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Supporting Information

Tertiary amine-directed and involved carbonylative cyclizations through Pd/Cu-cocatalyzed multiple C–X (X = H or N) bond cleavage

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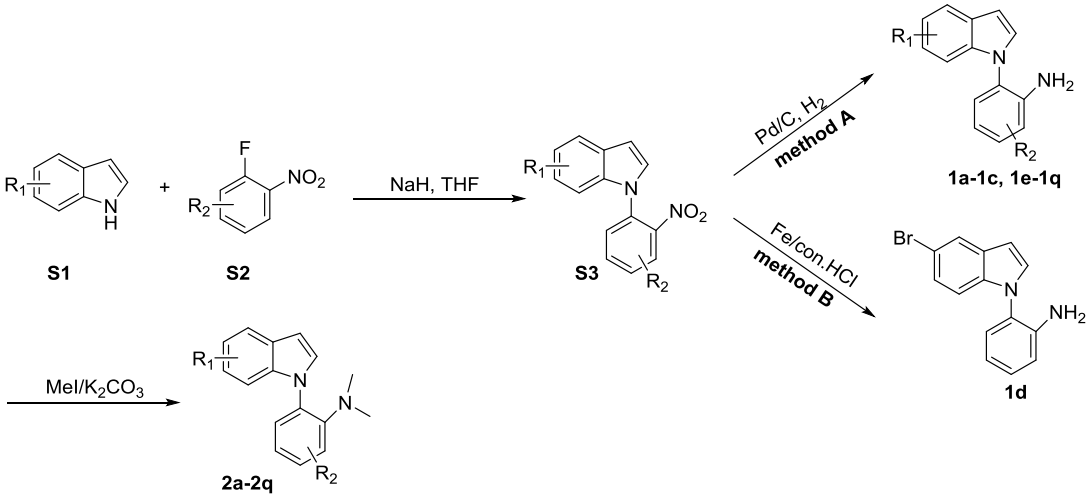
1. General

Unless specifically stated, all reagents were commercially obtained and where appropriate, purified prior to use. Unless other noted, all experiments were carried out in oven-dried Schlenk tube under a mixed CO/O_2 atmosphere with a balloon. THF, toluene and 1,4-dioxane, DMA were purified and dried according to the standard procedures. Reactions were monitored by thin layer chromatography (TLC) using silica gel plates. Flash column chromatography was performed over silica (300-400 mesh). Deuterated solvents were purchased from Cambridge Isotope Laboratories. The other regular chemicals were obtained from commercial suppliers with purity over 98% and used without further purification. Nuclear magnetic resonance spectra (^{1}H NMR, ^{13}C NMR and ^{19}F NMR) were recorded using a Bruker 400 MHz or 500 MHz spectrometer. The chemical shifts were reported ppm relative to tetramethylsilane (TMS) with the solvent resonance employed as the internal standard ($CHCl_3$ at 7.26). ^{13}C NMR was recorded at 100 MHz: $CDCl_3$, and 77.0 or 77.16 ppm are commonly used values. ^{19}F NMR spectra were recorded at 376 MHz. Multiplicities were given as: s (singlet); d (doublet); dd (doublets of doublet); t (triplet); q (quartet); m (multiplets). GC/MS date was collected using an Agilent 7890A series GC and 5975C Ms detector. High-resolution mass spectral (HRMS) data were recorded by an Bruker Daltonics micro TOF-spectrometer. Computational study was conducted using Guass 09 with B3LYP and the LANL2DZ basis set for Pd, 6-31 G(d,p) basis set for other atoms. Activation free energies are given in kcal/mol. Infrared spectra (FT-IR) were recorded using a BRUKER VERTEX 70 Spectrometer and analyzed as thin films, with absorption maxima (νmax) being quoted in wave numbers (cm^{-1}). Melting points (m.p.) were recorded using a JM 628 X-4 melting point apparatus.

2. Experimental procedures and Compound characterizations

2.1 General procedure for the preparation of the 2[1,2]



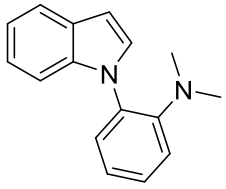
To the stirred solution of Indole **S1** (5 mmol) in dry THF (15 mL), was added NaH (1.5 equiv) at 0 ℃ under nitrogen atmosphere and the reaction mixture was stirred for 0.5 h at room temperature. **S2** (1.3 equiv) was added slowly and stirred for 24 h at 80 ℃ under nitrogen atmosphere. Upon completion of reaction, the reaction mixture was quenched with sat. aq. NH_4Cl, and extracted with EtOAc. The combined organic layer was washed with brine and dried over Na_2SO_4, filtered and concentrated under reduce pressure go give crude product **S3**, which could be used without further purification.

Method A: To a stirred solution of **S3** in absolute ethanol (30 mL), 10% Pd/C (20 mol%) was added. The reaction mixture was stirred at room temperature under a hydrogen atmosphere using hydrogen balloon until the completion of reaction. The reaction mixture was filtered through Celite and rinsed with EtOAc. The filtrate was evaporated in vacuum to obtain the desired amines **1a-1c**, **1e-1q**, which was used without further purification.

Method B: **S3** was dissolved in EtOH (60 mL) and water (15 mL). After adding concentrated HCl (0.1 mL) and iron powder (10.0 equiv) to the above solution, the resulting mixture was stirred vigorously at 100 ℃ under nitrogen atmosphere. Upon completion of the reaction, the reaction mixture was cooled to room temperature, diluted with water, and extracted with EtOAc. The combined organic layer was

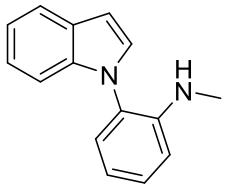
washed with brine, dried with anhydrous Na_2SO_4, and concentrated under vacuum to give crude product **1d**, which was used without further purification.

To a stirred solution of **1a-1q** in absolute DMF (15 mL), K_2CO_3 (2.5 equiv) was added. The reaction mixture was stirred for 1 h at room temperature under nitrogen atmosphere and MeI (2.2 equiv) was added. The reaction mixture was stirred at 40 °C until the completion of reaction. The reaction mixture was diluted with water, and extracted with EtOAc. The combined organic layer was washed with brine, dried with anhydrous Na_2SO_4, and concentrated under vacuum to give crude product **2a-2q**, which was purified by column chromatography with silica gel.



2a

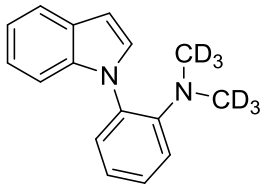
2-(1*H*-indol-1-yl)-*N*,*N*-dimethylaniline (2a)[3]. Following the general procedure, the product was isolated by column chromatography with petroleum ether/DCM (10 : 1) as the eluent to give a colorless gummy (0.71 g, 60%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.59 (t, *J* = 4.0 Hz, 1H), 7.27-7.21 (m, 4H), 7.19-7.00 (m, 2H), 7.02 (d, *J* = 8.0 Hz, 1H), 6.95 (t, *J* = 8.0 Hz, 1H), 6.59 (d, *J* = 4.0 Hz, 1H), 2.30 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 148.9, 136.0, 130.3, 128.7, 128.6, 120.8, 120.7, 120.6, 119.9, 110.9, 103.0, 102.9, 41.9. HRMS (ESI-TOF) Calcd for $C_{16}H_{16}N_2$ $[M+H]^+$: 237.1313, found: 237.1387.



2a-H

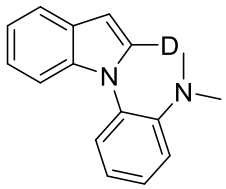
2-(1*H*-indol-1-yl)-*N*-methylaniline (2a-H). Following the general procedure, the product was isolated by column chromatography with petroleum ether/DCM (10 : 1) as the eluent to give a colorless gummy (0.45 g, 40%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.73-7.71 (m, 1H), 7.40-7.36 (m, 1H), 7.26-7.17 (m, 4H), 7.14-7.12 (m, 1H), 6.83-6.79 (m, 2H), 6.72 (d, *J* = 4.0 Hz, 1H), 3.60 (s, 1H), 2.78 (s, 3H). ^{13}C NMR (100

MHz, $CDCl_3$) δ 145.6, 136.5, 129.5, 128.8, 128.5, 128.4, 122.2, 120.9, 120.1, 116.5, 110.8, 110.7, 103.2, 30.2. HRMS (ESI-TOF) Calcd for $C_{15}H_{14}N_2Na$ $[M+Na]^+$: 245.1049, found: 245.1060.



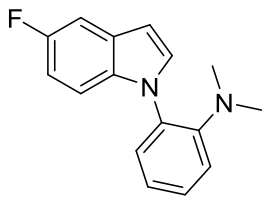
2a-*d*$_6$
>97%D

2-(1*H*-indol-1-yl)-*N*,*N*-bis(methyl-*d*$_3$)aniline (2a-*d*$_6$). Following the general procedure, the product was isolated by column chromatography with petroleum ether/DCM (10 : 1) as the eluent to give a colorless gummy (0.74 g, 61%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69-7.67 (m, 1H), 7.36-7.28 (m, 4H), 7.19-7.17 (m, 2H), 7.16 (d, *J* = 4.0 Hz, 1H), 7.05-7.01 (t, *J* = 8.0, 8.0 Hz, 1H), 6.69 (d, *J* = 4.0 Hz, 1H) HRMS (ESI-TOF) Calcd for $C_{16}H_{11}D_6N_2$ $[M+H]^+$: 243.1763, found: 243.1764.



2a-*d*$_1$
>99%D

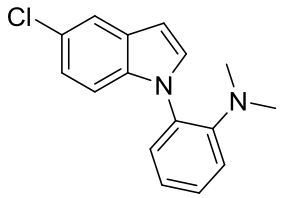
2-(1*H*-indol-1-yl-2-*d*)-*N*,*N*-dimethylaniline (2a-*d*$_1$). Following the general procedure, the product was isolated by column chromatography with petroleum ether/DCM (10 : 1) as the eluent to give a colorless gummy (0.45 g, 40%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.59-7.57 (m, 1H), 7.26-7.19 (m, 3H), 7.09-7.05 (m, 2H), 7.00 (d, *J* = 8.0 Hz, 1H), 6.93-6.89 (m, 1H), 6.58 (s, 1H), 2.29 (s, 6H). HRMS (ESI-TOF) Calcd for $C_{16}H_{16}DN_2$ $[M+H]^+$: 238.1449, found: 238.1457.



2b

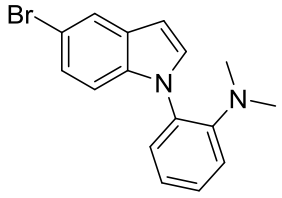
2-(5-fluoro-1*H*-indol-1-yl)-*N*,*N*-dimethylaniline (2b)[3]. Following the general

procedure, the product was isolated by column chromatography with petroleum ether/DCM (10 : 1) as the eluent to give a colorless gummy (0.69 g, 55%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.27 (d, *J* = 4.0 Hz, 1H), 7.23-7.19 (m, 3H), 7.18 (d, *J* = 8.0 Hz, 1H), 7.07 (t, *J* = 4.0 Hz, 1H), 6.99-6.88 (m, 1H), 6.83-6.78 (m, 1H), 6.52 (d, *J* = 4.0 Hz, 1H), 2.27 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 159.3, 157.0, 148.8, 132.5, 130.2 (d, *J* = 3.0 Hz), 128.9 (d, *J* = 11.0 Hz), 128.6, 128.3, 120.9, 118.5, 111.7 (d, *J* = 9.0 Hz), 110.3 (d, *J* = 20.0 Hz), 105.5 (d, *J* = 23.0 Hz), 102.9 (d, *J* = 5.0 Hz). HRMS (ESI-TOF) Calcd for $C_{16}H_{16}FN_2$ $[M+H]^+$: 255.1292, found: 255.1300.



2c

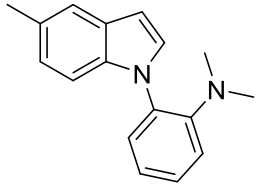
2-(5-chloro-1*H*-indol-1-yl)-*N*,*N*-dimethylaniline (2c)[3]. Following the general procedure, the product was isolated by column chromatography with petroleum ether/DCM (10 : 1) as the eluent to give a colorless gummy (0.78 g, 58%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.55 (d, *J* = 4.0 Hz, 1H), 7.28-7.26 (m, 2H), 7.20-7.18 (m, 1H), 7.10 (d, *J* = 8.0 Hz, 1H), 7.05-7.03 (m, 2H), 6.95 (s, 1H), 6.54-6.53 (m, 1H), 2.30 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 148.7, 134.3, 129.9, 129.6, 128.6, 128.4, 125.6, 122.2, 121.0, 120.0, 118.6, 112.0, 102.6, 41.9. HRMS (ESI-TOF) Calcd for $C_{16}H_{16}ClN_2$ $[M+H]^+$: 271.0997, found: 271.1000.



2d

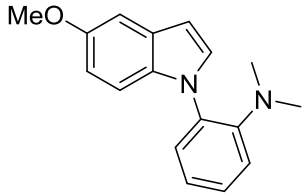
2-(5-bromo-1*H*-indol-1-yl)-*N*,*N*-dimethylaniline (2d). Following the general procedure, the product was isolated by column chromatography with petroleum ether/DCM (10 : 1) as the eluent to give a colorless gummy (0.71 g, 45%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69 (s, 1H), 7.25-7.21 (m, 2H), 7.17-7.14 (m, 2H), 7.05-6.99 (m,

2H), 6.94-6.92 (m, 1H), 6.52 (d, *J* = 4.0 Hz, 1H), 2.27 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 149.0, 134.8, 130.5, 130.1, 128.8, 128.7, 125.0, 123.3, 121.2, 118.8, 113.4, 112.7, 102.7, 42.1. HRMS (ESI-TOF) Calcd for $C_{16}H_{16}BrN_2$ $[M+H]^+$: 315.0491, found: 315.0502.



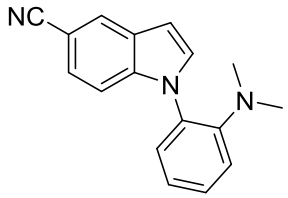
2e

***N,N*-dimethyl-2-(5-methyl-1*H*-indol-1-yl)-aniline (2e)[3]**. Following the general procedure, the product was isolated by column chromatography with petroleum ether/DCM (10 : 1) as the eluent to give a colorless gummy (0.75 g, 60%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35 (s, 1H), 7.21-7.16 (m, 3H), 7.09 (d, *J* = 8.0 Hz, 1H), 6.97 (d, *J* = 8.0 Hz, 1H), 6.91 (t, *J* = 8.0, 8.0 Hz, 2H), 6.48 (s, 1H), 2.36 (s, 3H), 2.28 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 149.5, 134.8, 129.2, 129.0, 128.8, 128.7, 123.6, 120.9, 120.5, 118.4, 110.1, 102.6, 42.0, 21.6. HRMS (ESI-TOF) Calcd for $C_{17}H_{19}N_2$ $[M+H]^+$: 251.1543, found: 251.1548.



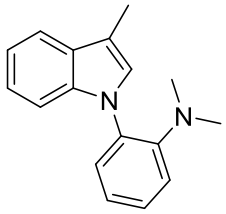
2f

2-(5-methoxy-1*H*-indol-1-yl)-*N,N*-dimethylaniline (2f)[3]. Following the general procedure, the product was isolated by column chromatography with petroleum ether/DCM (5 : 1) as the eluent to give a colorless gummy (0.70 g, 53%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.25-7.18 (m, 3H), 7.11 (d, *J* = 2.0 Hz, 1H), 7.05 (s, 1H), 7.02 (d, *J* = 8.0 Hz, 1H), 6.95-6.91 (m, 1H), 6.77 (t, *J* = 8.0, 4.0 Hz, 1H), 6.52 (d, *J* = 4.0 Hz, 1H), 3.79 (s, 3H), 2.32 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 154.3, 148.7, 131.2, 130.4, 129.1, 129.0, 128.5, 127.9, 120.8, 118.3, 112.0, 111.7, 102.5, 102.2, 55.8, 41.8. HRMS (ESI-TOF) Calcd for $C_{17}H_{19}N_2O$ $[M+H]^+$: 267.1492, found: 267.1500.



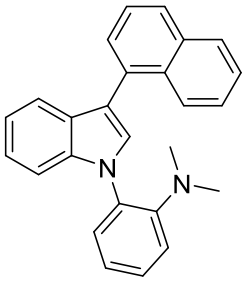
2g

1-(2-(dimethylamino)phenyl)-1*H*-indole-5-carbonitrile (2g). Following the general procedure, the product was isolated by column chromatography with petroleum ether/DCM (5 : 1) as the eluent to give a colorless semi-solid (0.50 g, 38%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 (s, 1H), 7.38 (d, *J* = 4.0 Hz, 1H), 7.33-7.27 (m, 2H), 7.22-7.16 (m, 2H), 7.06 (d, *J* = 8.0 Hz, 1H), 6.98 (t, *J* = 4.0, 8.0 Hz, 1H), 6.67 (s, 1H), 2.28 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 148.8, 137.4, 131.0, 128.9, 128.4, 128.3, 126.2, 124.9, 121.2, 118.8, 111.9, 103.7, 103.0, 41.9. HRMS (ESI-TOF) Calcd for $C_{17}H_{15}N_3$ $[M+H]^+$: 262.1266, found: 262.1330.



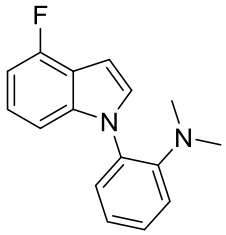
2h

***N*,*N*-dimethyl-2-(3-methyl-1*H*-indol-1-yl)aniline (2h)**. Following the general procedure, the product was isolated by column chromatography with petroleum ether/DCM (10 : 1) as the eluent to give a colorless semi-solid (0.64 g, 51%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.53 (d, *J* = 8.0 Hz, 1H), 7.21-7.15 (m, 3H), 7.10-7.04 (m, 3H), 6.99 (d, *J* = 8.0 Hz, 1H), 6.91 (t, *J* = 4.0, 8.0 Hz, 1H), 2.31 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 148.8, 136.2, 129.1, 128.7, 127.7, 126.1, 121.8, 119.3, 118.7, 118.3, 112.1, 110.9, 41.9, 9.83. HRMS (ESI-TOF) Calcd for $C_{17}H_{19}N_2$ $[M+H]^+$: 251.1543, found: 251.1548.



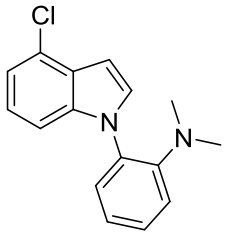
2i

***N,N*-dimethyl-2-(3-(naphthalen-1-yl)-1*H*-indol-1-yl)aniline (2i)**. Following the general procedure, the product was isolated by column chromatography with petroleum ether/DCM (5 : 1) as the eluent to give a light brown semi-solid (0.54 g, 30%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.11 (d, *J* = 8.0 Hz, 1H), 7.85 (d, *J* = 8.0 Hz, 1H), 7.80 (d, *J* = 8.0 Hz, 1H), 7.60 (d, *J* = 8.0 Hz, 1H), 7.50-7.46 (m, 3H), 7.43-7.37 (m, 2H), 7.35-7.32 (m, 2H), 7.29-7.25 (m, 1H), 7.19-7.14 (m, 1H), 7.09 (t, *J* = 8.0, 4.0 Hz, 2H), 7.02 (t, *J* = 8.0, 8.0 Hz, 1H), 2.4 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 148.9, 134.1, 128.6, 128.3, 128.2, 127.7, 127.2, 126.6, 125.7, 122.4, 120.3, 120.2, 111.1, 42.1. HRMS (ESI-TOF) Calcd for $C_{26}H_{22}N_2$ $[M+H]^+$: 363.1783, found:363.1857.



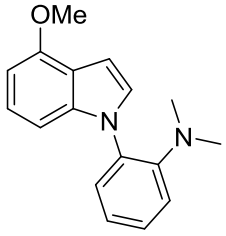
2j

2-(4-fluoro-1*H*-indol-1-yl)-*N,N*-dimethylaniline (2j). Following the general procedure, the product was isolated by column chromatography with petroleum ether/DCM (10 : 1) as the eluent to give a colorless gummy (0.57 g, 40%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.23-7.16 (m, 3H), 6.99-6.87 (m, 4H), 6.72-6.67 (m, 1H), 6.65 (d, *J* = 4.0 Hz, 1H), 2.27 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.5, 155.1, 148.9, 138.8 (d, *J* = 11.0 Hz), 128.7, 128.5, 122.4 (d, *J* = 8.0 Hz), 120.9, 118.6, 117.5, 107.1 (d, *J* = 3.0 Hz), 104.9 (d, *J* = 19.0 Hz), 99.0, 41.9. ^{19}F NMR (376 MHz, $CDCl_3$): δ -122.5. HRMS (ESI-TOF) Calcd for $C_{16}H_{16}FN_2$ $[M+H]^+$: 255.1292, found: 255.1298.



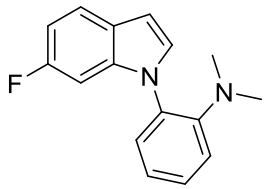
2k

2-(4-chloro-1*H*-indol-1-yl)-*N*,*N*-dimethylaniline (2k). Following the general procedure, the product was isolated by column chromatography with petroleum ether/DCM (10 : 1) as the eluent to give a colorless gummy (0.77 g, 53%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.26 (d, *J* = 4.0 Hz, 1H), 7.21 (t, *J* = 12.0, 12.0 Hz, 1H), 7.15 (d, *J* = 8.0 Hz, 1H), 7.05 (t, *J* = 8.0, 12.0 Hz, 2H), 6.98-6.94 (m, 2H), 6.91 (t, *J* = 8.0, 8.0 Hz, 1H), 6.67 (d, *J* = 4.0 Hz, 1H), 2.26 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 149.1, 137.1, 130.2, 129.6, 128.9, 128.8, 127.7, 126.2, 122.8, 121.3, 120.1, 118.9, 110.0, 101.8, 42.2. HRMS (ESI-TOF) Calcd for $C_{16}H_{16}ClN_2$ $[M+H]^+$: 271.0997, found: 271.1000.



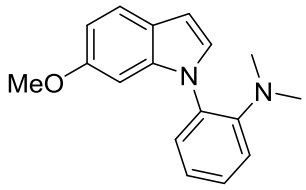
2l

2-(4-methoxy-1*H*-indol-1-yl)-*N*,*N*-dimethylaniline (2l). Following the general procedure, the product was isolated by column chromatography with petroleum ether/DCM (5 : 1) as the eluent to give a colorless gummy (0.93 g, 70%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.26 (t, *J* = 8.0, 8.0 Hz, 2H), 7.18 (s, 1H), 7.05 (t, *J* = 8.0, 8.0 Hz, 2H), 6.96 (d, *J* = 8.0, 1H), 6.84 (d, *J* = 8.0, 1H), 6.71 (d, *J* = 4.0 Hz, 1H), 6.51 (d, *J* = 8.0 Hz, 1H), 3.92 (s, 3H), 2.33 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 153.1, 137.5, 130.3, 128.8, 128.1, 127.3, 122.6, 119.0, 118.4, 104.3, 100.1, 99.8, 55.3, 41.9. HRMS (ESI-TOF) Calcd for $C_{17}H_{19}N_2O$ $[M+H]^+$: 267.1492, found: 267.1499.



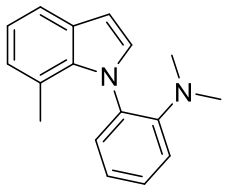
2m

2-(6-fluoro-1*H*-indol-1-yl)-*N*,*N*-dimethylaniline (2m). Following the general procedure, the product was isolated by column chromatography with petroleum ether/DCM (10 : 1) as the eluent to give a colorless gummy (0.79 g, 62%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.48-7.44 (m, 1H), 7.24-7.16 (m, 3H), 7.01 (d, *J* = 8.0 Hz, 1H), 6.93 (t, *J* = 8.0, 8.0 Hz, 1H), 6.86-6.79 (m, 1H), 6.55 (d, *J* = 4.0 Hz, 1H), 2.29 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 161.0, 158.7, 148.5, 138.7, 135.9 (d, *J* = 12.0 Hz), 128.9, 128.3, 125.0, 121.1 (d, *J* = 10.0 Hz), 118.3, 108.6 (d, *J* = 25.0 Hz), 102.9, 97.4 (d, *J* = 27.0 Hz), 41.7. ^{19}F NMR (376 MHz, $CDCl_3$): δ -120.8. HRMS (ESI-TOF) Calcd for $C_{16}H_{16}FN_2$ $[M+H]^+$: 255.1292, found: 255.1298.



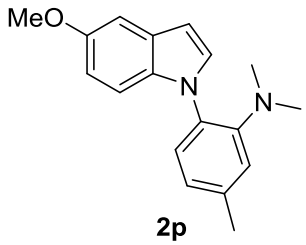
2n

2-(6-methoxy-1*H*-indol-1-yl)-*N*,*N*-dimethylaniline (2n). Following the general procedure, the product was isolated by column chromatography with petroleum ether/DCM (5 : 1) as the eluent to give a colorless gummy (0.60 g, 45%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.46 (d, *J* = 8.0 Hz, 1H), 7.27-7.23 (m, 2H), 7.15 (d, *J* = 4.0 Hz, 1H), 7.04 (d, *J* = 4.0 Hz, 1H), 6.97 (t, *J* = 8.0, 8.0 Hz, 1H), 6.76-6.73 (m, 1H), 6.67 (s, 1H), 6.53 (d, *J* = 4.0 Hz, 1H), 3.71 (s, 3H), 2.34 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.4, 136.7, 130.3, 128.7, 128.0, 127.6, 122.8, 121.1, 118.4, 109.9, 102.8, 94.4, 55.6, 41.8. HRMS (ESI-TOF) Calcd for $C_{17}H_{19}N_2O$ $[M+H]^+$: 267.1492, found: 267.1498.



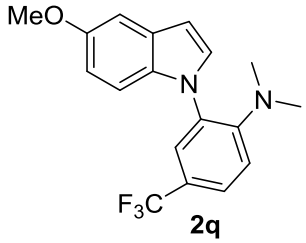
2o

***N,N*-dimethyl-2-(7-methyl-1*H*-indol-1-yl)-aniline (2o)**. Following the general procedure, the product was isolated by column chromatography with petroleum ether/DCM (10 : 1) as the eluent to give a colorless gummy (0.42 g, 33%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.43 (d, *J* = 8.0 Hz, 1H), 7.24 (t, *J* = 8.0, 8.0 Hz, 1H), 7.11 (d, *J* = 8.0 Hz, 1H), 7.03 (d, *J* = 4.0 Hz, 1H), 6.96-6.81 (m, 4H), 6.54 (s, 1H), 2.33 (s, 6H), 1.97 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 149.9, 135.2, 132.4, 130.8, 130.3, 129.4, 128.8, 124.5, 122.3, 120.0, 119.9, 118.8, 117.7, 103.0, 42.1, 18.7. HRMS (ESI-TOF) Calcd for $C_{17}H_{18}N_2$ $[M+H]^+$: 251.1548, found: 251.1545.



2p

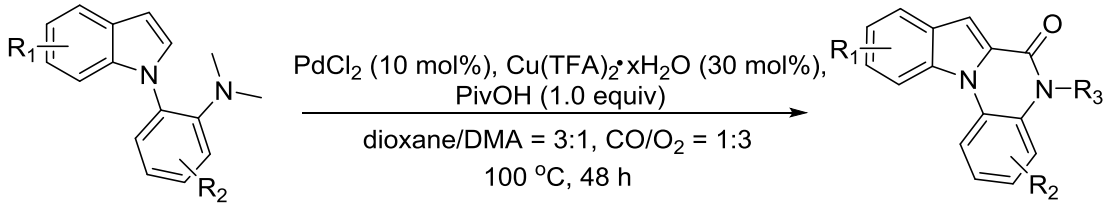
2-(5-methoxyl-1*H*-indol-1-yl)-*N,N*,5-trimethylaniline (2p). Following the general procedure, the product was isolated by column chromatography with petroleum ether/DCM (5 : 1) as the eluent to give a colorless gummy (0.35 g, 25%). ^{1}H NMR (400 MHz, CDCl3) δ 7.18 (d, *J* = 4.0 Hz, 1H), 7.06 (d, *J* = 8.0 Hz, 2H), 7.01 (s, 1H), 6.76-6.68 (m, 3H), 6.47 (d, *J* = 4.0 Hz, 1H), 3.74 (s, 3H), 2.28 (s, 3H), 2.26 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 154.4, 148.5, 137.9, 129.3, 129.0, 128.4, 128.0, 121.5, 119.0, 112.0, 111.8, 102.4, 102.2, 55.8, 41.9, 21.6. HRMS (ESI-TOF) Calcd for $C_{18}H_{20}N_2O$ $[M+H]^+$: 281.1654, found: 281.1652.



2q

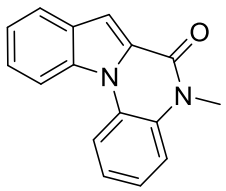
2-(5-methoxyl-1*H*-indol-1-yl)-*N*,*N*-dimethyl-4-(trifluoromethyl)aniline (2q). Following the general procedure, the product was isolated by column chromatography with petroleum ether/DCM (5 : 1) as the eluent to give a colorless gummy (0.45 g, 27%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.31 (d, *J* = 8.0 Hz, 1H), 7.22-7.14 (m, 3H), 7.07 (s, 1H), 7.05 (d, *J* = 4.0 Hz, 1H), 6.78 (d, *J* = 8.0 Hz, 1H), 6.54 (s, 1H), 3.78 (s, 3H), 2.35 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 154.7, 148.8, 132.9, 130.8, 130.0, 129.7, 129.2, 128.8, 128.4, 125.4, 122.7, 117.2 (d, *J* = 3.0 Hz), 115.1, 112.4, 111.5, 103.6, 102.5, 55.7, 41.4. ^{19}F NMR (376 MHz, $CDCl_3$): δ -62.4. HRMS (ESI-TOF) Calcd for $C_{18}H_{18}F_3N_2O$ $[M+H]^+$: 335.1366, found: 335.1350.

2.2 General procedure for the preparation of the 3



2a-2q **3a-3q**

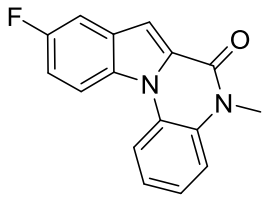
In an oven-dried Schlenk tube equipped with a stir-bar, **2a-2q** (0.5 mmol, 1.0 equiv), $PdCl_2$ (10 mol %), $Cu(TFA)_2 \cdot xH_2O$ (30 mol %), PivOH (1.0 equiv) were combined. A balloon filled V(CO)/V(O_2) = (1:3) (1 atm) was connected to the Schlenk tube via the side tube and purged for 3 times. Then dioxane/DMA = 3:1 (2.0 mL) were added to the tube via a syringe. The Schlenk tube was heated at 100 °C for 48 h, then cooled to room temperature. The reaction was quenched by aq. brine and extracted with EtOAc. The combined organic layer were washed with brine and dried over anhydrous Na_2SO_4, filtered and concentrated under reduce pressure. The residue was purified by column chromatography on silica gel to afford the corresponding products **3a-3q**.



3a

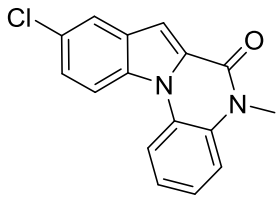
5-methylindolo[1,2-*a*]quinoxalin-6(5*H*)-one (3a)[3,4]. Following the general procedure, the product was isolated by column chromatography with petroleum

ether/EtOAc (4 : 1) as the eluent to give a brown solid (75 mg, 60%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.25-8.23 (m, 1H), 8.17 (d, *J* = 8.0 Hz, 1H), 7.80 (d, *J* = 8.0 Hz, 1H), 7.48 (s, 1H), 7.44-7.39 (m, 1H), 7.29-7.18 (m, 4H), 3.61 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.6, 134.2, 129.8, 129.2, 128.1, 125.3, 124.1, 123.2, 122.4, 115.5, 115.4, 114.2, 106.8, 28.9. HRMS (ESI-TOF) Calcd for $C_{16}H_{13}N_2O$ $[M+H]^+$: 249.1022, found: 249.1020.



3b

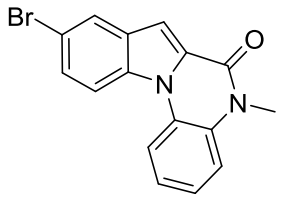
9-Fluoro-5-methylindolo[1,2-*a*]quinoxalin-6(5*H*)-one (3b)[3,4]. Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (4 : 1) as the eluent to give a brown solid (68 mg, 51%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.20-8.18 (m, 1H), 8.14-8.11 (m, 1H), 7.44-7.33 (m, 2H), 7.31-7.26 (m, 3H), 7.19-7.15 (m, 1H), 3.64 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.6, 156.2, 154.9, 129.6, 128.7, 128.6, 128.5, 128.2, 125.0, 123.2, 122.1, 114.5, 113.8, 106.4 (d, *J* = 22.0 Hz), 105.2 (d, *J* = 5.0 Hz), 27.7. HRMS (ESI-TOF) Calcd for $C_{16}H_{11}FN_2NaO$ $[M+Na]^+$: 289.0748, found: 289.0740.



3c

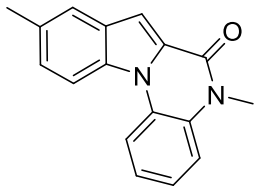
9-chloro-5-methylindolo[1,2-*a*]quinoxalin-6(5*H*)-one (3c)[3,4]. Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (4 : 1) as the eluent to give a brown solid (74 mg, 52%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.16 (t, *J* = 8.0, 4.0 Hz, 1H), 8.07 (d, *J* = 8.0 Hz, 1H), 7.72 (s, 1H), 7.39-7.19 (m, 6H), 3.58 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.1, 132.3, 130.1, 129.7, 129.1, 128.0, 126.1, 125.4, 124.5, 123.3, 122.2, 115.7, 115.2, 115.1, 105.9,

29.0. HRMS (ESI-TOF) Calcd for $C_{16}H_{12}ClN_2O$ $[M+H]^+$: 283.0633, found: 283.0640.



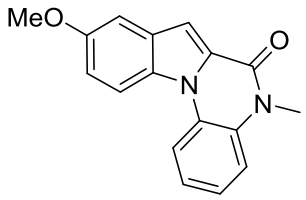
3d

9-bromo-5-methylindolo[1,2-*a*]quinoxalin-6(5*H*)-one (3d). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (4 : 1) as the eluent to give a brown solid (46 mg, 41%) (m.p. 226-228 °C). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.14 (d, *J* = 4.0 Hz, 1H), 8.01 (d, *J* = 8.0 Hz, 1H), 7.88 (s, 1H), 7.47 (d, *J* = 8.0 Hz, 1H), 7.37 (s, 1H), 7.28 (d, *J* = 4.0 Hz, 3H), 3.62 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.4, 132.9, 131.0, 130.1, 129.2, 128.3, 126.4, 125.7, 124.9, 123.7, 116.0, 115.7, 115.6, 106.1, 29.3. IR (neat) 2962, 2920, 2851, 1660, 1619, 1519, 1450, 1397, 1262, 1221, 1102, 801, 779, 743, 725 cm^{-1}. HRMS (ESI-TOF) Calcd for $C_{16}H_{12}BrN_2O$ $[M+H]^+$: 327.0128, found: 327.0139.



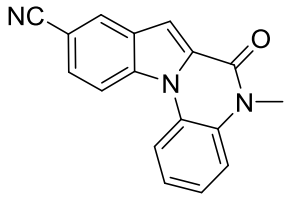
3e

5,9-dimethylindolo[1,2-*a*]quinoxalin-6(5*H*)-one (3e)[3,4]. Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (4 : 1) as the eluent to give a brown solid (66 mg, 50%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.24 (d, *J* = 8.0, 1H), 8.07 (d, *J* = 8.0 Hz, 1H), 7.58 (s, 1H), 7.42 (s, 1H), 7.30-7.24 (m, 4H), 3.63 (s, 3H), 2.45 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.6, 132.6, 132.0, 129.8, 129.5, 128.1, 127.1, 126.7, 123.9, 123.2, 122.6, 115.5, 115.2, 113.8, 106.3, 28.9, 21.3. HRMS (ESI-TOF) Calcd for $C_{17}H_{14}N_2O$ $[M+H]^+$: 263.1106, found: 263.1183.



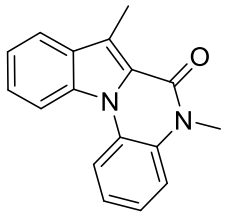
3f

9-methoxy-5-methylindolo[1,2-*a*]quinoxalin-6(5*H*)-one (3f)[3,4]. Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (3 : 1) as the eluent to give a brown solid (86 mg, 62%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.12 (t, *J* = 4.0, 4.0 Hz, 1H), 8.00 (d, *J* = 12.0 Hz, 1H), 7.36 (s, 1H), 7.25-7.18 (m, 3H), 7.11 (s, 1H), 7.03-7.00 (m, 1H), 3.82 (s, 3H), 3.59 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.6, 156.3, 155.4, 130.0, 129.6, 129.3, 128.4, 126.4, 123.1, 116.2, 115.5, 115.0, 114.9, 106.2, 103.0, 55.5, 28.9. HRMS (ESI-TOF) Calcd for $C_{17}H_{15}N_2O_2$ $[M+H]^+$: 279.1128, found: 279.1135.



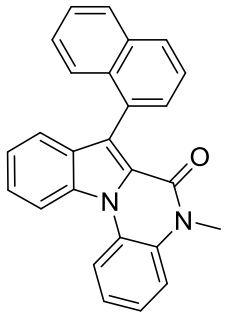
3g

5-methyl-6-oxo-5,6-dihydroindolo[1,2-*a*]quinoxaline-9-carbonitrile (3g). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (3 : 1) as the eluent to give a brown solid (55 mg, 40%) (m.p. 269-271 °C). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.27-8.20 (m, 2H), 8.14 (s, 1H), 7.63 (d, *J* = 8.0 Hz, 1H), 7.54 (s, 1H), 7.35-7.29 (m, 3H), 3.65 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.2, 135.4, 130.3, 129.0, 128.8, 127.5, 126.0, 125.7, 123.9, 119.6, 116.3, 116.0, 115.4, 107.3, 106.2, 29.9. IR (neat) 2960, 2923, 2852, 2220, 1729, 1656, 1604, 1504, 1455, 1420, 1297, 1260, 1100, 1029, 895, 802, 744 cm^{-1}. HRMS (ESI-TOF) Calcd for $C_{17}H_{12}N_3O$ $[M+H]^+$: 274.0975, found: 274.0973.



3h

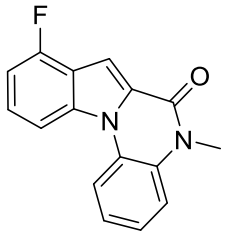
5,7-dimethylindolo[1,2-*a*]quinoxalin-6(5H)-one (3h). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (4 : 1) as the eluent to give a light brown solid (50 mg, 38%) (m.p. 190-192 °C). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.07 (t, *J* = 8.0, 8.0 Hz, 2H), 7.71 (d, *J* = 4.0 Hz, 1H), 7.38 (d, *J* = 8.0 Hz, 1H), 7.26 (t, *J* = 8.0, 8.0 Hz, 1H), 7.17 (d, *J* = 16.0 Hz, 3H), 3.50 (d, *J* = 4.0 Hz, 3H), 2.73 (d, *J* = 4.0 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 157.8, 132.8, 130.0, 129.8, 126.8, 125.5, 123.5, 123.0, 122.9, 121.6, 120.9, 118.9, 115.1, 114.9, 113.9, 28.4, 9.8. IR (neat) 2917, 1652, 1507, 1451, 1420, 1381, 1304, 1257, 1080, 800, 729 cm^{-1}. HRMS (ESI-TOF) Calcd for $C_{17}H_{15}N_2O$ $[M+H]^+$: 263.1179, found: 263.1182.



3i

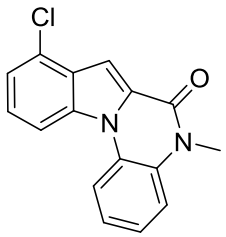
5-methyl-7-(naphthalene-1-yl)lindolo[1,2-*a*]quinoxalin-6(5*H*)-one (3i). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (3 : 1) as the eluent to give a light brown solid (81 mg, 43%) (m.p. 232-234 °C). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.37 (d, *J* = 8.0 Hz, 1H), 8.29 (d, *J* = 8.0 Hz, 1H), 7.88 (t, *J* = 12.0, 8.0 Hz, 2H), 7.54-7.45 (m, 4H), 7.38-7.27 (m, 2H), 7.25-7.14 (m, 5H), 3.47 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.1, 133.4, 131.2, 128.4, 128.1, 127.9, 126.1, 125.7, 125.6, 125.4, 125.0, 124.1, 122.9, 122.4, 122.3, 115.4, 113.9, 28.6. IR (neat) 2961, 2920, 1720, 1655, 1592, 1448, 1420, 1301, 1255, 1081, 1057, 959, 862, 803, 778, 733 cm^{-1}. HRMS (ESI-TOF) Calcd for $C_{26}H_{18}N_2NaO$

$[M+Na]^+$: 397.1311, found:397.1312.



3j

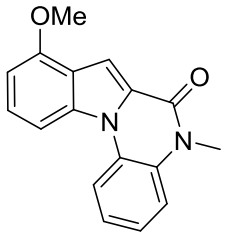
8-fluoro-5-methyllindolo[1,2-*a*]quinoxalin-6(5*H*)-one (3j). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (4 : 1) as the eluent to give a brown solid (65 mg, 49%) (m.p. 200-202 °C). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.24 (d, *J* = 8.0 Hz, 1H), 7.96 (d, *J* = 12.0 Hz, 1H), 7.58 (s, 1H), 7.38-7.33 (m, 1H), 7.29-7.19 (m, 3H), 6.98 (t, *J* = 8.0, 8.0 Hz, 1H), 5H), 3.63 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.4, 156.2, 155.9, 136.1 (d, *J* = 10.0 Hz), 129.9, 126.3, 125.8, 124.7, 123.3, 115.7 (d, *J* = 20.0 Hz), 110.3 (d, *J* = 4.0 Hz), 107.1 (d, *J* = 18.0 Hz), 102.6, 29.0. ^{19}F NMR (376 MHz, $CDCl_3$): δ -118.6. IR (neat) 2921, 2851, 1656, 1601, 1508, 1474, 1392, 1374, 1303, 1238, 1100, 1029, 814, 742, 732 cm^{-1}. HRMS (ESI-TOF) Calcd for $C_{16}H_{11}FN_2O$ $[M+H]^+$: 267.0934, found:267.0929.



3k

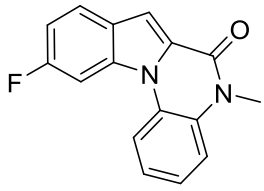
3-chloro-5-methyllindolo[1,2-*a*]quinoxalin-6(5*H*)-one (3k). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (4 : 1) as the eluent to give a brown solid (76 mg, 54%) (m.p. 178-180 °C). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.21 (t, *J* = 4.0, 4.0 Hz, 1H), 8.07 (d, *J* = 8.0 Hz, 1H), 7.60 (s, 1H), 7.33-7.19 (m, 5H), 3.63 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.2, 134.5, 129.9, 128.4, 126.2, 125.6, 124.7, 123.4, 122.1, 115.7, 115.5, 112.7, 105.2, 29.0. IR (neat) 2919, 2850, 1661, 1596, 1502, 1429, 1368, 1297, 1257,

1191, 967, 811, 771, 743, 733 cm^{-1}. HRMS (ESI-TOF) Calcd for $C_{16}H_{11}ClN_2O$ $[M+H]^+$: 283.0638, found:283.0636.



3l

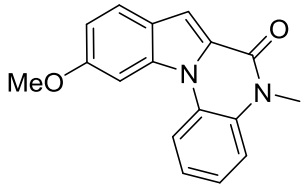
8-methoxy-5-methyllindolo[1,2-*a*]quinoxalin-6(5*H*)-one (3l). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (3 : 1) as the eluent to give a brown solid (88 mg, 63%) (m.p. 193-195 °C). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.22 (d, *J* = 4.0 Hz, 1H), 7.73 (d, *J* = 8.0 Hz, 1H), 7.63 (s, 1H), 7.24 (t, *J* = 4.0, 4.0 Hz, 3H), 6.65 (d, *J* = 8.0 Hz, 1H), 3.93 (s, 3H), 3.61 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.4, 154.5, 135.2, 129.9, 126.6, 126.2, 124.0, 122.9, 120.5, 115.3, 106.8, 104.2, 101.4, 55.3, 28.7. IR (neat) 2932, 1665, 1647, 1603, 1552, 1506, 1461, 1431, 1376, 1303, 1264, 1140, 1086, 1075, 769, 737 cm^{-1}. HRMS (ESI-TOF) Calcd for $C_{17}H_{14}N_2O_2$ $[M+H]^+$: 279.1134, found:279.1127.



3m

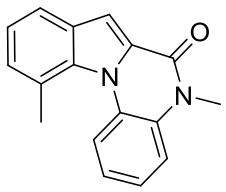
10-fluoro-5-methyllindolo[1,2-*a*]quinoxalin-6(5*H*)-one (3m). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (4 : 1) as the eluent to give a brown solid (55 mg, 41%) (m.p. 233-235 °C). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97 (t, *J* = 4.0, 4.0 Hz, 1H), 7.73-7.65 (m, 2H), 7.38 (s, 1H), 7.21-7.18 (m, 1H), 7.04-7.00 (m, 1H), 3.56 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 162.3, 159.9, 156.1, 133.5 (d, *J* = 12.0 Hz), 129.8, 128.6 (d, *J* = 4.0 Hz), 126.1, 125.5, 124.4, 124.0 (d, *J* = 11.0 Hz), 123.1, 115.6, 114.9, 111.7 (d, *J* = 24.0 Hz), 106.7, 100.8 (d, *J* = 28.0 Hz), 28.8. ^{19}F NMR (376 MHz, $CDCl_3$): δ -114.4.

IR (neat) 2961, 2922, 2851, 1657, 1610, 1560, 1488, 1393, 1298, 1258, 1142, 1097, 983, 821, 738, 724 cm^{-1}. HRMS (ESI-TOF) Calcd for $C_{16}H_{11}FN_2O_2$ $[M+H]^+$: 267.0934, found:267.0932.



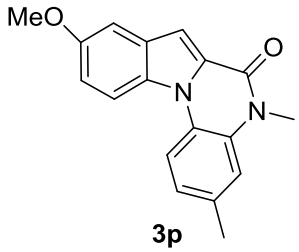
3n

10-methoxy-5-methyllindolo[1,2-*a*]quinoxalin-6(5*H*)-one (3n). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (3 : 1) as the eluent to give a brown solid (90 mg, 65%) (m.p. 156-158 °C).. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.14 (d, *J* = 8.0 Hz, 1H), 7.68 (d, *J* = 8.0 Hz, 1H), 7.56 (s, 1H), 7.43 (s, 1H), 7.25-7.19 (m, 1H), 6.97 (d, *J* = 8.0 Hz, 1H), 3.90 (s, 3H), 3.60 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.6, 134.2, 129.8, 129.2, 128.0, 126.6, 125.3, 124.1, 123.2, 122.4, 115.6, 115.4, 114.1, 106.8, 28.9. IR (neat) 2917, 2829, 1655, 1608, 1561, 1490, 1426, 1300, 1270, 1218, 1123, 1031, 820, 800, 737, 724 cm^{-1}. HRMS (ESI-TOF) Calcd for $C_{17}H_{14}N_2O_2$ $[M+H]^+$: 279.1134, found:279.1129.



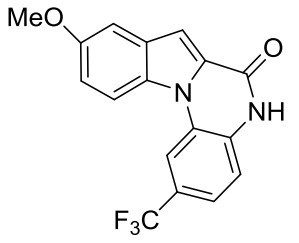
3o

5,11-dimethyllindolo[1,2-*a*]quinoxalin-6(5*H*)-one (3o). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (4 : 1) as the eluent to give a brown solid (62 mg, 47%) (m.p. 136-138 °C).. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.62 (t, *J* = 4.0, 4.0 Hz, 1H), 7.44 (s, 1H), 7.41 (d, *J* = 8.0 Hz, 1H), 7.26-7.14 (m, 5H), 3.58 (s, 3H), 2.55 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.2, 134.6, 130.7, 130.4, 129.9, 128.7, 126.3, 124.0, 123.9, 123.3, 122.1, 120.3, 119.8, 114.8, 108.3, 29.1, 22.2. IR (neat) 2921, 1622, 1504, 1452, 1403, 1301, 1261, 1098, 1050, 828, 778, 769, 729 cm^{-1}. HRMS (ESI-TOF) Calcd for $C_{17}H_{14}N_2NaO_2$ $[M+Na]^+$: 285.0998, found:285.0988.



3p

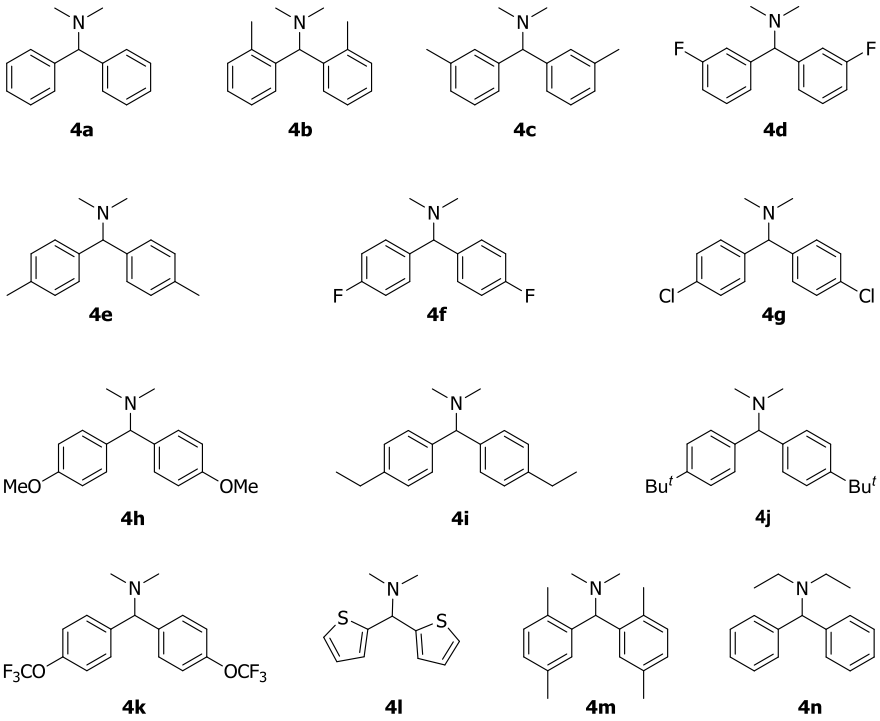
9-methoxy-3,5-dimethyllindolo[1,2-*a*]quinoxalin-6(5*H*)-one (3p). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (3 : 1) as the eluent to give a brown solid (51 mg, 35%) (m.p. 204-206 °C). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.06 (t, *J* = 12.0, 8.0 Hz, 2H), 7.38 (s, 1H), 7.16 (d, *J* = 4.0 Hz, 1H), 7.06(t, *J* = 8.0, 8.0 Hz, 3H), 3.84 (s, 3H), 3.61 (s, 3H), 3.39 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 156.5, 155.3, 133.8, 130.0, 129.6, 129.3, 128.3, 124.3, 123.7, 116.2, 116.1, 115.0, 114.8, 105.8, 103.0, 55.6, 28.9, 21.3. IR (neat) 2962, 2920, 2851, 1660, 1619, 1519, 1450, 1397, 1363, 1262, 1221, 1102, 1023, 801, 779, 743, 725 cm^{-1}. HRMS (ESI-TOF) Calcd for $C_{18}H_{17}N_2O_2$ $[M+H]^+$: 293.1285, found:293.1280.



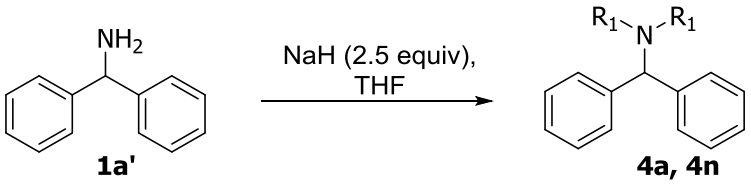
3r

9-methoxy-2-(trifluromethyl)indolo[1,2-*a*]quinoxalin-6(5*H*)-one (3r). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (2 : 1) as the eluent to give a light brown solid (50 mg, 30%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.26-8.20 (m, 2H), 7.38 (s, 1H), 8.13 (s, 1H), 7.62 (d, *J* = 8.0 Hz, 1H), 7.53 (s, 1H), 7.34 (s, 3H), 3.65 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 155.9, 135.1, 130.1, 128.7, 128.5, 127.2, 125.8 (d, *J* = 30.0 Hz), 123.6, 119.3, 116.0 (d, *J* = 24.0 Hz), 115.1, 107.0, 105.9, 99.9, 29.1. ^{19}F NMR (376 MHz, $CDCl_3$): δ -100.0. IR (neat) 2925, 1664, 1620, 1454, 1401, 1343, 1288, 1257, 1109, 1086, 1037, 972, 837, 801, 725 cm^{-1}. HRMS (ESI-TOF) Calcd for $C_{17}H_{12}F_3N_2O_2$ $[M+H]^+$: 333.0851, found: 333.0853.

2.3 General procedure for the preparation of the 4

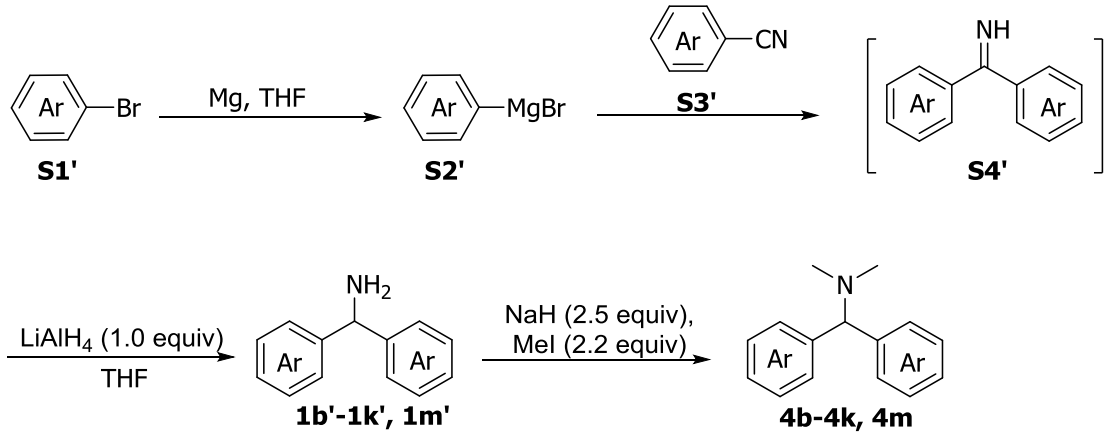


Method C for the preparation of 4a, 4n



NaH (2.5 equiv) was added slowly to a cold solution of **1a'** (10 mmol, 1.0 equiv) in dry THF (15 mL) under N_2, after being stirred at room temperature for 2 h, alkyl iodide (2.2 equiv) was then added. The mixture was heated to 30 °C and stirred for 12 h. After being stirred at 30 °C for 12 h, the reaction mixture was quenched with sat. aq. NH_4Cl, and extracted with EtOAc. The combined organic layer was washed with brine and dried over Na_2SO_4, filtered and concentrated under reduce pressure to give crude product. The residue was purified by column chromatography on silica gel to afford the **4a** and **4n**.

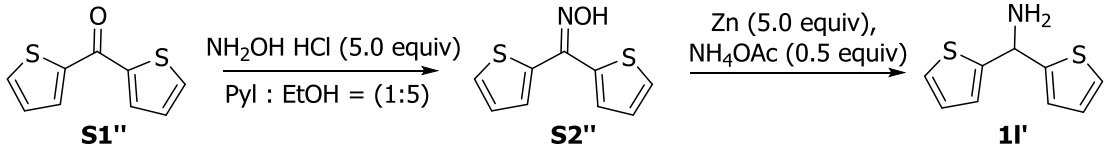
Method D for the preparation of 4b-4k, 4m[5]

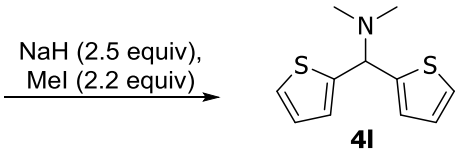


To a flame-dried 100 mL three-necked round-bottomed flask, magnesium (20 mmol, 2.0 equiv.) and a few crystals of iodine was added. Fill the flak with argon and equip with a refluxing condenser, THF (30 mL) was added through a syringe. Then added the corresponding aryl halide **S1'** (12 mmol, 1.2 equiv.) slowly. The mixture was slowly heated to reflux under an argon atmosphere and kept at reflux for 3 h. The resulting light brown solution was allowed cooling to room temperature and then the corresponding aryl nitrile **S3'** (10 mmol in 10 mL THF, 1.0 equiv.) was added. The reaction mixture was heated to reflux for 24 h and then cooled to 0 °C. To this mixture was transferred a suspension of $LiAlH_4$ (10 mmol, 1.0 equiv) in THF (20 mL) and heated to reflux, which was maintained for 12 h. The reaction mixture was cooled to 0 °C, and carefully quenched by slow addition of water (1 mL), then 10 % aq NaOH (1 mL), and finally water (2 mL). The mixture was filtered through a Celite pad and washed with DCM. The combined organic layer was washed with brine and dried over Na_2SO_4, filtered and concentrated under reduce pressure to afford **1b'-1k', 1m'**, which could be used directly in the next step without further purification.

NaH (2.5 equiv) was added slowly to a cold solution of **1b'-1k', 1m'** in dry THF (15 mL) under N_2, after being stirred at room temperature for 2 h, MeI (2.2 equiv) was then added. The mixture was heated to 30 °C and stirred for 12 h. After being stirred at 30 °C for 12 h, the reaction mixture was quenched with sat. aq. NH_4Cl, and extracted with EtOAc. The combined organic layer was washed with brine and dried over Na_2SO_4, filtered and concentrated under reduce pressure. The residue was purified by column chromatography on silica gel to afford the **4b'-4k', 4m'.**

Method E for the preparation of 4l[5]



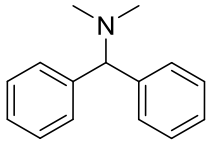


To a 100 mL pressure vessel was added the ketone **S1''** (10 mmol, 1.0 equiv), hydroxylamine hydrochloride (5.0 equiv), pyridine and EtOH (1:5). The flask was sealed and the solution was heated to reflux for 10 h. After completion, the solvent was removed under reduced pressure and the residue was partitioned between EtOAc and H_2O. The aqueous layer was extracted with EtOAc and washed with brine and dried over Na_2SO_4, filtered and concentrated under reduce pressure to give crude product **S2''**, which could be used directly in the next step without further purification.

To a stirred suspension of oxime **S2''** in EtOH and concentrated ammonia solution (1:4) was added NH_4OAc (0.5 equiv), followed by portion-wise addition of zinc powder (5.0 equiv). The mixture was heated to 50 °C and once the vigorous bubbling stopped, the solution was heated to reflux for 8 h. The mixture was then cooled to room temperature and diluted with EtOAc, stirred for 30 min and filtered. The filtrate was transferred to a separation funnel, the organic layer was collected and the aqueous layer was extracted with EtOAc. The combined organic layer was dried over Na_2SO_4, concentrated under reduce pressure to give the crude amine **1l'**, which could be used directly in the next step without further purification.

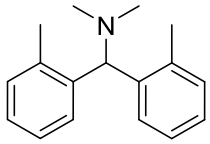
NaH (2.5 equiv) was added slowly to a cold solution of crude amine **1l'** in dry THF (15 mL) under N_2, after being stirred at room temperature for 2 h, MeI (2.2 equiv) was then added. The mixture was heated to 30 °C and stirred for 12 h. After being stirred at 30 °C for 12 h, the reaction mixture was quenched with sat. aq. NH_4Cl, and extracted with EtOAc. The combined organic layer was washed with brine and dried over Na_2SO_4, filtered and concentrated under reduce pressure to give crude product.

The residue was purified by column chromatography on silica gel to afford the **4l**.



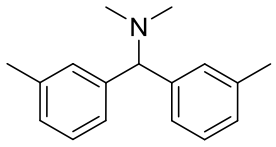
4a

***N,N*-Dimethyl-1,1-diphenylmethanamine (4a)[6]**. Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (20 : 1) as the eluent to give a white solid (1.05 g, 50%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36 (d, *J* = 8.0 Hz, 4H), 7.20 (t, *J* = 8.0, 8.0 Hz, 4H), 7.10 (t, *J* = 8.0, 4.0 Hz, 3H), 3.98 (s, 1H), 2.12 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.4, 128.4, 127.7, 126.9, 78.0, 44.7. HRMS (ESI-TOF) Calcd for $C_{15}H_{18}N$ $[M+H]^+$: 212.1434, found: 212.1443.



4b

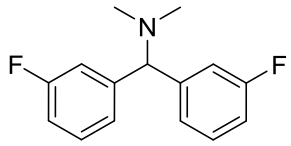
***N,N*-Dimethyl-1,1-di-*o*-tolylmethanamine (4b)**. Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (20 : 1) as the eluent to give a a pale yellow solid (0.96 g, 40%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.52 (d, *J* = 8.0 Hz, 2H), 7.09 (d, *J* = 4.0 Hz, 2H), 7.01 (t, *J* = 4.0 Hz, 4H), 4.51 (s, 1H), 2.27 (s, 6H), 2.15 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.5, 136.2, 130.3, 128.7, 128.6, 126.3, 126.0, 67.1, 44.2, 20.1. HRMS (ESI-TOF) Calcd for $C_{17}H_{21}N$ $[M+H]^+$: 240.1747, found: 240.1753.



4c

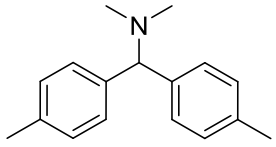
***N,N*-Dimethyl-1,1-di-*m*-tolylmethanamine (4c)**. Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (20 : 1) as the eluent to give a pale yellow oil (1.02 g, 43%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.16 (d, *J* = 8.0 Hz, 4H), 7.09 (t, *J* = 8.0 Hz, 2H), 7.90 (d, *J* = 8.0 Hz, 2H), 3.88 (s, 1H), 2.22 (s, 6H), 2.11 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.4, 138.0, 128.3,

127.6, 124.8, 78.2, 44.9, 21.5. HRMS (ESI-TOF) Calcd for $C_{17}H_{22}N$ $[M+H]^+$: 240.1747, found: 240.1753.



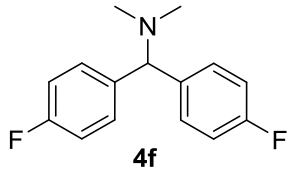
4d

1,1-bis(3-fluorophenyl)-*N*,*N*-dimethylmethanamine (4d). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (20 : 1) as the eluent to give a pale yellow oil (0.98 g, 40%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.18-7.14 (m, 2H), 7.10 (t, *J* = 8.0, 12.0 Hz, 4H), 6.83-6.79 (m, 2H), 3.99 (s, 1H), 2.11 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 164.2, 161.7, 145.5, 145.4, 130.0, 129.9, 123.3, 114.6, 114.3, 114.1, 113.9, 44.4. ^{19}F NMR (376 MHz, $CDCl_3$) δ -112.8. HRMS (ESI-TOF) Calcd for $C_{15}H_{16}F_2N$ $[M+H]^+$: 248.1245, found: 248.1255.



4e

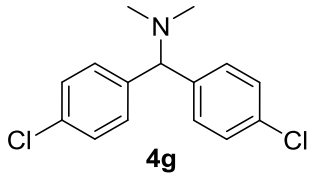
***N*,*N*-Dimethyl-1,1-di-*p*-tolylmethanamine (4e)[7].** Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (20 : 1) as the eluent to give a pale yellow solid (1.26 g, 53%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.22 (d, *J* = 4.0 Hz, 4H), 7.00 (d, *J* = 8.0 Hz, 4H), 3.91 (s, 1H), 2.19 (s, 6H), 2.11 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.7, 136.3, 129.1, 127.5, 44.7, 21.0. HRMS (ESI-TOF) Calcd for $C_{17}H_{22}N$ $[M+H]^+$: 240.1747, found: 240.1756.



4f

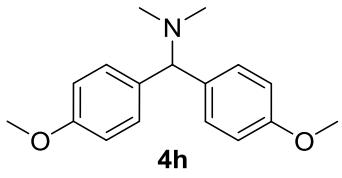
1,1-bis(4-fluorophenyl)-*N*,*N*-dimethylmethanamine (4f)[8]. Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (20 : 1) as the eluent to give a pale yellow solid (1.23 g, 50%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.29-7.26 (m, 4H), 6.91-6.86. (t, *J* = 8.0, 12.0 Hz, 4H) 3.98 (s,

1H), 2.09 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 163.0, 160.5, 138.9, 138.9, 129.0, 115.4, 115.2, 44.5. ^{19}F NMR (376 MHz, $CDCl_3$): δ -115.8. HRMS (ESI-TOF) Calcd for $C_{15}H_{16}F_2N$ $[M+H]^+$: 248.1245, found: 248.1255.



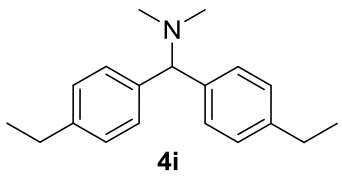
4g

***N,N*-Dimethyl[bis(4-chlorophenyl)methyl]amine (4g)[9]**. Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (20 : 1) as the eluent to give a pale white solid (1.54 g, 55%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.24 (d, *J* = 8.0 Hz, 4H), 7.17 (d, *J* = 8.0 Hz, 4H), 3.95 (s, 1H), 2.07 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 141.5, 132.7, 129.0, 128.9, 128.8, 128.7, 128.6, 44.4. HRMS (ESI-TOF) Calcd for $C_{15}H_{16}Cl_2N$ $[M+H]^+$: 280.0654, found: 280.0668.



4h

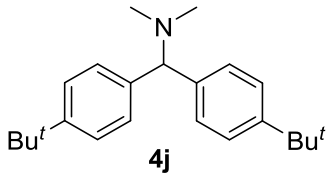
1,1-bis(4-methoxyphenyl)-*N,N*-dimethylmethanamine (4h)[7]. Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (10 : 1) as the eluent to give a white solid (1.13 g, 42%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.24 (d, *J* = 8.0 Hz, 4H), 6.74 (d, *J* = 8.0 Hz, 4H), 3.90 (s, 1H), 3.67 (s, 6H), 2.10 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 158.4, 135.9, 128.6, 113.8, 76.5, 55.1, 44.6. HRMS (ESI-TOF) Calcd for $C_{17}H_{22}NO_2$ $[M+H]^+$: 272.1645, found: 272.1652.



4i

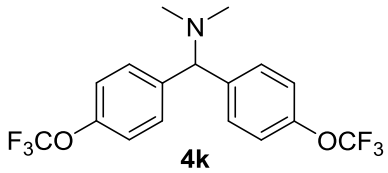
1,1-bis(4-ethylphenyl)-*N,N*-dimethylmethanamine (4i). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (20 : 1) as the eluent to give a pale yellow oil (1.18 g, 45%). ^{1}H NMR

(400 MHz, $CDCl_3$) δ 7.25 (t, *J* = 4.0 Hz, 4H), 7.00 (d, *J* = 4.0 Hz, 4H), 3.91 (s, 1H), 2.50-2.45 (m, 4H), 2.09 (s, 6H), 1.10-1.06 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 142.6, 141.0, 127.9, 127.6, 44.8, 28.4, 15.4. HRMS (ESI-TOF) Calcd for $C_{19}H_{26}N$ $[M+H]^+$: 268.2060, found: 268.2071.



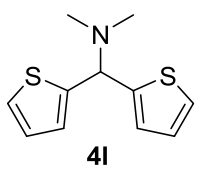
4j

1,1-bis(4-(*tert*-butyl)phenyl)-*N*,*N*-dimethylmethanamine (4j). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (15 : 1) as the eluent to give a pale yellow solid (0.97 g, 30%). ^1H NMR (400 MHz, $CDCl_3$) δ 7.28 (d, *J* = 8.0 Hz, 4H), 7.21(d, *J* = 8.0 Hz, 4H), 3.91 (s, 1H), 2.10 (s, 6H), 1.20 (s, 18H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 149.4, 140.5, 127.3, 125.2, 44.8, 34.3, 31.4, 31.3. HRMS (ESI-TOF) Calcd for $C_{23}H_{34}N$ $[M+H]^+$: 324.2686, found: 324.2688.



4k

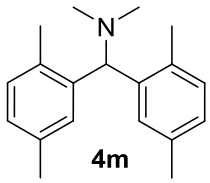
***N*,*N*-Dimethyl-1,1-bis(4-(trifluoromethoxy)phenyl)methanamine (4k)**. Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (10 : 1) as the eluent to give a pale yellow solid (1.25 g, 33%). ^1H NMR (400 MHz, $CDCl_3$) δ 7.32 (d, *J* = 8.0 Hz, 4H), 7.03(d, *J* = 8.0 Hz, 4H), 4.00 (s, 1H), 2.05 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 148.2 (d, *J* = 2.0 Hz), 141.5, 128.9, 124.3 (d, *J* = 255.0 Hz), 121.3, 120.9, 119.2 (d, *J* = 256.0 Hz), 44.3. ^{19}F NMR (376 MHz, $CDCl_3$) δ -58.0. HRMS (ESI-TOF) Calcd for $C_{17}H_{16}F_6NO_2$ $[M+H]^+$: 380.1080, found: 380.1090.



4l

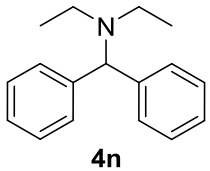
***N*,*N*-Dimethyl-1,1-di(4-(thiophen-2-yl)methanamine (4l)**. Following the general

procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (20 : 1) as the eluent to give a light brown solid (0.67 g, 30%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.19 (t, *J* = 4.0 Hz, 2H), 6.88 (d, *J* = 4.0 Hz, 4H), 4.96 (s, 1H), 2.20 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 144.6, 126.3, 126.1, 125.1, 66.0, 42.8. HRMS (ESI-TOF) Calcd for $C_{11}H_{14}NS_2$ $[M+H]^+$: 224.0562, found: 224.0572.



