Supporting Information
For

C-N Cross-Coupling via Photoexcitation of Nickel-Amine Complexes

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1. General Information

Anhydrous DMAc solvent, aryl halides and amines were purchased from Sigma-Aldrich, TCI or Alfa Aesar. 2,2,6,6-tetramethyl-1-piperidinyloxy (TEMPO) and piperidine-d_{11} were purchased from Sigma-Aldrich. All commercially available solvents and reagents were degassed and used without further purifications. The photoreactor was custom designed and built (see section below). Organic solutions were concentrated under reduced pressure on a Büchi rotary evaporator using a water bath. Flash column chromatography was performed using the CombiFlash® Rf+ Lumen instrument. Reactions were analyzed by TLC using TLC silica gel F254 250 µm precoated-plates from Merck. Developed chromatogram was visualized using a UV lamp and permanganate stain was used for UV-inactive compounds.

The ^{1}H, ^{13}C, ^{19}F NMR spectra were recorded on a Bruker Avance Neo (400, 101, and 376 MHz, respectively) instrument. Deuterated solvents were purchased from Cambridge Isotope Laboratories (Andover, MA) and used as received. All ^{1}H NMR experiments are reported in δ units, parts per million (ppm), and were measured relative to the signals for residual chloroform (7.26 ppm) or dimethylsulfoxide (2.50 ppm) in the deuterated solvents. Data for ^{1}H NMR are reported as follows: chemical shift (δ ppm), multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, p = quintet, m = multiplet, dd = doublet of doublets, dt = doublet of triplets…etc, br = broad), coupling constant (Hz) and integration. All ^{13}C NMR spectra are reported in ppm relative to $CDCl_3$ (77.16 ppm) or DMSO-d_6 (39.52 ppm). Mass spectrometry analysis was performed using an Agilent 6220 TOF LC/MS (“OTOF”) interfaced to an Agilent 1200 HPLC with electrospray (ESI), multi-mode (combined ESI and APCI), atmospheric pressure photoionization (APPI), and Direct Analysis in Real Time (DART) sources at Colorado State University.

2. Reaction Development and Optimization

General Procedure A

Under nitrogen atmosphere in a glovebox, a stir bar, an aryl halide (0.40 mmol, 1.0 equiv.) and 1 mL of DMAc solution containing dissolved $NiBr_2 \cdot 3H_2O$ (0.02 mmol, 0.05 equiv., 5.5 mg) was added to a 0.5 dram glass vial. The glass vial was then capped using a screw cap equipped with a PTFE/silicone septum and sealed with a strip of Parafilm®. The capped vial was then brought out of the glovebox and liquid amine (degassed, 1.40 mmol, 3.5 equiv.) was added via a Hamilton® syringe. Solid amines were weighed and added inside the glovebox. The capped glass vial containing the reaction mixture was then placed in a 3D-printed vial holder and subjected to 365 nm LED irradiation with fan cooling to maintain the vial at room temperature. After the time specified in the reaction schemes, the reaction mixture was washed with water, extracted with EtOAc or DCM and concentrated under vacuum. Purification of the crude product by flash chromatography on silica gel using the indicated solvent system afforded the desired product.

General Procedure B

Under nitrogen atmosphere in a glovebox, a stir bar, an aryl halide (0.40 mmol, 1.0 equiv.), quinuclidine (0.60 mmol, 1.5 equiv., 66.7 mg) and 1 mL of DMAc solution containing dissolved $NiBr_2 \cdot 3H_2O$ (0.02 mmol, 0.05 equiv., 5.5 mg) was added to a 0.5 dram glass vial. The glass vial was then capped using a screw cap equipped with a PTFE/silicone septum and sealed with a strip of Parafilm®. The capped vial was then brought out of the glovebox and liquid amine (degassed, 0.60 mmol, 1.5 equiv.) was added via a Hamilton® syringe. Solid amines were weighed and added inside the glovebox. The capped glass vial containing the reaction mixture was then placed in a 3D-printed vial holder and subjected to 365 nm LED irradiation with fan cooling to maintain the vial at room temperature. After the time specified in the reaction schemes, the reaction mixture was washed with water, extracted with EtOAc or DCM and concentrated under vacuum. Purification of the crude product by flash chromatography on silica gel using the indicated solvent system afforded the desired product.

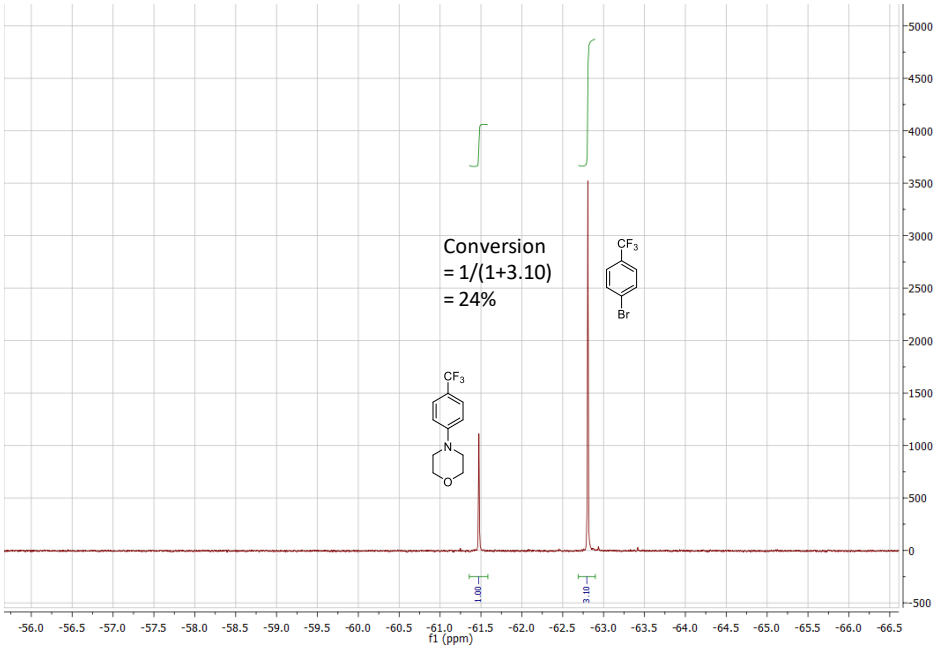
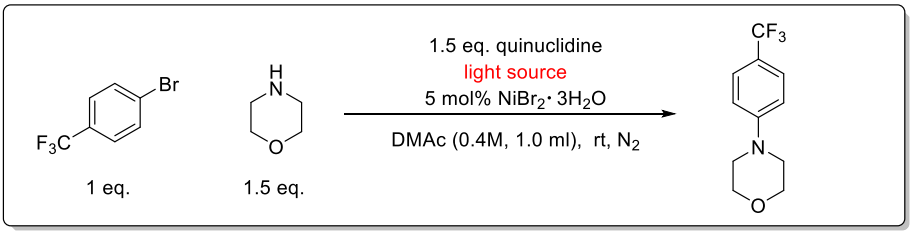


Figure S1. Conversion of the C-N coupled product determined from ^{19}F NMR.

We used 4-bromobenzotrifluoride and morpholine as our model substrates and employed general procedure B to perform control experiments and reaction optimizations detailed below (Fig. S2-S7). We monitored the conversion of the C-N coupled product (4-(4-(trifluoromethyl)phenyl)morpholine) as a

function of time (e.g. 1 h, 2 h, and 3 h) using ^{19}F NMR (Fig. S1). We assumed that during the course of the reaction, the number of CF_3 groups in the reaction mixture is conserved, allowing the conversion of the C-N coupled product to be calculated (see Fig. S1). This method is sufficiently accurate that ^{19}F NMR conversion closely matches isolated yield. For example, C-N coupled product was isolated at 91% yield with ^{19}F NMR conversion of 95%. To obtain ^{19}F NMR conversion as a function of time, we withdrew a ~10 µL aliquot from the reaction mixture under oxygen-free conditions and diluted the sample with ~600 µl of deuterated chloroform before subjecting the sample to ^{19}F NMR spectroscopy.

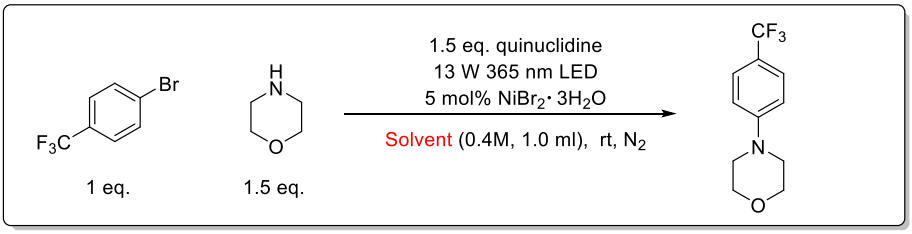
During reaction optimization, we determined that no reaction occurred in the absence of nickel salts or without irradiation at either room temperature or 80 °C (Fig. S2). 405 nm light gave slower conversion than 365 nm light (52% vs. 72% at 1 hour) but achieved similar conversion at 3 hours. With no added quinuclidine, 55% conversion was obtained. DMF and DMSO gave similarly high conversion (>90%) to DMAc while MeOH and MeCN gave considerably lower conversion (Fig. S3). Various nickel salts at different loadings have similar performance (Fig. S4). The effect of types of added organic bases were also investigated (Fig. S5 and S6). Quinuclidine gave the best performance while bases such as DMAP, DBU and PMDETA almost completely shut off reactivity. Fig. S7 shows that excess morpholine substrate can also function as a base. For example, when morpholine substrate was introduced at 3.5 eq., 94% of conversion was obtained with no added base.



hv	^{19}F-NMR Conversion		
	1 hr	2 hr	3 hr
no light	----------	----------	0%
no light (80°C)	----------	----------	0%
405 nm	52%	81%	93%
365 nm	72%	94%	95% (91%)*
365 nm (no nickel)	----------	----------	0%
365 nm (no base)	----------	----------	55%

*Isolated yield

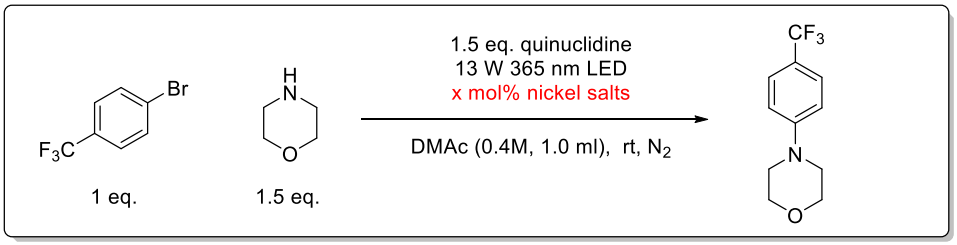
Figure S2. Control experiment and effect of light source.



Solvent	^{19}F-NMR Conversion		
	1 hr	2 hr	3 hr
DMAc (365 nm)	72%	94%	95% (91%)*
DMSO (365 nm)	----------	----------	93%
MeOH (365 nm)	----------	----------	60%
DMF (365 nm)	----------	----------	93%
MeCN (365 nm)	----------	----------	46%

*Isolated yield

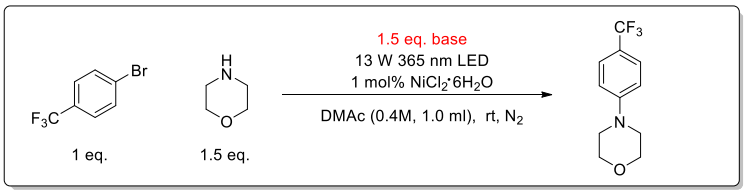
Figure S3. Effect of solvent.



Nickel salts	^{19}F-NMR Conversion		
	1 hr	2 hr	3 hr
$NiBr_2$•glyme 5%	81%	96%	95%
$NiCl_2$•$6H_2O$ 5%	76%	96%	95%
$NiCl_2$•glyme 5%	68%	95%	95%
$NiBr_2$•$3H_2O$ 5%	72%	94%	95% (91%)*
$NiBr_2$•$3H_2O$ 1%	82%	95%	95%
$NiBr_2$•$3H_2O$ 2%	85%	96%	95%
$NiBr_2$•$3H_2O$ 8%	74%	95%	95%
$NiBr_2$•$3H_2O$ 10%	74%	95%	95%

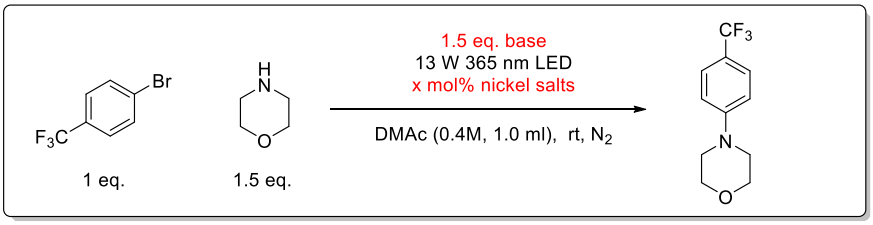
*Isolated yield

Figure S4. Effect of types and loadings of nickel salts. The lower light penetration into the $NiBr_2$•$3H_2O$ 5%, 8% and 10% solutions could explain their lower conversions compared to $NiBr_2$•$3H_2O$ 1% in the 1st hour,



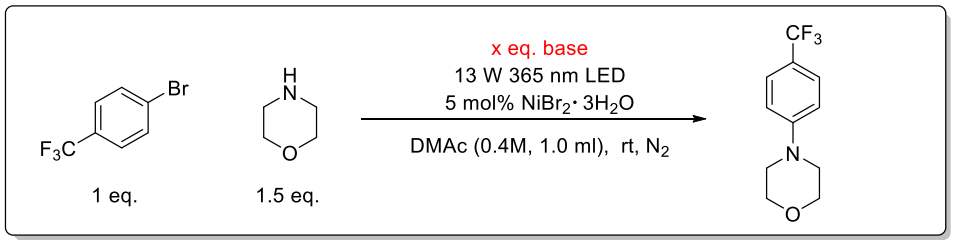
Base	^{19}F-NMR Conversion		
	1 hr	2 hr	3 hr
quinuclidine 1.5eq	79%	94%	94%
DABCO 1.5eq	14%	26%	35%
DIPEA 1.5eq	21%	48%	68%
morpholine 1.5eq	20%	47%	64%
N-Me morpholine 1.5eq	31%	46%	52%
DMAP 1.5eq	0%	1%	2%
TEA 1.5eq	43%	70%	78%
DBU 1.5eq	0%	0%	2%
PMDETA 1.5eq	0%	0%	0%
proton sponge 1.5eq	2%	4%	7%

Figure S5. Effect of added base.



Base	Nickel	^{19}F-NMR Conversion		
		1 hr	2 hr	3 hr
morpholine 1.5eq	$NiBr_2 \bullet 3H_2O$ 5%	65%	85%	93%
morpholine 1.5eq	$NiBr_2 \bullet 3H_2O$ 2%	57%	80%	88%
morpholine 1.5eq	$NiBr_2 \bullet 3H_2O$ 1%	34%	63%	74%
morpholine 1.5eq	$NiCl_2 \bullet 6H_2O$ 5%	34%	65%	79%
morpholine 1.5eq	$NiCl_2 \bullet 6H_2O$ 2%	27%	58%	75%
morpholine 1.5eq	$NiCl_2 \bullet 6H_2O$ 1%	20%	47%	64%
DIPEA 1.5eq	$NiBr_2 \bullet 3H_2O$ 5%	45%	79%	85%
DIPEA 1.5eq	$NiBr_2 \bullet 3H_2O$ 2%	44%	76%	81%
DIPEA 1.5eq	$NiBr_2 \bullet 3H_2O$ 1%	23%	50%	68%
DIPEA 1.5eq	$NiCl_2 \bullet 6H_2O$ 5%	29%	69%	84%
DIPEA 1.5eq	$NiCl_2 \bullet 6H_2O$ 2%	28%	65%	79%
DIPEA 1.5eq	$NiCl_2 \bullet 6H_2O$ 1%	21%	48%	68%
TEA 1.5eq	$NiBr_2 \bullet 3H_2O$ 5%	51%	77%	86%
TEA 1.5eq	$NiBr_2 \bullet 3H_2O$ 2%	50%	78%	86%
TEA 1.5eq	$NiBr_2 \bullet 3H_2O$ 1%	36%	65%	77%
TEA 1.5eq	$NiCl_2 \bullet 6H_2O$ 5%	36%	68%	82%
TEA 1.5eq	$NiCl_2 \bullet 6H_2O$ 2%	31%	64%	81%
TEA 1.5eq	$NiCl_2 \bullet 6H_2O$ 1%	43%	70%	78%

Figure S6. Effect of nickel salts and added base.



Base	^{19}F-NMR Conversion		
	1 hr	2 hr	3 hr
morpholine 0.0eq	----------	----------	55%
morpholine 1.0eq	52%	75%	84%
morpholine 1.5eq	65%	85%	93%
morpholine 1.8eq	63%	86%	94%
morpholine 2.0eq	66%	90%	94%
DIPEA 1.5eq	45%	79%	85%
DIPEA 1.8eq	27%	66%	83%
DIPEA 2.0eq	23%	60%	81%
TEA 1.5eq	51%	77%	86%
TEA 1.8eq	50%	78%	87%

Figure S7. Effect of base loading.

3. Photoreactor Development

This C-N coupling reaction utilizes a high radiant flux setup to achieve reduced reaction times. To this end, a photoreactor was developed (Fig. S8) that makes use of industrial strength light-emitting diodes (LEDs) which provide high radiant flux at 365 nm or 405 nm. Such powerful LEDs produce enough heat that active cooling is needed both to protect the LED and ensure that its emission profile remains constant throughout the reaction. To facilitate this, the LEDs were mounted to a metal core printed circuit board (MCPCB) which in turn is mounted to an aluminum heatsink. The MCPCB **(b)** enables efficient heat transfer from the LED to the heatsink **(c)**. This heatsink is then actively cooled by a 60mm computer fan **(d)**. In addition, the reaction chamber is separately cooled by a 40mm computer fan **(a)** to allow for consistent reaction conditions. This chamber also has a reflective interior surface coating **(e)** consisting of aluminum tape to maximize reflection of emitted light back to the reaction vial. A removable vial holder **(f)** ensures consistent vial placement 5 mm from the LED and allows for irradiation of 0.5 dram, 1.5 dram, and 20 mL vials. Lastly, the LED/MCPCB mounted to the heatsink/fan assembly forms a modular block **(g)** which allows for facile exchange of LEDs with differing emission wavelengths. The reactor is constructed from commercially available parts (Table S1) with the exception of the reaction chamber and vial holder (Table S9).

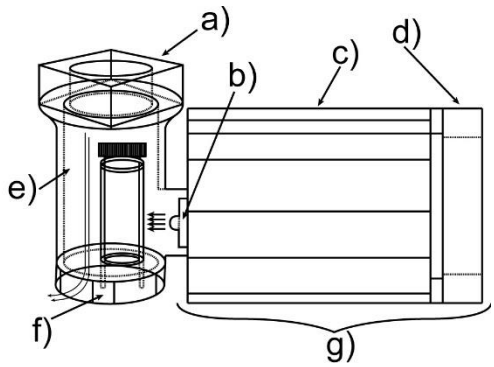


Figure S8. A schematic of the photoreactor.

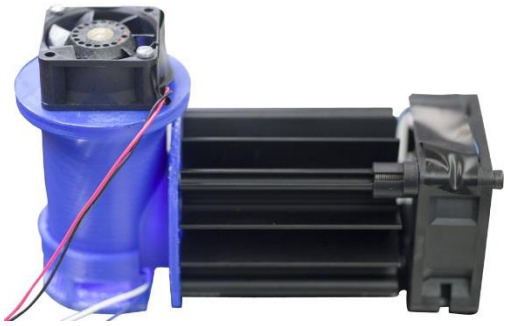
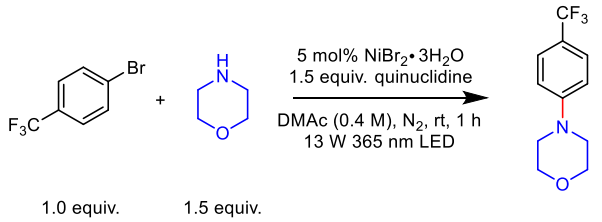


Figure S9. A photograph of the photoreactor with 365nm LED turned on and 0.5 dram vial holder attached.

Table S1. Parts needed for photoreactor construction are listed by manufacturer with specifications and part numbers.

Part	Source	Manufacturer	Specifications	Part Number
365 nm LED	commercial	LED Engin	3.3W radiant flux at 700 mA, 15.5 V	LZ4-04UV00
405 nm LED	commercial	LED Engin	4.1W radiant flux at 700 mA, 15.5 V	LZ4-00UB00
60 mm fan	commercial	Delta Electronics	51.7 cfm airflow at 750 mA, 12 V	QFR-0612DH-B
40 mm fan	commercial	Delta Electronics	20.56 cfm airflow at 430 mA, 12 V	THA0412AD
Fan power supply	commercial	Mean Well	12 V, 240 W, switching	HLG-240H-12
LED power supply	commercial	Cincon	18 V, 150 W, switching	TRH150A180
LED driver	commercial	LEDdynamics	Output: Input V – 2.5 V, 700 mA	3023-D-N-700
Heatsink	commercial	Wakefield	2.75'' diameter, 3'' thick aluminum	882-300AB
Reactor chamber	3D-printed	N/A	Fits 40 mm fan, 65 mm heatsink	N/A
Vial Holder	3D-printed	N/A	.5 dram, 1.5 dram, or 20mL vials	N/A

The vial holder, reactor body, and fan adapter parts were designed in-house using Autodesk Inventor software and 3D-printed using stereolithography with a Form2 printer (FormLabs) or fused filament fabrication with a Creator Pro (Flashforge). Vial position in the reaction chamber was optimized by 3D-printing vial holders with distances of 5 mm, 10 mm, and 15 mm from the LED emitter surface to the vial. The 5 mm position yielded higher NMR conversion after 1 hour compared to other distances under standard reaction conditions on a 0.2 mmol scale (Fig. S10). All reactions reported in the main text were performed at the 5 mm irradiation distance.



Entry	Deviation from conditions above	Yield
1	5 mm irradiation distance	91%
2	10 mm irradiation distance	75%
3	15 mm irradiation distance	69%

Figure S10. The model reaction was performed on a 0.2 mmol scale (half scale compared to other reported reactions) with varying irradiation distances. In the main text, at 0.4 mmol scale 72% yield was achieved after 1 hour at 5mm irradiation distance. Yields were determined by ^{19}F NMR.

Temperature monitoring of the reaction was performed by inserting a type-K thermocouple (VWR) through a septum into a 0.5 dram vial equipped with a stir bar and 1 mL DMAc to simulate reaction conditions. The temperature inside the vial was initially 23.9°C prior to irradiation. During irradiation, the temperature varied from 27.6-28.1°C over the course of 3 hours (Fig. S11).

Figure S11. Temperature Monitoring Setup. A 0.5 dram vial equipped with a stir bar and 1 mL DMAc was monitored via a type K thermocouple inserted through the septum **(left)** and sealed with Parafilm. The vial was placed in the photoreactor as shown **(right)** and irradiated for 3 hours. The photo shown is before irradiation.

4. UV-Visible Spectroscopy

UV-visible spectroscopy was performed for each reaction component and combination of reaction components using a Cary 5000 spectrophotometer (Agilent Technologies). Morpholine and 4-bromobenzotrifluoride (4-BrBzCF$_3$) are both colorless liquids without significant molar absorptivity at wavelengths greater than 300 nm (Fig. S12) at the concentrations present in the C-N coupling reaction mixture.

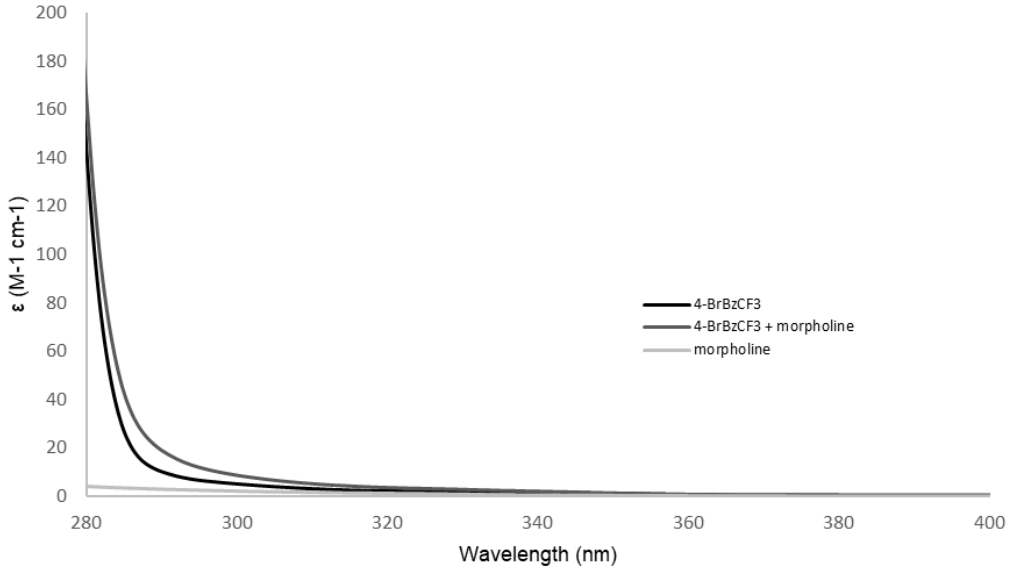


Figure S12. Molar absorptivity vs. wavelength for 4-bromobenzotrifluoride and morpholine individually and combined in DMAc, 0.4 M in 4-bromobenzotrifluoride and 1.4 M in morpholine.

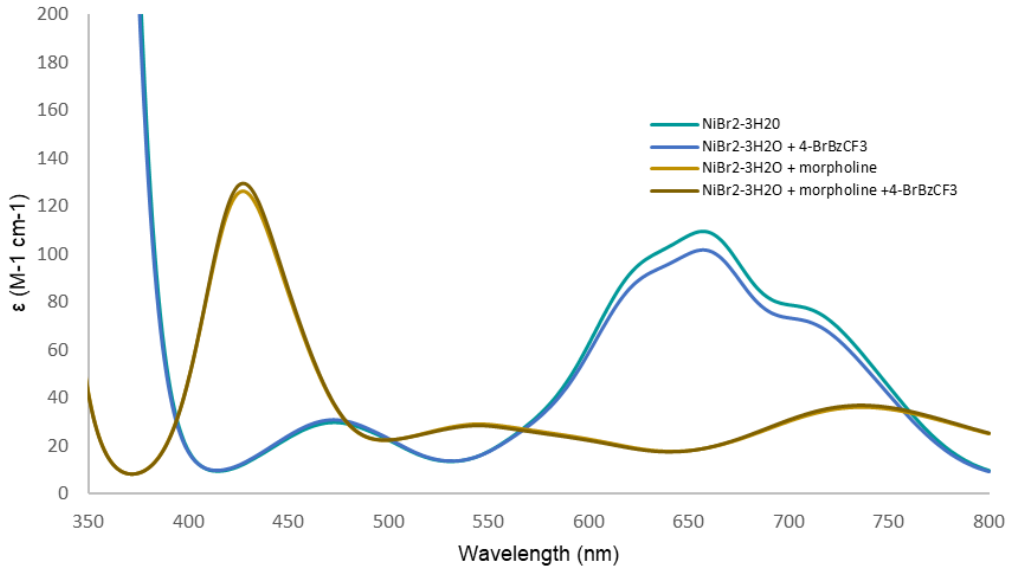


Figure S13. Molar absorptivity vs. wavelength for $NiBr_2 \cdot 3H_2O$ and its combinations with 4-bromobenzotrifluoride and morpholine in DMAc.

UV-visible spectroscopy was also performed for $NiBr_2•3H_2O$ alone and in combination with 4-$BrBzCF_3$ and morpholine. $NiBr_2•3H_2O$ has a distinctive absorption profile which was not altered with addition of 4-$BrBzCF_3$. However, upon addition of morpholine, the λ_{max} was blue-shifted from 657 nm to 427 nm (Fig. S13).

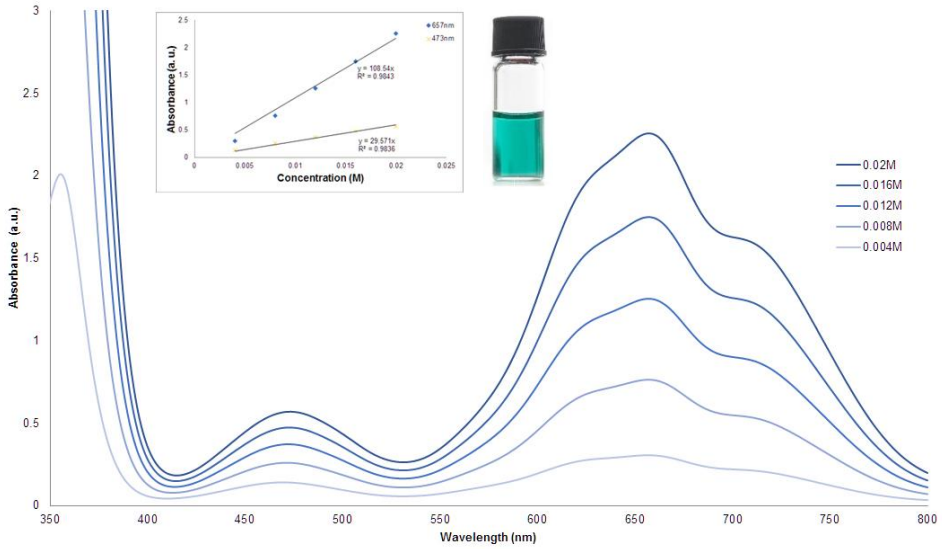


Figure S14. Absorption spectra of $NiBr_2•3H_2O$ at concentrations ranging from 0.02 – 0.004 M in DMAC. **Inset:** a photo of the solution and linear regressions at 657 nm and 473 nm.

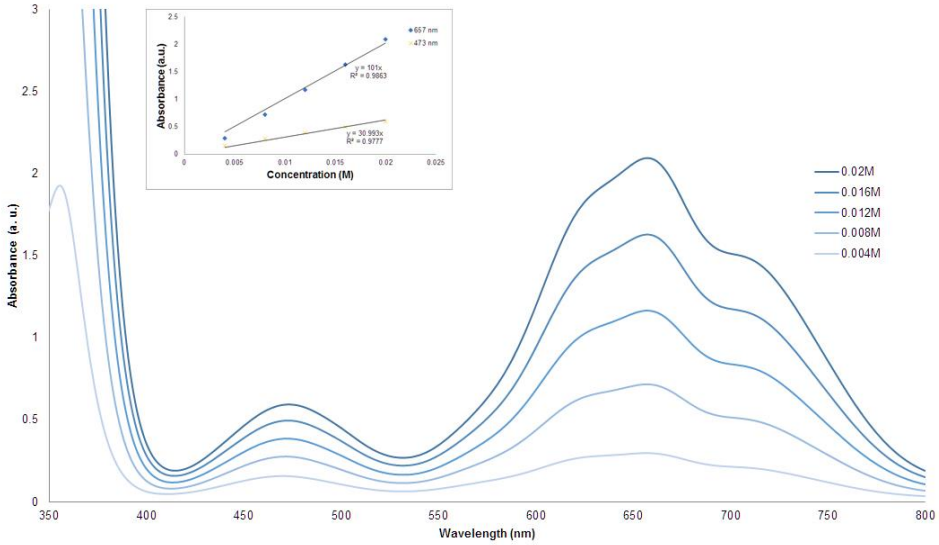


Figure S15. Absorption spectra of $NiBr_2•3H_2O$ + 4-$BrBzCF_3$ at concentrations ranging from 0.02 – 0.004 M ($NiBr_2•3H_2O$) and 0.4 – 0.08 M (4-$BrBzCF_3$) in DMAC. **Inset:** linear regressions at 657 nm and 473 nm.

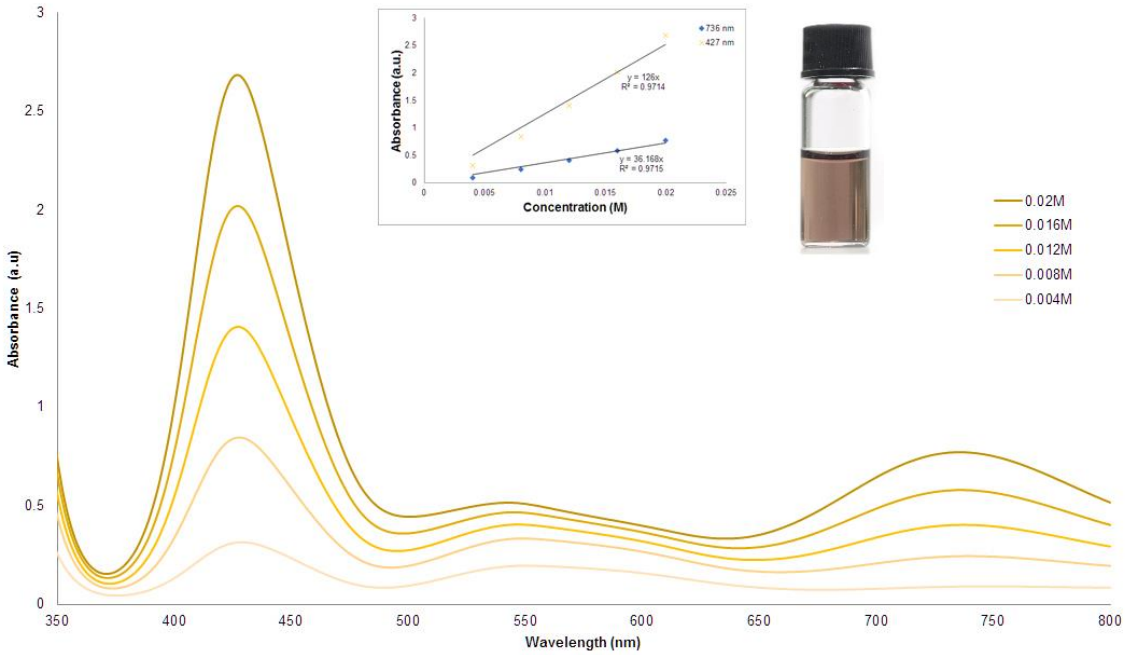


Figure S16. Absorption spectra of $NiBr_2•3H_2O$ + morpholine at concentrations ranging from 0.02 – 0.004 M ($NiBr_2•3H_2O$) and 1.4 – 0.28 M (morpholine) in DMAc. **Inset:** a photo of the mixture and linear regressions at 736 nm and 427 nm.

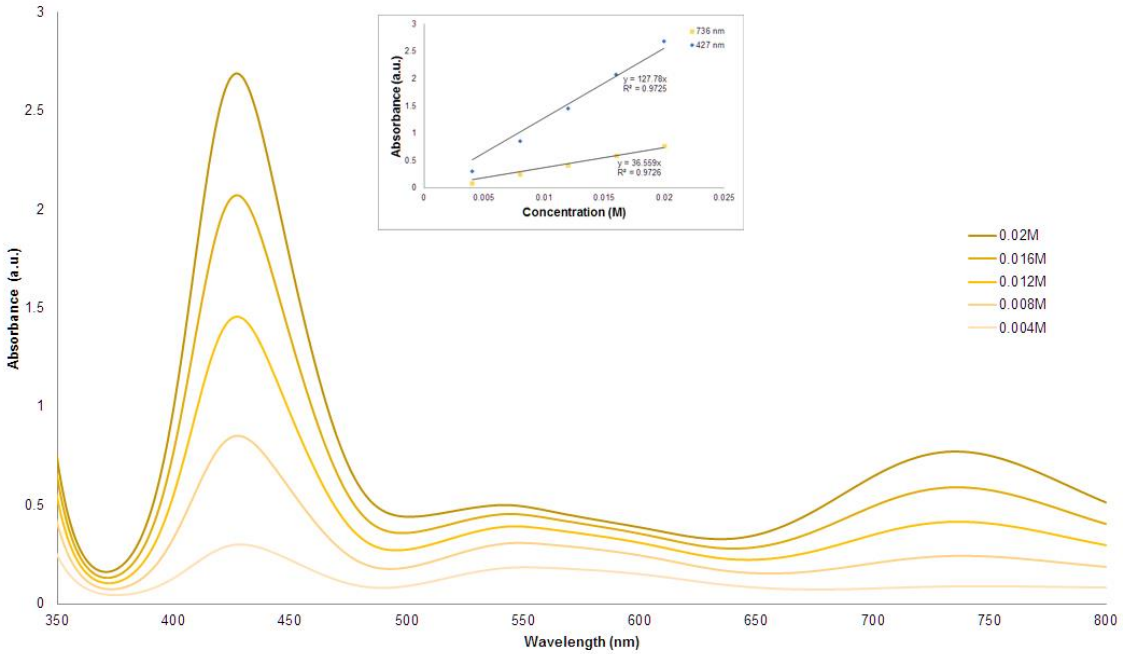


Figure S17. Absorption spectra of $NiBr_2•3H_2O$ + morpholine + 4-$BrBzCF_3$ at concentrations ranging from 0.02 – 0.004 M ($NiBr_2•3H_2O$), 1.4 – 0.28 M (morpholine), and 0.4-0.08 M (4-$BrBzCF_3$) in DMAC. **Inset:** linear regressions at 736 nm and 427 nm.

Molar absorptivity for each major peak and secondary peak of each combination were calculated according to Beer's Law (Table S2) with 5 data points used for each reported value (Fig. S13-S17). The R^2 coefficient of determination is also reported for each peak.

Table S2. Molar absorptivity for the most prominent peaks of each reagent combination. Data was extracted from spectra collected for 5 concentrations ranging from 0.02 - 0.008 M in $NiBr_2•3H_2O$.

Solution	λ_{max} (nm)	λ_2 (nm)	ε_{max} ($s^{-1}M^{-1}$)	ε_2 ($s^{-1}M^{-1}$)	R^2_{max}	R^2_2
$NiBr_2•3H_2O$	657	473	109	30	.984	.984
$NiBr_2•3H_2O$ + morpholine	427	736	126	36	.971	.971
$NiBr_2•3H_2O$ + 4-$BrBzCF_3$	657	473	101	31	.986	.977
$NiBr_2•3H_2O$ + morpholine + 4-$BrBzCF_3$	427	736	128	37	.973	.973

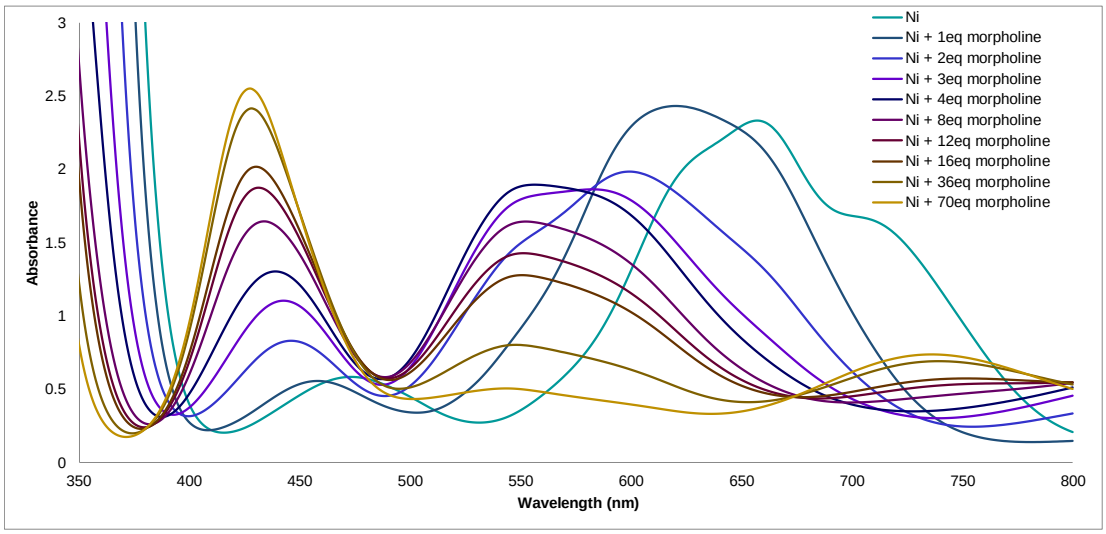


Figure S18. Absorption spectra of $NiBr_2•3H_2O$ + morpholine at concentrations ranging from 0.02 M ($NiBr_2•3H_2O$), 0.02 M – 1.40 M (morpholine, 1 equiv. to 70 equiv. relative to Ni) in DMAc.

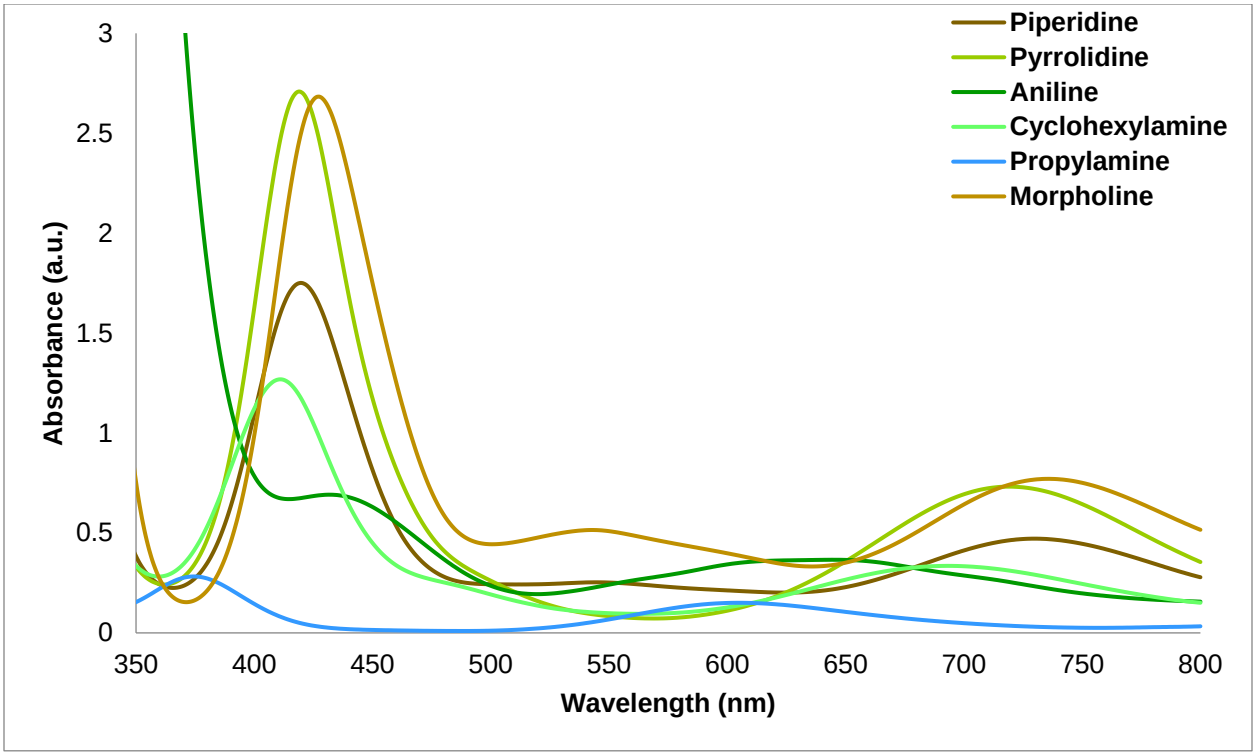


Figure S19. UV-visible absorption spectra of $[NiBr_2(amine)_n]$ complexes are plotted for 6 amines in DMAc. Each solution was 0.02 M in $NiBr_2 \cdot 3H_2O$ and 1.4 M in amine.

The spectra of $[NiBr_2(morpholine)_n]$, $[NiBr_2(pyrrolidine)_n]$, and $[NiBr_2(piperidine)_n]$ show similar curve shapes and λ_{max} = 427 nm, λ_{max} = 419 nm, and λ_{max} = 420 nm, respectively (Fig. S19). This appears characteristic of Ni-amine complexes with secondary amines. With primary amines, the λ_{max} is blue-shifted somewhat. The spectra of $[NiBr_2(cyclohexylamine)_n]$ and $[NiBr_2(propylamine)_n]$ showed λ_{max} = 411 nm and λ_{max} = 375 nm, respectively. The spectrum of the cyclohexylamine complex shares characteristics of both primary and secondary Ni-amine complexes in terms of how blue-shifted the λ_{max} is and the presence and location of secondary peaks. The $[NiBr_2(aniline)_n]$ complex shows a strikingly different absorption spectrum.

5. Fluorimetry

Spectrofluorometer FS5 (Edinburgh Instruments) was used to monitor the emission of the nickel-amine complex (Fig. S19). A solution of 0.02 M $NiBr_2 \cdot 3H_2O$ in DMAc was prepared in a glovebox in a 1 cm quartz cuvette, capped with a septum screw cap, and the seal was reinforced with Parafilm. Morpholine was degassed by sparging with N_2 for 30 minutes and added to the cuvette via syringe under N_2 to make a 1.4 M solution. The resulting mixture was equal in concentration to the C-N coupling reaction conditions described in this work. This mixture was excited at 365 nm with a Xenon lamp and emission was scanned from 375-800 nm. All fluorescence measurements were corrected internally with a reference detector. A sharp emission peak at 386 nm and a broad emission peak at 484 nm were observed (Fig. S20).

Next, excitation wavelength was varied from 240nm to 440nm, monitoring emission intensity at 484 nm ($\lambda_{max,emission}$ determined in Fig. S20). Notably, the emission intensity (at 484 nm) peaks at excitation wavelength of 359 nm, which is within the range of the emission spectrum for the 365 nm LED used in C-N coupling reactions (Fig. S21). This suggests that 365 nm LED is an optimum light source for the C-N coupling reaction and might explain the slower reaction rate at 405 nm irradiation.

In addition, a Stern-Volmer quenching study was attempted by introducing 4-bromobenzotrifluoride, degassed by sparging with N_2, in increments of 0.01 eq (Fig. S22). While quenching was not observed, the shoulder of the λ_{max} = 484 nm emission peak grew in height and a new side peak appeared at λ = 524 nm. Thus, addition of aryl halide altered the emission of the Ni-amine complex. Work is underway to determine the structural change that underlies the formation of this new emission peak.

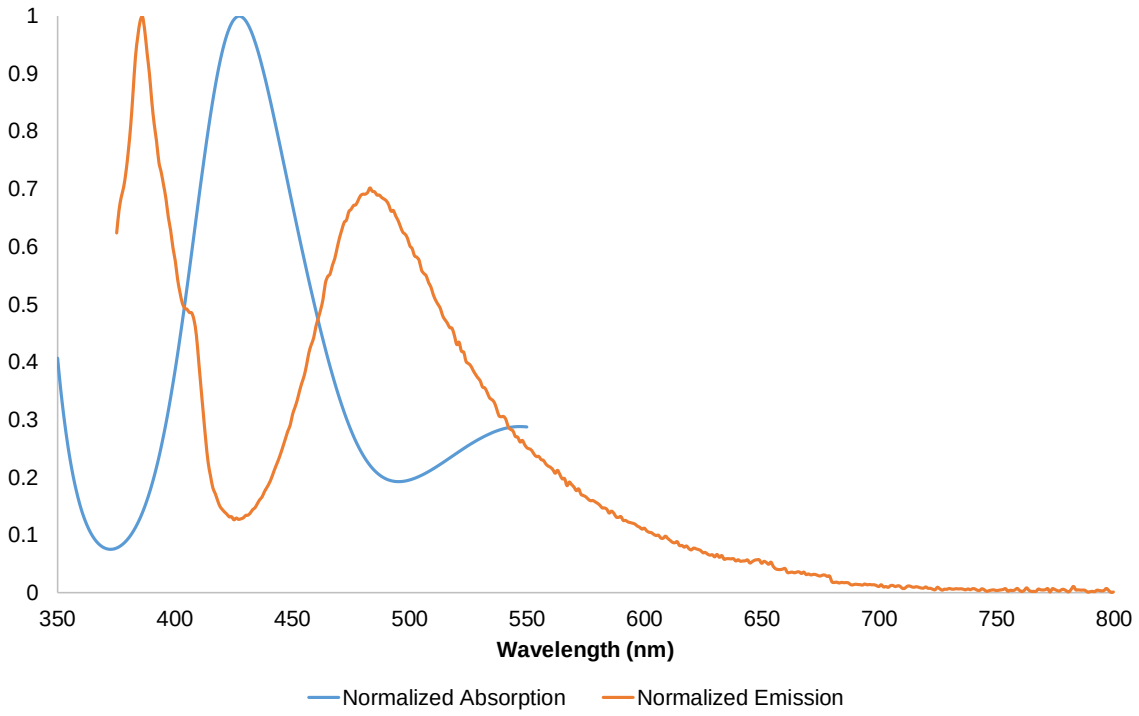


Figure S20. Normalized UV-vis absorption and emission spectrums of nickel-morpholine complex. 0.02 M of $NiBr_2 \cdot 3H_2O$ and 1.4 M of morpholine were dissolved in DMAc. For the emission spectrum, the complex was excited at 365 nm and emission was monitored from 375-800 nm (orange trace).

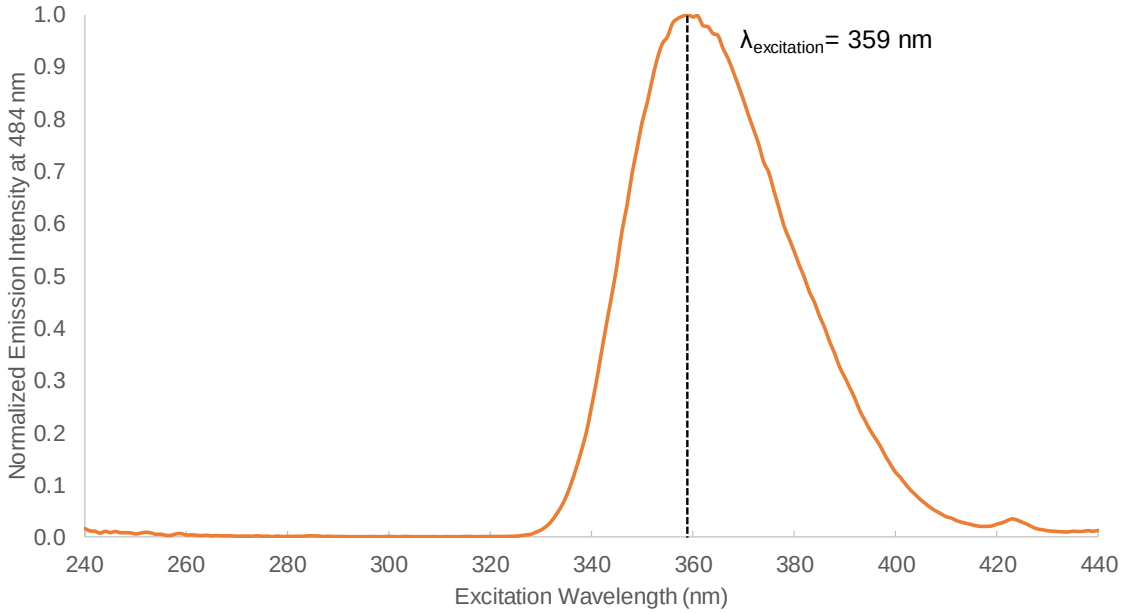


Figure S21. Normalized emission intensity (at λ = 484 nm) as a function of excitation wavelength. 0.02 M of $NiBr_2 \cdot 3H_2O$ and 1.4 M of morpholine were dissolved in DMAc. The emission intensity at λ = 484 nm is maximum when excitation source at 359 nm is used.

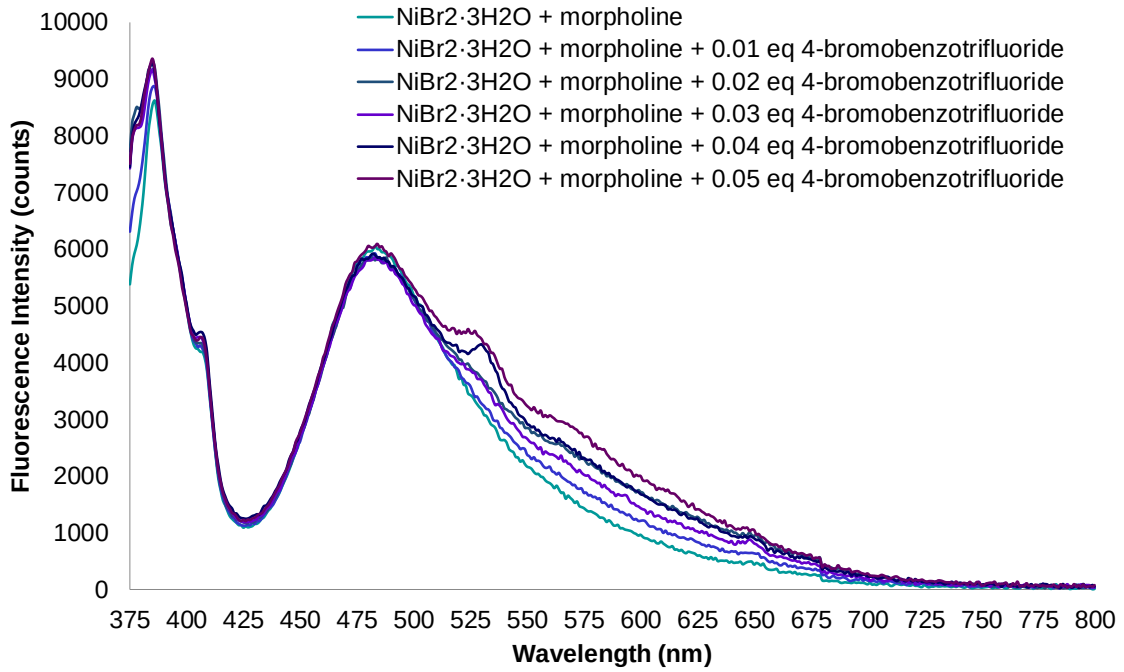


Figure S22. Emission spectrum as a function of increasing 4-bromobenzotrifluoride concentration. 0.02 M of $NiBr_2 \cdot 3H_2O$ and 1.4 M of morpholine were dissolved in DMAc. 4-bromobenzotrifluoride was increasingly added from 0.004M (0.01 eq) to 0.020M (0.05 eq).

6. Kinetic Isotope Effect

The following second order rate expression was solved numerically by the Runge–Kutta RK4 method to obtain the observed second order rate constant k_{obs} (Fig. S23 and S24).

A = amine; B = aryl halide; C = C-N coupled product.

$$\frac{d[A]}{dt} = -2k_{obs}[A][B], [A]_0 = 1.4M$$

the factor of 2 here accounts for the consumption of the amine as both the substrate and base to neutralize the produced acid.

$$\frac{d[B]}{dt} = -k_{obs}[A][B], [B]_0 = 0.4M$$

$$\frac{d[C]}{dt} = k_{obs}[A][B], [C]_0 = 0.0M$$

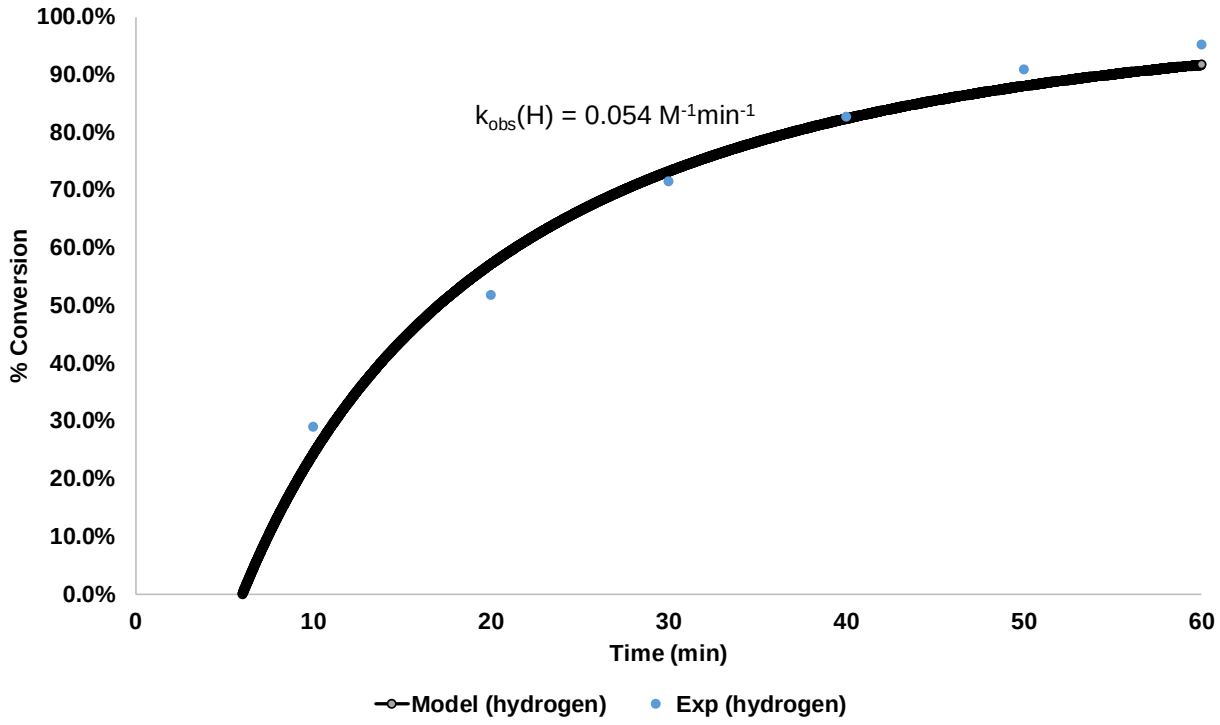


Figure S23. Reactions conditions: 1.0 equiv. of 4-bromobenzotrifluoride (0.4 mmol), 3.5 equiv. of piperidine (H), 5 mol% $NiBr_2$•$3H_2O$ and irradiation at 365 nm. The observed rate constant (k_{obs}) was determined by solving the second order rate equation model via numerical integration (RK4 method, time step = 0.01 min). An inhibition period of 6 min was included in the model fitting. The determined rate constant value is k_{obs}(H) = 0.054 $M^{-1}min^{-1}$.

