Electronic Supplementary Material (ESI) for Chemical Communications.

- Electronic Supporting Information -

Ruthenium(II)-catalyzed amide directed spiroannulation with naphthoquinones: access to spiro-isoindolinone frameworks

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General information

[Ru(*p*-cymene)Cl_2]$_2$ was purchased from Alfa Aesar company. Benzoic acids, $MeONH_2$.HCl, trifluoroethanol (TFE), naphthoquinone, and KOAc were purchased from Avra chemicals and Spectrochem. All the compounds were utilized without further purification. Commercial grade solvent was directly used for the reaction without drying.

All reactions were monitored by thin layer chromatography (TLC) on Merck 60 F 254 precoated silica plates and visualized using a UV lamp (366 or 254 nm) or by use of potassium permanganate, 5 g K_2CO_3, / 100 mL water. Products were isolated by column chromatography (Merck silica gel 100-200 μm).

^{13}C and ^{1}H NMR spectra were recorded on a Bruker 400 or Bruker 500 MHz spectrometers. Chemical shift values (δ) are reported in ppm and calibrated to the residual solvent peak $CDCl_3$ δ = 7.2600 ppm for ^{1}H, δ = 77.16 for ^{13}C; or calibrated to tetramethylsilane (δ = 0.00). All NMR spectra were recorded at ambient temperature (290 K) unless otherwise noted. ^{1}H NMR spectra are reported as follows: chemical shift (multiplicity, coupling constant, integration). The following abbreviations are used to indicate multiplicities: s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet; dd, doublet of doublet; dt, doublet of triplet; dq, doublet of quartet; td, triplet of doublet; tt, triplet of triplet; dq, doublet of quartet; br, broad.

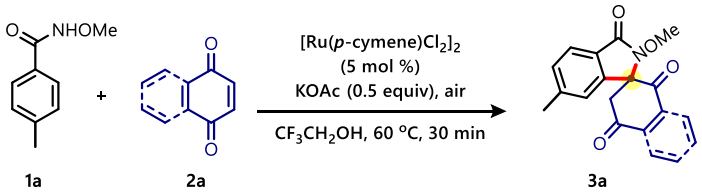
Mass spectra were recorded by electron spray ionization (ESI) method on a Q-TOF Micro with lock spray source.

References (*from manuscript*):

(9) (a) P. J. Seaton and S. J. Gould, *J. Am. Chem. Soc.*, 1988, **110**, 5912; (b) M. P. Gore, S. J. Gould and D. D. Weller, *J. Org. Chem.*, 1991, **56**, 2289; (c) M. C. Cone, C. R. Melville, M. P. Gore and S. J. Gould, *J. Org. Chem.*, 1993, **58**, 1058; (d) W. Martin Owton, *J. Chem. Soc. - Perkin Trans. 1*, 1999, **14**, 2409; (e) M. A. Colucci, G. D. Couch and C. J. Moody, *Org. Biomol. Chem.*, 2008, **6**, 637; (f) J. Iribarra, D. Vásquez, C. Theoduloz, J. Benites, D. Ríos and J. A. Valderrama, *Molecules*, 2012, **17**, 11616; (g) X. L. Xu and Z. Li, *Angew. Chem. Int. Ed.*, 2017, **56**, 8196.

(10) (a) E. A. Couladouros and A. T. Strongilos, *Tetrahedron Lett.*, 2000, 41, 535; (b) J. G. Handique and J. B. Baruah, *J. Mol. Catal. A Chem.*, 2002, **184**, 85; (c) C. D. S. Lisboa, V. G. Santos, B. G. Vaz, N. C. De Lucas, M. N. Eberlin and S. J. Garden, *J. Org. Chem.*, 2011, **76**, 5264; (d) E. Yagodkin, K. A. McGarry and C. J. Douglas, *Org. Prep. Proced. Int.*, 2011, **43**, 360.

Optimization of reaction conditions:

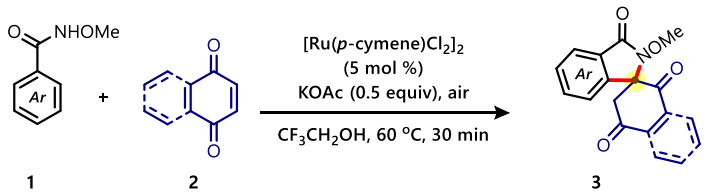


1a 2a 3a

entry	deviation from standard conditions	**3a** (%)
1	none	84
2	DMF instead of TFE	NP
3	DCE instead of TFE	NP
4	THF instead of TFE	NP
5	MeOH instead of TFE	<10
6	HFIP, or TCE instead of TFE	66
7	TCE instead of TFE	29
8	H_2O instead of TFE	NR
9	Acetic acid instead of TFE	NR
10	NaOAc instead of KOAc	73
11	K_2CO_3 instead of KOAc	<5
12	K_3PO_4 instead of KOAc	<5
13	At room temperature	38[b]
14	at 80 °C	35
15	without [Ru(*p*-cymene)Cl_2]$_2$	trace
16	Without KOAc	trace
17	[Ru(*p*-cymene)$(OAc)_2$] instead of [Ru(*p*-cymene)Cl_2]$_2$	52[c]
18	Pd$(OAc)_2$ instead of [Ru(*p*-cymene)Cl_2]$_2$	trace
19	[Cp*$IrCl_2$]$_2$ instead of [Ru(*p*-cymene)Cl_2]$_2$	trace
10	reaction in 1.5 mmol scale	76[d]

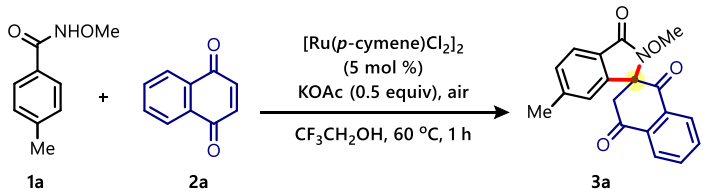
[a]Reaction conditions: **1a** (0.15 mmol, 1.0 equiv), **2a** (1.2 equiv), [Ru(*p*-cymene)Cl_2]$_2$ (5 mol %), KOAc (0.5 equiv), TFE= 0.3 mL, air at 60 °C for 30 min. [b]Reaction was performed for 24 h. [c]10 mol % catalyst was used. [d]Reaction time was 1 h. TFE: trifluoroethanol; DCE: 1,2-dichloroethane; HFIP: hexafluoroisopropanol; TCE: 2,2,2-trichloroethanol; NP: complex reaction mixture with no product formation; NR: no reaction with recovery of starting materials.

Typical ruthenium(II)-catalyzed *spiroannulation* between hydroxamic acid esters (1) and quinone (2):



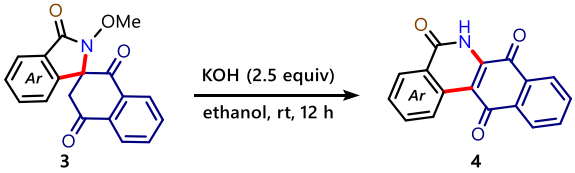
Procedure: To an oven dried screw cap reaction tube (10 × 1.5 cm), corresponding benzamide **1** (0.15 mmol, 1.0 equiv), quinone (**2**, 1.2 equiv), [Ru(*p*-cymene)Cl_2]$_2$ (5.0 mol %), and KOAc (0.5 equiv) were taken. Then trifluoroethanol (0.3 mL) was added in it and the mixture was stirred at 60 °C for 30 min under air. Then the solvent was evaporated under reduced pressure. In order to get pure spiroisoindolinone **3**, the resulting residue was purified by column chromatography on silica gel with a gradient eluent of hexane and ethyl acetate.

Typical scaled up ruthenium(II)-catalyzed *spiroannulation* between hydroxamic acid esters (1a) and quinone (2a):



Procedure: To an oven dried screw cap reaction tube (10 × 1.5 cm), corresponding benzamide **1a** (1.5 mmol, 1.0 equiv), quinone (**2a**, 1.2 equiv), [Ru(*p*-cymene)Cl_2]$_2$ (5.0 mol %), and KOAc (0.5 equiv) were taken. Then trifluoroethanol (3.0 mL) was added in it and the mixture was stirred at 60 °C for 1 h under air. Then the solvent was evaporated under reduced pressure. In order to get pure spiroisoindolinone **3a**, the resulting residue was purified by column chromatography on silica gel with a gradient eluent of hexane and ethyl acetate. Product obtained 76% (365 mg).

Typical synthesis of benzo[b]phenanthridine-5,7,12(*6H*)-triones (4) through transannulation of spiroisoindolinones (3):



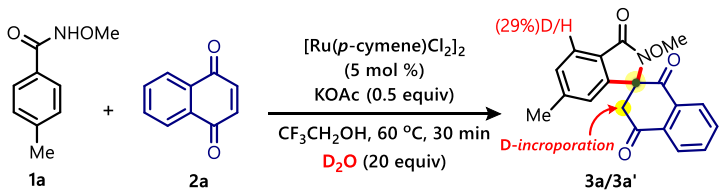
3 4

Procedure: To an oven dried screw cap reaction tube (10 × 1.5 cm), corresponding spiroisoindolinone (**3**) (0.1 mmol, 1.0 equiv) and KOH (2.5 equiv) were taken. Then ethanol (1.0 mL) was added in it and the mixture was stirred at room temperature for 12 h under air. After completion (monitored by TLC), the reaction was quenched with 0.1 mL acetic acid and then the solvent was evaporated under reduced pressure. In order to get pure quinone **4**, the resulting residue was purified by column chromatography on silica gel with a gradient eluent of dichloromethane (DCM) and ethyl acetate.

Solubility of these products are very less in common organic solvents. NMR spectroscopic data of these compounds are recorded in dilute $CDCl_3$ solution.

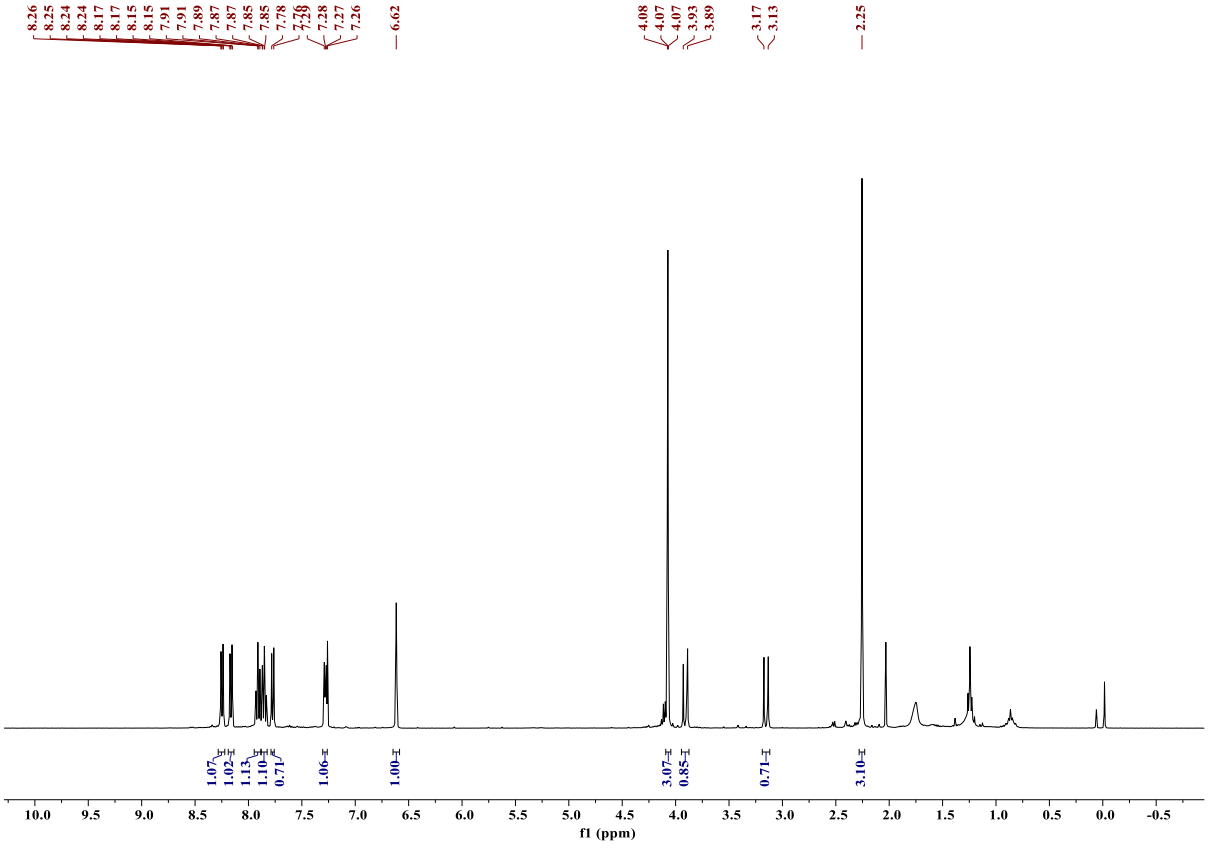
Mechanistic studies:

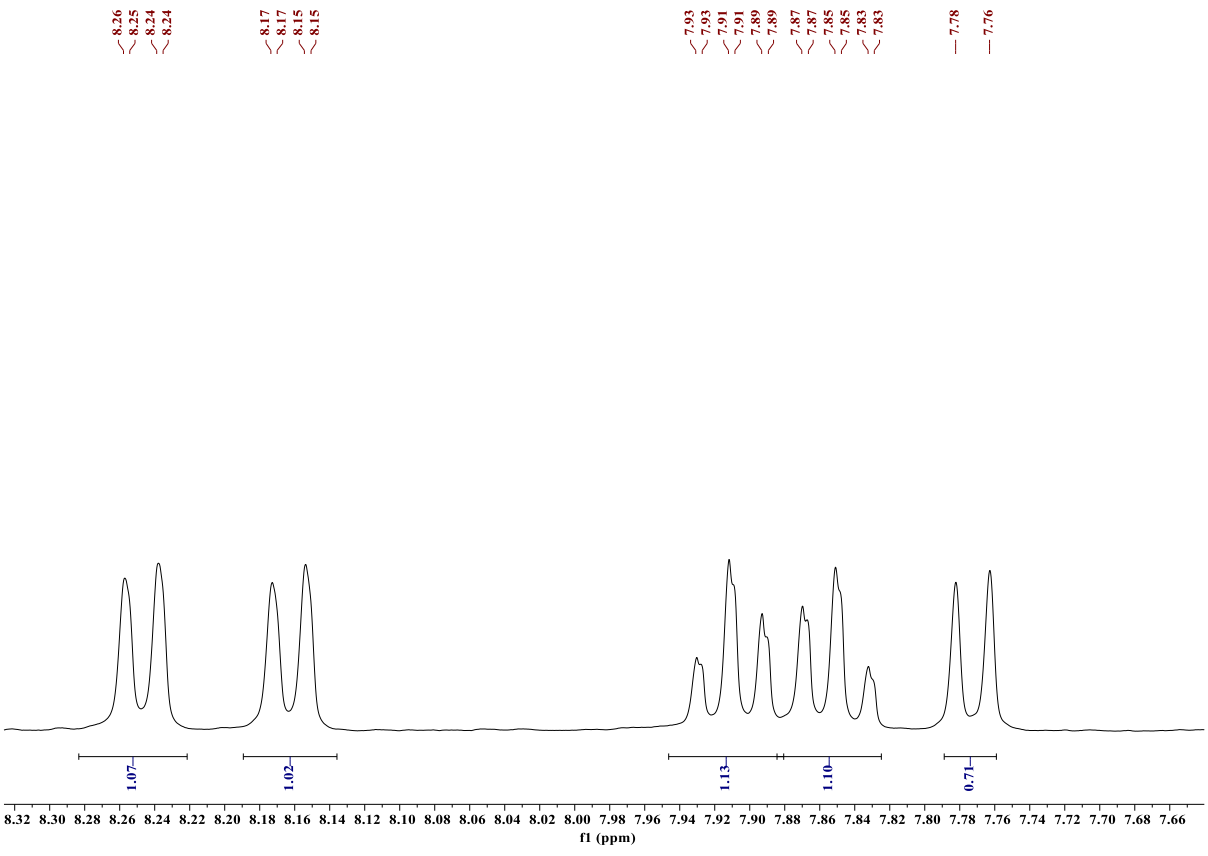
(a) H/D-Scrambling study:



1a **2a** **3a/3a'**

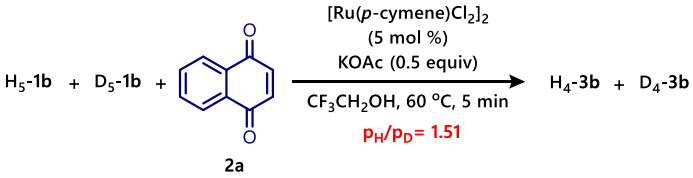
Procedure: To an oven dried screw cap reaction tube (10 × 1.5 cm), corresponding benzamide **1a** (0.15 mmol, 1.0 equiv), quinone (**2a**, 1.2 equiv), [Ru(*p*-cymene)Cl_2]$_2$ (5.0 mol %), KOAc (0.5 equiv), and D_2O (20.0 equiv) were taken. Then trifluoroethanol (0.3 mL) was added in it and the mixture was stirred at 60 °C for 30 min under air. Then the solvent was evaporated under reduced pressure. In order to get pure product **3a/3a′**, the resulting residue was purified by column chromatography on silica gel with a gradient eluent of hexane and ethyl acetate. The H/D-scrambling was observed through ^{1}H NMR spectroscopy.


8.26
8.25
8.24
8.24
8.17
8.17
8.15
8.15
7.91
7.91
7.89
7.87
7.87
7.85
7.85
7.78
7.28
7.27
7.26
6.62
4.08
4.07
4.07
3.93
3.89
3.17
3.13
2.25
1.07
1.02
1.13
1.10
0.71
1.06
1.00
3.07
0.85
0.71
3.10
f1 (ppm)

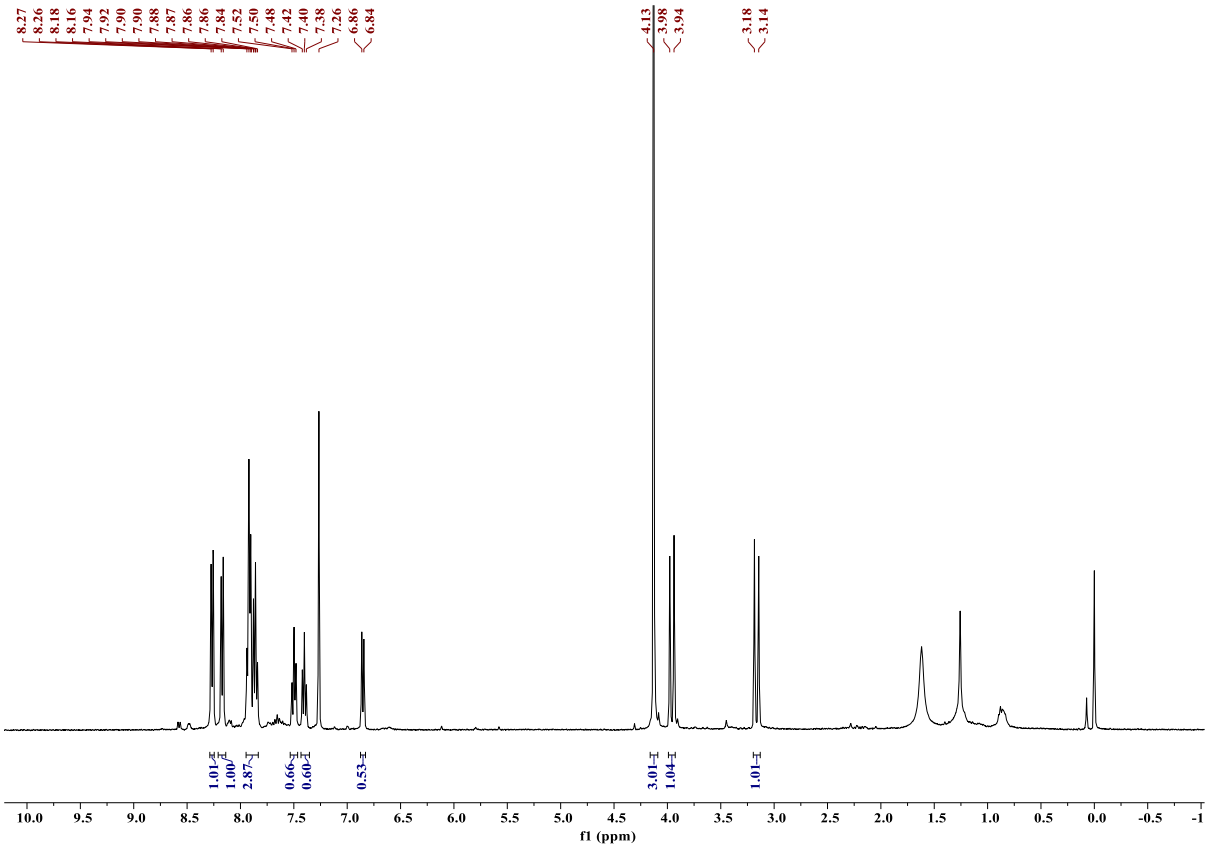

8.26
8.25
8.24
8.24
8.17
8.17
8.15
8.15
7.93
7.93
7.91
7.91
7.89
7.89
7.87
7.87
7.85
7.85
7.83
7.83
7.78
7.76
1.07
1.02
1.13
1.10
0.71
f1 (ppm)

(b) Kinetic Isotope Effect (KIE) Study:

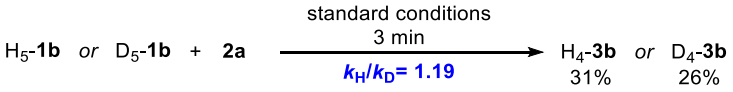
Competition Experiment-



Procedure: To an oven dried screw cap reaction tube (10 × 1.5 cm), corresponding benzamides H_5-**1b** (20.0 mg, 0.5 equiv), D_5-**1b** (20.0 mg, 0.5 equiv), quinone (**2a**, 1.2 equiv), [Ru(*p*-cymene)Cl_2]$_2$ (5.0 mol %), and KOAc (0.5 equiv) were taken. Then trifluoroethanol (0.5 mL) was added in it and the mixture was stirred at 60 °C for 5 min under air. Then the solvent was evaporated under reduced pressure. In order to get pure spiroisoindolinone, the resulting residue was purified by column chromatography on silica gel with a gradient eluent of hexane and ethyl acetate. The value of p_H/p_D was calculated using NMR.

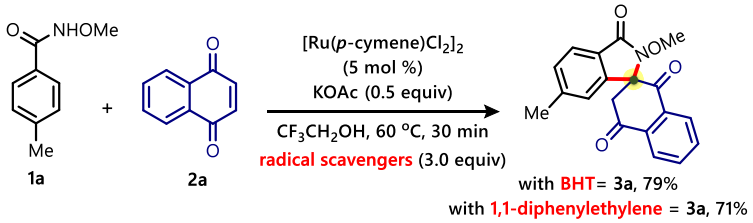


Parallel Experiment-



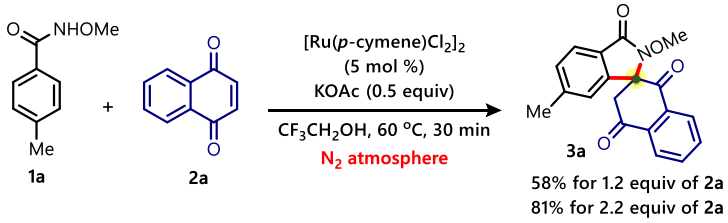
Procedure: In two separate oven dried screw cap reaction tubes (10 × 1.5 cm), corresponding benzamides H_5-**1b** (20.0 mg, 0.5 equiv) and D_5-**1b** (20.0 mg, 0.5 equiv) were taken. Then quinone (**2a**, 1.2 equiv), [Ru(*p*-cymene)Cl_2]$_2$ (5.0 mol %), and KOAc (0.5 equiv) were added in each of them followed by the addition of trifluoroethanol (0.25 mL). The reaction tubes were stirred at 60 ^oC for 3 min under air. Then the solvent was evaporated under reduced pressure. In order to get pure spiroisoindolinone, the resulting residue was purified by column chromatography on silica gel with a gradient eluent of hexane and ethyl acetate. The value of k_H/k_D was calculated using the ratio of isolated yields.

(c) Radical scavenger study:



Procedure: To an oven dried screw cap reaction tube (10 × 1.5 cm), corresponding benzamide **1a** (0.15 mmol, 1.0 equiv), quinone (**2a**, 1.2 equiv), [Ru(*p*-cymene)Cl_2]$_2$ (5.0 mol %), KOAc (0.5 equiv), and radical scavenger (3.0 equiv) were taken. Then trifluoroethanol (0.3 mL) was added in it and the mixture was stirred at 60 °C for 30 min under air. Then the solvent was evaporated under reduced pressure. In order to get pure spiroisoindolinone **3a**, the resulting residue was purified by column chromatography on silica gel with a gradient eluent of hexane and ethyl acetate.

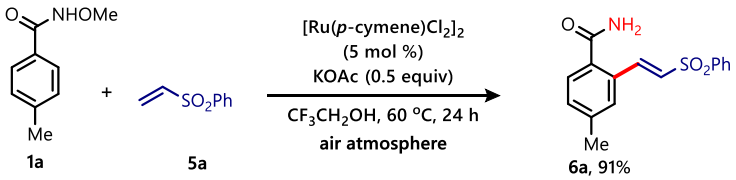
(d) Studying the role of aerial oxygen:



Procedure: To an oven dried test tube (10 × 1.5 cm), corresponding benzamide **1a** (0.15 mmol, 1.0 equiv), quinone (**2a**, 1.2 equiv), [Ru(*p*-cymene)Cl_2]$_2$ (5.0 mol %), KOAc (0.5 equiv), and radical scavenger (3.0 equiv) were taken. The test tube was closed with a rubber septum and it was backfilled with N_2 gas. Then trifluoroethanol (0.3 mL) was added in it and the reaction mixture was degassed with N_2 for 2 minutes. Then the reaction was stirred at 60 °C for 30 min. Next the solvent was evaporated under reduced pressure. In order to get pure spiroisoindolinone **3a**, the resulting residue was purified by column chromatography on silica gel with a gradient eluent of hexane and ethyl acetate.

The same experiment was repeated with 2.2 equiv of quinone **2a**. The increase in yield with increasing quinone amount hints of the crucial role of aerial oxygen in the transformation.

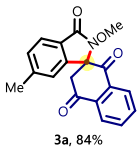
(e) Reaction with phenyl vinyl sulfone (5a):



Procedure: To an oven dried test tube (10 × 1.5 cm), corresponding benzamide **1a** (0.25 mmol, 1.0 equiv), phenyl vinyl sulfone (**5a**, 1.5 equiv), [Ru(*p*-cymene)Cl_2]$_2$ (5.0 mol %), and KOAc (0.5 equiv) were taken. Then trifluoroethanol (0.3 mL) was added in it and the reaction was stirred at 60 °C for 24 h under air. Next the solvent was evaporated under reduced pressure. In order to get pure product **6a**, the resulting residue was purified by column chromatography on silica gel with a gradient eluent of hexane and ethyl acetate.

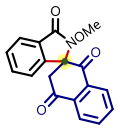
The cleavage of N–O bond hints of the formation of Ru(0)-species during the reaction.

NMR spectroscopic data of synthesized compounds:



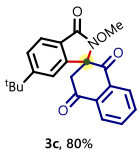
3a, 84%

2-Methoxy-6-methyl-1'H-spiro[isoindoline-1,2'-naphthalene]-1',3,4'(3'H)-trione (3a): yield 84% (41 mg) as grey sticky liquid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.35 – 8.10 (m, 2H), 8.01 – 7.69 (m, 3H), 7.36 – 7.22 (m, 1H), 6.64 (s, 1H), 4.08 (s, 3H), 3.92 (d, *J* = 16.2 Hz, 1H), 3.17 (d, *J* = 16.2 Hz, 1H), 2.27 (s, 3H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 193.0, 189.9, 165.7, 144.0, 140.9, 135.8, 135.5, 135.2, 134.3, 131.0, 128.7, 127.1, 126.3, 124.9, 122.0, 73.3, 65.3, 46.3, 22.2 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{19}H_{15}NO_4Na$ 344.0899; Found 344.0894.



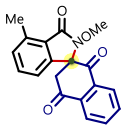
3b, 72%

2-Methoxy-1'H-spiro[isoindoline-1,2'-naphthalene]-1',3,4'(3'H)-trione (3b): yield 72% (33 mg) as grey sticky liquid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.26 (d, *J* = 7.7 Hz, 1H), 8.16 (d, *J* = 7.6 Hz, 1H), 7.95 – 7.89 (m, 2H), 7.88 – 7.81 (m, 1H), 7.53 – 7.46 (m, 1H), 7.43 – 7.36 (m, 1H), 6.85 (d, *J* = 7.7 Hz, 1H), 4.12 (s, 3H), 3.95 (d, *J* = 16.1 Hz, 1H), 3.16 (d, *J* = 16.1 Hz, 1H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 192.9, 189.8, 165.4, 140.5, 135.9, 135.6, 135.2, 134.3, 133.0, 130.1, 129.1, 128.7, 127.1, 125.1, 121.6, 73.6, 65.3, 46.3 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{18}H_{13}NO_4Na$ 330.0742; Found 330.0741.



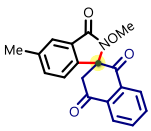
3c, 80%

6-(tert-Butyl)-2-methoxy-1'H-spiro[isoindoline-1,2'-naphthalene]-1',3,4'(3'H)-trione (3c): yield 80% (44 mg) as grey sticky liquid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.28 (d, *J* = 7.6 Hz, 1H), 8.17 (d, *J* = 7.6 Hz, 1H), 7.98 – 7.78 (m, 3H), 7.57 – 7.49 (m, 1H), 6.82 (s, 1H), 4.10 (s, 3H), 3.92 (d, *J* = 16.2 Hz, 1H), 3.19 (d, *J* = 16.1 Hz, 1H), 1.12 (s, 9H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 192.9, 190.1, 165.7, 157.2, 140.6, 135.9, 135.5, 135.1, 134.4, 128.6, 127.5, 126.8, 126.2, 124.7, 118.3, 73.6, 65.3, 46.4, 35.4, 31.1 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{22}H_{21}NO_4Na$ 386.1368; Found 386.1365.



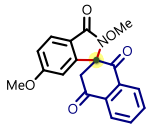
3d, 55%

2-Methoxy-4-methyl-1'H-spiro[isoindoline-1,2'-naphthalene]-1',3,4'(3'H)-trione (3d): yield 55% (26 mg) as grey sticky liquid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.24 (d, *J* = 7.7 Hz, 1H), 8.16 (d, *J* = 7.6 Hz, 1H), 7.93 – 7.87 (m, 1H), 7.87 – 7.78 (m, 1H), 7.25 – 7.18 (m, 2H), 6.66 (d, *J* = 7.0 Hz, 1H), 4.09 (s, 3H), 3.91 (d, *J* = 16.1 Hz, 1H), 3.15 (d, *J* = 16.1 Hz, 1H), 2.71 (s, 3H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 193.1, 190.1, 166.7, 141.0, 139.6, 135.9, 135.4, 135.1, 134.4, 132.3, 132.1, 128.7, 127.1, 126.0, 119.1, 72.9, 65.2, 46.4, 17.5 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{19}H_{15}NO_4Na$ 344.0899; Found 344.0894.



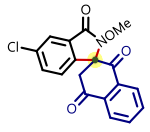
3e, 86%

2-Methoxy-5-methyl-1'H-spiro[isoindoline-1,2'-naphthalene]-1',3,4'(3'H)-trione (3e): yield 86% (41 mg) as grey sticky liquid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.22 (d, *J* = 7.7 Hz, 1H), 8.12 (d, *J* = 7.7 Hz, 1H), 7.95 – 7.75 (m, 2H), 7.67 (s, 1H), 7.17 (d, *J* = 7.9 Hz, 1H), 6.70 (d, *J* = 7.9 Hz, 1H), 4.08 (s, 3H), 3.90 (d, *J* = 16.1 Hz, 1H), 3.11 (d, *J* = 16.1 Hz, 1H), 2.36 (s, 3H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 192.9, 189.9, 165.5, 140.5, 137.7, 135.8, 135.4, 135.1, 134.3, 133.7, 129.0, 128.6, 127.0, 125.3, 121.4, 73.4, 65.2, 46.3, 21.4 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{19}H_{15}NO_4Na$ 344.0899; Found 344.0897.



