Supporting Information

peri-Selective C−H Activation-Initiated Spiroannulation Leading to Spiro Polycyclic Compounds with Unique Photo-Physical Property and Strong Anticancer Activity

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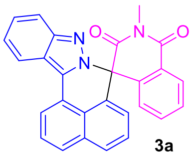
I. General experimental information

Commercial reagents were used without further purification unless otherwise noted. 3-Aryl-1*H*-indazoles **1**,[1] diazo homophthalimides **2**,[2] and diazonaphthalen-2(1*H*)-ones **4** [3] were prepared based on literature procedures. Melting points were recorded with a micro melting point apparatus and uncorrected. The ^{1}H NMR spectra were recorded at 400 MHz or 600 MHz. The ^{13}C NMR spectra were recorded at 100 MHz or 150 MHz. The ^{19}F NMR spectra were recorded at 376 MHz or 565 MHz. Chemical shifts were expressed in parts per million (δ), and were reported as s (singlet), d (doublet), t (triplet), q (quartet), dd (doublet of doublets), td (triplet of doublets), m (multiplet), etc. The coupling constants *J* were given in Hz. High resolution mass spectra (HRMS) were obtained *via* ESI-TOF mode. All reactions were monitored by thin layer chromatography (TLC) using silica gel plates (silica gel 60 F254 0.25 mm), and components were visualized by observation under UV light (254 and 365 nm).

II. Experimental procedures and spectroscopic data

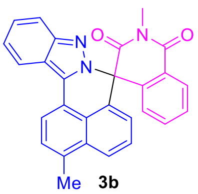
1. Typical procedure for the synthesis of 3a and spectroscopic data of 3a-3gg

To a reaction tube equipped with a stir bar were charged with 3-(naphthalen-1-yl)-1*H*-indazole (**1a**, 24.4 mg, 0.1 mmol), HFIP (1 mL), $[IrCp^*Cl_2]_2$ (1.2 mg, 0.0015 mmol), Cs_2CO_3 (9.8 mg, 0.03 mmol), Ag_2O (11.6 mg, 0.05 mmol) and 4-diazo-2-methylisoquinoline-1,3(2*H*,4*H*)-dione (**2a**, 20.1 mg, 0.1 mmol). The tube was then sealed, and the resulting mixture was stirred at 100 °C under air for 2 h. Upon completion, it was cooled to room temperature, filtered through a pad of celite, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography using hexane/ethyl acetate (5:1) as eluent to afford **3a**. Other products **3b-3gg** were obtained in a similar manner.


3a

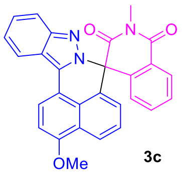
2'-Methyl-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3a)

Eluent: hexane/ethyl acetate (5:1). Yellow solid (34.8 mg, 84%), mp 277.2-278.4 ºC. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.44-8.42 (m, 2H), 8.28 (d, *J* = 8.8 Hz, 1H), 7.86-7.84 (m, 2H), 7.71 (t, *J* = 7.6 Hz, 1H), 7.65 (d, *J* = 8.8 Hz, 1H), 7.53 (t, *J* = 7.6 Hz, 1H), 7.47-7.39 (m, 2H), 7.36-7.32 (m, 1H), 7.28-7.24 (m, 1H), 7.01 (d, *J* = 7.6 Hz, 1H), 6.90 (d, *J* = 7.6 Hz, 1H), 3.41 (s, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$, 100 MHz): δ 169.6, 163.9, 149.8, 141.9, 134.8, 133.5, 132.6, 132.0, 129.2, 129.1, 128.8, 128.3, 128.0, 127.2, 127.1, 126.6, 125.5, 124.3, 123.5, 123.4, 123.3, 121.6, 121.2, 118.6, 118.1, 70.3, 27.9. HRMS (ESI) *m*/*z*: $[M+Na]^+$ Calcd for $C_{27}H_{17}N_3NaO_2$ 438.1213; Found 438.1215.


3b

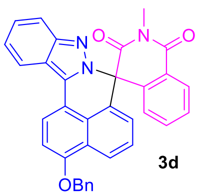
2',3-Dimethyl-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3b)

Eluent: hexane/ethyl acetate (5:1). Yellow solid (32.2 mg, 75%), mp 312.7-313.0 ºC. ^{1}H NMR (CDCl$_3$, 400 MHz): δ 8.42 (d, J = 7.6 Hz, 1H), 8.32 (d, J = 7.2 Hz, 1H), 8.25 (d, J = 8.4 Hz, 1H), 7.80 (d, J = 8.4 Hz, 1H), 7.63 (d, J = 8.8 Hz, 1H), 7.54-7.49 (m, 2H), 7.45-7.41 (m, 2H), 7.34-7.30 (m, 1H), 7.24-7.20 (m, 1H), 7.02 (d, J = 7.6 Hz, 1H), 6.89 (d, J = 7.6 Hz, 1H), 3.40 (s, 3H), 2.72 (s, 3H). ^{13}C{^{1}H} NMR (CDCl$_3$, 100 MHz): δ 169.7, 164.0, 149.9, 142.0, 135.3, 134.8, 133.1, 132.8, 132.2, 129.1, 128.8, 128.1, 127.9, 127.1, 126.4, 125.5, 125.3, 124.4, 123.4, 123.1, 121.8, 121.6, 121.3, 118.5, 117.8, 70.2, 27.9, 19.8. HRMS (ESI) *m*/*z*: $[M+Na]^+$ Calcd for $C_{28}H_{19}N_3NaO_2$ 452.1369; Found 452.1374.



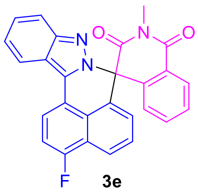
3-Methoxy-2'-methyl-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3c)

Eluent: hexane/ethyl acetate (4:1). Yellow solid (30 mg, 67%), mp ＞320 ºC. ^{1}H NMR (CDCl$_3$, 400 MHz): δ 8.42 (d, J = 8.0 Hz, 1H), 8.34 (d, J = 8.0 Hz, 1H), 8.28 (d, J = 8.0 Hz, 1H), 8.21 (d, J = 8.4 Hz, 1H), 7.61 (d, J = 8.8 Hz, 1H), 7.50 (t, J = 7.6 Hz, 1H), 7.44-7.38 (m, 2H), 7.33-7.29 (m, 1H), 7.19 (t, J = 8.0 Hz, 1H), 7.04-7.00 (m, 2H), 6.89 (d, J = 7.6 Hz, 1H), 4.06 (s, 3H), 3.40 (s, 3H). ^{13}C{^{1}H} NMR (CDCl$_3$, 100 MHz): δ 169.8, 164.0, 155.8, 149.8, 142.0, 134.8, 132.4, 132.3, 129.1, 128.8, 128.1, 127.0, 126.1, 126.0, 125.9, 124.4, 124.3, 123.5, 122.7, 122.5, 121.3, 118.4, 117.3, 116.3, 104.9, 70.0, 55.9, 27.9. HRMS (ESI) *m*/*z*: $[M+Na]^+$ Calcd for $C_{28}H_{19}N_3NaO_3$ 468.1319; Found 468.1315.



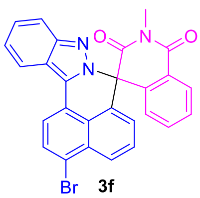
3-(Benzyloxy)-2'-methyl-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3d)

Eluent: hexane/ethyl acetate (5:1). Yellow solid (35 mg, 67%), mp 269.5-270.2 ºC. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.42 (d, *J* = 7.6 Hz, 1H), 8.37 (d, *J* = 8.4 Hz, 1H), 8.33 (d, *J* = 8.0 Hz, 1H), 8.20 (d, *J* = 8.8 Hz, 1H), 7.62 (d, *J* = 8.4 Hz, 1H), 7.54-7.50 (m, 3H), 7.46-7.38 (m, 5H), 7.31 (t, *J* = 7.6 Hz, 1H), 7.22-7.18 (m, 1H), 7.10 (d, *J* = 8.0 Hz, 1H), 7.04 (d, *J* = 7.6 Hz, 1H), 6.90 (d, *J* = 7.6 Hz, 1H), 5.34 (s, 2H), 3.41 (s, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz): δ 169.8, 164.0, 154.7, 149.8, 141.9, 136.4, 134.8, 132.4, 129.1, 128.8, 128.3, 128.1, 127.4, 127.0, 126.2, 126.1, 124.5, 124.4, 123.6, 122.7, 122.4, 121.3, 118.4, 117.3, 116.5, 106.3, 70.5, 70.0, 27.9. HRMS (ESI) *m*/*z*: [M+Na]$^+$ Calcd for $C_{34}H_{23}N_3NaO_3$ 544.1632; Found 544.1637.


3e

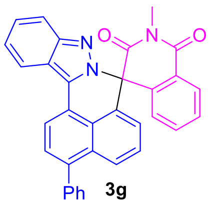
3-Fluoro-2'-methyl-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3e)

Eluent: hexane/ethyl acetate (5:1). Yellow solid (32.2 mg, 74%), mp 284.3-285.6 ºC. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.44 (dd, J_1 = 8.0 Hz, J_2 = 1.2 Hz, 1H), 8.34 (dd, J_1 = 8.4 Hz, J_2 = 5.2 Hz, 1H), 8.21 (d, *J* = 8.8 Hz, 1H), 8.13 (d, *J* = 8.4 Hz, 1H), 7.63 (d, *J* = 8.8 Hz, 1H), 7.56-7.44 (m, 3H), 7.40-7.32 (m, 2H), 7.27-7.23 (m, 1H), 7.08 (d, *J* = 7.2 Hz, 1H), 6.89 (d, *J* = 8.0 Hz, 1H), 3.41 (s, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz): δ 169.5, 163.8, 158.4 (d, J_{C-F} = 254.3 Hz), 149.9, 141.5, 134.9, 132.9 (d, J_{C-F} = 3.6 Hz), 131.5, 129.3, 128.9, 128.0, 127.2, 127.0 (d, J_{C-F} = 1.4 Hz), 126.5, 124.7 (d, J_{C-F} = 5.1 Hz), 124.4, 124.1 (d, J_{C-F} = 17.3 Hz), 123.5, 122.0 (d, J_{C-F} = 5.1 Hz), 121.6 (d, J_{C-F} = 7.9 Hz), 121.0, 120.1 (d, J_{C-F} = 5.1 Hz), 118.6, 117.8, 111.0 (d, J_{C-F} = 20.9 Hz), 69.9, 28.0. ^{19}F NMR ($CDCl_3$, 376 MHz): δ -120.02 (dd, ^1J = 9.8 Hz, ^2J = 5.6 Hz). HRMS (ESI) *m*/*z*: [M+Na]$^+$ Calcd for $C_{27}H_{16}FN_3NaO_2$ 456.1119; Found 456.1112.


3f

3-Bromo-2'-methyl-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3f)

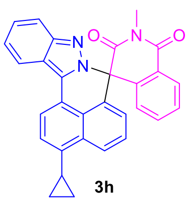
Eluent: hexane/acetone (5:1). Yellow solid (33.9 mg, 69%), mp 303.2-303.9 ºC. [1]H NMR ($CDCl_3$, 400 MHz): δ 8.36 (dd, J_1 = 8.0 Hz, J_2 = 1.2 Hz, 1H), 8.21 (d, J = 8.4 Hz, 1H), 8.16 (d, J = 8.0 Hz, 1H), 8.12 (d, J = 8.8 Hz, 1H), 7.91 (d, J = 8.0 Hz, 1H), 7.56 (d, J = 8.8 Hz, 1H), 7.48-7.42 (m, 2H), 7.37 (td, J_1 = 8.0 Hz, J_2 = 0.8 Hz, 1H), 7.28-7.24 (m, 1H), 7.20-7.16 (m, 1H), 6.99 (d, J = 7.6 Hz, 1H), 6.80 (d, J = 7.6 Hz, 1H), 3.32 (s, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$, 100 MHz): δ 169.4, 163.8, 149.9, 141.5, 134.9, 133.2, 132.2, 131.3, 131.2, 129.4, 128.9, 128.7, 128.1, 127.8, 127.3, 126.6, 124.5, 124.4, 123.7, 123.4, 122.7, 121.7, 121.0, 118.7, 118.1, 70.0, 28.0. HRMS (ESI) *m*/*z*: $[M+Na]^+$ Calcd for $C_{27}H_{16}BrN_3NaO_2$ 516.0318; Found 516.0319.



3g

2'-Methyl-3-phenyl-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3g)

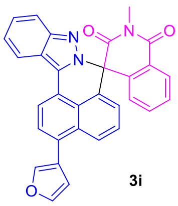
Eluent: hexane/ethyl acetate (5:1). Yellow solid (36.4 mg, 74%), mp 169.1-170.3 ºC. [1]H NMR ($CDCl_3$, 400 MHz): δ 8.49 (d, J = 7.6 Hz, 1H), 8.45 (dd, J_1 = 8.0 Hz, J_2 = 1.6 Hz, 1H), 8.32 (d, J = 8.8 Hz, 1H), 7.93 (dd, J_1 = 8.8 Hz, J_2 = 1.2 Hz, 1H), 7.68-7.65 (m, 2H), 7.57-7.47 (m, 7H), 7.38-7.33 (m, 2H), 7.30-7.26 (m, 1H), 7.02 (dd, J_1 = 7.2 Hz, J_2 = 0.8 Hz, 1H), 6.97 (dd, J_1 = 7.2 Hz, J_2 = 0.4 Hz, 1H), 3.42 (s, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$, 100 MHz): δ 169.8, 163.9, 149.9, 141.9, 140.9, 139.9, 134.9, 132.8, 132.1, 132.0, 130.0, 129.2, 128.8, 128.6, 128.2, 127.9, 127.6, 127.2, 126.5, 125.7, 124.5, 123.7, 123.4, 122.8, 121.4, 121.3, 118.6, 118.1, 70.3, 28.0. HRMS (ESI) *m*/*z*: $[M+Na]^+$ Calcd for $C_{33}H_{21}N_3NaO_2$ 514.1526; Found 514.1543.



3h

3-Cyclopropyl-2'-methyl-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3h)

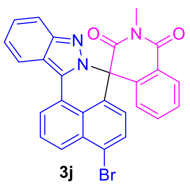
Eluent: hexane/ethyl acetate (5:1). Yellow solid (36.1 mg, 79%), mp 217.0-218.7 ºC. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.44-8.41 (m, 2H), 8.33-8.31 (m, 1H), 8.25-8.23 (m, 1H), 7.64-7.62 (m, 1H), 7.52-7.39 (m, 4H), 7.34-7.29 (m, 1H), 7.24-7.20 (m, 1H), 7.03-7.00 (m, 1H), 6.90-6.88 (m, 1H), 3.40 (s, 3H), 2.35-2.31 (m, 1H), 1.14-1.09 (m, 2H), 0.84-0.81 (m, 2H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz): δ 169.7, 164.0, 149.9, 142.0, 140.2, 134.8, 133.8, 133.0, 132.2, 129.1, 128.8, 128.1, 127.1, 126.4, 125.9, 125.4, 125.2, 124.4, 123.4, 123.1, 121.8, 121.6, 121.3, 118.5, 117.9, 70.2, 27.9, 13.7, 6.8, 6.7. HRMS (ESI) *m/z*: $[M+Na]^+$ Calcd for $C_{30}H_{21}N_3NaO_2$ 478.1526; Found 478.1529.



3i

3-(Furan-3-yl)-2'-methyl-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3i)

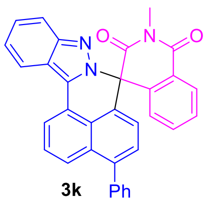
Eluent: hexane/ethyl acetate (5:1). Yellow solid (39.5 mg, 82%), mp 241.7-242.1 ºC. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.45-8.41 (m, 2H), 8.27 (d, J = 8.8 Hz, 1H), 8.16 (dd, J_1 = 8.4 Hz, J_2 = 0.4 Hz, 1H), 7.69-7.64 (m, 3H), 7.61-7.60 (m, 1H), 7.53 (td, J_1 = 7.6 Hz, J_2 = 0.8 Hz, 1H), 7.45 (td, J_1 = 8.0 Hz, J_2 = 1.2 Hz, 1H), 7.42-7.38 (m, 1H), 7.36-7.32 (m, 1H), 7.27-7.23 (m, 1H), 7.03 (dd, J_1 = 7.6 Hz, J_2 = 0.8 Hz, 1H), 6.93 (d, J = 7.6 Hz, 1H), 6.70 (d, J = 0.8 Hz, 1H), 3.40 (s, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz): δ 169.7, 163.9, 149.9, 143.3, 141.8, 140.8, 134.8, 133.0, 132.1, 131.9, 131.5, 129.2, 128.8, 128.1, 128.0, 127.2, 127.1, 126.7, 125.8, 124.5, 124.3, 123.7, 123.4, 122.8, 121.4, 121.2, 118.6, 118.1, 112.3, 70.2, 28.0. HRMS (ESI) *m/z*: $[M+Na]^+$ Calcd for $C_{31}H_{19}N_3NaO_3$ 504.1319; Found 504.1311.



3j

4-Bromo-2'-methyl-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3j)

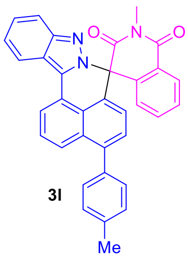
Eluent: hexane/ethyl acetate (5:1). Yellow solid (25.1 mg, 51%), mp ＞320 ºC. ^{1}H NMR (CDCl$_3$, 400 MHz): δ 8.48 (d, J = 7.2 Hz, 1H), 8.44 (d, J = 8.0 Hz, 1H), 8.26-8.24 (m, 2H), 7.82 (t, J = 7.6 Hz, 1H), 7.71 (d, J = 8.0 Hz, 1H), 7.64 (d, J = 8.8 Hz, 1H), 7.55 (t, J = 7.6 Hz, 1H), 7.49-7.45 (m, 1H), 7.37-7.33 (m, 1H), 7.29-7.25 (m, 1H), 6.90 (d, J = 8.0 Hz, 1H), 6.84 (d, J = 8.0 Hz, 1H), 3.40 (s, 3H). ^{13}C{^{1}H} NMR (CDCl$_3$, 100 MHz): δ 169.2, 163.7, 150.0, 141.3, 134.9, 132.6, 132.2, 131.4, 130.6, 129.4, 128.9, 128.7, 128.1, 127.5, 127.3, 125.9, 124.54, 124.47, 124.4, 124.0, 123.7, 122.4, 121.1, 118.7, 118.2, 70.0, 28.0. HRMS (ESI) m/z: [M+Na]$^+$ Calcd for $C_{27}H_{16}BrN_3NaO_2$ 516.0318; Found 516.0312.



3k

2'-Methyl-4-phenyl-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3k)

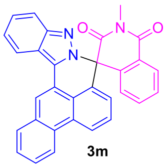
Eluent: hexane/ethyl acetate (5:1). Yellow solid (42.7 mg, 87%), mp 277.5-378.3 ºC. ^{1}H NMR (CDCl$_3$, 400 MHz): δ 8.38-8.36 (m, 2H), 8.21 (d, J = 8.4 Hz, 1H), 7.80 (d, J = 8.4 Hz, 1H), 7.59-7.54 (m, 2H), 7.49-7.34 (m, 7H), 7.29-7.25 (m, 2H), 7.21-7.17 (m, 1H), 6.96 (d, J = 7.2 Hz, 1H), 6.90-6.88 (m, 1H), 3.45 (s, 3H). ^{13}C{^{1}H} NMR (CDCl$_3$, 100 MHz): δ 169.7, 164.0, 149.9, 141.8, 141.7, 139.5, 134.9, 132.1, 131.9, 131.8, 130.0, 129.2, 128.8, 128.5, 128.2, 127.9, 127.5, 127.22, 127.16, 126.8, 125.1, 124.5, 123.65, 123.63, 123.4, 121.7, 121.3, 118.6, 118.1, 70.3, 28.0. HRMS (ESI) m/z: [M+Na]$^+$ Calcd for $C_{33}H_{21}N_3NaO_2$ 514.1526; Found 514.1532.



3l

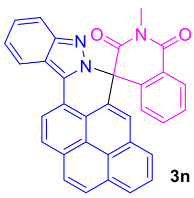
2'-Methyl-4-(*p*-tolyl)-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3l)

Eluent: hexane/ethyl acetate (5:1). Yellow solid (43.2 mg, 85%), mp 285.6-286.2 ºC. ^{1}H NMR (CDCl$_3$, 400 MHz): δ 8.44 (d, J = 7.6 Hz, 2H), 8.29 (d, J= 8.4 Hz, 1H), 7.91 (dd, J_1 = 8.8 Hz, J_2 = 0.8 Hz, 1H), 7.67-7.61 (m, 2H), 7.54 (td, J_1 = 7.6 Hz, J_2 = 0.8 Hz, 1H), 7.48 (td, J_1 = 7.6 Hz, J_2 = 1.6 Hz, 1H), 7.37-7.25 (m, 7H), 7.02 (d, J = 7.6 Hz, 1H), 6.97 (dd, J_1 = 7.6 Hz, J_2 = 0.8 Hz, 1H), 3.42 (s, 3H), 2.45 (s, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$, 100 MHz): δ 169.8, 164.0, 149.9, 141.9, 141.8, 137.7, 136.6, 134.9, 132.2, 132.0, 131.5, 129.9, 129.22, 129.19, 128.8, 128.2, 127.5, 127.14, 127.11, 126.9, 125.2, 124.5, 123.7, 123.6, 123.4, 121.7, 121.3, 118.6, 118.1, 70.3, 28.0, 21.3. HRMS (ESI) *m*/*z*: $[M+Na]^+$ Calcd for $C_{34}H_{23}N_3NaO_2$ 528.1682; Found 528.1688.


3m

2'-Methyl-1'*H*-spiro[dibenzo[*de,g*]indazolo[3,2-*a*]isoquinoline-8,4'-isoquinoline]-1',3'(2'*H*)-dione (3m)

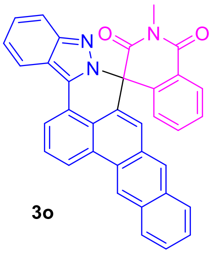
Eluent: dichloromethane. Yellow solid (21.2 mg, 46%), mp 315.0-316.7 ºC. ^1H NMR ($CDCl_3$, 400 MHz): δ 8.71-7.69 (m, 2H), 8.64-8.62 (m, 1H), 8.46-8.42 (m, 2H), 8.08-8.06 (m, 1H), 7.70-7.67 (m, 3H), 7.58 (t, J = 8.0 Hz, 1H), 7.53 (t, J = 7.6 Hz, 1H), 7.44 (t, J = 7.6 Hz, 1H), 7.39-7.35 (m, 1H), 7.33-7.30 (m, 1H), 7.11 (d, J = 7.2 Hz, 1H), 6.89 (d, J = 8.0 Hz, 1H), 3.43 (s, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$, 100 MHz): δ 169.7, 163.9, 149.9, 141.7, 134.8, 132.9, 132.0, 131.7, 131.0, 129.9, 129.3, 129.2, 128.9, 128.1, 128.0, 127.8, 127.4, 127.2, 125.7, 124.5, 123.8, 123.4, 123.05, 122.98, 122.6, 121.3, 118.7, 118.1, 70.1, 28.0. HRMS (ESI) *m*/*z*: $[M+Na]^+$ Calcd for $C_{31}H_{19}N_3NaO_2$ 488.1369; Found 488.1374.


3n

2'-Methyl-1'*H*-spiro[indazolo[2,3-*b*]phenanthro[3,4,5-*defg*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3n)

Eluent: hexane/ethyl acetate (5:1). Yellow solid (21.2 mg, 43%), mp ＞320 ºC. ^1H NMR ($CDCl_3$, 400 MHz): δ 8.83 (d, J = 8.0 Hz, 1H), 8.45 (d, J = 7.6 Hz, 1H), 8.33 (d, J = 8.4 Hz, 1H), 8.29 (d, J = 8.4 Hz, 1H), 8.10 (d, J = 6.8 Hz, 1H), 8.01-7.95 (m, 2H), 7.92-7.86 (m, 2H), 7.60 (d, J = 8.4 Hz, 1H), 7.52-7.49 (m, 2H), 7.41 (t, J = 7.6

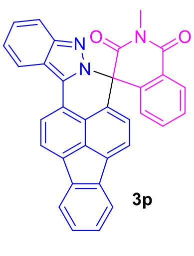
Hz, 1H), 7.30-7.27 (m, 1H), 7.24-7.20 (m, 1H), 7.01 (d, J = 7.6 Hz, 1H), 3.36 (s, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$, 100 MHz): δ 169.7, 164.1, 150.1, 142.0, 135.0, 132.8, 132.4, 131.4, 131.2, 130.2, 129.3, 128.9, 128.3, 127.8, 127.6, 127.5, 127.2, 126.9, 126.74, 126.70, 126.0, 124.7, 124.6, 124.2, 123.5, 121.4, 121.3, 121.2, 120.6, 118.7, 118.5, 70.6, 28.0. HRMS (ESI) *m/z*: $[M+Na]^+$ Calcd for $C_{33}H_{19}N_3NaO_2$ 512.1369; Found 512.1372.



3o

2'-Methyl-1'*H*-spiro[benzo[*de*]indazolo[2,3-*b*]naphtho[2,3-*g*]isoquinoline-10,4'-isoquinoline]-1',3'(2'*H*)-dione (3o)

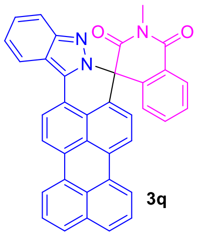
Eluent: dichloromethane. Yellow solid (30.7 mg, 60%), mp ＞320 ºC. ^1H NMR (DMSO-d_6, 400 MHz): δ 9.56 (s, 1H), 9.14 (d, J = 8.4 Hz, 1H), 8.77 (d, J = 7.6 Hz, 1H), 8.57-8.54 (m, 2H), 8.39 (dd, J_1 = 8.0 Hz, J_2 = 1.2 Hz, 1H), 8.27 (d, J = 8.4 Hz, 1H), 8.07-8.03 (m, 2H), 7.80 (s, 1H), 7.69-7.56 (m, 5H), 7.41-7.38 (m, 1H), 7.34-7.30 (m, 1H), 7.11 (d, J = 7.6 Hz, 1H), 3.34 (s, 3H). $^{13}C\{^1H\}$ NMR (CF_3CO_2D, 100 MHz): δ 168.2, 164.8, 143.4, 142.4, 137.0, 135.8, 134.4, 133.5, 132.8, 132.4, 131.9, 131.4, 130.0, 129.0, 128.8, 128.3, 128.2, 128.1, 128.0, 127.6, 127.5, 127.2, 127.1, 126.9, 126.7, 126.2, 125.4, 123.0, 122.0, 121.9, 119.5, 117.5, 111.6, 72.0, 27.9. HRMS (ESI) *m/z*: $[M+H]^+$ Calcd for $C_{35}H_{22}N_3O_2$ 516.1707; Found 516.1711.



3p

2'-Methyl-1'*H*-spiro[fluoreno[2,1,9-*def*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3p)

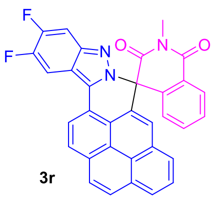
Eluent: hexane/ethyl acetate (5:1). Yellow solid (34.1 mg, 70%), mp ＞320 ºC. ^1H NMR ($CDCl_3$, 400 MHz): δ 8.46 (dd, J_1 = 8.0 Hz, J_2 = 0.8 Hz, 1H), 8.37 (d, J= 7.2 Hz, 1H), 8.27 (d, J= 8.8 Hz, 1H), 8.07 (d, J = 7.2 Hz, 1H), 7.90 (d, J = 6.4 Hz, 1H), 7.84-7.82 (m, 1H), 7.79 (d, J= 7.6 Hz, 1H), 7.67 (d, J= 8.8 Hz, 1H), 7.56-7.52 (m, 1H), 7.47-7.43 (m, 1H), 7.41-7.34 (m, 3H), 7.31-7.26 (m, 1H), 7.10 (d, *J* = 7.6 Hz, 1H), 6.85 (d, *J* = 8.0 Hz, 1H), 3.45 (s, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz): δ 169.3, 164.0, 149.6, 141.3, 139.4, 138.9, 137.7, 136.6, 134.9, 132.5, 132.3, 132.1, 129.2, 129.0, 128.4, 128.1, 127.7, 127.3, 126.0, 124.3, 123.7, 123.5, 122.2, 122.14, 122.07, 122.0, 121.1, 120.8, 120.3, 118.7, 118.1, 70.7, 28.1. HRMS (ESI) *m/z*: $[M+Na]^+$ Calcd for $C_{33}H_{19}N_3NaO_2$ 512.1369 ; Found 512.1358.



3q

2'-Methyl-1'*H*-spiro[benzo[10,5]anthra[2,1,9-*def*]indazolo[3,2-*a*]isoquinoline-6,4'-isoquinoline]-1',3'(2'*H*)-dione (3q)

Eluent: hexane/ethyl acetate (4:1). Red solid (45.7 mg, 85%), mp 236.1-237.3 ºC. ^1H NMR ($CDCl_3$, 400 MHz): δ 8.45 (d, *J* = 7.6 Hz, 1H), 8.28 (d, *J* = 8.0 Hz, 1H), 8.21-8.17 (m, 2H), 8.05 (d, *J* = 7.6 Hz, 1H), 7.95-7.93 (m, 2H), 7.67-7.61 (m, 3H), 7.53 (t, *J* = 7.2 Hz, 1H), 7.46 (t, *J* = 7.2 Hz, 1H), 7.39 (t, *J* = 8.0 Hz, 1H), 7.35-7.31 (m, 2H), 7.21 (t, *J* = 7.6 Hz, 1H), 6.96-6.94 (m, 2H), 3.47 (s, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$, 100 MHz): δ 169.7, 164.0, 149.9, 141.7, 134.9, 134.4, 132.4, 132.0, 131.5, 131.2, 130.2, 129.7, 129.2, 128.9, 128.8, 128.7, 128.5, 128.05, 128.01, 127.2, 126.7, 126.6, 126.0, 124.5, 124.3, 123.4, 122.4, 122.2, 121.3, 121.2, 121.1, 121.0, 120.6, 118.5, 118.1, 70.4, 28.0. HRMS (ESI) *m/z*: $[M+H]^+$ Calcd for $C_{37}H_{22}N_3O_2$ 540.1707; Found 540.1702.

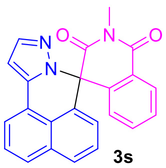


3r

11,12-Difluoro-2'-methyl-1'*H*-spiro[indazolo[2,3-*b*]phenanthro[3,4,5-*defg*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3r)

Eluent: hexane/ethyl acetate (5:1). Yellow solid (22.3 mg, 42%), mp ＞320 ºC. ^1H NMR (CF_3CO_2D, 400 MHz): δ 9.23 (d, *J* = 8.4 Hz, 1H), 8.89 (d, *J* = 8.0 Hz, 1H), 8.78-8.74 (m, 1H), 8.71 (d, *J* = 8.4 Hz, 1H), 8.58 (d, *J* = 7.6

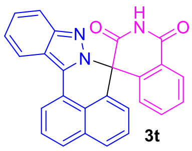
Hz, 1H), 8.49 (d, J = 9.2 Hz, 1H), 8.38 (d, J = 9.2 Hz, 1H), 8.34 (d, J = 7.6 Hz, 1H), 8.28 (t, J = 7.6 Hz, 1H), 8.14 (t, J = 7.6 Hz, 1H), 8.10-8.06 (m, 1H), 7.97 (s, 1H), 7.82 (d, J = 7.6 Hz, 1H), 7.64-7.61 (m, 1H), 3.57 (s, 3H). $^{13}C\{^1H\}$ NMR (CF_3CO_2D, 150 MHz): δ 168.4, 164.8, 144.3 (d, $J_{C\text{-}F}$ = 7.7 Hz), 140.0 (d, $J_{C\text{-}F}$ = 11.0 Hz), 137.1, 136.2, 134.8, 132.5, 131.4, 131.2, 130.7, 130.1, 129.7, 129.6, 128.4, 128.3, 128.0, 127.1, 127.0, 126.7, 126.1, 124.3, 124.1, 123.5, 122.4, 114.5, 109.9 (d, $J_{C\text{-}F}$ = 20.9 Hz), 99.8 (d, $J_{C\text{-}F}$ = 23.0 Hz), 72.8, 27.9. ^{19}F NMR ($CDCl_3$, 376 MHz): δ -133.02 – -133.12 (m), -138.27 – -138.37 (m). HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{33}H_{18}F_2N_3O_2$ 526.1362; Found 526.1354.



3s

2'-Methyl-1'*H*-spiro[benzo[*de*]pyrazolo[5,1-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3s)

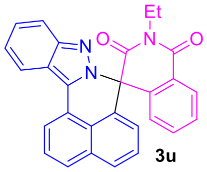
Eluent: hexane/ethyl acetate (4:1). Yellow solid (5.4 mg, 15%), mp 179.9-181.1 ºC. ^1H NMR ($CDCl_3$, 400 MHz): δ 8.43-8.40 (m, 1H), 7.96 (d, J= 7.2 Hz, 1H), 7.86-7.82 (m, 2H), 7.66 (d, J = 1.6 Hz, 1H), 7.63 (t, J= 7.6 Hz, 1H), 7.55-7.52 (m, 2H), 7.38 (t, J= 7.6 Hz, 1H), 7.03-7.01 (m, 1H), 6.96 (d, J= 7.6 Hz, 1H), 6.88 (d, J= 2.0 Hz, 1H), 3.36 (s, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz): δ 169.9, 163.9, 142.2, 141.3, 140.5, 134.8, 133.5, 132.8, 129.2, 129.0, 128.8, 128.6, 128.0, 127.0, 126.4, 125.5, 124.9, 123.2, 122.2, 121.9, 101.0, 68.9, 27.8. HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{23}H_{15}N_3NaO_2$ 388.1056; Found 388.1065.



3t

1'*H*-Spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3t)

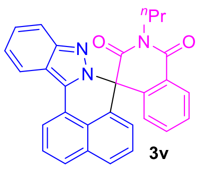
Eluent: hexane/acetone (2:1). Yellow solid (35.1 mg, 87%), mp 294.6-295.8 ºC. ^1H NMR (DMSO-d_6, 400 MHz): δ 12.19 (s, 1H), 8.61 (d, J= 6.4 Hz, 1H), 8.51 (d, J = 8.0 Hz, 1H), 8.29 (d, J = 7.6 Hz, 1H), 8.06-8.04 (m, 2H), 7.83-7.80 (m, 1H), 7.63-7.54 (m, 4H), 7.40-7.37 (m, 1H), 7.31-7.25 (m, 2H), 6.91 (d, J = 7.2 Hz, 1H). $^{13}C\{^1H\}$ NMR (DMSO-d_6, 100 MHz): δ 169.9, 164.2, 149.5, 143.5, 135.7, 133.3, 132.9, 131.4, 129.8, 129.5, 129.1, 128.8, 128.01, 127.95, 127.7, 127.6, 126.5, 124.1, 123.8, 123.0, 122.8, 122.4, 122.1, 118.3, 117.8, 69.8. HRMS (ESI) *m*/*z*: $[M+Na]^+$ Calcd for $C_{26}H_{15}N_3NaO_2$ 424.1056; Found 424.1063.



3u

2'-Ethyl-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3u)

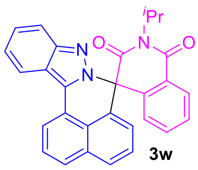
Eluent: hexane/ethyl acetate (5:1). Yellow solid (34.8 mg, 81%), mp 231.4-232.0 ºC. ^{1}H NMR ($CDCl_3$, 600 MHz): δ 8.44-8.42 (m, 2H), 8.28 (d, *J* = 8.4 Hz, 1H), 7.86-7.84 (m, 2H), 7.72 (t, *J* = 7.2 Hz, 1H), 7.66 (d, *J* = 8.4 Hz, 1H), 7.53 (t, *J* = 7.2 Hz, 1H), 7.46-7.40 (m, 2H), 7.35 (t, *J* = 7.2 Hz, 1H), 7.28-7.26 (m, 1H), 7.01 (d, *J* = 7.2 Hz, 1H), 6.89 (d, *J* = 7.8 Hz, 1H), 4.11-4.02 (m, 2H), 1.18 (t, *J* = 7.2 Hz, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$, 100 MHz): δ 169.1, 163.5, 149.8, 141.9, 134.7, 133.6, 132.6, 131.9, 129.14, 129.10, 128.8, 128.3, 128.0, 127.2, 127.1, 126.5, 125.3, 124.5, 123.5, 123.4, 123.3, 121.6, 121.2, 118.7, 118.1, 70.2, 36.4, 12.8. HRMS (ESI) *m*/*z*: $[M+Na]^+$ Calcd for $C_{28}H_{19}N_3NaO_2$ 452.1369; Found 452.1373.



3v

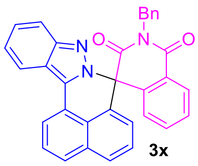
2'-Propyl-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3v)

Eluent: hexane/acetone (8:1). Yellow solid (35 mg, 79%), mp 132.1-133.1 ºC. ^{1}H NMR ($CDCl_3$, 600 MHz): δ 8.43-8.41 (m, 2H), 8.27 (d, *J* = 8.4 Hz, 1H), 7.85-7.84 (m, 2H), 7.70 (t, *J* = 7.8 Hz, 1H), 7.65 (d, *J* = 8.4 Hz, 1H), 7.53-7.51 (m, 1H), 7.46-7.43 (m, 1H), 7.41 (t, *J* = 7.8 Hz, 1H), 7.34 (t, *J* = 7.2 Hz, 1H), 7.27-7.25 (m, 1H), 7.01 (d, *J* = 7.8 Hz, 1H), 6.90 (d, *J* = 8.4 Hz, 1H), 4.00-3.92 (m, 2H), 1.65-1.56 (m, 2H), 0.86 (t, *J* = 7.2 Hz, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$, 100 MHz): δ 169.4, 163.7, 149.8, 141.8, 134.7, 133.5, 132.7, 132.0, 129.2, 129.1, 128.9, 128.3, 128.0, 127.3, 127.1, 126.5, 125.4, 124.5, 123.5, 123.4, 123.3, 121.6, 121.2, 118.7, 118.1, 70.3, 42.7, 21.0, 11.3. HRMS (ESI) *m*/*z*: $[M+Na]^+$ Calcd for $C_{29}H_{21}N_3NaO_2$ 466.1526; Found 466.1517.


3w

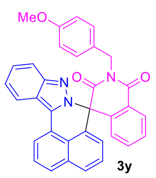
2'-Isopropyl-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3w)

Eluent: hexane/ethyl acetate (8:1). Yellow solid (36.3 mg, 82%), mp 235.4-236.2 ºC. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.43-8.40 (m, 2H), 8.27 (d, J = 8.4 Hz, 1H), 7.84 (d, J = 8.0 Hz, 2H), 7.71-7.66 (m, 2H), 7.53-7.49 (m, 1H), 7.44-7.39 (m, 2H), 7.34 (td, J_1 = 6.8 Hz, J_2 = 0.8 Hz, 1H), 7.27-7.24 (m, 1H), 7.04 (d, J = 7.2 Hz, 1H), 6.86 (d, J = 7.6 Hz, 1H), 5.20-5.09 (m, 1H), 1.44 (d, J = 6.8 Hz, 3H), 1.32 (d, J = 7.2 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz): δ 169.4, 164.0, 149.7, 141.6, 134.5, 133.6, 132.4, 132.1, 129.14, 129.09, 128.9, 128.3, 127.8, 127.2, 127.0, 126.4, 125.3, 125.1, 123.5, 123.32, 123.28, 121.6, 121.2, 118.7, 118.0, 70.9, 46.6, 19.9, 18.8. HRMS (ESI) m/z: [M+Na]$^+$ Calcd for $C_{29}H_{21}N_3NaO_2$ 466.1526; Found 466.1516.


3x

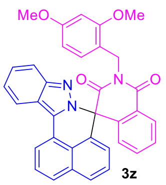
2'-Benzyl-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3x)

Eluent: hexane/acetone (8:1). Yellow solid (37.3 mg, 76%), mp 231.5-232.0 ºC. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.40 (d, J = 7.2 Hz, 2H), 8.26 (d, J = 8.4 Hz, 1H), 7.81 (t, J = 8.8 Hz, 2H), 7.70-7.65 (m, 2H), 7.50-7.47 (m, 1H), 7.41 (t, J = 8.0 Hz, 1H), 7.36-7.23 (m, 6H), 7.20-7.19 (m, 2H), 6.87 (d, J = 7.2 Hz, 2H), 5.20 (s, 2H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz): δ 169.3, 163.5, 149.9, 141.9, 136.2, 134.9, 133.5, 132.3, 131.9, 129.1, 129.0, 128.7, 128.4, 128.3, 128.0, 127.6, 127.2, 127.1, 126.4, 125.5, 124.3, 123.4, 123.2, 121.6, 121.2, 118.7, 118.1, 70.4, 44.3. HRMS (ESI) m/z: [M+Na]$^+$ Calcd for $C_{33}H_{21}N_3NaO_2$ 514.1526; Found 514.1523.


3y

2'-(4-Methoxybenzyl)-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3y)

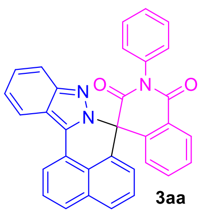
Eluent: hexane/ethyl acetate (4:1). Yellow solid (43.2 mg, 83%), mp 211.3-212.1 ºC. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.41-8.38 (m, 2H), 8.26 (d, J = 8.4 Hz, 1H), 7.82-7.78 (m, 2H), 7.69-7.64 (m, 2H), 7.49-7.45 (m, 1H), 7.39 (td, J_1 = 7.6 Hz, J_2 = 1.2 Hz, 1H), 7.35-7.31 (m, 1H), 7.28-7.23 (m, 4H), 6.86-6.83 (m, 2H), 6.74-6.71 (m, 2H), 5.13 (s, 2H), 3.72 (s, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz): δ 169.3, 163.5, 159.1, 149.9, 141.9, 134.8, 133.5, 132.3, 131.9, 130.3, 129.1, 129.0, 128.5, 128.3, 127.9, 127.2, 127.1, 126.4, 125.5, 124.3, 123.42, 123.39, 123.2, 121.6, 121.2, 118.7, 118.1, 113.8, 70.4, 55.3, 43.8. HRMS (ESI) *m*/*z*: $[M+Na]^+$ Calcd for $C_{34}H_{23}N_3NaO_3$ 544.1632; Found 544.1627.



3z

2'-(2,4-Dimethoxybenzyl)-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3z)

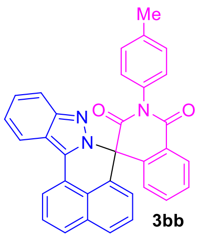
Eluent: hexane/ethyl acetate (4:1). Yellow solid (42.9 mg, 78%), mp 230.0-231.1 ºC. ^{1}H NMR (DMSO-d_6, 400 MHz): δ 8.61 (d, J = 7.6 Hz, 1H), 8.51 (d, J = 8.8 Hz, 1H), 8.32 (d, J = 6.8 Hz, 1H), 8.07-8.04 (m, 2H), 7.81 (t, J = 8.0 Hz, 1H), 7.67-7.62 (m, 2H), 7.59-7.55 (m, 2H), 7.42-7.38 (m, 1H), 7.32-7.28 (m, 1H), 7.24 (d, J = 7.2 Hz, 1H), 7.00 (d, J = 8.4 Hz, 1H), 6.96 (d, J = 8.0 Hz, 1H), 6.49 (d, J = 2.4 Hz, 1H), 6.38 (dd, J_1 = 8.4 Hz, J_2 = 2.0 Hz, 1H), 5.03 (d, J = 15.2 Hz, 1H), 4.97 (d, J = 15.2 Hz, 1H), 3.70 (s, 3H), 3.66 (s, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz): δ 168.9, 163.6, 160.2, 158.3, 149.8, 141.9, 134.7, 133.4, 132.6, 132.0, 130.0, 129.1, 129.0, 128.9, 128.2, 128.0, 127.2, 127.0, 126.3, 125.8, 124.6, 123.6, 123.4, 123.3, 121.6, 121.2, 118.6, 118.1, 116.7, 103.9, 98.3, 70.5, 55.3, 55.2, 39.8. HRMS (ESI) *m*/*z*: $[M+Na]^+$ Calcd for $C_{35}H_{25}N_3NaO_4$ 574.1737; Found 574.1729.



3aa

2'-Phenyl-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3aa)

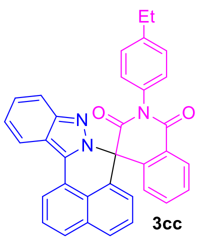
Eluent: hexane/ethyl acetate (5:1). Yellow solid (34.3 mg, 72%), mp 168.6-169.3 ºC. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.47-8.45 (m, 1H), 8.39 (d, *J* = 7.2 Hz, 1H), 8.24 (d, *J* = 8.4 Hz, 1H), 7.87 (d, *J* = 8.4 Hz, 1H), 7.83 (d, *J* = 8.4 Hz, 1H), 7.70-7.65 (m, 2H), 7.56-7.46 (m, 3H), 7.41-7.33 (m, 4H), 7.26-7.22 (m, 2H), 7.17 (d, *J* = 7.2 Hz, 2H), 7.00 (d, *J* = 7.6 Hz, 1H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz): δ 169.2, 163.8, 149.9, 141.7, 135.1, 134.5, 133.7, 132.5, 132.2, 129.4, 129.3, 129.22, 129.19, 128.8, 128.3, 127.3, 127.2, 126.5, 125.5, 124.8, 123.5, 123.4, 121.7, 121.2, 118.7, 118.1, 71.0. HRMS (ESI) *m*/*z*: $[M+Na]^+$ Calcd for $C_{32}H_{19}N_3NaO_2$ 500.1369; Found 500.1373.



3bb

2'-(*p*-Tolyl)-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3bb)

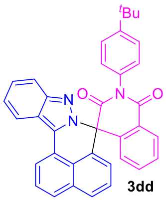
Eluent: hexane/ethyl acetate (5:1). Yellow solid (38.3 mg, 78%), mp 250.7-251.8 ºC. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.46 (d, *J* = 8.0 Hz, 1H), 8.38 (d, *J* = 7.2 Hz, 1H), 8.24 (d, *J* = 8.8 Hz, 1H), 7.85 (d, *J* = 8.0 Hz, 1H), 7.82 (d, *J* = 8.0 Hz, 1H), 7.70-7.64 (m, 2H), 7.56-7.45 (m, 3H), 7.36-7.32 (m, 1H), 7.25-7.22 (m, 2H), 7.18 (d, *J* = 8.4 Hz, 2H), 7.05 (d, *J* = 7.6 Hz, 2H), 6.98 (d, *J* = 7.6 Hz, 1H), 2.31 (s, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz): δ 169.3, 163.9, 149.9, 141.7, 138.8, 135.0, 133.6, 132.5, 132.2, 131.9, 129.9, 129.4, 129.3, 129.2, 128.29, 128.26, 128.0, 127.3, 127.2, 126.5, 125.4, 124.9, 123.6, 123.42, 123.39, 121.7, 121.2, 118.7, 118.1, 71.0, 21.2. HRMS (ESI) *m*/*z*: $[M+Na]^+$ Calcd for $C_{33}H_{21}N_3NaO_2$ 514.1526; Found 514.1521.



3cc

2'-(4-Ethylphenyl)-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3cc)

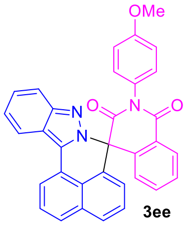
Eluent: dichloromethane. Yellow solid (42.4 mg, 84%), mp 241.5-242.4 ºC. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.46 (dd, J_1 = 8.0 Hz, J_2 = 1.6 Hz, 1H), 8.39 (d, J = 7.2 Hz, 1H), 8.24 (d, J = 8.4 Hz, 1H), 7.86 (d, J = 8.0 Hz, 1H), 7.83 (d, J = 8.4 Hz, 1H), 7.70-7.65 (m, 2H), 7.58-7.46 (m, 3H), 7.36-7.32 (m, 1H), 7.26-7.20 (m, 4H), 7.07 (d, J = 7.6 Hz, 2H), 7.00 (d, J = 7.6 Hz, 1H), 2.61 (q, J = 8.0 Hz, 2H), 1.17 (t, J = 7.6 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz): δ 169.3, 163.9, 149.9, 145.0, 141.6, 135.0, 133.6, 132.5, 132.3, 132.0, 129.4, 129.3, 129.2, 128.7, 128.3, 128.0, 127.3, 127.1, 126.5, 125.4, 124.9, 123.6, 123.44, 123.38, 121.6, 121.2, 118.7, 118.1, 71.0, 28.6, 15.4. HRMS (ESI) *m*/*z*: [M+Na]$^+$ Calcd for $C_{34}H_{23}N_3NaO_2$ 528.1682; Found 528.1680.



3dd

2'-(4-(*tert*-Butyl)phenyl)-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3dd)

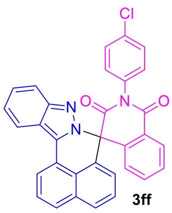
Eluent: hexane/ethyl acetate (5:1). Yellow solid (45.3 mg, 85%), mp 279.9-281.5 ºC. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.48-8.46 (m, 1H), 8.38 (d, J = 6.4 Hz, 1H), 8.24 (d, J = 8.4 Hz, 1H), 7.86 (d, J = 8.0 Hz, 1H), 7.82 (d, J = 8.0 Hz, 1H), 7.70-7.65 (m, 2H), 7.56-7.45 (m, 3H), 7.41-7.38 (m, 2H), 7.36-7.32 (m, 1H), 7.26-7.22 (m, 2H), 7.09 (d, J = 7.2 Hz, 2H), 7.02 (dd, J_1 = 7.6 Hz, J_2 = 0.8 Hz, 1H), 1.25 (s, 9H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz): δ 169.4, 163.9, 151.7, 149.9, 141.5, 135.1, 133.7, 132.5, 132.4, 131.7, 129.4, 129.3, 129.2, 128.34, 128.28, 127.6, 127.3, 127.2, 126.5, 126.3, 125.5, 125.0, 123.6, 123.5, 123.4, 121.6, 121.2, 118.7, 118.2, 71.1, 34.7, 31.3. HRMS (ESI) *m*/*z*: [M+Na]$^+$ Calcd for $C_{36}H_{27}N_3NaO_2$ 556.1995; Found 556.1992.



3ee

2'-(4-Methoxyphenyl)-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3ee)

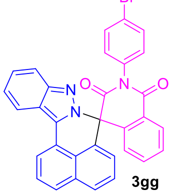
Eluent: hexane/acetone (3:1). Yellow solid (38.5 mg, 76%), mp 159.3-160.2 ºC. ^{1}H NMR ($CDCl_3$, 600 MHz): δ 8.46 (d, *J* = 7.8 Hz, 1H), 8.40 (d, *J* = 7.8 Hz, 1H), 8.25 (d, *J* = 8.4 Hz, 1H), 7.87 (d, *J* = 7.8 Hz, 1H), 7.84 (d, *J* = 8.4 Hz, 1H), 7.70-7.67 (m, 2H), 7.56 (t, *J* = 7.2 Hz, 1H), 7.52-7.47 (m, 2H), 7.36-7.33 (m, 1H), 7.24-7.22 (m, 2H), 7.09-7.08 (m, 2H), 7.00 (d, *J* = 7.8 Hz, 1H), 6.90 (d, *J* = 9.0 Hz, 2H), 3.75 (s, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz): δ 169.4, 164.0, 159.6, 149.9, 141.6, 135.0, 133.6, 132.5, 132.2, 129.4, 129.3, 129.2, 128.29, 128.27, 127.3, 127.1, 127.0, 126.5, 125.4, 124.9, 123.6, 123.42, 123.39, 121.7, 121.2, 118.7, 118.1, 114.5, 71.0, 55.5. HRMS (ESI) *m*/*z*: $[M+Na]^+$ Calcd for $C_{33}H_{21}N_3NaO_3$ 530.1475; Found 530.1467.



3ff

2'-(4-Chlorophenyl)-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3ff)

Eluent: hexane/ethyl acetate (5:1). Yellow solid (36.1 mg, 71%), mp 219.2-220.1 ºC. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.45 (dd, J_1 = 8.0 Hz, J_2 = 1.2 Hz, 1H), 8.40 (d, *J* = 7.2 Hz, 1H), 8.25 (d, *J* = 8.4 Hz, 1H), 7.87 (d, *J* = 8.4 Hz, 1H), 7.84 (d, *J* = 8.4 Hz, 1H), 7.71-7.67 (m, 2H), 7.58-7.46 (m, 3H), 7.37-7.33 (m, 3H), 7.27-7.20 (m, 2H), 7.12 (d, *J* = 8.4 Hz, 2H), 7.00-6.98 (m, 1H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz): δ 169.1, 163.7, 150.0, 141.7, 135.3, 134.8, 133.7, 133.0, 132.4, 132.1, 129.8, 129.5, 129.44, 129.41, 129.2, 128.39, 128.36, 127.4, 127.3, 126.5, 125.4, 124.6, 123.5, 123.44, 123.39, 121.8, 121.2, 118.6, 118.1, 70.9. HRMS (ESI) *m*/*z*: $[M+Na]^+$ Calcd for $C_{32}H_{18}ClN_3NaO_2$ 534.0980; Found 534.0992.



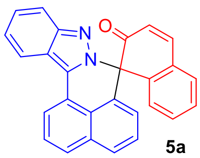
3gg

2'-(4-Bromophenyl)-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinoline]-1',3'(2'*H*)-dione (3gg)

Eluent: hexane/ethyl acetate (5:1). Yellow solid (38.8 mg, 70%), mp 232.7-233.5 ºC. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.44 (d, J = 8.0 Hz, 1H), 8.39 (d, J = 7.2 Hz, 1H), 8.24 (d, J = 8.4 Hz, 1H), 7.87-7.82 (m, 2H), 7.70-7.66 (m, 2H), 7.57-7.45 (m, 5H), 7.36-7.32 (m, 1H), 7.26-7.19 (m, 2H), 7.05 (d, J = 7.2 Hz, 2H), 6.98 (d, J = 8.0 Hz, 1H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz): δ 169.1, 163.6, 150.0, 141.7, 135.3, 133.7, 133.5, 132.4, 132.3, 132.1, 130.1, 129.5, 129.4, 129.2, 128.39, 128.36, 127.4, 127.3, 126.5, 125.4, 124.6, 123.5, 123.43, 123.38, 122.9, 121.8, 121.2, 118.6, 118.1, 70.9. HRMS (ESI) *m*/*z*: [M+H]$^+$ Calcd for $C_{32}H_{19}BrN_3O_2$ 556.0655; Found 556.0658.

2. Typical procedure for the synthesis of 5a and spectroscopic data of 5a-5n

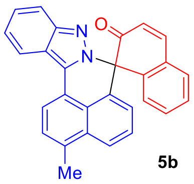
To a reaction tube equipped with a stir bar were charged with 3-(naphthalen-1-yl)-1*H*-indazole (**1a**, 24.4 mg, 0.1 mmol), HFIP (1 mL), [IrCp*Cl_2]$_2$ (1.2 mg, 0.0015 mmol), Cs_2CO_3 (9.8 mg, 0.03 mmol), Ag_2O (11.6 mg, 0.05 mmol) and 1-diazonaphthalen-2(1*H*)-one (**4a**, 17 mg, 0.1 mmol). The tube was then sealed, and the resulting mixture was stirred at 100 °C under air for 2 h. Upon completion, it was cooled to room temperature, filtered through a pad of celite, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography using hexane/ethyl acetate (5:1) as eluent to afford **5a**. Other products **5b-5n** were obtained in a similar manner.



5a

2'*H*-Spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,1'-naphthalen]-2'-one (5a)

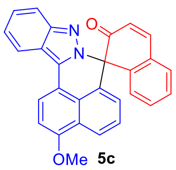
Eluent: hexane/ethyl acetate (5:1). Yellow solid (26.6 mg, 69%), mp 289.9-291.7 ºC. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.30 (d, J = 7.2 Hz, 1H), 8.18 (d, J = 8.4 Hz, 1H), 7.72-7.68 (m, 2H), 7.65-7.55 (m, 3H), 7.41 (d, J = 7.6 Hz, 1H), 7.29-7.21 (m, 3H), 7.17-7.10 (m, 2H), 7.07 (d, J = 7.6 Hz, 1H), 6.82 (d, J = 7.6 Hz, 1H), 6.10 (d, J = 10.0 Hz, 1H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz): δ 193.3, 149.7, 147.0, 145.6, 133.8, 132.05, 131.97, 131.3, 130.0, 129.8, 128.8, 128.5, 128.1, 127.0, 126.7, 126.5, 124.8, 124.0, 123.1, 122.9, 121.6, 121.2, 121.1, 118.6, 118.1, 73.2. HRMS (ESI) *m/z*: $[M+H]^+$ Calcd for $C_{27}H_{17}N_2O$ 385.1335; Found 385.1322.



5b

3-Methyl-2'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,1'-naphthalen]-2'-one (5b)

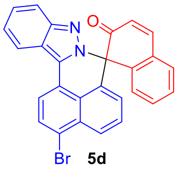
Eluent: hexane/ethyl acetate (4:1). Yellow solid (25.3 mg, 63%), mp 269.1-270.3 ºC. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.29 (d, *J* = 7.2 Hz, 1H), 8.25 (d, *J* = 8.4 Hz, 1H), 7.94 (dd, J_1 = 8.4 Hz, J_2 = 0.8 Hz, 1H), 7.72 (d, *J* = 10.0 Hz, 1H), 7.66 (d, *J* = 8.0 Hz, 1H), 7.51-7.49 (m, 2H), 7.40 (t, *J* = 7.6 Hz, 1H), 7.35 (td, J_1 = 7.6 Hz, J_2 = 1.2 Hz, 1H), 7.32-7.28 (m, 1H), 7.23-7.15 (m, 3H), 6.89 (d, *J* = 8.0 Hz, 1H), 6.19 (d, *J* = 10.0 Hz, 1H), 2.70 (s, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz): δ 193.4, 149.7, 146.9, 145.7, 135.0, 133.0, 132.5, 132.2, 131.3, 130.0, 129.8, 128.9, 128.8, 127.6, 126.6, 126.3, 124.73, 124.69, 123.2, 122.6, 122.3, 121.7, 121.3, 121.1, 118.5, 117.9, 73.0, 19.8. HRMS (ESI) *m/z*: $[M+H]^+$ Calcd for $C_{28}H_{19}N_2O$ 399.1492; Found 399.1503.



5c

3-Methoxy-2'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,1'-naphthalen]-2'-one (5c)

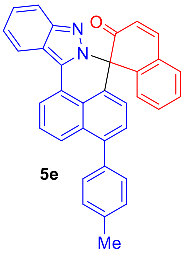
Eluent: hexane/ethyl acetate (3:1). Yellow solid (29.5 mg, 71%), mp 278.9-279.8 ºC. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.23 (dd, J_1 = 8.0 Hz, J_2 = 1.6 Hz, 1H), 8.15-8.13 (m, 2H), 7.66-7.63 (m, 1H), 7.57 (d, *J* = 8.8 Hz, 1H), 7.42 (d, *J* = 7.6 Hz, 1H), 7.31-7.17 (m, 3H), 7.15-7.09 (m, 3H), 6.92-6.90 (m, 1H), 6.82 (d, *J* = 8.0 Hz, 1H), 6.12 (dd, J_1 = 10.0 Hz, J_2 = 2.0 Hz, 1H), 3.97 (d, *J* = 1.6 Hz, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz): δ 193.6, 155.6, 149.7, 146.9, 145.7, 132.4, 131.8, 131.3, 130.0, 129.8, 128.8, 128.7, 126.6, ,126.0, 125.9, 125.5, 124.3, 122.7, 122.3, 121.9, 121.8, 121.3, 118.4, 117.4, 116.9, 104.7, 72.8, 55.8. HRMS (ESI) *m/z*: $[M+H]^+$ Calcd for $C_{28}H_{19}N_2O_2$ 415.1441; Found 415.1440.



5d

3-Bromo-2'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,1'-naphthalen]-2'-one (5d)

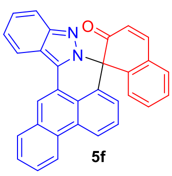
Eluent: hexane/ethyl acetate (4:1). Yellow solid (31.2 mg, 67%), mp ＞320 ºC. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.24-8.21 (m, 3H), 7.97 (d, J = 8.0 Hz, 1H), 7.75 (d, J = 10.0 Hz, 1H), 7.68 (d, J = 8.8 Hz, 1H), 7.53 (d, J = 7.6 Hz, 1H), 7.49 (t, J = 7.6 Hz, 1H), 7.39 (td, J_1 = 7.6 Hz, J_2 = 0.8 Hz, 1H), 7.35-7.31 (m, 1H), 7.28-7.23 (m, 2H), 7.21 (d, J = 7.6 Hz, 1H), 6.89 (d, J = 7.6 Hz, 1H), 6.20 (d, J = 10.0 Hz, 1H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz): δ 193.0, 149.8, 147.1, 145.2, 132.6, 132.3, 131.4, 131.3, 131.1, 130.1, 129.9, 129.0, 128.9, 127.9, 127.7, 126.8, 125.9, 124.3, 124.0, 123.3, 122.4, 121.5, 121.2, 121.0, 118.7, 118.2, 72.8. HRMS (ESI) *m*/*z*: $[M+H]^+$ Calcd for $C_{27}H_{16}BrN_2O$ 463.0441; Found 463.0445.



5e

4-(*p*-Tolyl)-2'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,1'-naphthalen]-2'-one (5e)

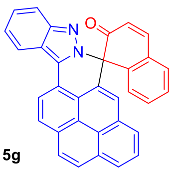
Eluent: hexane/ethyl acetate (4:1). Yellow solid (32 mg, 67%), mp 285.0-286.2 ºC. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.41 (d, J = 7.2 Hz, 1H), 8.28 (d, J = 8.4 Hz, 1H), 7.86 (d, J = 8.4 Hz, 1H), 7.73 (d, J = 10.0 Hz, 1H), 7.68 (d, J = 8.8 Hz, 1H), 7.61-7.57 (m, 1H), 7.51 (d, J = 7.6 Hz, 1H), 7.39-7.35 (m, 1H), 7.34-7.22 (m, 8H), 7.16 (d, J = 7.6 Hz, 1H), 6.97 (d, J = 7.6 Hz, 1H), 6.20 (d, J = 10.0 Hz, 1H), 2.44 (s, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz): δ 193.4, 149.8, 147.0, 145.5, 141.0, 137.5, 136.9, 132.2, 131.4, 130.9, 130.1, 129.93, 129.88, 129.2, 129.0, 128.9, 127.5, 126.9, 126.7, 126.6, 124.5, 124.2, 123.5, 122.9, 121.6, 121.25, 121.20, 118.6, 118.2, 73.2, 21.3. HRMS (ESI) *m*/*z*: $[M+H]^+$ Calcd for $C_{34}H_{23}N_2O$ 475.1805; Found 475.1795.



5f

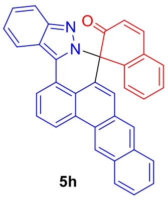
2'*H*-Spiro[dibenzo[*de*,*g*]indazolo[3,2-*a*]isoquinoline-8,1'-naphthalen]-2'-one (5f)

Eluent: hexane/ethyl acetate (3:1). Yellow solid (28.8 mg, 66%), mp ＞320 ºC. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.57 (s, 1H), 8.55-8.49 (m, 2H), 8.34 (d, *J* = 8.4 Hz, 1H), 7.96-7.94 (m, 1H), 7.67 (d, *J* = 10.0 Hz, 1H), 7.62 (d, *J* = 8.8 Hz, 1H), 7.58-7.55 (m, 2H), 7.46-7.42 (m, 2H), 7.29-7.10 (m, 5H), 6.81 (d, *J* = 7.6 Hz, 1H), 6.16 (d, *J* = 10.0 Hz, 1H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz): δ 193.6, 149.8, 147.0, 145.3, 132.6, 132.0, 131.8, 131.3, 131.1, 130.1, 129.9, 129.8, 129.2, 129.0, 128.9, 127.8, 127.4, 127.3, 126.8, 125.3, 123.2, 123.0, 122.9, 122.3, 122.0, 121.9, 121.3, 118.6, 118.2, 72.7. HRMS (ESI) *m*/*z*: $[M+H]^+$ Calcd for $C_{31}H_{19}N_2O$ 435.1492; Found 435.1484.


5g

2'*H*-Spiro[indazolo[2,3-*b*]phenanthro[3,4,5-*defg*]isoquinoline-7,1'-naphthalen]-2'-one (5g)

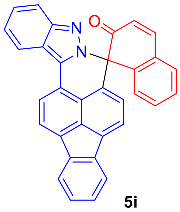
Eluent: hexane/ethyl acetate (3:1). Yellow solid (25.6 mg, 56%), mp ＞320 ºC. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.90 (d, *J* = 8.0 Hz, 1H), 8.41 (d, *J* = 8.4 Hz, 1H), 8.34 (d, *J* = 8.0 Hz, 1H), 8.14 (dd, J_1 = 7.2 Hz, J_2 = 1.2 Hz, 1H), 8.07-8.01 (m, 2H), 7.97-7.90 (m, 2H), 7.83 (d, *J* = 10.0 Hz, 1H), 7.72-7.70 (m, 2H), 7.60 (d, *J* = 7.6 Hz, 1H), 7.42 (td, J_1 = 7.6 Hz, J_2 = 1.2 Hz, 1H), 7.36-7.32 (m, 1H), 7.30-7.24 (m, 2H), 7.08 (d, *J* = 7.6 Hz, 1H), 6.24 (d, *J* = 10.0 Hz, 1H). ^{13}C{^{1}H} NMR ($CDCl_3$, 100 MHz): δ 193.0, 150.0, 147.0, 145.6, 132.8, 131.4, 131.3, 131.0, 130.5, 130.1, 130.0, 129.05, 128.98, 127.62, 127.58, 126.74, 126.67, 126.51, 126.46, 126.1, 125.6, 124.9, 124.1, 123.1, 121.8, 121.5, 121.3, 121.1, 120.3, 118.7, 118.5, 73.5. HRMS (ESI) *m*/*z*: $[M+H]^+$ Calcd for $C_{33}H_{19}N_2O$ 459.1492; Found 459.1503.


5h

2'*H*-Spiro[benzo[*de*]indazolo[2,3-*b*]naphtho[2,3-*g*]isoquinoline-10,1'-naphthalen]-2'-one (5h)

Eluent: hexane/ethyl acetate (3:1). Yellow solid (32.9 mg, 68%), mp ＞320 ºC. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 9.13 (s, 1H), 8.81 (d, *J* = 8.4 Hz, 1H), 8.55 (d, *J* = 7.6 Hz, 1H), 8.31 (d, *J* = 8.8 Hz, 1H), 8.19 (s, 1H), 8.10 (d, *J* =

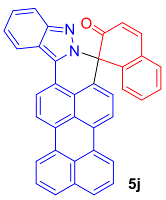
7.6 Hz, 1H), 7.94 (d, J = 7.6 Hz, 1H), 7.88 (t, J = 8.0 Hz, 1H), 7.79 (d, J = 10.0 Hz, 1H), 7.70 (d, J = 8.4 Hz, 1H), 7.60-7.50 (m, 3H), 7.46-7.42 (m, 2H), 7.35-7.24 (m, 3H), 7.08 (d, J = 8.0 Hz, 1H), 6.20 (d, J = 10.0 Hz, 1H). $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz): δ 192.7, 149.8, 146.8, 145.0, 132.4, 132.3, 132.2, 131.44, 131.39, 130.1, 130.0, 129.8, 129.5, 129.3, 129.0, 128.6, 128.1, 127.8, 127.7, 127.6, 127.0, 126.7, 126.4, 125.1, 123.0, 122.3, 121.9, 121.51, 121.46, 121.2, 118.7, 118.4, 73.1. HRMS (ESI) *m*/*z*: $[M+H]^+$ Calcd for $C_{35}H_{21}N_2O$ 485.1648; Found 485.1652.



