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Supporting Information

Intramolecular *Ipso*-Arylative Cyclization of Aryl-Alkynoates and *N*-Arylpropiolamides with Aryldiazonium Salts through Merged Gold/Visible Light Photoredox Catalysis

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Table of Contents

1. General information 2
2. All procedures 3
   2.1 General procedure for akynoic acid synthesis: 3
   2.2 General procedure for preparation of aryl-alkynoates and *N*-arylpropiolamides: 3
   2.3 General procedure for preparation of aryl diazonium salt: 11
   2.4 Intramolecular *ipso*-arylative cyclization of aryl-alkynoates and *N*-arylpropiolamides: 11
3. Product modifications 24
   3.1 Aromatization of 3a: 24
   3.2 Partial reduction of 3a: 25
4. Additional experiments 26
   4.1 Reactions of –OBn, –NTs, –SMe group bearing substrates: 26
   4.2 Failed substrates: 26
5. Mechanistic investigations 27
   5.1 Proof for intermediacy of Au(III)−Ar species (II): 27
   5.2 Procedure for the synthesis of phosphonium salt $[((4\text{-}OCH_3)C_6H_4)_3PC_6H_5]BF_4$ (I): 29
6. ORTEP diagram 31
7. Spectral data 32

1. General information

Practical considerations

Unless otherwise specified, all reactions were carried out in oven dried vials or reaction vessels with magnetic stirring under argon atmosphere. Screens were performed in 5 mL glass schlenk tube, and all other reactions were performed in round-bottom flasks with rubber septa. All experiments were monitored by analytical thin layer chromatography (TLC). TLC was performed on pre-coated silica gel plates. After elution, plate was visualized under UV illumination at 254 nm for UV active materials. Further visualization was achieved by staining in Iodine, potassium permanganate solution and charring on a hot plate. Solvents were removed in vacuo and heated with a water bath at 35 °C. Silica gel finer than 100-200 mesh was used for flash column chromatography. Columns were packed as slurry of silica gel in petroleum ether and equilibrated with the appropriate solvent mixture prior to use. The compounds were loaded neat or as a concentrated solution using the appropriate solvent system. The elution was assisted by applying pressure with an air pump.

Materials

Unless otherwise noted, materials obtained from commercial. Anhydrous dimethyl sulfoxide, triethylamine, dichloromethane, acetonitrile, and petroleum ether were dried by using standard protocol under nitrogen. Gold catalyst, ruthenium catalyst was purchased from Sigma–Aldrich Chemical Company. Deuterated solvents were used as supplied.

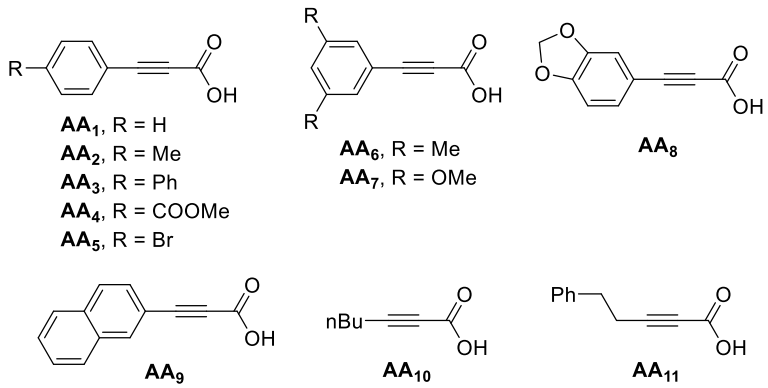
Instrumentation

Photocatalytic reaction was carried out using a household lamp with a 32 W CFL bulb was used for the light source of reactions. Melting points are uncorrected and recorded using digital Buchi Melting Point Apparatus B-540. ^{1}H NMR spectra, ^{13}C NMR spectra and ^{31}P NMR spectra were recorded on Bruker AV, 200/400/500 MHz spectrometers in appropriate solvents using TMS as internal standard or the solvent signals as secondary standards and the chemical shifts are shown in δ scales. Multiplicities of ^{1}H NMR signals are designated as s (singlet), d (doublet), dd (doublet of doublet), dt (doublet of triplet), t (triplet), quin (quintet), br. s. (broad signal), m (multiplet)… etc. HRMS (ESI) data were recorded on a Thermo Scientific Q-Exactive, Accela 1250 pump. Single-crystal data was collected on a Super Nova Dual source X-ray diffractometer system (Agilent Technologies) equipped with CCD area detector and graphite-monochromatized (MoK_{α}= 0.71073Å, CuK_{α}= 1.54184Å) radiation.

2. All procedures

2.1 General procedure for akynoic acid synthesis:

The alkynoic acid **AA$_1$–AA$_{11}$** were reported in the literature and prepared according to the literature known procedure.[1]



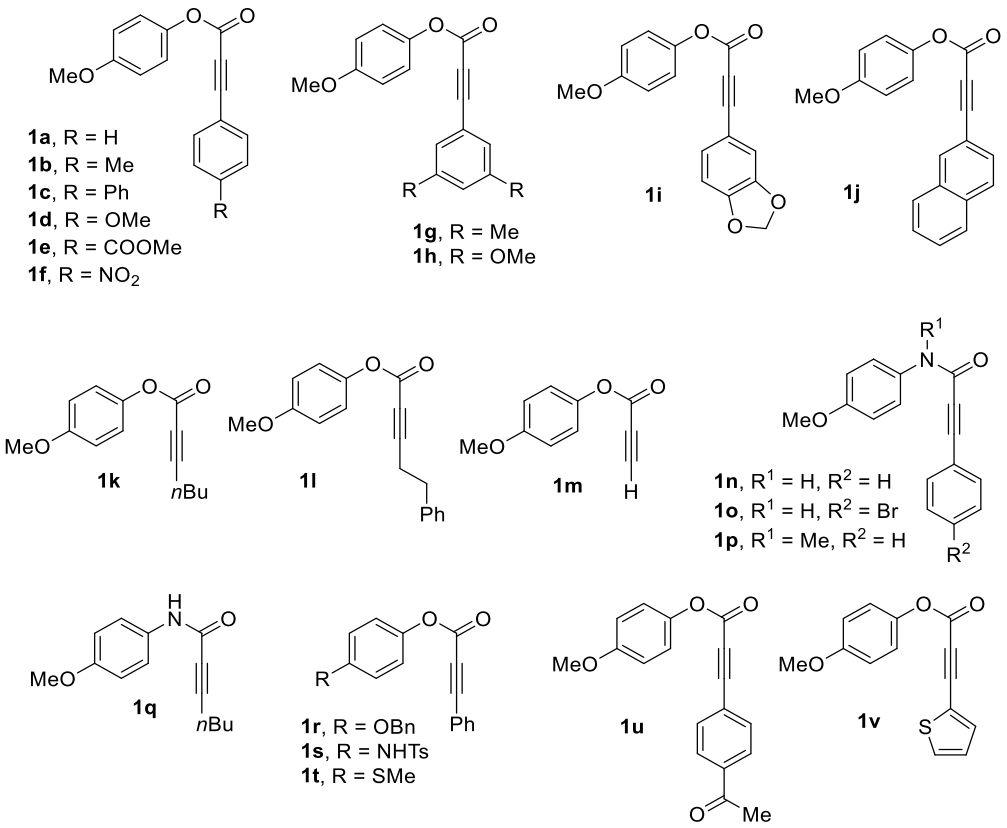
2.2 General procedure for preparation of aryl-alkynoates and *N*-arylpropiolamides:

The aryl-alkynoate **1a**, **1d**, **1m**, **1n** and **1p** were reported in the literature and prepared according to the literature known procedure.[2] The other aryl-alkynoate **1b**, **1c**, **1e-1l, 1o, 1q-1v** were prepared from literature known procedure with slight modifications.

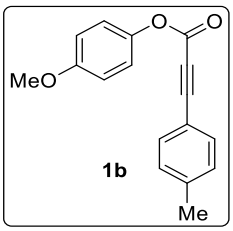
General procedure for Synthesis of Aryl-Alkynoate and N-Arylpropiolamides Substrates: Aryl-alkynoates and *N*-Arylpropiolamides were prepared according to reported procedures.[3] EDC.HCl (1.5 equiv) was added to a stirred solution of phenol (1.2 mmol) [or aniline (1.2 mmol)], propiolic acid derivative (1.1 equiv) and DMAP (0.30 equiv) in CH_2Cl_2 (5 mL) in a flask. The clear reaction mixture was stirred at 0 °C for 1 h and then kept at room temperature for 5 h. After evaporating all the volatiles under reduced pressure, purification by

1. (a) Y. Hajbi, C. Neagoie, B. Biannic, A. Chilloux, E. Vedrenne, B. Baldeyrou, C. Bailly, J.-Y. Merour, S. Rosca, S. Routier and A. Lansiaux, *Eur. J. Med. Chem*., 2010, **45**, 5428; (b) M. Arndt, E. Risto, T. Krause and L. J. Gooßen, *Chem Cat Chem*, 2012, **4**, 484; (c) X.-H. Liu, J.-G. Ma, Z. Niu, G.-M. Yang and P. Cheng, *Angew. Chem., Int. Ed.*, 2015, **54**, 988; (d) M. Zhou, M. Chen, Y. Zhou, K. Yang, J. Su, J. Du and Q. Song, *Org. Lett.*, 2015, **17**, 1786; (e) J. Lim, J. Choi, H.-S. Kim, I. S. Kim, K. C. Nam, J. Kim and S. Lee, *J. Org. Chem*., 2016, **81**, 303; (f) J. Meesin, P. Katrun, C. Pareseecharoen, M. Pohmakotr, V. Reutrakul, D. Soorukram and C. Kuhakarn, *J. Org.Chem.* 2016, **81**, 2744.
2. (a) M. A. Aparece and P. A. Vadola, *Org. Lett*., 2014, **16**, 6008; (b) L.-J. Wang, A.-Q. Wang, Y. Xia, X.-X. Wu, X.-Y. Liu and Y.-M. Liang, *Chem. Commun*., 2014, **50**, 13998; (c) J. Wang, X. Mou, B. Zhang, W. Liu, C. Yang, L. Xu, Z. Xu and S. Wang, *Tetrahedron Lett*., 2016, **57**, 1239.
3. (a) T. Morishita, H. Yoshida and J. Ohshita, *Chem. Commun*., 2010, **46**, 640; (b) J. H. Do, H. N. Kim, J. Yoon, J. S. Kim, H.-J. Kim, *Org. Lett.*, 2010, **12**, 932; (c) M. Kuhn, F. C. Falk and J. Paradies, *Org. Lett*., 2011, **13**, 4100; (d) K. Hirano, Y. Inaba, K. Takasu, S. Oishi, Y. Takemoto, N. Fujii and H. Ohno, *J. Org. Chem*. 2011, **76**, 9068; (e) A. C. Shaikh, S. Shalini, R. Vaidhyanathan, M. V. Mane, A. K. Barui, C. R. Patra, Y. Venkatesh, P. R. Bangal and N. T. Patil, *Eur. J. Org. Chem*., 2015, 4860.

flash column chromatography on silica gel (eluent: petroleum ether/ethyl acetate) was performed to afford the desired aryl alkynoate.

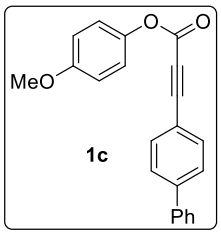


4-Methoxyphenyl 3-(*p*-tolyl)propiolate (**1b**):



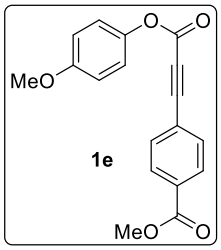
(**1b**): White solid, 200 mg, 62% yield; mp = 93-95 °C; R_f = 0.40 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.53 (d, *J* = 8.0 Hz, 2 H), 7.22 (d, *J* = 8.0 Hz, 2 H), 7.12 (d, *J* = 8.8 Hz, 2 H), 6.93 (d, *J* = 8.8 Hz, 2 H), 3.82 (s, 3 H), 2.41 (s, 3 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 157.6, 152.9, 143.7, 141.7, 133.2, 129.4, 122.3, 116.2, 114.5, 89.2, 80.0, 55.6, 21.8; **HRMS** (**ESI**) calcd for $C_{17}H_{15}O_3$ $(M + H)^+$ 267.1016, found 267.1014.

4-Methoxyphenyl 3-([1,1'-biphenyl]-4-yl)propiolate (**1c**):



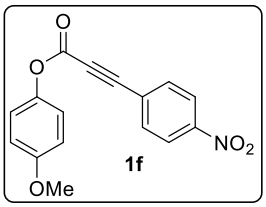
(**1c**): White solid, 265 mg, 67% yield; mp = 115-117 °C; R_f = 0.50 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.75 - 7.67 (m, 2 H), 7.67 - 7.58 (m, 4 H), 7.49 (t, *J* = 7.6 Hz, 2 H), 7.45 - 7.38 (m, 1 H), 7.14 (d, *J* = 9.2 Hz, 2 H), 6.94 (d, *J* = 9.2 Hz, 2 H), 3.83 (s, 3 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 157.6, 152.8, 143.8, 143.6, 139.7, 133.7, 129.0, 128.2, 127.3, 127.1, 122.2, 118.0, 114.6, 88.7, 80.9, 55.6; **HRMS** (**ESI**) calcd for $C_{22}H_{17}O_3(M + H)^+$ 329.1172, found 329.1171.

Methyl 4-(3-(4-methoxyphenoxy)-3-oxoprop-1-yn-1-yl)benzoate (**1e**):



(**1e**): White solid, 209 mg, 56% yield; mp = 108-110 °C; R_f = 0.40 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 8.08 (d, *J* = 8.4 Hz, 2 H), 7.70 (d, *J* = 8.4 Hz, 2 H), 7.12 (d, *J* = 9.2 Hz, 2 H), 6.93 (d, *J* = 9.2 Hz, 2 H), 3.96 (s, 3 H), 3.83 (s, 3 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 166.0, 157.7, 152.4, 143.5, 133.0, 132.0, 129.7, 123.8, 122.2, 116.0, 114.8, 114.6, 86.9, 82.2, 55.6, 52.5; **HRMS** (**ESI**) calcd for $C_{18}H_{15}O_5$ $(M + H)^+$ 311.0914, found 311.0914.

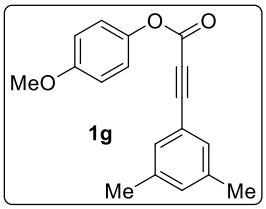
4-Methoxyphenyl 3-(4-nitrophenyl)propiolate (1f):



(**1f**): White solid, 150 mg, 42% yield; mp = 119-121 °C; R_f = 0.30 (petroleum ether/ethyl acetate = 80/30); **^{1}H NMR (400 MHz, $CDCl_3$) δ** = 8.43 - 8.18 (m, *J* = 7.9 Hz, 2 H), 7.91 - 7.74 (m, *J* =

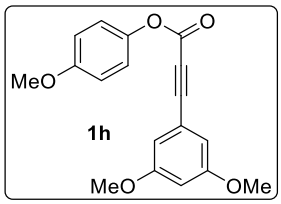
7.3 Hz, 2 H), 7.19 - 7.05 (m, *J* = 7.9 Hz, 2 H), 7.02 - 6.84 (m, *J* = 7.3 Hz, 2 H), 3.83 (br. s., 3 H); **^{13}C NMR (100 MHz, CDCl$_3$) δ** = 197 157.8, 152.0, 148.7, 143.4, 133.8, 125.9, 123.8, 122.1, 114.6, 85.0, 83.7, 77.3, 76.7, 55.6; **HRMS** (**ESI**) calcd for $C_{16}H_{12}O_5N$ $(M + H)^+$ 298.0710, found 298.0705.

4-Methoxyphenyl 3-(3,5-dimethylphenyl)propiolate (**1g**):



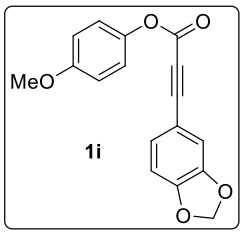
(**1g**): White solid, 237 mg, 70% yield; mp = 65-66 °C; R_f = 0.45 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **CDCl$_3$**) **δ** = 7.24 (br. s., 2 H), 7.10 (br. s., 3 H), 6.91 (br. s., 2 H), 3.79 (br. s., 3 H), 2.31 (br. s., 6 H); **^{13}C NMR** (**125 MHz**, **CDCl$_3$**) **δ** = 157.6, 152.8, 143.6, 138.3, 132.9, 130.8, 122.2, 118.8, 114.5, 89.2, 79.7, 55.5, 21.0; **HRMS** (**ESI**) calcd for $C_{18}H_{17}O_3$ $(M + H)^+$ 281.1172, found 281.1171.

4-Methoxyphenyl 3-(3,5-dimethoxyphenyl)propiolate (**1h**):



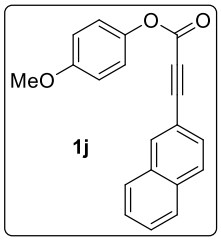
(**1h**): White solid, 252 mg, 67% yield; mp = 65-66 °C; R_f = 0.20 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **CDCl$_3$**) **δ** = 7.18 - 7.08 (m, 2 H), 6.98 - 6.89 (m, 2 H), 6.77 (d, *J* = 2.3 Hz, 2 H), 6.59 (t, *J* = 2.3 Hz, 1 H), 3.82 (s, 3 H), 3.81 (s, 6 H); **^{13}C NMR** (**125 MHz**, **CDCl$_3$**) **δ** = 160.6, 157.7, 152.7, 143.6, 122.2, 120.4, 114.6, 110.7, 104.6, 88.6, 79.6, 55.6, 55.5; **HRMS** (**ESI**) calcd for $C_{18}H_{17}O_5$ $(M + H)^+$ 313.1071, found 313.1070.

4-Methoxyphenyl 3-(benzo[d][1,3]dioxol-5-yl)propiolate (**1i**):



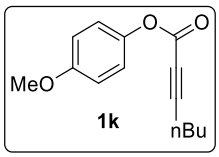
(**1i**): White solid, 214 mg, 60% yield; mp = 65-66 °C; R_f = 0.30 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.20 (d, *J* = 1.5 Hz, 1 H), 7.11 (d, *J* = 9.2 Hz, 2 H), 7.06 - 7.00 (m, 1 H), 6.92 (d, *J* = 9.2 Hz, 2 H), 6.83 (d, *J* = 8.0 Hz, 1 H), 6.04 (s, 2 H), 3.82 (s, 3 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 157.6, 152.9, 150.3, 147.7, 143.6, 129.2, 122.3, 114.5, 112.6, 112.2, 108.8, 101.8, 89.2, 79.3, 55.6; **HRMS** (**ESI**) calcd for $C_{17}H_{13}O_5$ $(M + H)^+$ 297.0757, found 297.0757.

4-Methoxyphenyl 3-(naphthalen-2-yl)propiolate (**1j**):



(**1j**): White solid, 164 mg, 45% yield; mp = 91-93 °C; R_f = 0.40 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 8.22 (s, 1 H), 7.87 (d, *J* = 8.4 Hz, 3 H), 7.67 - 7.52 (m, 3 H), 7.15 (d, *J* = 9.2 Hz, 2 H), 6.95 (d, *J* = 9.2 Hz, 2 H), 3.83 (s, 3 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 157.7, 152.8, 143.7, 134.6, 134.0, 132.6, 128.5, 128.3, 128.2, 128.1, 127.9, 127.1, 122.3, 116.5, 114.6, 89.1, 80.5, 55.6; **HRMS** (**ESI**) calcd for $C_{20}H_{15}O_3$ $(M + H)^+$ 303.1016, found 303.1015.

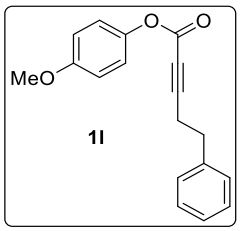
4-Methoxyphenyl hept-2-ynoate (**1k**):



(**1k**): Yellow liquid, 182 mg, 65% yield; R_f = 0.60 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.09 - 7.02 (m, 2 H), 6.92 - 6.87 (m, 2 H), 3.80 (s, 3 H), 2.40 (t, *J* = 7.1 Hz, 2 H), 1.67 - 1.55 (m, 2 H), 1.53 - 1.40 (m, 2 H), 0.95 (t, *J* = 7.4 Hz, 3 H); **^{13}C NMR**

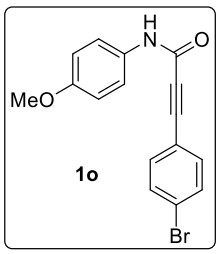
(**125 MHz**, **$CDCl_3$**) **δ =** 157.5, 152.5, 143.6, 122.2, 114.5, 92.2, 72.7, 55.5, 29.4, 21.9, 18.5, 13.4; **HRMS** (**ESI**) calcd for $C_{14}H_{17}O_3$ $(M + H)^+$ 233.1172, found 233.1171.

4-Methoxyphenyl 5-phenylpent-2-ynoate (**1l**):



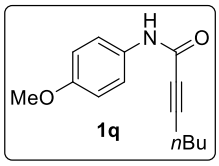
(**1l**):White solid, 210 mg, 62% yield; mp = 50-53 °C; R_f = 0.60 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.32 (br. s., 2 H), 7.23 (br. s., 3 H), 7.09 - 7.00 (m, 2 H), 6.93 - 6.84 (m, 2 H), 3.78 (br. s., 3 H), 2.92 (br. s., 2 H), 2.67 (br. s., 2 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 157.5, 152.3, 143.5, 139.4, 128.6, 128.3, 126.7, 122.1, 114.5, 90.9, 73.3, 55.5, 33.7, 20; **HRMS** (**ESI**) calcd for $C_{18}H_{17}O_3$ $(M + H)^+$ 281.1172, found 281.1171.

3-(4-Bromophenyl)-N-(4-methoxyphenyl)propiolamide (**1o**):



(**1o**): White solid, 226 mg, 57% yield; mp = 170-172 °C; R_f = 0.40 (petroleum ether/ethyl acetate = 80/40); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.68 (br. s., 1 H), 7.51 (d, *J* = 8.4 Hz, 2 H), 7.48 (d, *J* = 9.2 Hz, 2 H), 7.41 (d, *J* = 8.4 Hz, 2 H), 6.88 (d, *J* = 8.8 Hz, 2 H), 3.81 (s, 3 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 156.9, 150.6, 133.9, 131.9, 130.3, 124.9, 121.8, 119.0, 114.3, 84.4, 84.3, 55.5; **HRMS** (**ESI**) calcd for $C_{16}H_{13}O_2NBr$ $(M + H)^+$ 330.0124, found 330.0124.

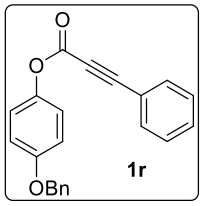
***N*-(4-Methoxyphenyl)hept-2-ynamide** (**1q**):



(**1q**): White solid, 197 mg, 70% yield; mp = 62-64 °C; R_f = 0.60 (petroleum ether/ethyl acetate = 60/40); **^{1}H NMR** (**400 MHz**, **$CDCl_3$**) **δ** = 7.49 (br. s., 1 H), 7.46 - 7.39 (m, 2 H), 6.88 - 6.83 (m, 2 H), 3.79 (s, 3 H), 2.33 (t, *J* = 7.1 Hz, 2 H), 1.62 - 1.51 (m, 2 H), 1.49 - 1.39 (m, 2 H), 0.93 (t, *J*

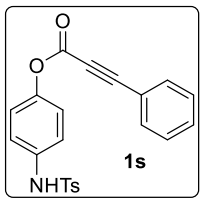
= 7.3 Hz, 3 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 156.6, 151.1, 130.5, 126.9, 121.7, 114.1, 88.4, 76.0, 55.4, 29.7, 22.0, 18.3, 13.5; **HRMS** (**ESI**) calcd for $C_{14}H_{18}O_2N$ $(M + H)^+$ 232.1332, found 232.1332.

4-(Benzyloxy)phenyl 3-phenylpropiolate (1r):



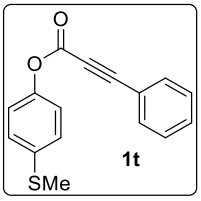
(**1r**): White solid, 240 mg, 61% yield; mp = 105-107 °C; R_f = 0.40 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR (500 MHz, $CDCl_3$) δ** = 7.64 (d, *J* = 7.2 Hz, 2 H), 7.55 - 7.47 (m, 1 H), 7.47 - 7.38 (m, 6 H), 7.38 - 7.32 (m, 1 H), 7.16 - 7.10 (m, *J* = 8.8 Hz, 2 H), 7.05 - 6.98 (m, *J* = 9.2 Hz, 2 H), 5.08 (s, 2 H); **^{13}C NMR (125 MHz, $CDCl_3$) δ** = 152.7, 143.8, 136.7, 133.2, 131.0, 128.7, 128.6, 128.1, 127.5, 122.3, 119.3, 116.0, 115.5, 88.6, 80.3, 70.4; **HRMS** (**ESI**) calcd for $C_{22}H_{16}O_3Na$ $(M + Na)^+$ 391.0992, found 391.0989.

4-((4-Methylphenyl)sulfonamido)phenyl 3-phenylpropiolate (1s):



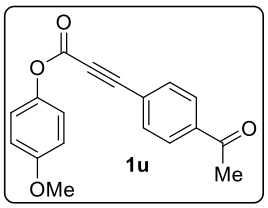
(**1s**): Thick liquid, 192 mg, 38% yield; R_f = 0.30 (petroleum ether/ethyl acetate = 70/30); **^{1}H NMR (500 MHz, $CDCl_3$) δ** = 7.69 (d, *J* = 8.0 Hz, 2 H), 7.64 - 7.57 (m, *J* = 7.6 Hz, 2 H), 7.49 (t, *J* = 7.4 Hz, 1 H), 7.41 (t, *J* = 7.6 Hz, 2 H), 7.26 - 7.20 (m, *J* = 7.6 Hz, 2 H), 7.17 - 7.11 (m, *J* = 8.4 Hz, 2 H), 7.10 - 7.04 (m, *J* = 8.8 Hz, 2 H), 2.38 (s, 3 H); **^{13}C NMR (125 MHz, $CDCl_3$) δ** = 152.1, 147.3, 144.0, 135.8, 134.7, 133.1, 131.1, 129.7, 128.7, 127.2, 122.6, 122.2, 119.1, 89.0, 80.0, 77.3, 76.7, 21.5; **HRMS** (**ESI**) calcd for $C_{22}H_{18}O_4NS$ $(M + H)^+$ 392.0951, found 392.0946.

4-(Methylthio)phenyl 3-phenylpropiolate (1t):



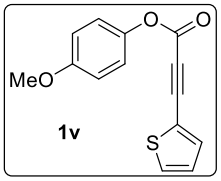
(**1t**): White solid, 225 mg, 70% yield; mp = 62-63 °C; R_f = 0.30 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR (500 MHz, CDCl$_3$) δ** = 7.64 (d, *J* = 7.3 Hz, 2 H), 7.55 - 7.46 (m, 1 H), 7.46 - 7.37 (m, 2 H), 7.35 - 7.28 (m, *J* = 8.5 Hz, 2 H), 7.17 - 7.08 (m, *J* = 8.5 Hz, 2 H), 2.50 (s, 3 H); **^{13}C NMR (125 MHz, CDCl$_3$) δ** = 152.3, 147.8, 136.5, 133.2, 131.1, 128.7, 127.9, 121.9, 119.2, 88.8, 80.2, 16.3; **HRMS** (**ESI**) calcd for $C_{16}H_{13}O_2S$ $(M + H)^+$ 269.0631, found 269.0630.

4-Methoxyphenyl 3-(4-acetylphenyl)propiolate (1u):



(**1u**): White solid, 223 mg, 63% yield; mp = 104-107 °C; R_f = 0.30 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR (500 MHz, CDCl$_3$) δ** = 8.02 - 7.96 (m, *J* = 8.4 Hz, 2 H), 7.77 - 7.68 (m, *J* = 8.4 Hz, 2 H), 7.16 - 7.07 (m, 2 H), 6.98 - 6.88 (m, *J* = 9.2 Hz, 2 H), 3.82 (s, 3 H), 2.64 (s, 3 H); **NMR (125 MHz, CDCl$_3$) δ =** 197.0, 157.7, 152.4, 143.5, 138.3, 133.2, 128.3, 123.9, 122.1, 114.6, 86.8, 82.4, 55.6, 26.7; **HRMS** (**ESI**) calcd for $C_{18}H_{15}O_4$ $(M + H)^+$ 295.0965, found 295.0961.

4-Methoxyphenyl 3-(thiophen-2-yl)propiolate (1v):

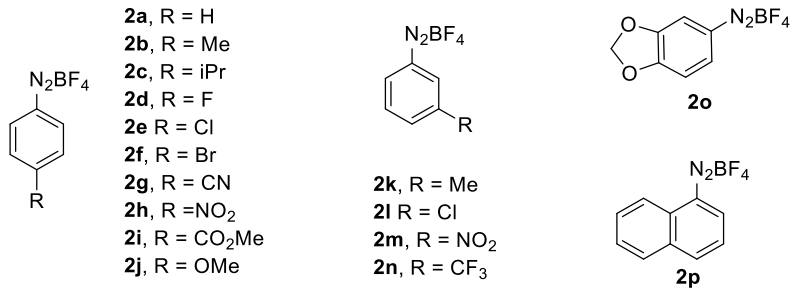


(**1v**): White solid, 19 mg, 63% yield; mp = 76-78 °C; R_f = 0.30 (petroleum ether/ethyl acetate = 70/30); **^{1}H NMR (500 MHz, CDCl$_3$) δ** = 7.55 (d, *J* = 3.4 Hz, 1 H), 7.52 (d, *J* = 5.0 Hz, 1 H), 7.15 - 7.07 (m, 3 H), 6.93 (d, *J* = 9.2 Hz, 2 H), 3.82 (s, 3 H); **^{13}C NMR (125 MHz, CDCl$_3$) δ** =

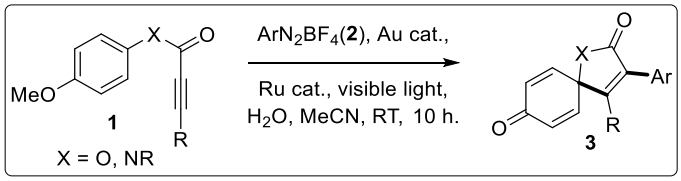
157.7, 152.7, 143.6, 137.0, 131.7, 127.6, 122.2, 119.1, 114.6, 84.6, 82.7, 55.6; **HRMS** (**ESI**) calcd for $C_{14}H_{11}O_3S$ $(M + H)^+$ 259.0423, found 259.0423.

2.3 General procedure for preparation of aryl diazonium salt:

The aryl diazonium salt **2a – 2p** were reported in the literature and prepared according to the literature known procedure.[4]



2.4 Intramolecular *ipso*-arylative cyclization of aryl-alkynoates and *N*-arylpropiolamides:

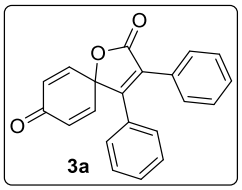


Representative procedure: To a schlenk tube containing a stir bar were added 4-methoxyphenyl 3-phenylpropiolate (**1a**) (25 mg, 0.10 mmol), phenyldiazonium salts (**2a**) (57 mg, 0.30 mmol, 3.0 equiv), $[(4\text{-}OCH_3)C_6H_4)]_3PAuCl$ (5 mg, 10 mol%), $Ru(bpy)_3(PF_6)_2$ (5 mg, 5 mol%), H_2O (18 mg, 1.00 mmol, 10.0 equiv) and CH_3CN (2 mL). The reaction vial was fitted with a cap, evacuated and back filled with N_2 and rt for 10 h under continuous irradiation with a 32 W CFL bulb was used for the light source of reaction. When the reaction was completed, the reaction

4. (a) J. Salabert, R. M. Sebastian, A. Vallribera, J. F. Cívicos and C. Na´ jera,´ *Tetrahedron*, 2013, **69**, 2655. (b) W. Erb, A. Hellal, M. Albini, J. Rouden and J. Blanchet, *Chem. - Eur. J.*, 2014, **20**, 6608. (c) R. Cai, M. Lu, E. Y. Aguilera, Y. Xi, N. G. Akhmedov, J. L. Petersen, H. Chen and X. Shi, *Angew. Chem., Int. Ed.*, 2015, **54**, 8772. (d) M. J. Hansen, M. M. Lerch, W. Szymanski and B. L. Feringa, *Angew. Chem., Int. Ed*., 2016, **55**, 13514. (e) L. Huang, M. Rudolph, F. Rominger and A. S. K. Hashmi, *Angew. Chem., Int. Ed*., 2016, **55**, 4808. (f) M. M. D. Pramanikab and N. Rastogi, *Chem. Commun*., 2016, **52**, 8557. (g) N. Zhang, Z.-J. Quan, Z. Zhang, Y.-X. Da and X.-C. Wang , *Chem. Commun*., 2016, **52**, 14234. (h) T. Cornilleau, P. Hermange and E. Fouquet, *Chem. Commun*., 2016, **52**, 10040. (i) M. D. Perretti, D. M. Monzón, F. P. Crisóstomo, V. S. Martín and R. Carrillo, *Chem. Commun*., 2016, **52**, 9036. (j) Z.-H. Yang, Z.-H. Chen, Y.-L. An and S.-Y. Zhao, *RSC Adv*., 2016, **6**, 23438.

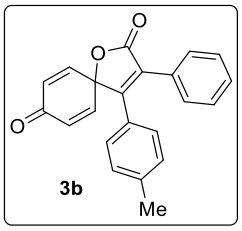
mixture was diluted with CH_2Cl_2 (10 mL) and filtered through a celite pad which was washed several times with CH_2Cl_2 (50 mL). The combined filtrate was concentrated in vacuo and the resulting residue was purified by column chromatography on silica (eluent: petroleum ether/ethyl acetate) to afford the product **3a** in 76% yield.

3,4-Diphenyl-1-oxaspiro[4.5]deca-3,6,9-triene-2,8-dione (**3a**):



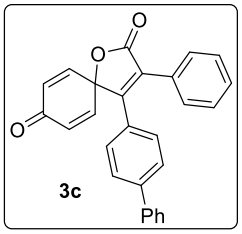
(**3a**): Off white solid, 24 mg, 76% yield; mp = 172-176 °C; R_f = 0.40 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**400 MHz**, **$CDCl_3$**) **δ** = 7.32 - 7.38 (m, 2 H) 7.17 - 7.32 (m, 6 H) 7.08 (d, *J* = 7.34 Hz, 2 H) 6.67 (d, *J* = 9.78 Hz, 2 H) 6.33 (d, *J* = 9.78 Hz, 2 H); **^{13}C NMR** (**100 MHz**, **$CDCl_3$**) **δ** = 183.9, 170.6, 158.5, 143.0, 132.0, 130.2, 130.1, 129.4, 129.3, 129.2, 129.0, 128.9, 128.5, 127.9, 81.3; **HRMS** (**ESI**) calcd for $C_{21}H_{15}O_3$ $(M + H)^+$ 315.1016, found 315.1017.

3-Phenyl-4-(*p*-tolyl)-1-oxaspiro[4.5]deca-3,6,9-triene-2,8-dione (**3b**):



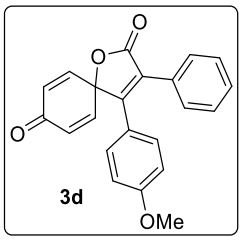
(**3b**): White solid, 24 mg, 72% yield; mp = 170-174 °C; R_f = 0.40 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.48 - 7.41 (m, 2 H), 7.37 - 7.29 (m, 3 H), 7.07 (q, *J* = 8.4 Hz, 4H), 6.73 (d, *J* = 10.3 Hz, 2H), 6.40 (d, *J* = 10.3 Hz, 2H), 2.32 (s, 3 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 184.0, 170.8, 158.6, 143.2, 140.7, 131.9, 129.7, 129.3, 129.2, 129.1, 128.8, 128.5, 127.8, 127.1, 81.2, 21.4; **HRMS** (**ESI**) calcd for $C_{22}H_{17}O_3$ $(M + H)^+$ 329.1172, found 329.1172.

4-([1,1'-Diphenyl]-4-yl)-3-phenyl-1-oxaspiro[4.5]deca-3,6,9-triene-2,8-dione (**3c**):



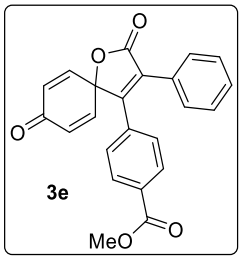
(**3c**): Off white solid, 26 mg, 66% yield; mp = 80-82 °C; R_f = 0.35 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**400 MHz**, **$CDCl_3$**) **δ** = 7.61 - 7.43 (m, 9 H), 7.42 - 7.32 (m, 4 H), 7.29 (s, 1 H), 6.81 (d, *J* = 9.8 Hz, 2 H), 6.48 (d, *J* = 9.8 Hz, 2 H); **^{13}C NMR** (**100 MHz**, **$CDCl_3$**) **δ** = 184.0, 170.7, 157.9, 143.2, 143.0, 139.4, 132.0, 129.7, 129.5, 129.3, 129.2, 129.0, 128.9, 128.9, 128.6, 128.4, 128.1, 127.8, 127.5, 127.2, 127.0, 81.1; **HRMS** (**ESI**) calcd for $C_{27}H_{19}O_3$ $(M + H)^+$ 391.1329, found 391.1329.

4-(3,5-Dimethoxyphenyl)-3-phenyl-1-oxaspiro[4.5]deca-3,6,9-triene-2,8-dione (**3d**):



(**3d**): White solid, 24 mg, 70% yield; mp = 153-155 °C; R_f = 0.30 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**200 MHz**, **$CDCl_3$**) **δ** = 7.42 - 7.43 (m, 2 H), 7.37 - 7.30 (m, 3 H), 7.34 - 7.30 (m, 1 H), 7.14 (d, *J* = 8.8 Hz, 2 H), 6.75 (d, *J* = 9.9 Hz, 2 H), 6.78 (d, *J* = 8.8 Hz, 2 H), 6.43 (d, *J* = 9.9 Hz, 2 H), 3.78 (s, 3 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 184.0, 170.8, 161.1, 158.0, 143.5, 131.8, 129.5, 129.4, 129.3, 129.2, 128.6, 128.0, 122.1, 114.4, 81.0, 55.3; **HRMS** (**ESI**) calcd for $C_{22}H_{17}O_4$ $(M + H)^+$ 345.1121, found 345.1122.

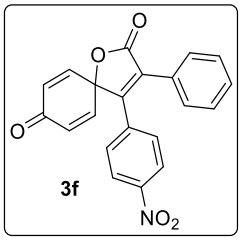
3,4-Diphenyl-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione (**3e**):



(**3e**): Yellow solid, 24 mg, 65% yield; mp = 171-173 °C; R_f = 0.35 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**200 MHz**, **$CDCl_3$**) **δ** = 7.97 (d, *J* = 8.3 Hz, 2 H), 7.50 - 7.18 (m, 7 H), 6.82 -

6.70 (d, J = 10.3 Hz, 2 H), 6.46 - 6.35 (d, J = 10.3 Hz, 2 H), 3.91 (s, 3 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 183.5, 170.2, 166.0, 157.1, 142.6, 134.6, 132.1, 131.7, 130.3, 130.2, 130.1, 129.8, 129.2, 128.9, 128.6, 128.4, 128.1, 127.3, 127.2, 127.0, 81.2, 52.4; **HRMS** (**ESI**) calcd for $C_{23}H_{17}O_5$ $(M + H)^+$ 373.1071, found 373.1073.

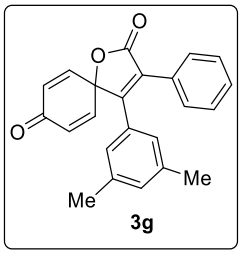
4-(4-Nitrophenyl)-3-phenyl-1-oxaspiro[4.5]deca-3,6,9-triene-2,8-dione (**3f**):



3f

(**3f**): Thick liquid, 20 mg, 58% yield; R_f = 0.30 (petroleum ether/ethyl acetate = 70/30); **^{1}H NMR** (**400 MHz**, **$CDCl_3$**) **δ** = 8.18 (d, J = 8.5 Hz, 2 H), 7.42 - 7.31 (m, 7 H), 6.75 (s, 1 H), 6.78 (s, 1 H), 6.48 - 6.37 (m, J = 9.8 Hz, 2 H); **^{13}C NMR** (**100 MHz**, **$CDCl_3$**) **δ** = 183.2, 169.7, 155.4, 148.6, 142.2, 136.7, 132.4, 131.5, 130.2, 129.3, 129.2, 128.9, 128.3, 127.9, 124.2, 81.1; **HRMS** (**ESI**) calcd for $C_{21}H_{14}O_5N$ $(M + H)^+$ 360.0866, found 360.0864.

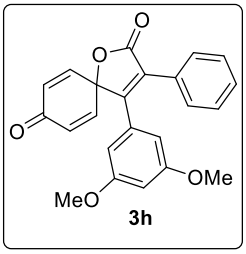
4-(3,5-Dimethylphenyl)-3-phenyl-1-oxaspiro[4.5]deca-3,6,9-triene-2,8-dione (**3g**):



3g

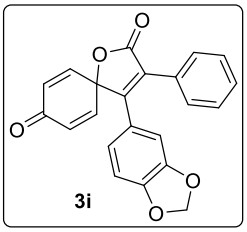
(**3g**): White solid, 27 mg, 79% yield; mp = 220-222 °C; R_f = 0.40 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.48 - 7.43 (m, 2 H), 7.36 - 7.28 (m, 3 H), 6.98 (s, 1 H), 6.73 (t, J = 5.0 Hz, 4 H), 6.39 (d, J = 9.9 Hz, 2 H), 2.20 (s, 6 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = ^{13}C NMR (126MHz ,CHLOROFORM-d) δ = 184.0, 170.8, 159.0, 143.1, 138.5, 131.9, 131.8, 130.0, 129.2, 129.1, 129.0, 128.7, 128.4, 125.4, 81.3, 21.2; **HRMS** (**ESI**) calcd for $C_{23}H_{19}O_3$ $(M + H)^+$ 343.1329, found 343.1328.

4-(3,5-Dimethoxyphenyl)-3-phenyl-1-oxaspiro[4.5]deca-3,6,9-triene-2,8-dione (**3h**):



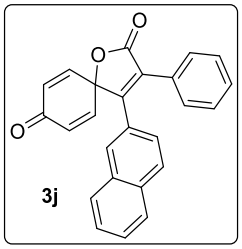
(**3h**): White solid, 26 mg, 69% yield; mp = 130-132 °C; R_f = 0.20 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**200 MHz**, **$CDCl_3$**) **δ** = 7.54 - 7.42 (m, 2 H), 7.38 - 7.32 (m, 3 H), 6.80 - 6.68 (m, 2 H), 6.50 - 6.37 (m, 3 H), 6.27 (d, *J* = 2.3 Hz, 2 H), 3.62 (s, 6 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 184.0, 170.6, 160.9, 158.2, 143.1, 131.9, 131.7, 129.4, 129.3, 129.2, 128.9, 128.5, 106.1, 101.9, 81.2, 55.3; **HRMS** (**ESI**) calcd for $C_{23}H_{19}O_5$ $(M + H)^+$ 375.1227, found 375.1227.

4-(Benzo[d][1,3]dioxol-5-yl)-3-phenyl-1-oxaspiro[4.5]deca-3,6,9-triene-2,8-dione (**3i**):



(**3i**): Off white solid, 28 mg, 79% yield; mp = 179-181 °C; R_f = 0.25 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.52 - 7.42 (m, 2 H), 7.41 - 7.28 (m, 3 H), 6.78 - 6.65 (m, 4 H), 6.60 (s, 1 H), 6.48 - 6.37 (m, 2 H), 5.97 (s, 2 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 184.0, 170.7, 157.9, 149.3, 148.1, 143.2, 131.9, 129.4, 129.2, 129.1, 128.7, 128.6, 123.5, 122.5, 108.9, 108.2, 101.7, 81.1; **HRMS** (**ESI**) calcd for $C_{22}H_{15}O_5$ $(M + H)^+$ 359.0914, found 359.0913.

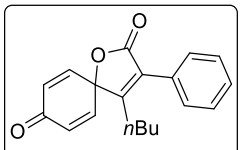
4-(Naphthalen-2-yl)-3-phenyl-1-oxaspiro[4.5]deca-3,6,9-triene-2,8-dione (**3j**):



(**3j**): Off white solid, 26 mg, 72% yield; mp = 169-171 °C; R_f = 0.30 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.81 (d, *J* = 8.4 Hz, 1 H), 7.77 - 7.64 (m, 3 H), 7.57 - 7.45 (m, 4 H), 7.36 - 7.28 (m, 3 H), 7.16 (dd, *J* = 1.5, 8.4 Hz, 1 H), 6.86 - 6.78 (m, 2

H), 6.47 - 6.40 (m, *J* = 9.9 Hz, 2 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 183.8, 170.7, 158.2, 143.2, 133.6, 132.7, 132.0, 129.5, 129.3, 128.9, 128.9, 128.6, 128.5, 127.8, 127.7, 127.7, 127.6, 127.0, 125.0, 81.3; **HRMS** (**ESI**) calcd for $C_{25}H_{17}O_3$ $(M + H)^+$ 365.1172, found 365.1172.

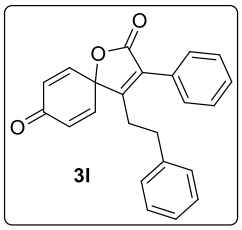
4-Butyl-3-phenyl-1-oxaspiro[**4.5**]**deca-3,6,9-triene-2,8-dione** (**3k**):



3k

(**3k**): White solid, 23 mg, 80% yield; mp = 120-122 °C; R_f = 0.50 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.51 - 7.41 (m, 5 H), 6.64 - 6.59 (m, *J* = 9.9 Hz, 2 H), 6.52 - 6.46 (m, *J* = 9.9 Hz, 2 H), 2.35 - 2.28 (m, 2 H), 1.40 - 1.32 (m, 2 H), 1.27 - 1.20 (m, 2 H), 0.78 (t, *J* = 7.2 Hz, 3 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 184.1, 171.2, 161.9, 143.6, 131.7, 129.7, 129.5, 129.2, 128.7, 128.5, 81.9, 30.5, 25.9, 22.8, 13.4; **HRMS** (**ESI**) calcd for $C_{19}H_{19}O_3$ $(M + H)^+$ 295.1329, found 295.1330.

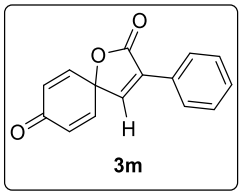
4-Phenethyl-3-phenyl-1-oxaspiro[**4.5**]**deca-3,6,9-triene-2,8-dione** (**3l**):



3l

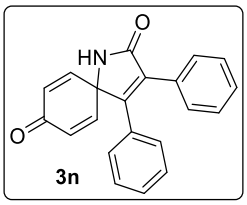
(**3l**): White solid, 26 mg, 76% yield; mp = 133-137 °C; R_f = 0.50 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.58 - 7.44 (m, 5 H), 7.26 - 7.16 (m, 3 H), 6.89 (d, *J* = 6.9 Hz, 2 H), 6.40 (d, *J* = 9.9 Hz, 2 H), 6.33 (d, *J* = 9.9 Hz, 2 H), 2.64 (s, 4 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 184.0, 171.1, 160.1, 143.1, 139.1, 131.8, 130.2, 129.5, 129.4, 128.9, 128.6, 128.4, 128.4, 126.8, 82.0, 32.9, 28.1; **HRMS** (**ESI**) calcd for $C_{23}H_{19}O_3$ $(M + H)^+$ 343.1329, found 343.1328.

3-Phenyl-1-oxaspiro[**4.5**]**deca-3,6,9-triene-2,8-dione** (**3m**):



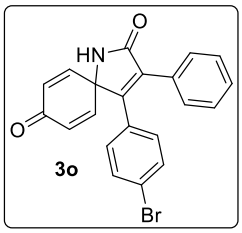
(**3m**): White solid, 7 mg, 29% yield; mp = 224-226 °C; R_f = 0.35 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**200 MHz**, **$CDCl_3$**) **δ** = 7.89 (ddd, *J* = 1.5, 2.4, 4.5 Hz, 2 H), 7.51 - 7.42 (m, 3 H), 7.22 (s, 1 H), 6.69 - 6.56 (m, 2 H), 6.49 - 6.36 (m, 2 H); **^{13}C NMR** (**100 MHz**, **$CDCl_3$**) **δ** = 183.8, 144.6, 142.9, 131.1, 130.4, 128.9, 128.4, 127.2, 79.0; **HRMS** (**ESI**) calcd for $C_{15}H_{11}O_3$ $(M + H)^+$ 239.0703, found 239.0702.

3,4-Diphenyl-1-azaspiro[**4.5**]**deca-3,6,9-triene-2,8-dione** (**3n**):



(**3n**): Off white solid, 24 mg, 78% yield; mp = 246-248 °C; R_f = 0.35 (petroleum ether/ethyl acetate = 60/40); **^{1}H NMR** (**200 MHz**, **$CDCl_3$**) **δ** = 7.39 (dd, *J* = 2.3, 6.9 Hz, 2 H), 7.33 - 7.22 (m, 6 H), 7.12 (d, *J* = 7.6 Hz, 2 H), 6.76 (br. s., 1 H), 6.73 (d, *J* = 9.9 Hz, 2 H), 6.35 (d, *J* = 9.9 Hz, 2 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 184.3, 171.8, 152.7, 145.8, 134.9, 131.6, 131.5, 130.1, 129.4, 128.8, 128.6, 128.3, 128.3, 62.7; **HRMS** (**ESI**) calcd for $C_{21}H_{16}O_2N$ $(M + H)^+$ 314.1176, found 314.1174.

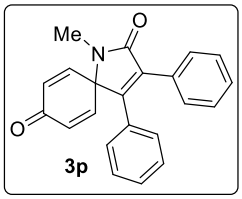
4-(**4-Bromophenyl**)**-3-phenyl-1-azaspiro**[**4.5**]**deca-3,6,9-triene-2,8-dione** (**3o**):



(**3o**): Off white solid, 29 mg, 74% yield; mp = 248-250 °C; R_f = 0.30 (petroleum ether/ethyl acetate = 60/40); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.43 - 7.35 (m, 4 H), 7.35 - 7.28 (m, 3 H), 7.01 (d, *J* = 8.4 Hz, 2 H), 6.88 (br. s., 1 H), 6.78 - 6.64 (m, *J* = 9.9 Hz, 2 H), 6.45 - 6.33 (m, *J* = 9.9 Hz, 2 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 184.0, 171.6, 151.2, 145.5, 135.5, 132.0, 131.7,

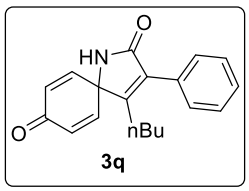
130.5, 129.9, 129.8, 129.4, 129.0, 128.4, 124.0, 77.3, 76.7, 62.5; **HRMS** (**ESI**) calcd for $C_{21}H_{16}O_2NBr$ $(M + H)^+$ 392.0281, found 392.0285.

1-Methyl-3,4-diphenyl-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione (**3p**):



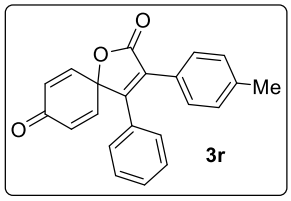
(**3p**): Off white solid, 25 mg, 76% yield; mp = 158-161 °C; R_f = 0.45 (petroleum ether/ethyl acetate = 60/40); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.41 (dd, *J* = 2.5, 7.1 Hz, 2 H), 7.32 - 7.21 (m, 6 H), 7.11 (d, *J* = 7.6 Hz, 2 H), 6.64 - 6.55 (d, *J* = 9.9 Hz, 2 H), 6.56 - 6.44 (d, *J* = 10.3 Hz, 2 H), 2.96 (s, 3 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 184.1, 169.6, 149.7, 145.7, 135.4, 133.1, 131.7, 130.5, 129.4, 129.2, 128.9, 128.6, 128.3, 128.1, 119.8, 67.0, 26.1; **HRMS** (**ESI**) calcd for $C_{22}H_{18}O_2N$ $(M + H)^+$ 328.1332, found 328.1331.

4-Butyl-3-phenyl-1-azaspiro[4.5]deca-3,6,9-triene-2,8-dione (**3q**):



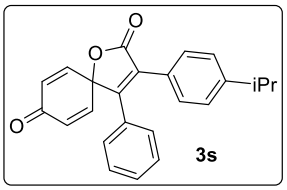
(**3q**): Off white solid, 24 mg, 81% yield; mp = 100-102 °C; R_f = 0.35 (petroleum ether/ethyl acetate = 60/40); **^{1}H NMR** (**400 MHz**, **$CDCl_3$**) **δ** = 7.47 - 7.42 (m, 4 H), 7.42 - 7.36 (m, 1 H), 7.11 (s, 1 H), 6.57 (s, 1 H), 6.60 (s, 1 H), 6.44 (s, 1 H), 6.46 (s, 1 H), 2.28 - 2.20 (m, 2 H), 1.35 - 1.29 (m, 2 H), 1.22 - 1.13 (m, 2 H), 0.76 (t, *J* = 7.3 Hz, 3 H); **^{13}C NMR** (**100 MHz**, **$CDCl_3$**) **δ** = 184.6, 172.7, 155.3, 146.4, 135.3, 131.4, 130.8, 128.7, 128.6, 128.5, 63.3, 31.0, 25.8, 22.7, 13.4; **HRMS** (**ESI**) calcd for $C_{19}H_{20}O_2N$ $(M + H)^+$ 294.1489, found 294.1487.

