N-Acyloxyphthalimides as Nitrogen Radical Precursors in the Visible Light Photocatalyzed Room Temperature C–H Amination of Arenes and Heteroarenes

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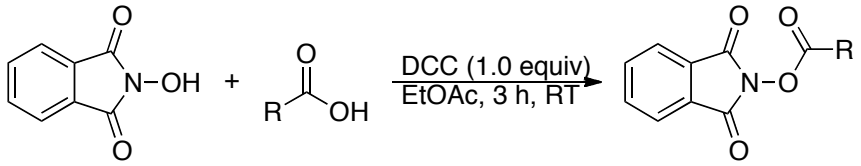
1. Materials and Methods: All reagents were purchased from common suppliers and dried over P_2O_5 prior to use unless otherwise noted. Tris[2-phenylpyridinato-C^2,*N*]iridium(III) ($Ir(ppy_3)$) was purchased from Sigma Aldrich. Ethyl acetate (EtOAc) and hexanes for column chromatography were purchased from VWR. Silica gel for flash column chromatography was purchased from Dynamic Adsorbents. $CDCl_3$ was purchased from Cambridge Isotope Laboratories, Inc. Thin layer chromatography (TLC) was performed on Merck TLC plates pre-coated with silica gel 60 F_{254}. NMR spectra were recorded on a Varian vnmrs 700 (699.76 MHz for ^1H; 175.95 MHz for ^{13}C), Varian vnmrs 500 (500.10 MHz for ^1H; 125.75 MHz for ^{13}C, 470.56 MHz for ^{19}F), or Varian MR400 (400.52 MHz for ^1H; 100.71 for ^{13}C; 376.87 MHz for ^{19}F) with the residual solvent peak ($CDCl_3$: ^1H: δ = 7.26 ppm, ^{13}C: δ = 77.16 ppm) as the internal reference unless otherwise noted. Chemical shifts are reported in parts per million (ppm) (δ) relative to tetramethylsilane. Multiplicities are reported as follows: br (broad resonance), s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet). Coupling constants (*J*) are reported in Hz. Infrared (IR) spectroscopy was performed on a Perkin-Elmer Spectrum BX FT-IR spectrometer and peaks are reported in cm^{-1}. Melting points were determined with a Mel-Temp 3.0, a Laboratory Devices Inc, USA instrument and are uncorrected. High-resolution mass spectra were recorded on a Micromass AutoSpec Ultima Magnetic Sector mass spectrometer. Gas chromatography was carried out on a Shimadzu 17A using a Restek Rtx®-5 (Crossbond 5% diphenyl/95% dimethyl polysiloxane; 15 m, 0.25 mm ID, 0.25 *μ*m df) column. All stock solutions were made using volumetric glassware. All reagents were weighed out in a nitrogen-filled drybox with exclusion of air and moisture, unless otherwise noted.

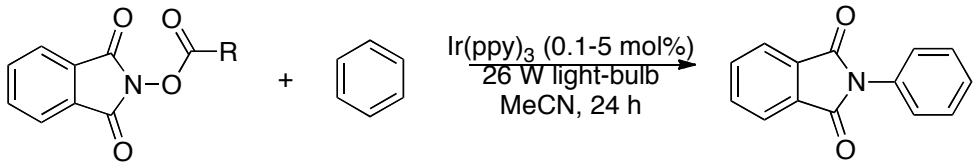
2. General Procedures:

A. General procedure for synthesis of substituted N-acyloxyphthalimides:[1]



In a 250 mL round bottom flask equipped with magnetic stir bar was added N-hydroxyphthalimide (4.29 mmol, 700 mg, 1.0 equiv) and dicyclohexylcarbodiimide (4.29 mmol, 885 mg, 1.0 equiv). Ethyl acetate (125 mL) was then added followed by the appropriate carboxylic acid (4.29 mmol, 1.0 equiv) and the reaction was stirred at room temperature, open to air for 3 h, during which time the reaction mixture became cloudy and a white solid precipitated from the solution. The white solid was removed via vacuum filtration and the filtrate was dried with $MgSO_4$ and further dried *in vacuo* to give the crude product. Recrystallization of the crude solid from hot ethanol provided the pure substituted N-acyloxyphthalimide.

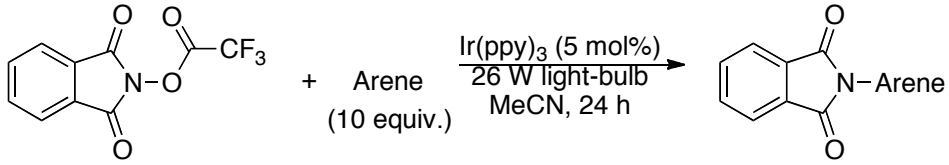
B. General procedure for optimization reactions (Table 1, Table S1 & Table S2)



In a N_2-filled drybox, substituted N-acyloxyphthalimide **1** (0.05 mmol, 1.0 equiv) and $Ir(ppy)_3$ (0.0025 mmol, 0.05 equiv) were weighed into a 4 mL scintillation vial equipped with a micro

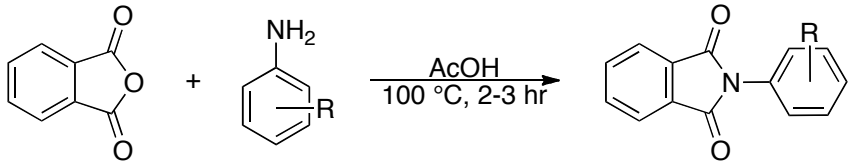
stirbar. Acetonitrile (0.5 mL, 0.1 M solution in **1**) was then added followed by benzene (0.5 mmol, 44 μL 10.0 equiv). The reaction vial was sealed with a Teflon-lined cap, removed from the N_2-filled drybox, and placed on a stir-plate. Two 26 W compact fluorescent light bulbs were placed on opposite sides of the vial at approximately 5 cm distance. The reaction mixture was stirred at room temperature for 24 h. It was then diluted with CH_2Cl_2 (3.0 mL) and a GC standard (neopentylbenzene, 0.0579 mmol, 10 μL, 1.16 equiv) was added. An aliquot (~0.6 mL) was removed for analysis, and yields were determined by GC.

C. General procedure for isolation reactions (Table 2 & Table 3):



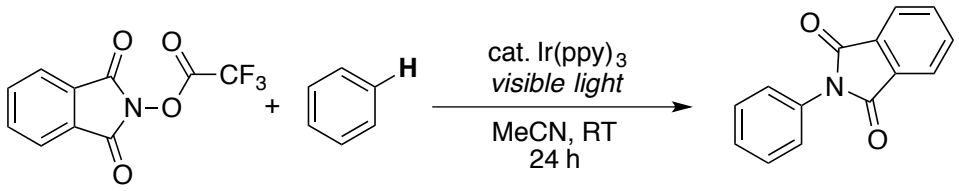
In a N_2-filled drybox, trifluoroacyloxyphthalimide (**1g**) (0.25 mmol, 65 mg, 1.0 equiv) and $Ir(ppy)_3$ (0.0125 mmol, 8.0 mg, 0.05 equiv) were weighed into a 4 mL scintillation vial equipped with a micro stirbar. Acetonitrile (2.5 mL, 0.1 M solution **1**) was then added followed by the arene substrate (2.5 mmol, 10.0 equiv). The reaction vial was sealed with a Teflon-lined cap, removed from the N_2-filled drybox, and placed on a stir-plate. Two 26 W compact fluorescent light bulbs were placed on opposite sides of the vial at approximately 5 cm distance. The reaction mixture was stirred at room temperature for the indicated time.

D. General procedure for synthesis of authentic samples:[3]



Phthalic anhydride (60 mg, 0.40 mmol, 1.0 equiv) was added to a 20 mL vial equipped with a magnetic stir bar. Acetic acid (1.00 mL) was added via syringe followed by the appropriate aniline derivative (0.40 mmol, 1.0 equiv). The reaction was heated at 100 ºC for 2-3 h, and then the reaction mixture was quenched with water, upon which time a white solid precipitated from solution. The precipitate was collected via vacuum filtration, washed with water, and dried *in vacuo* to give the desired product.

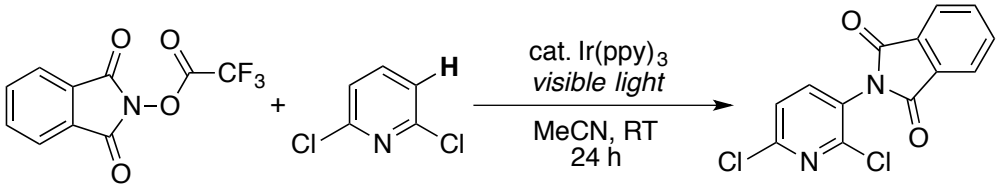
3. Table S1. Optimization of Photocatalytic C–H Amination:



Entry	mol % [Ir]	equiv benzene	yield (%)[a]
1	none	10	nd[b]
2	5[c]	10	nd[b]
3	0.5	10	55[d]
4	1.0	10	65[d]
5	**5**	**10**	**81**
6	5	5	62
7	5	2.5	56
8	5	1	23

Conditions: General procedure **B** was followed using **1g** (0.05 mmol, 1.0 equiv), $Ir(ppy)_3$ (0.5-5 mol %), benzene (1-10 equiv), MeCN (0.1 M in **1g**), and visible light for 24 h, rt. [a]GC yields using neopentylbenzene as a standard. [b]nd = not detected. [c]No light. [d]Isolated yield.

4. Table S2. Optimization of Electron Deficient Heteroarene Substrates:

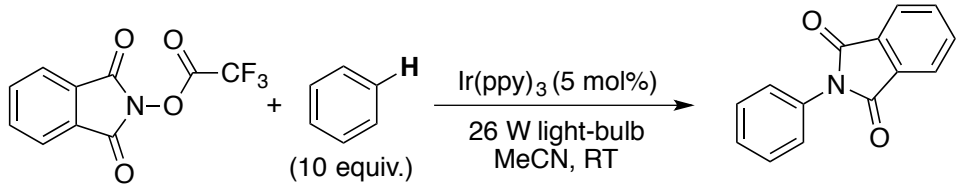


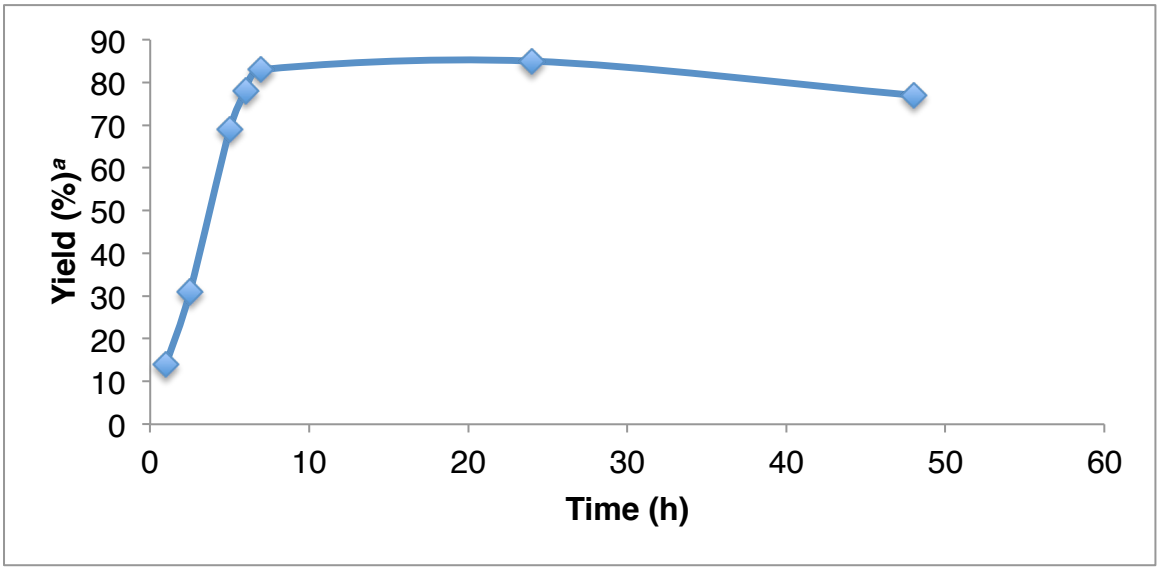
Entry	mol % [Ir]	equiv 2,6-dichloropyridine	Concentration of **1g** in MeCN	yield (%)[a]
1	5	10	0.1 M	59 ± 5
2	5	5	0.1 M	27 ± 1
3	5	20	0.1 M	67 ± 4
4	5	30	0.1 M	80 ± 6
5	5	40	0.1 M	77 ± 3
6	5	50	0.1 M	83 ± 6
7	10	10	0.1 M	36 ± 0
8	2.5	10	0.1 M	59 ± 5
9	5	10	0.05 M	49 ± 3
10	5	10	0.2 M	62 ± 1
11	5	10	0.3 M	63 ± 2
12	5	10	0.5 M	61 ± 4
13	5	10	1 M	59 ± 3
14	**5**	**20**	**0.2 M**	**77 ± 4**

15	5	30	0.2 M	80 ± 7
16	5	50	0.2 M	80 ± 3

Conditions: General procedure **B** was followed using **1g** (0.05 mmol, 1.0 equiv), $Ir(ppy)_3$ (2.5-10 mol %), 2,6-dichloropyridine (5-50 equiv), MeCN (0.05-1 M in **1g**), and visible light for 24 h, rt. [a]GC yields using neopentylbenzene as a standard. Reactions done in duplicate.

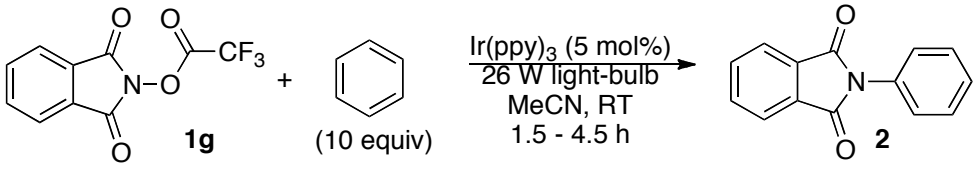
5. Figure S1. Time Study of Benzene C–H Amination:

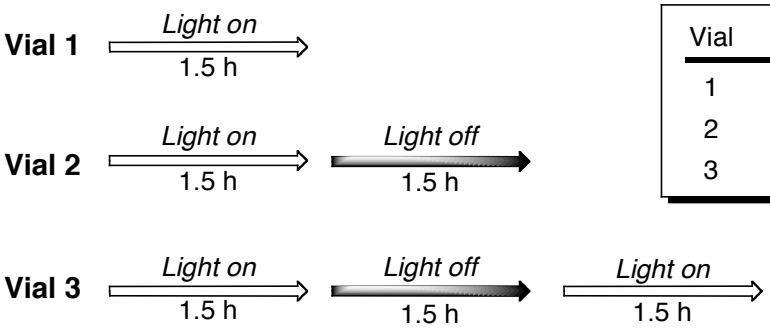




Conditions: General procedure **B** was followed using **1g** (0.05 mmol, 1.0 equiv), $Ir(ppy)_3$ (5 mol %), benzene (10 equiv), MeCN (0.1 M in **1g**), and visible light for 2-48 h, rt. [a]GC yields using neopentylbenzene as a standard.

6. Scheme S1. Radical Chain Probe Experiment:

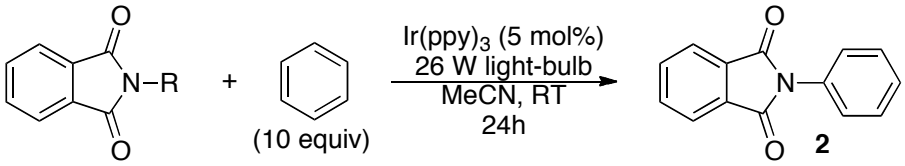




Vial	Yield **2**
1	19%
2	17%
3	32%

Conditions: General procedure **B** was followed using **1g** (0.05 mmol, 1.0 equiv), $Ir(ppy)_3$ (0.05 equiv), visible light, and benzene (10 equiv) in MeCN (0.1 M in **1g**). The reaction mixtures were stirred at room temperature for the given time. Yields were determined by GC using neopentylbenzene as a standard.

7. Table S3. Control Reactions

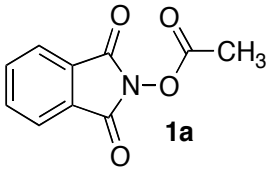


Entry	R	mol% [Ir]	Visible light	Yield[a]
1	$OCOCF_3$ (**1g**)	none	yes	nd
2	**1g**	5	no	nd
3[b]	**1g**	none	no	nd
4[b]	**1g**	5	no	nd
5[b,c]	**1g**	none	no	nd
6	Br	none	yes	<10%
7	Br	5	yes	<10%
8[b]	Br	5	no	nd
9	Ts	none	yes	<10%
10	Ts	5	yes	38%
11	Ts	5	no	nd
12[b]	Ts	none	no	nd

Conditions: General procedure **B** was followed using N-substituted phthalimides (0.05 mmol, 1.0 equiv), $Ir(ppy)_3$ (0.05 equiv), visible light, and benzene (10 equiv) in MeCN (0.1 M in **1g**). The reaction mixtures were stirred at room temperature for 24 h. [a]Yields were determined by GC using neopentylbenzene as a standard. nd = not detected. [b]80 °C. [c]trifluoroacetic acid (1.0 equiv) added.

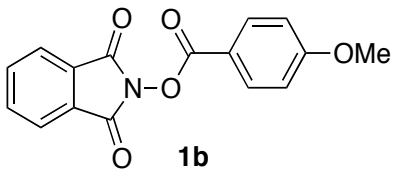
8. Substituted N-acyloxyphthalimide Characterization:

N-acetoxyphthalimide (1a): General procedure **A** was followed using acetic acid (4.29 mmol, 258 mg, 0.25 mL) as the carboxylic acid substrate. The product was obtained as a white solid (547 mg, 62% yield). The structure of **1a** was confirmed by comparison of ^{1}H NMR data to that reported in the literature.[1] ^{1}H NMR ($CDCl_3$, 700 MHz): δ 7.89 (dd, *J* = 5.6, 3.5 Hz, 2H), 7.79 (dd, *J* = 5.6, 3.5 Hz, 2H), 2.40 (s, 3H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 166.7, 162.0, 134.9, 129.1, 124.1, 17.9.



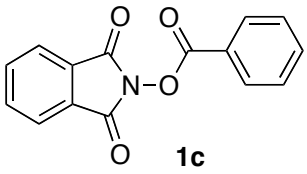
1a

1,3-dioxoisoindolin-2-yl 4-methoxybenzoate (1b): General procedure **A** was followed using *p*-methoxybenzoic acid (4.29 mmol, 653 mg) as the carboxylic acid substrate. The product was obtained as a white solid (865 mg, 70% yield). The structure of **1b** was confirmed by comparison of ^{1}H and ^{13}C NMR data to that reported in the literature.[4] ^{1}H NMR ($CDCl_3$, 700 MHz): δ 8.14 (d, *J* = 8.4 Hz, 2H), 7.92-7.91 (m, 2H), 7.81-7.80 (m, 2H), 6.99 (d, *J* = 8.4 Hz, 2H) 3.90 (s, 3H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 165.0, 162.5, 162.4, 134.9, 133.1, 129.2, 124.1, 117.4, 114.4, 55.8.



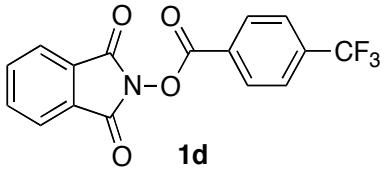
1b

1,3-dioxoisoindolin-2-yl benzoate (1c): General procedure **A** was followed using benzoic acid (4.29 mmol, 524 mg) as the carboxylic acid substrate. The product was obtained as a white solid (805 mg, 70% yield). The structure of **1c** was confirmed by comparison of ^{1}H and ^{13}C NMR data to that reported in the literature.[4] ^{1}H NMR ($CDCl_3$, 700 MHz): δ 8.21-8.19 (m, 2H), 7.94-7.92 (m, 2H), 7.83-7.80 (m, 2H), 7.70 (tt, *J* = 7.7, 1.4 Hz, 1H), 7.55-7.53 (m, 2H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 162.9, 162.2, 135.0, 134.9, 130.8, 129.2, 129.0, 125.4, 124.2.



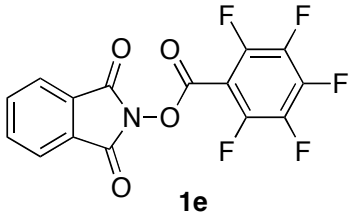
1c

1,3-dioxoisoindolin-2-yl 4-(trifluoromethyl)benzoate (1d): General procedure **A** was followed using *p*-trifluoromethylbenzoic acid (4.29 mmol, 815 mg) as the carboxylic acid substrate. The product was obtained as a white solid (934 mg, 65% yield). The structure of **1d** was confirmed by comparison of ^{1}H NMR data to that reported in the literature.[4] ^{1}H NMR ($CDCl_3$, 700 MHz): δ 8.32 (d, *J* = 8.4 Hz, 2H), 7.94 (dd, *J* = 5.6, 2.8 Hz, 2H), 7.84-7.81 (multiple peaks, 4H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 161.9, 161.9, 136.3 (q, *J* = 33 Hz), 135.1, 131.2, 129.0, 128.8, 126.1 (q, *J* = 4 Hz), 124.3, 123.5 (q, *J* = 273 Hz). ^{19}F NMR ($CDCl_3$, 376.87 MHz): δ –63.4.



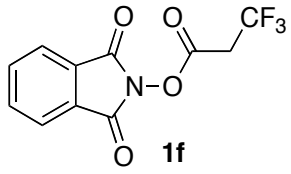
1d

1,3-dioxoisoindolin-2-yl 2,3,4,5,6-pentafluorobenzoate (1e): General procedure **A** was followed using pentafluorobenzoic acid (4.29 mmol, 910 mg) as the carboxylic acid substrate. The product was obtained as a white solid (1.127 g, 73% yield, mp = 111-112 °C.). ^{1}H NMR ($CDCl_3$, 700 MHz): δ 7.94 (dd, *J* = 5.6, 2.8 Hz, 2H), 7.84 (dd, *J* = 5.6, 2.8 Hz, 2H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 161.3, 156.1 (m), 147.5-145.8 (m), 145.8-144.2 (m), 139.0-137.3 (m), 135.2, 128.9, 124.4, 103.4 (td, *J* = 14, 5 Hz). ^{19}F NMR ($CDCl_3$, 376.87 MHz): δ –132.9 thru –132.9 (m), –143.3 (tt, *J* = 21, 7 Hz), –158.8 thru –158.9 (m). HRMS: EI (m/z) M^+ calcd for $C_{15}H_4F_5NO_4$: 357.0060; found: 357.0058.

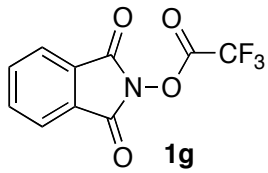


1e

1,3-dioxoisoindolin-2-yl 3,3,3-trifluoropropanoate (1f): General procedure **A** was followed using 3,3,3-trifluoropropanoic acid (4.29 mmol, 549 mg, 0.38 mL) as the carboxylic acid substrate. The product was obtained as a white solid (351 mg, 31% yield, mp = 108-110 ºC). ^{1}H NMR ($CDCl_3$, 700 MHz): δ 7.92-7.90 (m, 2H), 7.83-7.81 (m, 2H), 3.58 (q, *J* = 9.5 Hz, 2H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 161.3, 160.8 (q, *J* = 4 Hz), 135.2, 128.8, 124.4, 122.6 (q, *J* = 277 Hz), 32.9 (q, *J* = 33 Hz). ^{19}F NMR ($CDCl_3$, 376.87 MHz): δ –63.1 (t, *J* = 9.5 Hz). δ HRMS: ESI+ (m/z): $[M+H]^+$ calcd for $C_{11}H_7F_3NO_4$: 274.0322; found: 274.0317.


1f

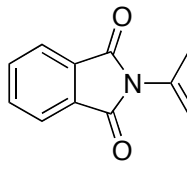
N-(trifluoromethyl)acyloxyphthalimide (1g): N-Hydroxyphthalimide (1.0 g, 6.12 mmol, 1.0 equiv) was added to an oven-dried Schlenk flask equipped with a magnetic stir bar, and the flask was evacuated and back-filled with nitrogen. Dry acetonitrile (6 mL) and trifluoroacetic anhydride (1.73 mL, 12.26 mmol, 2.0 equiv) were then added via syringe, and the mixture was stirred at room temperature for 4 h. The volatiles were then removed *in vacuo*, and the remaining white solid was dried *in vacuo* for an additional 12 h. The product was obtained as a moisture sensitive white solid (1.16 g, 80% yield). ^{1}H NMR (C_6D_6, 400 MHz): δ 7.09 (dd, *J* = 3.2, 5.6 Hz, 2H), 6.67 (dd, *J* = 2.8, 5.6, 2H). ^{13}C NMR (C_6D_6, 175.95 MHz): δ 160.2, 155.3 (q, *J* = 45 Hz), 134.6, 128.5, 124.0, 114.7 (q, *J* = 286 Hz) ^{19}F NMR (C_6D_6, 400 MHz): δ –72.6. HRMS EI (m/z): M^+ calcd for $C_{10}H_4F_3NO_4$: 259.0088; found: 259.0092.


1g

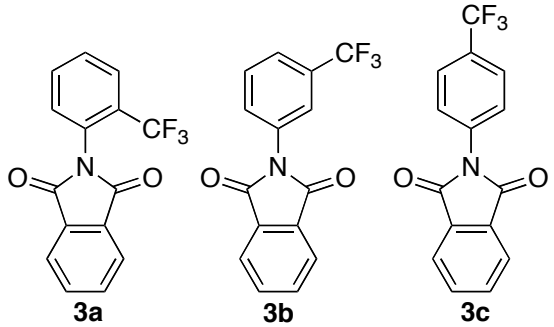
9. Product Characterization:

N-phenylphthalimide (2):

General procedure **C** was followed using benzene (2.5 mmol, 195 mg, 0.22 mL) as the arene substrate. After 24 h, the volatiles were removed *in vacuo,* and the crude mixture was purified by column chromatography to afford **2** as a white solid in 76% yield (95 mg). The structure of **2** was confirmed by comparison of ^{1}H and ^{13}C NMR data to that reported in the literature.[5,6] ^{1}H ($CDCl_3$, 700 MHz): δ 7.96 (dd, *J* = 4.9, 2.8 Hz, 2H), 7.79 (dd, *J* = 4.9, 2.8 Hz, 2H), 7.51 (t, *J* = 7.7 Hz, 2H), 7.45-7.44 (m, 2H), 7.42-7.40 (m, 1H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 167.4, 134.5, 131.9, 131.8, 129.2, 128.2, 126.7, 123.9.


2

N-(trifluoromethylbenzene)phthalimide (3):[2]


3a **3b** **3c**

General procedure **C** was followed using trifluorotoluene (2.5 mmol, 365 mg, 0.31 mL) as the arene substrate. After 24 h, the volatiles were evaporated *in vacuo* and the crude mixture was

purified by column chromatography to give a mixture of **3a**, **3b**, and **3c** as a white solid. The structures of **3a**, **3b**, and **3c** were determined by synthesis of authentic samples (using general procedure **E**). Isomer ratios were determined by ^{19}F NMR spectroscopy.

Isolated Yield: 23% (17 mg, 1.0: 8.4: 2.8)

R_f (isolated mixture of isomers): 0.47 (30% EtOAc/70% hexanes)

IR (υ, cm^{-1}); (isolated mixture of isomers): 2921, 2852, 1708, 1494, 1453, 1375, 1313, 1109, 1062, 875, 804

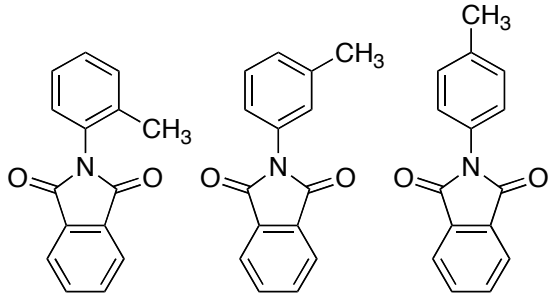
HRMS (isolated mixture of isomers): EI (m/z) M^+ calcd for $C_{15}H_8F_3NO_2$: 291.0507; found: 291.0514.

3a: ^1H NMR ($CDCl_3$, 700 MHz): δ 7.97-7.94 (m, 2H), 7.84 (d, *J* = 7.7 Hz, 1H), 7.82-7.79 (m, 2H), 7.71 (t, *J* = 7.7 Hz, 1 H), 7.63 (t, *J* = 7.7 Hz, 1H), 7.37 (d, *J* = 7.7 Hz, 1H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 167.2, 134.6, 133.3, 132.0, 131.8, 130.2, 129.9 (q, *J* = 2 Hz), 129.7 (q, *J* = 31 Hz), 127.7 (q, *J* = 5 Hz), 124.1, 123.1 (q, *J* = 273 Hz), ^{19}F NMR ($CDCl_3$, 376.87 MHz): δ –61.42 (s). mp = 103-105 °C.

3b: ^1H NMR ($CDCl_3$, 700 MHz): δ 8.00-7.97 (m, 2H), 7.84-7.78 (m, 2H), 7.78 (br s, 1H), 7.67 (m, 3H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 167.1, 135.1, 132.7, 132.0 (q, *J* = 33 Hz), 131.8, 130.0, 129.9, 125.0 (q, *J* = 4 Hz), 124.3, 123.9 (q, *J* = 273 Hz), 123.7 (q, *J* = 4 Hz). ^{19}F NMR ($CDCl_3$, 376.87 MHz): δ –62.69 (s). mp = 84-87 °C.

3c: ^1H NMR ($CDCl_3$, 700 MHz): δ 8.00-7.97 (m, 2H), 7.84-7.81 (m, 2H), 7.78 (d, *J* = 8.4 Hz, 2H), 7.65 (d, *J* = 8.4 Hz, 2H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 166.9, 135.1, 134.9, 131.7, 130.0 (q, *J* = 33 Hz), 126.6, 126.4 (q, *J* = 4 Hz), 124.2, 124.0 (q, *J* = 272 Hz). ^{19}F NMR ($CDCl_3$, 470.56 MHz): δ –62.66 (s). mp = 216-218 °C.

N-(tolyl)phthalimide (4):[2,5,6]



4a **4b** **4c**

General procedure **C** was followed using toluene (2.5 mmol, 230 mg, 0.27 mL) as the arene substrate. After 24 h, the volatiles were evaporated *in vacuo* and the crude mixture was purified by column chromatography to give a mixture of **4a**, **4b**, and **4c** as a white solid. The structures of **4a**, **4b**, and **4c** were confirmed by synthesis of authentic samples (using general procedure **E**) and isomer ratios were determined by ^1H NMR spectroscopy.

Isolated Yield: 80% (47 mg, 2.0: 1.0: 1.2)

R_f (isolated mixture of isomers): 0.77 (30% EtOAc/70% hexanes)

IR (υ, cm^{-1}); (isolated mixture of isomers): 1708, 1465, 1377, 1110, 1080, 884, 770, 715.

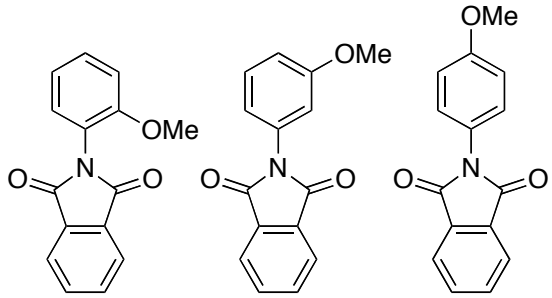
HRMS (isolated mixture of isomers): EI (m/z) M^+ calcd for $C_{15}H_{11}NO_2$: 237.0790; found: 237.0793.

