stirred for 5 hours at room temperature before being filtered through celite. The filtrate was then concentrated, and the resulting crude oil was dissolved in ethyl acetate (20 mL) and washed with an aqueous solution of tetrasodium EDTA (20 mL, 0.1 M). The aqueous layer was then extracted with ethyl acetate (2x20 mL). The combined organic layers were washed with brine, dried over magnesium sulfate, filtered, concentrated, and purified by silica gel column chromatography (0–20% acetone in hexanes) to yield the pure product (54 mg, 0.27 mmol, 54%) as a clear oil.

^{1}H NMR (500 MHz, $(CD_3)_2SO$) δ 8.17 (dd, *J* = 8.3, 1.2 Hz, 1H), 7.99 (d, *J* = 5.9 Hz, 1H), 7.88 (d, *J* = 8.2 Hz, 1H), 7.79 – 7.72 (m, 1H), 7.62 (ddd, *J* = 8.2, 6.9, 1.2 Hz, 1H), 7.36 (d, *J* = 5.8 Hz, 1H), 4.46 (t, *J* = 6.5 Hz, 2H), 1.87 – 1.74 (m, 2H), 1.56 – 1.44 (m, 2H), 0.96 (t, *J* = 7.4 Hz, 3H).

^{13}C NMR (125 MHz, $(CD_3)_2SO$) δ 159.85, 139.69, 137.47, 130.78, 127.05, 126.32, 123.46, 118.88, 114.73, 65.48, 30.56, 18.97, 13.78.

Spectral data are consistent with those reported in the literature: Lian, Y.; Coffey, S. B.; Li, Q.; Londregan, A. T. *Org Lett.,* **18**, 1362–1365 (2016).



4-((4-(*tert*-butyl)phenyl)thio)pyrimidine (58)

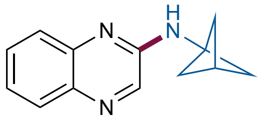
From **4-fluoropyrimidine (45)**. After irradiation, 4-t*ert*-butyl thiophenol (5 equiv, 0.42 mL) and DIPEA (5 equiv, 0.44 mL) was added to the crude reaction mixture. The mixture was heated to 80 ºC for 3 hours. Upon complete consumption of the aryl fluoride, the contents of the vial were concentrated down to a total volume of ~5 mL *in vacuo.* Diethyl ether (~30 mL) was then added to the crude mixture before filtering through a pad a celite. The filtrate was then transferred to a separatory funnel and saturated sodium bicarbonate (30 mL) was added. The aqueous layer was then extracted with diethyl ether (3x30 mL). The combined organic layers were then washed with brine, dried over magnesium sulfate, filtered, concentrated, and purified by column chromatography (0-15% ethyl acetate in hexanes) to afford the pure product (66 mg, 0.27 mmol, 54%) as a beige solid.

^{1}H NMR (500 MHz, $(CD_3)_2CO$) δ 8.85 (s, 1H), 8.44 (d, *J* = 5.6 Hz, 1H), 7.63 (d, *J* = 8.3 Hz, 2H), 7.59 (d, *J* = 8.2 Hz, 2H), 6.89 (d, *J* = 5.5 Hz, 1H), 1.38 (s, 4H).

^{13}C NMR (125 MHz, $(CD_3)_2CO$) δ 172.45, 157.91, 156.15, 153.61, 135.44, 127.19, 124.27, 117.13, 34.58, 30.56.

IR (film) ν_{max} 2960, 1555, 1531, 1436, 1375, 833, 755, 740, 664, 500 cm^{-1}.

HRMS (GC-EI-TOF) m/z calcd. for $C_{14}H_{17}N_2S^+$ ($[M+H]^+$) 245.1112, found 245.1112.



N**-(bicyclo[1.1.1]pentan-1-yl)quinoxalin-2-amine (59)**

From **2-fluoroquinoxaline (51)**. The final reaction mixture was stirred with tetrasodium EDTA (500 mg) and water (10 mL) for 30 minutes. The mixture was then extracted with 9:1 pentane:ether (5x20 mL). The combined organic layers were then dried over magnesium sulfate, filtered, and concentrated. The resulting crude material was then dissolved in 2.5 mL DMSO and 1-bicyclo[1.1.1]pentylamine hydrochloride (1.5 equiv, 90 mg) and DIPEA (3.0 equiv, 0.26 mL) were added. The mixture was stirred for 16 hours at room temperature. The reaction mixture was then diluted with EtOAc (20 mL) and washed with water (3x20 mL) and brine (1x20 mL). The organic layer was then dried over magnesium sulfate, filtered, concentrated, and purified by silica gel chromatography (0-5% MeOH in DCM) to yield the pure product (63 mg, 0.30 mmol, 60%) as an off-white solid.

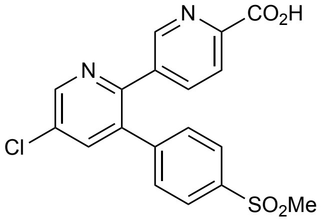
^{1}H NMR (500 MHz, $(CD_3)_2CO$) δ 8.27 (s, 1H), 7.79 (dd, *J* = 8.2, 1.5 Hz, 1H), 7.64 (dd, *J* = 8.4, 1.5 Hz, 1H), 7.56 (ddd, *J* = 8.3, 6.9, 1.5 Hz, 1H), 7.36 (ddd, *J* = 8.3, 6.9, 1.5 Hz, 1H), 7.32 (s, 1H), 2.51 (s, 1H), 2.24 (s, 6H).

^{13}C NMR (125 MHz, $(CD_3)_2CO$) δ 152.85, 142.45, 139.56, 137.63, 129.88, 129.18, 127.07, 124.31, 52.80, 50.73, 25.43.

IR (film) ν_{max} 3252, 2998, 2872, 1584, 1531, 1489, 1407, 1302, 1281, 1191, 756, 605, 552 cm^{-1}

HRMS (GC-EI-TOF) m/z calcd. for $C_{13}H_{14}N_3^+$ ([M+H]$^+$) 212.1188, found 212.1185.

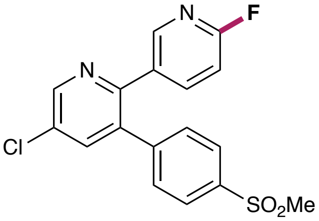
25) Decarboxylative functionalization of biorelevant molecules



5-(5-chloro-3-(4-(methylsulfonyl)phenyl)-2-pyridyl)picolinic acid (**S3**) was synthesized according to previous literature reports.[5]

^{1}H NMR (500 MHz, $(CD_3)_2SO$) δ 8.90 (d, J = 2.4 Hz, 1H), 8.55 (d, J = 2.1 Hz, 1H), 8.20 (d, J = 2.4 Hz, 1H), 7.99 (d, J = 8.1 Hz, 1H), 7.92 (d, J = 8.5 Hz, 2H), 7.88 (dd, J = 8.1, 2.3 Hz, 1H), 7.58 (d, J = 8.5 Hz, 2H), 3.27 (s, 3H).

^{13}C NMR (125 MHz, $(CD_3)_2CO$) δ 164.59, 151.45, 149.73, 148.17, 146.66, 142.85, 141.23, 138.99, 138.22, 138.09, 136.51, 131.50, 130.75, 127.73, 123.48, 43.32.



5-chloro-6'-fluoro-3-(4-(methylsulfonyl)phenyl)-2,3'-bipyridine (60)

Prepared according to the general fluorination procedure **A** outlined above using NFTPT (228 mg, 1.0 mmol, 2.0 equiv.), $[Cu(MeCN)_4]BF_4$ (471 mg, 1.5 mmol, 3 equiv), and 5-chloro-3-(4-(methylsulfonyl)phenyl)-[2,3'-bipyridine]-6'-carboxylic acid (194.4 mg, 0.5 mmol, 1 equiv) in MeCN (10 mL, 50 mM). Irradiation time: 36 h. 1-bromo-3-5-bis(trifluoromethyl)benzene (87 µL, 0.5 mmol 1.0 equiv.) was added as the internal standard for ^{19}F NMR analysis (*d*$_6$-DMSO) (56% yield)

The final reaction mixture was stirred with tetrasodium EDTA (500 mg) and water (10 mL) for 30 minutes. The mixture was then extracted with 3:1 pentane:ether (5x20 mL). The combined organic layers were then dried over magnesium sulfate, filtered, and concentrated. The product was then purified via silica gel column chromatography (0-20% acetone in hexanes) to yield the pure product (87 mg, 0.24 mmol, 48%) as a white solid.

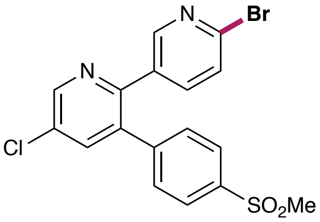
^{1}H NMR (500 MHz, $(CD_3)_2CO$) δ 8.79 (d, *J* = 2.4 Hz, 1H), 8.18 (d, *J* = 2.4 Hz, 1H), 8.06 (d, *J* = 2.4 Hz, 1H), 8.01 – 7.95 (m, 2H), 7.94 – 7.87 (m, 1H), 7.67 – 7.61 (m, 2H), 7.04 (dd, *J* = 8.5, 2.9 Hz, 1H), 3.18 (s, 3H).

^{13}C NMR (125 MHz, $(CD_3)_2CO$) δ 163.10 (d, *J* = 238.1 Hz), 151.48, 148.72 (d, *J* = 15.8 Hz), 147.96, 143.13, 142.96 (d, *J* = 8.3 Hz), 141.09, 138.06, 136.05, 132.99 (d, *J* = 4.7 Hz), 130.97, 130.68, 127.68, 108.76 (d, *J* = 38.2 Hz), 43.32.

^{19}F NMR (376 MHz, $(CD_3)_2SO$) δ -68.89 (dd, *J* = 7.8, 2.9 Hz, 1F).

IR (film) ν_{max} 1593, 1485, 1429, 1405, 1293, 1277, 1243, 1146, 1127, 1086, 960, 829, 784, 543, 533, 502 cm^{-1}.

HRMS (GC-EI-TOF) m/z calcd. for $C_{17}H_{13}ClFN_2O_2S$ ($[M+H]^+$) 363.0370, found 363.0368.



5-chloro-6'-bromo-3-(4-(methylsulfonyl)phenyl)-2,3'-bipyridine (61)

Prepared according to the general bromination procedure outlined above using DBDMH (64.3 mg, 0.225 mmol, 1.0 equiv.), NFTPT (68.1 mg, 0.3 mmol, 1.0 equiv.), $[Cu(MeCN)_4]BF_4$ (94.4 mg, 0.3 mmol, 1.0 equiv), and 5-chloro-3-(4-(methylsulfonyl)phenyl)-[2,3'-bipyridine]-6'-carboxylic acid (116.6 mg, 0.3 mmol, 1.0 equiv.) in MeCN (5 mL, 50 mM). Irradiation time: 12 h.

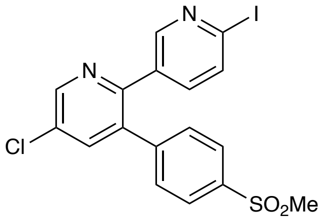
The final reaction mixture was stirred with tetrasodium EDTA (200 mg) and water (10 mL) for 30 minutes. The mixture was then extracted with ethyl acetate (3x20 mL). The combined organic layers were then washed with brine (20 mL), dried over magnesium sulfate, filtered, and concentrated. The product was then purified via silica gel column chromatography (0-20% acetone in hexanes) to yield the pure product (93.9 mg, 0.3 mmol, 74%) as a white solid.

^{1}H NMR (500 MHz, $(CD_3)_2CO$) δ 8.80 (d, *J* = 2.3 Hz, 1H), 8.34 (dd, *J* = 2.5, 0.7 Hz, 1H), 8.07 (d, *J* = 2.4 Hz, 1H), 8.02 – 7.96 (m, 2H), 7.70 – 7.62 (m, 3H), 7.56 (dd, *J* = 8.3, 0.8 Hz, 1H), 3.18 (s, 3H).

^{13}C NMR (125 MHz, $(CD_3)_2CO$) δ 151.32, 150.98, 148.07, 142.99, 141.46, 141.19, 140.07, 138.17, 136.15, 134.23, 131.17, 130.67, 127.73, 127.42, 43.31.

IR (film) ν_{max} 1293, 1144, 1086, 778, 773, 585, 552, 543, 523, 483 cm^{-1}.

HRMS (GC-EI-TOF) m/z calcd. for $C_{17}H_{13}BrClN_2O_2S$ ([M+H]$^+$) 422.9570, found 422.9568.



5-chloro-6'-iodo-3-(4-(methylsulfonyl)phenyl)-2,3'-bipyridine (62):

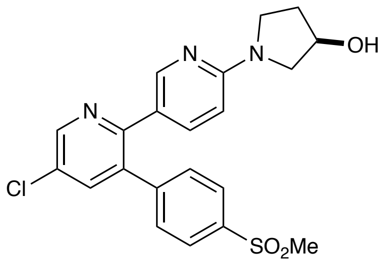
Prepared according to the general iodination procedure outlined above using NFTPT (68.1 mg, 0.3 mmol, 1.0 equiv.), $[Cu(MeCN)_4]BF_4$ (94.4 mg, 0.3 mmol, 1.0 equiv.), NIS (67.5 mg, 0.3 mmol, 1.0 equiv.), and 5-chloro-3-(4-(methylsulfonyl)phenyl)-[2,3'-bipyridine]-6'-carboxylic acid (116.6 mg, 0.3 mmol, 1.0 equiv.) in MeCN (5 mL, 0.1 M). Irradiation time: 12 h. Purification by flash chromatography (gradient 0–50% EtOAc in hexane) afforded an impure mixture of the desired product and undesired 5-chloro-6'-fluoro-3-(4-(methylsulfonyl)phenyl)-2,3'-bipyridine. The mixture of products was purified by reverse phase column chromatography (20–100% acetonitrile in water, 0.1% formic acid modifier). The desired fractions were pooled and volatiles were removed *in vacuo*. The remaining water was transferred to a separatory funnel containing 10 mL of saturated aqueous sodium bicarbonate and 10 mL ethyl acetate. The layers were separated and the aqueous layer was extracted with ethyl acetate (3 x 10 mL). The combined organic layers were washed with brine, dried over magnesium sulfate, filtered, and concentrated to afford the pure product (77.2 mg, 0.16 mmol, 55% yield) as a white solid.

^{1}H NMR (500 MHz, $(CD_3)_2CO$) δ 8.79 (d, *J* = 2.3 Hz, 1H), 8.33 (d, *J* = 2.5 Hz, 1H), 8.06 (d, *J* = 2.3 Hz, 1H), 8.02 – 7.96 (m, 2H), 7.79 (d, *J* = 8.2 Hz, 1H), 7.68 – 7.62 (m, 2H), 7.43 (dd, *J* = 8.2, 2.6 Hz, 1H), 3.18 (s, 3H).

^{13}C NMR (126 MHz, $(CD_3)_2CO$) δ 151.48, 151.44, 143.02, 141.18, 138.98, 138.19, 136.12, 134.41, 134.22, 131.13, 130.66, 127.73, 117.53, 43.30.

IR (film) νmax 2921, 2853, 1570, 1550, 1309, 1150, 1122, 1075, 956, 837, 775, 767, 588, 550, 541, 523 cm^{-1}.

HRMS (GC-EI-TOF) m/z calcd. for C17H12ClIN2O2S ($[M+H]^+$) 470.94309, found 470.94231.



(*R*)-1-(5-chloro-3-(4-(methylsulfonyl)phenyl)-[2,3'-bipyridin]-6'-yl)pyrrolidin-3-ol (63):

Prepared according to the general fluorination procedure outlined above using NFTPT (91.2 mg, 0.4 mmol, 2.0 equiv.), $[Cu(MeCN)_4]BF_4$ (189 mg, 0.6 mmol, 3 equiv.), and 5-chloro-3-(4-(methylsulfonyl)phenyl)-[2,3'-bipyridine]-6'-carboxylic acid (77.8 mg, 0.2 mmol, 1 equiv.) in MeCN (10 mL, 50 mM). Irradiation time: 36 h.

After irradiation, (*R*)-pyrrolidin-3-ol (348.5 mg, 4.0 mmol, 20 equiv.) and DIPEA (0.697 mL, 4.0 mmol, 20 equiv.) were added sequentially to the crude reaction mixture. The resulting mixture was heated to 80 ºC for 48 hours. After the reaction was complete, volatiles were removed *in vacuo* and the resulting crude oil was dissolved in ethyl acetate (20 mL) and transferred to a separatory funnel containing 20 mL saturated aqueous sodium bicarbonate. The two layers were then filtered through celite before being separated. The aqueous layer was then extracted with ethyl acetate (2x20 mL). The combined organic layers were washed with brine, dried over magnesium sulfate, filtered, concentrated, and purified by reverse phase column chromatography (0–100% acetonitrile in water, 0.1% formic acid modifier). The desired fractions were pooled and volatiles were removed *in vacuo*. The remaining water was transferred to a separatory funnel containing 10 mL of saturated aqueous sodium bicarbonate and 20 mL ethyl acetate. The layers were separated and the aqueous layer was extracted with ethyl acetate (3x20 mL). The combined organic layers were washed with brine, dried over magnesium sulfate, filtered, and concentrated to afford the pure product (31.0 mg, 0.072 mmol, 36% yield) as a beige solid.

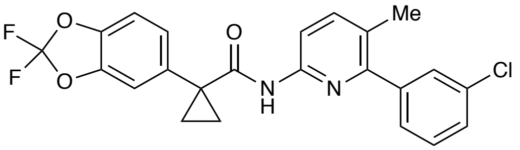
^{1}H NMR (500 MHz, $(CD_3)_2SO$) δ 8.73 (d, *J* = 2.4 Hz, 1H), 7.98 (d, *J* = 2.4 Hz, 1H), 7.96 (d, *J* = 2.3 Hz, 1H), 7.94 (d, *J* = 8.4 Hz, 2H), 7.58 (d, *J* = 8.4 Hz, 2H), 7.40 (dd, *J* =

8.8, 2.4 Hz, 1H), 6.35 (d, *J* = 8.8 Hz, 1H), 5.00 (s, 1H), 4.36 (s, 1H), 3.43 (m, 3H), 3.27 (m, 4H), 1.99 (dtd, *J* = 13.1, 8.8, 4.6 Hz, 1H), 1.92 – 1.83 (m, 1H).

^{13}C NMR (126 MHz, $(CD_3)_2SO$) δ 156.62, 153.52, 149.78, 147.90, 144.31, 140.41, 138.49, 138.46, 134.73, 130.82, 129.08, 127.73, 121.66, 105.84, 69.50, 55.38, 45.00, 43.79, 33.90.

IR (film) νmax 3168 (br.), 2923, 2778, 1608, 1518, 1422, 1353, 1307, 1146, 833, 782, 772, 586, 522 cm^{-1}.

HRMS (GC-EI-TOF) m/z calcd. for C21H20ClN3O3S ($[M+H]^+$) 430.09921, found 430.09964.



3-{6-[1-(2,2-difluoro-2H-1,3-benzodioxol-5-yl)cyclopropaneamido]-3-methylpyridin-2-yl}chlorobenzene (64)

Prepared according to the general chlorination procedure outlined above using $[Cu(MeCN)_4]BF_4$ (157.3 mg, 0.5 mmol, 1.0 equiv.), $ZnCl_2$ (68 mg, 0.5 mmol, 1 equiv.), NFTPT (170 mg, 0.75 mmol, 1.5 equiv.), and Lumacaftor (226.2 mg, 0.5 mmol, 1 equiv) in MeCN (5 mL, 0.1 M). Irradiation time: 36 h.

The final reaction mixture was stirred with tetrasodium EDTA (200 mg) and water (3 mL) for 30 minutes. The mixture was then transferred to a separatory funnel before water (15 mL) was added. The aqueous layer was then extracted with 3:1 pentane:ether (3x20 mL). The combined pentane/ether layers were then dried over magnesium sulfate, filtered, concentrated, and purified by silica column chromatography (0-100% DCM in hexanes) to yield the 95% pure product (94 mg, 0.21 mmol, 42%) as a white solid. An analytical sample was prepared by iterative silica column chromatography.

^{1}H NMR (500 MHz, $(CD_3)_2CO$) δ 7.98 (s, 1H), 7.95 (d, *J* = 8.4 Hz, 1H), 7.57 (d, *J* = 8.4 Hz, 1H), 7.40 (d, *J* = 1.8 Hz, 1H), 7.35 – 7.22 (m, 5H), 7.19 (d, *J* = 8.2 Hz, 1H), 2.15 (s, 3H), 1.51 (q, *J* = 3.9 Hz, 2H), 1.10 (q, *J* = 3.9 Hz, 2H).

^{13}C NMR (125 MHz, $(CD_3)_2CO$) δ 171.24, 154.56, 149.38, 143.69, 143.11, 142.12, 140.85, 136.01, 133.40, 131.69 (t, *J* = 252.8 Hz), 129.63, 128.80, 127.83, 127.40, 127.17, 126.51, 112.71, 112.55, 110.19, 31.05, 18.28, 16.20.

^{19}F NMR (376 MHz, $(CD_3)_2CO$) δ -50.94 (s, 2F).

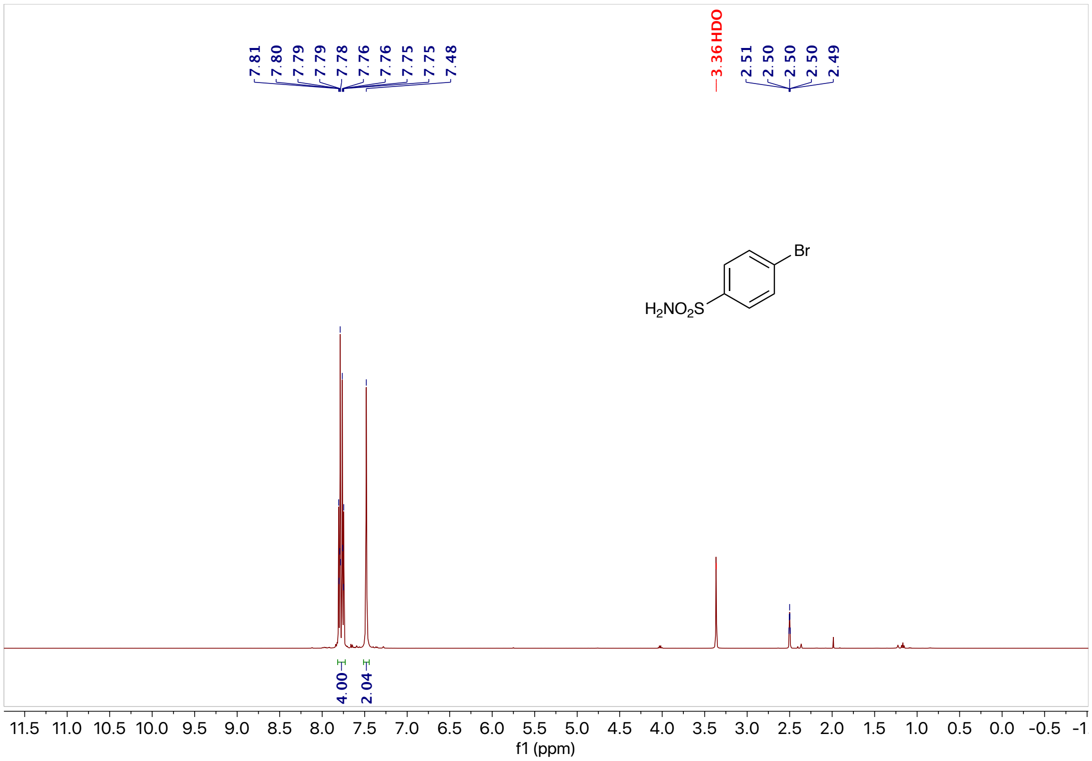
IR (film) ν_{max} 1672, 1499, 1370, 1234, 1142, 1032, 792, 759, 701, 628 cm^{-1}.

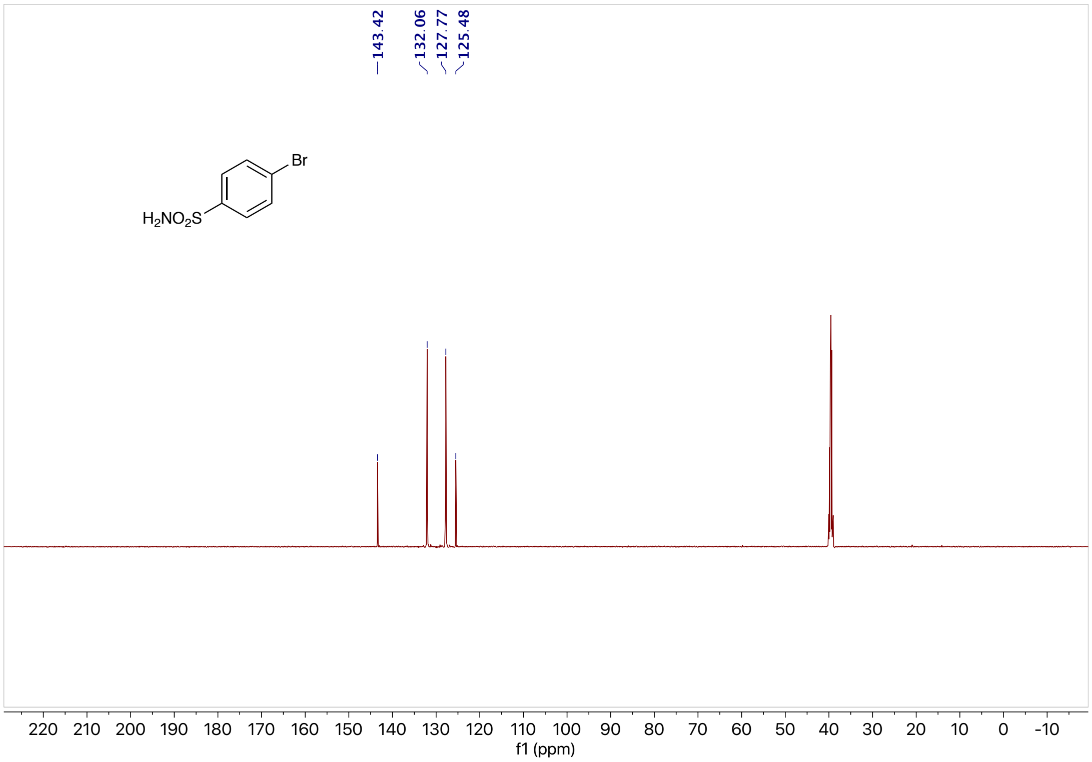
HRMS (GC-EI-TOF) m/z calcd. for $C_{23}H_{18}ClF_2N_2O_3$ ($[M+H]^+$) 443.0974, found 443.0976.

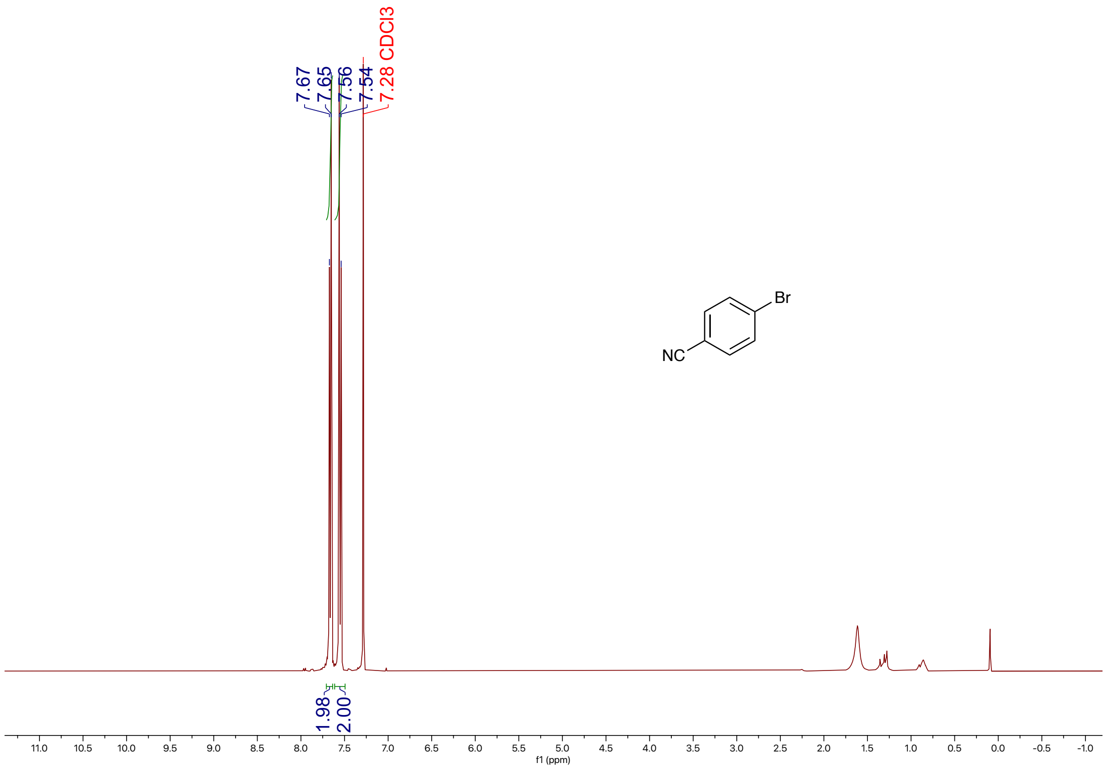
26) References

1. Le, C. C.; Wismer, M. K.; Shi, Z.-C.; Zhang, R.; Conway, D. V.; Li, G.; Vachal, P.; Davies, I. W.; MacMillan, D. W. C. A General Small-Scale Reactor To Enable Standardization and Acceleration of Photocatalytic Reactions. *ACS Cent. Sci.* **2017**, *3*, 647–653.
2. Pangborn, A. B.; Giardello, M. A.; Grubbs, R. H.; Rosen, R. K.; Timmers, F. J. Safe and Convenient Procedure for Solvent Purification. *Organometallics* **1996**, *15*, 1518–1520.
3. Still, W. C.; Kahn, M.; Mitra, A. Rapid Chromatographic Technique for Preparative Separations with Moderate Resolution. *J. Org. Chem.* **1978**, *43*, 2923–2925.
4. Chateauneuf, J.; Lusztyk, J.; Ingold, K. U. Spectroscopic and kinetic characteristics of aroyloxyl radicals. 1. The 4-methoxybenzoyloxyl radical. *J. Am. Chem. Soc.*, **1988**, *110*, 2877–2885.
5. Dow, N. D.; Pedersen, P. S.; Chen, T. Q.; Blakemore, D. C.; Dechert-Schmitt, A. M.; Knauber, T.; MacMillan, D. W. C. Decarboxylative Borylation and Cross-Coupling of (Hetero)aryl Acids Enabled by Copper Charge Transfer Catalysis. *J. Am.Chem. Soc.* **2022**, *144*, 6163–6172.