4-Phenyl-3-(*p*-tolyl)-1-oxaspiro[4.5]deca-3,6,9-triene-2,8-dione (**3r**):



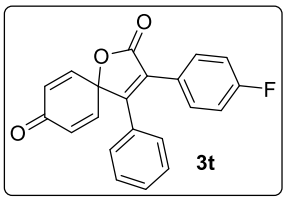
(**3r**): White solid, 24 mg, 73% yield; mp = 160-164 °C; R_f = 0.40 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.39 - 7.28 (m, 5 H), 7.18 - 7.14 (m, 2 H), 7.11 (d, *J* = 8.0 Hz, 2 H), 2.33 (s, 3 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 183.9, 170.8, 157.5, 143.2, 139.6, 131.9, 130.3, 130.1, 129.2, 129.1, 128.9, 127.9, 125.9, 81.3, 21.4; **HRMS** (**ESI**) calcd for $C_{22}H_{17}O_3$ $(M + H)^+$ 329.1172, found 329.1174.

3-(4-Isopropylphenyl)-4-phenyl-1-oxaspiro[4.5]deca-3,6,9-triene-2,8-dione (**3s**):



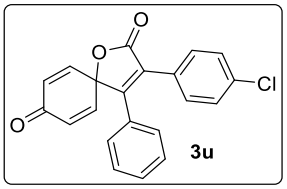
(**3s**): White solid, 24 mg, 69% yield; mp = 145-148 °C; R_f = 0.40 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.42 - 7.34 (m, 3 H), 7.33 - 7.28 (m, 2 H), 7.20 - 7.13 (m, 4 H), 6.74 (d, *J* = 9.9 Hz, 2 H), 6.39 (d, *J* = 9.9 Hz, 2 H), 2.88 (td, *J* = 7.0, 13.8 Hz, 1 H), 1.22 (d, *J* = 6.9 Hz, 6 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 183.9, 170.9, 157.5, 150.4, 143.2, 131.9, 130.4, 130.1, 129.1, 128.9, 127.9, 126.6, 126.2, 81.3, 33.9, 23.7; **HRMS** (**ESI**) calcd for $C_{24}H_{21}O_3$ $(M + H)^+$ 357.1485, found 357.1486.

3-(4-Fluorophenyl)-4-phenyl-1-oxaspiro[4.5]deca-3,6,9-triene-2,8-dione (**3t**):



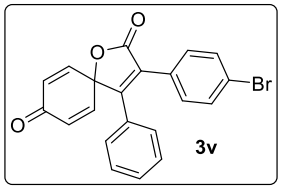
(**3t**): White solid, 19 mg, 59% yield; mp = 145-49 °C; R_f = 0.40 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.44 (dd, *J* = 5.3, 8.8 Hz, 2 H), 7.41 - 7.36 (m, 1 H), 7.34 - 7.29 (m, 2 H), 7.14 (d, *J* = 7.2 Hz, 2 H), 6.99 (t, *J* = 8.8 Hz, 2 H), 6.76 - 6.70 (m, *J* = 9.9 Hz, 2 H), 6.43 - 6.37 (m, *J* = 9.9 Hz, 2 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = ^{13}C NMR (126MHz ,CHLOROFORM-d) δ = 183.8, 170.5, 164.1, 162.1, 158.3, 142.8, 132.0, 131.2, 131.2, 130.3, 130.0, 129.1, 128.2, 127.8, 124.9, 115.8, 115.6, 81.4; **HRMS** (**ESI**) calcd for $C_{21}H_{14}O_3F$ $(M + H)^+$ 333.0921, found 333.0923.

3-(4-Chlorophenyl)-4-phenyl-1-oxaspiro[4.5]deca-3,6,9-triene-2,8-dione (**3u**):



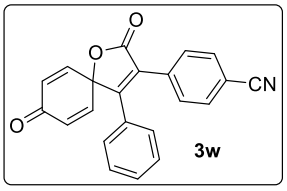
(**3u**): White solid, 21 mg, 63% yield; mp = 174-178 °C; R_f = 0.40 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.35 - 7.28 (m, 3H), 7.27 - 7.22 (m, 2 H), 7.22 - 7.17 (m, 2 H), 7.06 (d, *J* = 7.6 Hz, 2 H), 6.70 - 6.60 (m, 2 H), 6.37 - 6.28 (m, 2 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 183.7, 170.3, 158.9, 142.6, 135.6, 132.1, 130.5, 130.5, 129.9, 129.1, 128.8, 128.2, 127.8, 127.3, 81.4; **HRMS** (**ESI**) calcd for $C_{21}H_{14}O_3Cl$ $(M + H)^+$ 349.0626, found 349.0627.

3-(4-Bromophenyl)-4-phenyl-1-oxaspiro[4.5]deca-3,6,9-triene-2,8-dione (**3v**):



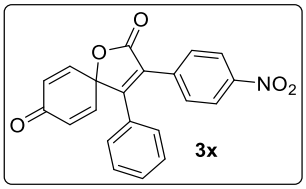
(**3v**): White solid, 24 mg, 62% yield; mp = 152-156 °C; R_f = 0.40 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.45 - 7.37 (m, 3 H), 7.34 - 7.29 (m, 4 H), 7.17 - 7.11 (m, 2 H), 6.76 - 6.70 (m, 2 H), 6.40 (d, *J* = 9.9 Hz, 2 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 183.7, 170.2, 159.0, 142.6, 132.1, 131.8, 130.7, 130.5, 129.8, 129.1, 128.2, 127.8, 123.9, 81.5; **HRMS** (**ESI**) calcd for $C_{21}H_{14}O_3Br$ $(M + H)^+$ 393.0121, found 393.0122.

4-(2,8-Dioxo-4-Phenyl-1-oxaspiro[4.5]deca-3,6,9-trien-3-yl)benzonitrile (**3w**):



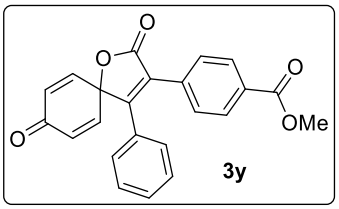
(**3w**): Off white solid, 21 mg, 63% yield; mp = 203-207 °C; R_f = 0.30 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.57 (q, *J* = 8.8 Hz, 4 H), 7.47 - 7.40 (m, 1 H), 7.34 (t, *J* = 7.6 Hz, 2 H), 7.16 - 7.08 (m, 2 H), 6.74 (d, *J* = 9.9 Hz, 2 H), 6.43 (d, *J* = 9.9 Hz, 2 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 183.5, 169.7, 161.3, 142.1, 133.4, 132.3, 132.2, 130.9, 129.8, 129.3, 127.7, 118.1, 113.0, 81.7; **HRMS** (**ESI**) calcd for $C_{22}H_{14}O_3N$ $(M + H)^+$ 340.0968, found 340.0969.

3-(4-Nitrophenyl)-4-phenyl-1-oxaspiro[4.5]deca-3,6,9-triene-2,8-dione (**3x**):



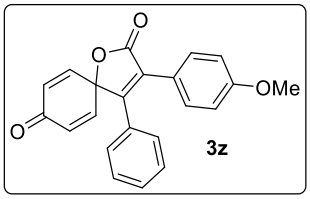
(**3x**): White solid, 21 mg, 58% yield; mp = 210-214 °C; R_f = 0.20 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 8.15 (d, *J* = 9.2 Hz, 2 H), 7.63 (d, *J* = 8.5 Hz, 2 H), 7.48 - 7.39 (m, 1 H), 7.35 (t, *J* = 7.6 Hz, 2 H), 7.14 (d, *J* = 7.9 Hz, 2 H), 6.74 (s, 1 H), 6.76 (s, 1 H), 6.44 (d, *J* = 9.8 Hz, 2 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 183.5, 169.7, 161.8, 147.9, 142.0, 135.2, 132.4, 131.0, 130.2, 129.3, 129.3, 127.7, 127.4, 123.6, 81.7; **HRMS** (**ESI**) calcd for $C_{21}H_{14}O_5N$ $(M + H)^+$ 360.0866, found 360.0866.

Methyl 4-(2,8-dioxo-4-phenyl-1-oxaspiro[4.5]deca-3,6,9-trien-3-yl)benzoate (**3y**):



(**3y**): White solid, 21 mg, 58% yield; mp = 173-175 °C; R_f = 0.30 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.97 (d, *J* = 8.4 Hz, 2 H), 7.51 (d, *J* = 8.4 Hz, 2 H), 7.42 - 7.36 (m, 1 H), 7.31 (t, *J* = 7.6 Hz, 2 H), 7.13 (d, *J* = 7.2 Hz, 2 H), 6.75 (d, *J* = 9.9 Hz, 2 H), 6.42 (d, *J* = 9.9 Hz, 2 H), 3.91 (s, 3 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 183.7, 170.1, 166.4, 160.2, 142.5, 133.3, 132.1, 130.7, 130.6, 129.7, 129.6, 129.2, 129.1, 128.5, 127.8, 81.5, 52.3; **HRMS** (**ESI**) calcd for $C_{23}H_{17}O_5$ $(M + H)^+$ 373.1071, found 373.1069.

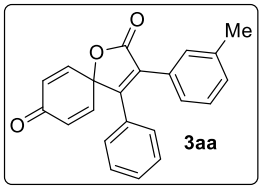
1-(2-Methoxyphenyl)benzo[a]oxazolo[4,3,2-cd]indolizin-10-ium tetrafluoroborate (**3z**):



(**3z**): White solid, 23 mg, 67% yield; mp = 180-184 °C; R_f = 0.20 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.44 - 7.35 (m, 3 H), 7.33 - 7.28 (m, 2 H), 7.16 (d, *J* = 7.2 Hz, 2H), 6.82 (d, *J* = 8.8 Hz, 2 H), 6.73 (d, *J* = 9.9 Hz, 2 H), 6.39 (d, *J* = 9.9 Hz, 2 H), 3.80

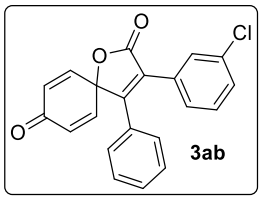
(s, 3 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 183.9, 170.9, 160.4, 156.3, 143.2, 131.8, 130.6, 130.5, 130.1, 129.0, 128.7, 127.9, 121.2, 113.9, 81.2, 55.2; **HRMS** (**ESI**) calcd for $C_{22}H_{17}O_4$ $(M + H)^+$ 345.1121, found 345.1122.

4-Phenyl-3-(*m*-tolyl)-1-oxaspiro[4.5]deca-3,6,9-triene-2,8-dione (**3aa**):



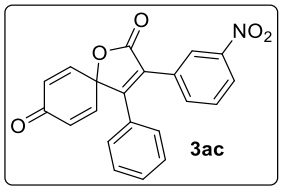
(**3aa**): White solid, 26 mg, 80% yield; mp = 177-181 °C; R_f = 0.40 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.38 - 7.33 (m, 1 H), 7.31 - 7.24 (m, 3 H), 7.19 - 7.08 (m, 5 H), 6.77 - 6.70 (m, 2 H), 6.44 - 6.36 (m, 2 H), 2.27 (s, 3 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 183.9, 170.7, 158.2, 143.1, 138.2, 131.9, 130.2, 129.7, 129.5, 128.9, 128.8, 128.3, 127.9, 126.3, 81.2, 21.4; **HRMS** (**ESI**) calcd for $C_{22}H_{17}O_3$ $(M + H)^+$ 329.1172, found 329.1172.

3-(3-Chlorophenyl)-4-phenyl-1-oxaspiro[4.5]deca-3,6,9-triene-2,8-dione (**3ab**):



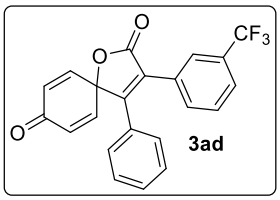
(**3ab**): White solid, 23 mg, 67% yield; mp = 106-110 °C; R_f = 0.40 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.50 - 7.46 (m, 1 H), 7.43 - 7.30 (m, 5 H), 7.23 (d, *J* = 7.6 Hz, 1 H), 7.15 (s, 1 H), 7.15 - 7.13 (m, 1 H), 6.73 (d, *J* = 9.9 Hz, 2 H), 6.42 (d, *J* = 9.9 Hz, 2 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 183.7, 170.1, 159.7, 142.6, 142.5, 134.5, 132.2, 132.1, 130.6, 129.7, 129.6, 129.6, 129.2, 129.1, 127.8, 127.3, 81.4; **HRMS** (**ESI**) calcd for $C_{21}H_{14}O_3Cl$ $(M + H)^+$ 349.0626, found 349.0627.

3-(3-Nitrophenyl)-4-phenyl-1-oxaspiro[4.5]deca-3,6,9-triene-2,8-dione (**3ac**):



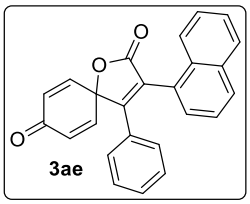
(**3ac**): White solid, 20 mg, 56% yield; mp = 112-115 °C; R_f = 0.20 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 8.33 - 8.27 (m, 1 H), 8.20 (dd, *J* = 1.3, 8.2 Hz, 1 H), 7.80 (d, *J* = 7.6 Hz, 1 H), 7.51 (t, *J* = 8.0 Hz, 1 H), 7.46 - 7.41 (m, 1 H), 7.35 (t, *J* = 7.8 Hz, 2 H), 7.15 (d, *J* = 7.2 Hz, 2 H), 6.76 (d, *J* = 9.9 Hz, 2 H), 6.44 (d, *J* = 9.9 Hz, 2 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 183.5, 169.8, 161.2, 148.2, 142.1, 135.0, 132.4, 130.9, 130.5, 129.6, 129.4, 129.2, 127.6, 127.2, 124.2, 124.1, 81.7; **HRMS** (**ESI**) calcd for $C_{21}H_{14}O_5N$ $(M + H)^+$ 360.0866, found 360.0868.

4-Phenyl-3-(3-(trifluoromethyl)phenyl)-1-oxaspiro[4.5]deca-3,6,9-triene-2,8-dione (**3ad**):



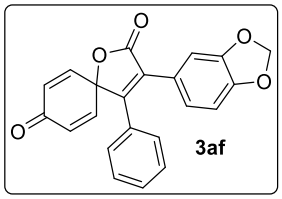
(**3ad**): White solid, 19 mg, 51% yield; mp = 69-73 °C; R_f = 0.30 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.70 (s, 1 H), 7.64 (d, *J* = 8.0 Hz, 1 H), 7.59 (d, *J* = 7.6 Hz, 1 H), 7.47 - 7.38 (m, 2 H), 7.33 (t, *J* = 7.8 Hz, 2 H), 7.14 (d, *J* = 7.2 Hz, 2 H), 6.75 (d, *J* = 9.9 Hz, 2 H), 6.43 (d, *J* = 9.9 Hz, 2 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 183.7, 170.1, 160.2, 142.4, 132.4, 132.2, 130.7, 129.6, 129.5, 129.2, 129.0, 128.0, 127.7, 126.1, 126.1, 81.6; **HRMS** (**ESI**) calcd for $C_{22}H_{14}O_3F_3$ $(M + H)^+$ 383.0890, found 383.0891.

3-(Naphthalen-1-yl)-4-phenyl-1-oxaspiro[4.5]deca-3,6,9-triene-2,8-dione (**3ae**):



(**3ae**): Off white solid, 19 mg, 52% yield; mp = 225-227 °C; R_f = 0.35 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **$CDCl_3$**) **δ** = 7.95 - 7.86 (m, 2 H), 7.63 (d, *J* = 8.4 Hz, 1 H), 7.53 - 7.47 (m, 2 H), 7.45 - 7.41 (m, 2 H), 7.26 - 7.18 (m, 1 H), 7.17 - 7.05 (m, 4 H), 6.96 - 6.86 (m, 2 H), 6.57 6.48 (d, *J* = 9.9 Hz, 2 H); **^{13}C NMR** (**125 MHz**, **$CDCl_3$**) **δ** = 184.0, 170.8, 160.4, 143.7, 143.3, 133.7, 132.0, 130.6, 130.6, 130.0, 129.8, 129.7, 128.8, 128.7, 128.4, 127.6, 127.2, 126.8, 126.3, 125.4, 124.4, 81.4; **HRMS** (**ESI**) calcd for $C_{25}H_{17}O_3$ $(M + H)^+$ 365.1172, found 365.1172.

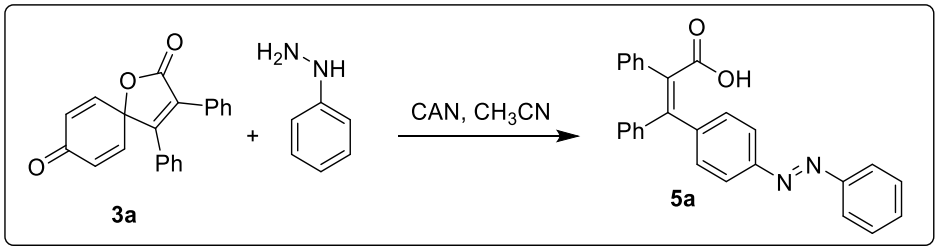
3-(Benzo[d][1,3]dioxol-5-yl)-4-phenyl-1-oxaspiro[4.5]deca-3,6,9-triene-2,8-dione (3af):



(**3af**): White solid, 20 mg, 57% yield; mp = 209-211 °C; R_f = 0.20 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR (500 MHz, DMSO-d$_6$) δ** = 8.88 (t, *J* = 8.2 Hz, 1 H), 8.78 (d, *J* = 7.6 Hz, 1 H), 8.66 (d, *J* = 8.4 Hz, 2 H), 8.36 (d, *J* = 7.2 Hz, 2 H), 8.01 (t, *J* = 7.8 Hz, 1 H), 7.91 - 7.80 (m, 4 H), 2.99 (s, 3 H); **^{13}C NMR (125 MHz, DMSO-d$_6$) δ** = 150.2, 146.4, 142.5, 137.9, 135.6, 133.3, 132.7, 132.6, 132.4, 130.5, 127.6, 127.0, 124.6, 122.1, 121.3, 118.4, 108.4, 19.4; **HRMS (ESI)** calcd for $C_{22}H_{15}O_5$ $(M + H)^+$ 359.0914, found 359.0912.

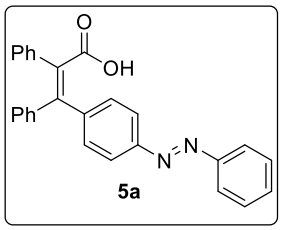
3. Product modifications

3.1 Aromatization of 3a:



The azobenzene **5a** was synthesized by incubating **3a** (100 mg, 3.14 mmol) with phenylhydrazine (100 mM) in 2 mL acetonitrile in the presence of 3 mol% of cerium(IV) ammonium nitrate at rt for 16 h. After reaction was completed, solution was concentrated under reduced pressure. The crude product was subjected to column chromatography on silica gel (eluent: petroleum ether/ethyl acetate) to yield the desired **5a** (62 mg, 48% yield).

(Z)-2,3-Diphenyl-3-(4-((E)-phenyldiazenyl)phenyl)acrylic acid (5a):

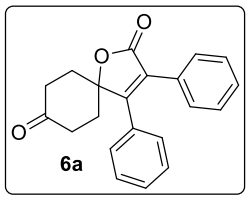


(**5a**): Thick liquid, 62 mg, 48% yield; R_f = 0.40 (petroleum ether/ethyl acetate = 60/40); ^{1}H **NMR** (**500 MHz**, **CDCl$_3$**) **δ** = 7.98 - 7.94 (m, *J* = 7.2 Hz, 2 H), 7.92 (d, *J* = 8.4 Hz, 2 H), 7.56 - 7.49 (m, 3 H), 7.46 (d, *J* = 8.4 Hz, 2 H), 7.23 - 7.13 (m, 8 H), 7.04 - 6.98 (m, *J* = 7.2 Hz, 2 H); **^{13}C NMR** (**125 MHz**, **CDCl$_3$**) **δ** = 174.7, 152.7, 152.3, 147.4, 144.7, 140.1, 137.1, 133.0, 131.1, 130.9, 130.0, 129.1, 128.3, 128.0, 127.9, 127.7, 122.9, 122.8; **HRMS** (**ESI**) calcd for $C_{27}H_{21}O_2N_2$ $(M + H)^+$ 405.1598, found 405.1596.

3.2 Partial reduction of 3a:

To a solution of **3a** (100 mg, 0.318 mmol) in MeOH (8 mL), 5% Pd-C (16 mg) was added and the resulting suspension was kept stirring under H_2 atmosphere at rt for 2 h. The catalyst was filtered off and the filtrate was concentrated to afford a residue which was subjected to column chromatography on silica gel (eluent: petroleum ether/ethyl acetate) to gave the product **6a** (51 mg, 51% yield).

3, 4-Diphenyl-1-oxaspiro[4.5]dec-3-ene-2,8-dione (**6a**):

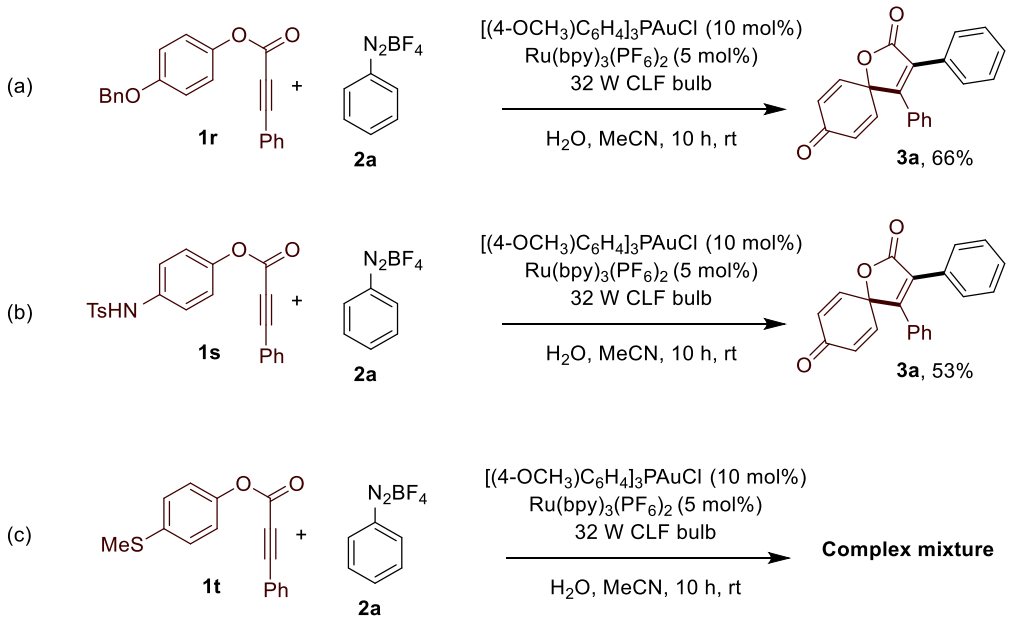


(**6a**): Off white solid, 51 mg, 51% yield; mp = 246-248 °C; R_f = 0.45 (petroleum ether/ethyl acetate = 80/20); **^{1}H NMR** (**500 MHz**, **CDCl$_3$**) **δ** = 7.48 - 7.35 (m, 5 H), 7.31 - 7.20 (m, 4 H), 7.16 (dd, *J* = 3.1, 6.5 Hz, 2 H), 2.96 (dt, *J* = 6.3, 14.4 Hz, 2 H), 2.50 - 2.42 (m, 2 H), 2.29 (dt, *J* = 5.0, 13.7 Hz, 2 H), 2.21 - 2.13 (m, 2 H); **^{13}C NMR** (**125 MHz**, **CDCl$_3$**) **δ** = 208.5, 170.8, 164.4, 131.9, 129.4, 129.2, 129.1, 128.8, 128.2, 127.7, 127.3, 85.2, 37.5, 33.9; **HRMS** (**ESI**) calcd for $C_{21}H_{19}O_3$ $(M + H)^+$ 319.1329, found 319.1327.

4. Additional experiments

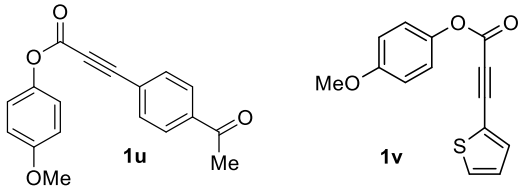
4.1 Reactions of –OBn, –NTs, –SMe group bearing substrates:

Substrates containing electron-rich group other than –OMe has been prepared. For example, substrates 4-(benzyloxy)phenyl 3-phenylpropiolate (**1r**), 4-((4-methylphenyl)sulfonamido)phenyl 3-phenylpropiolate (**1s**) and 4-(methylthio)phenyl 3-phenylpropiolate (**1t**) were examined in which **1r** leads to desired dearomatization product **3a** in 66% yield. However **1s** leads to imine hydrolyzed product **3a** in 53% yield and **1t** doesn't work under this condition.



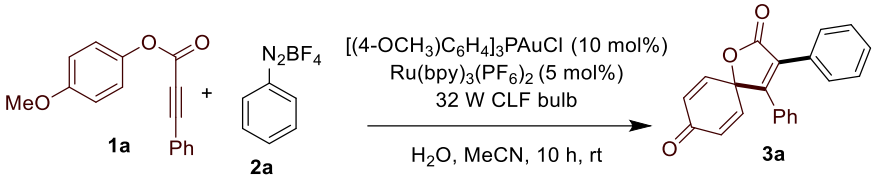
4.2 Failed substrates:

Under the standard reaction condition, aryl-alkynoates such 4-methoxyphenyl 3-(4-acetylphenyl) (**1u**) and 4-methoxyphenyl 3-(thiophen-2-yl)propiolate (**1v**) were unable to furnish the desired products.



5. Mechanistic investigations

5.1 Proof for intermediacy of Au(III)−Ar species (II):

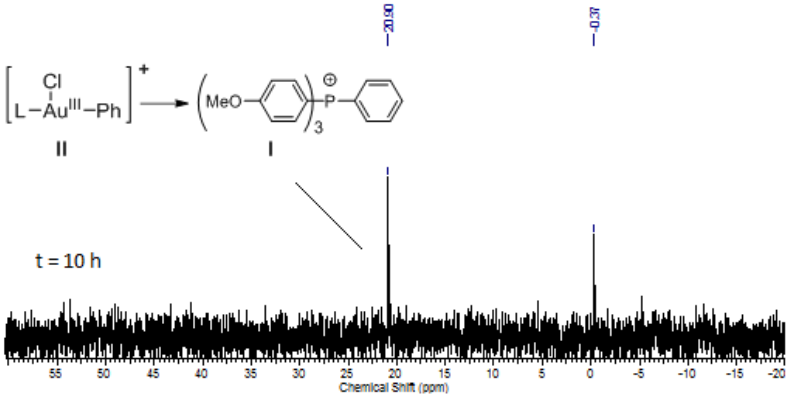


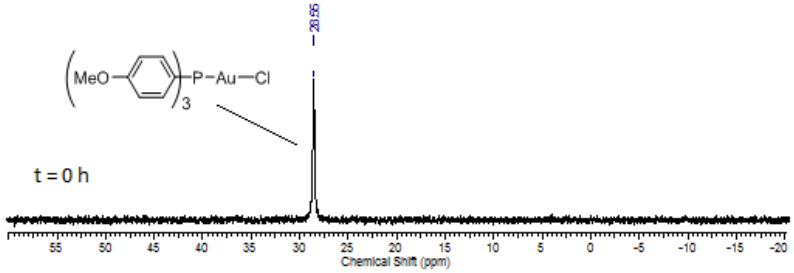
The transient Au(III)−Ar species **II** is highly unstable and very difficult to isolate.[5] To prove the intermediacy of Au(III)−Ar species, the standard reaction was monitored under ^{31}P NMR. After 10 h, when **1a** was fully consumed, ^{31}P NMR signal of $[(4\text{-}OCH_3)C_6H_4)]_3PAuCl$ (^{31}P NMR at δ 28.5 ppm) disappeared and a new peak appeared at δ 20.9 ppm; which can be accounted for the species **I**.[6] It was further detected in HRMS. The observed peak at δ 20.9 ppm was found to be characteristic of a standard phosphonium ion $[\{(4\text{-}OCH_3)C_6H_4\}_3PC_6H_5]BF_4$ (**I**) sample which was synthesized using known procedures.[7d] The formation of **I** could be as a result of reductive elimination from **II** implying the fact that the reaction is proceeding via the intermediacy of Au(III)−Ar species **II**.[7]

After 10 h**: ^{31}P NMR (162 MHz, CH_3CN) δ** = 20.9; **HRMS** (**ESI**) calcd for $C_{27}H_{66}O_3P^+$ $(M)^+$ 429.1614, found 429.1605.

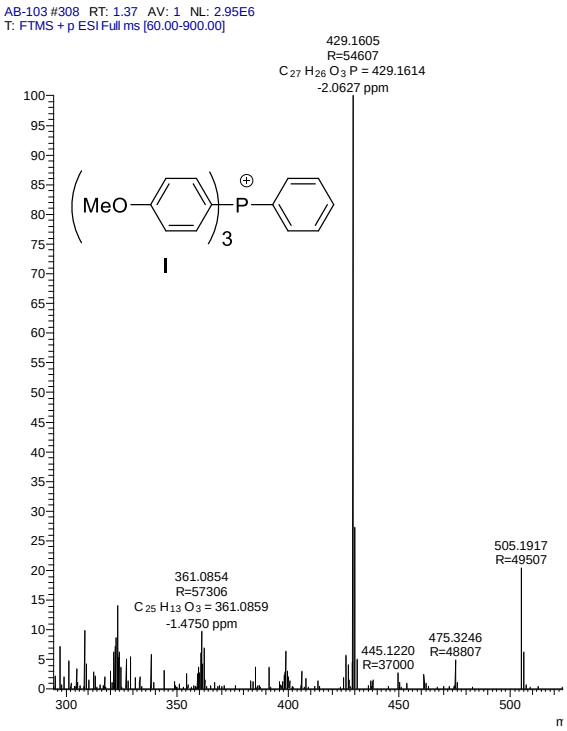
5. W. J. Wolf, M. S. Winston and F. D. Toste, *Nat. Chem*., 2014, **6**, 159.
6. A. F. Fearnley, J. An, M. Jackson, P. Lindovska and R. M. Denton, *Chem. Commun*., 2016, **52**, 4987.
7.(a) X.-Z. Shu, M. Zhang, Y. He, H. Frei and F. D. Toste, *J. Am. Chem. Soc*., 2014, **136**, 5844; (b) Y. He, H. Wu and F. D. Toste, Chem. Sci., 2015, 6, 1194; (c) V. Gauchot, D. R. Sutherland and A. -L. Lee, *Chem. Sci*. 2017, **8**, 2885. (d) M. O. Akram, P. S. Mali and N. T. Patil, *Org. Lett*., 2017, **19**, 3075.

^{31}P NMR:

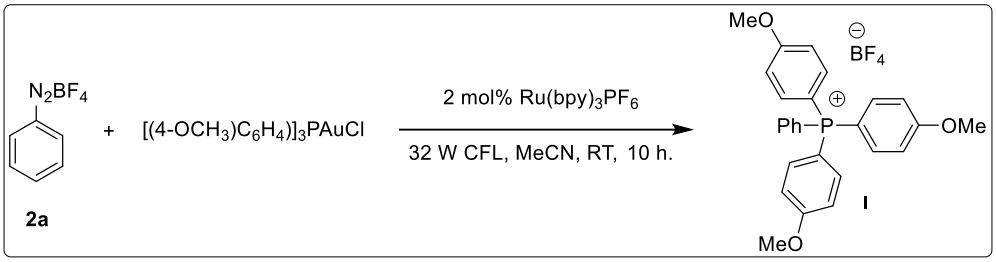

20.90
-0.37
II
I
t = 10 h
Chemical Shift (ppm)


28.65
t = 0 h
Chemical Shift (ppm)

HRMS:


AB-103 #308 RT: 1.37 AV: 1 NL: 2.95E6
T: FTMS + p ESI Full ms [60.00-900.00]
429.1605
R=54607
C 27 H 26 O 3 P = 429.1614
-2.0627 ppm
I
361.0854
R=57306
C 25 H 13 O 3 = 361.0859
-1.4750 ppm
445.1220
R=37000
475.3246
R=48807
505.1917
R=49507

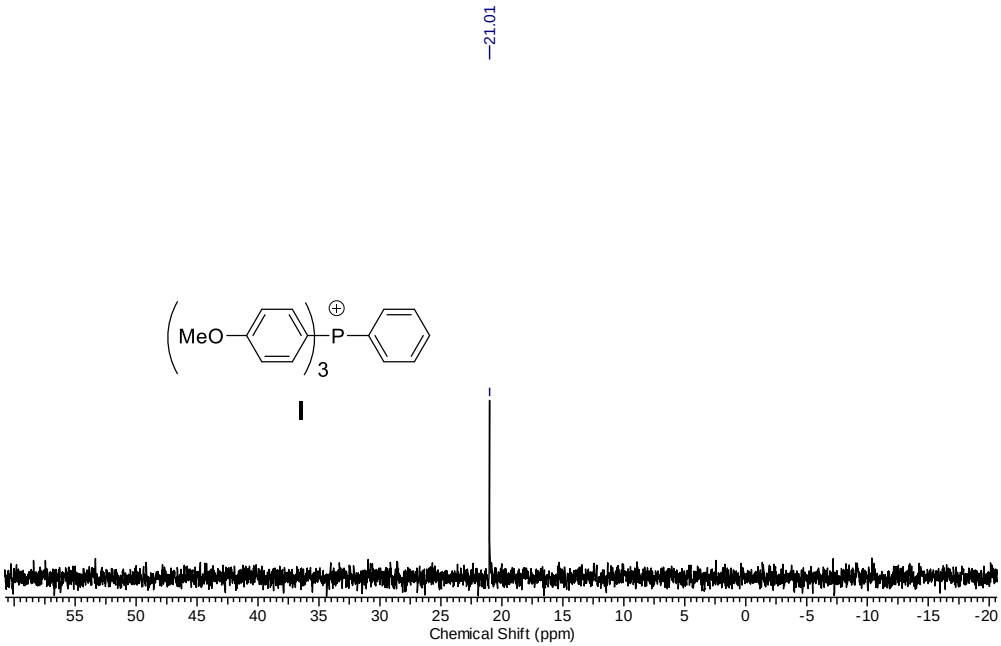
5.2 Procedure for the synthesis of phosphonium salt [((4-OCH$_3$)C$_6$H$_4$)$_3$PC$_6$H$_5$]BF$_4$ (I):



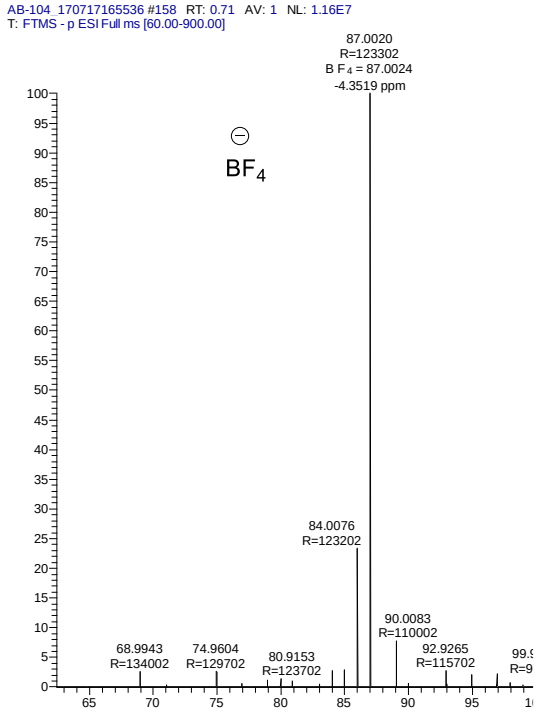
A Schlenk tube was loaded with the [(4-OCH$_3$)C$_6$H$_4$]$_3$PAuCl (29 mg, 0.050 mmol), diazonium salt **2a** (10 mg, 0.055 mmol, 1.1 equiv) and [Ru(bpy)$_3$(PF$_6$)$_2$] (2.1 mg, 0.0025 mmol, 5 mol %). The reaction vessel was wrapped in aluminium foil before MeCN (1 mL) was added at 0 °C, and the mixture was degassed using 3 freeze-pump-thaw cycles. The foil was removed and the reaction mixture was stirred for 10 h at room temperature, under light irradiation using 23 W CFL bulb. The mixture was then diluted with diethyl ether (25 mL) and the precipitate was filtered out. The solid precipitate was recrystallized with DCM/diethyl ether to afford the corresponding phosphonium salt [{(4-OCH$_3$)C$_6$H$_4$}$_3$PC$_6$H$_5$]BF$_4$ (**I**) as brown solid with an trace impurity.

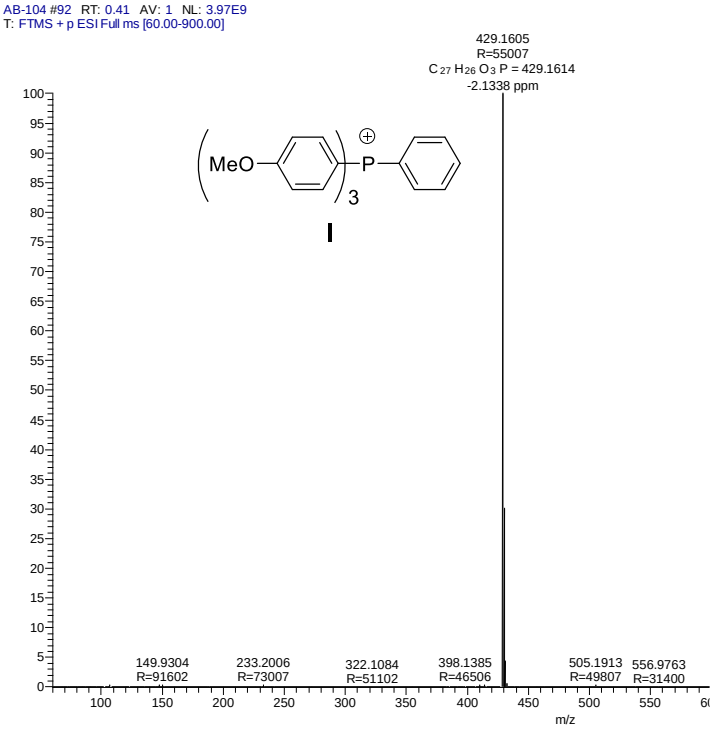
Compound I:[6] 14 mg, yield: 55 %; brown solid; **^{1}H NMR** (**400 MHz**, **CD$_3$CN**) **δ** = 7.91 - 7.81 (m, 1 H), 7.73 - 7.68 (m, 2 H), 7.66 – 7.59 (m, 2 H), 7.56 - 7.47 (m, 6 H), 7.21 (dd, *J* = 2.4, 9.2 Hz, 6 H), 3.91 (s, 9 H); **^{31}P NMR** (**162 MHz, CD$_3$CN**) **δ** = 21.0; **HRMS** (**ESI**) calcd for C$_{27}$H$_{66}$O$_3$P$^+$ (M)$^+$ 429.1614, found 429.1605 and BF$_4^-$ (M)$^-$ 87.0024, found 87.0020.

^{31}P NMR:

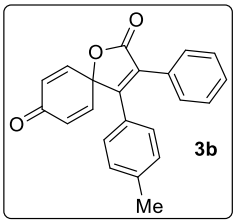
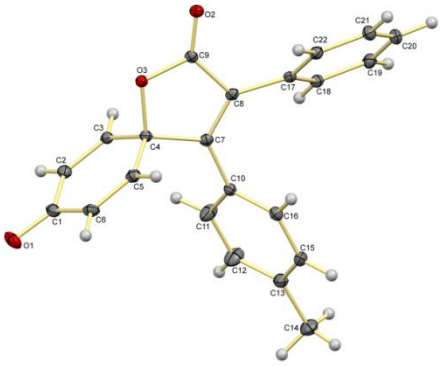
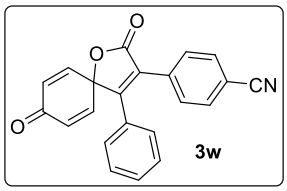
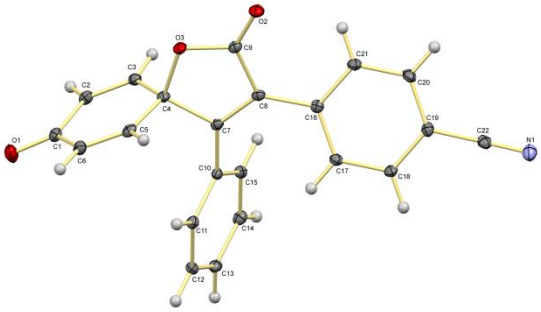
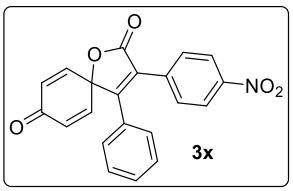
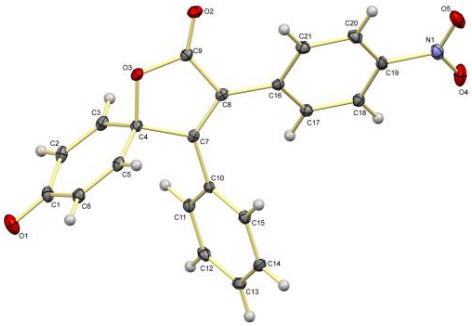

21.01
MeO
P
3
I
55 50 45 40 35 30 25 20 15 10 5 0 -5 -10 -15 -20
Chemical Shift (ppm)

HRMS:

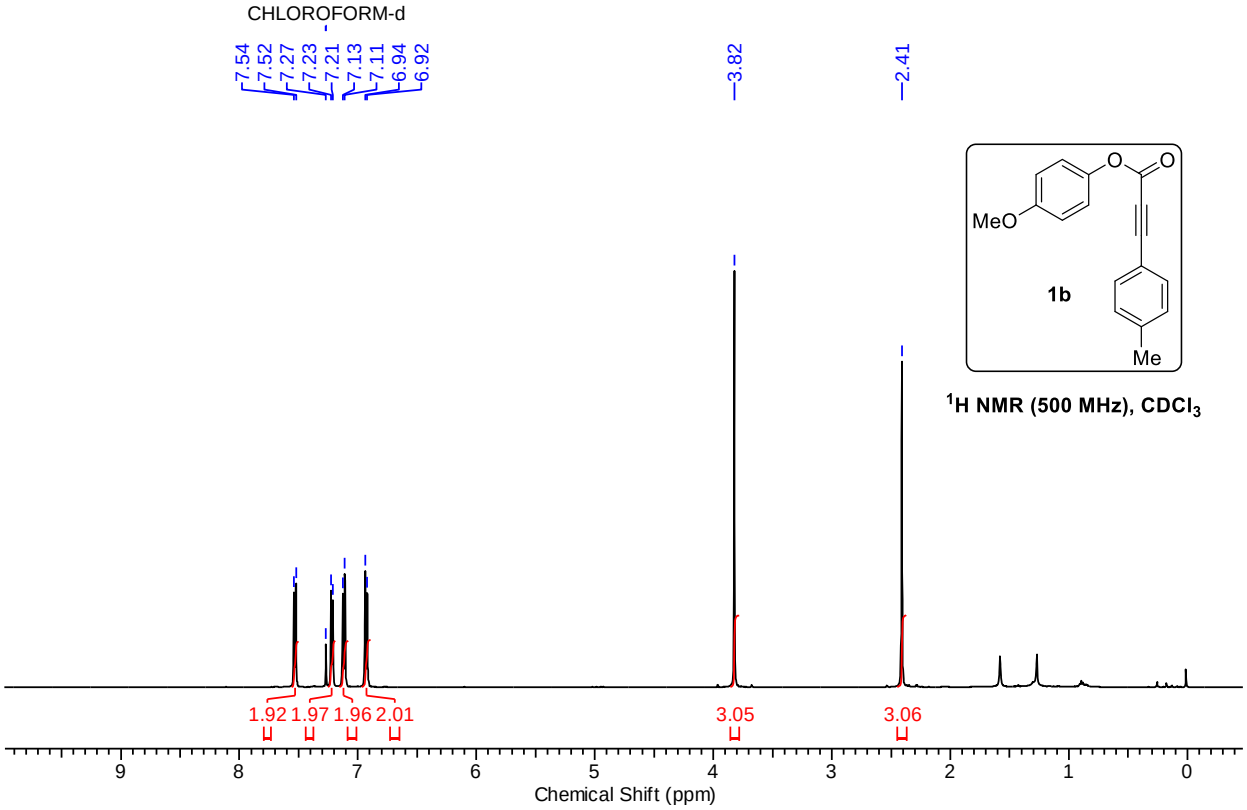

AB-104_170717165536 #158 RT: 0.71 AV: 1 NL: 1.16E7
T: FTMS - p ESI Full ms [60.00-900.00]
87.0020
R=123302
B F4 = 87.0024
-4.3519 ppm
BF4
84.0076
R=123202
90.0083
R=110002
68.9943
R=134002
74.9604
R=129702
80.9153
R=123702
92.9265
R=115702


AB-104 #92 RT: 0.41 AV: 1 NL: 3.97E9
T: FTMS + p ESI Full ms [60.00-900.00]
429.1605
R=55007
C27 H26 O3 P = 429.1614
-2.1338 ppm
MeO
P
3
I
149.9304
R=91602
233.2006
R=73007
322.1084
R=51102
398.1385
R=46506
505.1913
R=49807
556.9763
R=31400
m/z

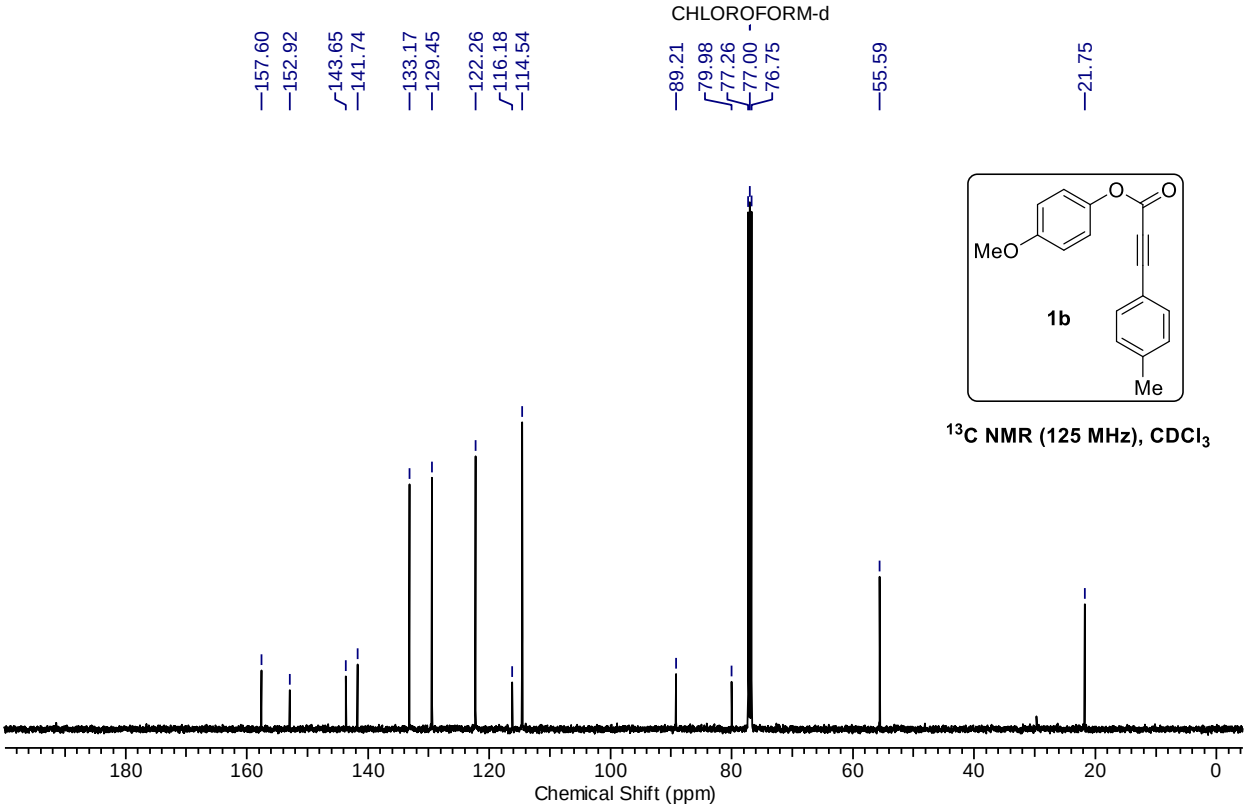
6. ORTEP diagram

Sr. No	Compound Structure	ORTEP Diagram
	 **CCDC No. 1546724**	
2	 **CCDC No. 1546720**	
3	 **CCDC No. 1546726**	