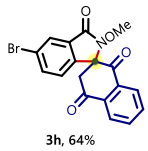
3f, 74%

2,6-Dimethoxy-1'H-spiro[isoindoline-1,2'-naphthalene]-1',3,4'(3'H)-trione (3f): yield 74% (37 mg) as grey sticky liquid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.26 – 8.19 (m, 1H), 8.19 – 8.11 (m, 1H), 7.96 – 7.73 (m, 3H), 7.03 – 6.90 (m, 1H), 6.33 (s, 1H), 4.04 (s, 3H), 3.87 (d, *J* = 16.1 Hz, 1H), 3.68 (s, 3H), 3.16 (d, *J* = 16.1 Hz, 1H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 192.8, 189.8, 165.9, 163.5, 142.7, 135.8, 135.5, 135.1, 134.3, 128.7, 127.0, 126.7, 121.1, 115.1, 108.2, 73.3, 65.3, 55.8, 46.4 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{19}H_{15}NO_5Na$ 360.0848; Found 360.0846.



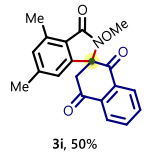
3g, 70%

5-Chloro-2-methoxy-1'H-spiro[isoindoline-1,2'-naphthalene]-1',3,4'(3'H)-trione (3g): yield 70% (36 mg) as grey sticky liquid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.23 (d, *J* = 7.7 Hz, 1H), 8.14 (d, *J* = 7.7 Hz, 1H), 7.95 – 7.81 (m, 3H), 7.39 – 7.30 (m, 1H), 6.79 (d, *J* = 8.2 Hz, 1H), 4.08 (s, 3H), 3.91 (d, *J* = 16.1 Hz, 1H), 3.14 (d, *J* = 16.1 Hz, 1H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 192.4, 189.3, 163.9, 138.5, 136.6, 135.7 (2C), 135.3, 134.0, 133.0, 131.0, 128.7, 127.2, 125.2, 123.0, 73.3, 65.3, 46.1 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{18}H_{12}ClNO_4Na$ 364.0353; Found 364.0352.



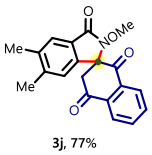
3h, 64%

5-Bromo-2-methoxy-1'H-spiro[isoindoline-1,2'-naphthalene]-1',3,4'(3'H)-trione (3h): yield 64% (37 mg) as grey sticky liquid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.28 – 8.20 (m, 1H), 8.18 – 8.12 (m, 1H), 8.02 (d, *J* = 1.8 Hz, 1H), 7.97 – 7.82 (m, 2H), 7.56 – 7.45 (m, 1H), 6.73 (d, *J* = 8.2 Hz, 1H), 4.09 (s, 3H), 3.92 (d, *J* = 16.1 Hz, 1H), 3.15 (d, *J* = 16.1 Hz, 1H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 192.4, 189.2, 163.8, 139.0, 135.8 (2C), 135.7, 135.3, 134.1, 131.1, 128.8, 128.2, 127.2, 124.4, 123.2, 73.4, 65.3, 46.0 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{18}H_{12}BrNO_4Na$ 407.9847; Found 407.9839.



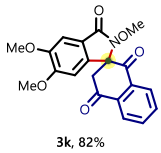
3i, 50%

2-Methoxy-4,6-dimethyl-1'H-spiro[isoindoline-1,2'-naphthalene]-1',3,4'(3'H)-trione (3i): yield 50% (25 mg) as grey sticky liquid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.23 (d, *J* = 7.6 Hz, 1H), 8.19 – 8.12 (m, 1H), 7.94 – 7.78 (m, 2H), 7.02 (s, 1H), 6.44 (s, 1H), 4.04 (s, 3H), 3.87 (d, *J* = 16.1 Hz, 1H), 3.15 (d, *J* = 16.1 Hz, 1H), 2.65 (s, 3H), 2.19 (s, 3H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 193.3, 190.2, 167.1, 143.3, 141.5, 139.3, 135.8, 135.4, 135.1, 134.3, 133.0, 128.7, 127.0, 123.3, 119.6, 72.8, 65.2, 46.4, 22.0, 17.4 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{20}H_{17}NO_4Na$ 358.1055; Found 358.1053.



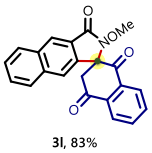
3j, 77%

2-Methoxy-5,6-dimethyl-1'H-spiro[isoindoline-1,2'-naphthalene]-1',3,4'(3'H)-trione (3j): yield 77% (39 mg) as grey sticky liquid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.23 (d, *J* = 7.7 Hz, 1H), 8.14 (d, *J* = 7.6 Hz, 1H), 7.98 – 7.76 (m, 2H), 7.63 (s, 1H), 6.57 (s, 1H), 4.05 (s, 3H), 3.88 (d, *J* = 16.1 Hz, 1H), 3.12 (d, *J* = 16.1 Hz, 1H), 2.26 (s, 3H), 2.13 (s, 3H) ppm; ^{13}C NMR (101 MHz, $CDCl_3$) δ 193.1, 190.0, 166.0, 142.7, 139.3, 138.5, 135.8, 135.4, 135.1, 134.3, 128.6, 127.0, 126.6, 125.7, 122.4, 73.2, 65.2, 46.4, 20.7, 20.0 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{20}H_{17}NO_4Na$ 358.1055; Found 358.1054.



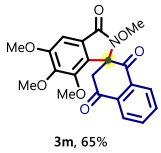
3k, 82%

2,5,6-Trimethoxy-1'H-spiro[isoindoline-1,2'-naphthalene]-1',3,4'(3'H)-trione (3k): yield 82% (45 mg) as grey sticky liquid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.22 (d, *J* = 7.6 Hz, 1H), 8.15 (d, *J* = 7.6 Hz, 1H), 7.93 – 7.80 (m, 2H), 7.33 (s, 1H), 6.28 (s, 1H), 3.98 (s, 3H), 3.89 (s, 3H), 3.82 (d, *J* = 16.2 Hz, 1H), 3.62 (s, 3H), 3.20 (d, *J* = 16.2 Hz, 1H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 193.0, 190.0, 166.8, 153.5, 151.1, 135.8, 135.4, 135.1, 134.4 (2C), 128.6, 126.8, 121.3, 106.5, 104.2, 73.1, 65.4, 56.5, 56.2, 46.5 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{20}H_{17}NO_6Na$ 390.0954; Found 390.0948.



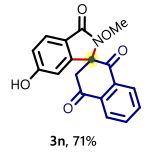
3l, 83%

2-Methoxy-1'H-spiro[benzo[f]isoindole-1,2'-naphthalene]-1',3,4'(2H,3'H)-trione (3l): yield 83% (44 mg) as grey sticky liquid; **^{1}H NMR** (400 MHz,) δ 8.42 (s, 1H), 8.31 (d, *J* = 7.7 Hz, 1H), 8.18 (d, *J* = 7.7 Hz, 1H), 8.01 – 7.91 (m, 2H), 7.90 – 7.83 (m, 1H), 7.64 (d, *J* = 7.7 Hz, 1H), 7.58 – 7.49 (m, 2H), 7.24 (s, 1H), 4.18 (s, 3H), 4.03 (d, *J* = 16.1 Hz, 1H), 3.24 (d, *J* = 16.1 Hz, 1H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 193.1, 189.8, 165.0, 135.9, 135.6, 135.5, 135.3, 135.1, 134.3, 133.4, 129.6, 128.9, 128.6 (2C), 127.7, 127.2, 126.0, 125.9, 121.2, 73.3, 65.4, 46.6 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{22}H_{15}NO_4Na$ 380.0899; Found 380.0898.



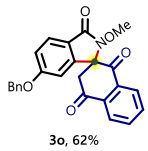
3m, 65%

2,5,6,7-Tetramethoxy-1'H-spiro[isoindoline-1,2'-naphthalene]-1',3,4'(3'H)-trione (3m): yield 65% (39 mg) as grey sticky liquid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.20 (d, *J* = 7.8 Hz, 1H), 8.15 (d, *J* = 7.7 Hz, 1H), 7.89 – 7.80 (m, 1H), 7.81 – 7.73 (m, 1H), 7.16 (s, 1H), 3.89 (s, 3H), 3.87 (s, 3H), 3.78 (s, 3H), 3.63 (d, *J* = 16.6 Hz, 1H), 3.50 – 3.40 (m, 4H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 192.1, 190.1, 166.6, 156.3, 148.0, 145.5, 136.3, 135.2, 134.2, 133.7, 128.4, 126.4, 126.2, 124.6, 102.5, 71.8, 65.4, 61.1, 60.0, 56.6, 44.6 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{21}H_{19}NO_7Na$ 420.1059; Found 420.1053.



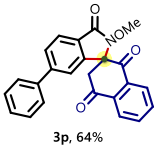
3n, 71%

6-Hydroxy-2-methoxy-1'H-spiro[isoindoline-1,2'-naphthalene]-1',3,4'(3'H)-trione (3n): yield 71% (34 mg) as grey sticky solid; **^{1}H NMR** (400 MHz, DMSO-d_6) δ 10.52 (s, 1H), 8.25 – 7.89 (m, 4H), 7.64 (d, *J* = 8.3 Hz, 1H), 6.93 (d, *J* = 8.3 Hz, 1H), 6.44 (s, 1H), 3.95 (d, *J* = 16.1 Hz, 1H), 3.77 (s, 3H), 3.5 (d, *J*= 16.1 Hz, 1H, merged with water peak) ppm; **^{13}C NMR** (101 MHz, DMSO) δ 193.3, 190.1, 165.5, 162.0, 143.2, 135.8, 135.5, 135.2, 133.7, 127.8, 126.5, 126.0, 118.8, 117.5, 108.8, 72.5, 64.8, 45.7 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{18}H_{13}NO_5Na$ 346.0691; Found 346.0683.



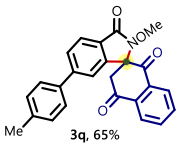
3o, 62%

6-(Benzyloxy)-2-methoxy-1'H-spiro[isoindoline-1,2'-naphthalene]-1',3,4'(3'H)-trione (3o): yield 62% (38 mg) as grey sticky liquid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.23 (d, *J* = 7.7 Hz, 1H), 8.14 (d, *J* = 7.2 Hz, 1H), 7.93 – 7.87 (m, 1H), 7.87 – 7.79 (m, 2H), 7.36 – 7.21 (m, 5H), 7.05 (dd, *J* = 8.5, 2.0 Hz, 1H), 6.38 (s, 1H), 4.92 (s, 2H), 4.06 (s, 3H), 3.89 (d, *J* = 16.1 Hz, 1H), 3.14 (d, *J* = 16.1 Hz, 1H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 192.8, 189.7, 165.8, 162.6, 142.6, 135.7, 135.5 (2C), 135.1, 134.3, 128.9, 128.7, 128.5, 127.6, 127.1, 126.8, 121.3, 116.2, 108.8, 73.3, 70.7, 65.3, 46.4 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{25}H_{19}NO_5Na$ 436.1161; Found 436.1158.



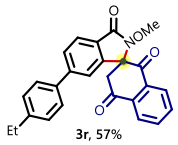
3p, 64%

2-Methoxy-6-phenyl-1'H-spiro[isoindoline-1,2'-naphthalene]-1',3,4'(3'H)-trione (3q): yield 64% (37 mg) as grey sticky liquid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.25 (d, *J* = 7.6 Hz, 1H), 8.17 (d, *J* = 7.6 Hz, 1H), 7.98 – 7.81 (m, 3H), 7.68 (d, *J* = 8.0 Hz, 1H), 7.40 – 7.28 (m, 5H), 7.00 (s, 1H), 4.11 (s, 3H), 3.96 (d, *J* = 16.1 Hz, 1H), 3.25 (d, *J* = 16.1 Hz, 1H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 192.9, 189.7, 165.4, 146.4, 141.2, 139.7, 135.8, 135.7, 135.2, 134.2, 129.3, 129.1, 128.7, 128.6, 127.8, 127.45, 127.07, 125.41, 120.3, 73.5, 65.4, 46.3 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{24}H_{17}NO_4Na$ 406.1055; Found 406.1055.



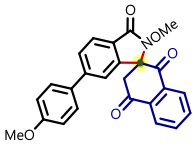
3q, 65%

2-Methoxy-6-(p-tolyl)-1'H-spiro[isoindoline-1,2'-naphthalene]-1',3,4'(3'H)-trione (3q): yield 65% (39 mg) as grey sticky liquid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.26 (d, *J* = 7.7 Hz, 1H), 8.17 (d, *J* = 7.7 Hz, 1H), 7.98 – 7.81 (m, 3H), 7.67 (d, *J* = 8.0 Hz, 1H), 7.28 – 7.14 (m, 4H), 6.99 (s, 1H), 4.12 (s, 3H), 3.96 (d, *J* = 16.1 Hz, 1H), 3.25 (d, *J* = 16.1 Hz, 1H), 2.35 (s, 3H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 192.9, 189.8, 165.5, 146.4, 141.3, 138.7, 136.8, 135.9, 135.6, 135.2, 134.3, 129.9, 129.1, 128.8, 127.5, 127.3, 127.1, 125.4, 120.1, 73.6, 65.4, 46.4, 21.2 ppm.



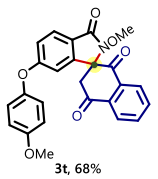
3r, 57%

6-(4-Ethylphenyl)-2-methoxy-1'H-spiro[isoindoline-1,2'-naphthalene]-1',3,4'(3'H)-trione (3r): yield 57% (35 mg) as grey sticky liquid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.26 (d, *J* = 7.6 Hz, 1H), 8.17 (d, *J* = 7.6 Hz, 1H), 7.97 – 7.82 (m, 3H), 7.68 (d, *J* = 8.0 Hz, 1H), 7.29 – 7.18 (m, 4H), 7.00 (s, 1H), 4.12 (s, 3H), 3.96 (d, *J* = 16.1 Hz, 1H), 3.25 (d, *J* = 16.1 Hz, 1H), 2.65 (q, *J* = 7.6 Hz, 2H), 1.23 (t, *J* = 7.6 Hz, 3H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 192.9, 189.8, 165.5, 146.4, 145.0, 141.2, 137.0, 135.9, 135.6, 135.2, 134.3, 129.1, 128.7, 128.7, 127.5, 127.4, 127.1, 125.4, 120.1, 73.6, 65.4, 46.3, 28.6, 15.6 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{26}H_{21}NO_4Na$ 434.1368; Found 434.1366.



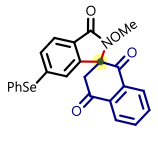
3s, 61%

2-Methoxy-6-(4-methoxyphenyl)-1'H-spiro[isoindoline-1,2'-naphthalene]-1',3,4'(3'H)-trione (3s): yield 61% (38 mg) as grey sticky liquid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.26 (d, *J* = 7.7 Hz, 1H), 8.17 (d, *J* = 7.6 Hz, 1H), 7.94 – 7.82 (m, 3H), 7.68 – 7.61 (m, 1H), 7.30 – 7.24 (m, 2H), 6.97 (s, 1H), 6.90 (d, *J* = 8.7 Hz, 2H), 4.11 (s, 3H), 3.95 (d, *J* = 16.1 Hz, 1H), 3.81 (s, 3H), 3.25 (d, *J* = 16.1 Hz, 1H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 193.0, 189.8, 165.6, 160.1, 146.0, 141.3, 135.8, 135.6, 135.2, 134.2, 132.0, 128.7, 128.5 (2C), 127.0, 125.3, 119.7, 114.5 (2C), 73.5, 65.3, 55.5, 46.3 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{25}H_{19}NO_5Na$ 436.1161; Found 436.1156.



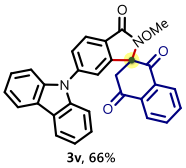
3t, 68%

2-Methoxy-6-(4-methoxyphenoxy)-1'H-spiro[isoindoline-1,2'-naphthalene]-1',3,4'(3'H)-trione (3t): yield 68% (44 mg) as grey sticky liquid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.19 – 8.11 (m, 2H), 7.89 – 7.80 (m, 2H), 7.77 (d, *J* = 8.5 Hz, 1H), 6.91 (d, *J* = 8.4 Hz, 1H), 6.87 – 6.79 (m, 4H), 6.33 (s, 1H), 4.07 (s, 3H), 3.88 (d, *J* = 16.3 Hz, 1H), 3.80 (s, 3H), 3.14 (d, *J* = 16.3 Hz, 1H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 192.6, 189.9, 165.6, 163.2, 157.0, 147.9, 142.7, 135.7, 135.5, 135.1, 134.4, 128.6, 127.0, 126.8, 122.2, 121.8, 117.7, 115.3, 110.3, 73.4, 65.4, 55.8, 46.4 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{25}H_{19}NO_6Na$ 452.1110; Found 452.1106.



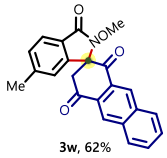
3u, 72%

2-Methoxy-6-(phenylselanyl)-1'H-spiro[isoindoline-1,2'-naphthalene]-1',3,4'(3'H)-trione (3u): yield 72% (50 mg) as grey sticky liquid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.13 – 8.01 (m, 2H), 7.88 – 7.78 (m, 2H), 7.71 (d, *J* = 8.0 Hz, 1H), 7.46 – 7.31 (m, 4H), 7.27 – 7.21 (m, 2H), 6.54 (s, 1H), 4.09 (s, 3H), 3.86 (d, *J* = 16.1 Hz, 1H), 3.06 (d, *J* = 16.2 Hz, 1H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 192.3, 189.6, 165.1, 141.4, 141.3, 135.7, 135.5, 135.4, 135.0, 134.1, 130.9, 130.0, 129.2, 128.6, 127.2, 127.1, 126.6, 125.2, 122.0, 73.3, 65.3, 46.1 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{24}H_{17}NO_4SeNa$ 486.0220; Found 486.0216.



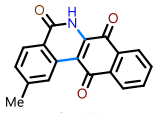
3v, 66%

6-(9H-Carbazol-9-yl)-2-methoxy-1'H-spiro[isoindoline-1,2'-naphthalene]-1',3,4'(3'H)-trione (3v): yield 66% (47 mg) as grey sticky liquid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.20 (dd, *J* = 6.9, 2.4 Hz, 1H), 8.17 – 8.11 (m, 2H), 8.06 (d, *J* = 7.6 Hz, 2H), 7.86 – 7.79 (m, 2H), 7.75 (d, *J* = 8.1 Hz, 1H), 7.37 – 7.24 (m, 4H; $CDCl_3$ peak is merged), 7.19 (d, *J* = 8.2 Hz, 2H), 7.11 (s, 1H), 4.16 (s, 3H), 4.00 (d, *J* = 16.1 Hz, 1H), 3.30 (d, *J* = 16.1 Hz, 1H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 192.5, 189.6, 164.7, 142.1 (2C), 139.8, 135.8 (2C), 135.2, 134.2, 128.6, 128.0, 127.3, 127.2, 126.8, 126.5, 124.0, 121.1, 120.6, 119.6, 109.4, 73.6, 65.5, 46.4 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{30}H_{20}N_2O_4Na$ 495.1321; Found 495.1311.



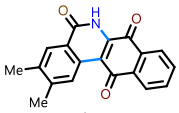
3w, 62%

2'-Methoxy-6'-methyl-1H-spiro[anthracene-2,1'-isoindoline]-1,3',4(3H)-trione (3w): yield 62% (35 mg) as yellowish sticky liquid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 8.81 (s, 1H), 8.75 (s, 1H), 8.20 – 8.14 (m, 1H), 8.14 – 8.08 (m, 1H), 7.83 – 7.74 (m, 3H), 7.30 – 7.26 (m, 1H), 6.63 (s, 1H), 4.12 (s, 3H), 4.00 (d, *J* = 16.1 Hz, 1H), 3.21 (d, *J* = 16.1 Hz, 1H), 2.21 (s, 3H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 193.2, 190.0, 165.8, 144.0, 141.2, 135.6, 135.5, 131.4 (2C), 131.0, 130.5, 130.4 (2C), 130.3, 129.8, 129.2, 126.4, 124.9, 122.1, 73.4, 65.4, 46.6, 22.2 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{23}H_{17}NO_4Na$ 394.1055; Found 394.1052.



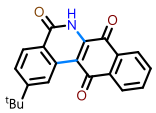
4a, 96%

2-Methylbenzo[b]phenanthridine-5,7,12(6H)-trione (4a): yield 96% (28 mg) as yellow solid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 9.53 (brs, 1H), 9.29 (s, 1H), 8.40 (d, *J* = 8.2 Hz, 1H), 8.26 (d, *J* = 7.7 Hz, 1H), 8.18 (d, *J* = 7.6 Hz, 1H), 7.76 (t, *J* = 7.6 Hz, 1H), 7.51 (d, *J* = 8.2 Hz, 1H), 2.59 (s, 3H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 183.0, 178.8, 161.0, 145.6, 136.9, 135.7, 133.8, 133.6, 133.5, 131.6, 129.9, 128.8, 128.2, 127.5, 126.6, 126.3, 113.8, 22.5 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{18}H_{11}NO_3Na$ 312.0637; Found 312.0632.



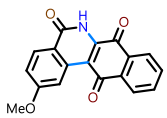
4b, 89%

2,3-Dimethylbenzo[b]phenanthridine-5,7,12(6H)-trione (4b): yield 89% (27 mg) as red solid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 9.49 (brs, 1H), 9.23 (s, 1H), 8.32 – 8.21 (m, 2H), 8.23 – 8.14 (m, 1H), 7.85 – 7.74 (m, 2H), 2.49 (s, 3H), 2.44 (s, 3H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 183.2, 178.8, 161.0, 144.8, 140.3, 136.3, 135.6, 133.8, 133.6, 131.3, 130.0, 129.3, 128.5, 127.5, 126.7, 126.5, 114.1, 20.9, 20.2 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{19}H_{13}NO_3Na$ 326.0793; Found 326.0788.



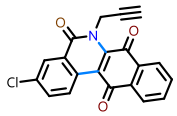
4c, 94%

2-(tert-Butyl)benzo[b]phenanthridine-5,7,12(6H)-trione (4c): yield 94% (31 mg) as yellow solid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 9.59 (s, 1H), 9.52 (brs, 1H), 8.49 – 8.39 (m, 1H), 8.35 – 8.25 (m, 1H), 8.23 – 8.14 (m, 1H), 7.93 – 7.84 (m, 1H), 7.83 – 7.69 (m, 2H), 1.48 (s, 9H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 183.1, 178.8, 160.9, 158.4, 136.9, 135.7, 133.8, 133.6, 133.5, 129.9, 128.1, 128.0, 127.5, 126.6, 126.2, 125.4, 114.1, 35.9, 31.3 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{21}H_{17}NO_3Na$ 354.1106; Found 354.1102.



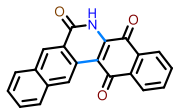
4d, 85%

2-Methoxybenzo[b]phenanthridine-5,7,12(6H)-trione (4d): yield 85% (26 mg) as yellow solid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 9.49 (brs, 1H), 9.03 (s, 1H), 8.53 – 8.37 (m, 1H), 8.33 – 8.24 (m, 1H), 8.22 – 8.13 (m, 1H), 7.99 – 7.85 (m, 1H), 7.82 – 7.70 (m, 1H), 7.25 – 7.23 (m, 1H), 4.04 (s, 3H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 183.1, 178.8, 164.6, 160.6, 137.5, 135.7 (2C), 133.8, 133.7, 130.0 (2C), 127.5, 126.6, 122.2, 119.4, 113.3, 110.2, 55.9 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{18}H_{11}NO_4Na$ 328.0586; Found 328.0583.



4e, 76%

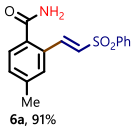
3-Chloro-6-(prop-2-yn-1-yl)benzo[b]phenanthridine-5,7,12(6H)-trione (4e): yield 76% (26 mg) as yellow solid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 9.36 (d, *J* = 9.0 Hz, 1H), 8.50 (s, 1H), 8.18 (d, *J* = 7.4 Hz, 1H), 8.11 (d, *J* = 7.3 Hz, 1H), 7.89 – 7.67 (m, 3H), 5.53 (s, 2H), 2.27 (s, 1H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 183.4, 181.2, 161.0, 140.8, 137.1, 134.8, 134.6, 134.0, 132.6, 132.1, 130.6, 130.3, 128.6, 128.2, 126.8, 126.7, 117.7, 79.5, 72.6, 36.1 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{20}H_{10}ClNO_3Na$ 370.0247; Found 370.0246.



4f, 79%

Dibenzo[b,j]phenanthridine-5,7,14(6H)-trione (4f): yield 79% (26 mg) as red solid; **^{1}H NMR** (400 MHz, Chloroform-*d*) δ 10.07 (s, 1H), 9.43 (brs, 1H), 9.11 (s, 1H), 8.37 – 8.25 (m, 1H), 8.24 – 8.13 (m, 2H), 8.12 – 8.04 (m, 1H), 7.93 – 7.83 (m, 1H), 7.84 – 7.75 (m, 1H), 7.74 – 7.63 (m, 2H) ppm; **^{13}C NMR** (101 MHz, $CDCl_3$) δ 183.3, 179.0, 161.7, 136.4, 136.3, 135.6, 133.8, 133.7, 132.8, 130.1, 130.0, 129.7, 129.6, 129.4, 129.2,

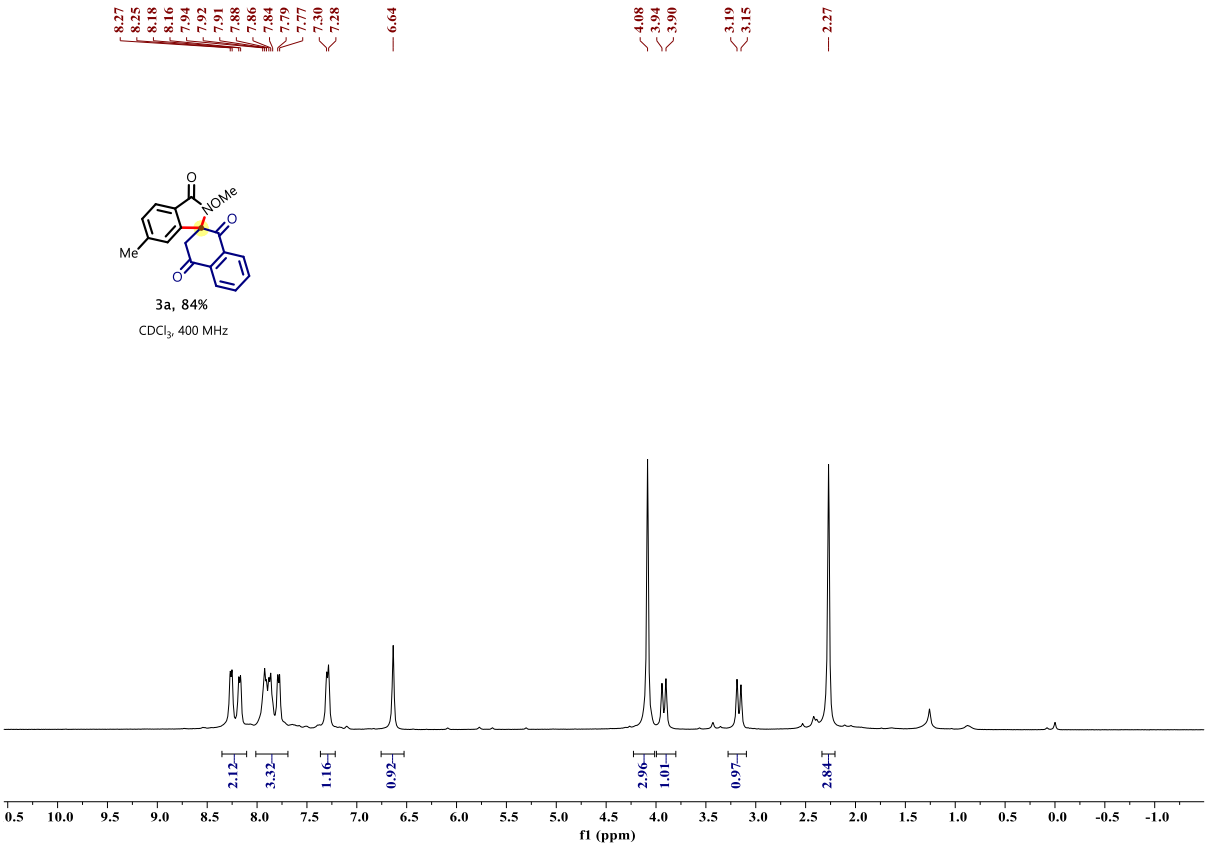
128.4, 128.3, 127.5, 126.6, 125.2, 114.4 ppm; HRMS (ESI) m/z: [M+Na]+ Calcd. for $C_{21}H_{11}NO_3Na$ 348.0637; Found 348.0626.

