

Palladium Catalyzed Multicomponent Synthesis of Fully Substituted Alkylidene Furanones

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Table of Contents

General information	S2
General procedures	S3
Characterization data	S4
Compounds 5A-5E	S4
Compounds 10a-10ac and 12	S7
Copies of the ¹ H and ¹³ C NMR spectra	S27
Crystallographic data for compound 10a	S62

General information

Reagents and solvents were purchased from commercial sources (Aldrich, Acros, Merck, Fluka and VWR International) and preserved under argon. More sensitive compounds were stored in a desiccator or glove-box if required. Reagents were used without further purification unless otherwise noted.

All reactions were performed under argon (or nitrogen) unless otherwise noted. When needed, glassware was dried overnight in an oven ($T > 100\text{ }^{\circ}\text{C}$) or under vacuum with a heat gun ($T > 200\text{ }^{\circ}\text{C}$). When solvents are indicated as dry, they were either purchased as such, distilled prior to use or were dried by a passage through a column of anhydrous alumina or copper using a Puresolv MD 5 from Innovative Technology Inc., based on the Grubb's design.

Flash column chromatography was performed using Silicycle P60 silica: 230-400 mesh (40-63 μm) silica. Reactions were monitored using Merck Kieselgel 60F254 aluminium or glass backed plates. TLC's were visualized by UV fluorescence (254 nm) then stained with one of the following TLC stains: KMnO_4 , phosphomolybdic acid, ninhydrin, *p*-anisaldehyde, vanillin.

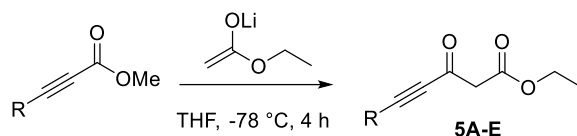
NMR spectra were recorded on a Brüker Avance III-400, Brüker Avance-400 or Brüker DPX-400 spectrometer at room temperature, ^1H frequency is at 400.13 MHz, ^{13}C frequency is at 100.62 MHz. Chemical shifts (δ) were reported in parts per million (ppm) relative to residual solvent peaks rounded to the nearest 0.01 MHz for proton and 0.1 MHz for carbon (ref: CHCl_3 [^1H : 7.26 ppm, ^{13}C : 77.2 ppm]). Coupling constants (J) were reported in Hz to the nearest 0.1 Hz. Peak multiplicity was indicated as follows: s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet) and br (broad). IR spectra were recorded in a Jasco FT/IR-4100 spectrometer outfitted with a PIKE technology MIRacle™ ATR accessory as neat films compressed onto a zinc selenide window. The spectra are reported in cm^{-1} . Abbreviations used are: w (weak), m (medium), s (strong) and br (broad).

Mass spectra were obtained with a Waters ACQUITY H-class UPLC/MS ACQ- SQD by electron ionization (EI positive and negative) or a Finnigan TSQ7000 by electrospray ionization (ESI +). The accurate masses were measured by the mass spectrometry service of the EPFL by ESI-TOF using a QTOF Ultima from Waters.

Melting points were determined using a Stuart SMP30.

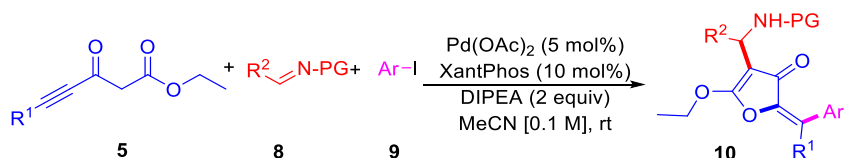
General procedures

General procedure A:



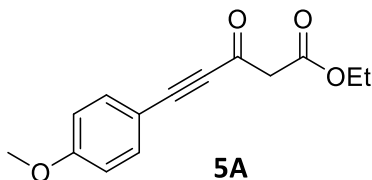
To a solution of diisopropylamine (1.31 mmol, 2.1 equiv) in THF (2.3 mL) was added *n*-BuLi (2.5 M in hexane, 1.25 mmol, 2.0 equiv) at -78 °C and the reaction mixture was stirred at the same temperature for 40 minutes. Ethyl acetate (1.25 mmol, 2.0 equiv) was added dropwise at -78 °C. After stirring at the same temperature for 45 min, a solution of the corresponding propiolate (0.63 mmol, 1.0 equiv) in THF (2.3 mL) was added at -78 °C. The resulting solution was stirred at the same temperature for 4 h. The reaction was quenched with water. The mixture was extracted with Et₂O. The organic extracts were dried over anhydrous Na₂SO₄. The solvent was evaporated, and the residue was purified by flash chromatography on silica gel to afford compounds **5A-5E**.

General procedure B:



To a solution of ynone **5** (0.15 mmol, 1.5 equiv), imine **8** (0.1 mmol, 1.0 equiv), aryl iodide **9** (0.1 mmol, 1 equiv), XantPhos (0.01 mmol, 0.1 equiv) and Pd(OAc)₂ (0.005 mmol, 0.05 equiv) in dry CH₃CN (1 mL) was added DIPEA (0.2 mmol, 2.0 equiv). The reaction mixture was stirred at rt for 2 h, then concentrated under reduced pressure. The crude product was purified by flash chromatography on silica gel to afford the pure product **10**.

Characterization data



Ethyl 5-(4-methoxyphenyl)-3-oxopent-4-ynoate was prepared according to general procedure A.

Yield: 100.8 mg, 65%, eluent: PE/AcOEt 98:2.

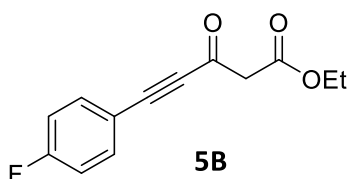
¹H NMR (400.13 MHz, CDCl₃): mixture of keto and enol forms in a ratio of 2:3 δ 11.98 (s, 1H), 7.55-7.51 (m, 1.3H), 7.49-7.45 (m, 2H), 6.92 – 6.85 (m, 3.3H), 5.41 (s, 1H), 4.24 (q, *J* = 7.2 Hz, 1.3H), 4.23 (q, *J* = 7.2 Hz, 2H), 3.84 (s, 2H), 3.83 (s, 3H), 3.66 (s, 1.3H), 1.31 (t, *J* = 7.2 Hz, 3H), 1.29 (t, *J* = 7.2 Hz, 2H).

¹³C NMR (100.62 MHz, CDCl₃): δ 178.8, 172.4, 166.4, 162.2, 161.0, 155.8, 135.5, 134.1, 114.6, 114.3, 112.9, 111.3, 96.7, 94.5, 94.2, 87.6, 82.7, 61.7, 60.7, 55.6, 55.5, 51.5, 14.3, 14.3 enol and ketone mixture.

IR (ν_{max}, cm⁻¹): 2978 (w), 2197 (m), 1742 (m), 1668 (m), 1600 (s), 1511 (m), 1299 (s), 1255 (s), 1210 (s).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₁₄H₁₄O₄Na 269.0790; Found 269.0794.

Aspect: Pale yellow amorphous solid.



Ethyl 5-(4-fluorophenyl)-3-oxopent-4-ynoate was prepared according to general procedure A.

Yield: 72 mg, 52%, eluent: PE/AcOEt 98:2.

¹H NMR (400.13 MHz, CDCl₃): mixture of keto and enol forms in a ratio of 1:2 δ 11.95 (s, 0.5H), 7.61 – 7.56 (m, 2H), 7.54 – 7.49 (m, 1H), 7.12 – 7.03 (m, 3H), 5.44 (s, 0.5H), 4.24 (q, *J* = 7.2 Hz, 2H), 4.23 (q, *J* = 7.1 Hz, 1H), 3.68 (s, 2H), 1.31 (t, *J* = 7.1 Hz, 1.5H), 1.30 (t, *J* = 7.2 Hz, 3H).

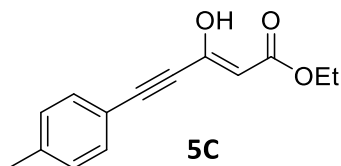
¹³C NMR (100.62 MHz, CDCl₃): δ 178.8, 172.3, 166.2, 164.3 (d, *J* = 254.6 Hz), 163.5 (d, *J* = 252.5 Hz), 155.3, 135.8 (d, *J* = 9.0 Hz), 134.5 (d, *J* = 8.7 Hz), 117.1 (d, *J* = 3.6 Hz), 116.4 (d, *J* =

22.4 Hz), 116.1 (d, $J = 22.3$ Hz), 115.7 (d, $J = 3.4$ Hz), 97.4, 92.4, 92.0, 87.4, 83.4, 61.8, 60.8, 51.5, 14.3, 14.3.

IR (ν_{\max} , cm^{-1}): 2990 (w), 2209 (m), 1740 (s), 1671 (s), 1600 (s), 1507 (m), 1408 (m), 1288 (m), 1208 (s)

HRMS (ESI) m/z : $[M + \text{Na}]^+$ Calcd for $\text{C}_{13}\text{H}_{11}\text{FO}_3\text{Na}$ 257.0590; Found 269.0590.

Aspect: Pale yellow amorphous solid.



Ethyl (Z)-3-hydroxy-5-(p-tolyl)pent-2-en-4-ynoate was prepared according to general procedure A.

Yield: 60 mg, 41%, eluent: PE/AcOEt 96:4.

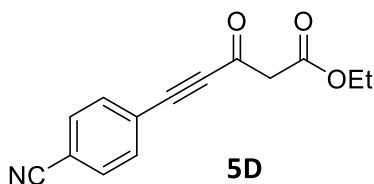
^1H NMR (400.13 MHz, CDCl_3): δ 11.97 (s, 1H), 7.42 (d, $J = 7.7$ Hz, 2H), 7.17 (d, $J = 7.8$ Hz, 2H), 5.43 (s, 1H), 4.24 (q, $J = 7.1$ Hz, 2H), 2.37 (s, 3H), 1.31 (t, $J = 7.1$ Hz, 3H).

^{13}C NMR (100.62 MHz, CDCl_3): δ 172.4, 155.7, 140.5, 132.3, 129.4, 117.9, 97.0, 94.0, 83.1, 60.7, 21.8, 14.4.

IR (ν_{\max} , cm^{-1}): 2987 (w), 2208 (m), 1746 (w), 1657 (m), 1597 (s), 1417 (m), 1382 (m), 1351 (m), 1291 (m), 1212 (s).

HRMS (ESI) m/z : $[M + \text{Na}]^+$ Calcd for $\text{C}_{14}\text{H}_{14}\text{O}_3\text{Na}$ 253.0841; Found 253.0848.

Aspect: Pale yellow amorphous solid.



Ethyl 5-(4-cyanophenyl)-3-oxopent-4-ynoate was prepared according to general procedure A.

Yield: 60 mg, 40%, eluent: PE/AcOEt 9:1.

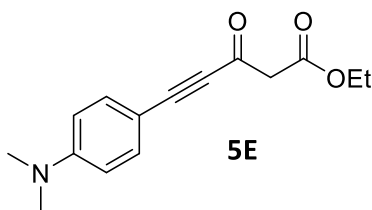
^1H NMR (400.13 MHz, CDCl_3): mixture of keto and enol forms in a ratio of 1:1 δ 11.92 (s, 1H), 7.70 – 7.61 (m, 8H), 5.49 (s, 1H), 4.25 (q, $J = 7.2$ Hz, 2H), 4.25 (q, $J = 7.2$ Hz, 2H), 3.70 (s, 2H), 1.32 (t, $J = 7.2$ Hz, 3H), 1.30 (t, $J = 7.2$ Hz, 3H).

¹³C NMR (100.62 MHz, CDCl₃): δ 178.5, 172.1, 165.9, 154.3, 133.6, 132.8, 132.5, 132.3, 125.7, 124.4, 118.2, 117.9, 114.6, 113.4, 98.6, 90.8, 89.6, 89.4, 87.0, 62.0, 61.1, 51.4, 14.3, 14.3.

IR (ν_{max}, cm⁻¹): 2226 (m), 1749 (w), 1613 (s), 1416 (m), 1383 (m), 1353 (m), 1289 (m), 1216 (s).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₁₄H₁₁NO₃Na 264.0637; Found 264.0640.

Aspect: Pale yellow amorphous solid.



Ethyl 5-(4-(dimethylamino)phenyl)-3-oxopent-4-ynoate was prepared according to general procedure A.

Yield: 73 mg, 45%, eluent: PE/AcOEt 9:1.

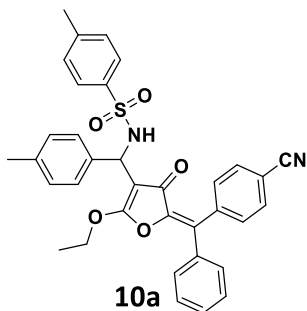
¹H NMR (400.13 MHz, CDCl₃): mixture of keto and enol forms in a ratio of 0.2:1 δ 12.01 (s, 0.2H), 7.45 (d, *J* = 9.1 Hz, 2H), 7.39 (d, *J* = 9.1 Hz, 0.4H), 6.62 (d, *J* = 9.1 Hz, 2.4H), 5.37 (s, 0.2H), 4.24 (q, *J* = 7.1 Hz, 2.4H), 3.65 (s, 2H), 3.04 (s, 6H), 3.01 (s, 1.2H), 1.30 (t, *J* = 7.1 Hz, 0.6H), 1.29 (t, *J* = 7.1 Hz, 3H).

¹³C NMR (100.62 MHz, CDCl₃): δ 178.5, 172.6, 166.8, 156.5, 152.1, 151.2, 135.5, 133.9, 111.7, 111.6, 107.0, 105.0, 98.0, 96.4, 95.6, 88.7, 82.6, 61.6, 60.5, 51.5, 40.2, 40.1, 14.4, 14.3 enol and ketone mixture.

IR (ν_{max}, cm⁻¹): 2162 (m), 1740 (m), 1660 (m), 1598 (s), 1526 (m), 1368 (m), 1077 (m).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₁₅H₁₇NO₃Na 282.1106; Found 282.1110.

Aspect: Pale orange amorphous solid.



(E)-N-((5-((4-Cyanophenyl)(phenyl)methylene)-2-ethoxy-4-oxo-4,5-dihydrofuran-3-yl)(p-tolyl)methyl)-4-methylbenzenesulfonamide was prepared according to general procedure B.

Yield: 54.3 mg (484.4 mg), 92% (82%), eluent: PE/AcOEt 70:30.