5i

2'*H*-Spiro[fluoreno[2,1,9-*def*]indazolo[3,2-*a*]isoquinoline-7,1'-naphthalen]-2'-one (5i)

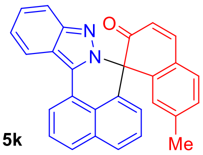
Eluent: hexane/ethyl acetate (3:1). Yellow solid (38.2 mg, 83%), mp >320 ºC. ^1H NMR (DMSO-d_6, 400 MHz): δ 8.63 (d, J= 7.2 Hz, 1H), 8.55 (d, J= 8.4 Hz, 1H), 8.36 (d, J= 7.6 Hz, 1H), 8.18-8.14 (m, 2H), 8.07 (d, J = 7.2 Hz, 1H), 8.01 (d, J = 6.8 Hz, 1H), 7.80 (d, J= 7.2 Hz, 1H), 7.62 (d, J= 8.8 Hz, 1H), 7.50-7.27 (m, 7H), 6.80 (d, J = 7.6 Hz, 1H), 6.33 (d, J = 10.0 Hz, 1H). $^{13}C\{^1H\}$ NMR ($CDCl_3$, 150 MHz): δ 193.1, 149.5, 147.1, 144.8, 139.4, 139.1, 136.9, 136.2, 132.4, 132.3, 131.9, 131.4, 130.2, 129.4, 128.9, 128.8, 128.1. 127.9, 126.9, 125.3, 124.1, 123.3, 122.2, 122.0, 121.8, 121.6, 121.0, 120.8, 120.1, 118.7, 118.1, 74.0. HRMS (ESI) *m*/*z*: $[M+H]^+$ Calcd for $C_{33}H_{19}N_2O$ 459.1492; Found 459.1501.



5j

2'*H*-Spiro[benzo[10,5]anthra[2,1,9-*def*]indazolo[3,2-*a*]isoquinoline-6,1'-naphthalen]-2'-one (5j)

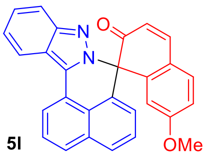
Eluent: hexane/ethyl acetate (4:1). Red solid (25.0 mg, 49%), mp 251.1-252.6 ºC. ^1H NMR (DMSO-d_6, 400 MHz): δ 8.57 (s, 2H), 8.51 (d, J = 8.4 Hz, 1H), 8.45 (d, J = 7.6 Hz, 1H), 8.33 (d, J= 7.6 Hz, 1H), 8.27 (d, J= 7.6 Hz, 1H), 8.14 (d, J= 10.0 Hz, 1H), 7.86-7.84 (m, 2H), 7.80 (d, J= 7.2 Hz, 1H), 7.62-7.60 (m, 2H), 7.56-7.48 (m, 2H), 7.41-7.30 (m, 3H), 7.12 (d, J= 8.0 Hz, 1H), 6.95 (d, J = 7.6 Hz, 1H), 6.29 (d, J = 10.0 Hz, 1H). $^{13}C\{^1H\}$ NMR (DMSO-d_6, 150 MHz): δ 193.8, 149.4, 148.7, 145.4, 134.6, 132.0, 131.7, 131.5, 131.3, 131.2, 130.9, 130.2, 129.83, 129.80, 129.6, 129.3, 129.2, 129.1, 128.5, 127.9, 127.7, 127.54, 127.50, 126.0, 124.1, 123.6, 122.8, 122.6, 122.4, 122.1, 122.0, 121.2, 118.3, 117.9, 72.8. HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{37}H_{21}N_2O$ 509.1648; Found 509.1642.



5k

7'-Methyl-2'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,1'-naphthalen]-2'-one (5k)

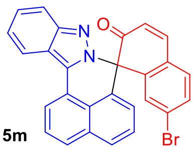
Eluent: hexane/ethyl acetate (3:1). Yellow solid (36.3 mg, 91%), mp 265.6-266.3 ºC. ^1H NMR ($CDCl_3$, 400 MHz): δ 8.38 (d, J = 7.2 Hz, 1H), 8.28 (d, J = 8.8 Hz, 1H), 7.79-7.75 (m, 2H), 7.71-7.62 (m, 3H), 7.39-7.29 (m, 3H), 7.25-7.21 (m, 1H), 7.15-7.14 (m, 2H), 6.69 (s, 1H), 6.11 (d, J = 10.0 Hz, 1H), 2.09 (s, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$, 100 MHz): δ 193.4, 149.7, 147.1, 145.6, 142.1, 133.8, 132.14, 132.10, 130.4, 130.1, 129.8, 128.4, 128.1, 127.0, 126.62, 126.57, 126.4, 124.9, 124.1, 123.1, 122.9, 121.2, 121.1, 120.4, 118.7, 118.1, 73.2, 21.6. HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{28}H_{19}N_2O$ 399.1492; Found 399.1497.



5l

7'-Methoxy-2'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,1'-naphthalen]-2'-one (5l)

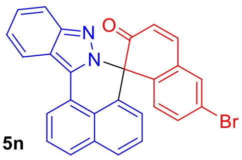
Eluent: hexane/ethyl acetate (4:1). Yellow solid (36.8 mg, 89%), mp 252.6-253.0 ºC. ^1H NMR ($CDCl_3$, 400 MHz): δ 8.37 (d, J = 7.2 Hz, 1H), 8.27 (d, J = 8.8 Hz, 1H), 7.80-7.76 (m, 2H), 7.70-7.63 (m, 3H), 7.43 (d, J = 8.4 Hz, 1H), 7.36 (t, J = 8.0 Hz, 1H), 7.33-7.29 (m, 1H), 7.25-7.21 (m, 1H), 7.18 (d, J = 7.2 Hz, 1H), 6.86 (dd, J_1 = 8.4 Hz, J_2 = 2.4 Hz, 1H), 6.41 (d, J = 2.4 Hz, 1H), 6.05 (d, J = 10.0 Hz, 1H), 3.54 (s, 3H). $^{13}C\{^1H\}$ NMR ($CDCl_3$, 100 MHz): δ 193.3, 162.1, 149.7, 147.7, 146.9, 133.8, 132.1, 131.8, 128.4, 128.0, 127.0, 126.64, 126.56, 124.7, 124.0, 123.1, 122.9, 122.2, 121.2, 121.1, 118.8, 118.6, 118.1, 116.1, 113.9, 73.3, 55.4. HRMS (ESI) *m*/*z*: $[M+H]^+$ Calcd for $C_{28}H_{19}N_2O_2$ 415.1441; Found 415.1450.



5m

7'-Bromo-2'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,1'-naphthalen]-2'-one (5m)

Eluent: hexane/ethyl acetate (4:1). Yellow solid (32.9 mg, 71%), mp 294.7-295.5 ºC. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.40 (d, *J* = 7.2 Hz, 1H), 8.28 (d, *J* = 8.4 Hz, 1H), 7.83-7.80 (m, 2H), 7.70-7.66 (m, 3H), 7.52-7.50 (m, 1H), 7.40-7.33 (m, 3H), 7.28-7.25 (m, 1H), 7.13 (d, *J* = 7.6 Hz, 1H), 7.04 (s, 1H), 6.20 (dd, J_1 = 10.0 Hz, J_2 = 1.6 Hz, 1H). $^{13}C\{^1H\}$ NMR ($CDCl_3$, 100 MHz): δ 192.3, 149.8, 147.0, 145.7, 133.8, 132.9, 132.3, 132.1, 131.2, 131.1, 128.8, 128.2, 128.0, 127.1, 126.9, 126.5, 126.0, 124.9, 123.8, 123.1, 123.0, 121.8, 121.4, 121.2, 118.6, 118.1, 72.7. HRMS (ESI) *m*/*z*: $[M+H]^+$ Calcd for $C_{27}H_{16}BrN_2O$ 463.0441; Found 463.0429.



5n

6'-Bromo-2'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,1'-naphthalen]-2'-one (5n)

Eluent: hexane/ethyl acetate (5:1). Yellow solid (29.5 mg, 64%), mp 154.7-156.0 ºC. ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.39-8.37 (m, 1H), 8.26 (d, *J* = 8.4 Hz, 1H), 7.81-7.78 (m, 2H), 7.68-7.62 (m, 4H), 7.39-7.30 (m, 3H), 7.26-7.22 (m, 1H), 7.12 (dd, J_1 = 7.6 Hz, J_2 = 0.8 Hz, 1H), 6.79 (d, *J* = 8.4 Hz, 1H), 6.21 (d, *J* = 10.0 Hz, 1H). $^{13}C\{^1H\}$ NMR ($CDCl_3$, 100 MHz): δ 192.5, 149.8, 145.2, 144.1, 134.0, 133.8, 132.4, 132.1, 131.5, 131.3, 130.8, 128.8, 128.2, 127.1, 126.9, 126.5, 124.9, 123.8, 123.11, 123.05, 122.8, 122.7, 121.3, 121.2, 118.5, 118.1, 72.8. HRMS (ESI) *m*/*z*: $[M+H]^+$ Calcd for $C_{27}H_{16}BrN_2O$ 463.0441; Found 463.0445.

3. Gram-scale synthesis of 3a

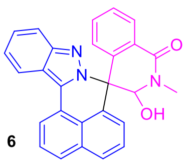
To a reaction tube equipped with a stir bar were charged with **1a** (732.9 mg, 3 mmol), HFIP (30 mL), $[IrCp^*Cl_2]_2$ (35.9 mg, 0.045 mmol), Cs_2CO_3 (293.2 mg, 0.9 mmol), Ag_2O (347.6 mg, 1.5 mmol) and **2a** (603.6

mg, 3 mmol). The tube was then sealed, and the resulting mixture was stirred at 100 °C under air for 6 h. Upon completion, it was cooled to room temperature, filtered through a pad of celite, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography using hexane/ethyl acetate (5:1) as eluent to afford **3a** (0.875 g, 70%).

4. Structural elaborations of 3a

4.1 Synthesis of 6[4]

To a two-necked flask equipped with a stir bar were charged with $LiAlH_4$ (30.4 mg, 0.8 mmol), $AlCl_3$ (106.7 mg, 0.8 mmol) and Et_2O (2 mL). The resulting mixture was stirred at 0 °C for 0.5 h. Then, a solution of **3a** (41.5 mg, 0.1 mmol) in Et_2O and chloroform (1:2 (v/v), 3 mL) was added in a dropwise manner. The resulting mixture was then stirred at 0 °C for 1 h. Upon completion, it was warmed to room temperature, quenched with H_2O, and extracted with DCM (10 mL × 3). The combined organic layers were dried over anhydrous Na_2SO_4, filtered through a pad of celite, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography with hexane/ethyl acetate (3:1) as eluent to afford **6**.



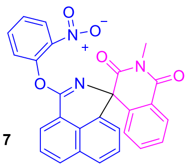
6

3'-Hydroxy-2'-methyl-2',3'-dihydro-1'*H*-spiro[benzo[*de*]indazolo[3,2-*a*]isoquinoline-7,4'-isoquinolin]-1'-one (6)

Eluent: hexane/ethyl acetate (3:1). White solid (16.4 mg, 39%), mp 173.6-174.2 ºC. ^{1}H NMR (DMSO-d_6, 400 MHz): δ 8.52 (d, *J* = 7.6 Hz, 1H), 8.47 (d, *J* = 8.0 Hz, 1H), 8.18 (d, *J* = 7.6 Hz, 1H), 8.00-7.98 (m, 2H), 7.75 (t, *J* = 7.6 Hz, 1H), 7.65 (d, *J* = 8.4 Hz, 1H), 7.58-7.52 (m, 2H), 7.47-7.44 (m, 1H), 7.39-7.35 (m, 1H), 7.29-7.26 (m, 1H), 7.12 (d, *J* = 7.2 Hz, 1H), 6.96 (d, *J* = 6.4 Hz, 1H), 6.86 (d, *J* = 8.0 Hz, 1H), 5.81 (d, *J* = 6.4 Hz, 1H), 2.83 (s, 3H). ^{13}C{^{1}H} NMR (DMSO-d_6, 150 MHz): δ 163.8, 148.7, 141.0, 133.3, 133.0, 132.1, 130.6, 129.1, 129.0, 128.7, 128.5, 128.4, 128.2, 128.0, 127.13, 127.05, 126.7, 125.1, 123.6, 123.3, 122.0, 121.3, 118.5, 118.0, 86.4, 72.0, 29.3. HRMS (ESI) *m*/*z*: [M+Na]$^+$ Calcd for $C_{27}H_{19}N_3NaO_2$ 440.1369; Found 440.1359.

4.2 Synthesis of 7

To a flask equipped with a stir bar were charged with **3a** (41.5 mg, 0.1 mmol), *m*-CPBA (25.9 mg, 0.15 mmol) and DCM (2 mL). The resulting mixture was stirred under reflux for 7 h. Upon completion, it was cooled to room temperature, quenced with saturated aqueous Na_2CO_3, and extracted with DCM (10 mL × 3). The combined organic layers were dried over anhydrous Na_2SO_4, filtered through a pad of celite, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography using hexane/ethyl acetate (3:1) as eluent to afford **7**.



7

2'-Methyl-3-(2-nitrophenoxy)-1'*H*-spiro[benzo[*de*]isoquinoline-1,4'-isoquinoline]-1',3'(2'*H*)-dione (7)

Eluent: hexane/ethyl acetate (3:1). White solid (27.5 mg, 59%), mp 89.1-90.4 ºC. ^{1}H NMR (DMSO-d_6, 400 MHz): δ 8.33 (d, J = 7.2 Hz, 1H), 8.29 (d, J = 8.0 Hz, 1H), 8.15 (dd, J_1 = 7.6 Hz, J_2 = 1.2 Hz, 1H), 8.06 (dd, J_1 = 8.4 Hz, J_2 = 1.6 Hz, 1H), 7.99 (d, J = 8.0 Hz, 1H), 7.85-7.77 (m, 2H), 7.64-7.53 (m, 3H), 7.51-7.44 (m, 2H), 6.98-6.95 (m, 2H), 3.15 (s, 3H). ^{13}C{^{1}H} NMR ($CDCl_3$, 150 MHz): δ 170.9, 164.5, 160.8, 146.3, 142.7, 142.6, 134.7, 134.6, 133.5, 132.6, 132.3, 128.6, 128.3, 127.9, 127.6, 127.5, 126.7, 126.6, 125.9, 125.8, 125.6, 125.2, 124.2, 123.5, 118.5, 68.8, 27.7. HRMS (ESI) *m*/*z*: [M+H]$^+$ Calcd for $C_{27}H_{18}N_3O_5$ 464.1241; Found 464.1245.

5. Cell anti-proliferative activity assay

Cell anti-proliferative activity against Hela, HCT-116, MDA-MB-231, HepG2 and HaCat was evaluated by the CCK-8 method.

Dilute Hela or HCT-116 cell suspensions in growth medium to desired density and 100 μL were taken to 96-well plate. The test compounds with different concentration gradients were prepared. Add 100 μL culture medium containing compounds into 96-well plate according to the plate map. Final DMSO concentration in each well was below 0.1%. Then the cell was incubated at 37 ºC, 5% CO_2 for 48 h. Equilibrate the assay plate to room temperature before measurement. Add 10 μL of CCK-8 into each well. Mix contents for 2 minutes on an orbital shaker to induce cell lysis. Incubate at 37 ºC and 5% CO_2 for 1.5 hours, and then the plates were recorded by measuring absorbance at 450 nm using an EnVision Multilabel Reader (PerkinElmer). The IC_{50} values were calculated using GraphPad Prism 6.0 software and determined by the concentration causing a half-maximal percent activity.

Dilute MDA-MB-231 or HepG2 cell suspensions in growth medium to desired density and 100 μL were taken to 96-well plate. The test compounds with different concentration gradients were prepared. Add 100 μL culture medium containing compounds into 96-well plate according to the plate map. Final DMSO concentration in each well was below 0.1%. Then the cell was incubated at 37 ºC, 5% CO_2 for 96 h. Equilibrate the assay plate to room temperature before measurement. Add 10 μL of CCK-8 into each well. Mix contents for 2 minutes on an orbital shaker to induce cell lysis. Incubate at 37 ºC and 5% CO_2 for 1.5 hours, and then the plates were recorded by measuring absorbance at 450 nm using an EnVision Multilabel Reader (PerkinElmer). The IC_{50} values were calculated using GraphPad Prism 6.0 software and determined by the concentration causing a half-maximal percent activity.

Dilute HaCat cell suspensions in growth medium to desired density and 100 μL were taken to 96-well plate. The test compounds with different concentration gradients were prepared. Add 100 μL culture medium containing compounds into 96-well plate according to the plate map. Final DMSO concentration in each well was below 0.1%. Then the cell was incubated at 37 ºC, 5% CO_2 for 72 h. Equilibrate the assay plate to room temperature before measurement. Add 10 μL of CCK-8 into each well. Mix contents for 2 minutes on an orbital shaker to induce cell lysis. Incubate at 37 ºC and 5% CO_2 for 1.5 hours, and then the plates were recorded by measuring absorbance at 450 nm using an EnVision Multilabel Reader (PerkinElmer). The IC_{50} values were calculated using GraphPad Prism 6.0 software and determined by the concentration causing a half-maximal percent activity.

All assays were conducted with two parallel samples and two repetitions, and 5-fluorouracil was used as the positive control. The results thus obtained were included in the Table S1. The representative microscopy images and corresponding cell viability curve for compound **3o** were shown as Figure S1 and Figure S2, respectively.

Table S1. Antiproliferative Activity of Selected Products

Compounds	IC_{50} (μM ± SD)				
	Hela	HCT-116	MDA-MB-231	HepG2	HaCat
3o	10.27 ± 0.05	>50	15.40±0.20	>50	7.615±0.04
3r	10.74 ± 0.46	21.35 ± 0.09	>50	>50	>50
3s	24.47 ± 0.48	>50	34.68±0.09	13.29±0.05	18.01±0.02
3t	12.08 ± 0.36	21.83 ± 0.28	21.76±0.40	11.80±0.11	24.61±0.16
5i	>50	7.385 ± 0.06	11.21±0.02	13.60±0.21	23.70±0.42
6	10.61 ± 0.17	20.52 ± 0.02	>50	44.48±0.09	28.29±0.40
7	6.438 ± 0.15	5.192 ± 0.05	>50	>50	7.615±0.04
5-FU	6.247 ± 0.12	6.202 ± 0.19	4.951±0.14	3.717±0.09	3.304±0.00

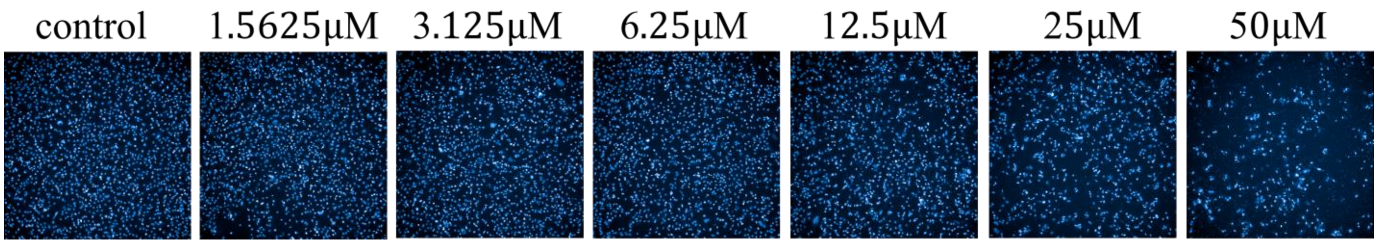


Figure S1 Hoechst staining of MDA-MB-231 cells exposed to various concentrations of **3o** (control, 1.5625, 3.125, 6.25, 12.5, 25, and 50 μM) for 96 h.

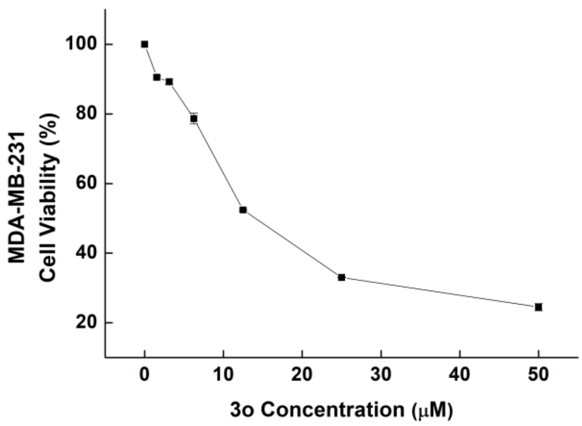
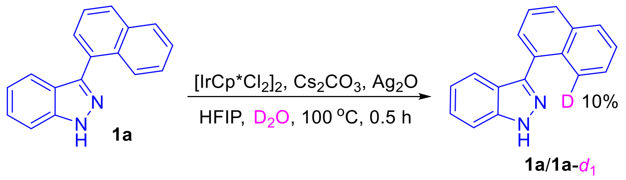


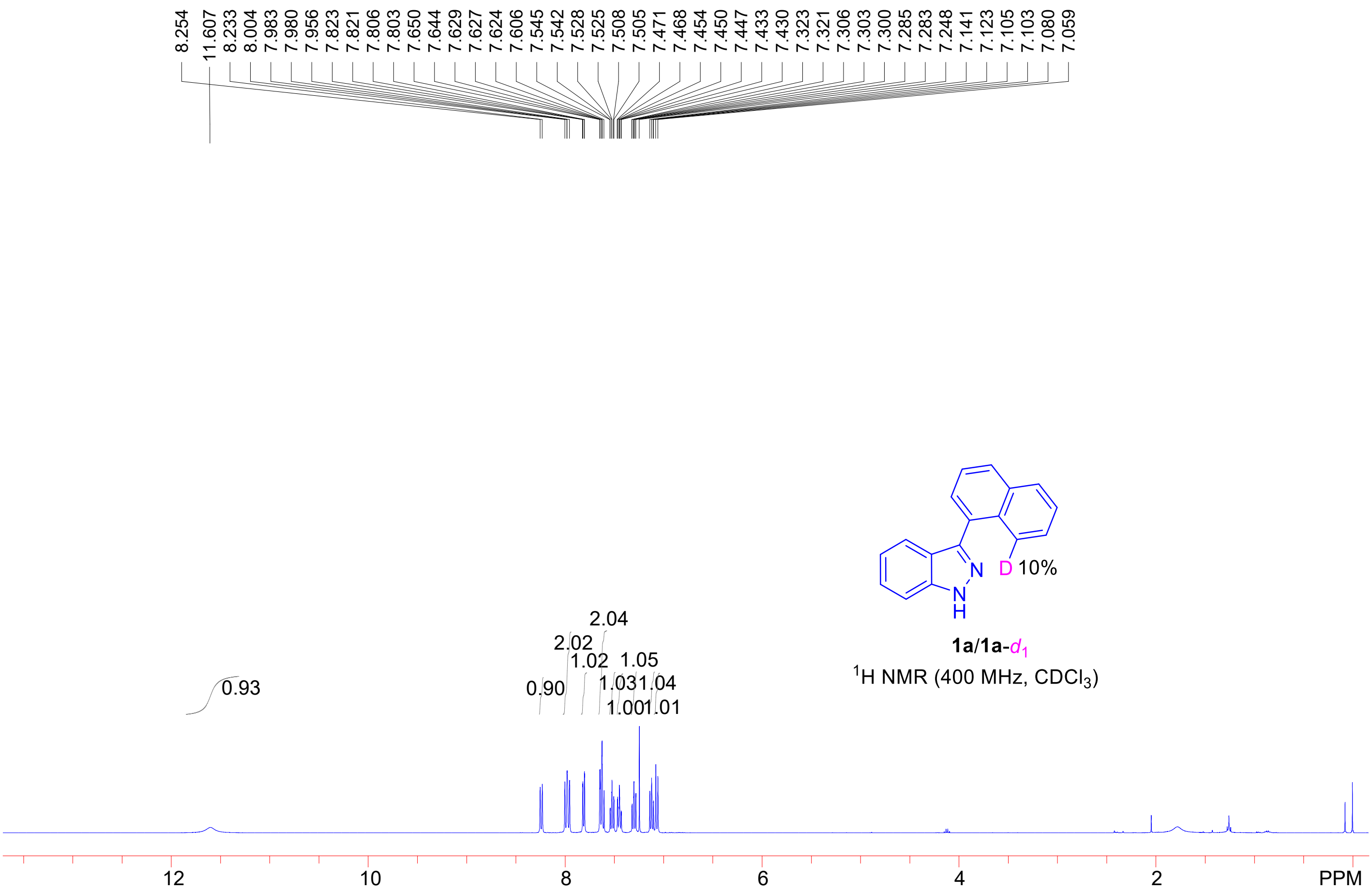
Figure S2 Viability of MDA-MB-231 cells exposed to various concentrations of **3o** (control, 1.5625, 3.125, 6.25, 12.5, 25, and 50 μM) for 96 h.

III. Mechanism studies

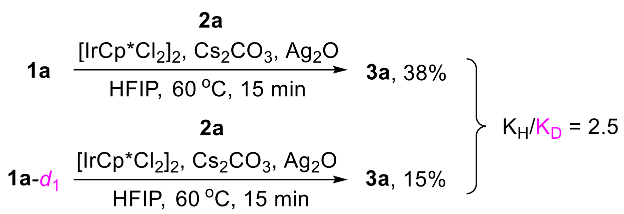
1. H/D exchange experiment



To a reaction tube equipped with a stir bar were charged with **1a** (24.4 mg, 0.1 mmol), HFIP (1 mL), D_2O (18 μL, 1 mmol), $[IrCp^*Cl_2]_2$ (1.2 mg, 0.0015 mmol), Cs_2CO_3 (9.8 mg, 0.03 mmol), and Ag_2O (11.6 mg, 0.05 mmol). The tube was then sealed and the mixture was stirred at 100 °C for 0.5 h. Afterwards, it was cooled to room temperature, filtered through a pad of celite and concentrated under reduced pressure. The residue was purified by silica gel column chromatography using hexane/ethyl acetate (5:1) as eluent to give a mixture of **1a** and **1a**-d_1. Upon analyzing the ^{1}H NMR spectrum of the mixture, the deuteration percentage on the *ortho*-positions of the phenyl ring of **1a** was determined to be 10%. This result confirms the occurrence of a reversible C−H bond metalation/activation.



2. Kinetic isotope effect study

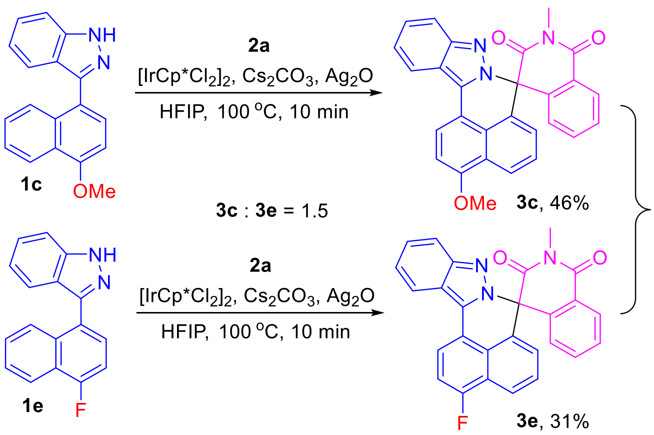


To a reaction tube equipped with a stir bar were charged with **1a** (24.4 mg, 0.1 mmol), HFIP (1 mL), $[IrCp^*Cl_2]_2$ (1.2 mg, 0.0015 mmol), Cs_2CO_3 (9.8 mg, 0.03 mmol), Ag_2O (11.6 mg, 0.05 mmol) and **2a** (20.1 mg, 0.1 mmol). The tube was then sealed, and the resulting mixture was stirred at 60 °C under air for 15 min. Afterwards, it was cooled to room temperature, filtered through a pad of celite, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography using hexane/ethyl acetate (5:1) as eluent to afford **3a** (15.6 mg, 38%).

To a reaction tube equipped with a stir bar were charged with **1a-*d*₁** (24.5mg, 0.1 mmol), HFIP (1 mL), $[IrCp^*Cl_2]_2$ (1.2 mg, 0.0015 mmol), Cs_2CO_3 (9.8 mg, 0.03 mmol), Ag_2O (11.6 mg, 0.05 mmol) and **2a** (20.1 mg, 0.1 mmol). The tube was then sealed, and the resulting mixture was stirred at 60 °C under air for 15 min. Afterwards,, it was cooled to room temperature, filtered through a pad of celite and concentrated under reduced pressure. The residue was purified by silica gel column chromatography using hexane/ethyl acetate (5:1) as eluent to afford **3a** (6.4 mg, 15%).

Based on these results, a kinetic isotope effect (KIE) value of 2.5 was obtained, indicating that the C−H bond cleavage process is most likely involved in the rate-determining step(s).

3. Electronic competition experiment



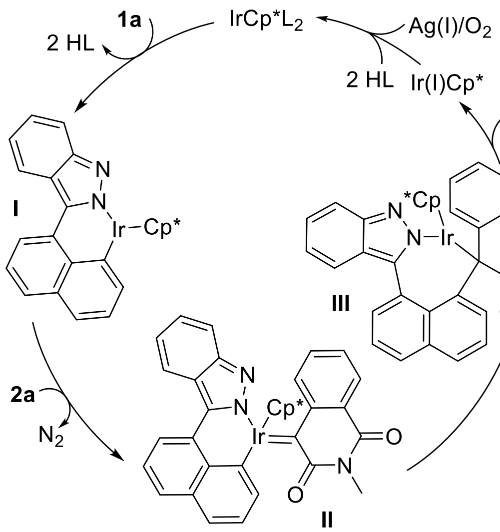
To a reaction tube equipped with a stir bar were added **1c** (27.4 mg, 0.1 mmol), HFIP (1 mL), $[IrCp^*Cl_2]_2$ (1.2 mg, 0.0015 mmol), Cs_2CO_3 (9.8 mg, 0.03 mmol), Ag_2O (11.6 mg, 0.05 mmol) and **2a** (20.1 mg, 0.1 mmol). The tube was then sealed, and the resulting mixture was stirred at 100 °C under air for 10 min. Afterwards, it was cooled to room temperature, filtered through a pad of celite, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography using hexane/ethyl acetate (5:1) as eluent to afford **3c** (20.3 mg, 46%).

To a reaction tube equipped with a stir bar were added **1e** (26.2 mg, 0.1 mmol), HFIP (1 mL), $[IrCp^*Cl_2]_2$ (1.2 mg, 0.0015 mmol), Cs_2CO_3 (9.8 mg, 0.03 mmol), Ag_2O (11.6 mg, 0.05 mmol) and **2a** (20.1 mg, 0.1 mmol). The tube was then sealed, and the resulting mixture was stirred at 100 °C under air for 10 min. Afterwards, it was cooled to room temperature, filtered through a pad of celite, and concentrated under reduced pressure. The residue was purified by silica gel column chromatography using hexane/ethyl acetate (5:1) as eluent to afford **3e** (13.6 mg, 31%).

The above-described electronic competing experiments showed that an electron-donating methoxy group substituted substrate **1c** reacted with **2a** 1.5 times faster than an electron-withdrawing fluoro group substituted substrate **1e**. This result likely suggests an electrophilic C–H bond activation process.

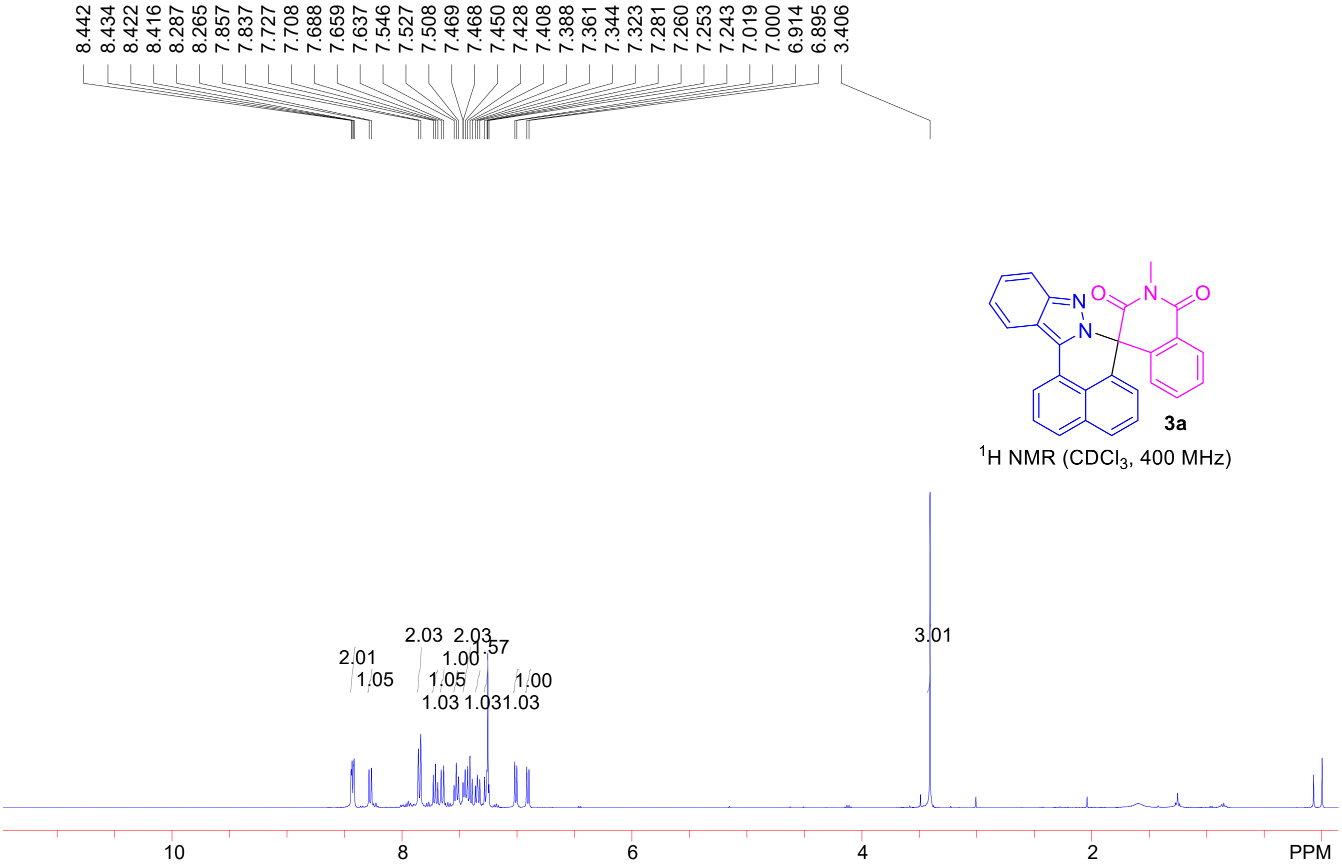
4. Proposed mechanism for the formation of 3a

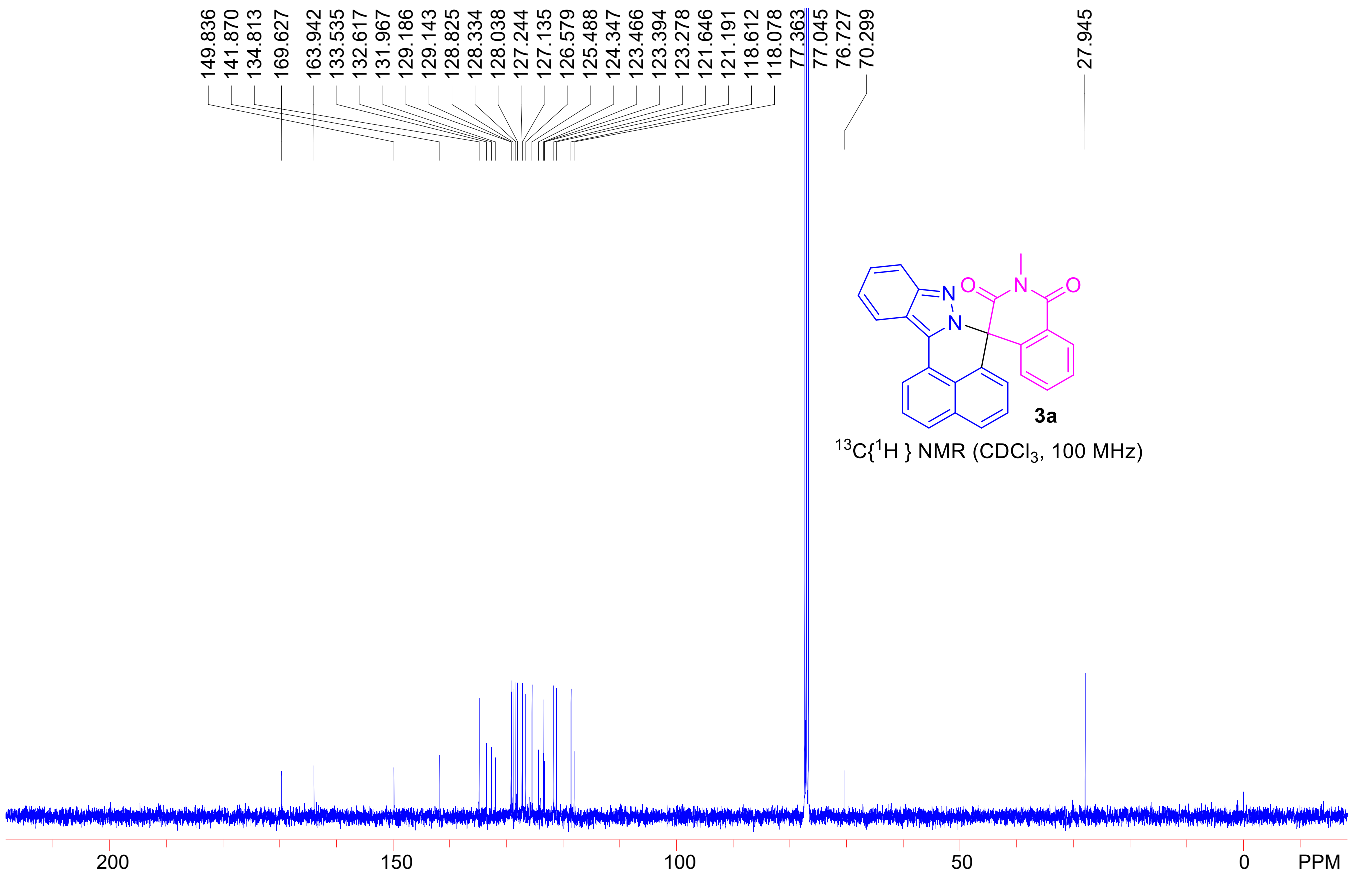
Based on the above mentioned preliminary mechanistic studies, a tentative pathway accounting for the formation of **3a** was proposed as follows. Initially, Ir(III) reacts with **1a** to furnish a five-membered iridacycle species **I** *via* C−H/N−H bond metalation. The following reaction of intermediate **I** with **2a** gives a carbene intermediate **II** through an extrusion of N_2. Next, α-migratory insertion occurs with **II** to deliver intermediate **III**. The subsequent reductive elimination occurs with **III** to release product **3a**. Meanwhile, the *in situ* generated Ir(I) species is oxidized back to Ir(III) by Ag(I) and O_2 to complete the catalytic cycle. By the way, the formation of product **5a** from the reaction of **1a** with **4a** should follow a similar pathway.

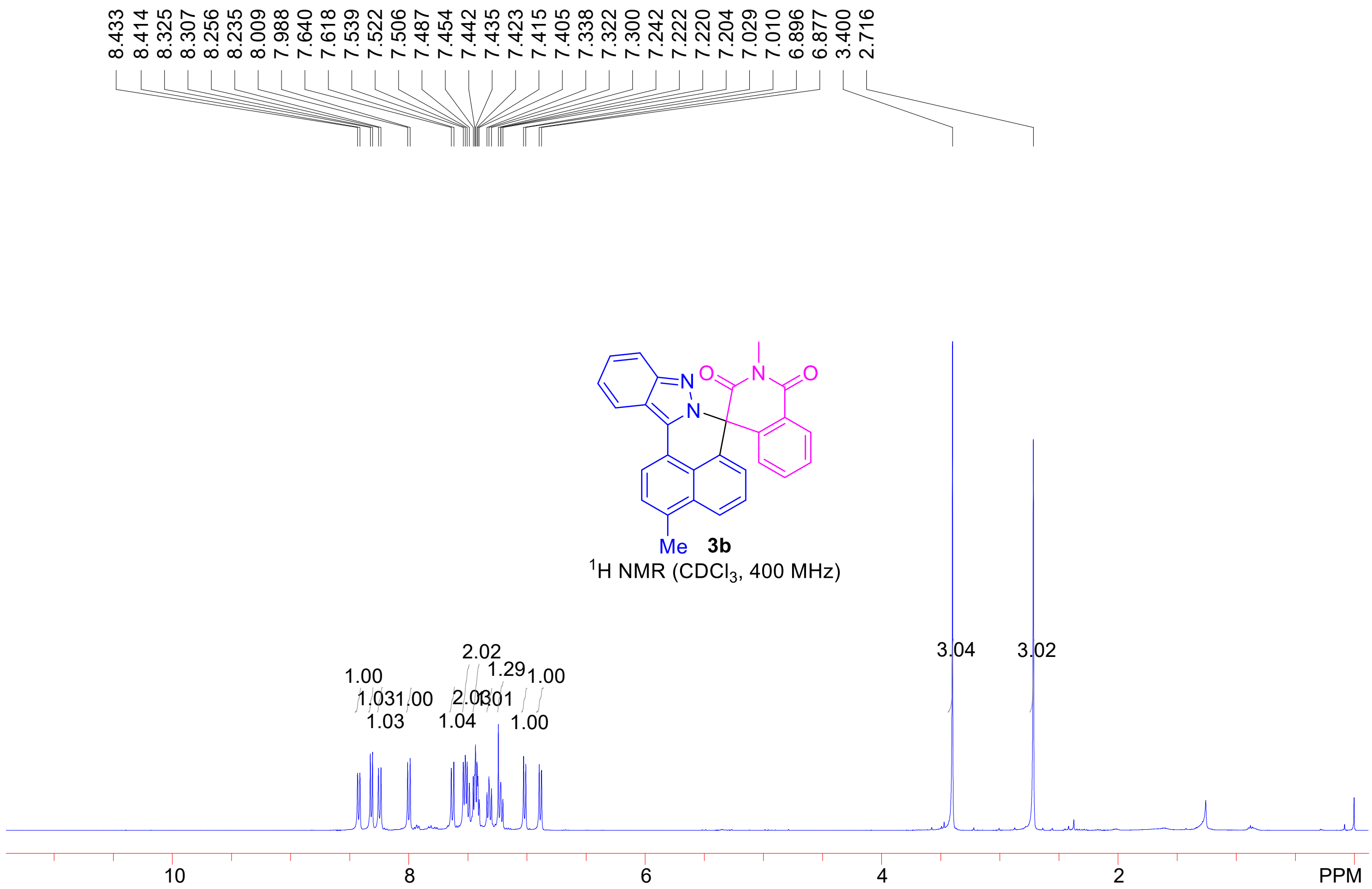


Plausible Mechanism Accounting for the Formation of **3a**

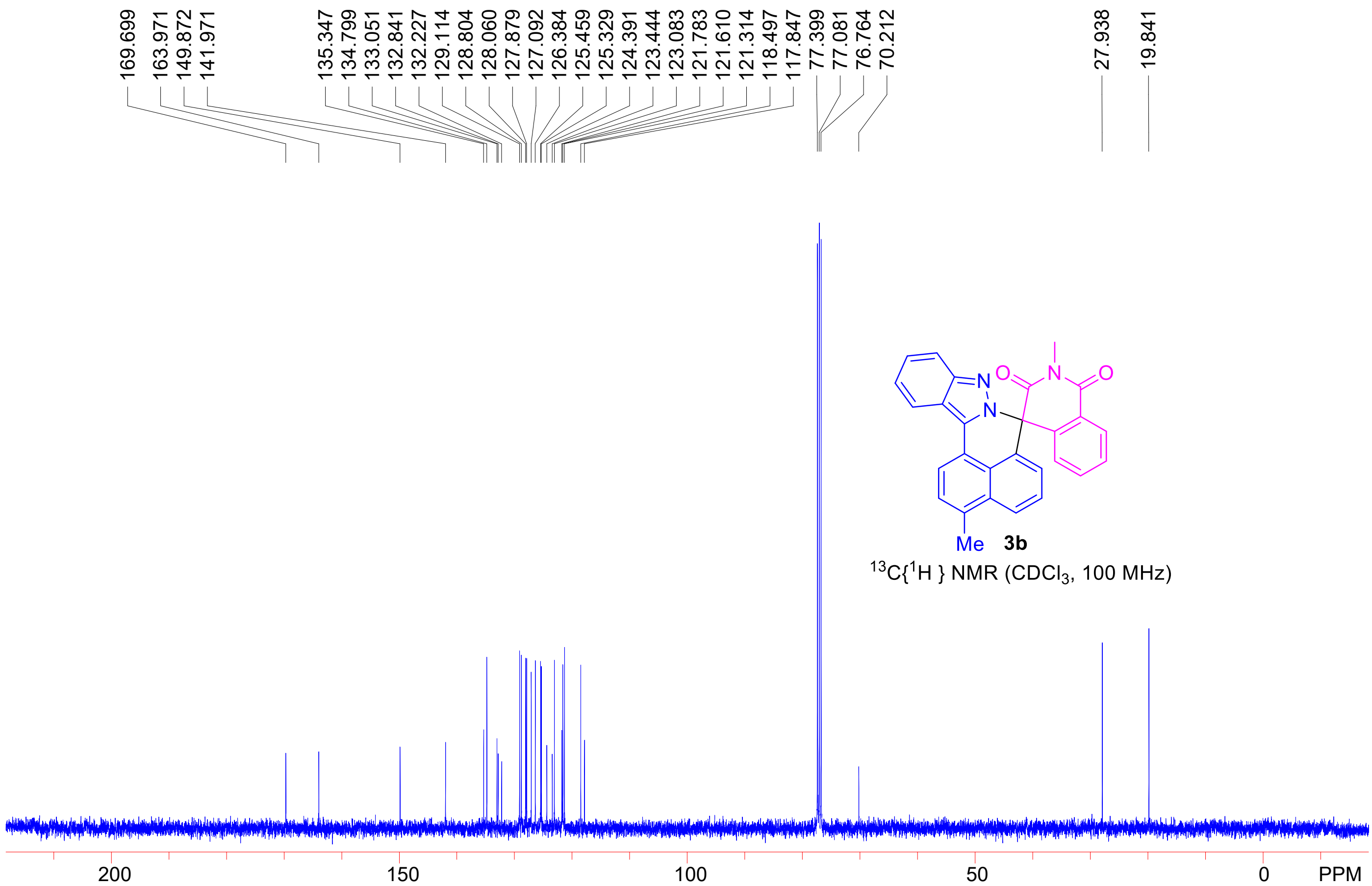
IV. NMR spectra of 3a-3gg



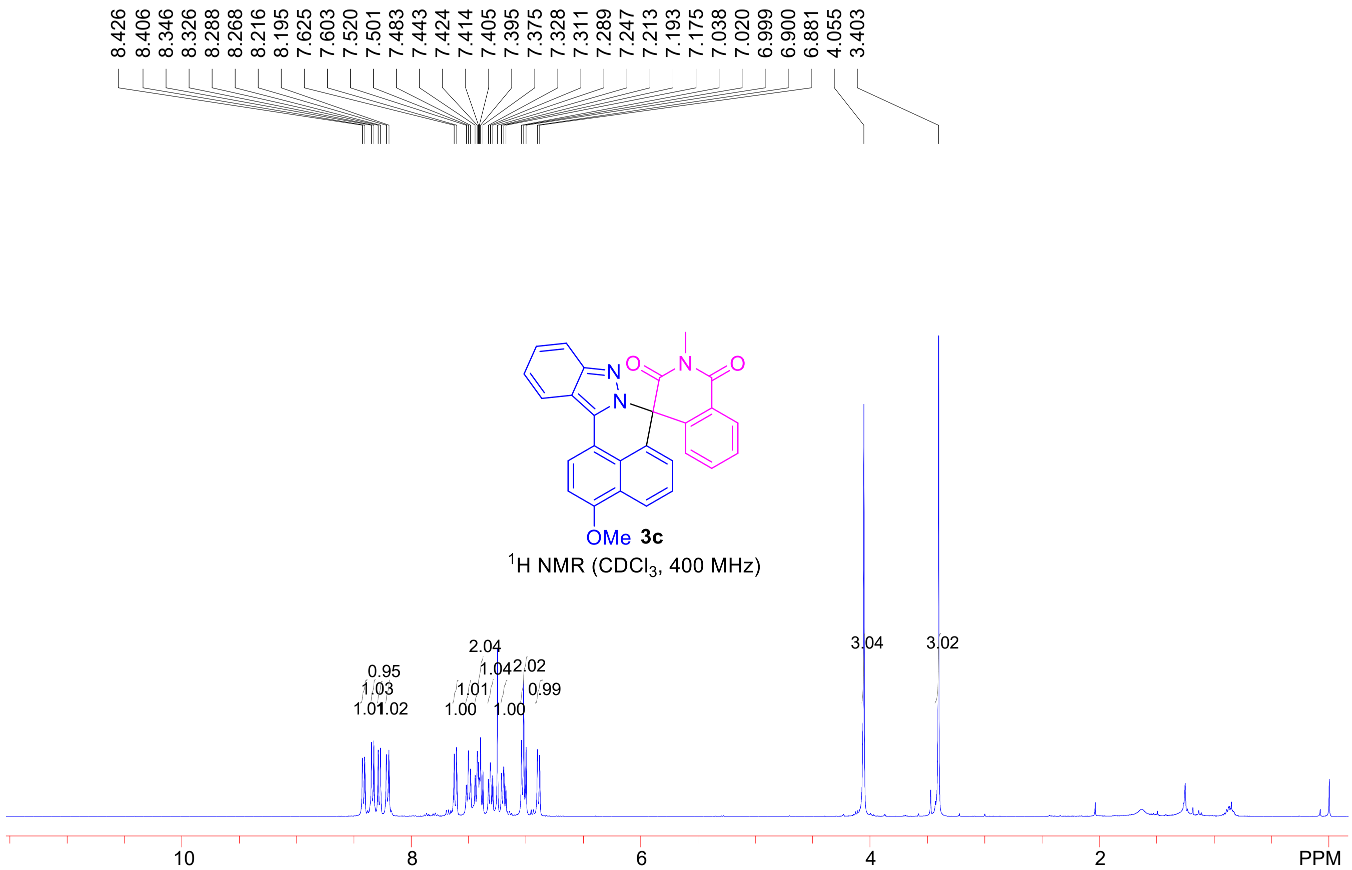




^{1}H NMR (CDCl$_3$, 400 MHz)



^{13}C{^{1}H } NMR (CDCl$_3$, 100 MHz)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OMe 3c
1H NMR (CDCl3, 400 MHz)
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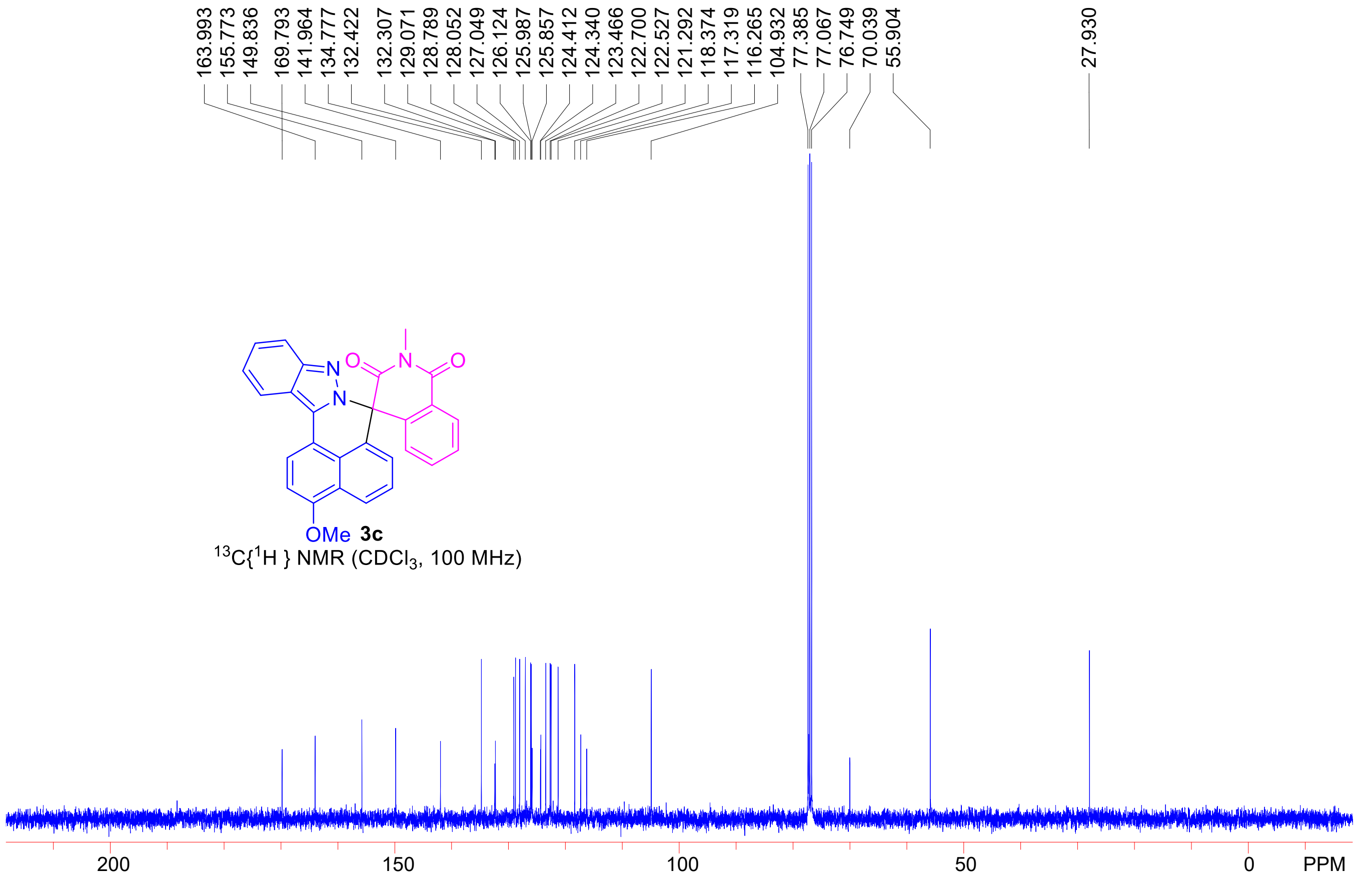
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OMe 3c
13C{1H } NMR (CDCl3, 100 MHz)
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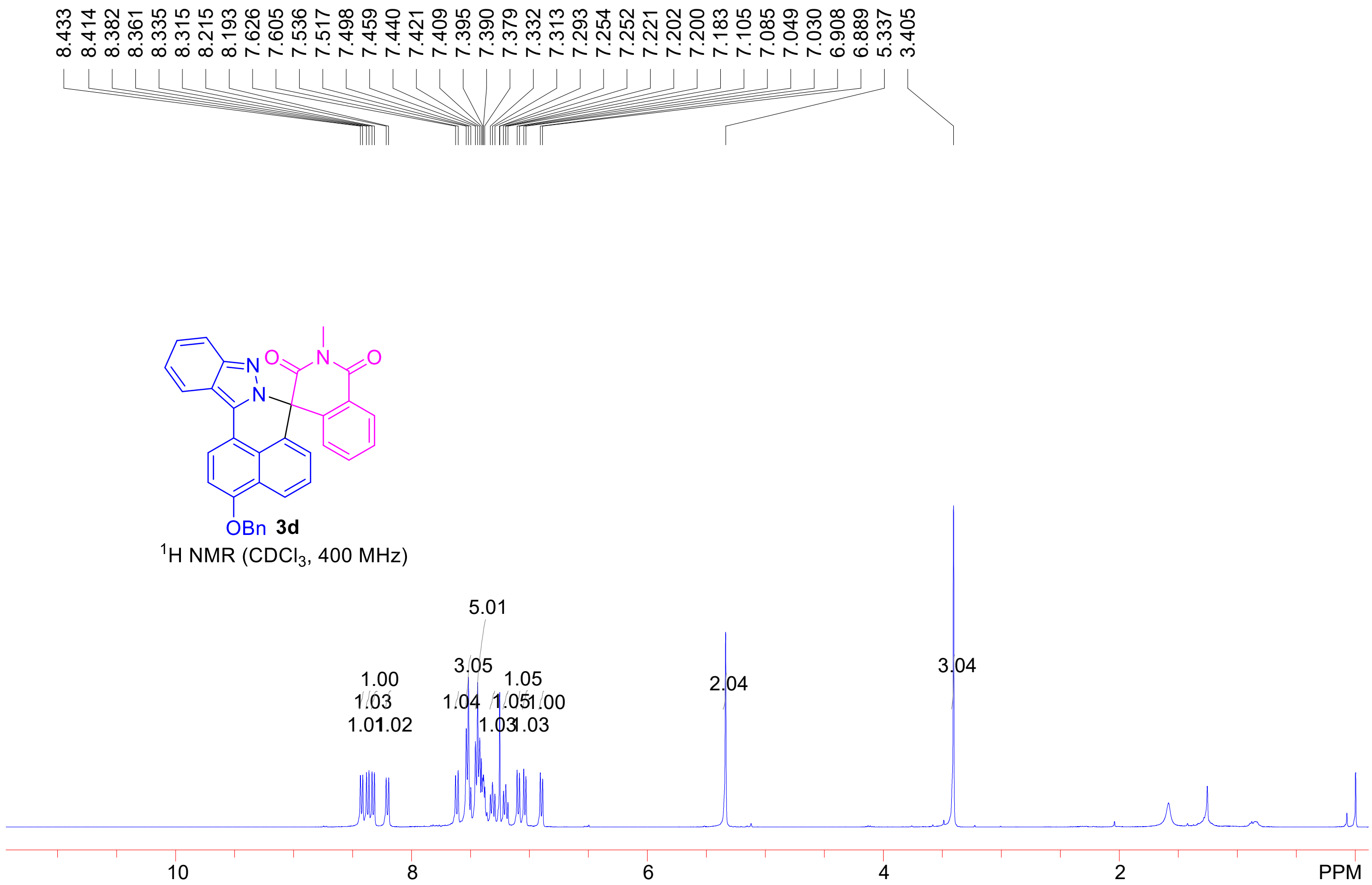
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N
N
O
N
O
OBn 3d
1H NMR (CDCl3, 400 MHz)
5.01
3.05
1.00
1.03
1.01 1.02
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1.05
1.05 1.00
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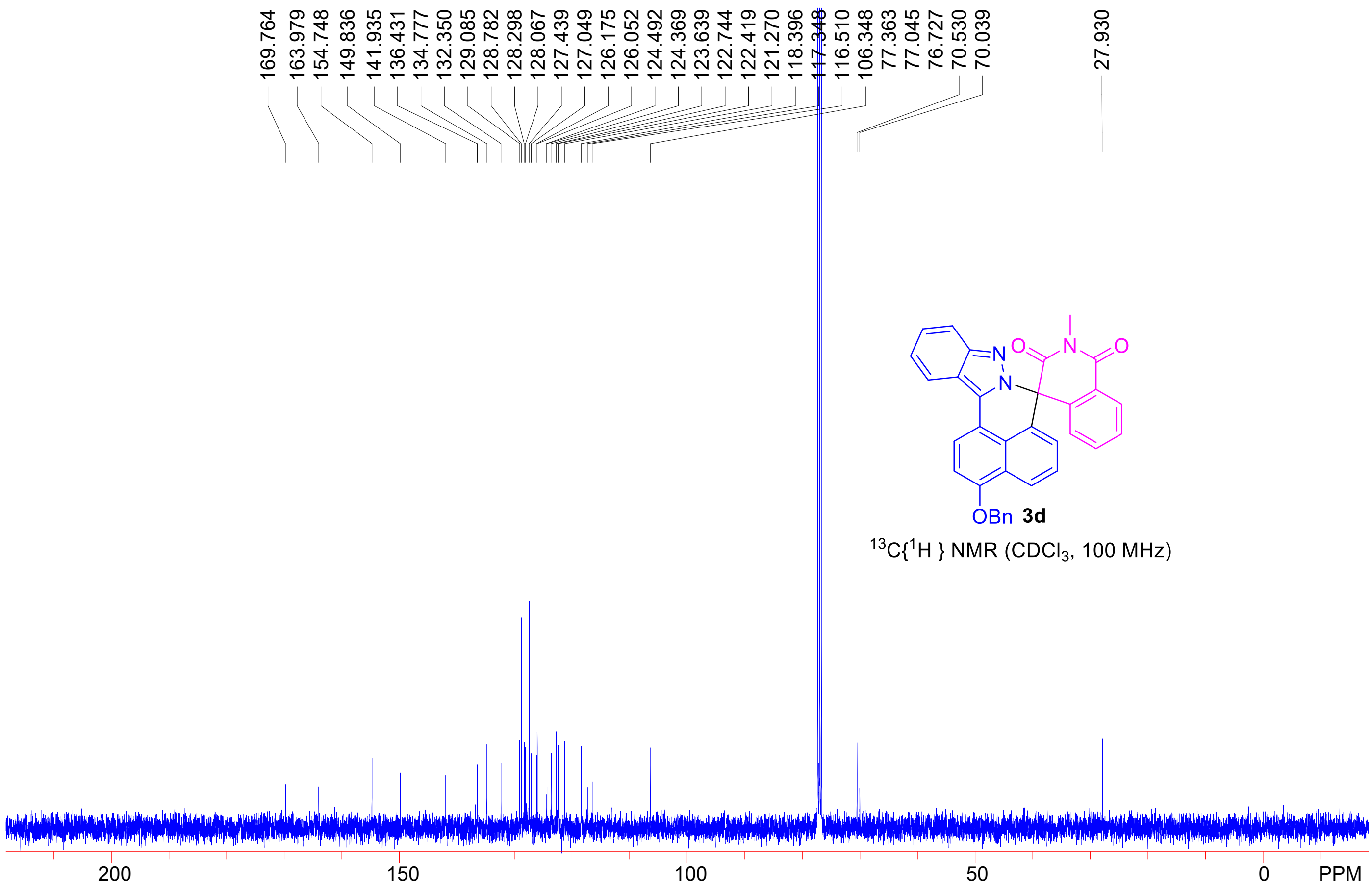
6
4
2
PPM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27.930
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O
N
O
OBn 3d
13C{1H } NMR (CDCl3, 100 MHz)
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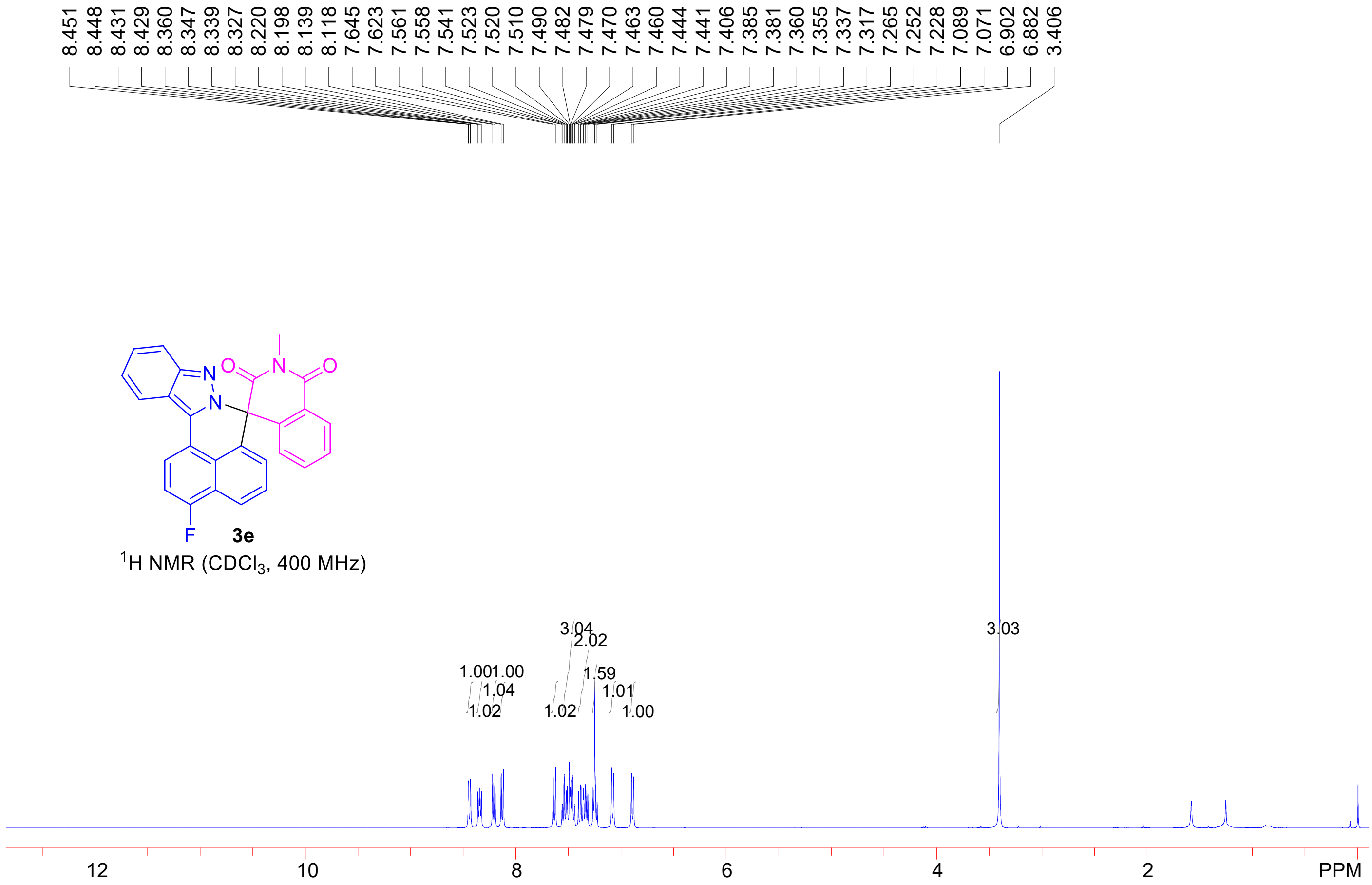
150
100
50
0
PPM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N
N
O
N
O
F
3e
1H NMR (CDCl3, 400 MHz)
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12
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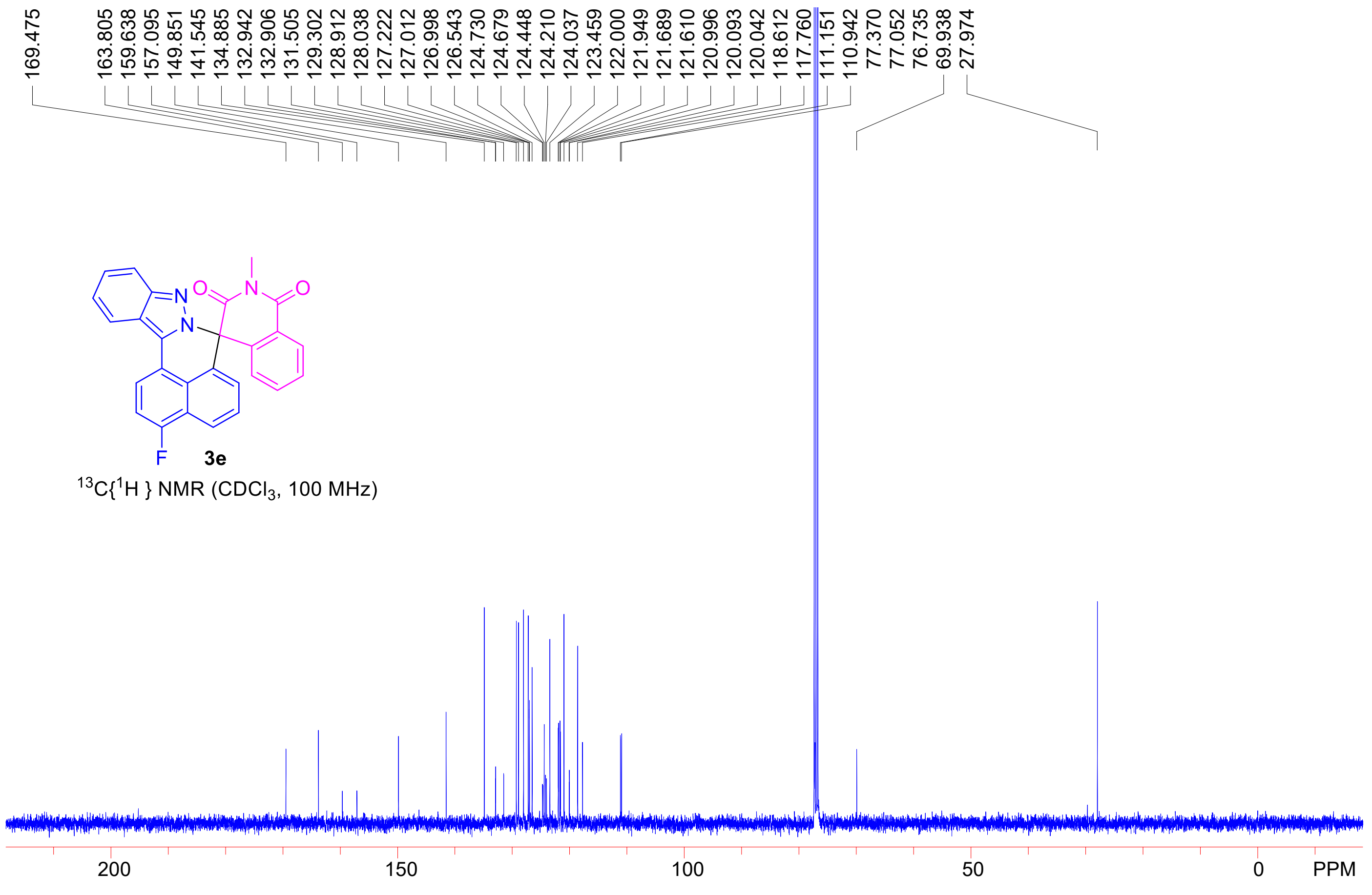
8
6
4
2
PPM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N
N
O
N
O
F
3e
13C{1H } NMR (CDCl3, 100 MHz)
200
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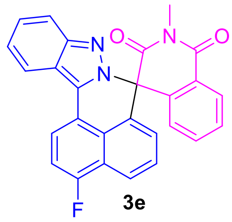
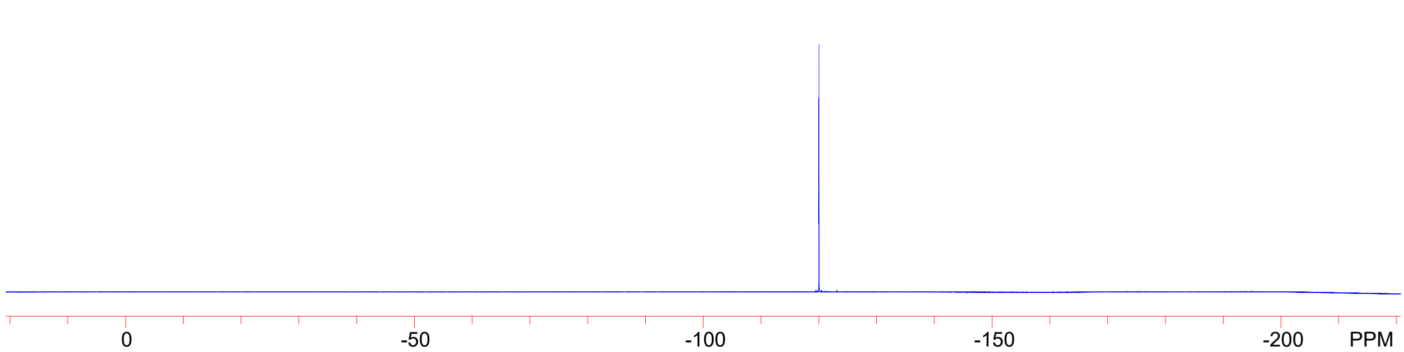
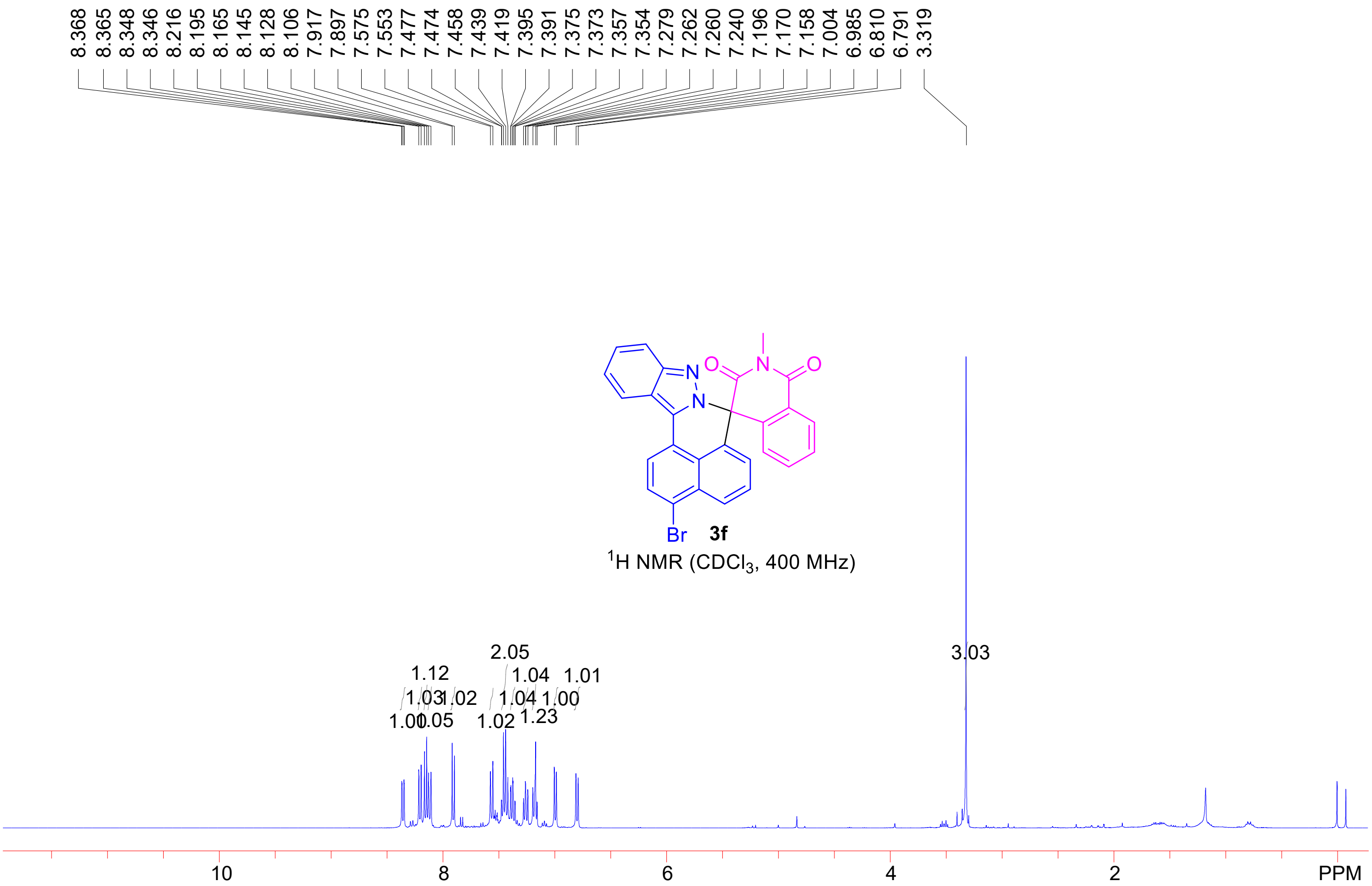
100
50
0
PPM