27) Spectral data



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2.00
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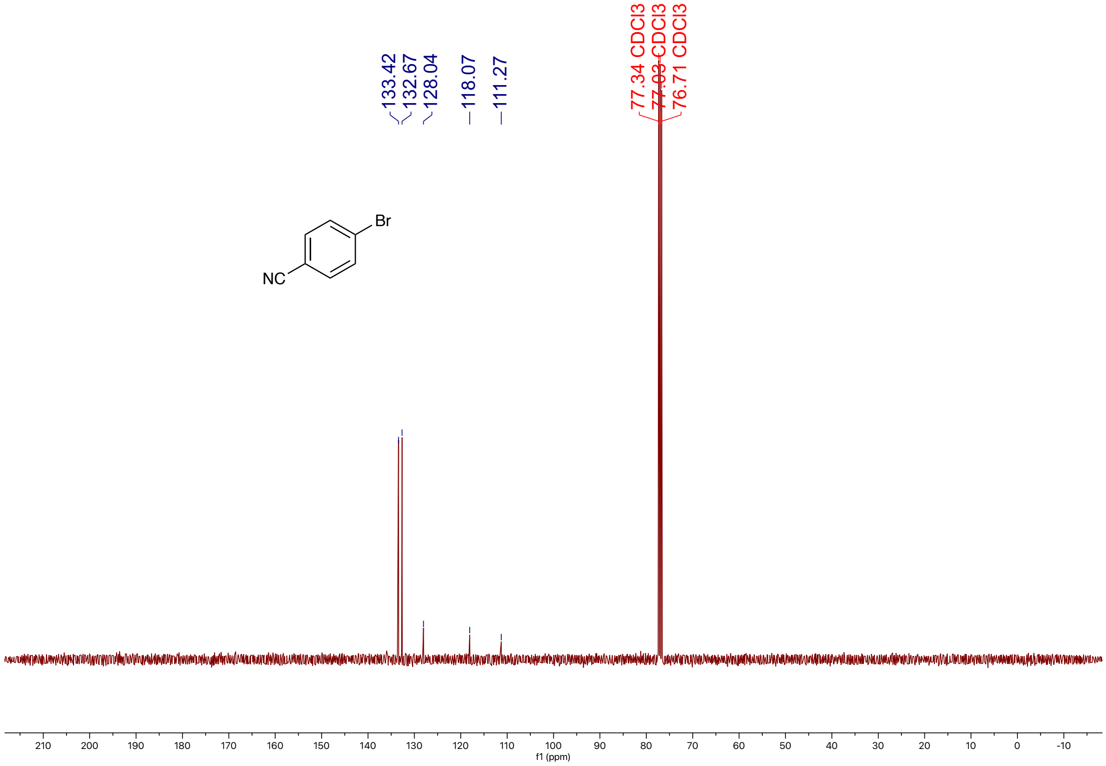
f1 (ppm)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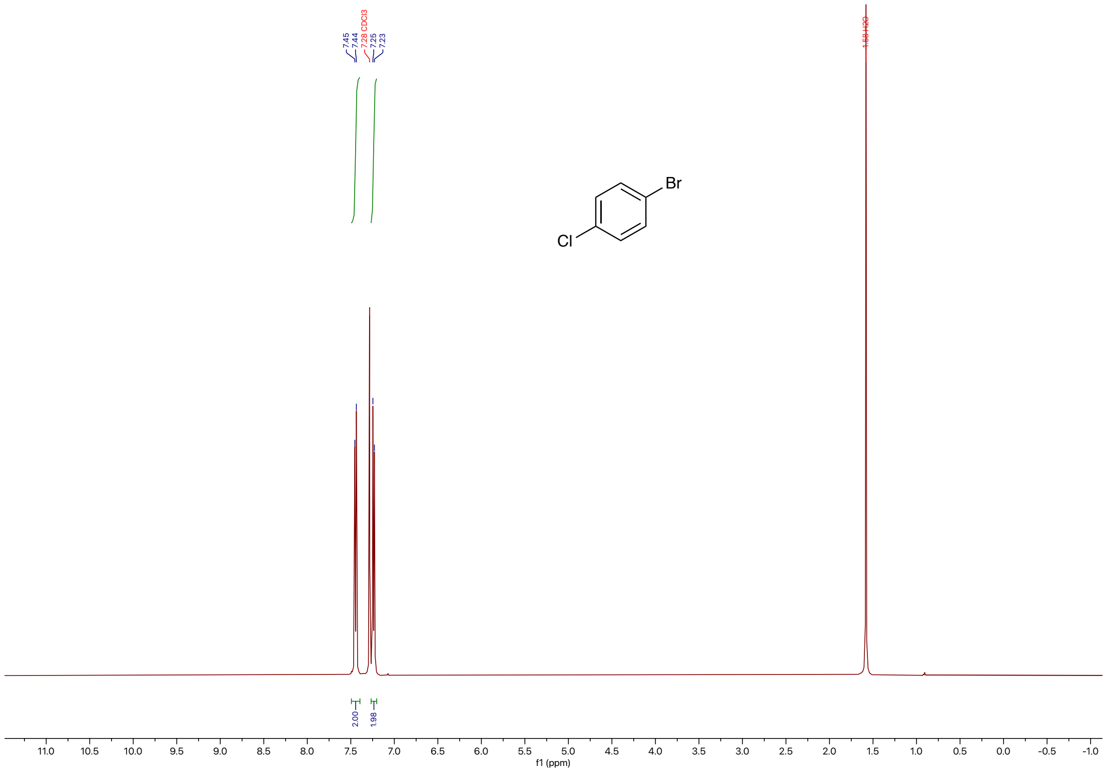
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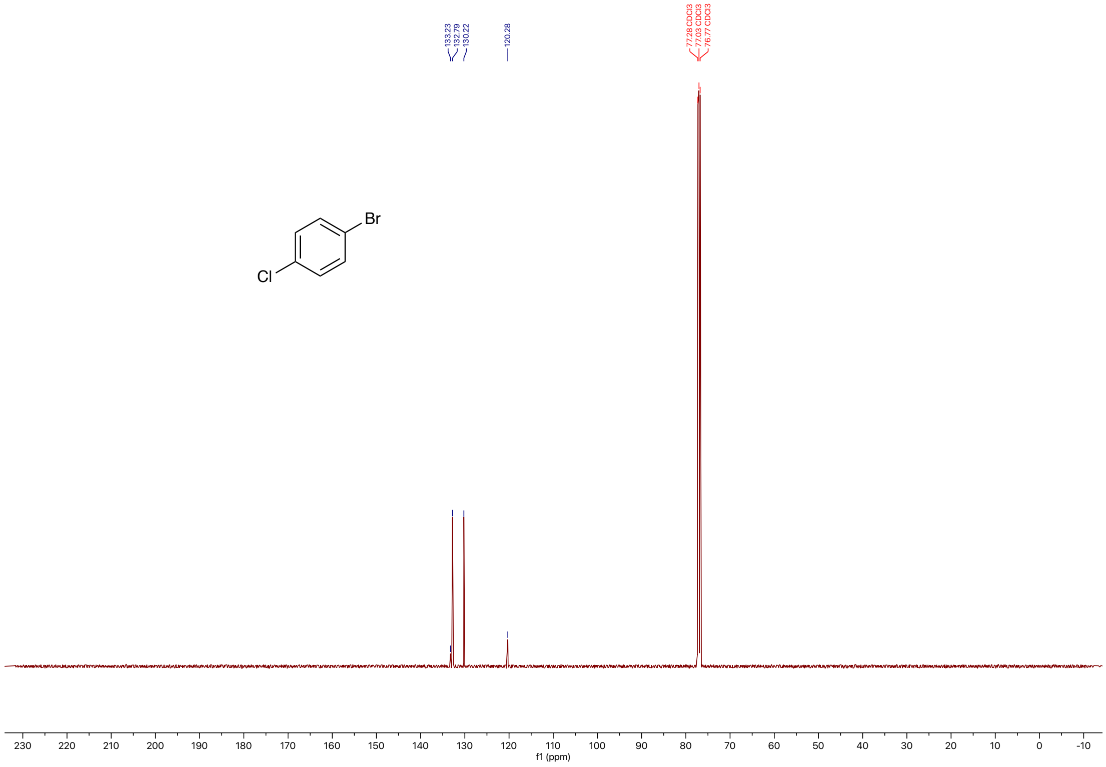
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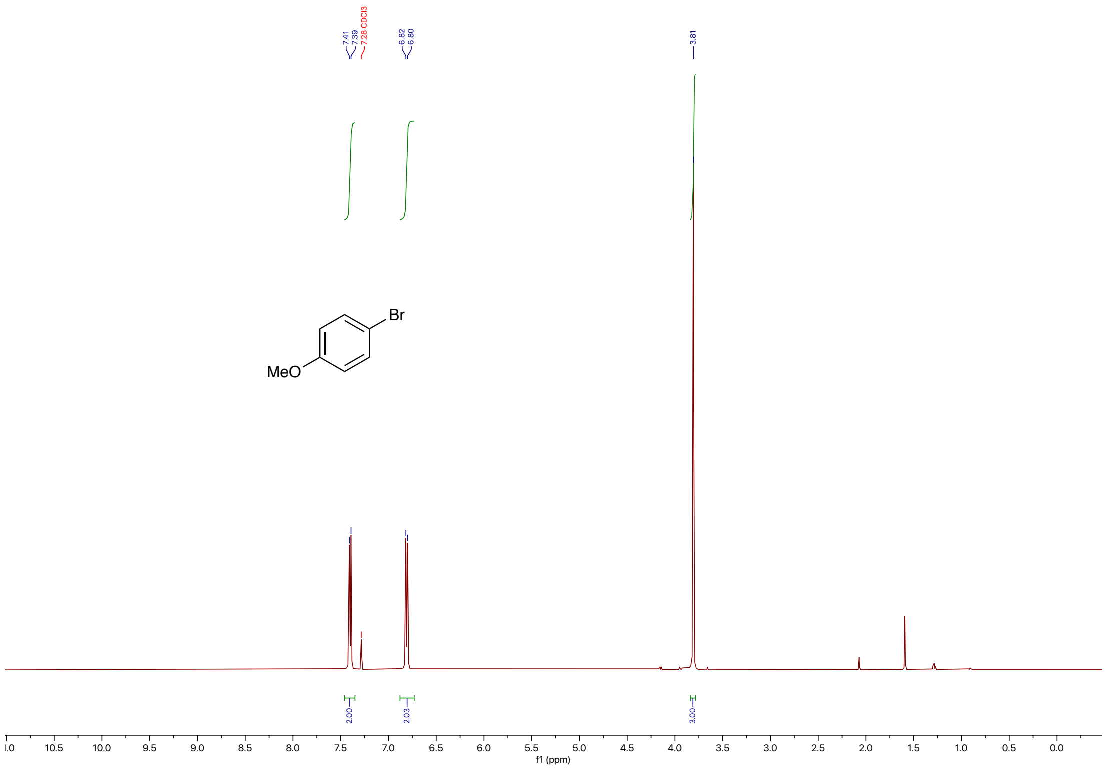
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2.03
3.00
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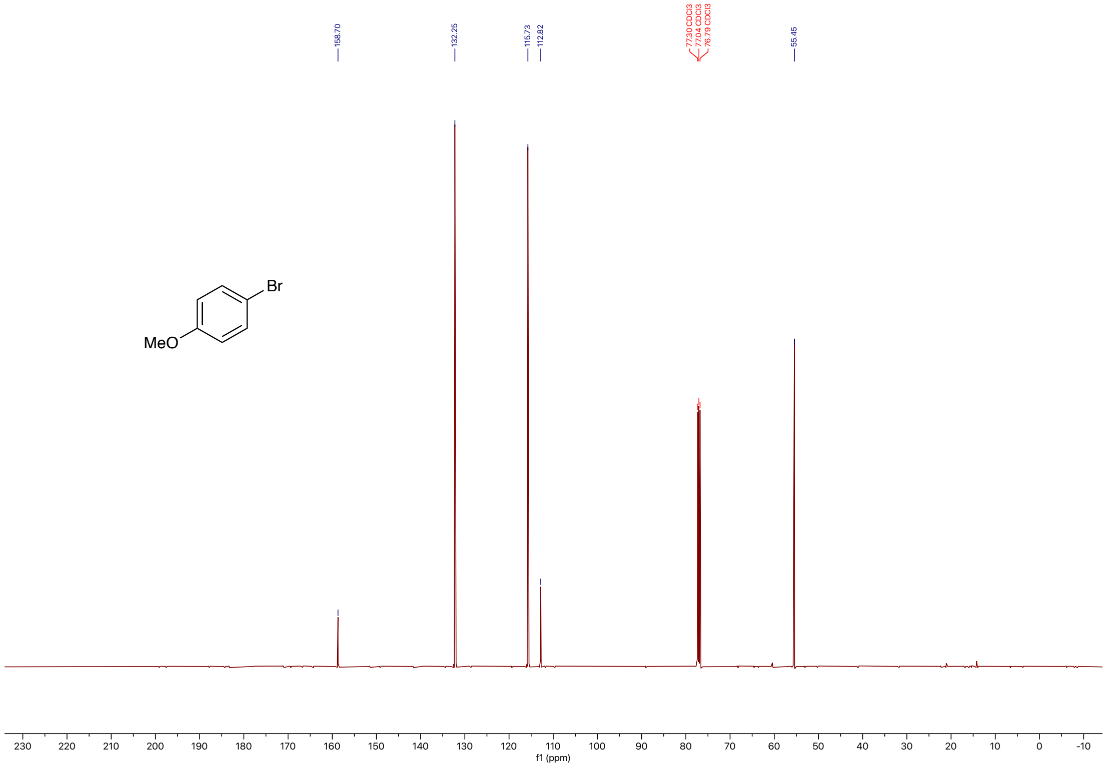
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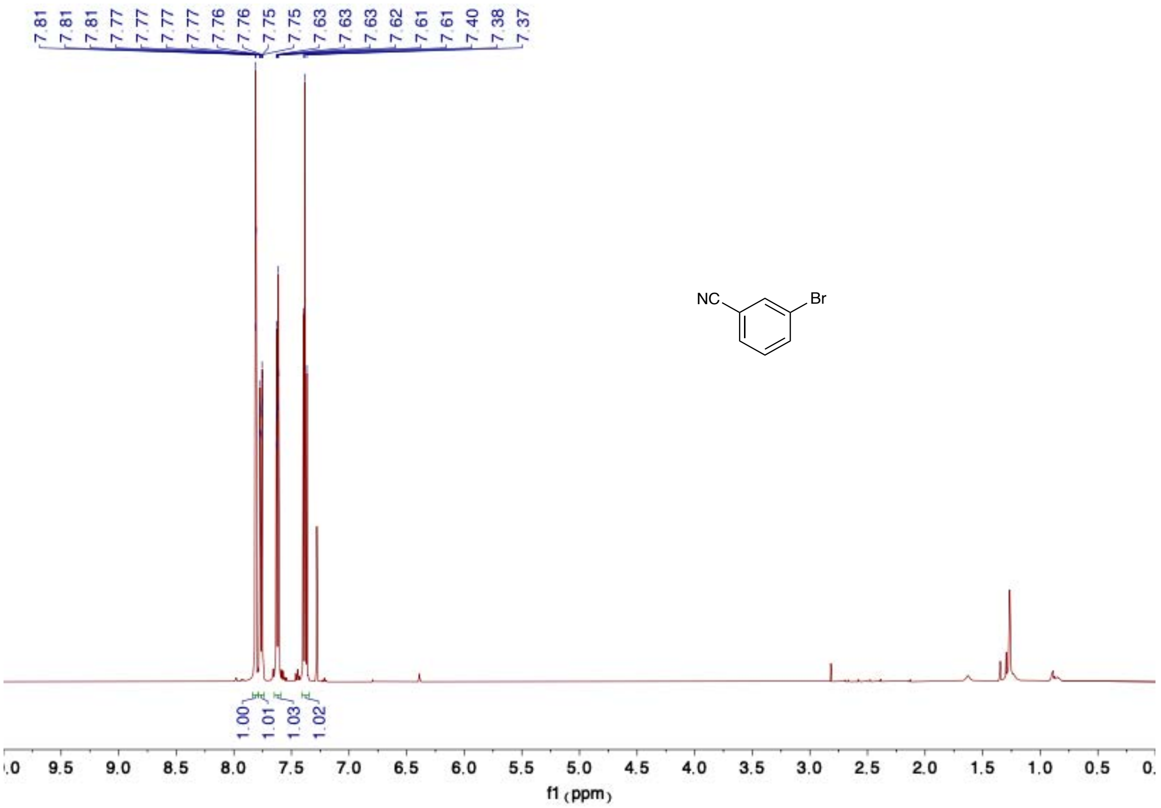
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1.02
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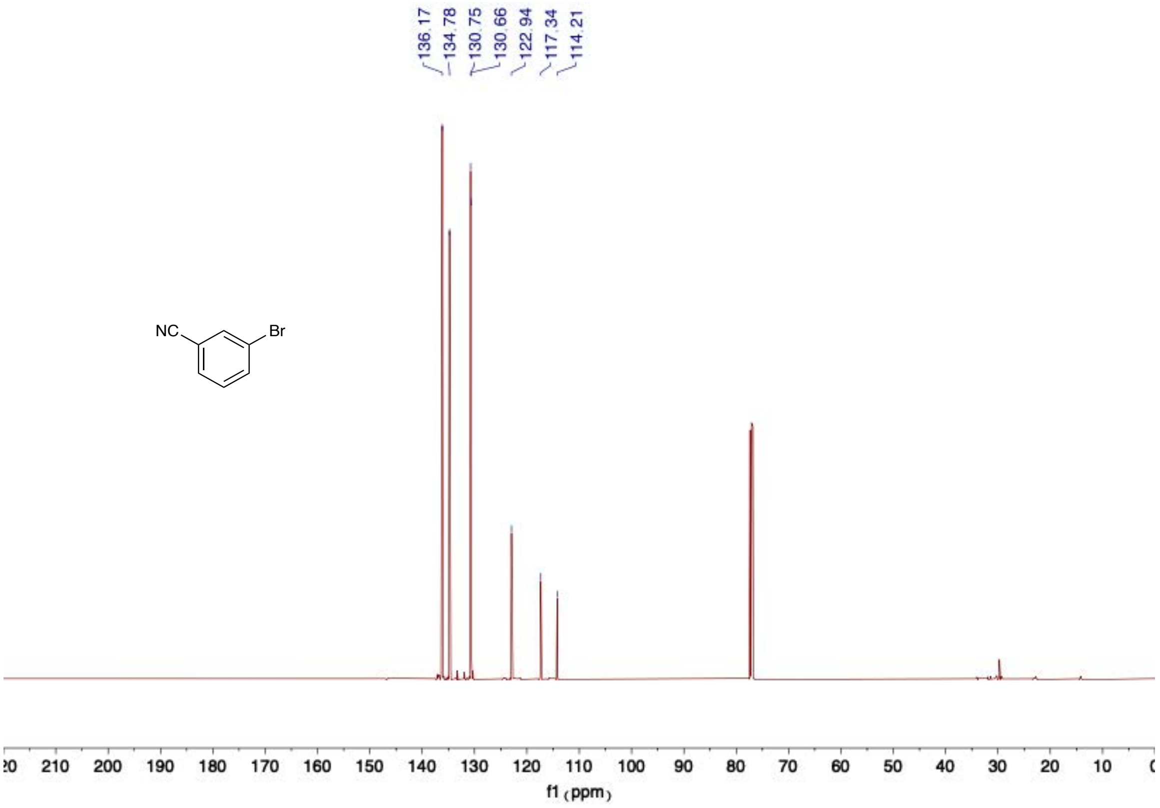
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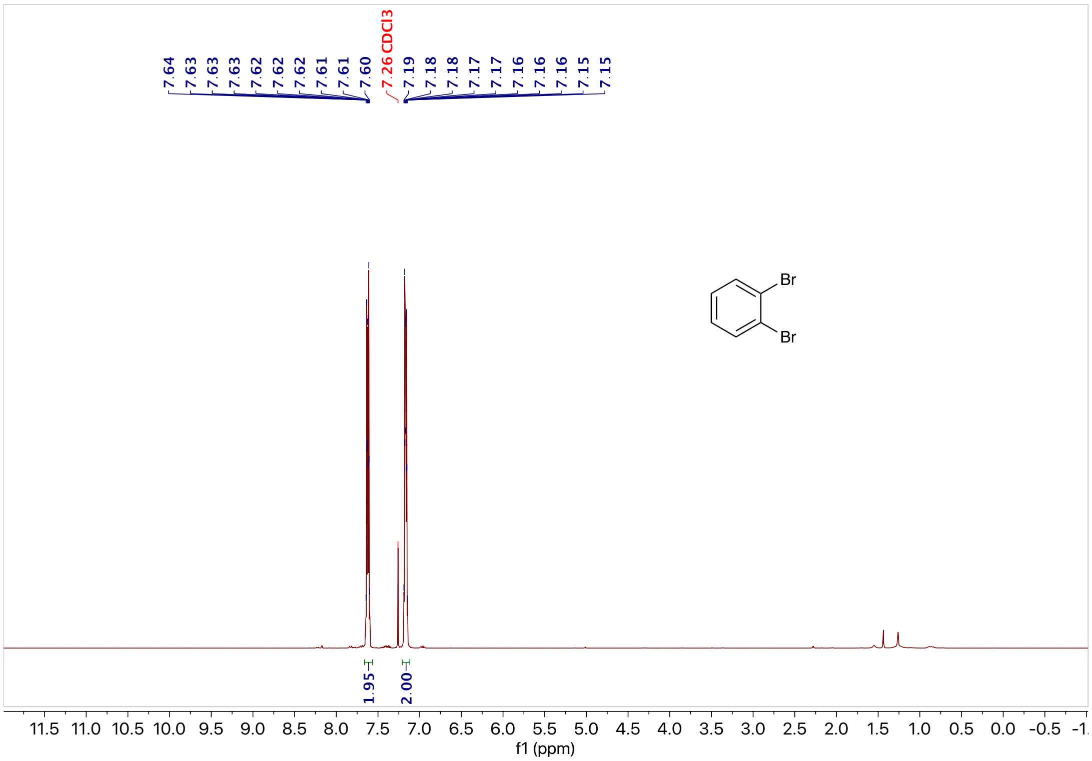
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7.18
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7.16
7.16
7.15
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Br
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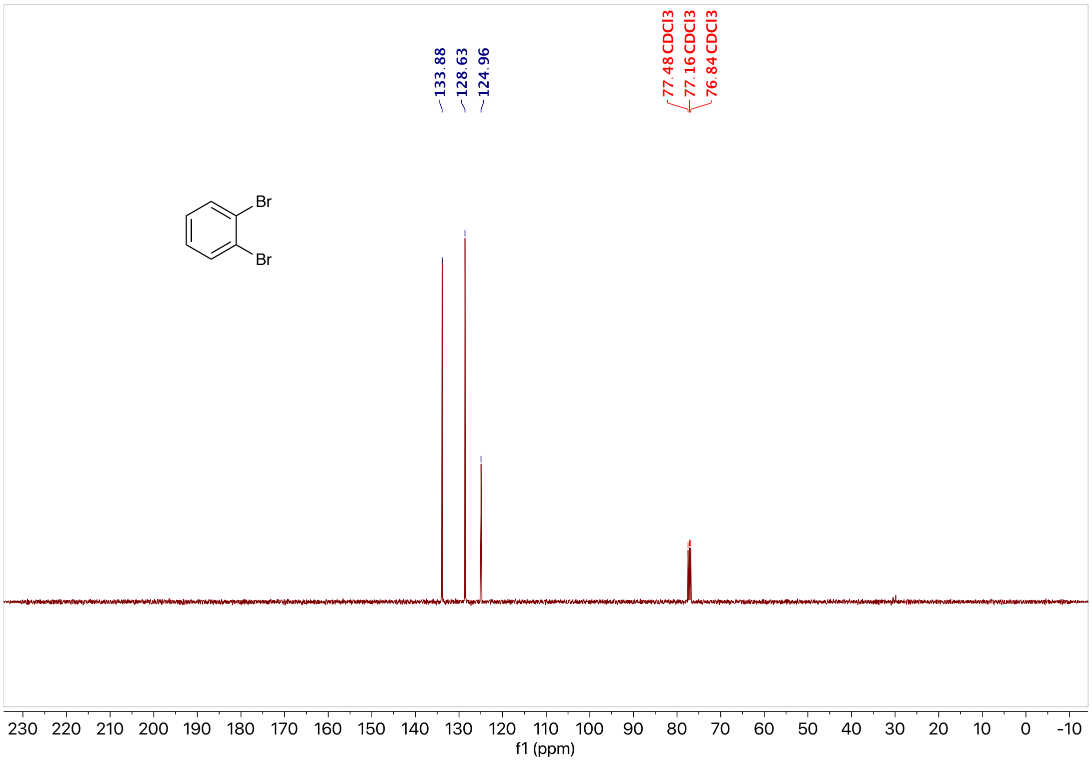
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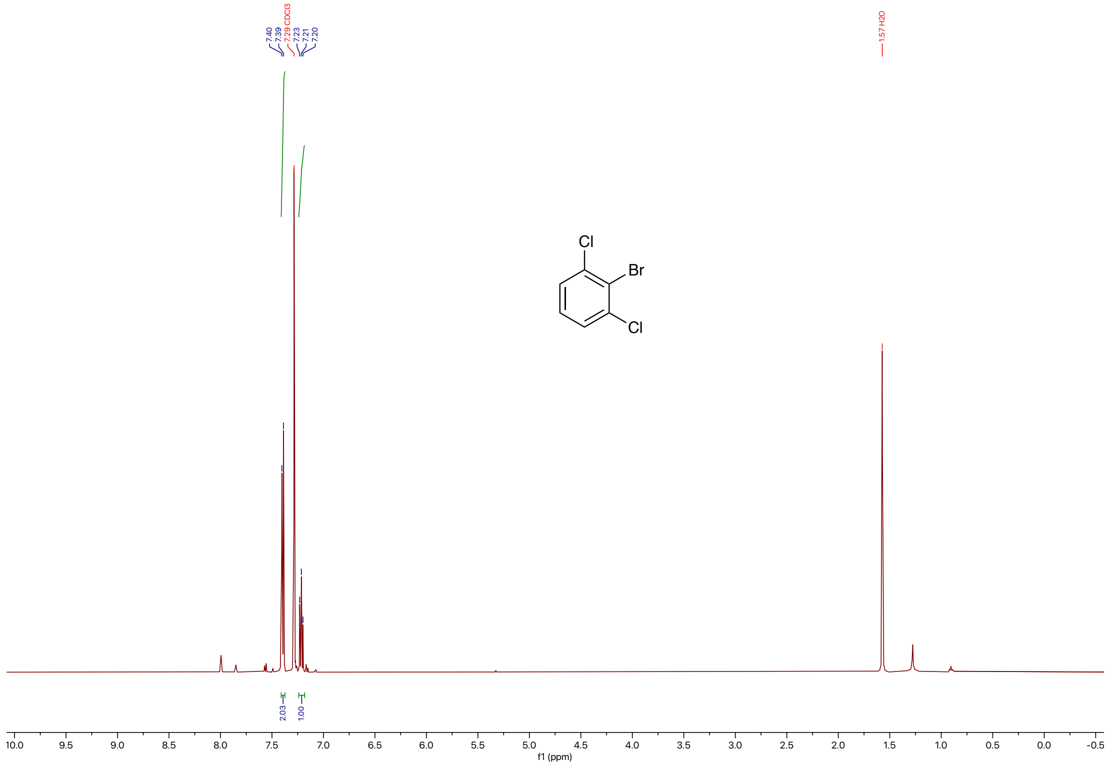
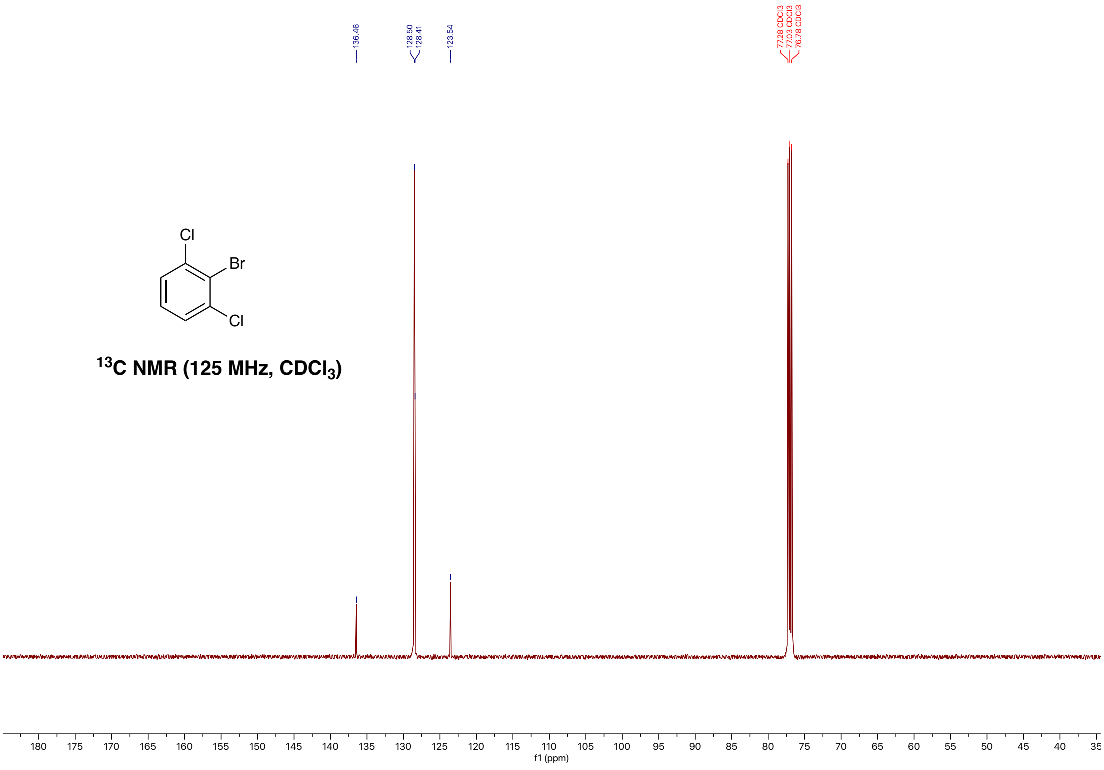
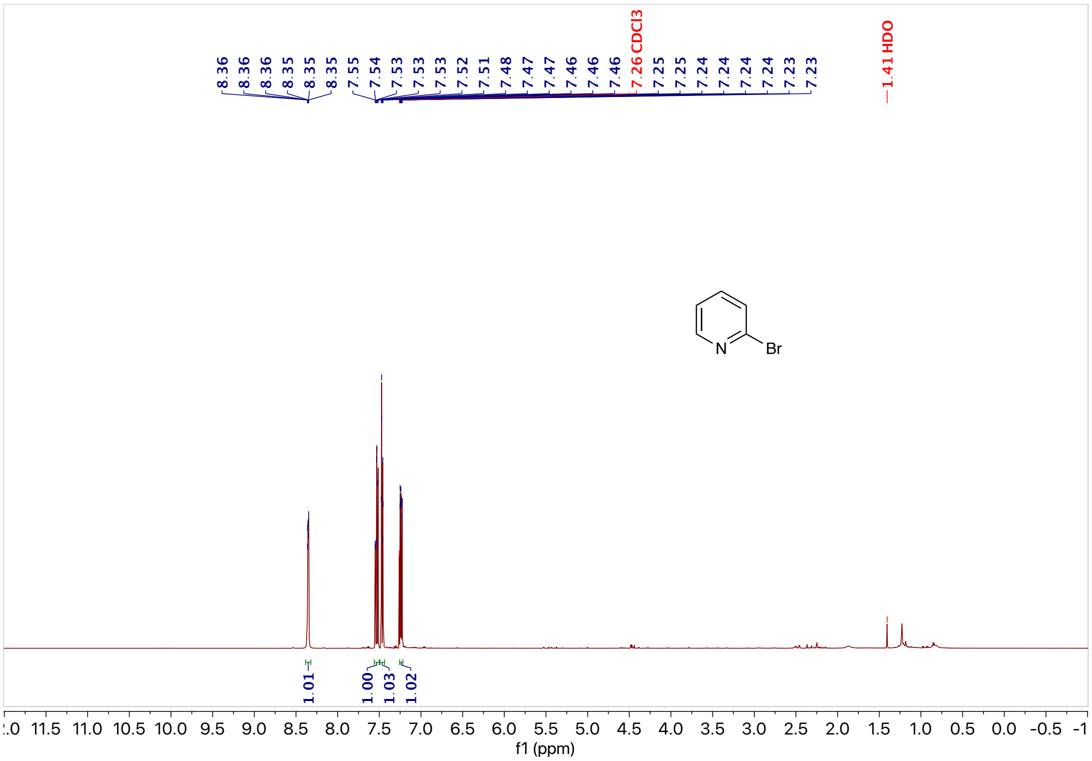



^{13}C NMR (125 MHz, CDCl$_3$)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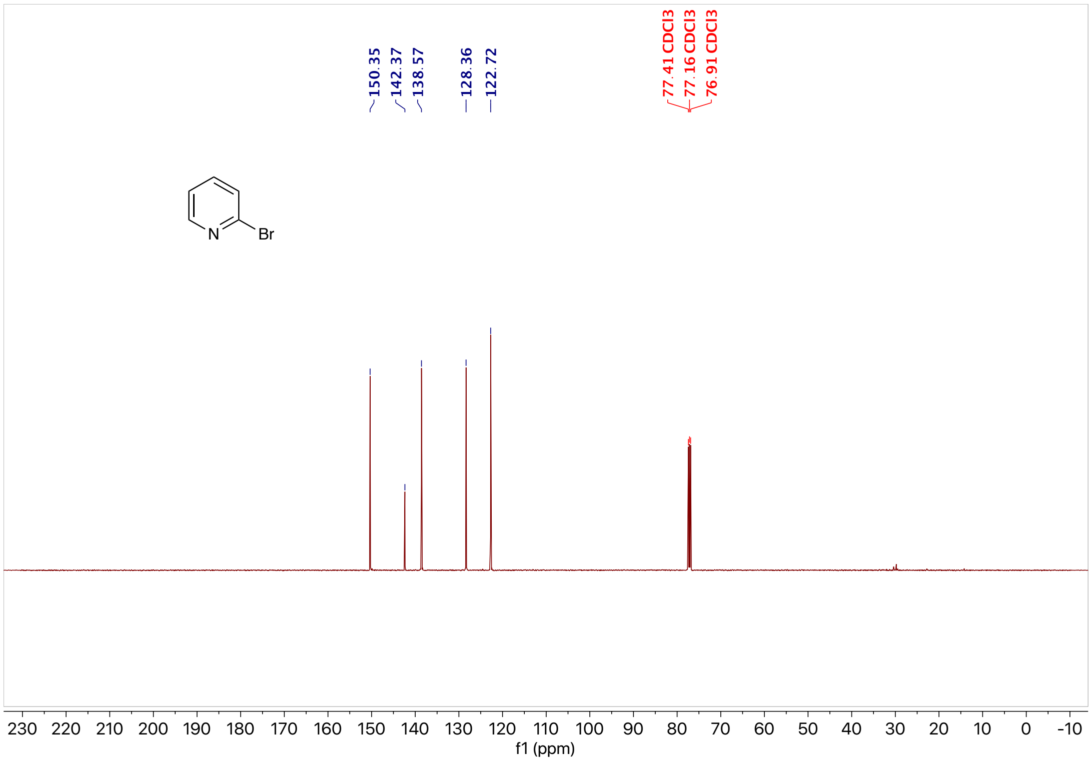
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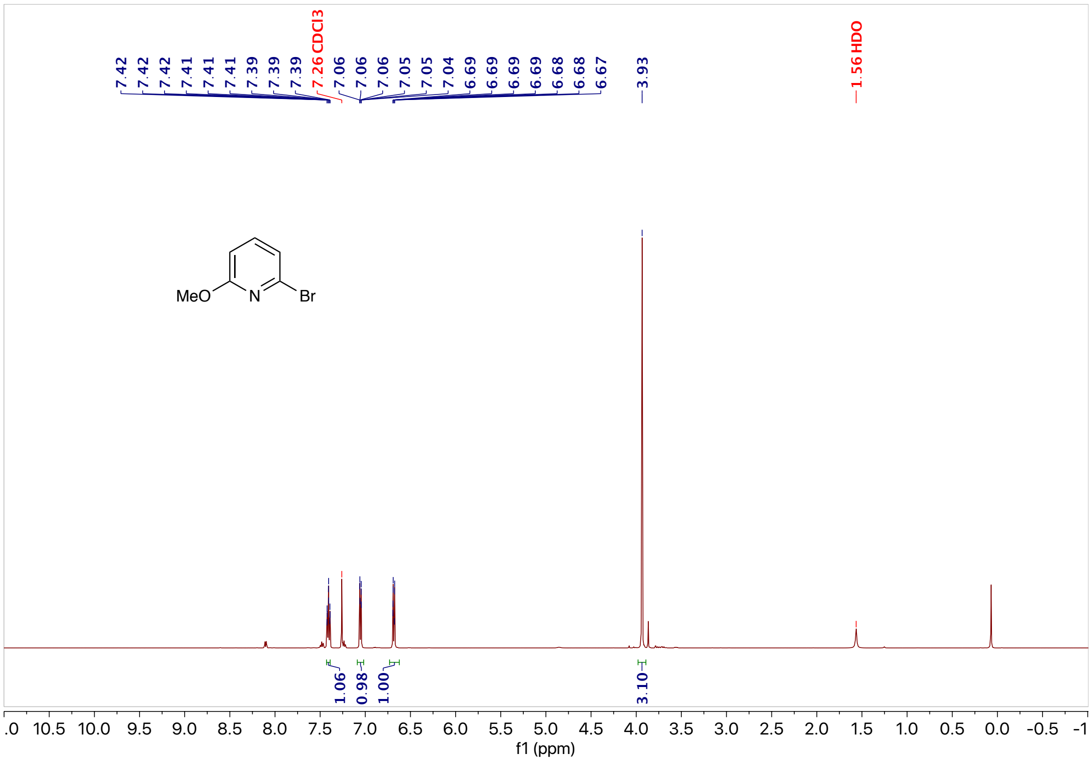
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MeO
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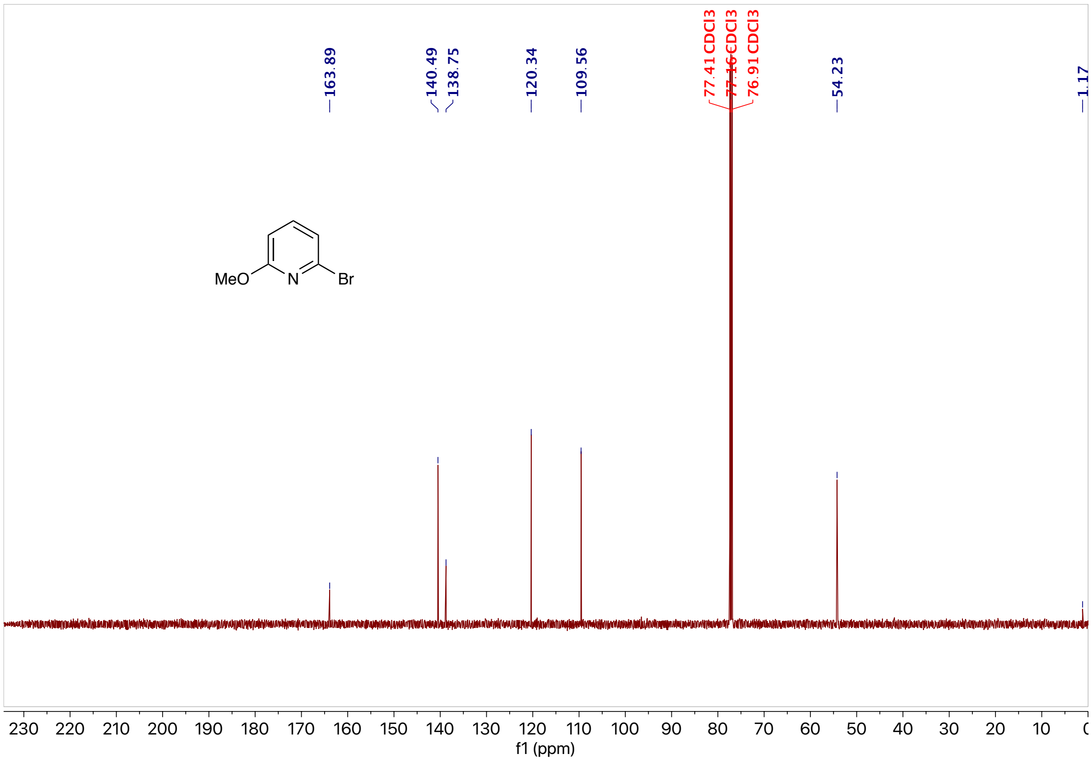
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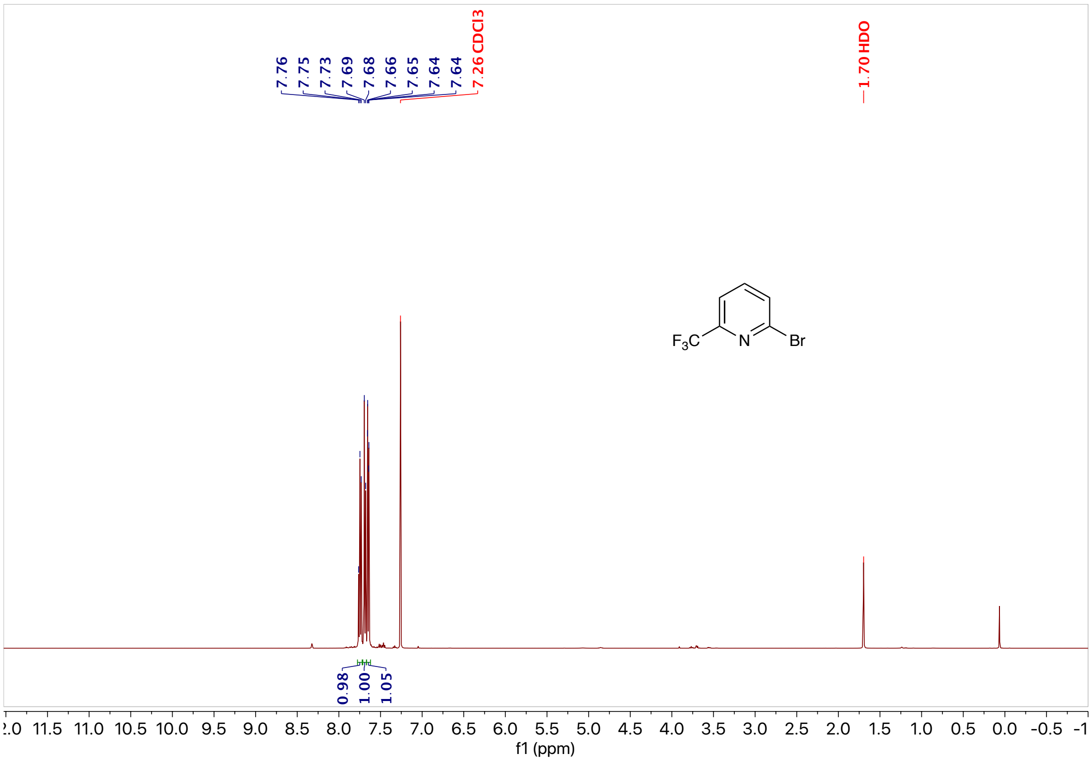
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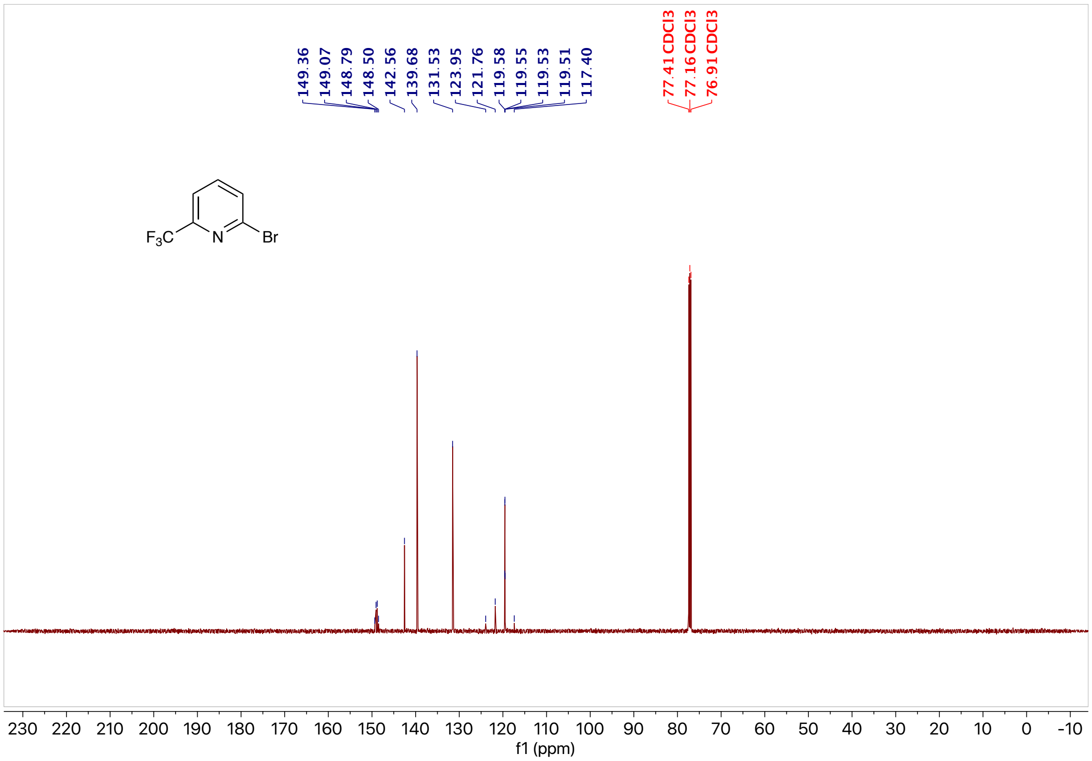
7.66
7.65
7.64
7.64
7.26 CDCl3
1.70 HDO
F3C
N
Br
0.98
1.00
1.05
2.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1
f1 (ppm)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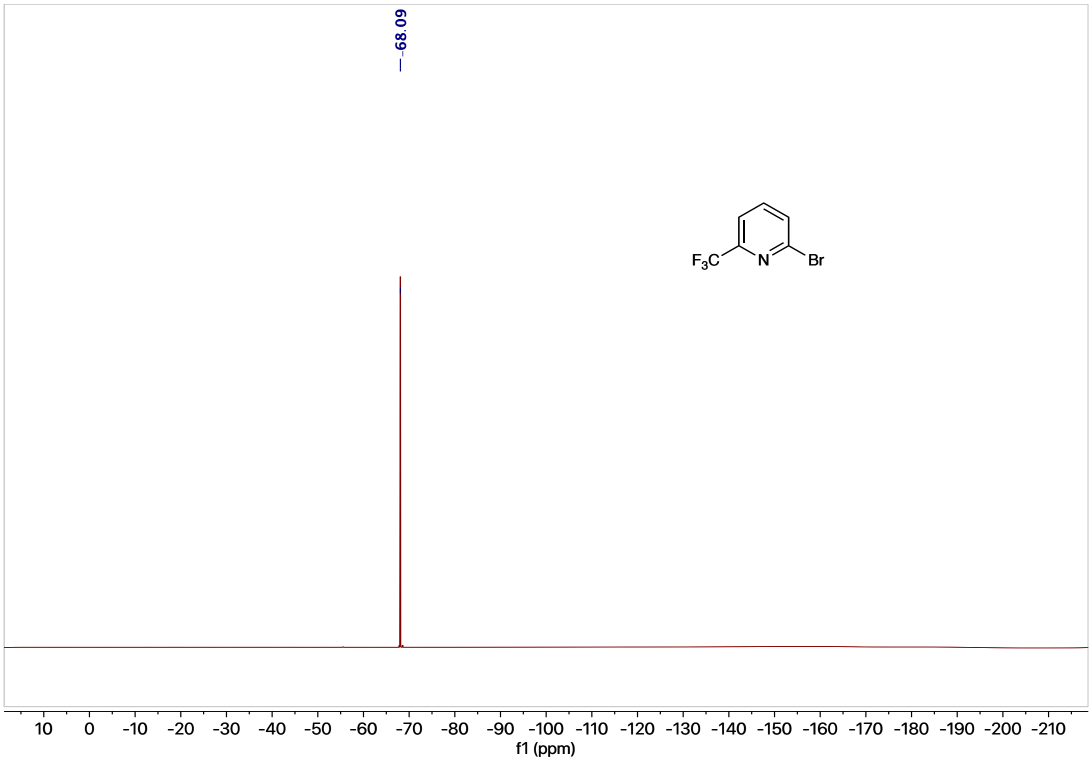
148.79
148.50
142.56
139.68
131.53
123.95
121.76
119.58
119.55
119.53
119.51
117.40
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
F3C
N
Br
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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Br
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-10
-20
-30
-40
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-60
-70
-80
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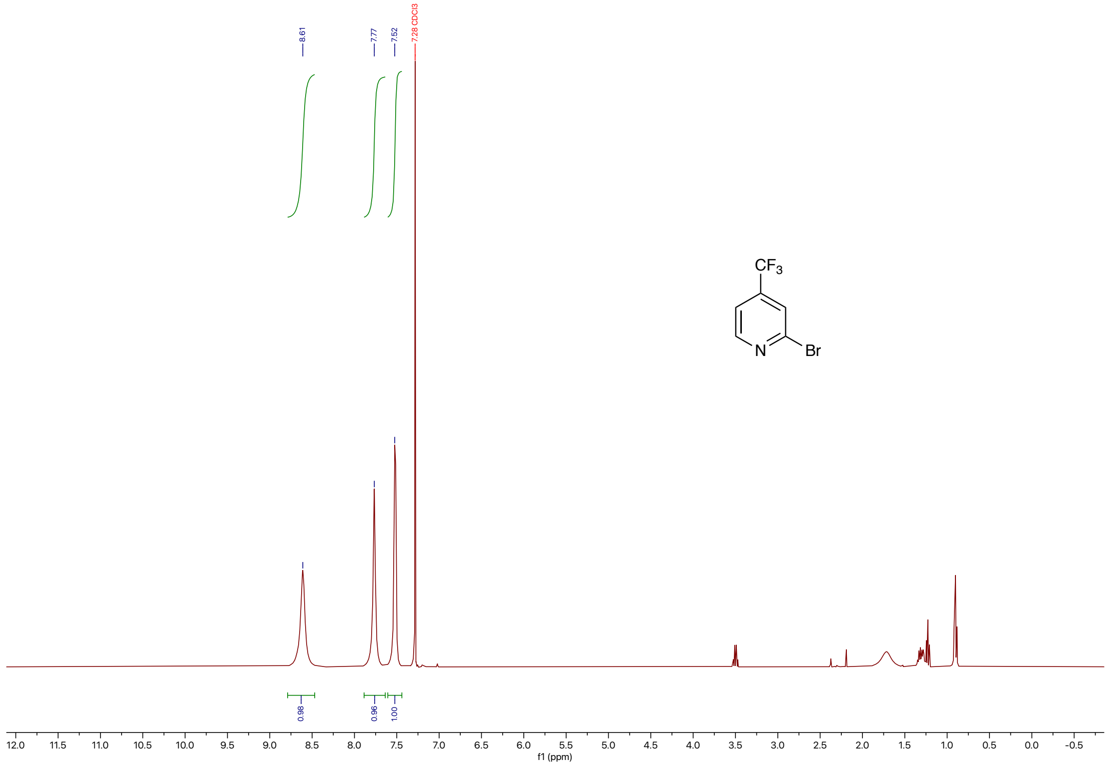
-190
-200
-210
f1 (ppm)