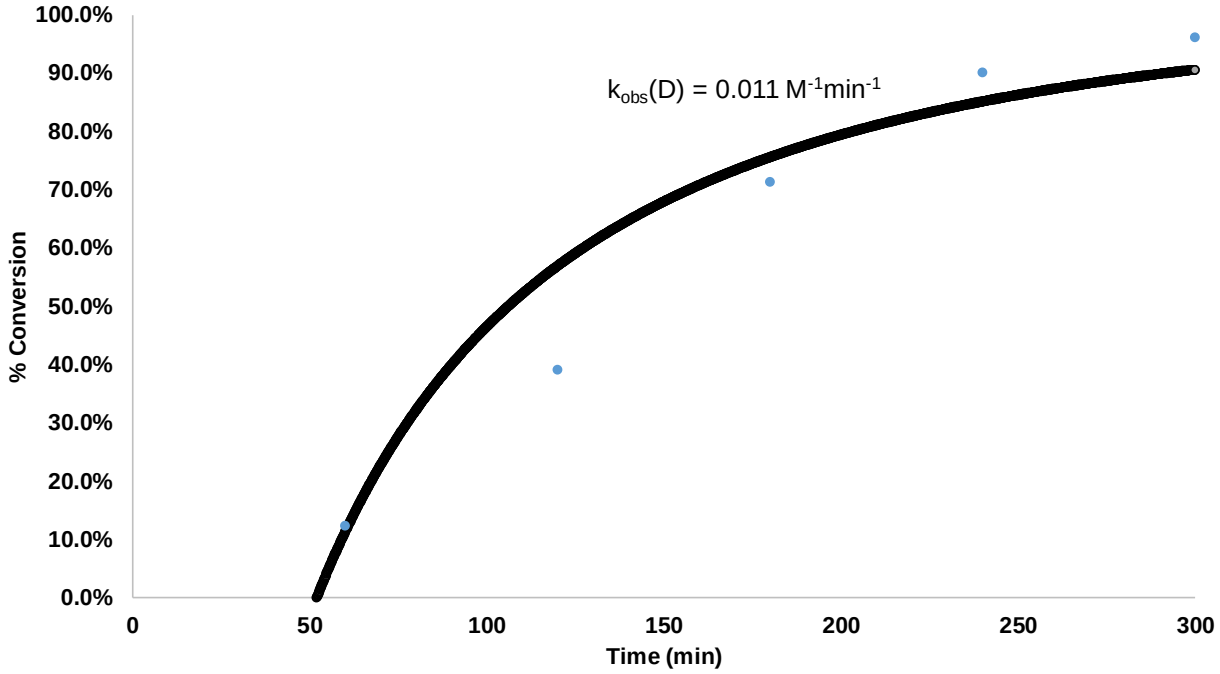


Figure S24. Reactions conditions: 1.0 equiv. of 4-bromobenzotrifluoride (0.4 mmol), 3.5 equiv. of piperidine (D), 5 mol% $NiBr_2•3H_2O$ and irradiation at 365 nm. The observed rate constant (k_{obs}) was determined by solving the second order rate equation model via numerical integration (RK4 method, time step = 0.1 min). An inhibition period of 52 min was included in the model fitting. The determined rate constant value is $k_{obs}(D) = 0.011\ M^{-1}min^{-1}$.

7. Computational Details

All calculations were performed using computational chemistry software package Gaussian 09 ver. D01. We acknowledge the use of computational resources provided by the XSEDE - Comet supercomputer (grant number CHE 160041).

Geometries of all molecular structures were optimized at the uM06/6-31+G(d,p)/CPCM-DMAc level of theory followed by frequency calculations to obtain zero point energy (ZPE) corrections, thermal corrections, and entropic TS terms using ideal gas approximations. The obtained Gibbs free energy, G^{0*}(298K, 1atm), by default has a standard reference state of 298.15K and 1 atm. However, a standard reference state of 298.15K and 1 mole/liter [G^{0}(298K, 1M)] is more relevant to our examined systems as the C-N cross-coupling reactions are carried out in the liquid phase in DMAc.

To obtain the Gibbs free energy with relevant standard state reference, G^{0}(298K, 1M) = G^{0*}(298K, 1atm) + RT ln(0.08206T), where R is the gas constant and T is the temperature. ΔG^{0}(298K, 1M) = ΔG^{0*}(298K, 1atm) when there is no mole change from the reactant to the product. However, for every net mole change ΔG^{0}(298K, 1M) = ΔG^{0*}(298K, 1atm) – 1.89 kcal/mol.

At the converged geometries, single point calculations at uM06/6-311+G(d,p)/CPCM-DMAc were performed; the various corrections and entropic TS terms from uM06/6-31+G(d,p) calculations were then applied to the energy obtained with uM06/6-311+G(d,p).

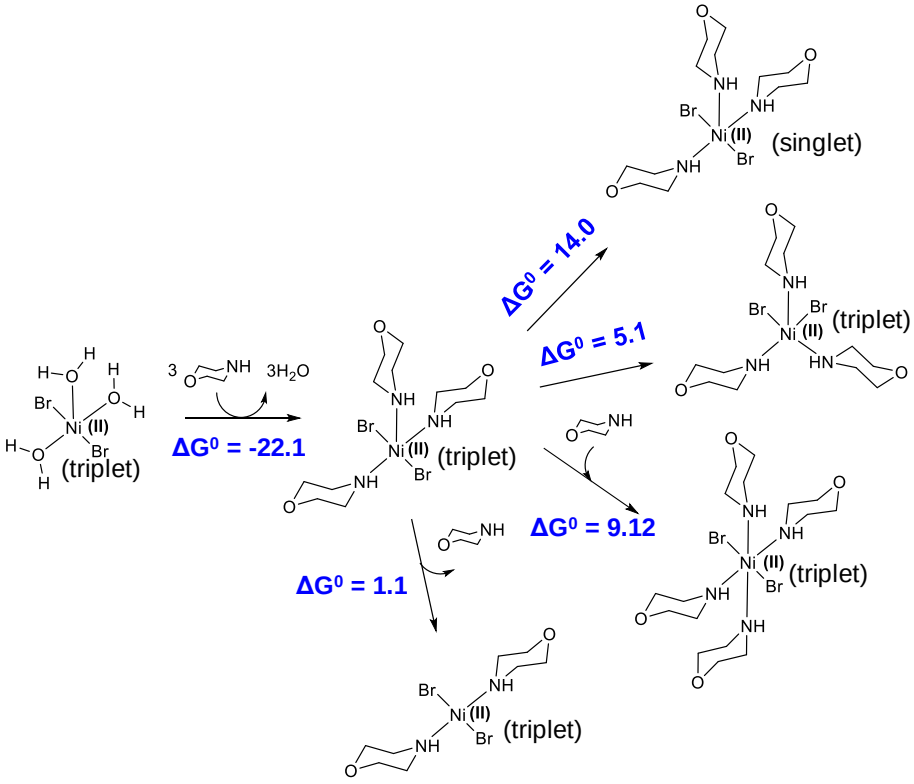
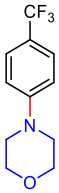


Figure S25. Stability of various nickel-amine complexes.

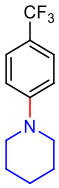
8. Characterizations



4-(4-(trifluoromethyl)phenyl)morpholine (1a)

General procedure A was followed using 4-bromobenzotrifluoride as the aryl halide, and morpholine as the amine. The reaction was run at room temperature for 3 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-15% EtOAc/hexanes to give the product as a white solid (80.2 mg, 87%). NMR data matched previously reported spectra.[1-2]

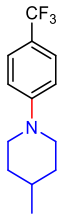
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.50 (d, *J* = 8.4 Hz, 2H), 6.92 (d, *J* = 8.8 Hz, 2H), 3.86 (t, *J* = 4.8 Hz, 4H), 3.24 (t, *J* = 5.2 Hz, 4H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 153.5, 126.6 (q, J_{C-F} = 3.8 Hz), 124.8 (q, J_{C-F} = 271.7 Hz), 121.1 (q, J_{C-F} = 32.9 Hz), 114.4, 66.8, 48.3.
^{19}F NMR (376 MHz, Chloroform-*d*) δ -61.4 (s, 3F).
HRMS (DART-TOF): calculated for $C_{11}H_{13}F_3NO$ ($[M+H]^+$) 232.0944, found 232.0943.



1-(4-(trifluoromethyl)phenyl)piperidine (2)

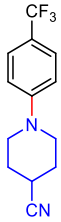
General procedure A was followed using 4-bromobenzotrifluoride as the aryl halide, and piperidine as the amine. The reaction was run at room temperature for 3 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-15% EtOAc/hexanes to give the product as a pale yellow oil (74.5 mg, 81%). NMR data matched previously reported spectra.[3]

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.46 (d, *J* = 8.7 Hz, 2H), 6.92 (d, *J* = 8.7 Hz, 2H), 3.27 (t, *J* = 5.2 Hz, 4H), 1.77 – 1.58 (m, 6H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 154.0, 126.5 (q, J_{C-F} = 3.7 Hz), 124.9 (q, J_{C-F} = 271.6 Hz), 119.7 (q, J_{C-F} = 32.7 Hz), 114.7, 49.4, 25.6, 24.4.
^{19}F NMR (376 MHz, Chloroform-*d*) δ -61.2 (s, 3F).
HRMS (DART-TOF): calculated for $C_{12}H_{15}F_3N$ ($[M+H]^+$) 231.1151, found 230.1162.



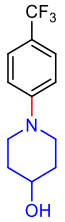
4-methyl-1-(4-(trifluoromethyl)phenyl)piperidine (3)
General procedure A was followed using 4-bromobenzotrifluoride as the aryl halide, and 4-methylpiperidine as the amine. The reaction was run at room temperature for 3 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-15% EtOAc/hexanes to give the product as a white solid (84.4 mg, 87%).

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.46 (d, *J* = 8.4 Hz, 2H), 6.92 (d, *J* = 8.6 Hz, 2H), 3.83 – 3.72 (m, 2H), 2.80 (td, *J* = 12.5, 2.7 Hz, 2H), 1.80 – 1.69 (m, 2H), 1.67 – 1.49 (m, 1H), 1.39 – 1.23 (m, 2H), 0.99 (d, *J* = 6.5 Hz, 3H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 153.7, 126.5 (q, J_{C-F} = 3.7 Hz), 125.0 (q, J_{C-F} = 271.4 Hz), 119.6 (q, J_{C-F} = 32.7 Hz), 114.7, 48.8, 33.8, 30.9, 22.0.
^{19}F NMR (376 MHz, Chloroform-*d*) δ -61.2 (s, 3F).
HRMS (DART-TOF): calculated for $C_{13}H_{17}F_3N$ ([M]) 244.1308, found 244.1307.



1-(4-(trifluoromethyl)phenyl)piperidine-4-carbonitrile (4)
General procedure A was followed using 4-bromobenzotrifluoride as the aryl halide, and piperidine-4-carbonitrile as the amine. The reaction was run at room temperature for 3 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-15% EtOAc/hexanes to give the product as a white solid (89.7 mg, 88%). NMR data matched previously reported spectra.[3]

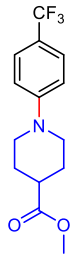
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.49 (d, *J* = 8.6 Hz, 2H), 6.93 (d, *J* = 8.5 Hz, 2H), 3.57 – 3.46 (m, 2H), 3.28 – 3.17 (m, 2H), 2.85 (tt, *J* = 8.0, 4.3 Hz, 1H), 2.12 – 1.91 (m, 4H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 153.1, 126.6 (q, J_{C-F} = 3.7 Hz), 124.7 (q, J_{C-F} = 272.0 Hz), 121.3 (q, J_{C-F} = 33.1 Hz), 121.2, 115.4, 46.9, 28.3, 26.3.
^{19}F NMR (376 MHz, Chloroform-*d*) δ -61.5 (s, 3F).
HRMS (DART-TOF): calculated for $C_{13}H_{14}F_3N_2$ ($[M+H]^+$) 255.1104, found 255.1093.



1-(4-(trifluoromethyl)phenyl)piperidin-4-ol (5)

General procedure A was followed using 4-bromobenzotrifluoride as the aryl halide, and 4-hydroxypiperidine as the amine. The reaction was run at room temperature for 3 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-40% EtOAc/hexanes to give the product as a white solid (82.4 mg, 84%). NMR data matched previously reported spectra.[3]

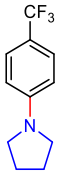
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.46 (d, *J* = 8.7 Hz, 2H), 6.92 (d, *J* = 8.8 Hz, 2H), 3.89 (tt, *J* = 8.7, 4.0 Hz, 1H), 3.74 – 3.56 (m, 2H), 3.03 (ddd, *J* = 13.0, 9.7, 3.2 Hz, 2H), 2.06 – 1.92 (m, 2H), 1.79 (s, 1H), 1.74 – 1.53 (m, 2H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 153.1, 126.5 (q, J_{C-F} = 3.8 Hz), 124.9 (q, J_{C-F} = 271.5 Hz), 120.1 (q, J_{C-F} = 32.7 Hz), 114.9, 67.7, 46.0, 33.8.
^{19}F NMR (376 MHz, Chloroform-*d*) δ -61.3 (s, 3F).
HRMS (DART-TOF): calculated for $C_{12}H_{15}F_3NO$ ($[M+H]^+$) 246.1100, found 246.1099.



methyl 1-(4-(trifluoromethyl)phenyl)piperidine-4-carboxylate (6)

General procedure A was followed using 4-bromobenzotrifluoride as the aryl halide, and methyl 4-piperidinecarboxylate as the amine. The reaction was run at room temperature for 3 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-15% EtOAc/hexanes to give the product as a white solid (78.8 mg, 69%).

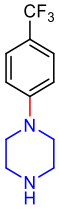
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.46 (d, *J* = 8.7 Hz, 2H), 6.92 (d, *J* = 8.6 Hz, 2H), 3.80 – 3.68 (m, 5H), 2.90 (ddd, *J* = 12.7, 11.3, 2.9 Hz, 2H), 2.51 (tt, *J* = 11.0, 4.0 Hz, 1H), 2.08 – 1.97 (m, 2H), 1.92 – 1.77 (m, 2H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 175.1, 153.4, 126.5 (q, J_{C-F} = 3.8 Hz), 124.9 (q, J_{C-F} = 271.7 Hz), 120.3 (q, J_{C-F} = 32.8 Hz), 115.0, 51.9, 48.0, 40.9, 27.8.
^{19}F NMR (376 MHz, Chloroform-*d*) δ -61.3 (s, 3F).
HRMS (DART-TOF): calculated for $C_{14}H_{17}F_3NO_2$ ($[M+H]^+$) 288.1206, found 288.1210.



1-(4-(trifluoromethyl)phenyl)pyrrolidine (7)

General procedure A was followed using 4-bromobenzotrifluoride as the aryl halide, and pyrrolidine as the amine. The reaction was run at room temperature for 3 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-15% EtOAc/hexanes to give the product as a white solid (66.0 mg, 77%). NMR data matched previously reported spectra.[1-2]

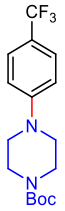
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.44 (d, *J* = 8.6 Hz, 2H), 6.55 (d, *J* = 8.6 Hz, 2H), 3.36 – 3.27 (m, 4H), 2.10 – 1.97 (m, 4H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 149.9, 126.5 (q, J_{C-F} = 3.7 Hz), 125.5 (q, J_{C-F} = 270.5 Hz), 116.8 (q, J_{C-F} = 32.5 Hz), 111.0, 47.7, 25.6.
^{19}F NMR (376 MHz, Chloroform-*d*) δ -60.6 (s, 3F).
HRMS (DART-TOF): calculated for $C_{11}H_{13}F_3N$ ($[M+H]^+$) 216.0995, found 216.1001.



1-(4-(trifluoromethyl)phenyl)piperazine (8)

General procedure A was followed using 4-bromobenzotrifluoride as the aryl halide, and piperazine as the amine. DMSO was used as the solvent instead of DMAc. The reaction was run at room temperature for 15 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-20% MeOH/DCM to give the product as a pale yellow solid (56.1 mg, 61%). NMR data matched previously reported spectra.[4]

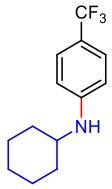
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.47 (d, *J* = 8.5 Hz, 2H), 6.91 (d, *J* = 8.6 Hz, 2H), 3.23 (t, *J* = 4.8 Hz, 4H), 3.02 (t, *J* = 5.0 Hz, 4H), 1.81 (s, 1H)
^{13}C NMR (101 MHz, Chloroform-*d*) δ 153.9, 126.5 (q, J_{C-F} = 3.8 Hz), 124.9 (q, J_{C-F} = 271.9 Hz), 120.6 (q, J_{C-F} = 32.6 Hz), 114.6, 49.2, 46.0.
^{19}F NMR (376 MHz, Chloroform-*d*) δ -61.4 (s, 3F).
HRMS (DART-TOF): calculated for $C_{11}H_{14}F_3N_2$ ($[M+H]^+$) 231.1104, found 231.1101.



***tert*-butyl 4-(4-(trifluoromethyl)phenyl)piperazine-1-carboxylate (9)**

General procedure B was followed using 4-bromobenzotrifluoride as the aryl halide, and *tert*-butyl piperazine-1-carboxylate as the amine. The reaction was run at room temperature for 3 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-15% EtOAc/hexanes to give the product as a white solid (112.4 mg, 85%). NMR data matched previously reported spectra.[1, 3]

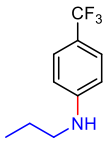
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.49 (d, *J* = 8.0 Hz, 2H), 6.92 (d, *J* = 8.4 Hz, 2H), 3.58 (t, *J* = 4.8 Hz, 4H), 3.23 (t, *J* = 5.6 Hz, 4H), 1.49 (s, 9H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 154.8, 153.3, 126.6 (q, J_{C-F} = 3.7 Hz), 124.8 (q, J_{C-F} = 271.7 Hz), 121.1 (q, J_{C-F} = 32.8 Hz), 115.1, 80.2, 48.2, 28.5.
^{19}F NMR (376 MHz, Chloroform-*d*) δ -61.4 (s, 3F).
HRMS (DART-TOF): calculated for $C_{16}H_{22}F_3N_2O_2$ ([M+H]$^+$) 331.1628, found 331.1630.



N-cyclohexyl-4-(trifluoromethyl)aniline (10)

General procedure A was followed using 4-bromobenzotrifluoride as the aryl halide, and cyclohexylamine as the amine. The reaction was run at room temperature for 15 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-15% EtOAc/hexanes to give the product as a pale yellow solid (68.1 mg, 70%). NMR data matched previously reported spectra.[1, 3]

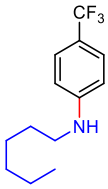
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.38 (d, *J* = 8.5 Hz, 2H), 6.57 (d, *J* = 8.5 Hz, 2H), 3.88 (d, *J* = 7.8 Hz, 1H), 3.38 – 3.20 (m, 1H), 2.13 – 1.96 (m, 2H), 1.86 – 1.72 (m, 2H), 1.73 – 1.59 (m, 1H), 1.47 – 1.32 (m, 2H), 1.32 – 1.07 (m, 3H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 149.9, 126.8 (q, J_{C-F} = 3.8 Hz), 125.2 (q, J_{C-F} = 271.1 Hz), 118.2 (q, J_{C-F} = 32.7 Hz), 112.10, 51.5, 33.3, 25.9, 25.0.
^{19}F NMR (376 MHz, Chloroform-*d*) δ -60.9 (s, 3F).
HRMS (DART-TOF): calculated for $C_{13}H_{17}F_3N$ ([M+H]$^+$) 244.1308, found 244.1293.



N-propyl-4-(trifluoromethyl)aniline (11)

General procedure A was followed using 4-bromobenzotrifluoride as the aryl halide, and propylamine as the amine. The reaction was run at room temperature for 15 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-15% EtOAc/hexanes to give the product as a pale yellow oil (33.1 mg, 41%). NMR data matched previously reported spectra.[2]

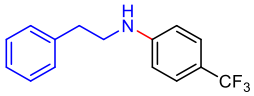
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.39 (d, *J* = 8.4 Hz, 2H), 6.59 (d, *J* = 8.5 Hz, 2H), 3.97 (s, 1H), 3.11 (q, *J* = 5.2 Hz, 2H), 1.66 (h, *J* = 7.2 Hz, 2H), 1.01 (t, *J* = 7.4 Hz, 3H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 151.0, 126.7 (q, $J_{C\text{-}F}$ = 3.7 Hz), 125.2 (q, $J_{C\text{-}F}$ = 271.2 Hz), 118.6 (q, $J_{C\text{-}F}$ = 32.7 Hz), 111.8, 45.4, 22.75, 11.7.
^{19}F NMR (376 MHz, Chloroform-*d*) δ -60.9 (s, 3F).
HRMS (DART-TOF): calculated for $C_{10}H_{13}F_3N$ ([M+H]$^+$) 204.0995, found 204.0989.



N-hexyl-4-(trifluoromethyl)aniline (12)

General procedure A was followed using 4-bromobenzotrifluoride as the aryl halide, and hexylamine as the amine. The reaction was run at room temperature for 15 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-15% EtOAc/hexanes to give the product as a pale yellow oil (55.9 mg, 57%). NMR data matched previously reported spectra.[1]

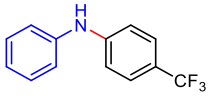
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.40 (d, *J* = 8.5 Hz, 2H), 6.59 (d, *J* = 8.5 Hz, 2H), 3.94 (s, 1H), 3.29 – 2.97 (m, 2H), 1.63 (p, *J* = 7.1 Hz, 2H), 1.46 – 1.28 (m, 6H), 1.00 – 0.83 (m, 3H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 151.0, 126.7 (q, $J_{C\text{-}F}$ = 3.9 Hz), 125.2 (q, $J_{C\text{-}F}$ = 271.2 Hz), 118.5 (q, $J_{C\text{-}F}$ = 32.7 Hz), 111.8, 43.7, 31.7, 29.4, 26.9, 22.8, 14.2.
^{19}F NMR (376 MHz, Chloroform-*d*) δ -60.9 (s, 3F).
HRMS (DART-TOF): calculated for $C_{13}H_{19}F_3N$ ([M+H]$^+$) 246.1464, found 246.1462.



N-phenethyl-4-(trifluoromethyl)aniline (13)

General procedure B was followed using 4-bromobenzotrifluoride as the aryl halide, and phenethylamine as the amine. The reaction was run at room temperature for 15 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-15% EtOAc/hexanes to give the product as a yellow oil (34.9 mg, 33%). NMR data matched previously reported spectra.[5]

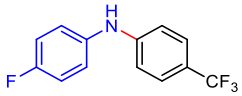
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.44 (d, *J* = 8.5 Hz, 2H), 7.40 – 7.33 (m, 2H), 7.32 – 7.22 (m, 3H), 6.63 (d, *J* = 8.5 Hz, 2H), 4.04 (s, 1H), 3.47 (q, *J* = 6.6 Hz, 2H), 2.96 (t, *J* = 6.9 Hz, 2H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 150.5, 138.9, 128.89, 128.86, 126.78 (q, J_{C-F} = 3.9 Hz),126.77, 125.1 (q, J_{C-F} = 271.3 Hz), 119.0 (q, J_{C-F} = 32.8 Hz), 112.1, 44.6, 35.4.
^{19}F NMR (376 MHz, Chloroform-*d*) δ -61.0 (s, 3F)
HRMS (DART-TOF): calculated for $C_{15}H_{15}F_3N$ ([M+H]$^+$) 266.1151, found 266.1154.



N-phenyl-4-(trifluoromethyl)aniline (14)

General procedure B was followed using 4-bromobenzotrifluoride as the aryl halide, and aniline as the amine. The reaction was run at room temperature for 15 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-10% EtOAc/hexanes to give the product as a pale yellow solid (63.8 mg, 67%). NMR data matched previously reported spectra.[1-2]

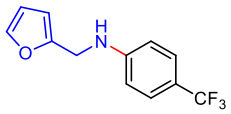
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.49 (d, *J* = 8.5 Hz, 2H), 7.36 (t, *J* = 8.4 Hz, 2H), 7.16 (d, *J* = 7.2 Hz, 2H), 7.12 – 7.02 (m, 3H), 5.91 (s, 1H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 146.9, 141.3, 129.7, 126.8 (q, J_{C-F} = 3.9 Hz), 124.8 (q, J_{C-F} = 271.8 Hz), 123.1, 121.8 (q, J_{C-F} = 32.8 Hz), 120.2, 115.5.
^{19}F NMR (376 MHz, Chloroform-*d*) δ -61.4 (s, 3F).
HRMS (DART-TOF): calculated for $C_{13}H_{11}F_3N$ ([M+H]$^+$) 238.0838, found 238.0826.



4-fluoro-N-(4-(trifluoromethyl)phenyl)aniline (15)

General procedure B was followed using 4-bromobenzotrifluoride as the aryl halide, and 4-Fluoroaniline as the amine. The reaction was run at room temperature for 15 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-10% EtOAc/hexanes to give the product as a yellow oil (46.9 mg, 46%).

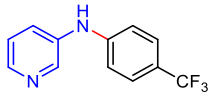
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.46 (d, *J* = 8.5 Hz, 2H), 7.18 – 7.08 (m, 2H), 7.08 – 6.99 (m, 2H), 6.93 (d, *J* = 8.4 Hz, 2H), 5.79 (s, 1H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 159.3 (d, $J_{C\text{-}F}$ = 243.6 Hz), 147.7, 137.1 (d, $J_{C\text{-}F}$ = 2.7 Hz), 126.9 (q, $J_{C\text{-}F}$ = 3.9 Hz), 124.8 (q, $J_{C\text{-}F}$ = 271.8 Hz), 123.2 (d, $J_{C\text{-}F}$ = 8.1 Hz), 121.5 (q, $J_{C\text{-}F}$ = 32.8 Hz), 116.4 (d, $J_{C\text{-}F}$ = 22.7 Hz), 114.7.
^{19}F NMR (376 MHz, Chloroform-*d*) δ -61.4 (s, 3F), -119.2 (m, 1F).
HRMS (DART-TOF): calculated for $C_{13}H_{10}F_4N$ ([M+H]$^+$) 256.0744, found 256.0737.



N-(furan-2-ylmethyl)-4-(trifluoromethyl)aniline (16)

General procedure B was followed using 4-bromobenzotrifluoride as the aryl halide, and furfurylamine as the amine. The reaction was run at room temperature for 15 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-20% EtOAc/hexanes to give the product as a pale yellow solid (27.3 mg, 28%). NMR data matched previously reported spectra.[1-2]

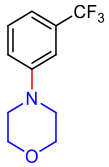
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.42 (d, *J* = 8.5 Hz, 2H), 7.39 – 7.36 (m, 1H), 6.68 (d, *J* = 8.5 Hz, 2H), 6.34 (dd, *J* = 3.3, 1.9 Hz, 1H), 6.25 (d, *J* = 3.2 Hz, 1H), 4.36 (s, 3H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 151.9, 150.1, 142.3, 126.7 (q, $J_{C\text{-}F}$ = 3.8 Hz), 125.0 (q, $J_{C\text{-}F}$ = 271.4 Hz), 119.6 (q, $J_{C\text{-}F}$ = 32.6 Hz), 112.3, 110.6, 107.5, 41.0.
^{19}F NMR (376 MHz, Chloroform-*d*) δ -61.1 (s, 3F).
HRMS (DART-TOF): calculated for $C_{12}H_{11}F_3NO$ ([M+H]$^+$) 242.0787, found 242.0776.



N-(4-(trifluoromethyl)phenyl)pyridin-3-amine (17)

General procedure B was followed using 4-bromobenzotrifluoride as the aryl halide, and 3-aminopyridine as the amine. The reaction was run at room temperature for 15 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-100% EtOAc/hexanes to give the product as a pale yellow solid (85.8 mg, 90%). NMR data matched previously reported spectra.[6]

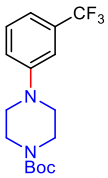
^{1}H NMR (400 MHz, DMSO-*d*$_6$) δ 8.85 (s, 1H), 8.44 (s, 1H), 8.17 (d, *J* = 6.4, 1H), 7.64 – 7.58 (m, 1H), 7.55 (d, *J* = 8.4 Hz, 2H), 7.32 (dd, *J* = 8.3, 4.7 Hz, 1H), 7.17 (d, *J* = 8.4 Hz, 2H).
^{13}C NMR (101 MHz, DMSO-*d*$_6$) δ 147.2, 142.9, 141.5, 138.7, 127.1 (q, $J_{C\text{-}F}$ = 3.8 Hz), 125.5, 125.2 (q, $J_{C\text{-}F}$ = 271.8 Hz), 124.40, 119.8 (q, $J_{C\text{-}F}$ = 32.3 Hz), 115.5.
^{19}F NMR (376 MHz, DMSO-*d*$_6$) δ -59.7 (s, 3F).
HRMS (DART-TOF): calculated for $C_{12}H_{10}F_3N_2$ ([M+H]$^+$) 239.0791, found 239.0792.



4-(3-(trifluoromethyl)phenyl)morpholine (18)

General procedure A was followed using 3-bromobenzotrifluoride as the aryl halide, and morpholine as the amine. The reaction was run at room temperature for 15 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-15% EtOAc/hexanes to give the product as a pale yellow oil solid (52.7 mg, 57%). NMR data matched previously reported spectra.[7]

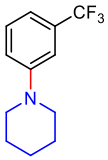
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.42 – 7.29 (m, 1H), 7.16 – 7.08 (m, 2H), 7.08 – 7.03 (m, 1H), 3.88 (t, *J* = 4.8, 4H), 3.21 (t, *J* = 4.8, 4H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 151.5, 131.7 (q, $J_{C\text{-}F}$ = 31.8 Hz), 129.8, 124.4 (q, $J_{C\text{-}F}$ = 273.4 Hz), 118.6, 116.4 (q, $J_{C\text{-}F}$ = 3.8 Hz), 112.0 (q, $J_{C\text{-}F}$ = 3.9 Hz), 66.9, 49.0.
^{19}F NMR (376 MHz, Chloroform-*d*) δ -62.8 (s, 3F).
HRMS (DART-TOF): calculated for $C_{11}H_{13}F_3NO$ ([M+H]$^+$) 232.0944, found 232.0934.



***tert*-butyl 4-(3-(trifluoromethyl)phenyl)piperazine-1-carboxylate (19)**

General procedure B was followed using 3-bromobenzotrifluoride as the aryl halide, and *tert*-butyl piperazine-1-carboxylate as the amine. The reaction was run at room temperature for 3 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-15% EtOAc/hexanes to give the product as a pale yellow oil (79.3 mg, 60%). NMR data matched previously reported spectra.[8]

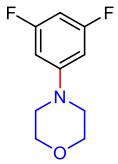
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.40 – 7.31 (m, 1H), 7.13 – 7.08 (m, 2H), 7.08 – 7.02 (m, 1H), 3.60 (t, *J* = 5.2, 4H), 3.18 (t, *J* = 5.2, 4H), 1.49 (s, 9H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 154.8, 151.5, 131.6 (q, $J_{C\text{-}F}$ = 31.8 Hz), 129.8, 124.4 (q, $J_{C\text{-}F}$ = 273.5 Hz), 119.4, 116.5 (q, $J_{C\text{-}F}$ = 3.9 Hz), 112.8 (q, $J_{C\text{-}F}$ = 3.9 Hz), 80.2, 49.0, 28.5.
^{19}F NMR (376 MHz, Chloroform-*d*) δ -62.8 (s, 3F).
HRMS (DART-TOF): calculated for $C_{16}H_{22}F_3N_2O_2$ ([M+H]$^+$) 331.1628, found 331.1632.



1-(3-(trifluoromethyl)phenyl)piperidine (20)

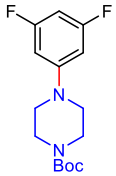
General procedure A was followed using 3-bromobenzotrifluoride as the aryl halide, and piperidine as the amine. The reaction was run at room temperature for 3 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-10% EtOAc/hexanes to give the product as a pale yellow oil (33.0 mg, 36%). NMR data matched previously reported spectra.[9]

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.32 (t, *J* = 8.0 Hz, 1H), 7.12 (s, 1H), 7.10 – 6.99 (m, 2H), 3.21 (t, *J* = 5.2, 4H), 1.76 – 1.67 (m, 4H), 1.66 – 1.57 (m, 2H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 152.3, 131.4 (q, $J_{C\text{-}F}$ = 31.6 Hz), 129.5, 124.6 (q, $J_{C\text{-}F}$ = 273.5 Hz), 119.2, 115.3 (q, $J_{C\text{-}F}$ = 3.9 Hz), 112.6 (q, $J_{C\text{-}F}$ = 3.9 Hz), 50.3, 25.8, 24.3.
^{19}F NMR (376 MHz, Chloroform-*d*) δ -62.7 (s, 3F).
HRMS (DART-TOF): calculated for $C_{12}H_{15}F_3N$ ([M+H]$^+$) 230.1151, found 230.1151.



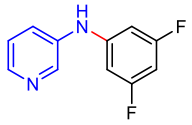
4-(3,5-difluorophenyl)morpholine (21)
General procedure A was followed using 1-bromo-3,5-difluorobenzene as the aryl halide, and morpholine as the amine. The reaction was run at room temperature for 3 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-15% EtOAc/hexanes to give the product as a white solid (56.3 mg, 71%). NMR data matched previously reported spectra.[10]

^{1}H NMR (400 MHz, Chloroform-*d*) δ 6.42 – 6.23 (m, 3H), 3.83 (t, *J* = 4.8 Hz, 4H), 3.14 (t, *J* = 4.8 Hz, 4H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 164.1 (dd, *J* = 245.4, *J* = 16.2 Hz), 153.4 (t, *J* = 12.2 Hz), 98.0 - 97.8 (m), 94.6 (t, *J* = 26.3 Hz), 66.7, 48.4.
^{19}F NMR (376 MHz, Chloroform-*d*) δ -109.7 – -109.9 (m, 2F).
HRMS (DART-TOF): calculated for $C_{10}H_{12}F_2NO$ ($[M+H]^+$) 200.0881, found 200.0874.



***tert*-butyl 4-(3,5-difluorophenyl)piperazine-1-carboxylate (22)**
General procedure B was followed using 1-bromo-3,5-difluorobenzene as the aryl halide, and *tert*-butyl piperazine-1-carboxylate as the amine. The reaction was run at room temperature for 3 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-15% EtOAc/hexanes to give the product as a white solid (73.4 mg, 62%).

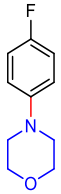
^{1}H NMR (400 MHz, Chloroform-*d*) δ 6.40 – 6.30 (m, 2H), 6.27 (tt, *J* = 8.8, 2.2 Hz, 1H), 3.55 (t, *J* = 5.2, 4H), 3.14 (t, *J* = 5.2, 4H), 1.48 (s, 9H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 164.1 (dd, *J* = 245.4, *J* = 15.8 Hz), 154.7, 153.2 (t, *J* = 12.3 Hz), 98.7 – 98.3 (m), 94.7 (t, *J* = 23.3 Hz), 80.3, 48.3, 28.5.
^{19}F NMR (376 MHz, Chloroform-*d*) δ -109.6 – -109.8 (m, 2F).
HRMS (DART-TOF): calculated for $C_{15}H_{21}F_2N_2O_2$ ($[M+H]^+$) 299.1556, found 299.1556.



N-(3,5-difluorophenyl)pyridin-3-amine (23)

General procedure B was followed using 1-bromo-3,5-difluorobenzene as the aryl halide, and 3-aminopyridine as the amine. The reaction was run at room temperature for 15 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-100% EtOAc/hexanes to give the product as a white solid (74.4 mg, 90%).

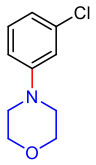
^{1}H NMR (400 MHz, DMSO-*d*$_6$) δ 8.81 (s, 1H), 8.39 (d, *J* = 2.7 Hz, 1H), 8.26 – 8.07 (m, 1H), 7.68 – 7.48 (m, 1H), 7.41 – 7.21 (m, 1H), 6.83 – 6.48 (m, 3H).
^{13}C NMR (101 MHz, DMSO-*d*$_6$) δ 163.4 (dd, *J* = 243.8, *J* = 16.3 Hz), 146.2 (t , *J* = 13.5 Hz), 142.6, 141.1, 138.1, 125.1, 124.0, 98.5 –98.0 (m), 94.5 (t , *J* = 26.7 Hz).
^{19}F NMR (376 MHz, DMSO-*d*$_6$) δ -109.5 (t, *J* = 9.3 Hz, 2F).
HRMS (DART-TOF): calculated for $C_{11}H_9F_2N_2$ ([M+H]$^+$) 207.0728, found 207.0730.



4-(4-fluorophenyl)morpholine (24)

General procedure B was followed using 1-bromo-4-fluorobenzene as the aryl halide, and morpholine as the amine. The reaction was run at room temperature for 15 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-15% EtOAc/hexanes to give the product as a colorless oil (27.3 mg, 38%). NMR data matched previously reported spectra.[11]

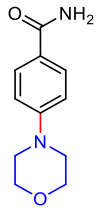
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.04 – 6.92 (m, 2H), 6.92 – 6.82 (m, 2H), 3.87 (t, *J* = 4.8 Hz, 4H), 3.09 (t, *J* = 4.8 Hz, 4H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 157.5 (d, $J_{C\text{-}F}$ = 240.3 Hz), 148.1, 117.6 (d, $J_{C\text{-}F}$ = 7.8 Hz), 115.8 (d, $J_{C\text{-}F}$ = 22.2 Hz), 67.1, 50.5.
^{19}F NMR (376 MHz, Chloroform-*d*) δ -124.2 – -124.3 (m, 1F).
HRMS (DART-TOF): calculated for $C_{10}H_{13}FNO$ ([M+H]$^+$) 182.0976, found 182.0976.



4-(3-chlorophenyl)morpholine (25)

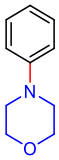
General procedure A was followed using 1-bromo-3-chlorobenzene as the aryl halide, and morpholine as the amine. The reaction was run at room temperature for 15 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-15% EtOAc/hexanes to give the product as a colorless oil (65.4 mg, 83%). NMR data matched previously reported spectra.[12]

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.18 (t, *J* = 8.1 Hz, 1H), 6.89 – 6.81 (m, 2H), 6.80 – 6.74 (m, 1H), 3.85 (t, *J* = 4.8 Hz, 4H), 3.15 (t, *J* = 5.2 Hz, 4H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 152.5, 135.2, 130.2, 119.8, 115.6, 113.7, 66.9, 49.0.
HRMS (ESI-TOF): calculated for $C_{10}H_{13}ClNO$ ($[M+H]^+$) 198.0680, found 198.0691.



4-morpholinobenzamide (26)
General procedure A was followed using 4-bromobenzamide as the aryl halide, and morpholine as the amine. The reaction was run at room temperature for 15 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-10% MeOH/DCM to give the product as a white solid (22.5 mg, 27%). NMR data matched previously reported spectra.[13]

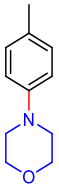
^{1}H NMR (400 MHz, DMSO-d_6) δ 7.88 – 7.64 (m, 3H), 7.09 – 6.83 (m, 3H), 3.74 (t, *J* = 4.8 Hz, 4H), 3.21 (t, *J* = 4.8 Hz, 4H).
^{13}C NMR (101 MHz, DMSO-d_6) δ 167.5, 152.9, 128.8, 123.9, 113.3, 65.9, 47.4.
HRMS (ESI-TOF): calculated for $C_{11}H_{15}N_2O_2$ ($[M+H]^+$) 207.1128, found 207.1121.



4-phenylmorpholine (27)

General procedure A was followed using 4-bromobenzene as the aryl halide, and morpholine as the amine. The reaction was run at room temperature for 15 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-15% EtOAc/hexanes to give the product as a white solid (34.8 mg, 53%). NMR data matched previously reported spectra.[12]

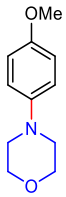
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.35 – 7.26 (m, 2H), 6.99 – 6.83 (m, 3H), 3.87 (t, *J* = 4.8 Hz, 4H), 3.17 (t, *J* = 4.8 Hz, 4H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 151.4, 129.3, 120.2, 115.8, 67.1, 49.5.
HRMS (DART-TOF): calculated for $C_{10}H_{14}NO$ ($[M+H]^+$) 164.1070, found 164.1075.



4-(p-tolyl)morpholine (28)

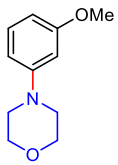
General procedure A was followed using 4-bromotoluene as the aryl halide, and morpholine as the amine. The reaction was run at room temperature for 15 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-15% EtOAc/hexanes to give the product as a white solid (23.4 mg, 33%). NMR data matched previously reported spectra.[12]

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.14 – 7.05 (m, 2H), 6.88 – 6.80 (m, 2H), 3.87 (t, *J* = 4.8 Hz, 4H), 3.11 (t, *J* = 4.8 Hz, 4H), 2.28 (s, 3H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 149.3, 129.8, 129.7, 116.2, 67.1, 50.1, 20.6.
HRMS (DART-TOF): calculated for $C_{11}H_{16}NO$ ($[M+H]^+$) 178.1226, found 178.1225.



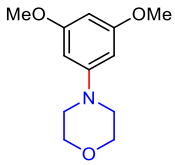
4-(4-methoxyphenyl)morpholine (29)
General procedure A was followed using 4-bromoanisole as the aryl halide, and morpholine as the amine. The reaction was run at room temperature for 15 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-15% EtOAc/hexanes to give the product as a white solid (5.6 mg, 7%). NMR data matched previously reported spectra.[12]

^{1}H NMR (400 MHz, Chloroform-*d*) δ 6.94 – 6.81 (m, 4H), 3.86 (t, *J* = 4.4 Hz, 4H), 3.77 (s, 3H), 3.06 (t, *J* = 4.8 Hz, 4H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 154.2, 145.8, 118.0, 114.7, 67.2, 55.7, 51.0.
HRMS (DART-TOF): calculated for $C_{11}H_{16}NO_2$ ($[M+H]^+$) 194.1176, found 194.1174.



4-(3-methoxyphenyl)morpholine (30)
General procedure A was followed using 3-bromoanisole as the aryl halide, and morpholine as the amine. The reaction was run at room temperature for 15 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-15% EtOAc/hexanes to give the product as a colorless oil (45.8 mg, 59%). NMR data matched previously reported spectra.[12]

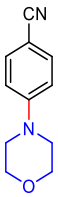
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.24 – 7.14 (m, 1H), 6.57 – 6.50 (m, 1H), 6.48 – 6.41 (m, 2H), 3.85 (t, *J* = 4.8 Hz, 4H), 3.80 (s, 3H), 3.16 (t, *J* = 4.8 Hz, 4H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 160.8, 152.8, 123.0, 108.6, 104.9, 102.4, 67.0, 55.3, 49.4.
HRMS (DART-TOF): calculated for $C_{11}H_{16}NO_2$ ($[M+H]^+$) 194.1176, found 194.1181.



4-(3,5-dimethoxyphenyl)morpholine (31)

General procedure A was followed using 1-bromo-3,5-dimethoxybenzene as the aryl halide, and morpholine as the amine. The reaction was run at room temperature for 15 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-15% EtOAc/hexanes to give the product as a white solid (47.4 mg, 53%). NMR data matched previously reported spectra.[14]

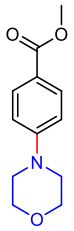
^{1}H NMR (400 MHz, Chloroform-*d*) δ 6.08 (d, *J* = 2.1 Hz, 2H), 6.04 (t, *J* = 2.1 Hz, 1H), 3.84 (t, *J* = 4.8 Hz, 4H), 3.78 (s, 6H), 3.14 (t, *J* = 4.8 Hz, 4H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 161.7, 153.4, 94.9, 92.0, 67.0, 55.4, 49.5.
HRMS (DART-TOF): calculated for $C_{12}H_{18}NO_3$ ($[M+H]^+$) 224.1281, found 224.1281.



4-morpholinobenzonitrile (32)

General procedure A was followed using 4-bromobenzonitrile as the aryl halide, and morpholine as the amine. The reaction was run at room temperature for 3 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-30% EtOAc/hexanes to give the product as a white solid (64.5 mg, 86%). NMR data matched previously reported spectra.[15]

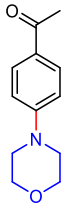
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.54 – 7.45 (m, 2H), 6.89 – 6.81 (m, 2H), 3.83 (t, *J* = 5.2 Hz, 4H), 3.27 (t, *J* = 5.2 Hz, 4H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 153.6, 133.6, 120.0, 114.1, 101.0, 66.5, 47.4.
HRMS (DART-TOF): calculated for $C_{11}H_{13}N_2O$ ($[M+H]^+$) 189.1022, found 189.1011.



methyl 4-morpholinobenzoate (33)

General procedure A was followed using methyl 4-bromobenzoate as the aryl halide, and morpholine as the amine. The reaction was run at room temperature for 15 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-30% EtOAc/hexanes to give the product as a white solid (57.7 mg, 65%). NMR data matched previously reported spectra.[16]

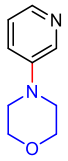
^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.95 – 7.91 (m, 2H), 6.89 – 6.81 (m, 2H), 3.88 – 3.80 (m, 7H), 3.27 (t, *J* = 4.8 Hz, 4H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 167.1, 154.3, 131.3, 120.4, 113.6, 66.7, 51.8, 47.8.
HRMS (DART-TOF): calculated for $C_{12}H_{16}NO_3$ ($[M+H]^+$) 222.1125, found 222.1121.



1-(4-morpholinophenyl)ethan-1-one (34)

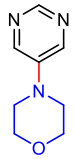
General procedure A was followed using 4'-bromoacetophenone as the aryl halide, and morpholine as the amine. The reaction was run at room temperature for 15 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-30% EtOAc/hexanes to give the product as a pale yellow solid (34.4 mg, 42%). NMR data matched previously reported spectra.[17]

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.88 (d, *J* = 8.8 Hz, 2H), 6.86 (d, *J* = 8.8 Hz, 2H), 3.85 (t, *J* = 4.8 Hz, 4H), 3.30 (t, *J* = 5.2 Hz, 4H), 2.52 (s, 3H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 196.6, 154.3, 130.5, 128.3, 113.4, 66.7, 47.7, 26.3.
HRMS (DART-TOF): calculated for $C_{12}H_{16}NO_2$ ($[M+H]^+$) 206.1176, found 206.1177.



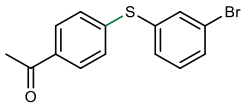
4-(pyridin-3-yl)morpholine (35)
General procedure B was followed using 3-bromopyridine as the aryl halide, and morpholine as the amine. The reaction was run at room temperature for 15 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-100% EtOAc/hexanes to give the product as a pale yellow oil (23.4 mg, 36%). NMR data matched previously reported spectra.[12]

^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.30 (s, 1H), 8.12 (t, *J* = 2.8 Hz, 1H), 7.18 – 7.14 (m, 2H), 3.86 (t, *J* = 4.8 Hz, 4H), 3.18 (t, *J* = 4.8 Hz, 4H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 147.0, 141.3, 138.5, 123.6, 122.2, 66.8, 48.7.
HRMS (DART-TOF): calculated for $C_9H_{13}N_2O$ ($[M+H]^+$) 165.1022, found 165.1018.



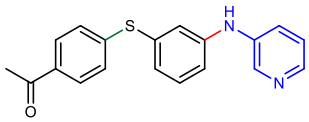
4-(pyrimidin-5-yl)morpholine (36)
General procedure B was followed using 5-bromopyrimidine as the aryl halide, and morpholine as the amine. The reaction was run at room temperature for 15 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-100% EtOAc/hexanes to give the product as a pale yellow oil (13.8 mg, 21%). NMR data matched previously reported spectra.[18]

^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.73 (s, 1H), 8.36 (s, 2H), 3.89 (t, *J* = 5.6 Hz, 4H), 3.23 (t, *J* = 4.8 Hz, 4H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 150.3, 144.3, 143.6, 66.5, 47.6.
HRMS (DART-TOF): calculated for $C_8H_{12}N_3O$ ($[M+H]^+$) 166.0975, found 166.0965.



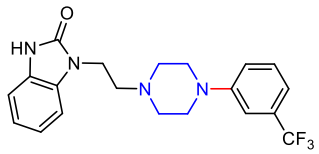
1-(4-((3-bromophenyl)thio)phenyl)ethan-1-one (37)
A 50 mL storage flask was charged with a stir bar, flame dried under vacuum and back filled with nitrogen three times. The flask was then charged with Cs_2CO_3 (1.466 g, 4.5 mmol, 1.5 equiv.), 4'-bromoacetophenone (0.597 g, 3.0 mmol, 1.00 equiv.), 3-bromothiophenol (0.851 g, 4.5 mmol, 1.5 equiv.) and 23 mL DMSO. The reaction mixture was evacuated and purged with inert gas (N_2) three times. The reaction mixture was then placed into an LED-lined beaker along with a tube for air cooling and stirred. After stirring for 12 hours, the reaction mixture was washed with water, extracted with EtOAc, and concentrated under vacuum. The product was isolated by flash chromatography (1:5 EtOAc:hexanes) as a white solid (0.516 g, 56%).

^{1}H NMR (400 MHz, Chloroform-*d*) δ 7.89 – 7.76 (m, 2H), 7.58 (t, *J* = 1.8 Hz, 1H), 7.53 – 7.43 (m, 1H), 7.40 – 7.32 (m, 1H), 7.31 – 7.20 (m, 3H), 2.56 (s, 3H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 197.1, 143.1, 135.4, 135.4, 135.3, 131.6, 131.5, 131.0, 129.2, 128.8, 123.4, 26.6.
HRMS (ESI-TOF): calculated for $C_{14}H_{12}BrOS$ ($[M+H]^+$) 306.9787, found 306.9813.



1-(4-((3-(pyridin-3-ylamino)phenyl)thio)phenyl)ethan-1-one (38)
General procedure B was followed using 1-(4-((3-bromophenyl)thio)phenyl)ethan-1-one (**37**) as the aryl halide, and 3-aminopyridine as the amine. The reaction was run at room temperature for 15 hours. Purification was done by flash chromatography on silica gel, eluting with a gradient of 0-80% EtOAc/hexanes to give the product as a pale yellow solid (113.4 mg, 88%).

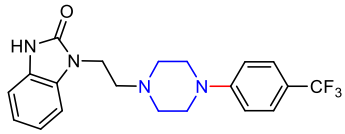
^{1}H NMR (400 MHz, Chloroform-*d*) δ 8.39 (d, *J* = 2.8 Hz, 1H), 8.20 (d, *J* = 4.4, 1H), 7.88 – 7.80 (m, 2H), 7.45 – 7.38 (m, 1H), 7.32 – 7.26 (m, 3H), 7.20 – 7.12 (m, 2H), 7.10 – 7.02 (m, 2H), 6.06 (s, 1H), 2.56 (s, 3H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 197.3, 144.3, 143.7, 142.9, 141.0, 139.0, 134.9, 134.0, 130.7, 129.1, 128.2, 126.3, 124.5, 123.9, 121.9, 117.6, 26.6.
HRMS (ESI-TOF): calculated for $C_{19}H_{17}N_2OS$ ($[M+H]^+$) 321.1056, found 321.1063.



1-(2-(4-(3-(trifluoromethyl)phenyl)piperazin-1-yl)ethyl)-1,3-dihydro-2H-benzo[d]imidazol-2-one (39, Flibanserin)

Using *tert*-butyl 4-(3-(trifluoromethyl)phenyl)piperazine-1-carboxylate (**19**) as the precursor, compound **39** was synthesized using previously published procedures.[19] NMR data matched previously reported spectra.[19]

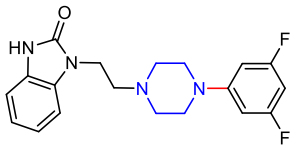
^{1}H NMR (400 MHz, Chloroform-*d*) δ 9.99 (s, 1H), 7.32 (t, *J* = 8.0 Hz, 1H), 7.15 – 6.97 (m, 7H), 4.07 (t, *J* = 6.8 Hz, 2H), 3.21 (t, *J* = 4.8 Hz, 4H), 2.79 (t, *J* = 6.9 Hz, 2H), 2.72 (t, *J* = 5.2 Hz, 4H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 155.8, 151.5, 131.6 (q, $J_{C\text{-}F}$ = 31.9 Hz), 130.5, 129.6, 128.2, 124.5 (q, $J_{C\text{-}F}$ = 273.5 Hz), 121.7, 121.4, 118.8, 115.9 (q, $J_{C\text{-}F}$ = 4.0 Hz), 112.2 (q, $J_{C\text{-}F}$ = 3.9 Hz), 109.8, 108.1, 55.9, 53.2, 48.8, 38.7.
^{19}F NMR (376 MHz, Chloroform-*d*) δ -62.8 (s, 3F).
HRMS (ESI-TOF): calculated for $C_{20}H_{21}F_3N_4O$ ([M+H]$^+$) 391.1740, found 391.1739.



1-(2-(4-(4-(trifluoromethyl)phenyl)piperazin-1-yl)ethyl)-1,3-dihydro-2H-benzo[d]imidazol-2-one (40)

Using *tert*-butyl 4-(4-(trifluoromethyl)phenyl)piperazine-1-carboxylate (**9**) as the precursor, compound **40** was synthesized using previously published procedures.[19]

^{1}H NMR (400 MHz, Chloroform-*d*) δ 10.02 (s, 1H), 7.45 (d, *J* = 8.7 Hz, 2H), 7.20 – 6.99 (m, 4H), 6.87 (d, *J* = 8.6 Hz, 2H), 4.07 (t, *J* = 6.8 Hz, 2H), 3.24 (t, *J* = 4.8 Hz, 4H), 2.78 (t, *J* = 6.8 Hz, 2H), 2.71 (t, *J* = 5.6 Hz, 4H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 155.7, 153.4, 130.4, 128.0, 126.5 (q, $J_{C\text{-}F}$ = 4.4 Hz), 124.9 (q, $J_{C\text{-}F}$ = 271.4 Hz), 121.7, 121.4, 120.6 (q, $J_{C\text{-}F}$ = 32.9 Hz), 114.6, 109.7, 108.1, 55.8, 53.1, 48.1, 38.6.
^{19}F NMR (376 MHz, Chloroform-*d*) δ -61.4 (s, 3F).
HRMS (ESI-TOF): calculated for $C_{20}H_{21}F_3N_4O$ ([M+H]$^+$) 391.1740, found 391.1767.



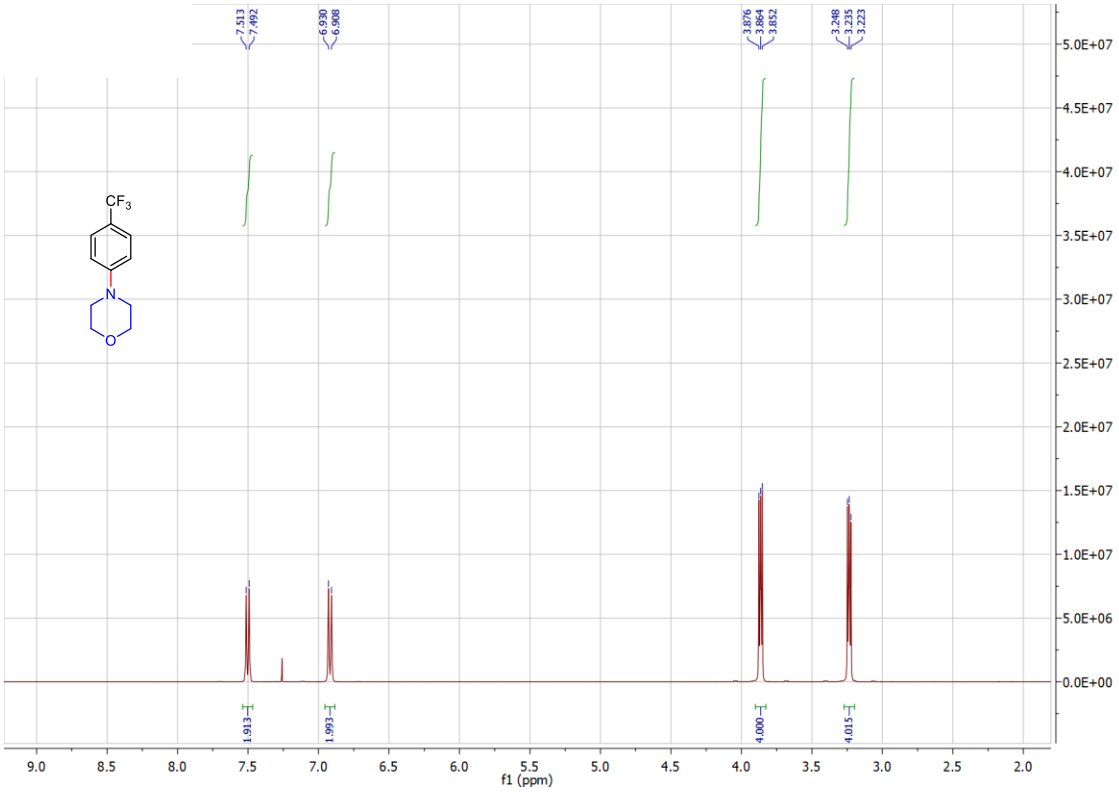
1-(2-(4-(3,5-difluorophenyl)piperazin-1-yl)ethyl)-1,3-dihydro-2H-benzo[d]imidazol-2-one (41)

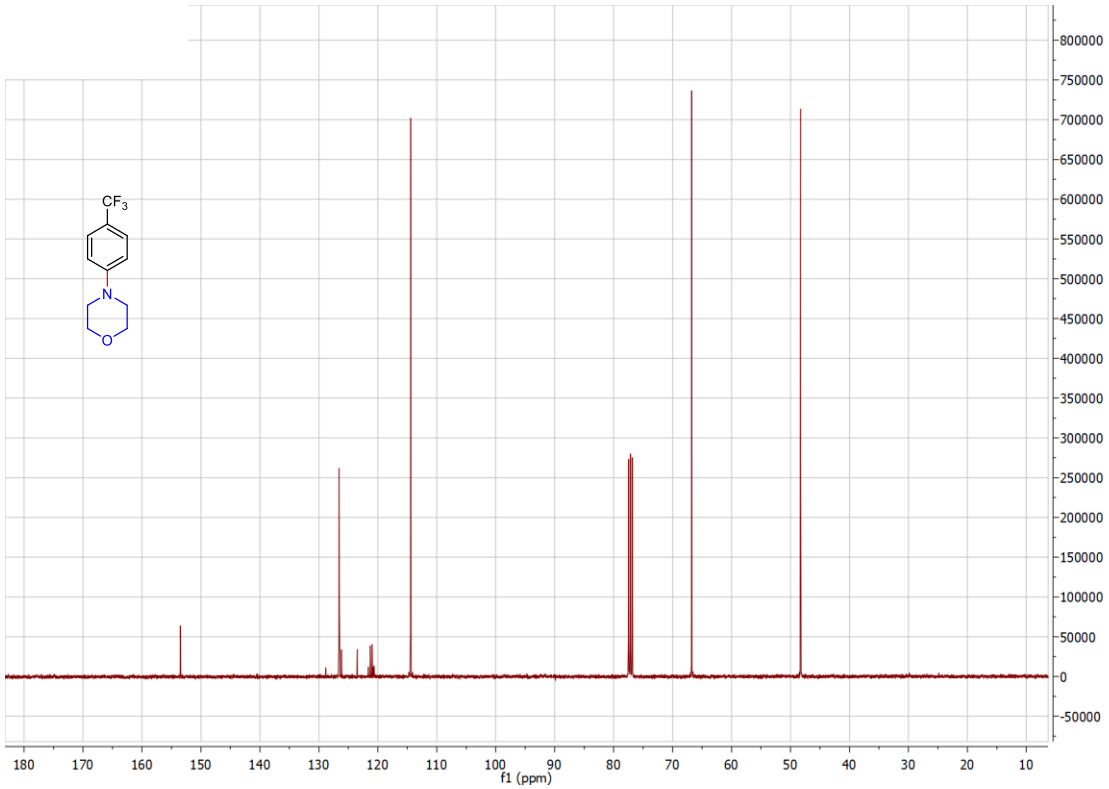
Using *tert*-butyl 4-(3,5-difluorophenyl)piperazine-1-carboxylate (**22**) as the precursor, compound **41** was synthesized using previously published procedures.[19]

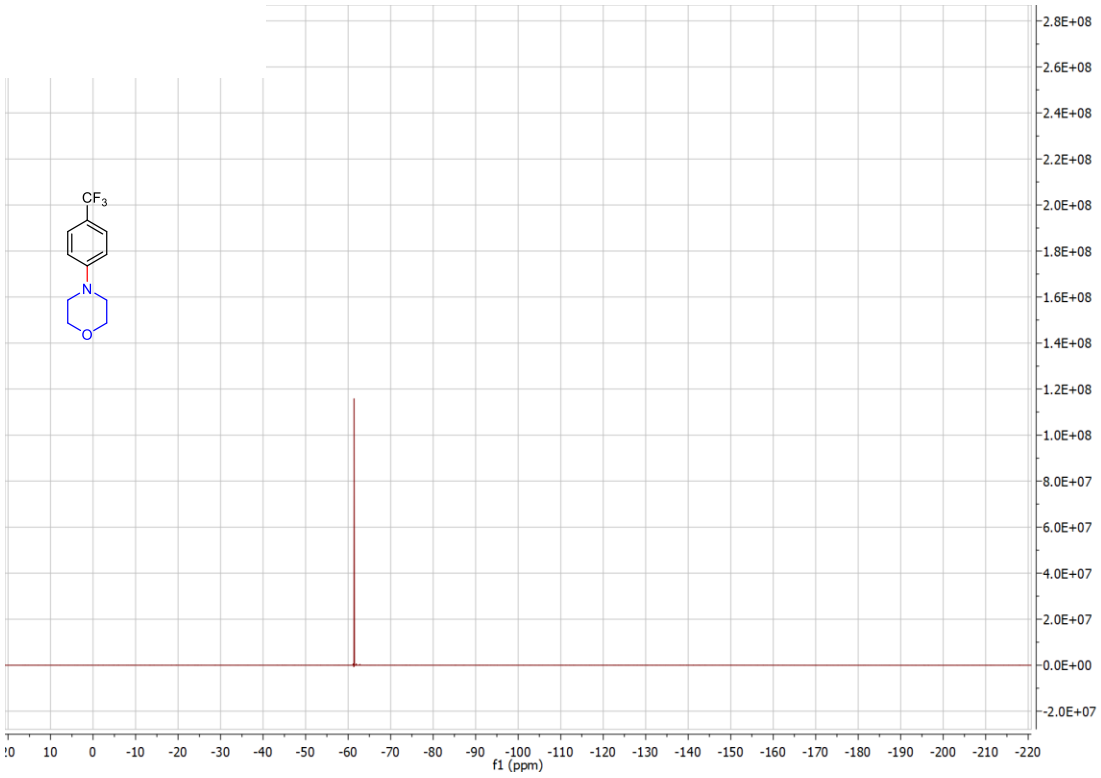
^{1}H NMR (400 MHz, Chloroform-*d*) δ 10.25 (s, 1H), 7.17 – 6.94 (m, 4H), 6.37 – 6.27 (m, 2H), 6.23 (tt, *J* = 8.9, 2.2 Hz, 1H), 4.06 (t, *J* = 6.8 Hz, 2H), 3.16 (t, *J* = 4.8 Hz, 4H), 2.77 (t, *J* = 6.8 Hz, 2H), 2.69 (t, *J* = 5.2 Hz, 4H).
^{13}C NMR (101 MHz, Chloroform-*d*) δ 164.1 (dd, *J* = 244.8, *J* = 16.1 Hz), 155.9, 153.2 (t, *J* = 12.3 Hz), 130.4, 128.2, 121.7, 121.4, 109.8, 108.0, 98.2 – 97.8 (m), 94.1 (t, *J* = 26.2 Hz), 55.8, 53.0, 48.2, 38.7.
^{19}F NMR (376 MHz, Chloroform-*d*) δ -110.0 – -110.1 (m, 2F).
HRMS (ESI-TOF): calculated for $C_{19}H_{21}F_2N_4O$ ($[M+H]^+$) 359.1678, found 359.1690.