¹H NMR (400.13 MHz, CDCl₃): δ 7.68 (d, *J* = 7.9 Hz, 2H), 7.57 (d, *J* = 8.0 Hz, 2H), 7.39 – 7.33 (m, 5H), 7.19 – 7.13 (m, 6H), 7.00 (d, *J* = 7.8 Hz, 2H), 6.35 (d, *J* = 9.9 Hz, 1H), 5.29 (d, *J* = 9.8 Hz, 1H), 4.36 (q, *J* = 7.1 Hz, 2H), 2.33 (s, 3H), 2.27 (s, 3H), 1.44 (t, *J* = 7.0 Hz, 3H).

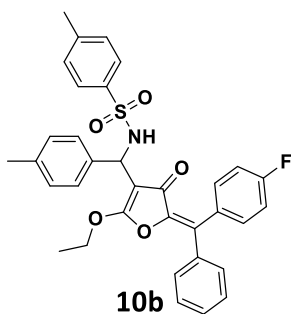
¹³C NMR (100.62 MHz, CDCl₃): δ 180.9, 173.3, 142.9, 141.9, 139.8, 138.2, 137.5, 136.9, 136.1, 131.9, 131.4, 130.4, 129.8, 129.3, 129.1, 128.6, 127.3, 126.6, 118.7, 113.0, 96.2, 67.7, 51.4, 21.7, 21.2, 15.0.

IR (ν_{max}, cm⁻¹): 2228 (w), 1643 (w), 1595 (s), 1422 (m), 1386 (m), 1346 (m), 1259 (w), 1160 (s), 1095 (m).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₅H₃₀N₂O₅SNa 613.1773; Found 613.1766.

Aspect: Brown solid.

Mp: 184 – 186°C.



(E)-N-((2-Ethoxy-5-((4-fluorophenyl)(phenyl)methylene)-4-oxo-4,5-dihydrofuran-3-yl)(p-tolyl)methyl)-4-methylbenzenesulfonamide was prepared according to general procedure B.

Yield: 43.0 mg, 74%, eluent: PE/AcOEt 80:20.

¹H NMR (400.13 MHz, CDCl₃): δ 7.61 – 7.58 (m, 2H), 7.40 – 7.35 (m, 3H), 7.25 – 7.16 (m, 6H), 7.13 (d, *J* = 8.0 Hz, 2H), 7.10 – 7.05 (m, 2H), 7.00 (d, *J* = 8.0 Hz, 2H), 6.49 (d, *J* = 9.9 Hz, 1H), 5.29 (d, *J* = 9.8 Hz, 1H), 4.30 (q, *J* = 7.1 Hz, 2H), 2.33 (s, 3H), 2.27 (s, 3H), 1.41 (t, *J* = 7.2 Hz, 3H).

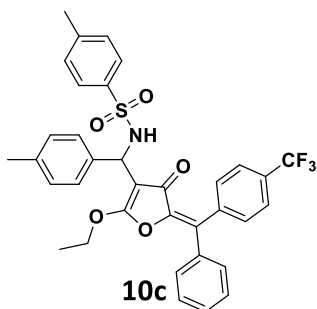
¹³C NMR (100.62 MHz, CDCl₃): δ 181.0, 172.8, 163.5 (d, *J* = 248.3 Hz), 142.8, 141.6, 138.2, 137.4, 137.2, 137.2, 132.8 (d, *J* = 8.4 Hz), 130.9, 130.7 (d, *J* = 3.3 Hz), 130.6, 129.5, 129.3, 129.1, 128.3, 127.4, 126.7, 115.3 (d, *J* = 21.7 Hz), 96.0, 67.3, 51.6, 21.7, 21.2, 15.0.

IR (ν_{max}, cm⁻¹): 1639 (m), 1598 (s), 1509 (m), 1424 (s), 1387 (m), 1345 (s), 1229 (m), 1162 (s), 1099 (s).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₄H₃₀FNO₅SNa 606.1726; Found 606.1725.

Aspect: Yellow solid.

Mp: 155 – 157°C.



(E)-N-((2-Ethoxy-4-oxo-5-(phenyl(4-(trifluoromethyl)phenyl)methylene)-4,5-dihydrofuran-3-yl)(*p*-tolyl)methyl)-4-methylbenzenesulfonamide was prepared according to general procedure B.

Yield: 44.8 mg, 70%, eluent: PE/AcOEt 80:20.

¹H NMR (400.13 MHz, CDCl₃): δ 7.64 (d, *J* = 7.9 Hz, 2H), 7.60 (d, *J* = 7.8 Hz, 2H), 7.38 – 7.35 (m, 5H), 7.20 – 7.14 (m, 6H), 7.01 (d, *J* = 7.8 Hz, 2H), 6.38 (d, *J* = 9.8 Hz, 1H), 5.30 (d, *J* = 9.8 Hz, 1H), 4.34 (q, *J* = 7.1 Hz, 2H), 2.34 (s, 3H), 2.27 (s, 3H), 1.44 (t, *J* = 7.0 Hz, 3H).

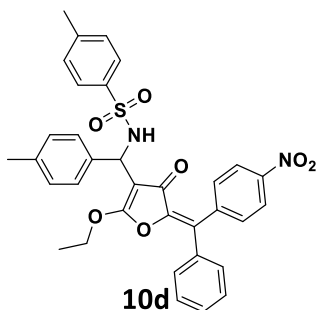
¹³C NMR (100.62 MHz, CDCl₃): δ 180.9, 173.2, 142.9, 141.9, 138.6, 138.2, 137.4, 137.0, 136.6, 131.1 (q, *J* = 32.2 Hz), 131.1, 130.5, 129.8, 129.6, 129.3, 129.1, 128.5, 127.3, 126.7, 125.1 (q, *J* = 3.6 Hz), 124.1 (q, *J* = 270.6 Hz), 96.0, 67.5, 51.4, 21.6, 21.2, 15.0.

IR (ν_{max}, cm⁻¹): 1642 (m), 1597 (s), 1424 (m), 1388 (m), 1324 (s), 1162 (s), 1117 (s), 1066 (s).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₅H₃₀F₃NO₅SNa 656.1694; Found 656.1704.

Aspect: Yellow pale solid.

Mp: 180 – 182 °C.



(E)-N-((2-Ethoxy-5-((4-nitrophenyl)(phenyl)methylene)-4-oxo-4,5-dihydrofuran-3-yl)(p-tolyl)methyl)-4-methylbenzenesulfonamide was prepared according to general procedure B.

Yield: 58.0 mg, 95%, eluent: PE/AcOEt 70:30.

¹H NMR (400.13 MHz, CDCl₃): δ 8.25 (d, *J* = 8.3 Hz, 2H), 7.57 (d, *J* = 7.9 Hz, 2H), 7.43 – 7.39 (m, 5H), 7.20 – 7.19 (m, 2H), 7.14 – 7.12 (m, 4H), 7.00 (d, *J* = 7.7 Hz, 2H), 6.31 (d, *J* = 9.8 Hz, 1H), 5.30 (d, *J* = 9.8 Hz, 1H), 4.38 (q, *J* = 7.1 Hz, 2H), 2.34 (s, 3H), 2.27 (s, 3H), 1.46 (t, *J* = 7.1 Hz, 3H).

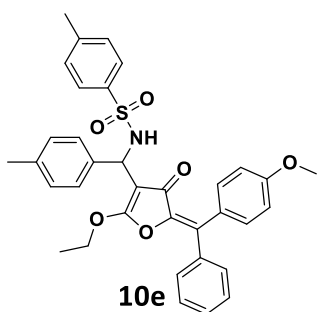
¹³C NMR (100.62 MHz, CDCl₃): δ 180.9, 173.4, 148.2, 142.9, 141.9, 141.8, 138.1, 137.5, 136.8, 135.9, 131.6, 130.4, 129.9, 129.3, 129.1, 128.7, 128.6, 127.3, 126.6, 123.4, 96.2, 67.8, 51.4, 21.7, 21.2, 15.1.

IR (ν_{max}, cm⁻¹): 1644 (m), 1597 (s), 1517 (m), 1425 (m), 1389 (m), 1343 (s), 1161 (s), 1099 (s).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₄H₃₀N₂O₇Na 633.1671; Found 633.1676.

Aspect: Brown solid.

Mp: 180 – 182 °C.



(E)-N-((2-Ethoxy-5-((4-methoxyphenyl)(phenyl)methylene)-4-oxo-4,5-dihydrofuran-3-yl)(p-tolyl)methyl)-4-methylbenzenesulfonamide was prepared according to general procedure B.

Yield: 27.5 mg, 46%, eluent: 70:30 PE/AcOEt.

¹H NMR (400.13 MHz, CDCl₃): δ 7.61 (d, *J* = 8.2 Hz, 2H), 7.36 – 7.34 (m, 3H), 7.22 – 7.18 (m, 6H), 7.14 (d, *J* = 8.2 Hz, 2H), 7.01 (d, *J* = 7.9 Hz, 2H), 6.90 (d, *J* = 8.8 Hz, 2H), 6.61 (d, *J* = 9.9 Hz, 1H), 5.29 (d, *J* = 9.9 Hz, 1H), 4.24 (q, *J* = 7.2 Hz, 2H), 3.85 (s, 3H), 2.33 (s, 3H), 2.28 (s, 3H), 1.38 (t, *J* = 7.1 Hz, 3H).

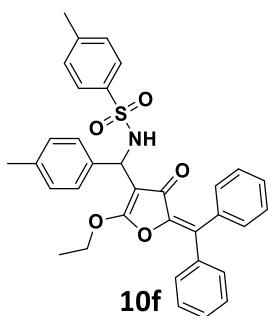
¹³C NMR (100.62 MHz, CDCl₃): δ 181.0, 172.3, 160.8, 142.8, 141.3, 138.2, 137.8, 137.3, 137.3, 132.6, 132.5, 130.7, 129.2, 129.0, 128.2, 127.3, 126.8, 126.8, 113.4, 95.8, 67.0, 55.4, 51.7, 21.7, 21.2, 15.0.

IR (ν_{max}, cm⁻¹): 1637 (m), 1595 (s), 1513 (m), 1425 (s), 1387 (m), 1342 (s), 1250 (s), 1162 (s), 1101 (s).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₅H₃₃NO₆SNa 618.1926; Found 618.1929.

Aspect: Yellow pale solid.

Mp: 152 – 154 °C.



N-((5-(Diphenylmethylene)-2-ethoxy-4-oxo-4,5-dihydrofuran-3-yl)(p-tolyl)methyl)-4-methylbenzenesulfonamide was prepared according to general procedure B.

Yield: 38.1 mg, 67% yield, eluent: 80:20 PE/AcOEt.

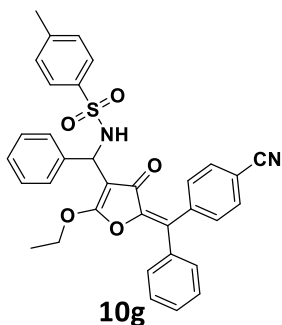
¹H NMR (400.13 MHz, CDCl₃): δ 7.60 (d, *J* = 8.3 Hz, 2H), 7.45 – 7.34 (m, 6H), 7.24 – 7.17 (m, 6H), 7.14 (d, *J* = 7.9 Hz, 2H), 7.01 (d, *J* = 7.9 Hz, 2H), 6.54 (d, *J* = 9.9 Hz, 1H), 5.29 (d, *J* = 9.9 Hz, 1H), 4.30 (q, *J* = 7.1 Hz, 2H), 2.33 (s, 3H), 2.27 (s, 3H), 1.41 (t, *J* = 7.2 Hz, 3H).

¹³C NMR (100.62 MHz, CDCl₃): δ 181.0, 172.7, 142.8, 141.6, 138.2, 137.3, 137.3, 137.3, 134.9, 131.7, 130.7, 130.6, 129.5, 129.3, 129.2, 129.1, 128.3, 128.1, 127.4, 126.8, 95.8, 67.2, 51.6, 21.7, 21.2, 15.0.

IR (ν_{max}, cm⁻¹): 1640 (m), 1596 (s), 1423 (s), 1388 (m), 1347 (s), 1258 (m), 1163 (s).

HRMS (ESI) m/z : $[M + Na]^+$ Calcd for $C_{34}H_{31}NO_5SNa$ 588.1821; Found 588.1828.

Aspect: Yellow oil.



(E)-N-((5-((4-Cyanophenyl)(phenyl)methylene)-2-ethoxy-4-oxo-4,5-dihydrofuran-3-yl)(phenyl)methyl)-4-methylbenzenesulfonamide was prepared according to general procedure B.

Yield: 49.5 mg, 86%, eluent: PE/AcOEt 70:30.

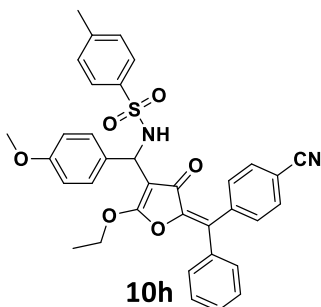
1H NMR (400.13 MHz, $CDCl_3$): δ 7.68 (d, $J = 8.0$ Hz, 2H), 7.58 (d, $J = 8.0$ Hz, 2H), 7.39 – 7.34 (m, 5H), 7.26 – 7.12 (m, 9H), 6.38 (d, $J = 9.8$ Hz, 1H), 5.34 (d, $J = 9.9$ Hz, 1H), 4.37 (q, $J = 7.0$ Hz, 2H), 2.33 (s, 3H), 1.45 (t, $J = 7.1$ Hz, 3H).

^{13}C NMR (100.62 MHz, $CDCl_3$): δ 180.9, 173.3, 143.0, 141.8, 139.8, 138.1, 136.1, 131.9, 131.4, 130.4, 129.9, 129.2, 129.1, 128.7, 128.6, 127.7, 127.3, 126.7, 118.7, 113.0, 96.0, 67.7, 51.6, 21.7, 15.0.

IR (ν_{max} , cm^{-1}): 2229 (w), 2228 (w), 1644 (m), 1596 (s), 1492 (w), 1425 (s), 1389 (m), 1346 (s), 1163 (s), 1109 (m).

HRMS (ESI) m/z : $[M + Na]^+$ Calcd for $C_{34}H_{28}N_2O_5SNa$ 599.1617; Found 599.1617.

Aspect: White solid.



(E)-N-((5-((4-Cyanophenyl)(phenyl)methylene)-2-ethoxy-4-oxo-4,5-dihydrofuran-3-yl)(4-methoxyphenyl)methyl)-4-methylbenzenesulfonamide was prepared according to general procedure B.

Yield: 52.9mg, 87%, eluent: PE/AcOEt 70:30.