8.61
7.77
7.52
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CF3
N
Br
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0.96
1.00
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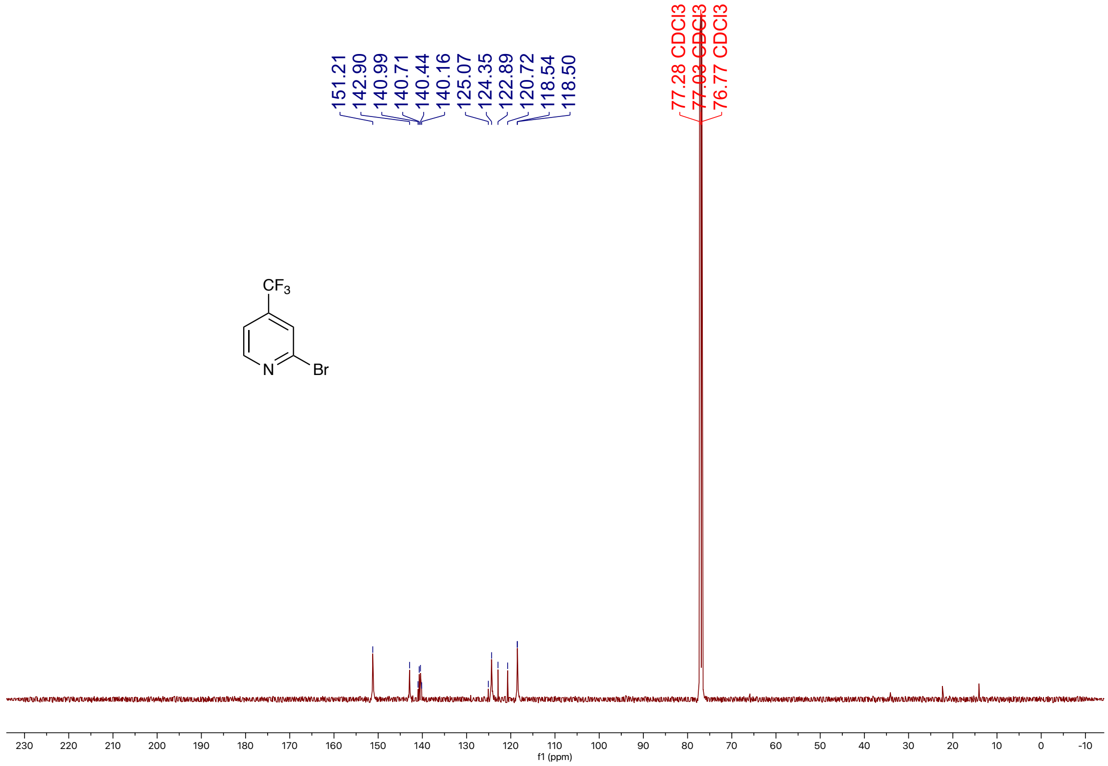
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)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142.90
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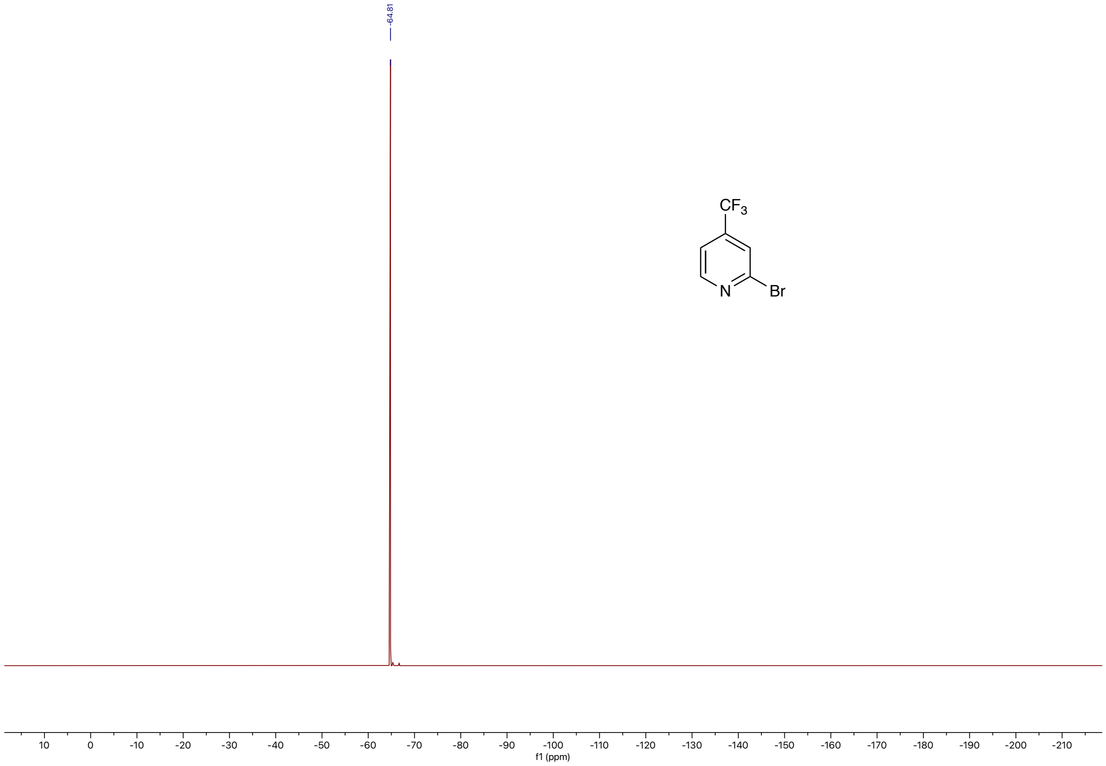
140.71
140.44
140.16
125.07
124.35
122.89
120.72
118.54
118.50
77.28 CDCl3
77.03 CDCl3
76.77 CDCl3
CF3
N
Br
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)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CF3
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Br
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-30
-40
-50
-60
-70
-80
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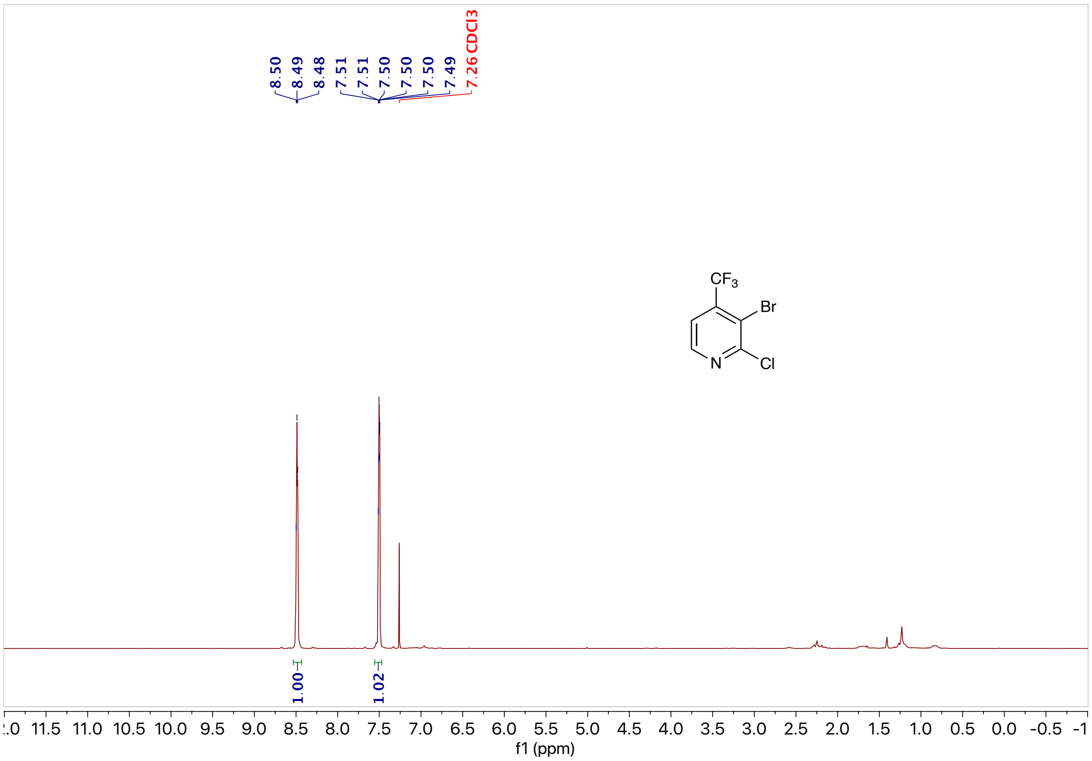
-190
-200
-210
f1 (ppm)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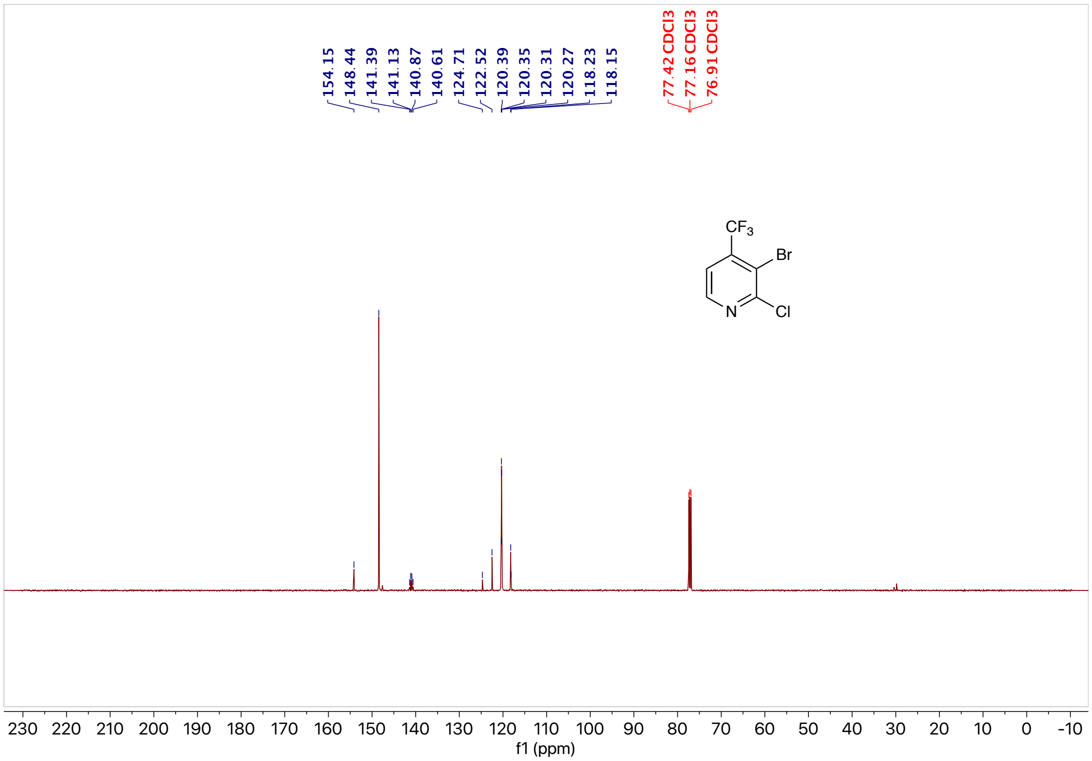
8.49
8.48
7.51
7.51
7.50
7.50
7.50
7.49
7.26 CDCl3
CF3
Br
N
Cl
1.00
1.02
11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1
f1 (ppm)


154.15
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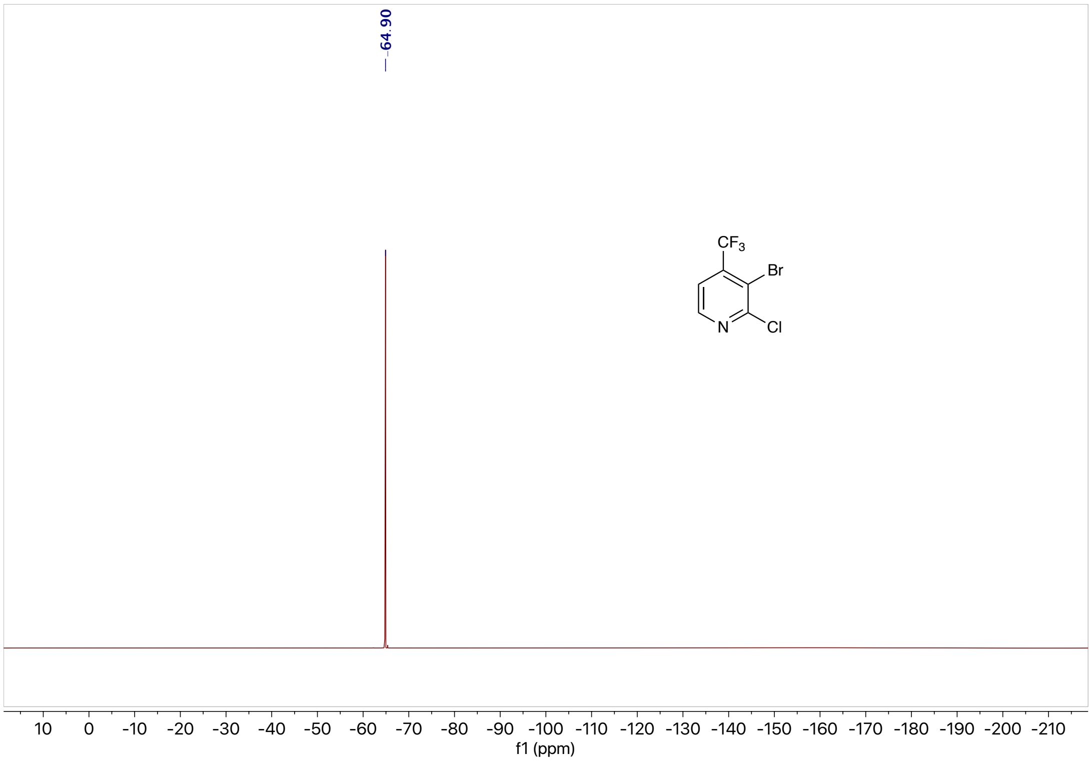
141.39
141.13
140.87
140.61
124.71
122.52
120.39
120.35
120.31
120.27
118.23
118.15
77.42 CDCl3
77.16 CDCl3
76.91 CDCl3
CF3
Br
N
Cl
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


-64.90
CF3
Br
N
Cl
10
0
-10
-20
-30
-40
-50
-60
-70
-80
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-130
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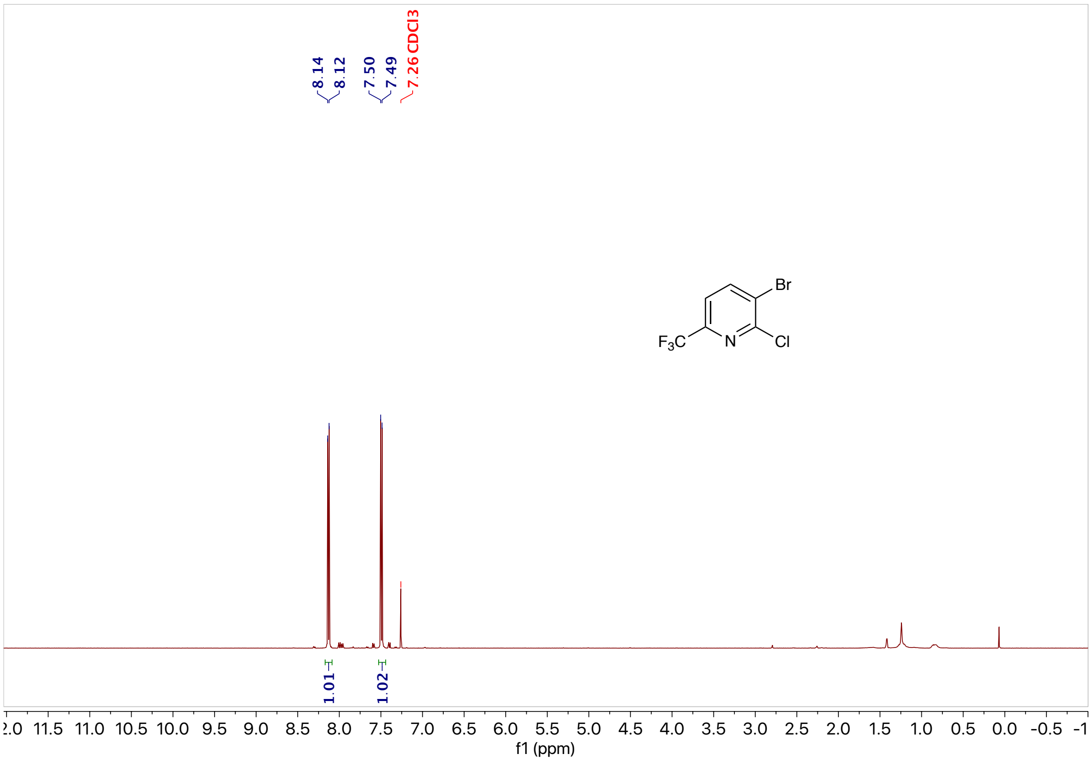
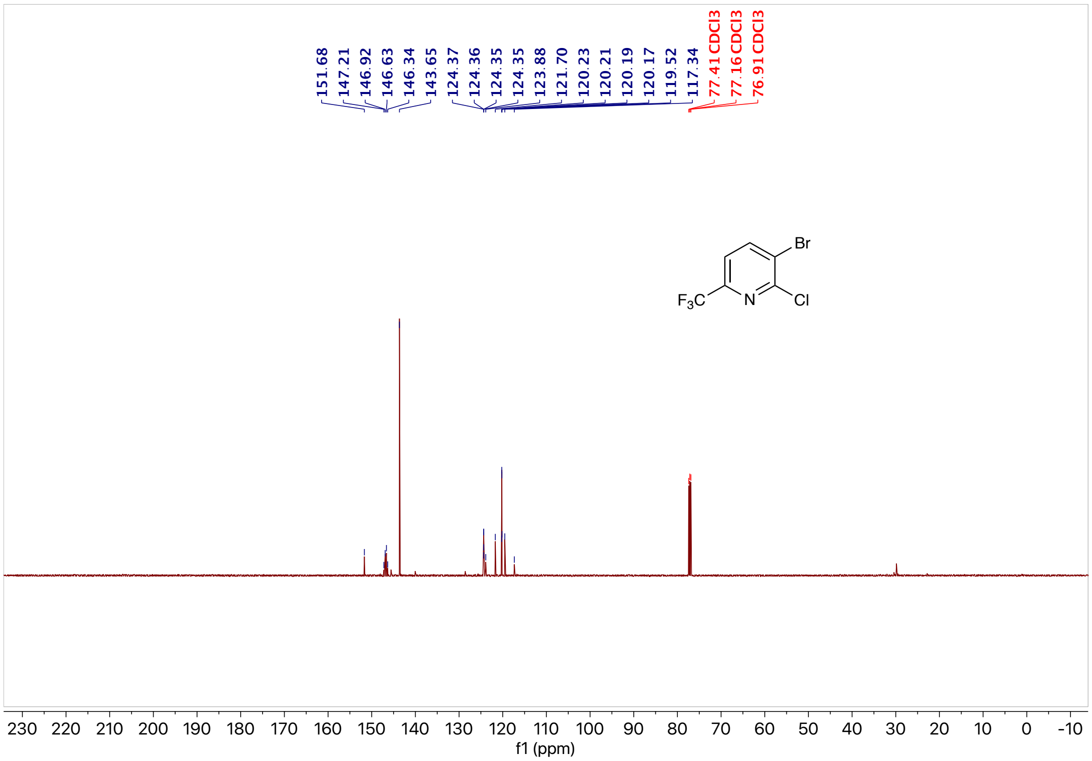
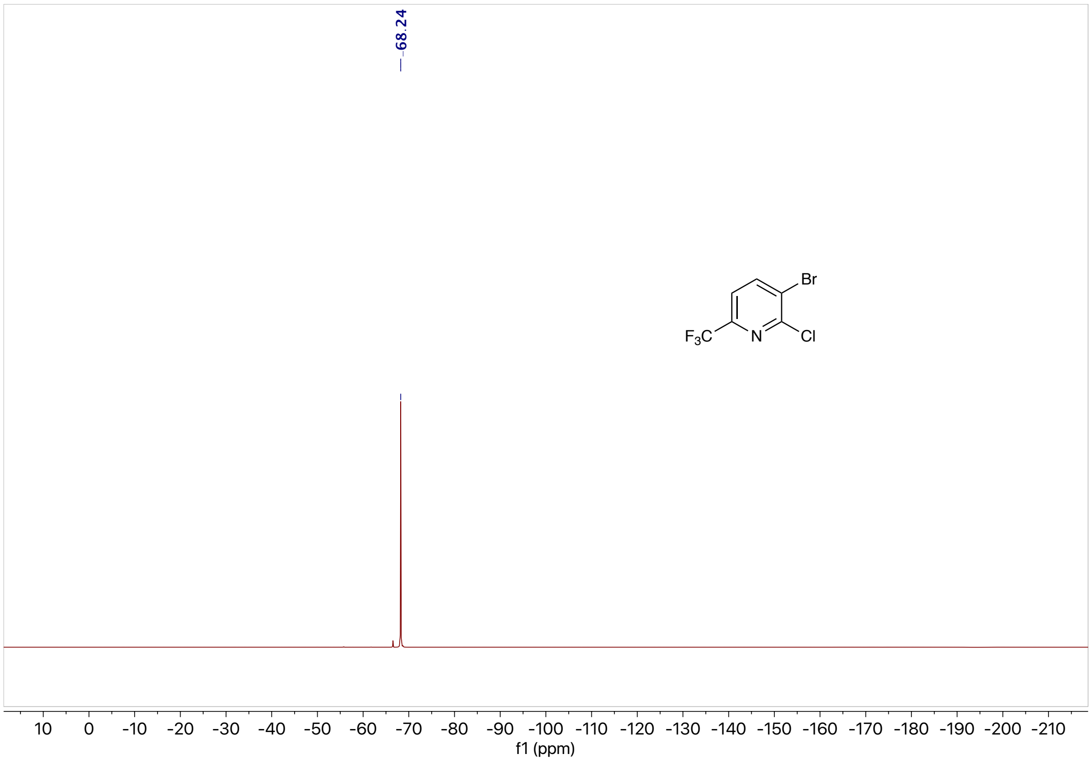
-160
-170
-180
-190
-200
-210
f1 (ppm)


8.14
8.12
7.50
7.49
7.26 CDCl3
Br
F3C
N
Cl
1.01
1.02
12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1
f1 (ppm)


151.68
147.21
146.92
146.63
146.34
143.65
124.37
124.36
124.35
124.35
123.88
121.70
120.23
120.21
120.19
120.17
119.52
117.34
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
Br
F3C
N
Cl
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)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Br
Cl
N
F3C
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0
-10
-20
-30
-40
-50
-60
-70
-80
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-130
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-150
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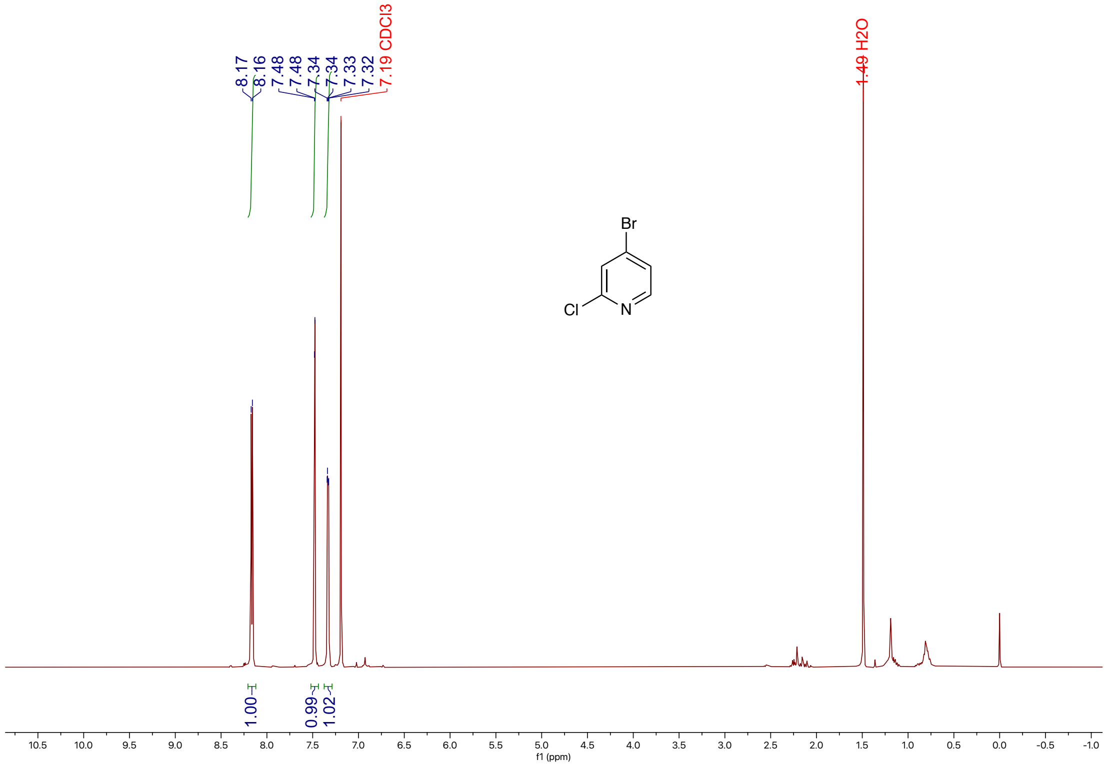
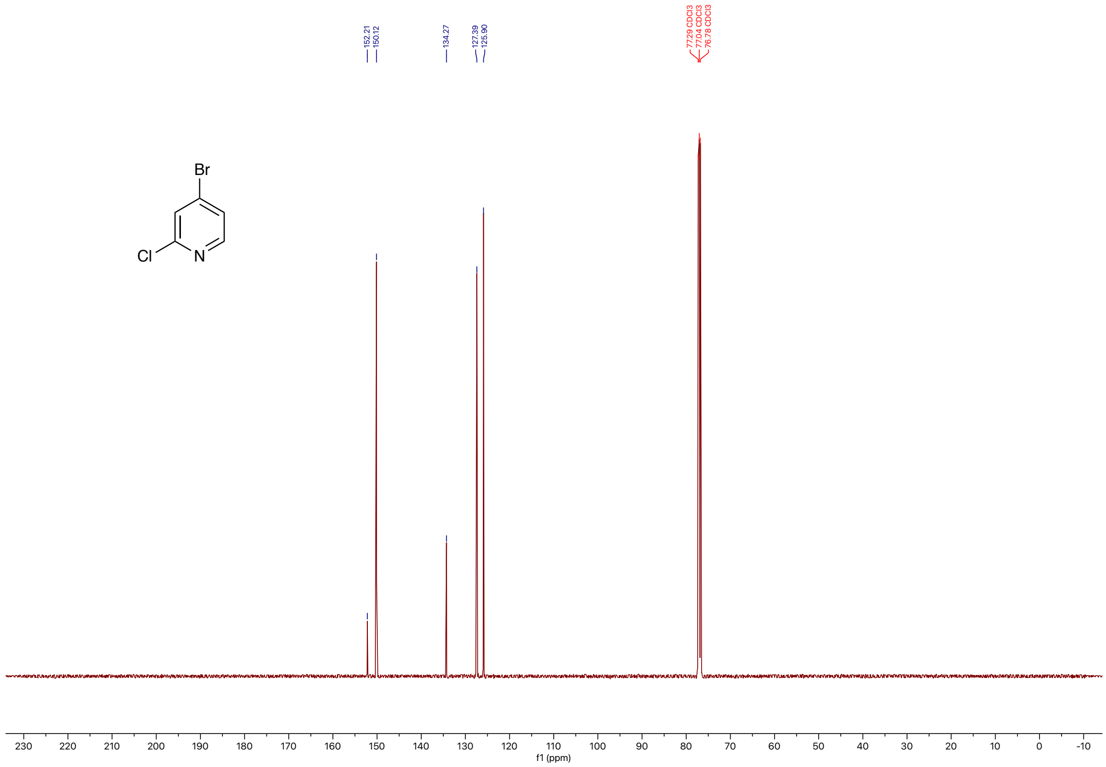
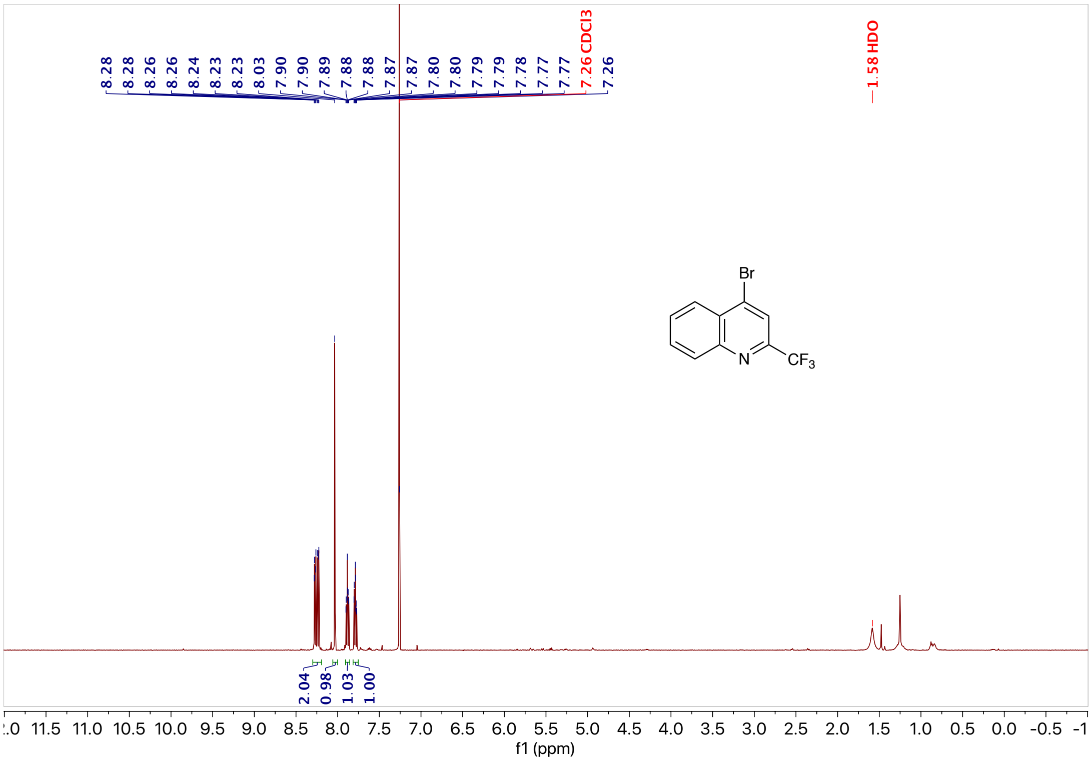
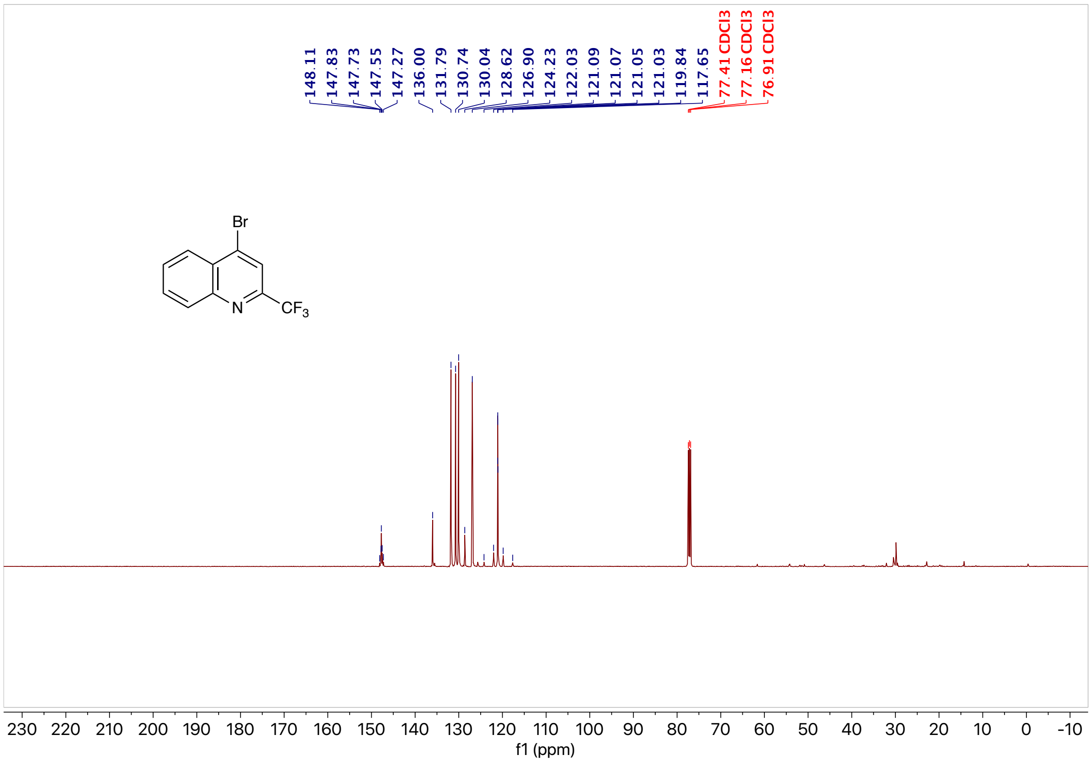
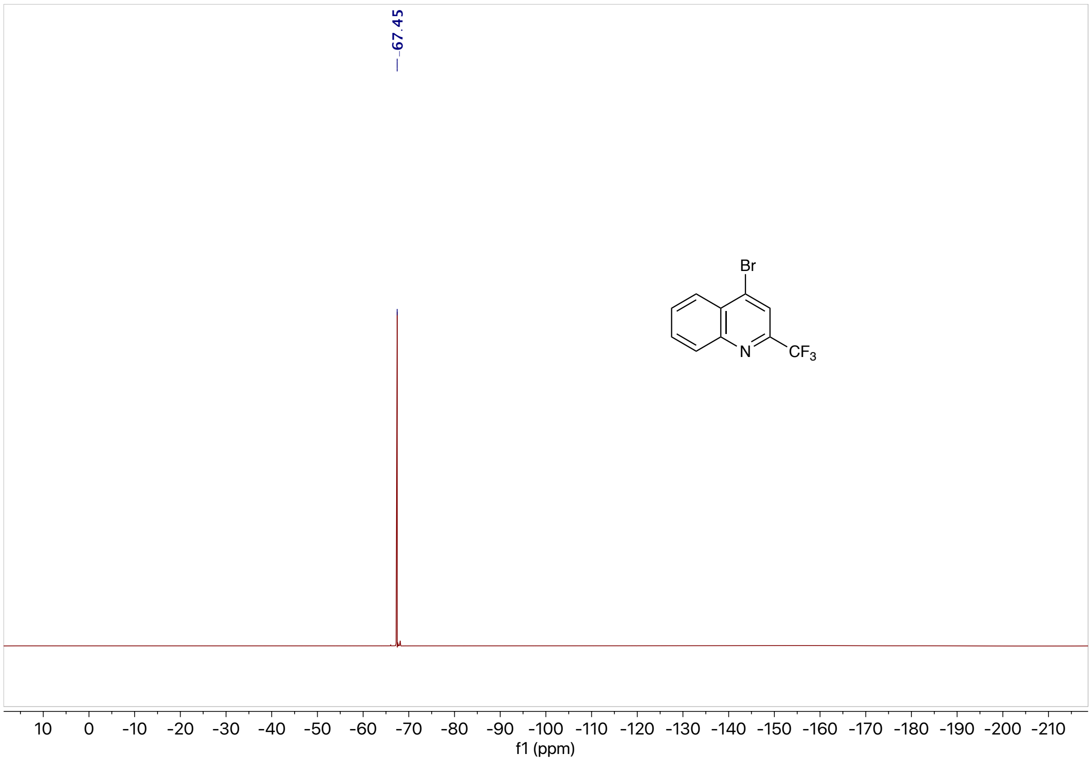
-180
-190
-200
-210
f1 (ppm)


8.17
8.16
7.48
7.48
7.34
7.34
7.33
7.32
7.19 CDCl3
1.49 H2O
Br
Cl
N
1.00
0.99
1.02
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
f1 (ppm)


152.21
150.12
134.27
127.39
125.90
77.29 CDCl3
77.04 CDCl3
76.78 CDCl3
Br
Cl
N
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)


8.28
8.28
8.26
8.26
8.24
8.23
8.23
8.03
7.90
7.90
7.89
7.88
7.88
7.87
7.87
7.80
7.80
7.79
7.79
7.78
7.77
7.77
7.26 CDCl3
7.26
1.58 HDO
Br
N
CF3
2.04
0.98
1.03
1.00
12.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1
f1 (ppm)


148.11
147.83
147.73
147.55
147.27
136.00
131.79
130.74
130.04
128.62
126.90
124.23
122.03
121.09
121.07
121.05
121.03
119.84
117.65
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
Br
N
CF3
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)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Br
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CF3
10
0
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-50
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-70
-80
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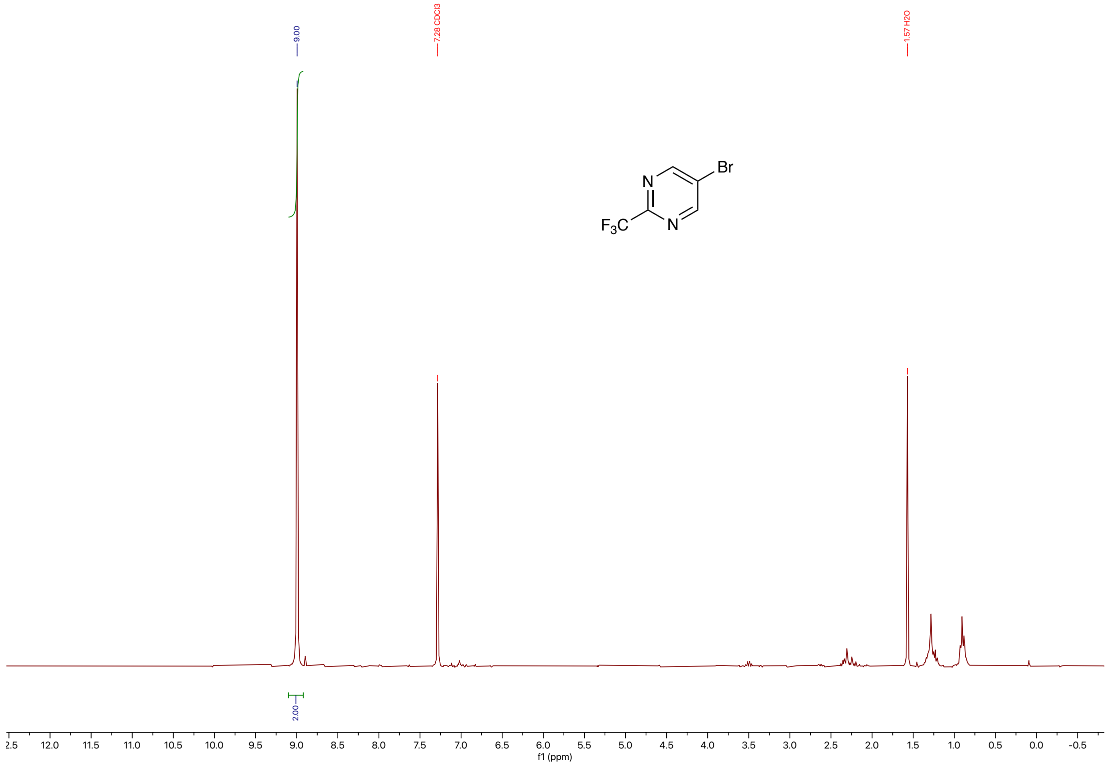
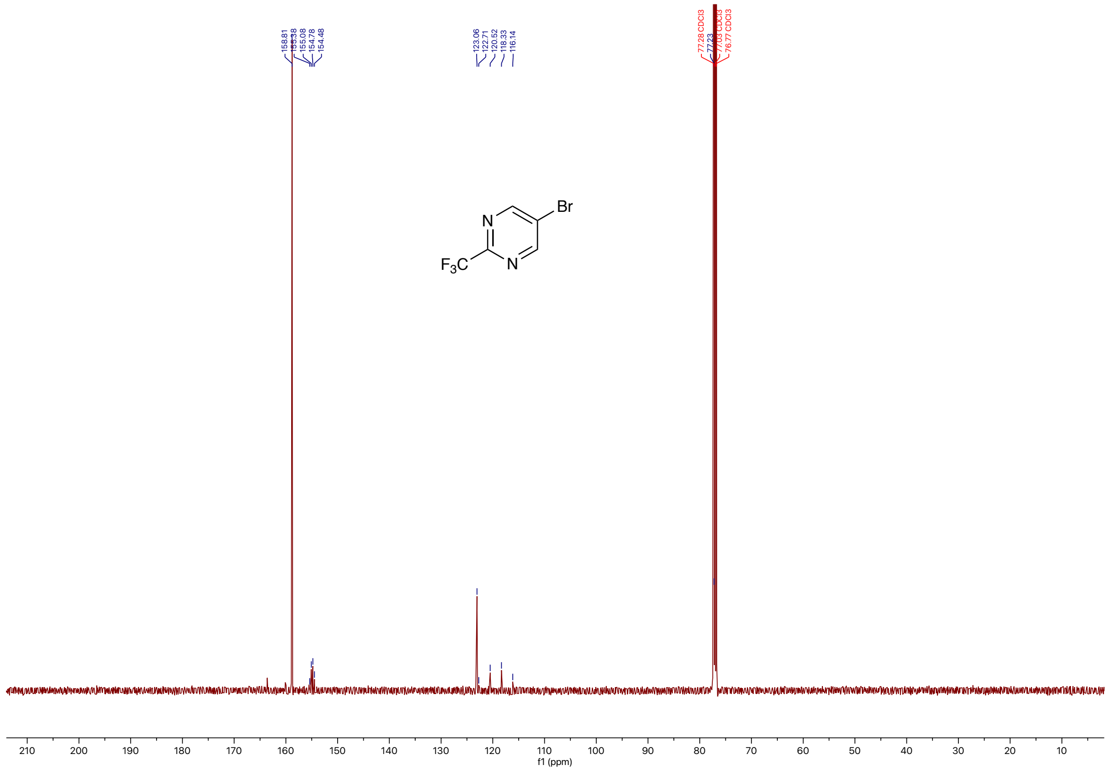
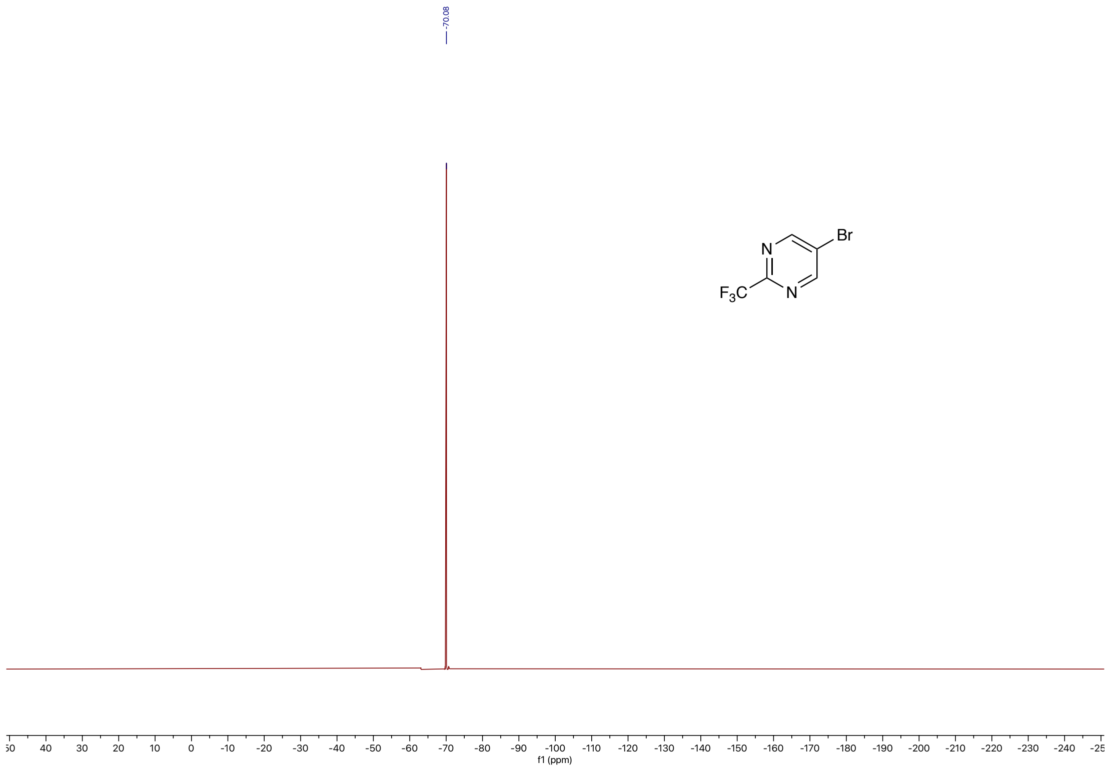
-180
-190
-200
-210
f1 (ppm)


9.00
7.28 CDCl3
1.57 H2O
N
Br
F3C
N
2.00
2.5
12.0
11.5
11.0
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)


158.81
155.38
155.08
154.78
154.48
123.06
122.71
120.52
118.33
116.14
77.28 CDCl3
77.23
77.03 CDCl3
76.77 CDCl3
N
Br
F3C
N
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