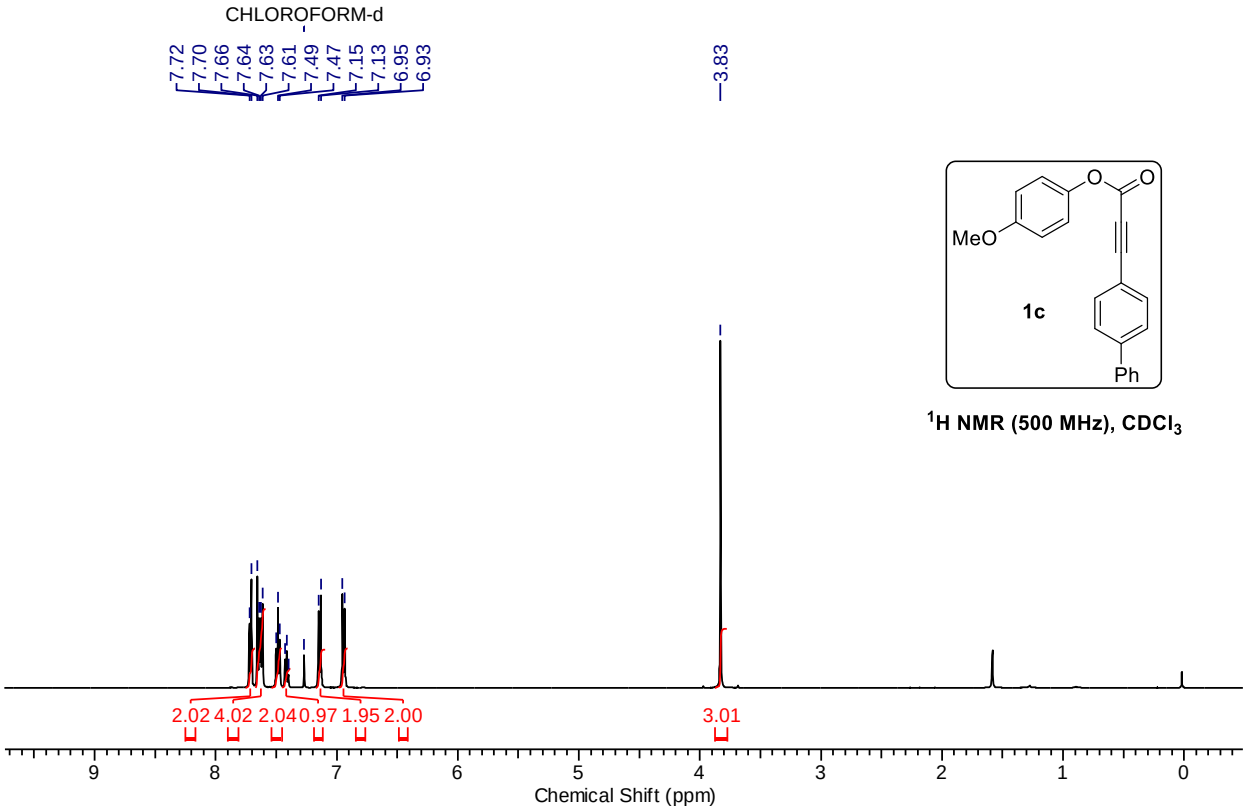
7. Spectral data



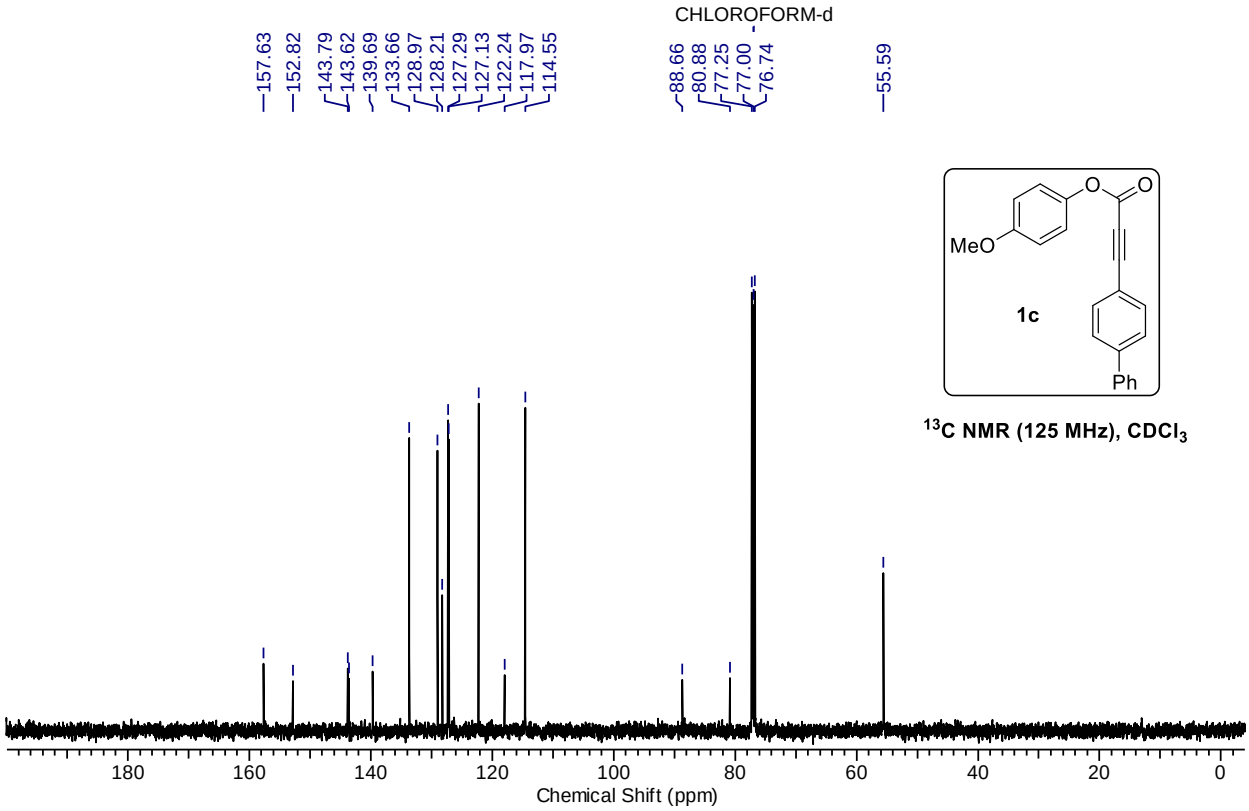
^{1}H NMR (500 MHz), $CDCl_3$



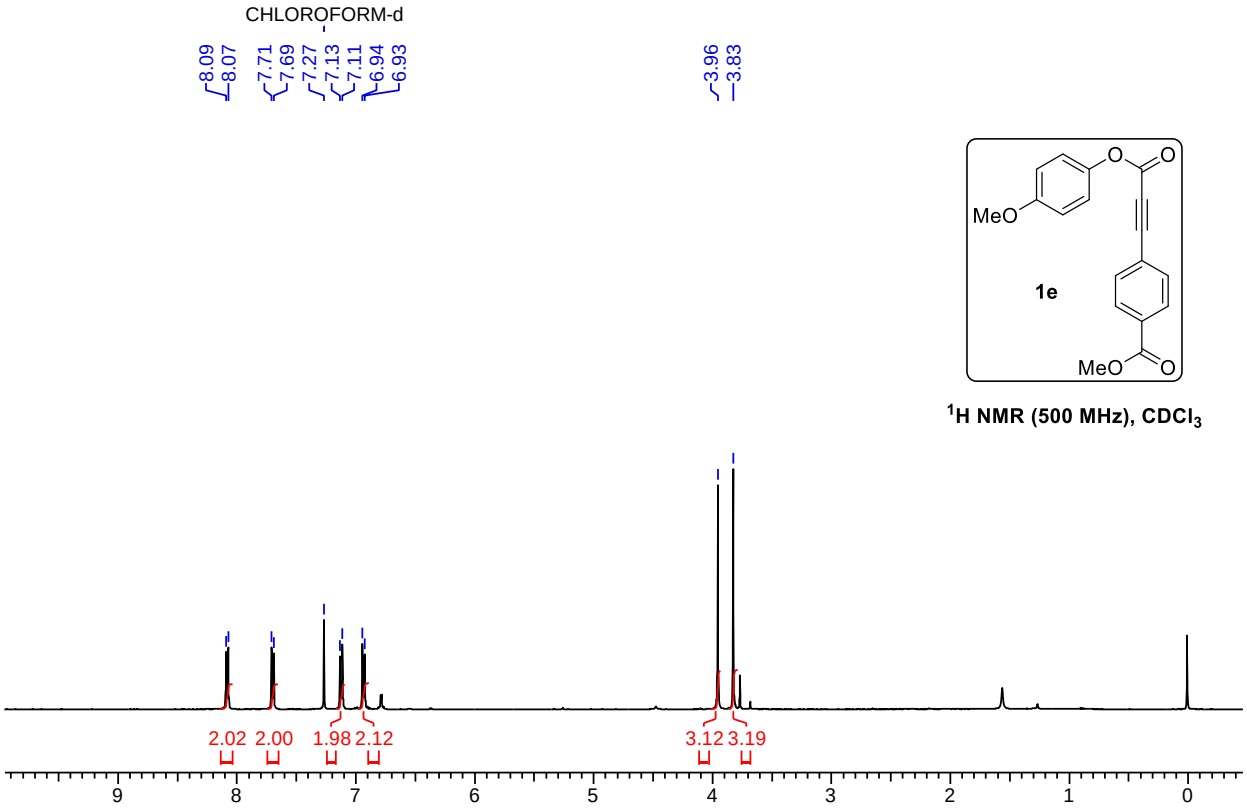
^{13}C NMR (125 MHz), $CDCl_3$



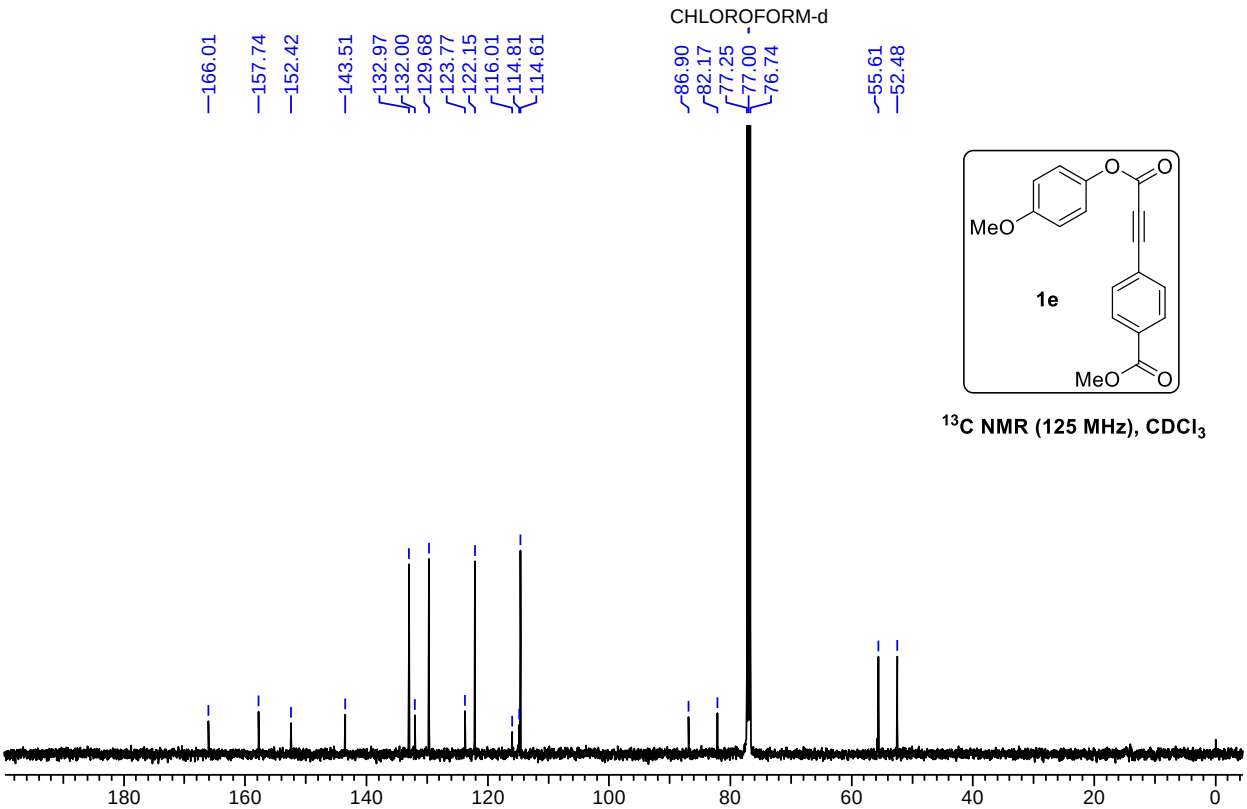
^{1}H NMR (500 MHz), $CDCl_3$



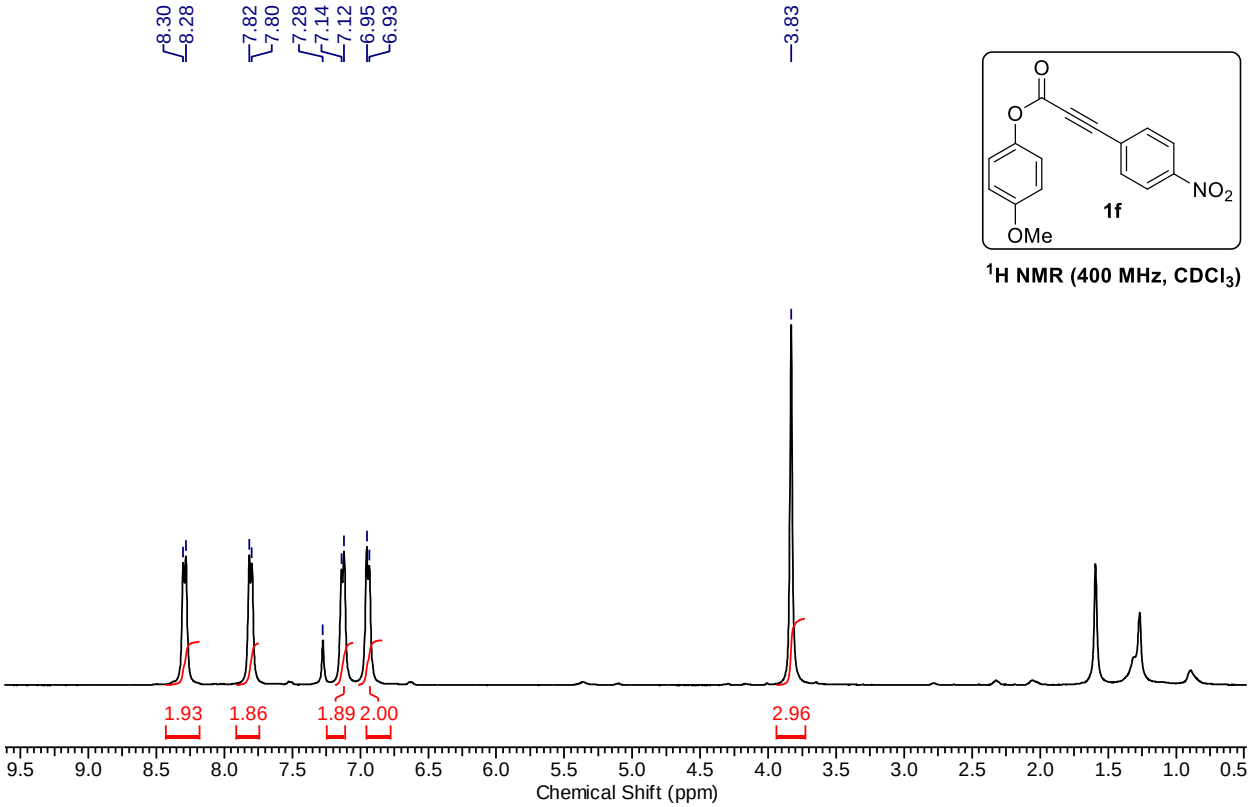
^{13}C NMR (125 MHz), $CDCl_3$



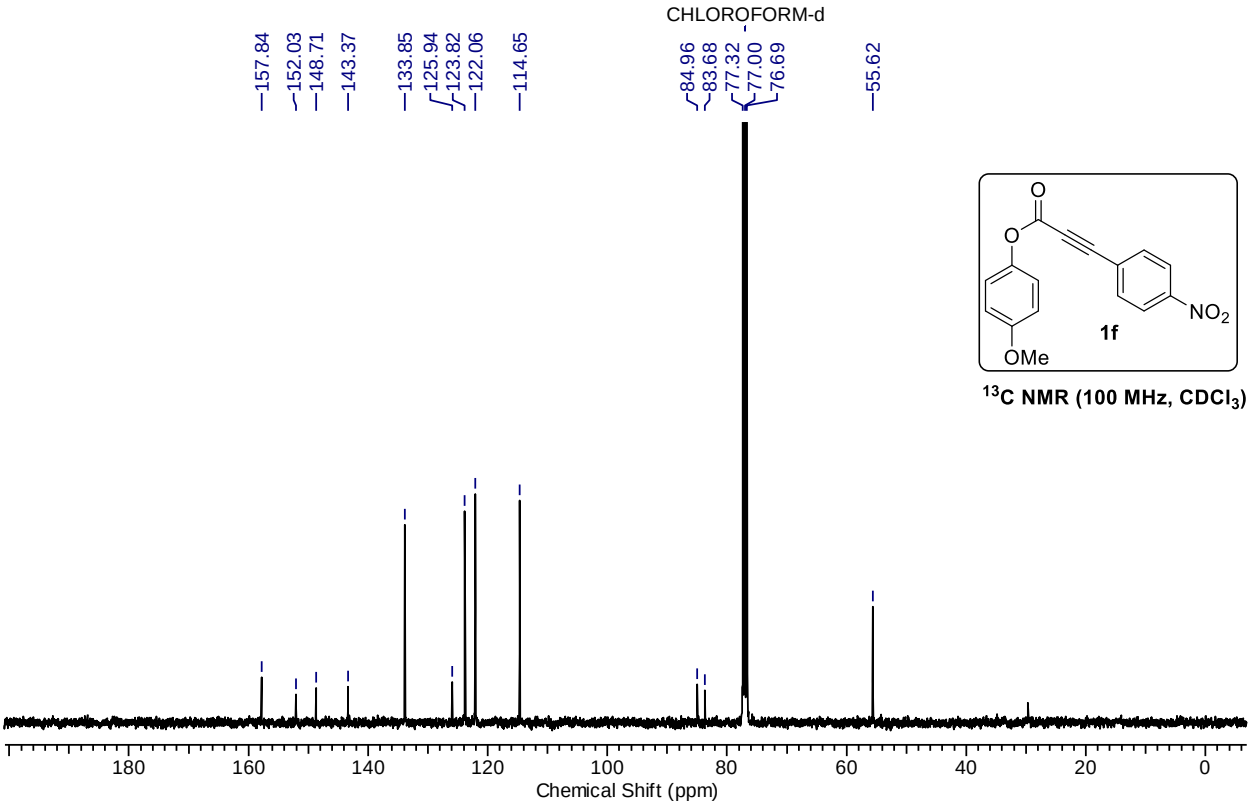
^{1}H NMR (500 MHz), $CDCl_3$



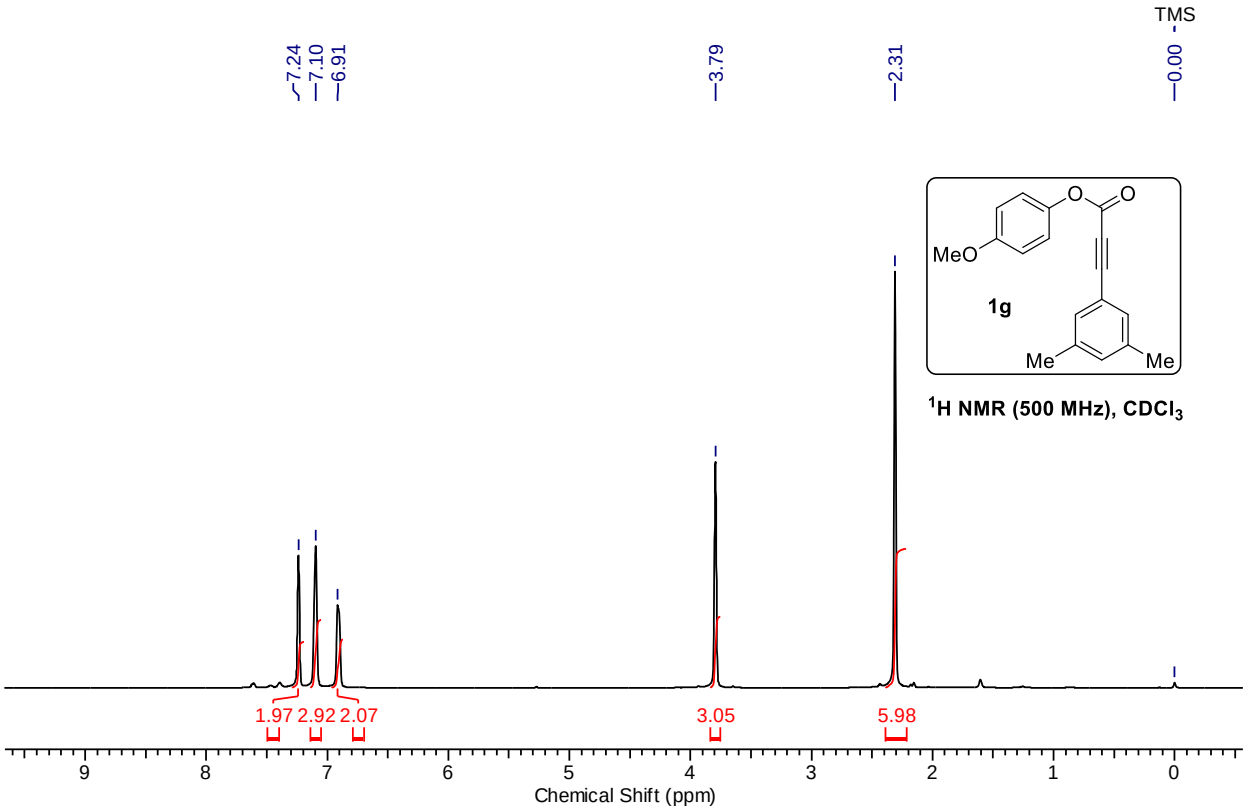
^{13}C NMR (125 MHz), $CDCl_3$



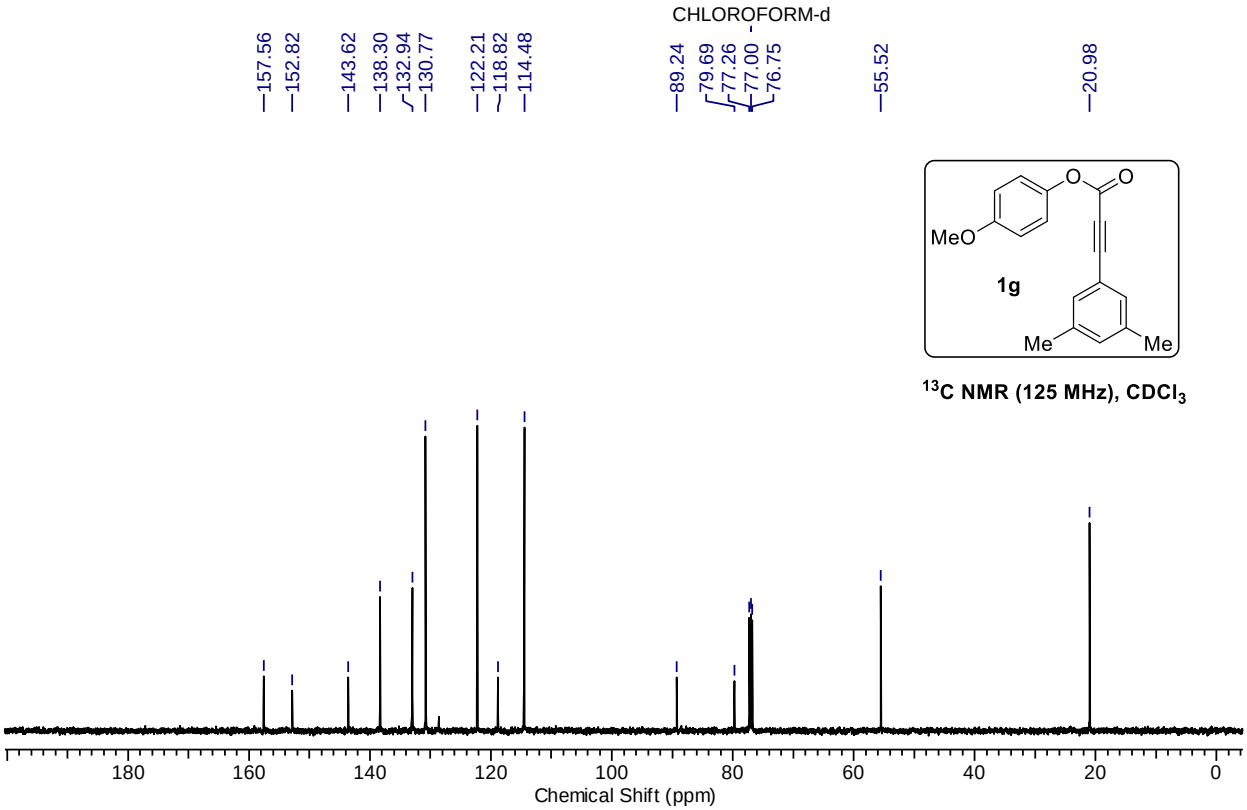
^{1}H NMR (400 MHz, $CDCl_3$)



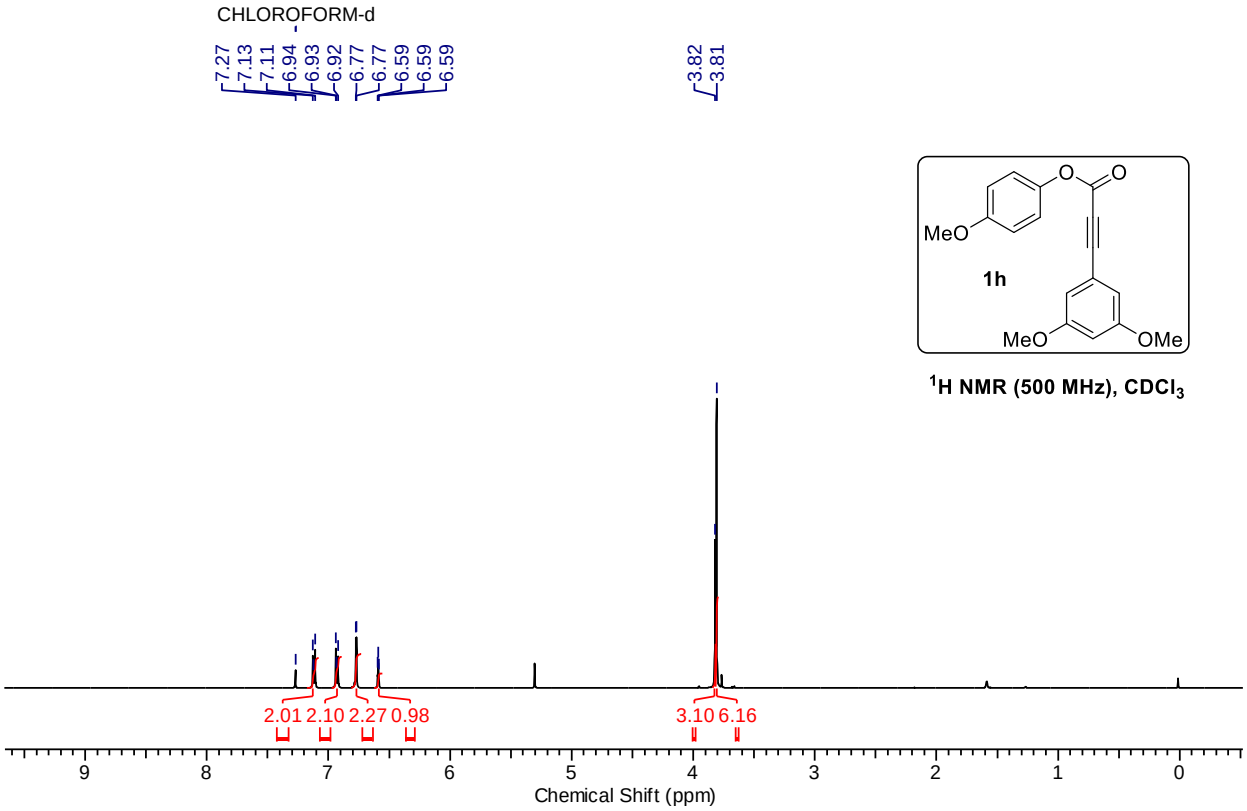
^{13}C NMR (100 MHz, $CDCl_3$)



