Supporting Information

Practical Access to Fluorescent 2,3-Naphthalimides Derivatives *via* Didehydro-Diels-Alder Reaction

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I. General Information

^{1}H NMR and ^{13}C NMR spectra were measured on a 400 MHz Bruker unit (400 MHz for ^{1}H NMR, 100 MHz for ^{13}C NMR) using $CDCl_3$ as the solvent at room temperature. Chemical shifts (δ) are given in parts per million relatively to the solvent peak, and coupling constants (J) are given in hertz. Melting points were obtained using an X-5 microscopic melting point apparatus (Beijing Tech, China). HRESIMS data were tested in the positive-ion mode on a SolariX 7.0 spectrometer and a Bruker micrOTOF II (Bruker, Karlsruhe, Germany). Dichloromethane (DCM) and tetrahydrofuran (THF) were freshly dried and distilled from CaH_2 and Na respectively.

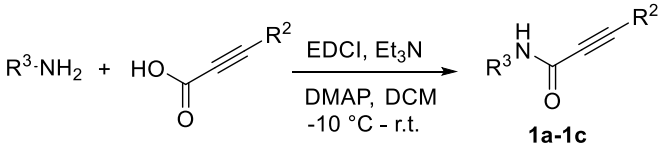
Unless otherwise noted, materials obtained from commercial suppliers (TCI, Adamas, Aldrich, Acros, Alfa, Accela, Innochem) were used without further purification. Deuterated solvents were purchased from Cambridge Isotope Laboratories and used without further purification. NaH was purchased from TCI (60% in mineral oil), n-BuLi (2.0 M in cyclohexane) was purchased from Sigma-aldrich (2.0 M in cyclohexane). Silica gel (200-300 mesh size) was used for column chromatography. TLC analysis of reaction mixtures were performed using silica gel plates.

II. General Experimental Procedures

Amines and acrylic acids were purchased from commercial suppliers (TCI, Adamas, Acros, Innochem, etc.). 3-phenylpropiolic acid, propioic acid, 2-butynoic acid and 2-hexynoic acid were purchased from commercial suppliers (Adamas, Alfa, TCI); the preparation of other substituted propiolic acids were described in previous reports.[1] Acrylic acids were purchased from commercial suppliers (TCI, Adamas, Acros, Innochem, etc.).

1. General procedure for the synthesis of substrates 1a-1c and 2aa-2az [2-4]

(1) The synthesis of substrates **1a-1c**: [2]

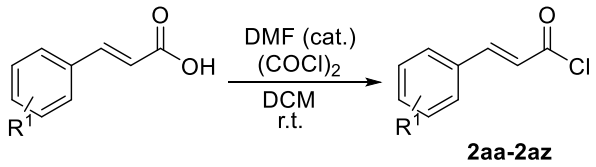


1a-1c

To a solution of EDCI (1.7 equiv.) and DMAP (0.1 equiv.) in anhydrous DCM was added triethylamine (1.8 equiv.) at -10 °C. Then propynoic acid (1.4 equiv.) was added by fraction, the

reaction was stirred for 20 min at -10 °C. Amine (1.0 equiv.) was dissolved in anhydrous DCM and was added subsequently. The mixture was then warmed to room temperature and stirred overnight. After completion of the reaction, water was added into the mixture and extracted with DCM, the organic layer was dried over anhydrous Na_2SO_4 and filtered, then the DCM was removed by rotary evaporation. Obtained the former crude product was purified by silica column chromatography (PE/EA = 15:1 - 3:1) to afford amide product.

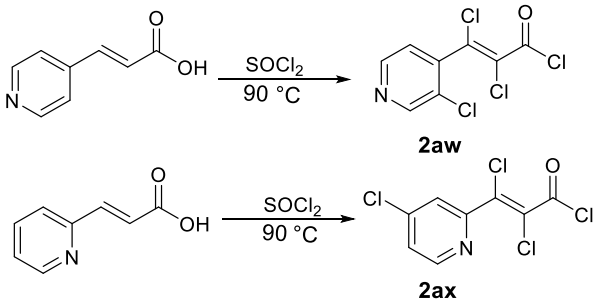
(2) The synthesis of substrates **2aa-2av, 2ay-2az**: [3]



2aa-2az

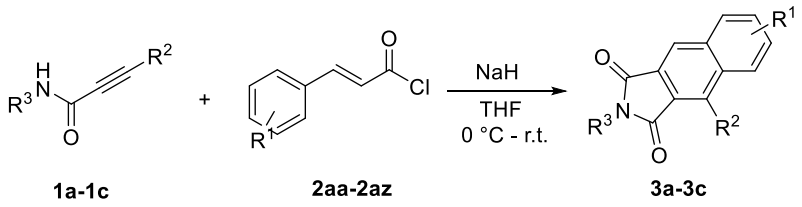
To a solution of carboxylic acid (1.0 equiv.) in anhydrous DCM was added oxalyl chloride (3 equiv.) and DMF (cat.) dropwise sequentially at room temperature in a round bottom flask. The resulting mixture was stirred at room temperature for about 2 h and monitored by TLC analysis. After reaction was completed, the solvent was removed by rotary evaporation. Concentration led to the acryoyl chloride, which was used directly for the next step.

(3) The synthesis of substrates **2aw-2ax**: [4]



The carboxylic acid (1.0 equiv.) was dissolved in $SOCl_2$ in a Schlenk tube. The resulting mixture was stirred at 90 °C for about 2 h. After reaction was completed, the solvent was removed by rotary evaporation. Concentration led to the acryoyl chloride, which was used directly for the next step.

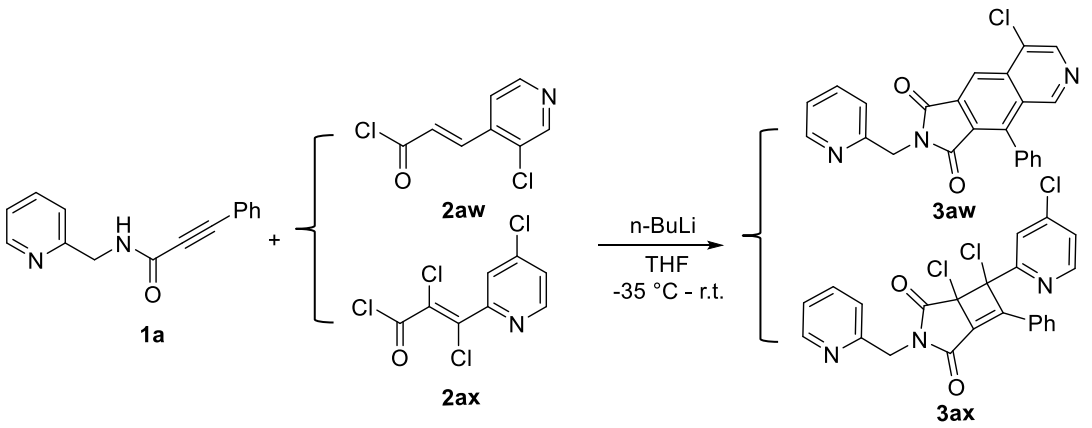
2. General procedure for the synthesis of compounds 3aa-3av, 3ay-3az, 3ba-3bi, 3bk-3bm and 3c



1a-1c **2aa-2az** **3a-3c**

Acetylene amide [2] **1a-1c** (0.25 mmol, 1.0 equiv.) was dissolved in anhydrous THF. The resulting solution was cooled to 0 °C with stirring, NaH (60% in mineral oil, 1.5 equiv.) was added by fraction. After stirring at 0 °C for 30 min, acryoyl chloride [3] **2aa-2az** (1.3 equiv.) was added. The reaction was stirred under room temperature for 3 h. The reaction mixture was quenched with water and extracted with EtOAc. The organic layer was dried over anhydrous Na_2SO_4 and filtered, then the EtOAc was removed by rotary evaporation. Obtained the former crude product was purified by silica column chromatography (PE/EA = 30:1 - 3:1) to give desired product **3aa-3av, 3ay-3az, 3ba-3bi, 3bk-3bm and 3c.**

3. General procedure for the synthesis of compounds 3aw and 3ax

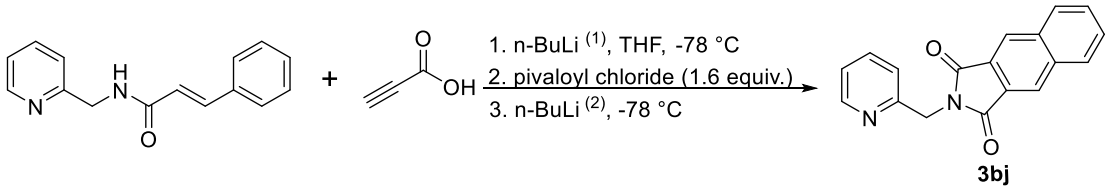


1a **2aw** **2ax** **3aw** **3ax**

Acetylene amide [2] **1aa** (59.0 mg, 0.25 mmol, 1.0 equiv.) was dissolved in anhydrous THF. The resulting solution was cooled to -35 °C with stirring, n-BuLi (2.0 M in cyclohexane, 0.38 mmol, 1.5 equiv.) was added by dropwise via syringe. After stirring at -35 °C for 30 min, acryoyl chloride [4] **2aw** or **2ax** (0.33 mmol, 1.3 equiv.) was added. The reaction was stirred under room temperature for 3 h. The reaction mixture was diluted with water and extracted with EtOAc. The organic layer was dried over anhydrous Na_2SO_4 and filtered, then the EtOAc was removed by rotary evaporation.

Obtained the former crude product was purified by silica column chromatography (PE/EA = 4:1) to give desired product **3aw** and **3ax.**

4. General procedure for the synthesis of compound 3bj

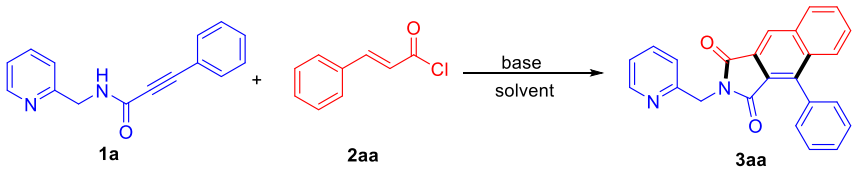


To a three necks flask A containing propioic acid (21.0 mg, 0.30 mmol) was added anhydrous THF (0.4 mL) at -78 °C, nBuLi (2.0 M in cyclohexane, 0.18 mL, 0.35 mmol) was added dropwise by syringe. The reaction mixture was allowed to stir at the same temperature for a period of time, until white suspension was generated, the reaction mixture was warmed to room temperature and stirred for 45 min, then cooled to 0 °C, pivaloyl chloride (48.2 mg, 0.40 mmol) was then added dropwise to the solution, and stirring was continued for 2 h. [5]

To a three neck flask B containing N-(pyridin-2-ylmethyl)cinnamamide (59.5 mg, 0.25 mmol) was added anhydrous THF (2 mL) at -78 °C, nBuLi (2.0 M in cyclohexane, 0.15 mL, 0.30 mmol) was added dropwise by syringe. The reaction mixture was allowed to stir at the same temperature for 15 min. Then, the reaction solution of flask A was added slowly to flask B by injection, the reaction mixture was warmed to room temperature and stirred for 3 h. The reaction mixture was quenched carefully with a saturated solution of NH_4Cl (0.2 mL), and the mixture was extracted with EtOAc for three times. The organic layers were combined and dried over anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. The former crude product was purified by silica column chromatography (PE/EA = 5:1) to give desired product **3bj** (55.4 mg, yellow solid, yield: 77%)**.**

III. Optimization of reaction conditions

Table S1. Optimization of reaction conditions [a, b, c]



1a 2aa 3aa

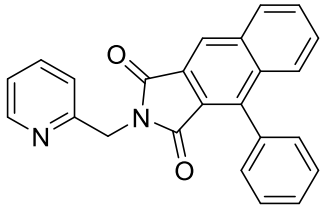
Entry	**2aa** (equiv.)	Base (equiv.)	Time (h)	Yield (%)
1	1.1	NaH (1.2)	1.0	62
2	1.3	NaH (1.5)	2.0	77
3	**1.3**	**NaH (1.5)**	**3.0**	**85**
4	1.3	Et_3N (1.5)[d]	3.0	41
5	1.3	DIPEA (1.5)[d]	3.0	73
6	1.3	Na_2CO_3 (1.5)	3.0	trace
7	1.3	K_2CO_3 (1.5)	3.0	trace
8	1.3	Cs_2CO_3 (1.5)	3.0	27
9	1.3	CH_3COOK(1.5)	3.0	14
10	1.3	n-BuLi (1.5)	3.0	75
11	**1.3**	**t-BuOK (1.5)**	**3.0**	**82**
12	1.3	NaH (1.5)	6.0	83

[a]Standard conditions: **1a** (0.25 mmol), **2aa**, base and dry THF (2.0 mL) in a reaction bottle under air. [b]Isolated yields. [c]T: **2aa** was added at 0 °C, and the mixture was warmed to room temperature and stirred; [d]Solvent: dry DCM.

During a medicinal chemistry study, we made the surprising discovery that 3-phenyl-N-(pyridin-2-ylmethyl) propiolamide **1a** reacted with cinnamoyl chloride **2aa** to produce a fluorescent compound. This compound was determined to be 1-phenyl-2,3-naphthalimide and was generated from the oxidation of an unstable dihydronaphthalene product by air,[10a,12] indicating the occurrence of the DDDA reaction. Thus, the reaction was studied using compounds **1aa** and **2aa** as the model substrates, and the results are summarized in Table 1. Using NaH (1.2 equiv.) as a base and THF as a solvent produced a 62% yield of **3aa** (Table 1, entry 1). The dosages of **2aa** and NaH, as well as the reaction time, were evaluated. Yield increased to 85% when 1.3 equiv. of **2aa** and 1.5 equiv. of

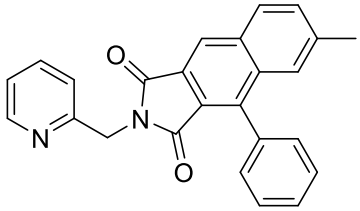
NaH was used and stirred for 3.0 h (entry 3). Other commonly used bases failed to afford a higher yield (entries 4-10), it should be noted that t-BuOK was also suitable for this reaction and delivered the target molecule in good yield (entry 11). Prolonging the reaction time also did not improve the yield (entry 12). Finally, the optimal reaction condition was determined, which completed the conversion in 85% yield (entry 3).

IV. Characterization Data for Products



3aa

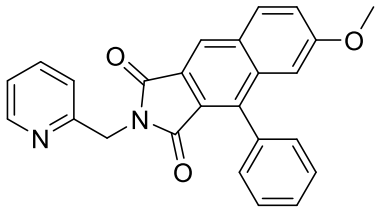
4-phenyl-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione:(**3aa**, 77.4 mg, yellow solid, yield: 85%) mp: 200-203 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.53 – 8.49 (m, 1H), 8.42 (s, 1H), 8.10 (d, *J* = 8.0 Hz, 1H), 7.82 (d, *J* = 8.5 Hz, 1H), 7.69 (ddd, *J* = 8.1, 6.9, 1.3 Hz, 1H), 7.60 (tp, *J* = 5.8, 1.8 Hz, 2H), 7.53 (qd, *J* = 4.8, 1.6 Hz, 3H), 7.42 (dd, *J* = 7.2, 2.3 Hz, 2H), 7.25 (s, 1H), 7.17 – 7.11 (m, 1H), 5.00 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.8, 167.2, 155.5, 149.7, 140.5, 136.8, 135.6, 135.6, 134.5, 130.5, 130.0, 129.2, 129.1, 128.7, 128.6, 128.3, 128.0, 124.6, 124.0, 122.5, 121.7, 43.2. HRMS calcd for $C_{24}H_{17}N_2O_2$ $[M + H]^+$ 365.1285, found 365.1279.



3ab

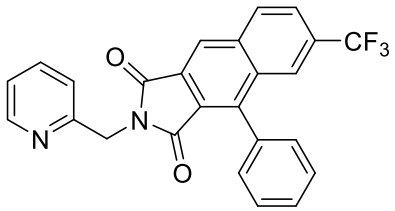
6-methyl-4-phenyl-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3ab**, 82.2 mg, yellow solid, yield: 87%) mp: 224-226 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.53 – 8.49 (m, 1H), 8.37 (s, 1H), 7.99 (d, *J* = 8.3 Hz, 1H), 7.59 (td, *J* = 7.7, 1.8 Hz, 1H), 7.57 – 7.49 (m, 5H), 7.41 (dd, *J* = 7.3, 2.3 Hz, 2H), 7.24 (s, 1H), 7.17 – 7.10 (m, 1H), 4.99 (s, 2H), 2.45 (s, 3H). ^{13}C NMR (100 MHz,

$CDCl_3$) δ 167.9, 167.3, 155.6, 149.7, 139.8, 139.7, 136.7, 135.8, 134.7, 133.8, 131.2, 130.3, 130.0, 128.5, 128.3, 127.8, 127.1, 124.4, 124.1, 122.5, 121.7, 43.2, 22.2. HRMS calcd for $C_{25}H_{19}N_2O_2$ [M + H]$^+$ 379.1441, found 379.1440.



3ac

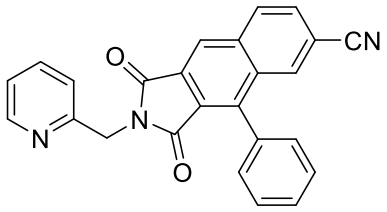
6-methoxy-4-phenyl-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione:(**3ac**, 76.8 mg, yellow solid, yield: 78%) mp: 213-215 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.60 – 8.45 (m, 1H), 8.33 (s, 1H), 7.98 (d, *J* = 8.9 Hz, 1H), 7.60 (td, *J* = 7.7, 1.8 Hz, 1H), 7.56 – 7.49 (m, 3H), 7.42 (dd, *J* = 7.6, 1.9 Hz, 2H), 7.32 (dd, *J* = 9.0, 2.5 Hz, 1H), 7.24 (s, 1H), 7.16 – 7.11 (m, 1H), 7.09 (d, *J* = 2.5 Hz, 1H), 4.99 (s, 2H), 3.74 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.9, 167.4, 160.3, 155.6, 149.6, 138.9, 137.5, 136.8, 134.7, 131.9, 130.7, 129.9, 128.6, 128.4, 125.8, 124.7, 124.3, 122.5, 121.7, 121.0, 107.7, 55.4, 43.1. HRMS calcd for $C_{25}H_{19}N_2O_3$ [M + H]$^+$ 395.1390, found 395.1380.



3ad

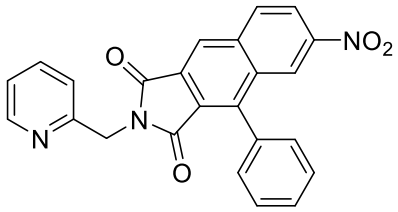
4-phenyl-2-(pyridin-2-ylmethyl)-6-(trifluoromethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione:

(**3ad**, 97.4 mg, yellow solid, yield: 93%) mp: 201-203 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.49 (d, *J* = 5.0 Hz, 1H), 8.48 (s, 1H), 8.23 (d, *J* = 8.6 Hz, 1H), 8.11 (s, 1H), 7.85 (dd, *J* = 8.6, 1.7 Hz, 1H), 7.61 (td, *J* = 7.7, 1.8 Hz, 1H), 7.58 – 7.54 (m, 3H), 7.42 (dd, *J* = 6.5, 2.9 Hz, 2H), 7.32 – 7.22 (m, 1H), 7.14 (dd, *J* = 7.5, 4.9 Hz, 1H), 5.01 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.2, 166.7, 155.1, 149.7, 141.3, 137.0, 136.8, 134.9, 133.3, 131.5, 130.6 (d, *J* = 33 Hz), 130.0, 130.0, 129.1, 128.5, 125.9 (q, *J* = 5 Hz), 125.1, 124.5 (d, *J* = 3 Hz), 124.1, 122.4, 121.8, 43.3. HRMS calcd for $C_{25}H_{16}F_3N_2O_2$ [M + H]$^+$ 433.1158, found 433.1164.



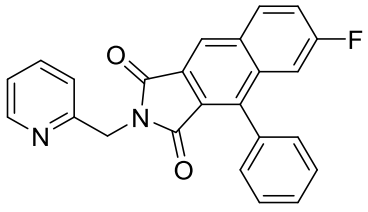
3ae

1,3-dioxo-4-phenyl-2-(pyridin-2-ylmethyl)-2,3-dihydro-1*H*-benzo[*f*]isoindole-6-carbonitrile: (**3ae**, 74.3 mg, yellow solid, yield: 76%) mp: 251-253 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.52 – 8.47 (m, 1H), 8.46 (s, 1H), 8.20 (d, *J* = 9.0 Hz, 2H), 7.82 (dt, *J* = 8.3, 1.4 Hz, 1H), 7.62 (td, *J* = 7.7, 1.7 Hz, 1H), 7.58 (dd, *J* = 4.4, 2.3 Hz, 3H), 7.40 (ddd, *J* = 6.8, 3.0, 1.2 Hz, 2H), 7.28 (s, 1H), 7.15 (dd, *J* = 7.5, 5.0 Hz, 1H), 5.01 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.9, 166.4, 155.0, 149.8, 140.9, 137.1, 136.8, 135.0, 134.4, 133.0, 131.6, 130.8, 130.0, 129.5, 129.4, 128.7, 125.6, 124.1, 122.7, 121.9, 118.4, 112.8, 43.4. HRMS calcd for $C_{25}H_{16}N_3O_2$ $[M+H]^+$ 390.1237, found 390.1237.



3af

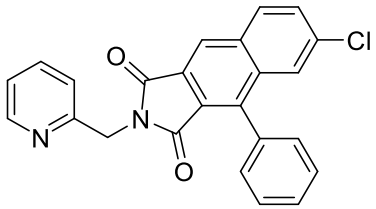
6-nitro-4-phenyl-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3af**, 62.4 mg, yellow solid, yield: 61%) mp: 225-227 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.75 (d, *J* = 2.1 Hz, 1H), 8.52 (s, 2H), 8.44 (dd, *J* = 8.8, 2.1 Hz, 1H), 8.26 (d, *J* = 8.9 Hz, 1H), 7.64 (d, *J* = 38.3 Hz, 4H), 7.44 (s, 2H), 7.32 (s, 1H), 7.22 (s, 1H), 5.06 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.8, 165.4, 153.7, 148.4, 146.6, 141.4, 137.3, 136.6, 134.1, 131.8, 131.1, 130.4, 129.1, 128.6, 127.7, 124.7, 123.8, 123.0, 122.1, 121.4, 121.3, 42.3. HRMS calcd for $C_{24}H_{16}N_3O_4$ $[M+H]^+$ 410.1135, found 410.1141.



3ag

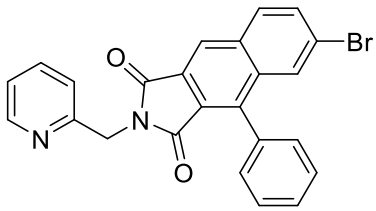
6-fluoro-4-phenyl-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3ag**, 86.9 mg, white solid, yield: 91%) mp: 221-223 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.50 (d, *J* = 4.7 Hz, 1H),

8.42 (s, 1H), 8.11 (dd, *J* = 8.8, 5.6 Hz, 1H), 7.61 (td, *J* = 7.6, 1.6 Hz, 1H), 7.54 (dd, *J* = 5.3, 1.9 Hz, 3H), 7.49 – 7.42 (m, 2H), 7.42 – 7.38 (m, 2H), 7.27 (d, *J* = 4.2 Hz, 1H), 7.15 (dd, *J* = 7.6, 4.8 Hz, 1H), 5.00 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 166.6, 166.0, 161.7 (d, *J* = 249 Hz), 154.4, 148.7, 138.8 (d, *J* = 6 Hz), 136.3(d, *J* = 9 Hz), 135.9, 133.0, 131.9 (d, *J* = 9 Hz), 131.5, 128.9, 127.9, 127.5, 126.6 (d, *J* = 2 Hz), 123.9, 123.4, 121.6, 120.8, 118.3 (d, *J* = 25 Hz), 111.8 (d, *J* = 22 Hz), 42.2. HRMS calcd for $C_{24}H_{16}FN_2O_2$ $[M + H]^+$ 383.1190, found 383.1192.



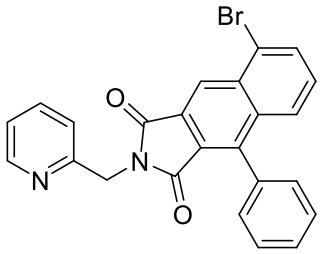
3ah

6-chloro-4-phenyl-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3ah**, 91.5 mg, yellow solid, yield: 92%) mp: 205-207 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 8.50 (dt, *J* = 4.8, 1.3 Hz, 1H), 8.39 (s, 1H), 8.04 (d, *J* = 8.7 Hz, 1H), 7.78 (d, *J* = 2.0 Hz, 1H), 7.61 (ddd, *J* = 13.4, 8.2, 2.0 Hz, 2H), 7.55 (dd, *J* = 5.1, 1.9 Hz, 3H), 7.43 – 7.37 (m, 2H), 7.28 – 7.23 (m, 1H), 7.14 (ddd, *J* = 7.6, 4.9, 1.1 Hz, 1H), 5.00 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 167.4, 166.9, 155.3, 149.8, 139.7, 136.8, 136.5, 135.7, 133.9, 133.8, 131.8, 130.0, 128.9, 128.5, 128.3, 127.6, 125.0, 124.3, 122.6, 121.8, 43.3. HRMS calcd for $C_{24}H_{16}ClN_2O_2$ $[M + H]^+$ 399.0895, found 399.0901.



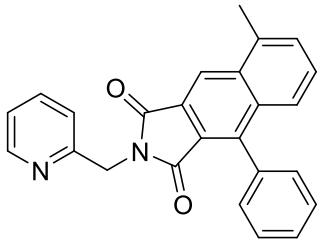
3ai

6-bromo-4-phenyl-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3ai**, 91.7 mg, yellow solid, yield: 83%) mp: 219-221 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) *δ* 8.50 (dd, *J* = 5.1, 1.8 Hz, 1H), 8.38 (s, 1H), 7.98 – 7.92 (m, 2H), 7.76 (dd, *J* = 8.7, 2.0 Hz, 1H), 7.63 – 7.57 (m, 1H), 7.55 (dd, *J* = 5.1, 2.0 Hz, 3H), 7.40 (dt, *J* = 5.8, 2.2 Hz, 2H), 7.26 (d, *J* = 7.7 Hz, 1H), 7.14 (dd, *J* = 7.5, 4.9 Hz, 1H), 4.99 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) *δ* 167.4, 166.8, 155.3, 149.7, 139.5, 136.8, 136.7, 134.0, 133.7, 132.5, 131.8, 130.8, 129.9, 128.9, 128.5, 128.3, 124.9, 124.3, 124.1, 122.6, 121.8, 43.2. HRMS calcd for $C_{24}H_{16}BrN_2O_2$ $[M + H]^+$ 443.0390, found 443.0391.



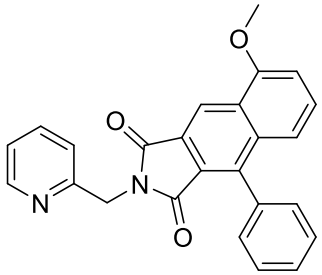
3aj

8-bromo-4-phenyl-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3aj**, 96.1 mg, yellow solid, yield: 87%) mp: 203-205 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.90 (s, 1H), 8.53 – 8.47 (m, 1H), 7.96 (d, *J* = 7.5 Hz, 1H), 7.78 (d, *J* = 8.5 Hz, 1H), 7.60 (td, *J* = 7.7, 1.8 Hz, 1H), 7.53 (dd, *J* = 4.7, 2.0 Hz, 3H), 7.45 – 7.36 (m, 3H), 7.29 – 7.23 (m, 1H), 7.14 (dd, *J* = 7.5, 5.0 Hz, 1H), 5.01 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.4, 166.8, 155.3, 149.7, 140.7, 137.2, 136.7, 134.5, 134.1, 133.1, 130.0, 129.2, 129.1, 128.8, 128.5, 128.33, 125.4, 124.7, 124.0, 122.5, 121.7, 43.3. HRMS calcd for $C_{24}H_{16}BrN_2O_2$ $[M + H]^+$ 433.0390, found 433.0383.



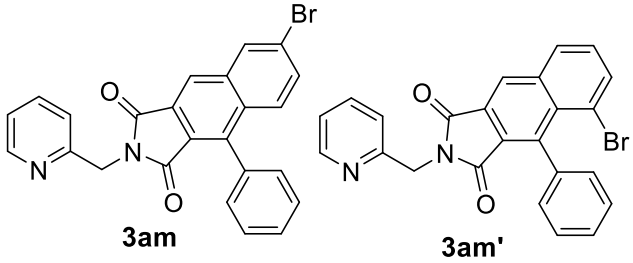
3ak

8-methyl-4-phenyl-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3ak**, 85.1 mg, yellow solid, yield: 90%) mp: 219-221 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.64 (d, *J* = 0.9 Hz, 1H), 8.51 (dt, *J* = 4.7, 1.4 Hz, 1H), 7.67 (d, *J* = 8.3 Hz, 1H), 7.60 (td, *J* = 7.7, 1.8 Hz, 1H), 7.52 (dd, *J* = 5.3, 2.0 Hz, 4H), 7.47 (dd, *J* = 8.3, 7.0 Hz, 1H), 7.42 – 7.38 (m, 2H), 7.27 – 7.24 (m, 1H), 7.14 (ddd, *J* = 7.6, 4.9, 1.1 Hz, 1H), 5.01 (s, 2H), 2.83 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.1, 167.3, 155.6, 149.6, 140.9, 137.2, 136.8, 136.0, 134.9, 130.0, 128.8, 128.5, 128.2, 127.6, 127.0, 123.6, 122.5, 121.7, 120.9, 43.2, 20.1. HRMS calcd for $C_{25}H_{19}N_2O_2$ $[M + H]^+$ 379.1441, found 379.1446.



3al

8-methoxy-4-phenyl-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3al**, 70.9 mg, yellow solid, yield: 72%) mp: 223-225 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.91 (d, J = 0.8 Hz, 1H), 8.50 (ddd, J = 4.9, 1.8, 0.9 Hz, 1H), 7.59 (td, J = 7.7, 1.8 Hz, 1H), 7.53 – 7.45 (m, 4H), 7.40 (dd, J = 7.2, 2.4 Hz, 2H), 7.37 – 7.32 (m, 1H), 7.25 (d, J = 9.5 Hz, 1H), 7.13 (ddd, J = 7.6, 4.8, 1.1 Hz, 1H), 7.01 (d, J = 7.8 Hz, 1H), 4.99 (s, 2H), 4.06 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.9, 167.4, 157.3, 155.7, 149.6, 139.9, 136.8, 136.7, 134.9, 130.0, 129.5, 128.5, 128.2, 127.7, 127.0, 124.5, 122.5, 121.7, 120.6, 119.5, 107.3, 56.1, 43.2. HRMS calcd for $C_{25}H_{19}N_2O_3$ $[M + H]^+$ 395.1390, found 395.1374.

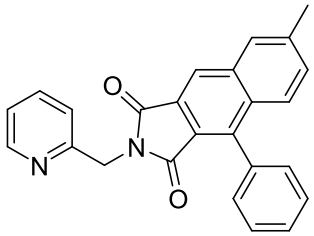


3am **3am'**

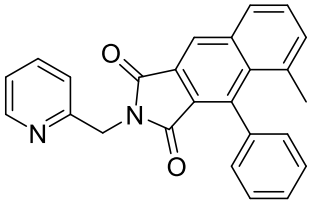
3am: 7-bromo-4-phenyl-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione

3am': 5-bromo-4-phenyl-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione

(95.0 mg, yellow solid, yield: 86%) mp: 205-207 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.49 (t, J = 4.5 Hz, 2.4H), 8.42 (s, 1.4H), 8.31 (s, 1H), 8.24 (d, J = 1.8 Hz, 1H), 8.08 (dd, J = 8.1, 1.3 Hz, 1.4H), 7.95 (dd, J = 7.6, 1.3 Hz, 1.4H), 7.70 – 7.65 (m, 2H), 7.60 (dddd, J = 13.7, 7.7, 5.0, 1.8 Hz, 3H), 7.53 (dd, J = 4.9, 1.9 Hz, 3.3H), 7.51 – 7.43 (m, 5.4H), 7.43 – 7.38 (m, 2.9H), 7.37 – 7.32 (m, 3.1H), 7.25 – 7.20 (m, 2H), 7.17 – 7.10 (m, 2.5H), 4.99 (s, 2H), 4.96 (s, 2.7H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.3, 167.0, 166.9, 166.7, 155.3, 155.3, 149.8, 149.7, 141.1, 140.6, 138.2, 137.6, 136.8, 136.7, 135.9, 134.2, 133.9, 132.5, 132.5, 132.4, 131.3, 130.4, 130.3, 130.0, 129.2, 128.9, 128.5, 128.4, 128.0, 127.7, 126.6, 125.6, 124.3, 123.9, 123.4, 122.9, 122.6, 122.5, 121.8, 121.7, 43.3, 43.3. HRMS calcd for $C_{24}H_{16}BrN_2O_2$ $[M + H]^+$ 465.0209, found 465.0244.



3an

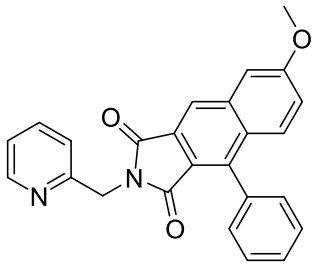


3an'

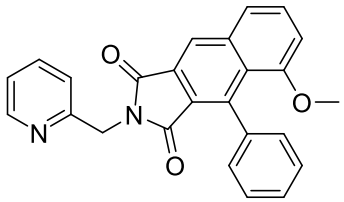
3an: 7-methyl-4-phenyl-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione

3an': 5-methyl-4-phenyl-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione

(86.0 mg, white solid, yield: 91%) mp: 214-216 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.50 (dq, J = 4.8, 2.6, 1.5 Hz, 1.7H), 8.41 (s, 1.1H), 8.33 (s, 0.6H), 7.96 (d, J = 8.0 Hz, 1.1H), 7.86 (s, 0.6H), 7.70 (d, J = 8.7 Hz, 0.6H), 7.63 – 7.55 (m, 2.6H), 7.55 – 7.49 (m, 2.1H), 7.47 (ddd, J = 6.7, 4.1, 1.2 Hz, 2.9H), 7.41 (dt, J = 6.8, 2.7 Hz, 2.5H), 7.37 (dt, J = 7.8, 2.1 Hz, 2.6H), 7.25 – 7.20 (m, 1.6H), 7.14 (dt, J = 6.9, 3.3 Hz, 1.7H), 5.00 (s, 1.2H), 4.96 (s, 2.0H), 2.57 (s, 1.7H), 2.02 (s, 3.0H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.0, 166.6, 166.3, 154.6, 154.5, 148.6, 140.2, 139.4, 138.6, 138.2, 137.5, 136.1, 135.9, 134.9, 133.7, 133.1, 132.8, 132.6, 130.4, 129.0, 129.0, 128.7, 128.4, 127.9, 127.6, 127.5, 127.3, 127.3, 127.1, 126.9, 126.0, 124.9, 124.5, 123.0, 122.2, 121.5, 120.8, 120.7, 42.2, 42.1, 24.0, 20.8. HRMS calcd for $C_{25}H_{19}N_2O_2$ $[M + H]^+$ 379.1441, found 379.1437.



3ao



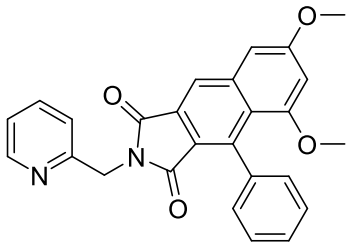
3ao'

3ao: 7-methoxy-4-phenyl-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione

3ao': 5-methoxy-4-phenyl-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione

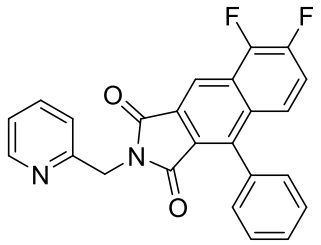
(82.7 mg, yellow solid, yield: 84%) mp: 200-202 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.37 (dq, J = 5.6, 1.7 Hz, 1.9H), 8.22 (s, 1H), 8.16 (s, 0.8H), 7.58 (d, J = 9.3 Hz, 0.8H), 7.53 (dd, J = 8.2, 1.2 Hz, 1H), 7.49 – 7.42 (m, 3.1H), 7.41 – 7.36 (m, 2.4H), 7.30 – 7.25 (m, 4.6H), 7.24 (d, J = 2.8 Hz, 0.9H), 7.17 – 7.14 (m, 2.4H), 7.12 – 7.06 (m, 2.5H), 7.03 – 6.97 (m, 2H), 6.81 (dd, J = 7.8, 1.2 Hz, 1H), 4.85 (s, 1.5H), 4.82 (s, 2H), 3.85 (s, 2.2H), 3.30 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.9, 167.6, 167.4, 167.1, 160.1, 159.3, 155.7, 155.6, 149.7, 149.6, 140.5, 140.3, 139.3, 137.7, 137.6, 136.8,

136.7, 134.7, 130.6, 130.2, 130.0, 129.9, 128.9, 128.6, 128.2, 128.2, 127.9, 127.1, 127.0, 126.9, 126.5, 124.6, 123.2, 123.2, 122.5, 122.4, 122.0, 121.8, 121.7, 121.6, 121.4, 109.9, 108.8, 55.8, 55.7, 43.2, 43.2. HRMS calcd for $C_{25}H_{19}N_2O_3$ $[M + H]^+$ 395.1390, found 395.1416.



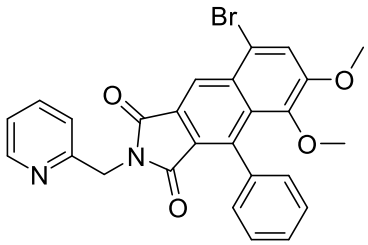
3ap

5,7-dimethoxy-4-phenyl-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3ap**, 74.2 mg, yellow solid, yield: 70%) mp: 210-212 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.47 (d, J = 4.8 Hz, 1H), 8.18 (s, 1H), 7.56 (td, J = 7.7, 1.9 Hz, 1H), 7.36 (d, J = 5.9 Hz, 3H), 7.24 (d, J = 5.1 Hz, 2H), 7.18 (d, J = 7.9 Hz, 1H), 7.10 (t, J = 6.3 Hz, 1H), 6.94 (d, J = 2.3 Hz, 1H), 6.52 (d, J = 2.3 Hz, 1H), 4.91 (s, 2H), 3.94 (s, 3H), 3.37 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.8, 167.2, 161.0, 160.3, 155.7, 149.6, 140.3, 139.3, 139.2, 136.8, 129.0, 127.9, 127.0, 126.9, 123.3, 122.6, 122.5, 122.2, 121.6, 102.0, 101.7, 55.8, 55.6, 43.1. HRMS calcd for $C_{26}H_{21}N_2O_4$ $[M + H]^+$ 425.1496, found 425.1491.



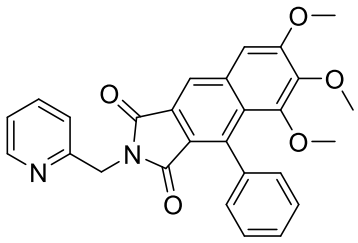
3aq

7,8-difluoro-4-phenyl-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3aq**, 88.0 mg, yellow solid, yield: 88%) mp: 201-203 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.68 (s, 1H), 8.49 (d, J = 4.8 Hz, 1H), 7.64 – 7.57 (m, 2H), 7.56 – 7.50 (m, 3H), 7.47 – 7.37 (m, 3H), 7.29 – 7.24 (m, 1H), 7.14 (t, J = 6.2 Hz, 1H), 5.00 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.0, 166.7, 155.1, 149.7, 147.5 (dd, J = 39 Hz), 145.1 (d, J = 12 Hz), 140.4, 136.8, 133.6, 132.7, 129.9, 129.3, 129.0 128.4, 127.3 (d, J = 13 Hz), 125.5 (t, J = 6 Hz), 124.2, 122.6, 121.8, 119.6 (d, J = 20 Hz), 116.8 (d, J = 6 Hz), 43.3. HRMS calcd for $C_{24}H_{15}F_2N_2O_2$ $[M + H]^+$ 401.1096, found 401.1098.



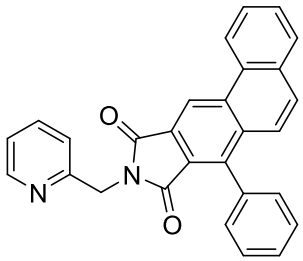
3ar

8-bromo-5,6-dimethoxy-4-phenyl-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3ar**, 104.2 mg, yellow solid, yield: 83%) mp: 188-190 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.78 (d, J = 1.8 Hz, 1H), 8.48 (dd, J = 5.1, 1.9 Hz, 1H), 7.77 (d, J = 1.9 Hz, 1H), 7.60 – 7.54 (m, 1H), 7.41 (d, J = 6.9 Hz, 3H), 7.36 – 7.29 (m, 2H), 7.20 (d, J = 7.9 Hz, 1H), 7.12 (dd, J = 7.6, 5.0 Hz, 1H), 4.95 (s, 2H), 3.96 (d, J = 1.9 Hz, 3H), 3.17 (d, J = 1.8 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.2, 166.6, 155.3, 152.7, 149.6, 146.8, 138.9, 138.1, 136.7, 131.6, 129.7, 128.0, 127.2, 126.7, 126.1, 124.7, 122.5, 121.6, 121.37, 120.4, 60.7, 56.8, 43.1. HRMS calcd for $C_{26}H_{20}BrN_2O_4$ $[M + H]^+$ 503.0601, found 503.0620.



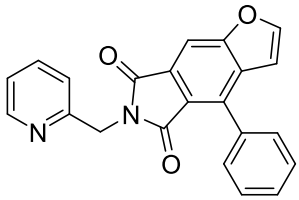
3as

5,6,7-trimethoxy-4-phenyl-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3as**, 71.5 mg, yellow solid, yield: 63%) mp: 224-226 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.49 (d, J = 5.0 Hz, 1H), 8.23 (d, J = 2.1 Hz, 1H), 7.62 – 7.54 (m, 1H), 7.43 (d, J = 7.2 Hz, 3H), 7.36 – 7.31 (m, 2H), 7.20 (d, J = 6.7 Hz, 2H), 7.16 – 7.09 (m, 1H), 4.93 (d, J = 2.1 Hz, 2H), 4.05 (d, J = 1.9 Hz, 3H), 3.89 (d, J = 1.7 Hz, 3H), 3.27 (d, J = 1.8 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.7, 167.1, 155.6, 155.5, 152.4, 149.5, 144.9, 139.0, 138.5, 136.7, 134.0, 128.0, 127.6, 127.1, 127.0, 125.8, 123.4, 123.4, 122.4, 121.5, 105.6, 61.1, 60.9, 56.2, 43.0. HRMS calcd for $C_{27}H_{23}N_2O_5$ $[M + H]^+$ 455.1601, found 455.1597.



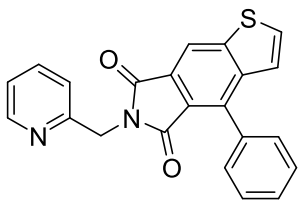
3at

7-phenyl-9-(pyridin-2-ylmethyl)-8*H*-naphtho[1,2-*f*]isoindole-8,10(9*H*)-dione: (**3at**, 77.6 mg, yellow solid, yield: 75%) mp: 250-252 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.28 (s, 1H), 8.85 (d, *J* = 8.2 Hz, 1H), 8.64 – 8.46 (m, 1H), 7.95 (dd, *J* = 7.9, 1.4 Hz, 1H), 7.83 (d, *J* = 9.2 Hz, 1H), 7.79 (ddd, *J* = 8.4, 6.9, 1.5 Hz, 1H), 7.76 – 7.73 (m, 1H), 7.71 (d, *J* = 9.1 Hz, 1H), 7.61 (td, *J* = 7.7, 1.8 Hz, 1H), 7.55 (qd, *J* = 5.2, 1.8 Hz, 3H), 7.44 (dd, *J* = 7.3, 2.2 Hz, 2H), 7.28 (d, *J* = 7.9 Hz, 1H), 7.17 – 7.12 (m, 1H), 5.03 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.3, 167.5, 155.7, 149.8, 140.3, 136.8, 135.0, 134.9, 134.2, 132.8, 130.8, 130.2, 130.2, 129.0, 128.9, 128.7, 128.7, 128.4, 128.1, 125.3, 125.3, 123.9, 122.6, 121.8, 118.7, 43.4. HRMS calcd for $C_{28}H_{19}N_2O_2$ $[M + H]^+$ 415.1441, found 415.1438.



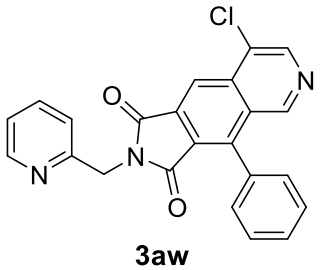
3au

4-phenyl-6-(pyridin-2-ylmethyl)-5*H*-furo[2,3-*f*]isoindole-5,7(6*H*)-dione: (**3au**, 71.7 mg, brown solid, yield: 81%) mp: 149-151 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.54 – 8.47 (m, 1H), 8.00 (d, *J* = 1.0 Hz, 1H), 7.82 (d, *J* = 2.3 Hz, 1H), 7.64 – 7.55 (m, 3H), 7.54 – 7.45 (m, 3H), 7.28 – 7.23 (m, 1H), 7.19 – 7.11 (m, 1H), 6.86 (dd, *J* = 2.2, 1.0 Hz, 1H), 4.99 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.8, 167.6, 157.1, 155.7, 149.7, 148.8, 136.8, 135.7, 134.0, 133.1, 130.1, 129.9, 129.0, 128.3, 122.5, 122.5, 121.7, 107.9, 107.2, 43.2. HRMS calcd for $C_{22}H_{15}N_2O_3$ $[M + H]^+$ 355.1077, found 355.1089.



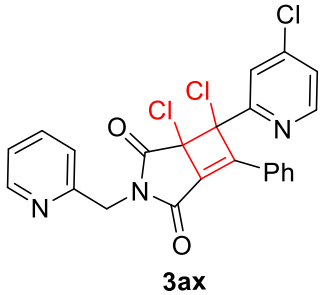
3av

4-phenyl-6-(pyridin-2-ylmethyl)-5*H*-thieno[2,3-*f*]isoindole-5,7(6*H*)-dione: (**3av**, 79.6 mg, brown solid, yield: 86%) mp: 175-177 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.50 (d, J = 4.9 Hz, 1H), 8.40 (s, 1H), 7.66 (d, J = 5.5 Hz, 1H), 7.60 (td, J = 7.7, 1.7 Hz, 1H), 7.54 – 7.44 (m, 5H), 7.35 (d, J = 5.5 Hz, 1H), 7.24 (s, 1H), 7.13 (dd, J = 7.5, 5.0 Hz, 1H), 4.99 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.9, 167.5, 155.6, 149.7, 144.5, 143.7, 137.1, 136.7, 134.8, 131.0, 129.9, 128.8, 128.4, 128.2, 125.0, 123.8, 122.5, 121.6, 118.0, 43.2. HRMS calcd for $C_{22}H_{15}N_2O_2S$ $[M + H]^+$ 371.0849, found 371.0852.



3aw

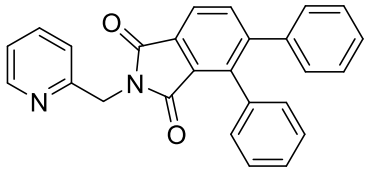
8-chloro-4-phenyl-2-(pyridin-2-ylmethyl)-1*H*-pyrrolo[3,4-*g*]isoquinoline-1,3(2*H*)-dione: (**3aw**, 52.9 mg, yellow solid, yield: 53%) ^{1}H NMR (400 MHz, $CDCl_3$) ^{1}H NMR (400 MHz,$CDCl_3$) δ 9.11 (s, 1H), 8.83 (s, 1H), 8.79 (s, 1H), 8.53 – 8.46 (m, 1H), 7.63 (td, J = 7.7, 1.8 Hz, 1H), 7.56 (q, J = 2.9 Hz, 3H), 7.45 (dd, J = 6.6, 2.9 Hz, 2H), 7.28 (d, J = 7.8 Hz, 1H), 7.17 (dd, J = 7.5, 4.9 Hz, 1H), 5.03 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 166.6, 166.0, 154.7, 151.7, 149.8, 145.0, 141.5, 136.9, 136.7, 132.8, 132.2, 130.9, 130.2, 129.5, 128.5, 125.8, 122.8, 121.9, 119.8, 43.4. HRMS calcd for $C_{23}H_{14}ClN_3O_2$ $[M + Na]^+$ 422.0667, found 422.0675.



3ax

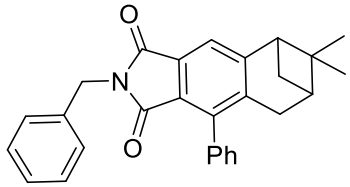
1,7-dichloro-7-(4-chloropyridin-2-yl)-6-phenyl-3-(pyridin-2-ylmethyl)-3-azabicyclo[3.2.0]hept-5-ene-2,4-dione: (**3ax**, 52.8 mg, brown solid, yield: 45%) mp: 138-140 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.68 (d, J = 5.3 Hz, 1H), 8.67 – 8.63 (m, 2H), 8.23 (dt, J = 4.7, 1.4 Hz, 1H), 8.07 (d, J = 1.8 Hz, 1H), 7.58 (td, J = 7.7, 1.8 Hz, 1H), 7.52 – 7.45 (m, 3H), 7.34 (dd, J = 5.3, 1.9 Hz, 1H), 7.14 (d, J = 7.8 Hz, 1H), 7.11 – 7.05 (m, 1H), 4.91 (d, J = 3.2 Hz, 2H). ^{13}C NMR

(100 MHz, $CDCl_3$) δ 169.5, 169.5, 152.8, 150.6, 149.9, 149.4, 146.5, 145.0, 137.0, 136.8, 131.7, 131.0, 128.9, 128.5, 125.1, 124.4, 122.8, 121.3, 68.4, 67.7, 43.9. HRMS calcd for $C_{23}H_{15}Cl_3N_3O_2$ $[M + H]^+$ 470.0224, found 470.0222.



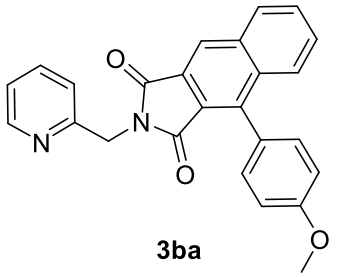
3ay

4,5-diphenyl-2-(pyridin-2-ylmethyl)isoindoline-1,3-dione: (**3ay**, 75.1 mg, yellow solid, yield: 77%) mp: 152-154 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.51 (d, J = 4.8 Hz, 1H), 7.94 (d, J = 7.6 Hz, 1H), 7.76 (d, J = 7.6 Hz, 1H), 7.60 (td, J = 7.7, 1.7 Hz, 1H), 7.24 (dd, J = 6.4, 4.7 Hz, 4H), 7.20 (t, J = 3.4 Hz, 3H), 7.14 (td, J = 5.0, 2.5 Hz, 3H), 7.08 – 7.03 (m, 2H), 4.96 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.8, 167.5, 155.6, 149.7, 148.4, 139.5, 139.5, 136.8, 135.9, 134.9, 131.9, 130.4, 129.8, 129.3, 128.1, 127.9, 127.7, 127.6, 122.7, 122.5, 121.7, 43.1. HRMS calcd for $C_{26}H_{19}N_2O_2$ $[M + H]^+$391.1441, found 391.1423.



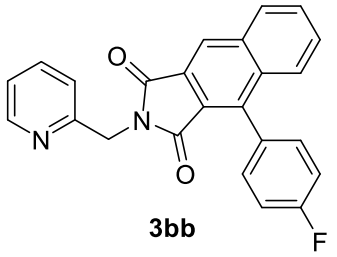
3az

2-benzyl-6,6-dimethyl-9-phenyl-5,6,7,8-tetrahydro-1*H*-5,7-methanobenzo[*f*]isoindole-1,3(2*H*)-dione: (**3az**, 93.6 mg, colorless oil, yield: 92%): ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.51 – 7.44 (m, 3H), 7.43 (s, 1H), 7.41 – 7.37 (m, 2H), 7.26 (qd, J = 6.7, 4.7 Hz, 5H), 4.72 (s, 2H), 2.98 (t, J = 5.6 Hz, 1H), 2.72 (d, J = 2.9 Hz, 2H), 2.66 (dt, J = 9.6, 5.8 Hz, 1H), 2.24 (tt, J = 6.0, 2.9 Hz, 1H), 1.39 (s, 3H), 1.22 (d, J = 9.6 Hz, 1H), 0.67 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.5, 167.8, 154.2, 141.1, 139.6, 139.2, 136.9, 135.7, 133.6, 130.3, 128.9, 128.7, 128.7, 128.6, 128.4, 128.4, 128.1, 127.7, 127.0, 120.4, 49.0, 41.5, 40.1, 38.7, 33.2, 31.3, 25.9, 21.5. HRMS calcd for $C_{28}H_{26}NO_2$ $[M + H]^+$408.1958, found 408.1955.



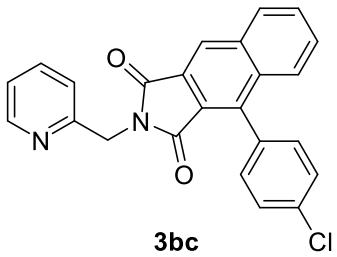
3ba

4-(4-methoxyphenyl)-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3ba**, 86.7 mg, yellow solid, yield: 88%) mp: 234-236 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.52 (d, J = 5.0 Hz, 1H), 8.40 (s, 1H), 8.09 (d, J = 8.1 Hz, 1H), 7.90 (d, J = 8.5 Hz, 1H), 7.68 (t, J = 7.4 Hz, 1H), 7.67 – 7.56 (m, 2H), 7.36 (d, J = 8.3 Hz, 2H), 7.27 (d, J = 6.8 Hz, 1H), 7.20 – 7.12 (m, 1H), 7.06 (d, J = 8.3 Hz, 2H), 5.03 (s, 2H), 3.90 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.8, 167.4, 159.9, 155.5, 154.8, 149.5, 140.6, 135.9, 135.7, 131.5, 130.5, 130.1, 129.2, 129.0, 128.8, 128.1, 126.4, 124.4, 122.6, 121.8, 113.8, 55.4, 43.1. HRMS calcd for $C_{25}H_{19}N_2O_3$ $[M + H]^+$ 395.1390, found 395.1381.



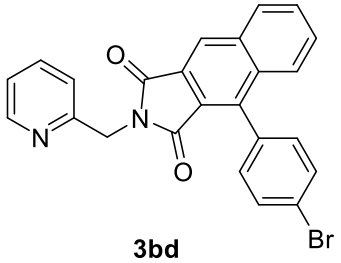
3bb

4-(4-fluorophenyl)-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3bb**, 75.4 mg, yellow solid, yield: 79%) mp: 236-238 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.49 (d, J = 4.8 Hz, 1H), 8.41 (d, J = 2.7 Hz, 1H), 8.09 (d, J = 8.1 Hz, 1H), 7.79 (d, J = 8.5 Hz, 1H), 7.68 (t, J = 7.6 Hz, 1H), 7.60 (tt, J = 7.9, 3.9 Hz, 2H), 7.42 – 7.33 (m, 2H), 7.28 – 7.17 (m, 3H), 7.13 (dd, J = 7.7, 4.8 Hz, 1H), 4.98 (d, J = 2.6 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.7, 167.3, 163.0 (d, J = 246 Hz), 155.4, 149.7, 139.4, 136.8, 135.6, 135.6, 132.0, 131.9, 130.6, 130.2 (d, J = 3 Hz), 129.4, 129.1, 128.4, 128.0, 124.8, 124.2, 122.6, 121.8, 115.4 (d, J = 22 Hz), 43.2. HRMS calcd for $C_{24}H_{16}FN_2O_2$ $[M + H]^+$ 383.1190, found 383.1185.



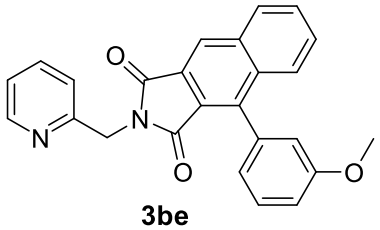
3bc

4-(4-chlorophenyl)-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione:（**3bc**, 72.6 mg, yellow solid, yield: 73%）mp: 231-233 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.47 (d, J = 4.9 Hz, 1H), 8.40 (s, 1H), 8.07 (d, J = 8.2 Hz, 1H), 7.75 (d, J = 8.4 Hz, 1H), 7.67 (t, J = 7.5 Hz, 1H), 7.62 – 7.55 (m, 2H), 7.47 (d, J = 8.2 Hz, 2H), 7.33 (d, J = 8.3 Hz, 2H), 7.23 (d, J = 7.2 Hz, 1H), 7.16 – 7.08 (m, 1H), 4.97 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.7, 167.3, 155.4, 149.8, 139.1, 136.8, 135.6, 135.4, 134.9, 132.9, 131.5, 130.6, 129.5, 129.2, 128.6, 128.4, 128.0, 125.0, 124.1, 122.6, 121.8, 43.3. HRMS calcd for $C_{24}H_{16}ClN_2O_2$ $[M + H]^+$ 399.0895, found 399.0893.