-70.08
Br
N
N
F_3C
40
30
20
10
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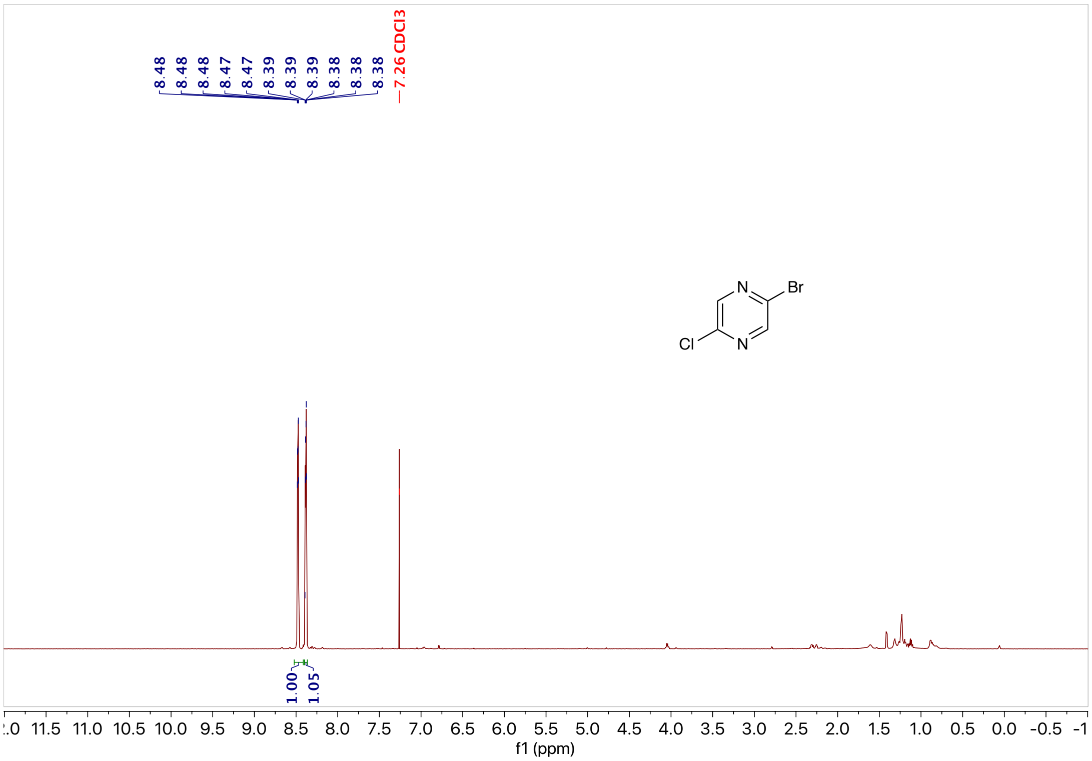
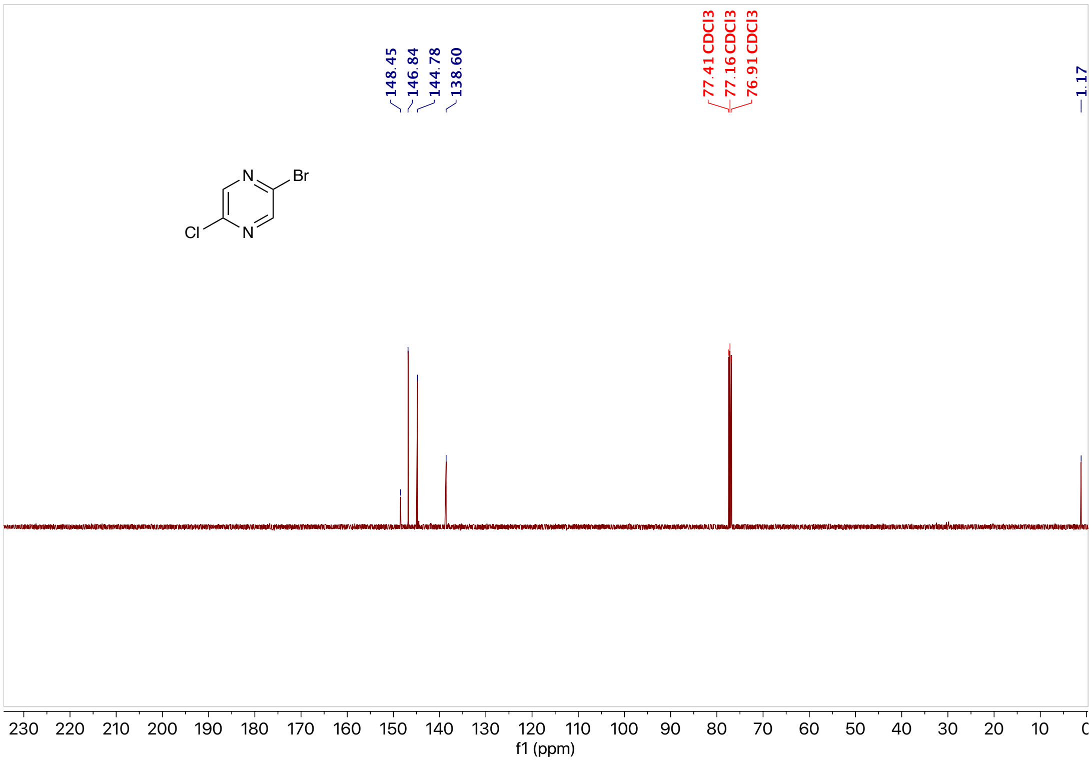
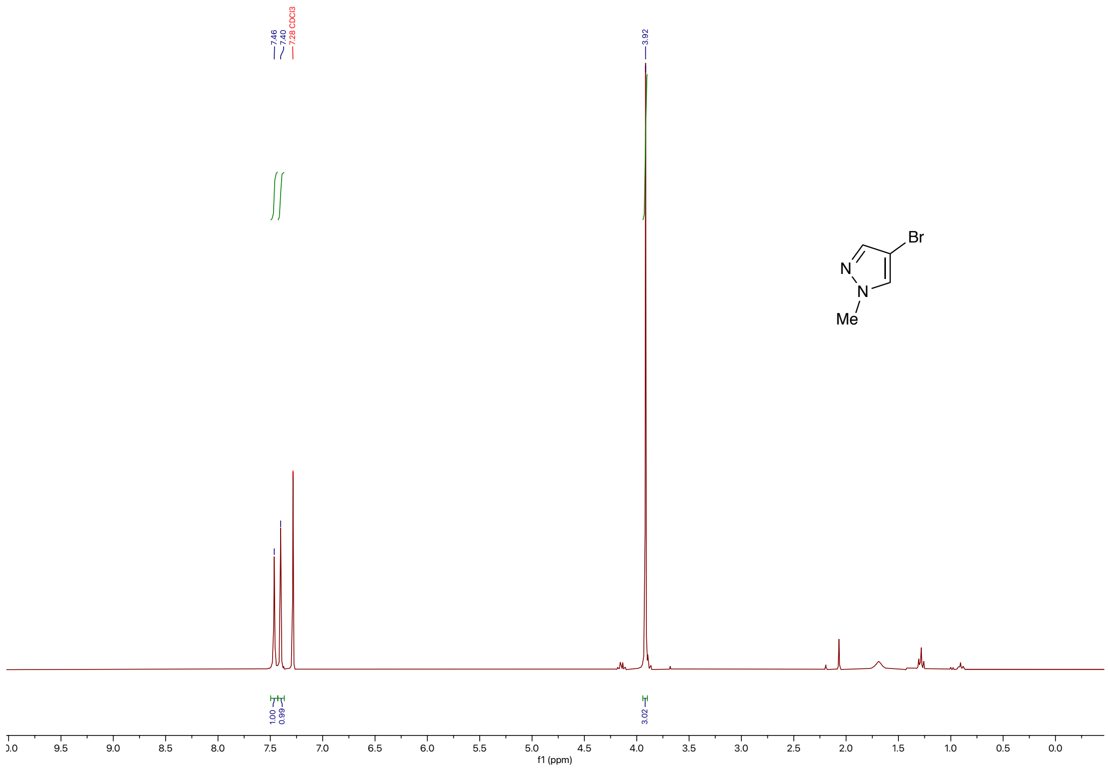
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
-220
-230
-240
-25
f1 (ppm)


8.48
8.48
8.48
8.47
8.47
8.39
8.39
8.39
8.38
8.38
8.38
7.26 CDCl3
N
Br
Cl
N
1.00
1.05
.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1
f1 (ppm)


148.45
146.84
144.78
138.60
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
1.17
N
Br
Cl
N
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)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7.40
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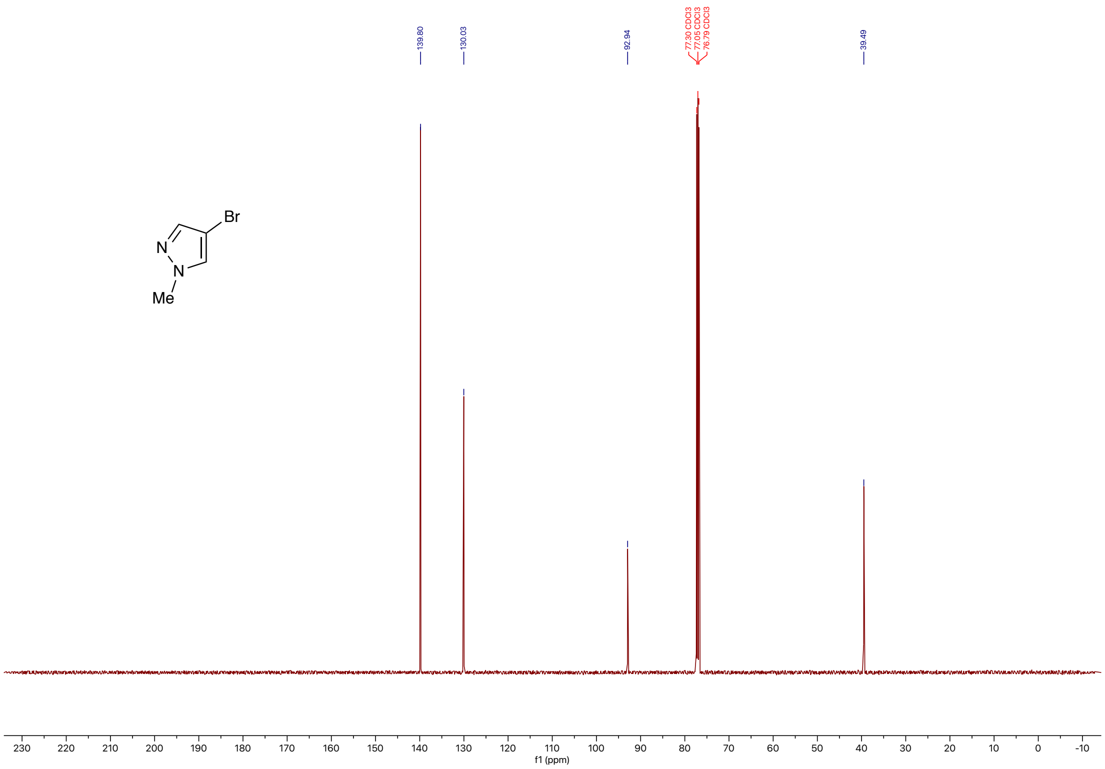
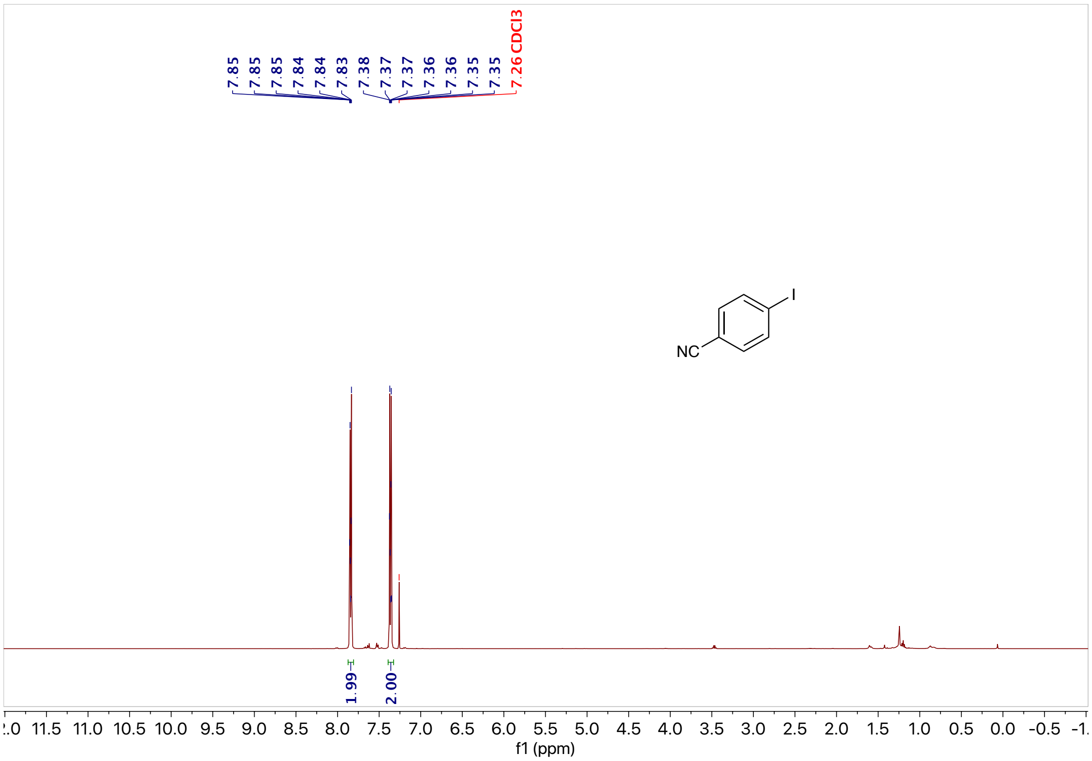
3.92
Br
N
N
Me
1.00
0.99
3.02
0.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


139.80
130.03
92.94
77.30 CDCl3
77.05 CDCl3
76.79 CDCl3
39.49
Br
N
N
Me
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)


7.85
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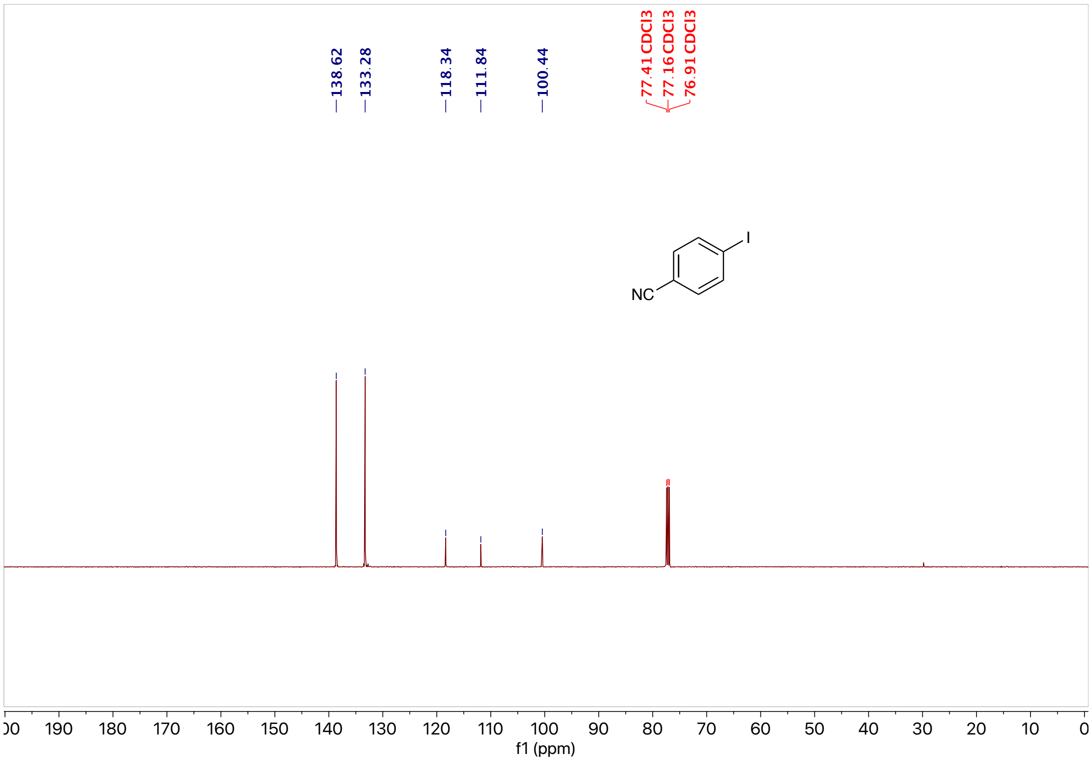
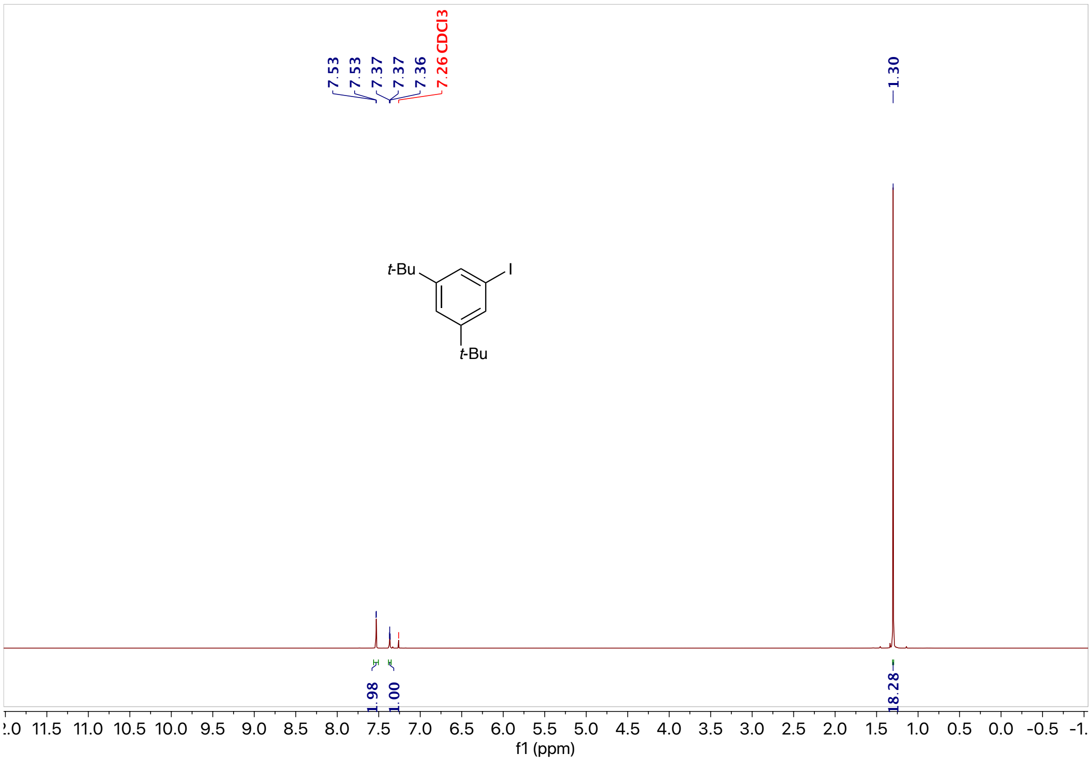
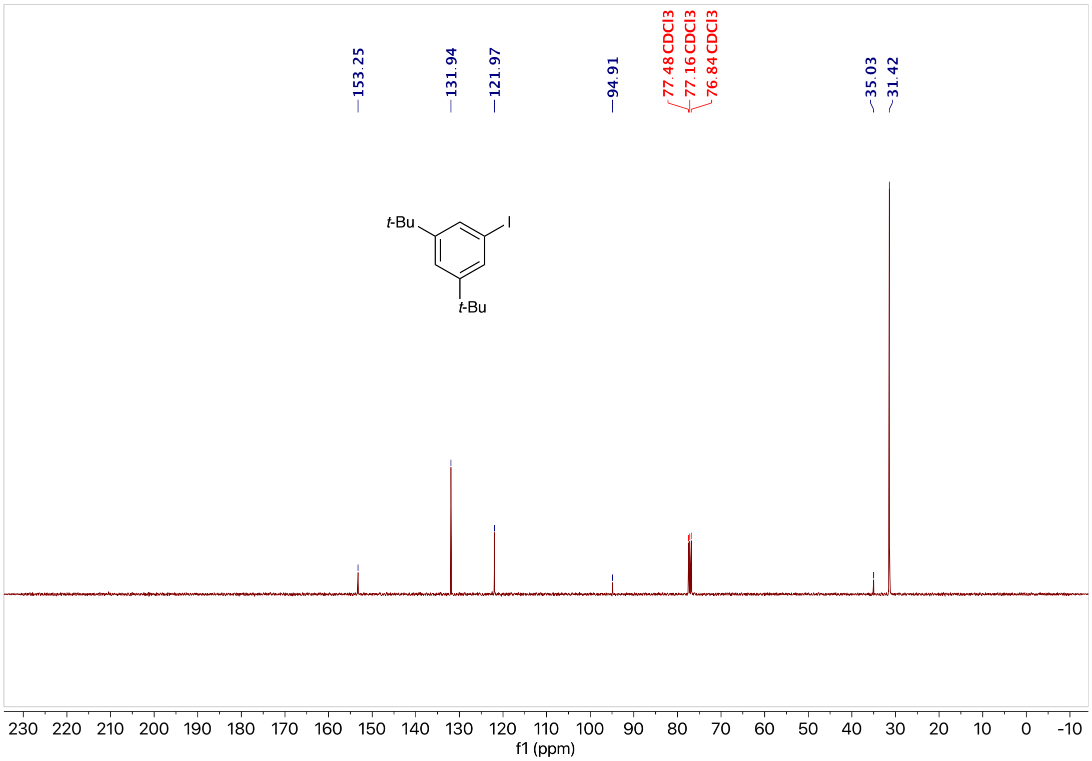
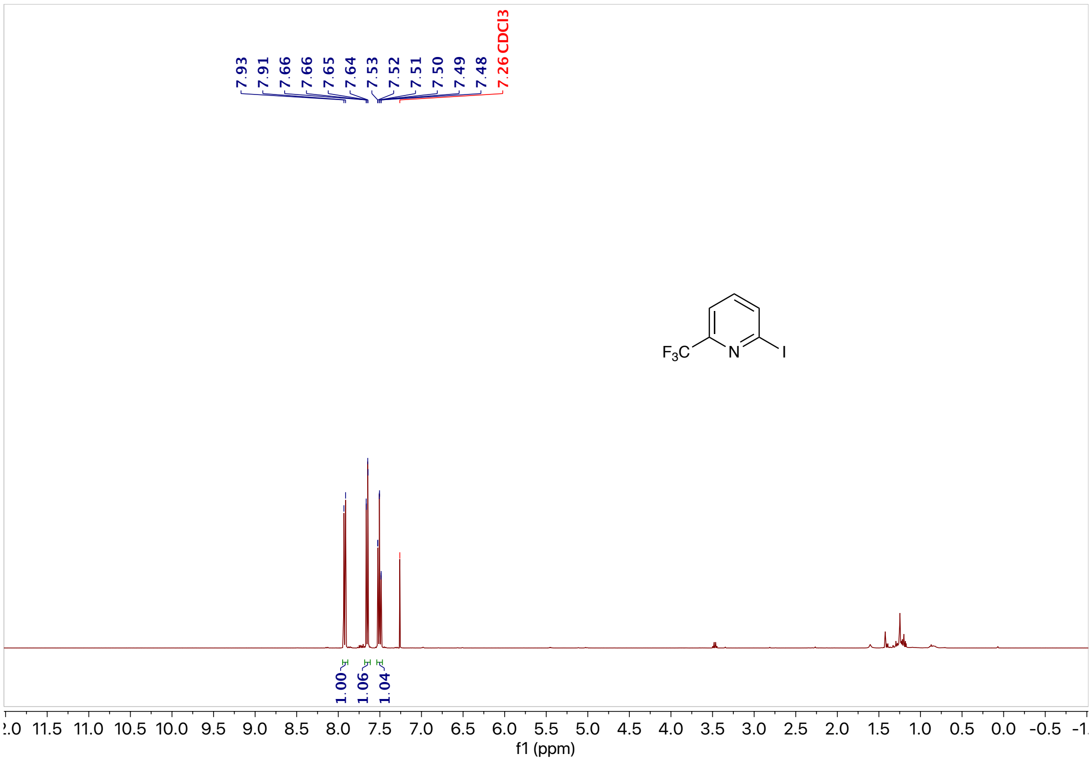
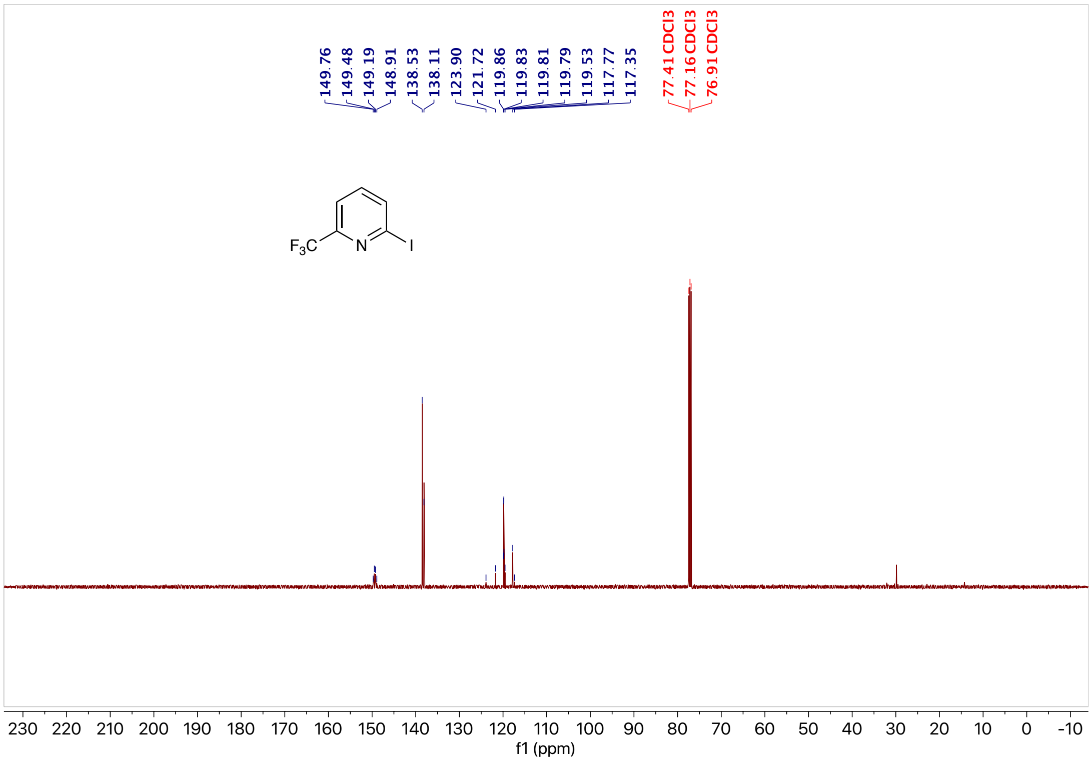
7.85
7.84
7.84
7.83
7.38
7.37
7.37
7.36
7.36
7.35
7.35
7.26 CDCl3
NC
I
1.99
2.00
2.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.
f1 (ppm)


138.62
133.28
118.34
111.84
100.44
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
NC
I
00 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.53
7.53
7.37
7.37
7.36
7.26 CDCl3
1.30
t-Bu
I
t-Bu
1.98
1.00
18.28
12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.
f1 (ppm)


153.25
131.94
121.97
94.91
77.48 CDCl3
77.16 CDCl3
76.84 CDCl3
35.03
31.42
t-Bu
I
t-Bu
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


7.93
7.91
7.66
7.66
7.65
7.64
7.53
7.52
7.51
7.50
7.49
7.48
7.26 CDCl3
F3C
N
I
1.00
1.06
1.04
2.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.
f1 (ppm)


149.76
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148.91
138.53
138.11
123.90
121.72
119.86
119.83
119.81
119.79
119.53
117.77
117.35
77.41 CDCl3
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F3C
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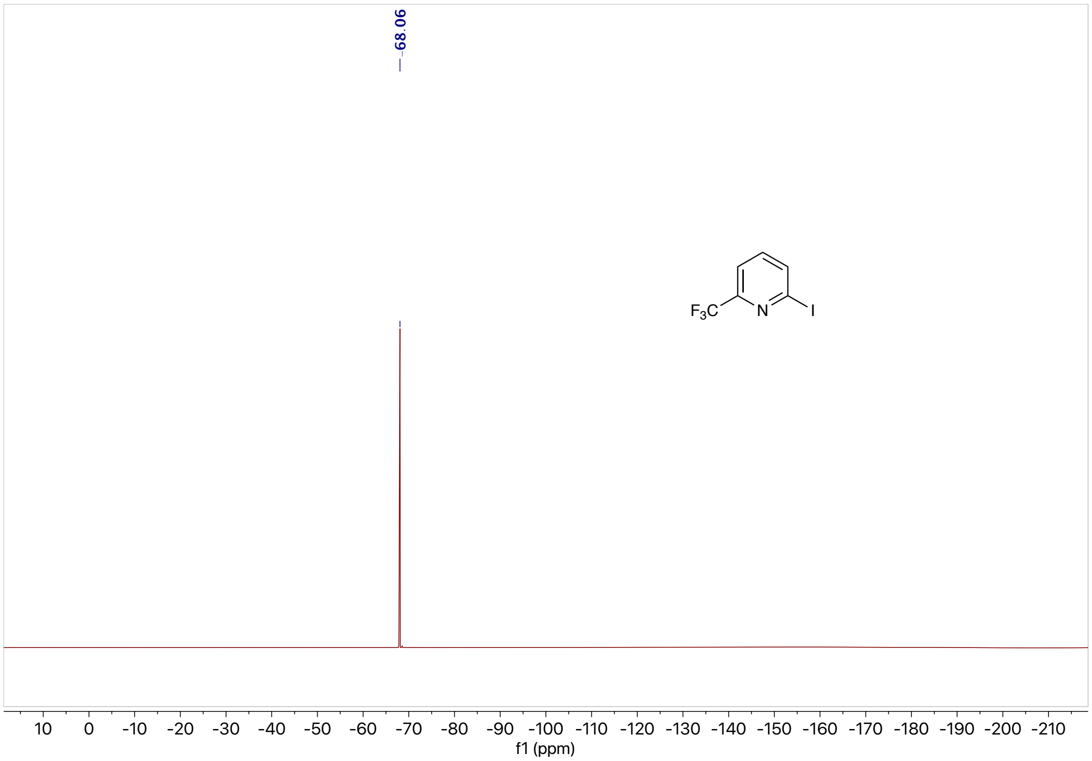
f1 (ppm)


-68.06
F3C
N
I
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0
-10
-20
-30
-40
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-60
-70
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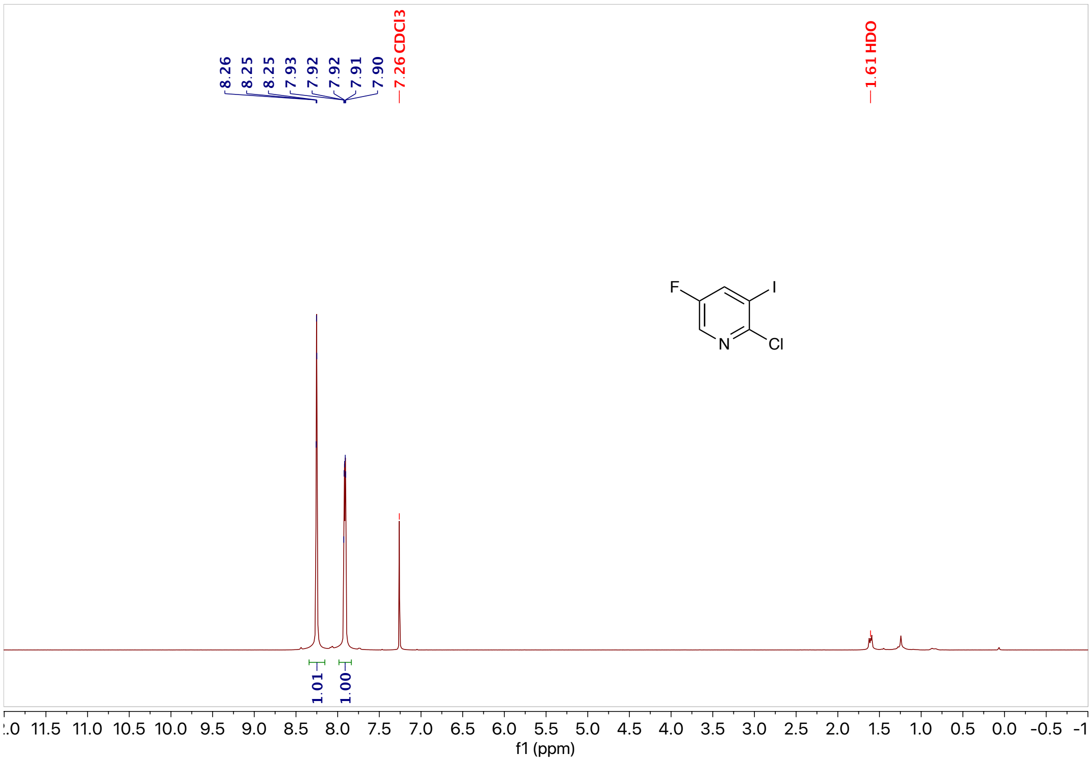
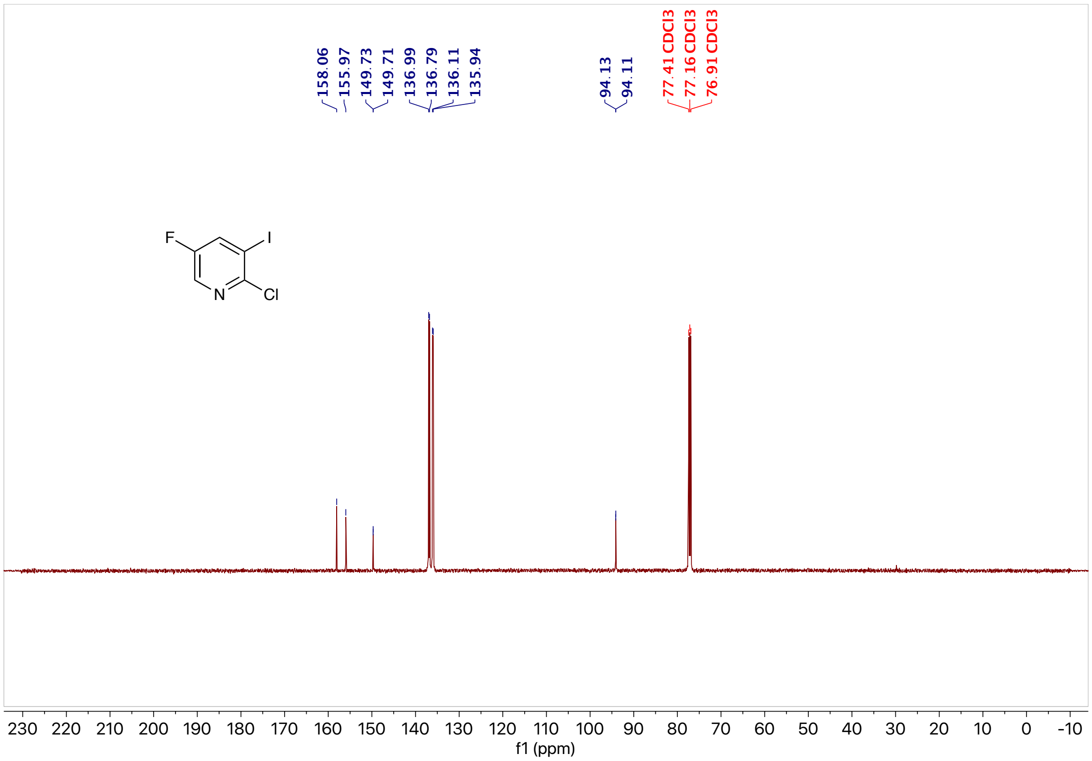
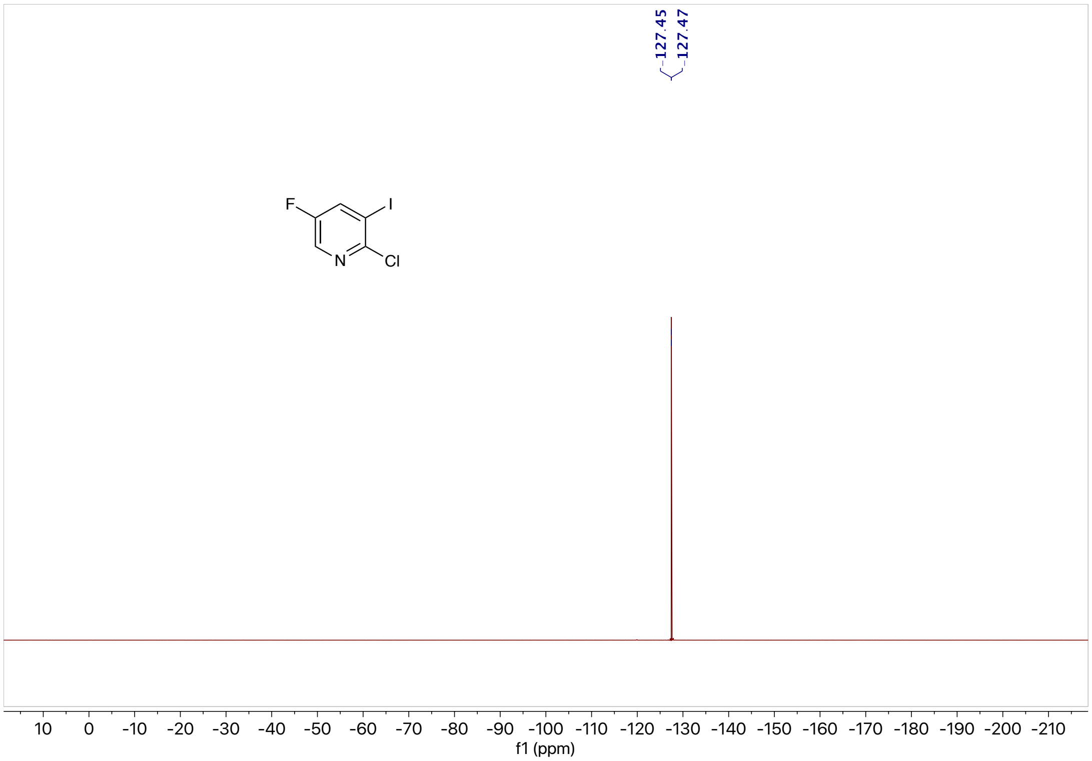
-190
-200
-210
f1 (ppm)


8.26
8.25
8.25
7.93
7.92
7.92
7.91
7.90
7.26 CDCl3
1.61 HDO
F
I
N
Cl
1.01
1.00
12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1
f1 (ppm)


158.06
155.97
149.73
149.71
136.99
136.79
136.11
135.94
94.13
94.11
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
F
I
N
Cl
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


-127.45
-127.47
F
I
N
Cl
10
0
-10
-20
-30
-40
-50
-60
-70
-80
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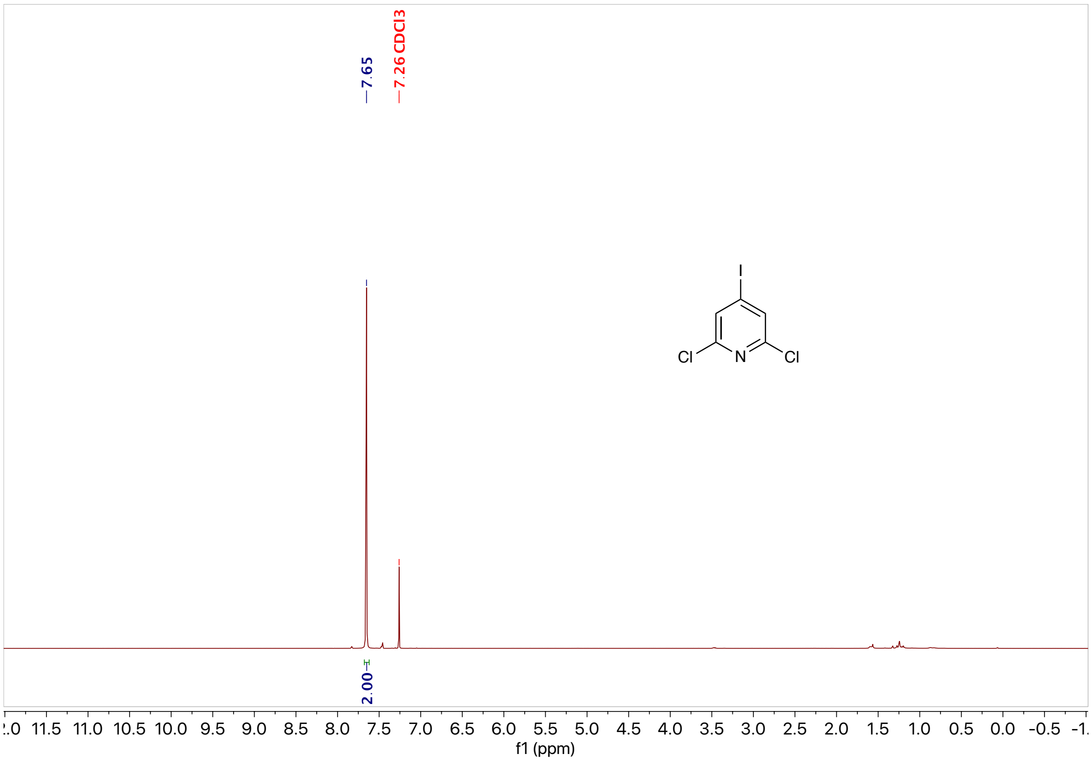
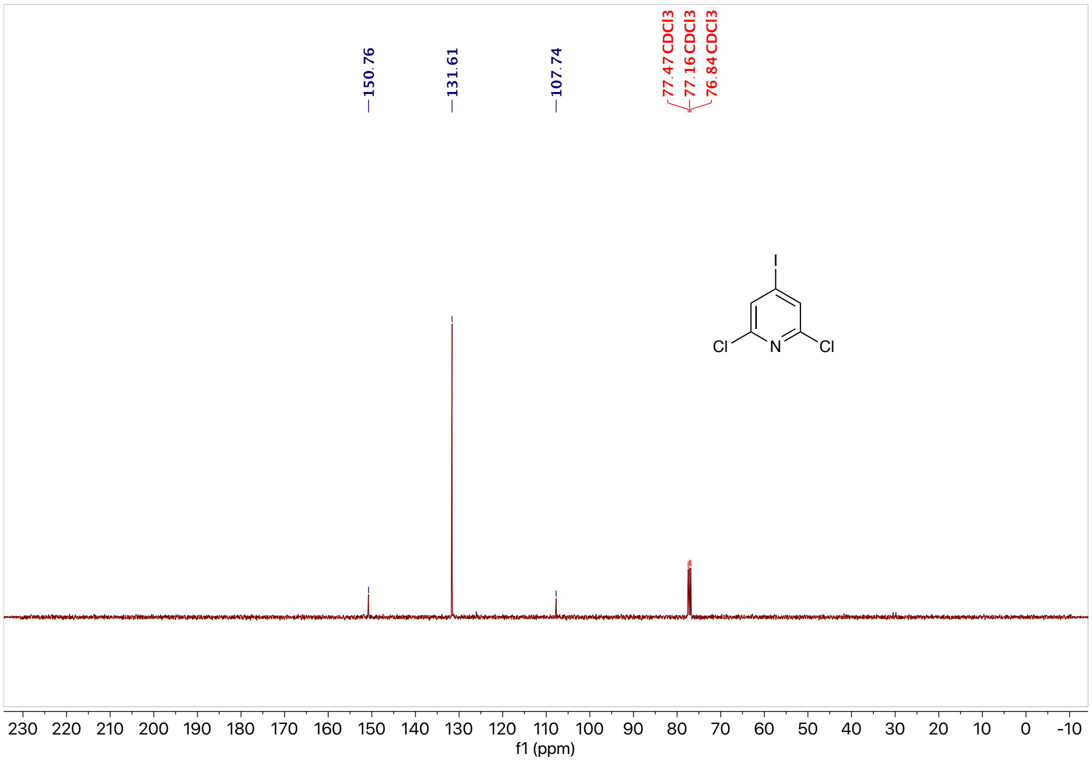
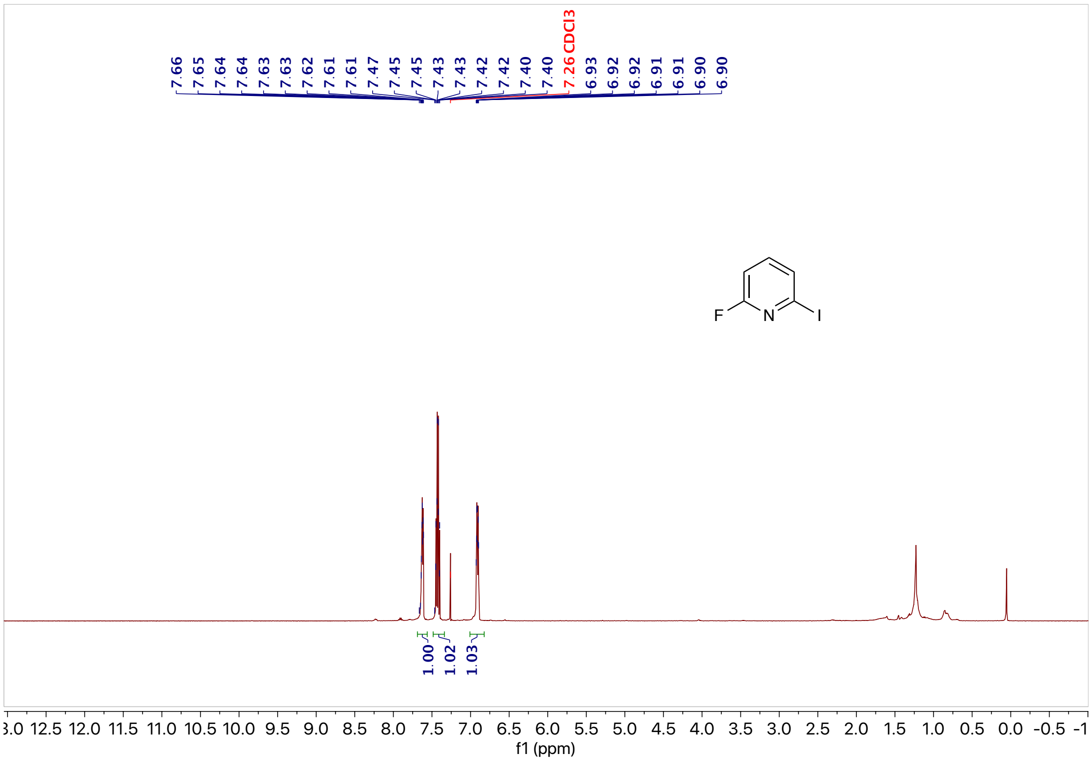
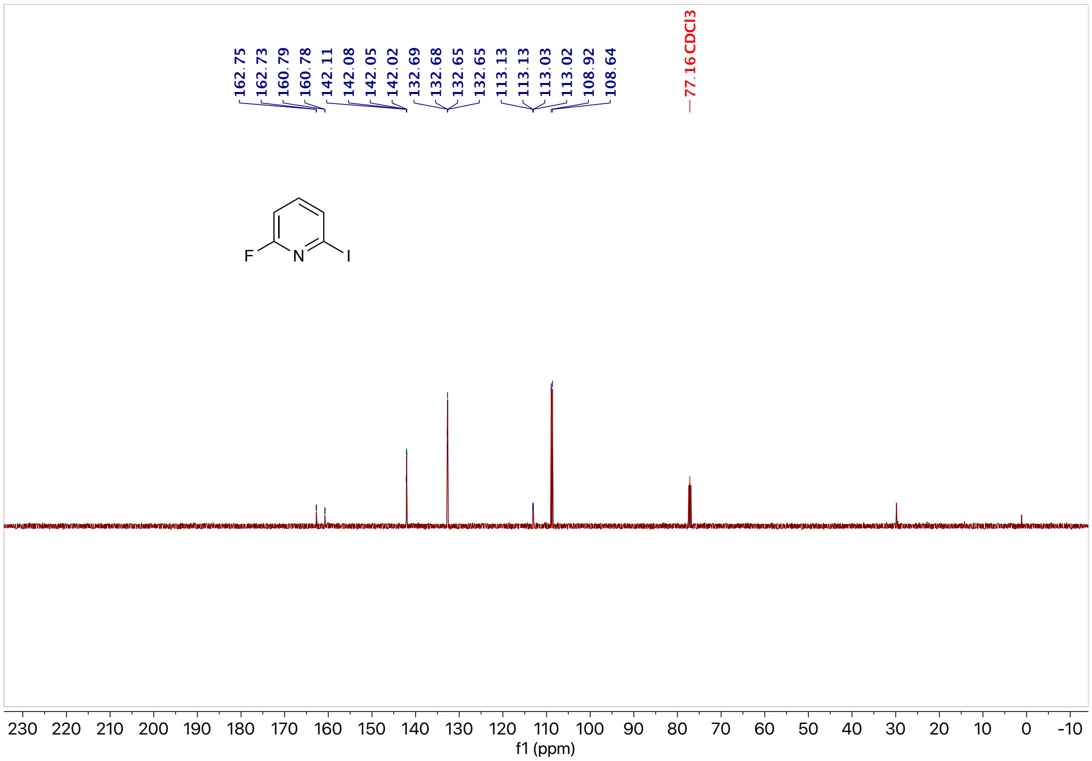
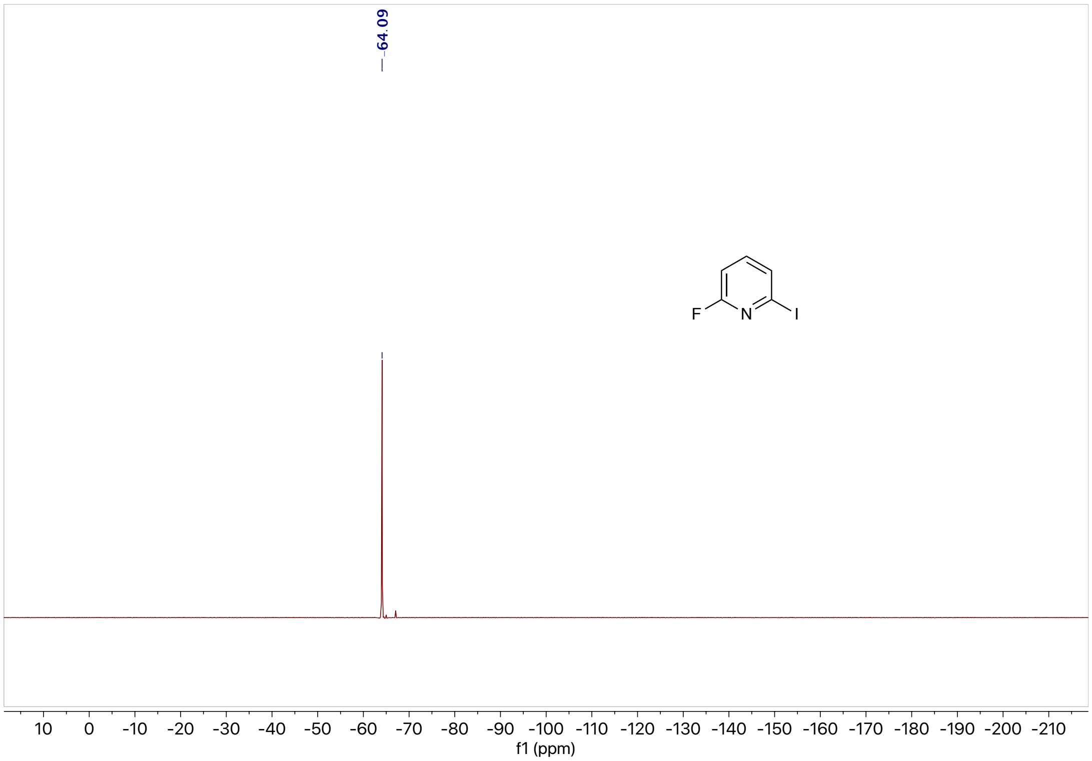
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
f1 (ppm)