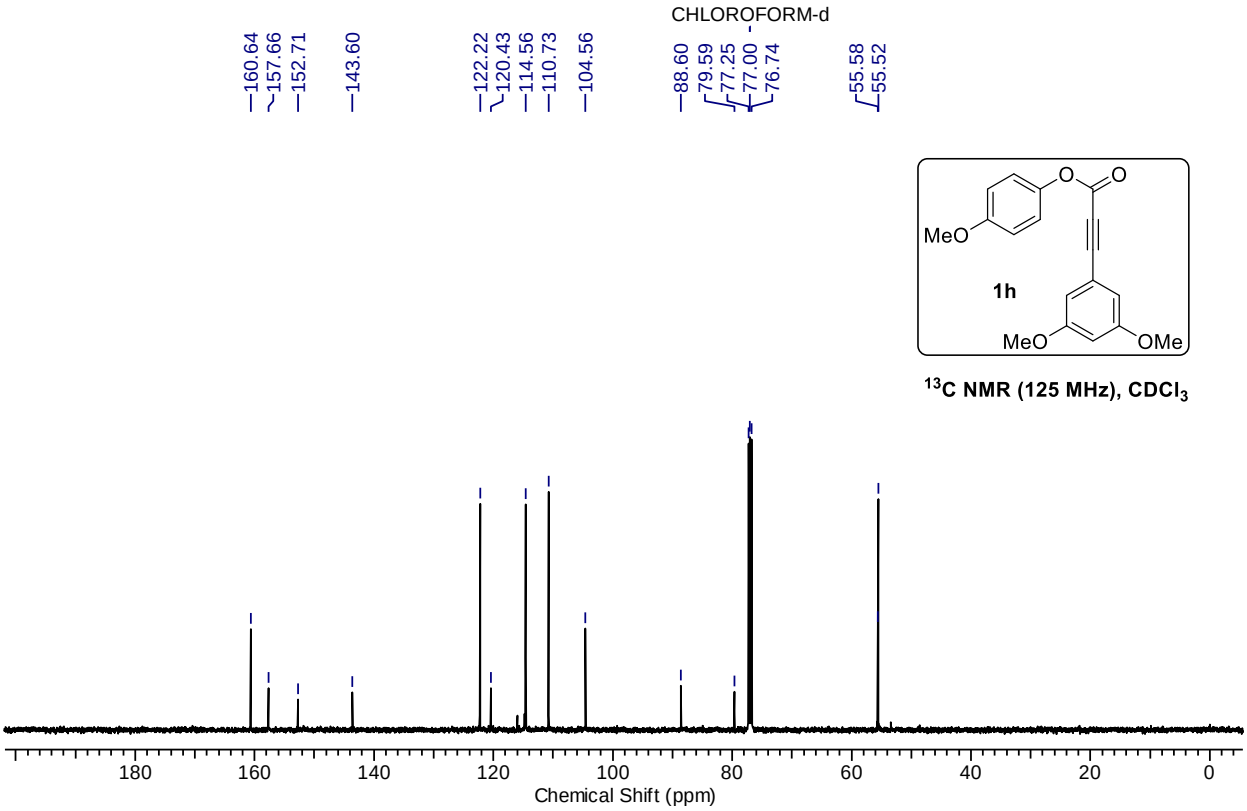
^{1}H NMR (500 MHz), $CDCl_3$



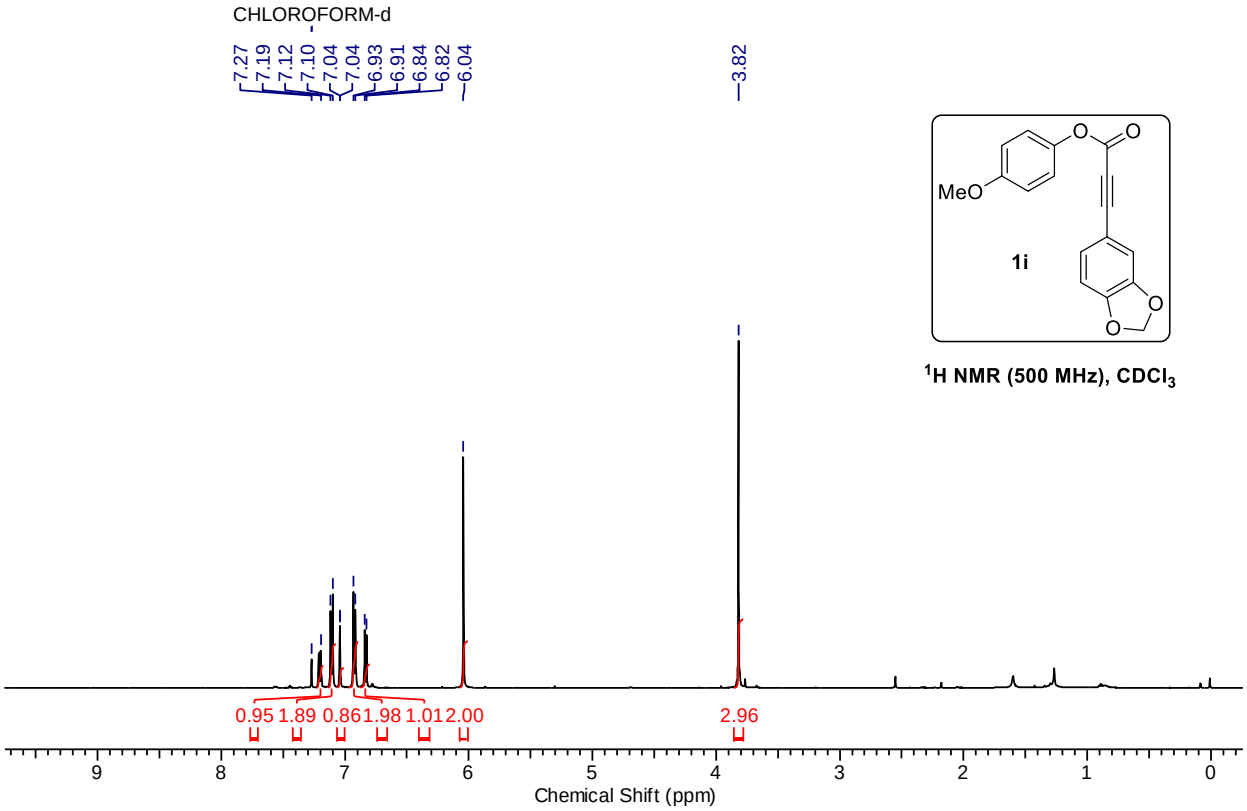
^{13}C NMR (125 MHz), $CDCl_3$



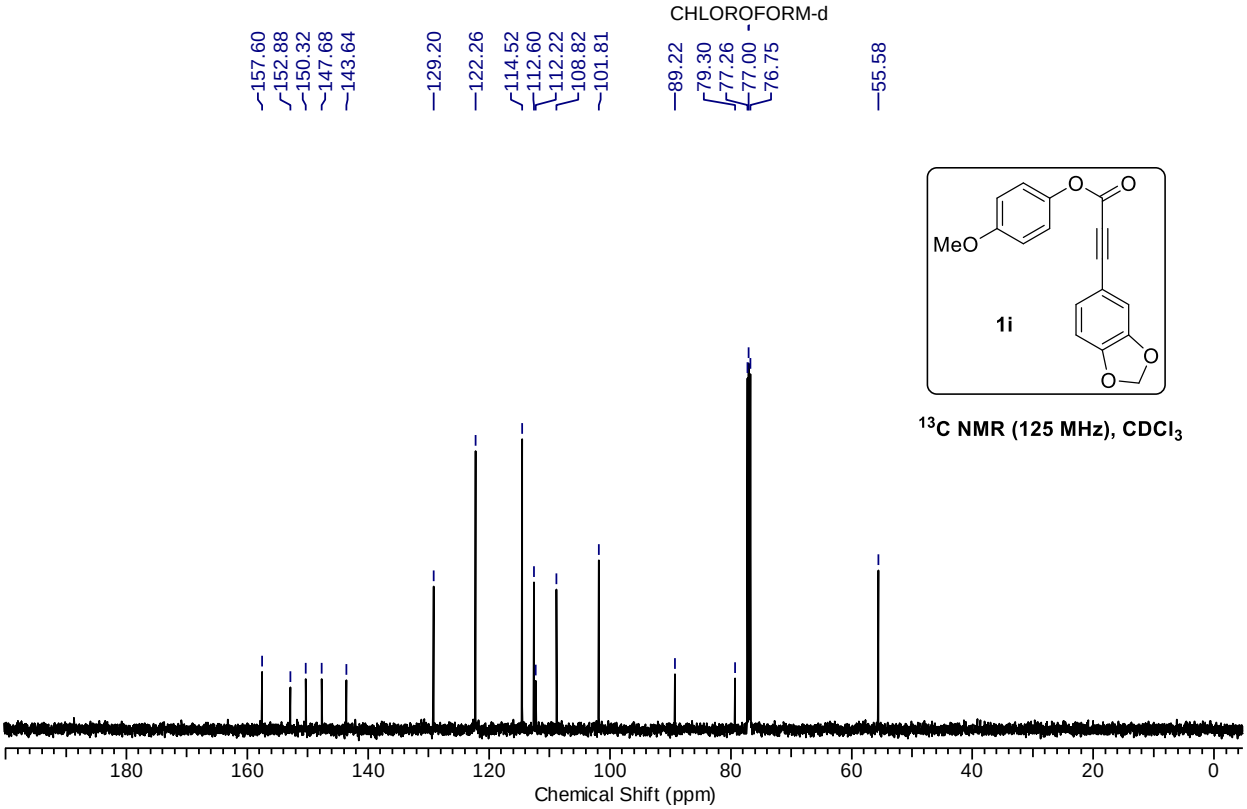
^{1}H NMR (500 MHz), $CDCl_3$



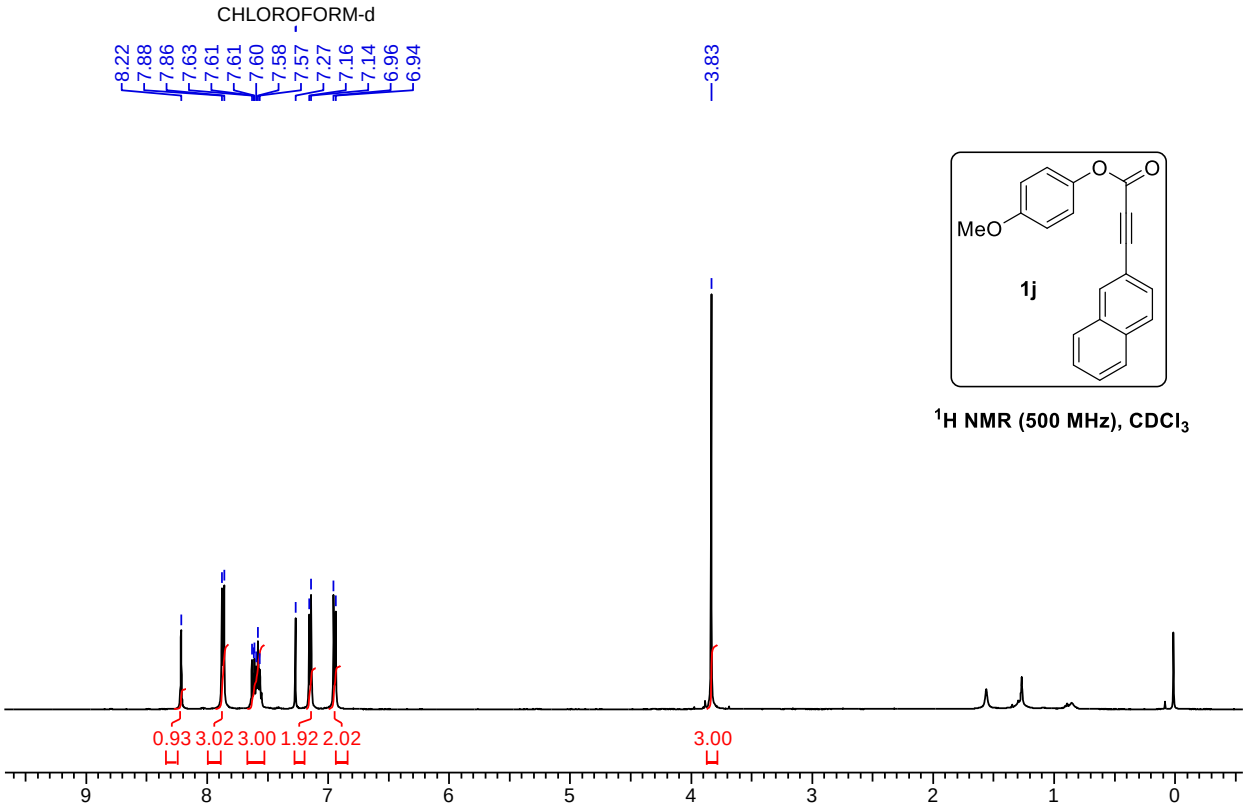
^{13}C NMR (125 MHz), $CDCl_3$



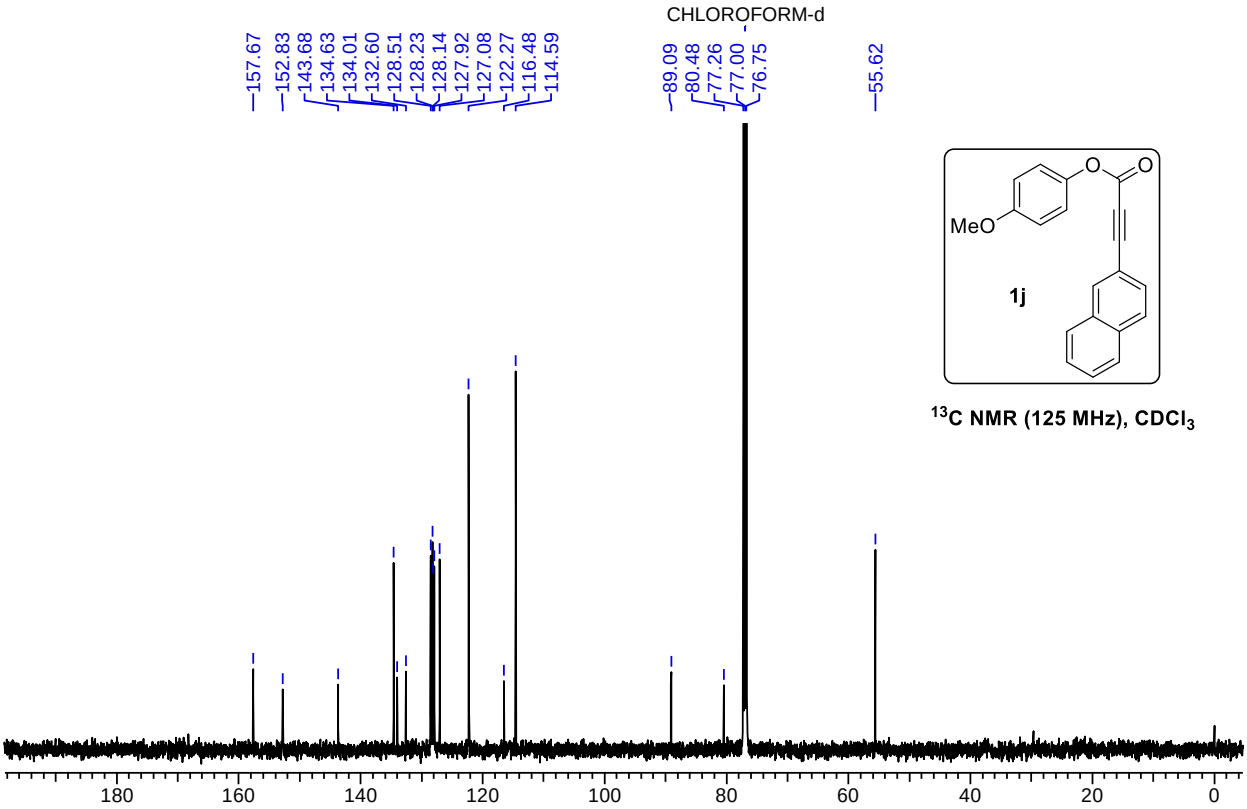
^{1}H NMR (500 MHz), $CDCl_3$



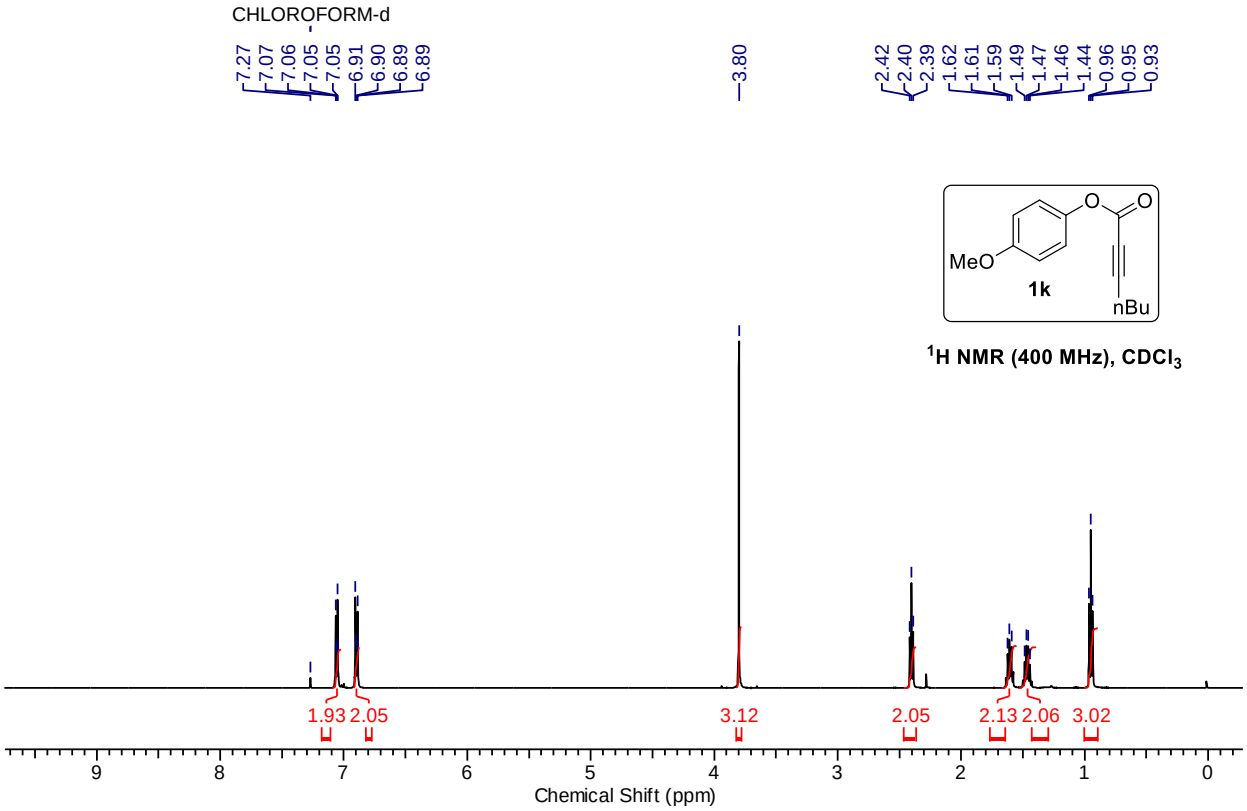
^{13}C NMR (125 MHz), $CDCl_3$



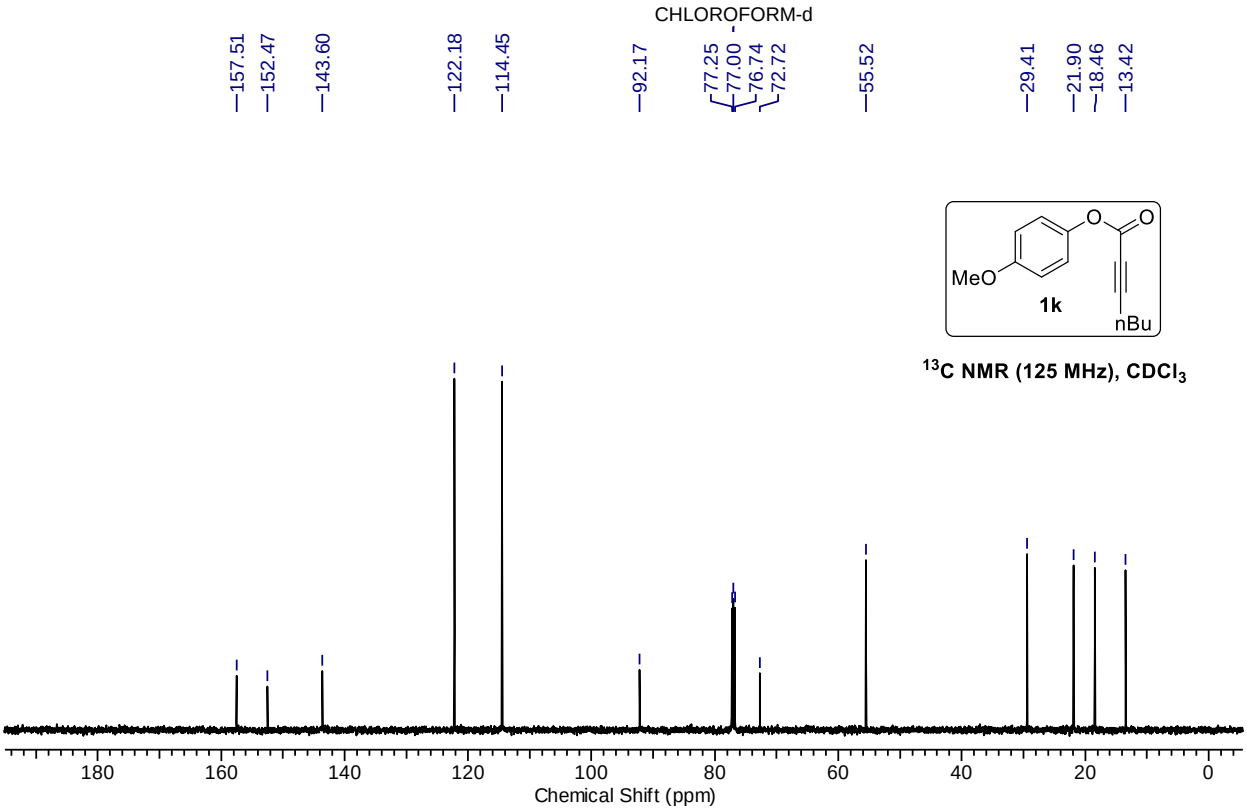
^{1}H NMR (500 MHz), $CDCl_3$



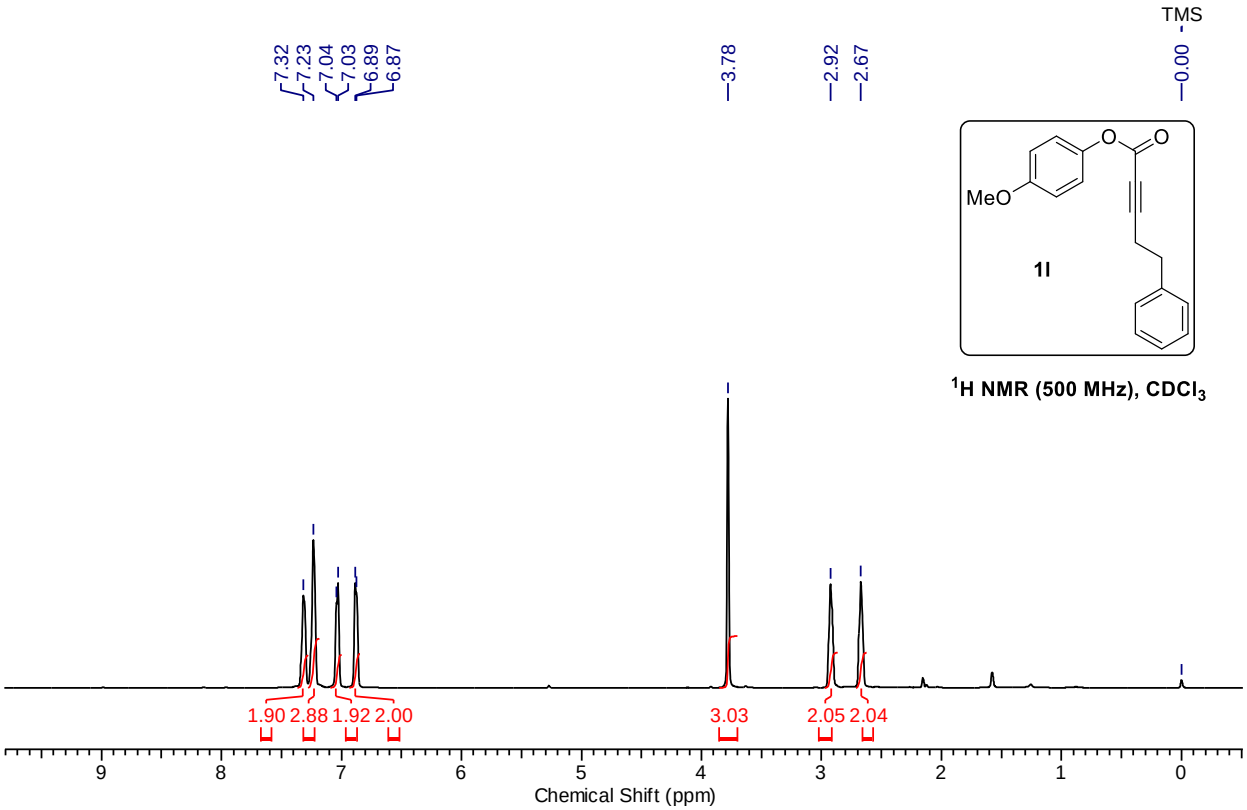
^{13}C NMR (125 MHz), $CDCl_3$



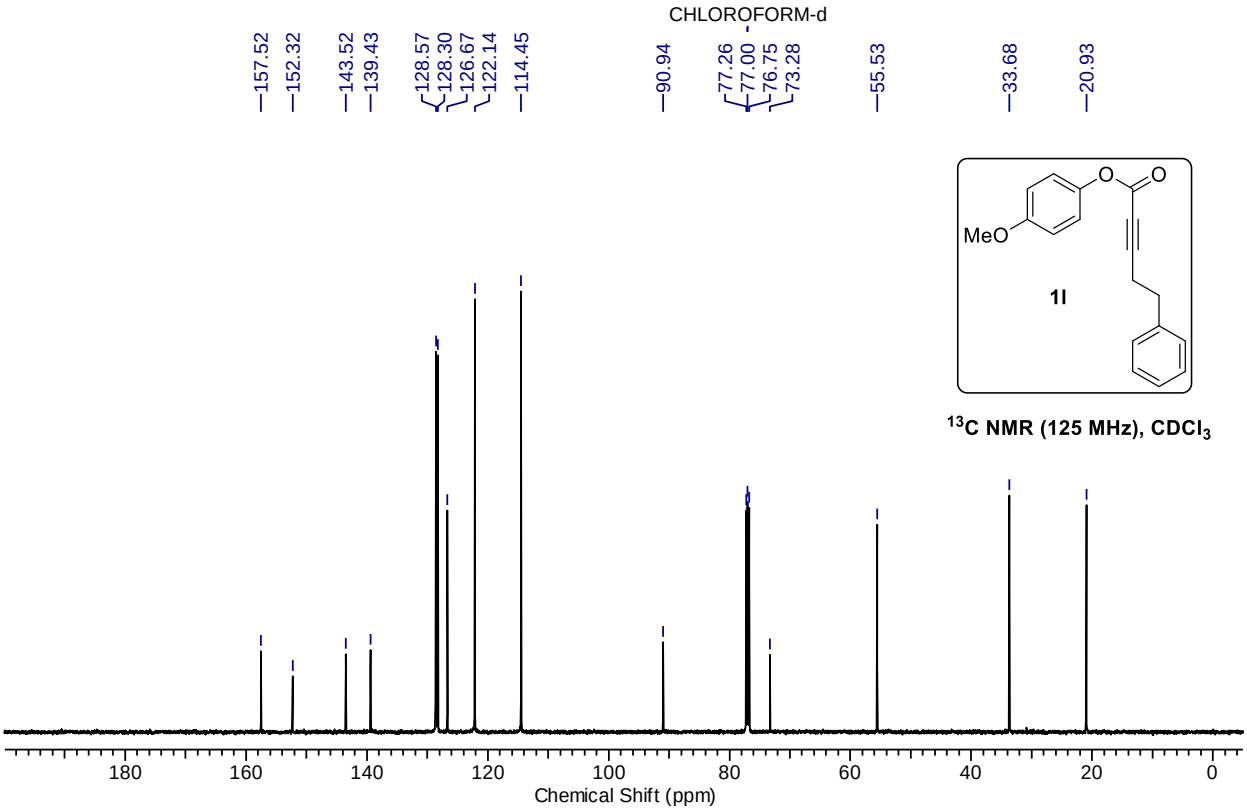
^{1}H NMR (400 MHz), $CDCl_3$



^{13}C NMR (125 MHz), $CDCl_3$



^{1}H NMR (500 MHz), $CDCl_3$



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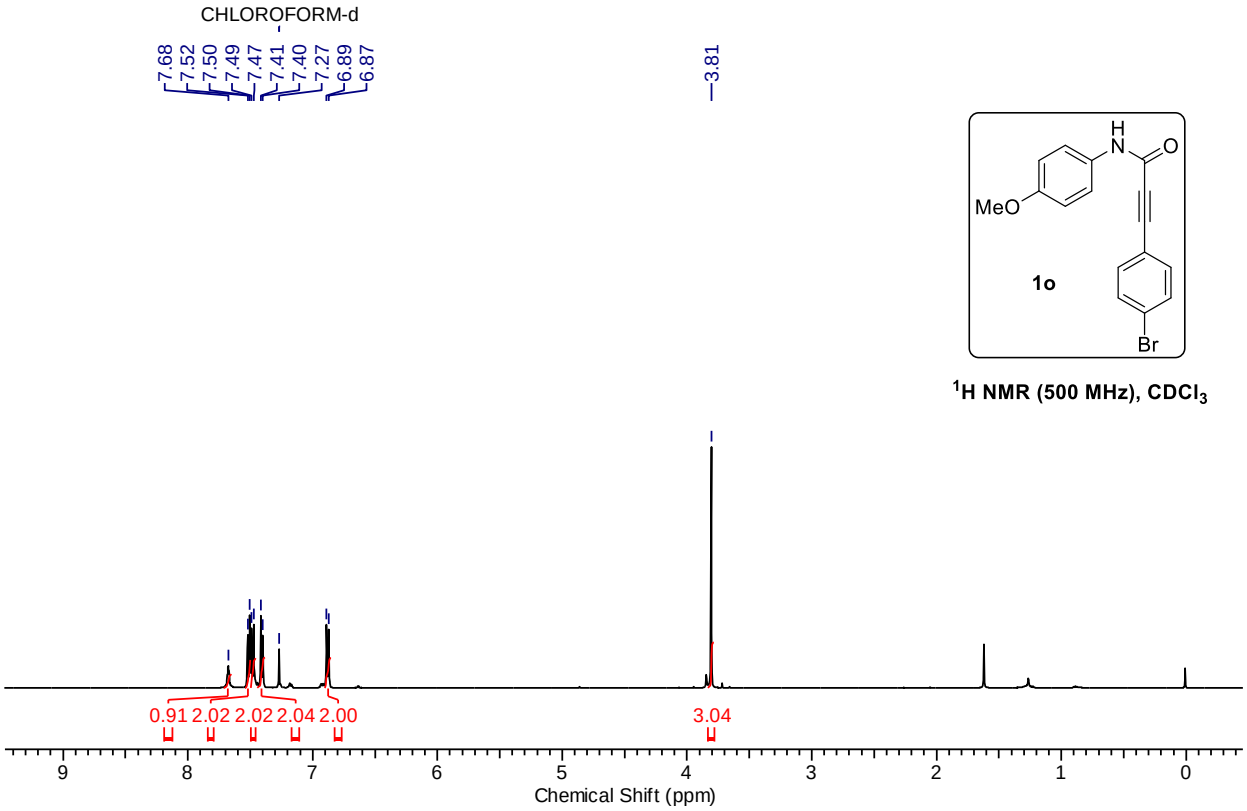
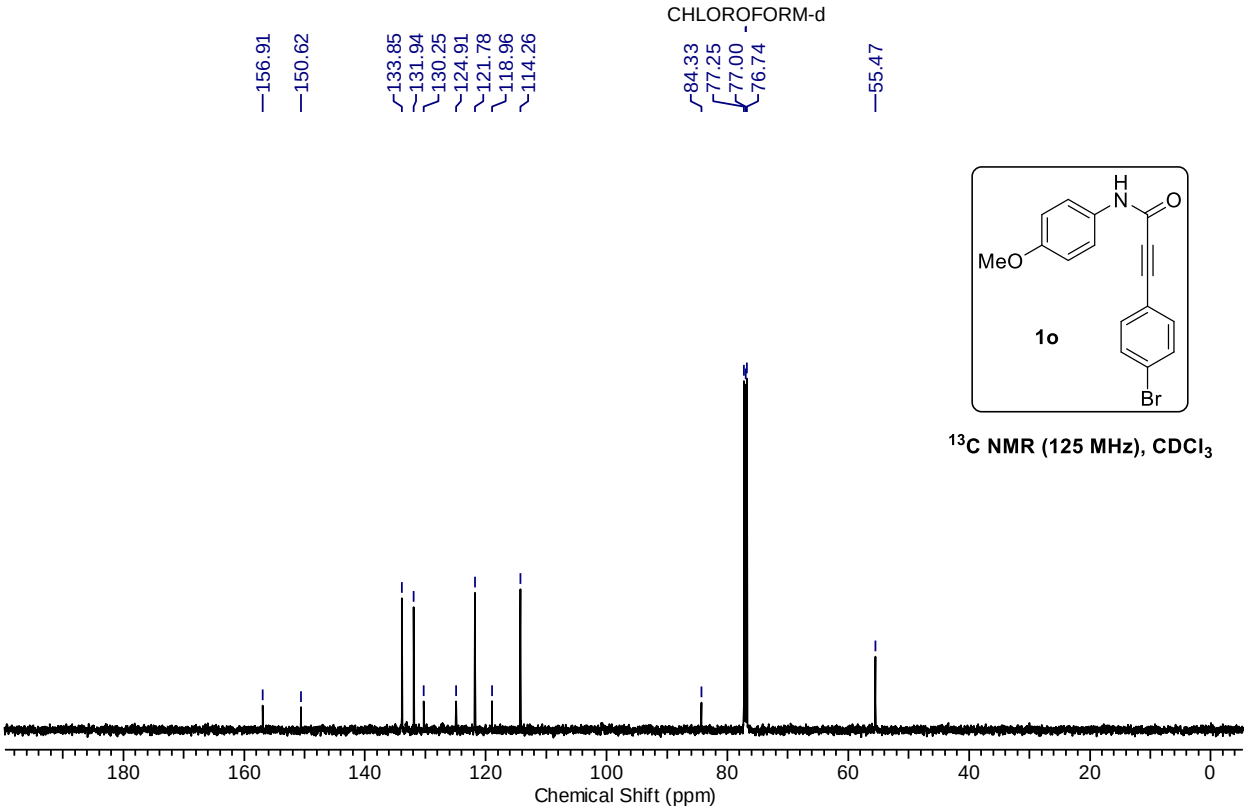
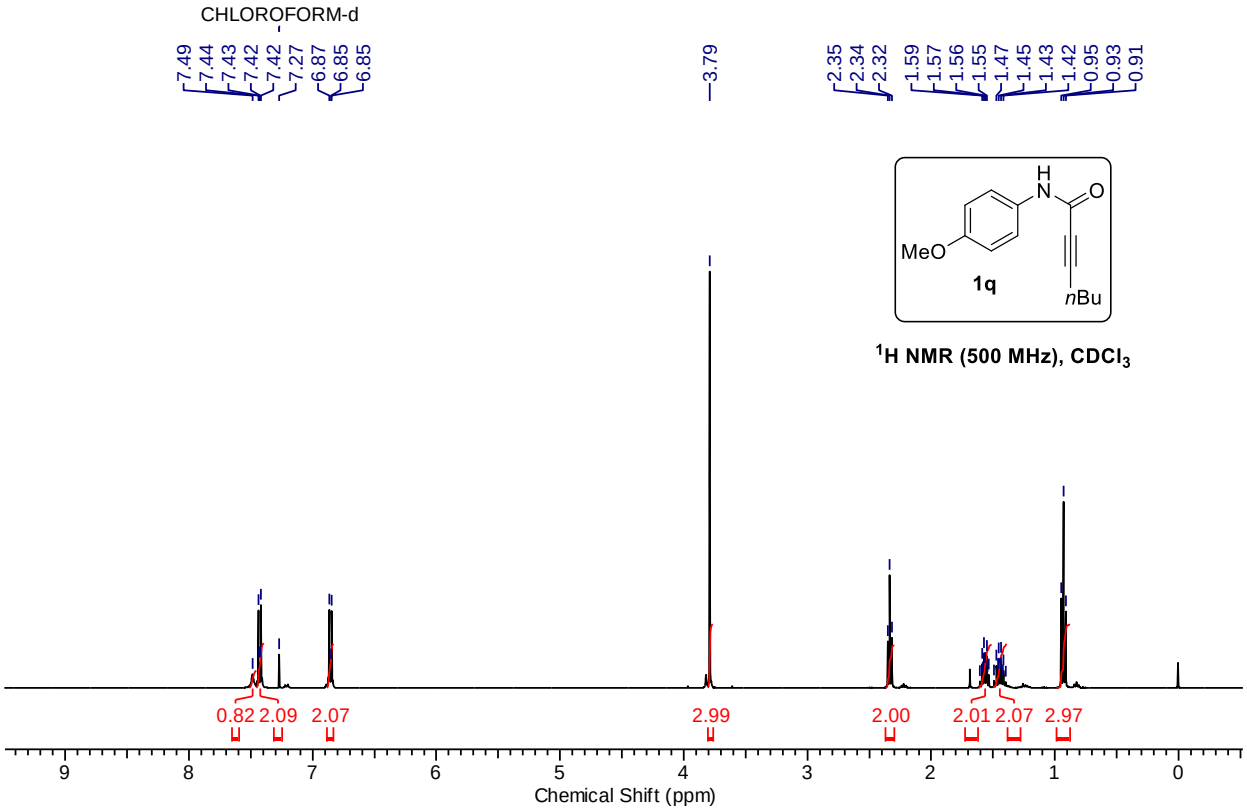


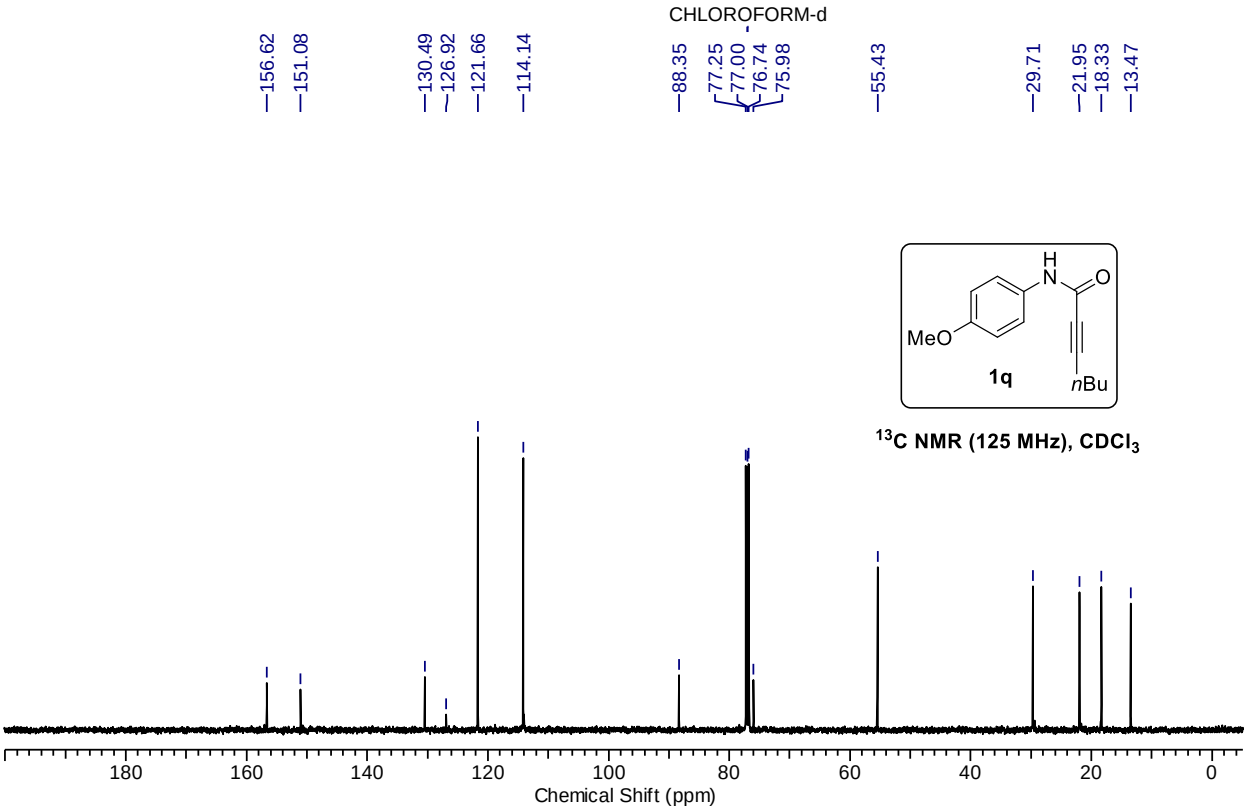
^{1}H NMR (500 MHz), $CDCl_3$



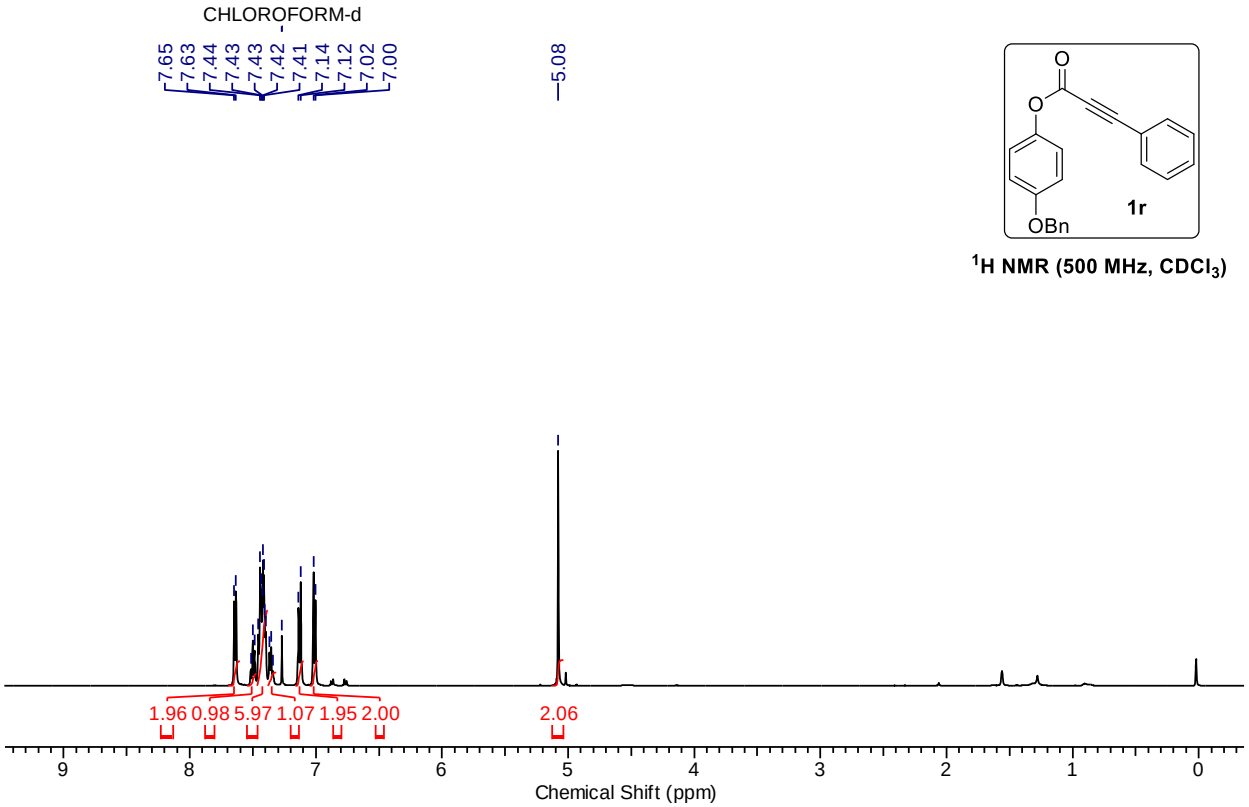
^{13}C NMR (125 MHz), $CDCl_3$



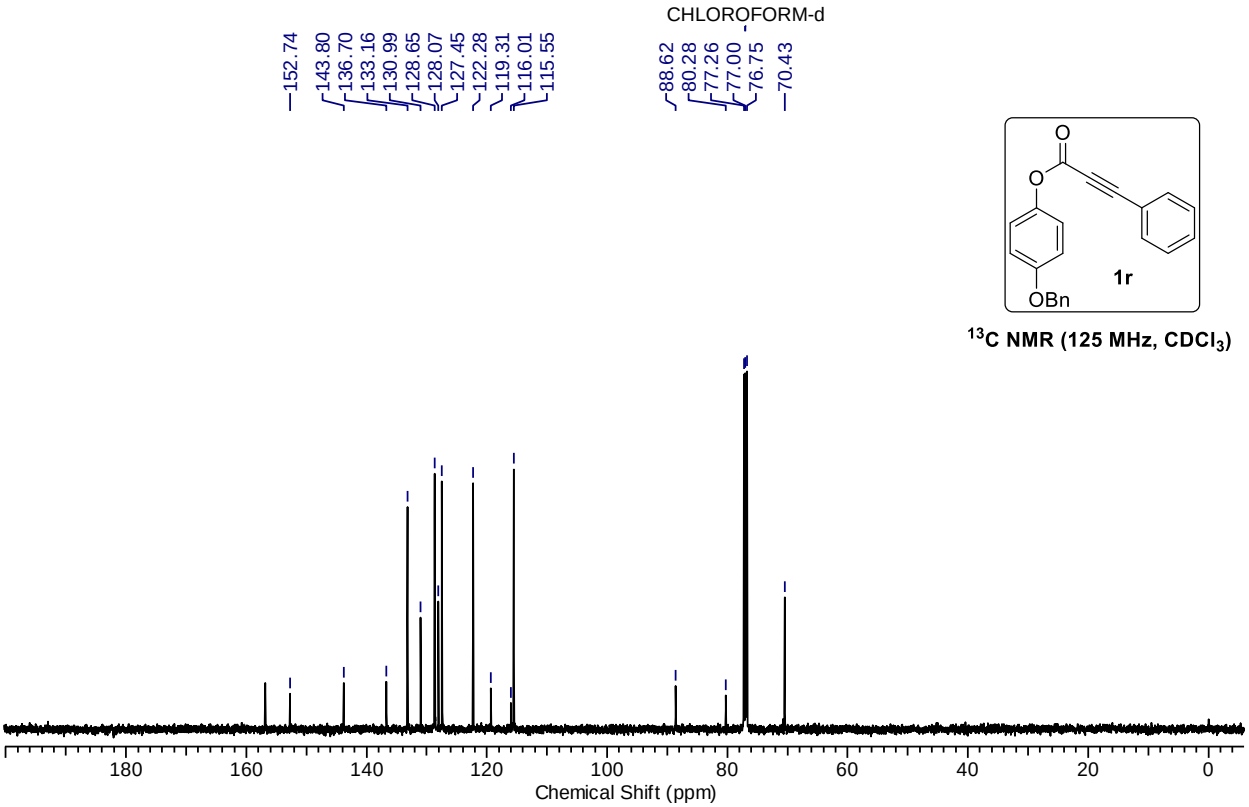
^{1}H NMR (500 MHz), $CDCl_3$



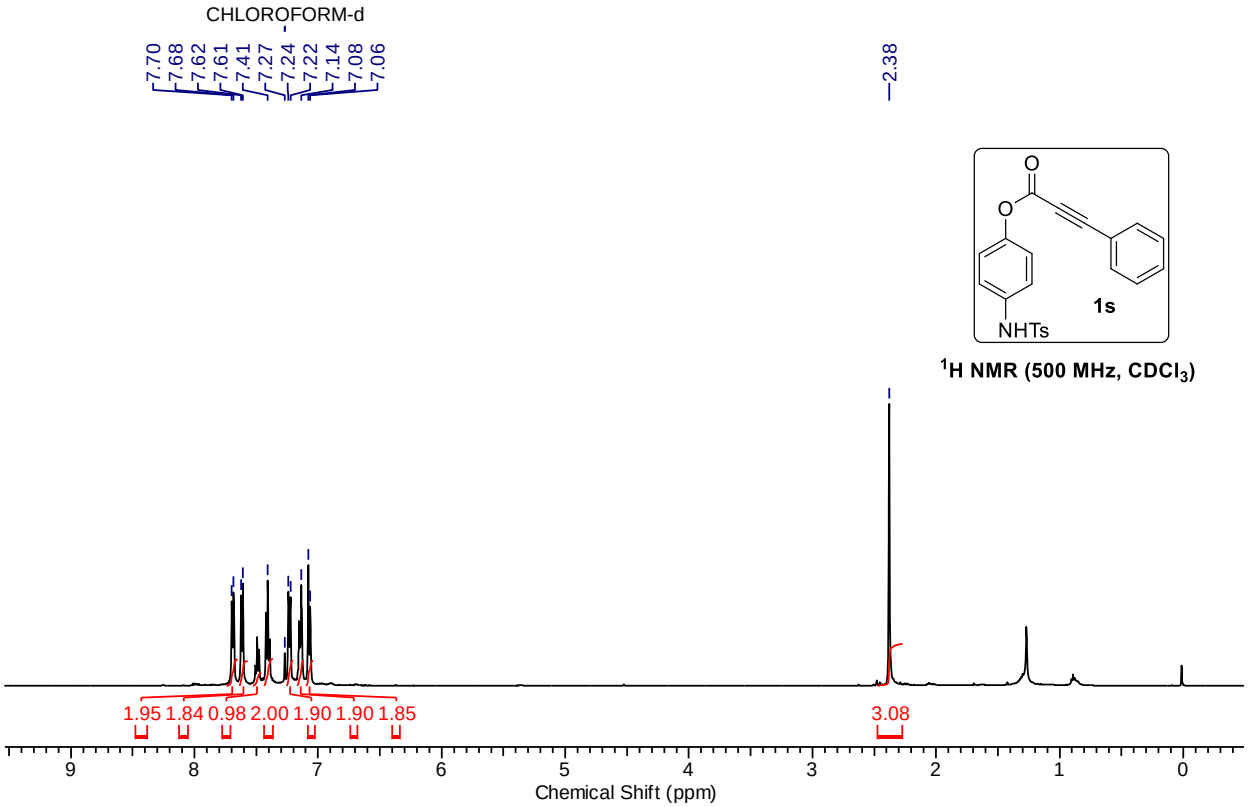
^{13}C NMR (125 MHz), $CDCl_3$



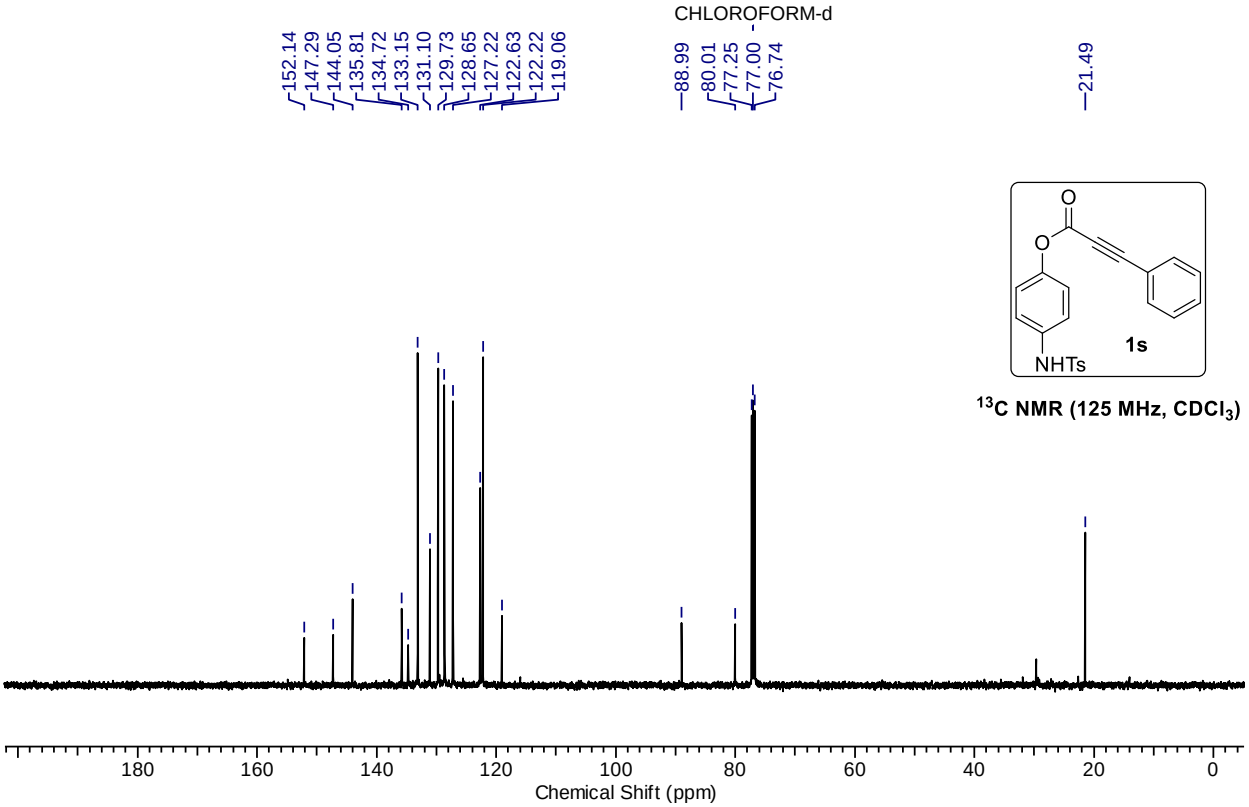
^{1}H NMR (500 MHz, $CDCl_3$)



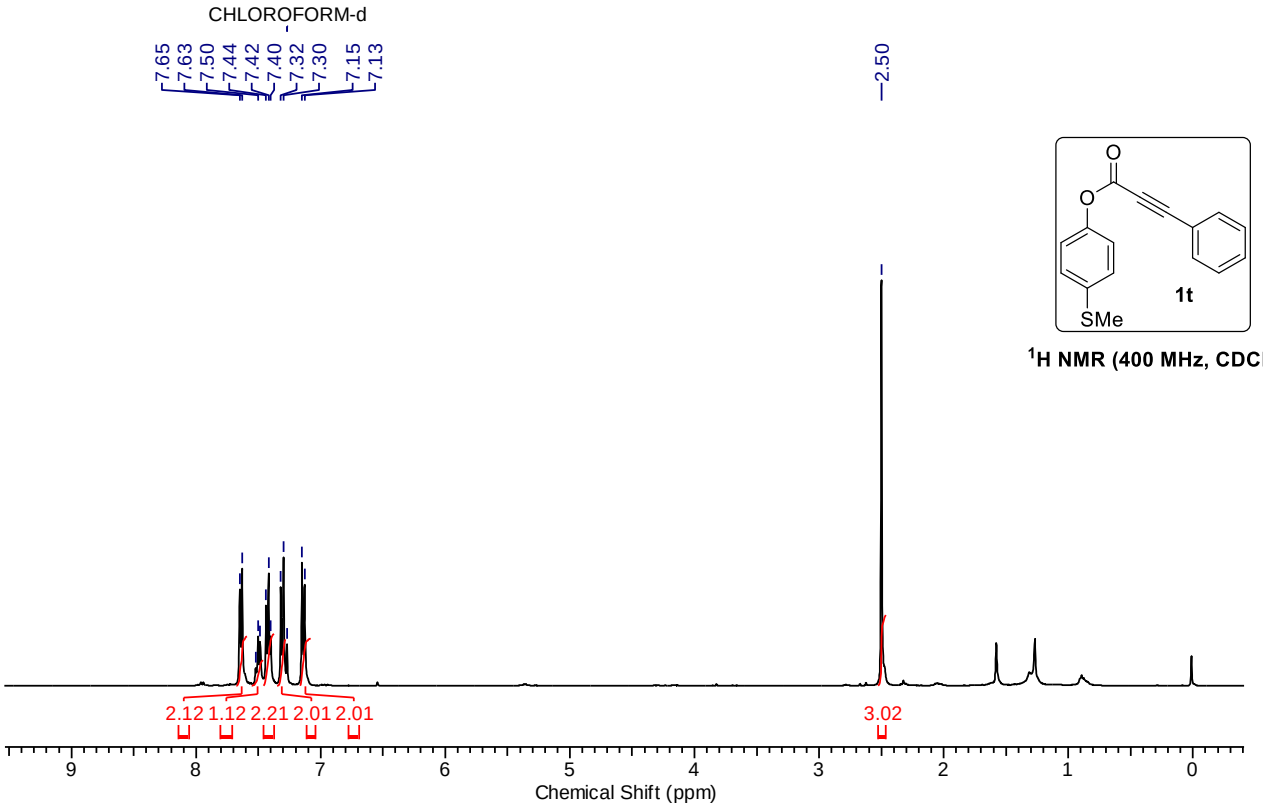
^{13}C NMR (125 MHz, $CDCl_3$)



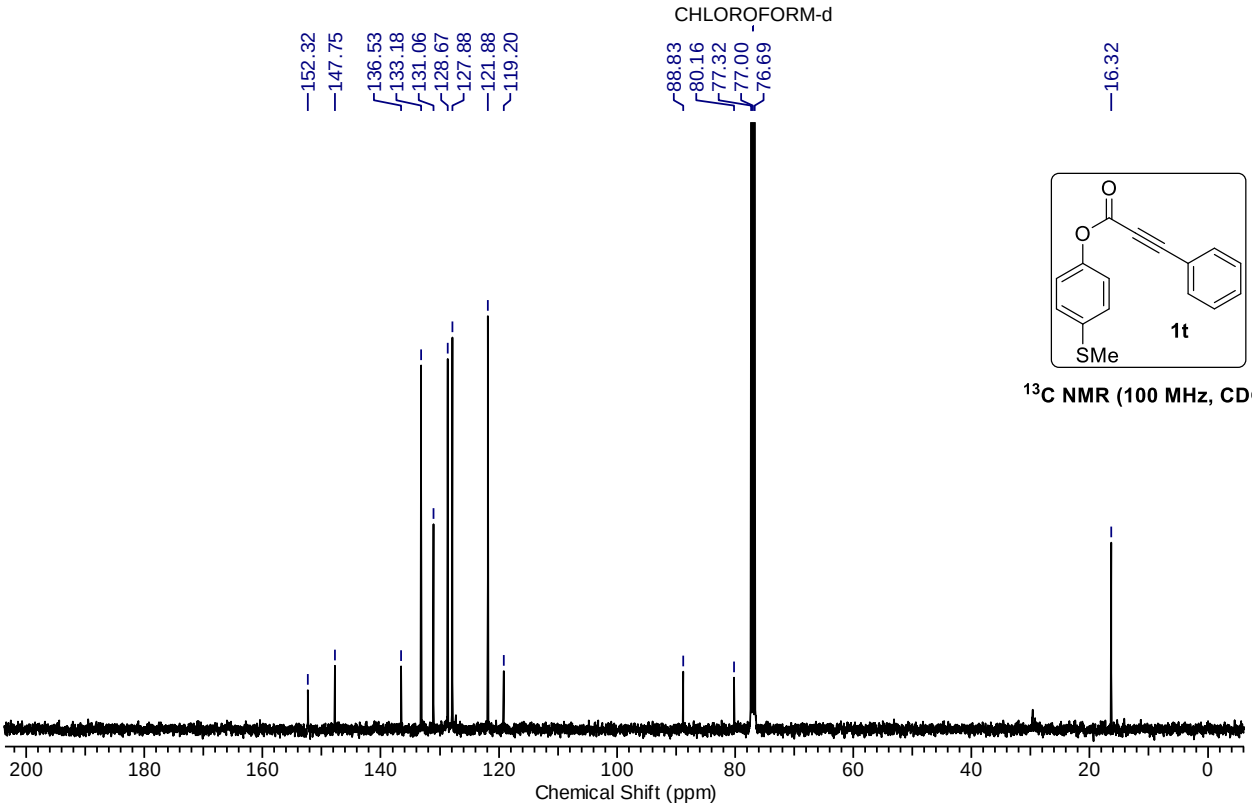
^{1}H NMR (500 MHz, $CDCl_3$)



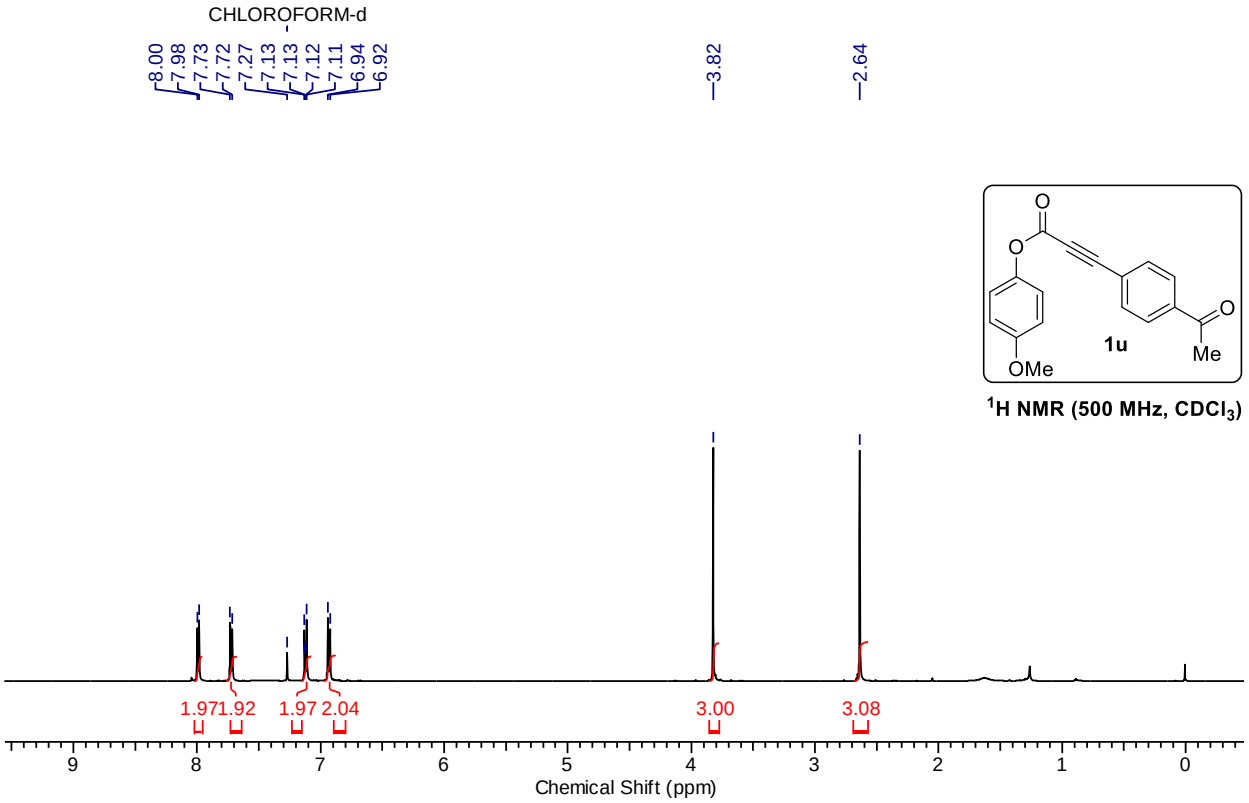
^{13}C NMR (125 MHz, $CDCl_3$)



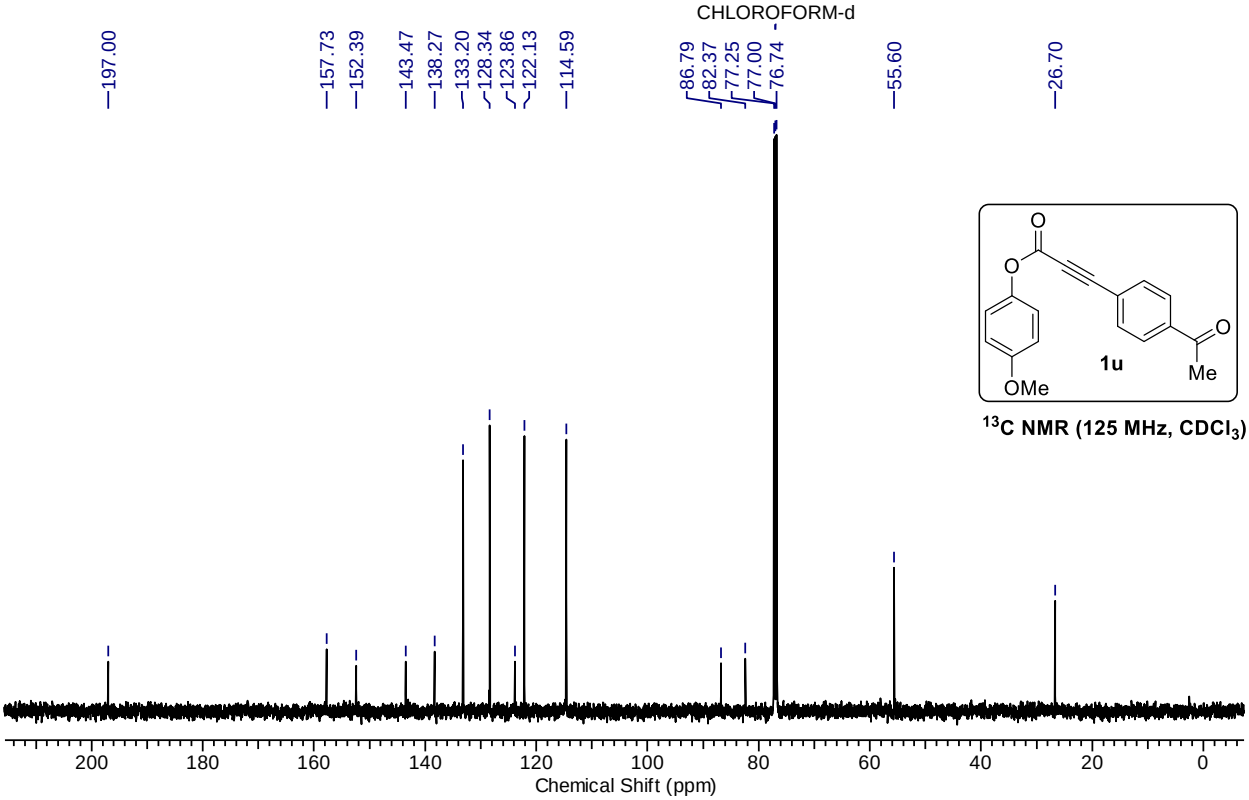
^{1}H NMR (400 MHz, $CDCl_3$)



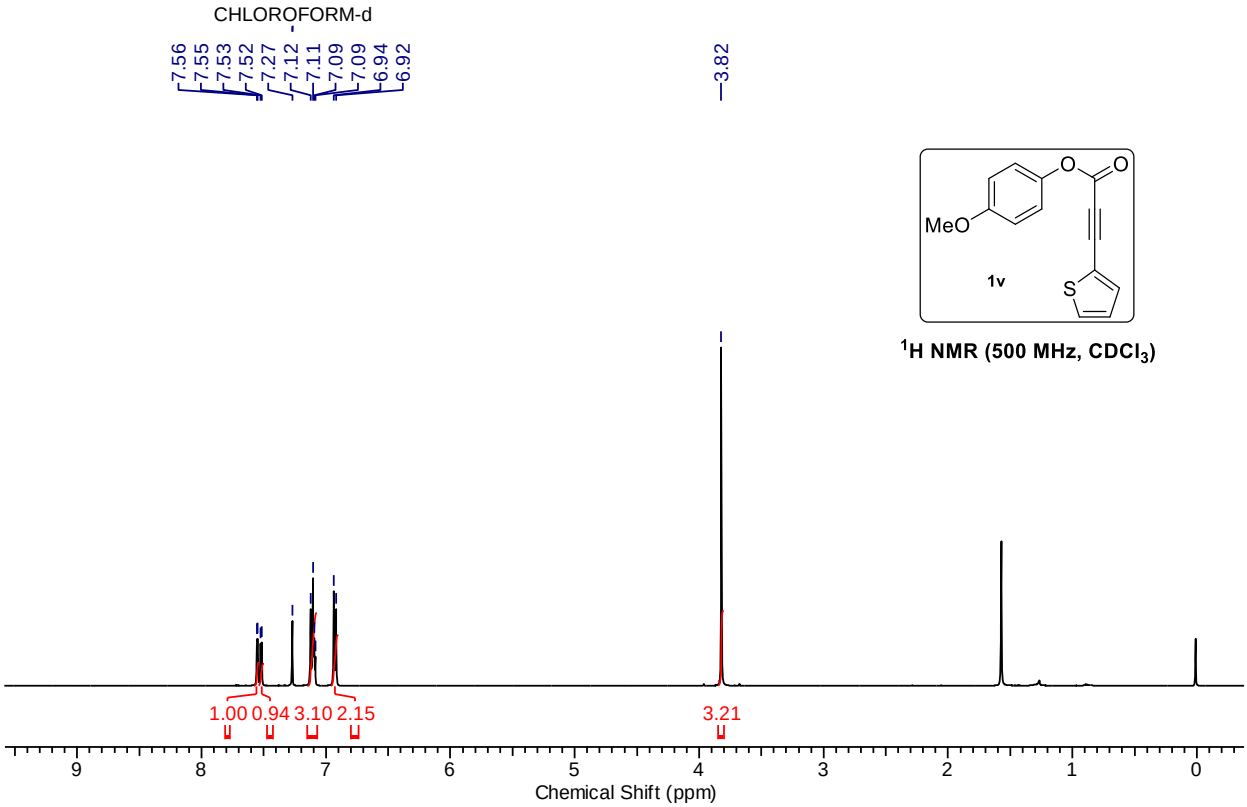
^{13}C NMR (100 MHz, $CDCl_3$)



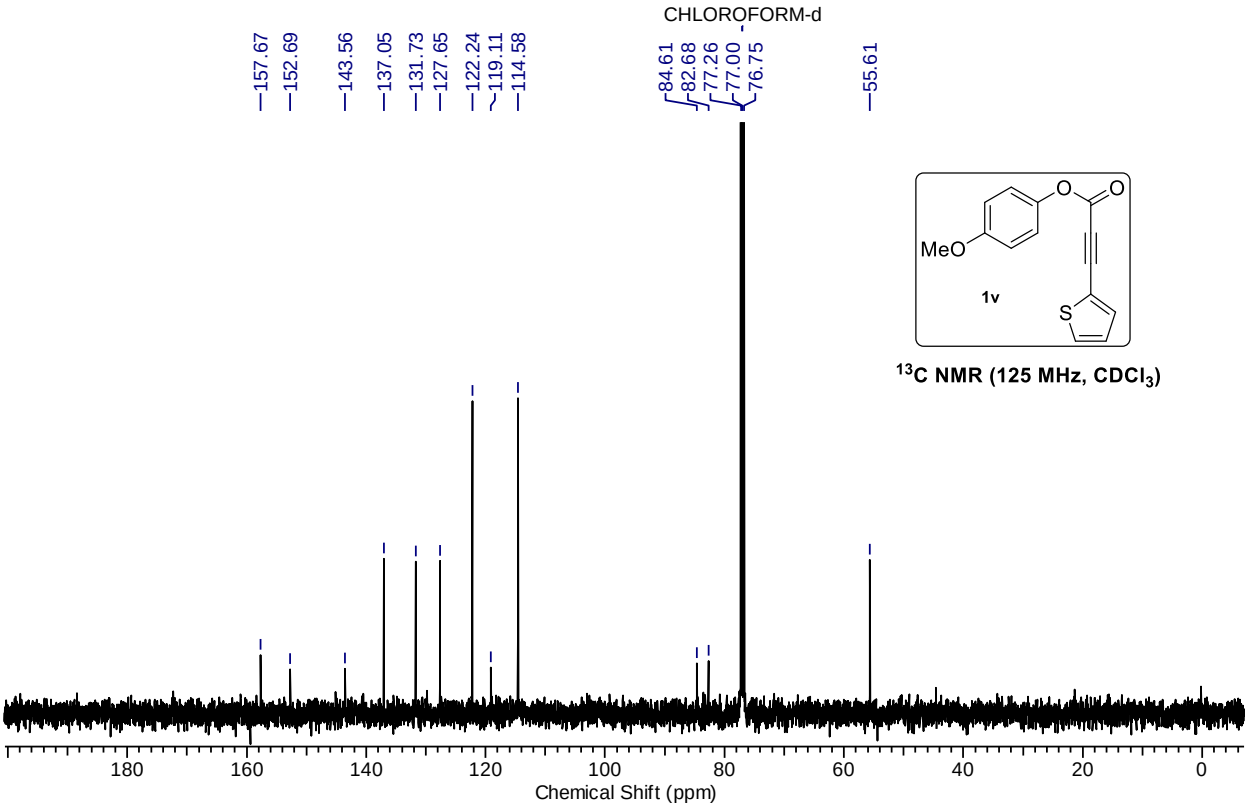
^{1}H NMR (500 MHz, $CDCl_3$)



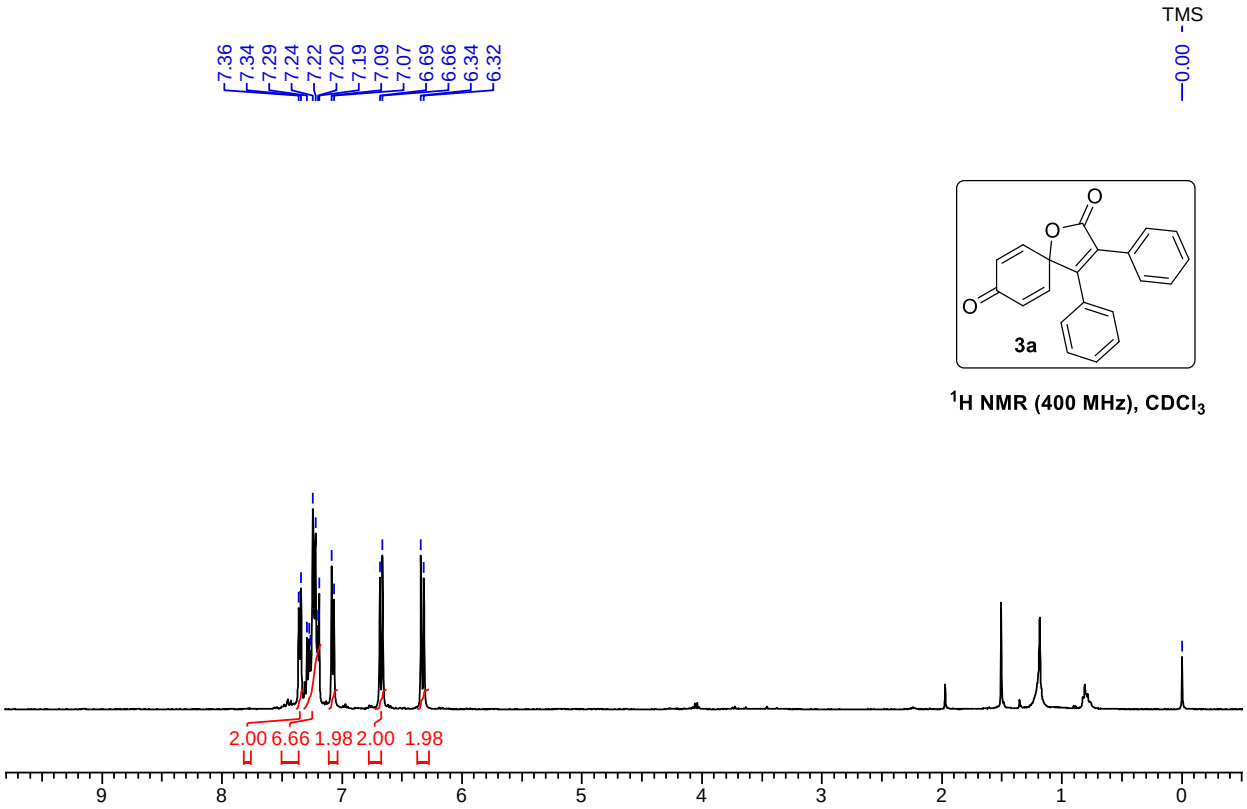
^{13}C NMR (125 MHz, $CDCl_3$)



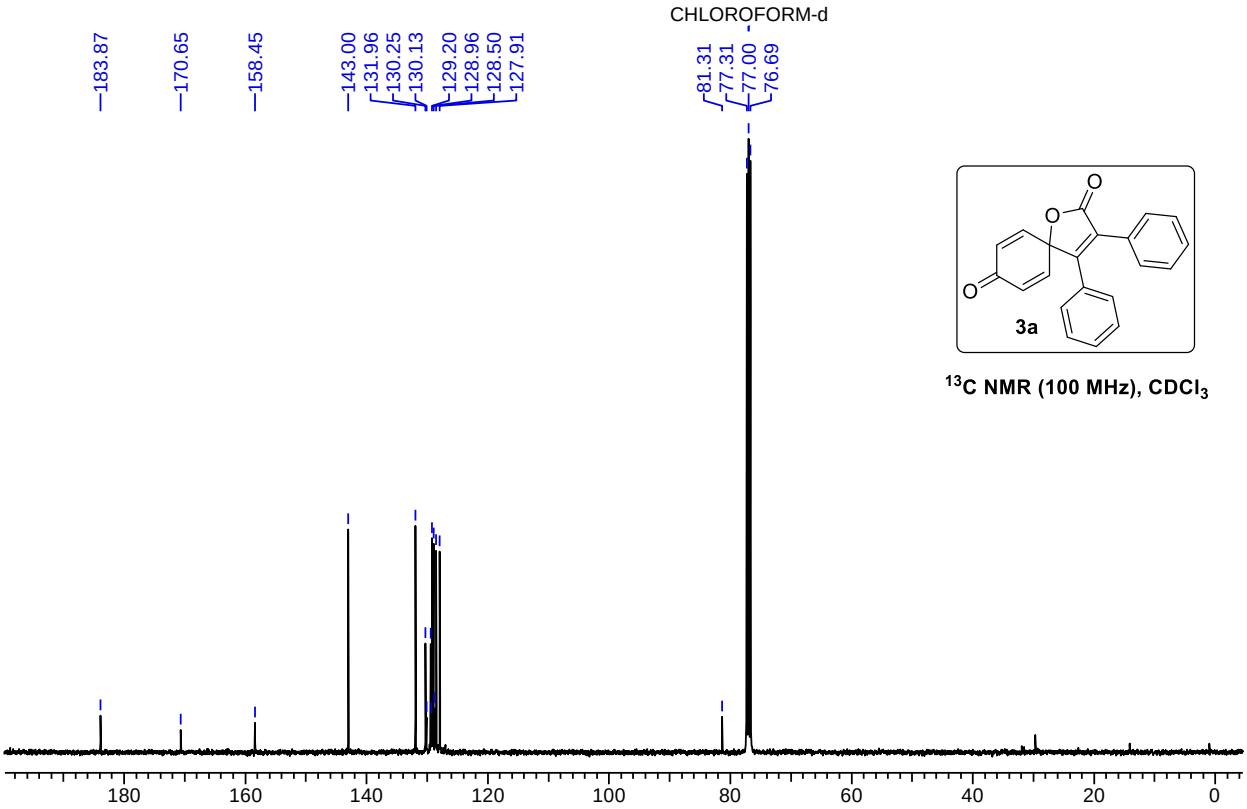
^{1}H NMR (500 MHz, $CDCl_3$)



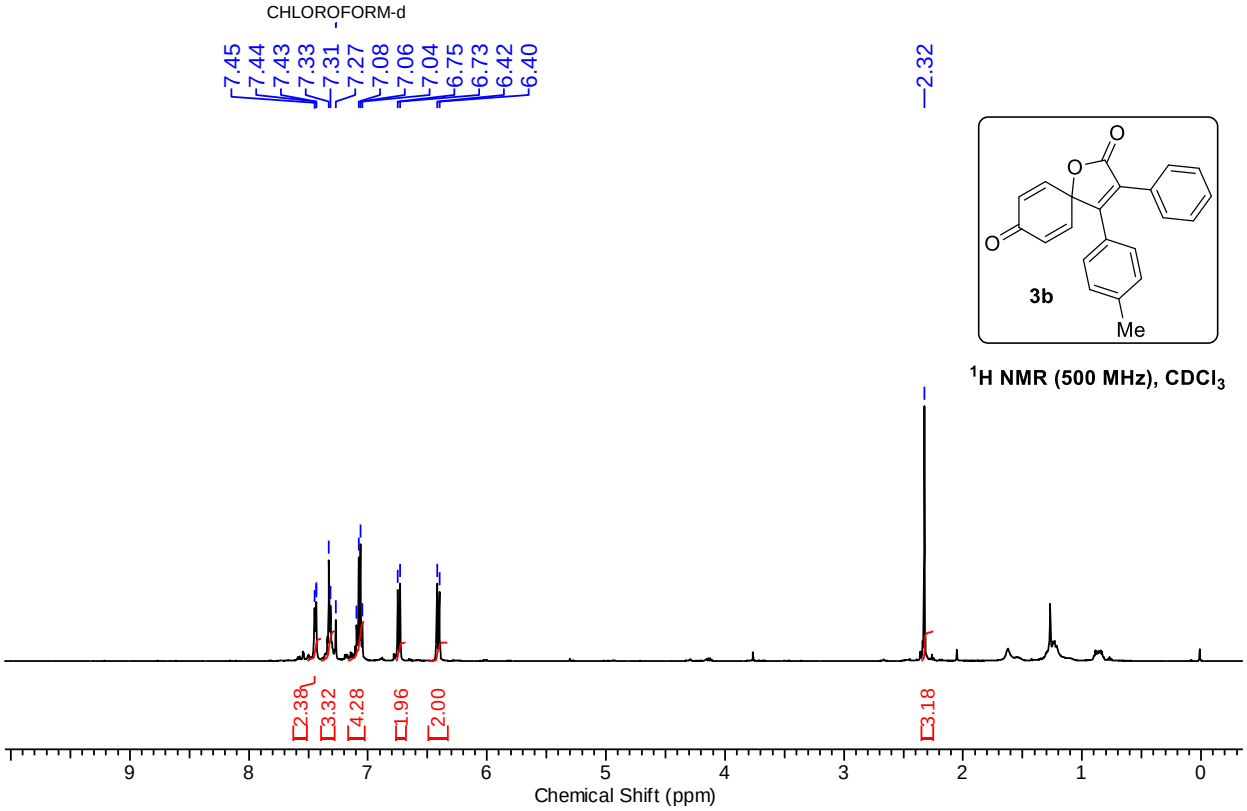
^{13}C NMR (125 MHz, $CDCl_3$)