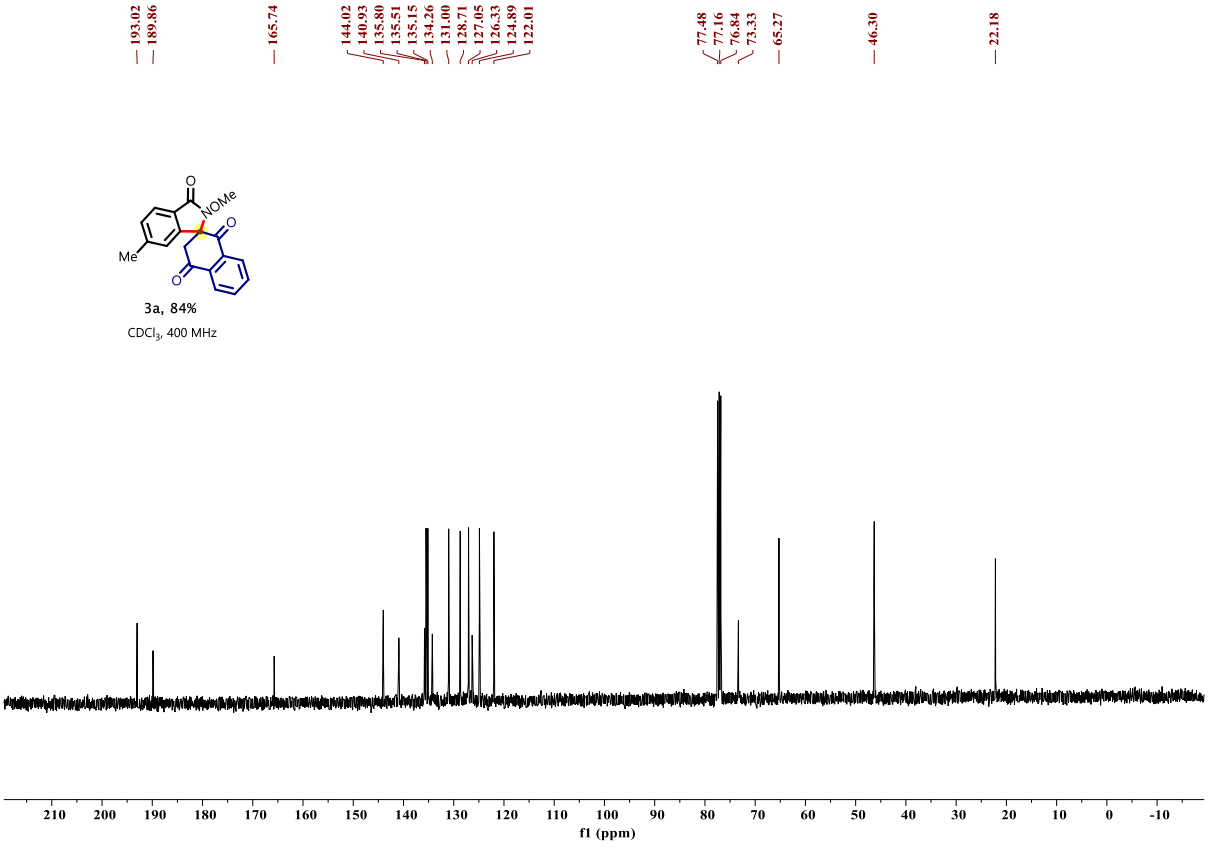


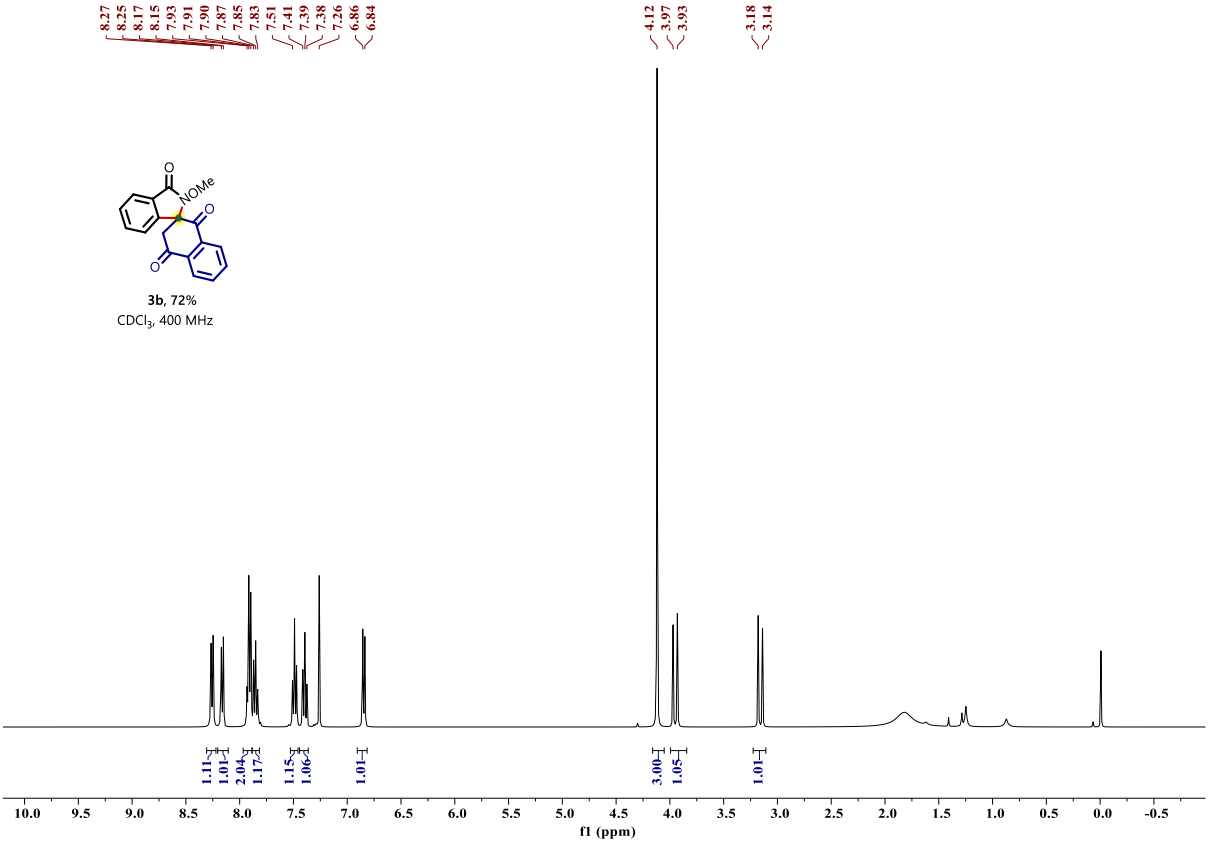
6a, 91%

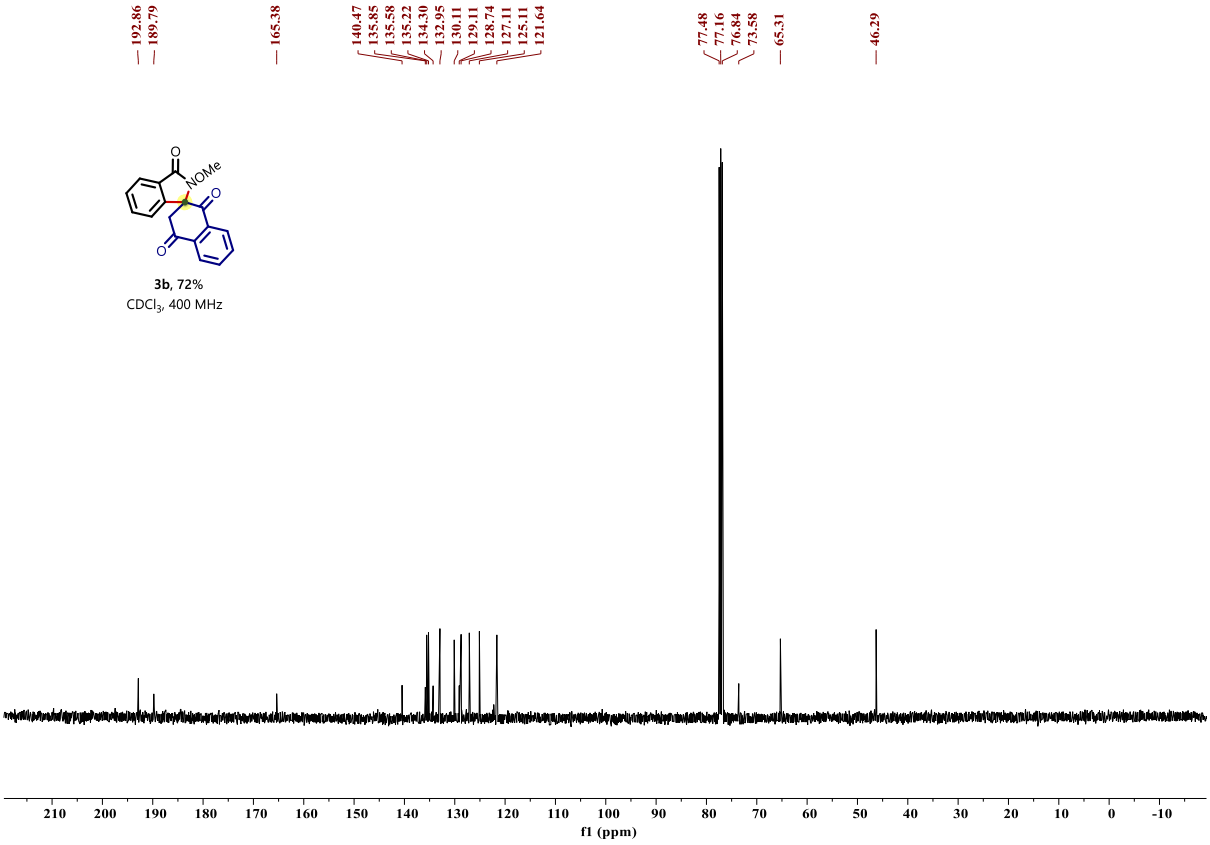
(E)-4-Methyl-2-(2-(phenylsulfonyl)vinyl)benzamide (6a): yield 91% (41 mg) as white solid; **^{1}H NMR** (400 MHz, DMSO-d_6) δ 8.07 (d, J = 15.4 Hz, 1H), 7.95 – 7.90 (m, 2H), 7.77 – 7.64 (m, 4H), 7.56 – 7.43 (m, 2H), 7.31 (d, J = 8.0 Hz, 1H), 2.32 (s, 3H) ppm; **^{13}C NMR** (101 MHz, DMSO) δ 169.7, 140.7, 140.2, 140.0, 135.0, 133.7, 131.2, 130.2, 129.7, 128.6, 128.0 (2C), 127.2, 20.7 ppm.

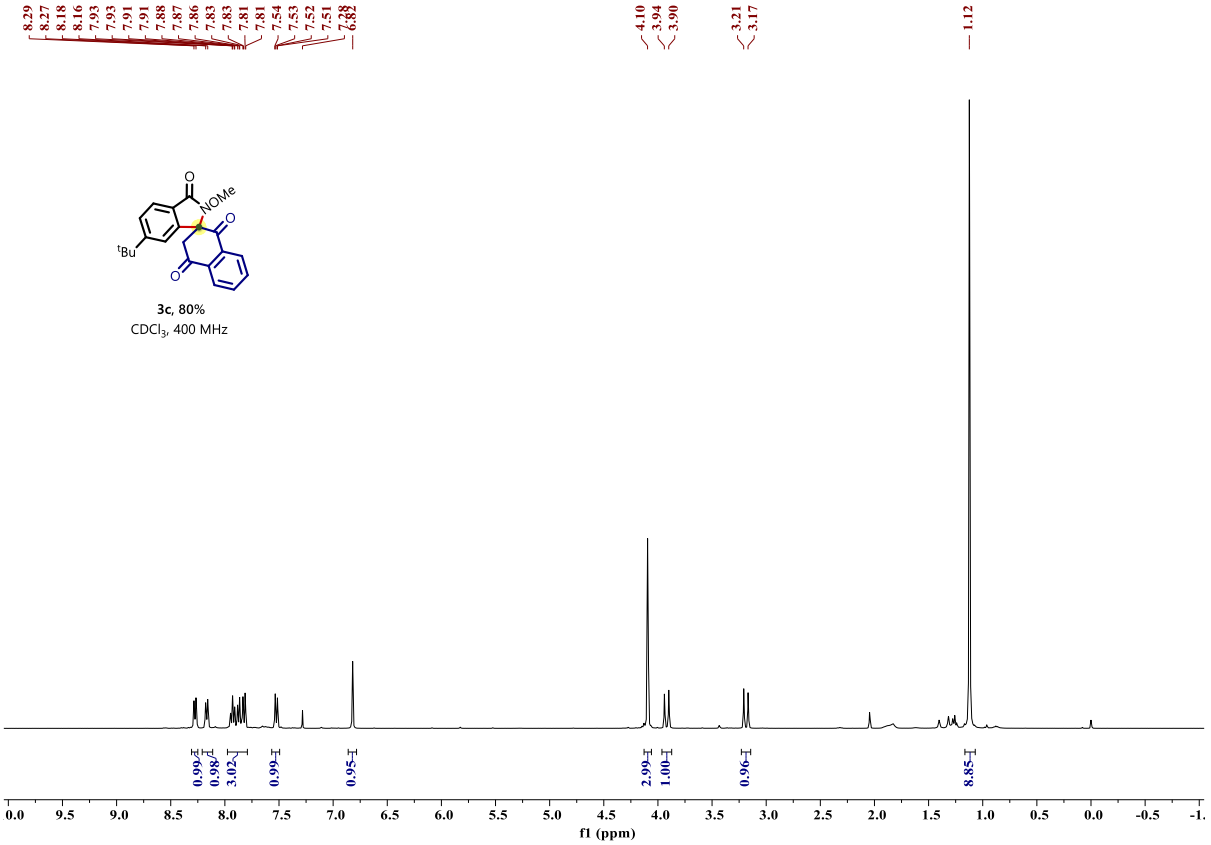
NMR Spectra of Synthesized Compounds


8.27
8.25
8.18
8.16
7.94
7.92
7.91
7.88
7.86
7.84
7.79
7.77
7.30
7.28
6.64
4.08
3.94
3.90
3.19
3.15
2.27
O
NOMe
Me
O
O
3a, 84%
CDCl3, 400 MHz
2.12
3.32
1.16
0.92
2.96
1.01
0.97
2.84
0.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)

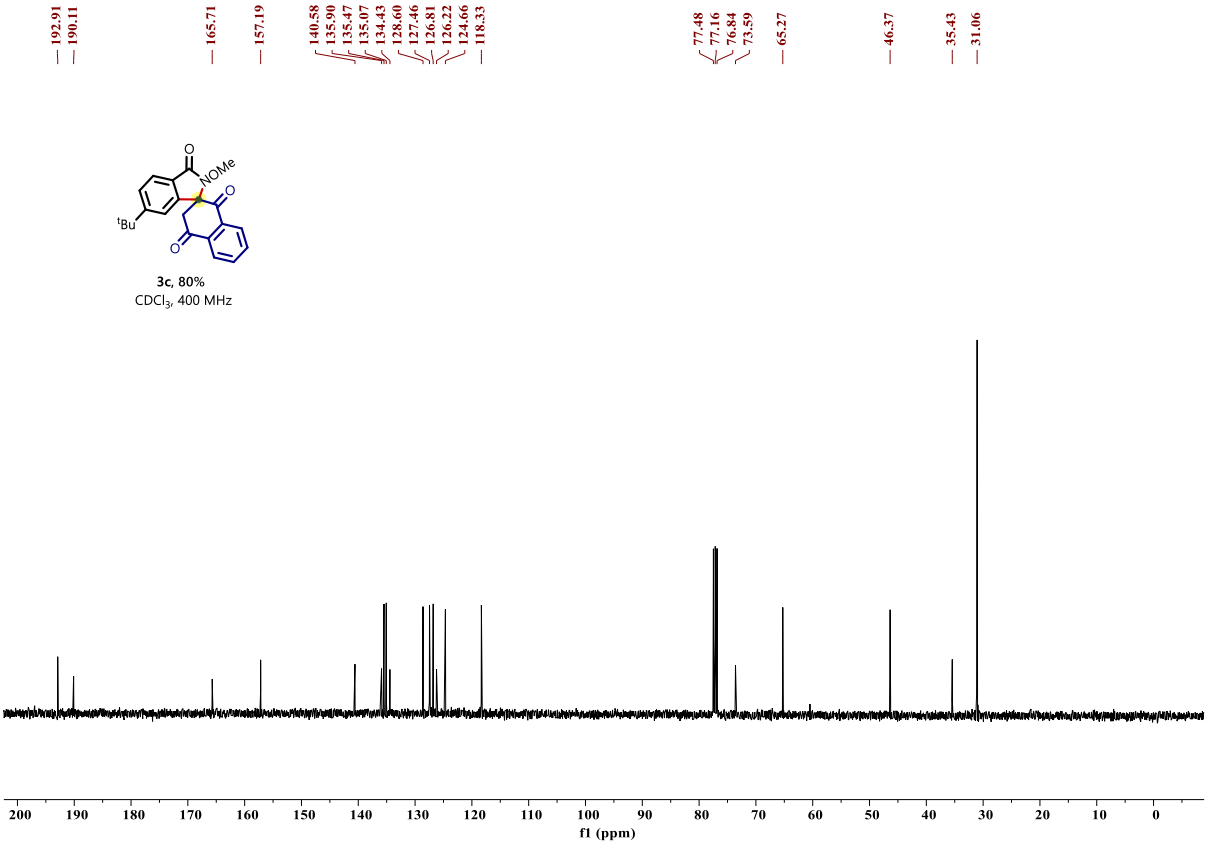

193.02
189.86
165.74
144.02
140.93
135.80
135.51
135.15
134.26
131.00
128.71
127.05
126.33
124.89
122.01
77.48
77.16
76.84
73.33
65.27
46.30
22.18
O
NOMe
Me
O
O
3a, 84%
CDCl3, 400 MHz
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)


8.27
8.25
8.17
8.15
7.93
7.91
7.90
7.87
7.85
7.83
7.51
7.41
7.39
7.38
7.26
6.86
6.84
4.12
3.97
3.93
3.18
3.14
NOMe
O
O
O
3b, 72%
CDCl3, 400 MHz
1.11
1.01
2.04
1.17
1.15
1.06
1.01
3.00
1.05
1.01
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

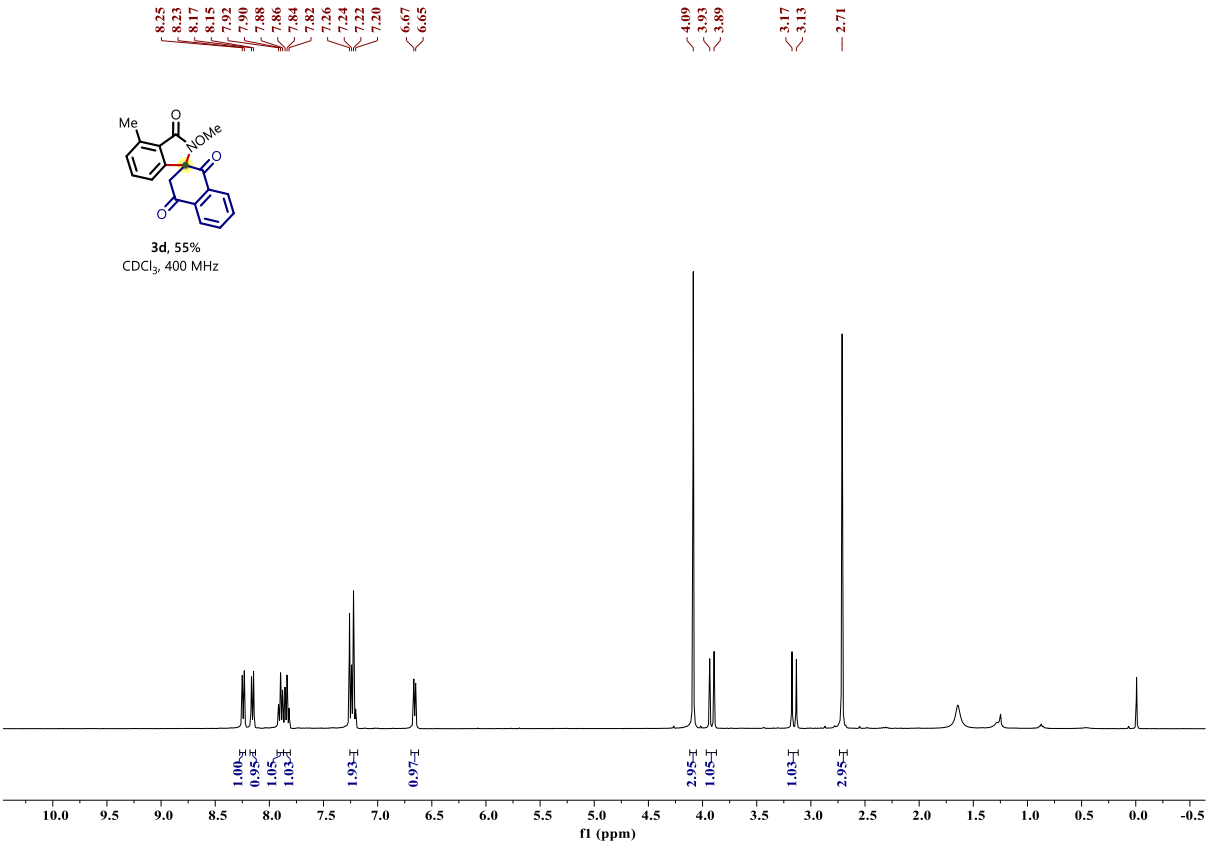

192.86
189.79
165.38
140.47
135.85
135.58
135.22
134.30
132.95
130.11
129.11
128.74
127.11
125.11
121.64
77.48
77.16
76.84
73.58
65.31
46.29
NOMe
O
O
O
3b, 72%
CDCl3, 400 MHz
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

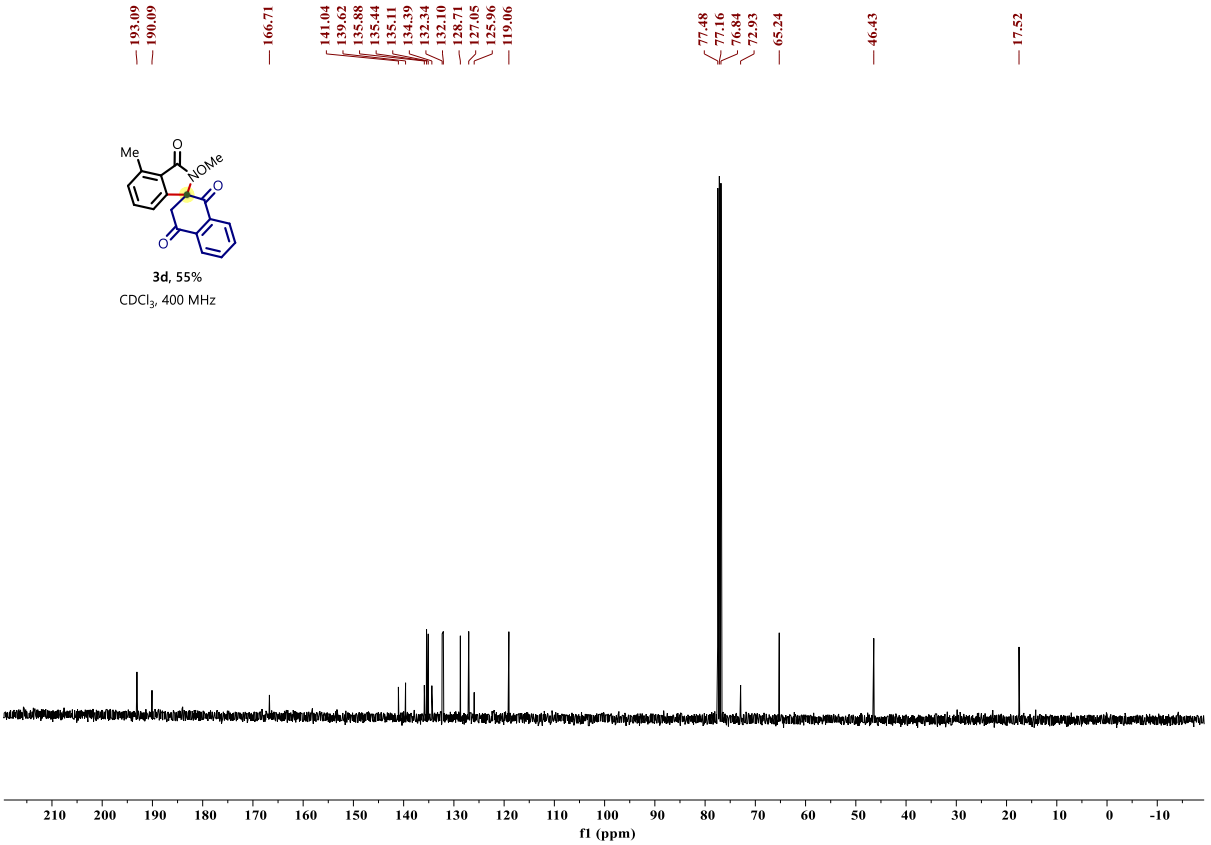


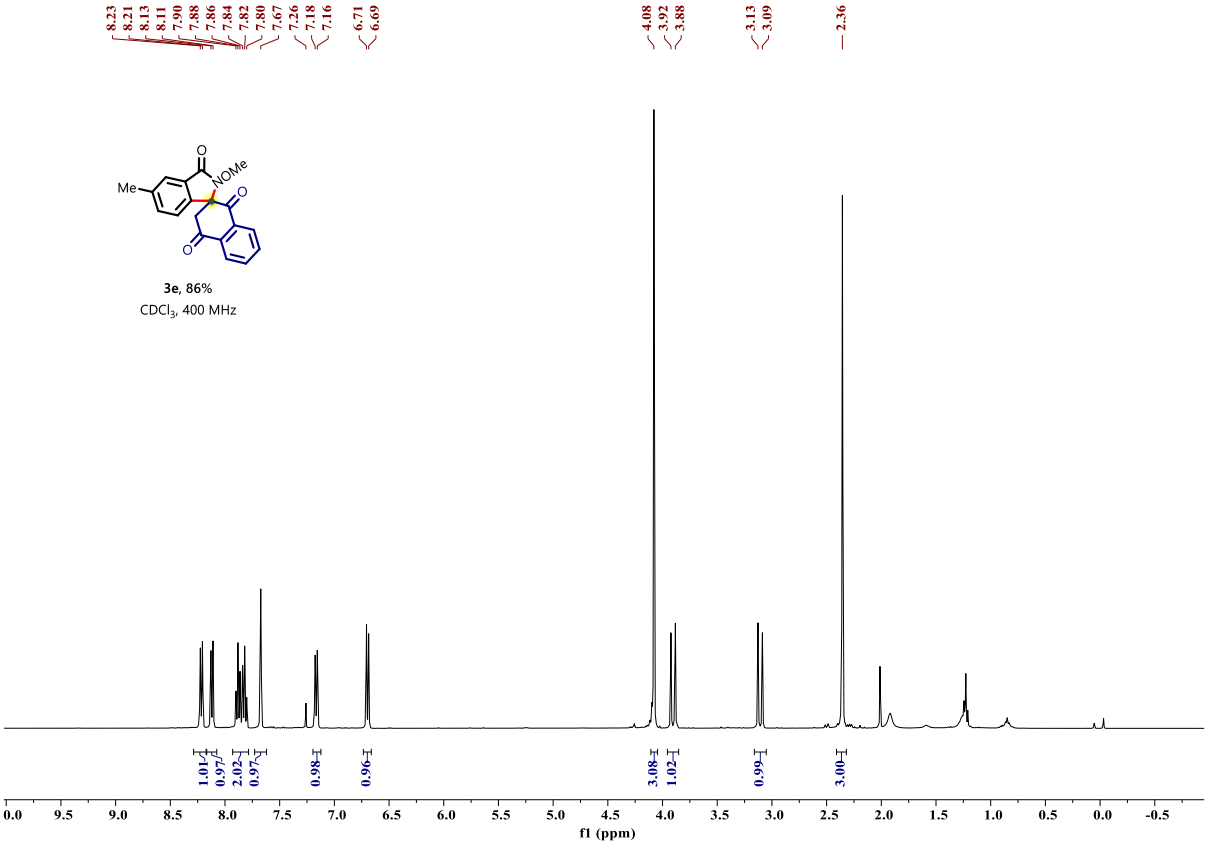
3c, 80%
$CDCl_3$, 400 MHz



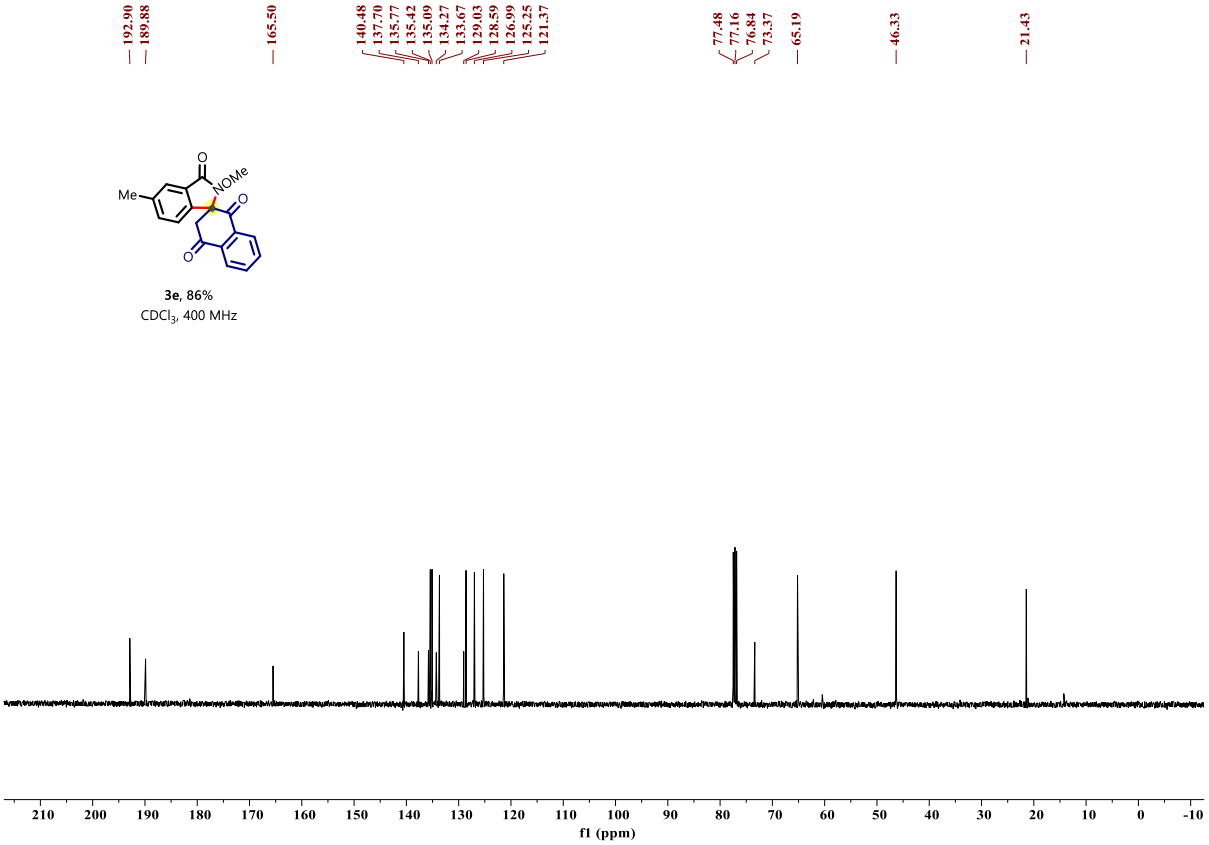
3c, 80%
$CDCl_3$, 400 MHz


8.25
8.23
8.17
8.15
7.92
7.90
7.88
7.86
7.84
7.82
7.26
7.24
7.22
7.20
6.67
6.65
4.09
3.93
3.89
3.17
3.13
2.71
Me
NOMe
O
O
O
3d, 55%
CDCl3, 400 MHz
1.00
0.95
1.05
1.03
1.93
0.97
2.95
1.05
1.03
2.95
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

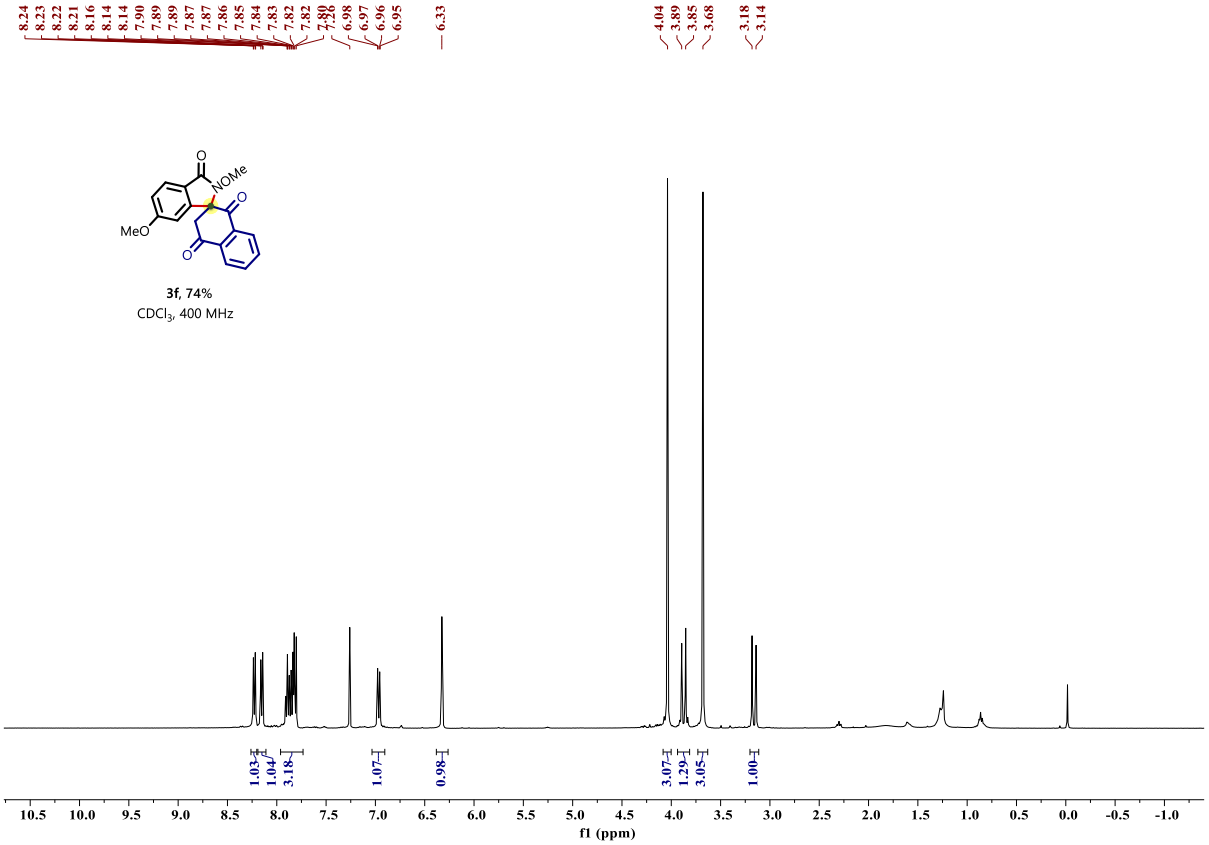

193.09
190.09
166.71
141.04
139.62
135.88
135.44
135.11
134.39
132.34
132.10
128.71
127.05
125.96
119.06
77.48
77.16
76.84
72.93
65.24
46.43
17.52
Me
NOMe
O
O
O
3d, 55%
CDCl3, 400 MHz
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