7.65
7.26 CDCl3
I
Cl
N
Cl
2.00
.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.
f1 (ppm)


150.76
131.61
107.74
77.47 CDCl3
77.16 CDCl3
76.84 CDCl3
I
Cl
N
Cl
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


7.66
7.65
7.64
7.64
7.63
7.63
7.62
7.61
7.61
7.47
7.45
7.45
7.43
7.43
7.42
7.42
7.40
7.40
7.26 CDCl3
6.93
6.92
6.92
6.91
6.91
6.90
6.90
F
N
I
1.00
1.02
1.03
3.0 12.5 12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1
f1 (ppm)


162.75
162.73
160.79
160.78
142.11
142.08
142.05
142.02
132.69
132.68
132.65
132.65
113.13
113.13
113.03
113.02
108.92
108.64
77.16 CDCl3
F
N
I
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


-64.09
F
N
I
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
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-120
-130
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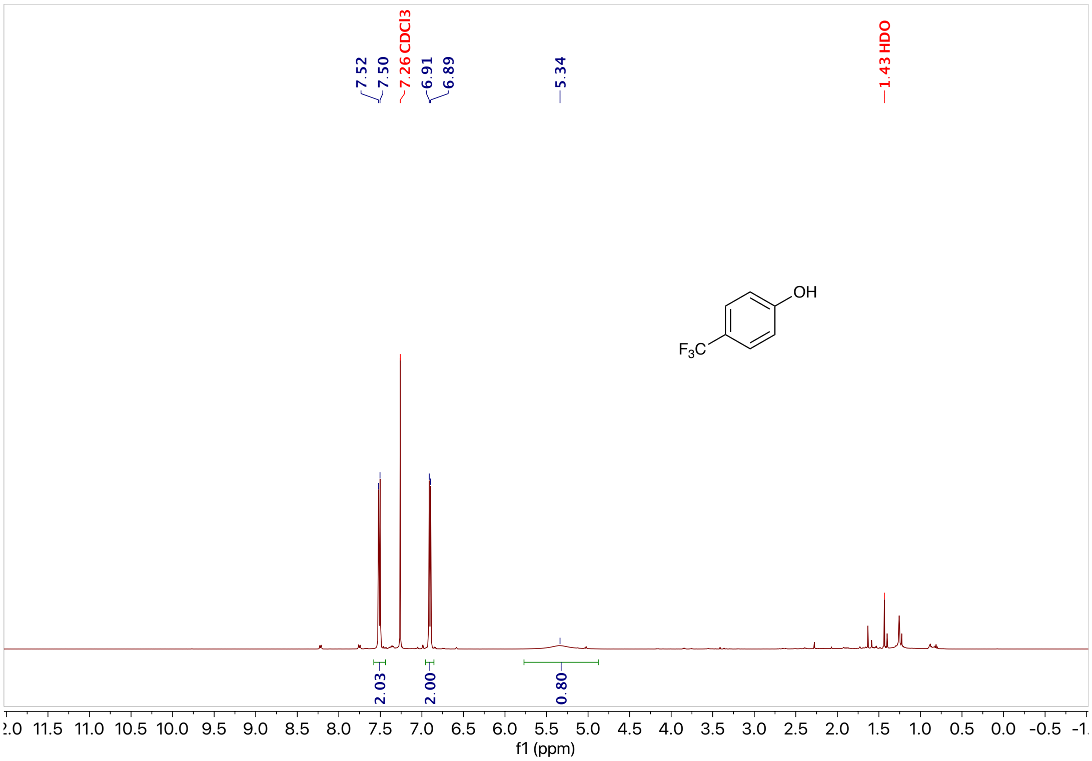
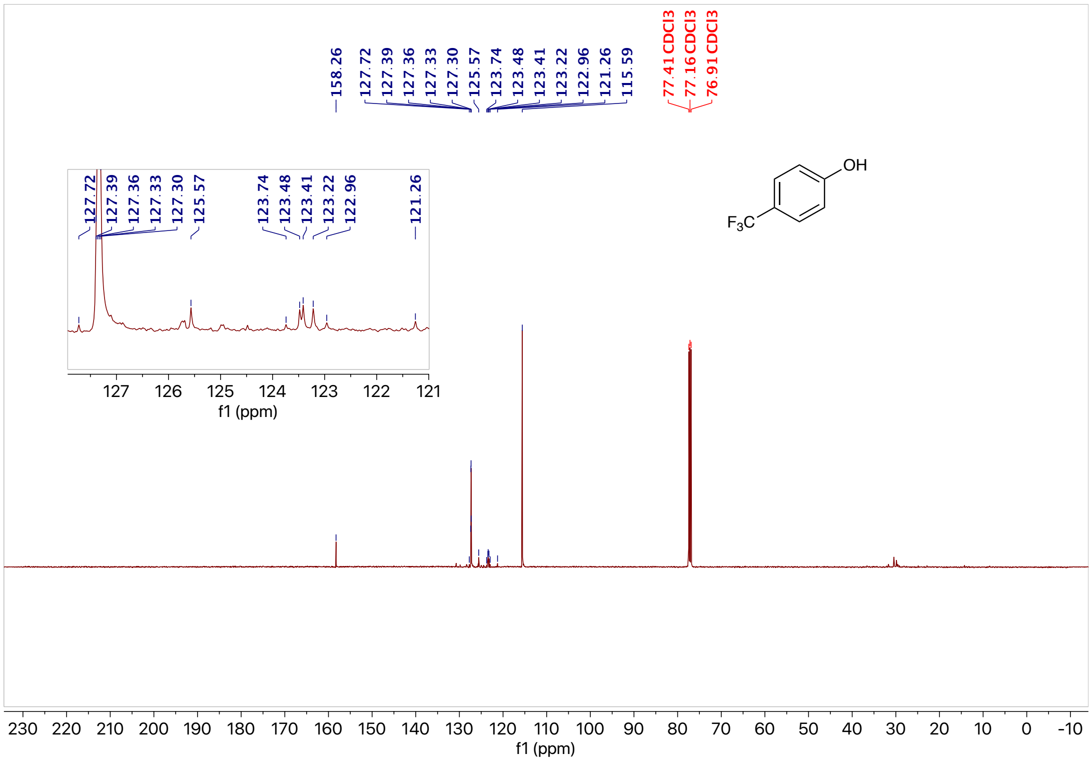
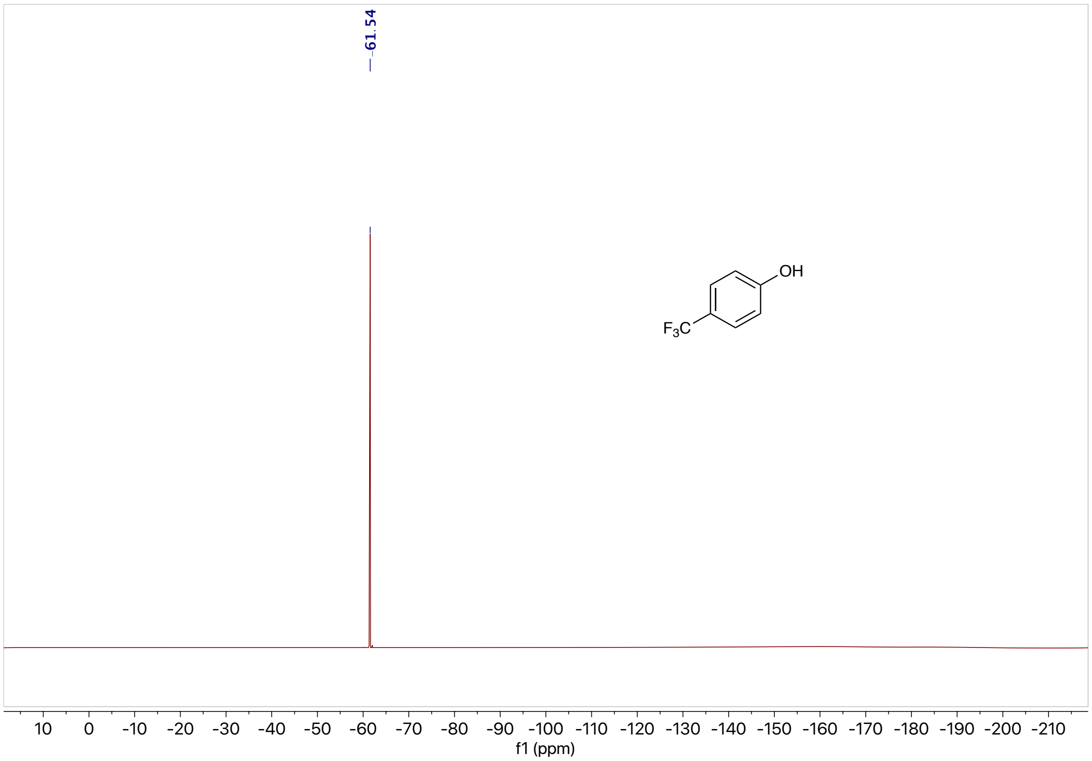
-180
-190
-200
-210
f1 (ppm)


7.52
7.50
7.26 CDCl3
6.91
6.89
5.34
1.43 HDO
OH
F3C
2.03
2.00
0.80
12.0 11.5 11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1
f1 (ppm)


158.26
127.72
127.39
127.36
127.33
127.30
125.57
123.74
123.48
123.41
123.22
122.96
121.26
115.59
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
OH
F3C
127 126 125 124 123 122 121
f1 (ppm)
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


-61.54
OH
F3C
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
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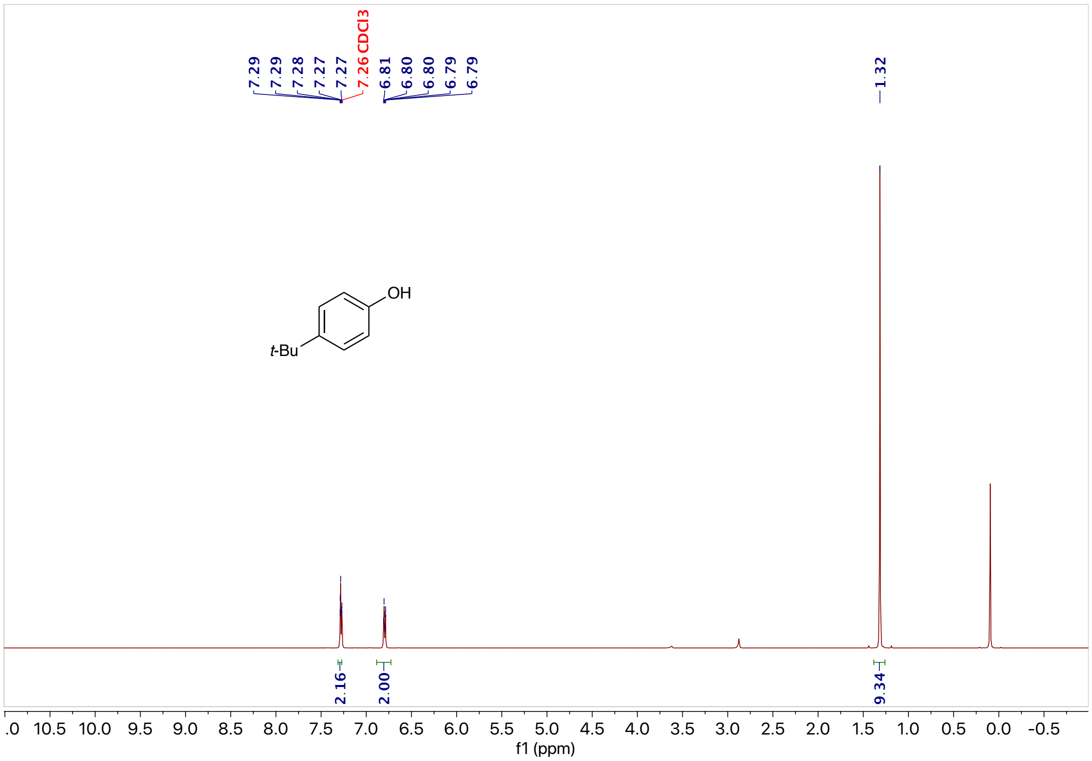
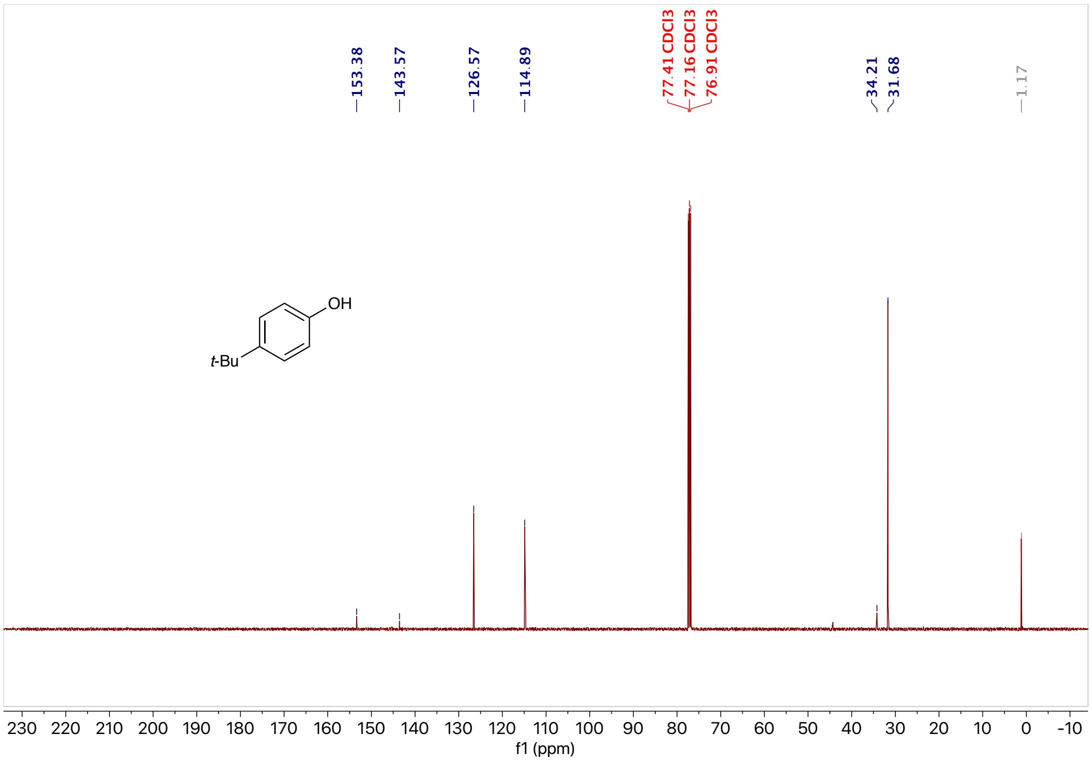
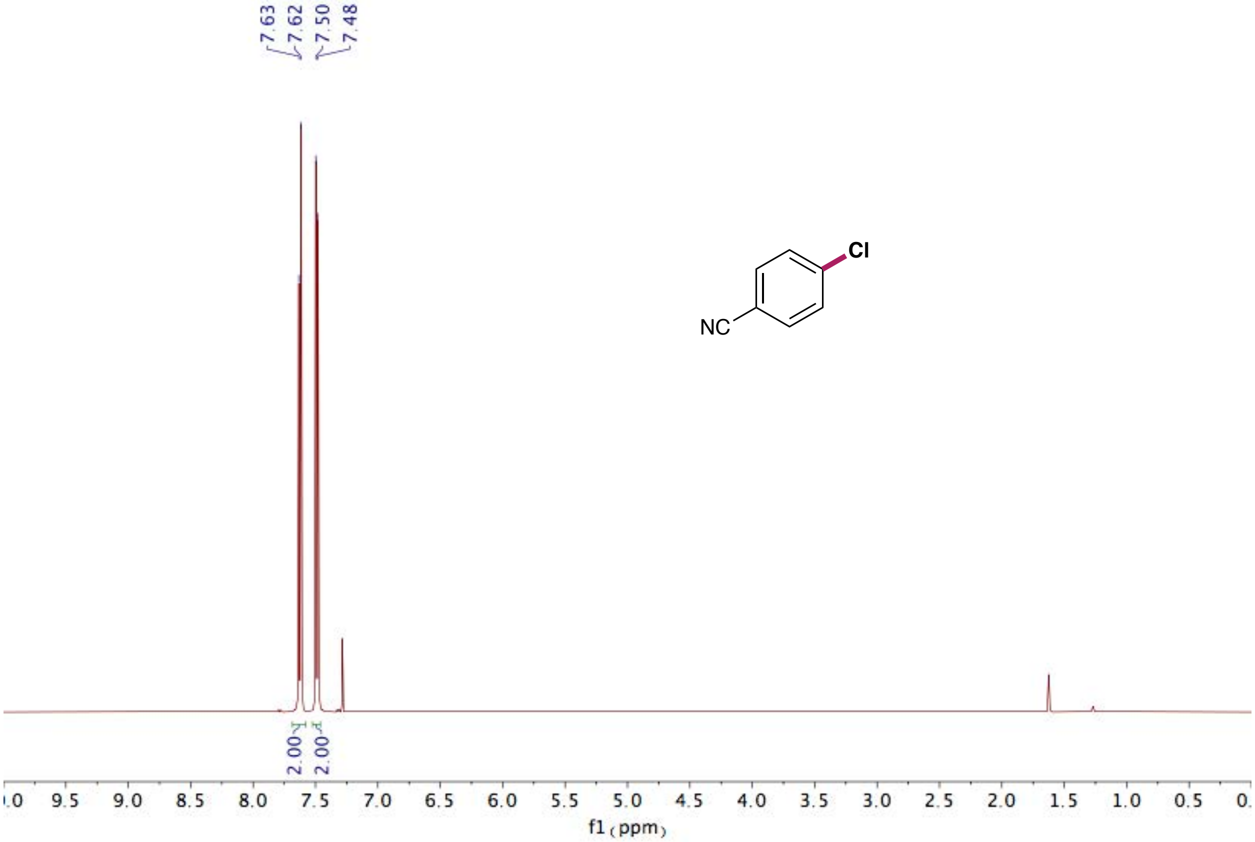
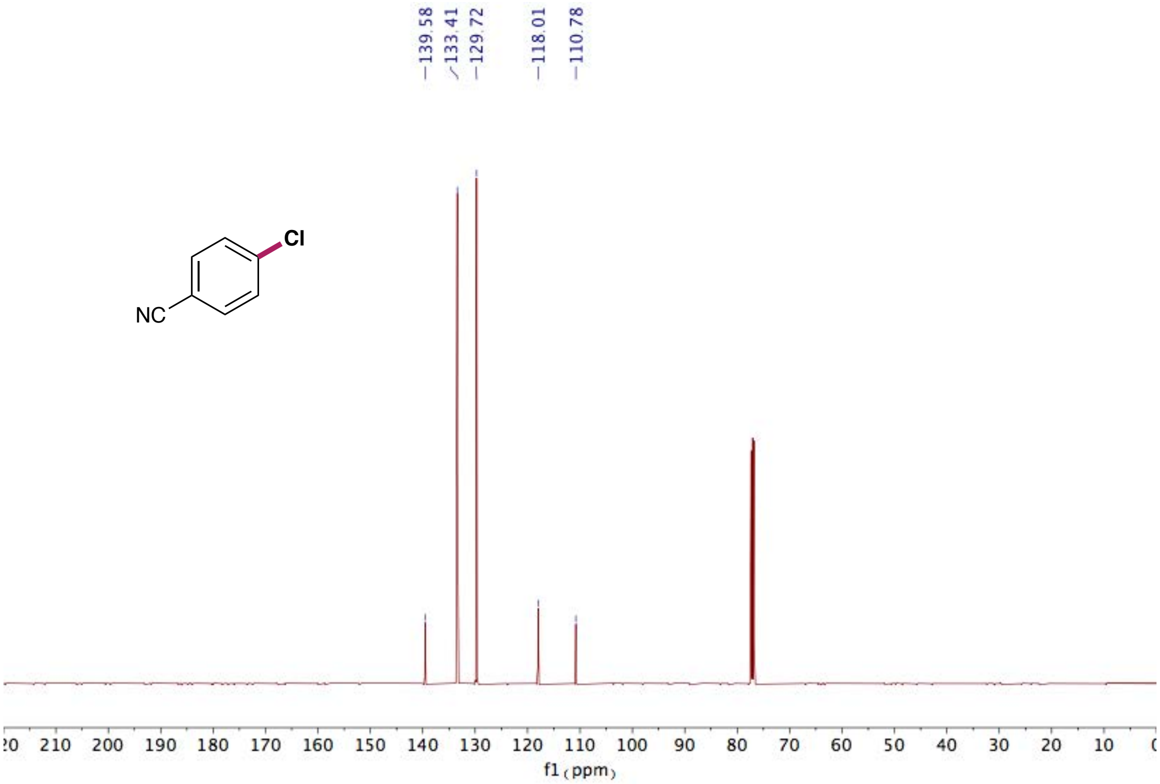
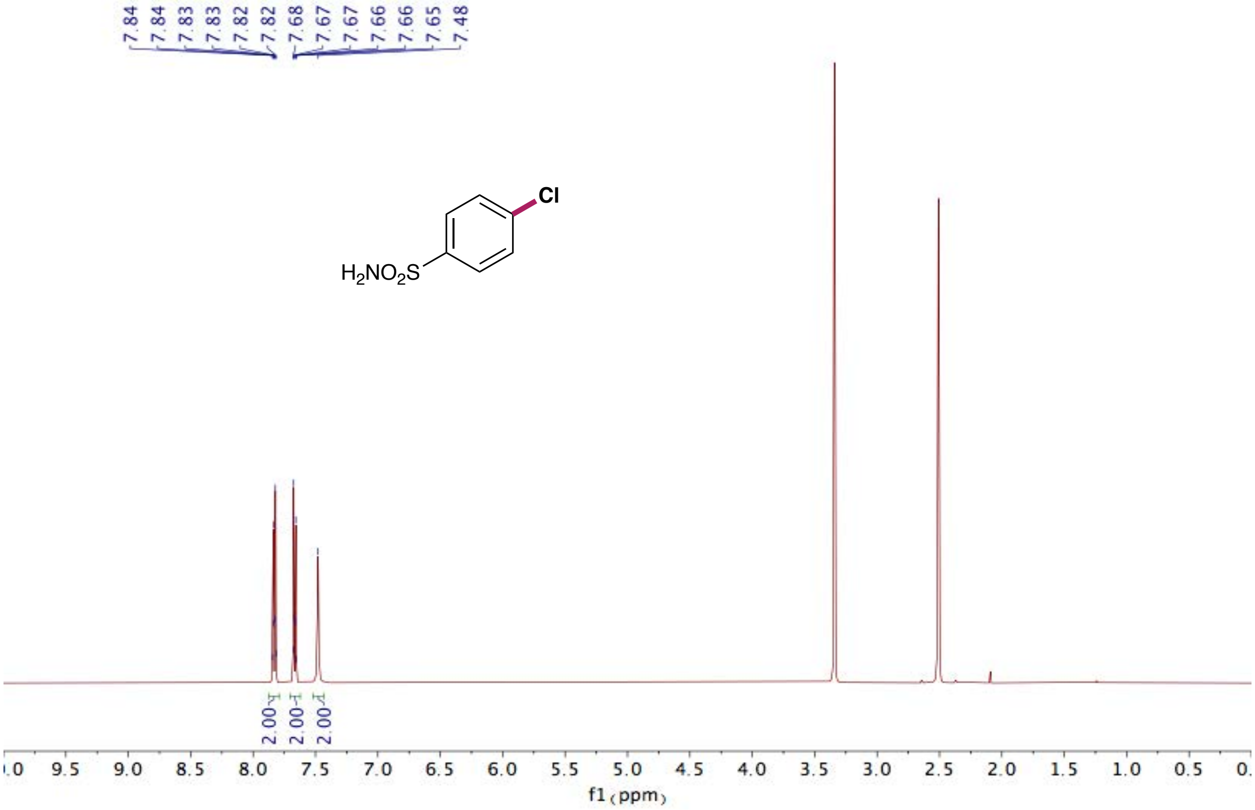
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
f1 (ppm)

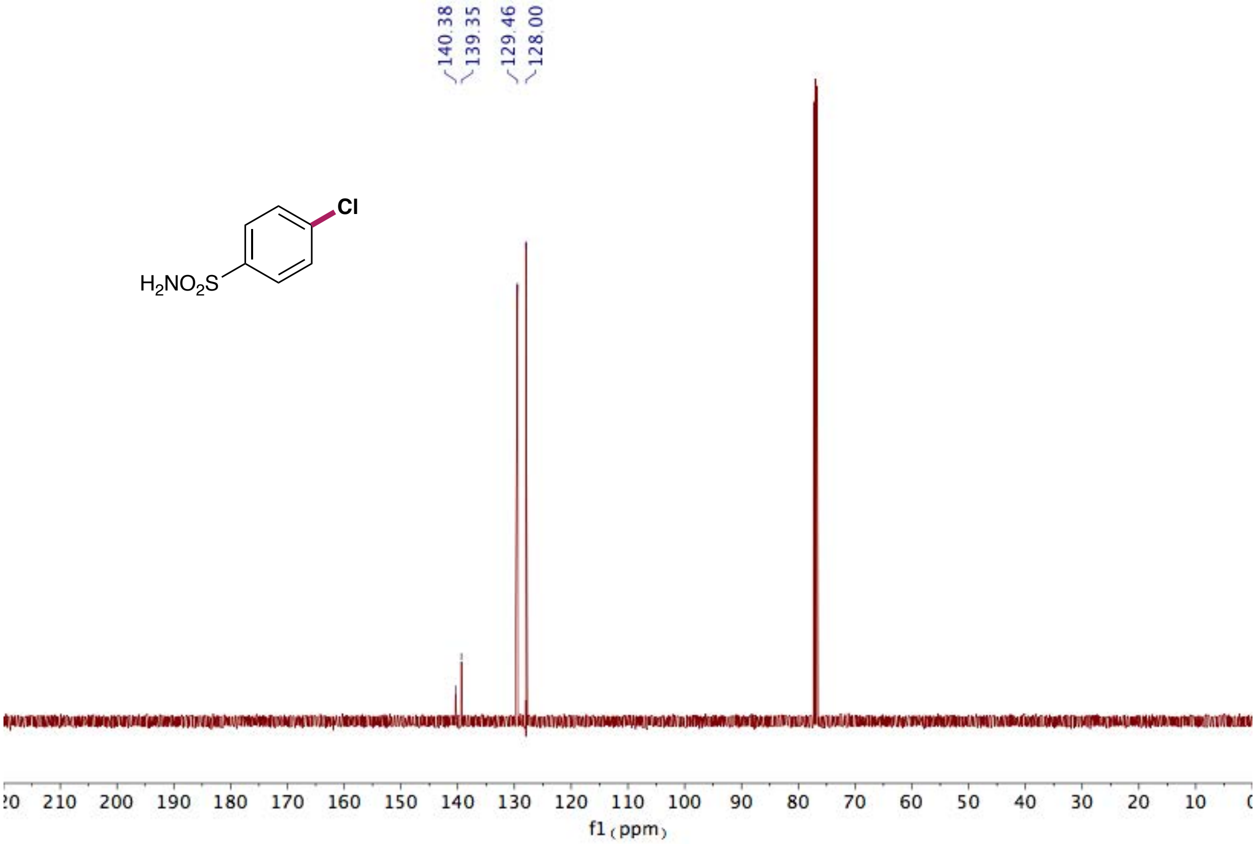

7.29
7.29
7.28
7.27
7.27
7.26 CDCl3
6.81
6.80
6.80
6.79
6.79
1.32
OH
t-Bu
2.16
2.00
9.34
.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

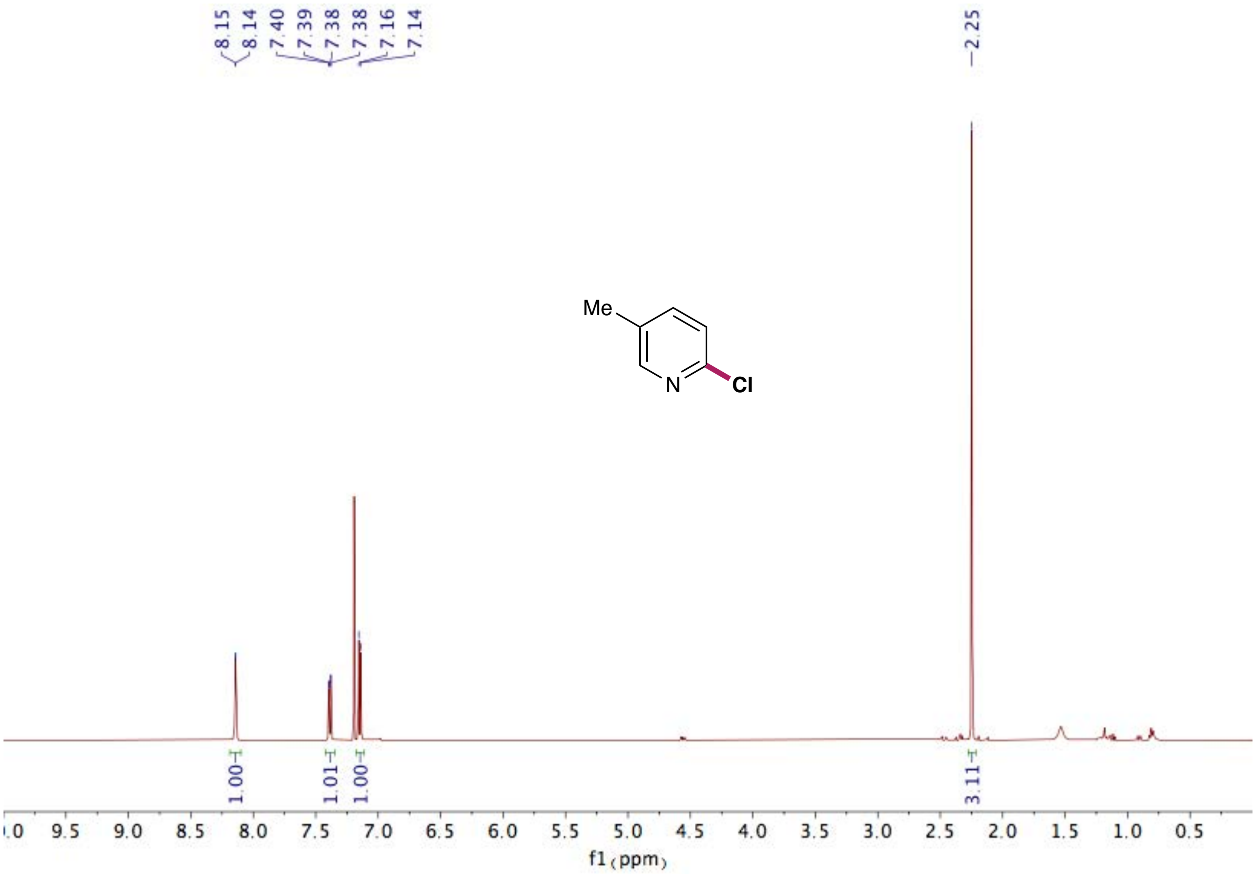

153.38
143.57
126.57
114.89
77.41 CDCl3
77.16 CDCl3
76.91 CDCl3
34.21
31.68
1.17
OH
t-Bu
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

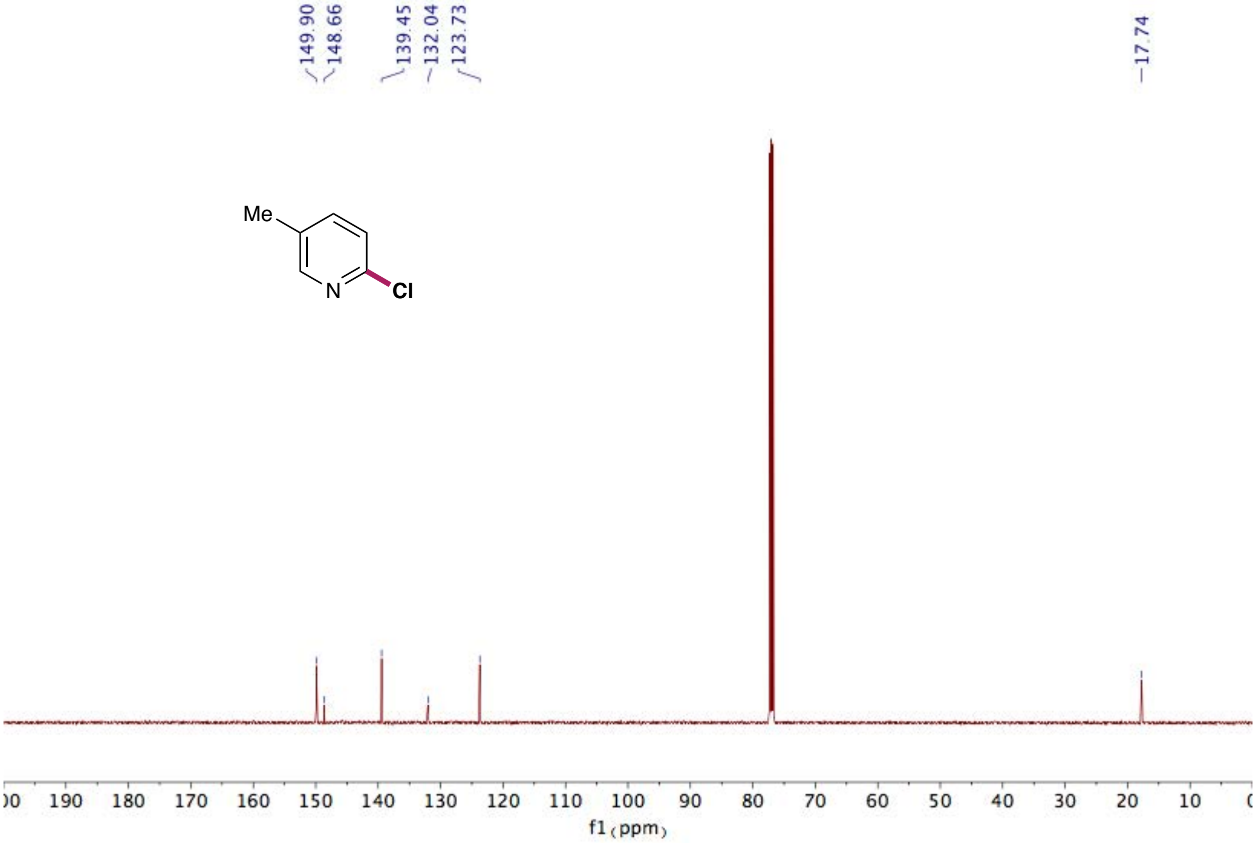

7.63
7.62
7.50
7.48
Cl
NC
2.00
2.00
.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.
f1 (ppm)

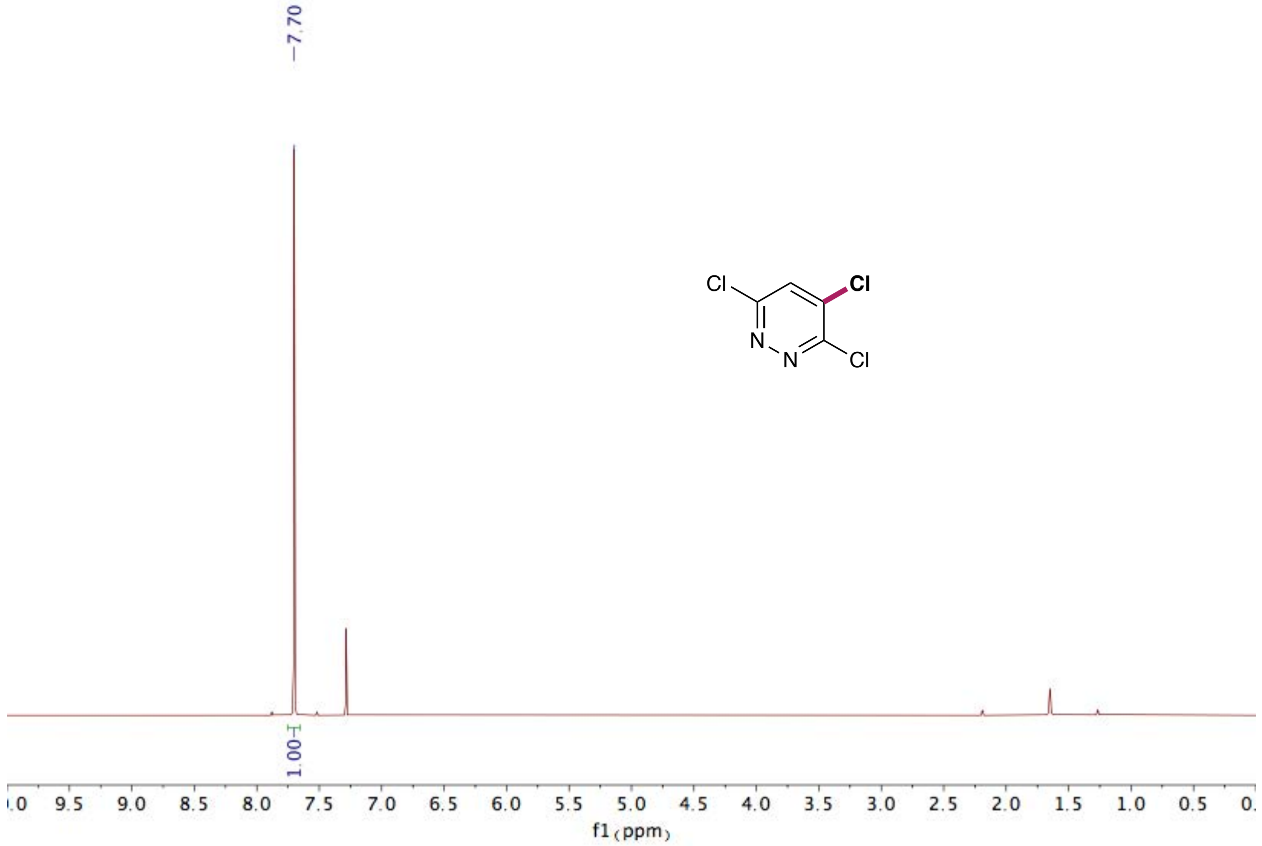

139.58
133.41
129.72
118.01
110.78
Cl
NC
20 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