9. NMR Spectrums

4-(4-(trifluoromethyl)phenyl)morpholine (1)



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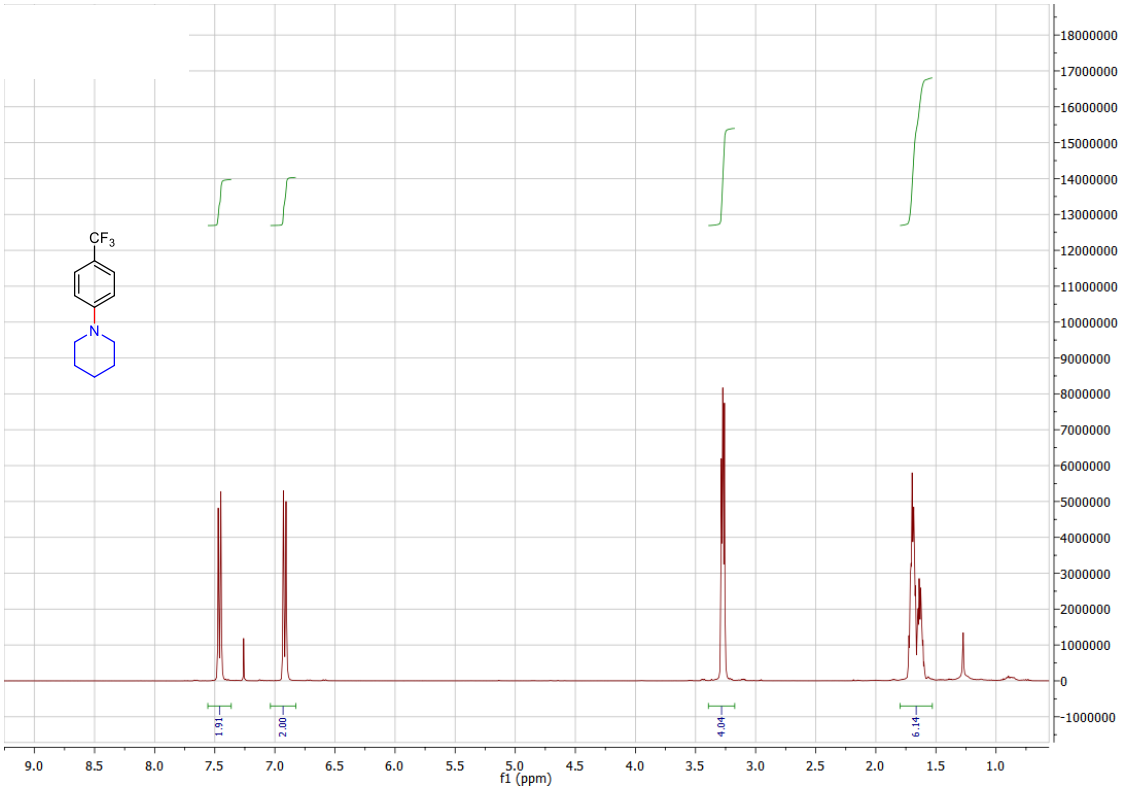
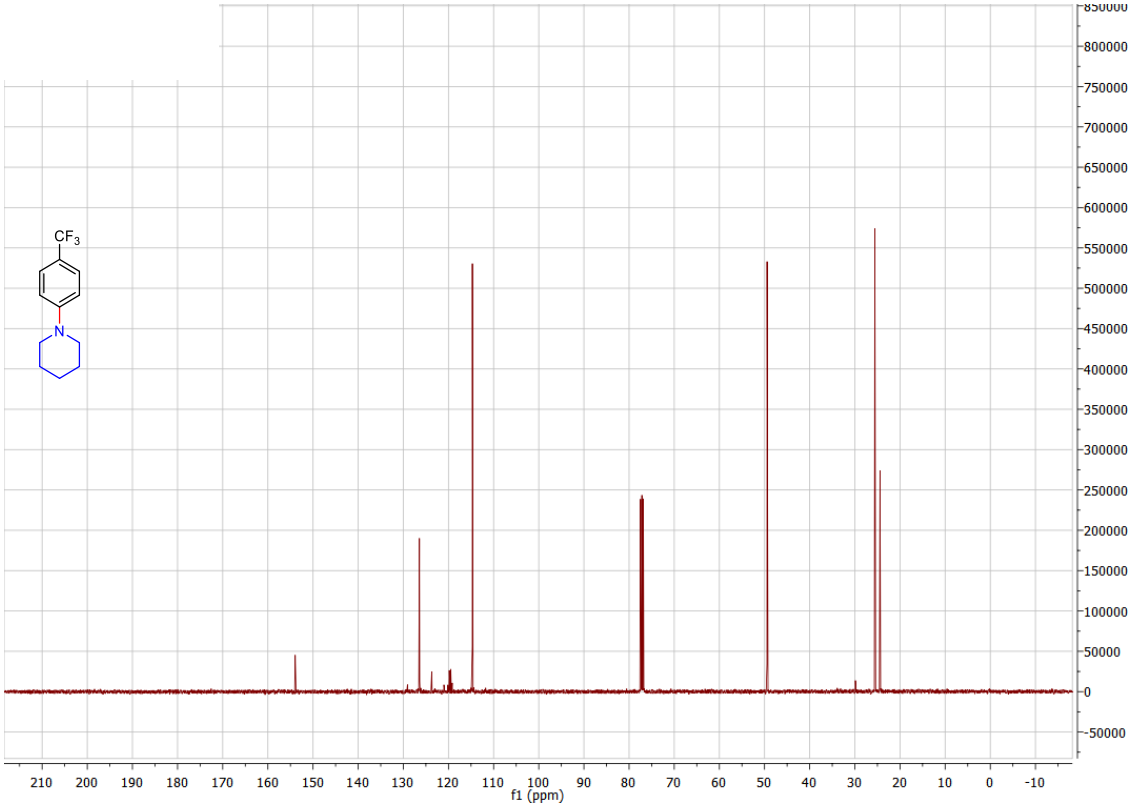
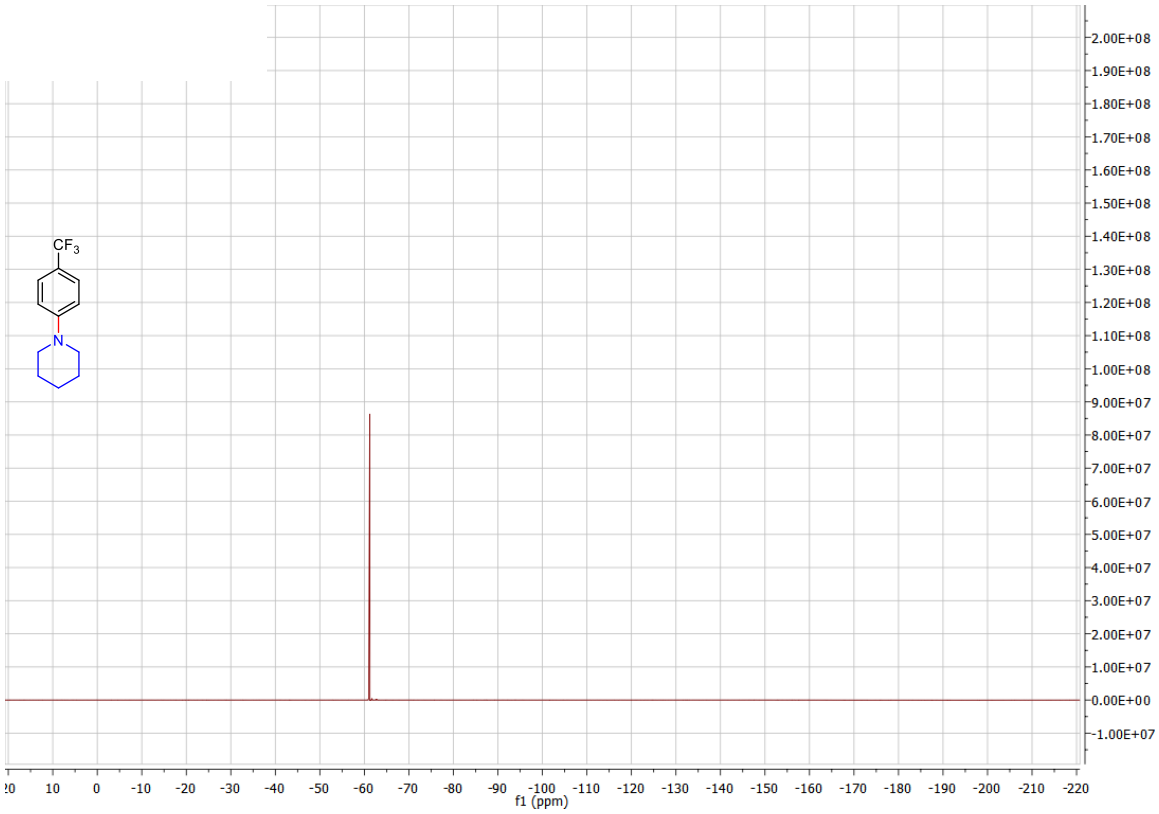
0.0E+00
-2.0E+07
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220
f1 (ppm)

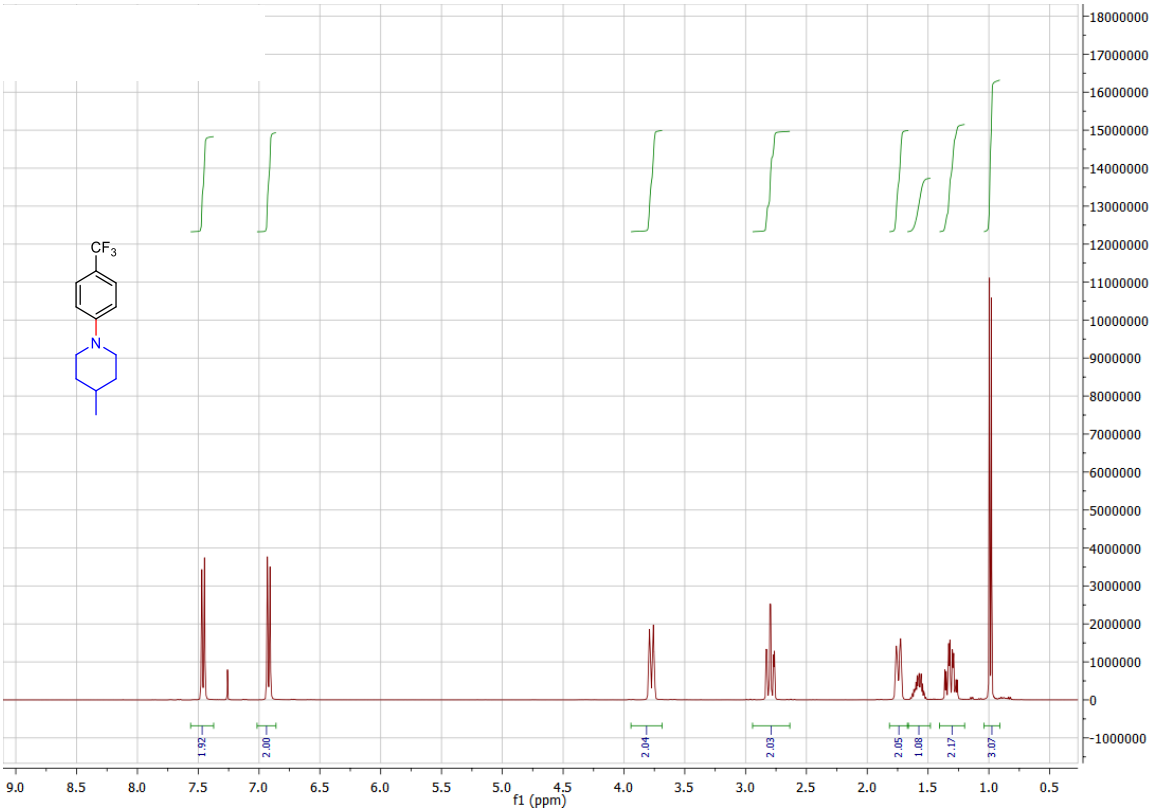
1-(4-(trifluoromethyl)phenyl)piperidine (2)

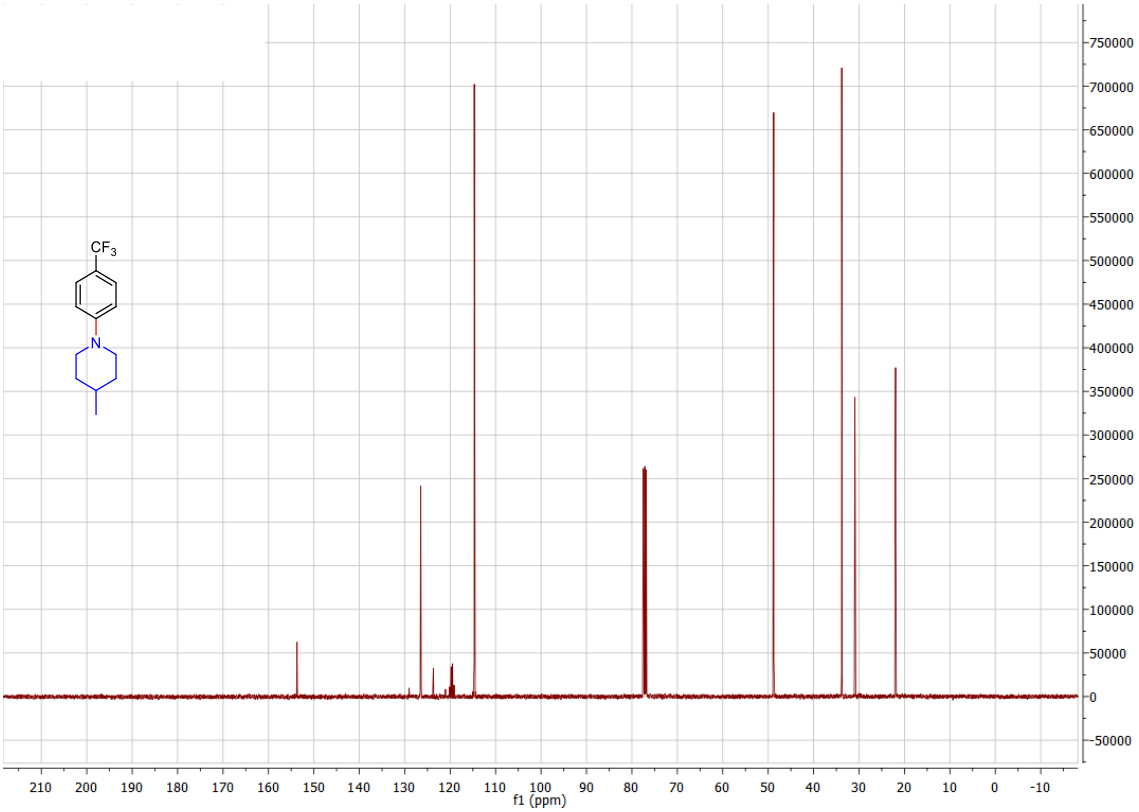


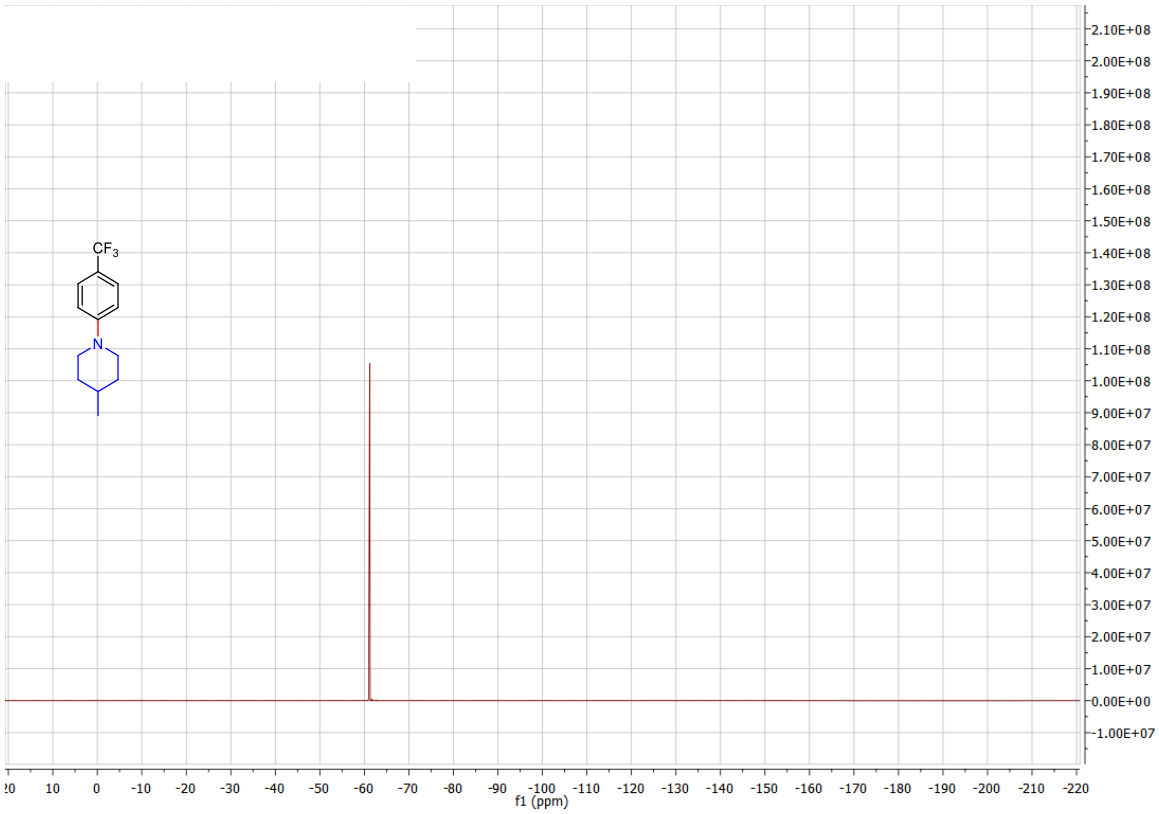



CF3
N
2.00E+08
1.90E+08
1.80E+08
1.70E+08
1.60E+08
1.50E+08
1.40E+08
1.30E+08
1.20E+08
1.10E+08
1.00E+08
9.00E+07
8.00E+07
7.00E+07
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
-1.00E+07
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220
f1 (ppm)

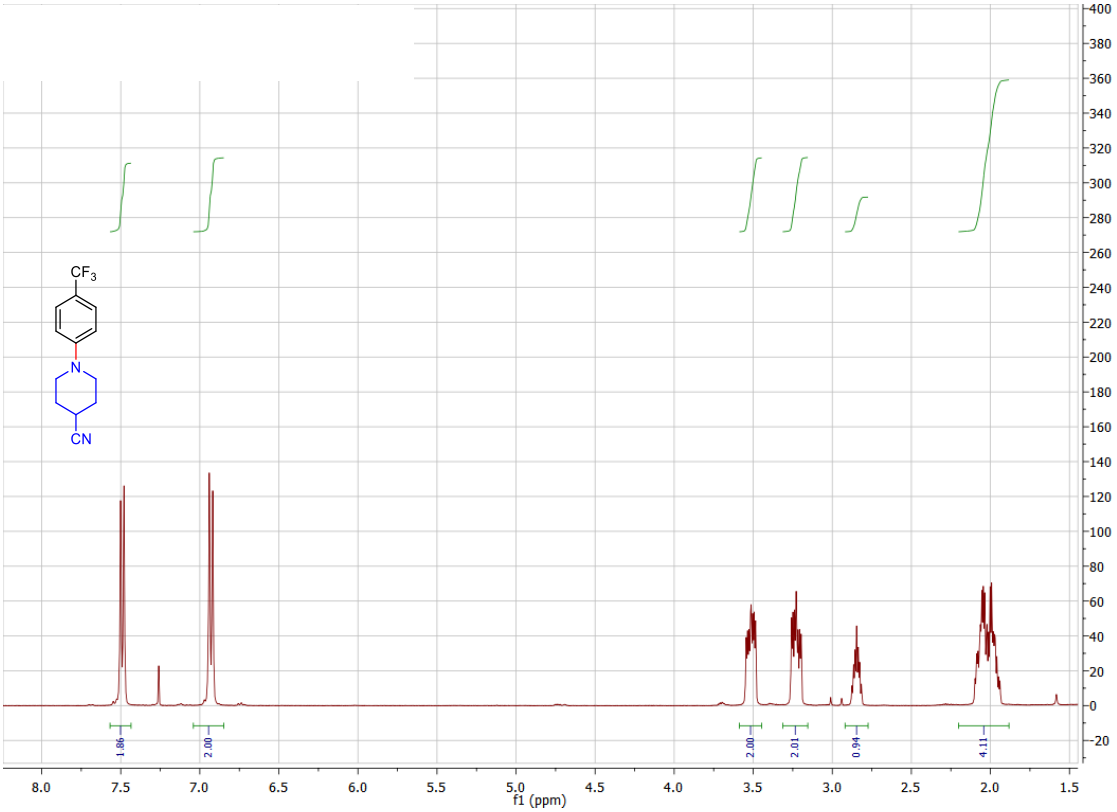
4-methyl-1-(4-(trifluoromethyl)phenyl)piperidine (3)

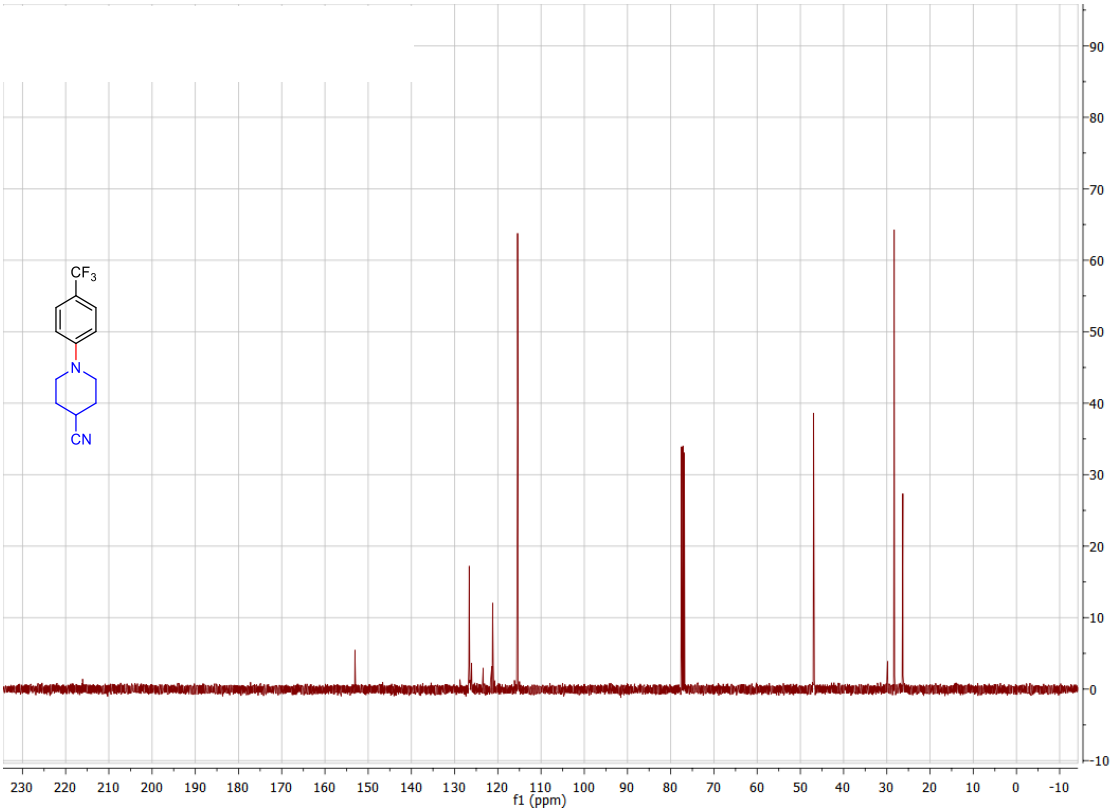


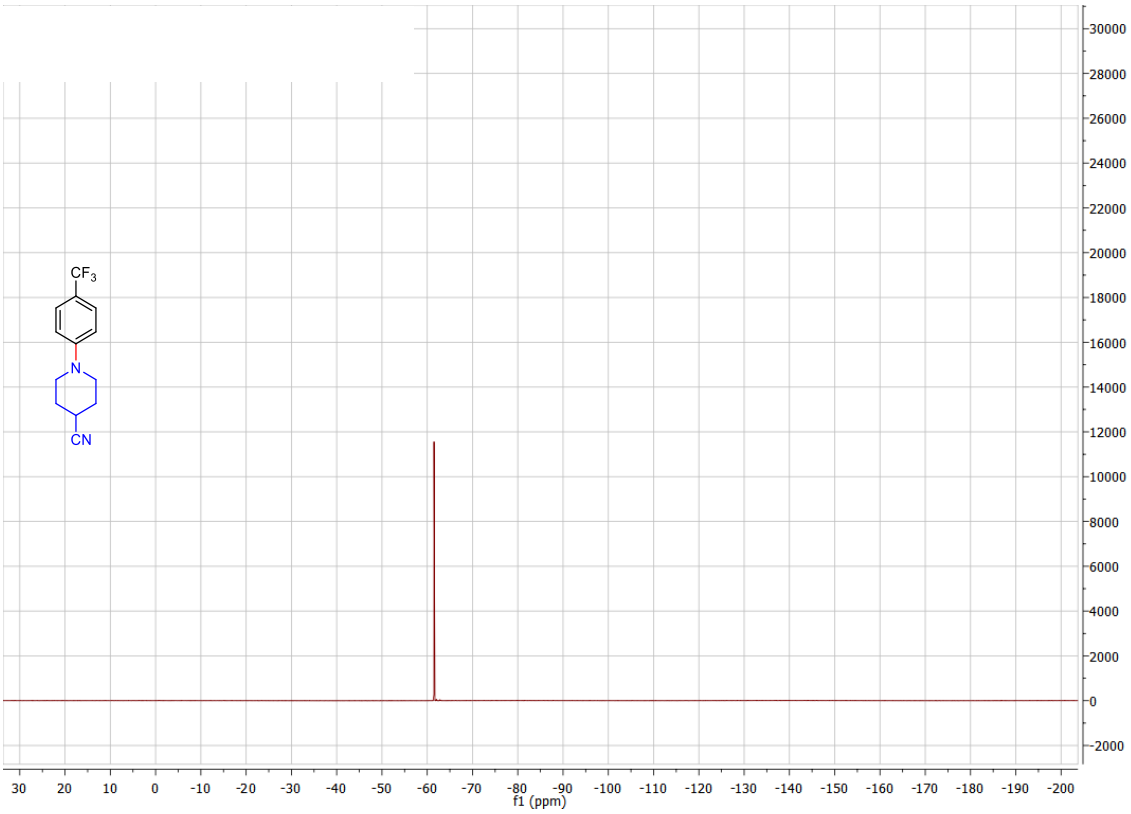



CF3
N
2.10E+08
2.00E+08
1.90E+08
1.80E+08
1.70E+08
1.60E+08
1.50E+08
1.40E+08
1.30E+08
1.20E+08
1.10E+08
1.00E+08
9.00E+07
8.00E+07
7.00E+07
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
-1.00E+07
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220
f1 (ppm)

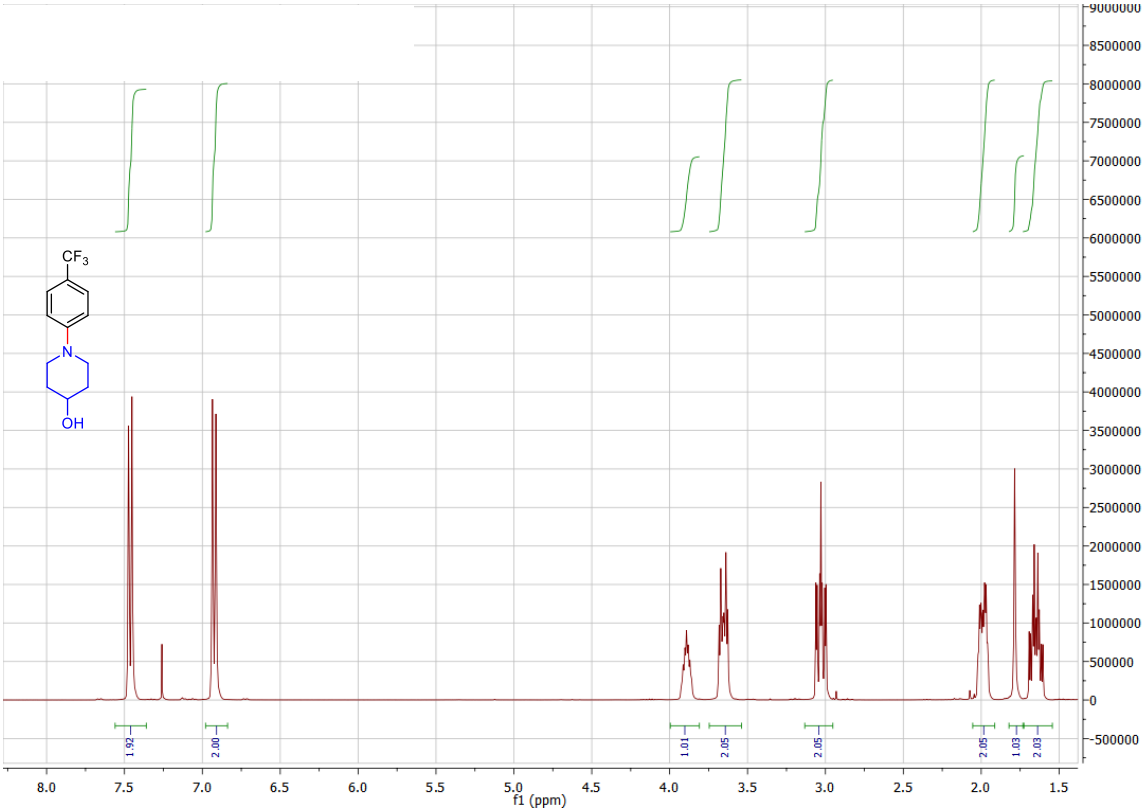
1-(4-(trifluoromethyl)phenyl)piperidine-4-carbonitrile (4)

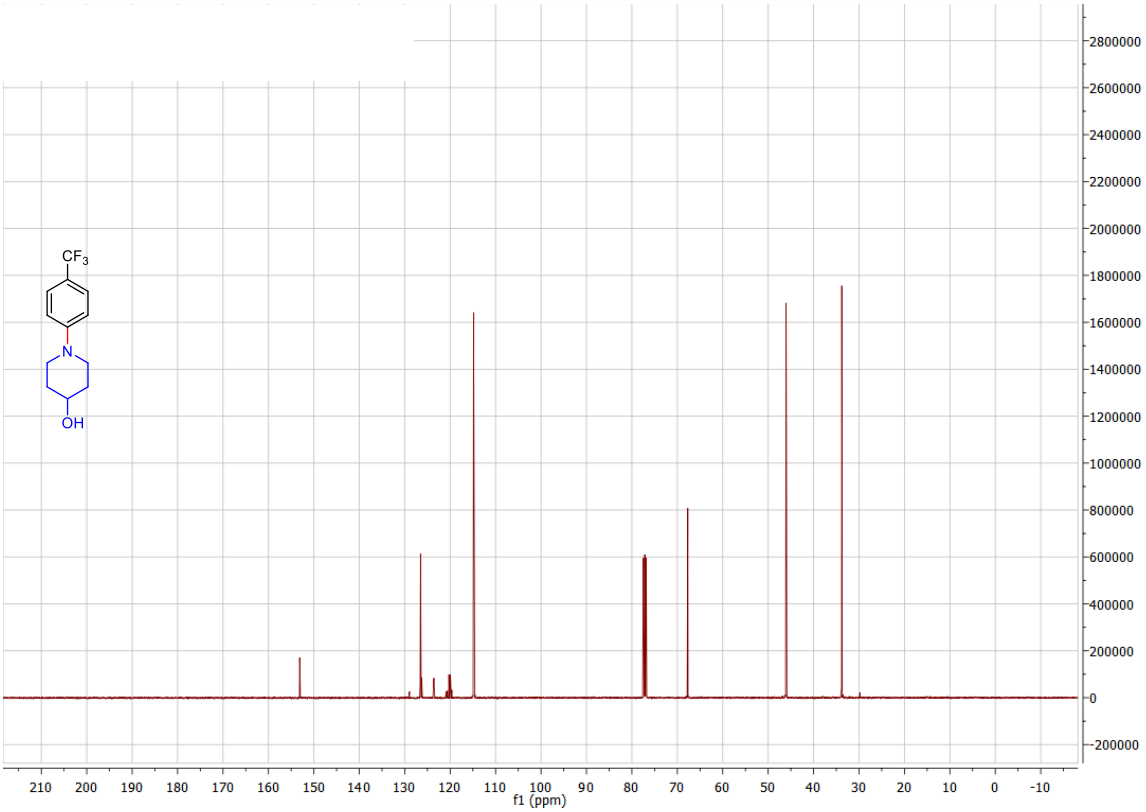


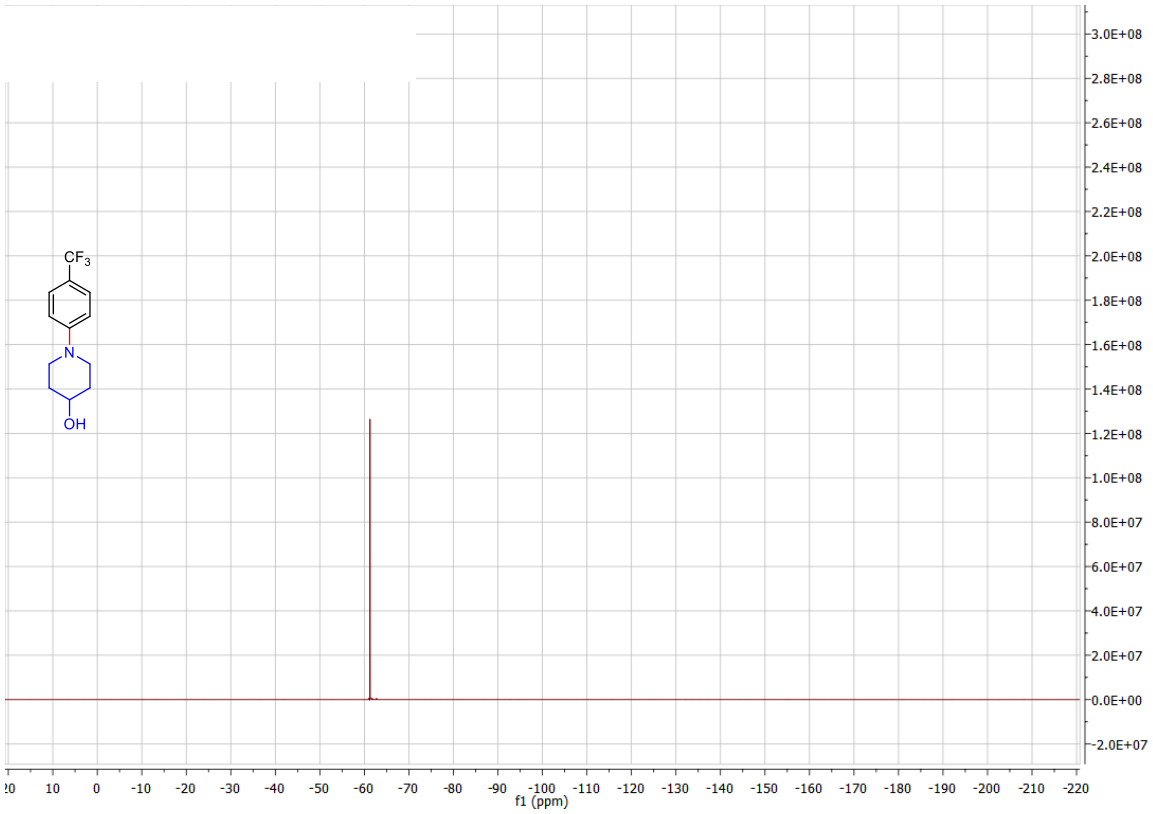



CF3
N
CN
30000
28000
26000
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
-2000
30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200
f1 (ppm)

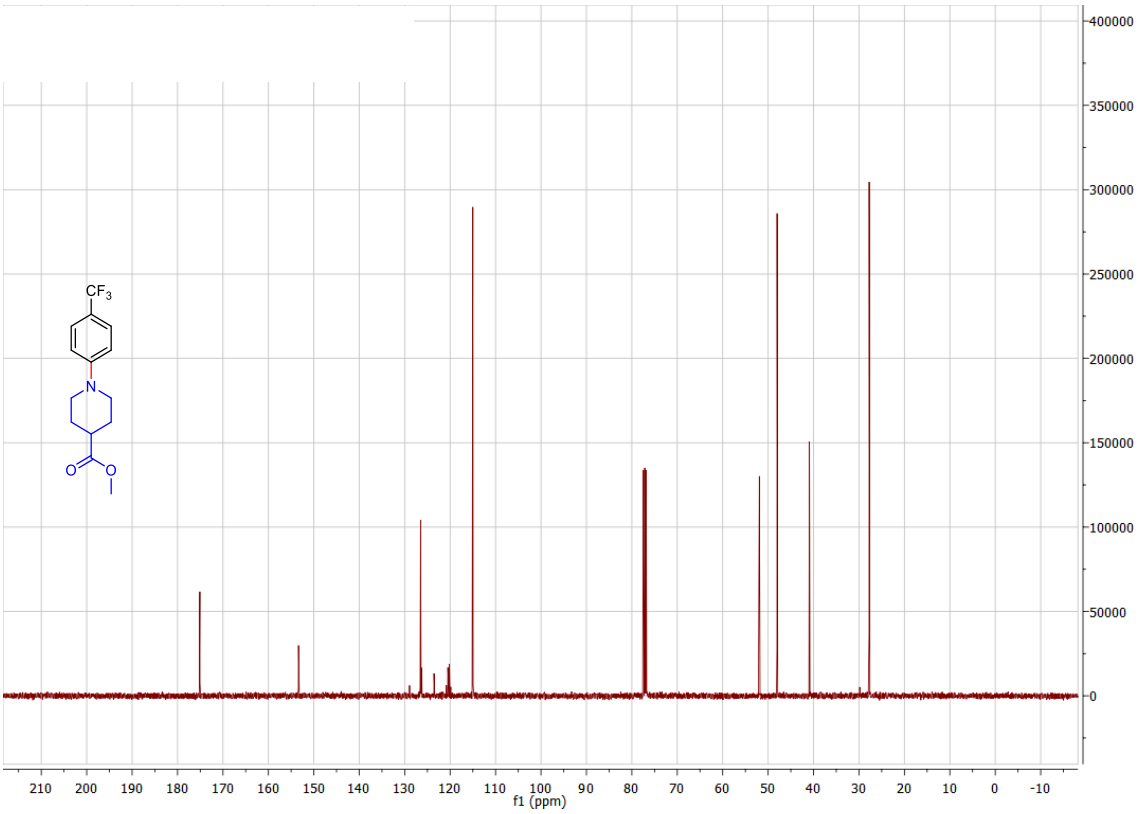
1-(4-(trifluoromethyl)phenyl)piperidin-4-ol (5)

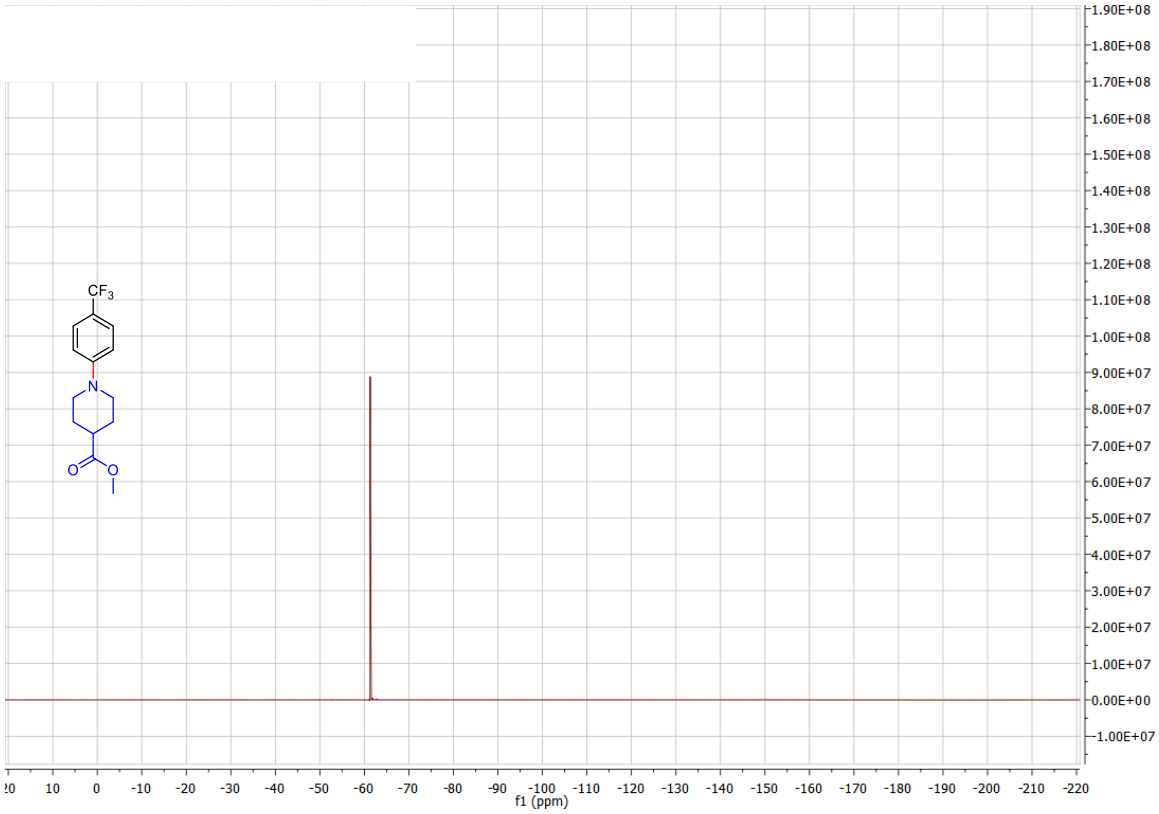




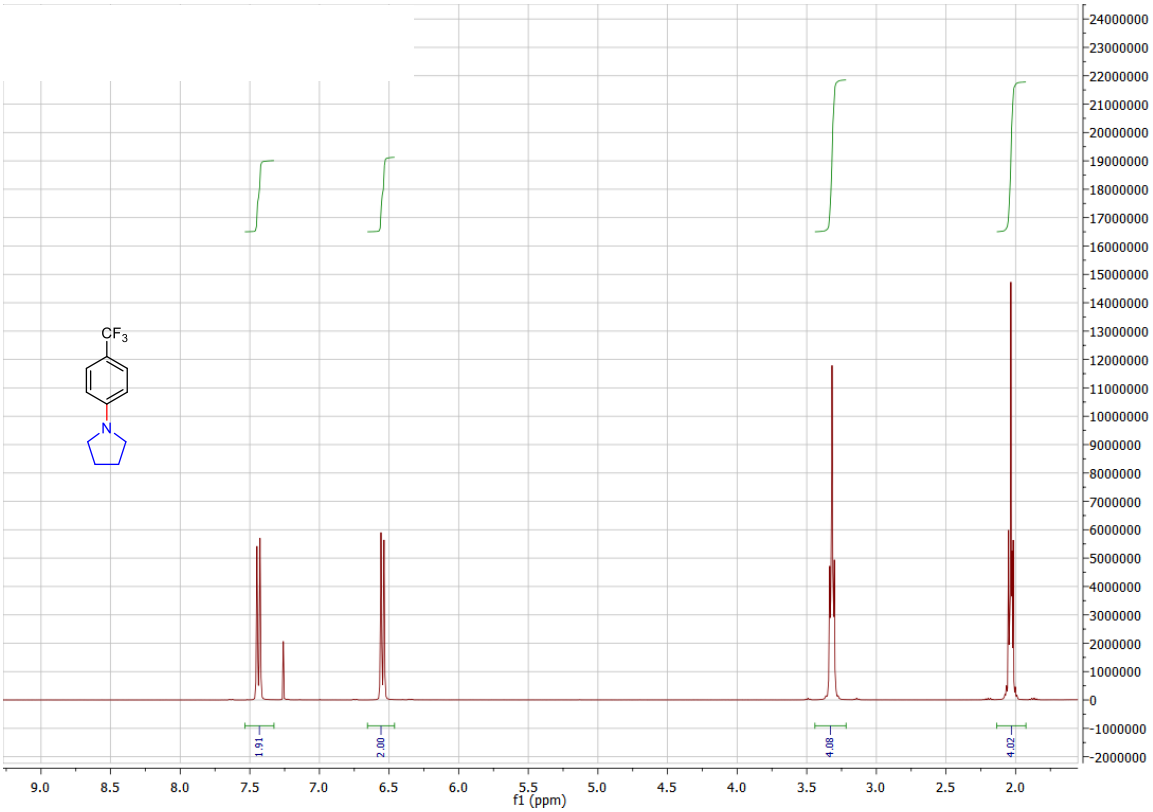

CF3
N
OH
3.0E+08
2.8E+08
2.6E+08
2.4E+08
2.2E+08
2.0E+08
1.8E+08
1.6E+08
1.4E+08
1.2E+08
1.0E+08
8.0E+07
6.0E+07
4.0E+07
2.0E+07
0.0E+00
-2.0E+07
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220
f1 (ppm)

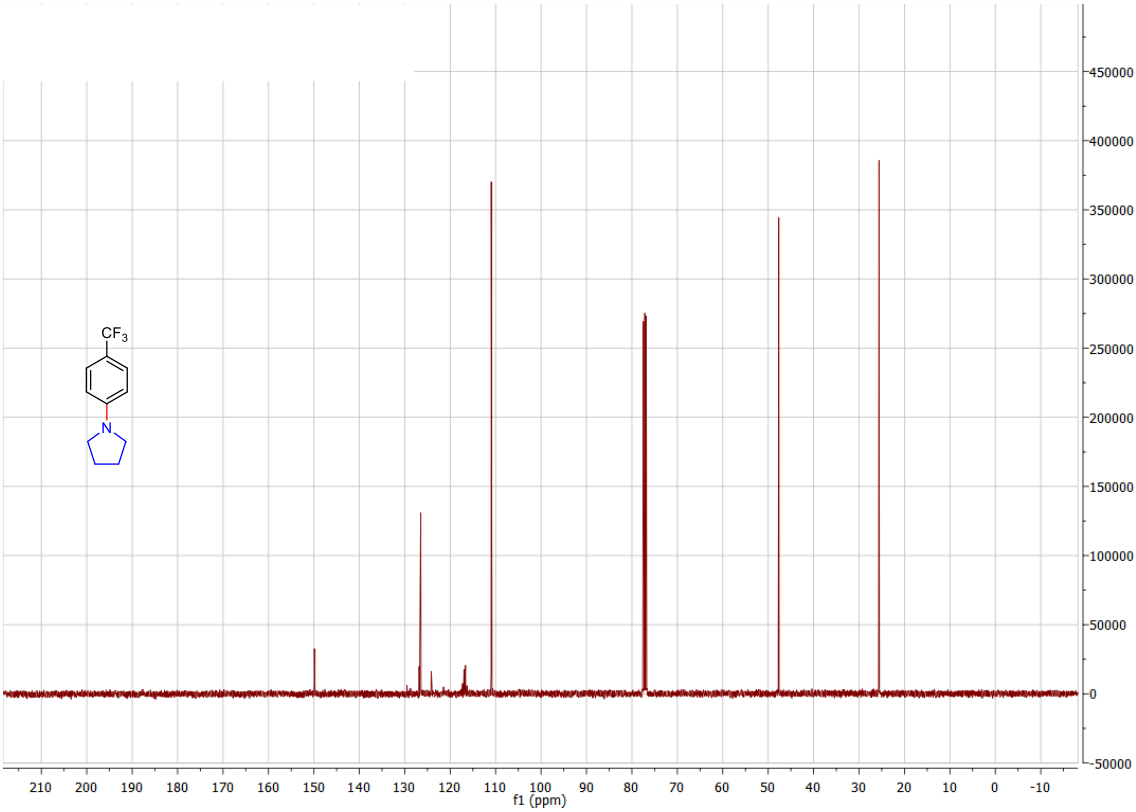
methyl 1-(4-(trifluoromethyl)phenyl)piperidine-4-carboxylate (6)

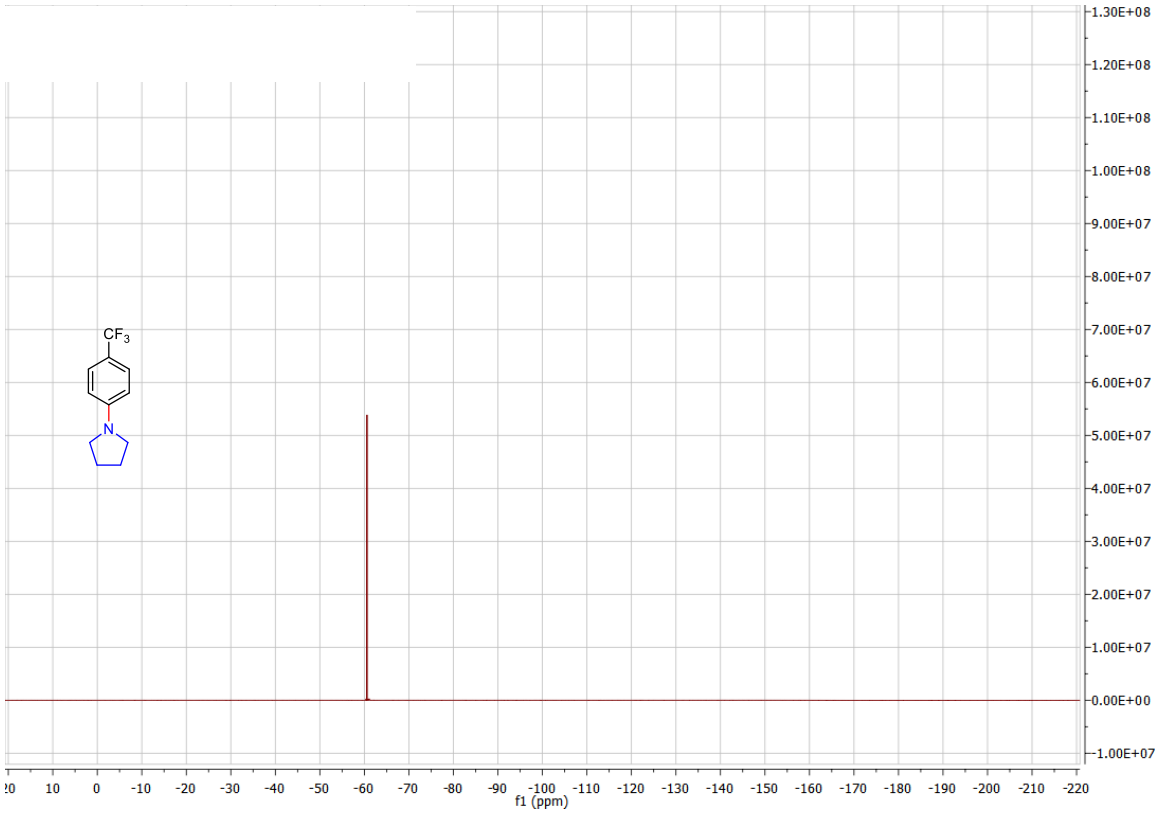



CF3
N
O
O
1.90E+08
1.80E+08
1.70E+08
1.60E+08
1.50E+08
1.40E+08
1.30E+08
1.20E+08
1.10E+08
1.00E+08
9.00E+07
8.00E+07
7.00E+07
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
-1.00E+07
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220
f1 (ppm)

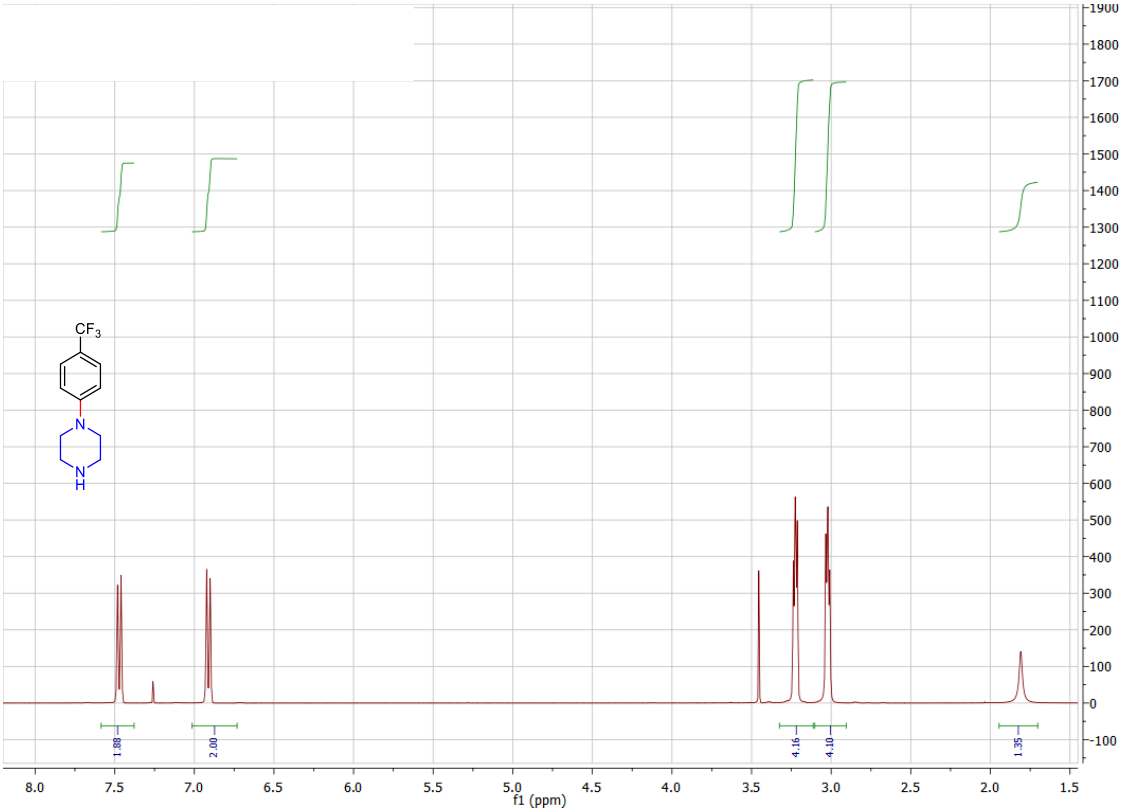
1-(4-(trifluoromethyl)phenyl)pyrrolidine (7)