3bd

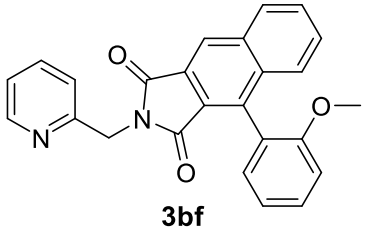
4-(4-bromophenyl)-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3bd**, 90.6 mg, yellow solid, yield: 82%) mp: 234-236 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.53 – 8.48 (m, 1H), 8.43 (s, 1H), 8.10 (d, J = 8.1 Hz, 1H), 7.79 (d, J = 8.5 Hz, 1H), 7.70 (t, J = 7.5 Hz, 1H), 7.66 (d, J = 8.1 Hz, 2H), 7.64 – 7.58 (m, 2H), 7.34 – 7.24 (m, 3H), 7.15 (dd, J = 7.5, 5.0 Hz, 1H), 5.00 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.6, 167.2, 155.3, 149.7, 139.0, 136.8, 135.6, 135.3, 133.3, 131.8, 131.6, 130.6, 129.5, 129.2, 128.3, 127.9, 124.9, 124.1, 123.1, 122.6, 121.8, 43.3. HRMS calcd for $C_{24}H_{16}BrN_2O_2$ $[M + H]^+$ 443.0390, found 443.0386.



3be

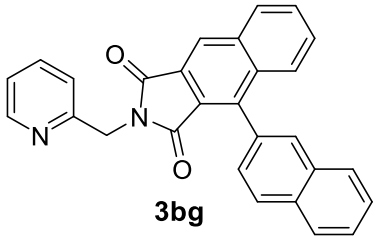
4-(3-methoxyphenyl)-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3be**, 91.6 mg, yellow solid, yield: 93%) mp: 190-192 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.50 (d, J = 4.8 Hz, 1H), 8.40 (s, 1H), 8.07 (d, J = 8.1 Hz, 1H), 7.84 (d, J = 8.5 Hz, 1H), 7.71 – 7.63 (m, 1H), 7.58 (tt, J = 7.8, 5.8, 2.0 Hz, 2H), 7.44 (t, J = 7.9 Hz, 1H), 7.25 (d, J = 7.5 Hz, 1H), 7.12 (t, J = 6.4 Hz, 1H), 7.04 (d, J = 8.1 Hz, 1H), 6.99 (d, J = 7.5 Hz, 1H), 6.94 (d, J = 2.5 Hz, 1H), 5.00 (s, 2H), 3.82 (d, J = 2.0 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.7, 167.0, 159.3, 155.5, 149.6, 140.2, 136.7, 135.8,

135.5, 130.4, 129.3, 129.2, 129.0, 128.7, 127.9, 124.6, 123.9, 122.5, 122.3, 121.7, 115.8, 113.9, 55.3, 43.2. HRMS calcd for $C_{25}H_{19}N_2O_3$ $[M + H]^+$ 395.1390, found 395.1388.



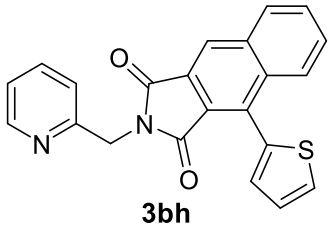
3bf

4-(2-methoxyphenyl)-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3bf**, 79.8 mg, yellow solid, yield: 81%) mp: 204-206 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.51 (d, J = 4.8 Hz, 1H), 8.41 (s, 1H), 8.08 (d, J = 8.2 Hz, 1H), 7.78 (d, J = 8.4 Hz, 1H), 7.66 (t, J = 7.7 Hz, 1H), 7.58 (d, J = 8.0 Hz, 2H), 7.50 (t, J = 7.7 Hz, 1H), 7.25 (d, J = 7.7 Hz, 2H), 7.10 (dd, J = 19.0, 8.1 Hz, 3H), 5.01 (s, 2H), 3.66 (t, J = 2.0 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.9, 167.2, 157.4, 155.7, 149.6, 137.0, 136.7, 135.6, 131.3, 130.5, 130.3, 129.0, 128.9, 128.5, 128.0, 124.8, 124.5, 123.4, 122.4, 121.6, 120.6, 111.2, 55.7, 43.2. HRMS calcd for $C_{25}H_{19}N_2O_3$ $[M + H]^+$ 395.1390, found 395.1379.



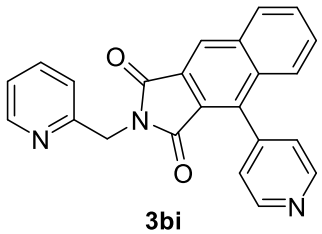
3bg

4-(naphthalen-2-yl)-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3bg**, 86.9 mg, yellow solid, yield: 84%) mp: 214-216 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.53 – 8.49 (m, 1H), 8.46 (s, 1H), 8.11 (d, J = 8.2 Hz, 1H), 8.00 (d, J = 8.4 Hz, 1H), 7.97 – 7.92 (m, 1H), 7.91 (s, 1H), 7.86 (dd, J = 11.3, 8.2 Hz, 2H), 7.68 (t, J = 7.5 Hz, 1H), 7.59 (dd, J = 7.8, 1.7 Hz, 1H), 7.54 (ddd, J = 8.4, 4.3, 1.8 Hz, 4H), 7.31 – 7.22 (m, 1H), 7.12 (dd, J = 7.5, 5.0 Hz, 1H), 5.00 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.8, 167.2, 155.4, 149.7, 140.4, 136.7, 135.7, 135.6, 133.2, 133.0, 131.9, 130.5, 129.4, 129.3, 129.1, 128.7, 128.4, 128.0, 127.8, 126.6, 126.49, 124.7, 124.1, 122.5, 121.7, 43.2. HRMS calcd for $C_{28}H_{19}N_2O_2$ $[M + H]^+$ 415.1441, found 415.1437.



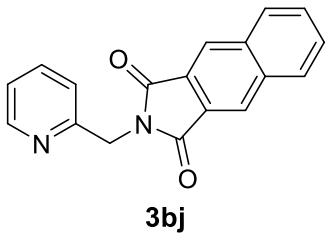
3bh

2-(pyridin-2-ylmethyl)-4-(thiophen-2-yl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione：(**3bh**, 78.6 mg, yellow solid, yield: 85%) ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.53– 8.49 (m, 1H), 8.44 (s, 1H), 8.11 – 8.06 (m, 1H), 8.03 (d, *J* = 8.3 Hz, 1H), 7.73 – 7.68 (m, 1H), 7.68 – 7.63 (m, 1H), 7.63 – 7.57 (m, 2H), 7.27 (d, *J* = 8.3 Hz, 1H), 7.24 (dd, *J* = 5.0, 3.5 Hz, 1H), 7.21 (dd, *J* = 3.5, 1.1 Hz, 1H), 7.15 (dd, *J* = 7.5, 4.9 Hz, 1H), 5.02 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.5, 166.8, 155.5, 149.7, 136.8, 136.6, 135.5, 133.9, 133.0, 130.4, 129.6, 129.3, 128.5, 128.0, 127.5, 127.2, 125.7, 125.4, 122.6, 121.8, 43.3. HRMS calcd for $C_{22}H_{15}N_2O_2S$ $[M + H]^+$ 371.0849, found 395.0852.



3bi

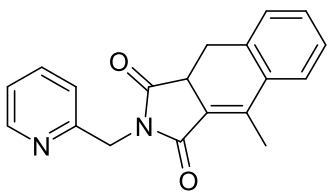
2-(pyridin-2-ylmethyl)-4-(pyridin-4-yl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3bi**, 43.8 mg, yellow solid, yield: 48%) mp: 250-252 ℃； ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.81 (d, J = 5.0 Hz, 2H), 8.50 (d, J = 4.9 Hz, 1H), 8.49 (s, 1H), 8.14 (d, J = 8.2 Hz, 1H), 7.77 – 7.71 (m, 1H), 7.69 (d, J = 8.1 Hz, 1H), 7.67 – 7.64 (m, 1H), 7.62 (dd, J = 7.6, 1.8 Hz, 1H), 7.44 (d, J = 5.1 Hz, 2H), 7.28 (d, J = 7.8 Hz, 1H), 7.18 – 7.14 (m, 1H), 5.01 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.4, 166.9, 155.1, 149.8, 149.0, 144.0, 136.9, 136.5, 135.7, 134.4, 130.8, 129.9, 129.5, 127.9, 127.8, 125.7, 125.4, 124.2, 122.7, 121.9, 43.3. HRMS calcd for $C_{23}H_{16}N_3O_2$ $[M + H]^+$ 366.1237, found 366.1233.



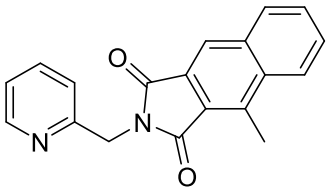
3bj

2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3bj**, 55.4 mg, yellow solid, yield: 77%) ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.49 – 8.45 (m, 1H), 8.30 (d, *J* = 1.2 Hz, 2H), 7.99 (dd, *J* = 6.2, 3.4 Hz, 2H), 7.66 – 7.61 (m, 2H), 7.60 – 7.54 (m, 1H), 7.25 – 7.18 (m, 1H), 7.13 – 7.07 (m, 1H),

5.03 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.9, 155.4, 149.6, 136.9, 135.6, 130.4, 129.3, 128.0, 125.0, 122.6, 121.8, 43.3. HRMS calcd for $C_{18}H_{13}N_2O_2$ $[M + H]^+$ 289.0972, found 289.0970.



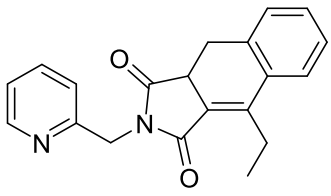
3bk



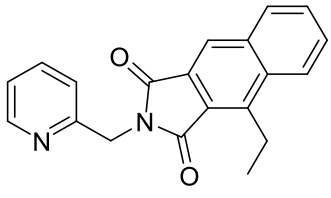
3bk'

3bk:9-methyl-2-(pyridin-2-ylmethyl)-3a,4-dihydro-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione (52.2 mg, yellow solid, total yield: 85%) ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.53 (dt, J = 4.9, 1.3 Hz, 1H), 7.64 (td, J = 7.7, 1.8 Hz, 1H), 7.56 – 7.51 (m, 1H), 7.36 – 7.32 (m, 2H), 7.30 (dd, J = 9.3, 3.9 Hz, 2H), 7.20 – 7.06 (m, 1H), 5.03 – 4.85 (m, 2H), 3.63 – 3.48 (m, 1H), 3.28 (dd, J = 15.1, 6.3 Hz, 1H), 2.85 (t, J = 15.5 Hz, 1H), 2.64 (d, J = 2.0 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.7, 168.6, 155.2, 149.8, 142.9, 136.8, 135.8, 135.7, 130.0, 128.6, 127.7, 126.2, 122.6, 122.3, 121.9, 43.5, 40.1, 29.0, 14.5. HRMS calcd for $C_{19}H_{17}N_2O_2$ $[M + H]^+$ 305.1285, found 305.1283.

3bk': 4-methyl-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione (12.3 mg, yellow solid, total yield: 85%) ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.56 – 8.53 (m, 1H), 8.28 – 8.21 (m, 2H), 8.03 (dd, J = 7.8, 1.6 Hz, 1H), 7.71 (dddd, J = 16.5, 8.2, 6.9, 1.5 Hz, 2H), 7.64 (td, J = 7.7, 1.8 Hz, 1H), 7.32 (d, J = 7.9 Hz, 1H), 7.20 – 7.14 (m, 1H), 5.07 (s, 2H), 3.11 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.0, 167.8, 155.7, 149.8, 137.8, 136.9, 136.0, 135.2, 131.0, 129.1, 128.9, 128.0, 126.1, 124.2, 123.4, 122.6, 121.8, 43.2, 13.4. HRMS calcd for $C_{19}H_{15}N_2O_2$ $[M + H]^+$ 303.1128, found 303.1121.



3bl

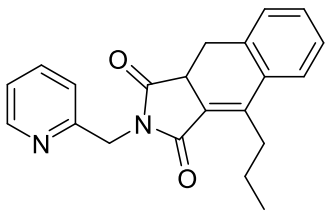


3bl'

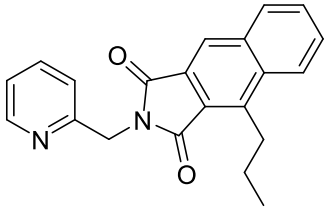
3bl: 9-ethyl-2-(pyridin-2-ylmethyl)-3a,4-dihydro-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione (50.1 mg, yellow solid, total yield: 81%) ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.47 (dd, J = 4.9, 1.5 Hz, 1H), 7.58 (td, J = 7.7, 1.7 Hz, 1H), 7.53 – 7.47 (m, 1H), 7.27 (dtt, J = 8.7, 6.0, 3.4 Hz, 3H), 7.23 – 7.17 (m, 1H), 7.10 (dd, J = 7.5, 4.9 Hz, 1H), 4.95 – 4.79 (m, 2H), 3.47 (dd, J = 15.9, 6.2 Hz, 1H), 3.28

(dd, *J* = 13.3, 7.2 Hz, 1H), 3.20 (dd, *J* = 15.1, 6.3 Hz, 1H), 3.00 (ddd, *J* = 13.1, 7.5, 1.5 Hz, 1H), 2.77 (t, *J* = 15.5 Hz, 1H), 1.15 (t, *J* = 7.5 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.6, 168.0, 155.1, 149.6, 149.0, 136.7, 136.2, 134.2, 129.8, 128.8, 127.6, 126.0, 122.5, 121.8, 121.5, 43.3, 39.9, 29.1, 21.1, 14.4. HRMS calcd for $C_{20}H_{19}N_2O_2$ $[M + H]^+$ 319.1441, found 319.1437.

3bl': 4-ethyl-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione (14.2 mg, yellow solid, total yield: 81%) ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.58 – 8.52 (m, 1H), 8.27 (d, *J* = 8.3 Hz, 1H), 8.24 (s, 1H), 8.07 – 8.01 (m, 1H), 7.75 – 7.70 (m, 1H), 7.70 – 7.66 (m, 1H), 7.67 – 7.61 (m, 1H), 7.31 (d, *J* = 7.9 Hz, 1H), 7.17 (dd, *J* = 7.5, 5.0 Hz, 1H), 5.07 (s, 2H), 3.66 (q, *J* = 7.6 Hz, 2H), 1.37 (t, *J* = 7.5 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.7, 168.1, 155.1, 149.7, 149.1, 136.7, 136.2, 134.2, 129.8, 128.8, 127.6, 126.0, 122.5, 121.8, 121.5, 43.4, 39.9, 29.1, 21.1, 14.4. HRMS calcd for $C_{20}H_{17}N_2O_2$ $[M + H]^+$ 317.1285, found 317.1282.



3bm

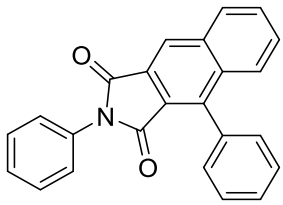


3bm'

3bm:9-propyl-2-(pyridin-2-ylmethyl)-3a,4-dihydro-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione (53.7 mg, yellow solid, total yield: 86%) ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.54 (q, *J* = 1.6 Hz, 1H), 7.65 (td, *J* = 7.7, 1.8 Hz, 1H), 7.59 – 7.51 (m, 1H), 7.37 – 7.27 (m, 3H), 7.26 (s, 2H), 7.22 – 7.13 (m, 1H), 5.01 – 4.87 (m, 2H), 3.54 (ddd, *J* = 16.0, 6.2, 1.5 Hz, 1H), 3.38 – 3.27 (m, 1H), 3.31 – 3.21 (m, 1H), 3.00 (dddd, *J* = 12.7, 9.6, 5.4, 1.6 Hz, 1H), 2.83 (t, *J* = 15.5 Hz, 1H), 1.70 – 1.49 (m, 1H), 0.98 (t, *J* = 7.4 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.7, 168.2, 155.1, 149.5, 147.7, 137.0, 136.2, 134.5, 129.8, 128.8, 127.6, 126.2, 122.6, 122.2, 121.8, 43.3, 40.0, 29.6, 29.2, 23.2, 14.2. HRMS calcd for $C_{21}H_{21}N_2O_2$ $[M + H]^+$ 333.1598, found 333.1596.

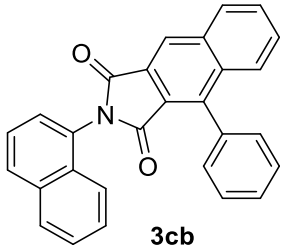
3bm': 4-propyl-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione (16.9 mg, yellow solid, total yield: 86%) mp: 152-154 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.54 (dt, *J* = 4.8, 1.4 Hz, 1H), 8.27 (s, 1H), 8.25 (d, *J* = 3.7 Hz, 1H), 8.03 (dd, *J* = 7.9, 1.7 Hz, 1H), 7.75 – 7.62 (m, 3H), 7.31 (d, *J* = 7.9 Hz, 1H), 7.21 – 7.14 (m, 1H), 5.08 (s, 2H), 3.67 – 3.56 (m, 2H), 1.83 – 1.68 (m, 2H), 1.09 (t, *J* = 7.3 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.7, 167.9, 155.7, 149.7, 142.7, 137.0,

135.6, 135.2, 131.2, 129.0, 128.8, 128.0, 126.1, 123.8, 123.5, 122.6, 121.7, 43.2, 29.0, 24.65, 14.56. HRMS calcd for $C_{21}H_{19}N_2O_2$ $[M + H]^+$ 331.1441, found 331.1438.



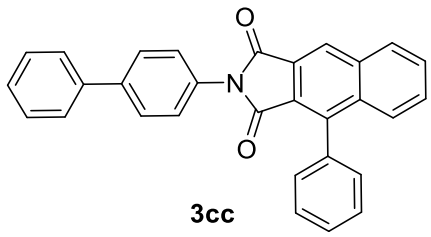
3ca

2,4-diphenyl-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3ca**, 52.4 mg, white solid, yield: 60%) mp: 205-207 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.51 (s, 1H), 8.14 (d, J = 8.1 Hz, 1H), 7.86 (d, J = 8.5 Hz, 1H), 7.72 (t, J = 7.5 Hz, 1H), 7.63 (t, J = 7.7 Hz, 1H), 7.55 (q, J = 4.4, 3.7 Hz, 3H), 7.46 (d, J = 3.0 Hz, 6H), 7.37 (dq, J = 6.0, 3.0 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.0, 166.5, 141.0, 135.8, 135.8, 134.5, 131.9, 130.5, 130.0, 129.4, 129.2, 129.0, 128.8, 128.7, 128.3, 128.2, 127.56, 126.8, 124.9, 123.5. HRMS calcd for $C_{24}H_{16}NO_2$ $[M + H]^+$ 350.1176, found 350.1174.



3cb

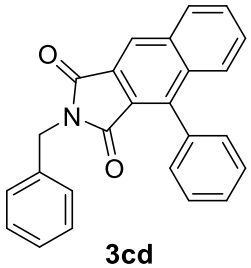
2-(naphthalen-1-yl)-4-phenyl-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3cb**, 74.8 mg, yellow solid, yield: 75%) mp: 212-214 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.44 (s, 1H), 8.03 (d, J = 8.1 Hz, 1H), 7.80 (q, J = 7.0, 5.2 Hz, 3H), 7.55 (ddd, J = 18.9, 14.4, 7.5 Hz, 3H), 7.44 – 7.35 (m, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.4, 167.0, 141.2, 135.8, 134.5, 134.3, 130.6, 130.3, 130.1, 130.0, 129.9, 129.4, 129.3, 128.8, 128.6, 128.6, 128.3, 127.8, 127.2, 127.1, 126.5, 125.4, 125.1, 123.7, 122.7. HRMS calcd for $C_{28}H_{18}NO_2$ $[M + H]^+$ 400.1332, found 400.1328.



3cc

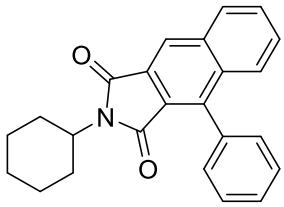
2-([1,1'-biphenyl]-4-yl)-4-phenyl-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3cc**, 65.9 mg, yellow solid, yield: 62%) mp: 225-227 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.52 (s, 1H), 8.14 (d, J = 8.2 Hz, 1H), 7.87 (d, J = 8.5 Hz, 1H), 7.73 (t, J = 7.5 Hz, 1H), 7.66 (dd, J = 12.4, 8.3 Hz, 3H), 7.59 (q,

J = 8.0, 6.7 Hz, 3H), 7.56 – 7.51 (m, 4H), 7.45 (t, *J* = 7.7 Hz, 4H), 7.36 (t, *J* = 7.3 Hz, 1H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.0, 166.5, 141.1, 140.5, 135.9, 135.8, 134.5, 131.1, 130.6, 130.0, 129.4, 129.3, 129.0, 128.8, 128.7, 128.3, 127.8, 127.7, 127.6, 127.4, 127.0, 125.0, 123.5. HRMS calcd for $C_{30}H_{20}NO_2$ $[M+H]^+$,426.1489, found 426.1486.



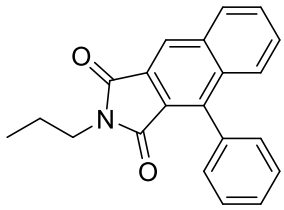
3cd

2-benzyl-4-phenyl-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3cd**, 78.0 mg, yellow solid, yield: 86%) mp: 199-201 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.37 (s, 1H), 8.08 (d, *J* = 8.2 Hz, 1H), 7.79 (d, *J* = 8.4 Hz, 1H), 7.67 (t, *J* = 7.5 Hz, 1H), 7.59 (d, *J* = 8.1 Hz, 1H), 7.57 – 7.52 (m, 3H), 7.44 (d, *J* = 7.2 Hz, 2H), 7.41 – 7.37 (m, 2H), 7.27 (q, *J* = 7.4 Hz, 3H), 4.83 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.7, 167.1, 140.4, 136.6, 135.6, 135.5, 134.5, 130.4, 130.0, 129.2, 129.0, 129.0, 128.7, 128.7, 128.3, 127.9, 127.8, 124.4, 123.9, 41.9. HRMS calcd for $C_{25}H_{18}NO_2$ $[M+H]^+$, 364.1332, found 364.1328.



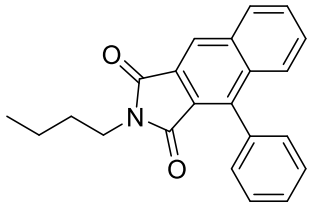
3ce

2-cyclohexyl-4-phenyl-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3ce**, 75.4 mg, yellow solid, yield: 85%) mp: 157-159 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.34 (s, 1H), 8.08 (d, *J* = 8.1 Hz, 1H), 7.78 (d, *J* = 8.5 Hz, 1H), 7.67 (t, *J* = 7.5 Hz, 1H), 7.60 – 7.53 (m, 4H), 7.44 – 7.38 (m, 2H), 4.13 (tt, *J* = 12.4, 3.9 Hz, 1H), 2.32 – 2.13 (m, 2H), 1.78 (dd, *J* = 45.7, 12.3 Hz, 4H), 1.65 (d, *J* = 12.2 Hz, 1H), 1.41 – 1.18 (m, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.1, 167.7, 139.9, 135.6, 135.5, 134.7, 130.3, 129.9, 129.0, 128.8, 128.6, 128.5, 128.3, 128.0, 124.0, 123.9, 51.2, 29.8, 26.1, 25.2. HRMS calcd for $C_{24}H_{22}NO_2$ $[M+H]^+$ 356.1645, found 356.1645.



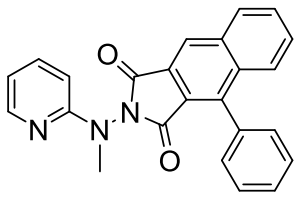
3cf

4-phenyl-2-propyl-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3cf**, 70.1 mg, yellow solid, yield: 89%) mp: 145-147 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.37 (s, 1H), 8.08 (d, J = 8.1 Hz, 1H), 7.81 (d, J = 8.4 Hz, 1H), 7.68 (t, J = 7.5 Hz, 1H), 7.61 – 7.58 (m, 1H), 7.57 – 7.53 (m, 3H), 7.45 – 7.37 (m, 2H), 3.63 (t, J = 7.4 Hz, 2H), 1.69 (q, J = 7.4 Hz, 2H), 0.93 (t, J = 7.4 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.1, 167.6, 140.2, 135.5, 134.6, 130.4, 130.0, 129.1, 129.0, 128.7, 128.6, 128.3, 128.0, 124.2, 124.0, 39.9, 21.9, 11.5. HRMS calcd for $C_{21}H_{18}NO_2$ $[M + H]^+$ 316.1332, found 316.1330.



3cg

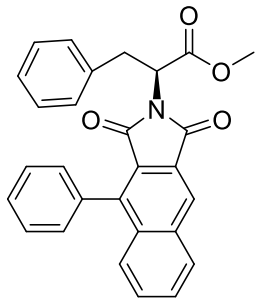
2-butyl-4-phenyl-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3cg**, 70.7 mg, yellow solid, yield: 86%) mp: 150-152 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.36 (s, 1H), 8.11 – 8.05 (m, 1H), 7.84 – 7.77 (m, 1H), 7.67 (ddd, J = 8.2, 6.9, 1.3 Hz, 1H), 7.61 – 7.57 (m, 1H), 7.57 – 7.53 (m, 3H), 7.44 – 7.39 (m, 2H), 3.80 – 3.50 (m, 2H), 1.65 (tt, J = 8.9, 6.8 Hz, 2H), 1.36 (dp, J = 14.8, 7.4 Hz, 2H), 0.92 (t, J = 7.4 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.1, 167.6, 140.1, 135.6, 135.5, 134.6, 130.4, 130.0, 129.1, 128.9, 128.6, 128.6 128.3, 128.1, 124.12, 124.0, 38.2, 30.6, 20.3, 13.8. HRMS calcd for $C_{22}H_{20}NO_2$ $[M+H]^+$330.1489, found 330.1490.



3ch

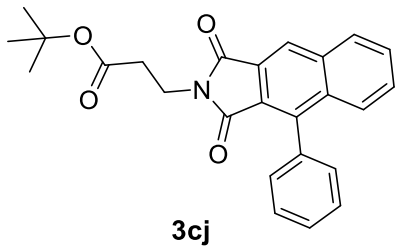
2-(methyl(pyridin-2-yl)amino)-4-phenyl-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**3ch**, 75.8 mg, yellow oil, yield: 80%) ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.49 (s, 1H), 8.24 – 8.08 (m, 2H), 7.86 (d, J = 8.5 Hz, 1H), 7.72 (dd, J = 8.2, 6.8 Hz, 1H), 7.63 (dd, J = 8.5, 7.0 Hz, 1H), 7.50 (ddd, J = 19.3,

14.7, 8.8 Hz, 6H), 6.78 – 6.69 (m, 1H), 6.62 (d, *J* = 8.5 Hz, 1H), 3.50 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 165.9, 165.5, 157.5, 148.2, 141.2, 137.9, 135.8, 135.8, 134.2, 130.6, 130.2, 129.9, 129.5, 129.3, 128.7, 128.7, 128.3, 126.0, 125.2, 121.9, 115.7, 106.6, 38.5. HRMS calcd for $C_{24}H_{18}N_3O_2$ $[M+H]^+$380.1394, found 380.1390.



3ci

Methyl-2-(1,3-dioxo-4-phenyl-1,3-dihydro-2*H*-benzo[*f*]isoindol-2-yl)-3-phenylpropanoate (**3ci**, 44.6 mg, white solid, yield: 41%) ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.32 (s, 1H), 8.06 (d, *J* = 8.1 Hz, 1H), 7.79 (d, *J* = 8.5 Hz, 1H), 7.70 – 7.64 (m, 1H), 7.56 (dtd, *J* = 16.0, 5.7, 4.5, 1.8 Hz, 4H), 7.39 (dt, *J* = 5.1, 2.1 Hz, 1H), 7.30 (dd, *J* = 5.7, 3.0 Hz, 1H), 7.21 – 7.11 (m, 5H), 5.18 (dd, *J* = 10.4, 6.0 Hz, 1H), 3.76 (s, 3H), 3.63 – 3.45 (m, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 169.4, 167.1, 166.4, 140.6, 137.0, 135.5, 135.5, 134.3, 130.4, 130.0, 129.9, 129.2, 129.1, 129.0, 128.7, 128.6, 128.3, 128.2, 127.3, 126.8, 124.6, 123.3, 53.3, 52.9, 34.6. HRMS calcd for $C_{28}H_{22}NO_4$ $[M+H]^+$436.1543,found 436.1541.

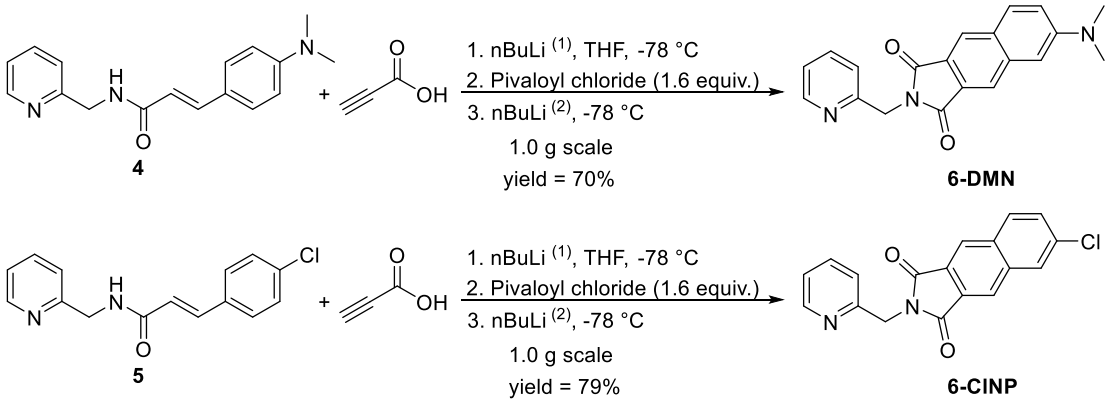


3cj

tert-butyl-3-(1,3-dioxo-4-phenyl-1,3-dihydro-2*H*-benzo[*f*]isoindol-2-yl)propanoate: (**3cj**, 48.1 mg, yellow solid, yield: 48%) mp: 127-129 ℃; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.22 (s, 1H), 7.98 – 7.91 (m, 1H), 7.70 – 7.64 (m, 1H), 7.53 (ddd, *J* = 8.1, 6.9, 1.3 Hz, 1H), 7.48 – 7.43 (m, 1H), 7.43 – 7.41 (m, 1H), 7.41 – 7.40 (m, 1H), 7.39 (d, *J* = 2.2 Hz, 2H), 7.26 – 7.23 (m, 1H), 3.87 – 3.72 (m, 2H), 2.65 – 2.41 (m, 2H), 1.25 (s, 9H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 170.1, 167.6, 167.3, 140.4, 135.6, 134.5, 130.5, 130.0, 130.0, 129.2, 129.1, 128.7, 128.7, 128.3, 127.9, 124.40, 123.9, 81.1,

34.2, 29.5, 28.1. HRMS calcd for $C_{25}H_{23}NO_4Na$ $[M+Na]^+$424.1519, found 424.1516.

V. Gram-Scale Reaction for the Synthesis of 6-DMN.



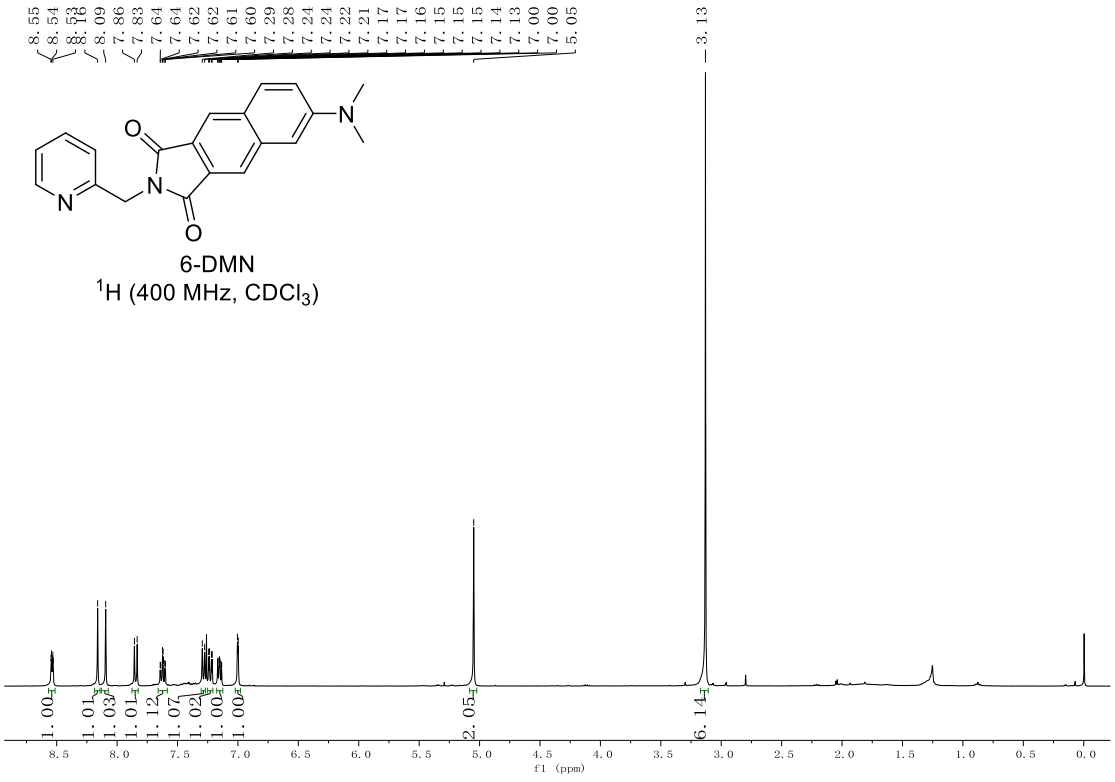
6-DMN: To a three necks flask A containing propioic acid (0.30 g, 4.27 mmol) was added anhydrous THF (5 mL) at -78 °C, nBuLi (2.0 M in cyclohexane, 2.49 mL, 4.98 mmol) was added dropwise by syringe. The reaction mixture was allowed to stir at the same temperature for a period of time, until white suspension was generated, the reaction mixture was warmed to room temperature and stirred for 45 min, then cooled to 0 °C, pivaloyl chloride (0.69 g, 5.69 mmol) was then added dropwise to the solution, and stirring was continued for 2 h. [5]

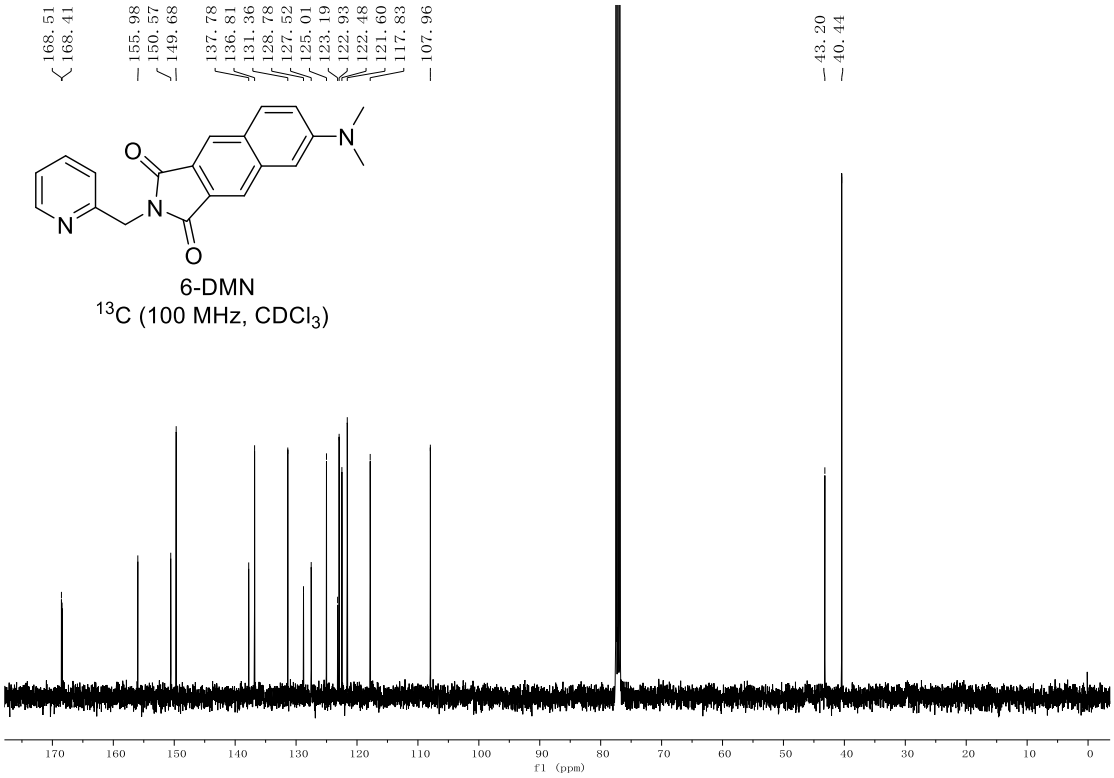
To a three neck flask B containing (E)-3-(4-(dimethylamino)phenyl)-N-(pyridin-2-ylmethyl)acrylamide **4** (1.0 g, 3.56 mmol) was added anhydrous THF (20 mL) at -78 °C, nBuLi (2.0 M in cyclohexane, 2.14 mL, 4.27 mmol) was added dropwise by syringe. The reaction mixture was allowed to stir at the same temperature for 15 min. Then, the reaction solution of flask A was added slowly to flask B by injection, the reaction mixture was warmed to room temperature and stirred for 3 h. The reaction mixture was quenched carefully with a saturated solution of NH_4Cl (5 mL), and the mixture was extracted with EtOAc for three times. The organic layers were combined and dried over anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. The former crude product was purified by silica column chromatography (PE/EA = 5:1) to give desired product **6-DMN** (0.83 g, 70%) as a luminous yellow solid.

6-ClNP: To a three necks flask A containing propioic acid (0.31 g, 4.41 mmol) was added anhydrous THF (5 mL) at -78 °C, nBuLi (2.0 M in cyclohexane, 2.58 mL, 5.15 mmol) was added dropwise by syringe. The reaction mixture was allowed to stir at the same temperature for a period

of time, until white suspension was generated, the reaction mixture was warmed to room temperature and stirred for 45 min, then cooled to 0 °C, pivaloyl chloride (0.71 g, 5.88 mmol) was then added dropwise to the solution, and stirring was continued for 2 h. [5]

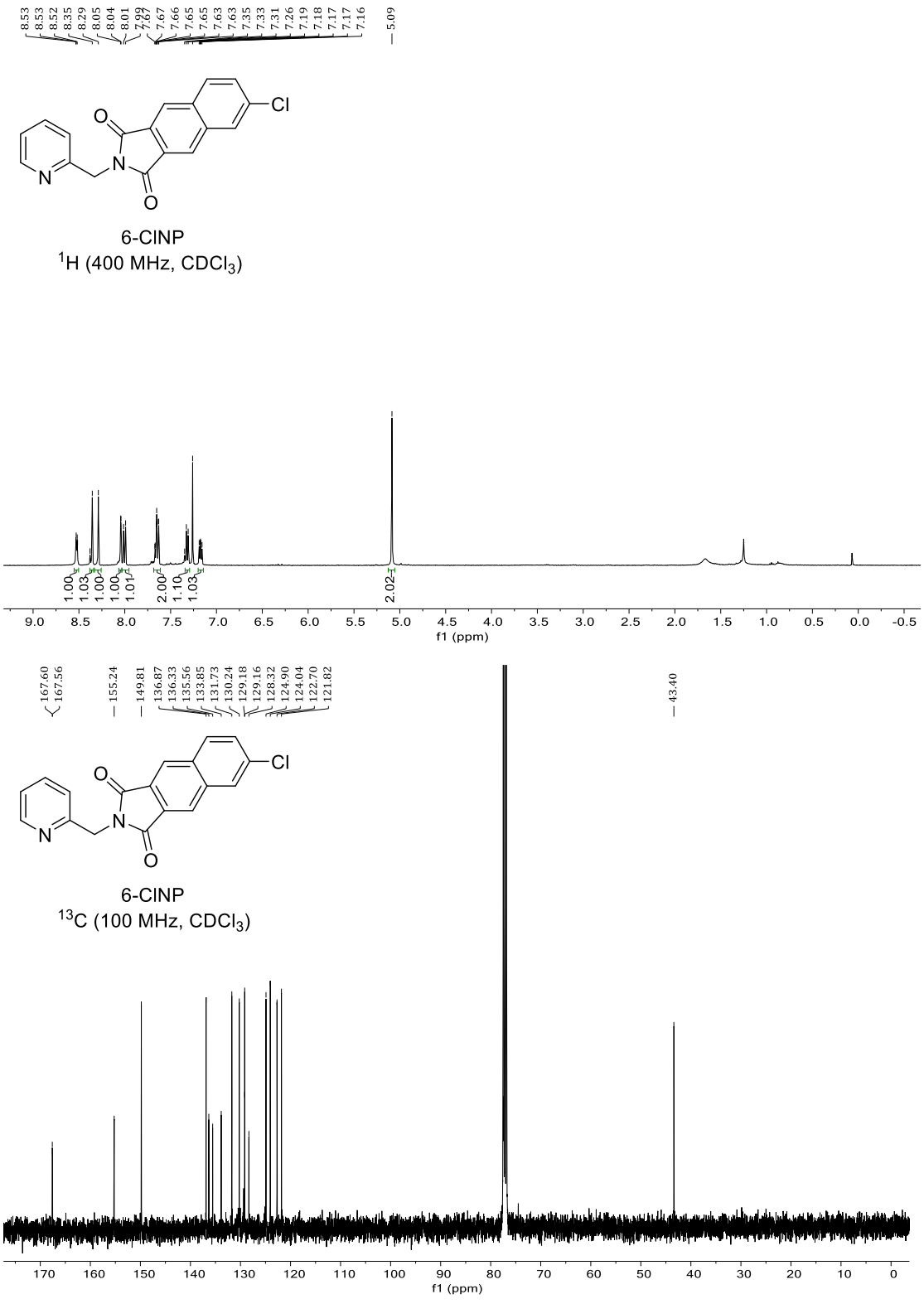
To a three neck flask B containing (E)-3-(4-chlorophenyl)-N-(pyridin-2-ylmethyl)acrylamide **5** (1.0 g, 3.68 mmol) was added anhydrous THF (20 mL) at -78 °C, nBuLi (2.0 M in cyclohexane, 2.21 mL, 4.41 mmol) was added dropwise by syringe. The reaction mixture was allowed to stir at the same temperature for 15 min. Then, the reaction solution of flask A was added slowly to flask B by injection, the reaction mixture was warmed to room temperature and stirred for 3 h. The reaction mixture was quenched carefully with a saturated solution of NH_4Cl (5 mL), and the mixture was extracted with EtOAc for three times. The organic layers were combined and dried over anhydrous Na_2SO_4, filtered, and concentrated under reduced pressure. The former crude product was purified by silica column chromatography (PE/EA = 5:1) to give desired product **6-ClNP** (0.93 g, 79%) as a pale yellow solid.





Characterization data:

6-(dimethylamino)-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**6-DMN**, luminous yellow solid, 0.83 g, yield: 70%): ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.57 – 8.51 (m, 1H), 8.16 (s, 1H), 8.09 (s, 1H), 7.85 (d, J = 9.1 Hz, 1H), 7.62 (td, J = 7.7, 1.9 Hz, 1H), 7.29 (d, J = 7.9 Hz, 1H), 7.23 (dd, J = 9.1, 2.6 Hz, 1H), 7.15 (ddd, J = 7.7, 4.9, 1.1 Hz, 1H), 7.00 (d, J = 2.6 Hz, 1H), 5.05 (s, 2H), 3.13 (s, 6H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 168.5, 168.4, 156.0, 150.6, 149.7, 137.8, 136.8, 131.4, 128.8, 127.5, 125.0, 123.2, 122.9, 122.5, 121.6, 117.8, 108.0, 43.2, 40.4. HRMS calcd for $C_{20}H_{18}N_3O_2$ $[M + H]^+$ 332.1394, found 332.1385.



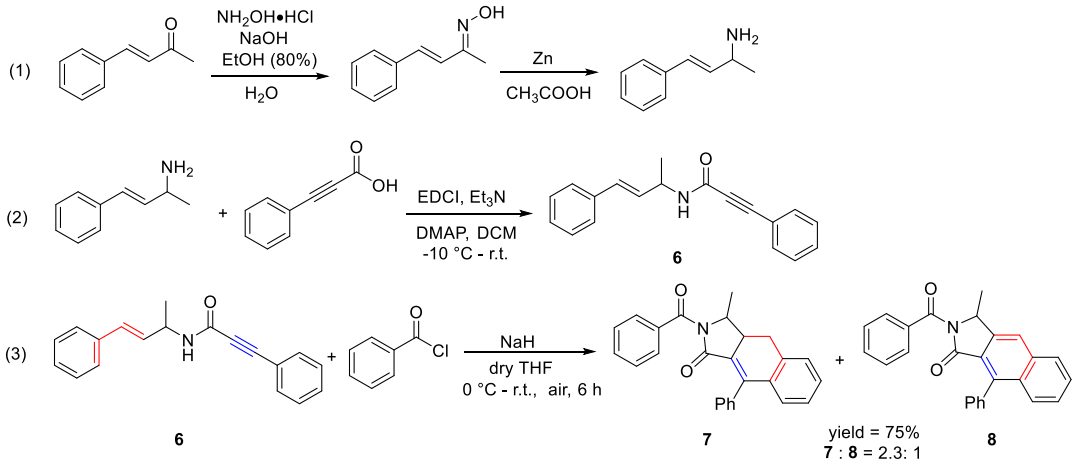
Characterization data:

6-chloro-2-(pyridin-2-ylmethyl)-1*H*-benzo[*f*]isoindole-1,3(2*H*)-dione: (**6-ClNP**, pale yellow solid, 0.93 g, yield: 79%) ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.55 – 8.50 (m, 1H), 8.37 (d, J = 9.9 Hz, 1H), 8.29 (s, 1H), 8.04 (d, J = 2.0 Hz, 1H), 8.00 (d, J = 8.7 Hz, 1H), 7.65 (ddd, J = 9.0, 7.1, 1.9 Hz,

2H), 7.33 (t, J = 7.7 Hz, 1H), 7.20 – 7.15 (m, 1H), 5.09 (s, 2H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 167.6, 167.6, 155.2, 149.8, 136.9, 136.3, 135.6, 133.9, 131.7, 130.2, 129.2, 129.2, 128.3, 124.9, 124.04, 122.70, 121.8, 43.4. HRMS calcd for $C_{18}H_{12}ClN_2O_2$ $[M + H]^+$323.0582, found 323.0571.

VI. Control Experiments

1. Reaction a:



To a mixture of hydroxylamine hydrochloride (0.27 g, 3.95 mmol) and (*E*)-4-cyclohexylbut-3-en-2-one (0.48 g, 3.29 mmol) in 80 % ethanol (3 mL) at room temperature was added sodium hydroxide (0.26 g, 6.58 mmol) by dropwise. The mixture was heated under reflux for 10 min and was then poured into ice-cooled aqueous HCl (1.7 M, 4.0 mL). The white solid was obtained, filtered, and washed with water to give the corresponding oxime. [6]

To a solution of the oxime in ethanol (4.1 mL) and acetic acid (4.1 mL) was added zinc dust (0.43 g, 6.58 mmol) in portions and then the solution was refluxed for 1.0 h. The precipitate was filtered and washed with ethanol (2 x 6.6 mL). The filtrate was concentrated and the residue was dissolved in aqueous HCl (6 M, 3.3 mL), and extracted with dichloromethane. The aqueous acidic layer was treated with solid sodium hydroxide (0.16 g, 4.08 mmol) and extracted with ether. The combined organic extracts were dried (BaO) and concentrated to give amine (0.19 g, 40% yield in two steps) as a colorless oil.[6]

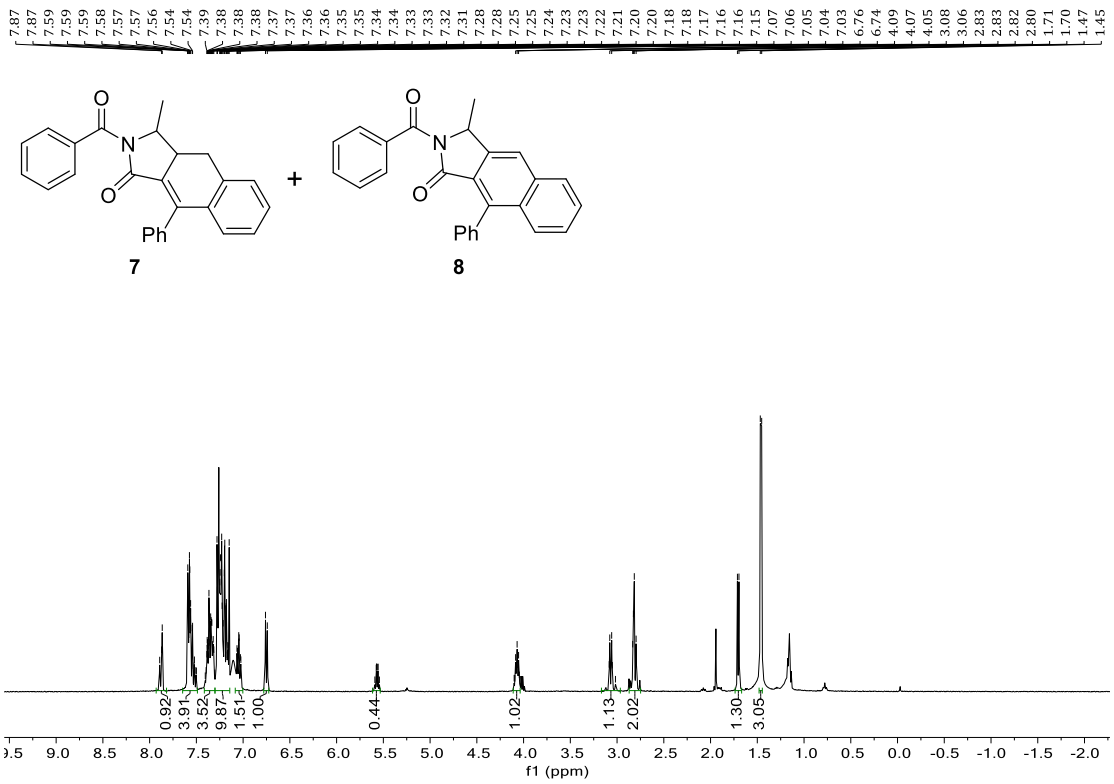
To a solution of EDCI (0.42 g, 2.19 mmol) and DMAP (15.7 mg, 0.13 mmol, 0.1 equiv.) in anhydrous DCM was added triethylamine (0.26 g, 2.58 mmol) at -10 °C. Then 3-phenylpropiolic

acid (0.28 g, 1.94 mmol) was added by fraction, the reaction was stirred for 20 min at -10 °C. Amine (0.19 g, 1.29 mmol) was dissolved in DCM and was added subsequently. The mixture was then warmed to room temperature and stirred overnight. After completion of the reaction, water was added into the mixture and extracted with DCM, the organic layer was dried over anhydrous Na_2SO_4 and filtered, then the DCM was removed by rotary evaporation. Obtained the former crude product was purified by silica column chromatography (PE/ EA = 3:1) to give product **6**[2] (0.25 g, yield: 73%).

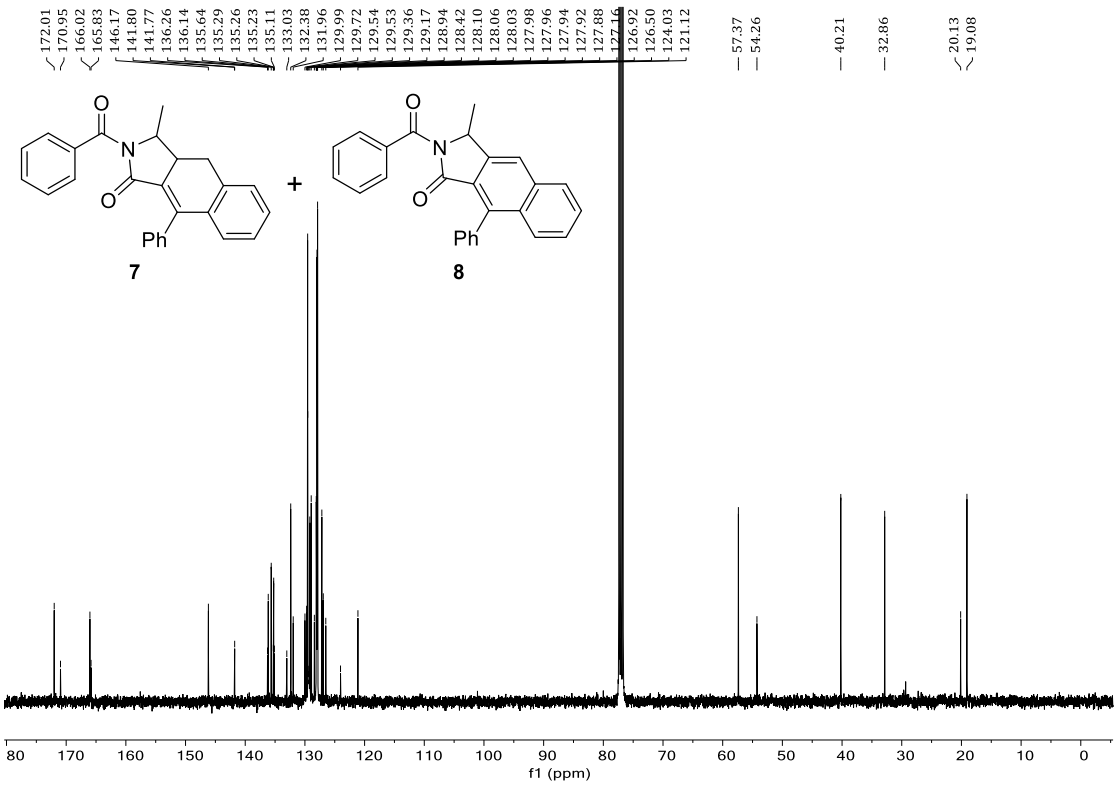
Acetylene amide **6** (68.5 mg, 0.25 mmol) was dissolved in anhydrous THF. The resulting solution was cooled to 0 °C with stirring, NaH (60% in mineral oil, 15.0 mg, 0.38 mmol) was added by fraction. After stirring at 0 °C for 30 min, benzoyl chloride (45.5 mg, 0.33 mmol) was added. The reaction was stirred under room temperature for 6 h. The reaction mixture was diluted with water and extracted with EtOAc. The organic layer was dried over anhydrous Na_2SO_4 and filtered, then the EtOAc was removed by rotary evaporation. Obtained the former crude product was purified by silica column chromatography (PE/EA = 80:1) to give the mixture of **7** and **8** (70.9 mg, 75%, **7:8** = 2.3:1).

Characterization data:

2-benzoyl-3-methyl-9-phenyl-2,3,3a,4-tetrahydro-1*H*-benzo[*f*]isoindol-1-one with 2-benzoyl-3-methyl-9-phenyl-2,3-dihydro-1*H*-benzo[*f*]isoindol-1-one (**7:8** = 2.3:1, white solid, 70.4 mg, yield: 75%)**:** ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 – 7.81 (m, 1H), 7.65 – 7.49 (m, 4H), 7.42 – 7.30 (m, 3.5H), 7.30 – 7.14 (m, 10H), 7.04 (td, *J* = 7.4, 2.0 Hz, 1.5H), 6.75 (d, *J* = 7.8 Hz, 1H), 5.61 – 5.53 (m, 0.44H), 4.10 – 4.04 (m, 1H), 3.16 – 2.96 (m, 1H), 2.81 (t, *J* = 5.8 Hz, 2H), 1.70 (d, *J* = 6.5 Hz, 1.3H), 1.46 (d, *J* = 6.0 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 172.0, 171.0, 166.0, 165.8, 146.2, 141.8, 141.8, 136.3, 136.1, 135.6, 135.3, 135.3, 135.2, 135.1, 133.0, 132.4, 132.0, 130.0, 129.7, 129.5, 129.5, 129.4, 129.2, 128.9, 128.4, 128.1, 128.1, 128.0, 128.0, 128.0, 127.9, 127.9, 127.9, 127.2, 126.9, 126.5, 124.0, 121.1, 57.4, 54.3, 40.2, 32.9, 20.1, 19.1.

