

Supporting Information

Improved Bimetallic Cobalt-Manganese Catalysts for Selective Oxidative Cleavage of Morpholine Derivatives

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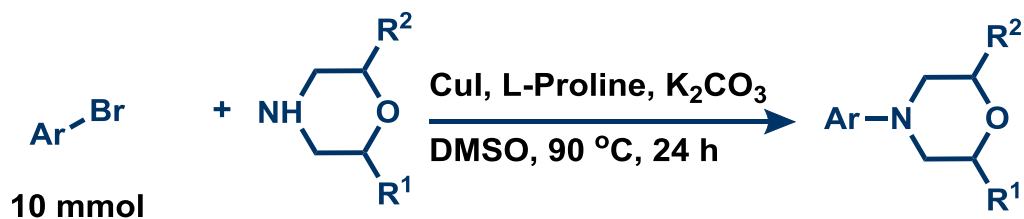
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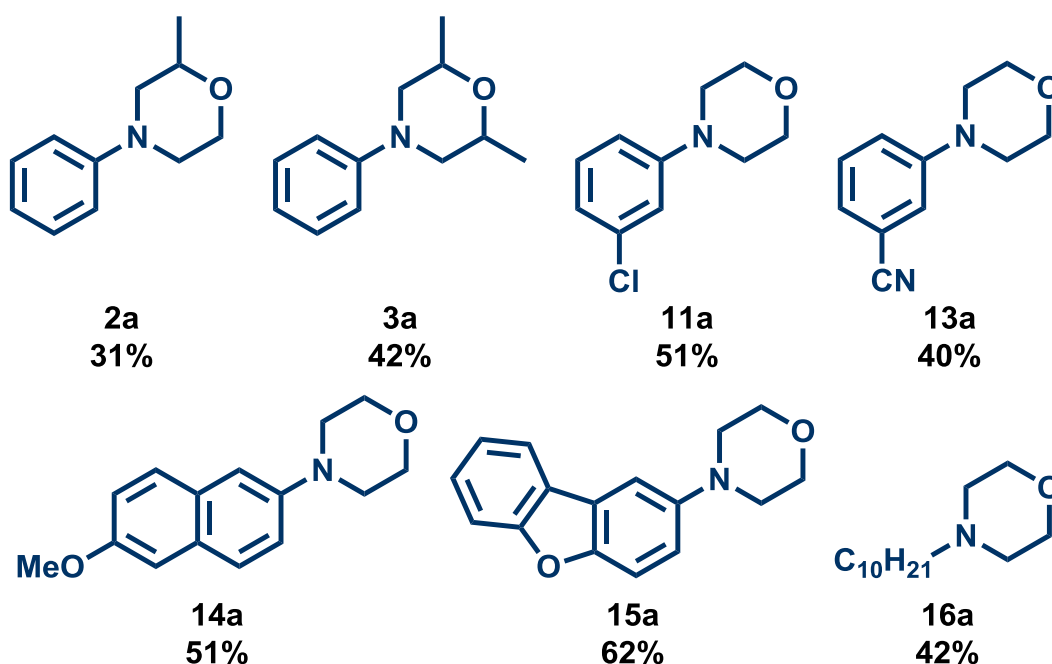
1. GENERAL EXPERIMENTAL DETAILS

- Most morpholines were obtained from commercial sources and used as supplied; others were prepared as detailed below.
- All metal catalysts were obtained from commercial sources and used as supplied
- Unless otherwise mentioned, all catalytic oxidation reactions were carried out in 4 mL glass vials, which were set in an alloy plate and placed inside 300 mL autoclave (Parr Instrument Company).
- All oxidation reactions were performed in a Parr® Instrument Company autoclave.
- Deuterated solvents were ordered from Deutero GmbH. NMR spectra were received using Bruker 300 Fourier, Bruker AV 300 and Bruker AV 400 spectrometers. Chemical shifts are reported in ppm, relative to the deuterated solvent. Coupling constants are expressed in Hertz (Hz). The following abbreviations are used: s = singlet, d = doublet, t = triplet, and m = multiplet. The residual solvent signals were used as references for ^1H and ^{13}C NMR spectra (CDCl_3 : $\delta\text{H} = 7.26$ ppm, $\delta\text{C} = 77.12$ ppm; $\text{DMSO}-d_6$: $\delta\text{H} = 2.50$ ppm, $\delta\text{C} = 39.52$ ppm). All measurements were carried out at room temperature unless otherwise stated.
- GC-FID analyses were carried out using an Agilent 7890B gas chromatograph fitted with an Agilent HP5 column (30 m x 0.25 mm I.D. x 0.25 μm).
- High resolution mass spectra (HRMS) were obtained either from a MAT 95 XP from Thermo (EI) or from an HPLC system 1200 and downstream ESI-TOF-MS 6210 from Agilent (ESI).
- Solvents were used directly without further purification. HPLC grade MeCN was supplied by Fisher Chemical. Linezolid was obtained from Gute Chemie–abcr.

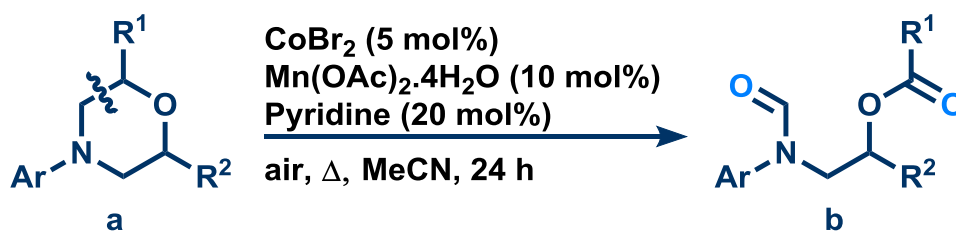
2. GENERAL PROCEDURE FOR THE SYNTHESIS OF SUBSTRATES



1. **General Procedure A (GP-A).** A mixture of aryl bromide (10 mmol), morpholines (20 mmol), K_2CO_3 (20 mmol), CuI (1.0 mmol) and L-proline (2.0 mmol) in 10 mL of DMSO was heated at 90 °C and for 24 h. The cooled mixture was partitioned between water and ethyl acetate. The organic layer was separated, and the aqueous layer was extracted with ethyl acetate. The combined organic layers were dried over Na_2SO_4 , and concentrated in vacuo. The desired products were isolated by silica gel column chromatography (*n*-heptane/ethyl acetate mixtures). (Ma, D.; Cai, Q; Zhang, H., Mild Method for Ullmann Coupling Reaction of Amines and Aryl Halides. *Org. Lett.*, **2003**, 5, 2453–2455.)



3. GENERAL PROCEDURE FOR CATALYTIC OXIDATIONS



General Procedure B (GP-B). To a 4 mL glass vial equipped with a magnetic stir bar, aryl morpholine (0.5 mmol), Mn(OAc)₂·4H₂O (6.1 mg; 5 mol%) and CoBr₂ (10.9 mg; 10 mol%) were added. The vial was capped and pierced with a small needle. HPLC grade acetonitrile (2 mL) was added *via* a 2 mL syringe. Pyridine (8 μL; 20 mol%) was added via a glass microsyringe. The vial was then placed into an aluminium heating block and then sealed inside an autoclave (Parr[®] Instrument Company). The autoclave was then pressurized with air (20 bar). The reaction mixture was stirred for 24 hours at 60 °C. Next, the reaction was cooled to room temperature. A sample of the reaction mixture was analyzed by GC-FID and using TLC. The product was purified via flash column chromatography (RediSep[®] Rf+ automatic column) using heptane/ethyl acetate. Solvent was removed *in vacuo* to yield the desired product.

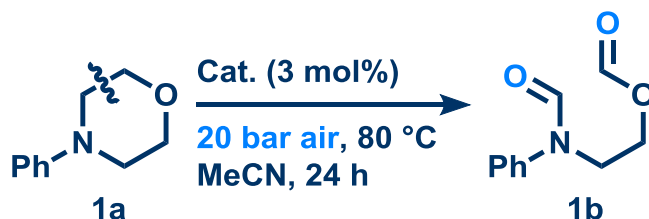
General Procedure C (GP-C). To a 4 mL glass vial equipped with a magnetic stir bar, aryl morpholine (0.5 mmol), Mn(OAc)₂·4H₂O (6.1 mg; 5 mol%) and CoBr₂ (10.9 mg; 10 mol%) were added. The vial was capped and pierced with a small needle. HPLC grade acetonitrile (2 mL) was added *via* a 2 mL syringe. Pyridine (8 μL; 20 mol%) was added via a glass microsyringe. The vial was then placed into an aluminium heating block and then sealed inside an autoclave (Parr[®] Instrument Company). The autoclave was then pressurized with air (30 bar). The reaction mixture was stirred for 24 hours at 100 °C. Next, the reaction was cooled to room temperature. A sample of the reaction mixture was analyzed by GC-FID and using TLC. The product was purified via flash column chromatography (RediSep[®] Rf+ automatic column) using heptane/ethyl acetate. Solvent was removed *in vacuo* to yield the desired product.

General Procedure D (GP-D). To a 4 mL glass vial equipped with a magnetic stir bar, aryl morpholine (0.5 mmol), Mn(OAc)₂·4H₂O (6.1 mg; 5 mol%) and CoBr₂ (10.9 mg; 10 mol%)

were added. The vial was capped and pierced with a small needle. HPLC grade acetonitrile (2 mL) was added *via* a 2 mL syringe. Pyridine (8 μ L; 20 mol%) was added via a glass microsyringe. The vial was then placed into an aluminium heating block and then sealed inside an autoclave (Parr[®] Instrument Company). The autoclave was then pressurized with air (20 bar). The reaction mixture was stirred for 24 hours at 120 °C. Next, the reaction was cooled to room temperature. A sample of the reaction mixture was analyzed by GC-FID and using TLC. The product was purified via flash column chromatography (RediSep[®] Rf+ automatic column) using heptane/ethyl acetate. Solvent was removed *in vacuo* to yield the desired product.

4. CATALYTIC EXPERIMENTS

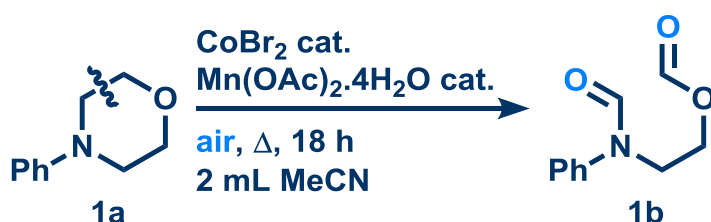
Table S1. Selective cleavage of C-C single bond of *N*-phenylmorpholine using different catalysts.



entry	catalyst	yield (%) ^a
1	Pd(OAc) ₂	0
2	Ru(acac) ₃	22
3	RuCl ₃	44
4	Fe(OAc) ₂	0
5	Co(OAc) ₂ ·4H ₂ O	0
6	AgCF ₃ SO ₃	0
7	Ag ₂ CO ₃	0
8	Mn(OAc) ₂ ·4H ₂ O	30
9	Mn(acac) ₂	0

Reaction conditions: **1a** (0.5 mmol), catalyst (3 mol%) in MeCN (2 mL), 20 bar air, 80 °C, 24 h. ^aYields determined by GC-FID using *n*-dodecane as an internal standard.

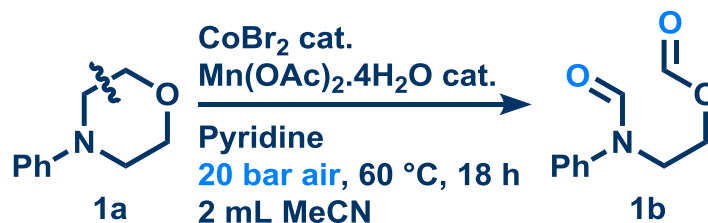
Table S2. Optimizing temperature and pressure for selective cleavage of C-C single bond of *N*-phenylmorpholine.



entry	temperature / °C	pressure / bar	yield 1b (%) ^a
1	r.t.	20	trace
2	40	10	44
3	40	20	72
4	60	20	>99 ^b

Reaction conditions: **1a** (0.5 mmol), CoBr₂ (10 mol%), Mn(OAc)₂·4H₂O (5 mol%) in MeCN (2 mL), 18 h. ^aYields determined by GC-FID using *n*-dodecane as an internal standard.
^bReaction stopped after 16 h.

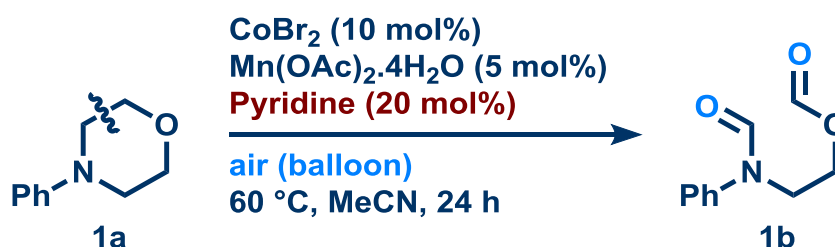
Table S3. Optimizing of catalysts and ligand for selective cleavage of C-C single bond of *N*-phenylmorpholine.



entry	pyridine / mol%	CoBr ₂ / mol%	Mn(OAc) ₂ ·4H ₂ O / mol%	yield 1b (%) ^a
1	20	5	5	91
2	20	10	5	>99 ^b
3	10	10	5	85

Reaction conditions: **1a** (0.5 mmol), CoBr₂ and Mn(OAc)₂·4H₂O in MeCN (2 mL), 20 bar air, 60 °C, 18 h. ^aYields determined by GC-FID using *n*-dodecane as an internal standard.
^bReaction stopped after 16 h.

Reaction using low pressure air.



1b was not detected, nor were any potential intermediates.

Reaction using N₂O gas. To a 4 mL glass vial equipped with a magnetic stir bar, **1a** (0.5 mmol), Mn(OAc)₂·4H₂O (6.1 mg; 5 mol%) and CoBr₂ (10.9 mg; 10 mol%) were added. The vial was capped and pierced with a small needle. HPLC grade acetonitrile (2 mL) was added *via* a syringe. Pyridine (8 μL; 20 mol%) was added via a glass microsyringe. The vial was then placed into an aluminium heating block and then sealed inside an autoclave (Parr Instrument Company). The autoclave was then pressurized with N₂O (6 bar). The reaction mixture was stirred overnight for 17 hours at 60 °C. Next, the reaction was cooled to room temperature. A sample of the reaction mixture was analyzed by GC-FID using *n*-dodecane as an internal standard.

Table S4. Comparison between air and N₂O as oxidant.

entry	oxidant (6 bar)	yield 1b (%)
1	N ₂ O	0
2	Air	80

^aYields determined by GC-FID using *n*-dodecane as an internal standard.

5. MECHANISTIC STUDIES

Radical trapping experiment using TEMPO. To a 4 mL glass vial equipped with a magnetic stir bar, **1a** (0.5 mmol), Mn(OAc)₂·4H₂O (6.1 mg; 5 mol%), CoBr₂ (10.9 mg; 10 mol%) and TEMPO (0.1-1.0 equiv.) were added. The vial was capped and pierced with a small needle. HPLC grade acetonitrile (2 mL) was added *via* a 2 mL syringe. Pyridine (8 µL; 20 mol%) was added via a glass microsyringe. The vial was then placed into an aluminium heating block and then sealed inside an autoclave (Parr Instrument Company). The autoclave was then pressurized with air (20 bar). The reaction mixture was stirred for 24 hours at 60 °C. Next, the reaction was cooled to room temperature. A sample of the reaction mixture was analyzed by GC-FID using *n*-dodecane as an internal standard.

Table S5. Reaction of *N*-phenylmorpholine with TEMPO under oxidation conditions.

entry	TEMPO (equiv.)	yield 1b (%)
1	0.1	0
2	0.2	0
3	0.5	0
4	1.0	0

^aYields determined by GC-FID using *n*-dodecane as an internal standard.

1b was not detected. Trace of a potential intermediate (m/z: 161) was detected by GC-MS (Figures S1-S4).

Figure S1. GC chromatogram of radical trapping experiment starting from **1a** and TEMPO (20 mol%).

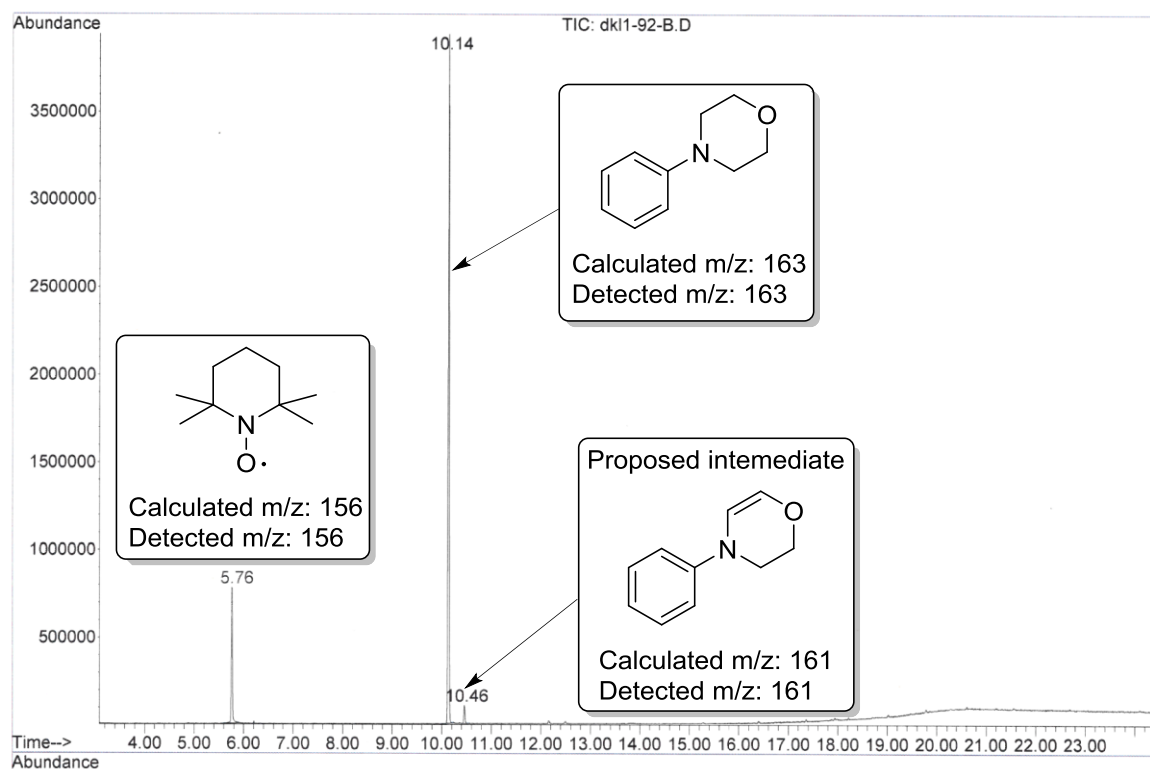


Figure S2. Mass spectrum of **1a** with retention time = 10.14 min.

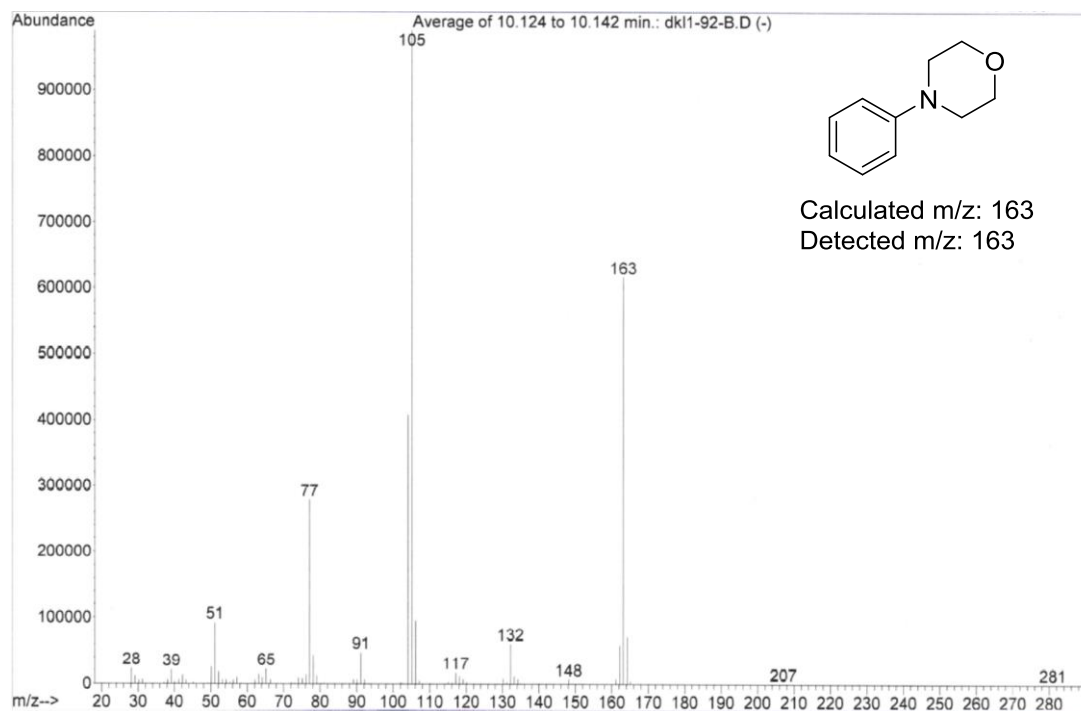


Figure S3. Mass spectrum of potential intermediate, starting from **1a**, with retention time = 10.46 min.

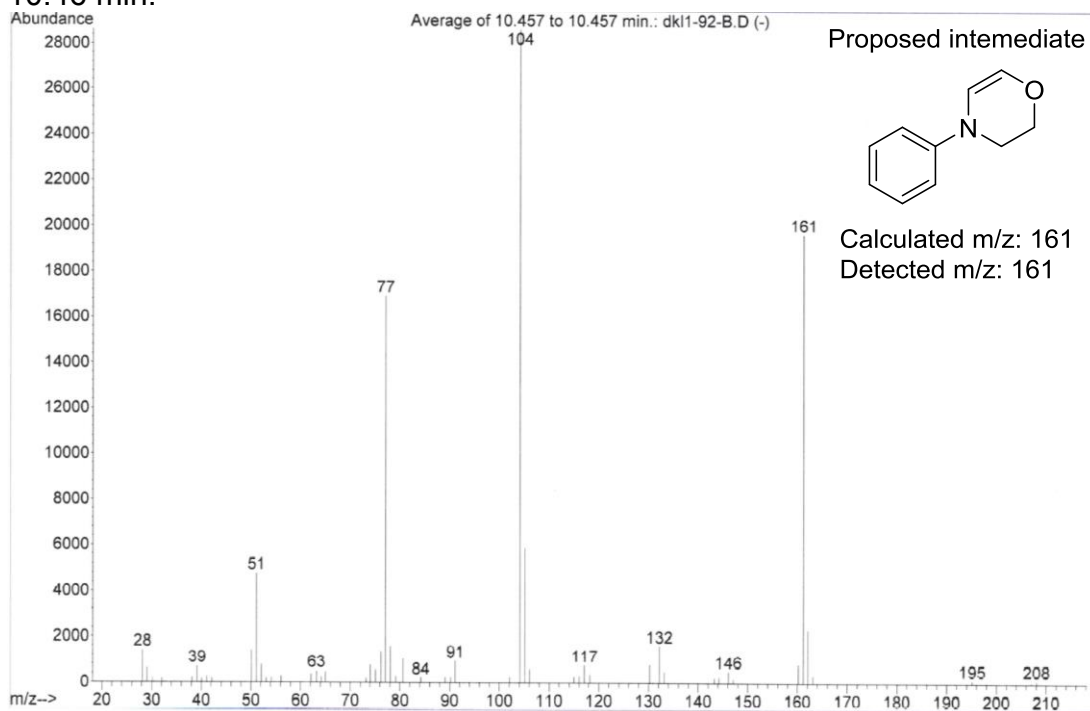
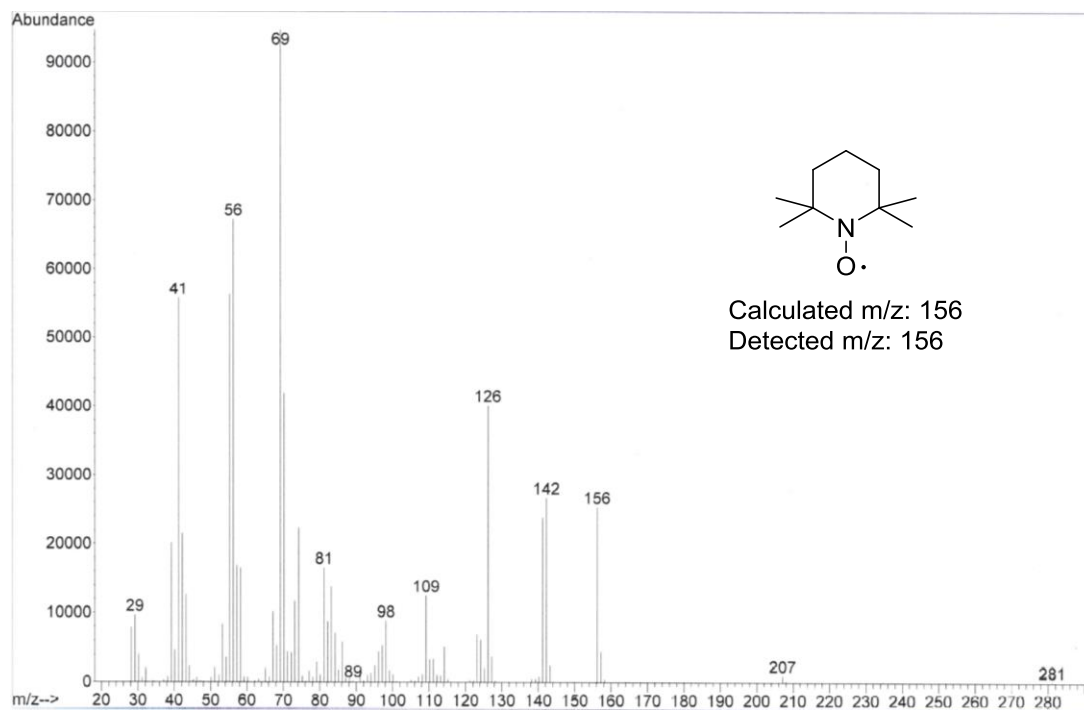


Figure S4. Mass spectrum of TEMPO with retention time = 5.76 min.



The radical trapping experiment was repeated using substrate **2a**. A corresponding potential intermediate (m/z : 175) was detected using GC-MS (Figure 7).

Figure S5. GC chromatogram of radical trapping experiment starting from **2a** and TEMPO (20 mol%).