4m

1,1-bis(2,5-dimethylphenyl)-*N*,*N*-dimethylmethanamine (4m). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (15 : 1) as the eluent to give a pale yellow solid (0.85 g, 32%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.33 (s, 2H), 6.90 (d, *J* = 8.0 Hz, 2H), 6.83 (d, *J* = 8.0 Hz, 2H), 4.44 (s, 1H), 2.23 (d, *J* = 8.0 Hz, 12H), 2.15 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 140.2, 135.3, 133.0, 130.1, 129.0, 127.1, 67.0, 44.3, 21.2, 19.7. HRMS (ESI-TOF) Calcd for $C_{19}H_{26}N$ $[M+H]^+$: 268.2060, found: 268.2069.



4n

***N*-benzhydry-*N*-ethylethanamine (4n)[10]**. Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (20 : 1) as the eluent to give a pale yellow oil (0.59 g, 25%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.35 (d, *J* = 4.0 Hz, 4H), 7.20-7.17 (m, 4H), 7.11 (t, *J* = 8.0 Hz, 2H), 4.64 (s, 1H), 2.50 (d, *J* = 8.0 Hz, 4H), 0.92 (t, *J* = 8.0, 4.0 Hz, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 143.3, 128.1, 128.0, 126.5, 71.2, 42.7, 10.9. HRMS (ESI-TOF) Calcd for $C_{17}H_{22}N$ $[M+H]^+$: 240.1747, found: 240.1759.

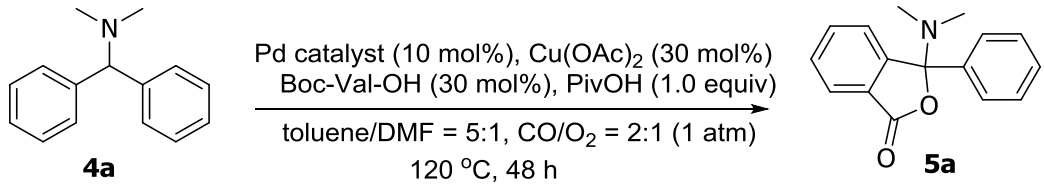
2.4 General procedure for the preparation of the 5

Optimization of Reaction Conditions

General optimization procedure: In an oven-dried Schlenk tube equipped with a stir-bar, **4a** (0.1 mmol, 1.0 equiv), Pd catalyst (10 mol %), Cu salts (30 mol %), ligand

(30 mol %), additive (1.0 equiv) were combined. A balloon filled V(CO)/V(O_2) (1 atm) was connected to the Schlenk tube via the side tube and purged for 3 times. Then solvent (1.2 mL) were added to the tube via a syringe. The reaction mixture was heated and determined by GC-MS. (**Caution**: the O_2 cylinder and CO cylinder should be stored separately. Damage to the cylinder such as a broken valve, can trigger a sudden and very rapid loss of containment. For CO in air, the explosion range is generally given as 12.5 % v/v to 74.2 % v/v CO with a minimum ignition temperature of ~605 ℃).

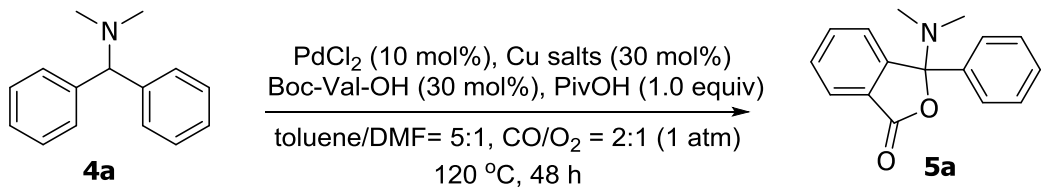
Table S1. Screening of Pd catalyst in this reaction[a]



Entry	Pd catalyst	Yield (%)[b]
1	none	ND[c]
2	$Pd(OAc)_2$	trace
3	$Pd(TFA)_2$	trace
4	$PdCl_2$	70

[a]Experiments were performed with **4a** (0.1 mmol, 1.0 equiv), Pd catalyst (10 mol %), $Cu(OAc)_2$ (30 mol %), Boc-Val-OH (30 mol %), PivOH (1.0 equiv), toluene/DMF = 5:1 (1.2 mL), V(CO)/V(O_2) = 2:1 (1 atm), 120 ℃, 48 h. [b]Determined by GC-MS.[c]ND = not determined.

Table S2. Screening of Cu salts in this reaction[a]

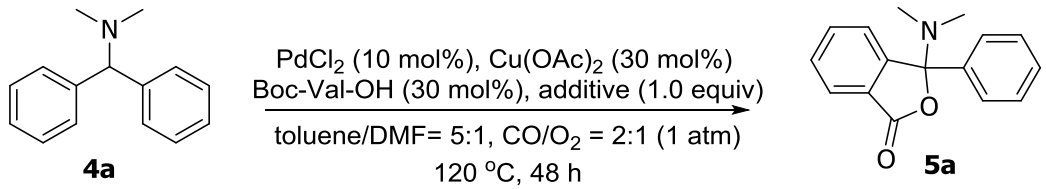


Entry	Cu salts	Yield (%)[b]
1	none	ND[c]
2	$Cu(OAc)_2$	70

3	$CuCl_2$	trace
4	$CuBr_2$	trace
5	CuF_2	trace
6	CuO	trace
7	$CuSO_4$	35
8	$Cu(OTf)_2$	trace
9	$Cu(acae)_2$	45

[a]Experiments were performed with **4a** (0.1 mmol, 1.0 equiv), $PdCl_2$ (10 mol %), Cu salts (30 mol %), Boc-Val-OH (30 mol %), PivOH (1.0 equiv), toluene/DMF = 5:1 (1.2 mL), V(CO)/V(O_2) = 2:1 (1 atm), 120 °C, 48 h. [b]Determined by GC-MS. [c]ND = not determined.

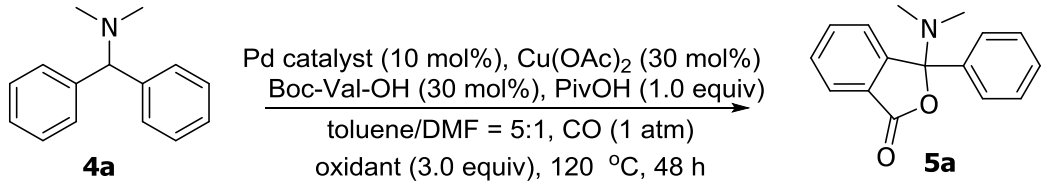
Table S3. Screening of additives in this reaction[a]



Entry	Additive	Yield (%)[b]
1	none	42
2	PivOH	70
3	Cs_2CO_3	ND[c]
4	AcOH	55
5	AdOH	45

[a] Experiments were performed with **4a** (0.1 mmol, 1.0 equiv), $PdCl_2$ (10 mol %), $Cu(OAc)_2$ (30 mol %), Boc-Val-OH (30 mol %), additive (1.0 equiv), toluene/DMF = 5:1 (1.2 mL), V(CO)/V(O_2) = 2:1 (1 atm), 120 °C, 48 h. [b]Determined by GC-MS. [c]ND = not determined.

Table S4. Screening of oxidants in this reaction[a]

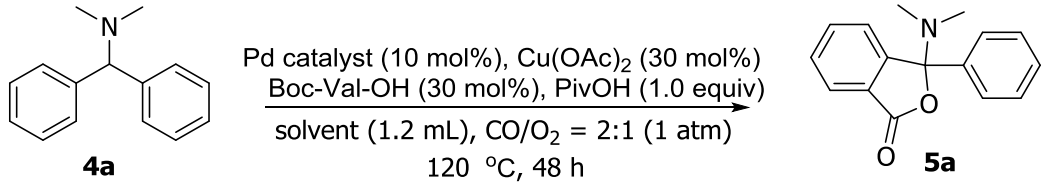


Entry	Oxidant	Yield (%)[b]
1	none	8

2[c]	O_2	70
3	AgAc	trace
4	Ag_2CO_3	trace
5	m-CPBA	trace
6	$K_2S_2O_8$	trace
7	NFSI	trace
8	$BiCl_3$	trace
9	$Mn(OAc)_2 \cdot 4H_2O$	15

[a]Experiments were performed with **4a** (0.1 mmol, 1.0 equiv), $PdCl_2$ (10 mol %), $Cu(OAc)_2$ (30 mol %), Boc-Val-OH (30 mol %), PivOH (1.0 equiv), toluene/DMF = 5:1 (1.2 mL), CO (1 atm), Oxidant (3.0 equiv), 120 °C, 48 h. [b]Determined by GC-MS. [c]$V(CO)/V(O_2)$ = 2:1 (1 atm).

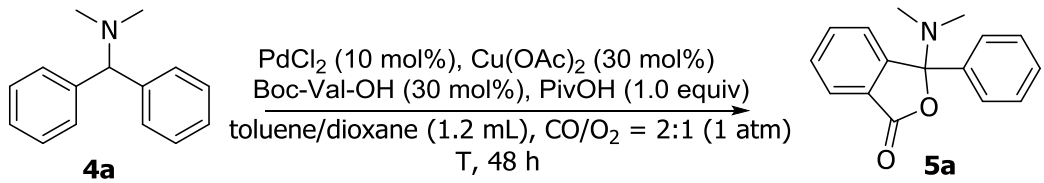
Table S5. Screening of solvents in this reaction[a]



Entry	Solvent	Yield (%)[b]
1	Toluene/DMF = 5:1	70
2	Toluene	trace
3	Toluene/Dioxane = 5:1	80
4	i-PrOH	trace
5	Toluene/DMSO = 5:1	30
6	Toluene/DMA = 5:1	35

[a]Experiments were performed with **4a** (0.1 mmol, 1.0 equiv), $PdCl_2$ (10 mol %), $Cu(OAc)_2$ (30 mol %), Boc-Val-OH (30 mol %), PivOH (1.0 equiv), Solvent (1.2 mL), $V(CO)/V(O_2)$ = 2:1 (1 atm), 120 °C, 48 h. [b]Determined by GC-MS.

Table S6. The effect of temperature on this reaction[a]

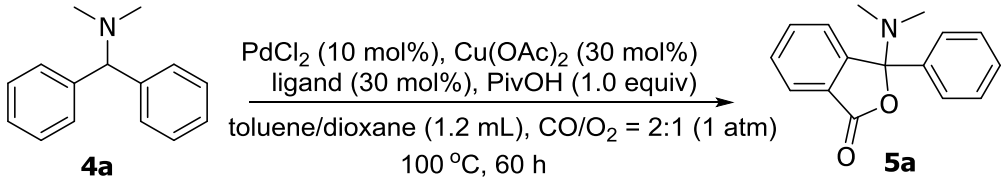


Entry	T (°C)	Yield (%)[b]
1	120	80
2	110	82

3[c]	100	90
4[c]	90	55
5[c]	80	45

[a]Experiments were performed with **4a** (0.1 mmol, 1.0 equiv), $PdCl_2$ (10 mol %), $Cu(OAc)_2$ (30 mol %), Boc-Val-OH (30 mol %), PivOH (1.0 equiv), toluene/dioxane = 5:1 (1.2 mL), $V(CO)/V(O_2)$ = 2:1 (1 atm), T, 48 h. [b]Determined by GC-MS. [c]60 h.

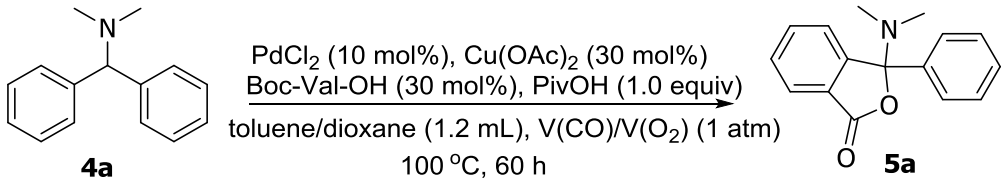
Table S7. Screening of Ligands in this reaction[a]



Entry	Ligand	Yield (%)[b]
1	none	35
2	Boc-Val-OH	90
3	Boc-Phe-OH	80
4	Fomc-Val-OH	72
5	Ac-Leu-OH	76

[a]Experiments were performed with **4a** (0.1 mmol, 1.0 equiv), $PdCl_2$ (10 mol %), $Cu(OAc)_2$ (30 mol %), ligand (30 mol %), PivOH (1.0 equiv), toluene/dioxane = 5:1 (1.2 mL), $V(CO)/V(O_2)$ = 2:1 (1 atm), 100 °C, 60 h. [b] Determined by GC-MS.

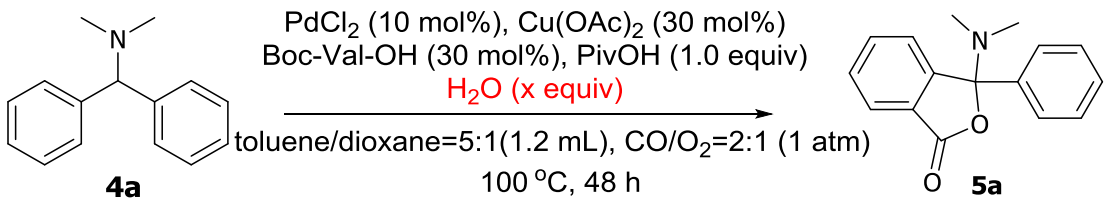
Table S8. The effect of the partial pressures ratio on this reaction[a]



Entry	Ratio of $V(CO)/V(O_2)$	Yield (%)[b]
1	1:1	46
2	2:1	90
3	4:1	35

[a]Experiments were performed with **4a** (0.1 mmol, 1.0 equiv), $PdCl_2$ (10 mol %), $Cu(OAc)_2$ (30 mol %), Boc-Val-OH (30 mol %), PivOH (1.0 equiv), toluene/dioxane = 5:1 (1.2 mL), $V(CO)/V(O_2)$ (1 atm), 100 °C, 60 h. [b] Determined by GC-MS.

Table S9. The effect of the amount of H_2O on this reaction[a]



Entry	Equivalent of additive H_2O	Yield (%)[b]
1	none	72
2	5	37
3	10	17
4	15	<10

[a]Experiments were performed with **4a** (0.1 mmol, 1.0 equiv), $PdCl_2$ (10 mol %), $Cu(OAc)_2$ (30 mol %), Boc-Val-OH (30 mol %), PivOH (1.0 equiv), toluene/dioxane = 5:1 (1.2 mL), $V(CO)/V(O_2)$ = 2:1 (1 atm), H_2O (x equiv), 100 °C, 48 h. [b]Determined by GC-MS.

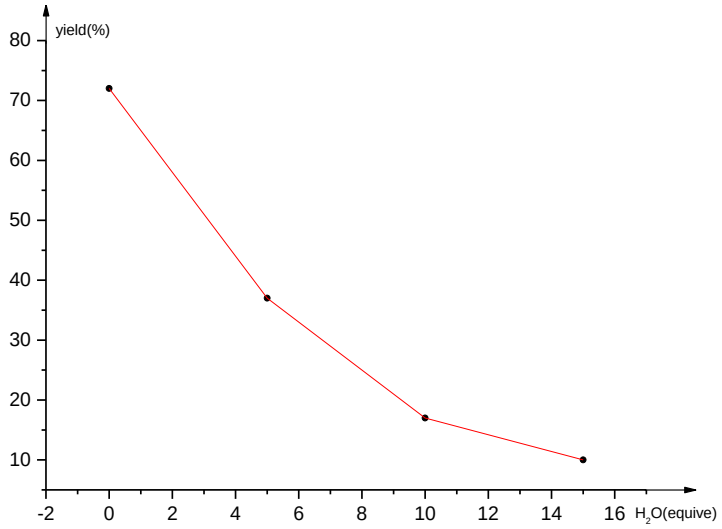
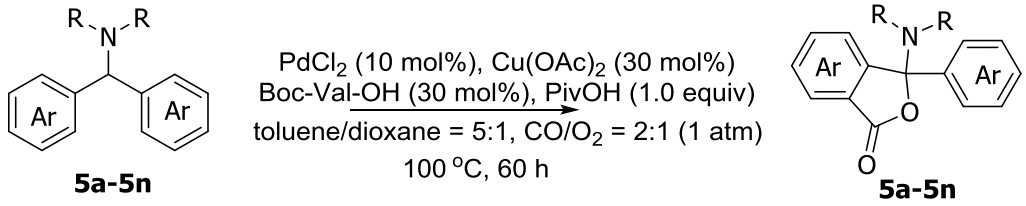


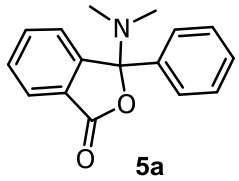
Figure S1. Yield of 5a with assistance of H_2O under the standard reaction conditions

General Procedure for the preparation of the desired products 5



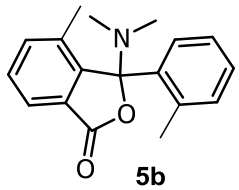
In an oven-dried Schlenk tube equipped with a stir-bar, **4a-4n** (0.5 mmol, 1.0 equiv), $PdCl_2$ (10 mol %), $Cu(OAc)_2$ (30 mol %), Boc-Val-OH (30 mol %), PivOH (1.0 equiv) were combined. A balloon filled $V(CO)/V(O_2)$ = (2:1) (1 atm) was connected to the Schlenk tube via the side tube and purged for 3 times. Then toluene/dioxane = 5:1 (3.0 mL) were added to the tube via a syringe. The Schlenk tube was heated at 100 °C for 60 h, then cooled to room temperature. The reaction was quenched by aq. brine and extracted with EtOAc. The combined organic layer were washed with brine and dried over anhydrous Na_2SO_4, filtered and concentrated under reduce pressure. The

residue was purified by column chromatography on silica gel to afford the corresponding products **5a-5n**.



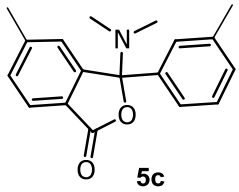
5a

3-(dimethylamino)-3-phenylisobenzofuran-1(3*H*)-one (5a). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (4 : 1) as the eluent to give a pale yellow solid (82 mg, 65%) (m.p. 74-76 °C). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.76 (d, *J* = 8.0 Hz, 2H), 7.62 (d, *J* = 8.0 Hz, 2H), 7.52-7.35 (m, 3H), 7.28-7.19 (m, 3H), 2.23 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.9, 150.7, 140.3, 134.3, 129.6, 128.8, 128.5, 125.9, 125.6 (d, *J* = 2.0 Hz), 123.0, 107.1, 38.8. IR (neat) 1757, 1604, 1461, 1280, 1238, 1096, 1056, 865, 797, 768, 700 cm^{-1}. HRMS (ESI-TOF) Calcd for $C_{16}H_{16}NO_2$ $[M+H]^+$: 254.1185, found: 254.1176. The absolute configuration is assigned based on the X-ray crystallographic data of compound **5a**.



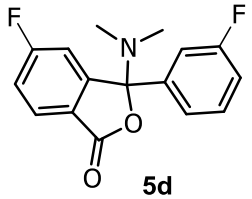
5b

3-(dimethylamino)-4-methyl-3-(*o*-tolyl)isobenzofuran-1(3*H*)-one (5b). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (4 : 1) as the eluent to give a light brown solid (63 mg, 45%) (m.p. 114-116 °C). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.00 (d, *J* = 8.0 Hz, 1H), 7.69 (d, *J* = 4.0 Hz, 1H), 7.36 (t, *J* = 8.0 Hz, 1H), 7.24-7.19 (m, 2H), 7.15-7.12 (m, 1H), 6.99 (d, *J* = 8.0, 1H), 2.52 (s, 3H), 2.07 (s, 3H), 1.99 (s, 3H), 1.95 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.2, 146.0, 137.7, 136.6, 134.7, 134.4, 133.5, 131.5, 130.4, 128.9, 128.4, 125.5, 122.7, 108.5, 22.0, 18.2. IR (neat) 1759, 1457, 1278, 1219, 771 cm^{-1}. HRMS (ESI-TOF) Calcd for $C_{18}H_{19}NO_2$ $[M+H]^+$ 282.1489, found: 282.1491.



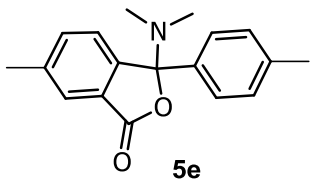
5c

3-(dimethylamino)-5-methyl-3-(*m*-tolyl)isobenzofuran-1(3*H*)-one (5c). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (4 : 1) as the eluent to give a white solid (70 mg, 50%) (m.p. 143-146 °C). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.64 (d, *J* = 8.0 Hz, 1H), 7.45 (t, *J* = 8.0, 12 Hz, 2H), 7.22-7.16 (m, 3H), 7.04 (d, *J* = 4.0 Hz, 1H), 2.34 (s, 3H), 2.27 (s, 3H), 2.24 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.9, 144.7, 136.3, 135.3, 133.3, 133.0, 132.2, 130.2, 129.0, 127.6, 127.1, 124.2, 121.4, 107.2, 20.7, 16.9. IR (neat) 1759, 1610, 1456, 1284, 1218, 1098, 1056, 929, 859, 773, 707 cm^{-1}. HRMS (ESI-TOF) Calcd for $C_{18}H_{20}NO_2$ $[M+H]^+$: 282.1489, found: 282.1500.



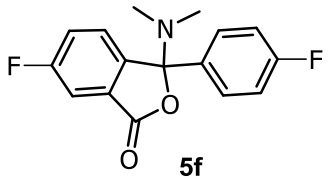
5d

3-(dimethylamino)-5-fluoro-3-(3-fluorophenyl)isobenzofuran-1(3*H*)-one (5d). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (4 : 1) as the eluent to give a semi-solid (77 mg, 53%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.79-7.75 (m, 1H), 7.38 (d, *J* = 8.0 Hz, 1H), 7.32-7.19 (m, 2H), 7.12-7.08 (m, 2H), 6.96-6.92 (m, 1H), 2.24 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.4, 168.0, 165.4, 164.3, 161.9, 153.0 (d, *J* = 9.0 Hz), 142.4 (d, *J* = 7.0 Hz), 130.6, 128.1, 121.8, 121.3, 118.2, 118.0, 115.9, 115.7, 113.2, 110.4, 110.1, 105.2, 38.8, 29.6. IR (neat) 1767, 1606, 1483, 1289, 1262, 1218, 864, 772 cm^{-1}. ^{19}F NMR (376 MHz, $CDCl_3$) δ 101.7 (d, *J* = 7.5 Hz), -111.3. HRMS (ESI-TOF) Calcd for $C_{18}H_{20}NO_2$ $[M+H]^+$: 290.0987, found: 290.0998.



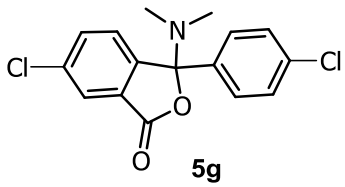
5e

3-(dimethylamino)-6-methyl-3-(*p*-tolyl)isobenzofuran-1(3*H*)-one (5e). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (4 : 1) as the eluent to give a light brown solid (73 mg, 52%) (m.p. 122-124 °C). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.62 (d, *J* = 8.0 Hz, 2H), 7.38 (d, *J* = 8.0 Hz, 1H), 7.17 (d, *J* = 8.0 Hz, 4H), 2.86 (s, 3H), 2.80 (s, 3H), 2.35 (s, 3H), 2.33 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 196.1, 170.8, 143.6, 141.9, 138.1, 134.7, 133.9, 130.2, 128.9, 128.8, 127.9, 38.9, 38.7, 34.7, 21.7, 21.4. IR (neat) 1725, 1641, 1606, 1501, 1450, 1398, 1277, 1219, 1179, 1070, 926, 771 cm^{-1}. HRMS (ESI-TOF) Calcd for $C_{18}H_{19}NNaO_2$ $[M+Na]^+$: 304.1308, found: 304.1320.



5f

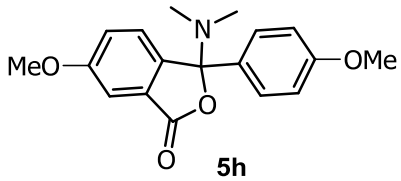
3-(dimethylamino)-6-fluoro-3-(4-fluorophenyl)isobenzofuran-1(3*H*)-one (5f). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (4 : 1) as the eluent to give a semi-solid (71 mg, 49%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.58-7.54 (t, *J* = 8.0 Hz, 2H), 7.41-7.36 (m, 2H), 7.25-7.20 (m, 1H), 6.98-6.94 (t, *J* = 8.0 Hz, 2H), 2.23 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.6 (d, *J* = 3.0 Hz), 164.9, 164.2, 162.4, 161.8, 146.4 (d, *J* = 3.0 Hz), 136.1 (d, *J* = 3.0 Hz), 129.4, 128.2, 124.9, 122.7, 116.6, 110.5, 107.0, 39.0. IR (neat) 1764, 1698, 1507, 1489, 1285, 1227, 1078, 899, 786, 780 cm^{-1}. ^{19}F NMR (376 MHz, $CDCl_3$) δ 110.33 (d, *J* = 1060.3 Hz), -112.55 (d, *J* = 11.28 Hz). HRMS (ESI-TOF) Calcd for $C_{18}H_{20}NO_2$ $[M+H]^+$: 290.0987, found: 290.0990.



5g

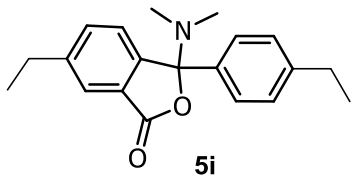
6-chloro-3-(4-chlorophenyl)-3-(dimethylamino)isobenzofuran-1(3*H*)-one (5g). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (4 : 1) as the eluent to give a semi-solid (93 mg, 58%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.78-7.72 (m, 1H), 7.56-7.47 (m, 3H), 7.42-7.32 (m,

1H), 7.26-7.19 (m, 2H), 2.23 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.6, 168.1, 150.3, 148.4, 138.9, 138.4, 136.2, 134.8, 134.5, 129.2, 127.1, 125.5, 124.2, 123.0, 106.6, 38.3. IR (neat) 1763, 1595, 1464, 1281, 1241, 1094, 1066, 870, 829, 771 cm^{-1}. HRMS (ESI-TOF) Calcd for $C_{18}H_{19}NNaO_2$ $[M+Na]^+$: 322.0396, found: 322.0405.



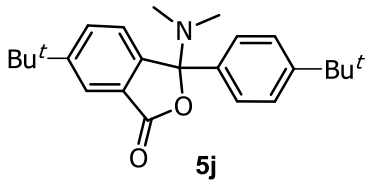
5h

3-(dimethylamino)-6-methoxy-3-(4-methoxyphenyl)isobenzofuran-1(3*H*)-one (5h). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (2 : 1) as the eluent to give a semi-solid (55 mg, 35%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.70 (d, *J* = 8.0 Hz, 2H), 7.46 (d, *J* = 12.0 Hz, 1H), 6.86 (t, *J* = 12.0, 4.0 Hz, 1H), 3.80 (d, *J* = 8.0 Hz, 6H), 2.89 (s, 3H), 2.80 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 194.3, 170.6, 163.2, 161.7, 140.3, 132.3, 130.3, 129.0, 113.4, 113.2, 112.8, 55.6, 55.4, 38.8, 34.7. IR (neat) 1636, 1598, 1312, 1283, 1252, 1167, 1064, 1028, 772 cm^{-1}. HRMS (ESI-TOF) Calcd for $C_{18}H_{19}NNaO_4$ $[M+Na]^+$: 336.1206, found: 336.1218.



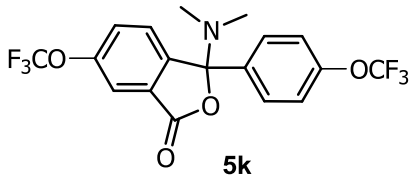
5i

3-(dimethylamino)-6-ethyl-3-(4-ethylphenyl)isobenzofuran-1(3*H*)-one (5i). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (4 : 1) as the eluent to give a light yellow solid (70 mg, 45%) (m.p. 122-124 °C). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.66 (d, *J* = 8.0 Hz, 2H), 7.42 (d, *J* = 4.0 Hz, 1H), 7.20-7.17 (m, 4H), 2.88 (s, 3H), 2.81 (s, 3H), 2.69-2.61 (m, 4H), 1.23-1.17 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 196.1, 171.0, 149.8, 147.9, 138.2, 134.9, 134.2, 130.3, 127.7, 127.6, 126.7, 38.9, 34.7, 28.9, 28.7, 15.2, 15.0. IR (neat) 1640, 1605, 1501, 1454, 1392, 1277, 1177, 1066, 932, 846, 757 cm^{-1}. HRMS (ESI-TOF) Calcd for $C_{20}H_{23}NNaO_2$ $[M+Na]^+$: 332.1621, found: 332.1625.



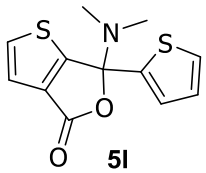
5j

6-(tert-butyl)-3-(4-tert-butyl)phenyl)-3-(dimethylamino)isobenzofuran-1(3*H*)-one (5j). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (3 : 1) as the eluent to give a yellow semi-solid (79 mg, 43%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.68 (d, *J* = 8.0 Hz, 2H), 7.41-7.33 (m, 5H), 2.88 (s, 3H), 2.81 (s, 3H), 1.28 (s, 9H), 1.25 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 196.0, 171.3, 156.5, 154.8, 137.9, 134.6, 133.9, 130.1, 125.1, 124.3, 39.0, 38.6, 36.4, 35.1, 34.7, 31.4, 31.1, 31.0, 30.8, 27.8. IR (neat) 1769, 1641, 1604, 1469, 1393, 1277, 1216, 1107, 1068, 931, 848, 771, 689 cm^{-1}. HRMS (ESI-TOF) Calcd for $C_{24}H_{32}NO_2$ $[M+H]^+$: 366.2428, found: 366.2438.



5k

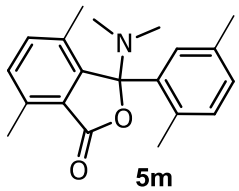
3-(dimethylamino)-6-(trifluoromethoxy)-3-(4-(trifluoromethoxy)phenyl)isobenzofuran-1(3*H*)-one (5k). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (3 : 1) as the eluent to give a yellow semi-solid (84 mg, 40%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.64 (t, *J* = 8.0, 4.0 Hz, 3H), 7.46 (d, *J* = 8.0 Hz, 1H), 7.39 (d, *J* = 8.0 Hz, 1H), 7.15 (t, *J* = 8.0 Hz, 2H), 2.24 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.9, 150.3, 149.5, 148.1, 138.3, 127.8 (d, *J* = 42.0 Hz), 124.5, 121.5 (d, *J* = 24.0 Hz), 117.5, 106.6, 38.8. IR (neat) 1769, 1258, 1218, 1169, 1085, 846, 771 cm^{-1}. ^{19}F NMR (376 MHz, $CDCl_3$) δ -57.8, -58.1. HRMS (ESI-TOF) Calcd for $C_{18}H_{14}F_6NO_4$ $[M+H]^+$: 422.0822, found: 422.0831.



5l

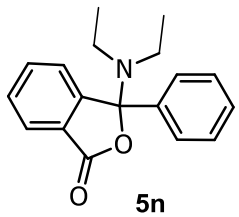
6-(dimethylamino)-6-(thiophen-2-yl)thieno[2,3-*o*]furan-4(6*H*)-one (5l). Following the general procedure, the product was isolated by column chromatography with

petroleum ether/EtOAc (4 : 1) as the eluent to give a brown semi-solid (27 mg, 20%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.85 (d, *J* = 4.0 Hz, 1H), 7.64 (d, *J* = 4.0 Hz, 1H), 7.58(d, *J* = 4.0 Hz, 1H), 7.12-7.09 (m, 2H), 2.97 (s, 3H), 2.78 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 184.5, 171.9, 146.1, 143.5, 141.4, 136.2, 134.8 (d, *J* = 20.0 Hz), 133.9, 131.2, 128.7, 128.6, 128.5, 36.7, 35.1, 26.4. IR (neat) 1714, 1624, 1528, 1412, 1354, 1278, 1114, 1055, 974, 858, 798 cm^{-1}. HRMS (ESI-TOF) Calcd for $C_{12}H_{11}NNaO_2S_2$ $[M+Na]^+$: 288.0123, found: 288.0130.



5m

3-(dimethylamino)-3-(2,5-dimethylphenyl)-4,7-dimethylisobenzofuran-1(3*H*)-on (5m). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (4 : 1) as the eluent to give a pale yellow semi-solid (56 mg, 36%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.19 (s, 1H), 7.15-7.09 (m, 2H), 7.06 (d, *J* = 8.0 Hz, 1H), 7.03 (d, *J* = 8.0 Hz, 1H), 2.82 (s, 3H), 2.75 (s, 3H), 2.42 (s, 3H), 2.18 (s, 6H), 1.98 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.0, 138.8, 137.5, 136.0, 135.5, 135.1, 132.7, 131.5, 131.2, 131.0, 130.5, 38.0, 34.1, 29.7, 20.8, 20.5, 19.5, 18.5. IR (neat) 1635, 1219, 812, 771 cm^{-1}. HRMS (ESI-TOF) Calcd for $C_{20}H_{23}NNaO_2$ $[M+Na]^+$: 332.1621, found: 332.1627.

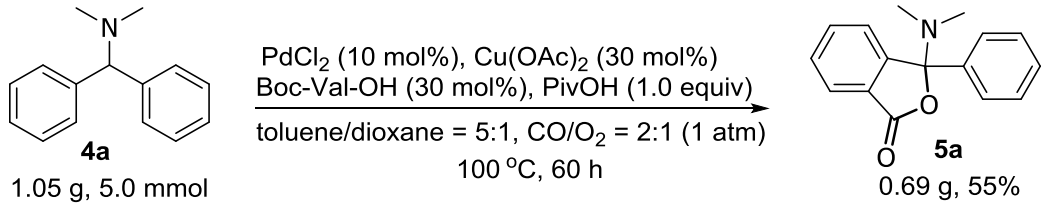


5n

3-(dimethylamino)-3-phenylisobenzofuran-1(3*H*)-on (5n). Following the general procedure, the product was isolated by column chromatography with petroleum ether/EtOAc (4 : 1) as the eluent to give a pale yellow semi-solid (49 mg, 35%). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.73 (d, *J* = 8.0 Hz, 2H), 7.48-7.43 (m, 3H), 7.38-7.31 (m, 4H), 3.38-3.33 (m, 2H), 3.21-3.16 (m, 2H), 1.06-0.97 (m, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 196.6, 169.9, 138.2, 137.1, 136.8, 133.0, 130.8, 130.2, 129.8, 128.2, 128.1,

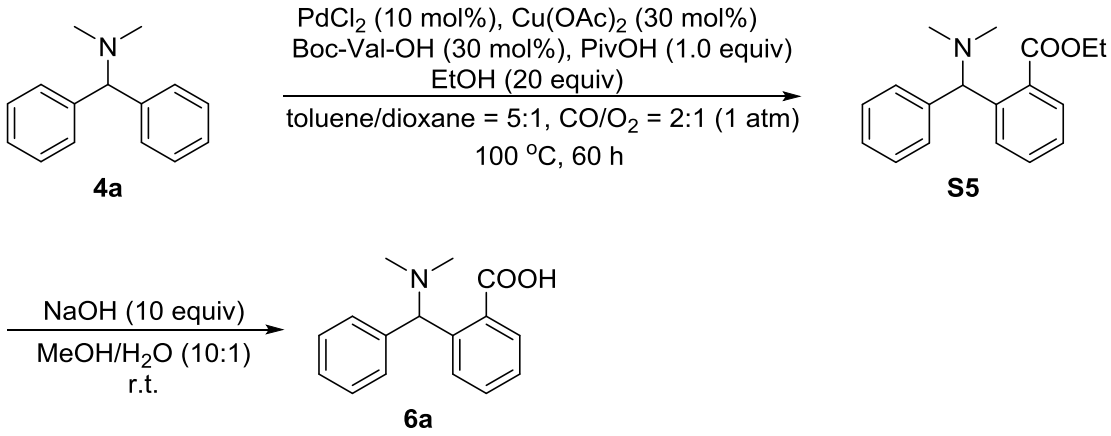
126.7, 43.2, 38.8, 13.7, 12.1. IR (neat) 1663, 1628, 1437, 1283, 1219, 1079, 933, 771, 702 cm^{-1}. HRMS (ESI-TOF) Calcd for $C_{18}H_{20}NO_2$ $[M+H]^+$: 282.1489, found: 282.1498.

2.5 Gram-scale synthesis of 5a



In an oven-dried Schlenk tube equipped with a stir-bar, **4a** (1.05 g, 5 mmol, 1.0 equiv), $PdCl_2$ (10 mol %), $Cu(OAc)_2$ (30 mol %), Boc-Val-OH (30 mol %), PivOH (1.0 equiv) were combined. A balloon filled $V(CO)/V(O_2)$ = 2:1 (1 atm) was connected to the Schlenk tube via the side tube and purged for 3 times. Then toluene/dioxane = 5:1 (18 mL) were added to the tube via a syringe. The Schlenk tube was heated at 100 °C for 60 h, then cooled to room temperature. The reaction was quenched by aq. brine and extracted with EtOAc. The combined organic layer were washed with brine and dried over anhydrous Na_2SO_4, filtered and concentrated under reduce pressure. The residue was purified by column chromatography on silica gel to afford **5a** (0.69 g, 55%).

2.6 General procedure for the preparation of 6a



In an oven-dried Schlenk tube equipped with a stir-bar, Amide **4a** (2.0 mmol, 1.0 equiv), $PdCl_2$ (10 mol %), $Cu(OAc)_2$ (30 mol %), Boc-Val-OH (30 mol %), PivOH (1.0 equiv) were combined. A balloon filled $V(CO)/V(O_2)$ = 2:1 (1 atm) was

connected to the Schlenk tube via the side tube and purged for 3 times. Then toluene/dioxane = 5:1 (6.0 mL) and EtOH (20 equiv) were added to the tube via a syringe. The Schlenk tube was heated at 100 °C for 60 h, then cooled to room temperature. The reaction was quenched by aq. brine and extracted with EtOAc. The combined organic layer were washed with brine and dried over anhydrous Na_2SO_4, filtered and concentrated under reduce pressure to afford **S5**, which could be used directly in the next step without further purification.

To a mixture of crude **S5** in MeOH/H_2O (10:1, 20 mL) was added NaOH (10 equiv). The reaction mixture was stirred at room temperature until completion of **S5** determined by GC-MS. The solvent was concentrated under reduce pressure, and diluted with H_2O, washed with EtOAc, the aqueous phase was acidified to PH 5-6 by aq. HCl (1N). The aqueous suspension was extracted with EtOAc and the combined organic layer was washed with brine and dried over anhydrous Na_2SO_4, filtered and concentrated under reduce pressure to afford **6a**, which could be used directly in the next step without further purification.

2-((dimethylamino)(phenyl)methyl)benzoic acid (6a). ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.19 (d, *J* = 4.0 Hz, 1H), 7.55 (d, *J* = 8.0 Hz, 2H), 7.46 (t, *J* = 8.0, 4.0 Hz, 1H), 7.32-7.26 (m, 5H), 5.32 (s, 1H), 2.54 (s, 6H). MS (ESI) Calcd for $C_{18}H_{20}NO_2$ $[M+H]^+$: 256, found: 256.

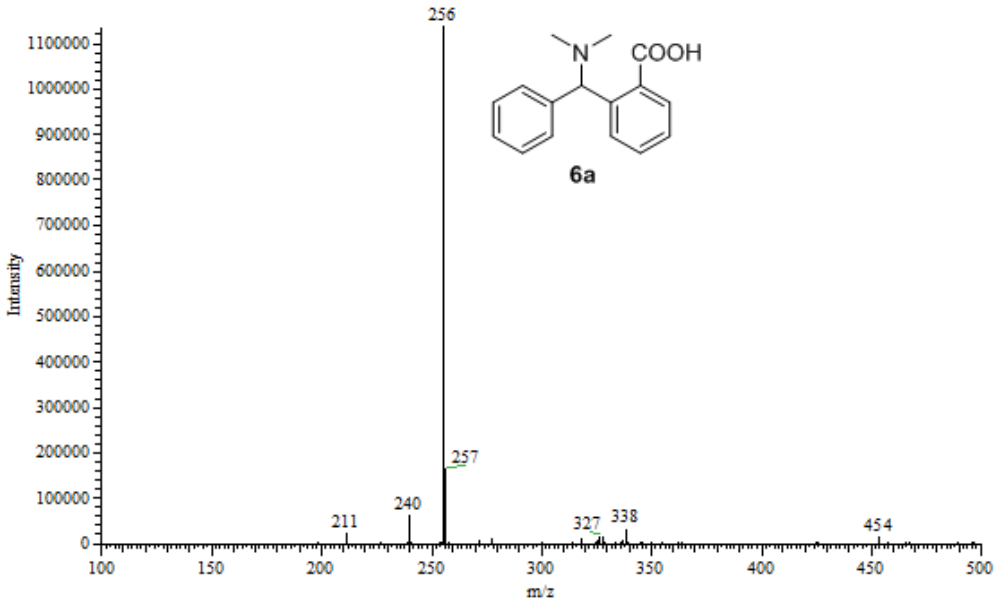
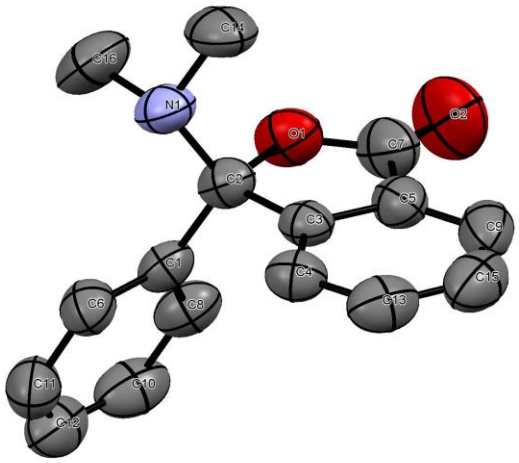


Figure S2

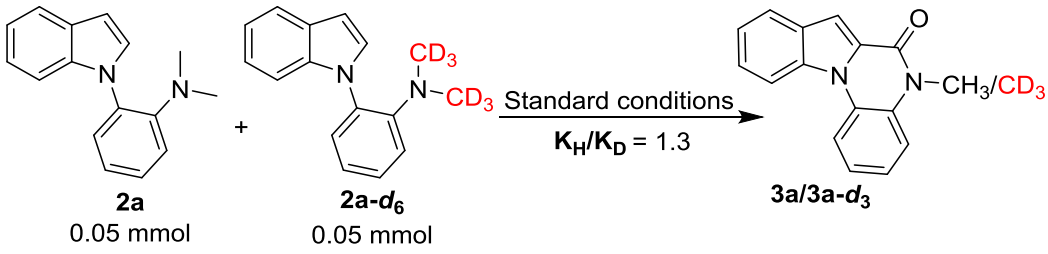
2.7 X-ray structure of 5a (CCDC 1944894)

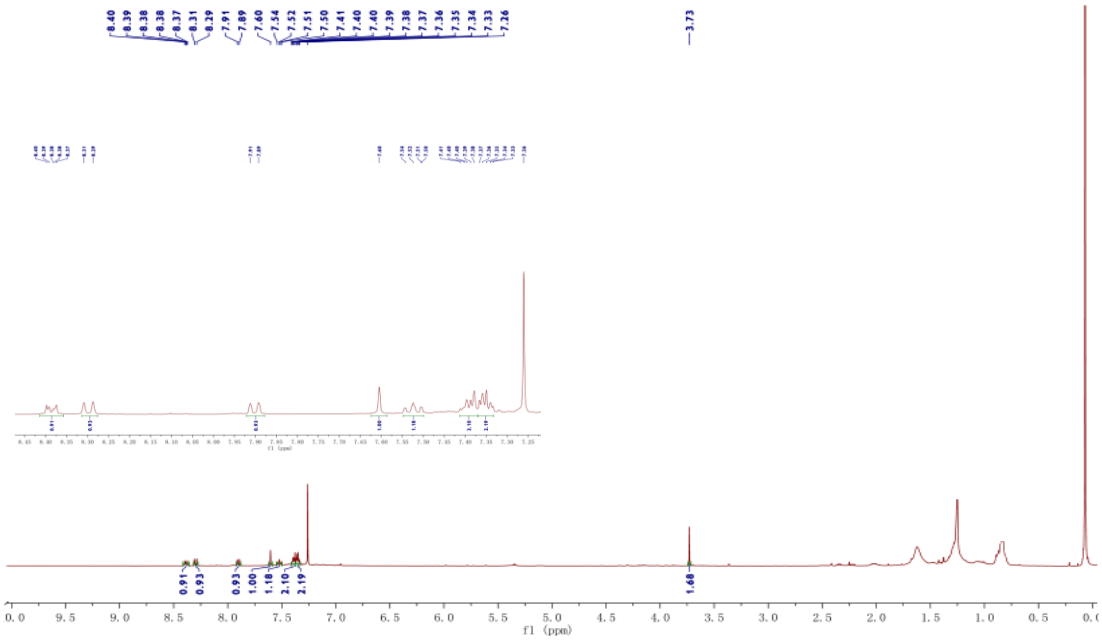


5a

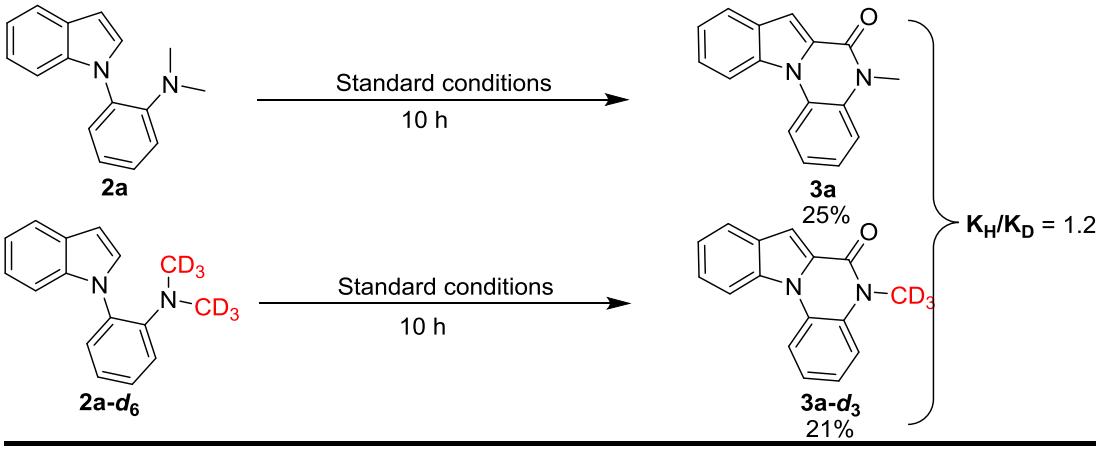
3. Mechanistic studies

3.1 General procedure for control experiment

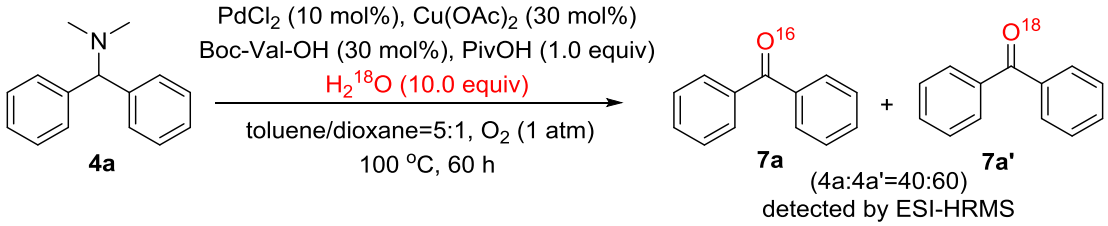




Note: The value of $\mathbf{K_H/K_D}$ was calculated from the ^{1}H NMR spectra above which should be the mixture of compound **3a** and **3a-*d*$_3$**. As a result, $\mathbf{K_H/K_D}$ = 1.68/(3-1.68) = 1.3



Note: The value of $\mathbf{K_H/K_D}$ was calculated from GC-MS yield.



In an oven-dried Schlenk tube equipped with a stir-bar, **4a** (0.2 mmol, 1.0 equiv), $PdCl_2$ (10 mol %), $Cu(OAc)_2$ (30 mol %), Boc-Val-OH (30 mol %), PivOH (1.0 equiv), $H_2{}^{18}O$ (10.0 equiv) were combined. A balloon filled with O_2 (1 atm) was connected to the Schlenk tube via the side tube and purged for 3 times. Then toluene/dioxane = 5:1 (3.0 mL) were added to the tube via a syringe. The Schlenk

tube was heated at 100 °C for 60 h, then cooled to room temperature. The reaction was quenched by aq. brine and extracted with EtOAc. The combined organic layer were washed with brine and dried over anhydrous Na_2SO_4, filtered and concentrated under reduce pressure. The residue was purified by column chromatography on silica gel to afford **7a(7a')**. The HRMS reveals the presence of ^{18}O incorporated product **7a** along with **7a'** as shown below.

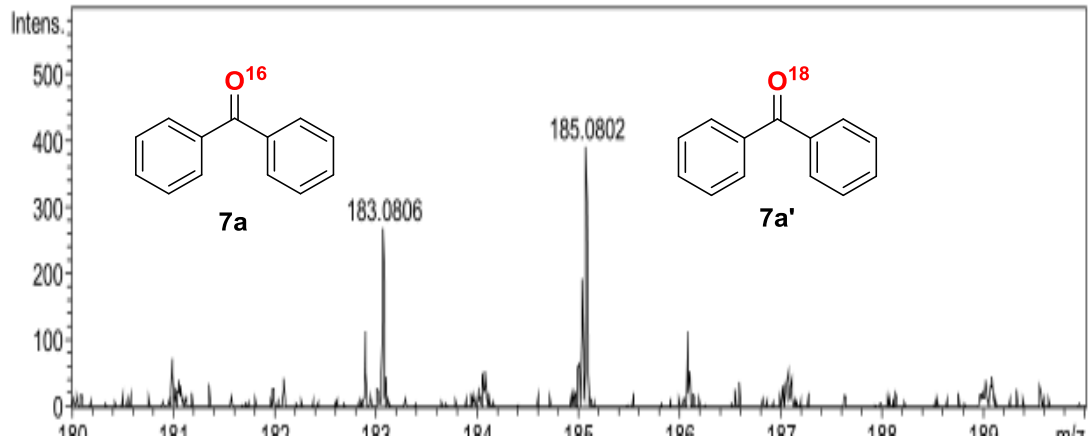
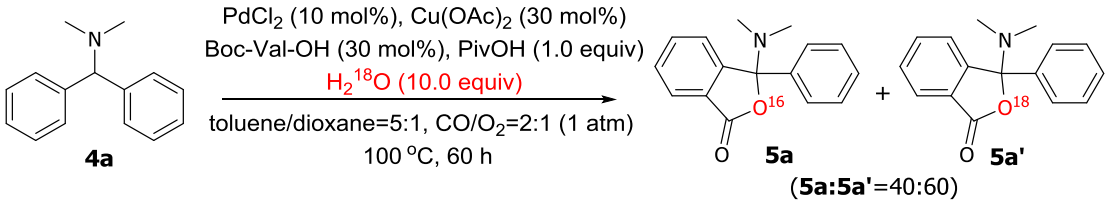


Figure S3



In an oven-dried Schlenk tube equipped with a stir-bar, **4a** (0.2 mmol, 1.0 equiv), $PdCl_2$ (10 mol %), $Cu(OAc)_2$ (30 mol %), Boc-Val-OH (30 mol %), PivOH (1.0 equiv), $H_2{}^{18}O$ (10.0 equiv) were combined. A balloon filled V(CO)/V(O_2) = 2:1 (1 atm) was connected to the Schlenk tube via the side tube and purged for 3 times. Then toluene/dioxane = 5:1 (3.0 mL) were added to the tube via a syringe. The Schlenk tube was heated at 100 °C for 60 h, then cooled to room temperature. The reaction was quenched by aq. brine and extracted with EtOAc. The combined organic layer were washed with brine and dried over anhydrous Na_2SO_4, filtered and concentrated under reduce pressure. The residue was purified by column chromatography on silica gel to afford **5a(5a')**. The HRMS reveals the presence of ^{18}O incorporated product **5a** along with **5a'** as shown below.

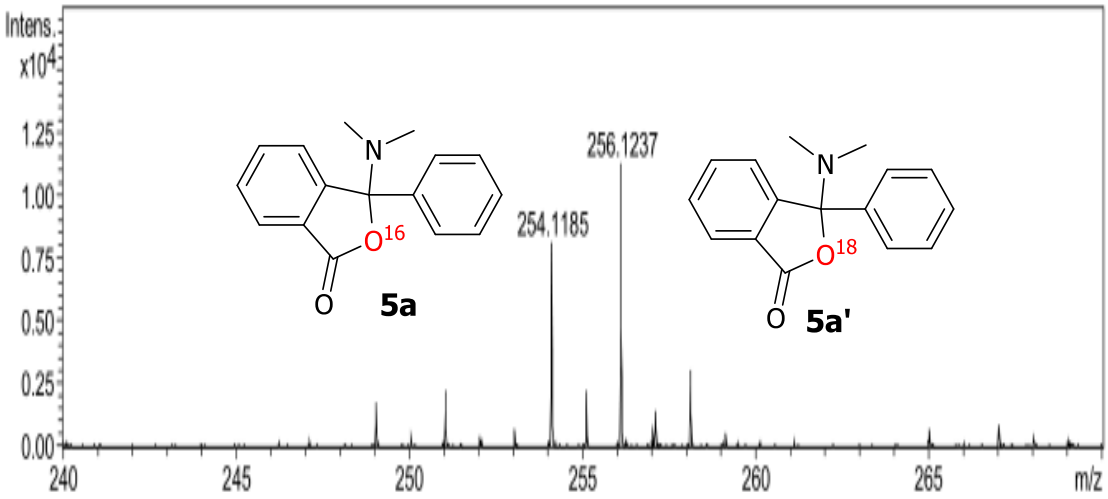
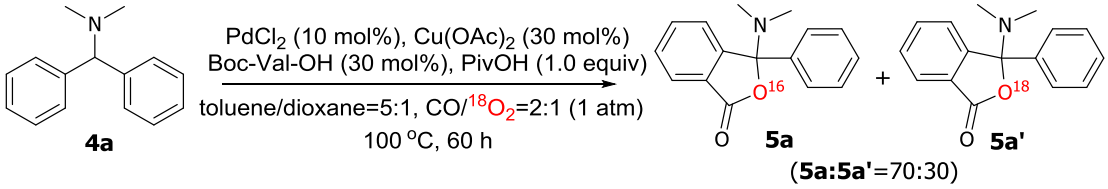


Figure S4



In an oven-dried Schlenk tube equipped with a stir-bar, **4a** (0.5 mmol, 1.0 equiv), $PdCl_2$ (10 mol %), $Cu(OAc)_2$ (30 mol %), Boc-Val-OH (30 mol %), PivOH (1.0 equiv) were combined. A balloon filled V(CO)/V($^{18}O_2$) = 2:1 (1 atm) was connected to the Schlenk tube via the side tube and purged for 3 times. Then toluene/dioxane = 5:1, (3.0 mL) were added to the tube via a syringe. The Schlenk tube was heated at 100 ˚C for 60 h, then cooled to room temperature. The reaction was quenched by aq. brine and extracted with EA. The combined organic layer were washed with brine and dried over anhydrous Na_2SO_4, filtered and concentrated under reduce pressure. The residue was purified by column chromatography on silica gel to afford **5a(5a')**. The HRMS reveals the presence of ^{18}O incorporated product **5a** along with **5a'** as shown below.

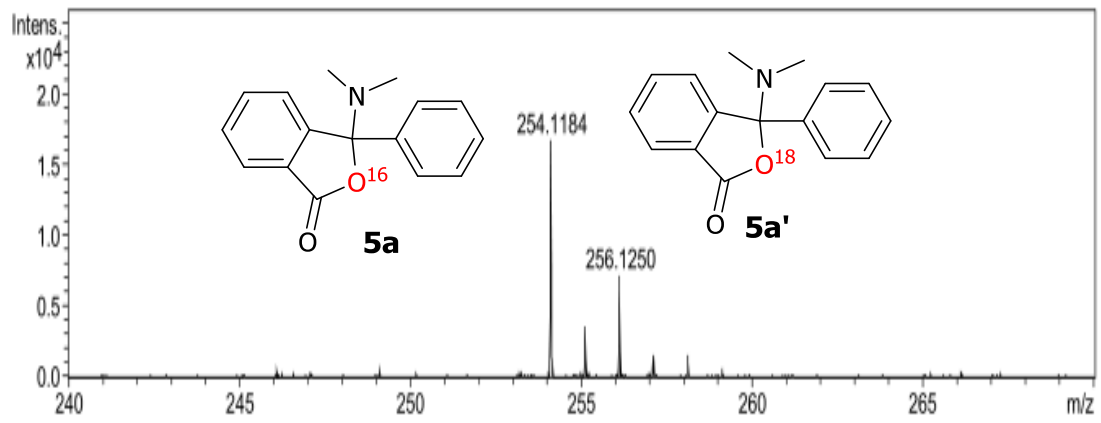
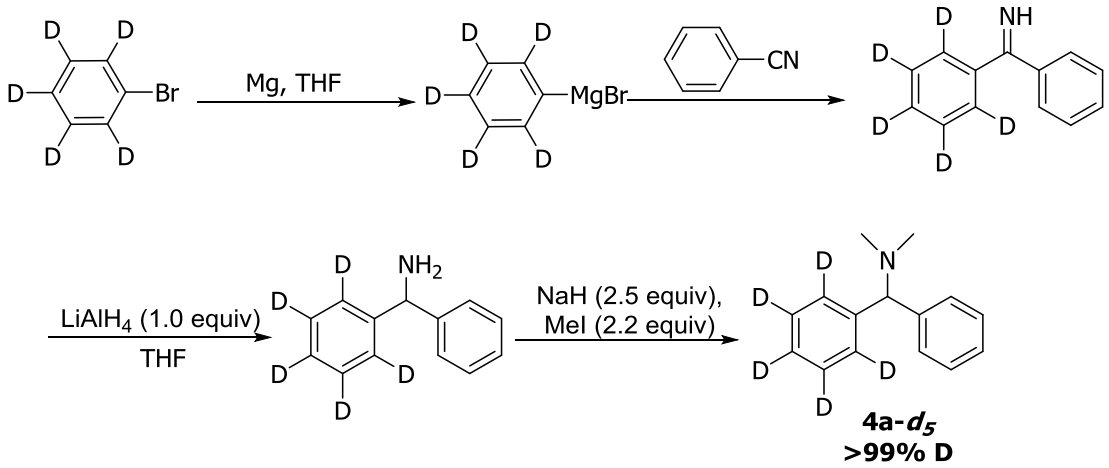


Figure S5

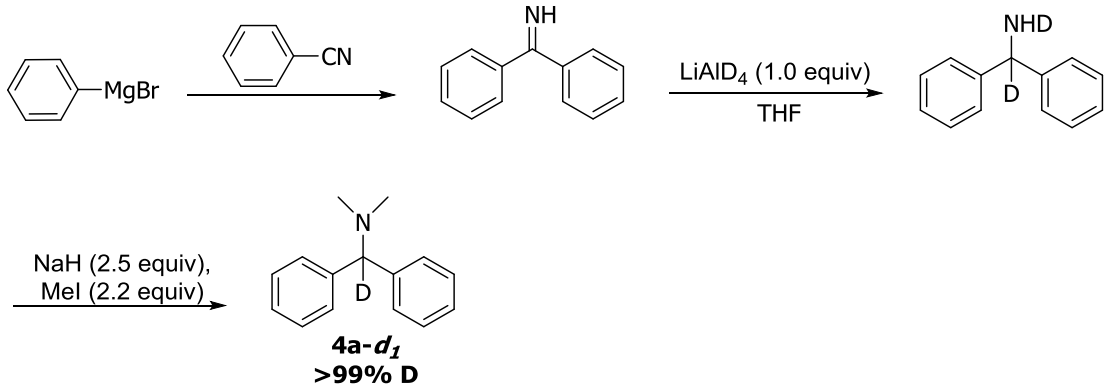
3.2 KIE Experiments

Preparation of deuterated 4a



***N,N*-Dimethyl-1-phenyl-1-(phenyl-d_5)methanamine (4a-d_5)**

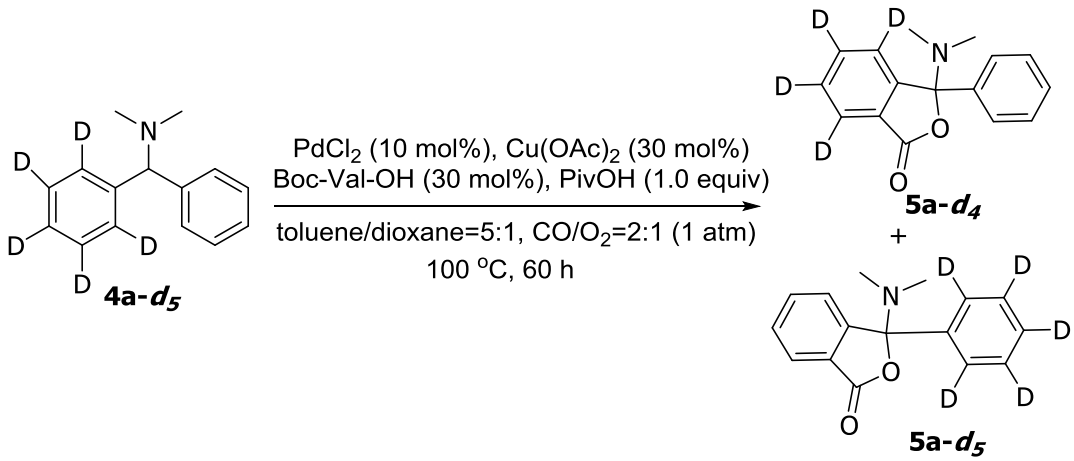
Following the general procedure, **4a-d_5** was obtained in 45% yield as a pale yellow solid (petroleum ether : ethyl acetate = 20 : 1), TLC R_f = 0.5 (PE/EA = 20/1). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38-7.34 (m, 2H), 7.21-7.17 (m, 2H), 7.11-7.09 (m, 1H), 4.01 (d, *J* = 8.0 Hz, 1H), 2.14 (t, *J* = 4.0 Hz, 6H). HRMS (ESI-TOF) Calcd for $C_{15}H_{12}D_5N$ $[M+H]^+$: 217.1676, found: 217.1749.



***N,N*-Dimethyl-1,1-diphenylmethanamine-*d* (4a-d_1)**

Following the general procedure, **4a-d_5** was obtained in 55% yield as a pale yellow solid (petroleum ether : ethyl acetate = 20 : 1), TLC R_f = 0.5 (PE/EA = 20/1). ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37-7.21 (m, 4H), 7.19-7.17 (m, 4H), 7.11-7.07 (m, *2*H), 2.13 (s, 6H). HRMS (ESI-TOF) Calcd for $C_{15}H_{16}DN$ $[M+H]^+$: 213.1424, found: 213.1497.

Intramolecular KIE experiment



The intramolecular KIE experiment was first conducted**.** Following the general procedure D. **4a-*d*$_5$** (1.0 mmol, 1.0 equiv), $PdCl_2$ (10 mol %), $Cu(OAc)_2$ (30 mol %), Boc-Val-OH (30 mol %), PivOH (1.0 equiv) were combined. A balloon filled V(CO)/V(O_2) = 2:1 (1 atm) was connected to the Schlenk tube via the side tube and purged for 3 times. Then toluene/dioxane = 5:1 (6.0 mL) were added to the tube via a syringe. The Schlenk tube was heated at 100 °C for 60 h. The **5a-*d*$_5$**(**5a-*d*$_4$**) was obtained and analyzed by ^{1}H NMR to reveal the ratio of **5a-*d*$_5$** and **5a-*d*$_4$** to be 4:1 (**KIE**) (**Figure S6**).

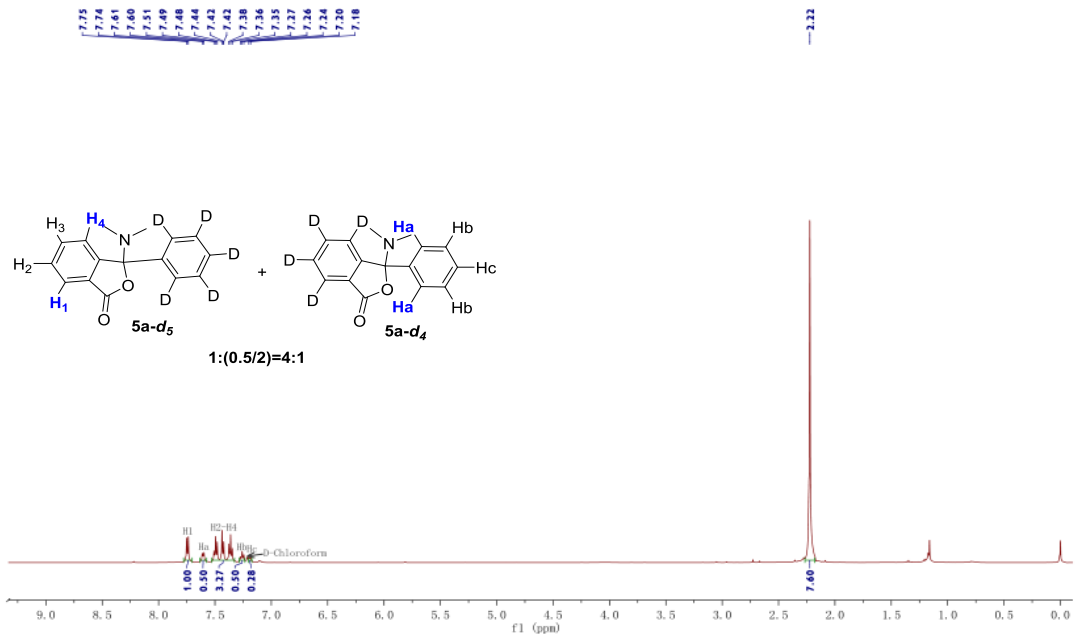
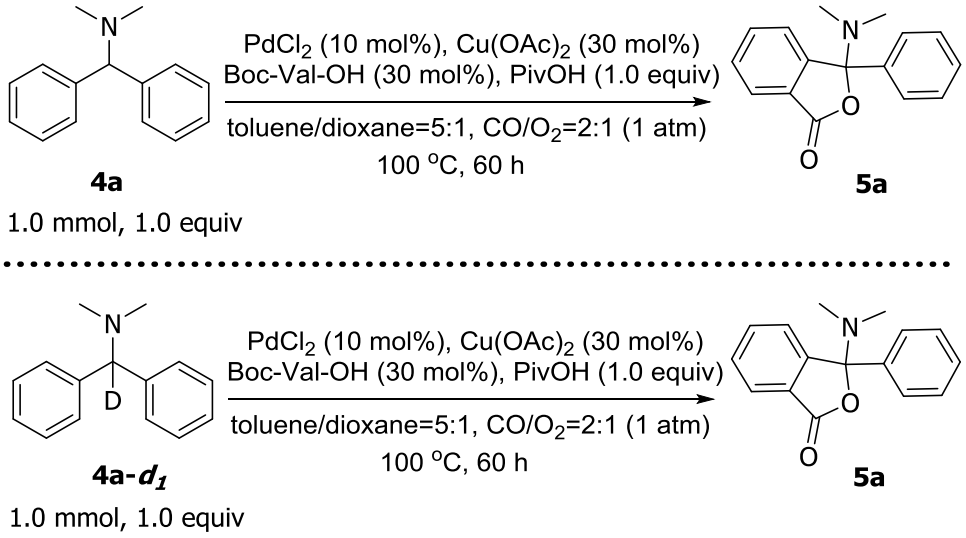


Figure S6

KIE for two parallel reactions



Furthermore, two parallel reactions of **4a** and **4a-*d*$_1$** respectively were performed to determine the corresponding **KIE** value. Following the general procedure. **4a**/**4a-*d*$_1$** (1.0 mmol, 1.0 equiv), $PdCl_2$ (10 mol %), $Cu(OAc)_2$ (30 mol %), Boc-Val-OH (30 mol %), PivOH (1.0 equiv) were combined. A balloon filled V(CO)/V(O_2) = 2:1 (1 atm) was connected to the Schlenk tube via the side tube and purged for 3 times. Then toluene/dioxane = 5:1 (6.0 mL) were added to the tube via a syringe. The Schlenk tube was heated at 100 °C. Each reaction was sampled at the following indicated points and analyzed by GC-MS. The GC-MS yields were calculated after calibrating the response of GC-MS.