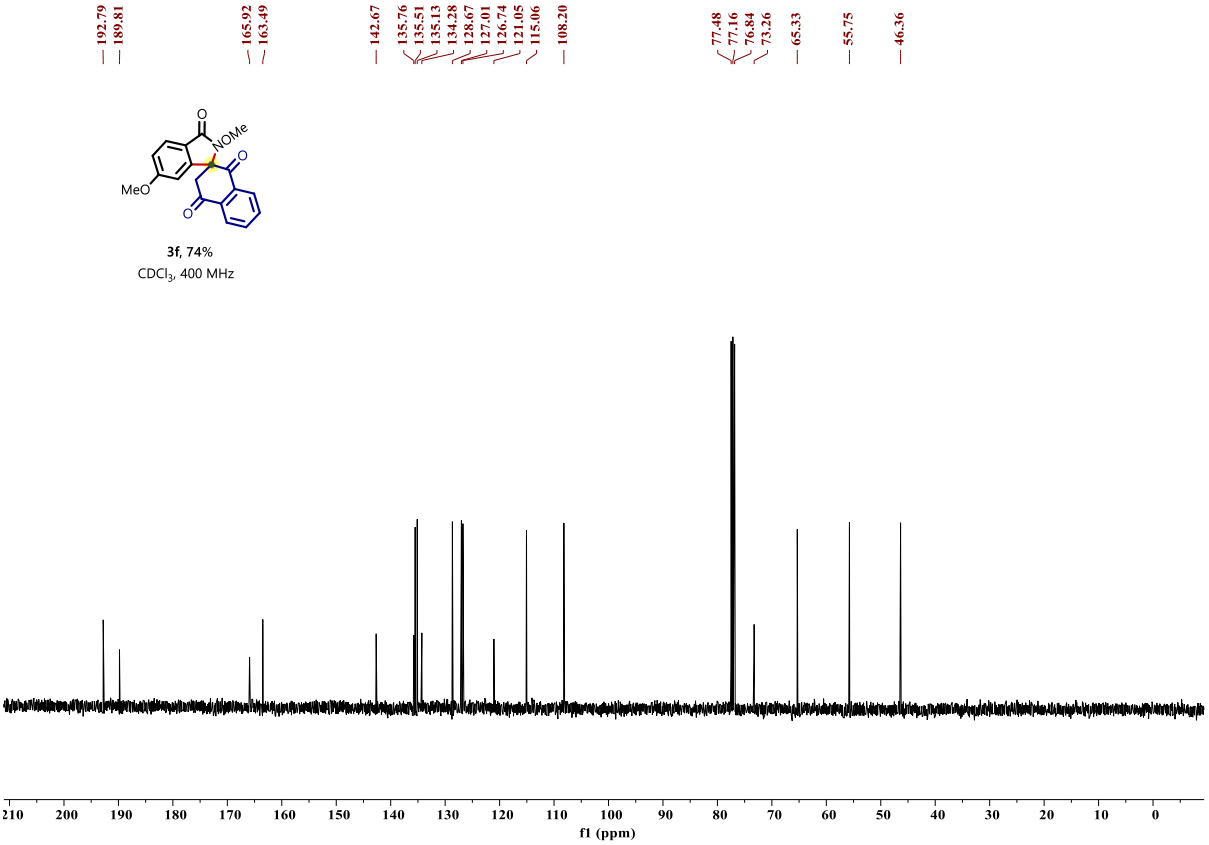


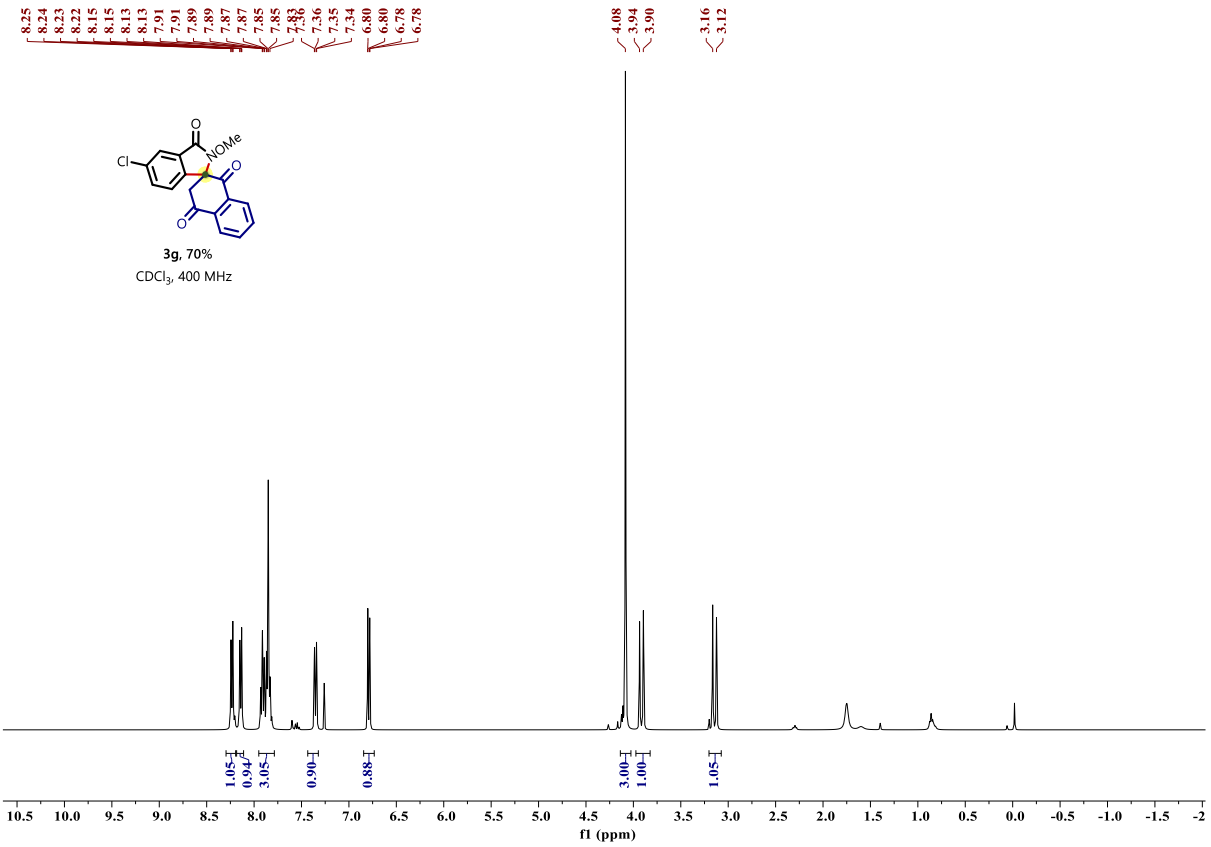
3e, 86%
$CDCl_3$, 400 MHz

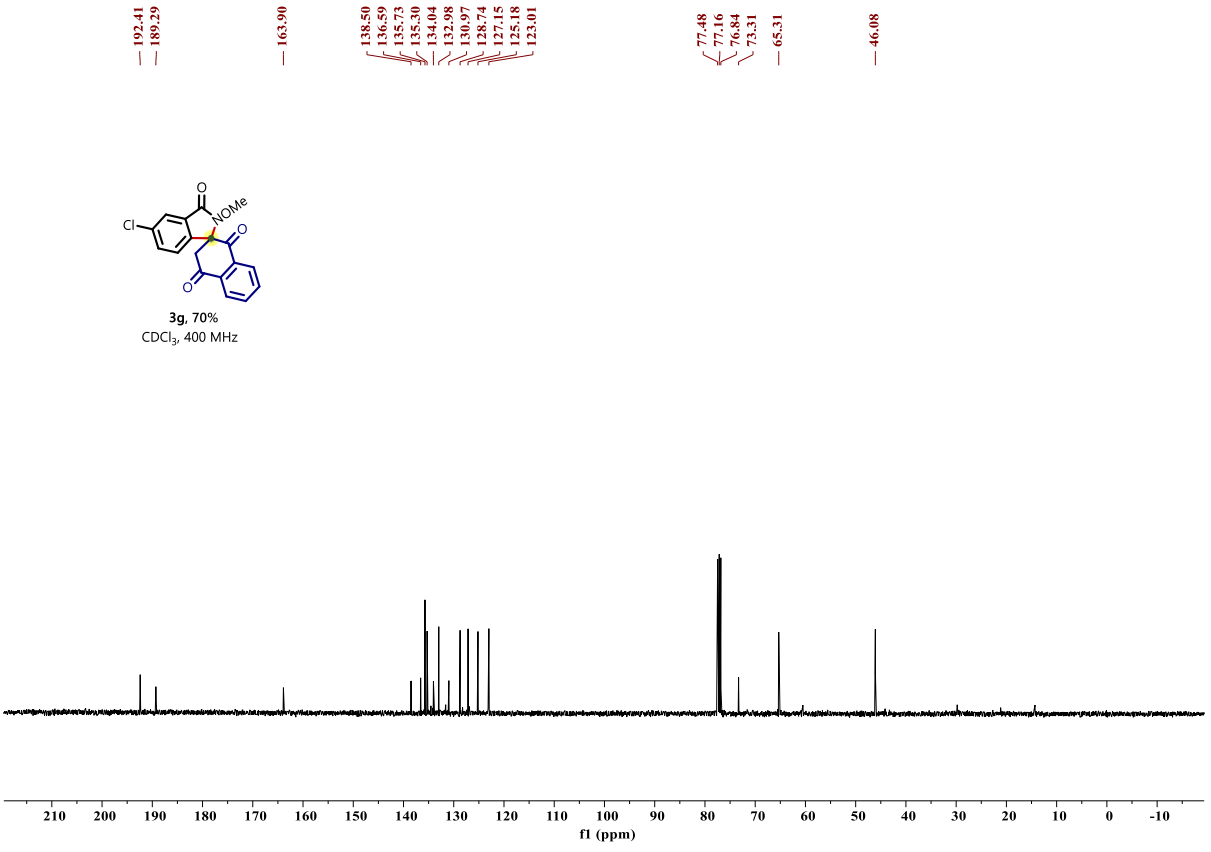


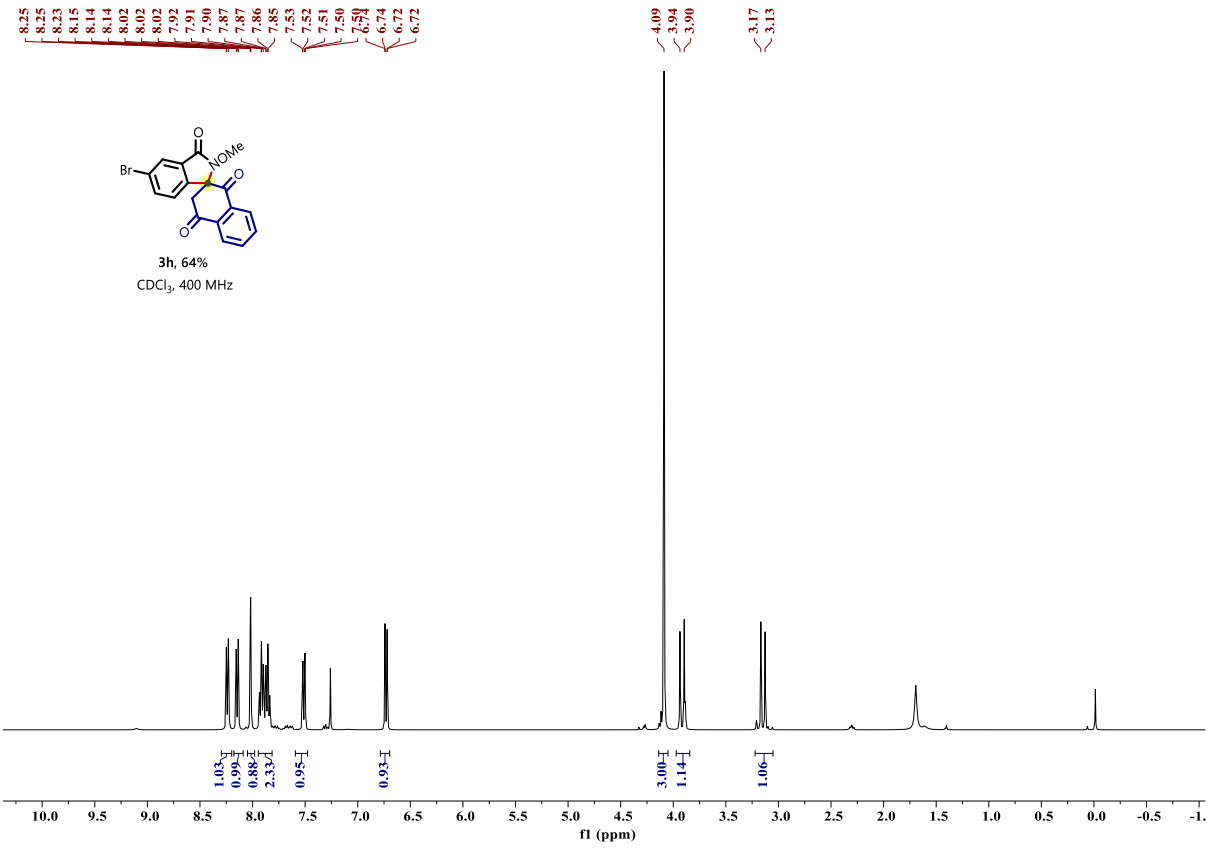
3e, 86%
$CDCl_3$, 400 MHz

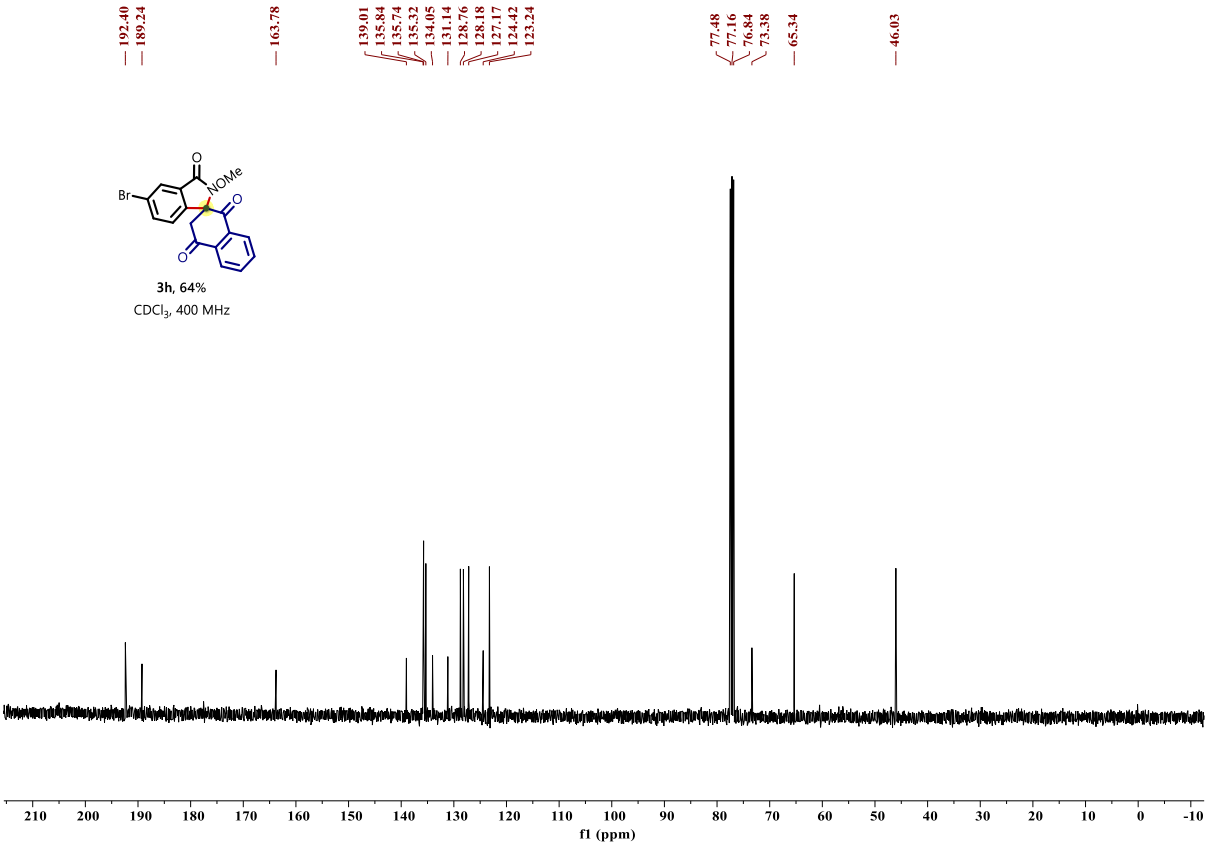

8.24
8.23
8.22
8.21
8.16
8.14
8.14
7.90
7.89
7.89
7.87
7.87
7.86
7.85
7.84
7.83
7.82
7.82
7.80
7.26
6.98
6.97
6.96
6.95
6.33
4.04
3.89
3.85
3.68
3.18
3.14
MeO
NOMe
O
O
O
3f, 74%
CDCl3, 400 MHz
1.03
1.04
3.18
1.07
0.98
3.07
1.29
3.05
1.00
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)

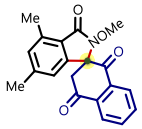

192.79
189.81
165.92
163.49
142.67
135.76
135.51
135.13
134.28
128.67
127.01
126.74
121.05
115.06
108.20
77.48
77.16
76.84
73.26
65.33
55.75
46.36
MeO
NOMe
O
O
O
3f, 74%
CDCl3, 400 MHz
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


8.25
8.24
8.23
8.22
8.15
8.15
8.13
8.13
7.91
7.91
7.89
7.89
7.87
7.87
7.85
7.85
7.83
7.36
7.35
7.34
6.80
6.80
6.78
6.78
4.08
3.94
3.90
3.16
3.12
Cl
NOMe
O
O
O
3g, 70%
CDCl3, 400 MHz
1.05
0.94
3.05
0.90
0.88
3.00
1.00
1.05
f1 (ppm)


192.41
189.29
163.90
138.50
136.59
135.73
135.30
134.04
132.98
130.97
128.74
127.15
125.18
123.01
77.48
77.16
76.84
73.31
65.31
46.08
Cl
NOMe
O
O
O
3g, 70%
CDCl3, 400 MHz
f1 (ppm)

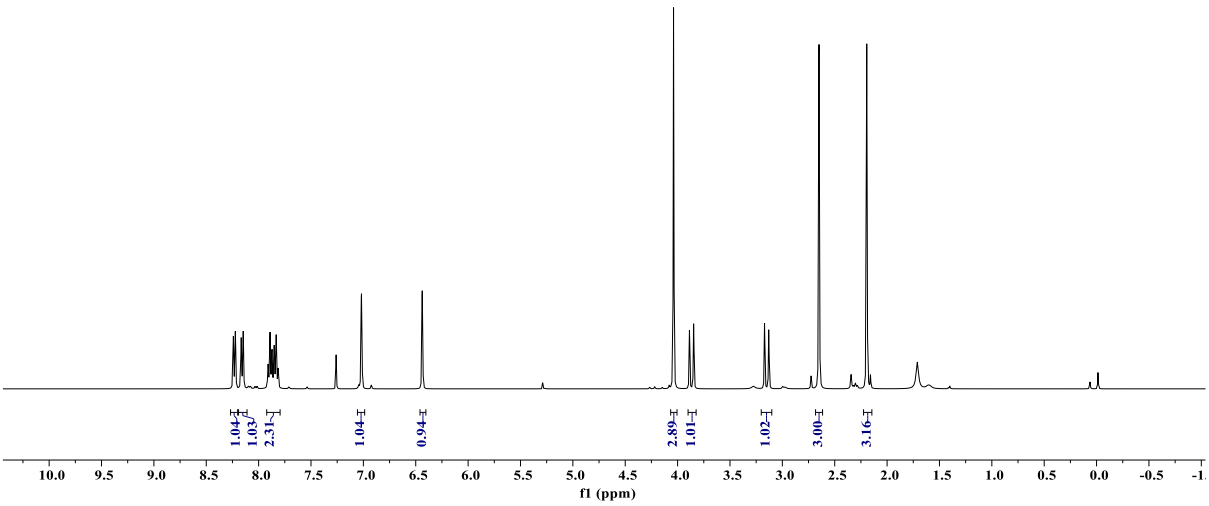

8.25
8.25
8.23
8.15
8.14
8.14
8.02
8.02
8.02
7.92
7.91
7.90
7.87
7.87
7.86
7.85
7.53
7.52
7.51
7.50
7.50
6.74
6.72
6.72
4.09
3.94
3.90
3.17
3.13
Br
NOMe
O
O
O
3h, 64%
CDCl3, 400 MHz
1.03
0.99
0.88
2.33
0.95
0.93
3.00
1.14
1.06
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.
f1 (ppm)

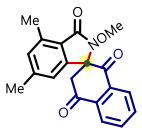

192.40
189.24
163.78
139.01
135.84
135.74
135.32
134.05
131.14
128.76
128.18
127.17
124.42
123.24
77.48
77.16
76.84
73.38
65.34
46.03
Br
NOMe
O
O
O
3h, 64%
CDCl3, 400 MHz
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)