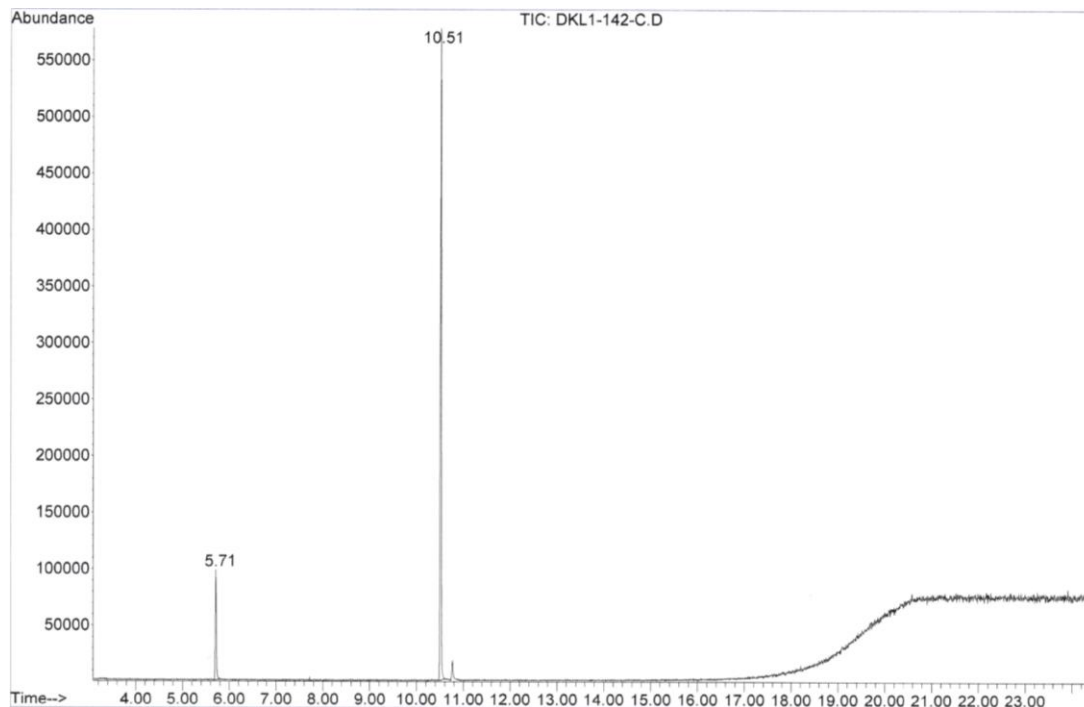


Figure S6. Mass spectrum of **2a** with retention time = 10.51 min.

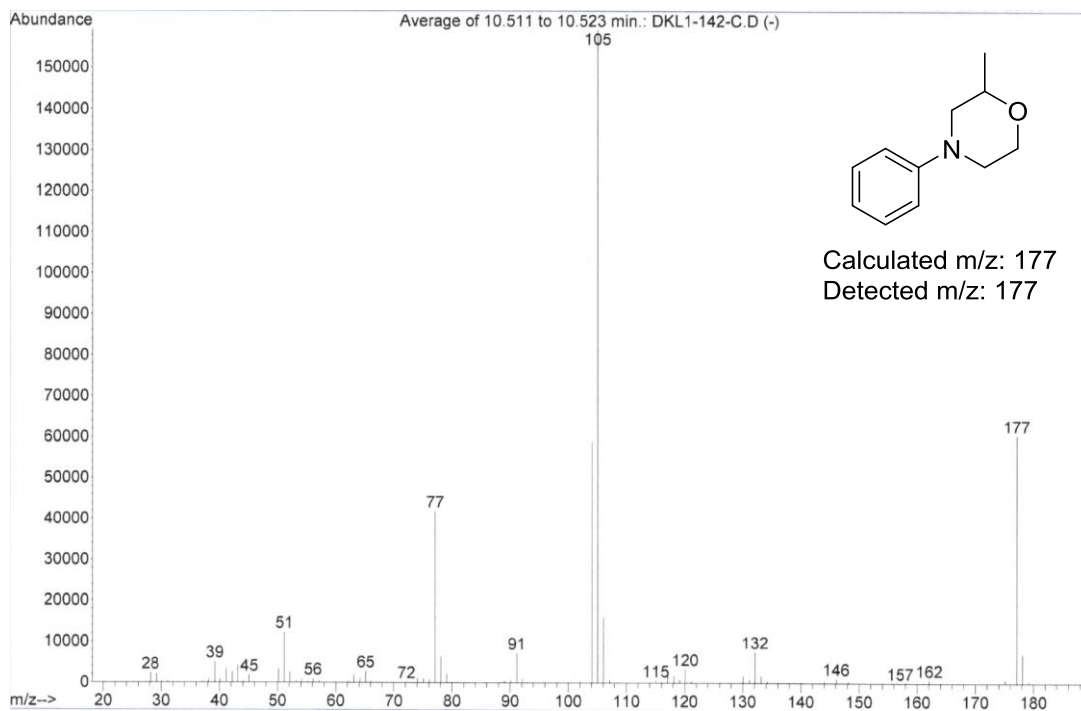
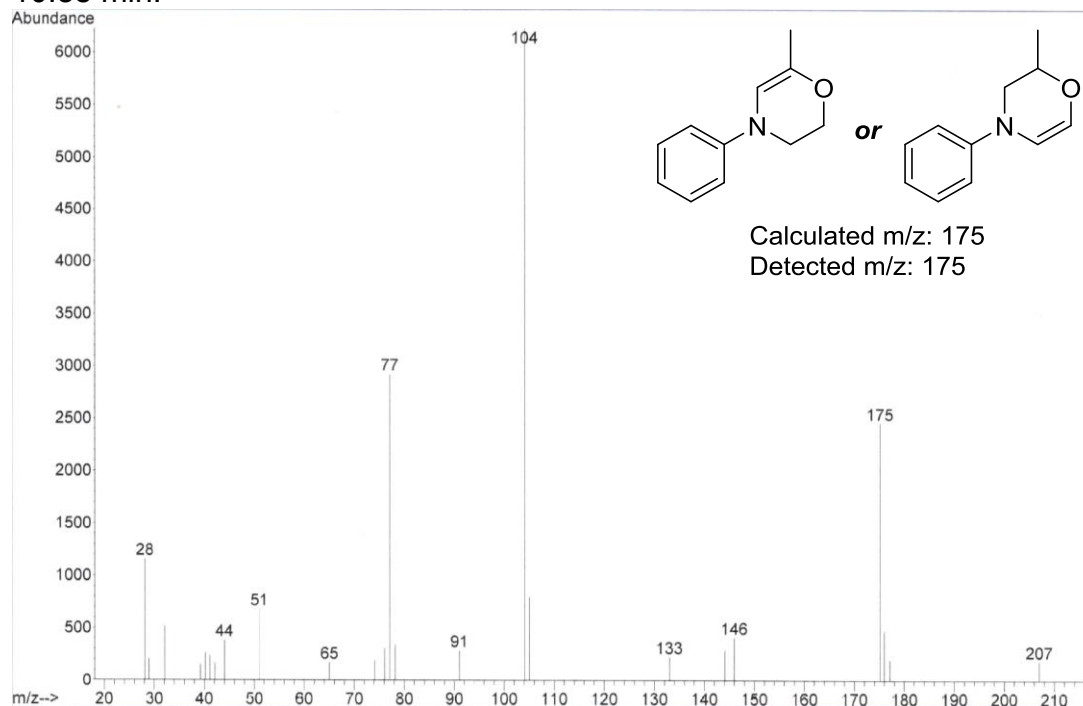


Figure S7. Mass spectrum of potential intermediate, starting from **2a**, with retention time = 10.88 min.

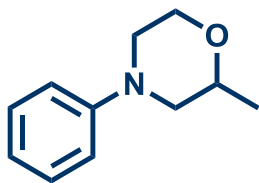


Radical trapping experiment using C₁₀F₂₁I. To a 4 mL glass vial equipped with a magnetic stir bar, **1a** (0.5 mmol), Mn(OAc)₂·4H₂O (6.1 mg; 5 mol%), CoBr₂ (10.9 mg; 10 mol%) and C₁₀F₂₁I (1.0 equiv.) were added. The vial was capped and pierced with a small needle. HPLC grade acetonitrile (2 mL) was added *via* a 2 mL syringe. Pyridine (8 μL; 20 mol%) was added via a glass microsyringe. The vial was then placed into an aluminium heating block and then sealed inside an autoclave (Parr Instrument Company). The autoclave was then pressurized with air (20 bar). The reaction mixture was stirred for 24 hours at 60 °C. Next, the reaction was cooled to room temperature. A sample of the reaction mixture was analyzed by GC-FID using *n*-dodecane as an internal standard.

No potential trapped intermediates were detected by GC-FID.

6. CHARACTERIZATION DATA FOR THE SUBSTRATES

2-methyl-4-phenylmorpholine (2a)

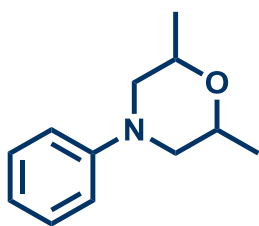


^1H NMR (300 MHz, CDCl_3): δ (ppm) 7.40–7.23 (m, 2H), 7.05–6.87 (m, 3H), 4.05 (ddd, J = 11.4, 3.5, 1.6 Hz, 1H), 3.89–3.68 (m, 2H), 3.56–3.30 (m, 2H), 2.86 (td, J = 11.8, 3.5 Hz, 1H), 2.52 (dd, J = 11.8, 10.2 Hz, 1H), 1.29 (d, J = 6.3 Hz, 3H).

$^{13}\text{C}\{^1\text{H}\}$ NMR (75 MHz, CDCl_3): δ (ppm) 151.24, 129.29, 120.05, 115.89, 71.90, 66.85, 55.73, 48.71, 19.19.

HR-MS (EI) m/z calcd for $\text{C}_{11}\text{H}_{15}\text{NO}$ [M^+]: 177.1148, found: 177.1149.

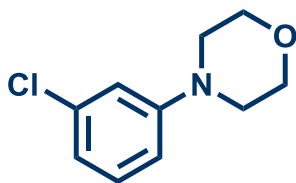
2,6-dimethyl-4-phenylmorpholine (3a)



^1H NMR (300 MHz, CDCl_3): δ (ppm) 7.37–7.26 (m, 2.67H), 7.05–6.74 (m, 3.54H), 4.19 (td, J = 6.3, 3.3 Hz, 0.43H), 3.84 (dq, J = 10.4, 6.3, 2.4 Hz, 2H), 3.48 (ddd, J = 11.1, 2.3, 1.2 Hz, 2H), 3.33–3.12 (m, 0.42H), 2.91 (ddd, J = 11.8, 6.1, 1.0 Hz, 0.40H), 2.60–2.25 (m, 2H), 1.29 (d, J = 6.3 Hz, 6H).

$^{13}\text{C}\{^1\text{H}\}$ NMR (75 MHz, CDCl_3): δ (ppm) 150.69, 128.89, 119.49, 115.59, 115.49, 71.38, 66.20, 54.58, 54.04, 18.81, 17.79.

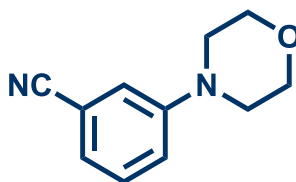
4-(3-chlorophenyl)morpholine (11a)



^1H NMR (300 MHz, CDCl_3): δ (ppm) 7.22–7.11 (m, 1H), 6.91–6.70 (m, 3H), 3.90–3.77 (m, 4H), 3.24–3.07 (m, 4H).

$^{13}\text{C}\{^1\text{H}\}$ NMR (75 MHz, CDCl_3): δ (ppm) 152.41, 135.10, 130.17, 119.74, 115.56, 113.66, 66.80, 48.93.

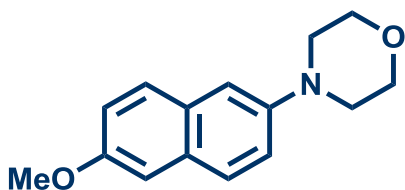
3-morpholinobenzonitrile (13a)



^1H NMR (300 MHz, CDCl_3): δ (ppm) 7.33 (dd, $J = 9.2, 7.4$ Hz, 1H), 7.17–7.03 (m, 3H), 3.94–3.74 (m, 4H), 3.26–3.09 (m, 4H).

$^{13}\text{C}\{^1\text{H}\}$ NMR (75 MHz, CDCl_3): δ (ppm) 151.41, 130.05, 123.02, 119.70, 119.35, 118.23, 113.12, 66.67, 48.52.

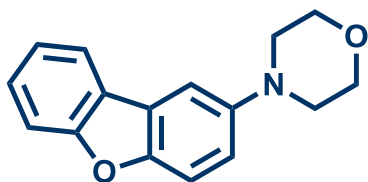
4-(6-Methoxynaphthalen-2-yl)morpholine (14a)



^1H NMR (400 MHz, CDCl_3): δ (ppm) 7.73–7.59 (m, 2H), 7.32–7.22 (m, 1H), 7.20–7.07 (m, 3H), 4.01–3.88 (m, 7H), 3.33–3.14 (m, 4H).

$^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz, CDCl_3): δ (ppm) 156.30, 147.70, 129.86, 129.69, 128.41, 127.75, 119.75, 119.01, 110.82, 105.90, 67.08, 55.38, 50.33.

4-(Dibenzo[b,d]furan-2-yl)morpholine (15a)

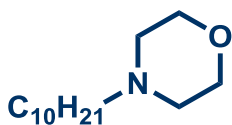


^1H NMR (400 MHz, CDCl_3): δ (ppm) 7.83 (ddd, $J = 7.7, 1.4, 0.7$ Hz, 1H), 7.46 (dt, $J = 8.3, 0.9$ Hz, 1H), 7.43–7.32 (m, 3H), 7.29–7.20 (m, 1H), 7.04 (dd, $J = 9.0, 2.5$ Hz, 1H), 4.07–3.73 (m, 4H), 3.28–3.01 (m, 4H).

$^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz, CDCl_3): δ (ppm) 156.92, 151.44, 127.18, 124.80, 124.57, 122.57, 120.60, 117.98, 112.06, 111.84, 107.92, 67.18, 51.51.

HR-MS (ESI): m/z calculated for $\text{C}_{16}\text{H}_{15}\text{NO}_2$ ($[\text{M}+\text{H}]^+$): 254.1176, found: 254.1176.

4-Decylmorpholine (16a)

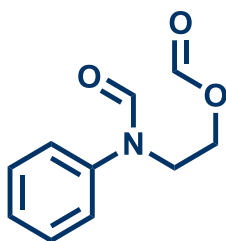


^1H NMR (400 MHz, CDCl_3) δ 3.74 – 3.67 (m, 4H), 2.42 (dd, $J = 4.2, 2.3$ Hz, 4H), 2.34 – 2.27 (m, 2H), 1.52 – 1.42 (m, 2H), 1.33 – 1.20 (m, 14H), 0.91 – 0.83 (m, 3H).

$^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz, CDCl_3) δ 67.15, 59.41, 53.95, 32.04, 29.72, 29.46, 27.68, 26.71, 22.82, 14.26.

7. CHARACTERIZATION DATA FOR THE PRODUCTS

2-(*N*-phenylformamido)ethyl formate (**1b**)



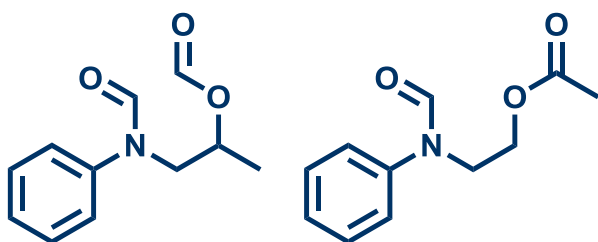
According to **GP-B**, the product **1b** was obtained as a yellow oil (93 mg, 0.48 mmol, 96%).

^1H NMR (400 MHz, CDCl_3): δ (ppm) 8.40 (s, 1H), 7.97 (t, $J = 0.7$ Hz, 1H), 7.46 – 7.40 (m, 2H), 7.35 – 7.30 (m, 1H), 7.23 – 7.18 (m, 2H), 4.34 (t, $J = 5.7$, 2H), 4.10 (t, $J = 5.6$ Hz, 2H).

$^{13}\text{C}\{^1\text{H}\}$ NMR (75 MHz, CDCl_3): δ (ppm) 44.15, 60.61, 124.44, 127.31, 129.80, 140.58, 160.54, 162.64

These data are consistent with the literature.²

1-(*N*-phenylformamido)propan-2-yl formate (**2b** & **2c**)



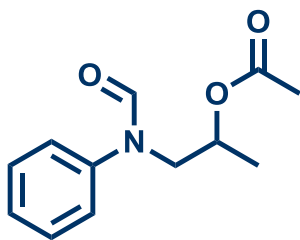
According to **GP-B**, the product mixture of **2b** and **2c** was obtained as a yellow oil (104 mg, 0.50 mmol, >99%).

^1H NMR (300 MHz, CDCl_3): δ (ppm) 8.39 (d, $J = 3.8$ Hz, 1H), 7.88 (s, 1H), 7.47 – 7.37 (m, 2H), 7.35 – 7.27 (m, 1H), 7.23 – 7.14 (m, 2H), 5.25 (m, $J = 7.5, 6.4, 4.4, 1.0$ Hz, 1H), 4.24 (t, $J = 5.5$ Hz, 1H), 4.10 – 3.91 (m, 2H), 1.90 (s, 1H), 1.28 (d, $J = 6.4$, 3H).

$^{13}\text{C}\{^1\text{H}\}$ NMR (75 MHz, CDCl_3): δ (ppm) 162.96, 160.46, 141.01, 129.91, 127.33, 124.43, 68.46, 61.49, 49.16, 44.39, 20.79, 17.94.

These data are consistent with the literature.²

1-(*N*-phenylformamido)propan-2-yl acetate (**3b**)



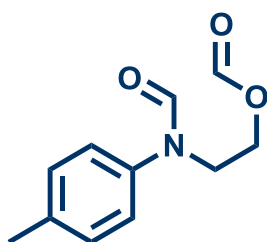
According to **GP-B**, the product **3b** was obtained as a yellow oil (73 mg, 0.33 mmol, 66%).

^1H NMR (300 MHz, CDCl_3): δ (ppm) 8.37 (s, 1H), 7.45 – 7.38 (m, 2H), 7.33 – 7.26 (m, 1H), 7.21 – 7.15 (m, 2H), 5.18 – 5.05 (m, 1H), 4.07 – 3.89 (m, 2H), 1.76 (s, 3H), 1.23 (d, J = 6.4 Hz, 3H).

$^{13}\text{C}\{^1\text{H}\}$ NMR (75 MHz, CDCl_3): δ (ppm) 170.49, 162.91, 141.36, 129.83, 127.10, 124.40, 68.92, 48.94, 21.04, 17.93.

These data are consistent with the literature.²

2-(*N*-*p*-tolylformamido)ethyl formate (**4b**)



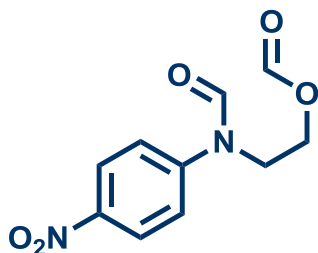
According to **GP-B**, the product **4b** was obtained as a yellow oil (88 mg, 0.43 mmol, 85%).

^1H NMR (300 MHz, CDCl_3): δ (ppm) 8.33 (s, 1H), 7.95 (p, J = 0.7 Hz, 1H), 7.24 – 7.17 (m, 2H), 7.10 – 7.04 (m, 2H), 4.30 (td, J = 5.7, 0.8 Hz, 2H), 4.05 (dd, J = 6.0, 5.3 Hz, 2H), 2.35 (s, 3H).

$^{13}\text{C}\{^1\text{H}\}$ NMR (75 MHz, CDCl_3): δ (ppm) 162.77, 160.64, 138.05, 137.43, 130.24, 124.66, 60.66, 44.26, 20.99.

These data are consistent with the literature.²

2-(*N*-(4-nitrophenyl)formamido)ethyl formate (**5b**)



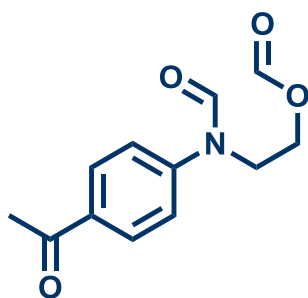
According to **GP-C**, the product **5b** was obtained as a yellow oil (51 mg, 0.22 mmol, 43%).

^1H NMR (300 MHz, CDCl_3): δ (ppm) 8.53 (s, 1H), 7.95 (t, $J = 0.7$ Hz, 1H), 7.77 – 7.68 (m, 2H), 7.38 – 7.30 (m, 2H), 4.43 – 4.34 (m, 2H), 4.19 – 4.10 (m, 2H).

$^{13}\text{C}\{^1\text{H}\}$ NMR (75 MHz, CDCl_3): δ (ppm) 161.80, 160.40, 144.77, 133.91, 123.26, 110.43, 60.61, 44.02

These data are consistent with the literature.²

2-(*N*-(4-acetylphenyl)formamido)ethyl formate (**6b**)



According to **GP-C**, the product **6b** was obtained as a yellow oil (91 mg, 0.39 mmol, 77%).

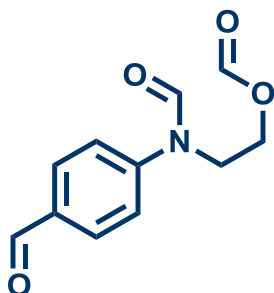
^1H NMR (300 MHz, CDCl_3): δ (ppm) 8.53 (s, 1H), 8.03 – 7.99 (dt, 2H), 7.95 (t, $J = 0.7$ Hz, 1H), 7.32 – 7.27 (dt, $J = 8.8, 2.0$ Hz, 2H), 4.36 (t, $J = 5.5$ Hz, 2H), 4.15 (t, $J = 5.6$ Hz, 2H).

$^{13}\text{C}\{^1\text{H}\}$ NMR (75 MHz, CDCl_3): δ (ppm) 196.63, 162.11, 160.47, 144.79, 135.28, 130.13, 122.82, 60.64, 43.88, 26.60.

HR-MS (EI) m/z calcd for $[\text{M}^+]$: 235.08391, found: 235.08392.

These data are consistent with the literature.²

2-(*N*-(4-formylphenyl)formamido)ethyl formate (**7b**)



According to **GP-C**, the product **7b** was obtained as a yellow oil (111 mg, 0.50 mmol, >99%).

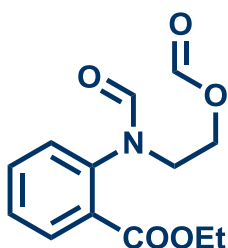
^1H NMR (300 MHz, CDCl_3): δ (ppm) 10.01 (s, 1H), 8.58 (s, 1H), 7.97 – 7.94 (m, 3H), 7.40 – 7.36 (m, 2H), 4.39 (t, J = 5.5 Hz, 2H), 4.19 – 4.16 (t, 2H).

$^{13}\text{C}\{^1\text{H}\}$ NMR (75 MHz, CDCl_3): δ (ppm) 190.78, 162.17, 160.57, 146.10, 134.57, 131.53, 123.17, 60.76, 44.07.

HR-MS (EI) m/z calcd for $[\text{M}^+]$: 221.06826, found: 221.06831.

These data are consistent with the literature.²

Ethyl 2-(*N*-(2-(formyloxy)ethyl)formamido)benzoate (**8b**)



According to **GP-D**, the product **8b** was obtained as a yellow oil (119 mg, 0.45 mmol, 90%).

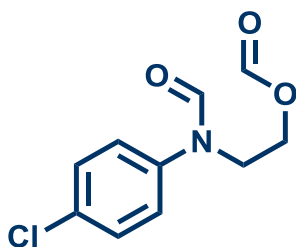
^1H NMR (400 MHz, CDCl_3): δ (ppm) 8.13 (s, 1H), 8.02 (ddd, J = 7.8, 1.6, 0.4 Hz, 1H), 7.93 (t, J = 0.7 Hz, 1H), 7.60 (ddd, J = 7.5, 1.7 Hz, 1H), 7.47 (td, J = 7.7, 1.3 Hz, 1H), 7.31 (ddd, J = 7.9, 1.3, 0.4 Hz, 1H), 4.39 – 4.24 (m, 4H), 4.00 (t, J = 5.6 Hz, 2H), 1.36 (t, J = 7.2 Hz, 3H).

$^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz, CDCl_3): δ (ppm) 165.59, 162.99, 160.68, 140.47, 133.43, 132.21, 129.94, 129.29, 128.69, 61.95, 61.28, 45.69, 14.28.

GC-MS (EI) (70 eV): m/z (%) = 265 (M^+).

These data are consistent with the literature.²

2-(*N*-(4-chlorophenyl)formamido)ethyl formate (9b)



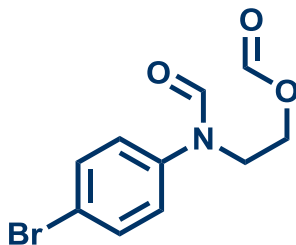
According to **GP-B**, the product **9b** was obtained as a yellow oil (102 mg, 0.45 mmol, 90%).

¹H NMR (300 MHz, CDCl₃): δ (ppm) 8.33 (s, 1H), 7.93 (t, *J* = 0.7 Hz, 1H), 7.41 – 7.31 (m, 2H), 7.18 – 7.08 (m, 2H), 4.30 (t, 5.5 Hz, 2H), 4.04 (t, *J* = 5.6 Hz, 2H).

¹³C{¹H} NMR (75 MHz, CDCl₃): δ (ppm) 162.32, 160.53, 139.31, 133.04, 129.99, 125.71, 60.62, 44.33.

These data are consistent with the literature.²

2-(*N*-(4-bromophenyl)formamido)ethyl formate (10b)



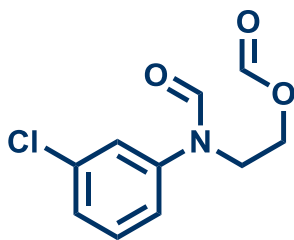
According to **GP-B**, the product **10b** was obtained as a yellow oil (114 mg, 0.42 mmol, 84%).

¹H NMR (300 MHz, CDCl₃): δ (ppm) 8.33 (s, 1H), 7.93 (dd, *J* = 1.1, 0.6 Hz, 1H), 7.57 – 7.46 (m, 2H), 7.12 – 7.01 (m, 2H), 4.30 (t, *J* = 5.5 Hz, 2H), 4.04 (t, *J* = 5.6 Hz, 2H).

¹³C{¹H} NMR (75 MHz, CDCl₃): δ (ppm) 162.24, 160.52, 139.83, 132.97, 125.93, 120.82, 60.62, 44.27.

These data are consistent with the literature.²

2-(*N*-(3-chlorophenyl)formamido)ethyl formate (**11b**)



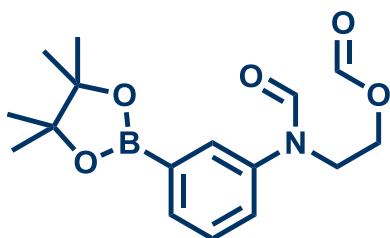
According to **GP-C**, the product **11b** was obtained as a yellow oil (80 mg, 0.35 mmol, 70%).

^1H NMR (300 MHz, CDCl_3): δ (ppm) 8.40 (s, 1H), 7.97 (p, $J = 0.7$ Hz, 1H), 7.36 (m, $J = 8.1$, 7.7, 0.5 Hz, 1H), 7.30 (ddd, $J = 8.1$, 1.9, 1.3 Hz, 1H), 7.23 (td, $J = 2.0$, 0.5 Hz, 1H), 7.10 (ddd, $J = 7.7$, 2.2, 1.3 Hz, 1H), 4.34 (t, $J = 5.5$ Hz, 2H), 4.08 (t, $J = 5.6$ Hz, 2H).

$^{13}\text{C}\{^1\text{H}\}$ NMR (75 MHz, CDCl_3): δ (ppm) 162.39, 160.60, 142.07, 135.59, 130.94, 127.56, 124.55, 122.44, 60.72, 44.41.

These data are consistent with the literature.²

2-(*N*-(3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)phenyl)formamido)ethyl formate (**12b**)



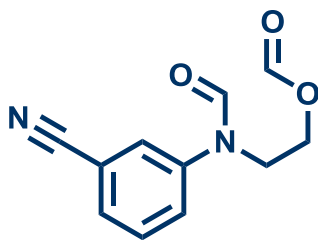
According to **GP-B**, the product **12b** was obtained as a yellow oil (89 mg, 0.28 mmol, 56%).