Table S10 KIE-H

SM	Time (h)	1	2	3	5	7	9	11	13	15	17
4a	Yield of 3a (%)	<5	<5	<5	13	18	21	25	29	32	35

Table S11 KIE-D

SM	Time (h)	1	2	3	5	7	9	11	13	15	17
4a-*d*$_1$	Yield of 3a (%)	<5	<5	<5	10	11	15	17	21	23	27

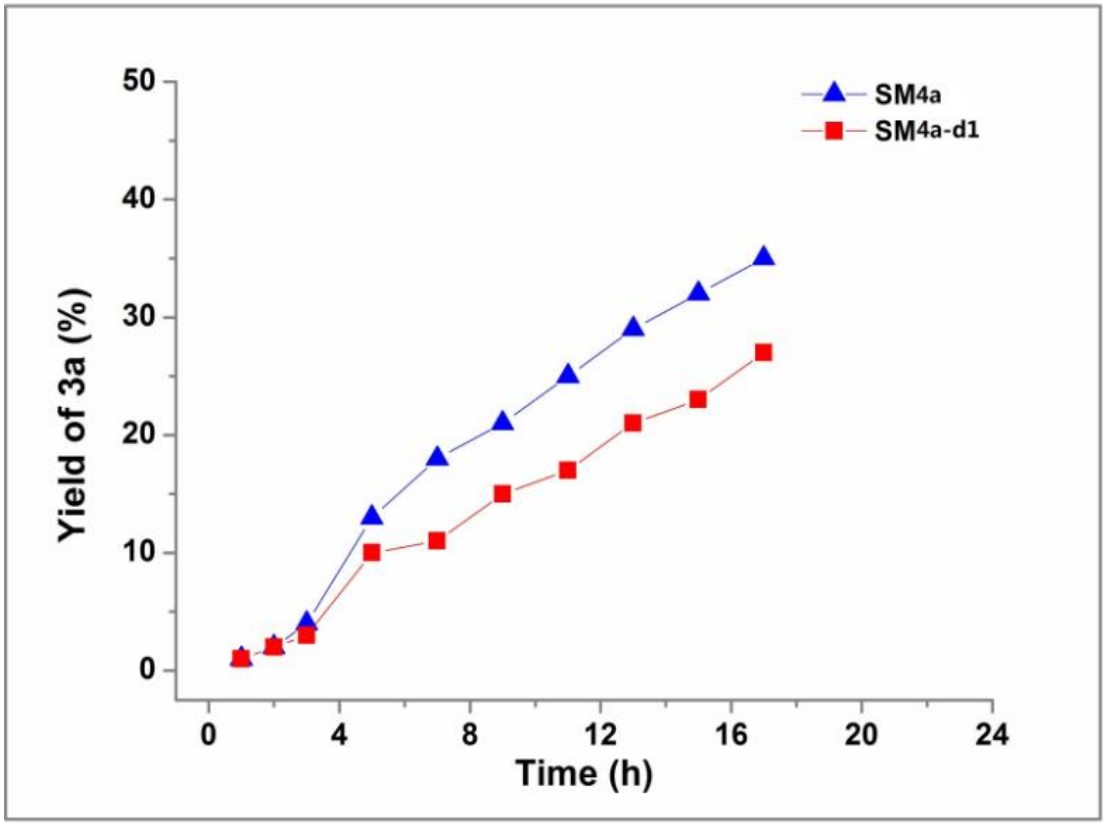
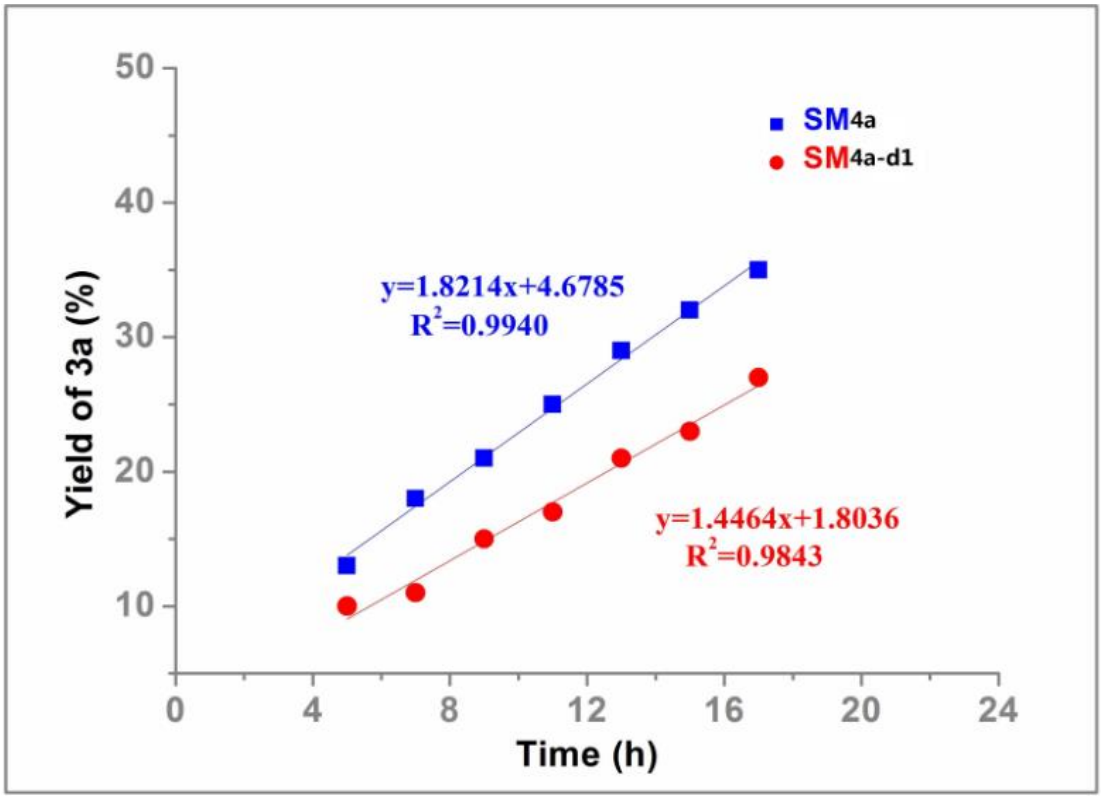


Figure S7



KIE = 1.8214/1.14464 = 1.3

Figure S8

3.3 Computational studies

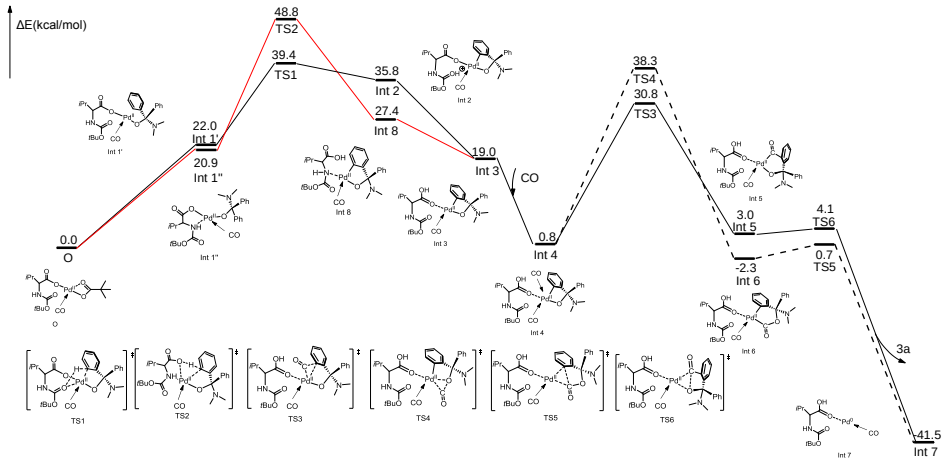


Figure S9. Zero-point energy profiles for migratory insertion with two molecules CO

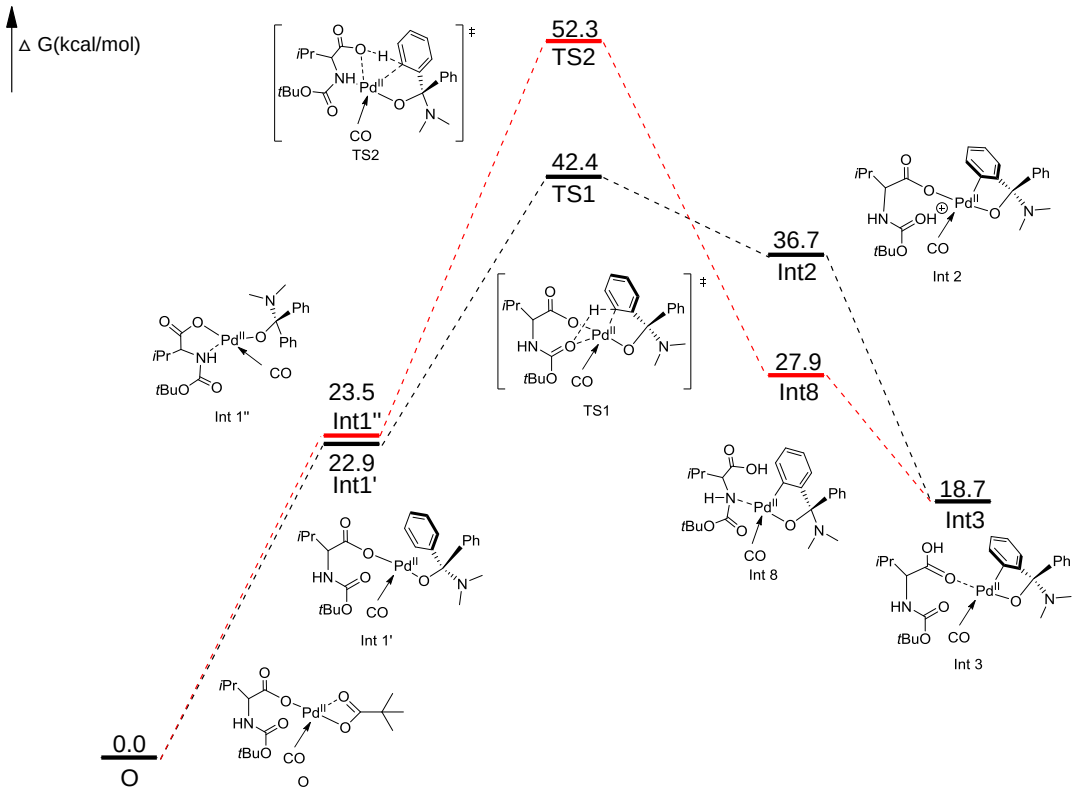


Figure S10. The free energy profile [kcal/mol] for C(sp^2)-H activation of Pd(II) complex

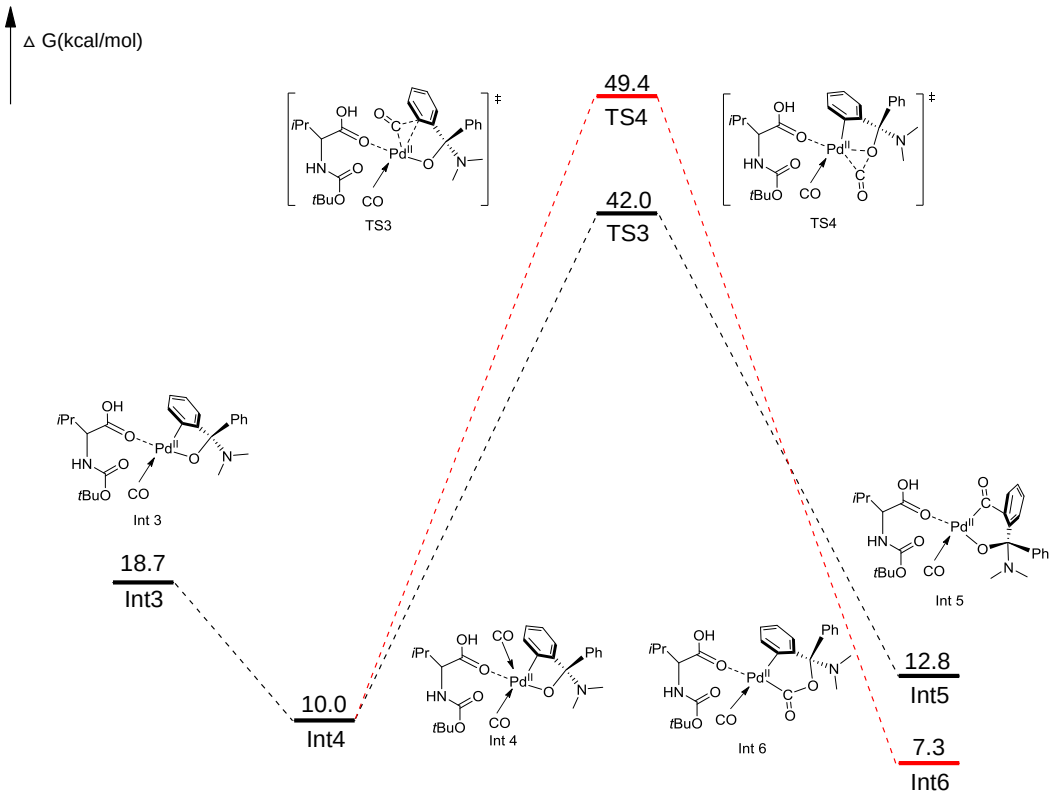


Figure S11. The free energy profile [kcal/mol] for Migratory insertion step

Table S12.

geometry	Δ E[d]	Δ H[d]	Δ S[e]	Δ G[d]
CO				
3a				
PIOH				
A				
O	0.0	0.0	0.0	0.0
Int 1'	22.0	22.2	-2.3	22.9
Int 1"	20.9	20.6	-9.7	23.5
Int 2	35.8	35.9	-2.7	36.7
Int 3	19.0	19.4	2.3	18.7
Int 3'	6.2	6.1	-10.1	9.1
Int 4	0.8	1.0	-30.2	10.0
Int 5	3.0	2.8	-33.5	12.8
Int 6	-2.3	-2.5	-32.9	7.3
Int 7	-41.5	-42.7	5.4	-44.3
Int 8	27.4	27.6	-1.0	27.9
TS1	39.4	39	-11.4	42.4
TS2	48.8	48.4	-13.1	52.3
TS3	30.8	30.4	-38.9	42.0
TS4	38.3	38	-38.2	49.4
TS5	0.7	0.1	-35.2	10.6
TS6	4.1	3.5	-38.2	14.9

[a] Basis set (BS) refers to the standard 6-31G(d,p) basis for C, H, O, N atoms and LANL2DZ valence basis set in combination with the corresponding effective core potential for Pd. [b] Relative activation energy and reaction parameters were calculated based on those of free O. [c] Parameters for all the transition state (TSs) should read as those with double dagger like $\Delta E^{\neq}$, $\Delta H^{\neq}$, $\Delta S^{\neq}$, and $\Delta G^{\neq}$. [d] In kcal/mol. [e] In kcal/(mol ·K).

B3-LYP geometries for all the optimized compounds and transition states.

CO

O	0.00000000	0.00000000	0.48768500
C	0.00000000	0.00000000	-0.65024600

PiVOH

C	-0.57318700	-0.01018000	-0.00000200
C	-0.97253300	-0.80515100	-1.26353200
H	-0.68907500	-0.26895100	-2.17524400
H	-0.49631300	-1.78836500	-1.28175200
H	-2.05819100	-0.94624400	-1.28131000
C	-1.25095200	1.36799500	-0.00010600
H	-2.33894800	1.24669800	-0.00011000
H	-0.96691100	1.94861900	0.88142900
H	-0.96688600	1.94849500	-0.88171200
C	-0.97256000	-0.80495900	1.26363500
H	-0.49636100	-1.78818100	1.28200900
H	-0.68911300	-0.26863200	2.17527800
H	-2.05822100	-0.94603300	1.28141900
C	0.94406900	0.18603000	0.00000100
O	1.52732200	1.24831200	-0.00000700
O	1.61654700	-0.99556300	0.00000900
H	2.56005100	-0.76180700	0.00000600

3a

C	3.19751500	-2.03036100	-0.51122800
C	2.26688300	-2.02704400	-1.56138500
C	1.15210300	-1.18403400	-1.54252800
C	0.99284000	-0.33779000	-0.44876900
C	1.91777100	-0.34411800	0.58709400
C	3.03057800	-1.18233000	0.58252900
H	4.05083500	-2.70011400	-0.55445100
H	2.41476200	-2.69488100	-2.40505700
H	0.43568000	-1.19328700	-2.35710500
H	3.73399000	-1.16336500	1.40874100
C	-0.11351600	0.66589400	-0.12906200
C	-1.44530000	-0.06317400	0.08759600

C	-1.86951400	-0.44854700	1.36306000
C	-2.22165000	-0.41612500	-1.02529700
C	-3.05041400	-1.17620800	1.52172400
H	-1.28518400	-0.16696100	2.23082500
C	-3.40043400	-1.14236700	-0.86349600
H	-1.90487100	-0.09783600	-2.01303500
C	-3.81799100	-1.52789400	0.41178900
H	-3.37051400	-1.46427200	2.51879900
H	-3.99441600	-1.40385700	-1.73454900
H	-4.73641100	-2.09346300	0.53861700
N	-0.23484200	1.71000400	-1.11305900
C	1.02573000	2.33338100	-1.52534000
H	1.72903300	1.58133000	-1.88481000
H	0.81563800	3.02108800	-2.34934100
H	1.50498500	2.90722800	-0.71665900
C	-1.22388000	2.74085800	-0.77089100
H	-2.17140700	2.28056200	-0.49042900
H	-0.89016700	3.38450900	0.05634700
H	-1.39416600	3.36732500	-1.65151000
O	0.33401700	1.21837200	1.17564800
C	1.50580200	0.65030900	1.60371700
O	2.04435300	0.95703700	2.63909700

A

C	3.47658000	-1.76075600	-0.28638800
C	2.95593000	-0.99144400	-1.32859400
C	1.85183800	-0.16750900	-1.11265000
C	1.25326500	-0.09180100	0.15278700
C	1.77666800	-0.87436600	1.18989000
C	2.88100000	-1.69992800	0.97317800
H	4.33603900	-2.40271400	-0.45602000
H	3.41117700	-1.03067700	-2.31425100
H	1.45389300	0.43602600	-1.92110700
H	1.30611300	-0.84267400	2.16675700
H	3.27215800	-2.29865100	1.79089700
C	-0.00630700	0.76520000	0.40256500
C	-1.23841700	-0.11381100	0.12171200
C	-1.55136900	-0.48067500	-1.19449600
C	-2.03438500	-0.59659400	1.16474500
C	-2.64100400	-1.30679300	-1.46151000
H	-0.94324900	-0.10571800	-2.01061500
C	-3.12465100	-1.42775200	0.89569100
H	-1.79976600	-0.31509000	2.18357600
C	-3.43287000	-1.78620700	-0.41542700
H	-2.87106600	-1.57759500	-2.48812900

H	-3.73426200	-1.79282100	1.71759100
H	-4.28077400	-2.43268300	-0.62269300
N	-0.00912500	1.94531000	-0.47088900
C	1.12426600	2.84556800	-0.24151300
H	2.06861400	2.30041900	-0.27817200
H	1.14129000	3.60231200	-1.03156800
H	1.06268800	3.37945900	0.72347400
C	-1.25401500	2.72057400	-0.41324700
H	-2.10934600	2.09511200	-0.66755000
H	-1.43015900	3.16506200	0.57892000
H	-1.19290600	3.52973500	-1.14739700
O	-0.07928500	1.12558200	1.79312400
H	0.78853300	1.46643500	2.04705500

O

Pd	-1.13435500	-0.67313800	-0.91506500
O	-0.12181600	0.61011000	-2.08824900
C	0.69766000	1.54275700	-1.63031300
O	1.33645800	2.24134400	-2.40099700
C	0.84965500	1.75573600	-0.10733900
H	0.23217500	1.04685200	0.45117300
N	2.23585400	1.49361300	0.26832600
C	2.69218200	0.22293800	0.47976800
O	1.97236000	-0.76901900	0.55891300
O	4.03463900	0.24350500	0.61784900
C	4.80452800	-0.98295200	0.88517800
C	4.64818600	-1.96731100	-0.27836100
H	5.32520300	-2.81529800	-0.13319400
H	3.62701200	-2.34307400	-0.34296600
H	4.90901200	-1.48266900	-1.22435400
C	6.24106100	-0.45884500	0.96165300
H	6.52996000	0.01522900	0.01925100
H	6.34099000	0.27808300	1.76371600
H	6.93079500	-1.28435700	1.16067000
C	4.37449400	-1.58950400	2.22478000
H	4.45947600	-0.84564000	3.02321200
H	3.34483300	-1.94553300	2.18148200
H	5.02919000	-2.43097900	2.47377700
C	0.44867800	3.19832100	0.27969400
H	1.15093600	3.86484700	-0.23977800
C	-0.96763600	3.53000100	-0.21506700
H	-1.03654300	3.48388000	-1.30564100
H	-1.70746900	2.83603100	0.19930900
H	-1.24606400	4.54338600	0.09159100
C	0.57111200	3.42010900	1.79345500

H	1.57056200	3.17381000	2.16195300
H	0.36264700	4.46504500	2.04518300
H	-0.14969600	2.79778400	2.33776600
H	2.92610400	2.16807800	-0.03443400
C	-4.56273000	-0.57938500	1.12102900
C	-5.66005300	0.00271800	0.20159300
H	-5.38210200	0.99390500	-0.16431100
H	-5.83797700	-0.64548700	-0.66262000
H	-6.59770800	0.08679800	0.76006800
C	-4.34459200	0.36018900	2.33181200
H	-5.27481200	0.44086200	2.90323400
H	-3.56959900	-0.02753200	3.00109100
H	-4.05137500	1.36103200	2.00494800
C	-4.94272400	-1.99095400	1.59696900
H	-5.09260500	-2.66969900	0.75275600
H	-4.16729900	-2.41967900	2.23703000
H	-5.87497500	-1.94435500	2.16878800
C	-3.26376600	-0.61682500	0.33838500
O	-2.80137200	0.43227300	-0.23141100
O	-2.56846600	-1.69085000	0.22380700
O	1.00622800	-2.75100300	-1.60312800
C	0.23301800	-1.96751900	-1.32144400

Int1'

Pd	-0.17553700	-0.47963700	0.70048600
O	2.83819000	-3.06844200	1.95920500
C	2.24172000	-2.25538400	1.26483900
O	0.95006000	-2.05683100	1.38596300
C	3.00623000	-1.43243200	0.18881700
H	2.39115800	-1.38463700	-0.71378100
N	3.11626000	-0.04573700	0.64364600
C	2.75264200	1.01194900	-0.14598200
O	2.09098800	0.91127900	-1.17316600
O	3.20985700	2.15998600	0.40082400
C	2.85870900	3.47510700	-0.16872500
C	1.34644300	3.69394000	-0.06195800
H	1.09289500	4.69026100	-0.43857000
H	0.79195900	2.95048200	-0.63591600
H	1.02614200	3.63862900	0.98338000
C	3.61639000	4.44168500	0.74517800
H	3.29397900	4.32533700	1.78388100
H	4.69363600	4.25802100	0.69517800
H	3.42653400	5.47413300	0.43740900
C	3.36784100	3.58403700	-1.60998900
H	4.43614400	3.34929000	-1.65360300

H	2.83032800	2.90489500	-2.27120700
H	3.23220300	4.61022900	-1.96661000
C	4.37412700	-2.06044400	-0.16689300
H	4.90871100	-2.22214700	0.77773500
C	4.17438400	-3.43279000	-0.82938900
H	3.61689000	-4.10826600	-0.17788900
H	3.63764400	-3.33296000	-1.78240700
H	5.14173500	-3.89632500	-1.04890000
C	5.20878600	-1.14283400	-1.07258100
H	5.44037800	-0.18607800	-0.59516200
H	6.15934900	-1.62386000	-1.32538700
H	4.68416200	-0.92737800	-2.01104800
H	3.74475300	0.15819700	1.40885600
C	-1.06185300	-3.62305900	-1.59204800
C	-2.39374300	-3.40083900	-1.21683000
C	-2.86263500	-2.11722600	-0.95212100
C	-2.02027600	-1.00025100	-1.08335300
C	-0.66495500	-1.23049800	-1.46370600
C	-0.20543500	-2.54120300	-1.71707500
H	-0.70730400	-4.63107000	-1.78183200
H	-3.07233200	-4.24344700	-1.11827100
H	-3.89085700	-1.97867400	-0.64296300
H	0.82624400	-2.68962400	-2.01933300
C	-2.45343000	0.45090000	-0.72563700
C	-3.75736200	0.43644800	0.11015300
C	-5.00649800	0.28777000	-0.51221500
C	-3.71335800	0.55612400	1.50212800
C	-6.17875500	0.24417000	0.24327100
H	-5.04859700	0.22496200	-1.59474300
C	-4.88601000	0.51325300	2.26029500
C	-6.12250300	0.35360000	1.63480400
H	-7.13711800	0.13084400	-0.25627800
H	-4.83120400	0.61209700	3.34098400
H	-7.03475500	0.32200300	2.22377700
N	-2.70834000	1.26617600	-1.91820900
C	-1.76868400	1.18375900	-3.03375900
H	-1.69312200	0.16353500	-3.41210900
H	-2.15995700	1.80178500	-3.84815300
H	-0.75898600	1.55256900	-2.78956200
C	-2.98742400	2.67411800	-1.60663900
H	-3.67678800	2.74860600	-0.76545300
H	-2.07780400	3.24047800	-1.35844000
H	-3.45798900	3.14185500	-2.47817500
O	-1.38485700	0.98210500	0.03452400

O	0.48934500	0.99276300	3.32197800
C	0.23767900	0.45878700	2.34840000
H	-0.01444200	-0.39553100	-1.71937000
H	-2.75517600	0.70300000	1.98503300

Int 2

Pd	0.72536600	1.37813300	-0.58580800
O	-2.95801600	2.79127300	-2.04680800
C	-2.21315200	2.04772100	-1.41966300
O	-1.01100400	1.70763800	-1.76185700
C	-2.80835500	1.42592500	-0.10963900
H	-3.88125700	1.31575700	-0.27370500
N	-2.23762900	0.07337000	0.05047200
C	-2.88577200	-1.06214200	0.10044800
O	-2.27166400	-2.21746800	-0.05318000
O	-4.16647200	-1.04780900	0.34065800
C	-5.09431800	-2.22928900	0.19782100
C	-4.75642000	-3.26166500	1.27230700
H	-5.51874600	-4.04651000	1.25927300
H	-3.78434400	-3.72535200	1.10213800
H	-4.76397000	-2.80038500	2.26390000
C	-6.45203700	-1.57850900	0.45689000
H	-6.48242900	-1.12599200	1.45141500
H	-6.66239900	-0.80520100	-0.28641800
H	-7.23635700	-2.33808300	0.39827100
C	-5.00318500	-2.77803800	-1.22532500
H	-5.16773300	-1.98231600	-1.95762000
H	-4.04138400	-3.25380500	-1.42051000
H	-5.78716500	-3.52863100	-1.36292400
C	-2.56659200	2.28777300	1.15522000
H	-1.47864100	2.34346700	1.30347900
C	-3.10747200	3.71227600	0.95998000
H	-2.66759100	4.20559200	0.09144700
H	-4.19297800	3.69979800	0.81006600
H	-2.89777100	4.31436900	1.84977800
C	-3.18376200	1.63909900	2.40341300
H	-2.77925800	0.64005800	2.59289600
H	-2.97897300	2.24968400	3.28838400
H	-4.27219900	1.55314300	2.30268500
H	-1.22116300	0.02885200	-0.09012200
C	0.17805100	-2.69792600	-2.02132400
C	1.13232100	-3.37016100	-1.24945600
C	1.93891100	-2.65745000	-0.36127600
C	1.78759200	-1.27335600	-0.20950400
C	0.79228300	-0.59674900	-0.94370300

C	0.00996500	-1.31099700	-1.86801100
H	-0.41787300	-3.24129900	-2.75104600
H	1.26415500	-4.44280300	-1.36010600
H	2.70302300	-3.17633600	0.20868000
H	-0.70645600	-0.77080600	-2.48334800
C	2.68018500	-0.40621000	0.68257300
C	4.15476000	-0.63296200	0.26204300
C	4.92050400	-1.67923300	0.79622100
C	4.72846000	0.18949200	-0.71424100
C	6.22825100	-1.89949100	0.36011300
H	4.48898300	-2.30034500	1.57439200
C	6.03458100	-0.03286500	-1.15333400
C	6.78983700	-1.07878300	-0.61967800
H	6.81014500	-2.71009100	0.79135800
H	6.46439100	0.61634100	-1.91170900
H	7.80771700	-1.24942400	-0.95967800
N	2.52936900	-0.80048300	2.10449400
C	1.14790100	-0.89386500	2.56695400
H	0.58814700	-1.61775800	1.96967300
H	1.14927300	-1.24722800	3.60385200
H	0.61245100	0.07156600	2.54127900
C	3.27973600	0.08055200	3.00685900
H	4.31654200	0.16444300	2.67863500
H	2.85381500	1.09392900	3.05783100
H	3.27242000	-0.35405200	4.01268400
O	2.36253500	0.95367100	0.47267200
O	1.11122100	4.47539400	0.07341400
C	0.92178400	3.37706500	-0.15935500
H	-1.39877800	-2.11605000	-0.51810800
H	4.14026100	1.00828700	-1.11158400

Int 3

Pd	0.90102700	1.18558400	-0.58425100
O	-3.19269900	1.78106300	-2.11936000
C	-2.24071100	1.47975600	-1.23591800
O	-1.06660100	1.41646200	-1.59766200
C	-2.79153200	1.18552300	0.16229200
H	-3.85754800	1.41181300	0.13572700
N	-2.66152400	-0.24345000	0.39943600
C	-3.66133700	-1.18491000	0.26447500
O	-3.44435900	-2.38061800	0.34102100
O	-4.86158300	-0.59597500	0.06642500
C	-6.08747100	-1.40576400	-0.07271000
C	-6.33568300	-2.20080800	1.21269900
H	-7.30150300	-2.71194200	1.14586200

H	-5.55383100	-2.94388100	1.37016500
H	-6.36678000	-1.52823200	2.07571600
C	-7.16691500	-0.33945900	-0.27266000
H	-7.21640900	0.32881900	0.59210000
H	-6.95770000	0.26080300	-1.16301300
H	-8.14401200	-0.81506100	-0.39755400
C	-5.97848400	-2.30863400	-1.30552600
H	-5.75288500	-1.71160100	-2.19497700
H	-5.19890400	-3.05926700	-1.17445300
H	-6.93385100	-2.81663200	-1.47192800
C	-2.11249200	2.04451800	1.25506300
H	-1.04550100	1.77994500	1.26677700
C	-2.24249300	3.54034100	0.92930600
H	-1.78105100	3.80233500	-0.02929000
H	-3.29472200	3.84597100	0.89045900
H	-1.75160800	4.14120300	1.70041800
C	-2.70946100	1.72618200	2.63174900
H	-2.61622500	0.66524000	2.87475800
H	-2.19350900	2.29981900	3.40771900
H	-3.77284000	1.99181900	2.67018300
H	-1.73102800	-0.64507700	0.44606000
C	0.07888300	-3.04587900	-0.97138200
C	1.14006200	-3.58555100	-0.24335900
C	2.10792300	-2.74629000	0.31072700
C	2.01269400	-1.35857500	0.16636000
C	0.92073600	-0.81260100	-0.53560600
C	-0.02359900	-1.65882800	-1.12670800
H	-0.67197600	-3.69498500	-1.41261200
H	1.22050900	-4.66143500	-0.11544300
H	2.94604400	-3.16923600	0.85592500
H	-0.84357000	-1.25041500	-1.71034100
C	3.05207100	-0.37006600	0.68399300
C	4.40559500	-0.66958300	-0.00839800
C	5.28081900	-1.64420100	0.49315500
C	4.75175300	-0.00321800	-1.18912400
C	6.46807800	-1.94842200	-0.17422700
H	5.03331300	-2.14339300	1.42412900
C	5.93741700	-0.30976800	-1.85945000
C	6.80022100	-1.28487000	-1.35689400
H	7.13622500	-2.70246500	0.23389600
H	6.18907100	0.21920000	-2.77516300
H	7.72411600	-1.52172800	-1.87758600
N	3.22724700	-0.49485100	2.14258800
C	1.98542100	-0.47124900	2.91211300

H	1.29721700	-1.24024700	2.55726700
H	2.22031300	-0.68396200	3.96085400
H	1.47198300	0.50485100	2.87315600
C	4.16108000	0.49048300	2.69722500
H	5.09496500	0.49052000	2.13373400
H	3.75281500	1.51290100	2.68724800
H	4.38671300	0.21814500	3.73435500
O	2.64517800	0.94756400	0.32786300
O	1.63642700	4.29808400	-0.51148600
C	1.25603200	3.22467700	-0.55612400
H	4.08600300	0.76308700	-1.56781000
H	-2.76370000	1.90489300	-2.98581300

Int 4

Pd	0.65658500	-0.81807900	-0.73550000
O	-2.23067400	0.77390300	-2.08759100
C	-2.91283300	1.53895000	-1.43762200
O	-3.90610500	2.26919700	-1.98652800
C	-2.75922000	1.81318600	0.06207700
H	-3.72671000	2.16827500	0.42805100
N	-2.40259900	0.59183300	0.76392600
C	-3.19265800	-0.52656200	0.80976600
O	-2.79408800	-1.61769700	1.19566100
O	-4.44462000	-0.23999400	0.39083300
C	-5.49675800	-1.27230200	0.34971100
C	-5.76157200	-1.80716100	1.76022000
H	-6.62261000	-2.48303700	1.73882600
H	-4.89639600	-2.34957800	2.14182800
H	-5.99360900	-0.98309000	2.44216000
C	-6.70304700	-0.48868900	-0.17375600
H	-6.96851100	0.31840300	0.51513900
H	-6.48156100	-0.04773400	-1.14997100
H	-7.56592700	-1.15282300	-0.27887700
C	-5.09793300	-2.38079800	-0.62978300
H	-4.86795100	-1.95520600	-1.61182600
H	-4.22712600	-2.92785400	-0.26807800
H	-5.93045900	-3.08154700	-0.74928000
C	-1.68350000	2.90242300	0.33043200
H	-0.71831100	2.47727000	0.02240600
C	-1.92597600	4.17790100	-0.49017000
H	-1.86701200	4.00099700	-1.56758900
H	-2.91041100	4.60821000	-0.27475600
H	-1.16984300	4.92722600	-0.23757700
C	-1.62228900	3.23184600	1.83007000
H	-1.43974600	2.34473200	2.44126600

H	-0.81841300	3.94836200	2.02523600
H	-2.56293700	3.68460400	2.16580200
H	-1.41771900	0.39392800	0.89723100
C	0.90689600	-1.08681200	3.61167700
C	2.00764600	-0.26269800	3.84444300
C	2.67917100	0.32650200	2.77103000
C	2.26367800	0.09038100	1.45774100
C	1.15064700	-0.73969000	1.22992000
C	0.47038300	-1.32459200	2.30237600
H	0.37490900	-1.53967400	4.44406800
H	2.33692700	-0.06665600	4.86129400
H	3.51078200	1.00454000	2.94140900
H	-0.41837400	-1.92585700	2.14150400
C	2.93692700	0.67936300	0.21798800
C	4.14772600	-0.21420900	-0.16866000
C	4.21678900	-0.80439900	-1.43404700
C	5.20056300	-0.43839900	0.72972900
C	5.29951100	-1.61244200	-1.79149600
H	3.42027100	-0.60533300	-2.14065900
C	6.28360100	-1.24235300	0.37570900
H	5.17628900	0.01953900	1.71225200
C	6.33639800	-1.83801300	-0.88700800
H	5.33305800	-2.05945000	-2.78178900
H	7.08734900	-1.40566900	1.08876800
H	7.17844200	-2.46738500	-1.16147000
N	3.42185800	2.04273200	0.47881200
C	2.35947900	2.98679800	0.82904400
H	1.72772100	2.57419200	1.61743800
H	2.81744700	3.90761200	1.20761000
H	1.71983300	3.24760500	-0.02868400
C	4.25605100	2.61702500	-0.57941900
H	5.10586300	1.96897800	-0.79471700
H	3.70265700	2.79139700	-1.51600600
H	4.64410000	3.58005700	-0.23025300
O	1.97403500	0.68798500	-0.82397400
O	0.27320000	-0.21587000	-3.89857700
C	0.35552900	-0.50326300	-2.80302200
H	-3.90760700	2.06421700	-2.93739300
C	-0.43864100	-2.41681000	-0.53271200
O	-0.94944200	-3.43511100	-0.47419800

Int 5

Pd	0.40460300	1.13754100	-0.90862500
O	-1.82094200	1.49948600	-1.23562000
C	-2.82950000	1.61660000	-0.55178100

O	-3.91891900	2.21701500	-1.04038500
C	-3.00701700	1.14799400	0.89504000
H	-4.06858800	1.26265800	1.12947600
N	-2.64718000	-0.24972400	1.03450200
C	-3.35913300	-1.30297500	0.50511200
O	-3.00584000	-2.46473500	0.60558400
O	-4.47614400	-0.84779800	-0.10210100
C	-5.41782000	-1.77438500	-0.76338900
C	-6.00717700	-2.74194700	0.26723300
H	-6.79517000	-3.33883700	-0.20300200
H	-5.24214700	-3.41326000	0.65756800
H	-6.45254200	-2.18737500	1.09928500
C	-6.49184500	-0.82365500	-1.29727200
H	-6.97904700	-0.28779600	-0.47735300
H	-6.05138300	-0.08693000	-1.97503300
H	-7.25313400	-1.38809900	-1.84330900
C	-4.70752500	-2.50060600	-1.90919200
H	-4.26769400	-1.77982300	-2.60534400
H	-3.91641100	-3.14858300	-1.53195800
H	-5.43203100	-3.10900500	-2.46008800
C	-2.17562000	2.02862900	1.86502200
H	-1.11585100	1.83588000	1.64164900
C	-2.44632700	3.52439200	1.64240200
H	-2.15973100	3.85632300	0.63947000
H	-3.50628800	3.76213300	1.78707600
H	-1.87090500	4.11843000	2.35826300
C	-2.45688300	1.63659700	3.32288500
H	-2.27233000	0.57581100	3.50874800
H	-1.81854400	2.21519200	3.99753500
H	-3.50007500	1.84648300	3.58686200
H	-1.71631700	-0.49181100	1.34462800
C	0.81748100	-3.28999500	1.97570600
C	2.00393400	-2.82900600	2.55472500
C	2.67723600	-1.74122900	2.00550800
C	2.18146000	-1.06070800	0.88368000
C	0.98182700	-1.52389800	0.31566100
C	0.31287900	-2.64433100	0.85492100
H	0.29181200	-4.14314800	2.39398900
H	2.40927300	-3.32182100	3.43433900
H	3.60231100	-1.39765600	2.45264000
H	-0.61712600	-2.96530900	0.39820100
C	3.02231200	0.08417800	0.25183200
C	4.26690900	-0.62729300	-0.36578000
C	5.42193900	-0.89709100	0.38090700

C	4.21460800	-1.05440000	-1.69796100
C	6.49856600	-1.57622900	-0.19231000
H	5.48155000	-0.55193500	1.40755900
C	5.28750300	-1.74063700	-2.26857700
H	3.32959400	-0.83126600	-2.28198900
C	6.43474400	-2.00559800	-1.51880100
H	7.38930000	-1.76761400	0.40056900
H	5.22693300	-2.06492900	-3.30415400
H	7.27137000	-2.53710100	-1.96402600
N	3.47835400	0.98755200	1.34645200
C	2.40599500	1.52434600	2.17862600
H	1.80691200	0.71942700	2.60865500
H	2.85064800	2.09099500	3.00444700
H	1.72864700	2.20755800	1.63367300
C	4.29614100	2.09631500	0.84624000
H	5.10025200	1.72187800	0.21217600
H	3.71346700	2.82470200	0.26139000
H	4.74509400	2.61736300	1.69930000
O	2.39870100	0.75650400	-0.78078200
O	1.40703700	4.18528800	-1.44031900
C	0.84932200	3.21175300	-1.23969300
H	-3.71418600	2.49253900	-1.95175400
C	0.27901600	-0.84051600	-0.80158300
O	-0.45211200	-1.37133400	-1.60191900

Int 6

Pd	0.52397500	1.44087000	-0.84501000
O	-1.97076000	1.40467700	-0.35083200
C	-2.89070800	1.37728400	0.45066700
O	-3.81612200	2.34696200	0.50303900
C	-3.12755400	0.27886500	1.48996600
H	-4.16637600	0.36072000	1.81655100
N	-2.92794500	-1.03180000	0.89806000
C	-3.76970900	-1.59188700	-0.03771100
O	-3.47984500	-2.58646600	-0.68197100
O	-4.92689700	-0.89716000	-0.11098200
C	-6.01818300	-1.32352400	-1.00839600
C	-6.50954000	-2.71715600	-0.60564300
H	-7.39183900	-2.97920500	-1.19841800
H	-5.73701200	-3.46799700	-0.77295400
H	-6.79529000	-2.72957200	0.45093100
C	-7.09240000	-0.26591400	-0.74392200
H	-7.40870100	-0.28765800	0.30305900
H	-6.71072300	0.73459600	-0.96756600
H	-7.96674200	-0.45376600	-1.37383400

C	-5.54511500	-1.27011400	-2.46439100
H	-5.16661700	-0.27168800	-2.70613200
H	-4.75742800	-2.00103900	-2.64753900
H	-6.38742800	-1.48305800	-3.13043400
C	-2.19206800	0.46580200	2.71671300
H	-1.16523000	0.30424100	2.35968000
C	-2.27897800	1.88616600	3.29488700
H	-1.95457500	2.65048300	2.58205300
H	-3.30263900	2.12712000	3.60268500
H	-1.63709700	1.96888700	4.17691200
C	-2.51083500	-0.58189500	3.79287000
H	-2.46016400	-1.59894400	3.39770600
H	-1.80080800	-0.49961100	4.62164100
H	-3.51763600	-0.42734100	4.19861900
H	-1.97223300	-1.35803500	0.80524100
C	-0.03322900	-2.76162700	-0.55687000
C	1.11751600	-3.25462900	0.05978100
C	2.18813200	-2.39994900	0.31652800
C	2.11967600	-1.03613100	-0.01455200
C	0.94598000	-0.52089900	-0.57856500
C	-0.10839300	-1.40228600	-0.87503300
H	-0.87468700	-3.40996200	-0.78308500
H	1.19326600	-4.30605200	0.32240100
H	3.08871600	-2.80111400	0.76724800
H	-1.00954700	-1.03037500	-1.35446100
C	3.34033500	-0.13663100	0.25740100
C	4.64948000	-0.91693800	0.01126400
C	5.13757500	-1.10435500	-1.28868300
C	5.33095500	-1.51264900	1.07964600
C	6.28498500	-1.86527100	-1.51122600
H	4.62335500	-0.64475100	-2.12460000
C	6.48033500	-2.27377200	0.85592800
H	4.95231800	-1.37101000	2.08612500
C	6.96215700	-2.45283900	-0.44063600
H	6.65163900	-1.99609500	-2.52544700
H	6.99765200	-2.72485600	1.69828600
H	7.85676400	-3.04361500	-0.61626300
N	3.34501000	0.43171100	1.58436600
C	2.08387900	0.75102800	2.24017100
H	1.40590700	-0.10189400	2.20383800
H	2.29827300	0.97444000	3.29120500
H	1.56637700	1.62361000	1.80496300
C	4.33915900	1.48572100	1.79774400
H	5.27986300	1.22469300	1.31252700

H	4.01240700	2.46059000	1.40412100
H	4.52126600	1.59216000	2.87258200
O	3.44022600	0.93535900	-0.77865100
O	-0.04131700	4.54748000	-1.32136300
C	0.12993500	3.43691900	-1.12763700
H	-3.58251400	3.00834200	-0.17179600
C	2.45519300	1.65424000	-1.32448900
O	2.71517900	2.52327200	-2.12514900

Int 7

Pd	3.55216100	-0.44347200	-0.01606600
O	1.37536100	-0.18074400	0.09693000
C	0.63891700	0.56029400	-0.53703300
O	1.13862000	1.32159300	-1.51287100
C	-0.84563200	0.68933800	-0.21922800
H	-1.40043400	0.75039200	-1.16379500
N	-1.25677300	-0.50726600	0.48291600
C	-2.52410500	-1.03401900	0.50167800
O	-2.80327200	-2.07107600	1.07455200
O	-3.37584600	-0.23711800	-0.19129800
C	-4.80078900	-0.59914900	-0.33202600
C	-5.46691500	-0.63832200	1.04671800
H	-6.54337000	-0.79802200	0.92823300
H	-5.05579600	-1.44286900	1.65635600
H	-5.32185200	0.31333500	1.56817800
C	-5.35540800	0.55301000	-1.17300200
H	-5.22554500	1.50900400	-0.65694300
H	-4.84677100	0.60778800	-2.14017900
H	-6.42351900	0.40284700	-1.35469300
C	-4.92886500	-1.93012500	-1.07930000
H	-4.40712700	-1.88027800	-2.04043200
H	-4.51377400	-2.74978400	-0.49276500
H	-5.98521400	-2.13710100	-1.27833200
C	-1.14522000	2.00183700	0.58798300
H	-2.21216800	1.90760800	0.81884200
C	-0.36288600	2.06944600	1.90475500
H	-0.50621500	1.16229600	2.49787000
H	0.71222900	2.19853900	1.73493300
H	-0.70559500	2.91847200	2.50394800
C	-0.95890600	3.27251700	-0.25377900
H	-1.49640600	3.21363600	-1.20945700
H	-1.35725200	4.13937800	0.28145100
H	0.09741200	3.48565800	-0.45379400
H	-0.54360500	-1.06183000	0.93573700
O	6.52691500	-0.83187200	-0.10462900

C	5.38280900	-0.68289500	-0.06831200
H	0.44079100	1.83366500	-1.94875200

Int 8

Pd	0.03191900	0.02436700	0.42728100
O	-2.88946100	-2.09540600	2.40630600
C	-2.28696300	-2.06708800	1.36006900
O	-1.15234200	-2.77667200	1.20091400
C	-2.89294300	-1.34729300	0.14060800
H	-3.68764800	-0.73321400	0.56196900
N	-1.94511100	-0.40899200	-0.56385500
C	-2.46547800	0.88133600	-0.96085400
O	-2.23406300	1.33140100	-2.06054000
O	-3.15919600	1.43359400	0.02824700
C	-3.79131300	2.78097600	-0.12364300
C	-4.82968600	2.72710600	-1.24571400
H	-5.37056900	3.67780600	-1.27899200
H	-4.36058000	2.56200400	-2.21628200
H	-5.55856300	1.93257700	-1.05813100
C	-4.45327700	2.98190200	1.23916600
H	-5.19187900	2.19923200	1.43395600
H	-3.70971600	2.96400600	2.04027200
H	-4.96197400	3.94976900	1.26154300
C	-2.70471000	3.82739700	-0.37633800
H	-1.95985200	3.81199900	0.42440000
H	-2.20612600	3.66261000	-1.33198400
H	-3.16355200	4.82082400	-0.38869300
C	-3.49865400	-2.37448800	-0.85800100
H	-2.65802300	-2.91768900	-1.31570600
C	-4.38345200	-3.40424200	-0.13617700
H	-3.82361400	-3.99830500	0.58996000
H	-5.20454500	-2.91292200	0.39670400
H	-4.81935600	-4.09175400	-0.86705100
C	-4.29360400	-1.67331700	-1.97191800
H	-3.69558200	-0.96246100	-2.54986200
H	-4.68489100	-2.41486700	-2.67463300
H	-5.14969600	-1.13195800	-1.55223000
H	-1.60794800	-0.81826700	-1.43264500
C	1.46973400	-2.96491800	-2.44829300
C	2.82507700	-2.97712100	-2.12628300
C	3.31450100	-2.10611600	-1.15161600
C	2.45936900	-1.22720600	-0.48264400
C	1.07926300	-1.22361500	-0.78065700
C	0.60598900	-2.09189900	-1.77535500
H	1.07916600	-3.62865100	-3.21493700

H	3.50083000	-3.66054200	-2.63264800
H	4.36734600	-2.11778500	-0.88740100
H	-0.44374900	-2.11966100	-2.06546000
C	2.94395400	-0.20838800	0.54873400
C	3.65438700	0.94030300	-0.21711600
C	4.95314900	0.78050200	-0.72315800
C	2.99508800	2.15134100	-0.44770200
C	5.56909600	1.80090200	-1.44722600
H	5.49158500	-0.13975500	-0.52334200
C	3.60787100	3.17281000	-1.17773700
H	2.00148700	2.28989100	-0.03880800
C	4.89619000	3.00204300	-1.68346800
H	6.57841100	1.65840100	-1.82450500
H	3.07644500	4.10612700	-1.34541700
H	5.37451100	3.79651400	-2.24966400
N	3.89286800	-0.81552000	1.49248000
C	3.35936300	-1.98504300	2.19655800
H	2.98391200	-2.72308700	1.48585900
H	4.17067700	-2.44738400	2.76890000
H	2.54657500	-1.72845300	2.89244300
C	4.44853400	0.12653500	2.47058900
H	4.85957300	1.00263000	1.96828700
H	3.70308000	0.46421700	3.20644600
H	5.26169100	-0.37081400	3.01052900
O	1.82015900	0.29317000	1.25391700
O	-0.94944000	1.96098600	2.75204900
C	-0.69680600	1.27845700	1.87578900
H	-0.63331300	-2.51218200	0.41897400

TS1

Pd	-0.34993000	-1.44217700	-0.70238300
O	3.73173900	-1.79225300	-1.76070700
C	2.75014900	-1.45685500	-1.10910800
O	1.54632300	-1.36478600	-1.60271100
C	3.00460400	-1.06313200	0.38512900
H	3.94658800	-0.51174200	0.38765700
N	1.95420600	-0.15126700	0.87204800
C	1.84487700	1.12504600	0.47370500
O	0.71137800	1.67290400	0.29209100
O	2.98895300	1.75711000	0.31323600
C	3.10367200	3.16907300	-0.15910000
C	2.42127000	4.09621000	0.84804000
H	2.61752900	5.13555600	0.56671900
H	1.34237400	3.93956300	0.87031300
H	2.82588000	3.93532000	1.85178700

C	4.61926200	3.37265200	-0.16282200
H	5.03204800	3.23042300	0.83962200
H	5.10356100	2.66632400	-0.84248200
H	4.85298300	4.38856700	-0.49340100
C	2.52913800	3.29347900	-1.57052500
H	2.98875100	2.55790400	-2.23740700
H	1.44720800	3.16025100	-1.58227000
H	2.75751500	4.29091000	-1.95887100
C	3.13595600	-2.27193500	1.34518000
H	2.16631400	-2.79375400	1.35261700
C	4.20537600	-3.26762200	0.87282400
H	4.01040800	-3.63678800	-0.13478300
H	5.19423400	-2.79608400	0.86017600
H	4.24733600	-4.11862600	1.56056200
C	3.43165000	-1.80559600	2.77992600
H	2.66696900	-1.12231800	3.15954400
H	3.48478800	-2.66522500	3.45569200
H	4.39676800	-1.28711700	2.82522900
H	1.04404500	-0.58690700	1.00488800
C	-2.00869000	2.01857000	3.76584400
C	-2.69360200	2.64891100	2.72362900
C	-2.96016600	1.95989000	1.54065800
C	-2.54837500	0.62969400	1.38050800
C	-1.87020700	0.00365300	2.43090000
C	-1.60038200	0.69305000	3.61615400
H	-1.79936400	2.55625200	4.68644600
H	-3.01993500	3.67981500	2.83187300
H	-3.49379600	2.45741900	0.73688200
H	-1.58018200	-1.03392700	2.30811500
H	-1.07744000	0.18997700	4.42544400
C	-2.83892100	-0.14687900	0.07331400
C	-2.27409900	0.65762900	-1.10184400
C	-3.02875900	1.50835100	-1.90889700
C	-0.89638200	0.44986800	-1.38308600
C	-2.44396100	2.11055900	-3.02654400
H	-4.07852700	1.66073700	-1.67739900
C	-0.35040800	1.01067100	-2.56088400
C	-1.11061300	1.85271900	-3.36768300
H	-3.04190100	2.76738400	-3.65333700
H	0.68283100	0.78705900	-2.81146100
H	-0.67975600	2.29737800	-4.26022000
N	-4.29281100	-0.33210100	-0.07783400
C	-4.99298900	-0.80896300	1.11806400
H	-4.82792000	-0.13536100	1.95915500

H	-6.06643600	-0.82283000	0.90194600
H	-4.69398500	-1.82588600	1.41760500
C	-4.64928100	-1.18402400	-1.22035900
H	-4.12031600	-0.86534400	-2.11971800
H	-4.41526200	-2.24361900	-1.04794000
H	-5.72491300	-1.08801100	-1.40414200
O	-2.20475300	-1.41102900	0.07702100
O	-0.18405700	-4.46529900	0.11770100
C	-0.17547300	-3.35683700	-0.14445400
H	-0.05994000	0.95413000	-0.35320200

TS2

Pd	0.06158100	0.19335500	-0.14162100
O	1.32146200	-2.46667500	-2.22248800
C	1.45523200	-2.28425000	-1.01544000
O	0.71148500	-2.73481900	-0.05121400
C	2.65619600	-1.42374300	-0.51868400
H	3.02802600	-0.80944500	-1.33938700
N	2.09852400	-0.48284400	0.52657800
C	2.83650100	0.66415000	0.97416800
O	2.84150900	0.99257100	2.14118300
O	3.40995600	1.28671000	-0.05413400
C	4.17135500	2.55704500	0.13585300
C	5.35669500	2.31877800	1.07362700
H	5.96546400	3.22743400	1.11496700
H	5.02384300	2.07778600	2.08348100
H	5.98790200	1.50697000	0.70124100
C	4.64465400	2.86574100	-1.28472100
H	5.27821300	2.06026100	-1.66632800
H	3.79503900	2.98907800	-1.96162700
H	5.22498900	3.79271200	-1.28724100
C	3.22553500	3.64129600	0.65673100
H	2.37839700	3.77629500	-0.02224700
H	2.85233800	3.39719800	1.65204600
H	3.76503300	4.59189700	0.71116900
C	3.76958100	-2.34745700	0.03854200
H	3.28827600	-2.97715300	0.80018900
C	4.28735100	-3.26549500	-1.08314200
H	3.48216200	-3.82699700	-1.56060500
H	4.78914600	-2.67949000	-1.86210200
H	5.01452000	-3.97728100	-0.67961500
C	4.94434700	-1.60362000	0.69260100
H	4.64562300	-1.01463200	1.56485900
H	5.69245500	-2.32478200	1.03756800
H	5.43589100	-0.93551500	-0.02328300

H	1.86126400	-1.02399400	1.35568700
C	-1.57872500	-1.73687100	3.45943600
C	-2.93149000	-1.51623000	3.18829200
C	-3.34542100	-1.07779700	1.92880800
C	-2.42279000	-0.87499200	0.90131300
C	-1.04266600	-1.15671200	1.14238500
C	-0.65016800	-1.54882600	2.44351000
H	-1.26010800	-2.06660600	4.44352800
H	-3.67237300	-1.67287700	3.96758900
H	-4.39421500	-0.86608000	1.75596500
H	0.39071000	-1.79510400	2.63197300
C	-2.81478400	-0.22956900	-0.43633100
C	-4.02960000	0.72030100	-0.23037900
C	-5.33971200	0.25709300	-0.41499100
C	-3.83450700	2.03958700	0.19694500
C	-6.43020700	1.09743400	-0.18092800
H	-5.48839800	-0.76272400	-0.75287100
C	-4.92508300	2.87844400	0.43050300
H	-2.82305600	2.40262000	0.33354700
C	-6.22736500	2.41178000	0.24236300
H	-7.43882900	0.72279800	-0.33362600
H	-4.75548000	3.90084400	0.75749500
H	-7.07552500	3.06651800	0.42225300
N	-3.16540300	-1.21887300	-1.44753000
C	-2.42199200	-2.48040900	-1.49723500
H	-2.41501400	-2.96788600	-0.52149700
H	-2.94381200	-3.14714300	-2.19229800
H	-1.38396300	-2.38382800	-1.84720800
C	-3.29252000	-0.64921100	-2.79122100
H	-3.85699300	0.28417900	-2.75976300
H	-2.31645600	-0.44502300	-3.25601500
H	-3.83421400	-1.35845800	-3.42621900
O	-1.74339700	0.63785700	-0.81889600
O	0.96258800	2.23806800	-2.31759200
C	0.71819900	1.48847500	-1.49679100
H	-0.30593500	-1.84322700	0.37343600

TS3

Pd	0.58007800	-0.95978800	-0.47964400
O	-1.99006100	-0.05628000	-2.11940700
C	-2.67574400	0.90945600	-1.85307800
O	-3.59691800	1.39894000	-2.70759800
C	-2.60193700	1.72186400	-0.55842200
H	-3.57273300	2.20977500	-0.42773100
N	-2.34613300	0.84716000	0.57413700

C	-3.15025900	-0.19700200	0.95352100
O	-2.82144200	-1.03658300	1.77981900
O	-4.33402100	-0.13619200	0.30488100
C	-5.37364700	-1.16113900	0.50960700
C	-5.84698500	-1.14128100	1.96620500
H	-6.69442800	-1.82433500	2.08474700
H	-5.04800300	-1.44979000	2.64067700
H	-6.17983200	-0.13634500	2.24449400
C	-6.48526900	-0.69354500	-0.43299900
H	-6.84077000	0.30099800	-0.14840000
H	-6.12181700	-0.64603000	-1.46353700
H	-7.32930900	-1.38831500	-0.39262900
C	-4.83936600	-2.53369800	0.08764400
H	-4.45087800	-2.49159400	-0.93480100
H	-4.04253100	-2.86542500	0.75371000
H	-5.65144700	-3.26745300	0.11457100
C	-1.48964800	2.80673500	-0.63666500
H	-0.52642600	2.27862200	-0.68491900
C	-1.61443500	3.67846400	-1.89501800
H	-1.48860200	3.10242100	-2.81567200
H	-2.58770800	4.18040300	-1.94154100
H	-0.83848300	4.44965200	-1.88399700
C	-1.52053700	3.68471000	0.62479200
H	-1.41301800	3.10021000	1.54231100
H	-0.70570700	4.41455400	0.59358000
H	-2.46426700	4.23965600	0.69021000
H	-1.39130900	0.75997600	0.89508800
C	0.52702200	0.50791800	3.78262200
C	1.58234300	1.41164900	3.66173000
C	2.33077000	1.47615400	2.48252900
C	2.07033900	0.63113600	1.40098200
C	1.06945400	-0.35613600	1.58799000
C	0.26851100	-0.38506400	2.74253700
H	-0.08225500	0.47877700	4.68053800
H	1.81031600	2.09193400	4.47791700
H	3.11312400	2.21788600	2.35605600
H	-0.53882200	-1.10475900	2.82848200
C	2.69496900	0.86226600	-0.01684400
C	3.74395900	-0.25425300	-0.26180500
C	3.79370800	-0.88478800	-1.51037600
C	4.66116900	-0.63941100	0.72528700
C	4.73235100	-1.88626500	-1.76604900
H	3.09056500	-0.56273300	-2.27095300
C	5.59866500	-1.64270200	0.47301100

H	4.64302600	-0.15368900	1.69653600
C	5.63574900	-2.27177100	-0.77358700
H	4.76043200	-2.36338000	-2.74230900
H	6.29899300	-1.93435300	1.25106900
H	6.36324500	-3.05466000	-0.96907900
N	3.38639400	2.18292800	-0.01448900
C	2.44050100	3.30108400	-0.10291000
H	1.65223600	3.19826200	0.64496400
H	2.98112100	4.23305000	0.09921900
H	1.96189600	3.37536700	-1.08970400
C	4.41599100	2.35150800	-1.04218600
H	5.21963800	1.62592300	-0.91435100
H	4.02359700	2.26352800	-2.06875100
H	4.84702600	3.35236600	-0.93226300
O	1.66664200	0.83982500	-0.95019600
O	-0.21805200	-2.69352700	-2.92847300
C	0.07768900	-2.04172100	-2.03809000
H	-3.54397800	0.85573000	-3.51272600
C	0.99045800	-2.05935100	0.99191700
O	1.36469900	-3.03062300	1.51237800

TS4

Pd	-0.11332400	-1.38422500	0.26999600
O	1.43826000	0.04387700	1.32204900
C	2.25978700	0.93476200	1.47897700
O	2.84043100	1.13600600	2.66785700
C	2.74123900	1.92295500	0.41668000
H	3.76670800	2.19015000	0.68694700
N	2.73592600	1.30835300	-0.89406600
C	3.51472100	0.23111200	-1.24964200
O	3.33149000	-0.41240400	-2.26985900
O	4.48337800	0.02446900	-0.32912500
C	5.49361700	-1.03757600	-0.50999600
C	6.30643100	-0.76949700	-1.78011400
H	7.12555400	-1.49241900	-1.84936900
H	5.68311900	-0.85815500	-2.67019700
H	6.74207900	0.23414200	-1.74876800
C	6.36359500	-0.88204400	0.73932100
H	6.82183900	0.11065500	0.77192700
H	5.76641600	-1.01642900	1.64615600
H	7.16048200	-1.63126700	0.73615600
C	4.80999000	-2.40816000	-0.53397600
H	4.20149200	-2.54639100	0.36575000
H	4.17336700	-2.51308000	-1.41257300
H	5.57036100	-3.19550100	-0.55153600

C	1.87569700	3.21913400	0.39082000
H	0.88314200	2.92913700	0.01918400
C	1.70254100	3.85270100	1.77870700
H	1.16113600	3.20598400	2.47409700
H	2.67131600	4.09521600	2.22918500
H	1.13398700	4.78271400	1.68704900
C	2.48751400	4.23202500	-0.58976100
H	2.61935800	3.80957300	-1.58835900
H	1.84015300	5.11024900	-0.67316400
H	3.46774800	4.57090600	-0.23440600
H	1.87145400	1.36104100	-1.42016800
C	-0.54892400	1.48631700	-2.88979500
C	-1.69230300	2.19053900	-2.50140600
C	-2.46309000	1.74958100	-1.42581500
C	-2.10345800	0.60835400	-0.68855600
C	-0.91012600	-0.02086600	-1.04778000
C	-0.15951000	0.35343600	-2.16647100
H	0.02332500	1.79643300	-3.76018200
H	-2.00590600	3.06722800	-3.06144000
H	-3.37514800	2.27724600	-1.17160500
H	0.71342300	-0.21696600	-2.47377600
C	-2.98431700	0.00660900	0.45870900
C	-4.46908600	-0.00678000	-0.01495300
C	-5.02290400	-1.17754700	-0.54254600
C	-5.28357200	1.13377200	0.06985100
C	-6.34132500	-1.20246200	-1.00262600
H	-4.41748900	-2.07359600	-0.57148800
C	-6.60322300	1.11001000	-0.38420300
H	-4.87984700	2.03028500	0.52903500
C	-7.13706600	-0.05855900	-0.93066700
H	-6.74948100	-2.12385000	-1.41034800
H	-7.21675600	2.00381100	-0.30223500
H	-8.16439900	-0.07997200	-1.28447900
N	-2.92618700	0.94022500	1.63599500
C	-1.59592000	1.36452700	2.04036200
H	-1.07829300	1.85657600	1.21420900
H	-1.69405600	2.09153200	2.85555500
H	-0.95836500	0.53906000	2.40737300
C	-3.62308200	0.37691800	2.79662700
H	-4.62520300	0.05158700	2.51406600
H	-3.09460900	-0.48525100	3.23185200
H	-3.71890600	1.15417900	3.56398500
O	-2.55273600	-1.26262500	0.76873000
O	1.26806400	-3.67784800	1.97642800

C	0.77060700	-2.82975700	1.39772000
H	2.45238200	0.50111400	3.29528200
C	-1.53199400	-2.30960900	-0.71283600
O	-2.36647600	-2.85410200	-1.29068200

TS5

Pd	0.35801400	1.58487900	-0.61088400
O	-2.05111700	1.46284100	0.44374300
C	-2.93057000	1.07097000	1.18850500
O	-3.87379100	1.89498300	1.67691300
C	-3.09192200	-0.36644200	1.68898700
H	-4.12869900	-0.48301700	2.01424500
N	-2.82401600	-1.31100500	0.61999500
C	-3.60213900	-1.44480700	-0.50648600
O	-3.25688900	-2.09427400	-1.48104700
O	-4.76991300	-0.78132900	-0.35577500
C	-5.80074800	-0.79690600	-1.41159000
C	-6.28272100	-2.23124600	-1.64857300
H	-7.12434000	-2.22300000	-2.34865800
H	-5.48526100	-2.84799000	-2.06359900
H	-6.62659600	-2.67766900	-0.71011000
C	-6.91084100	0.05999500	-0.79845300
H	-7.28582800	-0.39268900	0.12416500
H	-6.53845500	1.06129200	-0.56317200
H	-7.74355100	0.15445100	-1.50147600
C	-5.24886100	-0.14894500	-2.68513500
H	-4.87854700	0.85868600	-2.47078200
H	-4.43656800	-0.74230600	-3.10507300
H	-6.04744400	-0.06598200	-3.42926300
C	-2.14621100	-0.64324700	2.89086400
H	-1.11925500	-0.58106400	2.50289900
C	-2.30021800	0.40372700	4.00414400
H	-2.03758800	1.41237200	3.67220400
H	-3.32888300	0.43221700	4.38024700
H	-1.64457800	0.15280800	4.84335200
C	-2.38072100	-2.05772900	3.44135200
H	-2.27737500	-2.82029800	2.66622300
H	-1.66138700	-2.27789500	4.23628400
H	-3.38714400	-2.14470400	3.86734000
H	-1.85894200	-1.57553300	0.46013300
C	0.10044500	-2.63298000	-0.83652200
C	1.13215400	-3.10972600	-0.02016300
C	2.15404300	-2.25438900	0.38897100
C	2.12844000	-0.90360900	0.01750500
C	1.05681400	-0.40118100	-0.72487300

C	0.07186600	-1.28445100	-1.20234600
H	-0.68477700	-3.29480700	-1.19027700
H	1.16154500	-4.15766700	0.26472700
H	2.98688300	-2.64441700	0.96423200
H	-0.73668700	-0.93132100	-1.83510300
C	3.31836200	0.03148900	0.29821900
C	4.63209200	-0.66770100	-0.10633500
C	5.08430600	-0.63202800	-1.43181700
C	5.35530500	-1.40976500	0.83745800
C	6.23560400	-1.32820500	-1.80189300
H	4.54425900	-0.04923300	-2.16926000
C	6.50855600	-2.10227400	0.46456700
H	5.01402600	-1.42588700	1.86722100
C	6.95210200	-2.06583900	-0.85784100
H	6.57485700	-1.28790200	-2.83312700
H	7.06072100	-2.66694800	1.21084500
H	7.84981600	-2.60364200	-1.14947800
N	3.38675600	0.48301500	1.66541200
C	2.12822900	0.81980200	2.32336600
H	1.43640400	-0.02298400	2.28263900
H	2.34033800	1.03700900	3.37520100
H	1.62827500	1.70095000	1.88473600
C	4.39063500	1.52713600	1.89814400
H	5.32994100	1.26454200	1.41074000
H	4.06828800	2.50830600	1.51841500
H	4.57176700	1.61222100	2.97446000
O	3.20070400	1.17498600	-0.63766500
O	-0.12769900	4.66185900	-0.70688400
C	0.01886600	3.52709100	-0.65584900
H	-3.67966000	2.78469900	1.33370500
C	2.15550200	1.24390600	-1.50818500
O	2.29950700	1.50756400	-2.67152700

TS6

Pd	0.50250500	1.30847600	-0.93969100
O	-1.84374900	1.39544000	-1.12834100
C	-2.82140800	1.54690900	-0.41022000
O	-3.87291900	2.27145800	-0.81245000
C	-2.99893700	0.97081800	0.99702700
H	-4.04993800	1.10618000	1.26434200
N	-2.69430900	-0.44830900	1.00617000
C	-3.45685300	-1.41634800	0.39469800
O	-3.12159300	-2.58782100	0.32819500
O	-4.59649400	-0.87677000	-0.08848200
C	-5.60436000	-1.70619500	-0.77998100

C	-6.14925900	-2.76910400	0.17821500
H	-6.97591800	-3.30316900	-0.30124600
H	-5.37466500	-3.48773800	0.44659200
H	-6.53215600	-2.29999300	1.09013000
C	-6.68370100	-0.68031100	-1.13295100
H	-7.10063200	-0.22867500	-0.22796800
H	-6.26727400	0.11765600	-1.75436400
H	-7.49509300	-1.16398300	-1.68449600
C	-4.99305500	-2.31717600	-2.04438300
H	-4.57182100	-1.53347700	-2.68184700
H	-4.20636100	-3.02938100	-1.79527700
H	-5.77223700	-2.83513800	-2.61263600
C	-2.11299400	1.72869900	2.02087600
H	-1.06609900	1.52529600	1.75137000
C	-2.33727700	3.24647400	1.94567500
H	-2.06836300	3.66038700	0.96898100
H	-3.38386900	3.50336900	2.14430500
H	-1.72131000	3.75238500	2.69475500
C	-2.36915700	1.21077100	3.44370000
H	-2.21353700	0.13237400	3.52517600
H	-1.69596700	1.70517300	4.15079000
H	-3.39798600	1.42581900	3.75547100
H	-1.75471700	-0.74743600	1.23307300
C	0.44749500	-2.97261400	1.89169900
C	1.57543700	-2.57107500	2.61678800
C	2.43239800	-1.59490000	2.10813100
C	2.16076800	-0.98284400	0.88073300
C	1.02575000	-1.38434800	0.16806300
C	0.17327900	-2.38987400	0.65669800
H	-0.21230900	-3.74251200	2.28003500
H	1.79351200	-3.02942400	3.57738800
H	3.31801900	-1.30180800	2.66147500
H	-0.69812200	-2.69466800	0.08568700
C	3.09271600	0.03311000	0.18898600
C	4.33729800	-0.78311500	-0.27335100
C	5.40448900	-1.03920200	0.59814700
C	4.37809900	-1.31821100	-1.56596300
C	6.48887400	-1.81474600	0.18567000
H	5.38873800	-0.60570500	1.59238400
C	5.46065900	-2.09888600	-1.97548400
H	3.56178700	-1.10705600	-2.24628500
C	6.51973000	-2.35209200	-1.10251900
H	7.31152800	-1.99662500	0.87239800
H	5.47639700	-2.50600800	-2.98298400

H	7.36280600	-2.95771800	-1.42356500
N	3.53327100	1.05979400	1.15778000
C	2.48637300	1.70294600	1.94488700
H	1.87902200	0.96219900	2.46845800
H	2.96084100	2.34045300	2.69944000
H	1.81062600	2.34241300	1.34887800
C	4.38966400	2.07857100	0.54556100
H	5.18634500	1.60754900	-0.03151100
H	3.83646900	2.75402200	-0.12552500
H	4.84916400	2.67922800	1.33827600
O	2.48624700	0.53338800	-0.96150100
O	1.03843200	4.41777500	-1.40736500
C	0.70144300	3.35507200	-1.15199900
H	-3.66752600	2.60711400	-1.70319700
C	0.68408100	-0.69850200	-1.09981100
O	0.29924600	-1.15651500	-2.13926900