3i, 50%

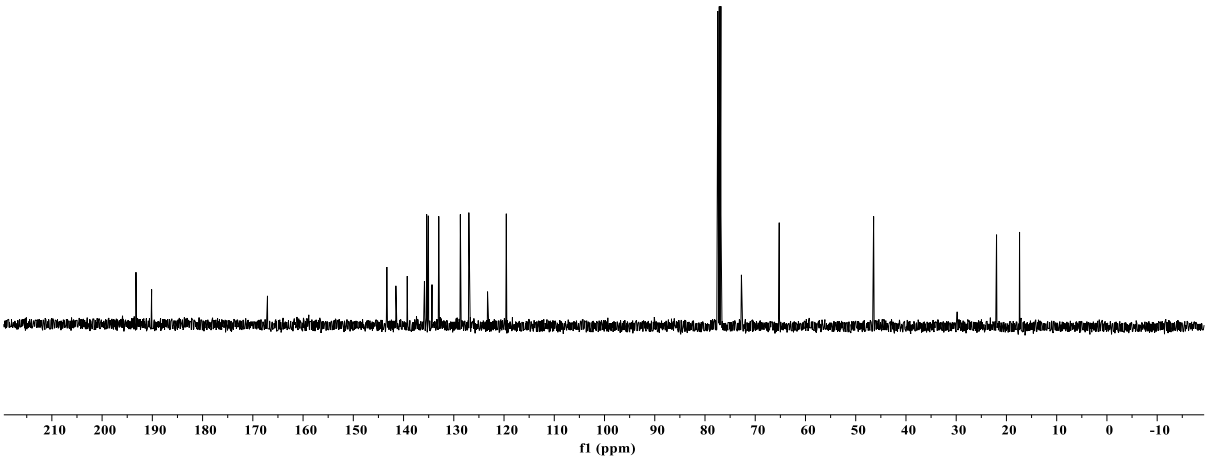
$CDCl_3$, 400 MHz

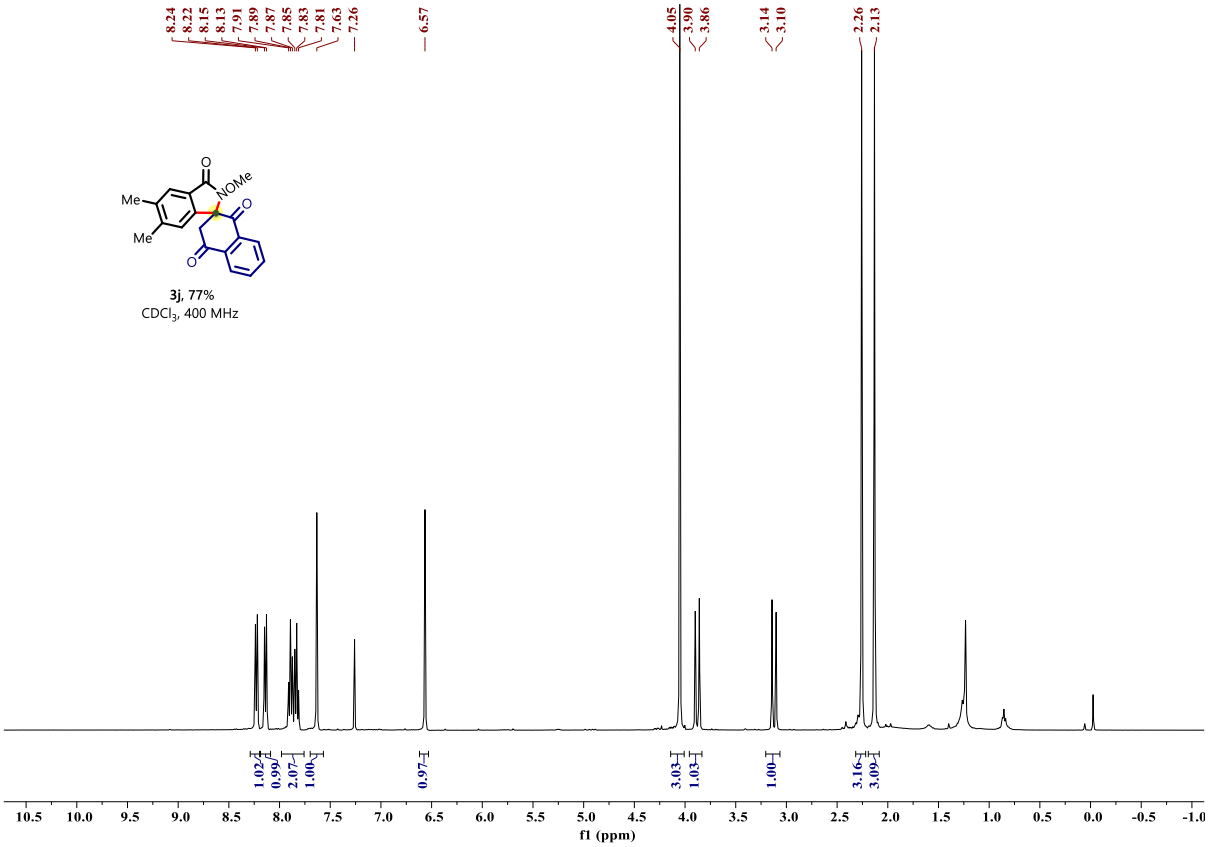




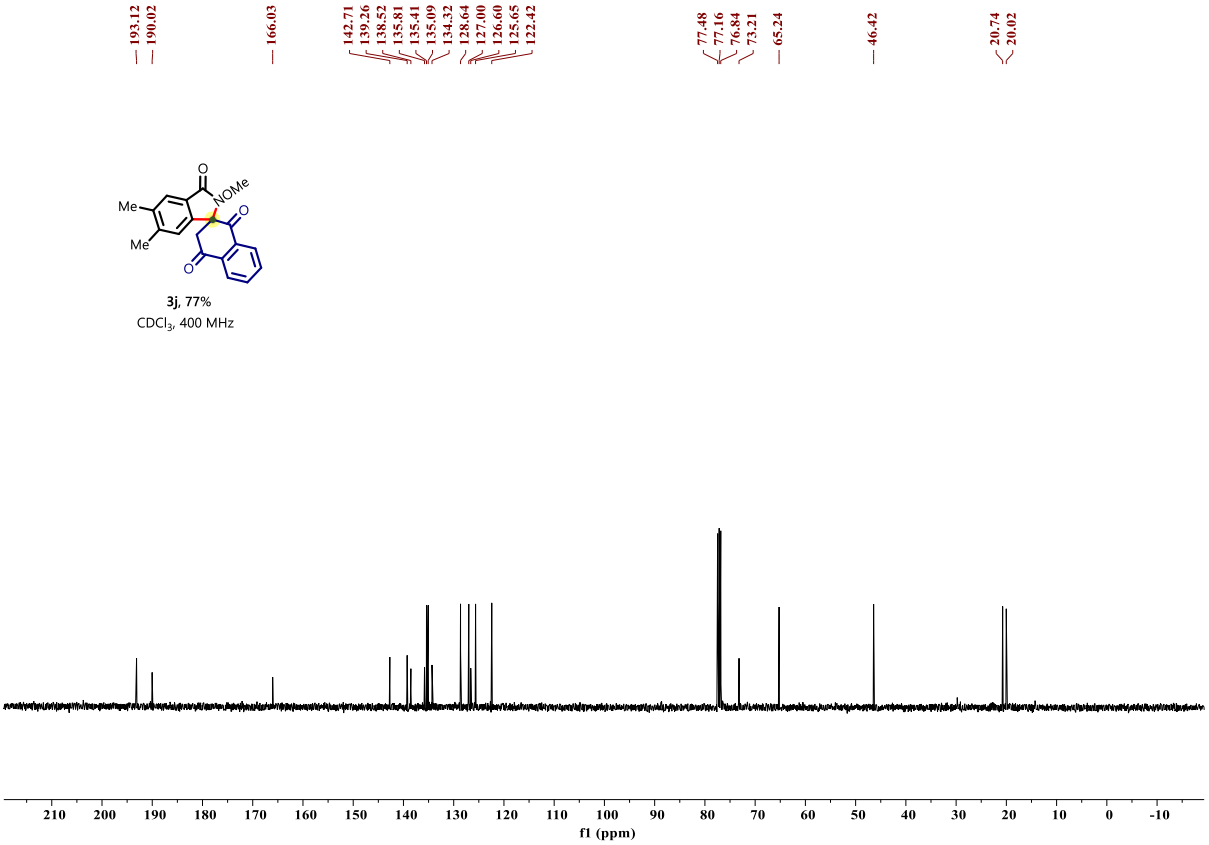
3i, 50%

$CDCl_3$, 400 MHz

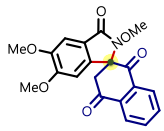




3j, 77%
$CDCl_3$, 400 MHz

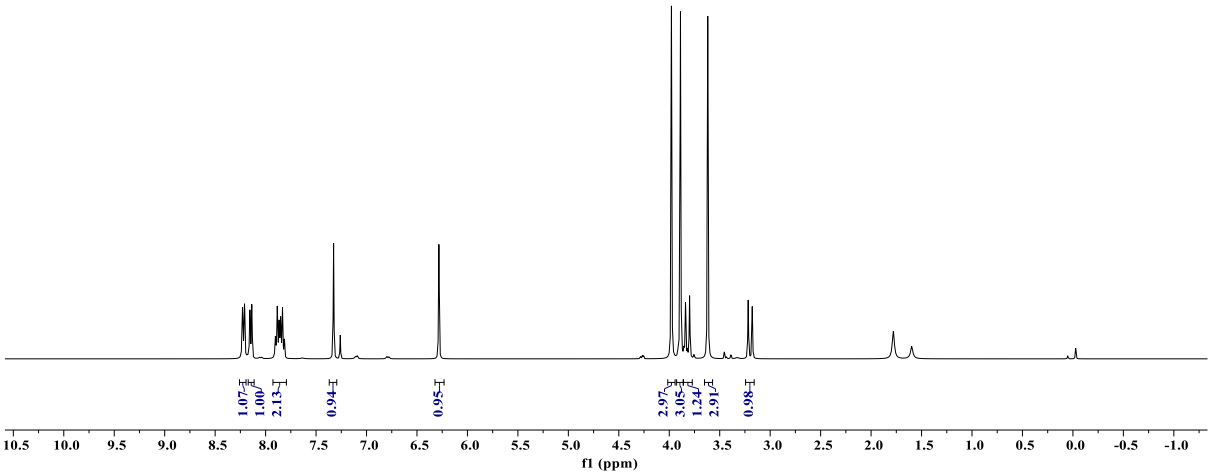


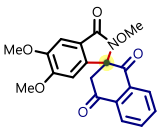
3j, 77%
$CDCl_3$, 400 MHz



3k, 82%

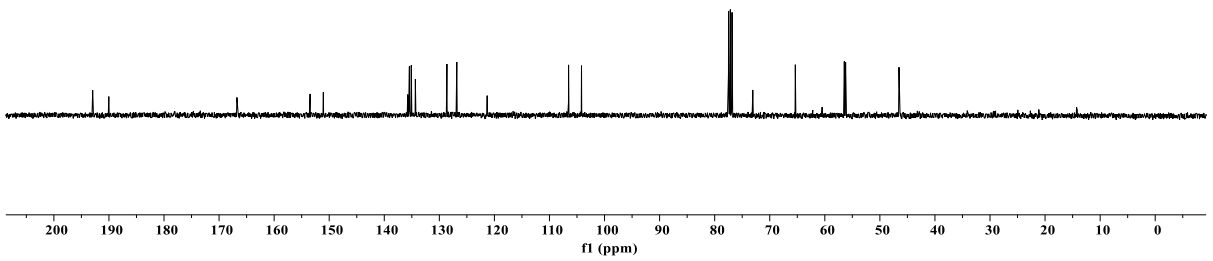
$CDCl_3$, 400 MHz

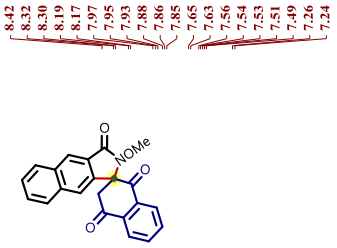




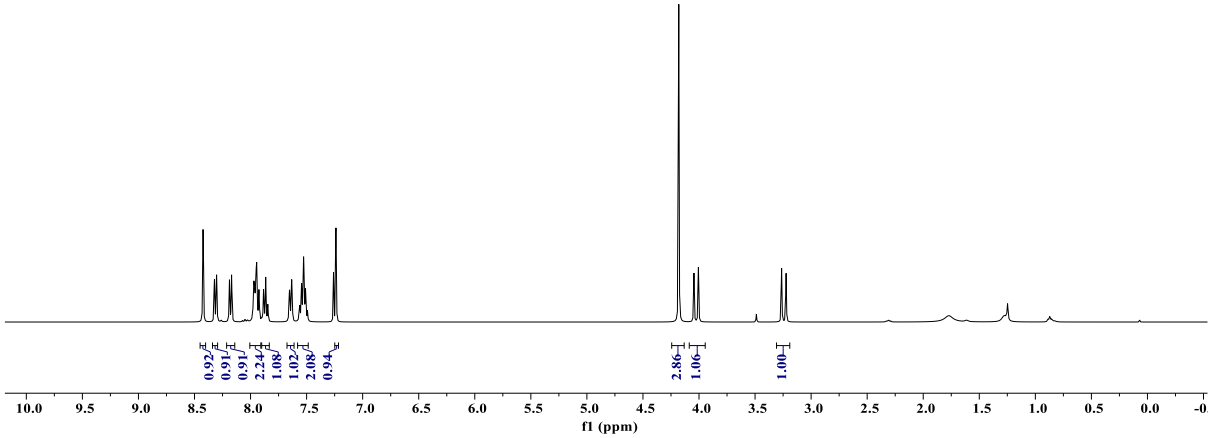
3k, 82%

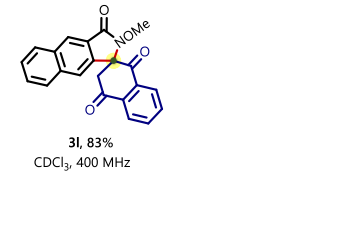
$CDCl_3$, 400 MHz



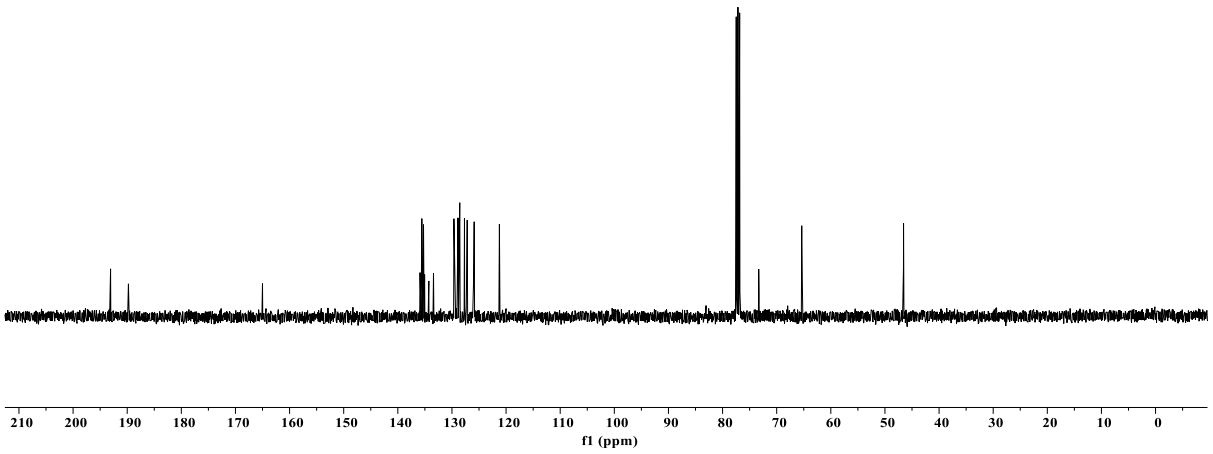


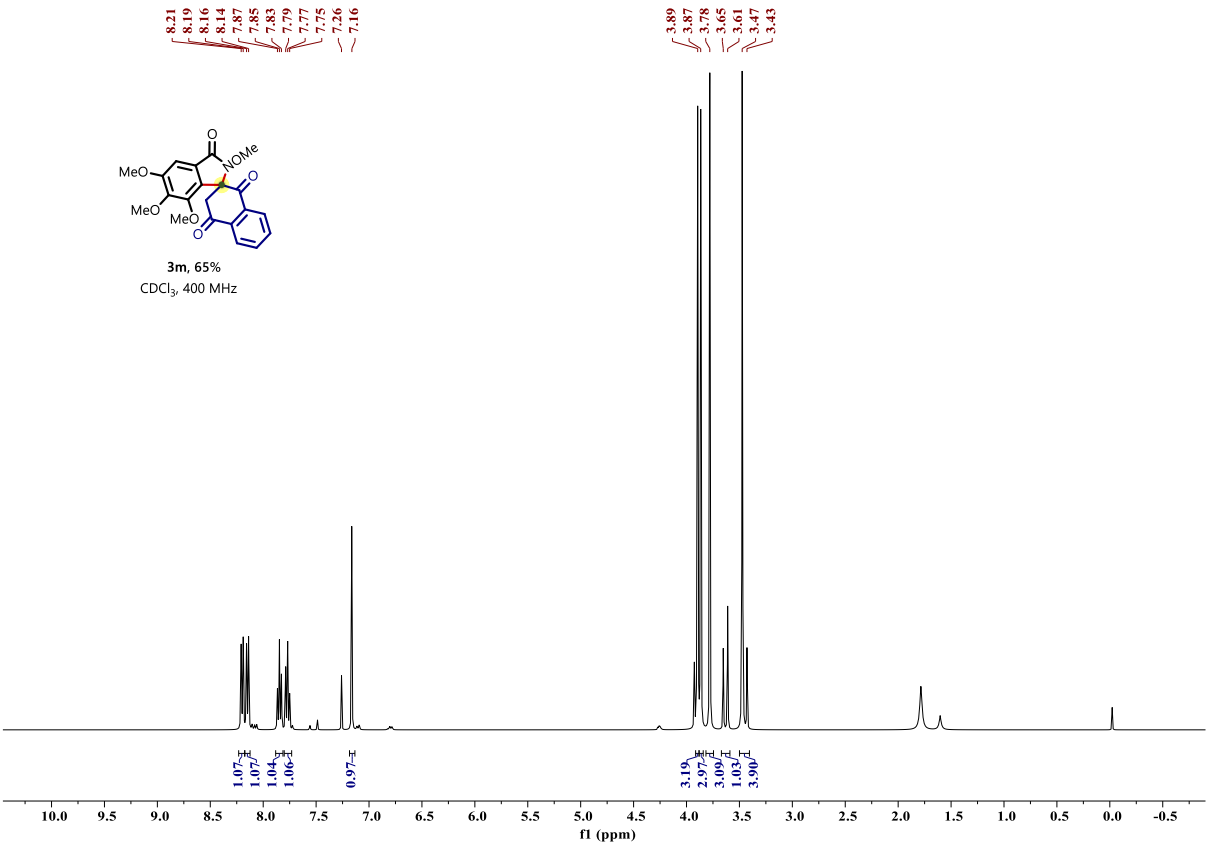
3l, 83%
$CDCl_3$, 400 MHz

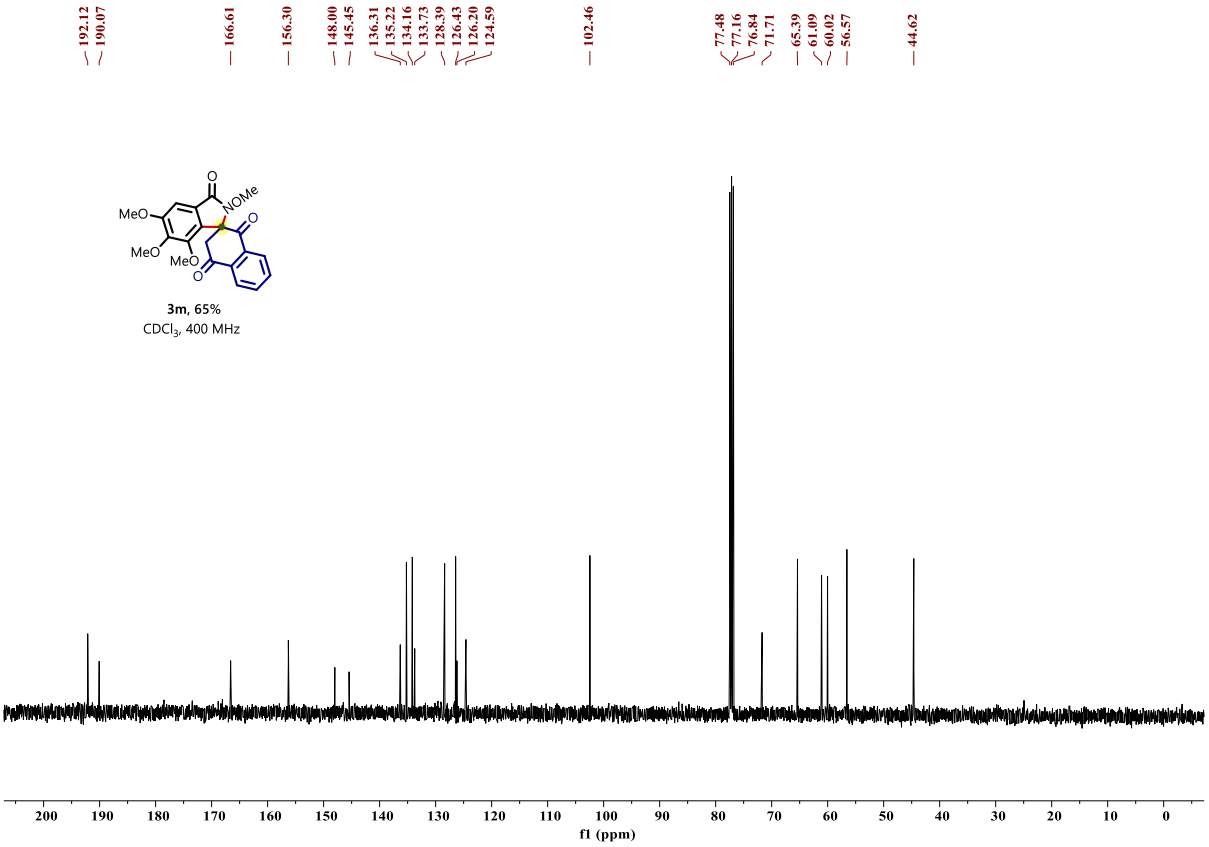


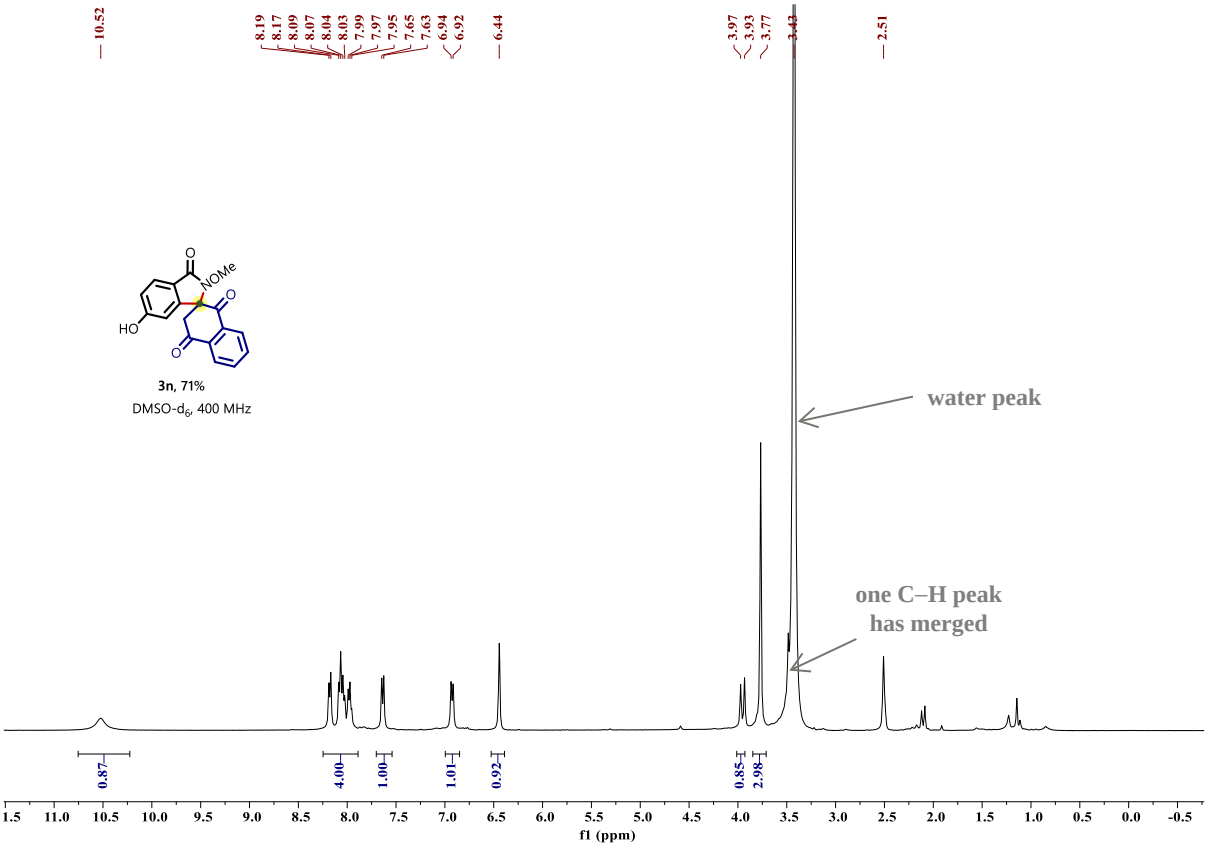


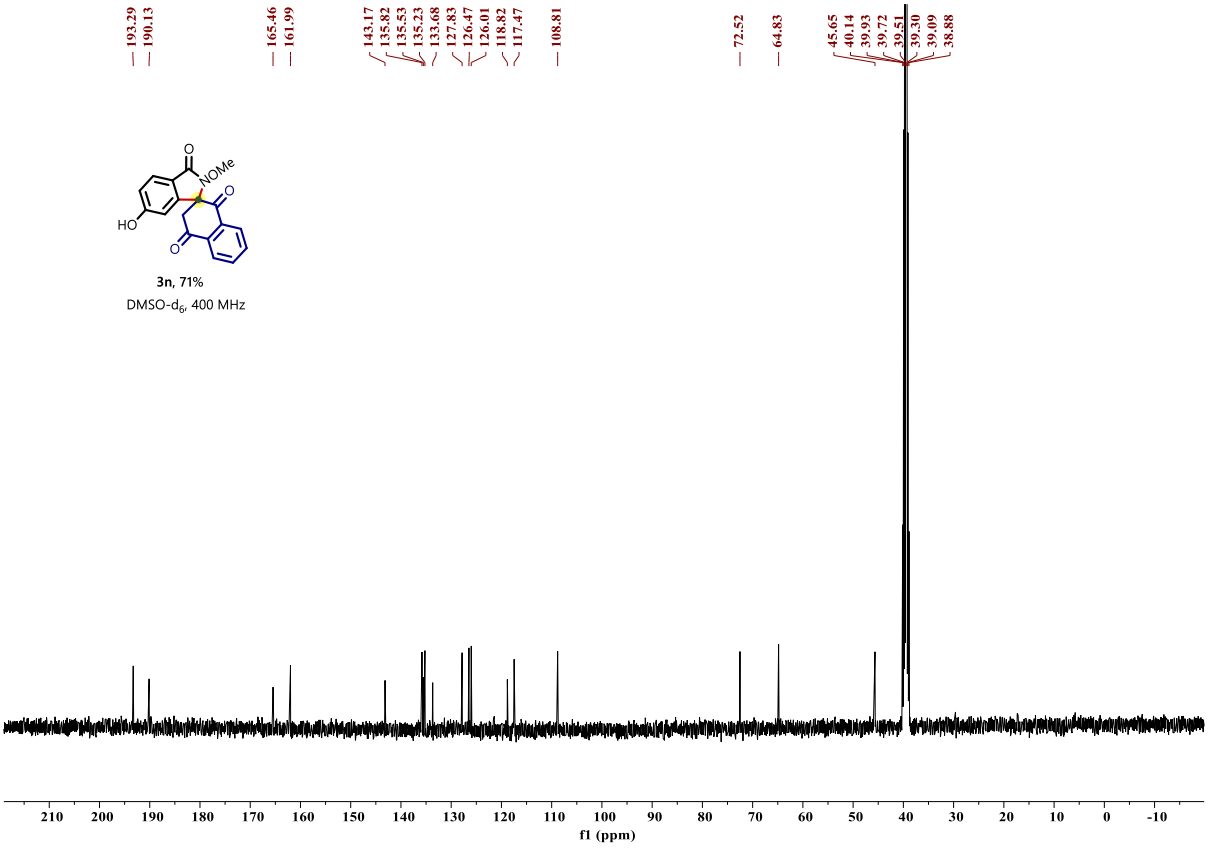
3l, 83%
$CDCl_3$, 400 MHz

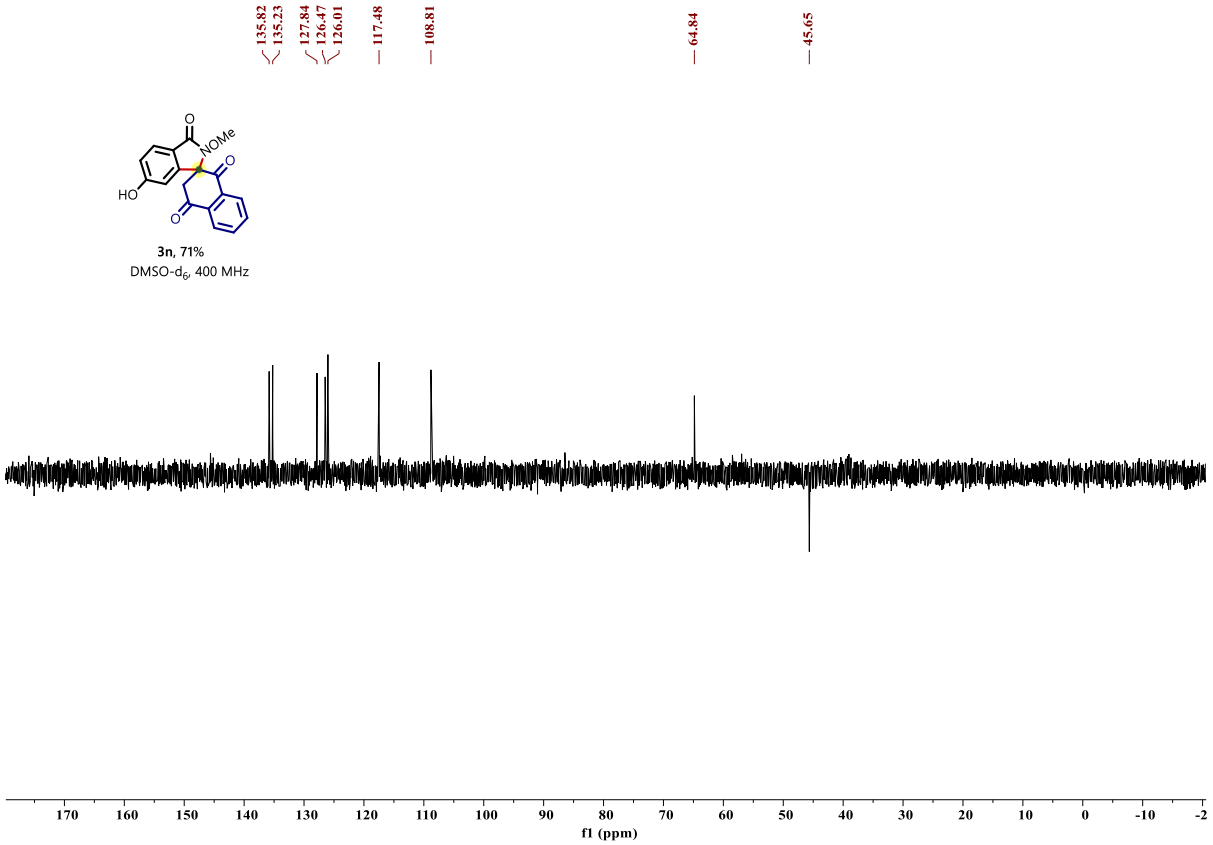


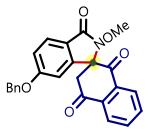

8.21
8.19
8.16
8.14
7.87
7.85
7.83
7.79
7.77
7.75
7.26
7.16
3.89
3.87
3.78
3.65
3.61
3.47
3.43
MeO
MeO
MeO
NOMe
O
O
O
3m, 65%
CDCl3, 400 MHz
1.07
1.07
1.04
1.06
0.97
3.19
2.97
3.09
1.03
3.90
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)


192.12
190.07
166.61
156.30
148.00
145.45
136.31
135.22
134.16
133.73
128.39
126.43
126.20
124.59
102.46
77.48
77.16
76.84
71.71
65.39
61.09
60.02
56.57
44.62
MeO
MeO
MeO
NOMe
O
O
O
3m, 65%
CDCl3, 400 MHz
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

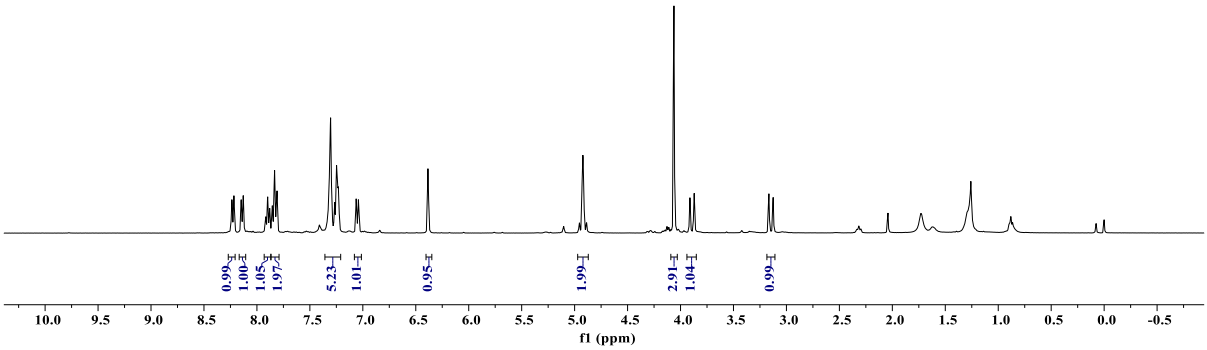

10.52
8.19
8.17
8.09
8.07
8.04
8.03
7.99
7.97
7.95
7.65
7.63
6.94
6.92
6.44
3.97
3.93
3.77
3.43
2.51
NOMe
HO
O
O
O
3n, 71%
DMSO-d6, 400 MHz
water peak
one C–H peak
has merged
0.87
4.00
1.00
1.01
0.92
0.85
2.98
f1 (ppm)

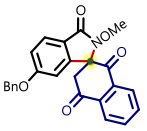

193.29
190.13
165.46
161.99
143.17
135.82
135.53
135.23
133.68
127.83
126.47
126.01
118.82
117.47
108.81
72.52
64.83
45.65
40.14
39.93
39.72
39.51
39.30
39.09
38.88
NOMe
HO
O
O
O
3n, 71%
DMSO-d6, 400 MHz
f1 (ppm)


135.82
135.23
127.84
126.47
126.01
117.48
108.81
64.84
45.65
O
NOMe
O
HO
O
3n, 71%
DMSO-d6, 400 MHz
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-2
f1 (ppm)