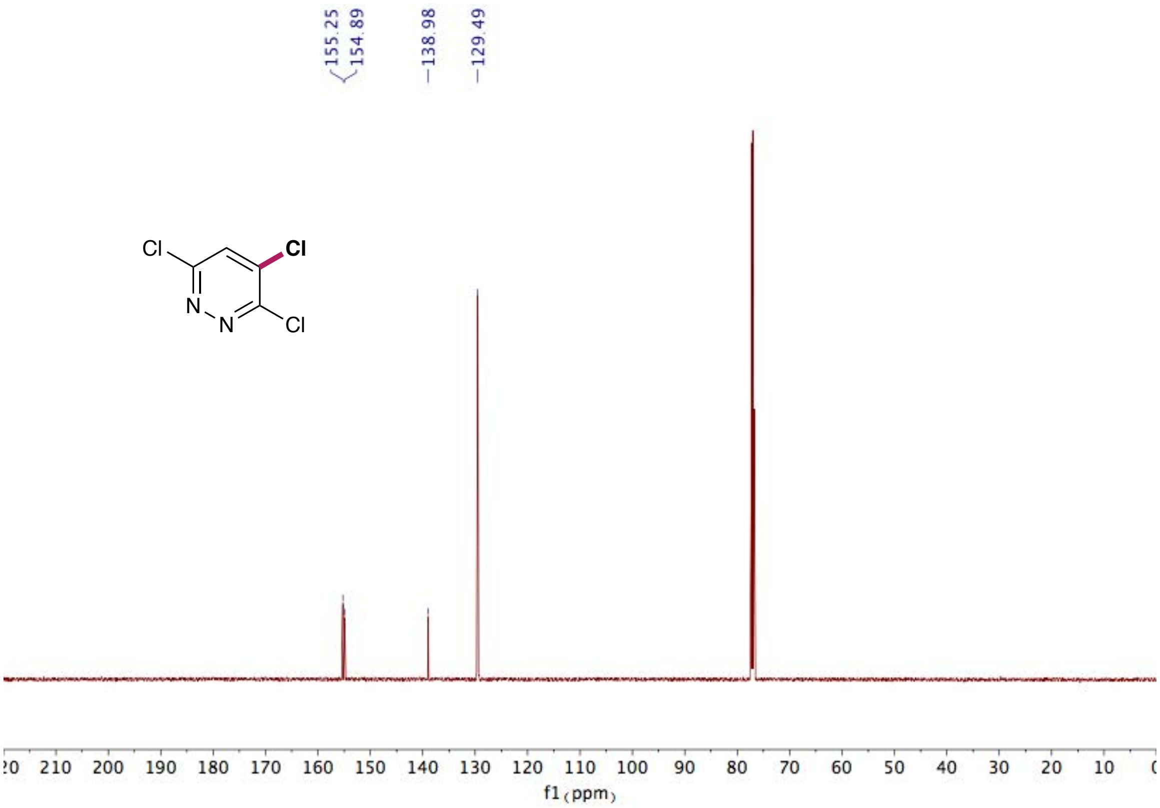

7.84
7.84
7.83
7.83
7.82
7.82
7.68
7.67
7.67
7.66
7.66
7.65
7.48
Cl
H_2NO_2S
2.00
2.00
2.00
.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)

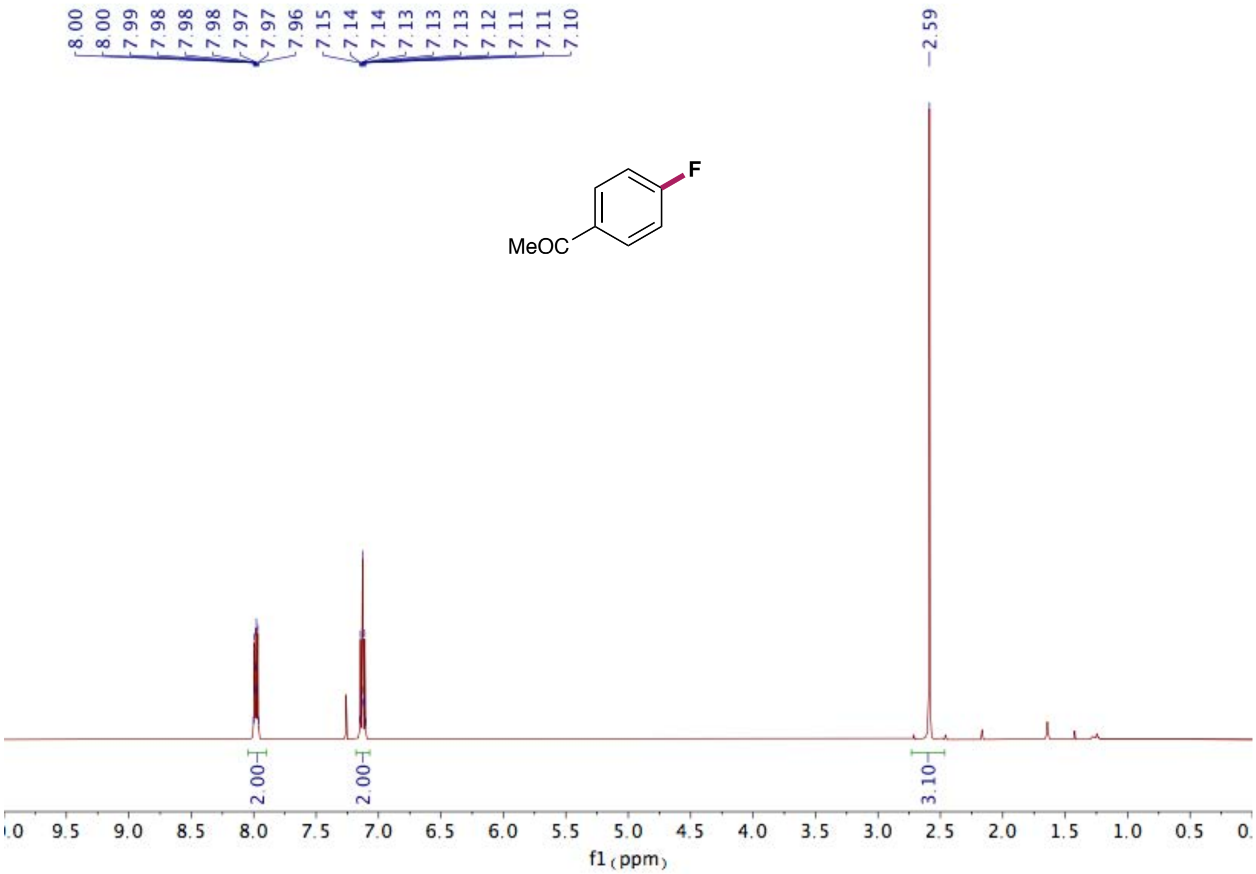

140.38
139.35
129.46
128.00
Cl
H_2NO_2S
20
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

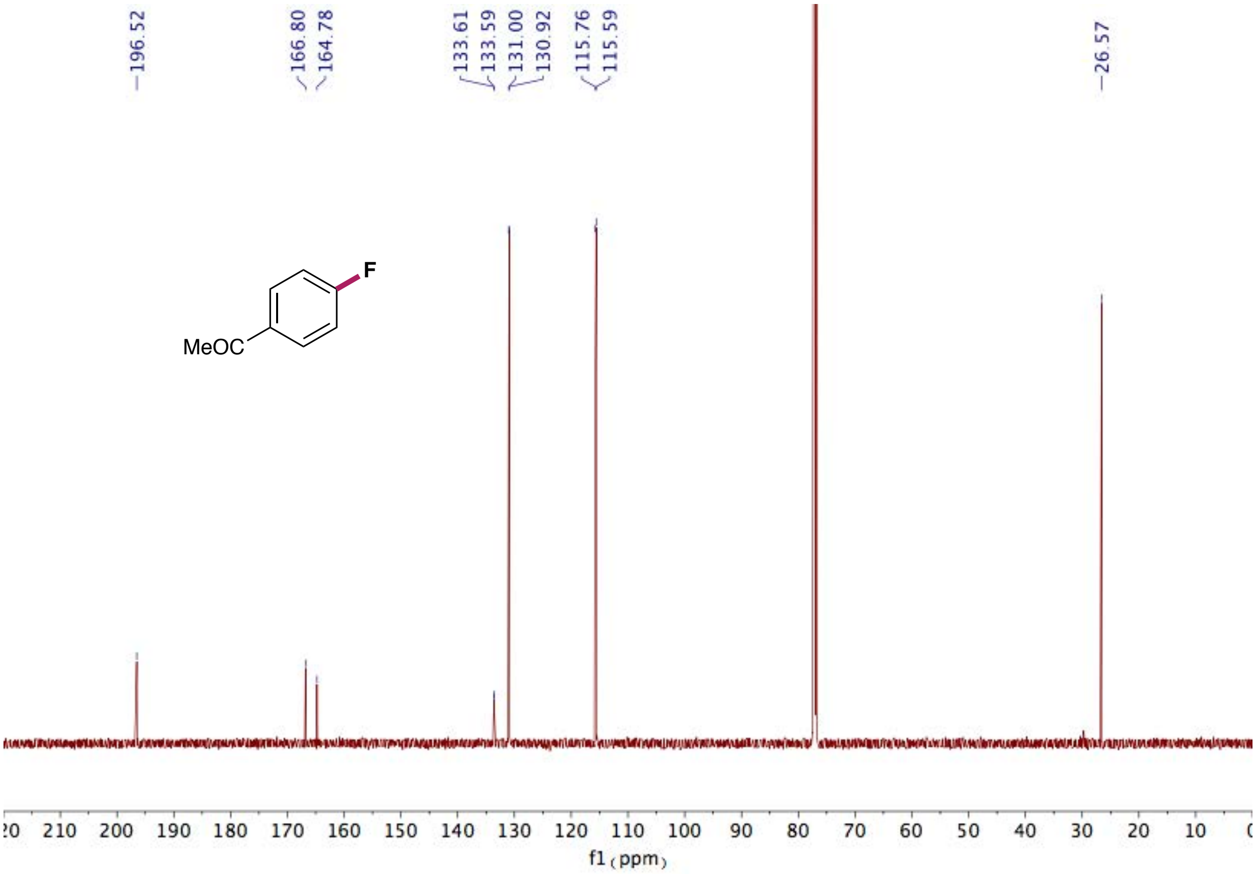

8.15
8.14
7.40
7.39
7.38
7.38
7.16
7.14
2.25
Me
N
Cl
1.00
1.01
1.00
3.11
.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

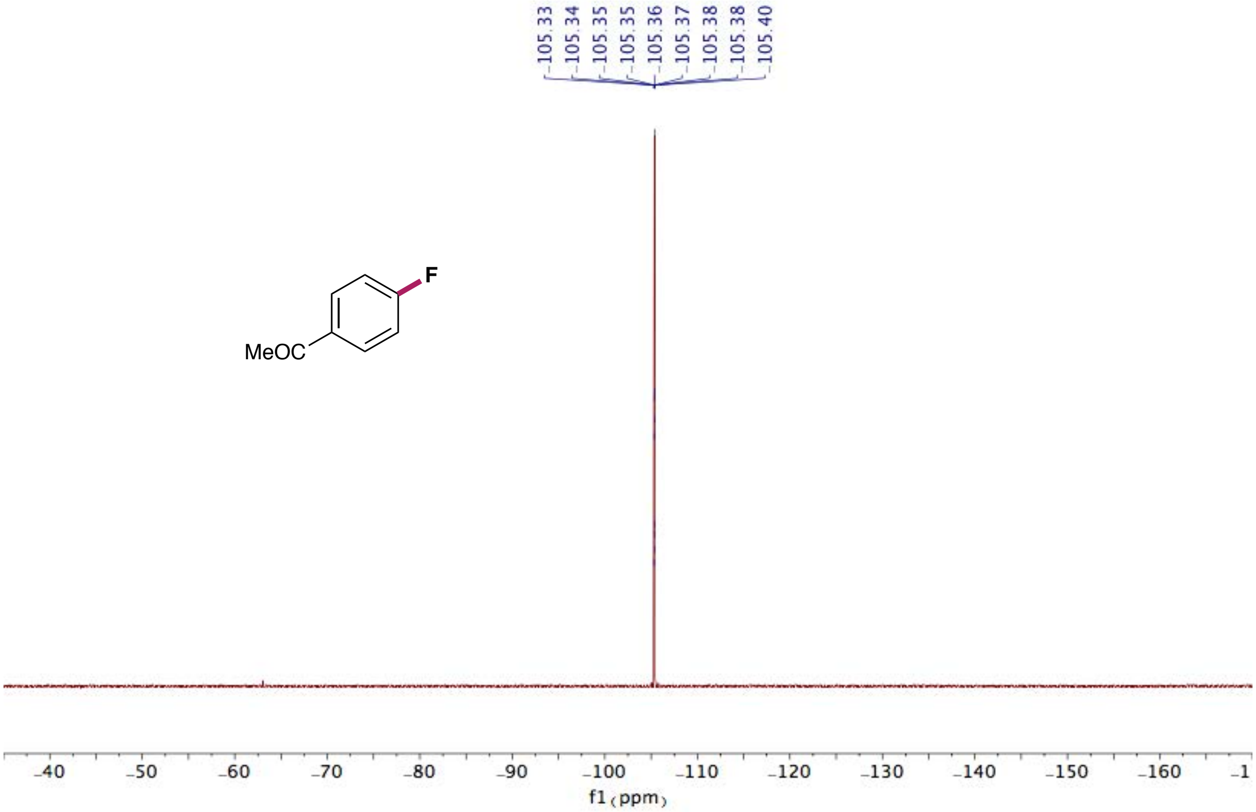

149.90
148.66
139.45
132.04
123.73
17.74
Me
N
Cl
)0
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
(
f1 (ppm)

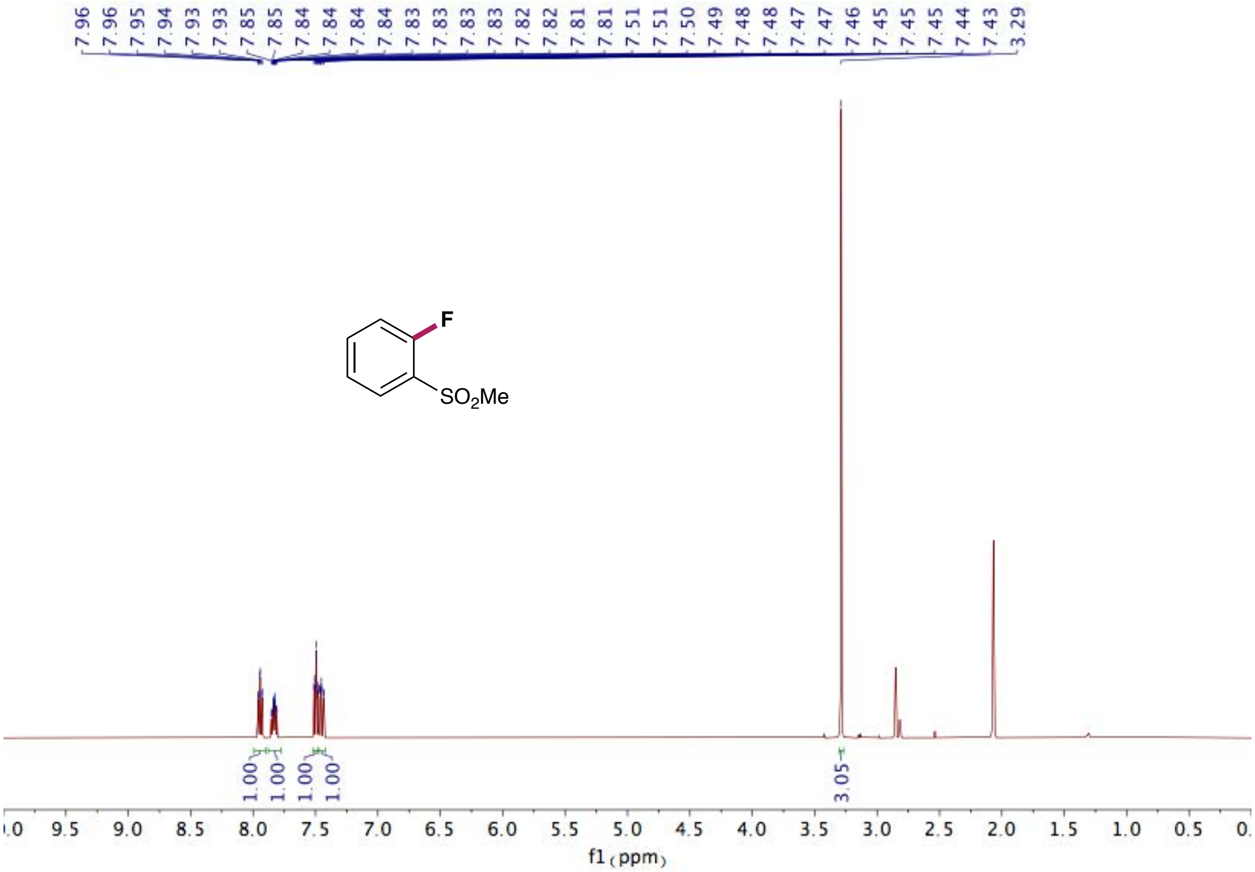

7.70
1.00
Cl
Cl
N
N
Cl
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

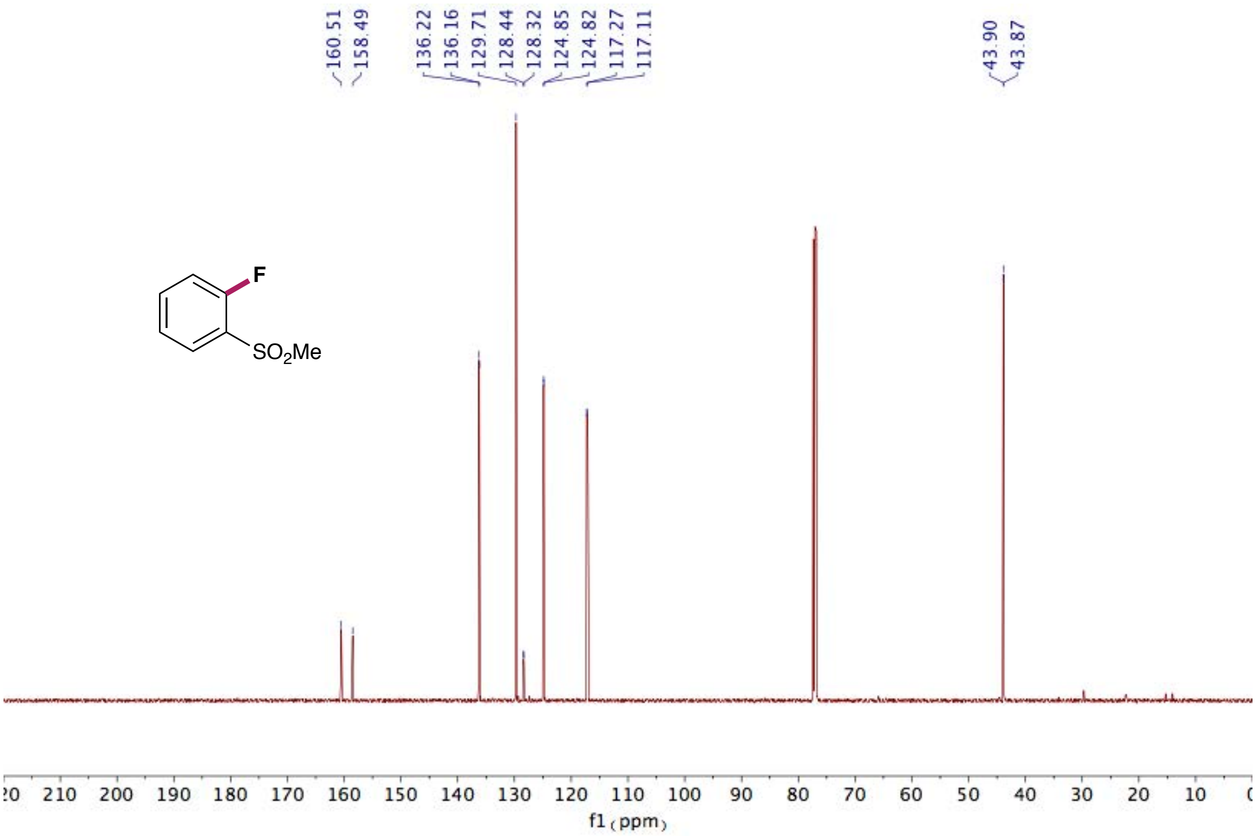

155.25
154.89
138.98
129.49
Cl
Cl
N
N
Cl
20 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

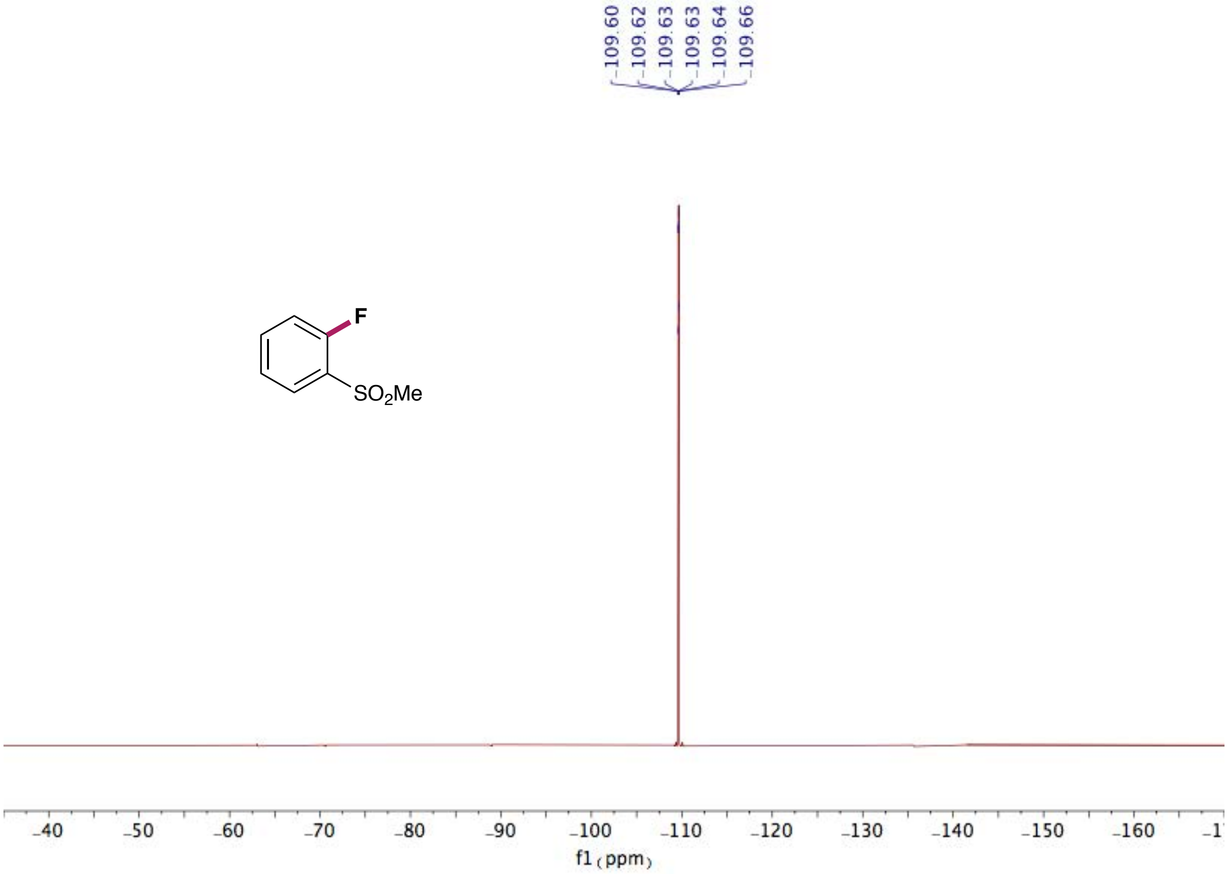

8.00
8.00
7.99
7.98
7.98
7.98
7.97
7.97
7.96
7.15
7.14
7.14
7.13
7.13
7.13
7.12
7.11
7.11
7.10
2.59
F
MeOC
2.00
2.00
3.10
.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)


196.52
166.80
164.78
133.61
133.59
131.00
130.92
115.76
115.59
26.57
F
MeOC
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


-105.33
-105.34
-105.35
-105.35
-105.36
-105.37
-105.38
-105.38
-105.40
F
MeOC
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-1
f1 (ppm)


7.96
7.96
7.95
7.94
7.93
7.93
7.85
7.85
7.84
7.84
7.84
7.84
7.83
7.83
7.83
7.83
7.82
7.82
7.81
7.81
7.51
7.51
7.50
7.49
7.48
7.48
7.47
7.47
7.46
7.45
7.45
7.45
7.44
7.43
3.29
F
SO_2Me
1.00
1.00
1.00
1.00
3.05
.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)


160.51
158.49
136.22
136.16
129.71
128.44
128.32
124.85
124.82
117.27
117.11
43.90
43.87
F
SO2Me
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


-109.60
-109.62
-109.63
-109.63
-109.64
-109.66
F
SO2Me
-40
-50
-60
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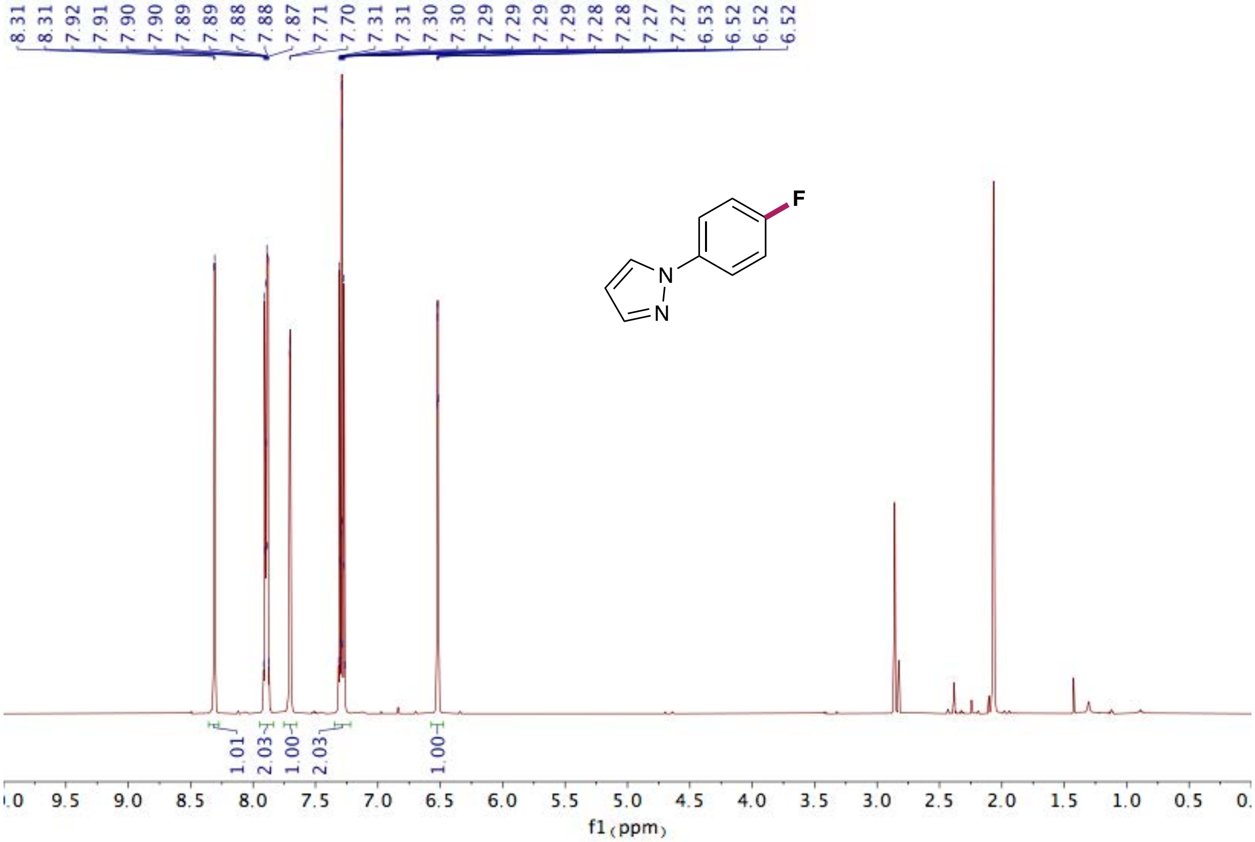
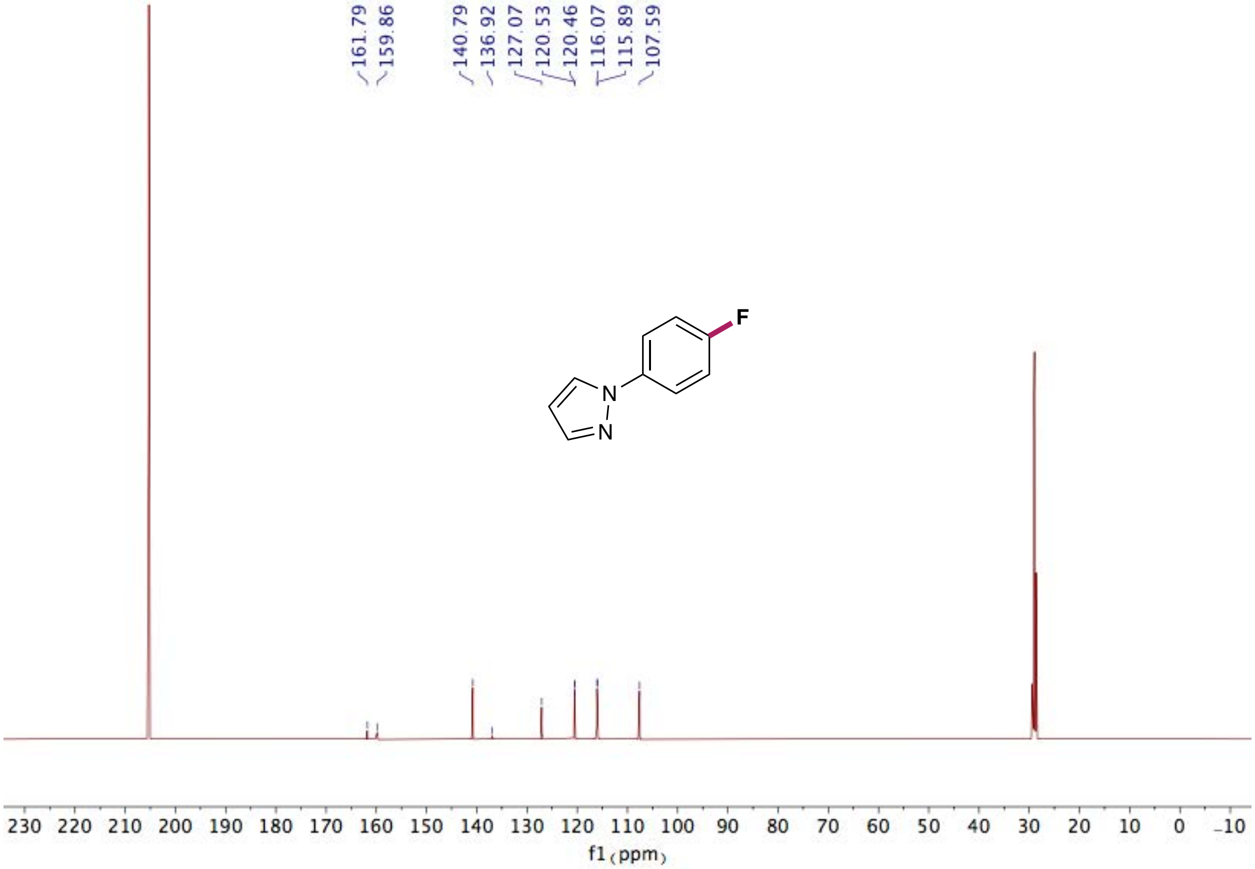
-110
-120
-130
-140
-150
-160
f1 (ppm)


8.31
8.31
7.92
7.91
7.90
7.90
7.89
7.89
7.88
7.88
7.87
7.71
7.70
7.31
7.31
7.30
7.30
7.29
7.29
7.29
7.29
7.28
7.28
7.27
7.27
6.53
6.52
6.52
6.52
F
N
N
1.01
2.03
1.00
2.03
1.00
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)


161.79
159.86
140.79
136.92
127.07
120.53
120.46
116.07
115.89
107.59
F
N
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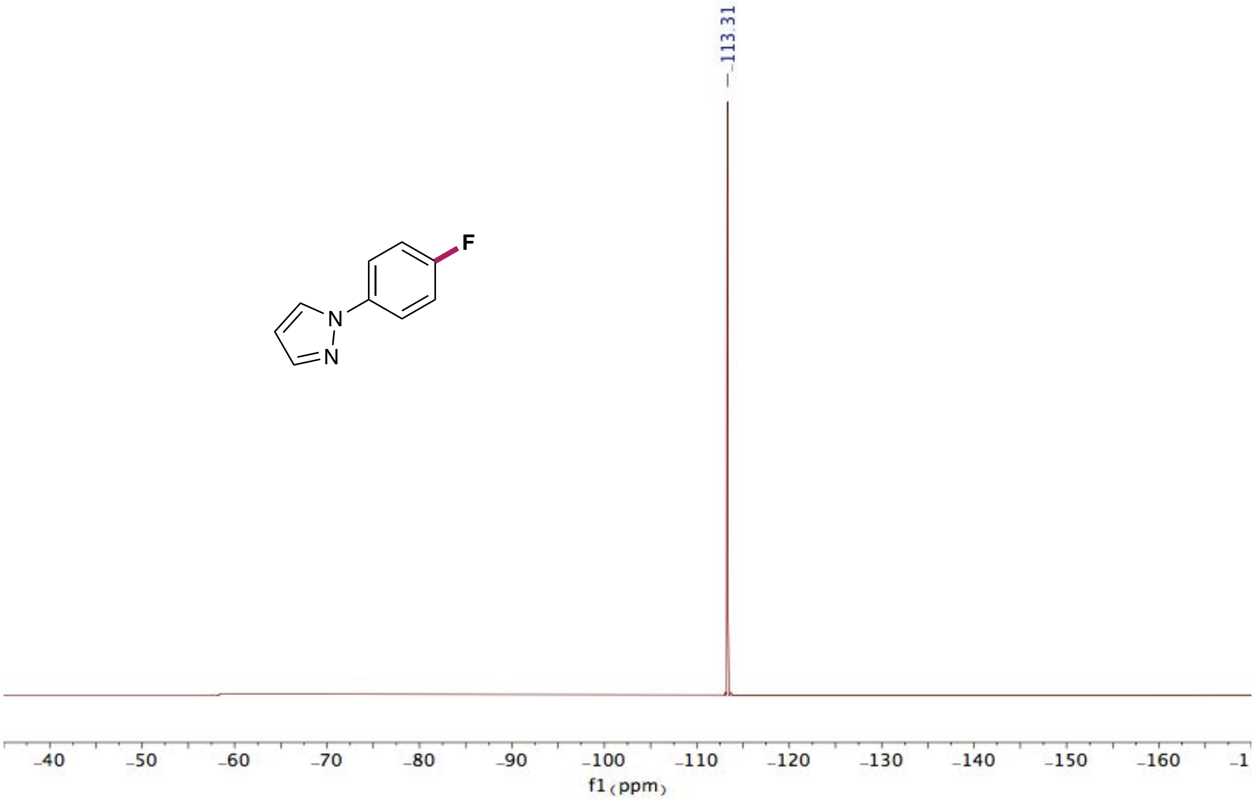
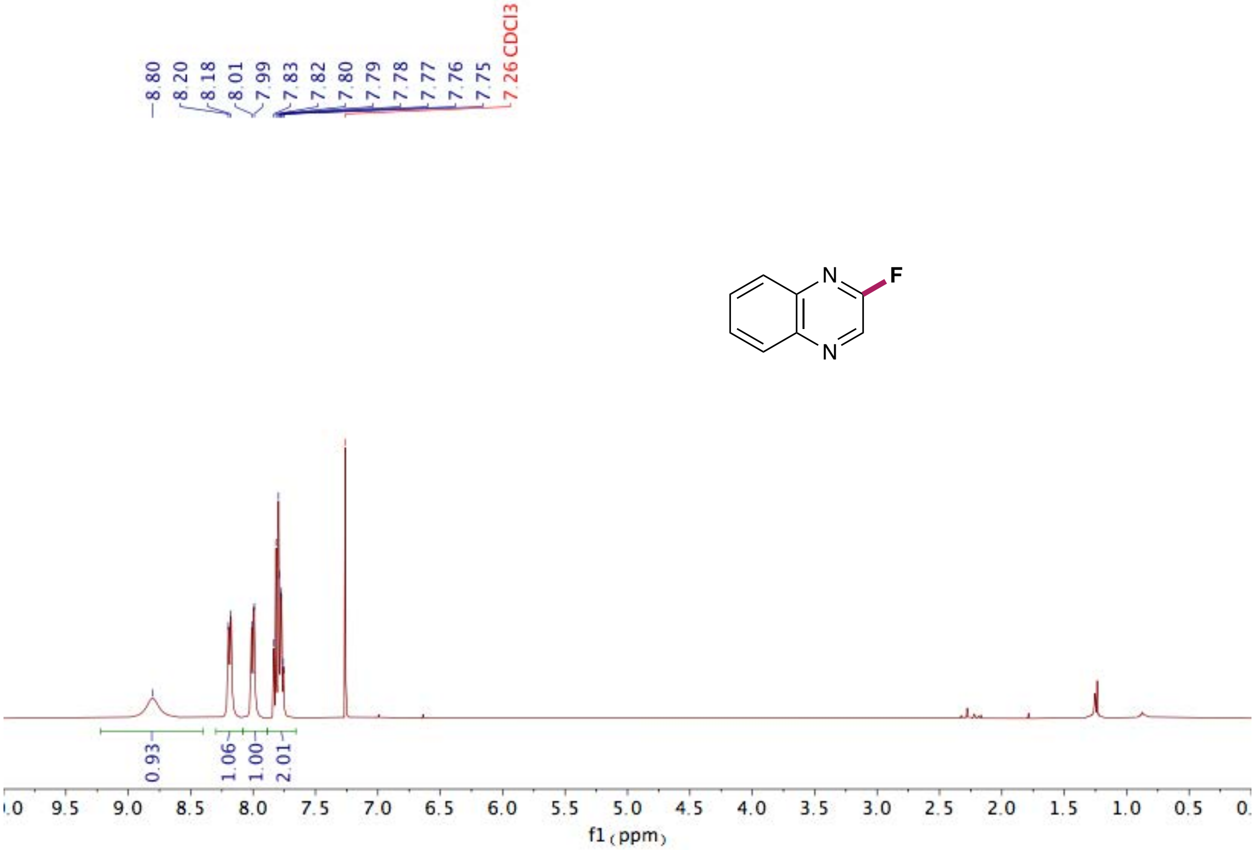
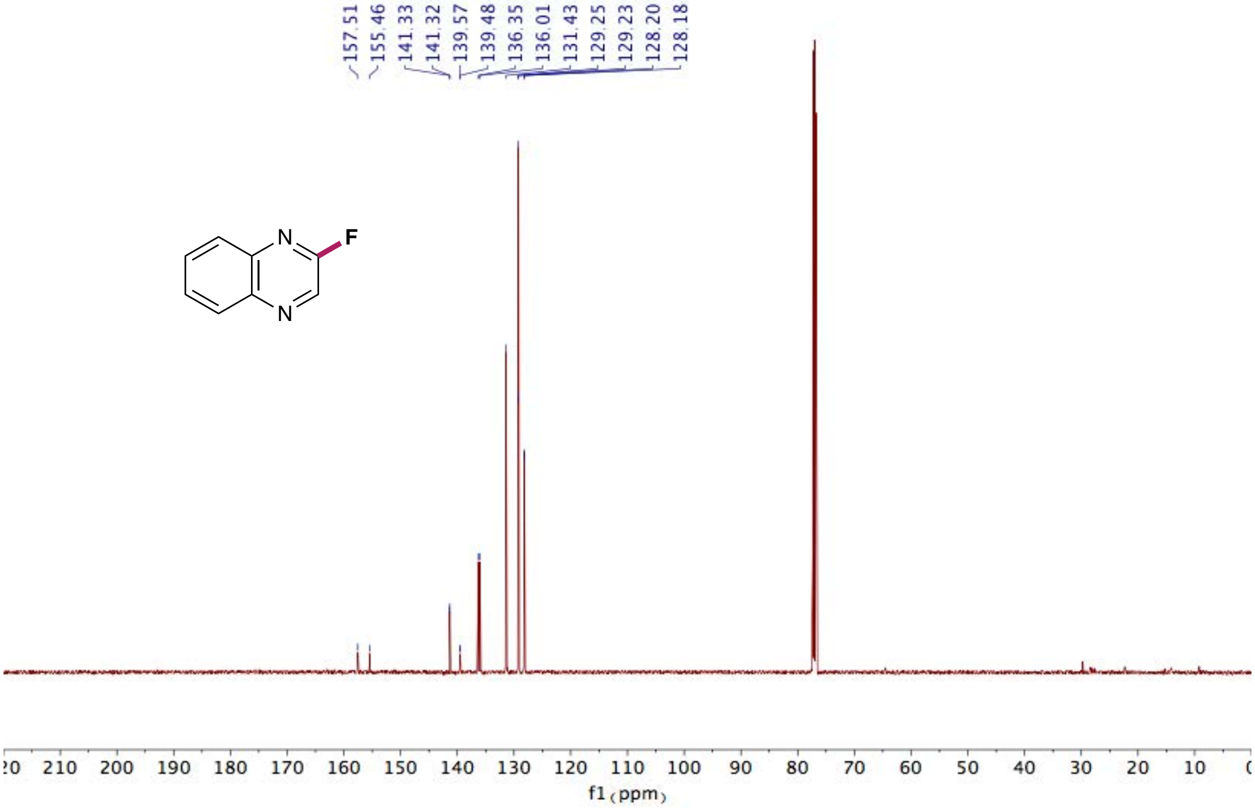
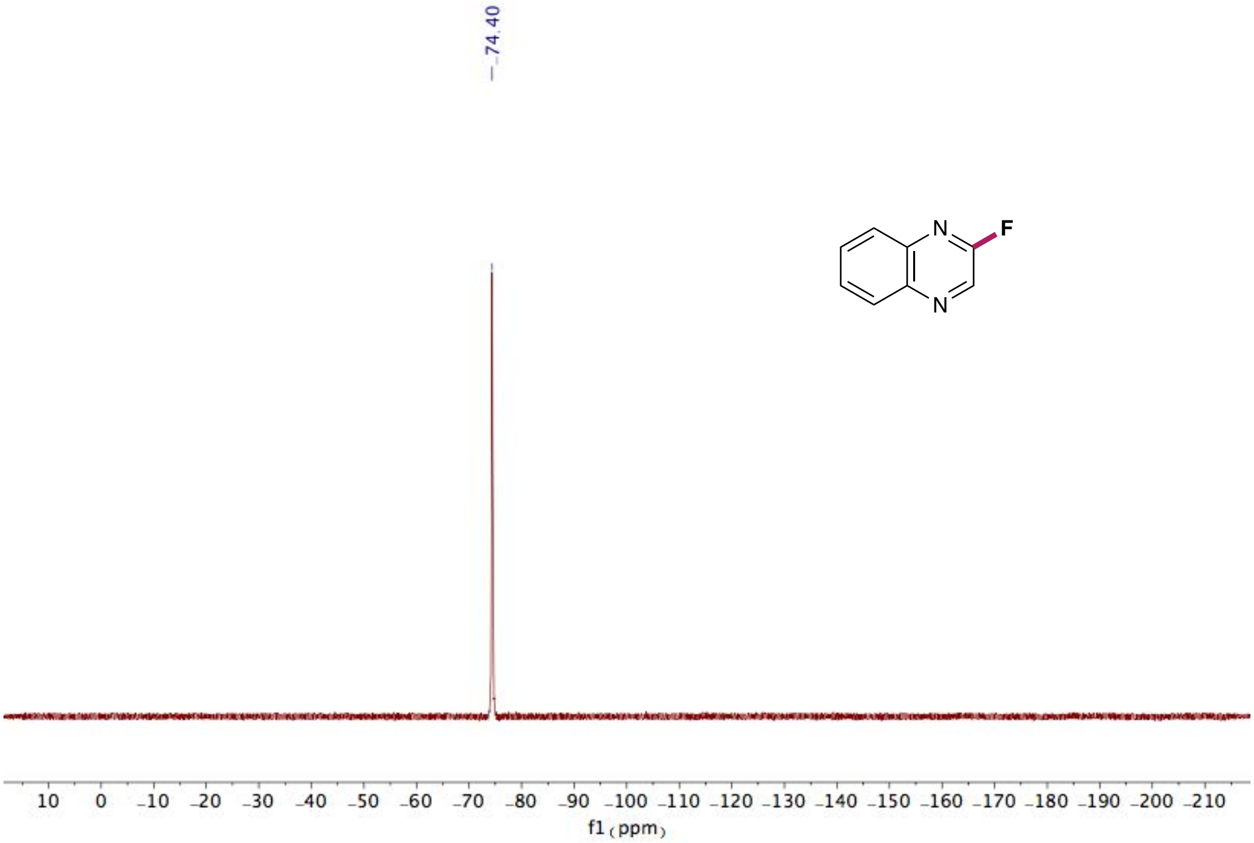
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)