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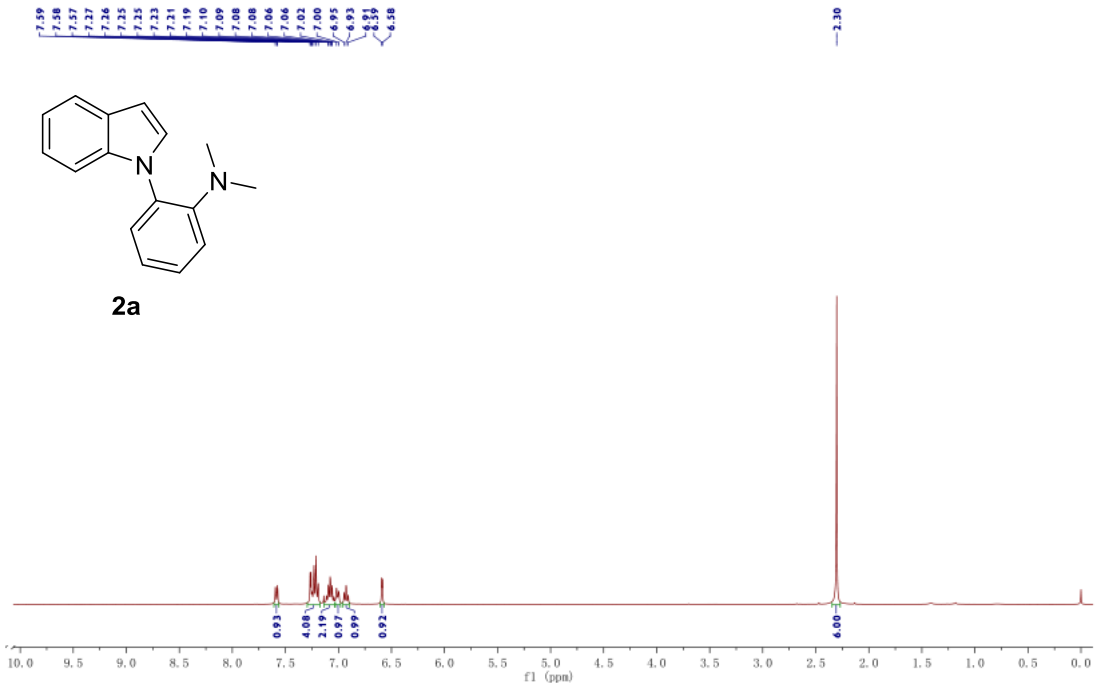
5. NMR Spectra



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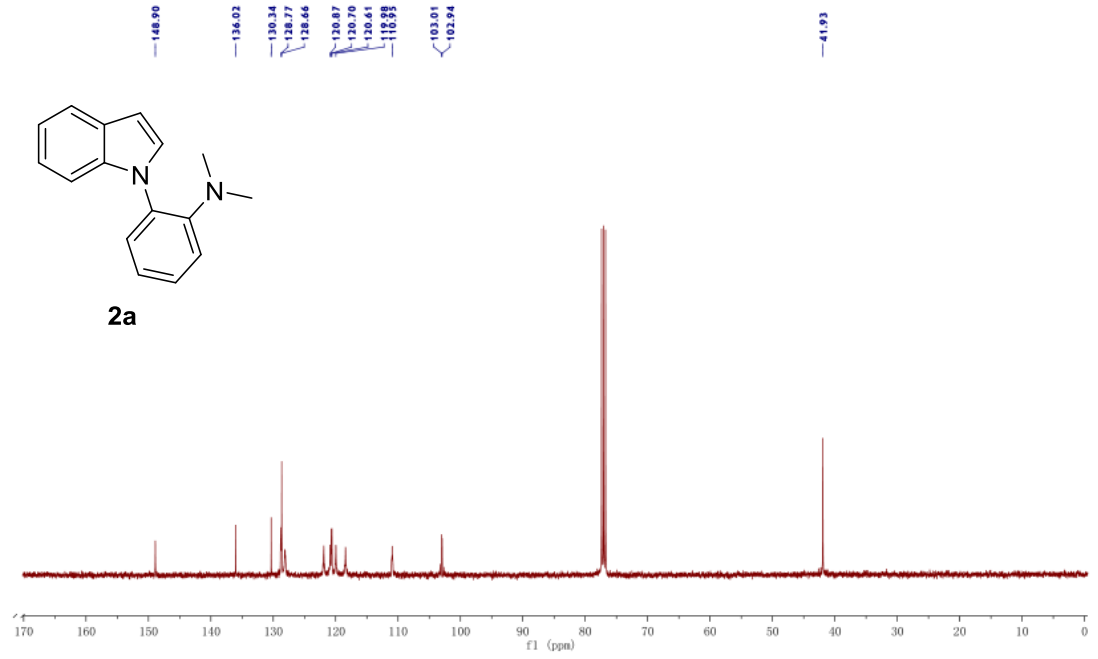

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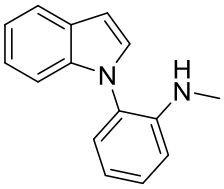

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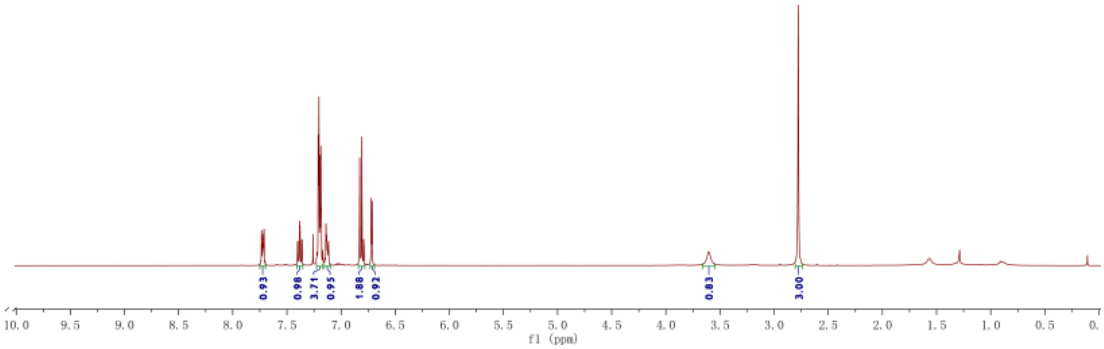

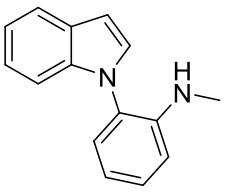

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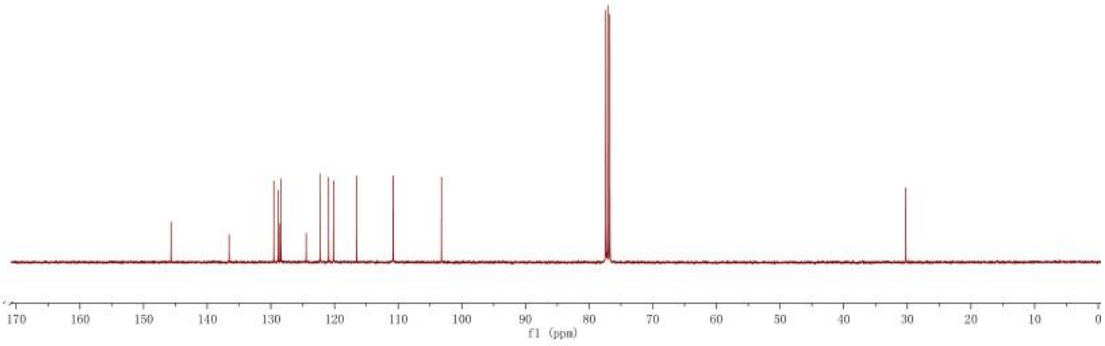
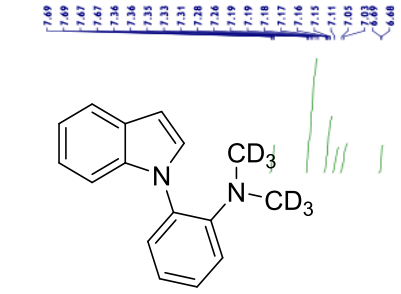
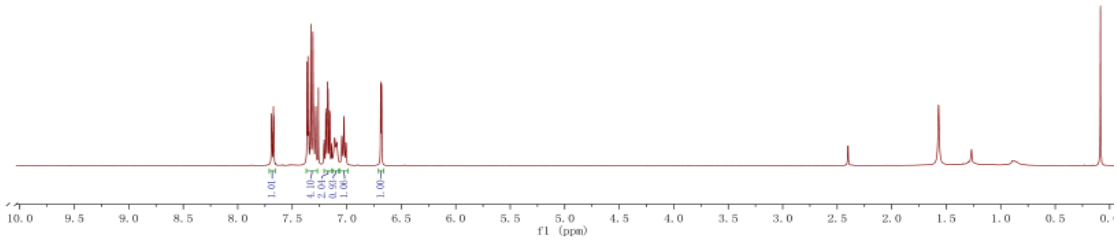
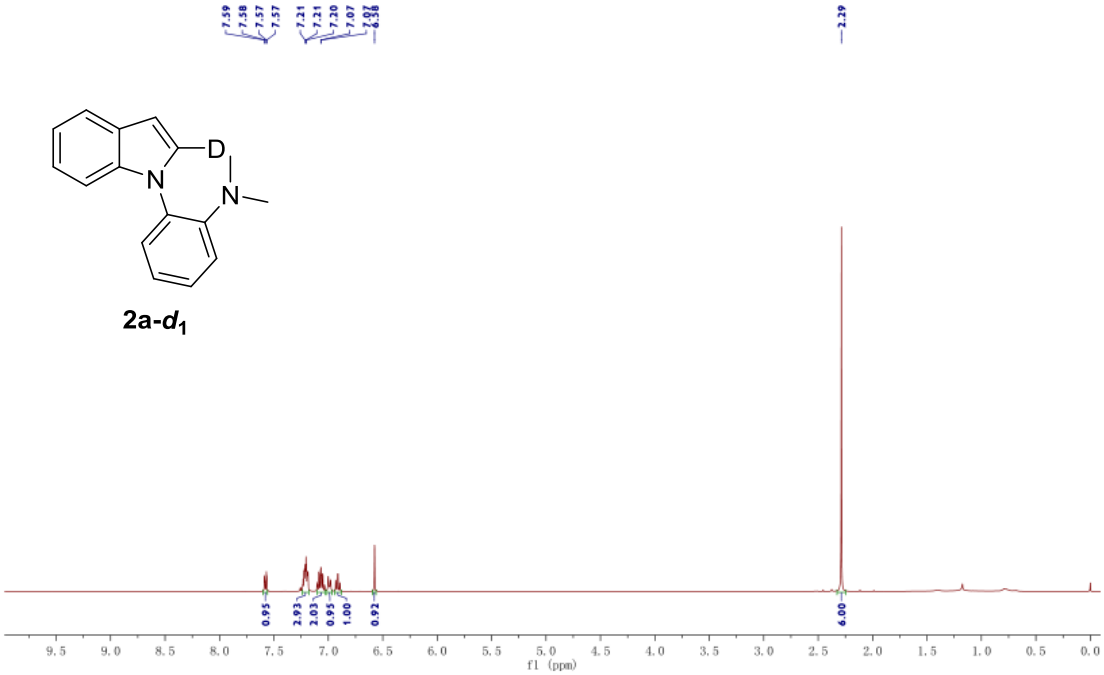


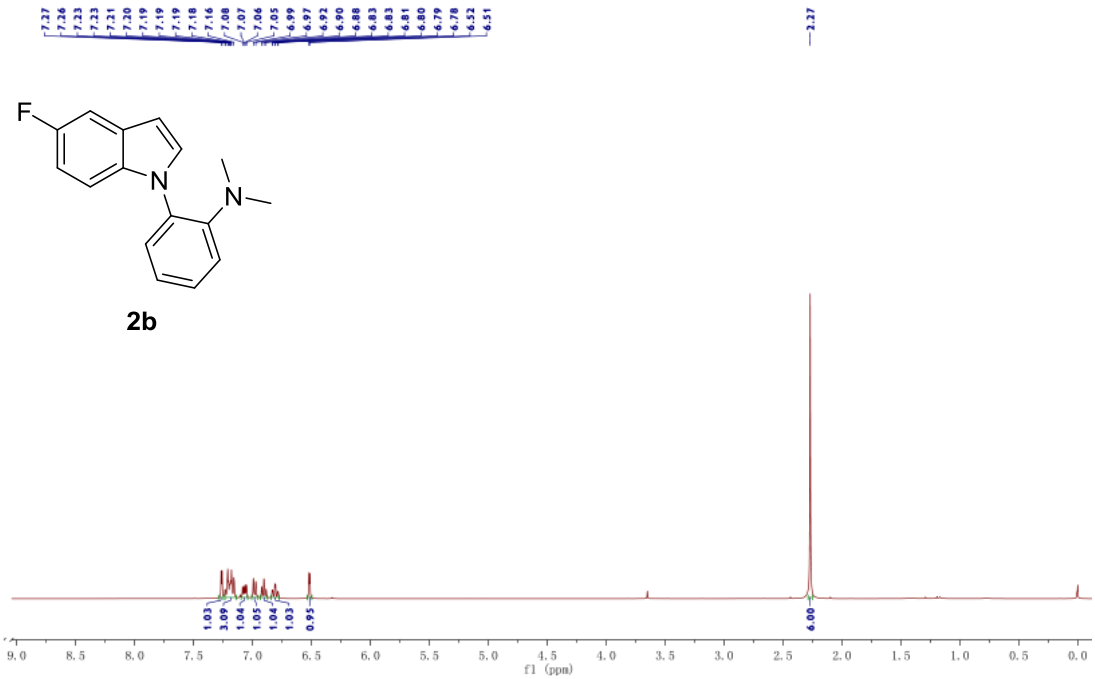


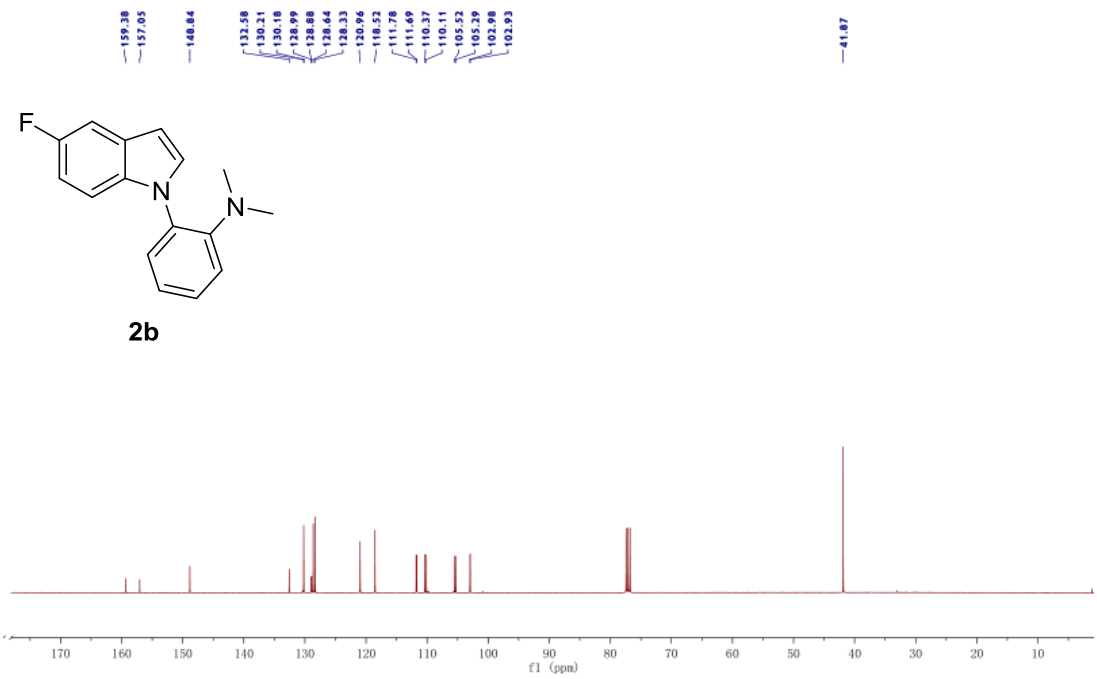
2a-d_6



2a-d_1




F
N
N
2b
7.27
7.26
7.23
7.23
7.21
7.20
7.19
7.19
7.19
7.18
7.16
7.08
7.07
7.06
7.05
6.99
6.97
6.92
6.90
6.88
6.83
6.81
6.80
6.79
6.78
6.52
6.51
2.27
1.03
3.09
1.04
1.05
1.04
1.03
0.95
6.00
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)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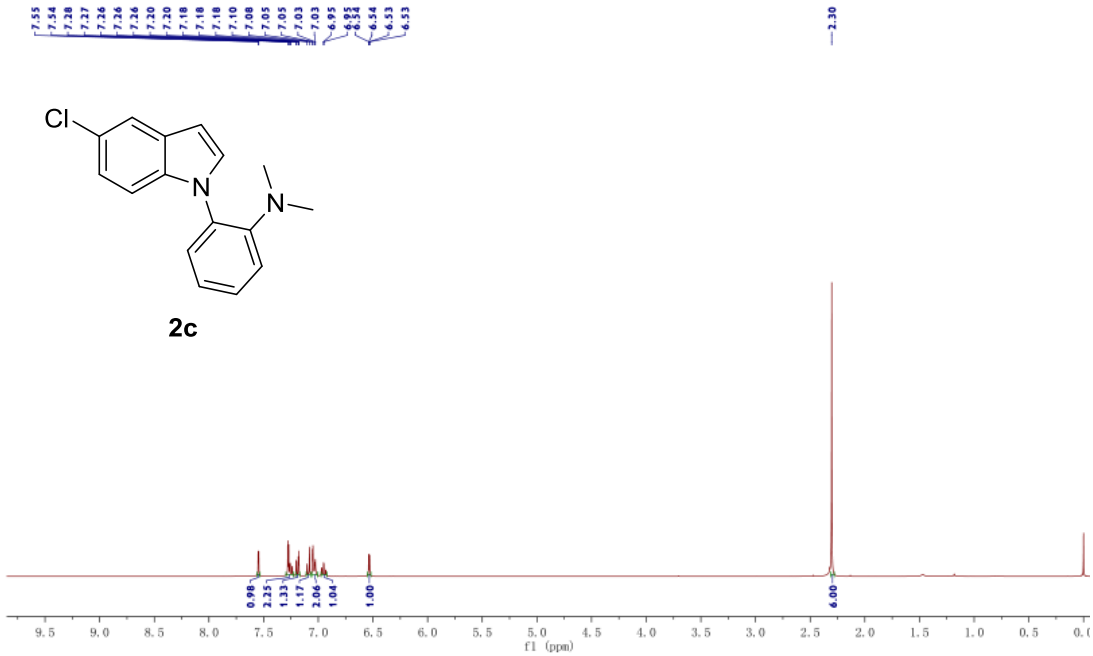
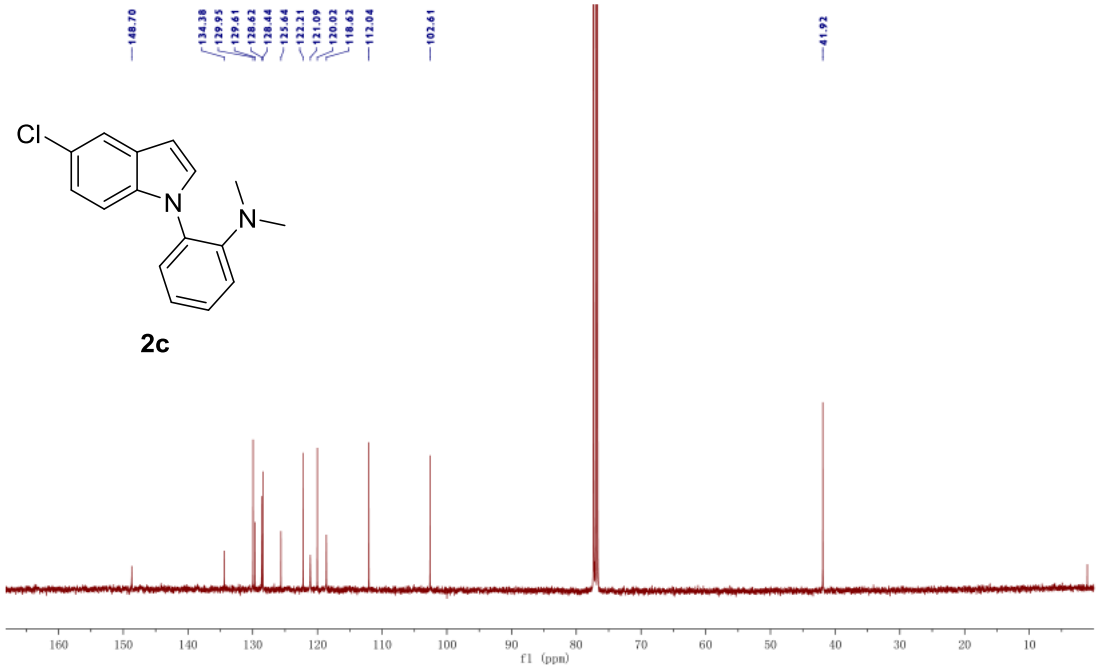
N
N
2b
159.38
157.05
148.84
132.58
130.21
130.18
128.99
128.88
128.64
128.33
120.96
118.52
111.78
111.69
110.37
110.11
105.52
105.29
102.98
102.93
41.87
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


Cl
N
N
2c
7.55
7.54
7.28
7.27
7.26
7.26
7.26
7.20
7.20
7.18
7.18
7.18
7.10
7.08
7.05
7.05
7.03
7.03
6.95
6.54
6.53
6.53
2.30
0.98
2.25
1.33
1.17
2.06
1.04
1.00
6.00
f1 (ppm)


Cl
N
N
2c
148.70
134.38
129.95
129.61
128.62
128.44
125.64
122.21
121.09
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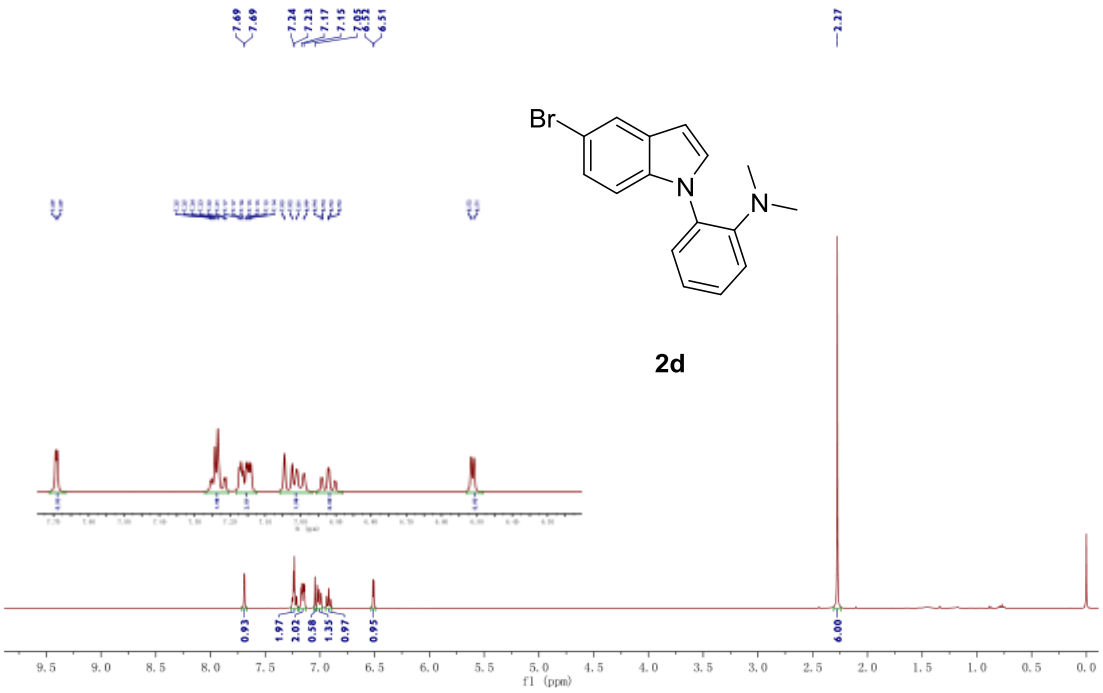
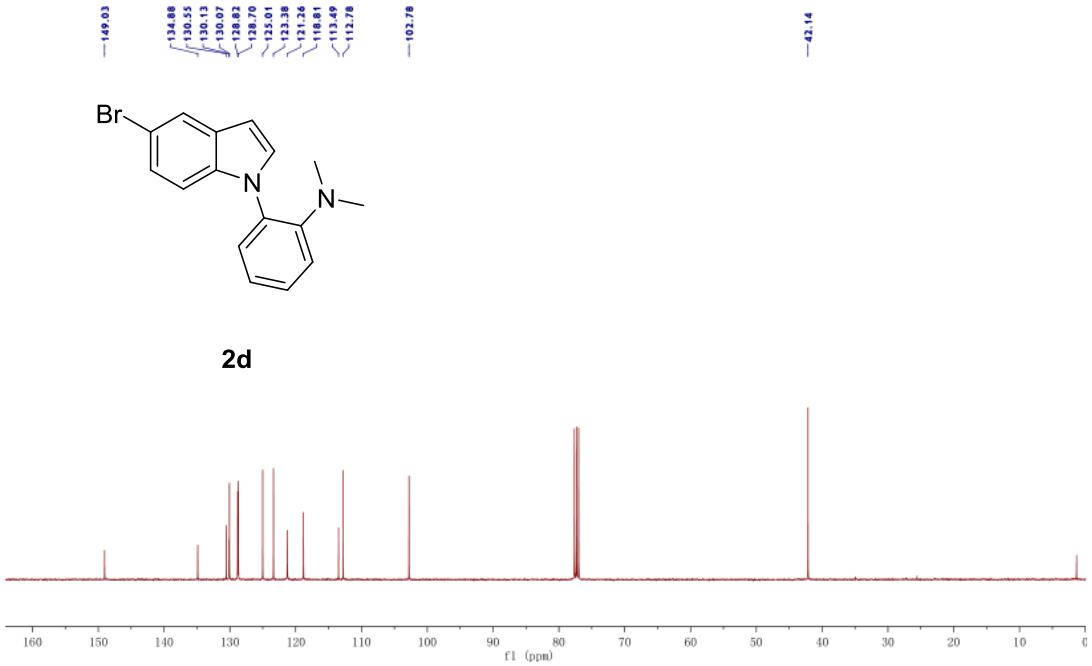
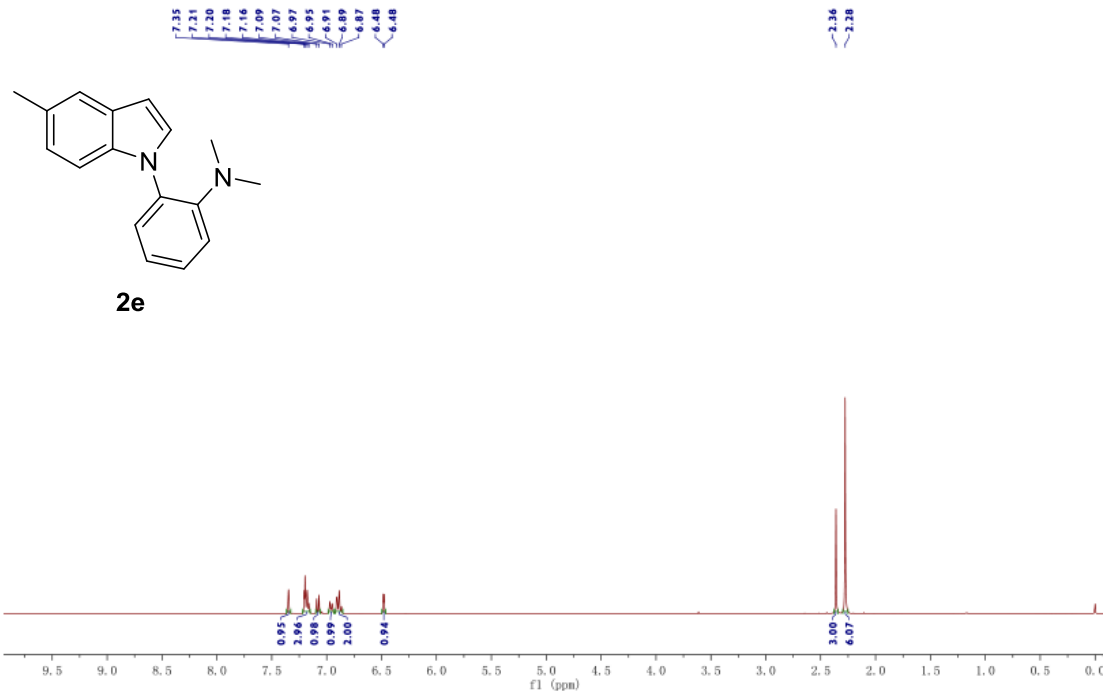
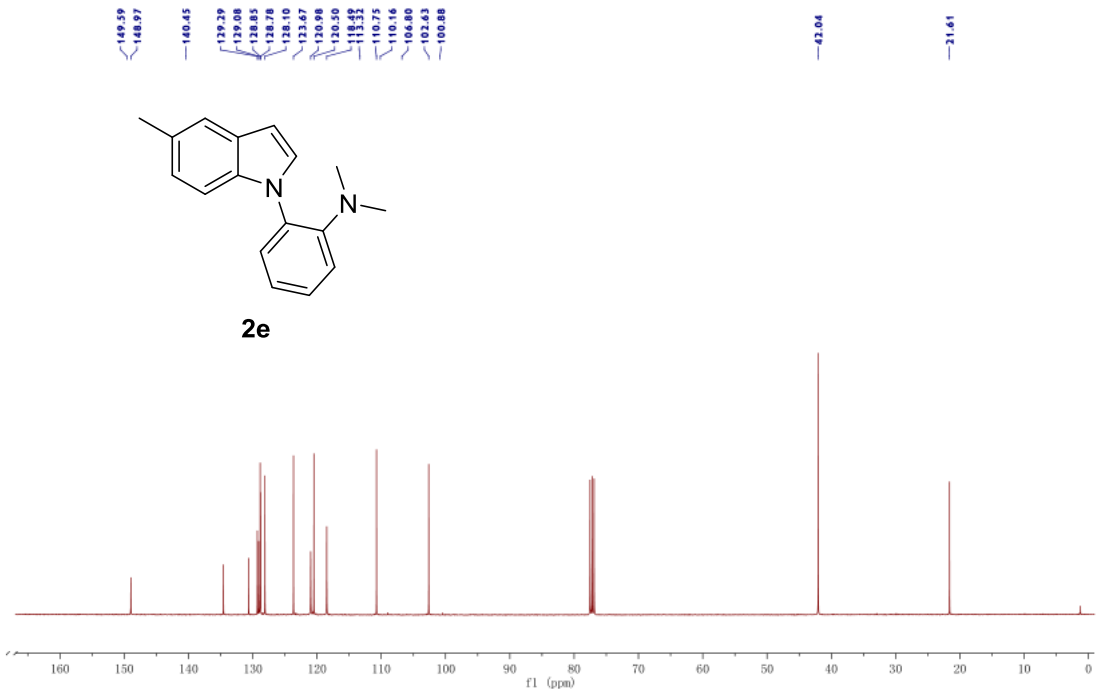
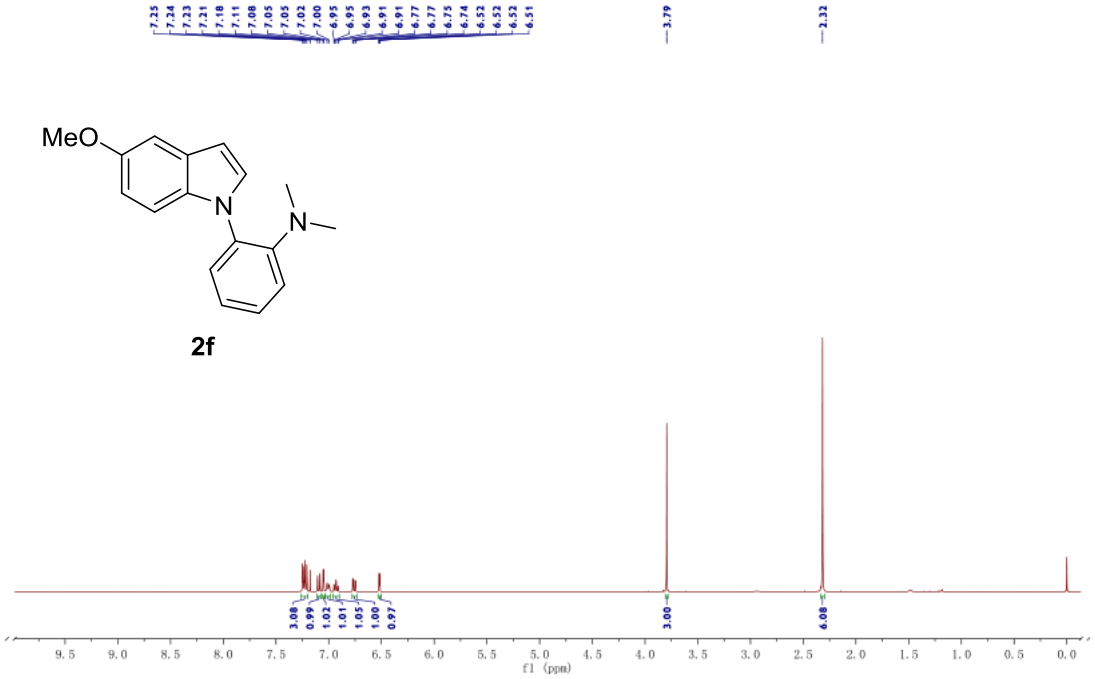
102.61
41.92
f1 (ppm)

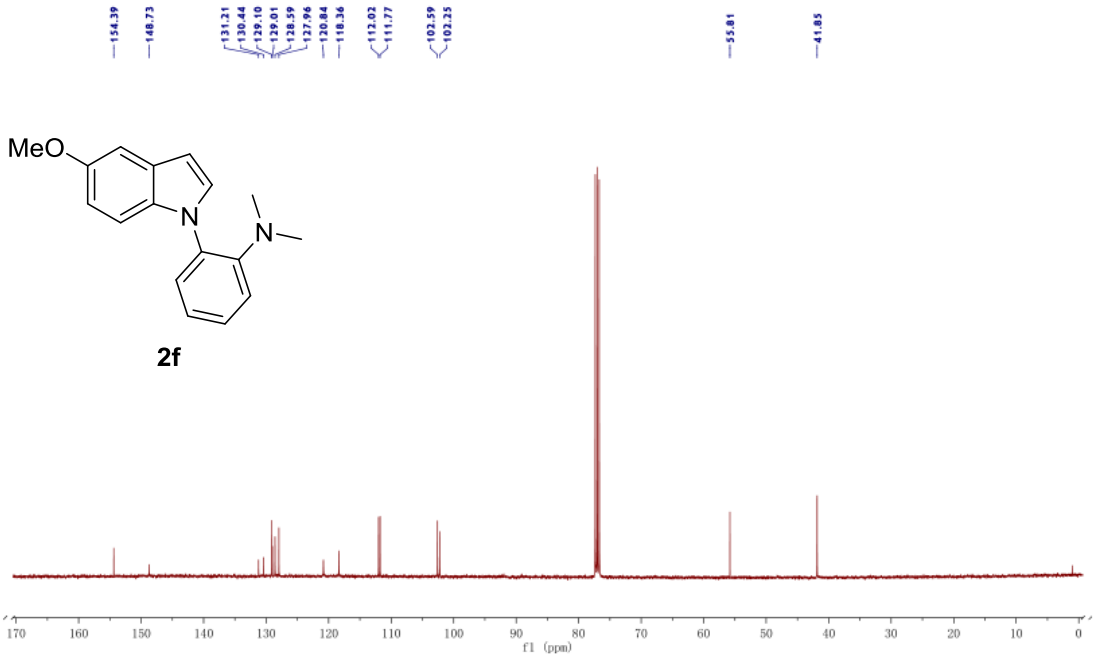

Br
N
N
2d
f1 (ppm)

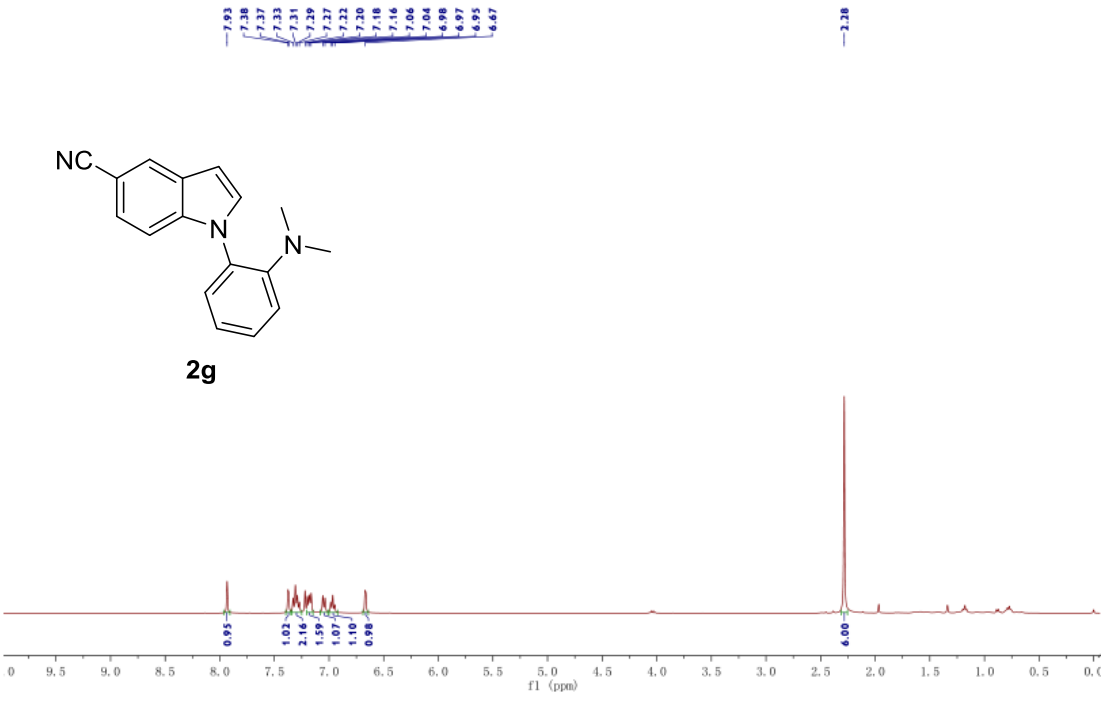

Br
N
N
2d
f1 (ppm)

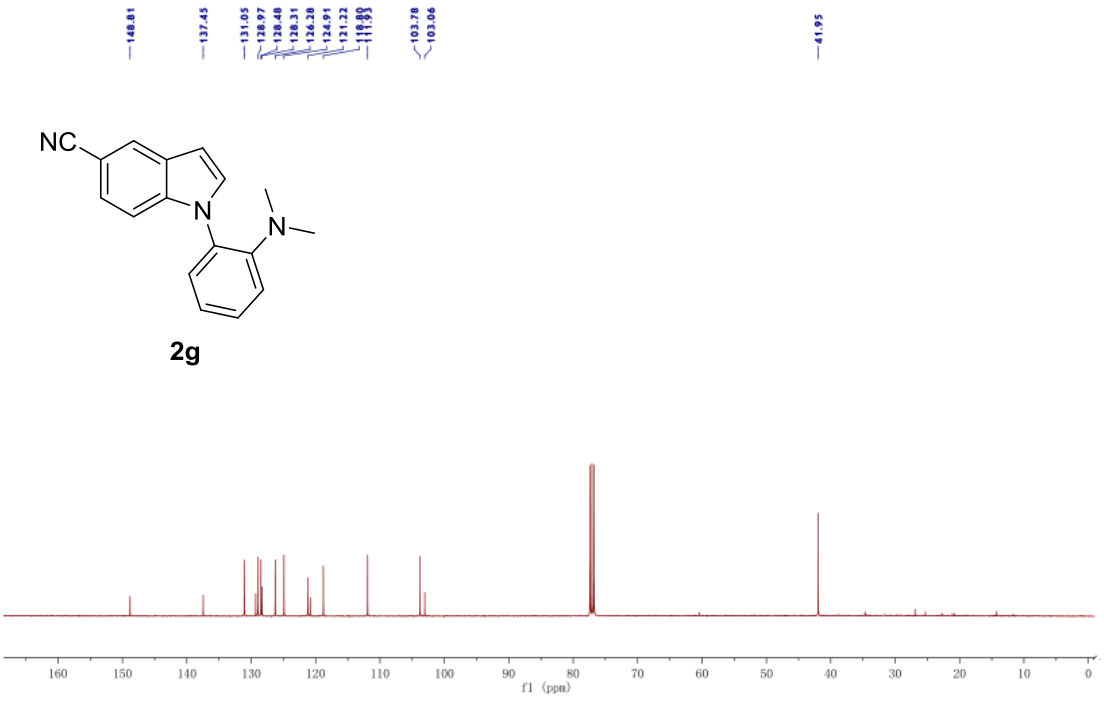

7.35
7.21
7.20
7.18
7.16
7.09
7.07
6.97
6.95
6.91
6.89
6.87
6.48
6.48
2.36
2.28
N
N
2e
0.95
2.96
0.98
0.99
2.00
0.94
3.00
6.07
f1 (ppm)

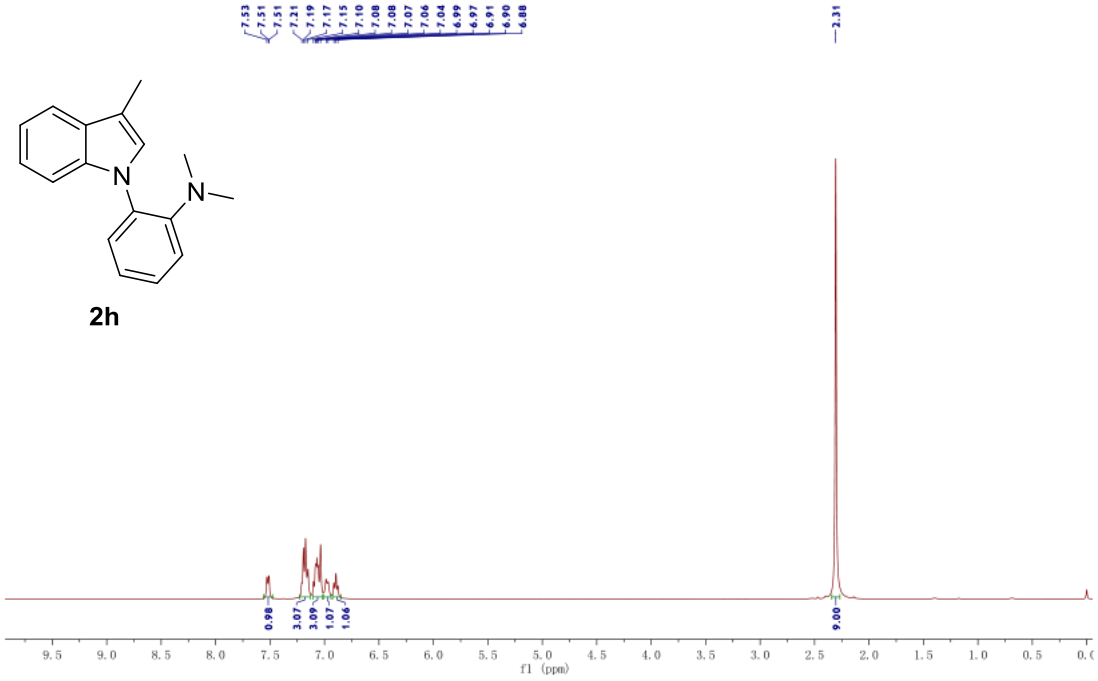

149.59
148.97
140.45
139.29
139.08
128.85
128.78
128.10
123.67
120.98
120.50
118.49
113.32
110.75
110.16
106.80
102.63
100.88
43.04
21.61
N
N
2e
f1 (ppm)


7.35
7.34
7.33
7.21
7.18
7.11
7.08
7.05
7.05
7.02
7.00
6.95
6.95
6.93
6.91
6.91
6.77
6.77
6.75
6.74
6.52
6.52
6.52
6.51
3.79
2.32
MeO
N
N
2f
3.08
0.99
1.02
1.01
1.05
1.00
0.97
3.00
6.08
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

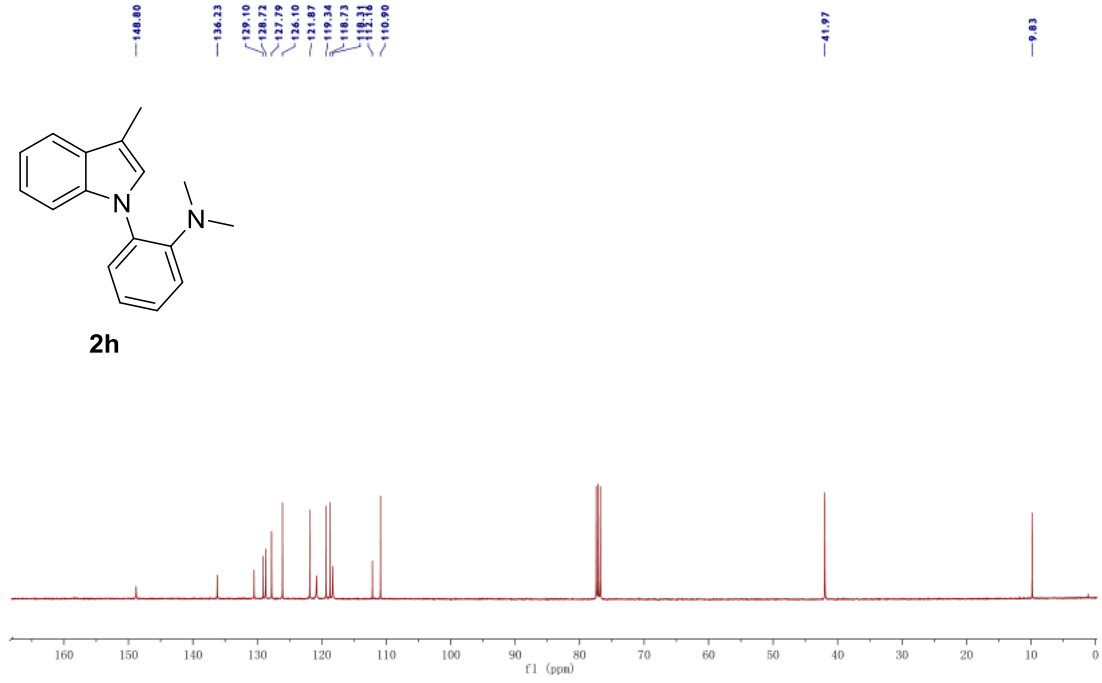

154.39
148.73
131.21
130.44
129.10
129.01
128.59
127.96
120.84
118.36
112.02
111.77
102.59
102.25
55.81
41.85
MeO
N
N
2f
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


NC
N
N
2g
7.93
7.38
7.37
7.33
7.31
7.29
7.27
7.22
7.20
7.18
7.16
7.06
7.04
6.98
6.97
6.95
6.67
2.28
0.95
1.03
2.14
1.59
1.07
1.10
0.98
6.00
f1 (ppm)

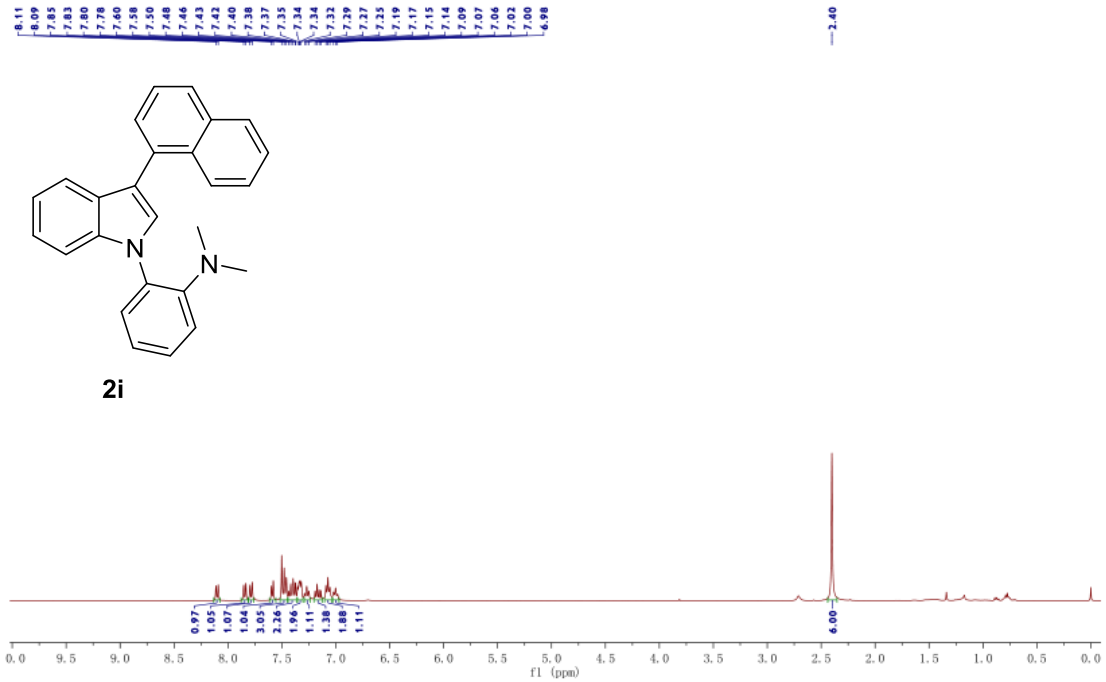

NC
N
N
2g
148.81
137.45
131.05
128.97
128.48
128.31
126.20
124.91
121.22
103.78
103.06
41.95
f1 (ppm)


7.53
7.51
7.51
7.21
7.19
7.17
7.15
7.10
7.08
7.08
7.07
7.06
7.04
6.99
6.97
6.91
6.90
6.88
2.31
0.98
3.07
3.09
1.07
1.06
9.00
f1 (ppm)

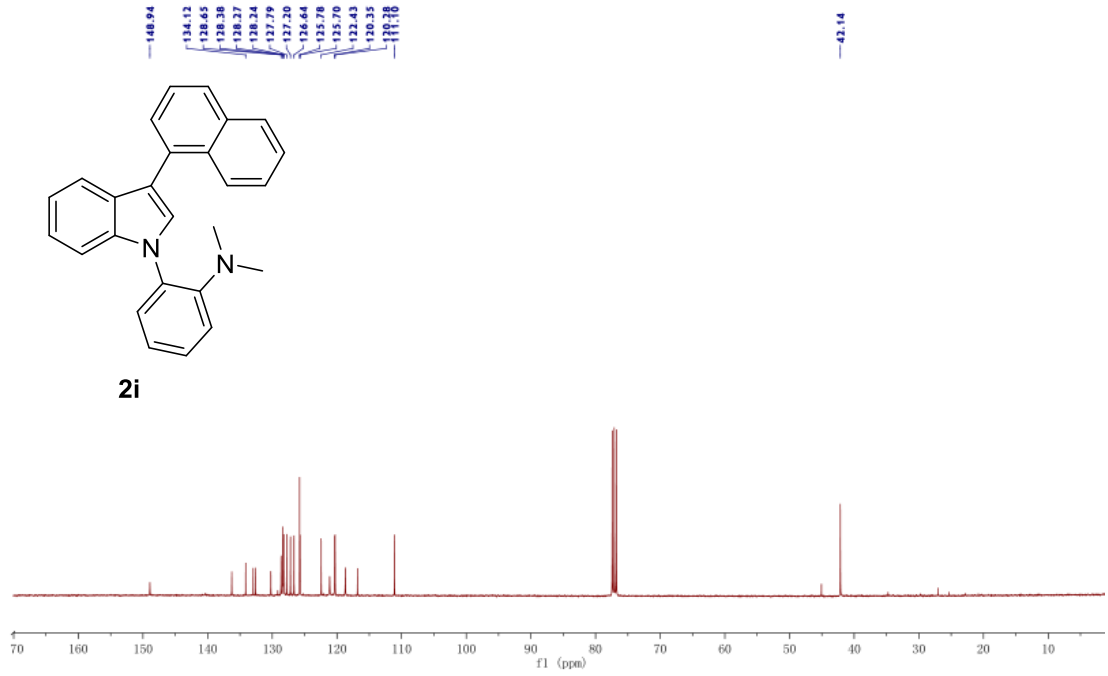
2h


148.80
136.23
129.10
128.72
127.79
126.10
121.87
119.34
118.73
112.16
110.90
41.97
9.83
f1 (ppm)

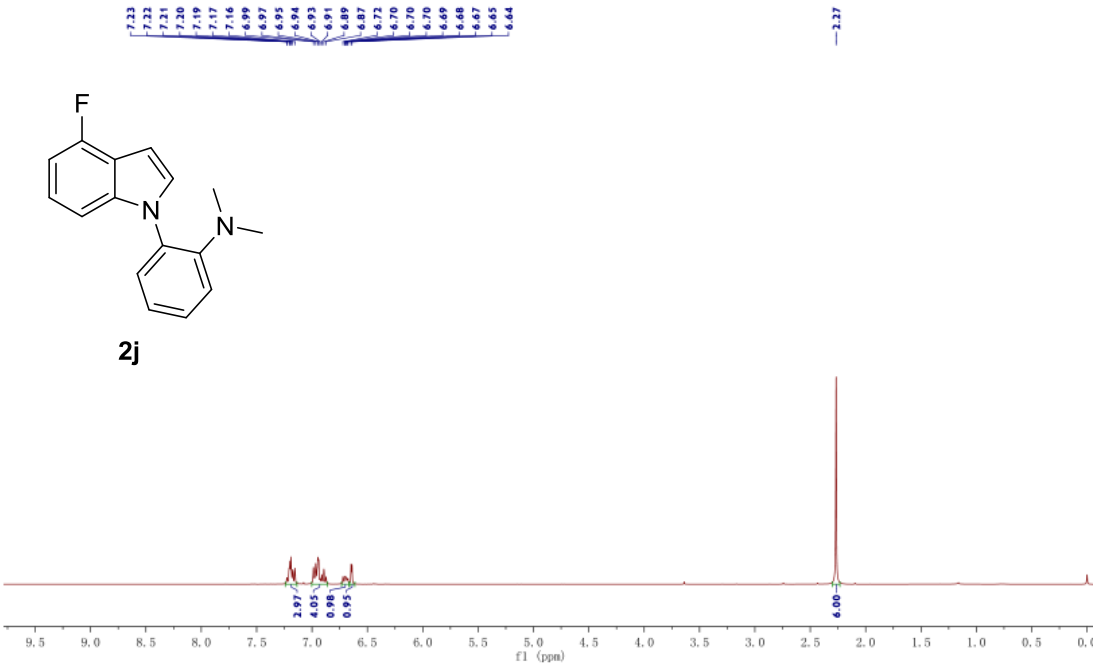
2h

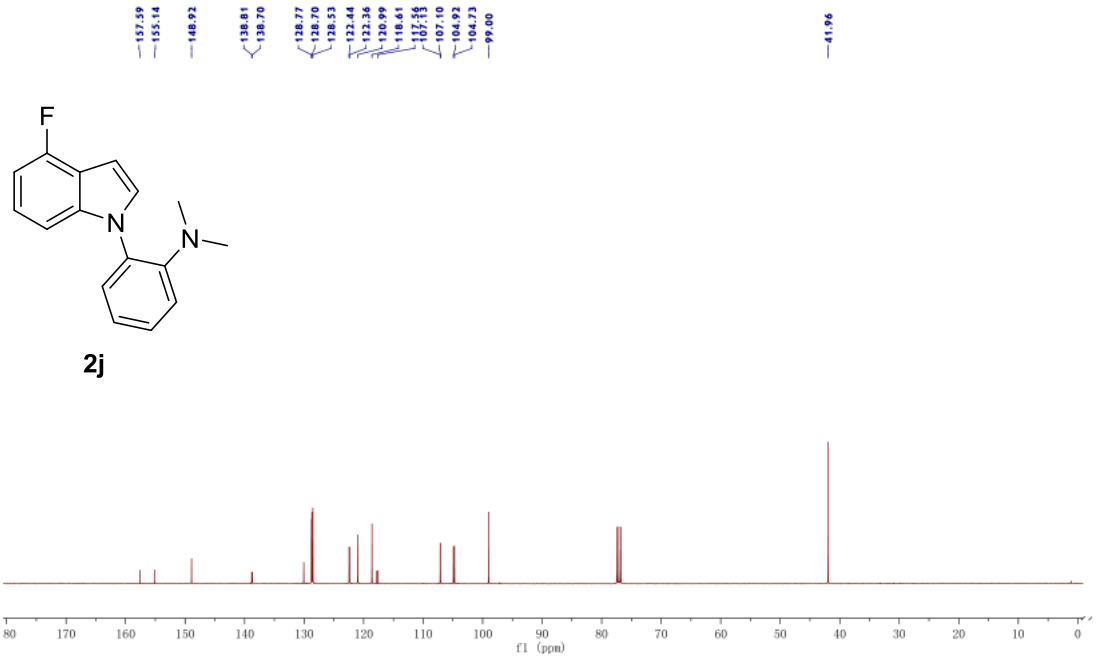

8.11
8.09
7.85
7.83
7.80
7.78
7.60
7.58
7.50
7.48
7.46
7.43
7.42
7.40
7.38
7.37
7.35
7.34
7.34
7.32
7.29
7.27
7.25
7.19
7.17
7.15
7.14
7.09
7.07
7.06
7.03
7.00
6.98
2.40
N
N
0.97
1.05
1.07
1.04
3.05
2.26
1.96
1.11
1.38
1.88
1.11
6.00
0.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

2i


148.94
134.12
128.65
128.38
128.27
128.24
127.79
127.20
126.64
125.78
125.70
122.43
120.35
111.18
111.10
42.14
N
N
70
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

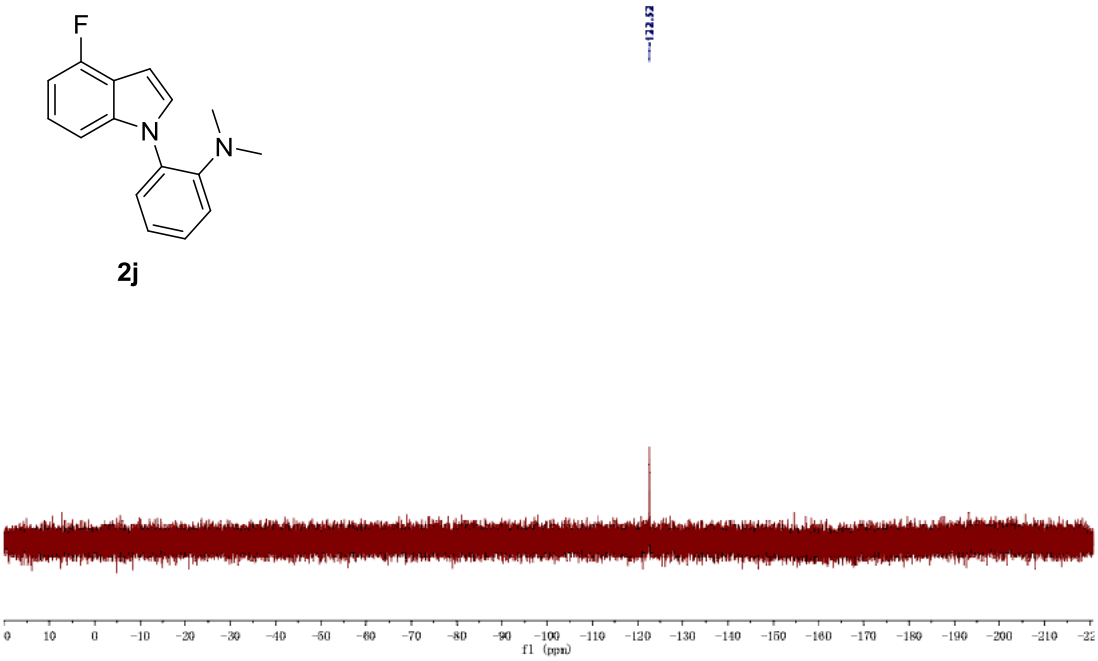
2i


7.23
7.22
7.21
7.20
7.19
7.17
7.16
6.99
6.97
6.95
6.94
6.93
6.91
6.89
6.87
6.72
6.70
6.70
6.70
6.69
6.68
6.67
6.65
6.64
2.37
F
N
N
2j
2.97
4.05
0.98
0.95
6.00
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)


157.59
155.14
148.92
138.81
138.70
128.77
128.70
128.53
123.44
122.36
120.99
118.61
117.16
117.13
107.10
104.92
104.73
99.00
41.96
F
N
N
2j
80
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

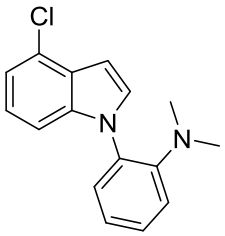
F
N
N

2j

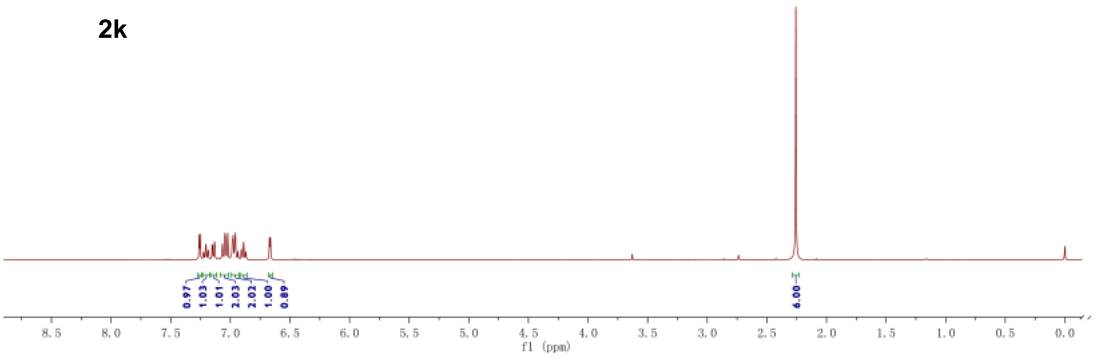

-122.53
f1 (ppm)

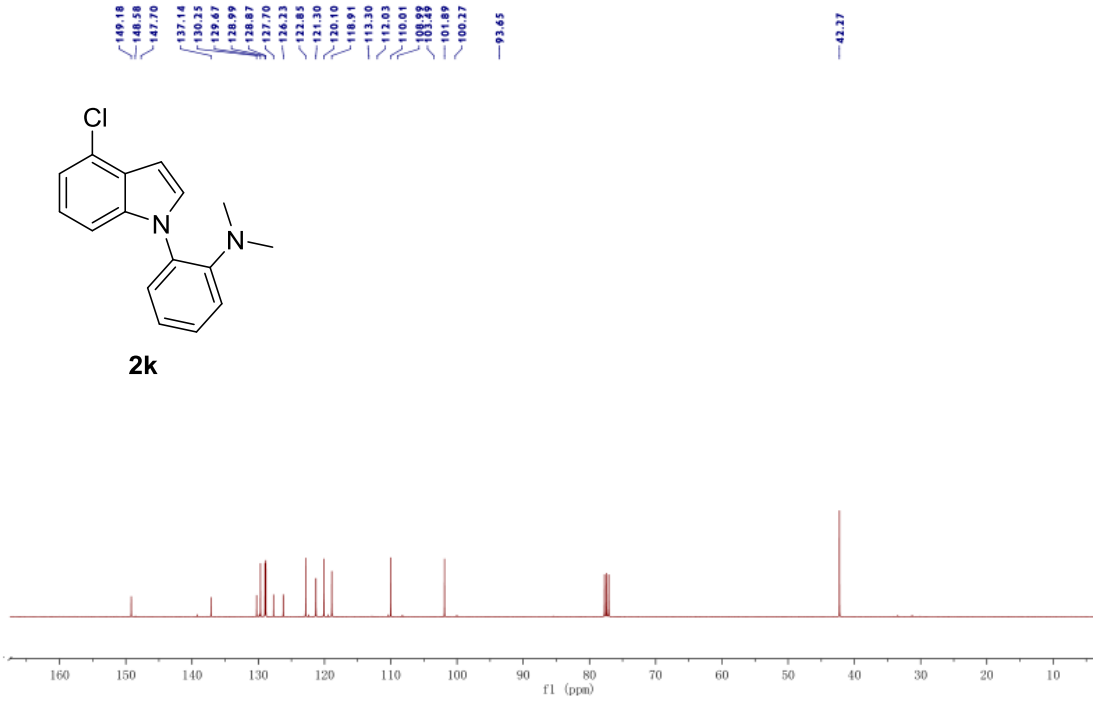

7.26
7.25
7.22
7.21
7.18
7.15
7.13
7.07
7.05
7.02
6.98
6.98
6.96
6.94
6.91
6.89
6.87
6.67
6.66