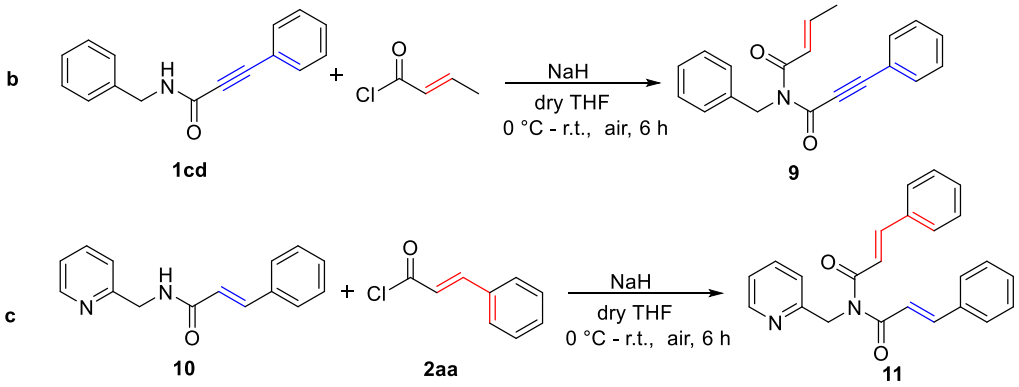


^{1}H-NMR ($CDCl_3$)

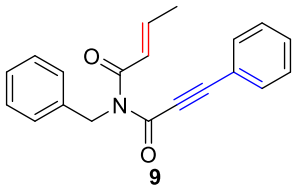


^{13}C-NMR ($CDCl_3$)

2. Reactions b and c:

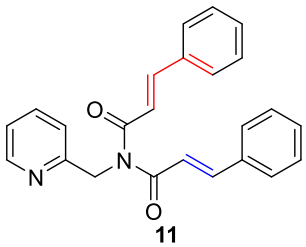


Amide[2] **1cd** (58.8 mg, 0.25 mmol) or **10**[2] (59.5 mg, 0.25 mmol) was dissolved in anhydrous THF. The resulting solution was cooled to 0 °C with stirring, NaH (60 % in oil, 1.5 equiv.) was added by fraction. After stirring at 0 °C for 30 min, acryoyl chloride [3] (1.3 equiv.) was added. The reaction was stirred under room temperature for 6 h. The reaction mixture was diluted with water and extracted with EtOAc. The organic layer was dried over anhydrous Na_2SO_4 and filtered, then the EtOAc was removed by rotary evaporation. Obtained the former crude product was purified by silica column chromatography (PE/EA = 20:1) to give products imides as stable compounds without further conversions.



9

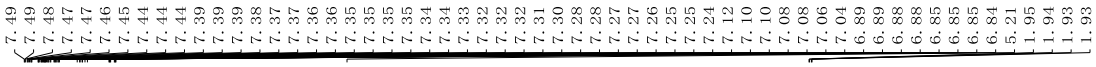
(*E*)-*N*-benzyl-*N*-(3-phenylpropioloyl)but-2-enamide: (compound **9**, yellowish oil) ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.49 (d, J = 1.3 Hz, 1H), 7.47 (d, J = 1.6 Hz, 1H), 7.46 – 7.43 (m, 1H), 7.40 – 7.36 (m, 2H), 7.36 – 7.30 (m, 4H), 7.29 – 7.23 (m, 1H), 7.09 (dq, J = 15.1, 6.9 Hz, 1H), 6.87 (dq, J = 15.1, 1.5 Hz, 1H), 5.21 (s, 2H), 1.94 (dd, J = 6.9, 1.6 Hz, 3H).

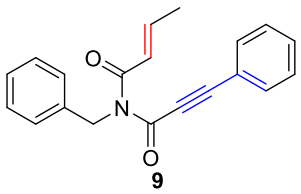


11

***N*-cinnamoyl-*N*-(pyridin-2-ylmethyl)cinnamamide:** (compound **11**, yellow oil) ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.55 (d, J = 4.3 Hz, 1H), 7.77 (d, J = 15.5 Hz, 2H), 7.64 (td, J = 7.7, 1.6 Hz, 1H),

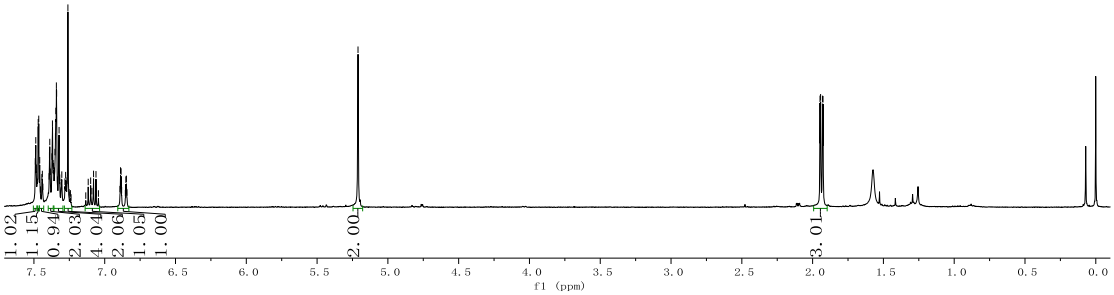
7.50 (dd, *J* = 7.0, 2.2 Hz, 4H), 7.32 (dd, *J* = 7.8, 2.5 Hz, 7H), 7.22 (d, *J* = 1.8 Hz, 2H), 7.16 (dd, *J* = 7.1, 5.3 Hz, 1H), 5.24 (s, 2H).

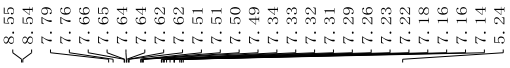


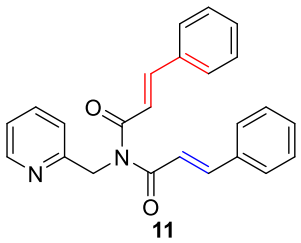


9

^{1}H NMR (400 MHz, $CDCl_3$)

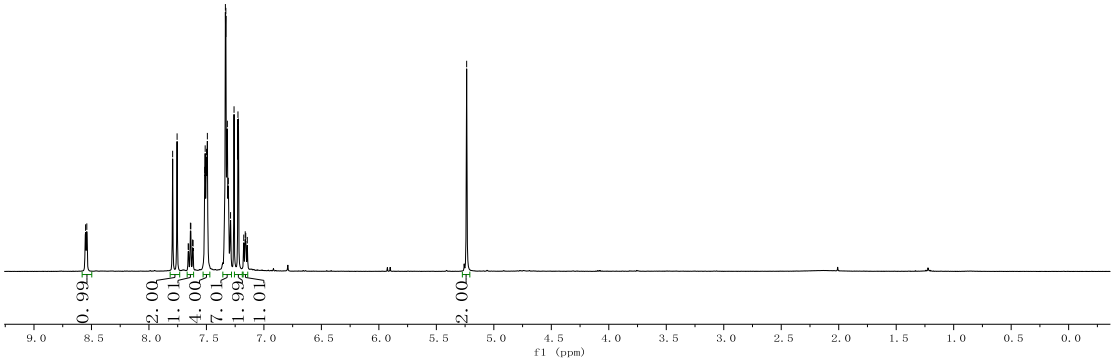






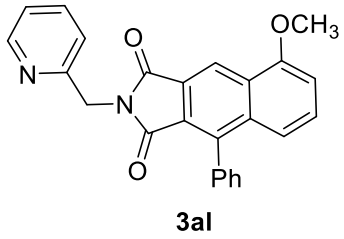
11

^{1}H NMR (400 MHz, $CDCl_3$)



VII. X-ray Crystal Structure and Details of Compound 3al

Crystals of **3al** was obtained by recrystallization from $CDCl_3$.



3al

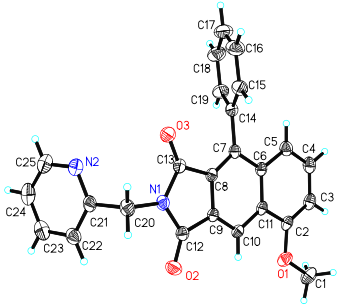


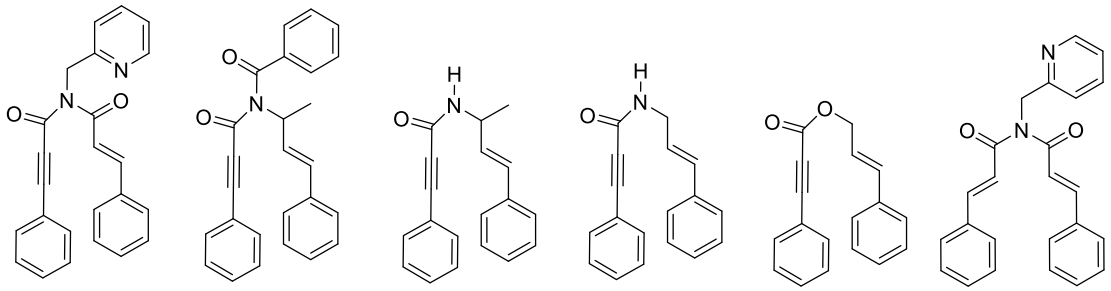
Table S2. Crystal data and structure refinement for $C_{25}H_{18}N_2O_3$

Identification code	cu_180513A_0m	
Empirical formula	$C_{25}\ H_{18}\ N_2\ O_3$	
Formula weight	394.43	
Temperature	297(2) K	
Wavelength	1.54178 Å	
Crystal system	Triclinic	
Space group	P-1	
Unit cell dimensions	a = 7.0612(3) Å	a= 88.150(2)°.
	b = 10.7290(4) Å	b= 87.486(2)°.
	c = 16.0800(6) Å	g = 84.532(2)°.
Volume	1211.02(8) $Å^3$	
Z	2	
Density (calculated)	1.409 Mg/m^3	
Absorption coefficient	3.687 mm^{-1}	
F(000)	528	
Crystal size	0.150 x 0.120 x 0.100 mm^3	
Theta range for data collection	2.752 to 65.759°.	
Index ranges	-8<=h<=7, -12<=k<=12, -18<=l<=18	
Reflections collected	20395	
Independent reflections	3993 [R(int) = 0.0626]	
Completeness to theta = 65.759°	95.2 %	
Absorption correction	None	
Refinement method	Full-matrix least-squares on F^2	
Data / restraints / parameters	3993 / 21 / 346	

Goodness-of-fit on F^2	1.039
Final R indices [I>2sigma(I)]	R1 = 0.0580, wR2 = 0.1612
R indices (all data)	R1 = 0.0623, wR2 = 0.1670
Extinction coefficient	0.0019(7)
Largest diff. peak and hole	0.304 and -0.340 e.$Å^{-3}$

VIII. Computational Details

Density functional theory calculations were carried out at the M06-2X level of theory in combination with def2-SVP basis sets. All relevant stationary points were characterized as minima or first-order transition states by evaluating the harmonic vibrational frequencies at the same level that had been applied for geometry optimization. Grimme-type empirical dispersion corrections were incorporated at the M062X level with zero dampening (M062X-D3). Zero-point energies (ZPE) and relative free energies (ΔG) at standard pressure (1 bar) and 323.15K were determined at the same level. The integration grid was set to ultrafine level for all the calculations. The DFT computations were performed using the Gaussian16.



Structures of calculated reactants

Table S3. HOMO-LUMO level of optimized reactant

	HOMO	LUMO	gap
oam	-7.603	-0.919	6.683
onh	-7.392	-0.595	6.797
onm	-7.364	-0.593	6.771
ono	-7.784	-1.457	6.327
ooh	-7.835	-0.726	7.109
2no	-7.835	-1.565	6.270

Table S4. HOMO-LUMO level of optimized product

	HOMO	LUMO	gap
oam	-7.051	-0.771	6.280
onh	-6.936	-0.607	6.329
onm	-6.919	-0.580	6.339
ono	-7.176	-0.910	6.267
ooh	-7.124	-0.794	6.330
2no	-7.061	-0.700	6.361

Table S5. HOMO-LUMO level of transition state

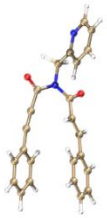
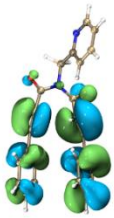
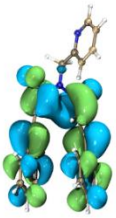
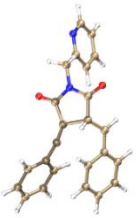
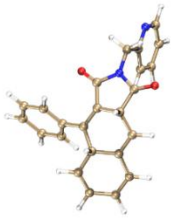
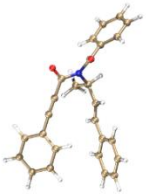
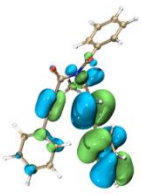
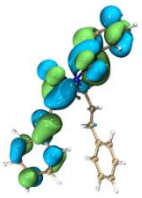
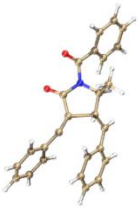
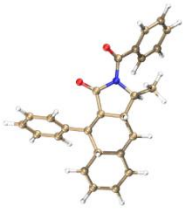
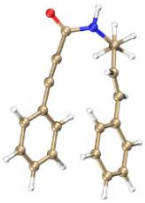
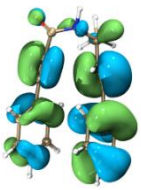
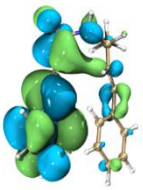
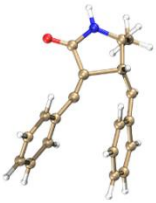
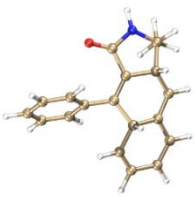
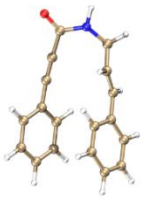
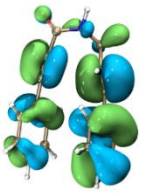
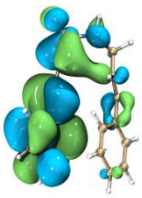
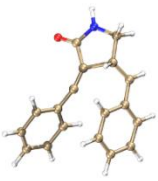
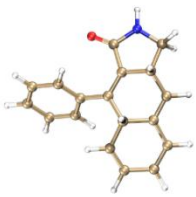
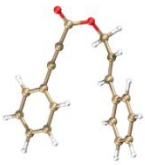
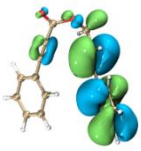
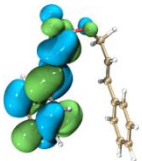
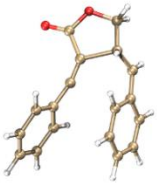
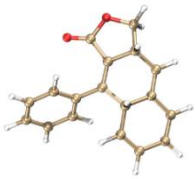
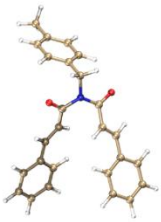
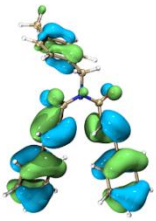
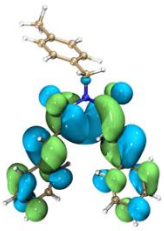
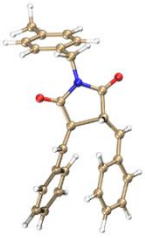
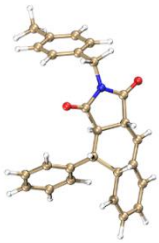
	HOMO	LUMO	gap
oam	-6.272	-1.608	4.665
onh	-6.234	-1.396	4.837
onm	-6.249	-1.328	4.921
ono	-6.467	-1.884	4.583
ooh	-6.387	-1.713	4.674
2no	-6.290	-1.749	4.541

Table S6. Gibbs free energy relative to the reactant (unit: kCal/mol)

	reactant	TS	product
oam	0	24.61594	-22.7108
onh	0	27.52382	-18.4764
onm	0	27.46107	-19.4835
ono	0	23.95706	-25.2579
ooh	0	28.2304	-18.8717
2no	0	31.7896	-1.3862

Table S7. Absolute electronic energy and Gibbs free energy (unit: k Cal/mol)

	E			G		
	reactant	TS	product	reactant	TS	product
oam	-757505.6781	-757482.5241	-757533.6233	-757290.1093	-757265.4934	-757312.8201
onh	-517008.4495	-516981.8904	-517031.1606	-516859.8443	-516832.3205	-516878.3207
onm	-541649.0737	-541622.2003	-541672.1916	-541483.419	-541455.9579	-541502.9025
ono	-742930.9169	-742907.804	-742960.7995	-742739.3136	-742715.3565	-742764.5714
ooh	-529457.0833	-529430.7798	-529481.3437	-529317.3393	-529289.1089	-529336.211
2no	-758301.0039	-758271.0311	-758307.1431	-758071.3517	-758039.5621	-758072.7379

	reactant	HOMO	LUMO	TS	product
ono					
oam					
onm					
onh					
ooh					
2no					

IX. DFT Optimized xyz Coorindates

oam-product

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C	1.980934	-2.468232	-0.242770
C	2.787452	-1.233714	-0.639675
C	0.660494	-2.495897	-0.491578
C	1.974397	0.053734	-0.432064
C	-0.017785	-1.306235	-1.097338
C	0.664421	-0.023838	-0.707646
C	-1.487879	-1.107043	-0.666017
C	-0.379899	1.035837	-0.569860
O	-0.241517	2.218372	-0.430150
H	0.002274	-1.389350	-2.204488
H	2.907286	-1.286848	-1.744487
C	3.971223	-3.503647	0.745620
C	2.675567	-3.585710	0.389382
C	4.193223	-1.220288	-0.100392
C	4.739224	-2.281459	0.510116
H	4.461019	-4.347319	1.234089
H	4.785655	-0.322191	-0.282285
H	5.779490	-2.244908	0.837387
H	0.068349	-3.382510	-0.245963
H	2.093270	-4.486030	0.596934
C	2.653581	1.297131	0.016342
C	3.286091	1.335918	1.266768
C	2.680499	2.435458	-0.796081
C	3.929147	2.493836	1.696562
H	3.264804	0.451199	1.906562
C	3.334252	3.589202	-0.369675
H	2.170037	2.415835	-1.759455
C	3.958971	3.621563	0.875975
H	4.407890	2.515739	2.676657
H	3.345527	4.471304	-1.011208
H	4.465626	4.528096	1.210549
N	-1.614777	0.358696	-0.587901
H	-1.615562	-1.551019	0.335664
C	-2.841206	1.056715	-0.617429
O	-2.977644	2.077207	-1.235215
C	-3.965275	0.457544	0.176097
C	-5.271686	0.655375	-0.281203
C	-3.741613	-0.214143	1.381481
C	-6.346539	0.147202	0.442294
H	-5.422136	1.213603	-1.206612
C	-4.820520	-0.706656	2.113535
H	-2.723861	-0.324037	1.760103
C	-6.120832	-0.536756	1.638412
H	-7.364957	0.290526	0.078728
H	-4.646601	-1.218677	3.060876
H	-6.963953	-0.930069	2.208466
C	-2.468932	-1.748980	-1.634399
H	-3.505927	-1.681219	-1.280899
H	-2.396798	-1.265536	-2.620024
H	-2.218578	-2.813586	-1.751121

oam-reactant

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C	-1.962266	2.101742	0.393772
C	-1.927298	2.765484	-0.843260
C	-0.867909	1.238603	0.873286
C	-1.456516	-1.979584	-0.426869
C	0.252420	0.934498	0.209687
C	-0.260050	-1.927856	-0.616390
C	1.361700	0.043935	0.720537
C	1.167882	-1.875774	-0.932979
O	1.685045	-2.698674	-1.640047
H	0.437036	1.351346	-0.786262
H	-1.043370	2.691208	-1.478228
C	-4.203700	2.982683	0.749794
C	-3.114765	2.228650	1.182321
C	-3.014793	3.516007	-1.278160
C	-4.159642	3.626520	-0.485512
H	-5.091207	3.063869	1.379409
H	-2.969822	4.020318	-2.244596
H	-5.010477	4.215834	-0.830202
H	-1.039058	0.790990	1.856944
H	-3.159434	1.711679	2.143478
C	-2.868847	-1.962847	-0.171248
C	-3.617034	-0.815707	-0.482729
C	-3.505696	-3.074605	0.403093
C	-4.982243	-0.783581	-0.213803
H	-3.120754	0.045135	-0.932611
C	-4.870630	-3.031773	0.668560

H	-2.919824	-3.964148	0.636636
C	-5.610016	-1.888003	0.362720
H	-5.554446	0.113380	-0.455448
H	-5.361703	-3.897066	1.115742
H	-6.680279	-1.859343	0.572535
N	1.890589	-0.818345	-0.361333
H	2.202318	0.715638	0.956152
C	3.041340	-0.370059	-1.081133
O	3.054027	-0.317503	-2.278921
C	4.226452	0.047770	-0.262339
C	4.517202	-0.538536	0.973008
C	5.101563	0.990004	-0.811080
C	5.669795	-0.171368	1.663736
H	3.847489	-1.299465	1.376644
C	6.244880	1.366830	-0.112654
H	4.869347	1.410783	-1.790484
C	6.528528	0.787164	1.125100
H	5.902169	-0.638307	2.621678
H	6.922030	2.109624	-0.536257
H	7.428111	1.078503	1.669519
C	1.031801	-0.722408	1.997208
H	0.852784	-0.015598	2.818650
H	0.136922	-1.346212	1.876521
H	1.872505	-1.367085	2.283275

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C	1.712076	2.239321	0.380429
C	2.579553	1.440366	1.169752
C	0.317195	2.007076	0.379016
C	1.745855	-0.767268	0.077916
C	-0.216550	0.880956	1.023019
C	0.506426	-0.602668	0.227227
C	-1.712342	0.616874	0.911284
C	-0.725201	-1.393541	-0.095313
O	-0.709853	-2.465054	-0.628945
H	0.188279	0.646151	2.015211
H	2.181602	0.838743	1.986215
C	3.665485	3.200714	-0.716520
C	2.300295	3.132358	-0.562391
C	3.971723	1.540409	1.020036
C	4.511948	2.388112	0.071613
H	4.098230	3.877538	-1.454721
H	4.624704	0.920343	1.636700
H	5.593642	2.443408	-0.059898
H	-0.292889	2.536638	-0.358562
H	1.642645	3.745537	-1.182503
C	3.051896	-1.241416	-0.215807
C	3.772096	-0.715287	-1.307677
C	3.659822	-2.216683	0.600359
C	5.054232	-1.175874	-1.584795
H	3.311276	0.059798	-1.922406
C	4.949406	-2.653655	0.322300
H	3.102940	-2.627743	1.443117
C	5.650242	-2.141038	-0.771766
H	5.598274	-0.769281	-2.438746
H	5.409401	-3.411132	0.958724
H	6.659205	-2.493675	-0.989305
N	-1.875809	-0.700476	0.274126
H	-2.151475	1.389980	0.262558
C	-3.146607	-1.331317	0.219112
O	-3.302926	-2.480025	0.524255
C	-4.284033	-0.468926	-0.241933
C	-5.562760	-0.746076	0.251861
C	-4.108473	0.530244	-1.204185
C	-6.653980	-0.001692	-0.186062
H	-5.679870	-1.554056	0.975998
C	-5.205369	1.262335	-1.654662
H	-3.114937	0.711076	-1.619412
C	-6.474883	1.003898	-1.137948
H	-7.649547	-0.210040	0.207912
H	-5.070526	2.032239	-2.415465
H	-7.331620	1.582992	-1.485963
C	-2.392535	0.664072	2.275334
H	-3.478681	0.520361	2.186198
H	-1.987901	-0.124007	2.927448
H	-2.212961	1.641333	2.744351

onh-product
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C	2.346694	-0.635282	0.086589
C	1.004679	-0.954282	0.741516
C	2.721710	0.649826	-0.034233
C	-0.063128	0.081165	0.350422
C	1.806941	1.742367	0.427397
C	0.356805	1.349943	0.258840
C	1.912131	3.075683	-0.343448
C	-0.409885	2.573484	-0.151616

O	-1.602385	2.727006	-0.265166
H	1.985349	1.941740	1.503848
H	1.145455	-0.778272	1.831029
C	2.749995	-3.013447	-0.350183
C	3.180492	-1.738066	-0.380620
C	0.597301	-2.399276	0.633569
C	1.418650	-3.345190	0.156172
H	3.387206	-3.817386	-0.721673
H	-0.388050	-2.666420	1.019091
H	1.098479	-4.388289	0.144231
H	3.689919	0.906571	-0.473407
H	4.162007	-1.487712	-0.788994
C	-1.469619	-0.343094	0.127378
C	-1.770004	-1.271993	-0.878902
C	-2.509120	0.169134	0.910912
C	-3.084057	-1.678094	-1.096597
H	-0.964009	-1.670376	-1.498592
C	-3.821848	-0.246082	0.699470
H	-2.281871	0.909469	1.678364
C	-4.112645	-1.169766	-0.303162
H	-3.305720	-2.393381	-1.890071
H	-4.623313	0.162432	1.316553
H	-5.142046	-1.490617	-0.470301
N	0.540807	3.536320	-0.382067
H	2.567460	3.798784	0.162048
H	2.312896	2.897732	-1.356920
H	0.259117	4.423239	-0.780439

onh-reactant
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C	-0.909622	-1.763229	0.021161
C	-1.178253	-1.034733	1.191046
C	0.459945	-1.915409	-0.501536
C	1.346417	1.438627	-0.235298
C	1.593526	-1.741985	0.185315
C	2.481053	1.035526	-0.091500
C	2.958589	-1.815684	-0.443392
C	3.815203	0.493472	0.191896
O	4.743700	1.194146	0.525388
H	1.571961	-1.531291	1.259547
H	-0.353689	-0.584669	1.747632
C	-3.302270	-2.076167	-0.281453
C	-1.990477	-2.275122	-0.708759
C	-2.486557	-0.829946	1.614879
C	-3.555006	-1.350656	0.880984
H	-4.130347	-2.484915	-0.862865
H	-2.676326	-0.244799	2.516162
H	-4.580942	-1.183234	1.212166
H	0.530596	-2.147221	-1.571389
H	-1.796085	-2.832924	-1.627842
C	-0.039851	1.790762	-0.356327
C	-0.827834	1.196492	-1.354438
C	-0.636220	2.653145	0.576938
C	-2.195582	1.444258	-1.402121
H	-0.358151	0.522084	-2.071597
C	-2.004925	2.897170	0.520962
H	-0.018046	3.113060	1.348687
C	-2.786540	2.289403	-0.462401
H	-2.806093	0.965361	-2.168794
H	-2.466058	3.562412	1.252266
H	-3.861145	2.474689	-0.496638
N	3.919114	-0.867681	0.098949
H	3.388621	-2.811839	-0.255454
H	2.862697	-1.714830	-1.538471
H	4.860018	-1.196827	0.285111

onh-TS
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C	-0.615347	2.149503	0.147294
C	0.193587	1.460961	1.090952
C	-1.965849	1.786571	-0.039391
C	-0.230363	-0.809045	0.062610
C	-2.487699	0.647349	0.592060
C	-1.489439	-0.799798	0.024739
C	-3.894278	0.192456	0.238260
C	-2.581798	-1.758098	-0.362113
O	-2.393522	-2.872360	-0.780710
H	-2.228133	0.506666	1.647787
H	-0.268352	0.880979	1.889218
C	1.388130	3.243852	-0.709823
C	0.028075	3.053162	-0.750886
C	1.580316	1.694994	1.142485
C	2.177125	2.549963	0.239078
H	1.865193	3.927162	-1.414013
H	2.186202	1.168304	1.881898
H	3.256760	2.705621	0.264090
H	-2.499698	2.211472	-0.894390
H	-0.581702	3.575592	-1.491358

C	1.138808	-1.186649	-0.033093
C	1.951054	-0.658009	-1.055917
C	1.710959	-2.058733	0.913623
C	3.291775	-1.016974	-1.139385
H	1.513249	0.039781	-1.771825
C	3.057148	-2.395327	0.829102
H	1.083270	-2.471170	1.704414
C	3.851918	-1.881464	-0.197888
H	3.908541	-0.609424	-1.941934
H	3.489268	-3.074473	1.565695
H	4.905972	-2.154433	-0.263069
N	-3.804089	-1.199241	-0.142171
H	-4.571250	0.314644	1.097717
H	-4.286172	0.806302	-0.589779
H	-4.621083	-1.741730	-0.393821

onm-product

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C	1.843646	1.484131	-0.304209
C	0.393001	1.401148	-0.771755
C	2.615497	0.383413	-0.308003
C	-0.235656	0.043938	-0.426049
C	2.057518	-0.945830	-0.707468
C	0.570130	-1.025160	-0.460354
C	2.603741	-2.192107	0.043713
C	0.240088	-2.455880	-0.144987
O	-0.839498	-2.985516	-0.033113
H	2.233610	-1.109886	-1.789570
H	0.430112	1.397749	-1.883937
C	1.559525	3.849571	0.279654
C	2.363463	2.781696	0.120019
C	-0.428900	2.615907	-0.426392
C	0.122379	3.750256	0.027849
H	1.970148	4.800235	0.623217
H	-1.499457	2.566592	-0.630737
H	-0.503809	4.625277	0.209297
H	3.668927	0.460701	-0.025598
H	3.429606	2.844850	0.348778
C	-1.689186	-0.042137	-0.120290
C	-2.204334	0.588623	1.020255
C	-2.559520	-0.744151	-0.959995
C	-3.563791	0.517301	1.314145
H	-1.528201	1.133745	1.682482
C	-3.920815	-0.806497	-0.670905
H	-2.157366	-1.257339	-1.834179
C	-4.426111	-0.176512	0.465232
H	-3.950850	1.004320	2.210468
H	-4.588643	-1.359841	-1.332601
H	-5.491853	-0.230334	0.692876
N	1.454607	-3.082357	-0.012348
H	1.480798	-4.033062	0.336953
C	3.026590	-1.902561	1.481235
H	3.225840	-2.842701	2.015508
H	3.939196	-1.292301	1.517756
H	2.226003	-1.363626	2.009990
H	3.446086	-2.634648	-0.509531

onm-reactant

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C	0.870936	-1.768777	-0.227057
C	1.246480	-0.960222	-1.311861
C	-0.524845	-1.851007	0.241835
C	-0.977590	1.621688	0.165981
C	-1.606369	-1.486297	-0.454777
C	-2.131813	1.340894	-0.078285
C	-3.023653	-1.470195	0.066955
C	-3.502529	0.987026	-0.466493
O	-4.313480	1.825917	-0.789588
H	-1.502495	-1.161470	-1.494835
H	0.486612	-0.389493	-1.849384
C	3.215995	-2.315830	0.119099
C	1.876052	-2.439324	0.482594
C	2.583288	-0.830386	-1.671558
C	3.574694	-1.508194	-0.958122
H	3.983003	-2.848201	0.684006
H	2.856882	-0.181670	-2.505241
H	4.623464	-1.399290	-1.238313
H	-0.644119	-2.201758	1.271882
H	1.599362	-3.062017	1.336687
C	0.422526	1.828544	0.405374
C	1.084591	1.060633	1.376284
C	1.154207	2.724814	-0.388706
C	2.461891	1.172212	1.532318
H	0.509350	0.359987	1.983216
C	2.531960	2.832083	-0.224494
H	0.633168	3.319426	-1.139836
C	3.187653	2.053205	0.729536
H	2.973950	0.559491	2.275424

H	3.098713	3.524722	-0.848202
H	4.269283	2.132483	0.848246
N	-3.787172	-0.351459	-0.488343
H	-3.521046	-2.363041	-0.349026
H	-4.757756	-0.527025	-0.726986
C	-3.128758	-1.534919	1.589953
H	-4.182963	-1.491106	1.894518
H	-2.699426	-2.468345	1.978440
H	-2.596217	-0.685496	2.043063

onm-TS

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C	-0.493580	2.068990	0.250638
C	0.385449	1.402824	1.146229
C	-1.824742	1.631170	0.085010
C	0.088817	-0.836133	0.070647
C	-2.258907	0.444772	0.693959
C	-1.167351	-0.925930	0.080943
C	-3.650270	-0.125100	0.409666
C	-2.195856	-1.983936	-0.197719
O	-1.944438	-3.087631	-0.611618
H	-1.950310	0.294424	1.735369
H	-0.015216	0.775738	1.941984
C	1.410265	3.319382	-0.622463
C	0.065285	3.040904	-0.633496
C	1.755734	1.728127	1.170344
C	2.269494	2.649113	0.282083
H	1.821553	4.055087	-1.315216
H	2.415202	1.219622	1.875856
H	3.336844	2.875469	0.284678
H	-2.393808	2.060963	-0.741412
H	-0.598360	3.546352	-1.338710
C	1.476067	-1.125727	-0.078338
C	2.218122	-0.536208	-1.120167
C	2.133347	-1.968671	0.838470
C	3.575834	-0.807017	-1.251074
H	1.713576	0.139387	-1.813048
C	3.494797	-2.217900	0.706334
H	1.559484	-2.428633	1.643843
C	4.220829	-1.643420	-0.339027
H	4.138560	-0.352250	-2.067845
H	3.993129	-2.875896	1.419958
H	5.287458	-1.847308	-0.441578
N	-3.439844	-1.534211	0.129906
H	-4.220888	-2.153911	-0.051990
C	-4.403838	0.553366	-0.729573
H	-5.358390	0.036745	-0.903649
H	-4.623445	1.602854	-0.490689
H	-3.818234	0.511793	-1.659422
H	-4.249728	-0.031535	1.330680

ono-product

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C	1.971880	-2.321931	0.118880
C	2.685371	-1.085525	-0.432824
C	0.757379	-2.633103	-0.365616
C	1.691957	0.069148	-0.640501
C	0.140088	-1.729782	-1.389239
C	0.503766	-0.286705	-1.154676
C	-1.383881	-1.718770	-1.390881
C	-0.735816	0.530021	-1.296437
O	-0.895253	1.720822	-1.291166
H	0.453832	-2.046999	-2.405731
H	2.992988	-1.347396	-1.468919
O	-2.121453	-2.665647	-1.381624
C	3.826006	-2.757682	1.660172
C	2.639850	-3.123274	1.138256
C	3.962595	-0.739788	0.283083
C	4.494319	-1.531311	1.225404
H	4.299077	-3.369348	2.429660
H	4.478872	0.168186	-0.033765
H	5.448030	-1.264568	1.683619
H	0.206110	-3.518458	-0.041016
H	2.128075	-4.024176	1.482642
C	2.051940	1.461312	-0.279541
C	2.463566	1.764869	1.026659
C	1.976105	2.488885	-1.226429
C	2.787963	3.072637	1.376394
H	2.516321	0.969797	1.772766
C	2.314423	3.794165	-0.877677
H	1.640542	2.258530	-2.238049
C	2.720033	4.088856	0.422819
H	3.094261	3.299541	2.398506
H	2.252014	4.586170	-1.624994
H	2.979798	5.112727	0.695882
N	-1.788518	-0.391963	-1.407470
C	-3.173691	0.008463	-1.400306
H	-3.256999	0.971044	-1.923035

H	-3.754948	-0.746906	-1.946376
C	-3.760354	0.160768	-0.010535
C	-3.022348	-0.064877	1.153882
C	-5.637465	0.687611	1.184237
C	-3.655151	0.103775	2.382988
H	-1.975213	-0.365755	1.103161
C	-4.991930	0.488219	2.405396
H	-6.688839	0.990405	1.159375
H	-3.106822	-0.063637	3.311419
H	-5.527746	0.632071	3.343625
N	-5.040814	0.529319	0.007829

ono-reactant
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C	-2.160642	-1.882923	-0.081738
C	-2.498227	-1.296325	1.150149
C	-0.864759	-1.657479	-0.735594
C	-1.035379	1.996723	-0.186313
C	0.125331	-0.878711	-0.275846
C	0.171825	1.896476	-0.246658
C	1.336946	-0.654048	-1.105852
C	1.619946	1.722228	-0.308887
O	2.384024	2.588493	0.037630
H	0.059758	-0.382272	0.690909
H	-1.769207	-0.681959	1.681442
O	1.718708	-1.453898	-1.923954
C	-4.400853	-2.820963	-0.203412
C	-3.128244	-2.649167	-0.745755
C	-3.766371	-1.465471	1.690962
C	-4.723895	-2.226834	1.014479
H	-5.141743	-3.419702	-0.735187
H	-4.015586	-0.993971	2.642676
H	-5.720542	-2.354694	1.439585
H	-0.719813	-2.123873	-1.715567
H	-2.876386	-3.108116	-1.704252
C	-2.466735	1.929775	-0.119820
C	-3.157819	1.162670	-1.072896
C	-3.171606	2.542046	0.927648
C	-4.534471	0.999702	-0.967321
H	-2.598225	0.683790	-1.877678
C	-4.549519	2.372468	1.025385
H	-2.628220	3.137058	1.662414
C	-5.230180	1.599988	0.083301
H	-5.065763	0.392230	-1.701109
H	-5.096035	2.844843	1.842670
H	-6.309533	1.465058	0.168034
N	2.086079	0.523778	-0.861758
C	3.484775	0.513332	-1.274266
H	3.574549	-0.141735	-2.148321
H	3.775247	1.530889	-1.561785
C	4.439945	0.032252	-0.202475
C	4.027987	-0.312400	1.087010
C	6.623529	-0.444210	0.284795
C	4.987691	-0.743291	1.999403
H	2.977923	-0.240224	1.370523
C	6.317056	-0.813325	1.595405
H	7.657655	-0.484386	-0.071304
H	4.698143	-1.019010	3.014800
H	7.102635	-1.144202	2.274710
N	5.713251	-0.034002	-0.591413

ono-TS
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C	-1.609955	2.264980	-0.175789
C	-2.573191	1.545476	-0.929493
C	-0.232594	2.162803	-0.478739
C	-1.413288	-0.771988	-0.462917
C	0.211176	1.219061	-1.415286
C	-0.245109	-0.458094	-0.815301
C	1.703012	1.052367	-1.563717
C	1.082130	-1.138941	-0.884022
O	1.290877	-2.288070	-0.611231
H	-0.333342	1.136694	-2.363967
H	-2.311273	1.130602	-1.902278
O	2.488314	1.921415	-1.831179
C	-3.351308	2.833676	1.430824
C	-2.042905	2.919328	1.014222
C	-3.908840	1.488352	-0.506095
C	-4.292097	2.100255	0.673373
H	-3.663988	3.326372	2.352575
H	-4.638181	0.932102	-1.097350
H	-5.326560	2.031561	1.013377
H	0.492759	2.612051	0.205173
H	-1.308190	3.470654	1.604873
C	-2.608908	-1.391897	-0.017343
C	-3.115959	-1.115007	1.269325
C	-3.324357	-2.262812	-0.864418
C	-4.291321	-1.719304	1.700096

H	-2.577170	-0.417696	1.913142
C	-4.509117	-2.842392	-0.427082
H	-2.933251	-2.479995	-1.858966
C	-4.994855	-2.579717	0.856006
H	-4.668516	-1.507100	2.701650
H	-5.054403	-3.516235	-1.089563
H	-5.921015	-3.044637	1.196053
N	2.075983	-0.261175	-1.311828
C	3.462363	-0.668022	-1.352275
H	3.971576	-0.080962	-2.127567
H	3.500431	-1.731758	-1.621244
C	4.195219	-0.472907	-0.039799
C	3.582538	0.046185	1.103156
N	5.476057	-0.839086	-0.066657
C	4.344998	0.184771	2.260245
H	2.530827	0.335019	1.090996
C	6.197188	-0.703760	1.040867
C	5.682512	-0.196755	2.234984
H	3.896461	0.586074	3.170453
H	7.244583	-1.015032	0.980078
H	6.317449	-0.106589	3.116299

ooh-product

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C	2.366332	-0.560438	0.095273
C	1.032166	-0.922899	0.746930
C	2.703162	0.734765	-0.029836
C	-0.064566	0.080011	0.357811
C	1.753285	1.802146	0.419304
C	0.322764	1.360411	0.267428
C	1.753363	3.096347	-0.410785
C	-0.471837	2.559032	-0.137070
O	-1.652284	2.715504	-0.203237
H	1.941604	2.049735	1.483677
H	1.165315	-0.746757	1.837188
C	2.844545	-2.926041	-0.336489
C	3.236684	-1.638500	-0.364062
C	0.666982	-2.378926	0.632073
C	1.519756	-3.298505	0.159036
H	3.508708	-3.710164	-0.702865
H	-0.312263	-2.675943	1.011138
H	1.231132	-4.350651	0.142985
H	3.665880	1.017775	-0.464731
H	4.213031	-1.358737	-0.765366
C	-1.457634	-0.380166	0.127816
C	-1.728646	-1.310757	-0.885452
C	-2.512094	0.101467	0.910749
C	-3.031239	-1.747012	-1.111671
H	-0.910254	-1.685543	-1.503505
C	-3.813022	-0.345738	0.690908
H	-2.307511	0.840825	1.685568
C	-4.075533	-1.269241	-0.319431
H	-3.231863	-2.462060	-1.910787
H	-4.626961	0.037961	1.307391
H	-5.095824	-1.614204	-0.493739
H	2.079053	2.892885	-1.443479
O	0.406689	3.551552	-0.430522
H	2.377909	3.892693	0.011397

ooh-reactant

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C	-1.915775	-1.159710	-0.395759
C	-2.506156	-2.044104	0.520742
C	-0.543837	-1.332128	-0.904181
C	2.028909	0.678149	0.282988
C	0.296756	-2.340315	-0.645646
C	2.574749	-0.402198	0.350096
C	1.663646	-2.429184	-1.251847
C	3.181700	-1.728241	0.495900
H	0.012417	-3.170263	0.008578
H	-1.947582	-2.910249	0.878482
C	-3.955994	0.167056	-0.363382
C	-2.660759	-0.052466	-0.827989
C	-3.798454	-1.825457	0.985800
C	-4.529351	-0.719568	0.546120
H	-4.519311	1.033003	-0.714639
H	-4.240368	-2.522410	1.699380
H	-5.542679	-0.551504	0.913385
H	-0.190198	-0.525247	-1.558062
H	-2.209672	0.647077	-1.535991
C	1.303227	1.913504	0.190875
C	-0.062519	1.928289	0.518953
C	1.930866	3.093819	-0.235301
C	-0.788597	3.110745	0.413906
H	-0.543411	1.008615	0.856186
C	1.195155	4.270640	-0.337580
H	2.992347	3.076323	-0.484012
C	-0.162749	4.281655	-0.015530

H	-1.849279	3.114028	0.669990
H	1.685248	5.186640	-0.669937
H	-0.734057	5.207452	-0.097035
O	2.679312	-2.697975	-0.286108
H	1.722594	-3.284526	-1.939265
H	1.898972	-1.515212	-1.818323
O	4.065697	-1.959105	1.263893

ooh-TS34

C	-0.582102	2.155359	0.156855
C	0.217194	1.466119	1.106963
C	-1.933585	1.796644	-0.041548
C	-0.257892	-0.844804	0.042644
C	-2.463905	0.659164	0.587482
C	-1.516766	-0.787546	0.018878
C	-3.858163	0.202821	0.204792
C	-2.632956	-1.716295	-0.349793
H	-2.219337	0.526352	1.648092
H	-0.251177	0.874194	1.892593
C	1.434198	3.224150	-0.700728
C	0.071005	3.050270	-0.741876
C	1.604783	1.677384	1.156111
C	2.213340	2.522035	0.248116
H	1.919826	3.899487	-1.406639
H	2.203968	1.144342	1.896297
H	3.295168	2.661796	0.271273
H	-2.454767	2.216324	-0.906954
H	-0.531645	3.577304	-1.484814
C	1.110021	-1.215822	-0.048330
C	1.923332	-0.684058	-1.069790
C	1.682484	-2.085275	0.901916
C	3.265245	-1.038799	-1.148607
H	1.485776	0.011671	-1.787787
C	3.030174	-2.415072	0.821917
H	1.054532	-2.500084	1.691198
C	3.825776	-1.899576	-0.203935
H	3.882801	-0.630096	-1.949876
H	3.463013	-3.091136	1.560809
H	4.880975	-2.168608	-0.265649
O	-3.844666	-1.173298	-0.146075
H	-4.570961	0.320607	1.031563
H	-4.224591	0.775671	-0.660309
O	-2.496170	-2.828954	-0.750950

2no-product

C	2.69228	-1.76811	0.75160
C	3.08548	-0.99800	-0.51031
C	1.46569	-2.33342	0.78861
C	2.00253	0.03508	-1.00622
C	0.59603	-2.01356	-0.37540
C	0.62617	-0.49973	-0.61769
C	-0.89047	-2.31439	-0.40435
C	-0.58011	-0.27899	-1.50521
O	-0.81389	0.61728	-2.27122
H	0.99781	-2.50433	-1.28747
H	3.09944	-1.75824	-1.31648
C	4.89775	-1.36478	1.73713
C	3.66629	-1.90723	1.82700
C	4.46620	-0.41050	-0.46931
C	5.30544	-0.60161	0.55908
H	5.60772	-1.48170	2.55739
H	4.77373	0.18565	-1.33238
H	6.30648	-0.16842	0.53629
H	1.11307	-2.94395	1.62224
H	3.36164	-2.46375	2.71588
C	2.17866	1.44629	-0.48215
C	2.61144	1.68685	0.82766
C	1.83461	2.53282	-1.29127
C	2.71155	2.99014	1.31042
H	2.87910	0.84858	1.47682
C	1.93374	3.83729	-0.80819
H	1.46225	2.34767	-2.30110
C	2.37582	4.06943	0.49289
H	3.05581	3.16273	2.33129
H	1.66080	4.67487	-1.45192
H	2.45574	5.08949	0.87165
N	-1.45380	-1.33068	-1.21829
C	-3.70675	-0.54584	-0.64592
C	-4.22736	-1.16661	0.49382
C	-3.93291	0.81955	-0.83722
C	-4.97100	-0.43436	1.41528
H	-4.03078	-2.22838	0.66018
C	-4.67751	1.54642	0.08957
H	-3.50739	1.31526	-1.71274
C	-5.21249	0.93197	1.22679
H	-5.37125	-0.93181	2.30179
H	-4.84434	2.61384	-0.07183
C	-6.04660	1.71101	2.20992

H	-7.11703	1.62798	1.96533
H	-5.91201	1.33394	3.23279
H	-5.78538	2.77753	2.19704
H	0.34038	-0.03739	0.34372
H	2.07366	0.07295	-2.10467
C	-2.85281	-1.32575	-1.61765
H	-3.17531	-2.37389	-1.66754
H	-2.89823	-0.88108	-2.62053
O	-1.49603	-3.22060	0.09985

2no-react

C	-2.93181	-2.36300	-0.14234
C	-3.68326	-1.30383	0.39469
C	-1.46890	-2.42220	-0.02779
C	-0.68786	2.16575	0.86452
C	-0.71154	-1.65379	0.76869
C	-0.00955	1.05697	0.53500
C	0.77119	-1.79284	0.73902
C	1.12320	0.60097	1.38657
O	1.72880	1.35813	2.11033
H	-1.15375	-0.93164	1.45503
H	-3.18046	-0.48207	0.90896
C	-4.99025	-3.35584	-0.96956
C	-3.60421	-3.38105	-0.83360
C	-5.06573	-1.27385	0.25123
C	-5.72425	-2.30216	-0.42745
H	-5.49842	-4.15908	-1.50480
H	-5.63306	-0.43897	0.66514
H	-6.80922	-2.27640	-0.53864
H	-0.94952	-3.15243	-0.65700
H	-3.02690	-4.20238	-1.26316
C	-1.84935	2.70999	0.14936
C	-2.52780	1.98297	-0.84371
C	-2.31837	3.98832	0.48425
C	-3.63511	2.52590	-1.48537
H	-2.20091	0.97364	-1.10235
C	-3.42255	4.53603	-0.16462
H	-1.80280	4.55645	1.26130
C	-4.08380	3.80592	-1.15078
H	-4.15613	1.94413	-2.24716
H	-3.77058	5.53435	0.10400
H	-4.95295	4.22978	-1.65588
N	1.52554	-0.73989	1.27102
C	3.91117	-0.59221	0.62841
C	4.14956	-1.38315	-0.50249
C	4.58511	0.62396	0.75465
C	5.05033	-0.96468	-1.47613
H	3.61001	-2.32661	-0.61065
C	5.48756	1.03729	-0.22565
H	4.38794	1.25572	1.62318
C	5.73728	0.25083	-1.35318
H	5.22749	-1.59299	-2.35255
H	6.00582	1.99223	-0.11239
C	6.72967	0.67967	-2.40247
H	7.66150	0.09909	-2.32092
H	6.33152	0.51921	-3.41435
H	6.98680	1.74190	-2.29811
H	-0.25116	0.48257	-0.35922
H	-0.35313	2.70967	1.75389
C	2.91118	-1.03315	1.67122
H	2.97222	-2.11473	1.82975
H	3.08973	-0.51073	2.61772
O	1.31317	-2.79916	0.33794

2no-TS

C	-2.593594	-1.756347	-0.838195
C	-3.096035	-1.578609	0.487087
C	-1.234089	-2.049584	-1.054014
C	-1.538947	0.246511	1.211485
C	-0.366442	-1.978560	0.048497
C	-0.329641	-0.231399	0.661351
C	1.121384	-2.178203	-0.055382
C	0.906672	-0.440164	1.515022
O	1.206022	0.170947	2.505125
H	-0.735202	-2.416199	0.983131
H	-2.586777	-2.040661	1.330247
C	-4.687749	-0.872756	-1.713825
C	-3.449785	-1.414913	-1.932744
C	-4.399576	-1.076480	0.684577
C	-5.163676	-0.680777	-0.388641
H	-5.313893	-0.579870	-2.557726
H	-4.785463	-0.972535	1.700154
H	-6.152081	-0.247776	-0.228175
H	-0.827178	-2.051385	-2.068369
H	-3.073195	-1.549925	-2.948948
C	-2.348235	1.297016	0.607639
C	-2.209723	1.692776	-0.736472
C	-3.336990	1.934644	1.380010

C	-3.016594	2.689554	-1.274026	H	3.909089	0.941568	2.132909
H	-1.472872	1.204655	-1.377456	C	5.436808	1.441766	-0.885194
C	-4.134108	2.941420	0.844125	H	5.455672	-0.002496	-2.488494
H	-3.465049	1.637164	2.423495	H	5.214988	2.647919	0.888038
C	-3.978008	3.326412	-0.486973	C	6.252020	2.462703	-1.635086
H	-2.890965	2.975902	-2.319504	H	7.327175	2.239516	-1.553823
H	-4.882662	3.428834	1.470929	H	5.997292	2.467985	-2.703778
H	-4.601255	4.115217	-0.910043	H	6.091004	3.472881	-1.236107
N	1.721686	-1.412620	0.936276	H	-0.015020	0.273140	-0.260086
C	3.966422	-0.502308	0.535343	H	-1.723581	0.044769	2.270393
C	4.398049	-0.753809	-0.771524	C	3.134969	-1.525193	1.272652
C	4.263880	0.729878	1.121734	H	3.443667	-2.544218	1.007295
C	5.124067	0.207204	-1.468787	H	3.219964	-1.387063	2.358232
H	4.146768	-1.707845	-1.241153	O	1.718235	-2.892732	-0.817620
C	4.991207	1.688060	0.417152				

X. References

[1] Tam, J.; Henault, M.; Melnyk, R. A., et al. *Anal Biochem* **2011,** *414*, 254-260.

[2] K. Singh, G. Kaur, P. S. Shanika, G. A. Dziwornu, J. Okombo, K. Chibale, *Bioorg. Med. Chem.* **2020**, *28*, 115530.

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[4] Cao, J.; Sun, K.; Dong, S.; Lu, T.; Dong, Y.; Du, D. *Org. Lett.* **2017,** *19*, 6724-6727.

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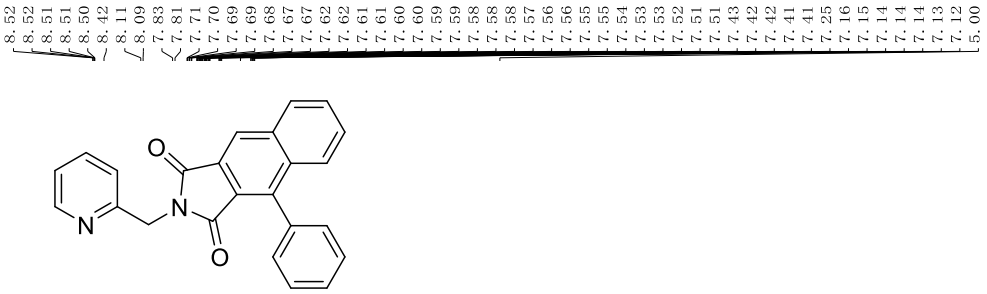
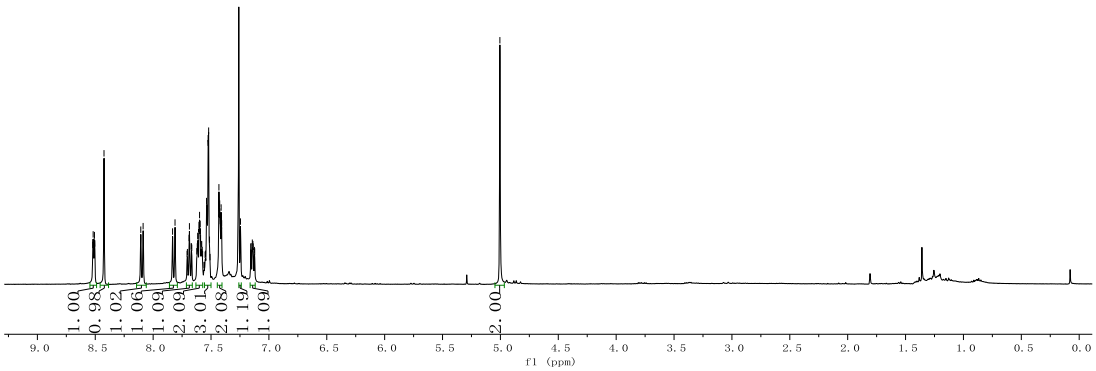
[6] X.-S. Wu, Y. Chen, M.-B. Li, M.-G. Zhou, S.-K. Tian, *J. Am. Chem. Soc.* **2012**, *134*, 14694-14697.