¹H NMR (400.13 MHz, CDCl₃): δ 7.68 (d, *J* = 7.9 Hz, 2H), 7.57 (d, *J* = 7.9 Hz, 2H), 7.39 – 7.34 (m, 5H), 7.19 – 7.12 (m, 6H), 6.71 (d, *J* = 8.4 Hz, 2H), 6.32 (d, *J* = 9.7 Hz, 1H), 5.28 (d, *J* = 9.7 Hz, 1H), 4.36 (q, *J* = 7.0 Hz, 2H), 3.74 (s, 3H), 2.33 (s, 3H), 1.45 (t, *J* = 7.1 Hz, 3H).

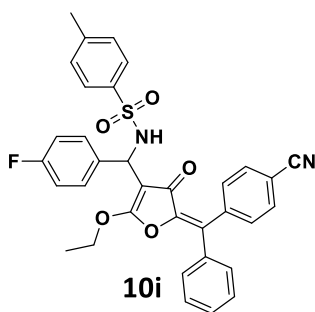
¹³C NMR (100.62 MHz, CDCl₃): δ 180.9, 173.3, 159.2, 142.9, 141.9, 139.8, 138.2, 136.1, 132.0, 131.9, 131.4, 130.4, 129.8, 129.1, 128.6, 128.0, 127.3, 118.7, 114.0, 113.0, 96.2, 67.7, 55.4, 51.2, 21.7, 15.0.

IR (ν_{max}, cm⁻¹): 2229 (w), 1644 (m), 1595 (s), 1513 (m), 1426 (s), 1390 (m), 1347 (s), 1249 (s), 1160 (s).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₅H₃₀N₂O₆SNa 629.1722; Found 629.1721.

Aspect: Light-brown powder.

Mp: 167 – 169 °C.



(E)-N-((5-((4-Cyanophenyl)(phenyl)methylene)-2-ethoxy-4-oxo-4,5-dihydrofuran-3-yl)(4-fluorophenyl)methyl)-4-methylbenzenesulfonamide was prepared according to general procedure B.

Yield: 48.1mg, 81%, eluent: PE/AcOEt 70:30.

¹H NMR (400.13 MHz, CDCl₃): δ 7.69 (d, *J* = 8.0 Hz, 2H), 7.56 (d, *J* = 8.0 Hz, 2H), 7.39 – 7.34 (m, 5H), 7.23 – 7.18 (m, 4H), 7.14 (d, *J* = 7.9 Hz, 2H), 6.86 (t, *J* = 8.5 Hz, 2H), 6.38 (d, *J* = 9.8 Hz, 1H), 5.31 (d, *J* = 9.7 Hz, 1H), 4.38 (q, *J* = 7.0 Hz, 2H), 2.33 (s, 3H), 1.45 (t, *J* = 7.1 Hz, 3H).

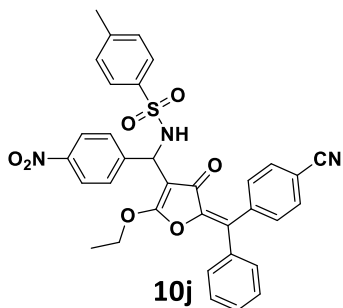
¹³C NMR (100.62 MHz, CDCl₃): δ 180.9, 173.3, 162.3 (d, *J* = 244.9 Hz), 143.1, 141.8, 139.7, 138.1, 136.0, 135.7 (d, *J* = 3.1 Hz), 132.0, 131.4, 130.5, 129.9, 129.5, 129.2, 128.7, 128.5 (d, *J* = 8.1 Hz), 127.3, 118.6, 115.4 (d, *J* = 21.3 Hz), 113.1, 95.9, 67.8, 51.1, 21.7, 15.0.

IR (ν_{max}, cm⁻¹): 2227 (w), 1642 (m), 1595 (s), 1509 (m), 1426 (s), 1390 (m), 1346 (s), 1227 (m), 1161 (s), 1114 (m), 1097 (m).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₄H₂₇FN₂O₅SNa 617.1522; Found 617.1528.

Aspect: White solid.

Mp: 173 – 175 °C.



(E)-N-((5-((4-Cyanophenyl)(phenyl)methylene)-2-ethoxy-4-oxo-4,5-dihydrofuran-3-yl)(4-nitrophenyl)methyl)-4-methylbenzenesulfonamide was prepared according to general procedure B.

Yield: 32.4 mg, 52%, eluent: PE/AcOEt 70:30.

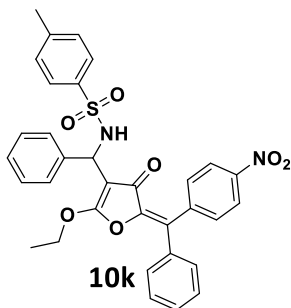
¹H NMR (400.13 MHz, CDCl₃): δ 8.03 (d, *J* = 8.3 Hz, 2H), 7.69 (d, *J* = 8.0 Hz, 2H), 7.56 (d, *J* = 8.0 Hz, 2H), 7.42 – 7.34 (m, 7H), 7.21 – 7.19 (m, 2H), 7.14 (d, *J* = 7.8 Hz, 2H), 6.52 (d, *J* = 9.5 Hz, 1H), 5.41 (d, *J* = 9.3 Hz, 1H), 4.42 (q, *J* = 6.9 Hz, 2H), 2.33 (s, 3H), 1.47 (t, *J* = 7.0 Hz, 3H).

¹³C NMR (100.62 MHz, CDCl₃): δ 180.8, 173.3, 147.3, 146.9, 143.5, 141.6, 139.5, 137.8, 135.8, 132.0, 131.4, 130.5, 130.3, 130.1, 129.3, 128.7, 127.6, 127.2, 123.9, 118.5, 113.3, 94.9, 68.2, 51.1, 21.6, 15.0.

IR (ν_{max}, cm⁻¹): 2227 (w), 1642 (m), 1595 (s), 1509 (m), 1426 (s), 1390 (m), 1346 (s), 1227 (m), 1161 (s), 1114 (m), 1097 (m).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₄H₂₇N₃O₇SNa 644.1467; Found 644.1467.

Aspect: Yellow oil.



(E)-N-((2-Ethoxy-5-((4-nitrophenyl)(phenyl)methylene)-4-oxo-4,5-dihydrofuran-3-yl)(phenyl)methyl)-4-methylbenzenesulfonamide was prepared according to general procedure B.

Yield: 51.8 mg, 87%, eluent: PE/AcOEt 70:30.

¹H NMR (400.13 MHz, CDCl₃): δ 8.27 – 8.24 (m, 2H), 7.58 (d, *J* = 8.3 Hz, 2H), 7.42 – 7.37 (m, 5H), 7.24 – 7.18 (m, 7H), 7.14 (d, *J* = 8.0 Hz, 2H), 6.36 (d, *J* = 9.9 Hz, 1H), 5.34 (d, *J* = 9.8 Hz, 1H), 4.39 (q, *J* = 7.2 Hz, 2H), 2.33 (s, 3H), 1.46 (t, *J* = 7.2 Hz, 3H).

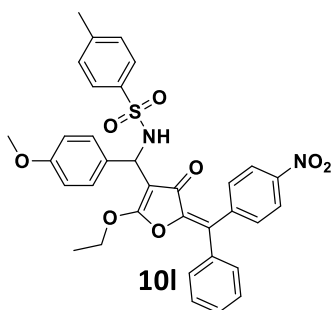
¹³C NMR (100.62 MHz, CDCl₃): δ 180.9, 173.4, 148.2, 143.0, 141.8, 141.8, 139.8, 138.1, 135.9, 131.6, 130.4, 129.9, 129.1, 128.7, 128.7, 127.7, 127.3, 126.7, 123.4, 96.1, 67.8, 51.6, 21.7, 15.1.

IR (ν_{max}, cm⁻¹): 1644 (m), 1596 (s), 1516 (m), 1425 (m), 1391 (m), 1343 (s), 1160 (s), 1103 (m).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₃H₂₈N₂O₇SNa 619.1515; Found 619.1521.

Aspect: Yellow pale solid.

Mp: 179 – 181 °C.



(E)-N-((2-Ethoxy-5-((4-nitrophenyl)(phenyl)methylene)-4-oxo-4,5-dihydrofuran-3-yl)(4-methoxyphenyl)methyl)-4-methylbenzenesulfonamide was prepared according to general procedure B.

Yield: 57.1 mg, 91%, eluent: PE/AcOEt 70:30.

¹H NMR (400.13 MHz, CDCl₃): δ 8.25 (d, *J* = 8.4 Hz, 2H), 7.57 (d, *J* = 7.9 Hz, 2H), 7.42 – 7.38 (m, 5H), 7.21 – 7.13 (m, 6H), 6.72 (d, *J* = 8.3 Hz, 2H), 6.29 (d, *J* = 9.8 Hz, 1H), 5.29 (d, *J* = 9.7 Hz, 1H), 4.39 (q, *J* = 7.0 Hz, 2H), 3.74 (s, 3H), 2.34 (s, 3H), 1.46 (t, *J* = 7.1 Hz, 3H).

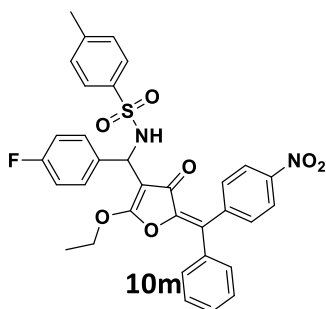
¹³C NMR (100.62 MHz, CDCl₃): δ 181.0, 173.4, 159.2, 148.1, 142.9, 141.9, 141.8, 138.2, 135.9, 132.0, 131.6, 130.4, 129.9, 129.1, 128.7, 128.6, 128.0, 127.3, 123.4, 114.0, 96.2, 67.8, 55.4, 51.2, 21.7, 15.1.

IR (ν_{max}, cm⁻¹): 2364 (w), 1641 (w), 1597 (s), 1513 (s), 1433 (m), 1419 (m), 1387 (m), 1345 (s), 1248 (m), 1161 (s), 1096 (s).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₄H₃₀N₂O₈SNa 649.1621; Found 649.1628.

Aspect: Brown solid.

Mp: 183 – 185 °C.



(E)-N-((2-Ethoxy-5-((4-nitrophenyl)(phenyl)methylene)-4-oxo-4,5-dihydrofuran-3-yl)(4-fluorophenyl)methyl)-4-methylbenzenesulfonamide was prepared according to general procedure B.

Yield: 55.4 mg, 90%, eluent: PE/AcOEt 70:30.

¹H NMR (400.13 MHz, CDCl₃): δ 8.26 (d, *J* = 7.9 Hz, 2H), 7.57 (d, *J* = 7.5 Hz, 2H), 7.42 – 7.39 (m, 5H), 7.23 – 7.20 (m, 4H), 7.15 (d, *J* = 7.8 Hz, 2H), 6.86 (t, *J* = 8.2 Hz, 2H), 6.36 (d, *J* = 9.7 Hz, 1H), 5.32 (d, *J* = 9.5 Hz, 1H), 4.40 (q, *J* = 7.0 Hz, 2H), 2.34 (s, 3H), 1.46 (t, *J* = 7.1 Hz, 3H).

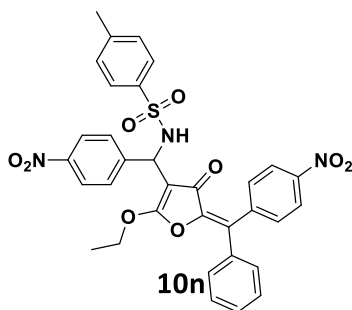
¹³C NMR (100.62 MHz, CDCl₃): δ 180.9, 173.4, 162.3 (d, *J* = 245.0 Hz), 148.2, 143.1, 141.8, 141.7, 138.0, 135.8, 135.6 (d, *J* = 3.0 Hz), 131.6, 130.4, 130.0, 129.2, 129.0, 128.7, 128.5 (d, *J* = 8.2 Hz), 127.3, 123.5, 115.4 (d, *J* = 21.4 Hz), 95.9, 67.9, 51.1, 21.7, 15.0.

IR (ν_{max}, cm⁻¹): 1642 (w), 1594 (s), 1515 (m), 1426 (m), 1386 (m), 1343 (s), 1227 (m), 1160 (s), 1096 (s).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₃H₂₇FN₂O₇SNa 637.1421; Found 637.1429.

Aspect: Yellow pale solid.

Mp: 177 – 179 °C.



(E)-N-((2-Ethoxy-5-((4-nitrophenyl)(phenyl)methylene)-4-oxo-4,5-dihydrofuran-3-yl)(4-nitrophenyl)methyl)-4-methylbenzenesulfonamide was prepared according to general procedure B.

Yield: 48.3 mg, 75%, eluent: PE/AcOEt 70:30.

¹H NMR (400.13 MHz, CDCl₃): δ 8.26 (d, *J* = 8.7 Hz, 2H), 8.03 (d, *J* = 8.8 Hz, 2H), 7.56 (d, *J* = 8.2 Hz, 2H), 7.42 – 7.40 (m, 7H), 7.22 – 7.21 (m, 2H), 7.14 (d, *J* = 8.0 Hz, 2H), 6.49 (d, *J* = 9.5 Hz, 1H), 5.42 (d, *J* = 9.5 Hz, 1H), 4.44 (q, *J* = 6.7 Hz, 2H), 2.34 (s, 3H), 1.49 (t, *J* = 7.1 Hz, 3H).

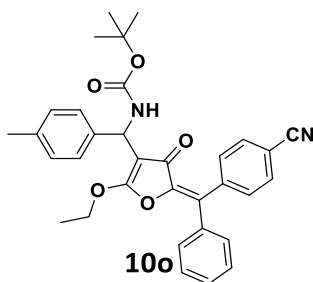
¹³C NMR (100.62 MHz, CDCl₃): δ 180.8, 173.4, 148.3, 147.4, 146.9, 143.6, 141.7, 141.5, 137.8, 135.6, 131.6, 130.4, 130.2, 129.8, 129.3, 128.8, 127.6, 127.2, 123.9, 123.5, 95.0, 68.3, 51.1, 21.7, 15.1.

IR (ν_{max}, cm⁻¹): 1643 (w), 1596 (s), 1518 (m), 1427 (m), 1388 (m), 1347 (s), 1162 (m), 1106 (m).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₃H₂₇N₃O₉Na 664.1366; Found 664.1373.

Aspect: Brown solid.

Mp: 186 – 188°C.



tert-Butyl (E)-((5-((4-cyanophenyl)(phenyl)methylene)-2-ethoxy-4-oxo-4,5-dihydrofuran-3-yl)(p-tolyl)methyl)carbamate was prepared according to general procedure B.