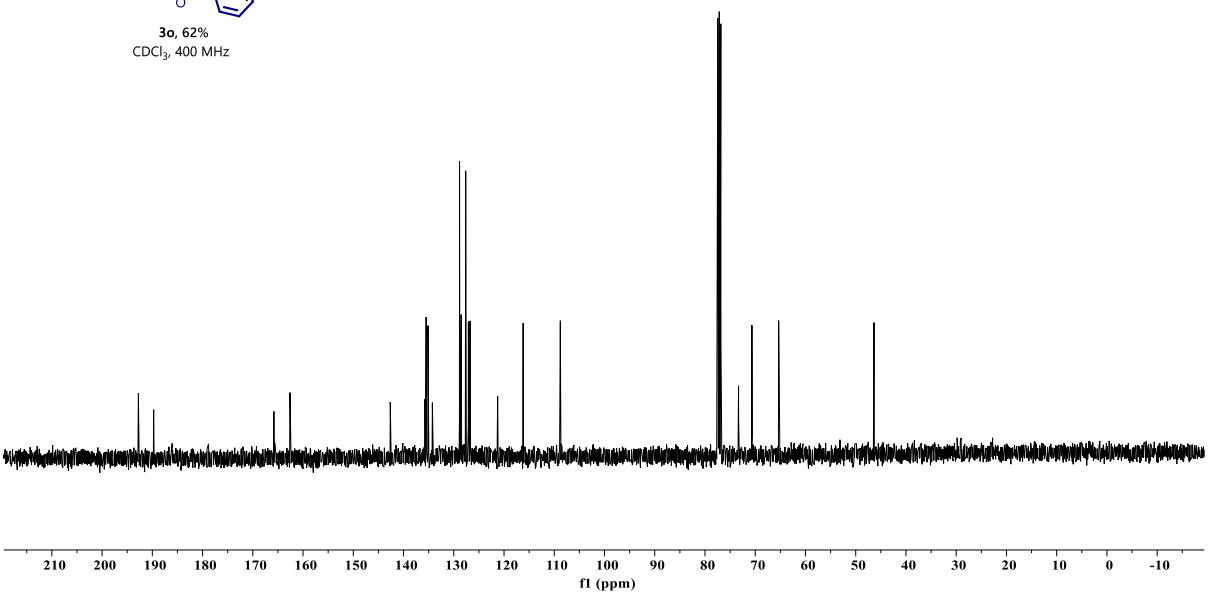


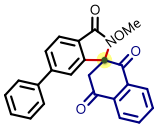
3o, 62%
$CDCl_3$, 400 MHz



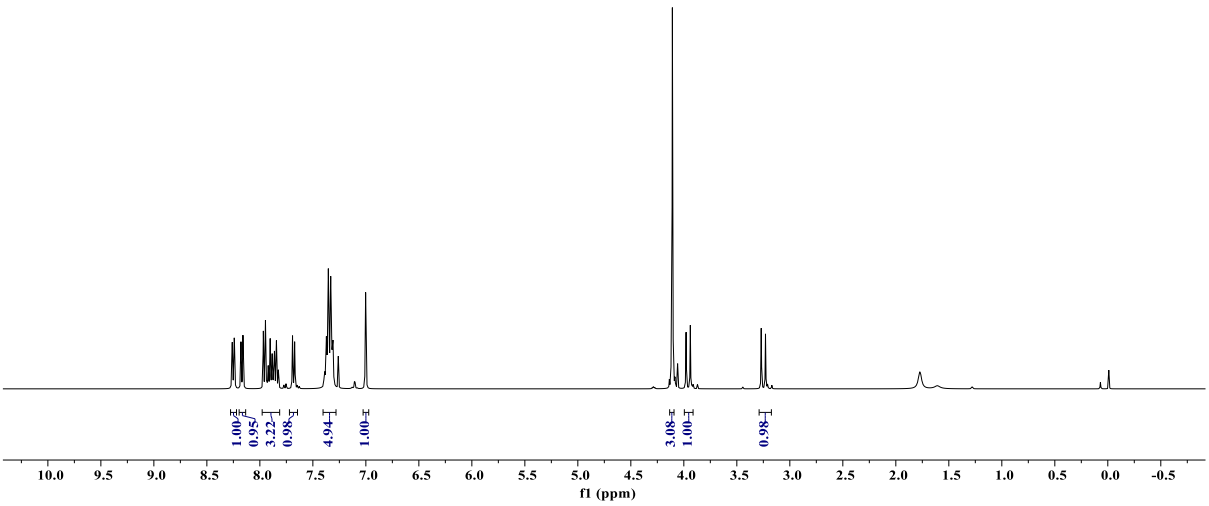


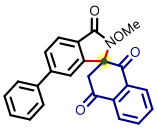
3o, 62%
$CDCl_3$, 400 MHz



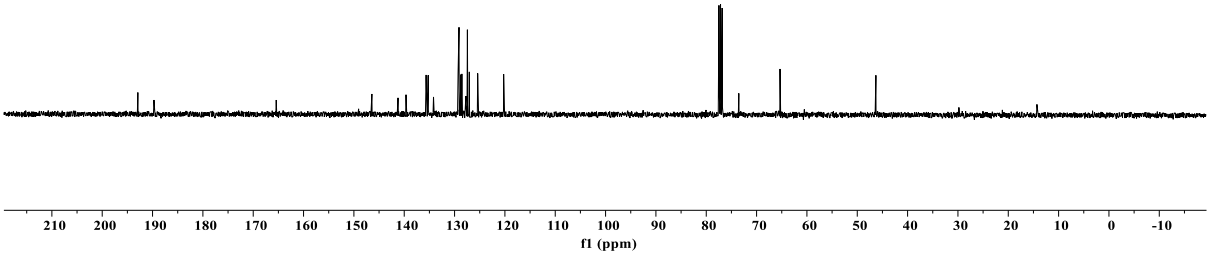


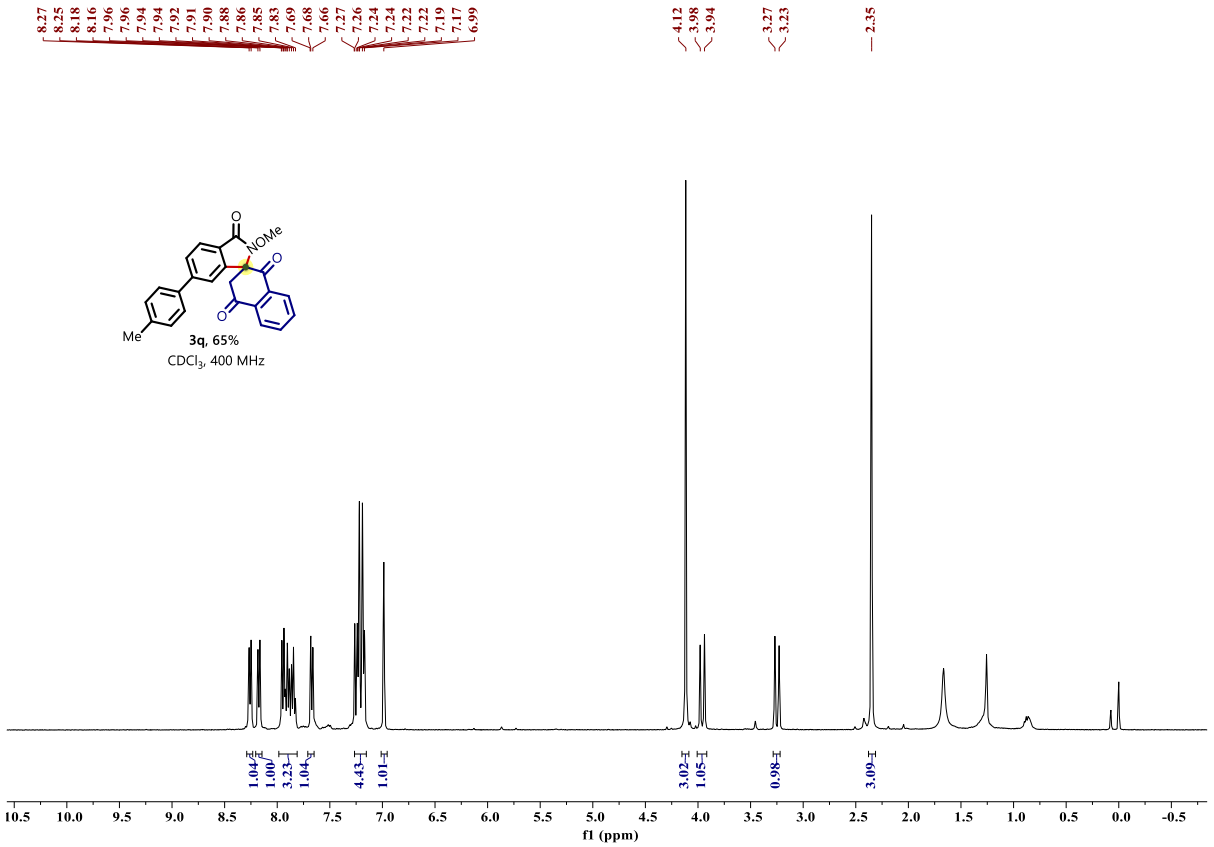
3p, 64%
$CDCl_3$, 400 MHz

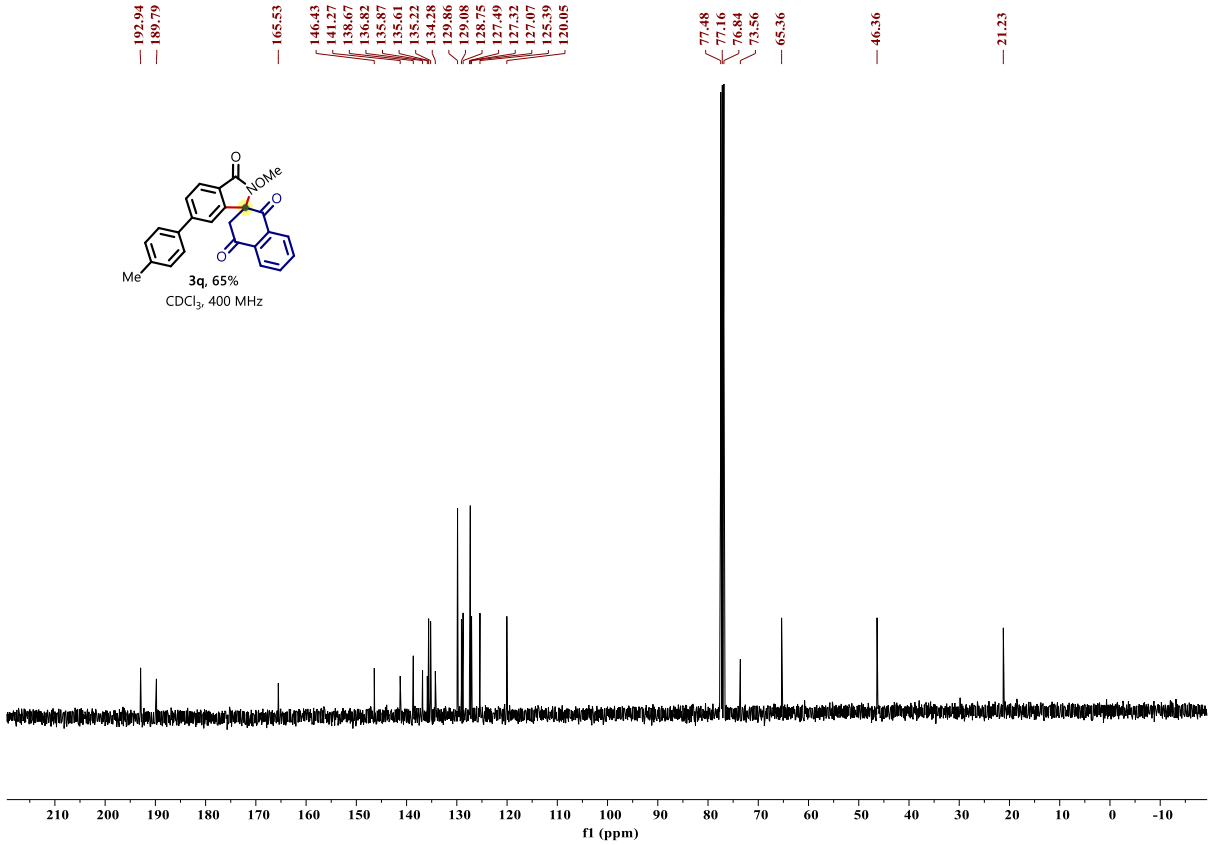


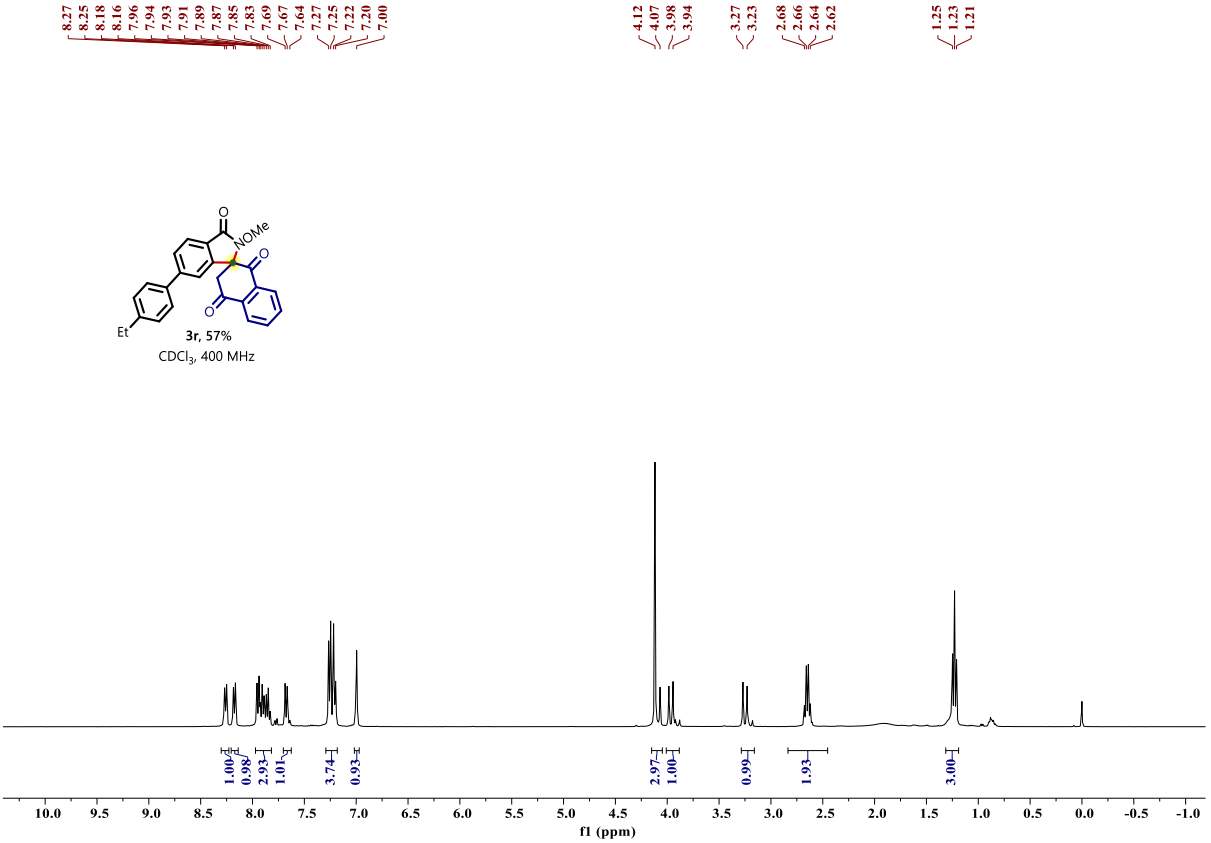


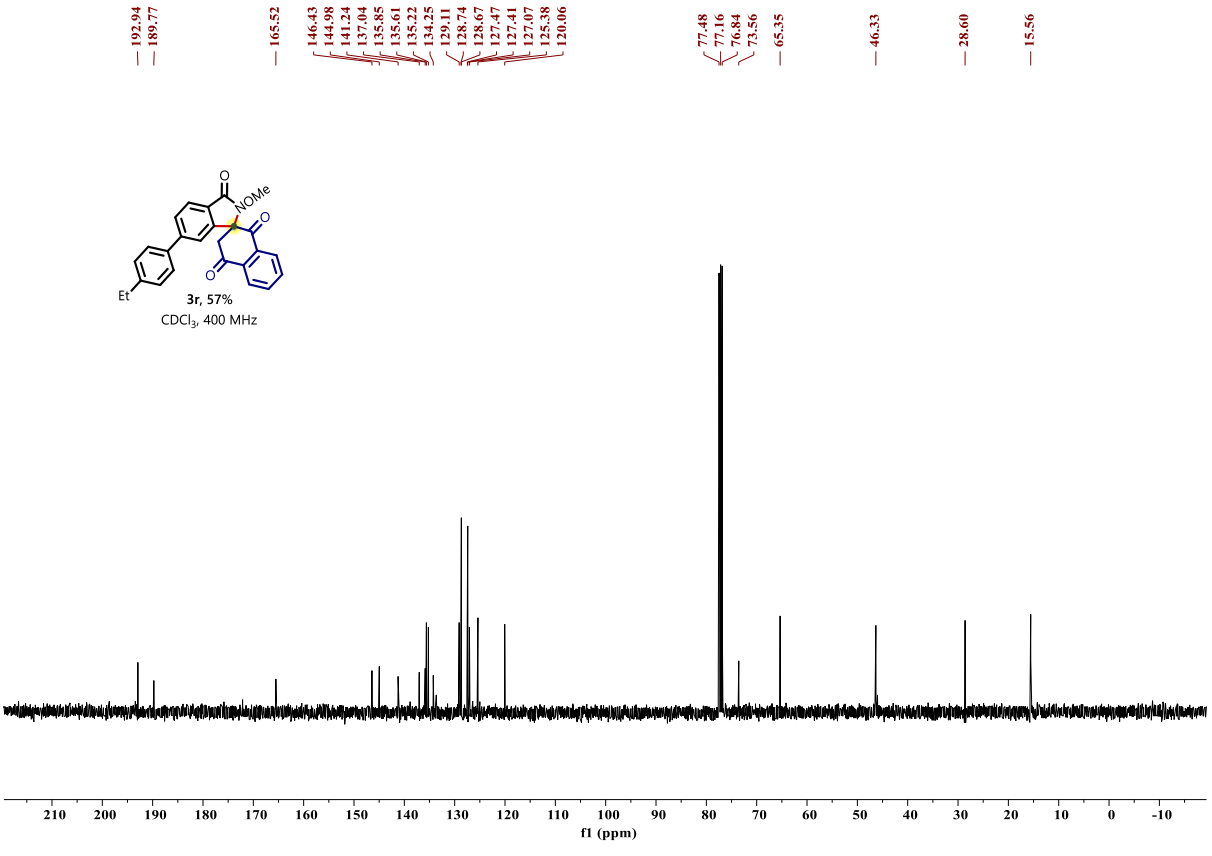
3p, 64%
$CDCl_3$, 400 MHz

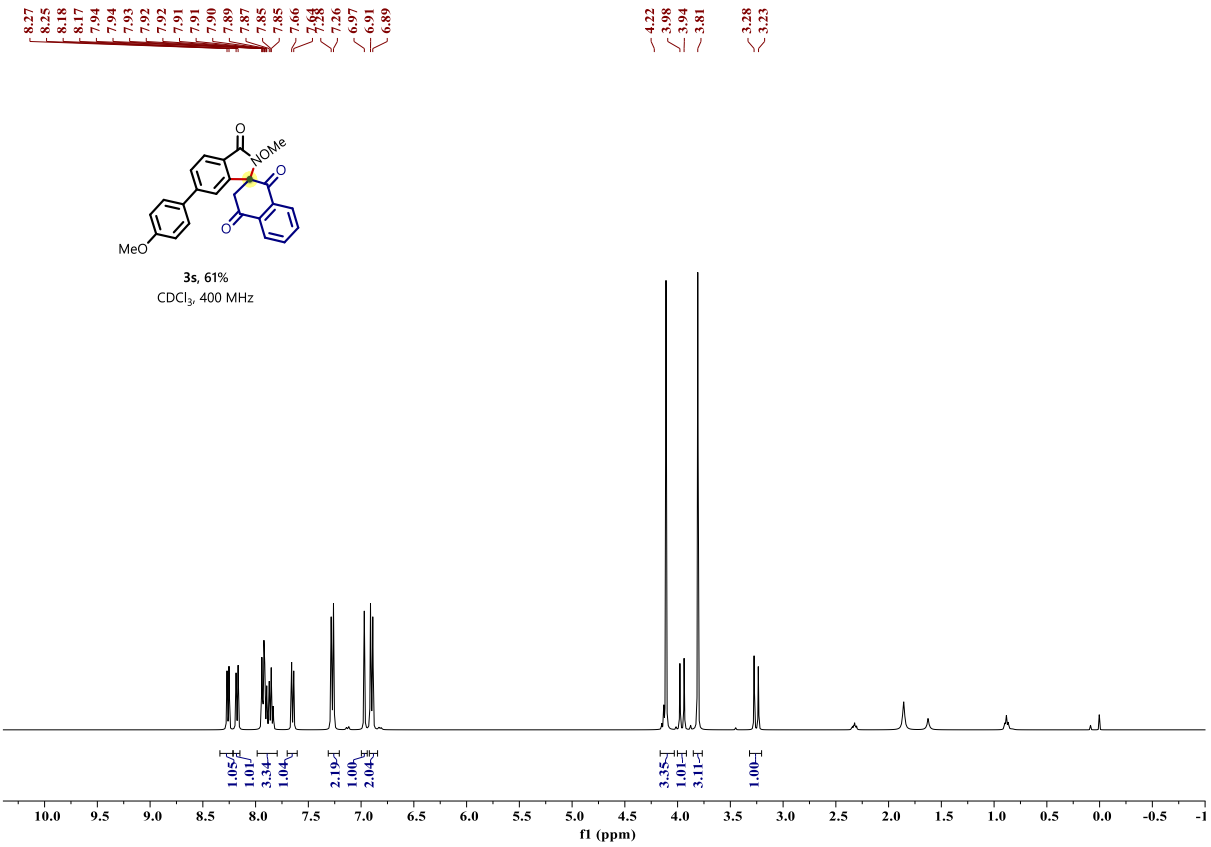


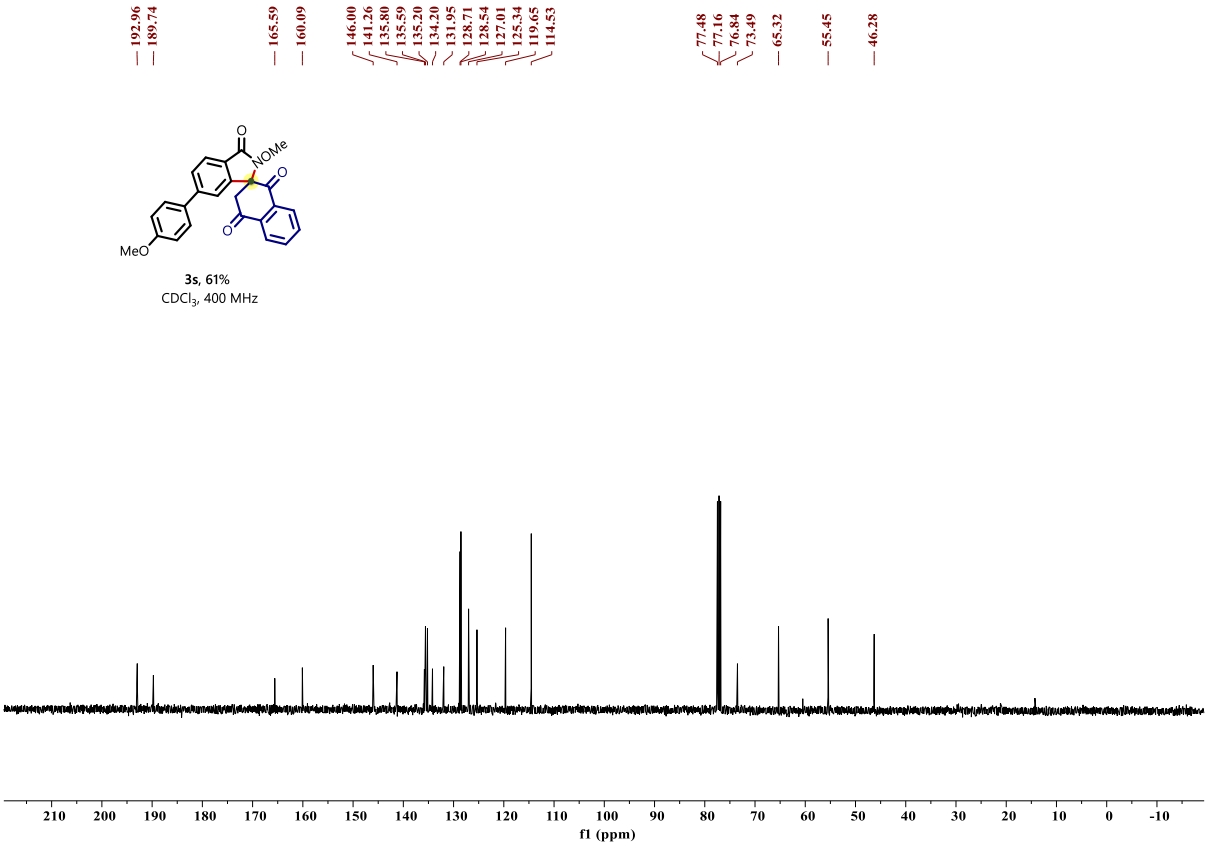

8.27
8.25
8.18
8.16
7.96
7.96
7.94
7.94
7.92
7.91
7.90
7.88
7.86
7.85
7.83
7.69
7.68
7.66
7.27
7.26
7.24
7.24
7.22
7.22
7.19
7.17
6.99
4.12
3.98
3.94
3.27
3.23
2.35
O
NOMe
O
O
Me
3q, 65%
CDCl3, 400 MHz
1.04
1.00
3.23
1.04
4.43
1.01
3.02
1.05
0.98
3.09
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)

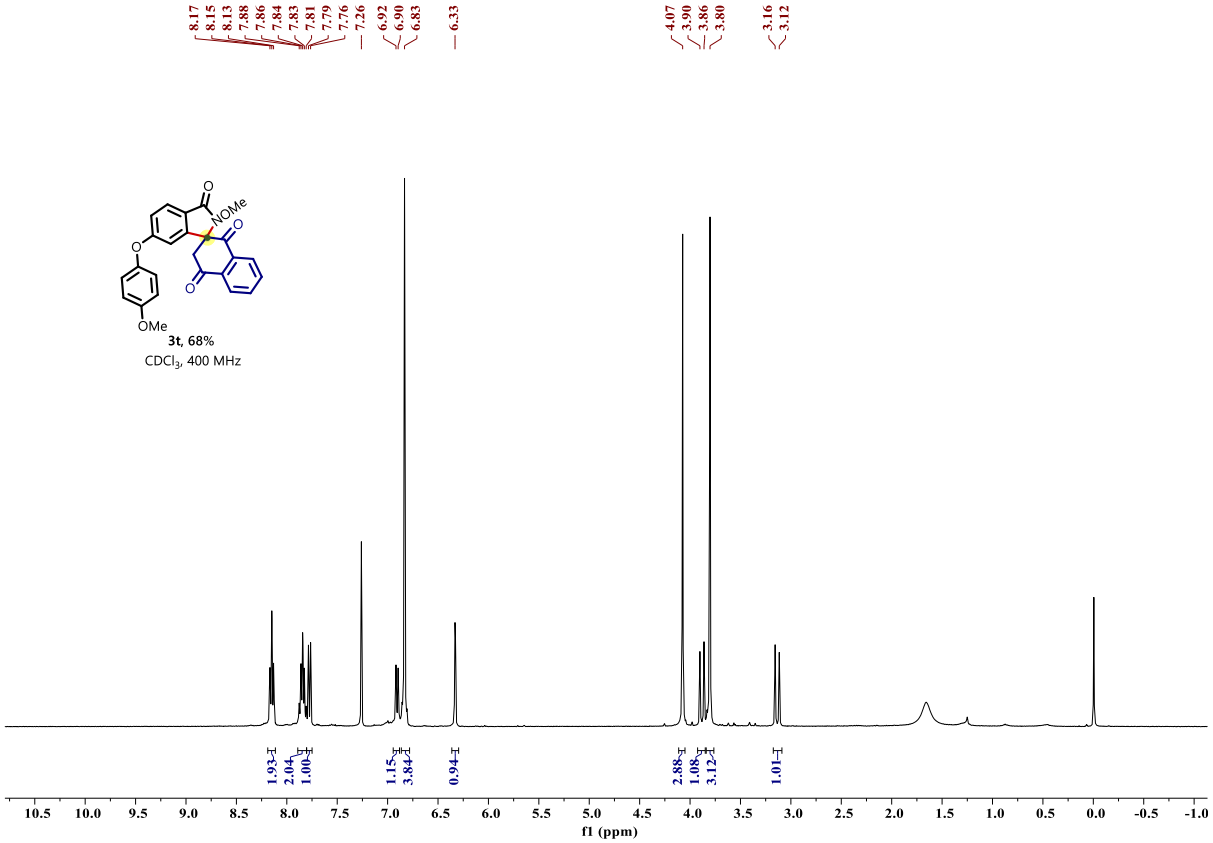

192.94
189.79
165.53
146.43
141.27
138.67
136.82
135.87
135.61
135.22
134.28
129.86
129.08
128.75
127.49
127.32
127.07
125.39
120.05
77.48
77.16
76.84
73.56
65.36
46.36
21.23
O
NOMe
O
O
Me
3q, 65%
CDCl3, 400 MHz
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

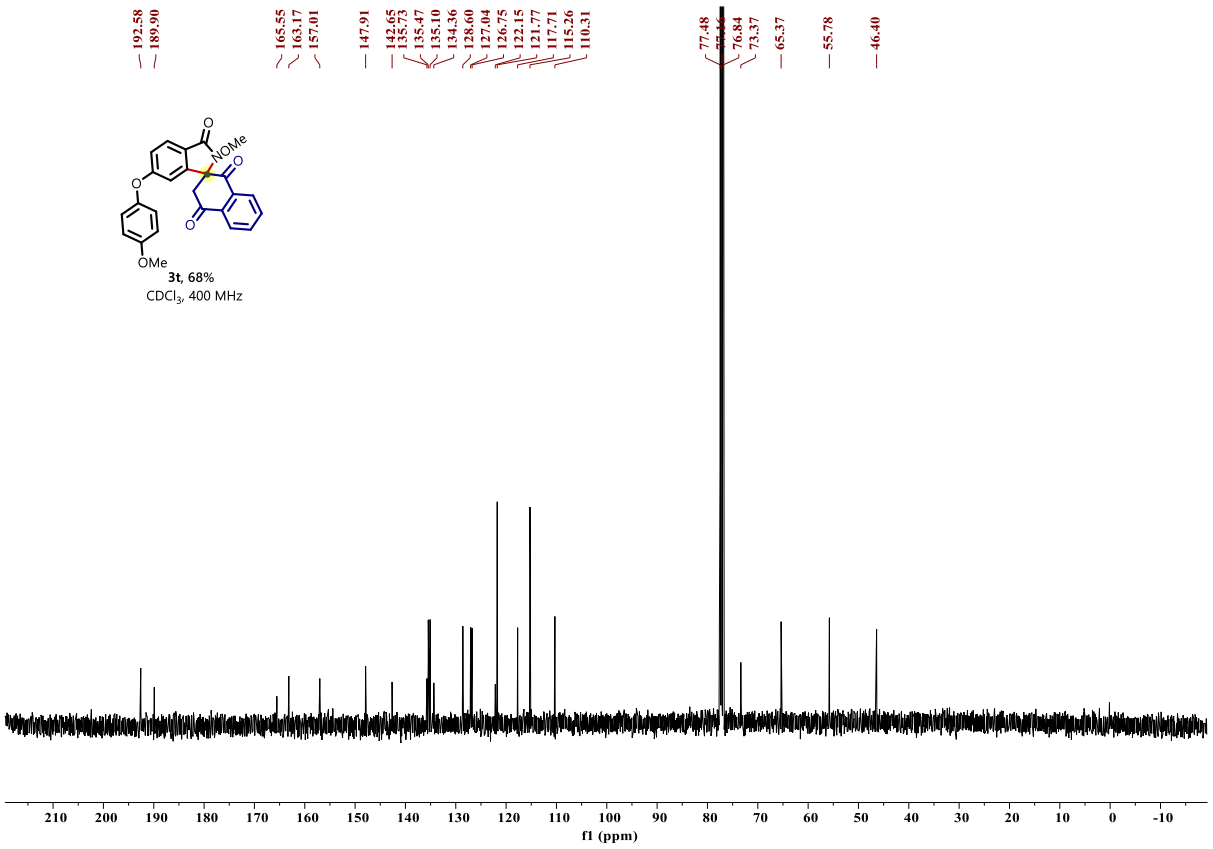

8.27
8.25
8.18
8.16
7.96
7.94
7.93
7.91
7.89
7.87
7.85
7.83
7.69
7.67
7.64
7.27
7.25
7.22
7.20
7.00
4.12
4.07
3.98
3.94
3.27
3.23
2.68
2.66
2.64
2.62
1.25
1.23
1.21
O
NOMe
O
O
Et
3r, 57%
CDCl3, 400 MHz
1.00
0.98
2.93
1.01
3.74
0.93
2.97
1.00
0.99
1.93
3.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
f1 (ppm)

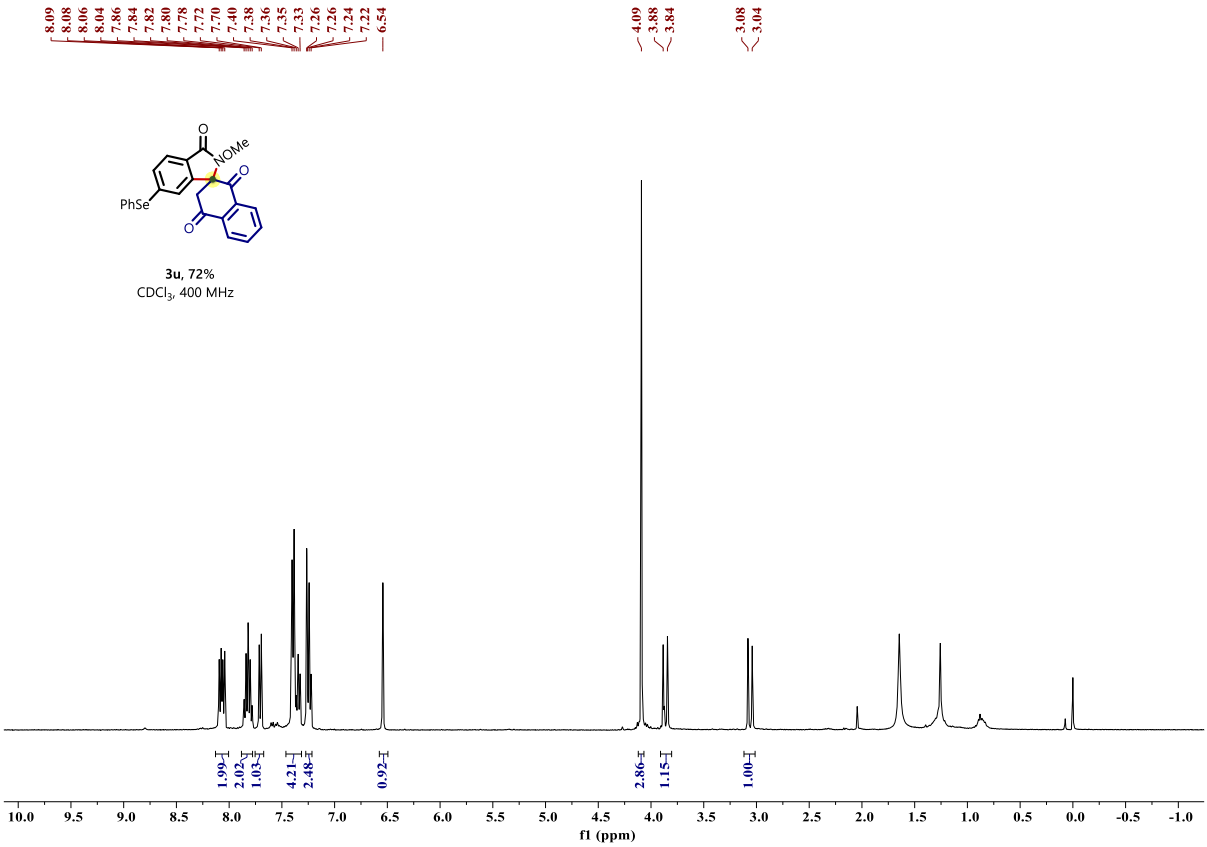

192.94
189.77
165.52
146.43
144.98
141.24
137.04
135.85
135.61
135.22
134.25
129.11
128.74
128.67
127.47
127.41
127.07
125.38
120.06
77.48
77.16
76.84
73.56
65.35
46.33
28.60
15.56
O
NOMe
O
O
Et
3r, 57%
CDCl3, 400 MHz
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)


8.27
8.25
8.18
8.17
7.94
7.94
7.93
7.92
7.92
7.91
7.91
7.90
7.89
7.87
7.85
7.85
7.66
7.64
7.28
7.26
6.97
6.91
6.89
4.22
3.98
3.94
3.81
3.28
3.23
NOMe
O
O
O
MeO
3s, 61%
CDCl3, 400 MHz
1.05
1.01
3.34
1.04
2.19
1.00
2.04
3.35
1.01
3.11
1.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1
f1 (ppm)

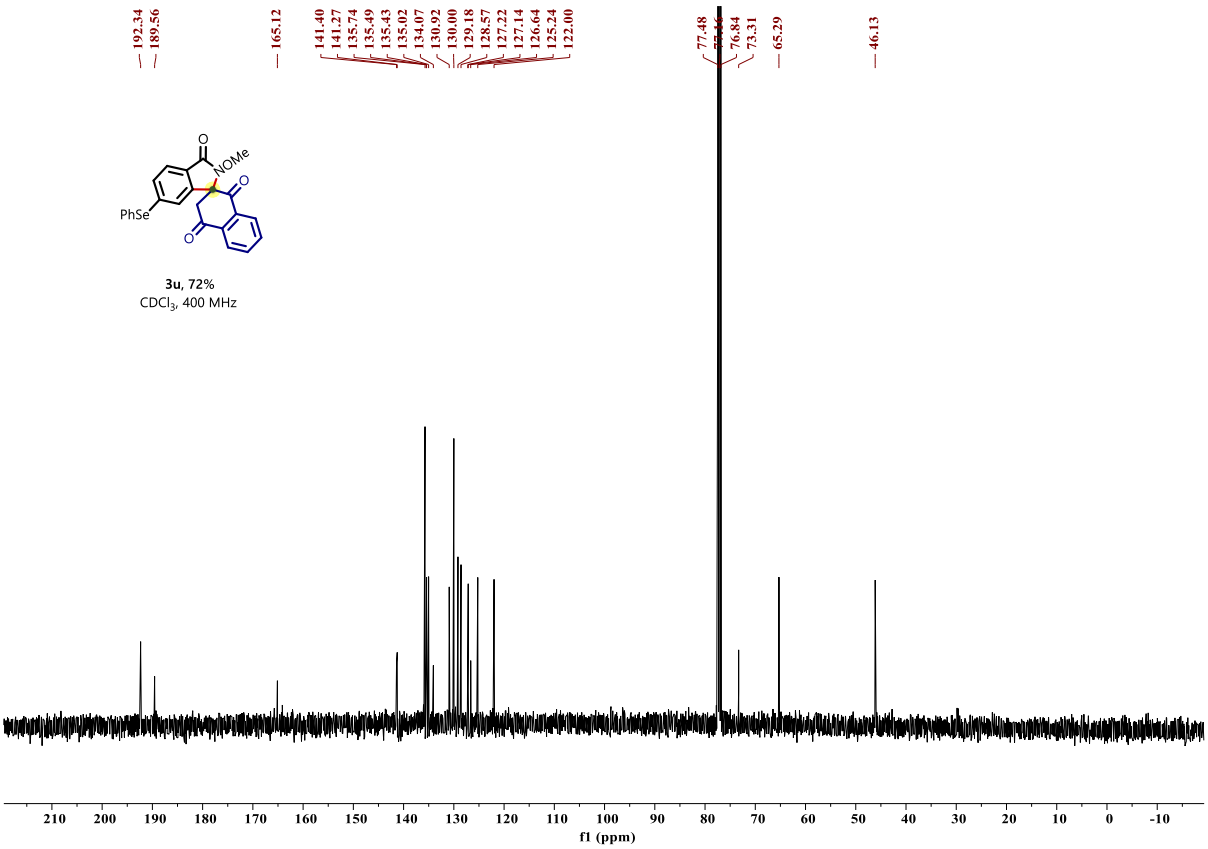

192.96
189.74
165.59
160.09
146.00
141.26
135.80
135.59
135.20
134.20
131.95
128.71
128.54
127.01
125.34
119.65
114.53
77.48
77.16
76.84
73.49
65.32
55.45
46.28
NOMe
O
O
O
MeO
3s, 61%
CDCl3, 400 MHz
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)


8.17
8.15
8.13
7.88
7.86
7.84
7.83
7.81
7.79
7.76
7.26
6.92
6.90
6.83
6.33
4.07
3.90
3.86
3.80
3.16
3.12
NOMe
O
O
O
O
OMe
3t, 68%
CDCl3, 400 MHz
1.93
2.04
1.00
1.15
3.84
0.94
2.88
1.08
3.12
1.01
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5 -1.0
f1 (ppm)