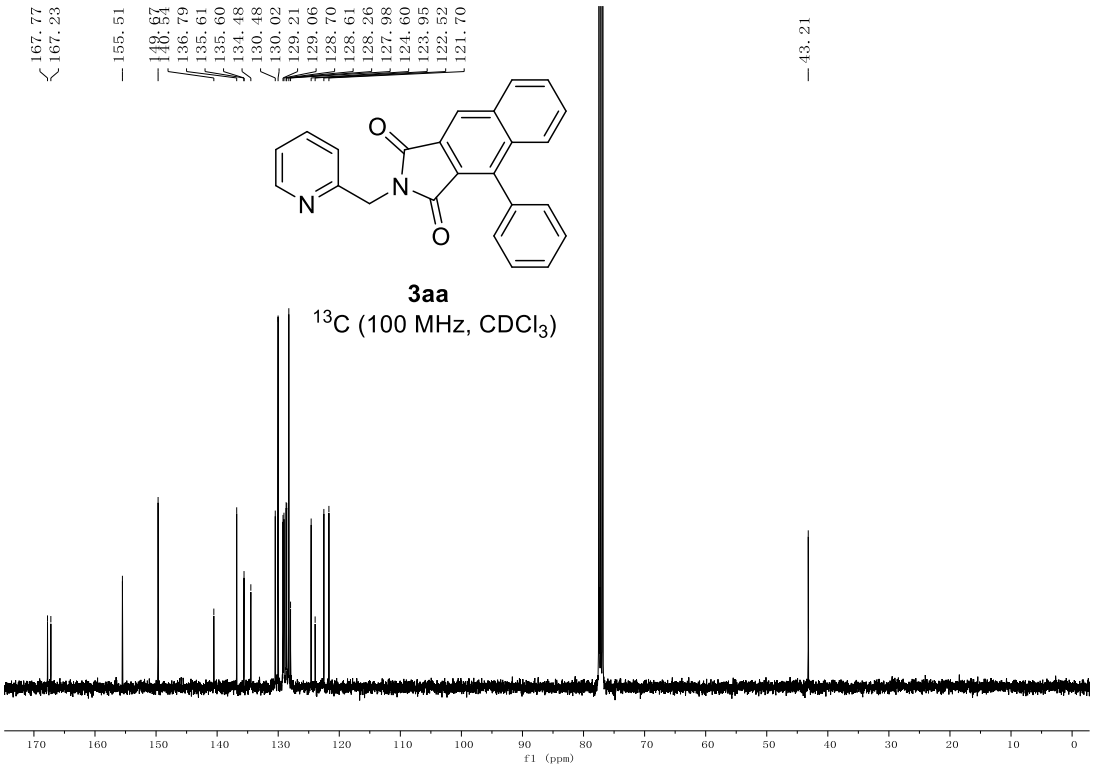
XI. NMR Spectra



3aa

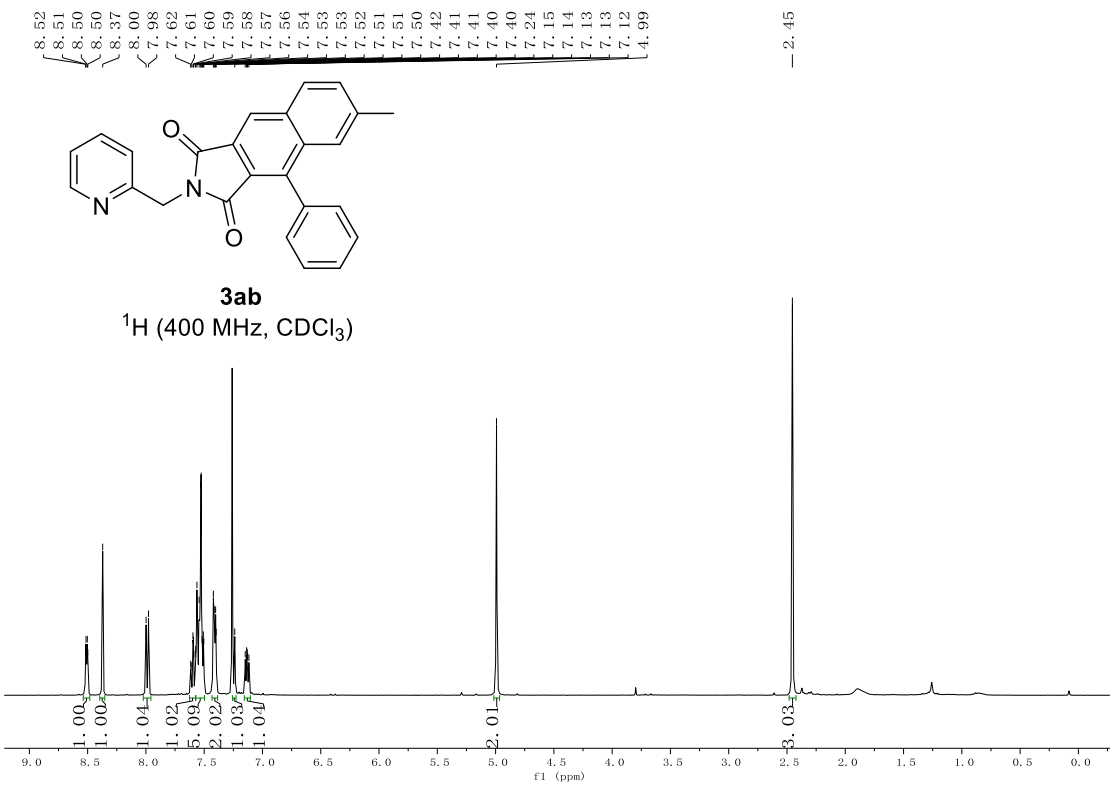
^{1}H (400 MHz, $CDCl_3$)

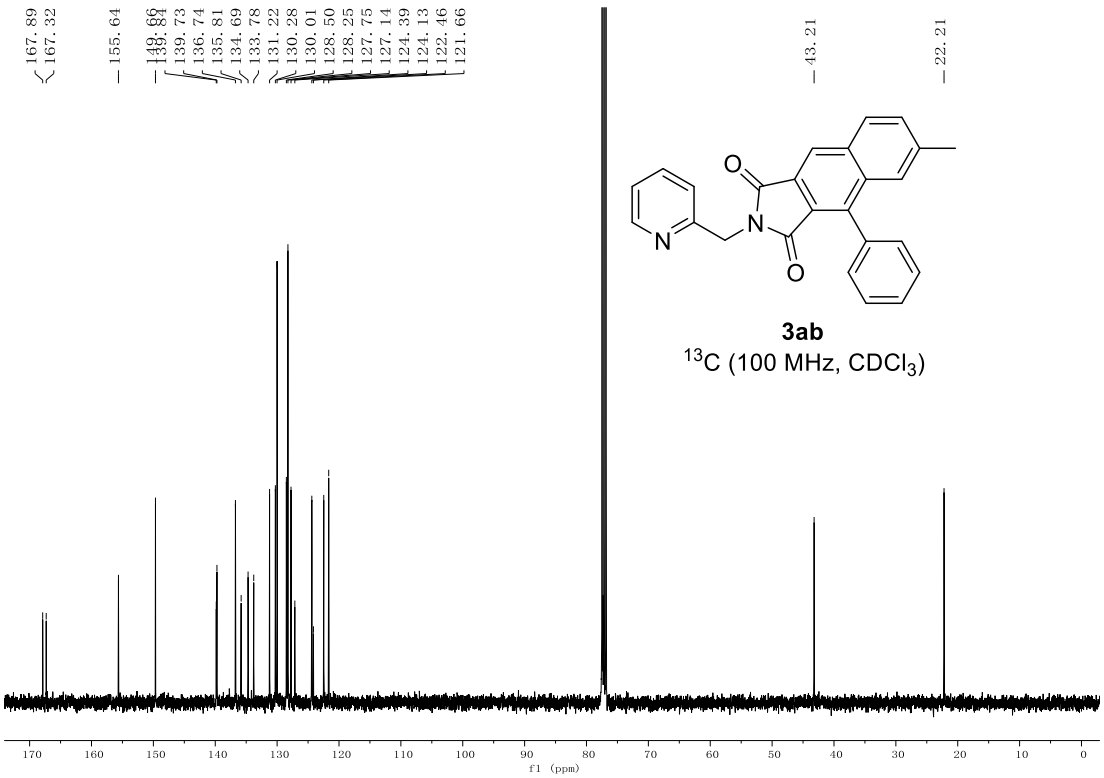


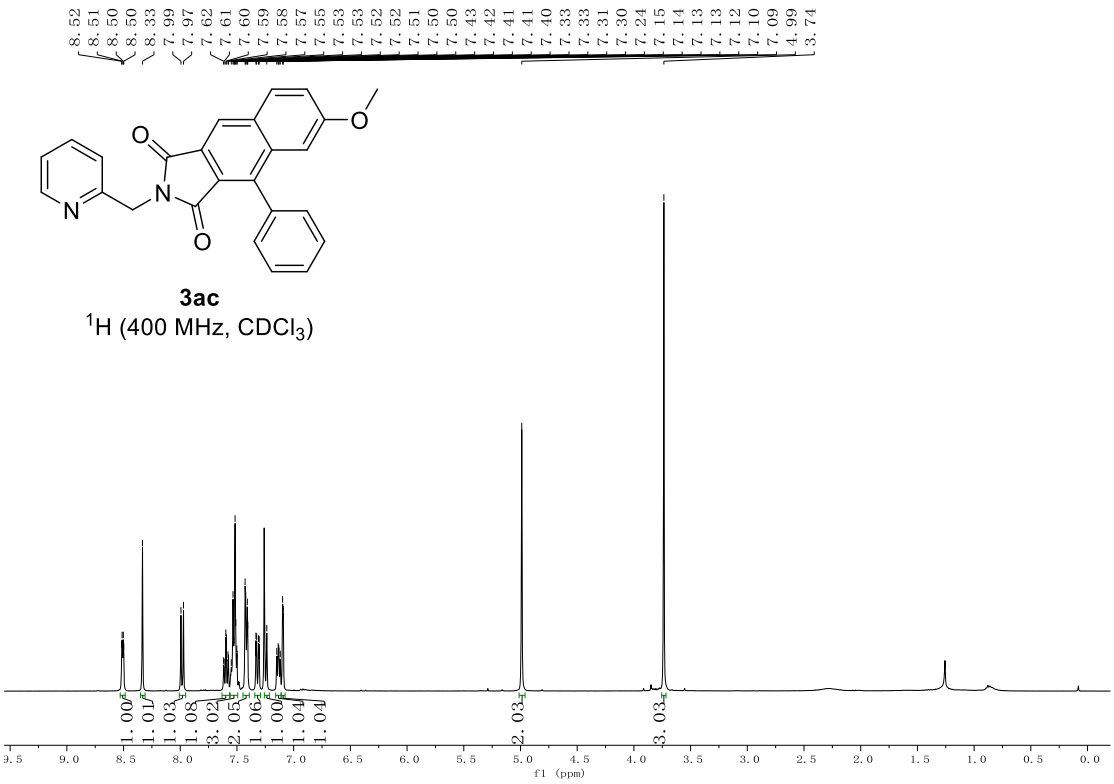


3aa

^{13}C (100 MHz, $CDCl_3$)

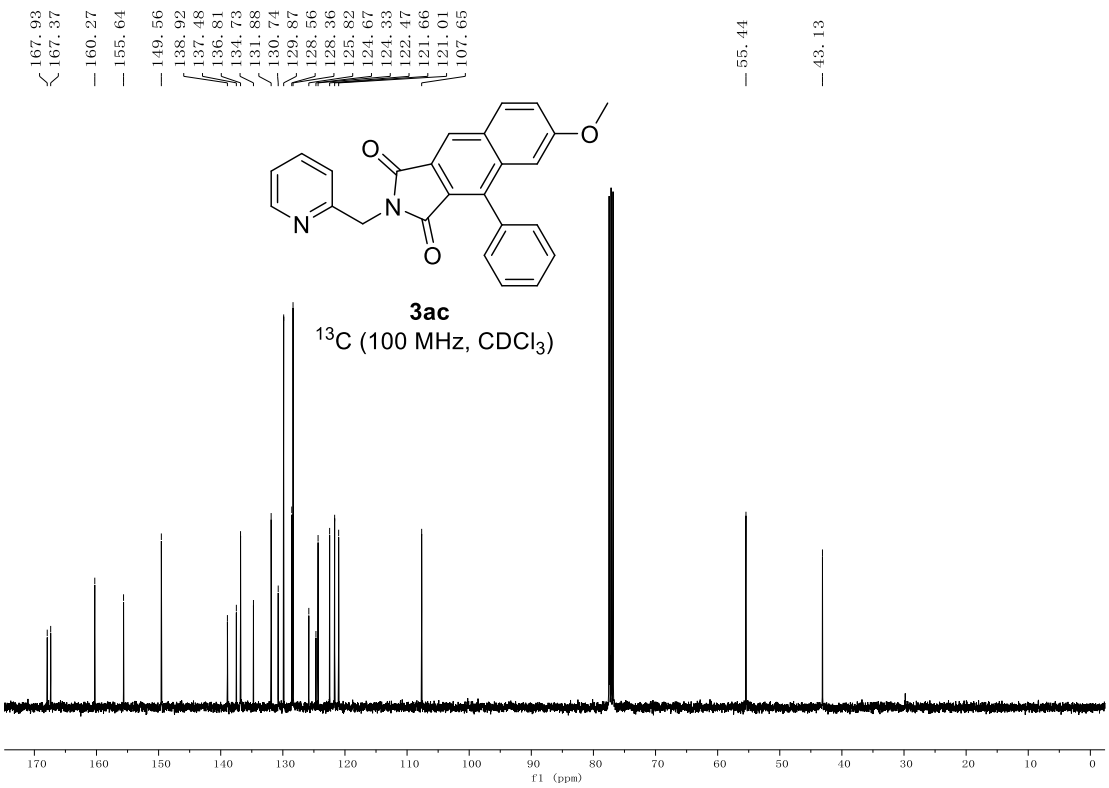

8.52
8.51
8.50
8.50
8.37
8.00
7.98
7.62
7.61
7.60
7.59
7.58
7.57
7.56
7.54
7.53
7.53
7.52
7.51
7.51
7.50
7.42
7.41
7.41
7.40
7.40
7.24
7.15
7.14
7.13
7.13
7.12
4.99
2.45
O
N
N
O
3ab
1H (400 MHz, CDCl3)
1.00
1.00
1.04
1.02
5.09
2.02
1.03
1.04
2.01
3.03
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


167.89
167.32
155.64
149.66
149.84
139.73
136.74
135.81
134.69
133.78
131.22
130.28
130.01
128.50
128.25
127.75
127.14
124.39
124.13
122.46
121.66
43.21
22.21
O
N
N
O
3ab
13C (100 MHz, CDCl3)
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)



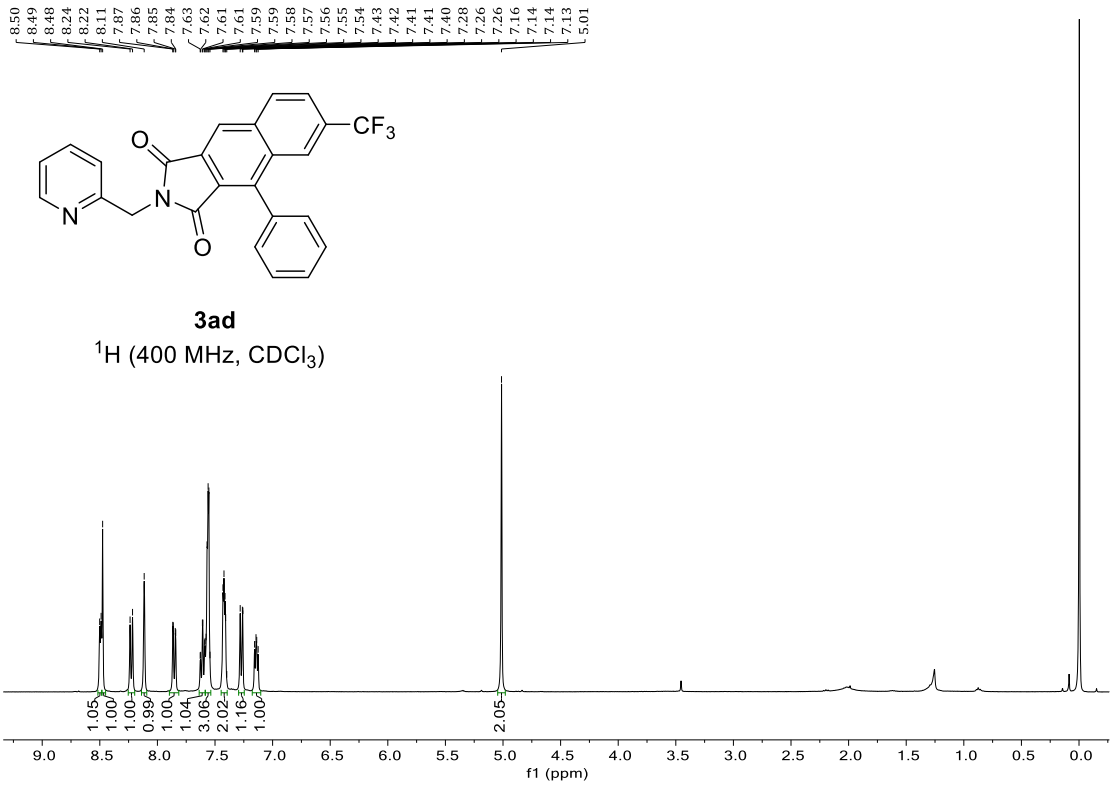
3ac

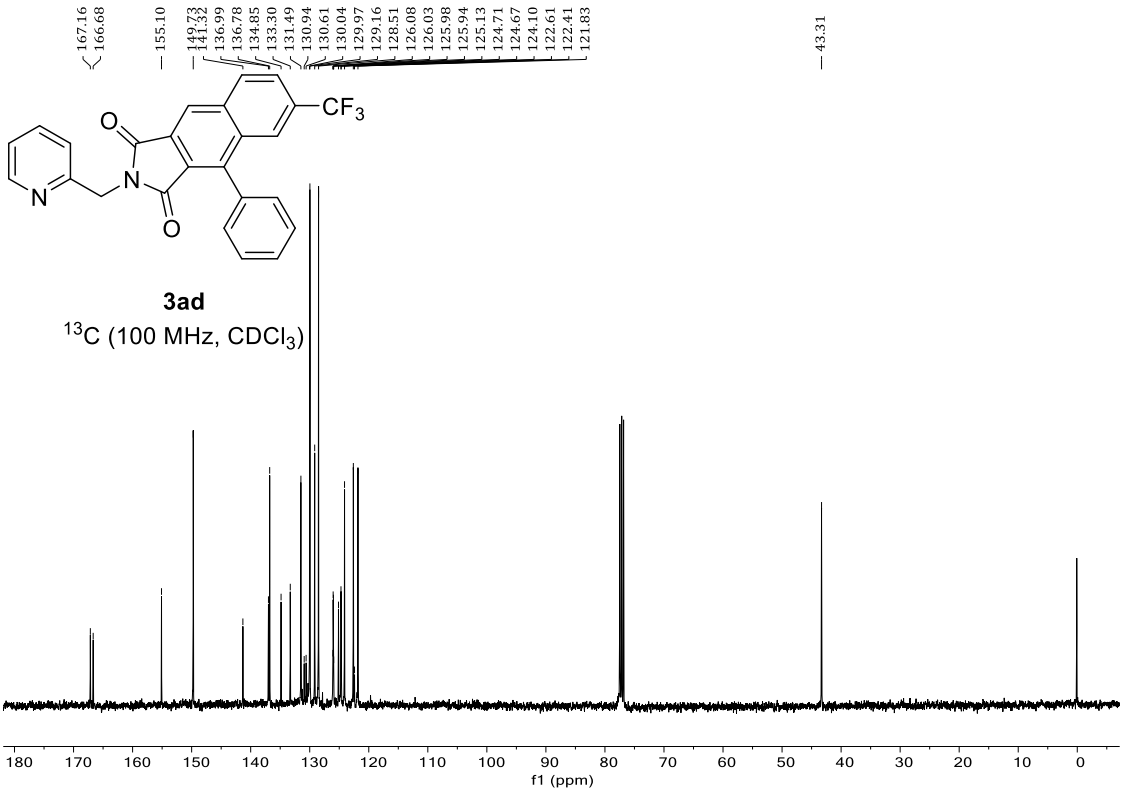
^{1}H (400 MHz, $CDCl_3$)

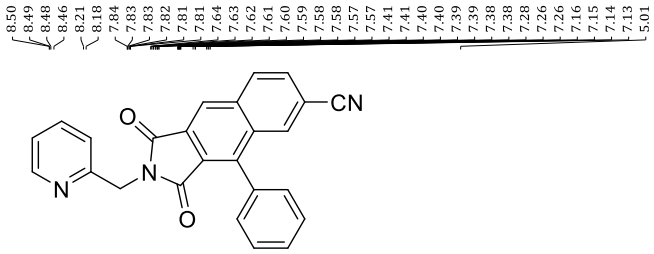


3ac

^{13}C (100 MHz, $CDCl_3$)

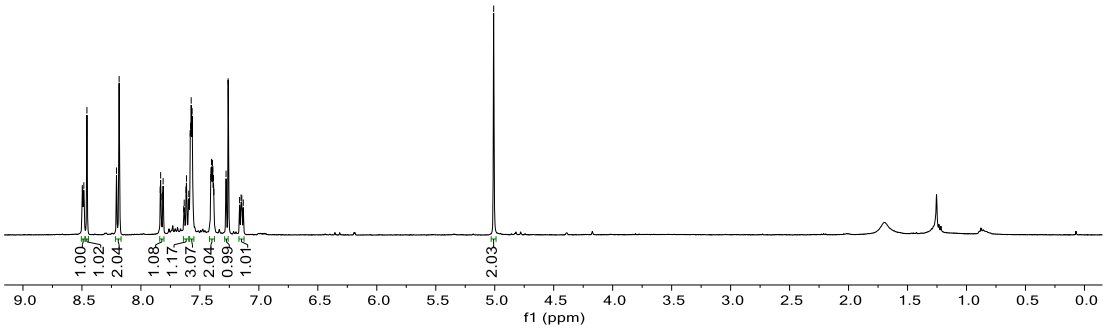

8.50
8.49
8.48
8.24
8.22
8.11
7.87
7.86
7.85
7.84
7.63
7.62
7.61
7.61
7.59
7.59
7.58
7.57
7.56
7.55
7.54
7.43
7.42
7.41
7.41
7.40
7.28
7.26
7.16
7.14
7.14
7.13
5.01
CF3
O
N
N
O
3ad
1H (400 MHz, CDCl3)
1.05
1.00
1.00
0.99
1.00
1.04
3.06
2.02
1.16
1.00
2.05
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

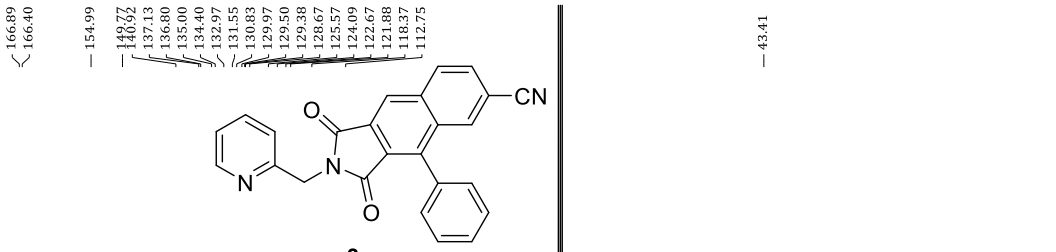

167.16
166.68
155.10
149.73
141.32
136.99
136.78
134.85
133.30
131.49
130.94
130.61
130.04
129.97
129.16
128.51
126.08
126.03
125.98
125.94
125.13
124.71
124.67
124.10
122.61
122.41
121.83
43.31
CF3
O
N
N
O
3ad
13C (100 MHz, CDCl3)
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)



3ae

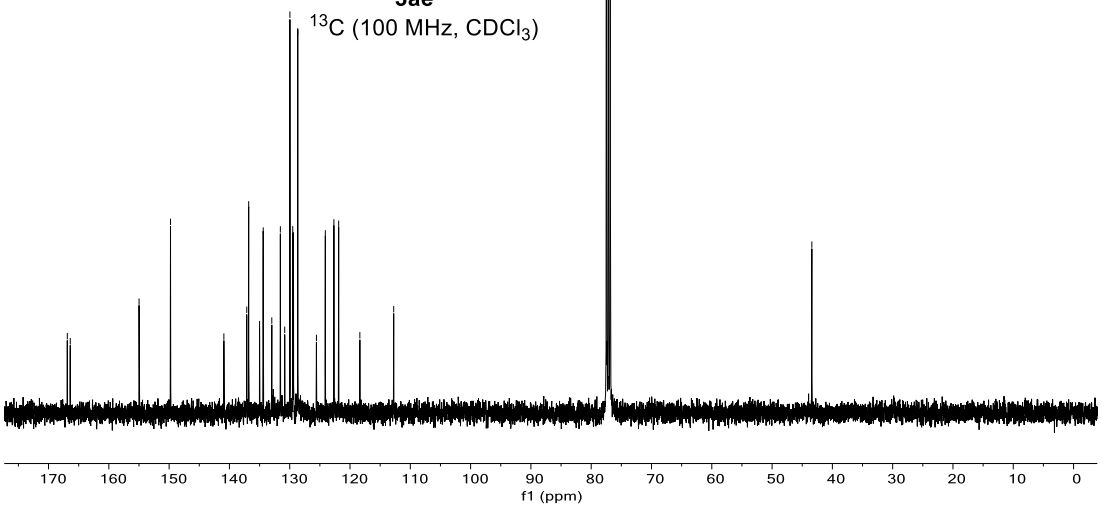
^{1}H (400 MHz, $CDCl_3$)

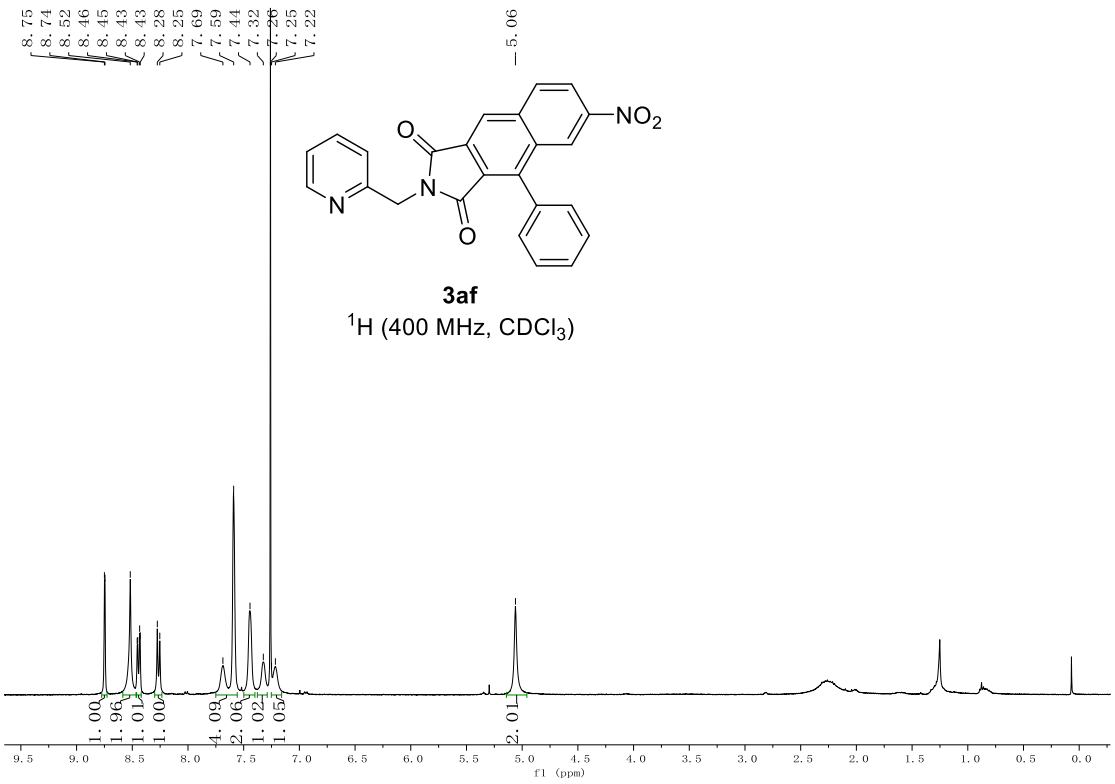




3ae

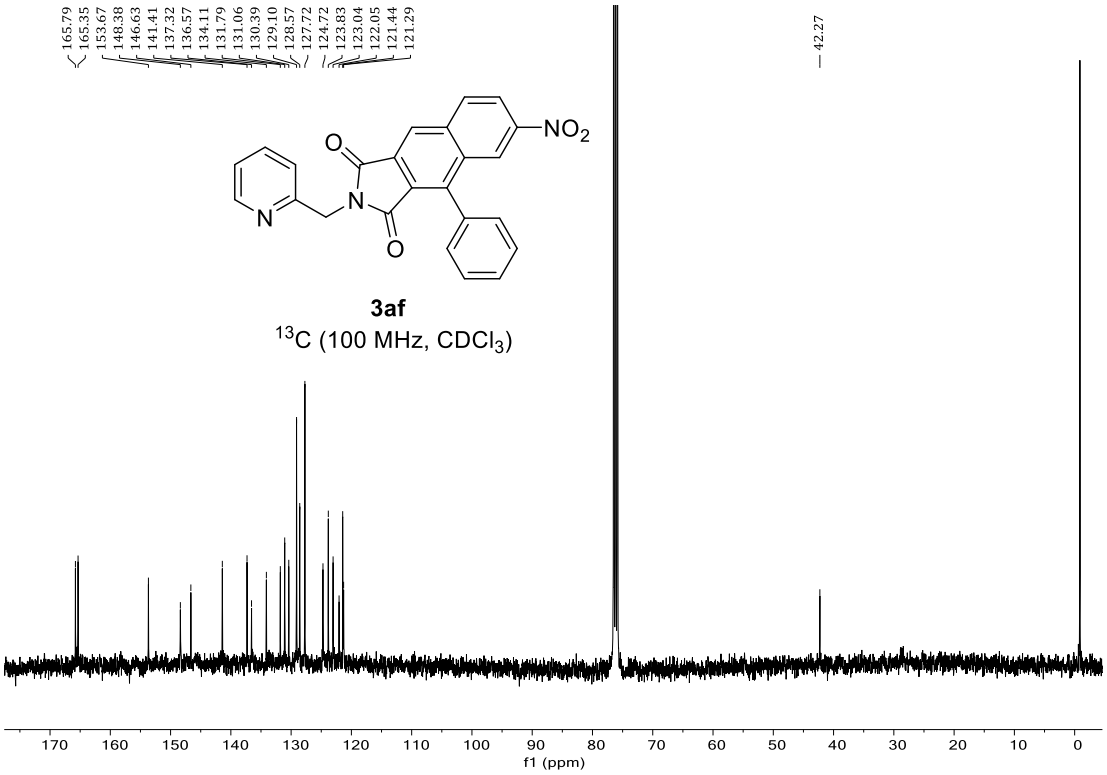
^{13}C (100 MHz, $CDCl_3$)





3af

^{1}H (400 MHz, $CDCl_3$)



3af

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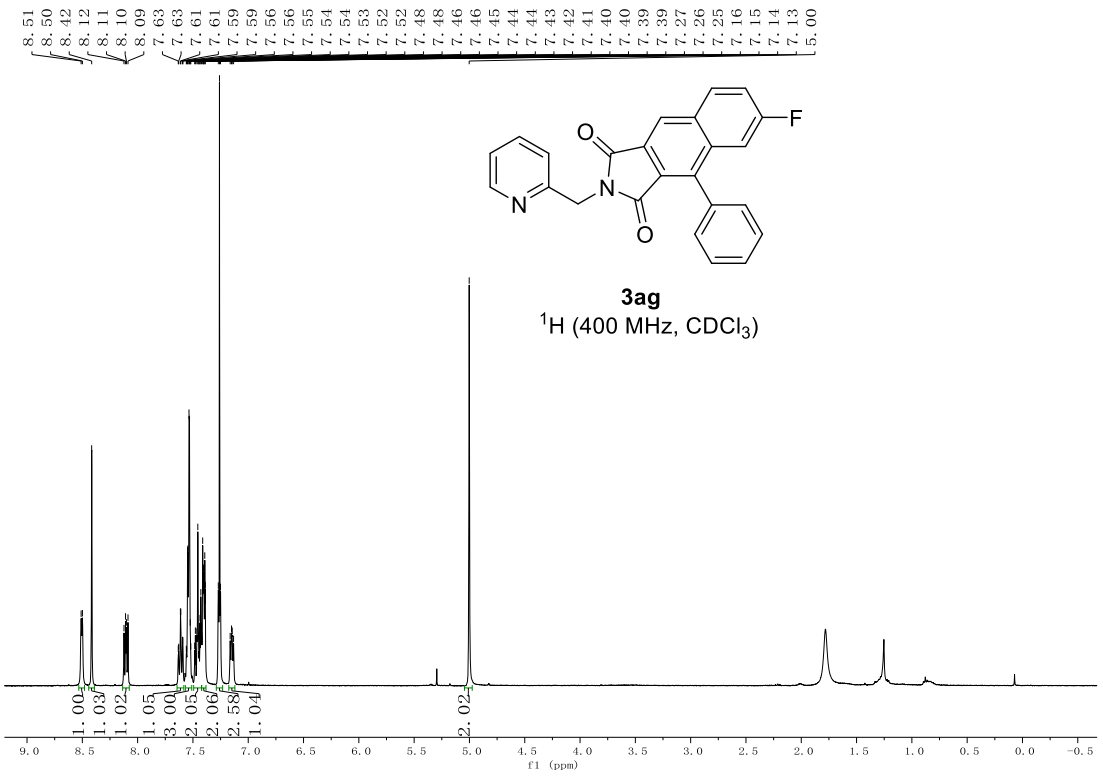
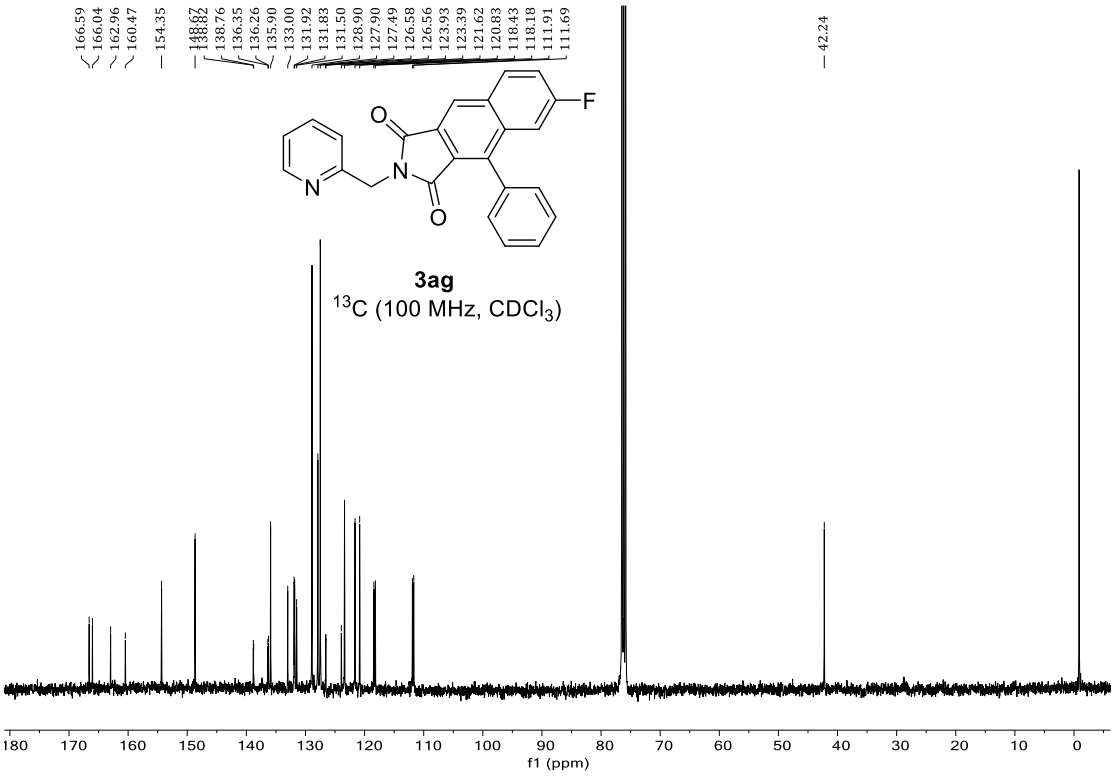


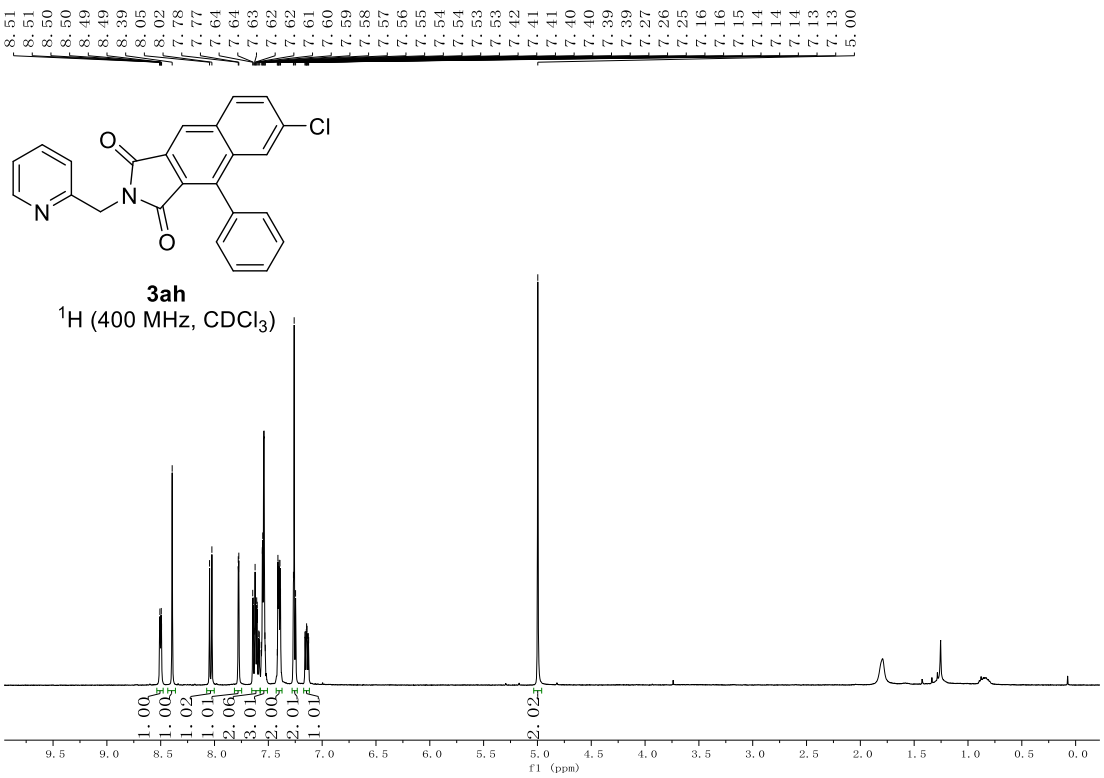
3ag

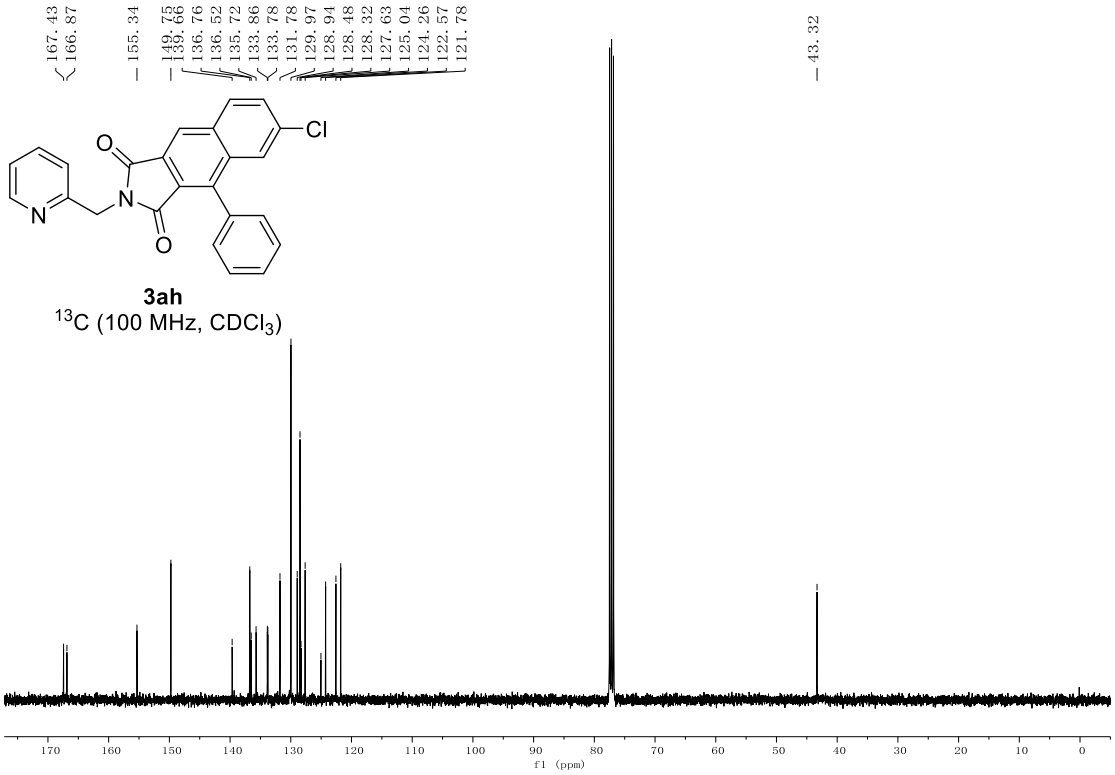
^{1}H (400 MHz, $CDCl_3$)

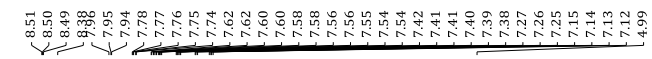


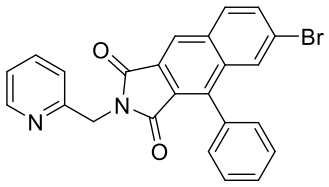
3ag

^{13}C (100 MHz, $CDCl_3$)


8.51
8.51
8.50
8.50
8.49
8.49
8.39
8.05
8.02
7.78
7.77
7.64
7.64
7.63
7.62
7.62
7.61
7.60
7.59
7.58
7.57
7.56
7.55
7.54
7.54
7.53
7.53
7.42
7.41
7.41
7.40
7.40
7.39
7.39
7.27
7.26
7.25
7.16
7.15
7.14
7.14
7.13
7.13
5.00
Cl
O
N
N
O
3ah
1H (400 MHz, CDCl3)
1.00
1.00
1.02
1.01
2.06
3.01
2.00
2.01
1.01
2.02
f1 (ppm)

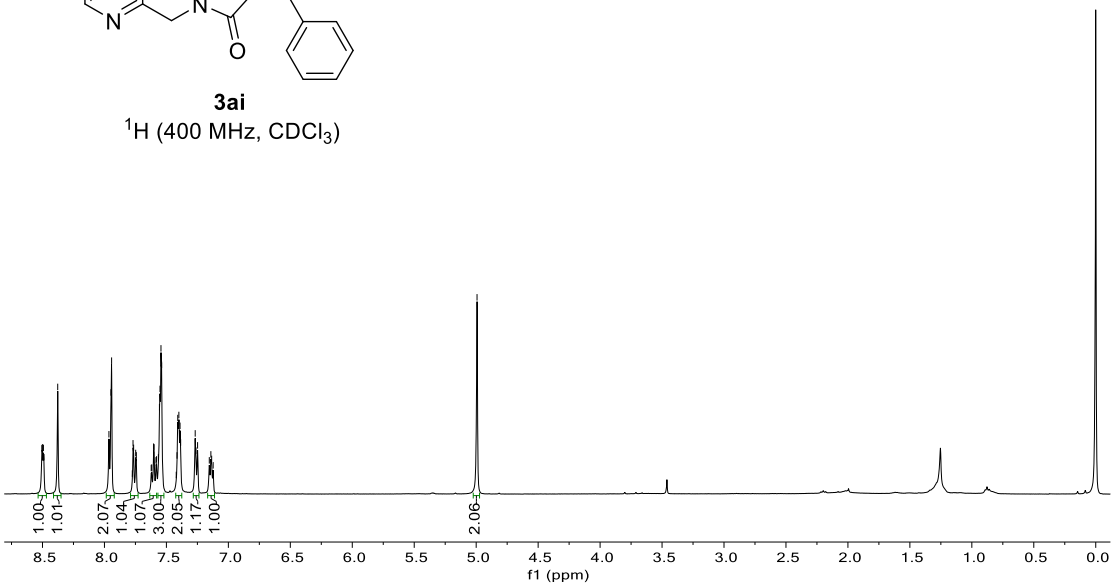

167.43
166.87
155.34
149.75
139.66
136.76
136.52
135.72
133.86
133.78
131.78
129.97
128.94
128.48
128.32
127.63
125.04
124.26
122.57
121.78
43.32
Cl
O
N
N
O
3ah
13C (100 MHz, CDCl3)
f1 (ppm)

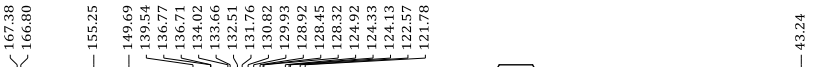


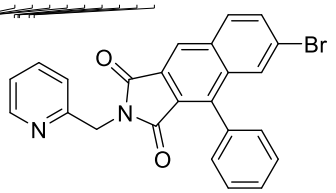


3ai

^{1}H (400 MHz, $CDCl_3$)

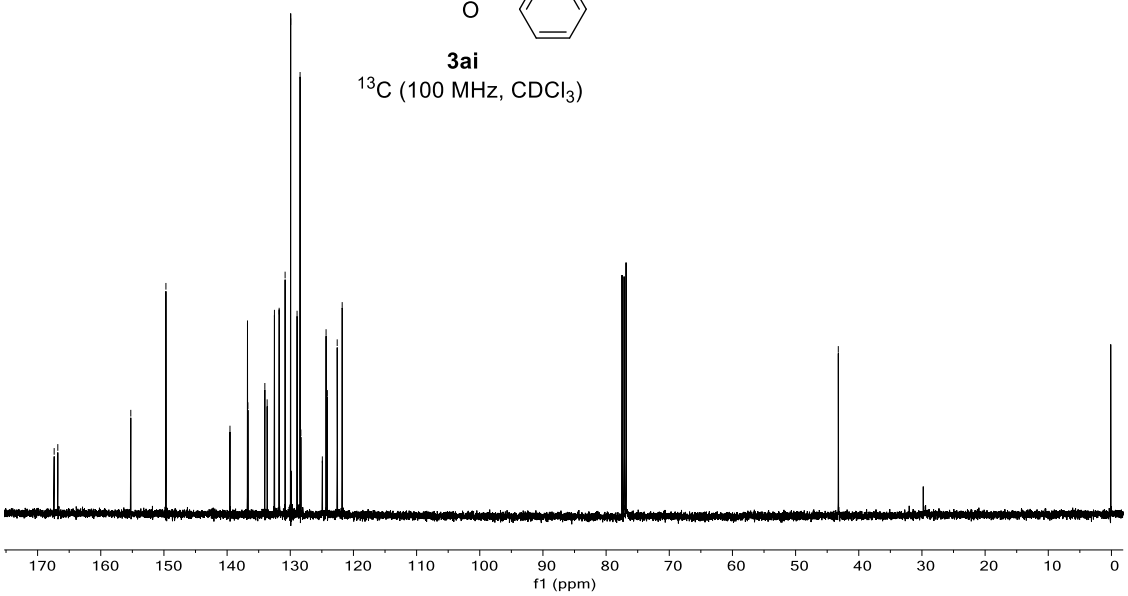


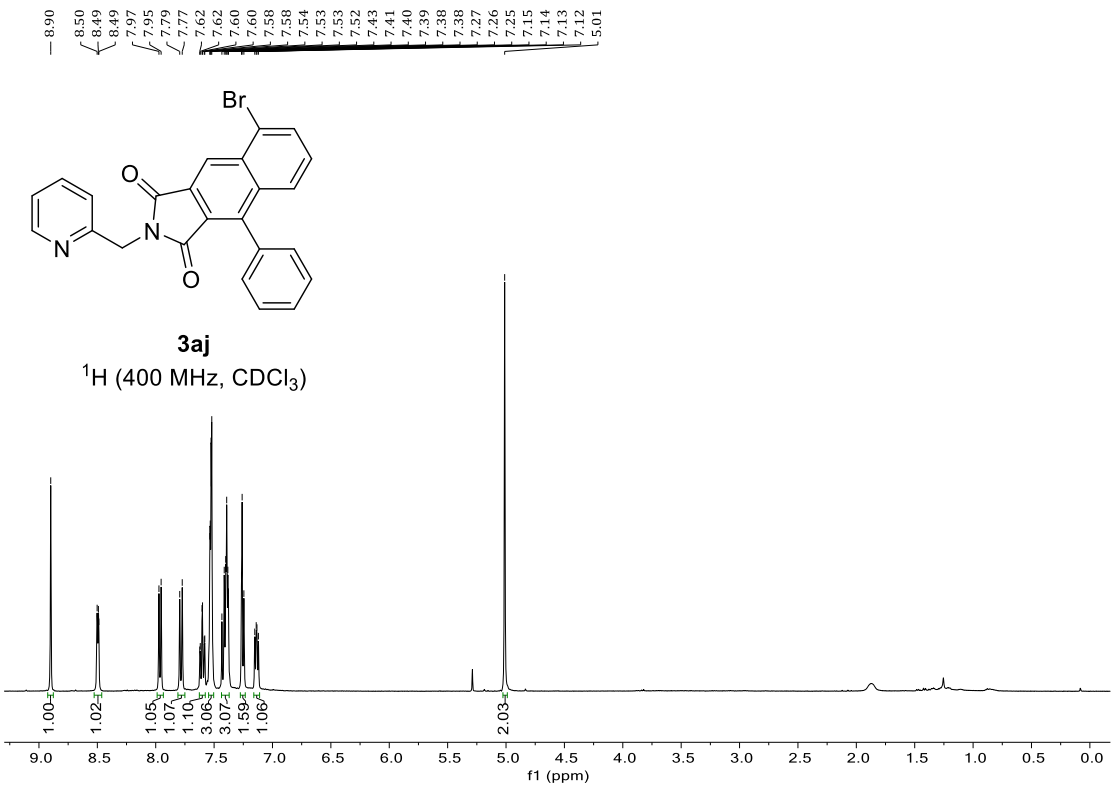


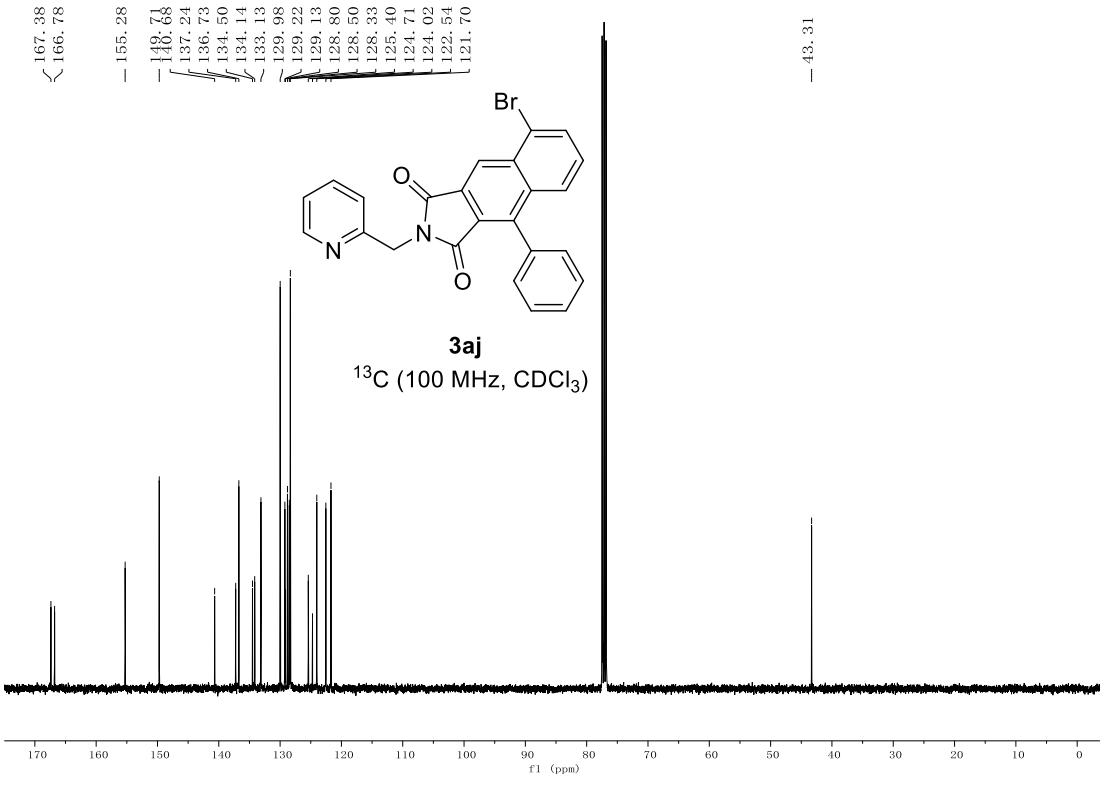


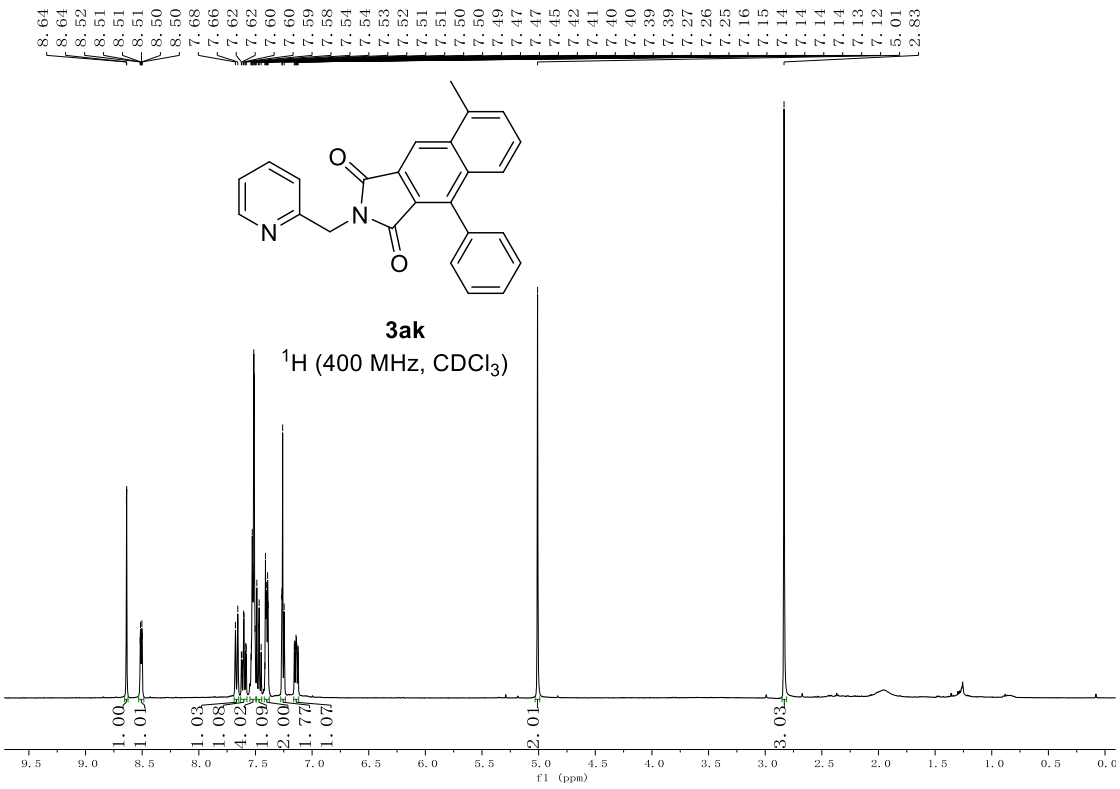
3ai

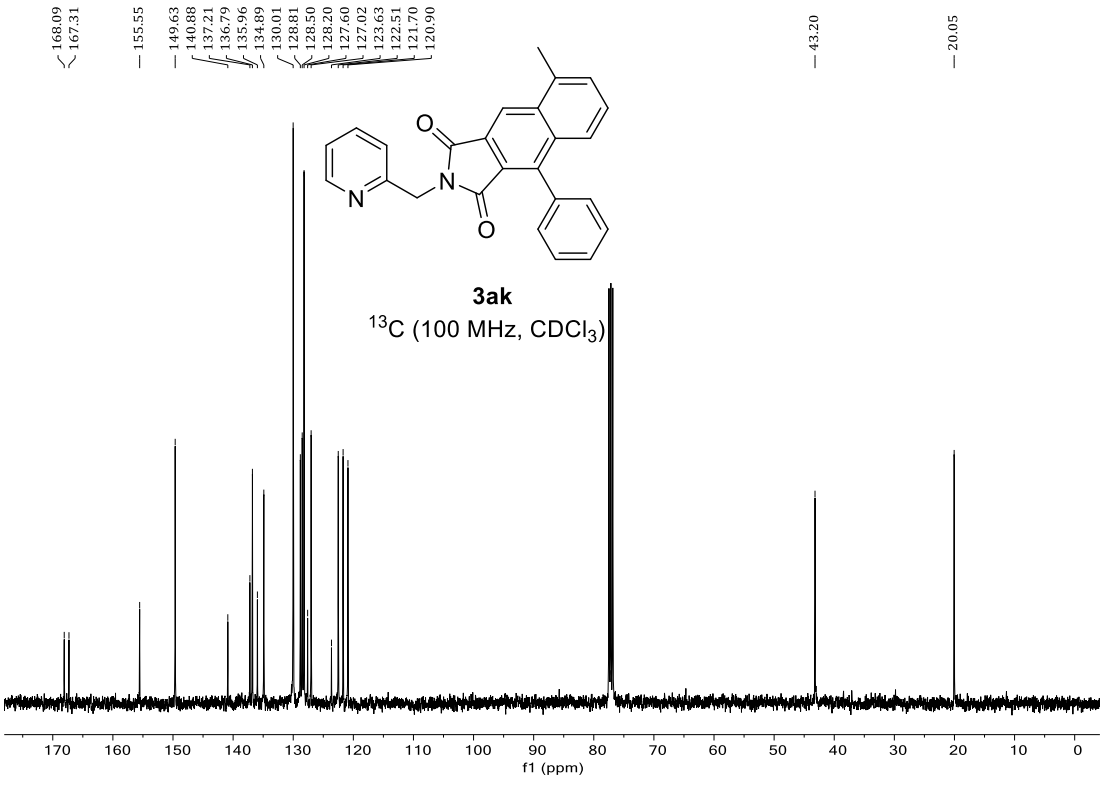
^{13}C (100 MHz, $CDCl_3$)

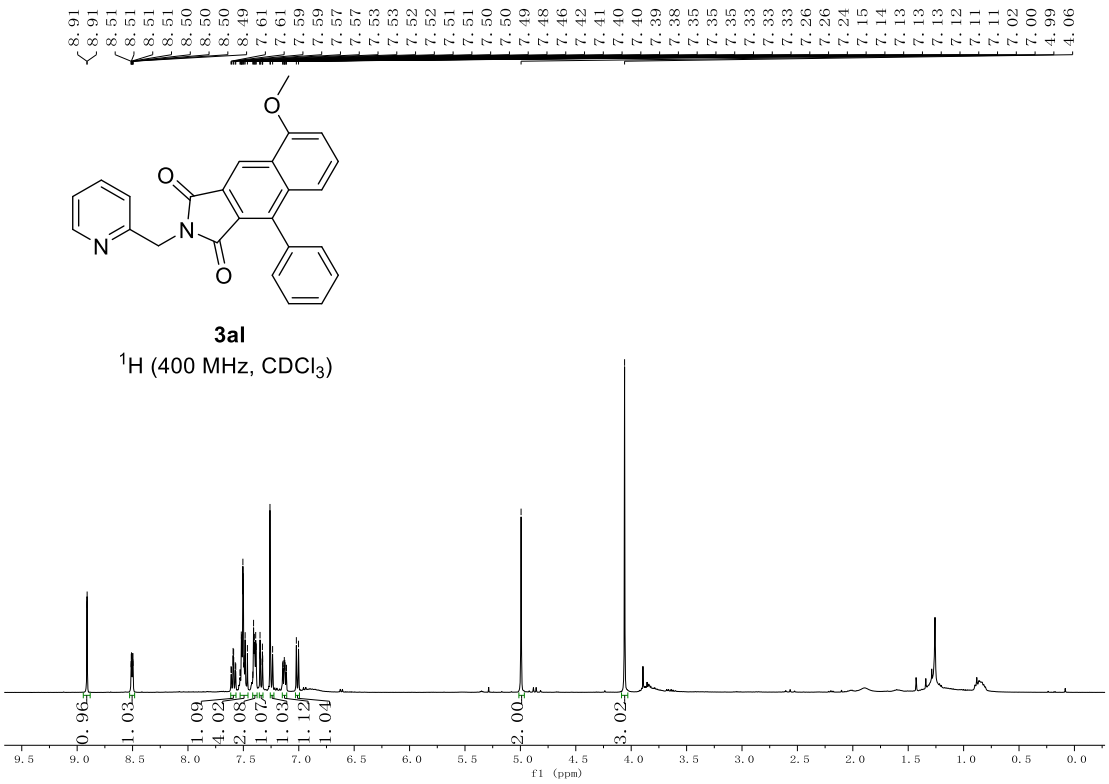



8.90
8.50
8.49
8.49
7.97
7.95
7.79
7.77
7.62
7.62
7.60
7.60
7.58
7.58
7.54
7.53
7.53
7.52
7.43
7.41
7.40
7.39
7.38
7.38
7.27
7.26
7.25
7.15
7.14
7.13
7.12
5.01
Br
O
N
N
O
3aj
1H (400 MHz, CDCl3)
1.00
1.02
1.05
1.07
1.10
3.06
3.07
1.59
1.06
2.03
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