Yield: 40.2 mg, 75%, eluent: PE/AcOEt 80:20.

¹H NMR (400.13 MHz, CDCl₃): δ 7.68 (d, *J* = 8.4 Hz, 2H), 7.43 (d, *J* = 8.3 Hz, 2H), 7.38 – 7.36 (m, 3H), 7.28 – 7.24 (s, 4H), 7.10 (d, *J* = 7.9 Hz, 2H), 6.54 (d, *J* = 9.0 Hz, 1H), 5.58 (d, *J* = 8.9 Hz, 1H), 4.49 – 4.41 (m, 2H), 2.30 (s, 3H), 1.46 (t, *J* = 7.1 Hz, 3H), 1.38 (s, 9H).

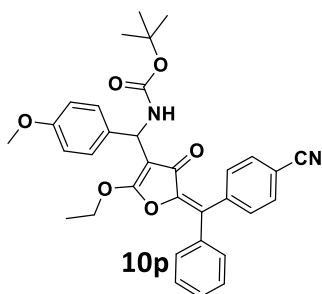
¹³C NMR (100.62 MHz, CDCl₃): δ 181.6, 173.8, 155.4, 142.3, 140.2, 139.8, 137.0, 136.3, 131.9, 131.5, 130.5, 129.7, 129.4, 128.8, 128.6, 126.2, 118.8, 112.8, 97.3, 79.5, 67.6, 48.3, 28.6, 21.2, 15.0.

IR (ν_{max}, cm⁻¹): 2227 (w), 1711 (s), 1641 (m), 1601 (s), 1493 (s), 1423 (s), 1388 (m), 1347 (s), 1163 (s), 1097 (s).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₃H₃₂N₂O₅Na 559.2209; Found 559.2220.

Aspect: Brown solid.

Mp: 111 – 112 °C.



tert-Butyl (E)-((5-((4-cyanophenyl)(phenyl)methylene)-2-ethoxy-4-oxo-4,5-dihydrofuran-3-yl)(4-methoxyphenyl)methyl)carbamate was prepared according to general procedure B.

Yield: 48.5 mg, 88%, eluent: PE/AcOEt 80:20.

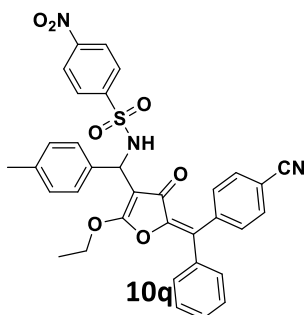
¹H NMR (400.13 MHz, CDCl₃): δ 7.69 (d, *J* = 8.4 Hz, 2H), 7.43 (d, *J* = 8.3 Hz, 2H), 7.39 – 7.37 (m, 3H), 7.31 – 7.25 (m, 4H), 6.82 (d, *J* = 8.8 Hz, 2H), 6.50 (d, *J* = 8.9 Hz), 5.56 (d, *J* = 8.9 Hz, 1H), 4.50 – 4.42 (m, 2H), 3.77 (s, 3H), 1.46 (t, *J* = 7.2 Hz, 3H), 1.38 (s, 9H).

¹³C NMR (100.62 MHz, CDCl₃): δ 181.6, 173.7, 158.9, 155.4, 142.3, 140.2, 136.3, 135.0, 131.9, 131.5, 130.5, 129.7, 128.8, 128.6, 127.5, 118.8, 114.0, 112.8, 97.4, 79.5, 67.6, 55.4, 48.0, 28.6, 15.0.

IR (ν_{max}, cm⁻¹): 2228 (w), 1708 (s), 1644 (m), 1601 (s), 1497 (s), 1426 (s), 1387 (s), 1348 (s), 1245 (s), 1164 (s), 1096 (s).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₃H₃₂N₂O₆Na 575.2158; Found 575.2158.

Aspect: Yellow oil.



(E)-N-((5-((4-Cyanophenyl)(phenyl)methylene)-2-ethoxy-4-oxo-4,5-dihydrofuran-3-yl)(p-tolyl)methyl)-4-nitrobenzenesulfonamide was prepared according to general procedure B.

Yield: 50.4 mg, 81%, eluent: PE/AcOEt 70:30.

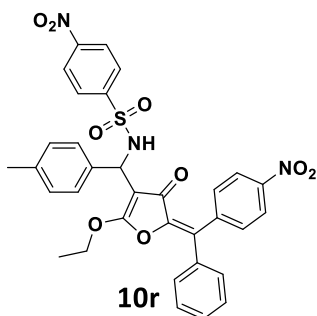
¹H NMR (400.13 MHz, CDCl₃): δ 8.04 (d, *J* = 8.7 Hz, 2H), 7.71 – 7.69 (m, 4H), 7.38 – 7.36 (m, 5H), 7.17 – 7.16 (m, 2H), 7.05 (d, *J* = 7.9 Hz, 2H), 6.92 – 6.90 (m, 3H), 5.35 (d, *J* = 7.4 Hz, 1H), 4.46 – 4.39 (m, 2H), 2.23 (s, 3H), 1.45 (t, *J* = 7.1 Hz, 3H).

¹³C NMR (100.62 MHz, CDCl₃): δ 181.0, 173.2, 149.5, 146.9, 141.7, 139.7, 138.1, 136.5, 135.8, 132.0, 131.4, 130.4, 130.2, 130.0, 129.3, 128.7, 128.4, 126.7, 123.5, 118.6, 113.2, 96.0, 68.1, 52.4, 21.1, 15.0.

IR (ν_{max}, cm⁻¹): 2229 (w), 1641 (w), 1593 (m), 1530 (m), 1426 (m), 1387 (w), 1348 (m), 1166 (m).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₄H₂₇N₃O₇SNa 644.1467; Found 644.1453.

Aspect: Yellow oil.



(E)-N-((2-Ethoxy-5-((4-nitrophenyl)(phenyl)methylene)-4-oxo-4,5-dihydrofuran-3-yl)(p-tolyl)methyl)-4-nitrobenzenesulfonamide was prepared according to general procedure B.

Yield: 49.0 mg, 76%, eluent: PE/AcOEt 70:30.

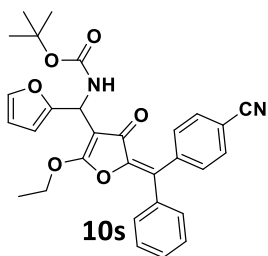
¹H NMR (400.13 MHz, CDCl₃): δ 8.27 (d, *J* = 8.8 Hz, 2H), 8.05 (d, *J* = 8.9 Hz, 2H), 7.70 (d, *J* = 8.9 Hz, 2H), 7.43 (d, *J* = 8.8 Hz, 2H), 7.39 – 7.35 (m, 3H), 7.20 – 7.17 (m, 2H), 7.05 (d, *J* = 8.0 Hz, 2H), 6.92 – 6.90 (m, 3H), 5.36 (d, *J* = 9.0 Hz, 1H), 4.51 – 4.38 (m, 2H), 2.23 (s, 3H), 1.47 (t, *J* = 7.2 Hz, 3H).

¹³C NMR (100.62 MHz, CDCl₃): δ 181.1, 173.3, 149.5, 148.3, 146.9, 141.7, 141.7, 138.1, 136.5, 135.7, 131.7, 130.4, 130.1, 129.7, 129.3, 128.7, 128.8, 126.7, 123.5, 123.5, 96.1, 68.2, 52.4, 21.1, 15.0.

IR (ν_{max}, cm⁻¹): 1643 (w), 1596 (m), 1522 (m), 1426 (m), 1388 (m), 1345 (s), 1165 (m), 1109 (m), 1096 (m).

HRMS: (ESI) m/z: [M + Na]⁺ Calcd for C₃₃H₂₇N₃O₉SNa 664.1366; Found 664.1373.

Aspect: Yellow oil.



tert-Butyl (E)-((5-((4-cyanophenyl)(phenyl)methylene)-2-ethoxy-4-oxo-4,5-dihydrofuran-3-yl)(furan-2-yl)methyl)carbamate was prepared according to general procedure B.

Yield: 48.4 mg, 94%, eluent: PE/AcOEt 80:20.

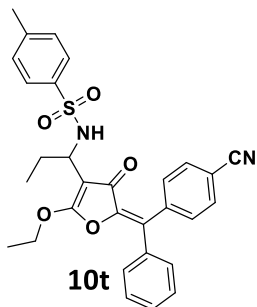
¹H NMR (400.13 MHz, CDCl₃): δ 7.67 (d, *J* = 7.9 Hz, 2H), 7.44 (d, *J* = 7.9 Hz, 2H), 7.39 – 7.38 (m, 3H), 7.30 – 7.28 (m, 3H), 6.26 (br s, 1H), 6.22 (d, *J* = 8.9 Hz, 1H), 6.17 (br s, 1H), 5.72 (d, *J* = 8.9 Hz, 1H), 4.50 (q, *J* = 7.1 Hz, 2H), 1.47 (t, *J* = 7.0 Hz, 3H), 1.41 (s, 9H).

¹³C NMR (100.62 MHz, CDCl₃): δ 181.5, 174.0, 155.3, 153.8, 142.2, 142.0, 140.1, 136.3, 131.9, 131.5, 130.5, 129.7, 128.9, 128.6, 118.8, 112.8, 110.4, 105.9, 94.7, 79.8, 67.7, 42.6, 28.5, 15.0.

IR (ν_{max}, cm⁻¹): 2229 (w), 1760 (m), 1707 (s), 1646 (m), 1600 (s), 1496 (m), 1429 (m), 1352 (s), 1252 (s), 1145 (s).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₀H₂₈N₂O₆Na; Found 535.1847.

Aspect: Brown oil.



(E)-N-(1-(5-((4-Cyanophenyl)(phenyl)methylene)-2-ethoxy-4-oxo-4,5-dihydrofuran-3-yl)propyl)-4-methylbenzenesulfonamide was prepared according to general procedure B.

Yield: 47.0 mg, 89%, eluent: PE/AcOEt 80:20.

¹H NMR (400.13 MHz, CDCl₃): δ 7.70 – 7.65 (m, 4H), 7.40 – 7.37 (m, 3H), 7.33 (d, *J* = 8.5 Hz, 2H), 7.21 (d, *J* = 7.9 Hz, 2H), 7.18 – 7.16 (m, 2H), 5.63 (d, *J* = 10.2 Hz, 1H), 4.38 – 4.25 (m, 2H), 4.01 (dt, *J* = 10.2, 7.5 Hz, 1H), 2.34 (s, 3H), 1.77 – 1.66 (m, 1H), 1.64 – 1.54 (m, 1H), 1.44 (t, *J* = 7.1 Hz, 3H), 0.84 (t, *J* = 7.3 Hz, 3H).

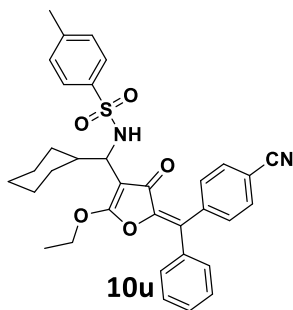
¹³C NMR (100.62 MHz, CDCl₃): δ 181.2, 173.5, 142.9, 141.7, 139.9, 138.4, 136.0, 131.9, 131.3, 130.4, 129.8, 129.1, 128.6, 128.4, 127.3, 118.7, 112.9, 95.4, 67.4, 49.7, 28.3, 21.7, 15.0, 10.6.

IR (ν_{max}, cm⁻¹): 2228 (w), 1642 (m), 1594 (s), 1423 (s), 1388 (m), 1343 (s), 1161 (s), 1085 (m).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₀H₂₈N₂O₅SNa 551.1617; Found 551.1624.

Aspect: Yellow pale solid.

Mp: 173 – 175 °C.



(E)-N-((5-((4-Cyanophenyl)(phenyl)methylene)-2-ethoxy-4-oxo-4,5-dihydrofuran-3-yl)(cyclohexyl)methyl)-4-methylbenzenesulfonamide was prepared according to general procedure B.

Yield: 56.5 mg, 97%, eluent: PE/AcOEt 80:20.

¹H NMR (400.13 MHz, CDCl₃): δ 7.69 (d, *J* = 8.4 Hz, 2H), 7.65 (d, *J* = 8.3 Hz, 2H), 7.39 – 7.36 (m, 3H), 7.33 (d, *J* = 8.3 Hz, 2H), 7.21 – 7.15 (m, 4H), 5.75 (d, *J* = 10.4 Hz, 1H), 4.35 – 4.20 (m, 2H), 3.81 (dd, *J* = 10.4, 8.1 Hz, 1H), 2.33 (s, 3H), 1.93 (d, *J* = 13.2, 1H), 1.67 – 1.54 (m, 6H), 1.43 (t, *J* = 7.1 Hz, 3H), 1.19 – 1.06 (m, 2H), 0.94 – 0.82 (m, 2H).

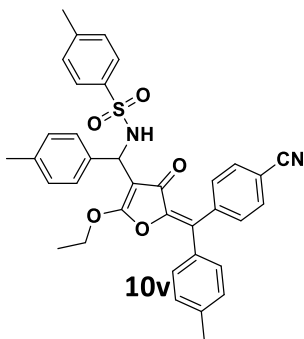
¹³C NMR (100.62 MHz, CDCl₃): δ 181.3, 173.9, 142.8, 141.7, 139.8, 138.4, 136.1, 131.9, 131.3, 130.4, 129.8, 129.0, 128.5, 128.3, 127.4, 118.7, 113.0, 94.6, 67.3, 53.4, 42.2, 29.7, 29.5, 26.3, 25.8, 25.9, 21.7, 15.1.

IR (ν_{max}, cm⁻¹): 2928 (m), 2852 (w), 2229 (w), 1644 (m), 1595 (s), 1420 (s), 1343 (s), 1160 (s), 1117 (m), 1097 (m).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₄H₃₄N₂O₅SNa 605.2086; Found 605.2103.

Aspect: Yellow pale solid.

Mp: 201 – 202 °C.



(E)-N-((5-((4-Cyanophenyl)(*p*-tolyl)methylene)-2-ethoxy-4-oxo-4,5-dihydrofuran-3-yl)(*p*-tolyl)methyl)-4-methylbenzenesulfonamide was prepared according to general procedure B.

Yield: 52.1 mg, 86%, eluent: PE/AcOEt 70:30.