3e

^{19}F NMR ($CDCl_3$, 376 MHz)





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6.810
6.791
3.319
Br 3f
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1.04
1.01
1.03
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2
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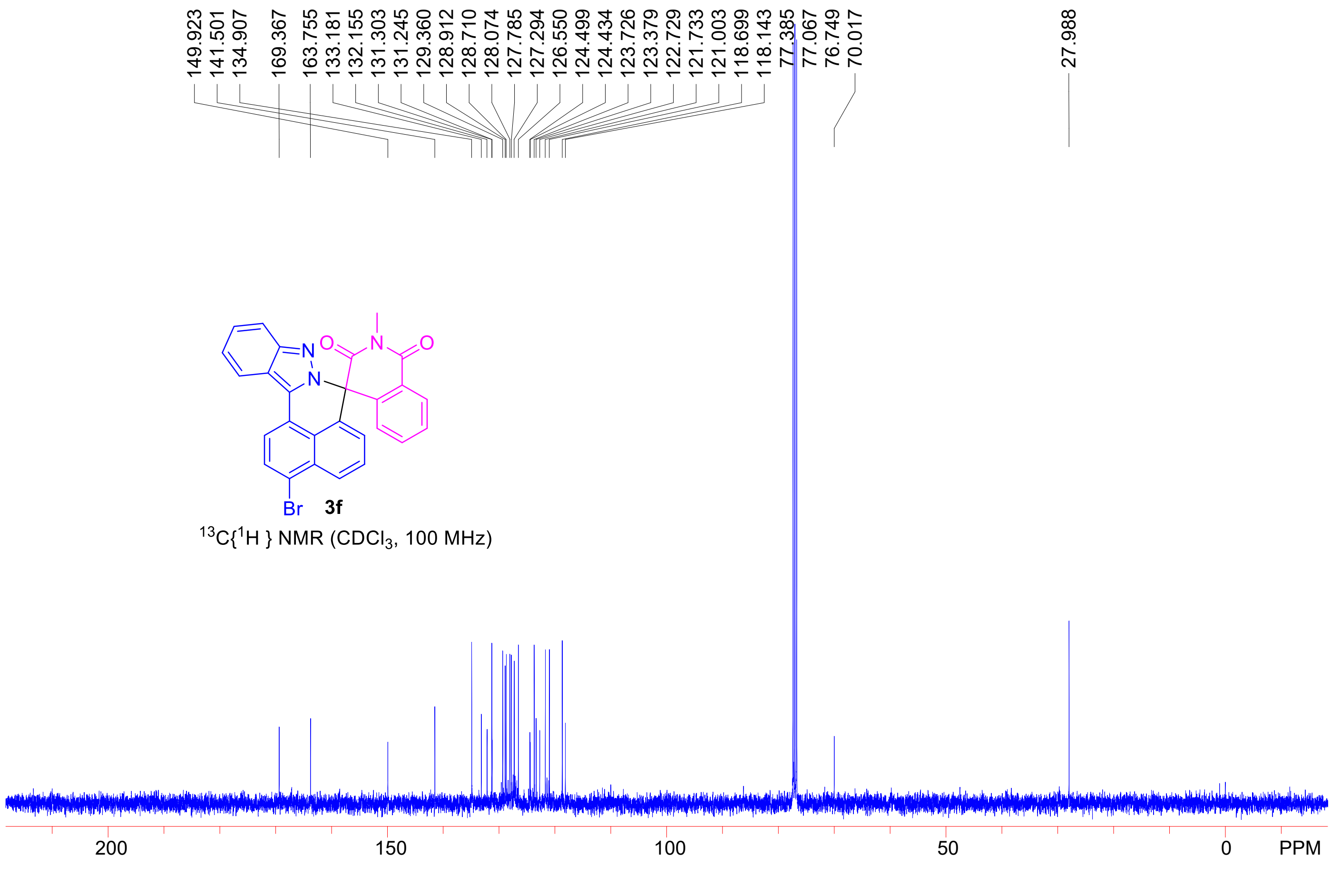

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122.729
121.733
121.003
118.699
118.143
77.385
77.067
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70.017
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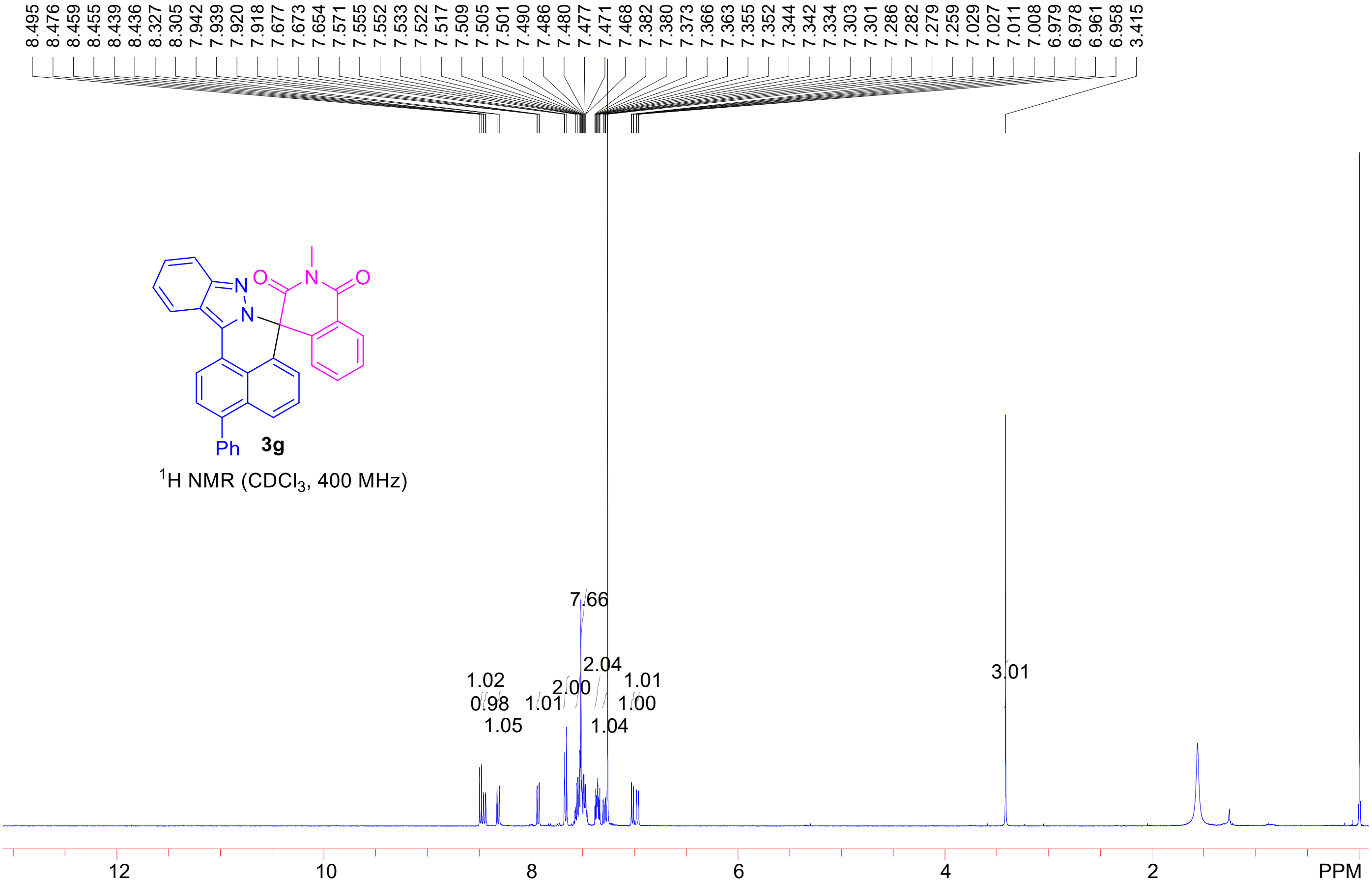
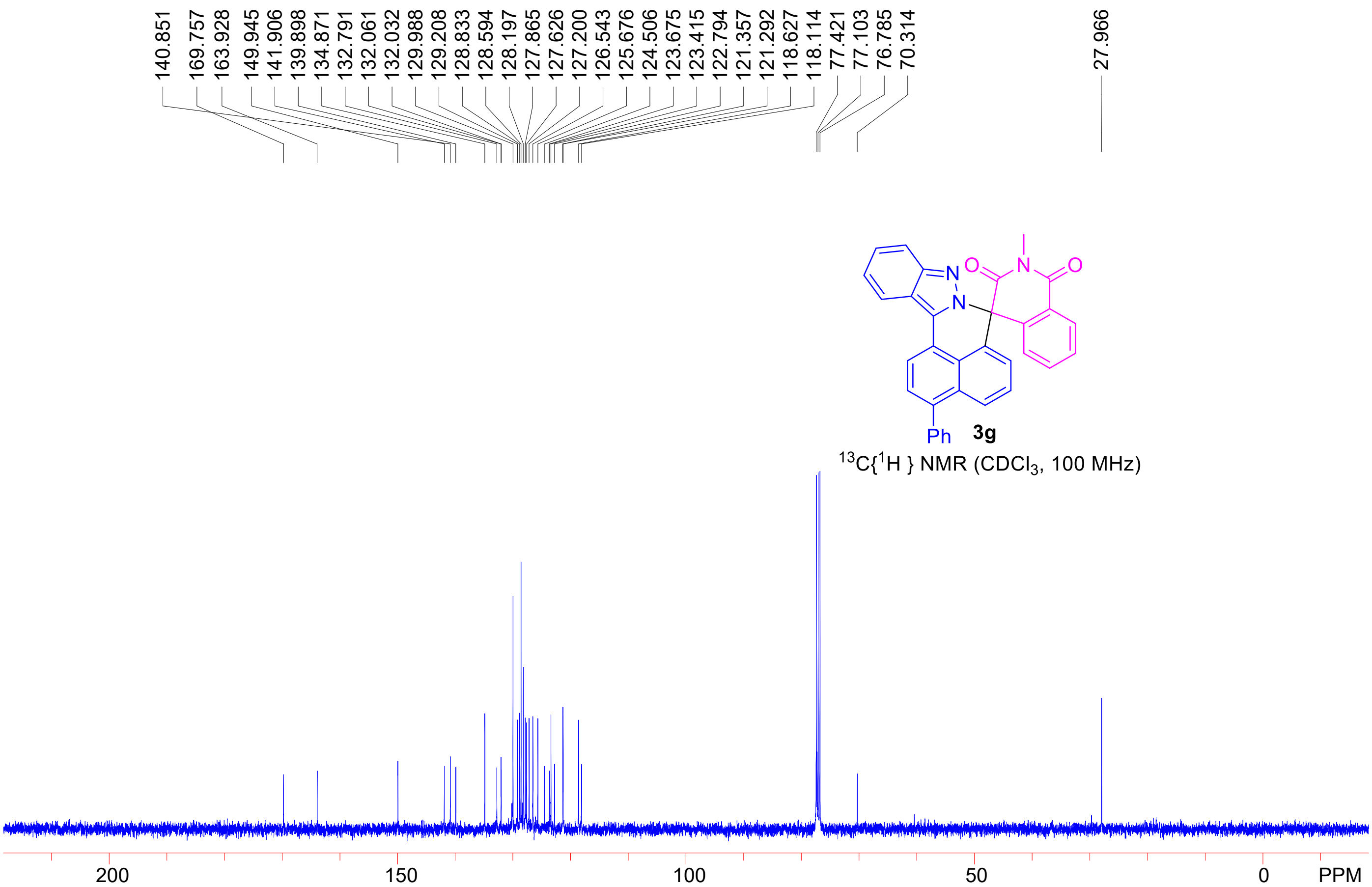
Br 3f
$^{13}C\{^1H\}$ NMR ($CDCl_3$, 100 MHz)
200
150
100
50
0
PPM



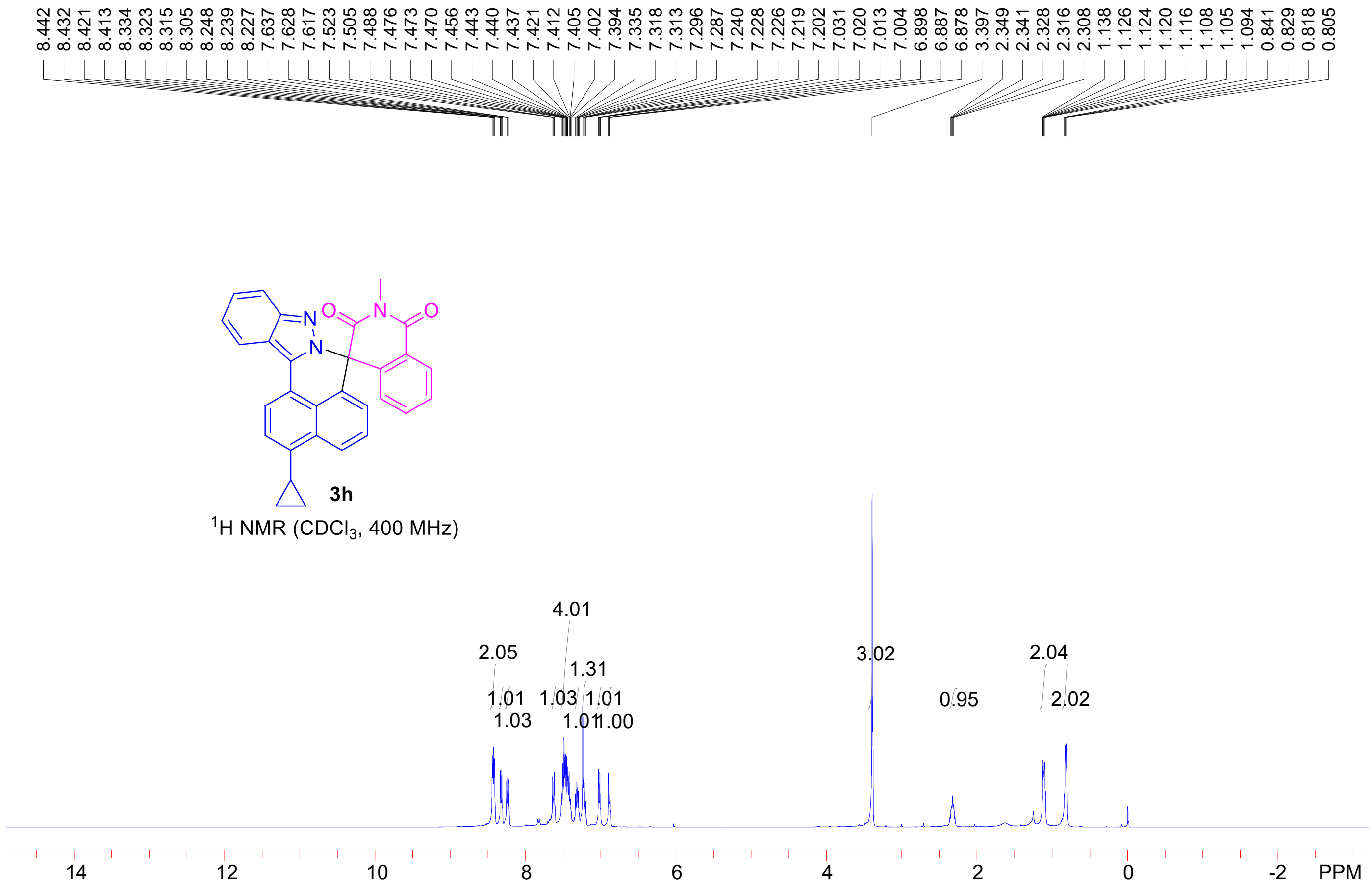
3g

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



3g

$^{13}C\{^1H\}$ NMR ($CDCl_3$, 100 MHz)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3h
^{1}H NMR (CDCl$_3$, 400 MHz)
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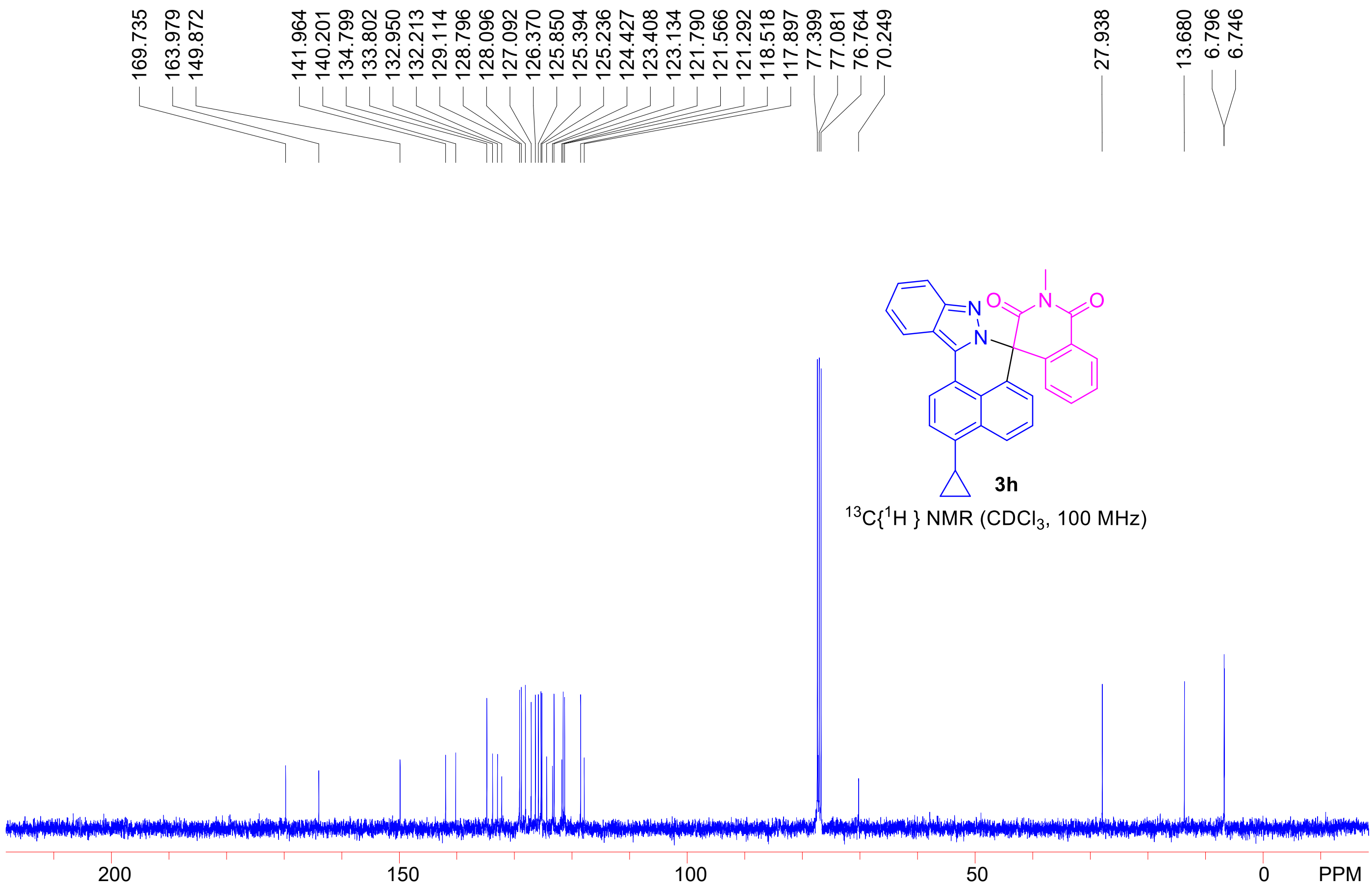
14 12 10 8 6 4 2 0 -2 PPM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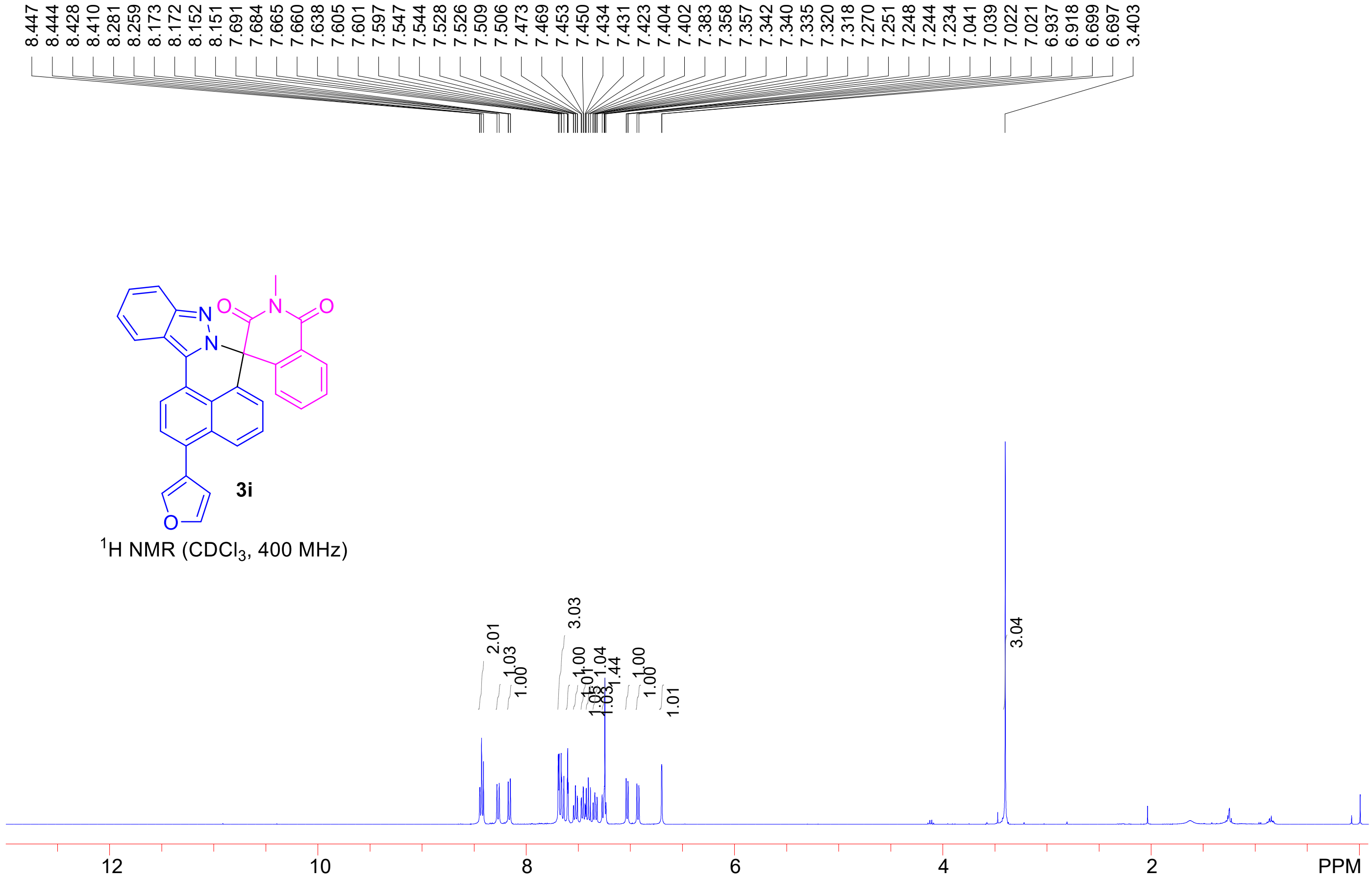
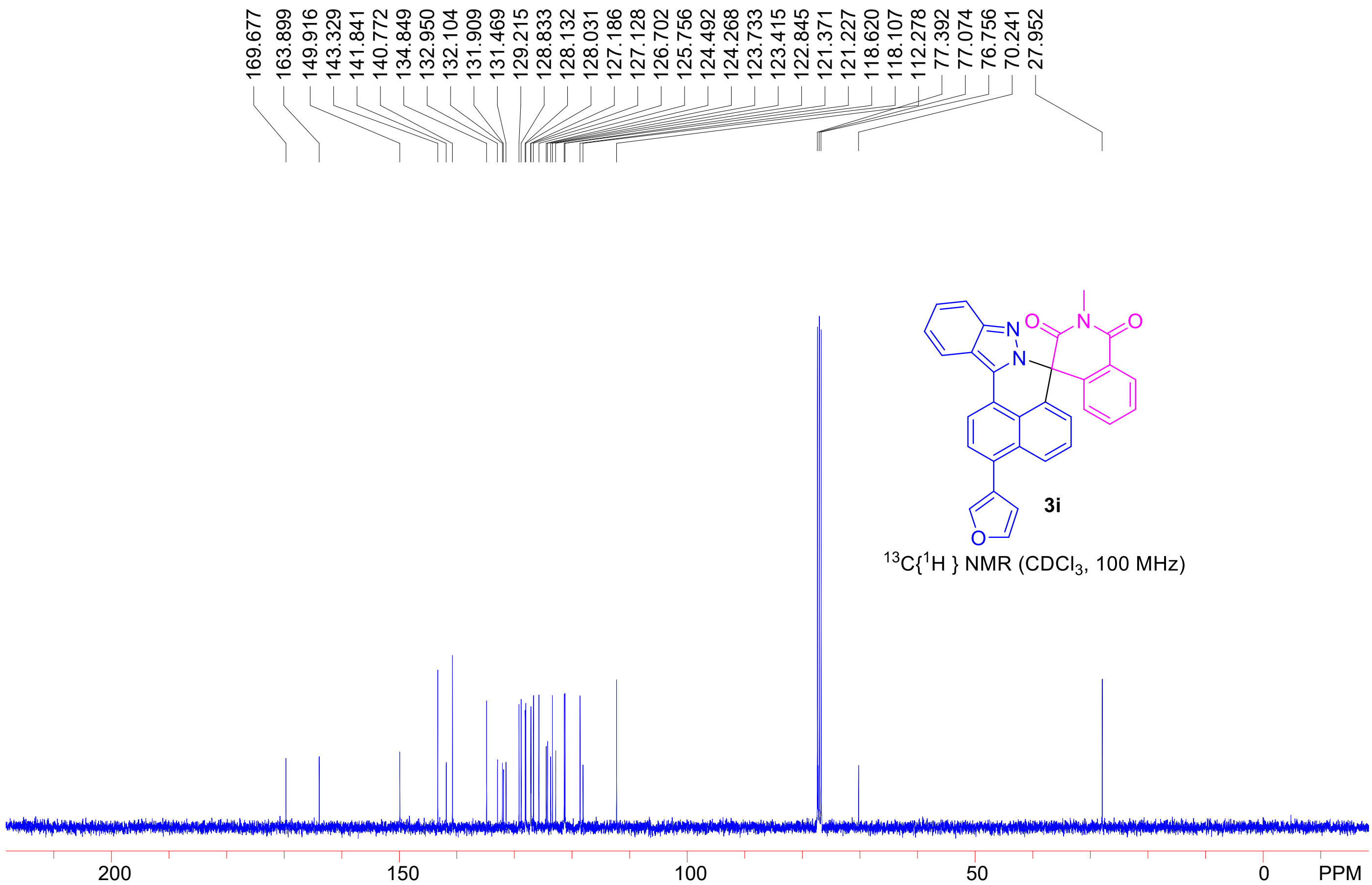


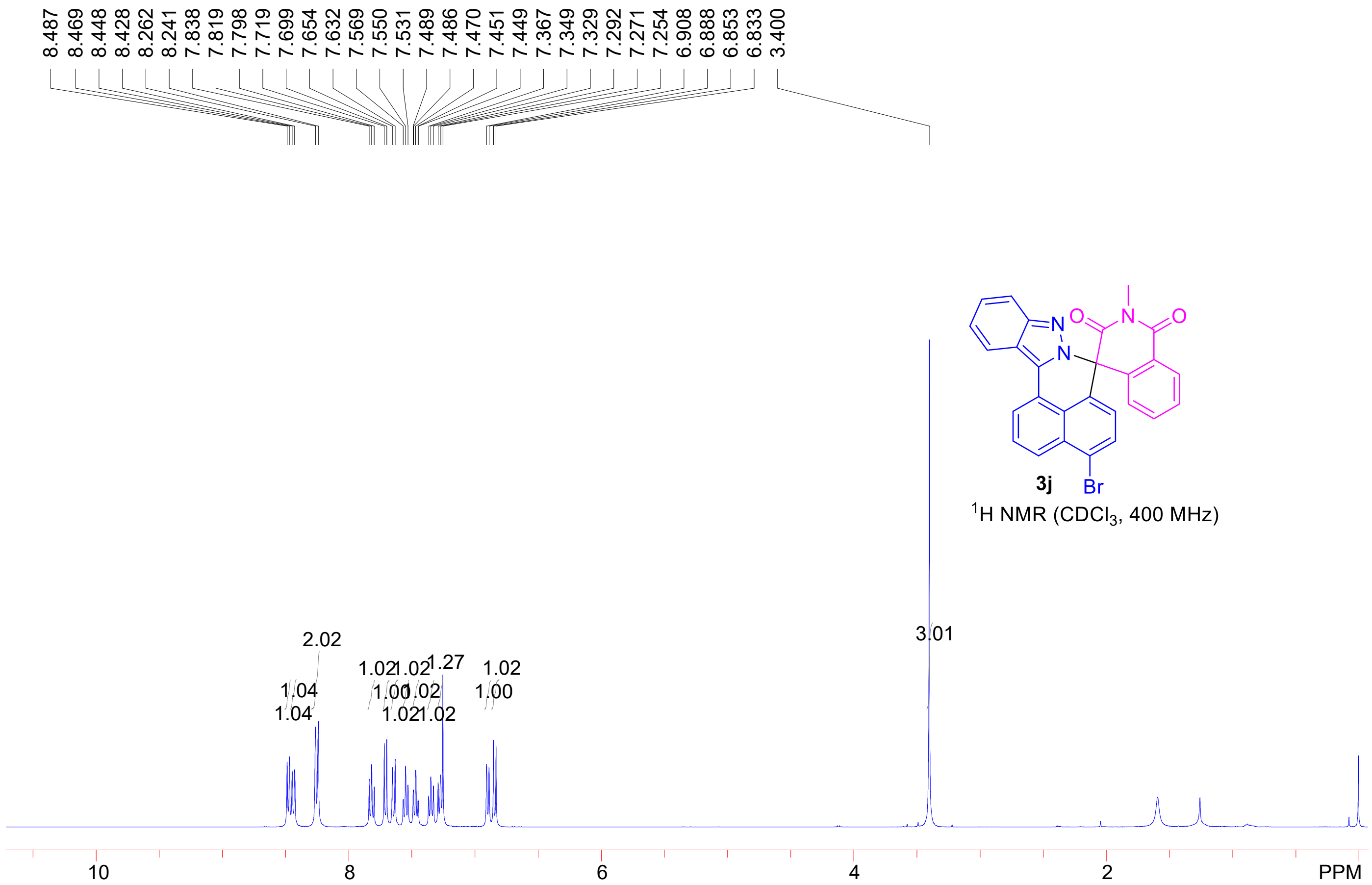
3i

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



3i

$^{13}C\{^1H\}$ NMR ($CDCl_3$, 100 MHz)



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6.833
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3j
Br
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1.02
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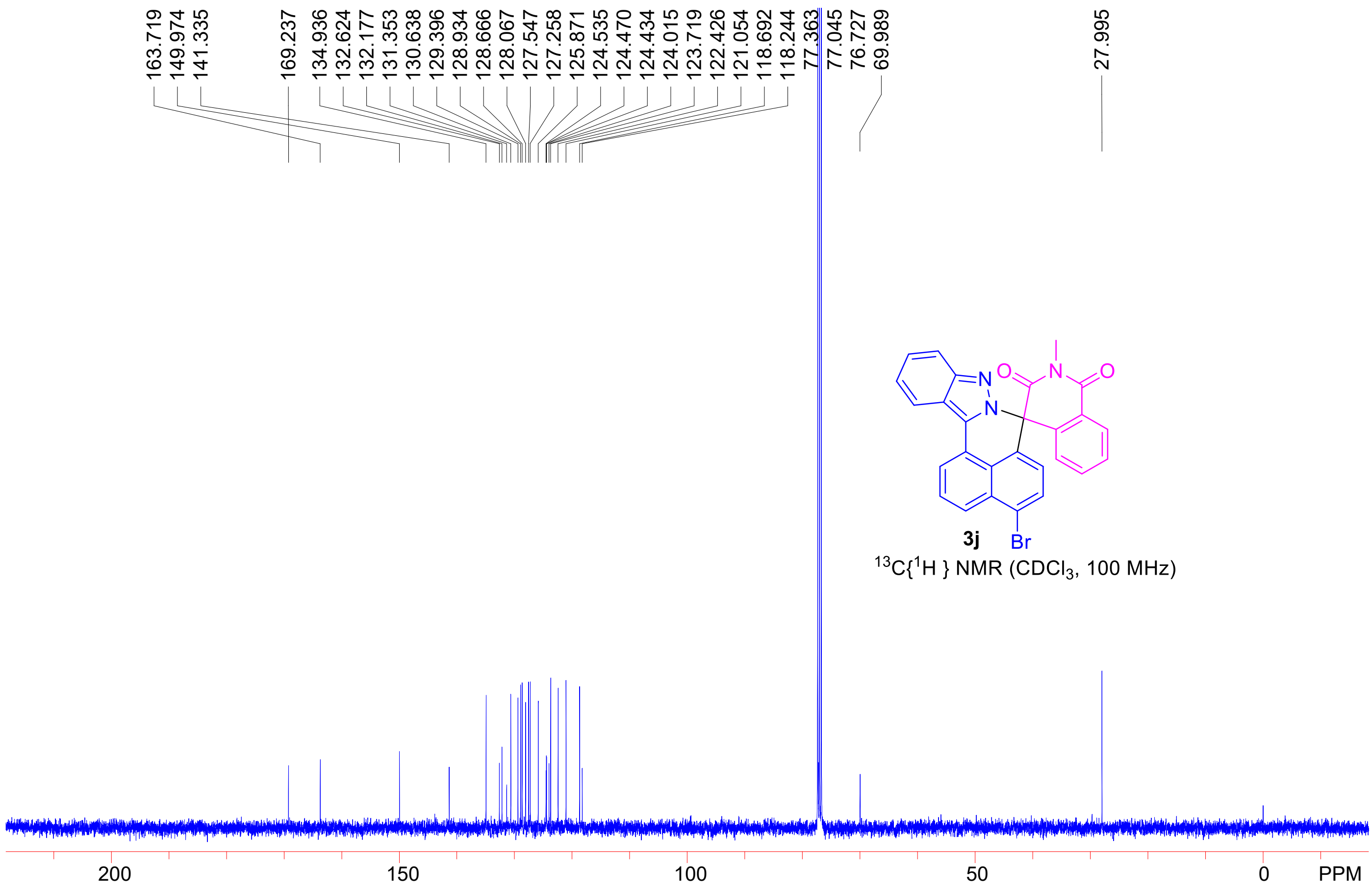
PPM



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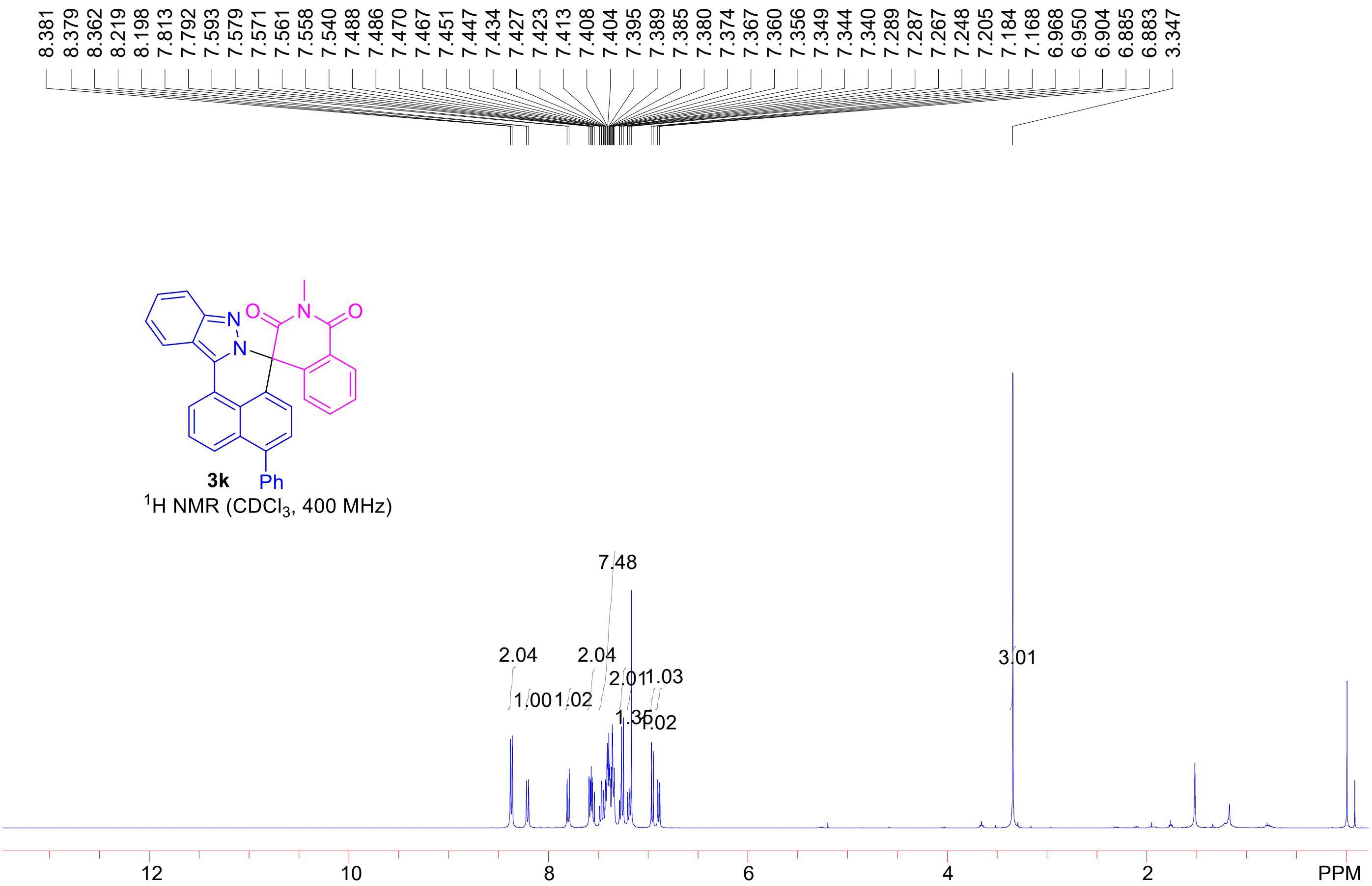
27.995
3j
Br
$^{13}C\{^1H\}$ NMR ($CDCl_3$, 100 MHz)
200
150
100
50
0
PPM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7.813
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7.593
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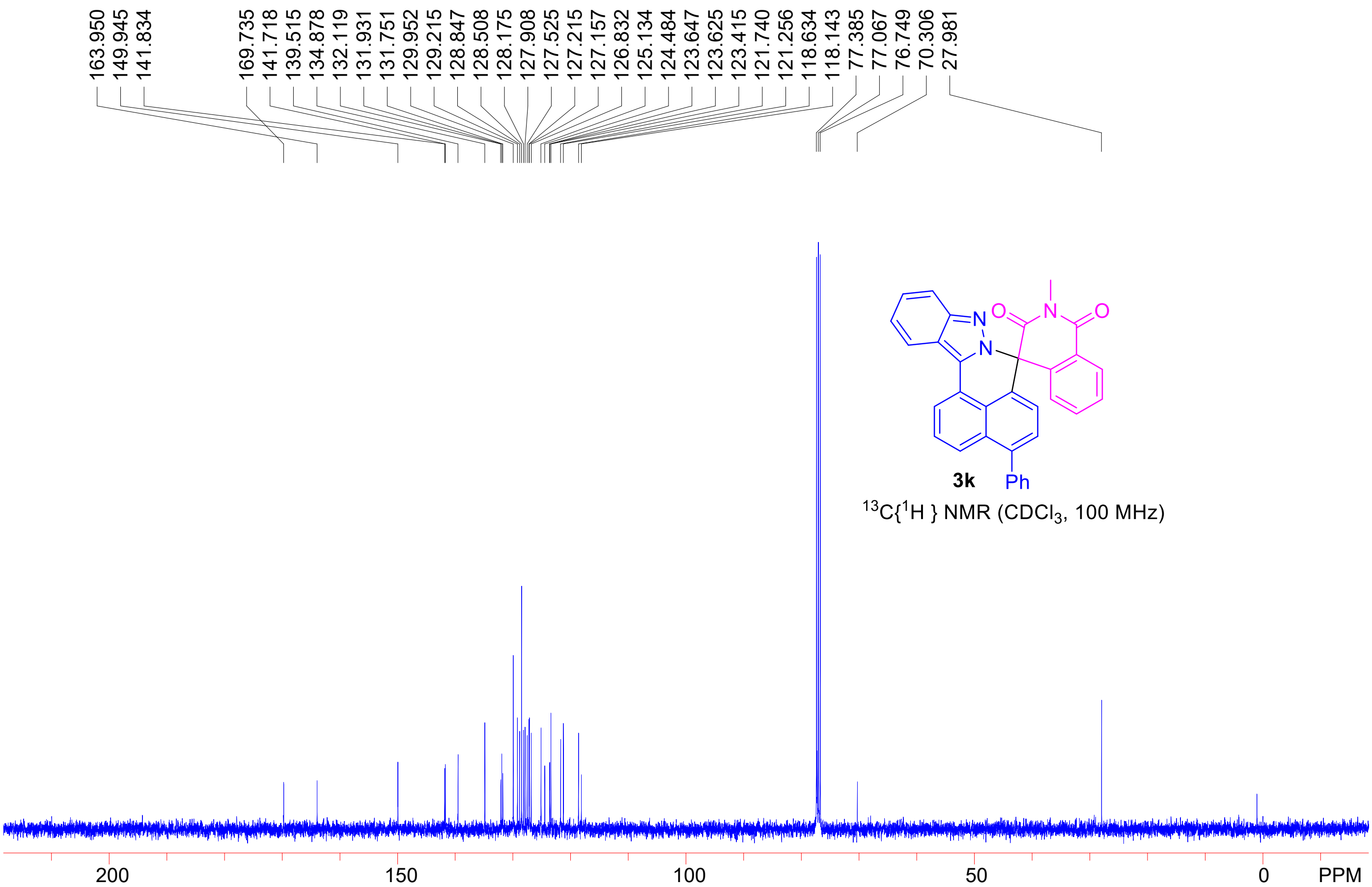
7.571
7.561
7.558
7.540
7.488
7.486
7.470
7.467
7.451
7.447
7.434
7.427
7.423
7.413
7.408
7.404
7.395
7.389
7.385
7.380
7.374
7.367
7.360
7.356
7.349
7.344
7.340
7.289
7.287
7.267
7.248
7.205
7.184
7.168
6.968
6.950
6.904
6.885
6.883
3.347
3k
Ph
^{1}H NMR (CDCl$_3$, 400 MHz)
7.48
2.04
2.04
2.01
1.03
1.00
1.02
1.35
1.02
3.01
12
10
8
6
4
2
PPM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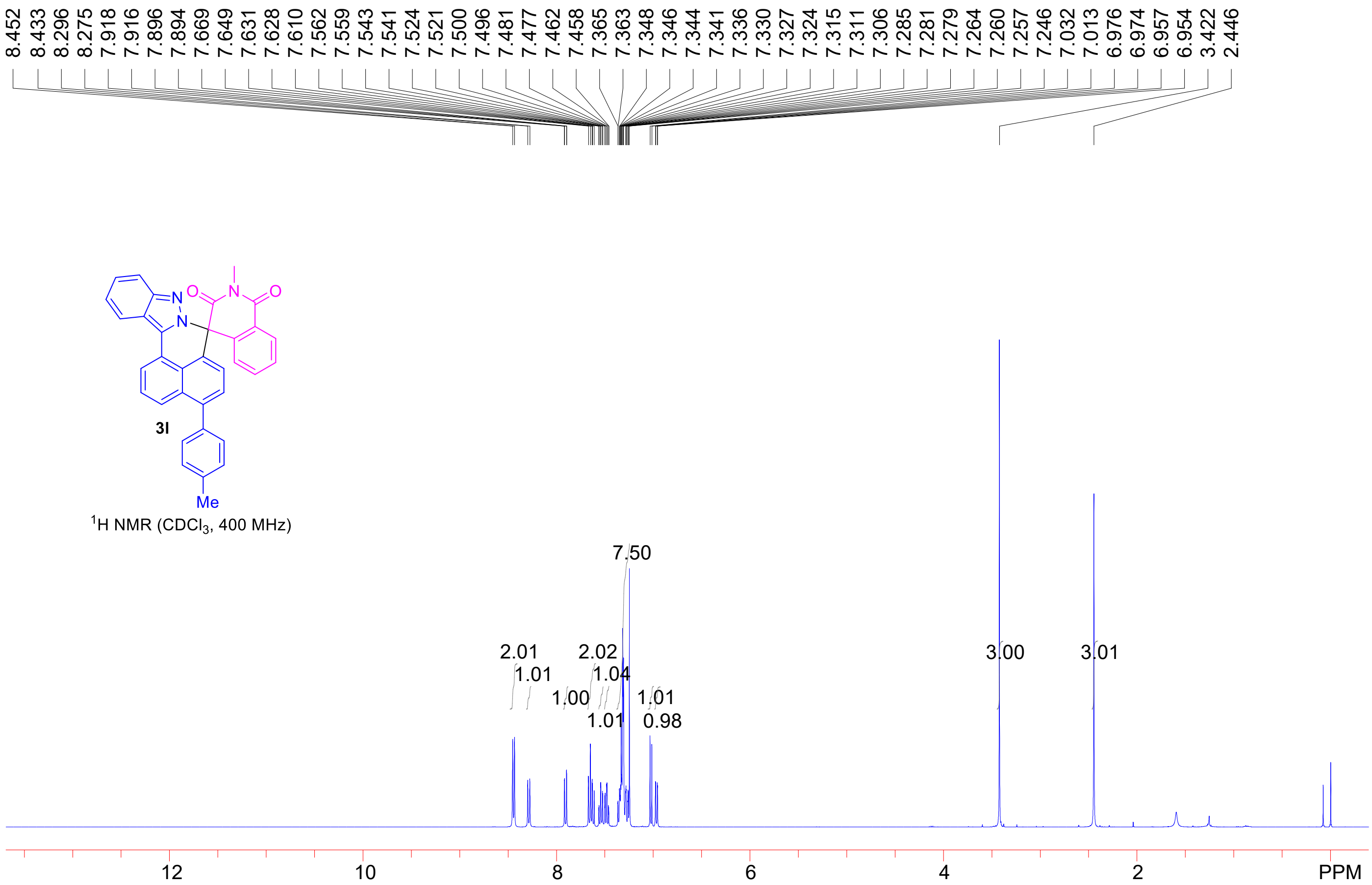
149.945
141.834
169.735
141.718
139.515
134.878
132.119
131.931
131.751
129.952
129.215
128.847
128.508
128.175
127.908
127.525
127.215
127.157
126.832
125.134
124.484
123.647
123.625
123.415
121.740
121.256
118.634
118.143
77.385
77.067
76.749
70.306
27.981
3k
Ph
^{13}C{^{1}H } NMR (CDCl$_3$, 100 MHz)
200
150
100
50
0
PPM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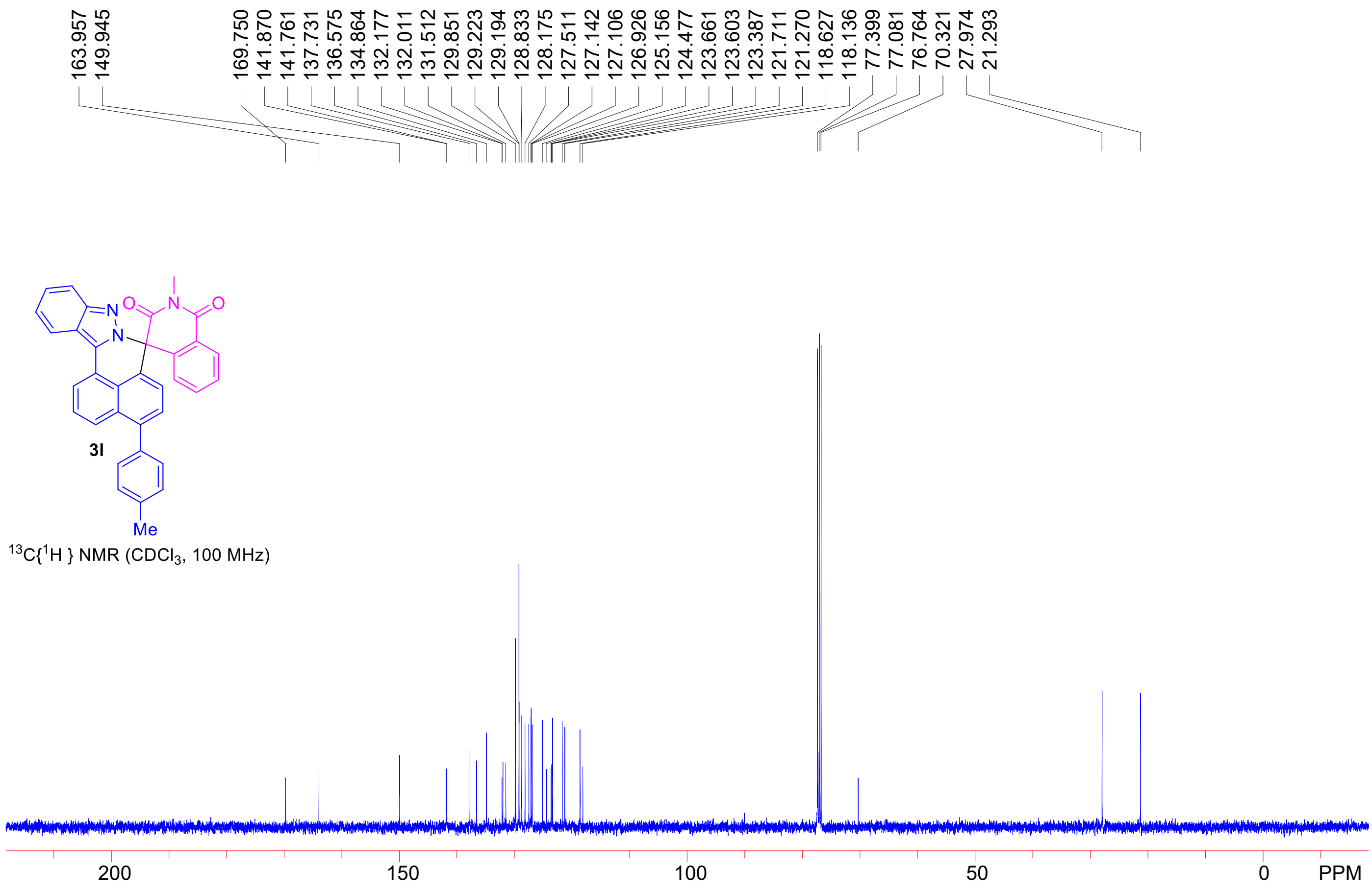
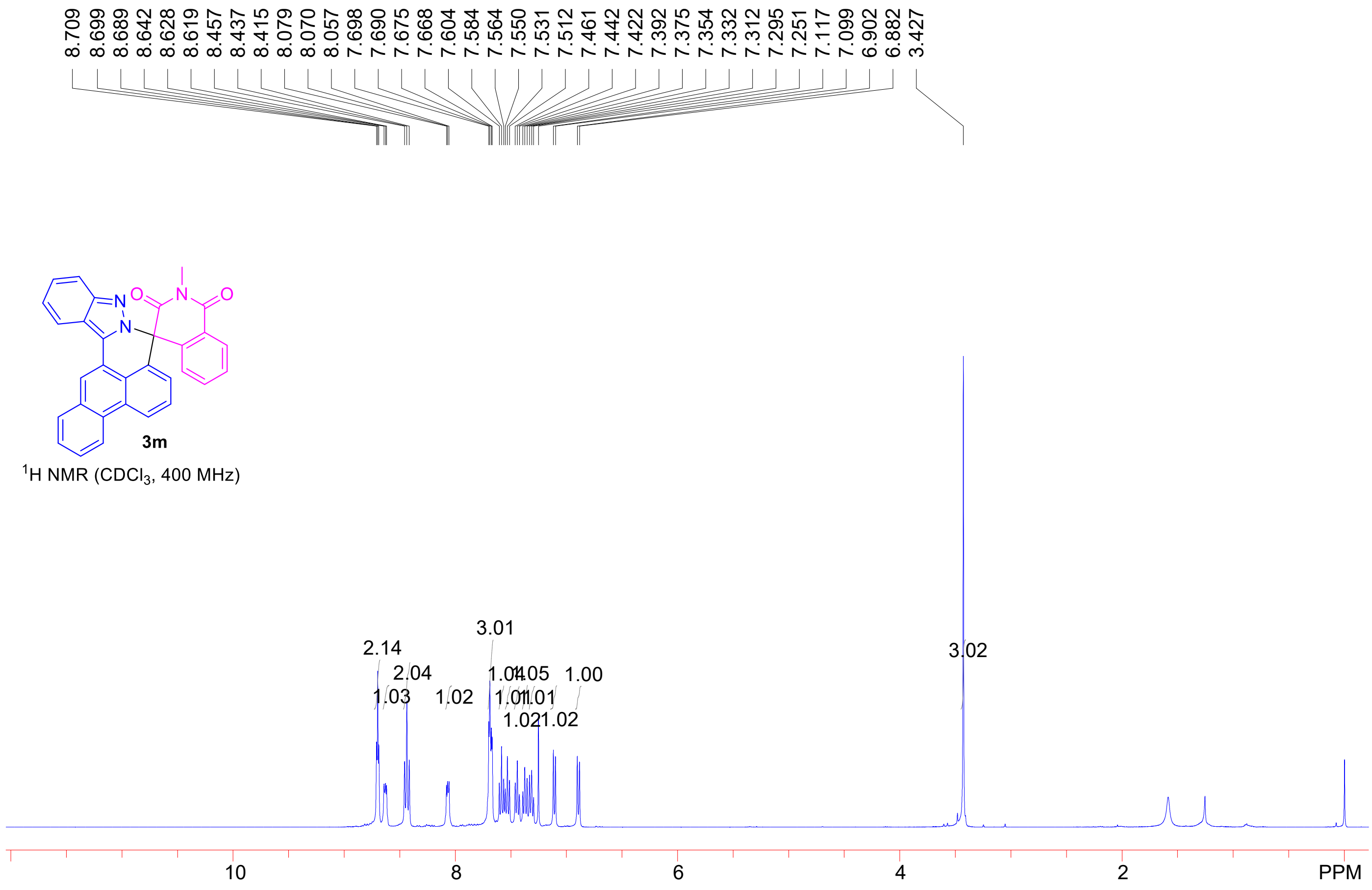
3l
Me
1H NMR (CDCl3, 400 MHz)
7.50
2.01
1.01
1.00
2.02
1.04
1.01
1.01
0.98
3.00
3.01
12
10
8
6
4
2
PPM