^1H NMR (300 MHz, CDCl_3): δ (ppm) 8.39 (s, 1H), 7.97 (t, $J = 0.7$ Hz, 1H), 7.75 (dt, $J = 7.3$, 1.1 Hz, 1H), 7.61 (ddd, $J = 2.4$, 1.1, 0.5 Hz, 1H), 7.43 (ddd, $J = 7.9$, 7.3, 0.6 Hz, 1H), 7.30 (dd, $J = 2.4$, 1.2 Hz, 1H), 4.32 (t, $J = 5.6$ Hz, 2H), 4.12 (t, $J = 5.3$ Hz, 2H), 1.35 (s, 12H).

$^{13}\text{C}\{^1\text{H}\}$ NMR (75 MHz, CDCl_3): δ (ppm) 24.87, 44.08, 60.66, 84.27, 127.34, 129.26, 130.50, 133.66, 140.09, 160.59, 162.75.

These data are consistent with the literature.²

2-(*N*-(3-cyanophenyl)formamido)ethyl formate (**13b**)



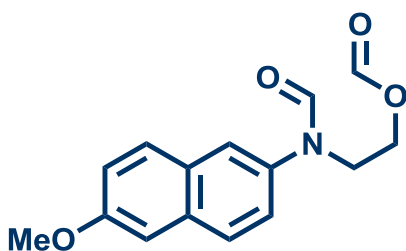
According to **GP-C**, the product **13b** was obtained as a yellow oil (88 mg, 0.41 mmol, 81%).

^1H NMR (300 MHz, CDCl_3): δ (ppm) 8.43 (s, 1H), 7.97 (t, J = 0.7 Hz, 1H), 7.67 – 7.51 (m, 3H), 7.47 (ddd, J = 7.7, 2.3, 1.5 Hz, 1H), 4.37 (t, J = 5.4 Hz, 1H), 4.11 (t, J = 5.5 Hz, 1H).

$^{13}\text{C}\{^1\text{H}\}$ NMR (75 MHz, CDCl_3): δ (ppm) 162.03, 160.50, 141.94, 131.04, 130.71, 128.39, 127.29, 117.72, 114.31, 60.75, 44.59

These data are consistent with the literature.²

2-(*N*-(6-methoxynaphthalen-2-yl)formamido)ethyl formate (**14b**)



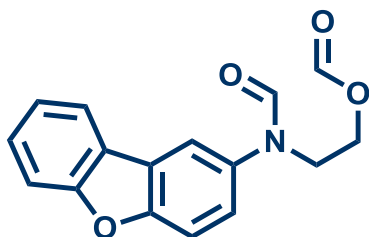
According to **GP-C**, the product **14b** was obtained as a yellow oil (82 mg, 0.30 mmol, 60%).

^1H NMR (400 MHz, Chloroform- d) δ 8.46 (s, 1H), 7.97 (t, J = 0.7 Hz, 1H), 7.79 (d, J = 8.8 Hz, 1H), 7.73 (d, J = 9.2 Hz, 1H), 7.56 (d, J = 2.2 Hz, 1H), 7.29 (dd, J = 8.7, 2.3 Hz, 1H), 7.22 (dd, J = 9.0, 2.5 Hz, 1H), 7.15 (d, J = 2.6 Hz, 1H), 4.37 (t, J = 5.7 Hz, 2H), 4.17 (t, J = 5.6 Hz, 2H), 3.94 (s, 3H).

$^{13}\text{C}\{^1\text{H}\}$ NMR (101 MHz, CDCl_3) δ 163.05, 160.74, 158.37, 136.02, 133.58, 129.33, 129.00, 128.78, 123.55, 123.22, 120.28, 105.82, 60.85, 55.55, 44.44.

These data are consistent with the literature.²

2-(*N*-(dibenzo[*b,d*]furan-2-yl)formamido)ethyl formate (**15b**)



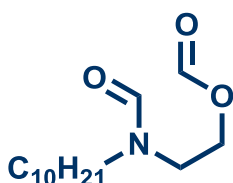
According to **GP-C** (using 1 equiv. of pyridine) the product **15b** was obtained as a yellow oil (38 mg, 0.135 mmol, 27%).

^1H NMR (300 MHz, CDCl_3) δ (ppm) 8.45 (s, 1H), 7.96 – 7.89 (m, 1H), 7.83 – 7.80 (m, 1H), 7.60 – 7.45 (m, 3H), 7.40 – 7.27 (m, 2H), 4.03 (t, J = 5.3 Hz, 2H), 3.84 (t, J = 5.3 Hz, 2H).

$^{13}\text{C}\{^1\text{H}\}$ NMR (75 MHz, CDCl_3) δ (ppm) 164.16, 157.04, 154.96, 136.34, 128.14, 125.45, 124.68, 123.56, 123.23, 121.00, 118.01, 112.67, 112.02, 60.59, 49.87.

These data are consistent with the literature.²

2-(*N*-(dibenzo[*b,d*]furan-2-yl)formamido)ethyl formate (**16b**)



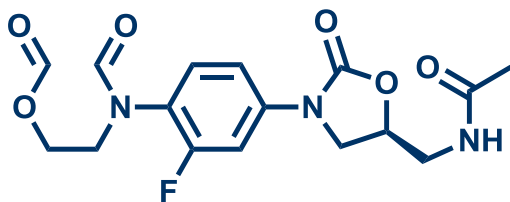
According to **GP-D** (using 1 equiv. of pyridine) the product **16b** was obtained as a yellow oil (22 mg, 0.085 mmol, 17%).

^1H NMR (300 MHz, CDCl_3) δ (ppm) 8.07 (s, 1H), 8.04 (p, J = 0.8 Hz, 1H), 4.35 – 4.21 (m, 2H), 3.58 (t, J = 5.7 Hz, 1H), 3.49 (t, J = 5.4 Hz, 1H), 3.37 – 3.21 (m, 2H), 1.53 (h, J = 7.0 Hz, 2H), 1.32 – 1.20 (m, 14H), 0.93 – 0.78 (m, 3H).

$^{13}\text{C}\{^1\text{H}\}$ NMR (75 MHz, CDCl_3) δ 163.30, 163.09, 160.76, 160.51, 77.58, 77.16, 76.74, 61.20, 60.72, 48.45, 45.99, 42.68, 41.32, 32.00, 31.98, 29.66, 29.64, 29.61, 29.44, 29.41, 29.39, 29.29, 28.86, 27.47, 26.99, 26.53, 22.79, 14.23.

These data are consistent with the literature.²

(S)-2-(N-(4-(5-(acetamidomethyl)-2-oxooxazolidin-3-yl)-2-fluorophenyl)formamido)ethyl formate (17b)



Synthesized according to **GP-C**. The product was purified via flash column chromatography (RediSep® Rf+ automatic column) using DCM/methanol. Solvent was removed *in vacuo* to yield **17b** as a yellow oil (150 mg, 0.41 mmol, 82%).

^1H NMR (300 MHz, DMSO- d_6): δ (ppm) 8.37 – 8.08 (m, 3H), 7.74 – 7.27 (m, 3H), 4.75 (m, J = 7.2 Hz, 1H), 4.20 – 4.04 (m, 2H), 3.94 (t, J = 5.3 Hz, 1H), 3.81 – 3.59 (m, 2H), 3.53 – 3.36 (m, 3H), 1.83 (s, 3H).

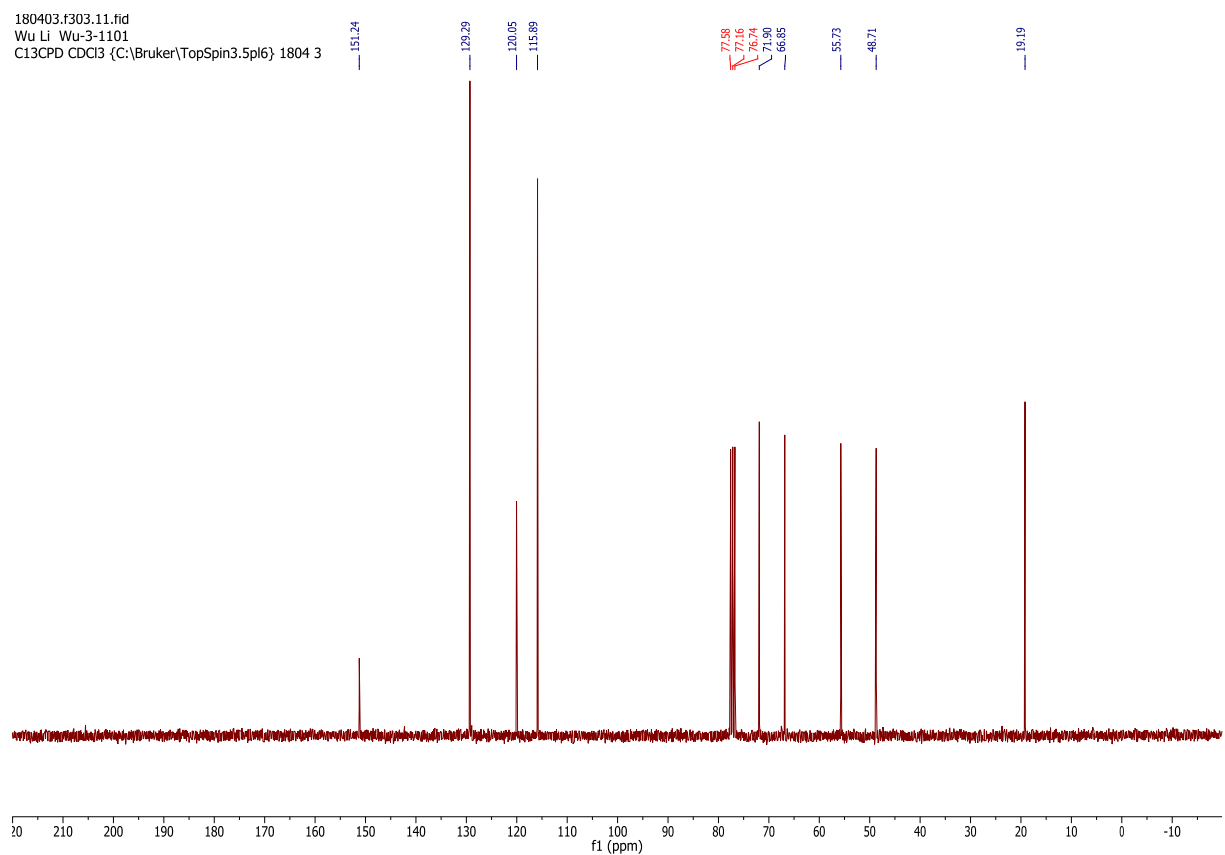
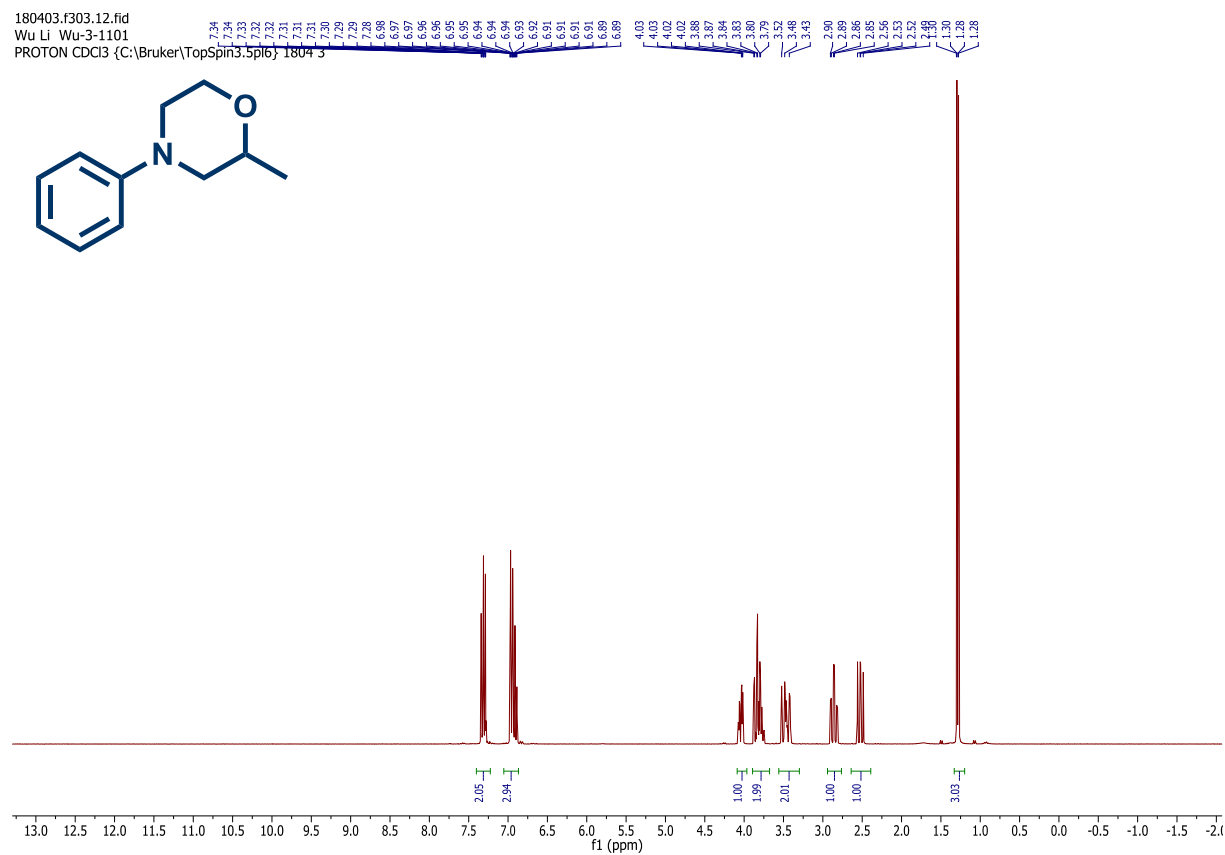
$^{13}\text{C}\{^1\text{H}\}$ NMR (75 MHz, DMSO- d_6): δ (ppm) 170.52, 163.61, 163.58, 163.40, 162.27, 162.24, 159.33, 156.35, 156.07, 154.45, 139.79, 139.74, 139.65, 139.60, 130.33, 129.92, 129.90, 123.25, 123.09, 121.24, 121.06, 114.56, 114.52, 114.37, 114.33, 106.60, 106.42, 106.25, 106.08, 72.24, 72.20, 61.04, 60.79, 48.17, 47.68, 43.94, 41.81, 22.89.

^{19}F NMR (282 MHz, DMSO- d_6): δ (ppm) -118.10 (m, J = 20.4, 12.9, 6.6 Hz), -121.61 (t, J = 10.9 Hz).

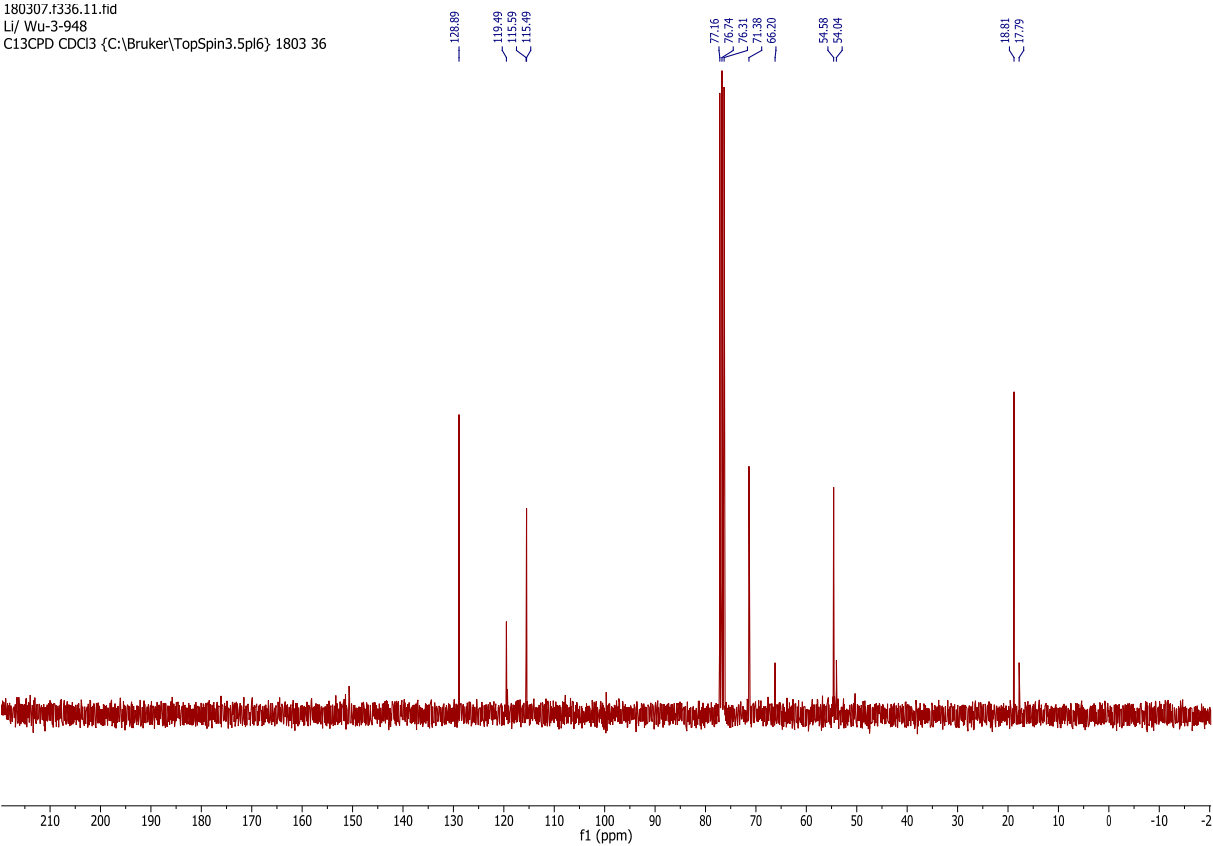
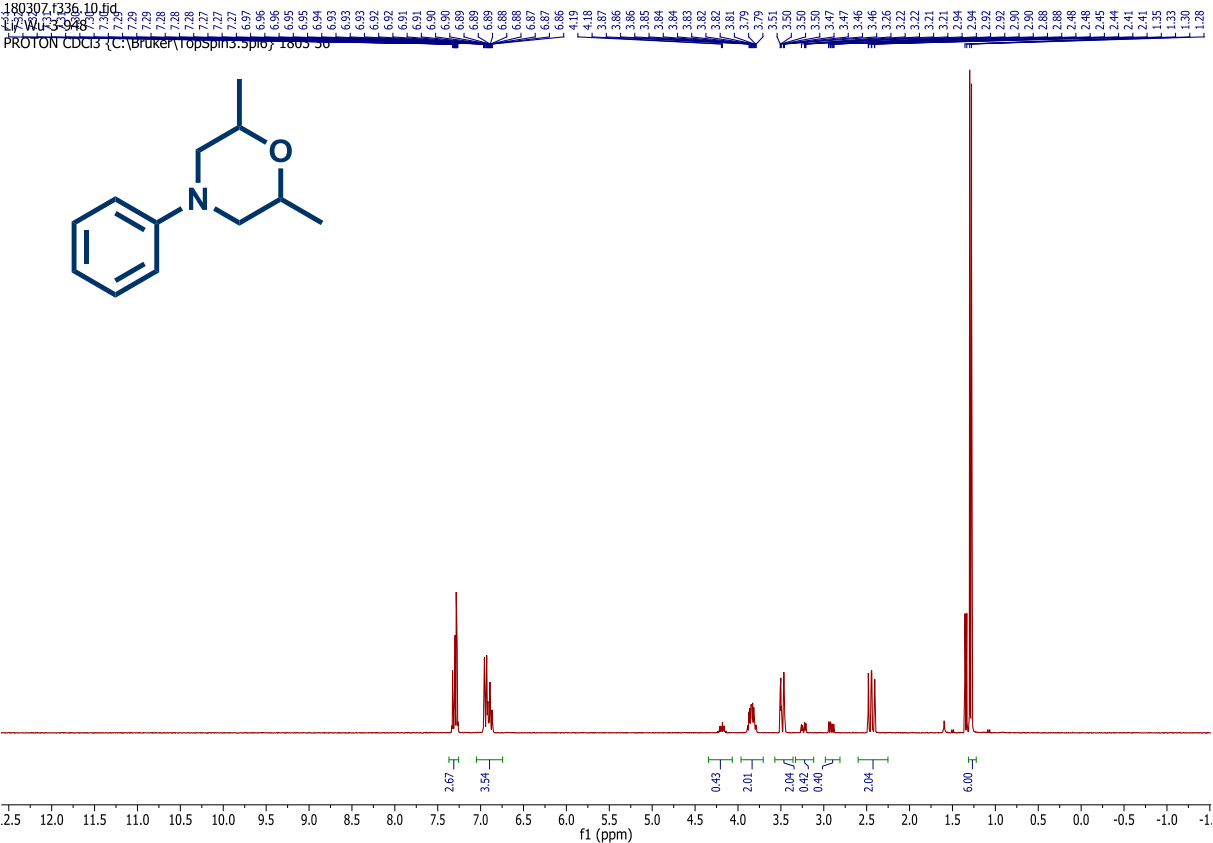
These data are consistent with the literature.²

8: ^1H NMR, ^{13}C NMR SPECTRA FOR SUBSTRATES

Original spectra for **2a**:



Original spectra for **3a**:

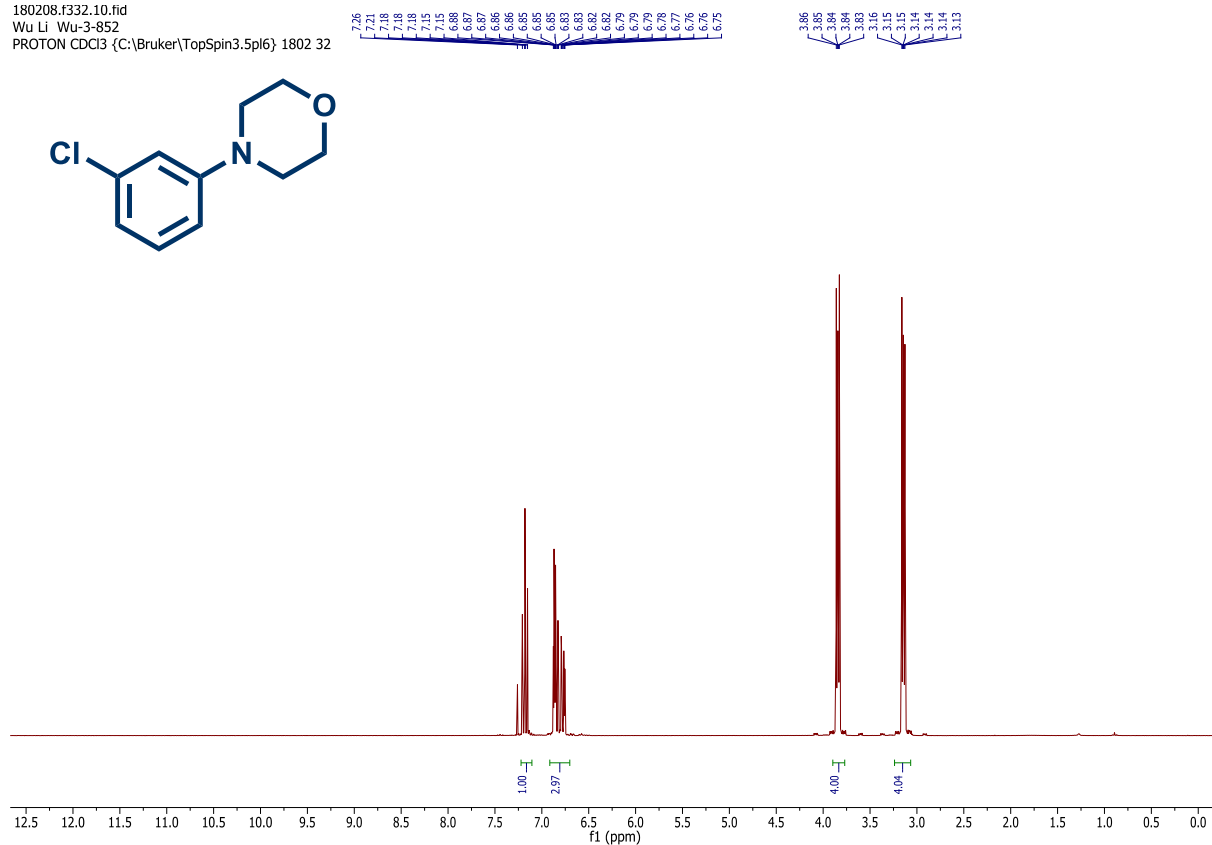
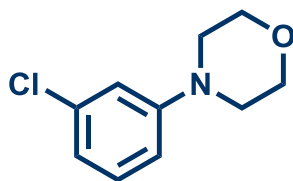


Original spectra for **11a**:

180208.f332.10.fid

Wu Li Wu-3-852

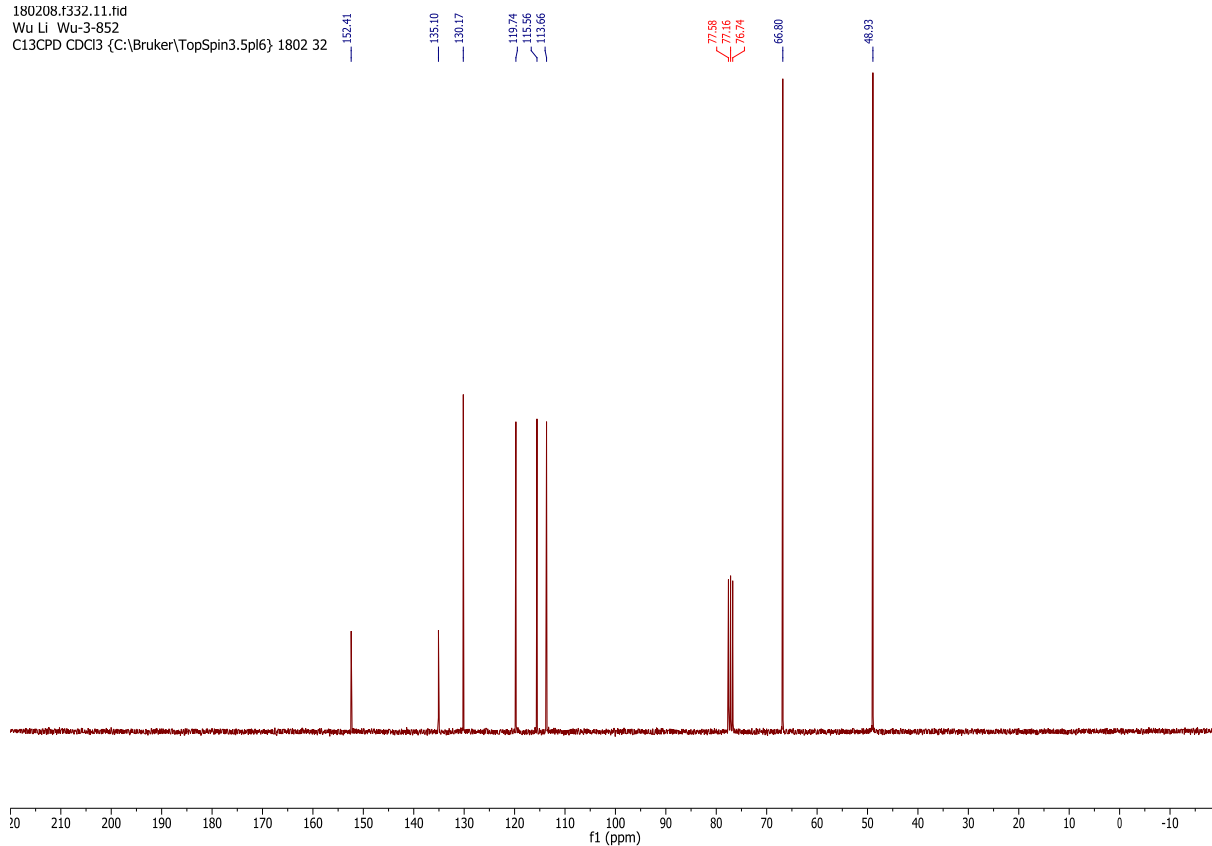
PROTON CDCl₃ {C:\Bruker\TopSpin3.5pl6} 1802 32