¹H NMR (400.13 MHz, CDCl₃): δ 7.67 (d, *J* = 8.4 Hz, 2H), 7.57 (d, *J* = 8.3 Hz, 2H), 7.33 (d, *J* = 8.5 Hz, 2H), 7.18 (d, *J* = 8.0 Hz, 2H), 7.15 – 7.11 (m, 4H), 7.07 (d, *J* = 8.2 Hz, 2H), 7.00 (d, *J* = 7.9 Hz, 2H), 6.36 (d, *J* = 9.8 Hz, 1H), 5.29 (d, *J* = 9.8 Hz, 1H), 4.37 (q, *J* = 7.2 Hz, 2H), 2.38 (s, 3H), 2.33 (s, 3H), 2.27 (s, 3H), 1.45 (t, *J* = 7.2 Hz, 3H).

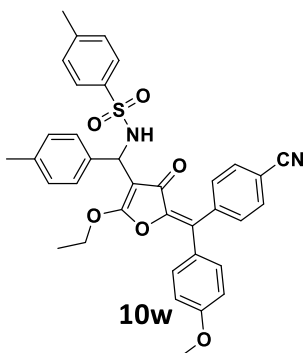
¹³C NMR (100.62 MHz, CDCl₃): δ 180.9, 173.2, 142.9, 141.6, 140.3, 140.0, 138.1, 137.4, 136.9, 133.1, 131.9, 131.4, 130.5, 129.4, 129.3, 129.2, 129.1, 127.3, 126.6, 118.7, 112.9, 96.1, 67.6, 51.5, 21.7, 21.5, 21.2, 15.1.

IR (ν_{max}, cm⁻¹): 2228 (w), 1641 (m), 1596 (s), 1426 (s), 1389 (m), 1345 (s), 1162 (s), 1102 (m).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₆H₃₂N₂O₅SNa 627.1930; Found 638.1933.

Aspect: Yellow pale solid.

Mp: 118 – 120 °C.



(Z)-N-((5-((4-Cyanophenyl)(4-methoxyphenyl)methylene)-2-ethoxy-4-oxo-4,5-dihydrofuran-3-yl)(*p*-tolyl)methyl)-4-methylbenzenesulfonamide was prepared according to general procedure B.

Yield: 53.3 mg, 86%, eluent: PE/AcOEt 70:30.

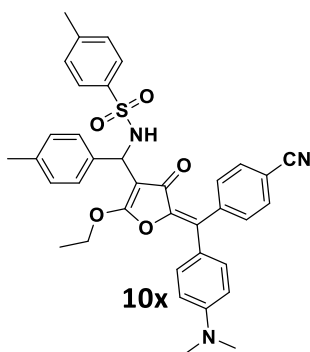
¹H NMR (400.13 MHz, CDCl₃): δ 7.68 (d, *J* = 8.2 Hz, 2H), 7.56 (d, *J* = 8.3 Hz, 2H), 7.32 (d, *J* = 8.2 Hz, 2H), 7.15 – 7.11 (m, 6H), 6.99 (d, *J* = 8.0 Hz, 2H), 6.88 (d, *J* = 8.9 Hz, 2H), 6.38 (d, *J* = 9.8 Hz, 1H), 5.29 (d, *J* = 9.8 Hz, 1H), 4.40 (q, *J* = 7.1 Hz, 2H), 3.84 (s, 3H), 2.32 (s, 3H), 2.26 (s, 3H), 1.47 (t, *J* = 7.2 Hz, 3H).

¹³C NMR (100.62 MHz, CDCl₃): δ 181.0, 173.0, 160.8, 142.8, 141.1, 140.2, 138.2, 137.4, 137.0, 132.3, 131.9, 131.4, 129.3, 129.1, 128.8, 128.1, 127.3, 126.6, 118.7, 114.1, 112.9, 96.1, 67.5, 55.6, 51.5, 21.7, 21.2, 15.1.

IR (ν_{max}, cm⁻¹): 2228 (w), 1639 (m), 1590 (s), 1512 (m), 1422 (s), 1386 (m), 1344 (s), 1257 (s), 1161 (s), 1103 (s).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₆H₃₂N₂O₆Na 643.1879; Found 643.1876.

Aspect: Yellow oil.



(Z)-N-((5-((4-Cyanophenyl)(4-(dimethylamino)phenyl)methylene)-2-ethoxy-4-oxo-4,5-dihydrofuran-3-yl)(*p*-tolyl)methyl)-4-methylbenzenesulfonamide was prepared according to general procedure B.

Yield: 40.3 mg, 64%, eluent: PE/AcOEt 60:40.

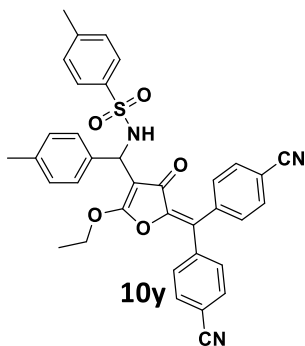
¹H NMR (400.13 MHz, CDCl₃): δ 7.69 (d, *J* = 8.4 Hz, 2H), 7.56 (d, *J* = 8.3 Hz, 2H), 7.31 (d, *J* = 8.4 Hz, 2H), 7.15 – 7.09 (m, 6H), 6.98 (d, *J* = 8.0 Hz, 2H), 6.62 (d, *J* = 9.2 Hz, 2H), 6.46 (d, *J* = 9.9 Hz, 1H), 5.29 (d, *J* = 9.8 Hz, 1H), 4.43 (q, *J* = 7.1 Hz, 2H), 3.03 (s, 6H), 2.31 (s, 3H), 2.26 (s, 3H), 1.48 (t, *J* = 7.1 Hz, 3H).

¹³C NMR (100.62 MHz, CDCl₃): δ 181.0, 172.3, 151.0, 142.8, 140.8, 139.9, 138.2, 137.3, 137.2, 132.4, 131.9, 131.4, 129.6, 129.2, 129.0, 127.3, 126.7, 122.5, 118.9, 112.6, 111.4, 95.8, 67.2, 51.6, 40.1, 21.7, 21.2, 15.1.

IR (ν_{max}, cm⁻¹): 2921 (w), 2230 (w), 1635 (m), 1575 (s), 1527 (m), 1421 (m), 1342 (s), 1160 (s), 1110 (s), 1046 (m).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₇H₃₅N₃O₅Na 656.2195; Found 656.2206.

Aspect: Orange oil.



***N*-((5-(Bis(4-Cyanophenyl)methylene)-2-ethoxy-4-oxo-4,5-dihydrofuran-3-yl)(*p*-tolyl)methyl)-4-methylbenzenesulfonamide** was prepared according to general procedure B.

Yield: 26.2 mg, 43%, eluent: PE/AcOEt 70:30.

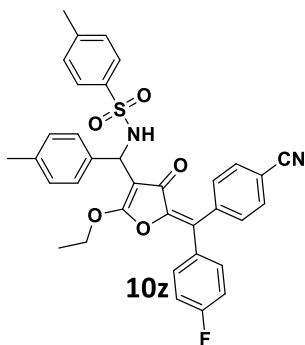
¹H NMR (400.13 MHz, CDCl₃): δ 7.71 – 7.67 (m, 4H), 7.56 (d, *J* = 8.3 Hz, 2H), 7.34 – 7.31 (m, 4H), 7.13 – 7.08 (m, 4H), 6.98 (d, *J* = 7.9 Hz, 2H), 6.23 (d, *J* = 9.7 Hz, 1H), 5.29 (d, *J* = 9.7 Hz, 1H), 4.38 (q, *J* = 7.2 Hz, 2H), 2.33 (s, 3H), 2.26 (s, 3H), 1.46 (t, *J* = 7.1 Hz, 3H).

¹³C NMR (100.62 MHz, CDCl₃): δ 180.6, 173.5, 142.9, 142.6, 140.6, 138.5, 138.1, 137.7, 136.6, 132.4, 132.2, 131.3, 130.9, 129.4, 129.1, 127.3, 126.6, 118.4, 118.1, 113.6, 113.4, 96.8, 68.1, 51.3, 21.7, 21.2, 15.0.

IR (ν_{max}, cm⁻¹): 2230 (w), 1646 (m), 1597 (s), 1424 (s), 1387 (m), 1346 (s), 1161 (s), 1098 (s).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₆H₂₉N₃O₅SNa 638.1726; Found 638.1735.

Aspect: Yellow oil.



(*Z*)-*N*-((5-((4-Cyanophenyl)(4-fluorophenyl)methylene)-2-ethoxy-4-oxo-4,5-dihydrofuran-3-yl)(*p*-tolyl)methyl)-4-methylbenzenesulfonamide was prepared according to general procedure B.

Yield: 35.6 mg, 59%, eluent: PE/AcOEt 70:30.

¹H NMR (400.13 MHz, CDCl₃): δ 7.69 (d, *J* = 8.5 Hz, 2H), 7.56 (d, *J* = 8.2 Hz, 2H), 7.33 (d, *J* = 8.5 Hz, 2H), 7.21 – 7.16 (m, 2H), 7.13 – 7.05 (m, 6H), 6.99 (d, *J* = 8.0 Hz, 2H), 6.32 (d, *J* = 9.8 Hz, 1H), 5.29 (d, *J* = 9.8 Hz, 1H), 4.37 (q, *J* = 7.1 Hz, 2H), 2.32 (s, 3H), 2.26 (s, 3H), 1.46 (t, *J* = 7.1 Hz, 3H).

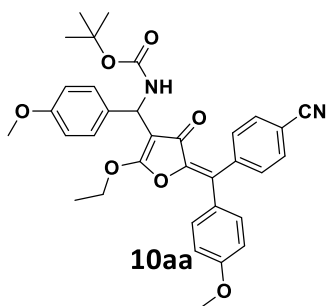
¹³C NMR (100.62 MHz, CDCl₃): δ 180.8, 173.3, 163.3 (d, *J* = 250.8 Hz), 142.9, 141.8, 139.6, 138.2, 137.5, 136.8, 132.5 (d, *J* = 8.4 Hz), 132.1 (d, *J* = 3.3 Hz), 132.0, 131.4, 129.3, 129.1, 127.9, 127.3, 126.6, 118.6, 115.9 (d, *J* = 21.7 Hz), 113.2, 96.3, 67.7, 51.4, 21.6, 21.2, 15.0.

IR (ν_{max}, cm⁻¹): 2228 (w), 1641 (w), 1594 (s), 1507 (m), 1424 (m), 1387 (m), 1348 (m), 1236 (m), 1161 (s), 1095 (m).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₅H₂₉FN₂O₅Na 631.1679; Found 631.1695.

Aspect: Yellow pale solid.

Mp: 186 – 188 °C.



tert-Butyl (Z)-((5-((4-cyanophenyl)(4-methoxyphenyl)methylene)-2-ethoxy-4-oxo-4,5-dihydrofuran-3-yl)(4-methoxyphenyl)methyl)carbamate was prepared according to general procedure B.

Yield: 40.9 mg, 70%, eluent: PE/AcOEt 70:30.

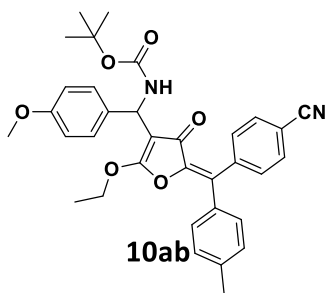
¹H NMR (400.13 MHz, CDCl₃): 7.69 (d, *J* = 8.0 Hz, 2H), 7.41 (d, *J* = 7.9 Hz, 2H), 7.30 (d, *J* = 8.2 Hz, 2H), 7.23 (d, *J* = 8.7 Hz, 2H), 6.88 (d, *J* = 8.8 Hz, 2H), 6.81 (d, *J* = 8.5 Hz, 2H), 6.53 (d, *J* = 8.5 Hz, 1H), 5.56 (d, *J* = 8.7 Hz, 1H), 4.52 – 4.47 (m, 2H), 3.83 (s, 3H), 3.77 (s, 3H), 1.48 (t, *J* = 7.2 Hz, 3H), 1.38 (s, 9H).

¹³C NMR (100.62 MHz, CDCl₃): δ 181.7, 173.4, 160.7, 158.8, 155.4, 141.5, 140.6, 135.1, 132.3, 131.9, 131.5, 128.5, 128.4, 127.5, 118.8, 114.1, 114.0, 112.7, 97.3, 79.4, 67.4, 55.5, 55.4, 48.0, 28.6, 15.0.

IR (ν_{max}, cm⁻¹): 2228 (w), 1709 (s), 1641 (m), 1592 (s), 1504 (s), 1425 (s), 1390 (m), 1348 (s), 1251 (s), 1168 (s), 1098 (s).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₄H₃₄N₂O₇Na 605.2264; Found 664.2278.

Aspect: Yellow oil.



tert-Butyl (E)-((5-((4-cyanophenyl)(p-tolyl)methylene)-2-ethoxy-4-oxo-4,5-dihydrofuran-3-yl)(4-methoxyphenyl)methyl)carbamate was prepared according to general procedure B.

Yield: 49.6 mg, 87%, eluent: PE/AcOEt 70:30.

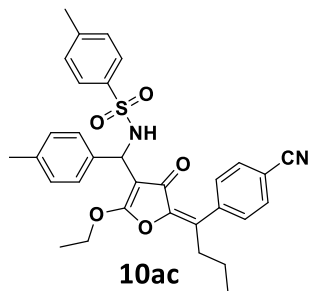
¹H NMR (400.13 MHz, CDCl₃): δ 7.68 (d, *J* = 8.4 Hz, 2H), 7.42 (d, *J* = 8.3 Hz, 2H), 7.30 (d, *J* = 8.5 Hz, 2H), 7.19 – 7.14 (m, 4H), 6.82 (d, *J* = 8.8 Hz, 2H), 6.52 (d, *J* = 8.9 Hz, 1H), 5.56 (d, *J* = 9.0 Hz, 1H), 4.51 – 4.44 (m, 2H), 3.77 (s, 3H), 2.38 (s, 3H), 1.47 (t, *J* = 7.2 Hz, 3H), 1.38 (s, 9H).

¹³C NMR (100.62 MHz, CDCl₃): δ 181.6, 173.6, 158.8, 155.4, 142.0, 140.5, 140.1, 135.1, 133.4, 131.9, 131.5, 130.6, 129.3, 128.9, 127.5, 118.8, 114.0, 112.7, 97.4, 79.4, 67.5, 55.4, 48.0, 28.6, 21.5, 15.0.

IR (ν_{max}, cm⁻¹): 2228 (w), 1710 (m), 1642 (m), 1596 (s), 1497 (s), 1427 (m), 1387 (m), 1346 (m), 1313 (m), 1245 (m), 1166 (s), 1097 (m).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₄H₃₄N₂O₆Na 589.2315; Found 589.2330.

Aspect: Yellow oil.