163.957 149.945 169.750 141.870 141.761 137.731 136.575 134.864 132.177 132.011 131.512 129.851 129.223 129.194 128.833 128.175 127.511 127.142 127.106 126.926 125.156 124.477 123.661 123.603 123.387 121.711 121.270 118.627 118.136 77.399 77.081 76.764 70.321 27.974 21.293
3l
Me
13C{1H } NMR (CDCl3, 100 MHz)
200
150
100
50
0
PPM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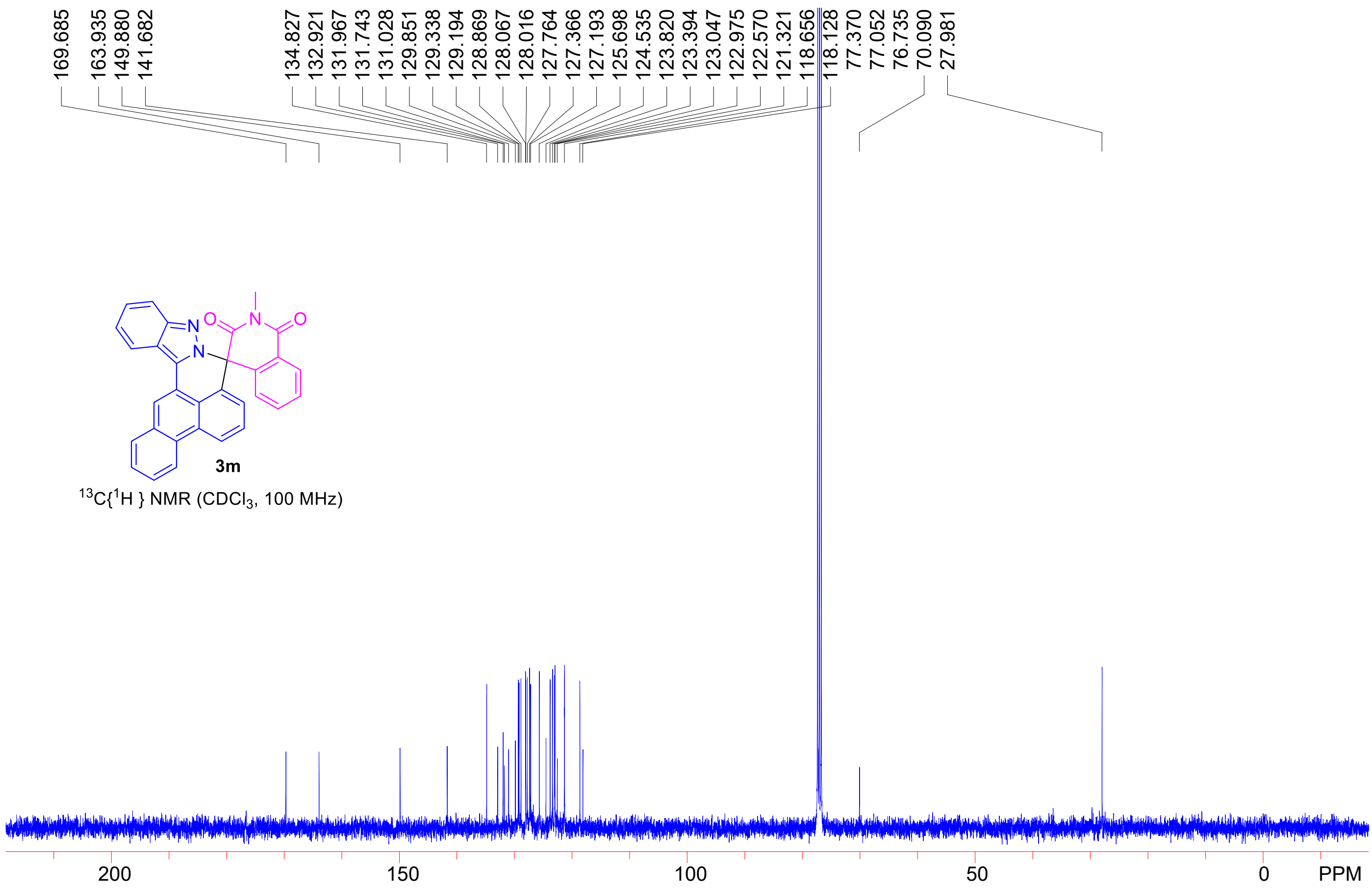
8.699
8.689
8.642
8.628
8.619
8.457
8.437
8.415
8.079
8.070
8.057
7.698
7.690
7.675
7.668
7.604
7.584
7.564
7.550
7.531
7.512
7.461
7.442
7.422
7.392
7.375
7.354
7.332
7.312
7.295
7.251
7.117
7.099
6.902
6.882
3.427
3m
¹H NMR (CDCl₃, 400 MHz)
2.14
2.04
1.03
1.02
3.01
1.04
1.05
1.00
1.01
1.01
1.02
1.02
3.02
10
8
6
4
2
PPM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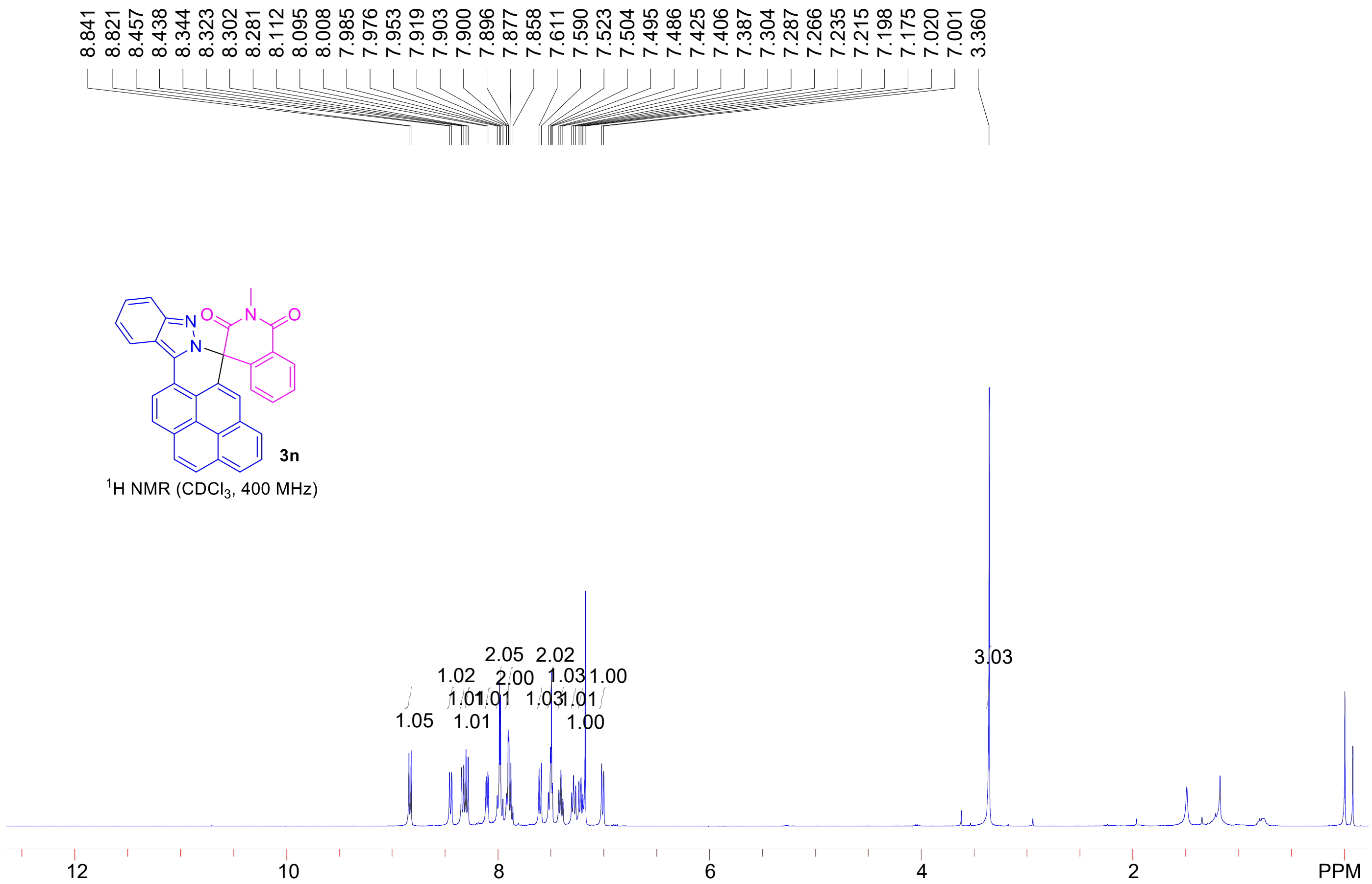
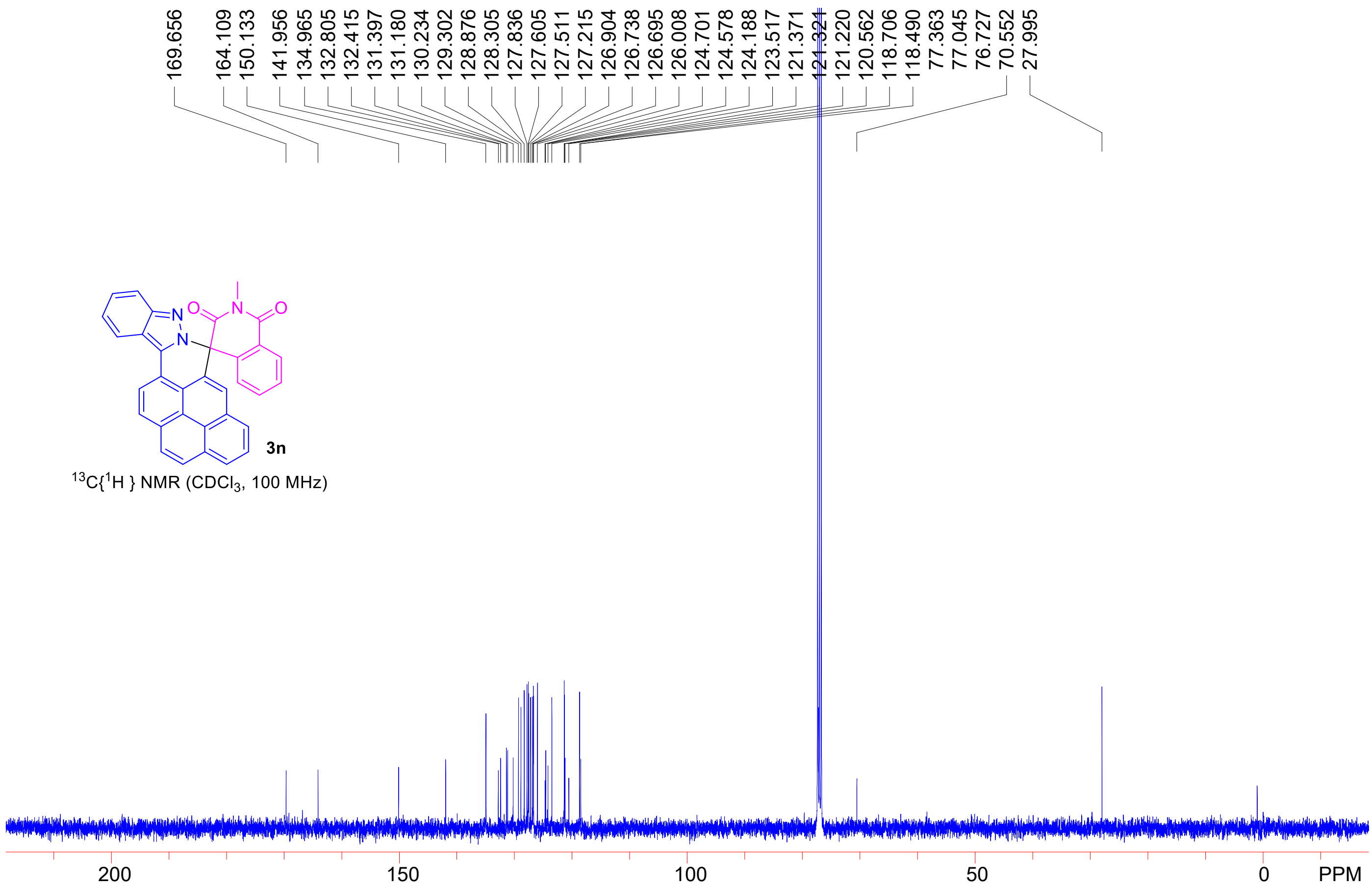
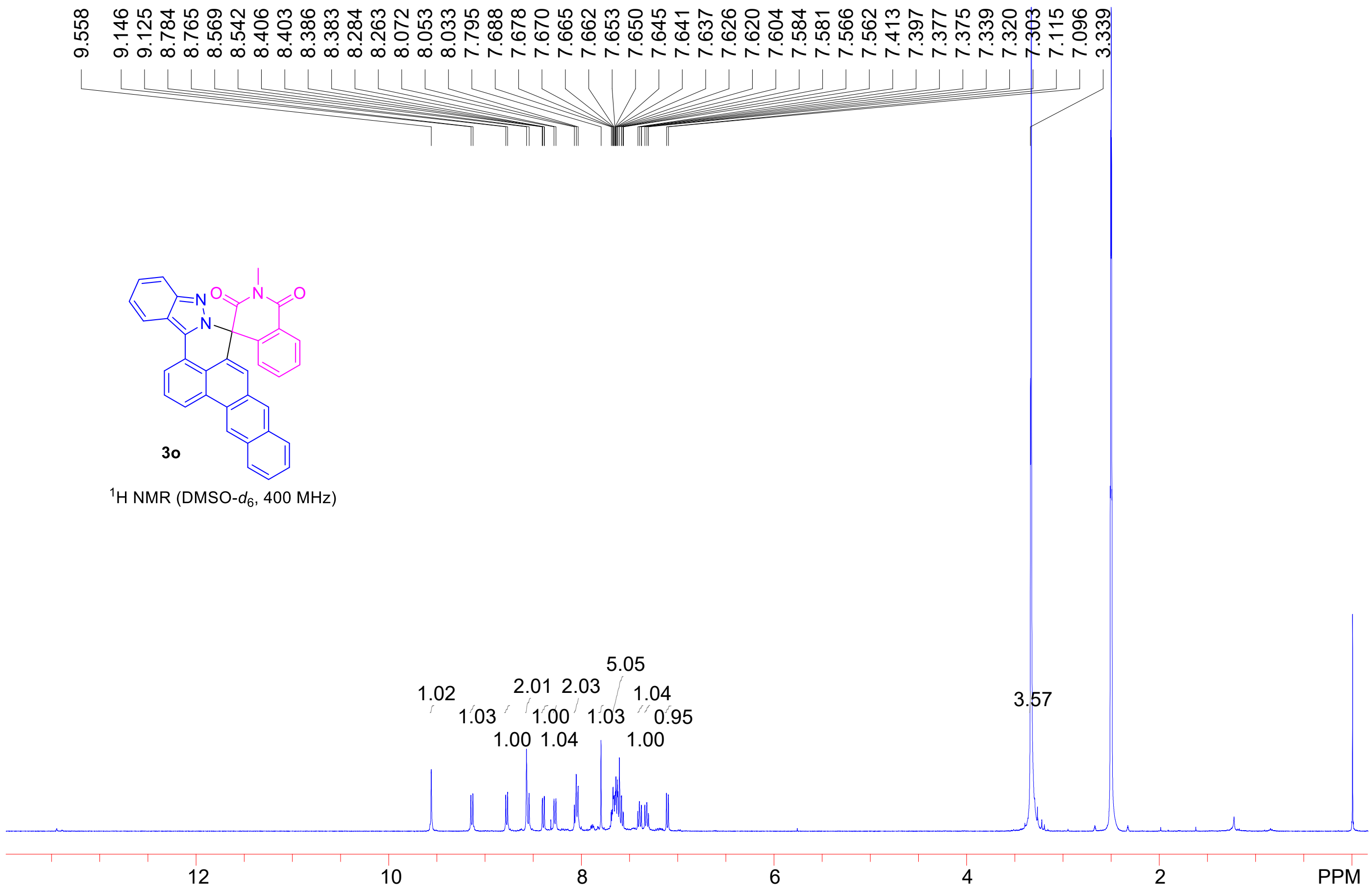
163.935
149.880
141.682
134.827
132.921
131.967
131.743
131.028
129.851
129.338
129.194
128.869
128.067
128.016
127.764
127.366
127.193
125.698
124.535
123.820
123.394
123.047
122.975
122.570
121.321
118.656
118.128
77.370
77.052
76.735
70.090
27.981
3m
¹³C{¹H } NMR (CDCl₃, 100 MHz)
200
150
100
50
0
PPM

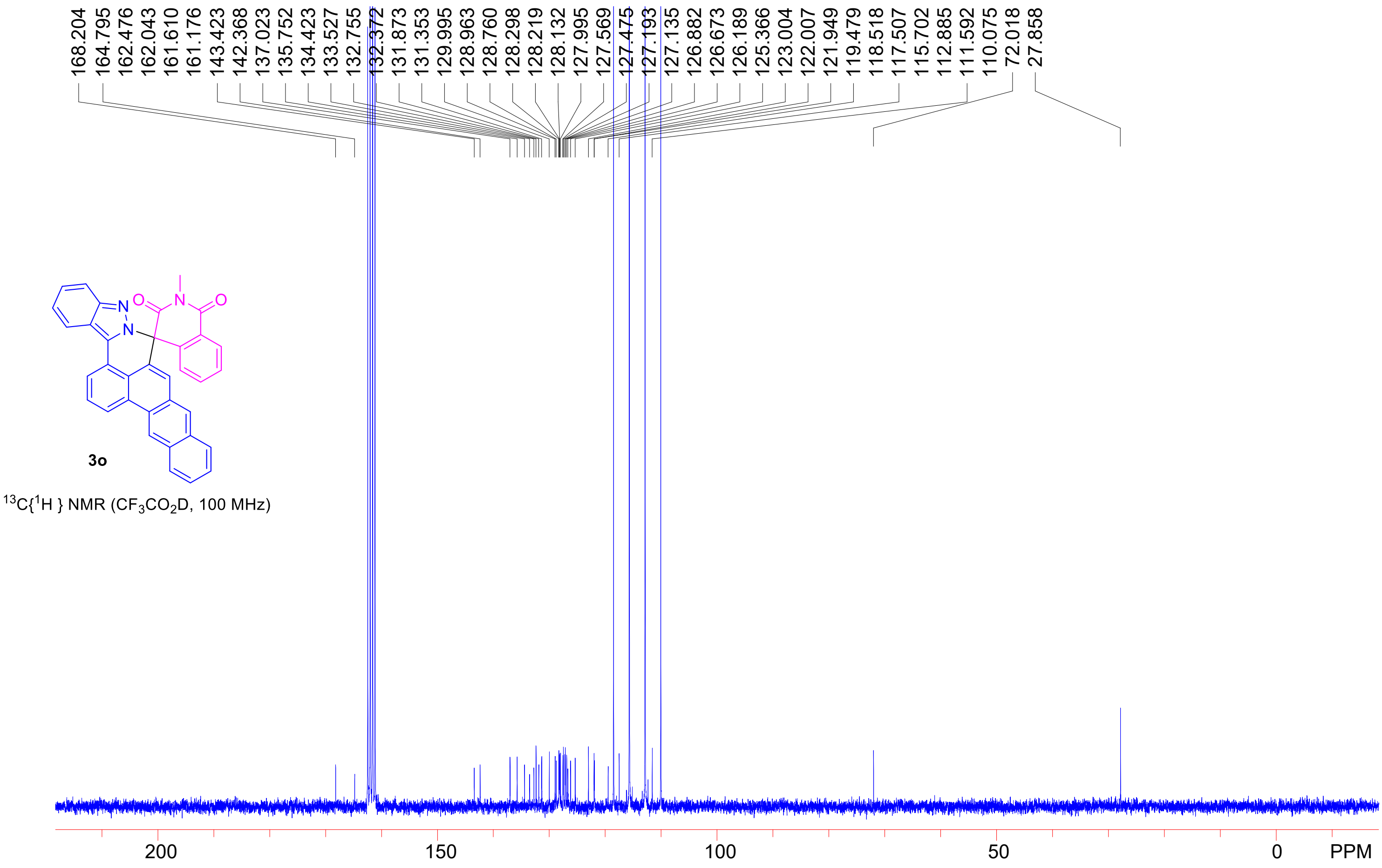

8.841
8.821
8.457
8.438
8.344
8.323
8.302
8.281
8.112
8.095
8.008
7.985
7.976
7.953
7.919
7.903
7.900
7.896
7.877
7.858
7.611
7.590
7.523
7.504
7.495
7.486
7.425
7.406
7.387
7.304
7.287
7.266
7.235
7.215
7.198
7.175
7.020
7.001
3.360
3n
1H NMR (CDCl3, 400 MHz)
1.05
1.02
1.01
1.01
1.01
2.05
2.00
2.02
1.03
1.03
1.01
1.00
1.00
3.03
12
10
8
6
4
2
PPM


169.656
164.109
150.133
141.956
134.965
132.805
132.415
131.397
131.180
130.234
129.302
128.876
128.305
127.836
127.605
127.511
127.215
126.904
126.738
126.695
126.008
124.701
124.578
124.188
123.517
121.371
121.321
121.220
120.562
118.706
118.490
77.363
77.045
76.727
70.552
27.995
3n
13C{1H } NMR (CDCl3, 100 MHz)
200
150
100
50
0
PPM



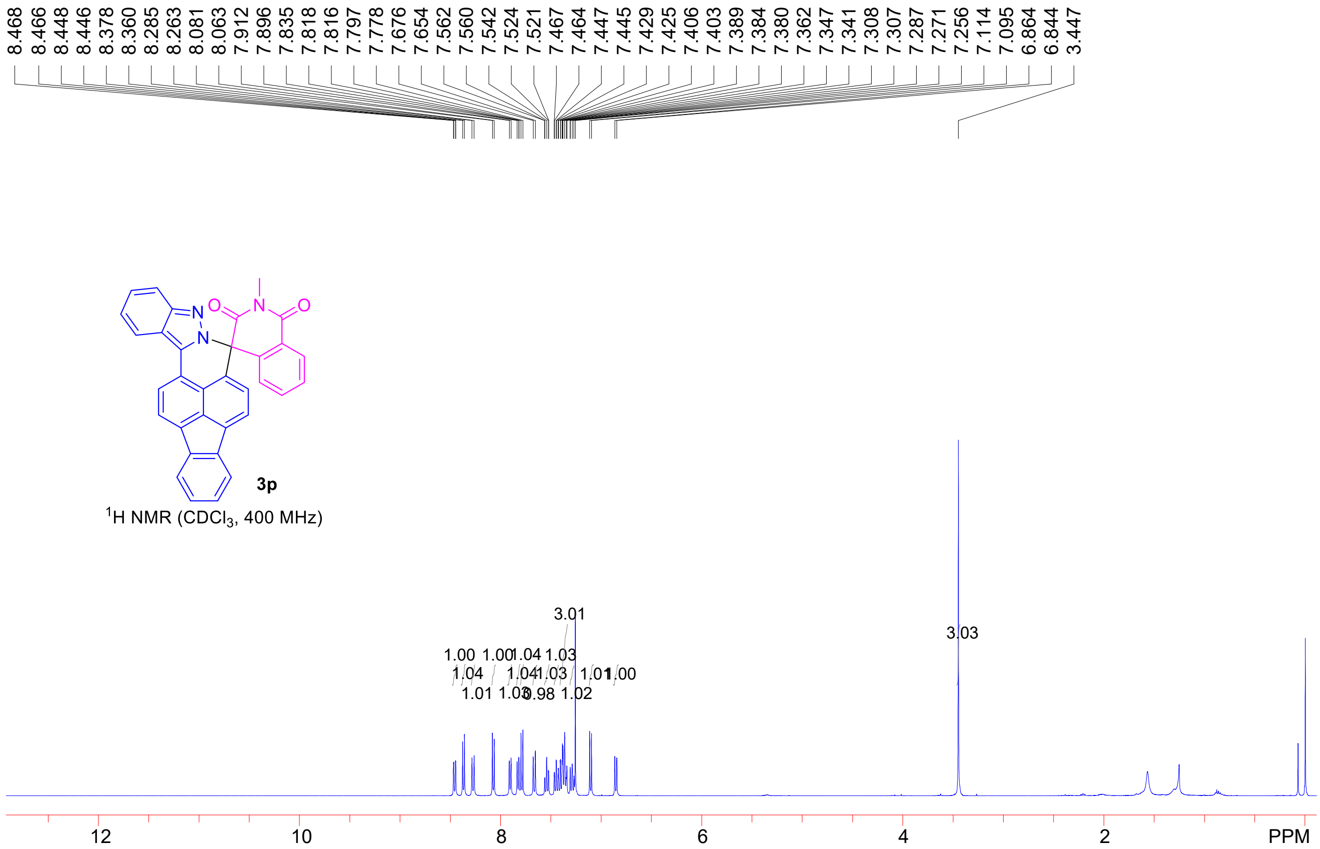
3o

^{1}H NMR (DMSO-d_6, 400 MHz)

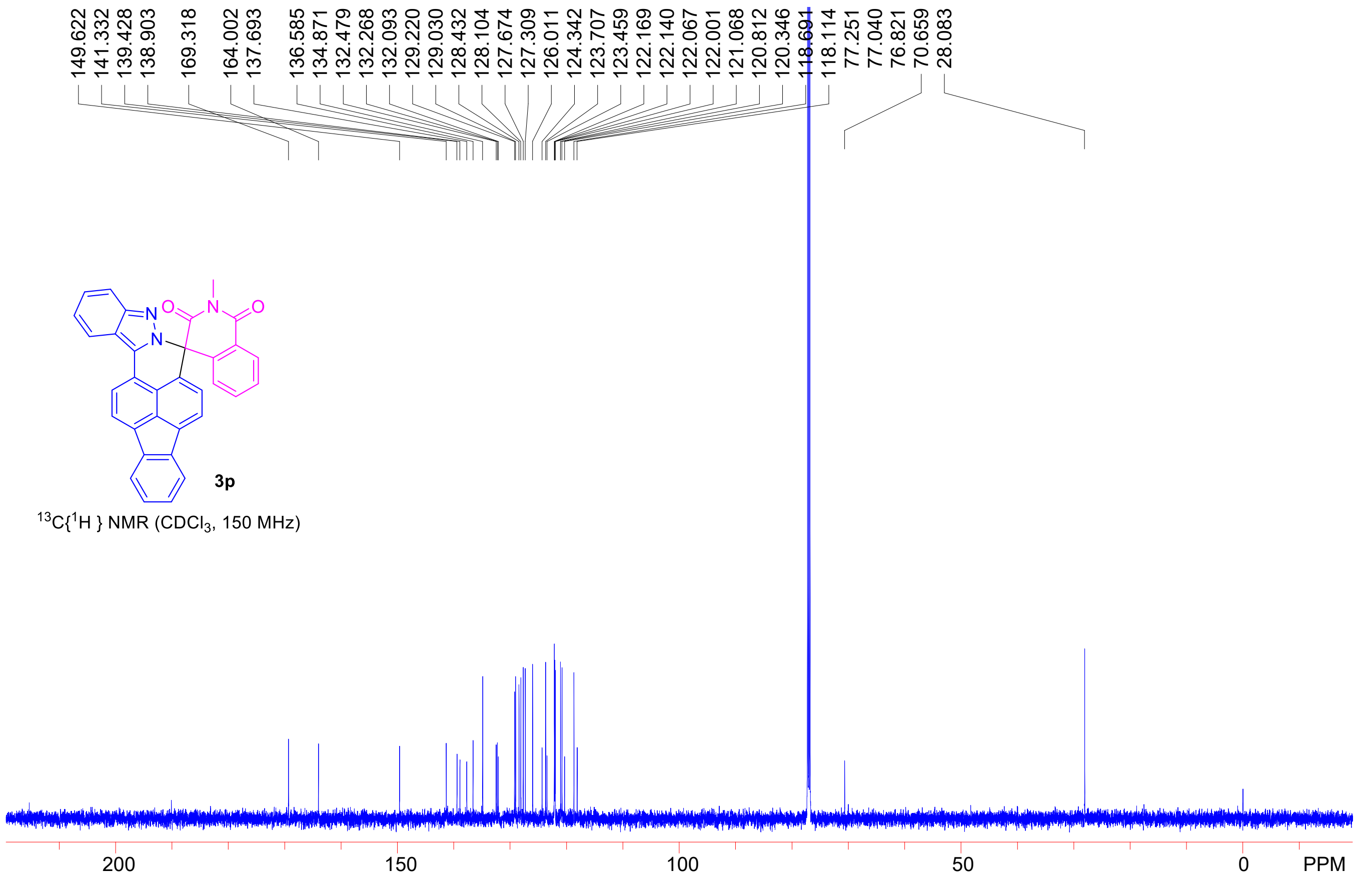


3o

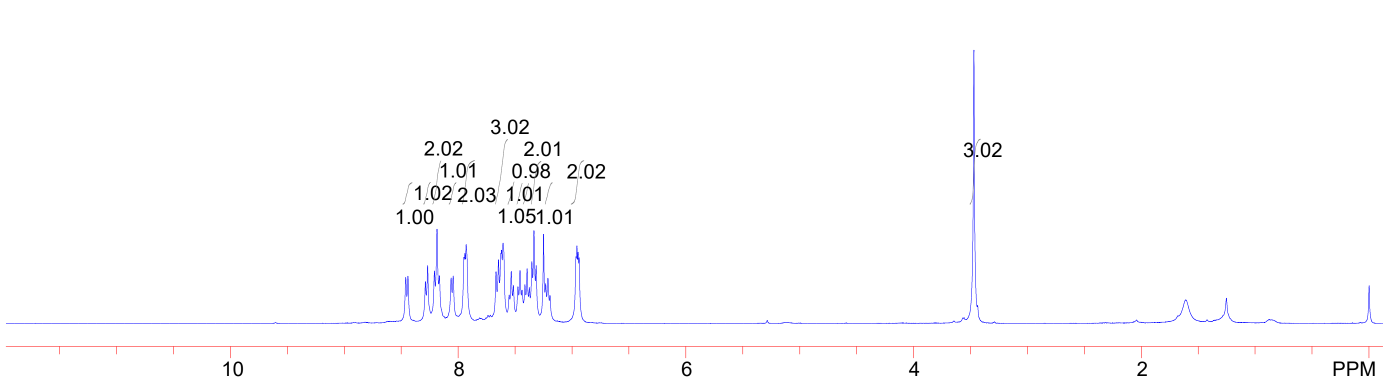
$^{13}C\{^{1}H\}$ NMR (CF_3CO_2D, 100 MHz)

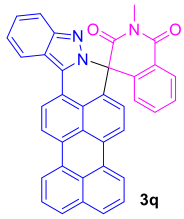


^{1}H NMR ($CDCl_3$, 400 MHz)



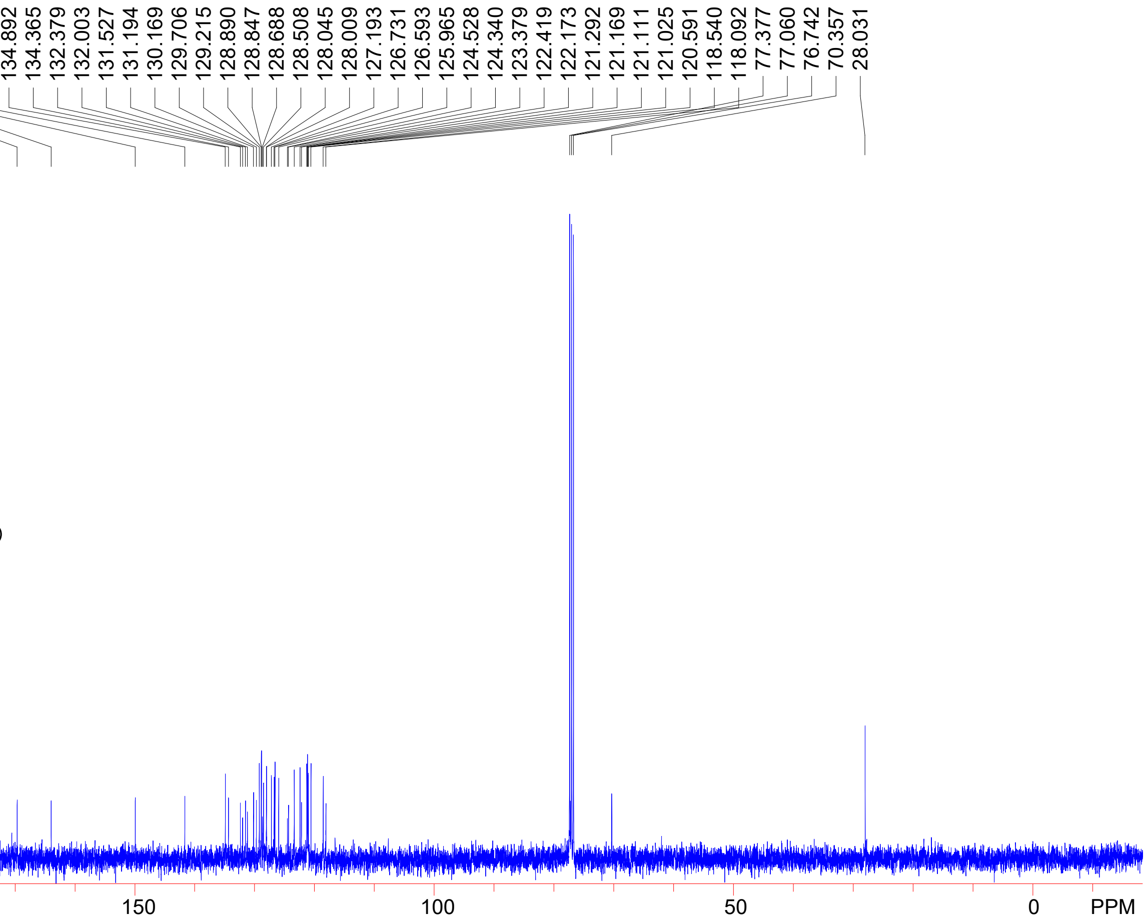
$^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 150 MHz)

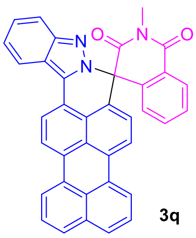




3q

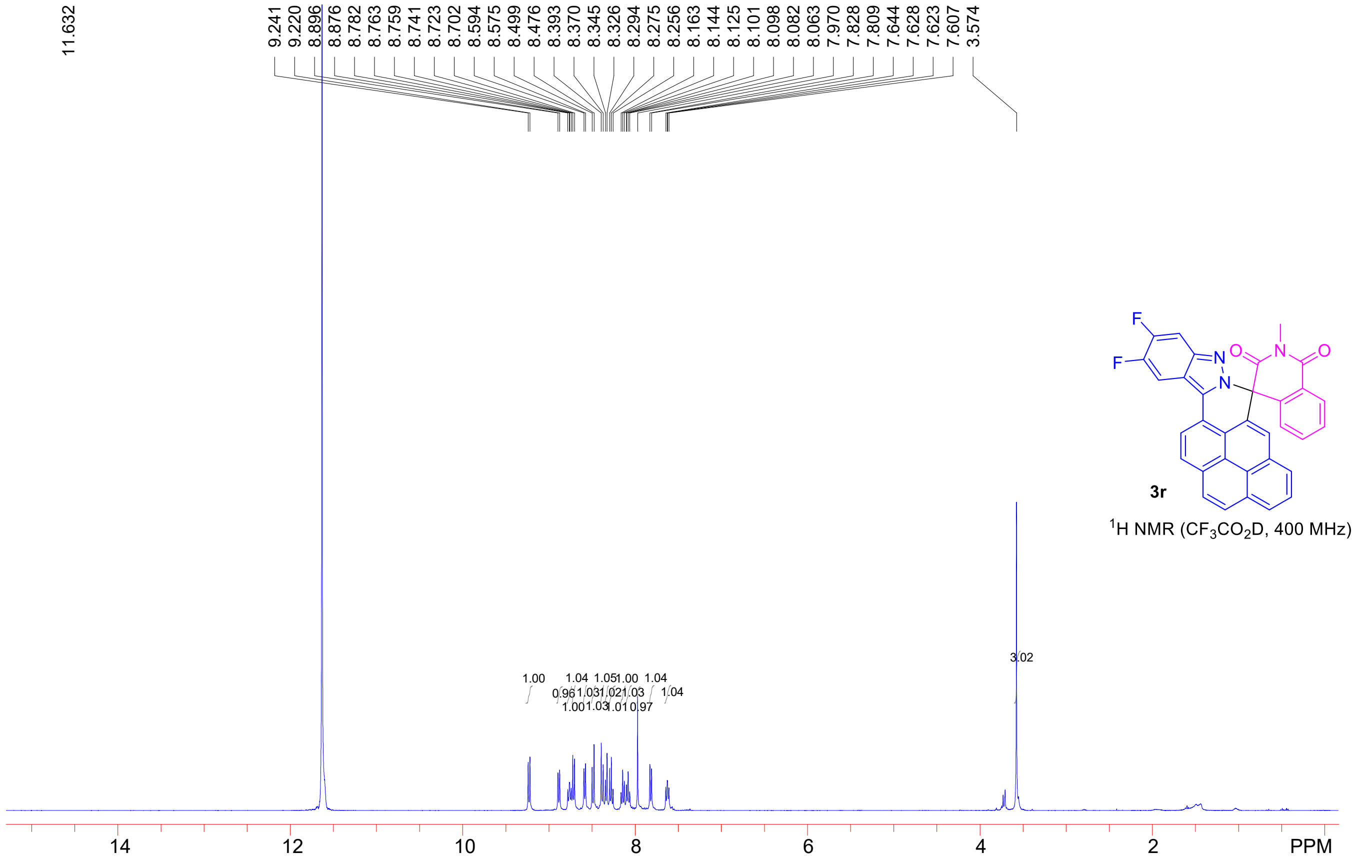
^{1}H NMR ($CDCl_3$, 400 MHz)





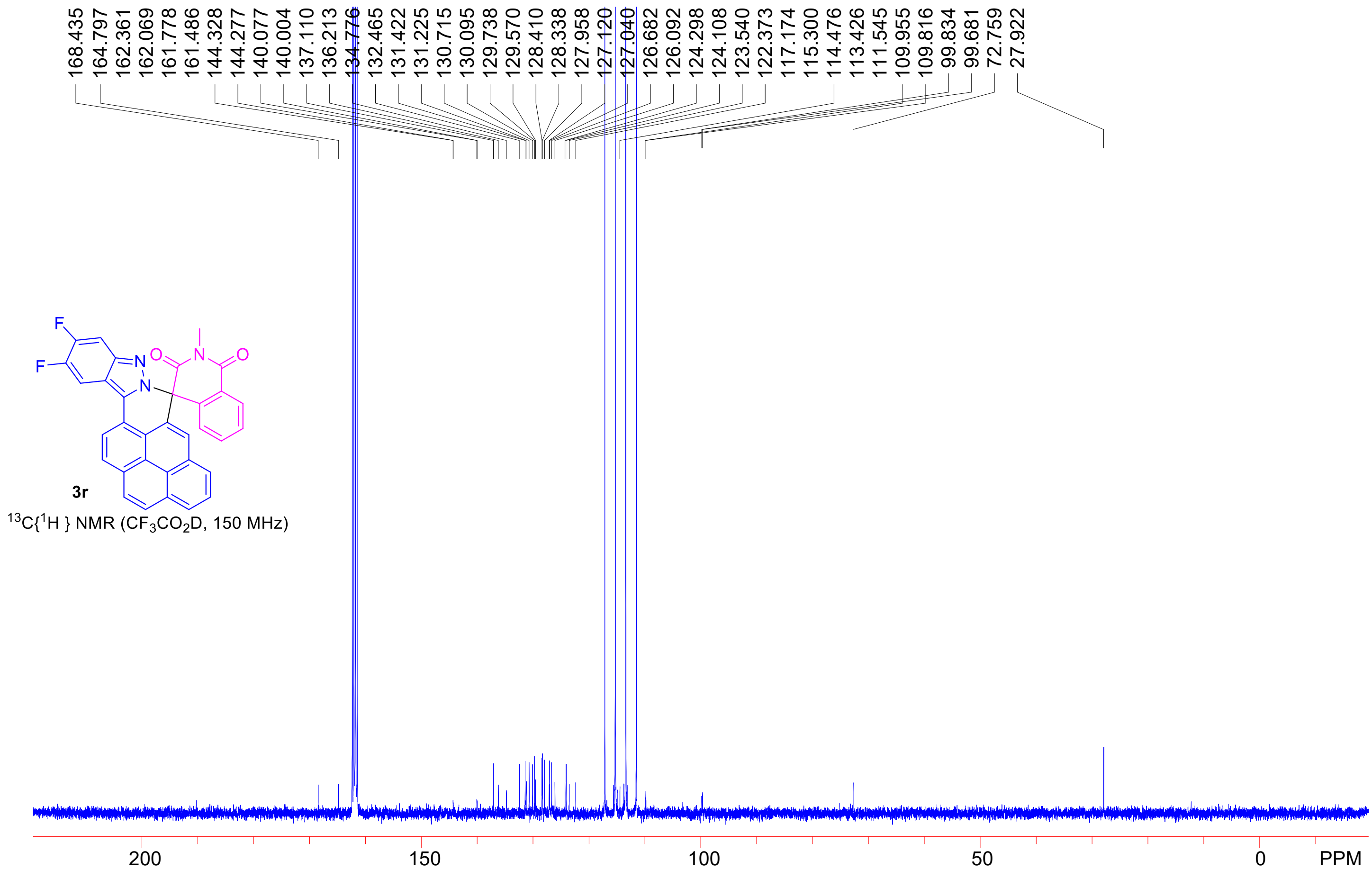
3q

$^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 100 MHz)



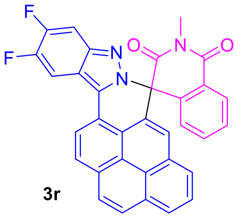
3r

^{1}H NMR (CF_3CO_2D, 400 MHz)



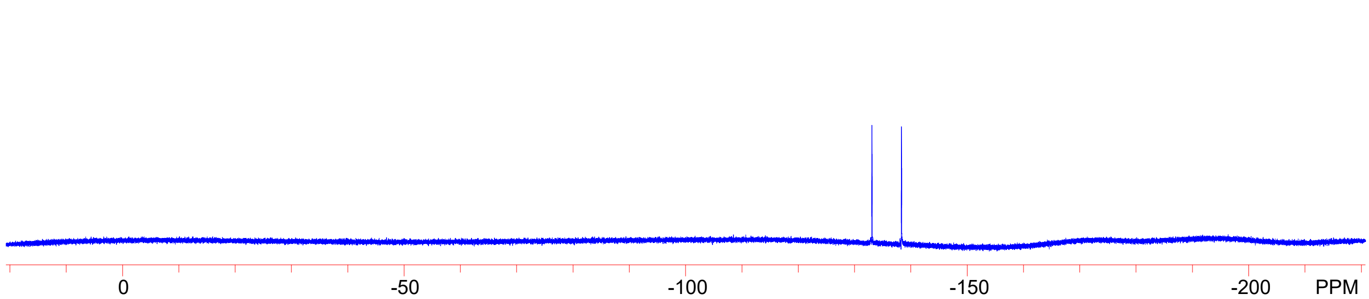
3r

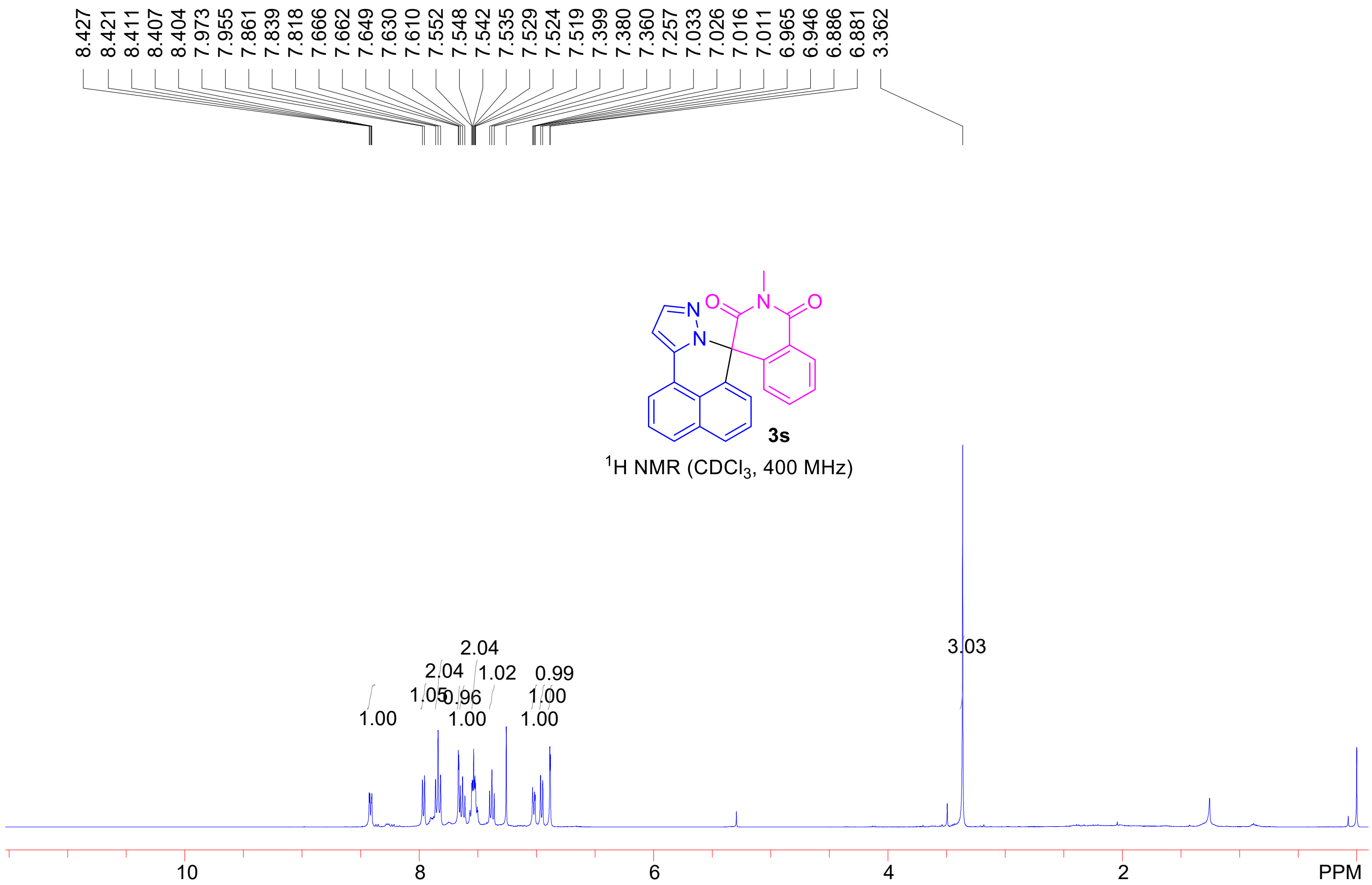
$^{13}C\{^1H\}$ NMR (CF_3CO_2D, 150 MHz)

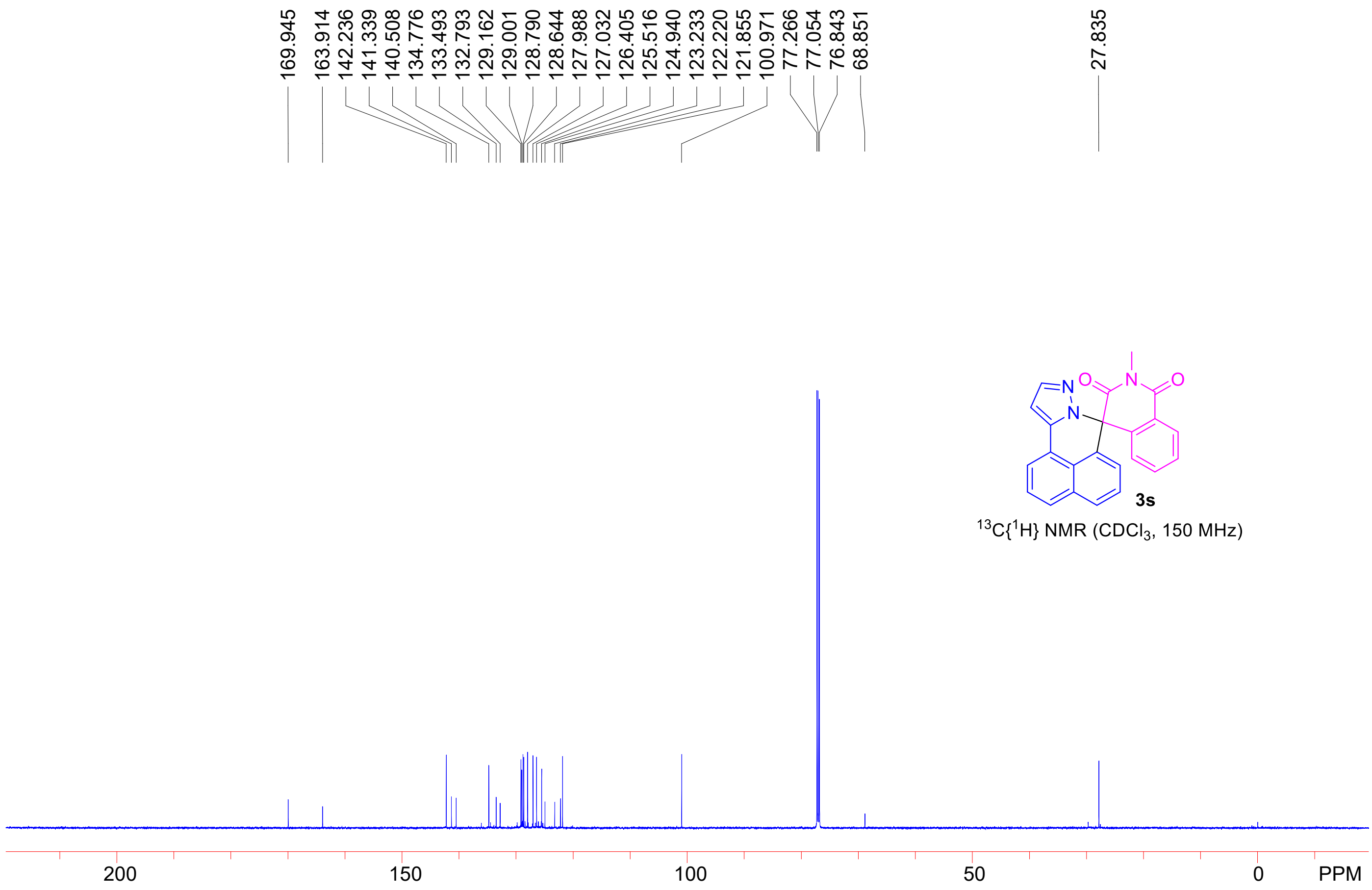


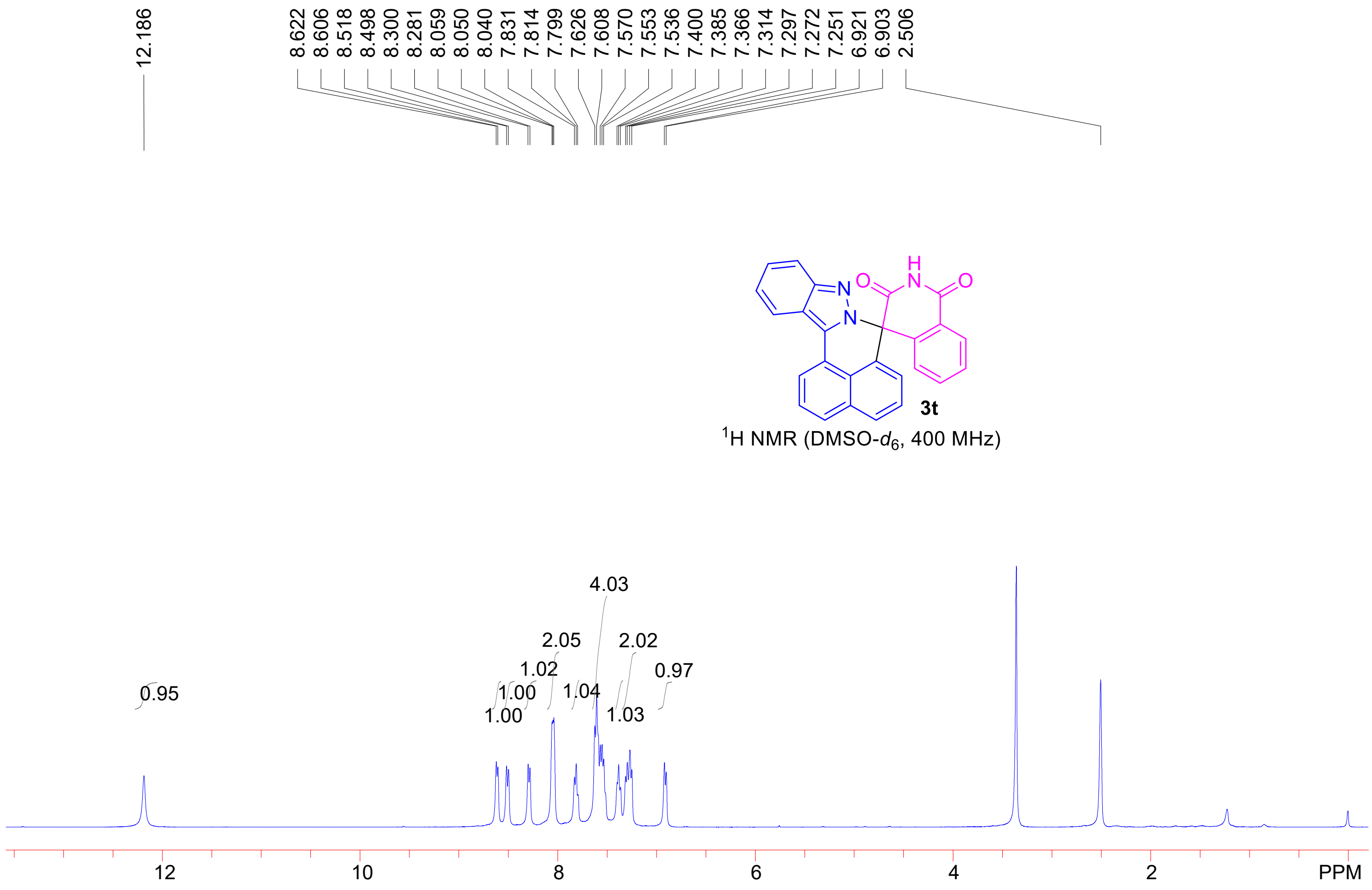
3r

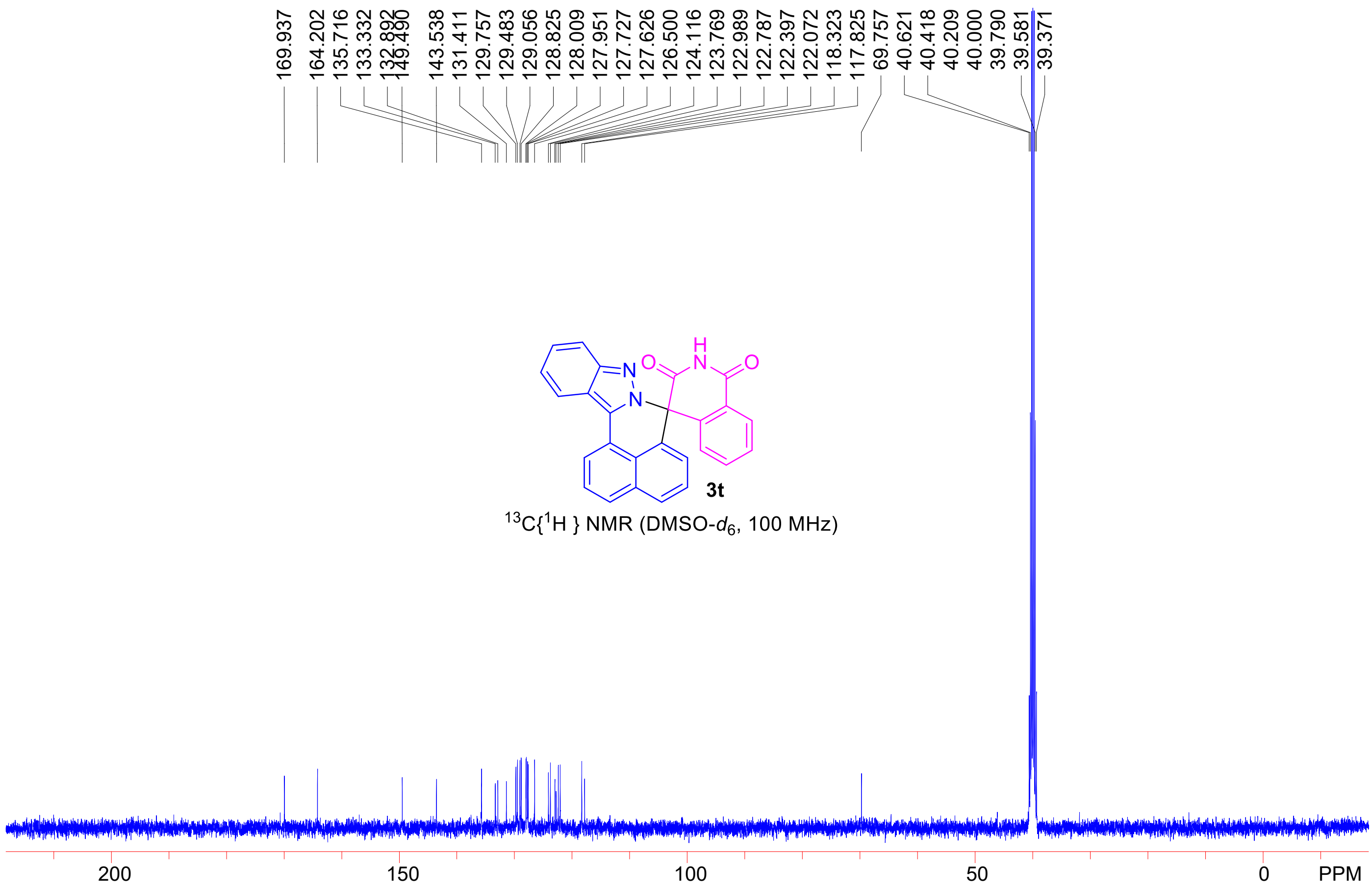
^{19}F NMR ($CDCl_3$, 376 MHz)

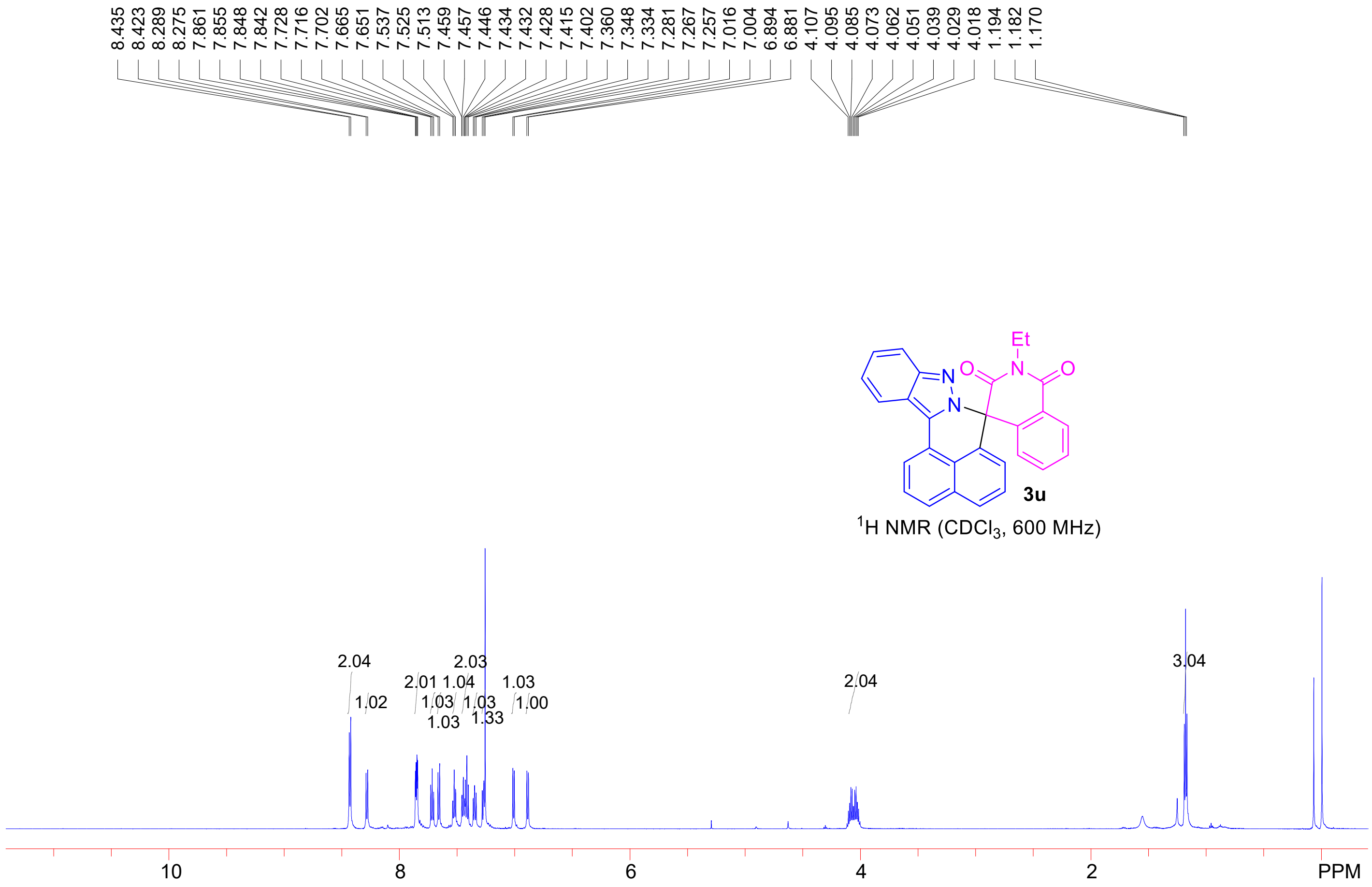



8.427
8.421
8.411
8.407
8.404
7.973
7.955
7.861
7.839
7.818
7.666
7.662
7.649
7.630
7.610
7.552
7.548
7.542
7.535
7.529
7.524
7.519
7.399
7.380
7.360
7.257
7.033
7.026
7.016
7.011
6.965
6.946
6.886
6.881
3.362
N
N
O
N
O
3s
^{1}H NMR (CDCl$_3$, 400 MHz)
2.04
2.04
1.02
0.99
1.05
0.96
1.00
1.00
1.00
1.00
3.03
10
8
6
4
2
PPM

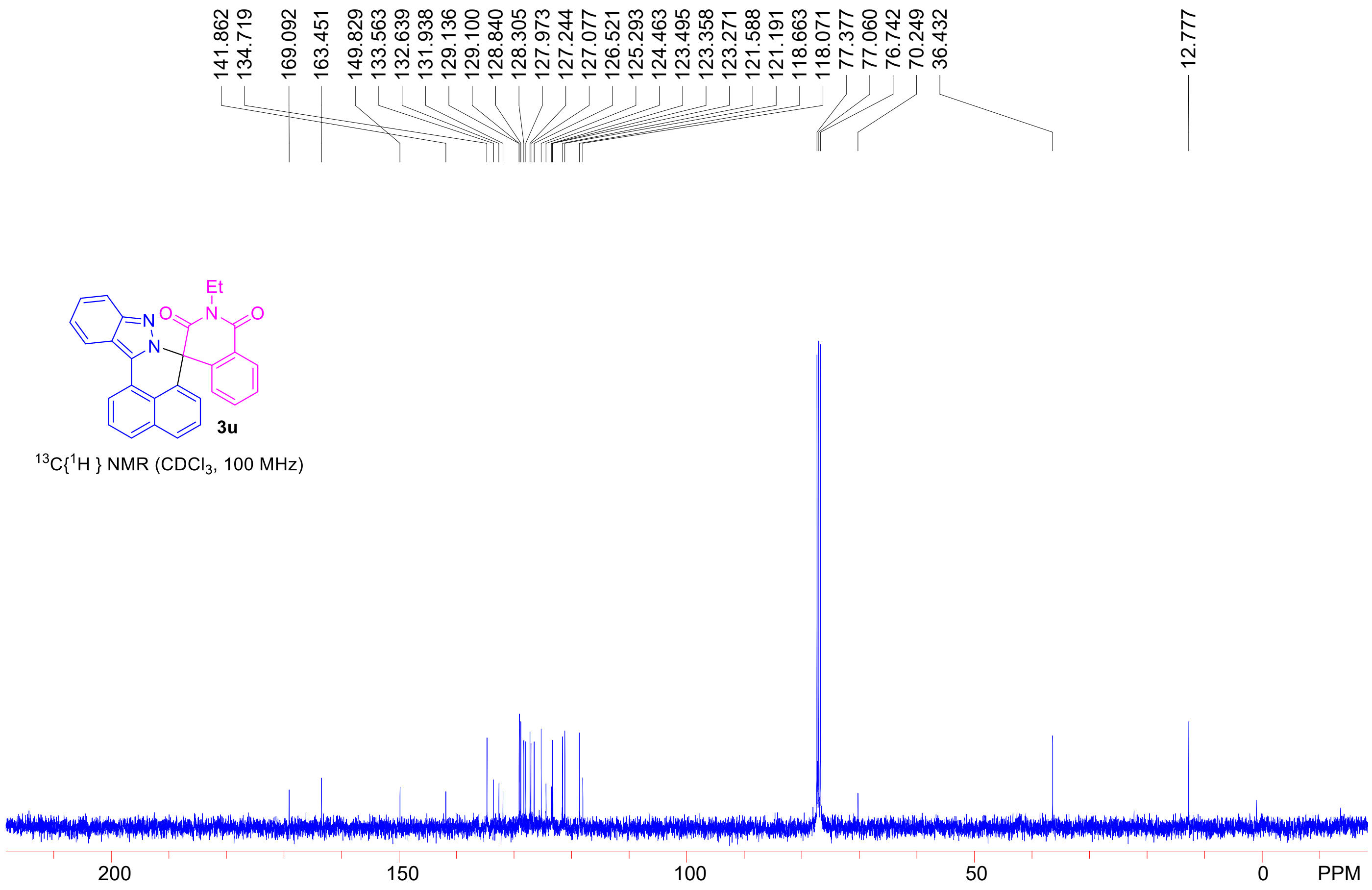

169.945
163.914
142.236
141.339
140.508
134.776
133.493
132.793
129.162
129.001
128.790
128.644
127.988
127.032
126.405
125.516
124.940
123.233
122.220
121.855
100.971
77.266
77.054
76.843
68.851
27.835
N
N
O
N
O
3s
^{13}C{^{1}H} NMR (CDCl$_3$, 150 MHz)
200
150
100
50
0
PPM


12.186
8.622 8.606 8.518 8.498 8.300 8.281 8.059 8.050 8.040 7.831 7.814 7.799 7.626 7.608 7.570 7.553 7.536 7.400 7.385 7.366 7.314 7.297 7.272 7.251 6.921 6.903 2.506
0.95 1.00 1.00 1.02 2.05 1.04 4.03 1.03 2.02 0.97
3t
^{1}H NMR (DMSO-d_6, 400 MHz)
12 10 8 6 4 2 PPM

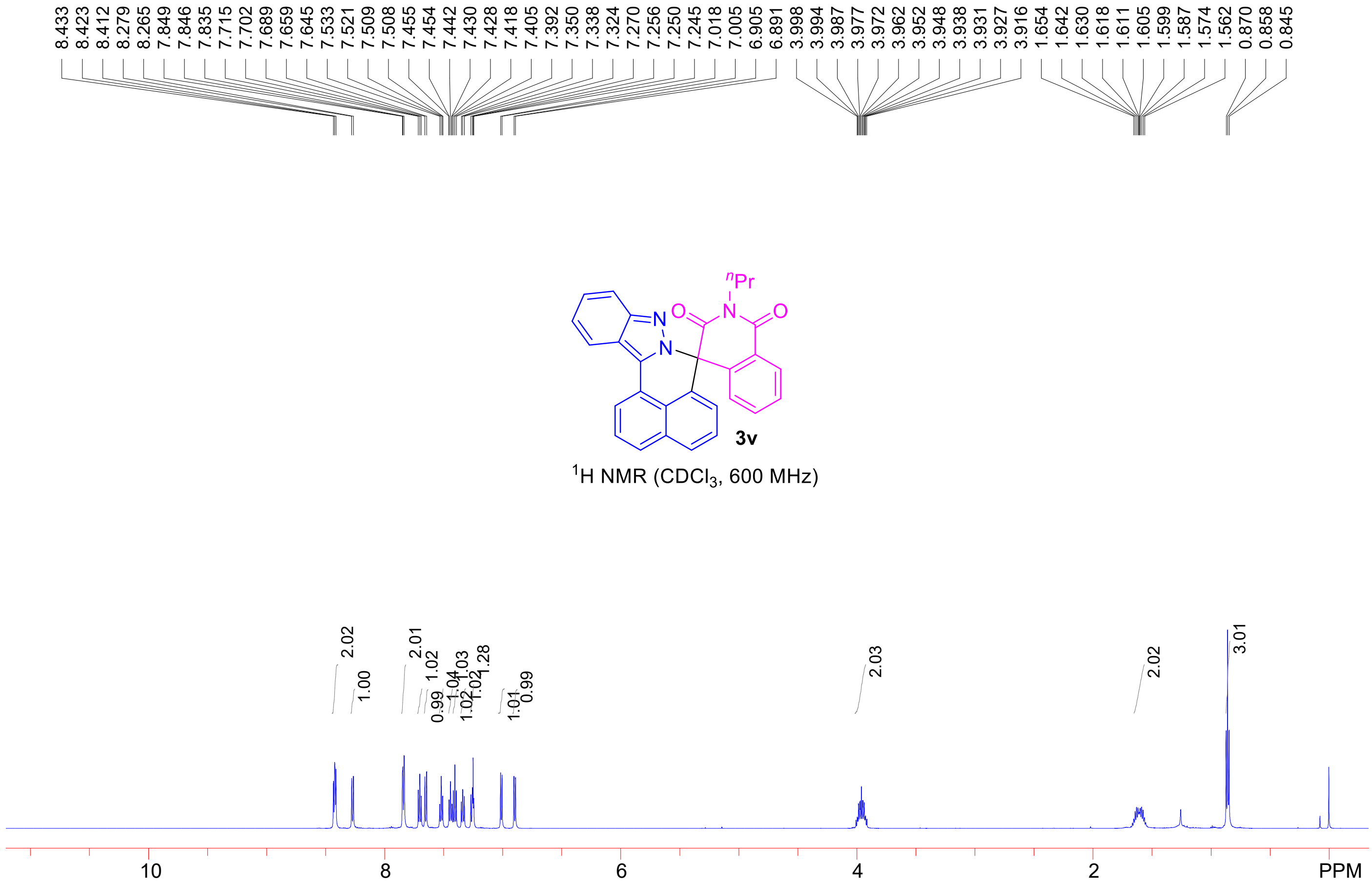

169.937 164.202 135.716 133.332 143.538 131.411 129.757 129.483 129.056 128.825 128.009 127.951 127.727 127.626 126.500 124.116 123.769 122.989 122.787 122.397 122.072 118.323 117.825 69.757 40.621 40.418 40.209 40.000 39.790 39.581 39.371
3t
^{13}C{^{1}H } NMR (DMSO-d_6, 100 MHz)
200 150 100 50 0 PPM



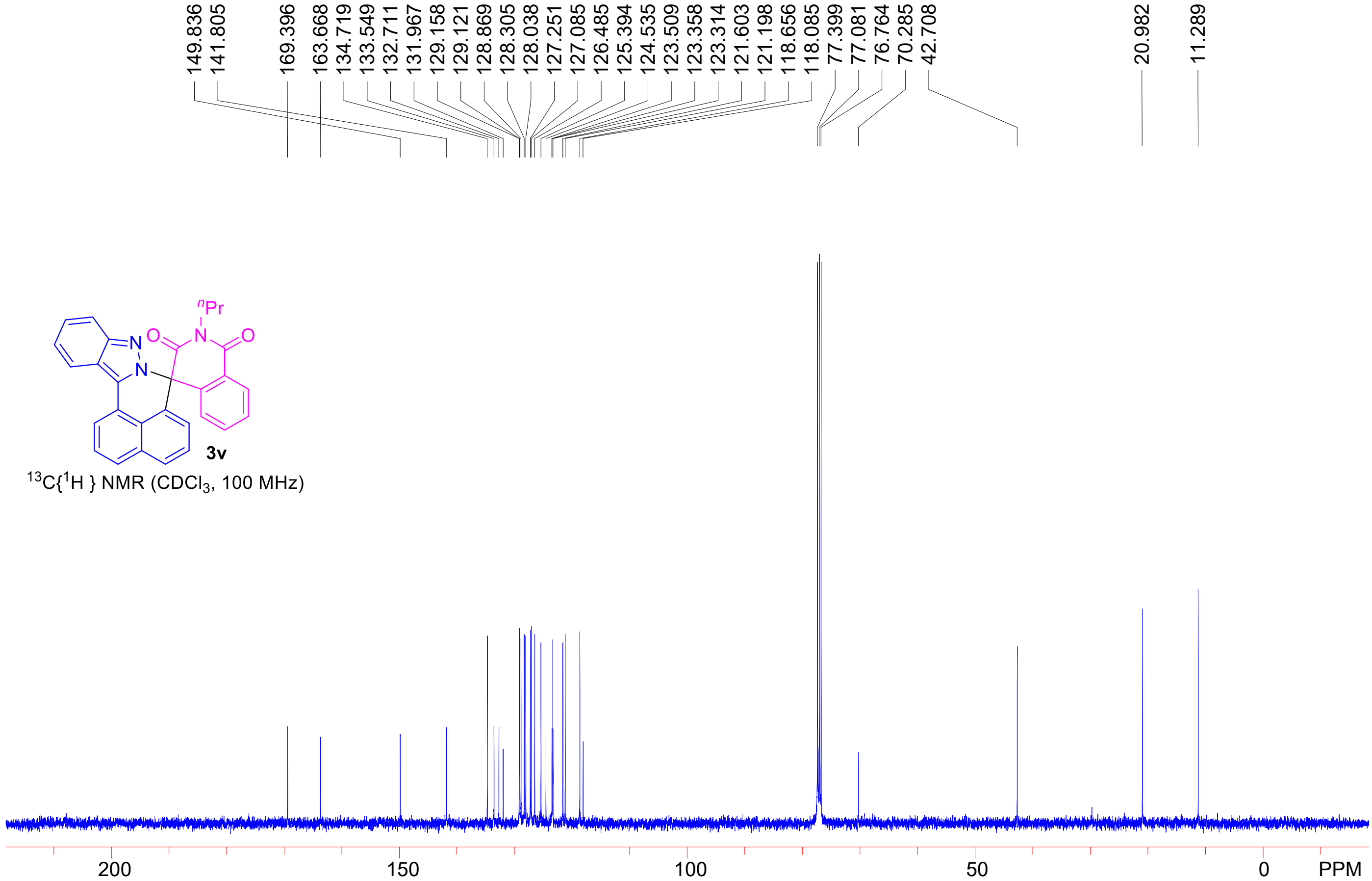
^1H NMR ($CDCl_3$, 600 MHz)