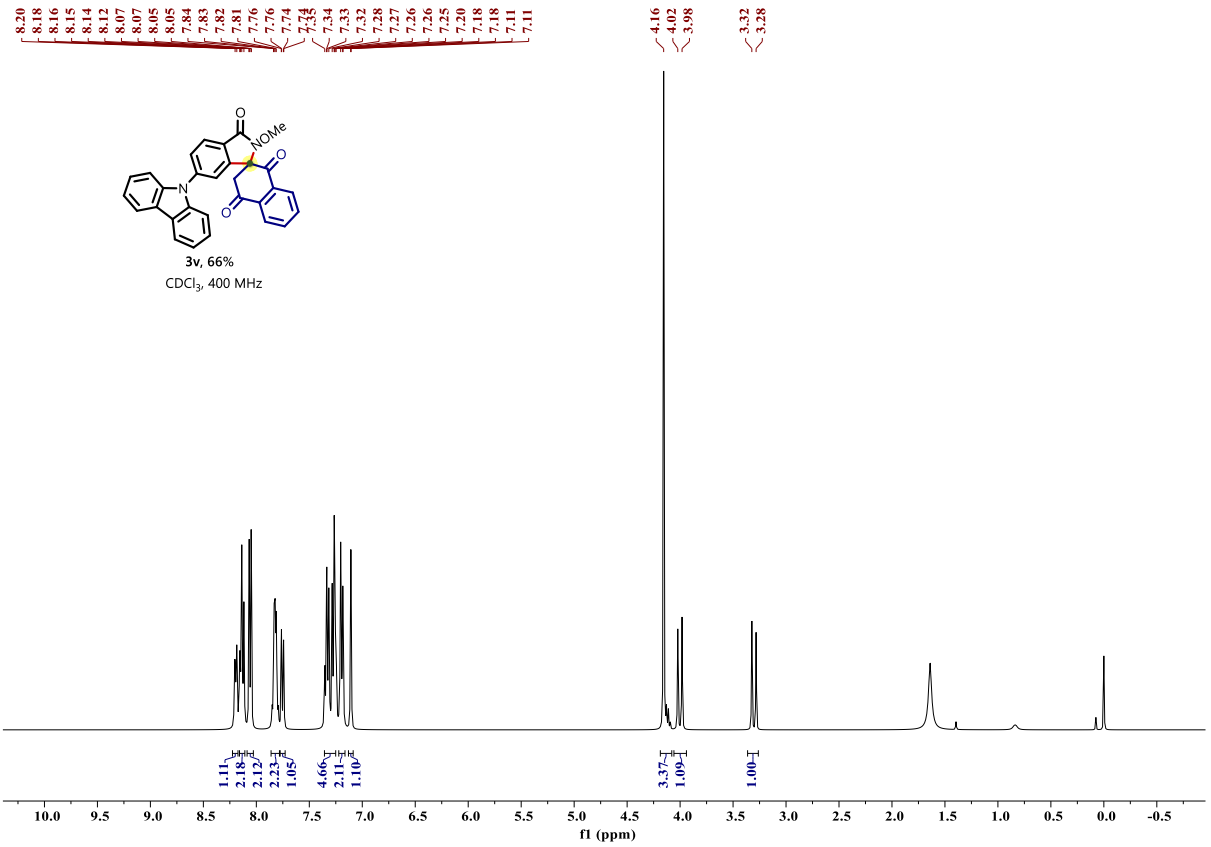

192.58
189.90
165.55
163.17
157.01
147.91
142.65
135.73
135.47
135.10
134.36
128.60
127.04
126.75
122.15
121.77
117.71
115.26
110.31
77.48
76.84
73.37
65.37
55.78
46.40
NOMe
O
O
O
O
OMe
3t, 68%
CDCl3, 400 MHz
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)

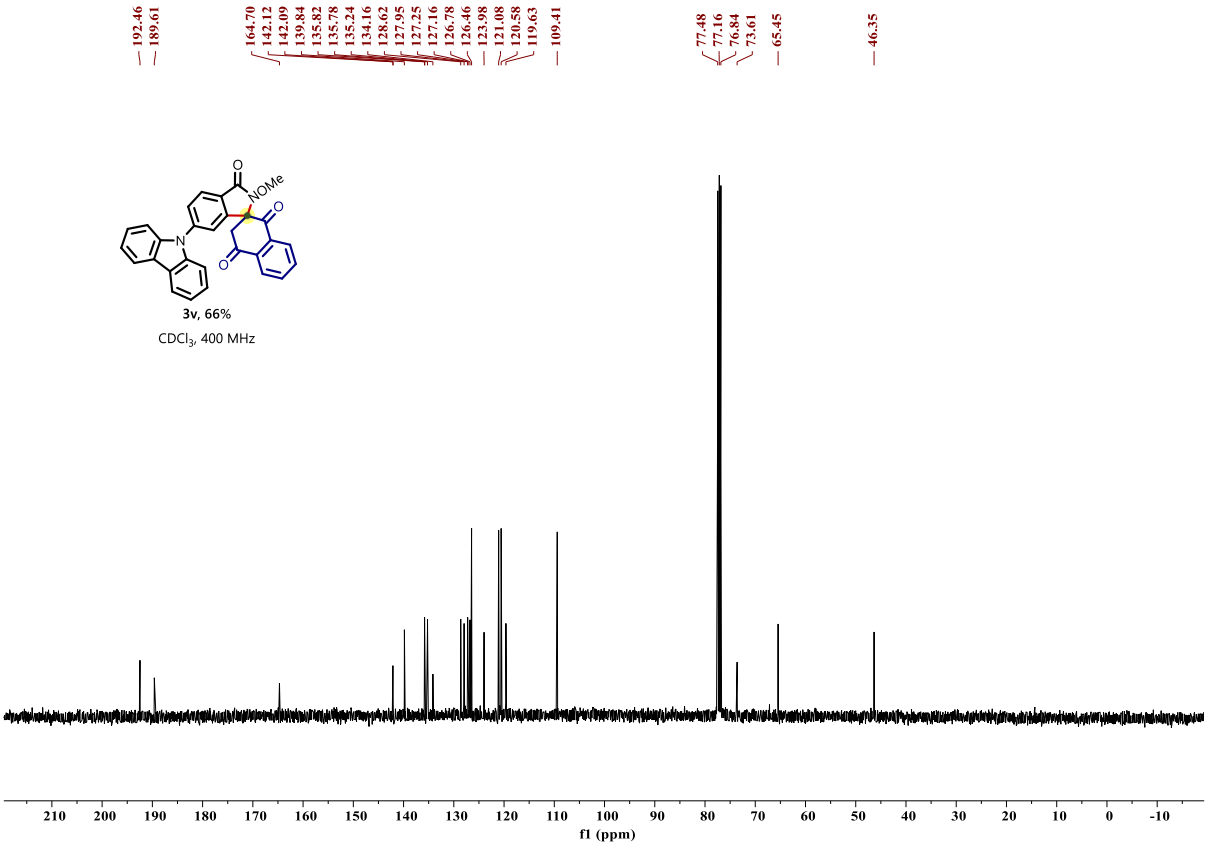


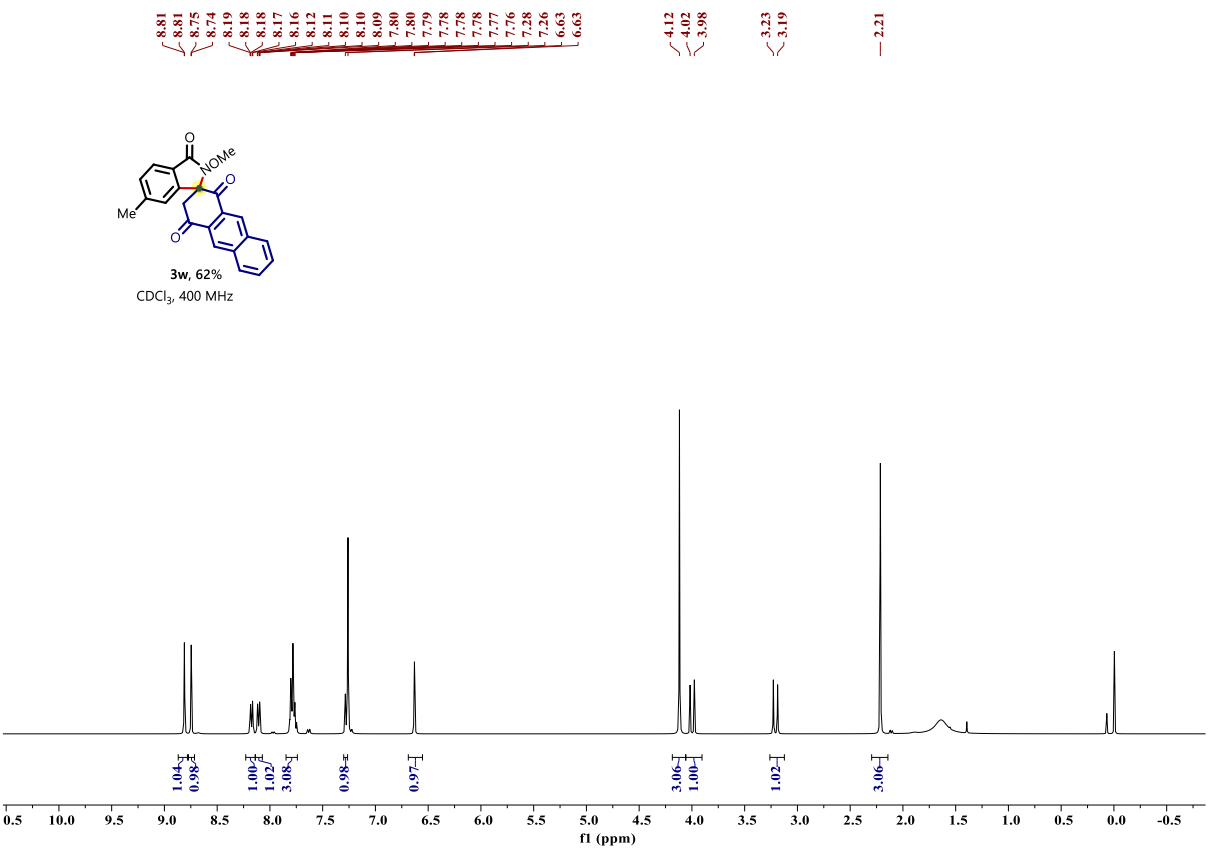
3u, 72%
$CDCl_3$, 400 MHz

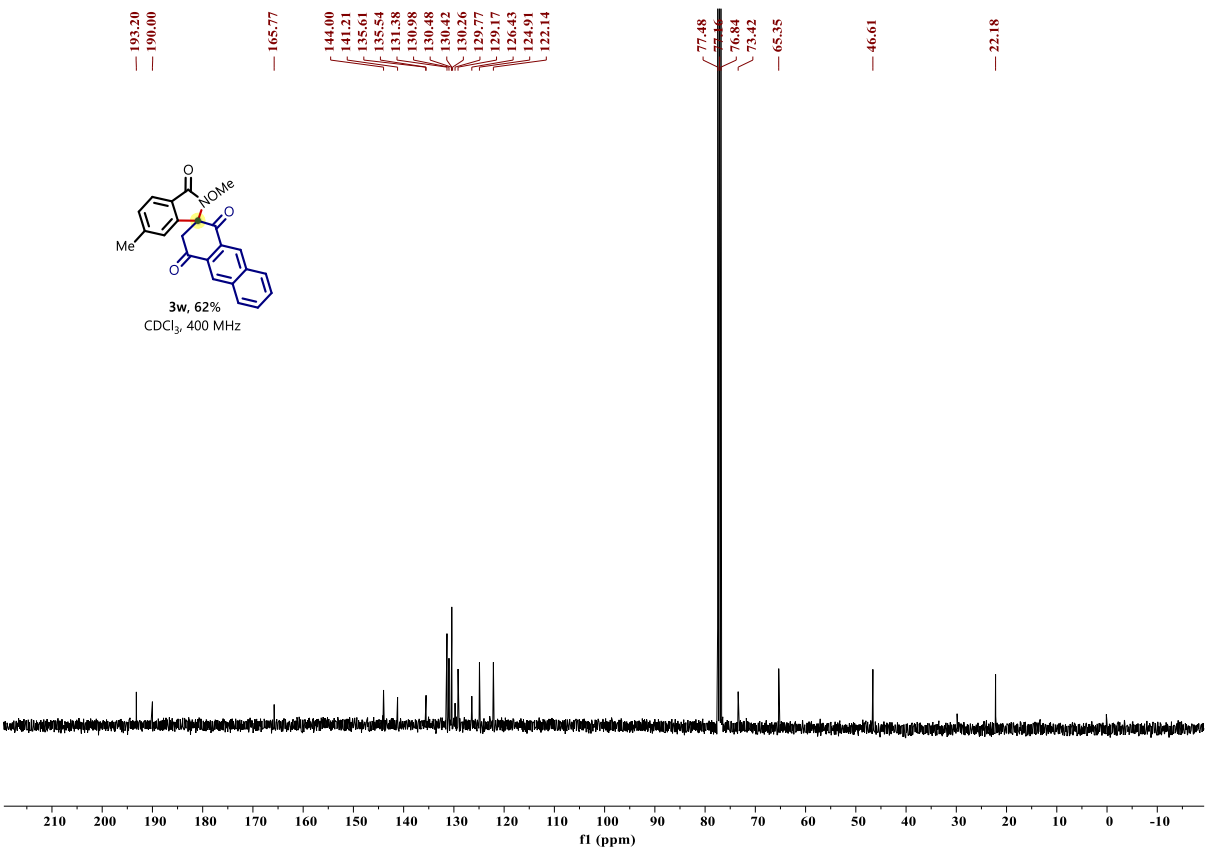


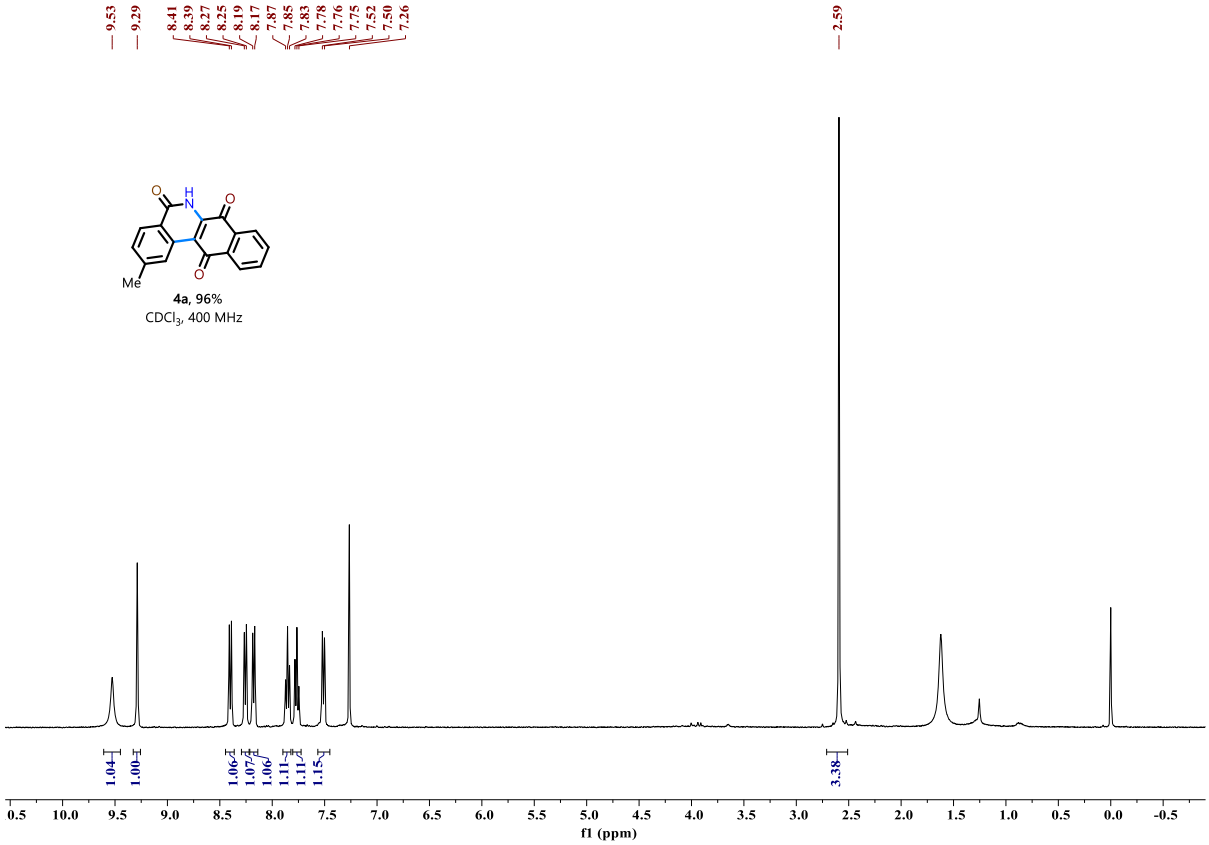
3u, 72%
$CDCl_3$, 400 MHz

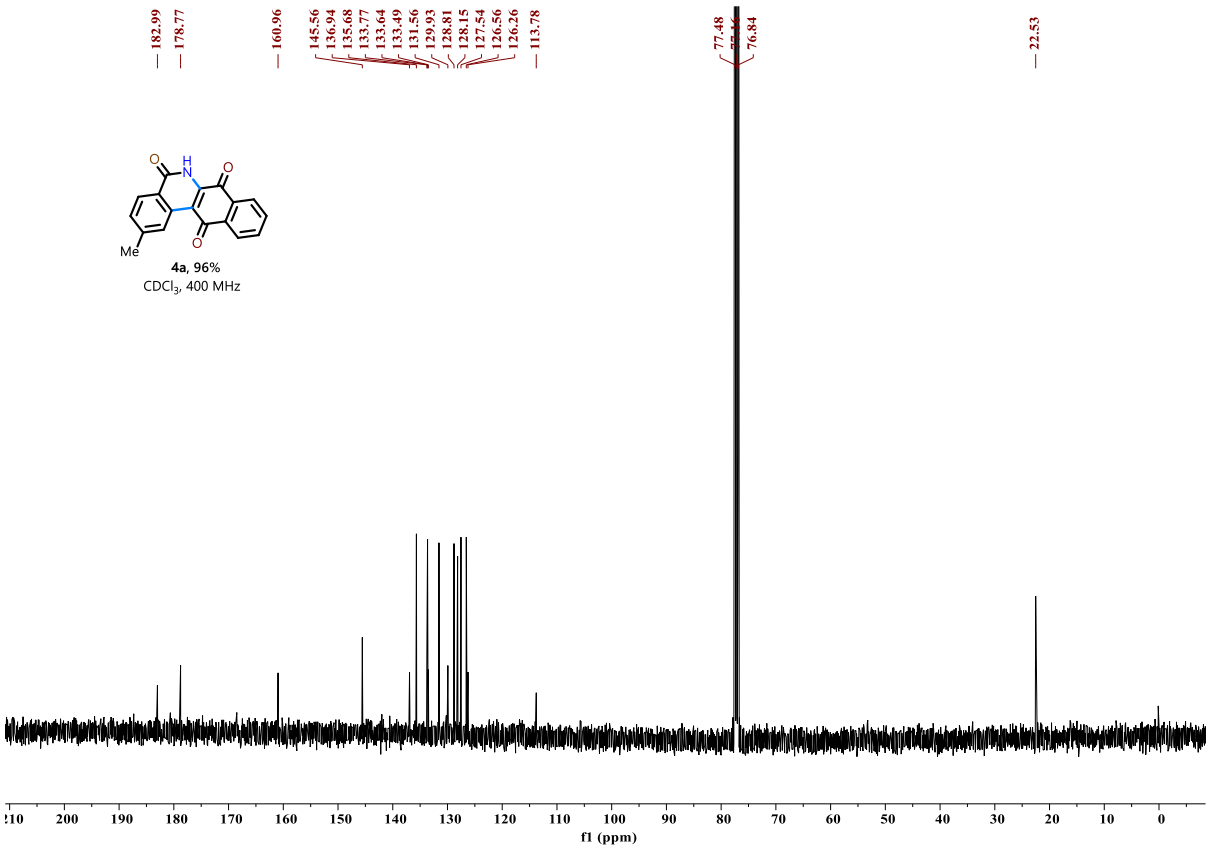

8.20
8.18
8.16
8.15
8.14
8.12
8.07
8.07
8.05
8.05
7.84
7.83
7.82
7.81
7.76
7.76
7.74
7.34
7.34
7.33
7.32
7.28
7.27
7.26
7.26
7.25
7.20
7.18
7.18
7.11
7.11
4.16
4.02
3.98
3.32
3.28
O
NOMe
O
N
O
3v, 66%
CDCl3, 400 MHz
1.11
2.18
2.12
2.23
1.05
4.66
2.11
1.10
3.37
1.09
1.00
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)

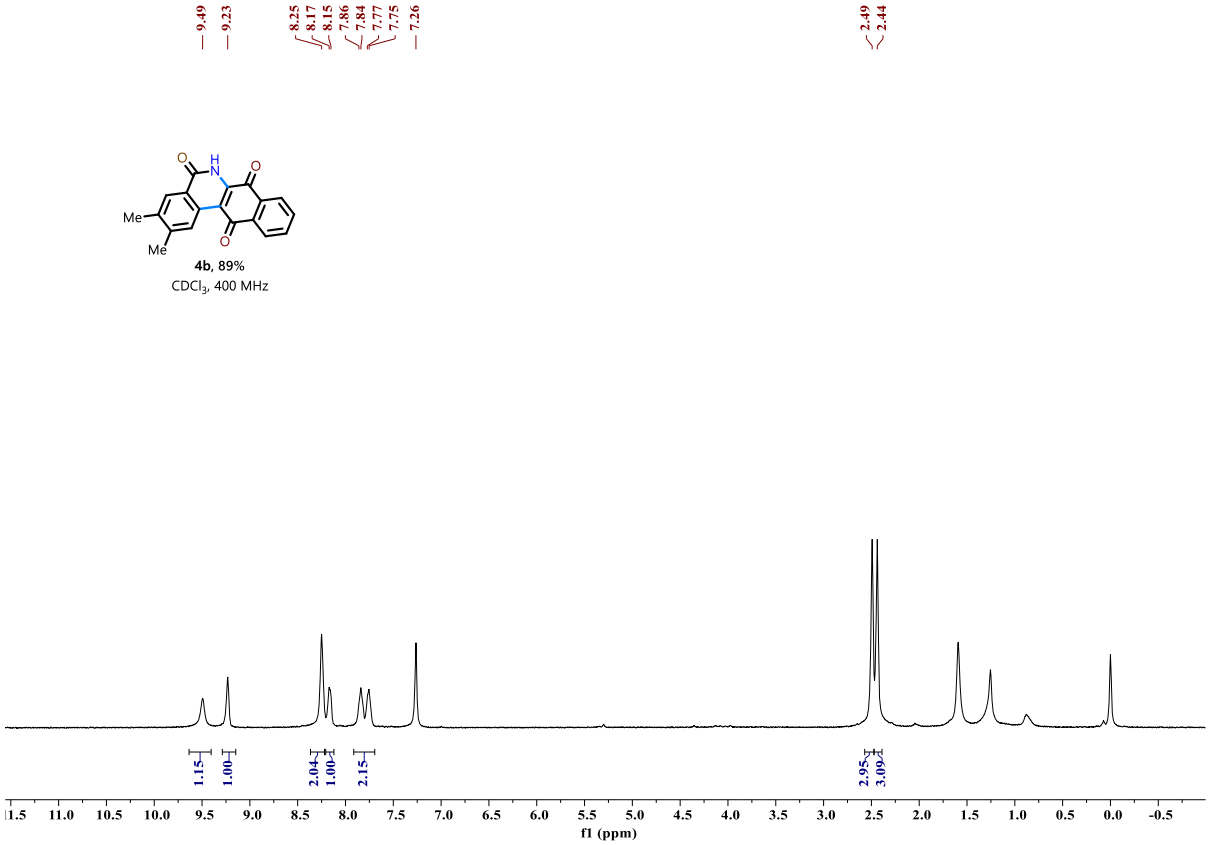

192.46
189.61
164.70
142.12
142.09
139.84
135.82
135.78
135.24
134.16
128.62
127.95
127.25
127.16
126.78
126.46
123.98
121.08
120.58
119.63
109.41
77.48
77.16
76.84
73.61
65.45
46.35
O
NOMe
O
N
O
3v, 66%
CDCl3, 400 MHz
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

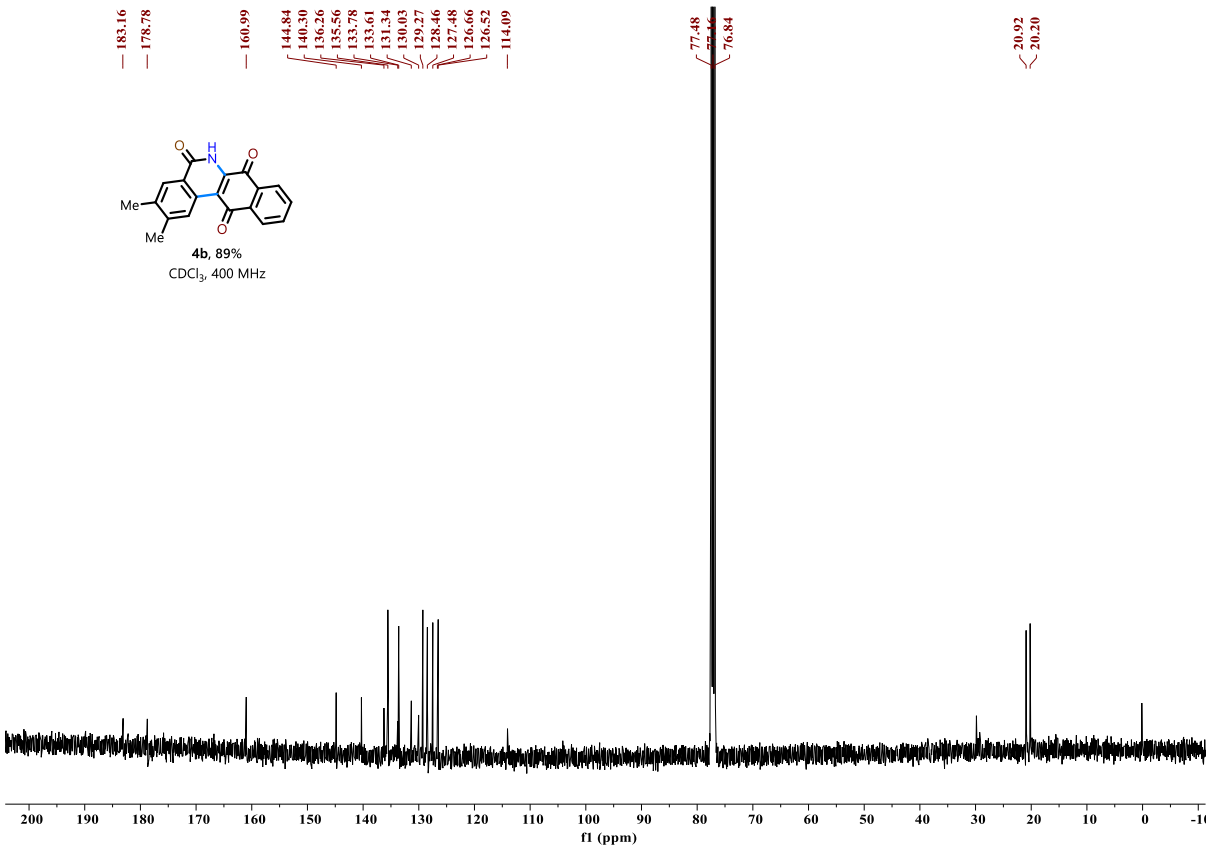

8.81
8.81
8.75
8.74
8.19
8.18
8.18
8.17
8.16
8.12
8.11
8.10
8.10
8.09
7.80
7.80
7.79
7.78
7.78
7.78
7.77
7.76
7.28
7.26
6.63
6.63
4.12
4.02
3.98
3.23
3.19
2.21
NOMe
Me
3w, 62%
CDCl3, 400 MHz
1.04
0.98
1.00
1.02
3.08
0.98
0.97
3.06
1.00
1.02
3.06
f1 (ppm)

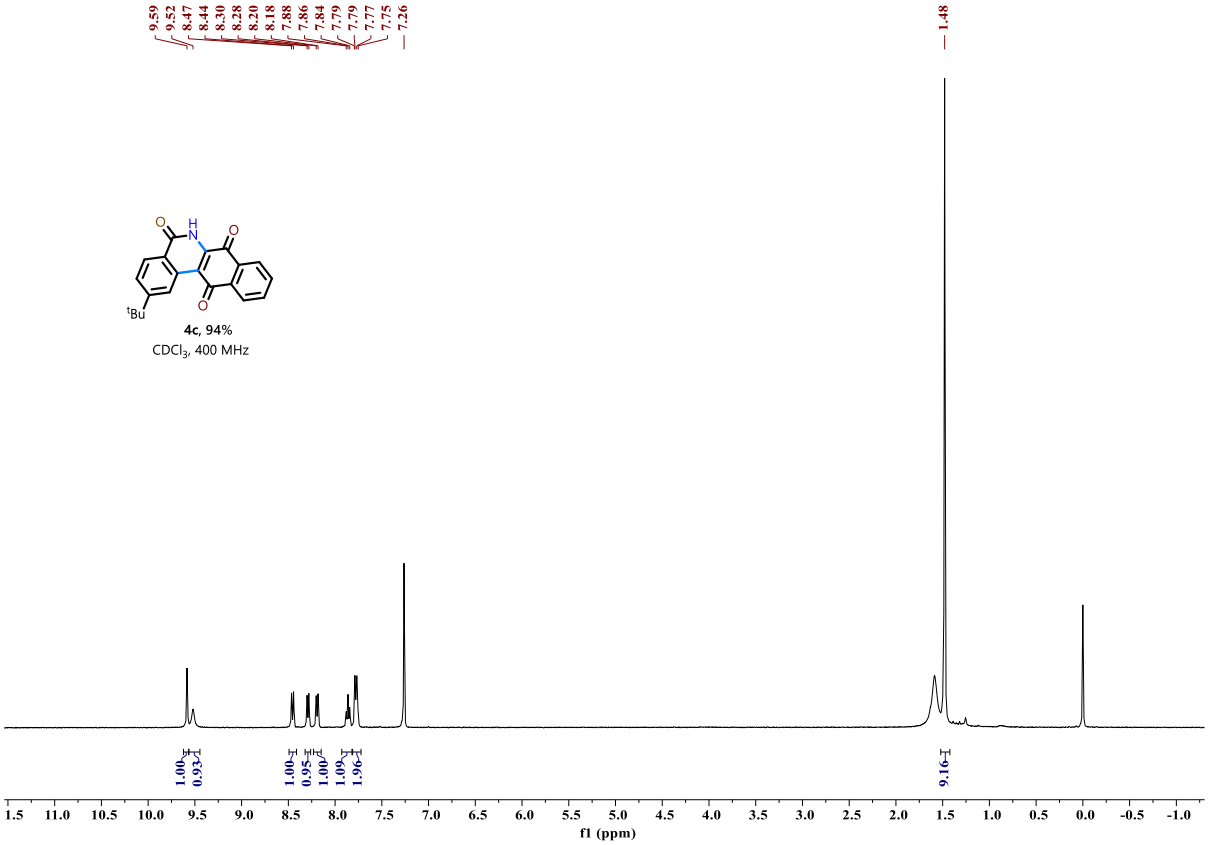

193.20
190.00
165.77
144.00
141.21
135.61
135.54
131.38
130.98
130.48
130.42
130.26
129.77
129.17
126.43
124.91
122.14
77.48
76.84
73.42
65.35
46.61
22.18
NOMe
Me
3w, 62%
CDCl3, 400 MHz
f1 (ppm)