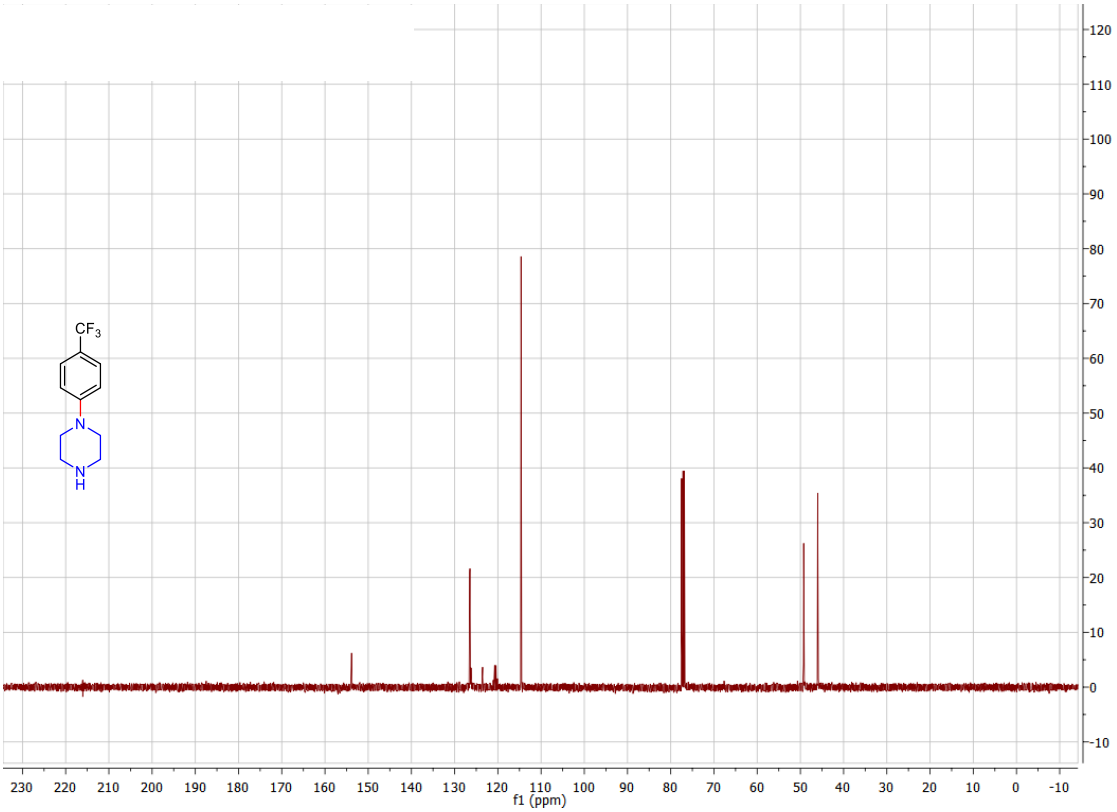


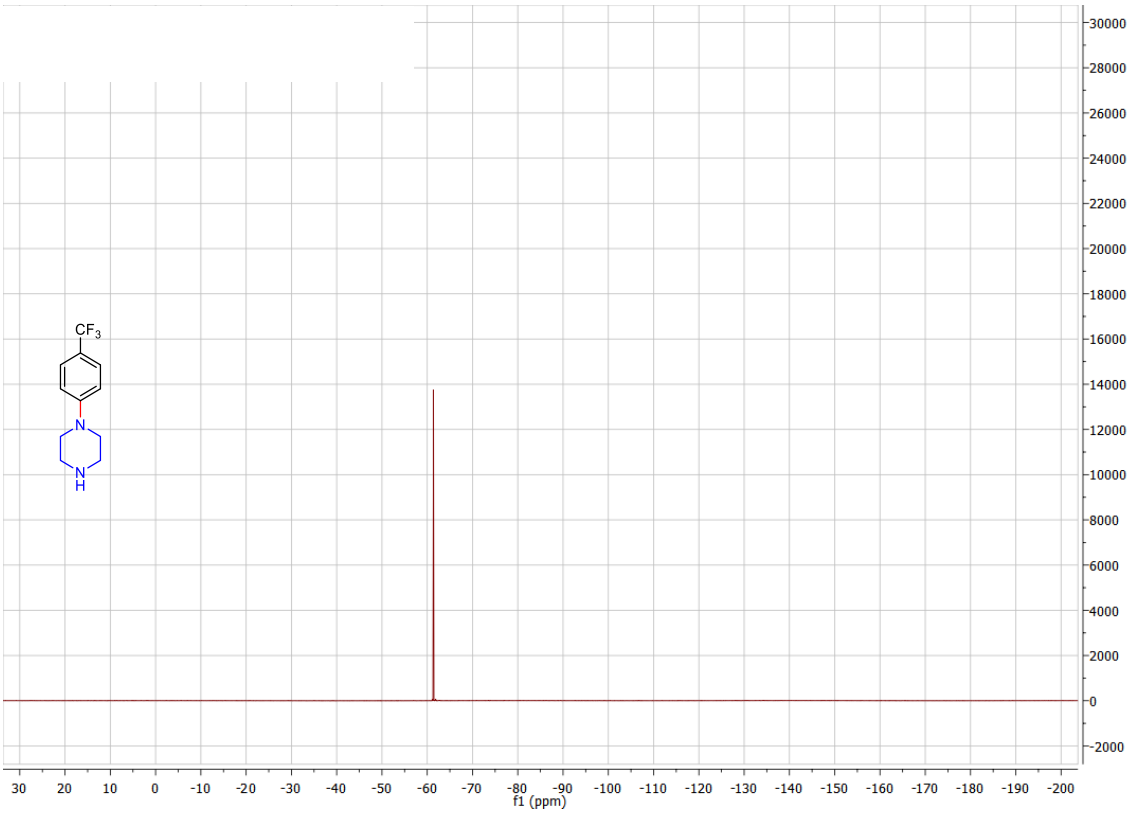



CF3
N
1.30E+08
1.20E+08
1.10E+08
1.00E+08
9.00E+07
8.00E+07
7.00E+07
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
-1.00E+07
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220
f1 (ppm)

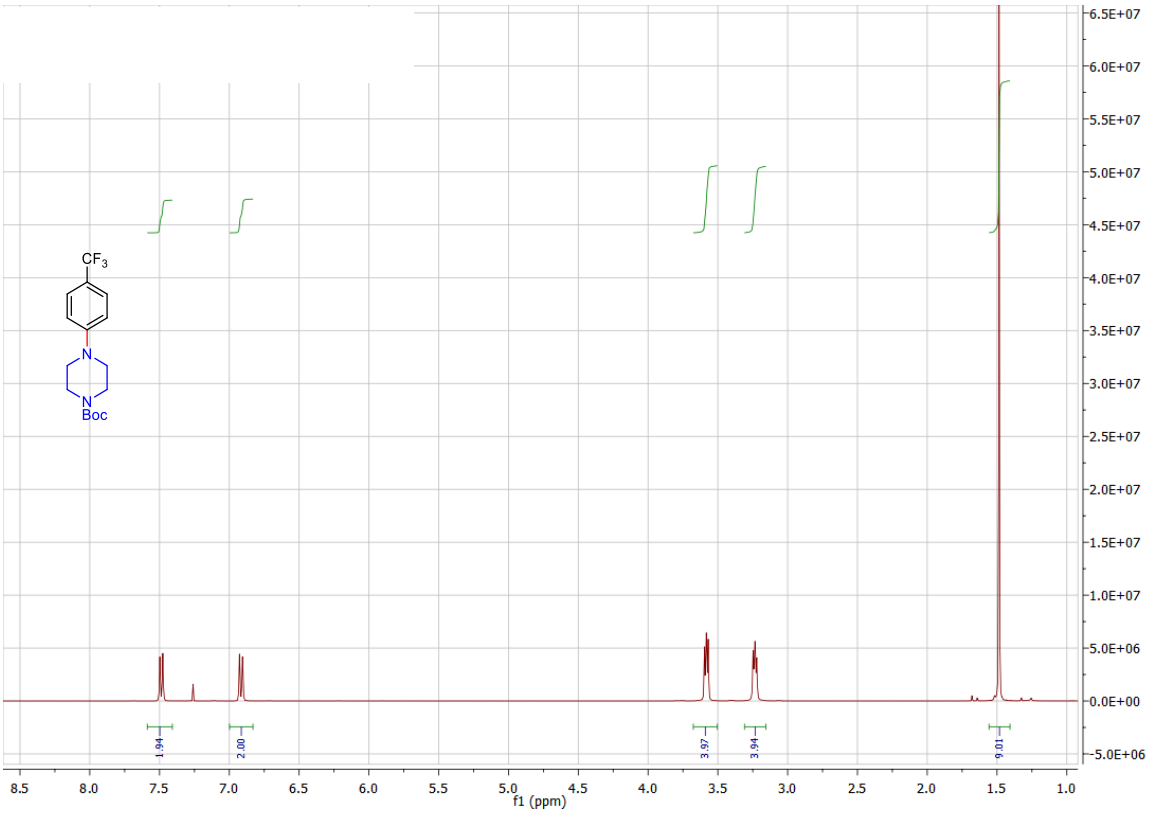
1-(4-(trifluoromethyl)phenyl)piperazine (8)

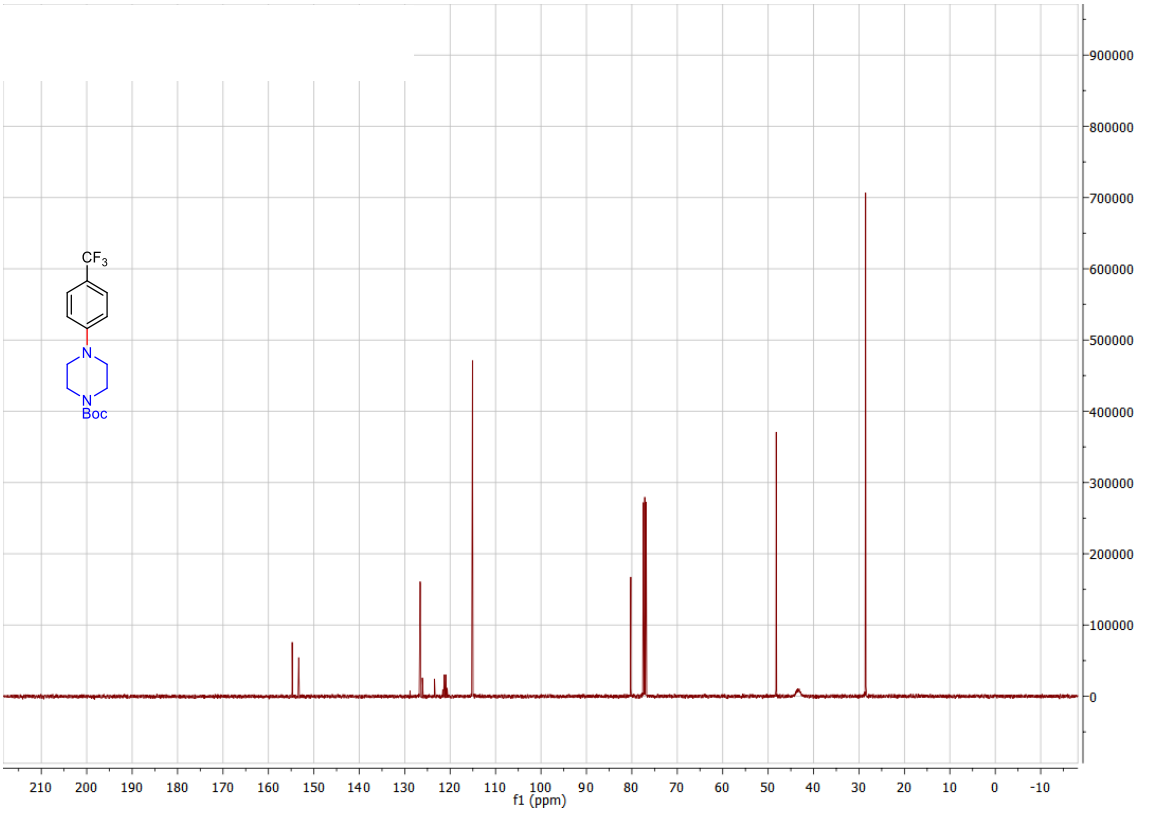


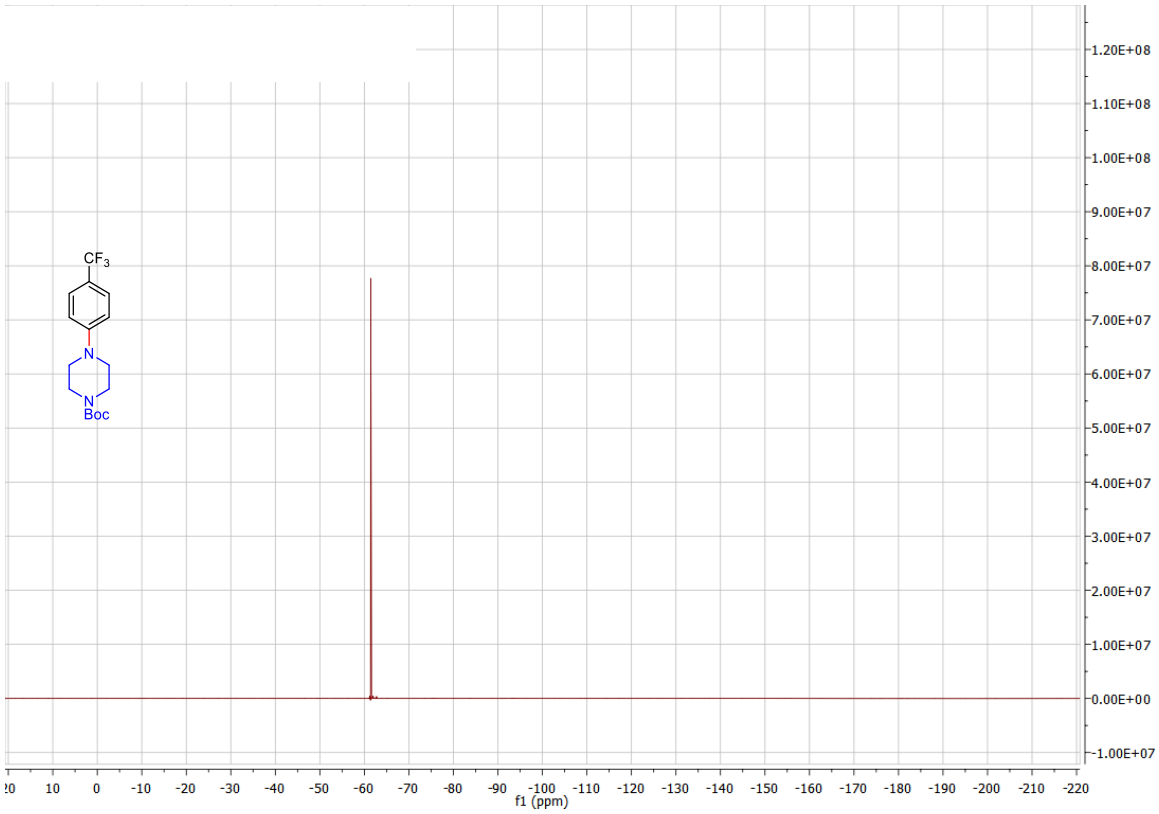



CF3
N
N
H
30000
28000
26000
24000
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
-2000
30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200
f1 (ppm)

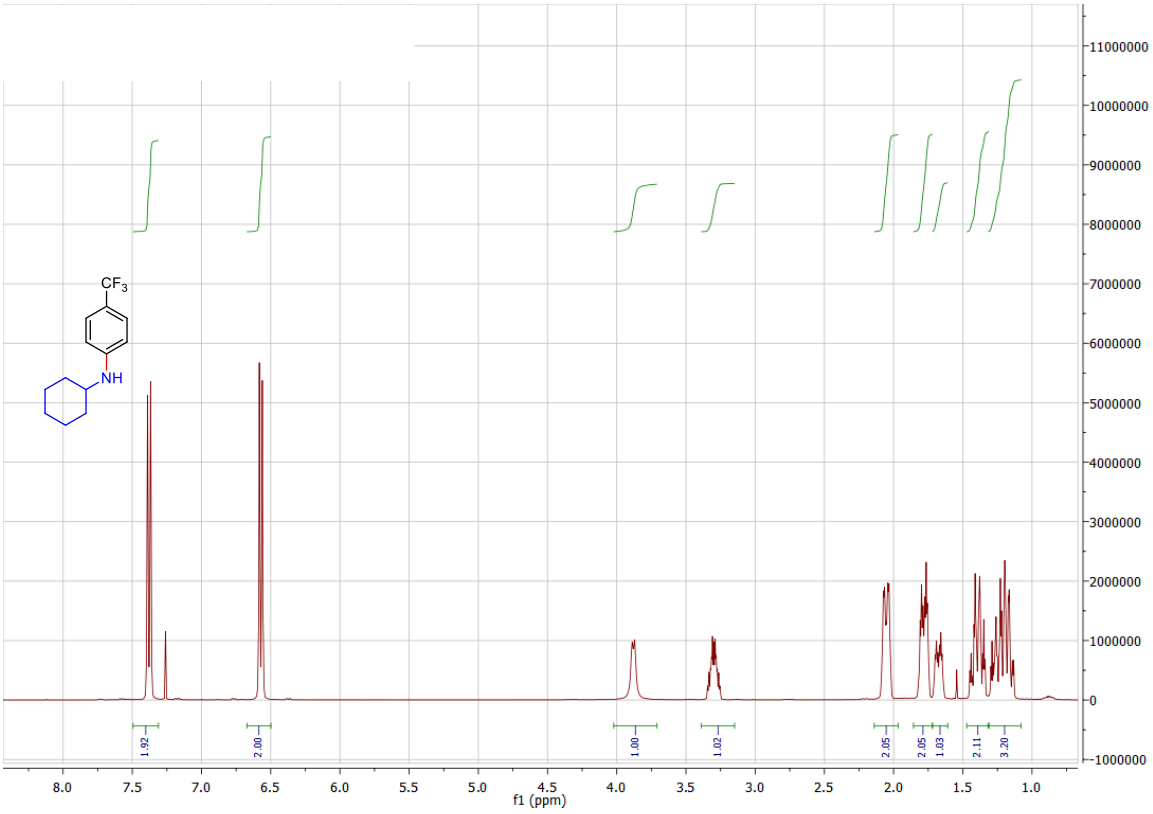
***tert*-butyl 4-(4-(trifluoromethyl)phenyl)piperazine-1-carboxylate (9)**

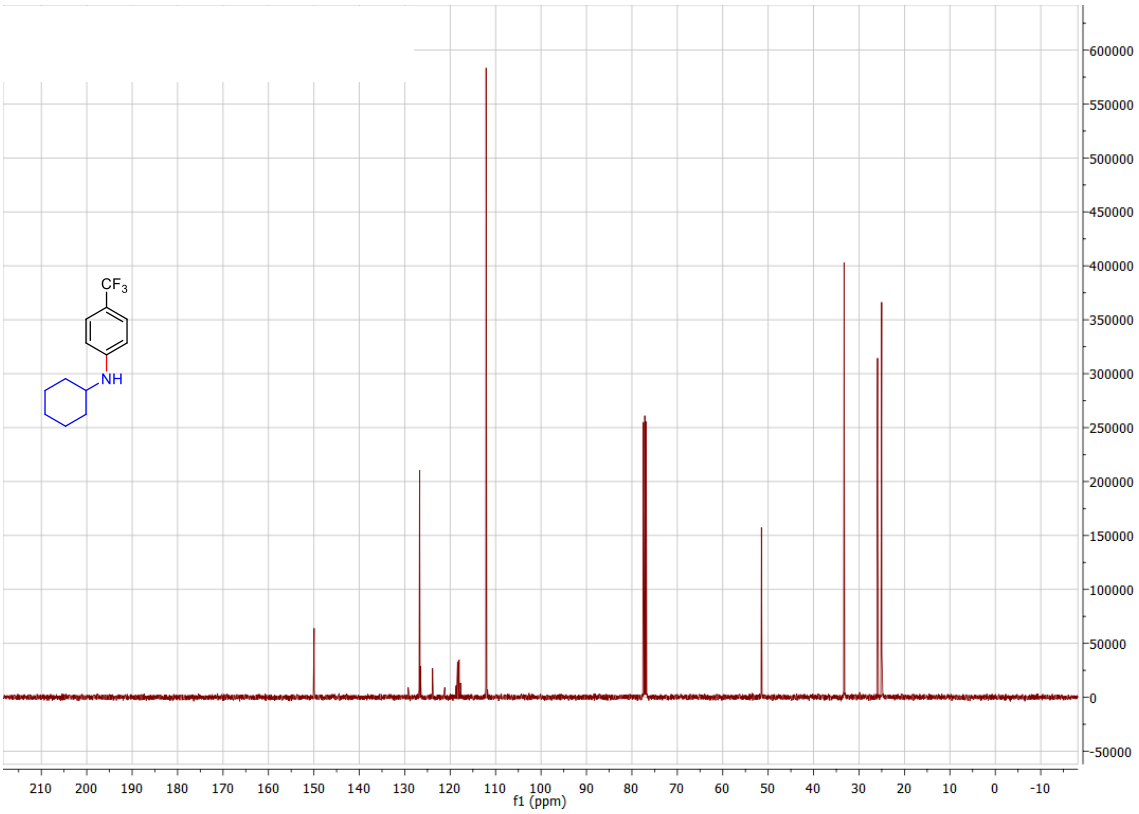


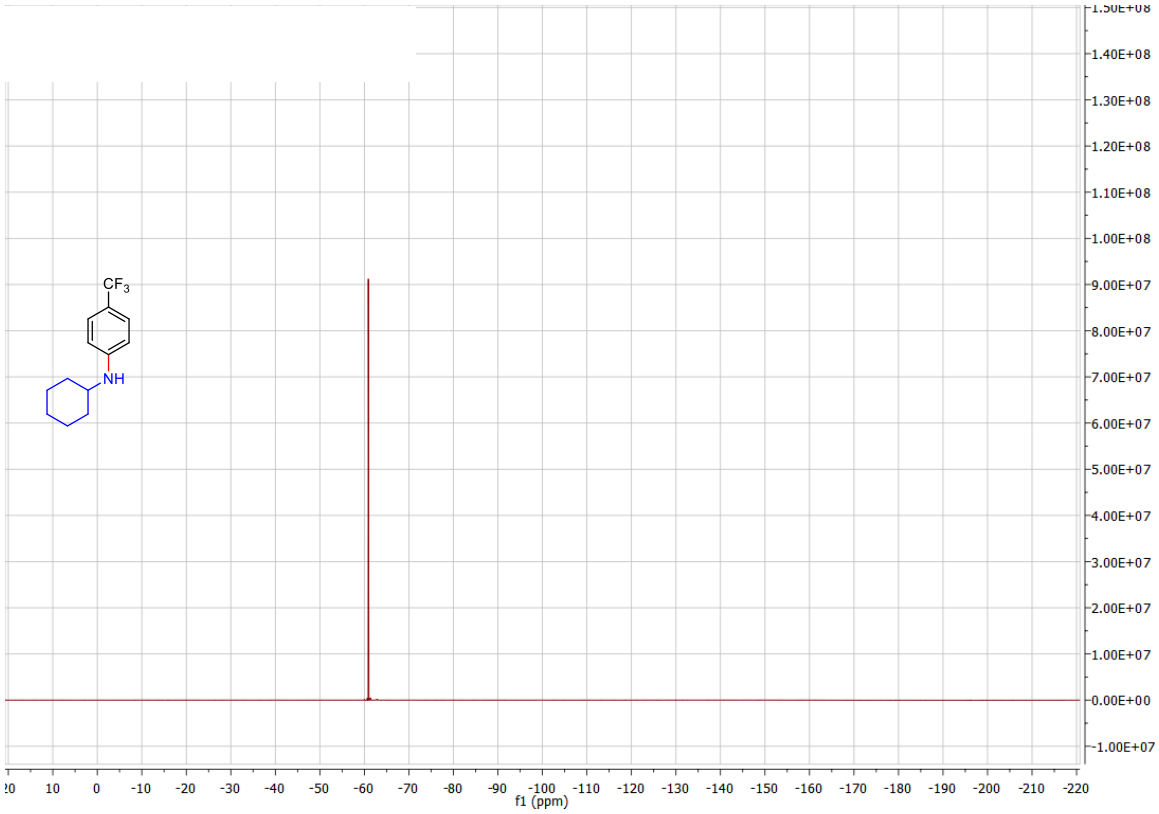



CF3
N
N
Boc
1.20E+08
1.10E+08
1.00E+08
9.00E+07
8.00E+07
7.00E+07
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
-1.00E+07
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
-220
f1 (ppm)

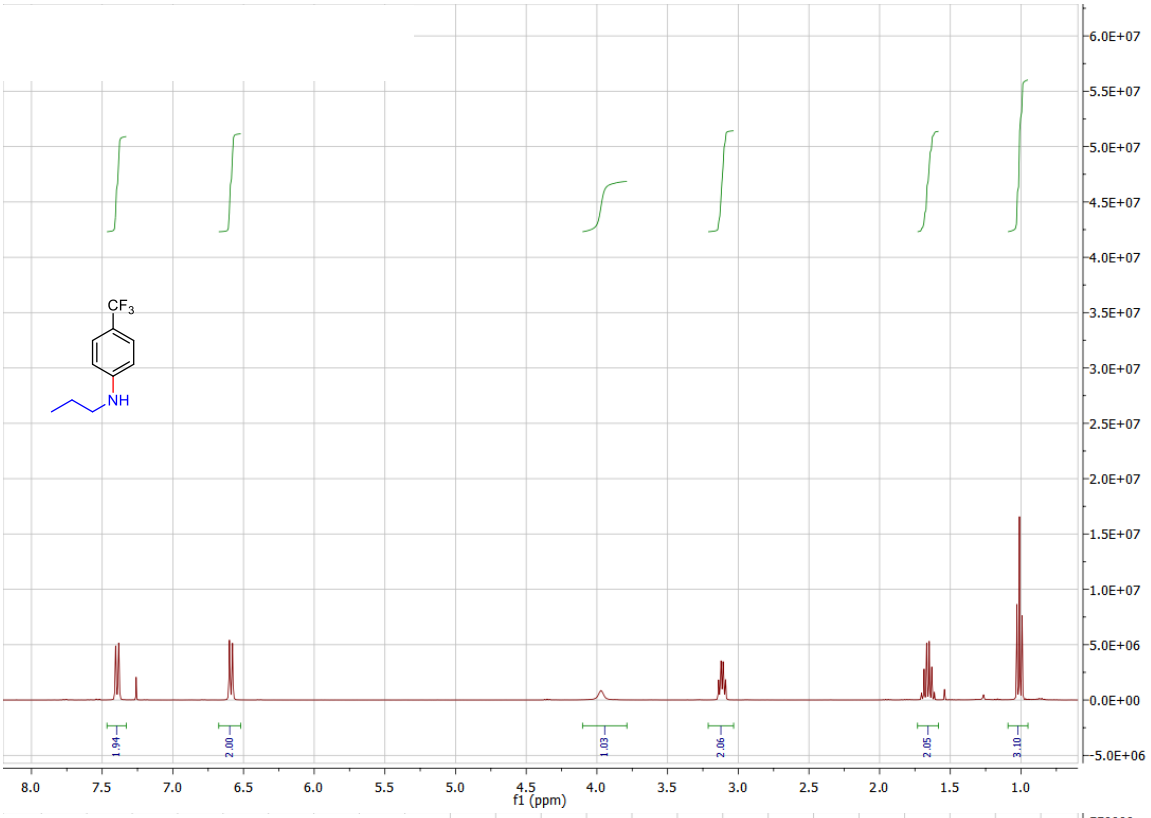
N-cyclohexyl-4-(trifluoromethyl)aniline (10)

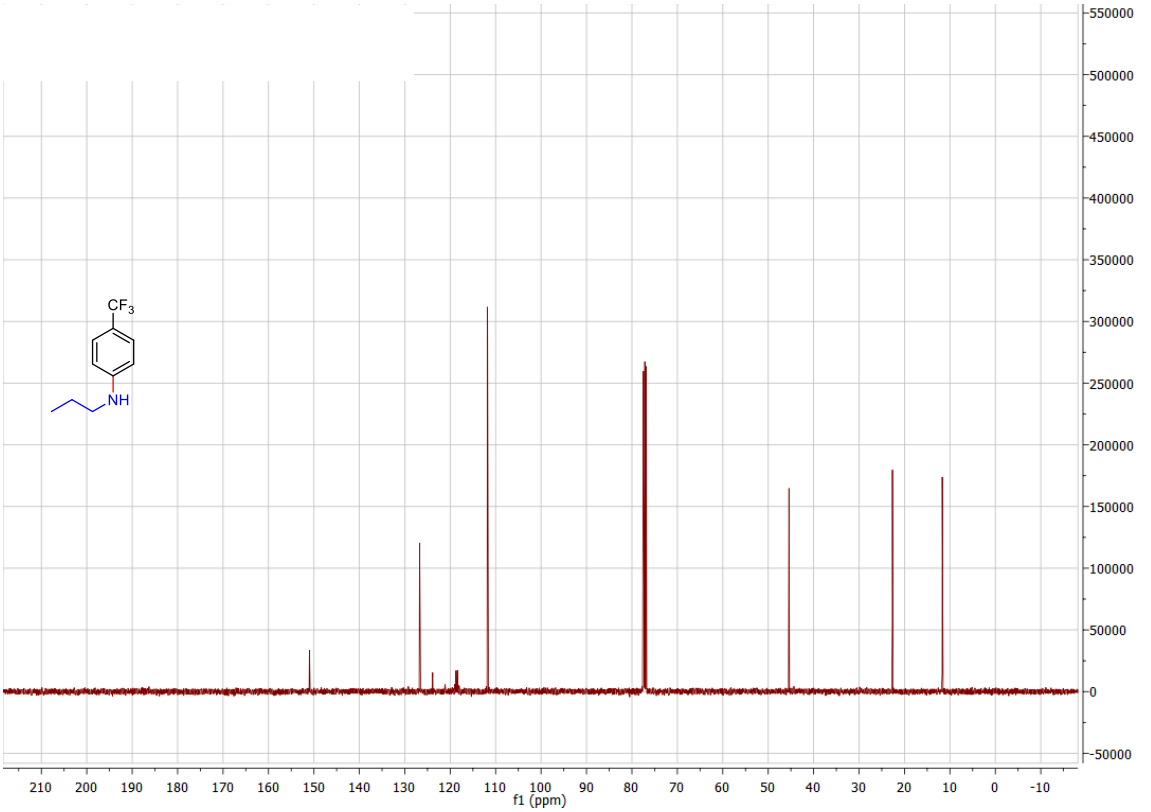


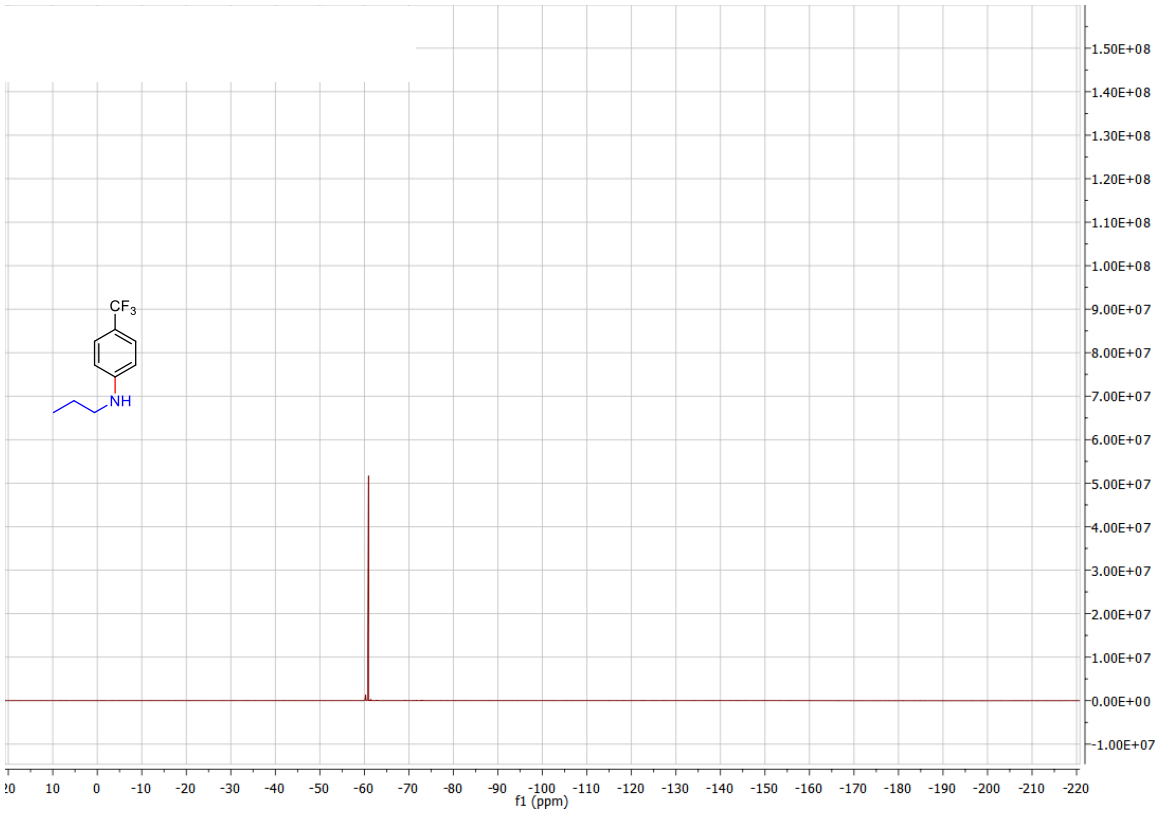



CF3
NH
1.40E+08
1.30E+08
1.20E+08
1.10E+08
1.00E+08
9.00E+07
8.00E+07
7.00E+07
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
-1.00E+07
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220
f1 (ppm)

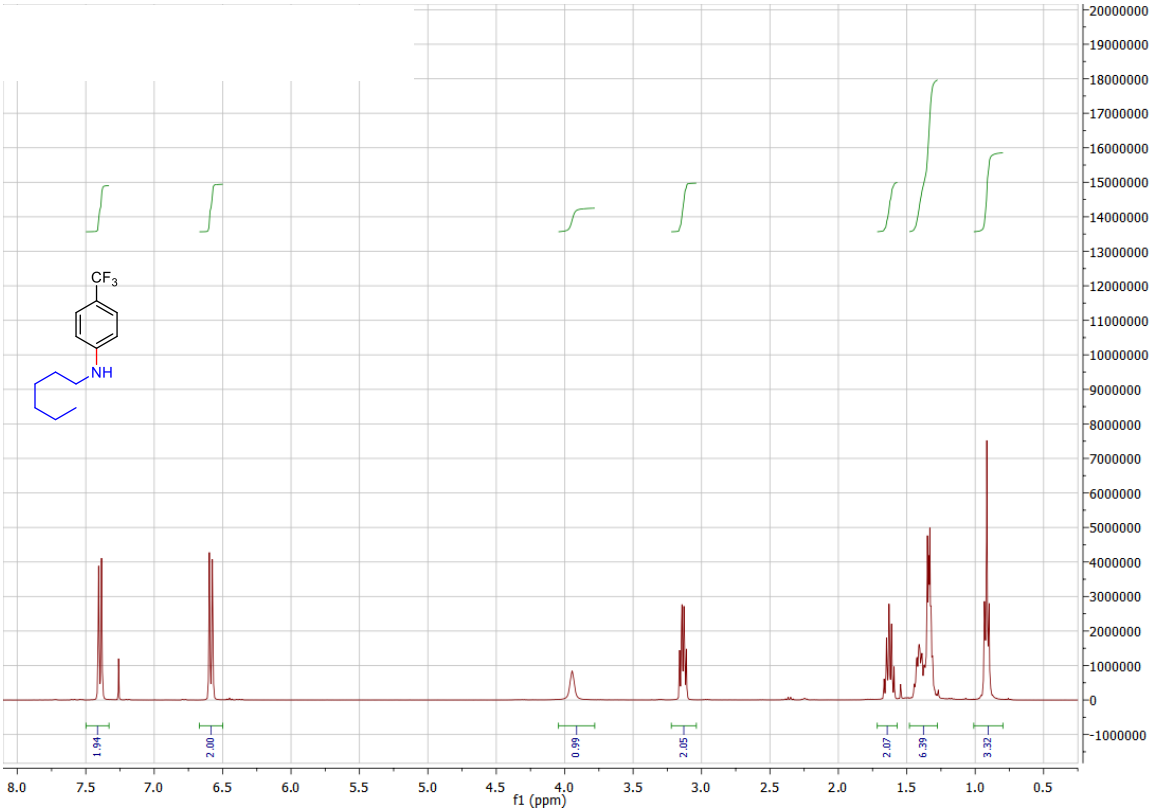
N-propyl-4-(trifluoromethyl)aniline (11)

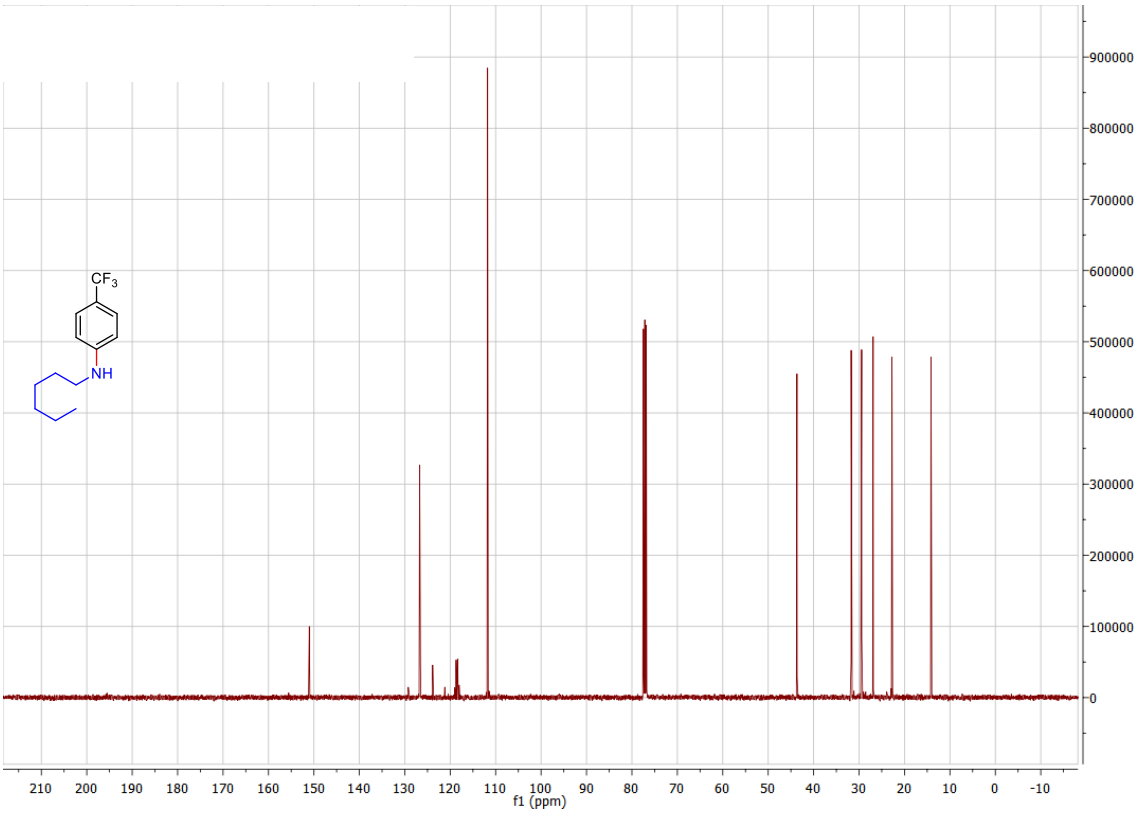


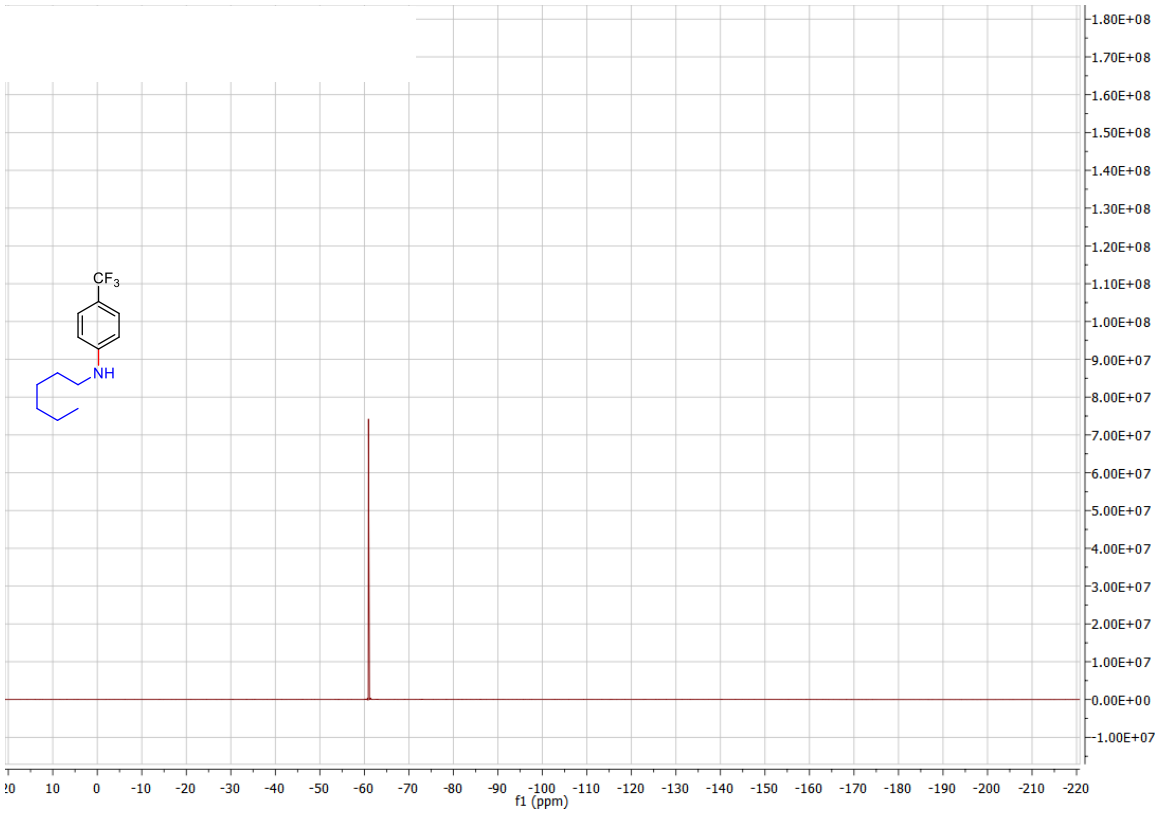



CF3
NH
1.50E+08
1.40E+08
1.30E+08
1.20E+08
1.10E+08
1.00E+08
9.00E+07
8.00E+07
7.00E+07
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
-1.00E+07
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220
f1 (ppm)

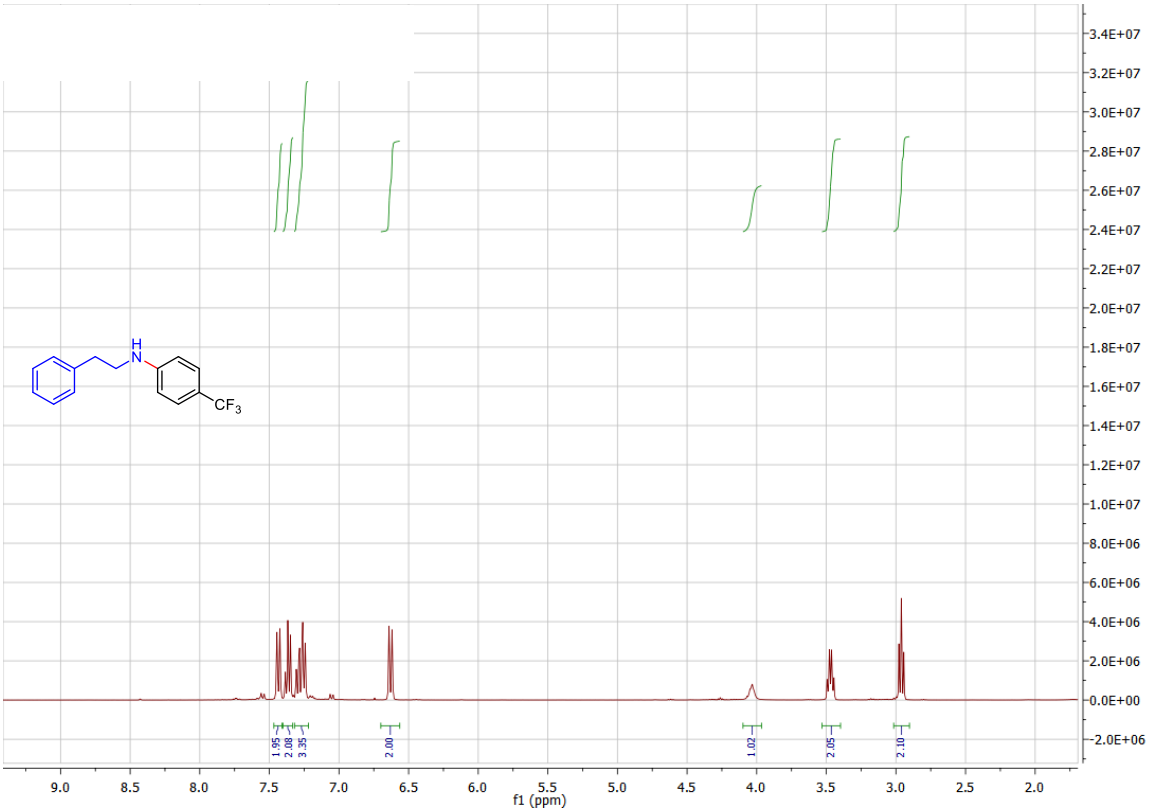
N-hexyl-4-(trifluoromethyl)aniline (12)

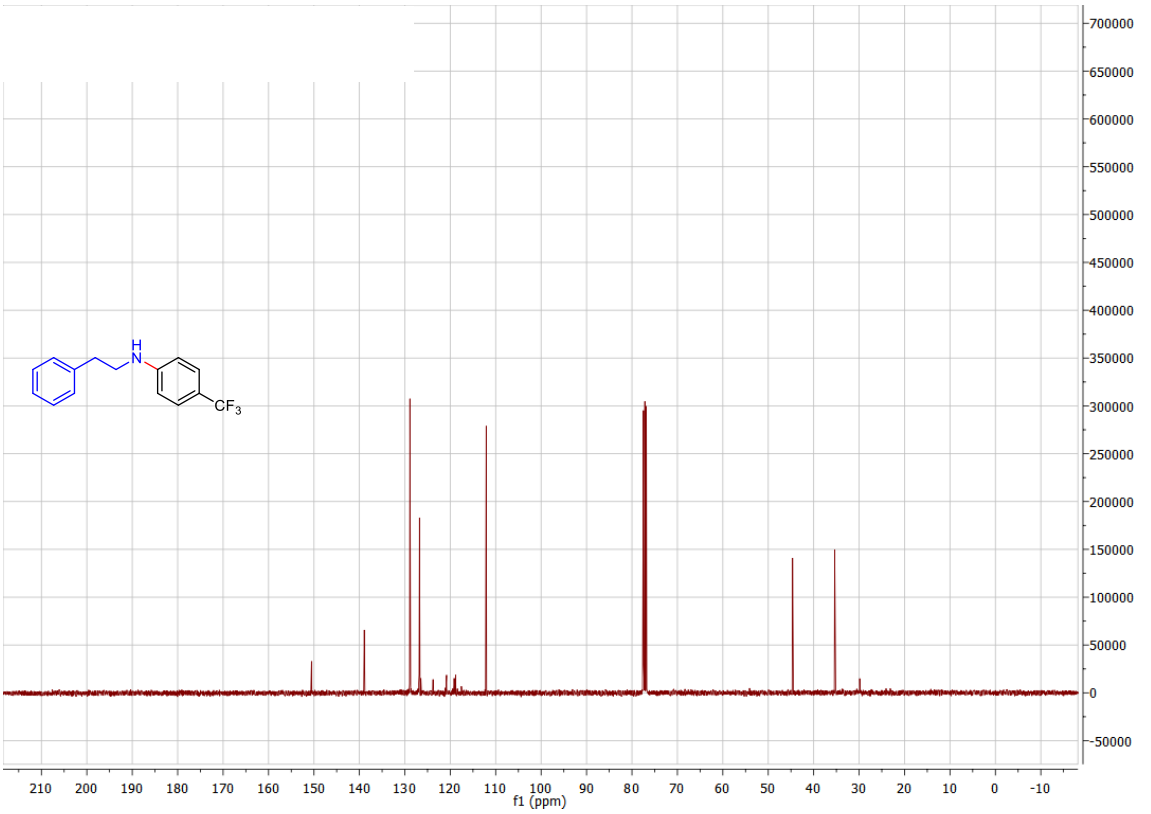


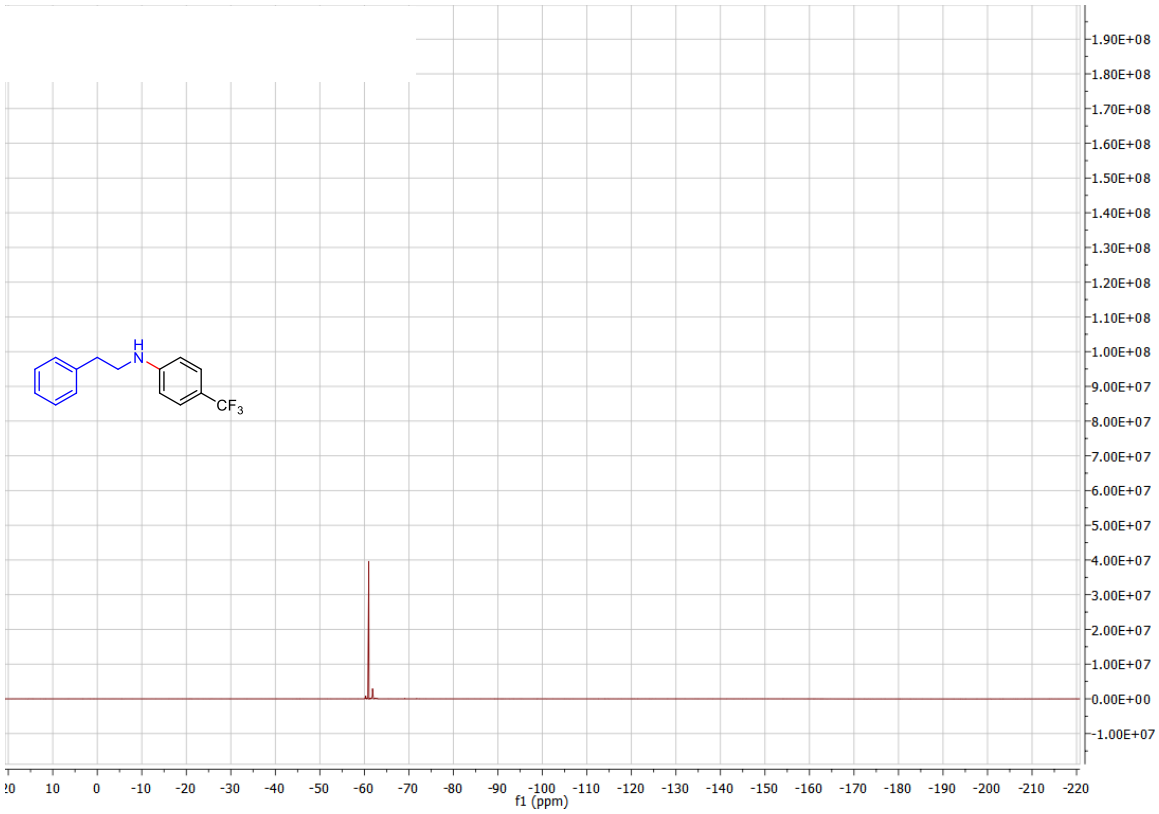



CF3
NH
1.80E+08
1.70E+08
1.60E+08
1.50E+08
1.40E+08
1.30E+08
1.20E+08
1.10E+08
1.00E+08
9.00E+07
8.00E+07
7.00E+07
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
-1.00E+07
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220
f1 (ppm)

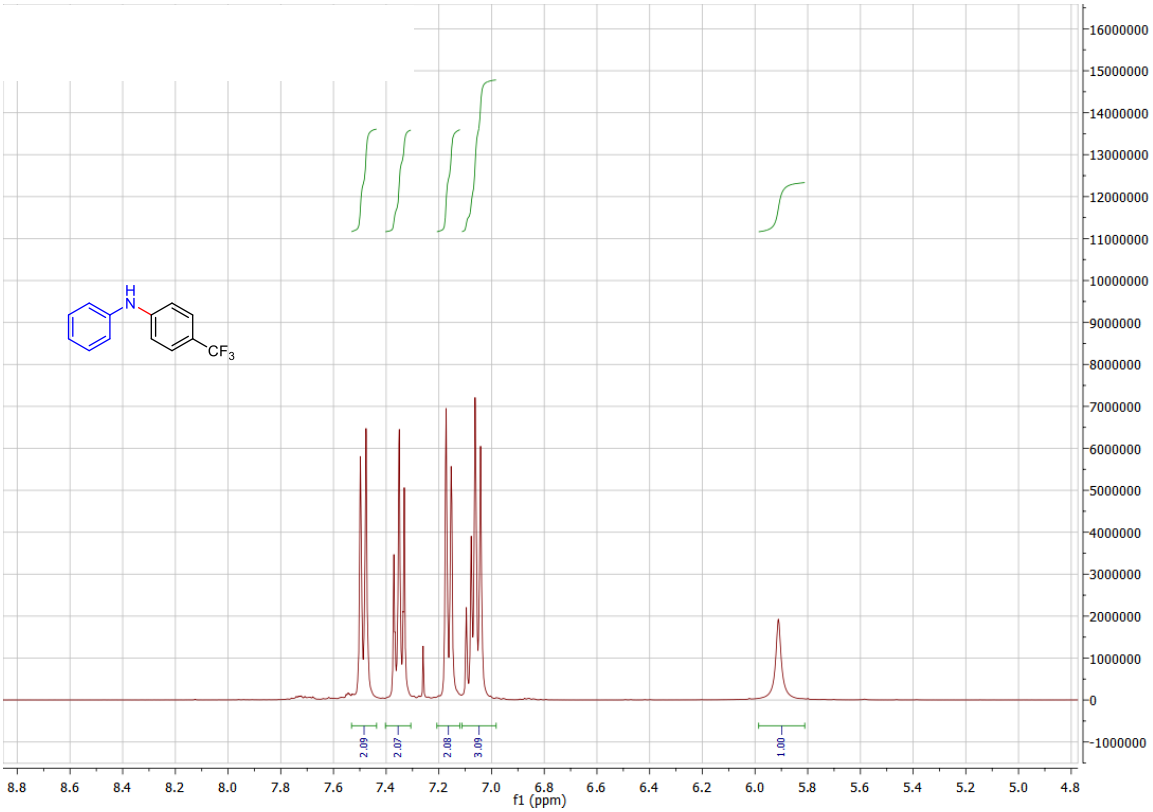
N-phenethyl-4-(trifluoromethyl)aniline (13)