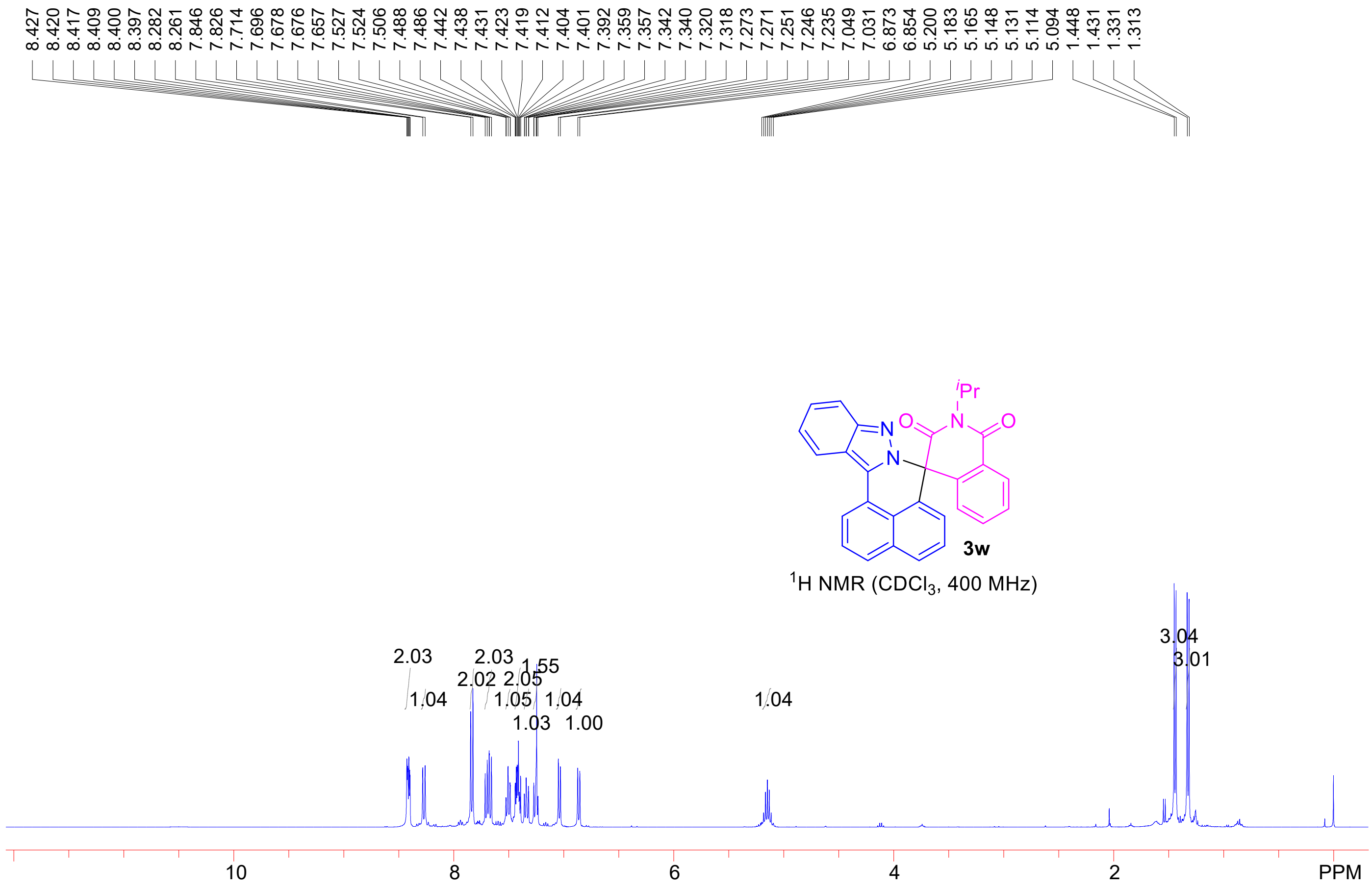
$^{13}C\{^1H\}$ NMR ($CDCl_3$, 100 MHz)

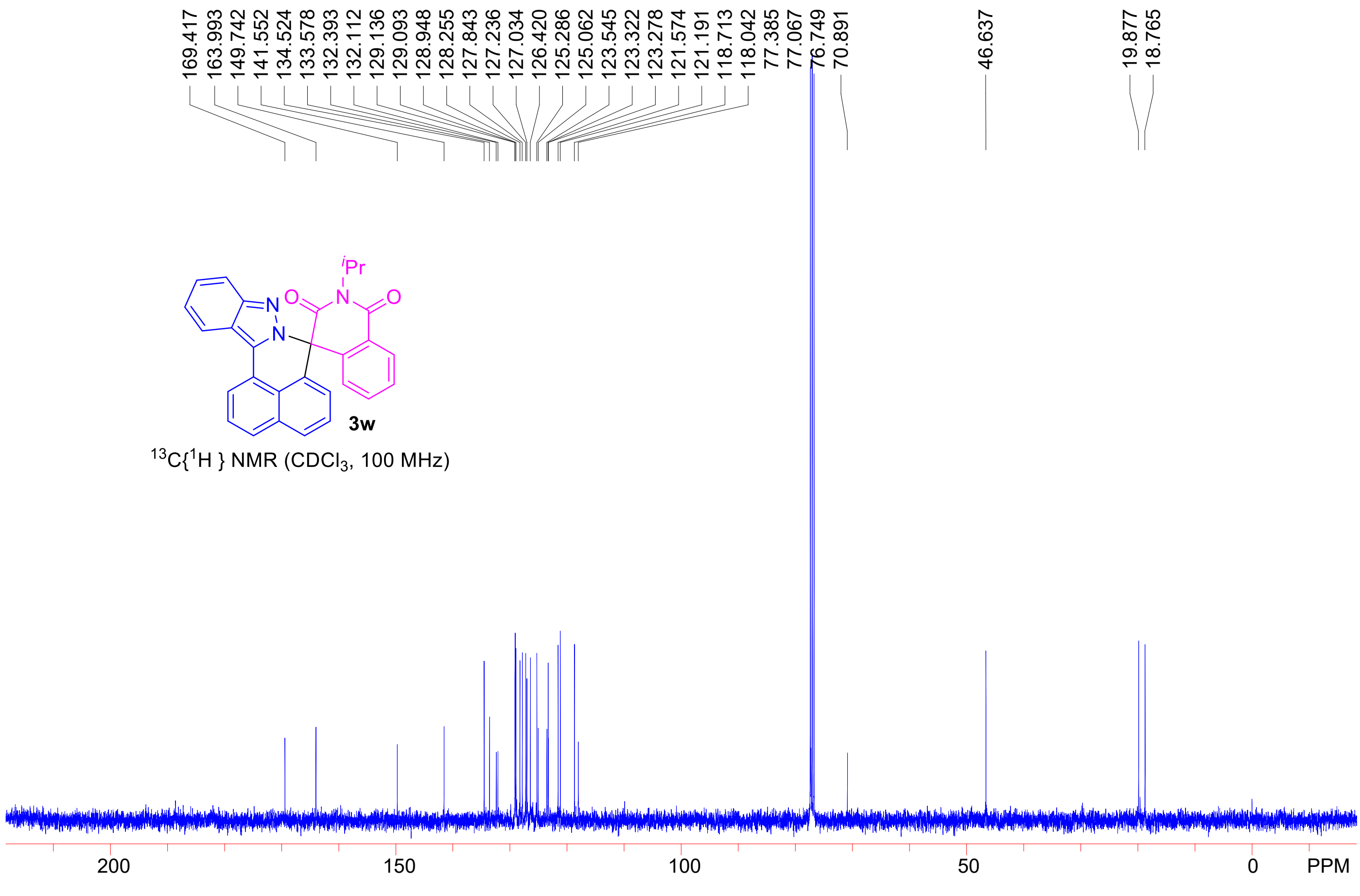


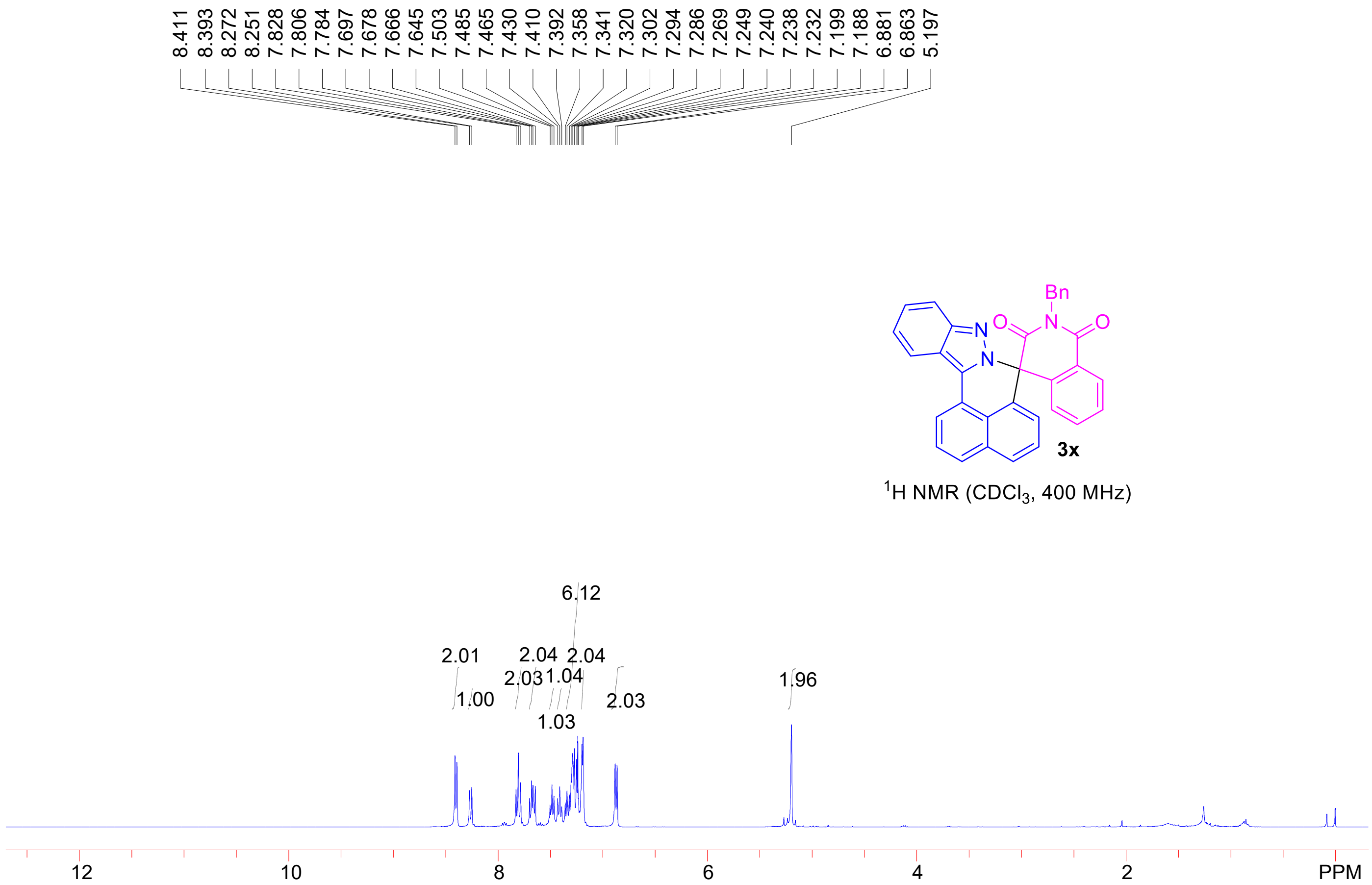
^{1}H NMR ($CDCl_3$, 600 MHz)

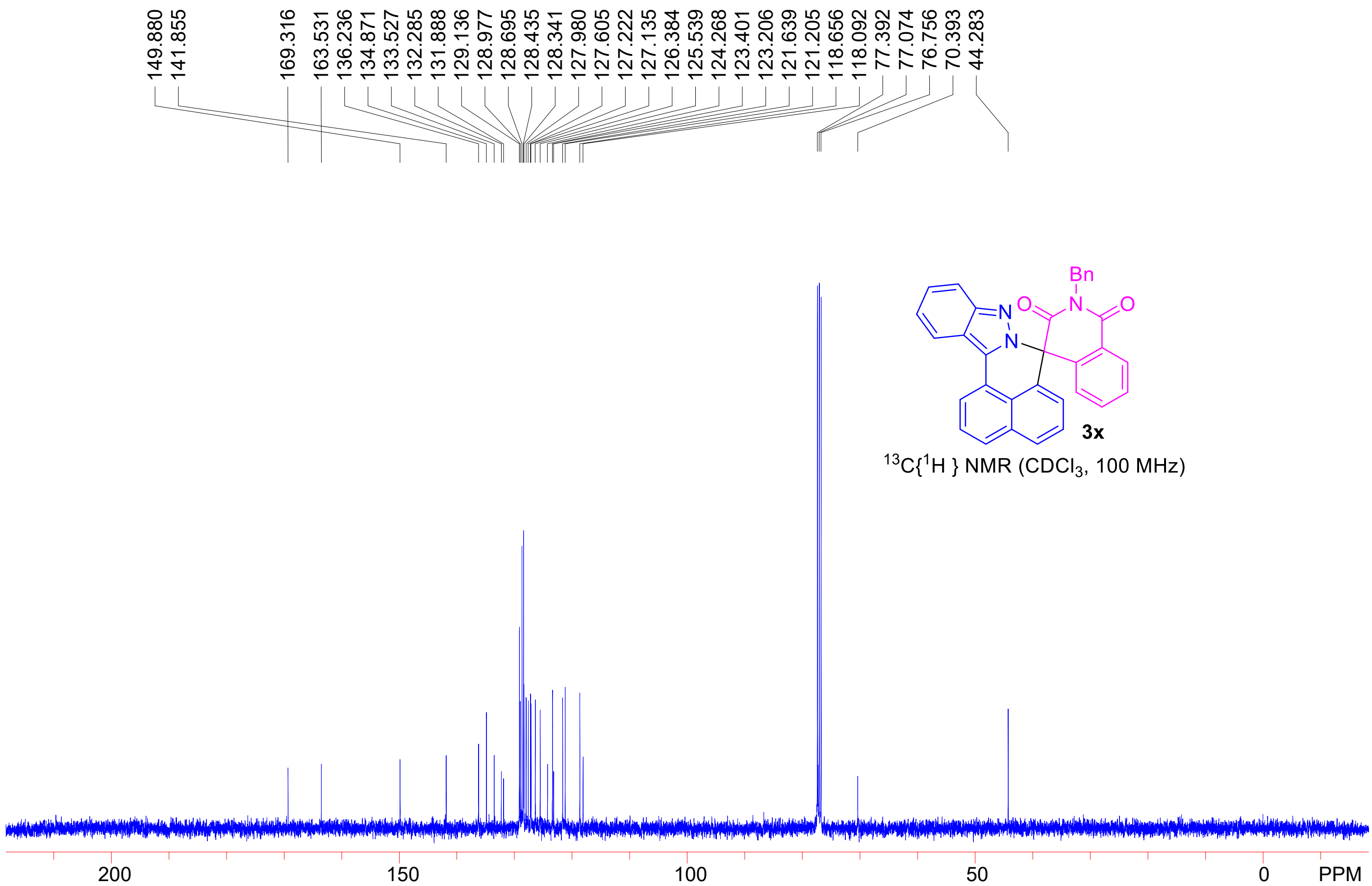


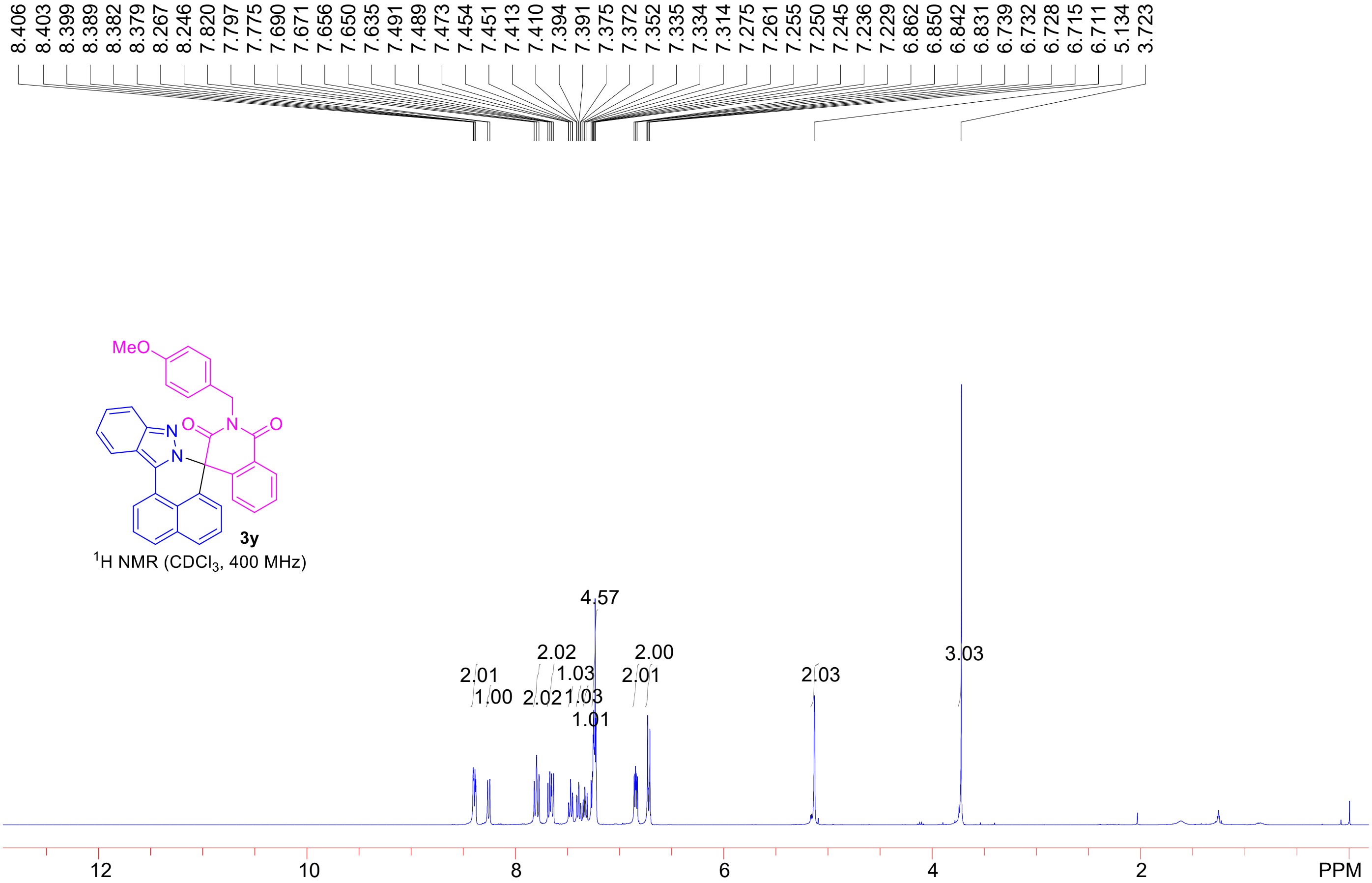
$^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 100 MHz)

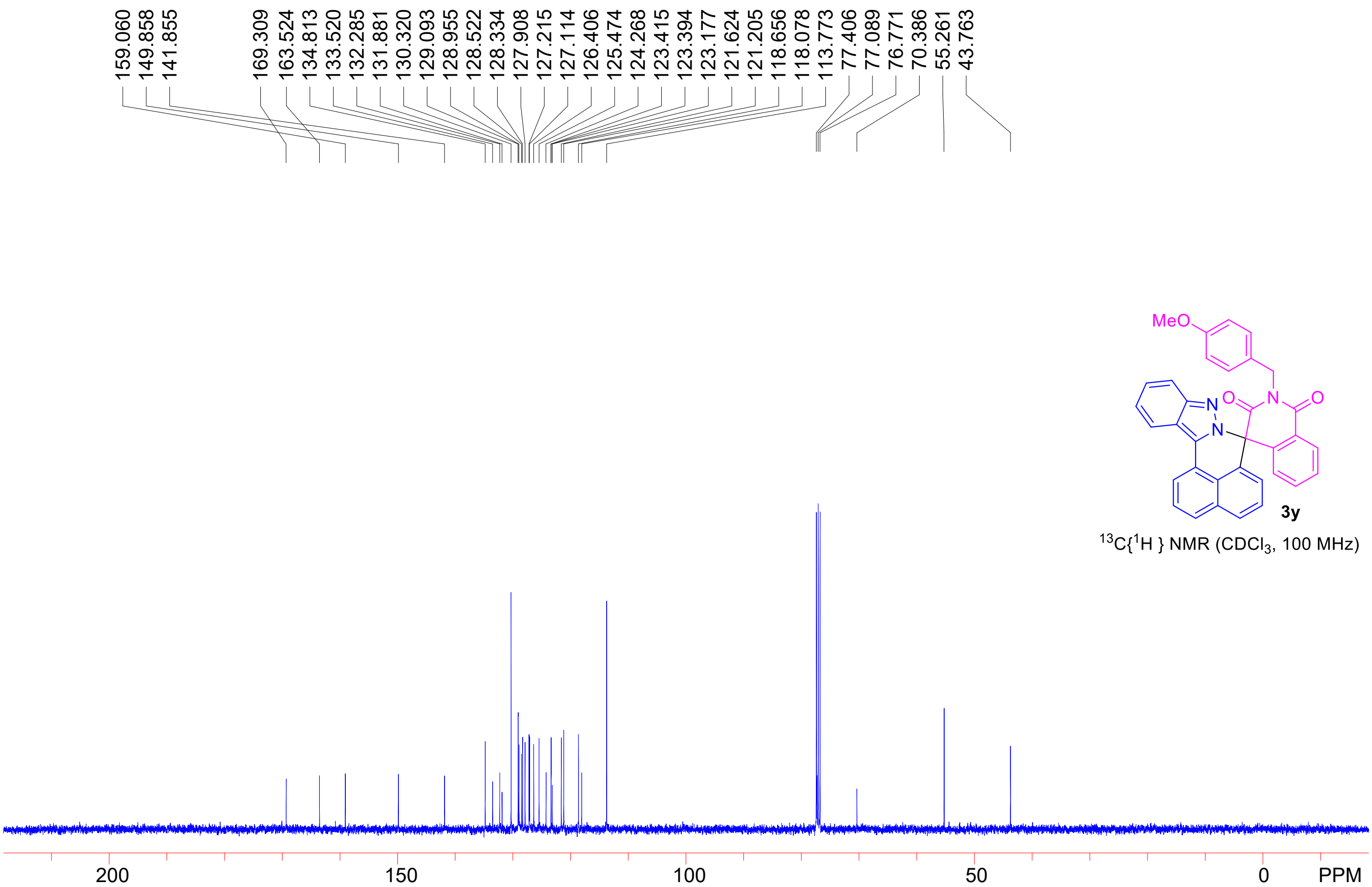

8.427 8.420 8.417 8.409 8.400 8.397 8.282 8.261 7.846 7.826 7.714 7.696 7.678 7.676 7.657 7.527 7.524 7.506 7.488 7.486 7.442 7.438 7.431 7.423 7.419 7.412 7.404 7.401 7.392 7.359 7.357 7.342 7.340 7.320 7.318 7.273 7.271 7.251 7.246 7.235 7.049 7.031 6.873 6.854 5.200 5.183 5.165 5.148 5.131 5.114 5.094 1.448 1.431 1.331 1.313
N
N
O
O
N
iPr
3w
1H NMR (CDCl3, 400 MHz)
2.03 1.04 2.03 2.02 2.05 1.55 1.05 1.04 1.03 1.00 1.04 3.04 3.01
10 8 6 4 2 PPM

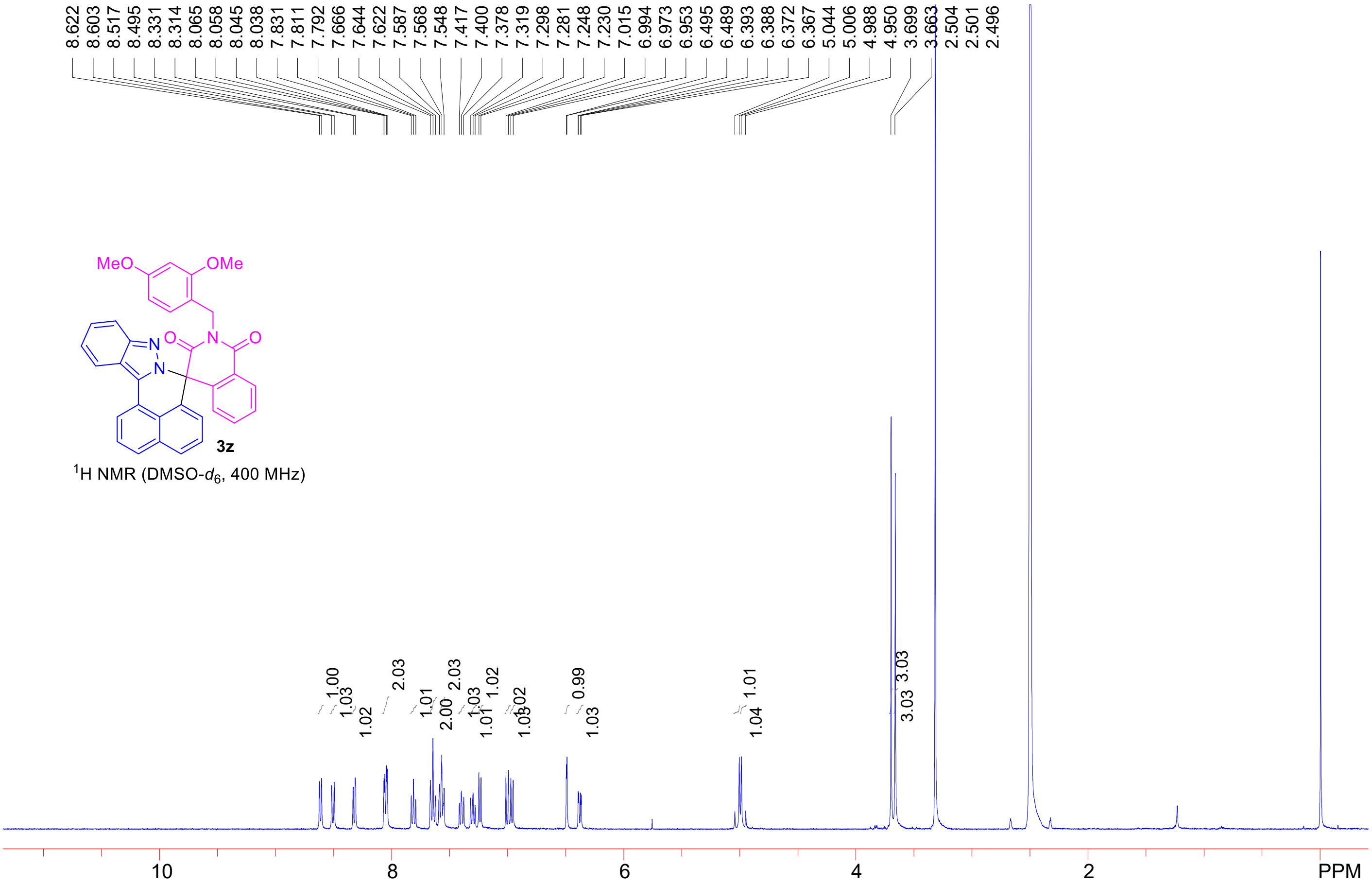

169.417 163.993 149.742 141.552 134.524 133.578 132.393 132.112 129.136 129.093 128.948 128.255 127.843 127.236 127.034 126.420 125.286 125.062 123.545 123.322 123.278 121.574 121.191 118.713 118.042 77.385 77.067 76.749 70.891 46.637 19.877 18.765
N
N
O
O
N
iPr
3w
13C{1H } NMR (CDCl3, 100 MHz)
200 150 100 50 0 PPM


8.411 8.393 8.272 8.251 7.828 7.806 7.784 7.697 7.678 7.666 7.645 7.503 7.485 7.465 7.430 7.410 7.392 7.358 7.341 7.320 7.302 7.294 7.286 7.269 7.249 7.240 7.238 7.232 7.199 7.188 6.881 6.863 5.197
Bn
N
O
3x
^{1}H NMR (CDCl$_3$, 400 MHz)
6.12
2.01
2.04 2.04
2.03 1.04
1.00
2.03
1.03
1.96
12
10
8
6
4
2
PPM

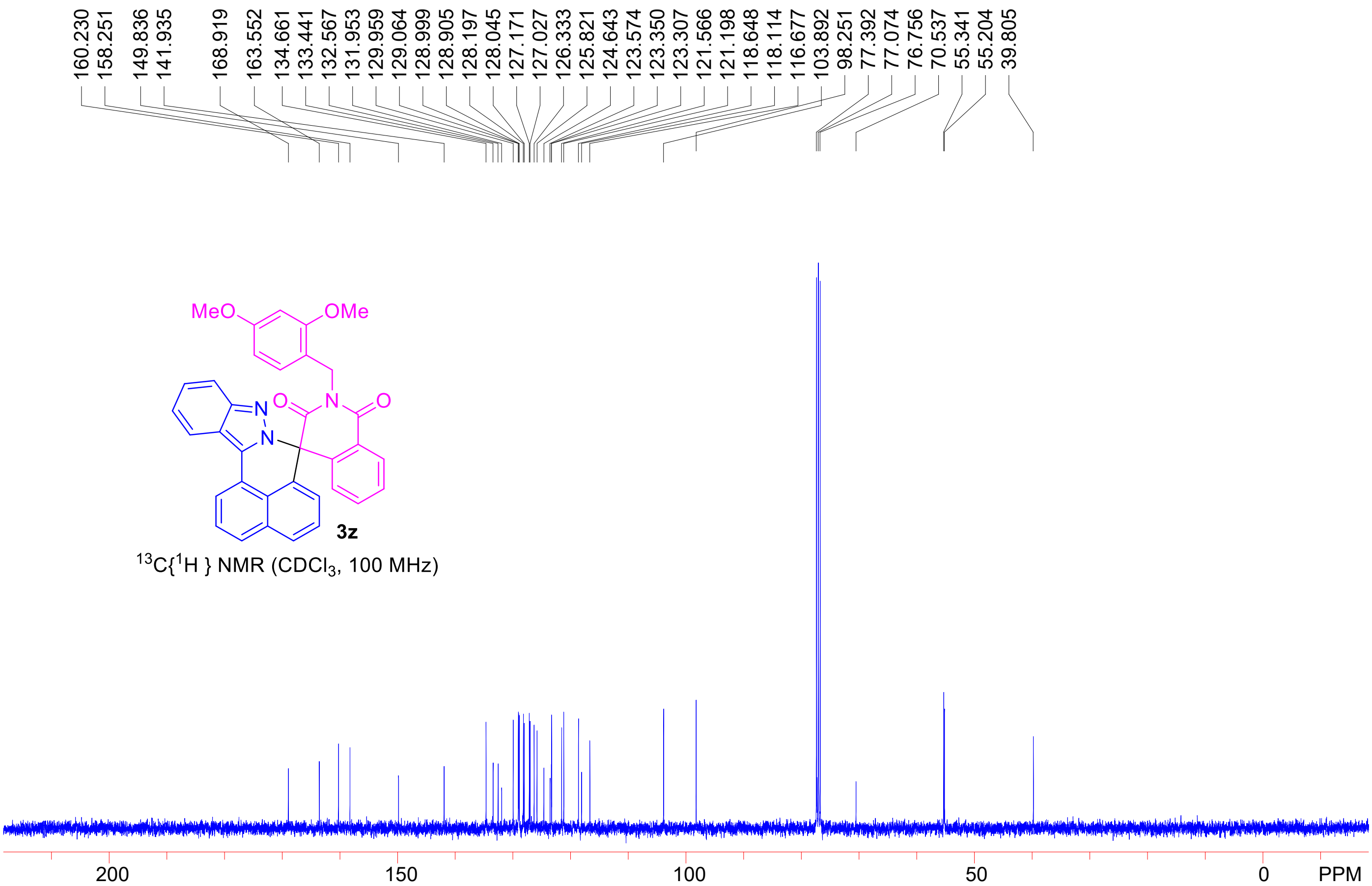

149.880 141.855 169.316 163.531 136.236 134.871 133.527 132.285 131.888 129.136 128.977 128.695 128.435 128.341 127.980 127.605 127.222 127.135 126.384 125.539 124.268 123.401 123.206 121.639 121.205 118.656 118.092 77.392 77.074 76.756 70.393 44.283
Bn
N
O
3x
^{13}C{^{1}H } NMR (CDCl$_3$, 100 MHz)
200
150
100
50
0
PPM


8.406 8.403 8.399 8.389 8.382 8.379 8.267 8.246 7.820 7.797 7.775 7.690 7.671 7.656 7.650 7.635 7.491 7.489 7.473 7.454 7.451 7.413 7.410 7.394 7.391 7.375 7.372 7.352 7.335 7.334 7.314 7.275 7.261 7.255 7.250 7.245 7.236 7.229 6.862 6.850 6.842 6.831 6.739 6.732 6.728 6.715 6.711 5.134 3.723
MeO
N
O
N
N
O
3y
^{1}H NMR (CDCl$_3$, 400 MHz)
2.01
1.00
2.02
2.02
1.03
1.03
1.01
4.57
2.00
2.01
2.03
3.03
12
10
8
6
4
2
PPM

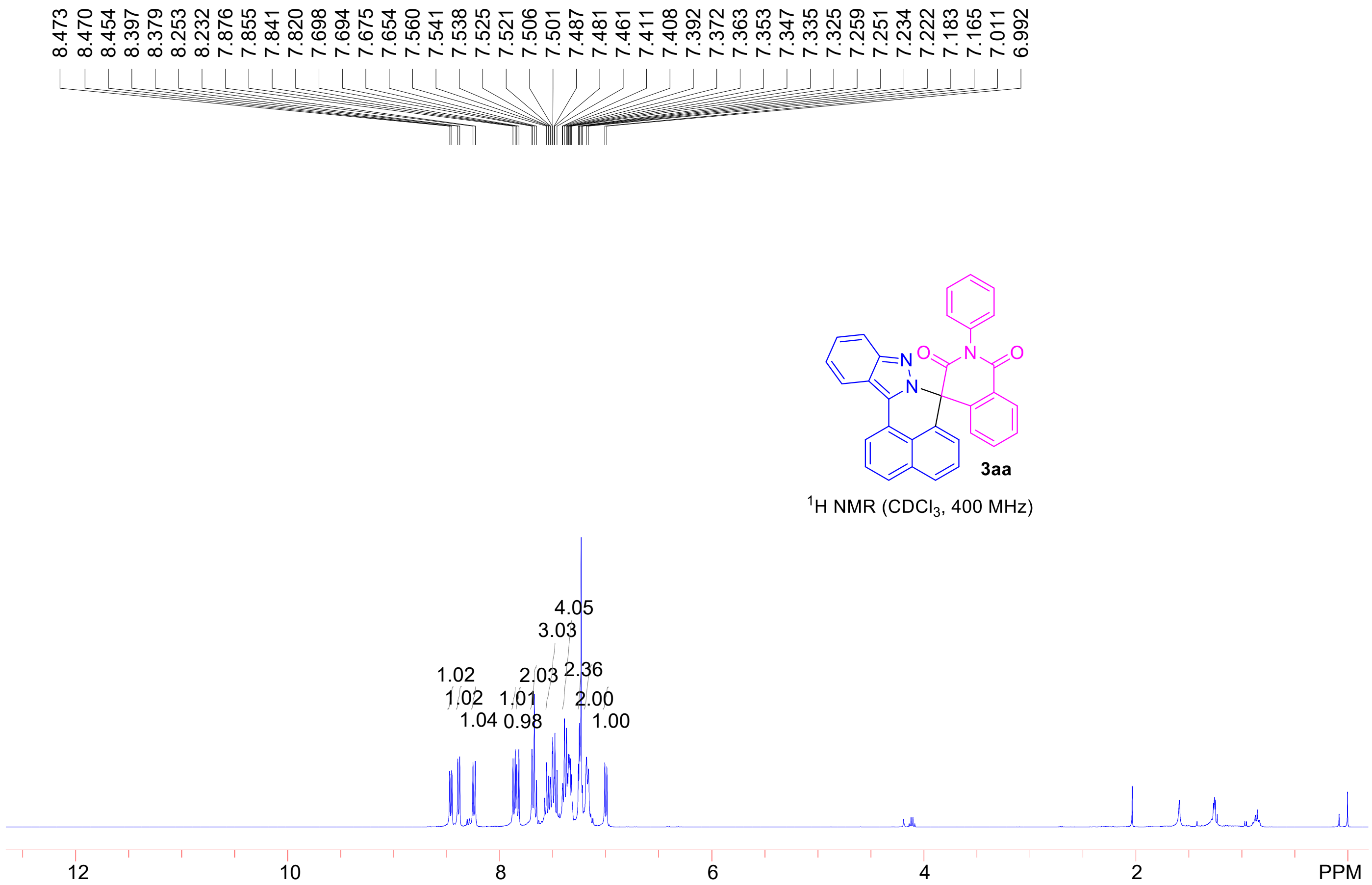

159.060 149.858 141.855 169.309 163.524 134.813 133.520 132.285 131.881 130.320 129.093 128.955 128.522 128.334 127.908 127.215 127.114 126.406 125.474 124.268 123.415 123.394 123.177 121.624 121.205 118.656 118.078 113.773 77.406 77.089 76.771 70.386 55.261 43.763
MeO
N
O
N
N
O
3y
^{13}C{^{1}H } NMR (CDCl$_3$, 100 MHz)
200
150
100
50
0
PPM

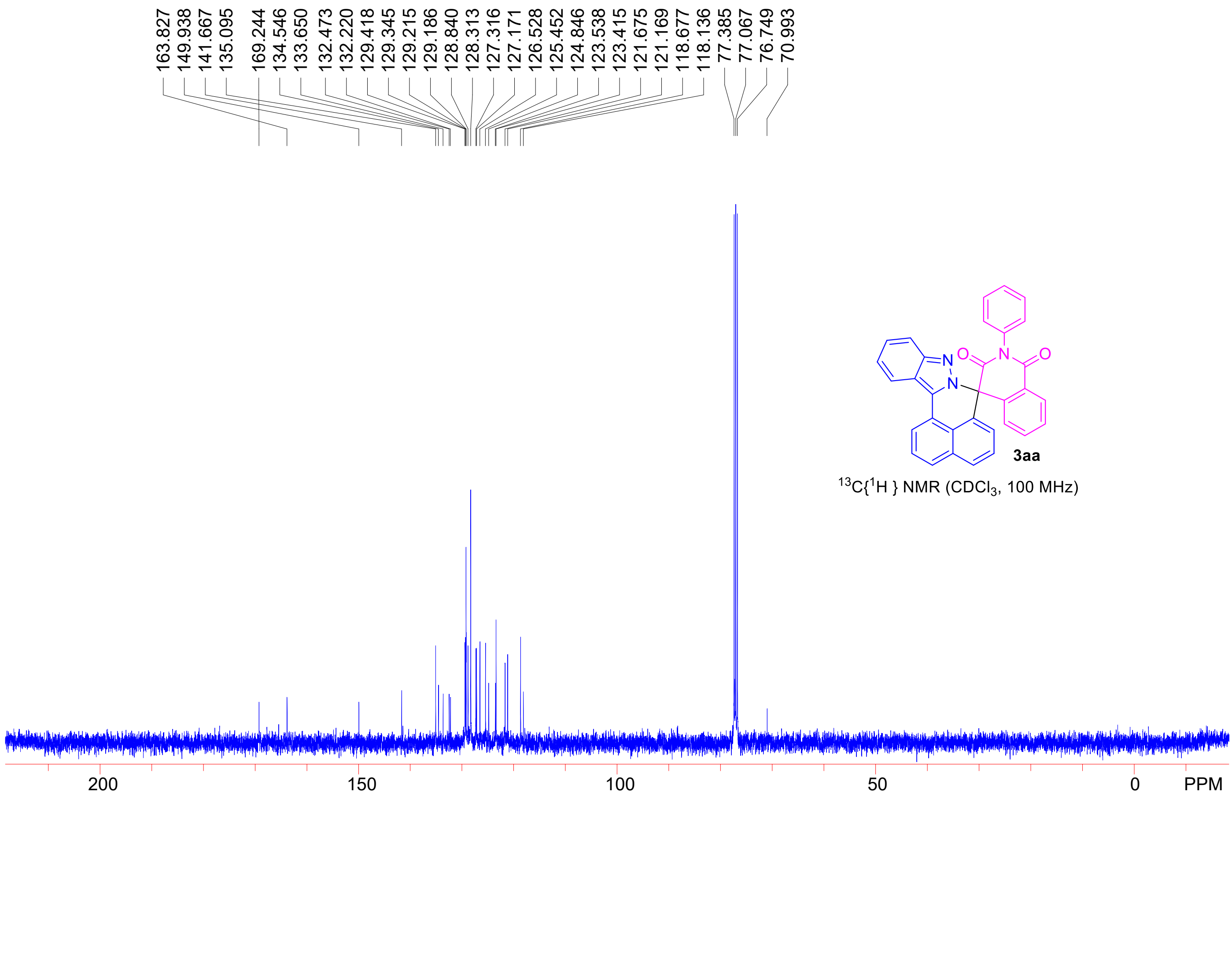


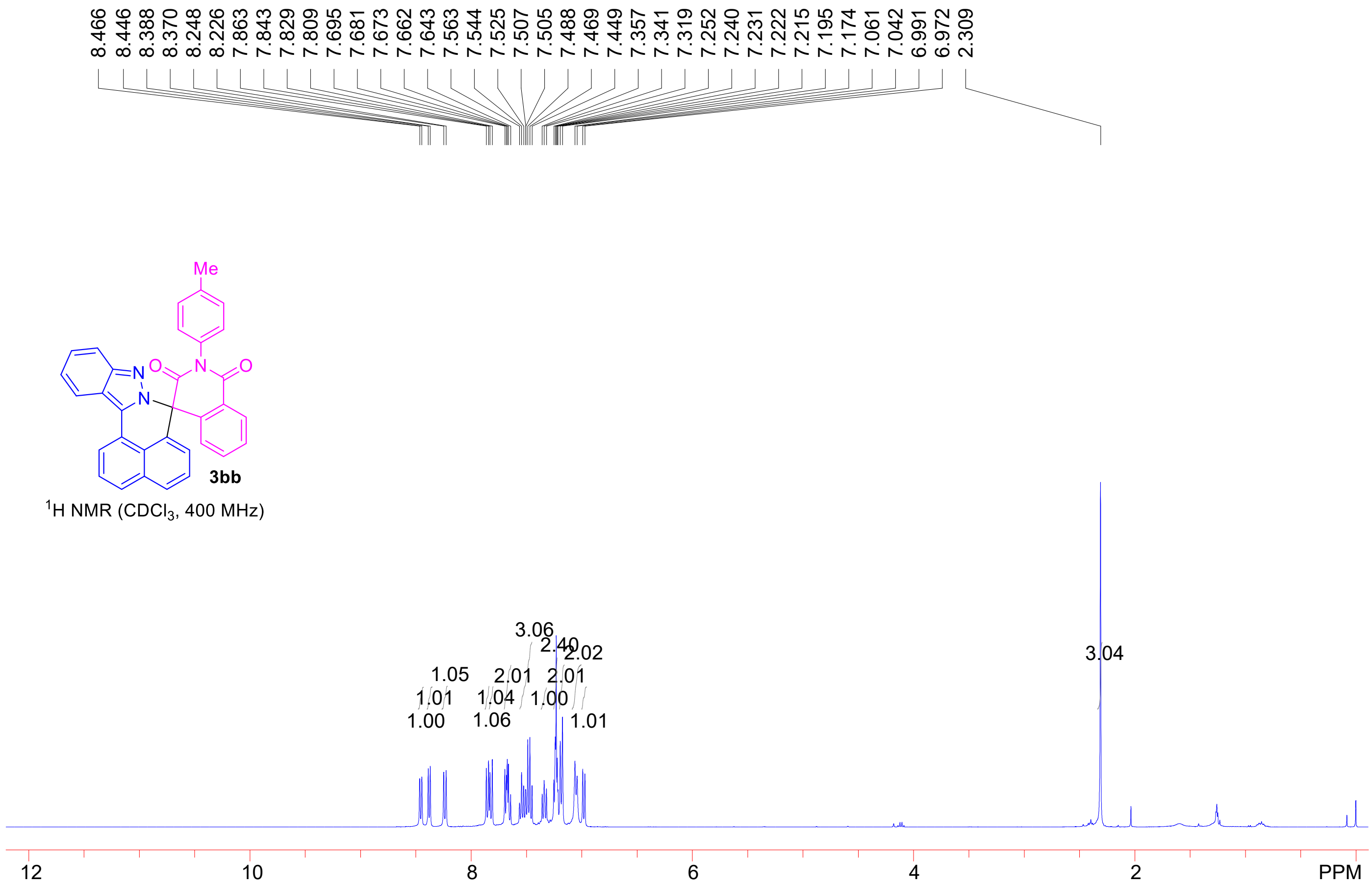
8.622 8.603 8.517 8.495 8.331 8.314 8.065 8.058 8.045 8.038 7.831 7.811 7.792 7.666 7.644 7.622 7.587 7.568 7.548 7.417 7.400 7.378 7.319 7.298 7.281 7.248 7.230 7.015 6.994 6.973 6.953 6.495 6.489 6.393 6.388 6.372 6.367 5.044 5.006 4.988 4.950 3.699 3.663 2.504 2.501 2.496
MeO
OMe
N
O
3z
^{1}H NMR (DMSO-d_6, 400 MHz)
1.00 1.03 1.02 2.03 1.01 2.00 2.03 1.03 1.01 1.02 1.03 1.02 0.99 1.03 1.01 1.04 3.03 3.03
10
8
6
4
2
PPM



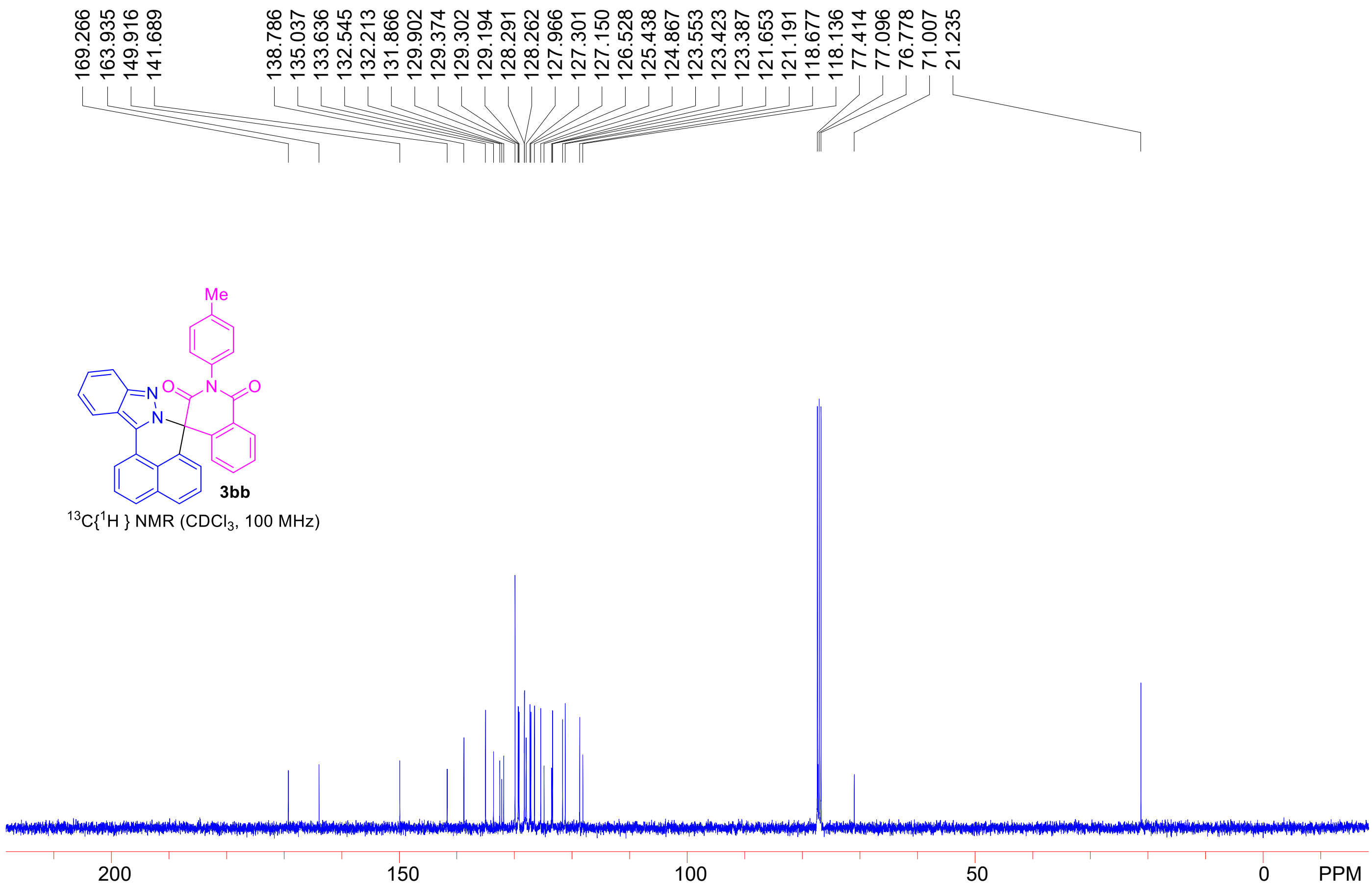
160.230 158.251 149.836 141.935 168.919 163.552 134.661 133.441 132.567 131.953 129.959 129.064 128.999 128.905 128.197 128.045 127.171 127.027 126.333 125.821 124.643 123.574 123.350 123.307 121.566 121.198 118.648 118.114 116.677 103.892 98.251 77.392 77.074 76.756 70.537 55.341 55.204 39.805
MeO
OMe
N
O
3z
^{13}C{^{1}H } NMR (CDCl$_3$, 100 MHz)
200
150
100
50
0
PPM


8.473 8.470 8.454 8.397 8.379 8.253 8.232 7.876 7.855 7.841 7.820 7.698 7.694 7.675 7.654 7.560 7.541 7.538 7.525 7.521 7.506 7.501 7.487 7.481 7.461 7.411 7.408 7.392 7.372 7.363 7.353 7.347 7.335 7.325 7.259 7.251 7.234 7.222 7.183 7.165 7.011 6.992
N
N
O
N
O
3aa
^{1}H NMR (CDCl$_3$, 400 MHz)
4.05
3.03
1.02
2.03
2.36
1.02
1.01
2.00
1.04
0.98
1.00
12
10
8
6
4
2
PPM

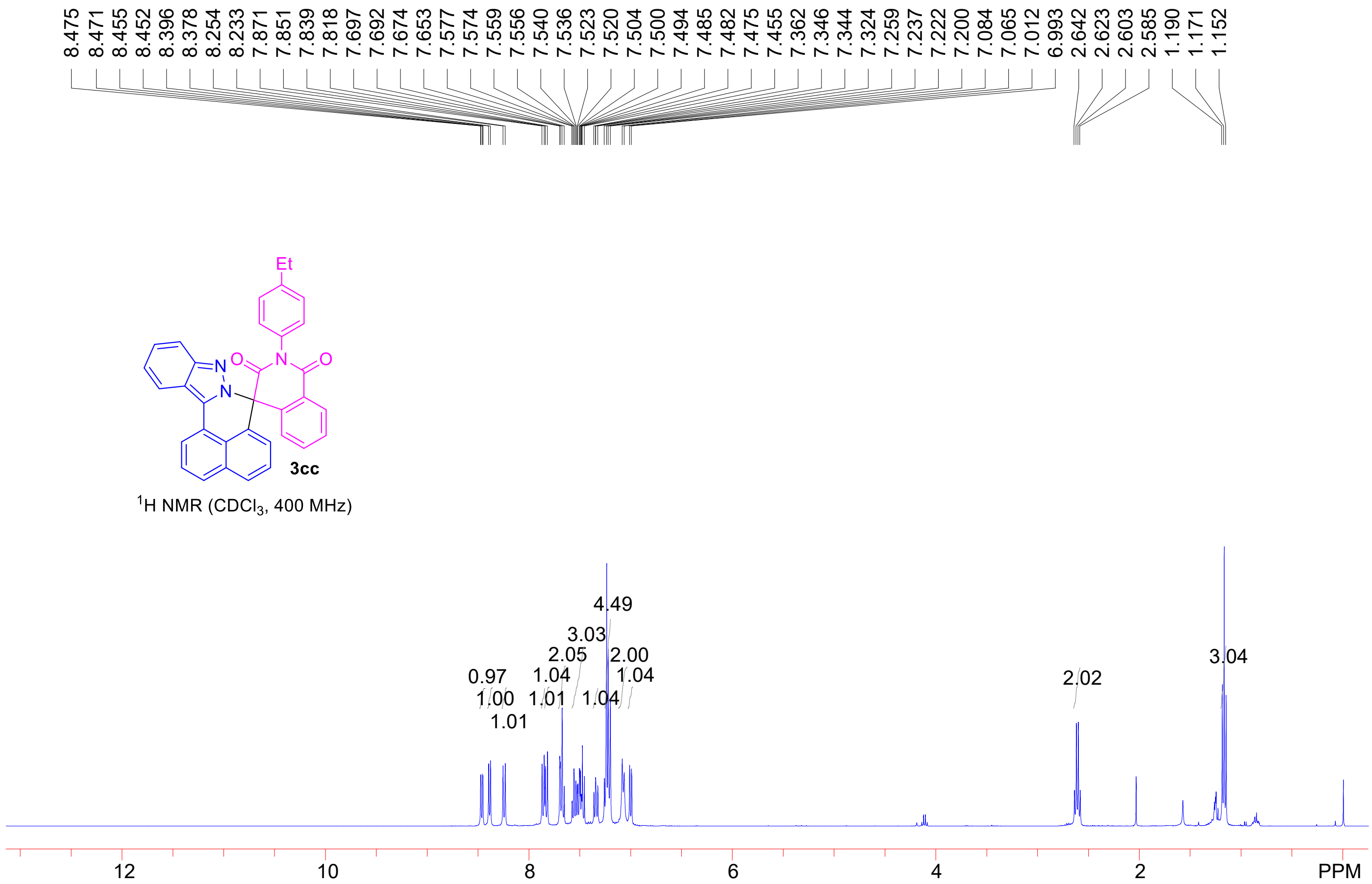

163.827 149.938 141.667 135.095 169.244 134.546 133.650 132.473 132.220 129.418 129.345 129.215 129.186 128.840 128.313 127.316 127.171 126.528 125.452 124.846 123.538 123.415 121.675 121.169 118.677 118.136 77.385 77.067 76.749 70.993
N
N
O
N
O
3aa
^{13}C{^{1}H } NMR (CDCl$_3$, 100 MHz)
200
150
100
50
0
PPM

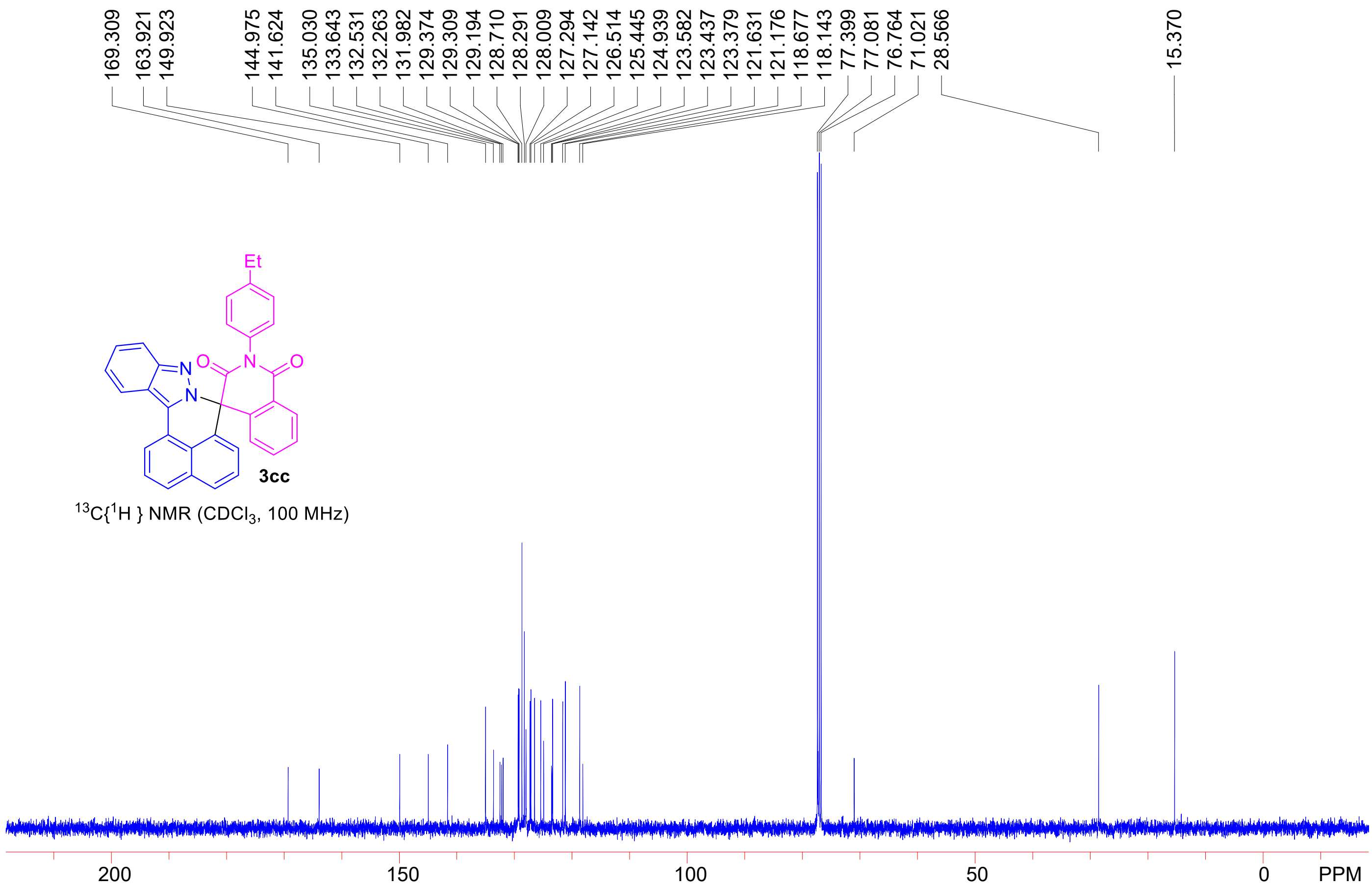


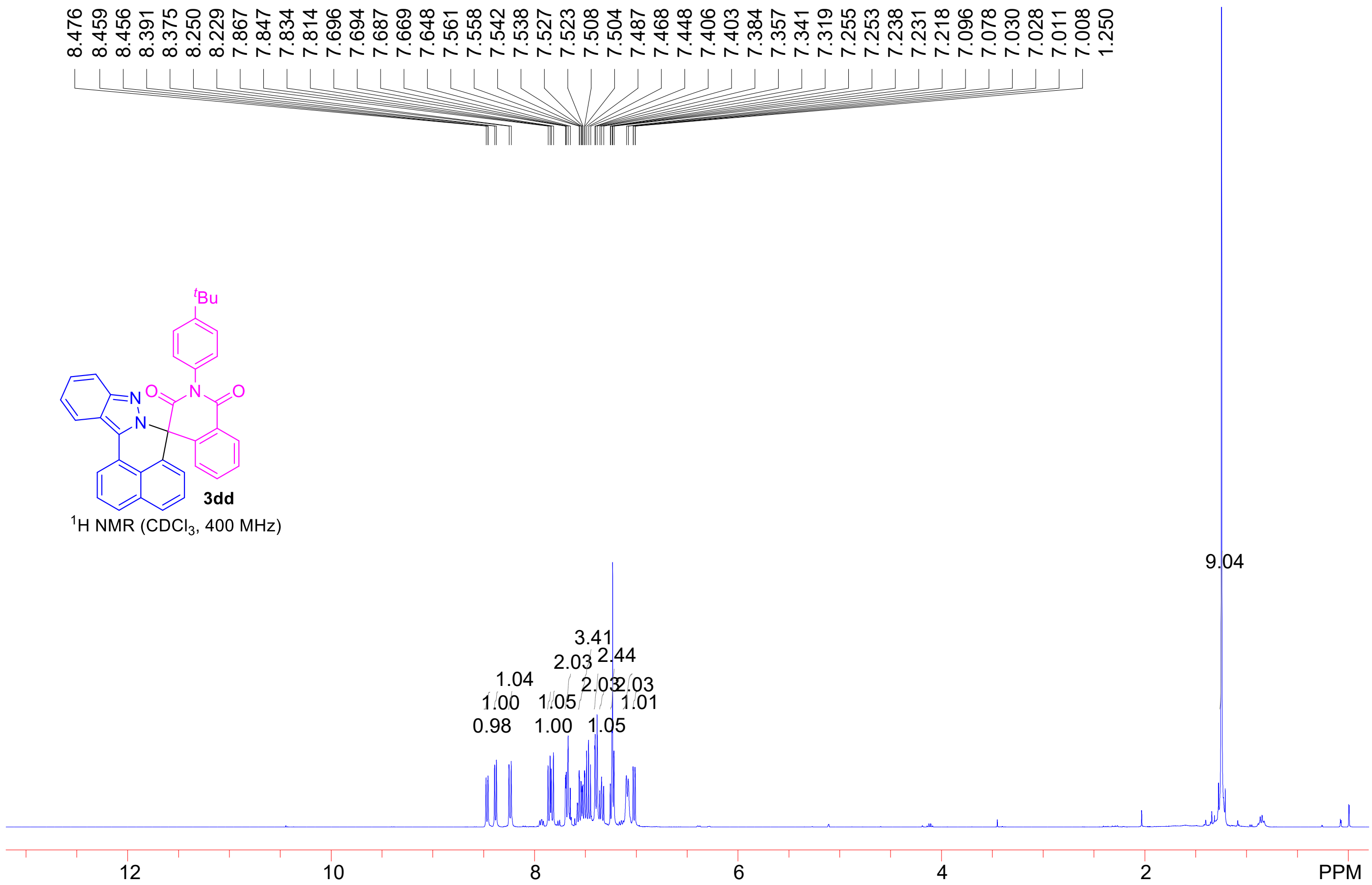
^{1}H NMR ($CDCl_3$, 400 MHz)

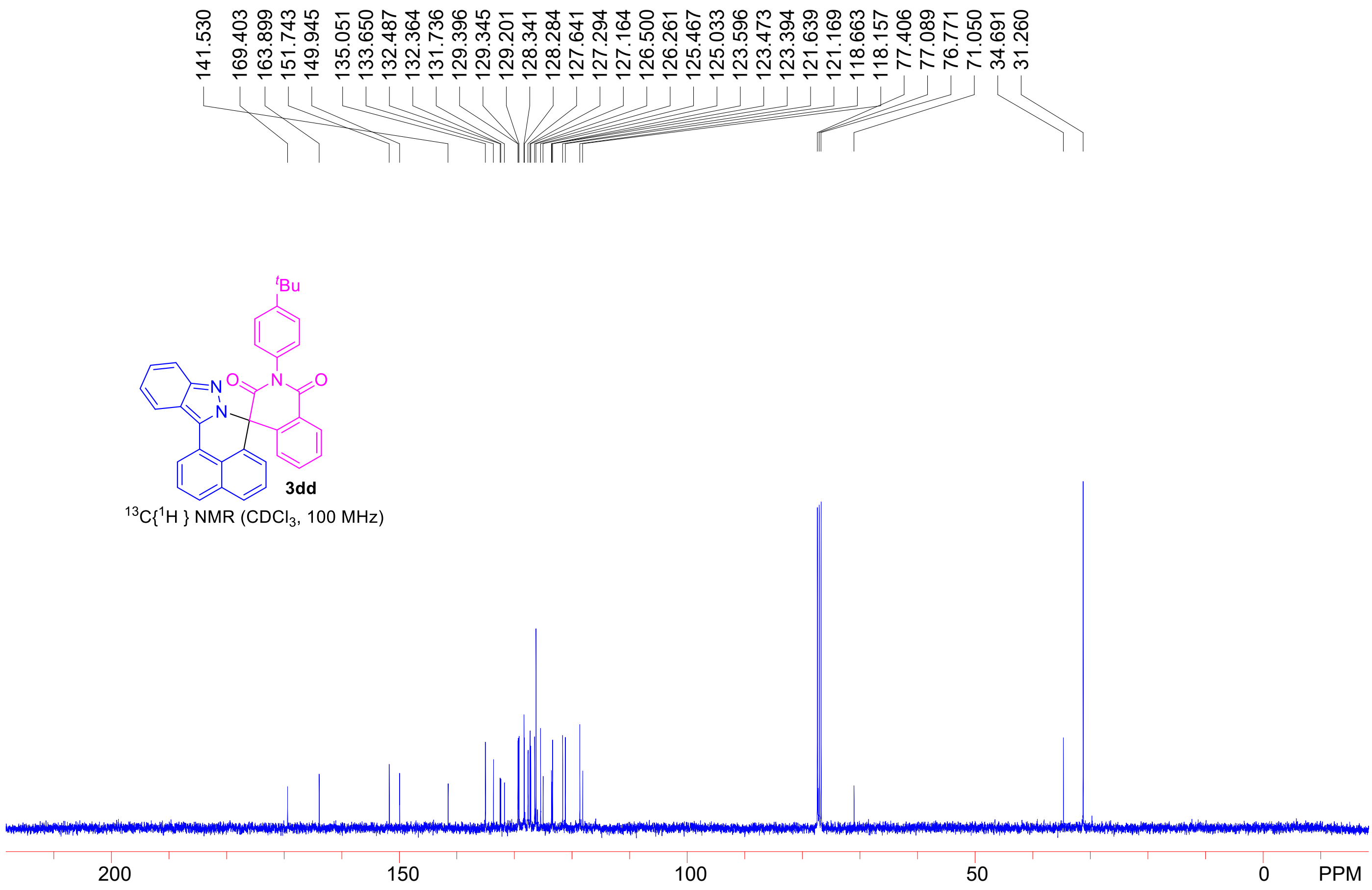


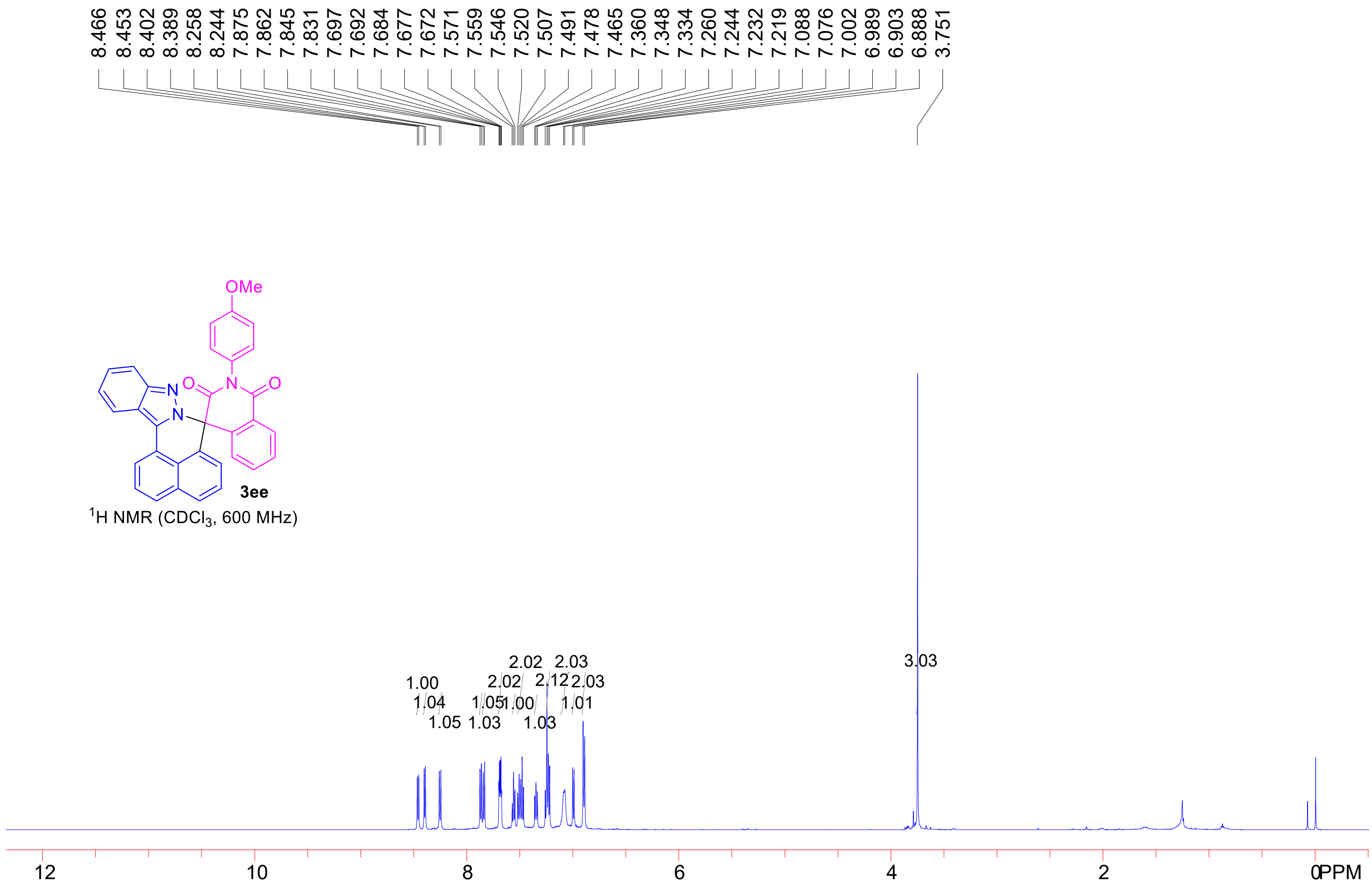
$^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 100 MHz)