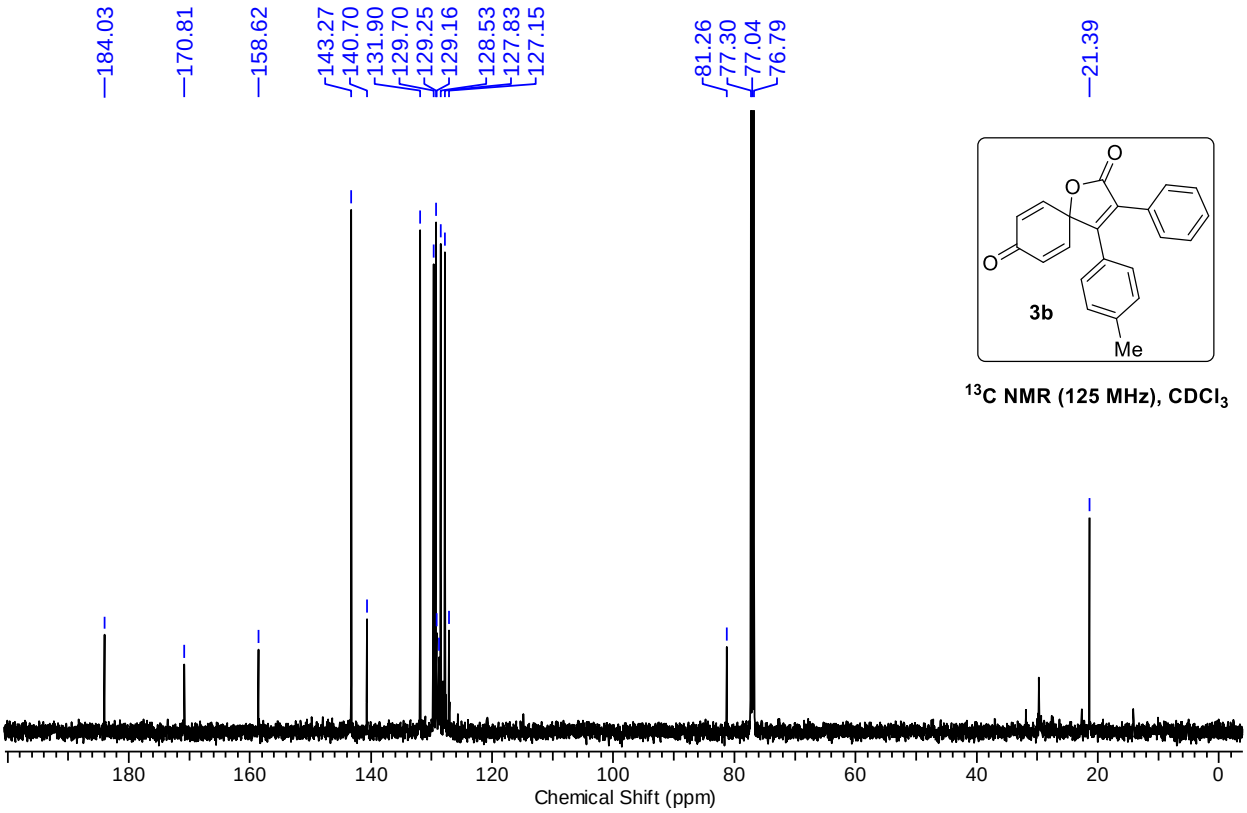
^{1}H NMR (400 MHz), $CDCl_3$



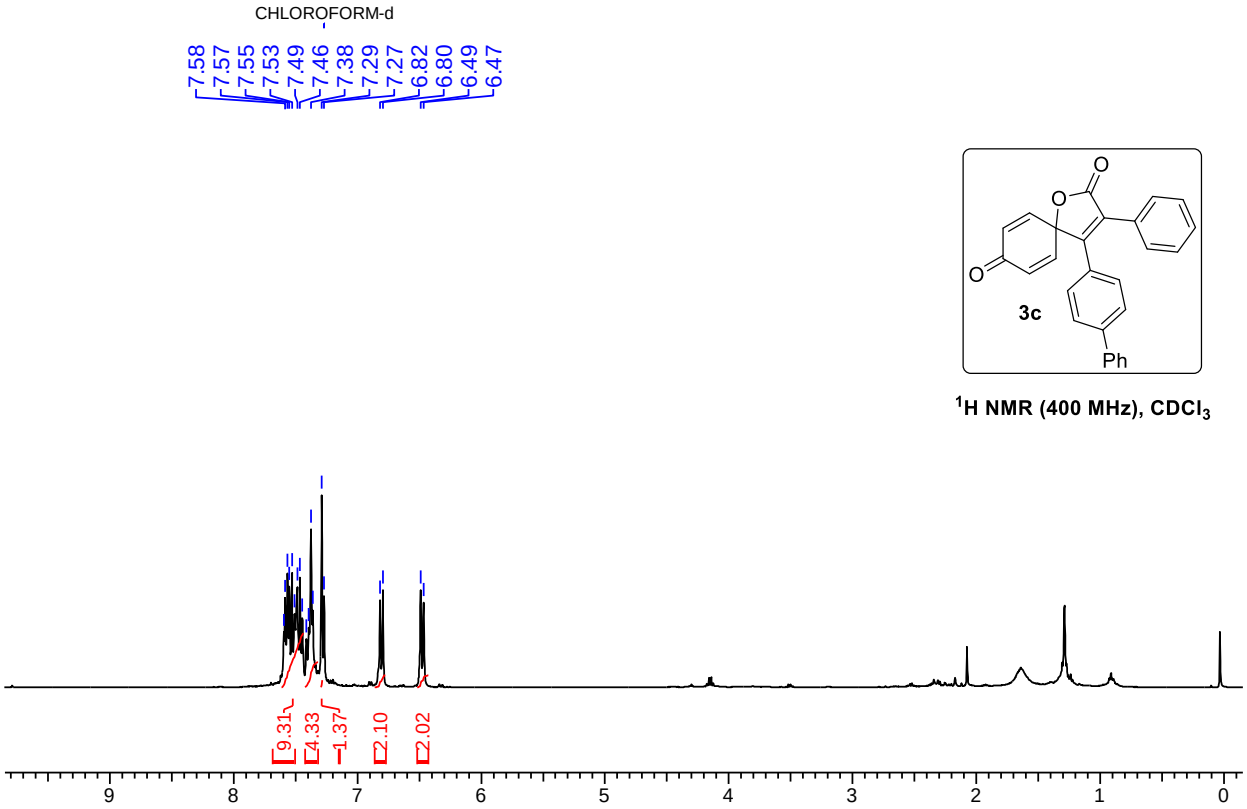
^{13}C NMR (100 MHz), $CDCl_3$



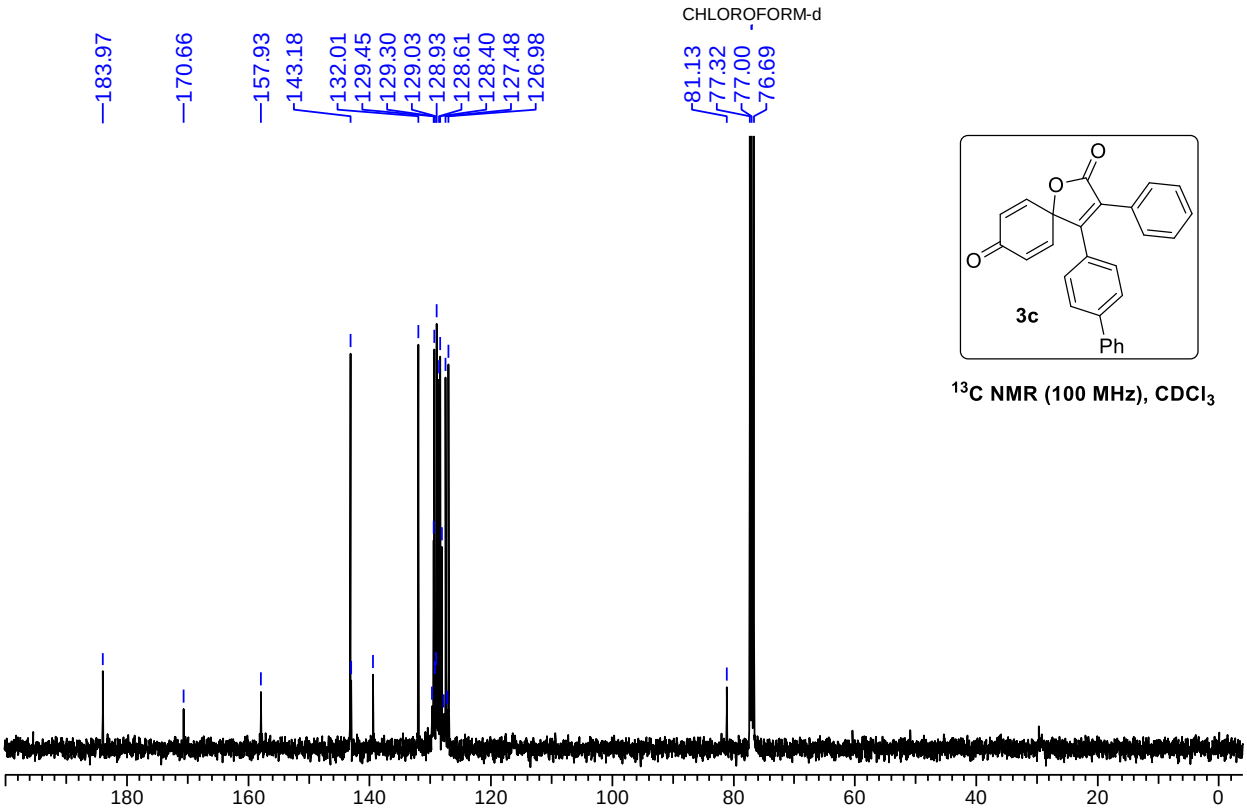
^{1}H NMR (500 MHz), $CDCl_3$



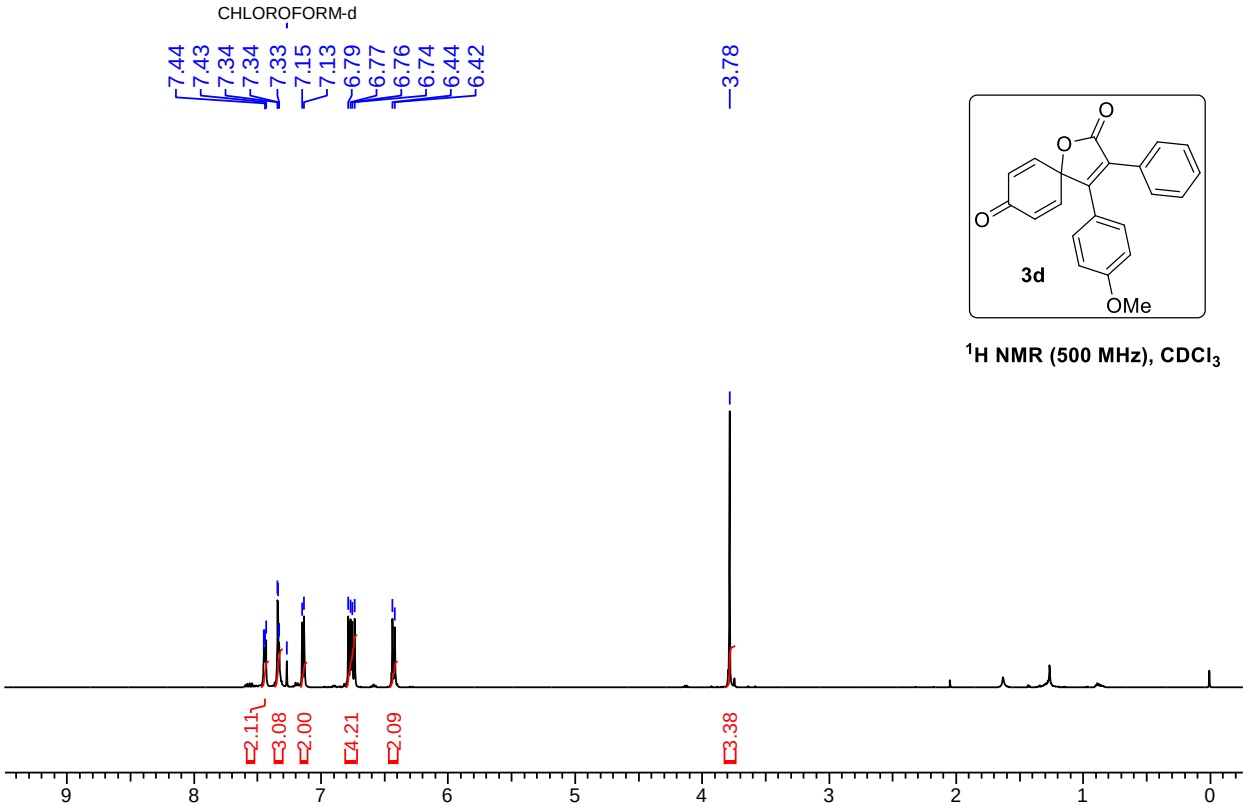
^{13}C NMR (125 MHz), $CDCl_3$



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



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



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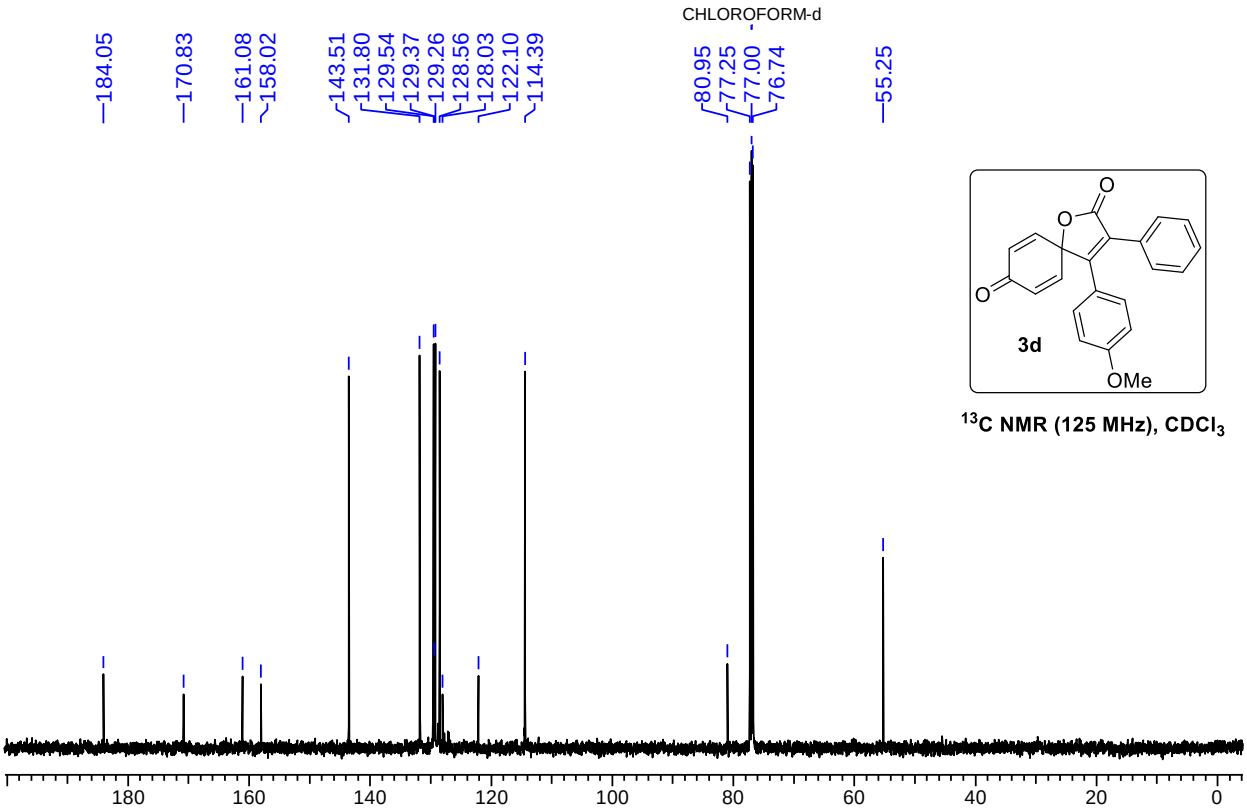
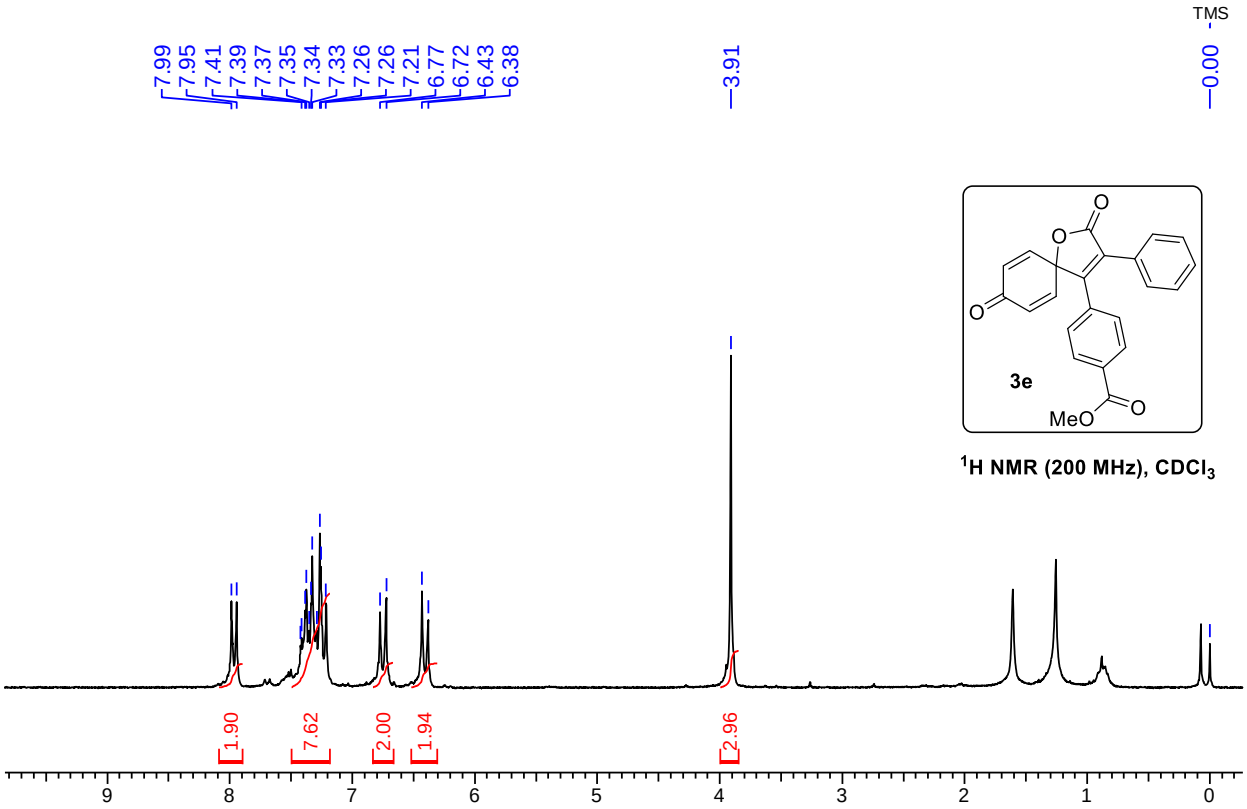
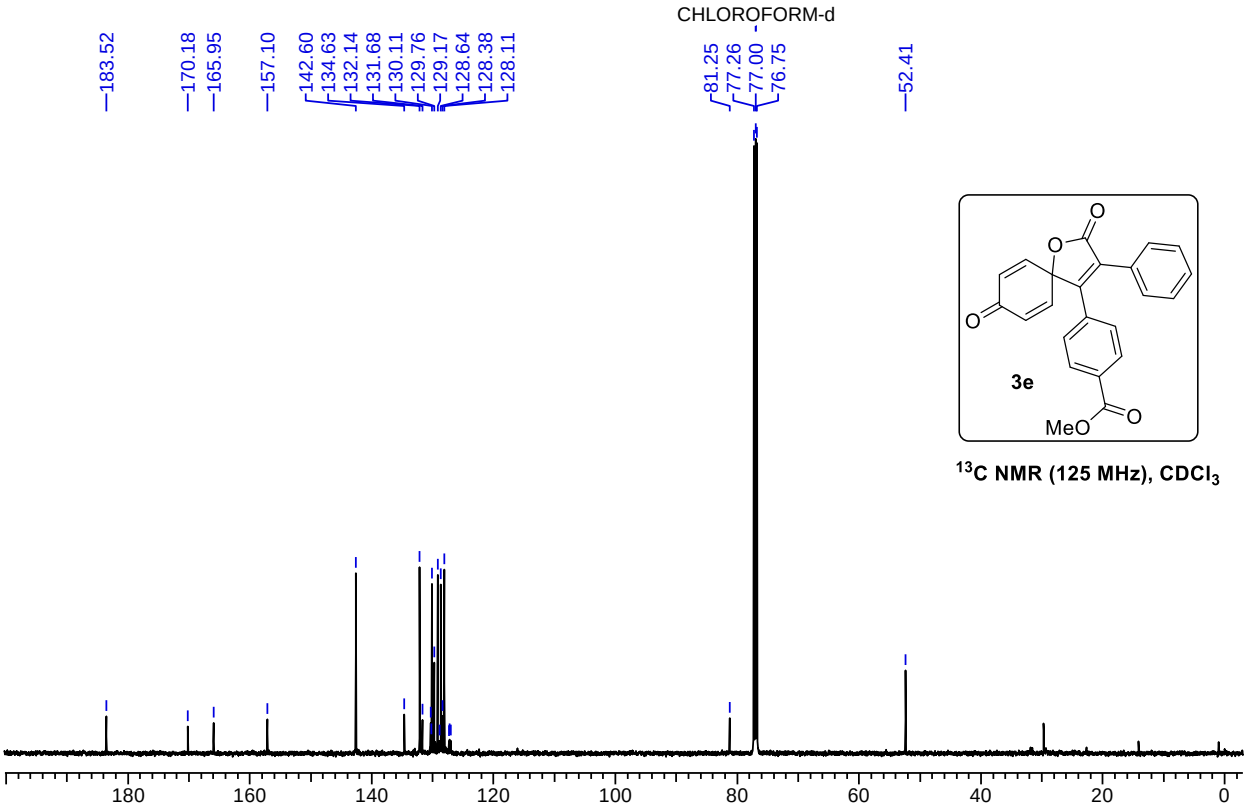