-113.31
F
N
N
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-1
f1 (ppm)


8.80
8.20
8.18
8.01
7.99
7.83
7.82
7.80
7.79
7.78
7.77
7.76
7.75
7.26 CDCl3
N
N
F
0.93
1.06
1.00
2.01
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)


157.51
155.46
141.33
141.32
139.57
139.48
136.35
136.01
131.43
129.25
129.23
128.20
128.18
N
N
F
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)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N
N
F
10
0
-10
-20
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-40
-50
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-70
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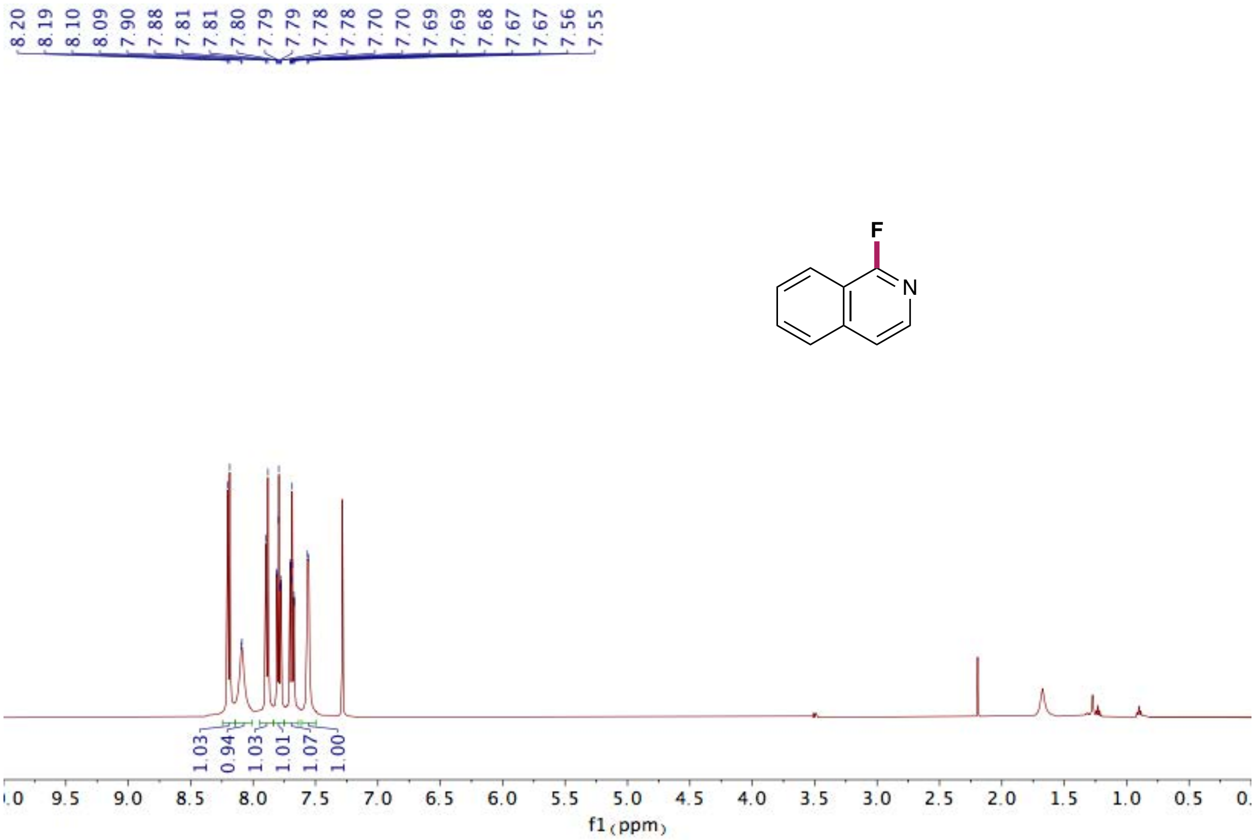
-190
-200
-210
f1 (ppm)


8.20
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7.88
7.81
7.81
7.80
7.79
7.79
7.78
7.78
7.70
7.70
7.69
7.69
7.68
7.67
7.67
7.56
7.55
F
N
1.03
0.94
1.03
1.01
1.07
1.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
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3.5
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2.5
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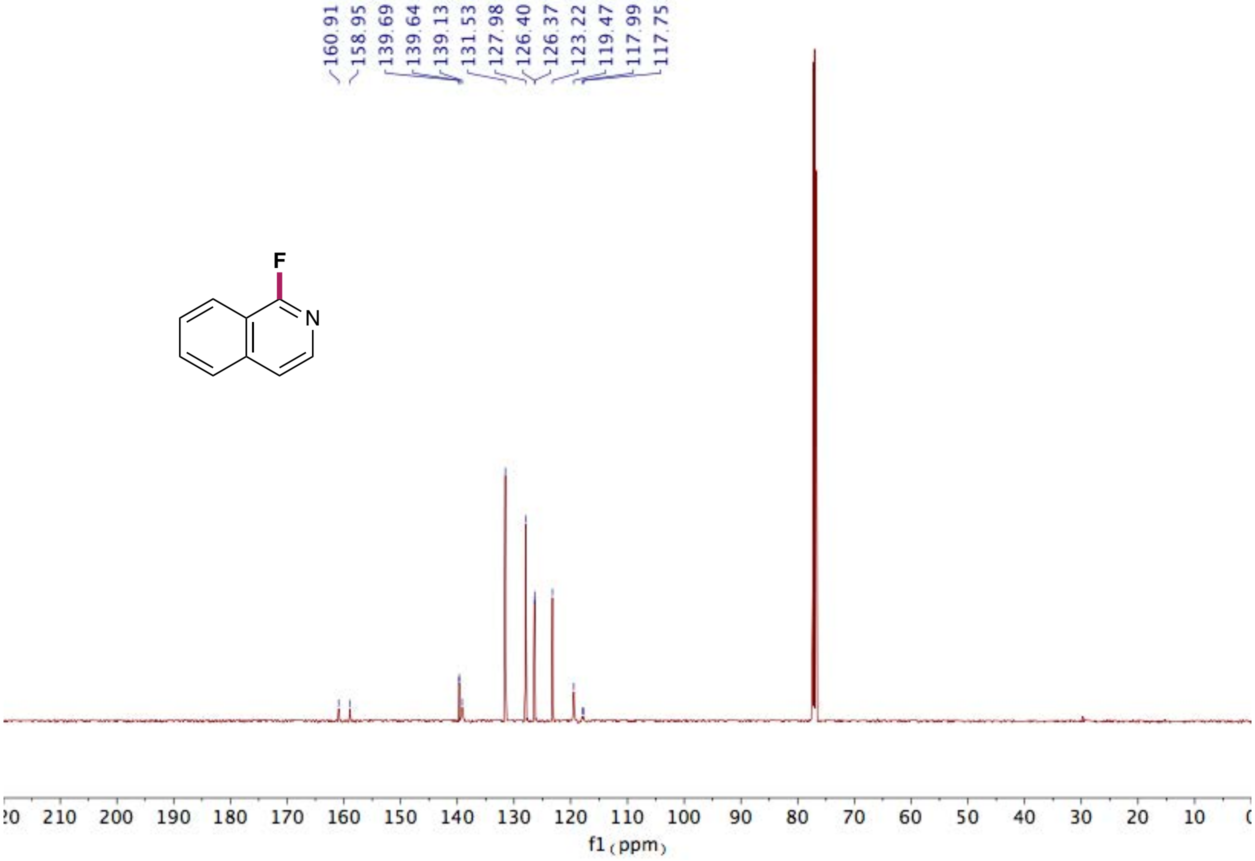
f1 (ppm)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158.95
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139.64
139.13
131.53
127.98
126.40
126.37
123.22
119.47
117.99
117.75
F
N
220
210
200
190
180
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100
90
80
70
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50
40
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10
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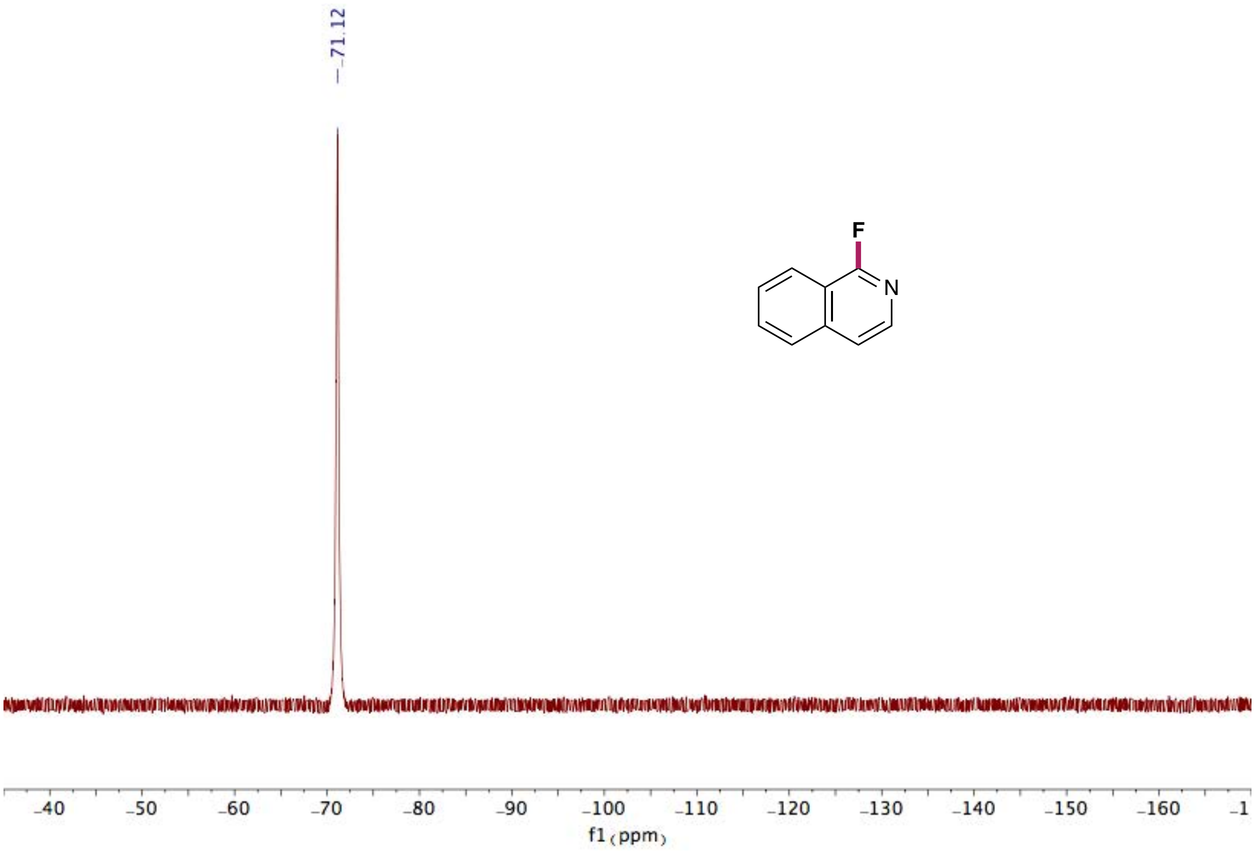
f1 (ppm)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-100
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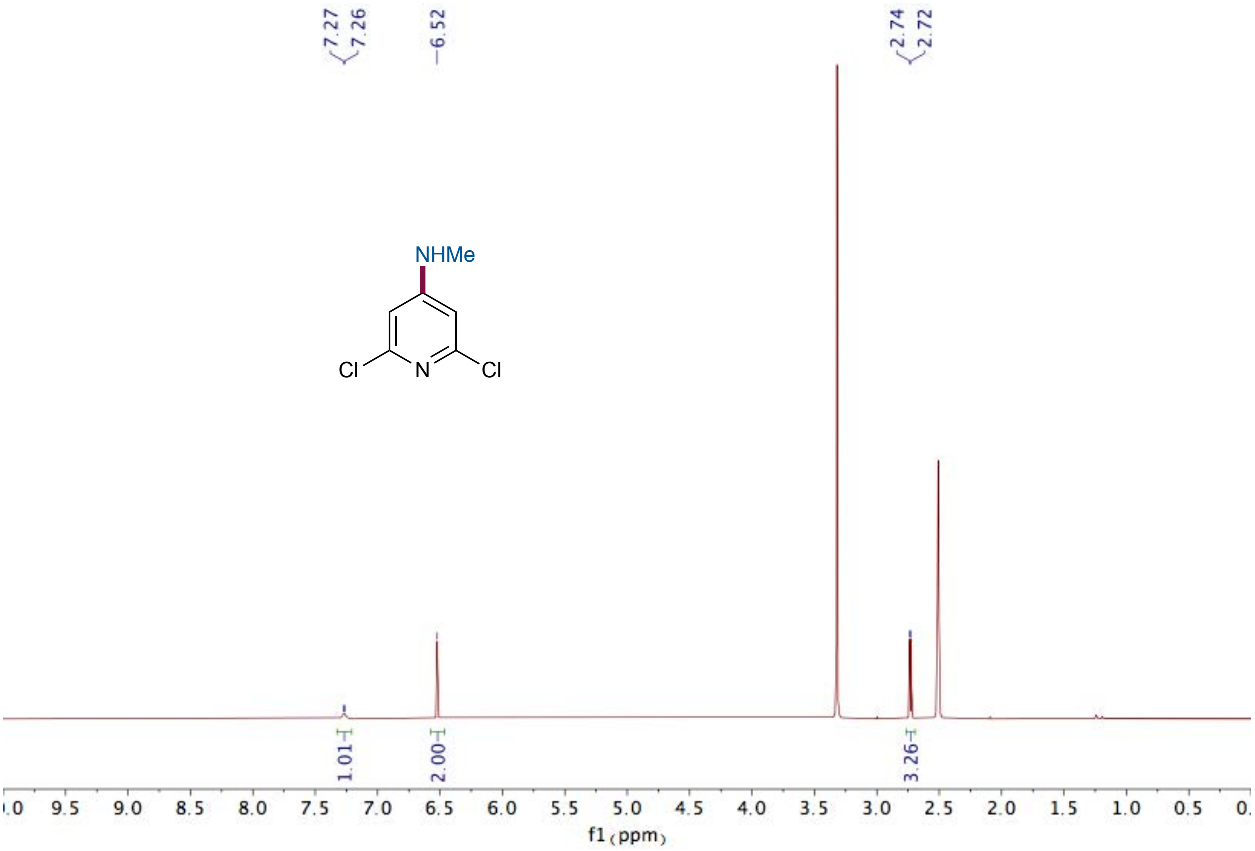
-120
-130
-140
-150
-160
-1
f1 (ppm)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Cl
N
Cl
1.01
2.00
3.26
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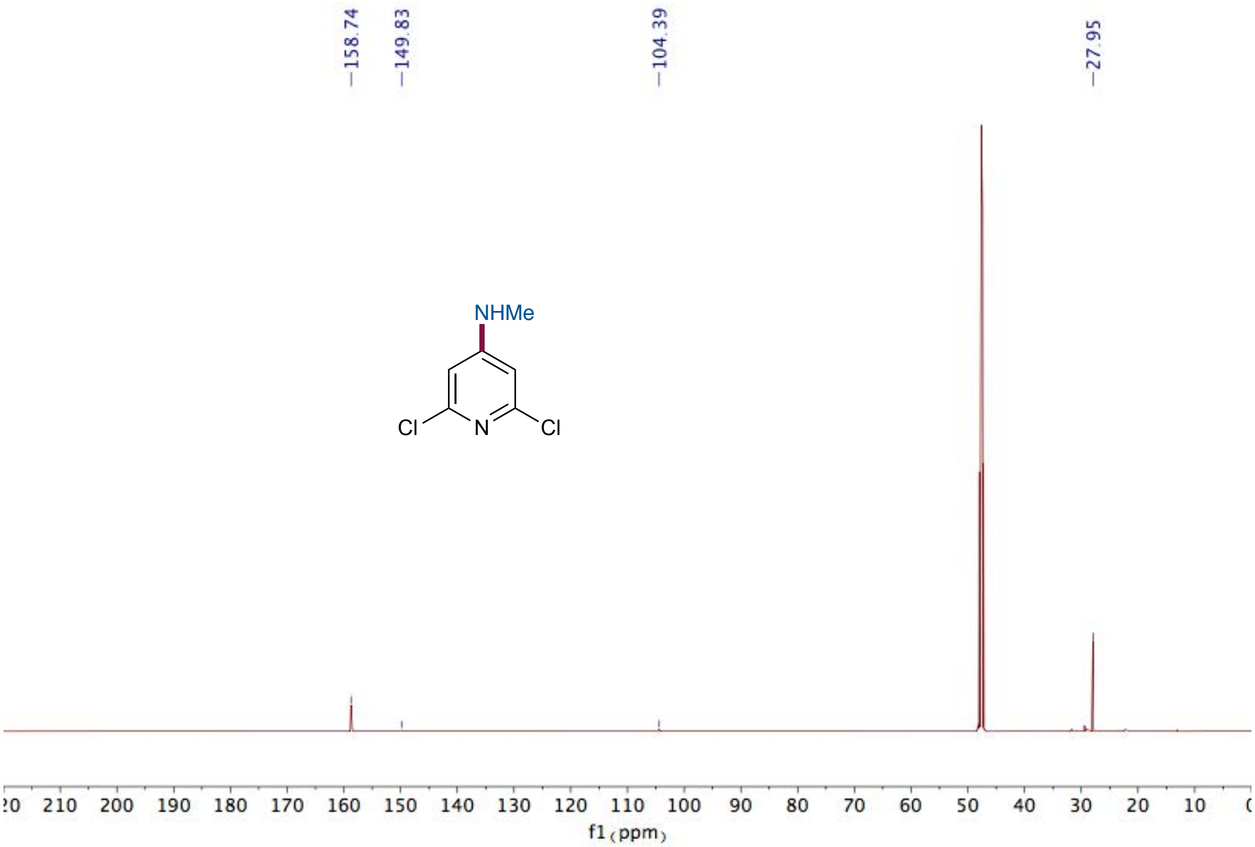
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)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Cl
N
Cl
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200
190
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150
140
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100
90
80
70
60
50
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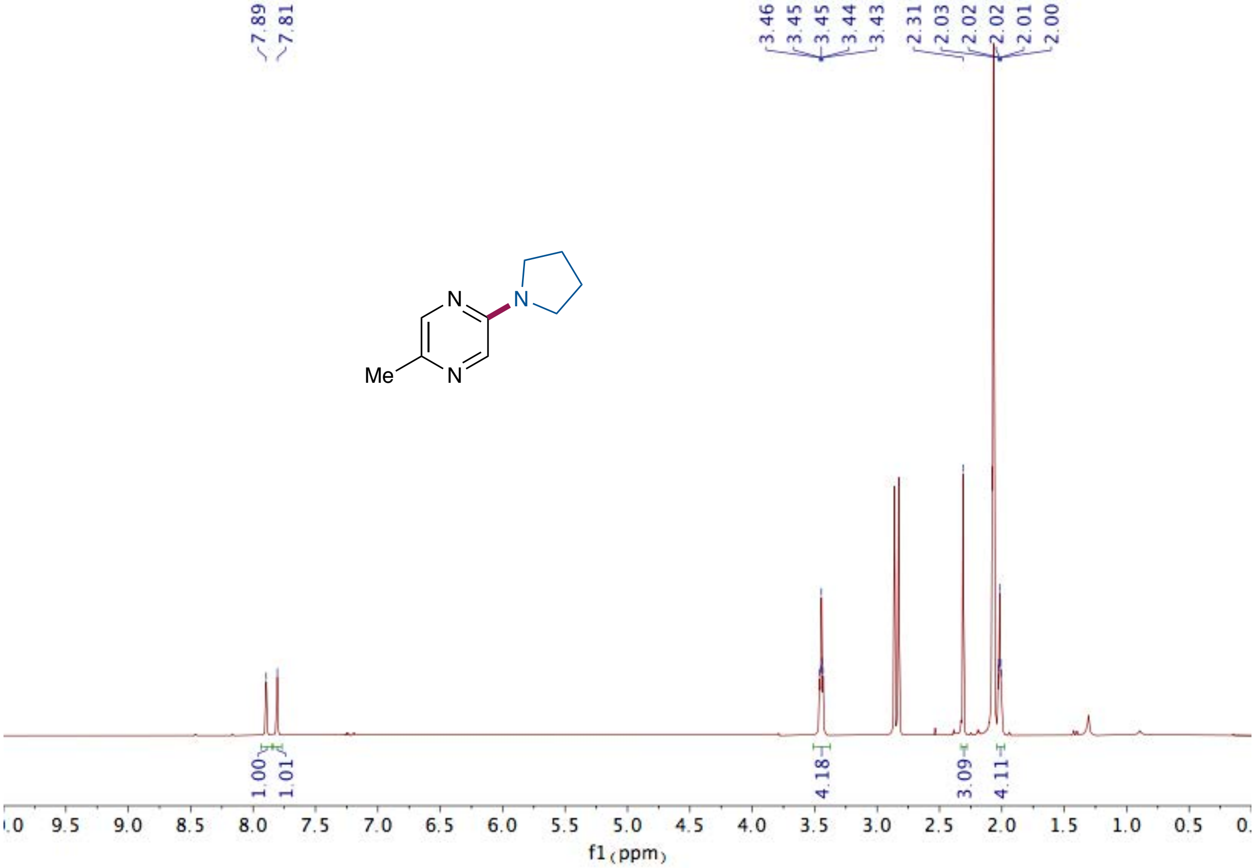
20
10
f1 (ppm)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3.43
2.31
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2.02
2.02
2.01
2.00
N
N
N
Me
1.00
1.01
4.18
3.09
4.11
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
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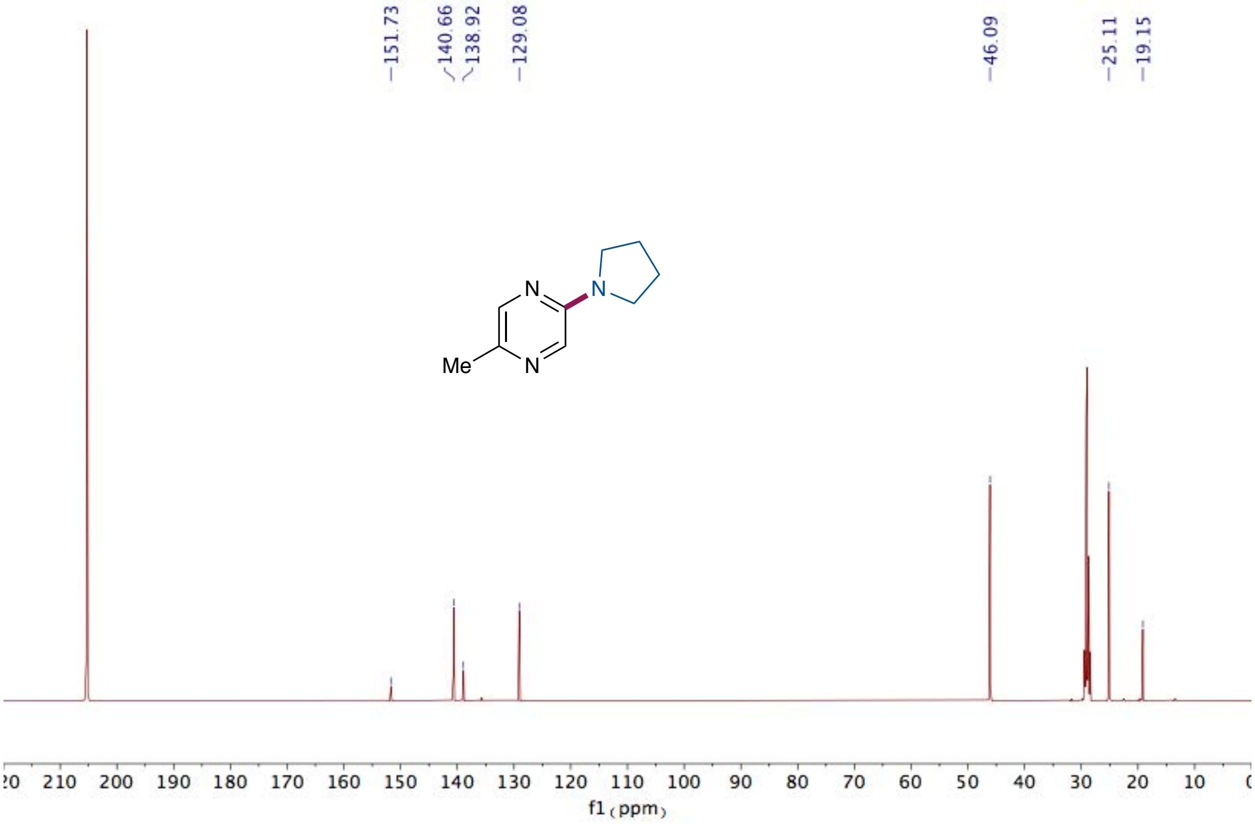
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)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46.09
25.11
19.15
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N
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Me
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200
190
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160
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140
130
120
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100
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80
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40
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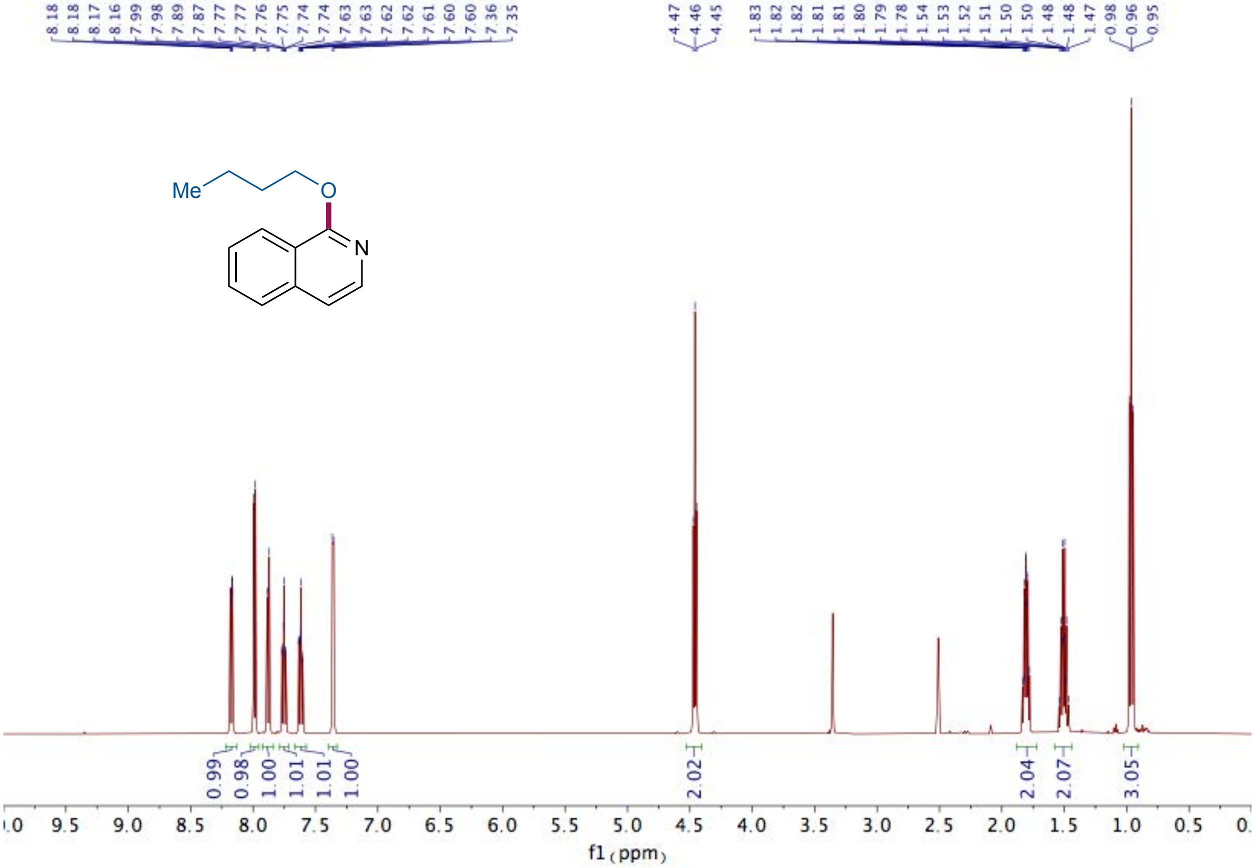
20
10
f1 (ppm)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7.76
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7.74
7.74
7.63
7.63
7.62
7.62
7.61
7.60
7.60
7.36
7.35
4.47
4.46
4.45
1.83
1.82
1.82
1.81
1.81
1.80
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1.78
1.54
1.53
1.52
1.51
1.50
1.50
1.48
1.48
1.47
0.98
0.96
0.95
Me
O
N
0.99
0.98
1.00
1.01
1.01
1.00
2.02
2.04
2.07
3.05
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
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5.0
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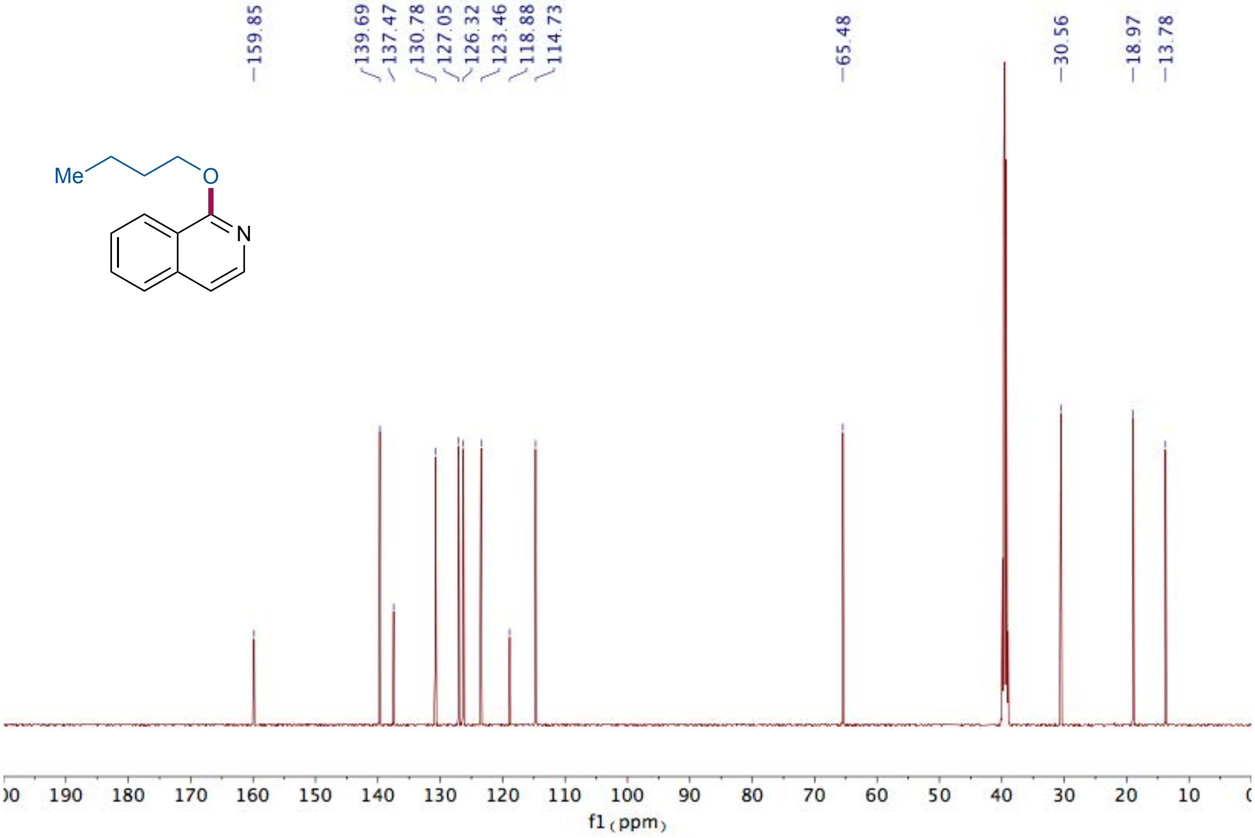
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)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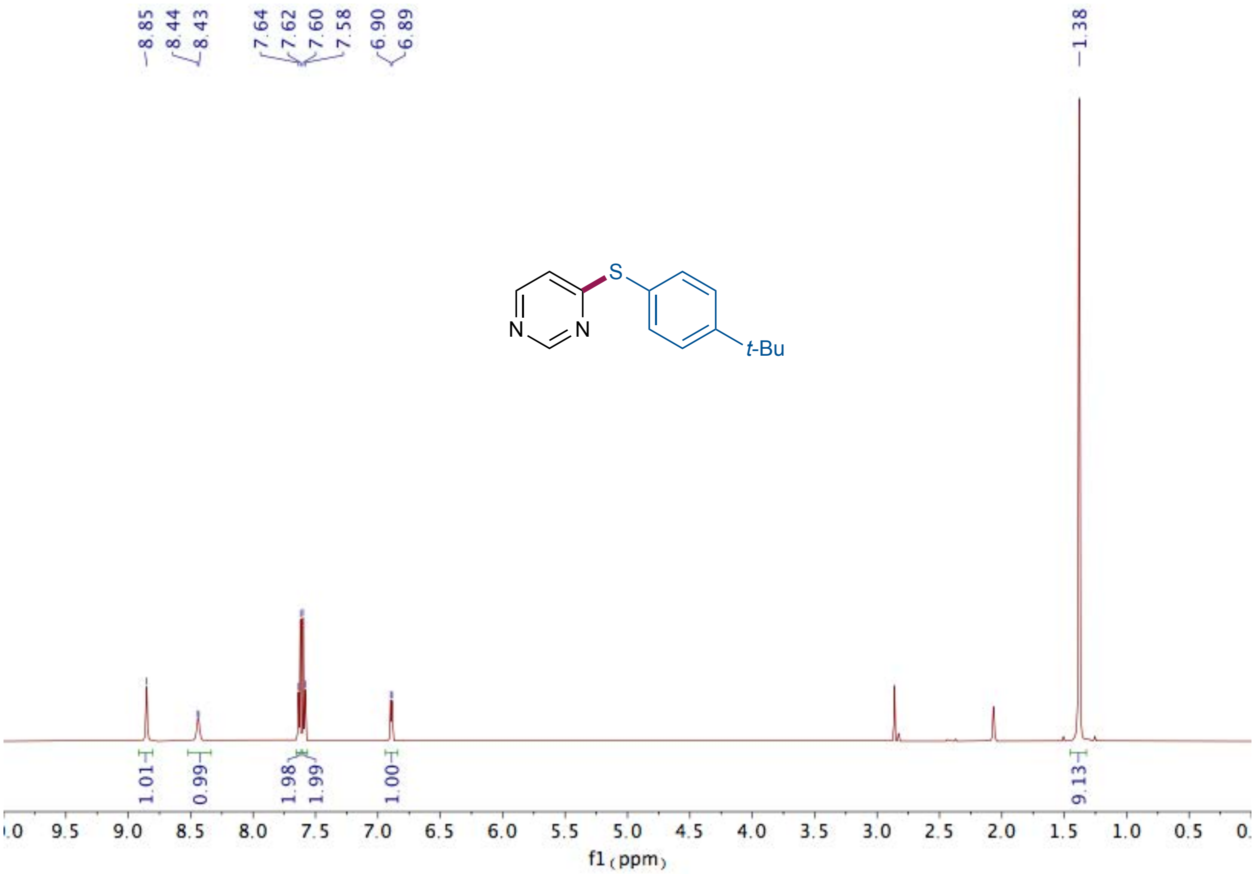
114.73
65.48
30.56
18.97
13.78
Me
O
N
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)



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8.43
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7.58
6.90
6.89
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S
t-Bu
1.01
0.99
1.98
1.99
1.00
9.13
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
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4.5
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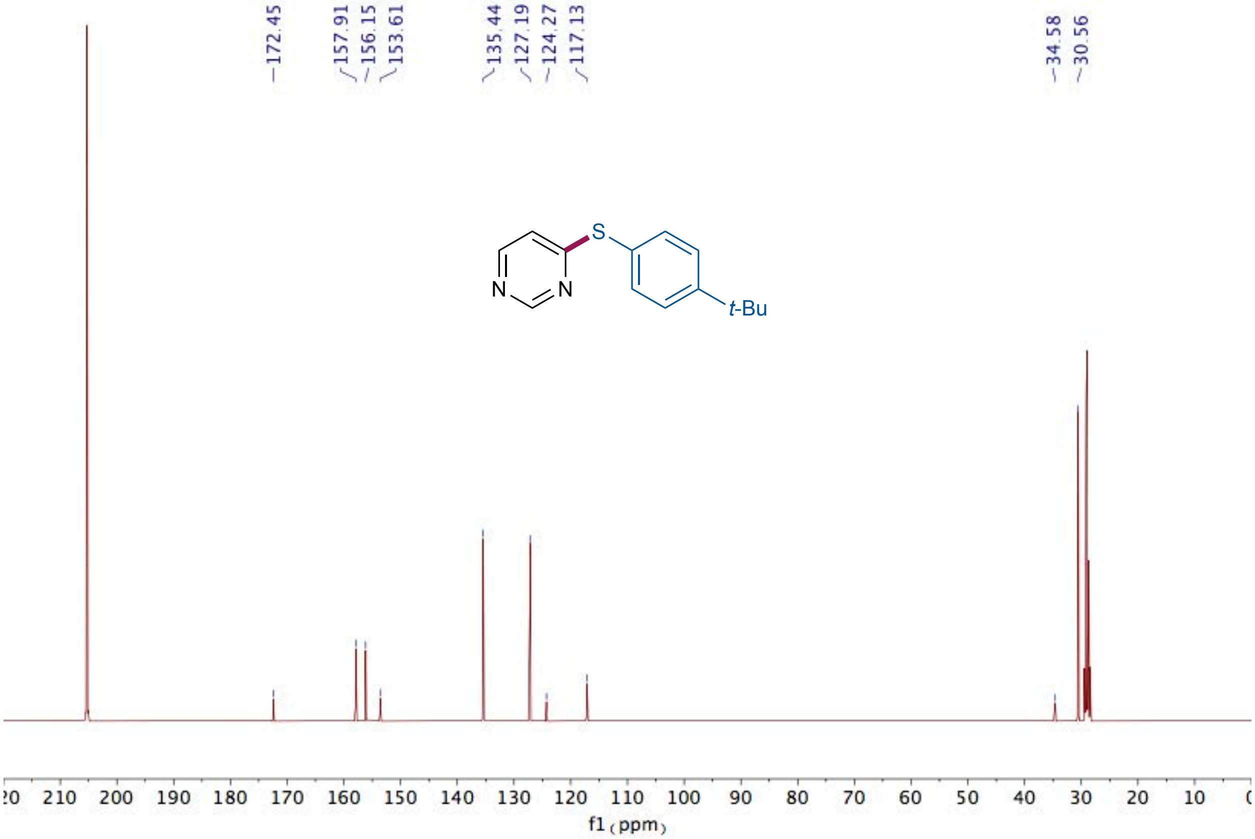
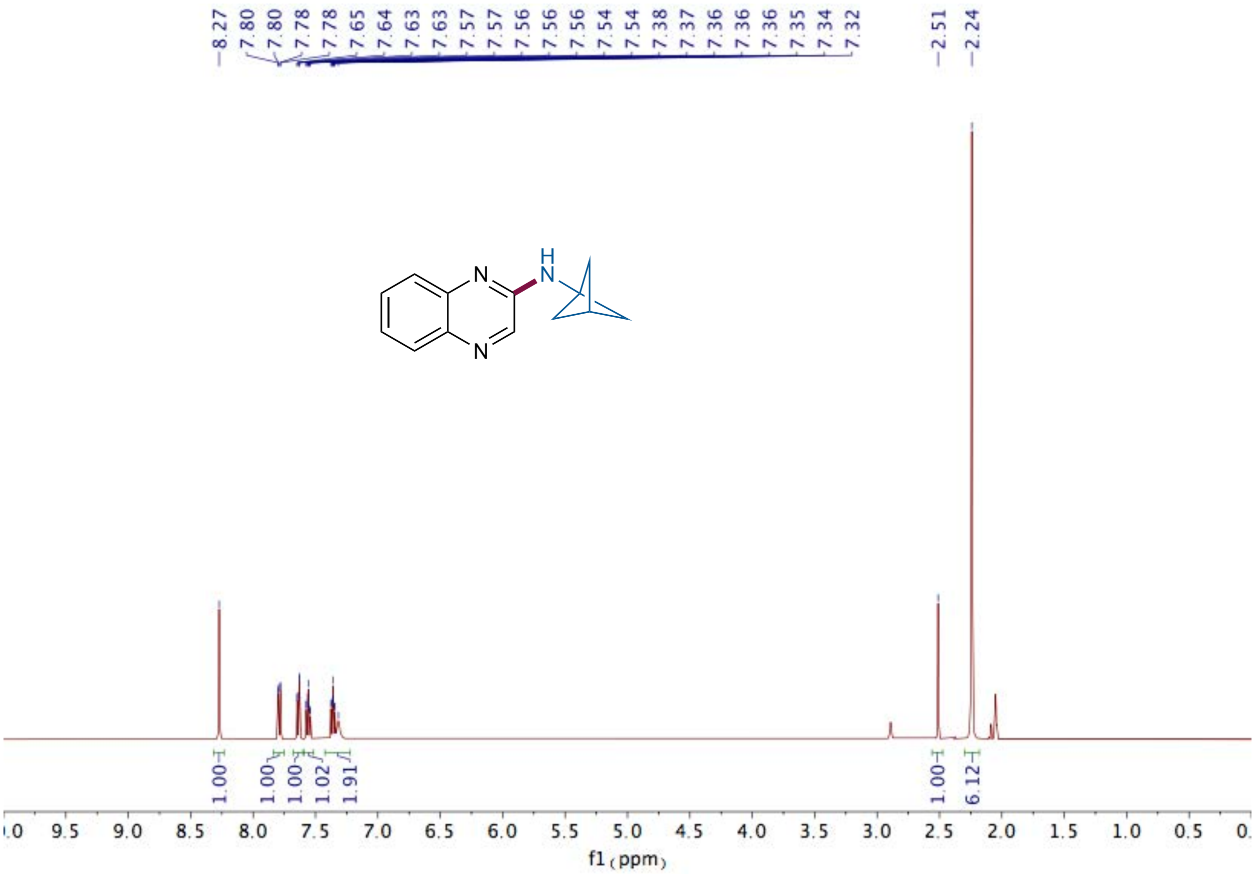
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.
f1 (ppm)