167.38
166.78
155.28
149.71
140.68
137.24
136.73
134.50
134.14
133.13
129.98
129.22
129.13
128.80
128.50
128.33
125.40
124.71
124.02
122.54
121.70
43.31
Br
O
N
N
O
3aj
13C (100 MHz, CDCl3)
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

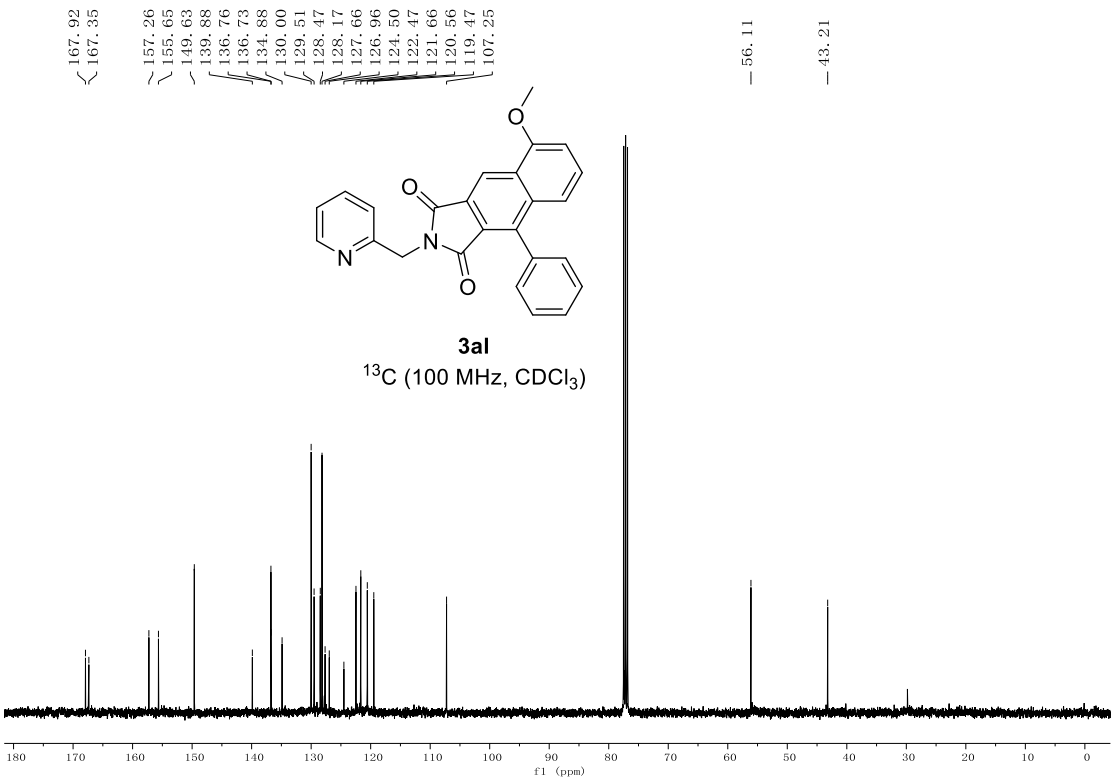

8.64
8.64
8.52
8.51
8.51
8.51
8.50
8.50
7.68
7.66
7.62
7.62
7.60
7.60
7.59
7.58
7.54
7.54
7.53
7.52
7.51
7.51
7.50
7.50
7.49
7.47
7.47
7.45
7.42
7.41
7.40
7.40
7.39
7.39
7.27
7.26
7.25
7.16
7.15
7.14
7.14
7.14
7.14
7.13
7.12
5.01
2.83
O
N
N
O
3ak
1H (400 MHz, CDCl3)
1.00
1.01
1.03
1.08
4.02
1.09
2.00
1.77
1.07
2.01
3.03
f1 (ppm)


168.09
167.31
155.55
149.63
140.88
137.21
136.79
135.96
134.89
130.01
128.81
128.50
128.20
127.60
127.02
123.63
122.51
121.70
120.90
43.20
20.05
O
N
N
O
3ak
13C (100 MHz, CDCl3)
f1 (ppm)



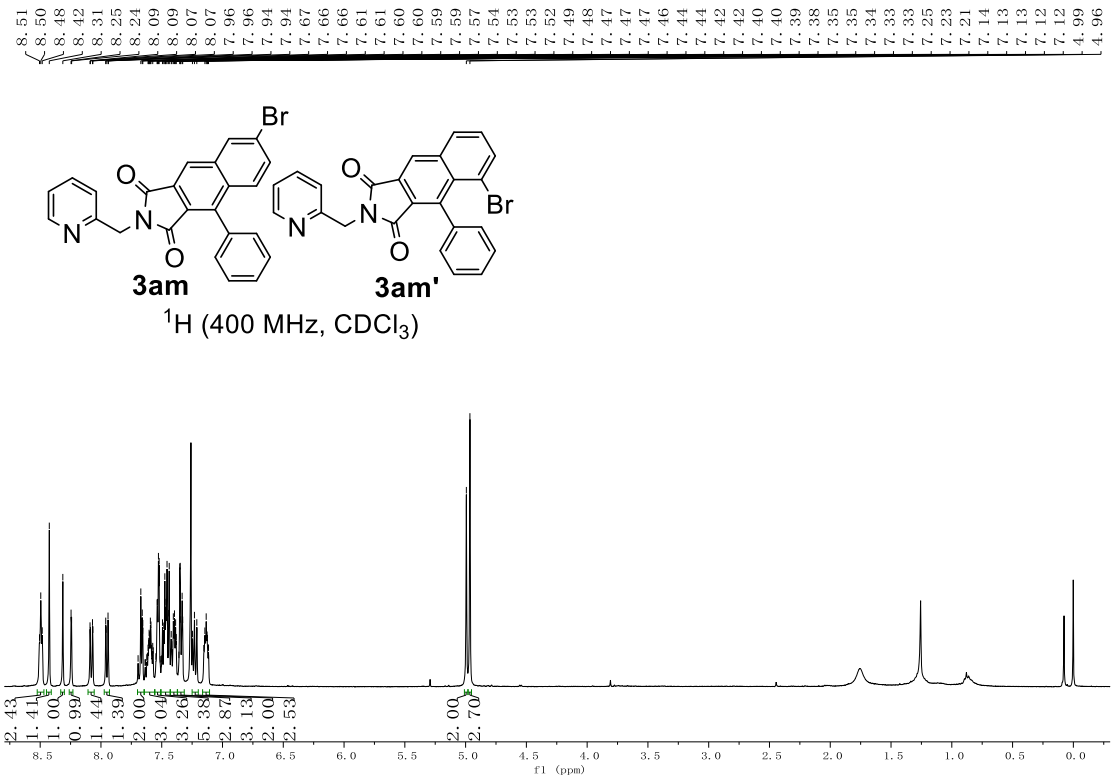
3al

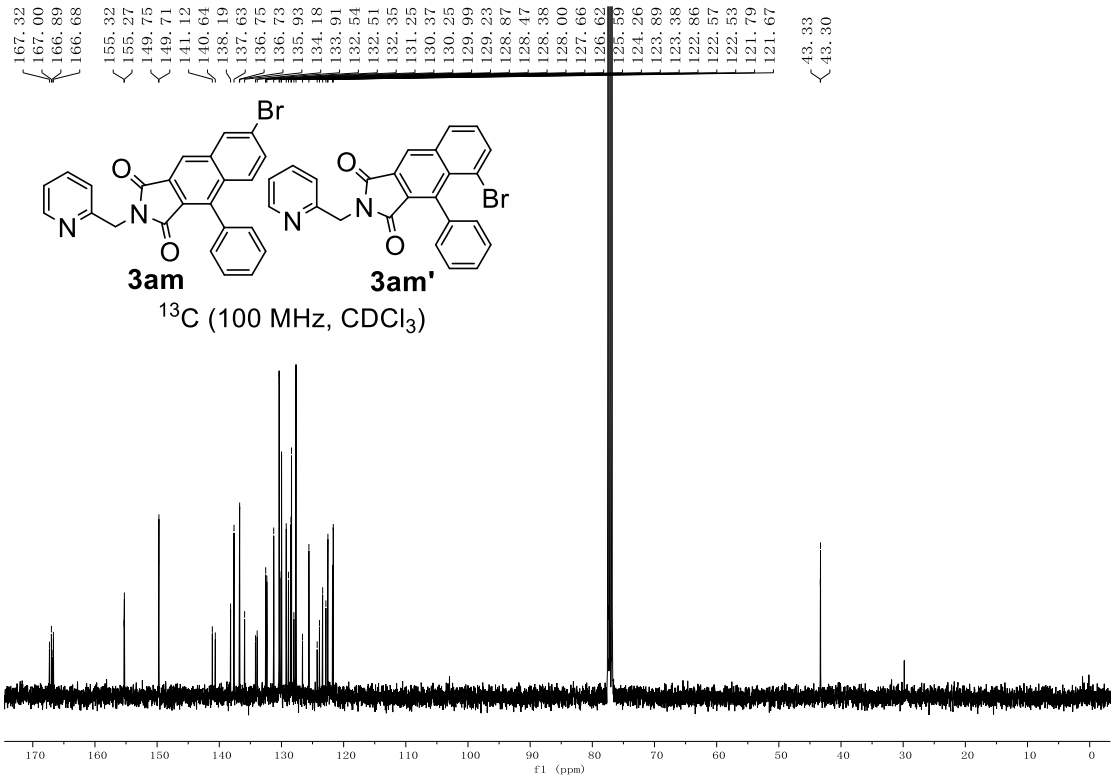
^{1}H (400 MHz, $CDCl_3$)

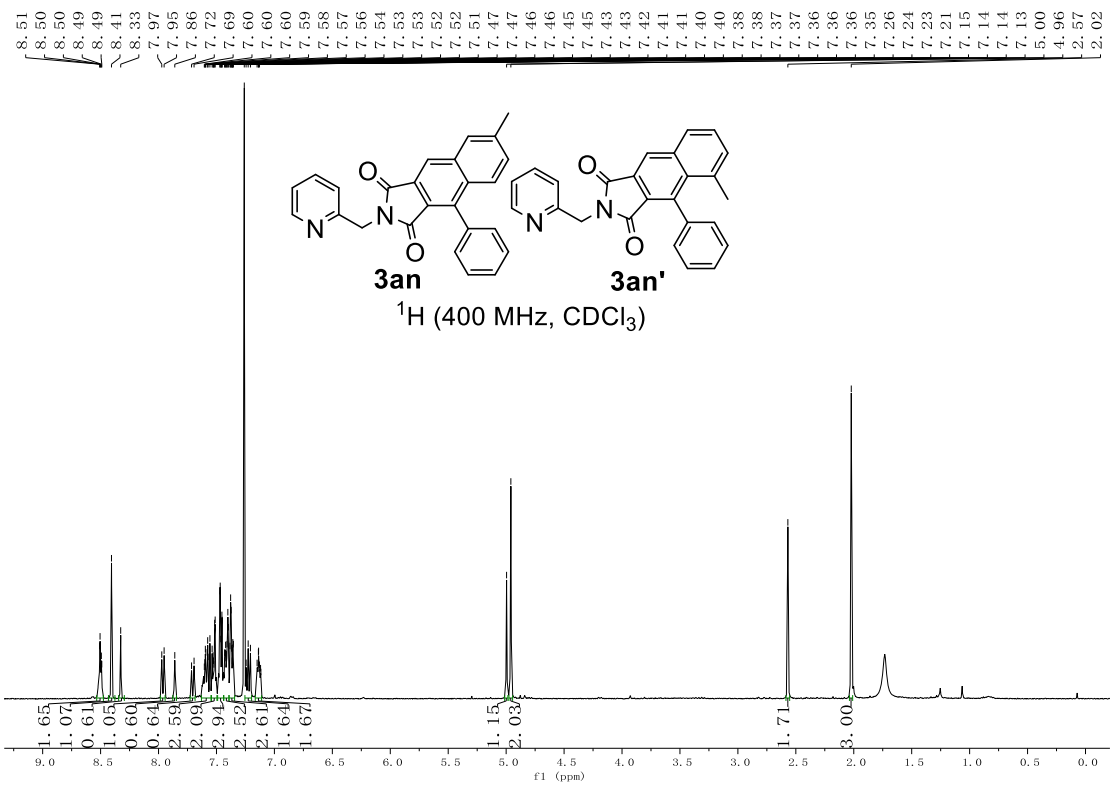


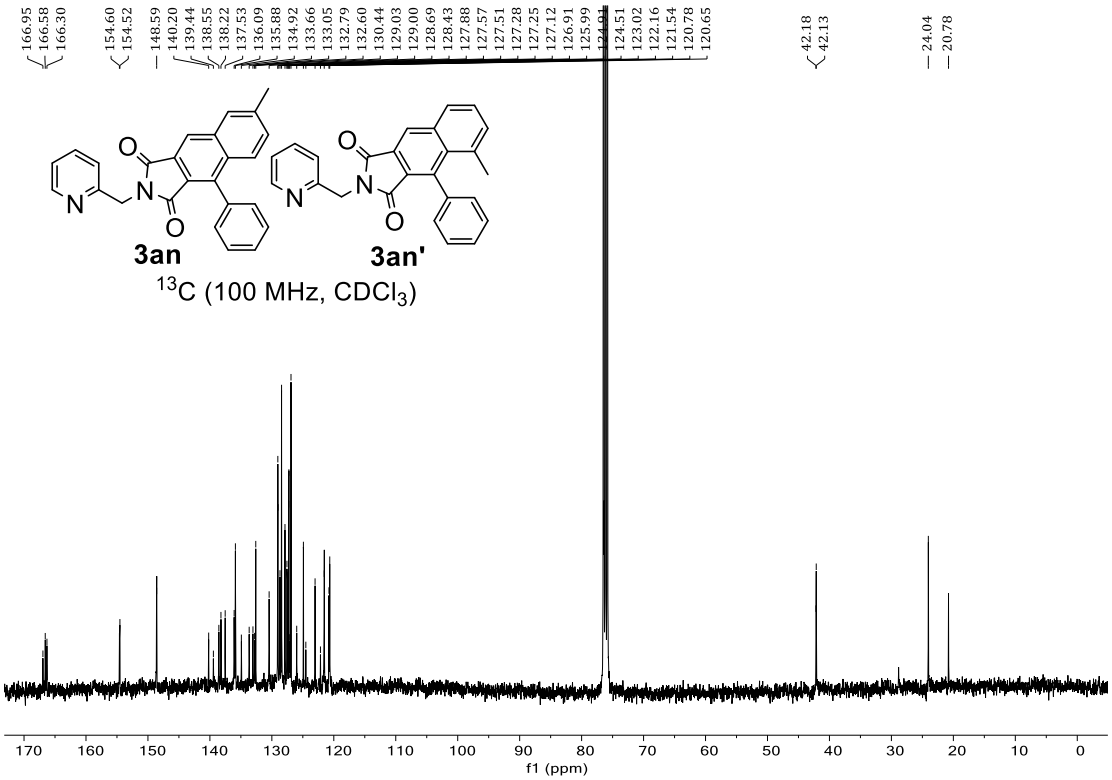
3al

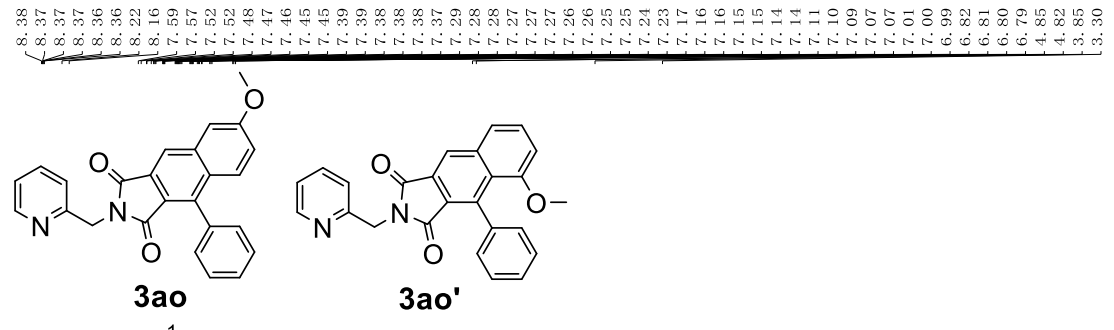
^{13}C (100 MHz, $CDCl_3$)


3am
3am'
^{1}H (400 MHz, $CDCl_3$)
f1 (ppm)


3am
3am'
^{13}C (100 MHz, $CDCl_3$)
f1 (ppm)

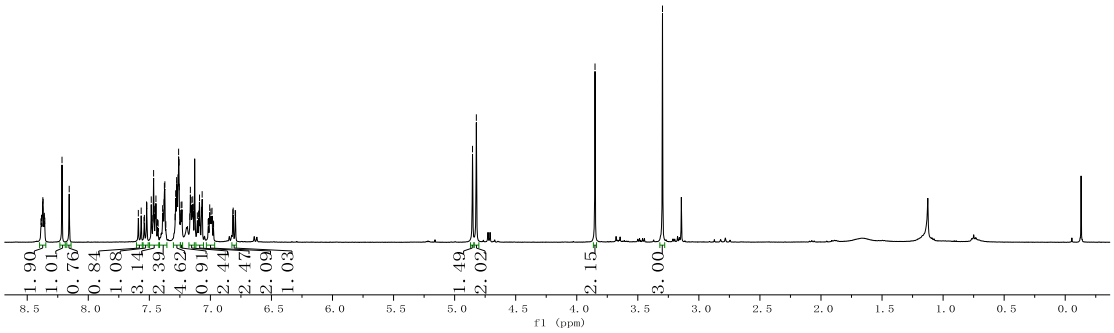

3an
3an'
^{1}H (400 MHz, $CDCl_3$)
f1 (ppm)

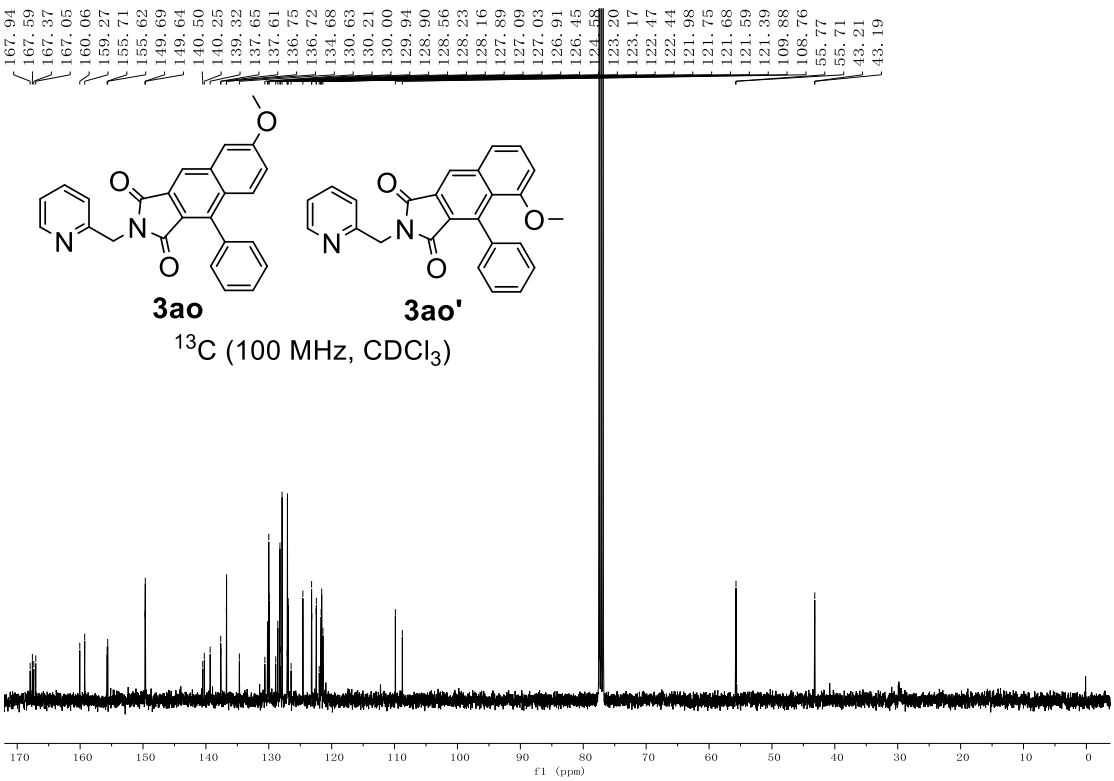

3an
3an'
^{13}C (100 MHz, $CDCl_3$)
f1 (ppm)



3ao **3ao'**

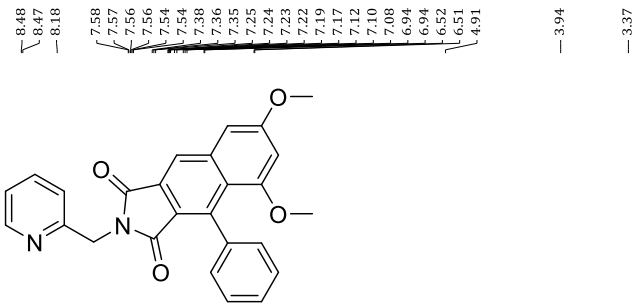
^{1}H (400 MHz, $CDCl_3$)





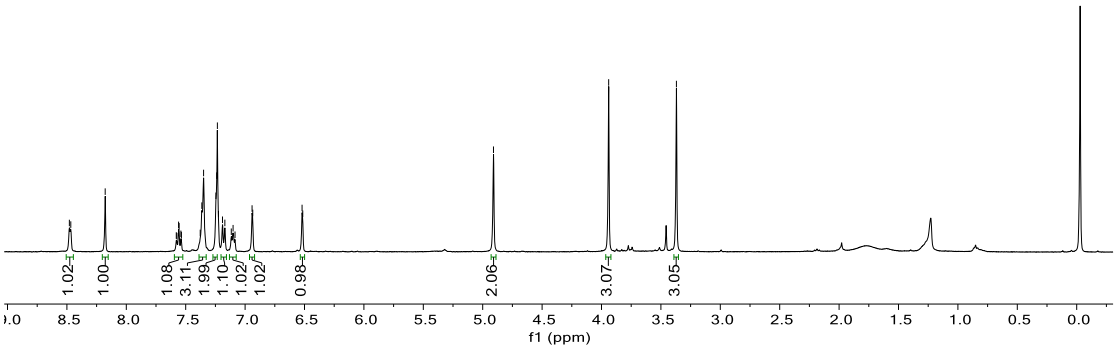
3ao **3ao'**

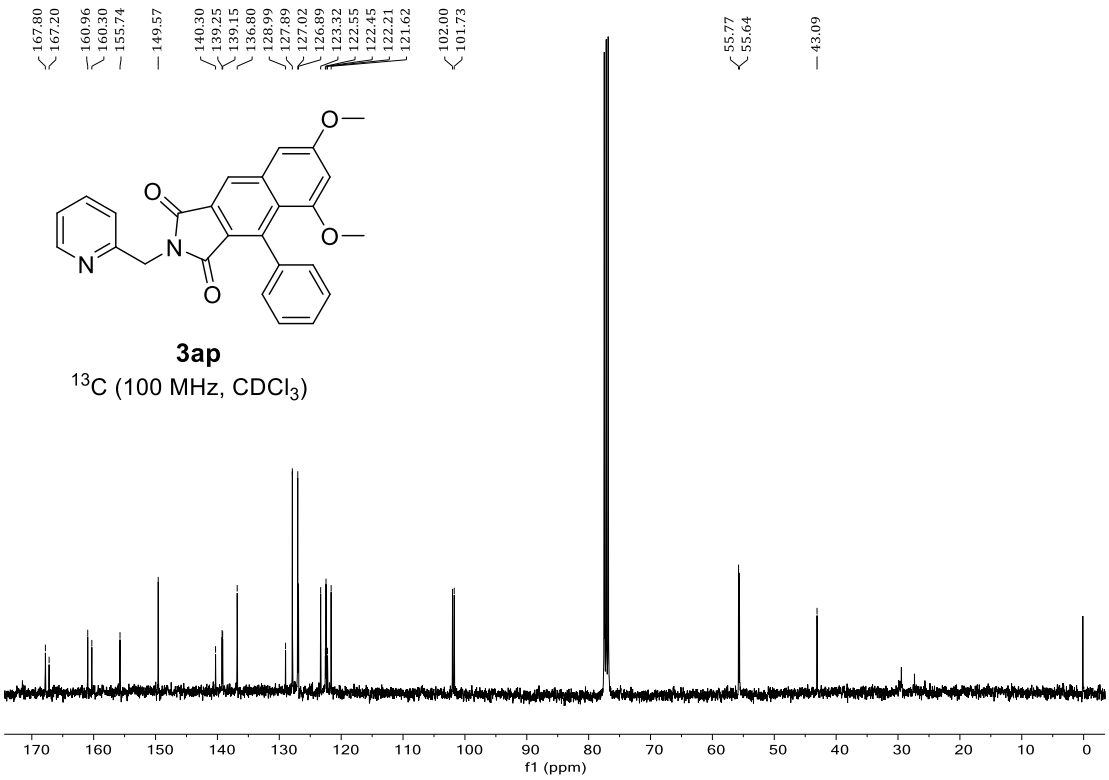
^{13}C (100 MHz, $CDCl_3$)



3ap

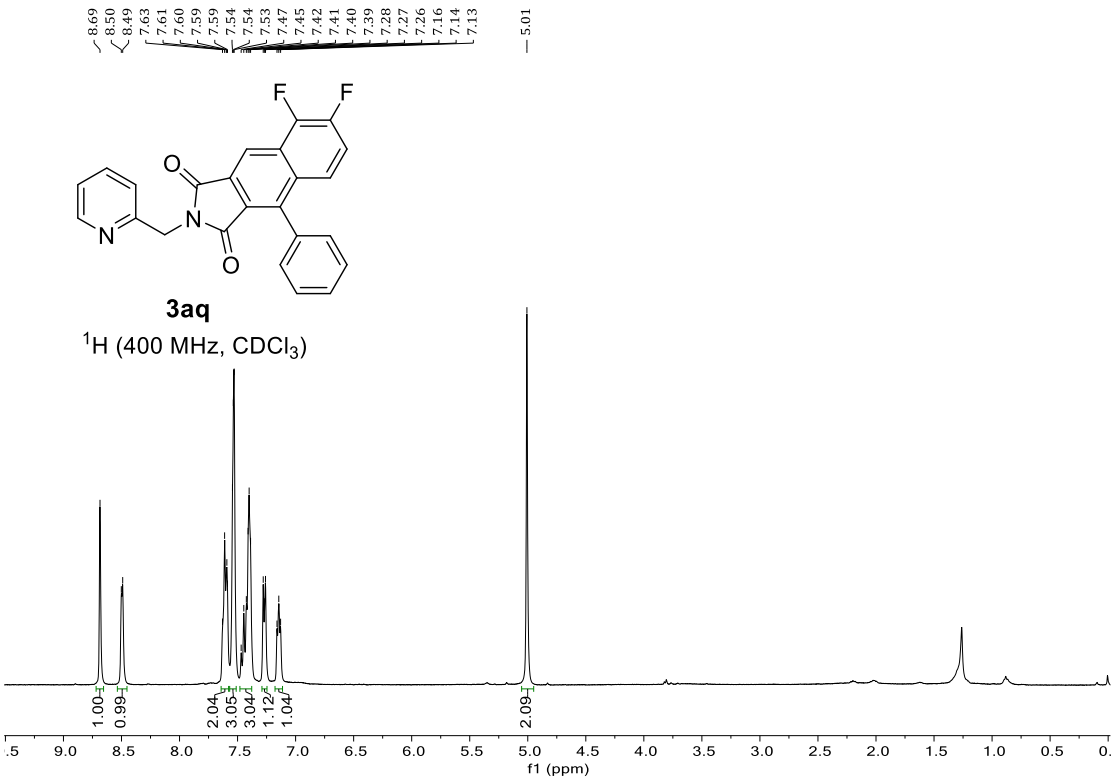
^{1}H (400 MHz, $CDCl_3$)

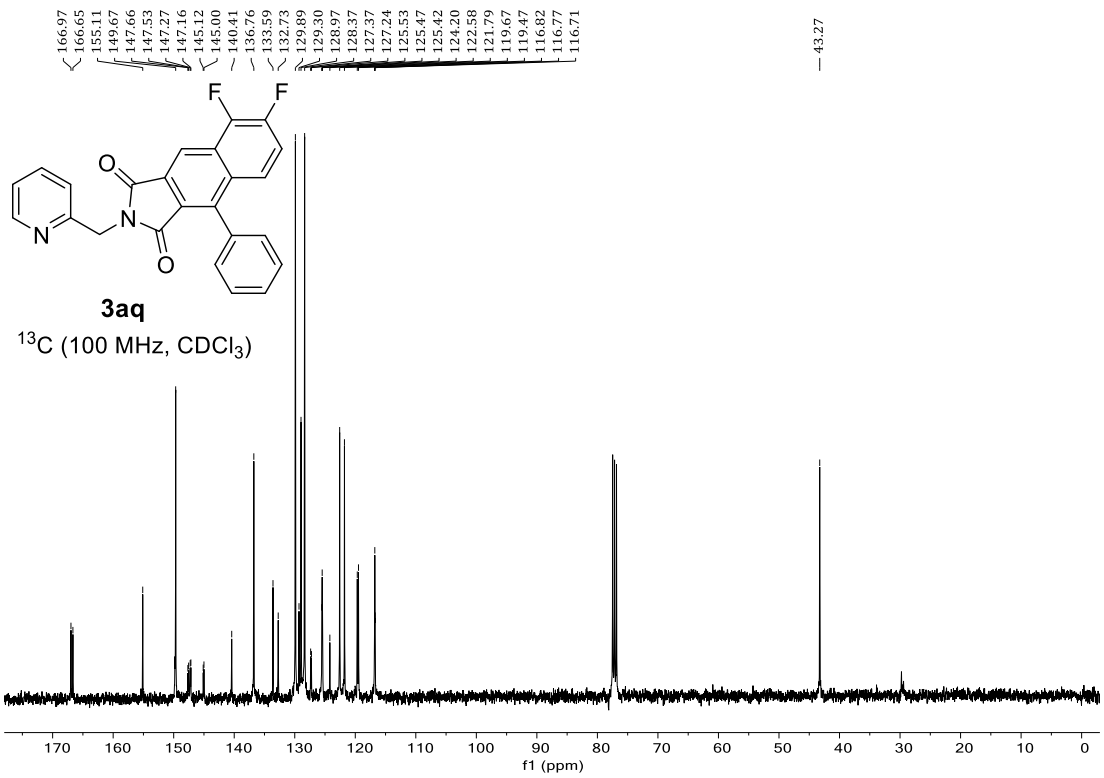


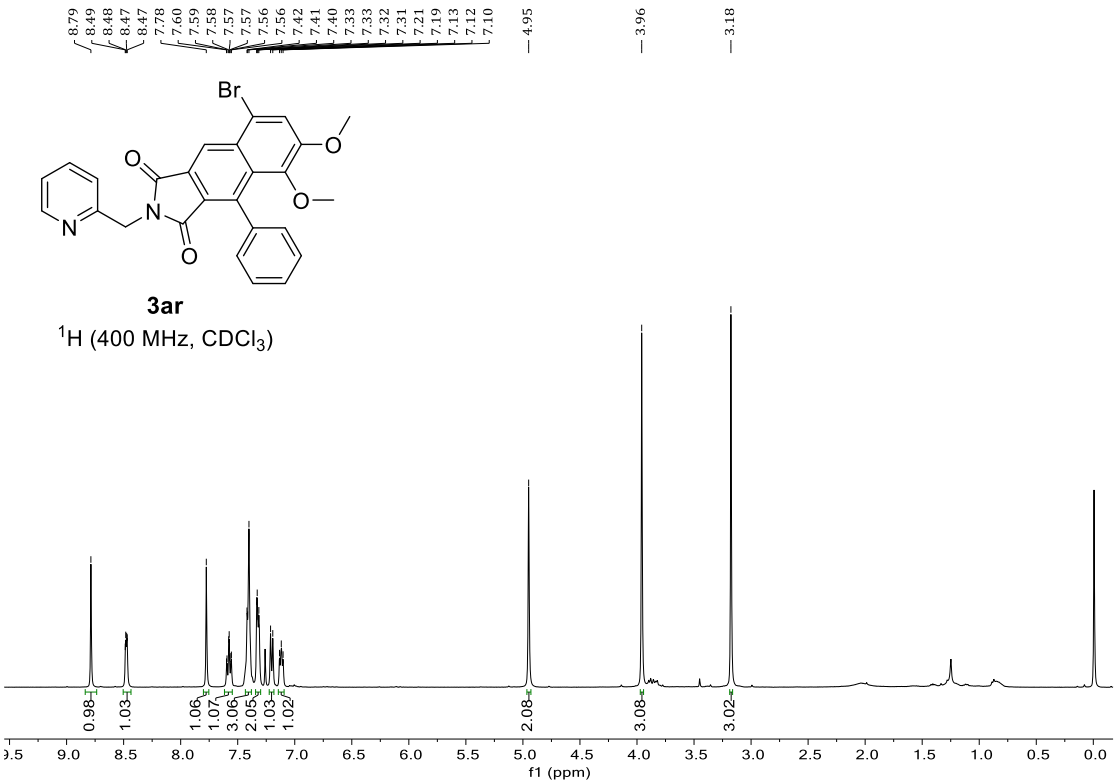


3ap

^{13}C (100 MHz, $CDCl_3$)

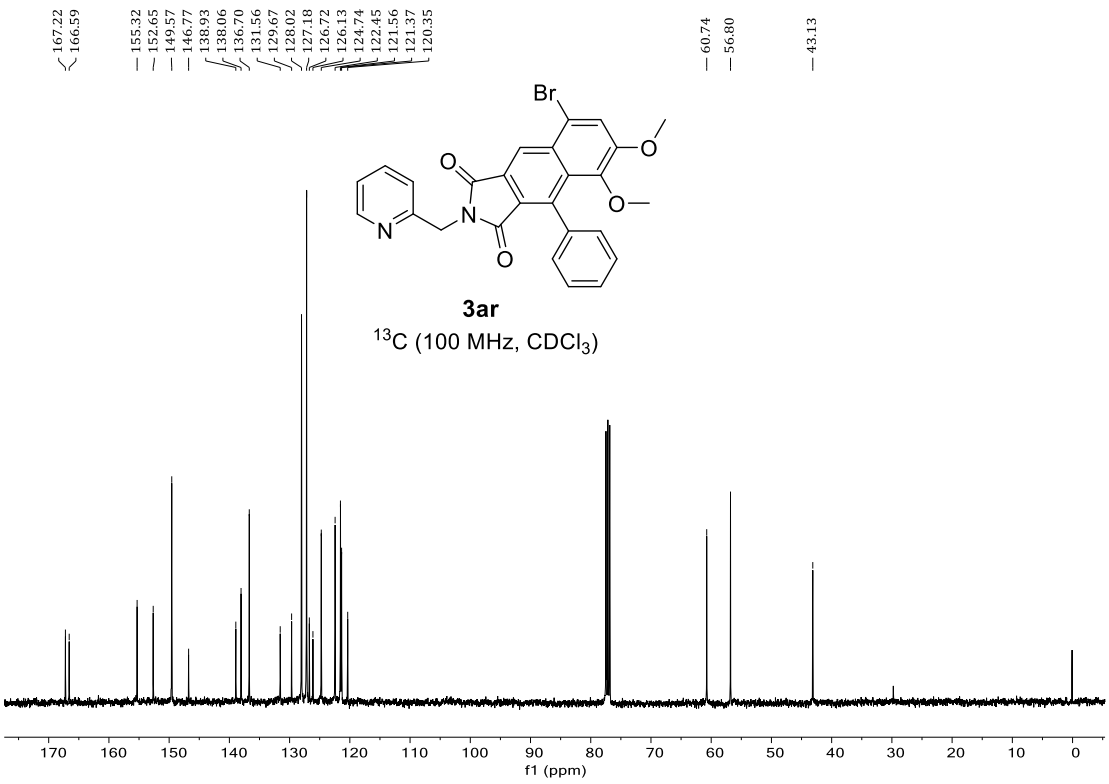

8.69
8.50
8.49
7.63
7.61
7.60
7.59
7.59
7.54
7.54
7.53
7.47
7.45
7.42
7.41
7.40
7.39
7.28
7.27
7.26
7.16
7.14
7.13
5.01
F
F
O
N
N
O
3aq
1H (400 MHz, CDCl3)
1.00
0.99
2.04
3.05
3.04
1.12
1.04
2.09
f1 (ppm)


166.97
166.65
155.11
149.67
147.66
147.53
147.27
147.16
145.12
145.00
140.41
136.76
133.59
132.73
129.89
129.30
128.97
128.37
127.37
127.24
125.53
125.47
125.42
124.20
122.58
121.79
119.67
119.47
116.82
116.77
116.71
43.27
F
F
O
N
N
O
3aq
13C (100 MHz, CDCl3)
f1 (ppm)



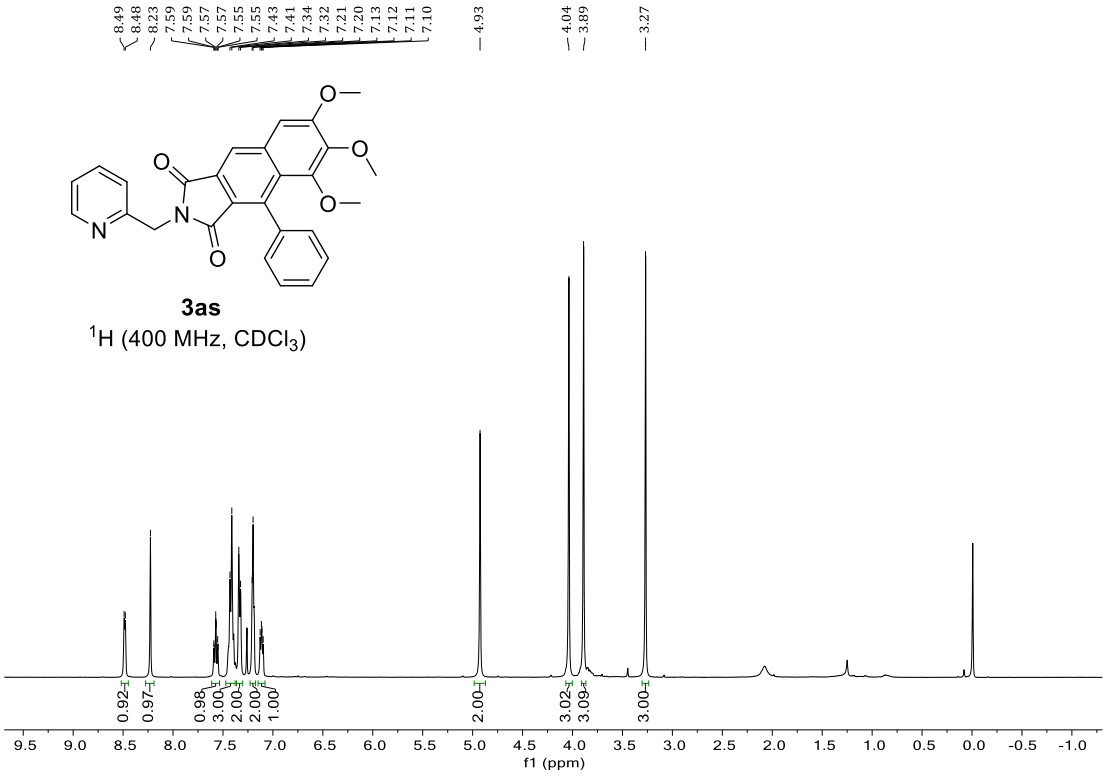
3ar

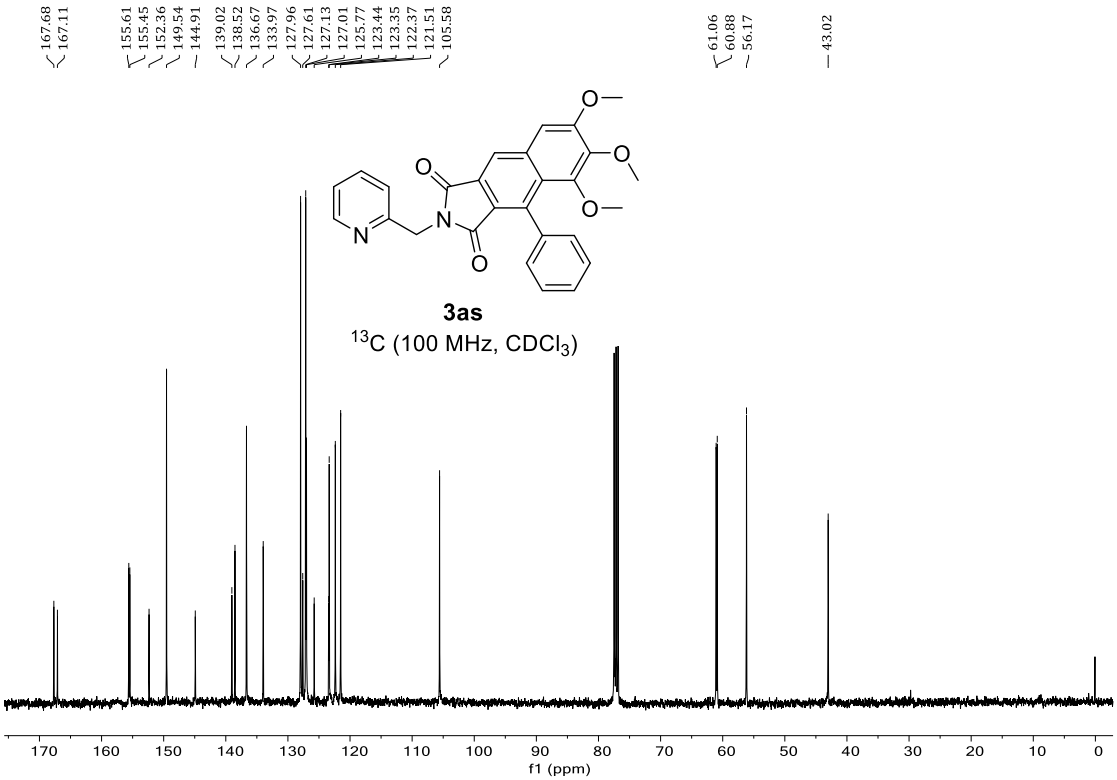
^{1}H (400 MHz, $CDCl_3$)

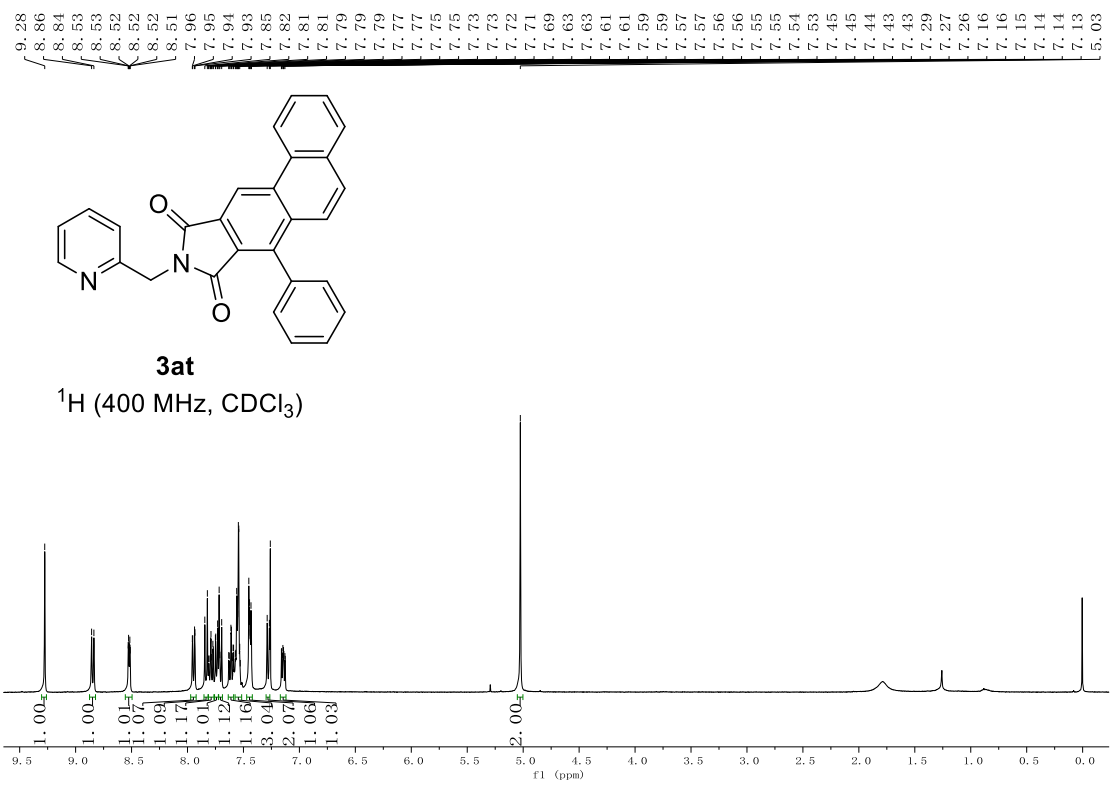


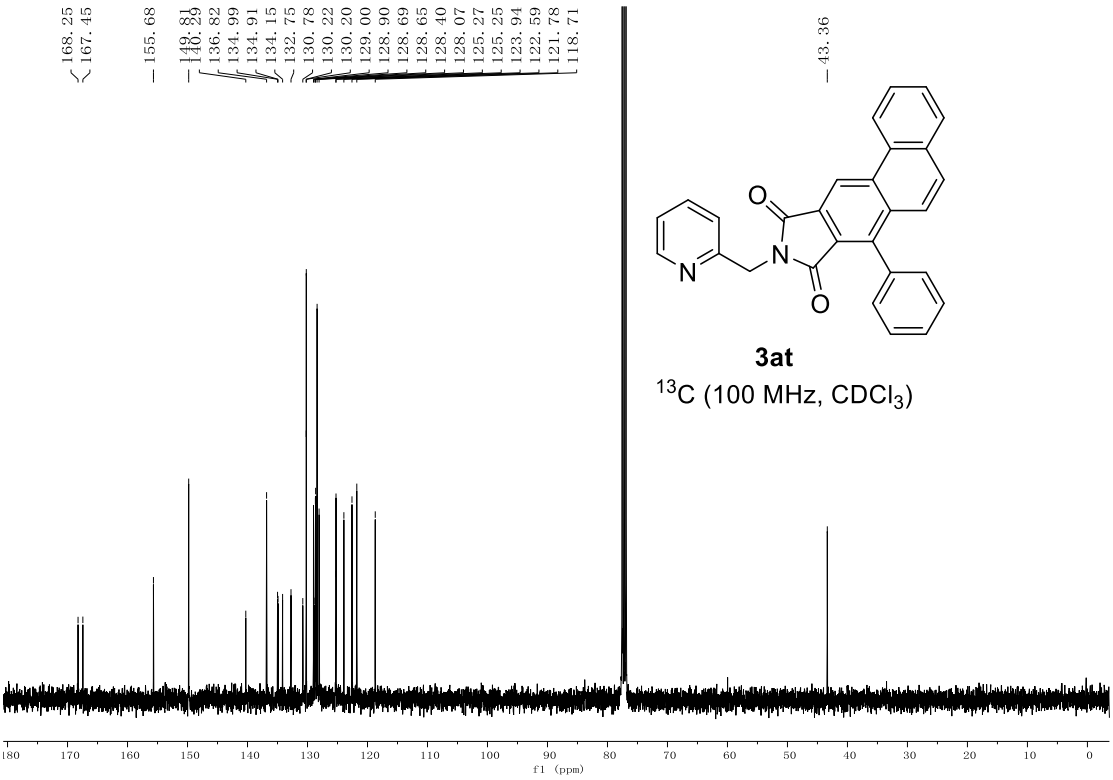
3ar

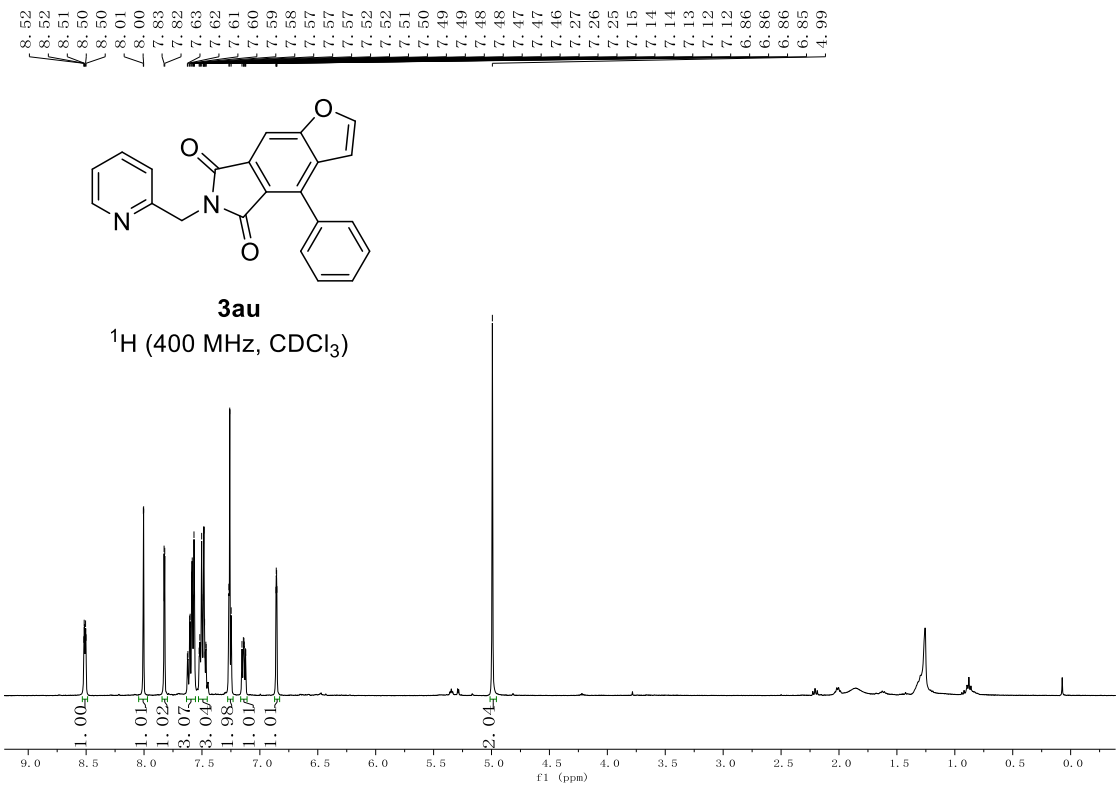
^{13}C (100 MHz, $CDCl_3$)

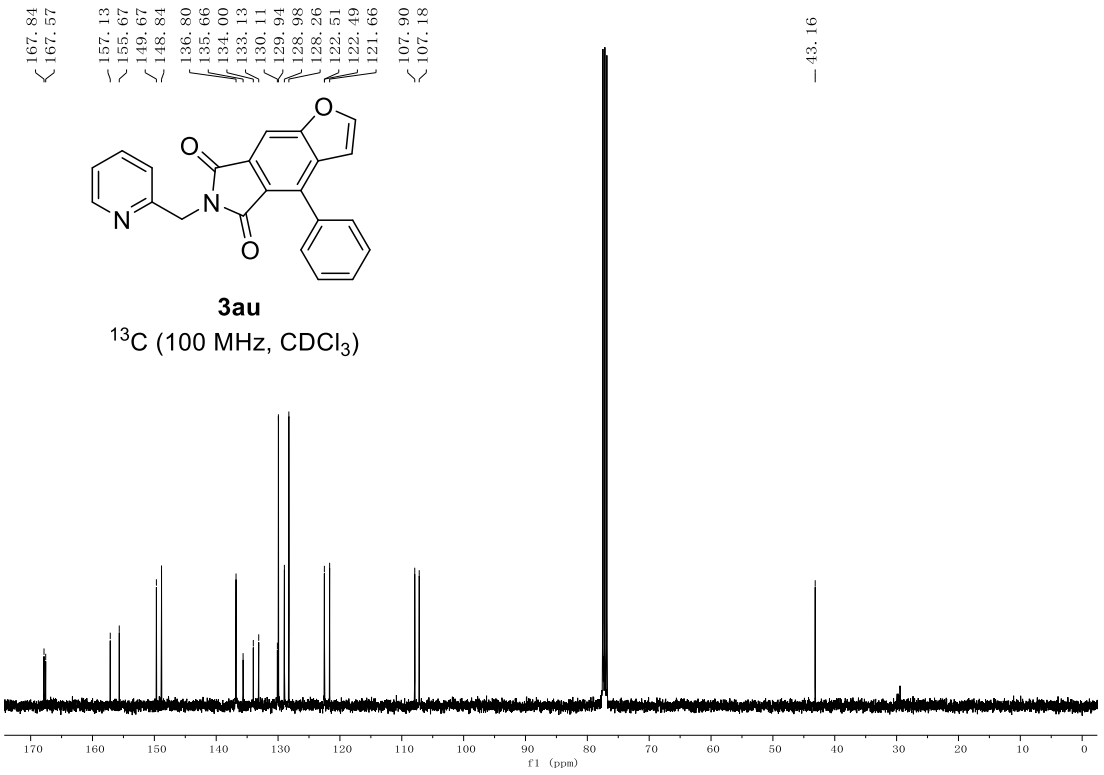

8.49
8.48
8.23
7.59
7.59
7.57
7.57
7.55
7.55
7.43
7.41
7.34
7.32
7.21
7.20
7.13
7.12
7.11
7.10
4.93
4.04
3.89
3.27
O
O
O
O
N
N
O
3as
1H (400 MHz, CDCl3)
0.92
0.97
0.98
3.00
2.00
2.00
1.00
2.00
3.02
3.09
3.00
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)

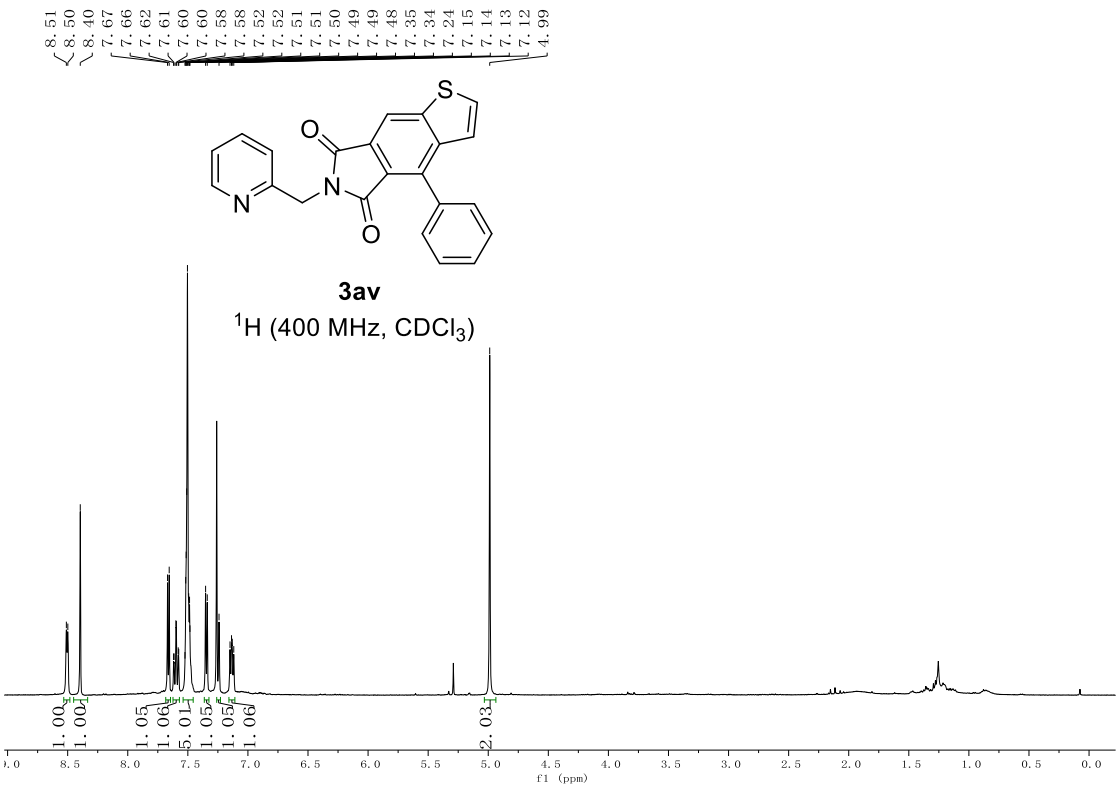

167.68
167.11
155.61
155.45
152.36
149.54
144.91
139.02
138.52
136.67
133.97
127.96
127.61
127.13
127.01
125.77
123.44
123.35
122.37
121.51
105.58
61.06
60.88
56.17
43.02
O
O
O
O
N
N
O
3as
13C (100 MHz, CDCl3)
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


9.28
8.86
8.84
8.53
8.53
8.52
8.52
8.52
8.51
7.96
7.95
7.94
7.93
7.85
7.82
7.81
7.81
7.79
7.79
7.79
7.77
7.77
7.75
7.75
7.73
7.73
7.72
7.71
7.69
7.63
7.63
7.61
7.61
7.59
7.59
7.57
7.57
7.56
7.56
7.55
7.55
7.54
7.53
7.45
7.45
7.44
7.43
7.43
7.29
7.27
7.26
7.16
7.16
7.15
7.14
7.14
7.13
5.03
O
N
N
O
3at
1H (400 MHz, CDCl3)
1.00
1.00
1.01
1.07
1.09
1.17
1.01
1.12
1.16
3.04
2.07
1.06
1.03
2.00
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)