(E)-N-((5-(1-(4-Cyanophenyl)butylidene)-2-ethoxy-4-oxo-4,5-dihydrofuran-3-yl)(p-tolyl)methyl)-4-methylbenzenesulfonamide was prepared according to general procedure B.

Yield: 38.4 mg, 69%, eluent: PE/AcOEt 70:30.

¹H NMR (400.13 MHz, CDCl₃): δ 7.67 (d, *J* = 8.4 Hz, 2H), 7.55 (d, *J* = 8.3 Hz, 2H), 7.34 (d, *J* = 8.4 Hz, 2H), 7.12 – 7.08 (m, 4H), 6.97 (d, *J* = 8.0 Hz, 2H), 6.38 (d, *J* = 9.8 Hz, 1H), 5.25 (d, *J* = 9.7 Hz, 1H), 4.45 (q, *J* = 7.2 Hz, 2H), 2.59 – 2.47 (m, 2H), 2.36 (s, 3H), 2.25 (s, 3H), 1.49 (t, *J* = 7.1 Hz, 3H), 1.38 – 1.30 (m, 2H), 0.89 (t, *J* = 7.3 Hz, 3H).

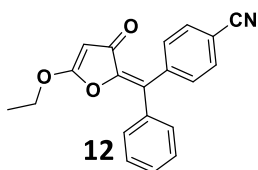
¹³C NMR (100.62 MHz, CDCl₃): δ 180.1, 172.7, 143.0, 142.8, 139.7, 138.1, 137.4, 137.1, 132.0, 131.3, 129.6, 129.2, 129.0, 127.3, 126.6, 118.7, 112.7, 96.2, 67.3, 51.5, 34.9, 21.6, 21.1, 20.7, 15.0, 13.9.

IR (ν_{max}, cm⁻¹): 2227 (w), 1597 (s), 1388 (m), 1345 (s), 1161 (s), 1091 (s).

HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₃₂H₃₂N₂O₅Na 579.1930; Found 579.1936.

Aspect: Pale yellow solid.

Mp: 132 – 134 °C.



(E)-4-((5-Ethoxy-3-oxofuran-2(3H)-ylidene)(phenyl)methyl)benzonitrile

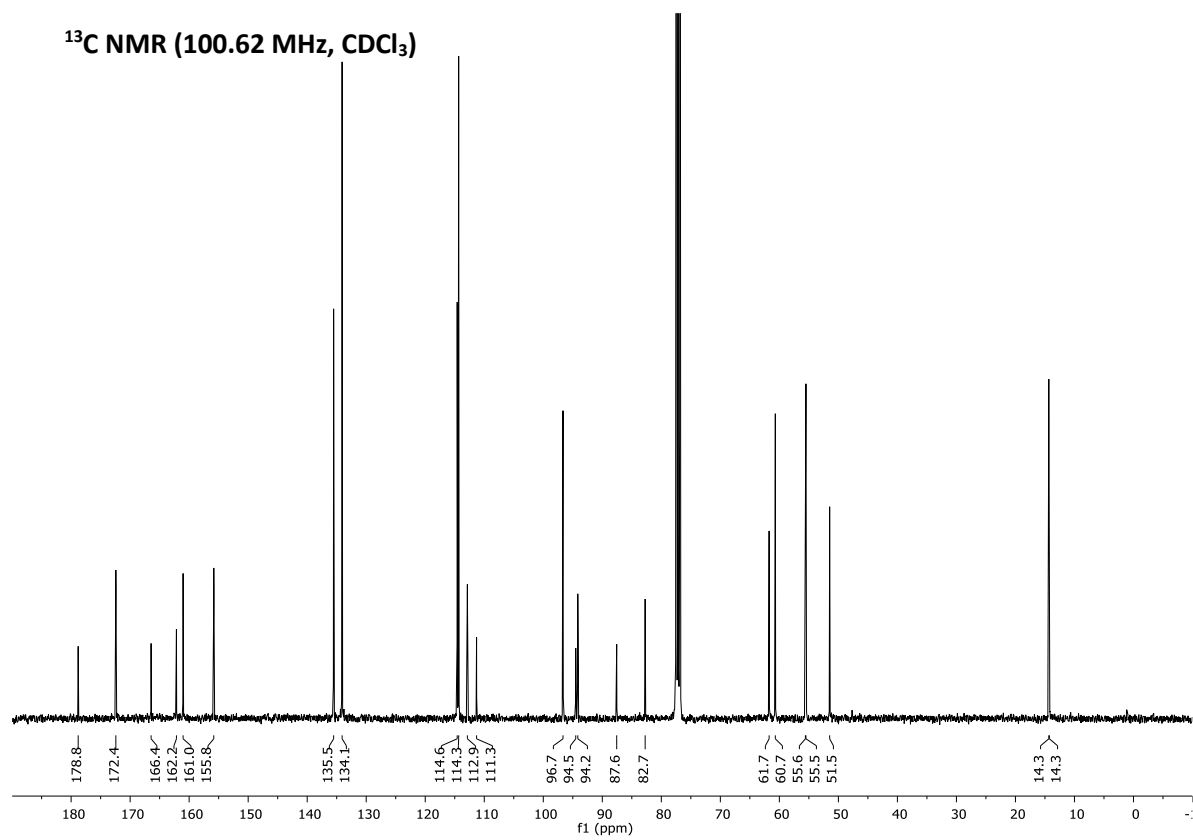
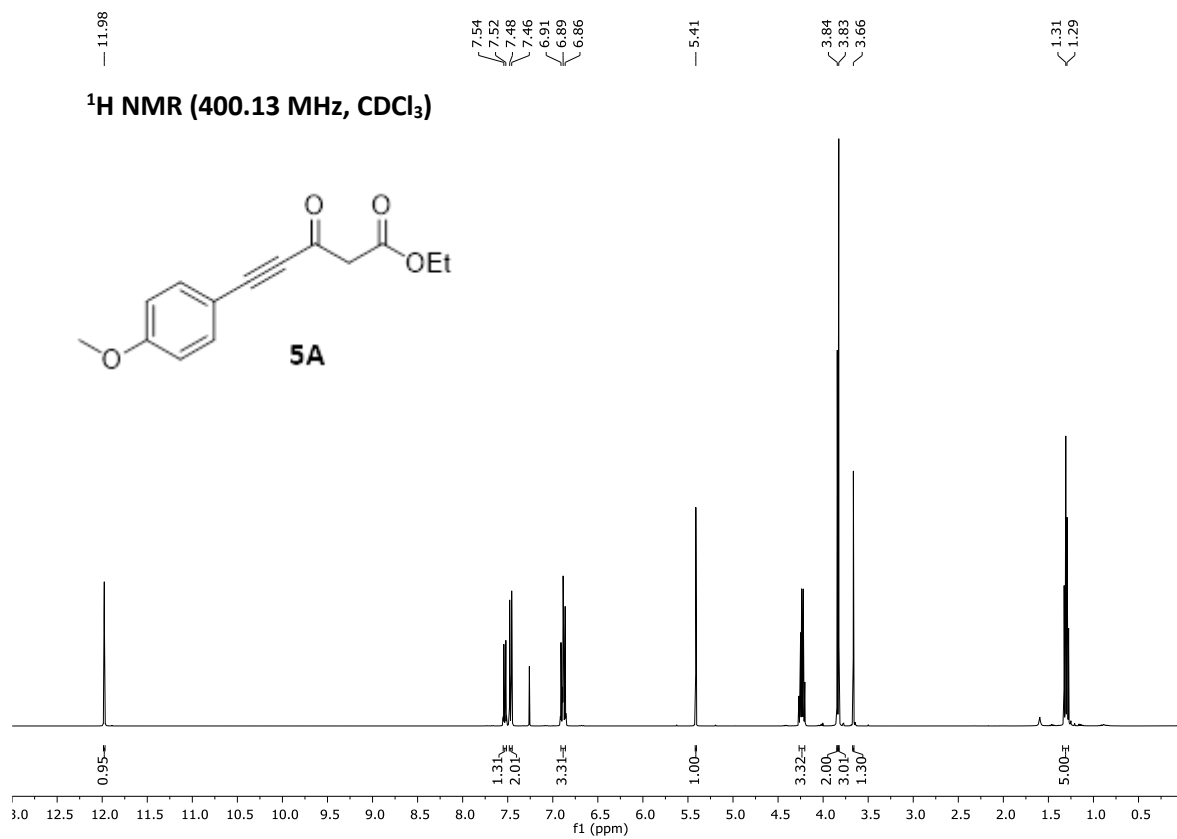
Yield: 10.7 mg, 34%, eluent: PE/AcOEt 70:30.

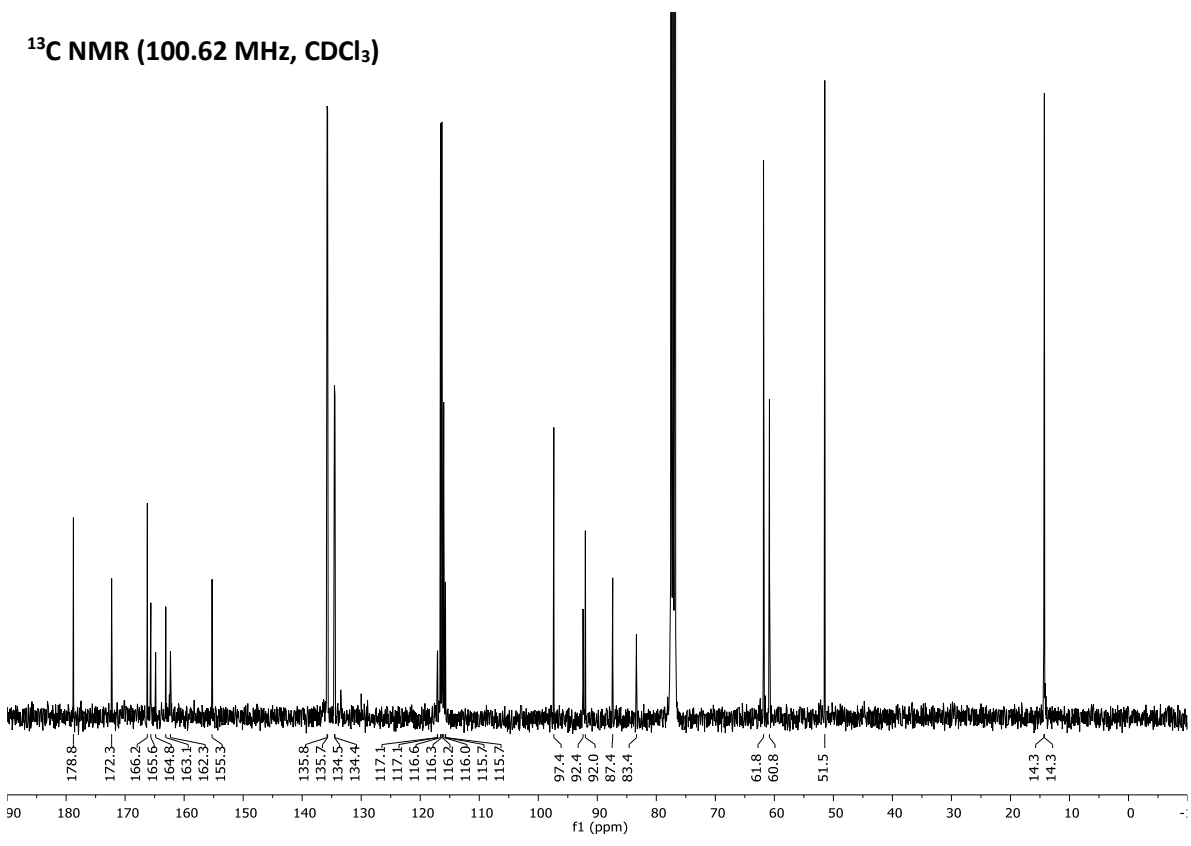
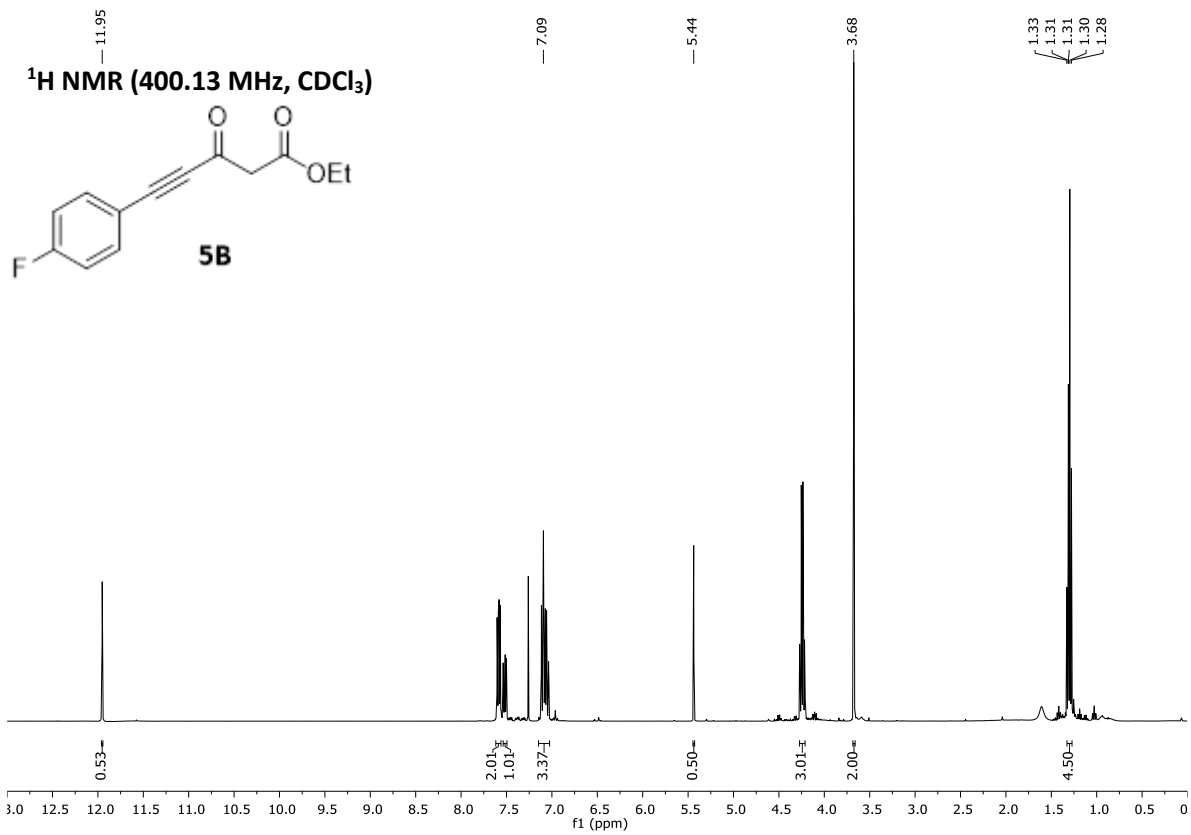
¹H NMR (400.13 MHz, CDCl₃): δ 7.66 (d, *J* = 8.2 Hz, 2H), 7.42 (d, *J* = 8.3 Hz, 2H), 7.40 – 7.35 (m, 3H), 7.35 – 7.30 (m, 2H), 4.98 (s, 1H), 4.29 (q, *J* = 7.1 Hz, 2H), 1.49 (t, *J* = 7.1 Hz, 3H).