2.26


Cl
N
N

2k


0.97
1.03
1.01
2.03
2.02
1.00
0.89
6.00
f1 (ppm)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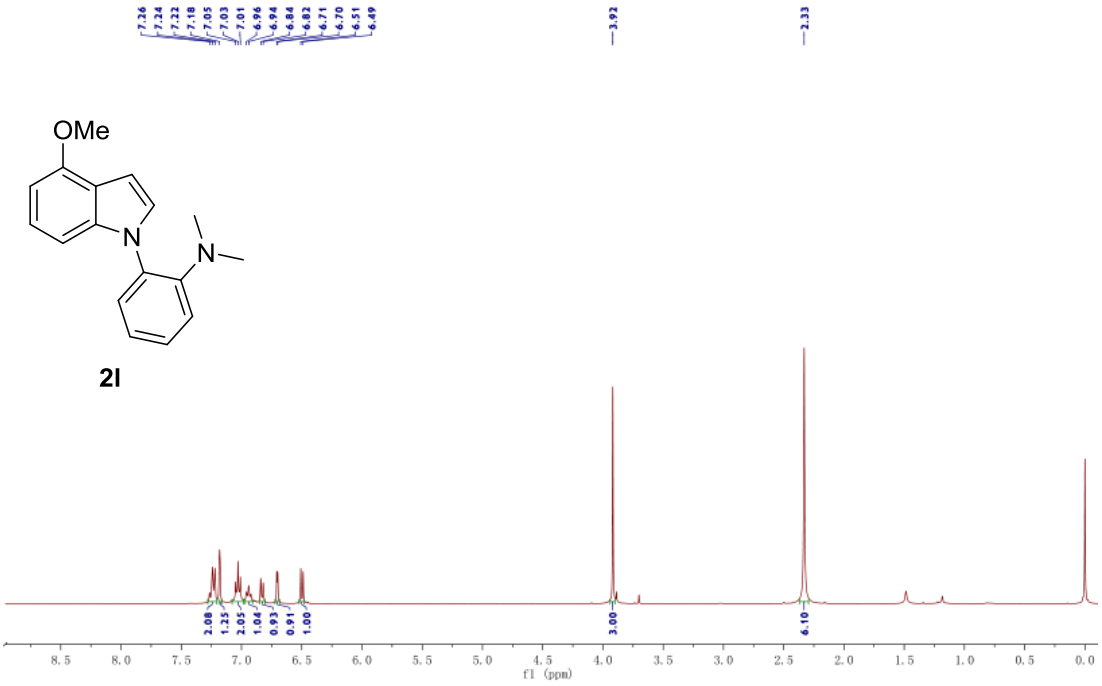
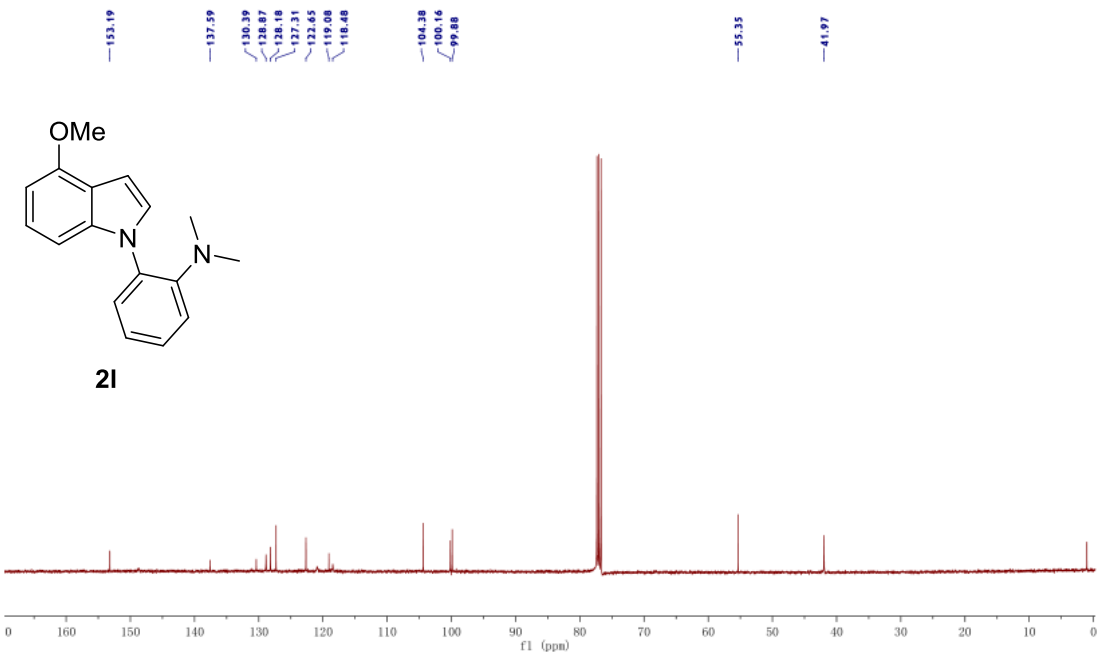
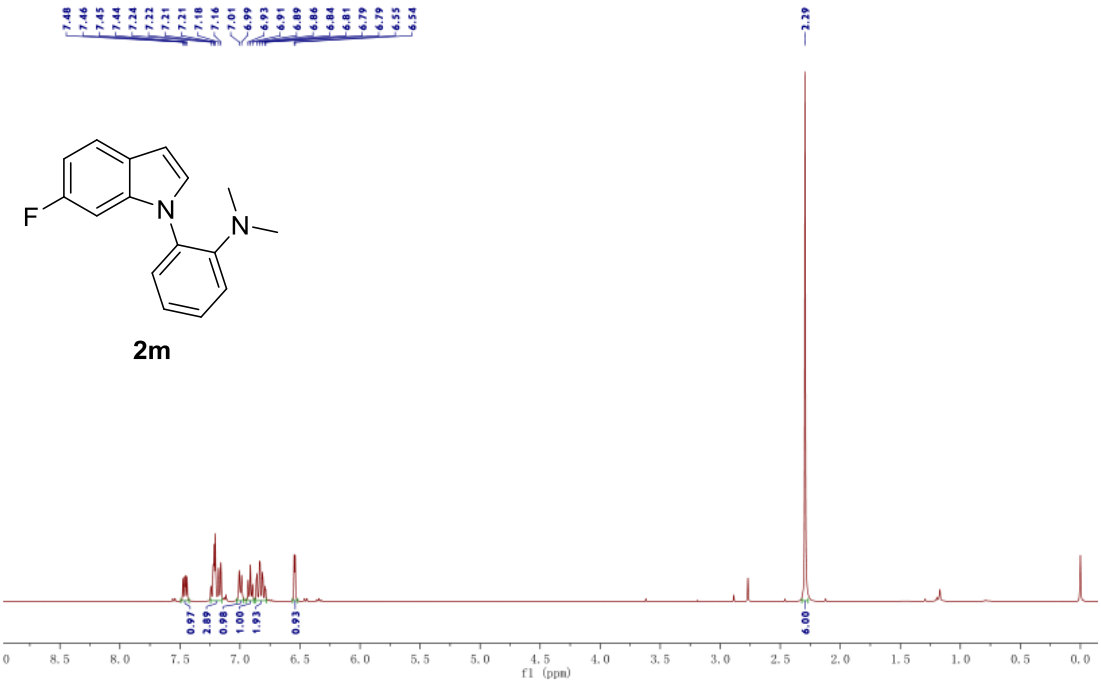
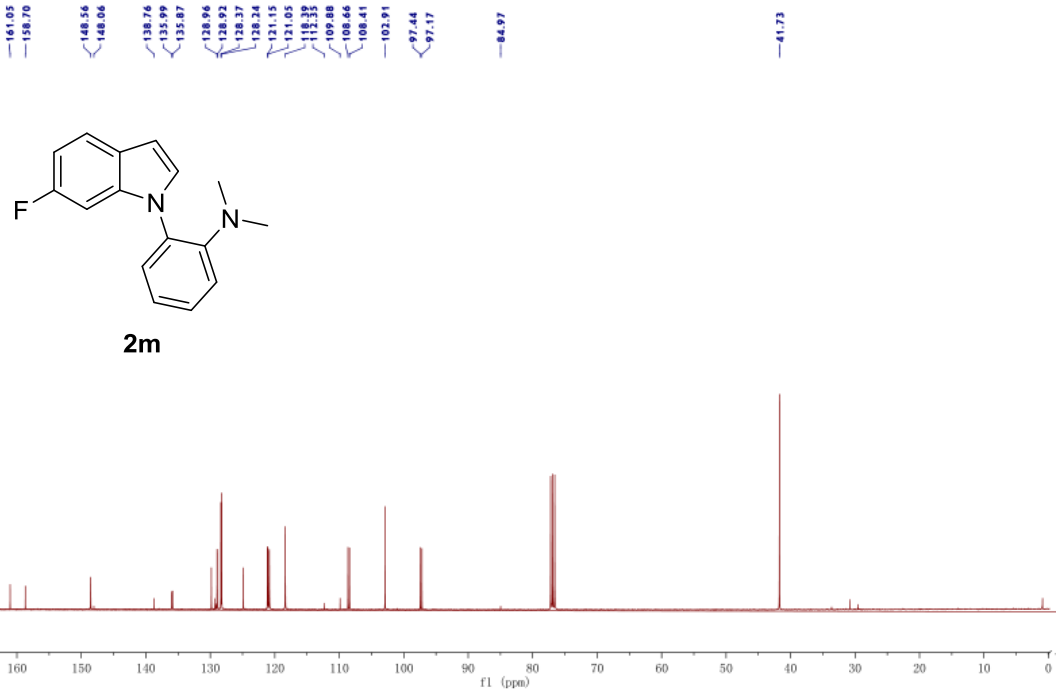
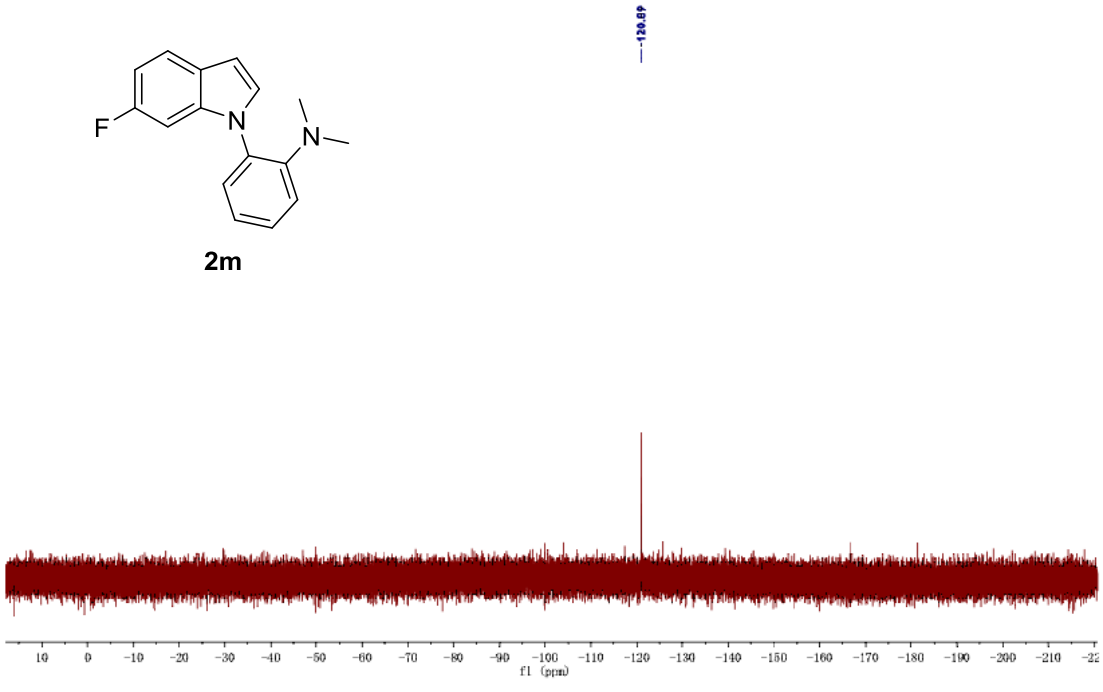
140.58
147.70
137.14
130.25
129.47
128.99
128.87
127.70
126.23
122.85
121.30
120.10
118.91
113.30
112.03
110.01
101.89
100.27
93.65
42.27
Cl
N
N
2k
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

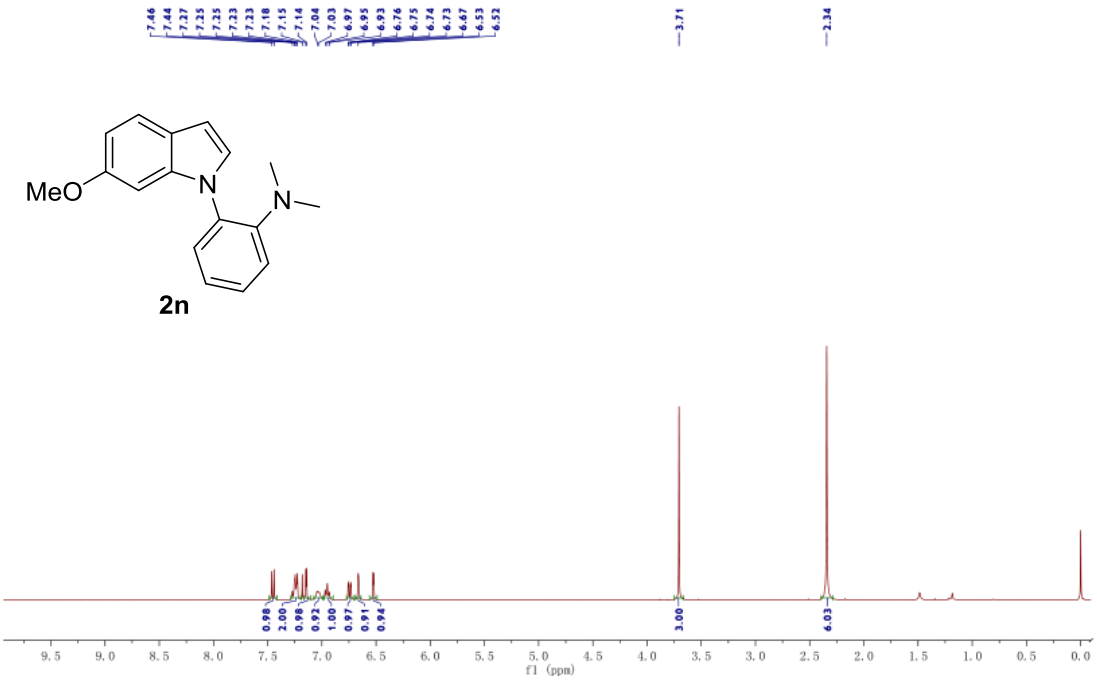

7.26
7.24
7.22
7.18
7.05
7.03
7.01
6.96
6.94
6.84
6.82
6.71
6.70
6.51
6.49
3.92
2.33
OMe
N
N
2l
2.08
1.35
2.05
1.04
0.93
0.91
1.00
3.00
6.10
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

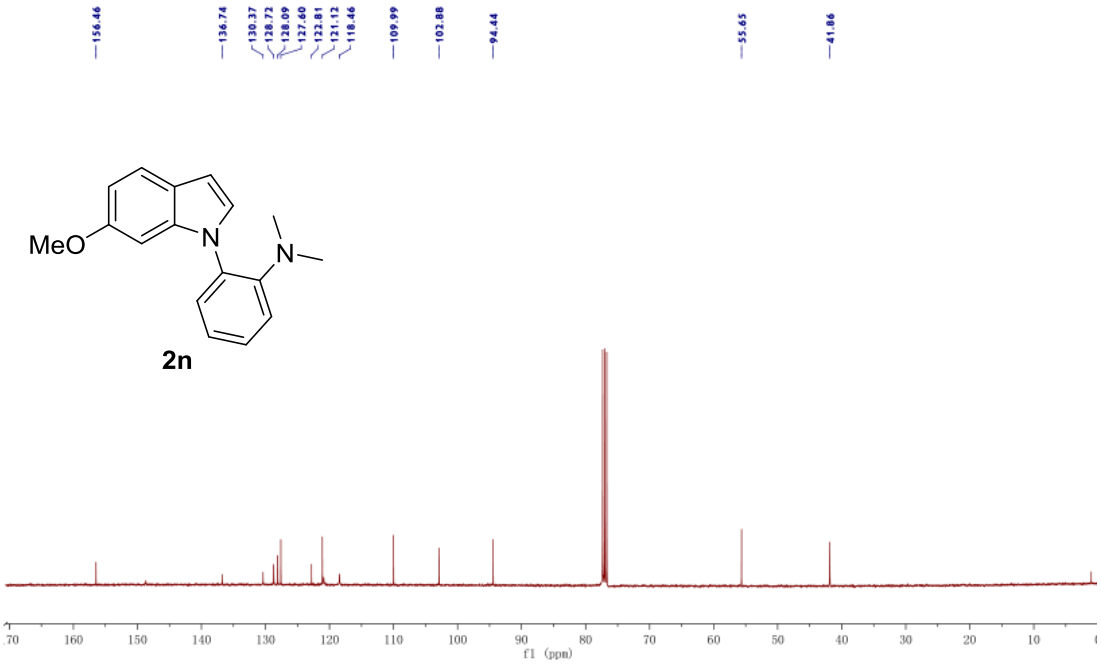

153.19
137.59
130.39
128.87
128.18
127.31
122.65
119.08
118.48
104.38
100.16
99.88
55.35
41.97
OMe
N
N
2l
0
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

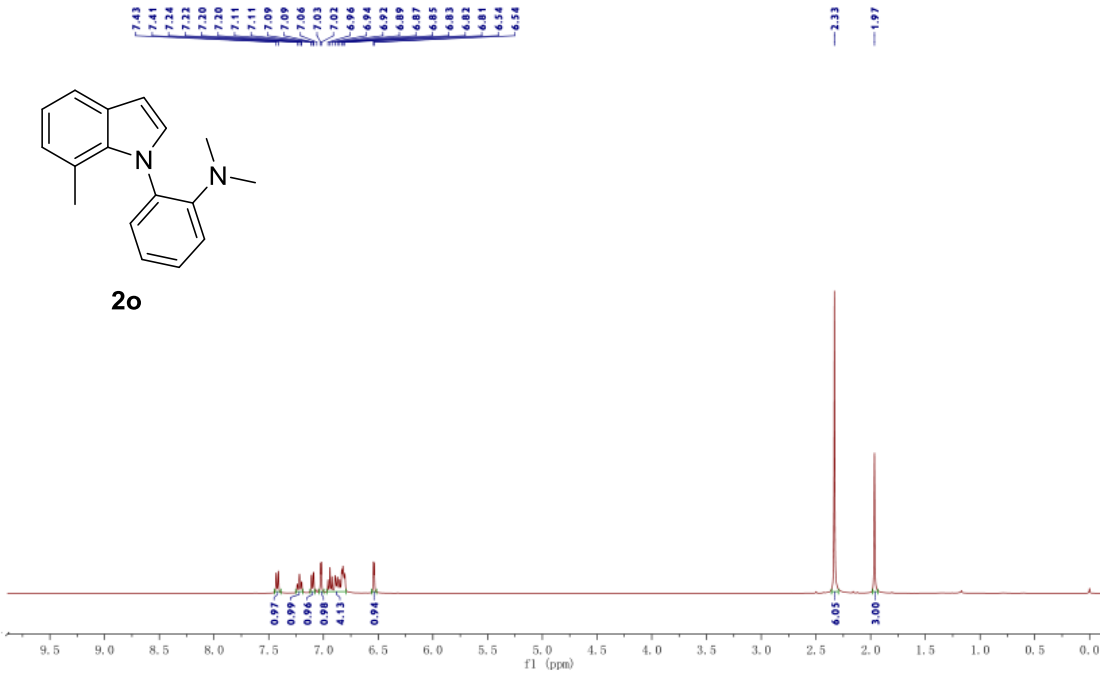

7.48
7.46
7.45
7.44
7.24
7.22
7.21
7.21
7.18
7.16
7.01
6.99
6.93
6.91
6.89
6.86
6.84
6.81
6.79
6.79
6.55
6.54
2.29
F
N
N
2m
0.97
2.89
0.98
1.00
1.93
0.93
6.00
0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


161.05
159.70
148.56
148.06
138.76
135.99
135.87
128.96
128.92
128.37
128.24
121.15
121.05
118.39
112.35
109.88
108.66
108.41
102.91
97.44
97.17
84.97
41.73
F
N
N
2m
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

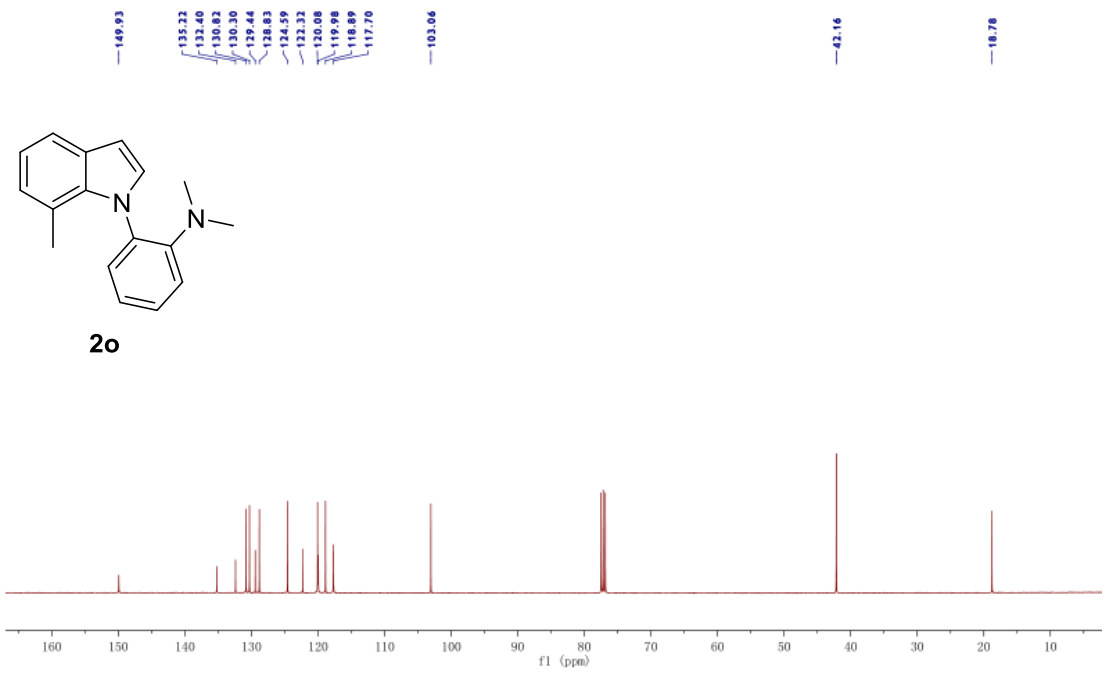

-120.89
F
N
N
2m
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
f1 (ppm)


7.46
7.44
7.37
7.25
7.25
7.23
7.23
7.18
7.15
7.14
7.04
7.03
6.97
6.95
6.93
6.76
6.75
6.74
6.73
6.67
6.53
6.52
3.71
2.34
MeO
N
N
2n
0.98
2.00
0.98
0.92
1.00
0.97
0.91
0.94
3.00
6.03
f1 (ppm)

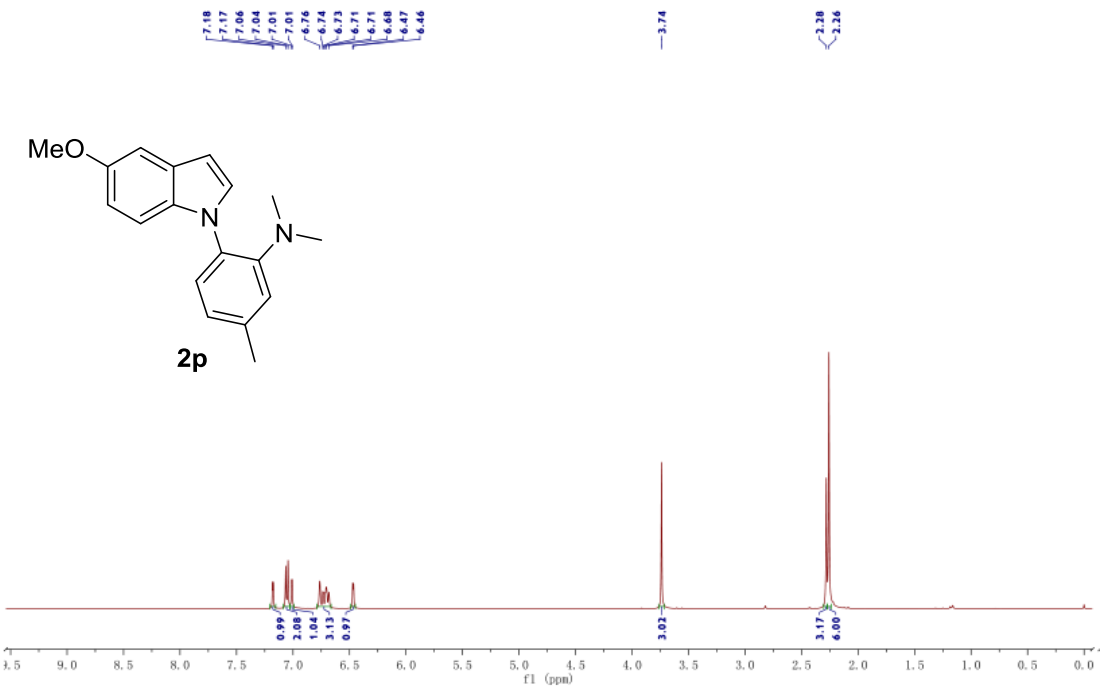

156.46
136.74
130.37
128.72
128.09
127.60
122.81
121.12
118.46
109.99
102.88
94.44
55.65
41.86
MeO
N
N
2n
f1 (ppm)

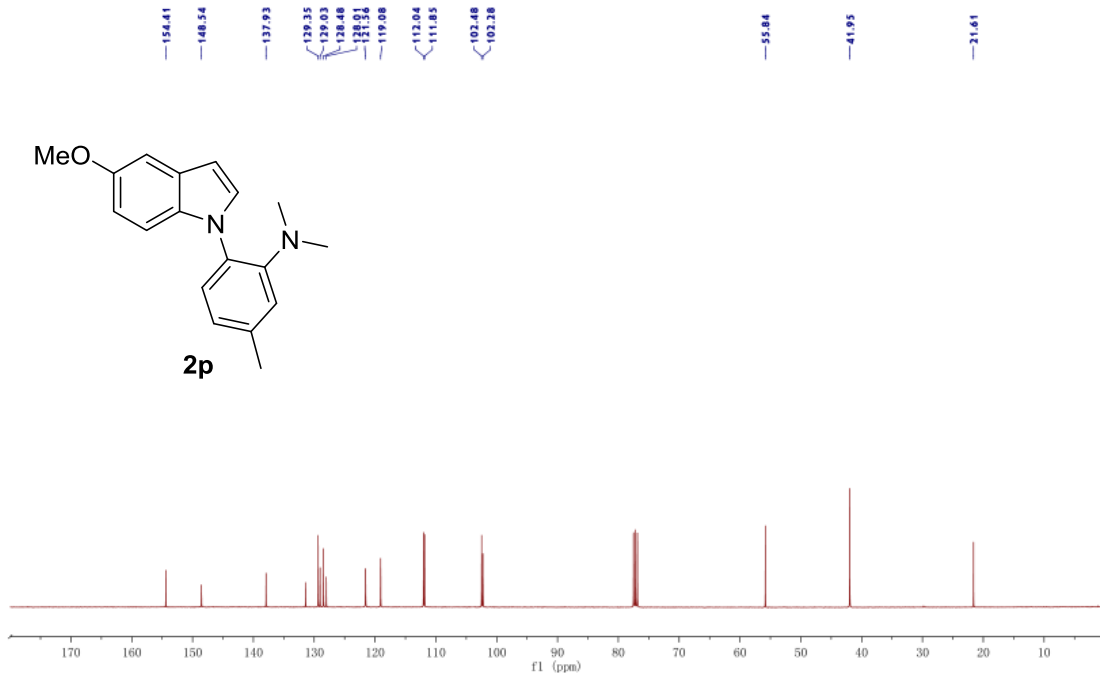

7.43
7.41
7.24
7.22
7.20
7.20
7.11
7.11
7.09
7.09
7.06
7.03
7.02
6.96
6.94
6.92
6.89
6.87
6.85
6.83
6.82
6.81
6.54
6.54
2.33
1.97
0.97
0.99
0.96
0.98
4.13
0.94
6.05
3.00
f1 (ppm)

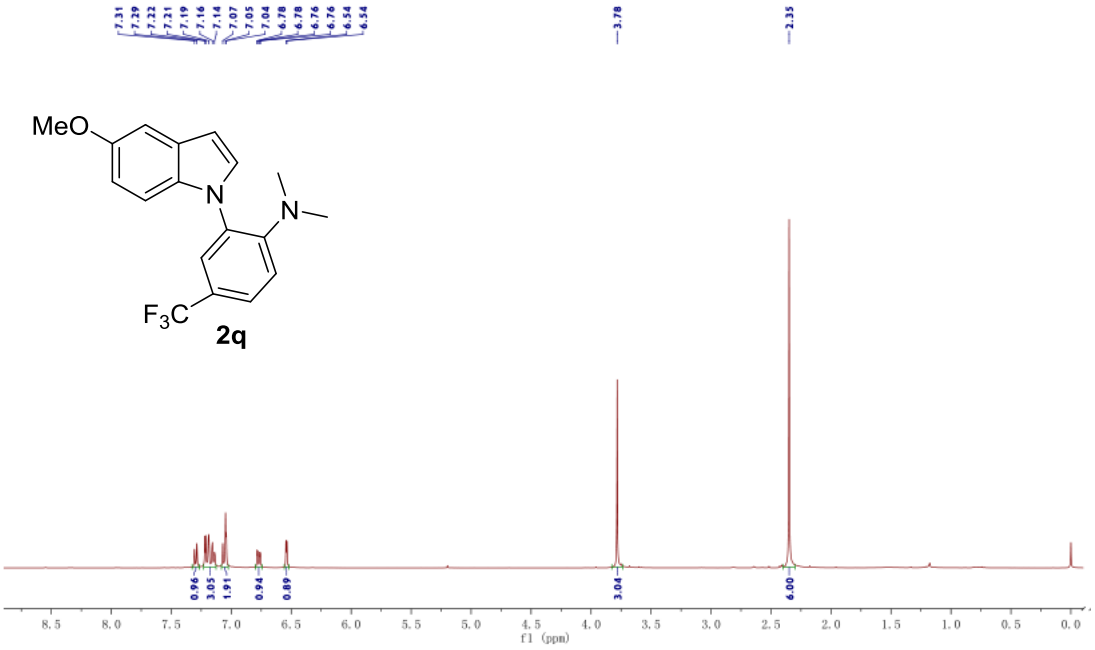
2o

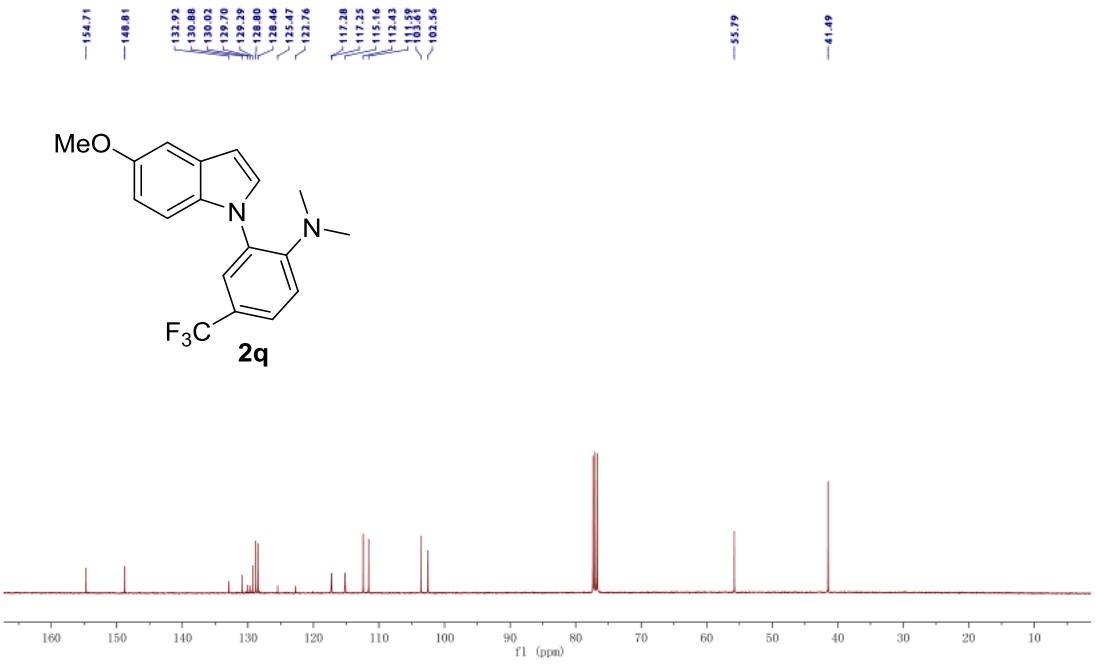

149.93
135.22
133.40
130.82
130.30
129.44
128.83
124.59
122.32
120.08
119.98
118.89
117.70
103.06
42.16
18.78
f1 (ppm)

2o


7.18
7.17
7.06
7.04
7.01
7.01
6.76
6.74
6.73
6.71
6.71
6.68
6.47
6.46
3.74
2.28
2.26
MeO
N
N
2p
0.99
2.08
1.04
3.13
0.97
3.02
3.17
6.00
f1 (ppm)

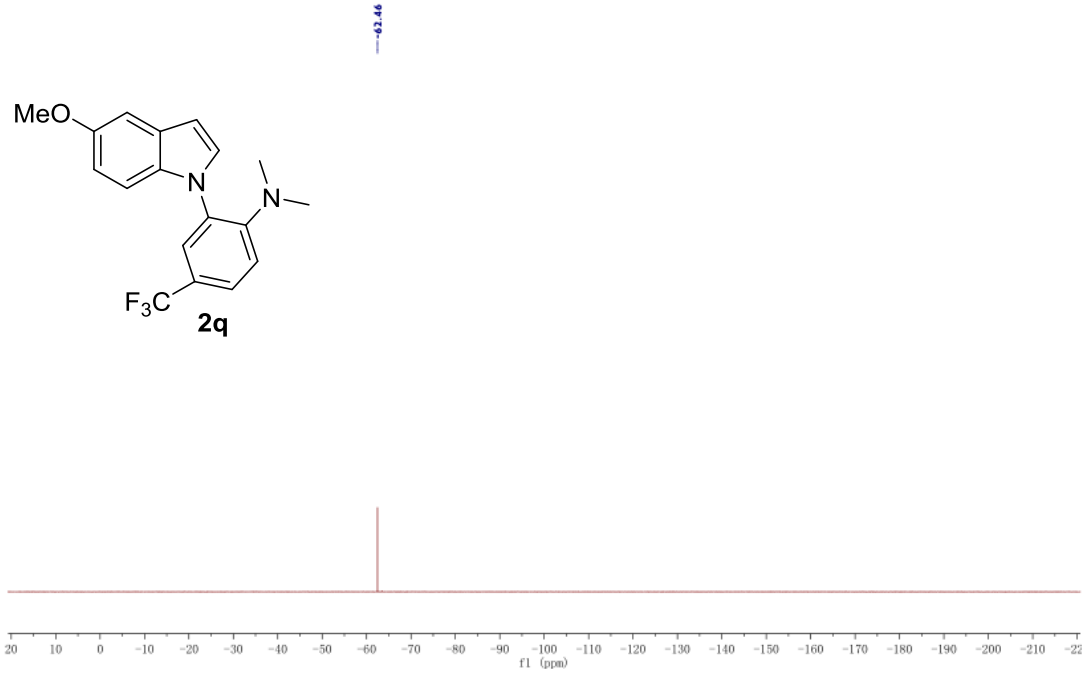

154.41
148.54
137.93
129.35
129.03
128.48
121.51
119.08
112.04
111.85
102.48
102.28
55.84
41.95
21.61
MeO
N
N
2p
f1 (ppm)


MeO
N
N
F3C
2q
7.31
7.29
7.22
7.21
7.19
7.16
7.14
7.07
7.05
7.04
6.78
6.78
6.76
6.76
6.54
6.54
3.78
2.35
0.96
3.05
1.91
0.94
0.89
3.04
6.00
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


MeO
N
N
F3C
2q
154.71
148.81
132.92
130.88
130.02
129.70
129.29
128.80
128.46
125.47
122.76
117.20
117.25
115.16
112.43
103.56
102.56
55.79
41.49
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

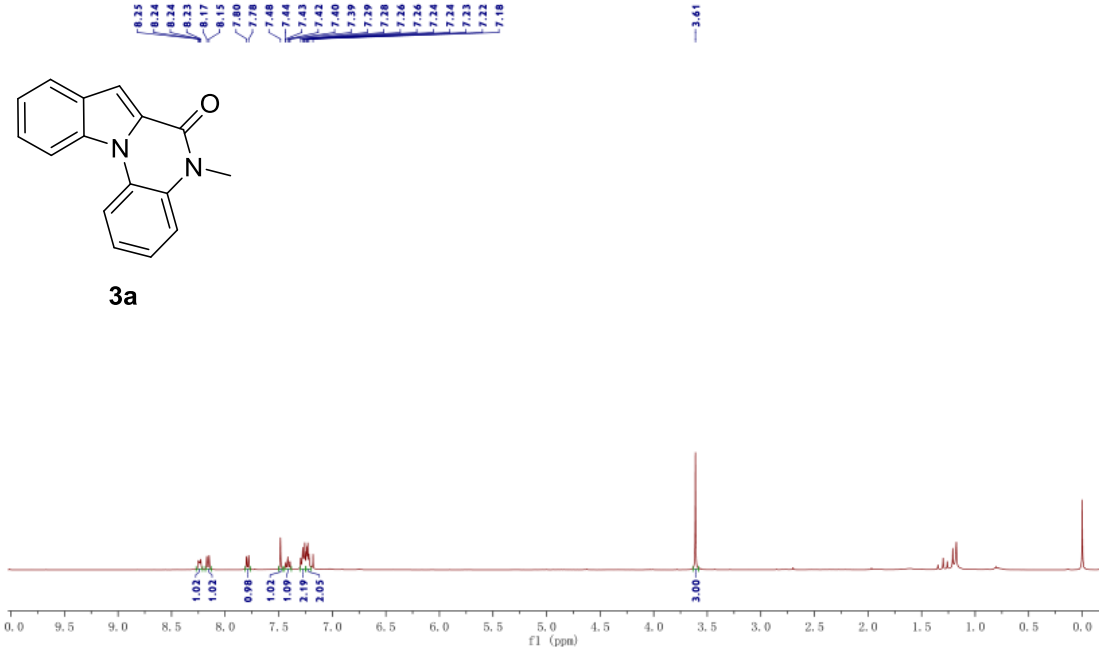
MeO
N
N
F3C

2q

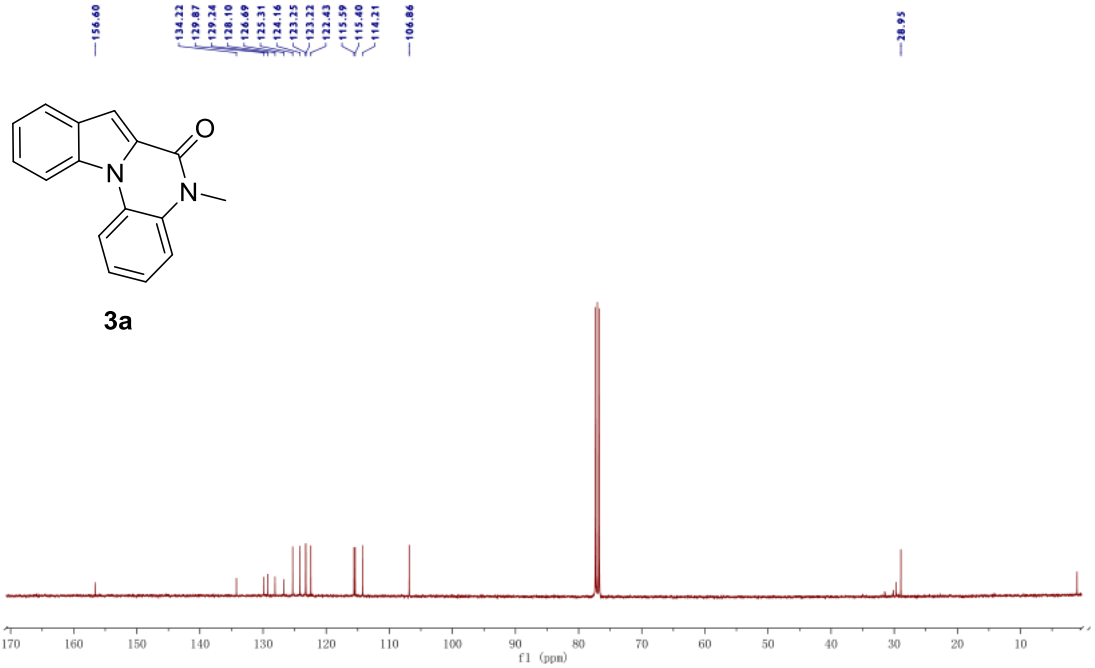

-62.46
20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)

O
N
N

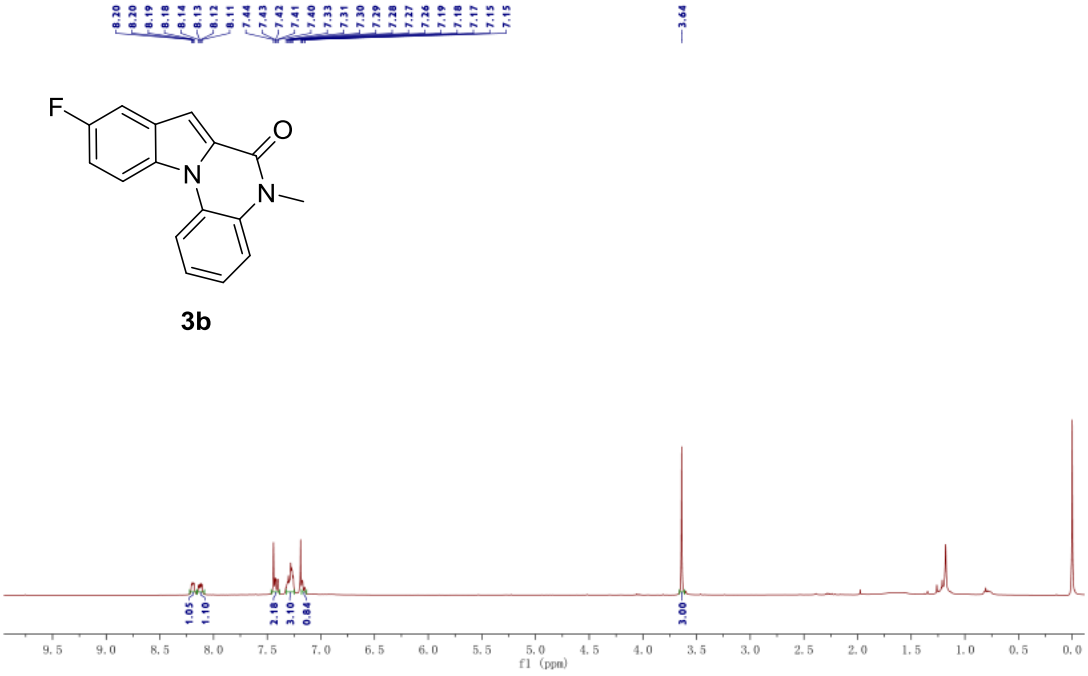
3a

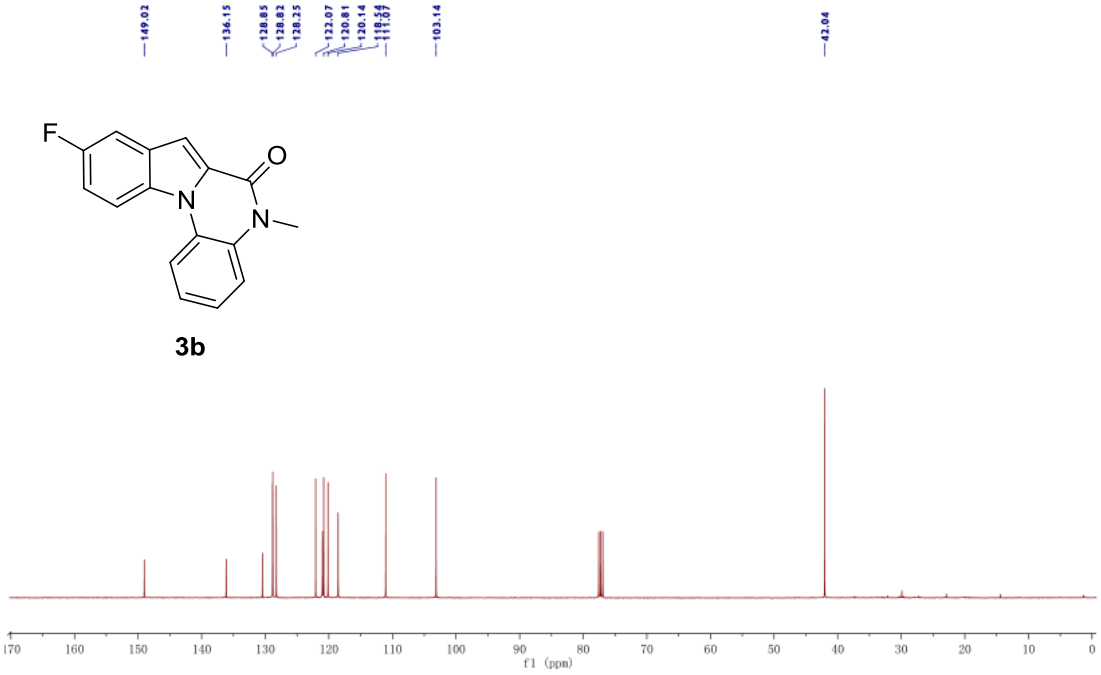

8.25
8.24
8.24
8.23
8.17
8.15
7.80
7.78
7.48
7.44
7.43
7.42
7.40
7.39
7.29
7.28
7.26
7.24
7.24
7.23
7.22
7.18
3.61
1.02
1.02
0.98
1.02
1.09
2.19
2.05
3.00
0.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

3a

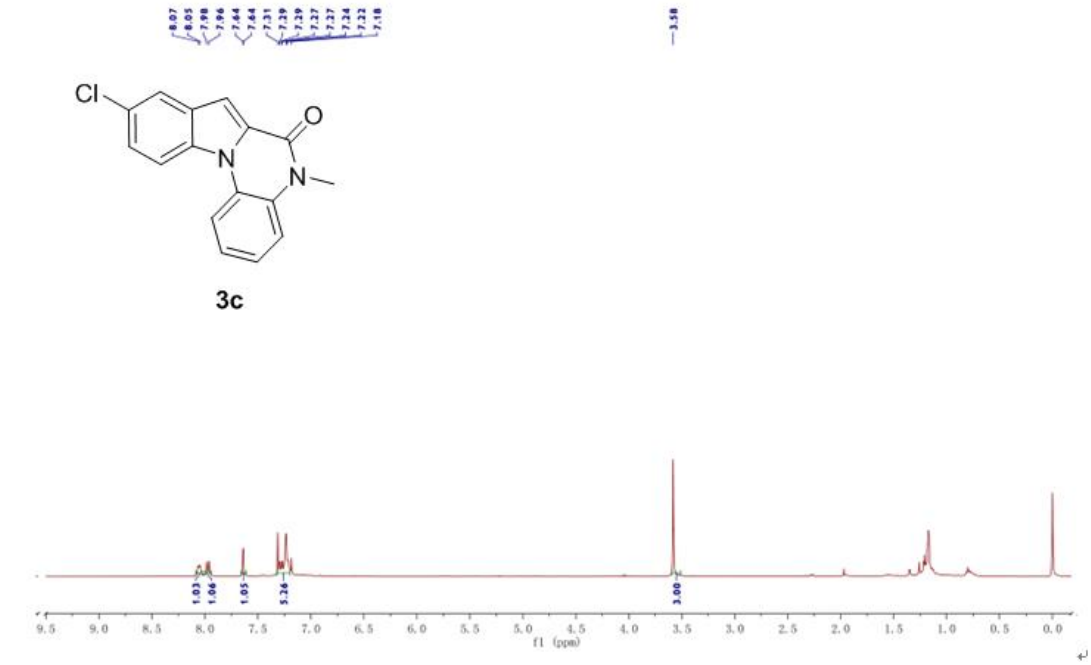


3b

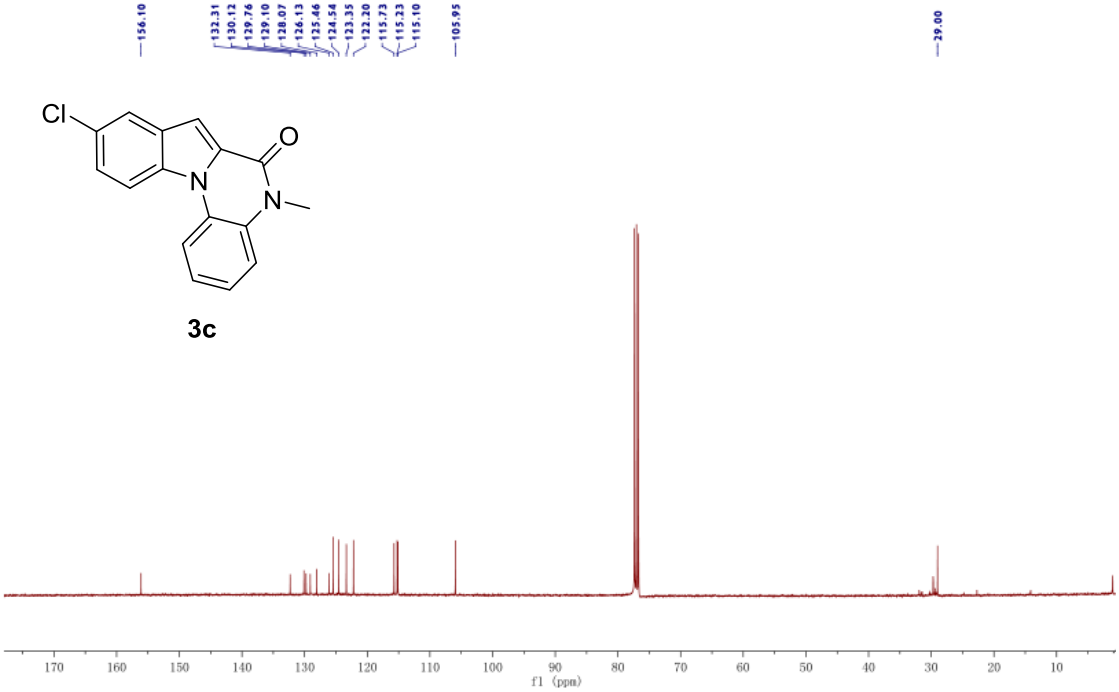



149.02
136.15
128.85
128.82
128.25
122.07
120.81
120.14
111.57
103.14
42.04
F
O
N
N
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

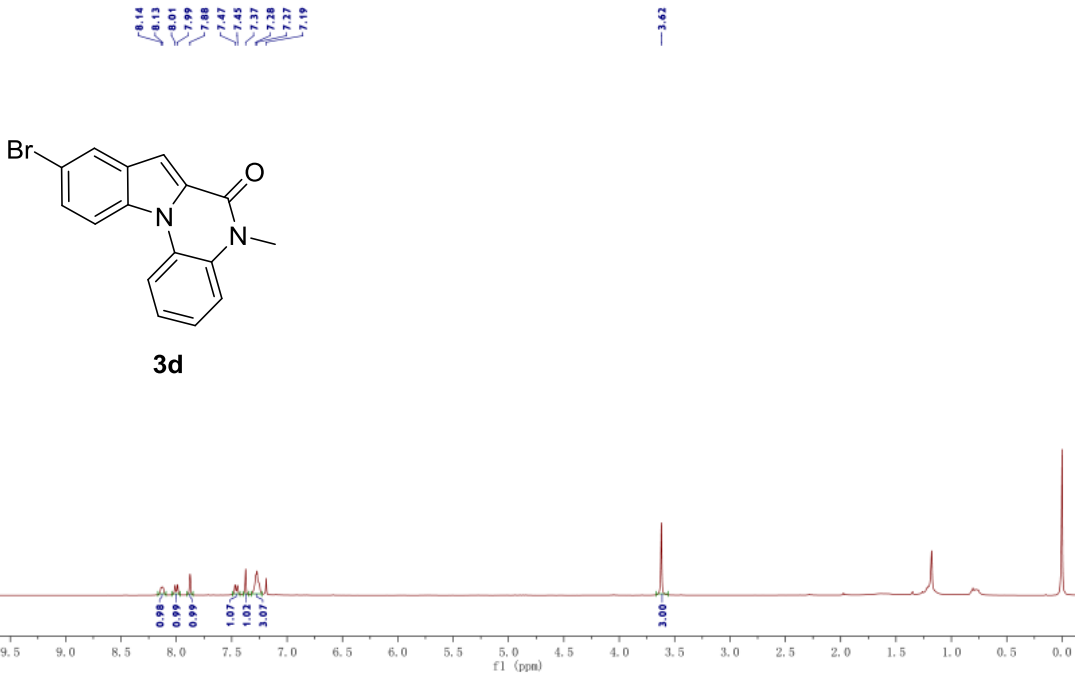
3b


8.07
8.05
7.98
7.96
7.44
7.44
7.31
7.29
7.29
7.27
7.27
7.24
7.22
7.18
3.58
Cl
O
N
N
1.03
1.06
1.03
5.26
3.00
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

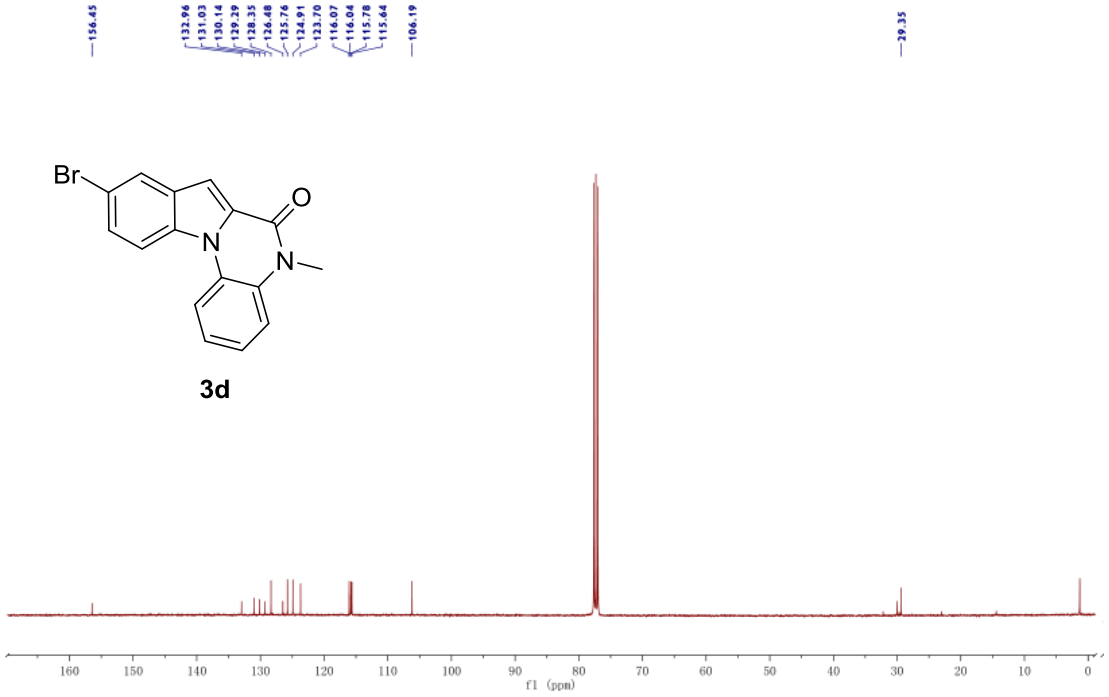
3c


156.10
132.31
130.12
129.76
129.10
128.07
126.13
125.46
124.54
123.35
122.20
115.73
115.23
115.10
105.95
29.00
Cl
O
N
N
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

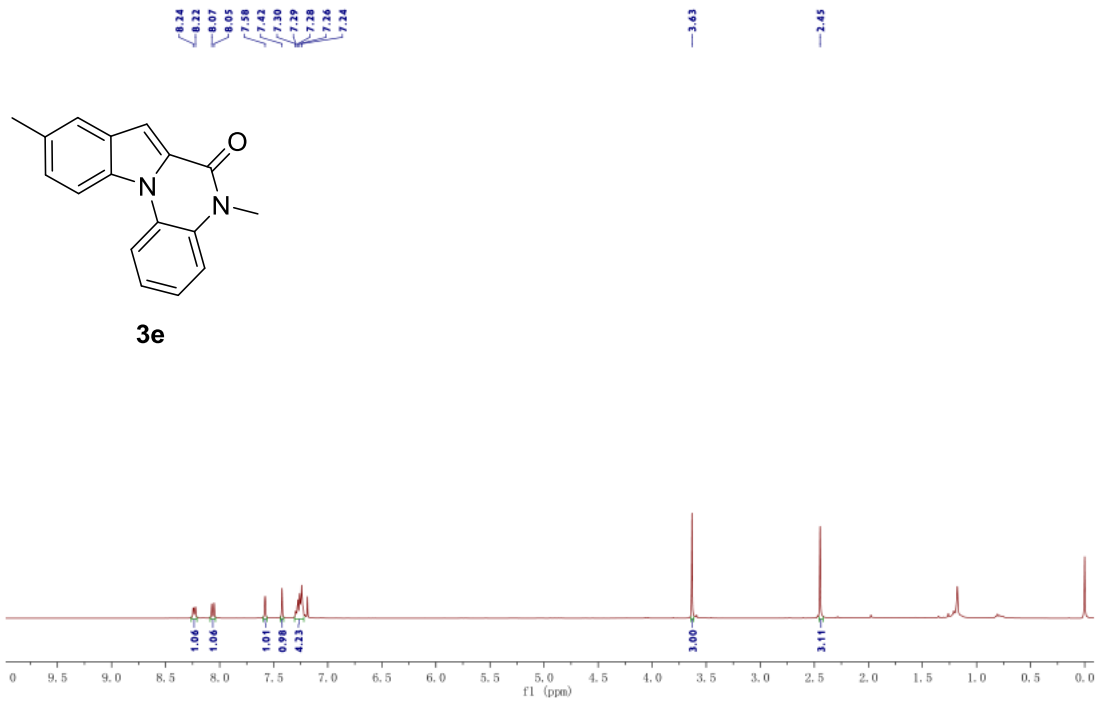
3c


8.14
8.13
8.01
7.99
7.88
7.47
7.45
7.37
7.28
7.27
7.19
3.62
Br
O
N
N
0.98
0.99
0.99
1.07
1.02
3.07
3.00
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

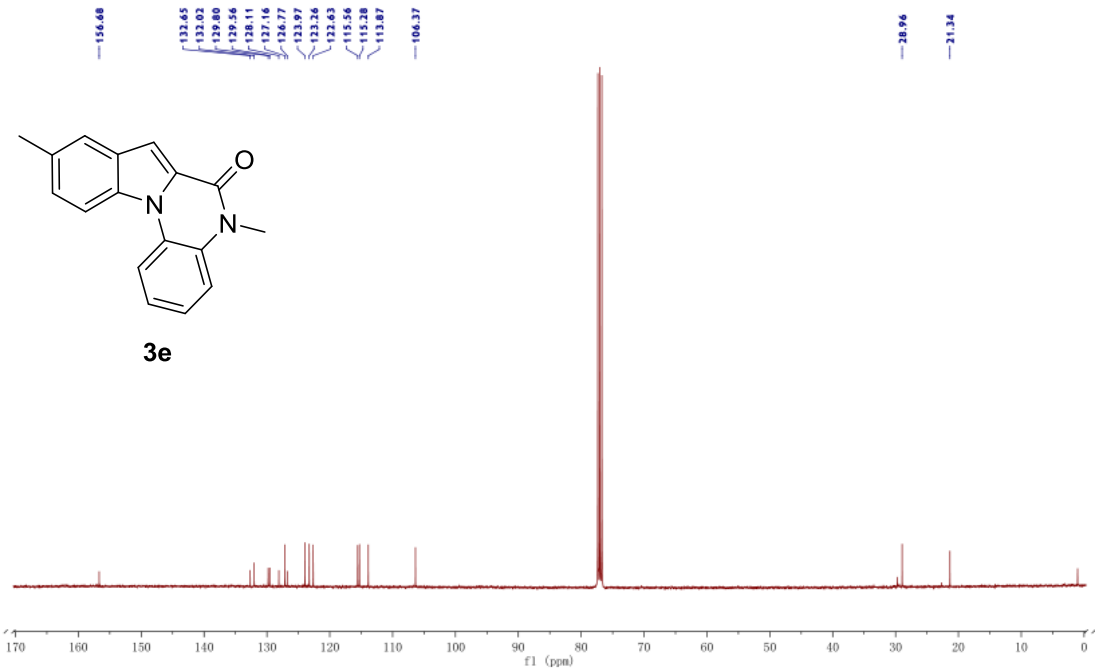
3d


156.45
132.96
131.03
130.14
129.29
128.35
126.48
125.76
124.91
123.70
116.07
116.04
115.78
115.64
106.19
29.35
Br
O
N
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

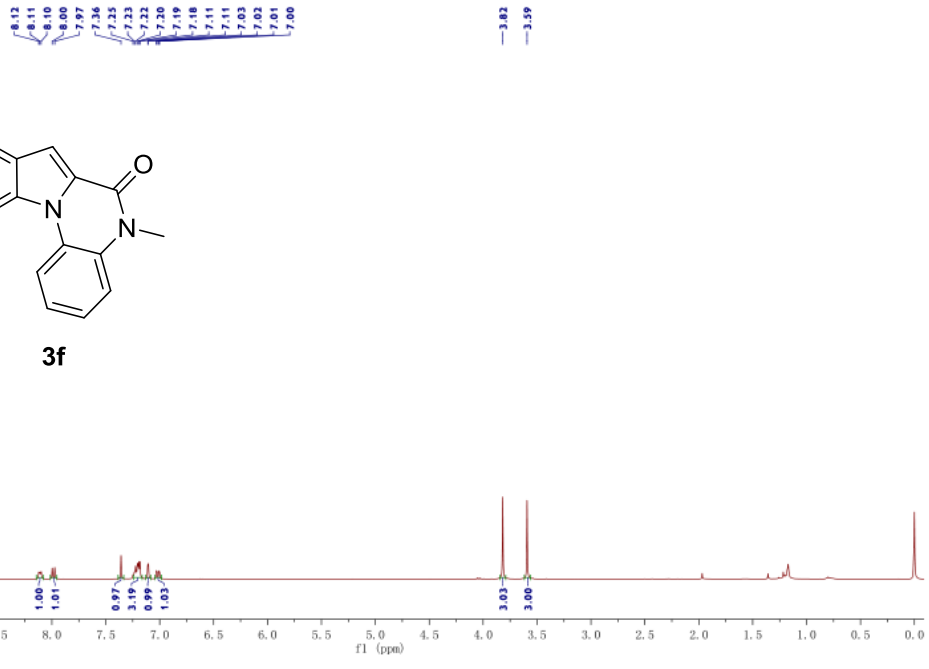
3d


8.24
8.22
8.07
8.05
7.58
7.42
7.30
7.29
7.28
7.26
7.24
3.63
2.45
O
N
N
1.06
1.06
1.01
0.98
4.23
3.00
3.11
0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

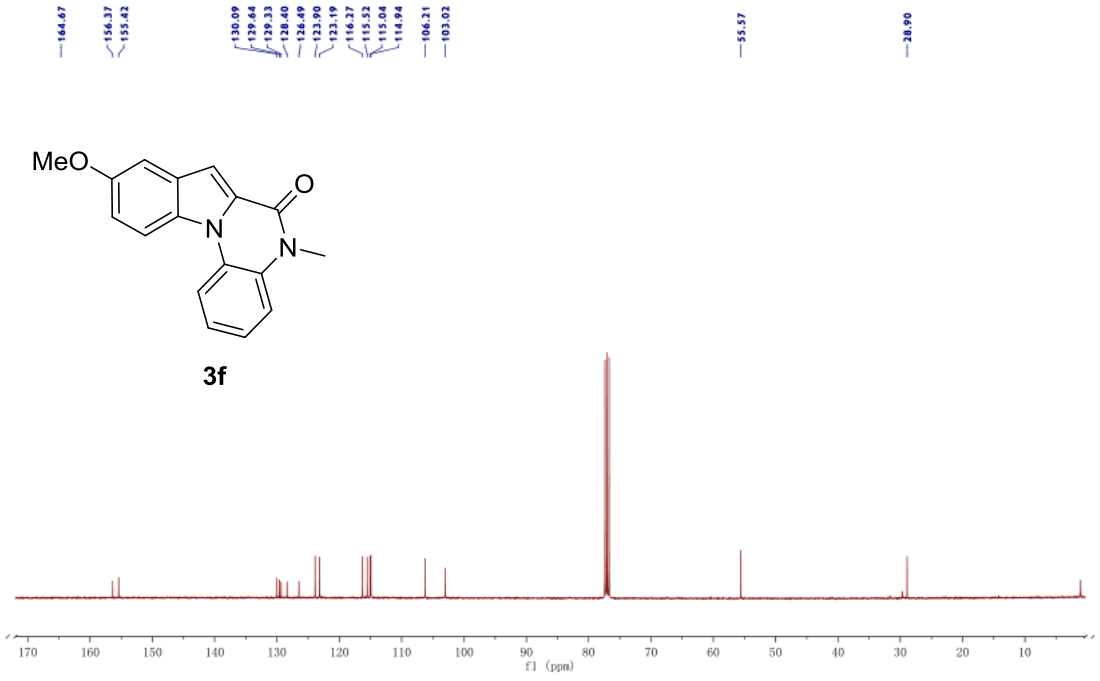
3e


156.68
132.65
132.02
129.80
129.56
128.11
127.16
126.77
123.97
123.26
122.63
115.56
115.28
113.87
106.37
28.96
21.34
O
N
N
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

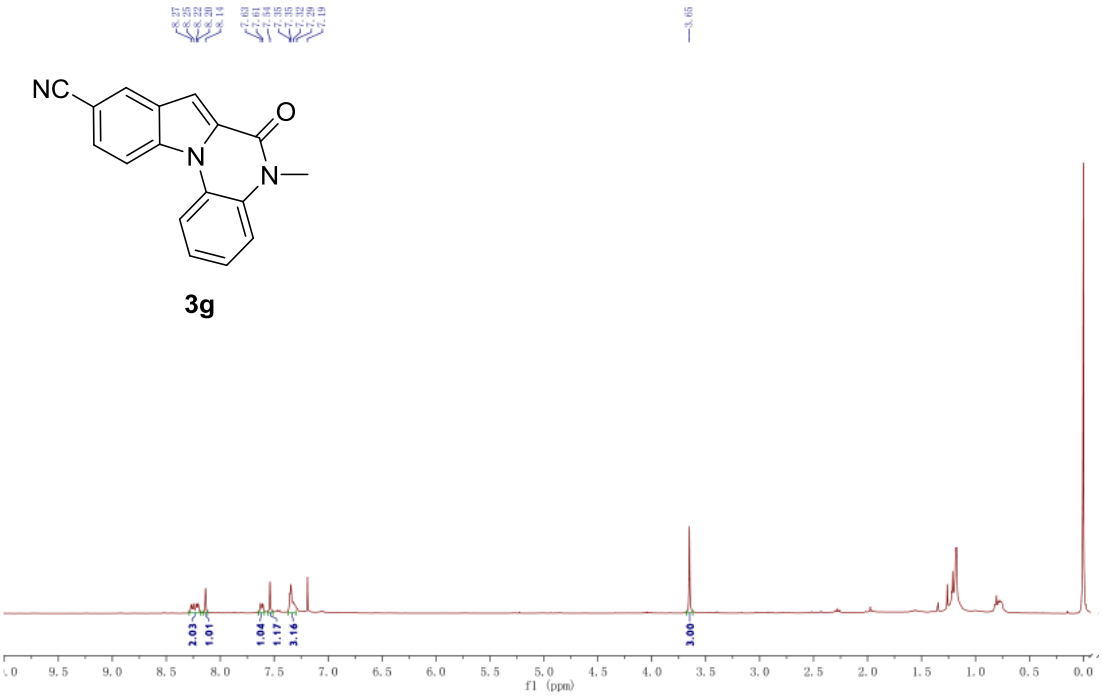
3e


8.12
8.11
8.10
8.00
7.97
7.36
7.25
7.23
7.22
7.20
7.19
7.18
7.11
7.11
7.03
7.02
7.01
7.00
3.82
3.59
MeO
O
N
N
1.00
1.01
0.97
3.19
0.99
1.03
3.03
3.00
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

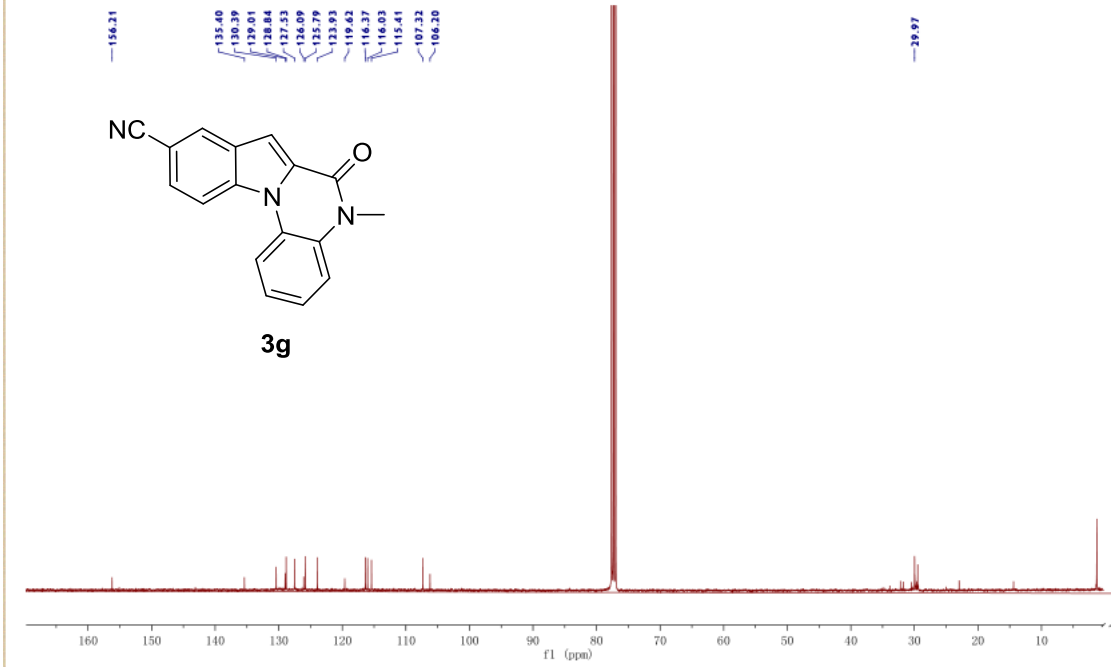
3f


164.67
156.37
155.42
130.09
129.64
129.33
128.40
126.49
123.90
123.19
116.27
115.53
115.04
114.94
106.21
103.02
55.57
28.90
MeO
O
N
N
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

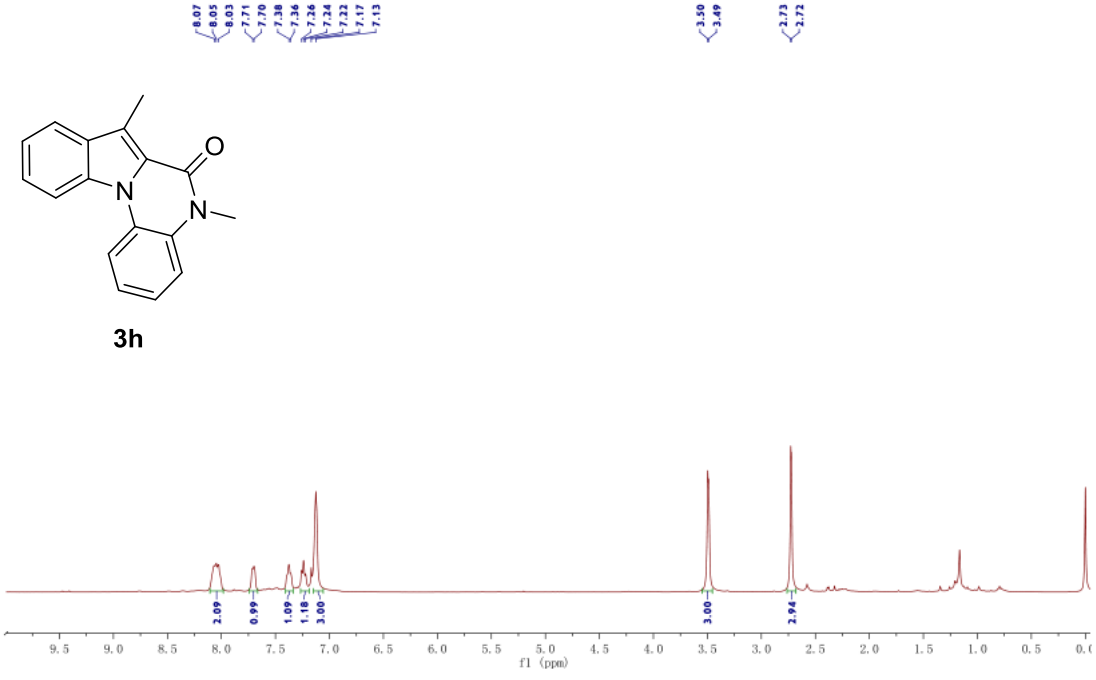
3f


8.65
NC
O
N
N
2.03
1.01
1.04
1.17
3.16
3.00
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

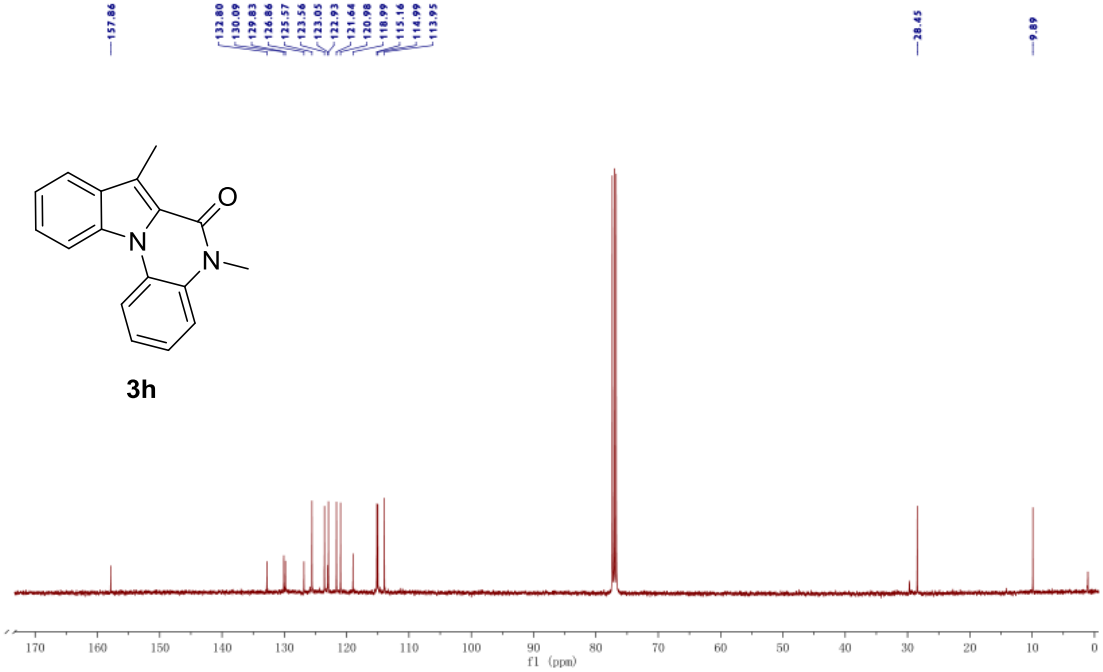
3g


156.21
135.40
130.39
129.01
128.84
127.53
126.09
125.79
123.93
119.62
116.37
116.03
115.41
107.32
106.20
29.97
NC
O
N
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