172.45
157.91
156.15
153.61
135.44
127.19
124.27
117.13
34.58
30.56
N
N
S
t-Bu
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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7.63
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7.57
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7.56
7.56
7.54
7.54
7.38
7.37
7.36
7.36
7.36
7.35
7.34
7.32
2.51
2.24
N
N
H
N
1.00
1.00
1.00
1.02
1.91
1.00
6.12
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
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5.0
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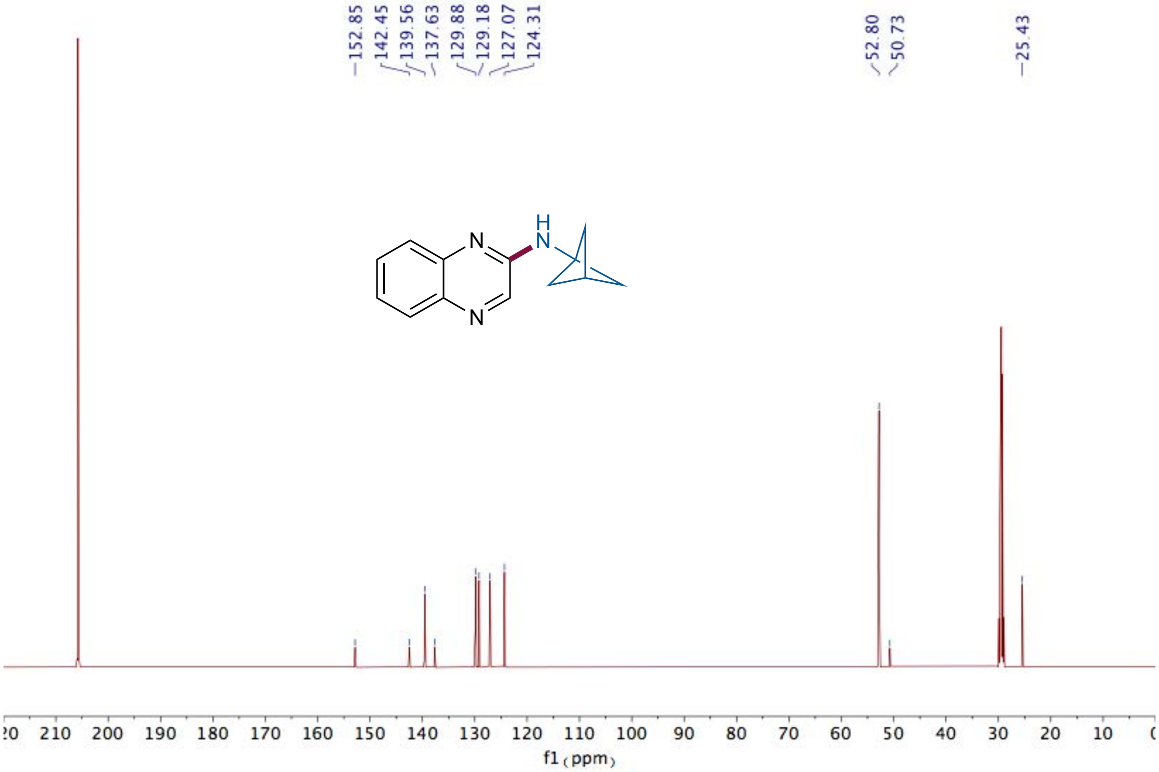
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)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139.56
137.63
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129.18
127.07
124.31
52.80
50.73
25.43
N
N
H
N
210
200
190
180
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160
150
140
130
120
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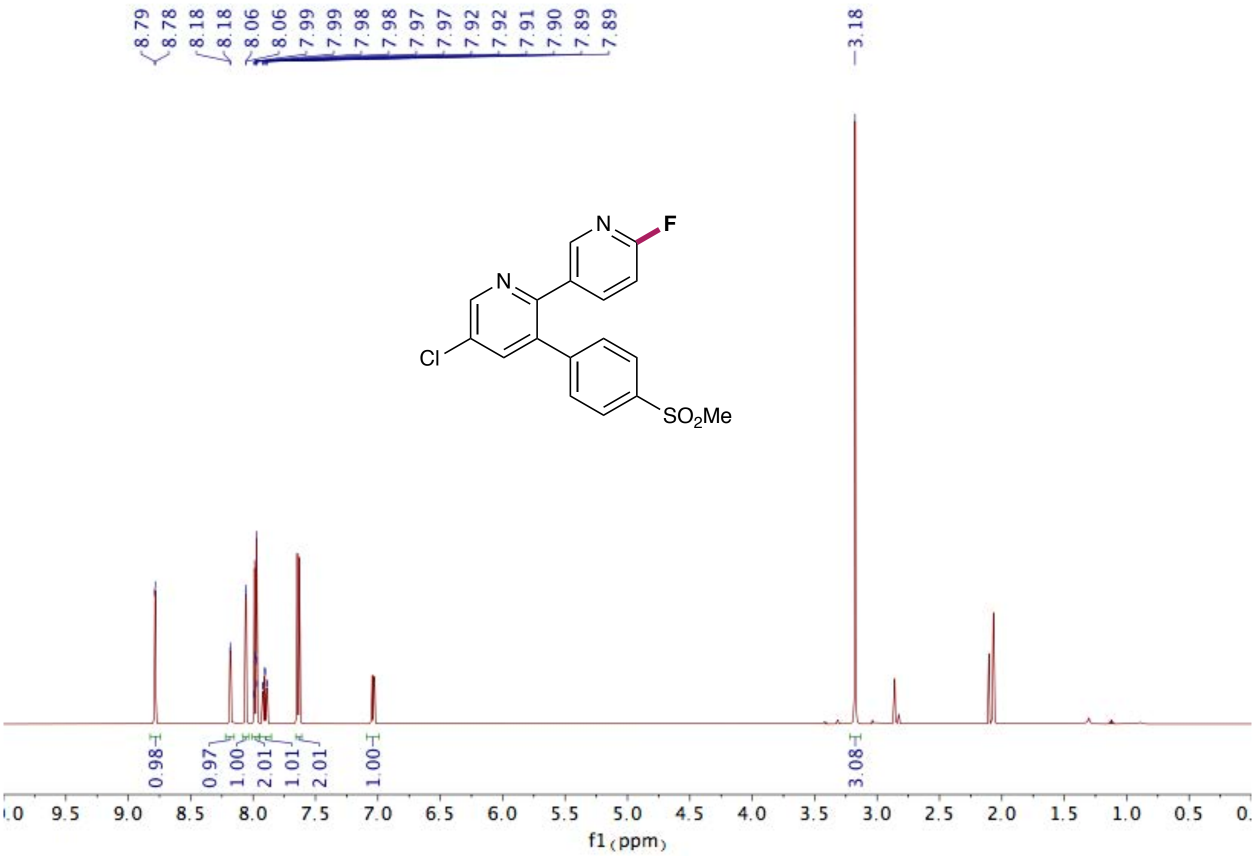
100
90
80
70
60
50
40
30
20
10
f1 (ppm)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7.98
7.97
7.97
7.92
7.92
7.91
7.90
7.89
7.89
3.18
N
F
N
Cl
SO2Me
0.98
0.97
1.00
2.01
1.01
2.01
1.00
3.08
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
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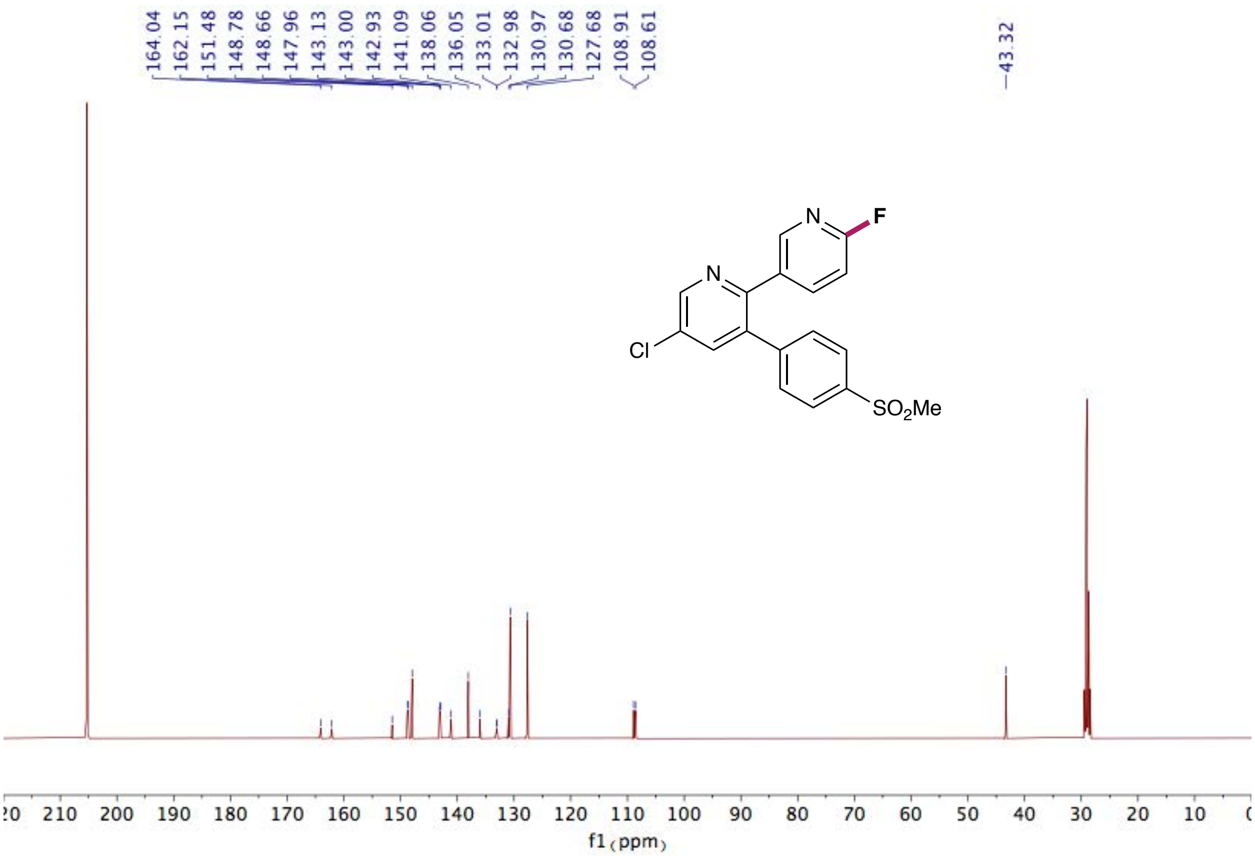
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)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143.00
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141.09
138.06
136.05
133.01
132.98
130.97
130.68
127.68
108.91
108.61
43.32
N
F
N
Cl
SO2Me
210
200
190
180
170
160
150
140
130
120
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100
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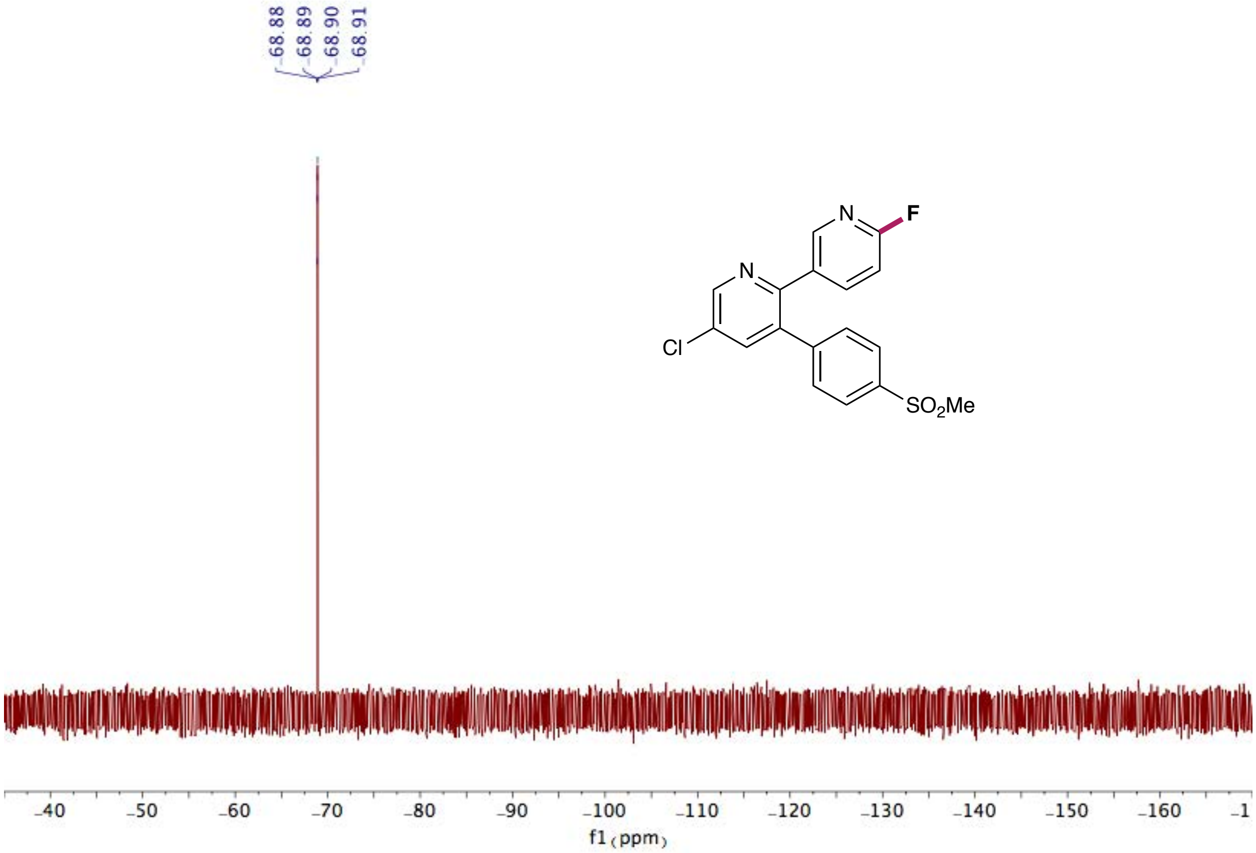
80
70
60
50
40
30
20
10
f1 (ppm)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N
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SO2Me
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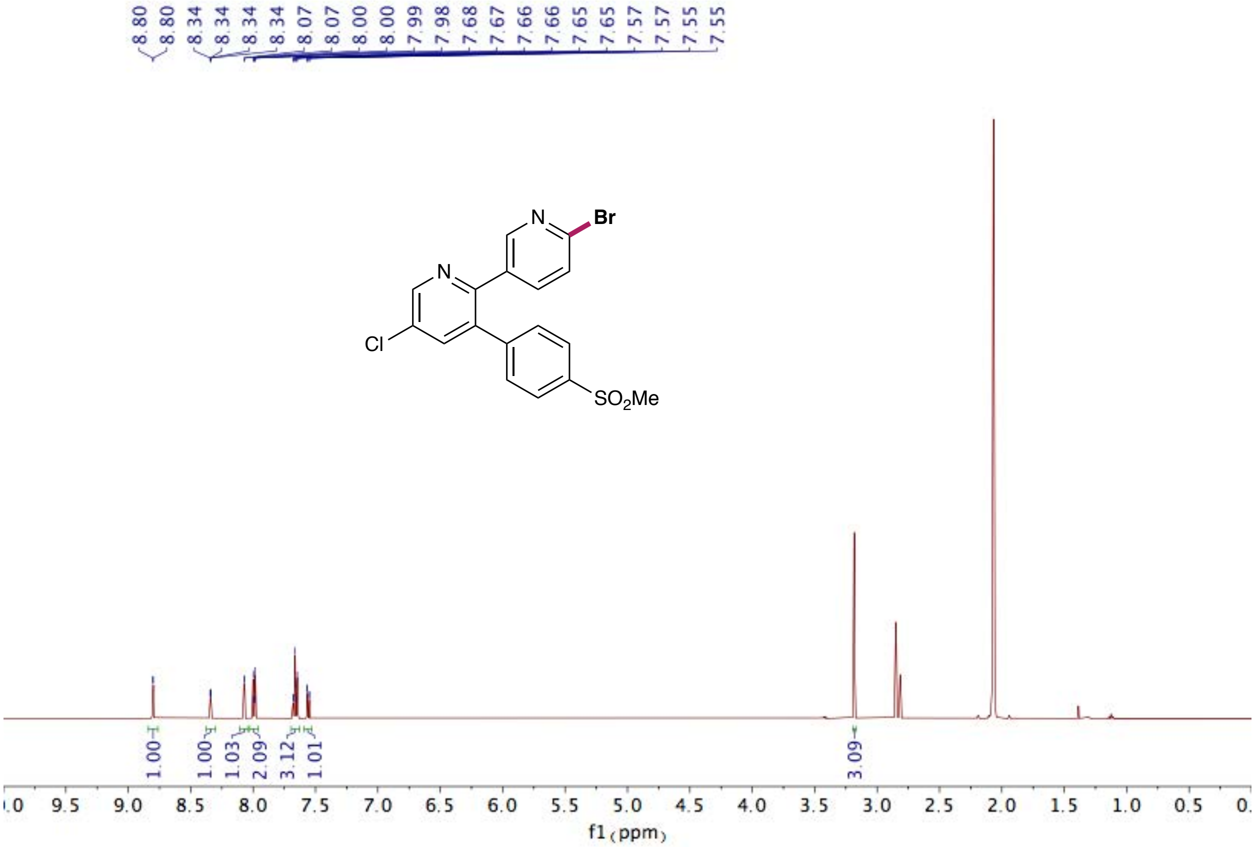
-150
-160
-1
f1 (ppm)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8.07
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8.00
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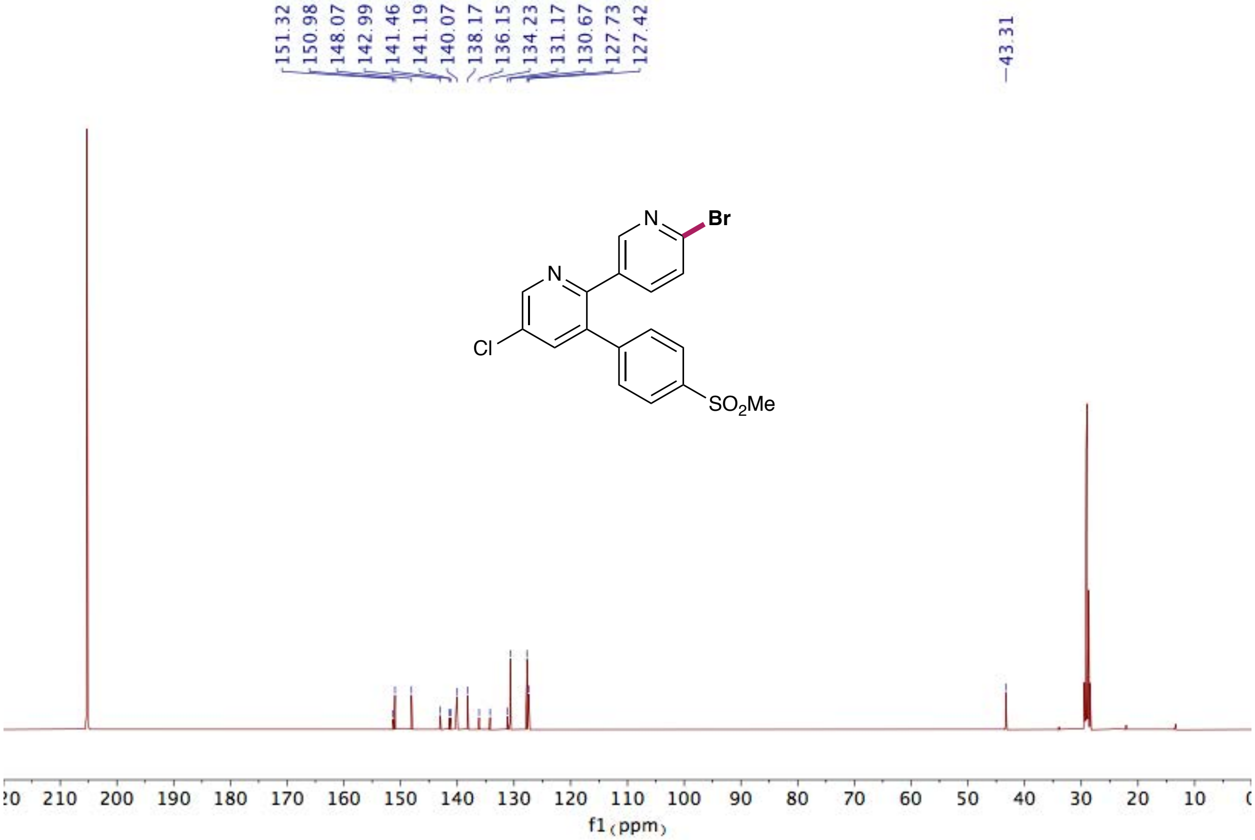
7.68
7.67
7.66
7.66
7.65
7.65
7.57
7.57
7.55
7.55
N
Br
N
Cl
SO2Me
1.00
1.00
1.03
2.09
3.12
1.01
3.09
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)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131.17
130.67
127.73
127.42
43.31
N
Br
N
Cl
SO2Me
210
200
190
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100
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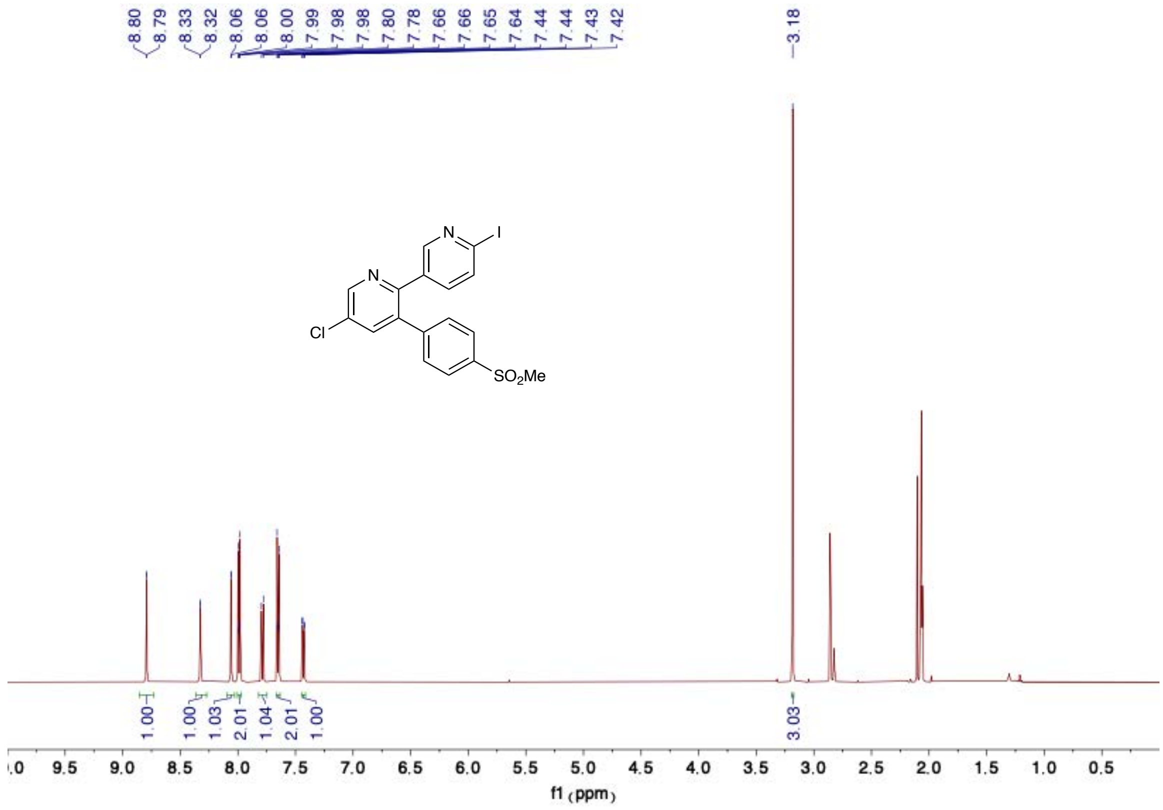
f1 (ppm)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8.06
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7.99
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7.80
7.78
7.66
7.66
7.65
7.64
7.44
7.44
7.43
7.42
3.18
N
N
I
Cl
SO$_2$Me
1.00
1.00
1.03
2.01
1.04
2.01
1.00
3.03
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
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5.0
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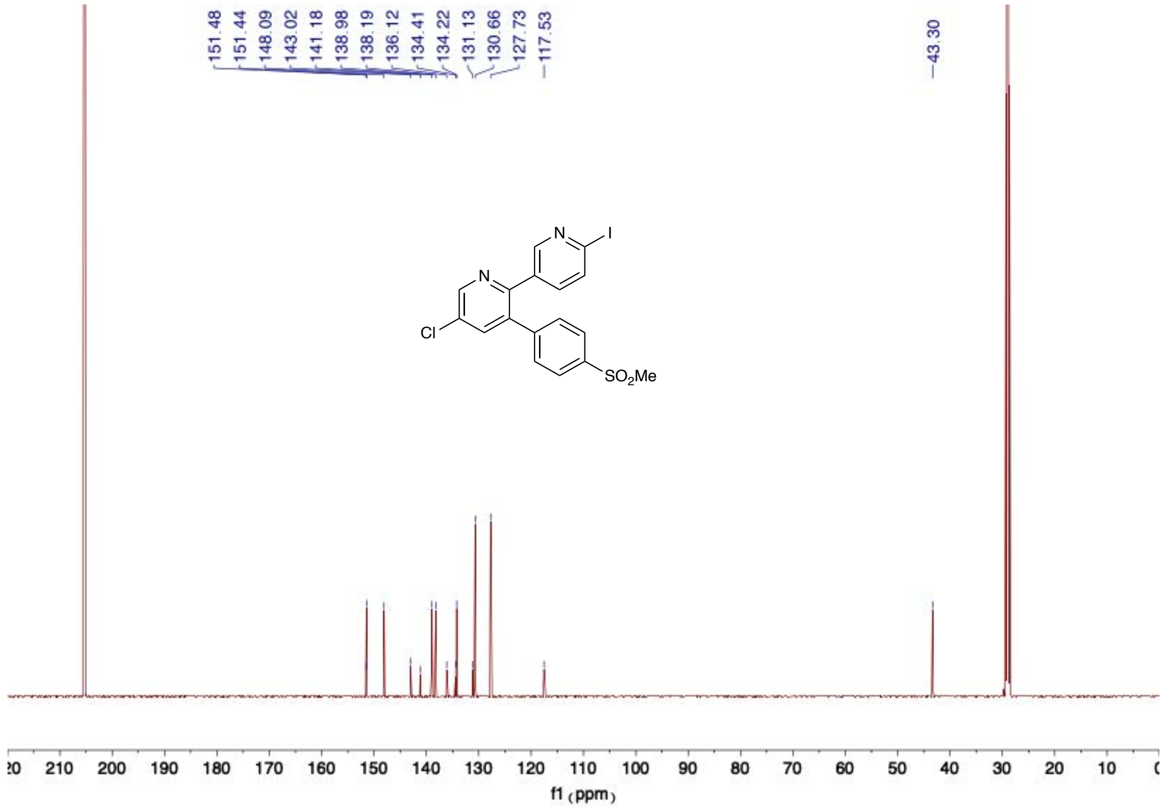
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)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136.12
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131.13
130.66
127.73
117.53
43.30
N
N
I
Cl
SO$_2$Me
210
200
190
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140
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120
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100
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80
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50
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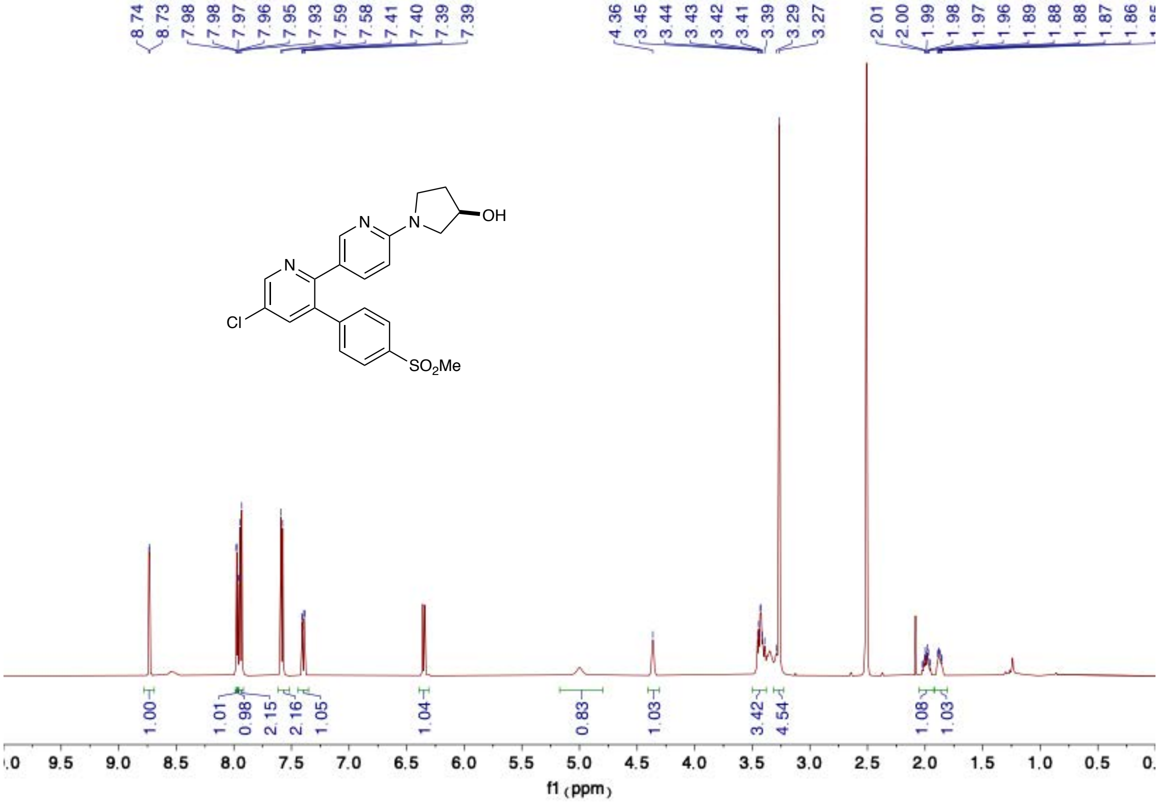
30
20
10
f1 (ppm)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7.39
7.39
4.36
3.45
3.44
3.43
3.42
3.41
3.39
3.29
3.27
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2.00
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1.98
1.97
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1.89
1.88
1.88
1.87
1.86
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N
OH
Cl
SO_2Me
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1.05
1.04
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3.42
4.54
1.08
1.03
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8.0
7.5
7.0
6.5
6.0
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5.0
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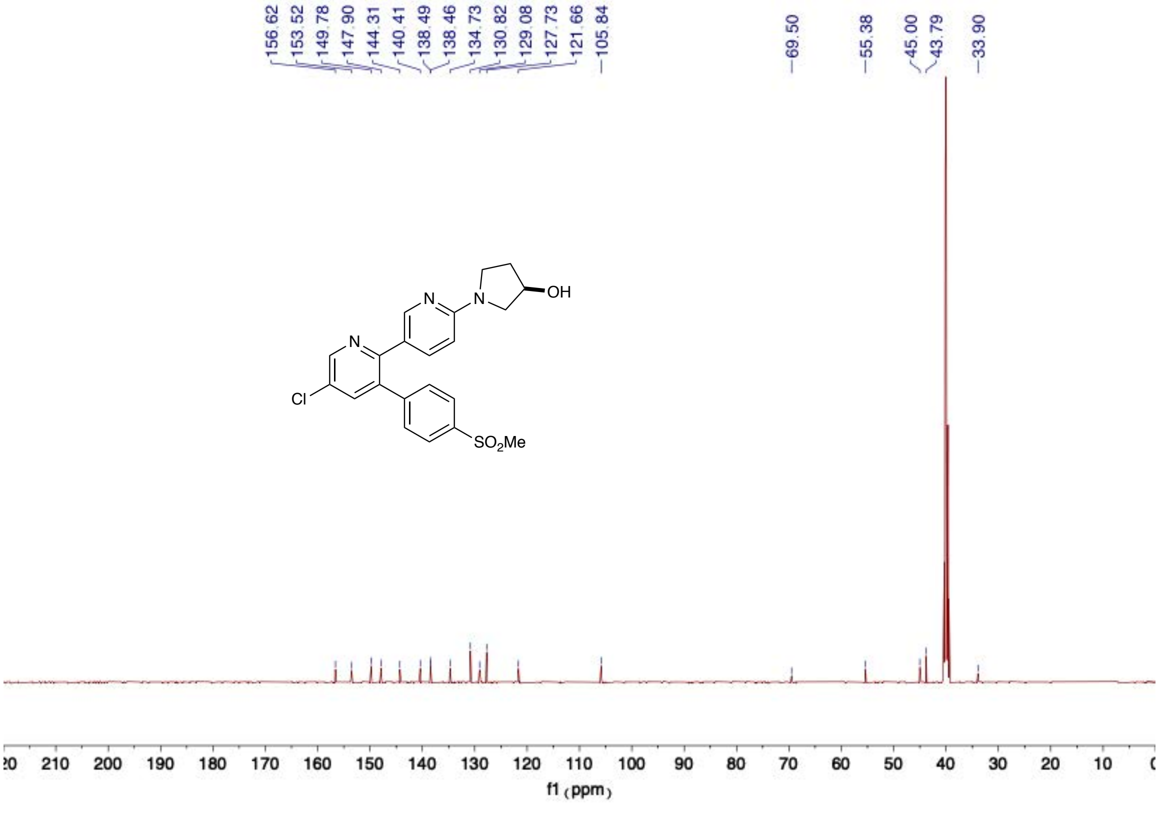
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)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129.08
127.73
121.66
105.84
69.50
55.38
45.00
43.79
33.90
N
N
N
OH
Cl
SO_2Me
210
200
190
180
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120
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100
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80
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50
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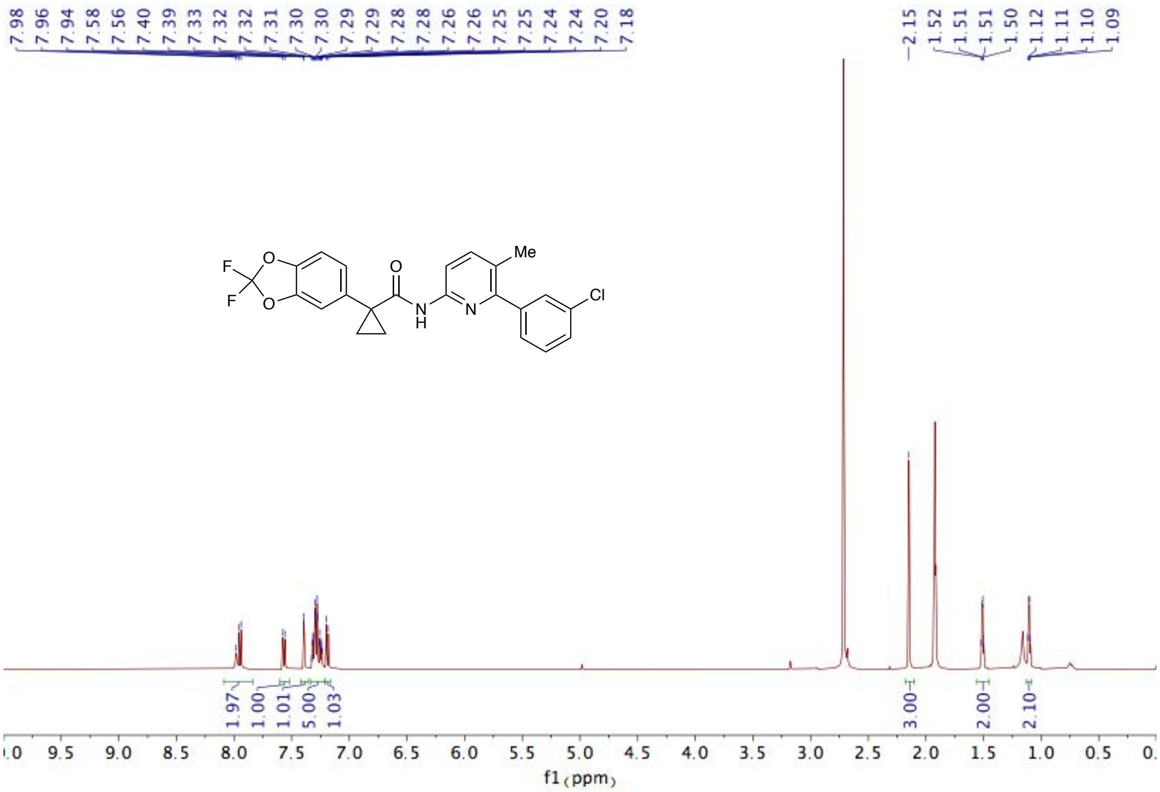
20
10
f1 (ppm)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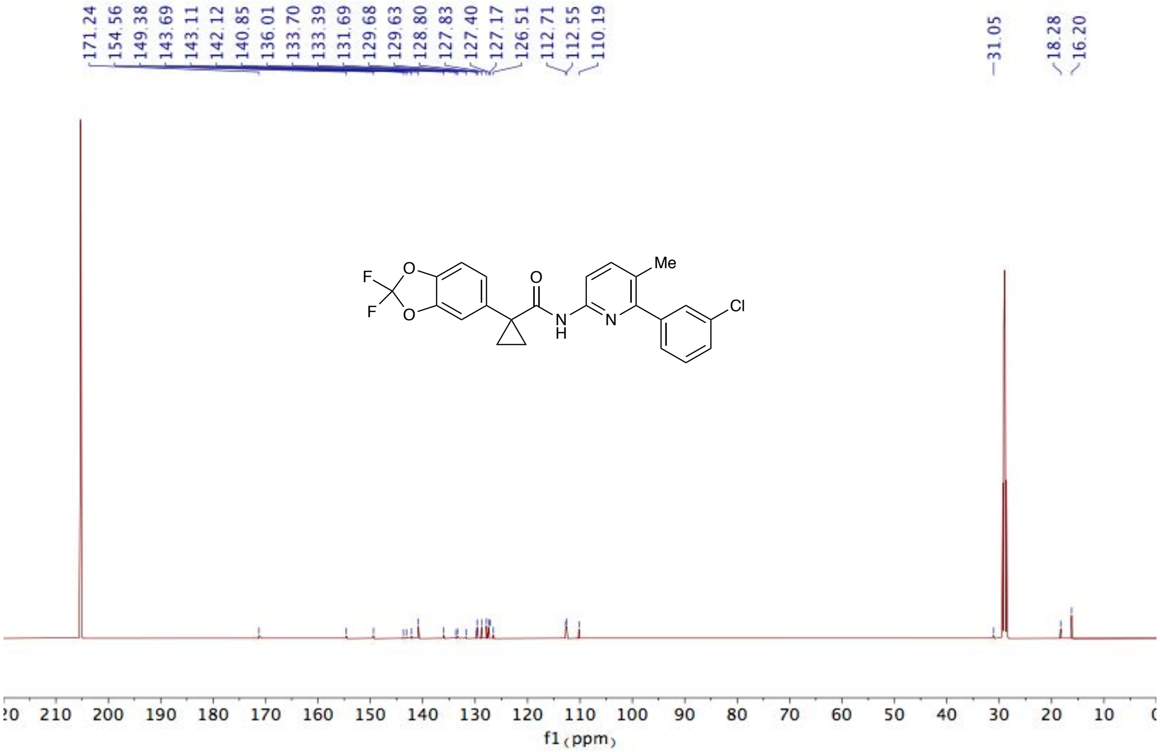
7.30
7.29
7.29
7.28
7.28
7.26
7.26
7.25
7.25
7.24
7.24
7.20
7.18
2.15
1.52
1.51
1.51
1.50
1.12
1.11
1.10
1.09
F
F
O
O
O
N
H
N
Me
Cl
1.97
1.00
1.01
5.00
1.03
3.00
2.00
2.10
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.
f1 (ppm)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136.01
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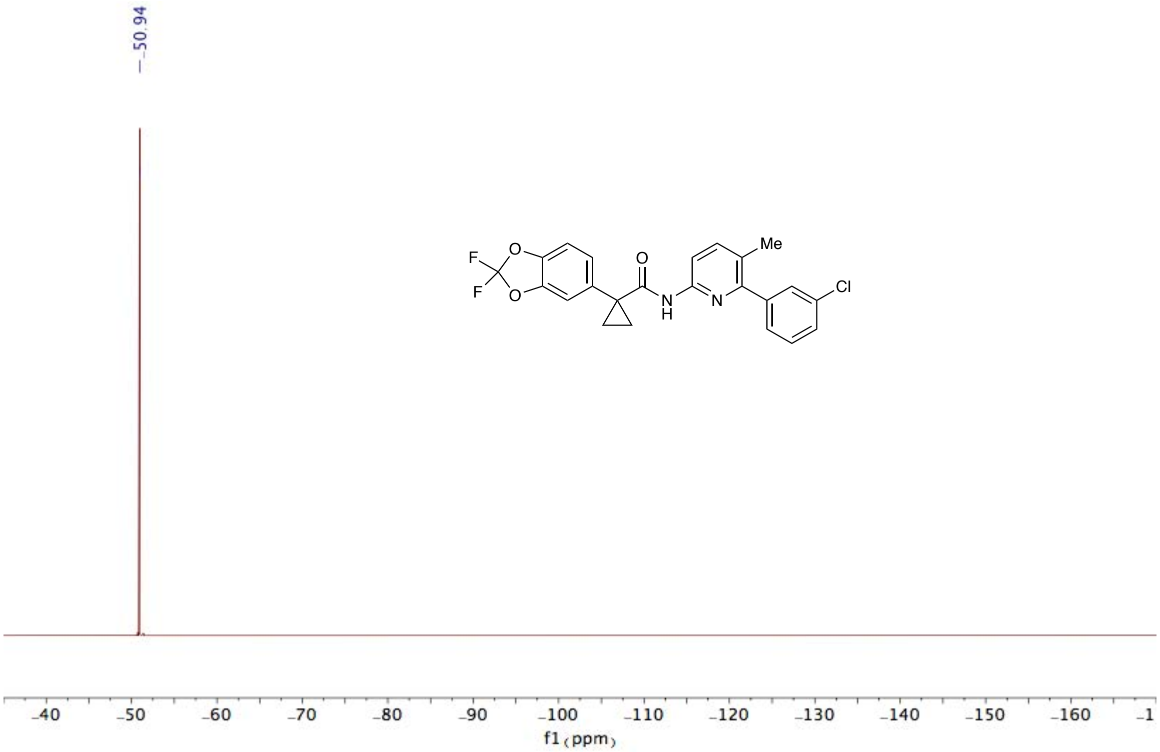
133.39
131.69
129.68
129.63
128.80
127.83
127.40
127.17
126.51
112.71
112.55
110.19
31.05
18.28
16.20
F
F
O
O
O
N
H
N
Me
Cl
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)



–50.94
F
F
O
O
O
N
H
N
Me
Cl
–40
–50
–60
–70
–80
–90
–100
–110
–120
–130
–140
–150
–160
–1
f1 (ppm)