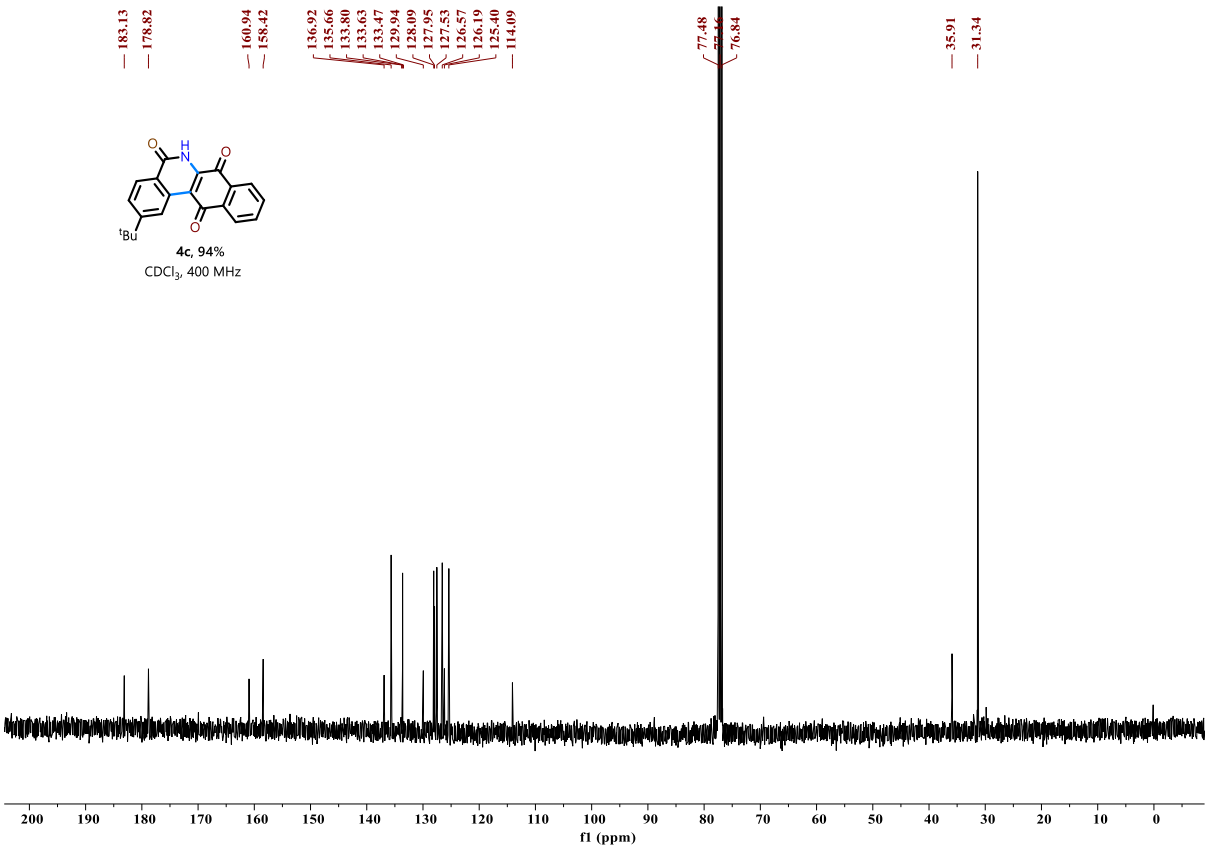

9.53
9.29
8.41
8.39
8.27
8.25
8.19
8.17
7.87
7.85
7.83
7.78
7.76
7.75
7.52
7.50
7.26
2.59
Me
4a, 96%
CDCl3, 400 MHz
1.04
1.00
1.06
1.07
1.06
1.11
1.11
1.15
3.38
f1 (ppm)

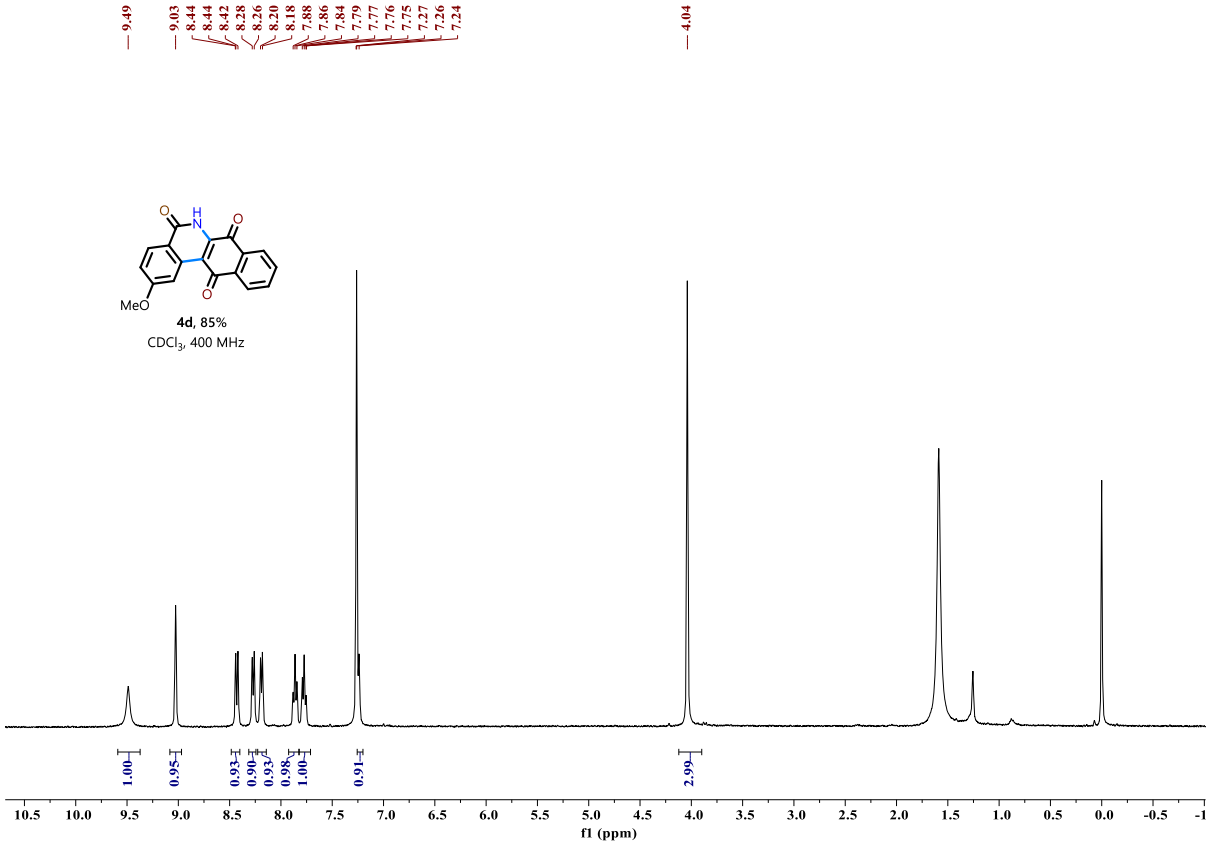

182.99
178.77
160.96
145.56
136.94
135.68
133.77
133.64
133.49
131.56
129.93
128.81
128.15
127.54
126.56
126.26
113.78
77.48
76.84
22.53
Me
4a, 96%
CDCl3, 400 MHz
f1 (ppm)

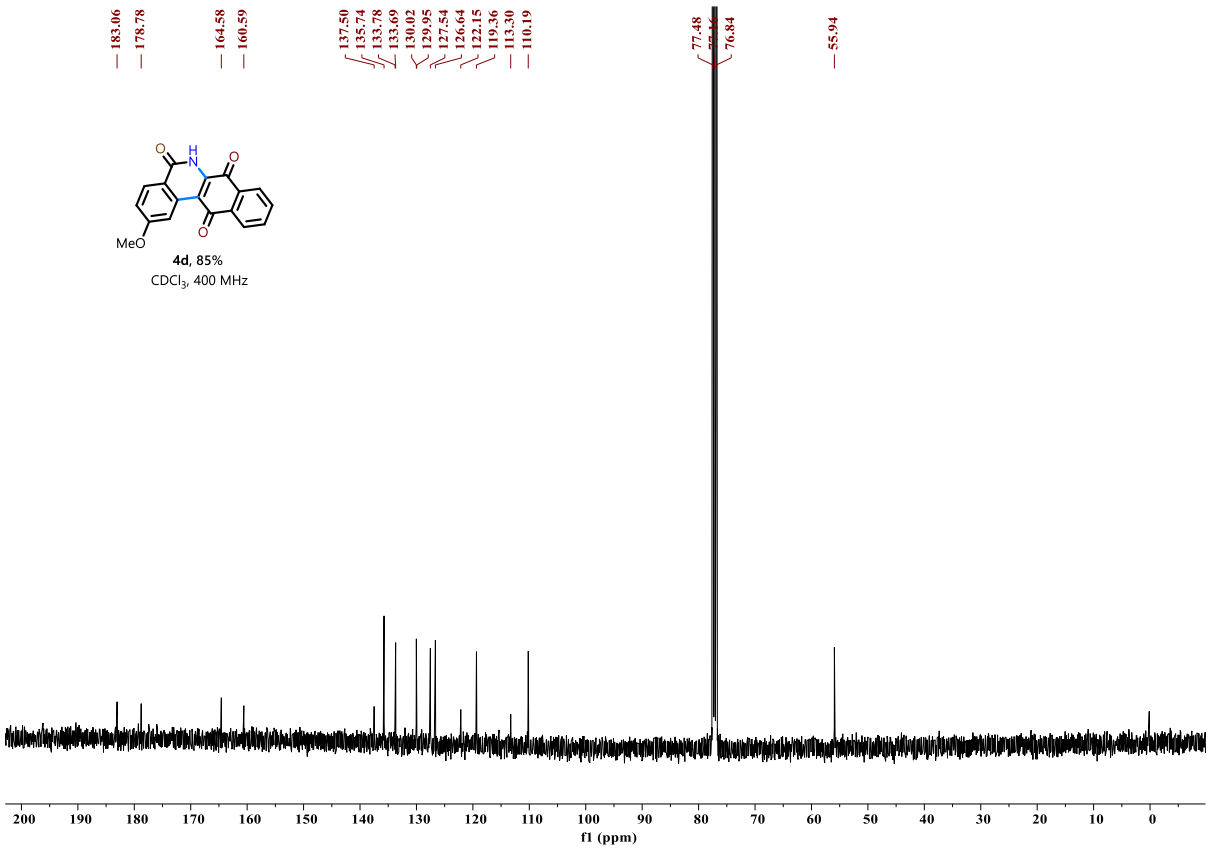

9.49
9.23
8.25
8.17
8.15
7.86
7.84
7.77
7.75
7.26
2.49
2.44
Me
Me
4b, 89%
CDCl3, 400 MHz
1.15
1.00
2.04
1.00
2.15
2.95
3.09
f1 (ppm)

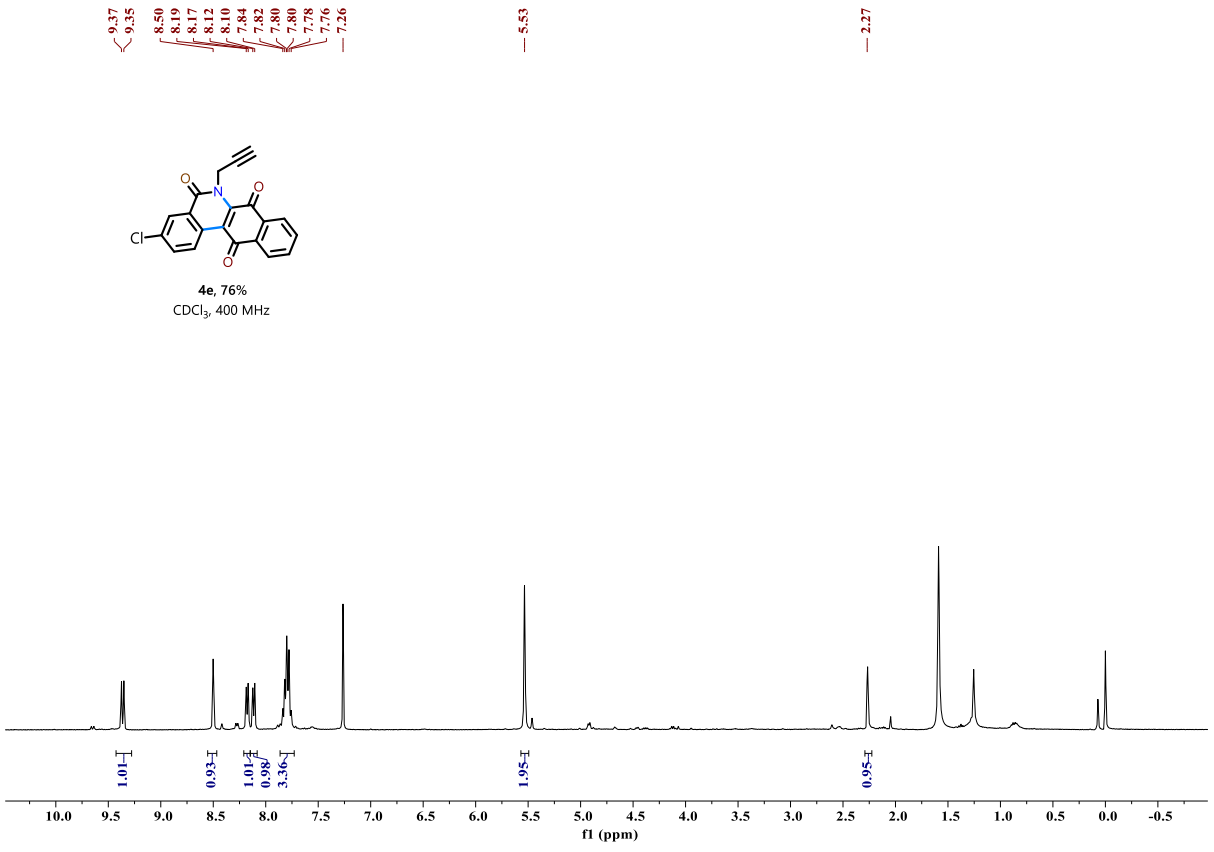

183.16
178.78
160.99
144.84
140.30
136.26
135.56
133.78
133.61
131.34
130.03
129.27
128.46
127.48
126.66
126.52
114.09
77.48
76.84
20.92
20.20
Me
Me
4b, 89%
CDCl3, 400 MHz
f1 (ppm)

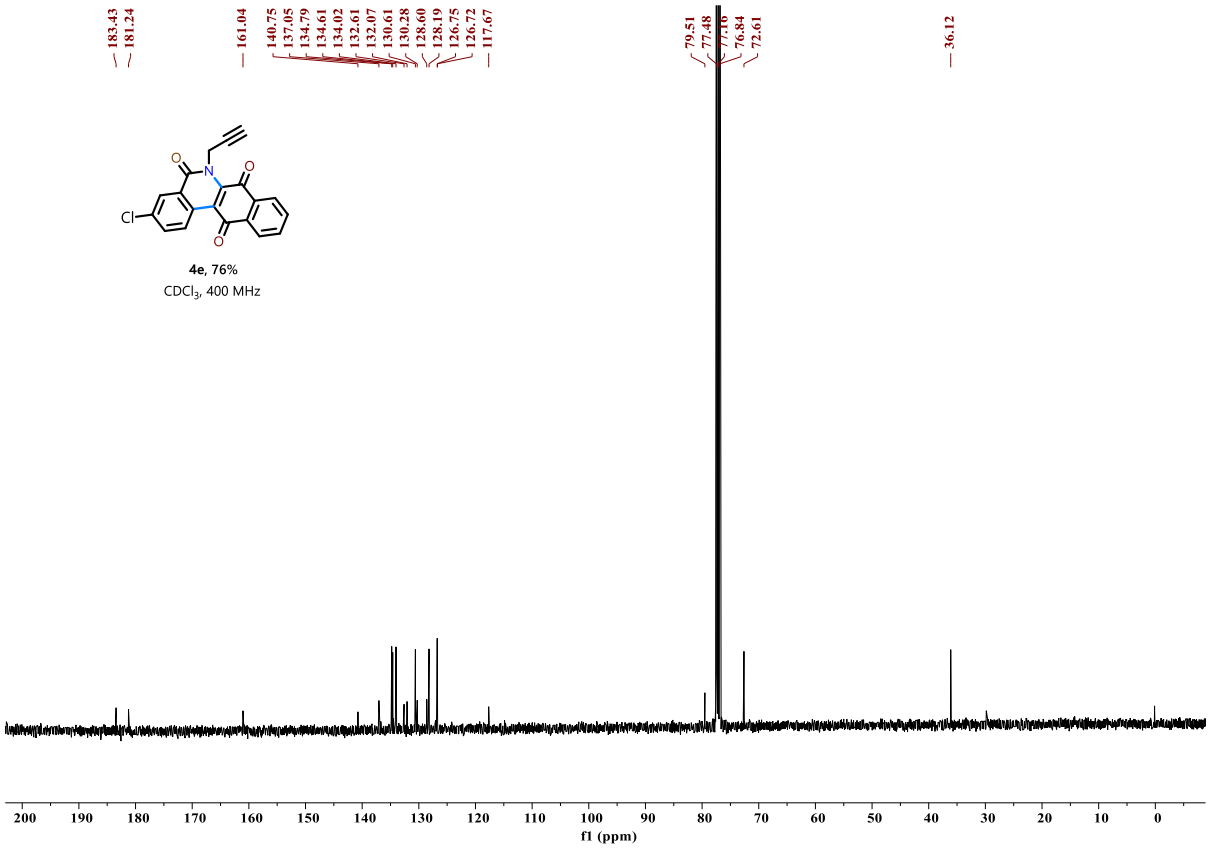

9.59
9.52
8.47
8.44
8.30
8.28
8.20
8.18
7.88
7.86
7.84
7.79
7.79
7.77
7.75
7.26
1.48
4c, 94%
CDCl3, 400 MHz
1.00
0.93
1.00
0.95
1.00
1.09
1.96
9.16
f1 (ppm)

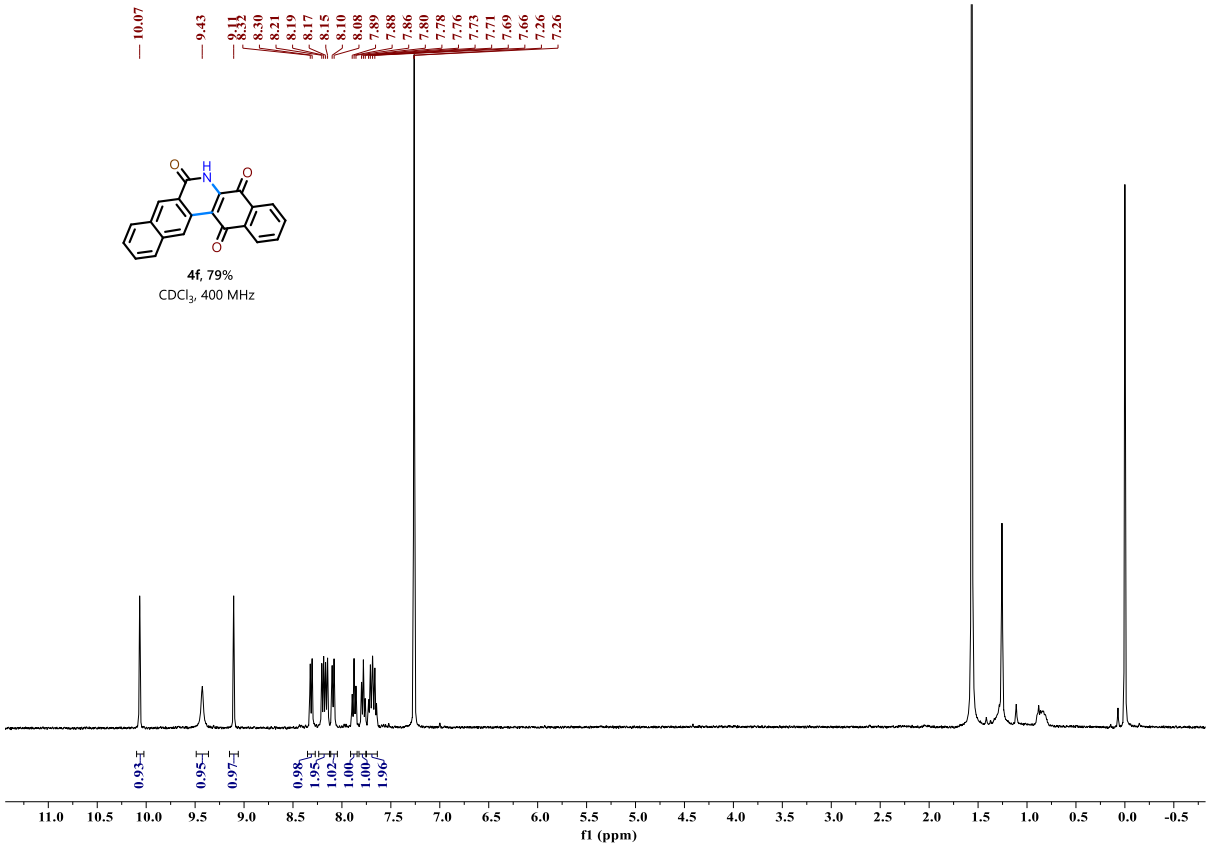

183.13
178.82
160.94
158.42
136.92
135.66
133.80
133.63
133.47
129.94
128.09
127.95
127.53
126.57
126.19
125.40
114.09
77.48
77.16
76.84
35.91
31.34
4c, 94%
CDCl3, 400 MHz
f1 (ppm)

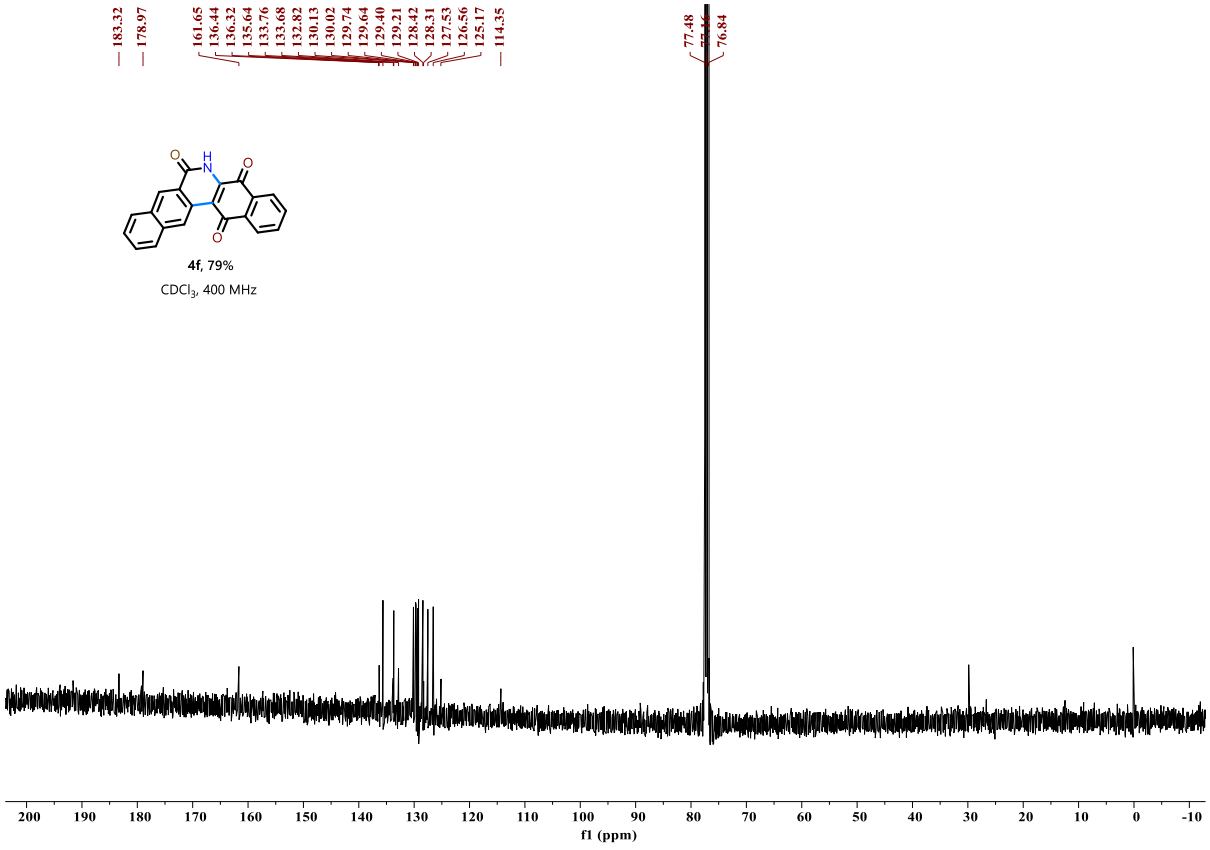

9.49
9.03
8.44
8.44
8.42
8.28
8.26
8.20
8.18
7.88
7.86
7.84
7.79
7.77
7.76
7.75
7.27
7.26
7.24
4.04
MeO
4d, 85%
CDCl3, 400 MHz
1.00
0.95
0.93
0.90
0.93
0.98
1.00
0.91
2.99
f1 (ppm)

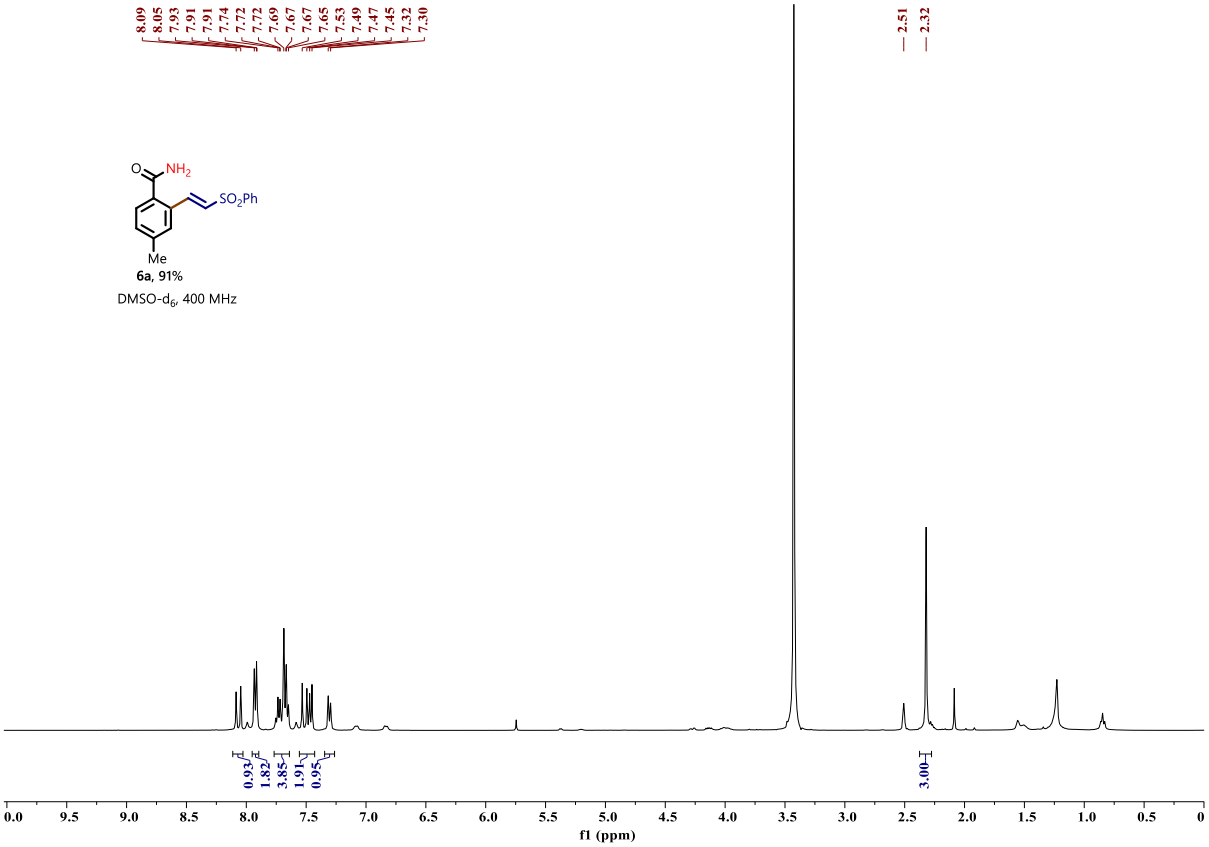

183.06
178.78
164.58
160.59
137.50
135.74
133.78
133.69
130.02
129.95
127.54
126.64
122.15
119.36
113.30
110.19
77.48
76.84
55.94
MeO
4d, 85%
CDCl3, 400 MHz
f1 (ppm)


9.37
9.35
8.50
8.19
8.17
8.12
8.10
7.84
7.82
7.80
7.80
7.78
7.76
7.26
5.53
2.27
O
N
O
Cl
O
4e, 76%
CDCl3, 400 MHz
1.01
0.93
1.01
0.98
3.36
1.95
0.95
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)


183.43
181.24
161.04
140.75
137.05
134.79
134.61
134.02
132.61
132.07
130.61
130.28
128.60
128.19
126.75
126.72
117.67
79.51
77.48
77.16
76.84
72.61
36.12
O
N
O
Cl
O
4e, 76%
CDCl3, 400 MHz
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

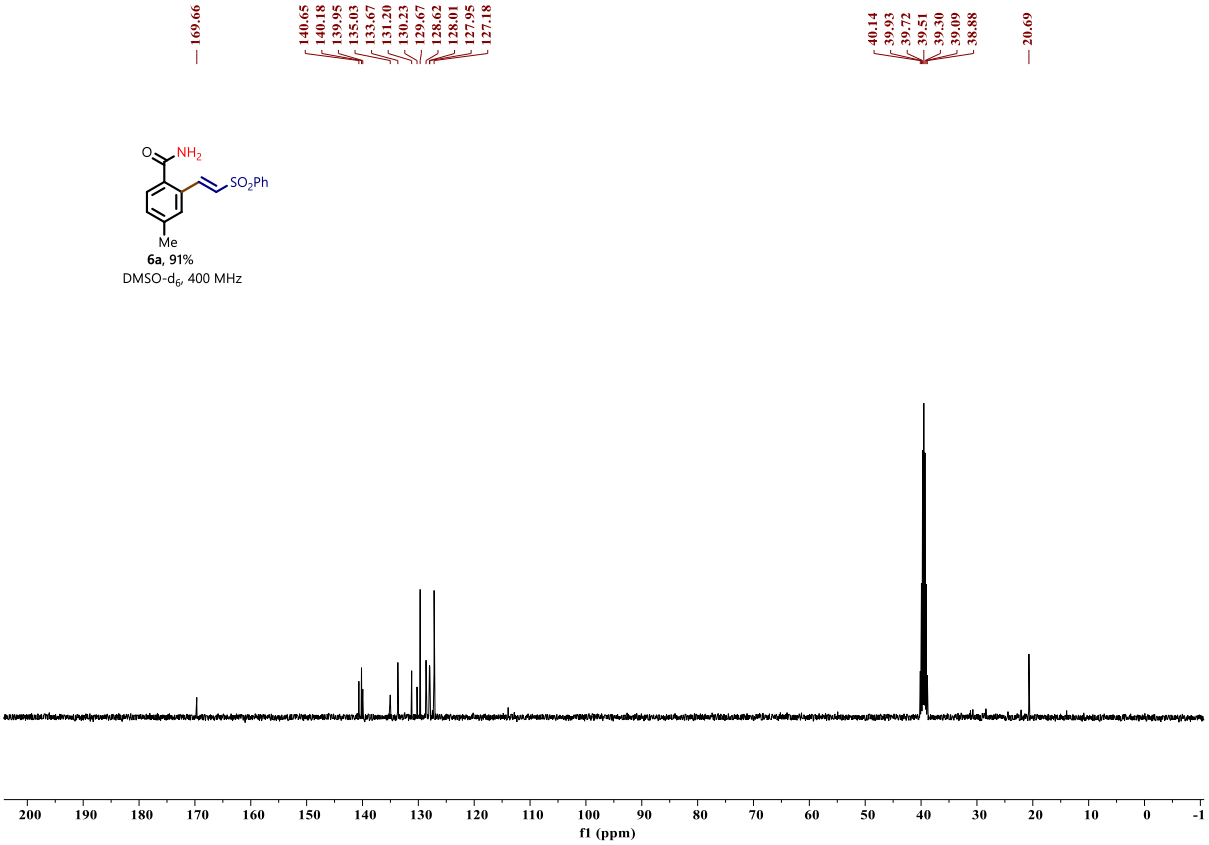

10.07
9.43
9.11
8.32
8.30
8.21
8.19
8.17
8.15
8.10
8.08
7.89
7.88
7.86
7.80
7.78
7.76
7.73
7.71
7.69
7.66
7.26
7.26
O
N
H
O
O
4f, 79%
CDCl3, 400 MHz
0.93
0.95
0.97
0.98
1.95
1.02
1.00
1.00
1.96
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0.5
f1 (ppm)


183.32
178.97
161.65
136.44
136.32
135.64
133.76
133.68
132.82
130.13
130.02
129.74
129.64
129.40
129.21
128.42
128.31
127.53
126.56
125.17
114.35
77.48
76.84
O
N
H
O
O
4f, 79%
CDCl3, 400 MHz
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
f1 (ppm)



6a, 91%

DMSO-d_6, 400 MHz



6a, 91%

DMSO-d_6, 400 MHz