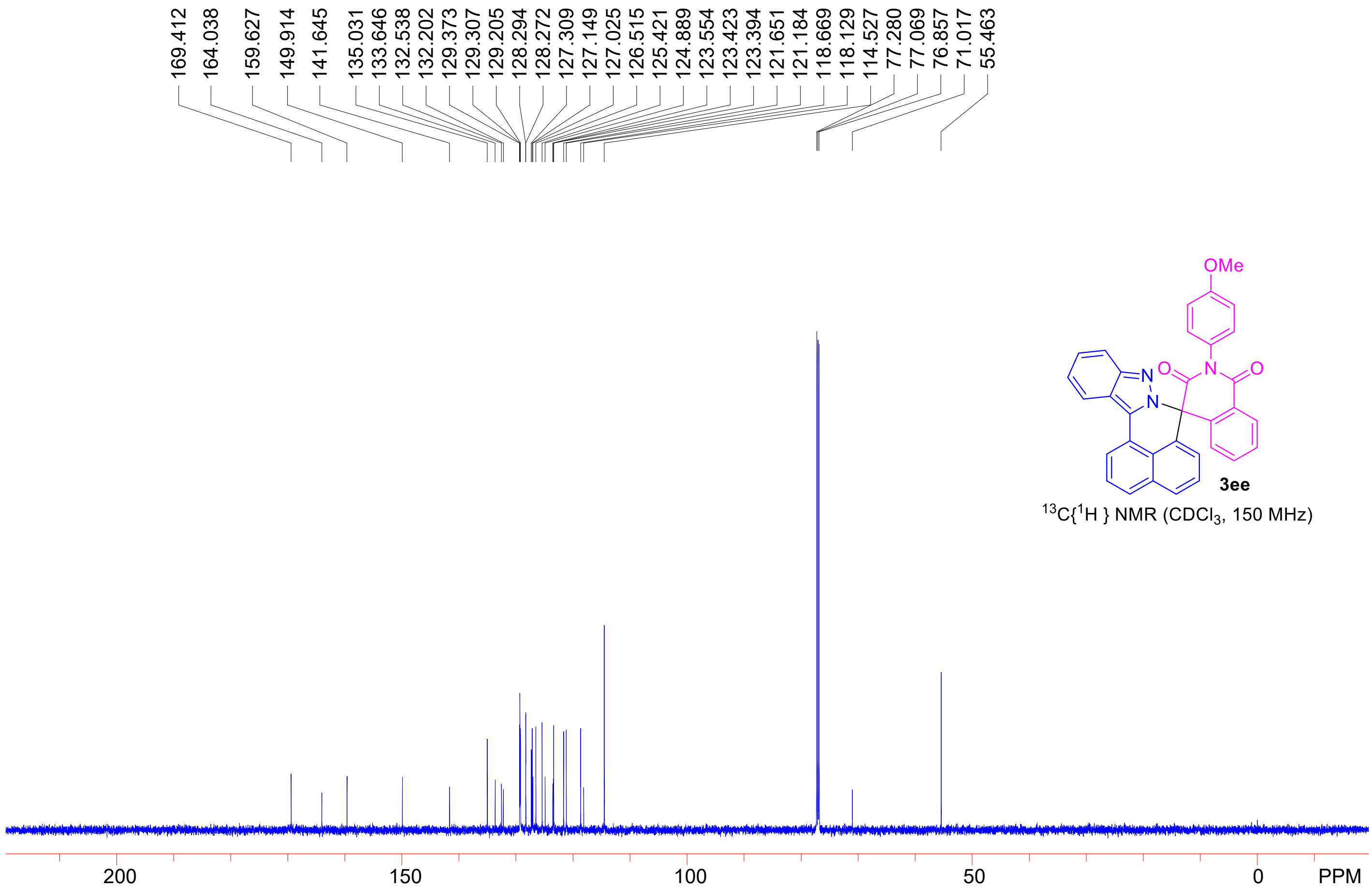

8.475 8.471 8.455 8.452 8.396 8.378 8.254 8.233 7.871 7.851 7.839 7.818 7.697 7.692 7.674 7.653 7.577 7.574 7.559 7.556 7.540 7.536 7.523 7.520 7.504 7.500 7.494 7.485 7.482 7.475 7.455 7.362 7.346 7.344 7.324 7.259 7.237 7.222 7.200 7.084 7.065 7.012 6.993 2.642 2.623 2.603 2.585 1.190 1.171 1.152
Et
N
N
O
N
O
3cc
^{1}H NMR (CDCl$_3$, 400 MHz)
0.97 1.00 1.01 1.04 1.01 2.05 3.03 4.49 1.04 2.00 1.04 2.02 3.04
12 10 8 6 4 2 PPM

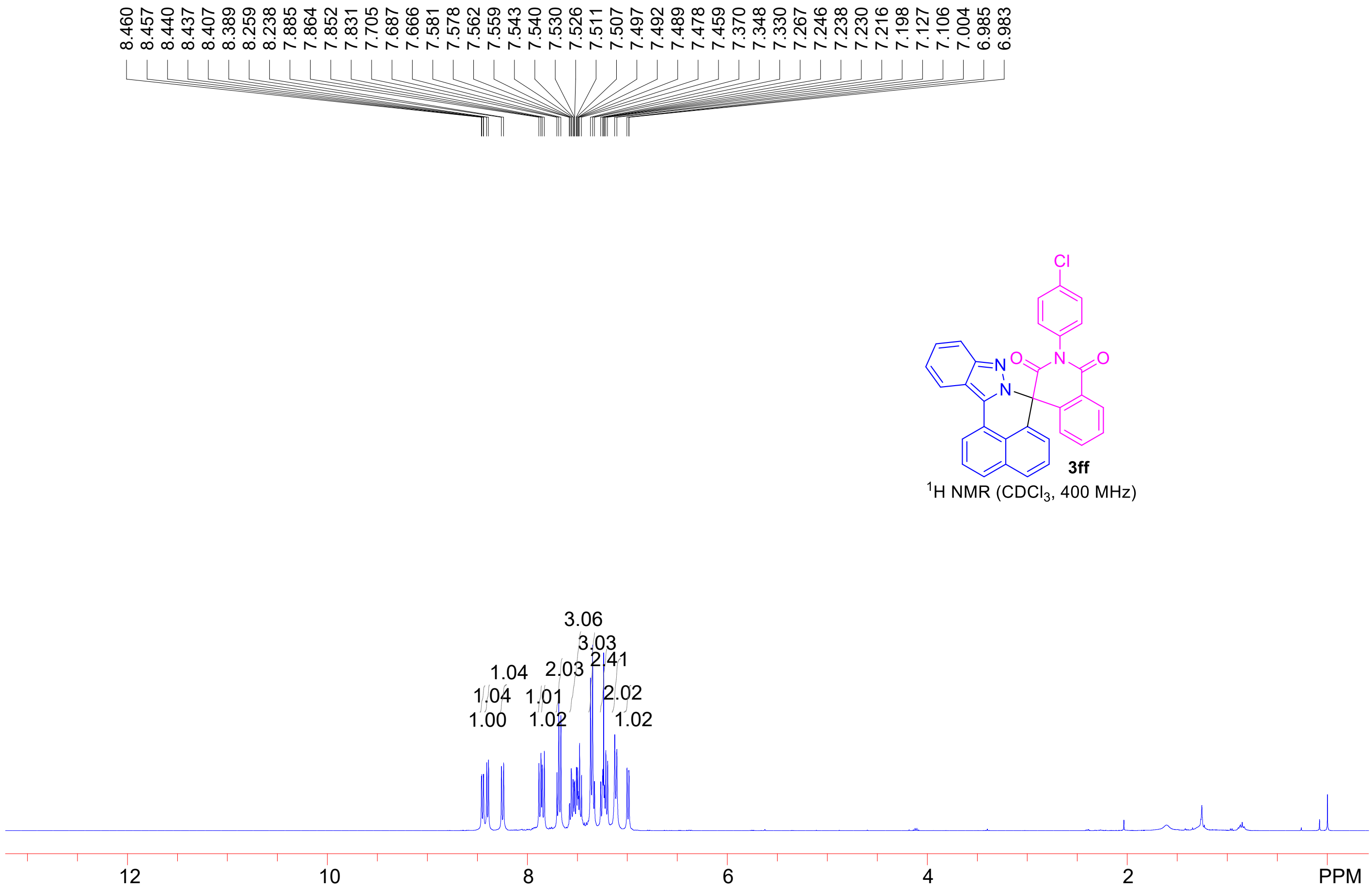

169.309 163.921 149.923 144.975 141.624 135.030 133.643 132.531 132.263 131.982 129.374 129.309 129.194 128.710 128.291 128.009 127.294 127.142 126.514 125.445 124.939 123.582 123.437 123.379 121.631 121.176 118.677 118.143 77.399 77.081 76.764 71.021 28.566 15.370
Et
N
N
O
N
O
3cc
^{13}C{^{1}H } NMR (CDCl$_3$, 100 MHz)
200 150 100 50 0 PPM

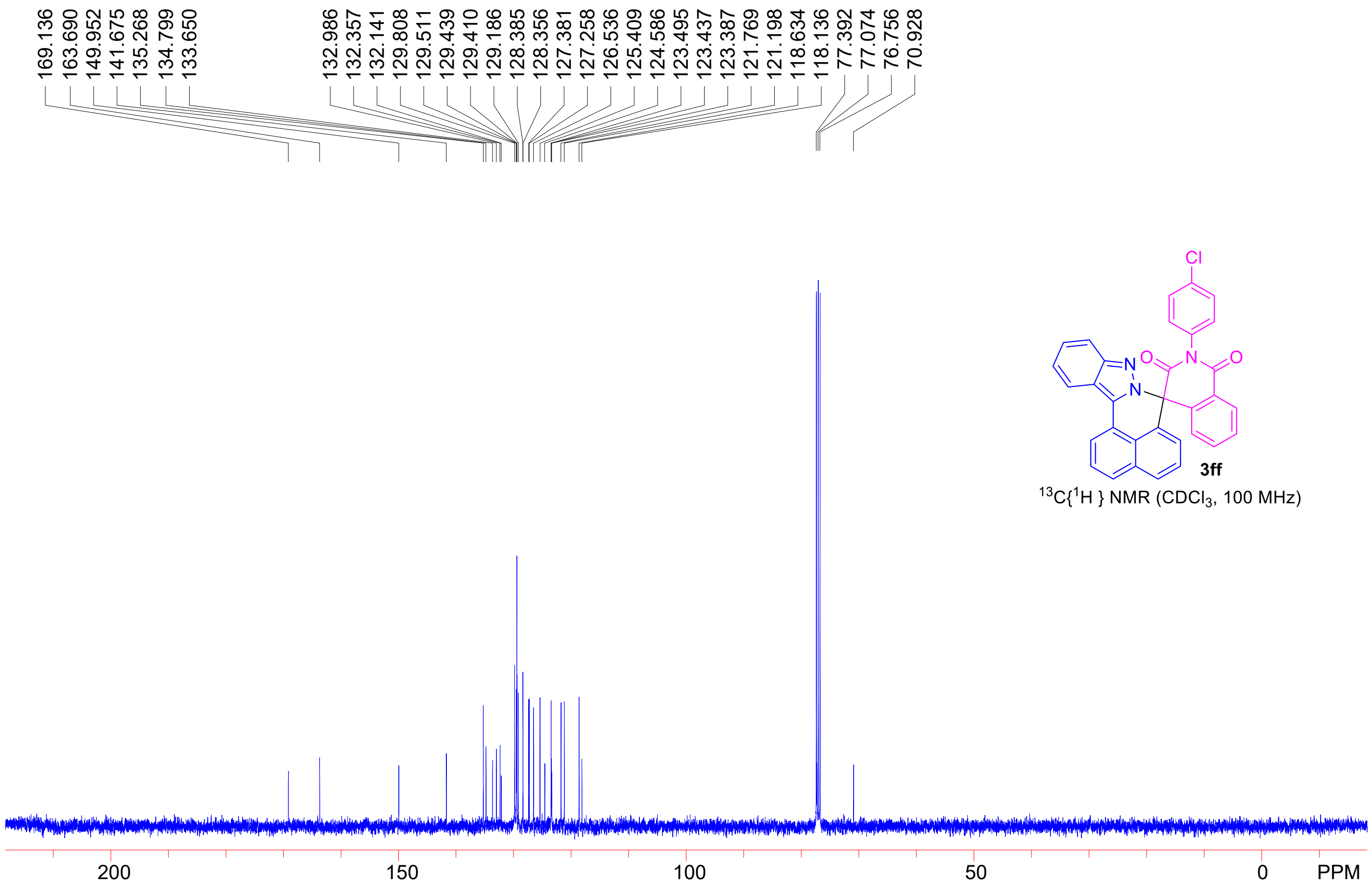

8.476 8.459 8.456 8.391 8.375 8.250 8.229 7.867 7.847 7.834 7.814 7.696 7.694 7.687 7.669 7.648 7.561 7.558 7.542 7.538 7.527 7.523 7.508 7.504 7.487 7.468 7.448 7.406 7.403 7.384 7.357 7.341 7.319 7.255 7.253 7.238 7.231 7.218 7.096 7.078 7.030 7.028 7.011 7.008 1.250
tBu
N
O
O
3dd
^{1}H NMR (CDCl$_3$, 400 MHz)
9.04
3.41
2.03
2.44
1.04
2.03
2.03
1.00
1.05
1.01
0.98
1.00
1.05
12
10
8
6
4
2
PPM

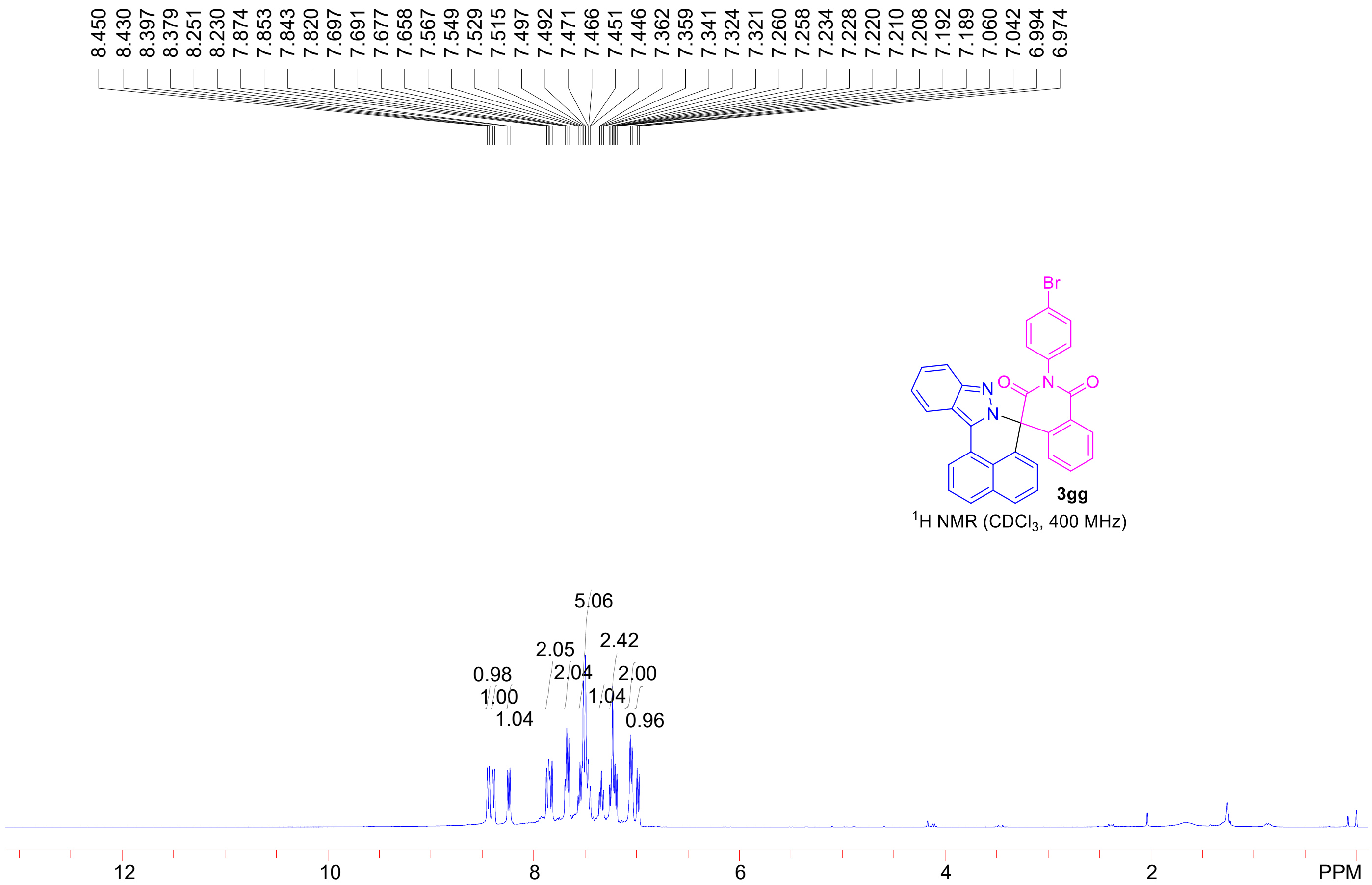

141.530 169.403 163.899 151.743 149.945 135.051 133.650 132.487 132.364 131.736 129.396 129.345 129.201 128.341 128.284 127.641 127.294 127.164 126.500 126.261 125.467 125.033 123.596 123.473 123.394 121.639 121.169 118.663 118.157 77.406 77.089 76.771 71.050 34.691 31.260
tBu
N
O
O
3dd
^{13}C{^{1}H } NMR (CDCl$_3$, 100 MHz)
200
150
100
50
0
PPM

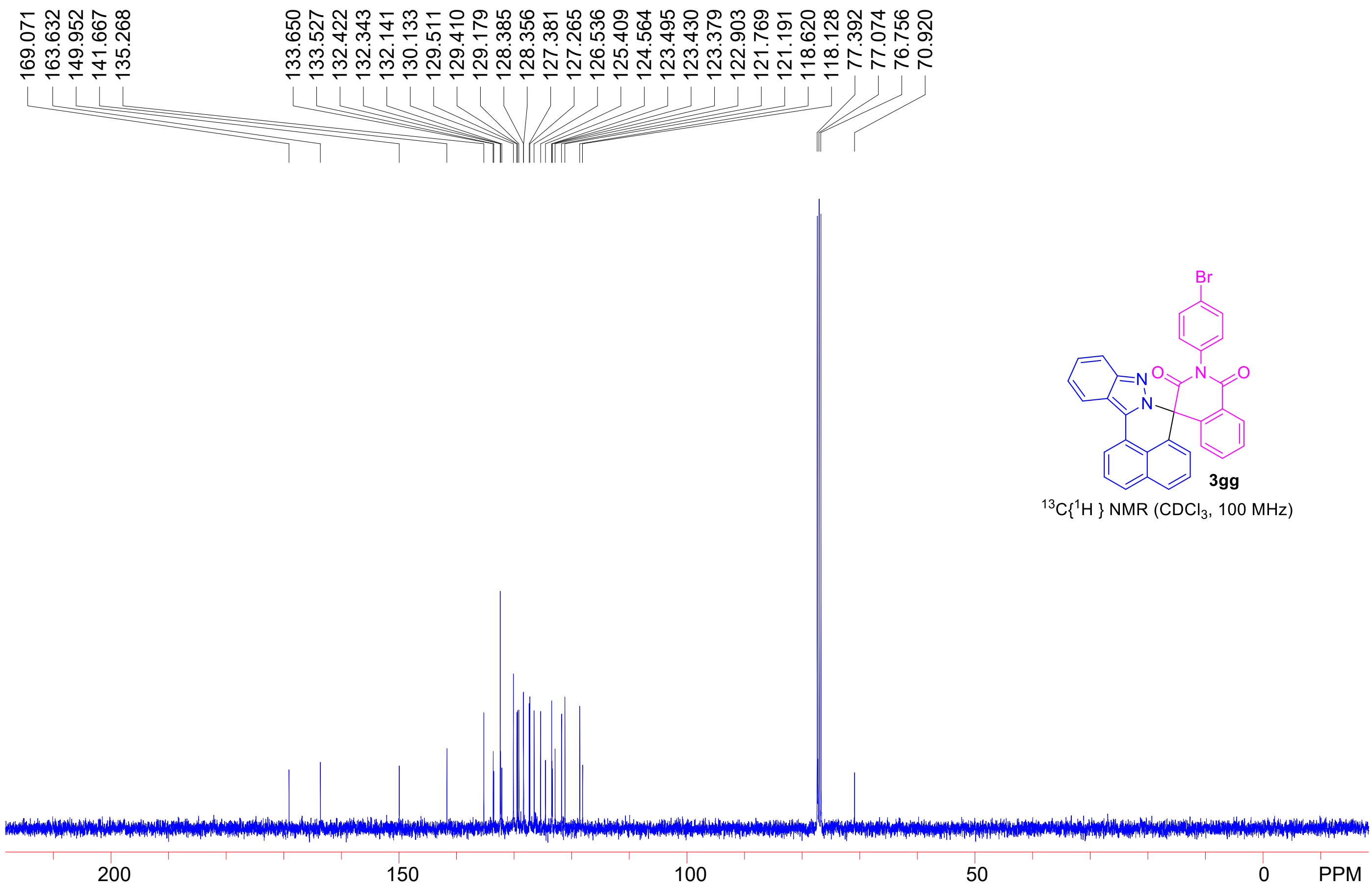

8.466
8.453
8.402
8.389
8.258
8.244
7.875
7.862
7.845
7.831
7.697
7.692
7.684
7.677
7.672
7.571
7.559
7.546
7.520
7.507
7.491
7.478
7.465
7.360
7.348
7.334
7.260
7.244
7.232
7.219
7.088
7.076
7.002
6.989
6.903
6.888
3.751
OMe
N
O
N
N
O
3ee
1H NMR (CDCl3, 600 MHz)
1.00
1.04
1.05
1.05
1.03
2.02
2.02
1.00
1.03
2.12
2.03
2.03
1.01
3.03
12
10
8
6
4
2
0
PPM


169.412
164.038
159.627
149.914
141.645
135.031
133.646
132.538
132.202
129.373
129.307
129.205
128.294
128.272
127.309
127.149
127.025
126.515
125.421
124.889
123.554
123.423
123.394
121.651
121.184
118.669
118.129
114.527
77.280
77.069
76.857
71.017
55.463
OMe
N
O
O
N
N
3ee
13C{1H } NMR (CDCl3, 150 MHz)
200
150
100
50
0
PPM

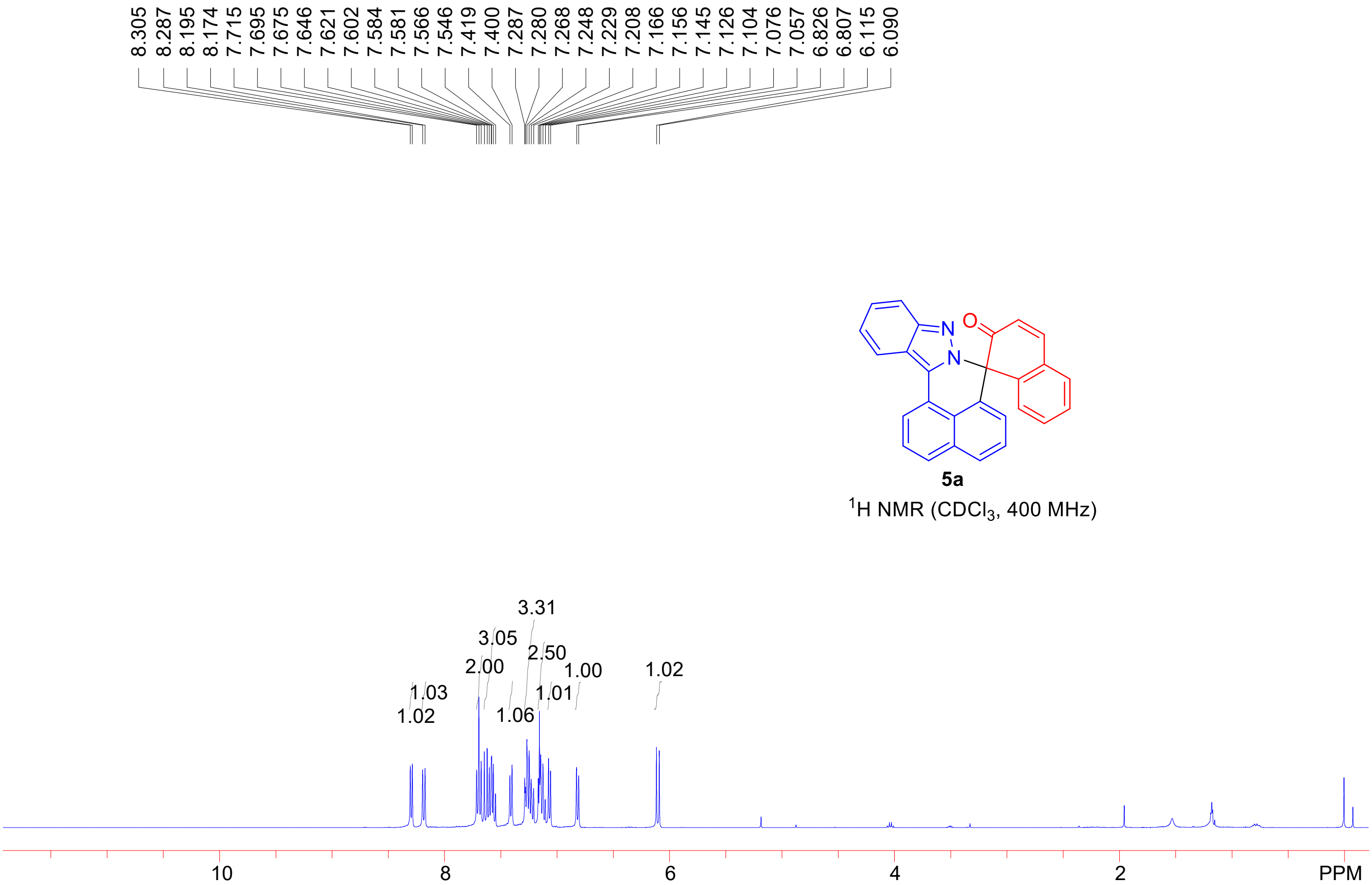

8.460 8.457 8.440 8.437 8.407 8.389 8.259 8.238 7.885 7.864 7.852 7.831 7.705 7.687 7.666 7.581 7.578 7.562 7.559 7.543 7.540 7.530 7.526 7.511 7.507 7.497 7.492 7.489 7.478 7.459 7.370 7.348 7.330 7.267 7.246 7.238 7.230 7.216 7.198 7.127 7.106 7.004 6.985 6.983
Cl
N
O
N
N
O
3ff
1H NMR (CDCl3, 400 MHz)
3.06
3.03
2.41
2.03
1.04
1.04
1.01
2.02
1.00
1.02
1.02
12
10
8
6
4
2
PPM

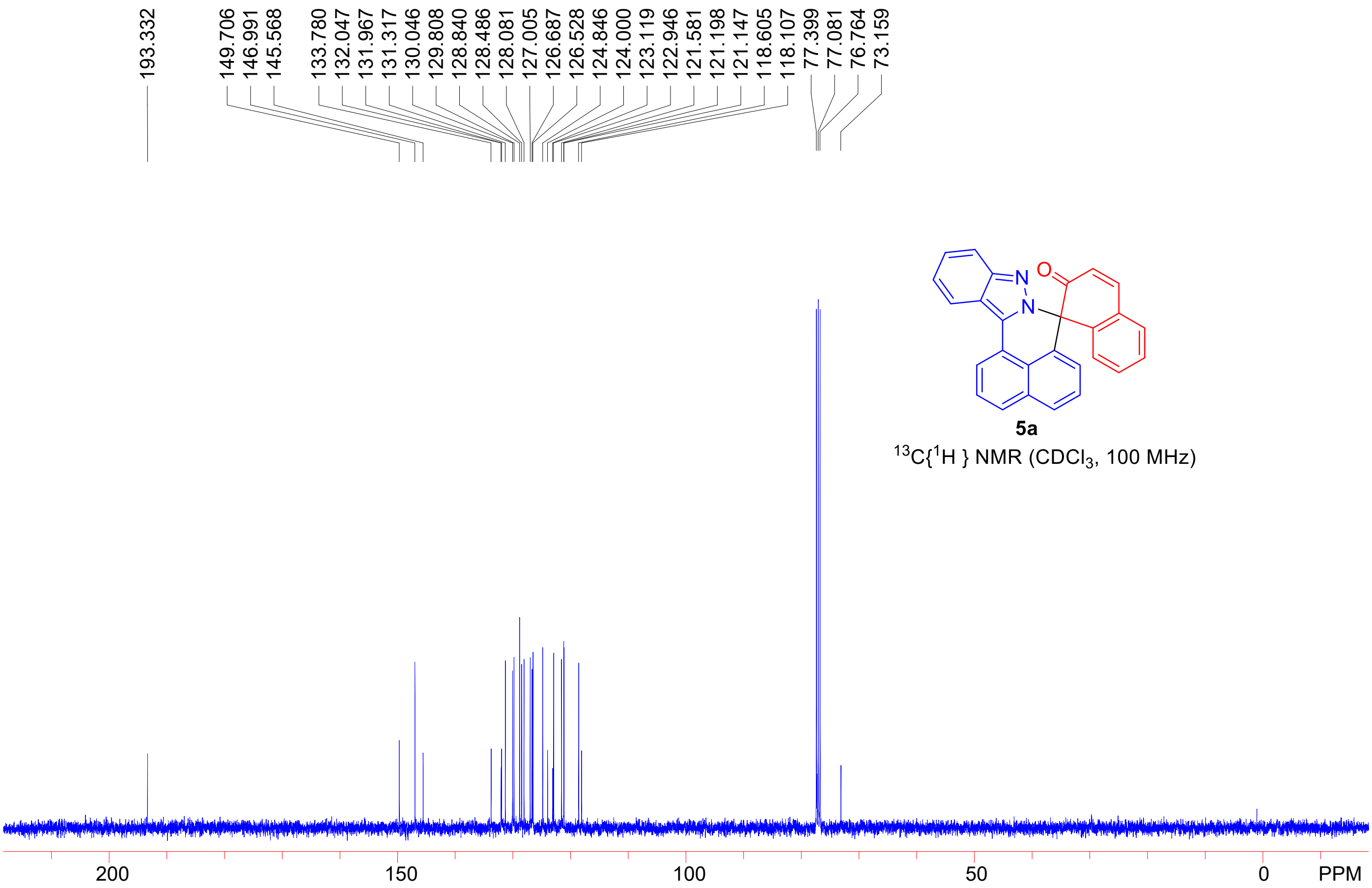

169.136 163.690 149.952 141.675 135.268 134.799 133.650 132.986 132.357 132.141 129.808 129.511 129.439 129.410 129.186 128.385 128.356 127.381 127.258 126.536 125.409 124.586 123.495 123.437 123.387 121.769 121.198 118.634 118.136 77.392 77.074 76.756 70.928
Cl
N
O
N
N
O
3ff
13C{1H } NMR (CDCl3, 100 MHz)
200
150
100
50
0
PPM

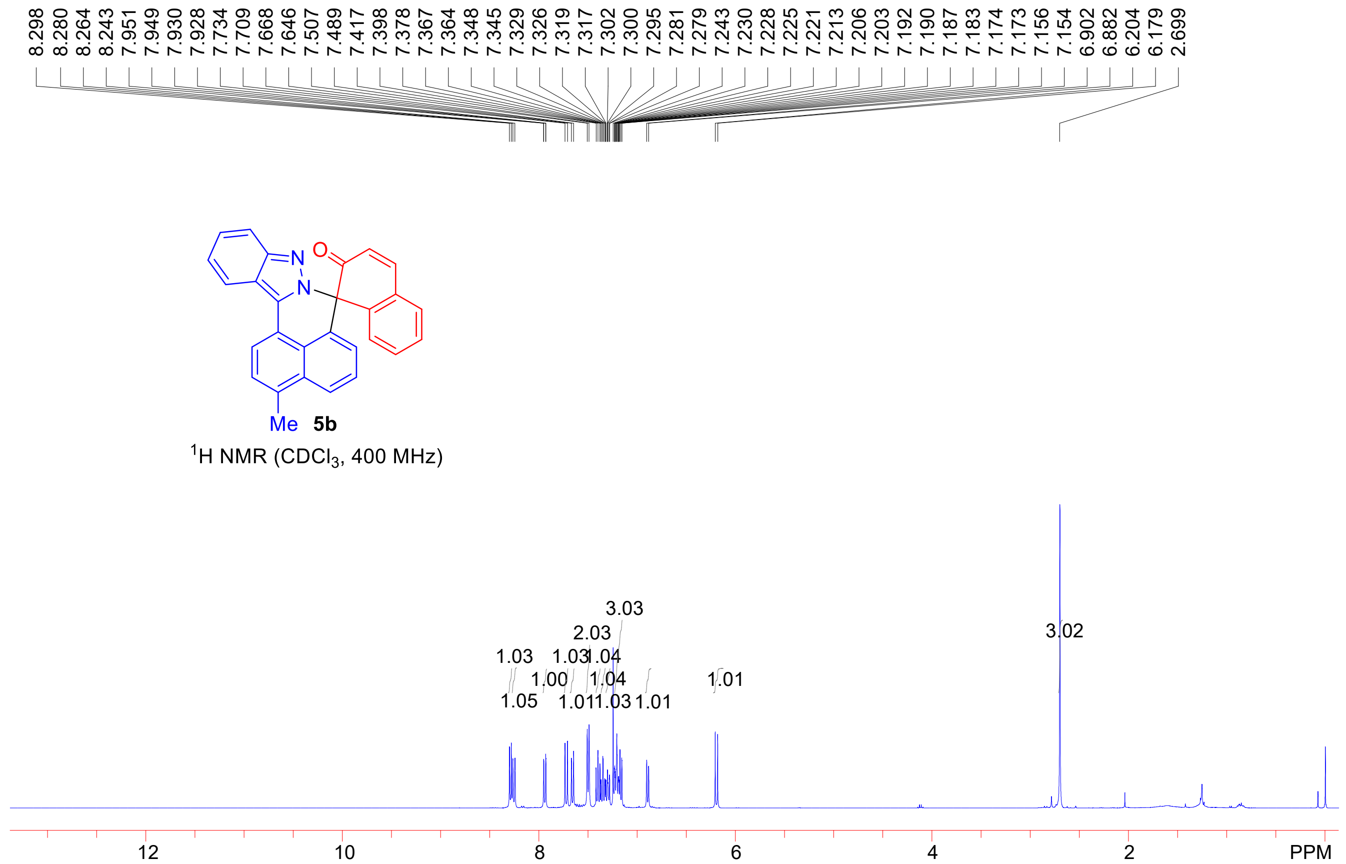

8.450 8.430 8.397 8.379 8.251 8.230 7.874 7.853 7.843 7.820 7.697 7.691 7.677 7.658 7.567 7.549 7.529 7.515 7.497 7.492 7.471 7.466 7.451 7.446 7.362 7.359 7.341 7.324 7.321 7.260 7.258 7.234 7.228 7.220 7.210 7.208 7.192 7.189 7.060 7.042 6.994 6.974
Br
O
N
O
N
N
3gg
^{1}H NMR (CDCl$_3$, 400 MHz)
5.06
2.05
2.42
0.98
2.04
2.00
1.00
1.04
1.04
0.96
12
10
8
6
4
2
PPM

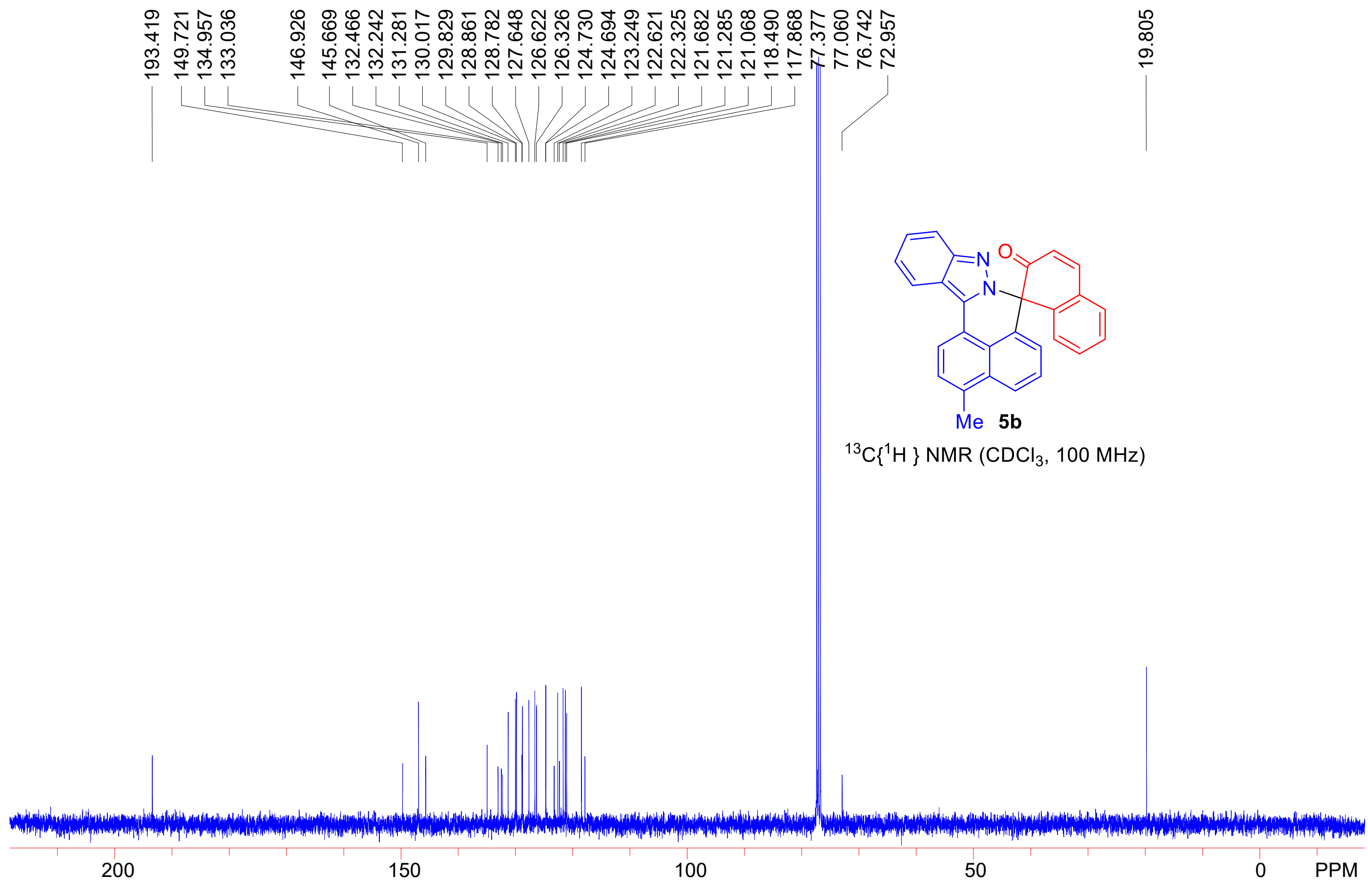

169.071 163.632 149.952 141.667 135.268 133.650 133.527 132.422 132.343 132.141 130.133 129.511 129.410 129.179 128.385 128.356 127.381 127.265 126.536 125.409 124.564 123.495 123.430 123.379 122.903 121.769 121.191 118.620 118.128 77.392 77.074 76.756 70.920
Br
O
N
O
N
N
3gg
^{13}C{^{1}H } NMR (CDCl$_3$, 100 MHz)
200
150
100
50
0
PPM

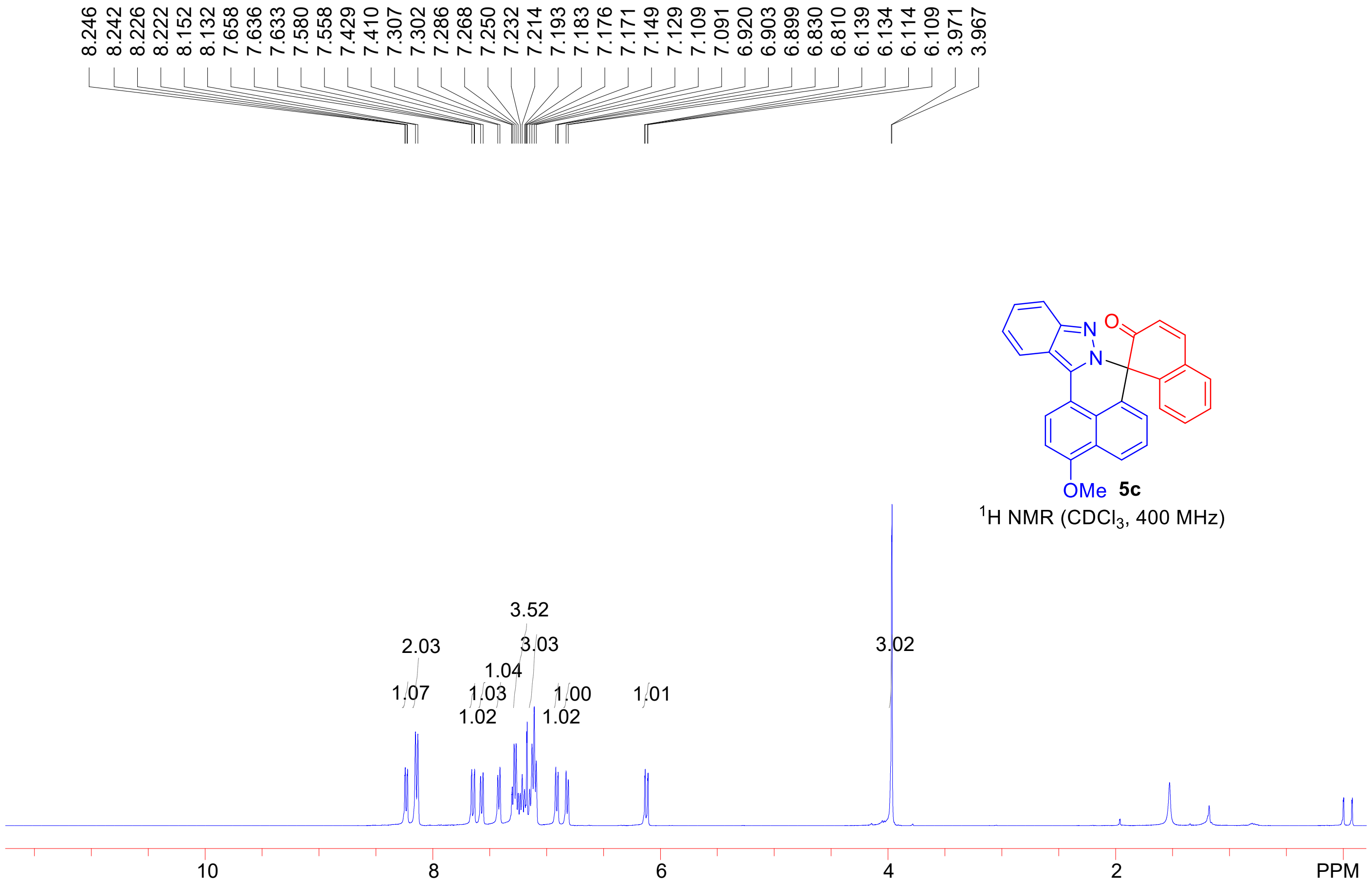
V. NMR spectra of 5a-5n



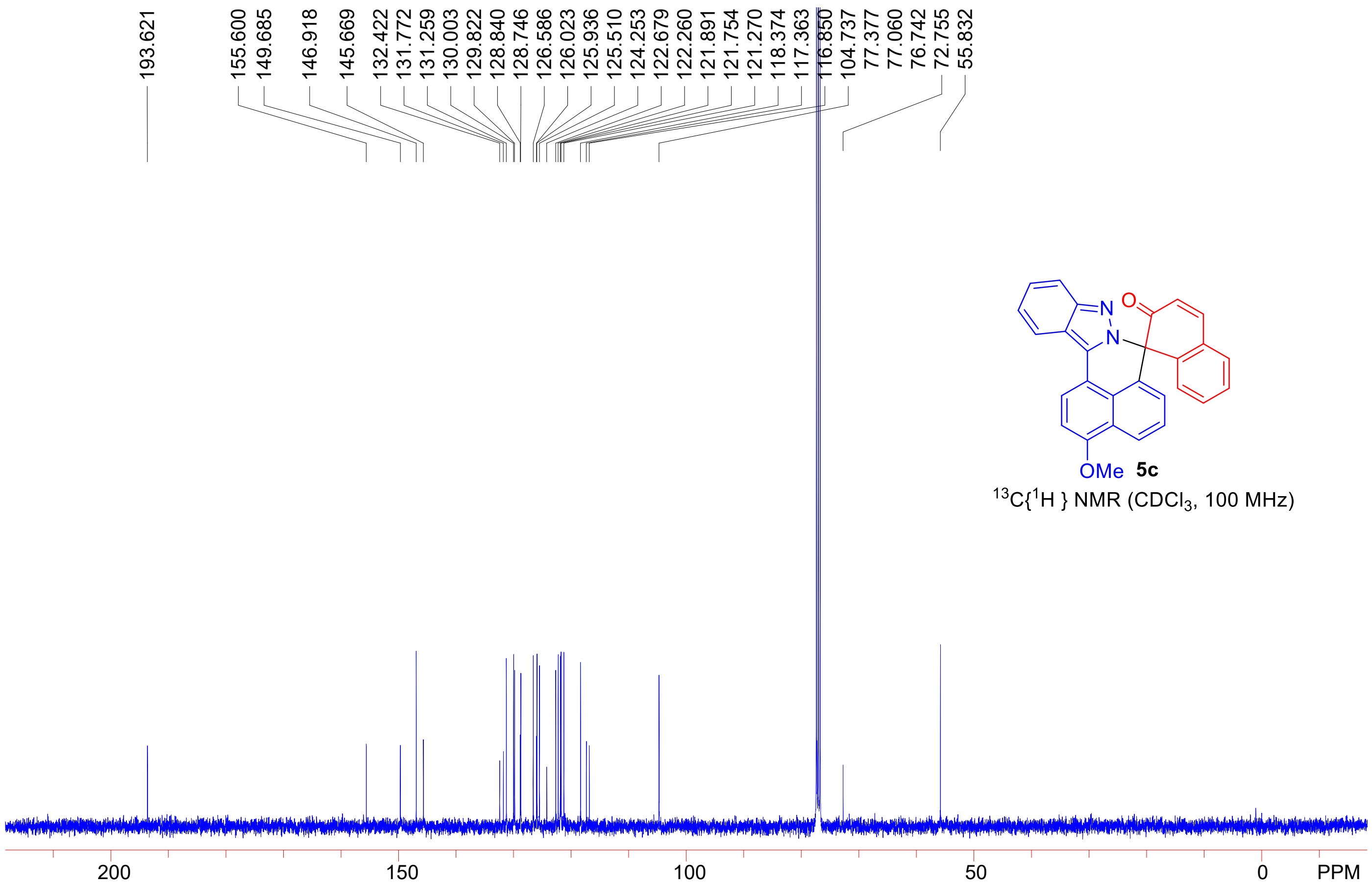



8.298
8.280
8.264
8.243
7.951
7.949
7.930
7.928
7.734
7.709
7.668
7.646
7.507
7.489
7.417
7.398
7.378
7.367
7.364
7.348
7.345
7.329
7.326
7.319
7.317
7.302
7.300
7.295
7.281
7.279
7.243
7.230
7.228
7.225
7.221
7.213
7.206
7.203
7.192
7.190
7.187
7.183
7.174
7.173
7.156
7.154
6.902
6.882
6.204
6.179
2.699
Me
5b
1H NMR (CDCl3, 400 MHz)
3.03
2.03
1.03
1.03
1.04
1.00
1.04
1.05
1.01
1.03
1.01
1.01
3.02
12
10
8
6
4
2
PPM

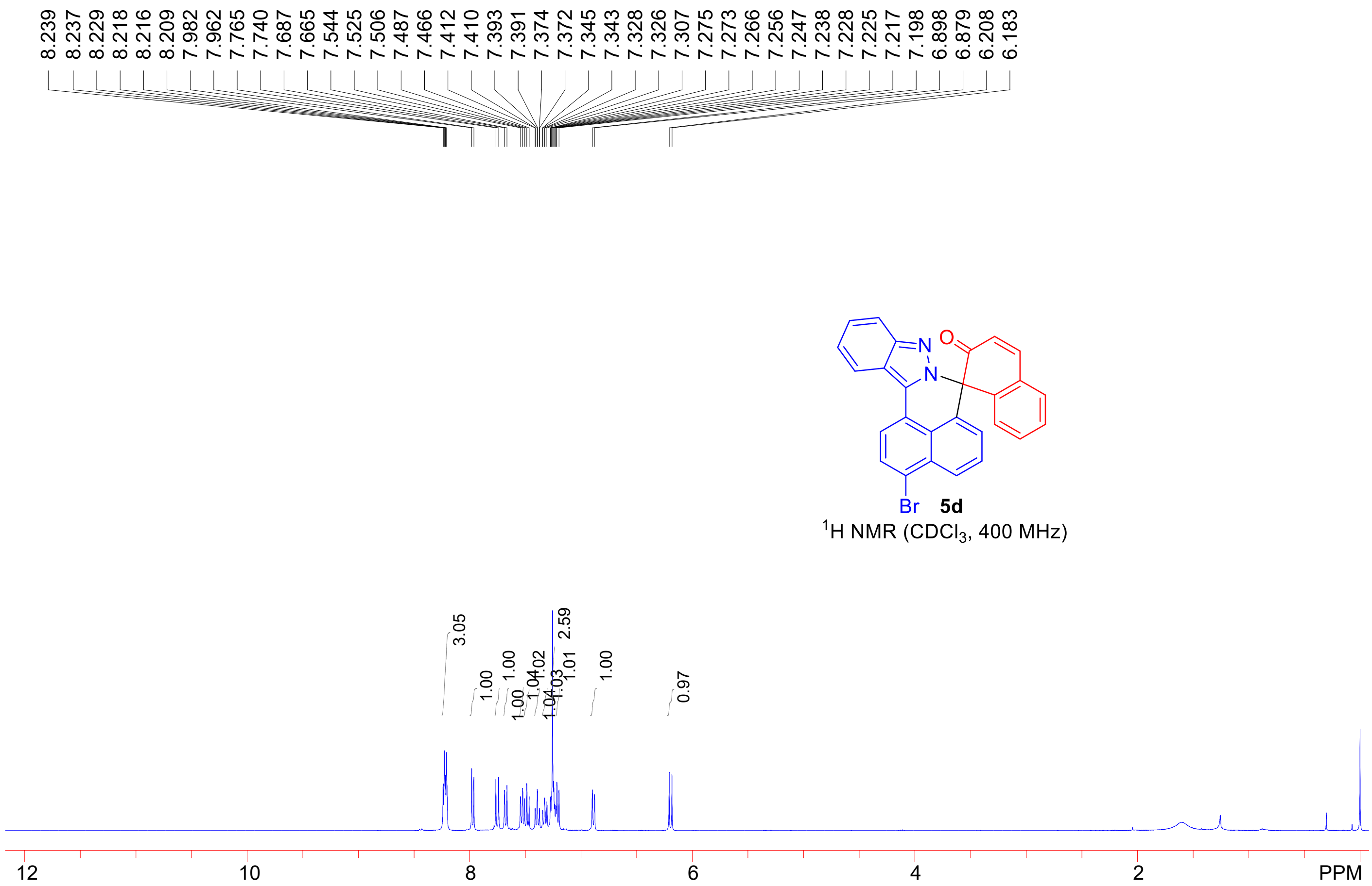

193.419
149.721
134.957
133.036
146.926
145.669
132.466
132.242
131.281
130.017
129.829
128.861
128.782
127.648
126.622
126.326
124.730
124.694
123.249
122.621
122.325
121.682
121.285
121.068
118.490
117.868
77.377
77.060
76.742
72.957
19.805
Me
5b
13C{1H } NMR (CDCl3, 100 MHz)
200
150
100
50
0
PPM

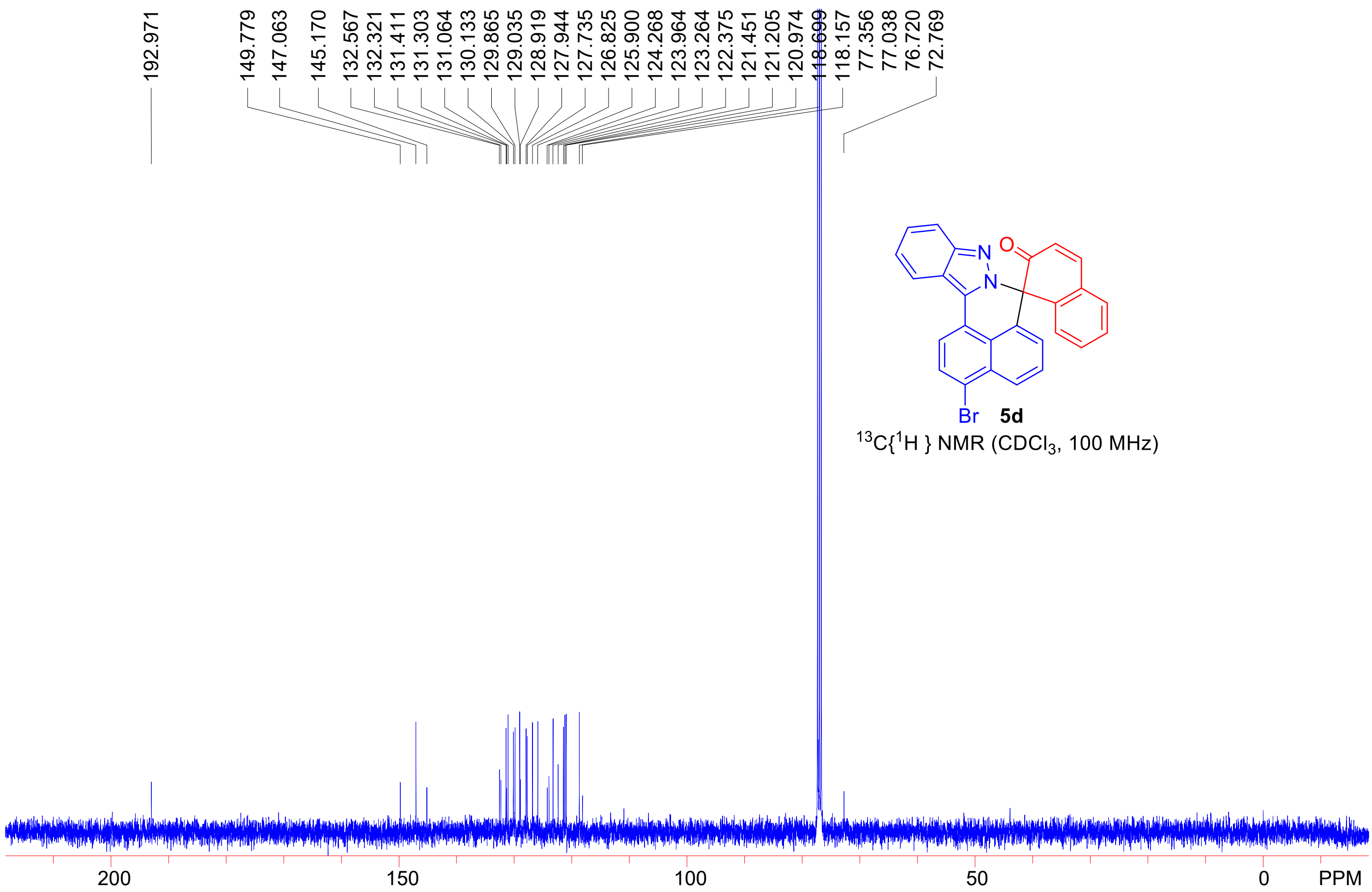


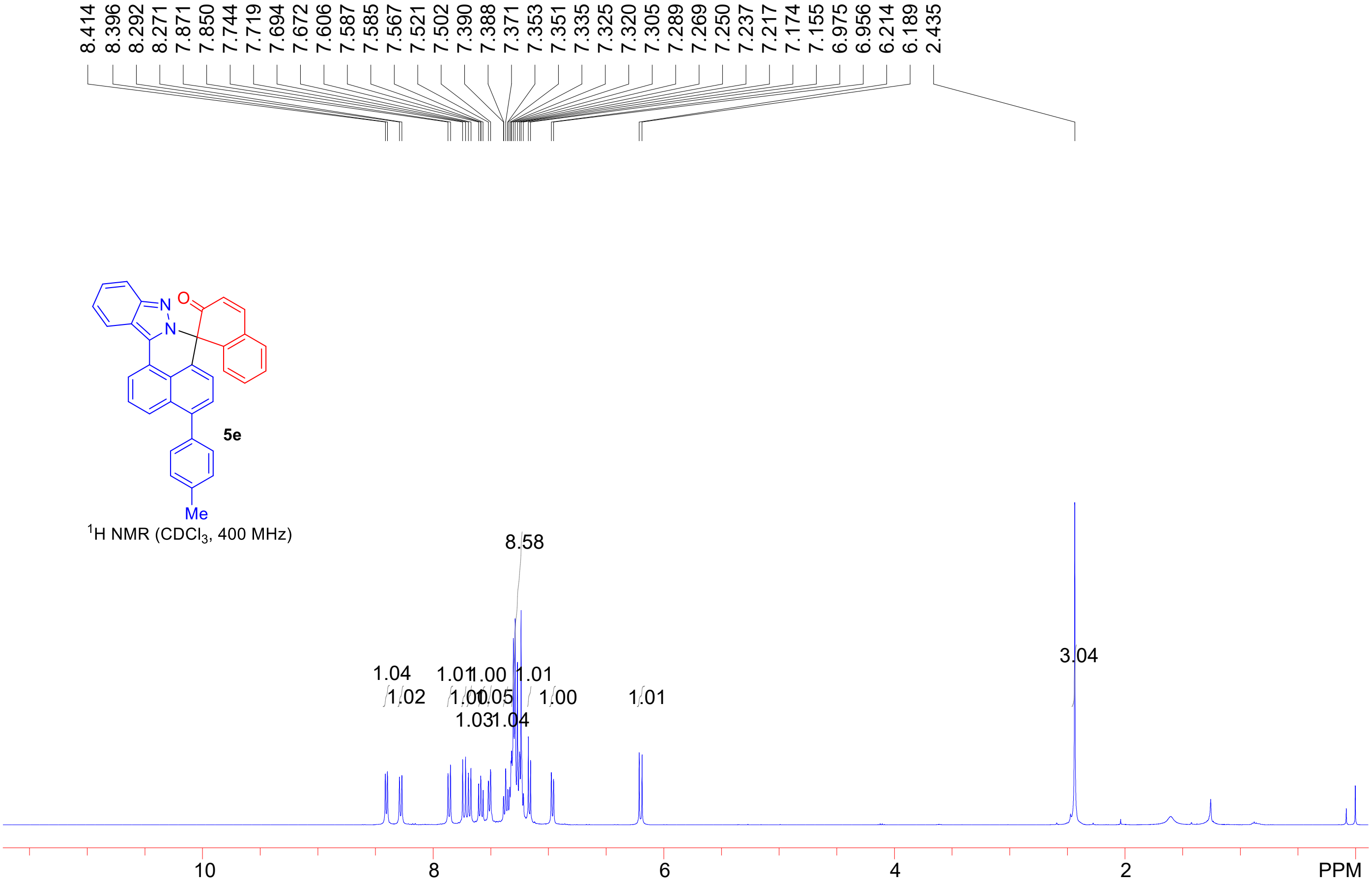
8.246 8.242 8.226 8.222 8.152 8.132 7.658 7.636 7.633 7.580 7.558 7.429 7.410 7.307 7.302 7.286 7.268 7.250 7.232 7.214 7.193 7.183 7.176 7.171 7.149 7.129 7.109 7.091 6.920 6.903 6.899 6.830 6.810 6.139 6.134 6.114 6.109 3.971 3.967
OMe 5c
1H NMR (CDCl3, 400 MHz)
3.52
2.03
3.03
1.04
1.07
1.03
1.00
1.01
1.02
1.02
3.02
10
8
6
4
2
PPM

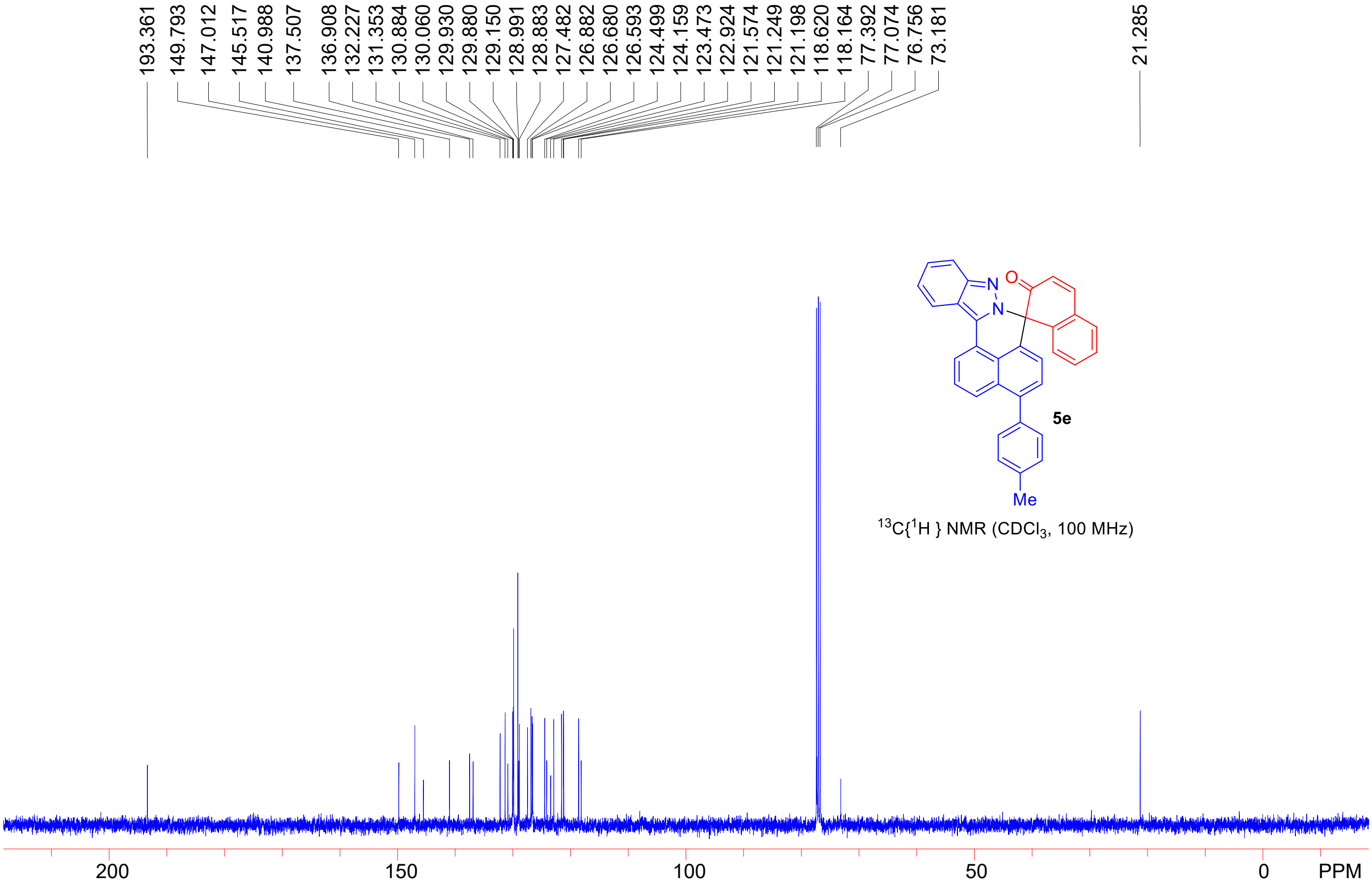


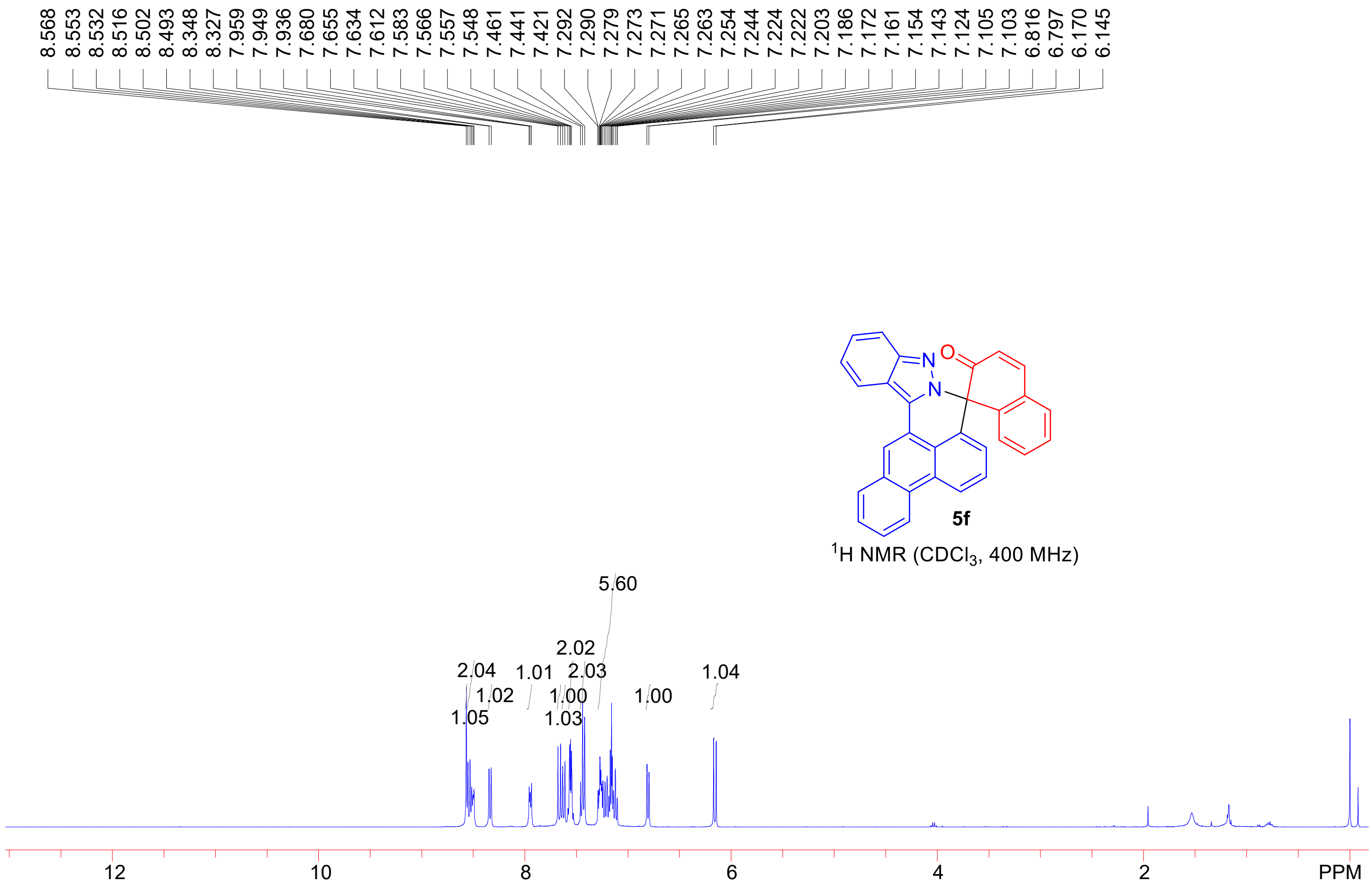
193.621
155.600 149.685 146.918 145.669 132.422 131.772 131.259 130.003 129.822 128.840 128.746 126.586 126.023 125.936 125.510 124.253 122.679 122.260 121.891 121.754 121.270 118.374 117.363 116.850 104.737 77.377 77.060 76.742 72.755 55.832
OMe 5c
13C{1H } NMR (CDCl3, 100 MHz)
200
150
100
50
0
PPM