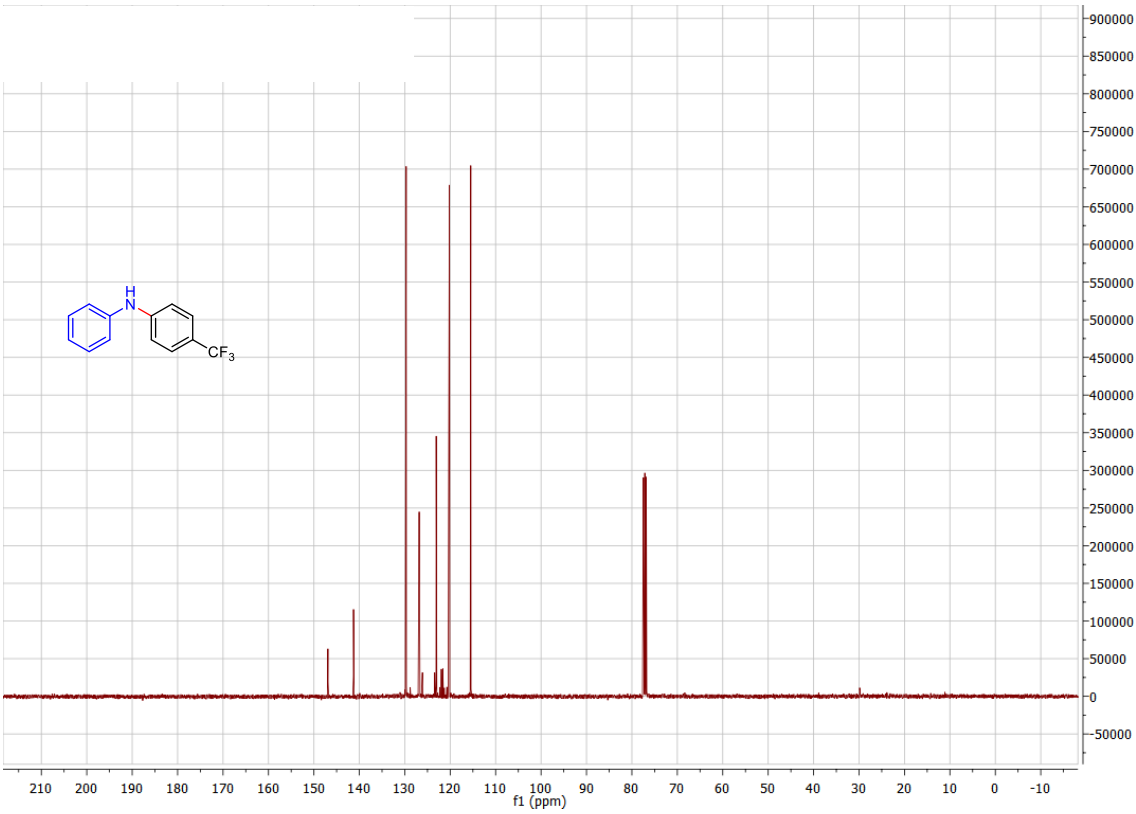


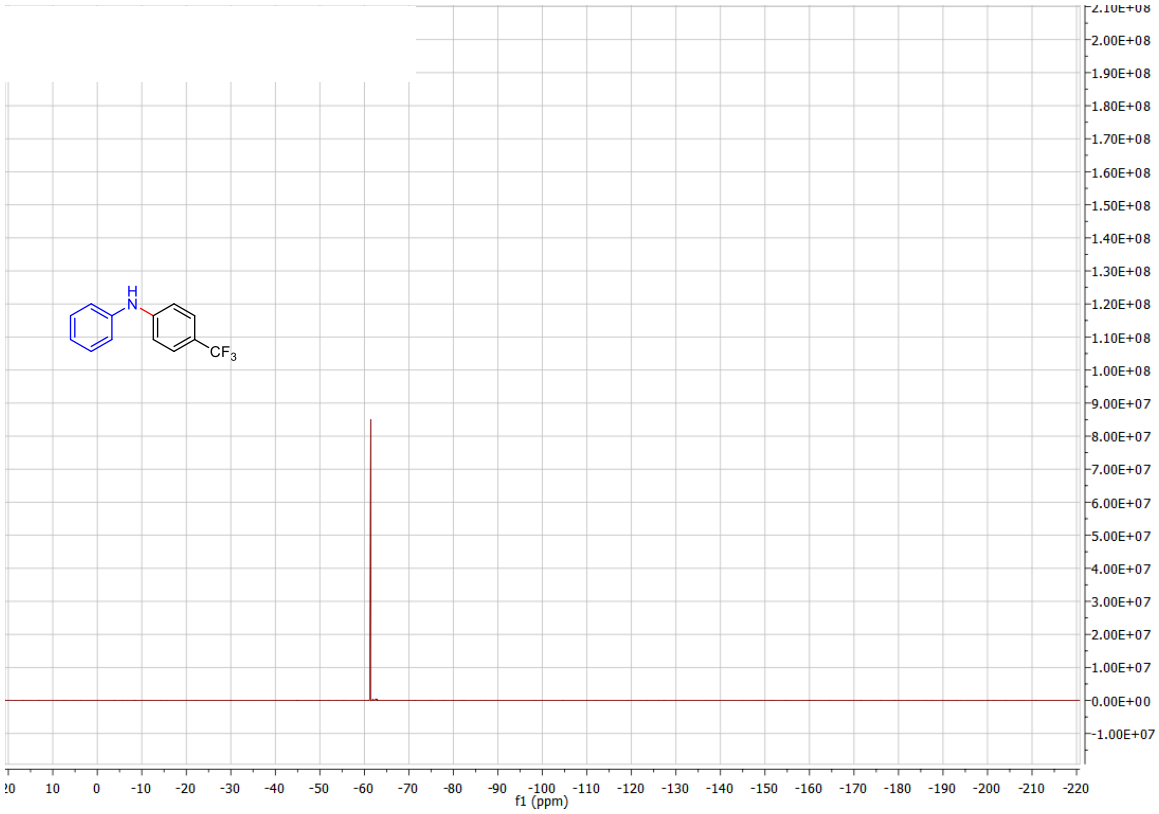



1.90E+08
1.80E+08
1.70E+08
1.60E+08
1.50E+08
1.40E+08
1.30E+08
1.20E+08
1.10E+08
1.00E+08
9.00E+07
8.00E+07
7.00E+07
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
-1.00E+07
H
N
CF3
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220
f1 (ppm)

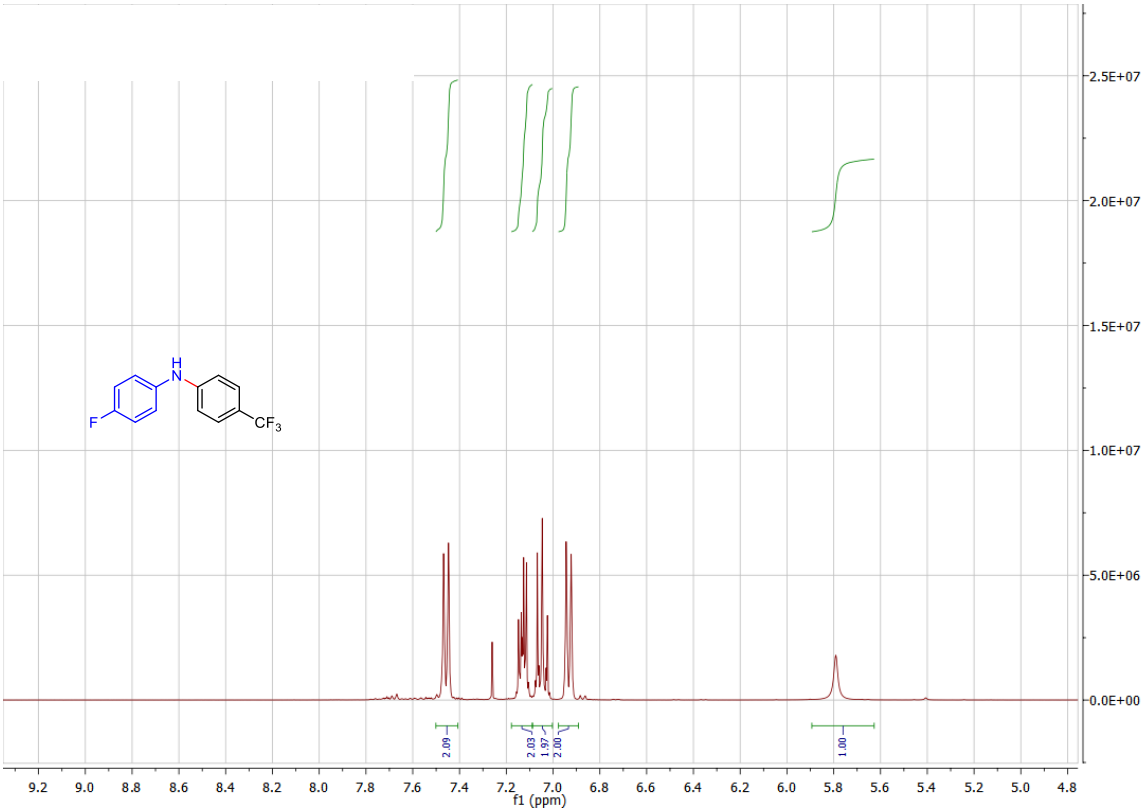
N-phenyl-4-(trifluoromethyl)aniline (14)

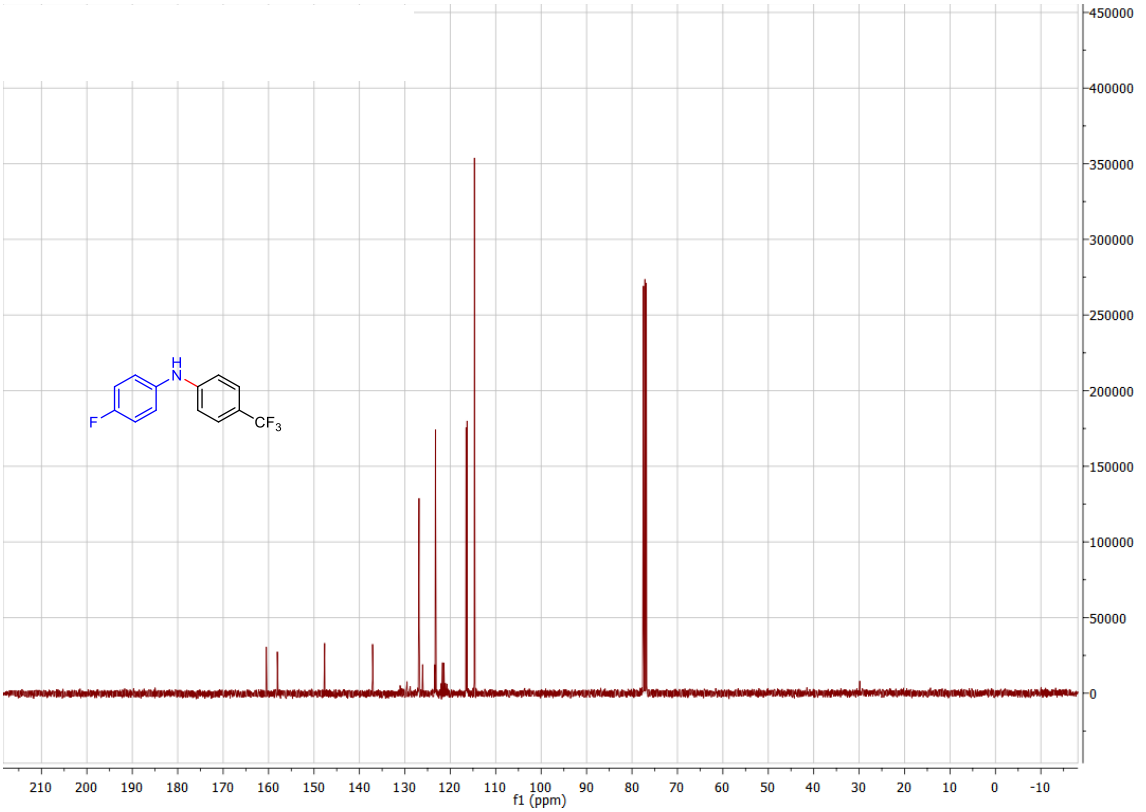


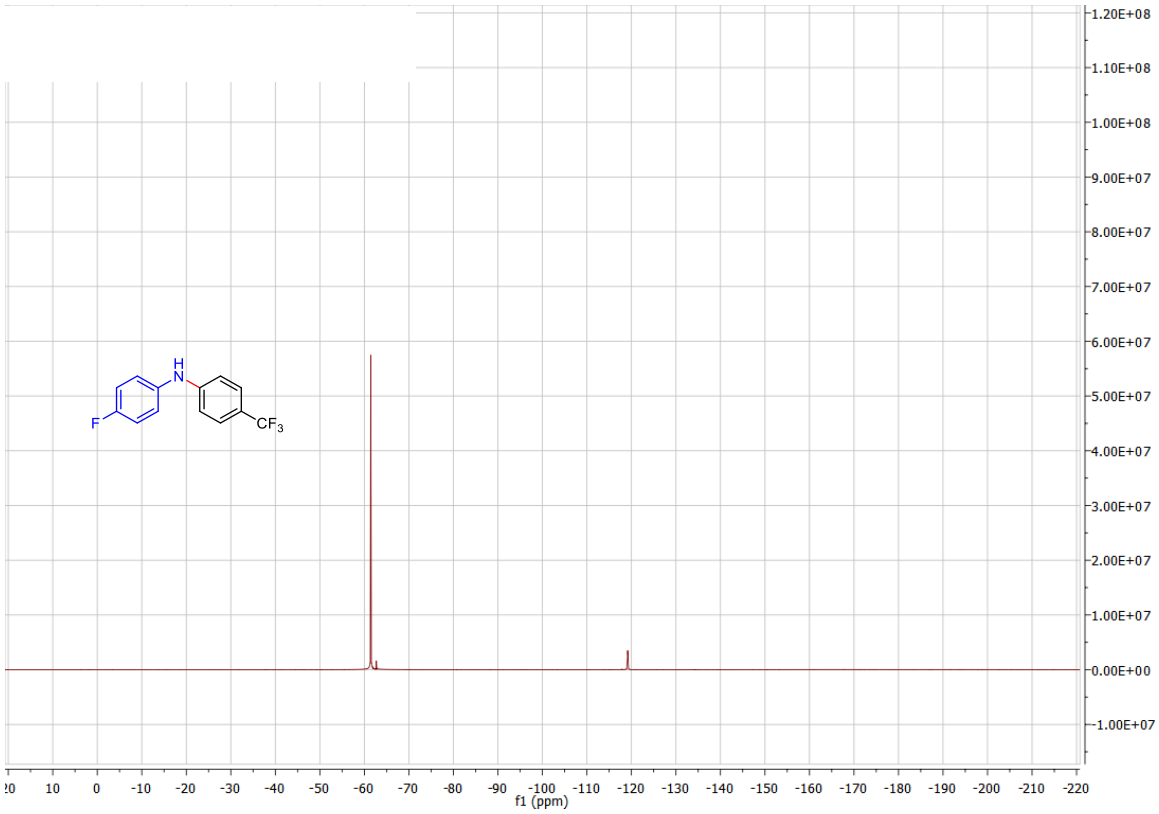



H
N
CF3
2.10E+08
2.00E+08
1.90E+08
1.80E+08
1.70E+08
1.60E+08
1.50E+08
1.40E+08
1.30E+08
1.20E+08
1.10E+08
1.00E+08
9.00E+07
8.00E+07
7.00E+07
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
-1.00E+07
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220
f1 (ppm)

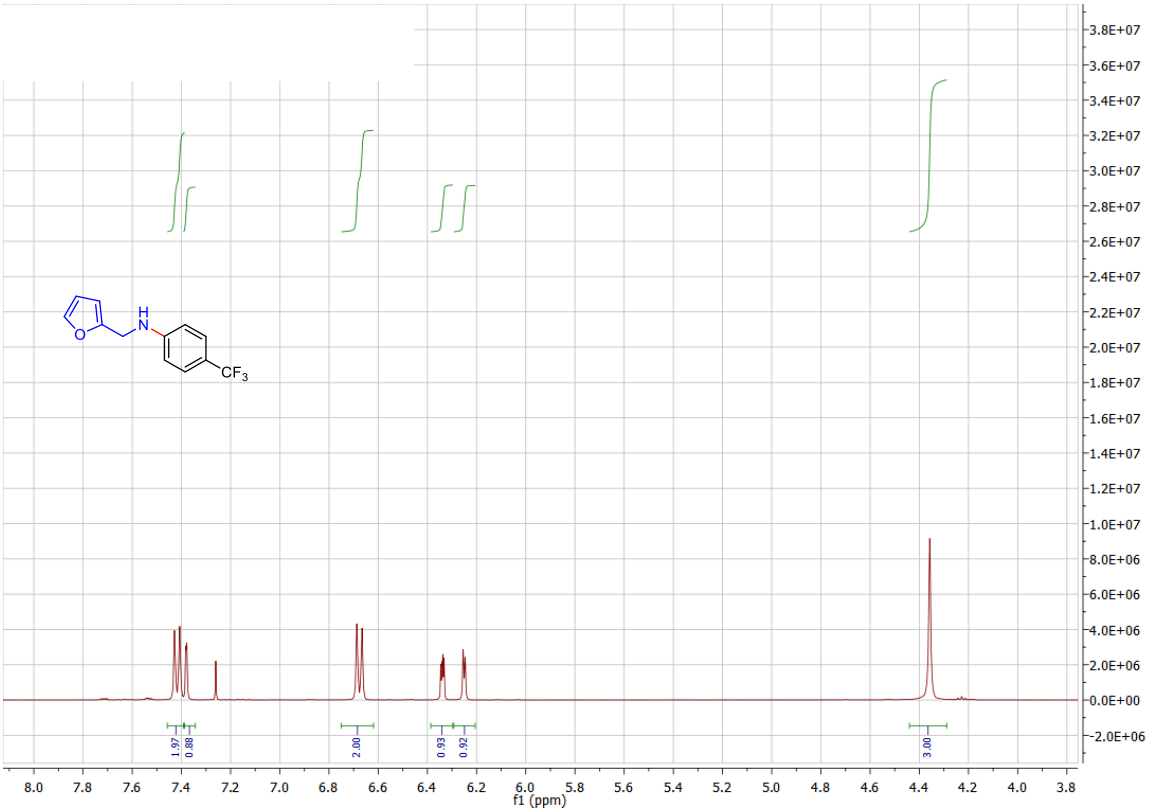
4-fluoro-N-(4-(trifluoromethyl)phenyl)aniline (15)

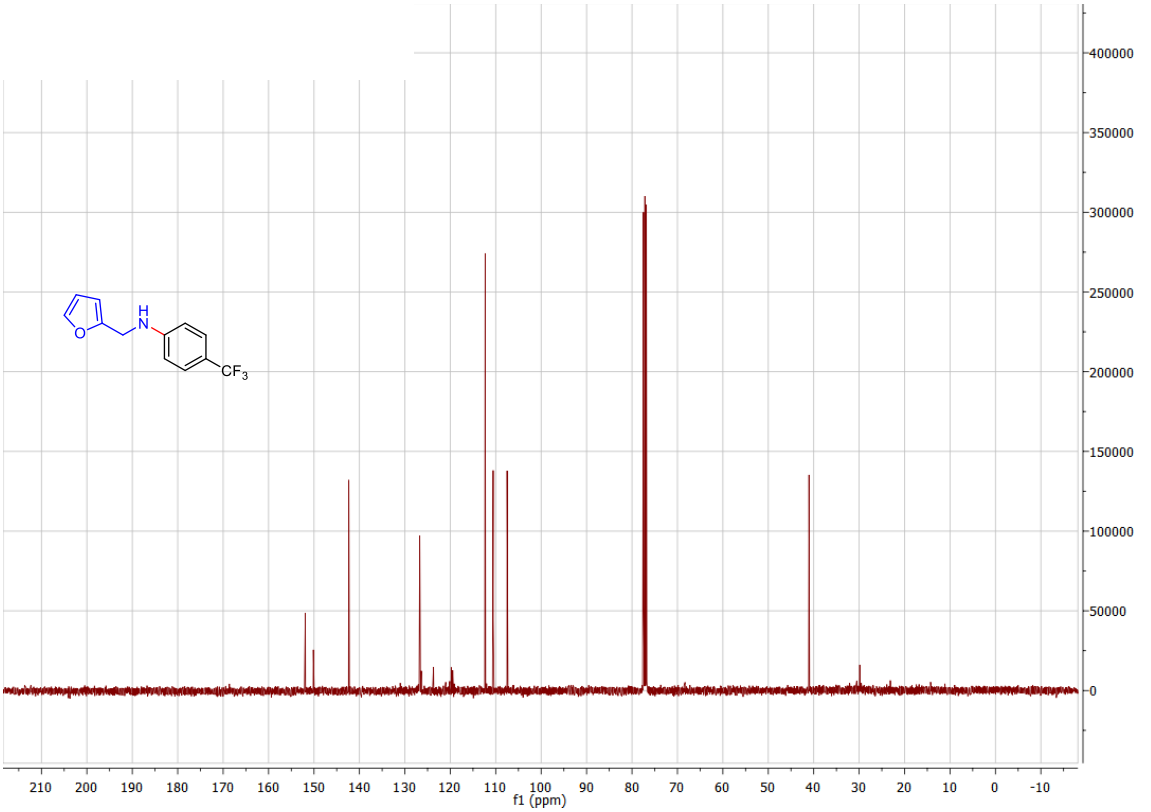


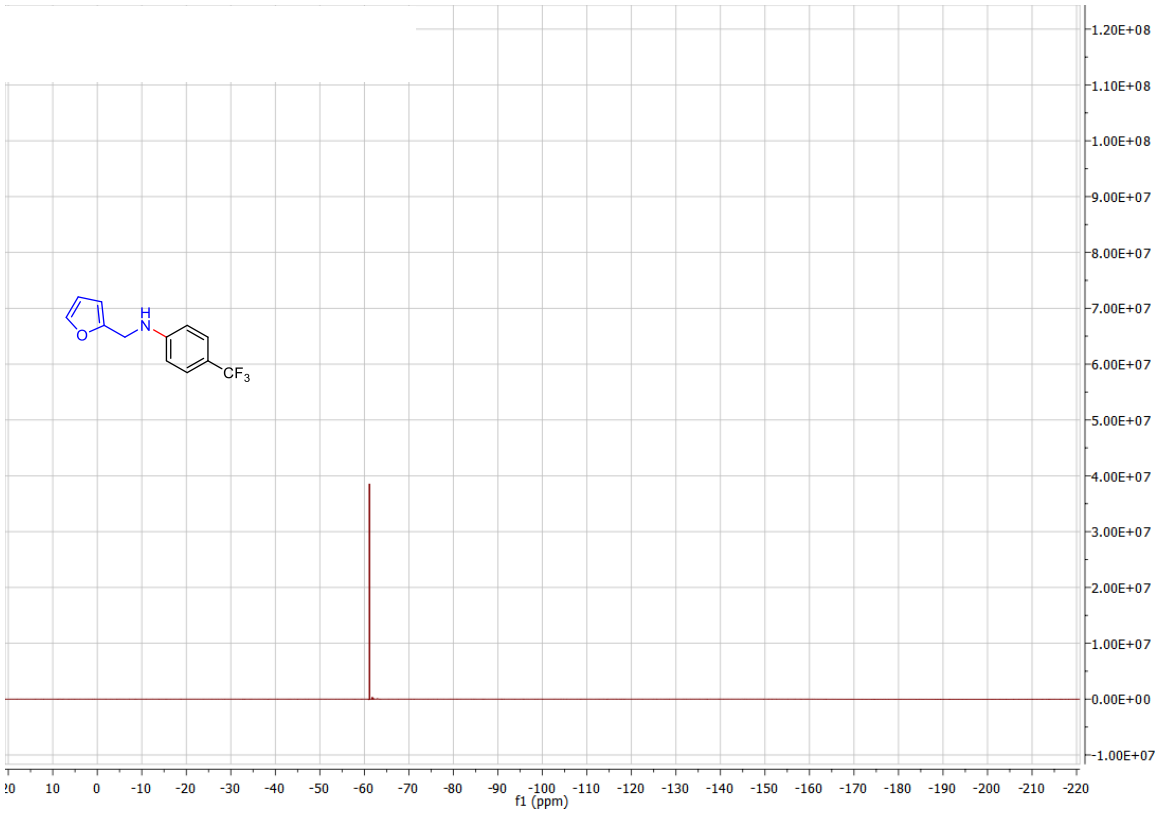



1.20E+08
1.10E+08
1.00E+08
9.00E+07
8.00E+07
7.00E+07
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
-1.00E+07
H
N
F
CF3
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220
f1 (ppm)

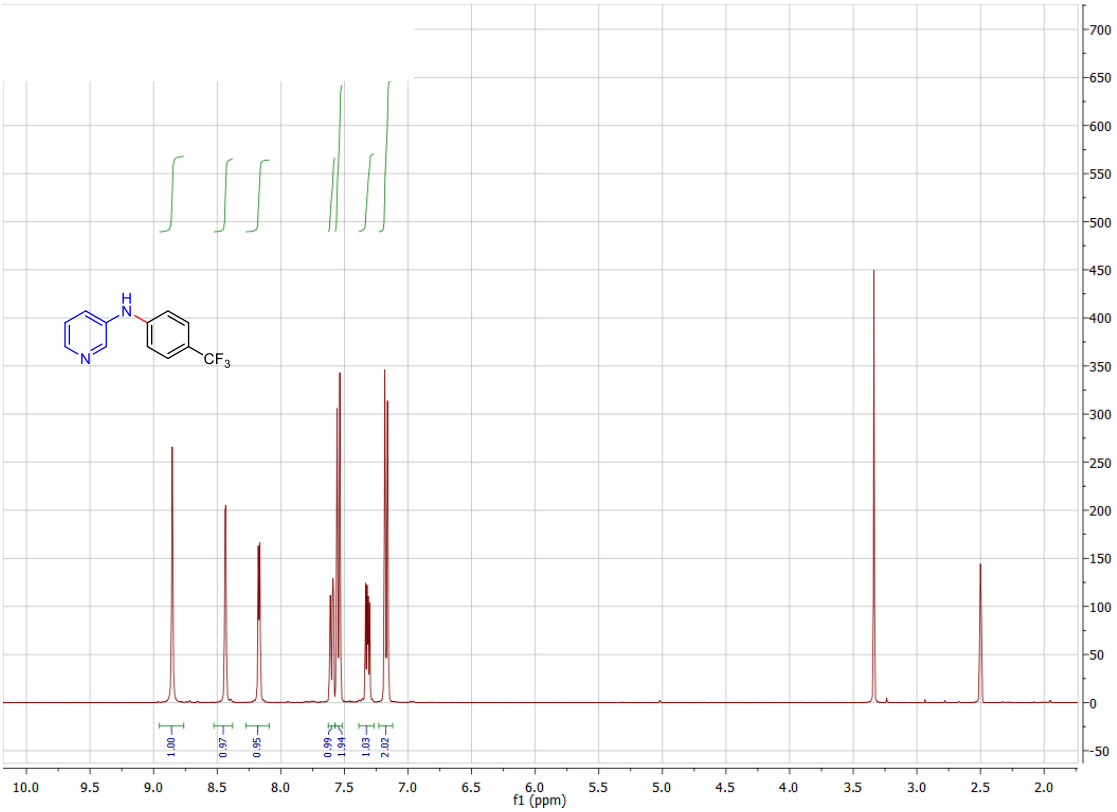
N-(furan-2-ylmethyl)-4-(trifluoromethyl)aniline (16)

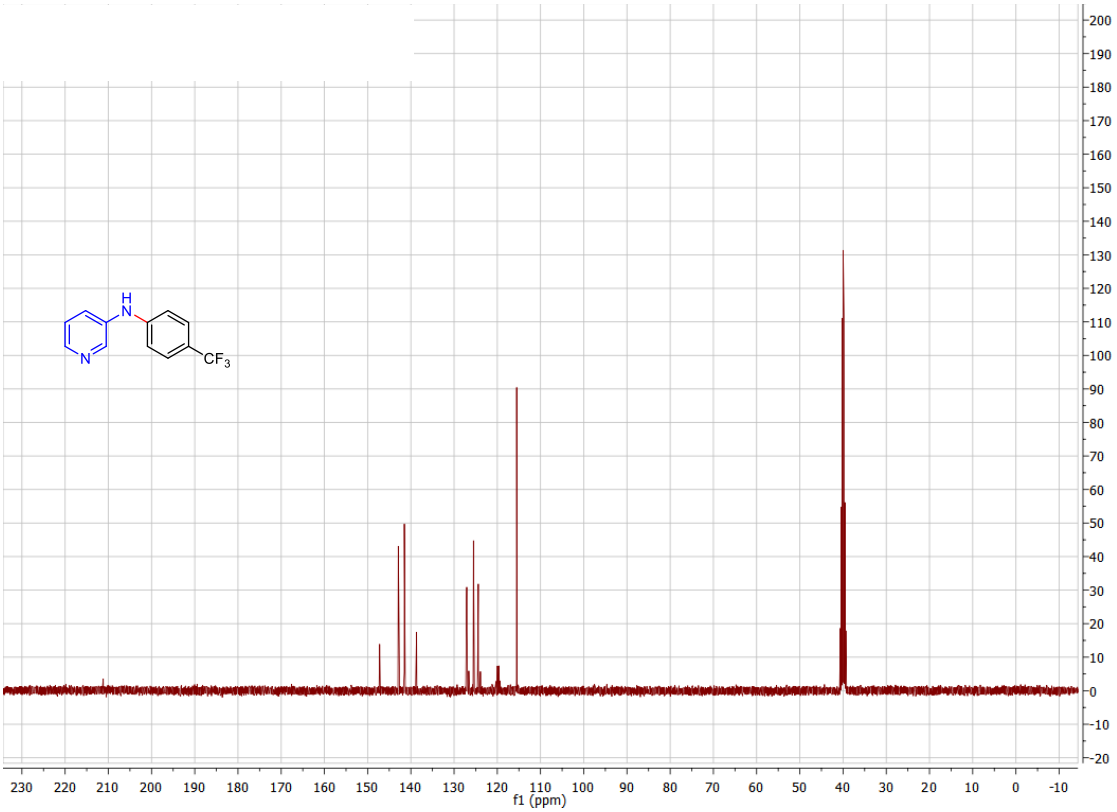


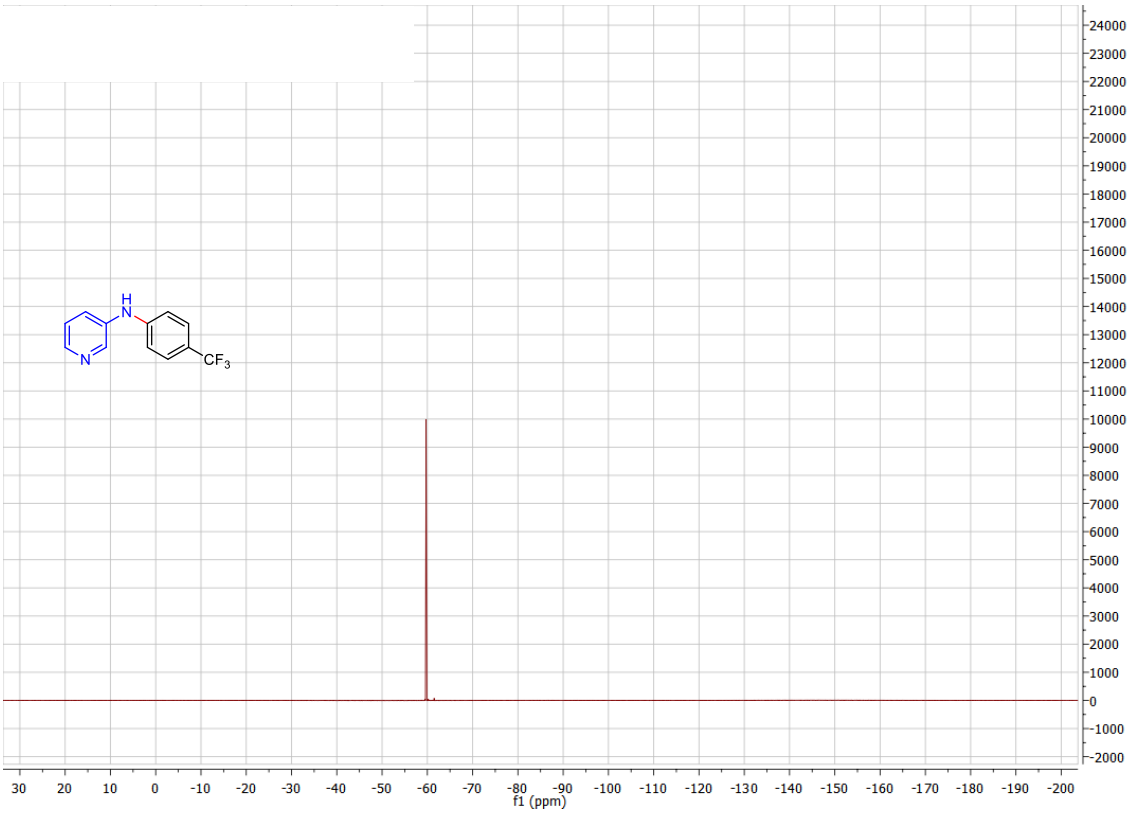



1.20E+08
1.10E+08
1.00E+08
9.00E+07
8.00E+07
7.00E+07
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
-1.00E+07
H
N
O
CF3
20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220
f1 (ppm)

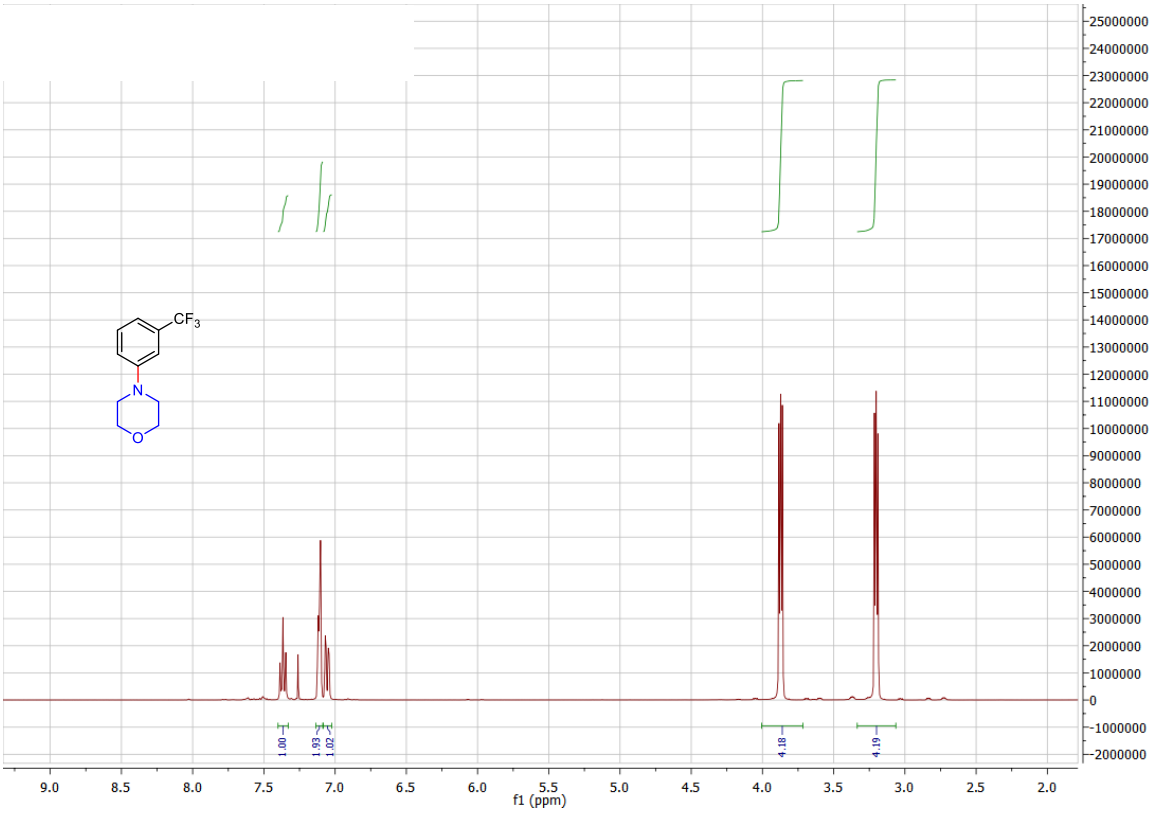
N-(4-(trifluoromethyl)phenyl)pyridin-3-amine (17)

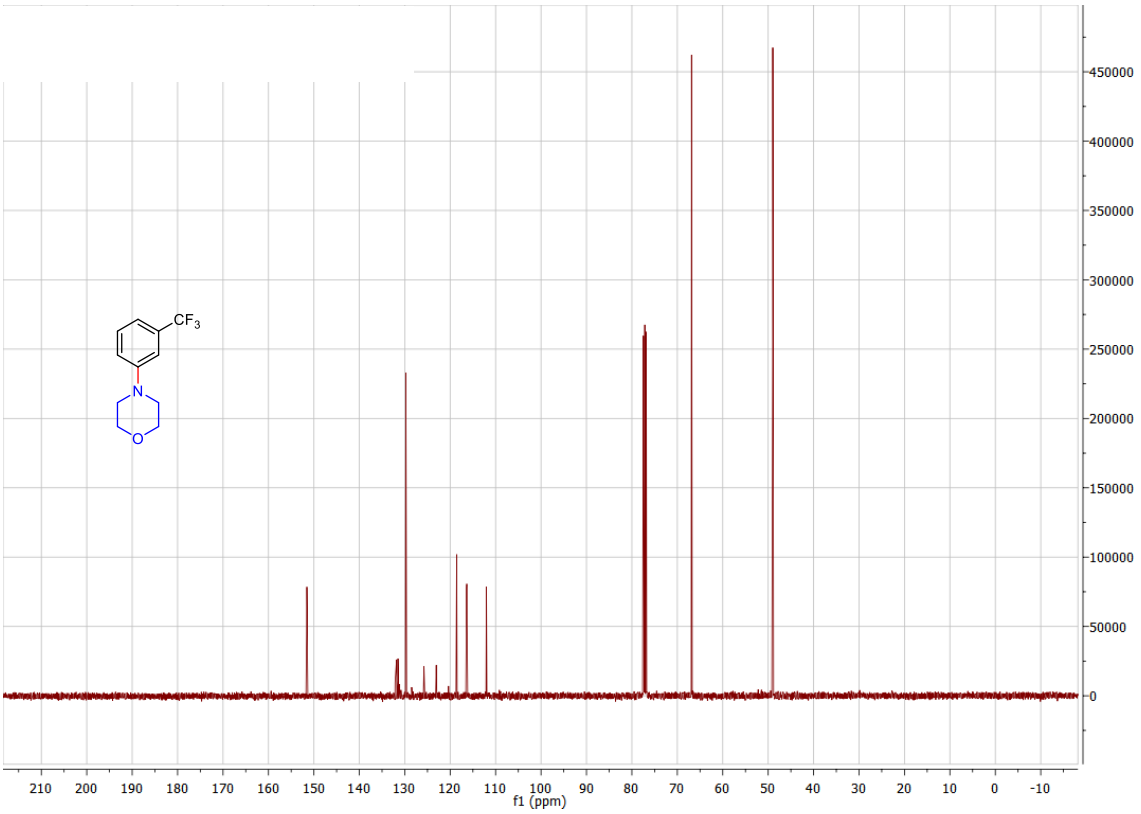


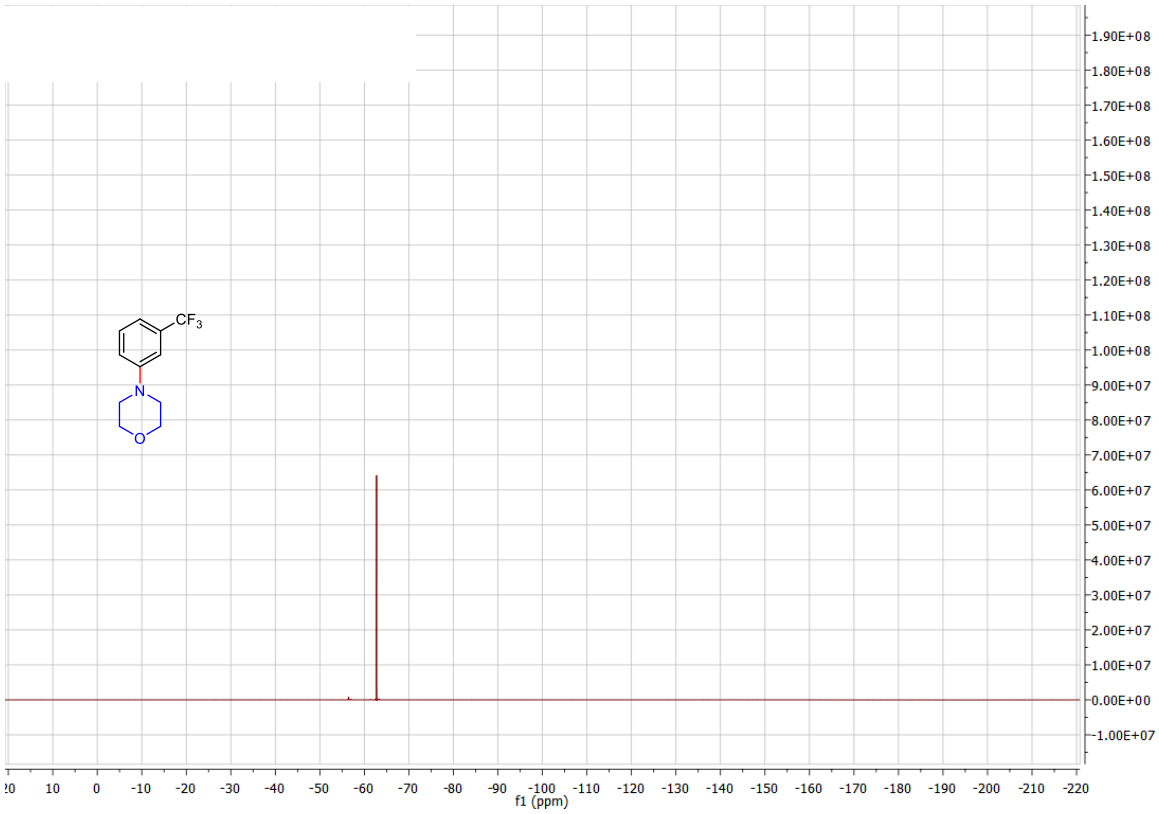



H
N
N
CF3
24000
23000
22000
21000
20000
19000
18000
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
-2000
30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200
f1 (ppm)

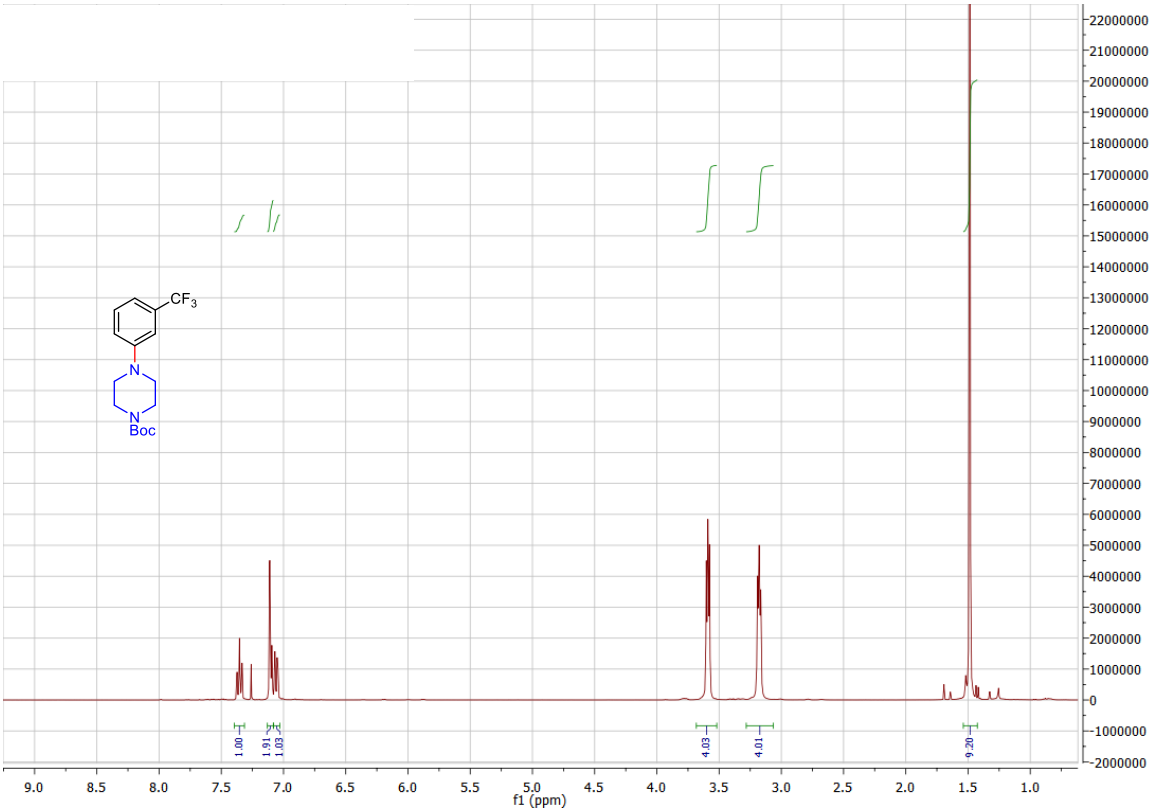
4-(3-(trifluoromethyl)phenyl)morpholine (18)

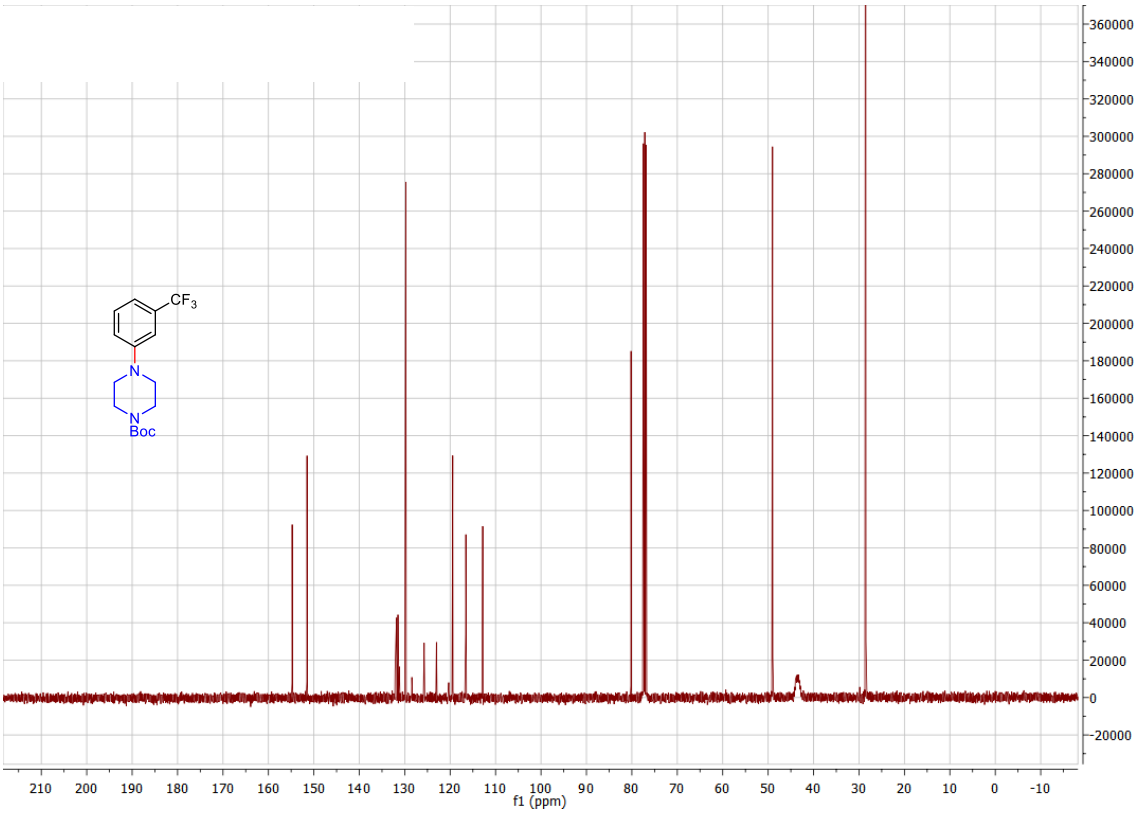


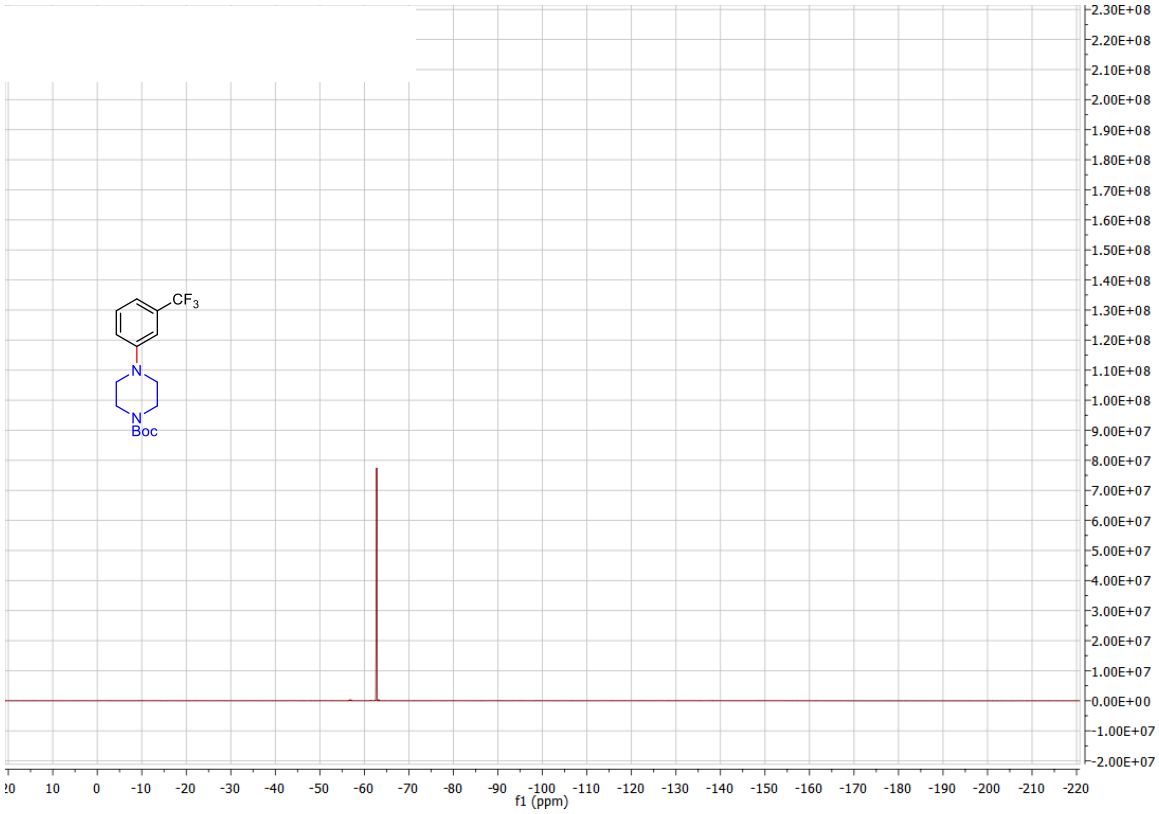



CF3
N
O
1.90E+08
1.80E+08
1.70E+08
1.60E+08
1.50E+08
1.40E+08
1.30E+08
1.20E+08
1.10E+08
1.00E+08
9.00E+07
8.00E+07
7.00E+07
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
-1.00E+07
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220
f1 (ppm)

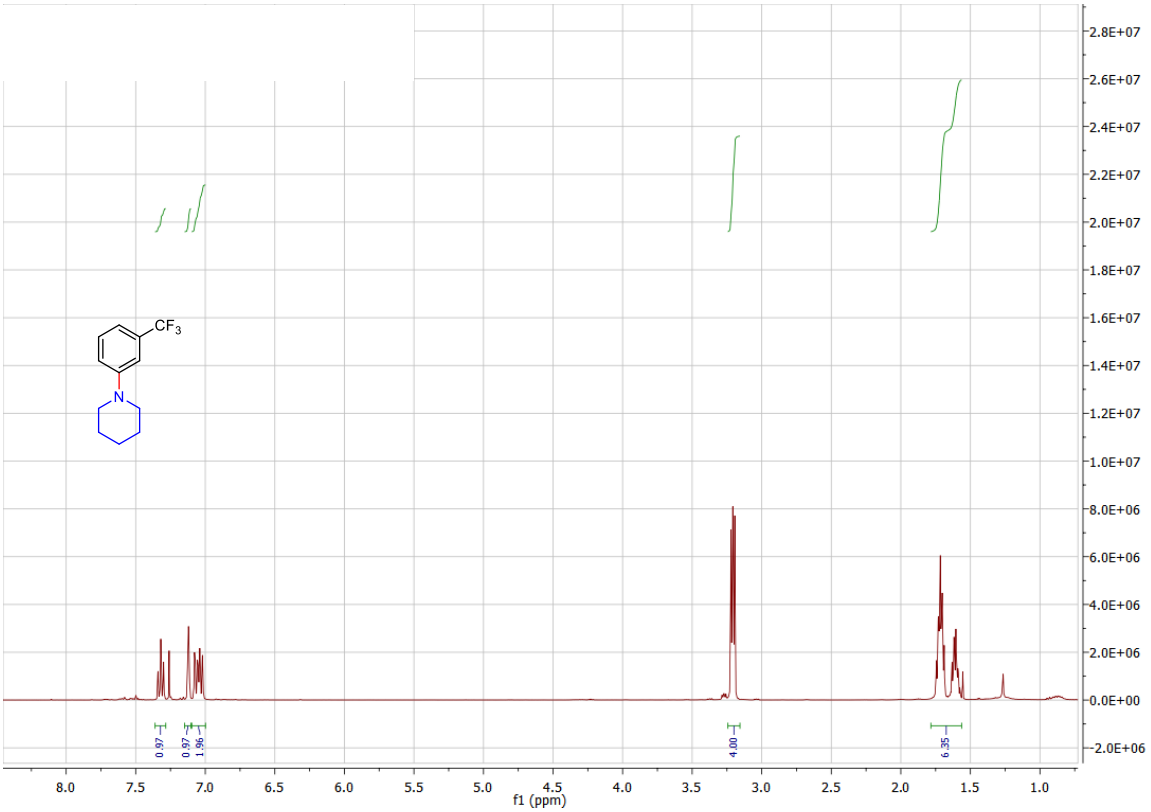
tert-butyl 4-(3-(trifluoromethyl)phenyl)piperazine-1-carboxylate (19)

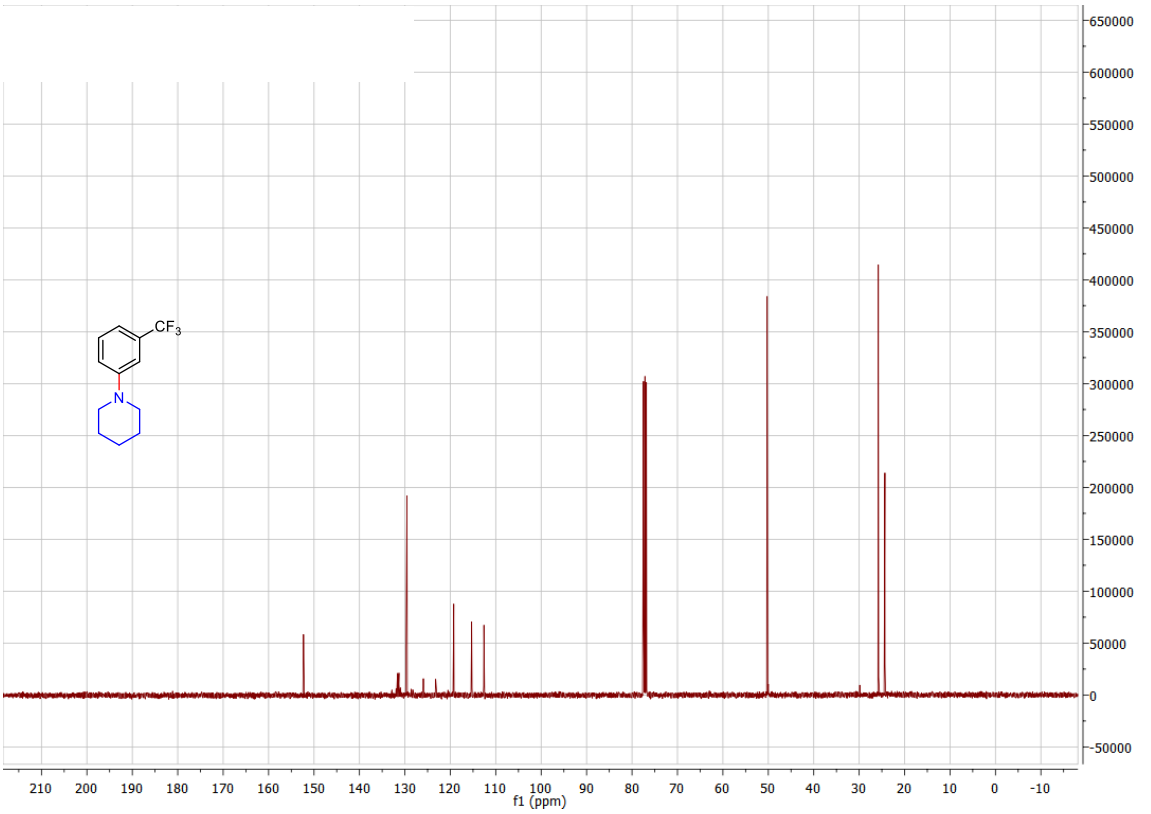


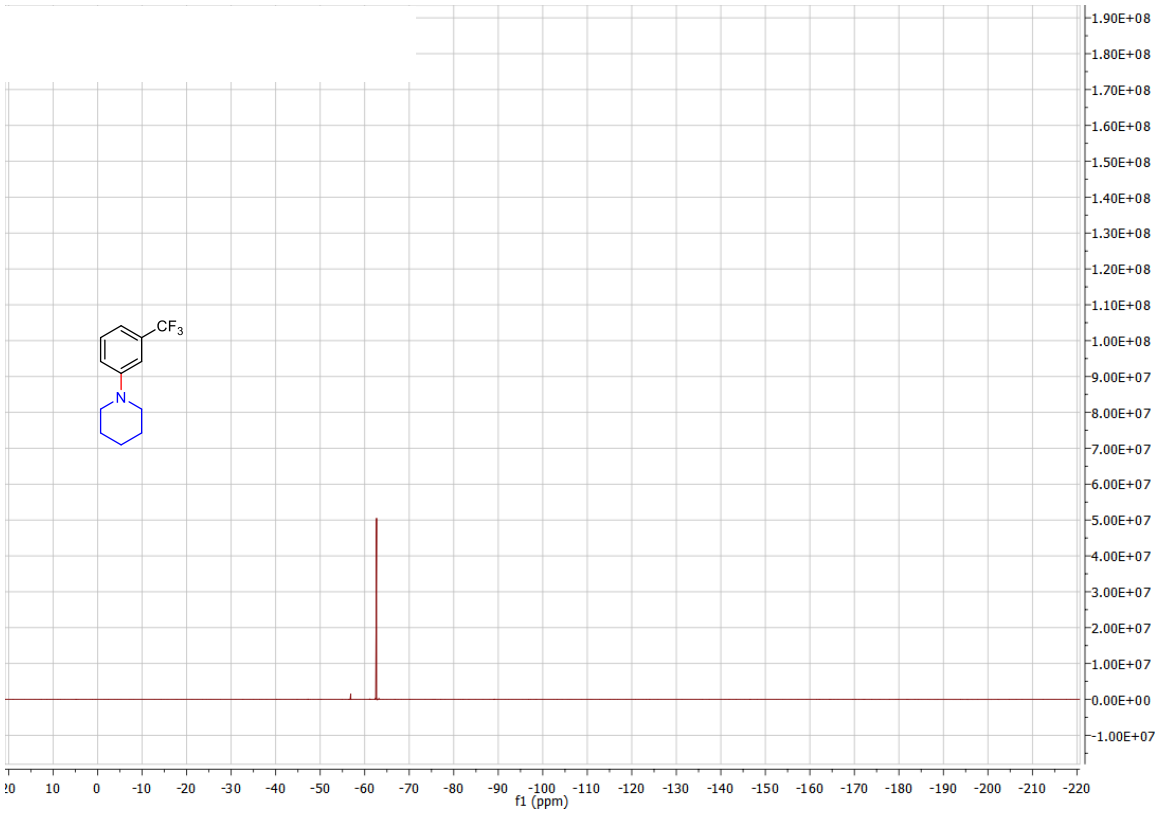



CF3
N
N
Boc
2.30E+08
2.20E+08
2.10E+08
2.00E+08
1.90E+08
1.80E+08
1.70E+08
1.60E+08
1.50E+08
1.40E+08
1.30E+08
1.20E+08
1.10E+08
1.00E+08
9.00E+07
8.00E+07
7.00E+07
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
-1.00E+07
-2.00E+07
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220
f1 (ppm)