180208.f332.11.fid

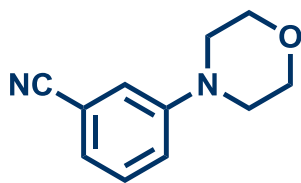
Wu Li Wu-3-852

C13CPD CDCl₃ {C:\Bruker\TopSpin3.5pl6} 1802 32

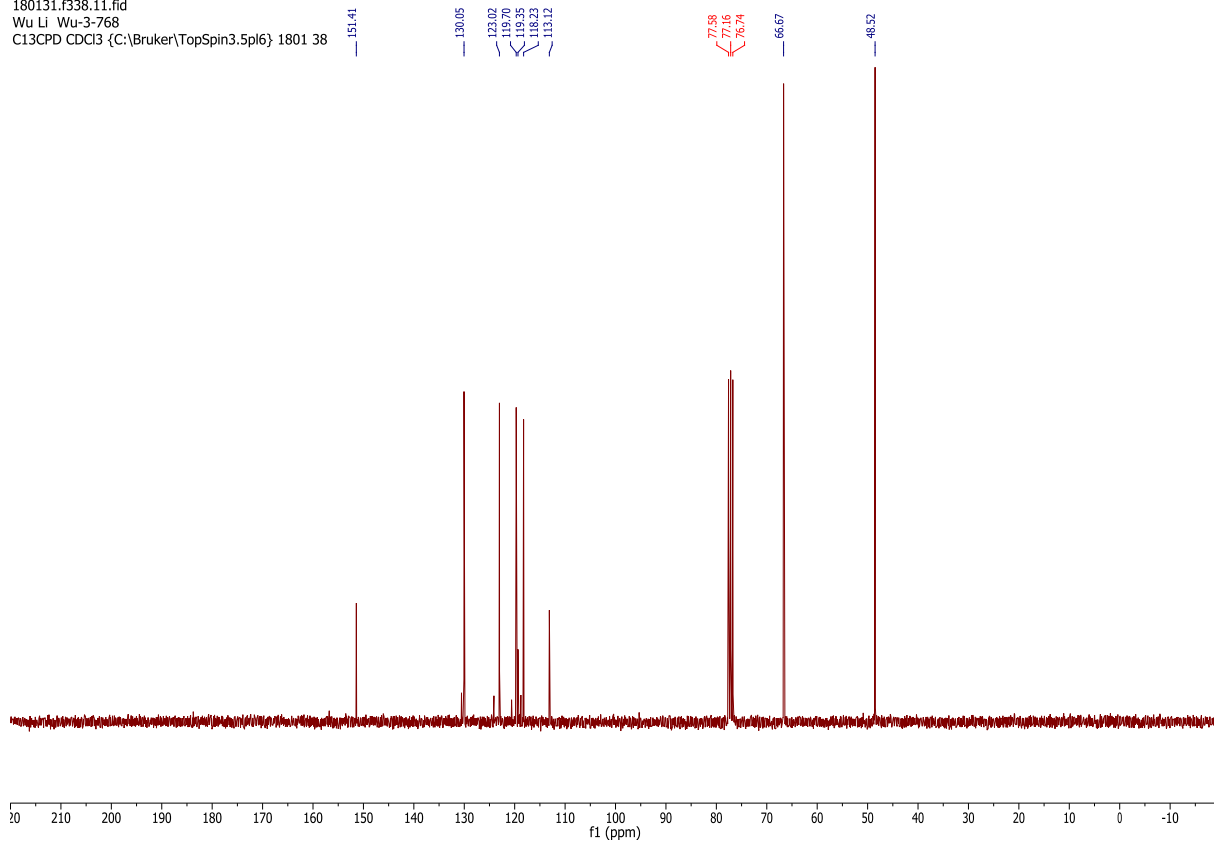


Original spectra for **13a**:

180131.f338.10.fid
Wu Li Wu-3-768
PROTON CDCl₃ {C:\Bruker\TopSpin3.5pl6} 1801 38

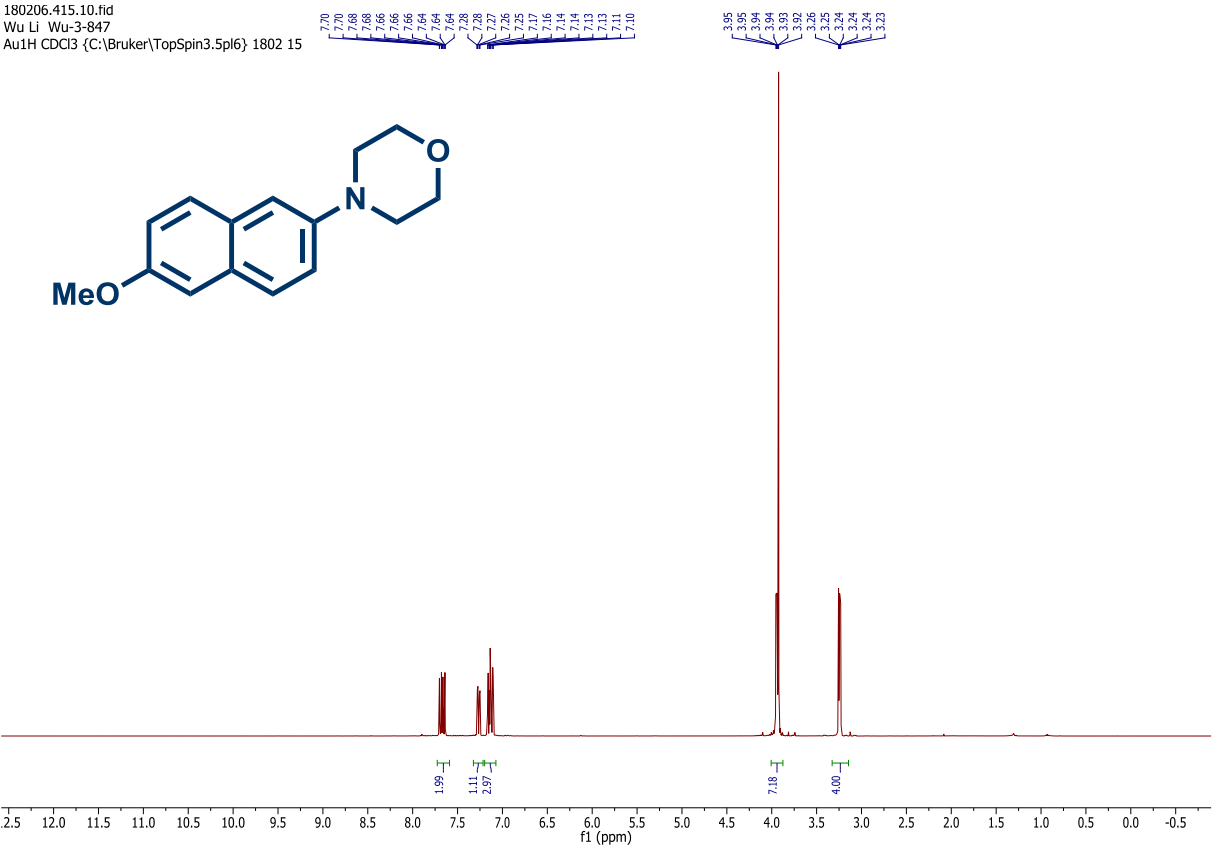
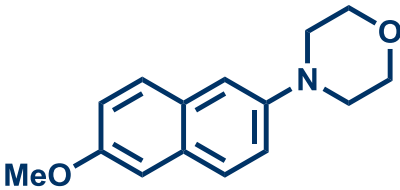


180131.f338.11.fid
Wu Li Wu-3-768
C13CPD CDCl₃ {C:\Bruker\TopSpin3.5pl6} 1801 38

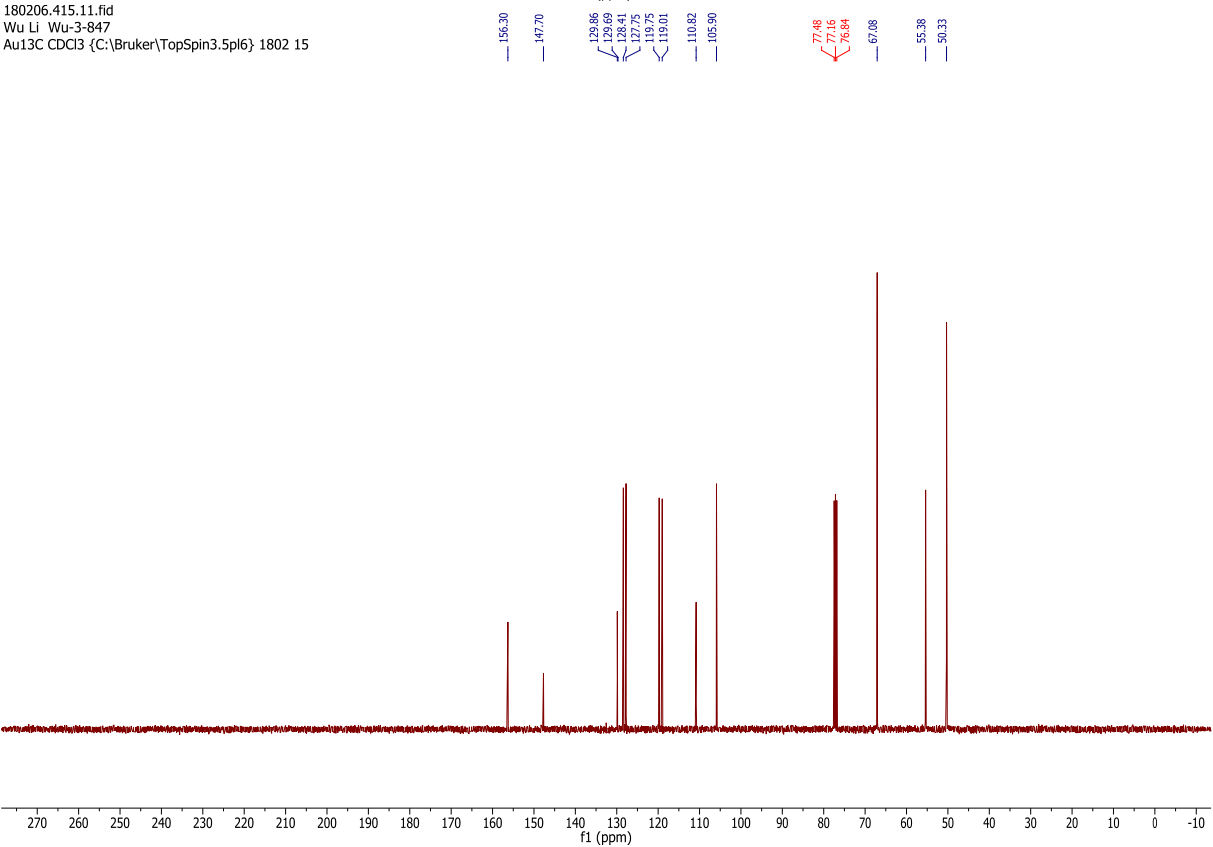


Original spectra for **14a**:

180206.415.10.fid
Wu Li Wu-3-847
Au1H CDCl3 {C:\Bruker\TopSpin3.5pl6} 1802 15

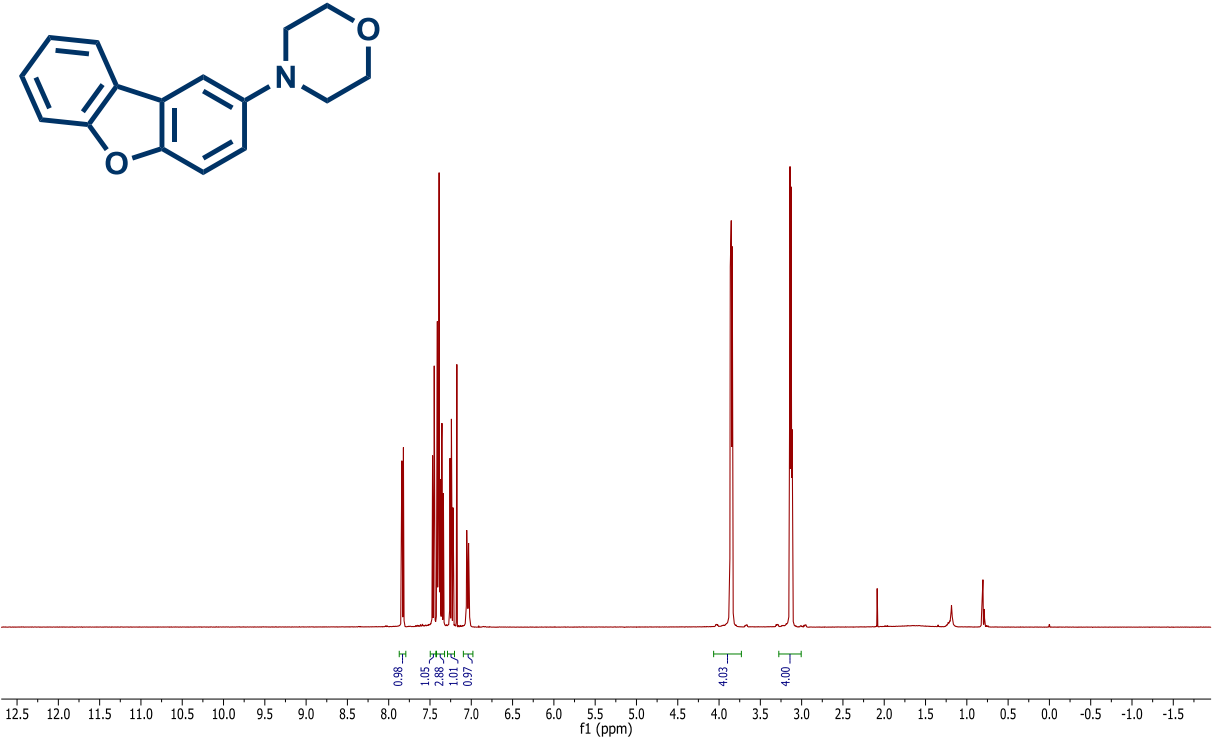


180206.415.11.fid
Wu Li Wu-3-847
Au13C CDCl3 {C:\Bruker\TopSpin3.5pl6} 1802 15

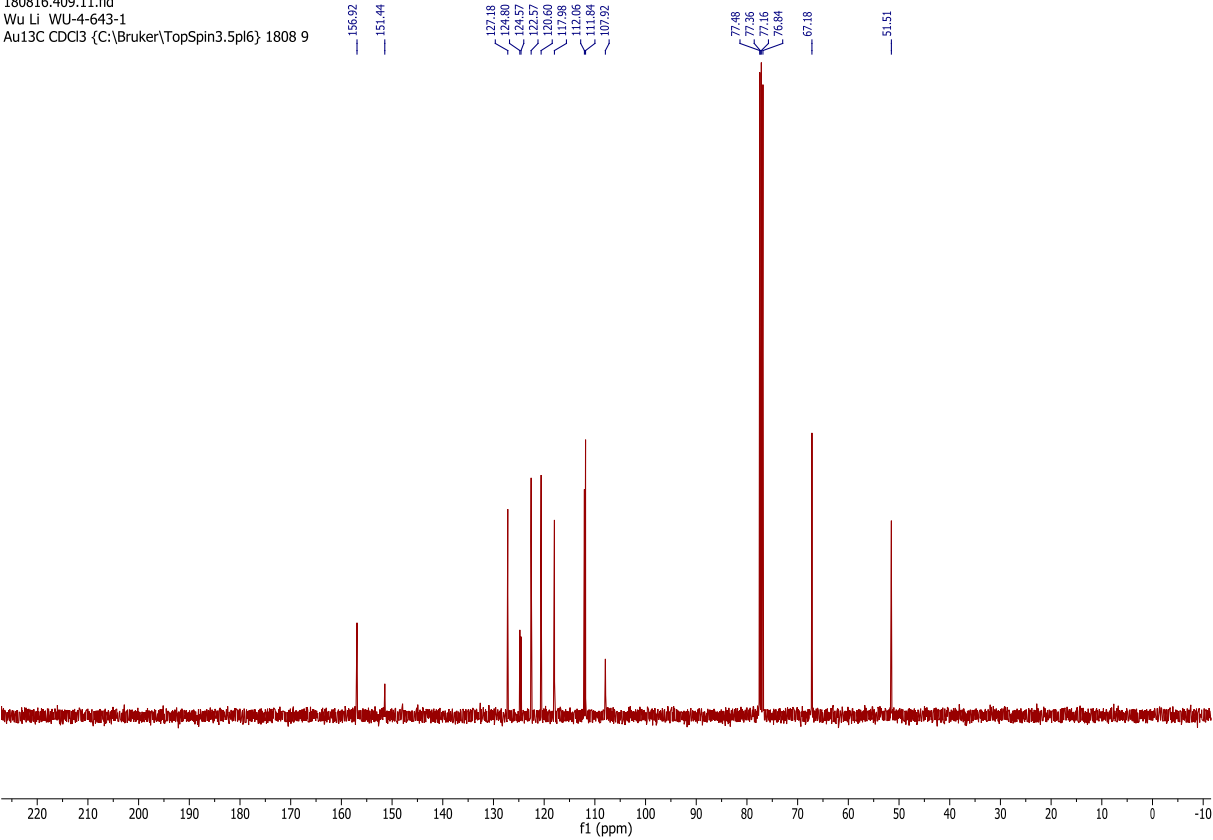


Original spectra for **15a**:

180816.409.10.fid
Wu Li WU-4-643-1
Au1H CDCl3 {C:\Bruker\TopSpin3.5pl6} 1808 9

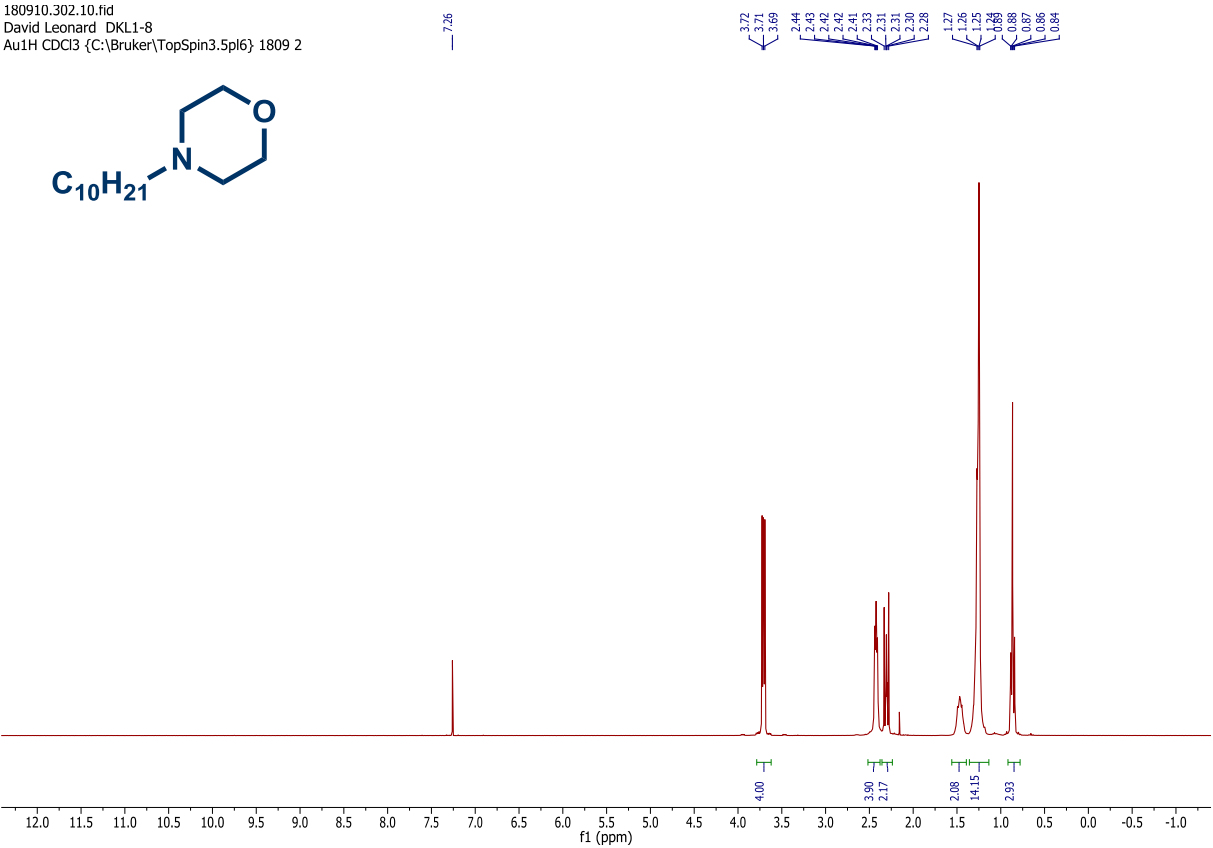
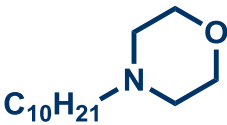


180816.409.11.fid
Wu Li WU-4-643-1
Au13C CDCl3 {C:\Bruker\TopSpin3.5pl6} 1808 9

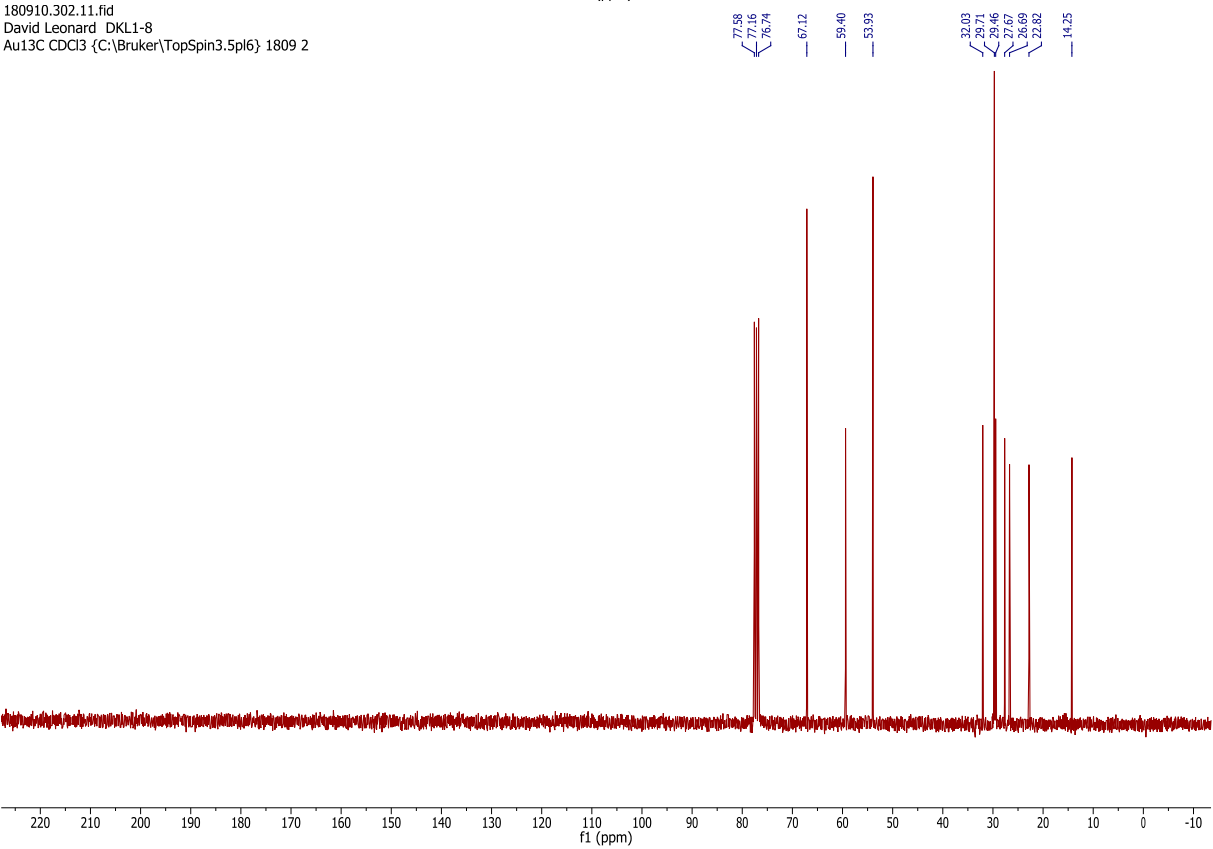


Original spectra for **16a**:

180910.302.10.fid
David Leonard DKL1-8
Au1H CDCl3 {C:\Bruker\TopSpin3.5pl6} 1809 2



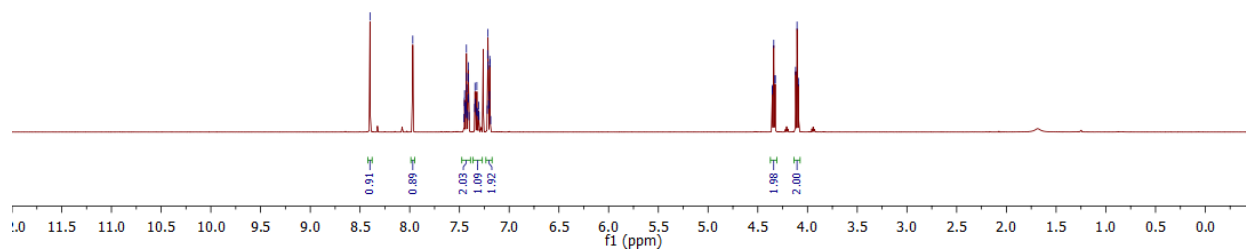
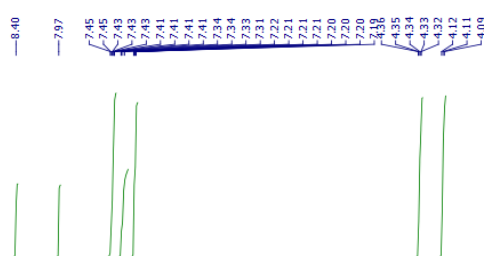
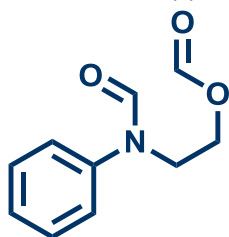
180910.302.11.fid
David Leonard DKL1-8
Au13C CDCl3 {C:\Bruker\TopSpin3.5pl6} 1809 2



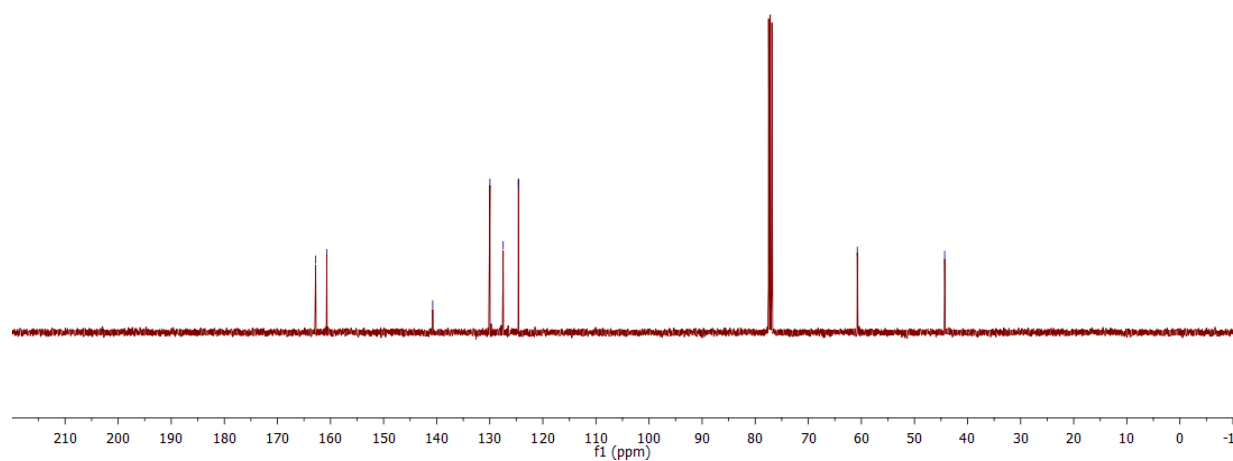
9: ^1H NMR, ^{13}C NMR & ^{19}F SPECTRA FOR PRODUCTS