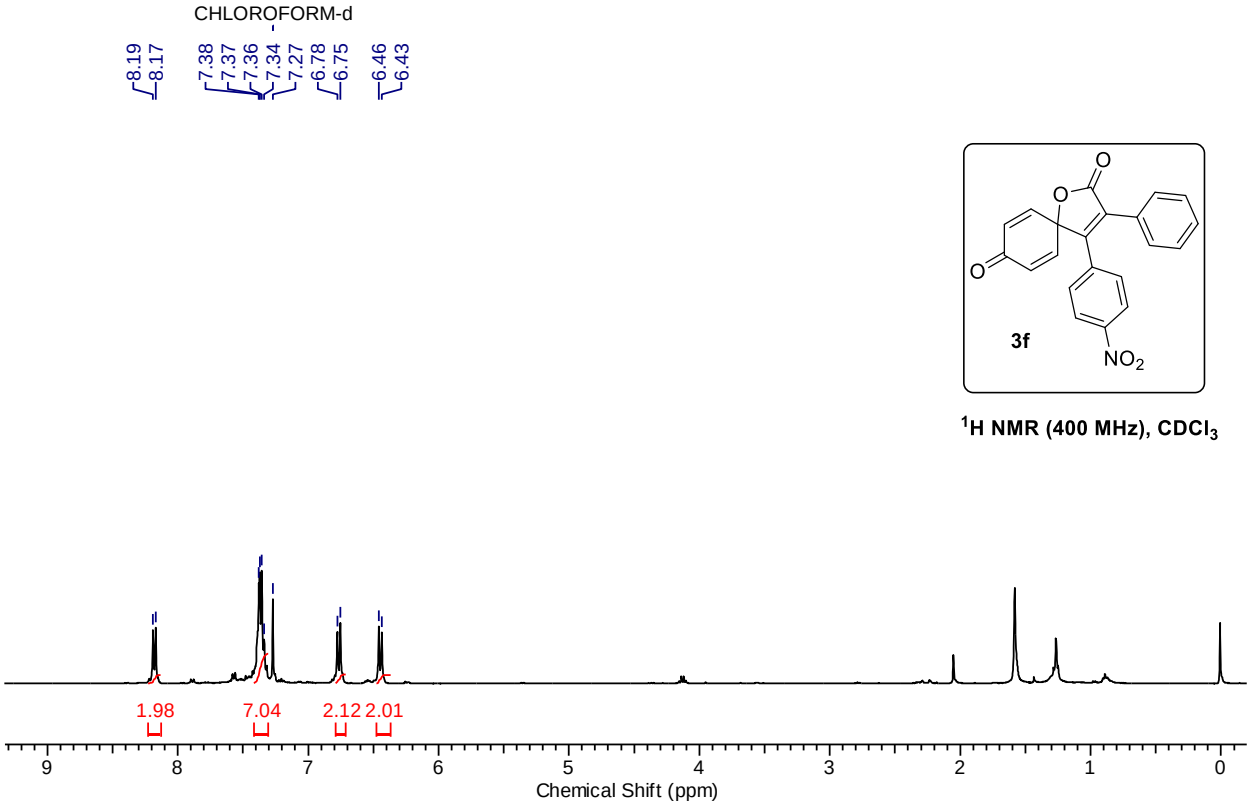
^{13}C NMR (125 MHz), $CDCl_3$



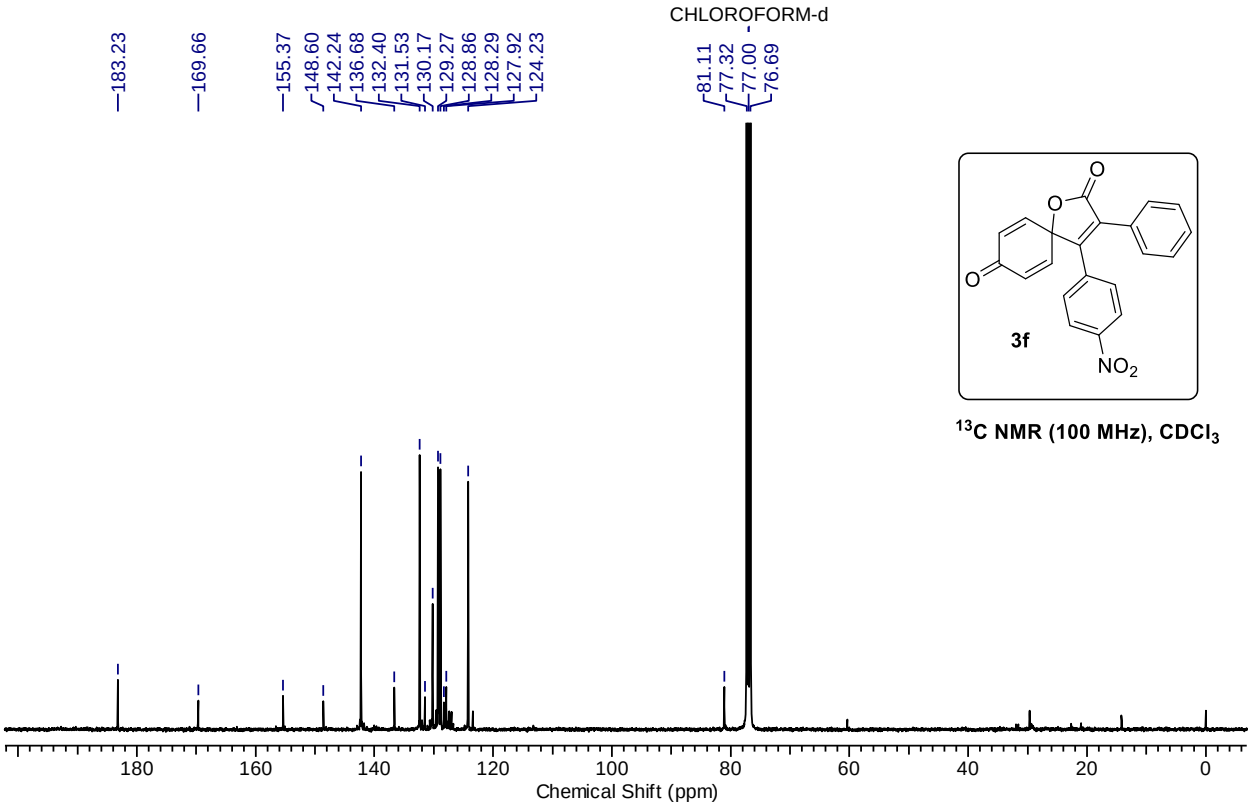
^{1}H NMR (200 MHz), $CDCl_3$



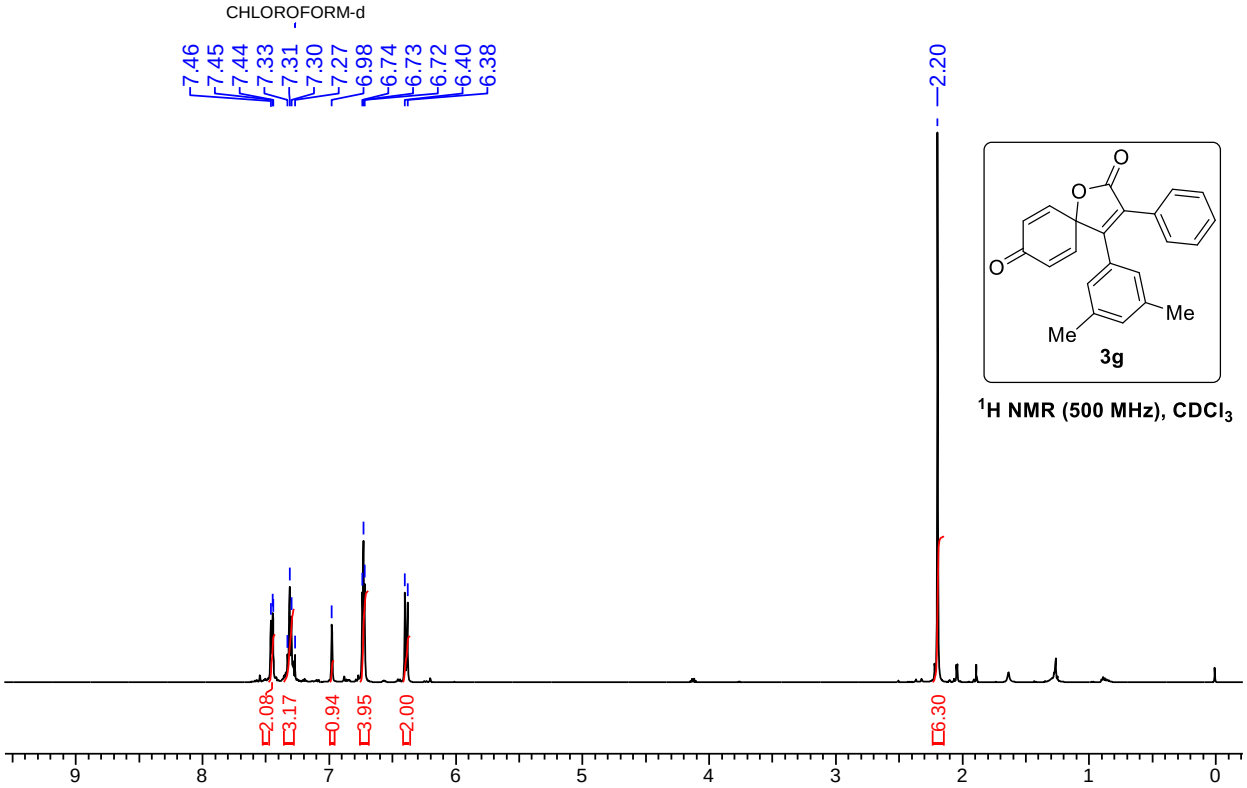
^{13}C NMR (125 MHz), $CDCl_3$



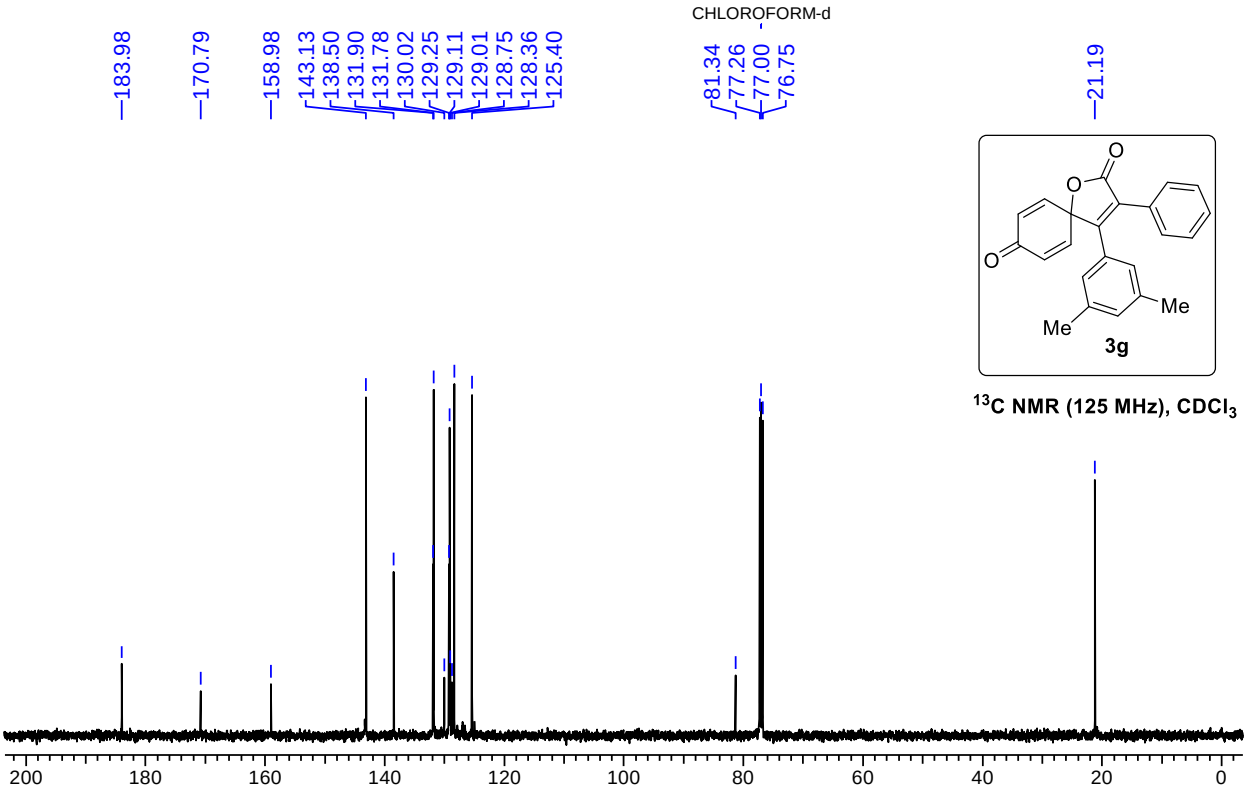
^{1}H NMR (400 MHz), $CDCl_3$



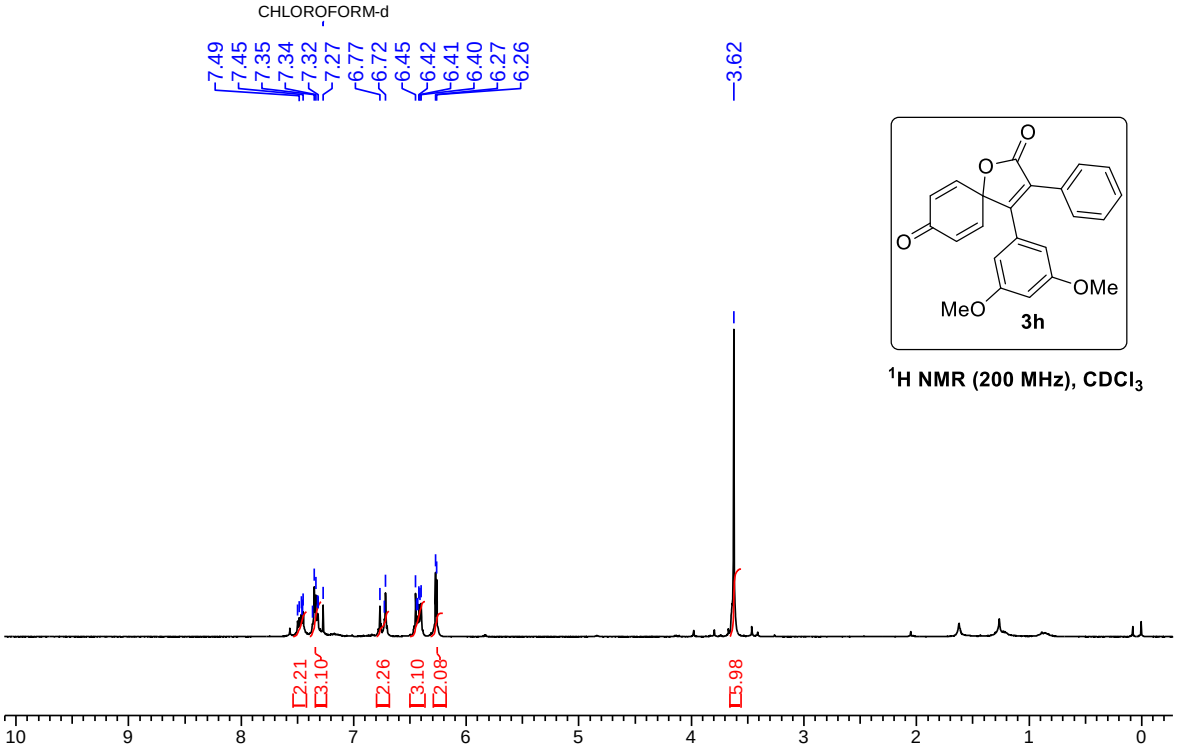
^{13}C NMR (100 MHz), $CDCl_3$



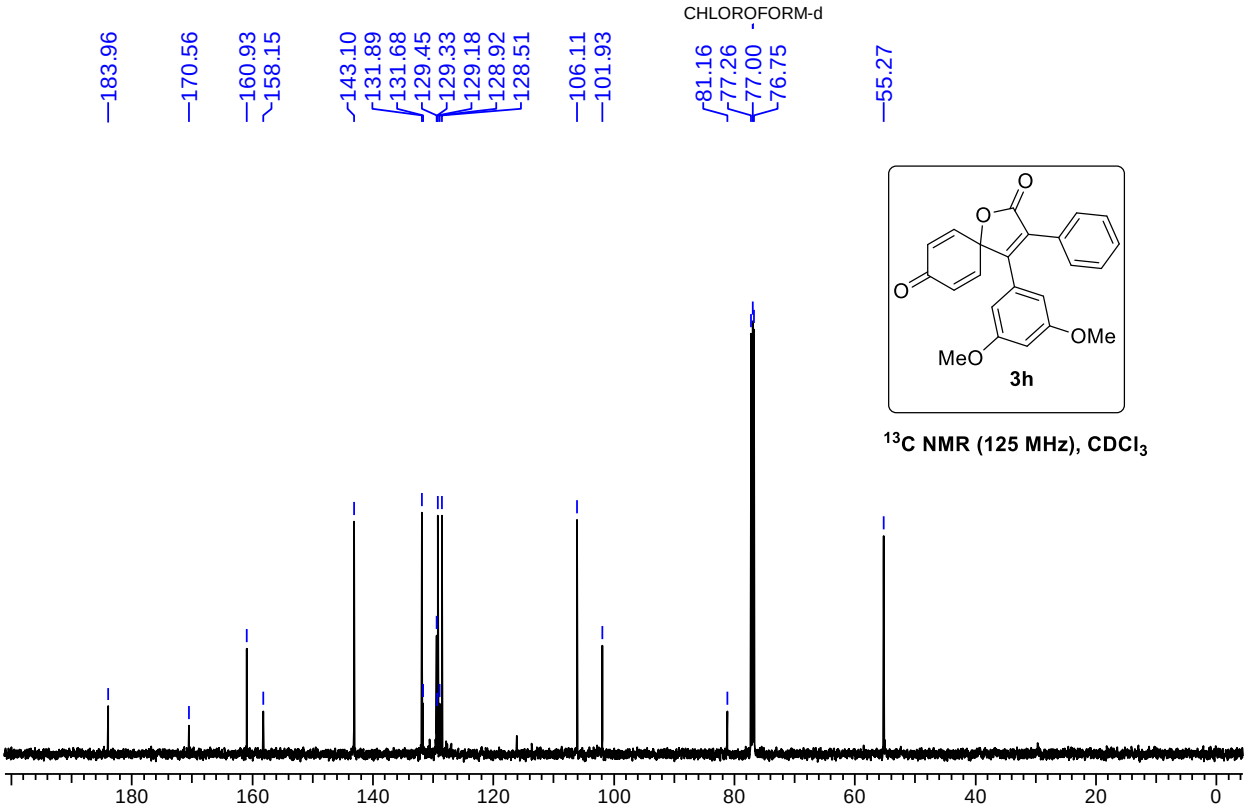
^{1}H NMR (500 MHz), $CDCl_3$



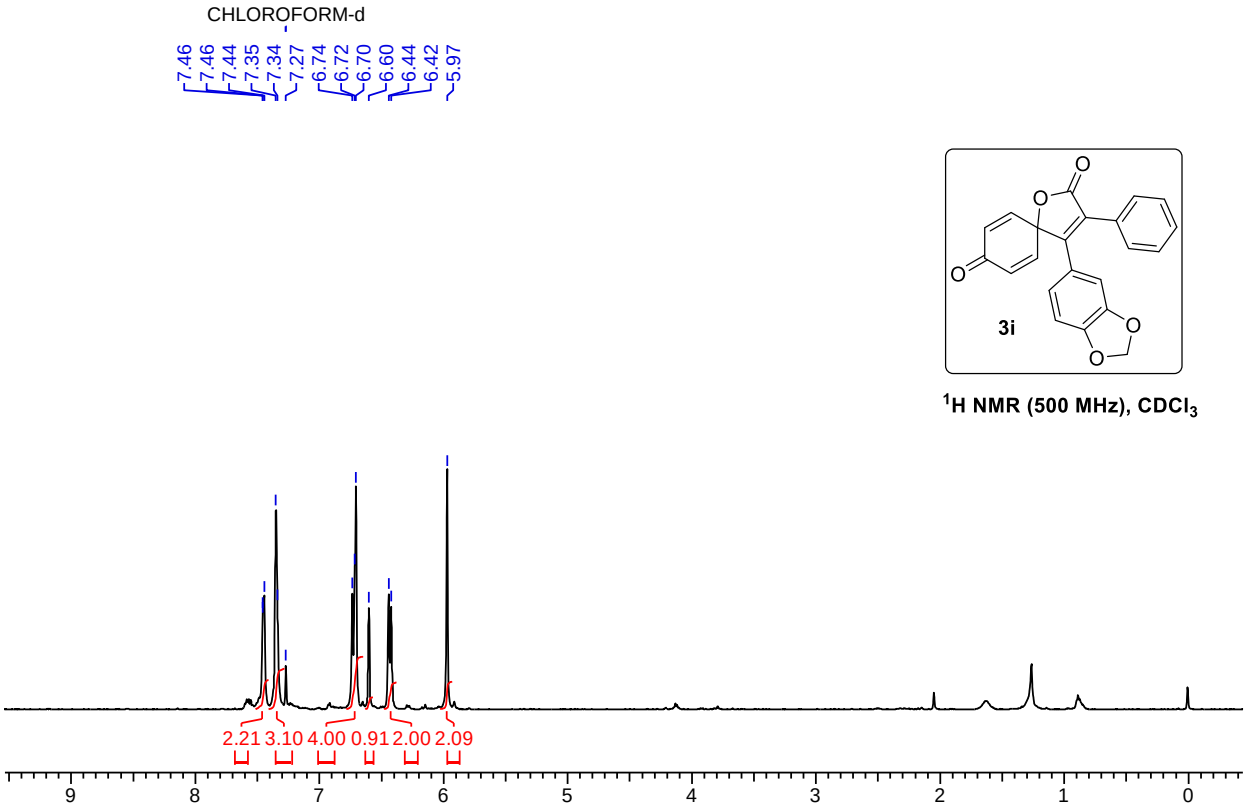
^{13}C NMR (125 MHz), $CDCl_3$



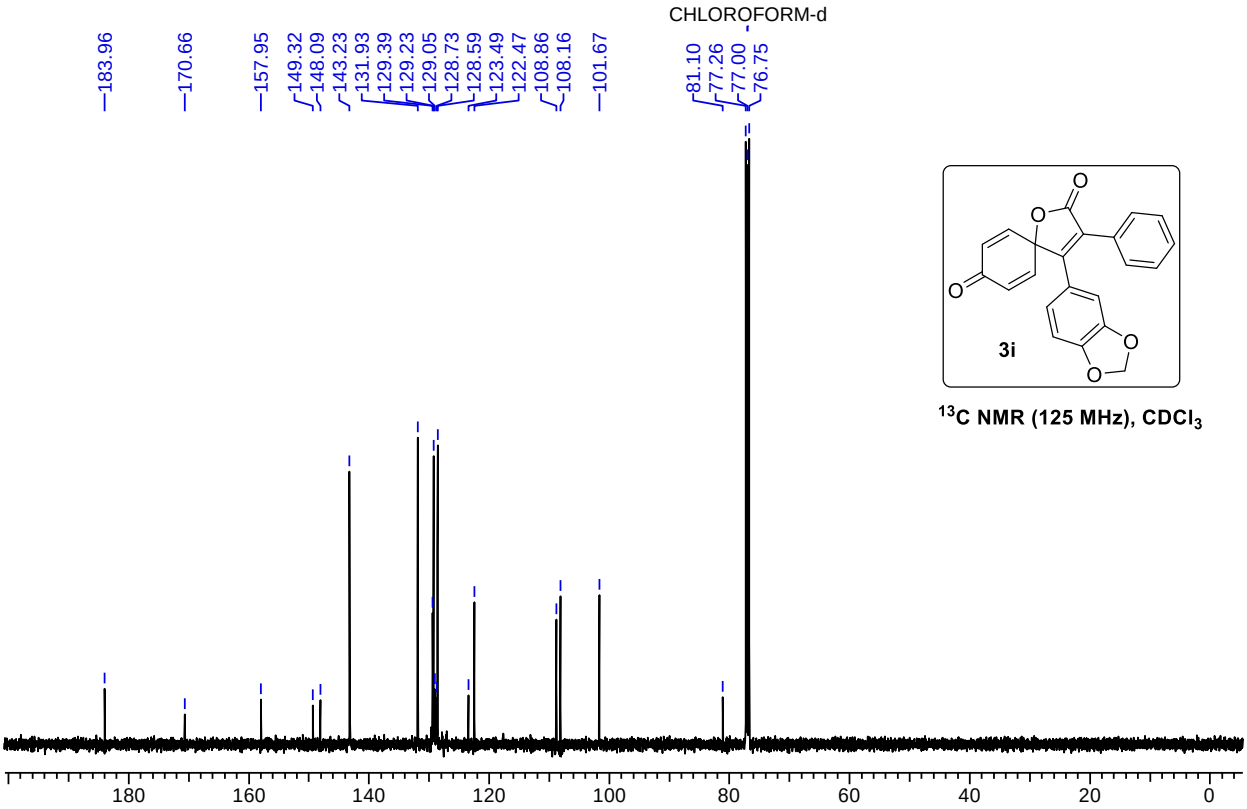
^{1}H NMR (200 MHz), $CDCl_3$



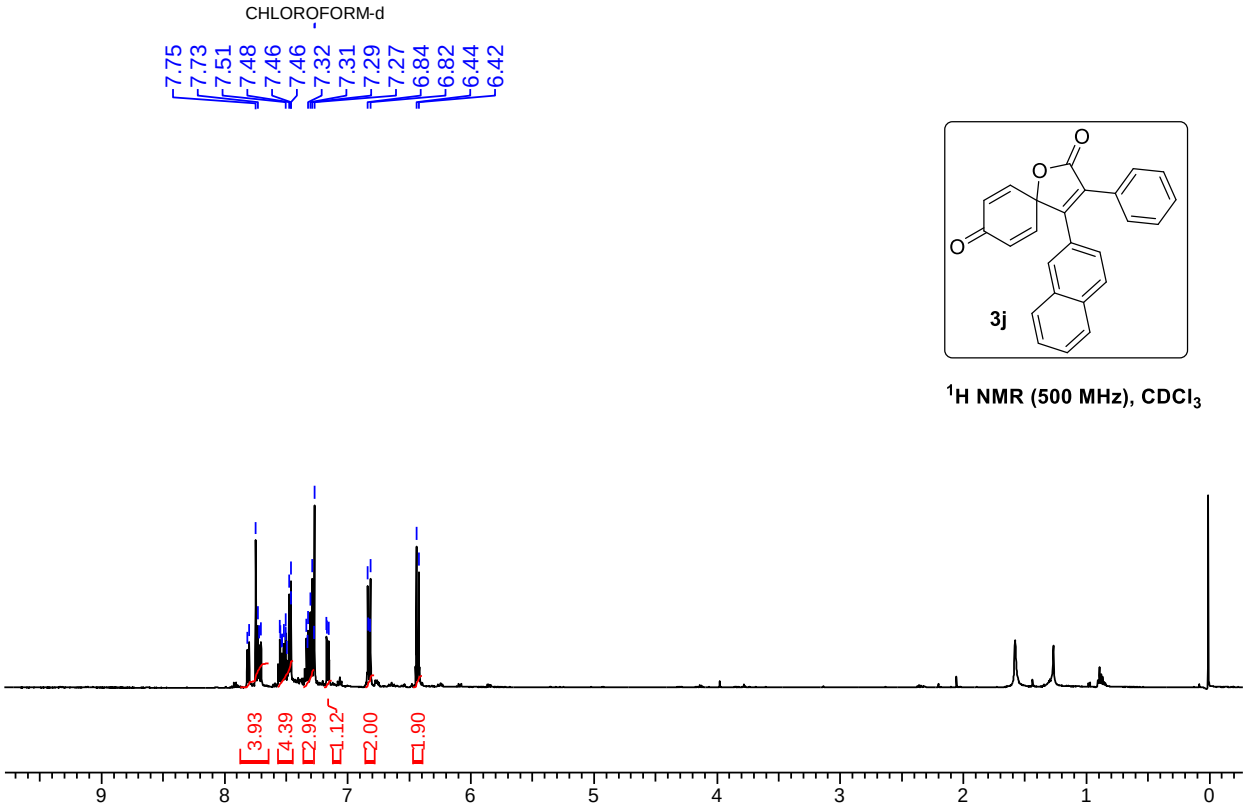
^{13}C NMR (125 MHz), $CDCl_3$



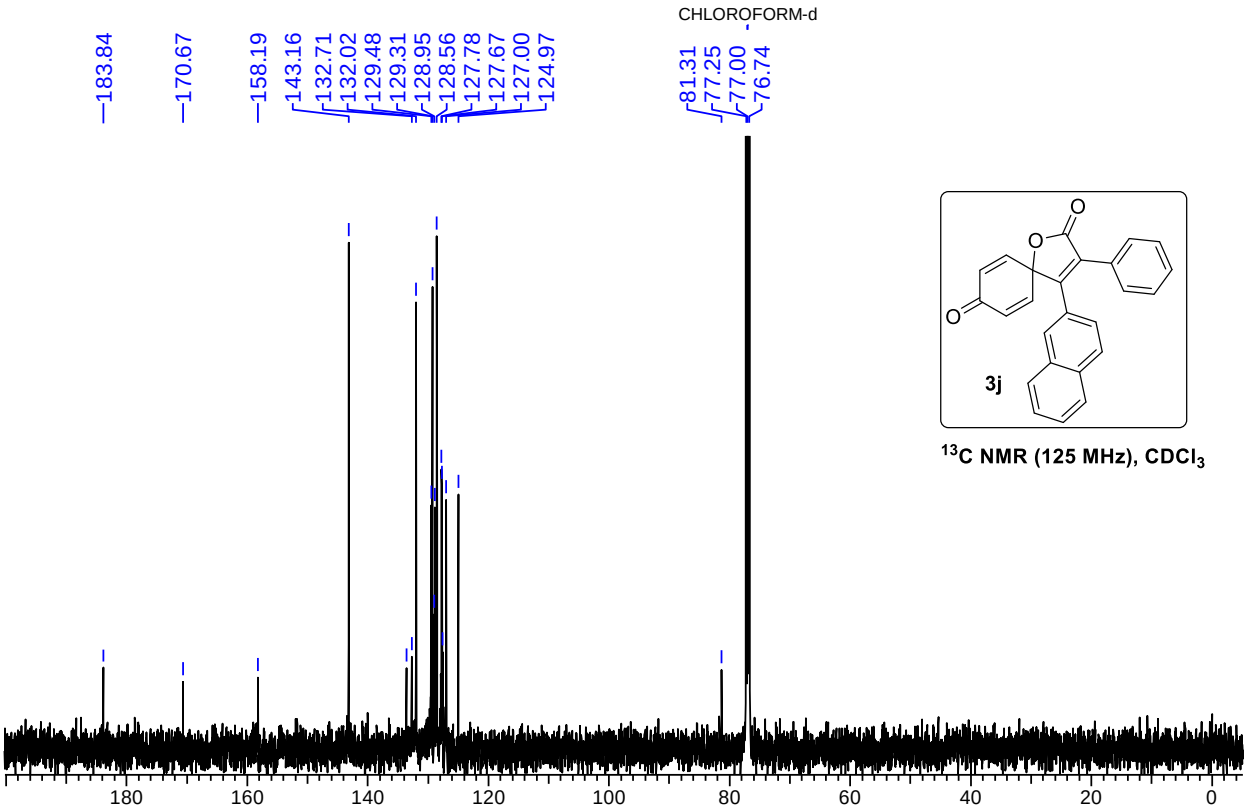
^{1}H NMR (500 MHz), $CDCl_3$



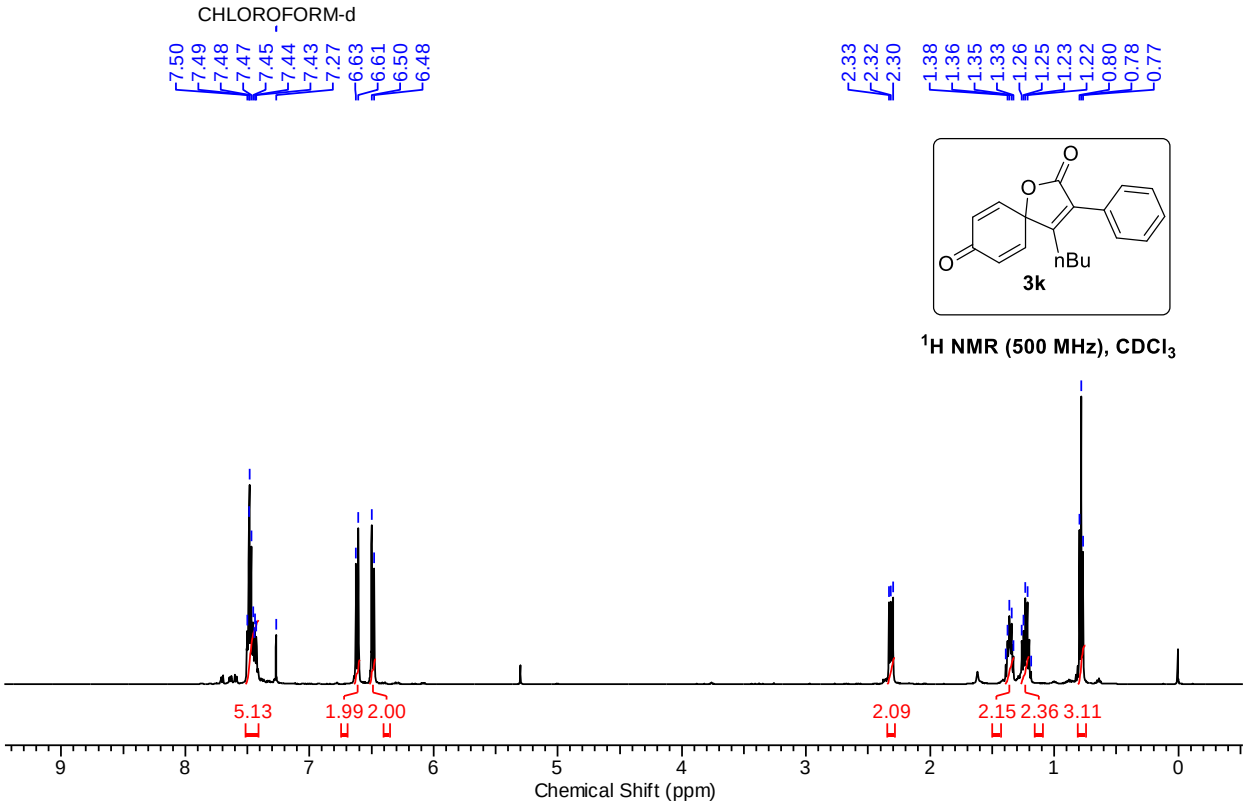
^{13}C NMR (125 MHz), $CDCl_3$



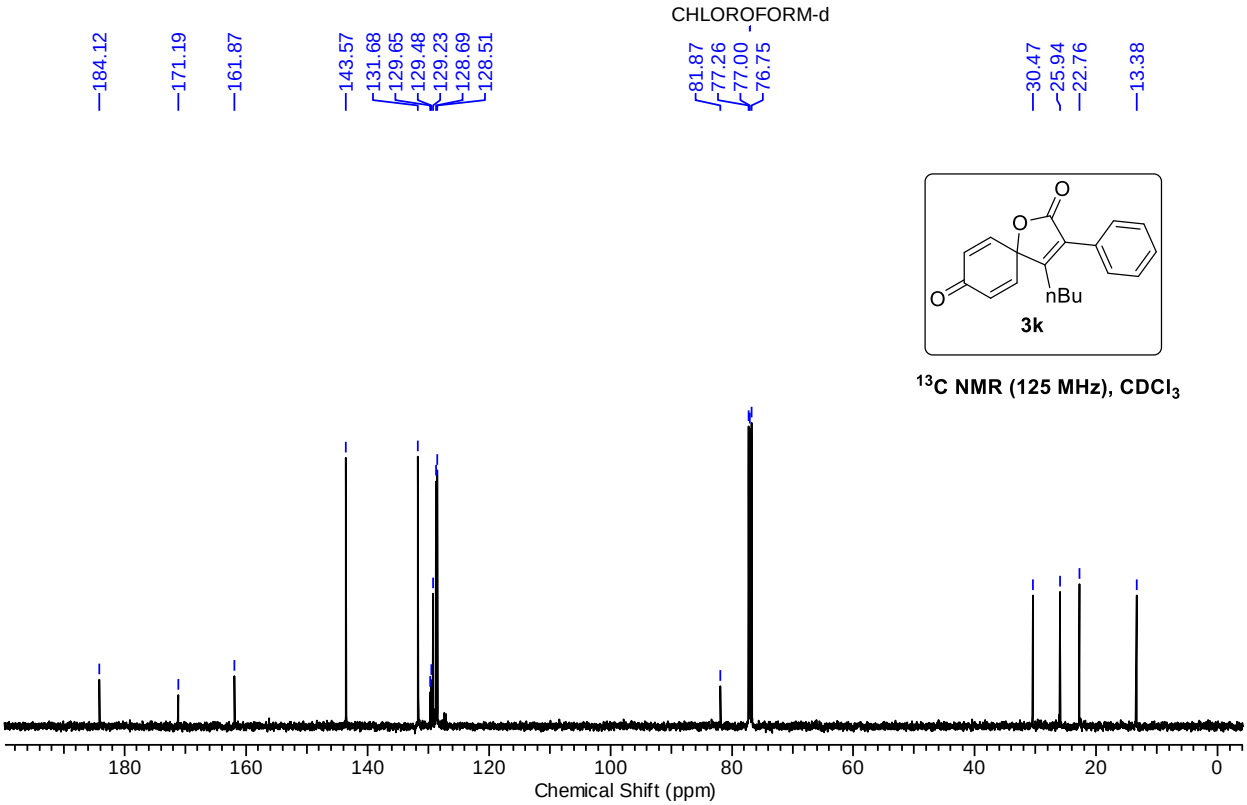
^{1}H NMR (500 MHz), $CDCl_3$



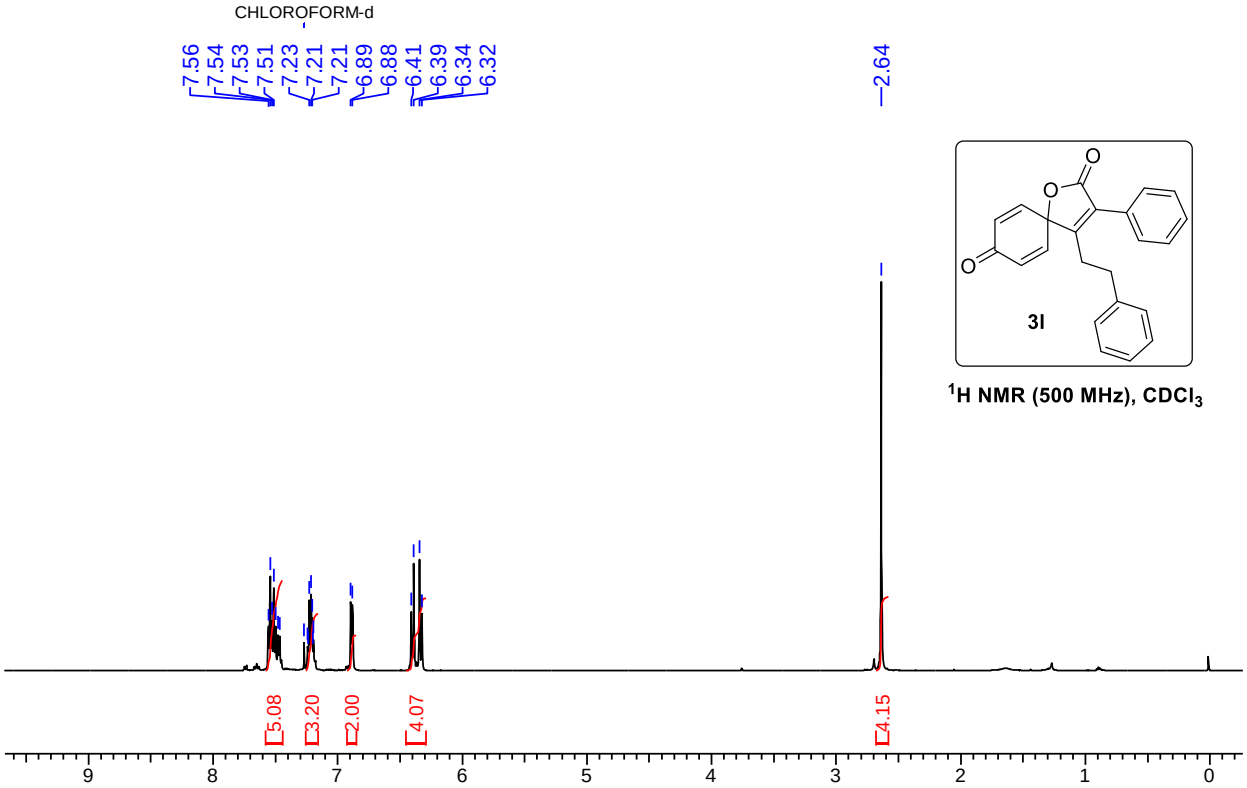
^{13}C NMR (125 MHz), $CDCl_3$



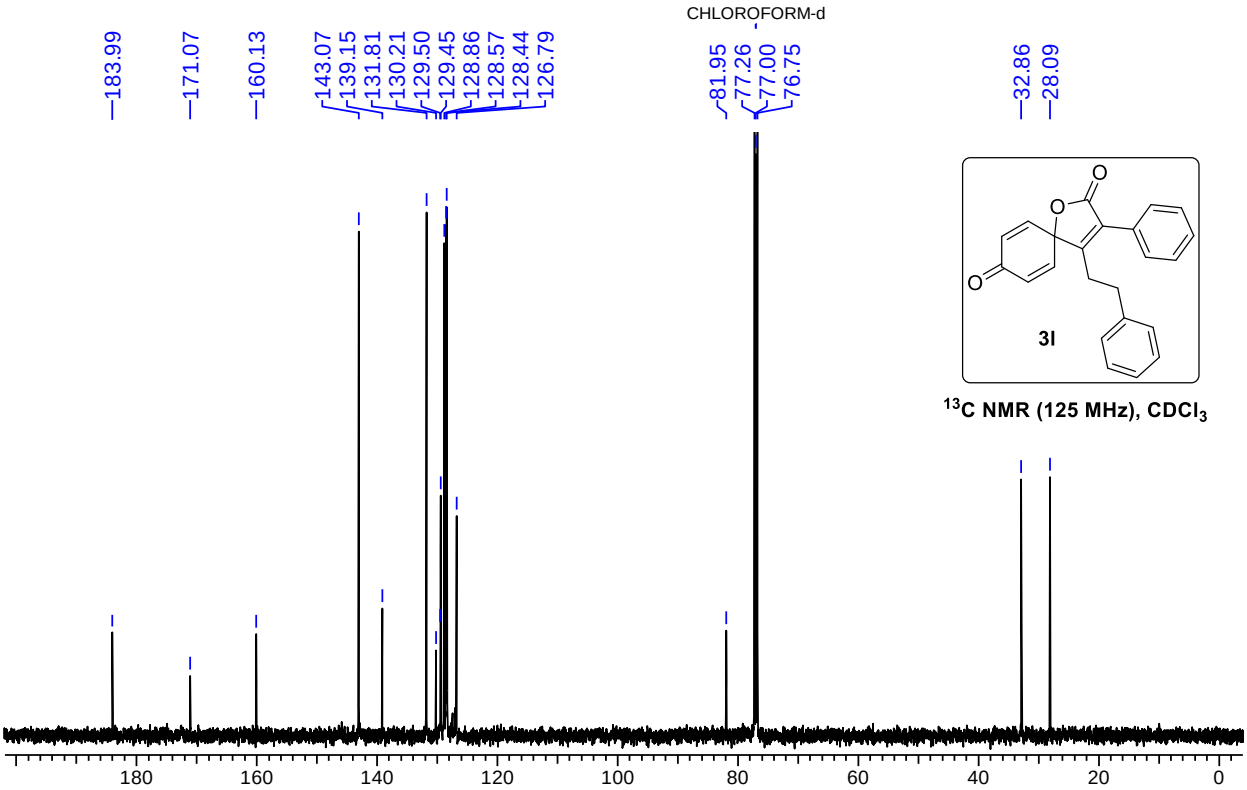
^{1}H NMR (500 MHz), $CDCl_3$



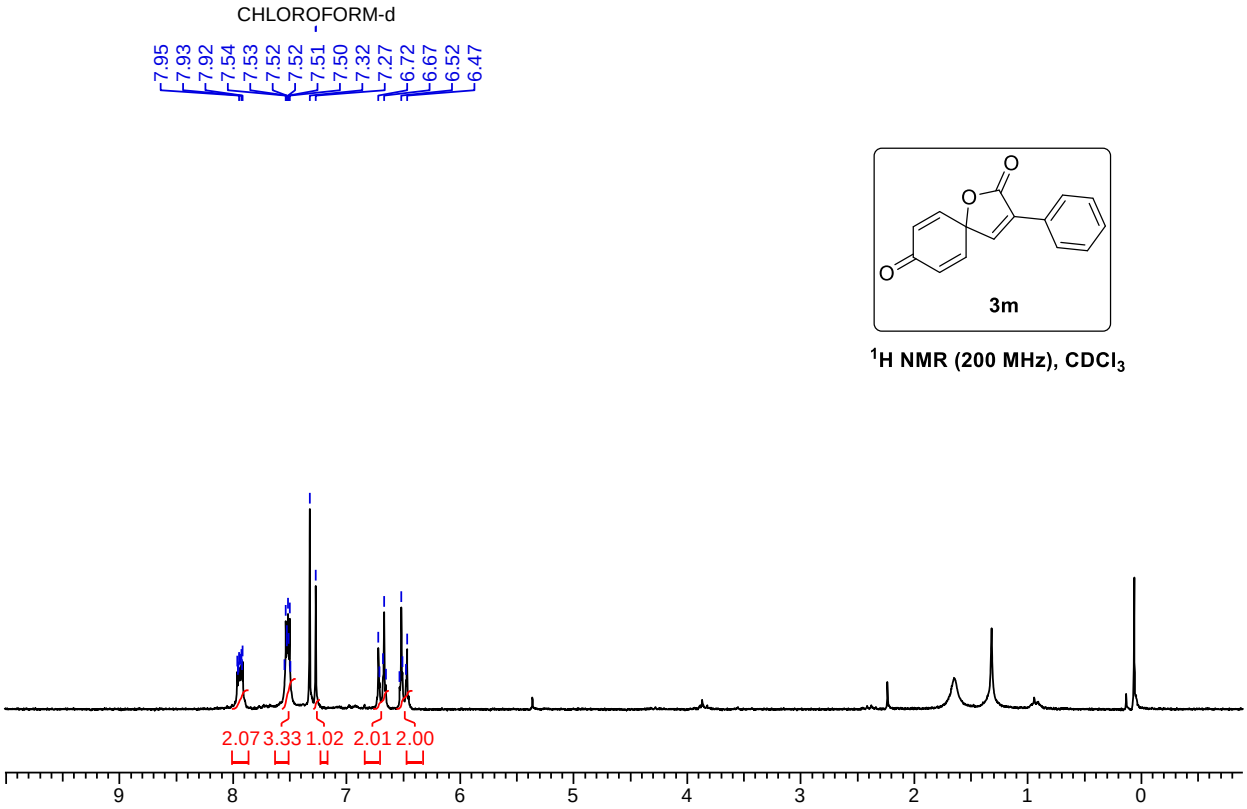
^{13}C NMR (125 MHz), $CDCl_3$



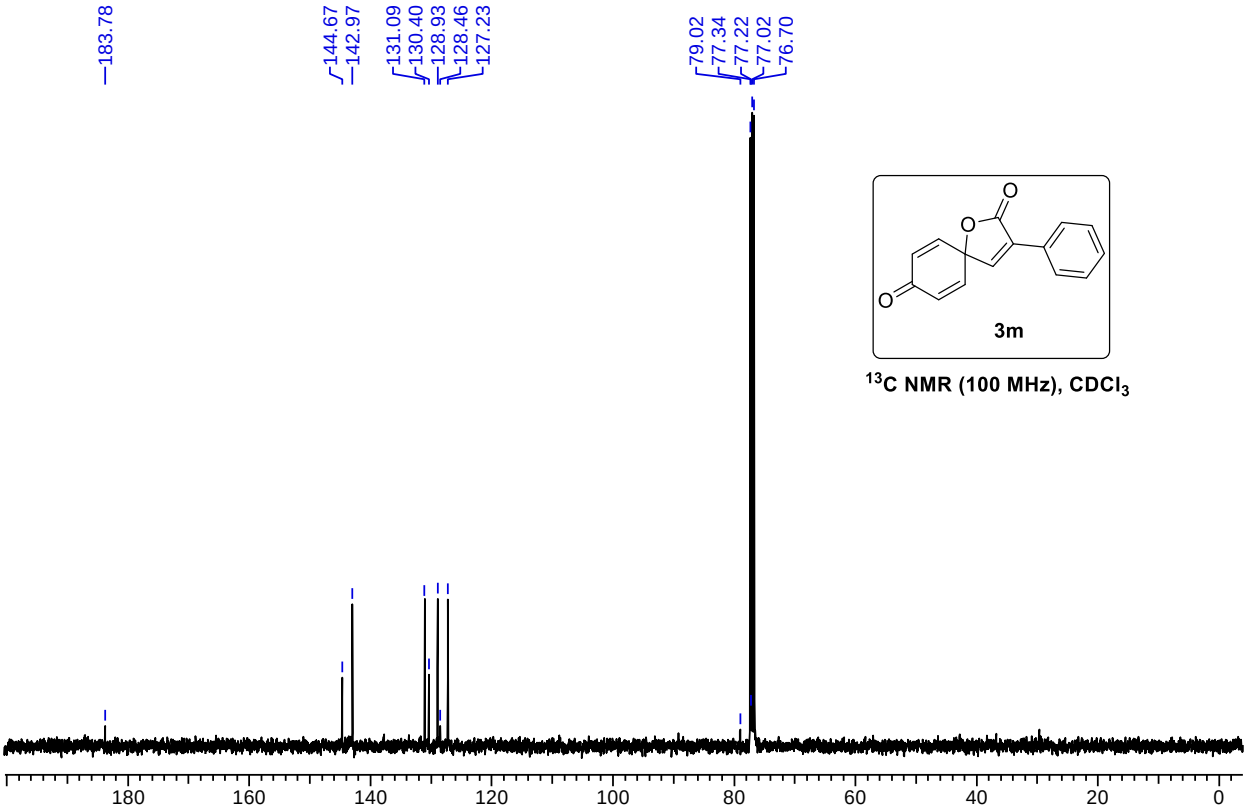
^{1}H NMR (500 MHz), $CDCl_3$



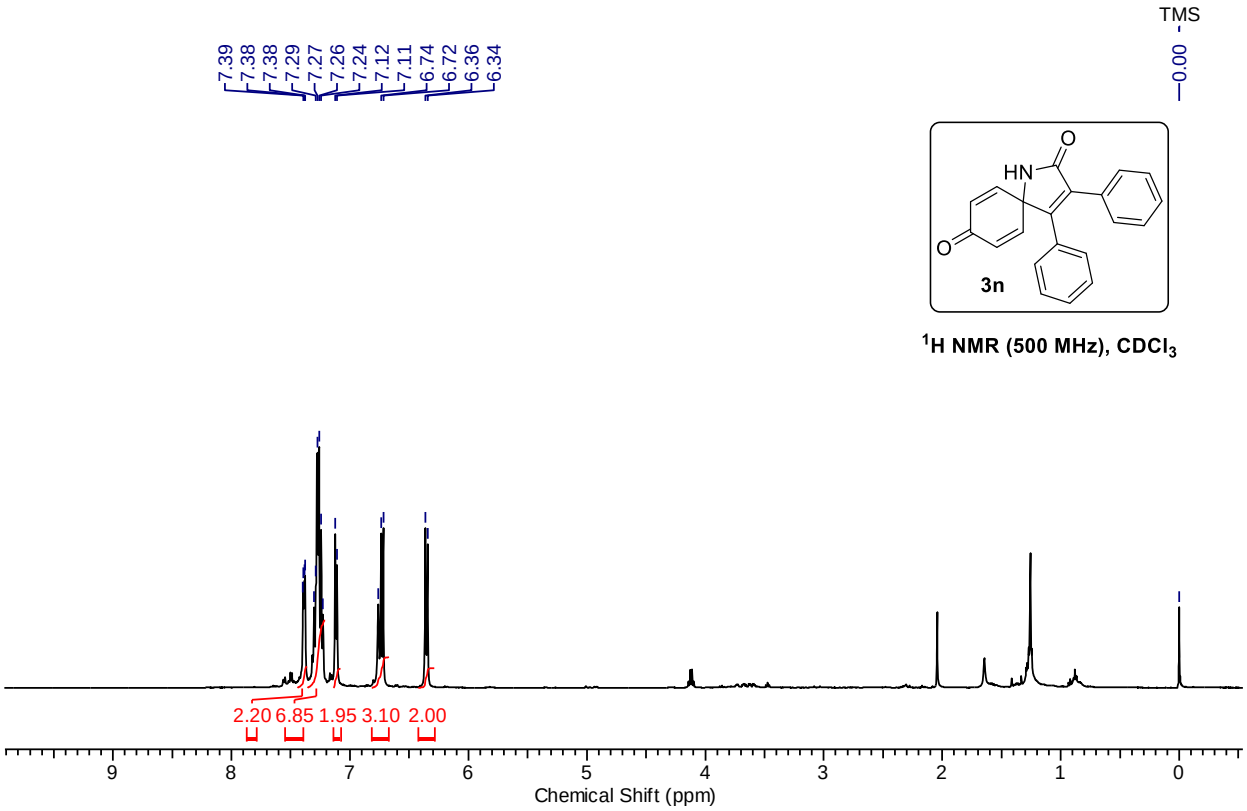
^{13}C NMR (125 MHz), $CDCl_3$



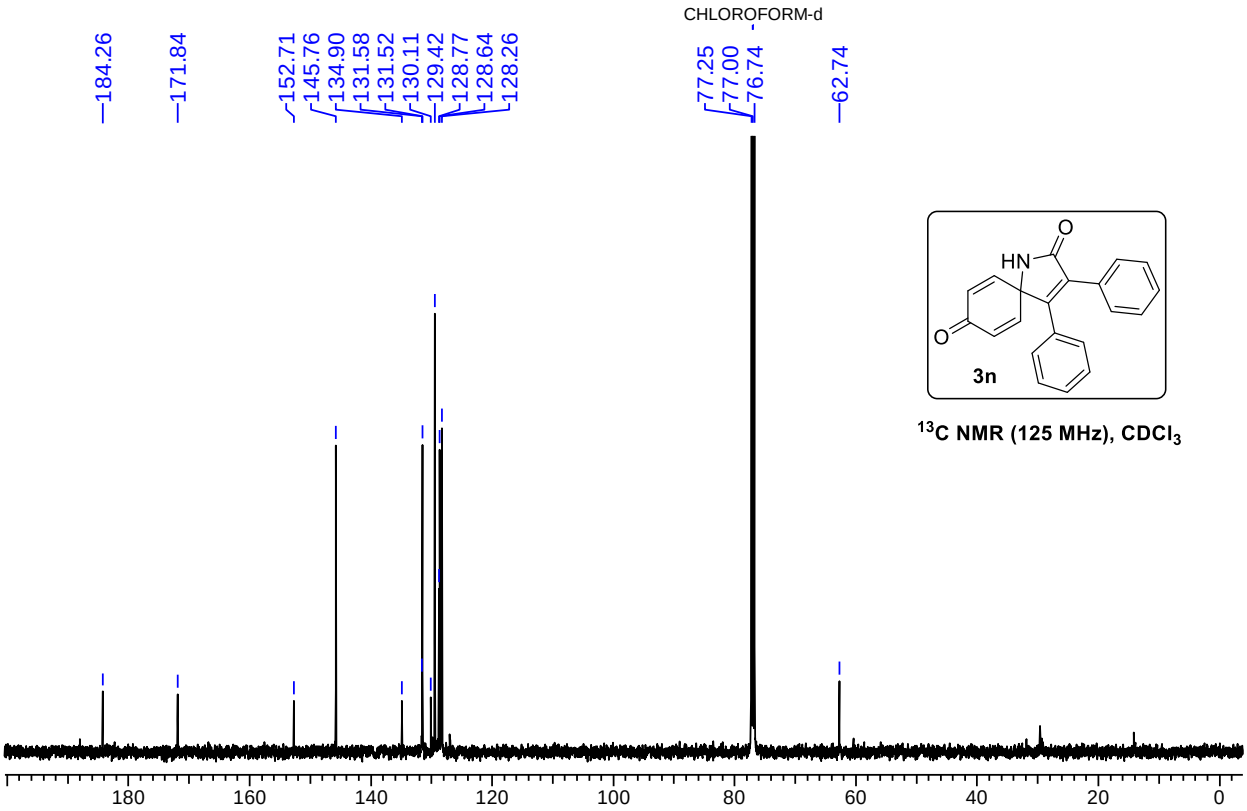
^{1}H NMR (200 MHz), $CDCl_3$



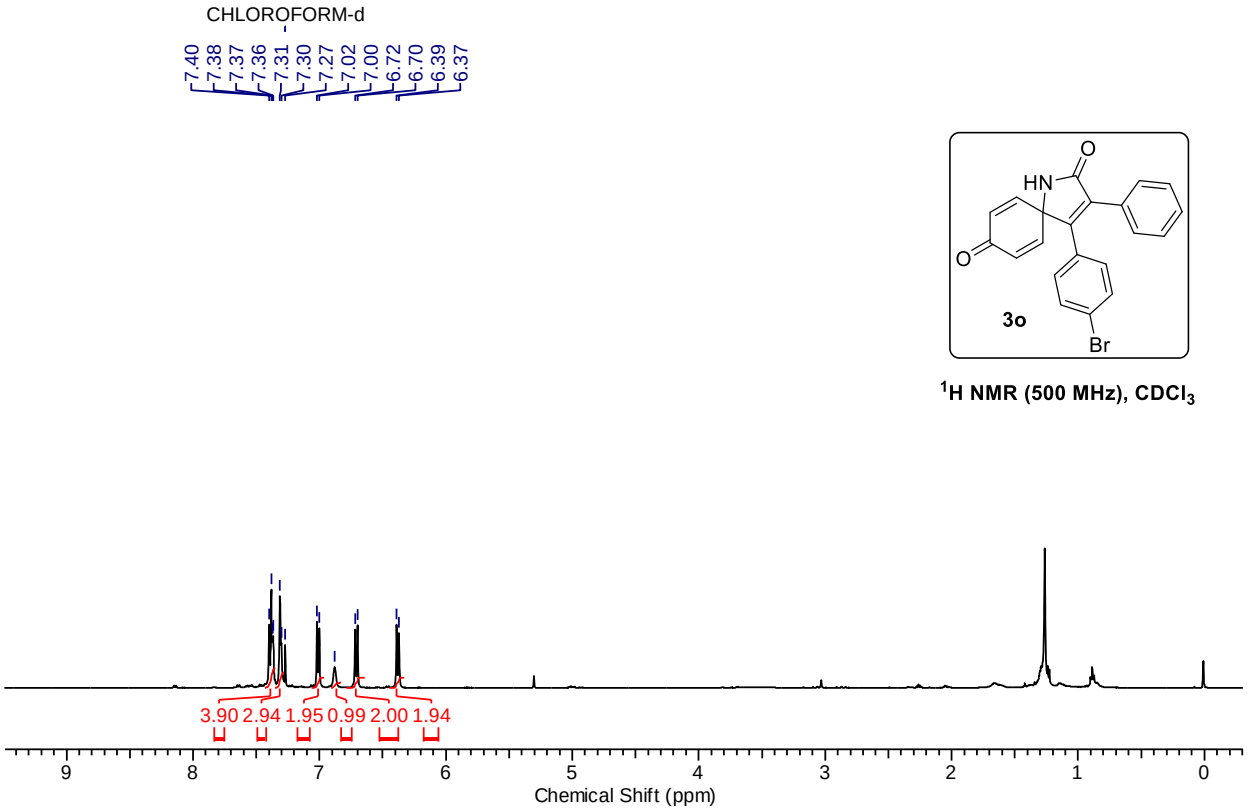
^{13}C NMR (100 MHz), $CDCl_3$



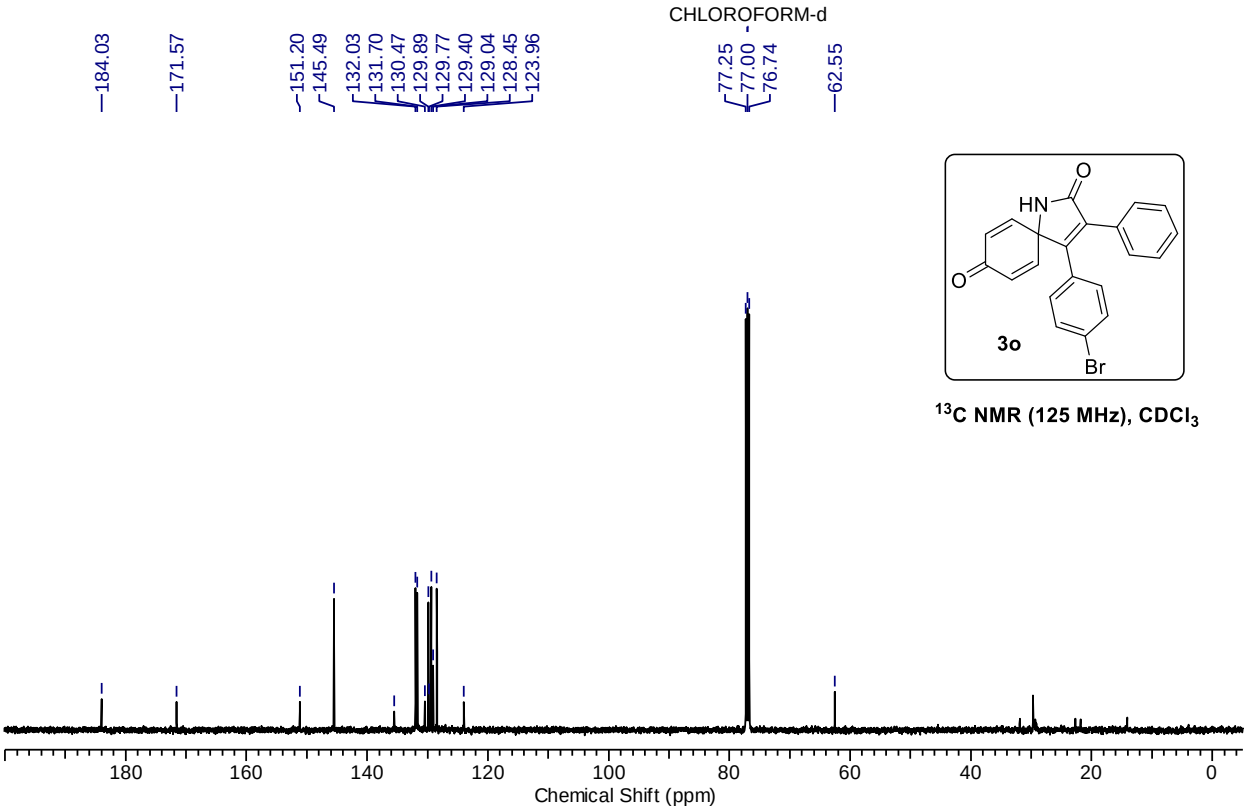
^{1}H NMR (500 MHz), $CDCl_3$



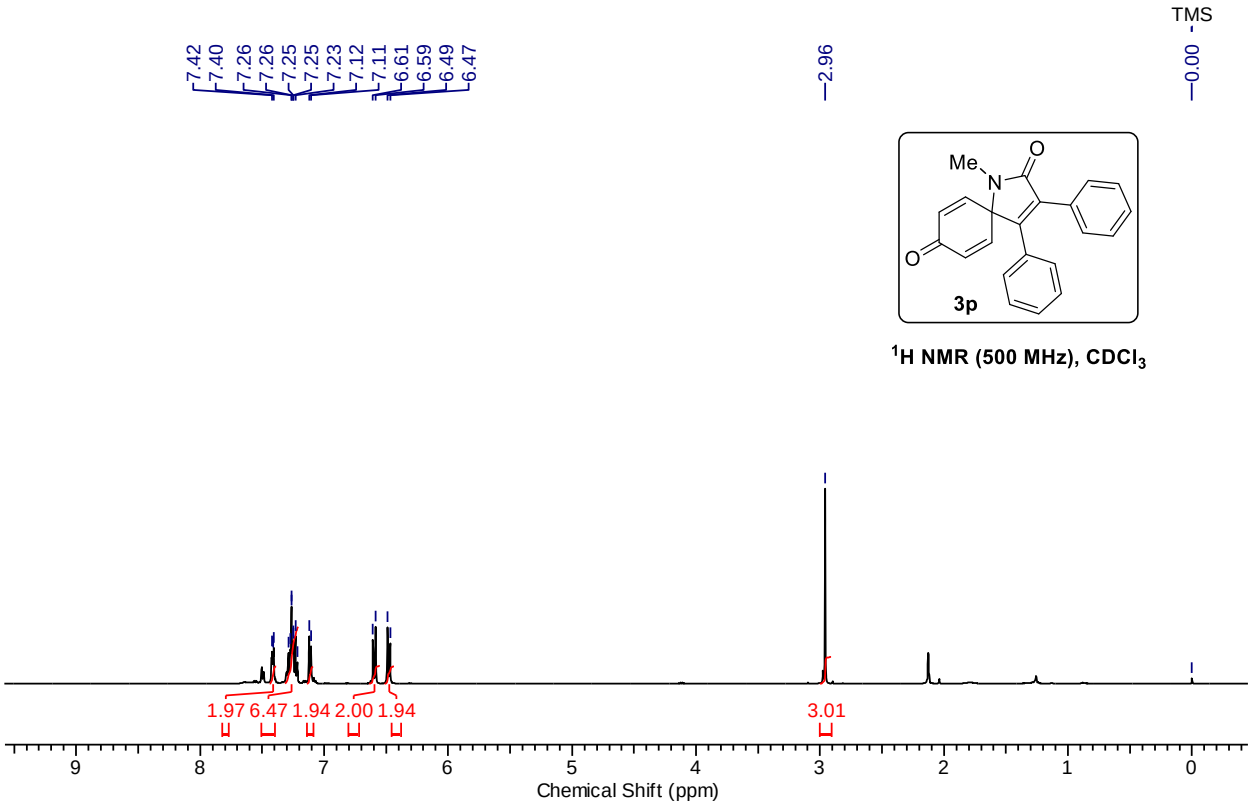