4a: ^{1}H NMR ($CDCl_3$, 700 MHz): δ 7.96 (dd, *J* = 4.9, 2.8 Hz, 2H), 7.80 (dd, *J* = 4.9, 2.8 Hz, 2H), 7.38-7.32 (m, 3H), 7.21 (d, *J* = 7.7 Hz) 2.22 (s, 3H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 167.5, 136.7, 134.5, 132.2, 131.3, 130.7, 129.6, 128.9, 127.0, 123.9, 18.2. mp = 151-152 °C.

4b: ^{1}H NMR ($CDCl_3$, 700 MHz): δ 7.96-7.95 (m, 2H), 7.79-7.78 (m, 2H), 7.40 (t, *J* = 7.7 Hz, 1H), 7.24-7.22 (m, 3H), 2.42 (s, 3H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 167.5, 139.3, 134.5, 131.9, 131.6, 129.2, 129.1, 127.4, 123.9, 123.8, 21.6. mp = 146-147 °C.

4c: ^{1}H NMR ($CDCl_3$, 700 MHz): δ 7.96-7.94 (m, 2H), 7.80-7.77 (m, 2H), 7.31 (s, 4H), 2.41 (s, 3H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 167.6, 138.3, 134.5, 132.0, 129.9, 129.1, 126.6, 123.8, 21.4. mp = 173-175 °C.

N-(methoxybenzene)phthalimide (5):[2]



5a **5b** **5c**

General procedure **C** was followed using anisole (2.5 mmol, 270 mg, 0.27 mL) as the arene substrate. After 24 h, the volatiles were evaporated *in vacuo* and the crude mixture was purified by column chromatography to give a mixture of **5a**, **5b**, and **5c** as a white solid. The structures of **5a**, **5b**, and **5c** were confirmed by synthesis of authentic samples (using general proceuure **E**) and isomer ratios were determined by ^{1}H NMR spectroscopy.

Isolated Yield: 81% (51 mg, 12: 1: 10.3)

R_f (isolated mixture of isomers): 0.54 (100% CH_2Cl_2)

IR (υ, cm^{-1}); (isolated mixture of isomers): 1703, 1505, 1384, 1251, 1113, 1021, 883, 768, 712.

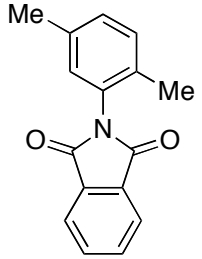
HRMS: EI (m/z); (isolated mixture of isomers): M^+ calcd for $C_{15}H_{11}NO_3$: 253.0739; found: 253.0746

5a: ^{1}H NMR ($CDCl_3$, 700 MHz): δ 7.95 (dd, *J* = 5.6, 2.8 Hz, 2H), 7.78 (dd, *J* = 5.6, 2.8 Hz, 2H), 7.45-7.43 (m, 1H), 7.26 (dd, *J* = 7.7, 1.4 Hz, 1H), 7.08 (td, *J* = 7.7, 1.4 Hz, 1H), 7.05-7.06 (m, 1H), 3.80 (s, 3H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 167.5, 155.6, 134.2, 132.4, 130.8, 130.1, 123.8, 121.0, 120.4, 112.3, 56.0. mp = 129-130 °C.

5b: ^{1}H NMR ($CDCl_3$, 700 MHz): δ 7.96 (dd, *J* = 5.6, 2.8 Hz, 2H), 7.80 (dd, *J* = 5.6, 2.8 Hz, 2H), 7.41 (t, *J* = 7.7 Hz, 1H), 7.03 (ddd, *J* = 7.7, 2.1, 0.7 Hz, 1H), 6.99 (t, *J* = 2.1 Hz, 1H) 6.96 (ddd, *J* = 7.7, 2.1, 0.7 Hz, 1H), 3.84 (s, 3H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 167.4, 160.2, 134.6, 132.8, 131.9, 130.0, 123.9, 119.0, 114.3, 112.5, 55.6. mp = 92-94 °C.

5c: ^{1}H NMR ($CDCl_3$, 700 MHz): δ 7.95 (dd, *J* = 5.6, 2.8 Hz, 2H), 7.78 (dd, *J* = 5.6, 2.8 Hz, 2H), 7.34-7.33 (m, 2H), 7.03-7.01 (m, 2H), 3.85 (s, 3H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 167.7, 159.4, 134.4, 132.0, 128.1, 124.4, 123.8, 114.6, 55.7. mp = 131-132 °C.

1-*N*-phthalimido-2,4-dimethylbenzene (6):[5,6]



6

General procedure **C** was followed using 1,4-dimethylbenzene (2.5 mmol, 265 mg, 0.31 mL) as the arene substrate. After 24 h, the reaction was diluted with EtOAc, and triethylamine (1 mL) was added to quench trifluoroacetic acid. The reaction mixture was concentrated *in vacuo*, and the residue was purified via column chromatography. The crude product was dissolved in EtOAc (~10 mL) and washed with 2M NaOH (3 x 10 mL). The organic layer was dried over Na_2SO_4, and the volatiles were evaporated *in vacuo* to give **6** as a white solid.

Isolated Yield: 88% (55 mg)

R_f: 0.52 (50% hexane/50% Et_2O)

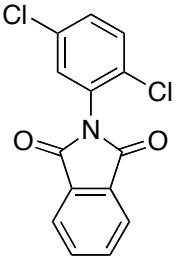
IR (υ, cm^{-1}): 2921, 2851, 1716, 1507, 1370, 1238, 1112, 1082, 873, 819, 717.

mp: 137-139 °C

HRMS: ESI$^+$ (m/z): $[M+H]^+$ calcd for $C_{16}H_{14}NO_2$: 252.1019; found: 252.1016.

NMR: ^{1}H ($CDCl_3$, 700 MHz): δ 7.97-7.94 (m, 2H), 7.80-7.77 (m, 2H), 7.25 (d, *J* = 7.7 Hz, 1H), 7.18 (dd, *J* = 7.7, 1.4 Hz, 1H), 7.03 (s, 1H), 2.36 (s, 3H), 2.16 (s, 3H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 167.5, 136.8, 134.4, 133.4, 132.2, 131.0, 130.5, 130.4, 129.3, 123.8, 20.9, 17.6.

1-*N*-phthalimido-2,4-dichlorobenzene (7):



7

General procedure **C** was followed using 1,4-dichlorobenzene (2.5 mmol, 370 mg) as the arene substrate. After 24 h, the reaction was diluted with EtOAc, and triethylamine (1 mL) was added to quench trifluoroacetic acid. The reaction mixture was concentrated *in vacuo*, and the residue was purified via column chromatography. The crude product was dissolved in EtOAc (~10 mL) and washed with 2M NaOH (3 x 10 mL). The organic layer was dried over Na_2SO_4, and the volatiles were evaporated *in vacuo* to give **7** as a white solid.

Isolated Yield: 40% (29 mg)

R_f: 0.41 (25% EtOAc/75% hexanes)

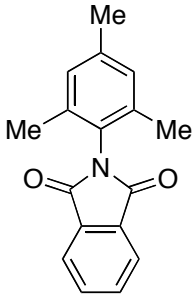
IR (υ, cm^{-1}): 1719, 1473, 1412, 1217, 1094, 1078, 864, 815, 710.

mp: 177-179 °C

HRMS: ESI^+ (m/z) $[M+H]^+$ calcd for $C_{14}H_8Cl_2NO_2$: 291.9927; found: 291.9923

NMR: ^1H ($CDCl_3$, 700 MHz): δ 8.00-7.97 (m, 2H), 7.84-7.81 (m, 2H), 7.51 (d, J = 8.4 Hz, 1H), 7.42 (dd, J = 8.4, 2.8 Hz, 1H), 7.37 (d, J = 2.8 Hz, 1H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 166.3, 134.8, 133.3, 131.9, 131.9, 131.3, 130.9, 130.9, 130.8, 124.3.

1-*N*-phthalimido-2,4,6-trimethylbenzene (8):[5]



8

General procedure **C** was followed using 1,3,5-trimethylbenzene (2.5 mmol, 300 mg, 0.35 mL) as the arene substrate. After 24 h, the reaction was diluted with EtOAc and triethylamine (1 mL) was added to quench trifluoroacetic acid. The reaction mixture was concentrated *in vacuo*, and the residue was purified via column chromatography to give **8** as a white solid.

Isolated Yield: 89% (59 mg)

R_f: 0.48 (25% EtOAc/75% hexanes)

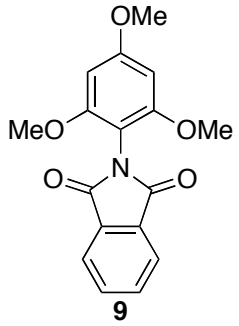
IR (υ, cm^{-1}): 2919, 1718, 1489, 1464, 1375, 1113, 1038, 882, 852, 715

mp: 154-156 °C

HRMS: ESI^+(m/z): $[M+H]^+$ calcd for $C_{17}H_{16}NO_2$: 266.1176; found: 266.1172

NMR: ^1H ($CDCl_3$, 700 MHz): δ 7.97-7.96 (m, 2H), 7.80-7.79 (m, 2H), 7.01 (s, 2H), 2.34 (s, 3H), 2.13 (s, 6H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 167.5, 139.4, 136.6, 134.4, 132.1, 129.4, 127.2, 123.8, 21.2, 18.1

1-N-phthalimido-2,4,6-trimethoxybenzene (9):



9

General procedure **C** was followed using 1,3,5-trimethoxybenzene (2.5 mmol, 420 mg) as the arene substrate. After 24 h, the volatiles were evaporated *in vacuo* and the crude mixture was purified by column chromatography to give **9** as a light yellow crystalline solid.

Isolated Yield: 73% (57 mg)

R_f: 0.24 (30% EtOAc/70% hexanes)

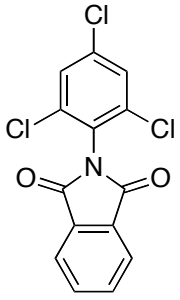
IR (υ, cm^{-1}): 2922, 1785, 1731, 1711, 1591, 1515, 1463, 1423, 1388, 1341, 1239, 1206, 1164, 1130, 1104, 1084, 1033, 946, 882, 817, 716.

mp: 195-196 °C

HRMS: EI (m/z) M^+ calcd for $C_{17}H_{15}NO_5$: 313.0950; found: 313.0946.

NMR: ^1H ($CDCl_3$, 700 MHz): δ 7.92-7.89 (m, 2H), 7.75-7.72 (m, 2H), 6.21 (s, 2H), 3.83 (s, 3H), 3.74 (s, 6H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 167.8, 162.2, 157.7, 133.9, 132.6, 123.5, 101.8, 91.2, 56.1, 55.6.

1-*N*-phthalimido-2,4,6-trichlorobenzene (10):



10

General procedure **C** was followed using 1,3,5-trichlorobenzene (2.5 mmol, 454 mg) as the arene substrate. After 24 h, the volatiles were evaporated *in vacuo* and the crude mixture was purified by column chromatography to give **10** as a white solid.

Isolated Yield: 42% (34 mg)

R_f: 0.65 (30% EtOAc/70% Hexanes)

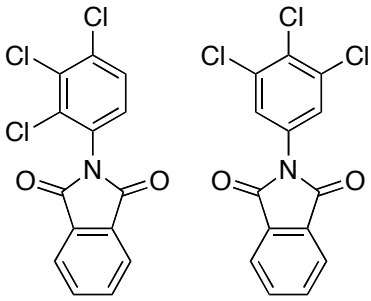
IR (υ, cm^{-1}): 3085, 2926, 1723, 1555, 1466, 1364, 1224, 1100, 872, 788, 714.

mp: 146-147 °C

HRMS: EI (m/z): M^+ calcd for $C_{14}H_6Cl_3NO_2$: 324.9464; found: 324.9464.

NMR: ^1H ($CDCl_3$, 700 MHz): δ 8.00-7.98 (m, 2H), 7.85-7.82 (m, 2H), 7.51 (s, 2H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): 165.6, 136.6, 136.3, 134.9, 131.9, 128.9, 127.2, 124.4.

***N*-(1,2,3-trichlorobenzene)phthalimide (11):**



11a **11b**

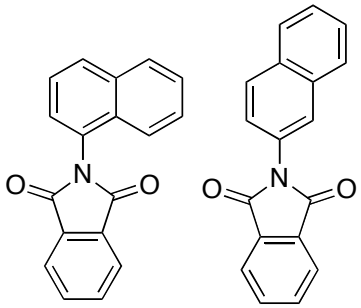
General procedure **C** was followed using 1,2,3-trichlorobenzene (2.5 mmol, 454 mg) as the arene substrate. After 24 h, the volatiles were evaporated *in vacuo* and the crude mixture was purified by column chromatography to give to give **11a** and **11b** as white solids (57% total yield; 5.4: 1). The regioisomeric ratio was determined by the amount of **11a** and **11b** separated by column chromatography.

11a: Isolated yield: 48% (39 mg, mp = 154-155 °C); R_f: 0.47 (30% Ethyl Acetate, 70% hexanes). MP: 176-177 °C. ^1H NMR ($CDCl_3$, 700 MHz): δ 7.98 (dd, J = 5.6, 2.8 Hz, 2H), 7.83 (dd, J = 5.6, 2.8 Hz, 2H), 7.54 (d, J = 8.4 Hz, 1H), 7.24 (d, J = 8.4 Hz, 1H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 166.3, 135.7, 134.9, 134.2, 133.4, 131.8, 129.9, 128.9, 128.8, 124.3. IR (υ, cm^{-1}): 1716, 1451,

1373, 1097, 881, 823, 791, 709. HRMS: EI (m/z): M^+ calcd for $C_{14}H_6Cl_3NO_2$: 324.9464; found: 324.9464.

11b: Isolated yield: 9% (7 mg, mp = 190-193 ºC); R_f: 0.50 (30% Ethyl Acetate, 70% Hexane). MP: 207-209 °C. ^{1}H NMR ($CDCl_3$, 700 MHz): δ 7.98 (dd, *J* = 5.6, 3.5 Hz, 2H), 7.83 (dd, *J* = 5.6, 3.5 Hz, 2H) 7.62 (s, 2H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 166.4, 135.1, 134.6, 131.3, 131.2, 131.0, 126.4, 124.3. IR (υ, cm^{-1}): 1719, 1589, 1555, 1439, 1376, 1227, 1163, 1095, 1081, 857, 787, 709. HRMS: EI (m/z): M^+ calcd for $C_{14}H_6Cl_3NO_2$: 324.9464; found: 324.9461.

N-Phthalimidonaphthalene (12):[5]



12a **12b**

General procedure **C** was followed using naphthalene (2.5 mmol, 320 mg) as the arene substrate. After 24 h, the reaction was diluted with EtOAc, and triethylamine (1 mL) was added to quench trifluoroacetic acid. The reaction mixture was concentrated *in vacuo*, and the residue was purified via column chromatography. The crude product was dissolved in EtOAc (~10 mL) and washed with 2M NaOH (3 x 10 mL). The organic layer was dried over Na_2SO_4, and the volatiles were evaporated *in vacuo* to give a mixture of **12a** and **12b** as a white solid. The structures of **12a** and **12b** were confirmed by synthesis of authentic samples (using general proceuure **E**) and isomer ratios were determined by ^{1}H NMR spectroscopy

Crude ratio: 7.1 : 1.0 (GC)

Isolated Yield: 79% (54 mg, 4.6 : 1 by ^{1}H NMR)

R_f (isolated mixture of isomers): 0.41 (25% EtOAc/75% hexanes)

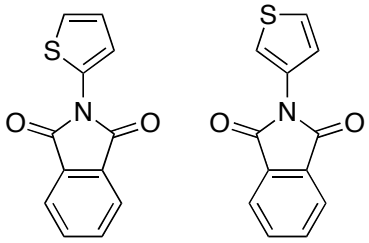
IR (υ, cm^{-1}); (isolated mixture of isomers): 1707, 1540, 1466, 1401, 1374, 1108, 1084, 774

HRMS; (isolated mixture of isomers): ESI$^+$ (m/z) $[M+H]^+$ calcd for $C_{18}H_{12}NO_2$: 274.0863; found: 274.0860

12a: ^{1}H NMR ($CDCl_3$, 700 MHz): δ 8.03-8.02 (m, 2H), 8.00 (d, *J* = 8.4 Hz, 1H), 7.96 (d, *J* = 8.4 Hz, 1H), 7.85-7.84 (m, 2H), 7.63-7.59 (m, 2H), 7.55-7.47 (multiple peaks, 3H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 167.9, 134.6, 134.6, 132.2, 130.4, 130.1, 129.7, 128.3, 127.3, 127.1, 126.7, 125.6, 124.1, 122.6.

12b: ^{1}H NMR ($CDCl_3$, 700 MHz): δ 8.00-7.98 (multiple peaks, 3H), 7.95 (d, *J* = 1.4 Hz, 1H), 7.91-7.89 (m, 2H), 7.83-7.80 (m, 2H), 7.56-7.52 (multiple peaks, 3H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 167.6, 134.6, 133.4, 132.7, 131.9, 129.2, 129.1, 128.4, 127.9, 126.8, 126.7, 125.7, 124.3, 123.9

N-Phthalimidothiophene (13):



13a **13b**

General procedure **C** was followed using thiophene (2.5 mmol, 210 mg, 0.20 mL) as the arene substrate. After 24 h, the volatiles were evaporated *in vacuo* and the crude mixture was purified by column chromatography to give a mixture of **13a** and **13b** as a yellow solid. The structure of **13a** was confirmed by synthesis of an authentic sample from commercially available 2-nitrothiophene (85% pure, 15% 3-nitrothiophene), phthalic anhydride, and iron powder following literature procedure.[7] The isolated authentic product mixture contained the same ratio of isomers (85:15) as the starting material nitrothiophene.

Isolated Yield: 69% (40 mg, 4.6 : 1)

R_f; (isolated mixture of isomers): 0.50 (30% EtOAc/70% Hexanes)

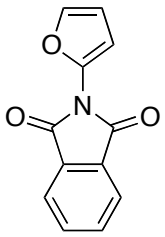
IR (υ, cm^{-1}); (isolated mixture of isomers): 3114, 2921, 1710, 1529, 1446, 1375, 1323,1243, 1108, 1061, 882, 779, 677

mp (isolated mixture of isomers): 162-164 °C

HRMS (isolated mixture of isomers): ESI^+ (m/z) $[M+H]^+$ calcd for $C_{12}H_8NO_2S$: 230.0270; found: 230.0265.

13a: ^1H NMR ($CDCl_3$, 700 MHz): δ 7.95-7.93 (m, 2H), 7.78-7.77 (m, 2H), 7.53 (dd, J = 5.2, 1.4 Hz, 1H), 7.22 (dd, J = 5.5, 1.4 Hz, 1H), 7.06 (dd, J = 5.5, 3.8 Hz, 1H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 166.1, 134.8, 132.4, 131.5, 125.4, 124.0, 122.0, 120.5.

2-*N*-Phthalimidofuran (14):



14

General procedure **C** was followed using furan (2.5 mmol, 170 mg, 0.18 mL) as the arene substrate. After 24 h, the volatiles were evaporated *in vacuo* and the crude mixture was purified by column chromatography to give **14** as a white solid.

Isolated Yield: 51% (27 mg)

R_f: 0.57 (25% EtOAc/75% hexanes)

IR (υ, cm^{-1}): 1728, 1603, 1497, 1388, 1222, 1152, 1082, 882, 713.

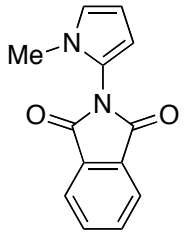
mp: 162-164 °C

HRMS: ESI^+ (m/z) $[M+H]^+$ calcd for $C_{12}H_8NO_3$: 214.0499; found: 214.0489

NMR: ^1H NMR ($CDCl_3$, 700 MHz): δ 7.99-7.96 (m, 2H), 7.83-7.80 (m, 2H), 7.47 (dd, *J* = 1.4, 2.1 Hz, 1H), 6.55 (dd, *J* = 2.1, 3.5 Hz, 1H), 6.46 (dd, *J* = 1.4, 3.5 Hz, 1H) ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 166.3, 141.8, 138.0, 134.9, 131.7, 124.3, 111.6, 106.8.

1-methyl-2-*N*-phthalimidopyrrole (15):

General procedure **C** was followed using N-methylpyrrole (2.5 mmol, 203 mg, 0.22 mL) as the arene substrate. After 24 h, the volatiles were evaporated *in vacuo* and the crude mixture was purified by column chromatography to give **15** as a white solid.



15

Isolated Yield: 51% (28 mg)

R_f: 0.35 (30% EtOAc/70% hexanes)

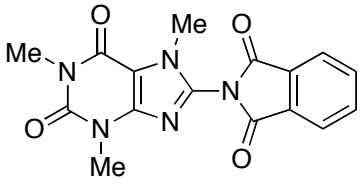
IR (υ, cm^{-1}): 2162, 1718, 1553, 1496, 1369, 1291, 1237, 1080, 880, 798, 697

mp: 172-173 °C

HRMS: ESI^+ (m/z): $[M+H]^+$ calcd for $C_{13}H_{11}N_2O_2$: 227.0815; found: 227.0815

NMR: ^1H ($CDCl_3$, 400 MHz): δ 7.99-7.95 (m, 2H), 7.84-7.79 (m, 2H), 6.72 (dd, *J* = 2.8, 2.1 Hz, 1H), 6.24 (dd, *J* = 4.2, 2.8 Hz, 1H), 6.20 (dd, *J* = 4.2, 2.1 Hz, 1H), 3.48 (s, 3H). ^{13}C NMR ($CDCl_3$, 175.9 MHz): δ 167.8, 134.7, 131.9, 124.1, 122.3, 118.7, 107.7, 107.7, 33.4.

8-(*N*-phthalimido)caffeine (16):



16

General procedure **C** was followed using caffeine (2.5 mmol, 486 mg) as the arene substrate. After 24 h, the reaction was diluted with EtOAc, and triethylamine (1 mL) was added to quench trifluoroacetic acid. The reaction mixture was concentrated *in vacuo*, and the residue was purified via column chromatography. The crude product was recrystallized from $CHCl_3/Et_2O$ to give **16** as a white solid.

Isolated Yield: 45% (38 mg)

R_f: 0.44 (100% Et_2O)

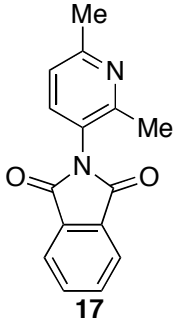
IR (υ, cm^{-1}): 1734, 1706, 1654, 1506, 1445, 1221, 1055, 1033, 879, 717.

mp: 228-229 °C

HRMS: ESI^+ (m/z) $[M+H]^+$ calcd for $C_{16}H_{14}N_5O_4$: 340.1040; found: 340.1033.

NMR: ^1H NMR ($CDCl_3$, 700 MHz): δ 8.02 (dd, *J* = 5.6, 2.8 Hz, 2H), 7.89 (dd, *J* = 5.6, 2.8 Hz, 2H), 3.90 (s, 3H), 3.59 (s, 3H), 3.44 (s, 3H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 165.6, 153.4, 151.6, 147.0, 137.1, 135.6, 131.6, 124.9, 108.3, 32.5, 30.1, 28.2.

2,6-dimethyl-3-(*N*-phthalimido)pyridine (17):



17

General procedure **C** was followed using 2,6-dimethylpyridine (2.5 mmol, 268 mg, 0.29 mL) as the arene substrate. After 24 h, the reaction was diluted with EtOAc, and triethylamine (1 mL) was added to quench trifluoroacetic acid. The volatiles were evaporated *in vacuo* and the crude mixture was purified by column chromatography to give **17** as a light brown solid.

Isolated Yield: 71% (34 mg)

R_f: 0.33 (20% NEt_3/20% EtOAc/60% hexanes)

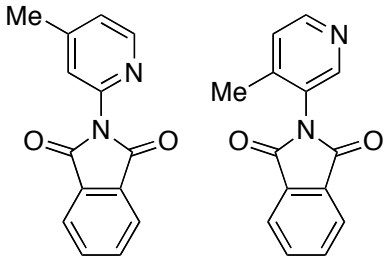
IR (υ, cm^{-1}): 2922, 2851, 1723, 1578, 1464, 1373, 1226, 1106, 885, 720

mp: 160-161 °C

HRMS: ESI$^+$ (m/z) $[M+H]^+$ calcd for $C_{15}H_{13}N_2O_2$: 253.0972; found: 253.0970

NMR: ^{1}H NMR ($CDCl_3$, 700 MHz): δ 7.96 (dd, *J* = 5.6, 3.5 Hz, 2H), 7.81 (dd, *J* = 5.6, 3.5 Hz, 2H), 7.41 (d, *J* = 8.4 Hz, 1H), 7.14 (d, *J* = 8.4 Hz, 1H), 2.60 (s, 3H), 2.41 (s, 3H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 167.1, 159.2, 156.1, 136.8, 134.7, 132.1, 124.4, 124.1, 121.6, 24.5, 21.4.

N-Phthalimido-4-picoline (18):



18a **18b**

General procedure **C** was followed using 4-methylpyridine (2.5 mmol, 233 mg, 0.24 mL) as the arene substrate. After 24 h, the reaction was diluted with EtOAc, and triethylamine (1 mL) was added to quench trifluoroacetic acid. The reaction mixture was concentrated *in vacuo* and the residue was purified via column chromatography to give a mixture of **18a** and **18b** as a light brown solid. The structures of **18a** and **18b** were confirmed by synthesis of authentic samples (using general procedure **E**) and isomer ratios were determined by ^{1}H NMR spectroscopy.

Crude ratio: 1.0 : 7.2 (GC)

Isolated Yield: 57% (34 mg; 1: >20 ^{1}H NMR)

R_f (isolated mixture of isomers): 0.26 (20% NEt_3/20% EtOAc/60% hexanes)

IR (υ, cm^{-1}) (isolated mixture of isomers): 2924, 1709, 1598, 1502, 1422, 1378, 1240, 1080, 843, 708

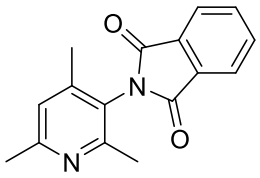
mp (isolated mixture of isomers): 147-149 °C

HRMS (isolated mixture of isomers): : ESI$^+$ (m/z): $[M+H]^+$ calcd for $C_{14}H_{11}N_2O_2$: 239.0815; found: 239.0820.

18a: ^{1}H NMR ($CDCl_3$, 700 MHz): δ 8.54 (d, *J* = 4.9 Hz, 1H), 7.98-7.96 (m, 2H), 7.81-7.79 (m, 2H), 7.25 (s, 1H), 7.19 (d, *J* = 4.9 Hz, 1H), 2.45 (s, 3H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 166.9, 150.1, 149.4, 146.2, 134.7, 131.9, 124.7, 124.1, 123.0, 21.2. mp: 145-146 °C

18b: ^{1}H NMR ($CDCl_3$, 700 MHz): δ 8.55 (d, *J* = 4.9 Hz, 1H), 8.44 (s, 1H), 7.99-7.96 (m, 2H), 7.84-7.82 (m, 2H), 7.31 (d, *J* = 4.9 Hz, 1H), 2.25 (s, 3H) ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 167.1, 150.2, 149.6, 146.1, 134.8, 132.0, 128.2, 125.9, 124.2, 18.0. mp: 147-148 °C

2,4,6-trimethyl-3-(*N*-phthalimido)pyridine (19):



General procedure **C** was followed using 2,4,6-trimethylpyridine (2.5 mmol, 302 mg, 0.33 mL) as the arene substrate. After 24 h, the reaction was diluted with EtOAc, and triethylamine (1 mL) was added to quench trifluoroacetic acid. The reaction mixture was concentrated *in vacuo* and the residue was purified via column chromatography to give **19** as a white solid.

Isolated Yield: 66% (44 mg)

R_f: 0.45 (20% NEt_3/20% EtOAc/60% hexanes)

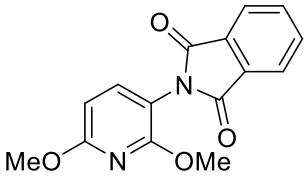
IR (υ, cm^{-1}): 2925, 2361, 1723, 1603, 1466, 1373, 1112, 866, 716

mp: 112-113 °C

HRMS: ESI^+ (m/z) $[M+H]^+$ calcd for $C_{16}H_{14}N_2O_2$: 267.1128; found: 267.1132

NMR: ^1H NMR ($CDCl_3$, 700 MHz): δ 7.97-7.95 (m, 2H), 7.83-7.80 (m, 2H), 7.00 (s, 1H), 2.53 (s, 3H), 2.35 (s, 3H), 2.12 (s, 3H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 167.0, 158.8, 156.3, 146.4, 134.7, 132.0, 124.1, 124.0, 123.3, 24.3, 21.1, 17.8.

2,6-dimethoxy-3-(*N*-phthalimido)pyridine (20):



General procedure **C** was followed using 2,6-dimethoxypyridine (2.5 mmol, 348 mg, 0.33 mL) as the arene substrate. After 24 h, the reaction was diluted with EtOAc, and triethylamine (1 mL) was added to quench trifluoroacetic acid. The reaction mixture was concentrated *in vacuo* and the residue was purified via column chromatography. The crude product was dissolved in DCM (~15 mL) and washed with 1M NaOH (3 x 6 mL). The organic layer was dried over Na_2SO_4, and the volatiles were evaporated *in vacuo* to give **20** as a white solid.

Isolated Yield: 79% (56 mg)

R_f: 0.63 (20% NEt_3/20% EtOAc/60% hexanes)

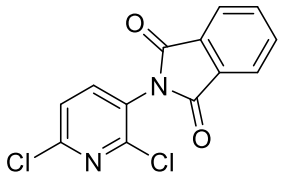
IR (υ, cm^{-1}): 2952, 2361, 1732, 1705, 1586, 1392, 1315, 1084, 1008, 880, 721

mp: 159-160 °C

HRMS: ESI$^+$ (m/z) $[M+H]^+$ calcd for $C_{15}H_{12}N_2O_4$: 285.0870; found: 285.0860

NMR: ^{1}H NMR ($CDCl_3$, 700 MHz): δ 7.95-7.92 (m, 2H), 7.79-7.77 (m, 2H), 7.45 (d, *J* = 8.4 Hz, 1H), 6.43 (d, *J* = 8.4 Hz, 1H), 3.96 (s, 3H), 3.92 (s, 3H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 167.5, 163.4, 158.6, 141.0, 134.3, 132.3, 123.9, 106.6, 101.8, 54.1, 54.0.

2,6-dichloro-3-(*N*-phthalimido)pyridine (21):



A modification from general procedure **C** was followed using 2,6-dichloropyridine (5 mmol, 740 mg, 20 equiv) as the arene substrate and acetonitrile (1.25 mL, 0.2 M solution **1g**). After 24 h, the reaction was diluted with EtOAc, and triethylamine (1 mL) was added to quench trifluoroacetic acid. The reaction mixture was concentrated *in vacuo* and the residue was purified via column chromatography. The crude product was dissolved in DCM (~15 mL) and washed with 1M NaOH (3 x 6 mL). The organic layer was dried over Na_2SO_4, and the volatiles were evaporated *in vacuo* to give **21** as a light brown solid.