Original spectra for **1b**:

180824.433.10.fid
Daid Leonard WL-677
Au1H CD CB {C:\Bruker\TopSpin3.5pl6} 1808 33



180824.433.11.fid
Daid Leonard WL-677
Au13C CD CB {C:\Bruker\TopSpin3.5pl6} 1808 33

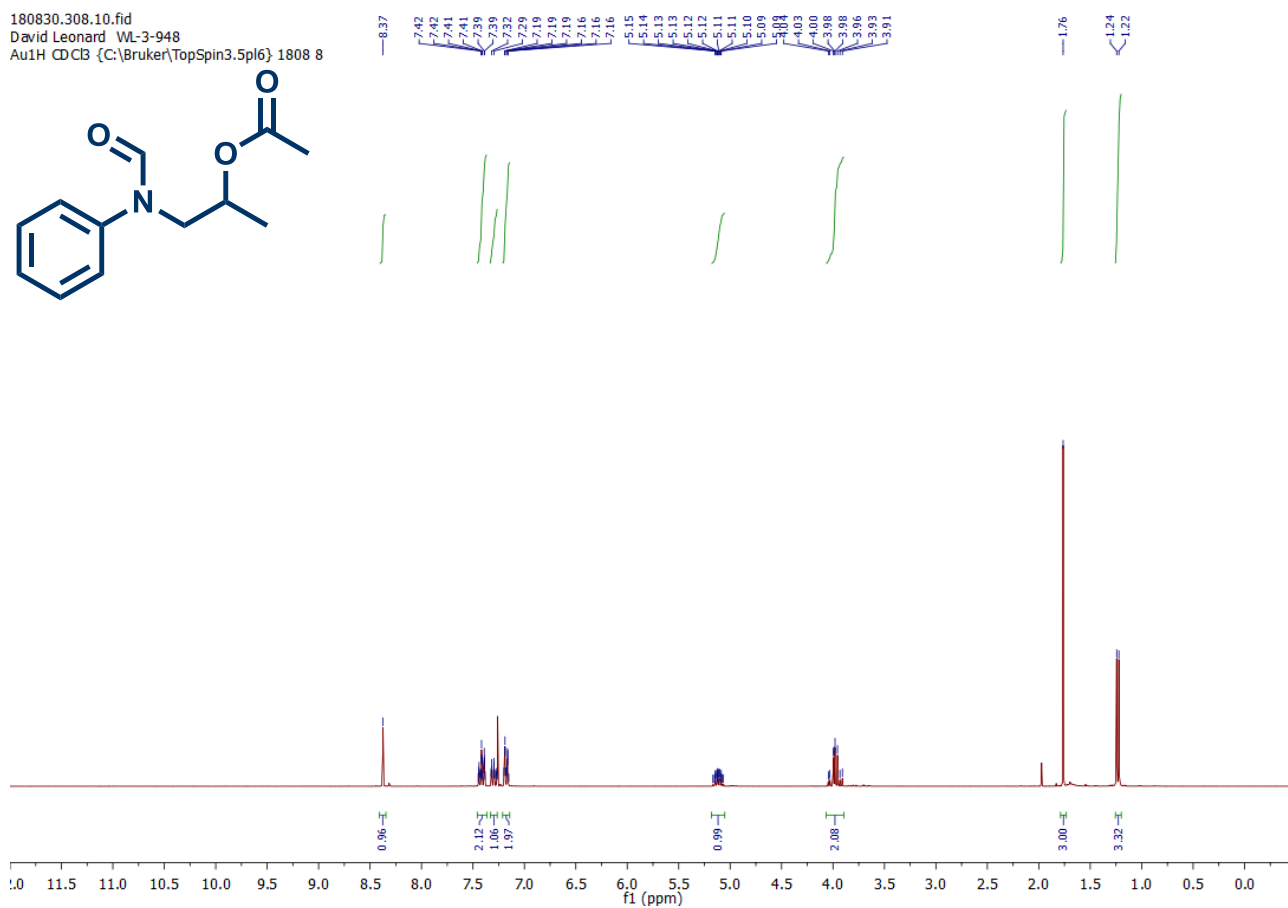
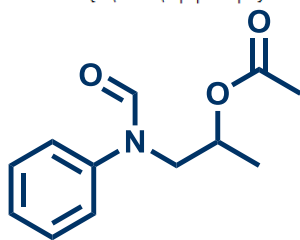


190820-28770-0-0
David Leonard - W13-1101
Au1H CD CB (C:Bruker)TopSpin3.5p16: 18087

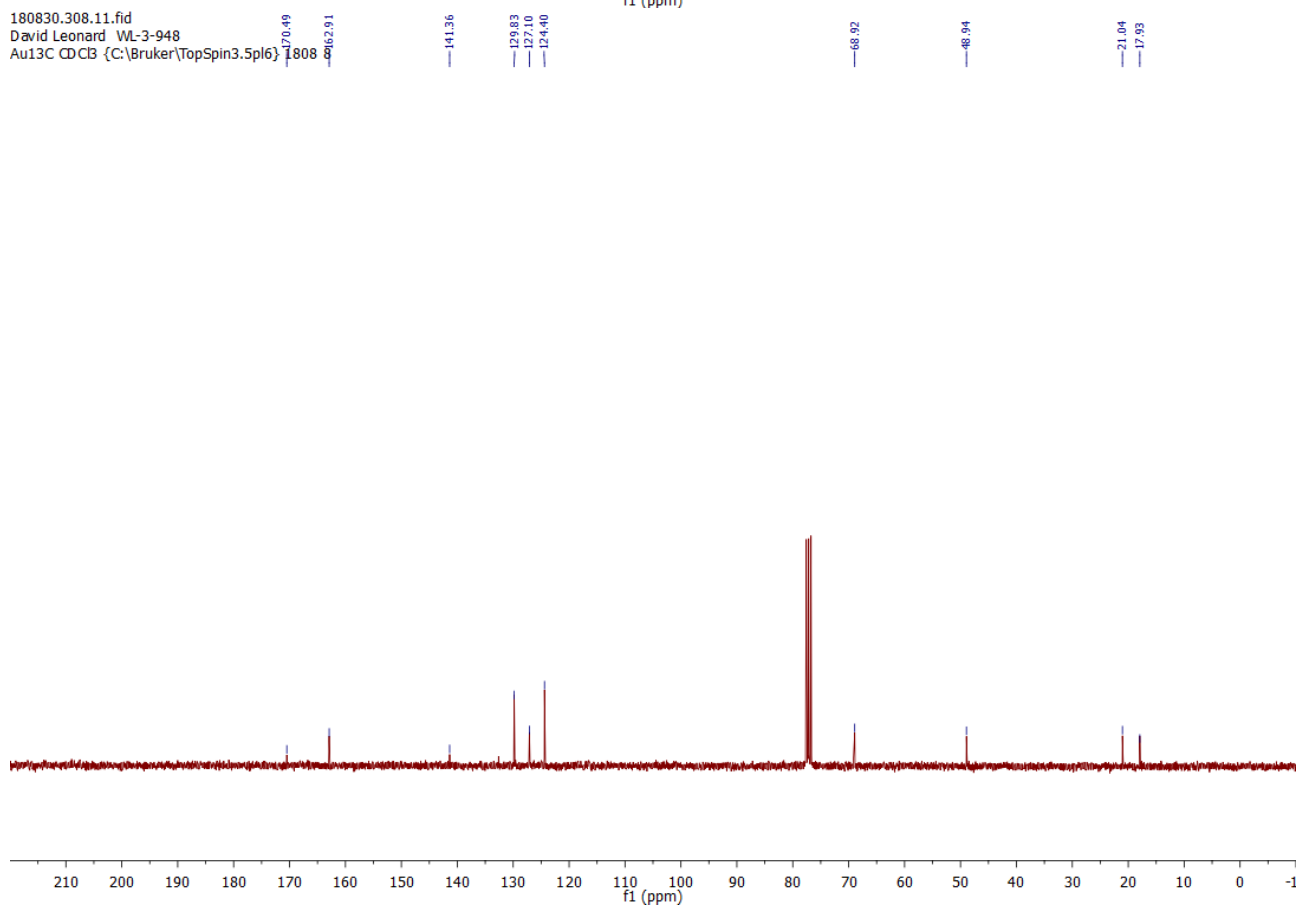


Original spectra for **3b**:

180830.308.10.fid
David Leonard WL-3-948
Au1H CDCl₃ {C:\Bruker\TopSpin3.5pl6} 1808 8

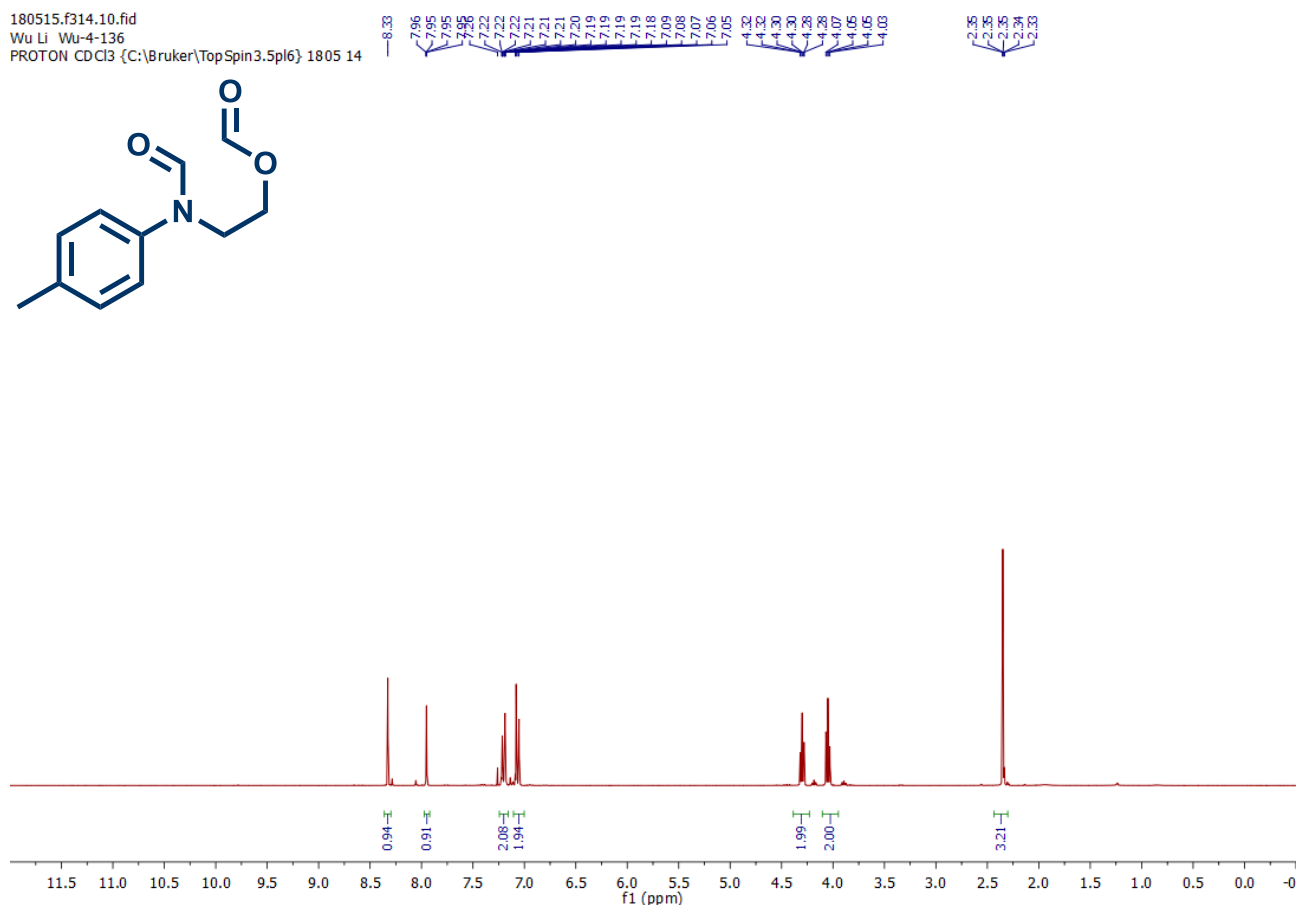
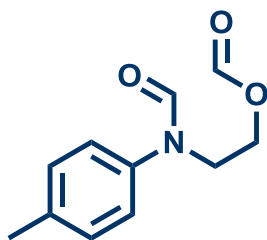


180830.308.11.fid
David Leonard WL-3-948
Au13C CDCl₃ {C:\Bruker\TopSpin3.5pl6} 1808 8

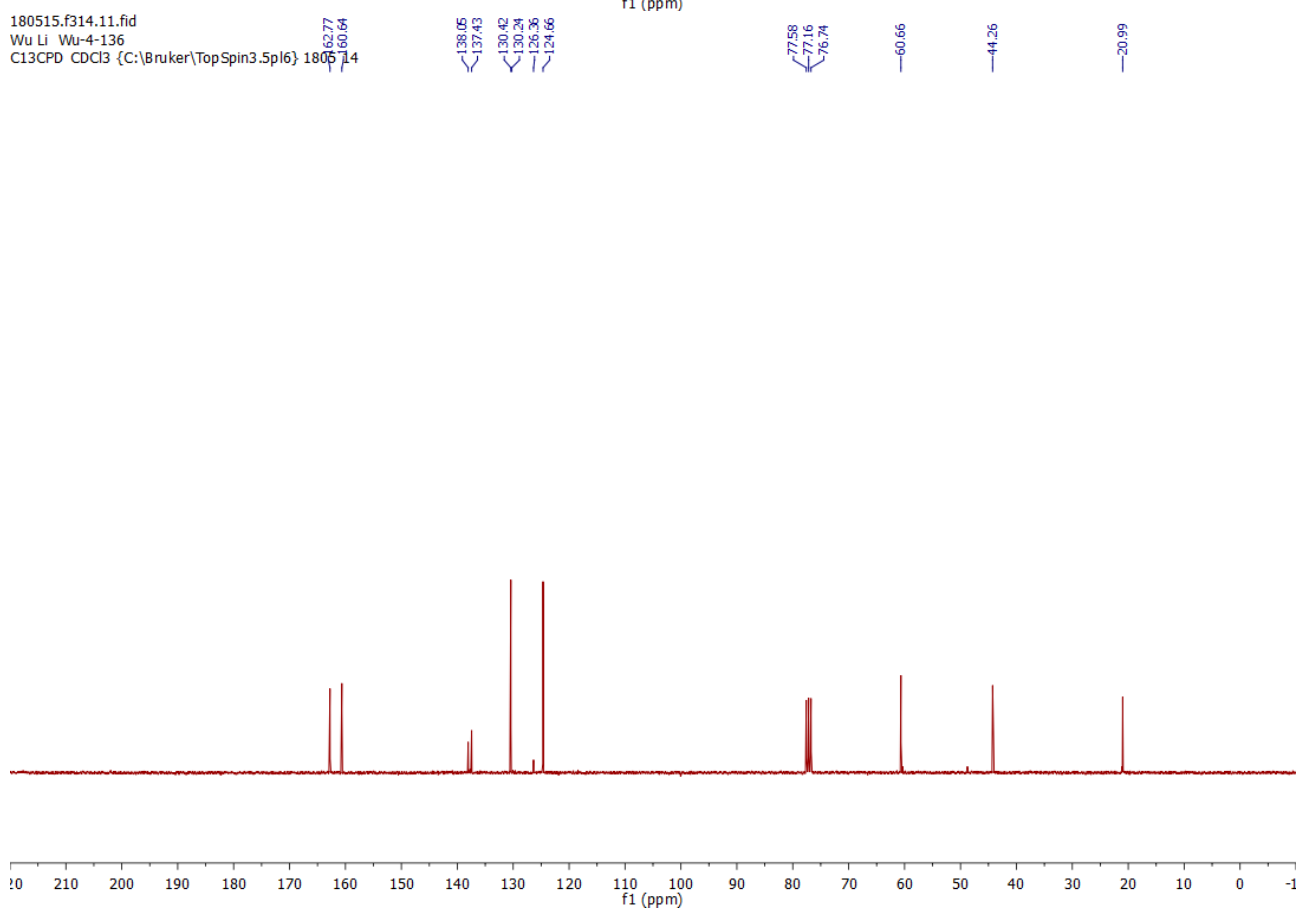


Original spectra for **4b**:

180515.f314.10.fid
Wu Li Wu-4-136
PROTON CDCl₃ {C:\Bruker\TopSpin3.5pl6} 1805 14

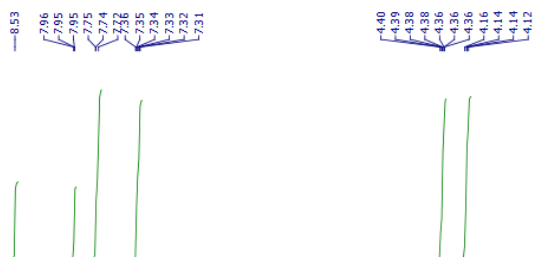
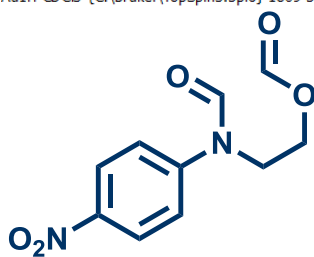


180515.f314.11.fid
Wu Li Wu-4-136
C13CPD CDCl₃ {C:\Bruker\TopSpin3.5pl6} 1805 14

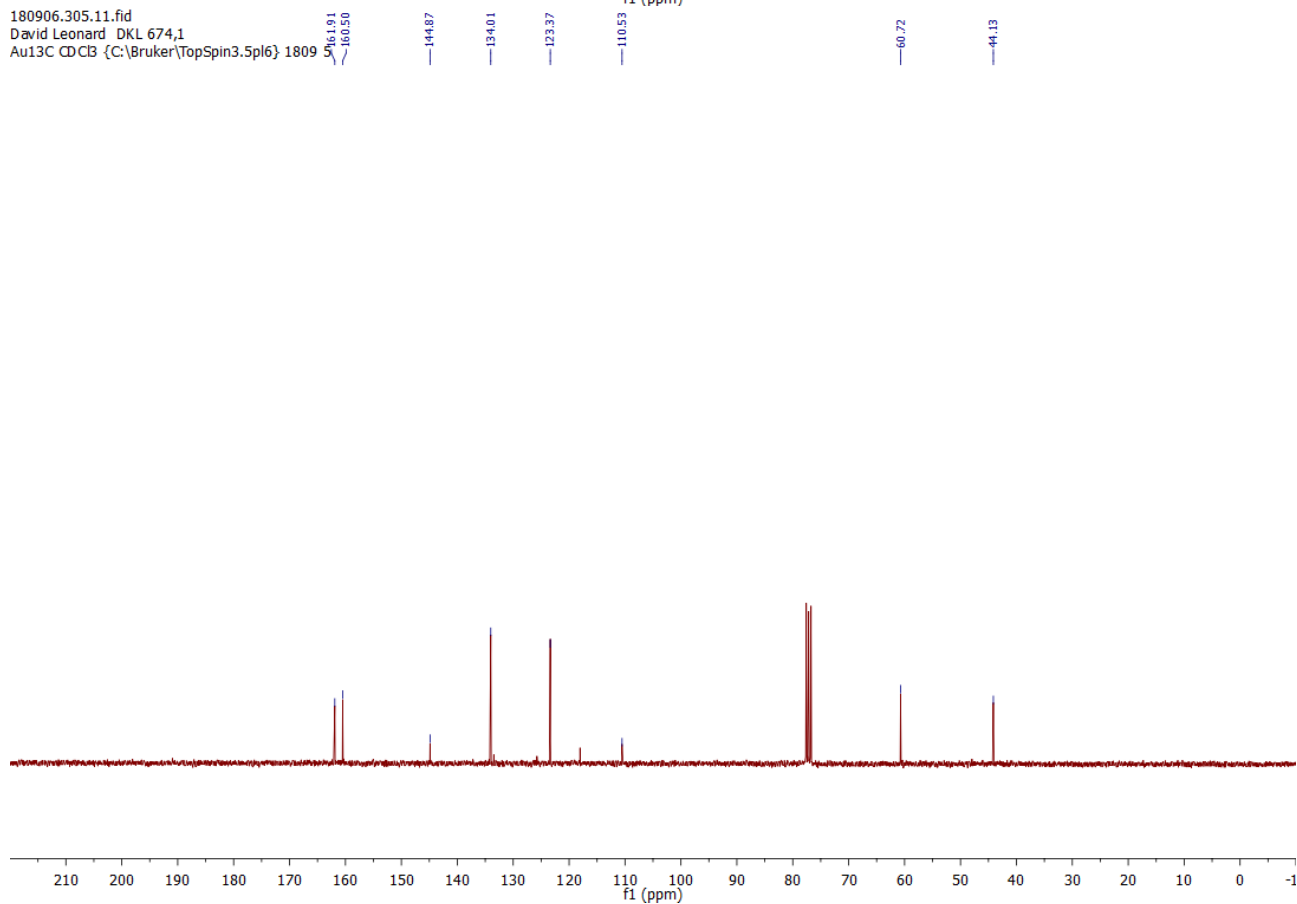


Original spectra for **5b**:

180906.305.10.fid
David Leonard DKL 674.1
Au1H CDCl₃ {C:\Bruker\TopSpin3.5pl6} 1809 5

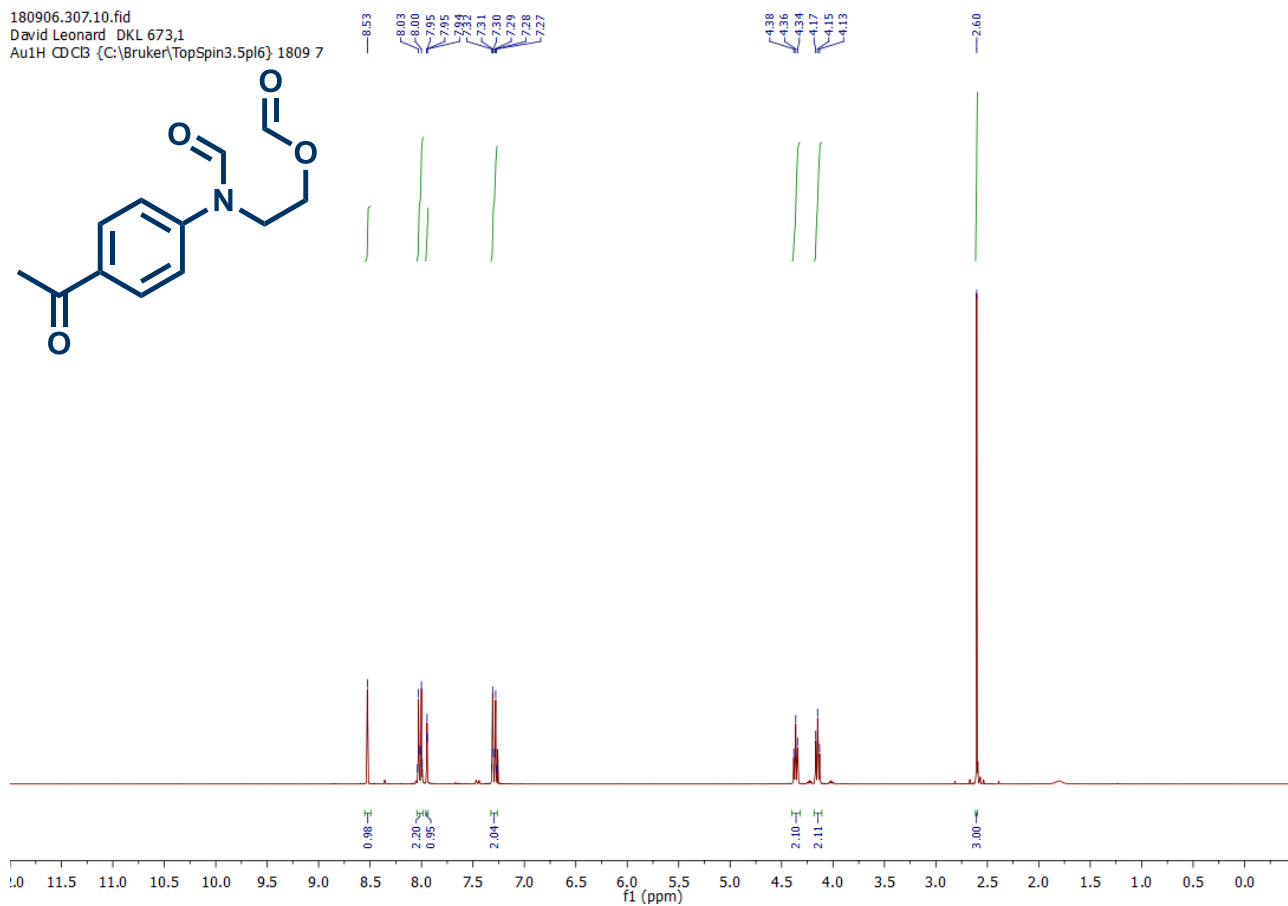
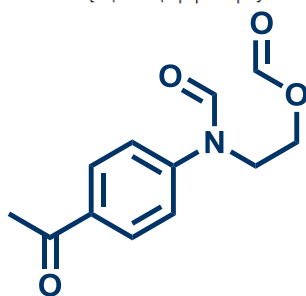


180906.305.11.fid
David Leonard DKL 674.1
Au13C CDCl₃ {C:\Bruker\TopSpin3.5pl6} 1809 5