^{13}C NMR (125 MHz), $CDCl_3$



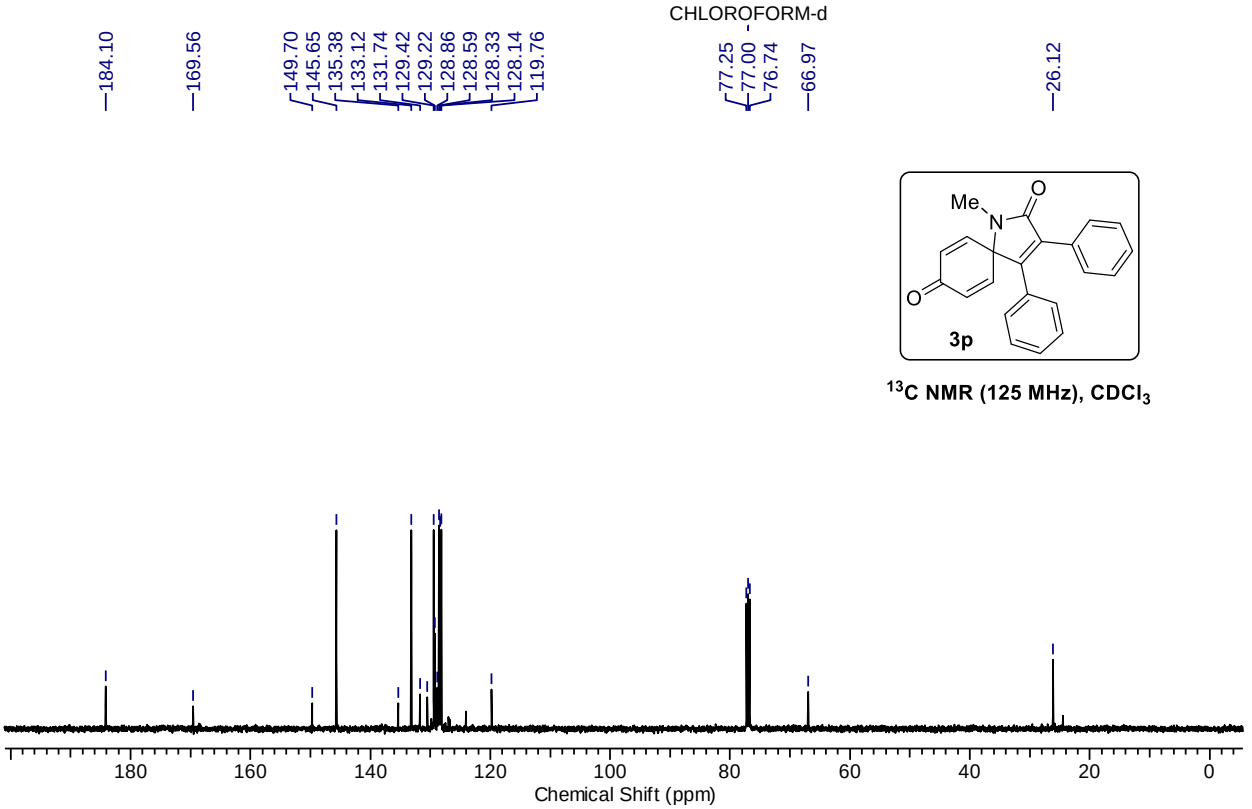
^{1}H NMR (500 MHz), $CDCl_3$



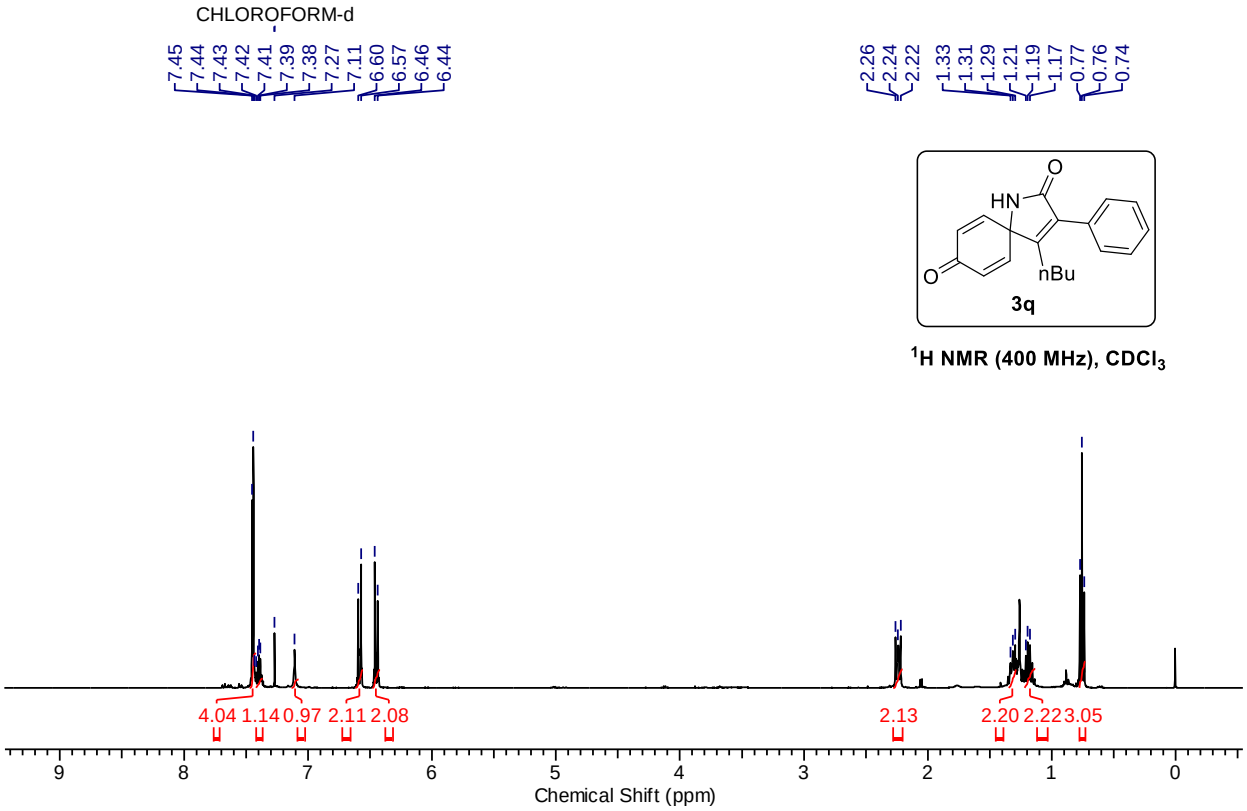
^{13}C NMR (125 MHz), $CDCl_3$



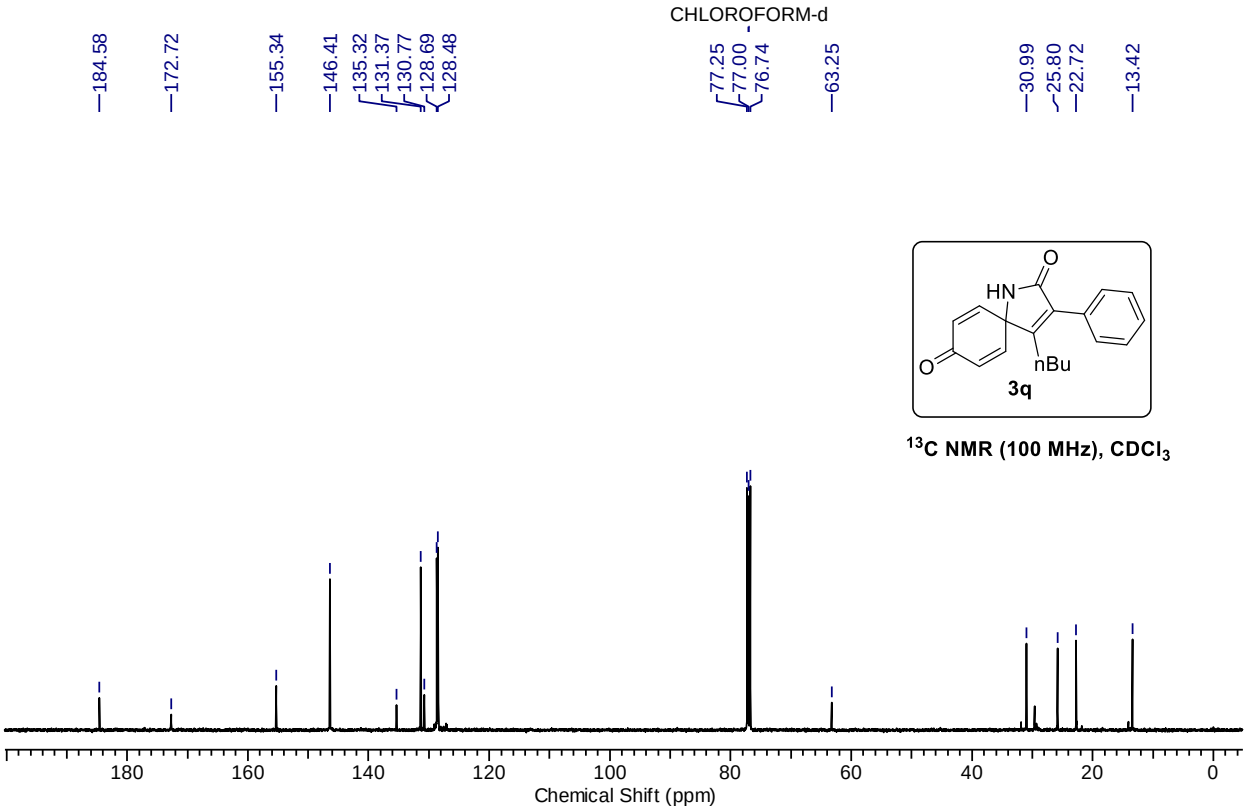
^{1}H NMR (500 MHz), $CDCl_3$



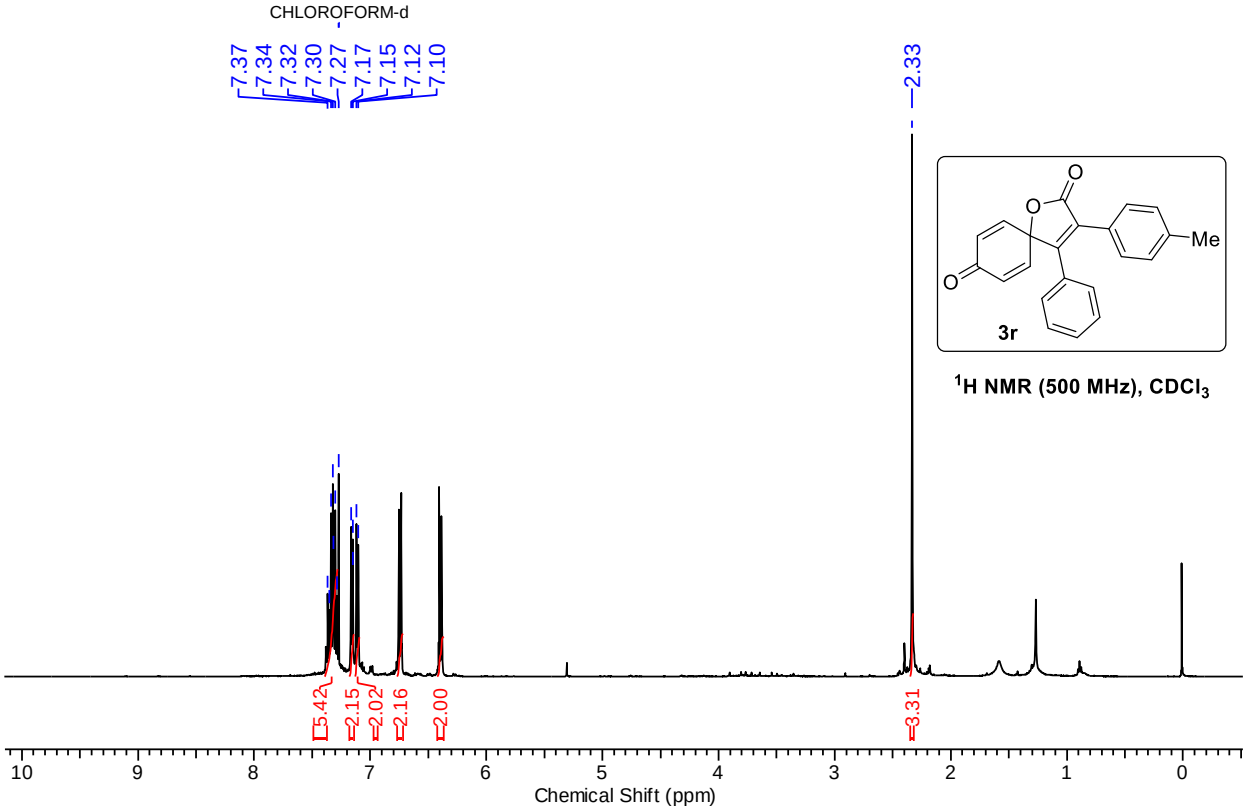
^{13}C NMR (125 MHz), $CDCl_3$



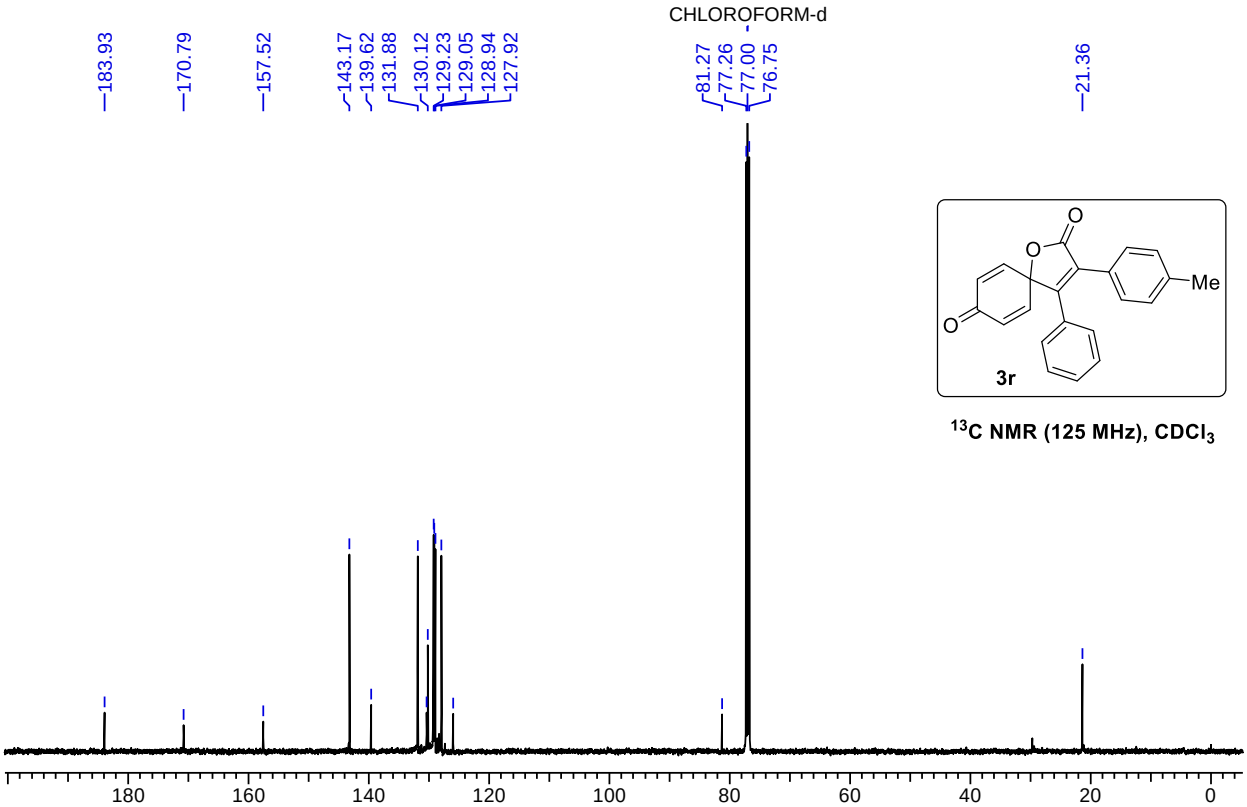
^{1}H NMR (400 MHz), $CDCl_3$



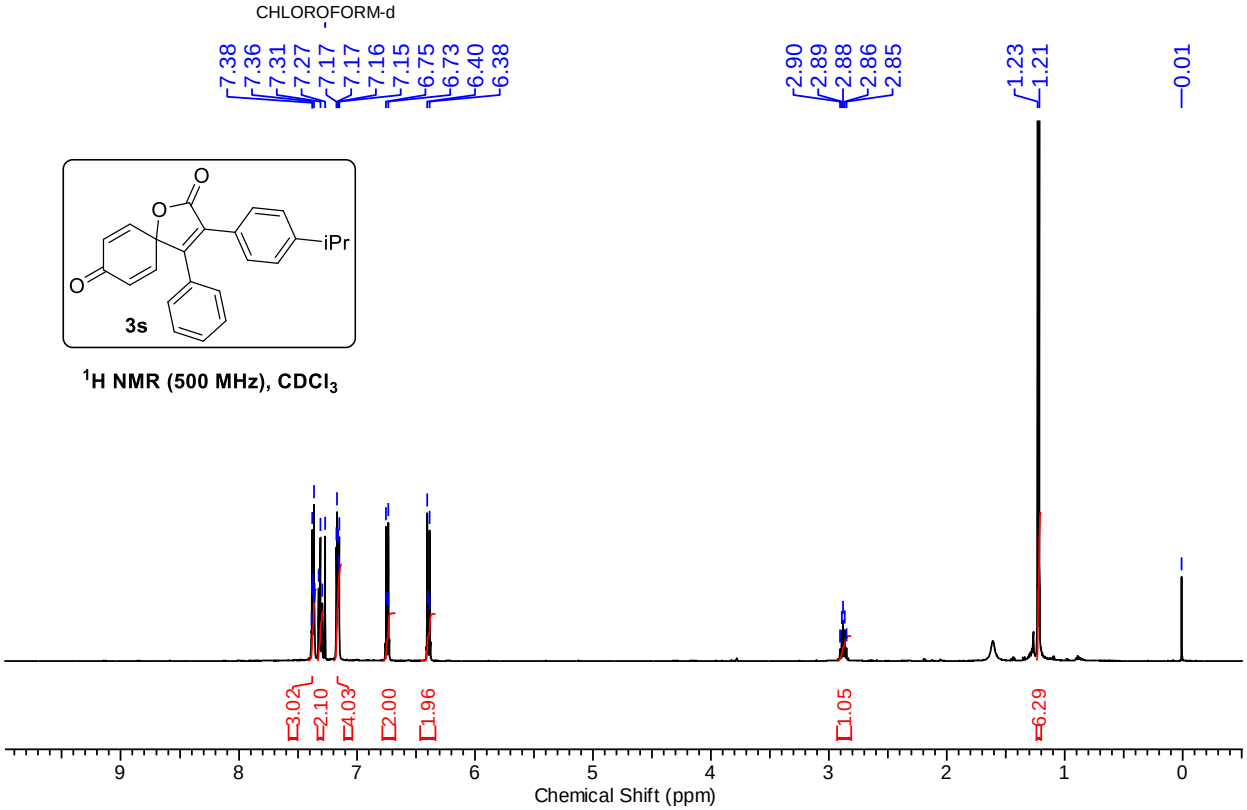
^{13}C NMR (100 MHz), $CDCl_3$



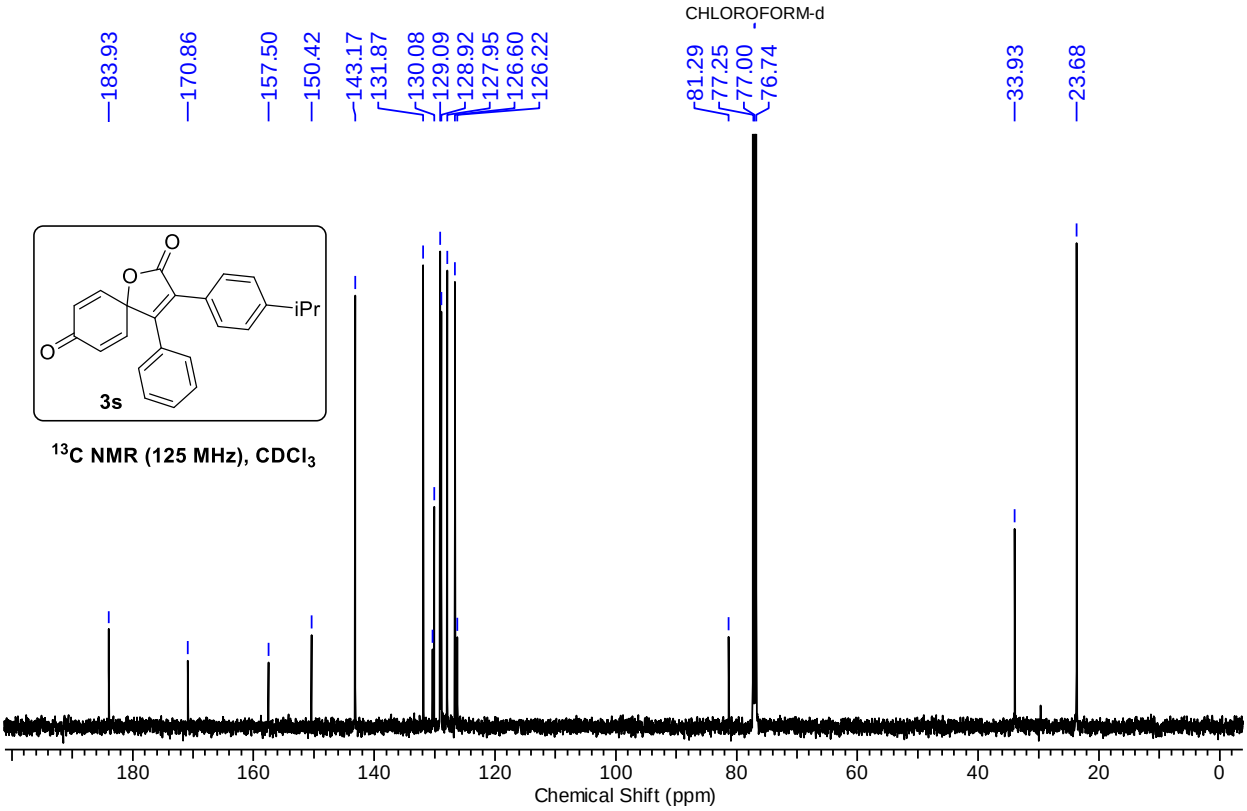
^{1}H NMR (500 MHz), $CDCl_3$



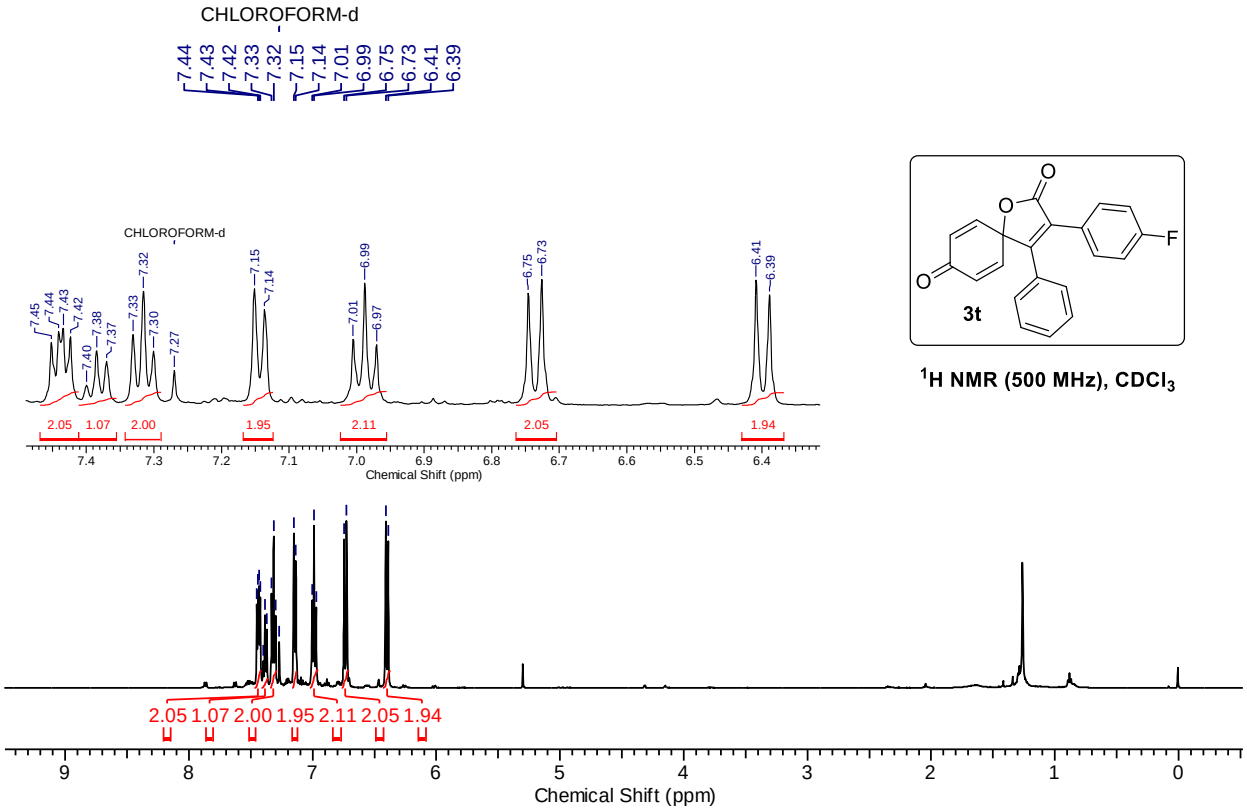
^{13}C NMR (125 MHz), $CDCl_3$



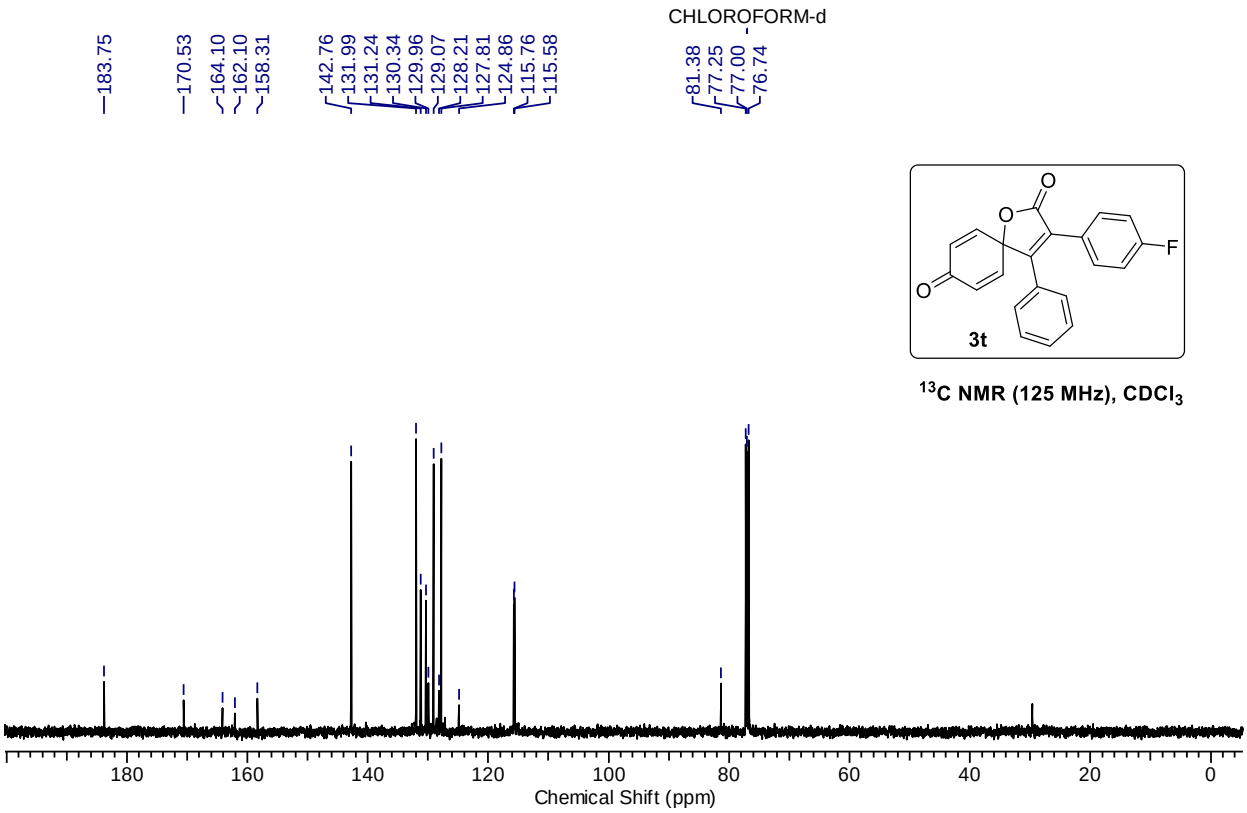
^{1}H NMR (500 MHz), $CDCl_3$



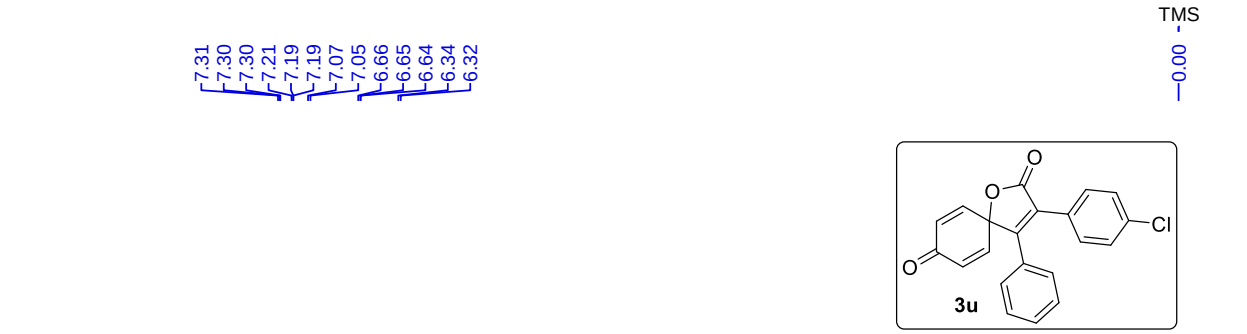
^{13}C NMR (125 MHz), $CDCl_3$



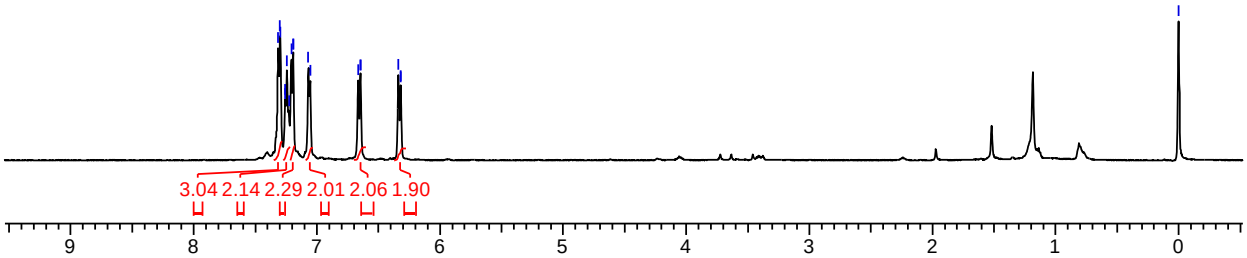
^{1}H NMR (500 MHz), $CDCl_3$

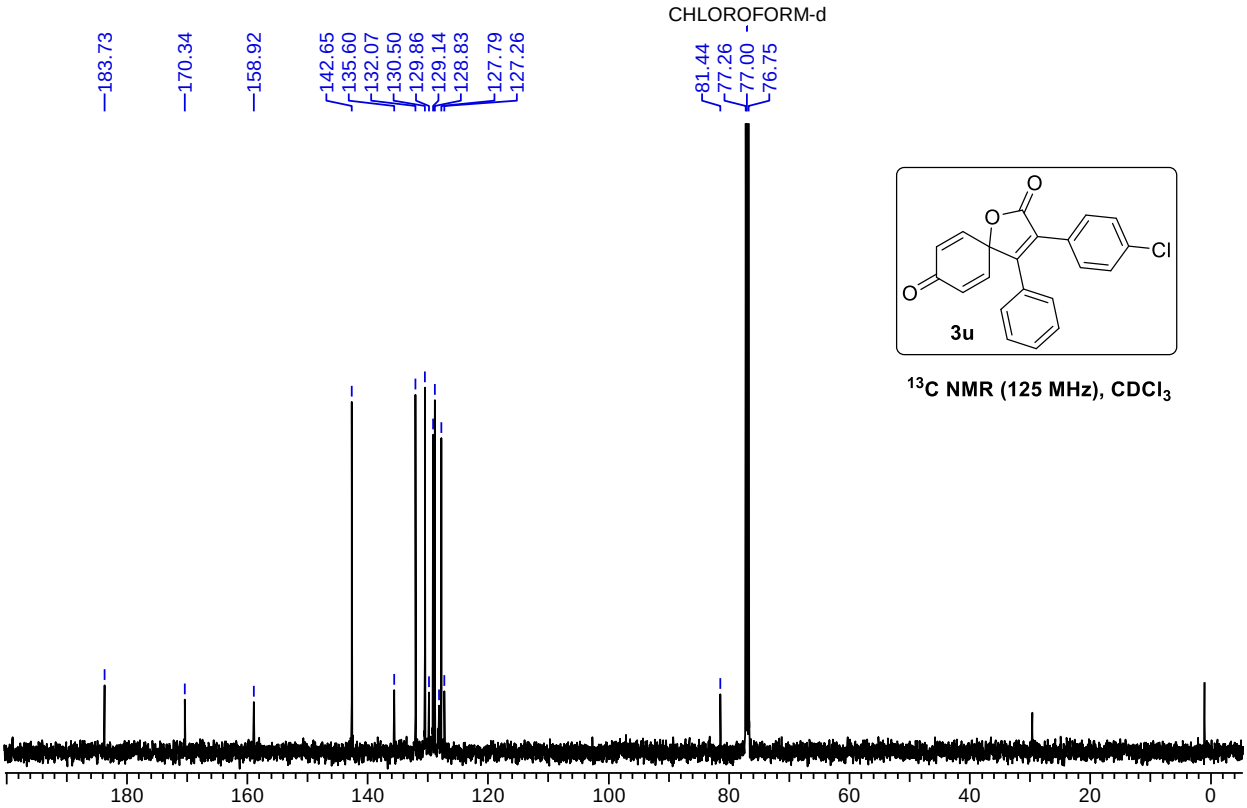


^{13}C NMR (125 MHz), $CDCl_3$

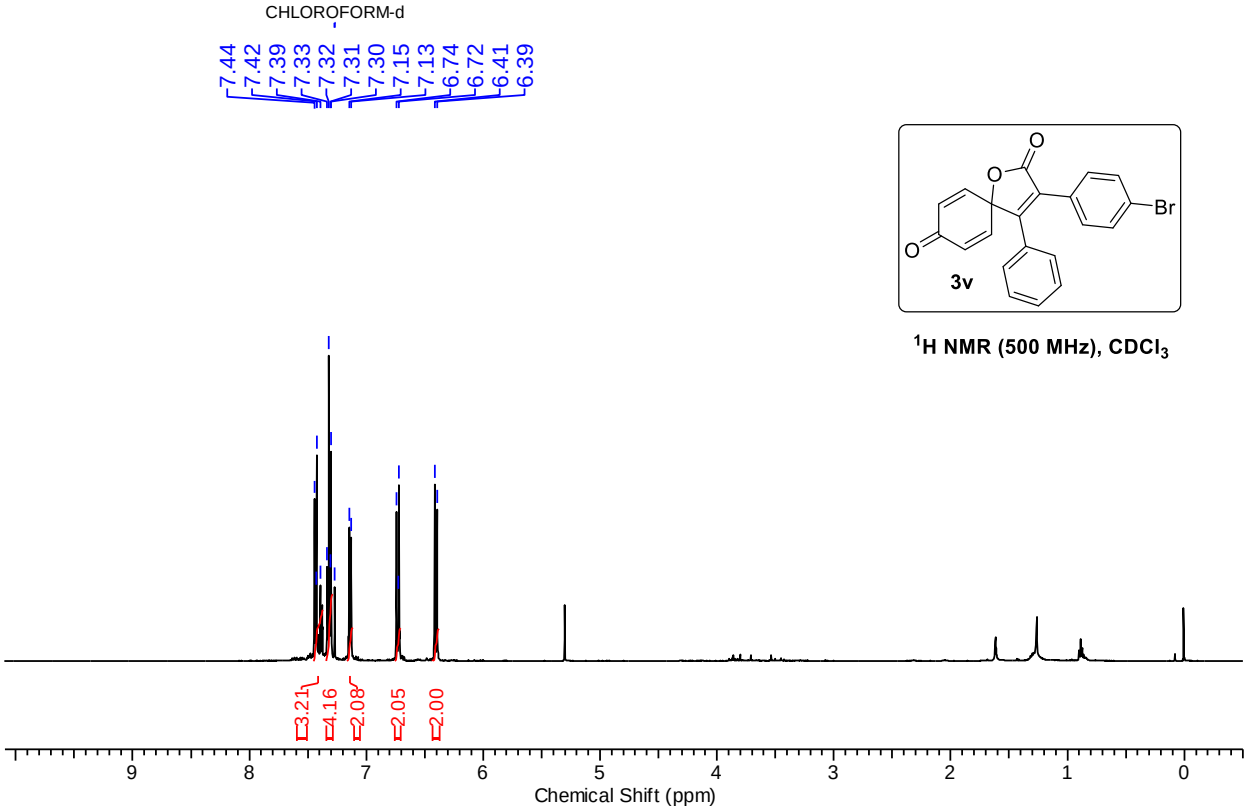


^{1}H NMR (500 MHz), $CDCl_3$

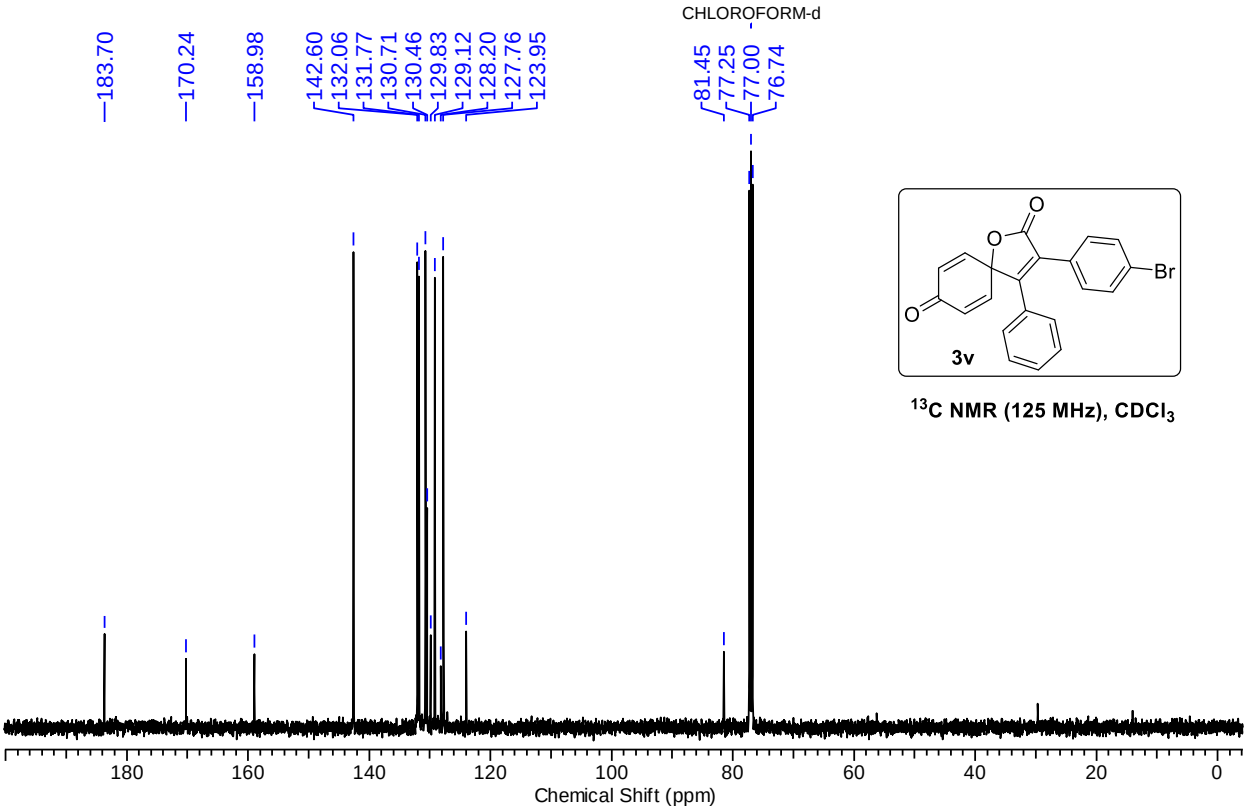




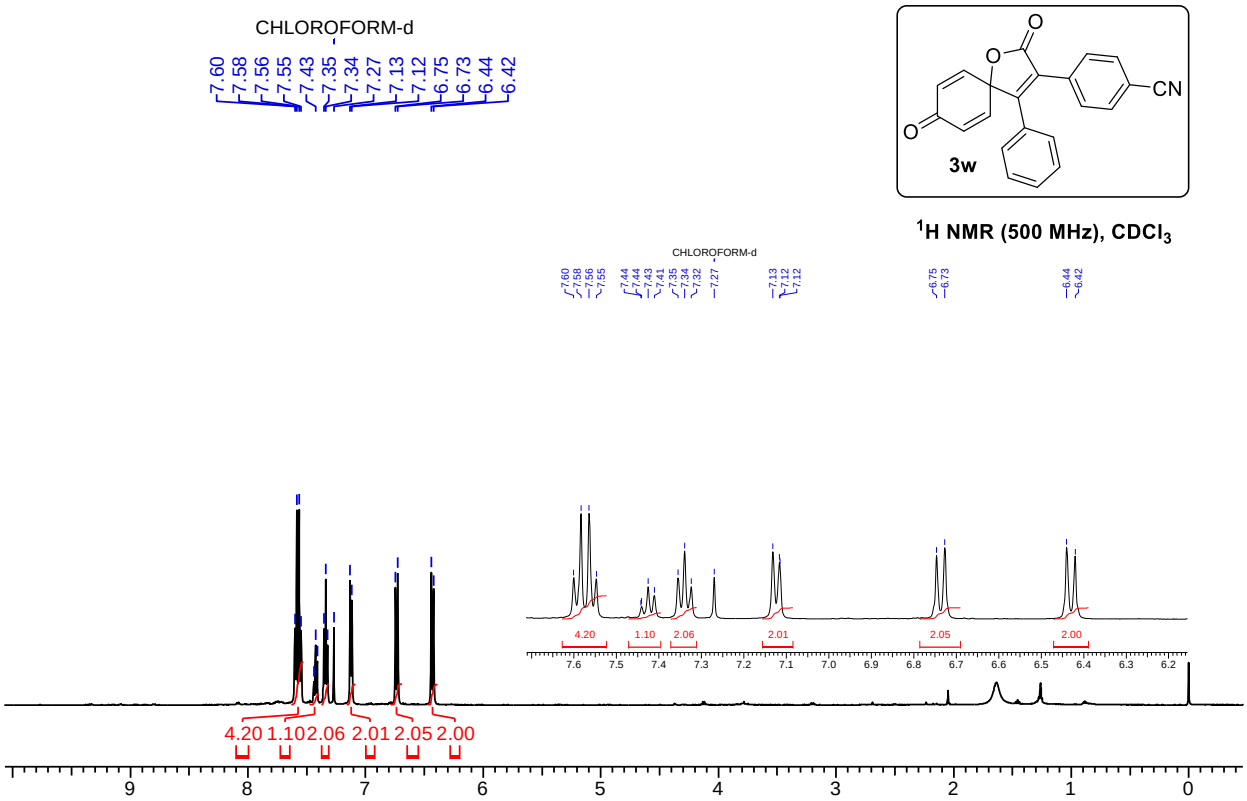
^{13}C NMR (125 MHz), $CDCl_3$



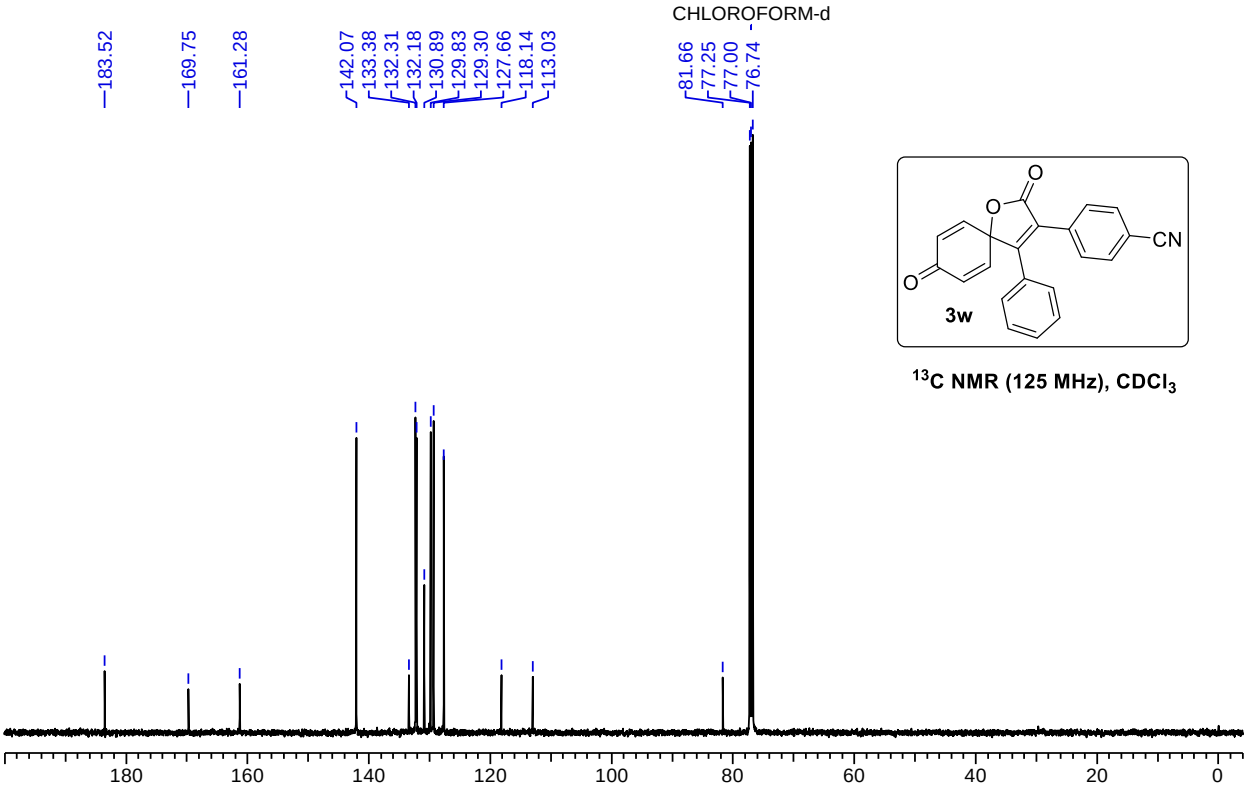
^{1}H NMR (500 MHz), $CDCl_3$



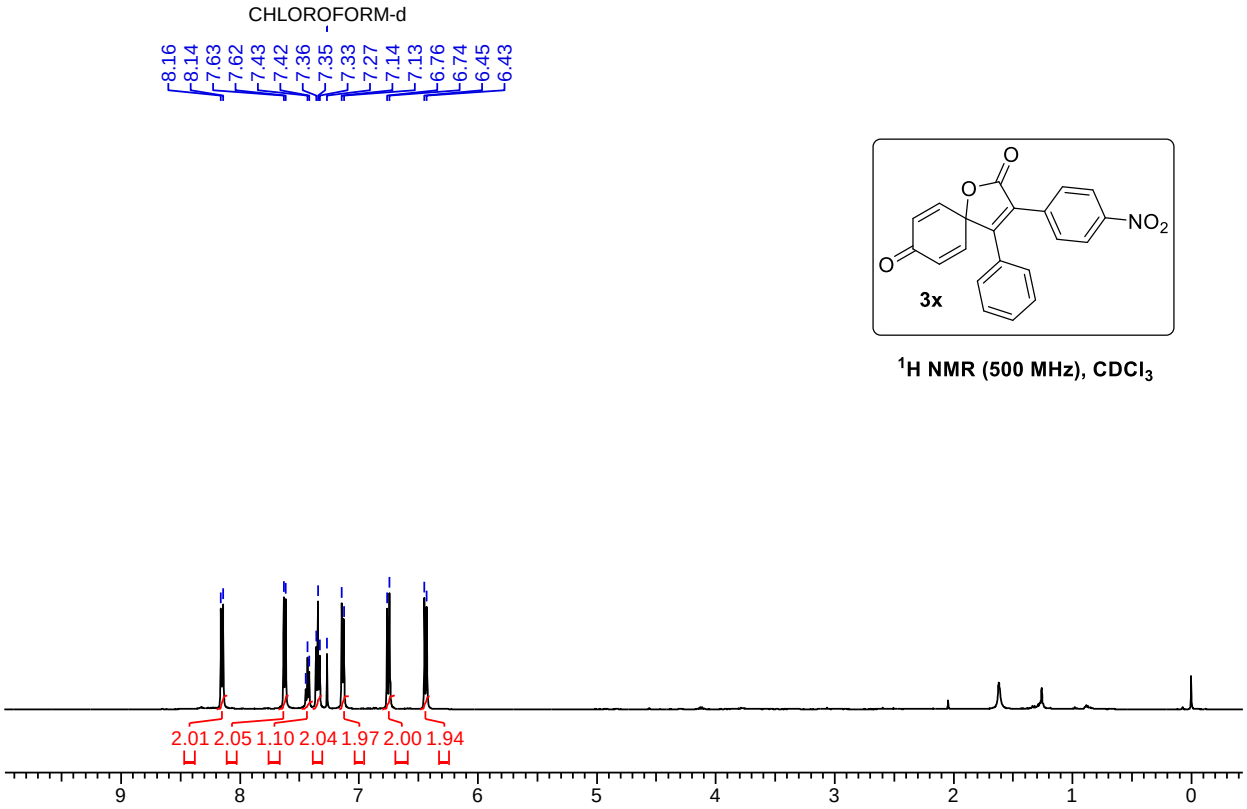
^{13}C NMR (125 MHz), $CDCl_3$



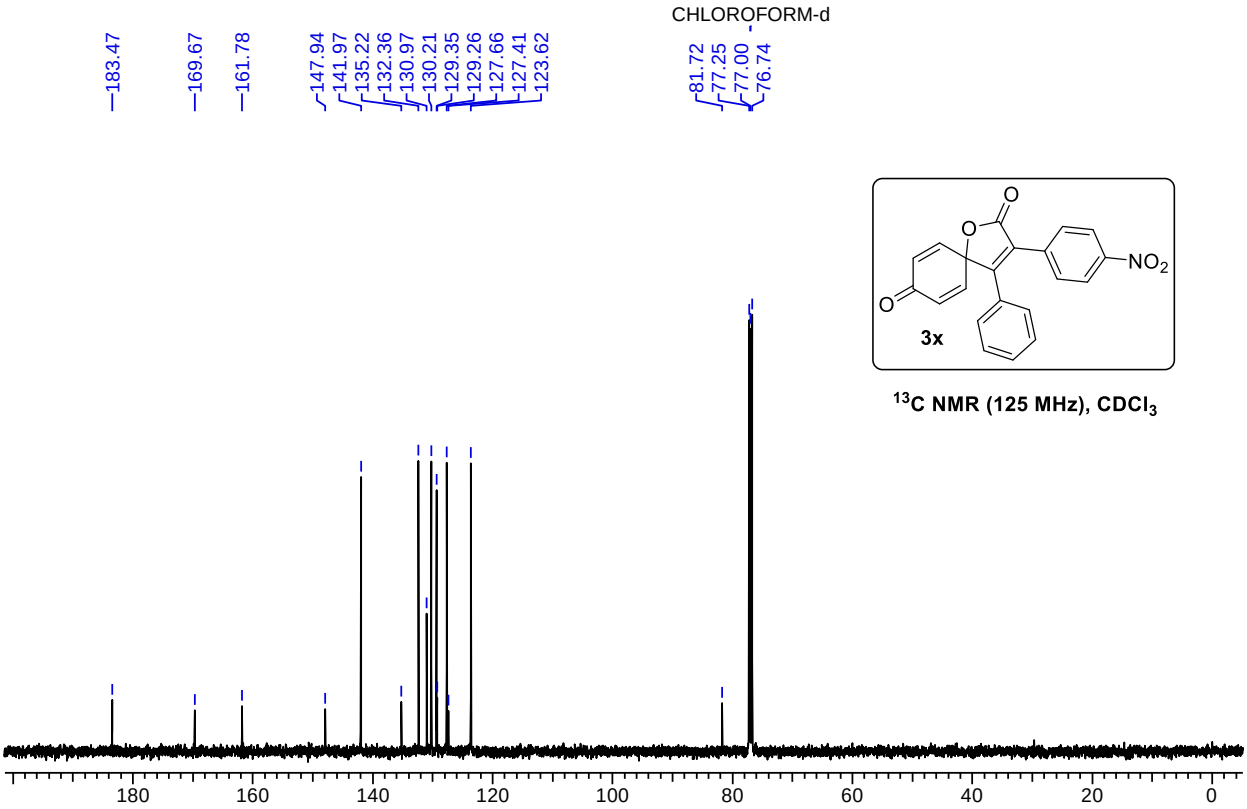
^{1}H NMR (500 MHz), $CDCl_3$



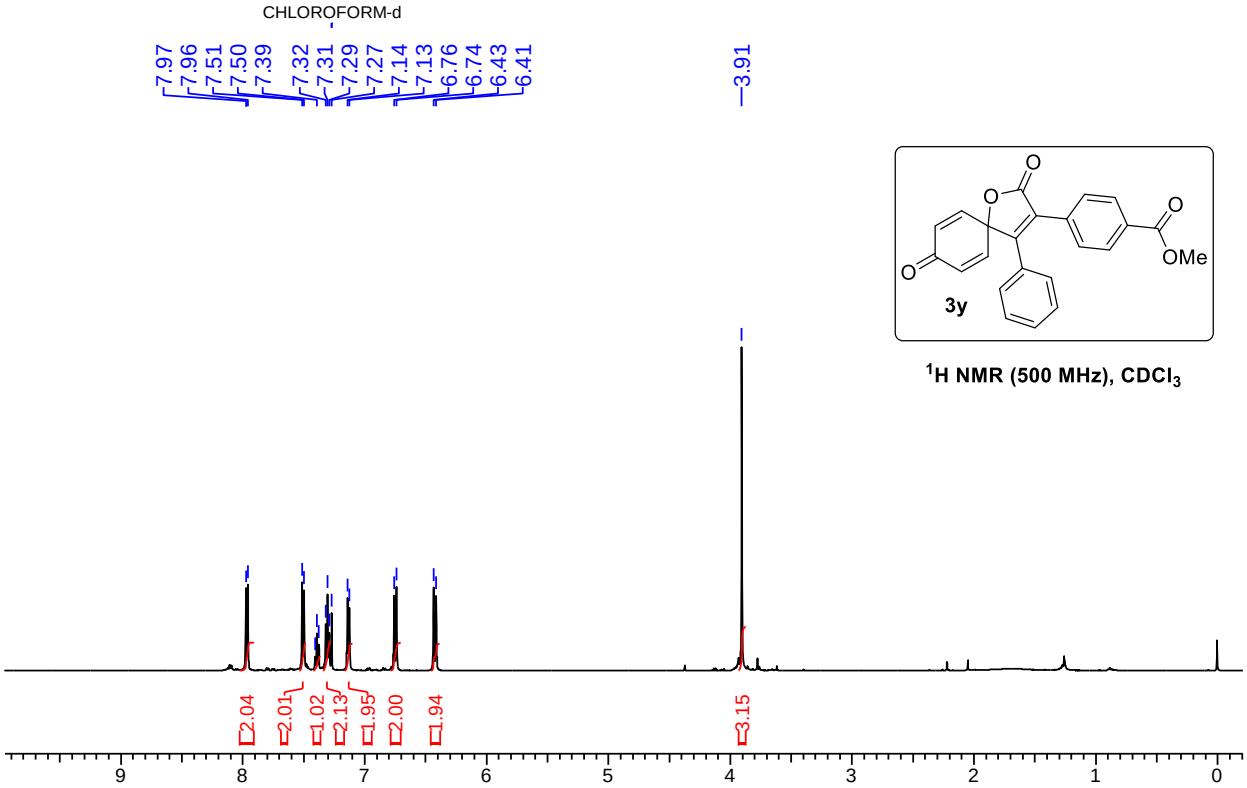
^{13}C NMR (125 MHz), $CDCl_3$



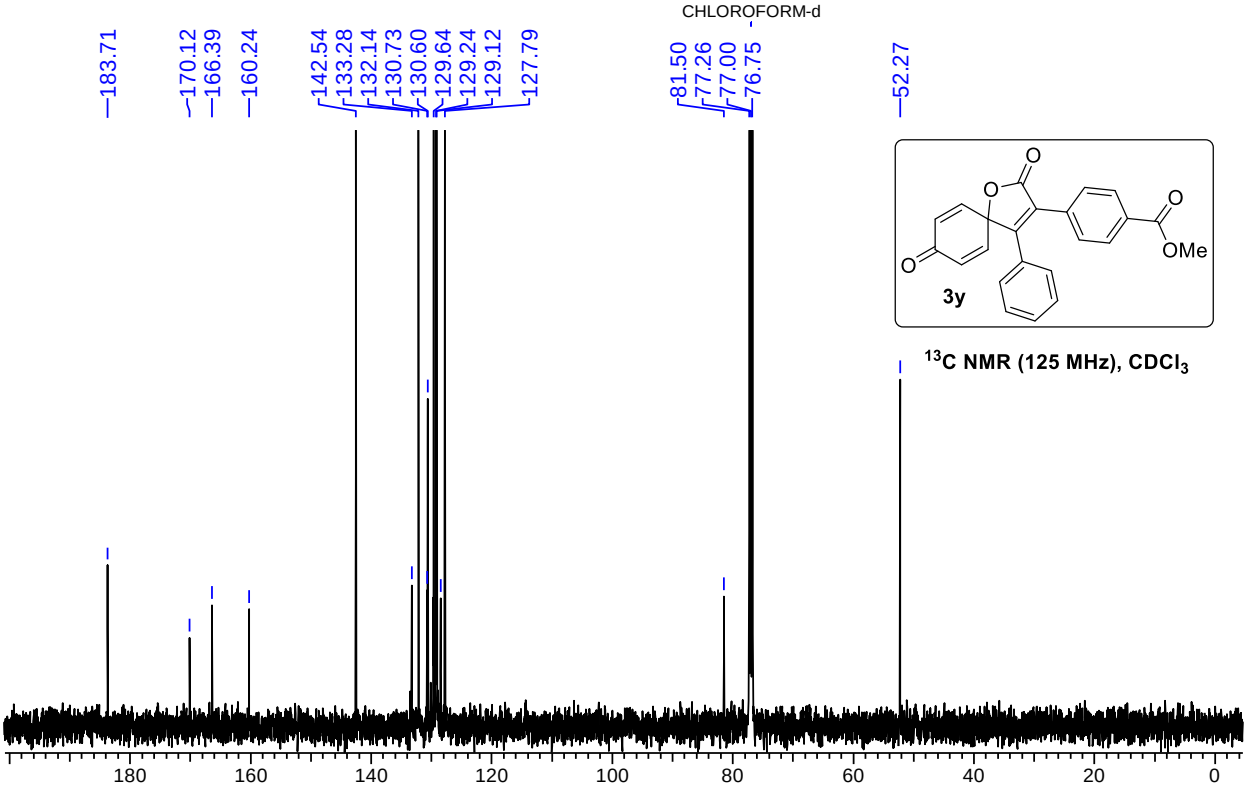
^{1}H NMR (500 MHz), $CDCl_3$



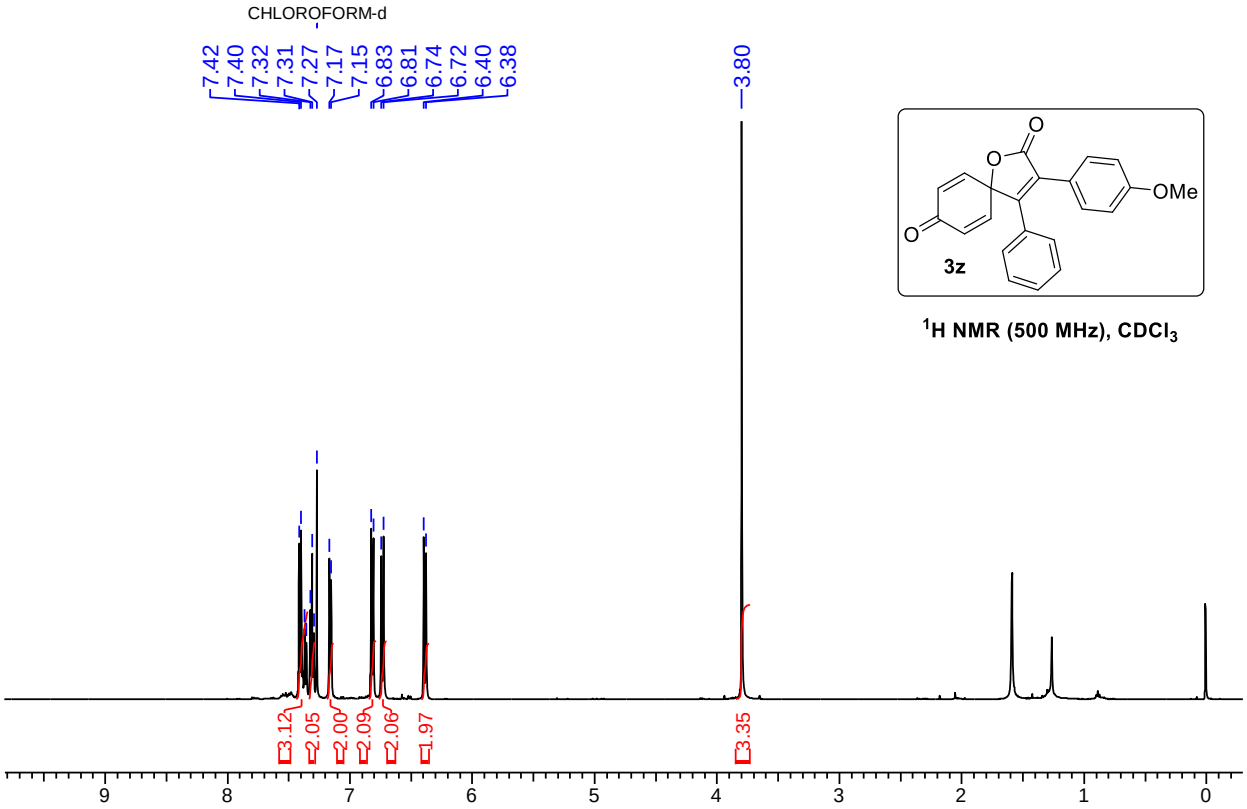