Isolated Yield: 51% (38 mg)

R_f: 0.36 (20% NEt_3/20% EtOAc/60% hexanes)

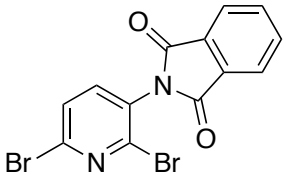
IR (υ, cm^{-1}): 2922, 2852, 1790, 1721, 1552, 1442, 1377, 1140, 1080, 826, 710

mp: 115-117 °C

HRMS: ESI$^+$ (m/z) $[M+H]^+$ calcd for $C_{13}H_6Cl_2N_2O_2$: 292.9879; found: 292.9879

NMR: ^{1}H NMR ($CDCl_3$, 700 MHz): δ 8.00-7.97 (m, 2H), 7.86-7.83 (m, 2H), 7.67 (d, *J* = 7.7 Hz, 1H), 7.45 (d, *J* = 7.7 Hz, 1H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 166.0, 151.0, 149.6, 141.4, 135.0, 131.8, 126.0, 124.4,124.0.

2,6-dibromo-3-(*N*-phthalimido)pyridine (22):



A modification from general procedure **C** was followed using 2,6-dibromopyridine (5 mmol, 1.18 g, 20 equiv) as the arene substrate and acetonitrile (1.25 mL, 0.2 M in **1g**). After 24 h, the

reaction was diluted with EtOAc, and triethylamine (1 mL) was added to quench trifluoroacetic acid. The reaction mixture was concentrated *in vacuo* and the residue was purified via column chromatography. The crude product was dissolved in DCM (~15 mL) and washed with 1M NaOH (3 x 6 mL). The organic layer was dried over Na_2SO_4, and the volatiles were evaporated *in vacuo* to give **22** as a light brown solid.

Isolated Yield: 32% (30 mg)

R_f: 0.36 (20% NEt_3/20% EtOAc/60% hexanes)

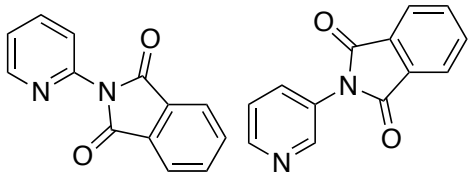
IR (υ, cm^{-1}): 2922, 2852, 1745, 1718, 1432, 1374, 1340, 1112, 1083, 855, 712

mp: 157-159 °C

HRMS: ESI^+ (m/z) $[M+H]^+$ calcd for $C_{13}H_6Br_2N_2O_2$: 380.8869; found: 380.8859

NMR: ^1H NMR ($CDCl_3$, 700 MHz): δ 8.00-7.98 (m, 2H), 7.86-7.83 (m, 2H), 7.62 (d, J = 7.7 Hz, 1H), 7.50 (d, J = 7.7 Hz, 1H). ^{13}C NMR ($CDCl_3$, 175.95 MHz): δ 166.0, 142.1, 141.2, 140.7, 135.1, 131.8, 129.0, 128.1, 124.4.

***N*-phthalimidopyridine (23):**



23a **23b**

A modification from general procedure **C** was followed using pyridine (5 mmol, 393 mg, 0.40 mL, 20 equiv) as the arene substrate and acetonitrile (1.25 mL, 0.2 M solution **1g**). After 24 h, the reaction was diluted with EtOAc, and triethylamine (1 mL) was added to quench trifluoroacetic acid. The reaction mixture was concentrated *in vacuo* and the residue was run through a plug of silica gel (~250 mL, 1:1:3 v/v, Et_3N:EtOAc:Hex). The crude mixture of products were dissolved in DCM (~15 mL) and washed with 1M NaOH (3 x 6 mL). The organic layer was dried over Na_2SO_4, and the volatiles were evaporated *in vacuo* to give a mixture of **23a** and **23b**. Isomer ratios were determined by ^1H NMR spectroscopy. The product mixture was separated via silica gel column chromatography to afford **23a** as a light yellow solid and **23b** as a white solid.

^1H NMR ratio (mixture of isolated products): 1 : 2

Isolated Yield (total of **23a** & **23b**) : 41% (23 mg)

23a:

R_f : 0.63 (50% DCM/50% Et_2O)

IR (υ, cm^{-1}): 2919, 2850, 1709, 1585, 1464, 1438, 1379, 1112, 1082, 882, 778, 711

mp: 201-203 °C

HRMS: ESI^+ (m/z) $[M+H]^+$ calcd for $C_{13}H_8N_2O_2$: 225.0659; found: 225.0659

NMR: ^1H NMR (CD_3CN, 700 MHz): δ 8.64 (dd, J = 2.1, 4.9 Hz, 1H), 7.98 (td, J = 2.1, 7.7Hz, 1H), 7.96-7.93 (m, 2H), 7.89-7.87 (m, 2H), 7.47-7.46 (m, 2H). ^{13}C NMR (CD_3CN, 175.95 MHz): δ 167.8, 150.5, 147.3, 139.5, 135.7, 132.9, 124.9, 124.5, 123.7.

23b:

R_f : 0.37 (50% DCM/50% Et_2O)

IR (υ, cm^{-1}): 2919, 2851, 1781, 1700, 1578, 1479, 1427, 1378, 1107, 879, 792, 708

mp: 155-156 °C

HRMS: ESI^+ (m/z) $[M+H]^+$ calcd for $C_{13}H_8N_2O_2$: 225.0659; found: 225.0662

NMR: ^1H NMR (CD_3CN, 700 MHz): δ 8.70 (br s, 1H), 8.63 (br s, 1H), 7.97-7.95 (m, 2H), 7.90-7.85 (m, 3H), 7.53 (dd, J = 4.9, 8.4 Hz, 1H). ^{13}C NMR (CD_3CN, 175.95 MHz): δ 168.0, 149.8, 148.7, 135.8, 135.2, 132.8, 130.1, 124.8, 124.5.

10. References:

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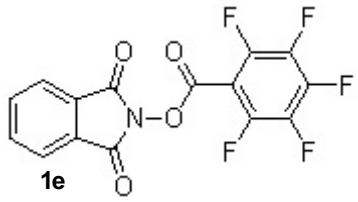
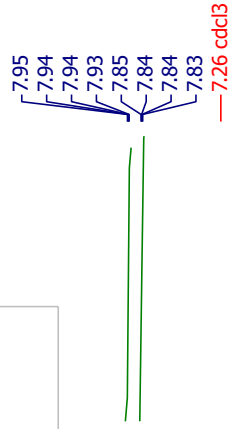
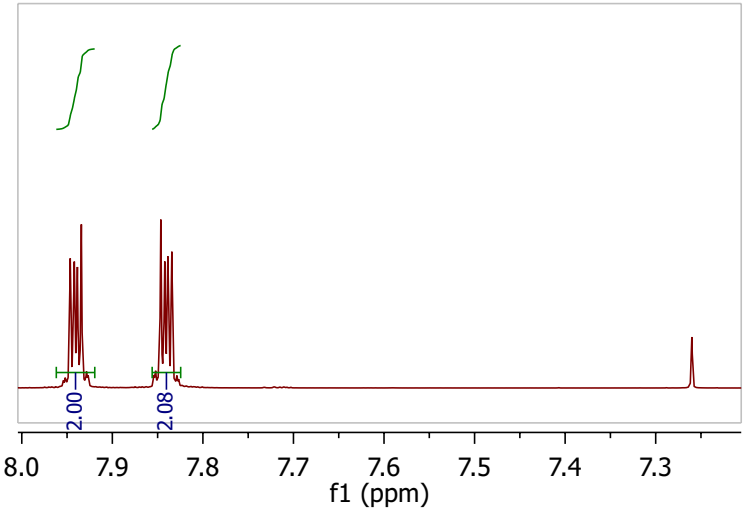
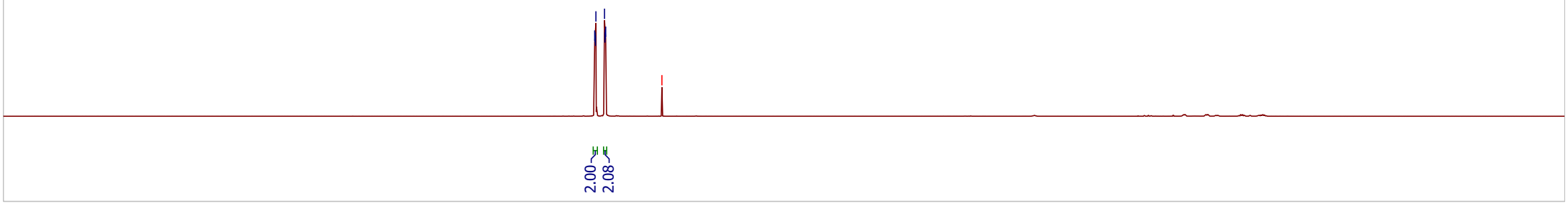
^{1}H NMR of **1e**



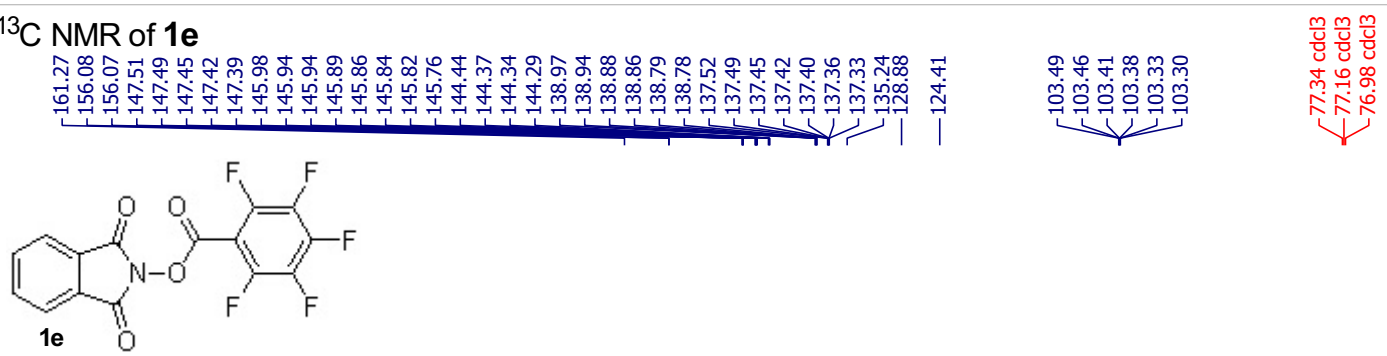
1e



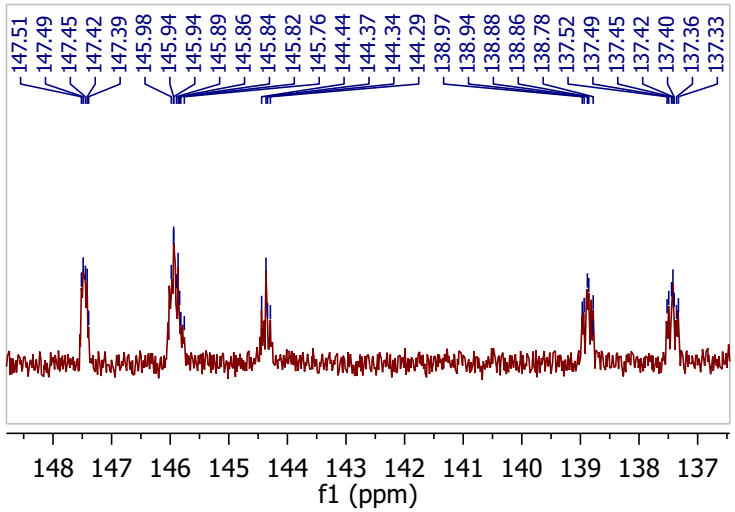


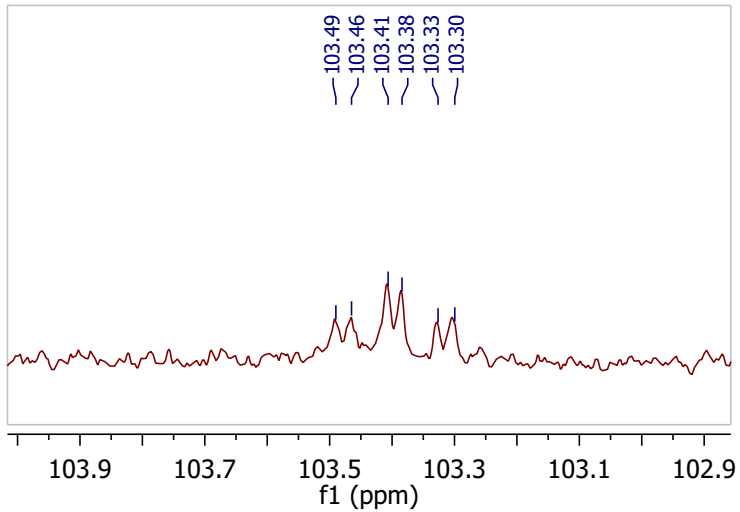


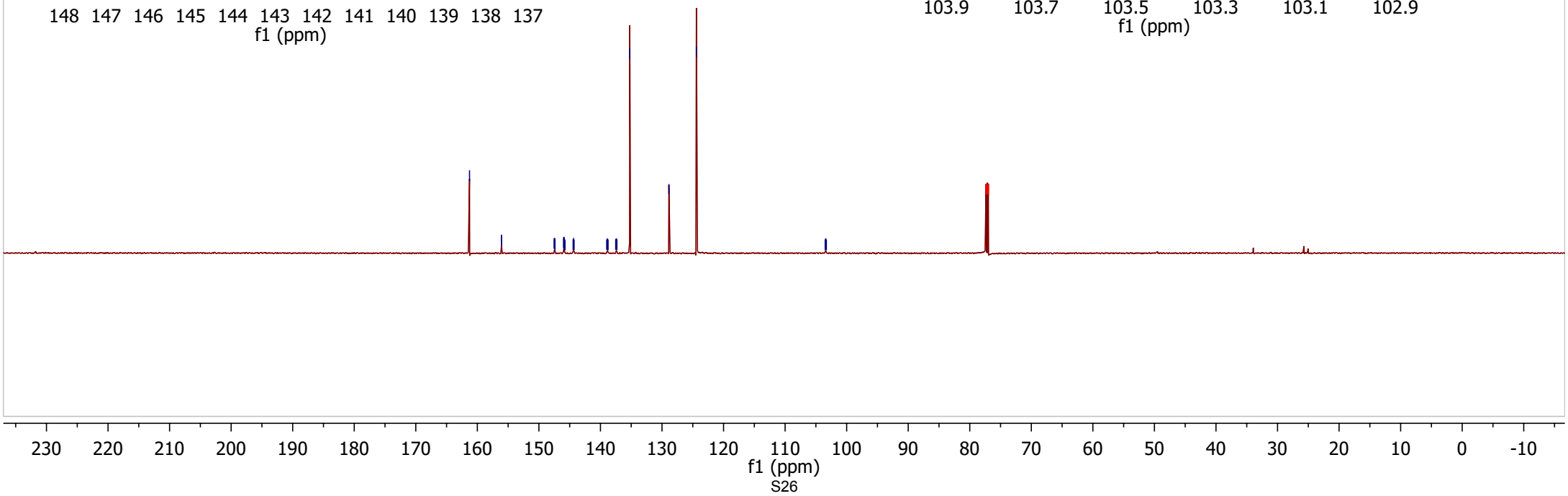
^{13}C NMR of **1e**



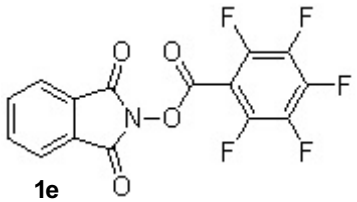
1e







^{19}F NMR of **1e**



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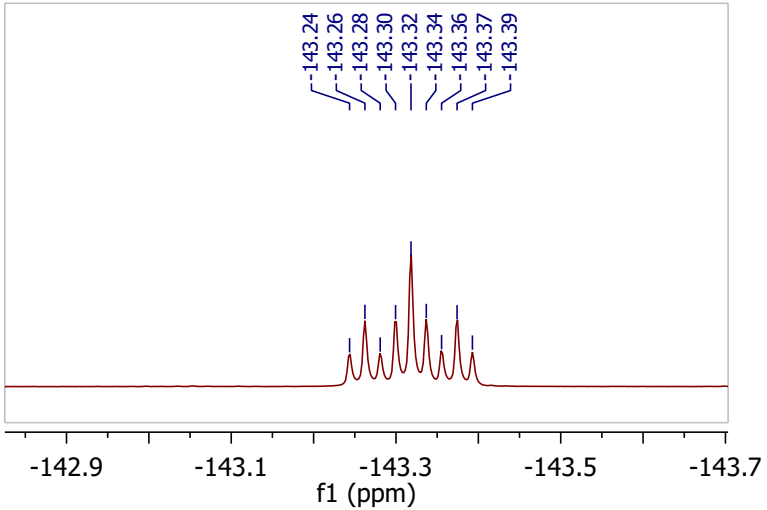
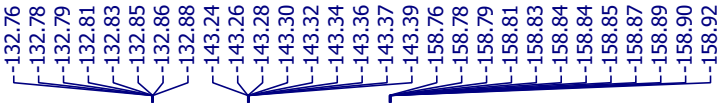
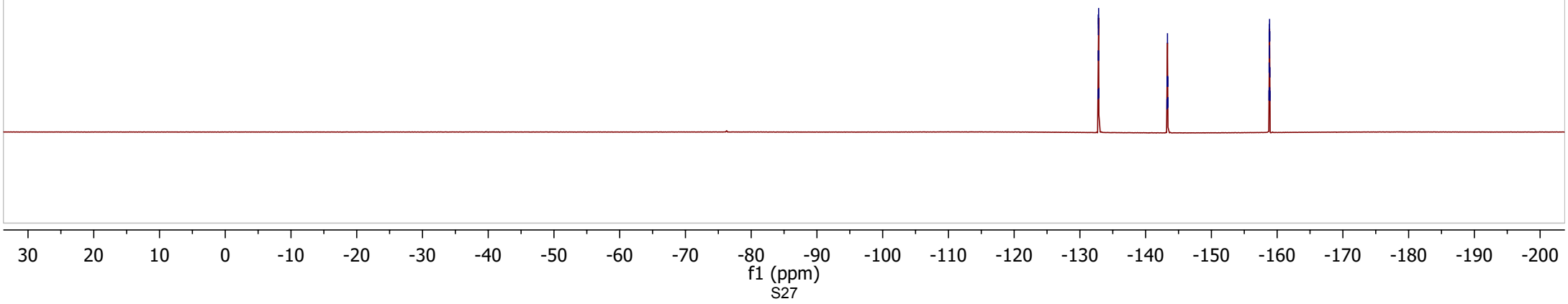
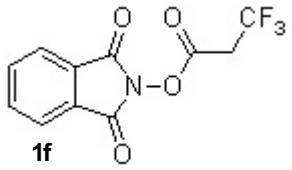


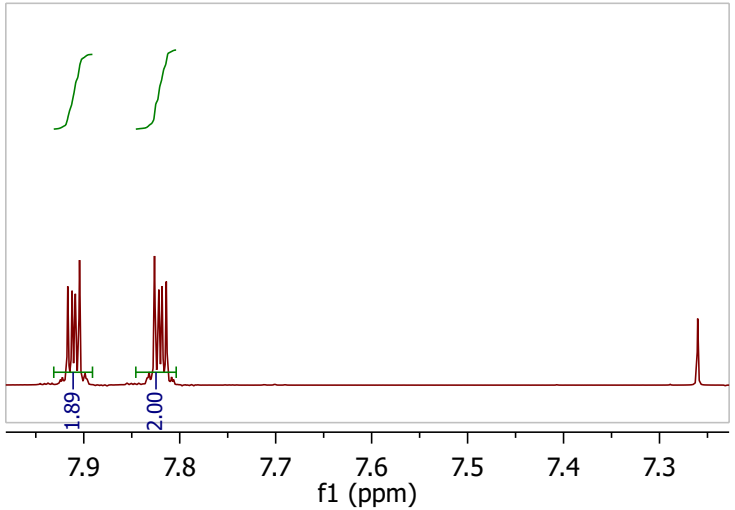




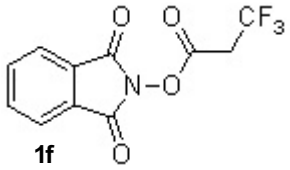
^{1}H NMR of **1f**



1f



^{13}C NMR of **1f**



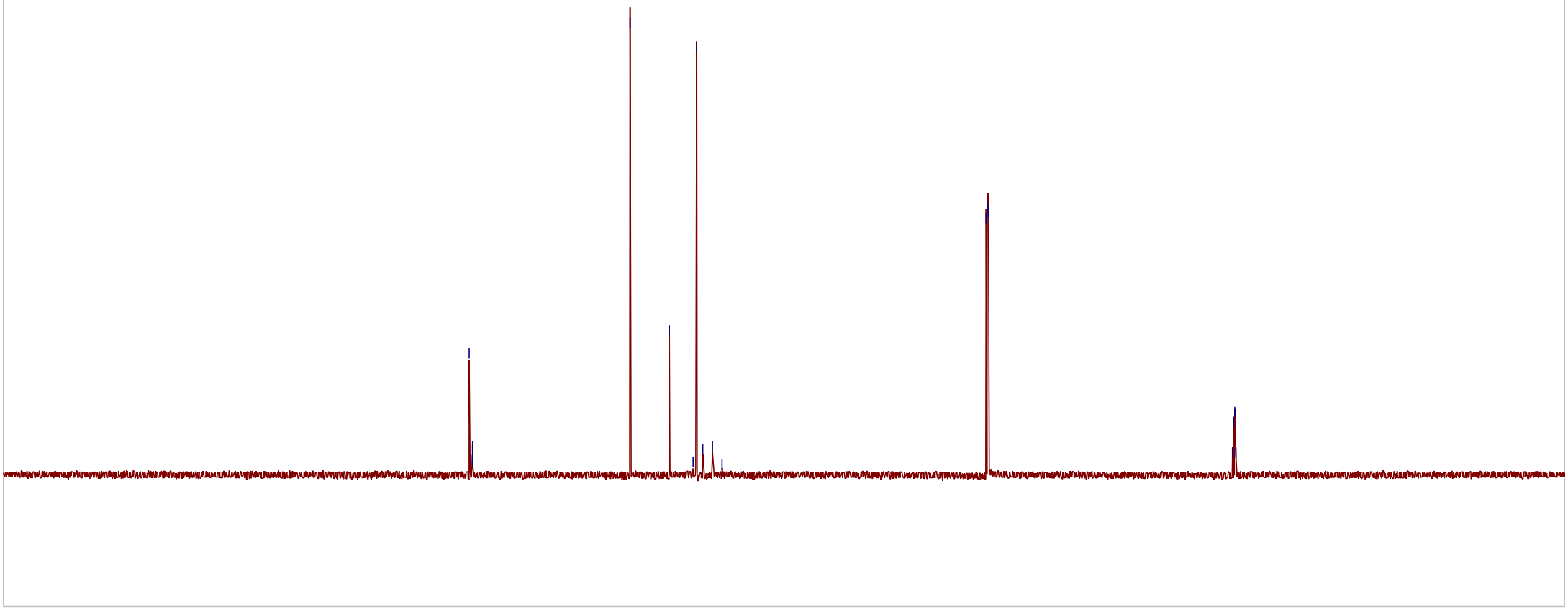
1f

161.33
160.82
160.79
160.77
160.74

135.19
128.81
124.95
124.36
123.38
121.80
120.25

77.34 cdcl3
77.16 cdcl3
76.98 cdcl3

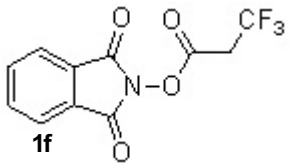
37.32
37.14
36.95
36.76



230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

f1 (ppm)

^{19}F NMR of **1f**



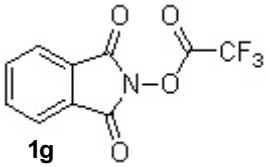
1f

-63.11
-63.14
-63.16

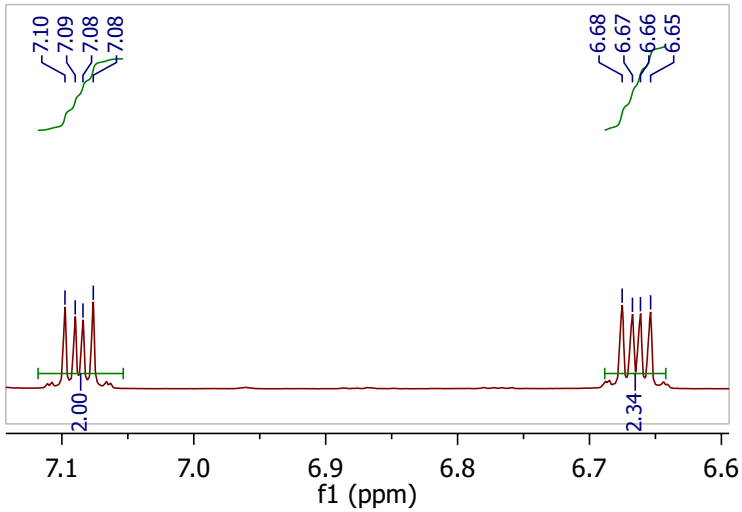
30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200

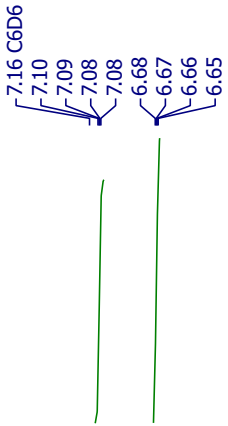
f1 (ppm)

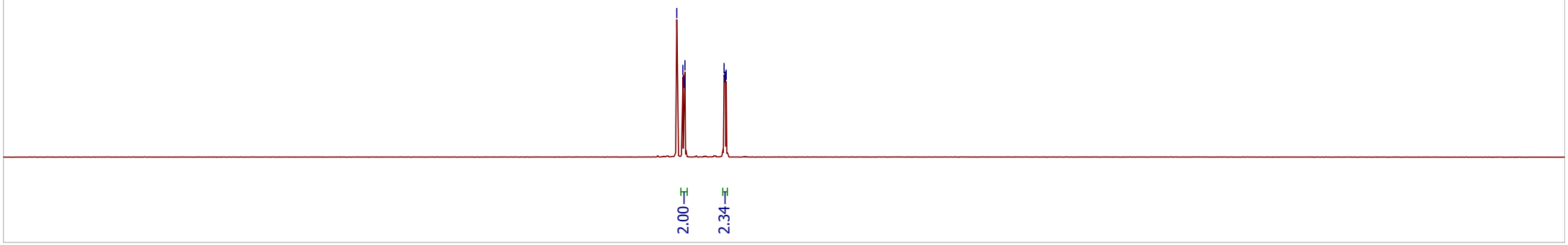
^{1}H NMR of **1g**

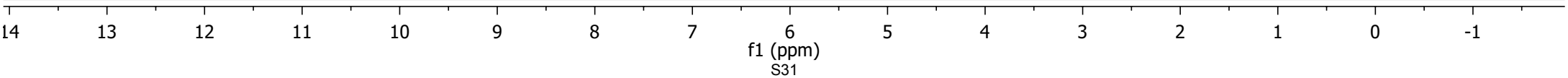


1g

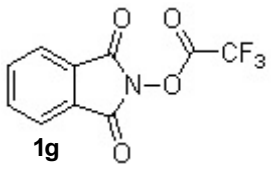






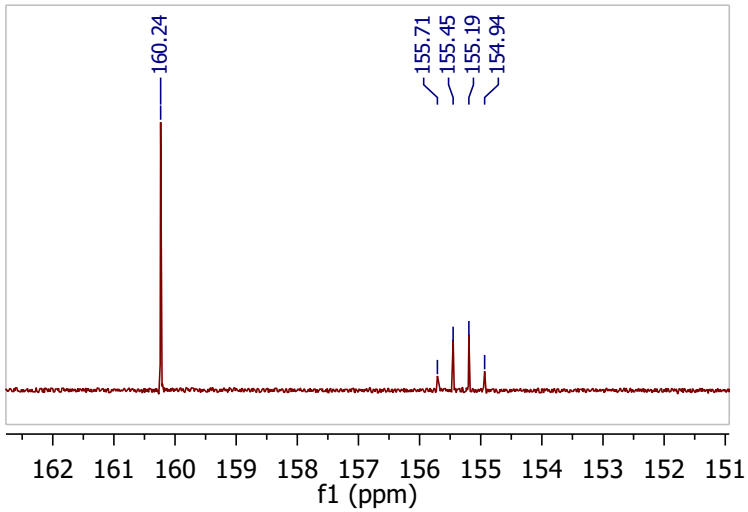


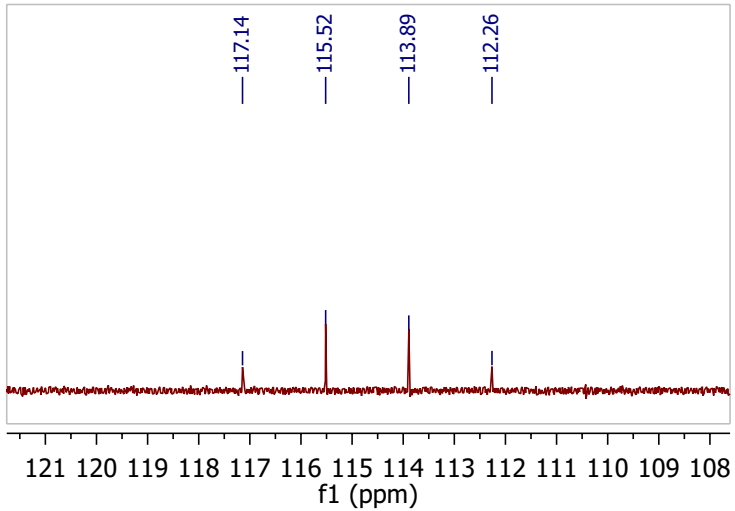
^{13}C NMR of **1g**



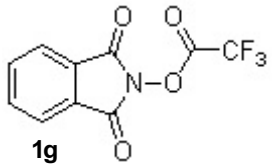
1g

160.24
155.71
155.45
155.19
154.94
134.61
128.50
128.20 c6d6
128.06 c6d6
127.92 c6d6
124.01
117.14
115.52
113.89
112.26