8.239
8.237
8.229
8.218
8.216
8.209
7.982
7.962
7.765
7.740
7.687
7.665
7.544
7.525
7.506
7.487
7.466
7.412
7.410
7.393
7.391
7.374
7.372
7.345
7.343
7.328
7.326
7.307
7.275
7.273
7.266
7.256
7.247
7.238
7.228
7.225
7.217
7.198
6.898
6.879
6.208
6.183
Br 5d
^{1}H NMR ($CDCl_3$, 400 MHz)
3.05
1.00
1.00
1.00
1.04
1.02
1.04
1.03
2.59
1.01
1.00
0.97
12
10
8
6
4
2
PPM

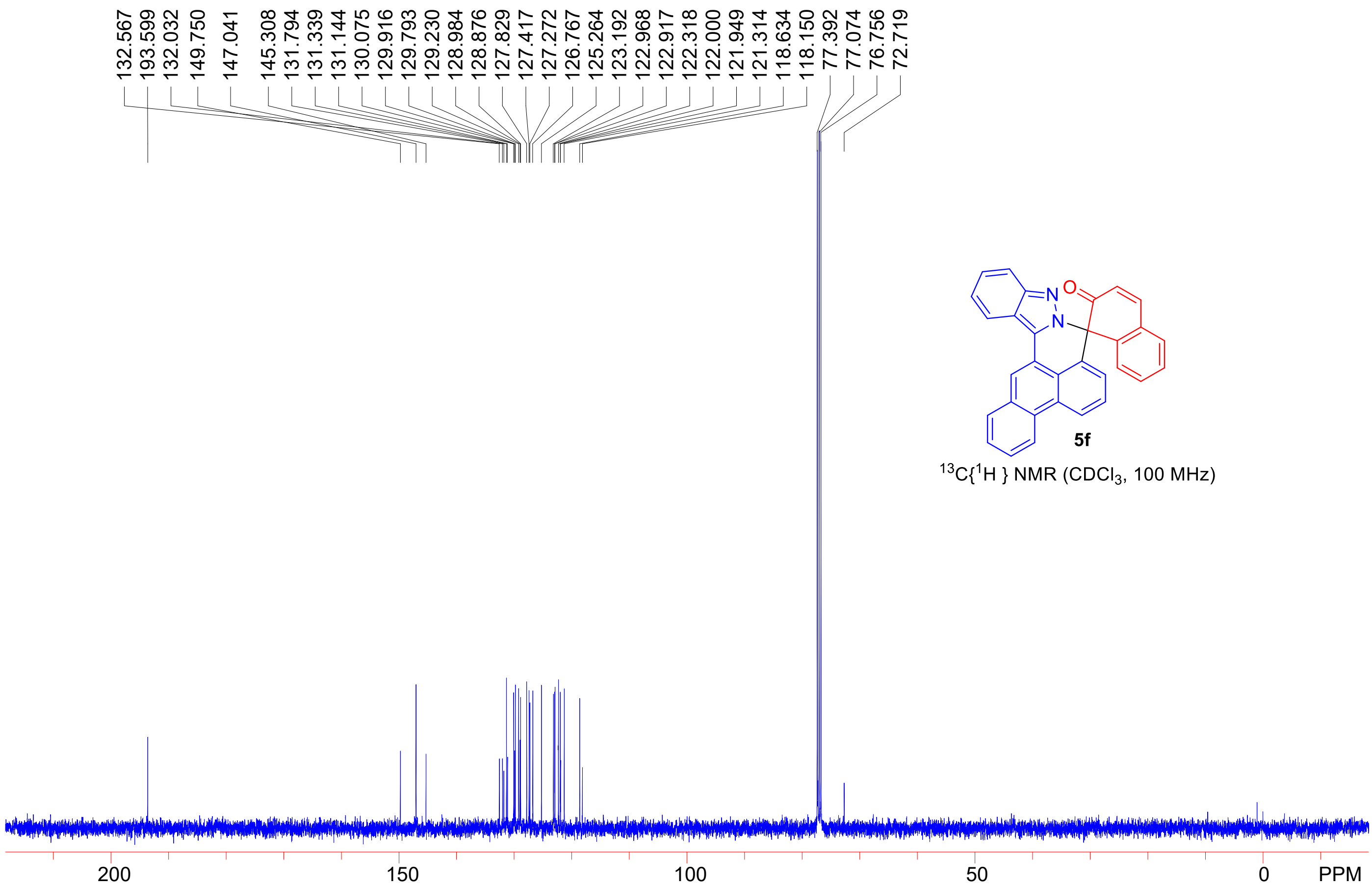

192.971
149.779
147.063
145.170
132.567
132.321
131.411
131.303
131.064
130.133
129.865
129.035
128.919
127.944
127.735
126.825
125.900
124.268
123.964
123.264
122.375
121.451
121.205
120.974
118.699
118.157
77.356
77.038
76.720
72.769
Br 5d
^{13}C{^{1}H } NMR ($CDCl_3$, 100 MHz)
200
150
100
50
0
PPM


8.414 8.396 8.292 8.271 7.871 7.850 7.744 7.719 7.694 7.672 7.606 7.587 7.585 7.567 7.521 7.502 7.390 7.388 7.371 7.353 7.351 7.335 7.325 7.320 7.305 7.289 7.269 7.250 7.237 7.217 7.174 7.155 6.975 6.956 6.214 6.189 2.435
N
O
N
5e
Me
^{1}H NMR (CDCl$_3$, 400 MHz)
8.58
1.04
1.02
1.01
1.00
1.00
1.05
1.03
1.04
1.01
1.00
1.01
3.04
10
8
6
4
2
PPM

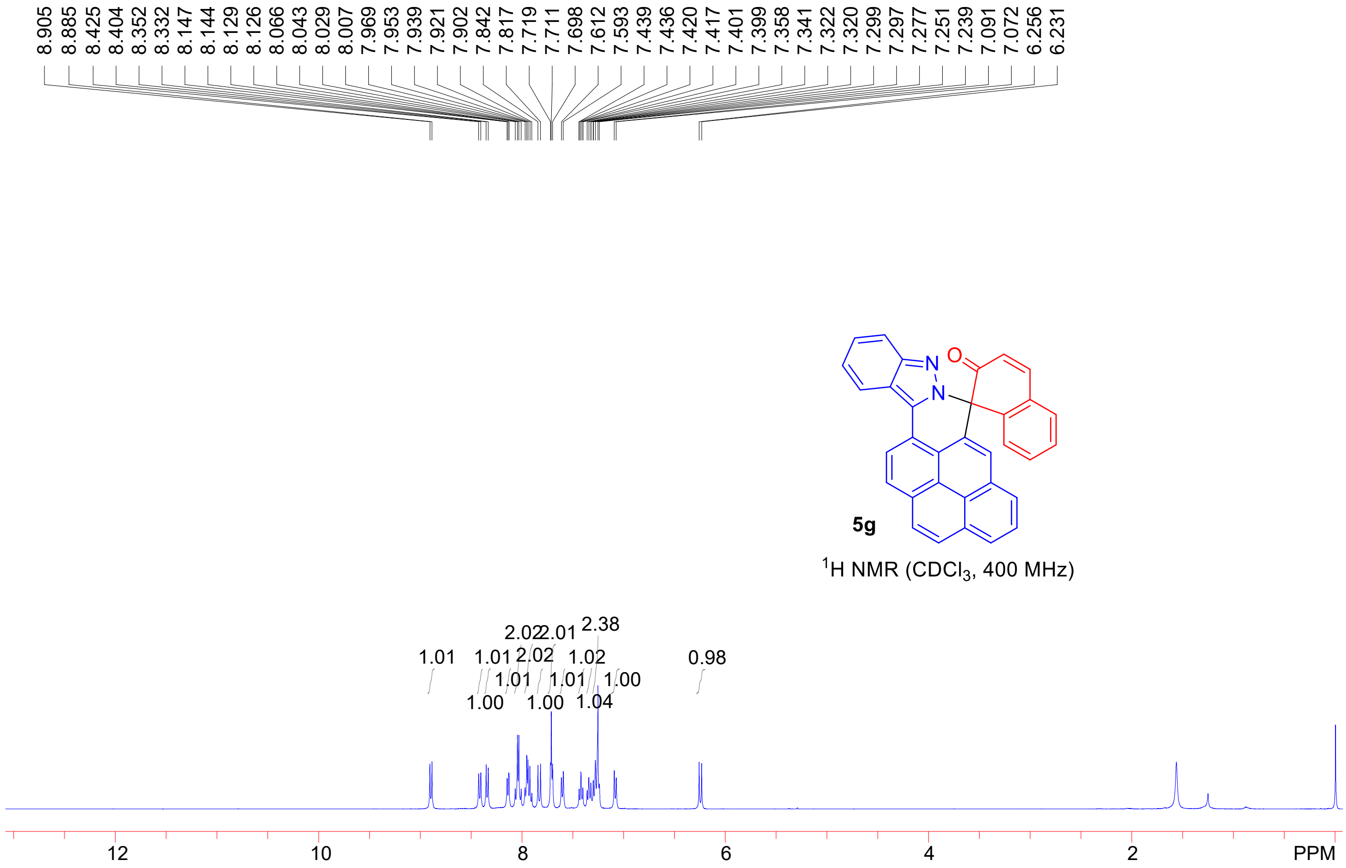

193.361 149.793 147.012 145.517 140.988 137.507 136.908 132.227 131.353 130.884 130.060 129.930 129.880 129.150 128.991 128.883 127.482 126.882 126.680 126.593 124.499 124.159 123.473 122.924 121.574 121.249 121.198 118.620 118.164 77.392 77.074 76.756 73.181
21.285
N
O
N
5e
Me
^{13}C{^{1}H } NMR (CDCl$_3$, 100 MHz)
200
150
100
50
0
PPM

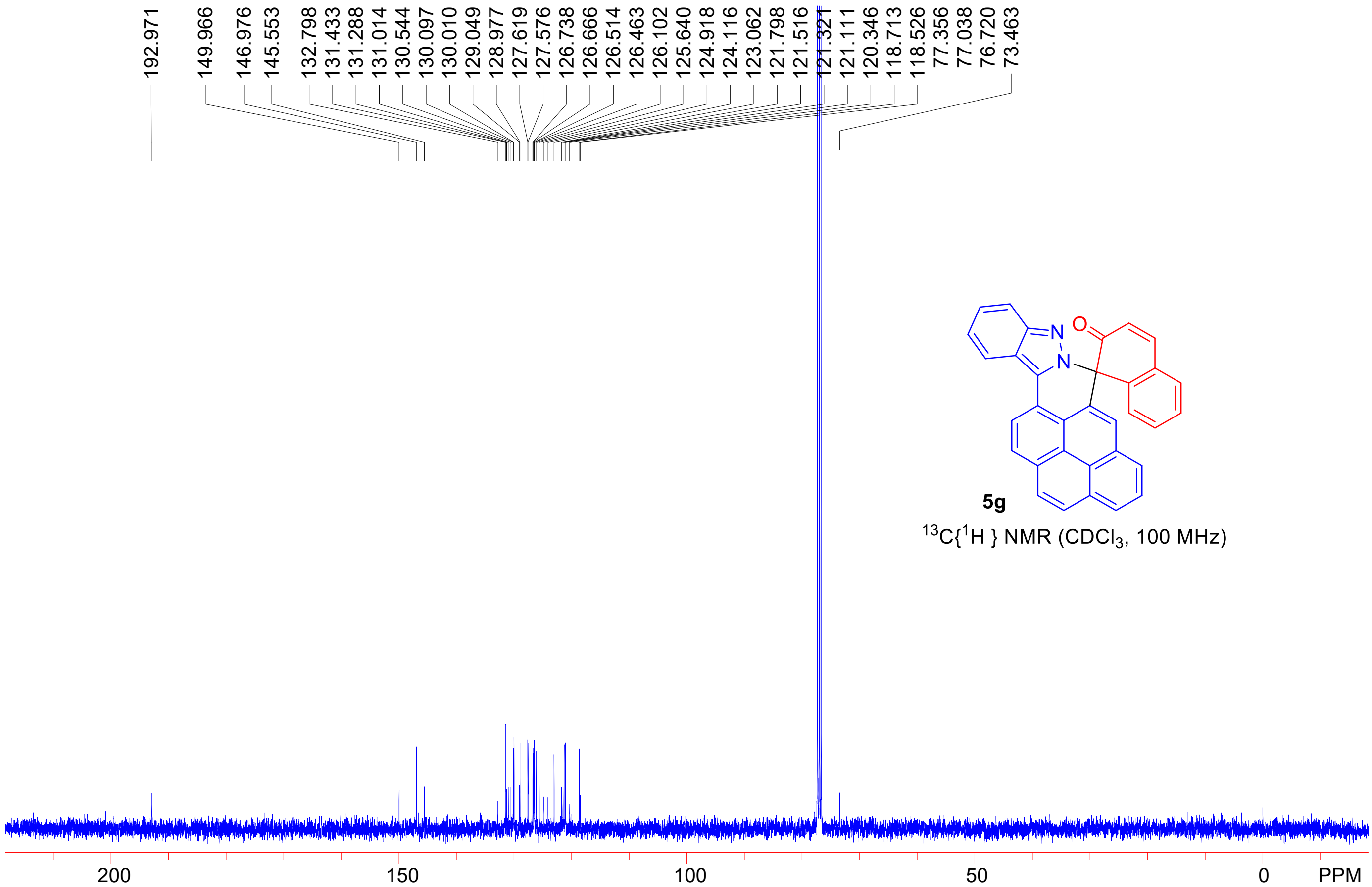


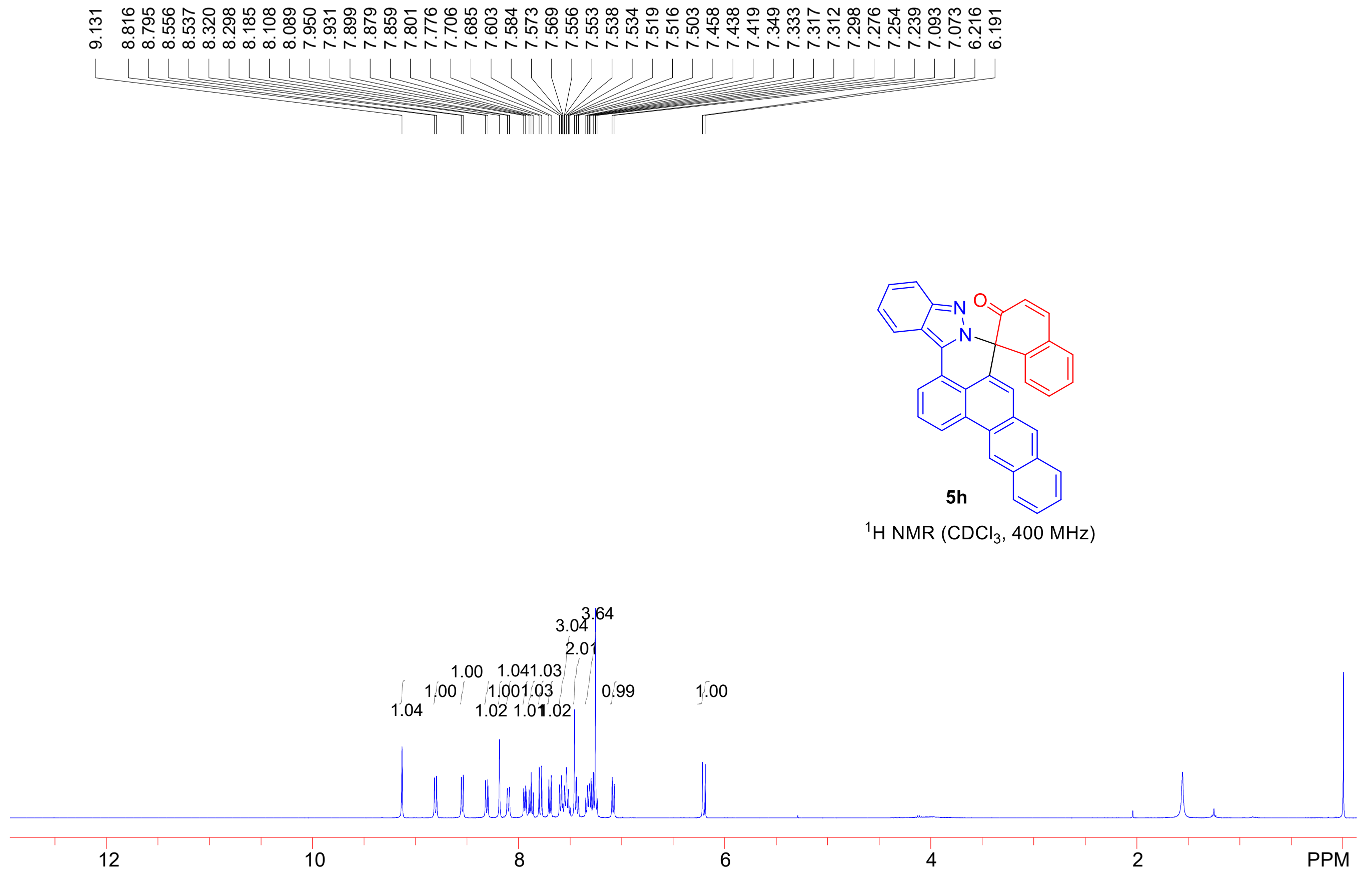
8.568
8.553
8.532
8.516
8.502
8.493
8.348
8.327
7.959
7.949
7.936
7.680
7.655
7.634
7.612
7.583
7.566
7.557
7.548
7.461
7.441
7.421
7.292
7.290
7.279
7.273
7.271
7.265
7.263
7.254
7.244
7.224
7.222
7.203
7.186
7.172
7.161
7.154
7.143
7.124
7.105
7.103
6.816
6.797
6.170
6.145
5f
^{1}H NMR (CDCl$_3$, 400 MHz)
5.60
2.02
2.04
1.01
2.03
1.02
1.00
1.00
1.04
1.05
1.03
12
10
8
6
4
2
PPM



132.567
193.599
132.032
149.750
147.041
145.308
131.794
131.339
131.144
130.075
129.916
129.793
129.230
128.984
128.876
127.829
127.417
127.272
126.767
125.264
123.192
122.968
122.917
122.318
122.000
121.949
121.314
118.634
118.150
77.392
77.074
76.756
72.719
5f
^{13}C{^{1}H } NMR (CDCl$_3$, 100 MHz)
200
150
100
50
0
PPM

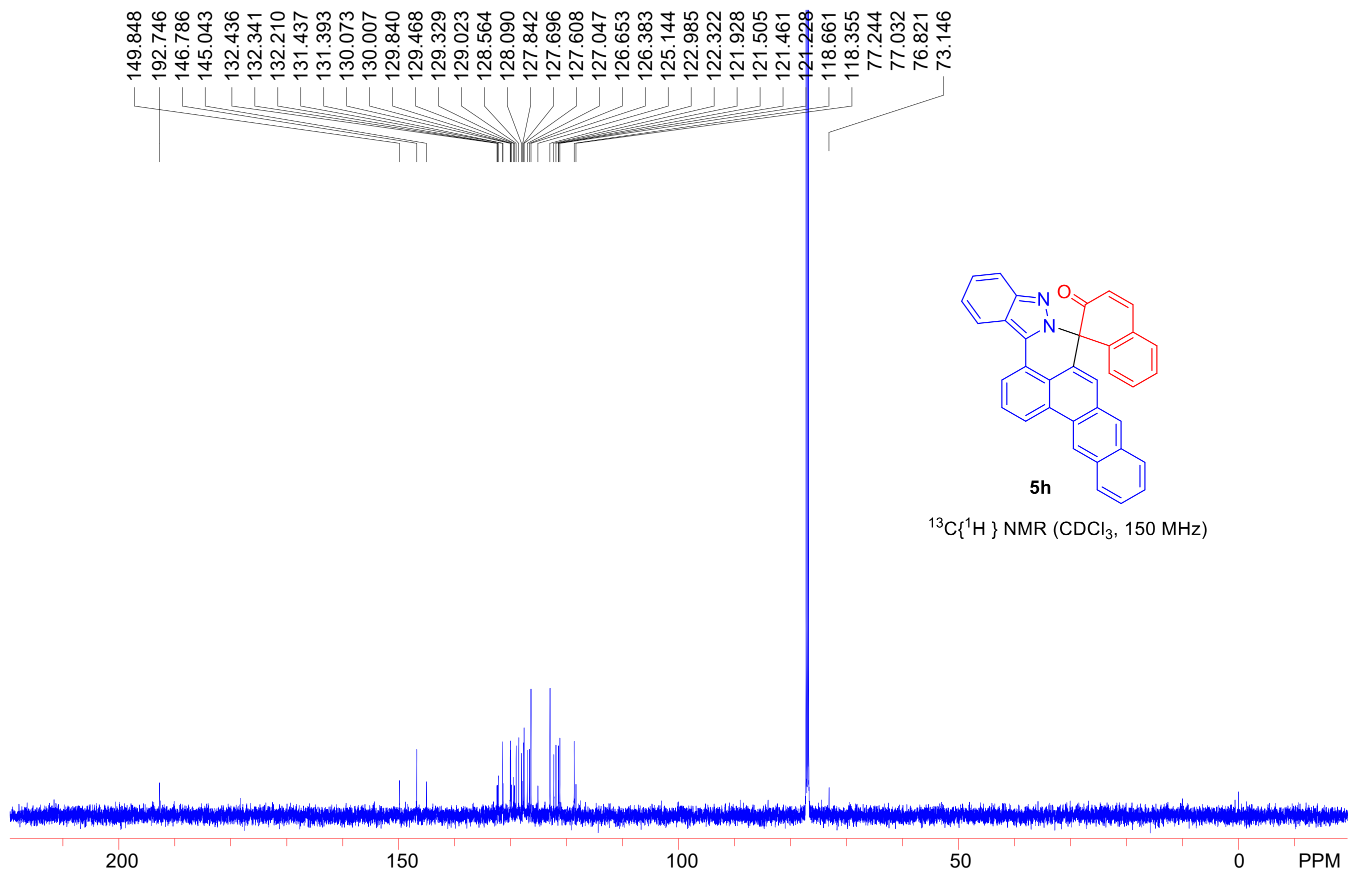

8.905 8.885 8.425 8.404 8.352 8.332 8.147 8.144 8.129 8.126 8.066 8.043 8.029 8.007 7.969 7.953 7.939 7.921 7.902 7.842 7.817 7.719 7.711 7.698 7.612 7.593 7.439 7.436 7.420 7.417 7.401 7.399 7.358 7.341 7.322 7.320 7.299 7.297 7.277 7.251 7.239 7.091 7.072 6.256 6.231
N
N
O
5g
1H NMR (CDCl3, 400 MHz)
1.01 1.00 1.01 1.01 2.02 2.02 2.01 1.00 1.01 1.02 2.38 1.04 1.00 0.98
12 10 8 6 4 2 PPM


192.971 149.966 146.976 145.553 132.798 131.433 131.288 131.014 130.544 130.097 130.010 129.049 128.977 127.619 127.576 126.738 126.666 126.514 126.463 126.102 125.640 124.918 124.116 123.062 121.798 121.516 121.321 121.111 120.346 118.713 118.526 77.356 77.038 76.720 73.463
N
N
O
5g
13C{1H } NMR (CDCl3, 100 MHz)
200 150 100 50 0 PPM



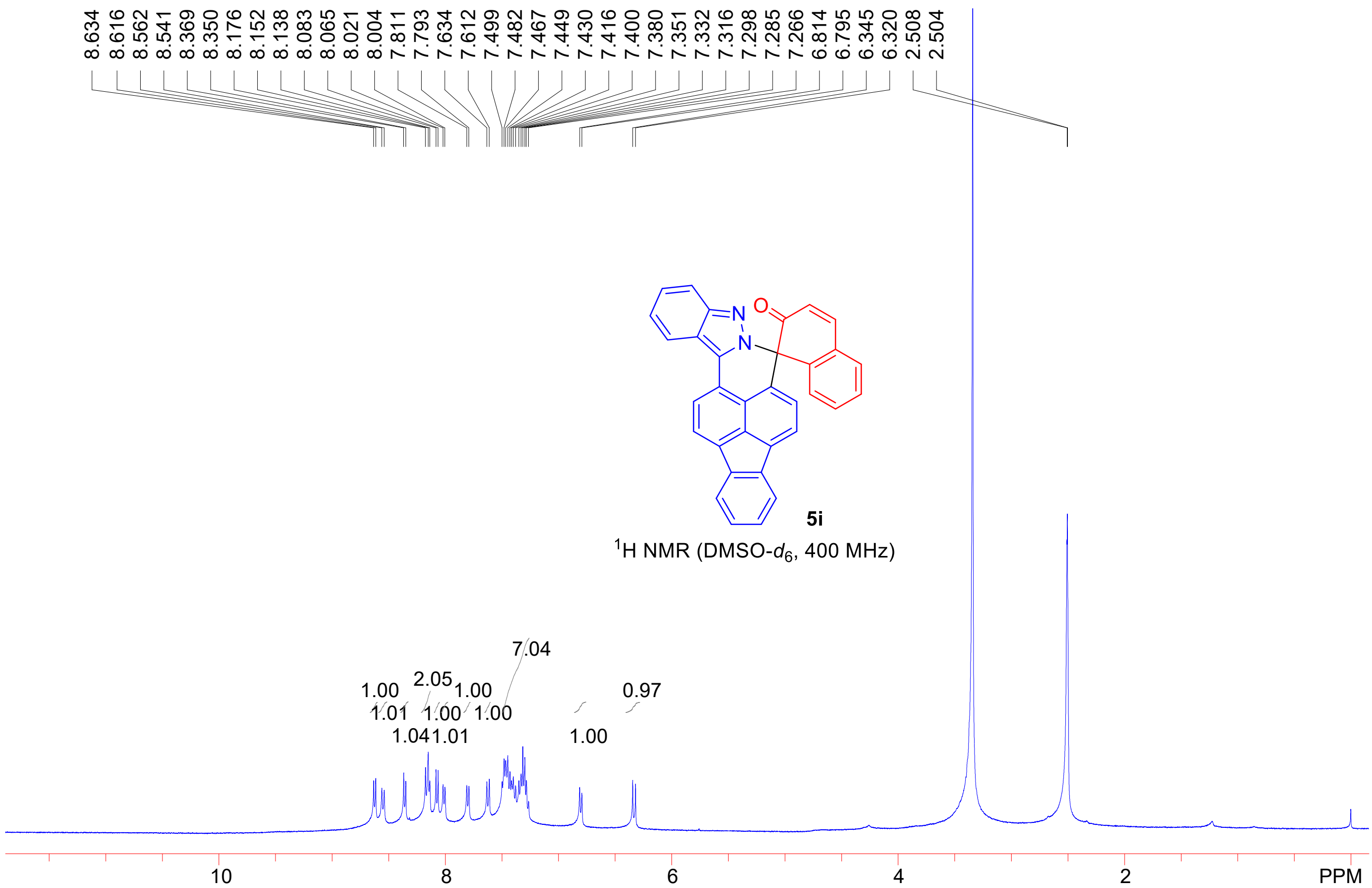
5h

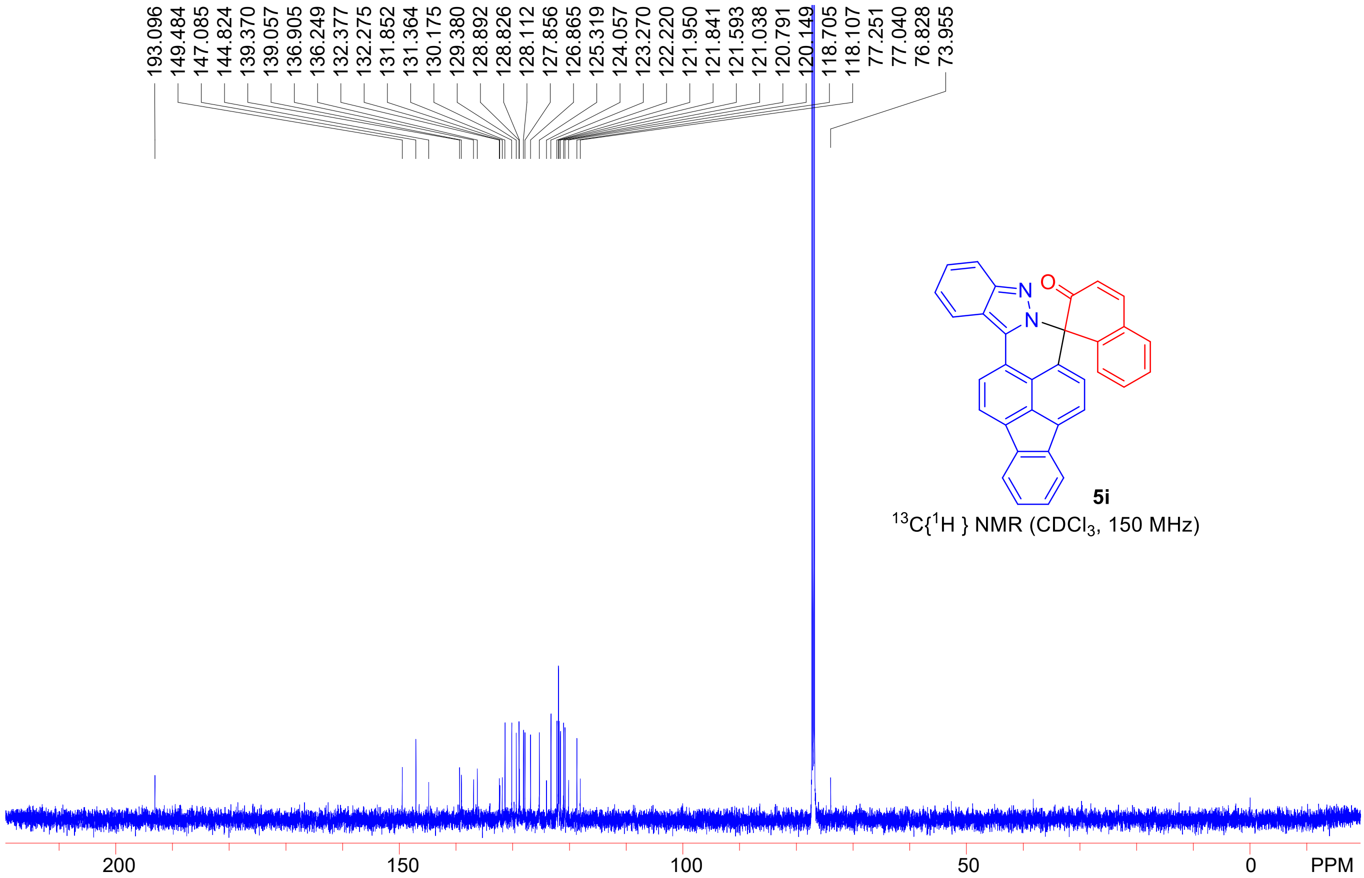
^{1}H NMR ($CDCl_3$, 400 MHz)

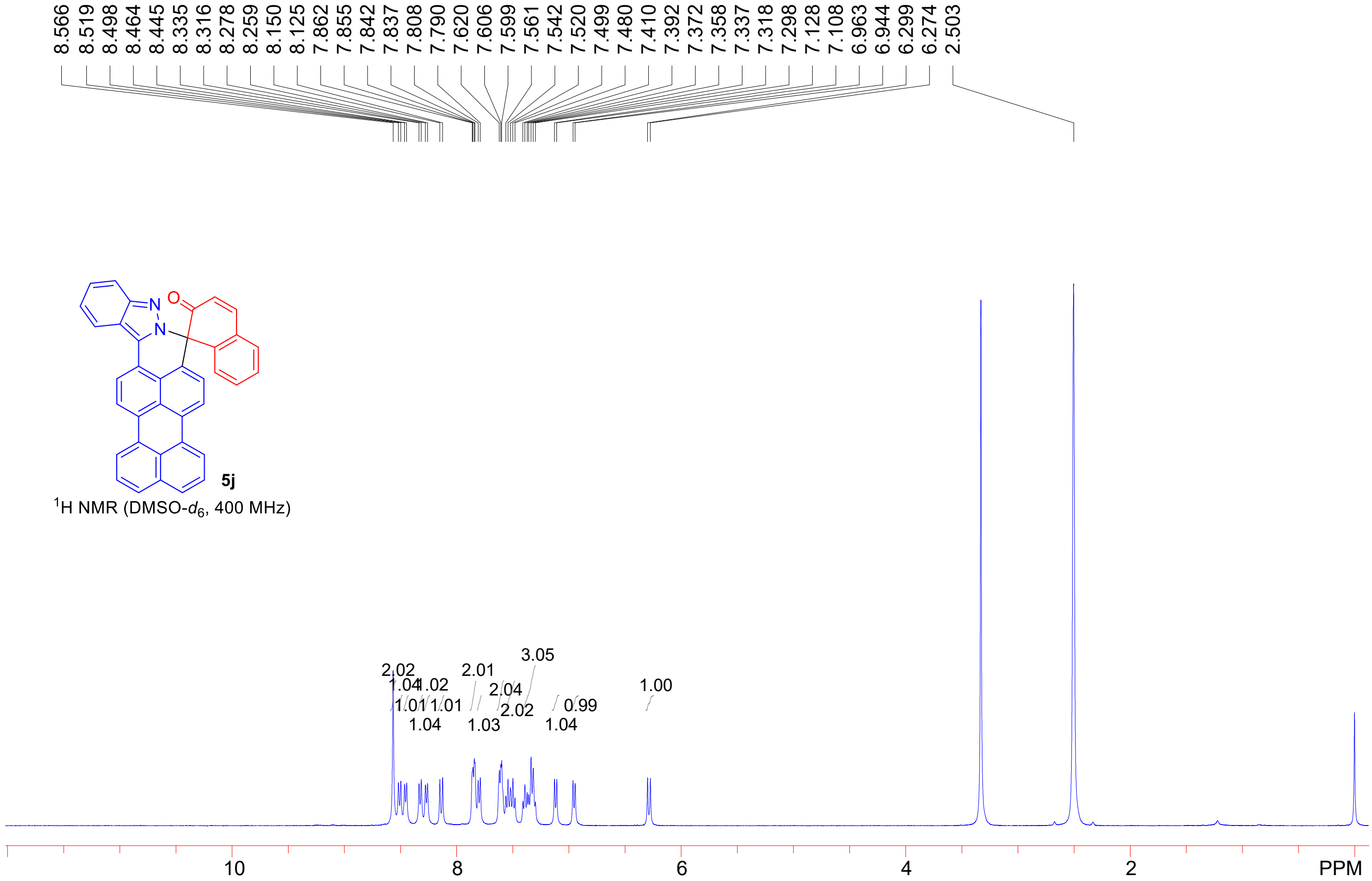


5h

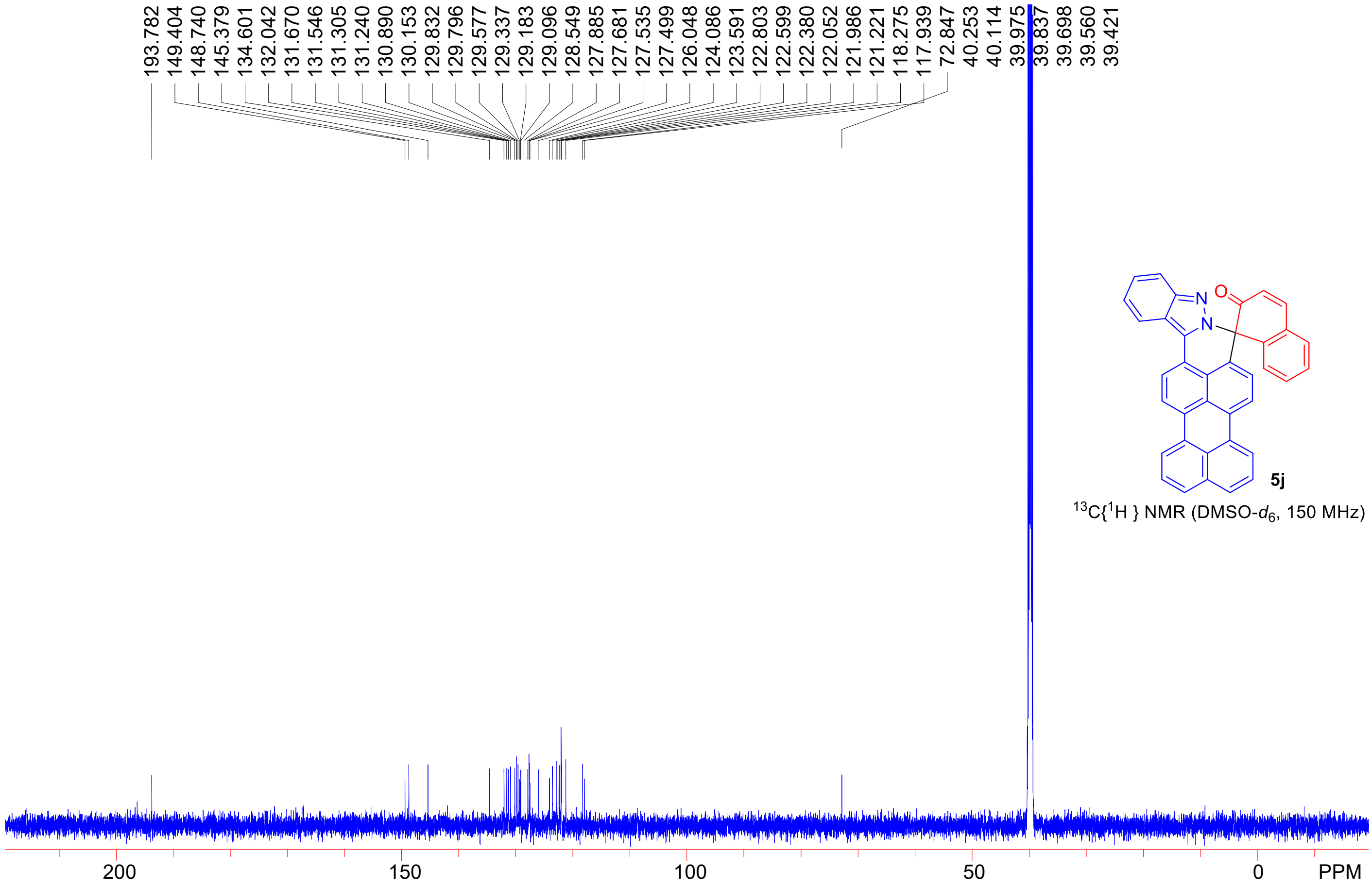
$^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 150 MHz)


8.634 8.616 8.562 8.541 8.369 8.350 8.176 8.152 8.138 8.083 8.065 8.021 8.004 7.811 7.793 7.634 7.612 7.499 7.482 7.467 7.449 7.430 7.416 7.400 7.380 7.351 7.332 7.316 7.298 7.285 7.266 6.814 6.795 6.345 6.320 2.508 2.504
N
N
O
5i
^{1}H NMR (DMSO-d_6, 400 MHz)
7.04
2.05
1.00 1.00
1.01 1.00 1.00
1.04 1.01
1.00
0.97
10
8
6
4
2
PPM

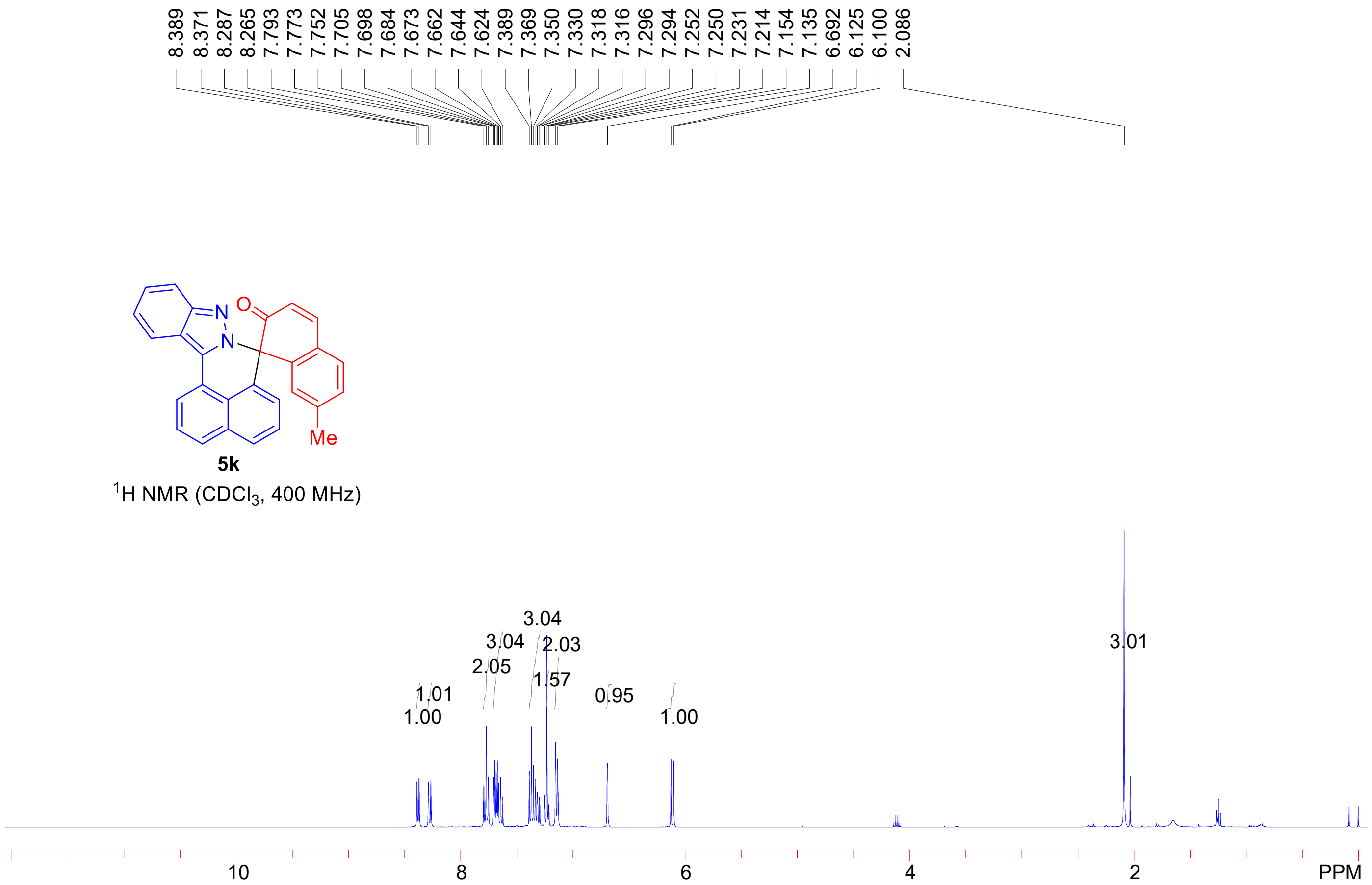

193.096 149.484 147.085 144.824 139.370 139.057 136.905 136.249 132.377 132.275 131.852 131.364 130.175 129.380 128.892 128.826 128.112 127.856 126.865 125.319 124.057 123.270 122.220 121.950 121.841 121.593 121.038 120.791 120.149 118.705 118.107 77.251 77.040 76.828 73.955
N
N
O
5i
^{13}C{^{1}H } NMR (CDCl$_3$, 150 MHz)
200
150
100
50
0
PPM

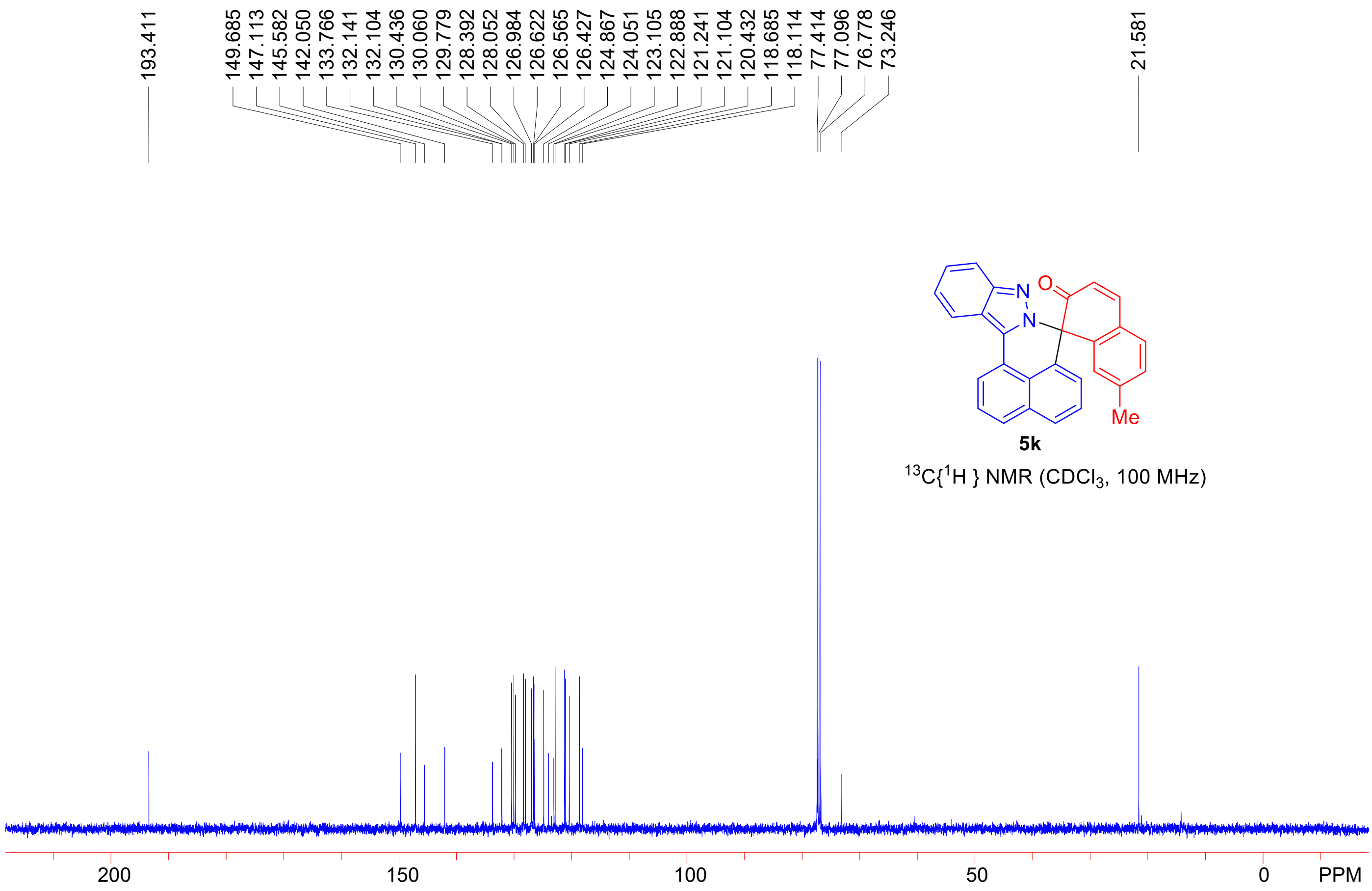


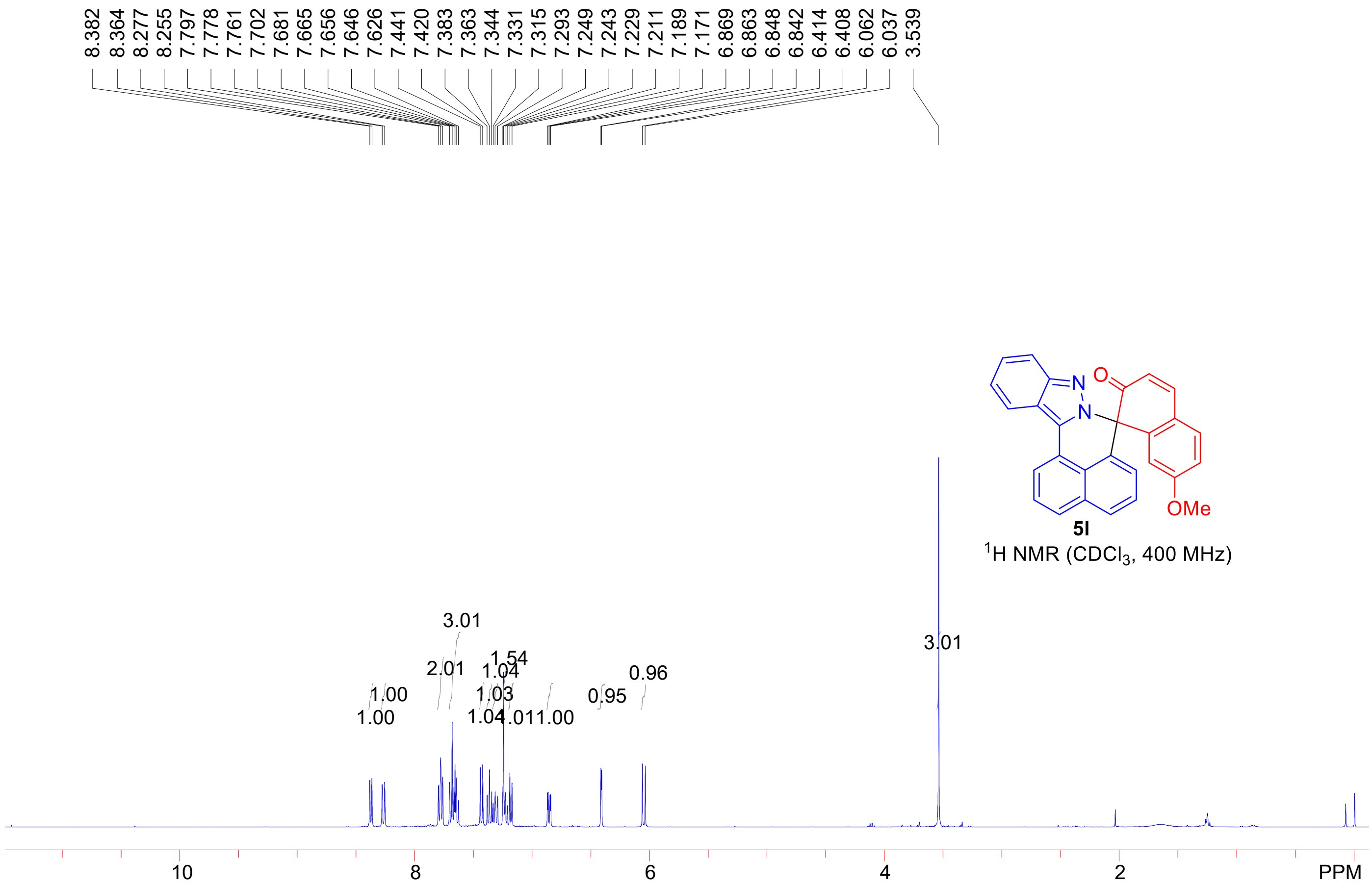
^{1}H NMR (DMSO-d_6, 400 MHz)

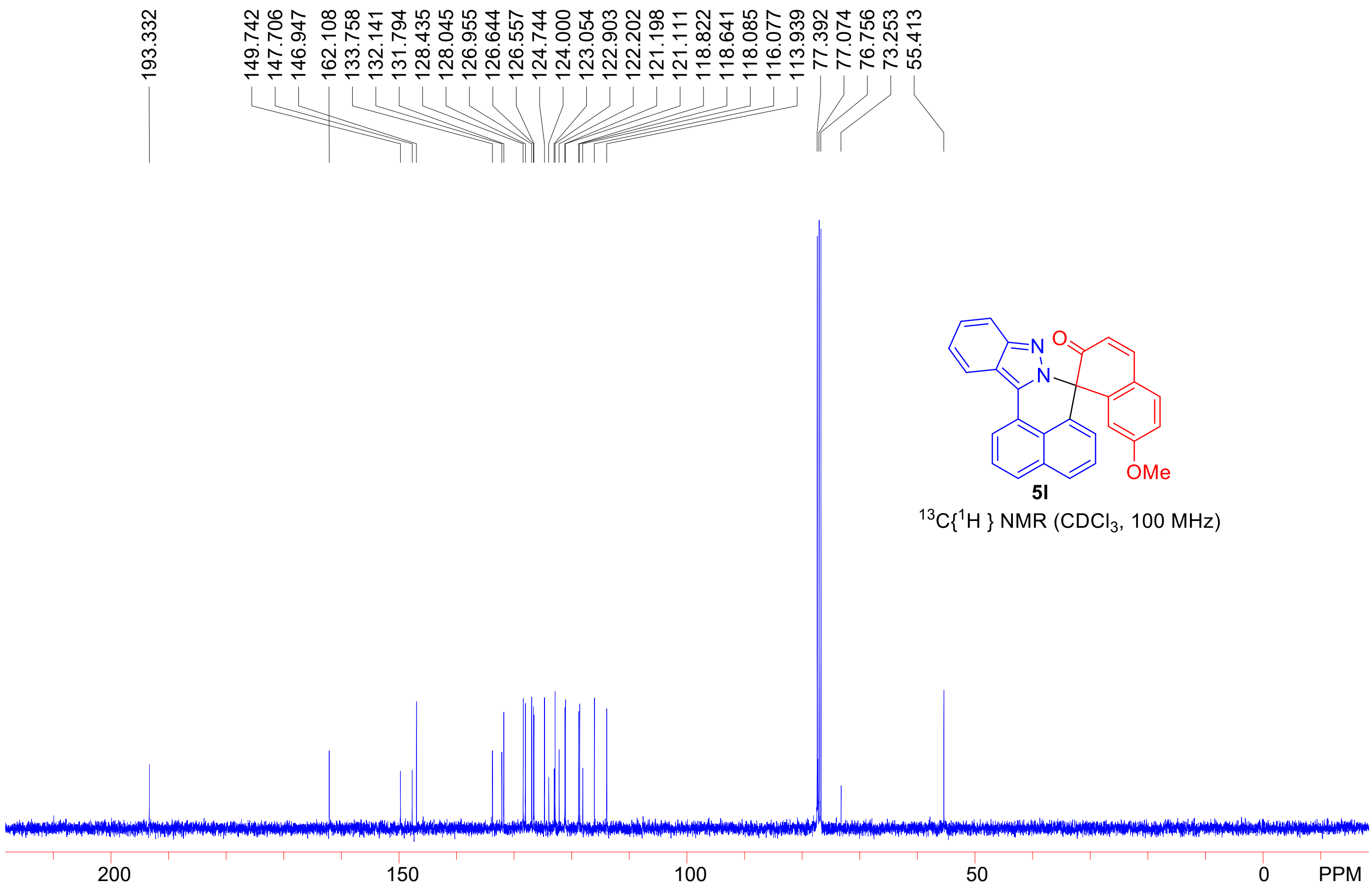


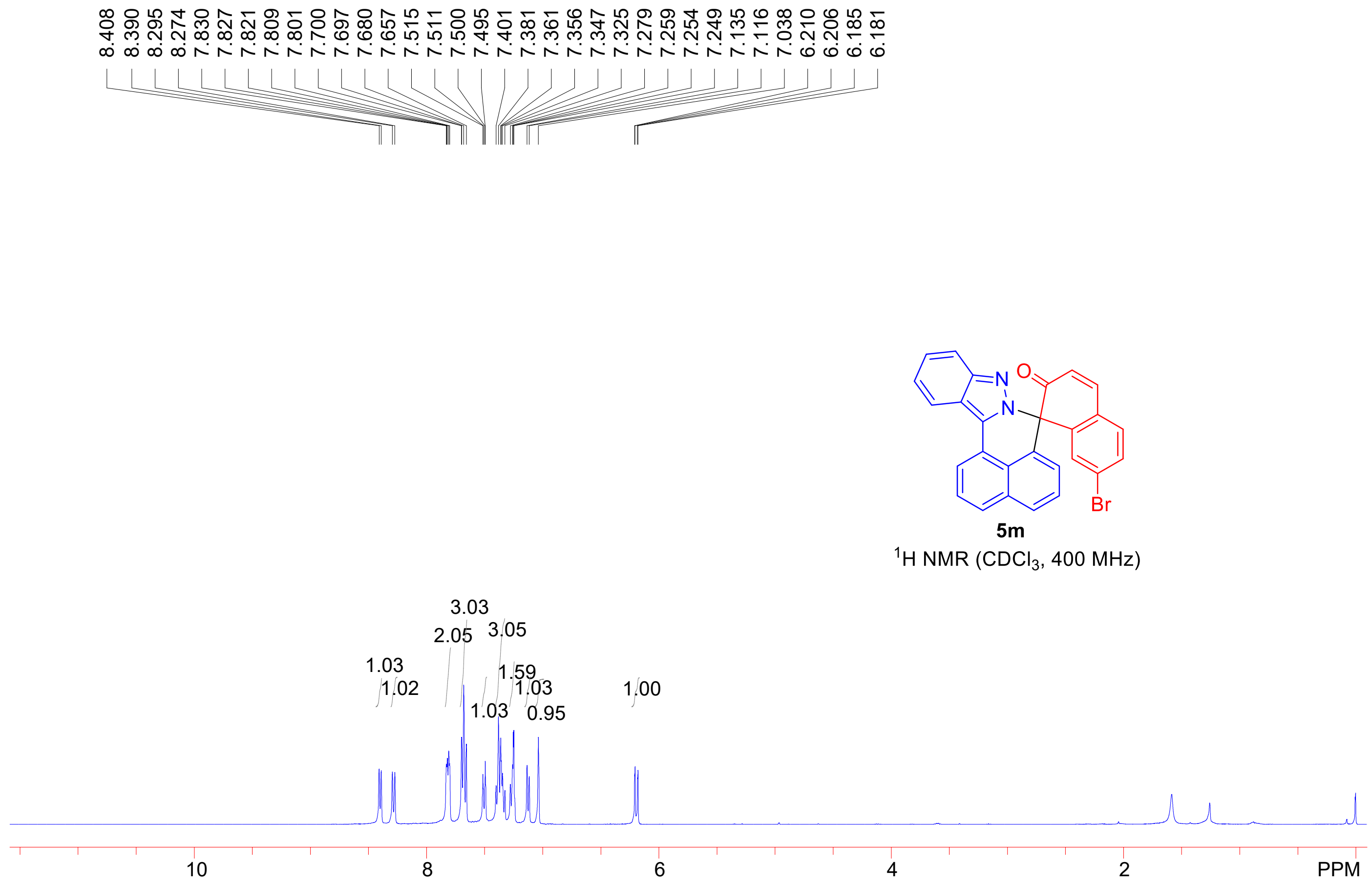
$^{13}C\{^{1}H\}$ NMR (DMSO-d_6, 150 MHz)


8.389
8.371
8.287
8.265
7.793
7.773
7.752
7.705
7.698
7.684
7.673
7.662
7.644
7.624
7.389
7.369
7.350
7.330
7.318
7.316
7.296
7.294
7.252
7.250
7.231
7.214
7.154
7.135
6.692
6.125
6.100
2.086
5k
^{1}H NMR (CDCl$_3$, 400 MHz)
1.00
1.01
2.05
3.04
3.04
2.03
1.57
0.95
1.00
3.01
10
8
6
4
2
PPM

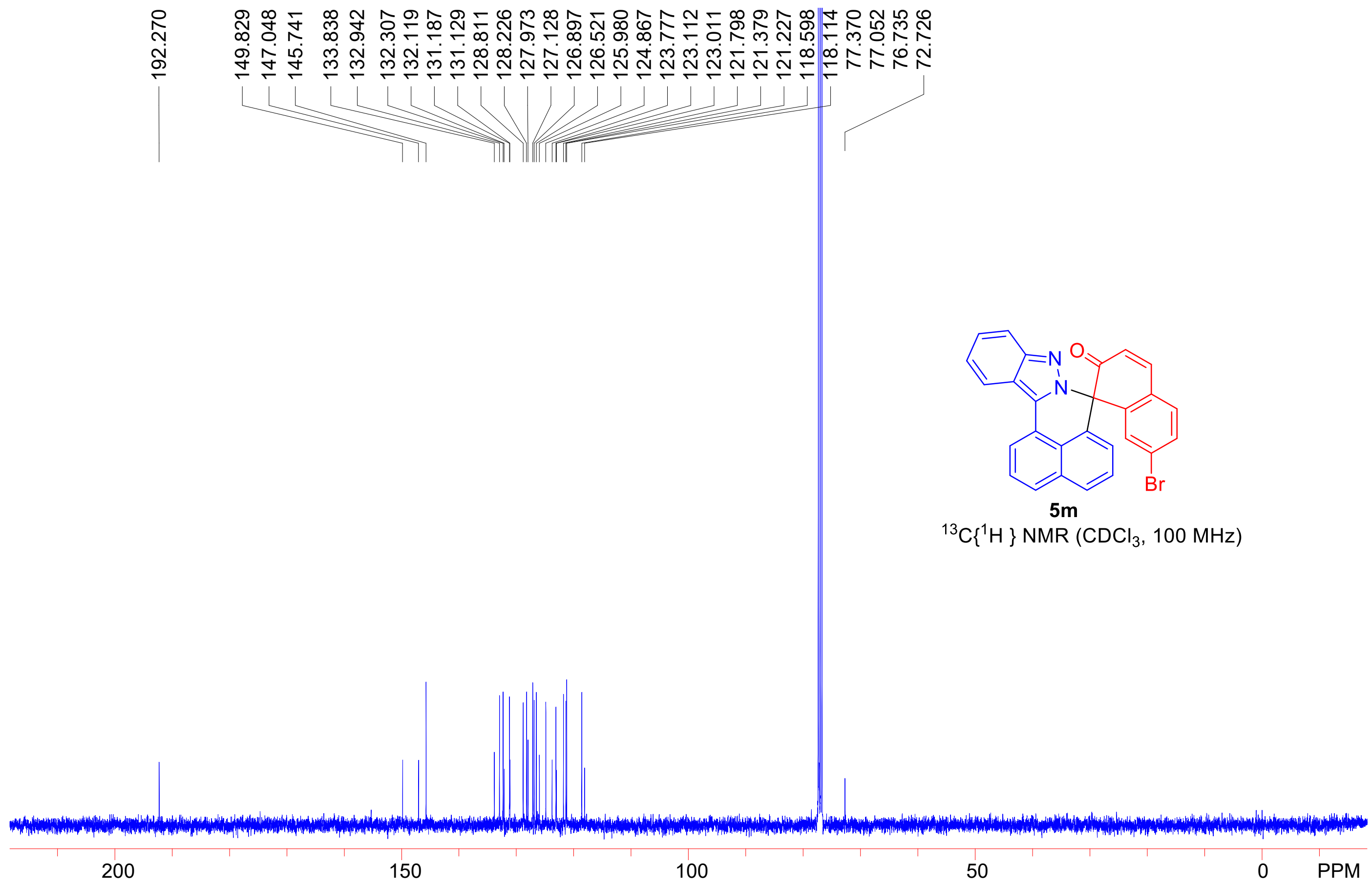

193.411
149.685
147.113
145.582
142.050
133.766
132.141
132.104
130.436
130.060
129.779
128.392
128.052
126.984
126.622
126.565
126.427
124.867
124.051
123.105
122.888
121.241
121.104
120.432
118.685
118.114
77.414
77.096
76.778
73.246
21.581
5k
^{13}C{^{1}H } NMR (CDCl$_3$, 100 MHz)
200
150
100
50
0
PPM


8.382 8.364 8.277 8.255 7.797 7.778 7.761 7.702 7.681 7.665 7.656 7.646 7.626 7.441 7.420 7.383 7.363 7.344 7.331 7.315 7.293 7.249 7.243 7.229 7.211 7.189 7.171 6.869 6.863 6.848 6.842 6.414 6.408 6.062 6.037 3.539
N
N
O
OMe
5l
^{1}H NMR (CDCl$_3$, 400 MHz)
3.01
2.01
1.54
1.04
1.00
1.03
1.00
1.04
1.01
1.00
0.95
0.96
3.01
10
8
6
4
2
PPM

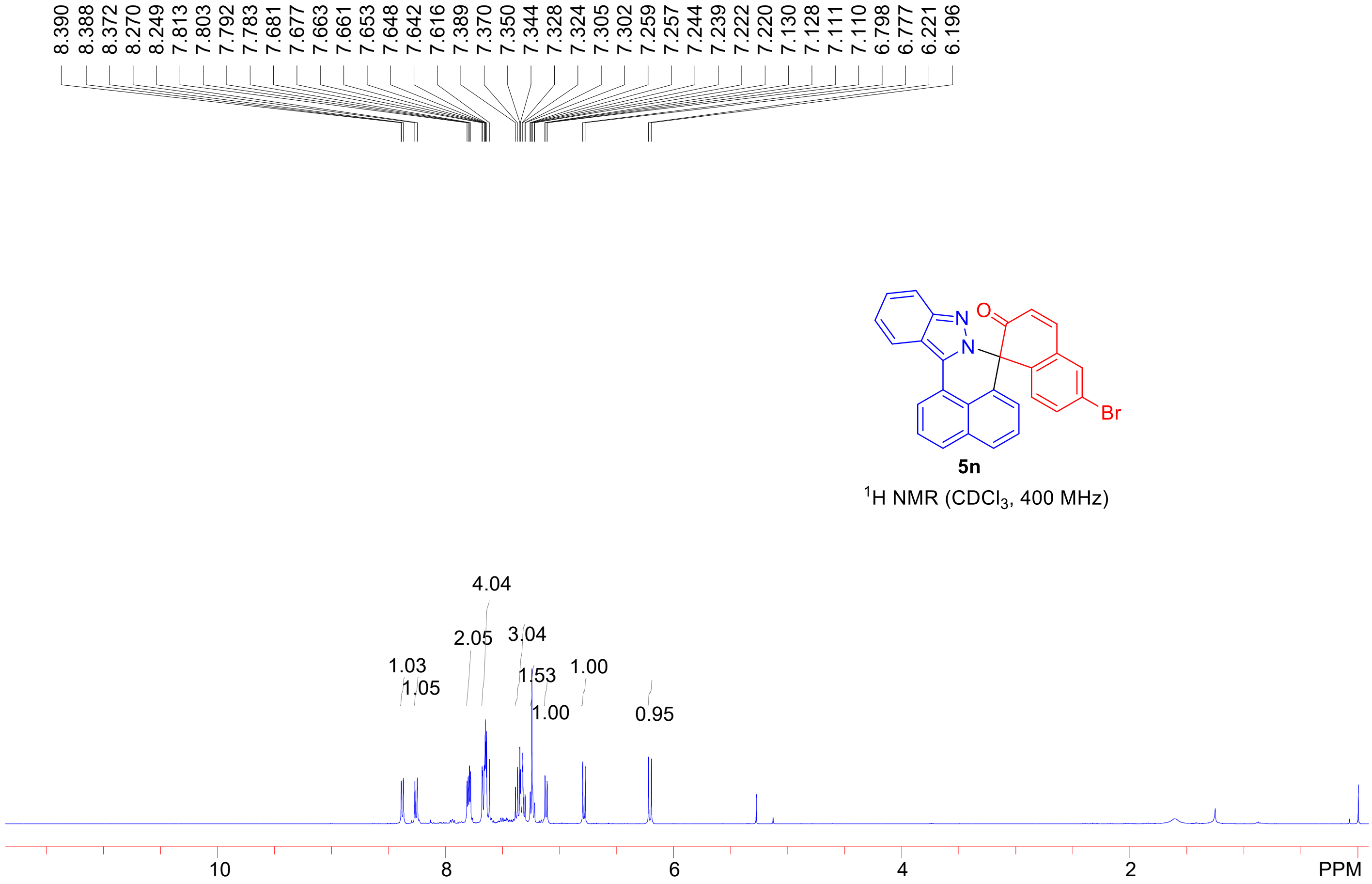

193.332 149.742 147.706 146.947 162.108 133.758 132.141 131.794 128.435 128.045 126.955 126.644 126.557 124.744 124.000 123.054 122.903 122.202 121.198 121.111 118.822 118.641 118.085 116.077 113.939 77.392 77.074 76.756 73.253 55.413
N
N
O
OMe
5l
^{13}C{^{1}H } NMR (CDCl$_3$, 100 MHz)
200
150
100
50
0
PPM