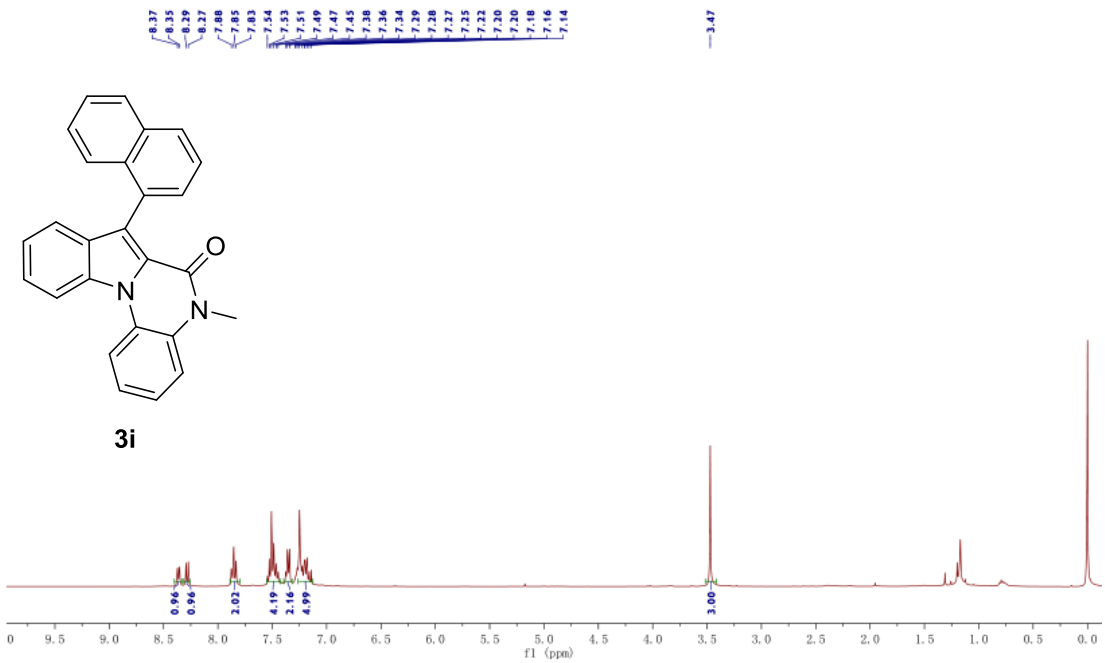
3g


8.07
8.05
8.03
7.71
7.70
7.38
7.36
7.26
7.24
7.22
7.17
7.13
3.50
3.49
2.73
2.72
O
N
N
2.09
0.99
1.09
1.18
3.00
3.00
2.94
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

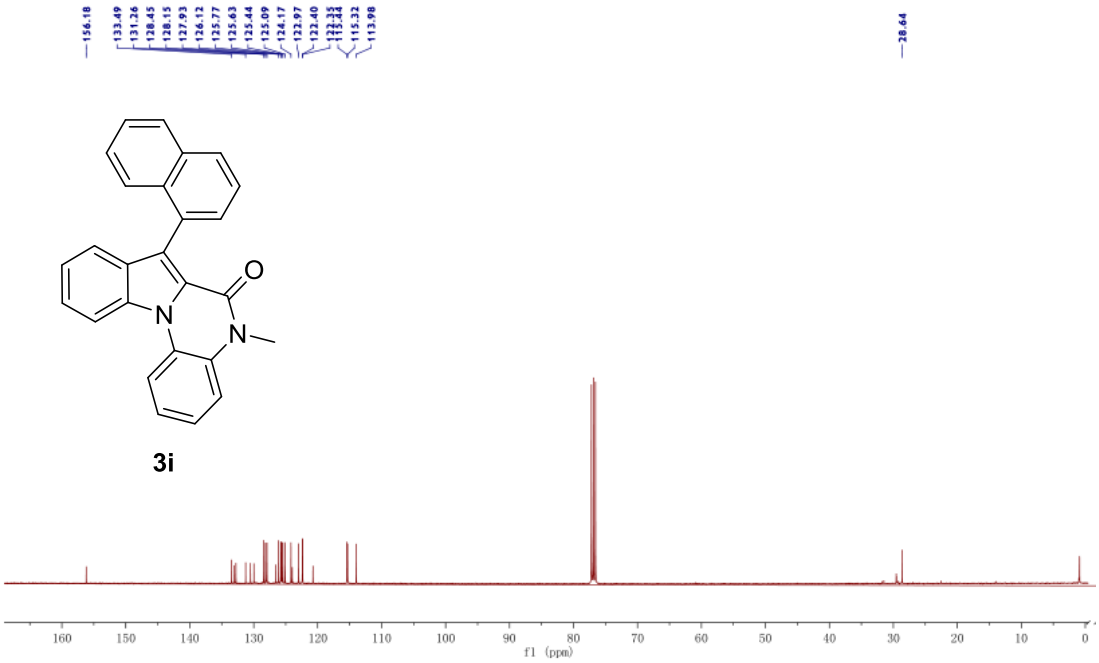
3h


157.86
132.80
130.09
129.83
126.86
125.57
123.56
123.05
122.93
121.64
120.98
118.99
115.16
114.99
113.95
28.45
9.89
O
N
N
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

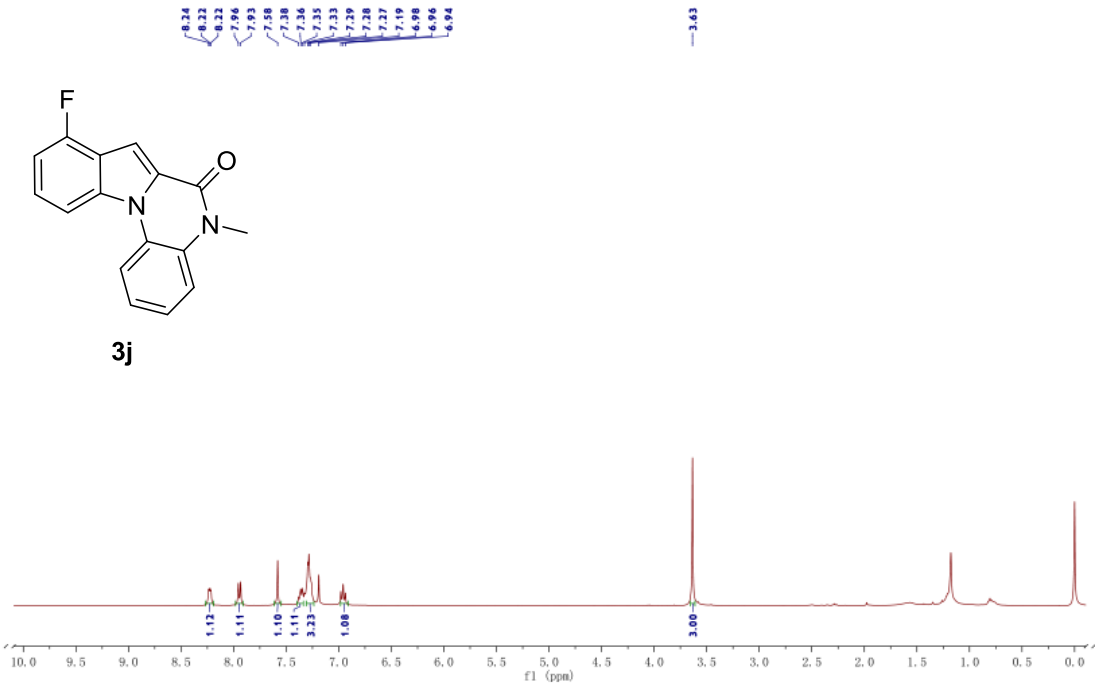
3h


8.37
8.35
8.29
8.27
7.88
7.85
7.83
7.54
7.53
7.51
7.49
7.47
7.45
7.38
7.36
7.34
7.29
7.28
7.27
7.25
7.22
7.20
7.18
7.16
7.14
3.47
O
N
N
0.96
0.96
2.02
4.19
2.16
4.99
3.00
0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

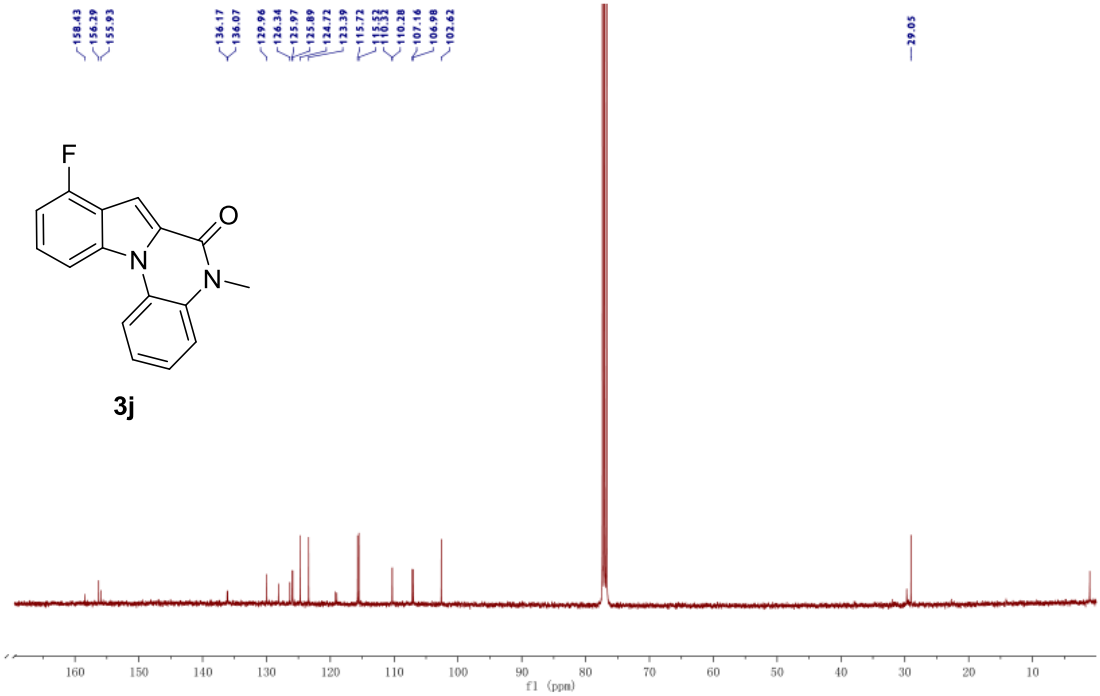
3i


156.18
133.49
131.26
128.45
128.15
127.93
126.12
125.77
125.63
125.44
125.09
124.17
122.97
122.40
115.32
113.98
28.64
O
N
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

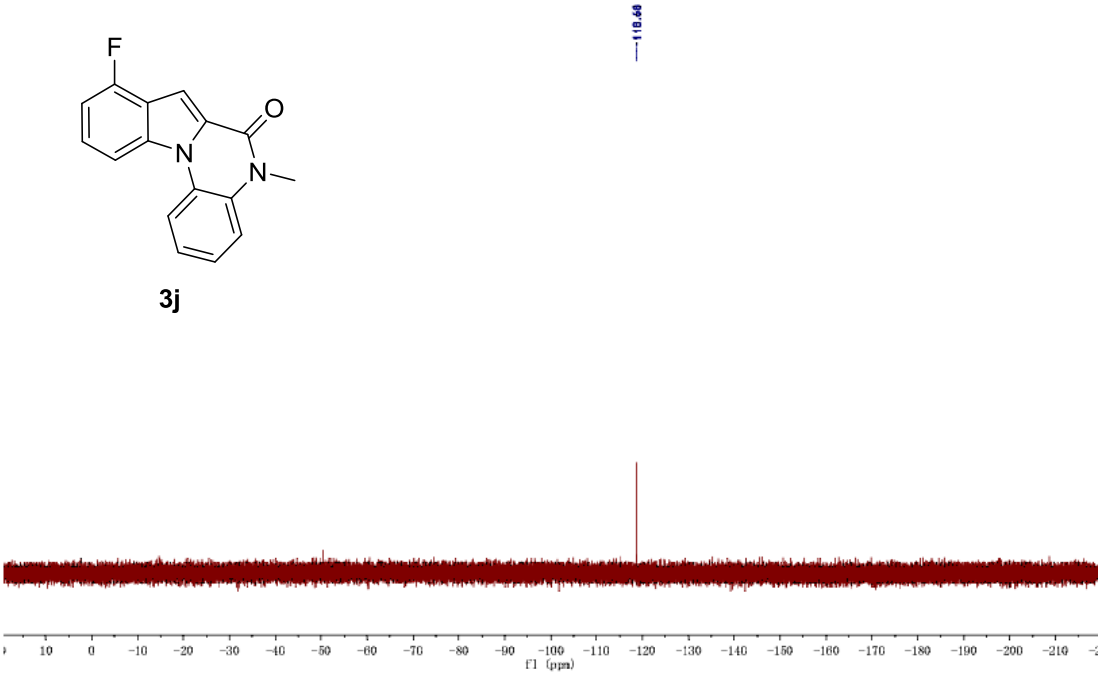
3i


8.24
8.22
8.22
7.96
7.93
7.58
7.38
7.36
7.35
7.33
7.29
7.28
7.27
7.19
6.98
6.96
6.94
3.63
F
O
N
N
1.12
1.11
1.10
1.11
3.23
1.08
3.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

3j

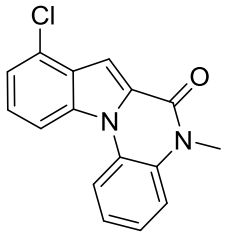

158.43
156.29
155.93
136.17
136.07
129.96
126.34
125.97
125.89
124.72
123.39
115.72
115.52
110.32
110.28
107.16
106.98
102.62
29.05
F
O
N
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

3j

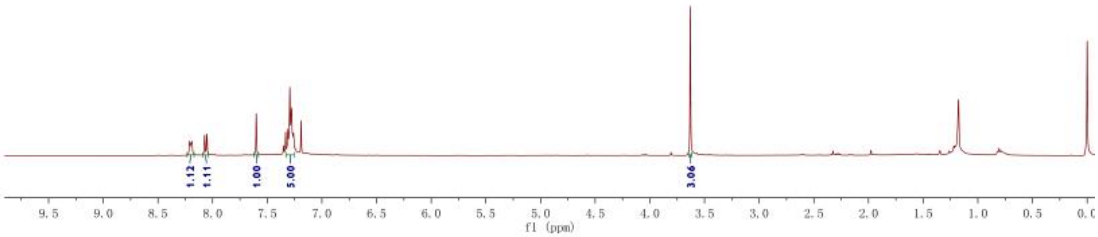

118.68
F
O
N
N
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
f1 (ppm)

3j


8.21
8.20
8.19
8.07
8.05
7.60
7.33
7.31
7.29
7.28
7.27
7.26
7.19
3.63


Cl
O
N
N

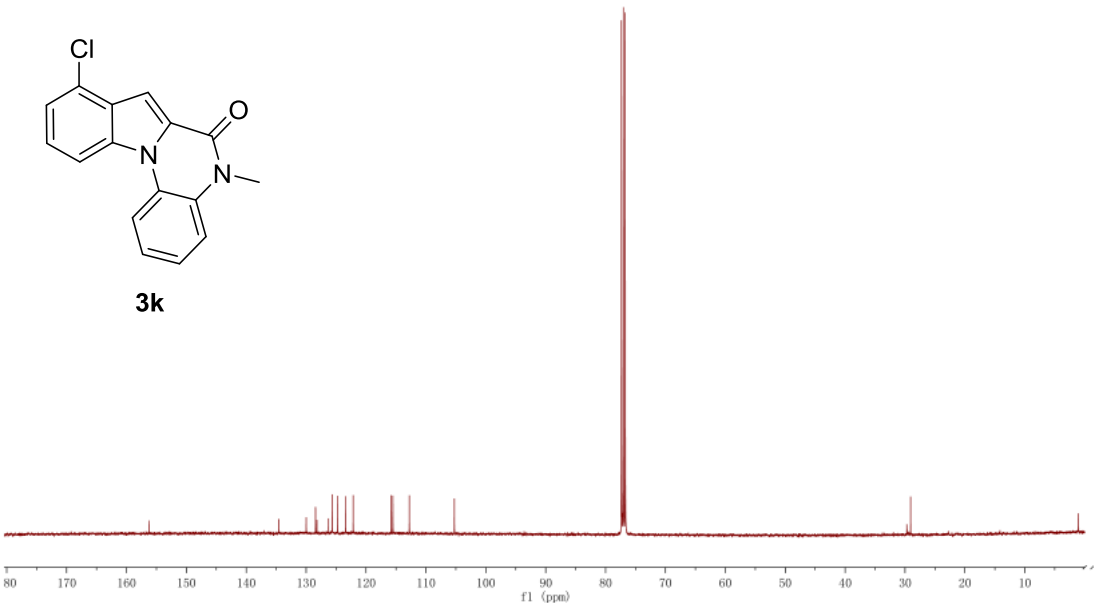
3k

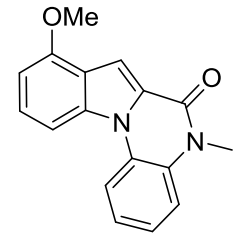

1.12
1.11
1.00
5.00
3.06
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)


156.22
134.57
129.99
128.44
128.21
126.27
125.67
124.77
123.41
122.15
115.78
115.51
112.78
105.25
29.07

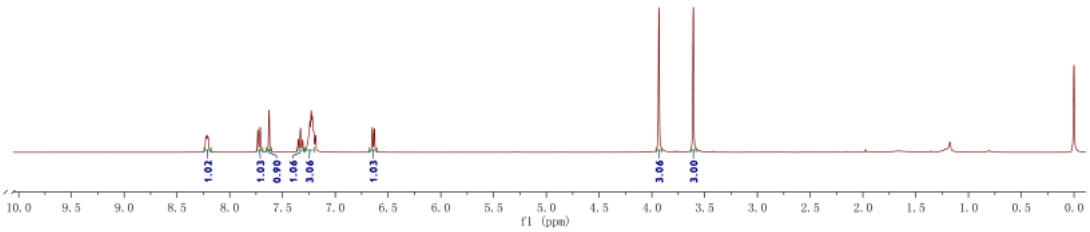
Cl
O
N
N

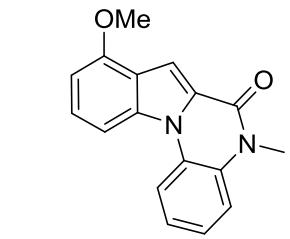
3k


80
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

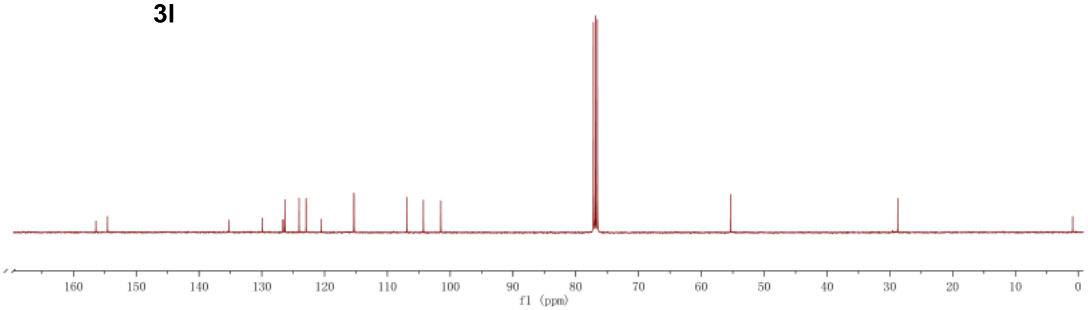

OMe
O
N
N

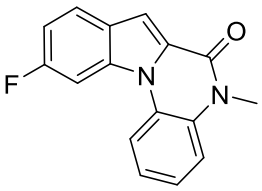
3l


1.02
1.03
0.90
1.06
3.06
1.03
3.06
3.00
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

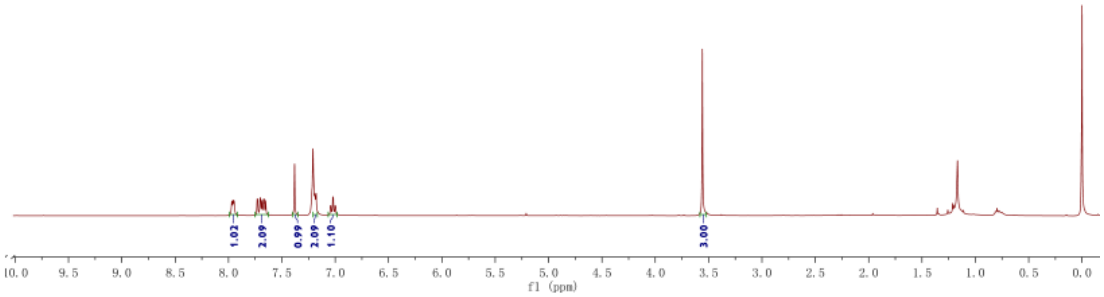

OMe
O
N
N

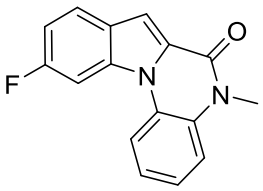
3l


160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

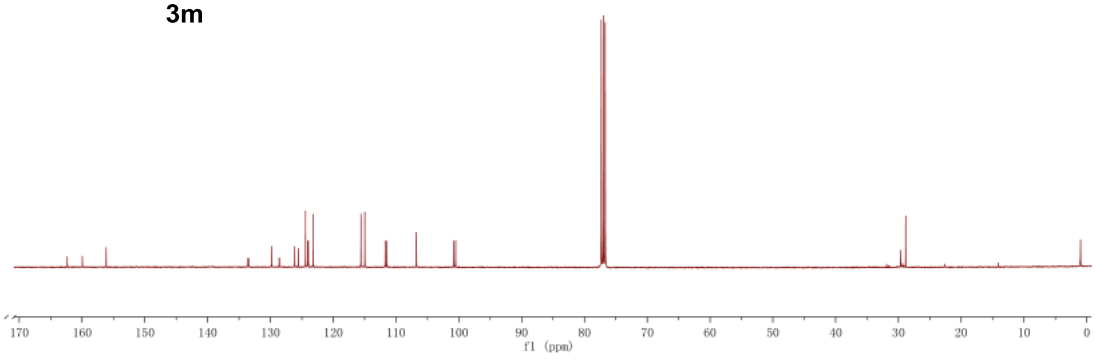


3m



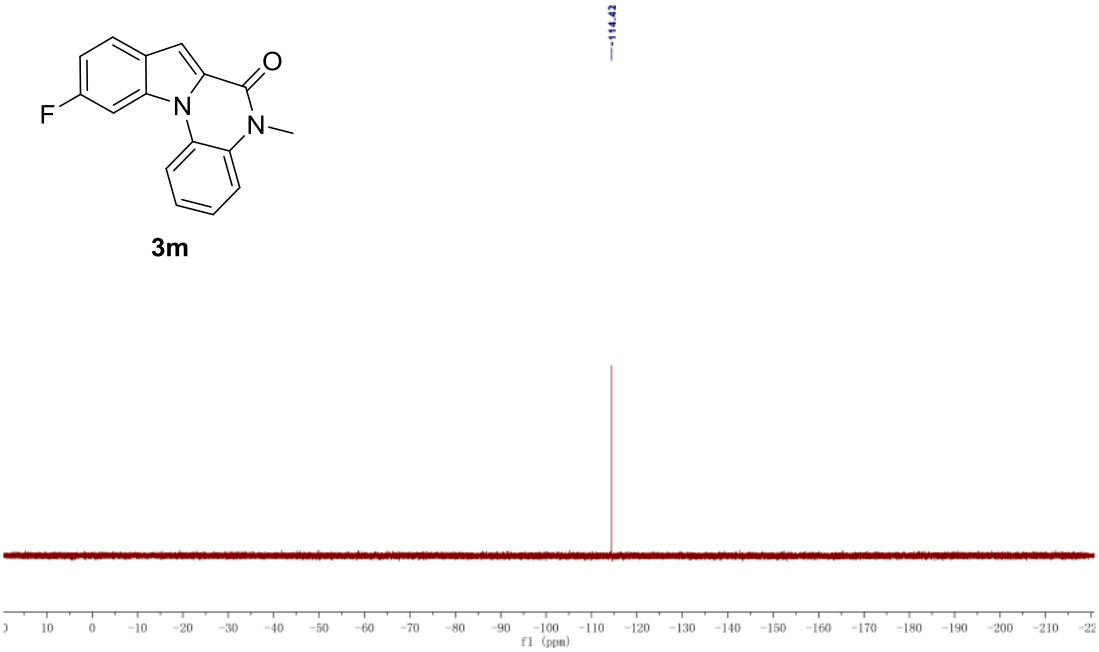


3m

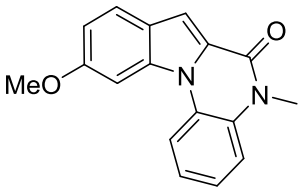


F
N
O
N

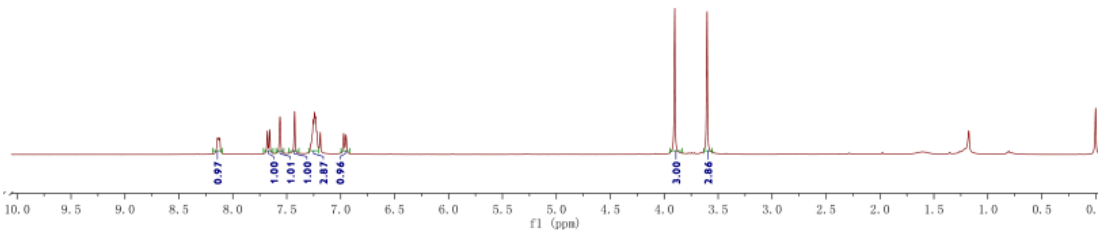
3m

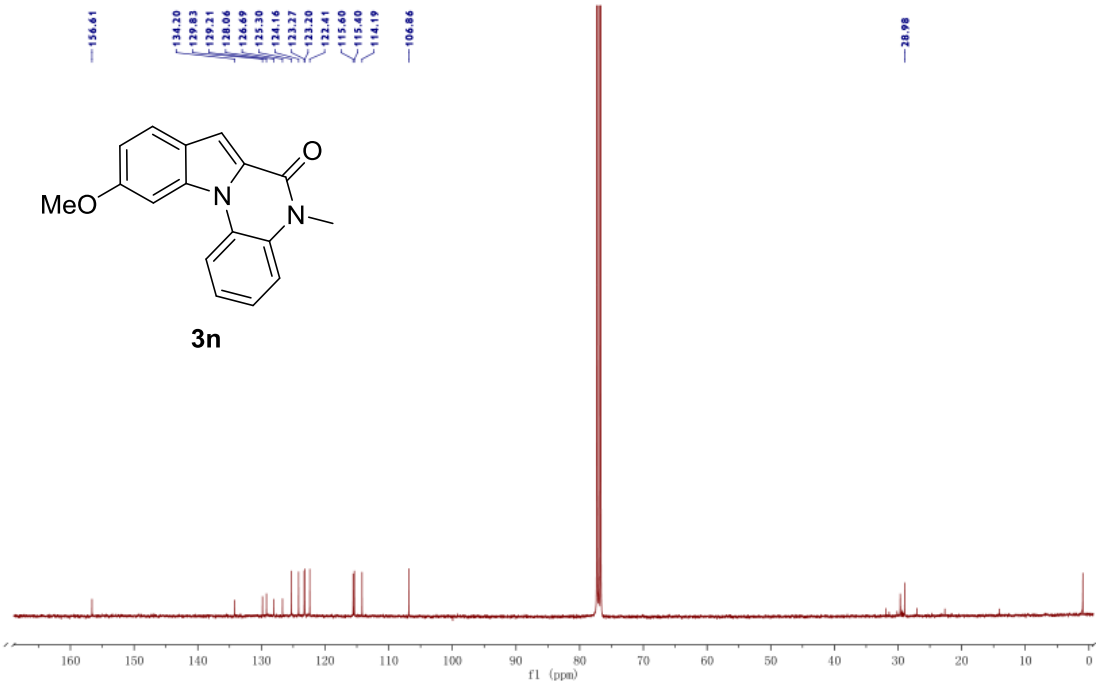

-114.42
10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -22
f1 (ppm)


8.14
8.14
8.12
7.68
7.66
7.56
7.43
7.25
7.24
7.23
7.22
7.19
6.97
6.95
3.90
3.60

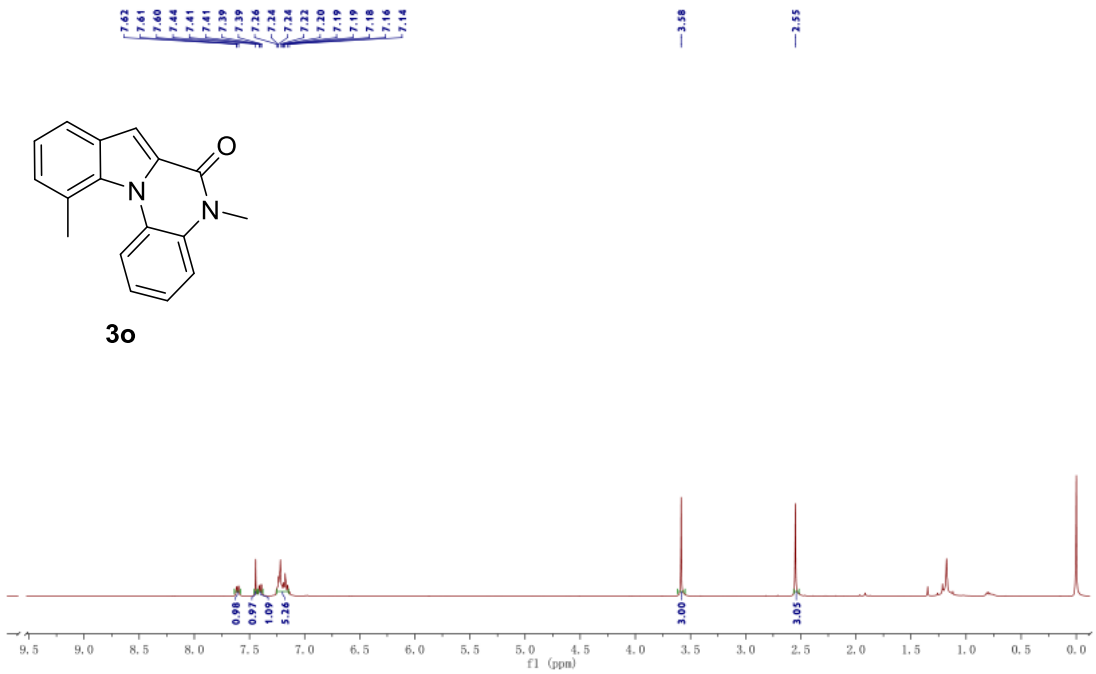

MeO
N
O
N

3n

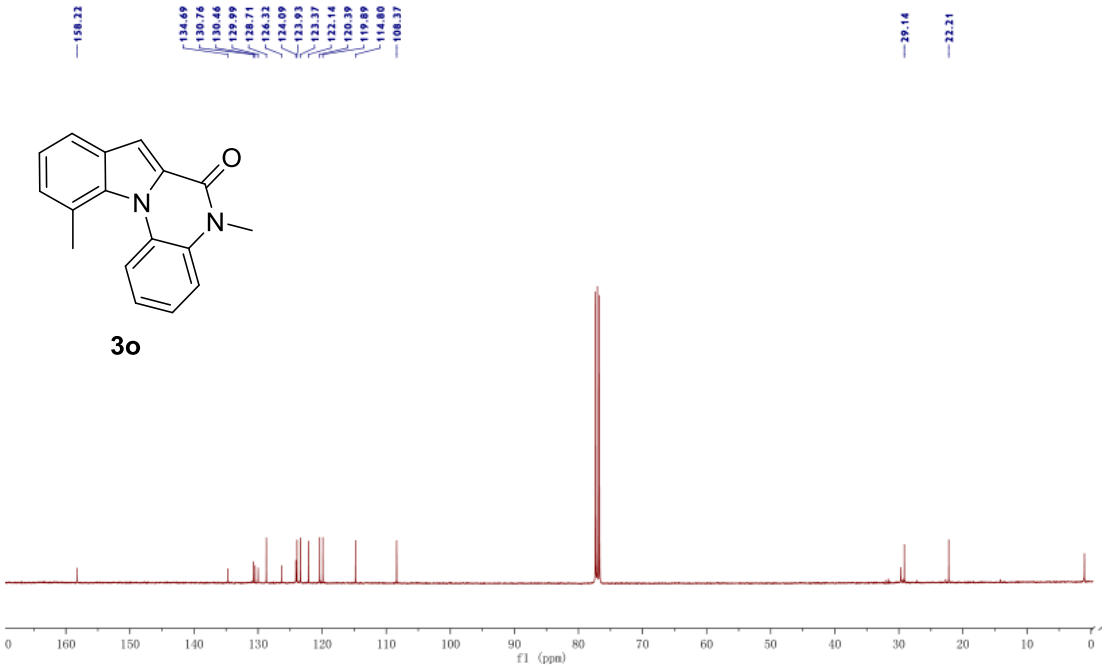

0.97
1.00
1.01
1.00
2.87
0.96
3.00
2.86
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.
f1 (ppm)

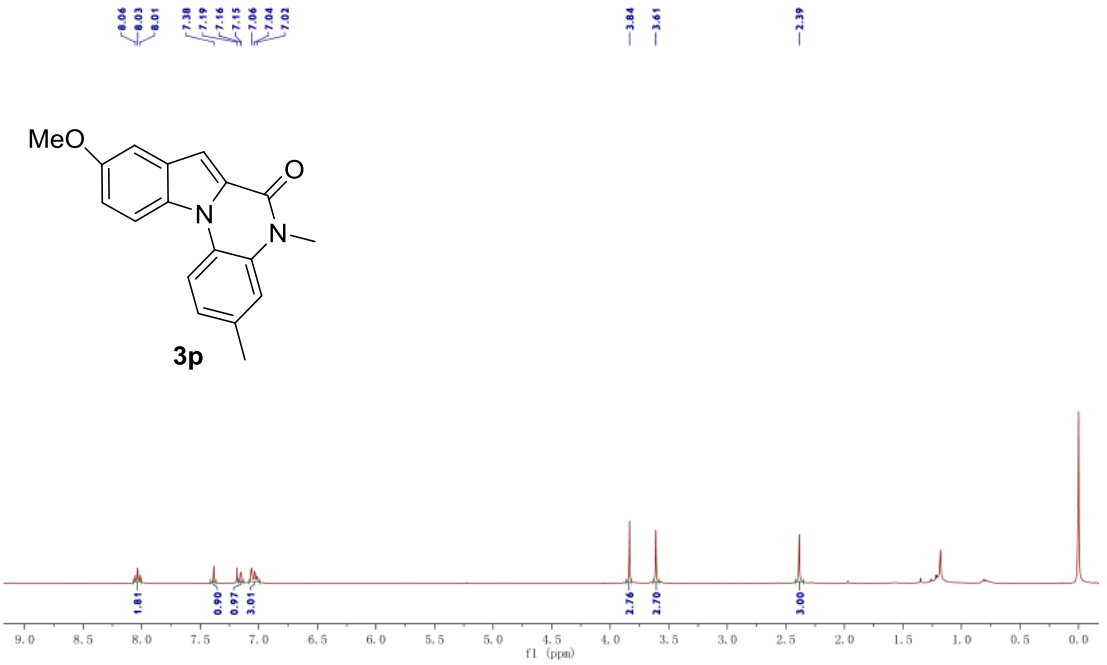

156.61
134.20
129.83
129.21
128.06
126.69
125.30
124.16
123.37
123.20
122.41
115.60
115.40
114.19
106.86
28.98
MeO
N
O
N
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

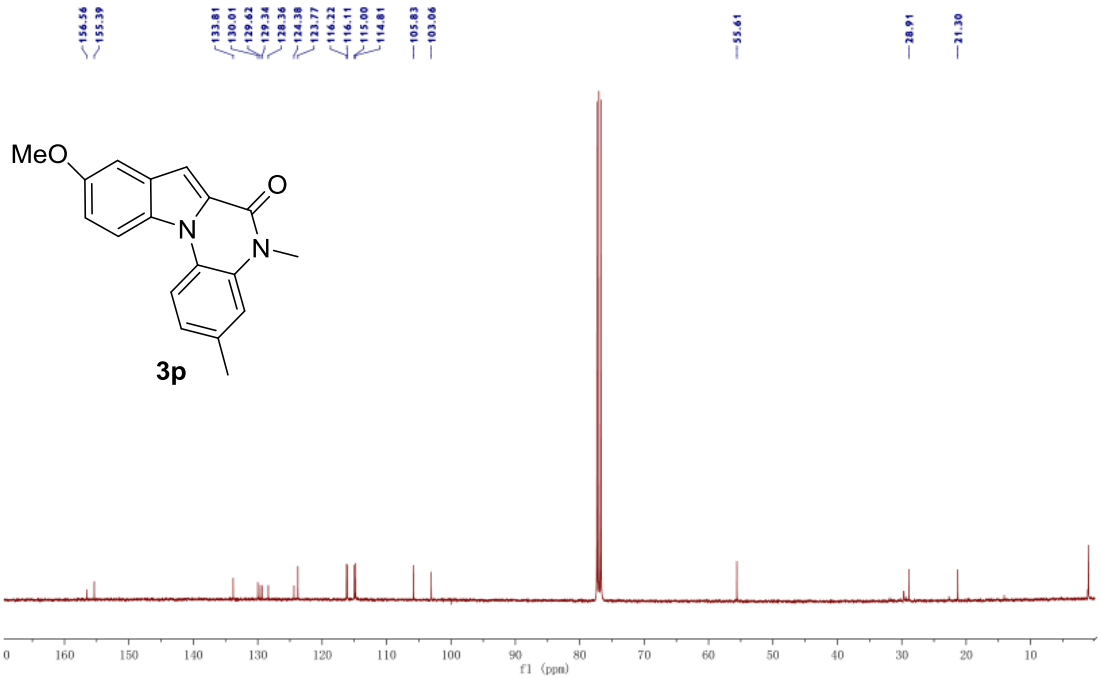
3n

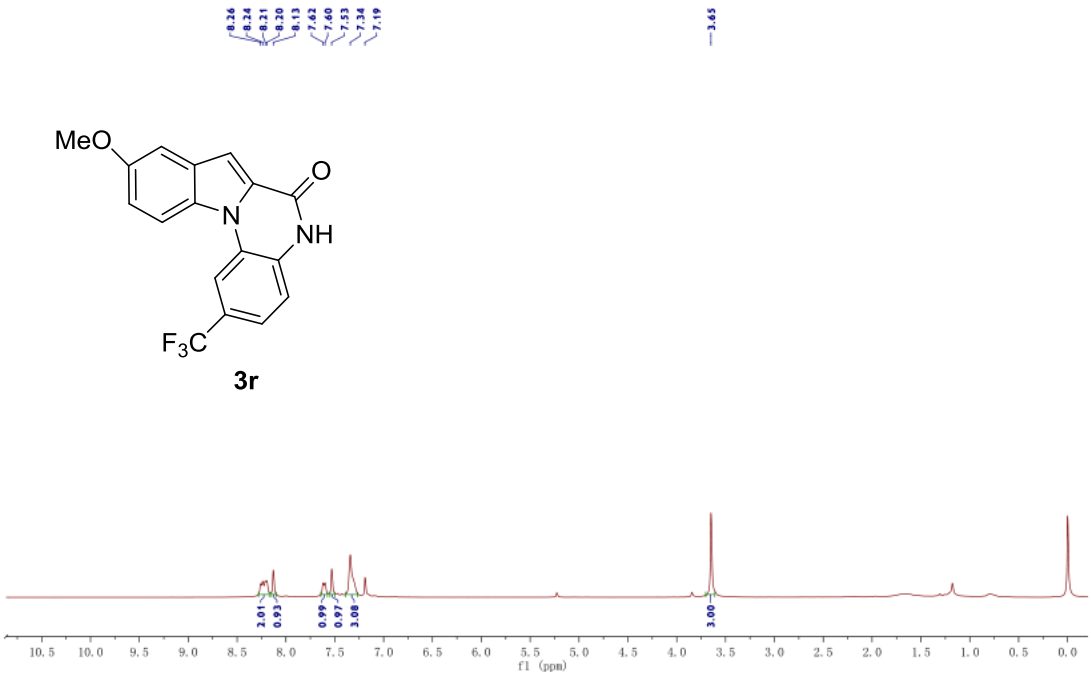

7.62
7.61
7.60
7.44
7.41
7.41
7.39
7.39
7.26
7.24
7.24
7.22
7.20
7.19
7.19
7.18
7.16
7.14
3.58
2.55
N
O
N
0.98
0.97
1.09
5.26
3.00
3.05
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

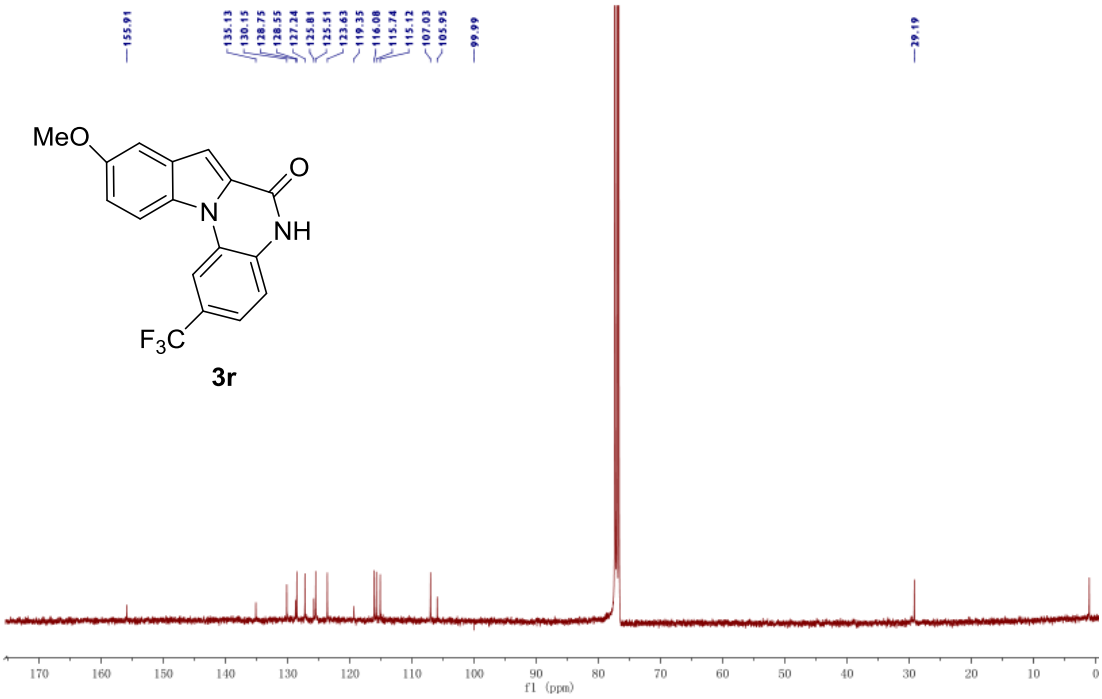
3o

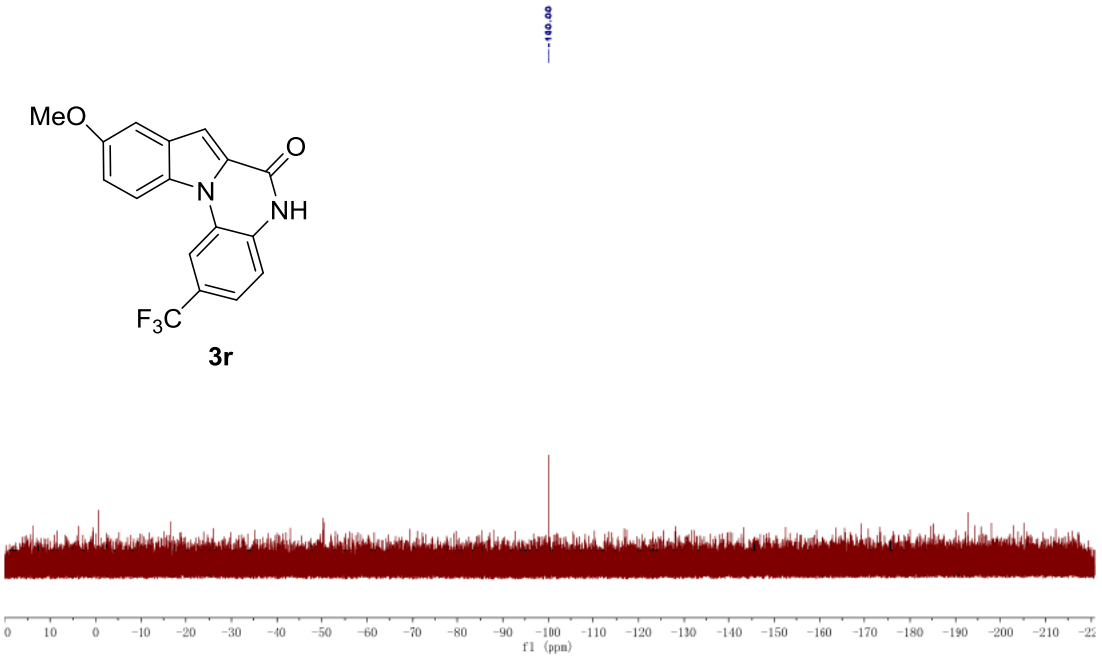

158.22
134.69
130.76
130.46
129.99
128.71
126.32
124.09
123.93
123.37
122.14
120.39
119.89
114.80
108.37
29.14
22.21
O
N
N
3o
f1 (ppm)

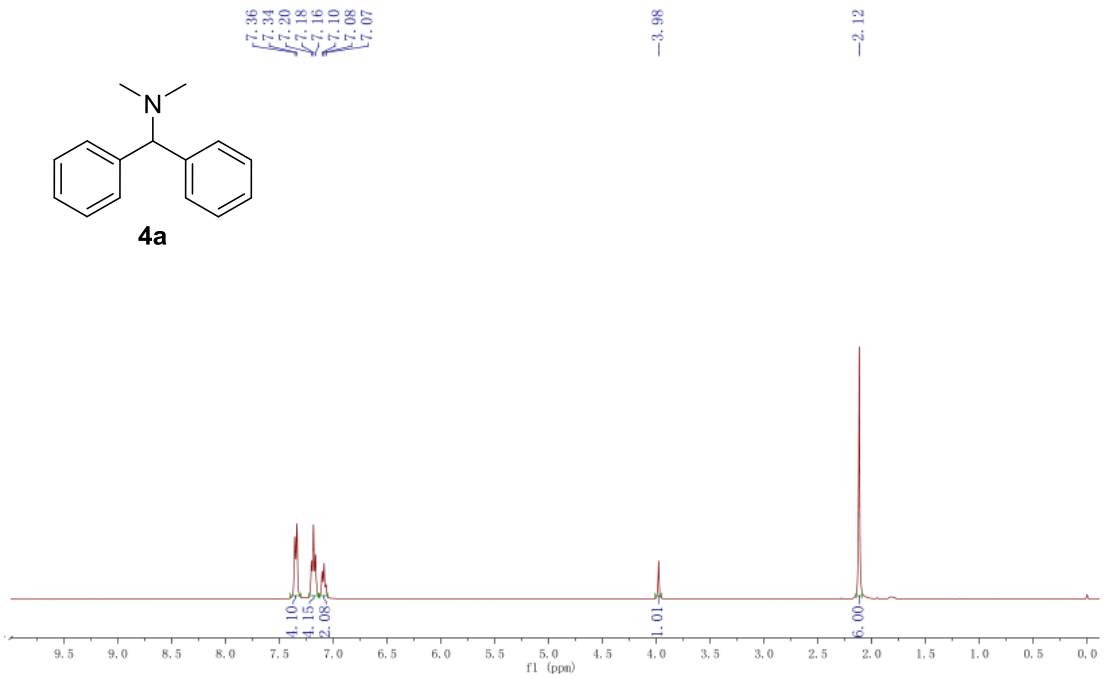

8.06
8.03
8.01
7.38
7.19
7.16
7.15
7.06
7.04
7.02
3.84
3.61
2.39
MeO
O
N
N
3p
1.81
0.90
0.97
3.01
2.74
2.70
3.00
f1 (ppm)

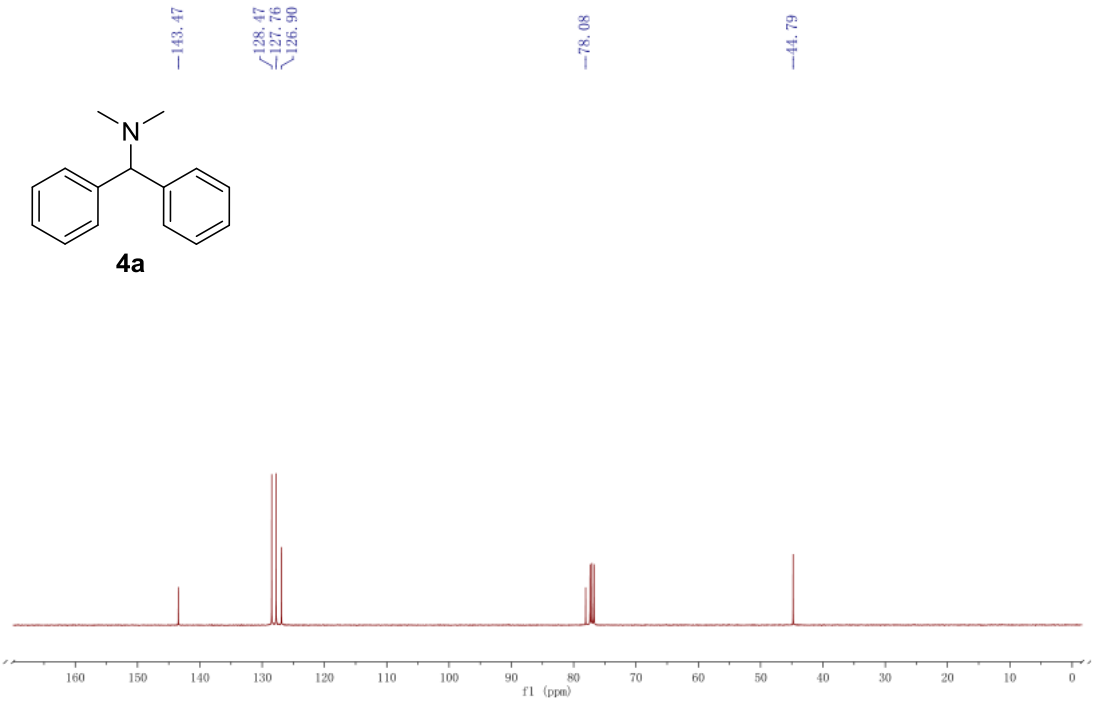

156.56
155.39
133.81
130.01
129.62
129.34
128.36
124.38
123.77
116.22
116.11
115.00
114.81
105.83
103.06
55.61
28.91
21.30
MeO
O
N
N
3p
0
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

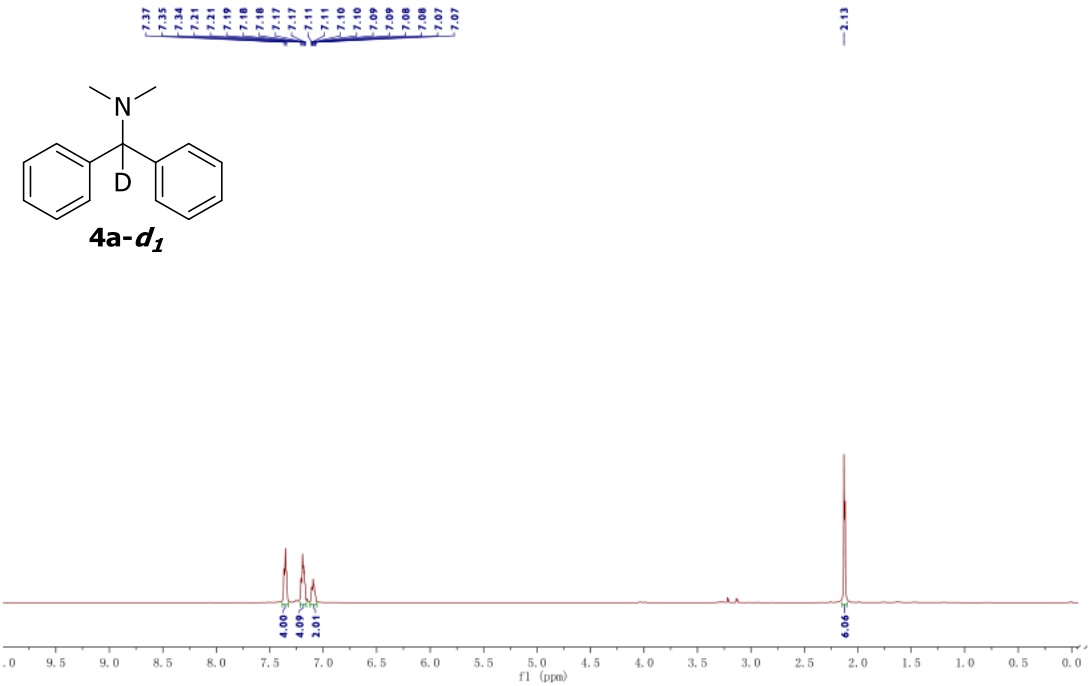

8.26
8.24
8.21
8.20
8.13
7.62
7.60
7.53
7.34
7.19
3.65
MeO
O
N
NH
F3C
3r
2.01
0.93
0.99
0.97
3.08
3.00
10.5
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

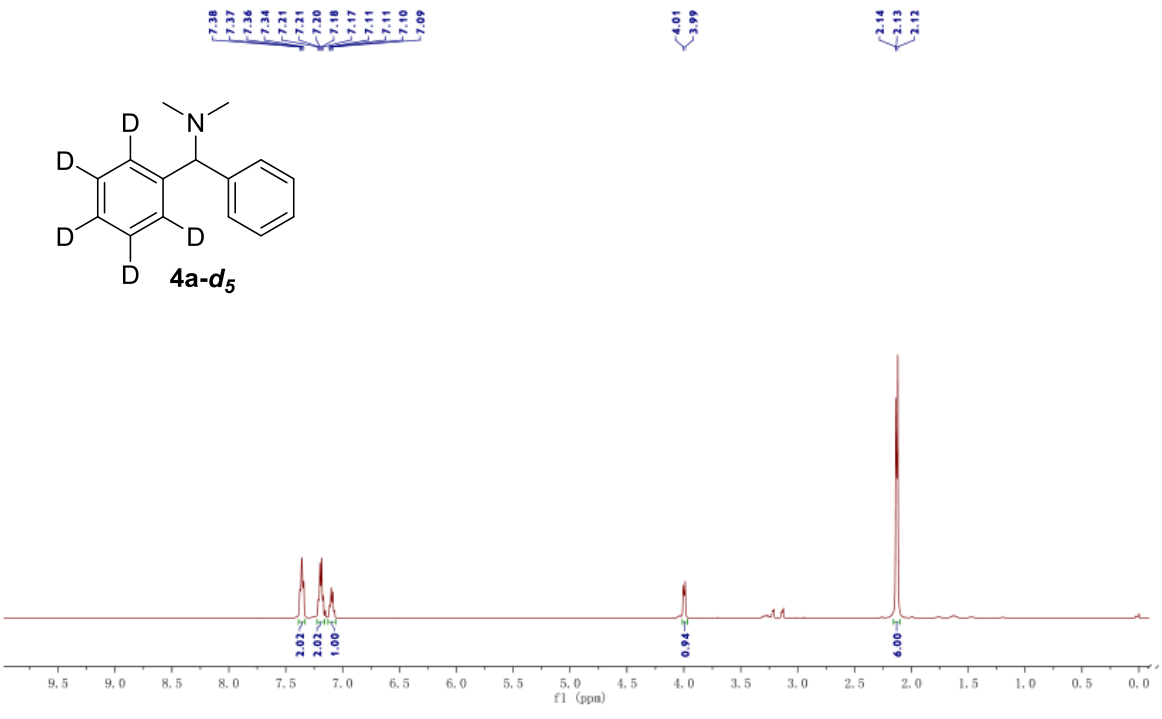

155.91
135.13
130.15
128.75
128.55
127.24
125.81
125.51
123.63
119.35
116.08
115.74
115.12
107.03
105.95
99.99
29.19
MeO
O
N
NH
F3C
3r
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

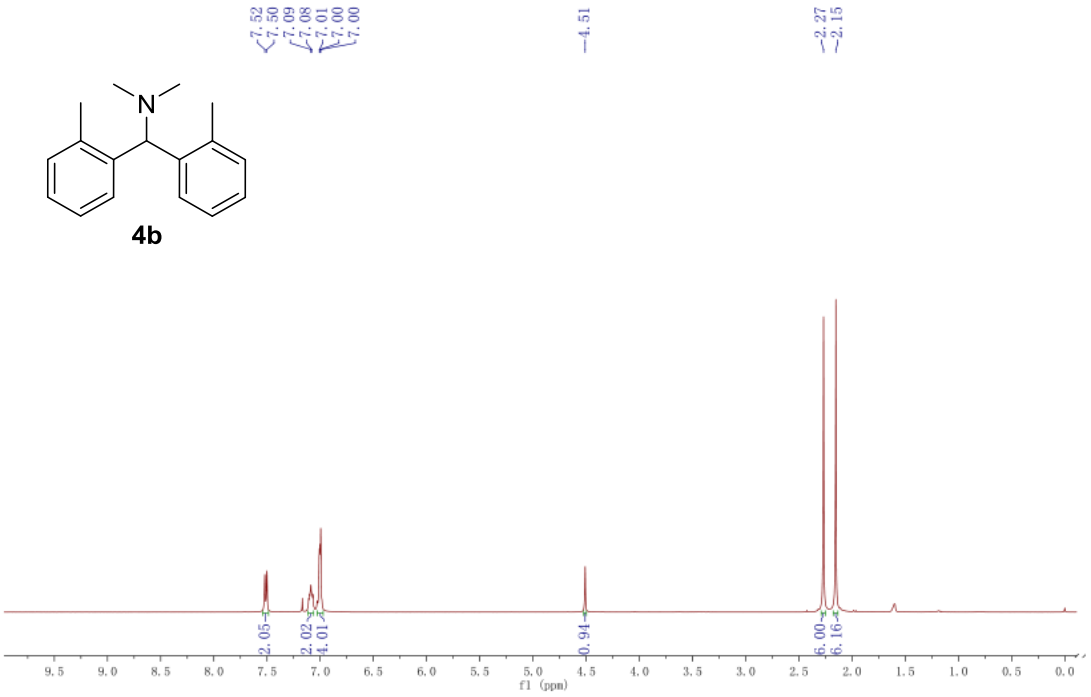

-140.60
MeO
O
N
NH
F3C
3r
0 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)

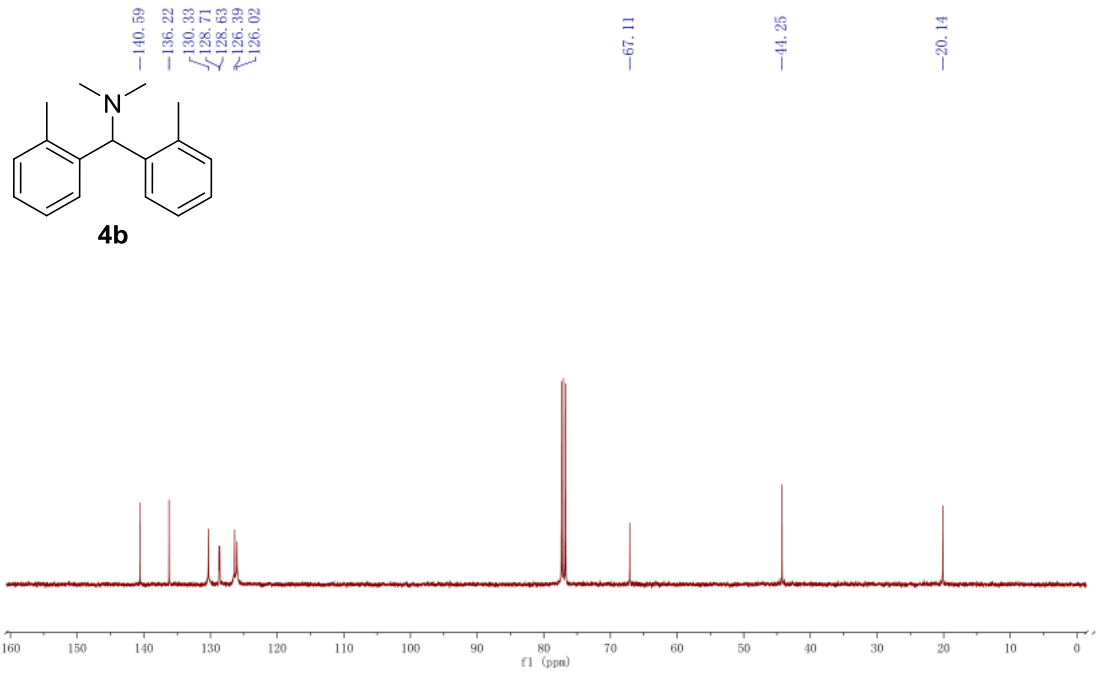

7.36
7.34
7.20
7.18
7.16
7.10
7.08
7.07
3.98
2.12
N
4a
4.10
4.15
2.08
1.01
6.00
f1 (ppm)

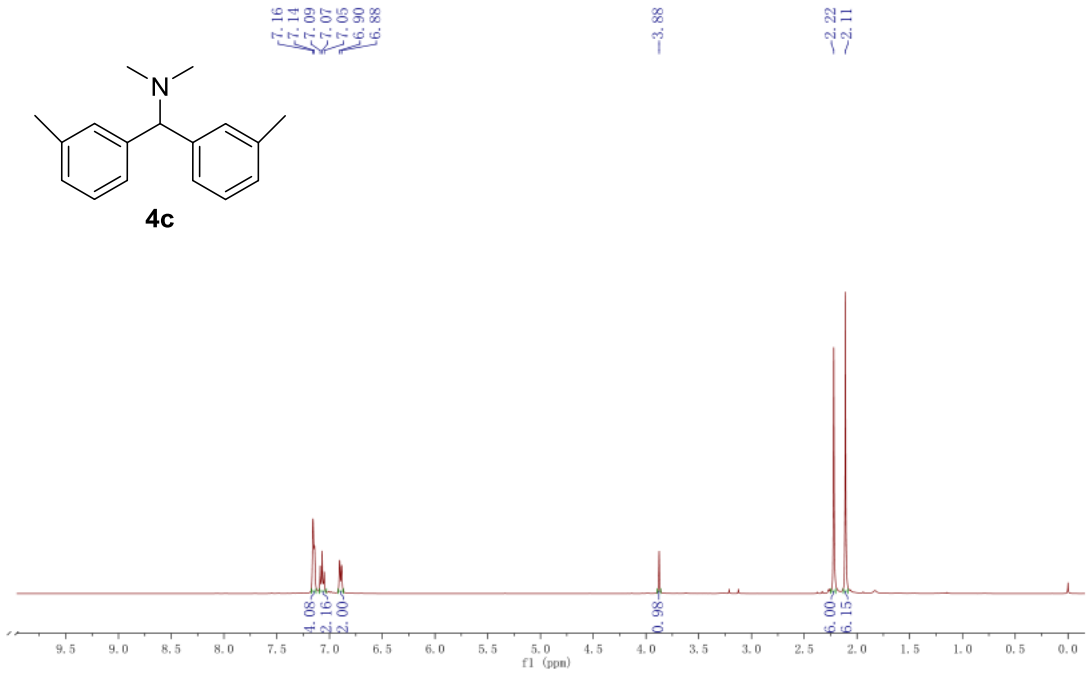

143.47
128.47
127.76
126.90
78.08
44.79
N
4a
f1 (ppm)

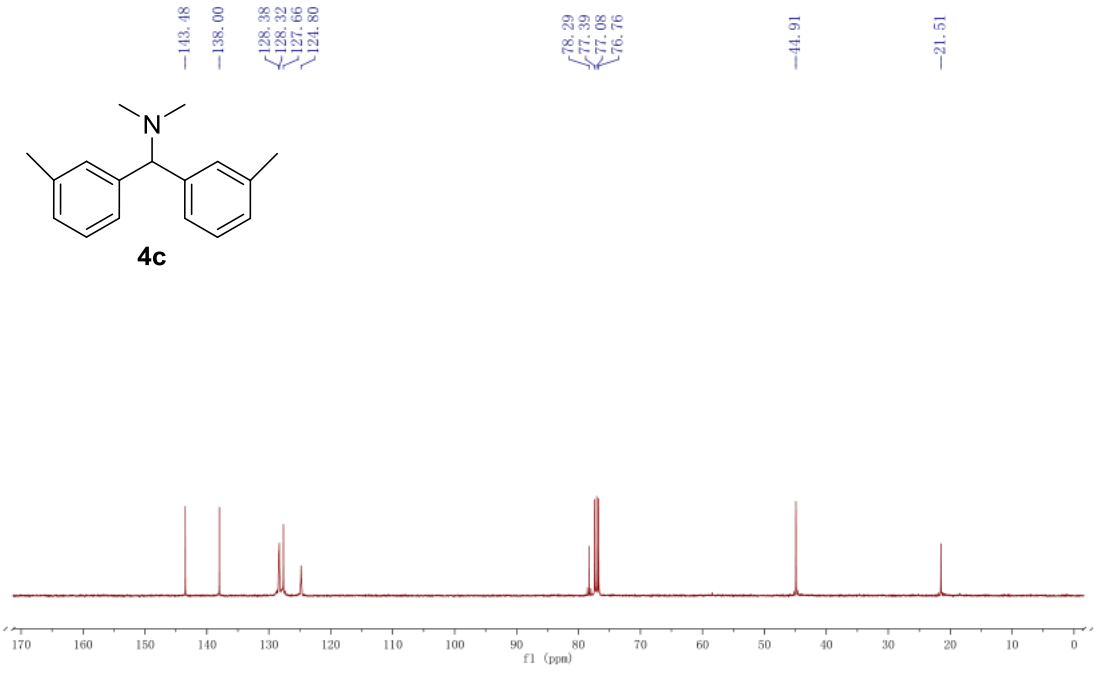

7.37
7.35
7.34
7.21
7.21
7.19
7.18
7.18
7.17
7.17
7.11
7.11
7.10
7.10
7.09
7.09
7.08
7.08
7.07
7.07
2.13
N
D
4a-d1
4.00
4.09
2.01
6.06
f1 (ppm)

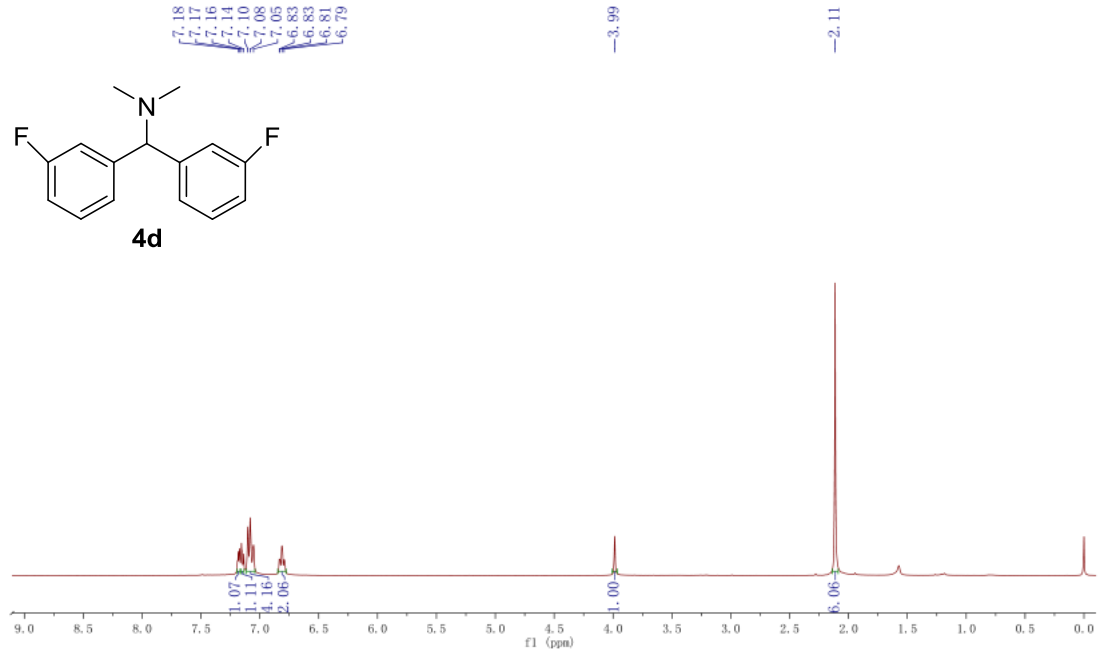

7.38
7.37
7.36
7.34
7.21
7.21
7.20
7.18
7.17
7.11
7.11
7.10
7.09
4.01
3.99
2.14
2.13
2.12
D
N
D
D
D
D
4a-d5
2.02
2.02
1.00
0.94
6.00
f1 (ppm)