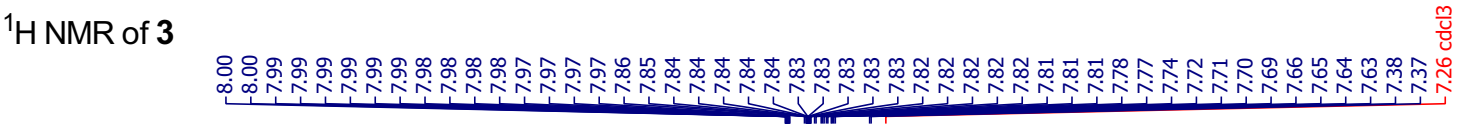


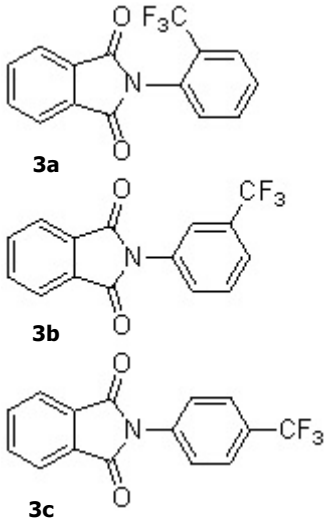
^{19}F NMR of **1g**

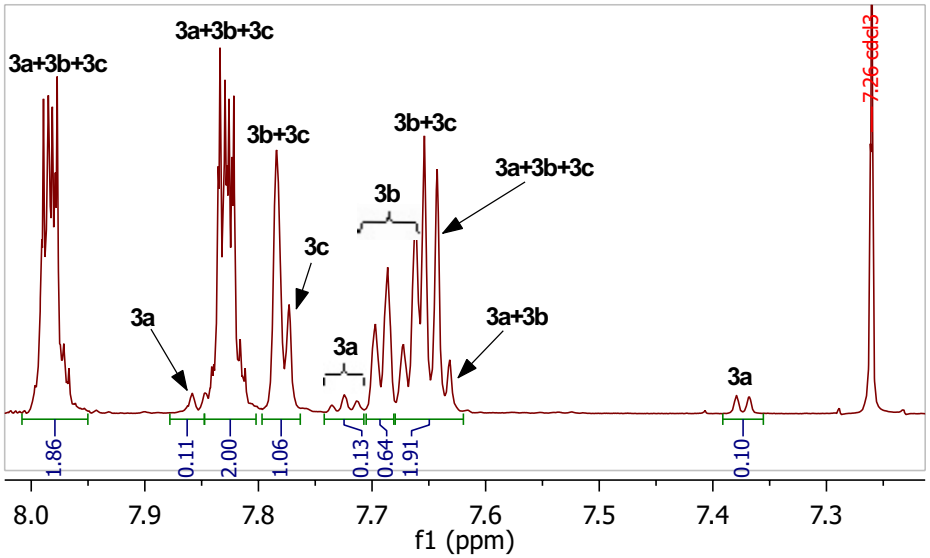


1g

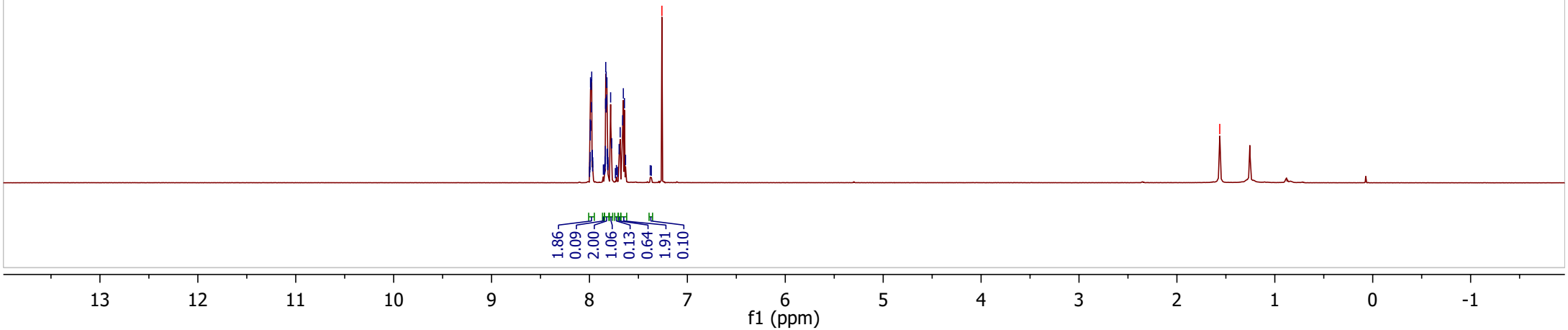
^{1}H NMR of **3**



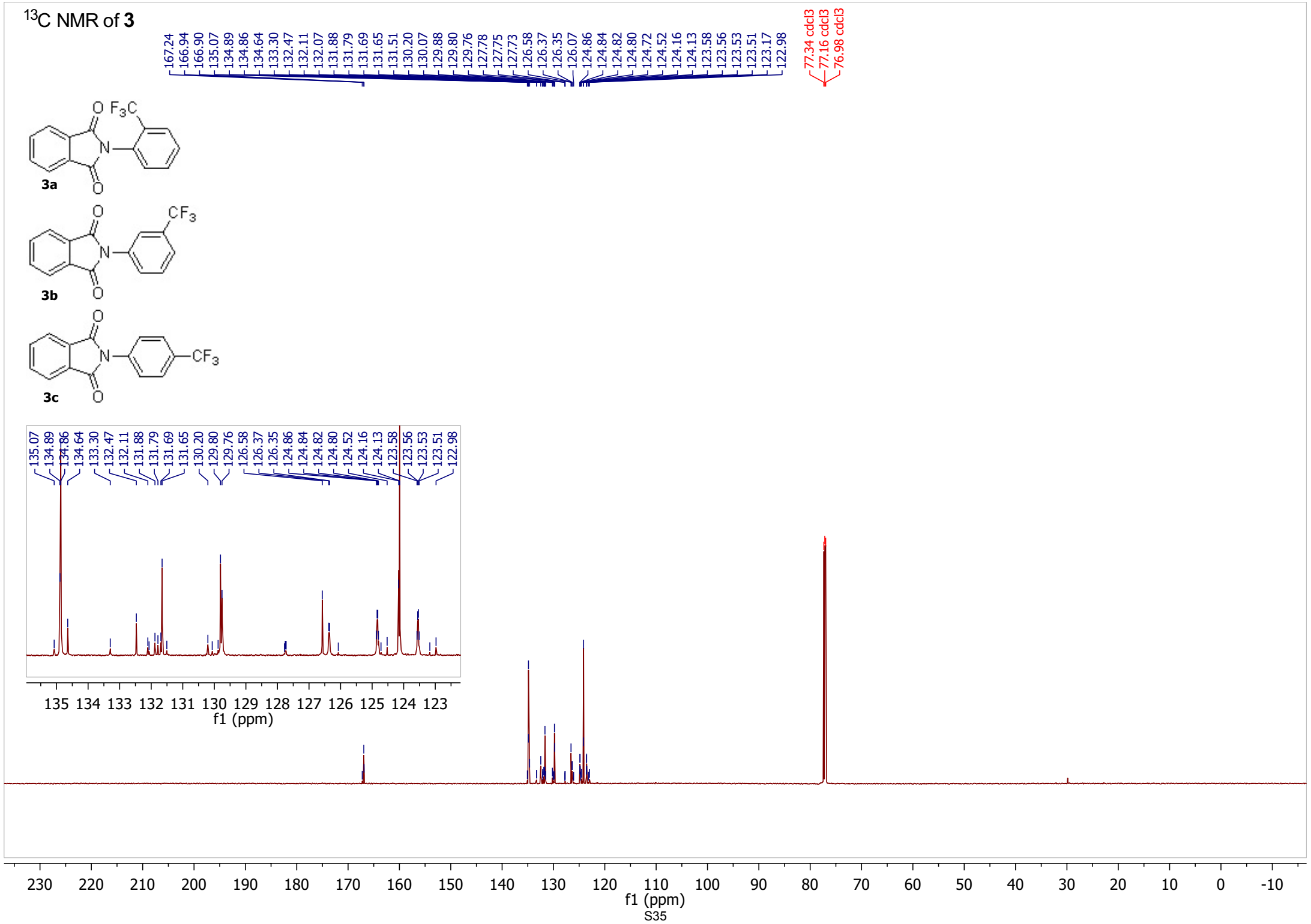




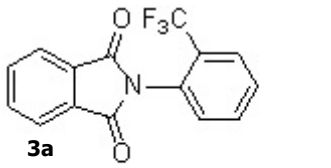
Isomeric ratio (det. by ^{19}F NMR)
3a:3b:3c = 1.0:8.4:2.8



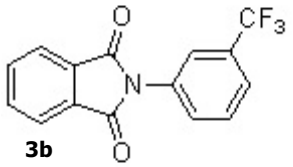
^{13}C NMR of **3**


167.24
166.94
166.90
135.07
134.89
134.86
134.64
133.30
132.47
132.11
132.07
131.88
131.79
131.69
131.65
131.51
130.20
130.07
129.88
129.80
129.76
127.78
127.75
127.73
126.58
126.37
126.35
126.07
124.86
124.84
124.82
124.80
124.72
124.52
124.16
124.13
123.58
123.56
123.53
123.51
123.17
122.98
77.34 cdcl3
77.16 cdcl3
76.98 cdcl3
O
F3C
N
O
3a
O
CF3
N
O
3b
O
N
CF3
O
3c
135 134 133 132 131 130 129 128 127 126 125 124 123
f1 (ppm)
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

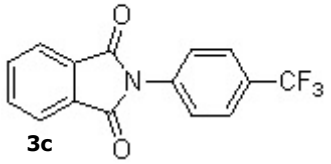
^{19}F NMR of **3**



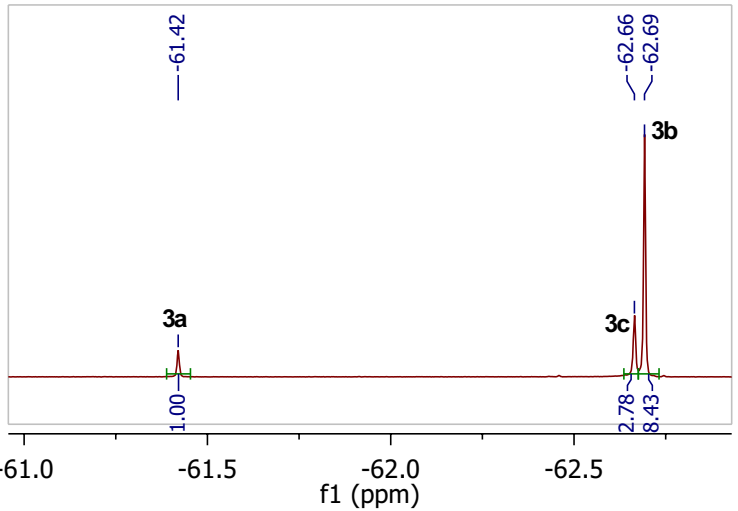
3a



3b



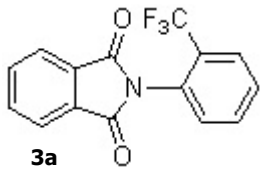
3c



Isomeric ratio

3a:3b:3c = 1.0:8.4:2.8

^{1}H NMR of **3a**



3a

7.970
7.968
7.963
7.958
7.955
7.951
7.945
7.943
7.846
7.835
7.816
7.814
7.808
7.804
7.800
7.796
7.791
7.789
7.722
7.711
7.700
7.637
7.626
7.615
7.584
7.376
7.365
7.260 cdcl3

1.905 HDO

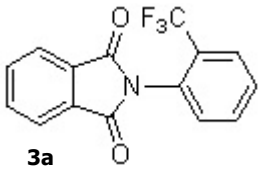
7.26 cdcl3

2.00
1.05
2.15
1.12
1.06
1.00

8.0 7.9 7.8 7.7 7.6 7.5 7.4 7.3
f1 (ppm)

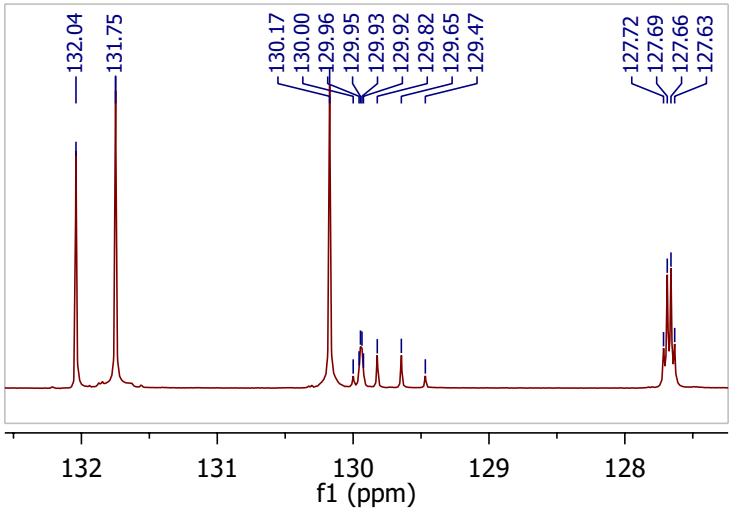
13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)

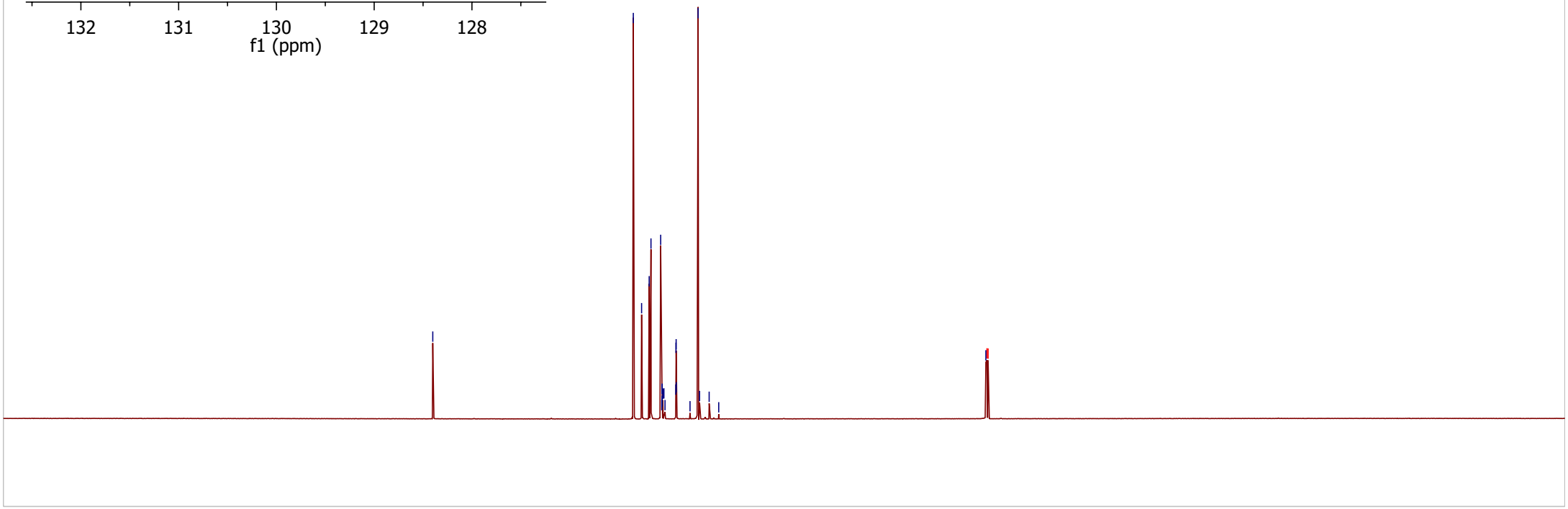
^{13}C NMR of **3a**



3a

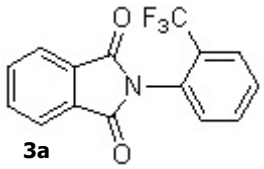
167.20
134.62
133.27
132.04
131.75
130.17
130.00
129.96
129.95
129.93
129.92
129.82
129.65
129.47
127.72
127.69
127.66
127.63
125.41
124.09
123.85
122.30
120.74
77.34
77.16 cdcl3
76.98 cdcl3





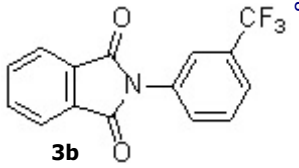
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

^{19}F NMR of **3a**



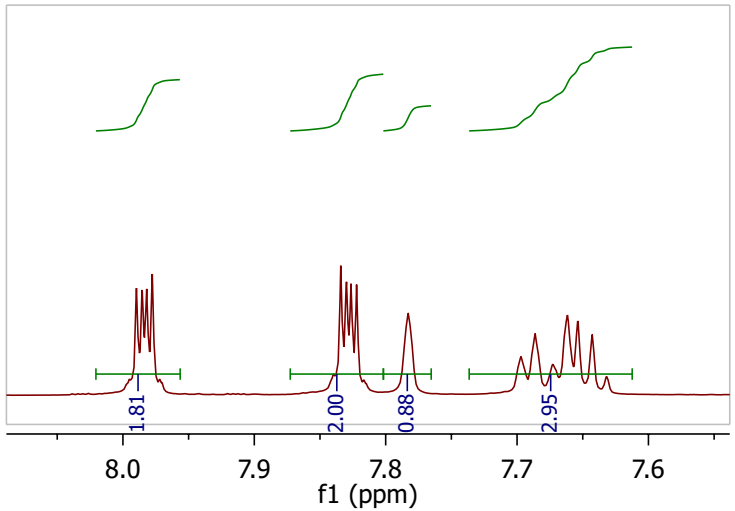
3a

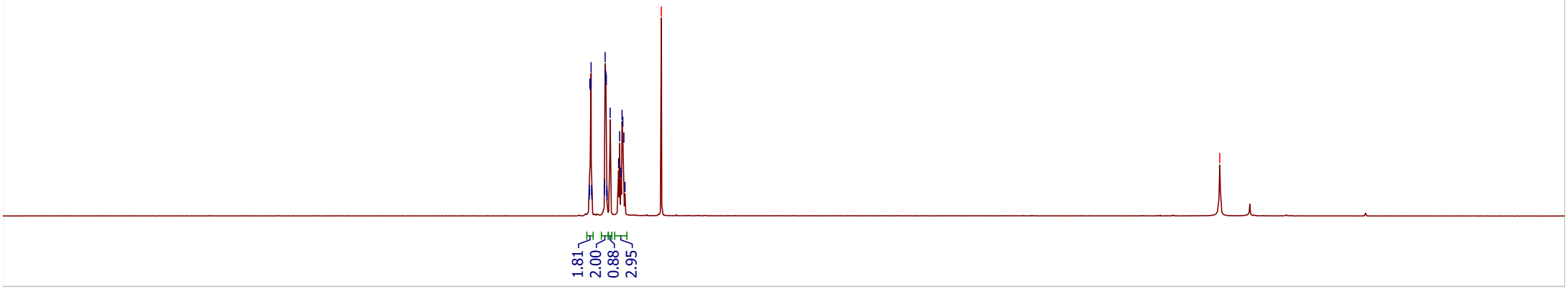
^{1}H NMR of **3b**



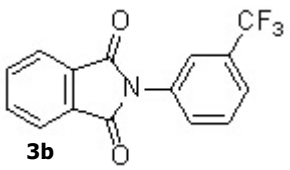
3b

8.00 7.99 7.99 7.99 7.98 7.98 7.97 7.97 7.84 7.84 7.83 7.83 7.83 7.82 7.82 7.81 7.78 7.70 7.69 7.67 7.66 7.65 7.64 7.63 — 7.26 cdcl3 — 1.56 HDO

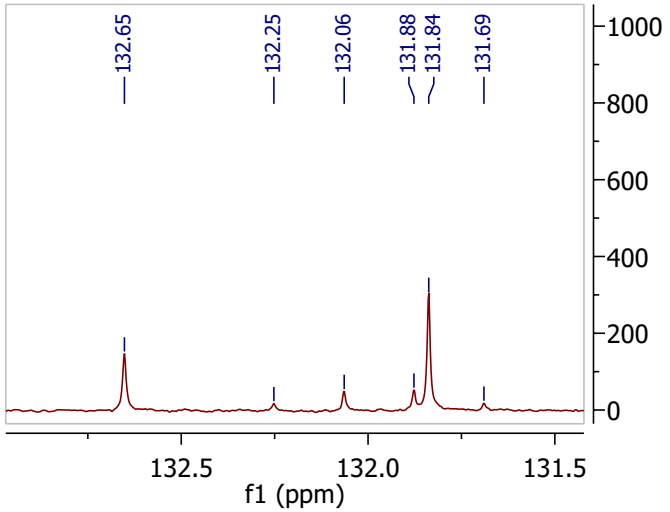


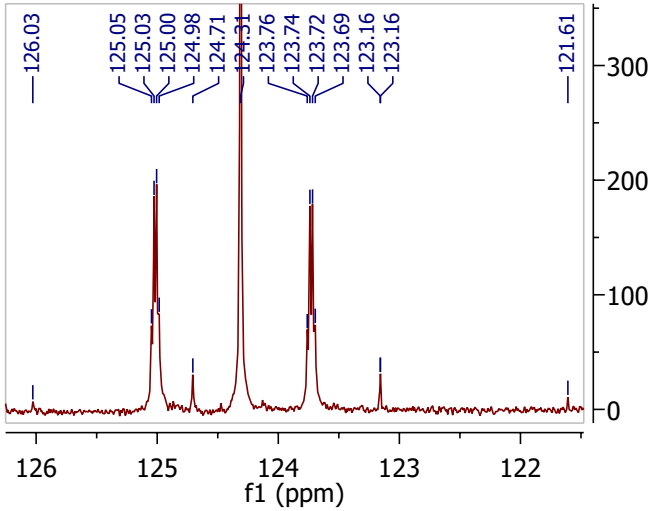


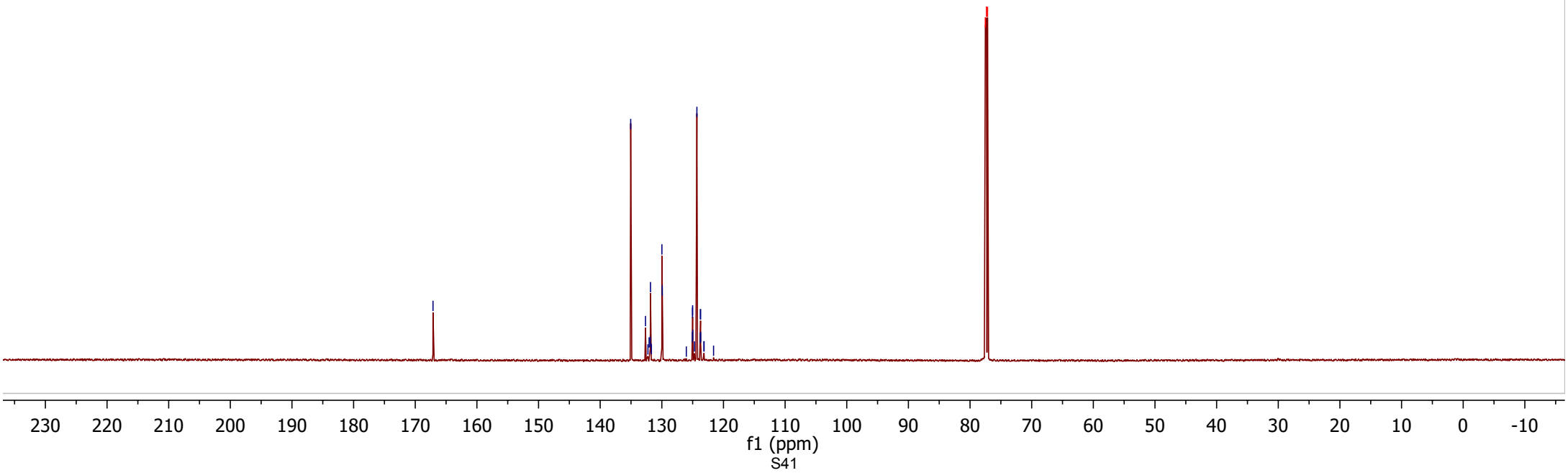
^{13}C NMR of **3b**



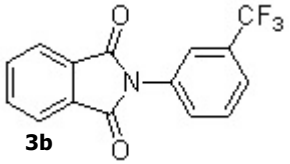
167.120
135.047
132.652
132.252
132.064
131.877
131.838
131.690
129.987
129.939
126.027
125.047
125.026
125.005
124.983
124.706
124.311
123.761
123.739
123.717
123.695
123.157
123.157
121.608
77.523 cdcl3
77.341 cdcl3
77.160 cdcl3





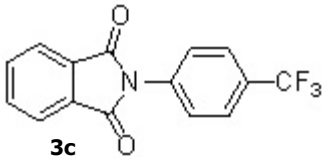


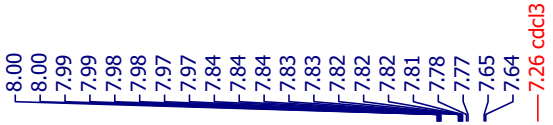
^{19}F NMR of **3b**



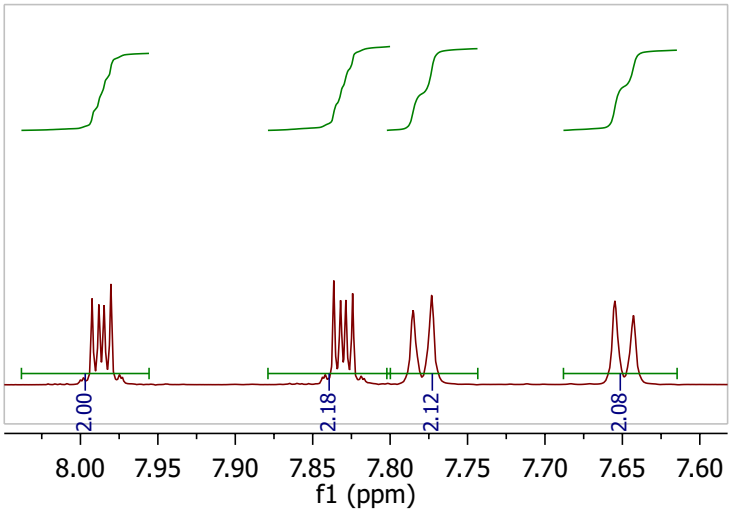
3b

^{1}H NMR of **3c**

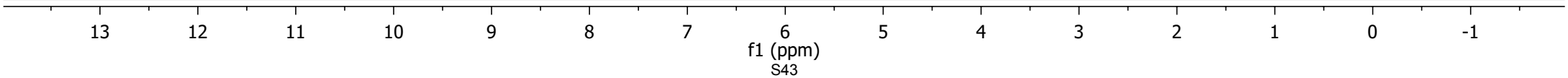

O
N
CF3
O
3c


8.00
8.00
7.99
7.99
7.98
7.98
7.97
7.97
7.84
7.84
7.84
7.83
7.83
7.82
7.82
7.82
7.81
7.78
7.77
7.65
7.64
7.26 cdcl3

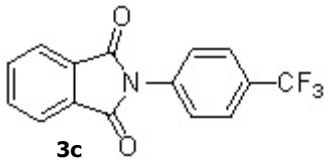

1.56 HDO
1.56 HDO


2.00
2.18
2.12
2.08
8.00
7.95
7.90
7.85
7.80
7.75
7.70
7.65
7.60
f1 (ppm)


2.00
2.18
2.12
2.08


13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
f1 (ppm)

^{13}C NMR of **3c**

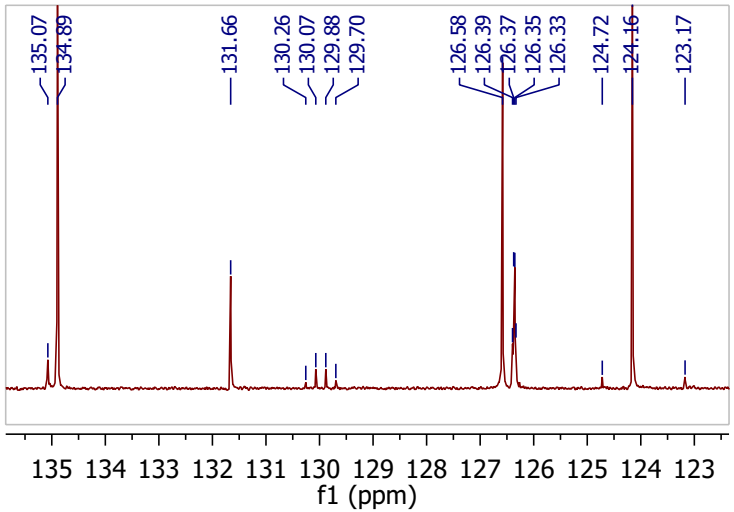


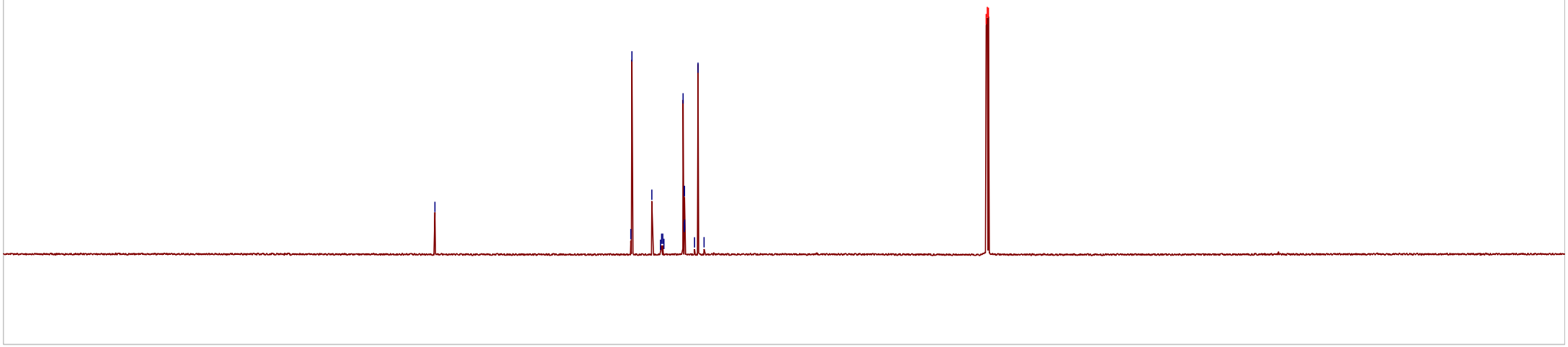
3c

166.898

135.073
134.894
131.659
130.257
130.070
129.883
129.695
126.581
126.395
126.374
126.352
126.331
124.719
124.156
123.173

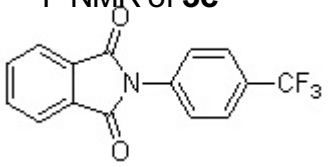
77.341 cdcl3
77.159 cdcl3
76.978 cdcl3





230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

^{19}F NMR of **3c**



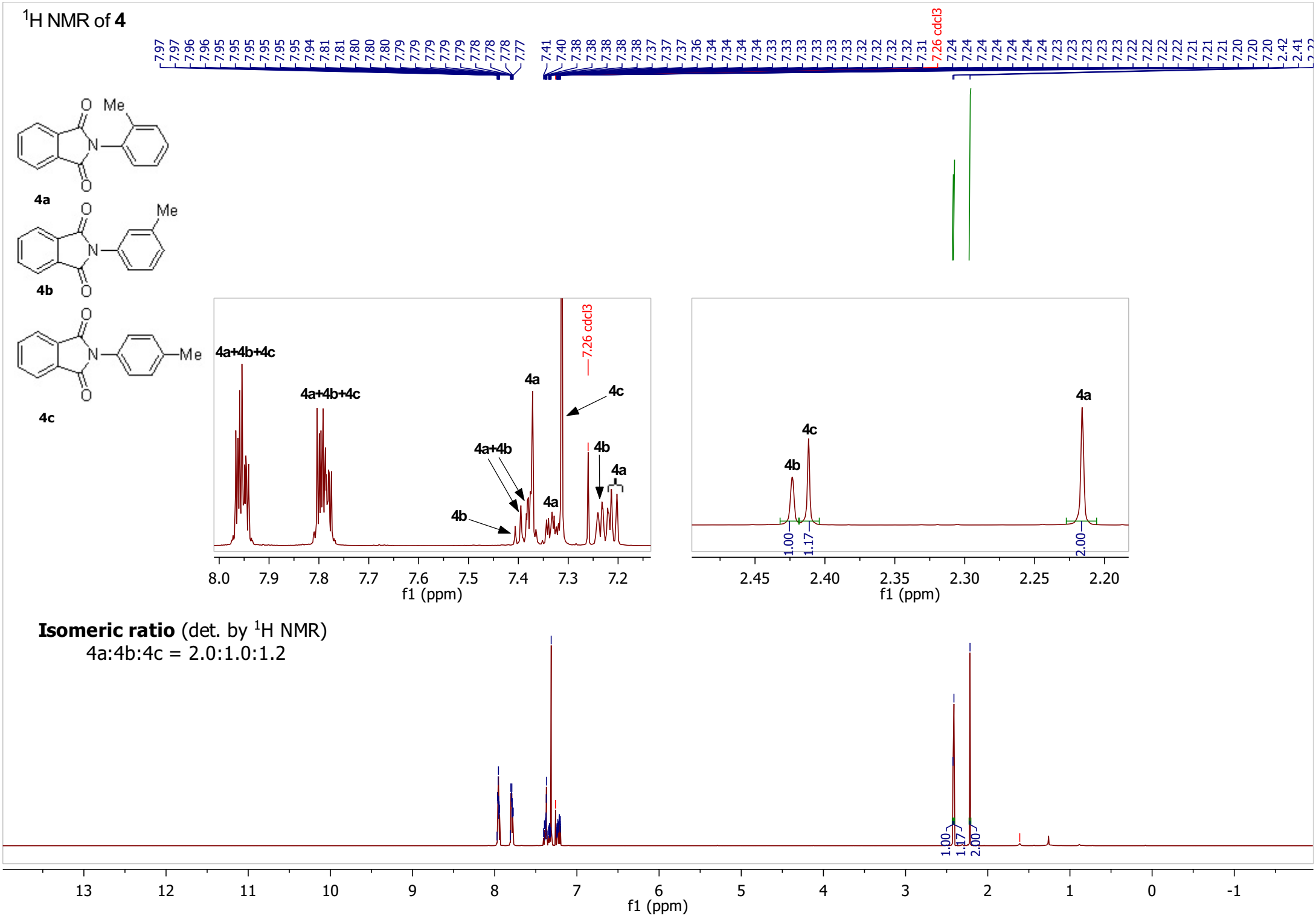
3c

-62.66

30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -20

f1 (ppm)