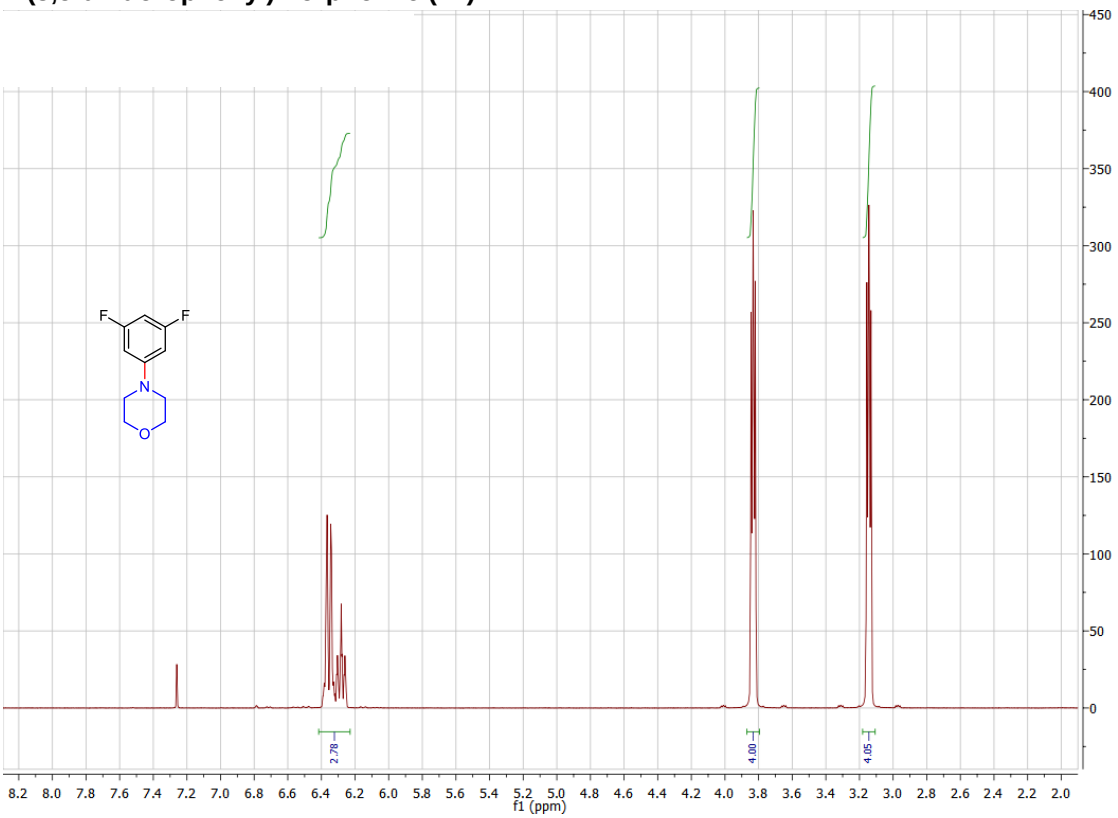
1-(3-(trifluoromethyl)phenyl)piperidine (20)

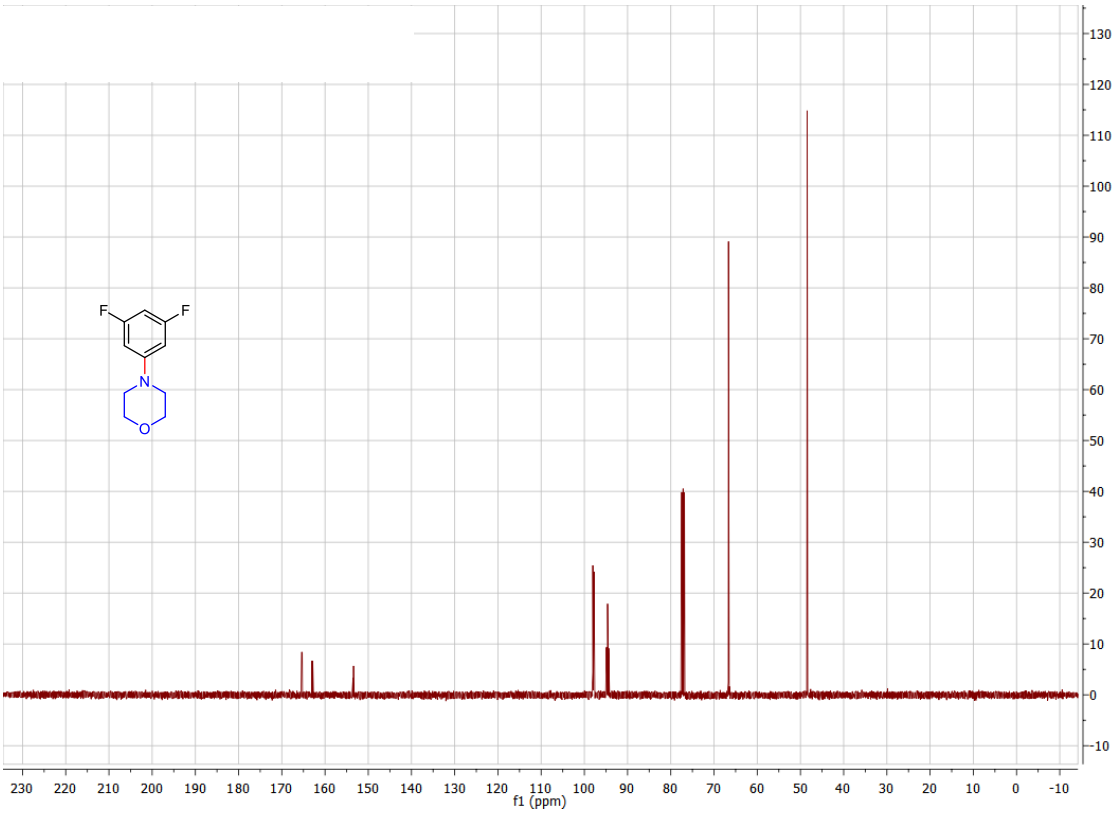


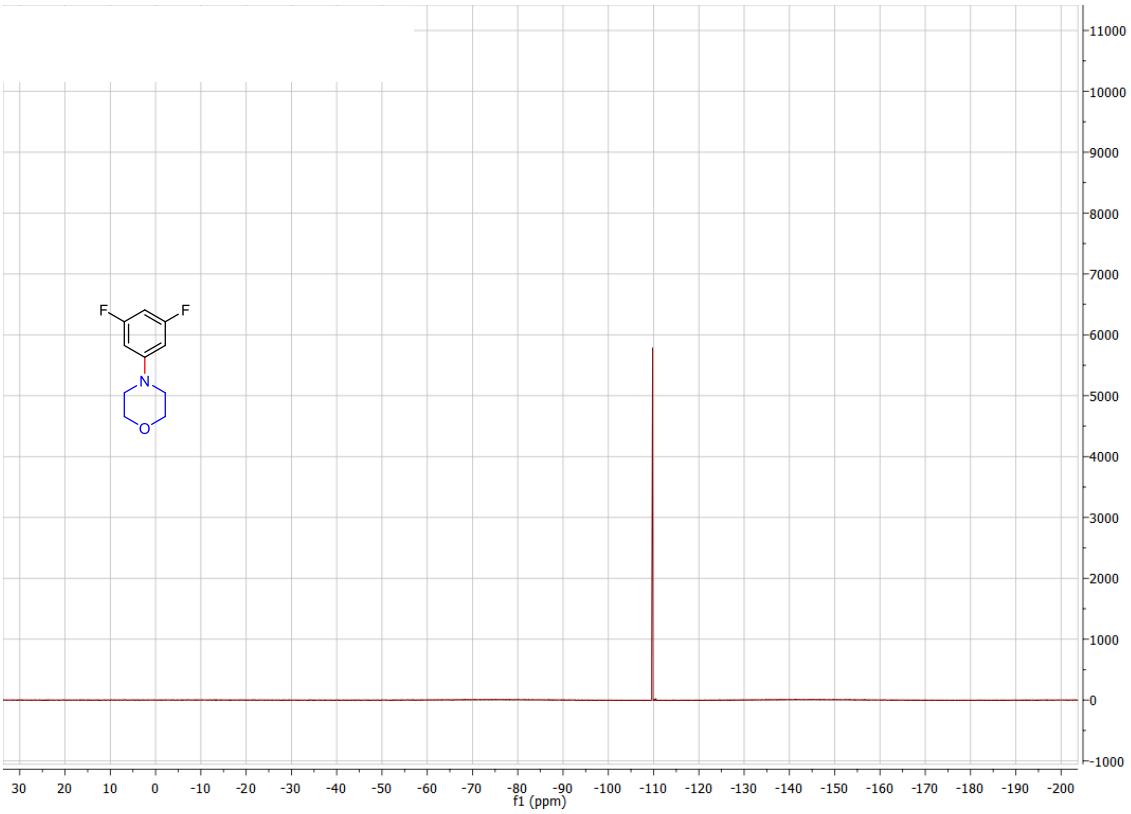



CF3
N
1.90E+08
1.80E+08
1.70E+08
1.60E+08
1.50E+08
1.40E+08
1.30E+08
1.20E+08
1.10E+08
1.00E+08
9.00E+07
8.00E+07
7.00E+07
6.00E+07
5.00E+07
4.00E+07
3.00E+07
2.00E+07
1.00E+07
0.00E+00
-1.00E+07
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220
f1 (ppm)

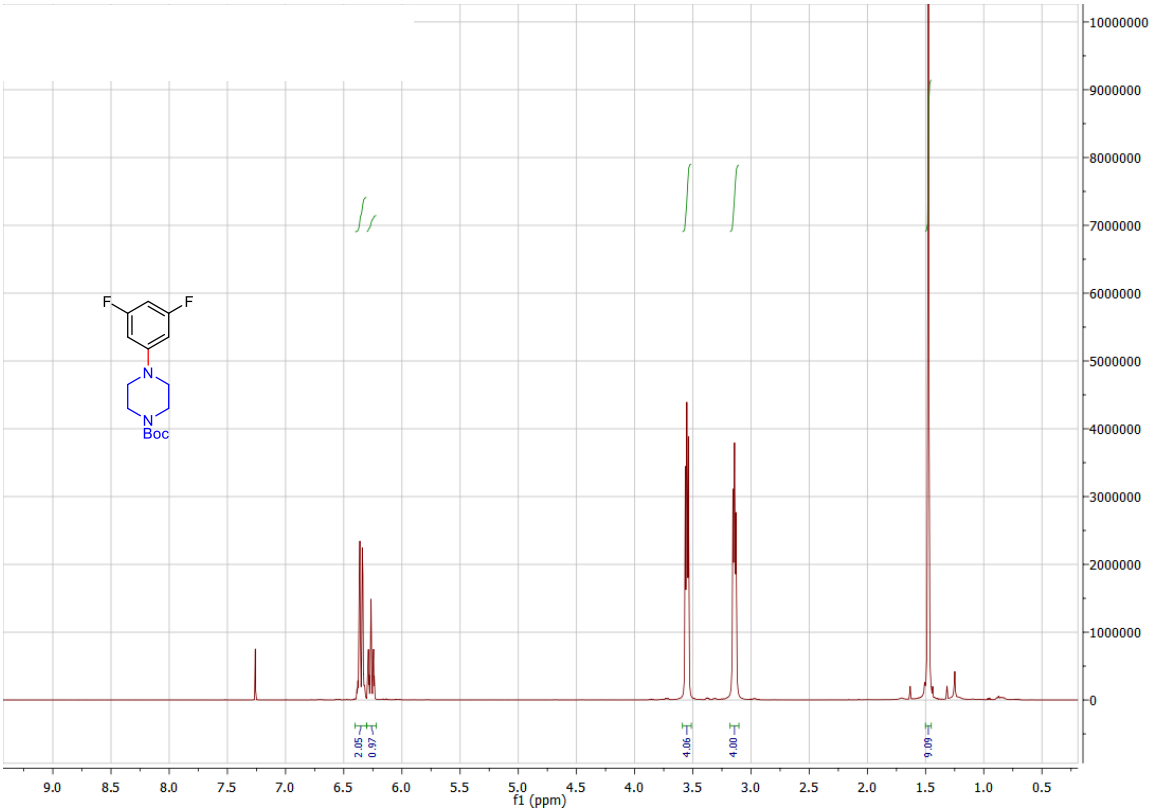
4-(3,5-difluorophenyl)morpholine (21)

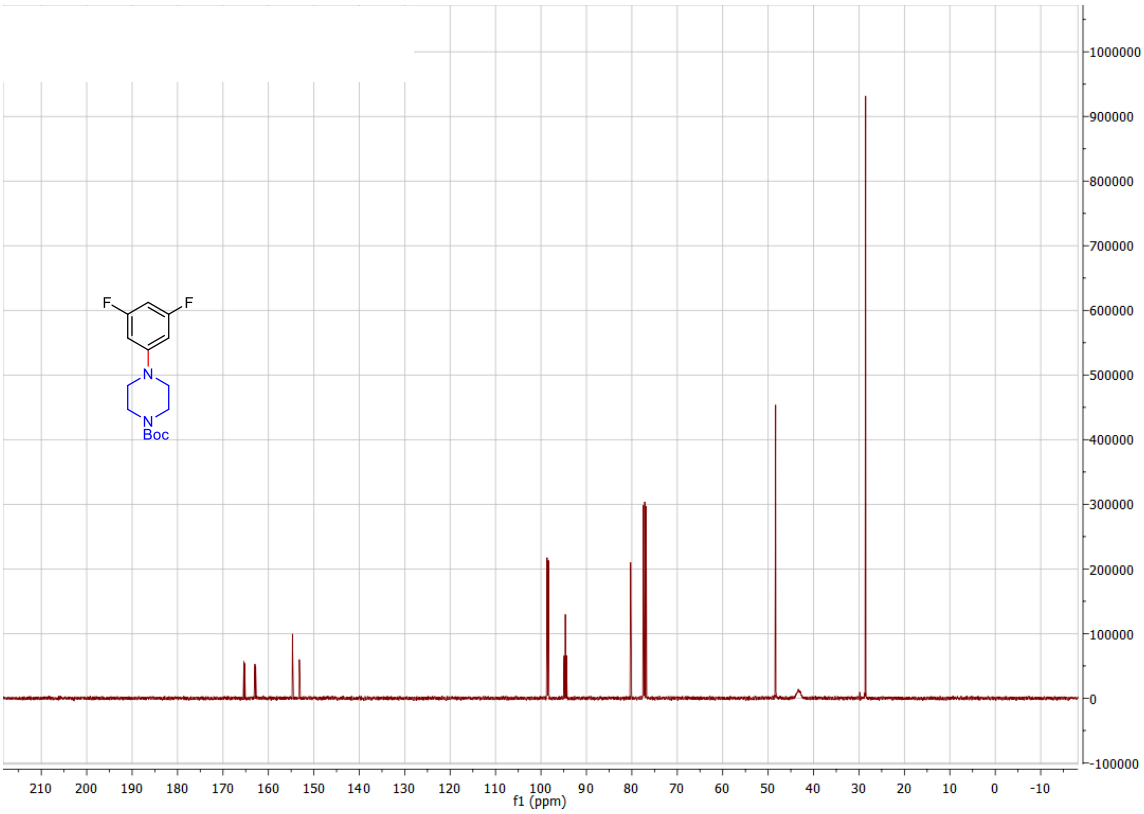


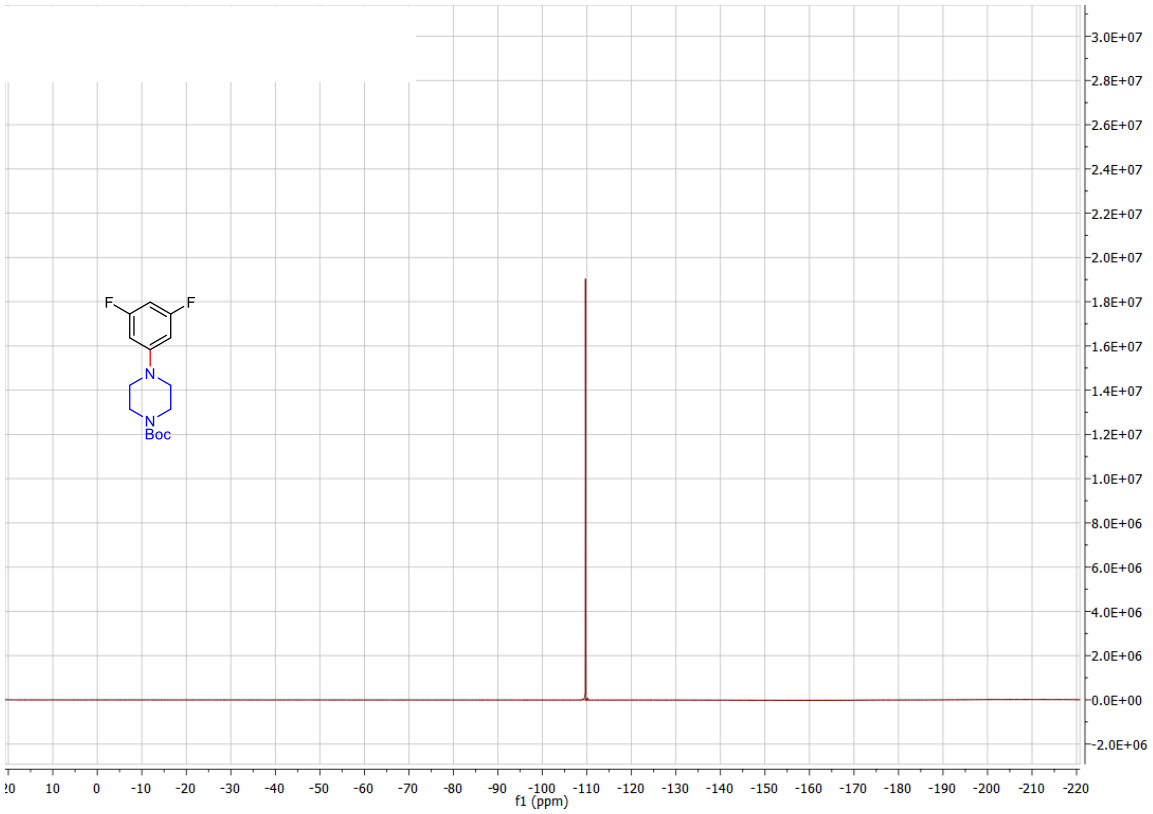



F
F
N
O
11000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
-1000
30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200
f1 (ppm)

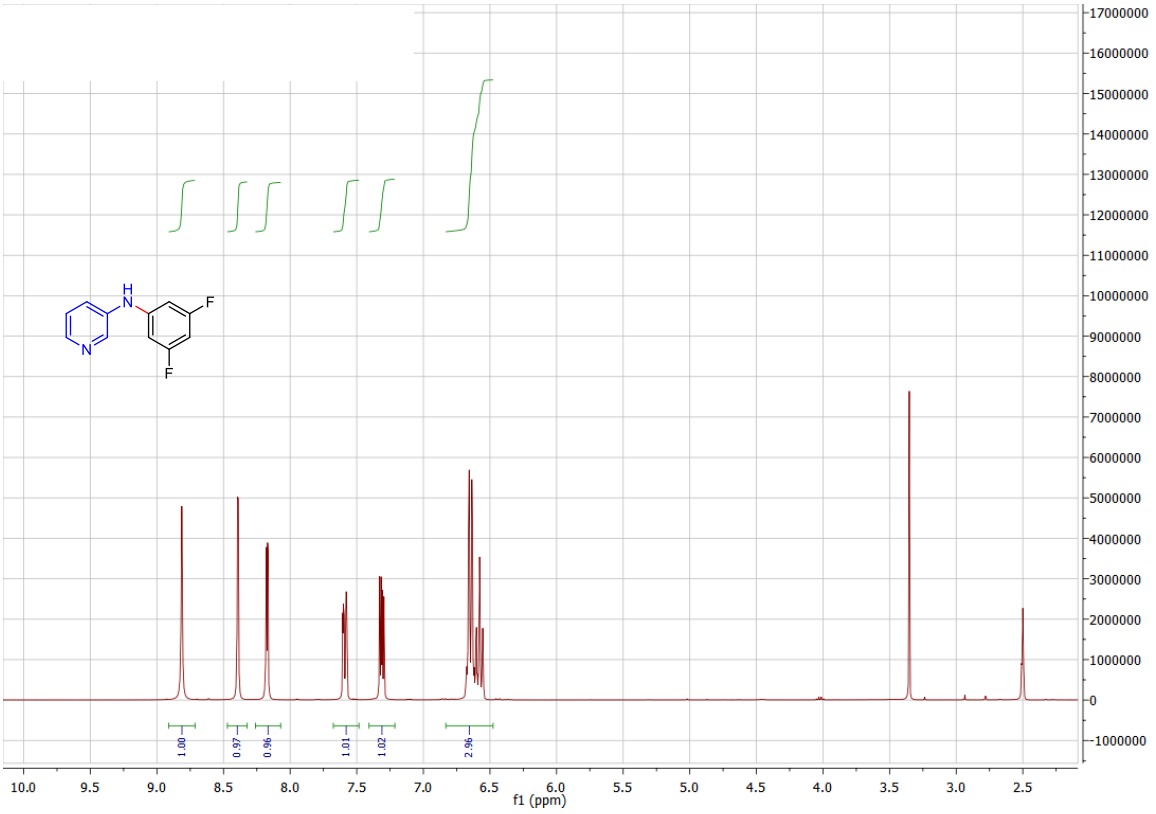
***tert*-butyl 4-(3,5-difluorophenyl)piperazine-1-carboxylate (22)**

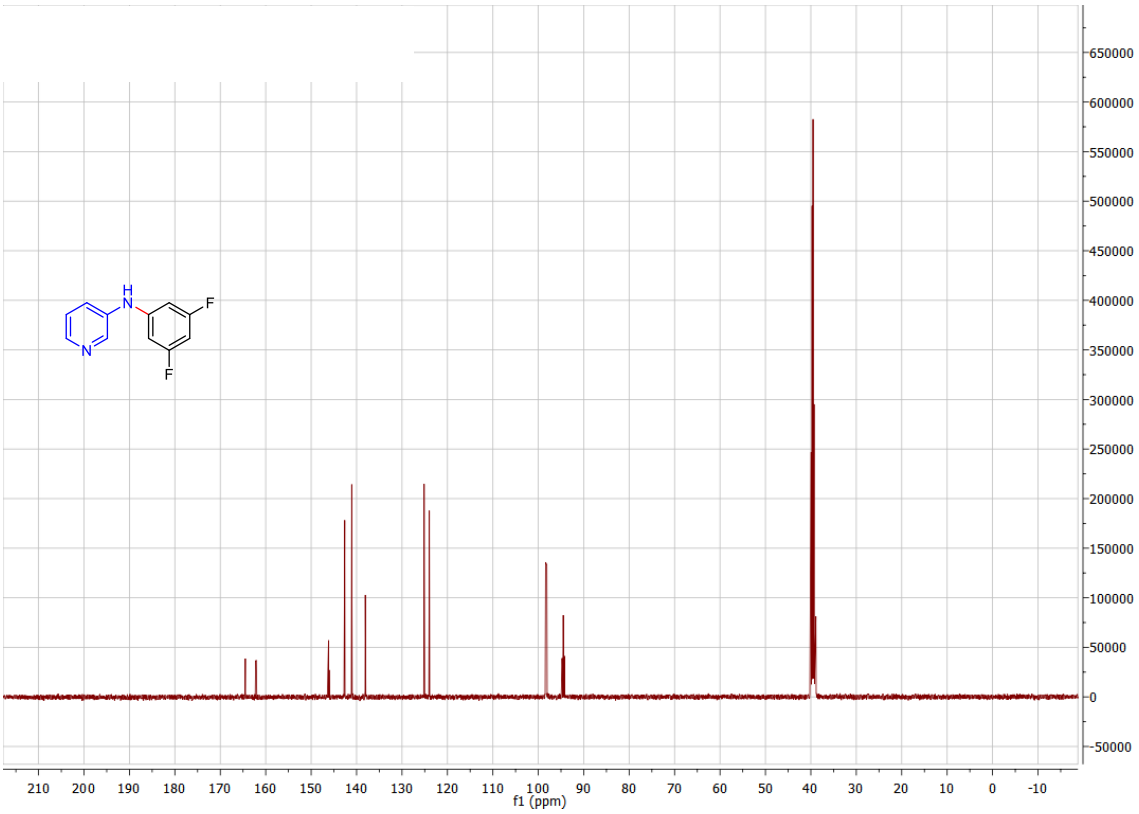


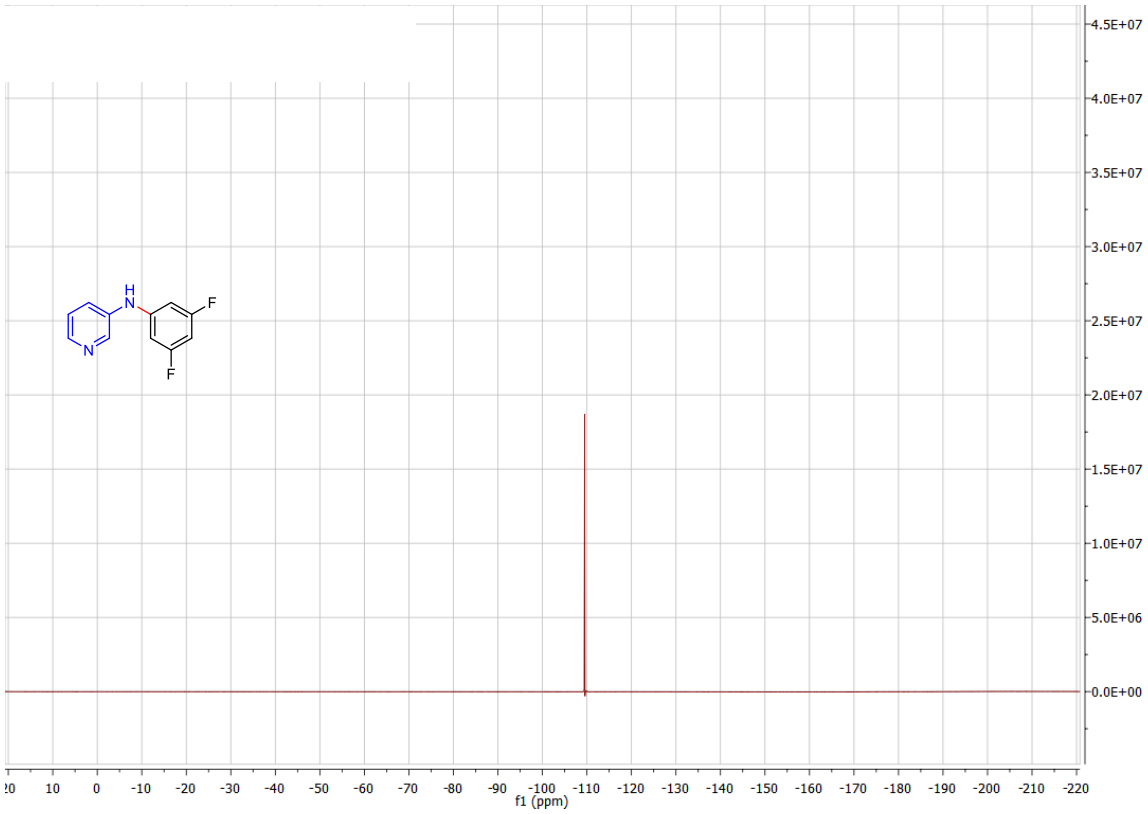



F
F
N
N
Boc
3.0E+07
2.8E+07
2.6E+07
2.4E+07
2.2E+07
2.0E+07
1.8E+07
1.6E+07
1.4E+07
1.2E+07
1.0E+07
8.0E+06
6.0E+06
4.0E+06
2.0E+06
0.0E+00
-2.0E+06
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220
f1 (ppm)

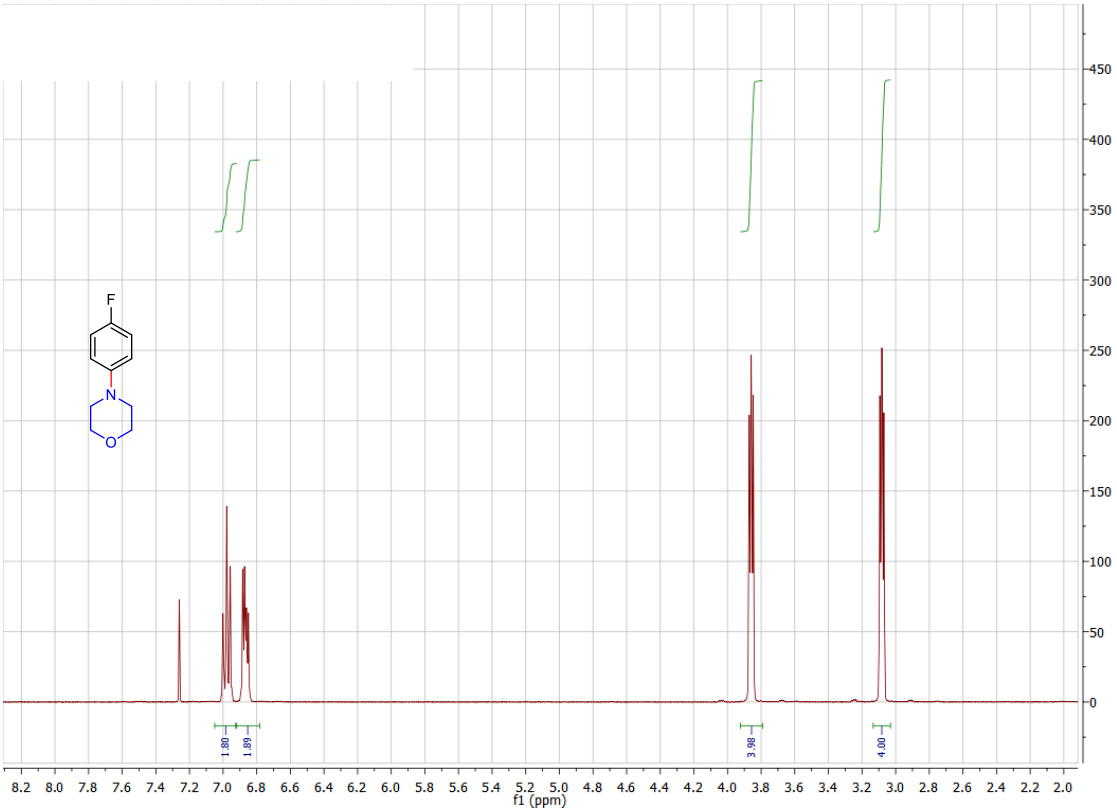
N-(3,5-difluorophenyl)pyridin-3-amine (23)

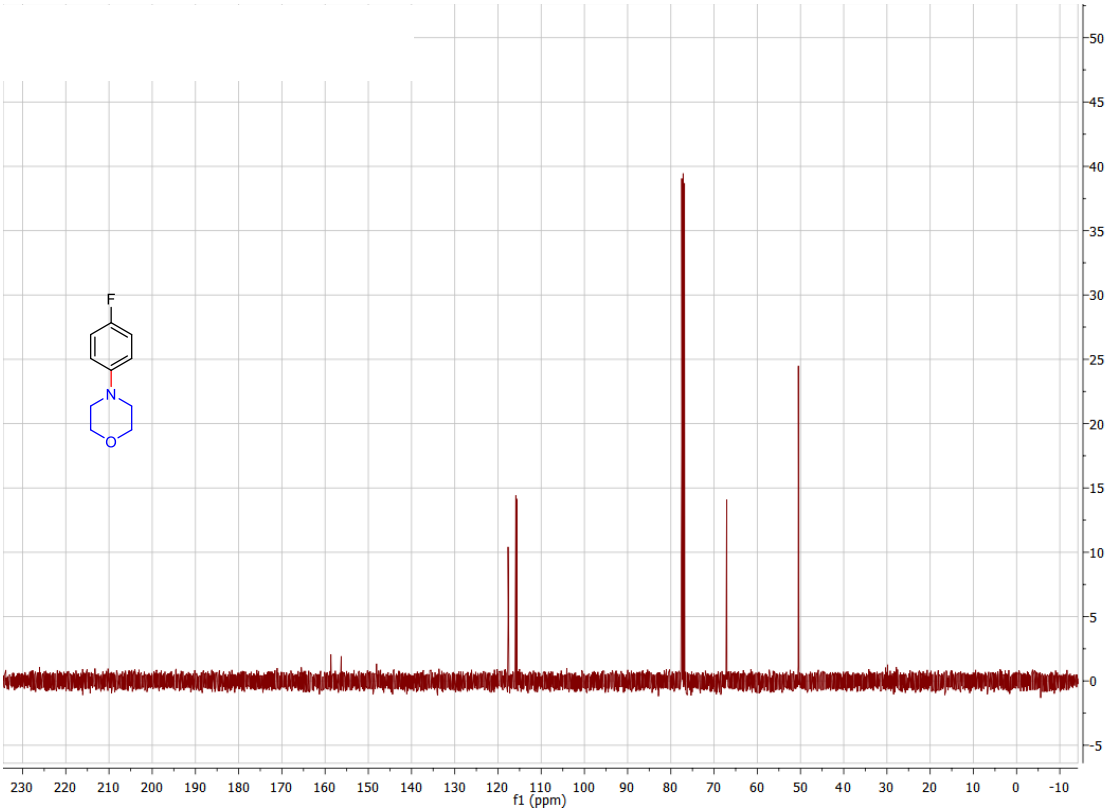


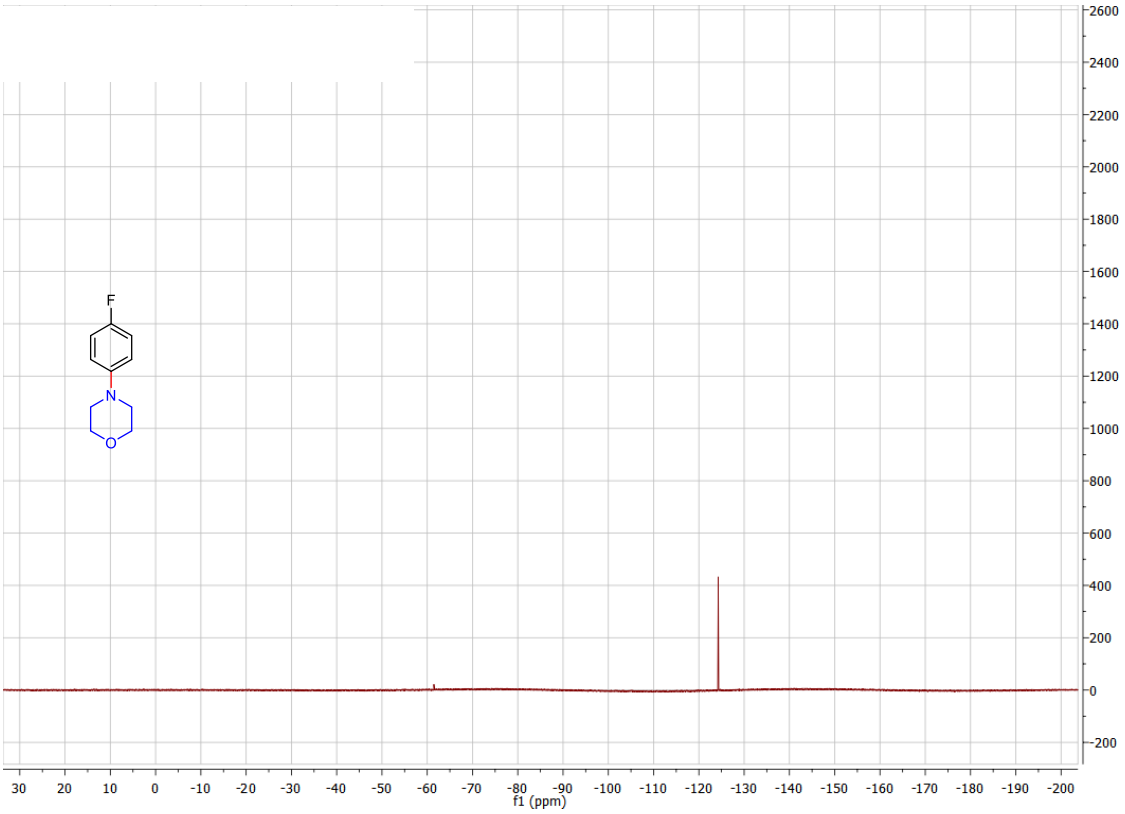



4.5E+07
4.0E+07
3.5E+07
3.0E+07
2.5E+07
2.0E+07
1.5E+07
1.0E+07
5.0E+06
0.0E+00
H
N
F
N
F
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220
f1 (ppm)

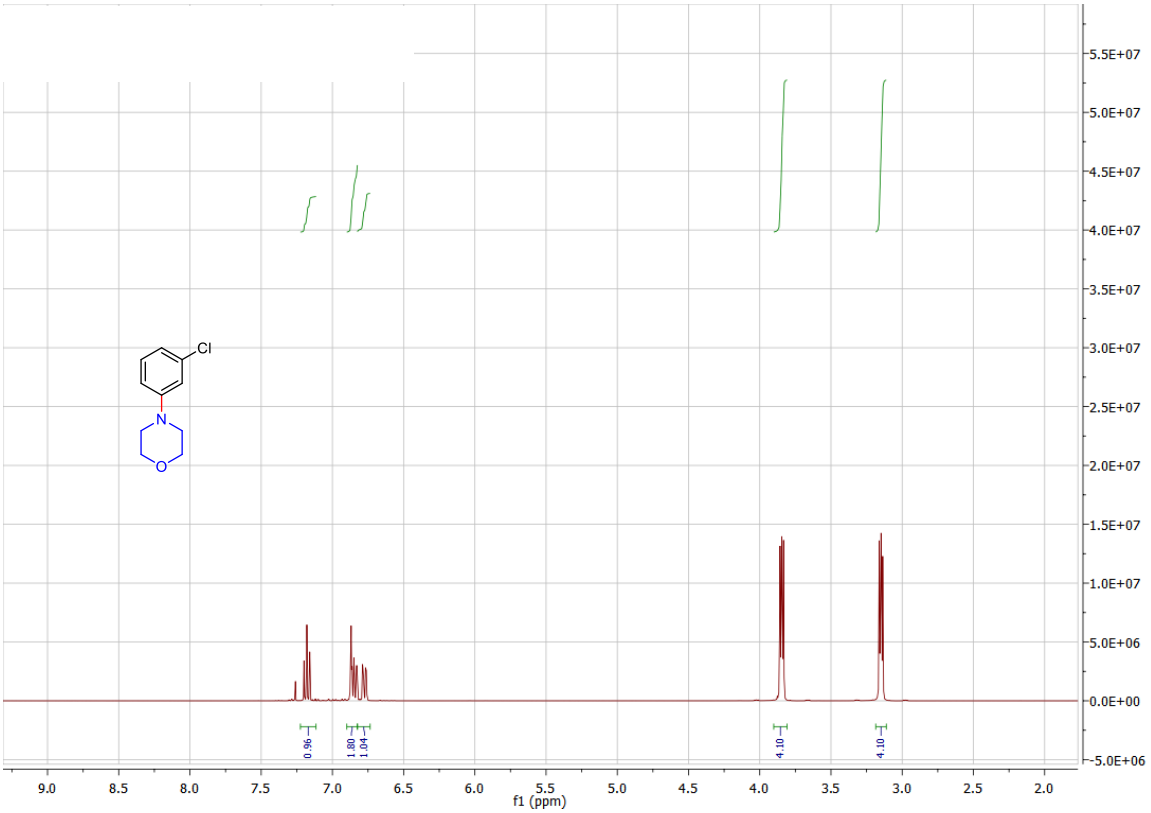
4-(4-fluorophenyl)morpholine (24)

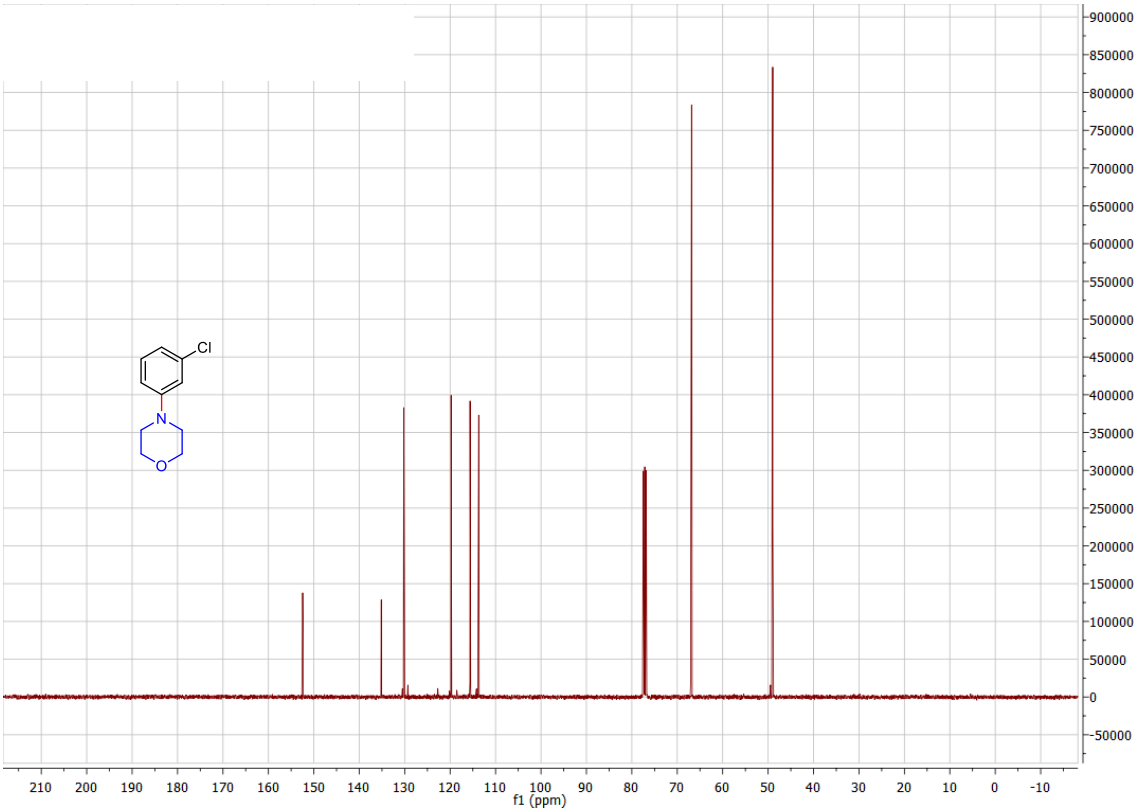




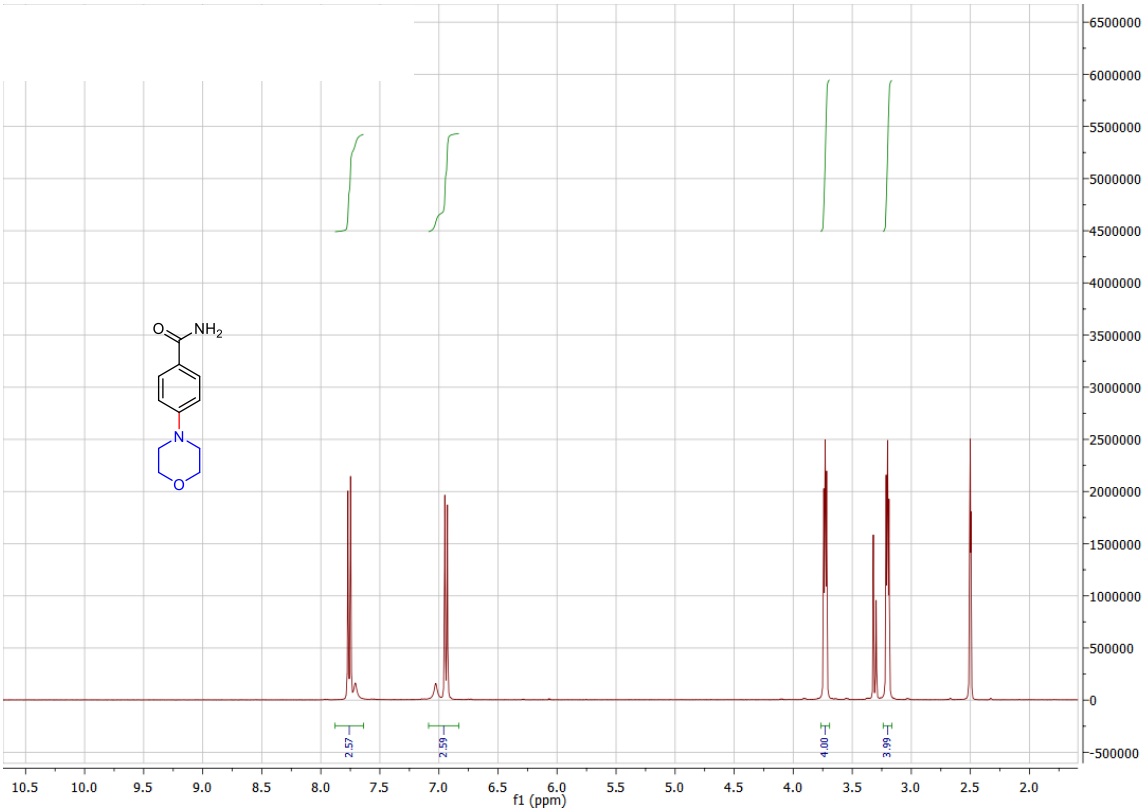

F
N
O
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
-200
30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200
f1 (ppm)

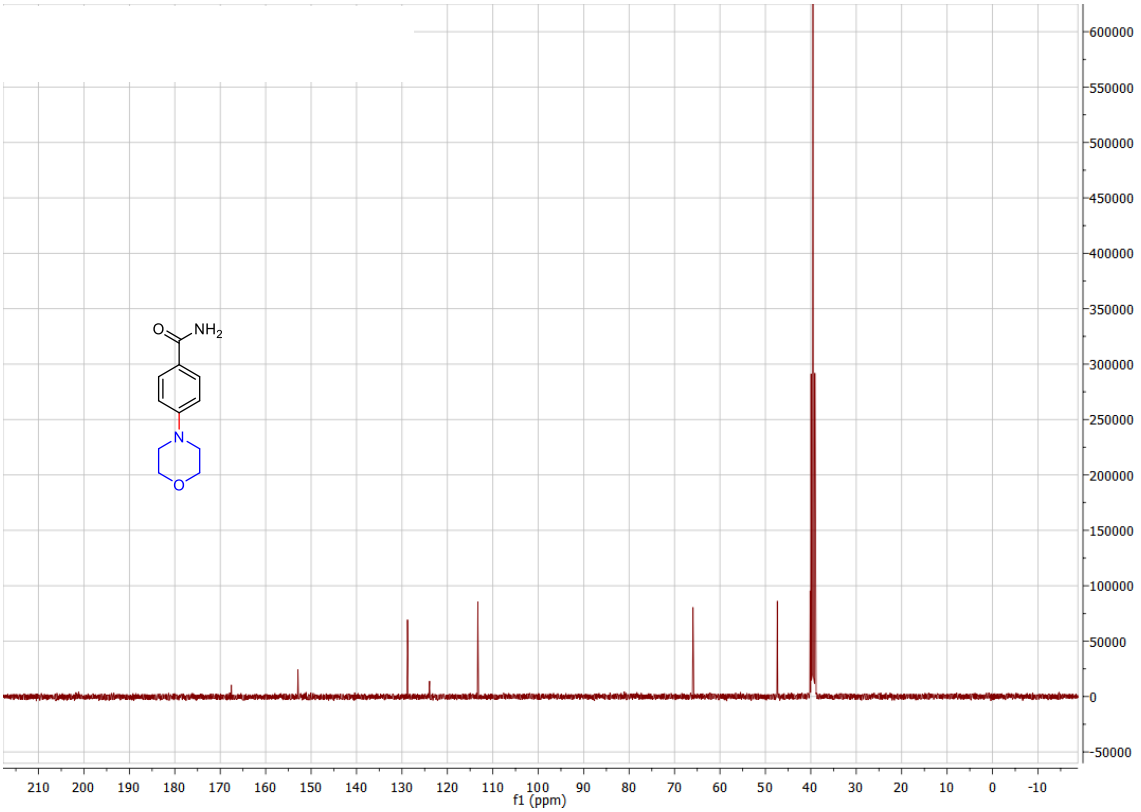
4-(3-chlorophenyl)morpholine (25)



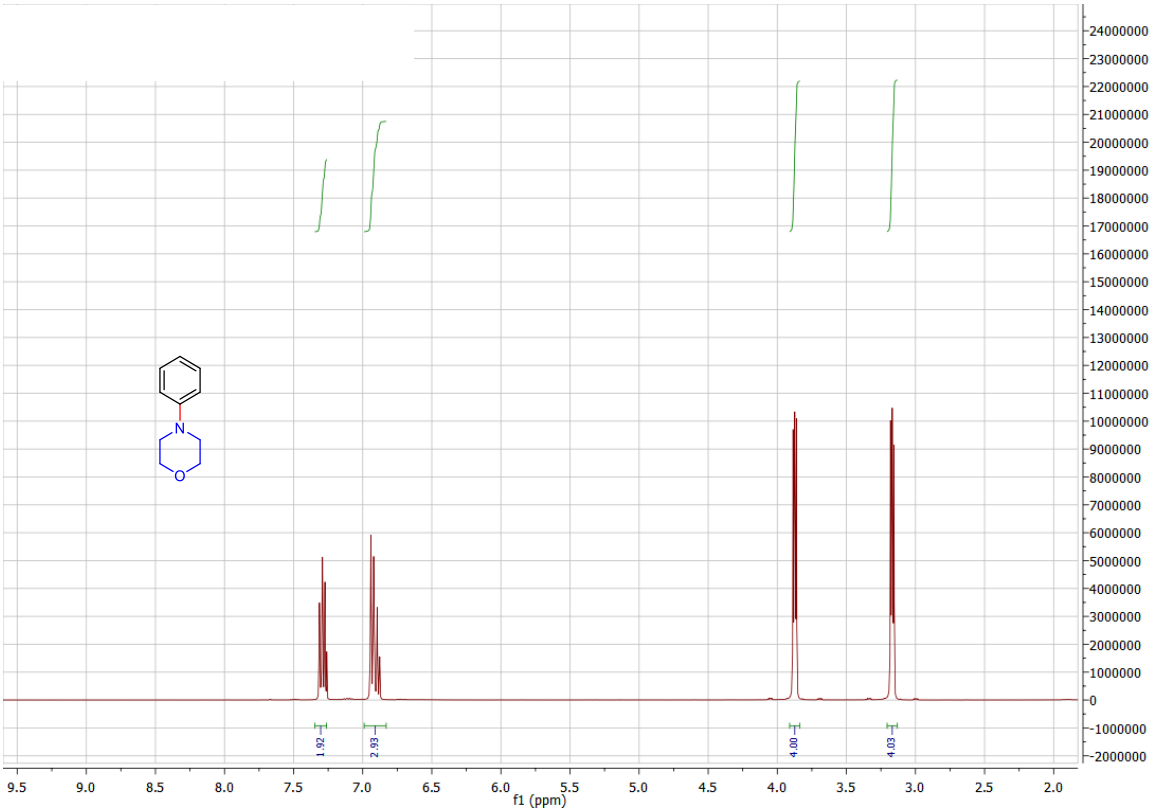


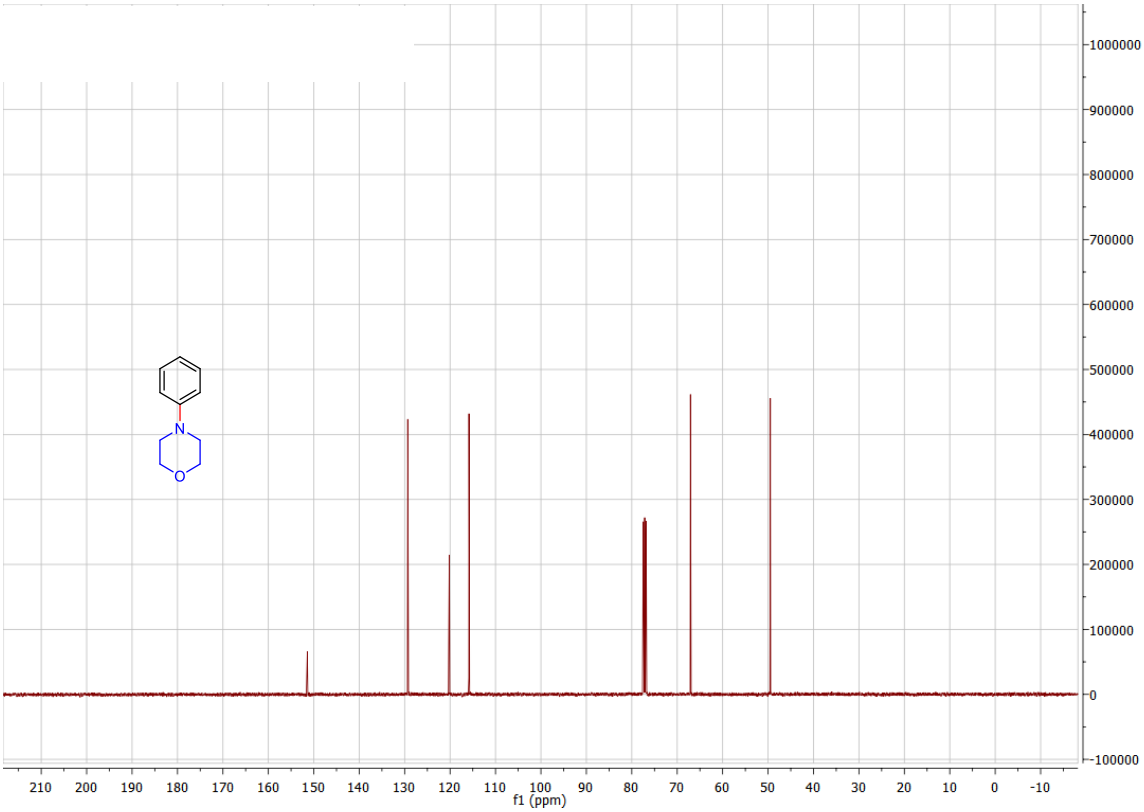
4-morpholinobenzamide (26)



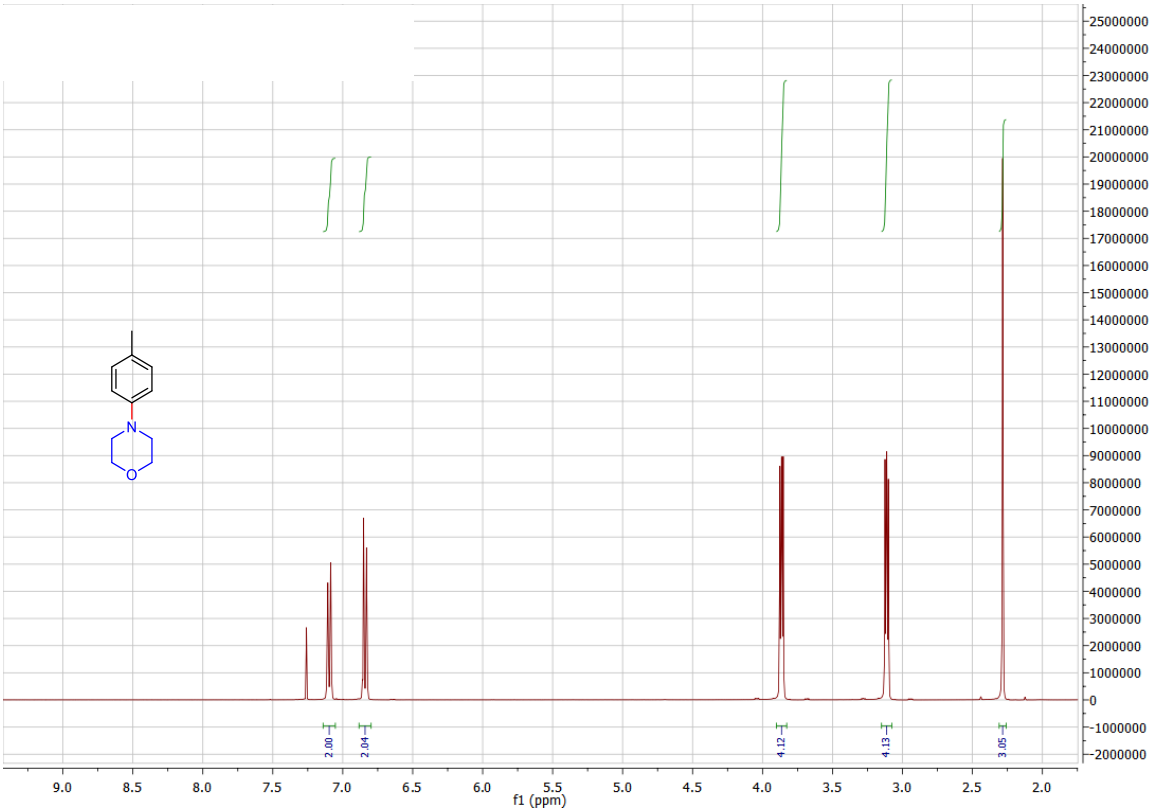


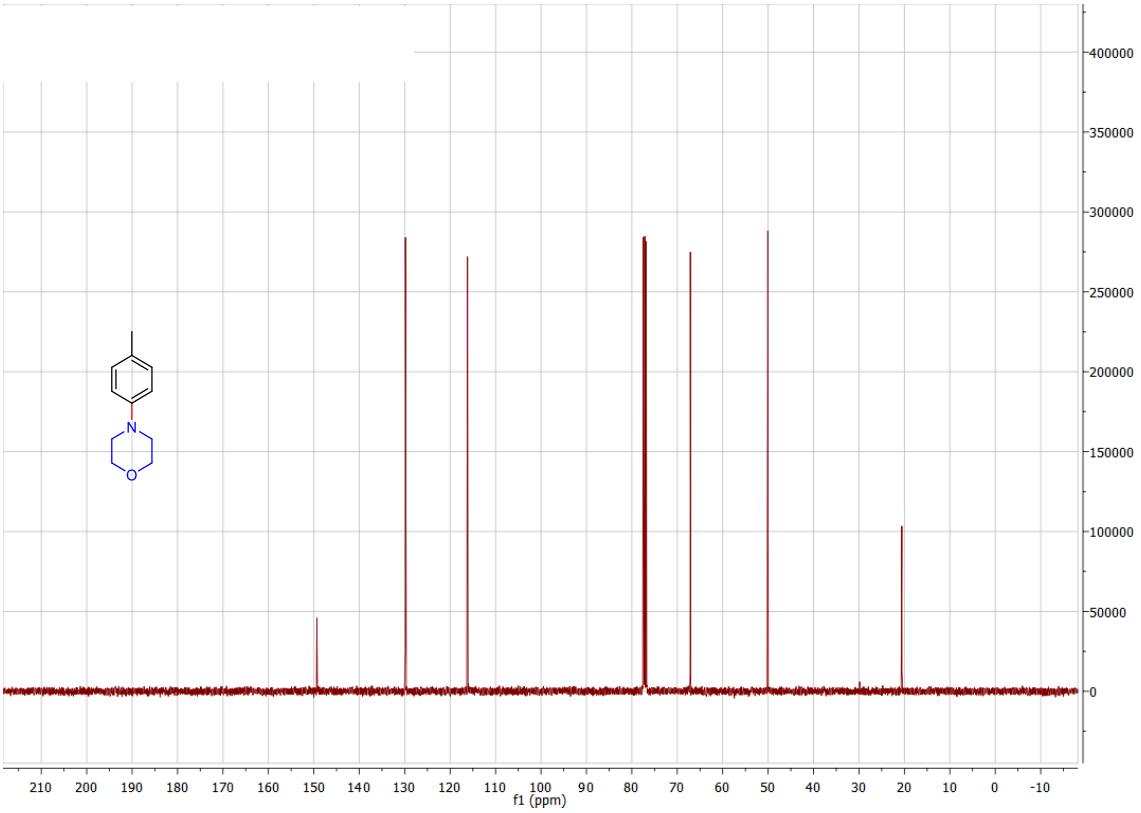
4-phenylmorpholine (27)