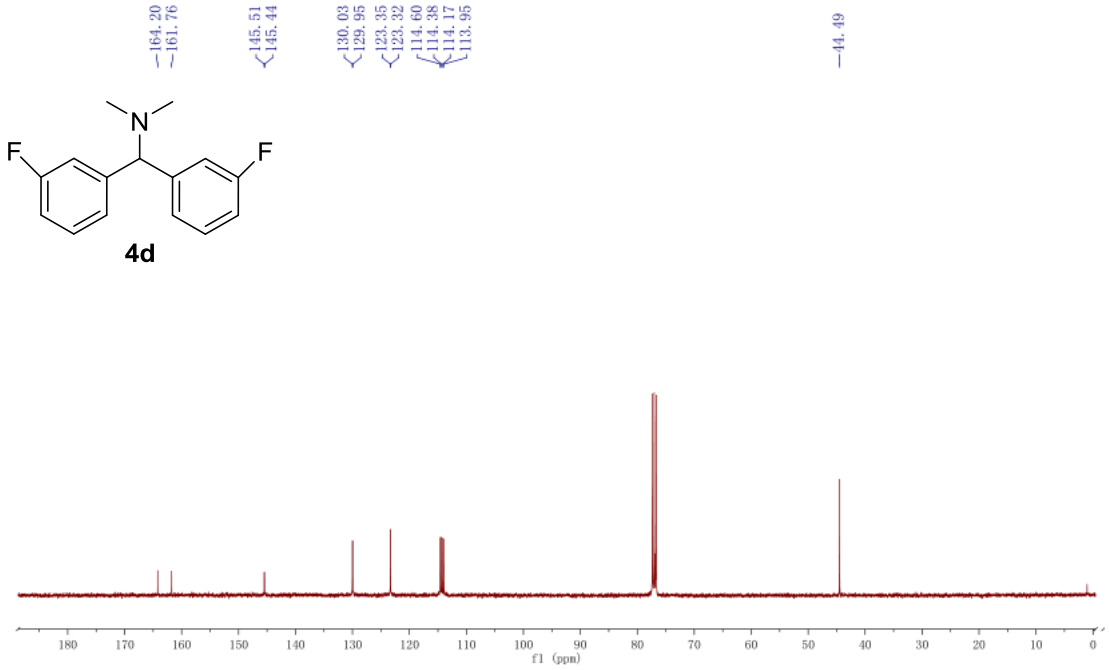

7.52
7.50
7.09
7.08
7.01
7.00
7.00
4.51
2.27
2.15
N
4b
2.05
2.02
4.01
0.94
6.00
6.16
f1 (ppm)


140.59
136.22
130.33
128.71
128.63
126.39
126.02
67.11
44.25
20.14
N
4b
f1 (ppm)


7.16
7.14
7.09
7.07
7.05
6.90
6.88
3.88
2.22
2.11
N
4c
4.08
2.16
2.00
0.98
6.00
6.15
f1 (ppm)

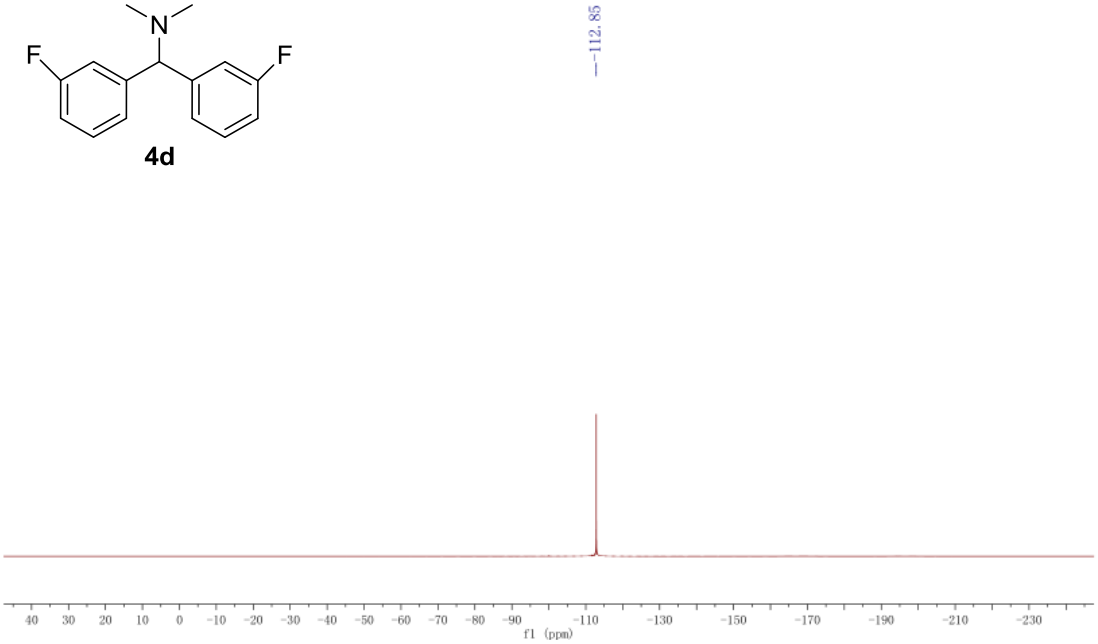

143.48
138.00
128.38
128.32
127.66
124.80
78.29
77.39
77.08
76.76
44.91
21.51
N
4c
f1 (ppm)


7.18
7.17
7.16
7.14
7.10
7.08
7.05
6.83
6.81
6.79
3.99
2.11
N
F
F
4d
1.07
1.11
4.16
2.06
1.00
6.06
f1 (ppm)


164.20
161.76
145.51
145.44
130.03
129.95
123.35
123.32
114.60
114.38
114.17
113.95
44.49
N
F
F
4d
f1 (ppm)

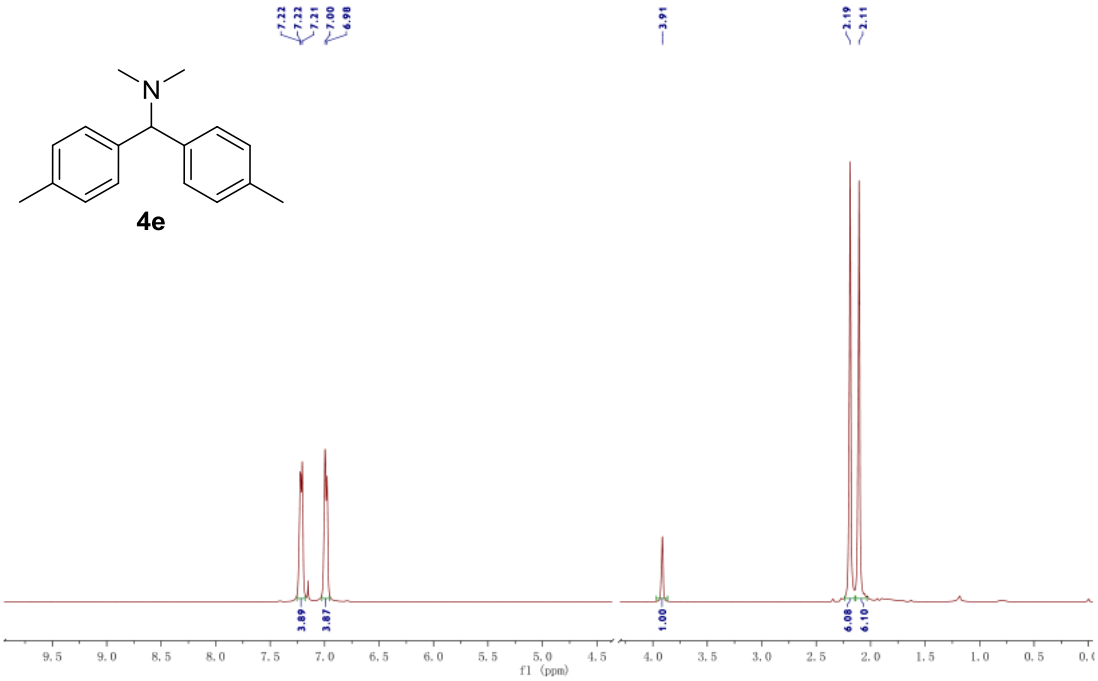
N
F
F

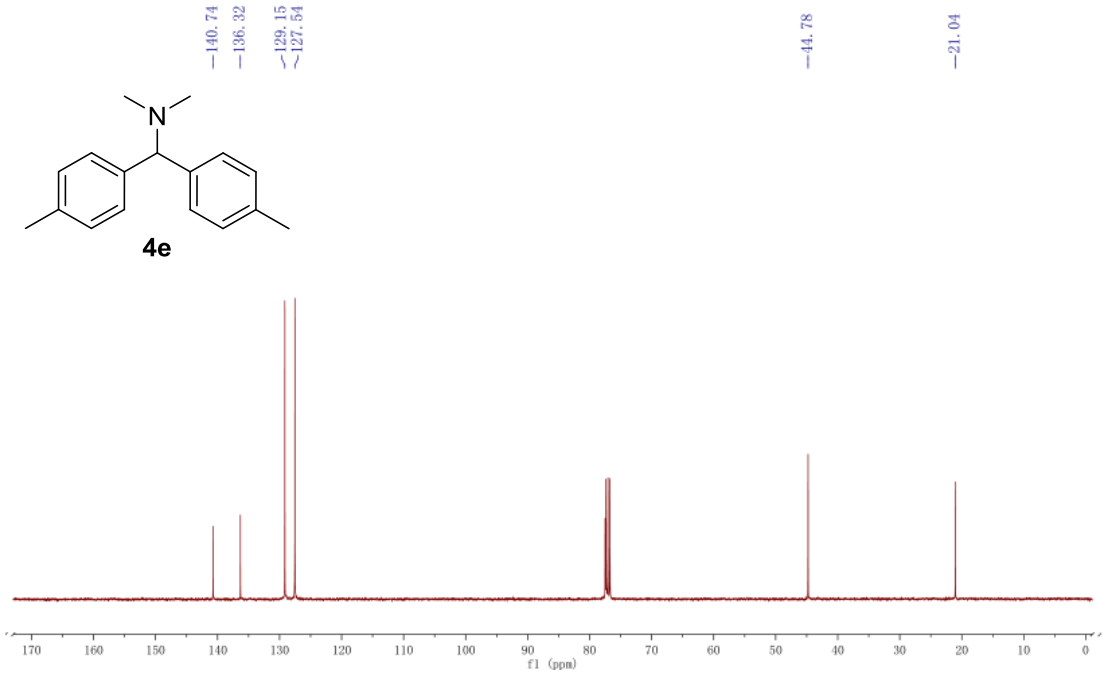
4d

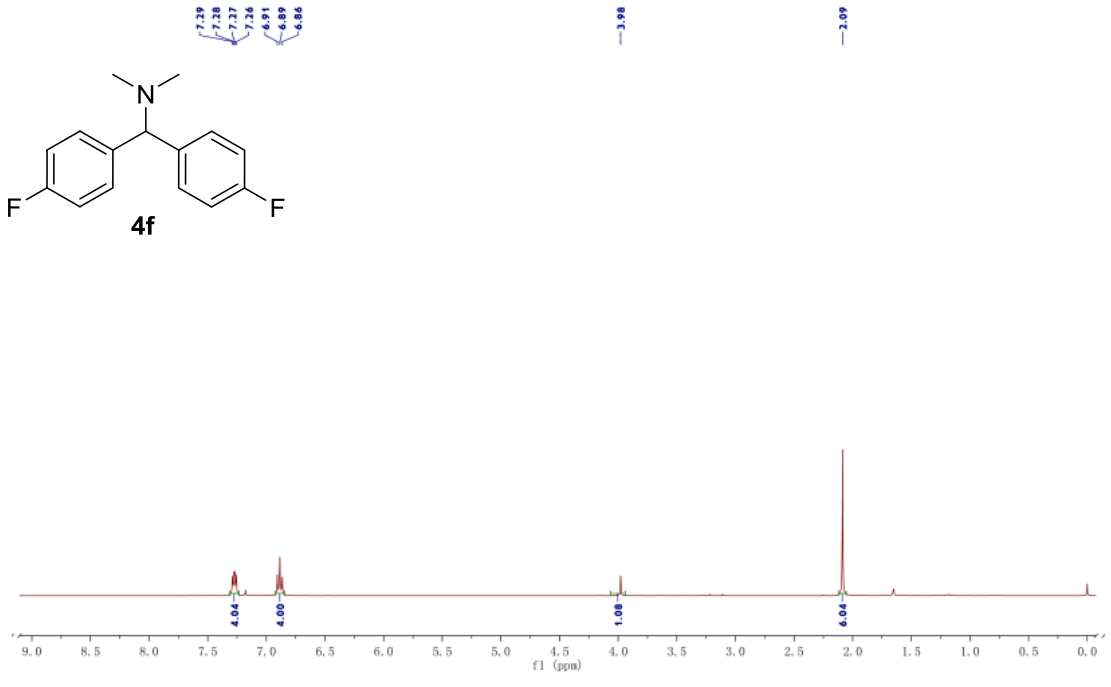

-112.85
40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -110 -130 -150 -170 -190 -210 -230
f1 (ppm)

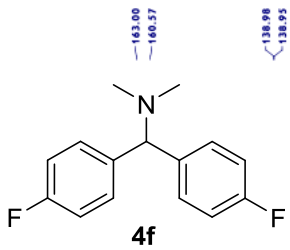
N

4e

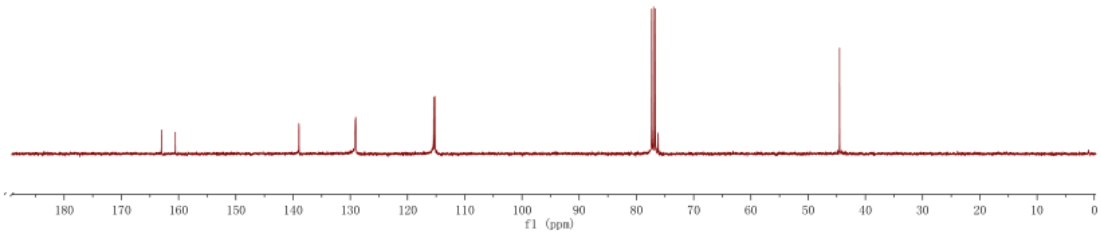

7.22
7.22
7.21
7.00
6.98
3.91
2.19
2.11
3.89
3.87
1.00
6.08
6.10
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

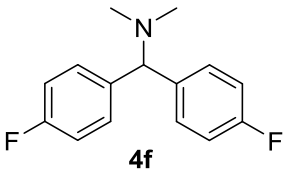

140.74
136.32
129.15
127.54
44.78
21.04
4e
f1 (ppm)


7.29
7.28
7.27
7.26
6.91
6.89
6.86
3.98
2.09
F
F
4f
4.04
4.00
1.00
6.04
f1 (ppm)

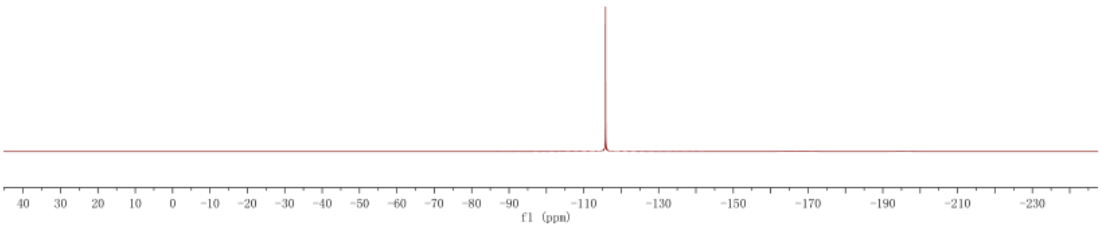

163.00
160.57
138.98
138.95
129.06
115.44
115.23
44.51
N
F
F

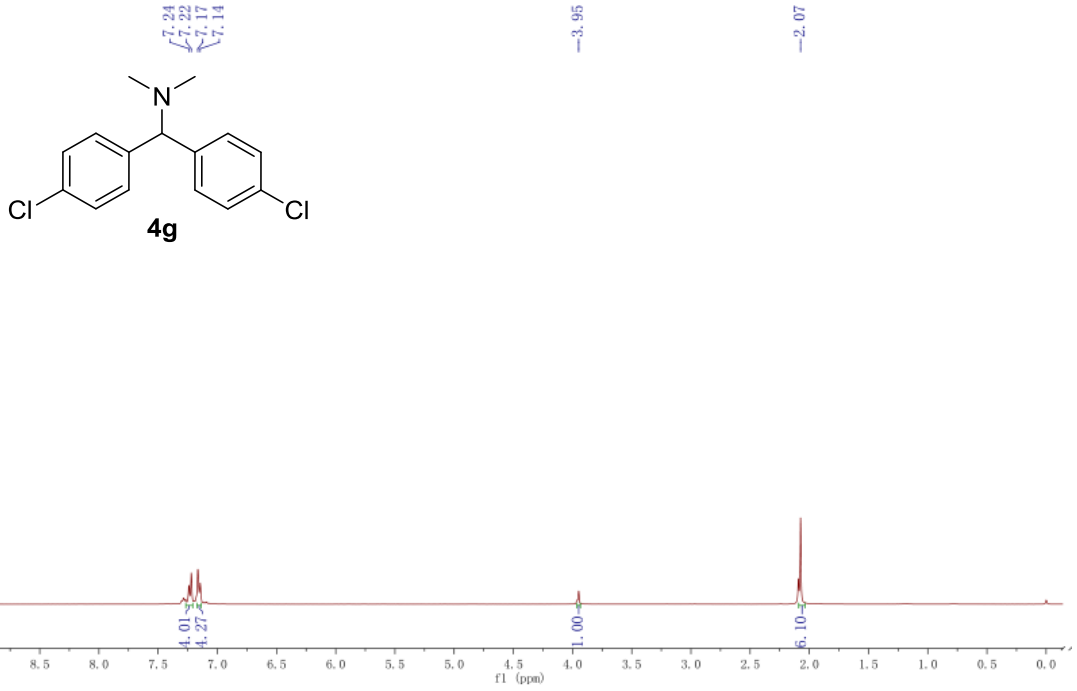
4f

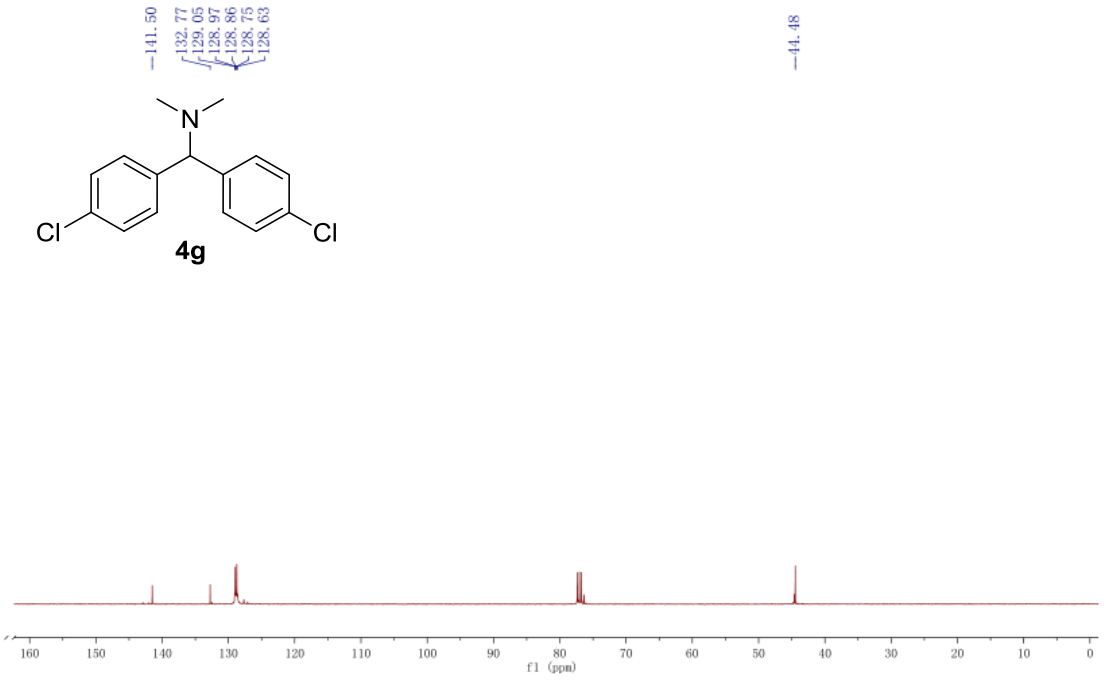

180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

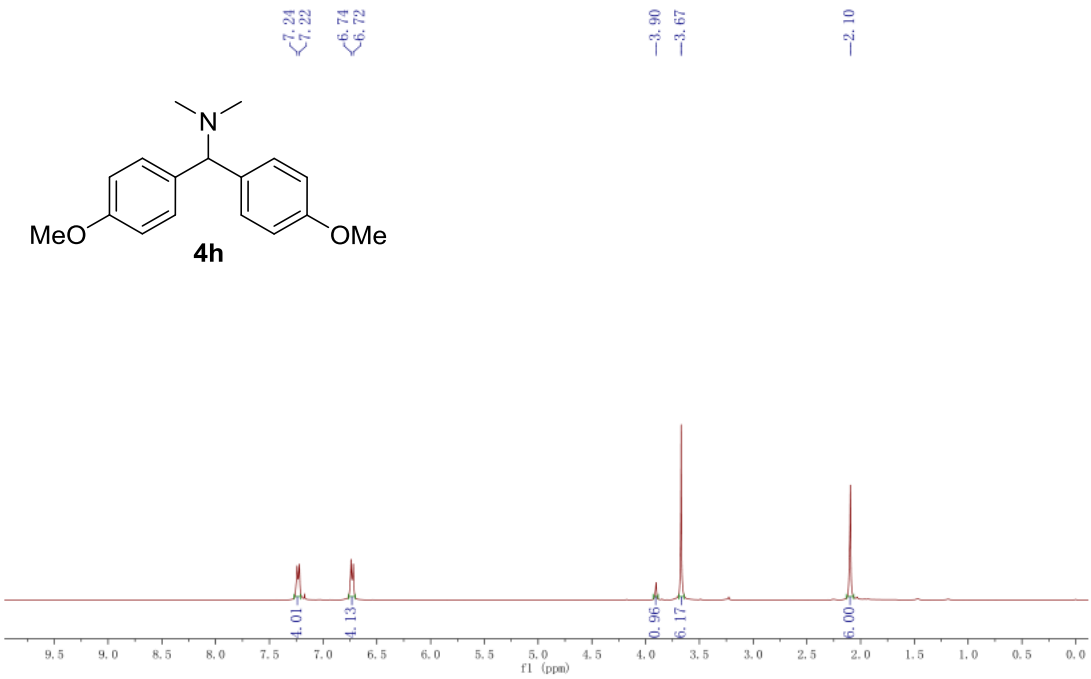

-115.82
N
F
F

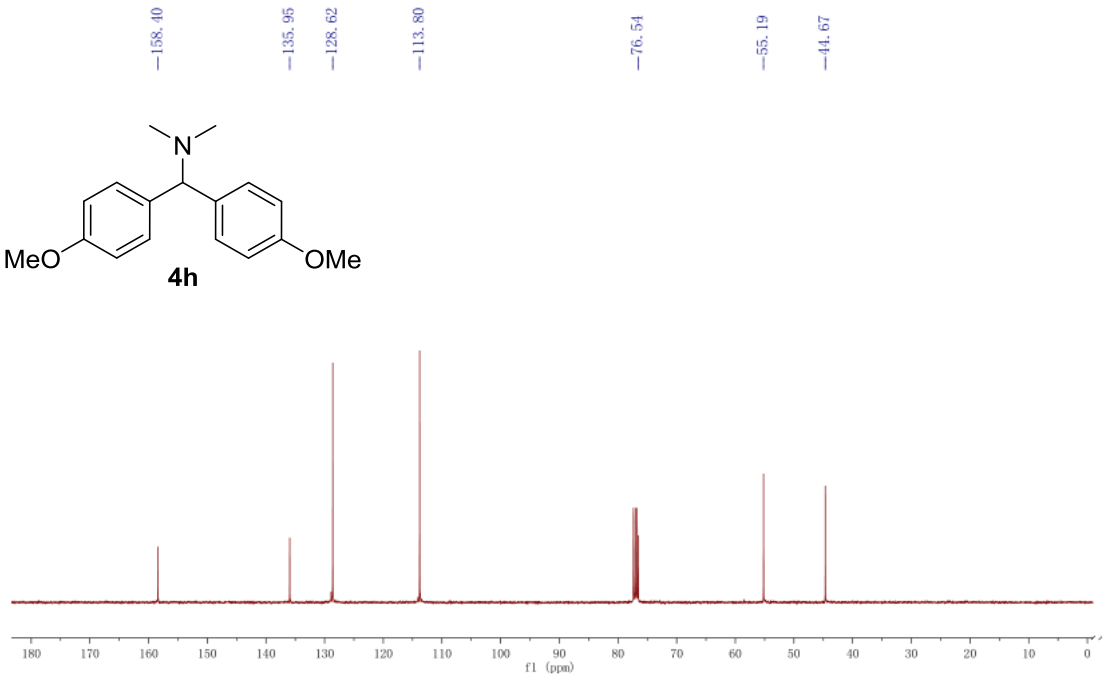
4f

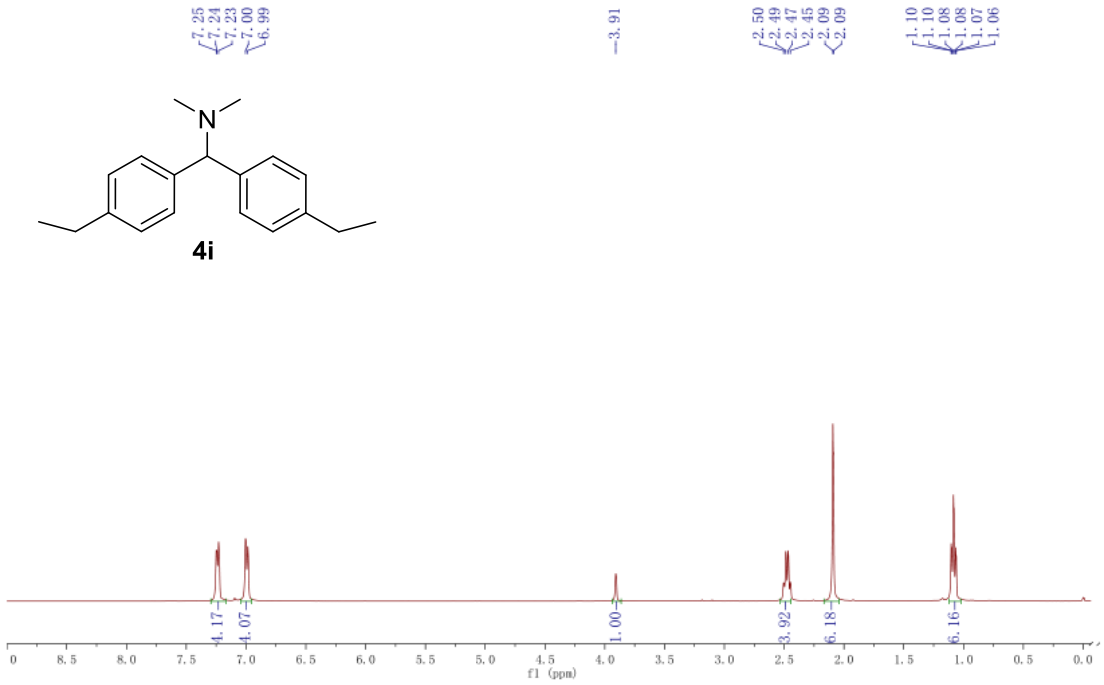

40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-110
-130
-150
-170
-190
-210
-230
f1 (ppm)

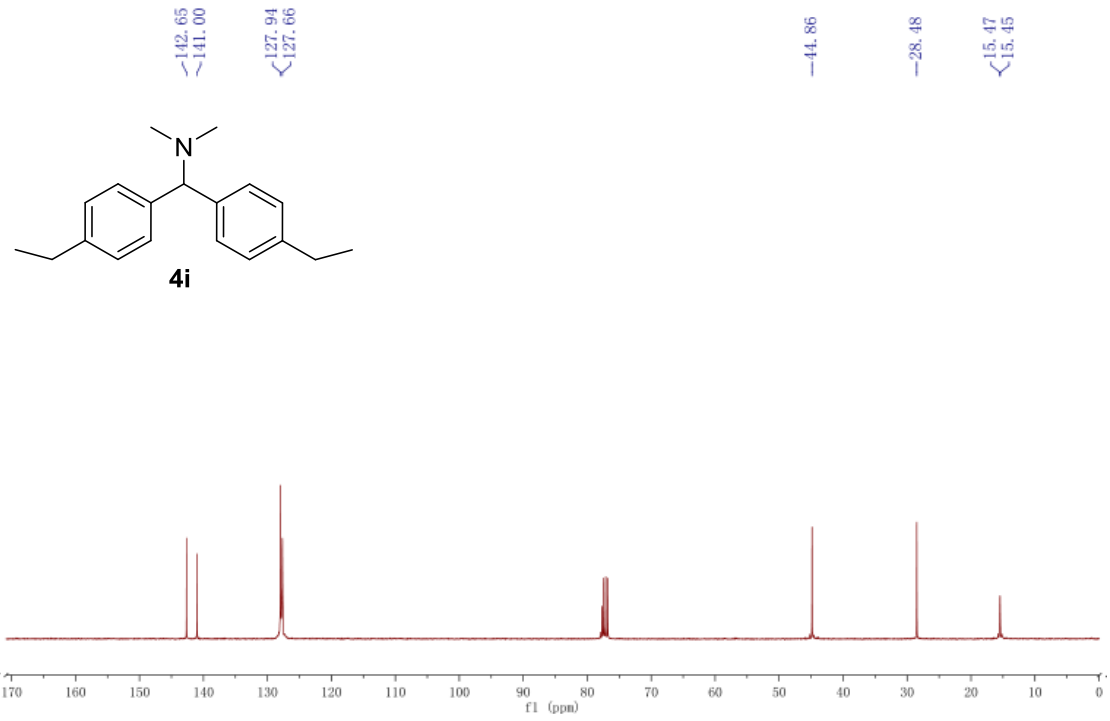

7.24
7.22
7.17
7.14
3.95
2.07
N
Cl
Cl
4g
4.01
4.27
1.00
6.10
f1 (ppm)

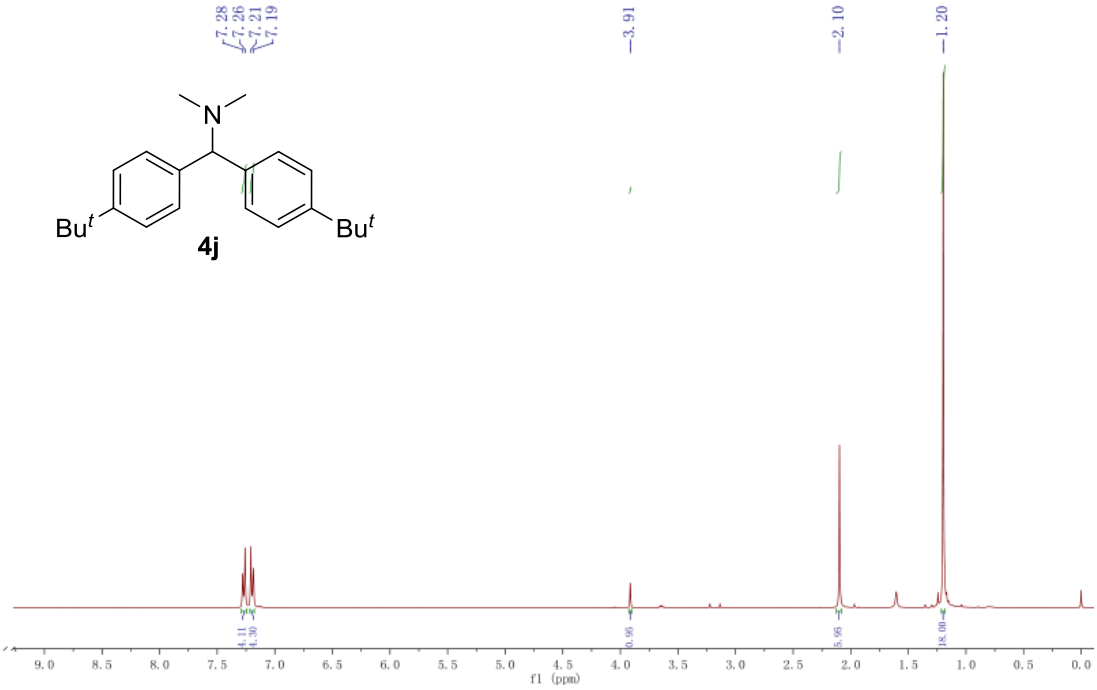

141.50
132.77
129.05
128.97
128.86
128.75
128.63
44.48
N
Cl
Cl
4g
f1 (ppm)

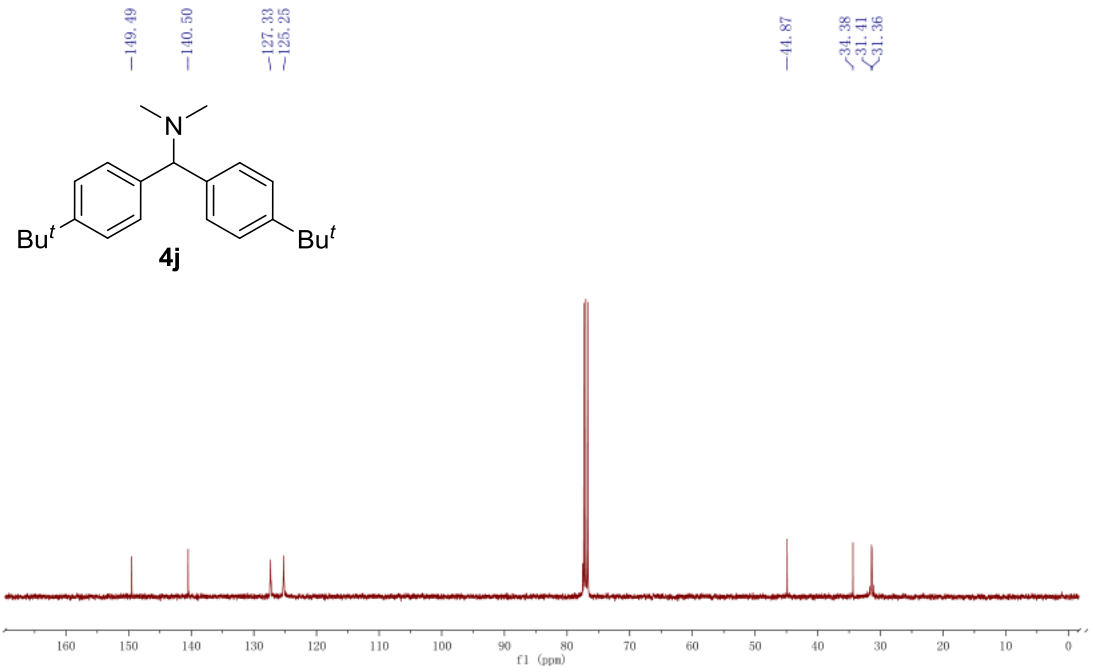

7.24
7.22
6.74
6.72
3.90
3.67
2.10
N
MeO
OMe
4h
4.01
4.13
0.96
6.17
6.00
f1 (ppm)

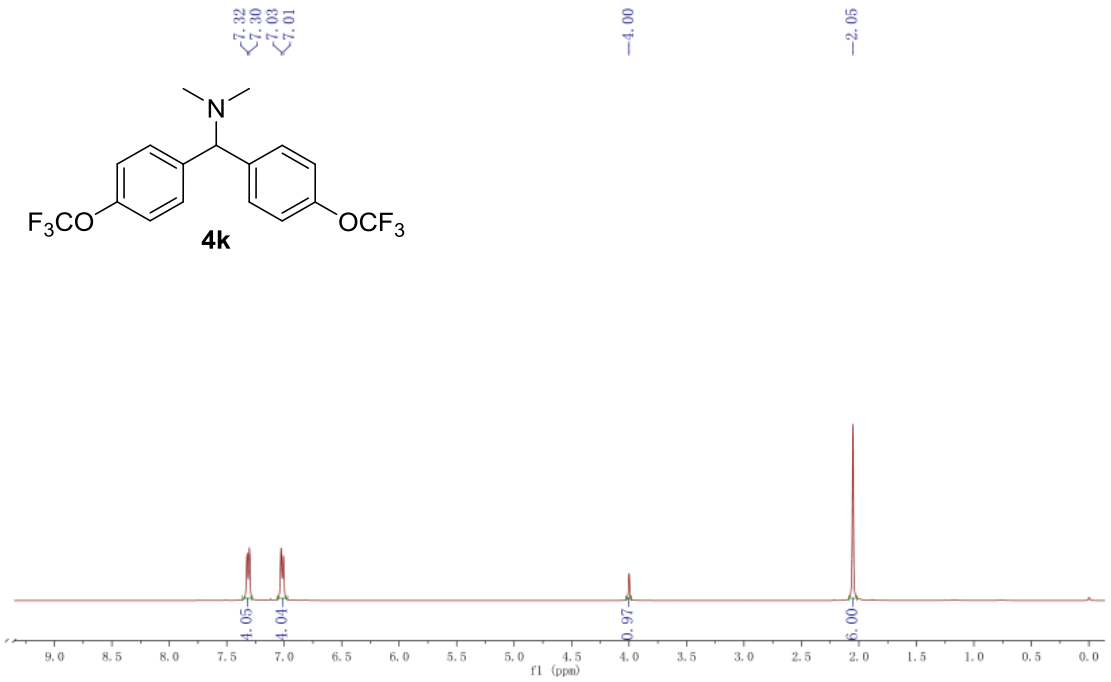

158.40
135.95
128.62
113.80
76.54
55.19
44.67
N
MeO
OMe
4h
f1 (ppm)

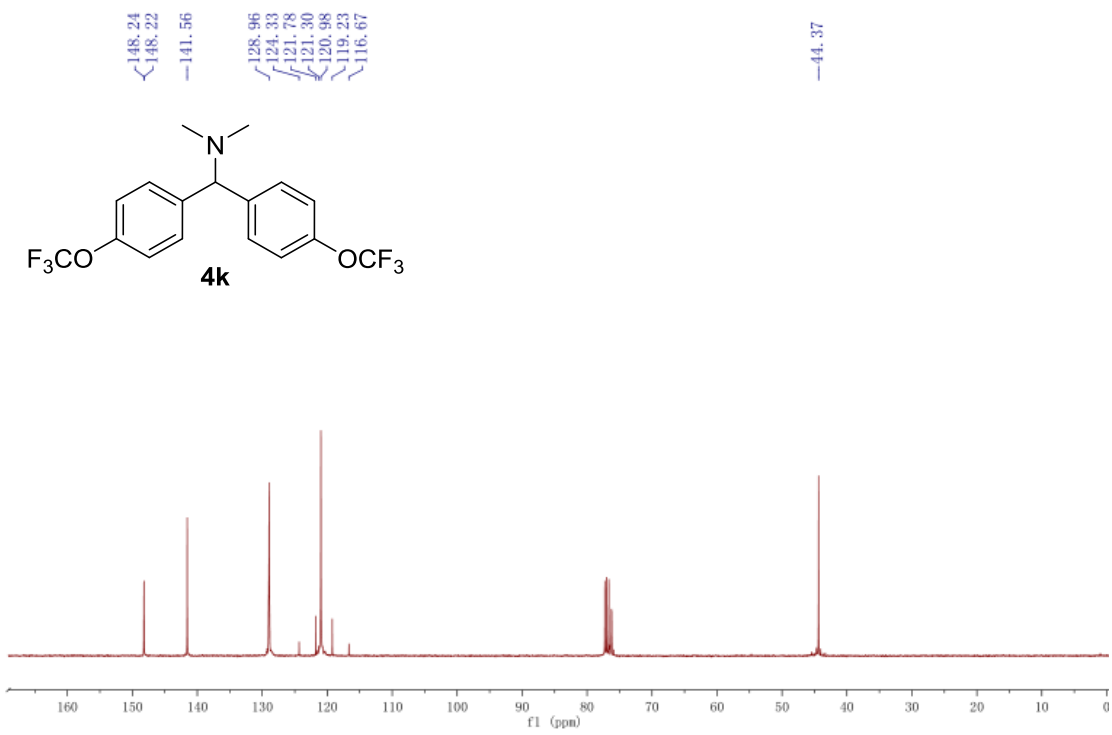

7.25
7.24
7.23
7.00
6.99
3.91
2.50
2.49
2.47
2.45
2.09
2.09
1.10
1.10
1.08
1.08
1.07
1.06
N
4i
4.17
4.07
1.00
3.92
6.18
6.16
f1 (ppm)


142.65
141.00
127.94
127.66
44.86
28.48
15.47
15.45
N
4i
f1 (ppm)


7.28
7.26
7.21
7.19
3.91
2.10
1.20
N
Bu^t
Bu^t
4j
4.11
4.30
6.98
5.66
18.00
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

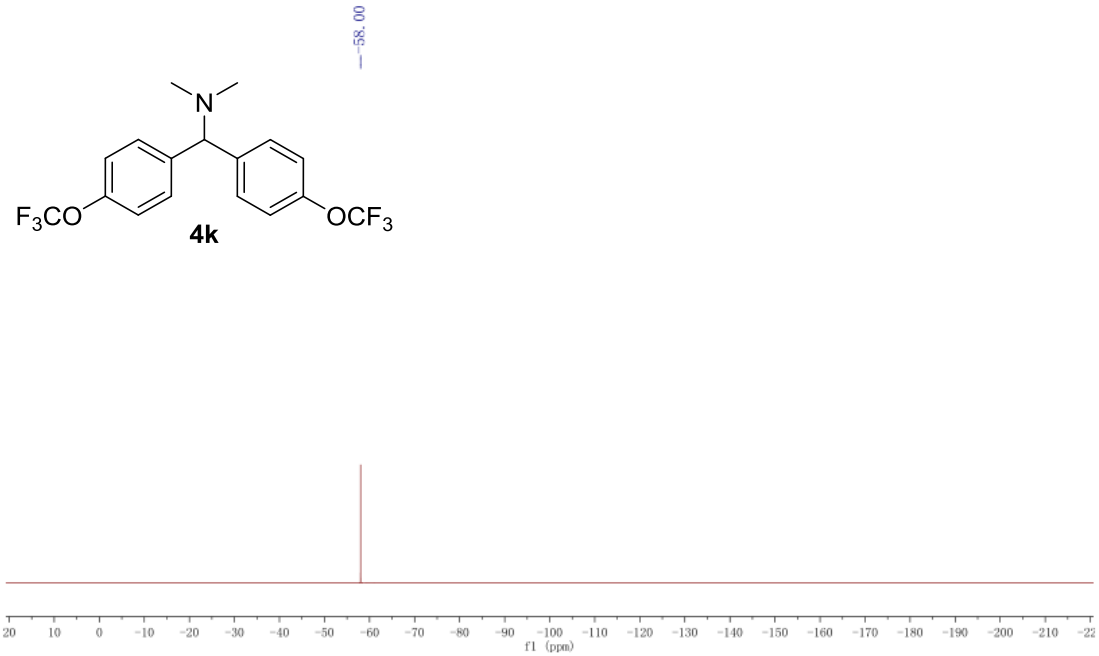

149.49
140.50
127.33
125.25
44.87
34.38
31.41
31.36
N
Bu^t
Bu^t
4j
160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.32
7.30
7.03
7.01
4.00
2.05
N
F3CO
OCF3
4k
4.05
4.04
0.97
6.00
f1 (ppm)


148.24
148.22
141.56
128.96
124.33
121.78
121.30
120.98
119.23
116.67
44.37
N
F3CO
OCF3
4k
f1 (ppm)

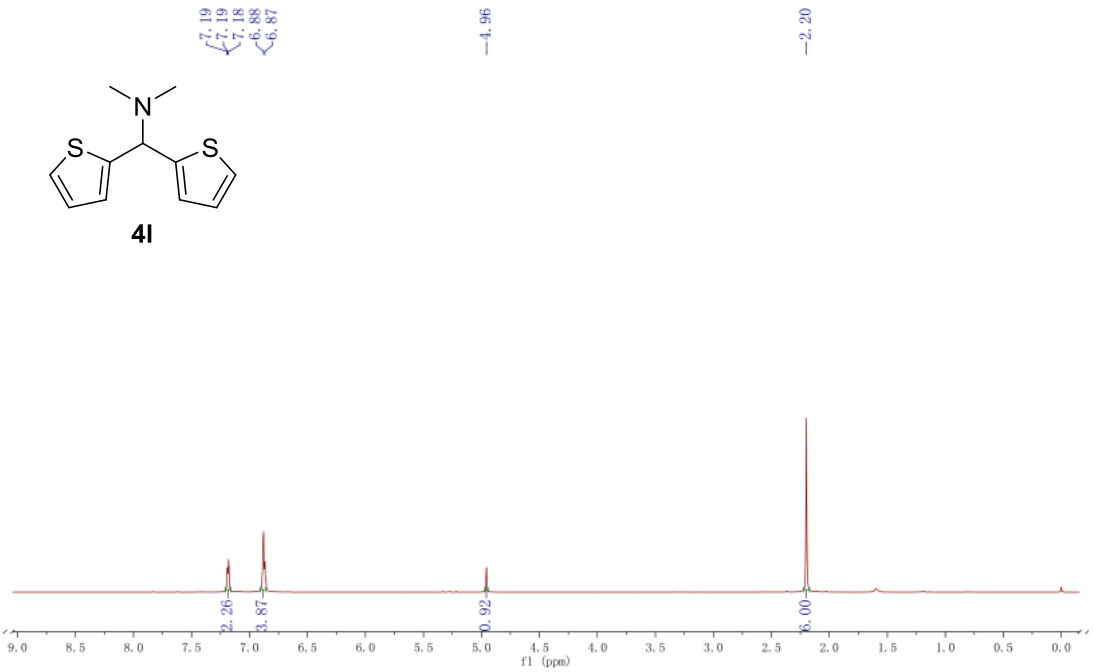
N
F3CO
OCF3

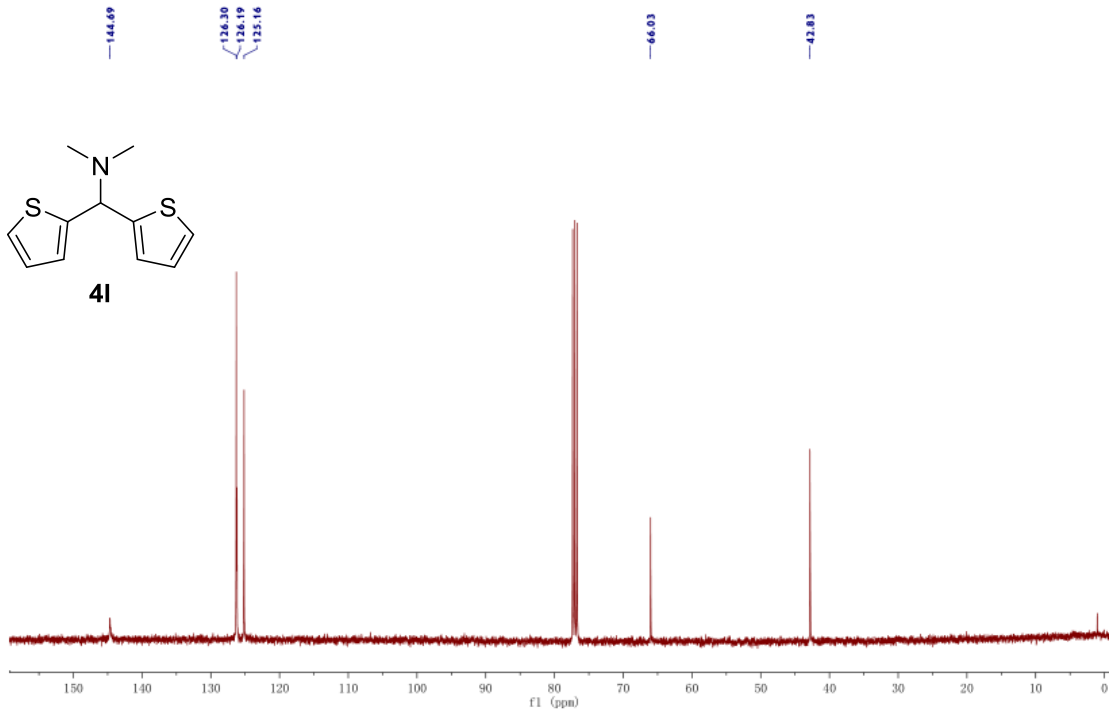
4k

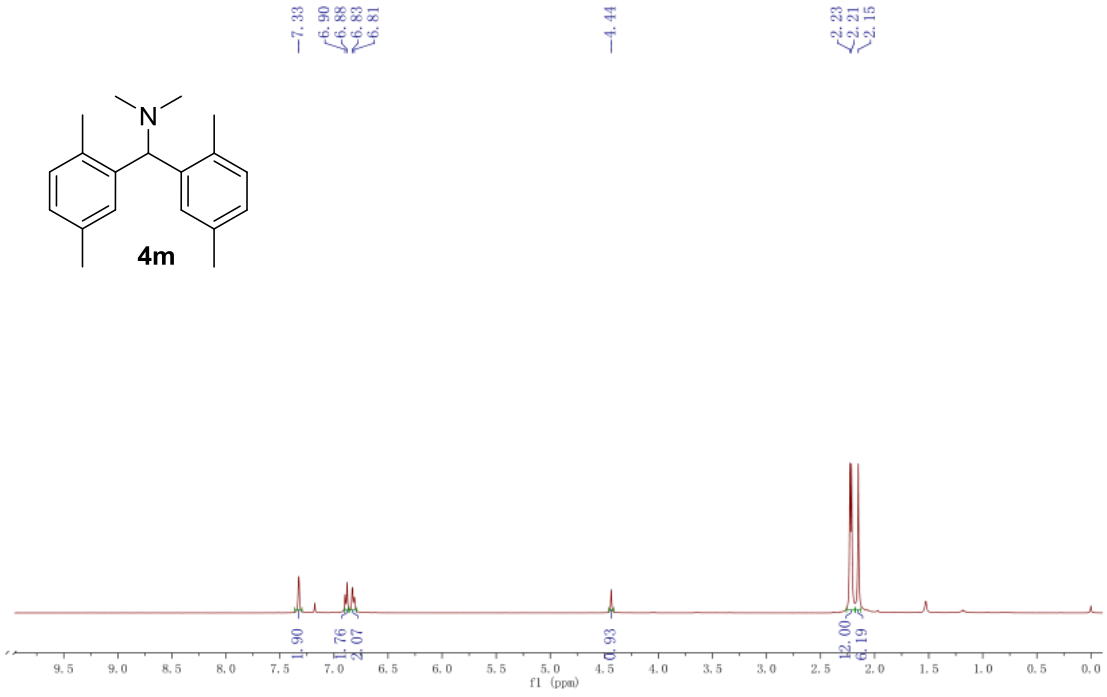

-58.00
20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -22
f1 (ppm)

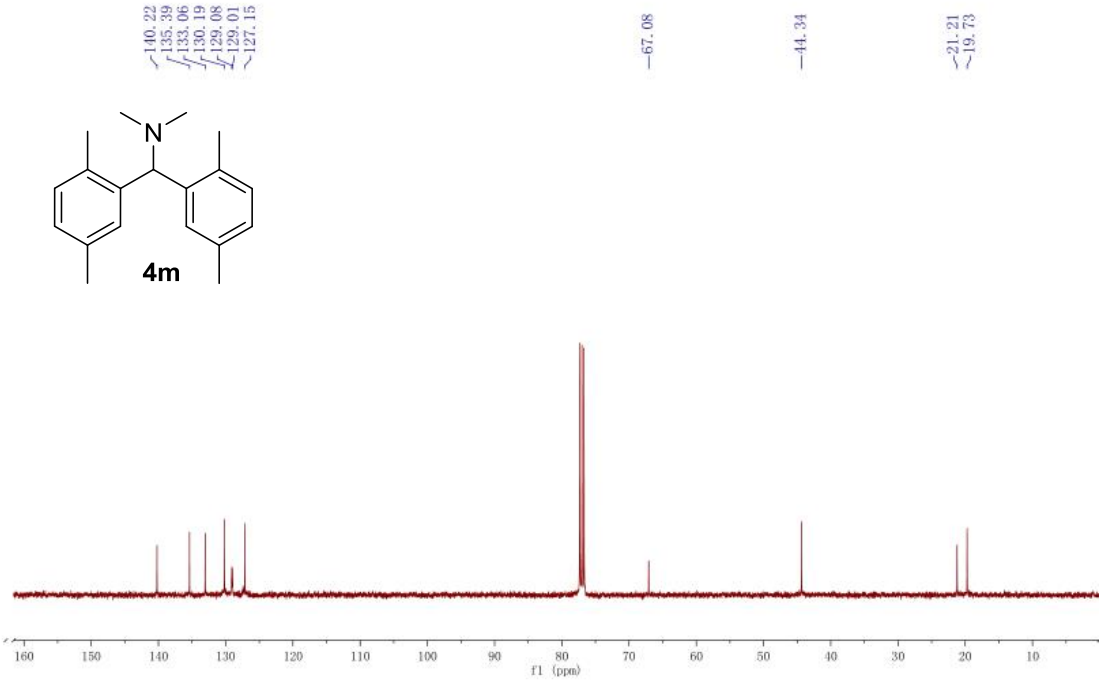
N
S
S

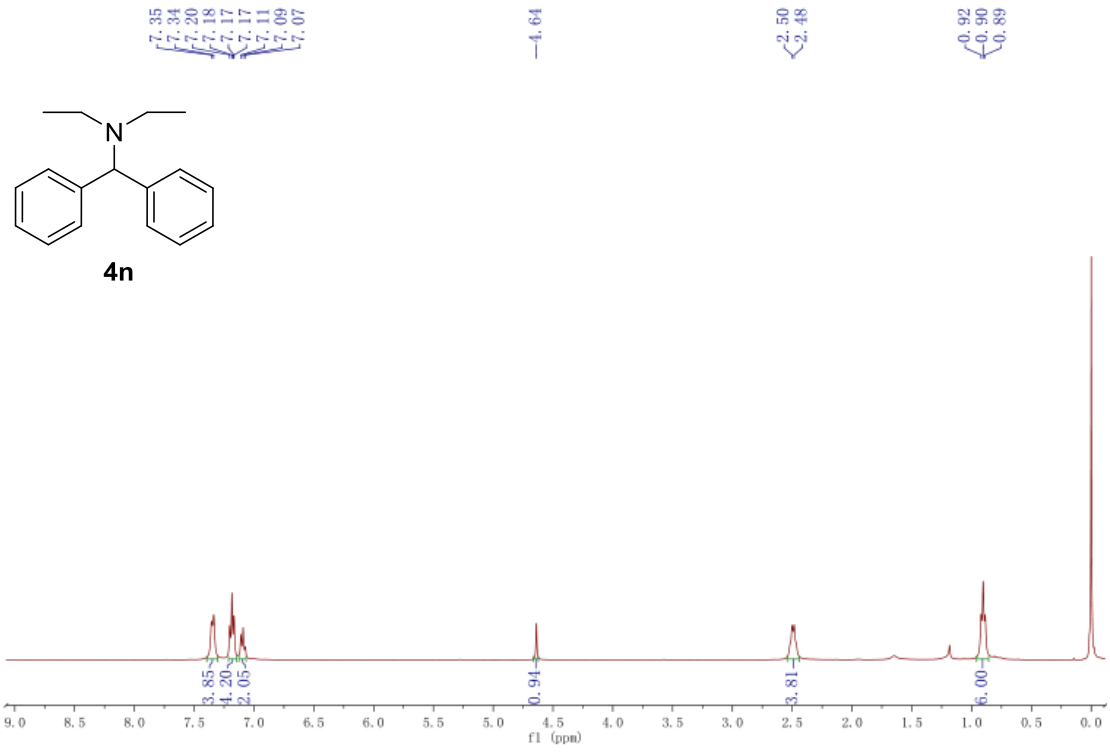
4l

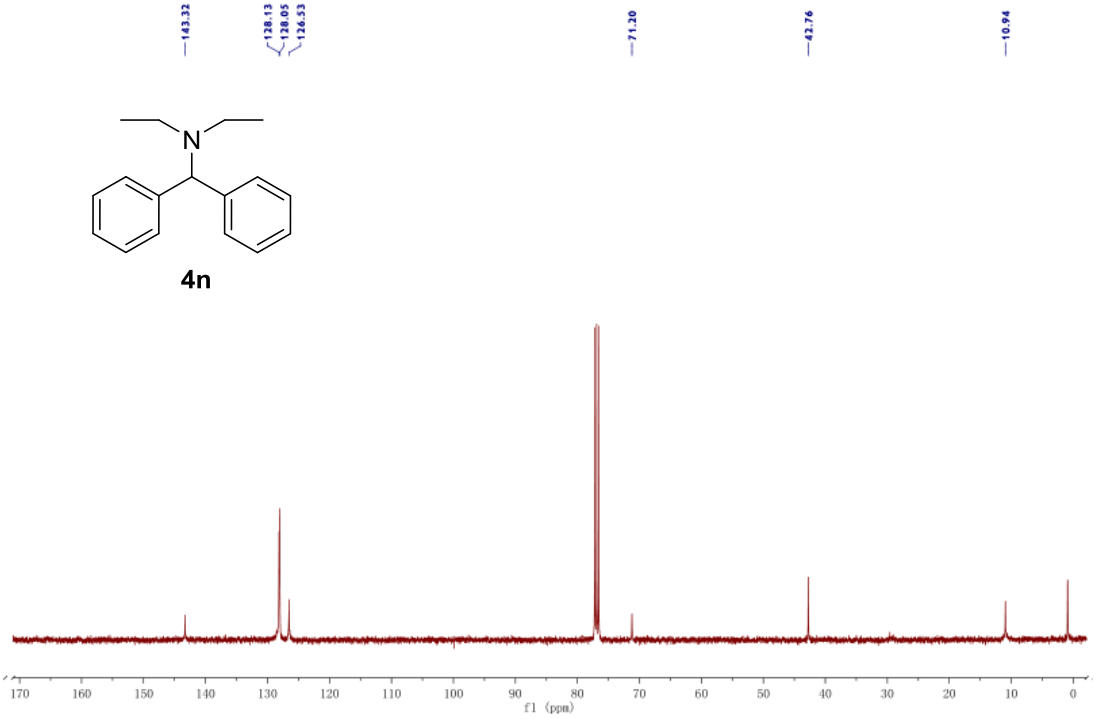

7.19
7.19
7.18
6.88
6.87
-4.96
-2.20
2.26
3.87
0.92
6.00
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

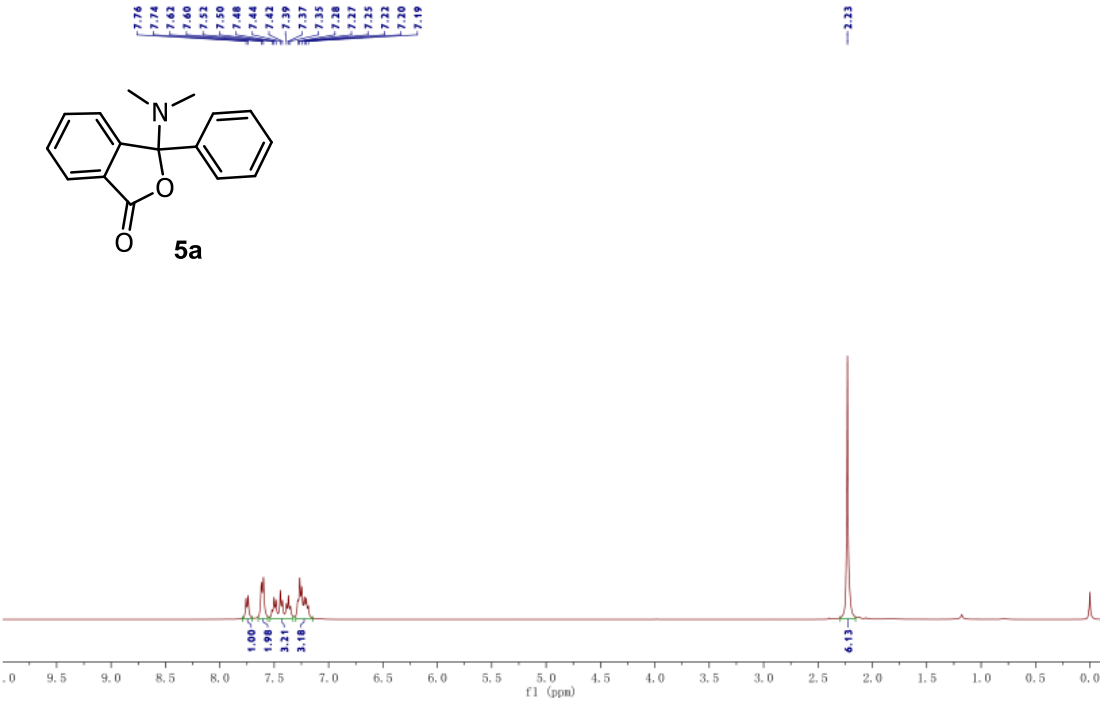

144.69
126.30
126.19
125.16
66.03
42.83
N
S
S
4l
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

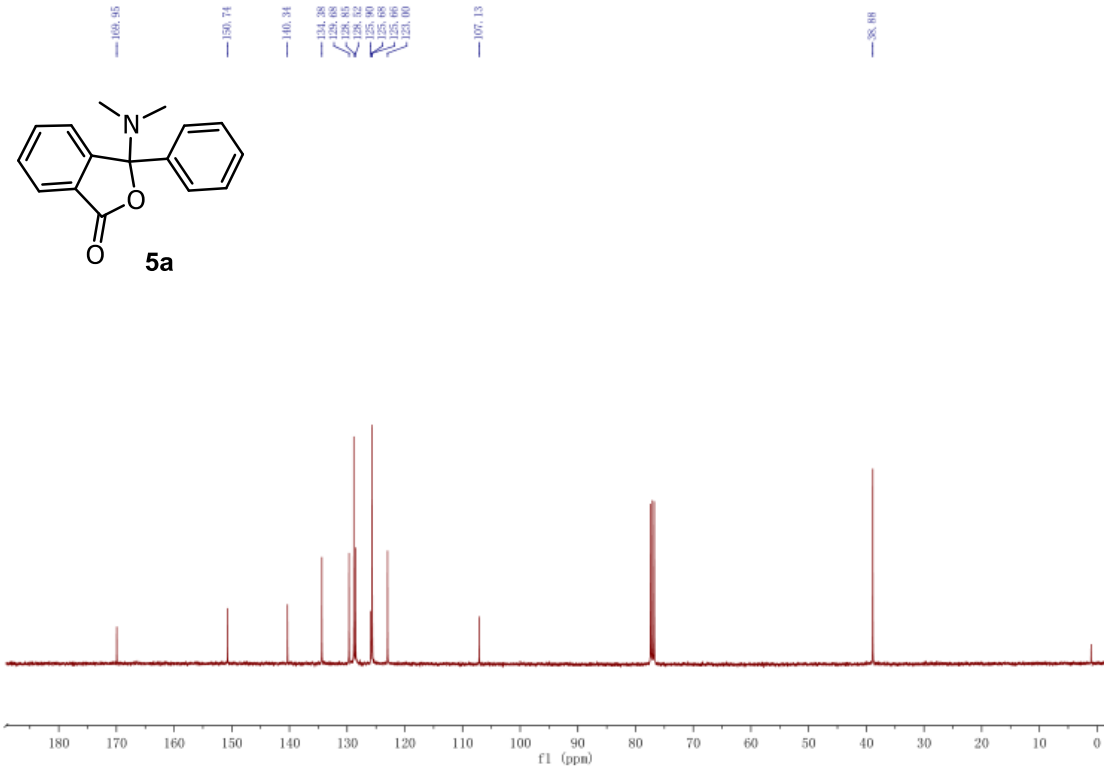

7.33
6.90
6.88
6.83
6.81
4.44
2.23
2.21
2.15
N
4m
1.90
1.76
2.07
0.93
12.00
6.19
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

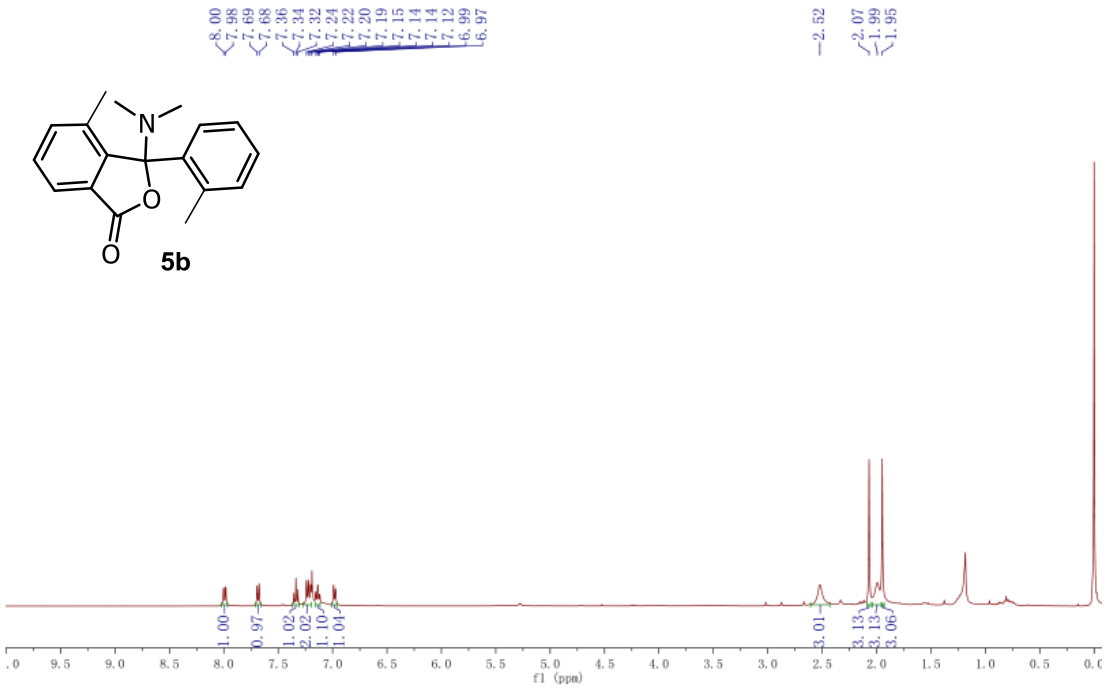

140.22
135.39
133.06
130.19
129.08
129.01
127.15
67.08
44.34
21.21
19.73
4m
f1 (ppm)

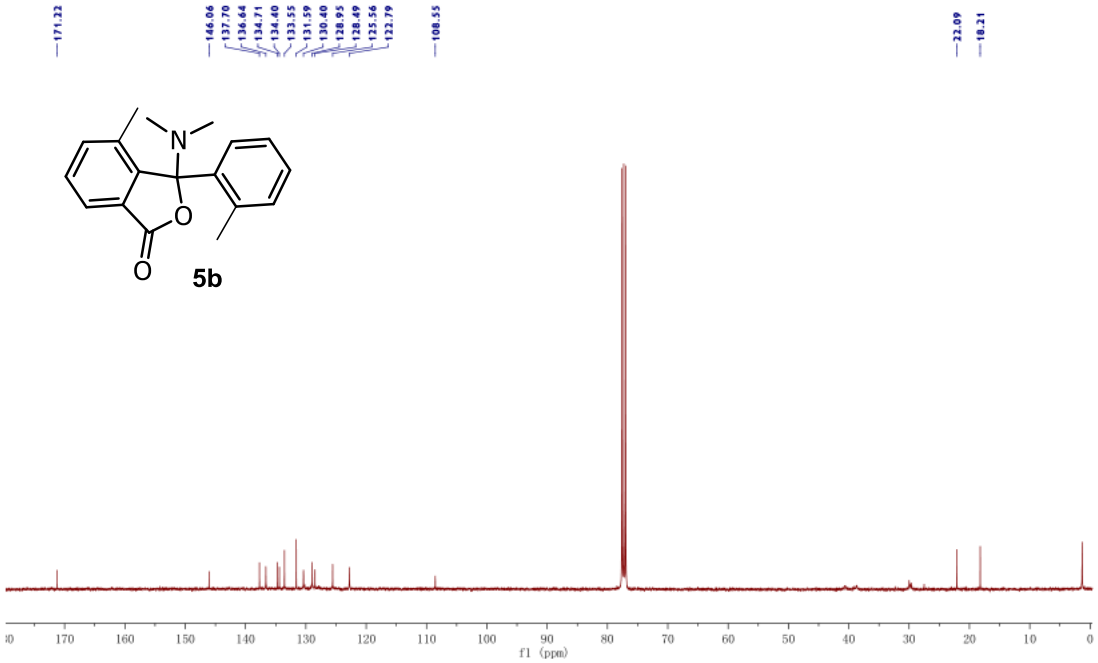

7.35
7.34
7.20
7.18
7.17
7.17
7.11
7.09
7.07
4.64
2.50
2.48
0.92
0.90
0.89
4n
3.85
4.20
2.05
0.94
3.81
6.00
f1 (ppm)