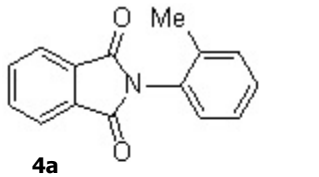
^{1}H NMR of **4**



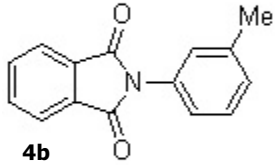
Isomeric ratio (det. by ^{1}H NMR)

4a:4b:4c = 2.0:1.0:1.2

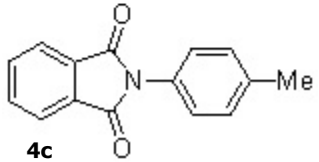
^{13}C NMR of **4**



4a

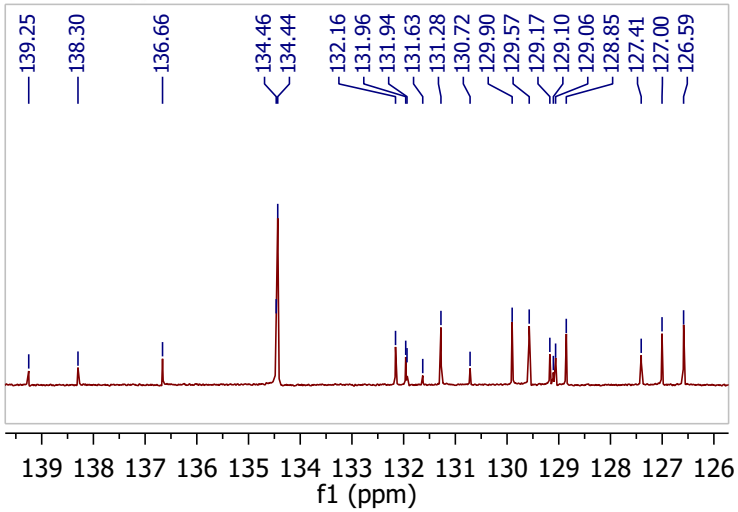


4b

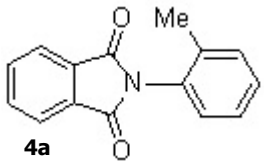


4c

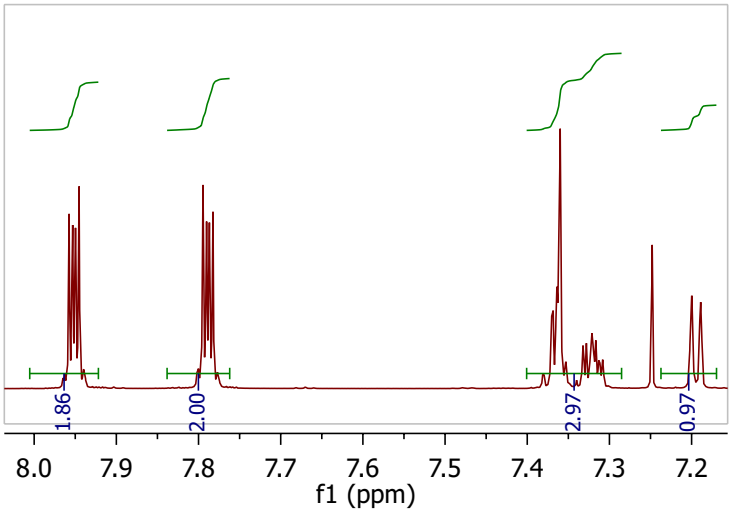
167.54
167.49
167.46
139.25
138.30
136.66
134.46
134.44
132.16
131.96
131.94
131.63
131.28
130.72
129.90
129.57
129.17
129.10
129.06
128.85
127.41
127.00
126.59
123.89
123.83
123.80
77.34 cdcl3
77.16 cdcl3
76.98 cdcl3
21.54
21.35
18.18

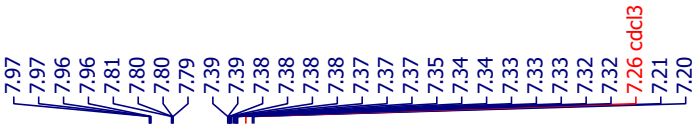


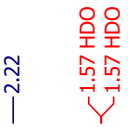
^{1}H NMR of **4a**



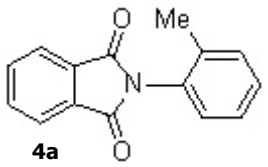
4a





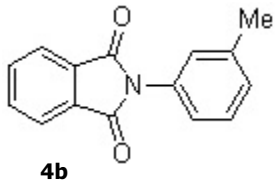


^{13}C NMR of **4a**



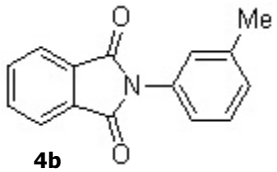
4a

^{1}H NMR of **4b**

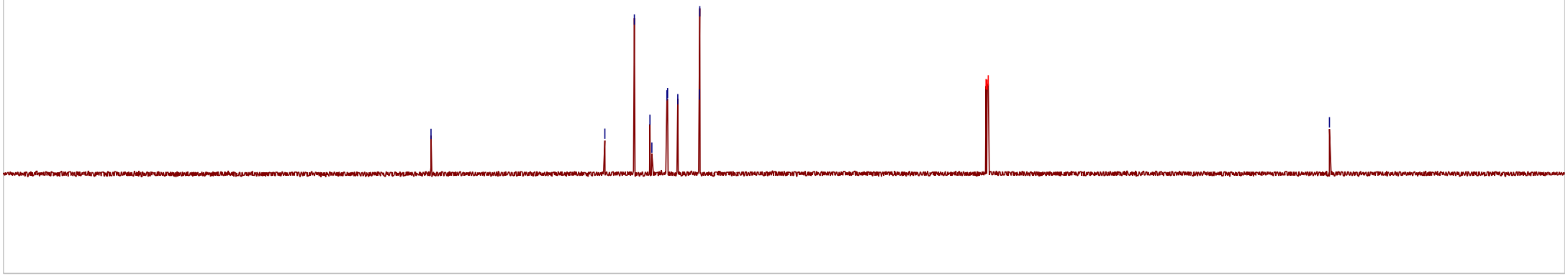


4b

^{13}C NMR of **4b**



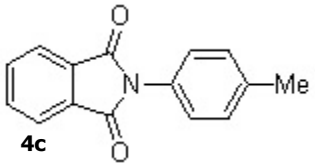
167.51
139.27
134.48
131.94
131.63
129.19
129.08
127.42
123.89
123.84
77.34 cdcl3
77.16 cdcl3
76.98 cdcl3
21.55



230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

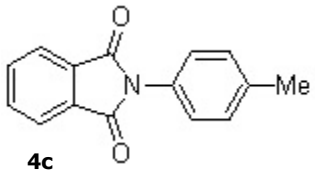
f1 (ppm)

^{1}H NMR of **4c**


O
N
Me
O
4c

7.96
7.95
7.95
7.94
7.79
7.79
7.78
7.78
7.31
7.26 cdcl3
2.41
2.00
2.13
4.10
3.25
f1 (ppm)
8.0
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1

^{13}C NMR of **4b**



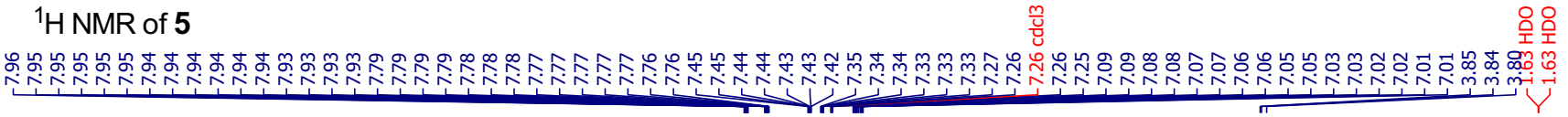
4c

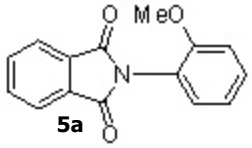
167.57
138.33
134.45
131.98
129.92
129.11
126.61
123.83
77.34 cdcl3
77.16 cdcl3
76.98 cdcl3
21.37

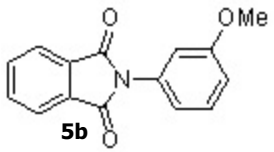
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

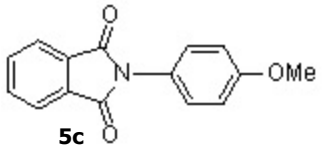
f1 (ppm)

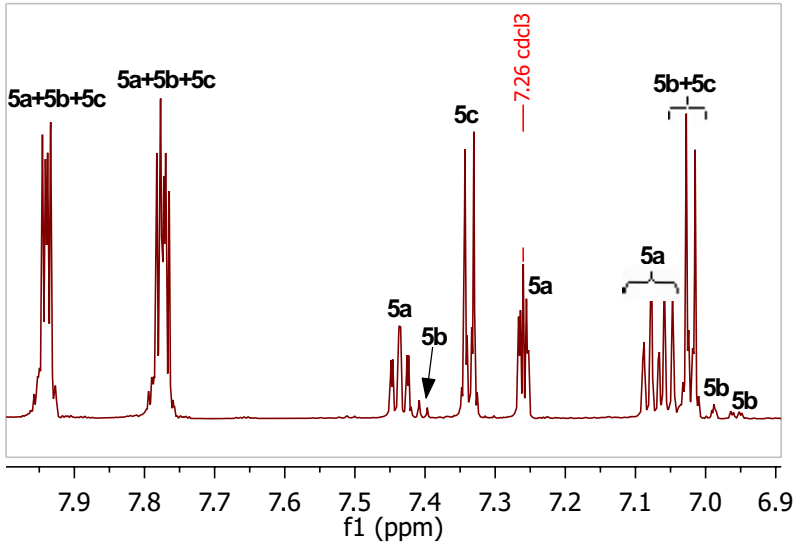
^{1}H NMR of **5**

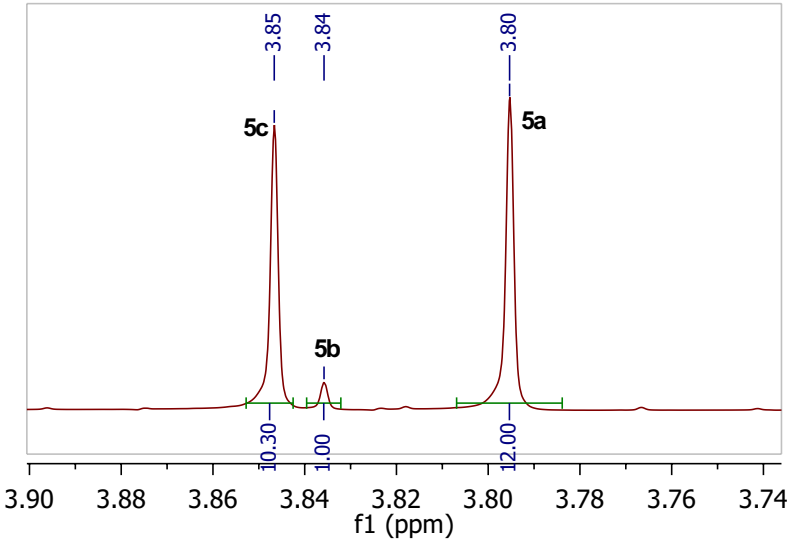






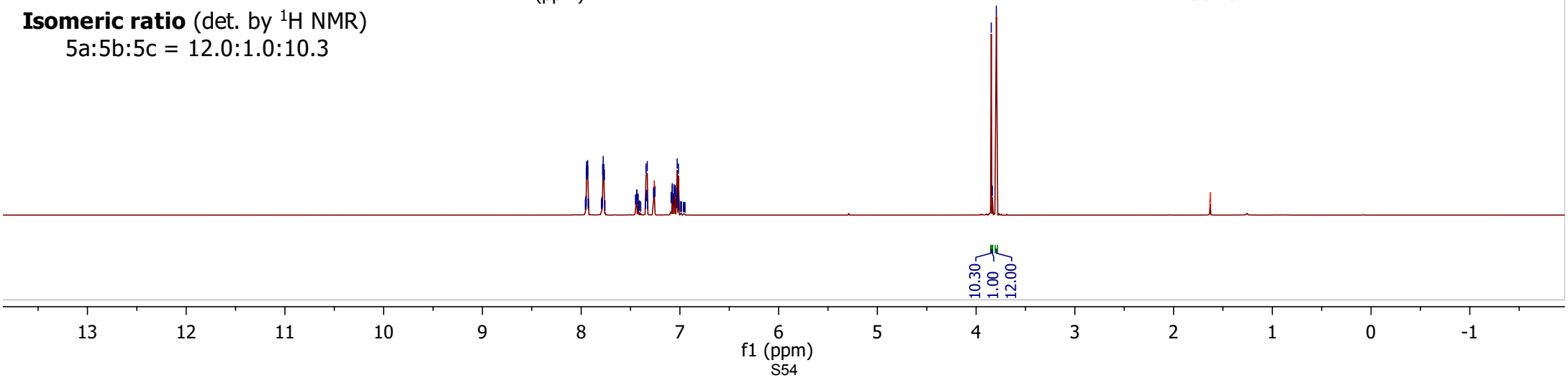




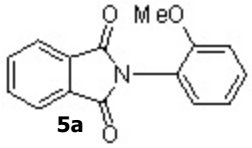


Isomeric ratio (det. by ^{1}H NMR)

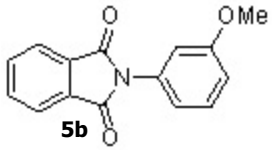
5a:5b:5c = 12.0:1.0:10.3



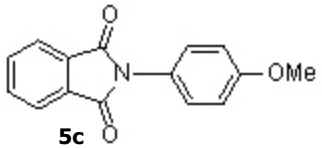
^{13}C NMR of **5**



5a

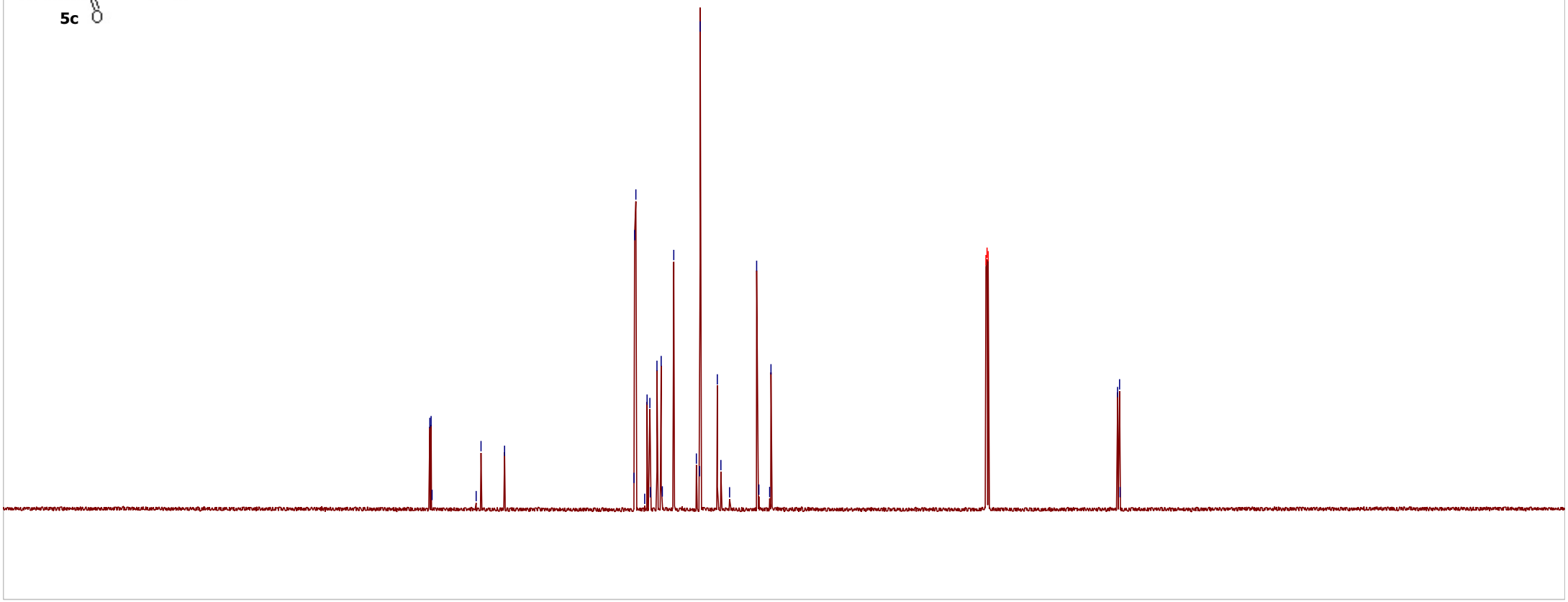


5b



5c

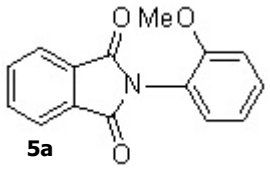
167.68
167.48
167.32
160.16
159.37
155.55
134.52
134.42
134.21
132.78
132.39
131.94
131.86
130.79
130.10
129.92
128.06
124.38
123.87
123.77
120.98
120.40
118.99
114.59
114.23
112.48
112.26
77.34 cdcl3
77.16 cdcl3
76.98 cdcl3
55.95
55.63
55.55



230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

f1 (ppm)

^{1}H NMR of **5a**

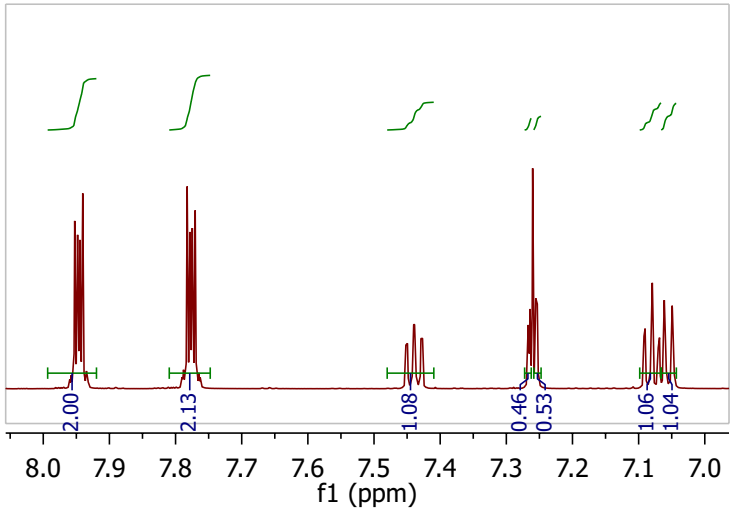


5a

7.95 7.95 7.94 7.94 7.78 7.78 7.77 7.77 7.45 7.45 7.44 7.44 7.44 7.44 7.43 7.43 7.27 7.26 7.26 cdcl3 7.26 7.25 7.09 7.09 7.08 7.08 7.07 7.07 7.06 7.06 7.05 7.05

3.80

1.58 HDO



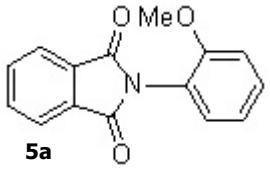
2.00 2.13 1.08 0.46 0.53 1.06 1.04

3.27

13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1

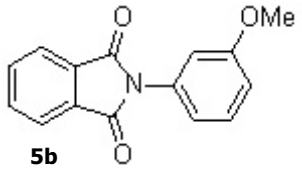
f1 (ppm)

^{13}C NMR of **5a**


O
Me
O
N
O
5a

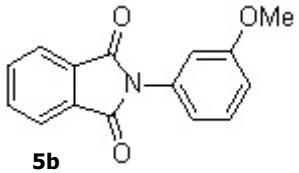
167.51
155.57
134.23
132.42
130.82
130.13
123.80
121.01
120.42
112.29
77.34 cdcl3
77.16 cdcl3
76.98 cdcl3
55.98
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

^{1}H NMR of **5b**



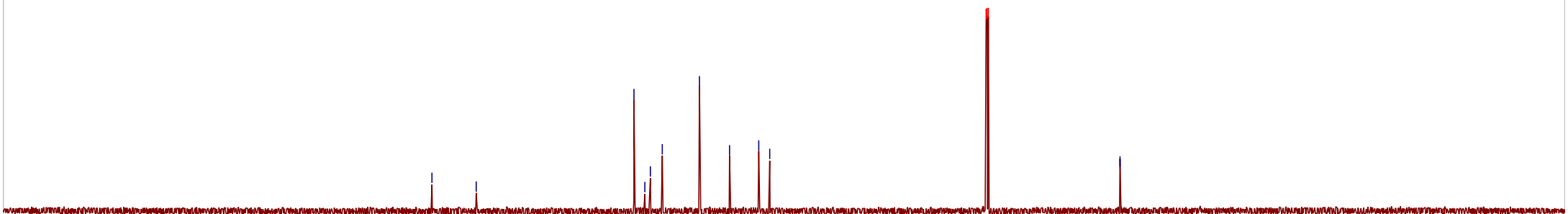
5b

^{13}C NMR of **5b**



5b

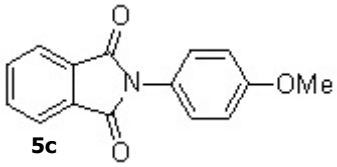
167.37
160.18
134.55
132.79
131.89
129.95
123.91
119.02
114.28
112.50
77.34 cdcl3
77.16 cdcl3
76.98 cdcl3
55.59



230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

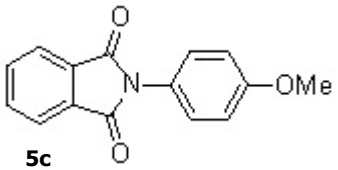
f1 (ppm)

^{1}H NMR of **5c**


O
N
OMe
O
5c

7.95
7.95
7.94
7.94
7.79
7.79
7.78
7.78
7.35
7.34
7.34
7.33
7.33
7.33
7.26 cdcl3
7.04
7.03
7.03
7.02
7.02
7.01
3.85
1.57 HDO
1.56 HDO
2.00
2.14
2.02
2.14
3.17
f1 (ppm)
S60

^{13}C NMR of **5c**



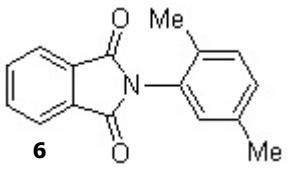
5c

167.72
159.41
134.45
131.98
128.09
124.41
123.82
114.63
77.34 cdcl3
77.16 cdcl3
76.98 cdcl3
55.66

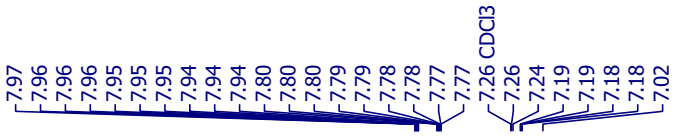
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

f1 (ppm)

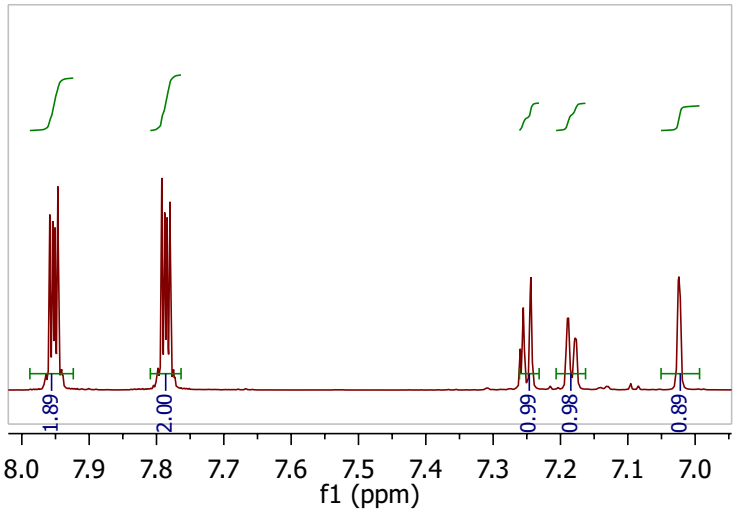
^{1}H NMR of **6**

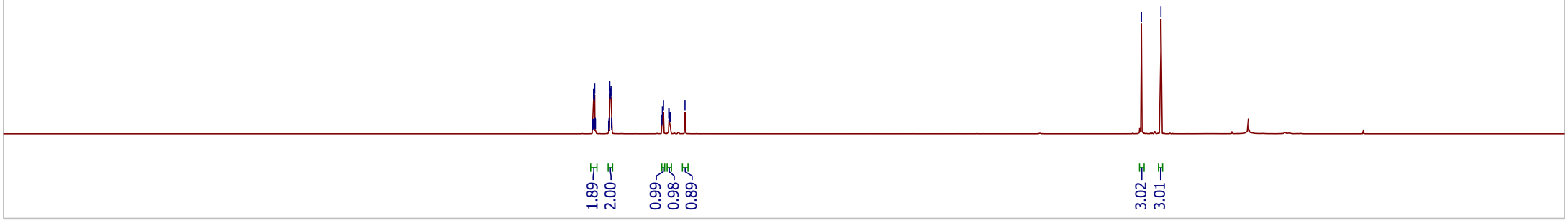

O
Me
N
O
Me

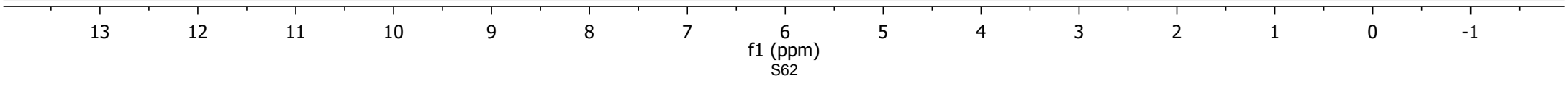
6


7.97
7.96
7.96
7.96
7.95
7.95
7.95
7.94
7.94
7.94
7.80
7.80
7.79
7.79
7.78
7.78
7.77
7.77
7.26 CDCl3
7.26
7.24
7.19
7.19
7.18
7.18
7.02

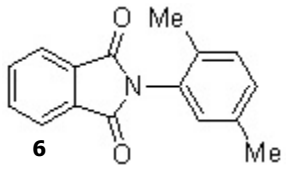

2.36
2.16


1.89
2.00
0.99
0.98
0.89
8.0
7.9
7.8
7.7
7.6
7.5
7.4
7.3
7.2
7.1
7.0
f1 (ppm)


1.89
2.00
0.99
0.98
0.89
3.02
3.01


13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
f1 (ppm)

^{13}C NMR of **6**



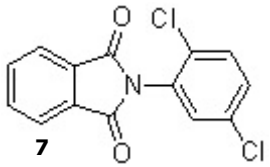
6

167.51
136.77
134.36
133.37
132.17
131.02
130.46
130.42
129.26
123.81
77.34 cdcl3
77.16 cdcl3
76.98 cdcl3
29.80 grease
20.91
17.64

230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

f1 (ppm)

^{1}H NMR of **7**



7

7.99 7.98 7.98 7.98 7.83 7.83 7.83 7.82 7.51 7.50 7.43 7.42 7.41 7.41 7.38 7.37 7.26 cdcl3

1.55 HDO

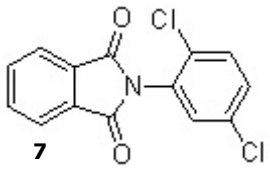
2.00 2.10 1.01 0.99 0.84

8.1 8.0 7.9 7.8 7.7 7.6 7.5 7.4 7.3 7.2
f1 (ppm)

2.00 2.10 1.01 0.99 0.84

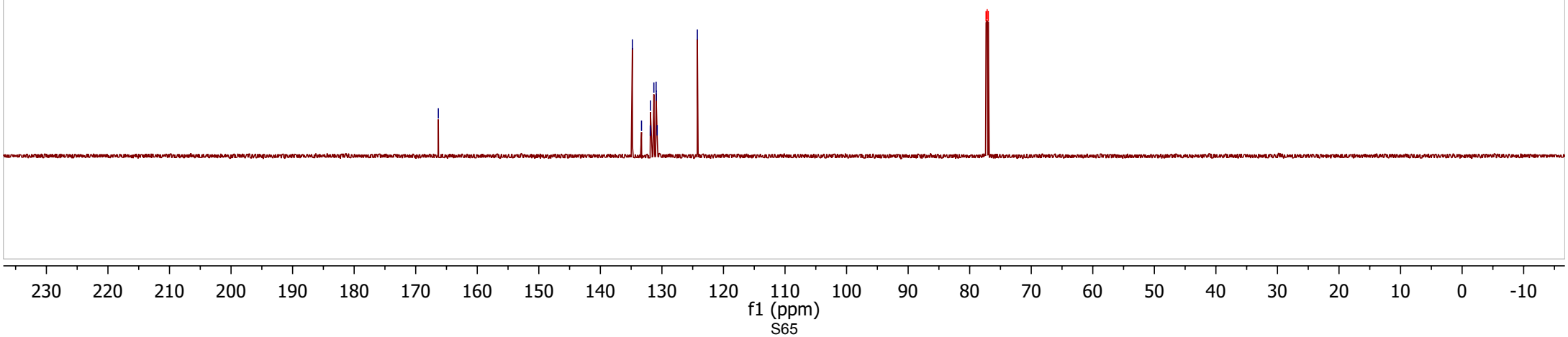
13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)

^{13}C NMR of **7**



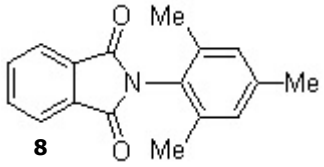
7

166.32
134.80
133.32
131.89
131.86
131.31
130.94
130.92
130.77
124.25
77.34 cdcl3
77.16 cdcl3
76.98 cdcl3