168.25
167.45
155.68
140.89
136.82
134.99
134.91
134.15
132.75
130.78
130.22
130.20
129.00
128.90
128.69
128.65
128.40
128.07
125.27
125.25
123.94
122.59
121.78
118.71
43.36
O
N
N
O
3at
13C (100 MHz, CDCl3)
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

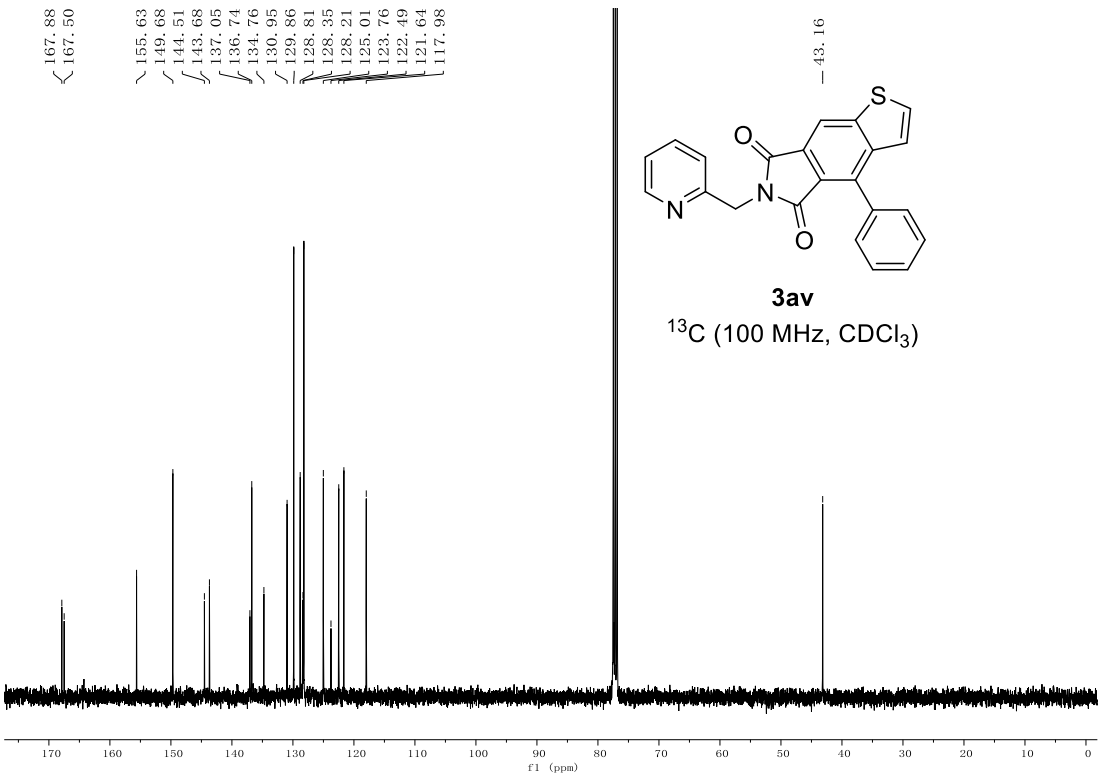

8.52
8.52
8.51
8.50
8.50
8.01
8.00
7.83
7.82
7.63
7.62
7.61
7.60
7.59
7.58
7.57
7.57
7.57
7.52
7.52
7.51
7.50
7.49
7.49
7.48
7.48
7.47
7.47
7.46
7.27
7.26
7.25
7.15
7.14
7.14
7.13
7.12
7.12
6.86
6.86
6.86
6.85
4.99
O
O
N
N
O
3au
1H (400 MHz, CDCl3)
1.00
1.01
1.02
3.07
3.04
1.98
1.01
1.01
2.04
9.0
8.5
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)


167.84
167.57
157.13
155.67
149.67
148.84
136.80
135.66
134.00
133.13
130.11
129.94
128.98
128.26
122.51
122.49
121.66
107.90
107.18
43.16
O
O
N
N
O
3au
13C (100 MHz, CDCl3)
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)



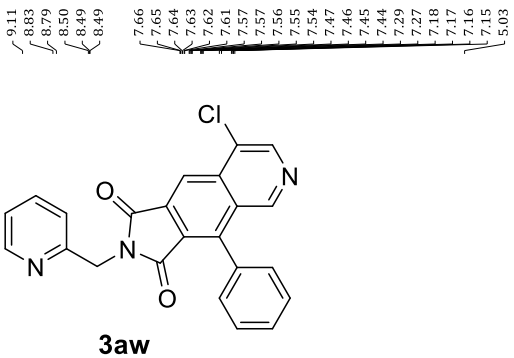
3av

^{1}H (400 MHz, $CDCl_3$)



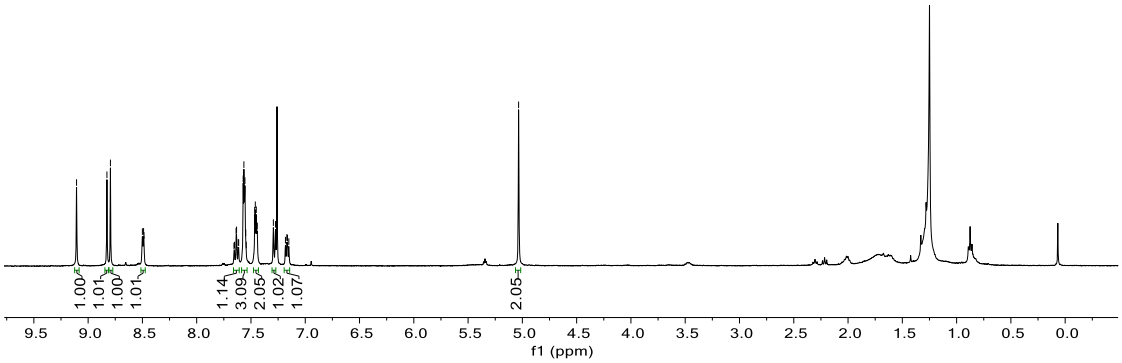
3av

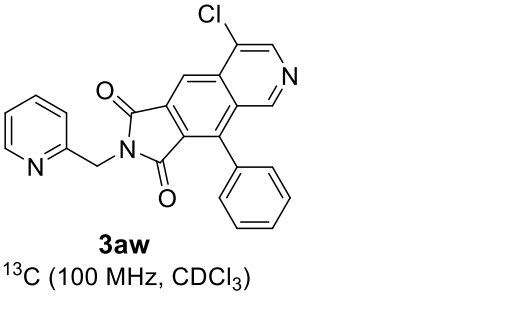
^{13}C (100 MHz, $CDCl_3$)



3aw

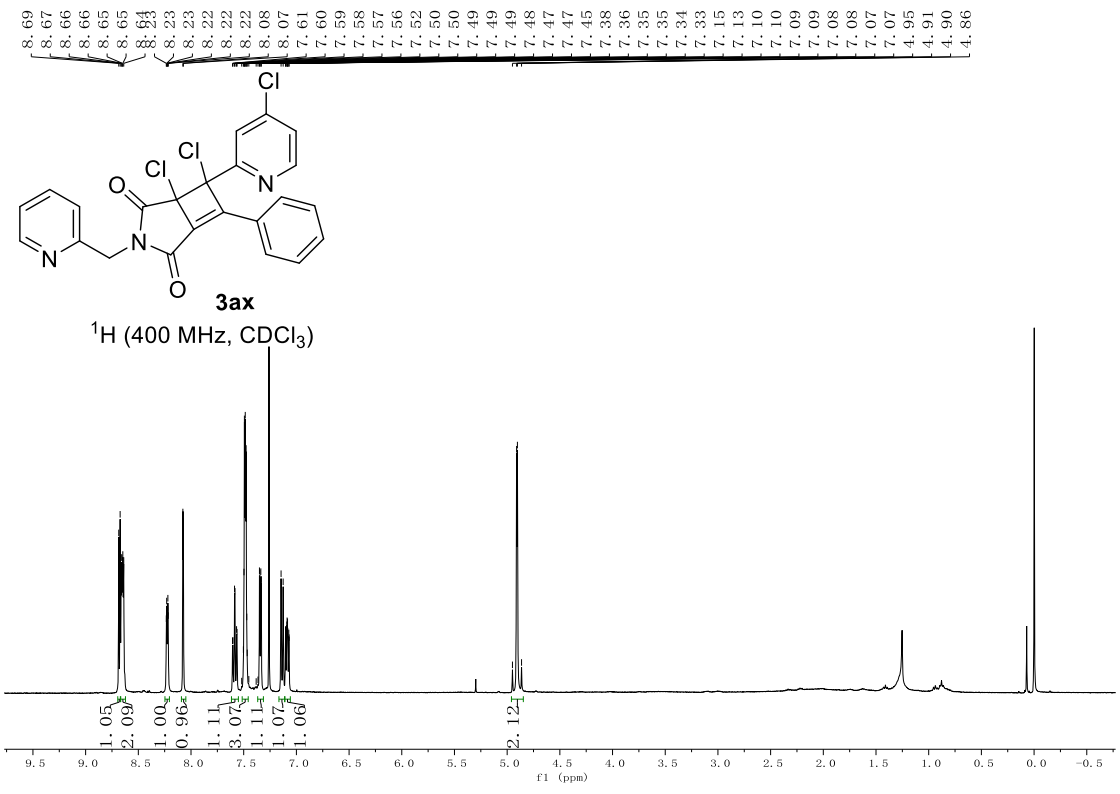
^{1}H (400 MHz, $CDCl_3$)



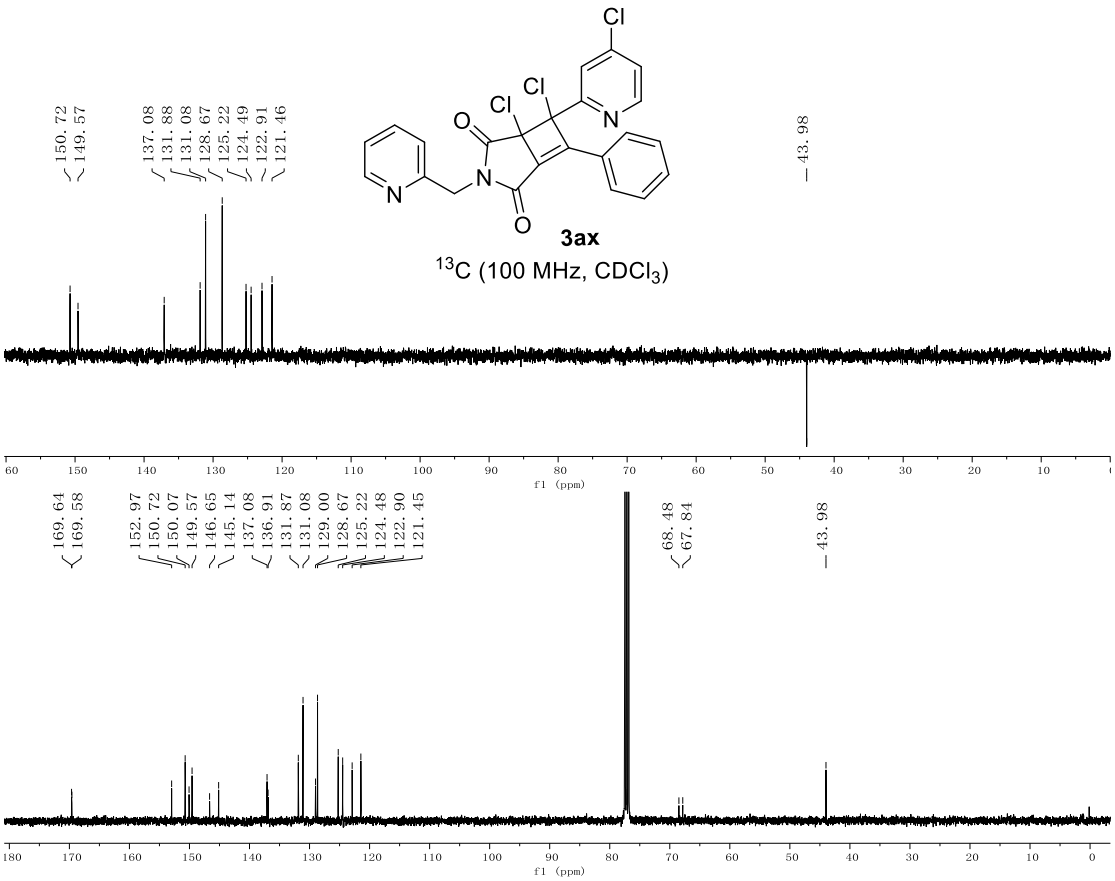


3aw

^{13}C (100 MHz, $CDCl_3$)

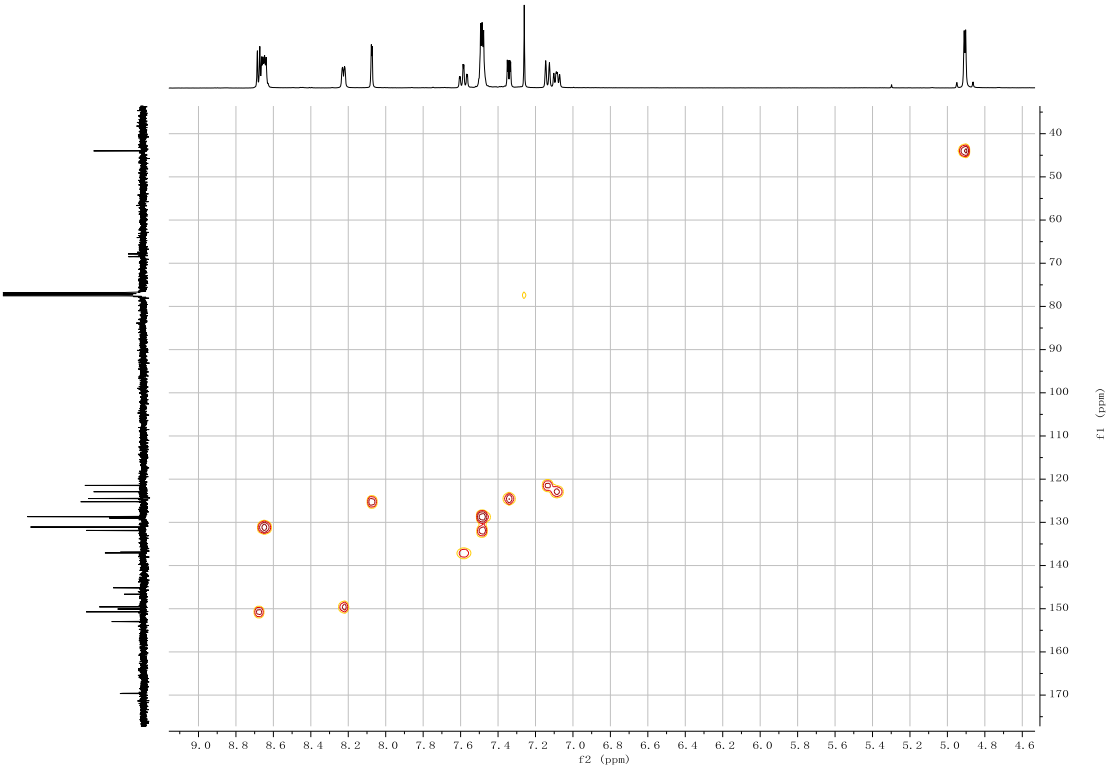


^{1}H-NMR ($CDCl_3$)

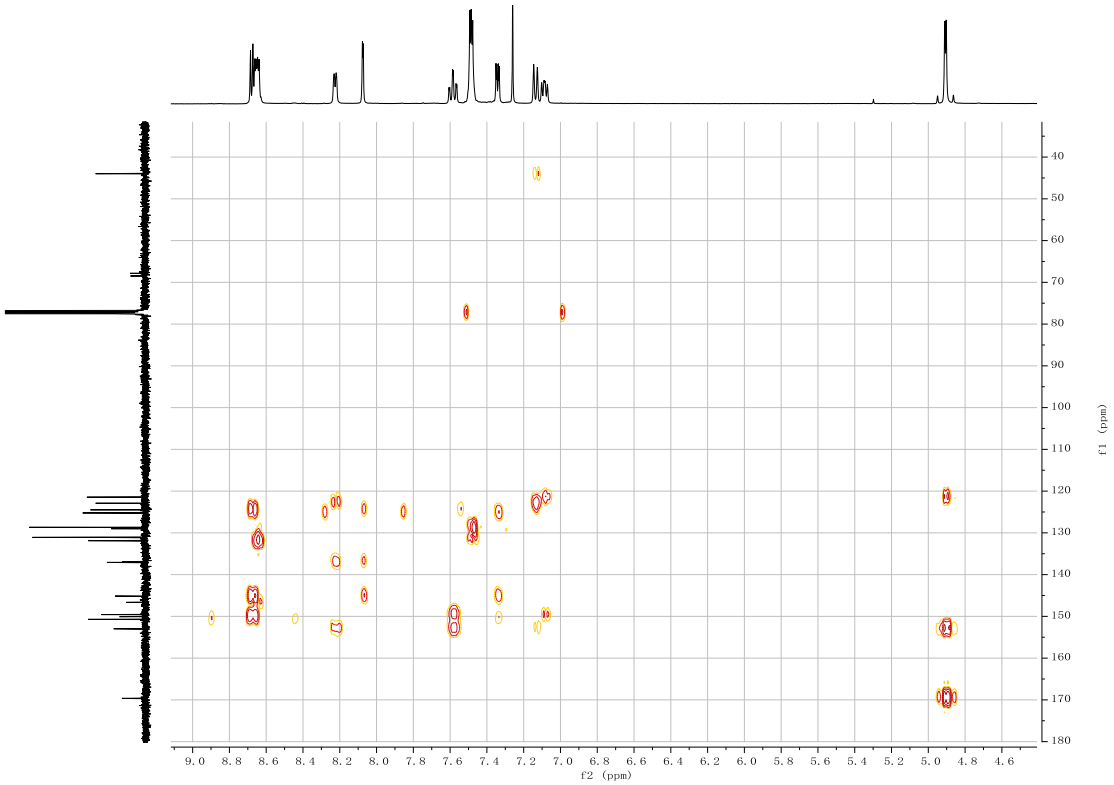


DEPT and ^{13}C-NMR ($CDCl_3$)

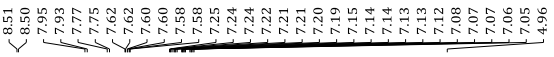
H-H COSY

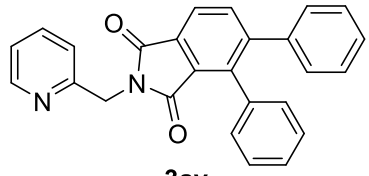


HSQC



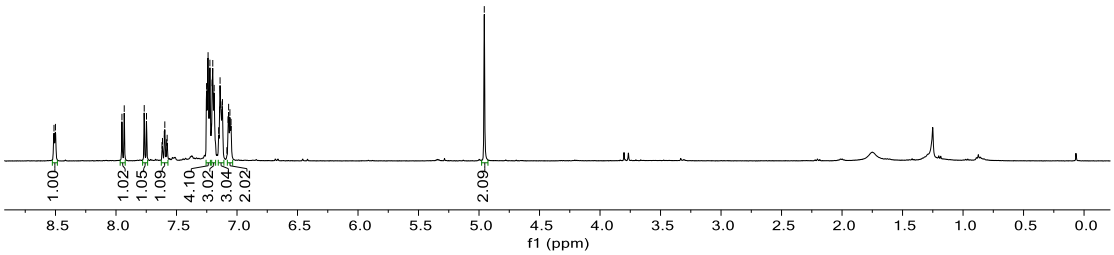
HMBC

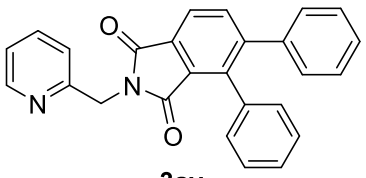




3ay

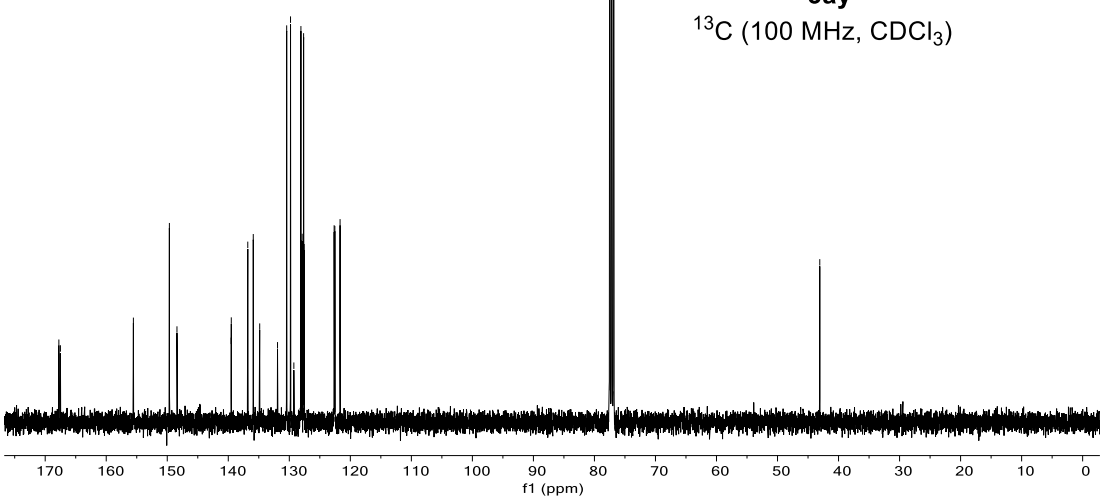
^{1}H (400 MHz, $CDCl_3$)

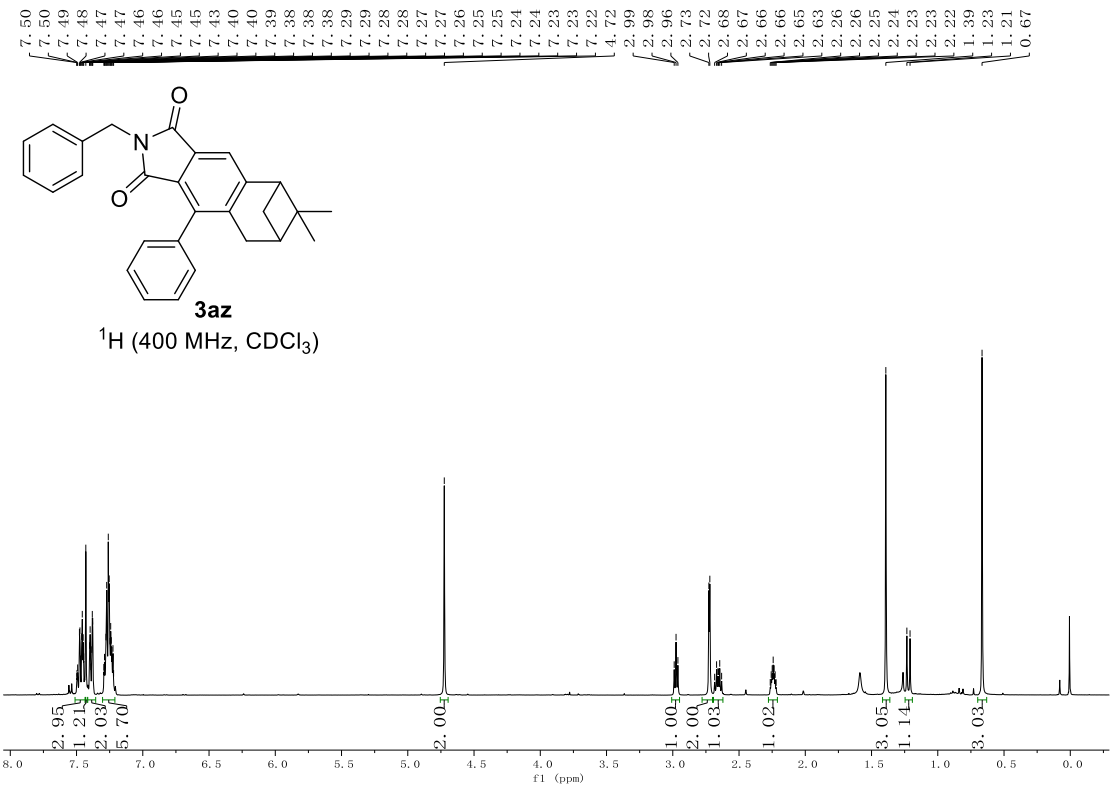


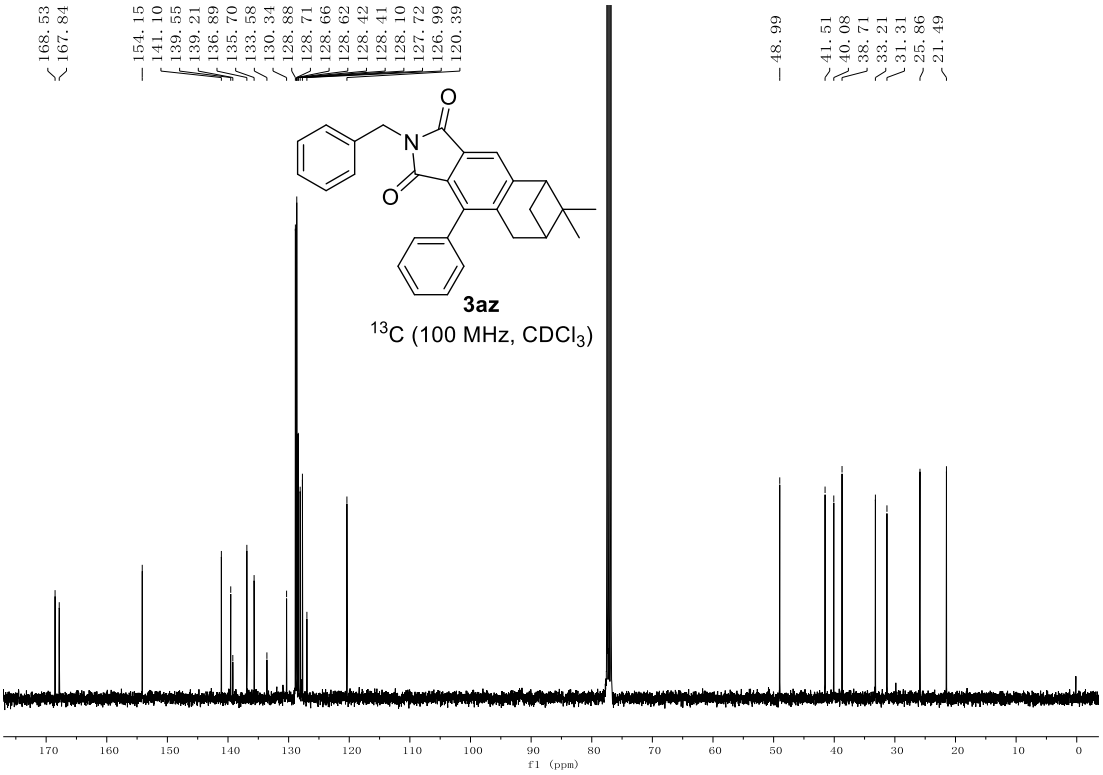


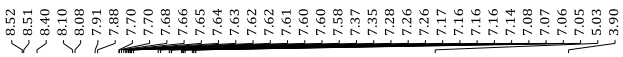
3ay

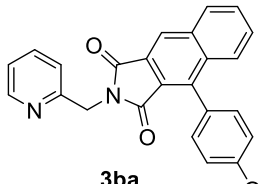
^{13}C (100 MHz, $CDCl_3$)




7.50 7.50 7.49 7.48 7.47 7.47 7.46 7.46 7.45 7.45 7.43 7.40 7.40 7.39 7.38 7.38 7.38 7.29 7.29 7.28 7.28 7.27 7.27 7.26 7.25 7.25 7.24 7.24 7.23 7.23 7.22 4.72 2.99 2.98 2.96 2.73 2.72 2.68 2.67 2.66 2.66 2.65 2.63 2.26 2.26 2.25 2.24 2.23 2.23 2.22 1.39 1.23 1.21 0.67
O
N
O
3az
1H (400 MHz, CDCl3)
2.95 1.21 2.03 5.70 2.00 1.00 2.00 1.03 1.02 3.05 1.14 3.03
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)

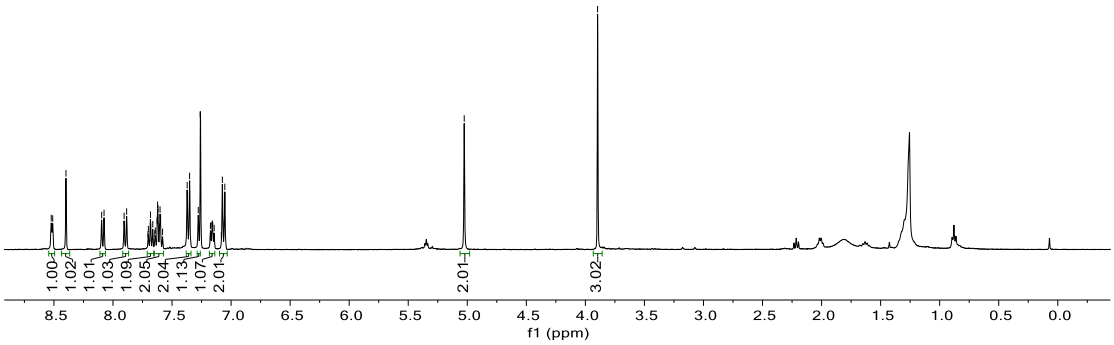

168.53 167.84 154.15 141.10 139.55 139.21 136.89 135.70 133.58 130.34 128.88 128.71 128.66 128.62 128.42 128.41 128.10 127.72 126.99 120.39 48.99 41.51 40.08 38.71 33.21 31.31 25.86 21.49
O
N
O
3az
13C (100 MHz, CDCl3)
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

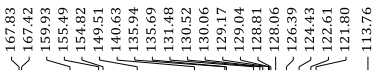


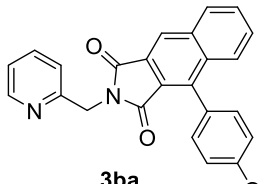


3ba

^{1}H (400 MHz, $CDCl_3$)

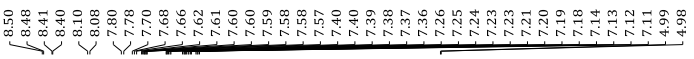


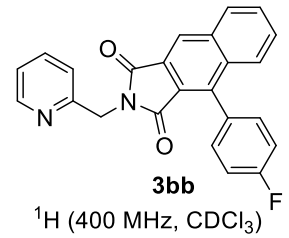




3ba

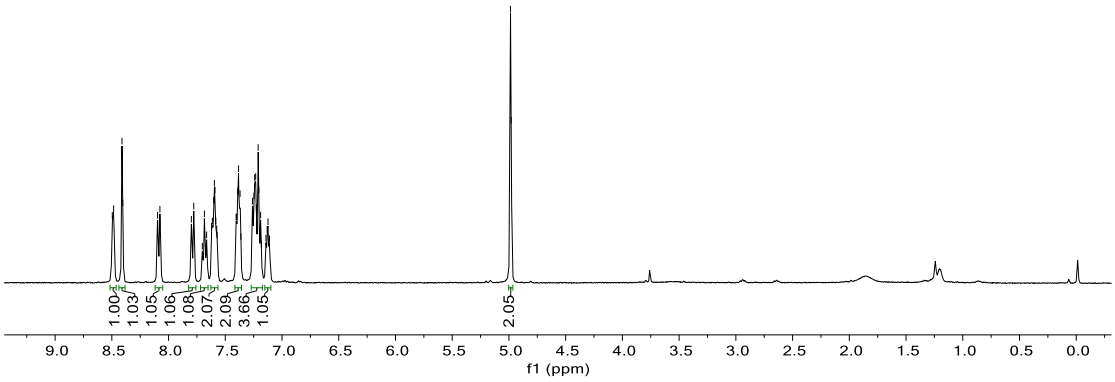
^{13}C (100 MHz, $CDCl_3$)

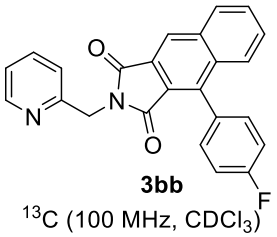




3bb

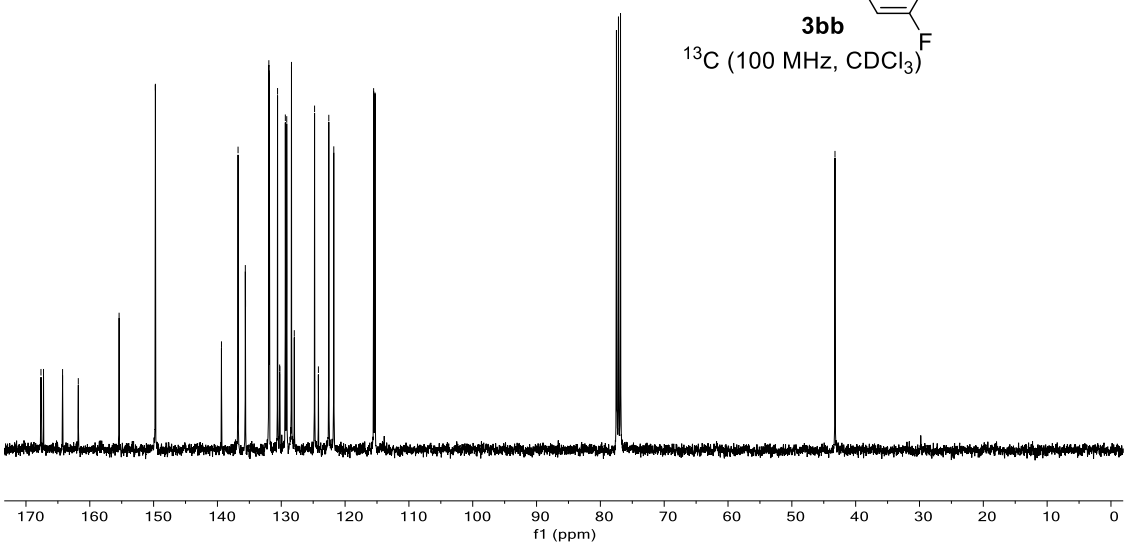
^{1}H (400 MHz, $CDCl_3$)

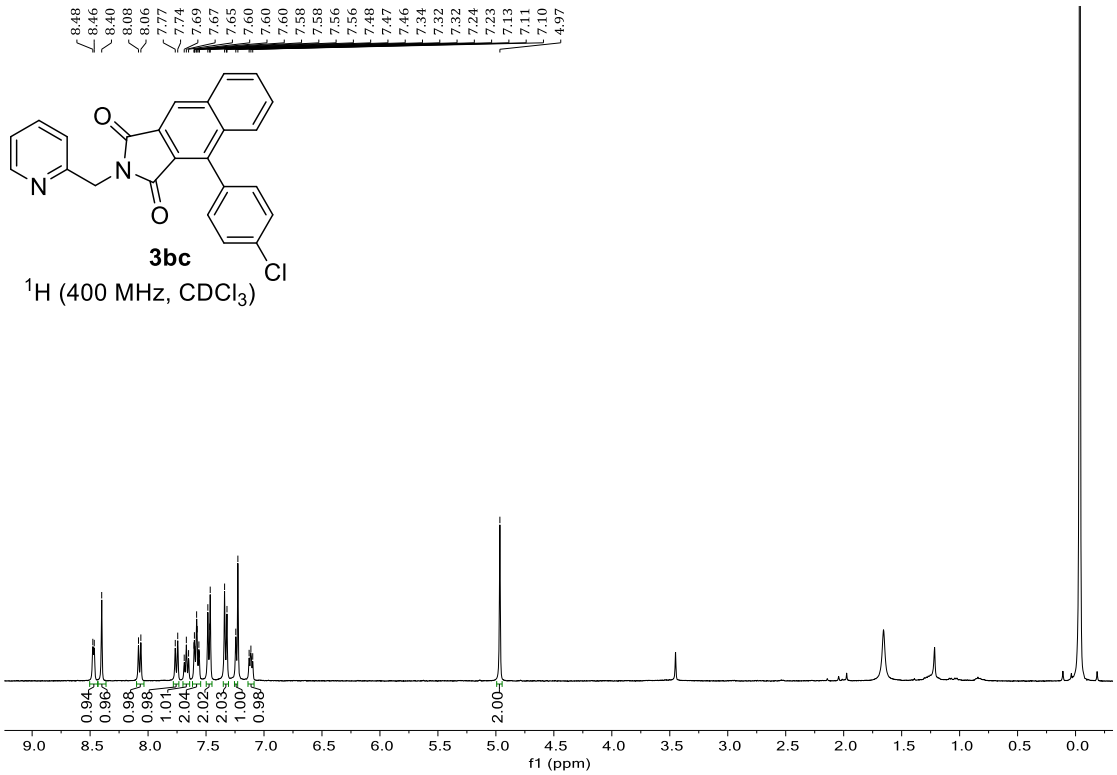


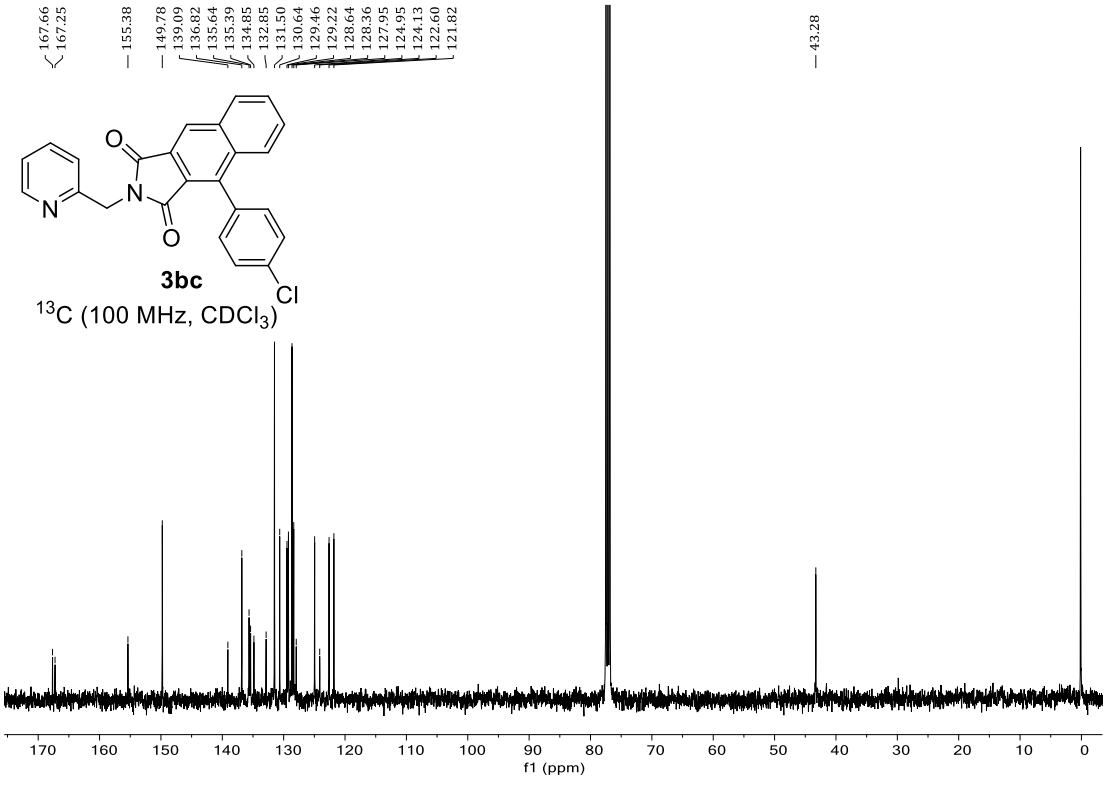


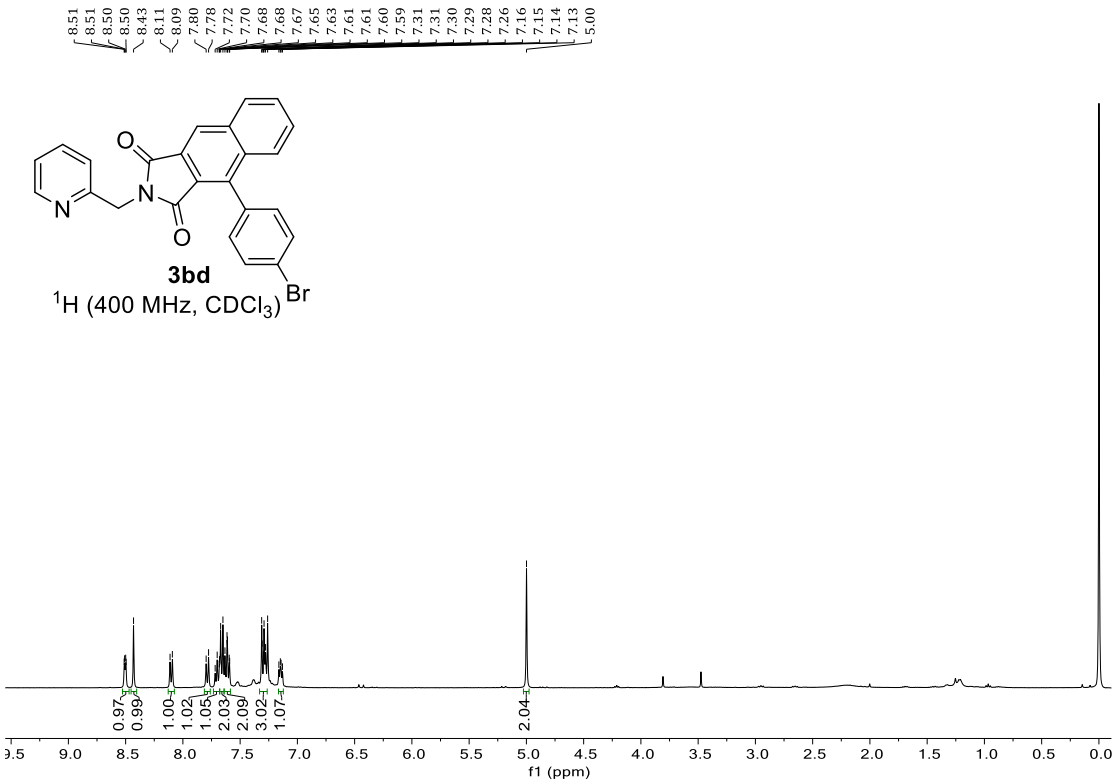
3bb

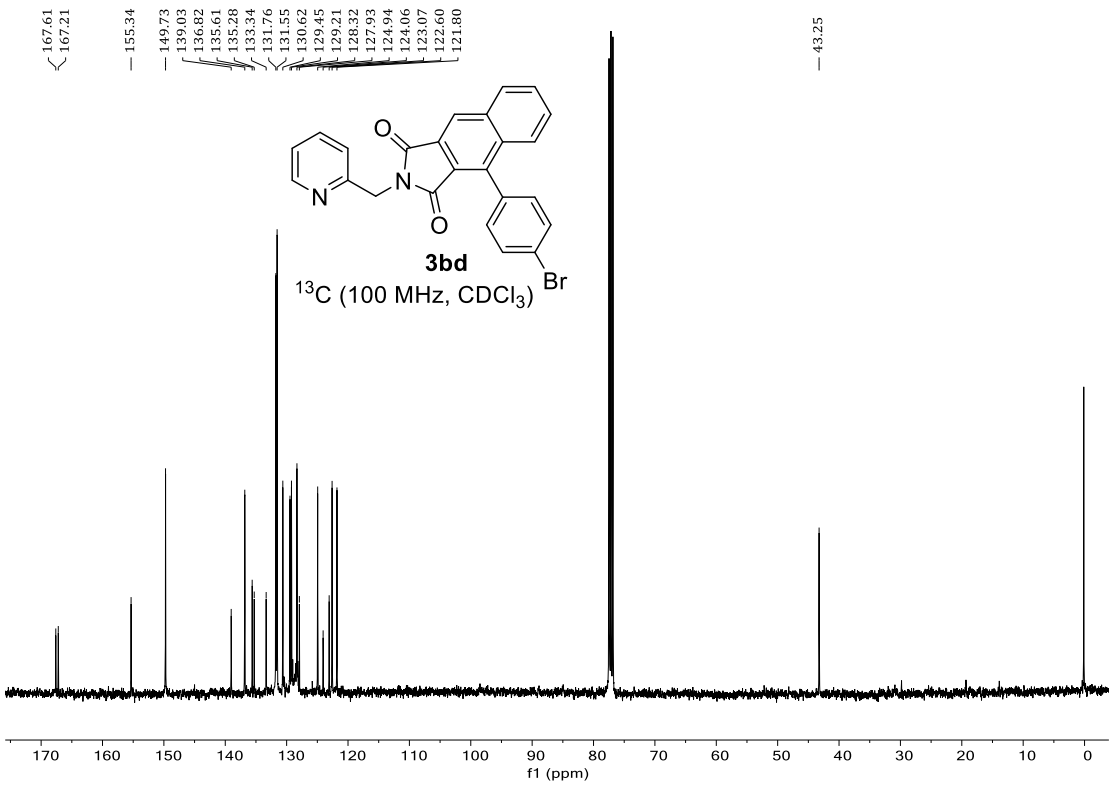
^{13}C (100 MHz, $CDCl_3$)

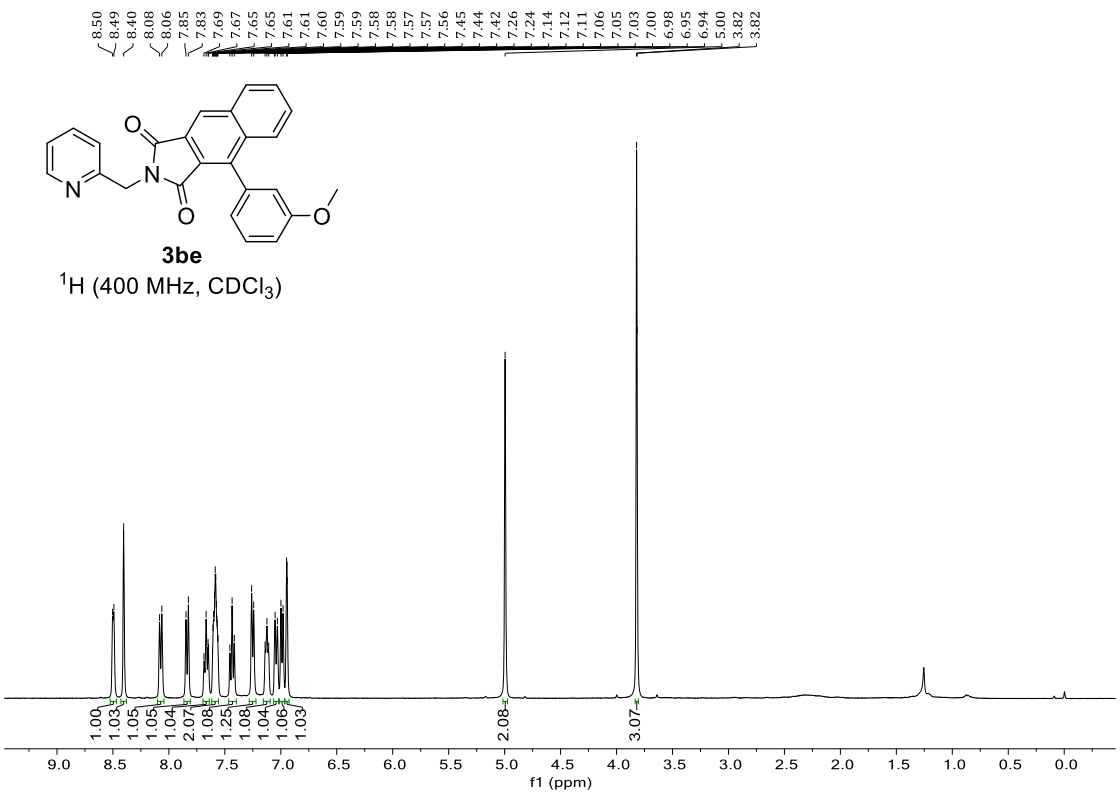


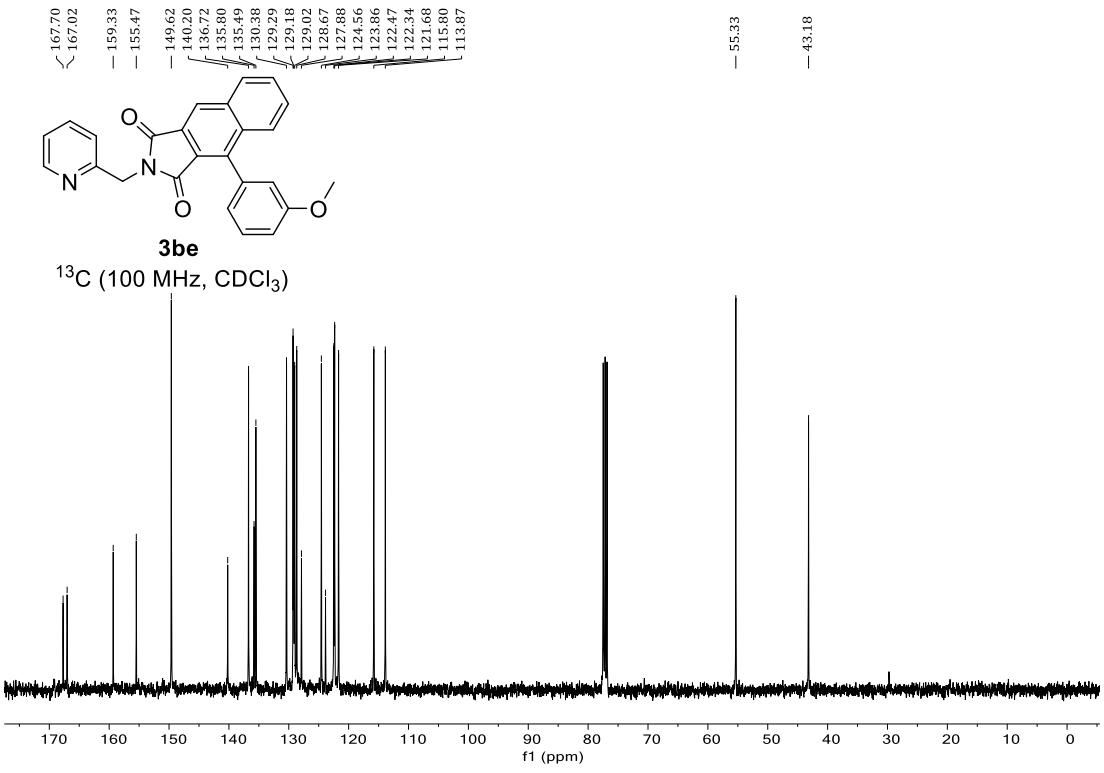

8.48
8.46
8.40
8.08
8.06
7.77
7.74
7.69
7.67
7.65
7.60
7.60
7.60
7.58
7.58
7.56
7.56
7.48
7.47
7.46
7.34
7.32
7.32
7.24
7.23
7.13
7.11
7.10
4.97
O
N
N
O
Cl
3bc
1H (400 MHz, CDCl3)
0.94
0.96
0.98
0.98
1.01
2.04
2.02
2.03
1.00
0.98
2.00
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

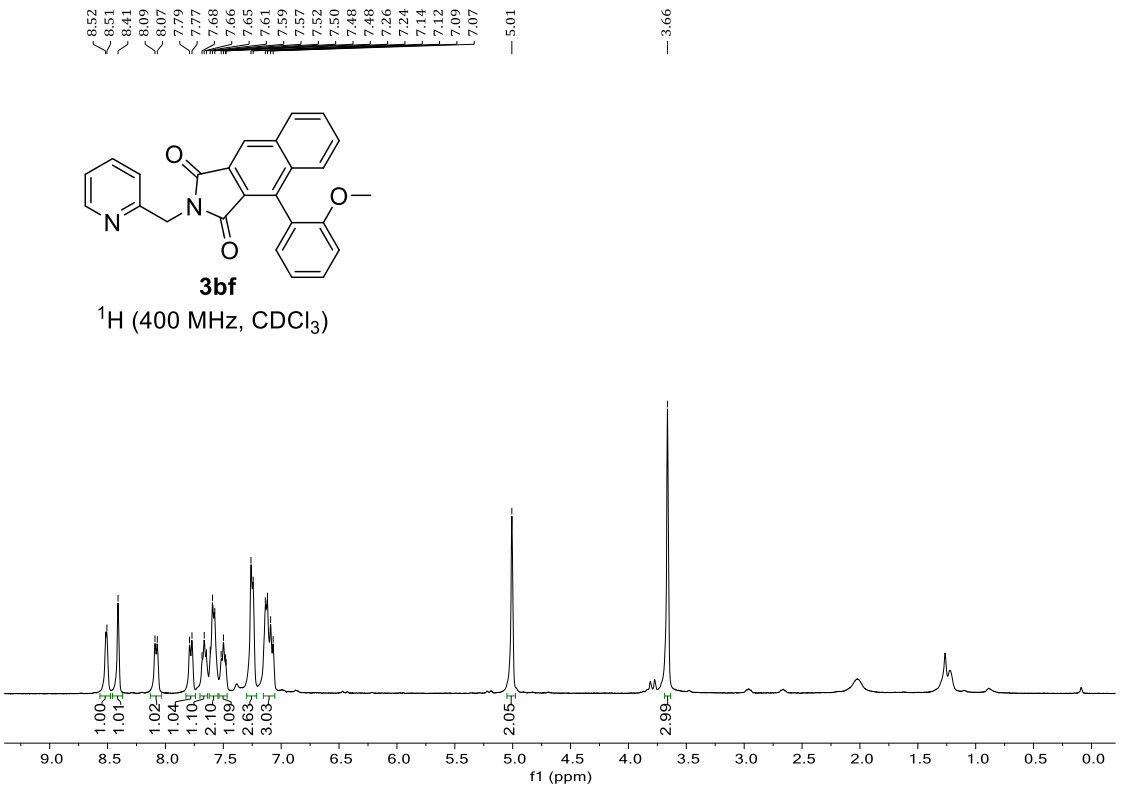

167.66
167.25
155.38
149.78
139.09
136.82
135.64
135.39
134.85
132.85
131.50
130.64
129.46
129.22
128.64
128.36
127.95
124.95
124.13
122.60
121.82
43.28
O
N
N
O
Cl
3bc
13C (100 MHz, CDCl3)
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

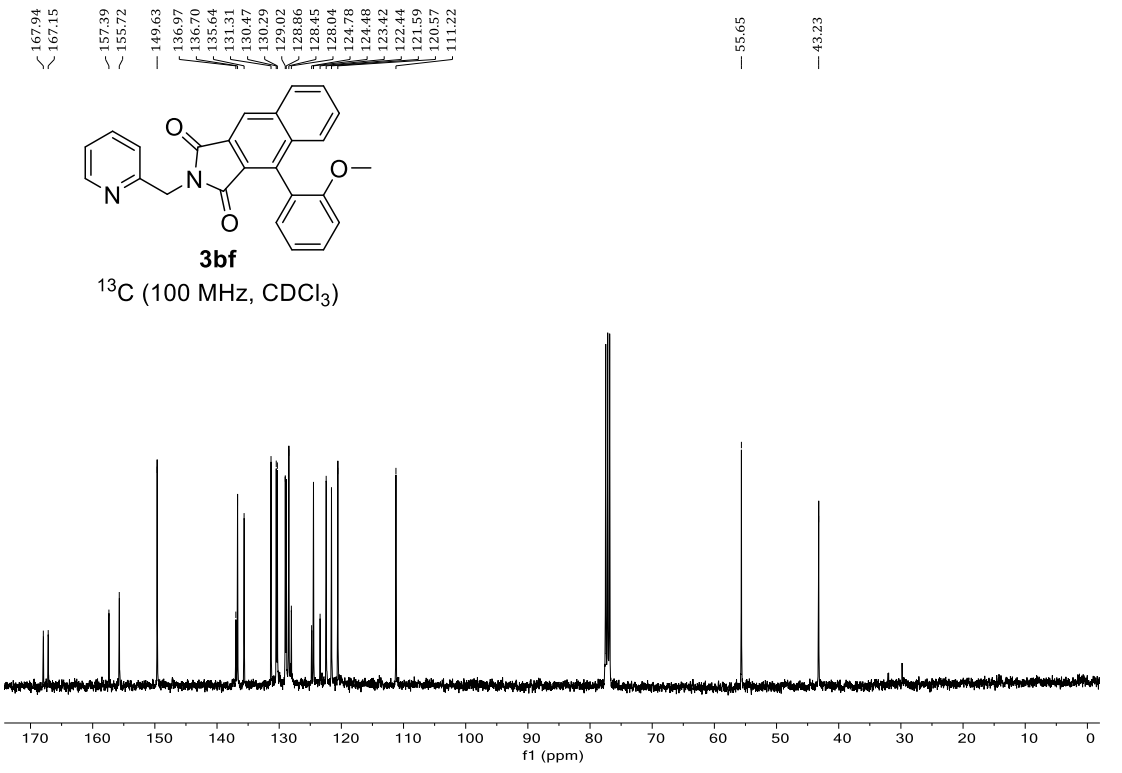

8.51
8.51
8.50
8.50
8.43
8.11
8.09
7.80
7.78
7.72
7.70
7.68
7.68
7.67
7.65
7.63
7.61
7.61
7.60
7.59
7.31
7.31
7.30
7.29
7.28
7.26
7.16
7.15
7.14
7.13
5.00
O
N
N
O
Br
3bd
1H (400 MHz, CDCl3)
0.97
0.99
1.00
1.02
1.05
2.03
2.09
3.02
1.07
2.04
f1 (ppm)