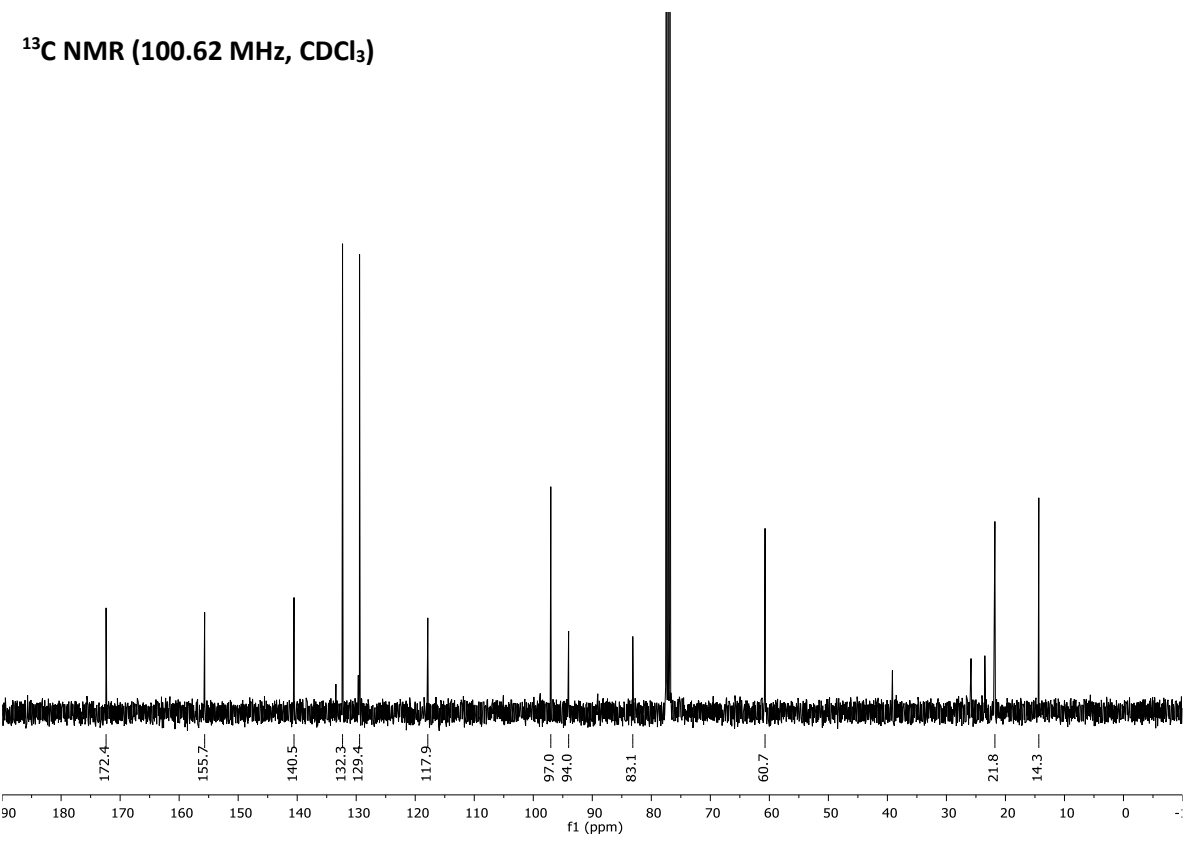
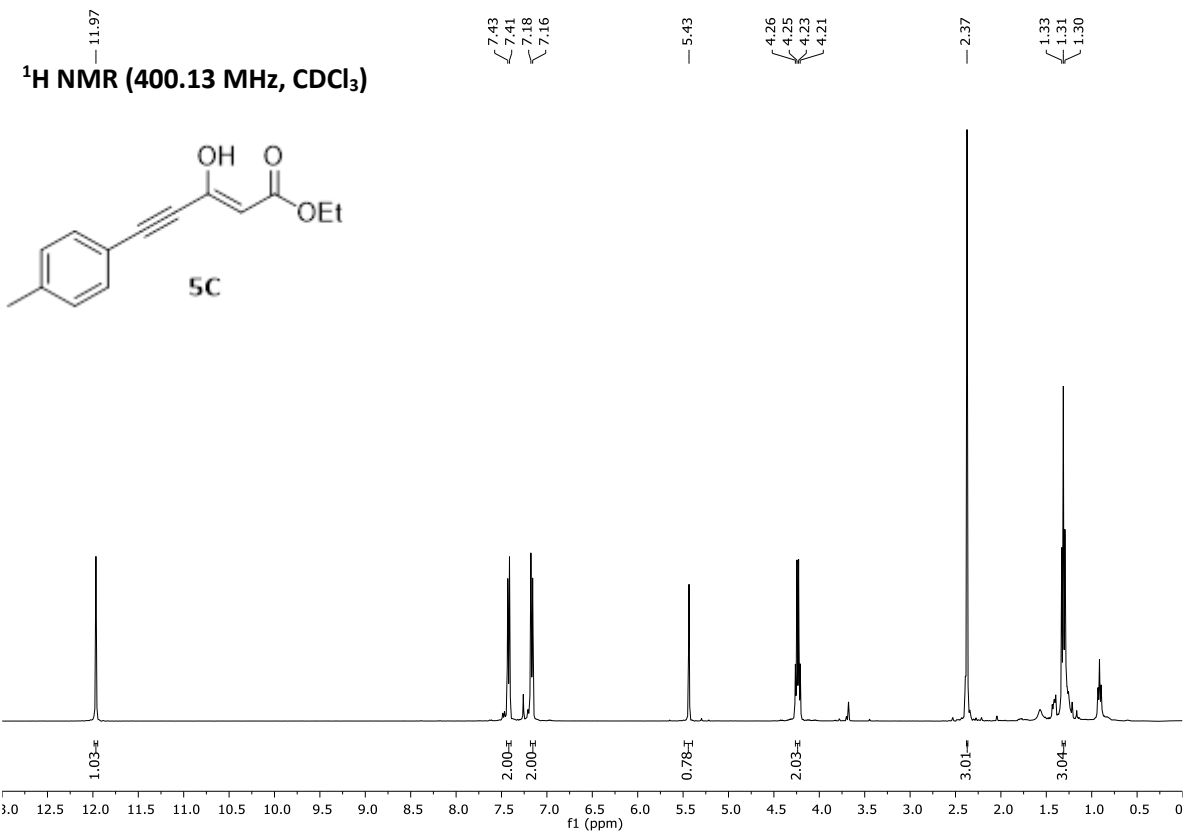
¹³C NMR (100.62 MHz, CDCl₃): δ 183.2, 179.5, 142.7, 140.7, 136.3, 131.9, 131.5, 130.7, 129.5, 128.6, 127.8, 118.9, 112.4, 82.4, 68.5, 14.3.

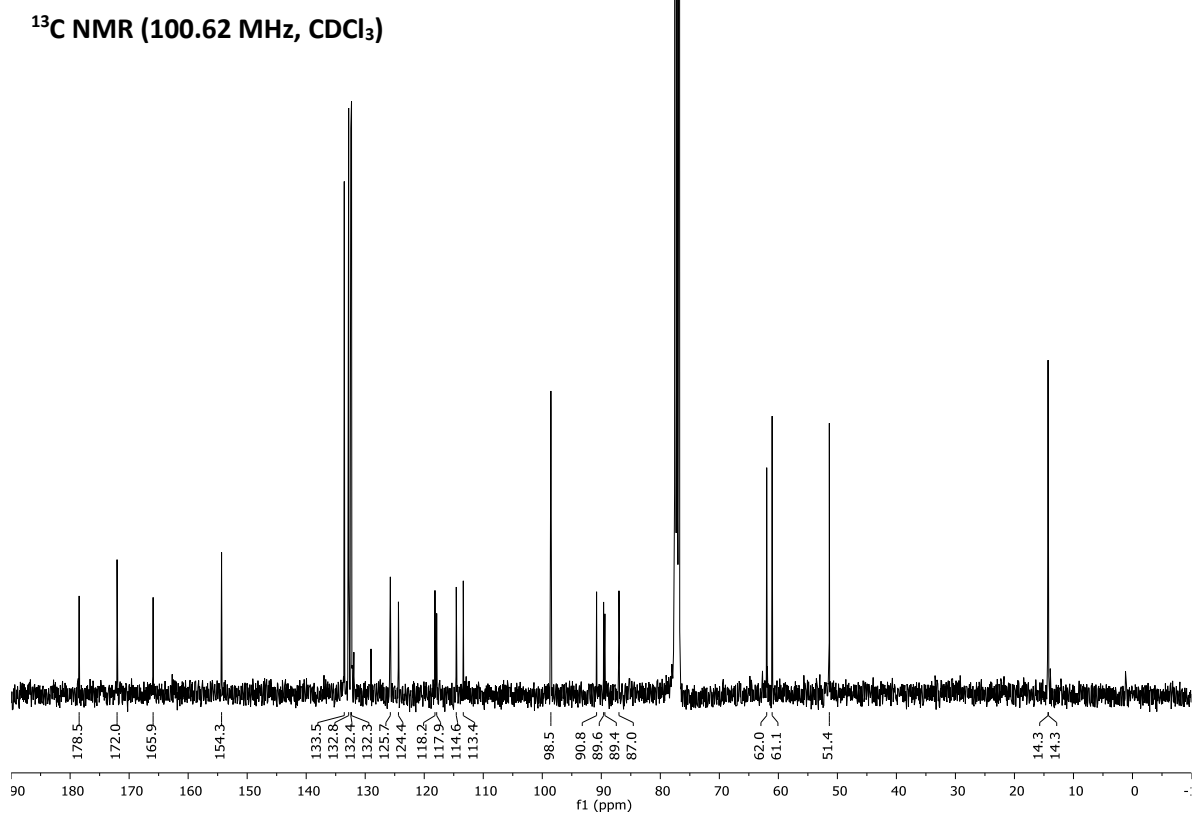
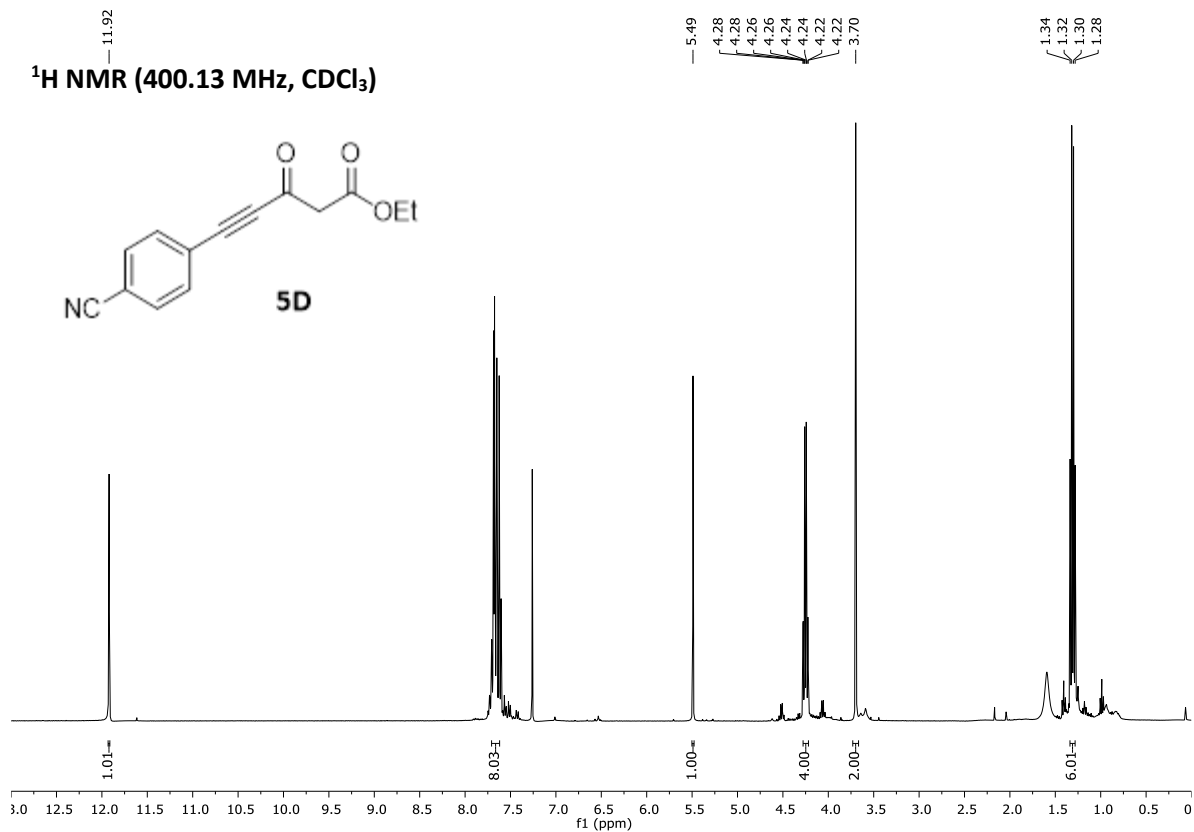
HRMS (ESI) m/z: [M + Na]⁺ Calcd for C₂₀H₁₅NO₃Na 340.0949; Found 340.0946.