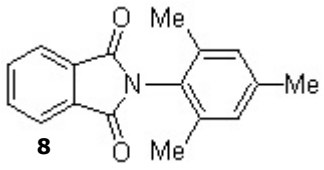
S65

^{1}H NMR of **8**

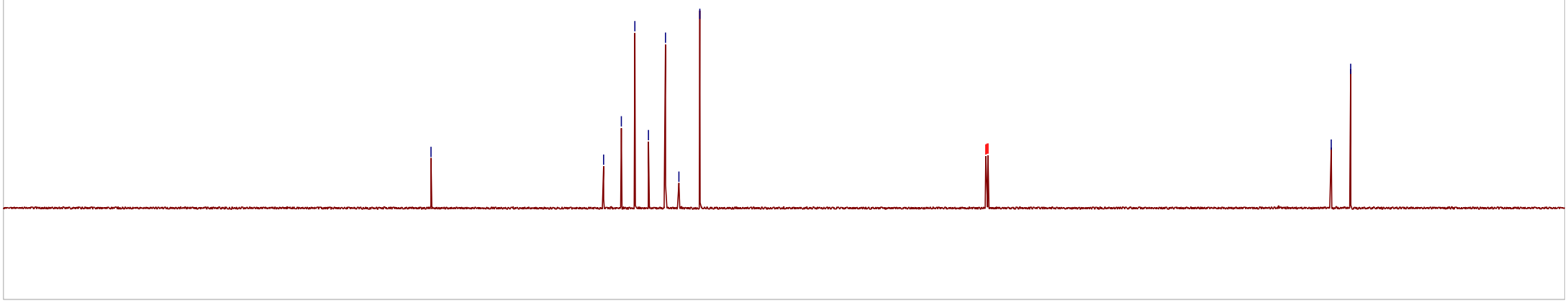

O
Me
N
Me
Me
O
8

7.97
7.96
7.96
7.96
7.80
7.80
7.79
7.79
7.26 cdcl3
7.01
2.34
2.13
7.26 cdcl3
2.00
2.09
2.02
8.0 7.9 7.8 7.7 7.6 7.5 7.4 7.3 7.2 7.1 7.0 6.9
f1 (ppm)
2.00
2.09
2.02
3.12
6.13
13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)

^{13}C NMR of **8**



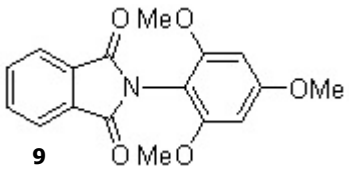
167.47
139.43
136.55
134.36
132.15
129.38
127.20
123.80
77.34 cdcl3
77.16 cdcl3
76.98 cdcl3
21.22
18.06



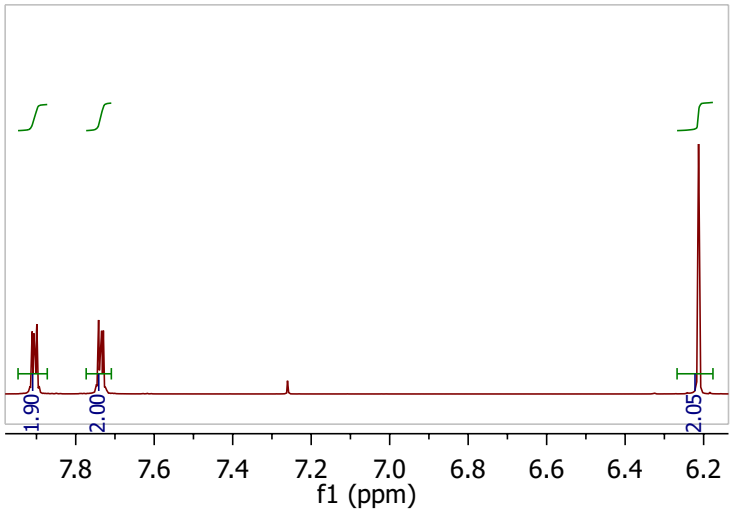
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

f1 (ppm)

^{1}H NMR of **9**

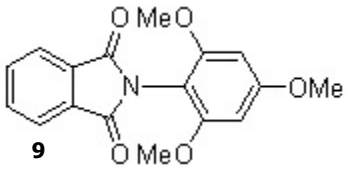

O
MeO
N
OMe
O
MeO

9


1.90
2.00
2.05
7.8
7.6
7.4
7.2
7.0
6.8
6.6
6.4
6.2
f1 (ppm)

7.91
7.91
7.90
7.90
7.74
7.74
7.73
7.73
7.26 cdcl3
6.21
3.83
3.74
1.71 HDO
1.90
2.00
2.05
3.16
6.09
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
f1 (ppm)

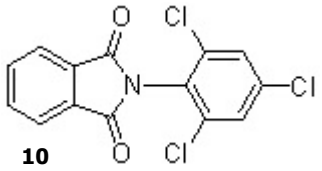
^{13}C NMR of **9**


O
MeO
N
OMe
O
MeO

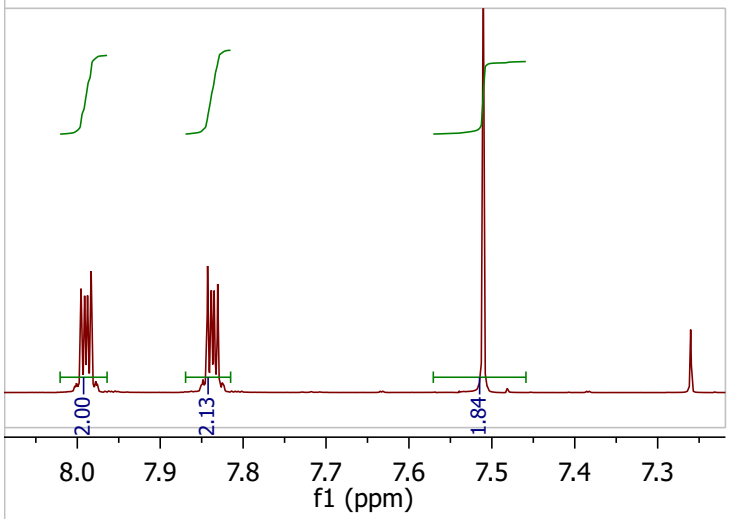
9

167.77
162.19
157.72
133.92
132.64
123.54
101.78
91.16
77.34 cdcl3
77.16 cdcl3
76.98 cdcl3
56.08
55.61
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

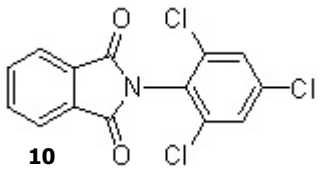
^{1}H NMR of **10**



10

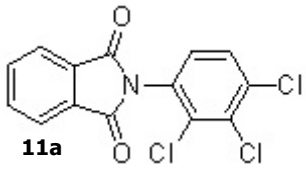


^{13}C NMR of **10**

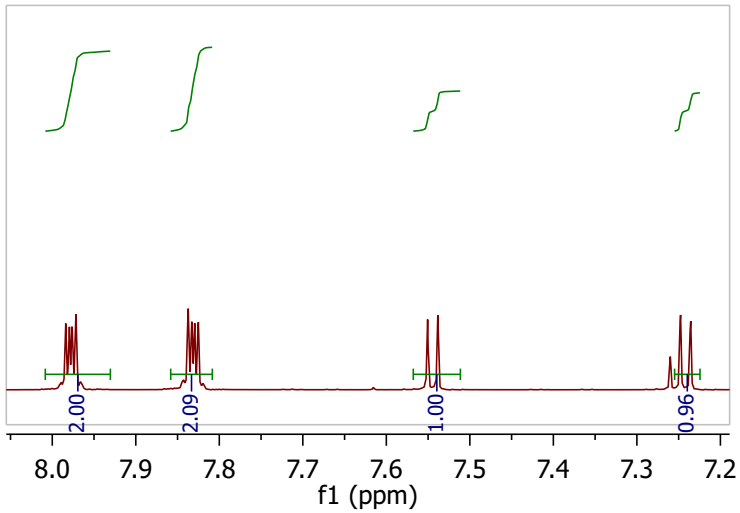


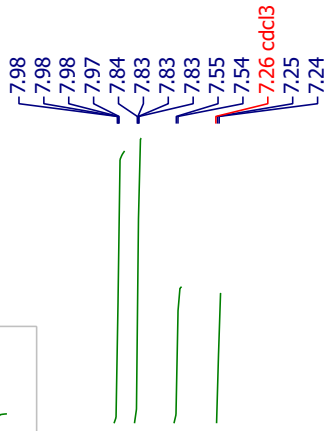
10

^{1}H NMR of **11a**

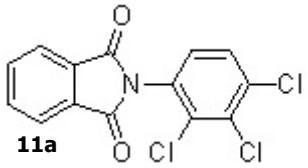


11a



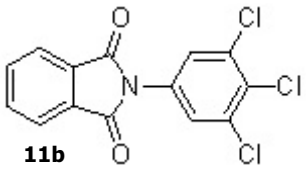


^{13}C NMR of **11a**

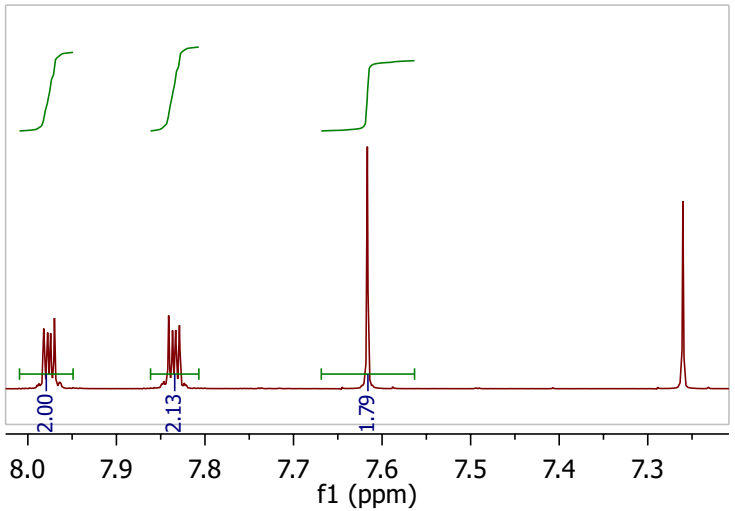


11a

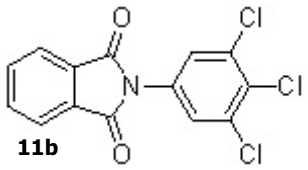
^{1}H NMR of **11b**



11b



^{13}C NMR of **11b**

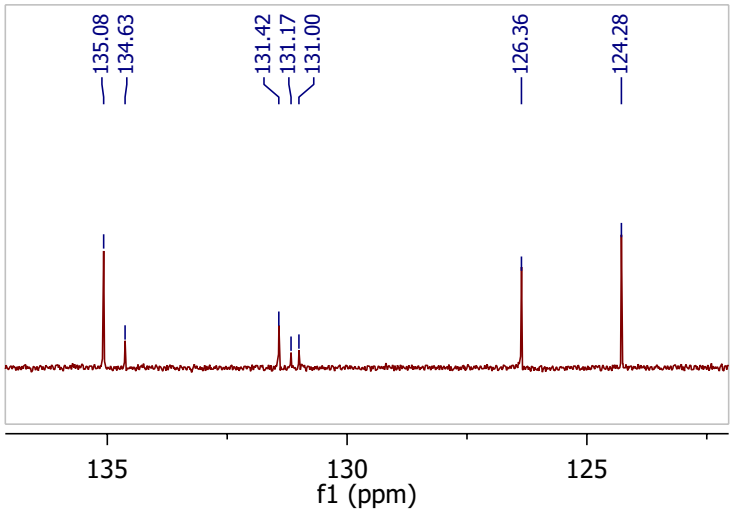


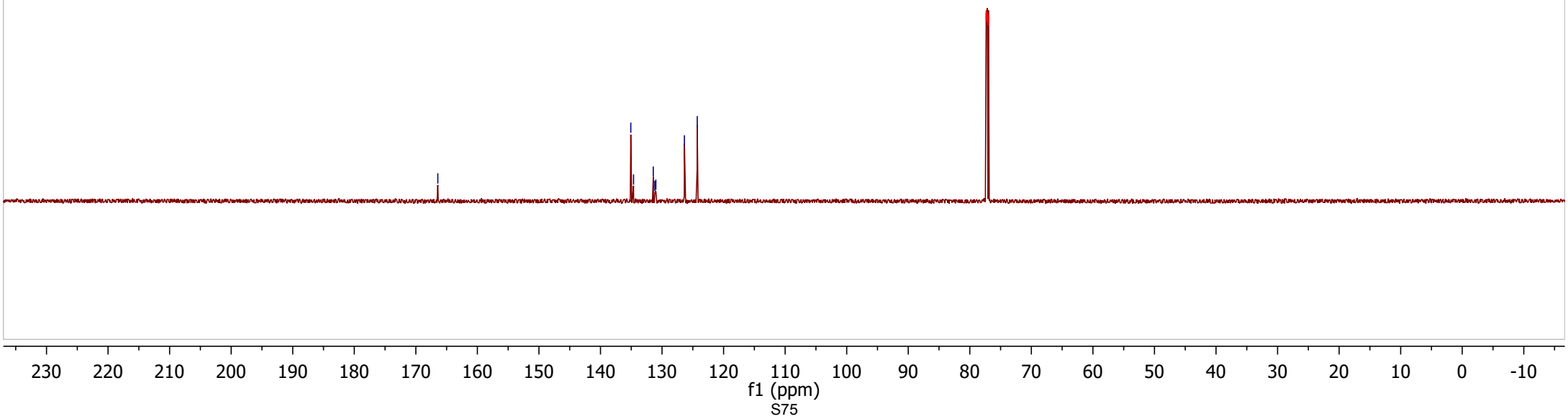
11b

166.42

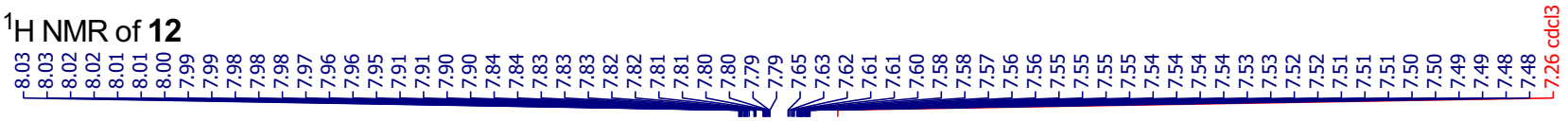
135.08
134.63
131.42
131.17
131.00
126.36
124.28

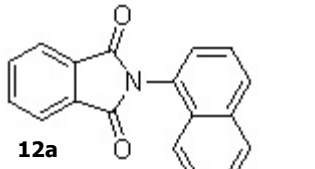
77.34 cdcl3
77.16 cdcl3
76.98 cdcl3

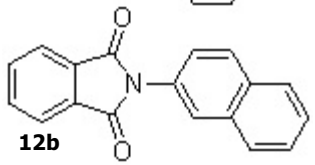


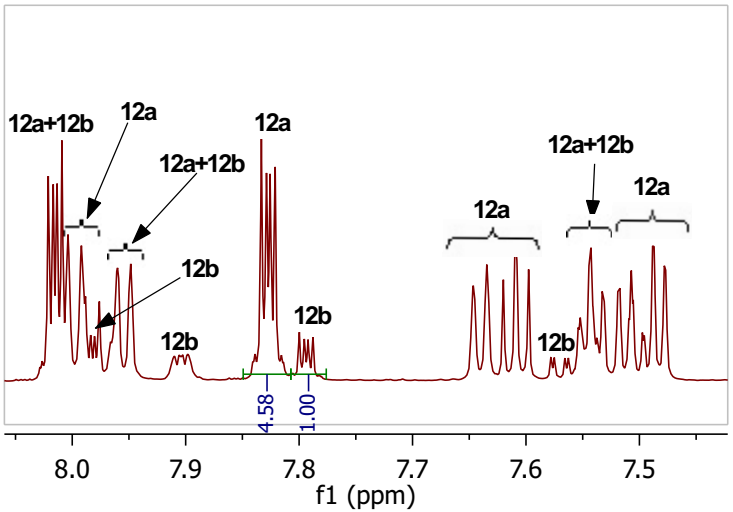


^{1}H NMR of **12**

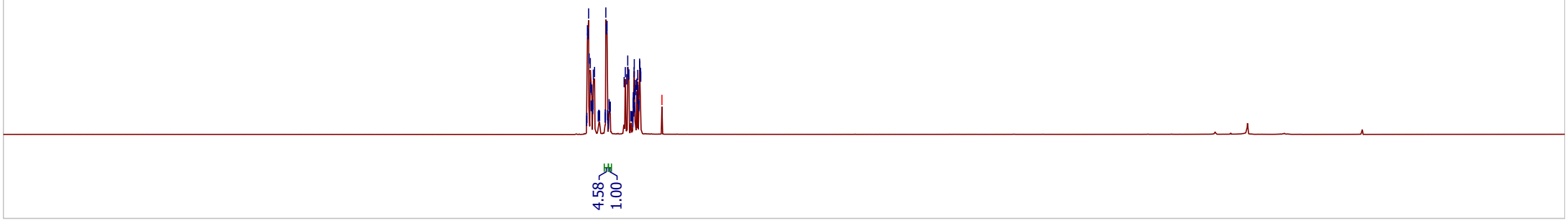




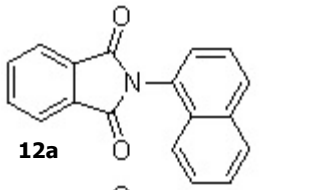




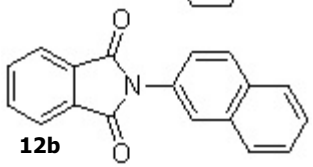
Isomeric ratio (det. by ^{1}H NMR)
12a:12b = 4.6:1.0



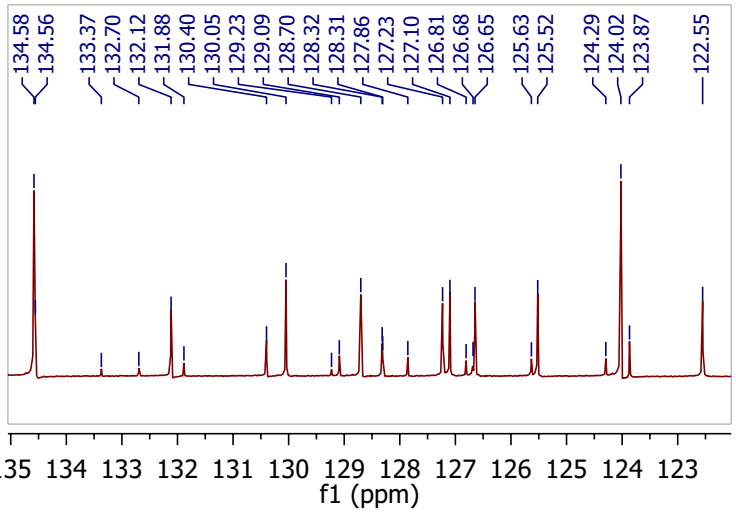
^{13}C NMR of **12**



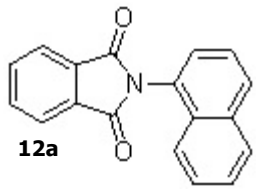
12a

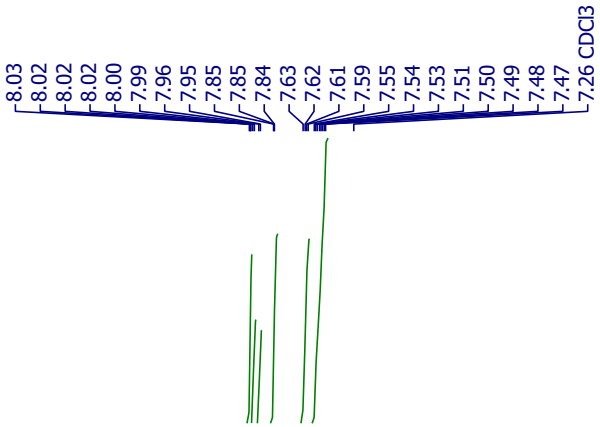


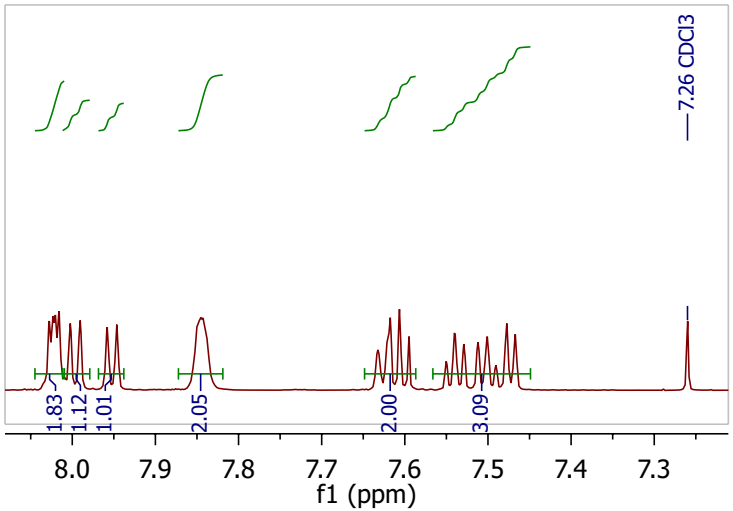
12b

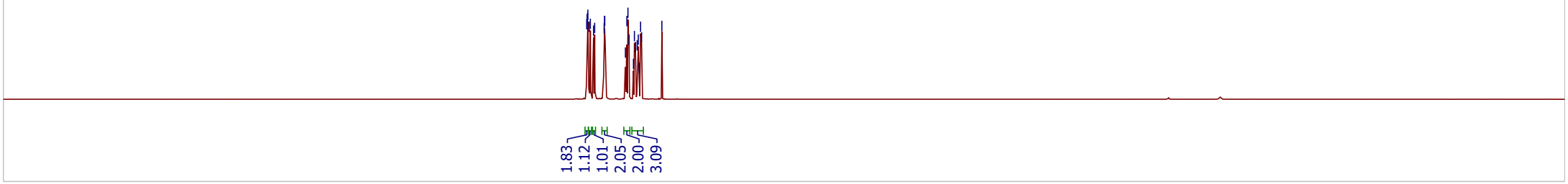


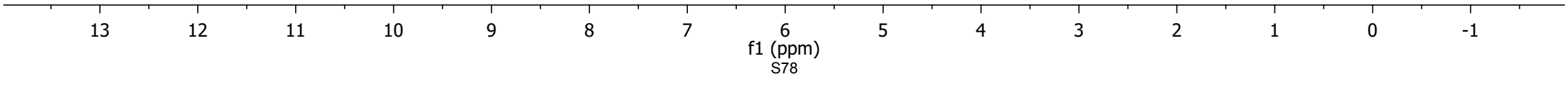
^{1}H NMR of **12a**


12a

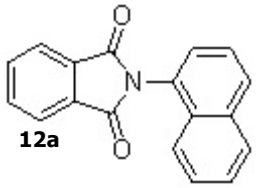

8.03
8.02
8.02
8.02
8.00
7.99
7.96
7.95
7.85
7.85
7.84
7.63
7.62
7.61
7.59
7.55
7.54
7.53
7.51
7.50
7.49
7.48
7.47
7.26 CDCl3


7.26 CDCl3
1.83
1.12
1.01
2.05
2.00
3.09
8.0
7.9
7.8
7.7
7.6
7.5
7.4
7.3
f1 (ppm)


1.83
1.12
1.01
2.05
2.00
3.09


13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
f1 (ppm)

^{13}C NMR of **12a**



167.92

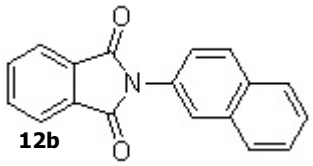
134.62
134.60
132.17
130.43
130.09
128.74
128.34
127.27
127.13
126.69
125.55
124.08
122.58

77.34 cdcl3
77.16 cdcl3
76.98 cdcl3

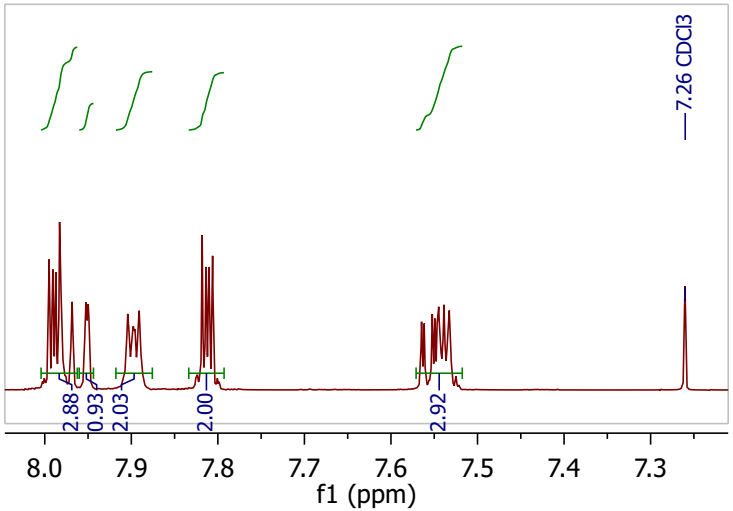
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

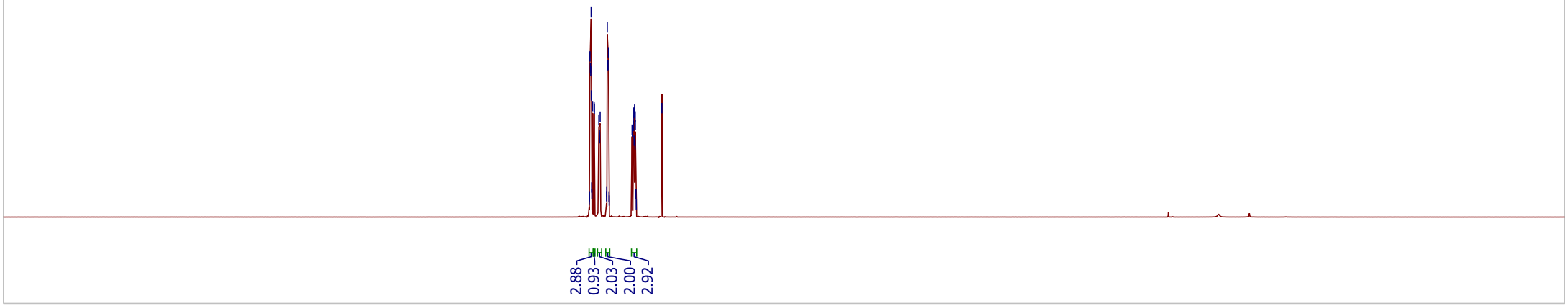
f1 (ppm)

^{1}H NMR of **12b**



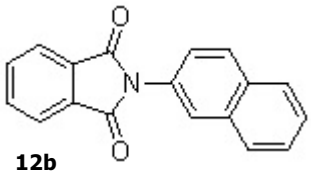
8.00 8.00 8.00 7.99 7.99 7.98 7.98 7.98 7.98 7.97 7.95 7.95 7.90 7.90 7.90 7.90 7.89 7.83 7.82 7.82 7.81 7.81 7.81 7.80 7.80 7.56 7.56 7.55 7.55 7.55 7.54 7.54 7.54 7.53 7.53 7.53 7.52 7.52 7.26 CDCl3





13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)

^{13}C NMR of **12b**

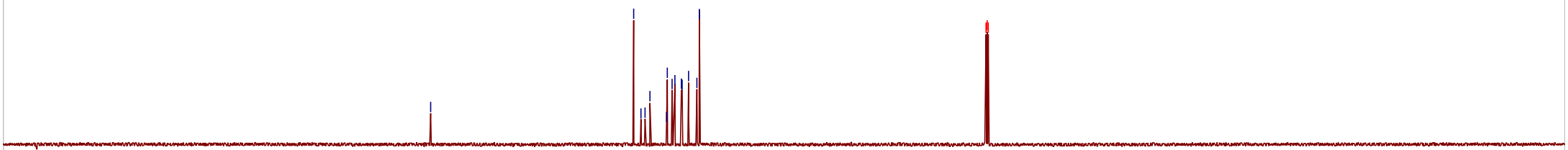


12b

167.57

134.59
133.40
132.74
131.94
129.24
129.12
128.35
127.89
126.84
126.71
125.67
124.32
123.92

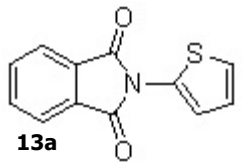
77.34 cdcl3
77.16 cdcl3
76.98 cdcl3



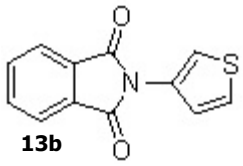
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

f1 (ppm)

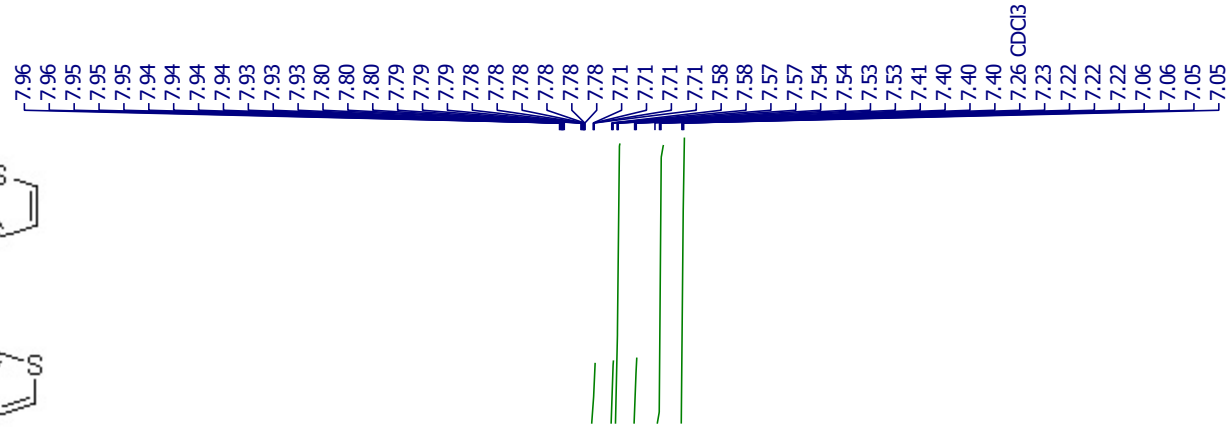
^{1}H NMR of **13**

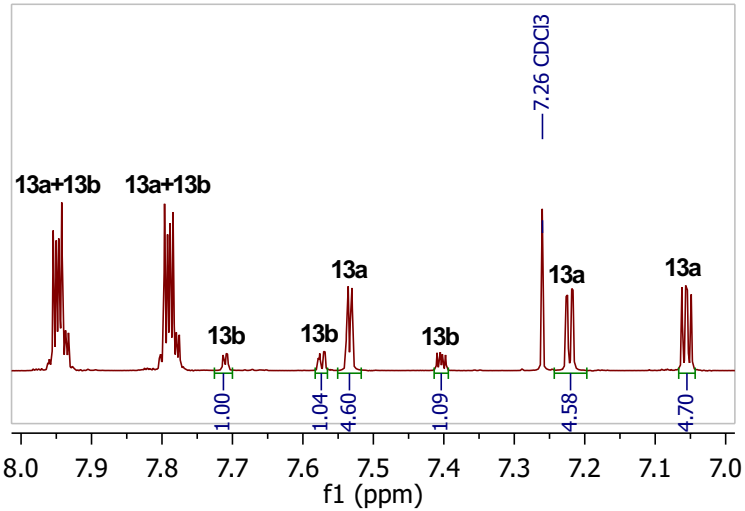


13a



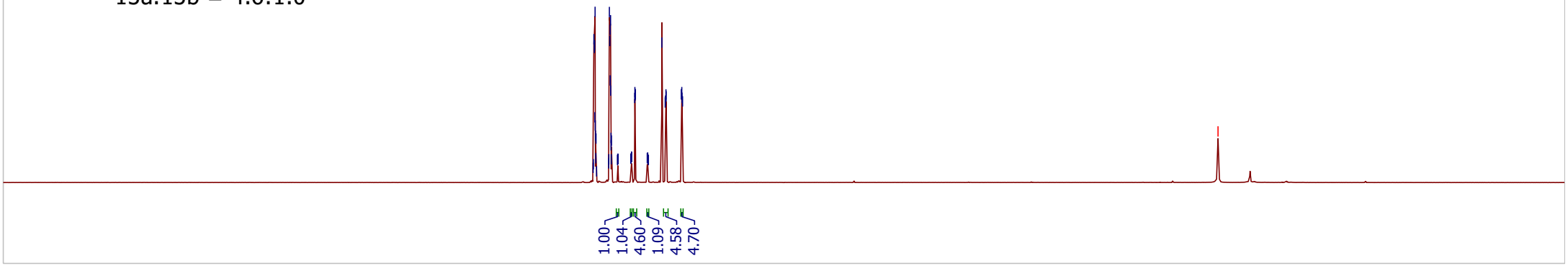
13b

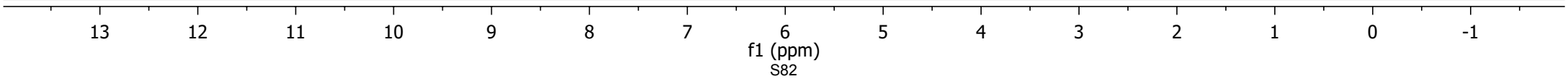




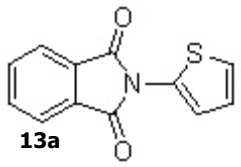
Isomeric ratio (det. by ^{1}H NMR)