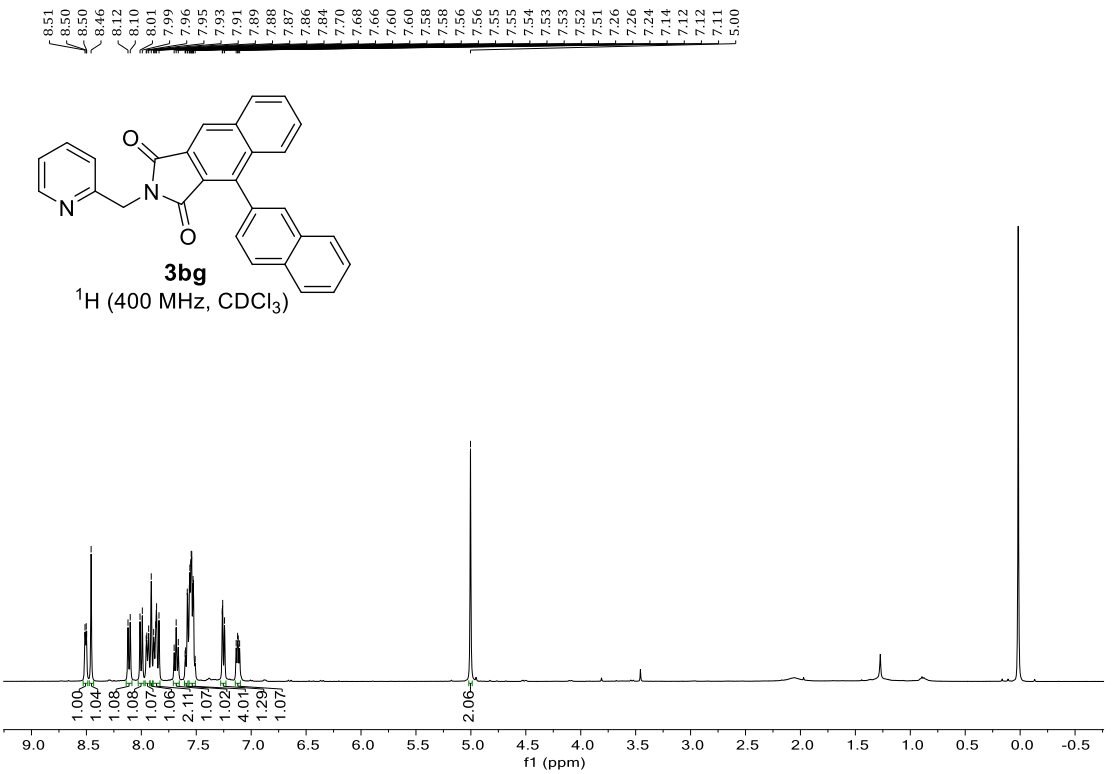

167.61
167.21
155.34
149.73
139.03
136.82
135.61
135.28
133.34
131.76
131.55
130.62
129.45
129.21
128.32
127.93
124.94
124.06
123.07
122.60
121.80
43.25
O
N
N
O
Br
3bd
13C (100 MHz, CDCl3)
f1 (ppm)

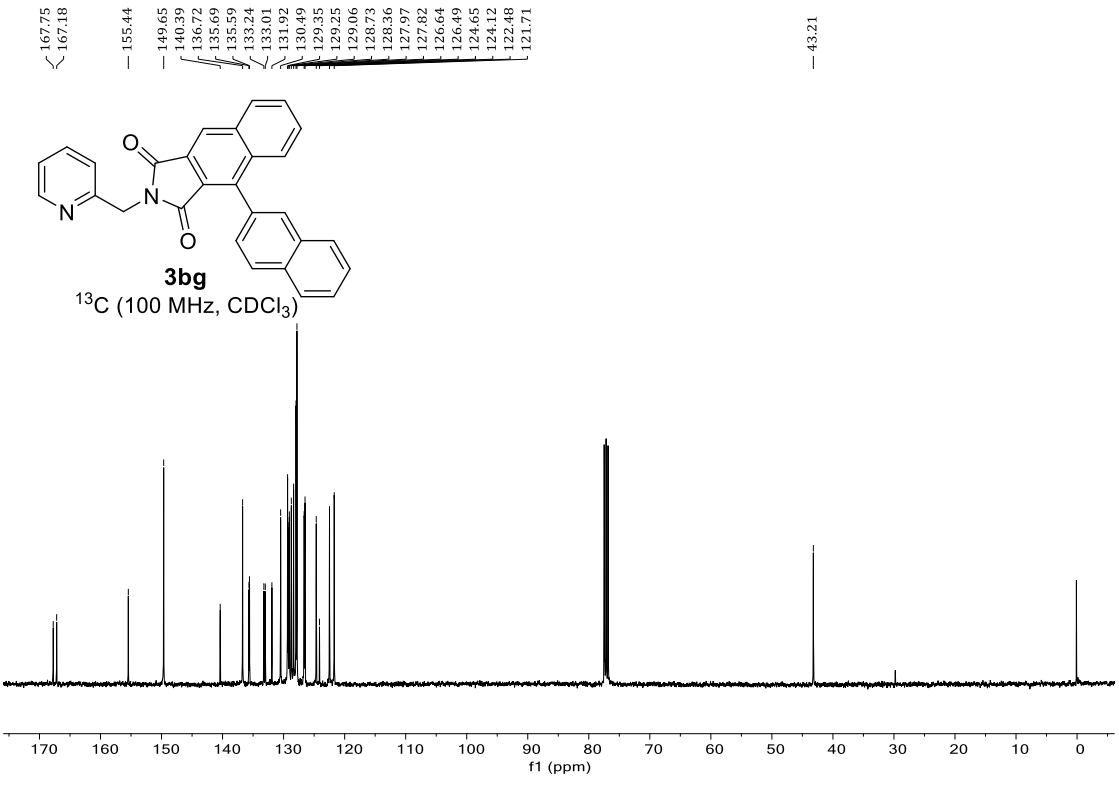

8.50
8.49
8.40
8.08
8.06
7.85
7.83
7.69
7.67
7.65
7.65
7.61
7.61
7.60
7.59
7.59
7.58
7.58
7.57
7.57
7.56
7.45
7.44
7.42
7.26
7.24
7.14
7.12
7.11
7.06
7.05
7.03
7.00
6.98
6.95
6.94
5.00
3.82
3.82
O
N
O
N
O
O
3be
1H (400 MHz, CDCl3)
1.00
1.03
1.05
1.05
1.04
2.07
1.08
1.25
1.08
1.04
1.06
1.03
2.08
3.07
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)

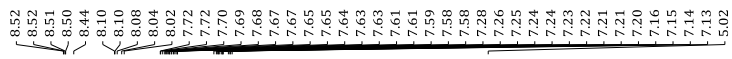

167.70
167.02
159.33
155.47
149.62
140.20
136.72
135.80
135.49
130.38
129.29
129.18
129.02
128.67
127.88
124.56
123.86
122.47
122.34
121.68
115.80
113.87
55.33
43.18
O
N
O
N
O
O
3be
13C (100 MHz, CDCl3)
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

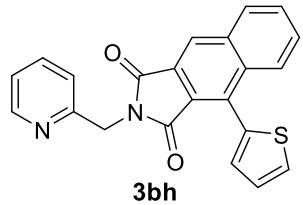

8.52
8.51
8.41
8.09
8.07
7.79
7.77
7.68
7.66
7.65
7.61
7.59
7.57
7.52
7.50
7.48
7.48
7.26
7.24
7.14
7.12
7.09
7.07
5.01
3.66
O
N
O
N
O
O
3bf
1H (400 MHz, CDCl3)
1.00
1.01
1.02
1.04
1.10
2.10
1.09
2.63
3.03
2.05
2.99
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


167.94
167.15
157.39
155.72
149.63
136.97
136.70
135.64
131.31
130.47
130.29
129.02
128.86
128.45
128.04
124.78
124.48
123.42
122.44
121.59
120.57
111.22
55.65
43.23
O
N
O
N
O
O
3bf
13C (100 MHz, CDCl3)
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.51
8.50
8.50
8.46
8.12
8.10
8.01
7.99
7.96
7.95
7.93
7.91
7.89
7.88
7.87
7.86
7.84
7.70
7.68
7.66
7.60
7.60
7.58
7.58
7.56
7.56
7.55
7.55
7.54
7.53
7.53
7.52
7.51
7.26
7.26
7.24
7.14
7.12
7.12
7.11
5.00
O
N
N
O
3bg
1H (400 MHz, CDCl3)
1.00
1.04
1.08
1.08
1.07
1.06
2.11
1.07
1.02
4.01
1.29
1.07
2.06
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)

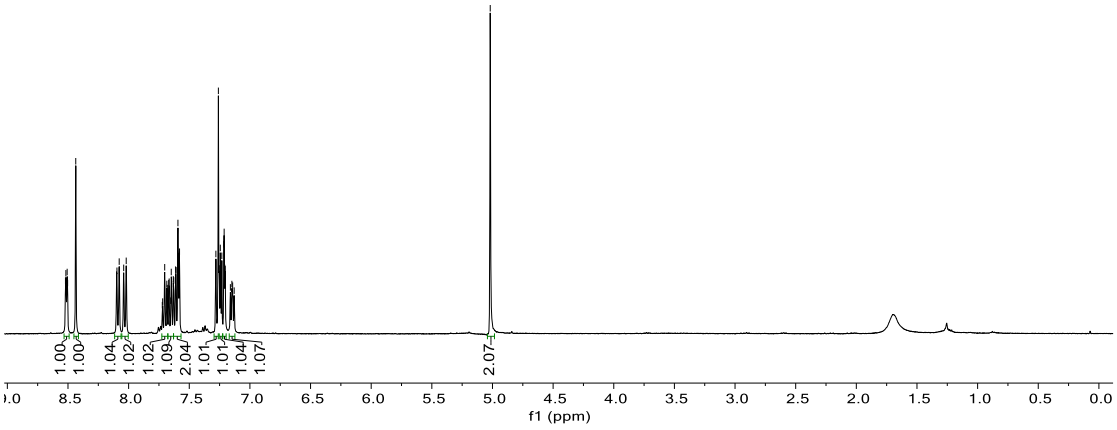

167.75
167.18
155.44
149.65
140.39
136.72
135.69
135.59
133.24
133.01
131.92
130.49
129.35
129.25
129.06
128.73
128.36
127.97
127.82
126.64
126.49
124.65
124.12
122.48
121.71
43.21
O
N
N
O
3bg
13C (100 MHz, CDCl3)
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

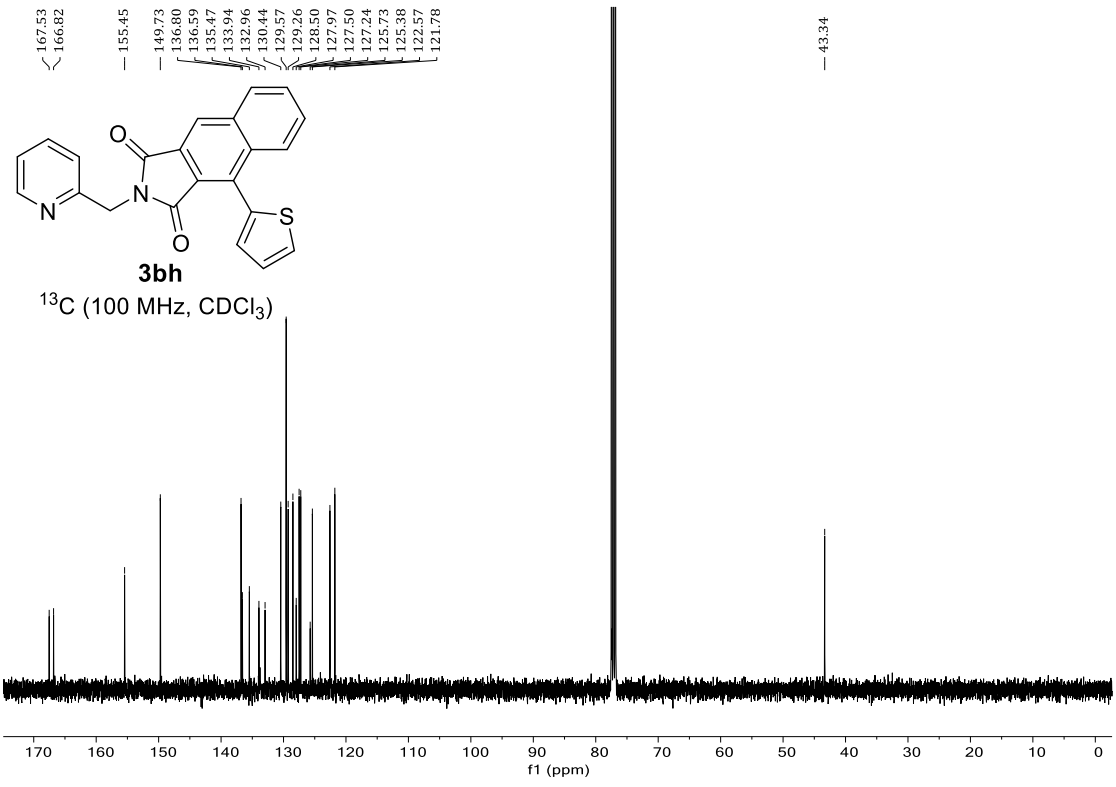




3bh

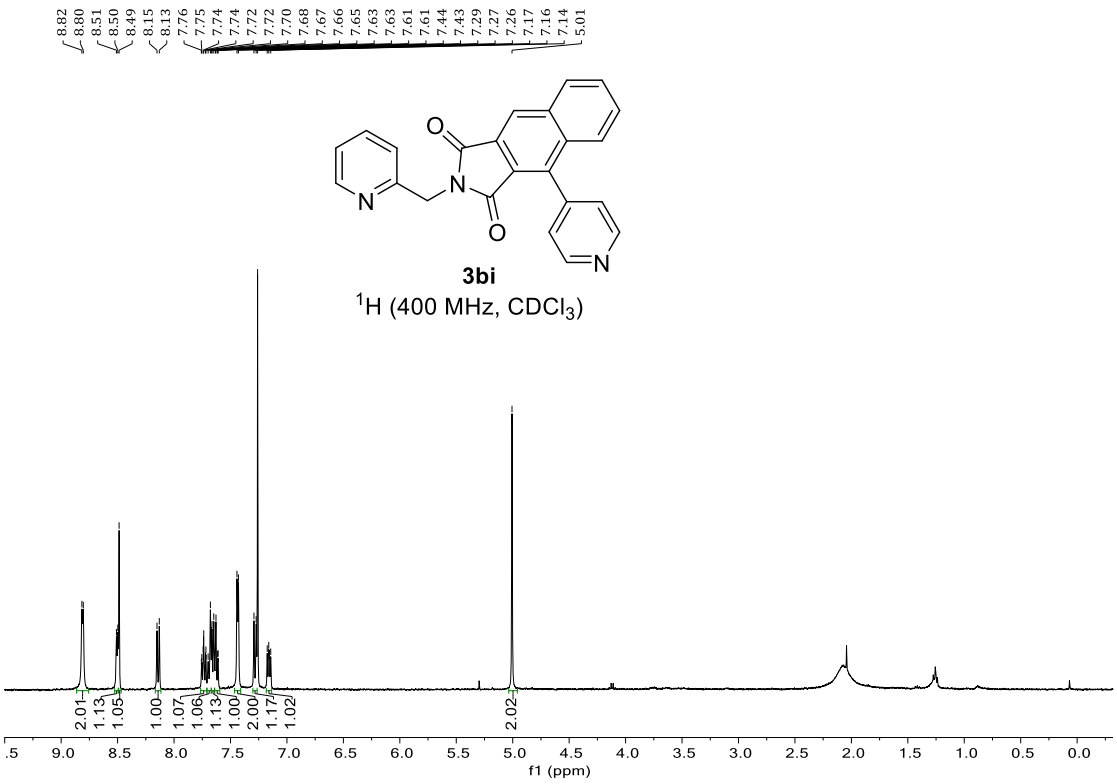
^{1}H (400 MHz, $CDCl_3$)

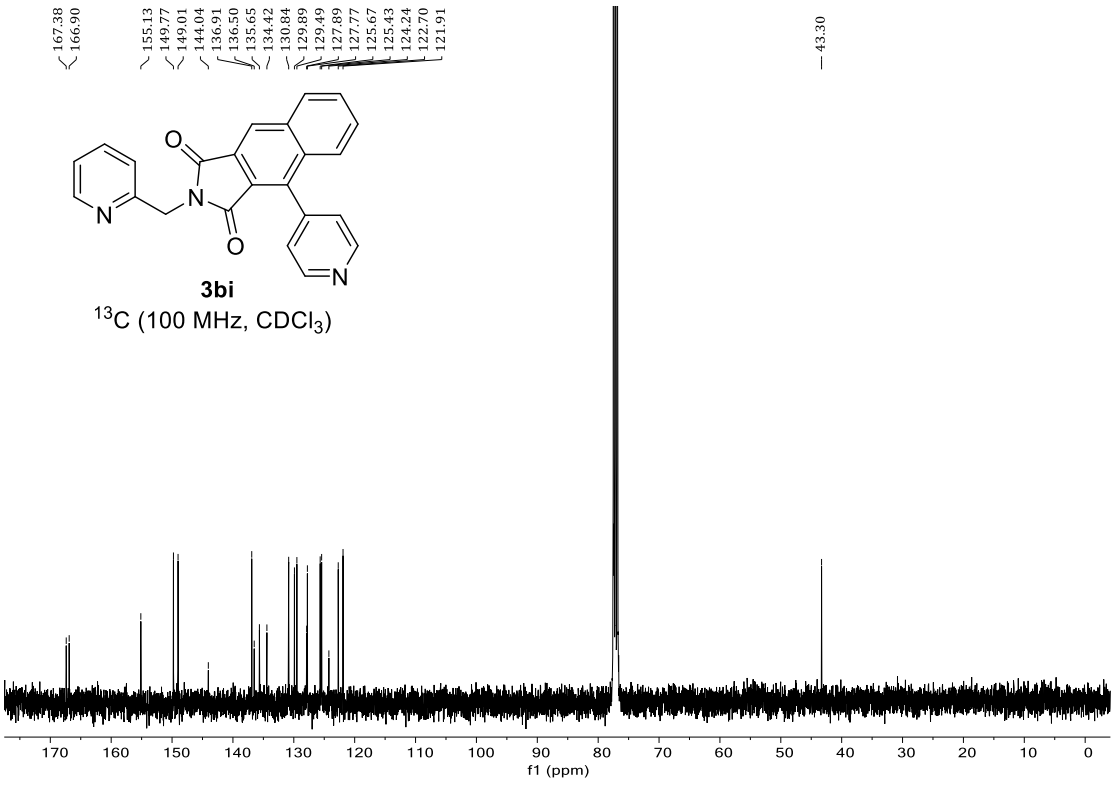


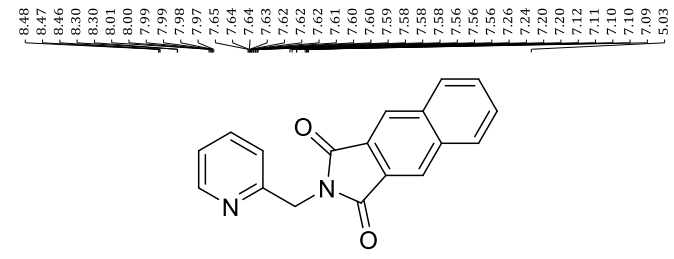


3bh

^{13}C (100 MHz, $CDCl_3$)

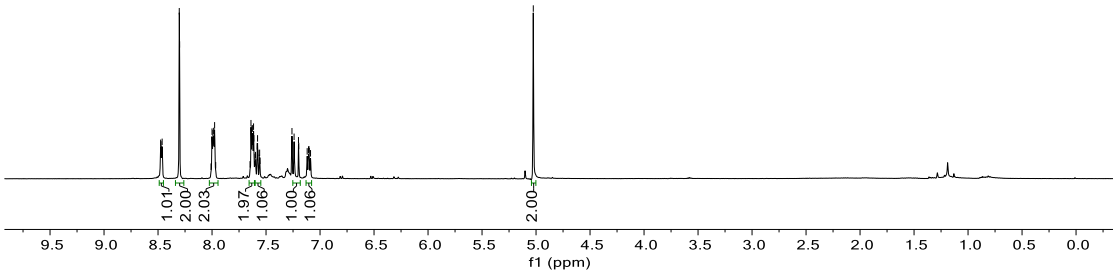

8.82
8.80
8.51
8.50
8.49
8.15
8.13
7.76
7.75
7.74
7.74
7.72
7.72
7.70
7.68
7.67
7.66
7.65
7.63
7.63
7.61
7.61
7.44
7.43
7.29
7.27
7.26
7.17
7.16
7.14
5.01
O
N
N
O
N
3bi
1H (400 MHz, CDCl3)
2.01
1.13
1.05
1.00
1.07
1.06
1.13
1.00
2.00
1.17
1.02
2.02
f1 (ppm)

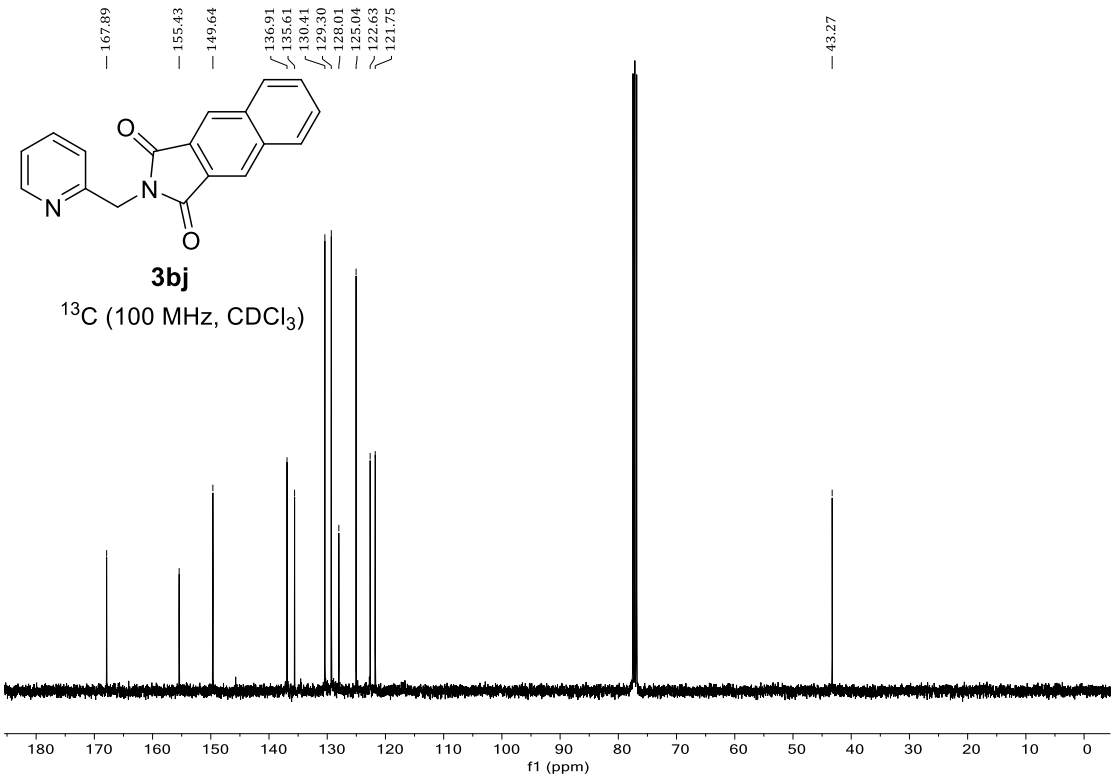

167.38
166.90
155.13
149.77
149.01
144.04
136.91
136.50
135.65
134.42
130.84
129.89
129.49
127.89
127.77
125.67
125.43
124.24
122.70
121.91
43.30
O
N
N
O
N
3bi
13C (100 MHz, CDCl3)
f1 (ppm)



3bj

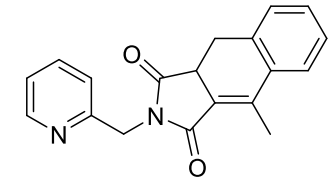
^{1}H (400 MHz, $CDCl_3$)





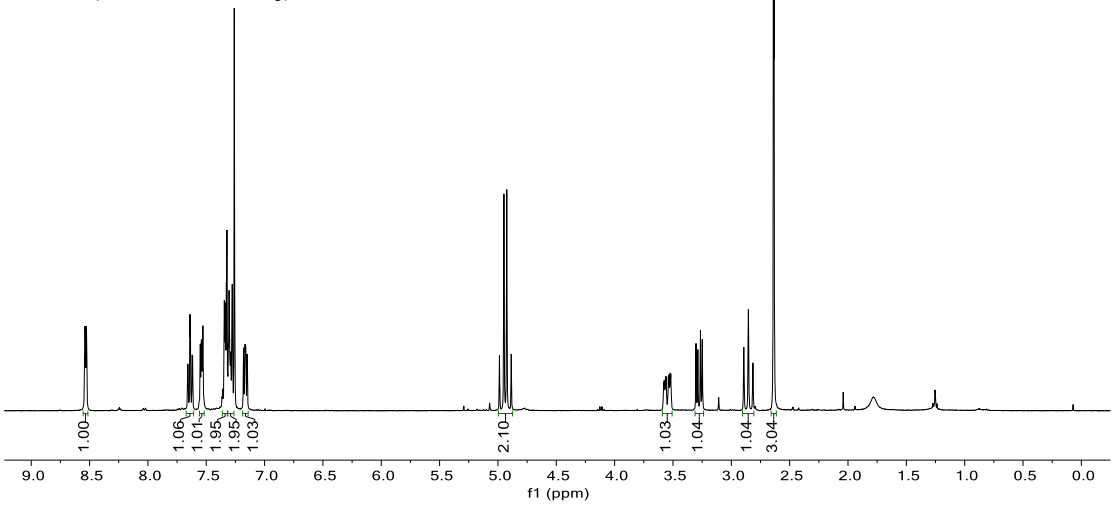
3bj

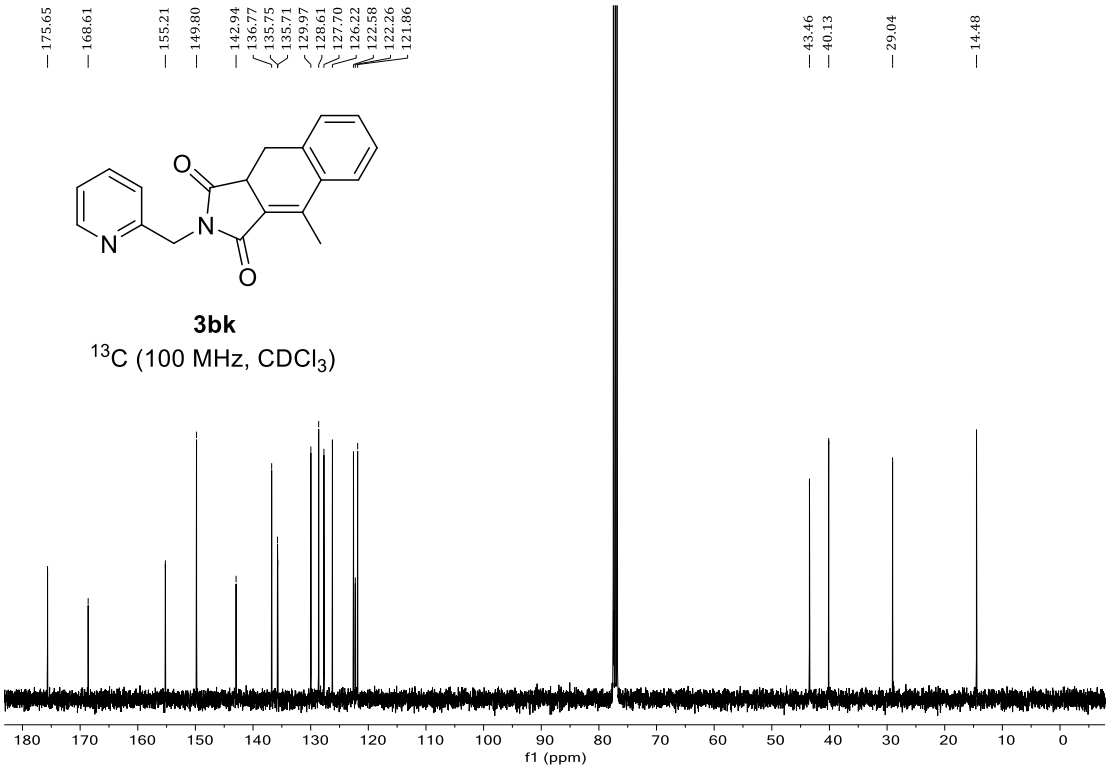
^{13}C (100 MHz, $CDCl_3$)



3bk

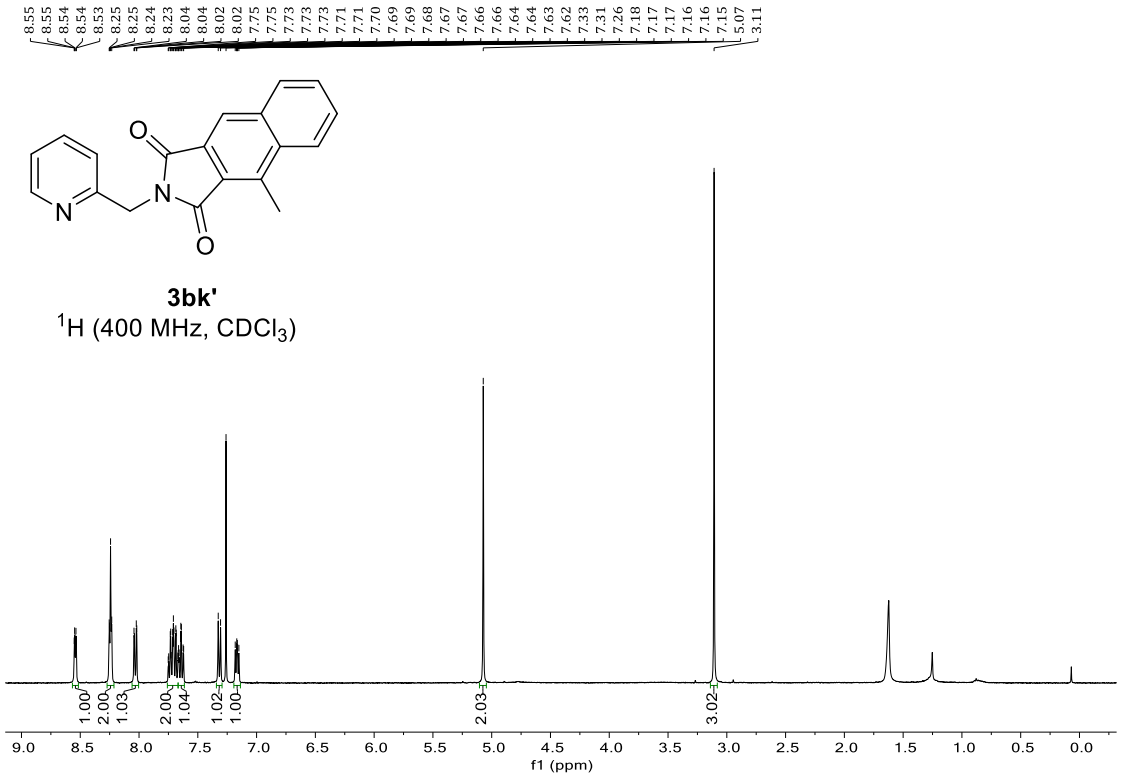
^{1}H (400 MHz, $CDCl_3$)





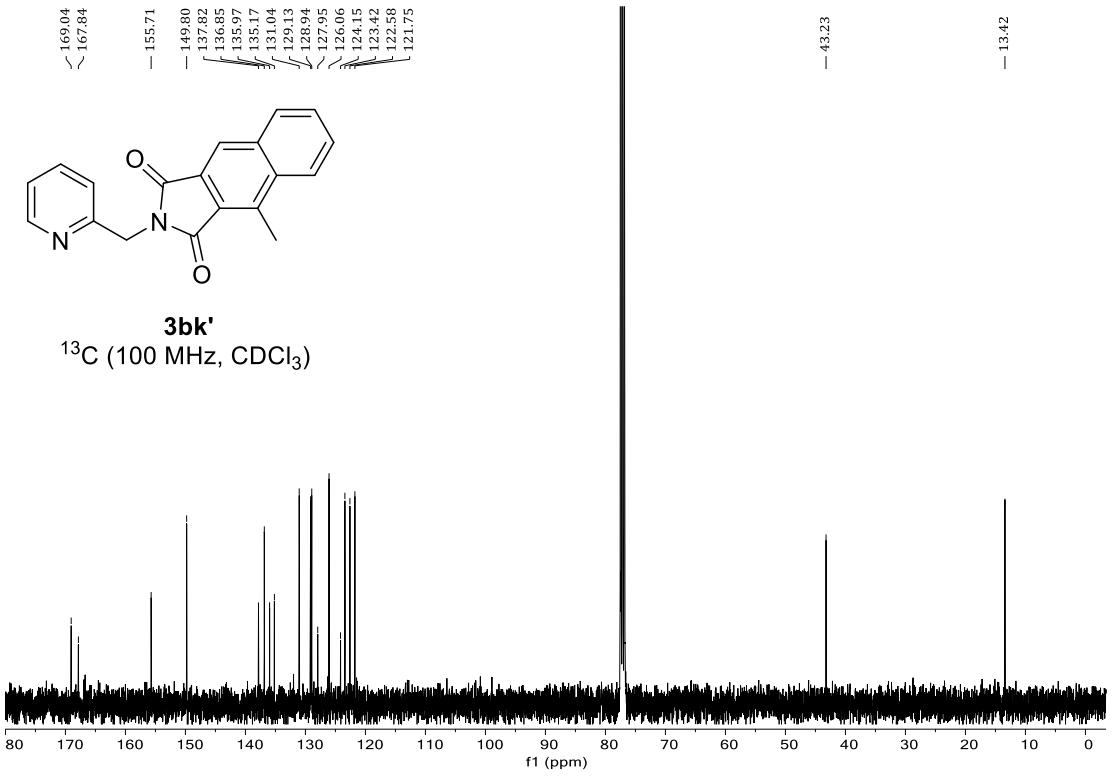
3bk

^{13}C (100 MHz, $CDCl_3$)



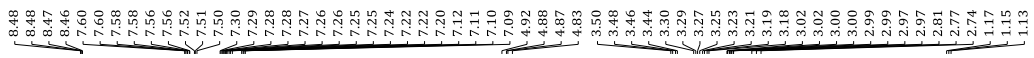
3bk'

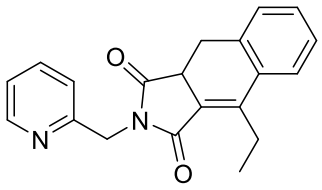
^{1}H (400 MHz, $CDCl_3$)



3bk'

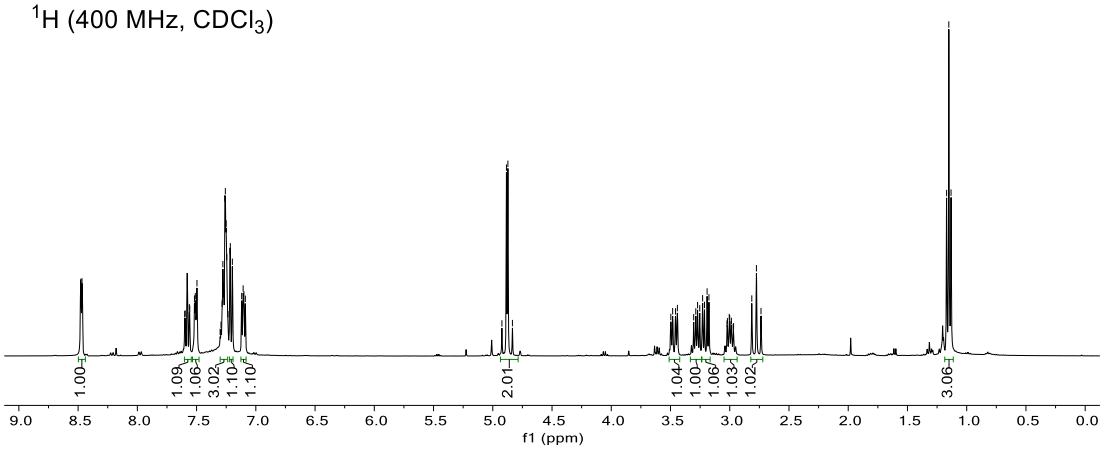
^{13}C (100 MHz, $CDCl_3$)

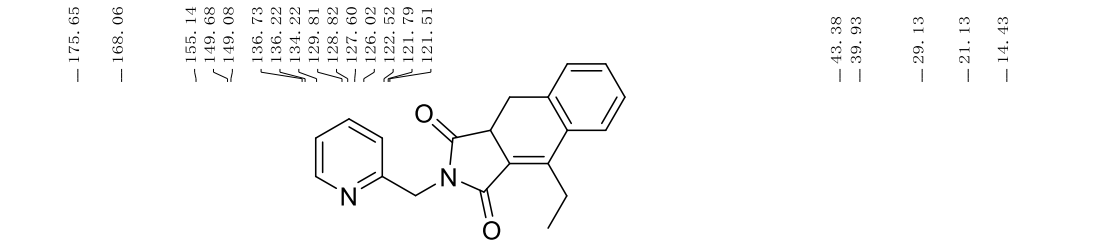




3bl

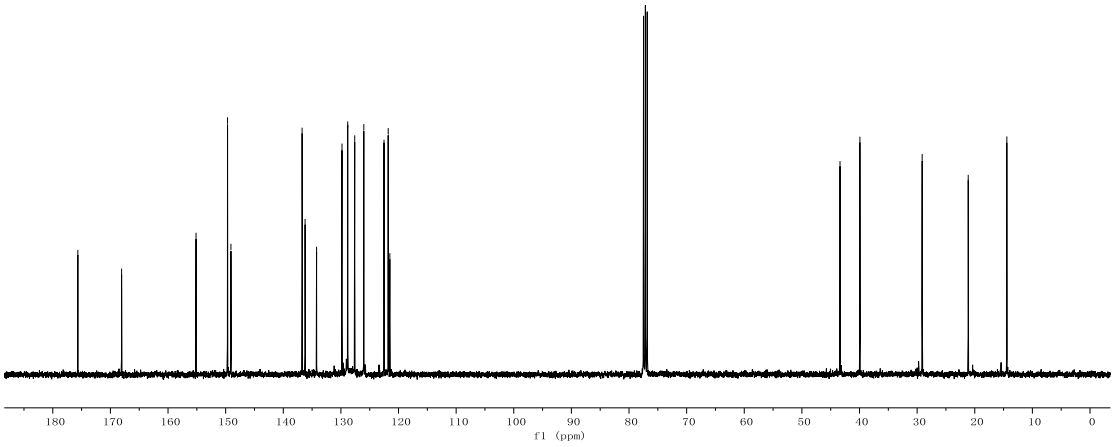
^{1}H (400 MHz, $CDCl_3$)

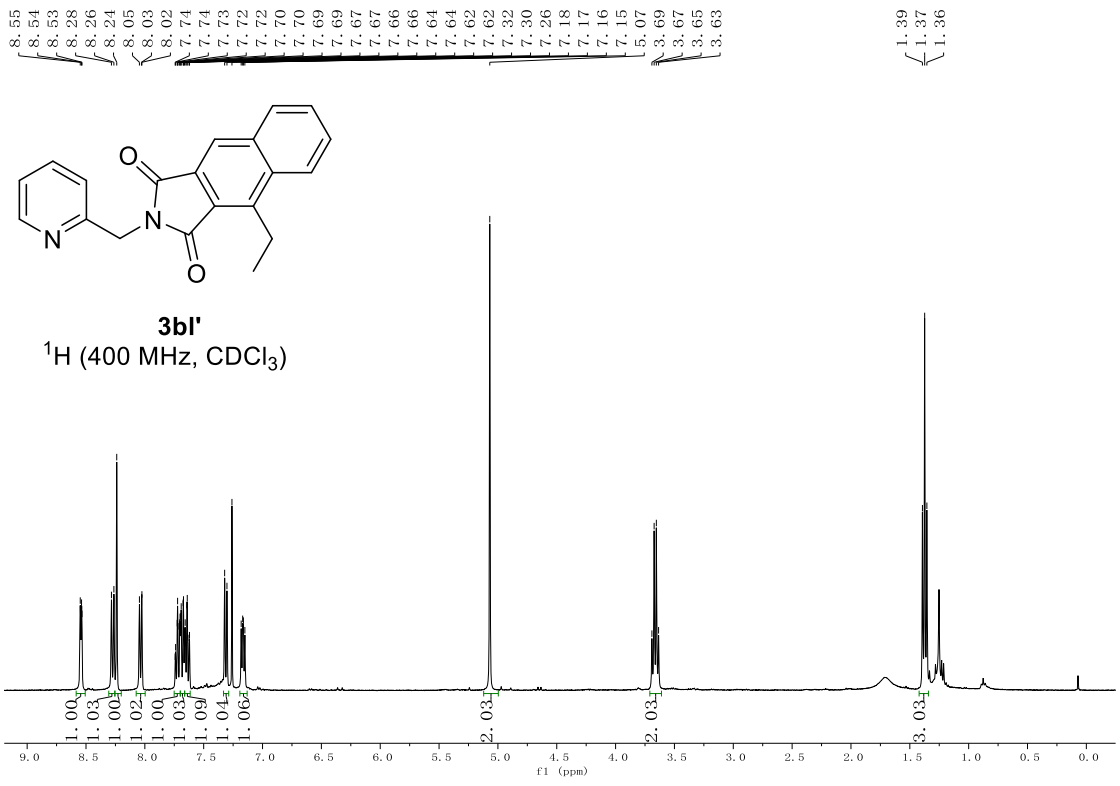


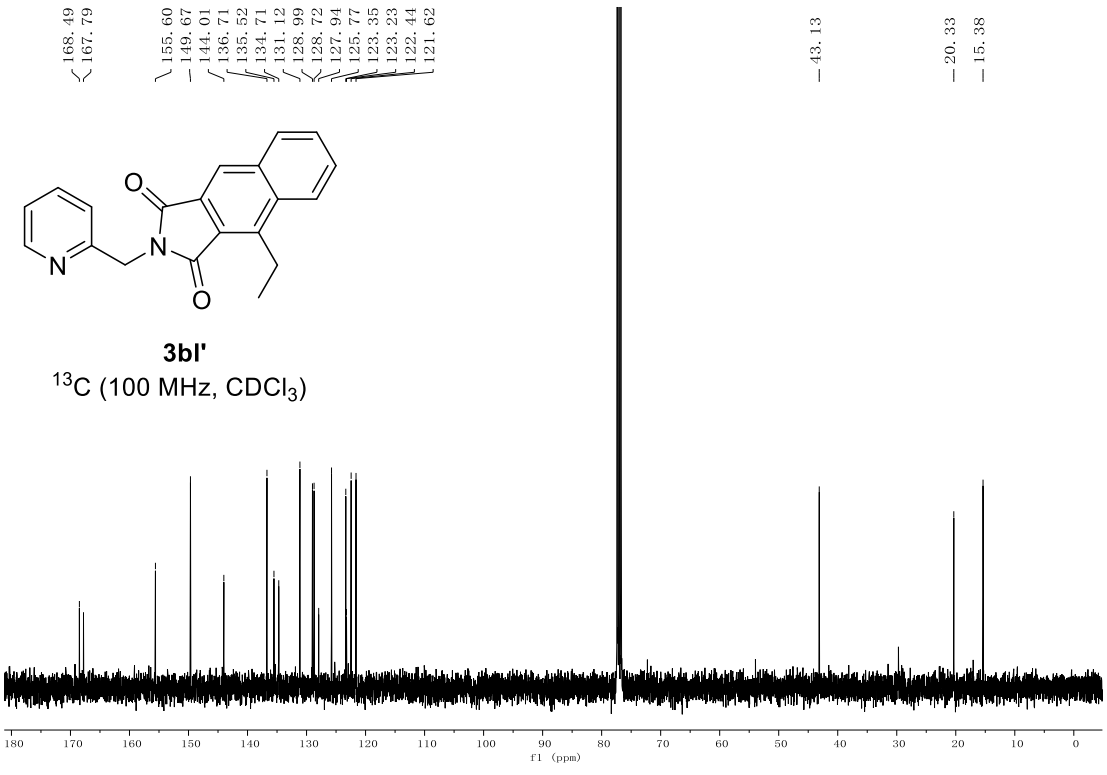


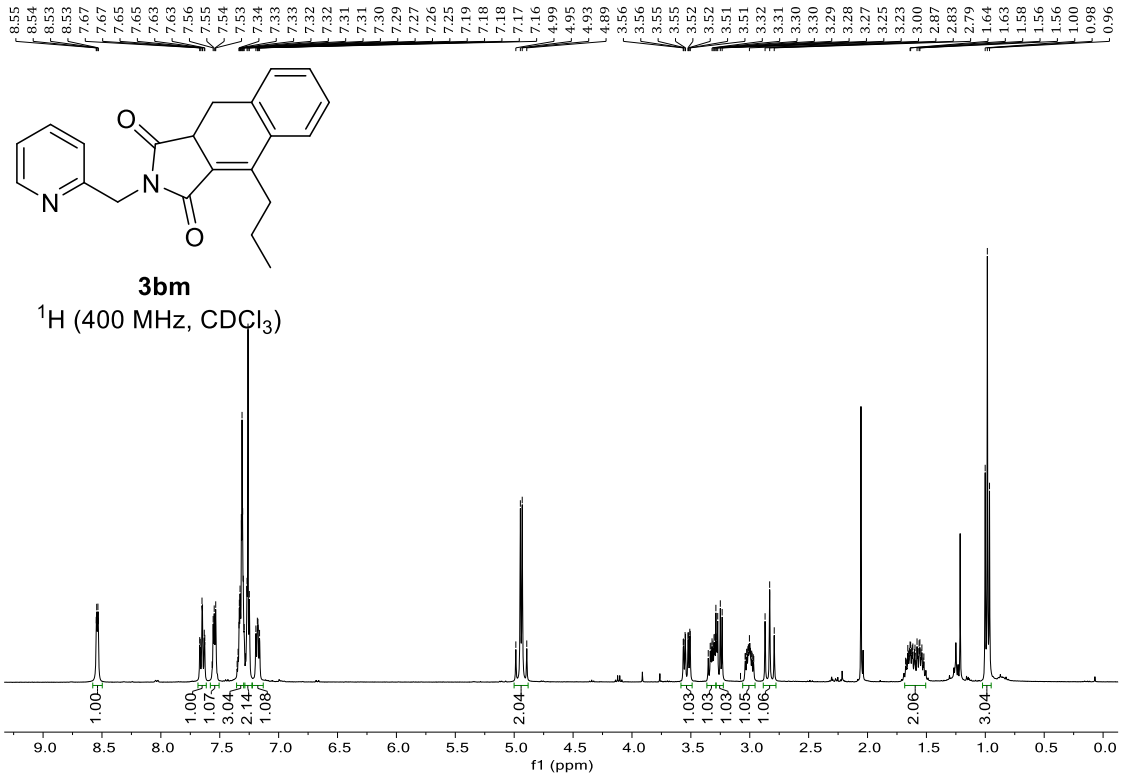
3bl

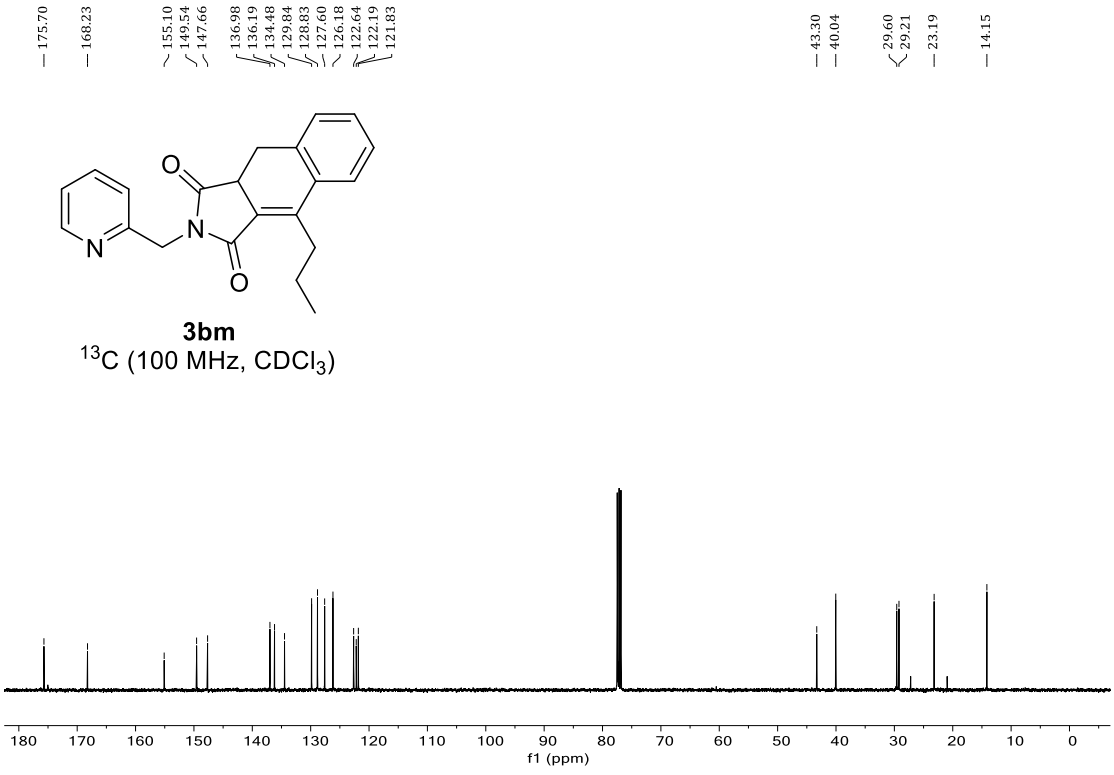
^{13}C (100 MHz, $CDCl_3$)

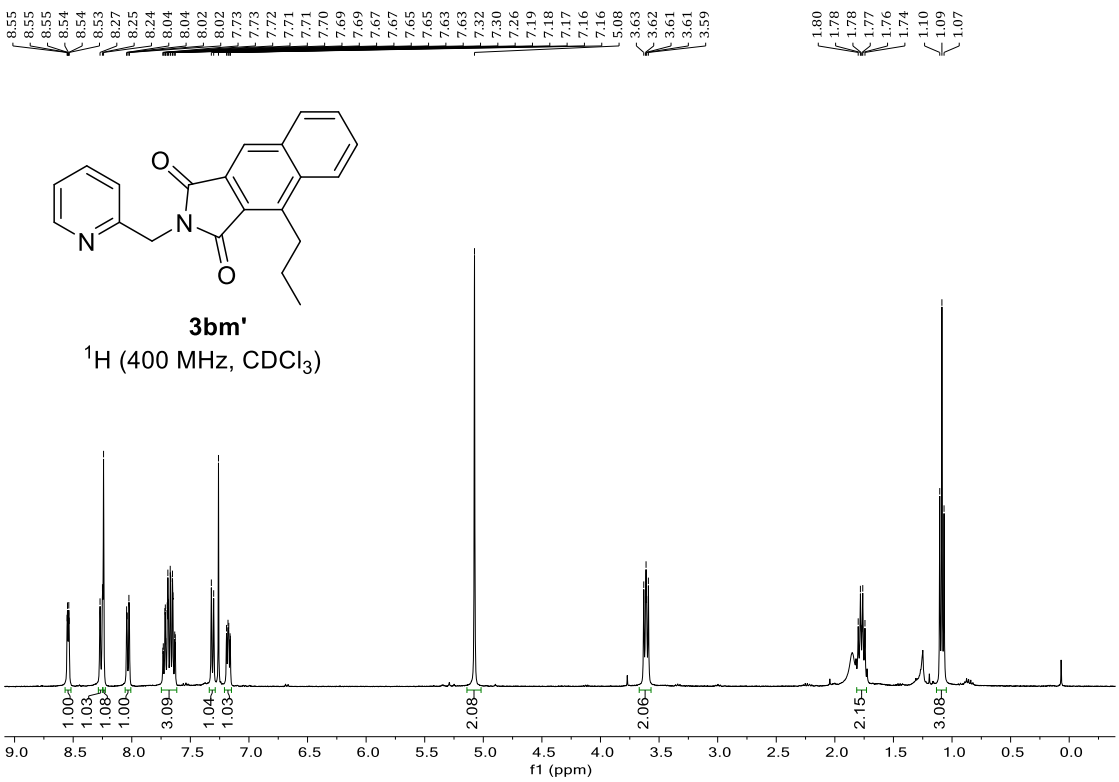


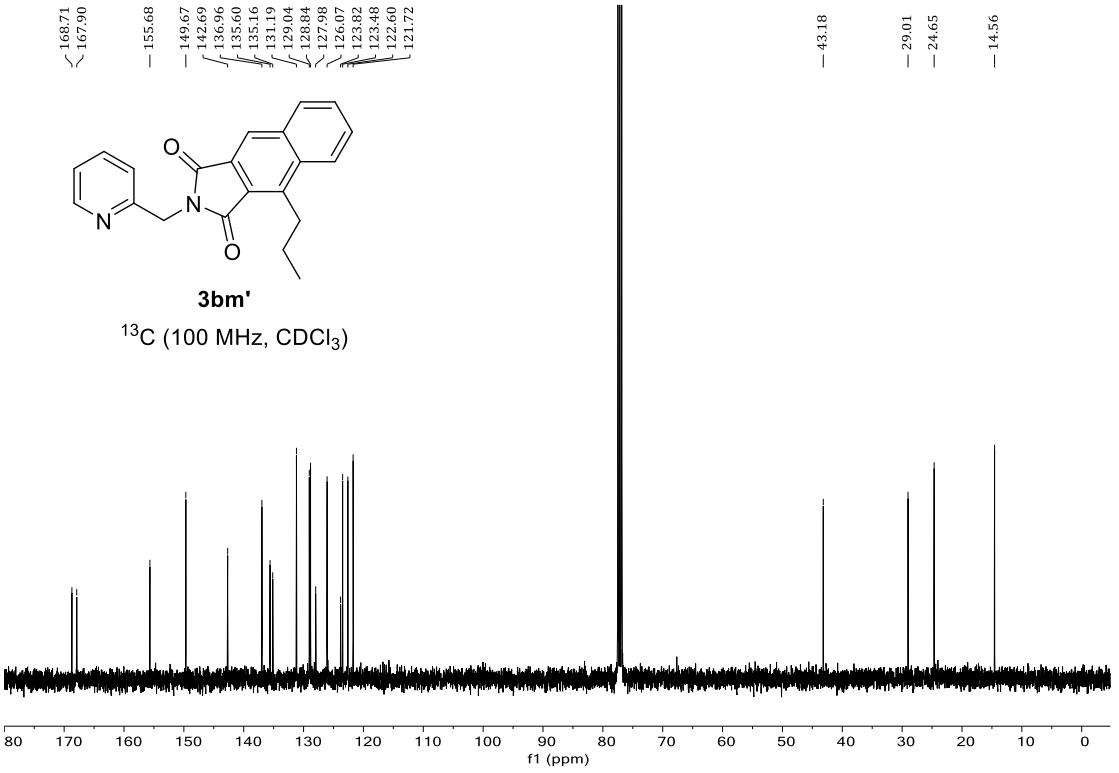

8.55
8.54
8.53
8.28
8.26
8.24
8.05
8.03
8.02
7.74
7.74
7.73
7.72
7.72
7.70
7.70
7.69
7.69
7.67
7.67
7.66
7.66
7.64
7.64
7.62
7.62
7.32
7.30
7.26
7.18
7.17
7.16
7.15
5.07
3.69
3.67
3.65
3.63
1.39
1.37
1.36
O
N
N
O
3bl'
1H (400 MHz, CDCl3)
1.00
1.03
1.00
1.02
1.00
1.03
1.09
1.04
1.06
2.03
2.03
3.03
9.0
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)