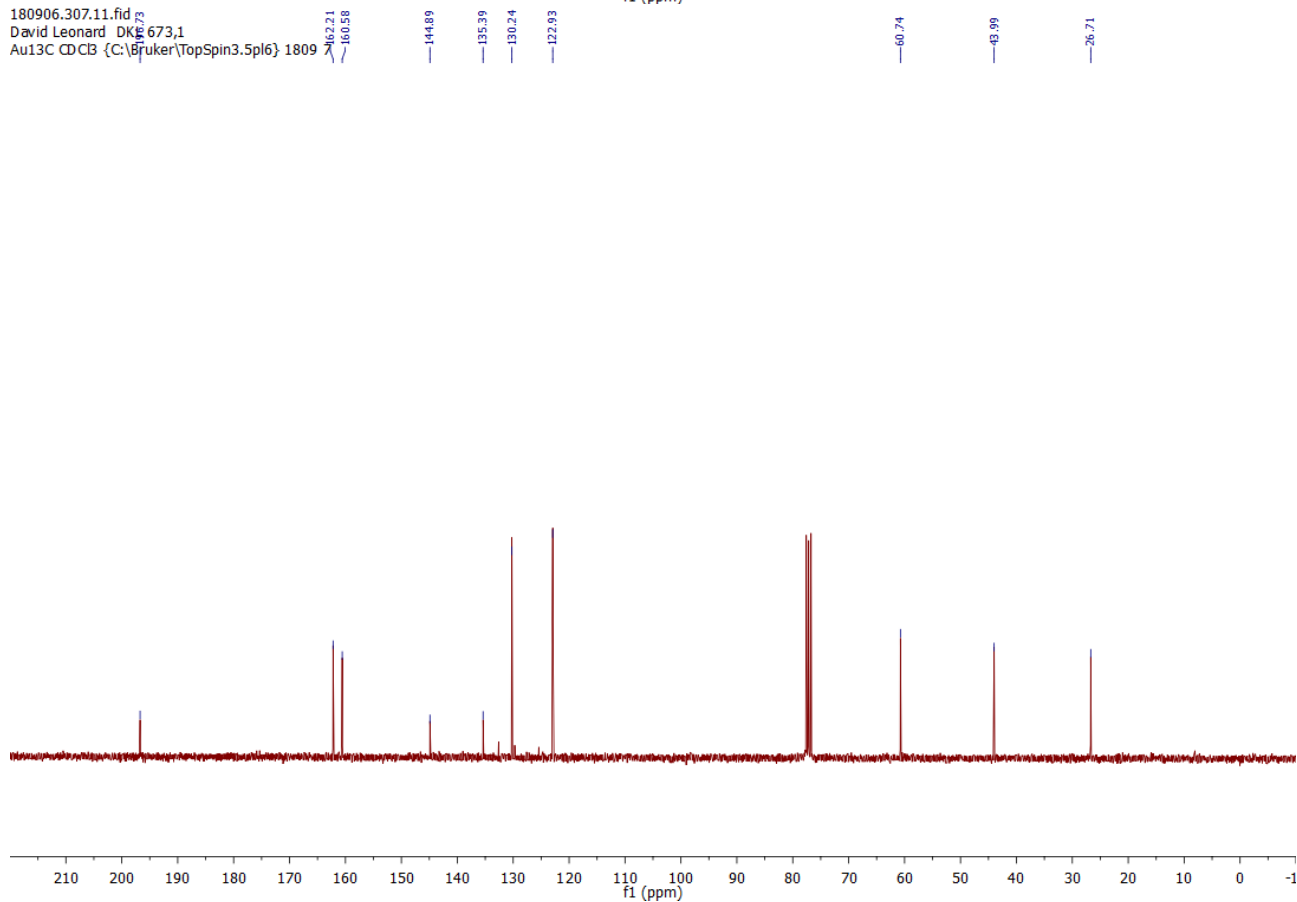


Original spectra for **6b**:

180906.307.10.fid
David Leonard DKL 673,1
Au1H CDCl₃ {C:\Bruker\TopSpin3.5pl6} 1809 7

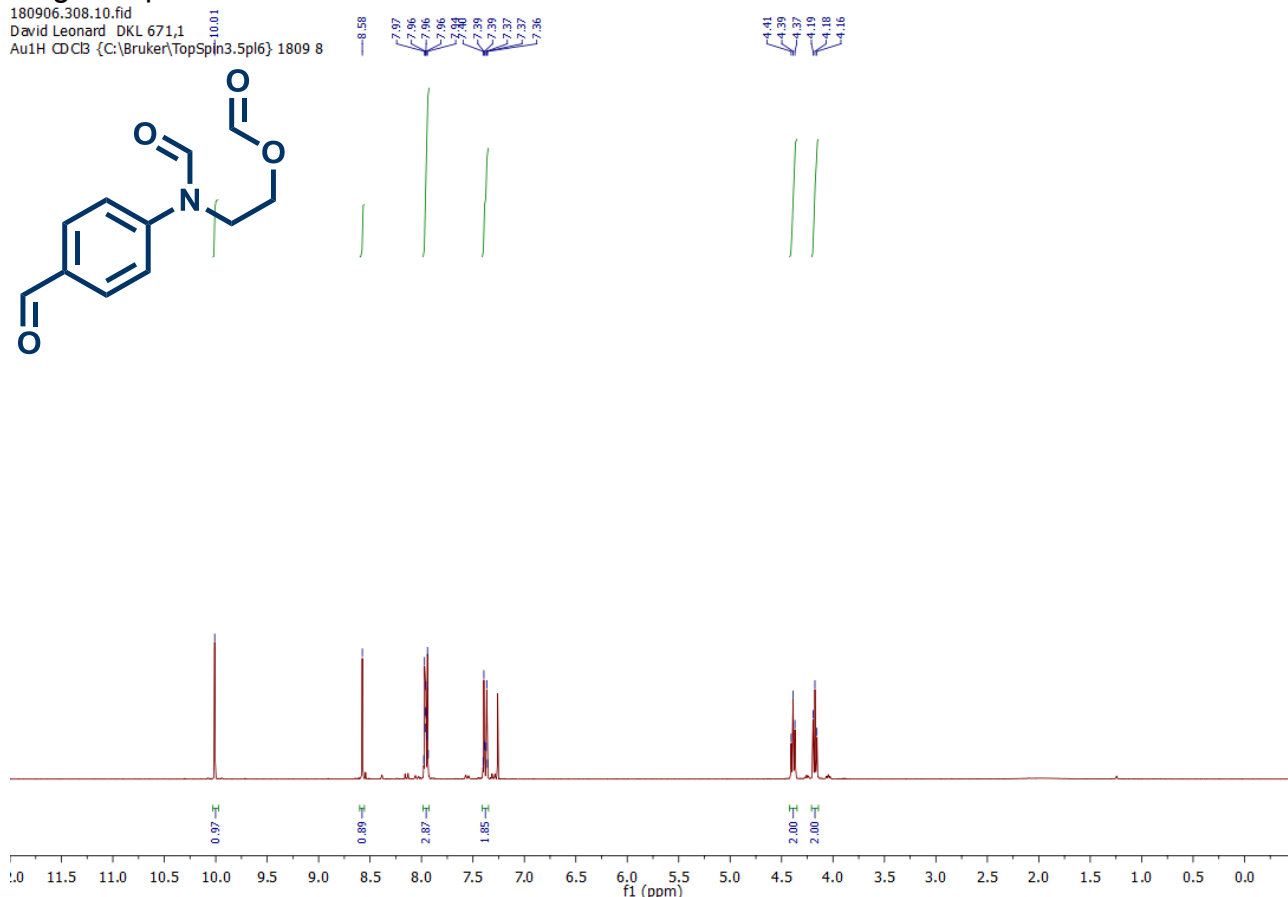
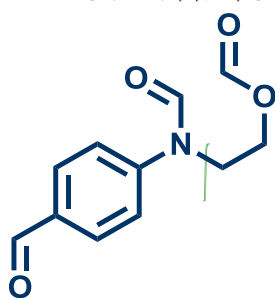


180906.307.11.fid
David Leonard DKL 673,1
Au13C CDCl₃ {C:\Bruker\TopSpin3.5pl6} 1809

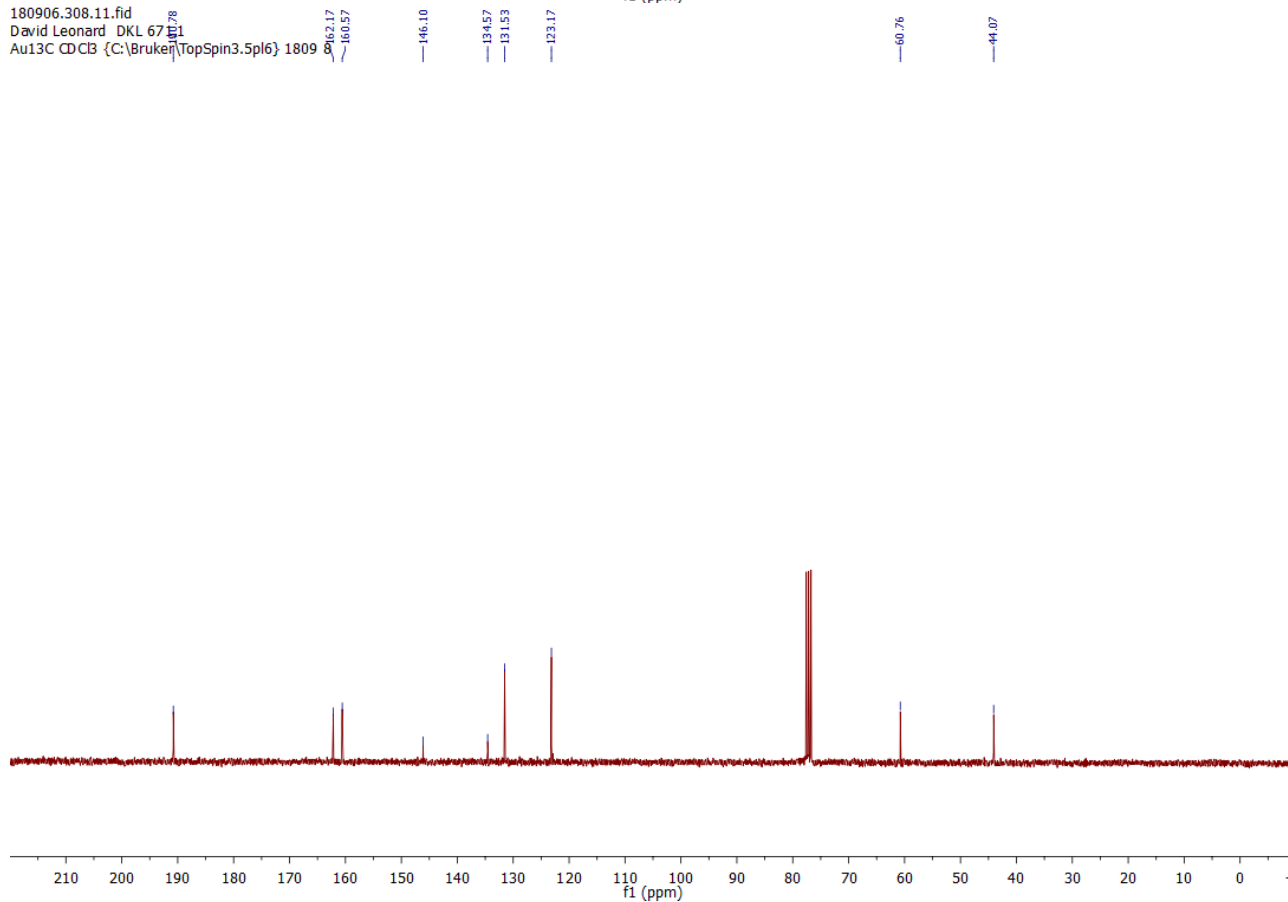


Original spectra for **7b**:

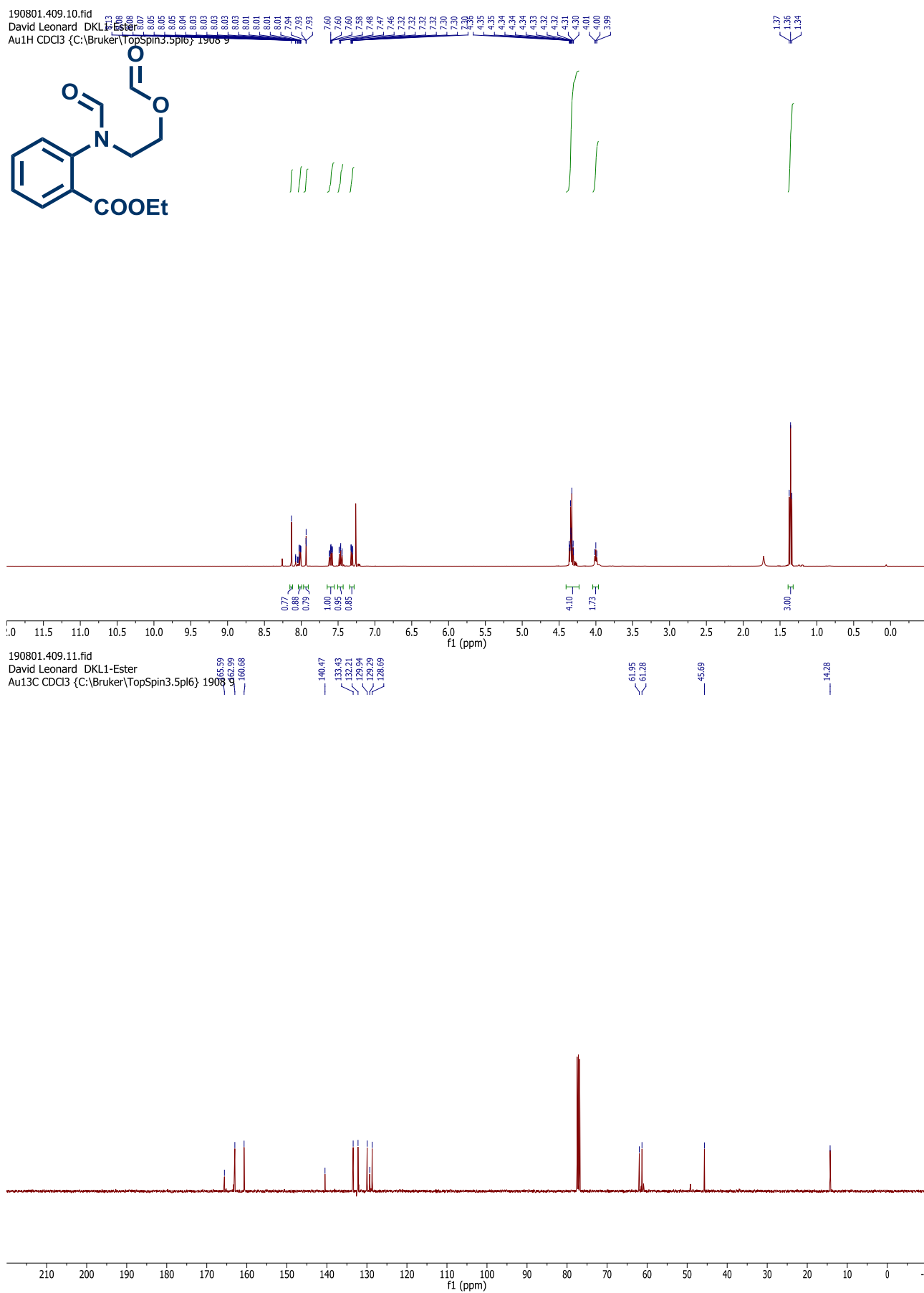
180906.308.10.fid
David Leonard DKL 671.1
Au1H CDCl₃ {C:\Bruker\TopSpin3.5pl6} 1809 8



180906.308.11.fid
David Leonard DKL 671.1
Au13C CDCl₃ {C:\Bruker\TopSpin3.5pl6} 1809 8

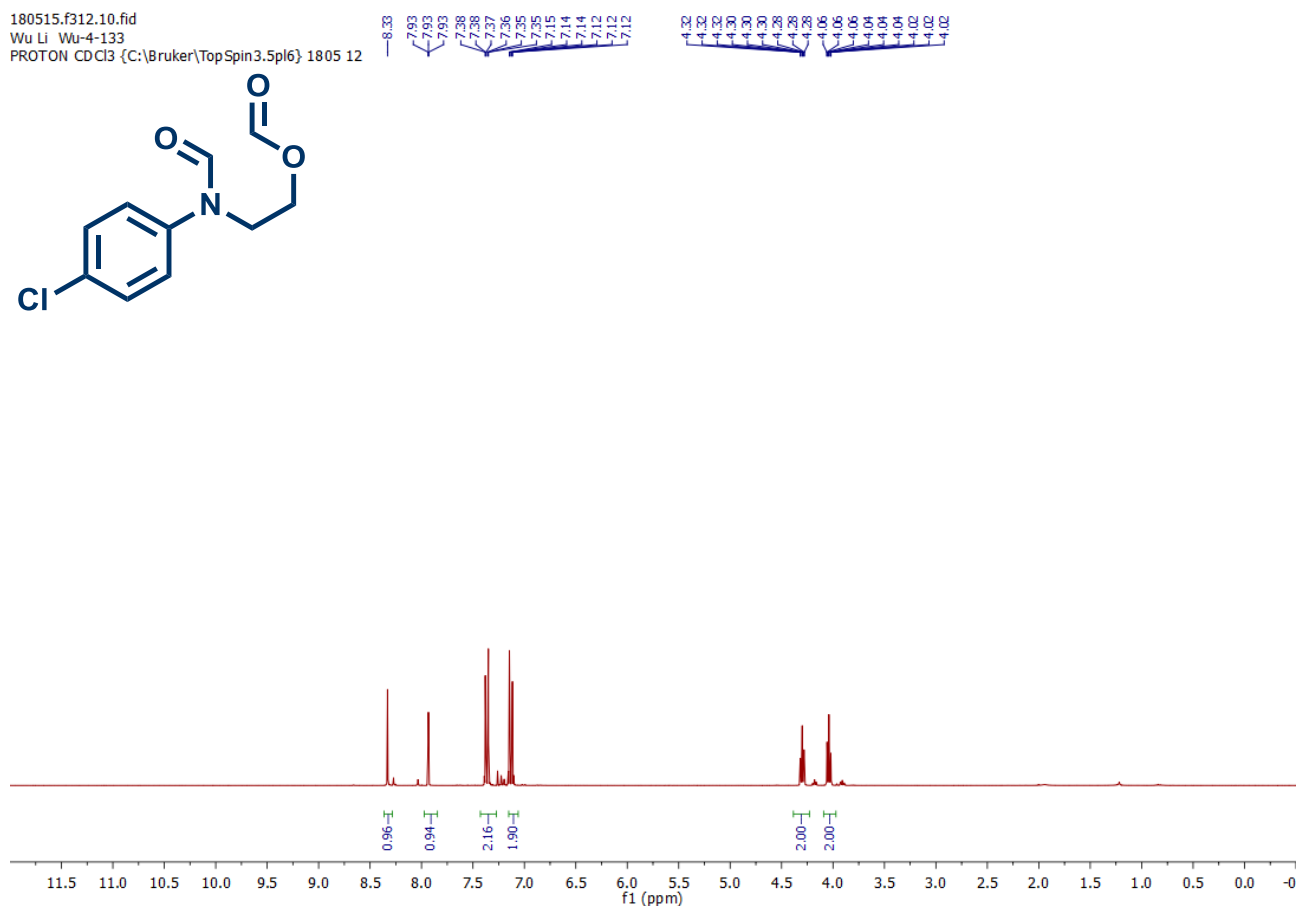
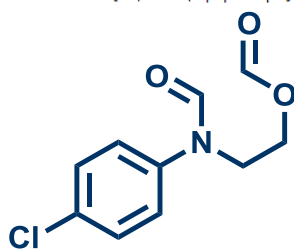


Original spectra for **8b**:

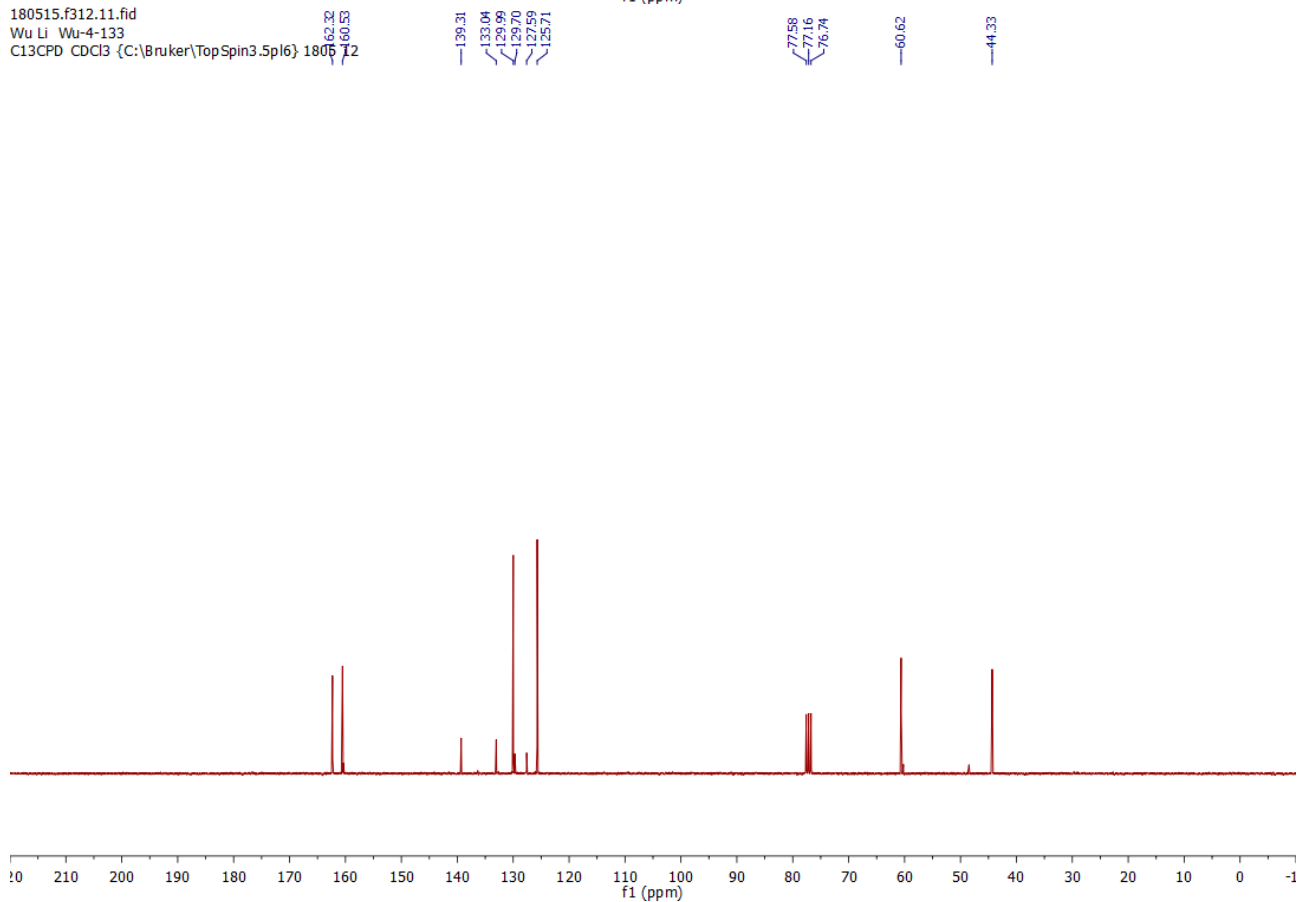


Original spectra for **9b**:

180515.f312.10.fid
Wu Li Wu-4-133
PROTON CDCl₃ {C:\Bruker\TopSpin3.5pl6} 1805 12

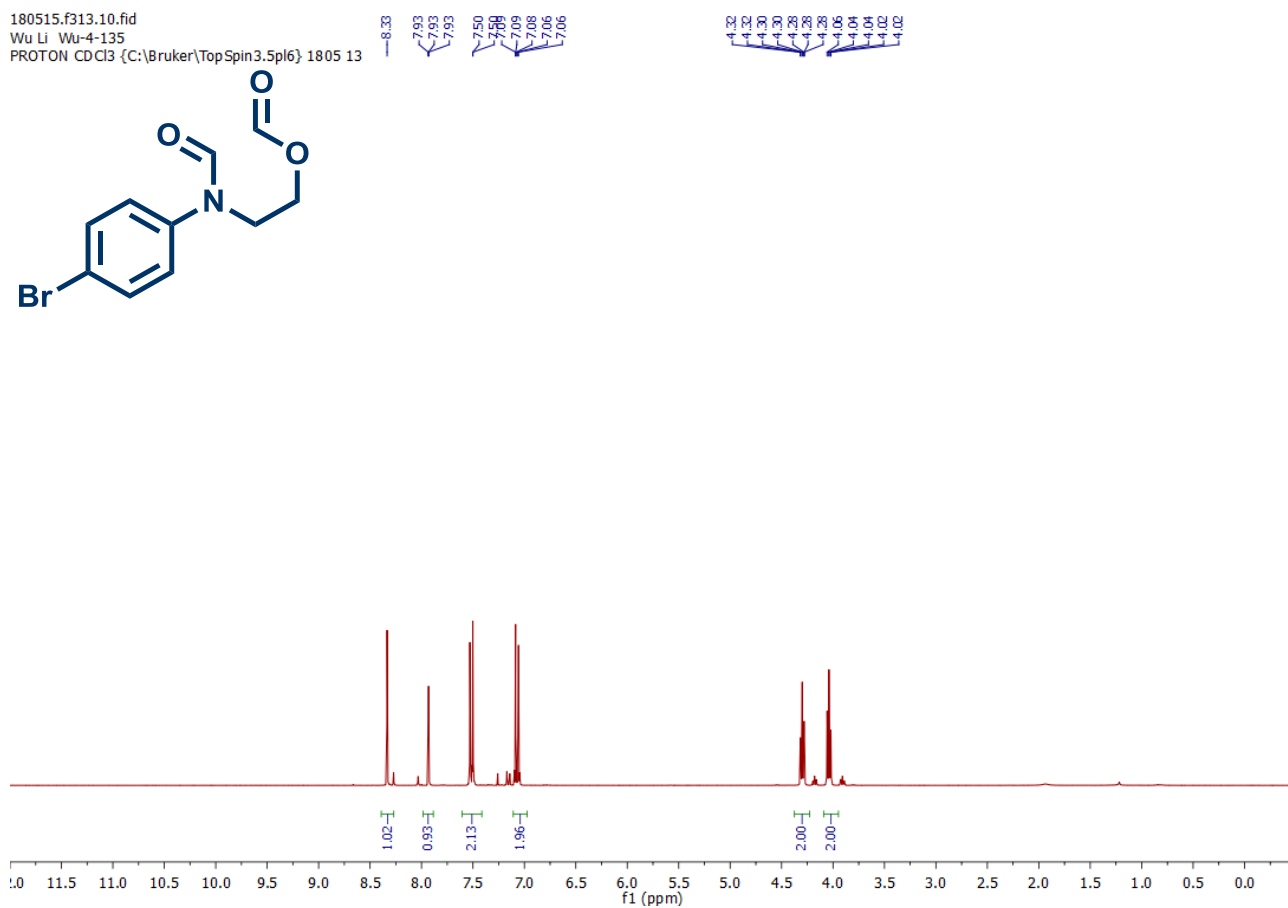
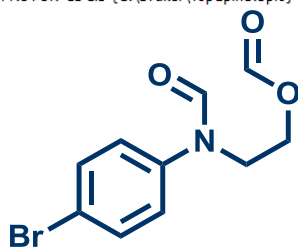