13a:13b = 4.6:1.0

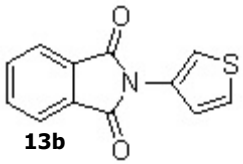




^{13}C NMR of **13**



13a



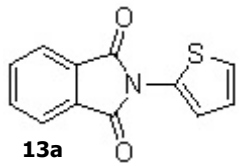
13b

166.80
166.13
134.80
134.61
132.41
131.76
131.57
130.00
125.42
124.95
124.06
123.87
123.40
122.09
120.58
117.74
77.34 cdcl3
77.16 cdcl3
76.98 cdcl3

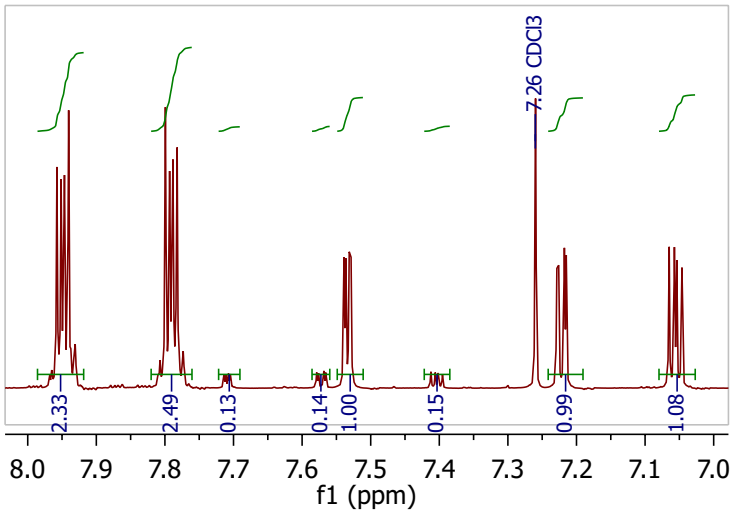
250 240 230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

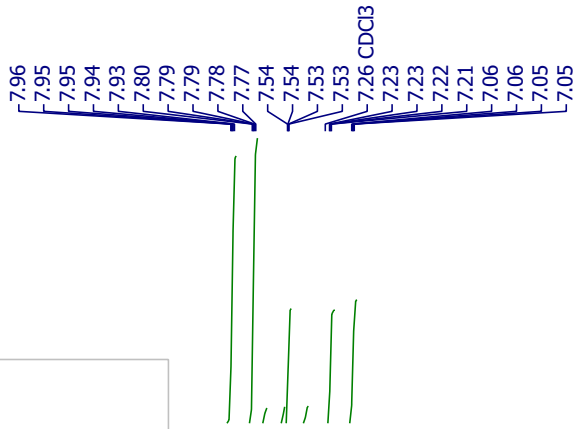
f1 (ppm)

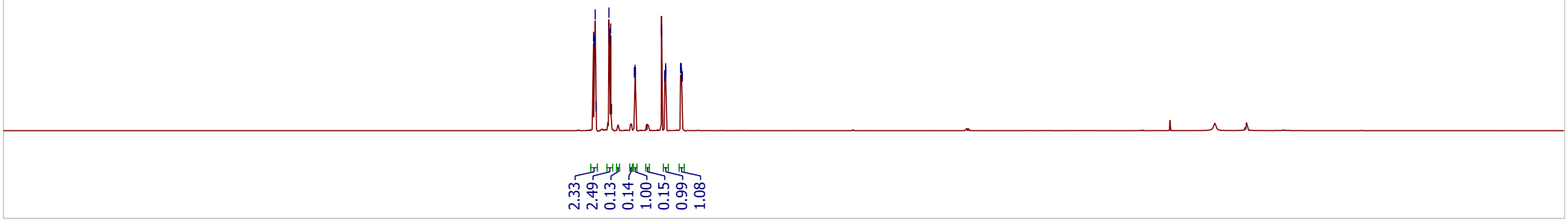
^{1}H NMR of **13a**

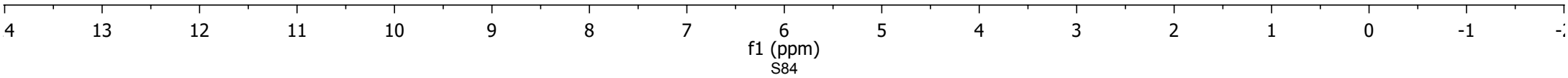


13a

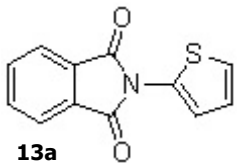








^{13}C NMR of **13a**

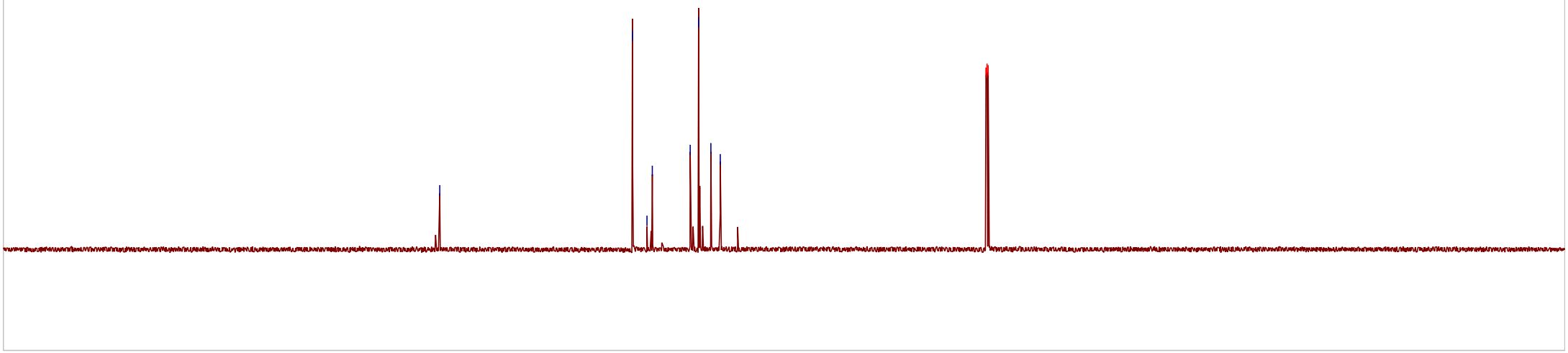


13a

166.07

134.77
132.41
131.54
125.39
124.02
122.03
120.50

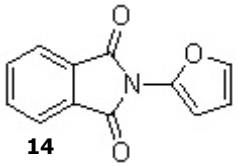
77.34 cdcl3
77.16 cdcl3
76.98 cdcl3



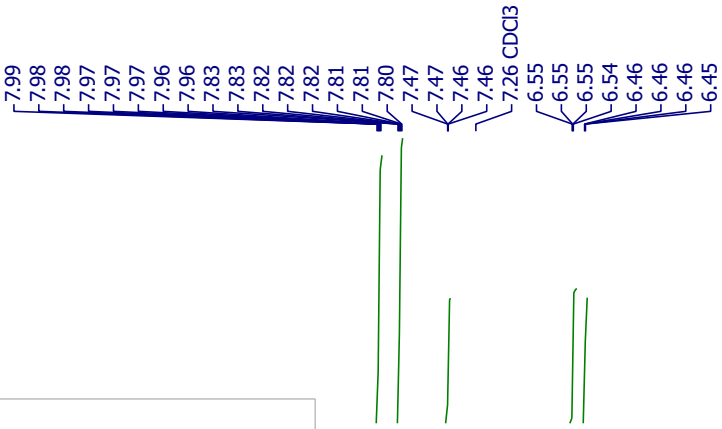
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

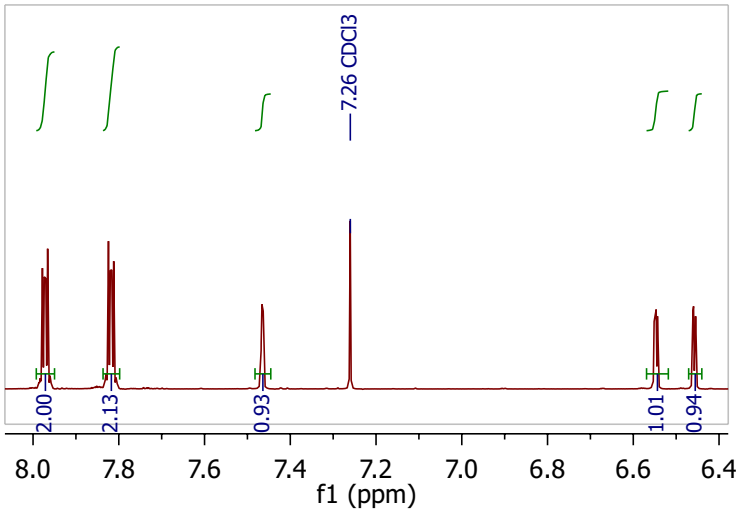
f1 (ppm)

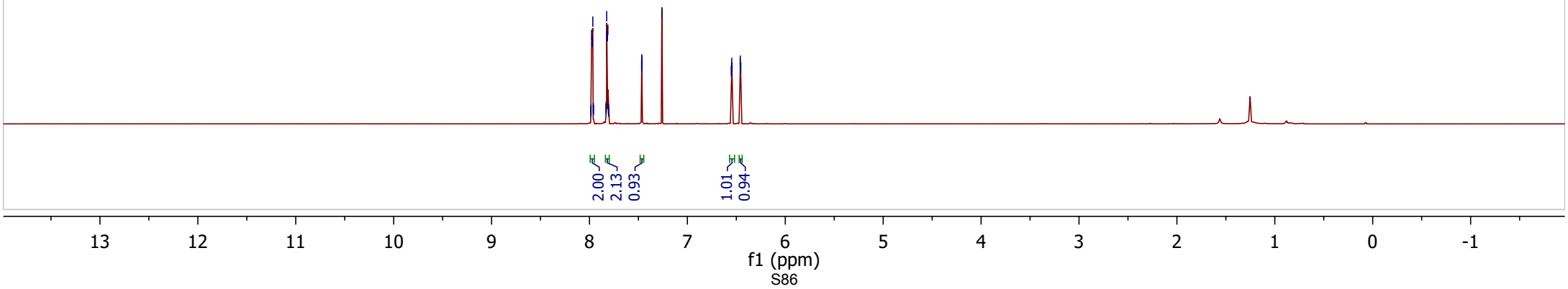
^{1}H NMR of **14**



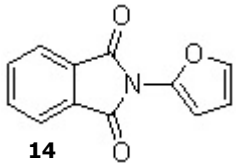
14



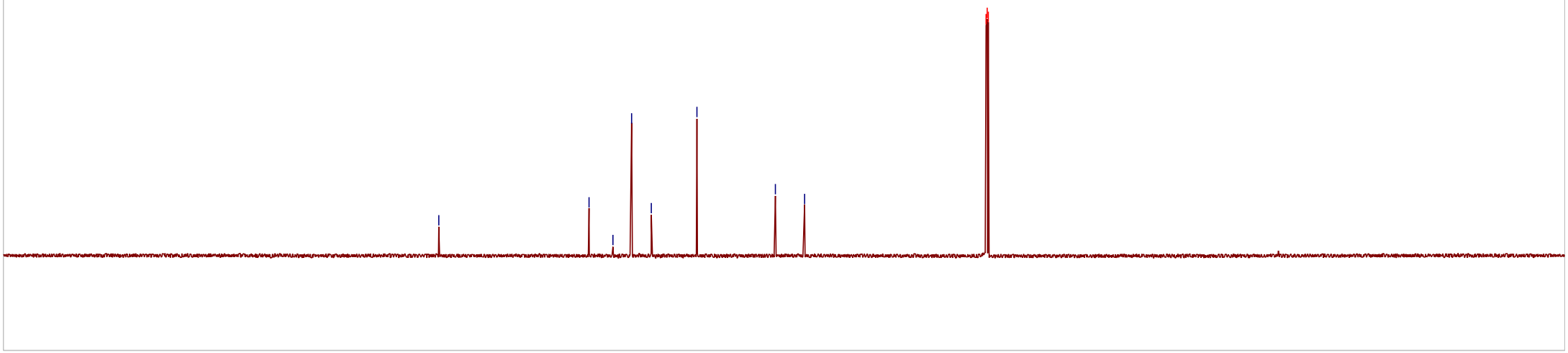




^{13}C NMR of **14**



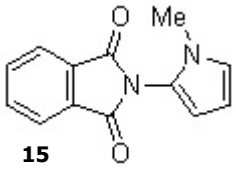
166.25
141.84
137.96
134.93
131.73
124.32
111.57
106.82
77.34 cdcl3
77.16 cdcl3
76.98 cdcl3



230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

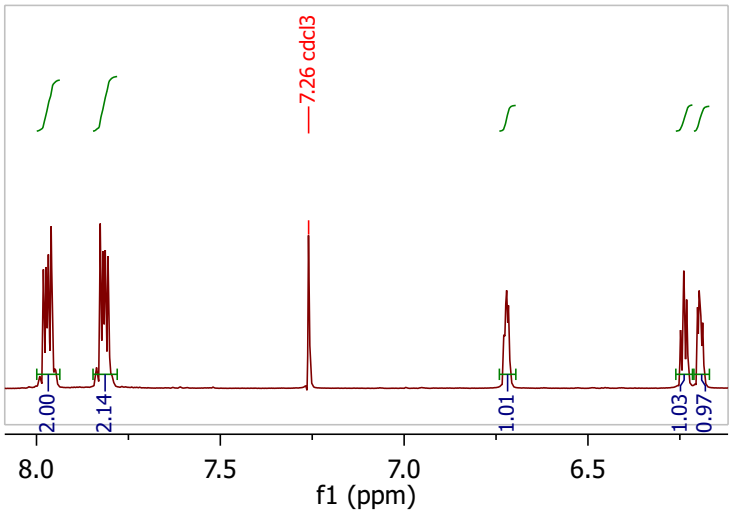
f1 (ppm)

^{1}H NMR of **15**



15

7.99 7.99 7.98 7.97 7.97 7.96 7.95 7.95 7.84 7.84 7.83 7.82 7.81 7.81 7.80 7.79 7.26 cdcl3 6.73 6.72 6.72 6.25 6.24 6.23 6.20 6.20 6.19 6.19 3.48 1.57 HDO

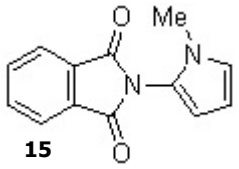


2.00 2.14 1.01 1.03 0.97 3.28

13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1

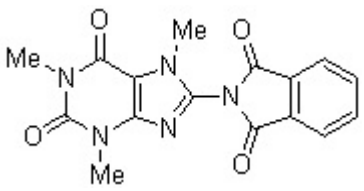
f1 (ppm)

^{13}C NMR of **15**


O
Me
N
N
O
15

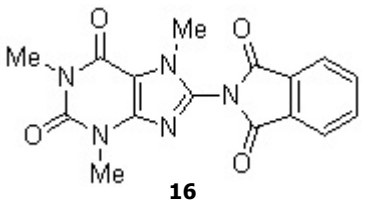
167.78
134.73
131.90
124.12
122.26
118.71
107.69
107.68
77.34 cdcl3
77.16 cdcl3
76.98 cdcl3
33.35
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

^{1}H NMR of **15**



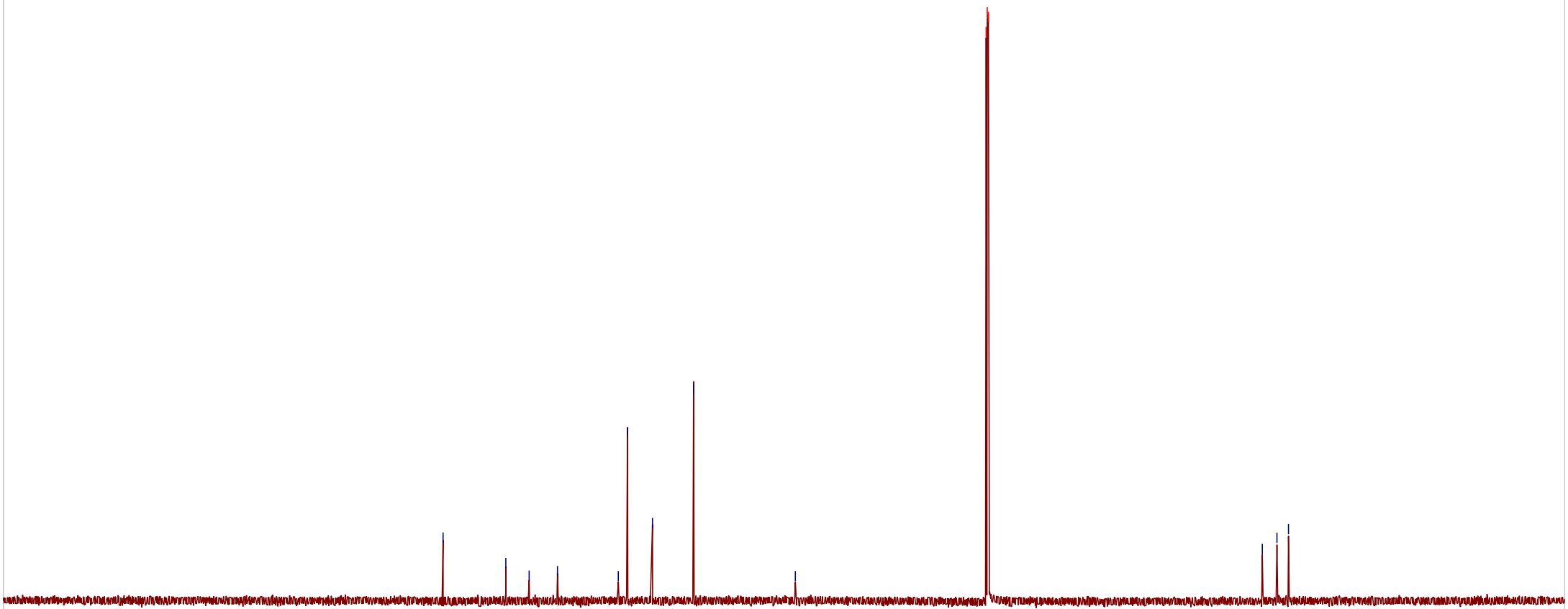
16

^{13}C NMR of **16**



16

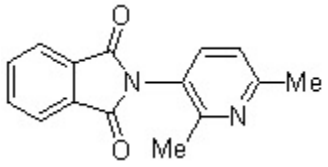
165.57
155.38
151.58
146.98
137.10
135.61
131.55
124.87
108.34
77.34 cdcl3
77.16 cdcl3
76.98 cdcl3
32.47
30.10
28.22



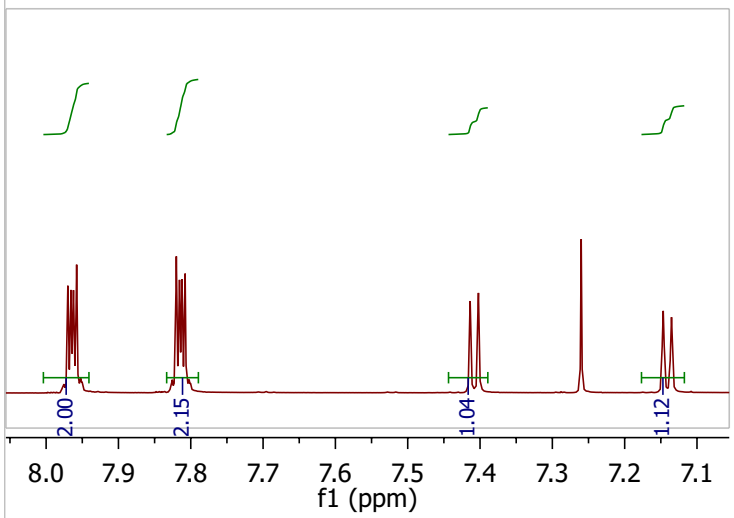
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

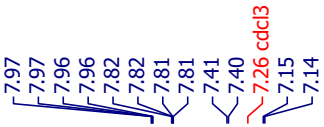
f1 (ppm)

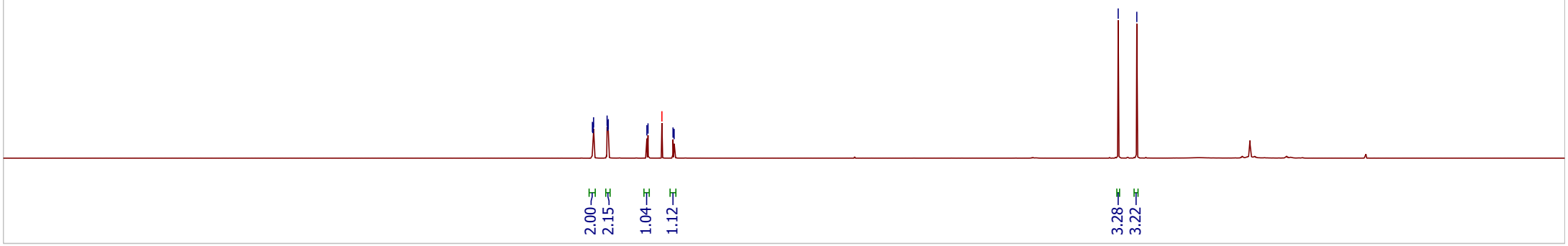
^{1}H NMR of **17**

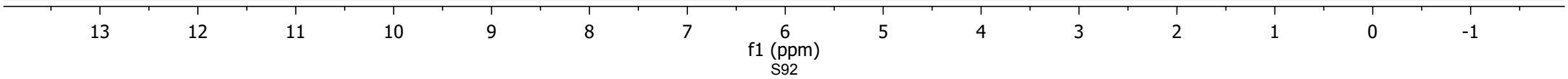


17

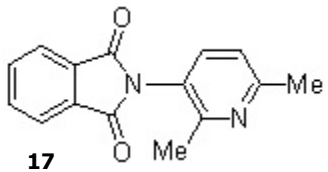






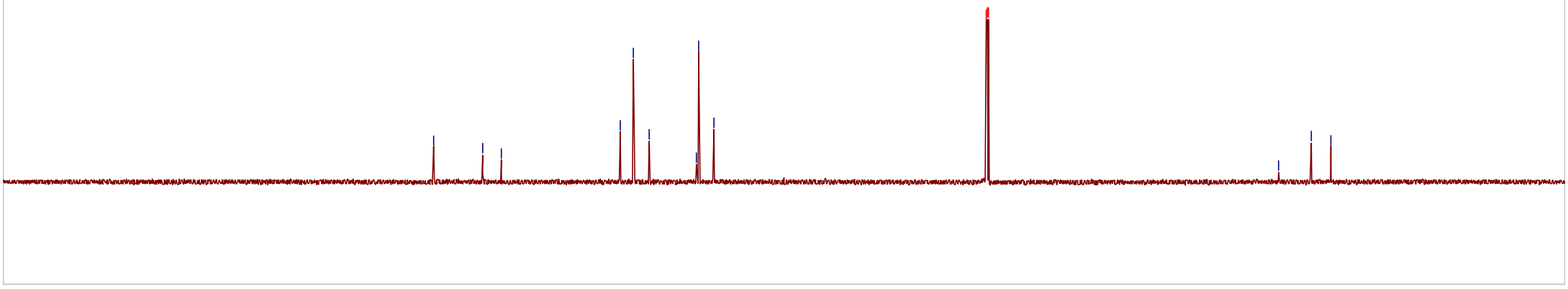


^{13}C NMR of **17**



17

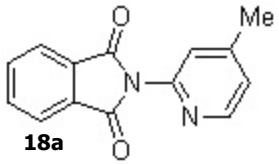
167.12
159.15
156.12
136.79
134.67
132.10
124.43
124.06
121.58
77.34 cdcl3
77.16 cdcl3
76.98 cdcl3
29.85 grease
24.53
21.35

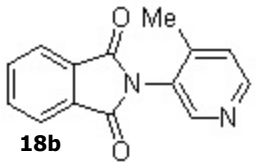


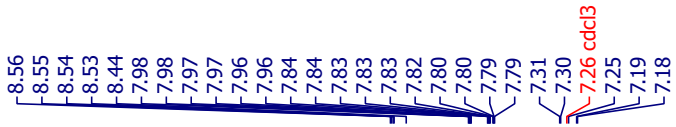
230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

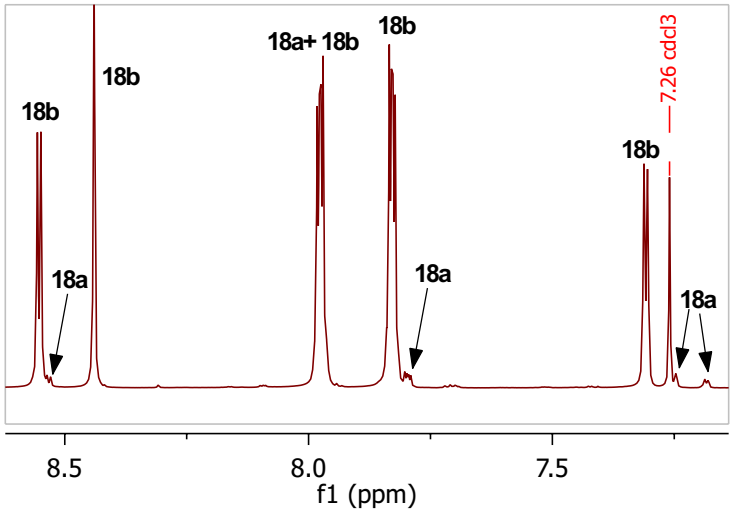
f1 (ppm)

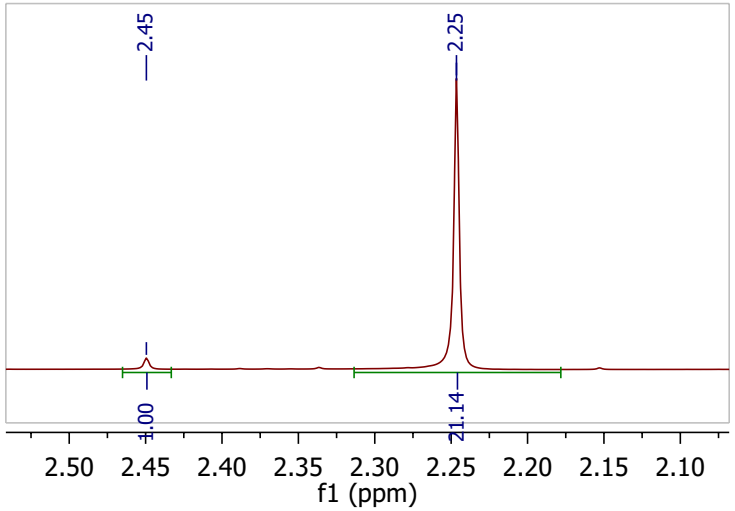
^{1}H NMR of **18**



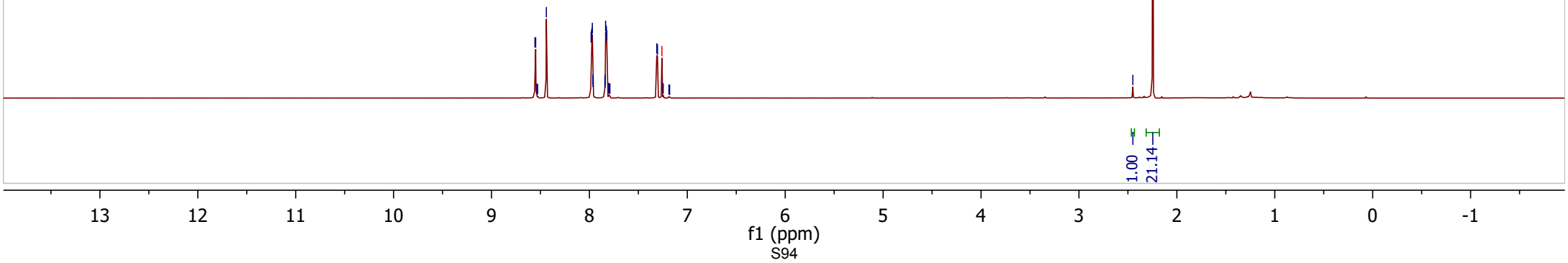




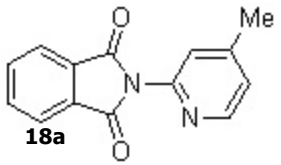




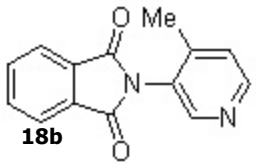
Isomeric ratio (det. by ^{1}H NMR)
18a:18b = 1.0:21.1



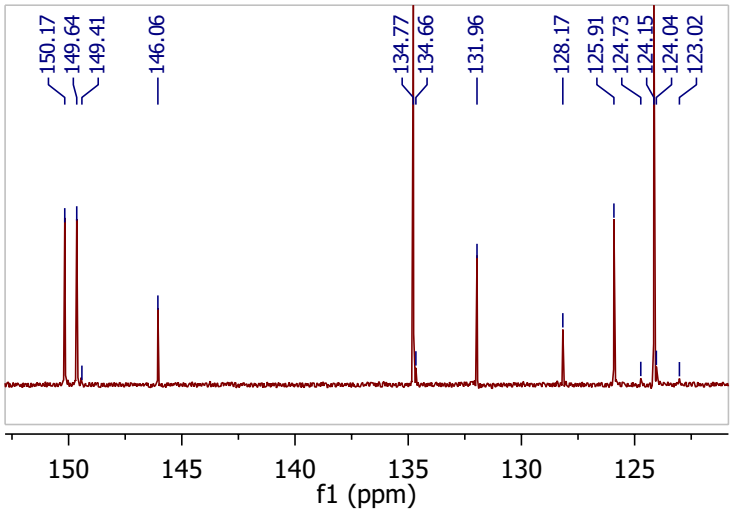
^{13}C NMR of **18**



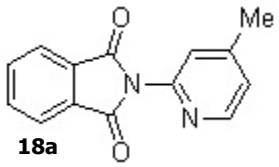
18a



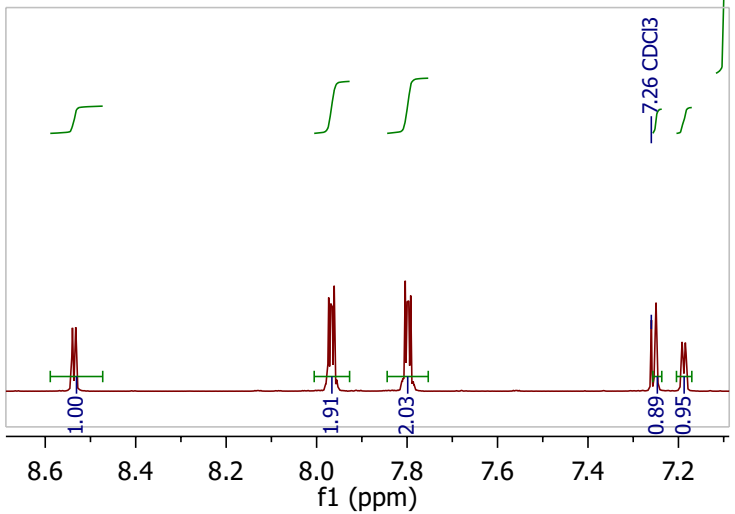
18b



^{1}H NMR of **18a**



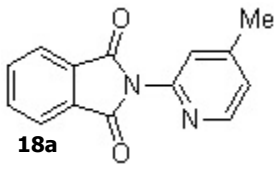
8.54 8.53 7.98 7.97 7.97 7.97 7.97 7.96 7.81 7.80 7.80 7.80 7.79 7.26 CDCl3 7.25 7.19 7.18 2.45