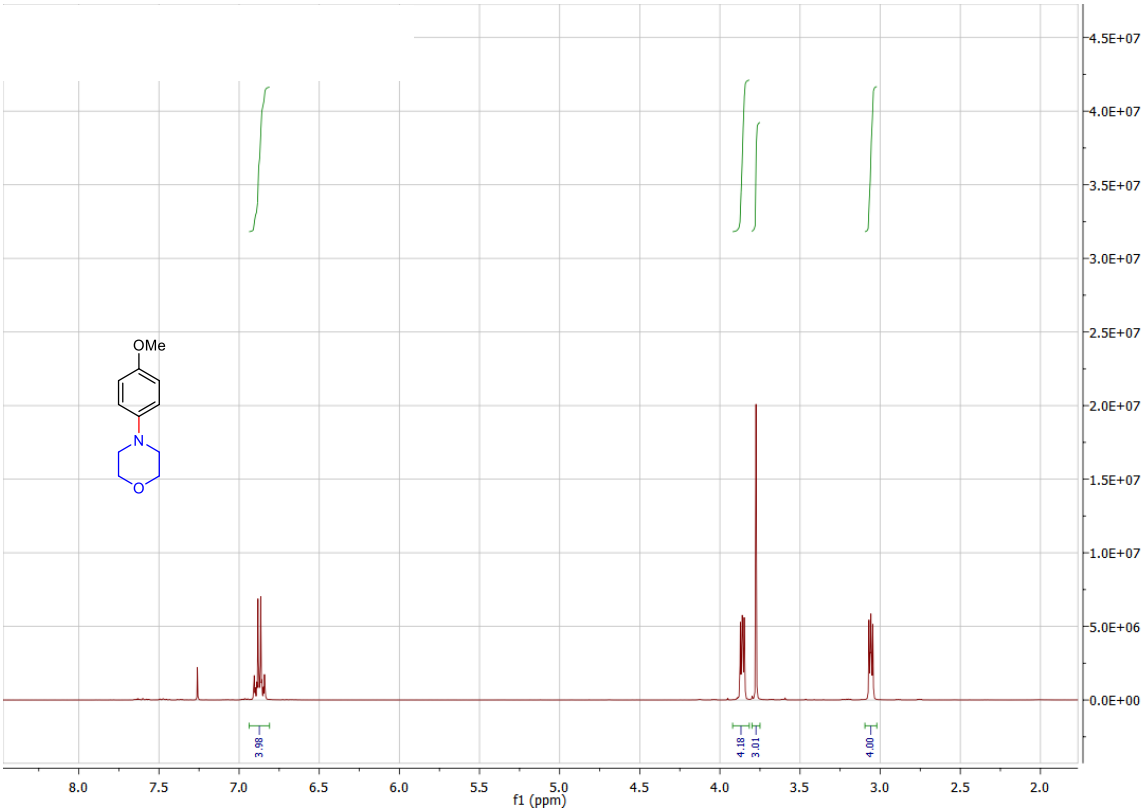


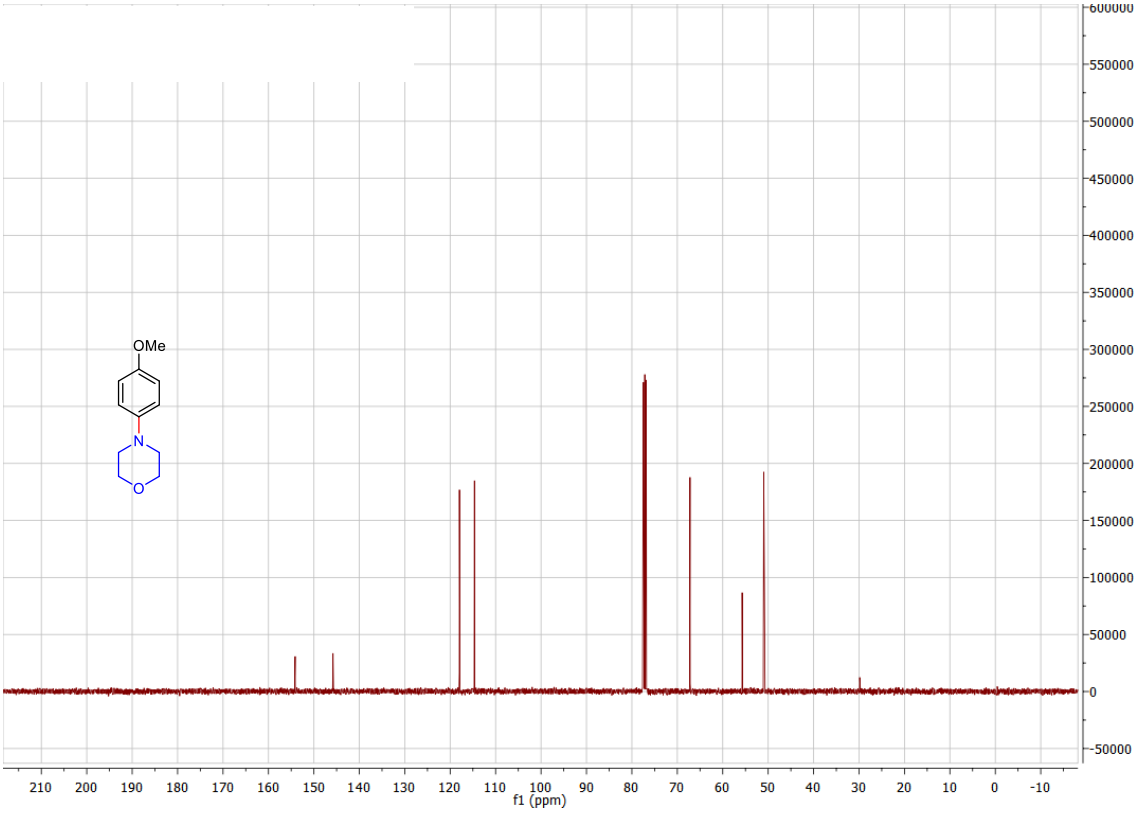
4-(p-tolyl)morpholine (28)



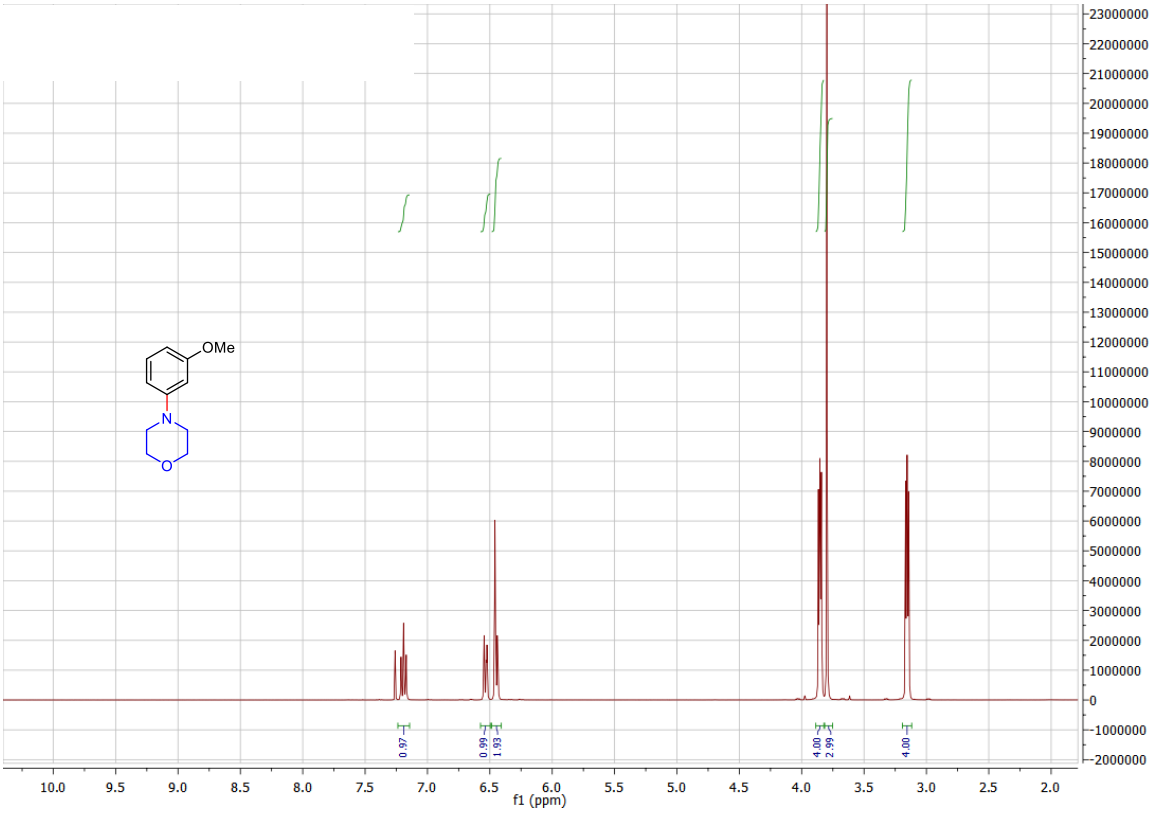


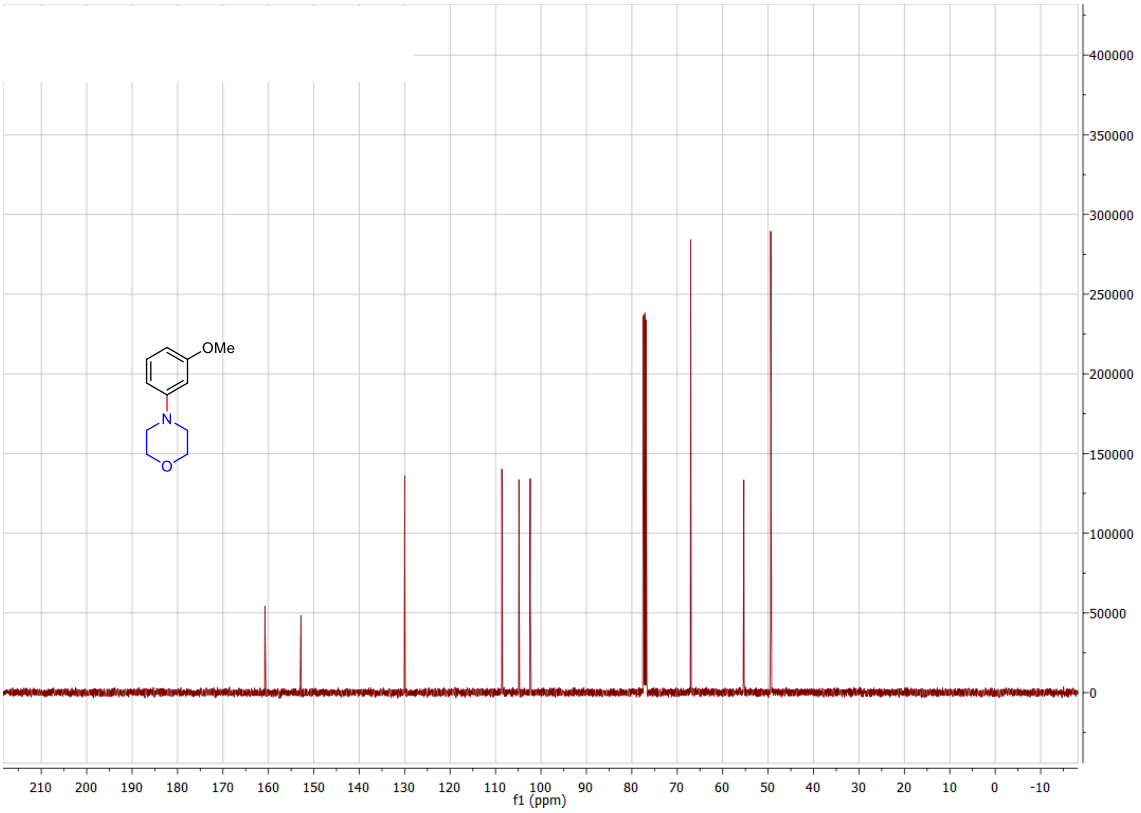
4-(4-methoxyphenyl)morpholine (29)



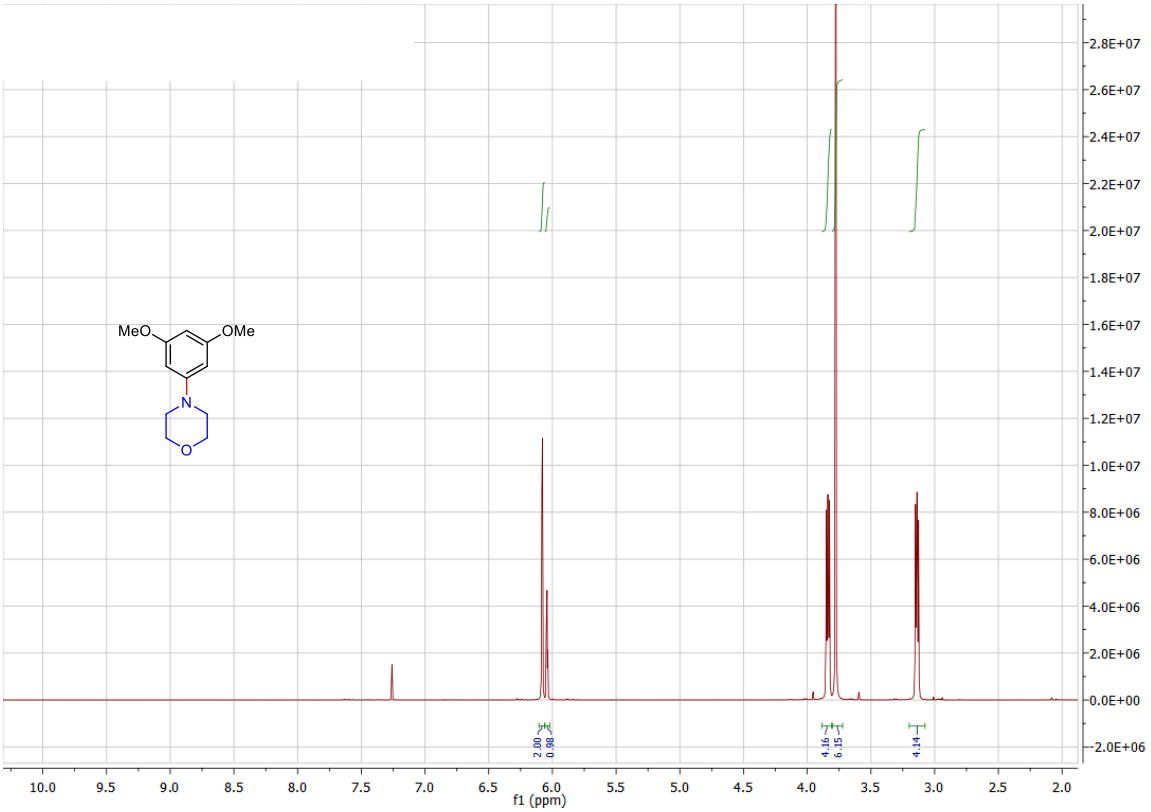


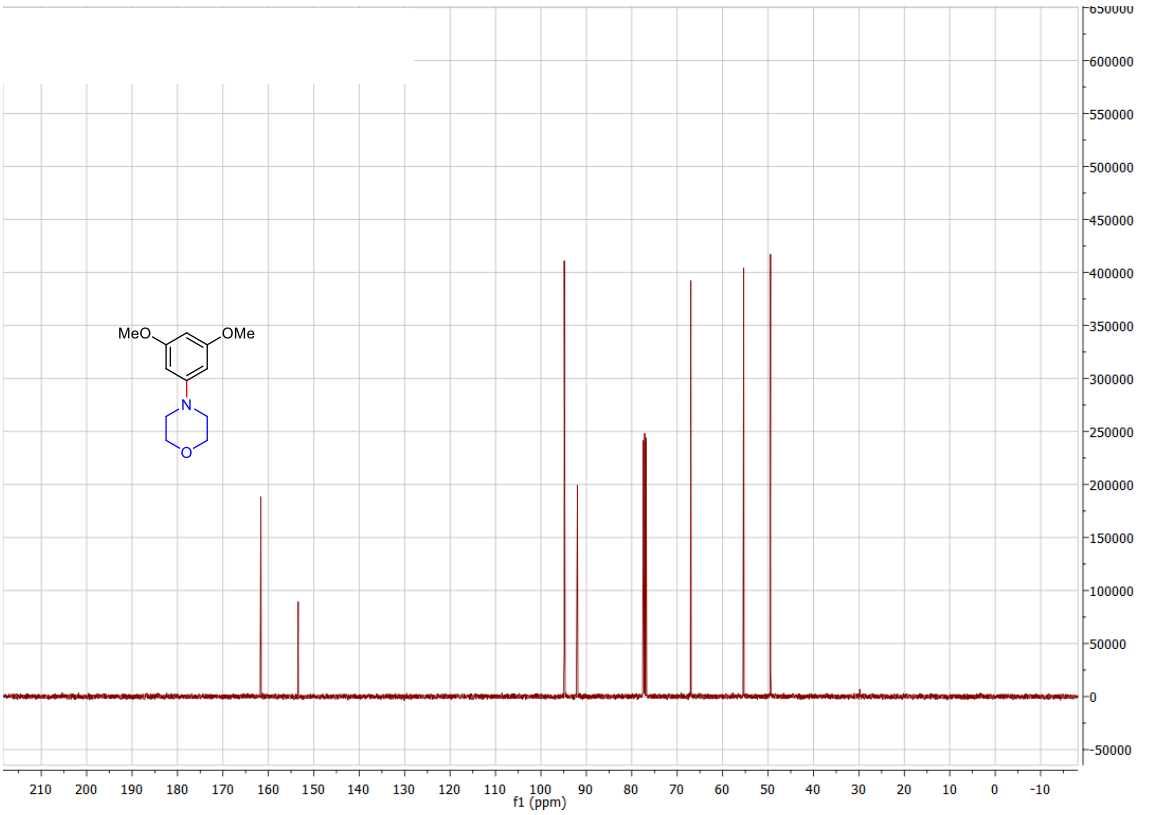
4-(3-methoxyphenyl)morpholine (30)



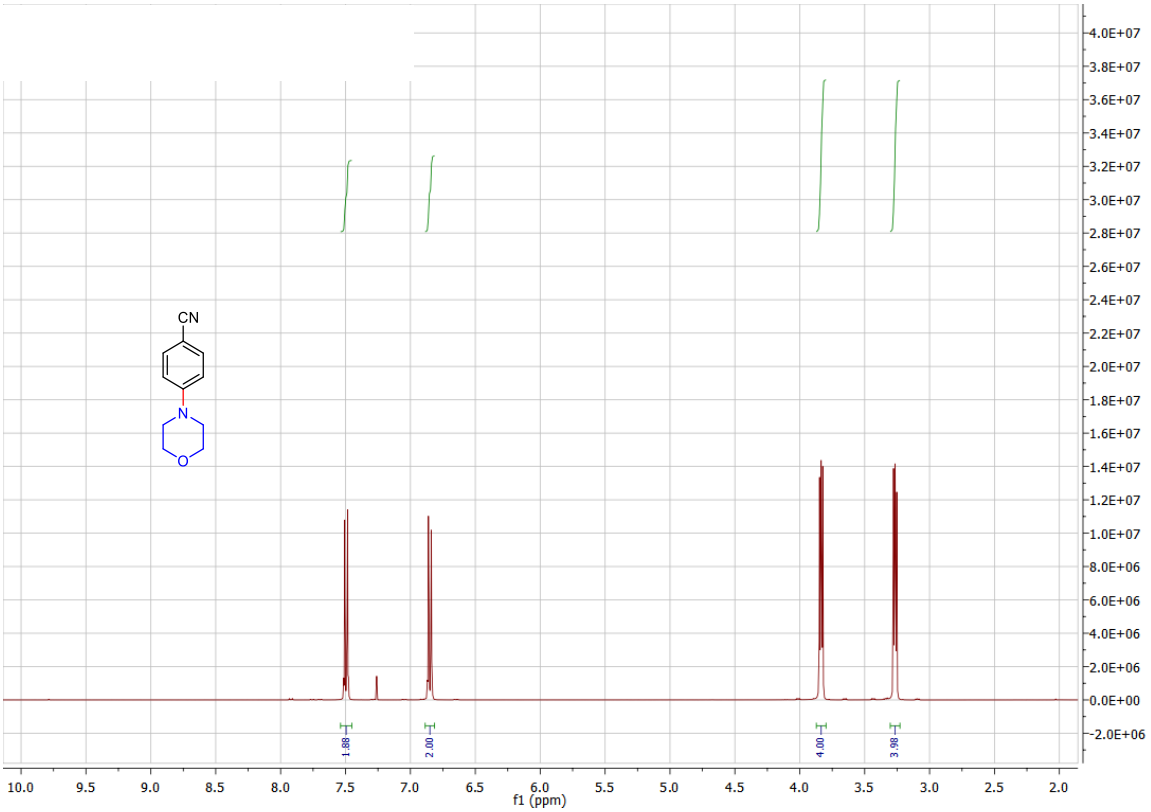


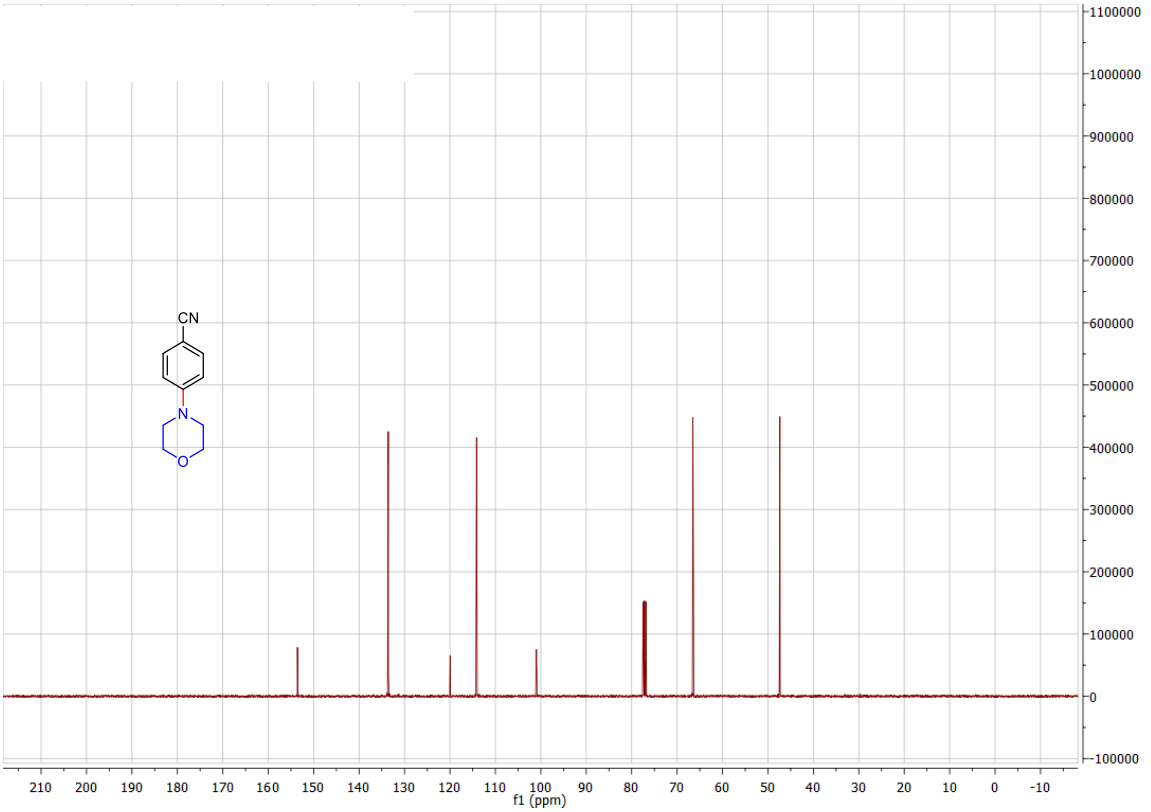
4-(3,5-dimethoxyphenyl)morpholine (31)



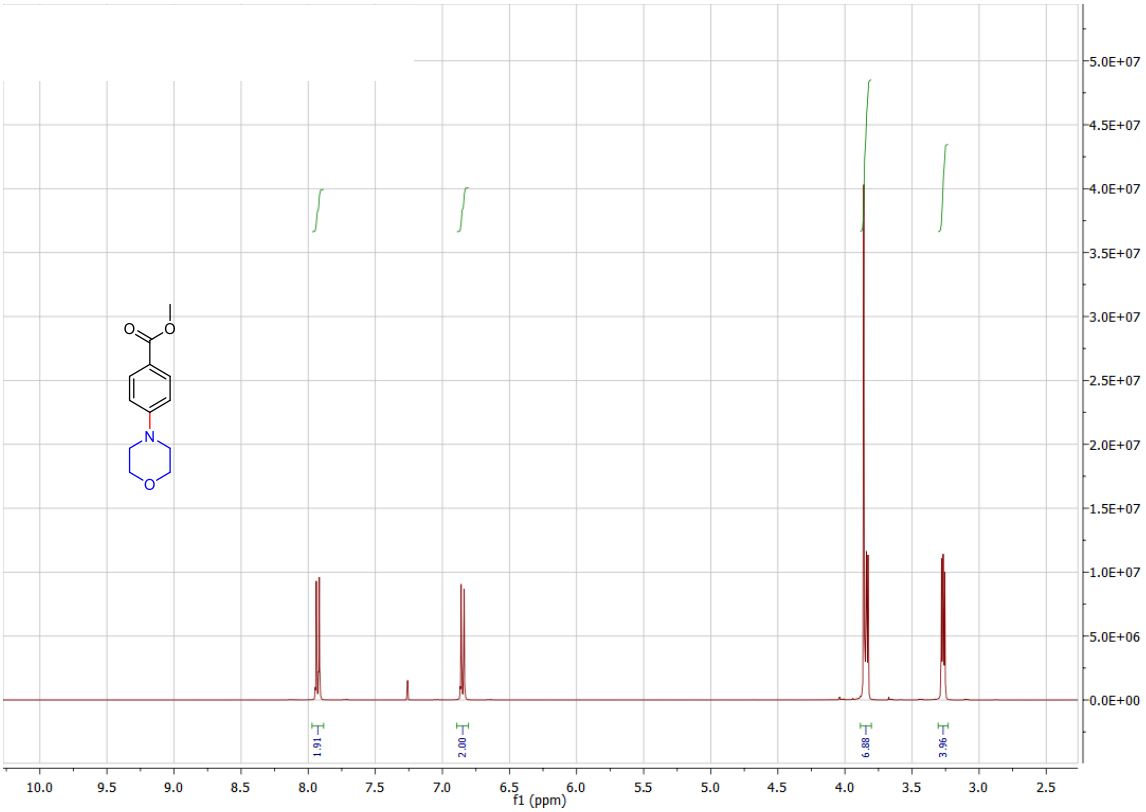


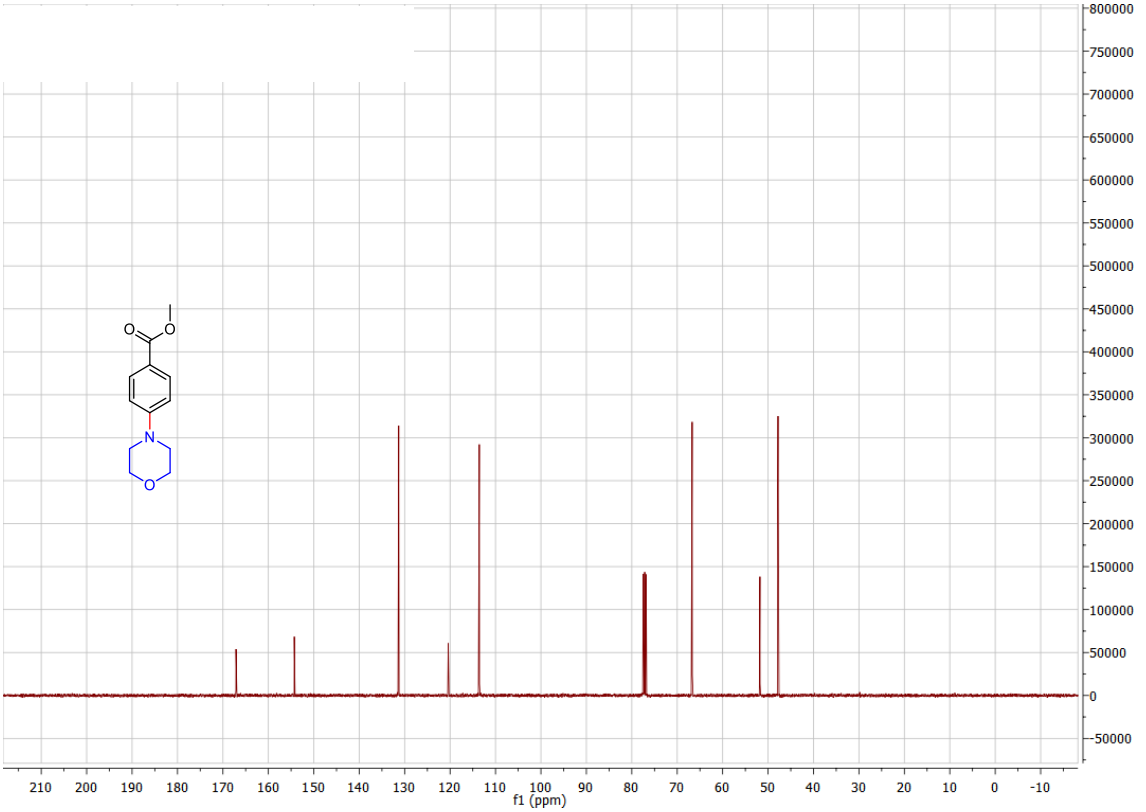
4-morpholinobenzonitrile (32)



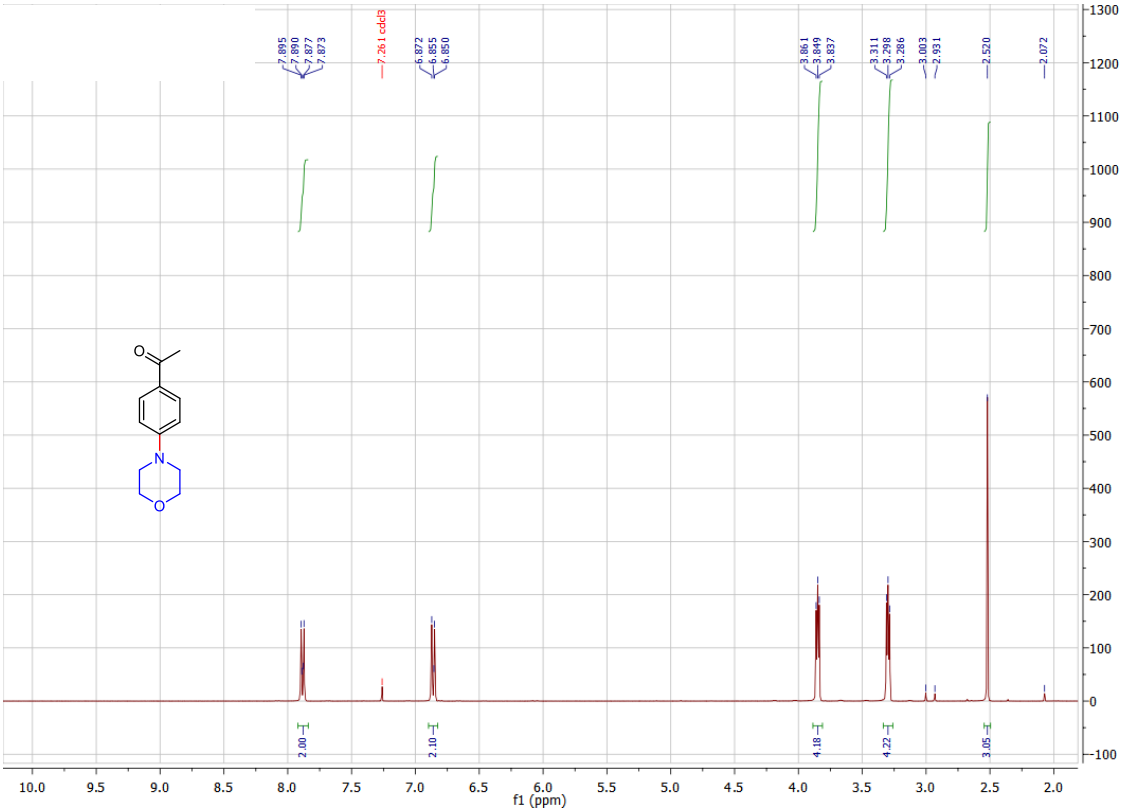


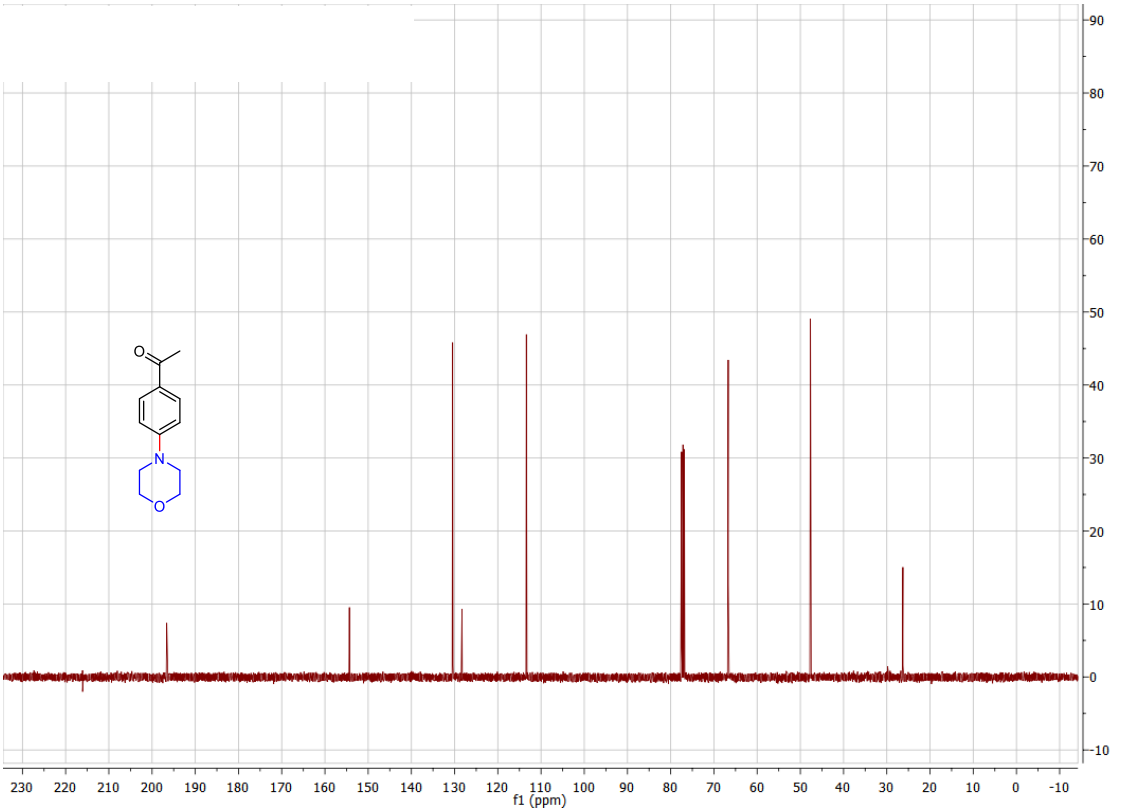
methyl 4-morpholinobenzoate (33)



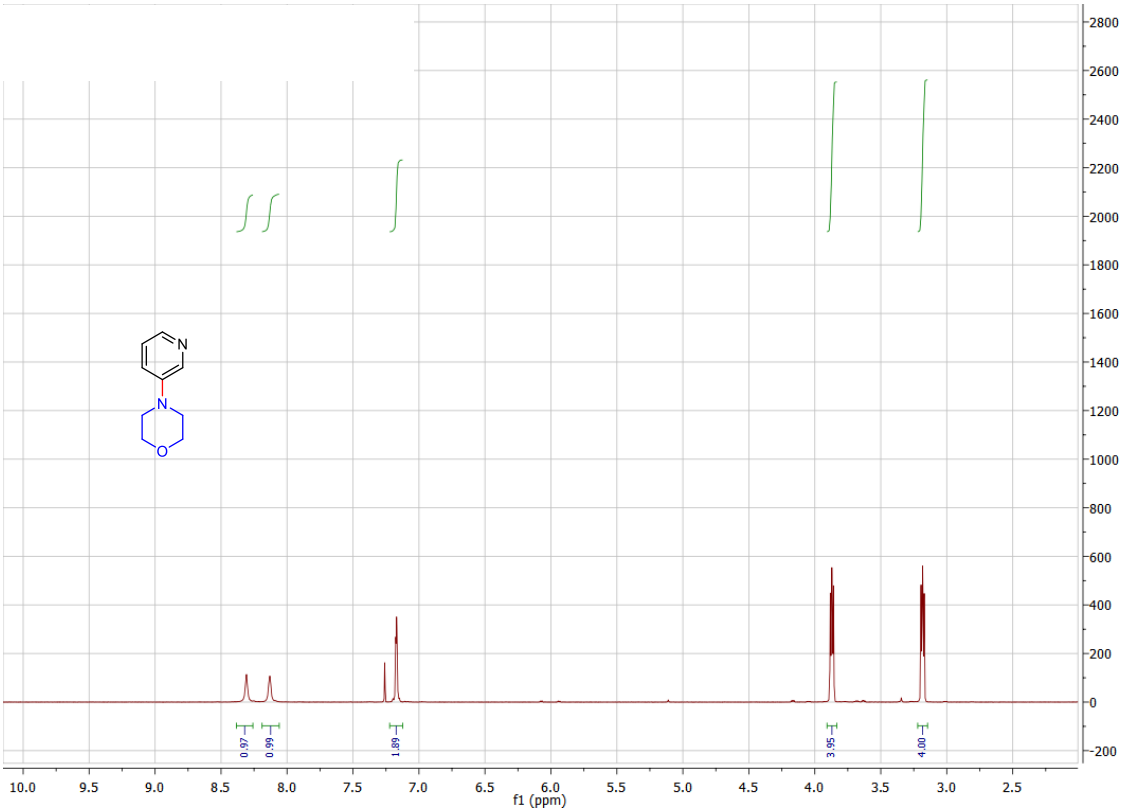


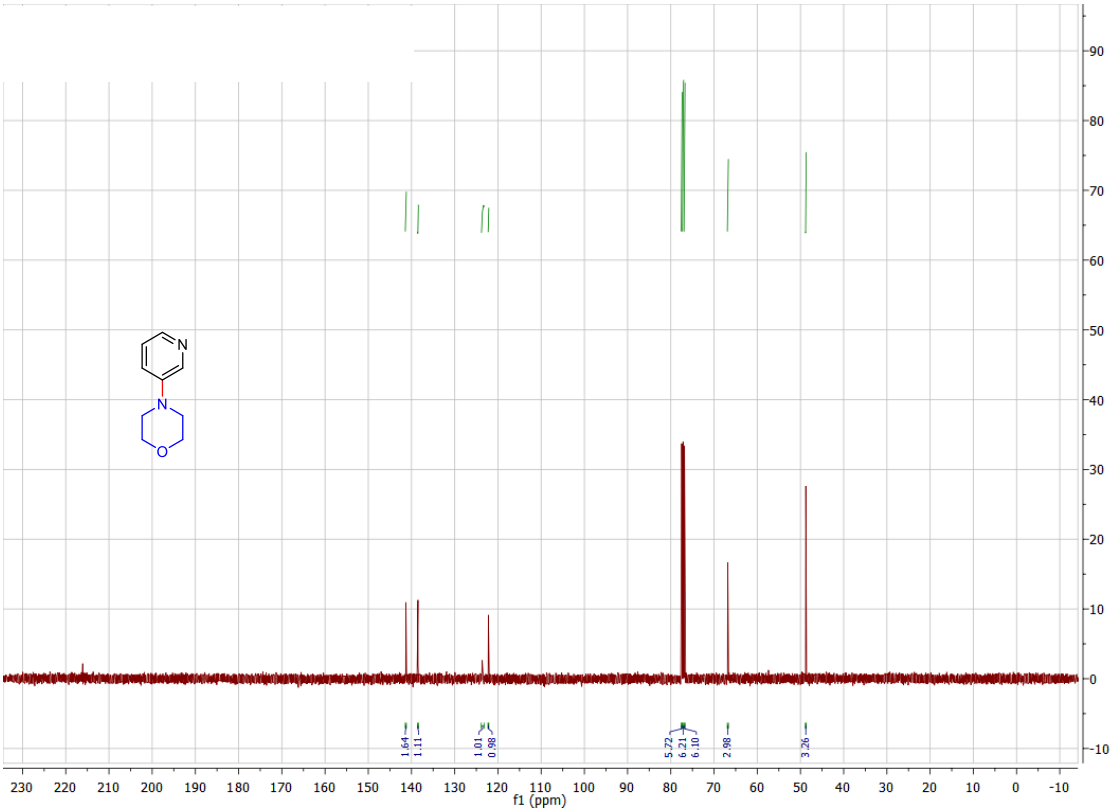
1-(4-morpholinophenyl)ethan-1-one (34)



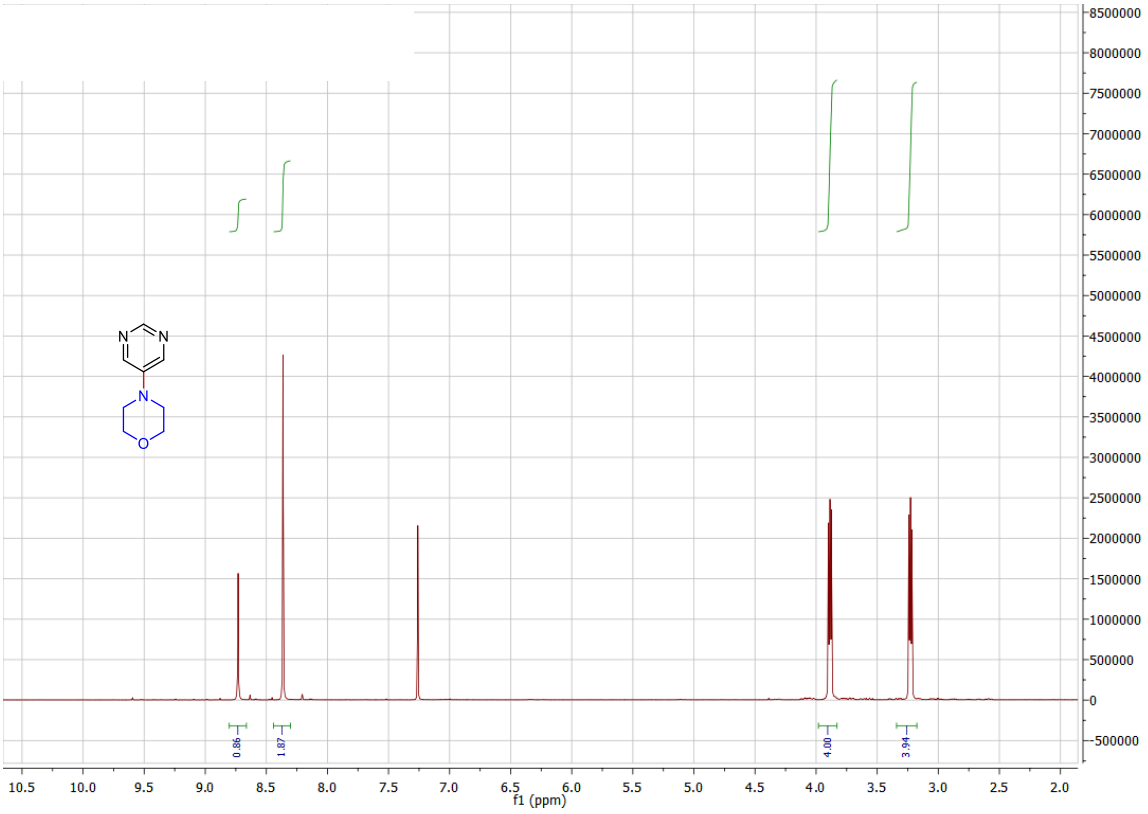


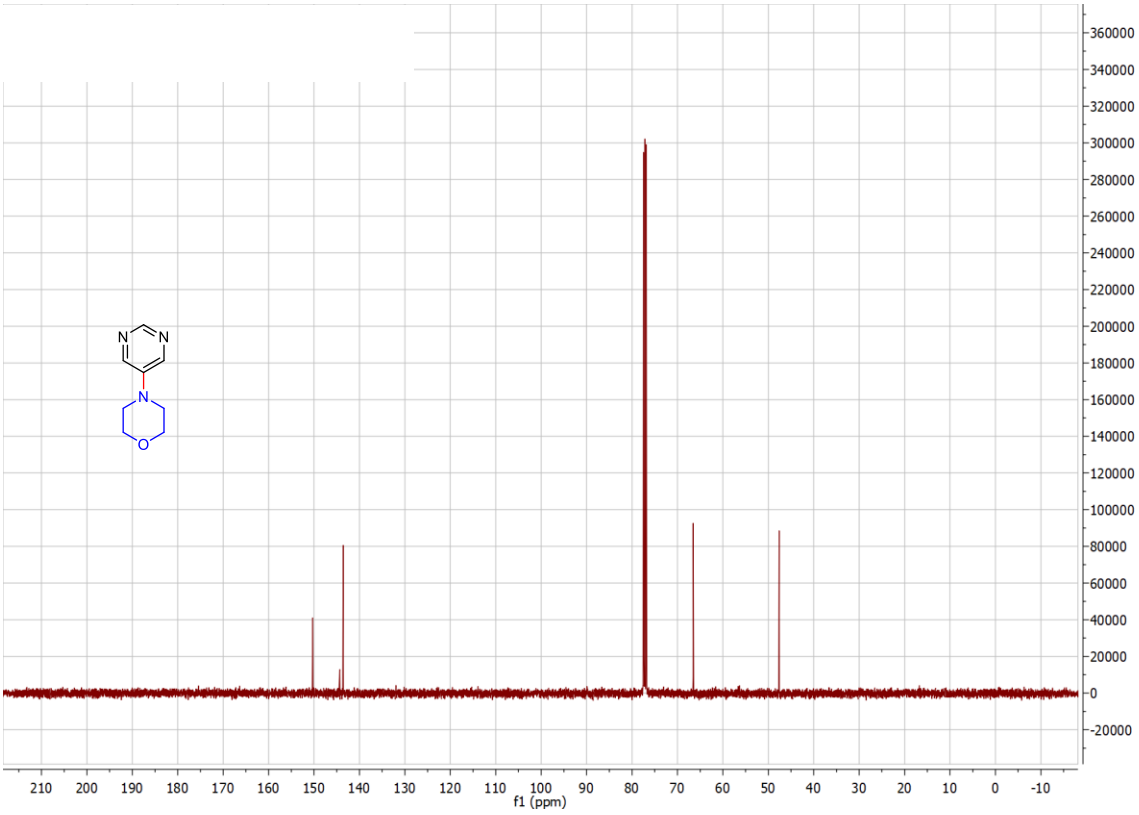
4-(pyridin-3-yl)morpholine (35)



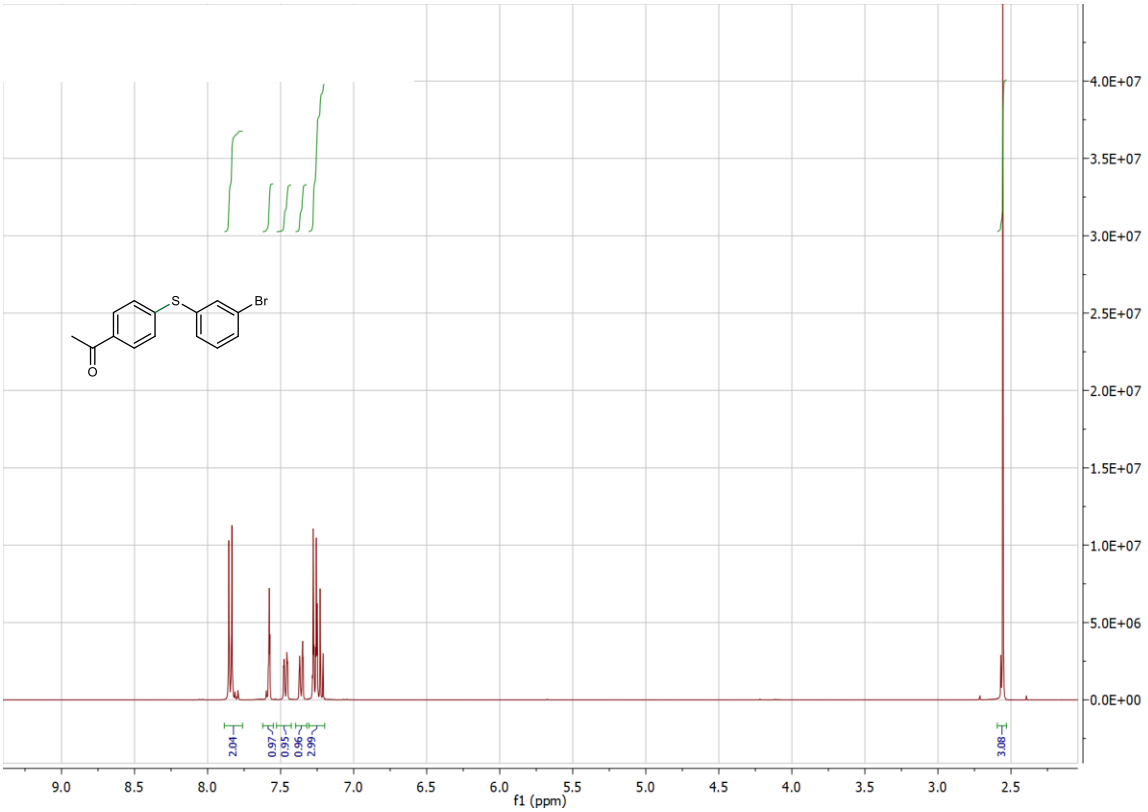


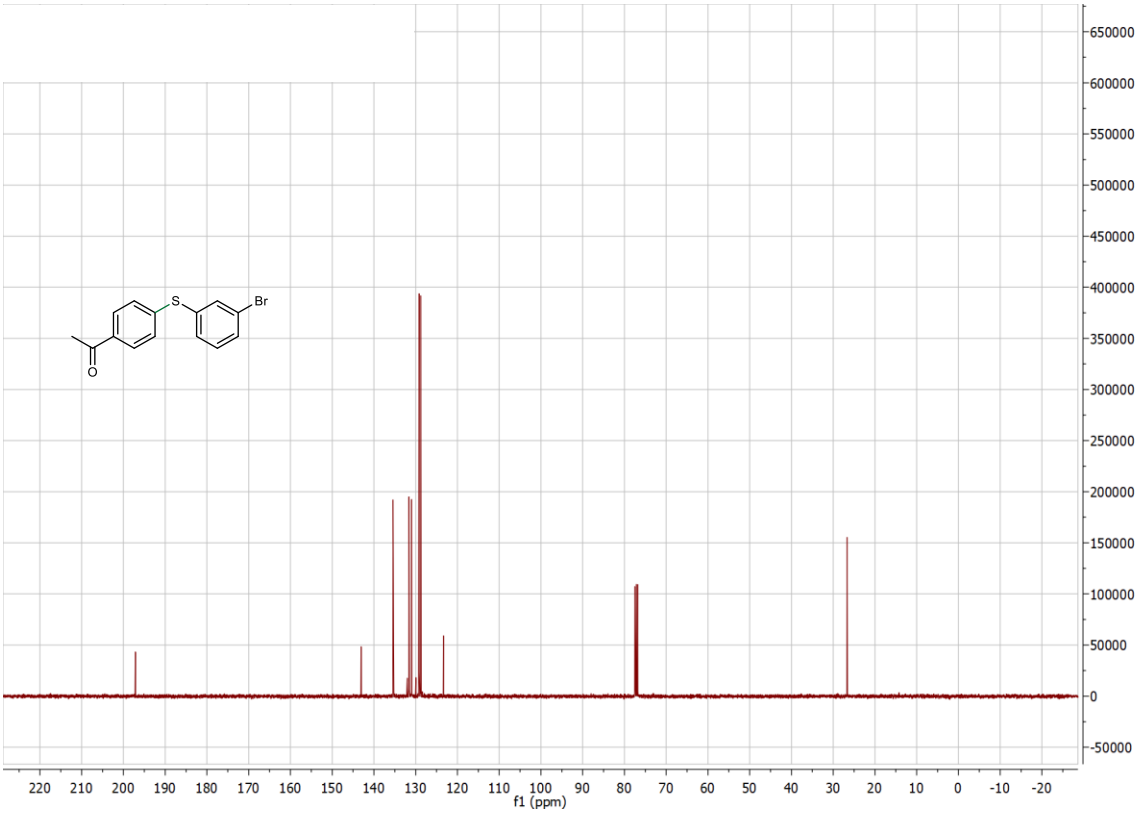
4-(pyrimidin-5-yl)morpholine (36)



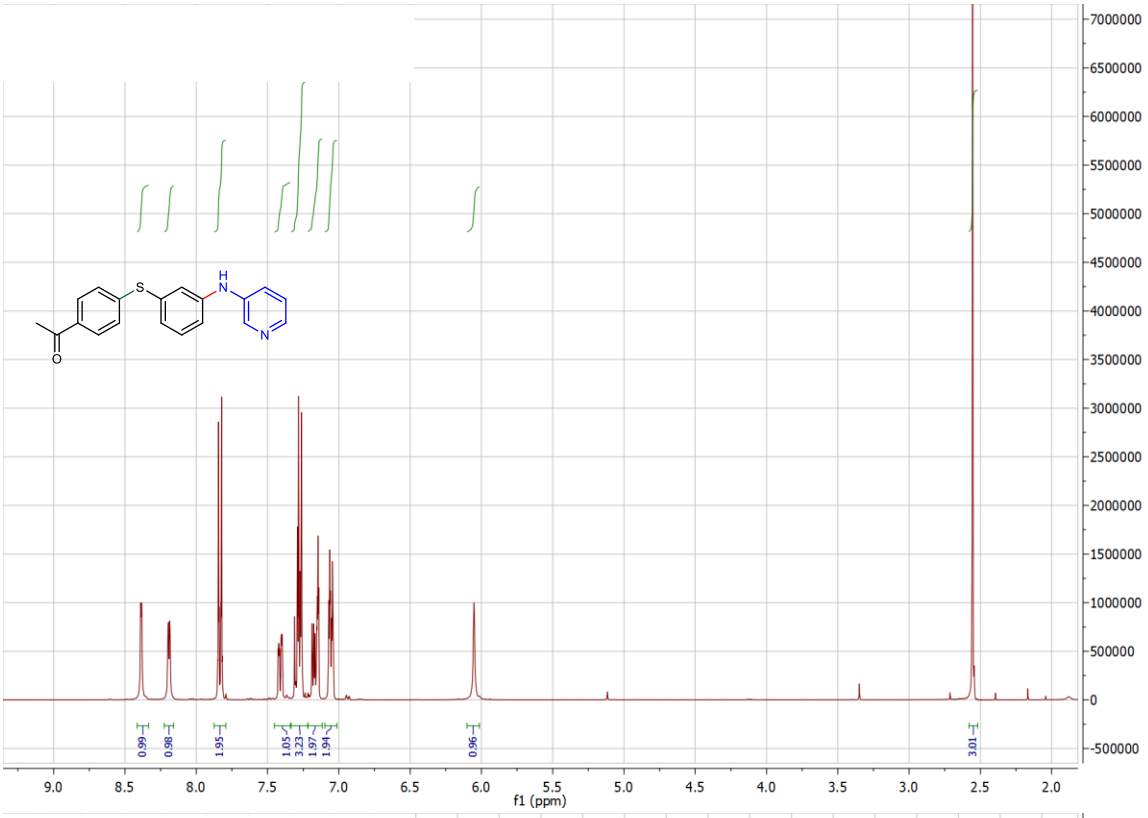


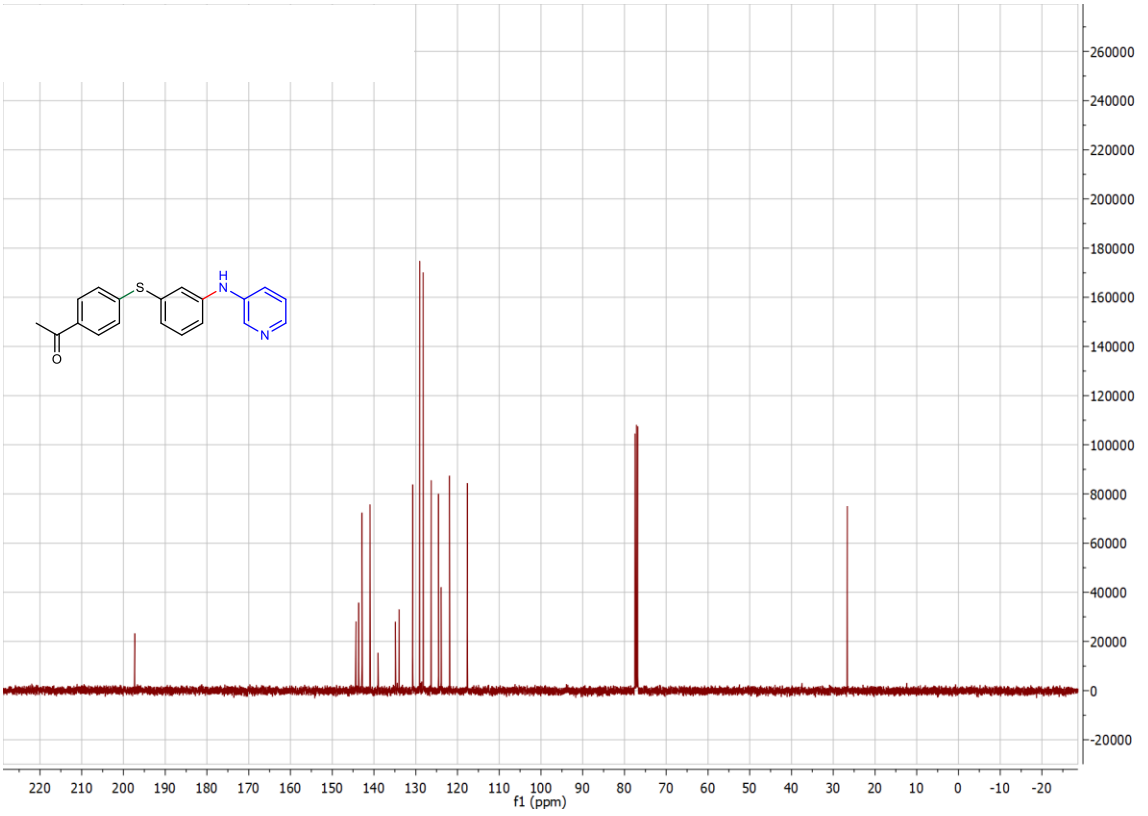
1-(4-((3-bromophenyl)thio)phenyl)ethan-1-one (37)