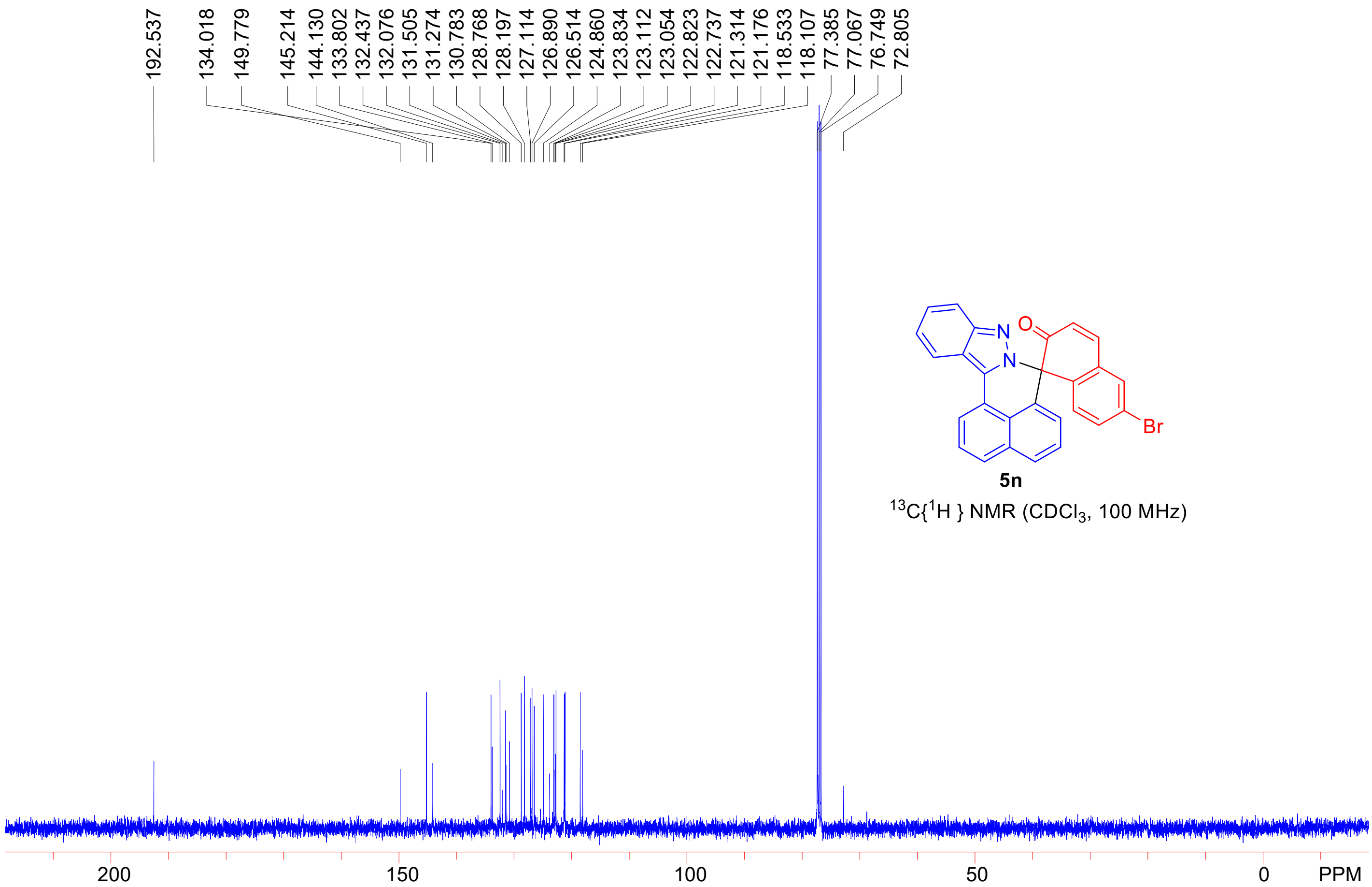


5m
^{1}H NMR ($CDCl_3$, 400 MHz)

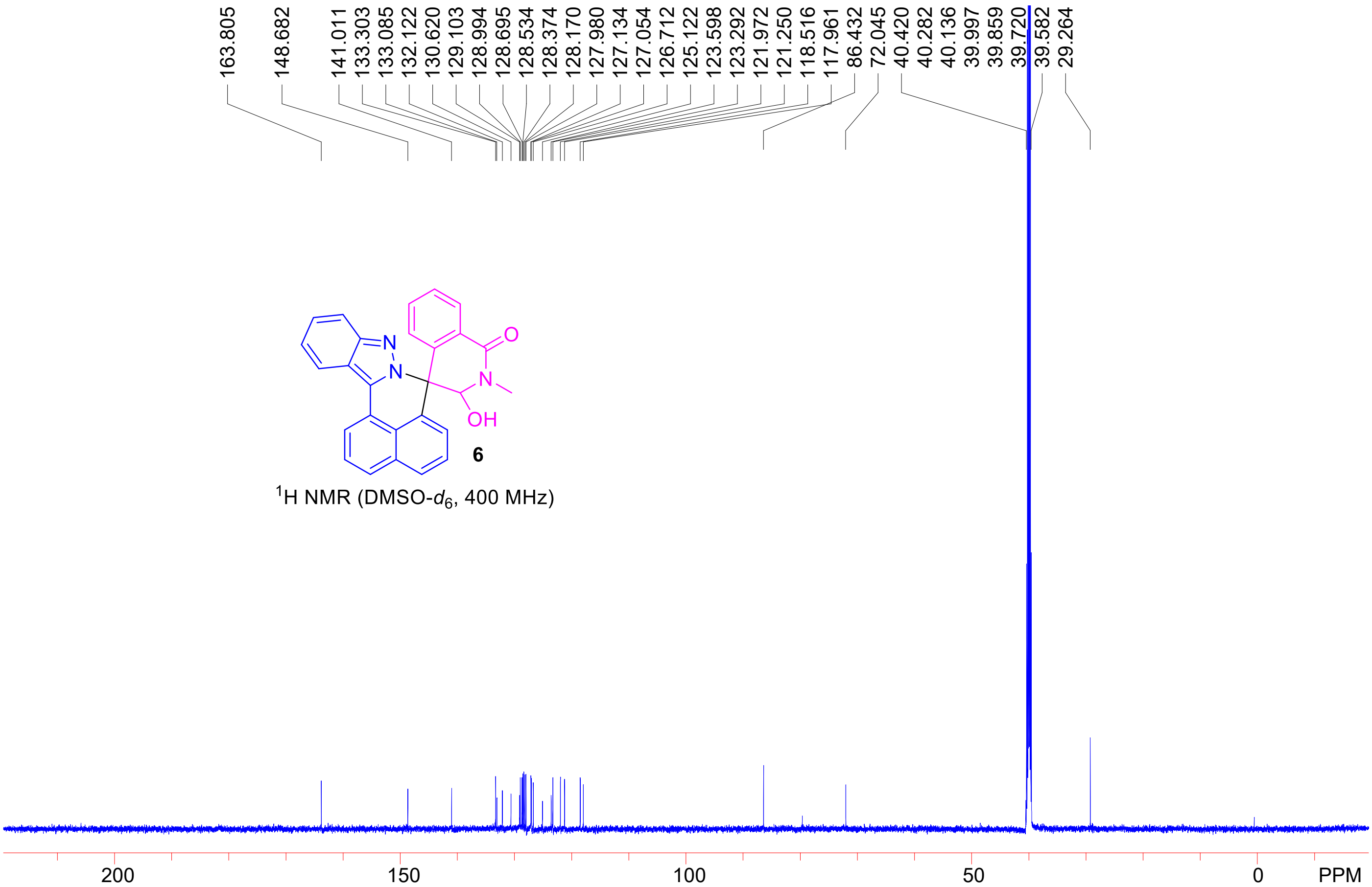


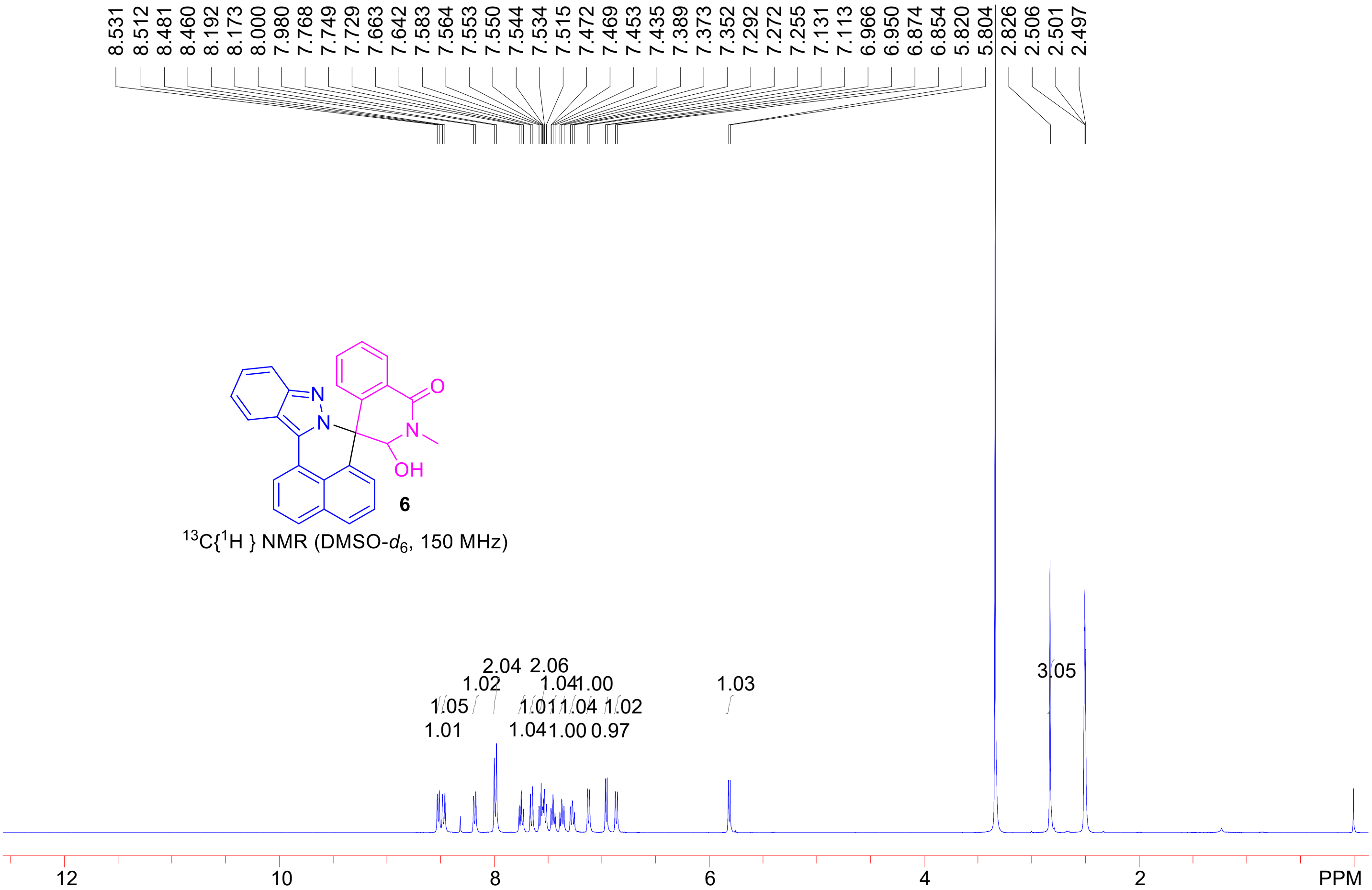
5m
$^{13}C\{^{1}H\}$ NMR ($CDCl_3$, 100 MHz)

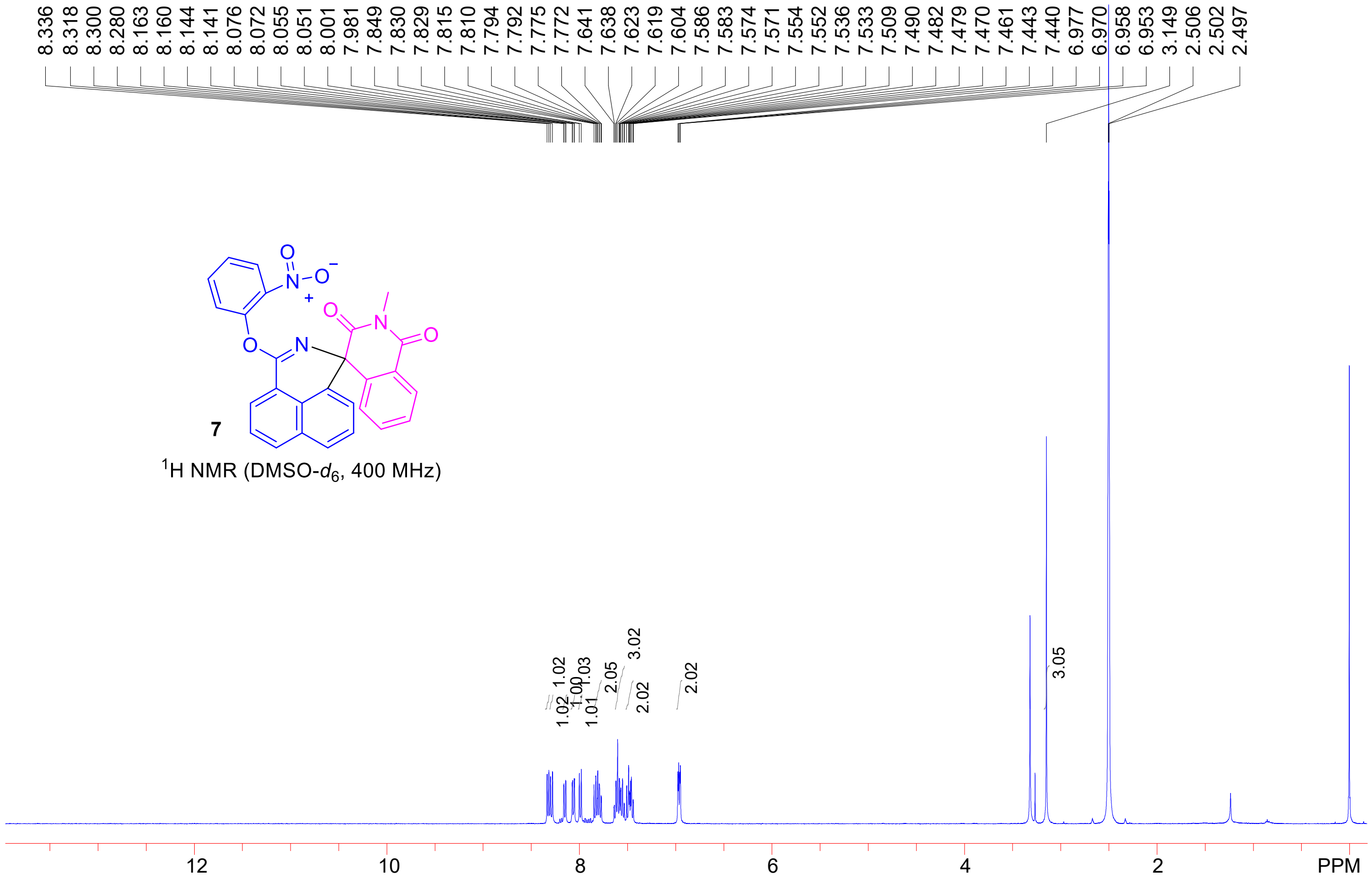

8.390
8.388
8.372
8.270
8.249
7.813
7.803
7.792
7.783
7.681
7.677
7.663
7.661
7.653
7.648
7.642
7.616
7.389
7.370
7.350
7.344
7.328
7.324
7.305
7.302
7.259
7.257
7.244
7.239
7.222
7.220
7.130
7.128
7.111
7.110
6.798
6.777
6.221
6.196
O
N
N
Br
5n
^{1}H NMR ($CDCl_3$, 400 MHz)
4.04
2.05
3.04
1.03
1.05
1.53
1.00
1.00
0.95
10
8
6
4
2
PPM


192.537
134.018
149.779
145.214
144.130
133.802
132.437
132.076
131.505
131.274
130.783
128.768
128.197
127.114
126.890
126.514
124.860
123.834
123.112
123.054
122.823
122.737
121.314
121.176
118.533
118.107
77.385
77.067
76.749
72.805
O
N
N
Br
5n
^{13}C{^{1}H } NMR ($CDCl_3$, 100 MHz)
200
150
100
50
0
PPM

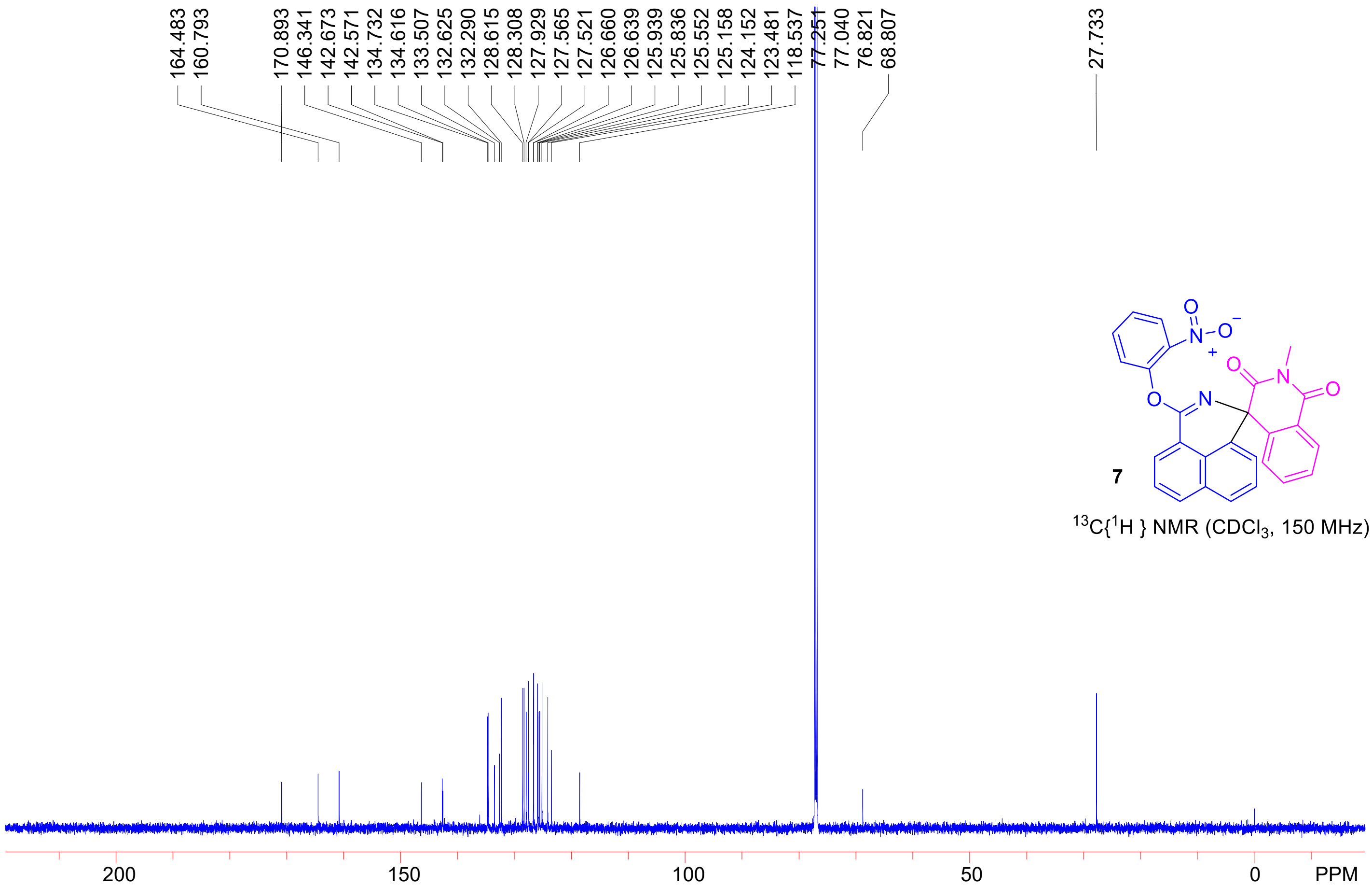
VI. NMR spectra of 6 and 7





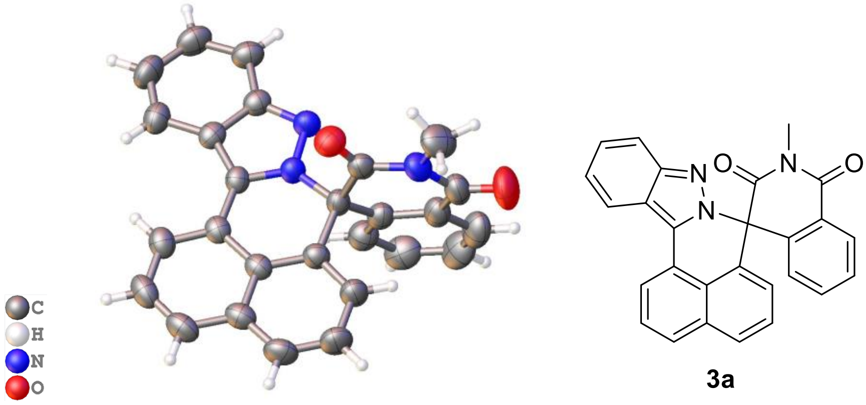


8.336
8.318
8.300
8.280
8.163
8.160
8.144
8.141
8.076
8.072
8.055
8.051
8.001
7.981
7.849
7.830
7.829
7.815
7.810
7.794
7.792
7.775
7.772
7.641
7.638
7.623
7.619
7.604
7.586
7.583
7.574
7.571
7.554
7.552
7.536
7.533
7.509
7.490
7.482
7.479
7.470
7.461
7.443
7.440
6.977
6.970
6.958
6.953
3.149
2.506
2.502
2.497
7
^{1}H NMR (DMSO-d_6, 400 MHz)
12
10
8
6
4
2
PPM



164.483
160.793
170.893
146.341
142.673
142.571
134.732
134.616
133.507
132.625
132.290
128.615
128.308
127.929
127.565
127.521
126.660
126.639
125.939
125.836
125.552
125.158
124.152
123.481
118.537
77.251
77.040
76.821
68.807
27.733
7
^{13}C{^{1}H } NMR ($CDCl_3$, 150 MHz)
200
150
100
50
0
PPM

VII. X-ray crystal structure and data of 3a



3a

Figure S3. X-ray crystal structure of **3a** with 50% ellipsoid probability

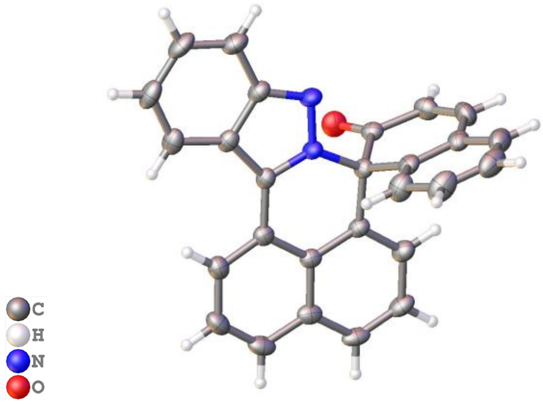
X-ray structure determination. Single crystals suitable for X-ray diffraction were obtained by slow evaporation of the solvent from a chloroform solution of **3a**. Crystal data collection and refinement parameters of **3a** are summarized in Table S2. Intensity data were collected at 293 K on a SuperNova Dual diffractometer using mirror-monochromated Cu Kα radiation, λ = 1.54184 Å. The data were corrected for decay, Lorentz, and polarization effects as well as absorption and beam corrections based on the multi-scan technique. Using Olex2, the structure was solved with the SHELXS structure solution program using Direct Methods and refined with the SHELXL refinement package using Least Squares minimisation. Nonhydrogen atoms were refined with anisotropic displacement parameters. The H-atoms were either located or calculated and subsequently treated with a riding model.

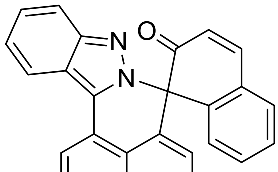
Table S2. Crystallographic data and structure refinement results of **3a**

Empirical formula	$C_{27}H_{17}N_3O_2$
Formula weight	415.43
Temperature/K	293(2)
Crystal system	monoclinic
Space group	$P2_1/c$
a/Å	10.5426(2)
b/Å	11.3200(2)
c/Å	17.0570(3)
α/°	90
β/°	101.834(2)

γ/°	90
Volume/Å^3	1992.35(6)
Z	4
ρ_{calc}g/cm^3	1.385
μ/mm^{-1}	0.716
F(000)	864.0
Crystal size/mm^3	0.2 × 0.12 × 0.1
Radiation	Cu Kα (λ = 1.54184)
2Θ range for data collection/°	8.57 to 142.932
Index ranges	-12 ≤ h ≤ 11, -11 ≤ k ≤ 13, -17 ≤ l ≤ 20
Reflections collected	8205
Independent reflections	3793 [R_{int} = 0.0230, R_{sigma} = 0.0290]
Data/restraints/parameters	3793/0/290
Goodness-of-fit on F^2	1.044
Final R indexes [I>=2σ (I)]	R_1 = 0.0523, wR_2 = 0.1451
Final R indexes [all data]	R_1 = 0.0616, wR_2 = 0.1553
Largest diff. peak/hole / e Å^{-3}	0.26/-0.24

VIII. X-ray crystal structure and data of 5a





5a

Figure S4. X-ray crystal structure of **5a** with 50% ellipsoid probability

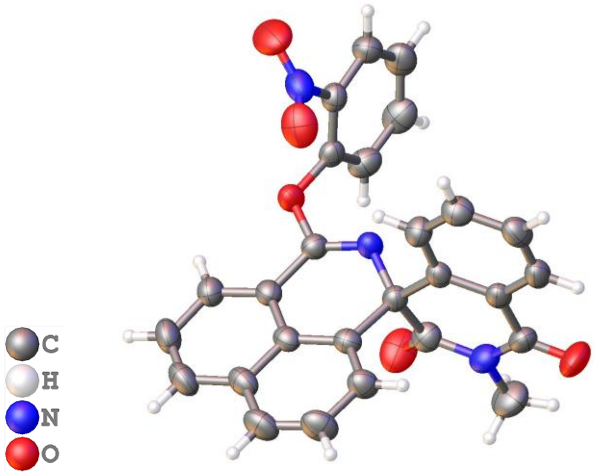
X-ray structure determination. Single crystals suitable for X-ray diffraction were obtained by slow evaporation of the solvent from a dichloromethane/methanol (1:1) solution of **5a**. Crystal data collection and refinement parameters of **5a** are summarized in Table S3. Intensity data were collected at 170 K on a SuperNova Dual diffractometer using mirror-monochromated Cu Kα radiation, λ = 1.54184 Å. The data were corrected for decay, Lorentz, and polarization effects as well as absorption and beam corrections based on the multi-scan technique. Using Olex2, the structure was solved with the SHELXS structure solution program using Direct Methods and refined with the SHELXL refinement package using Least Squares minimisation. Nonhydrogen atoms were refined with anisotropic displacement parameters. The H-atoms were either located or calculated and subsequently treated with a riding model.

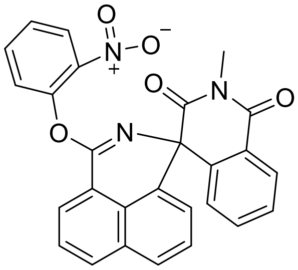
Table S3. Crystallographic data and structure refinement results of **5a**

Empirical formula	$C_{27}H_{16}N_2O$
Formula weight	384.42
Temperature/K	170.00(10)
Crystal system	orthorhombic
Space group	Pbca
a/Å	12.8646(3)
b/Å	13.5761(2)
c/Å	21.4206(4)
α/°	90
β/°	90

γ/°	90
Volume/Å^3	3741.13(12)
Z	8
ρ_{calc}g/cm^3	1.365
μ/mm^{-1}	0.660
F(000)	1600.0
Crystal size/mm^3	0.2 × 0.12 × 0.1
Radiation	Cu Kα (λ = 1.54184)
2Θ range for data collection/°	8.256 to 142.214
Index ranges	-15 ≤ h ≤ 7, -16 ≤ k ≤ 16, -25 ≤ l ≤ 26
Reflections collected	9320
Independent reflections	3537 [R_{int} = 0.0391, R_{sigma} = 0.0381]
Data/restraints/parameters	3537/0/271
Goodness-of-fit on F^2	1.065
Final R indexes [I>=2σ (I)]	R_1 = 0.0595, wR_2 = 0.1693
Final R indexes [all data]	R_1 = 0.0699, wR_2 = 0.1766
Largest diff. peak/hole / e Å^{-3}	0.30/-0.23

IX. X-ray crystal structure and data of 7





7

Figure S5. X-ray crystal structure of **7** with 50% ellipsoid probability

X-ray structure determination. Single crystals suitable for X-ray diffraction were obtained by slow evaporation of the solvent from a chloroform-*d* solution of **7**. Crystal data collection and refinement parameters of **7** are summarized in Table S4. Intensity data were collected at 294.53 K on a SuperNova Dual diffractometer using mirror-monochromated Cu Kα radiation, λ = 1.54184 Å. The data were corrected for decay, Lorentz, and polarization effects as well as absorption and beam corrections based on the multi-scan technique. Using Olex2, the structure was solved with the SHELXS structure solution program using Direct Methods and refined with the SHELXL refinement package using Least Squares minimisation. Nonhydrogen atoms were refined with anisotropic displacement parameters. The H-atoms were either located or calculated and subsequently treated with a riding model.

Table S4. Crystallographic data and structure refinement results of **7**

Empirical formula	$C_{27}H_{17}N_3O_5$
Formula weight	463.43
Temperature/K	294.53(10)
Crystal system	monoclinic
Space group	$P2_1/c$
a/Å	13.6356(4)
b/Å	8.3718(2)
c/Å	19.9438(6)
α/°	90

β/°	108.495(3)
γ/°	90
Volume/Å^3	2159.09(11)
Z	4
ρ_{calc}g/cm^3	1.426
μ/mm^{-1}	0.830
F(000)	960.0
Crystal size/mm^3	0.2 × 0.12 × 0.1
Radiation	Cu Kα (λ = 1.54184)
2Θ range for data collection/°	6.836 to 142.536
Index ranges	-16 ≤ h ≤ 16, -6 ≤ k ≤ 10, -24 ≤ l ≤ 24
Reflections collected	9321
Independent reflections	4063 [R_{int} = 0.0283, R_{sigma} = 0.0404]
Data/restraints/parameters	4063/0/317
Goodness-of-fit on F^2	1.087
Final R indexes [I>=2σ (I)]	R_1 = 0.0564, wR_2 = 0.1579
Final R indexes [all data]	R_1 = 0.0841, wR_2 = 0.1681
Largest diff. peak/hole / e Å^{-3}	0.30/-0.24

X. UV-vis, fluorescence experimental data and cell imaging results

1. UV-vis, fluorescence experimental data

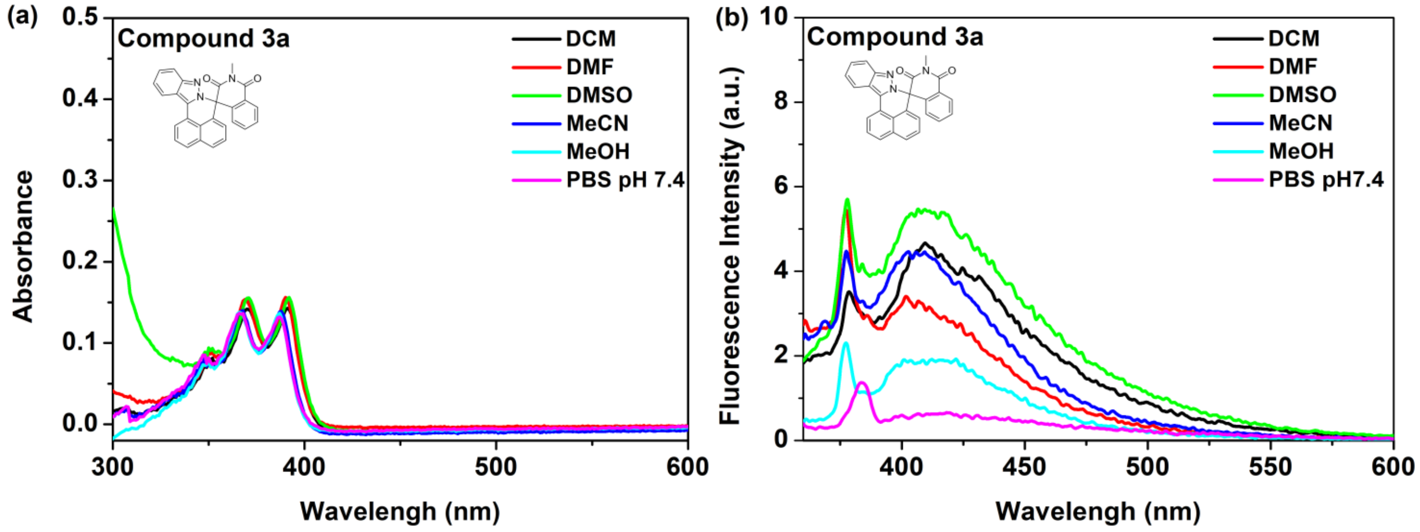


Figure S6. Absorption (a) and fluorescence (b) of compound **3a** in diverse solvents.

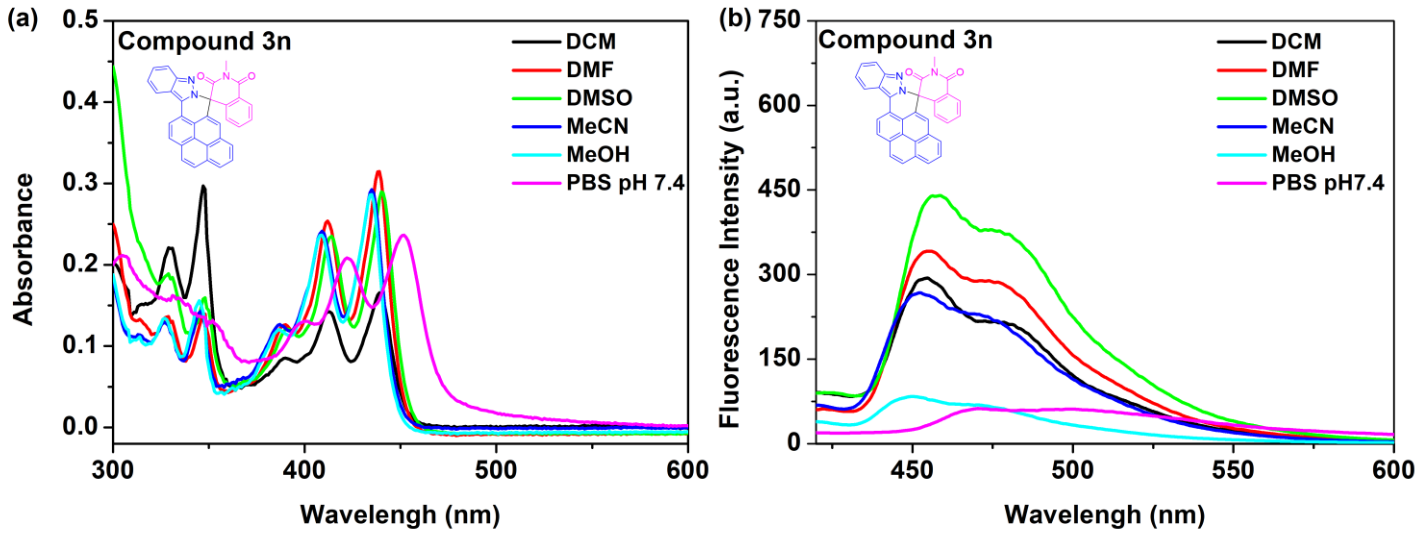


Figure S7 Absorption (a) and fluorescence (b) of compound **3n** in diverse solvents.

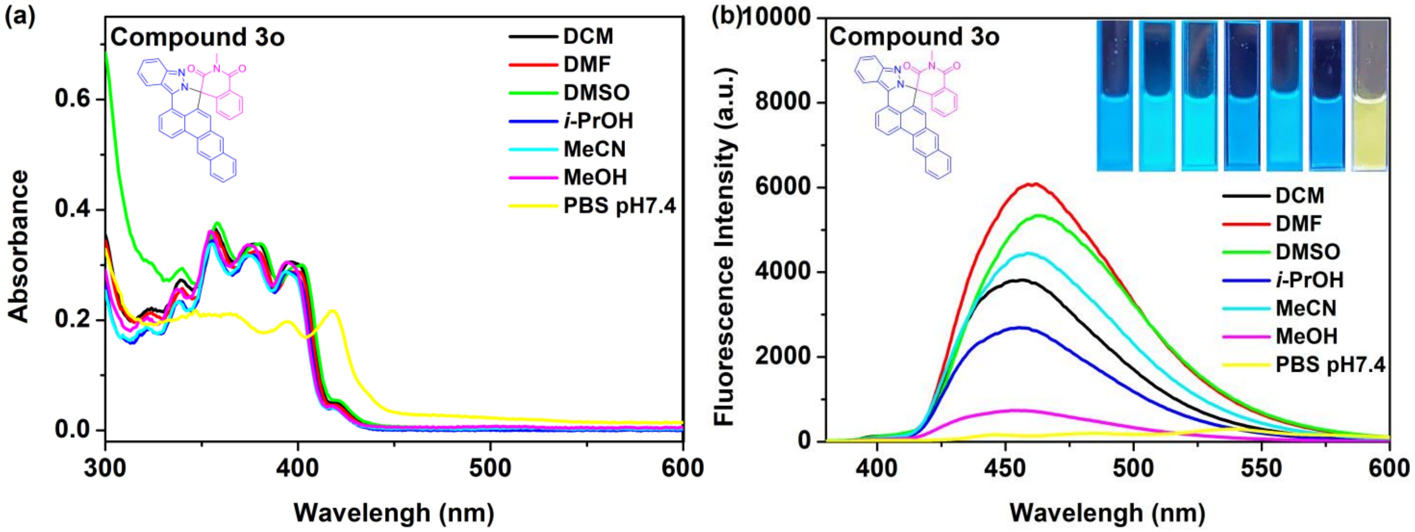


Figure S8. Absorption (a) and fluorescence (b) of compound **3o** in diverse solvents, insert: photos under 365 nm irradiation.

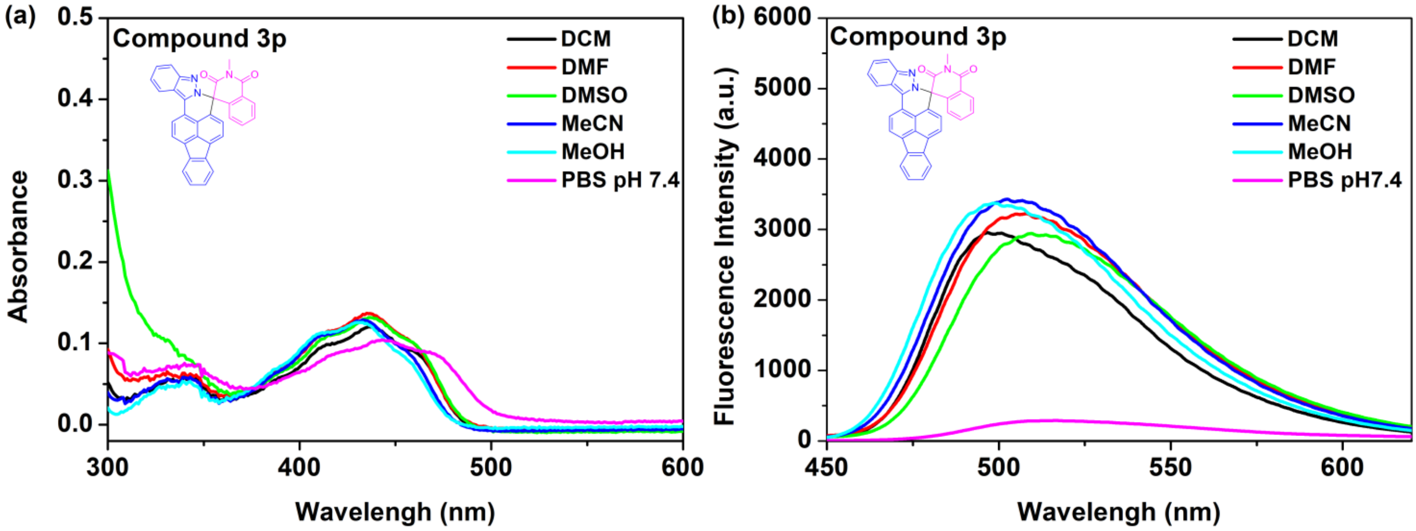


Figure S9. Absorption (a) and fluorescence (b) of compound **3p** in diverse solvents.

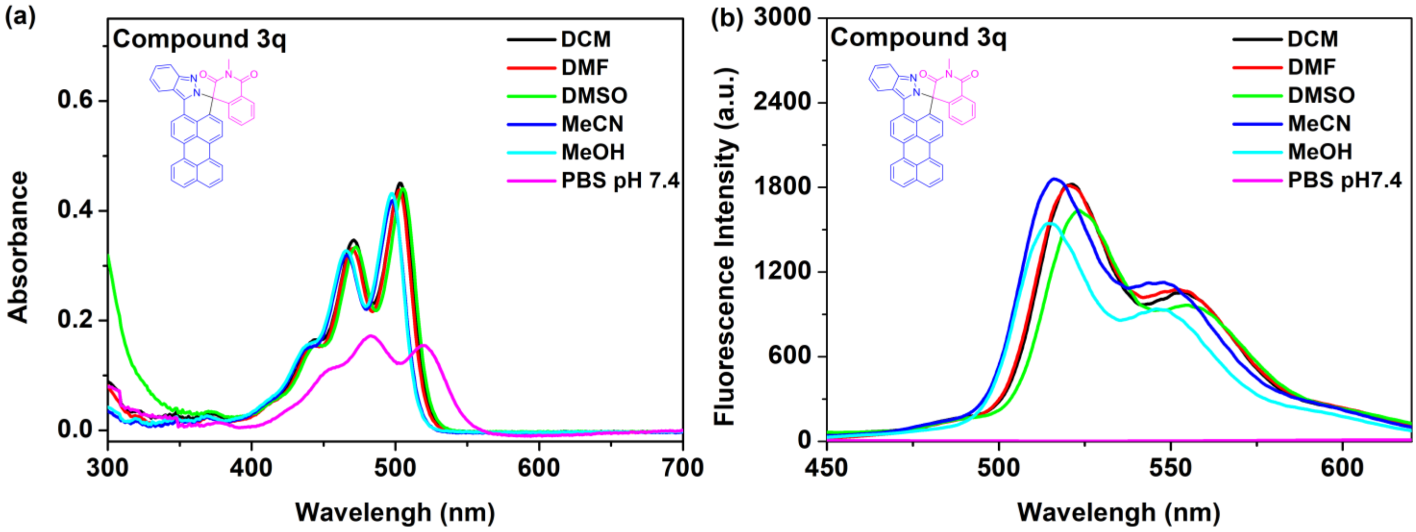


Figure S10. Absorption (a) and fluorescence (b) of compound **3q** in diverse solvents.

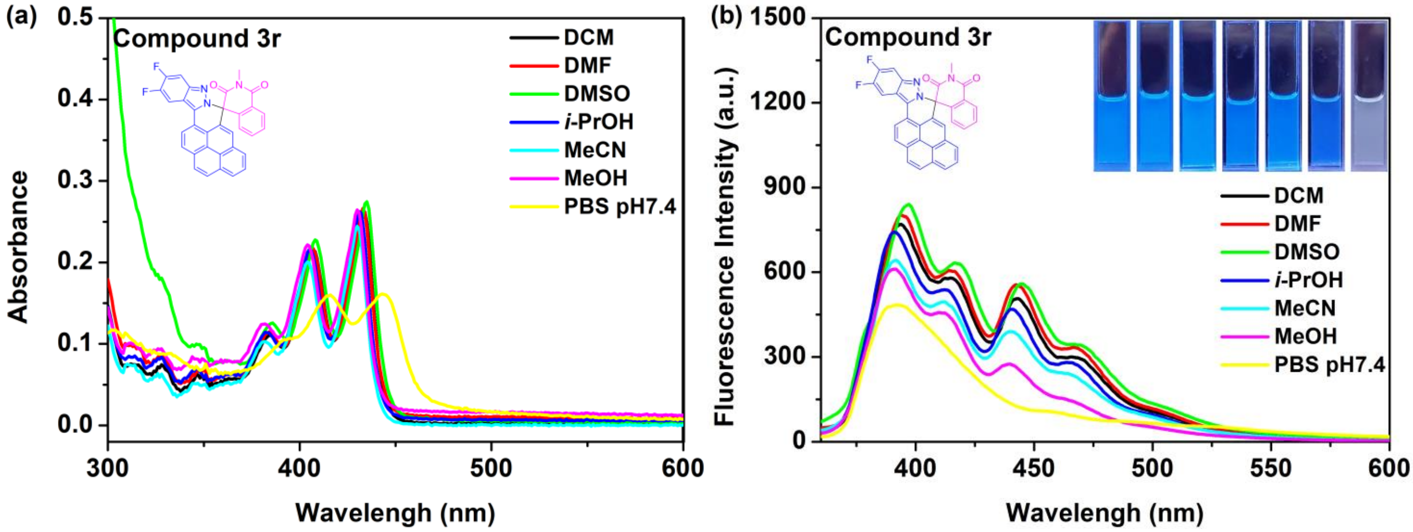


Figure S11. Absorption (a) and fluorescence (b) of compound **3r** in diverse solvents, insert: photos under 365 nm irradiation.

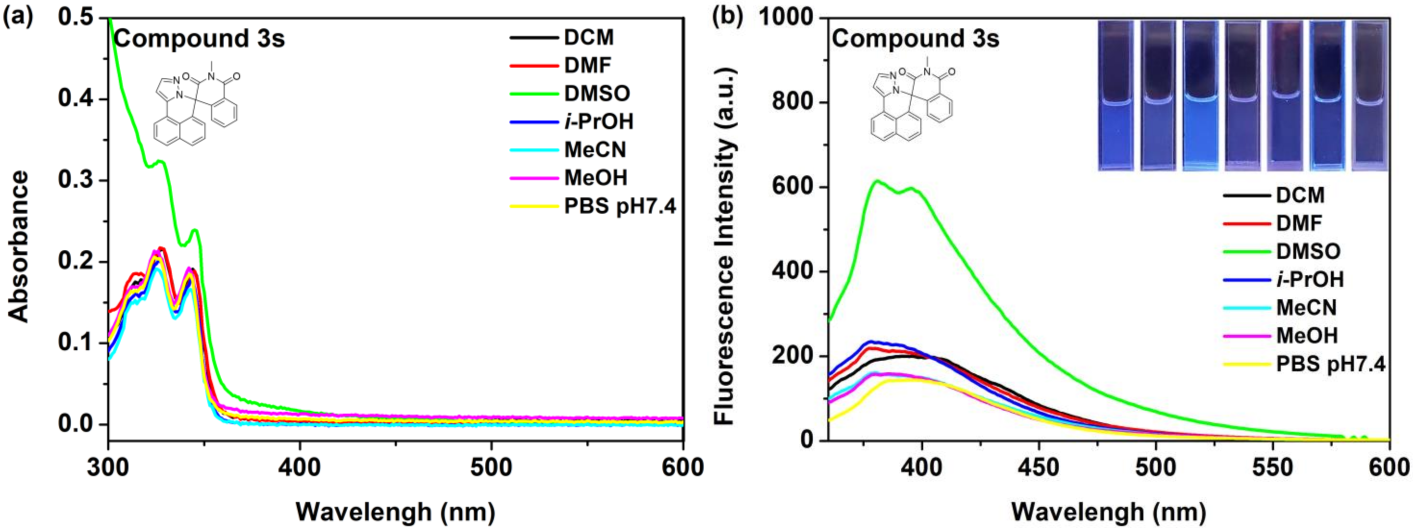


Figure S12. Absorption (a) and fluorescence (b) of compound **3s** in diverse solvents, insert: photos under 365 nm irradiation.

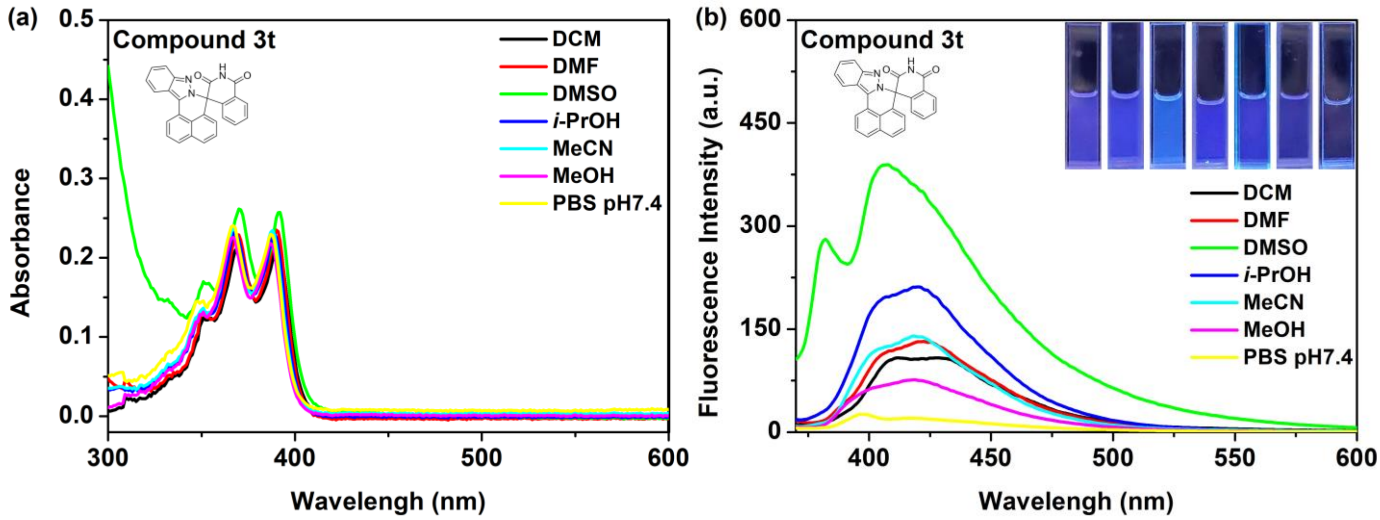


Figure S13. Absorption (a) and fluorescence (b) of compound **3t** in diverse solvents, insert: photos under 365 nm irradiation.

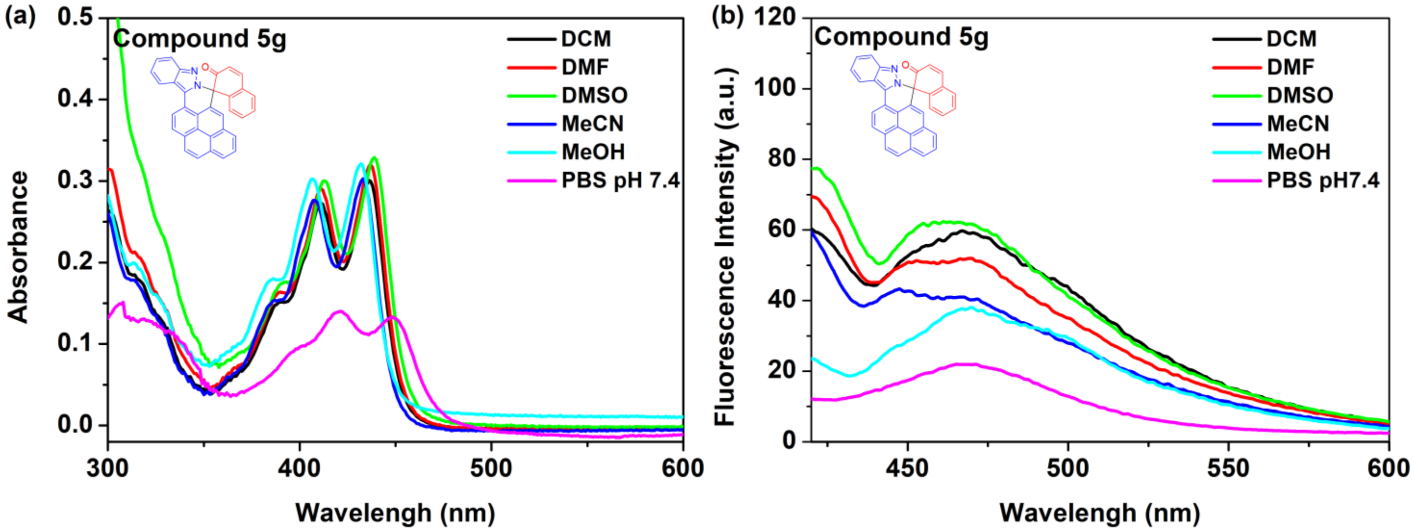


Figure S14. Absorption (a) and fluorescence (b) of compound **5g** in diverse solvents.

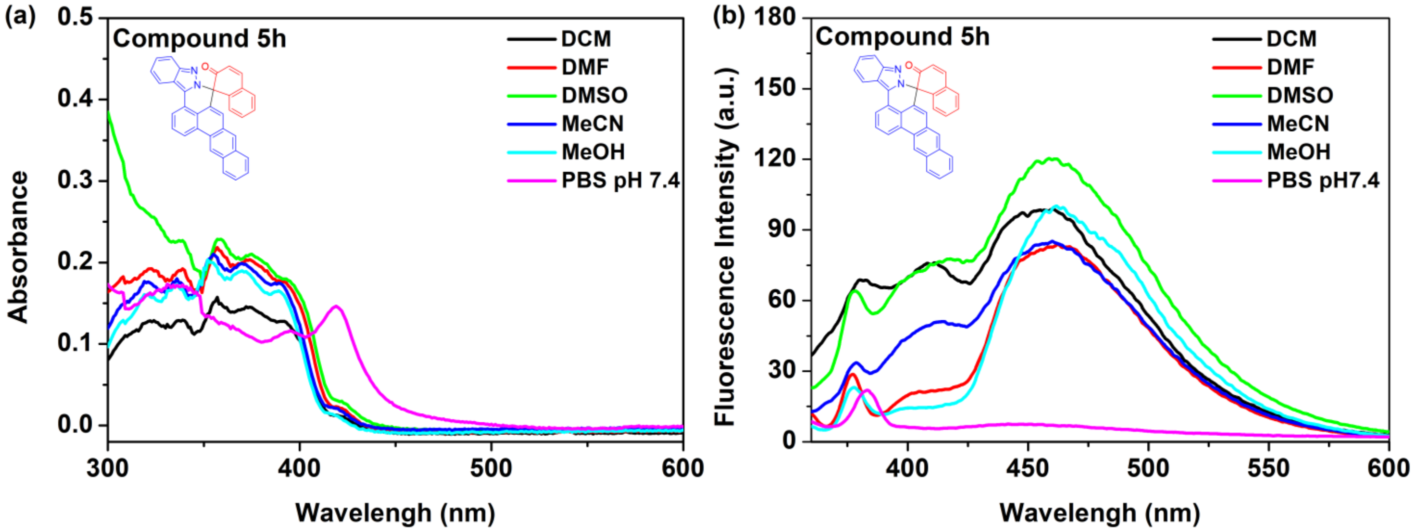


Figure S15. Absorption (a) and fluorescence (b) of compound **5h** in diverse solvents.

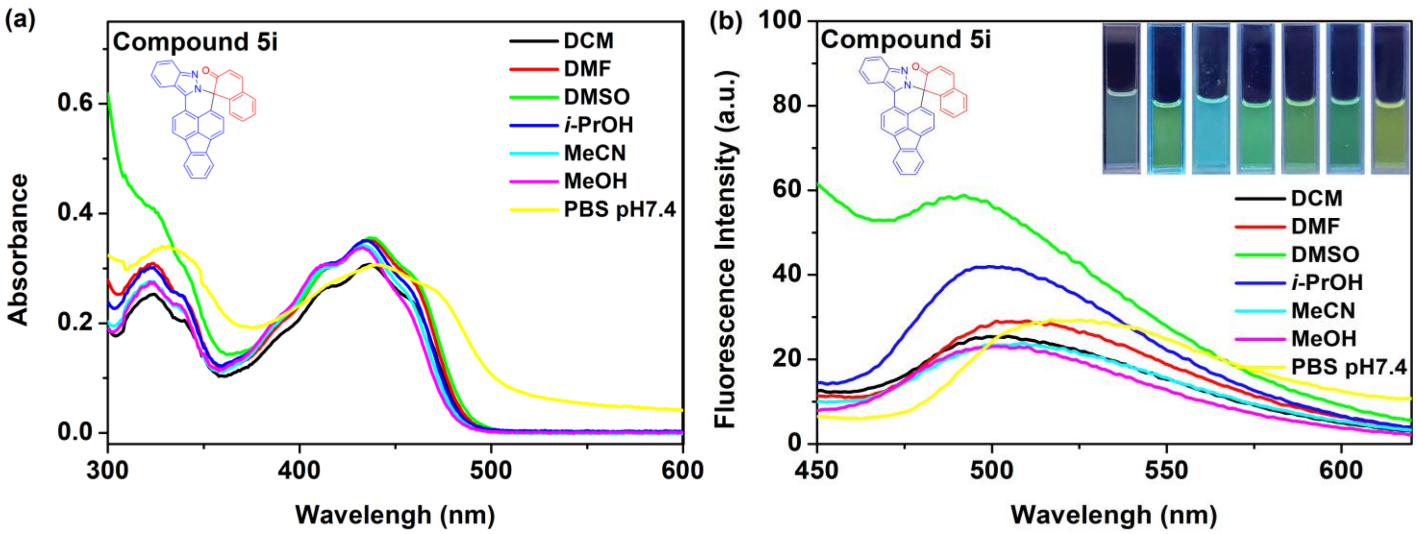


Figure S16. Absorption (a) and fluorescence (b) of compound **5i** in diverse solvents, insert: photos under 365 nm irradiation.

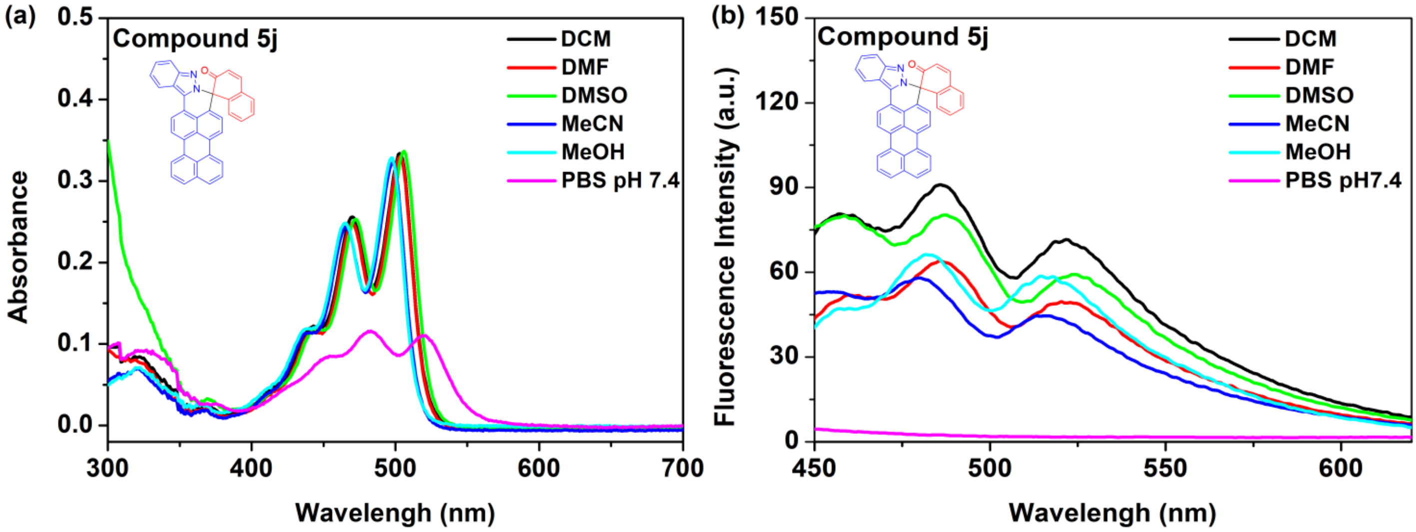


Figure S17. Absorption (a) and fluorescence (b) of compound **5j** in diverse solvents.

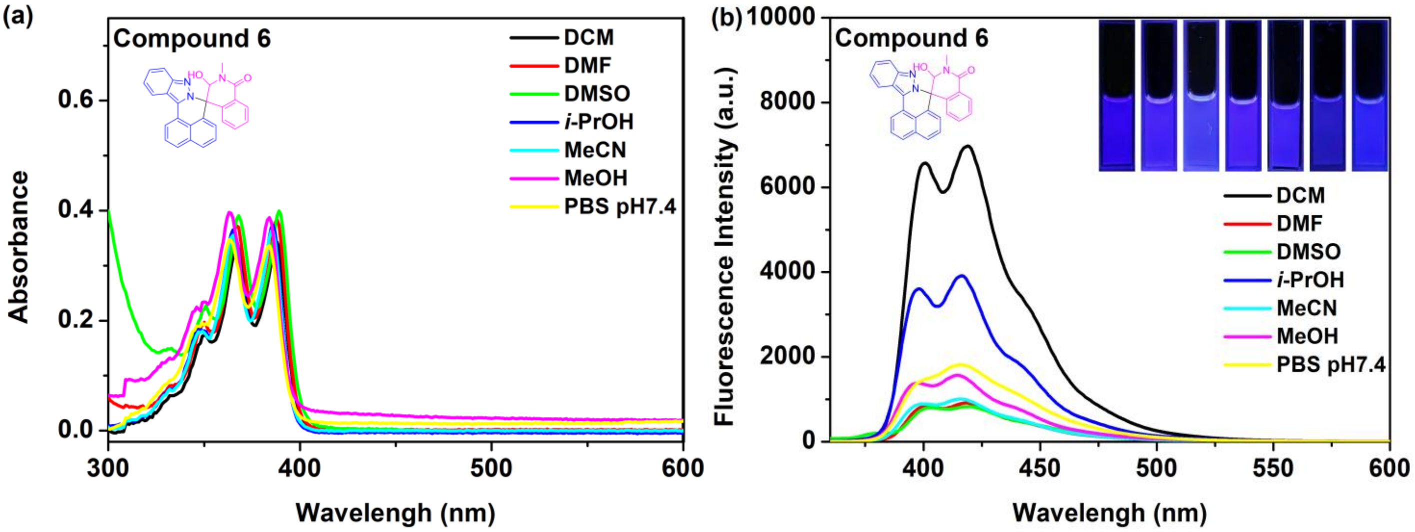


Figure S18. Absorption (a) and fluorescence (b) of compound **6** in diverse solvents, insert: photos under 365 nm irradiation.

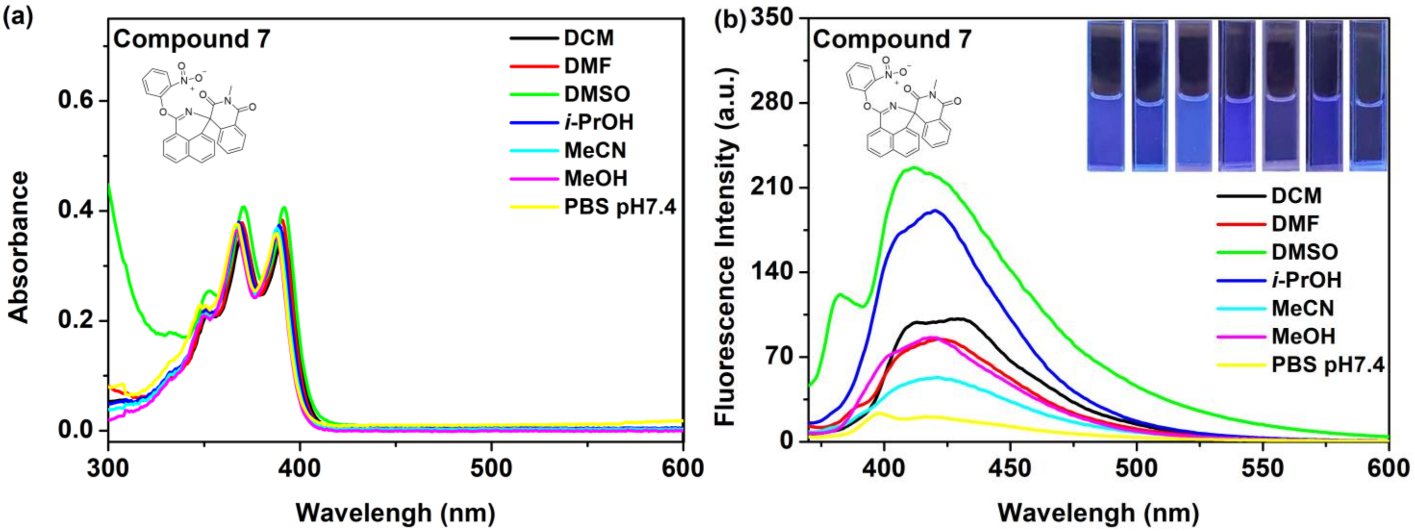


Figure S19.Absorption (a) and fluorescence (b) of compound **7** in diverse solvents, insert: photos under 365 nm irradiation.

2. Cell imaging results

Hela cells, sourced from Biomedical Engineering Center of Henan Normal University (Henan Xinxiang, China), were cultured in DMEM (Dulbecco's modified Eagle's medium) supplemented with 10% FBS (fetal bovine serum) at 37 °C under a 5% CO_2 atmosphere. Four Hela cells were rinsed with DPBS buffer (pH 7.4) and treated with **3o** (2, 5, 10, 20 μM) for 0.5 h. Before imaging, all cells were washed three times with DPBS, then the fluorescence imaging was carried out on an Olympus FV1200-IX81 confocal fluorescence microscope with 405 nm excitation for emission range of 440-490 nm (green was the pseudo color in the images).

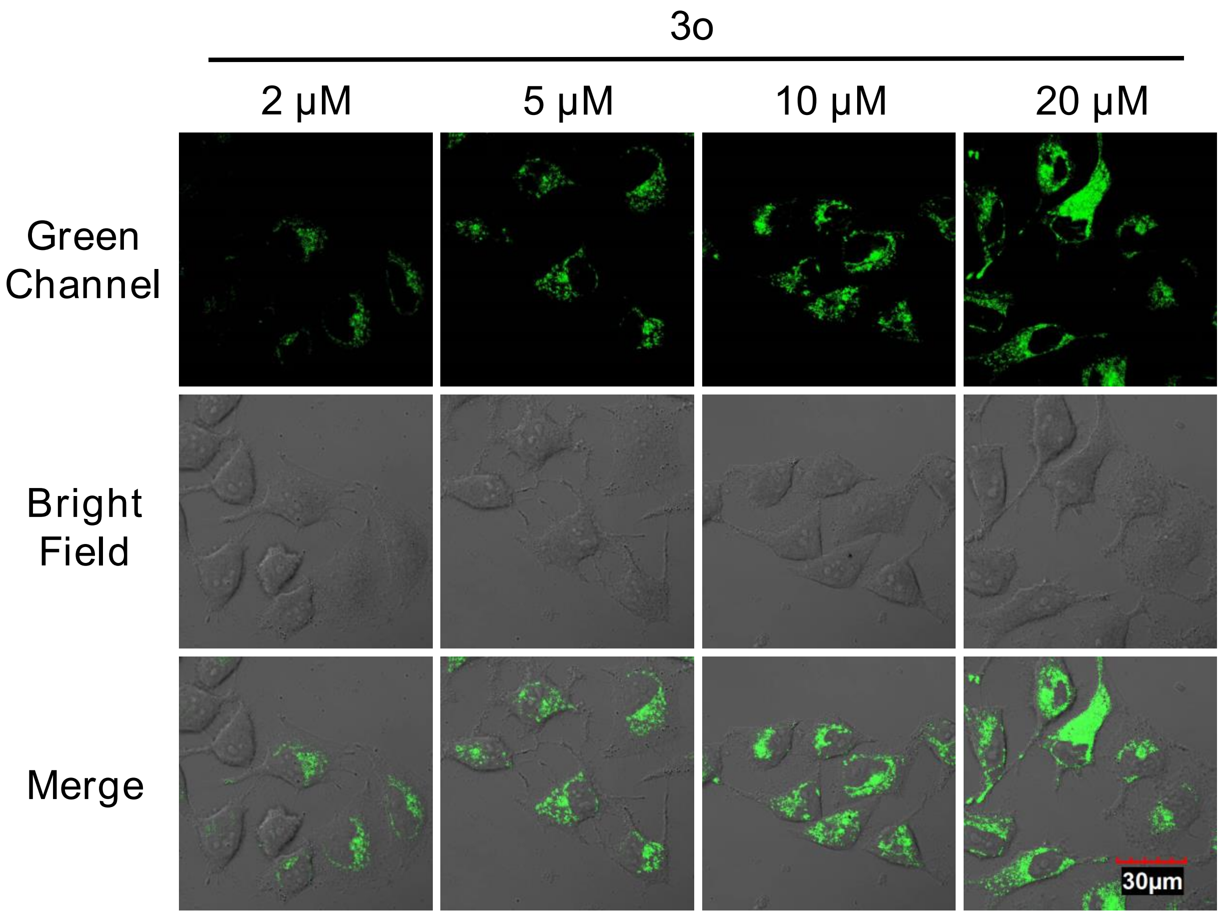


Figure S20. Fluorescence imaging of Hela cells by 2, 5, 10, and 20 μM **3o** staining. Excitation wavelength of 405 nm for green channel (440-490 nm). Scale bars: 30 μm.

XI. References

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