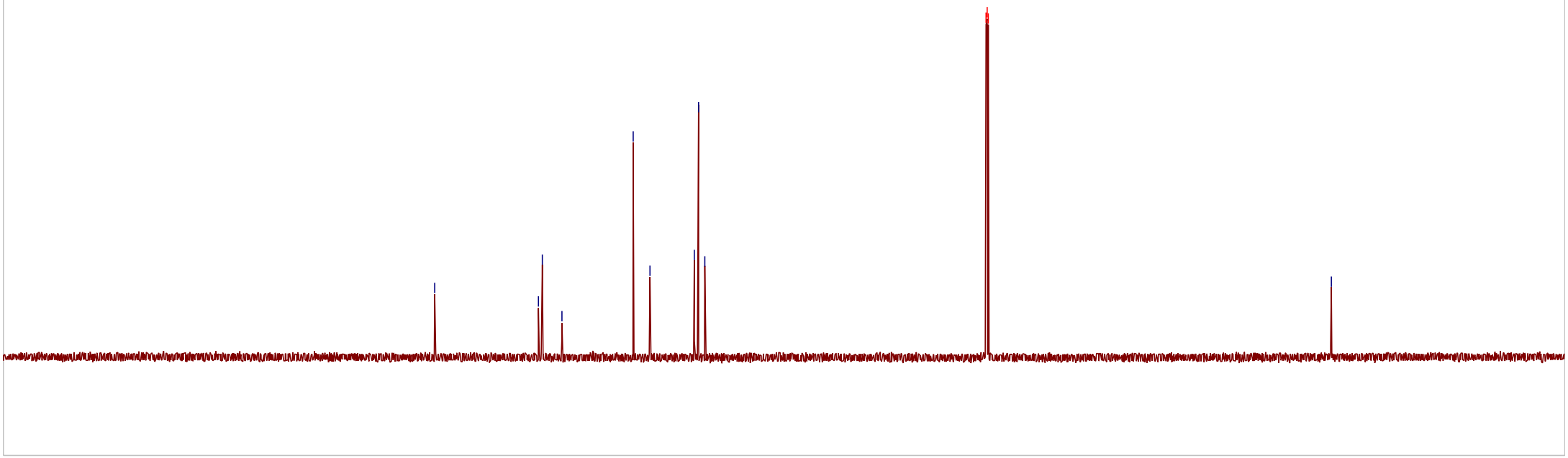
1.00 1.91 2.03 0.89 0.95 3.08

13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)

^{13}C NMR of **18a**



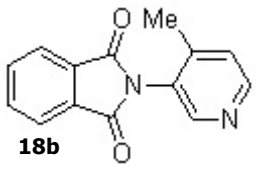
166.91
150.06
149.43
146.24
134.67
131.94
124.74
124.05
123.03
77.34 cdcl3
77.16 cdcl3
76.98 cdcl3
21.24

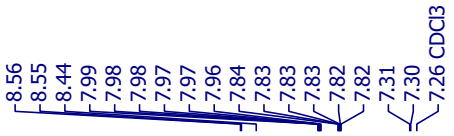


230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

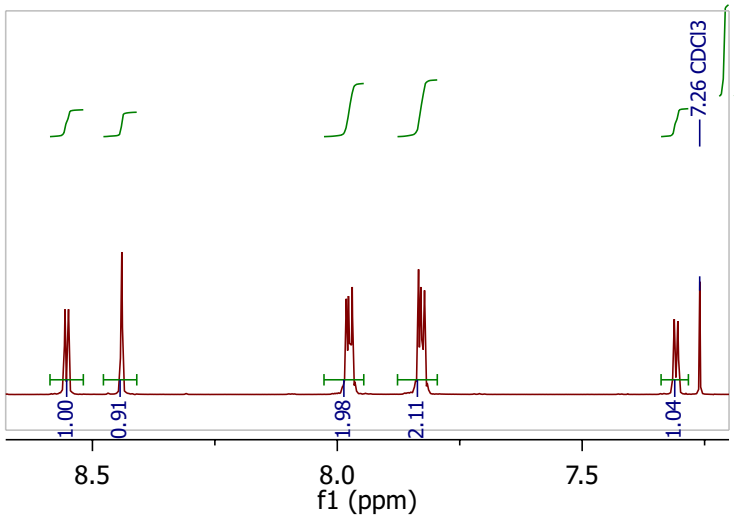
f1 (ppm)

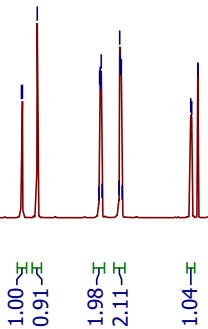
^{1}H NMR of **18b**


O
Me
N
N
O
18b

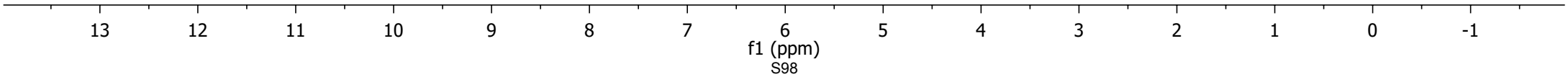

8.56
8.55
8.44
7.99
7.98
7.98
7.97
7.97
7.96
7.84
7.83
7.83
7.83
7.82
7.82
7.31
7.30
7.26 CDCl3


2.25

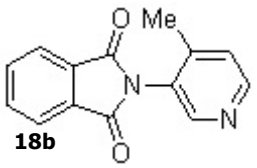

7.26 CDCl3
1.00
0.91
1.98
2.11
1.04
8.5
8.0
7.5
f1 (ppm)


1.00
0.91
1.98
2.11
1.04

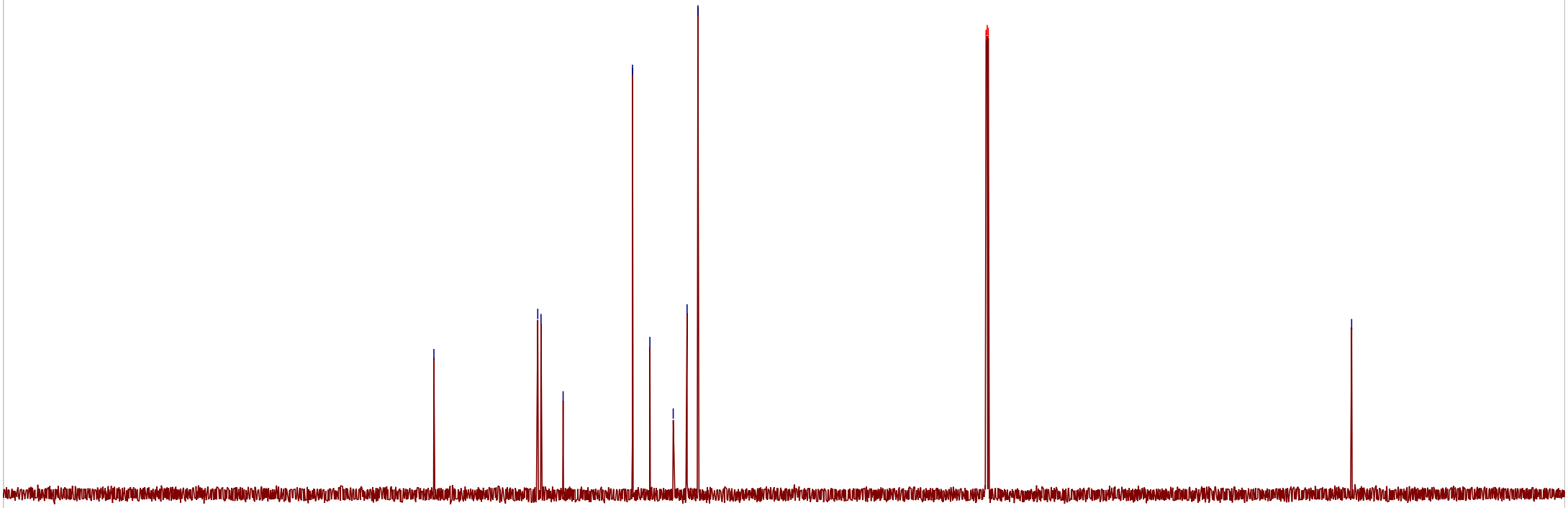
3.12


13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
f1 (ppm)

^{13}C NMR of **18b**



167.05
150.17
149.64
146.05
134.78
131.95
128.16
125.92
124.15
77.34 cdcl3
77.16 cdcl3
76.98 cdcl3
17.95

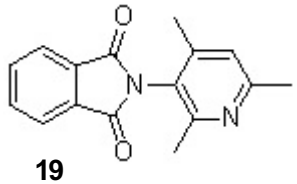


230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

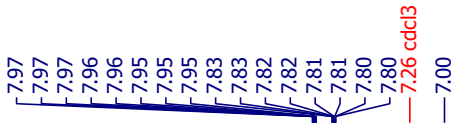
f1 (ppm)

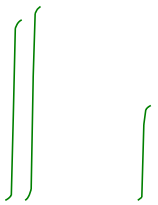
S99

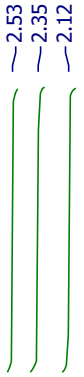
^{1}H NMR of **19**

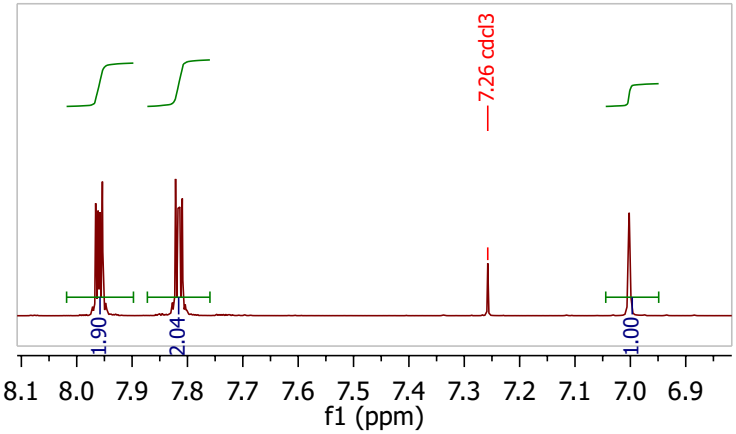


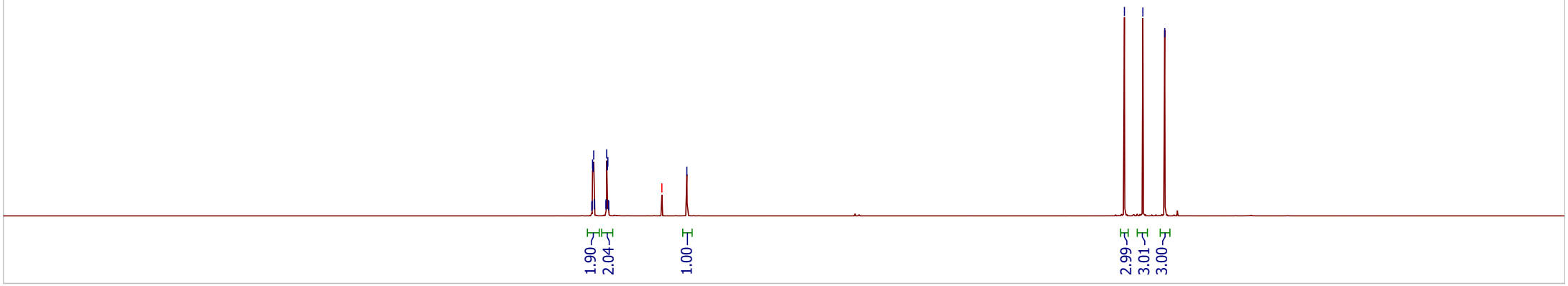
19

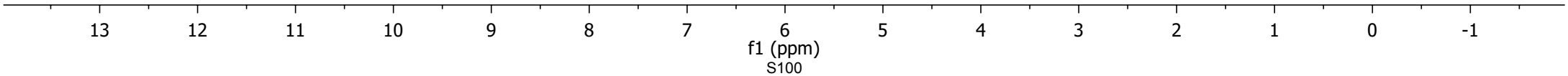




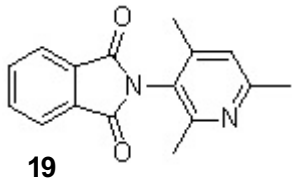






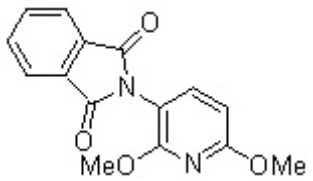


^{13}C NMR of **19**

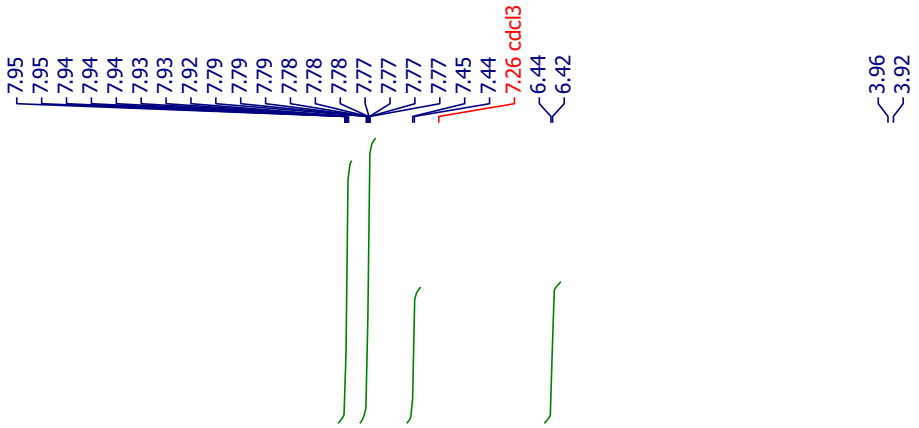


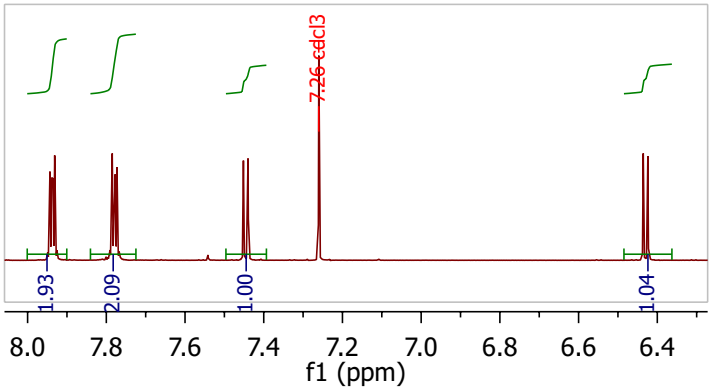
19

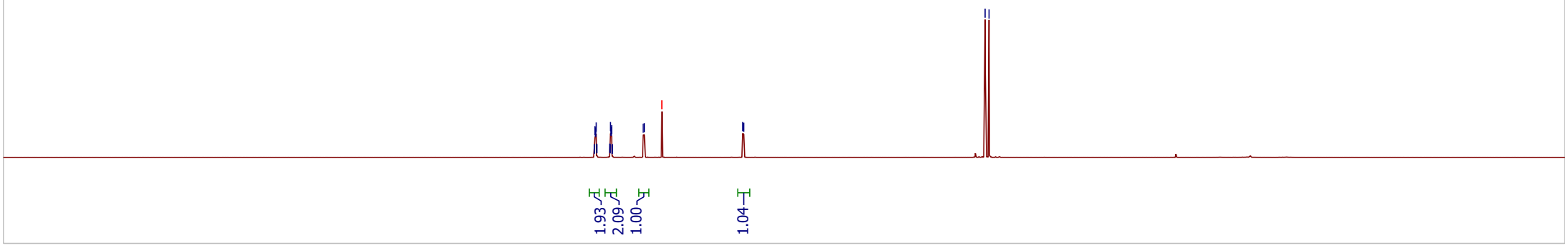
^{1}H NMR of **20**

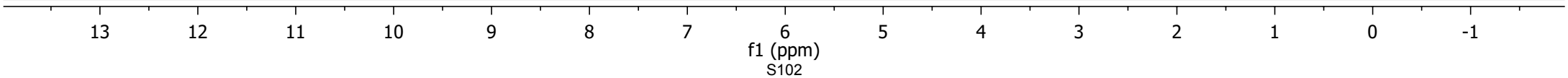


20

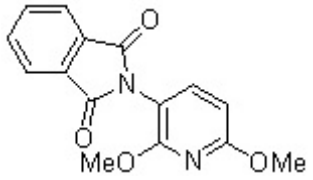






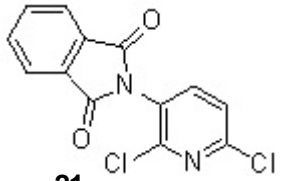


^{13}C NMR of **20**

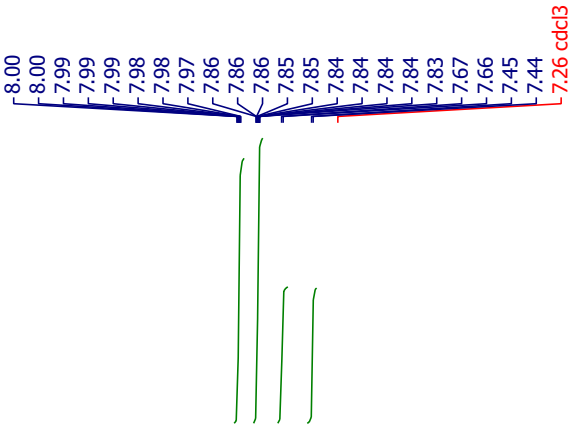


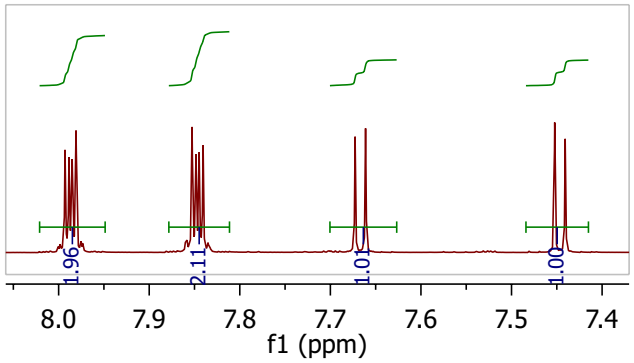
20

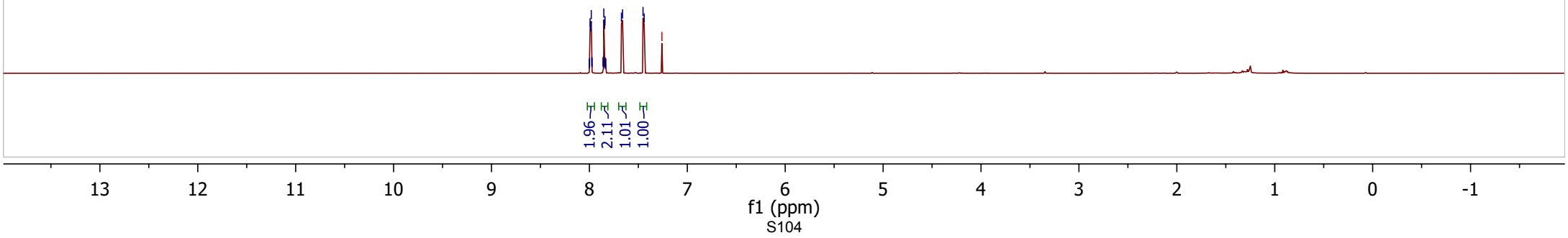
^{1}H NMR of **21**



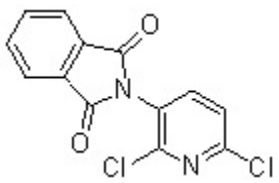
21





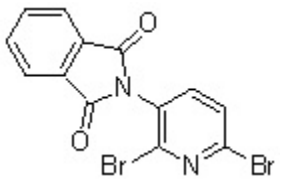


^{13}C NMR of **21**

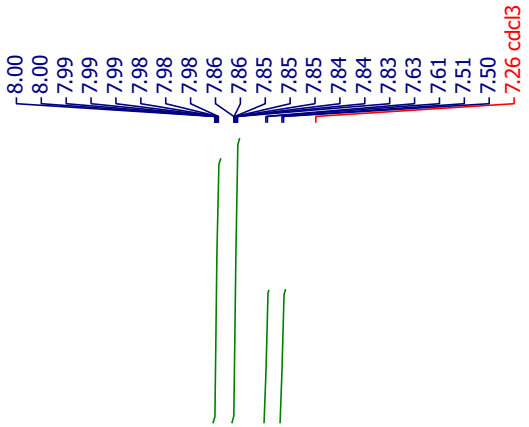


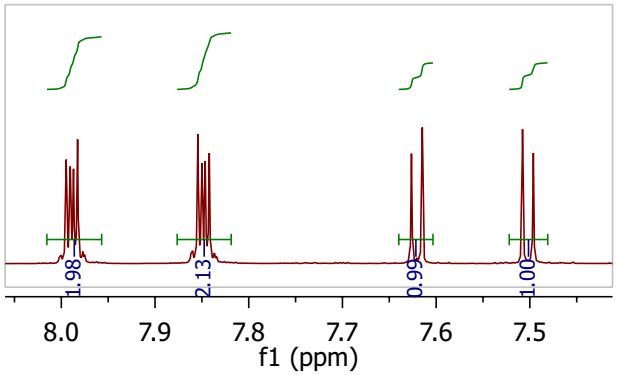
21

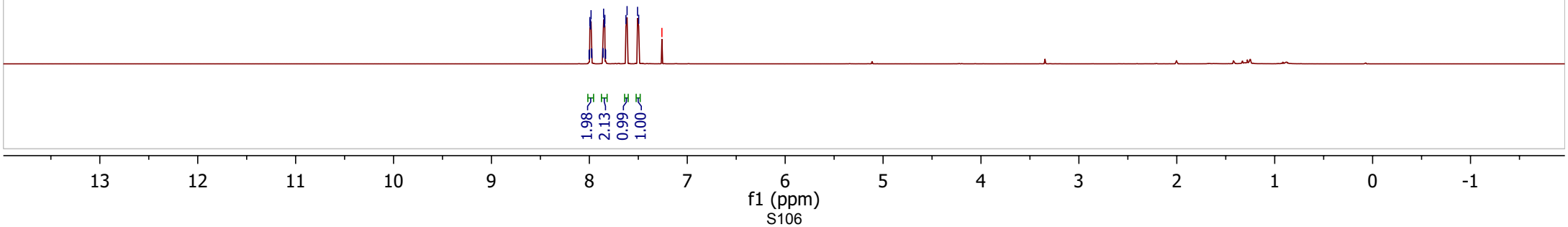
^{1}H NMR of **22**



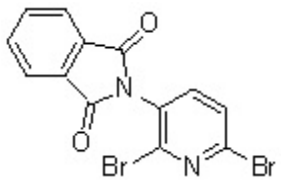
22





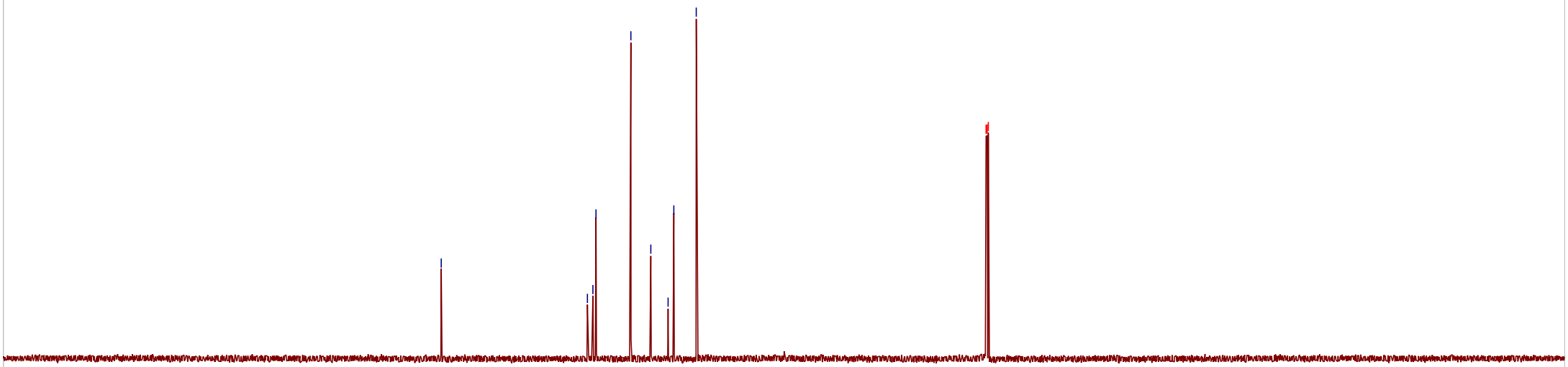


^{13}C NMR of **22**



22

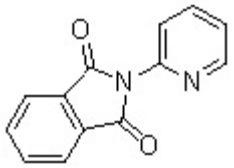
165.86
142.11
141.22
140.72
135.05
131.81
129.00
128.07
124.43
77.34 cdcl3
77.16 cdcl3
76.98 cdcl3



230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10

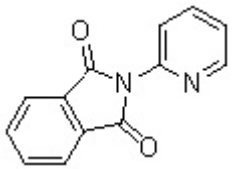
f1 (ppm)

^{1}H NMR of **23a**



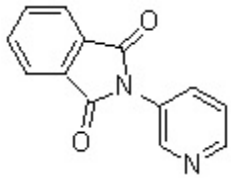
23a

^{13}C NMR of **23a**

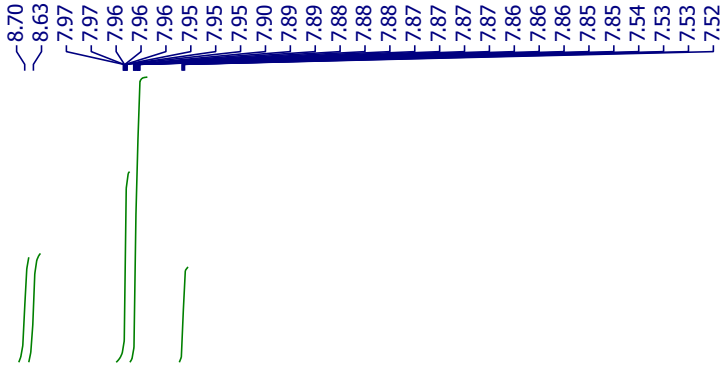


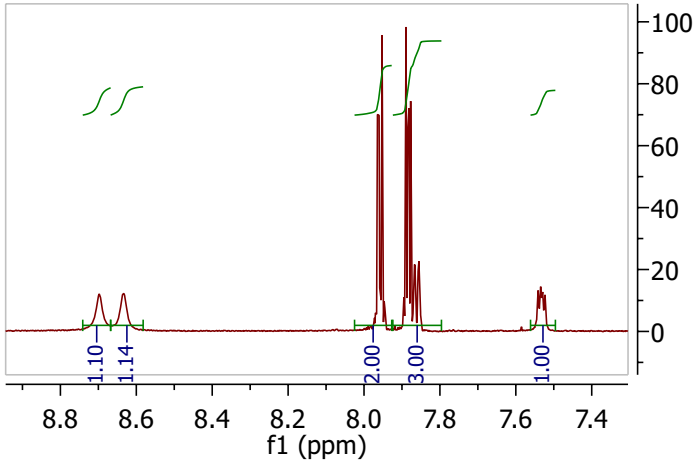
23a

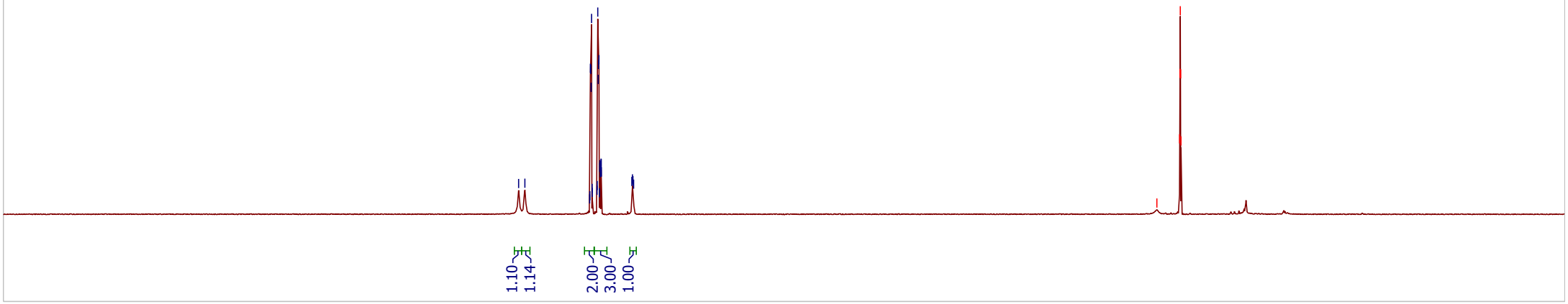
^{1}H NMR of **23b**



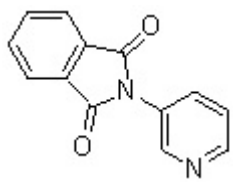
23b







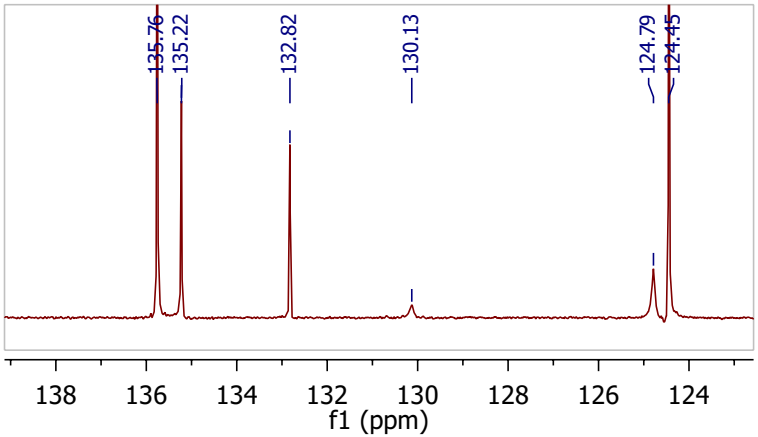
^{13}C NMR of **23b**



23b

168.02
149.81
148.68
135.76
135.22
132.82
130.13
124.79
124.45
118.26 cd3cn

1.64
1.52 cd3cn
1.40 cd3cn
1.28 cd3cn
1.17
1.05
0.93



230 220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)