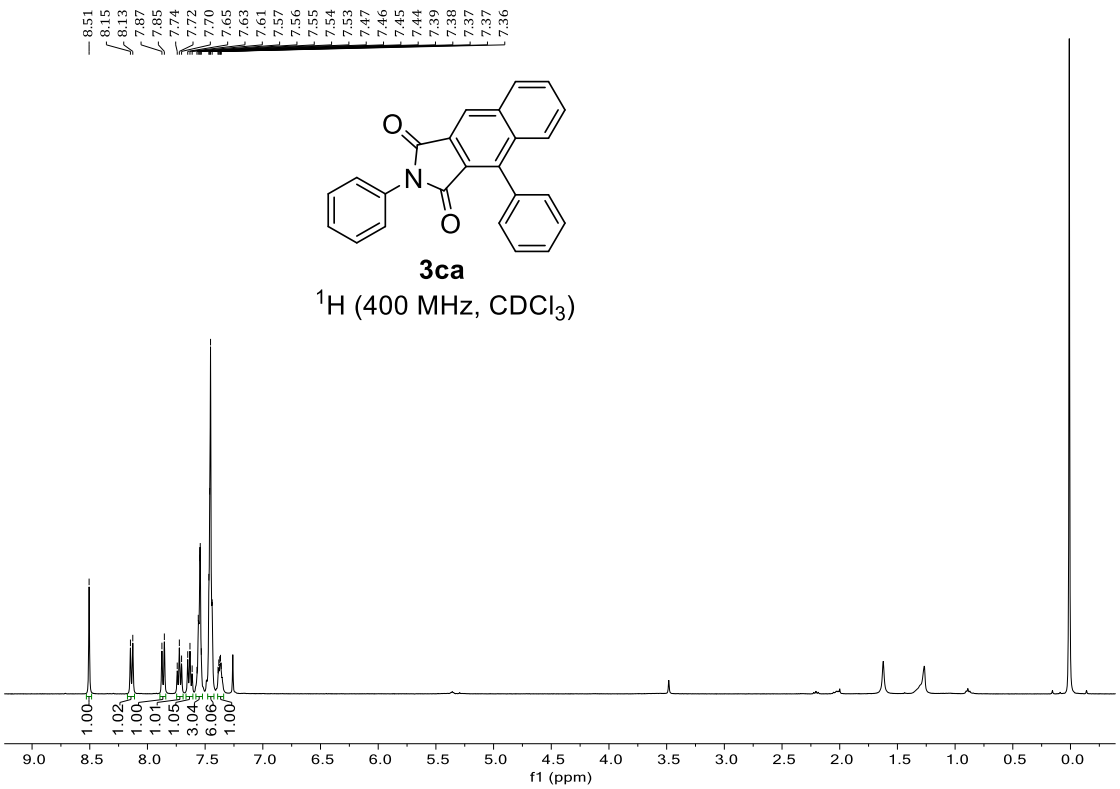

168.49
167.79
155.60
149.67
144.01
136.71
135.52
134.71
131.12
128.99
128.72
127.94
125.77
123.35
123.23
122.44
121.62
43.13
20.33
15.38
O
N
N
O
3bl'
13C (100 MHz, CDCl3)
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.55 8.54 8.53 8.53 7.67 7.67 7.65 7.65 7.63 7.63 7.56 7.55 7.54 7.53 7.34 7.33 7.33 7.32 7.32 7.31 7.31 7.30 7.29 7.27 7.26 7.25 7.19 7.18 7.18 7.17 7.16 4.99 4.95 4.93 4.89 3.56 3.56 3.55 3.55 3.52 3.52 3.51 3.51 3.32 3.31 3.30 3.30 3.29 3.28 3.27 3.25 3.23 3.00 2.87 2.83 2.79 1.64 1.63 1.58 1.56 1.56 1.00 0.98 0.96
O
N
N
O
3bm
1H (400 MHz, CDCl3)
1.00 1.00 1.07 3.04 2.14 1.08 2.04 1.03 1.03 1.03 1.05 1.06 2.06 3.04
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)


175.70 168.23 155.10 149.54 147.66 136.98 136.19 134.48 129.84 128.83 127.60 126.18 122.64 122.19 121.83 43.30 40.04 29.60 29.21 23.19 14.15
O
N
N
O
3bm
13C (100 MHz, CDCl3)
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

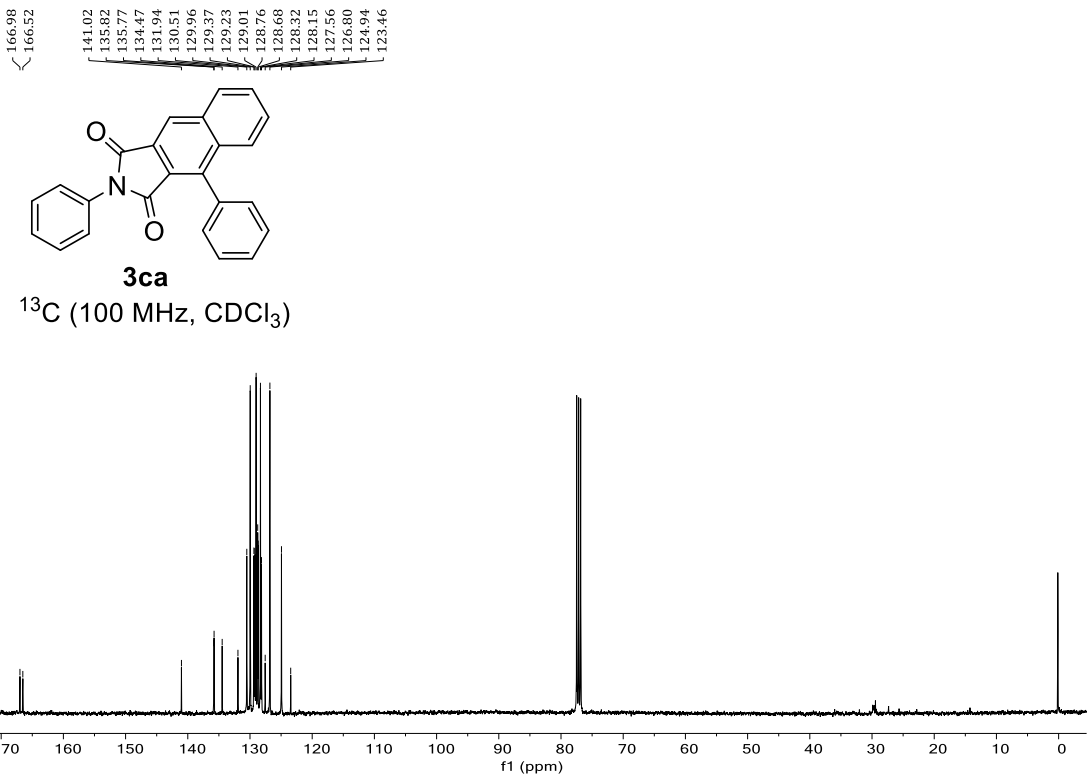

8.55 8.55 8.55 8.54 8.54 8.53 8.27 8.25 8.24 8.04 8.04 8.02 8.02 7.73 7.73 7.72 7.71 7.71 7.70 7.69 7.69 7.67 7.67 7.65 7.65 7.63 7.63 7.32 7.30 7.26 7.19 7.18 7.17 7.16 7.16 5.08 3.63 3.62 3.61 3.61 3.59
1.80 1.78 1.78 1.77 1.76 1.74 1.10 1.09 1.07
O
N
N
O
3bm'
1H (400 MHz, CDCl3)
1.00 1.03 1.08 1.00 3.09 1.04 1.03 2.08 2.06 2.15 3.08
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)


168.71 167.90 155.68 149.67 142.69 136.96 135.60 135.16 131.19 129.04 128.84 127.98 126.07 123.82 123.48 122.60 121.72
43.18 29.01 24.65 14.56
O
N
N
O
3bm'
13C (100 MHz, CDCl3)
80 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)



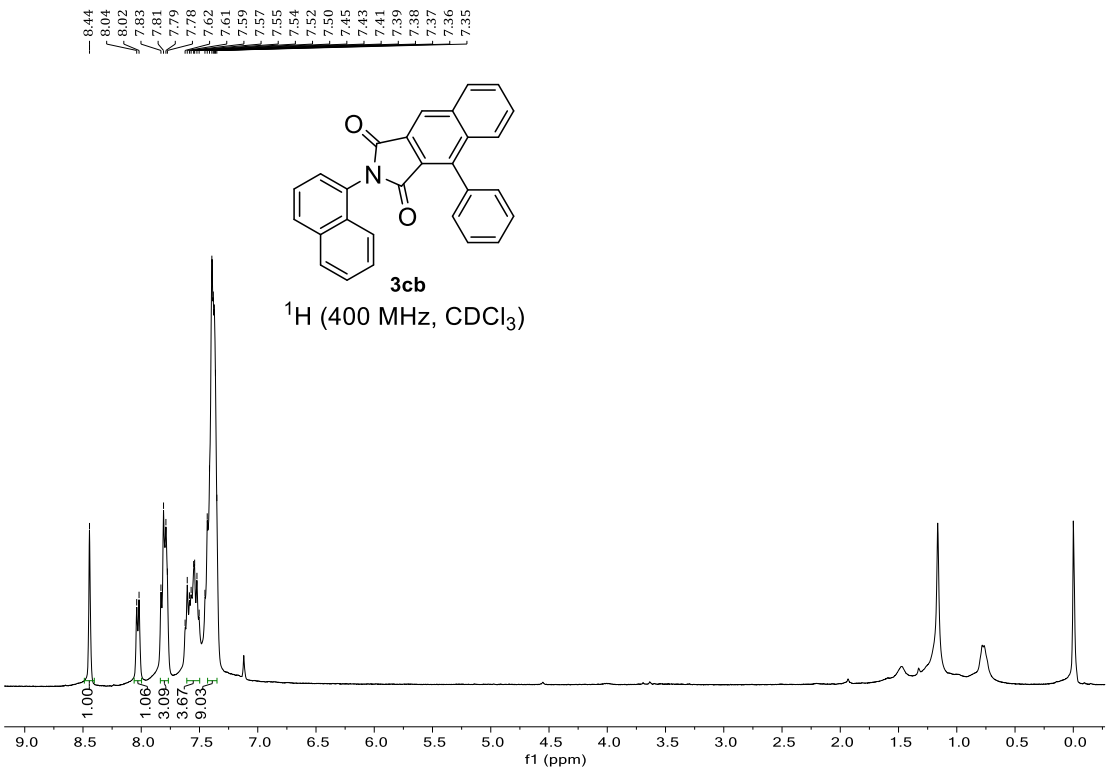
3ca

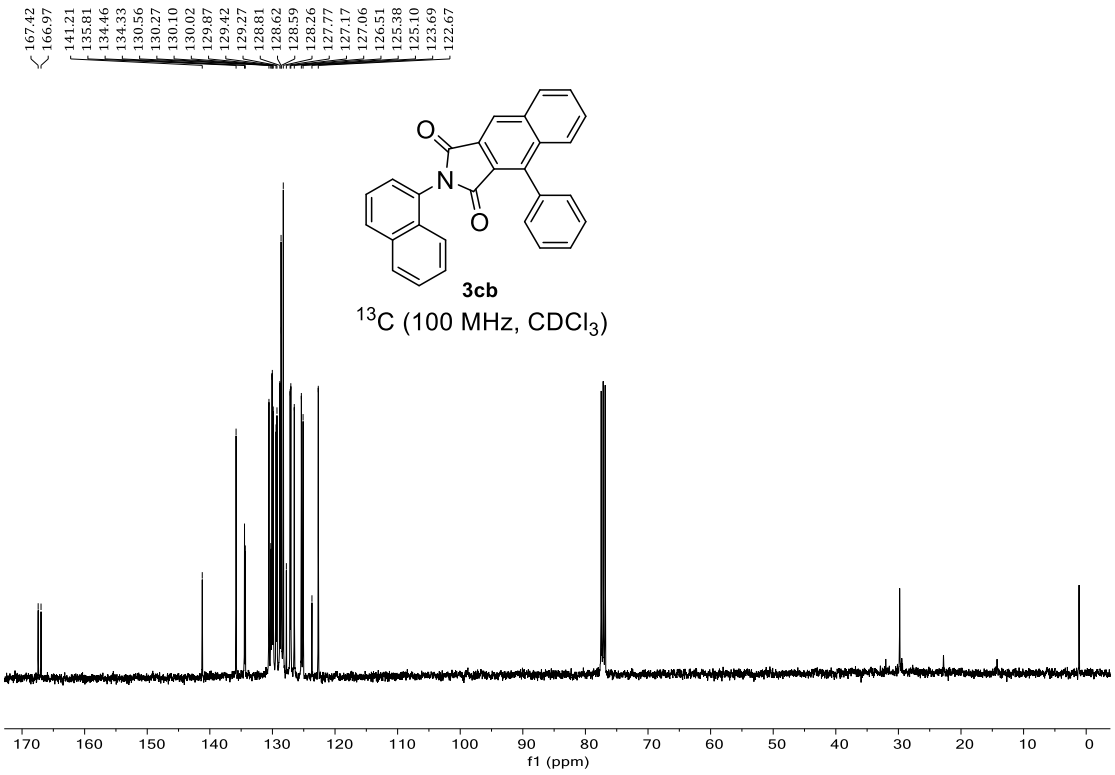
^{1}H (400 MHz, $CDCl_3$)

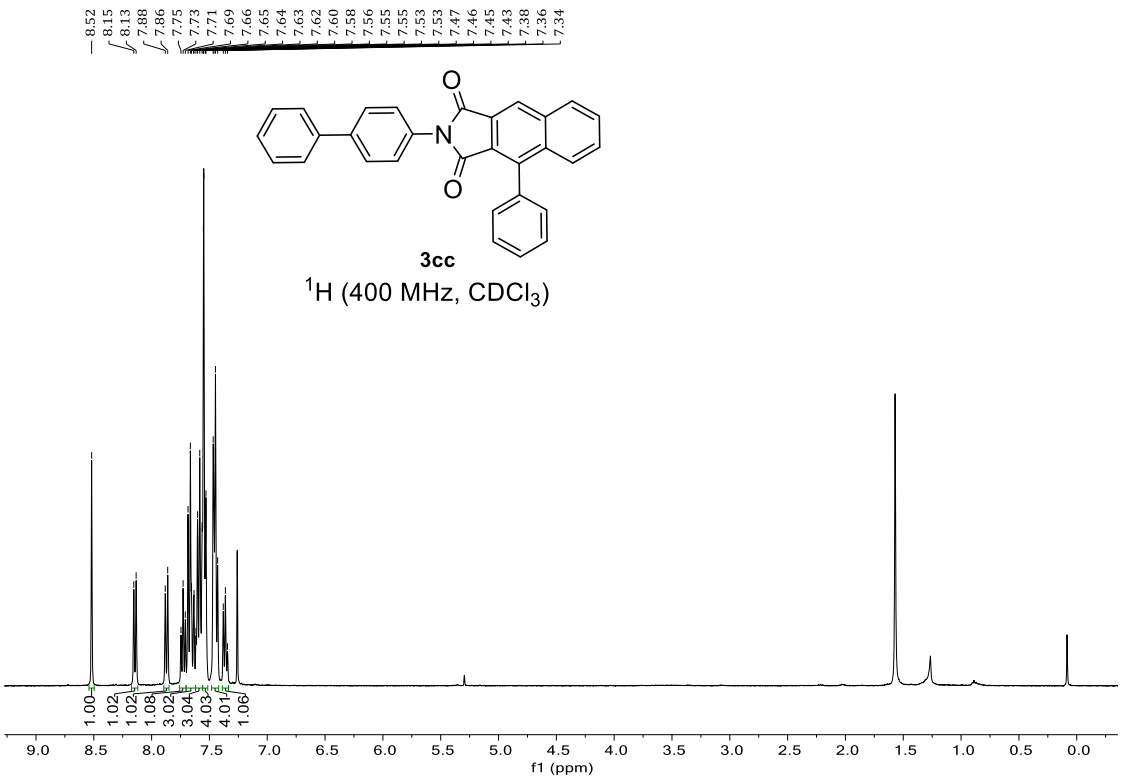


3ca

^{13}C (100 MHz, $CDCl_3$)

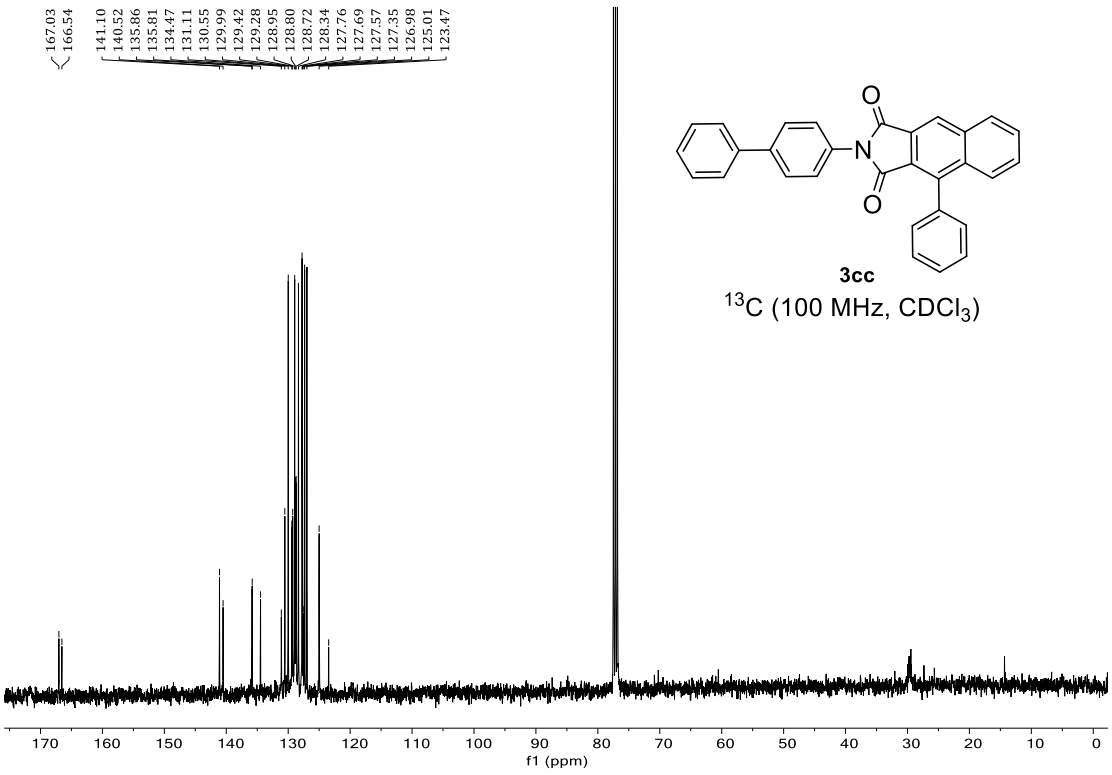

8.44
8.04
8.02
7.83
7.81
7.79
7.78
7.62
7.61
7.59
7.57
7.55
7.54
7.52
7.50
7.45
7.43
7.41
7.39
7.38
7.37
7.36
7.35
O
N
O
3cb
1H (400 MHz, CDCl3)
1.00
1.06
3.09
3.67
9.03
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


167.42
166.97
141.21
135.81
134.46
134.33
130.56
130.27
130.10
130.02
129.87
129.42
129.27
128.81
128.62
128.59
128.26
127.77
127.17
127.06
126.51
125.38
125.10
123.69
122.67
O
N
O
3cb
13C (100 MHz, CDCl3)
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)



3cc

^{1}H (400 MHz, $CDCl_3$)

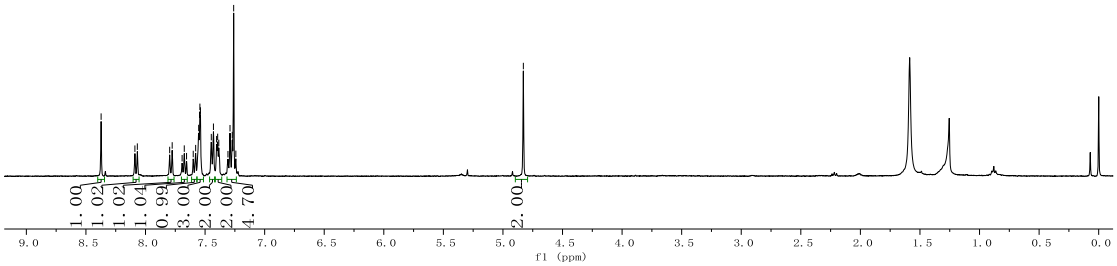


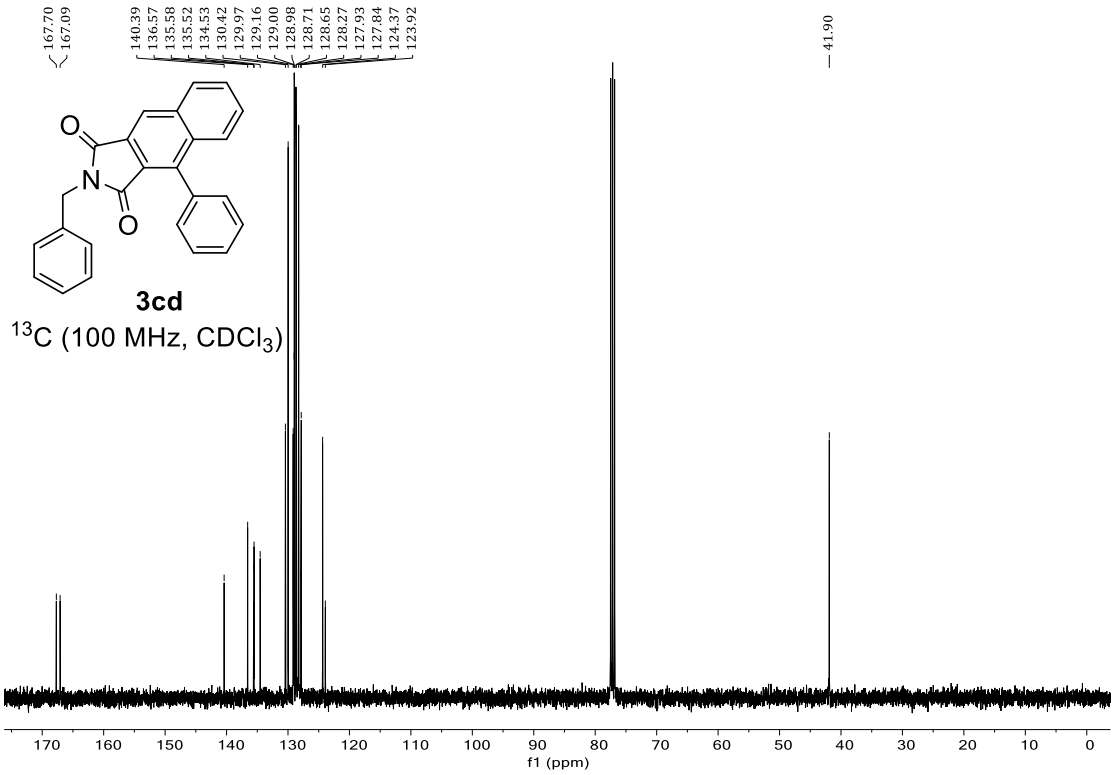
3cc

^{13}C (100 MHz, $CDCl_3$)

3cd

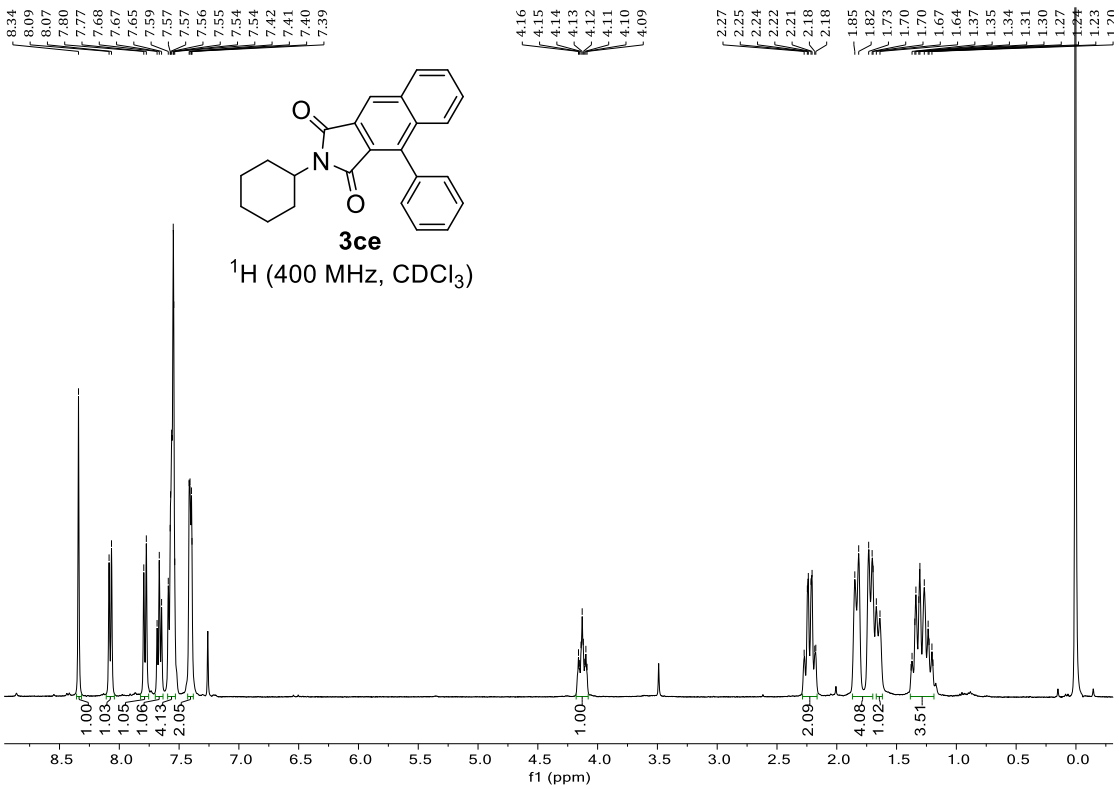
^{1}H (400 MHz, $CDCl_3$)

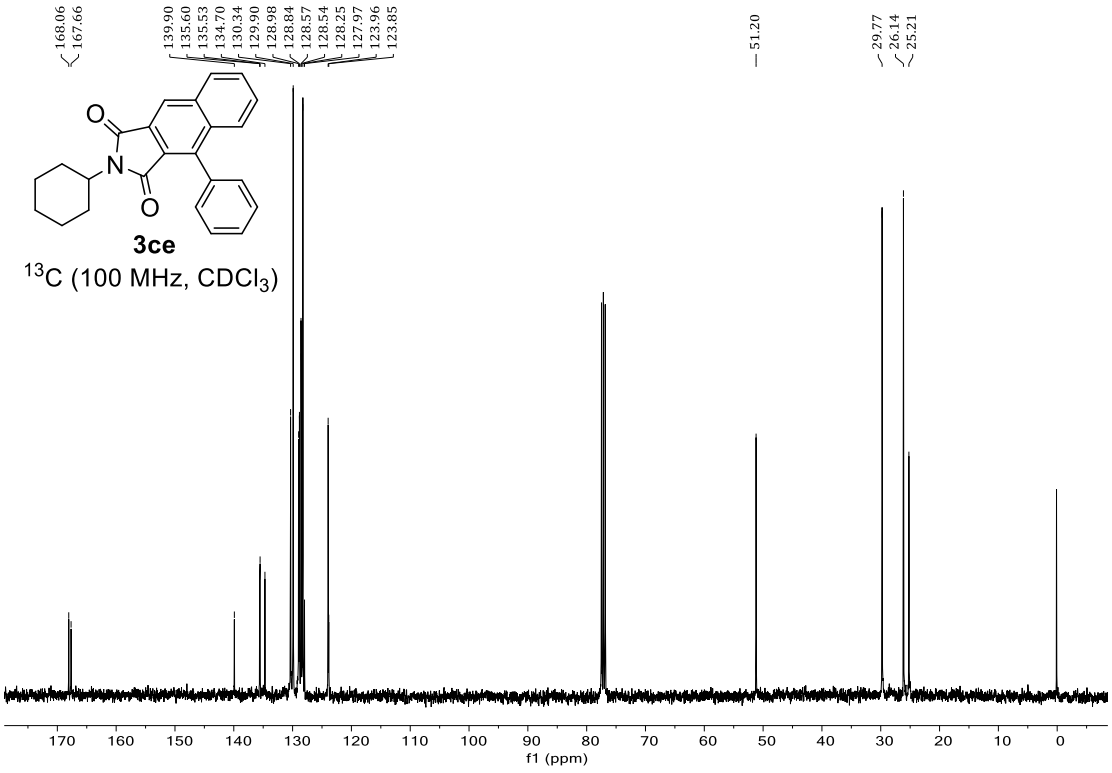


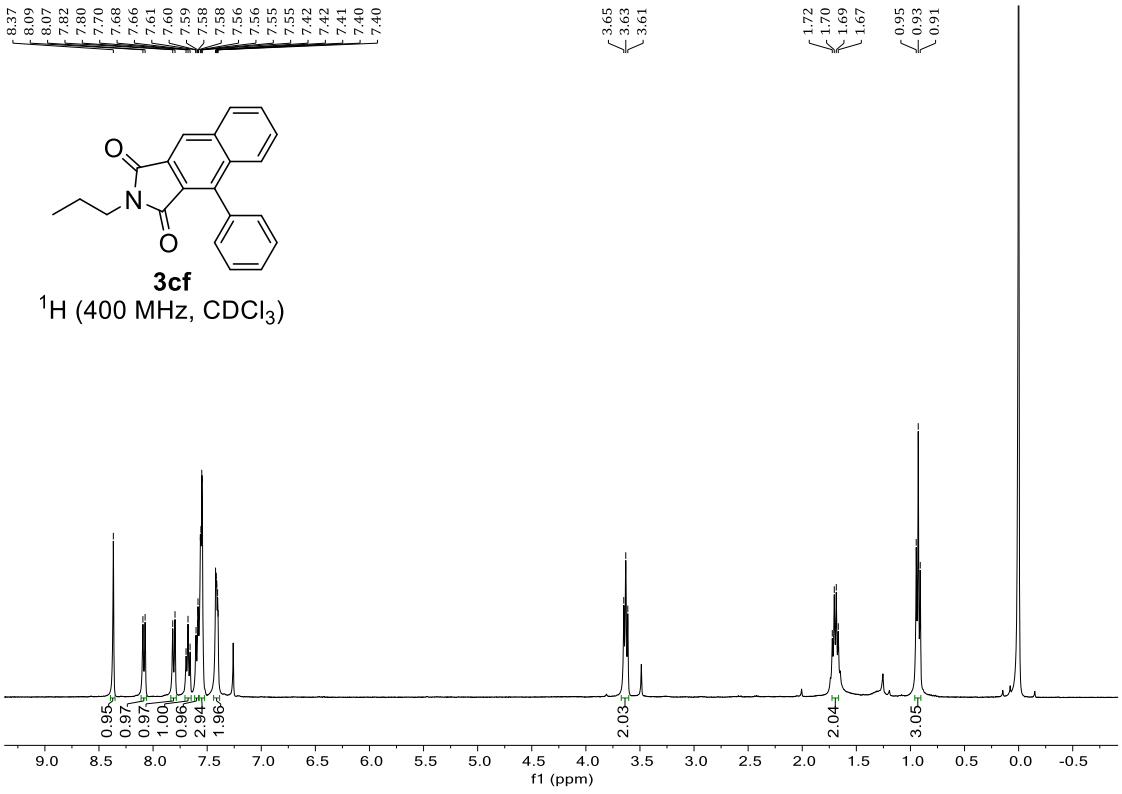


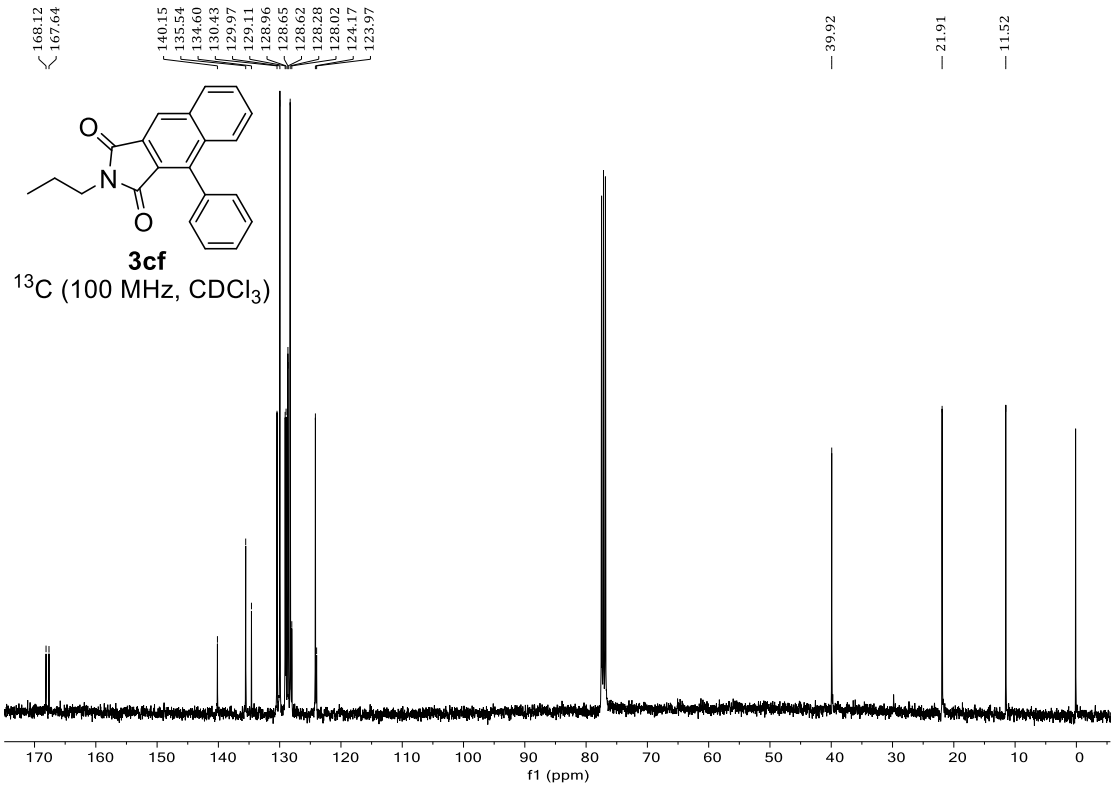
3cd

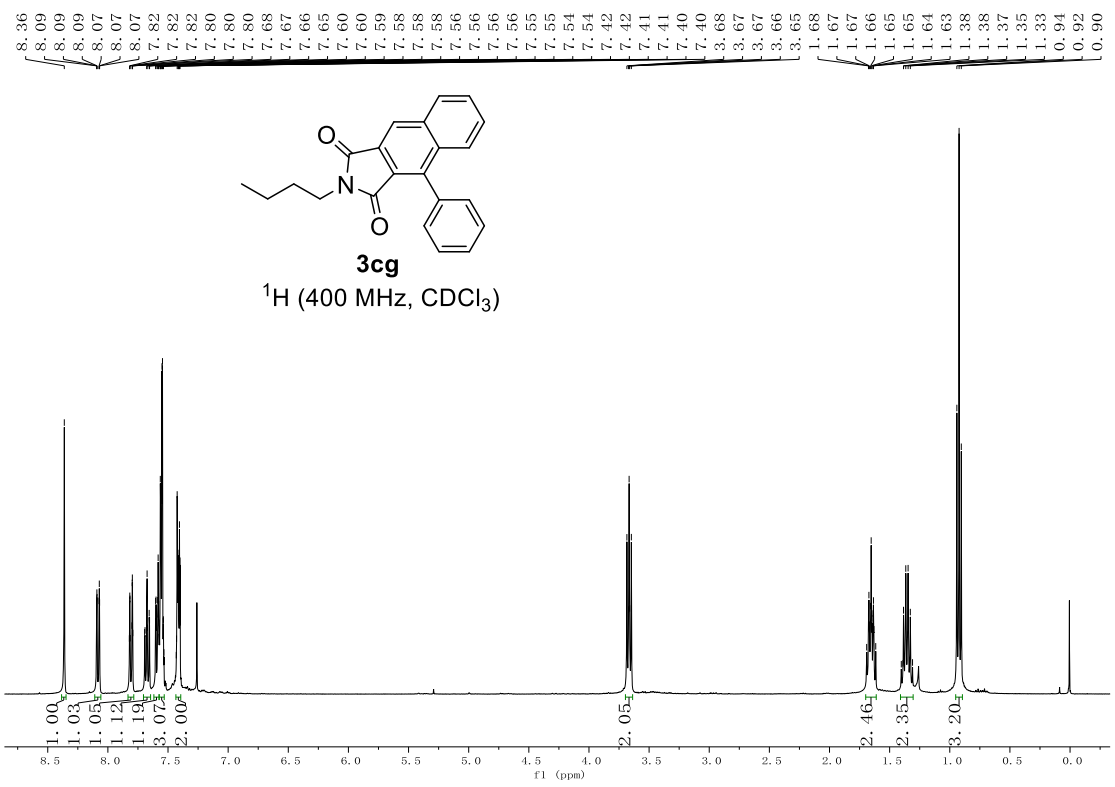
^{13}C (100 MHz, $CDCl_3$)

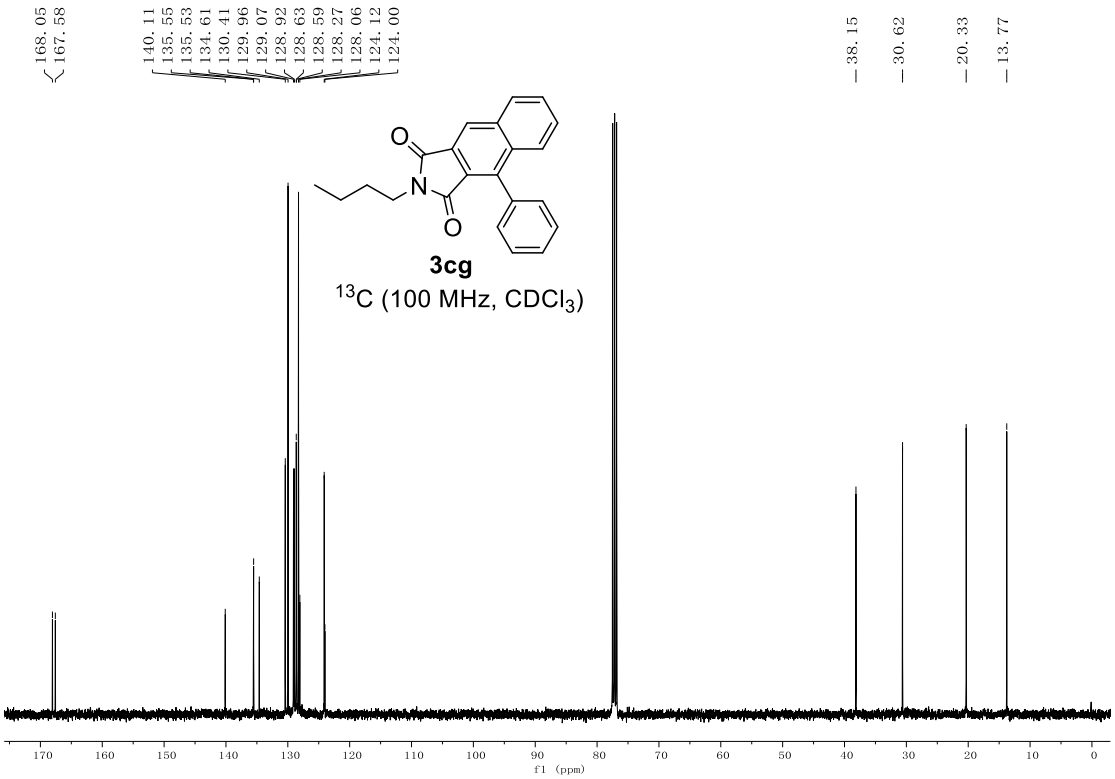

3ce
1H (400 MHz, CDCl3)
f1 (ppm)

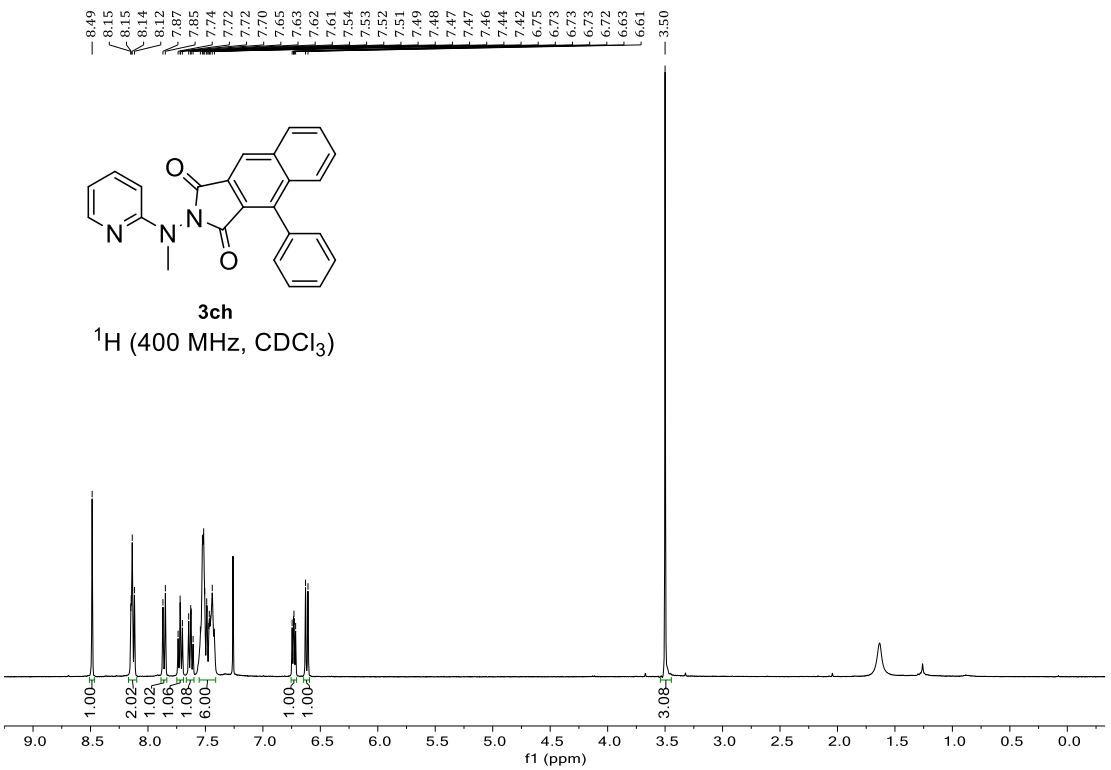

3ce
13C (100 MHz, CDCl3)
f1 (ppm)

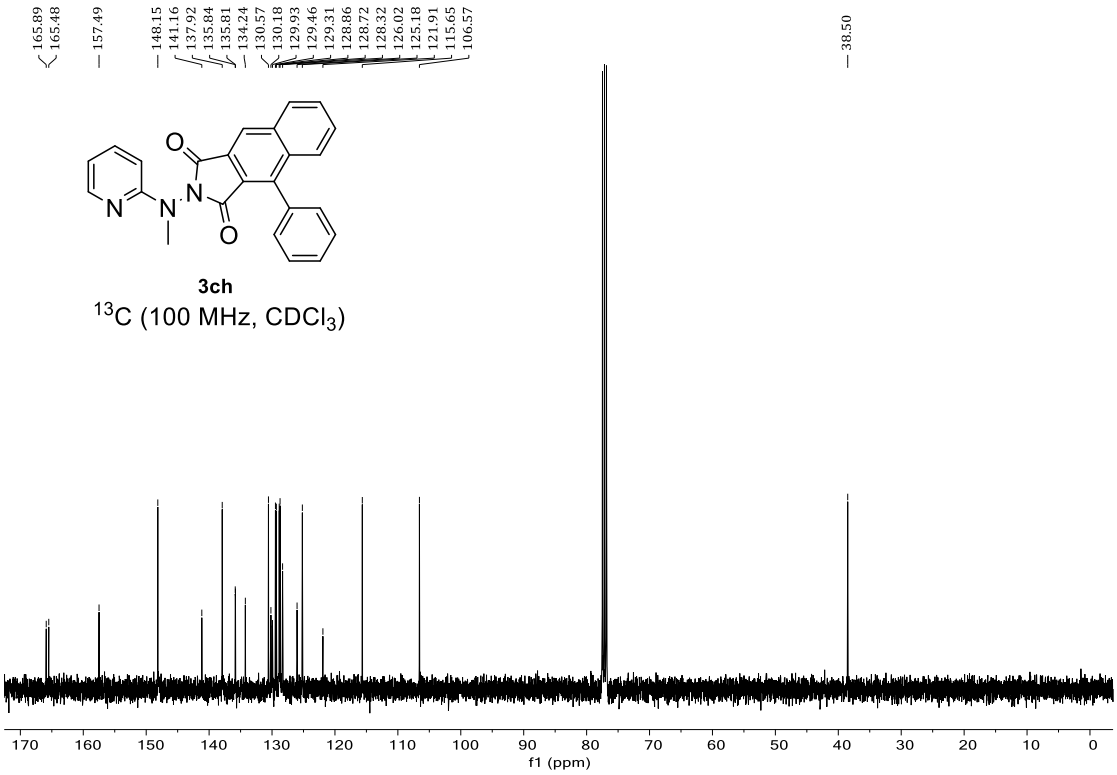

8.37
8.09
8.07
7.82
7.80
7.70
7.68
7.66
7.61
7.60
7.59
7.58
7.58
7.56
7.56
7.55
7.55
7.42
7.41
7.40
7.40
3.65
3.63
3.61
1.72
1.70
1.69
1.67
0.95
0.93
0.91
O
N
O
3cf
1H (400 MHz, CDCl3)
0.95
0.97
0.97
1.00
0.96
2.94
1.96
2.03
2.04
3.05
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)

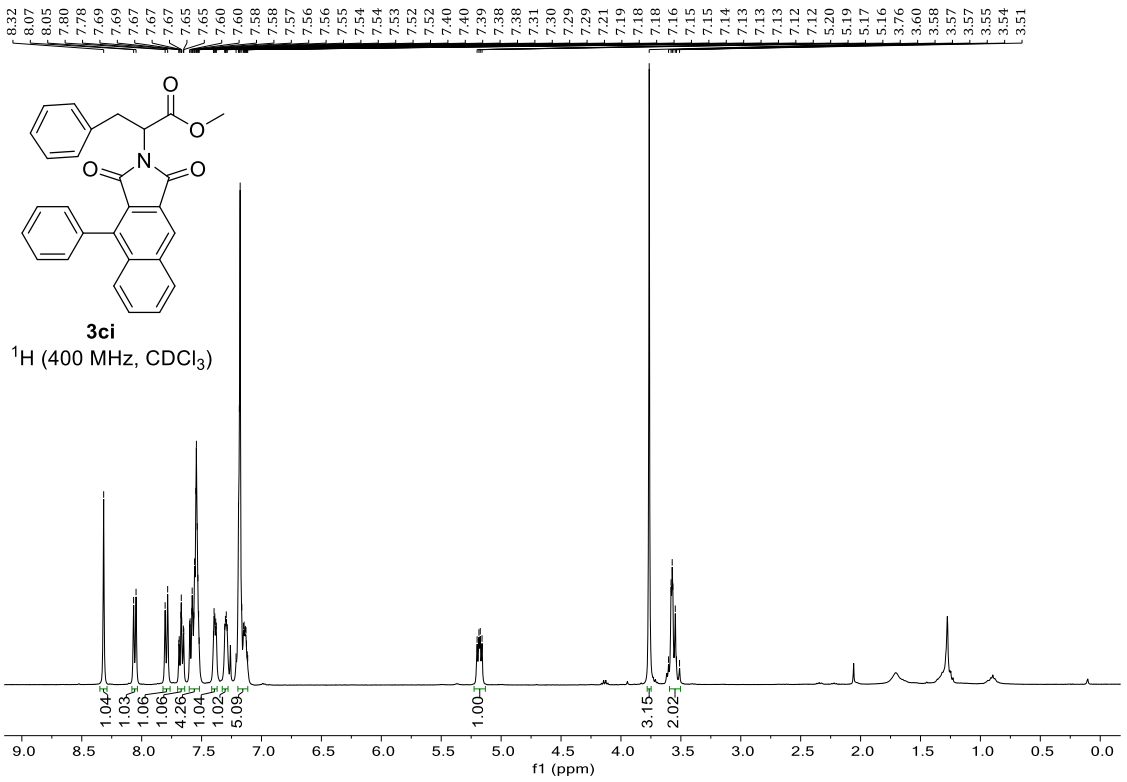

168.12
167.64
140.15
135.54
134.60
130.43
129.97
129.11
128.96
128.65
128.62
128.28
128.02
124.17
123.97
39.92
21.91
11.52
O
N
O
3cf
13C (100 MHz, CDCl3)
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


3cg
1H (400 MHz, CDCl3)
f1 (ppm)


3cg
13C (100 MHz, CDCl3)
f1 (ppm)

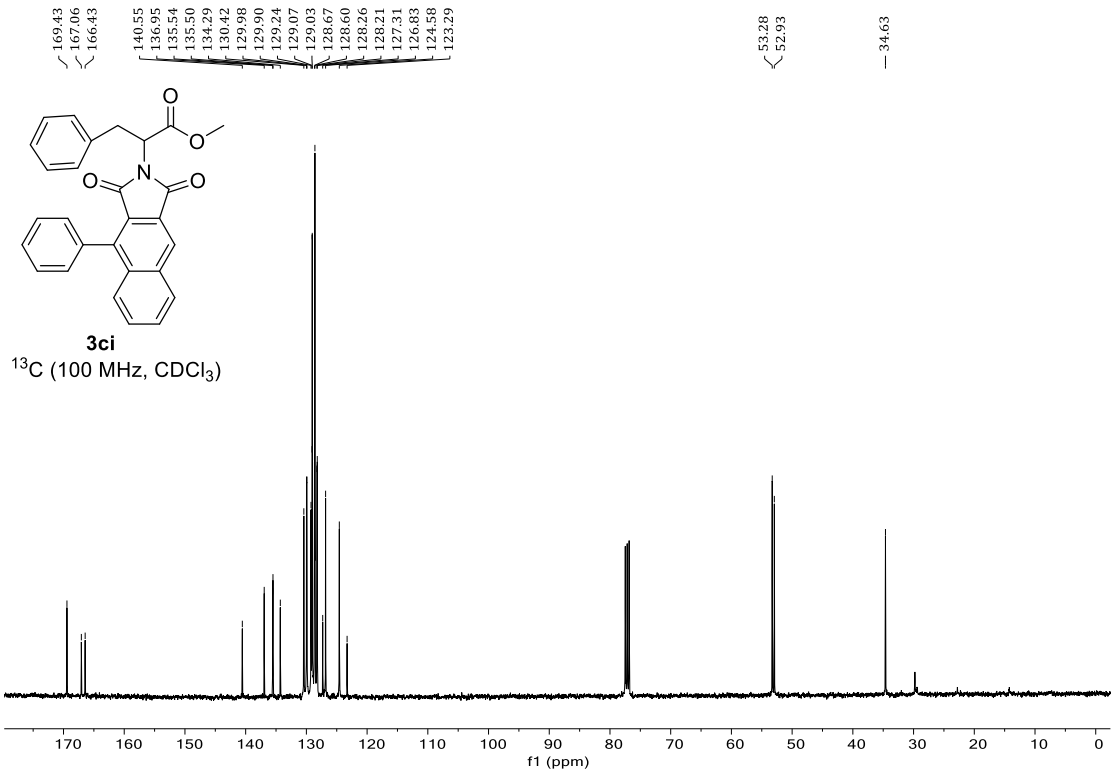

8.49
8.15
8.15
8.14
8.12
7.87
7.85
7.74
7.72
7.72
7.70
7.65
7.63
7.62
7.61
7.54
7.53
7.52
7.51
7.49
7.48
7.47
7.47
7.46
7.44
7.42
6.75
6.73
6.73
6.73
6.72
6.63
6.61
3.50
O
N
N
N
O
3ch
1H (400 MHz, CDCl3)
1.00
2.02
1.02
1.06
1.08
6.00
1.00
1.00
3.08
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


165.89
165.48
157.49
148.15
141.16
137.92
135.84
135.81
134.24
130.57
130.18
129.93
129.46
129.31
128.86
128.72
128.32
126.02
125.18
121.91
115.65
106.57
38.50
O
N
N
N
O
3ch
13C (100 MHz, CDCl3)
170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)



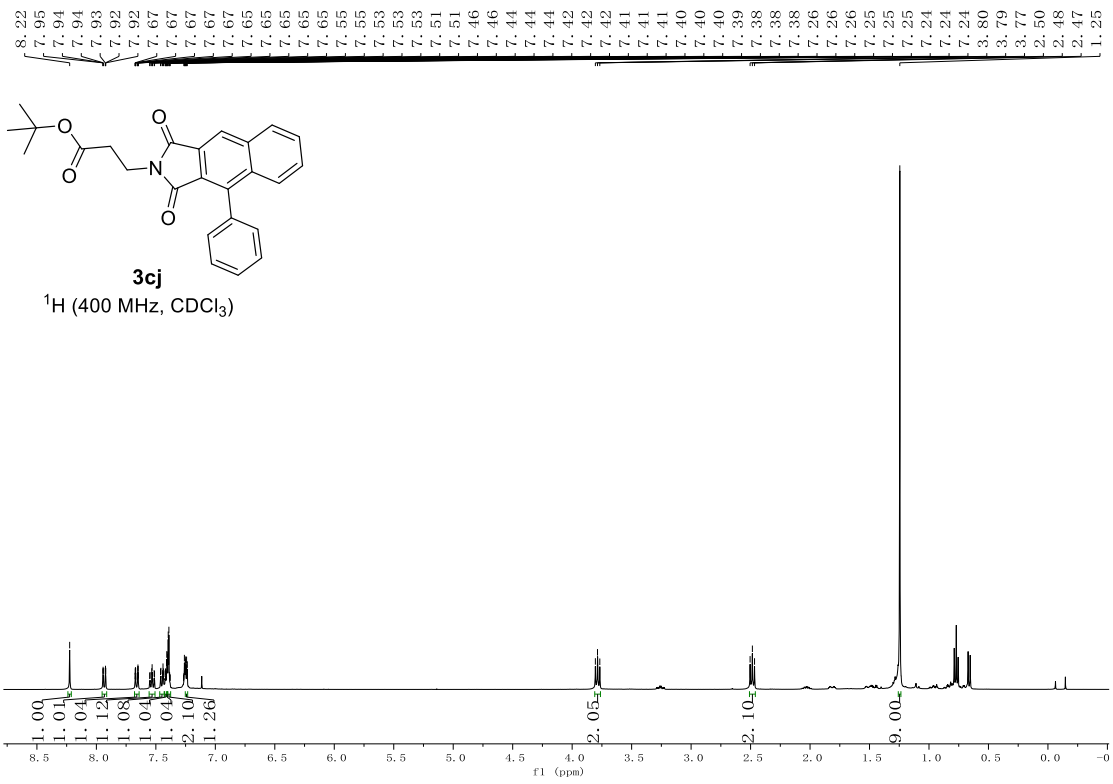
3ci

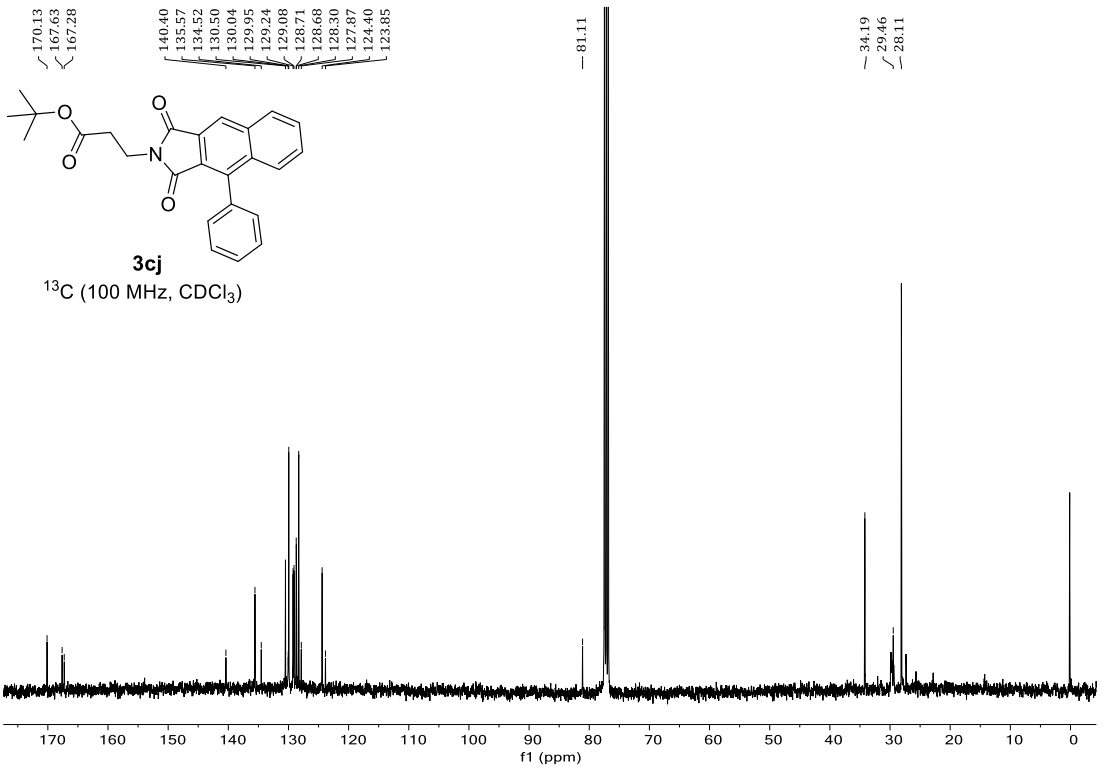
^{1}H (400 MHz, $CDCl_3$)



3ci

^{13}C (100 MHz, $CDCl_3$)


8.22
7.95
7.94
7.94
7.93
7.92
7.92
7.67
7.67
7.67
7.67
7.65
7.65
7.65
7.65
7.55
7.55
7.53
7.53
7.53
7.51
7.51
7.46
7.46
7.44
7.44
7.44
7.42
7.42
7.42
7.41
7.41
7.41
7.40
7.40
7.40
7.39
7.38
7.38
7.38
7.26
7.26
7.25
7.25
7.25
7.24
7.24
7.24
3.80
3.79
3.77
2.50
2.48
2.47
1.25
O
O
O
N
O
O
3cj
1H (400 MHz, CDCl3)
1.00
1.01
1.04
1.12
1.08
1.04
1.04
2.10
1.26
2.05
2.10
9.00
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)


170.13
167.63
167.28
140.40
135.57
134.52
130.50
130.04
129.95
129.24
129.08
128.71
128.68
128.30
127.87
124.40
123.85
81.11
34.19
29.46
28.11
O
O
O
N
O
O
3cj
13C (100 MHz, CDCl3)
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)