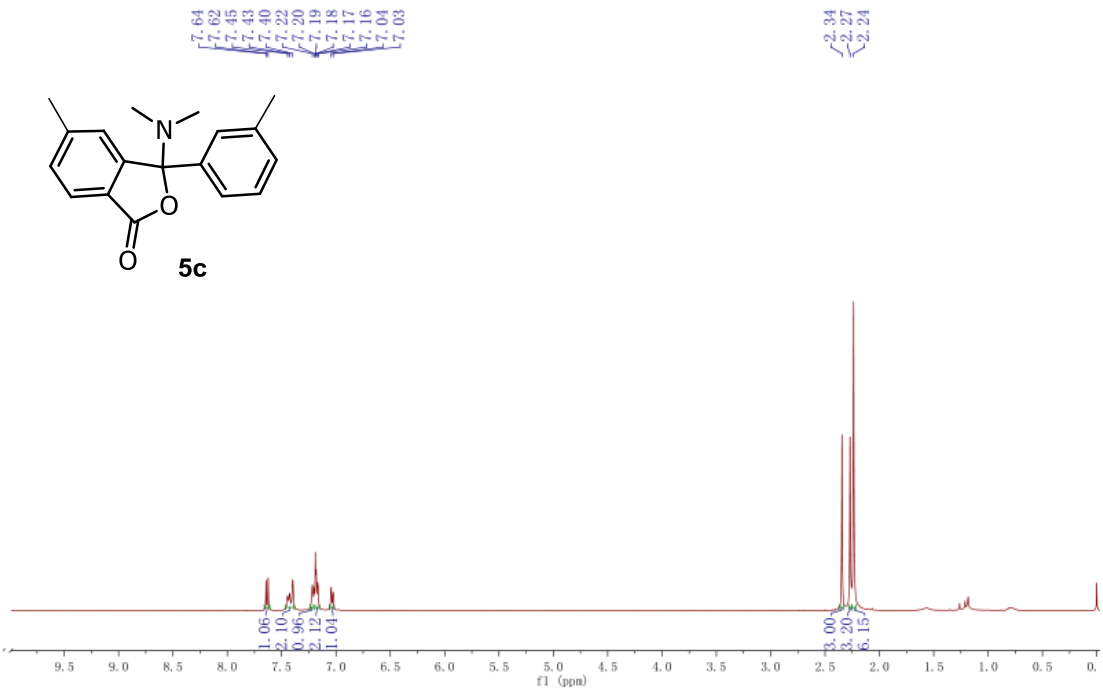

143.32
128.13
128.05
126.53
71.20
42.76
10.94
N
4n
f1 (ppm)

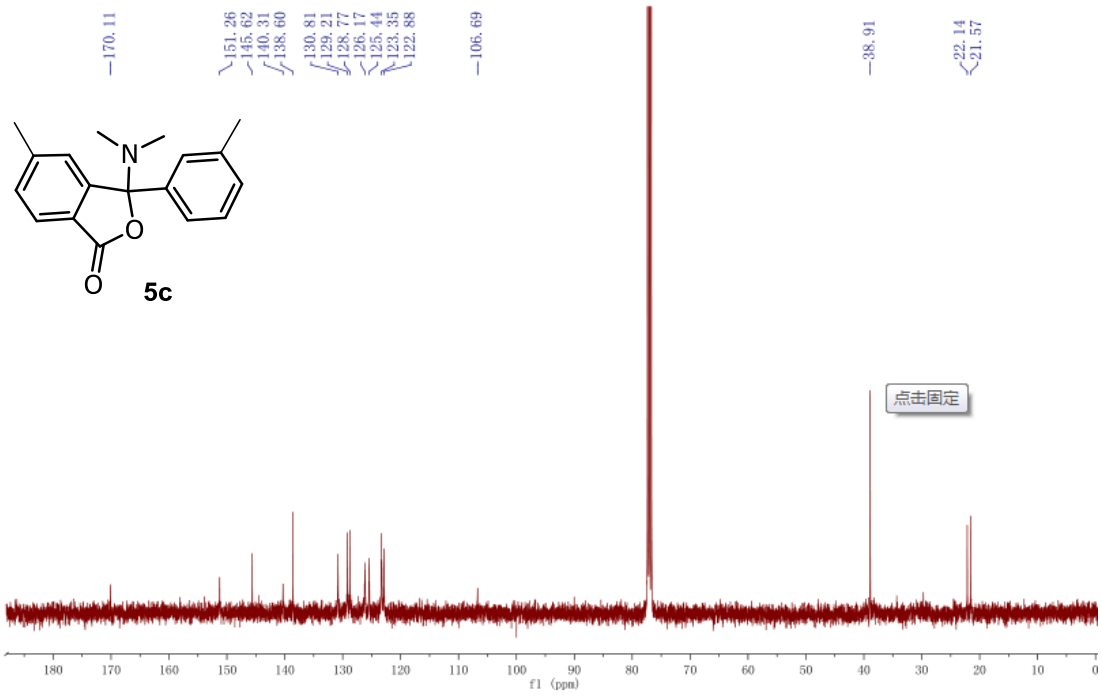

7.76
7.74
7.62
7.60
7.52
7.50
7.48
7.44
7.42
7.39
7.37
7.35
7.28
7.27
7.25
7.22
7.20
7.19
2.23
N
O
O
5a
1.00
1.98
3.21
3.18
6.13
f1 (ppm)

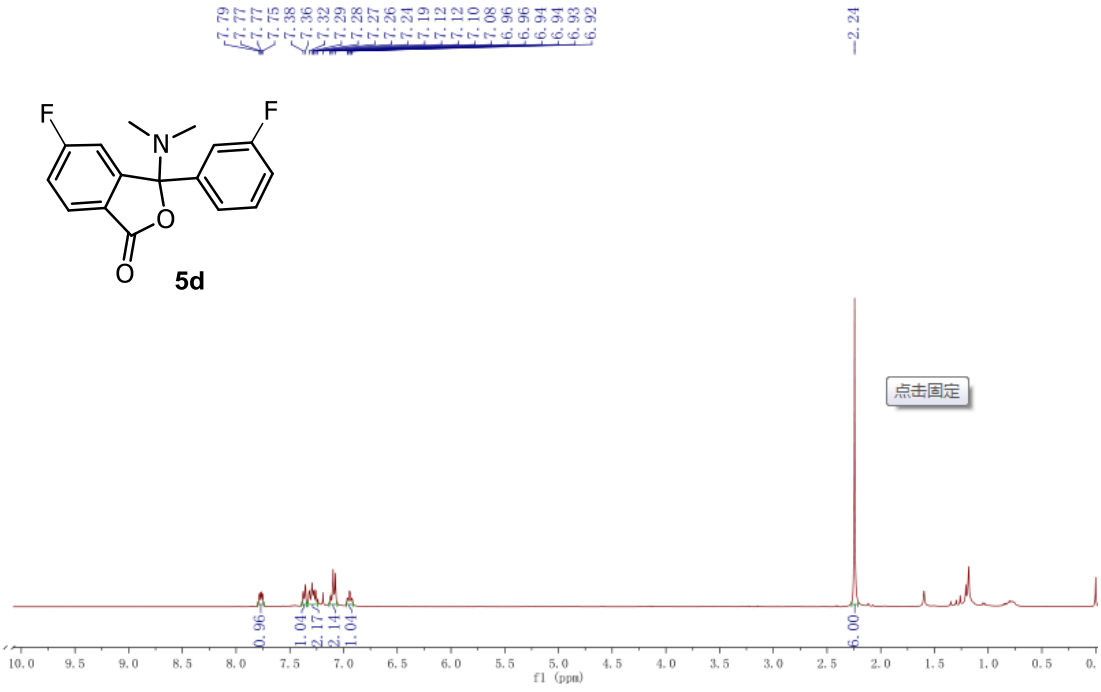

169.95
150.74
140.34
134.38
129.68
128.83
128.52
125.90
125.68
125.66
123.00
107.13
38.88
N
O
O
5a
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

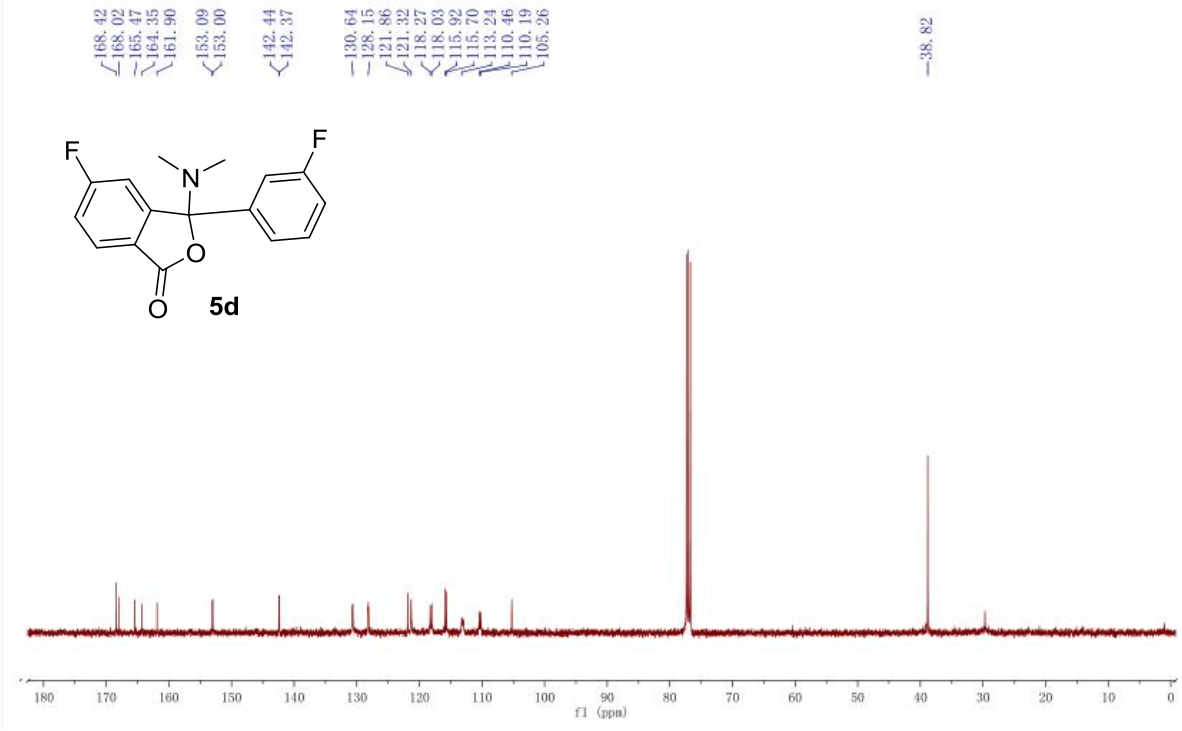

8.00
7.98
7.69
7.68
7.36
7.34
7.32
7.24
7.22
7.20
7.19
7.15
7.14
7.14
7.12
6.99
6.97
2.52
2.07
1.99
1.95
N
O
O
5b
1.00
0.97
1.02
2.02
1.10
1.04
3.01
3.13
3.13
3.06
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

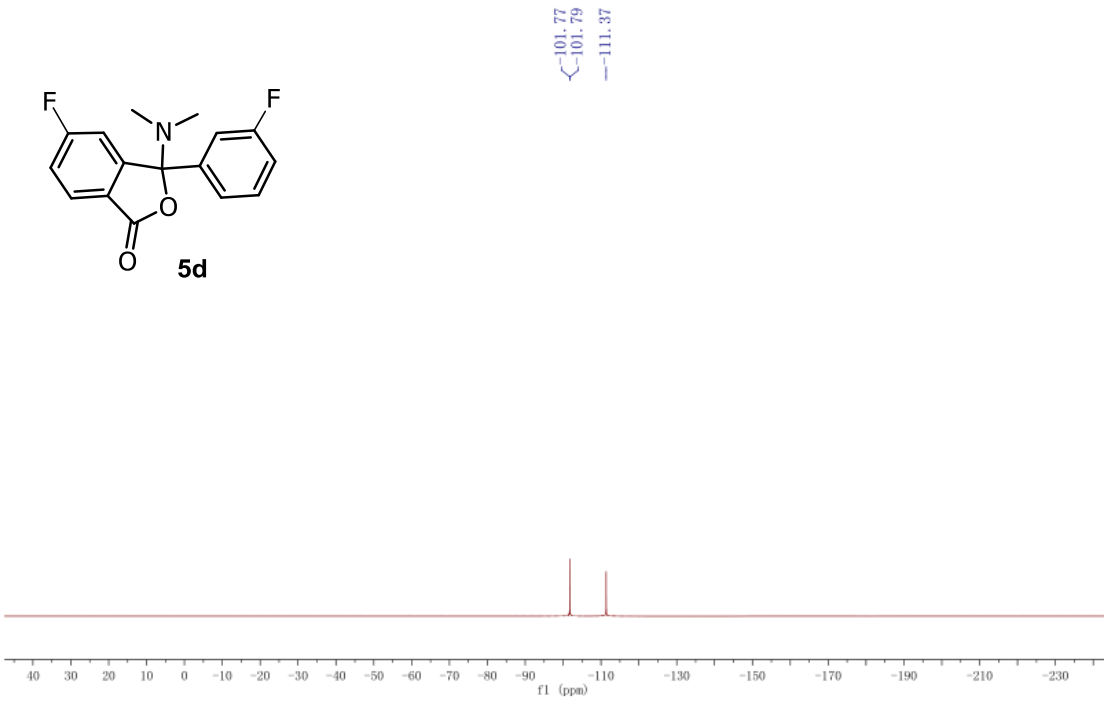

171.22
146.06
137.70
136.64
134.71
134.40
133.55
131.59
130.40
128.95
128.49
125.56
122.79
108.55
22.09
18.21
5b
f1 (ppm)

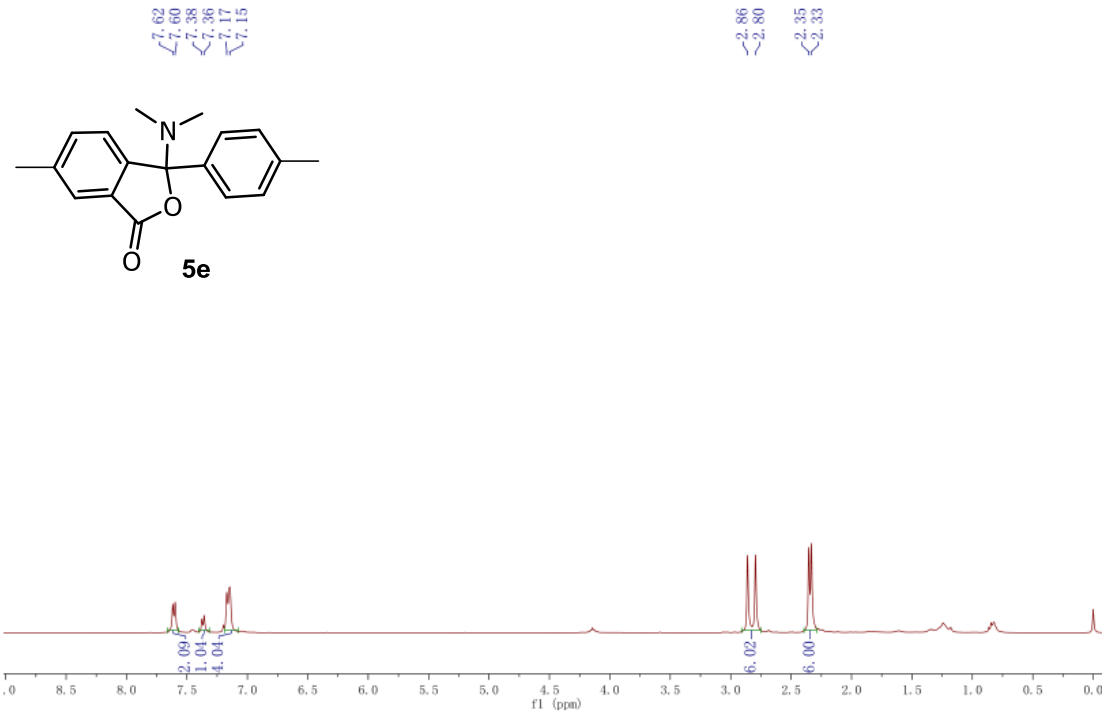

7.64
7.62
7.45
7.43
7.40
7.22
7.20
7.19
7.18
7.17
7.16
7.04
7.03
2.34
2.27
2.24
5c
1.06
2.10
0.96
2.12
1.04
3.00
3.20
6.15
f1 (ppm)

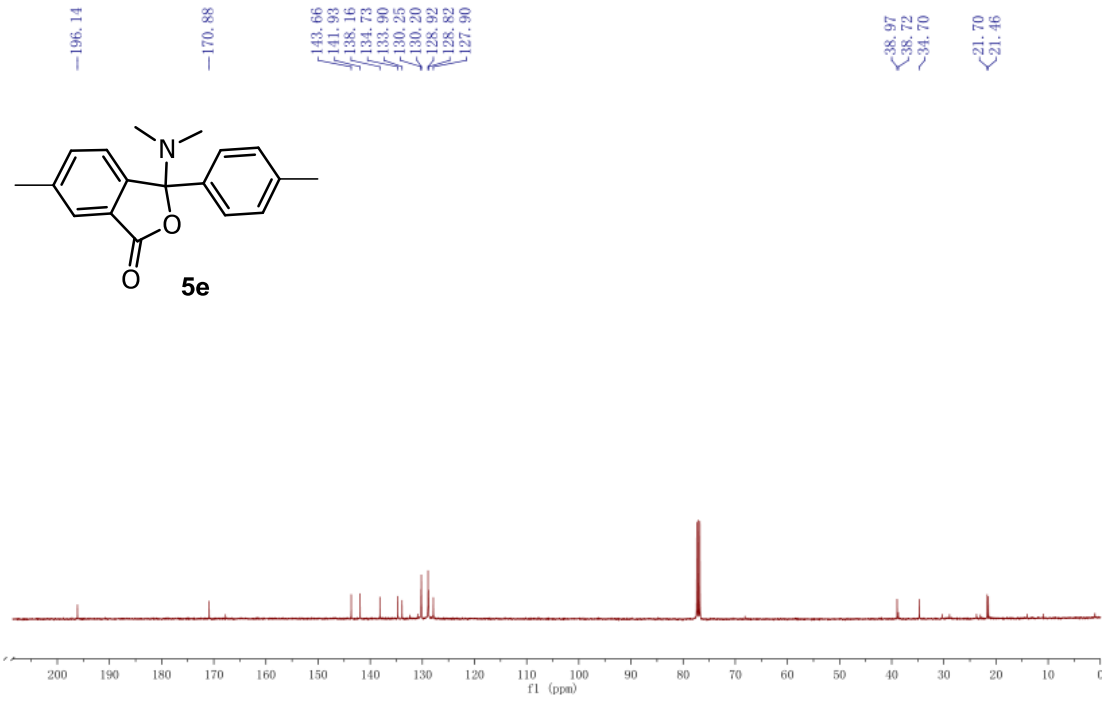

170.11
151.26
145.62
140.31
138.60
130.81
129.21
128.77
126.17
125.44
123.35
122.88
106.69
38.91
22.14
21.57
N
O
O
5c
点击固定
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

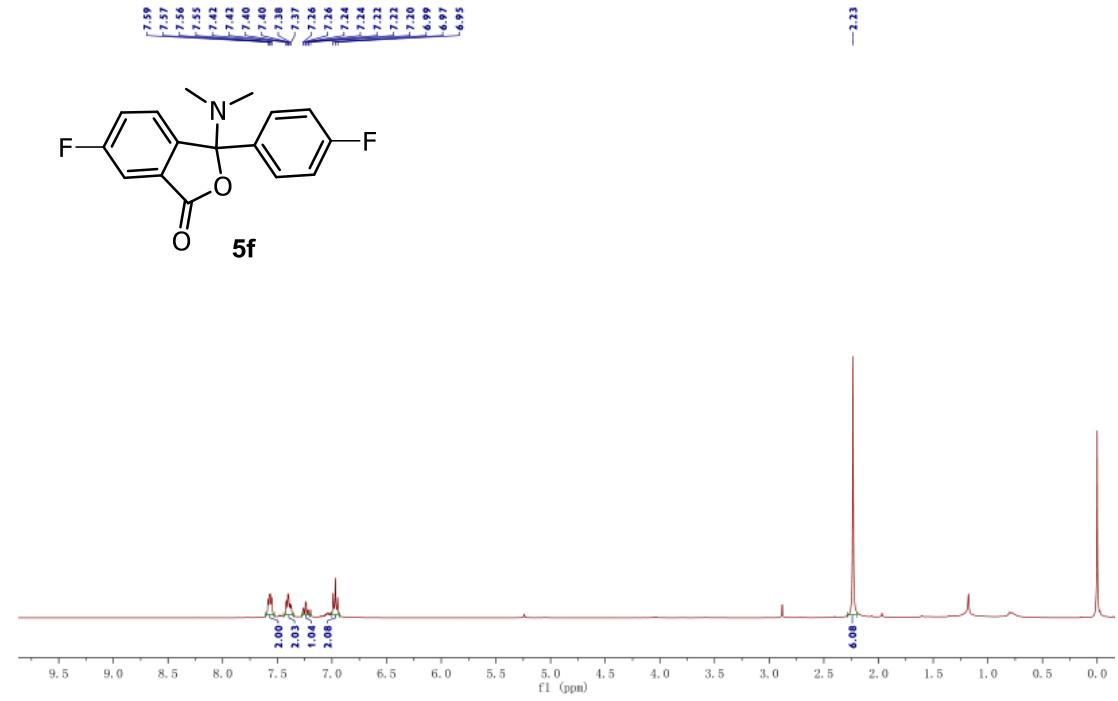

7.79
7.77
7.77
7.75
7.38
7.36
7.32
7.29
7.28
7.27
7.26
7.24
7.19
7.12
7.12
7.10
7.08
6.96
6.96
6.94
6.94
6.93
6.92
2.24
F
F
N
O
O
5d
点击固定
0.96
1.04
2.17
2.14
1.04
6.00
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.
f1 (ppm)


168.42
168.02
165.47
164.35
161.90
153.09
153.00
142.44
142.37
130.64
128.15
121.86
121.32
118.27
118.03
115.92
115.70
113.24
110.46
110.19
105.26
38.82
F
F
N
O
O
5d
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


101.77
101.79
111.37
F
F
N
O
O
5d
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-110
-130
-150
-170
-190
-210
-230
f1 (ppm)


7.62
7.60
7.38
7.36
7.17
7.15
2.86
2.80
2.35
2.33
N
O
O
5e
2.09
1.04
4.04
6.02
6.00
f1 (ppm)


196.14
170.88
143.66
141.93
138.16
134.73
133.90
130.25
130.20
128.92
128.82
127.90
38.97
38.72
34.70
21.70
21.46
N
O
O
5e
f1 (ppm)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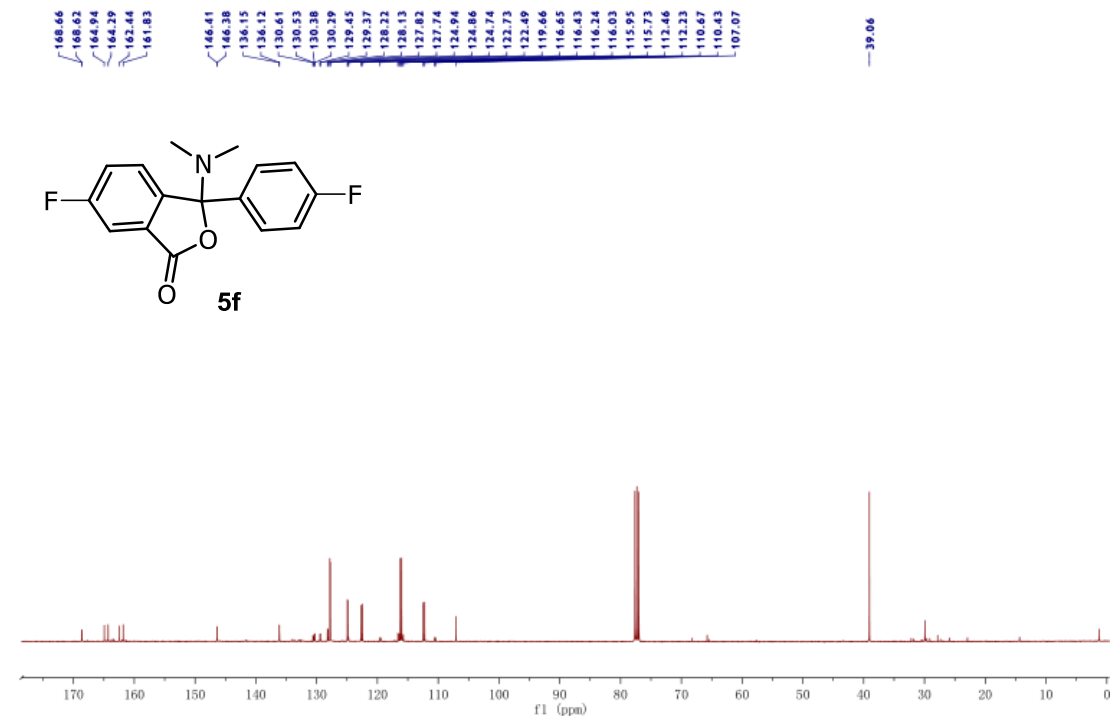
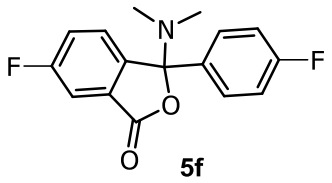
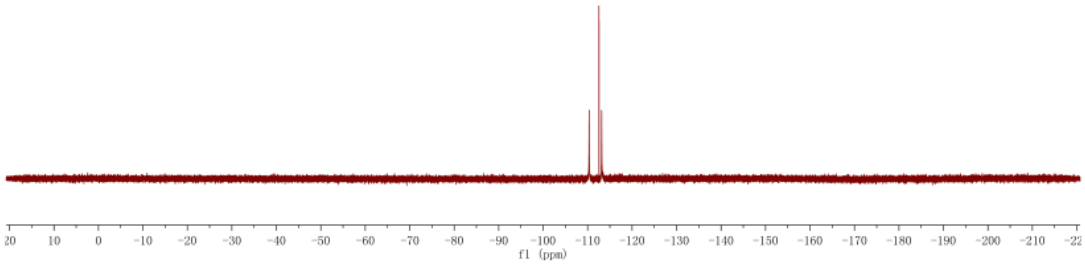
7.57
7.56
7.55
7.42
7.42
7.40
7.40
7.38
7.37
7.26
7.26
7.24
7.24
7.22
7.22
7.20
6.99
6.97
6.95
2.33
F
F
N
O
O
5f
2.00
2.03
1.04
2.08
6.08
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


168.66
168.62
164.94
164.29
162.44
161.83
146.41
146.38
136.15
136.12
130.61
130.53
130.38
130.29
129.45
129.37
128.22
128.13
127.82
127.74
124.94
124.86
124.74
123.73
122.49
119.66
116.65
116.43
116.24
116.03
115.95
115.73
112.46
112.23
110.67
110.43
107.07
39.06
F
F
N
O
O
5f
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


N
F
F
O
O

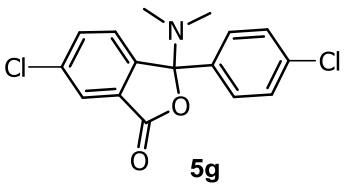
5f


110.33
112.55
112.58
113.15

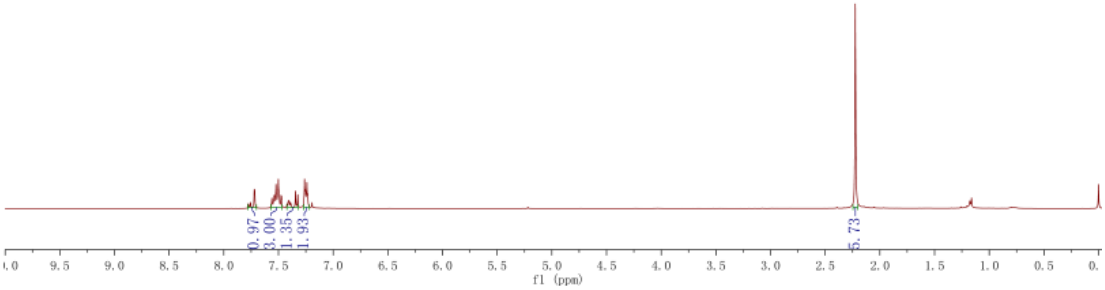

20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210
f1 (ppm)

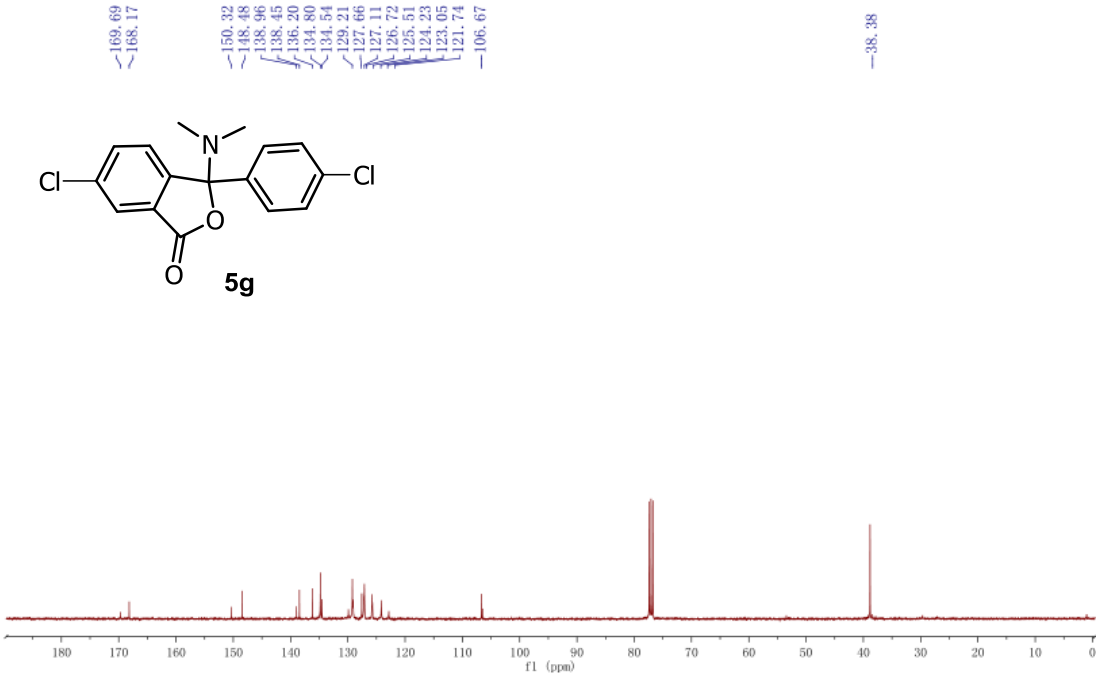

7.78
7.76
7.72
7.72
7.56
7.54
7.52
7.50
7.49
7.48
7.47
7.42
7.41
7.40
7.39
7.34
7.32
7.26
7.25
7.24
7.23
7.19

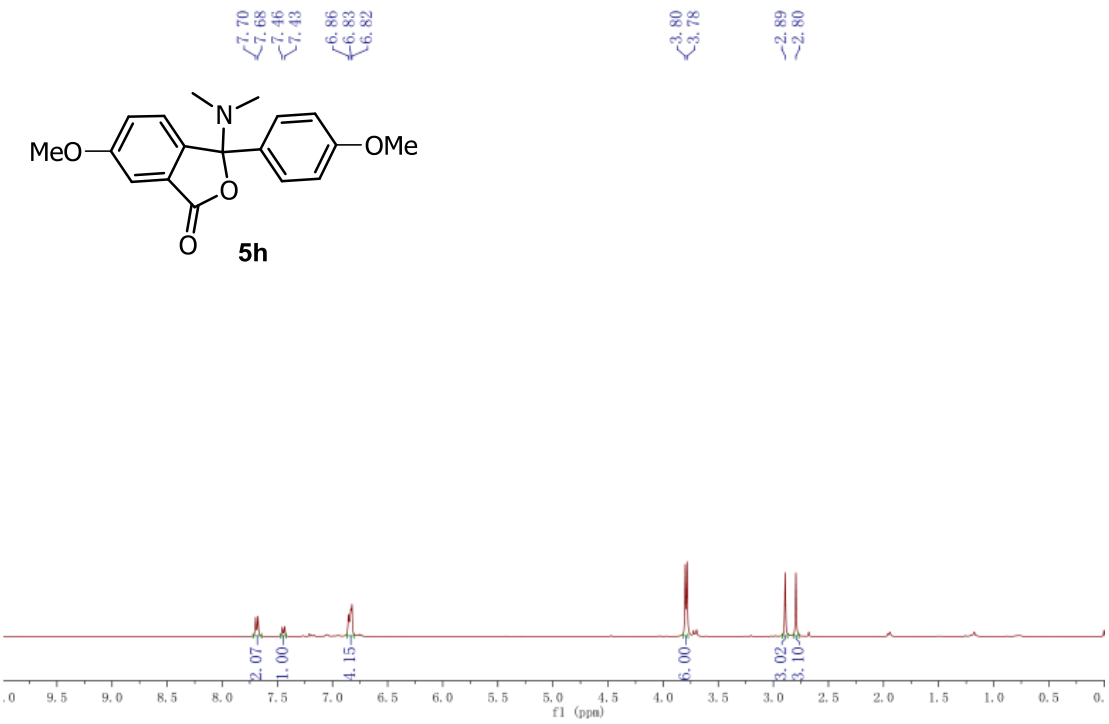

2.23

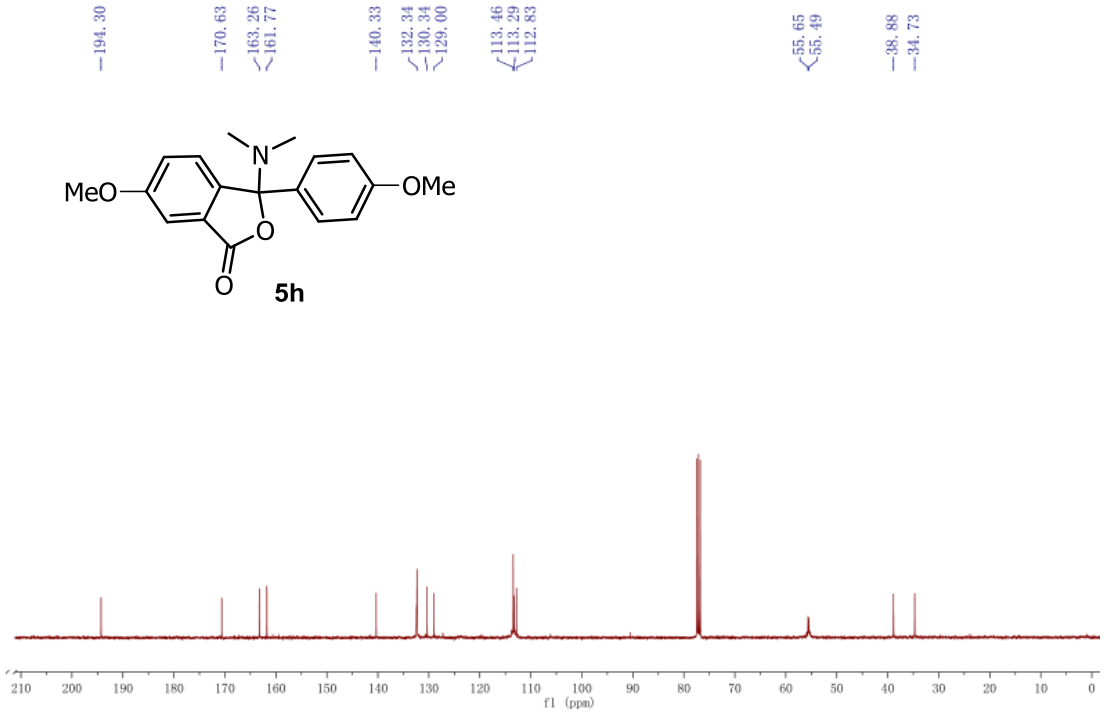

N
Cl
Cl
O
O

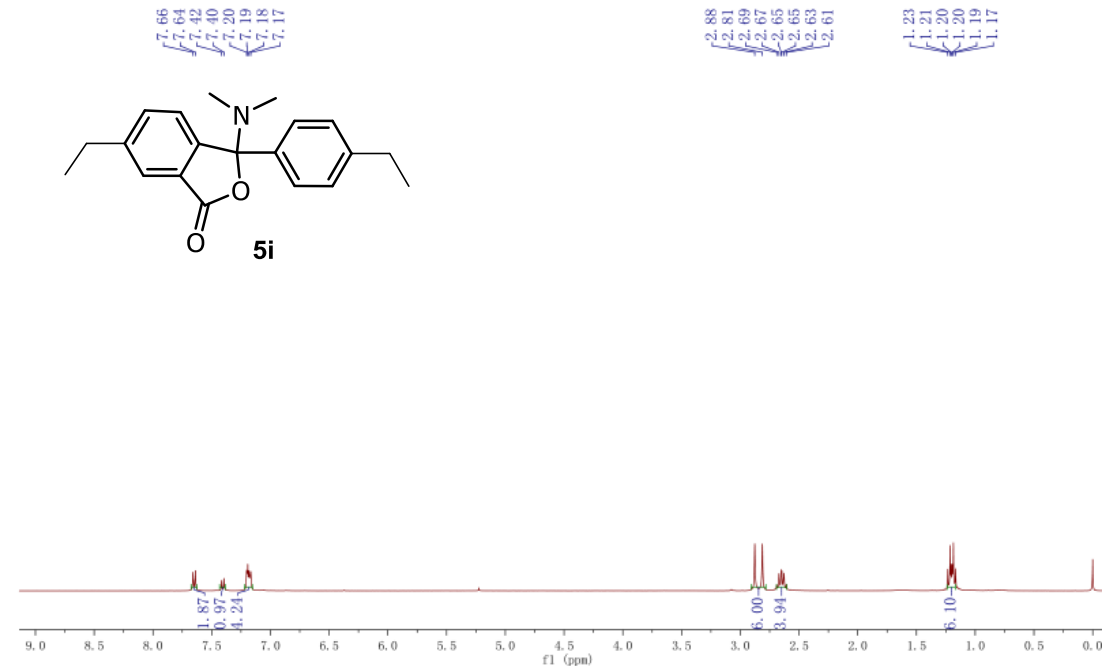
5g

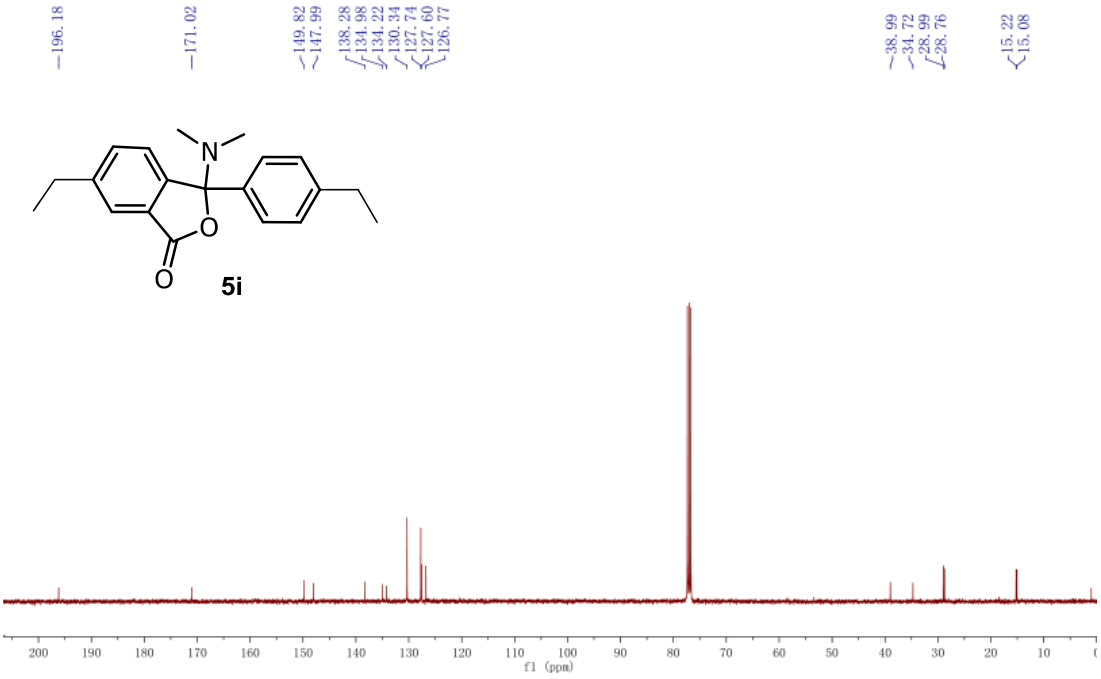

0.97
3.00
1.35
1.93
5.73
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

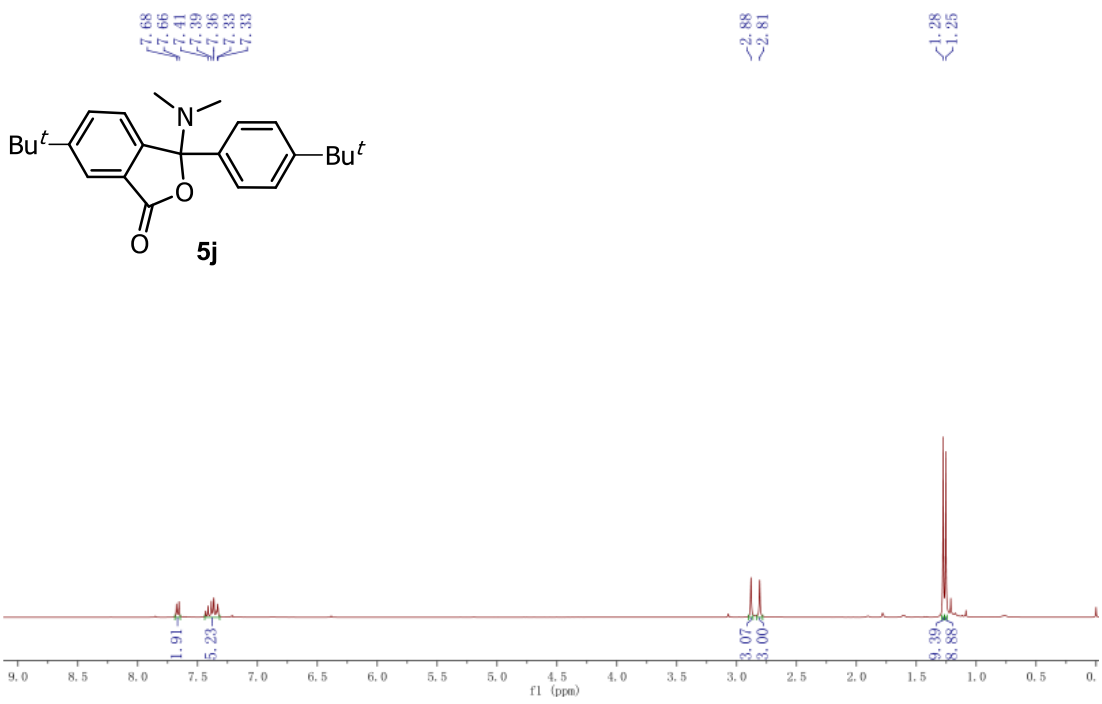

169.69
168.17
150.32
148.48
138.96
138.45
136.20
134.80
134.54
129.21
127.66
127.11
126.72
125.51
124.23
123.05
121.74
106.67
38.38
Cl
N
Cl
O
O
5g
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

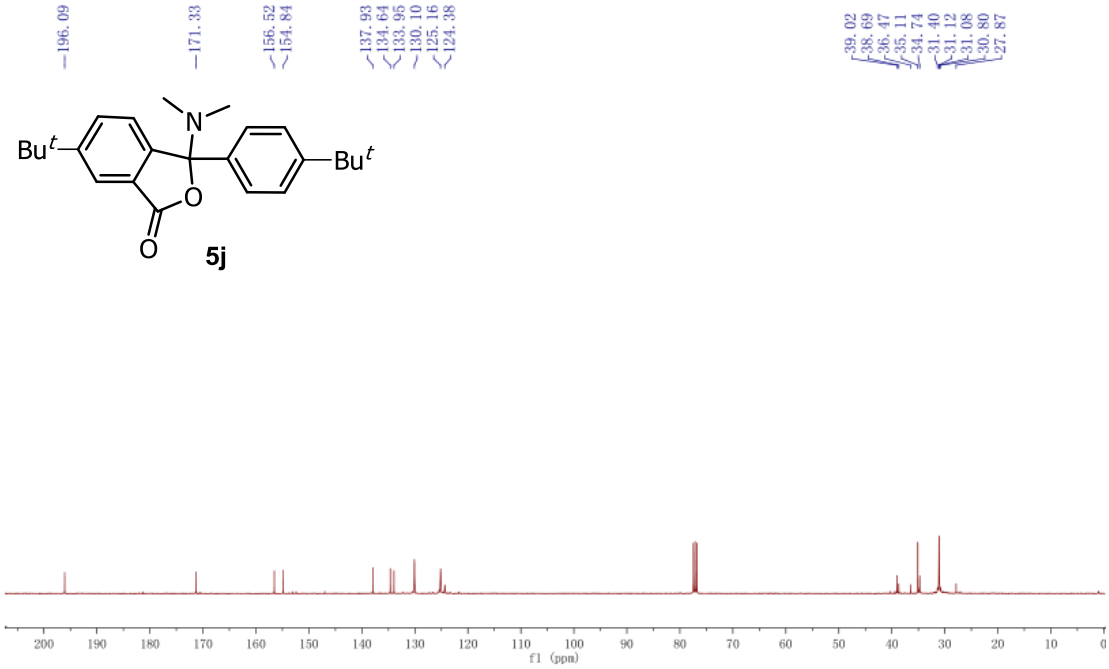

7.70
7.68
7.46
7.43
6.86
6.83
6.82
3.80
3.78
2.89
2.80
MeO
N
OMe
O
O
5h
2.07
1.00
4.15
6.00
3.02
3.10
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

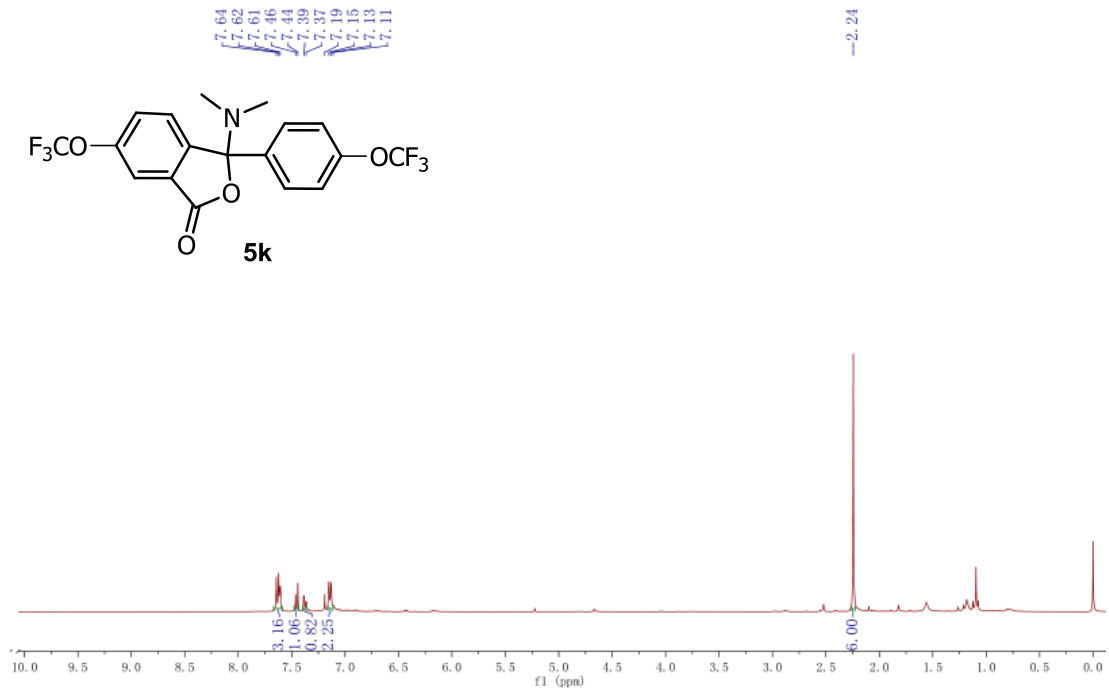

194.30
170.63
163.26
161.77
140.33
132.34
130.34
129.00
113.46
113.29
112.83
55.65
55.49
38.88
34.73
MeO
OMe
N
O
O
5h
f1 (ppm)

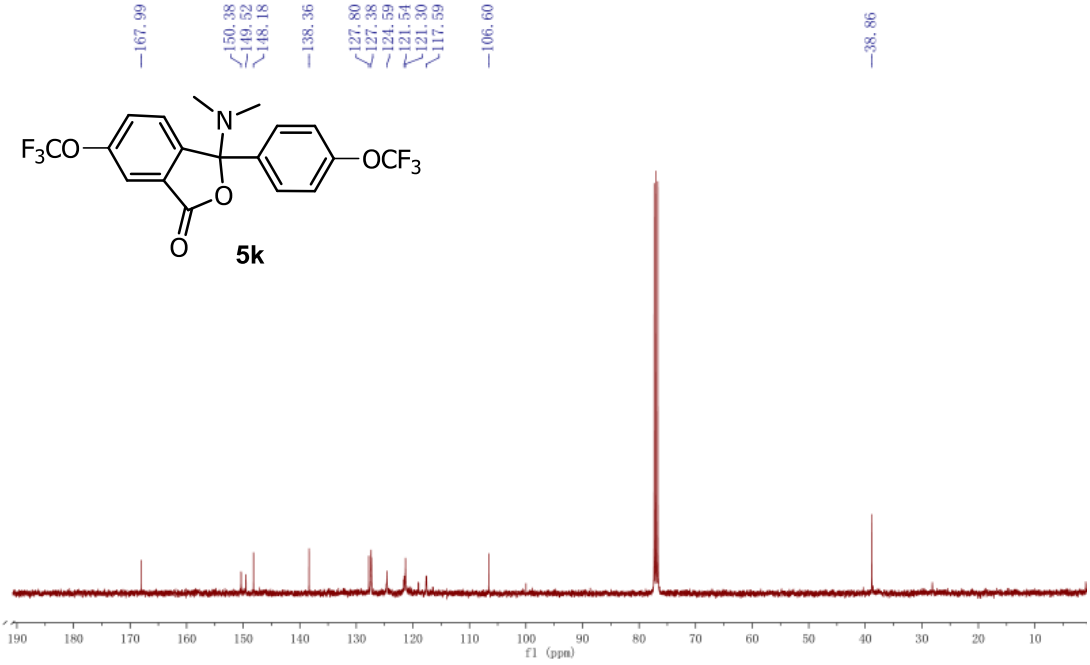

7.66
7.64
7.42
7.40
7.20
7.19
7.18
7.17
2.88
2.81
2.69
2.67
2.65
2.63
2.61
1.23
1.21
1.20
1.20
1.19
1.17
N
O
O
5i
1.87
0.97
4.24
6.00
3.94
6.10
f1 (ppm)

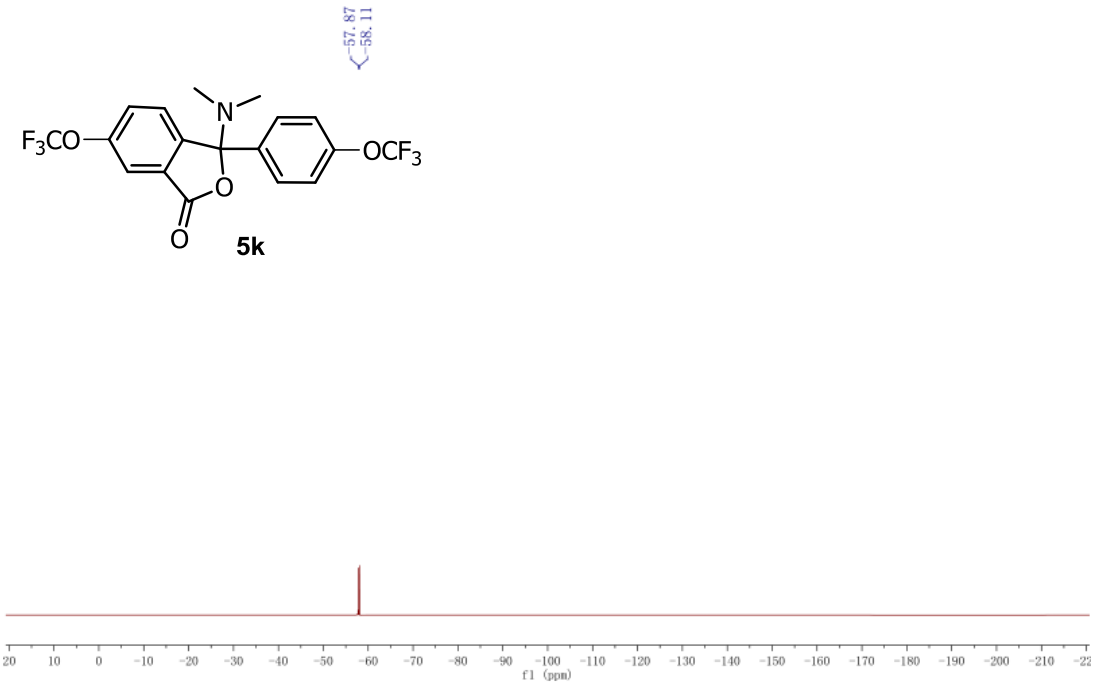

196.18
171.02
149.82
147.99
138.28
134.98
134.22
130.34
127.74
127.60
126.77
38.99
34.72
28.99
28.76
15.22
15.08
N
O
O
5i
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)


7.68
7.66
7.41
7.39
7.36
7.33
7.33
2.88
2.81
1.28
1.25
N
Bu^t
Bu^t
O
O
5j
1.91
5.23
3.07
3.00
9.39
8.88
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

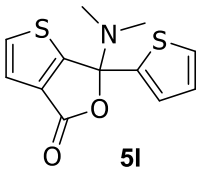

196.09
171.33
156.52
154.84
137.93
134.64
133.95
130.10
125.16
124.38
39.02
38.69
36.47
35.11
34.74
31.40
31.12
31.08
30.80
27.87
N
Bu^t
Bu^t
O
O
5j
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.64
7.62
7.61
7.46
7.44
7.39
7.37
7.19
7.15
7.13
7.11
2.24
N
F$_3$CO
OCF$_3$
O
O
5k
3.16
1.06
0.82
2.25
6.00
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

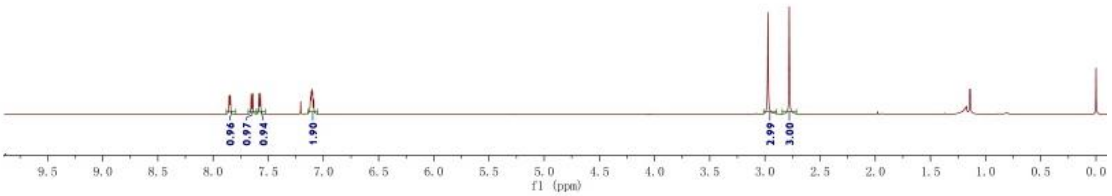

167.99
150.38
149.52
148.18
138.36
127.80
127.38
124.59
121.54
121.30
117.59
106.60
38.86
F3CO
OCF3
N
O
O
5k
f1 (ppm)


57.87
58.11
F3CO
OCF3
N
O
O
5k
f1 (ppm)

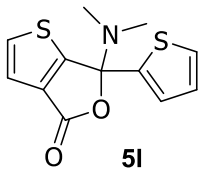

7.85
7.84
7.65
7.64
7.58
7.57
7.12
7.11
7.10
7.10
7.09
2.97
2.78


S
N
S
O
O

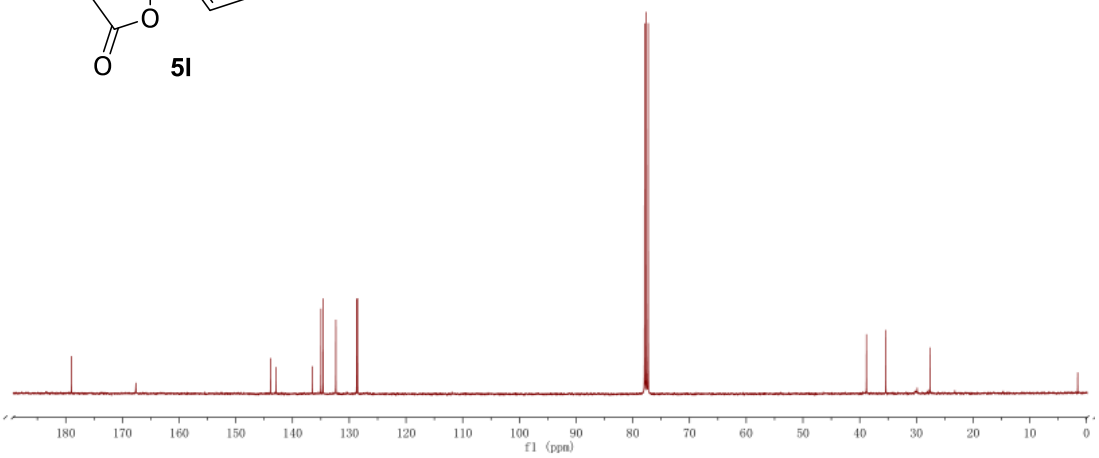
5l

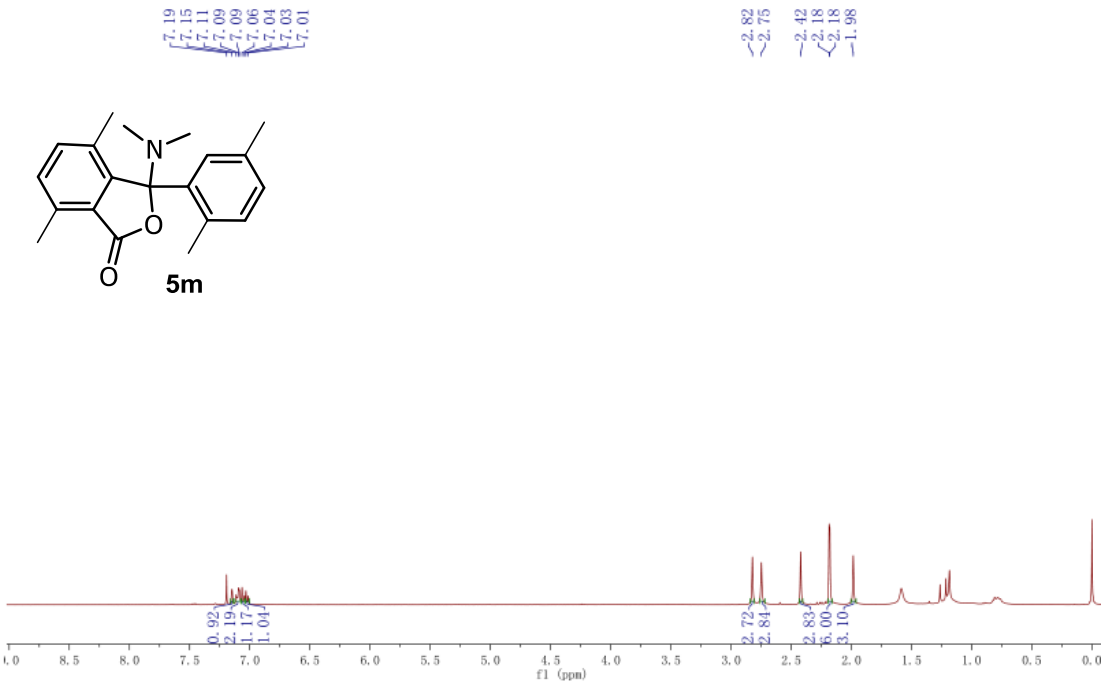

0.96
0.97
0.94
1.90
2.99
3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

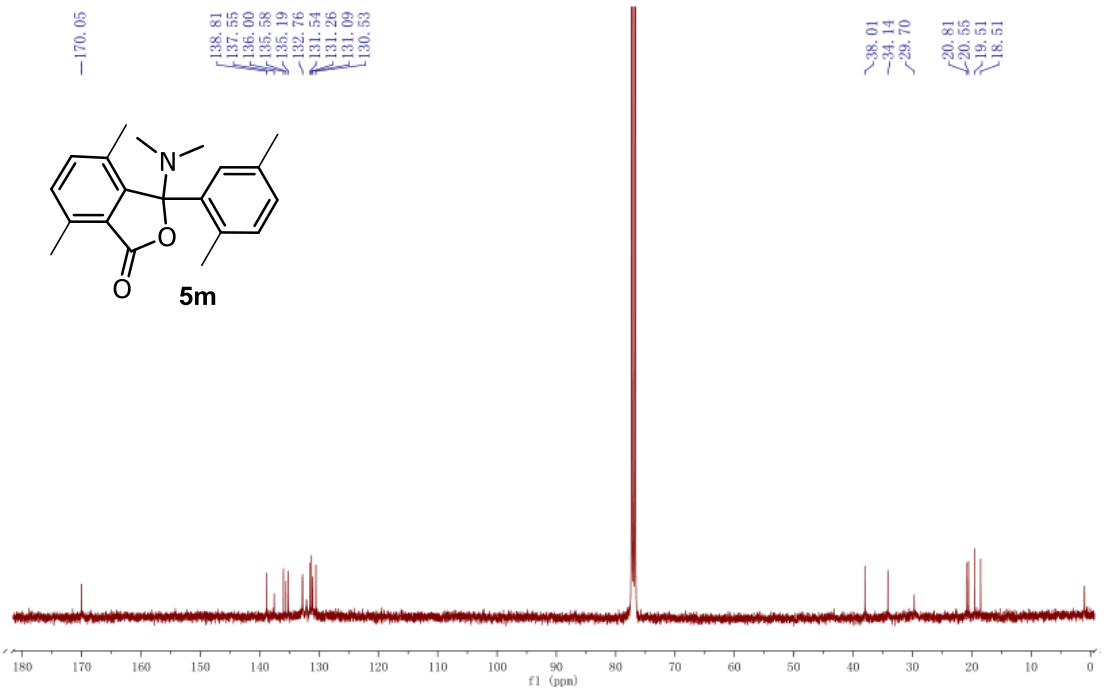

184.52
171.93
146.11
143.50
141.46
136.27
134.82
134.62
133.96
131.24
128.70
128.63
128.53
36.72
35.14
28.54
26.41
22.24

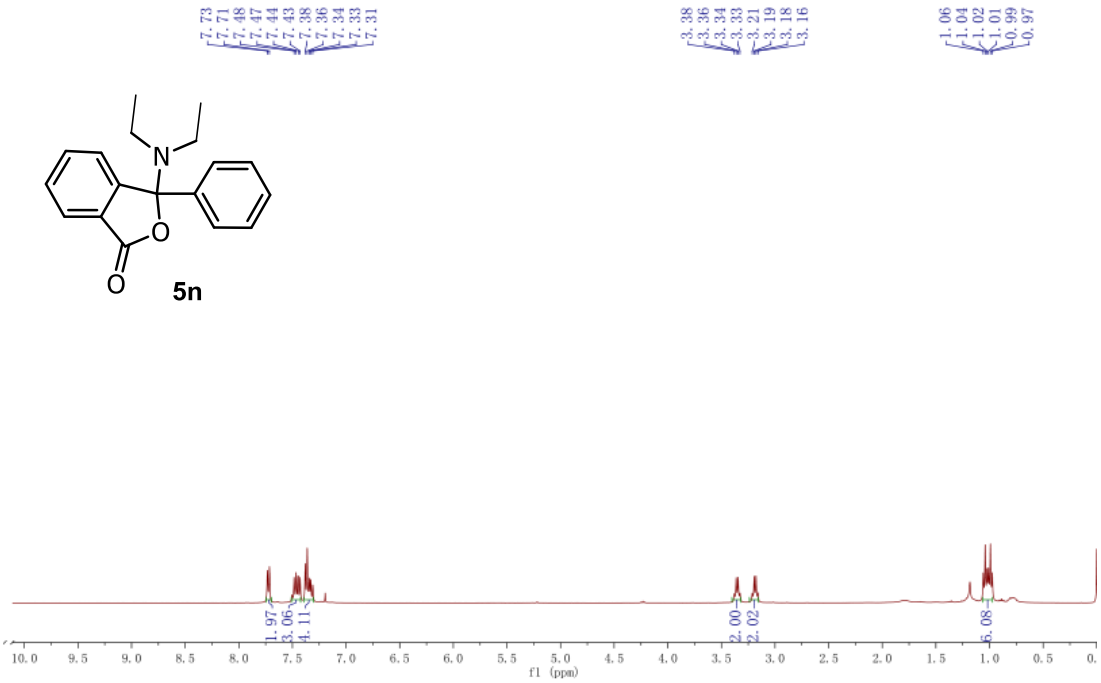

S
N
S
O
O

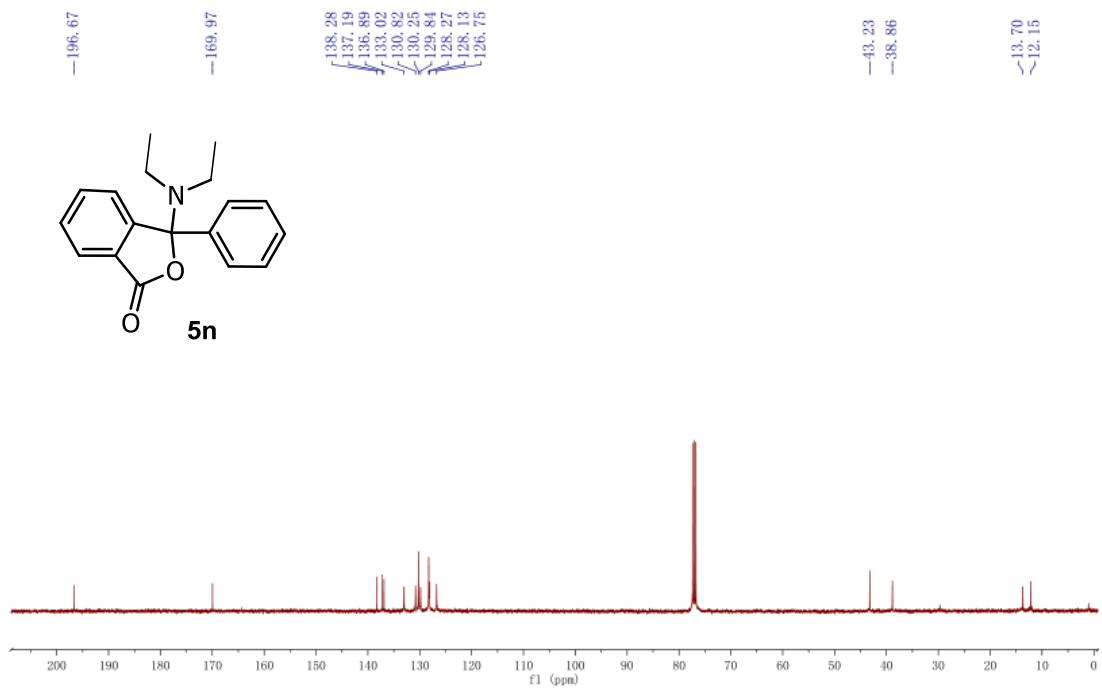
5l

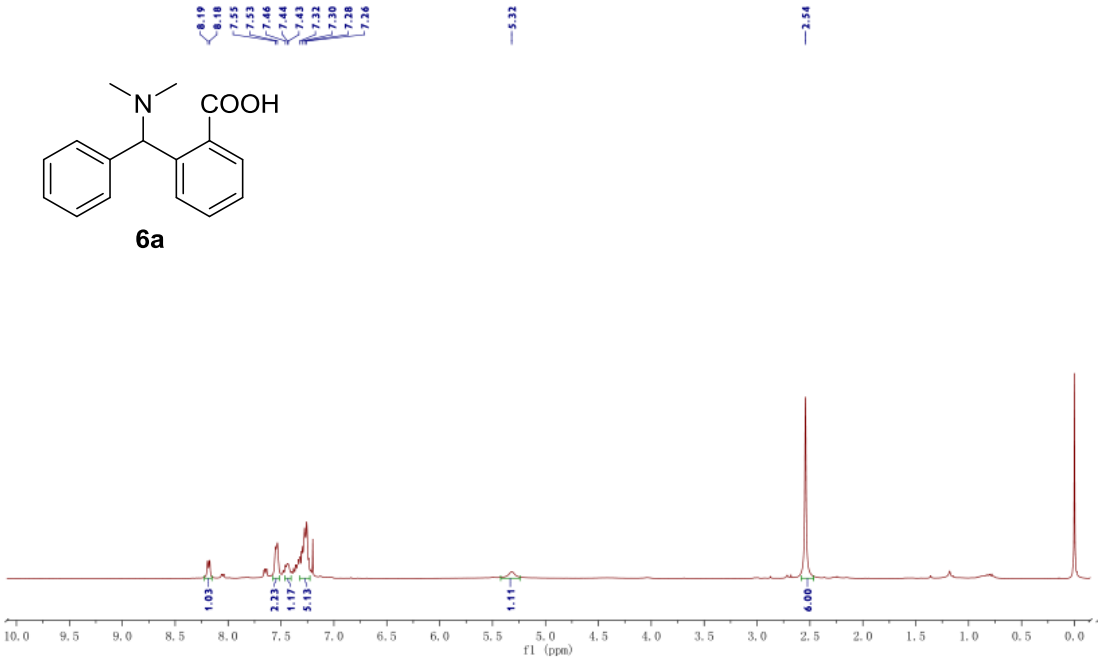

180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


7.19
7.15
7.11
7.09
7.09
7.06
7.04
7.03
7.01
2.82
2.75
2.42
2.18
2.18
1.98
5m
0.92
2.19
1.17
1.04
2.72
2.84
2.83
6.00
3.10
f1 (ppm)


170.05
138.81
137.55
136.00
135.58
135.19
132.76
131.54
131.26
131.09
130.53
38.01
34.14
29.70
20.81
20.55
19.51
18.51
5m
f1 (ppm)


7.73
7.71
7.48
7.47
7.44
7.43
7.38
7.36
7.34
7.33
7.31
3.38
3.36
3.34
3.33
3.21
3.19
3.18
3.16
1.06
1.04
1.02
1.01
0.99
0.97
5n
1.97
3.06
4.11
2.00
2.02
6.08
f1 (ppm)


196.67
169.97
138.28
137.19
136.89
133.02
130.82
130.25
129.84
128.27
128.13
126.75
43.23
38.86
13.70
12.15
5n
f1 (ppm)


8.19
8.18
7.55
7.53
7.46
7.44
7.43
7.32
7.30
7.28
7.26
5.32
2.54
N
COOH
1.03
2.23
1.17
5.13
1.11
6.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

6a