180515.f312.11.fid
Wu Li Wu-4-133
C13CPD CDCl₃ {C:\Bruker\TopSpin3.5pl6} 1805 12

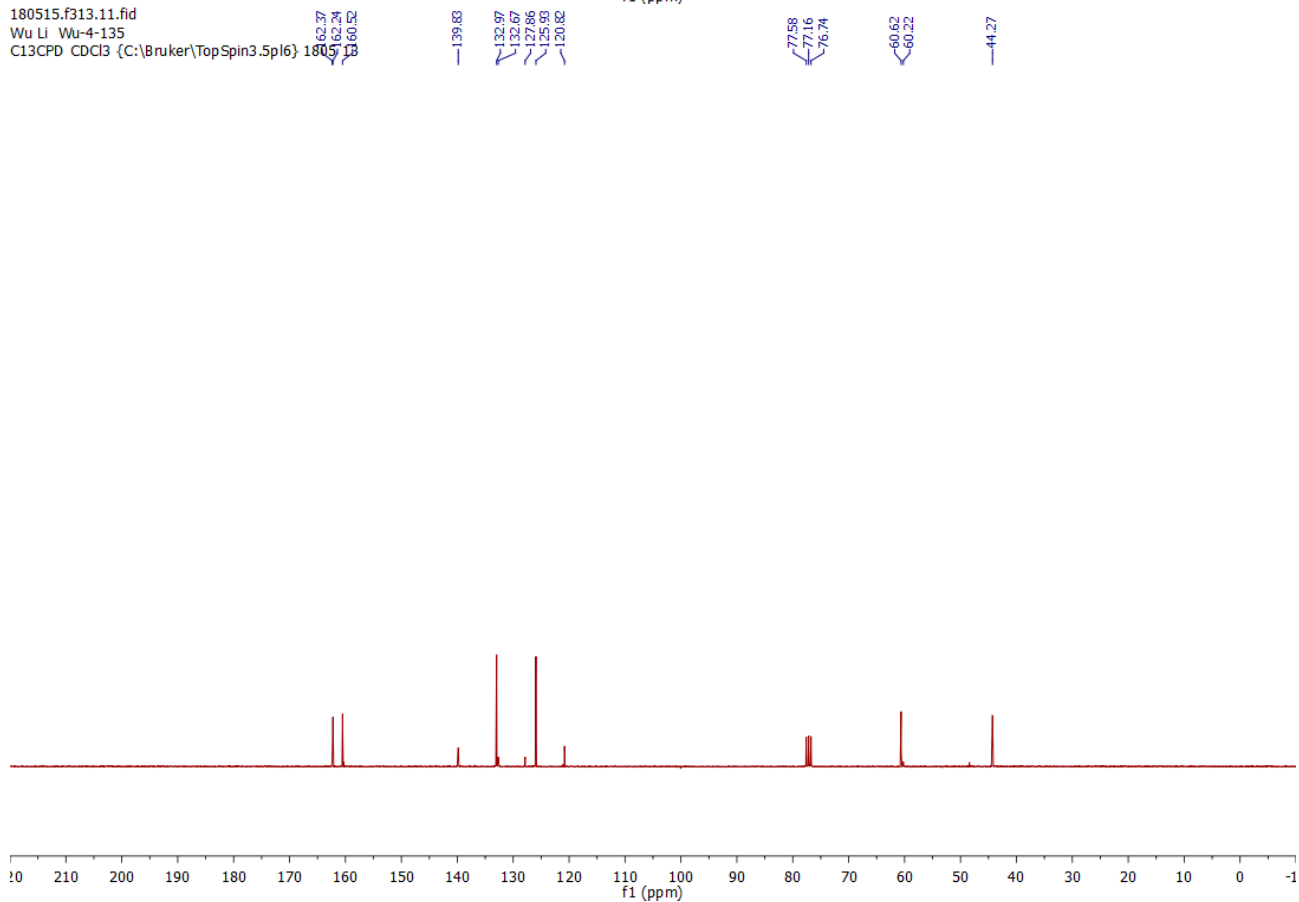


Original spectra for **10b**:

180515.f313.10.fid
Wu Li Wu-4-135
PROTON CDCl₃ {C:\Bruker\TopSpin3.5pl6} 1805 13

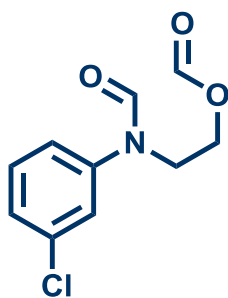


180515.f313.11.fid
Wu Li Wu-4-135
C13CPD CDCl₃ {C:\Bruker\TopSpin3.5pl6} 1805 13

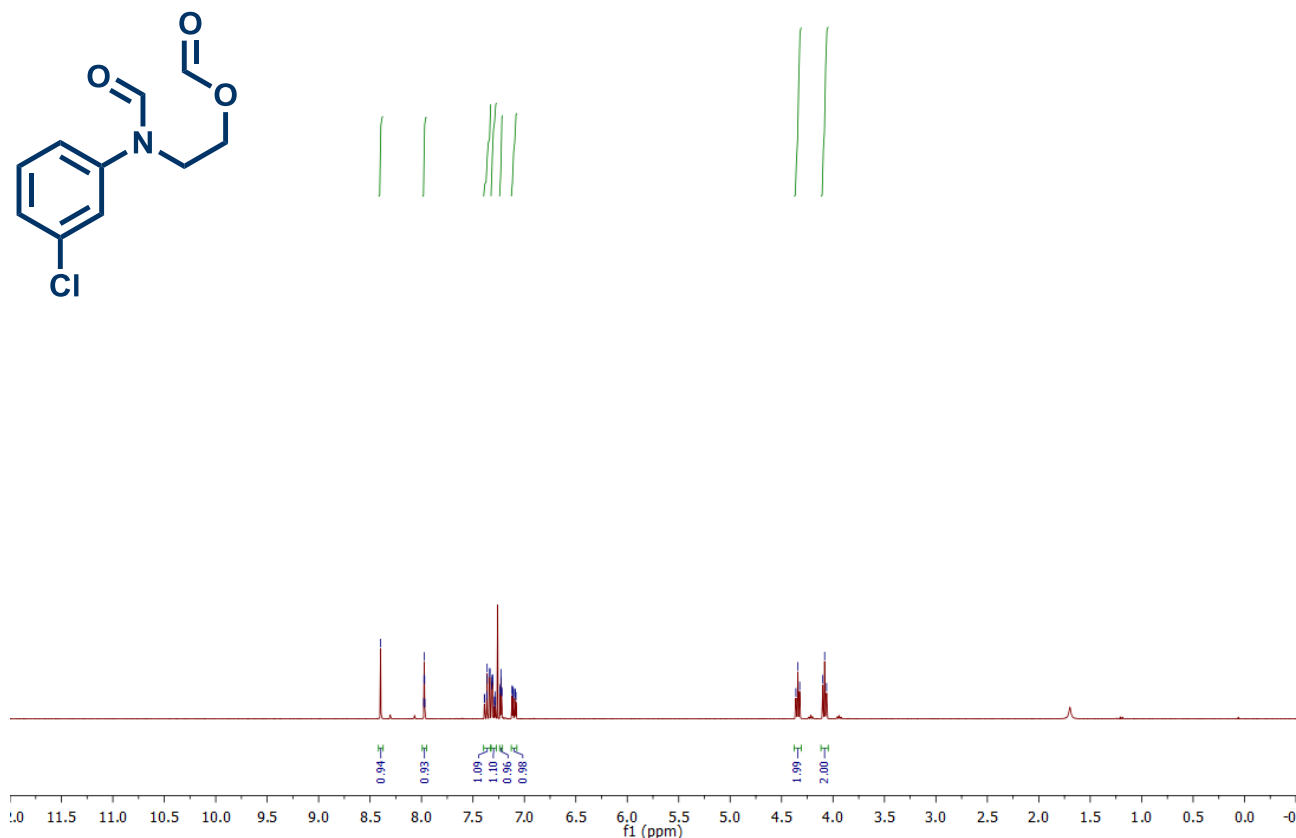


Original spectra for **11b**:

190627.f336.10.fid
David Leonard DKL1-124-C
PROTON CDCl₃ {C:\Bruker\TopSpin3.6.0} 1906 36

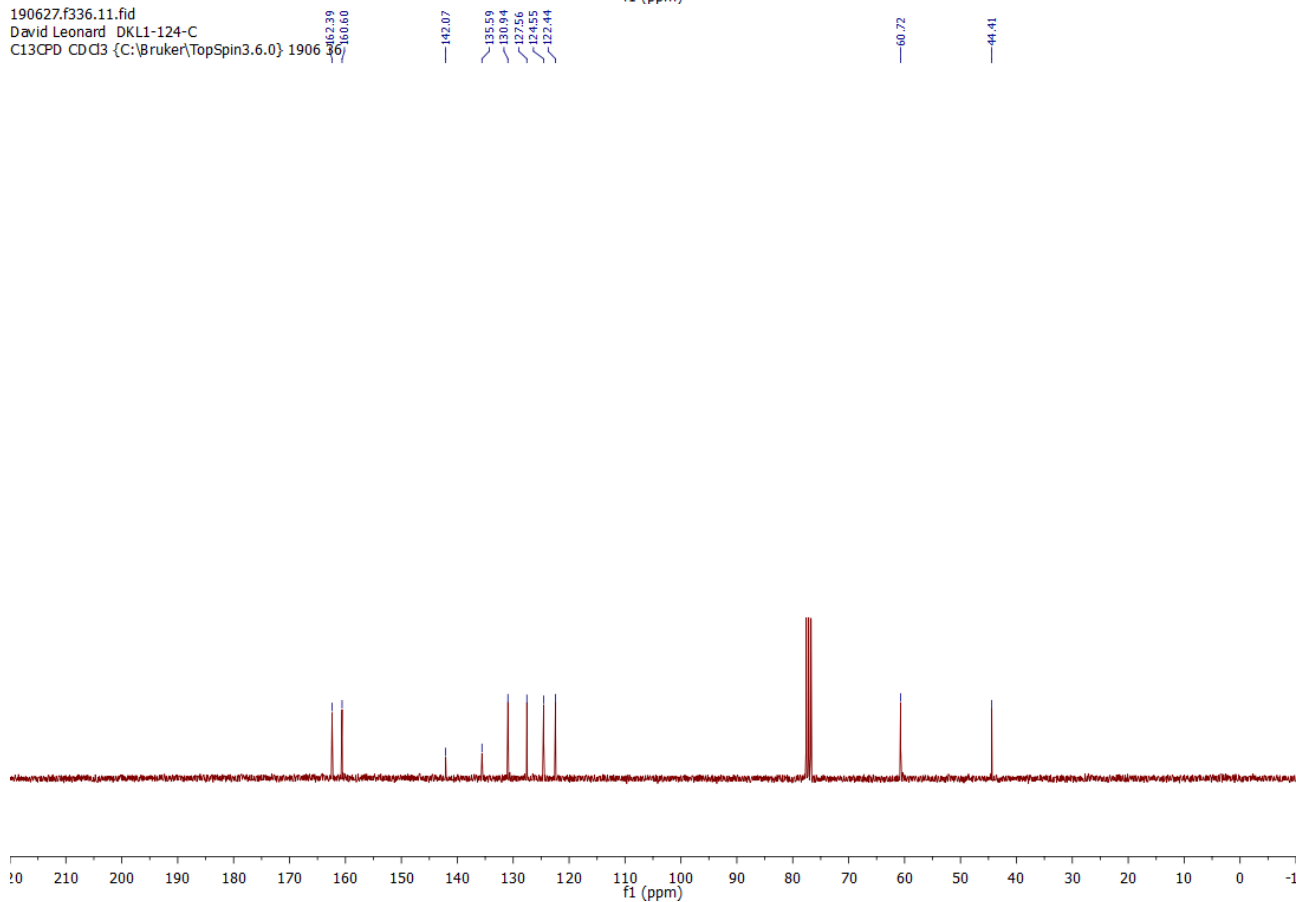


8.40
7.98
7.98
7.97
7.97
7.36
7.36
7.34
7.34
7.32
7.31
7.31
7.29
7.28
7.28
7.22
7.22
7.12
7.12
7.11
7.11
7.09
7.09
4.36
4.34
4.32
4.10
4.08
4.06



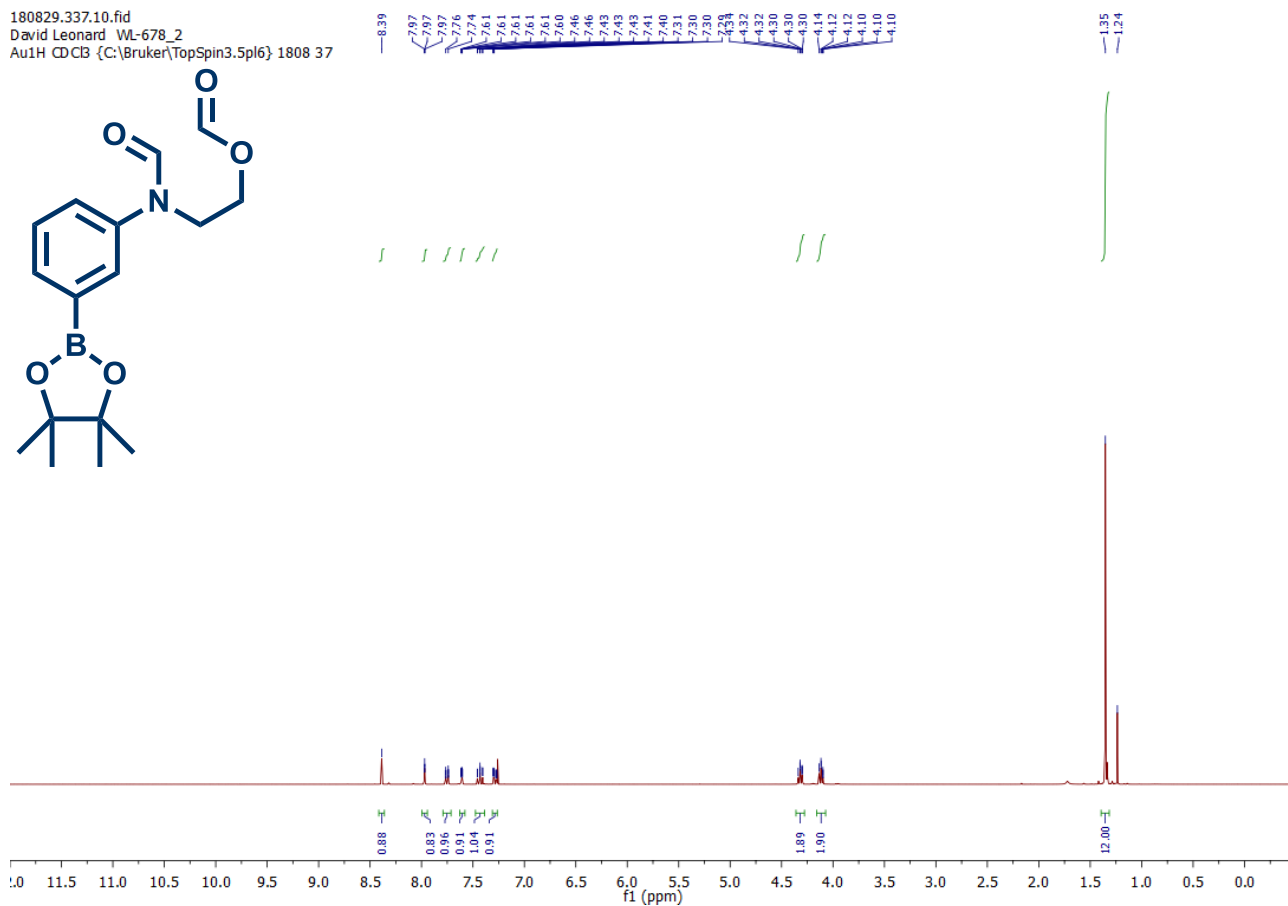
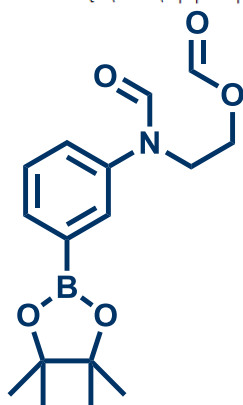
190627.f336.11.fid
David Leonard DKL1-124-C
C13CPD CDCl₃ {C:\Bruker\TopSpin3.6.0} 1906 36

162.39
160.60
142.07
135.59
130.94
127.56
124.55
122.44

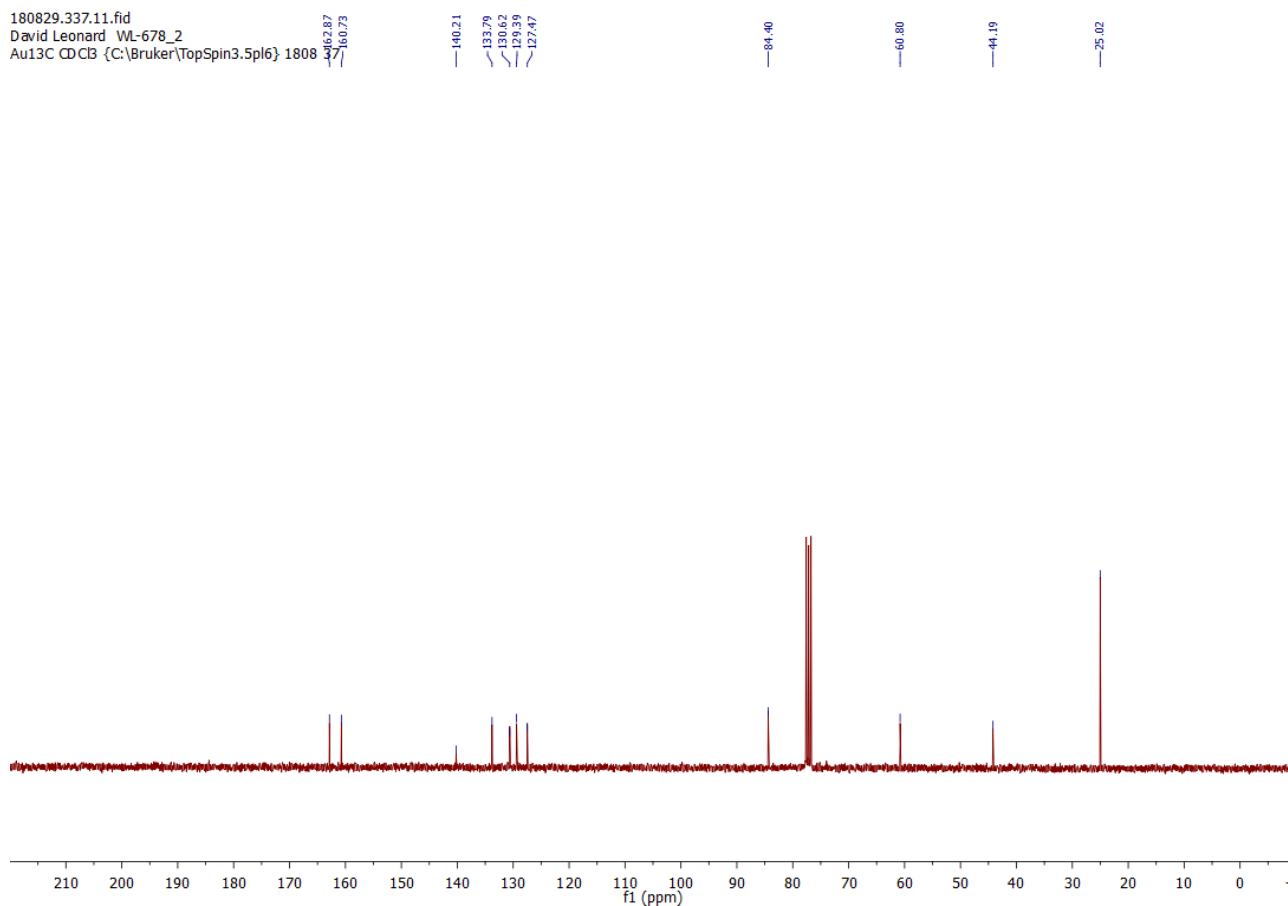


Original spectra for **12b**:

180829.337.10.fid
David Leonard WL-678_2
Au1H CDCl₃ {C:\Bruker\TopSpin3.5pl6} 1808 37

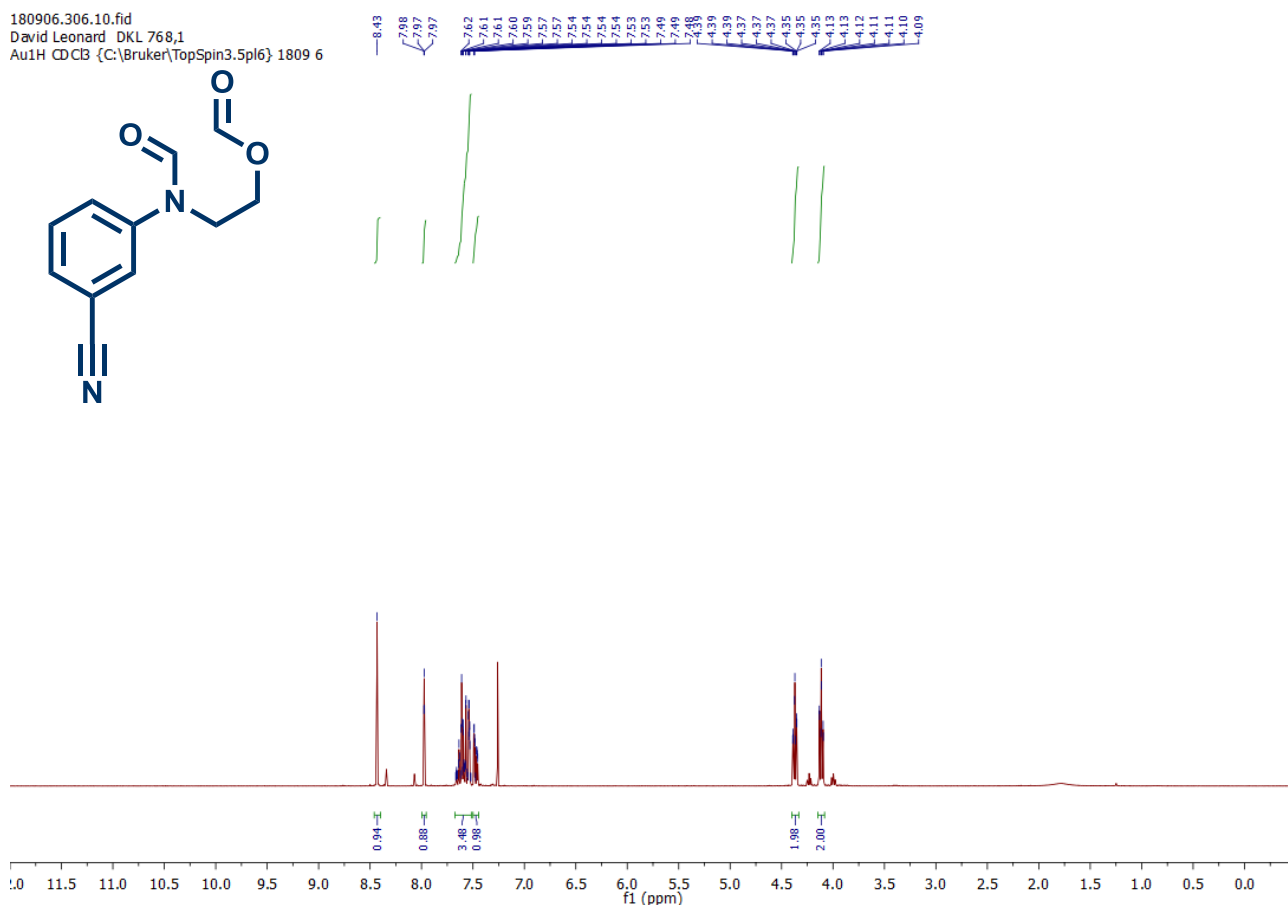
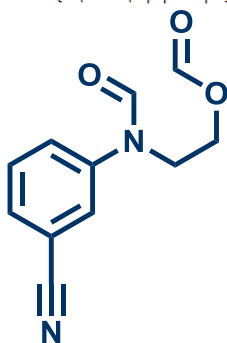


180829.337.11.fid
David Leonard WL-678_2
Au13C CDCl₃ {C:\Bruker\TopSpin3.5pl6} 1808 37

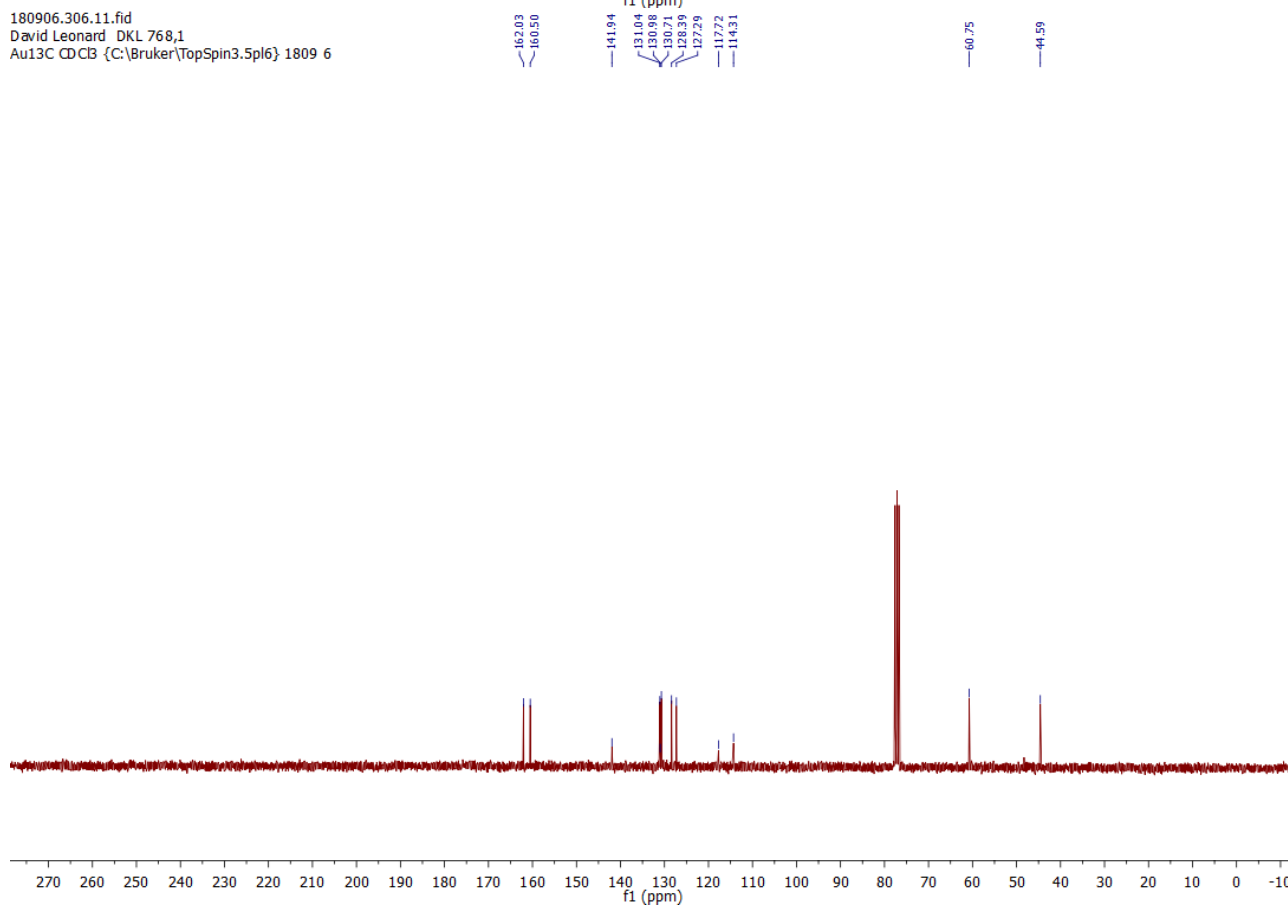


Original spectra for **13b**:

180906.306.10.fid
David Leonard DKL 768,1
Au1H CDCl₃ {C:\Bruker\TopSpin3.5pl6} 1809 6