^{13}C NMR (125 MHz), $CDCl_3$



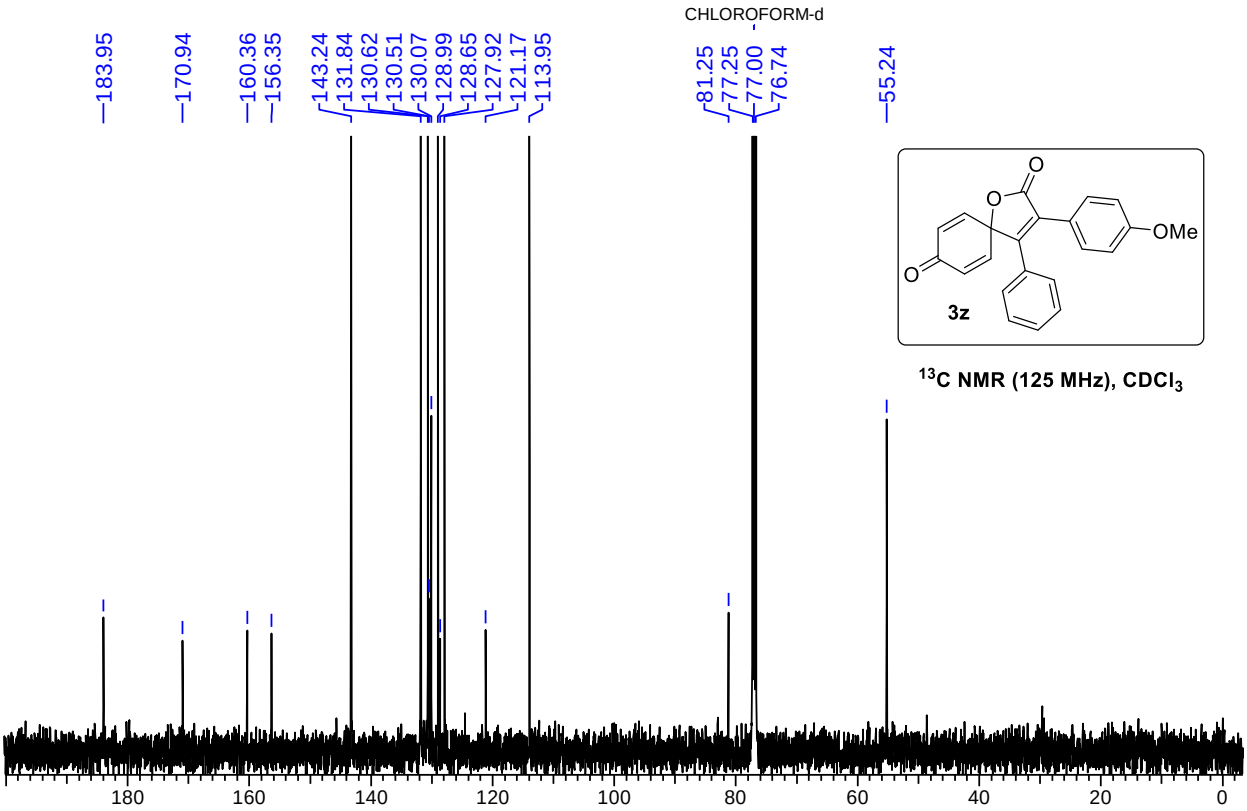
^{1}H NMR (500 MHz), $CDCl_3$



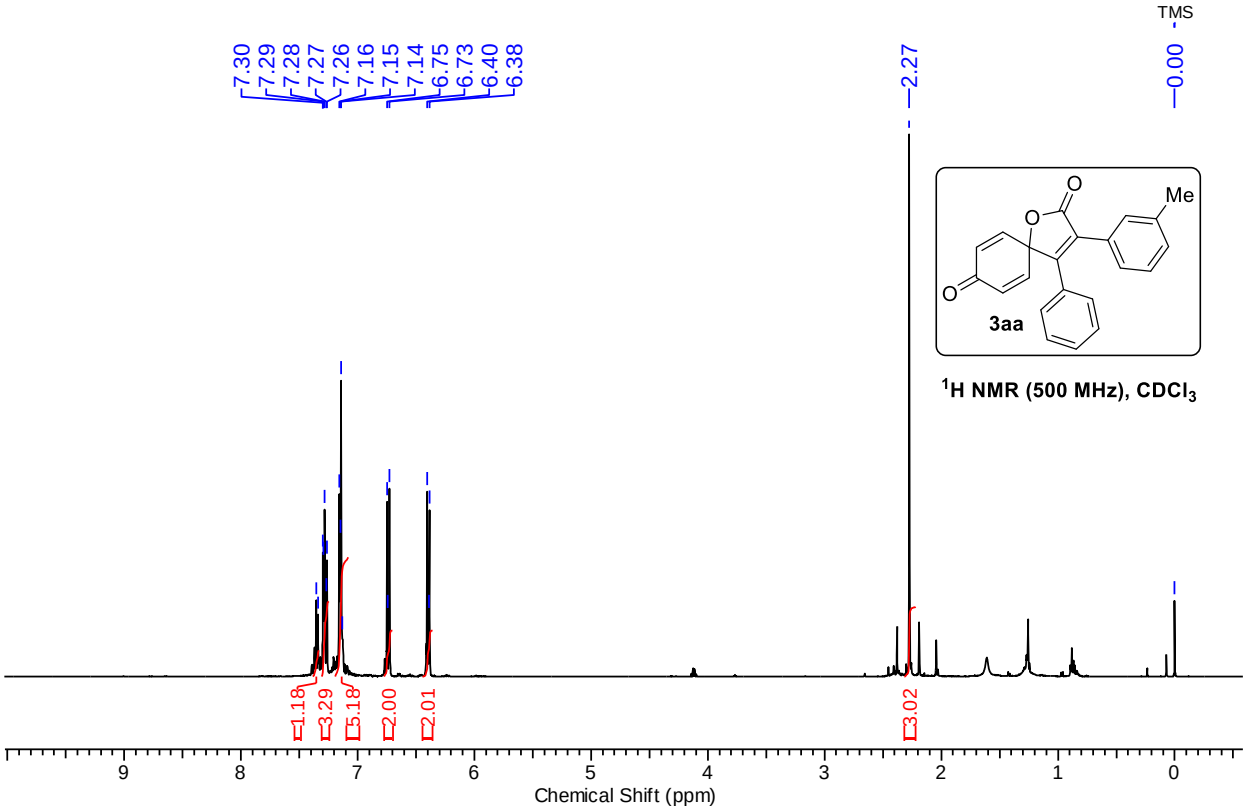
^{13}C NMR (125 MHz), $CDCl_3$



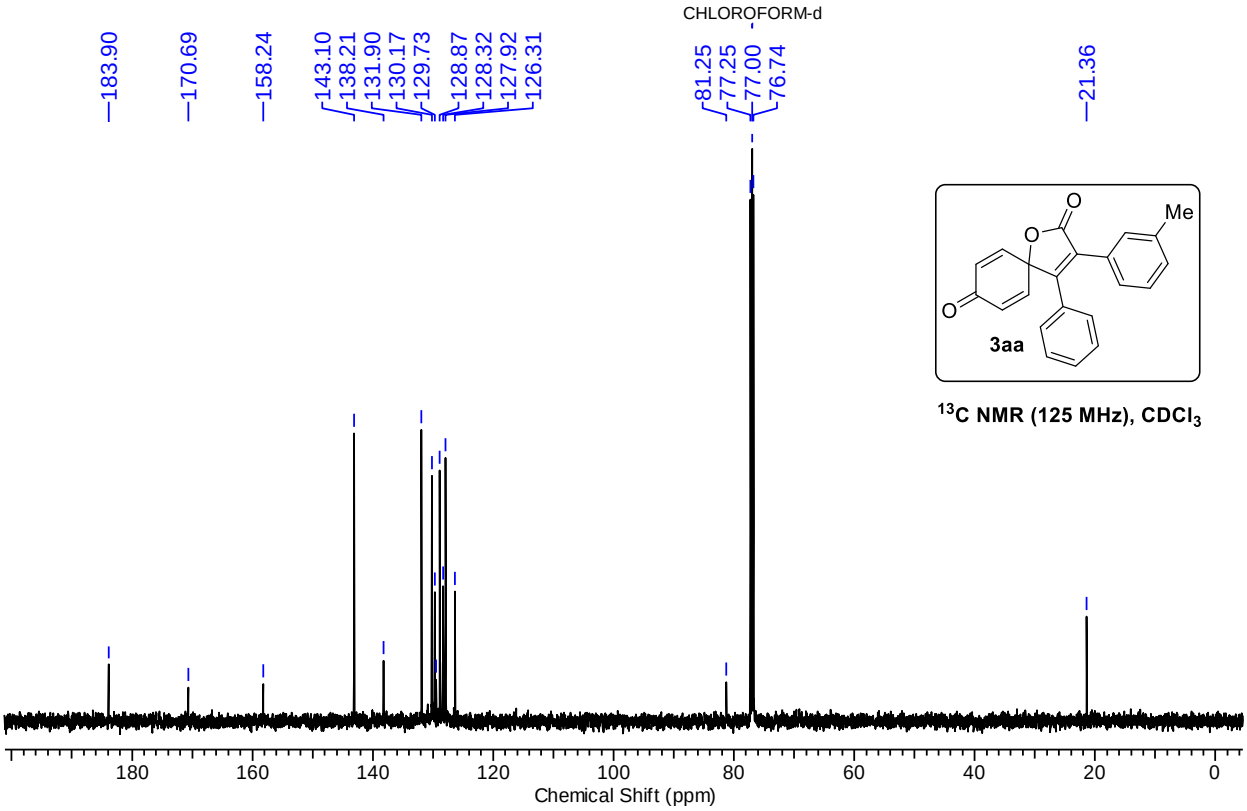
^{1}H NMR (500 MHz), $CDCl_3$



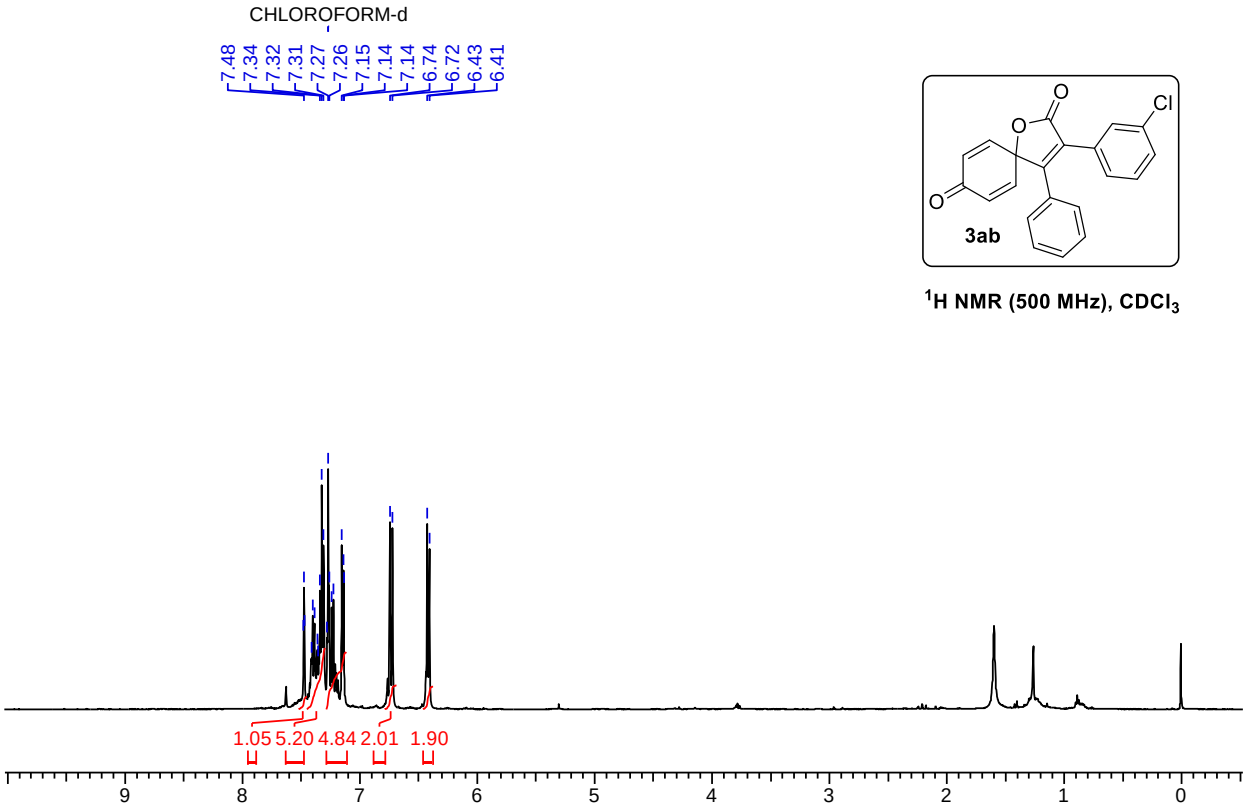
^{13}C NMR (125 MHz), $CDCl_3$



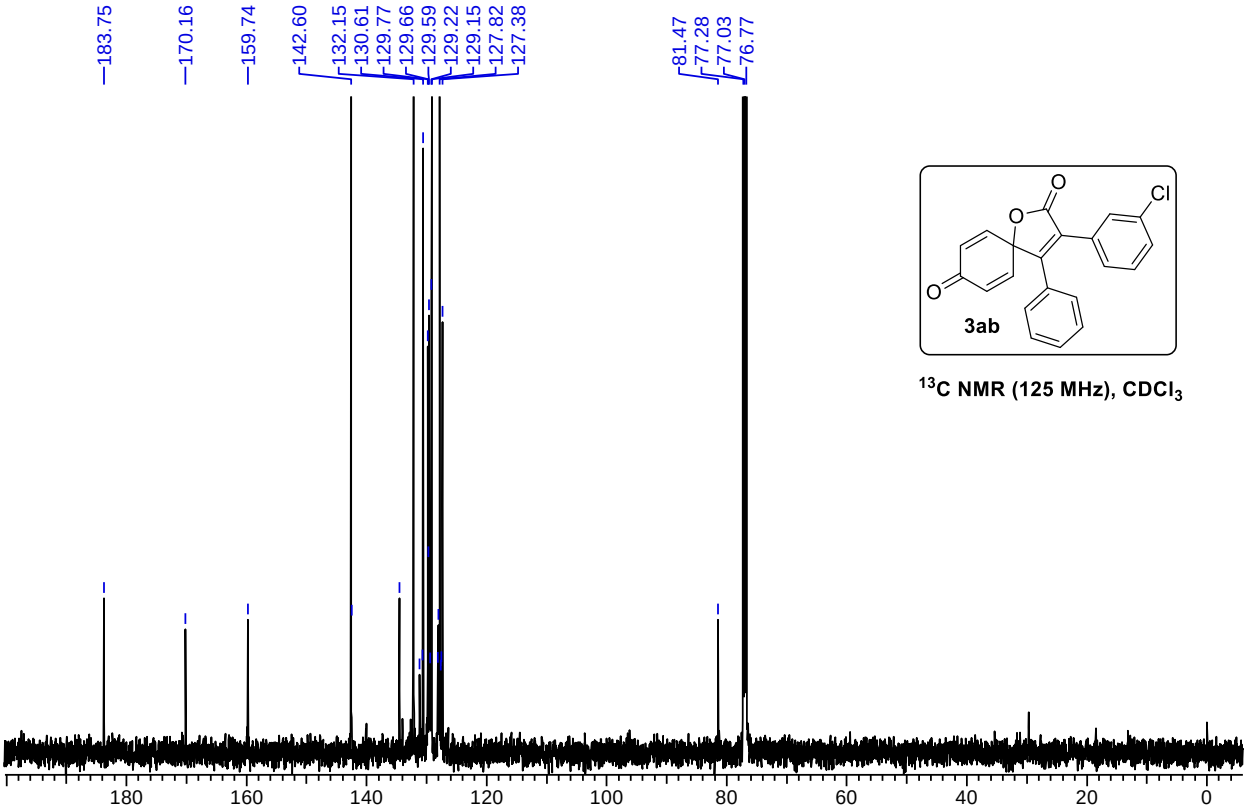
^{1}H NMR (500 MHz), $CDCl_3$



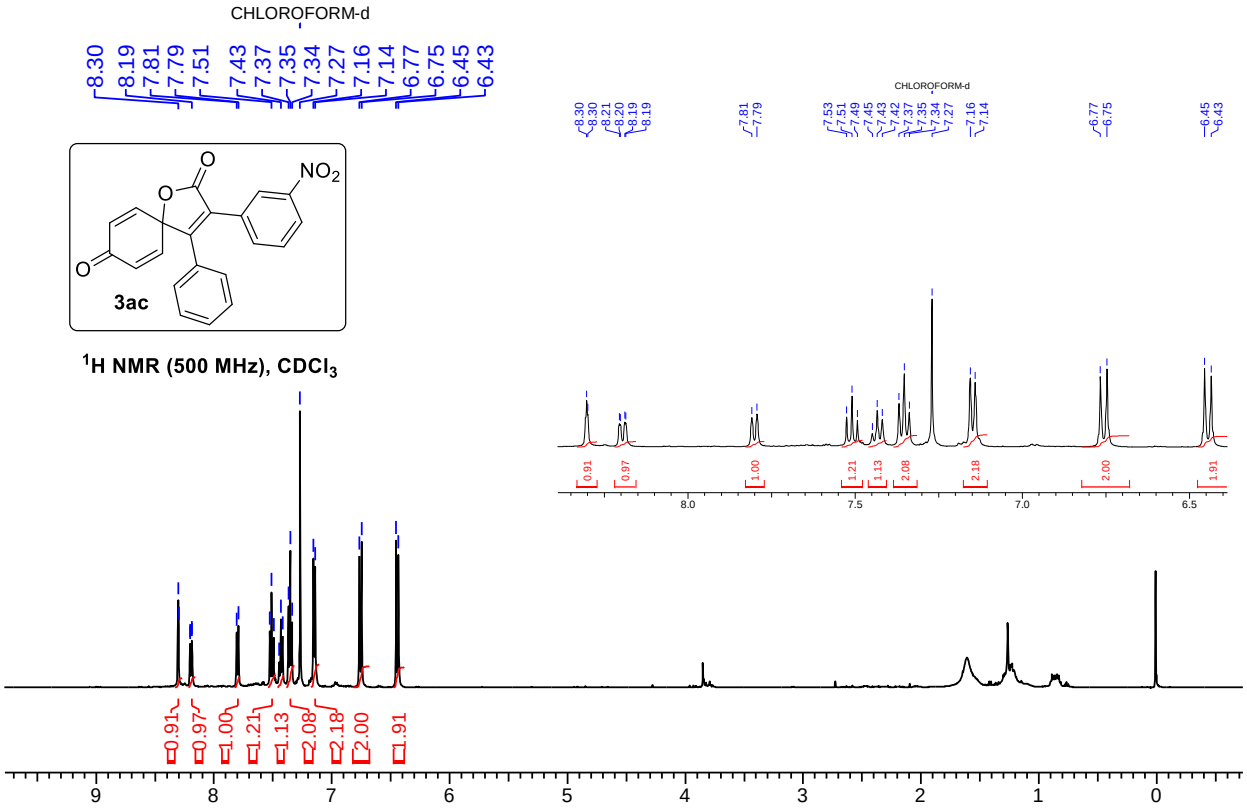
^{13}C NMR (125 MHz), $CDCl_3$



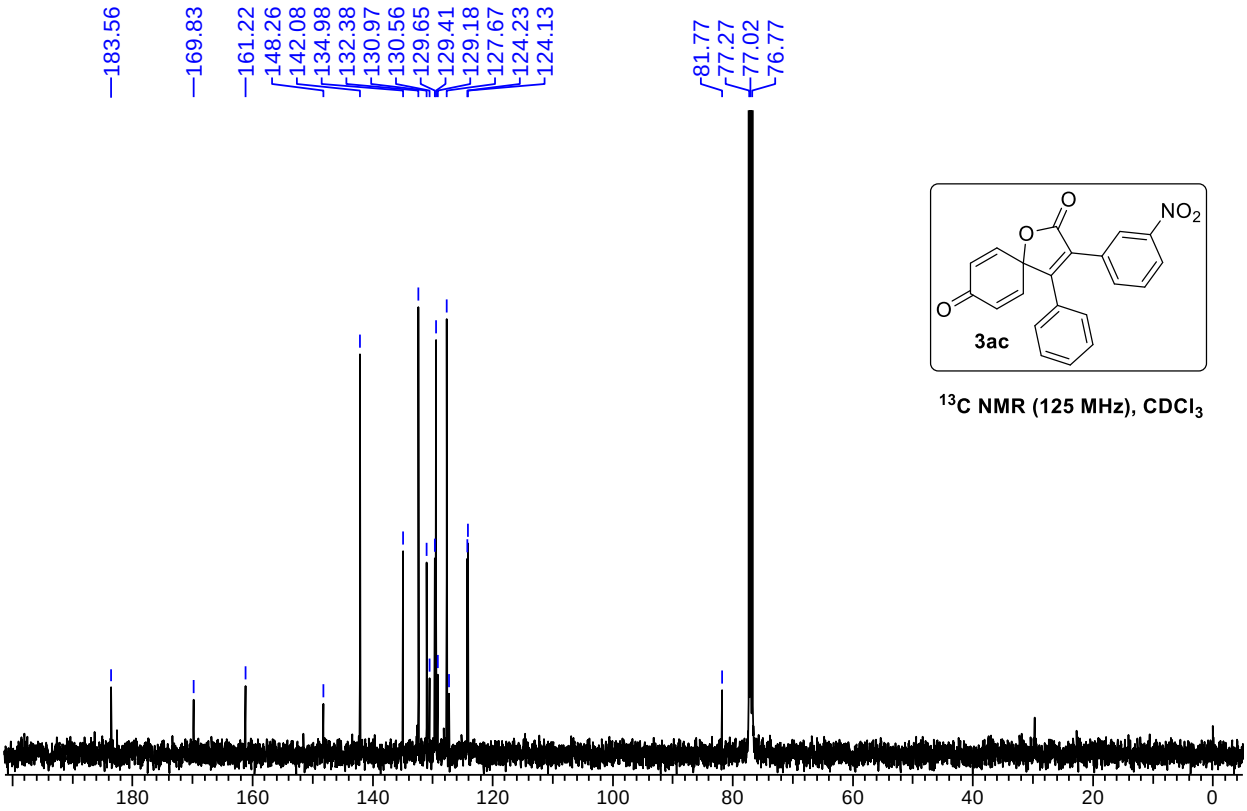
^{1}H NMR (500 MHz), $CDCl_3$



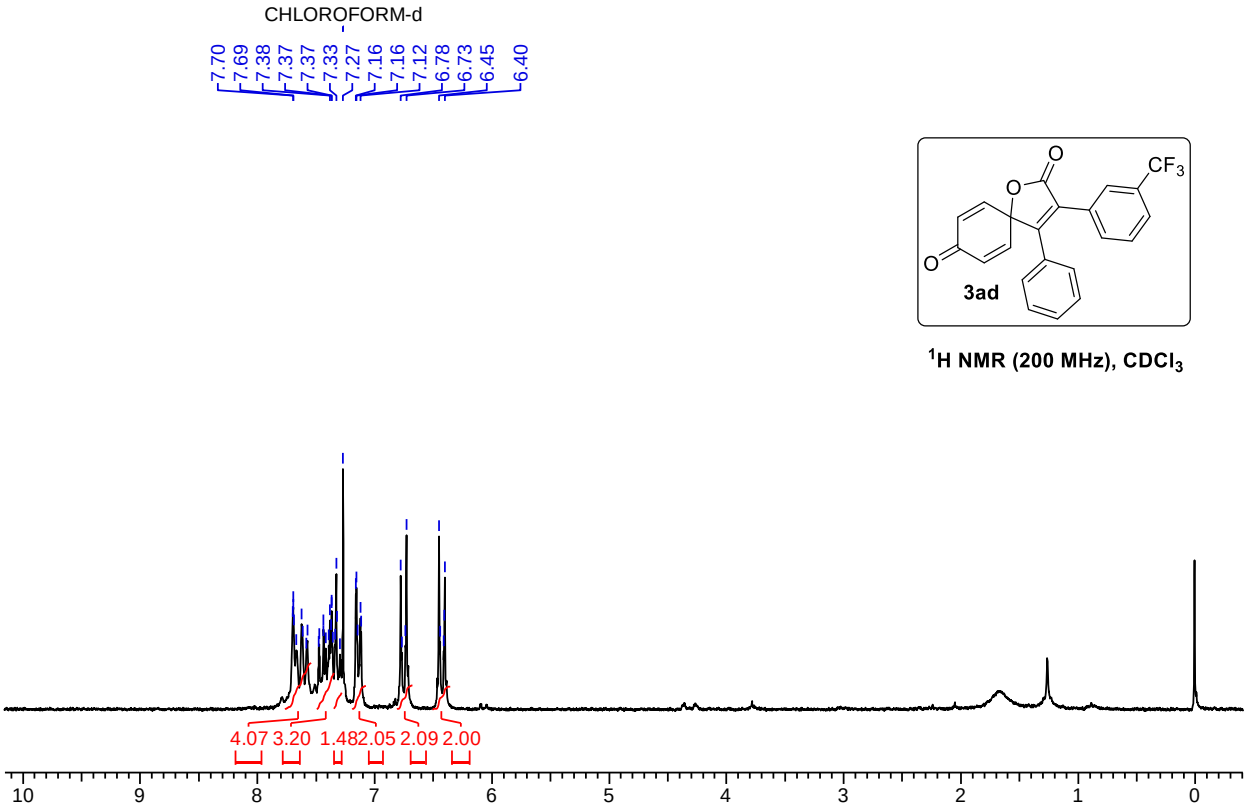
^{13}C NMR (125 MHz), $CDCl_3$



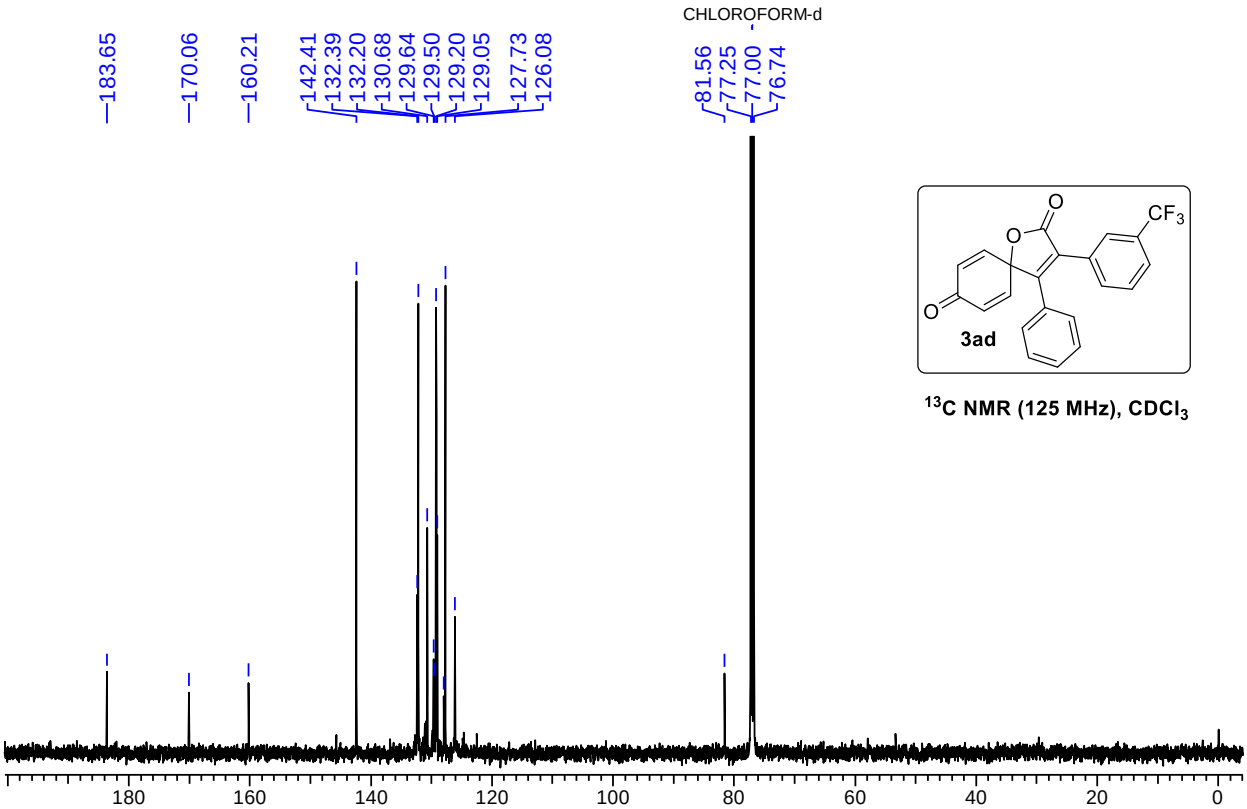
^{1}H NMR (500 MHz), $CDCl_3$



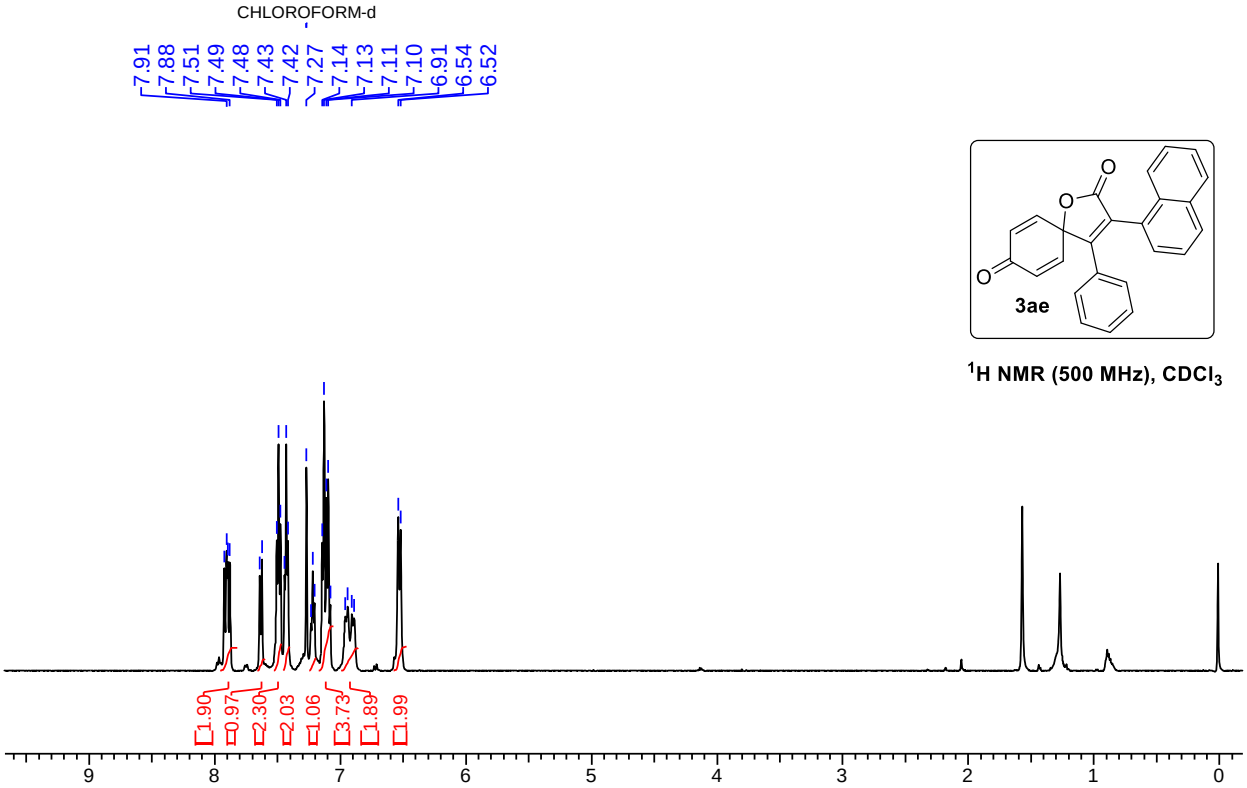
^{13}C NMR (125 MHz), $CDCl_3$



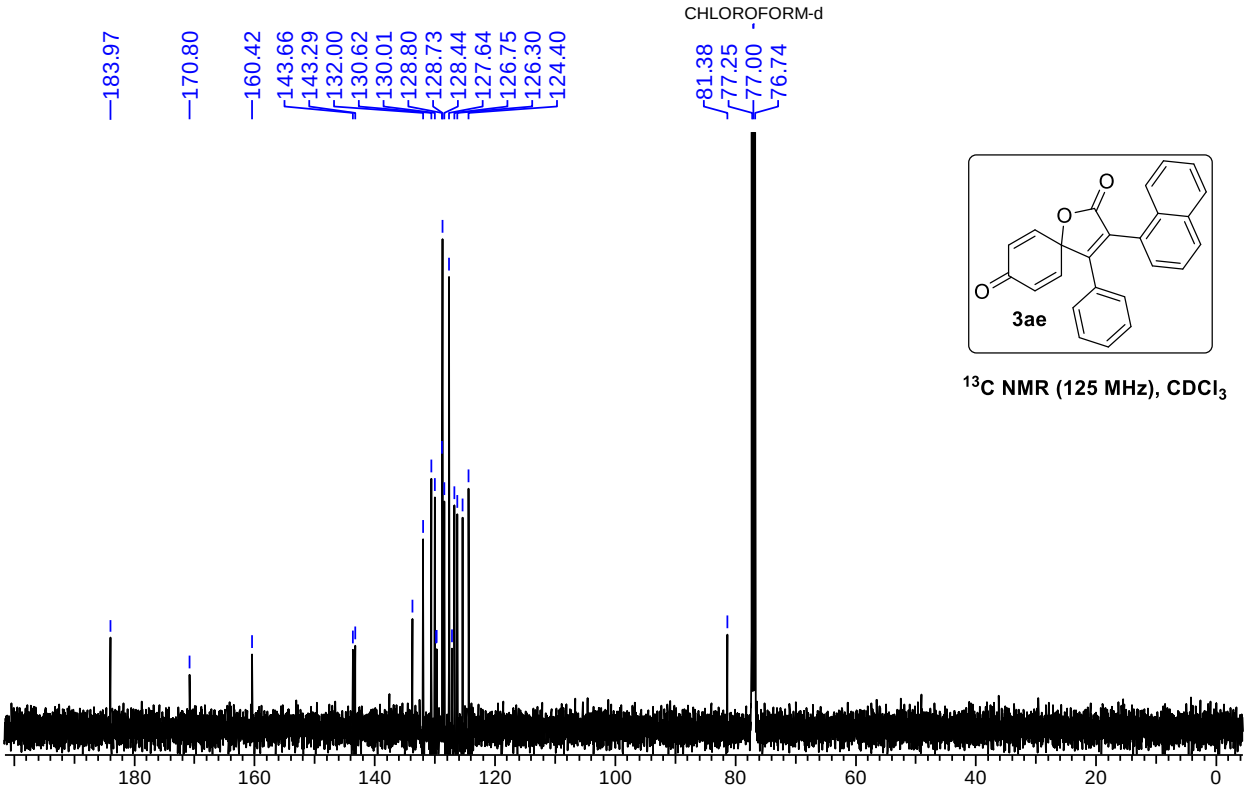
^{1}H NMR (200 MHz), $CDCl_3$



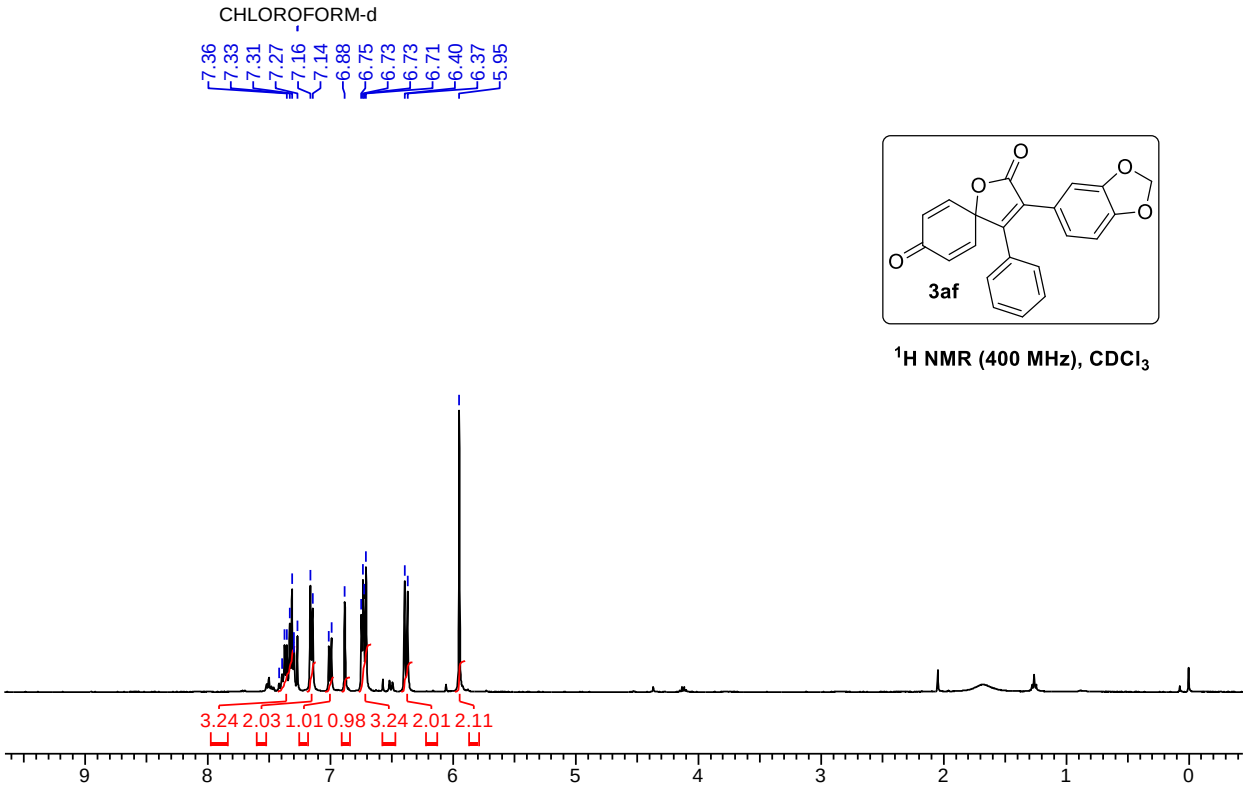
^{13}C NMR (125 MHz), $CDCl_3$



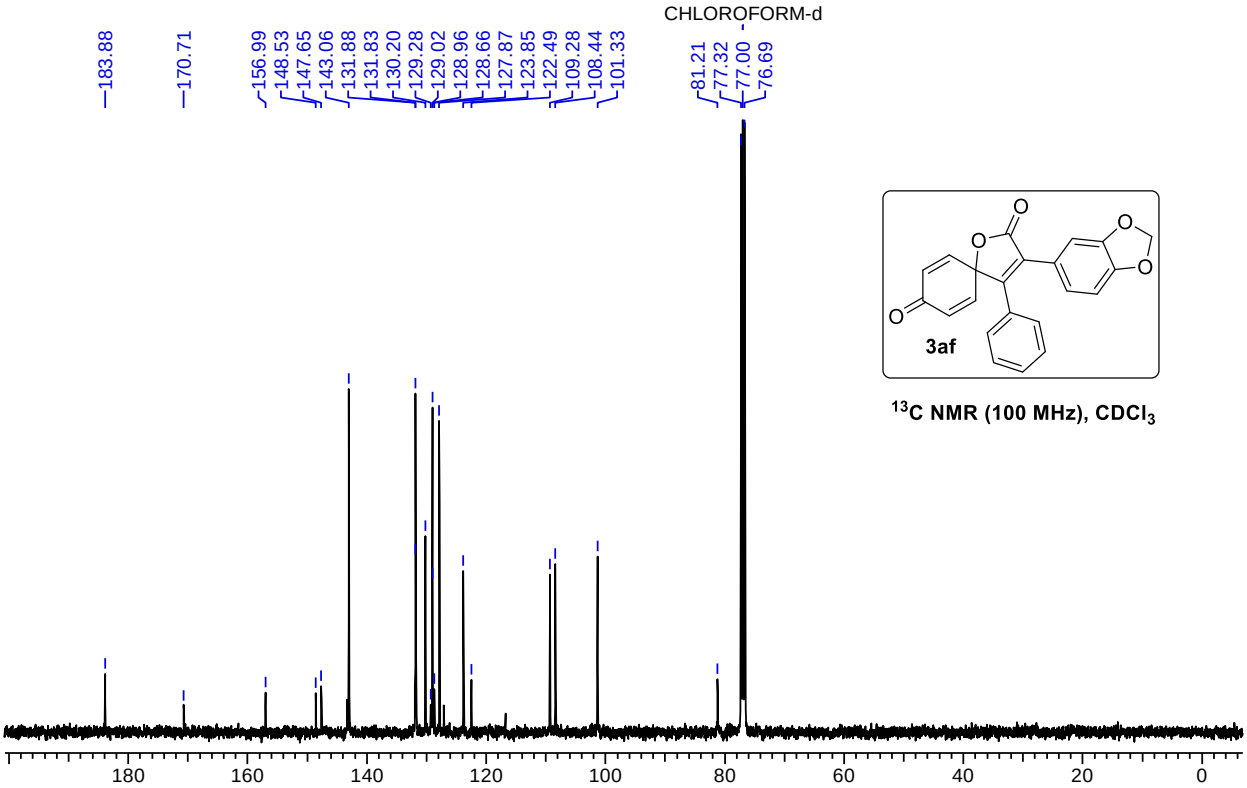
^{1}H NMR (500 MHz), $CDCl_3$



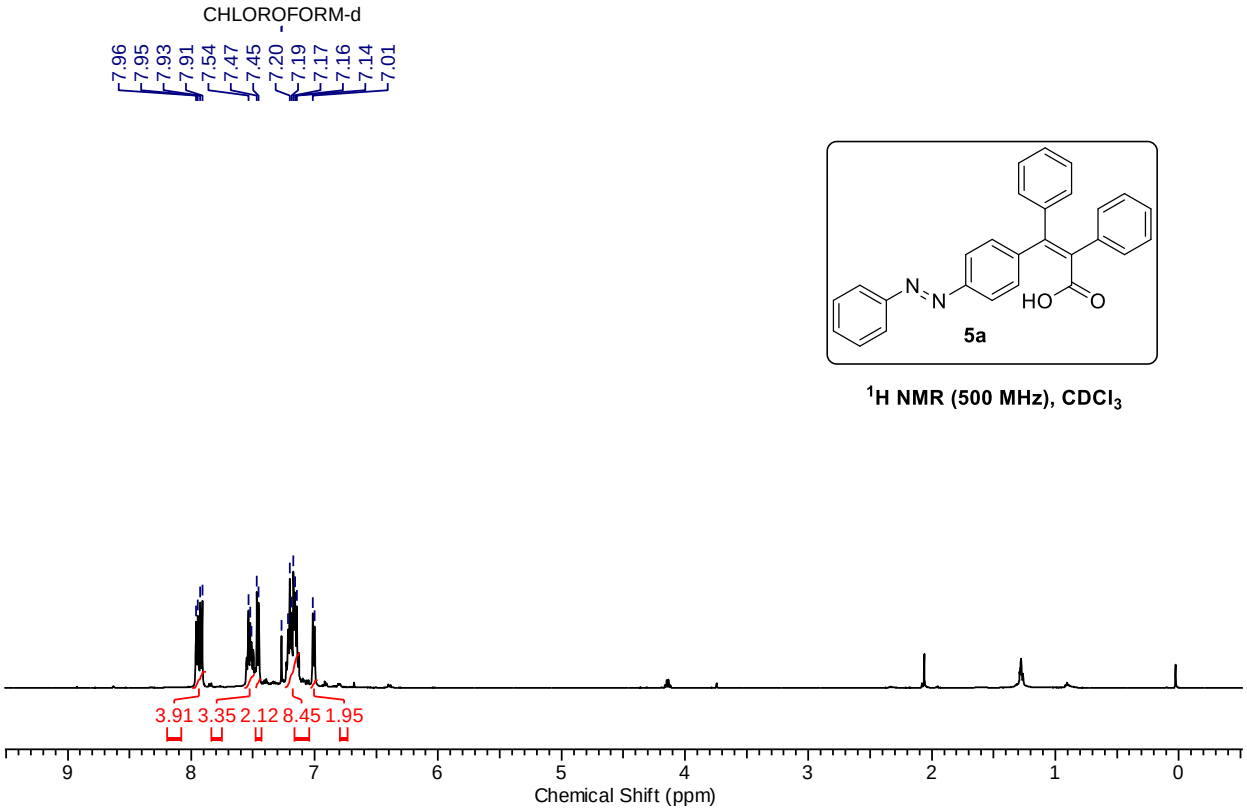
^{13}C NMR (125 MHz), $CDCl_3$



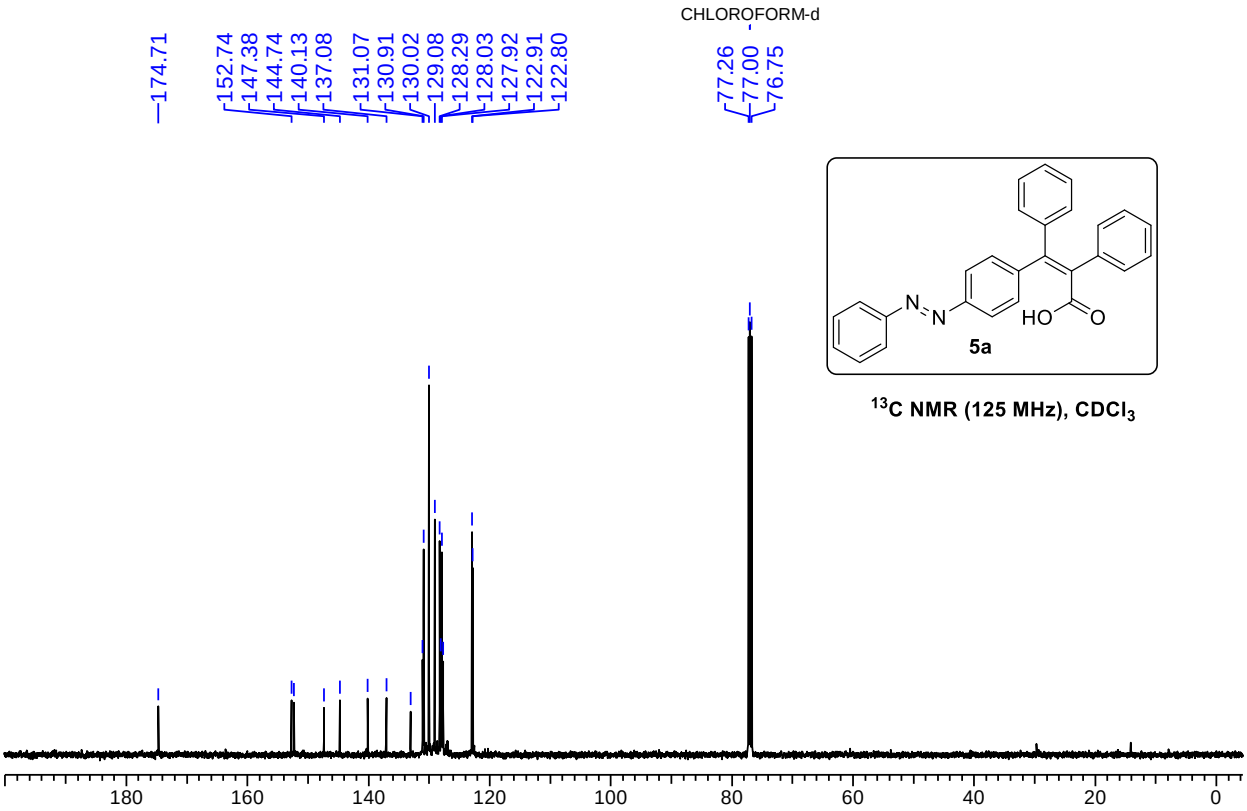
^{1}H NMR (400 MHz), $CDCl_3$



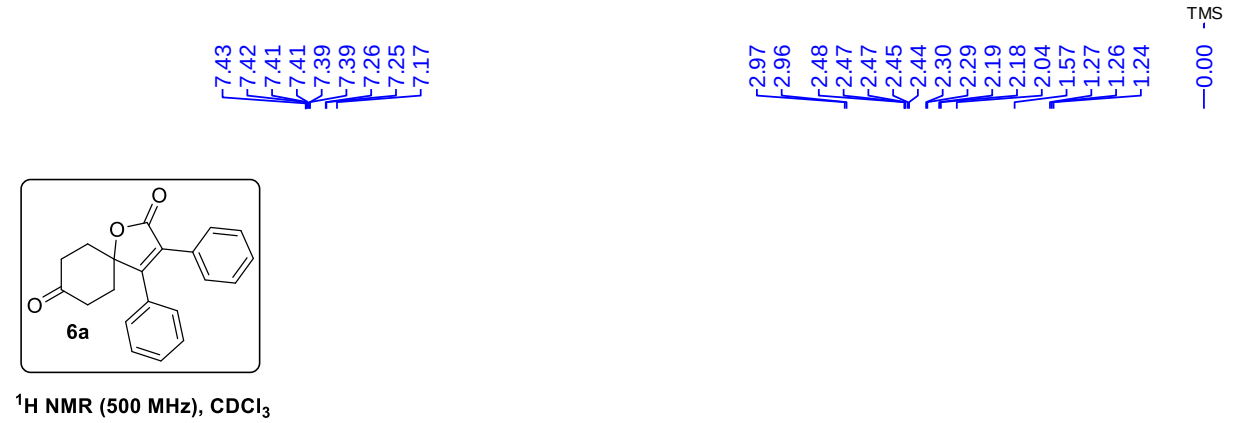
^{13}C NMR (100 MHz), $CDCl_3$



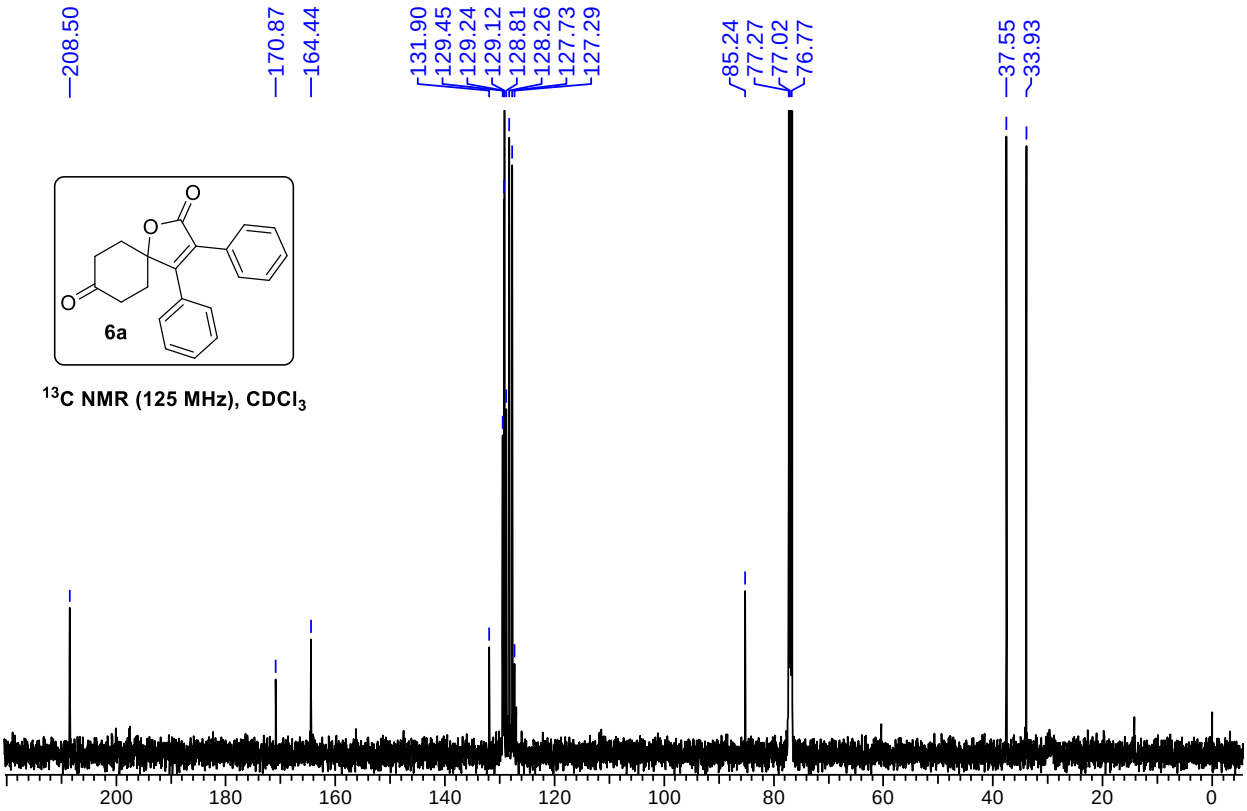
^{1}H NMR (500 MHz), $CDCl_3$



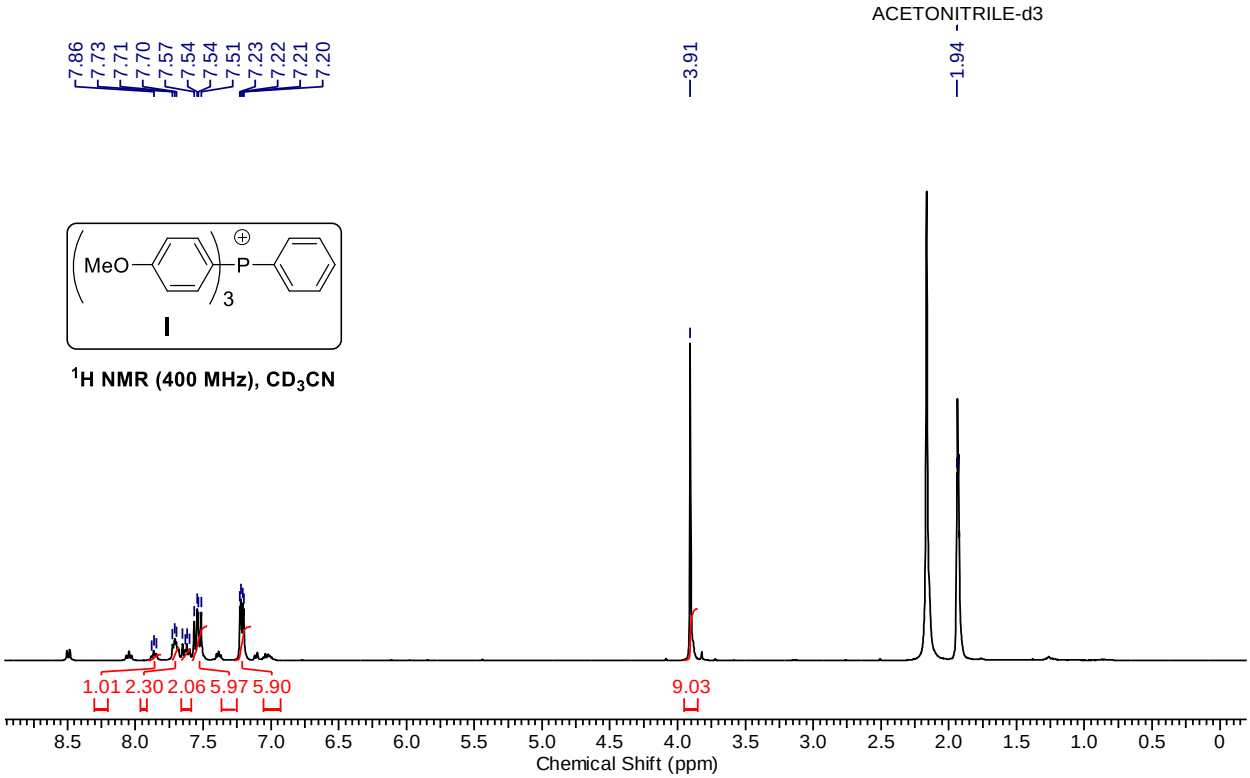
^{13}C NMR (125 MHz), $CDCl_3$



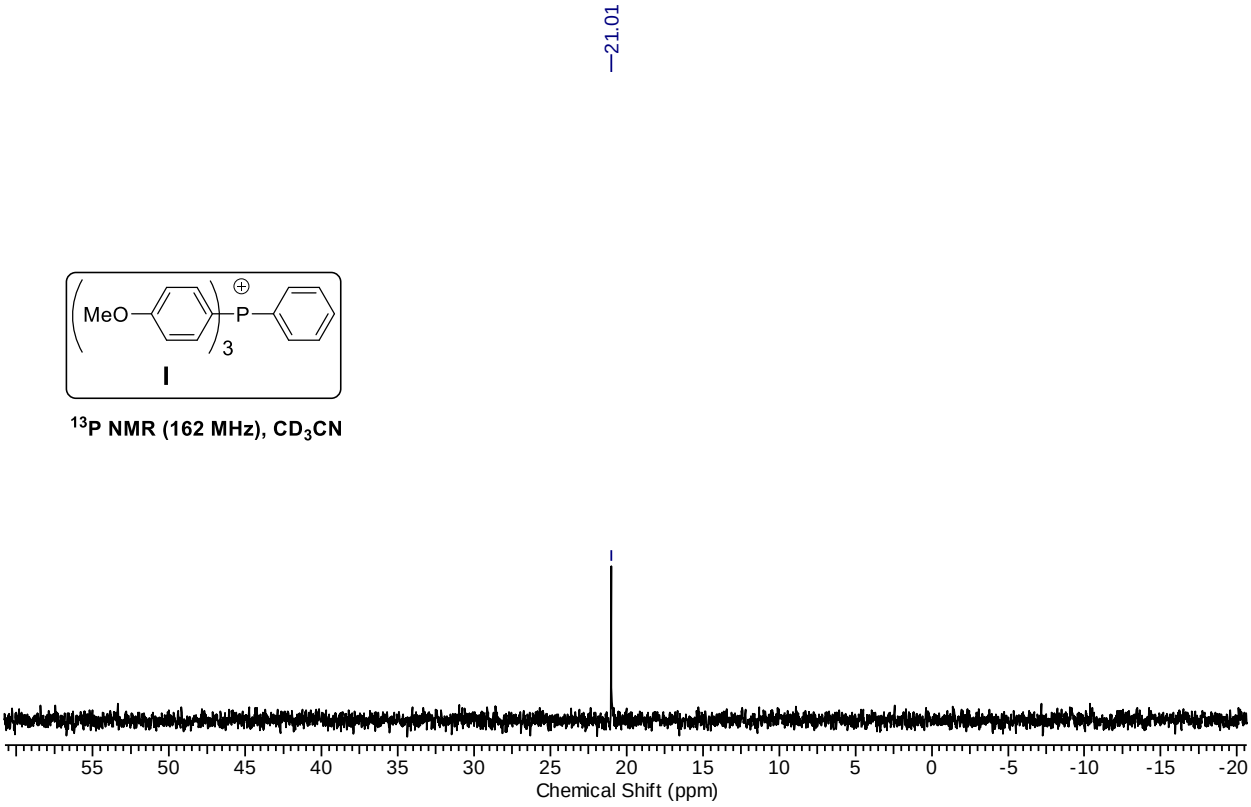
^{1}H NMR (500 MHz), $CDCl_3$



^{13}C NMR (125 MHz), $CDCl_3$



^{1}H NMR (400 MHz), CD_3CN



^{13}P NMR (162 MHz), CD_3CN