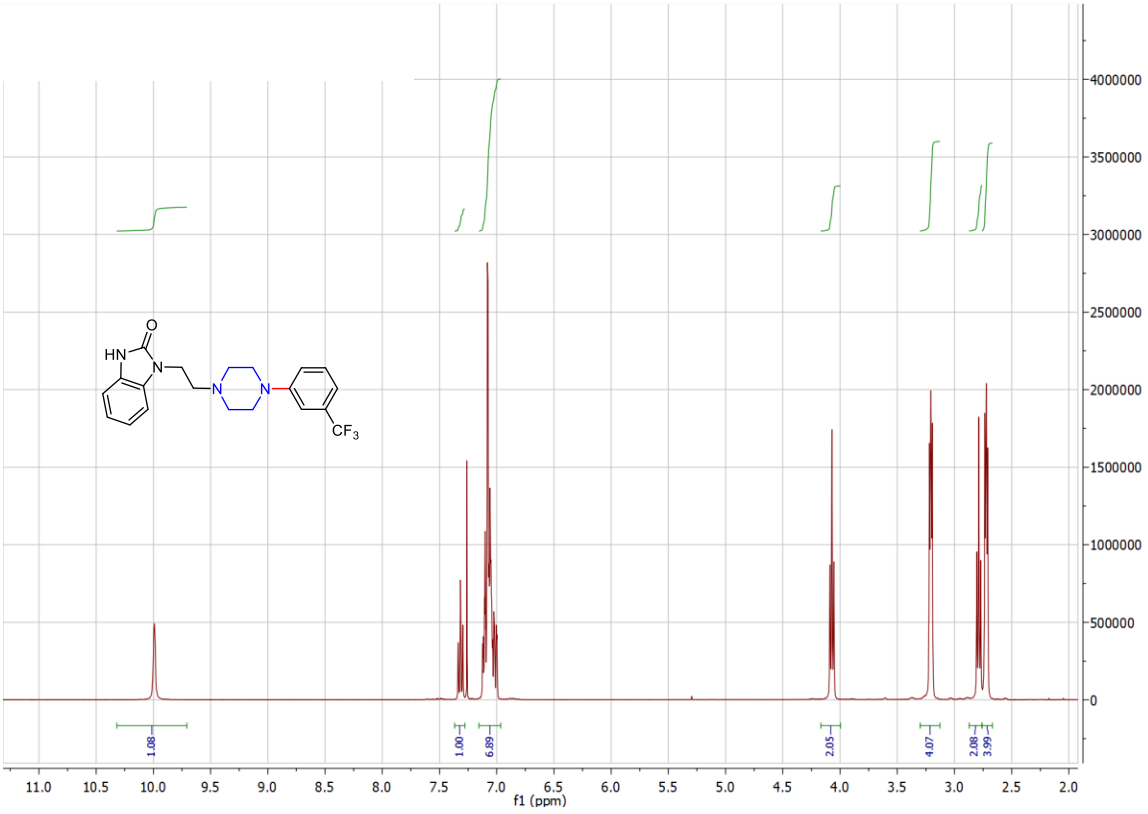


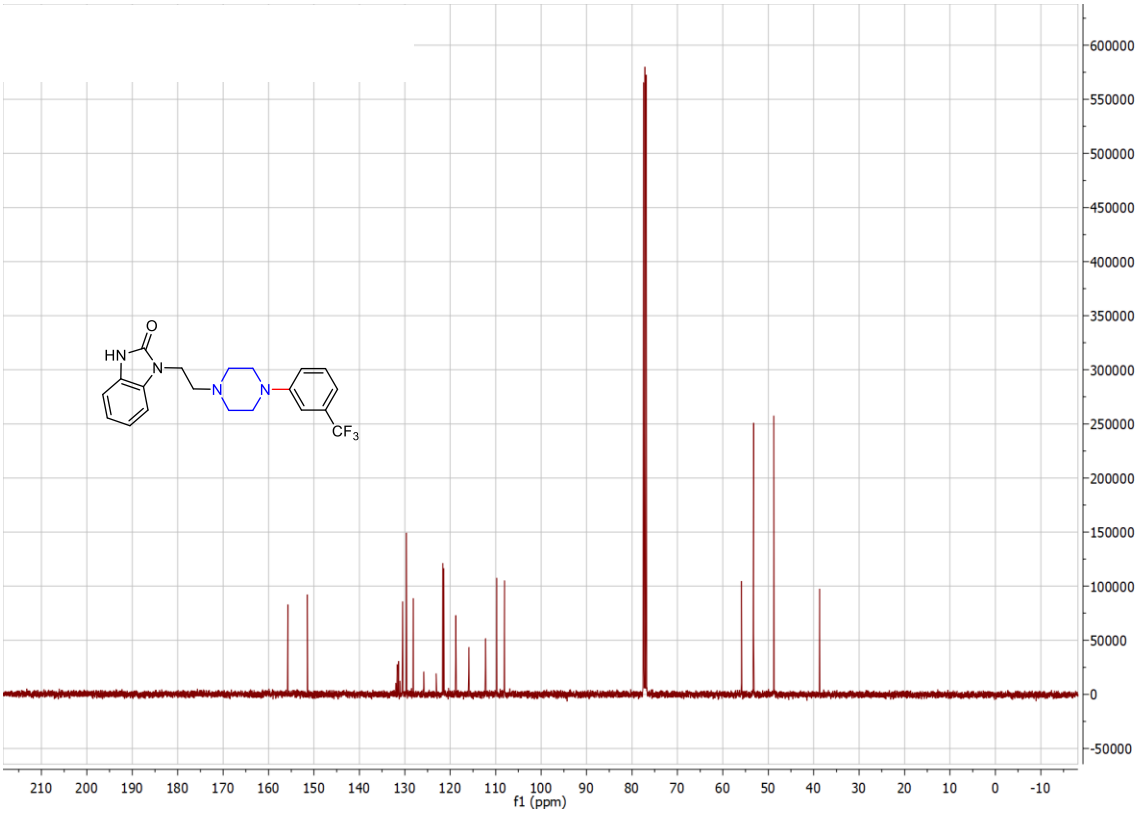
1-(4-((3-(pyridin-3-ylamino)phenyl)thio)phenyl)ethan-1-one (38)

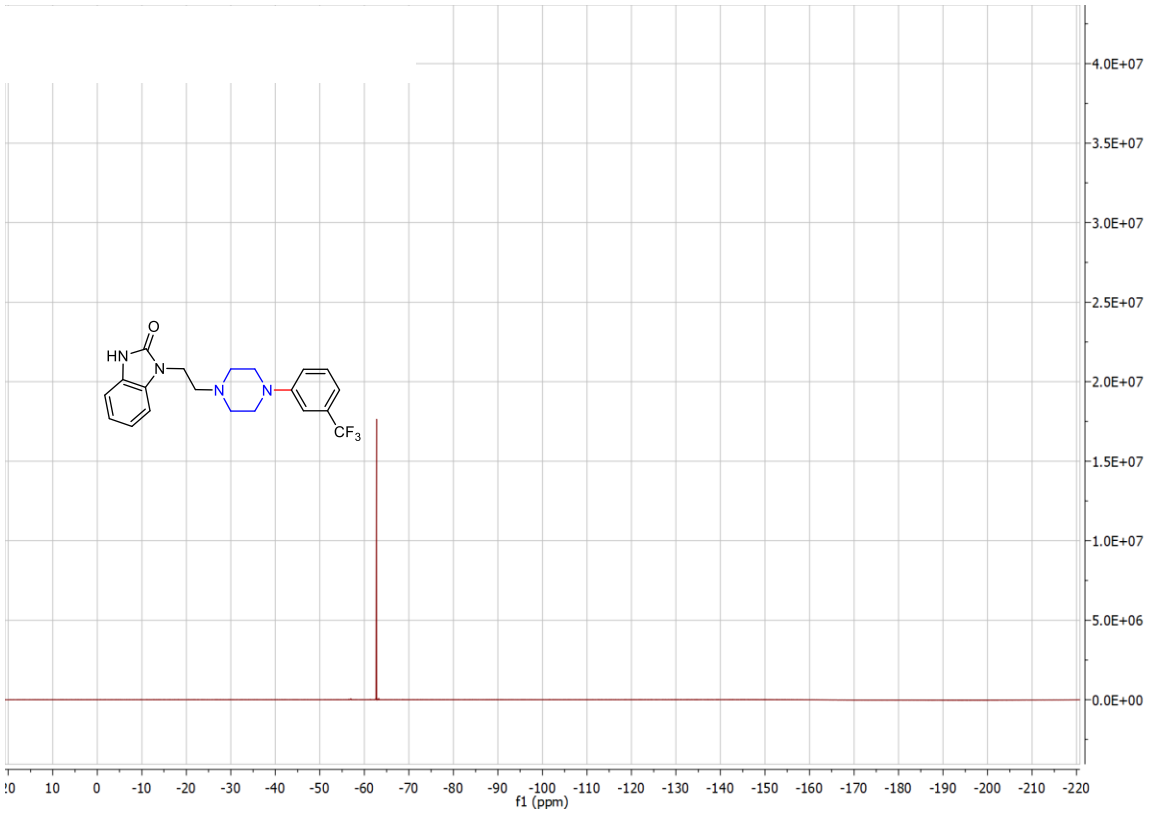




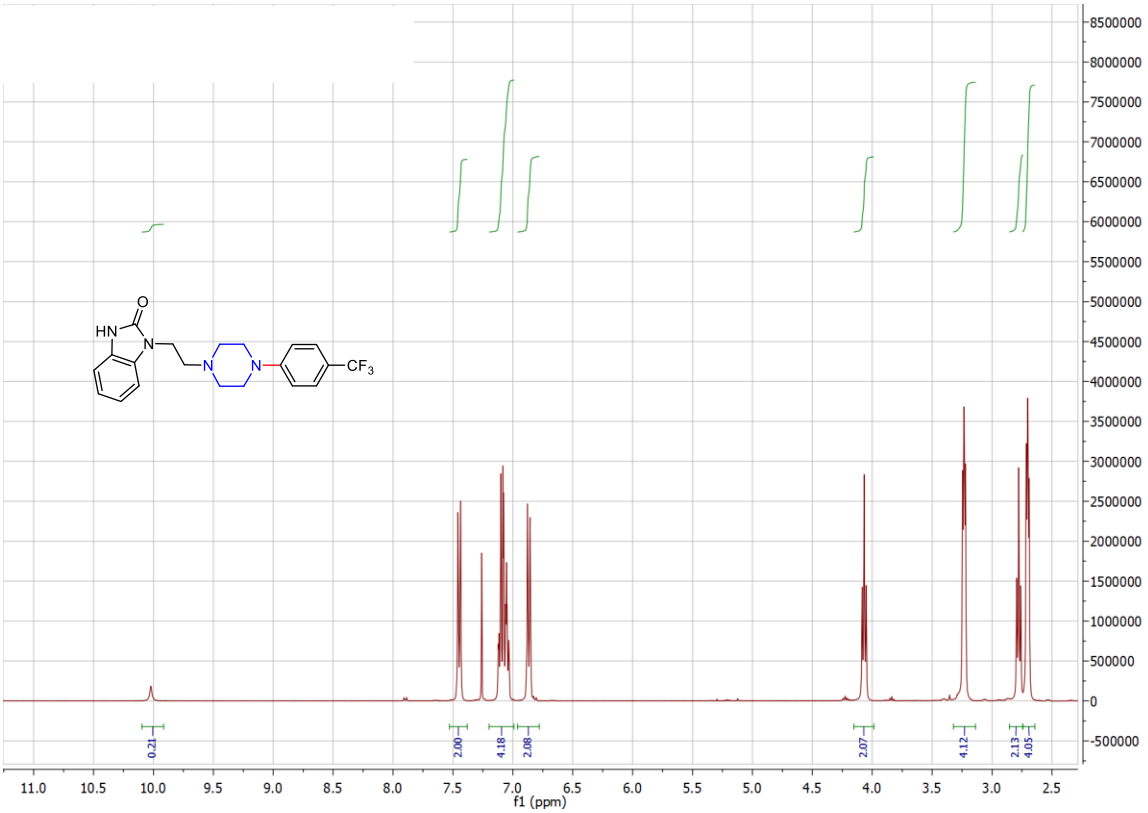
1-(2-(4-(3-(trifluoromethyl)phenyl)piperazin-1-yl)ethyl)-1,3-dihydro-2H-benzo[d]imidazol-2-one (39, Flibanserin)

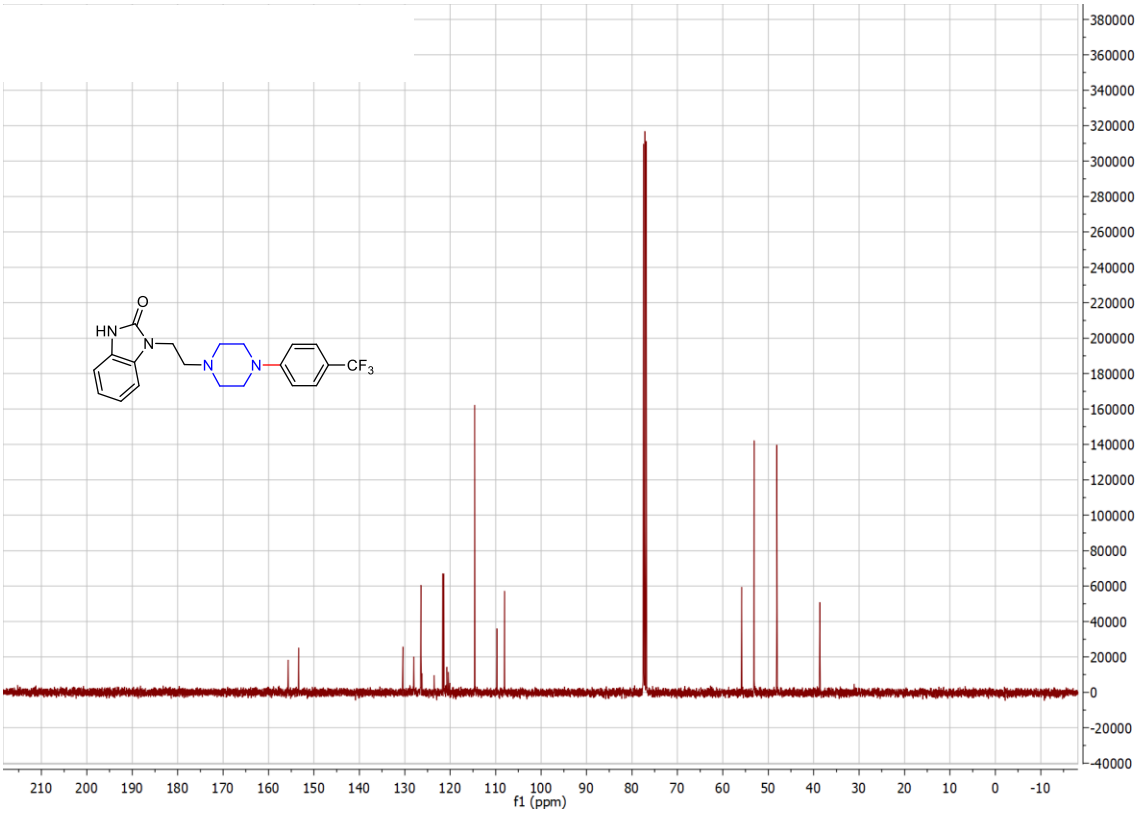


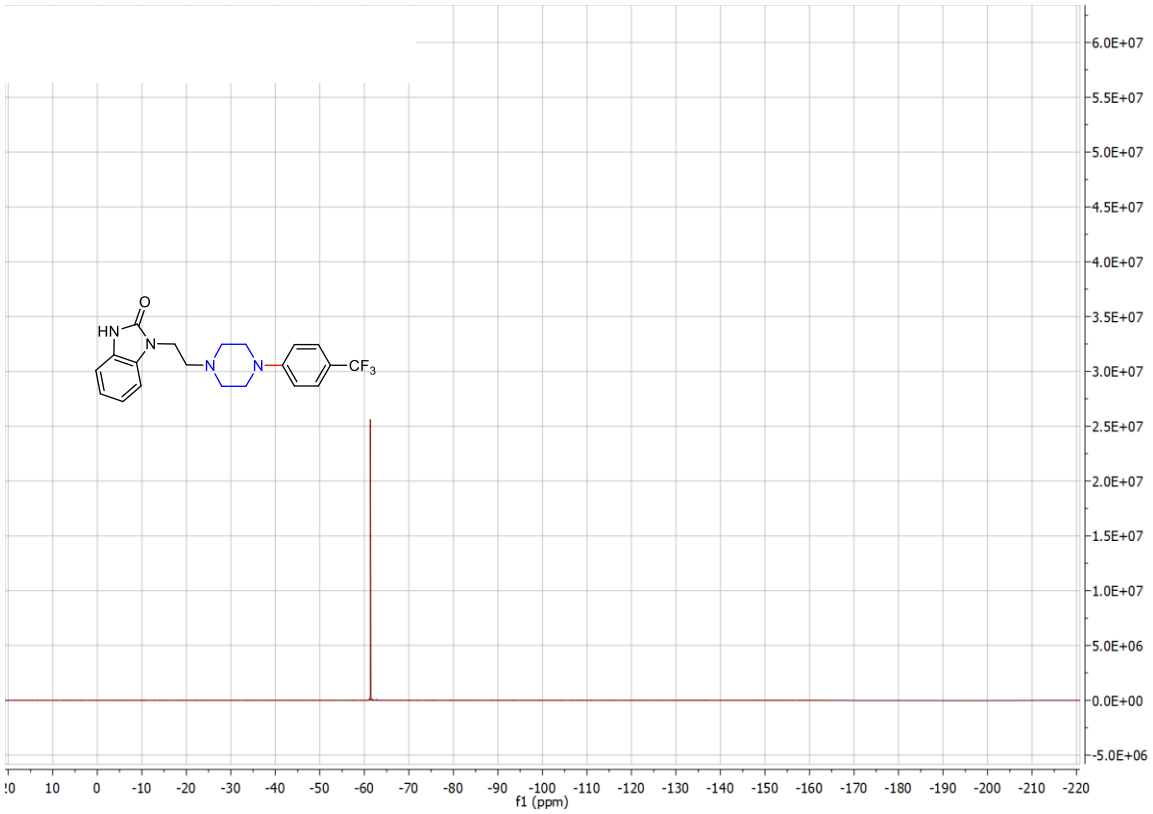



4.0E+07
3.5E+07
3.0E+07
2.5E+07
2.0E+07
1.5E+07
1.0E+07
5.0E+06
0.0E+00
HN
O
N
N
N
CF3
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220
f1 (ppm)

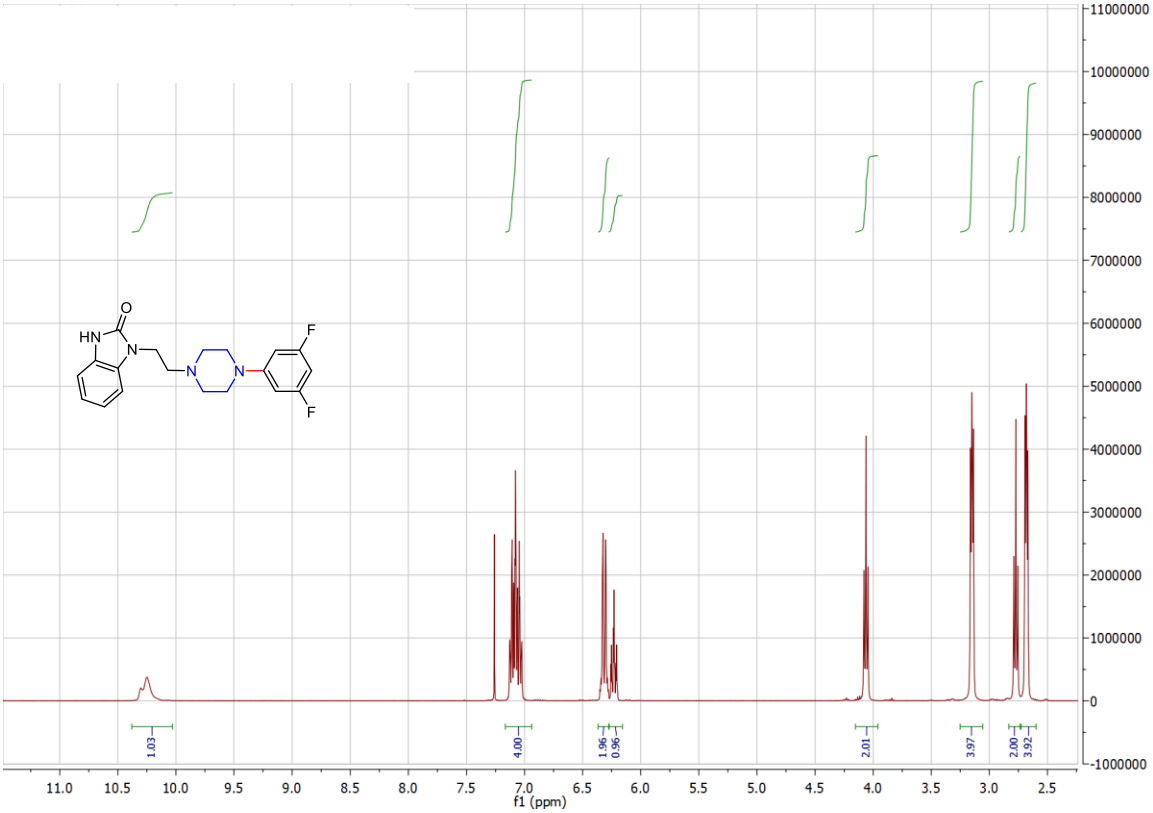
1-(2-(4-(4-(trifluoromethyl)phenyl)piperazin-1-yl)ethyl)-1,3-dihydro-2H-benzo[d]imidazol-2-one (40)

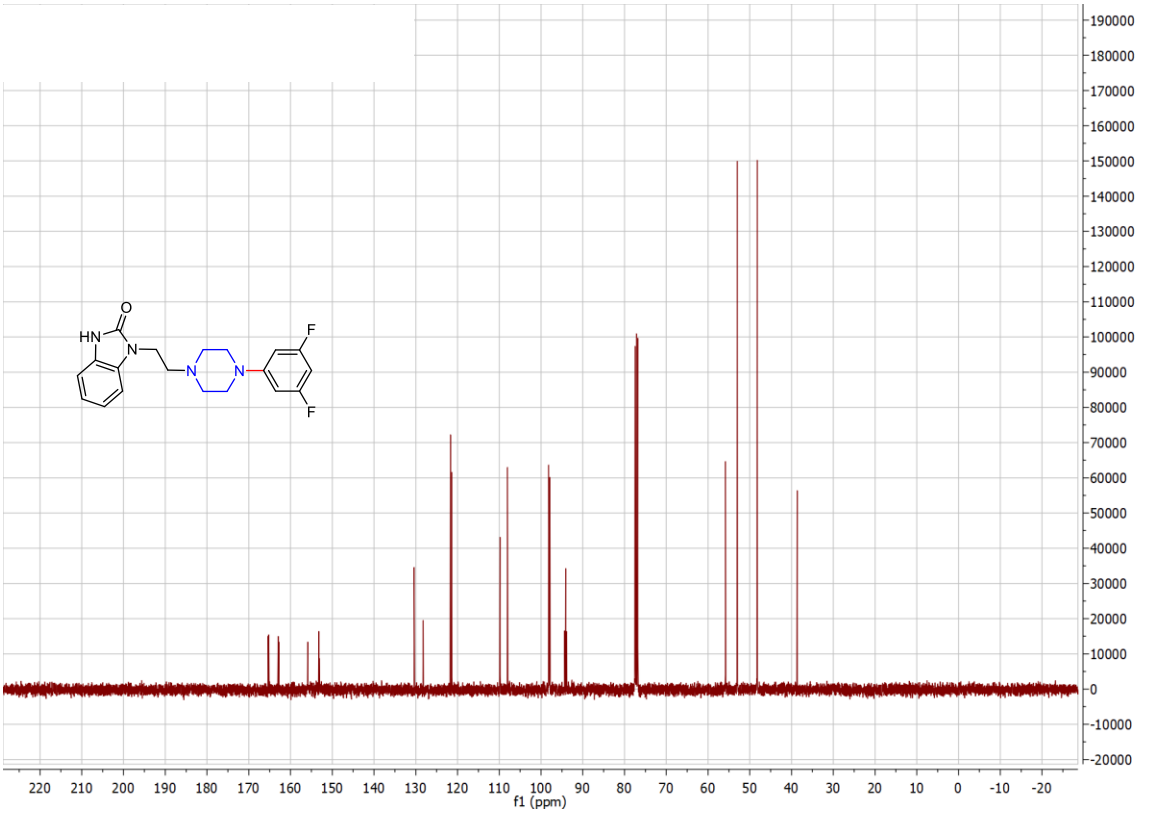


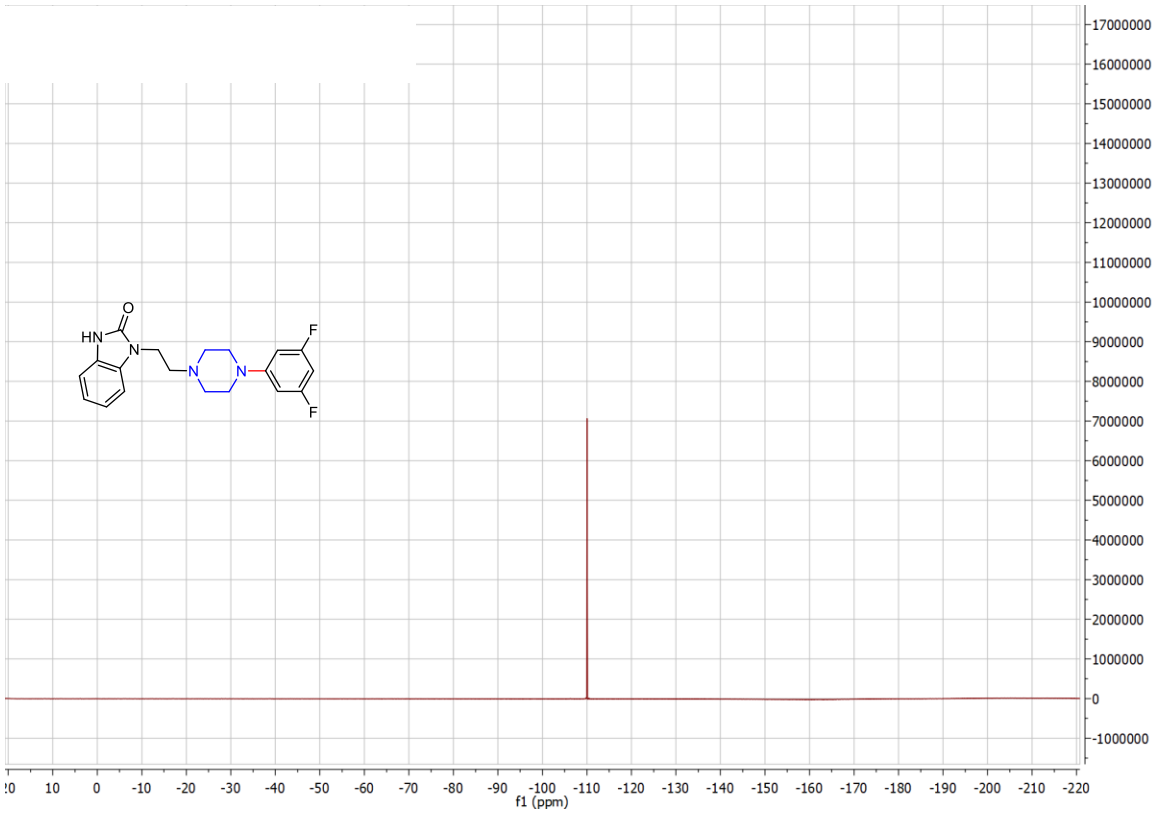



O
HN
N
N
N
CF3
6.0E+07
5.5E+07
5.0E+07
4.5E+07
4.0E+07
3.5E+07
3.0E+07
2.5E+07
2.0E+07
1.5E+07
1.0E+07
5.0E+06
0.0E+00
-5.0E+06
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220
f1 (ppm)

1-(2-(4-(3,5-difluorophenyl)piperazin-1-yl)ethyl)-1,3-dihydro-2H-benzo[d]imidazol-2-one (41)






O
HN
N
N
N
F
F
17000000
16000000
15000000
14000000
13000000
12000000
11000000
10000000
9000000
8000000
7000000
6000000
5000000
4000000
3000000
2000000
1000000
0
-1000000
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220
f1 (ppm)

10. Coordinates of Molecular Structures

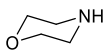
All coordinates are reported as XYZ Cartesian coordinates. Converged geometries were obtained from uM06/6-31+G** level of theory in CPCM-described solvent DMAc. Single point energies computed at uM06/6-311+G** level of theory (reported in parentheses) are arranged in the following order: E_{0K} (not ZPE and thermally corrected), H (298.15 K, 1atm), G^{0*} (298.15 K, 1 atm), and G^{0} (298.15 K, 1 M). They are stated in Hartrees units. All energies reported were calculated using the GAUSSIAN 09 ver. D.01 computational chemistry package.

(neutral radical, -2573.977116, -2573.974756, -2573.993946, -2573.990928)

Br	-0.72635	-0.03378	0.00000

(neutral singlet, -76.4258868, -76.40059986, -76.42268086, -76.41966234)

O	0.43536	-0.63393	0.00000
H	1.39785	-0.59540	0.00000
H	0.15034	0.28627	0.00000



(neutral singlet, -287.6861675, -287.5454232, -287.5800572, -287.5770387)

C	-2.20285	-1.19488	0.03114
C	-0.68934	-1.22820	0.03839
C	-0.68800	0.89095	1.14902
C	-2.20135	0.87981	1.11703
H	0.82476	0.14605	-0.00876
H	-0.35288	-1.76891	0.94449
H	-0.32704	-1.77882	-0.83761
H	-2.56141	-0.74273	-0.91041
H	-2.62160	-2.20263	0.11703
H	-0.35144	0.45326	2.10905
H	-0.32371	1.92389	1.10282
H	-2.61987	1.38523	1.99310
H	-2.55796	1.39525	0.20778
O	-2.70126	-0.44955	1.13290
N	-0.19030	0.14257	-0.00072

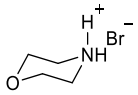
(cation radical, -287.468563, -287.3279498, -287.3634478, -287.3604293)

C	-2.19273	-1.17430	0.00632
C	-0.62494	-1.30141	0.14005
C	-0.62387	0.84902	1.26505

C	-2.19164	0.88899	1.08620
H	0.23164	0.46509	-0.61974
H	-0.42382	-1.84146	1.07150
H	-0.21144	-1.82689	-0.72117
H	-2.43120	-0.70249	-0.95567
H	-2.62409	-2.17553	0.06497
H	-0.42372	0.39134	2.23967
H	-0.20850	1.85532	1.20591
H	-2.62100	1.41165	1.94315
H	-2.43082	1.41192	0.15100
O	-2.65895	-0.42332	1.08296
N	-0.12917	0.02335	0.22506

(neutral radical, -287.0275981, -286.9009658, -286.9363828, -286.9333642)

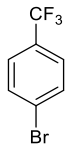
C	-2.17547	-0.64846	0.10330
C	-0.64102	-0.63892	0.10624
C	-0.63981	1.42547	1.18662
C	-2.17421	1.43430	1.19445
H	-0.26858	-1.16094	1.00352
H	-0.25286	-1.14664	-0.78156
H	-2.51172	-0.17754	-0.83794
H	-2.54145	-1.68130	0.12638
H	-0.26630	0.98645	2.12684
H	-0.25082	2.44397	1.09660
H	-2.53817	2.00388	2.05726
H	-2.51114	1.94050	0.27191
O	-0.15823	0.68782	0.08293
N	-2.66304	0.08328	1.24065



(neutral singlet, -2862.350059, -2862.1922, -2862.235191, -2862.232172)

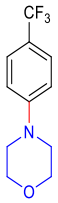
Br	-3.29026	-0.60111	-0.48400
C	-0.85911	-2.80788	1.40800
C	0.23144	-3.16340	2.39299
C	0.11581	-1.07208	3.42624
C	-0.98223	-0.60305	2.49856
H	-0.19782	-3.65770	3.28149
H	0.93863	-3.85504	1.92879
H	-0.44338	-2.35283	0.50225
H	-1.46388	-3.67394	1.12831
H	-0.31533	-1.51557	4.34017
H	0.73827	-0.22412	3.72194
H	-1.67411	0.08495	2.99032
H	-0.57097	-0.12038	1.60512
H	-2.30143	-2.19166	2.78134
H	-2.43804	-1.45253	1.27529

N	-1.75987	-1.78242	2.01446
O	0.95539	-2.01240	2.78335



(neutral singlet, -3142.571025, -3142.465352, -3142.511764, -3142.508745)

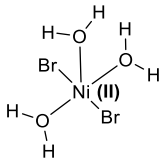
C	-0.08122	0.16040	0.00367
C	1.30734	0.15262	0.10060
C	1.98703	1.36195	0.09711
C	1.27553	2.55811	-0.00247
C	-0.11227	2.55393	-0.09729
C	-0.80053	1.34444	-0.09406
H	1.84883	-0.78548	0.17817
H	3.07202	1.37180	0.17203
H	-0.66232	3.48681	-0.17478
H	-1.88395	1.32823	-0.16747
C	2.04997	3.83745	-0.00491
F	1.27219	4.92203	-0.11569
F	2.77404	3.98569	1.12249
F	2.93411	3.88342	-1.02107
Br	-1.00562	-1.48756	0.00545



(neutral singlet, -855.6475516, -855.4136131, -855.4701661, -855.4671476)

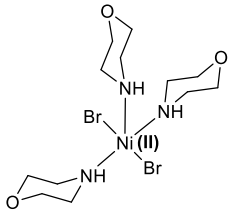
C	0.23250	-0.53250	2.26955
C	1.62064	-0.32627	2.15575
C	-0.56402	0.58090	2.61720
C	2.18403	0.92169	2.39090
H	2.28113	-1.13598	1.86551
C	0.00188	1.82080	2.84400
H	-1.63754	0.47548	2.73631
C	1.38336	2.00508	2.73379
H	3.25888	1.04340	2.28987
H	-0.63855	2.65765	3.11688
C	1.94652	3.36030	2.97353
F	1.65456	3.82521	4.20939
F	3.28188	3.40917	2.85022
F	1.44570	4.28040	2.11835
C	-1.65528	-1.85416	1.43352
C	0.51592	-2.89280	1.68221
C	-2.27717	-3.21854	1.62691
H	-1.54799	-1.64637	0.35316

H	-2.33156	-1.10627	1.85253
C	-0.20342	-4.21449	1.85288
H	0.84332	-2.77500	0.63226
H	1.40848	-2.91570	2.31602
H	-3.21612	-3.28527	1.06949
H	-2.48984	-3.38655	2.69701
H	0.41578	-5.02877	1.46517
H	-0.39303	-4.39829	2.92475
N	-0.34447	-1.78595	2.08387
O	-1.42802	-4.24303	1.14566



(neutral triplet, -6885.680612, -6885.589554, -6885.646443, -6885.643424)

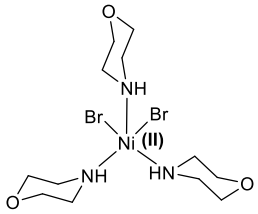
Ni	0.11804	-0.10548	-0.65494
Br	-1.64844	1.27260	0.19813
Br	2.17862	-1.24763	-1.11220
H	-0.51836	-1.19157	-2.95790
H	-1.78242	-0.47864	-2.40077
H	1.33105	1.21596	-2.61023
H	0.03969	2.02142	-2.25376
H	-1.35885	-1.60220	0.89417
H	-0.18383	-2.48962	0.38327
O	-1.00702	-0.99853	-2.14561
O	0.74576	1.47345	-1.88461
O	-0.40980	-1.60525	0.70468



(neutral triplet low energy configuration, -7519.51125, -7519.072274, -7519.153756, -7519.150738)

Ni	-0.24854	-0.30735	-0.97686
Br	-1.53752	1.36092	0.26651
Br	1.64298	-1.83653	-1.59336
C	0.00998	-1.45563	1.70527
C	-2.10403	-2.17012	0.77828
C	-0.09126	-2.57475	2.71830
H	-0.43954	-0.53742	2.10285
H	1.05872	-1.24351	1.45472
C	-2.14345	-3.26147	1.83080

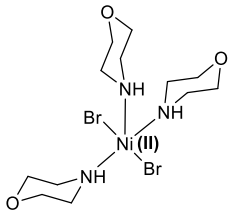
H	-2.61977	-1.26954	1.13451
H	-2.60742	-2.51403	-0.13419
H	0.37993	-2.29015	3.66413
H	0.41386	-3.48175	2.33877
H	-3.17440	-3.48089	2.12498
H	-1.69536	-4.18816	1.42772
C	0.12784	2.32670	-2.64613
C	1.81688	1.74481	-1.02406
H	1.34172	0.67717	-2.69068
C	1.11877	3.28825	-3.26998
H	-0.47993	2.83021	-1.88455
H	-0.55189	1.93423	-3.41182
C	2.75488	2.72083	-1.70024
H	1.25680	2.24538	-0.22361
H	2.37009	0.90610	-0.58257
H	0.60361	4.15414	-3.69702
H	1.67448	2.78361	-4.08157
H	3.43982	3.17006	-0.97472
H	3.35671	2.19853	-2.46645
C	-2.87136	-0.34275	-2.45895
C	-0.98526	-1.03964	-3.81197
H	-1.68296	-1.97798	-2.15770
C	-3.78236	-0.96529	-3.49505
H	-2.70476	0.72001	-2.67625
H	-3.31687	-0.40567	-1.46067
C	-1.96953	-1.63236	-4.79758
H	-0.74851	-0.00892	-4.10588
H	-0.05329	-1.61372	-3.79061
H	-4.72885	-0.41930	-3.55153
H	-4.00490	-2.01322	-3.22046
H	-1.57268	-1.57535	-5.81555
H	-2.15172	-2.69580	-4.55812
O	-1.44951	-2.87073	3.00273
O	-3.19788	-0.92687	-4.78474
O	2.03339	3.78118	-2.30564
N	0.82296	1.20528	-1.98229
N	-1.54478	-1.00289	-2.44069
H	-0.24369	-2.60685	0.04612
N	-0.71320	-1.79512	0.45960



(neutral triplet high energy configuration, -7519.502094, -7519.063493, -7519.145703, -7519.142684)

Ni	-0.34395	-0.31491	-0.97220
Br	-1.36625	1.53341	0.31260
Br	1.01148	1.31421	-2.30257
C	-2.21083	-2.75280	0.15754

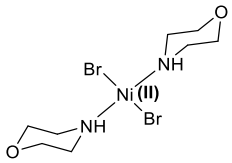
C	-0.62337	-1.74807	1.68530
C	-2.98582	-3.24119	1.36746
H	-1.51729	-3.53229	-0.18182
H	-2.91650	-2.54067	-0.65602
C	-1.45771	-2.26836	2.83610
H	0.15973	-2.48052	1.44715
H	-0.14057	-0.79929	1.95100
H	-3.48615	-4.18967	1.15047
H	-3.75551	-2.49713	1.64083
H	-0.82881	-2.50099	3.70052
H	-2.19837	-1.50634	3.14052
C	2.38277	-1.33783	-0.40696
C	1.03235	-3.10557	-1.35462
H	1.52126	-1.32660	-2.23882
C	3.61495	-2.12254	-0.80452
H	2.08761	-1.59613	0.61830
H	2.57388	-0.25978	-0.45247
C	2.31096	-3.83004	-1.72641
H	0.69966	-3.43503	-0.36190
H	0.23683	-3.33605	-2.07335
H	4.42713	-1.95614	-0.09083
H	3.96072	-1.79943	-1.80350
H	2.16693	-4.91383	-1.69087
H	2.61333	-3.55472	-2.75326
C	-2.67872	0.09055	-2.66104
C	-0.93185	-1.06739	-3.87771
H	-1.97299	-1.78841	-2.29008
C	-3.63292	-0.27319	-3.77825
H	-2.22283	1.07293	-2.84156
H	-3.20390	0.14247	-1.70019
C	-1.95912	-1.40683	-4.93701
H	-0.41536	-0.13251	-4.12208
H	-0.18047	-1.86353	-3.81042
H	-4.39079	0.50603	-3.90307
H	-4.15060	-1.22112	-3.54027
H	-1.48660	-1.47329	-5.92154
H	-2.43274	-2.38069	-4.71597
O	-2.12640	-3.46310	2.47032
O	-2.95503	-0.40235	-5.01480
O	3.35177	-3.51568	-0.81941
N	1.24320	-1.64579	-1.30454
N	-1.56791	-0.88568	-2.55112
H	-2.11130	-0.79304	0.70577
N	-1.44100	-1.53312	0.47248



(neutral singlet, -7519.49154, -7519.052241, -7519.131422, -7519.128404)

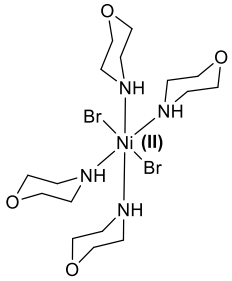
Ni	-0.33085	-0.07389	-0.76722

Br	-2.02137	1.37884	-0.04258
Br	1.65444	-1.35390	-1.09589
C	-0.51628	-1.04125	1.88582
C	-2.27445	-1.97954	0.49838
C	-0.73421	-2.17867	2.85995
H	-1.13788	-0.17902	2.15070
H	0.53317	-0.72389	1.87749
C	-2.42668	-3.07826	1.53192
H	-2.95349	-1.14603	0.70654
H	-2.50253	-2.37106	-0.49944
H	-0.52598	-1.85180	3.88299
H	-0.06054	-3.02241	2.62396
H	-3.46545	-3.41867	1.57430
H	-1.79259	-3.94236	1.26230
C	-0.34862	2.13861	-2.79627
C	1.32720	2.19534	-1.05699
H	1.09996	0.74808	-2.46632
C	0.54997	3.02643	-3.63198
H	-1.03165	2.73719	-2.18505
H	-0.95052	1.48257	-3.43276
C	2.16570	3.08879	-1.94618
H	0.66415	2.78999	-0.41746
H	1.96216	1.57295	-0.41695
H	-0.04839	3.68102	-4.27248
H	1.19691	2.40726	-4.28130
H	2.75349	3.78873	-1.34527
H	2.86508	2.47417	-2.54243
C	-2.80610	-0.83338	-3.02931
C	-0.65256	-1.33897	-3.99061
H	-1.42314	-2.14723	-2.30702
C	-3.44470	-1.71581	-4.08261
H	-2.80077	0.20961	-3.37867
H	-3.38690	-0.85357	-2.09861
C	-1.35509	-2.20184	-5.02012
H	-0.51168	-0.32899	-4.40648
H	0.34006	-1.74362	-3.75716
H	-4.44233	-1.35698	-4.35653
H	-3.54081	-2.74842	-3.69754
H	-0.82431	-2.19359	-5.97786
H	-1.40677	-3.24626	-4.66092
O	-2.08038	-2.62049	2.82582
O	-2.66906	-1.72639	-5.27157
O	1.35222	3.85932	-2.81333
N	0.46929	1.30748	-1.88188
N	-1.42150	-1.22457	-2.74663
H	-0.26957	-2.22752	0.25435
N	-0.89002	-1.45088	0.50675



(neutral triplet, -7231.802134, -7231.507317, -7231.575001, -7231.571983)

Ni	-0.32641	-0.74928	-1.12014
Br	-0.40296	1.55968	-0.68726
Br	1.16540	-2.51743	-1.56627
C	-2.00500	-2.79492	0.27120
C	-0.73772	-1.29030	1.68638
C	-2.79752	-3.20858	1.49373
H	-1.13875	-3.45274	0.13313
H	-2.62935	-2.86284	-0.62674
C	-1.57201	-1.76344	2.85854
H	0.17059	-1.89988	1.58831
H	-0.43848	-0.24343	1.81025
H	-3.10996	-4.25372	1.41195
H	-3.70376	-2.58373	1.58917
H	-0.98371	-1.74597	3.78055
H	-2.44482	-1.09973	2.99269
C	-2.95767	-0.46625	-2.48155
C	-1.00006	-0.41939	-3.91247
H	-1.66019	-2.02125	-2.83254
C	-3.80684	-0.63018	-3.72496
H	-2.84984	0.59453	-2.22384
H	-3.42913	-0.97808	-1.63445
C	-1.92309	-0.57969	-5.10238
H	-0.82138	0.64400	-3.70578
H	-0.03263	-0.90240	-4.09279
H	-4.78421	-0.15851	-3.58713
H	-3.96804	-1.70282	-3.93558
H	-1.51228	-0.06740	-5.97732
H	-2.04040	-1.64931	-5.35197
O	-2.01276	-3.09607	2.66736
O	-3.19404	-0.01045	-4.84071
N	-1.59692	-1.00902	-2.68941
H	-2.28222	-0.76662	0.46022
N	-1.48942	-1.41394	0.41342

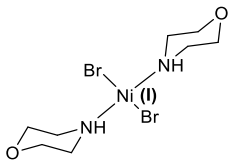


(neutral triplet, -7807.205703, -7806.622537, -7806.716298, -7806.71328)

Ni	-0.08903	0.33546	-2.31985
Br	-1.80567	2.13113	-2.01562

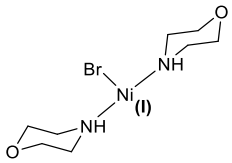
Br	1.53258	-1.54716	-2.65100
C	-2.91188	-1.12421	-1.84936
C	-1.81891	-1.88124	-3.83464
H	-1.03911	-1.93043	-1.99587
C	-3.60775	-2.46779	-1.75677
H	-3.51137	-0.41157	-2.42884
H	-2.78765	-0.70024	-0.84620
C	-2.52326	-3.21348	-3.68642
H	-2.44476	-1.20626	-4.42965
H	-0.85144	-2.01165	-4.33326
H	-4.60614	-2.36025	-1.32136
H	-3.02091	-3.14499	-1.10810
H	-2.72447	-3.66094	-4.66469
H	-1.88577	-3.91192	-3.11202
N	-1.59951	-1.24887	-2.51745
O	-3.77214	-3.05931	-3.03362
C	1.11806	-0.49240	0.65790
C	-0.99331	0.62096	0.86385
H	-0.62518	-1.09637	-0.14220
C	0.88723	-1.11610	2.01829
H	1.66516	0.45276	0.78560
H	1.71810	-1.15803	0.02821
C	-1.16517	-0.03674	2.21628
H	-0.51387	1.60325	0.97641
H	-1.96636	0.79707	0.39586
H	1.83717	-1.26454	2.54129
H	0.40175	-2.10264	1.90049
H	-1.73904	0.60632	2.89087
H	-1.71683	-0.98906	2.09809
N	-0.15182	-0.19448	-0.04076
O	0.08253	-0.28724	2.83808
C	2.88465	1.36293	-1.60901
C	1.49966	3.13164	-2.43211
H	1.09256	1.95825	-0.83552
C	3.72045	2.39935	-0.88700
H	3.29279	1.18003	-2.61147
H	2.91002	0.40821	-1.07861
C	2.36774	4.12250	-1.68497
H	1.90751	2.99778	-3.44478
H	0.47249	3.50662	-2.50565
H	4.76709	2.08399	-0.83432
H	3.34869	2.52816	0.14748
H	2.41578	5.07626	-2.21949
H	1.94025	4.30936	-0.68243
N	1.48316	1.80898	-1.77039
O	3.69574	3.64807	-1.55639
C	1.26482	0.67796	-5.17279
C	-1.10968	0.97494	-5.28022
H	0.15333	1.99922	-4.10581
C	1.39924	1.58692	-6.37940
H	1.17205	-0.36867	-5.48718
H	2.15298	0.74008	-4.53500
C	-0.91678	1.89631	-6.46609
H	-1.21615	-0.05230	-5.64465
H	-2.00398	1.24649	-4.70724
H	2.24737	1.28538	-7.00203

H	1.57173	2.62864	-6.04865
H	-1.76370	1.83238	-7.15620
H	-0.83106	2.94391	-6.12032
N	0.06360	1.01861	-4.38401
O	0.24377	1.53913	-7.19860



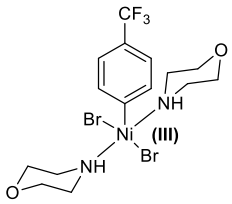
(anion radical, -7231.926212, -7231.632868, -7231.702509, -7231.69949)

Ni	-0.35732	-0.67021	-1.09591
Br	-0.29896	1.70418	-0.59596
Br	1.35794	-2.32294	-1.58790
C	-1.99992	-2.78396	0.32325
C	-0.80743	-1.24456	1.74507
C	-2.69732	-3.32664	1.55346
H	-1.09673	-3.37162	0.10603
H	-2.66282	-2.85890	-0.54755
C	-1.53809	-1.83515	2.93298
H	0.15236	-1.76165	1.59640
H	-0.59299	-0.18019	1.90020
H	-2.92189	-4.39265	1.44273
H	-3.64894	-2.78813	1.71869
H	-0.91444	-1.80977	3.83268
H	-2.46016	-1.25967	3.13644
C	-2.98840	-0.35499	-2.58244
C	-1.01810	-0.55188	-3.95215
H	-1.81966	-2.02588	-2.79850
C	-3.83223	-0.48844	-3.83390
H	-2.79209	0.70436	-2.36477
H	-3.52183	-0.77870	-1.72276
C	-1.91665	-0.68183	-5.16397
H	-0.74543	0.50227	-3.79472
H	-0.09030	-1.12219	-4.08106
H	-4.76151	0.08451	-3.74977
H	-4.09435	-1.54975	-4.00066
H	-1.44617	-0.25125	-6.05403
H	-2.12674	-1.74852	-5.36612
O	-1.87482	-3.19484	2.70252
O	-3.14104	0.00952	-4.96948
N	-1.68326	-1.01589	-2.72285
H	-2.40067	-0.78716	0.56128
N	-1.57561	-1.38663	0.49637



(neutral radical, -4657.723492, -4657.432192, -4657.495468, -4657.492449)

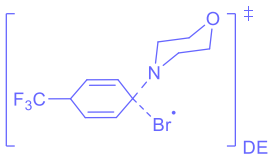
Ni	-2.04170	1.84086	-0.49747
Br	-4.33938	1.82767	-0.44783
C	-1.60848	-0.96100	0.17403
C	-1.57063	-0.50758	-2.20267
H	-0.17676	0.07558	-0.83649
C	-1.08659	-2.35151	-0.12345
H	-2.70632	-0.96437	0.19969
H	-1.24786	-0.60459	1.14597
C	-1.05281	-1.91431	-2.42221
H	-2.66731	-0.49329	-2.26155
H	-1.18209	0.17838	-2.96511
H	-1.46485	-3.07599	0.60456
H	0.01773	-2.36163	-0.07854
H	-1.40730	-2.31805	-3.37578
H	0.05240	-1.91428	-2.43712
C	0.30325	3.26372	-1.46733
C	-0.65841	4.13587	0.57713
H	0.29569	2.34674	0.36018
C	1.49668	4.16890	-1.24212
H	-0.44386	3.77262	-2.09114
H	0.60294	2.34424	-1.98412
C	0.56678	5.01371	0.72827
H	-1.44661	4.67631	0.03414
H	-1.05920	3.84887	1.55545
H	1.92562	4.49285	-2.19538
H	2.27951	3.63229	-0.67570
H	0.31227	5.95690	1.22139
H	1.32888	4.49889	1.34113
O	-1.51168	-2.78969	-1.40421
O	1.11925	5.33929	-0.53636
N	-0.35864	2.90680	-0.19183
N	-1.19649	0.00429	-0.86777



(neutral radical, -7800.296693, -7799.897882, -7799.984819, -7799.981801)

Ni	-0.73235	0.10750	-0.57588
Br	-2.24864	0.79006	-2.32532
Br	-2.45485	-0.73597	0.77280
C	0.31722	-0.00791	1.04877

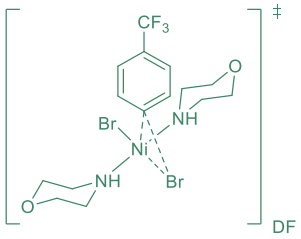
C	1.34939	-0.91313	1.25755
C	0.09409	1.01820	1.97134
C	2.15965	-0.80293	2.38964
H	1.56984	-1.71887	0.56226
C	0.89951	1.13193	3.09649
H	-0.72810	1.71963	1.83561
C	1.93292	0.21638	3.30451
H	2.96568	-1.51484	2.54161
H	0.71849	1.92852	3.81562
C	2.78673	0.37579	4.52023
F	3.37187	1.59011	4.56548
F	2.06816	0.27087	5.65710
F	3.76935	-0.53197	4.59585
C	-0.48694	-2.92141	-0.76763
C	-0.37705	-1.87985	-2.91827
H	0.95589	-1.63192	-1.40530
C	0.18504	-4.14381	-1.35748
H	-1.57576	-2.99409	-0.86554
H	-0.26171	-2.82951	0.29917
C	0.29787	-3.12633	-3.45131
H	-1.46563	-1.96477	-3.00737
H	-0.07112	-0.99821	-3.48675
H	-0.17111	-5.05108	-0.86050
H	1.28012	-4.08209	-1.21393
H	0.02920	-3.28484	-4.49999
H	1.39678	-3.01783	-3.39084
C	1.23900	1.15908	-2.62451
C	0.29390	2.77513	-1.09270
H	1.50601	1.20928	-0.61004
C	2.32946	2.16734	-2.93382
H	0.39746	1.27163	-3.31719
H	1.64475	0.14543	-2.71219
C	1.41818	3.72119	-1.45887
H	-0.57086	2.92564	-1.74718
H	-0.02248	2.93909	-0.05606
H	2.66492	2.05318	-3.96854
H	3.19727	2.00266	-2.27023
H	1.07177	4.75705	-1.40325
H	2.26440	3.60181	-0.75865
O	-0.10785	-4.27822	-2.73579
O	1.85859	3.49247	-2.78469
N	0.71996	1.35883	-1.24986
N	-0.06482	-1.68743	-1.47881



(neutral radical, 575.6 i cm^{-1}, -3429.579196, -3429.346592, -3429.408194, -3429.405175)

C	1.04254	0.98497	-0.53004

C	2.07033	1.88644	-0.38704
C	1.83538	3.14949	0.18773
C	0.54386	3.51685	0.57565
C	-0.50361	2.62823	0.41907
H	1.21056	0.01010	-0.98060
H	3.06734	1.62573	-0.73671
H	0.35042	4.51061	0.96882
H	-1.51831	2.92425	0.67156
C	2.98444	4.09232	0.31211
F	2.65574	5.24417	0.91134
F	3.50453	4.41263	-0.89214
F	4.00095	3.55775	1.01970
C	-0.25111	1.30206	-0.02184
Br	-1.73477	0.41600	-0.88516
C	0.85328	0.39323	2.44742
C	-1.49338	0.61360	2.44361
C	0.74228	-0.55379	3.64432
H	0.97220	1.42631	2.82501
H	1.74103	0.12902	1.85995
C	-1.57777	-0.35777	3.61922
H	-1.40926	1.63347	2.85768
H	-2.40580	0.54480	1.83735
H	1.60853	-0.43492	4.30194
H	0.70916	-1.59599	3.28539
H	-2.42713	-0.10302	4.26031
H	-1.70806	-1.38767	3.24704
N	-0.34121	0.23006	1.65103
O	-0.41004	-0.26983	4.41044



(neutral radical, 100.6 i cm^{-1}, -7800.284282, -7799.886982, -7799.97292, -7799.969902)

Ni	-1.95423	1.59416	0.67489
Br	-3.57027	2.59359	-0.84232
Br	-3.32723	0.51542	2.35533
C	-1.37045	1.41137	2.58579
C	-0.29655	0.55553	2.86831
C	-1.46473	2.65757	3.23255
C	0.74414	1.00215	3.66897
H	-0.25094	-0.44437	2.44711
C	-0.42206	3.09368	4.03495
H	-2.34926	3.27574	3.08902
C	0.68960	2.27322	4.24448
H	1.59735	0.35446	3.85031
H	-0.47956	4.07148	4.50993
C	1.78937	2.77561	5.11734
F	2.28516	3.95181	4.67871

F	1.37028	3.00442	6.38035
F	2.82313	1.92635	5.20053
C	-1.67792	-1.46294	0.20019
C	-1.54944	-0.09015	-1.74881
H	-0.21577	-0.10542	-0.19556
C	-1.03955	-2.58877	-0.58642
H	-2.76982	-1.50188	0.09758
H	-1.44669	-1.56053	1.26515
C	-0.91868	-1.24829	-2.49118
H	-2.64185	-0.12387	-1.83869
H	-1.22329	0.86441	-2.16902
H	-1.41261	-3.55728	-0.23963
H	0.05684	-2.57300	-0.44772
H	-1.20503	-1.22854	-3.54708
H	0.18386	-1.18004	-2.43274
C	0.23657	2.77716	-1.16003
C	-0.73011	4.30335	0.41724
H	0.37255	2.64420	0.86778
C	1.38019	3.75437	-1.35036
H	-0.56357	2.97776	-1.88454
H	0.60466	1.75650	-1.31584
C	0.44512	5.22938	0.19582
H	-1.54352	4.53399	-0.28133
H	-1.11610	4.41622	1.43592
H	1.75711	3.70876	-2.37651
H	2.20983	3.49777	-0.66668
H	0.13975	6.27384	0.30983
H	1.23990	5.02029	0.93694
O	-1.34739	-2.49186	-1.96518
O	0.96500	5.08693	-1.11491
N	-0.35645	2.88723	0.18904
N	-1.23512	-0.13886	-0.29809

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