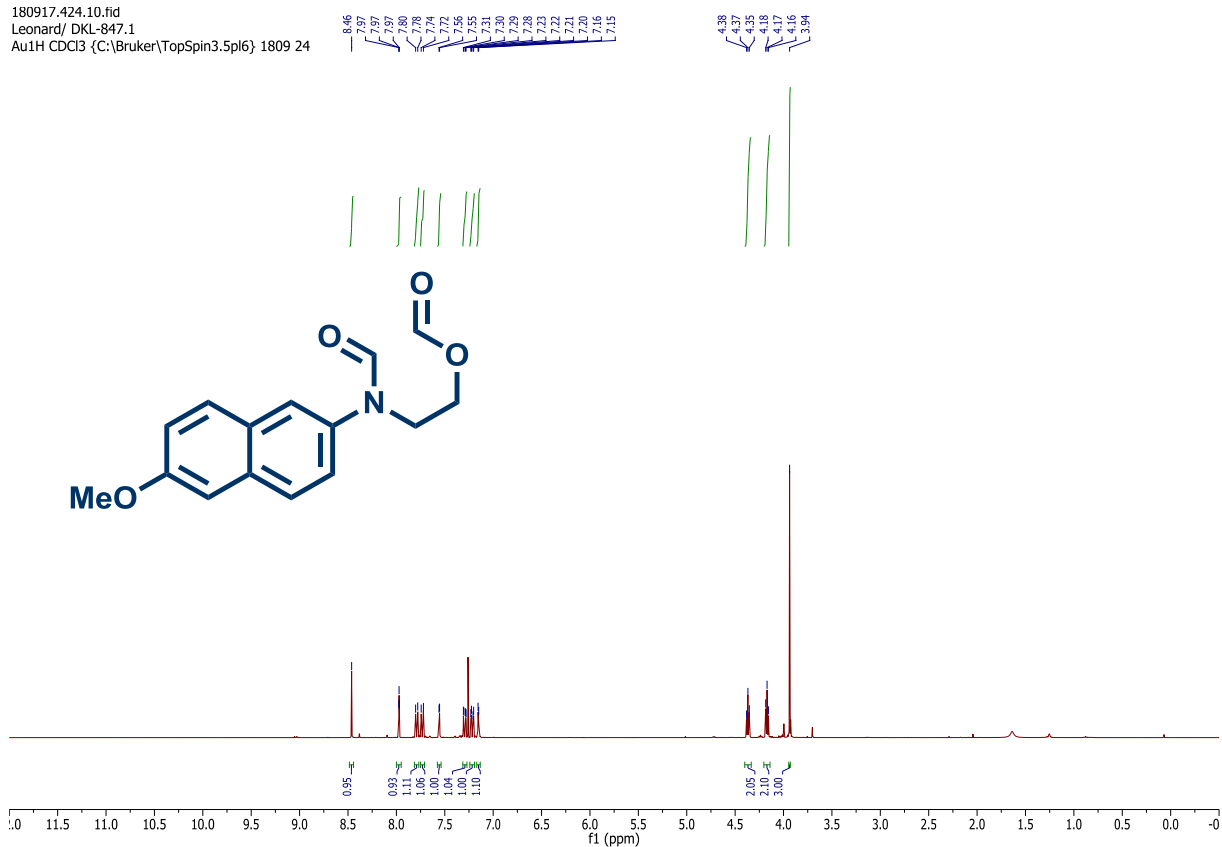


180906.306.11.fid
David Leonard DKL 768,1
Au13C CDCl₃ {C:\Bruker\TopSpin3.5pl6} 1809 6

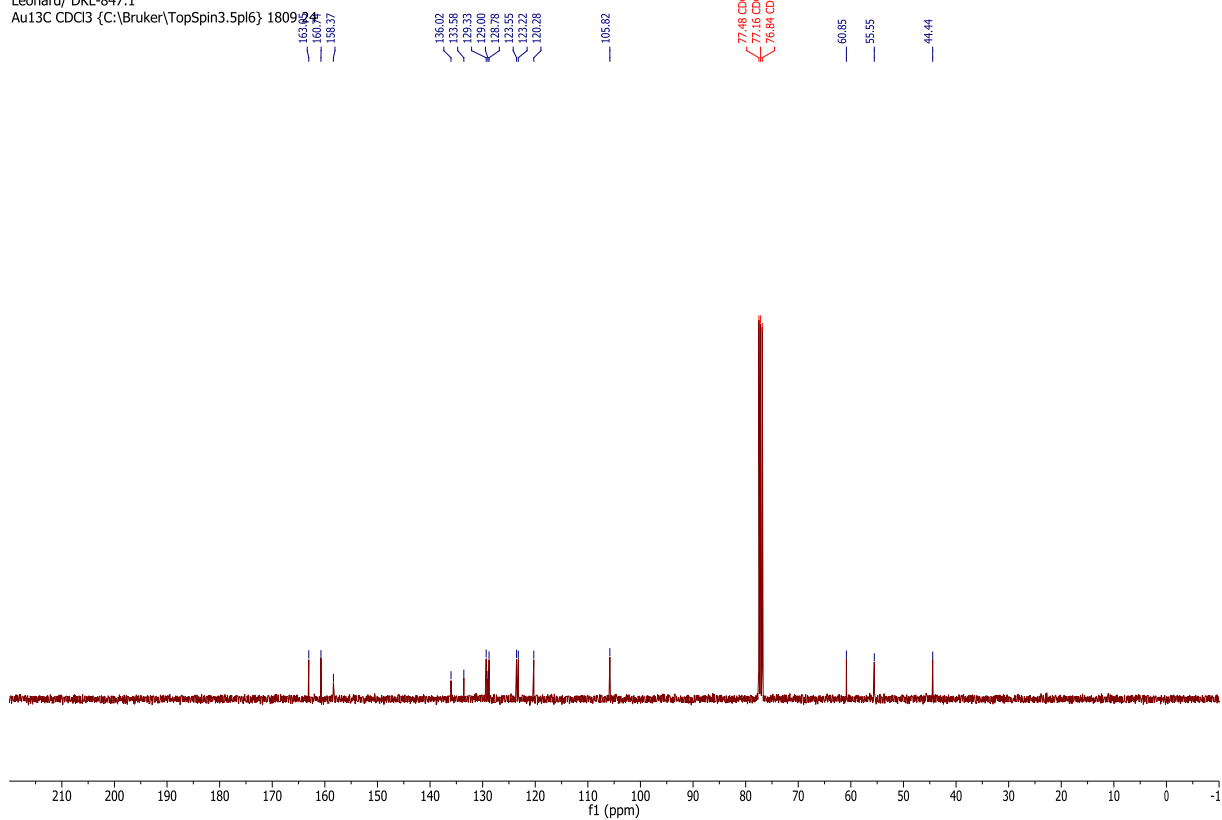


Original spectra for **14b**:

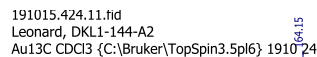
180917.424.10.fid
Leonard/ DKL-847.1
Au1H CDCl₃ {C:\Bruker\TopSpin3.5pl6} 1809 24



180917.424.11.fid
Leonard/ DKL-847.1
Au13C CDCl₃ {C:\Bruker\TopSpin3.5pl6} 1809 24

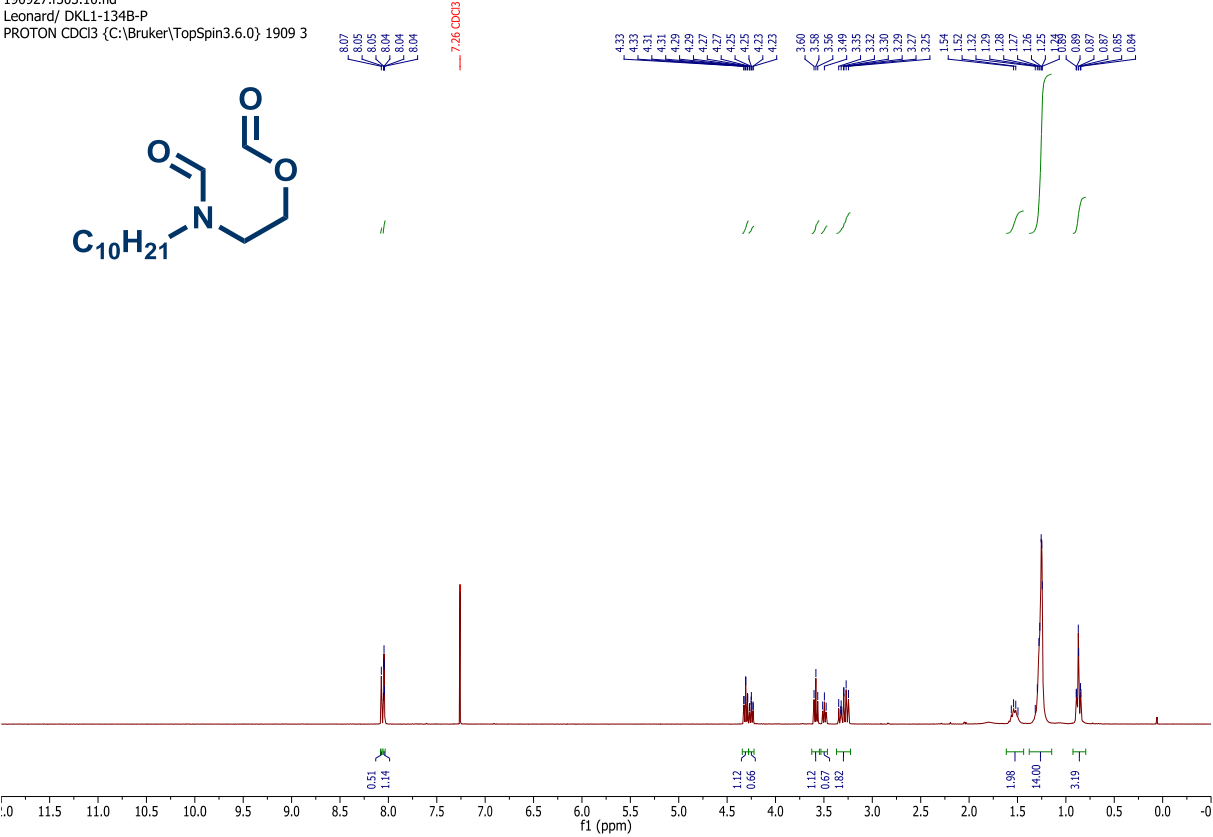
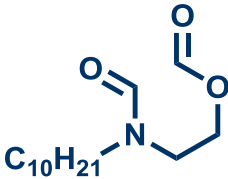


191021.f301.10.fid
David Leonaed DKL1-144-A2
PROTON CDCl3 {C:\Bruker\TopSpin3.6.0} 1910 1

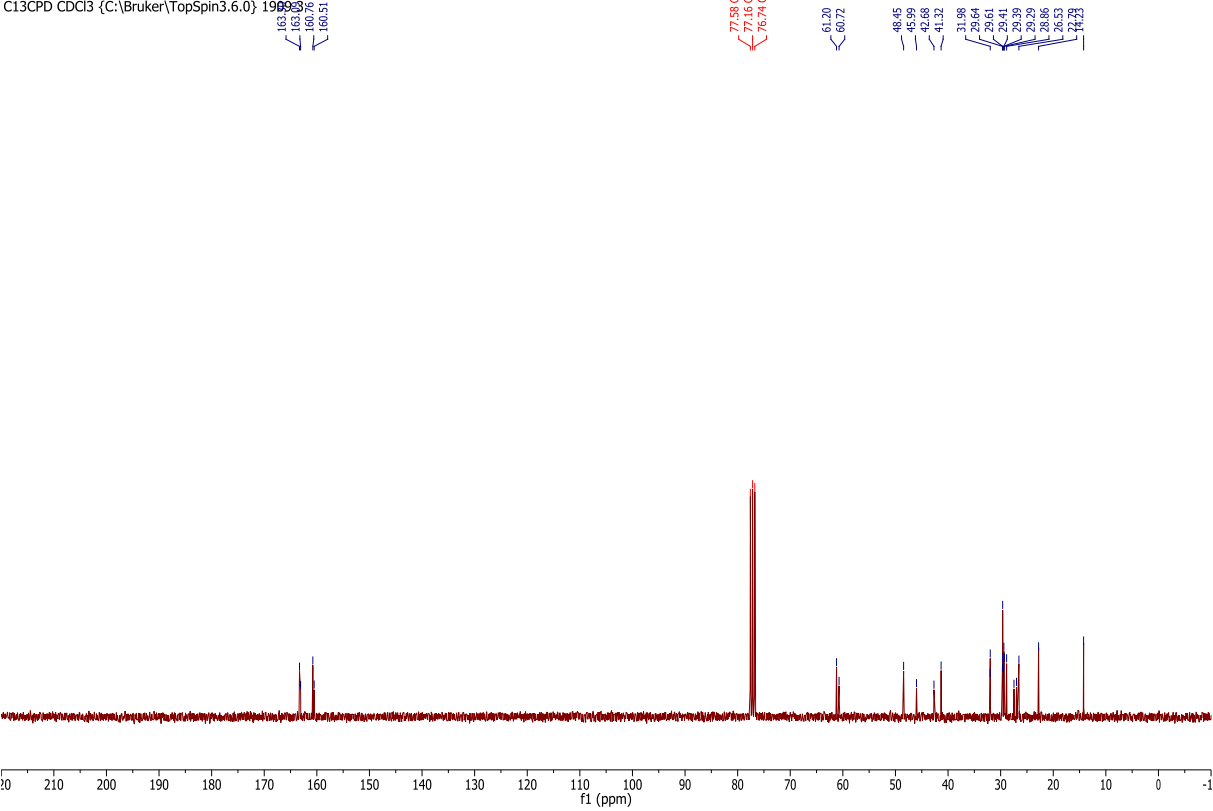


Original spectra for **16b**:

190927.f303.10.fid
Leonard/ DKL1-134B-P
PROTON CDCl3 {C:\Bruker\TopSpin3.6.0} 1909 3

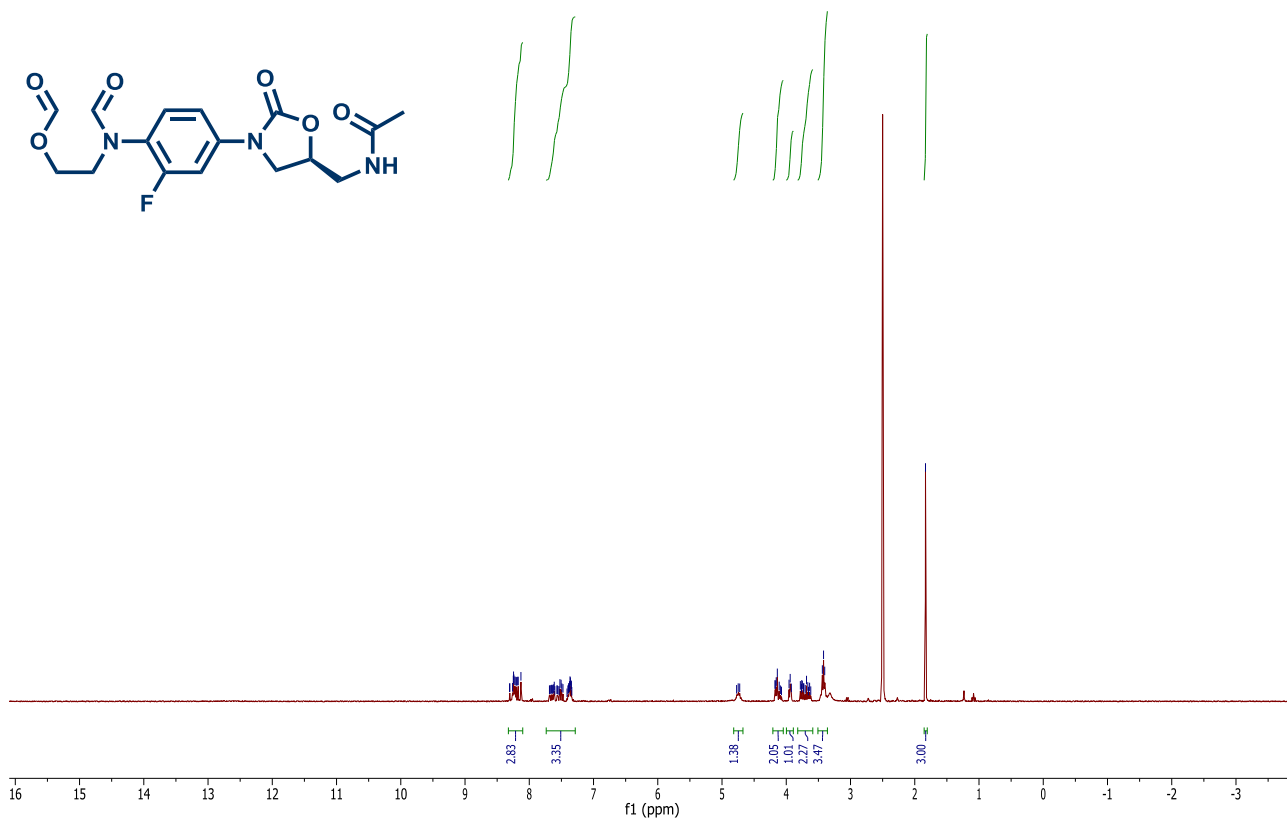


190927.f303.11.fid
Leonard/ DKL1-134B-P
C13CPD CDCl3 {C:\Bruker\TopSpin3.6.0} 1909 3

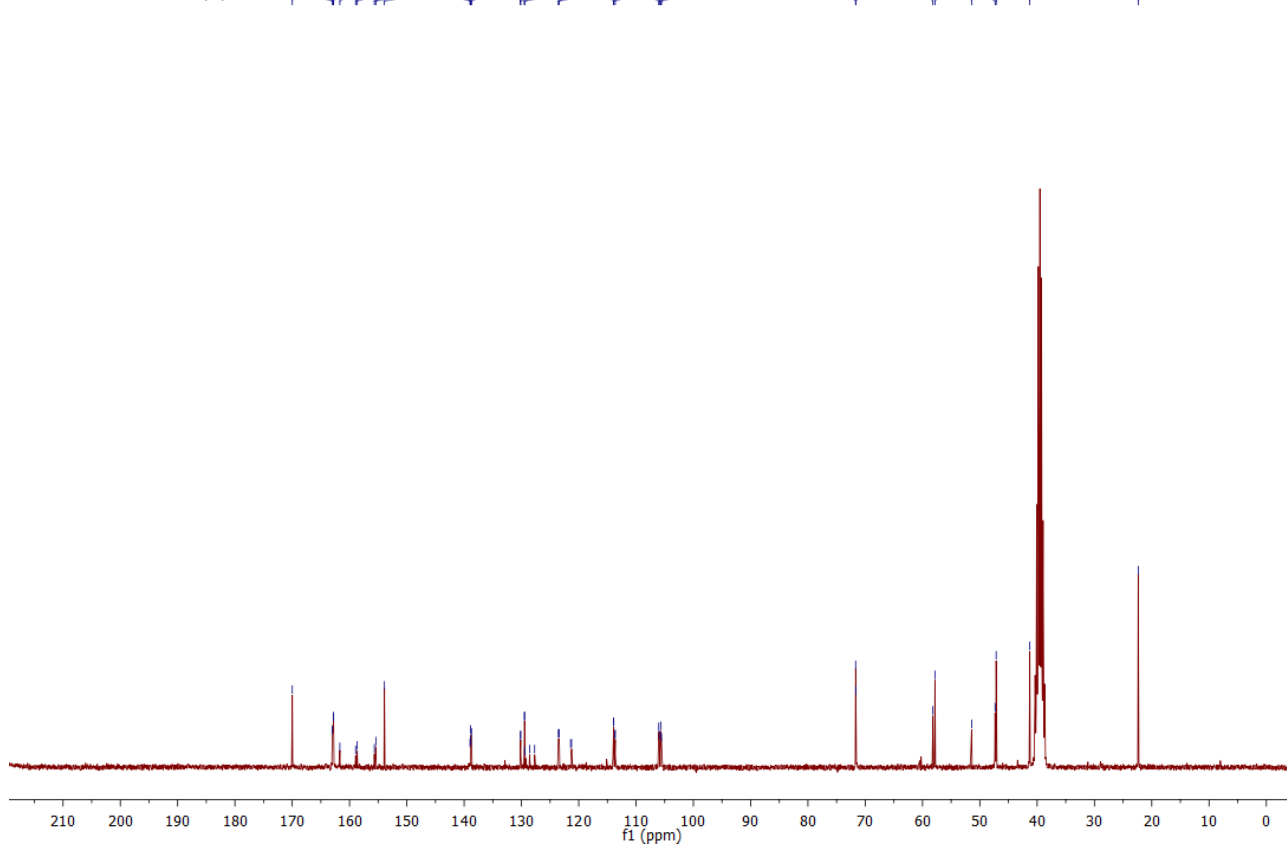


Original spectra for **17b**:

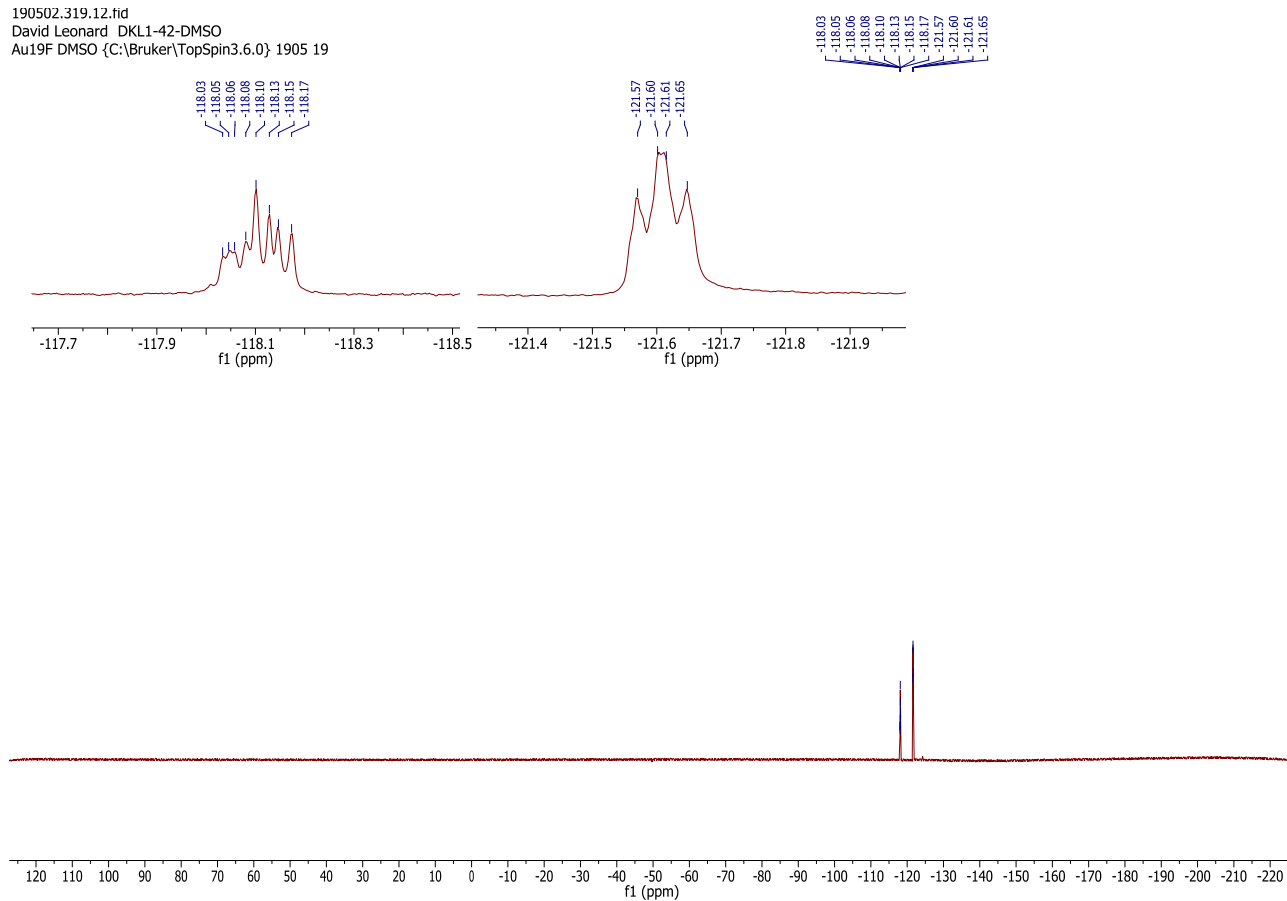
190503.f308.10.fid
David Leonard/ DKL-LIN-2
PROTON DMSO {C:\Bruker\TopSpin3.6.0\1905 8



190808.f336.10.fid
Leonard/ DKL-LIN-2
C13CPD DMSO {C:\Bruker\TopSpin3.6.0\1908 36

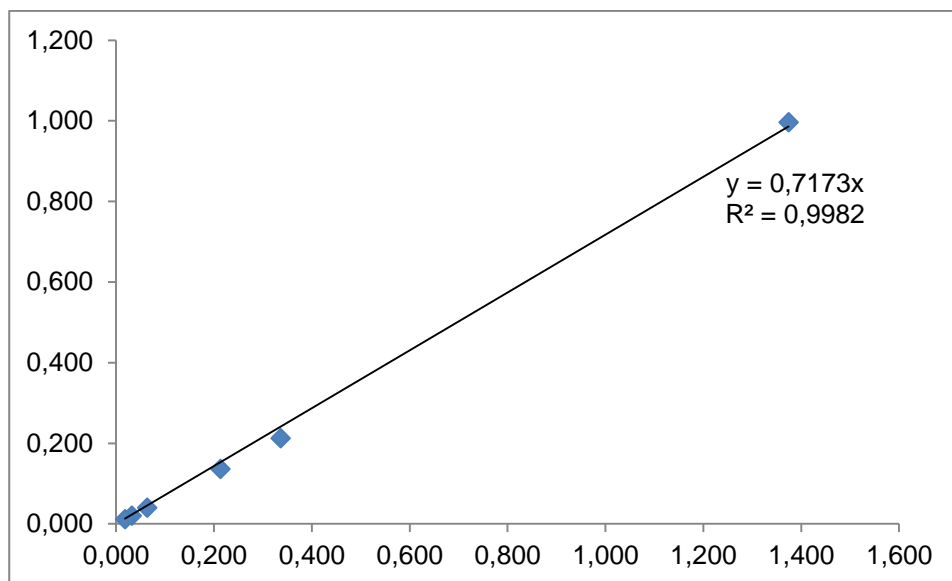


190502.319.12.ftd
David Leonard DKL1-42-DMSO
Au19F DMSO {C:\Bruker\TopSpin3.6.0} 1905 19



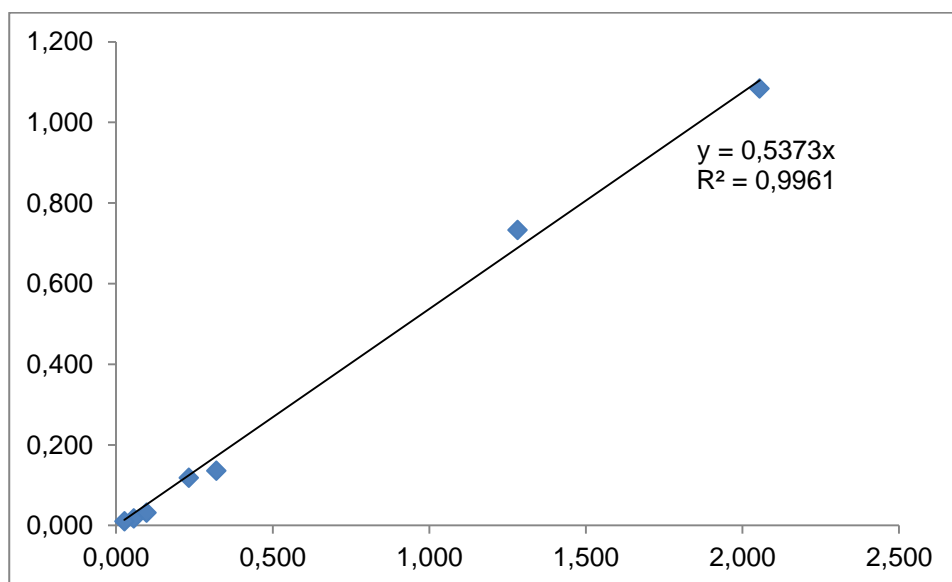
10. GC-FID CALIBRATIONS

GC-FID Calibration for 1a:



Response factor = 0,7173 as determined using ***n*-dodecane** as an internal standard.

GC-FID Calibration for 1b:



Response factor = 0,5373 as determined using ***n*-dodecane** as an internal standard.

11. REFERENCES

1. Ma, D.; Cai, Q; Zhang, H., Mild Method for Ullmann Coupling Reaction of Amines and Aryl Halides. *Org. Lett.*, **2003**, 5, 2453–2455.
2. Li, W.; Liu, W.; Leonard, D. K.; Rabeah, J.; Junge, K.; Brückner, J.; Beller, M., Practical Catalytic Cleavage of C(sp³)-C(sp³) Bonds in Amines. *Angew. Chem., Int. Ed.* **2019**, 131, 10803-10807.