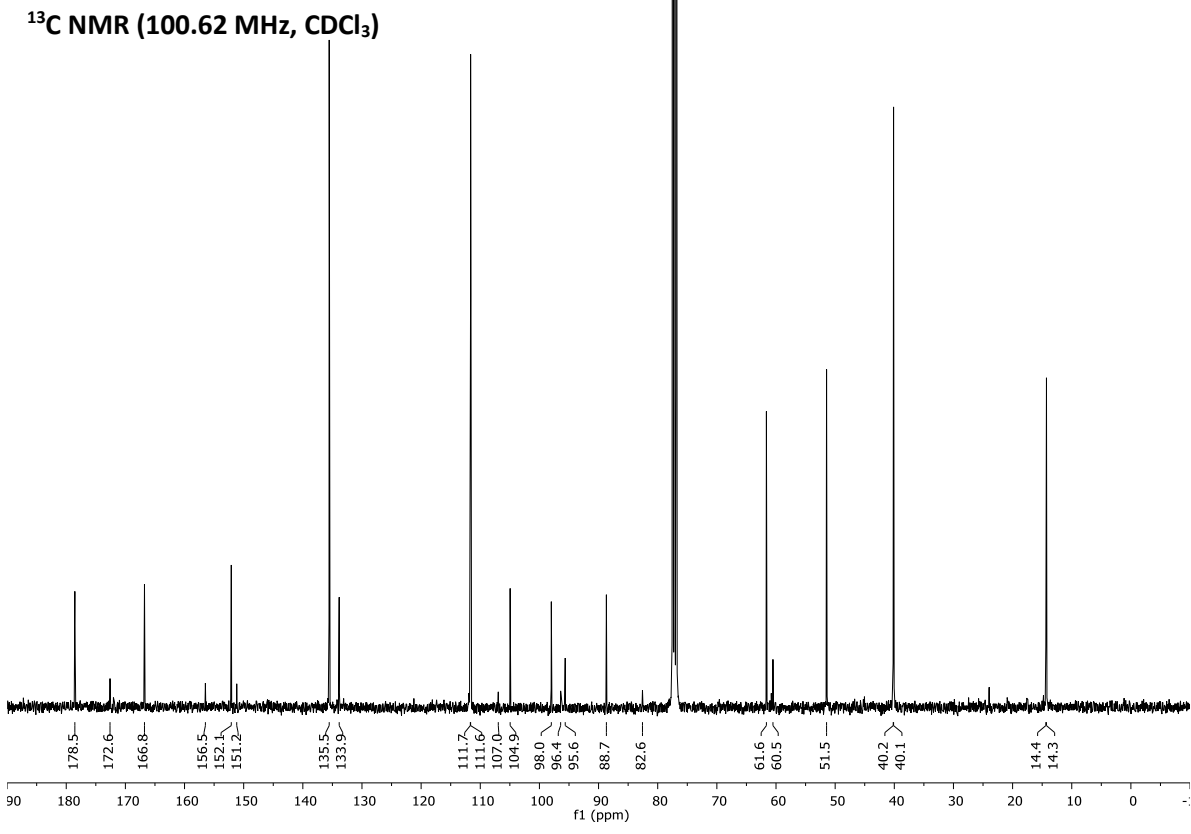
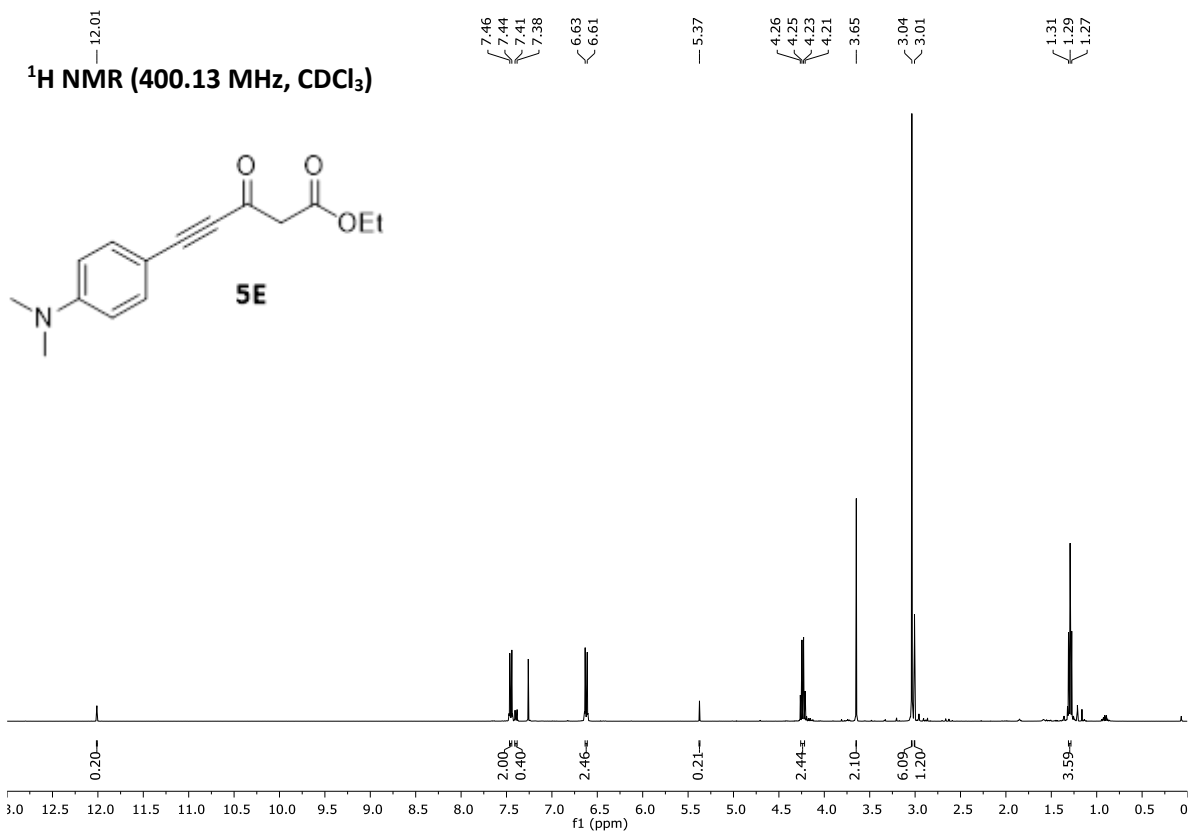
Aspect: Pale yellow amorphous solid.



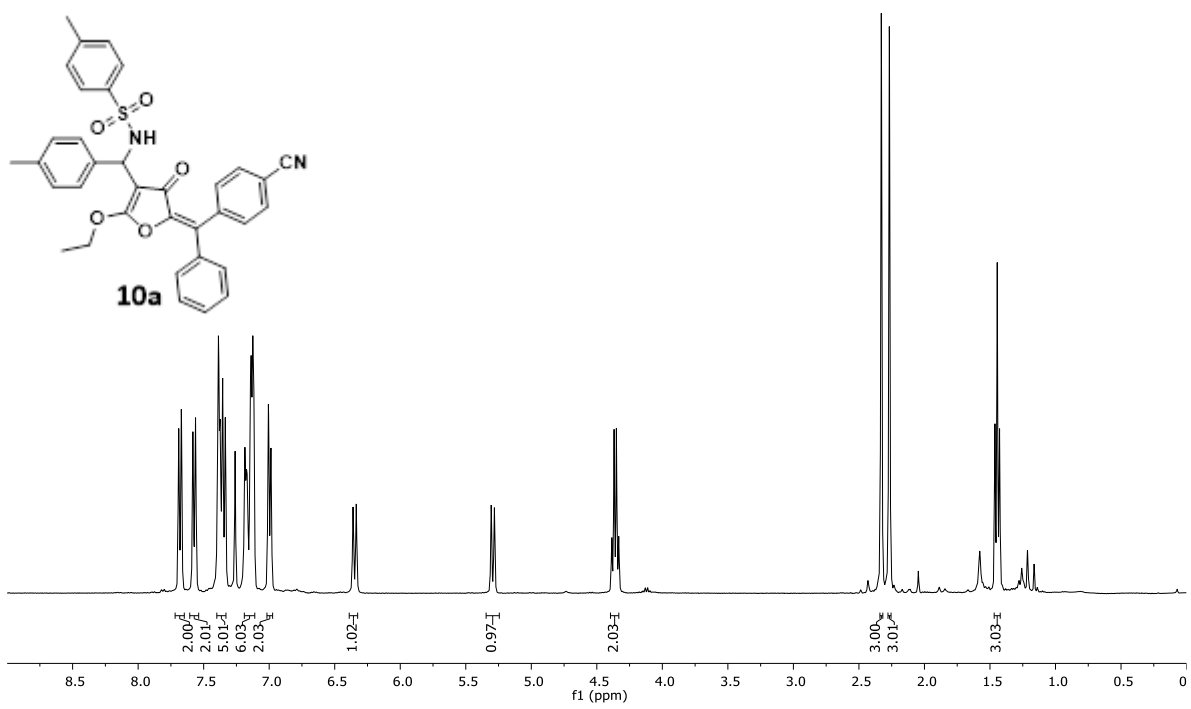




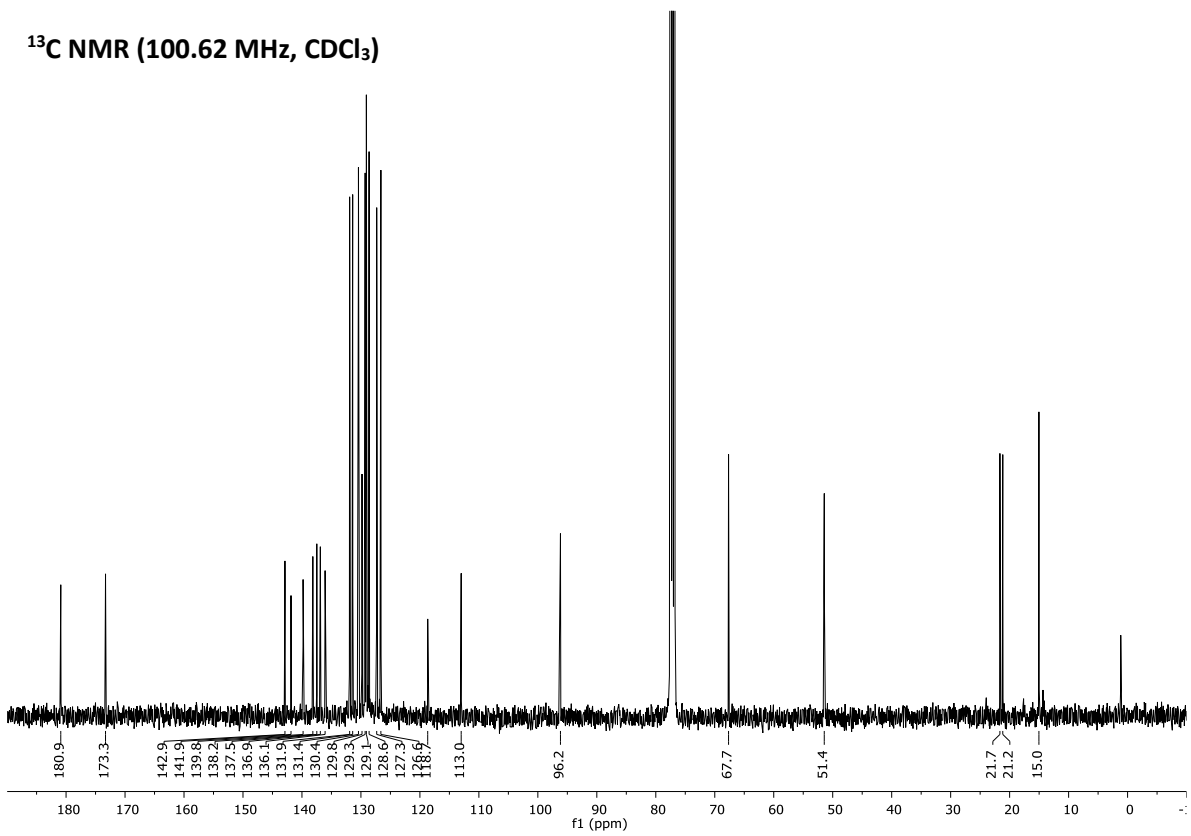


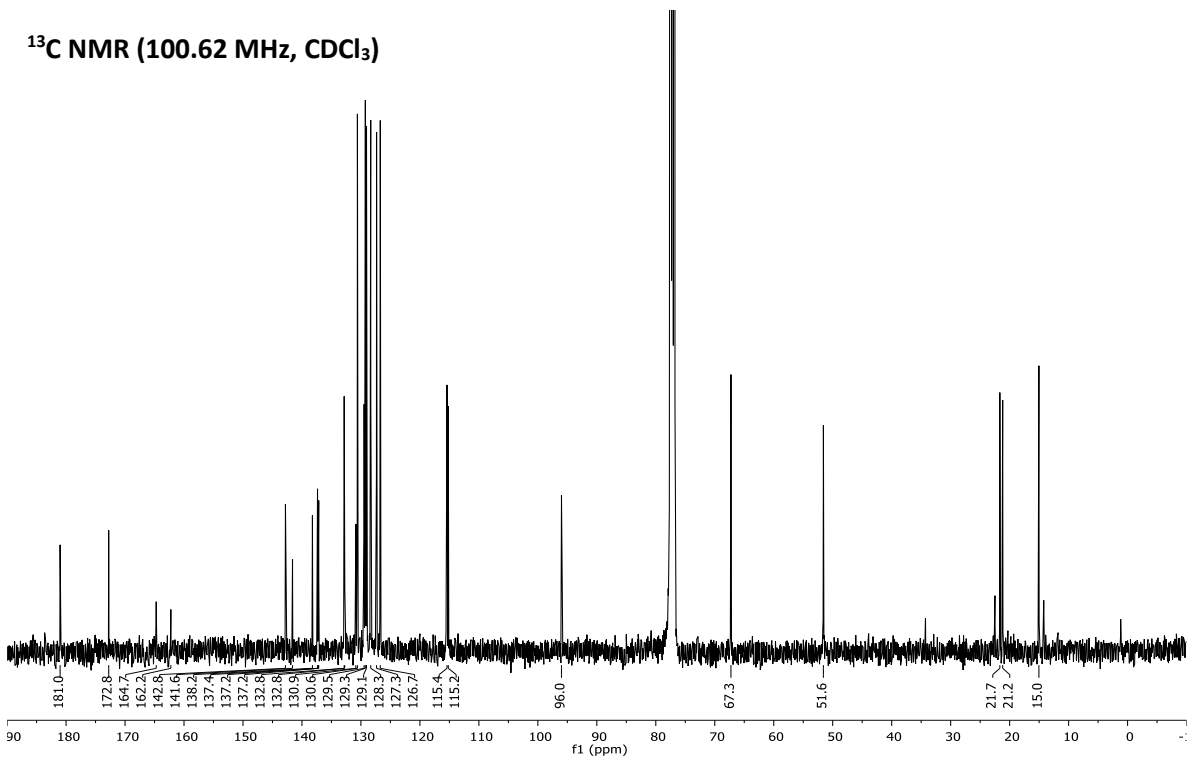
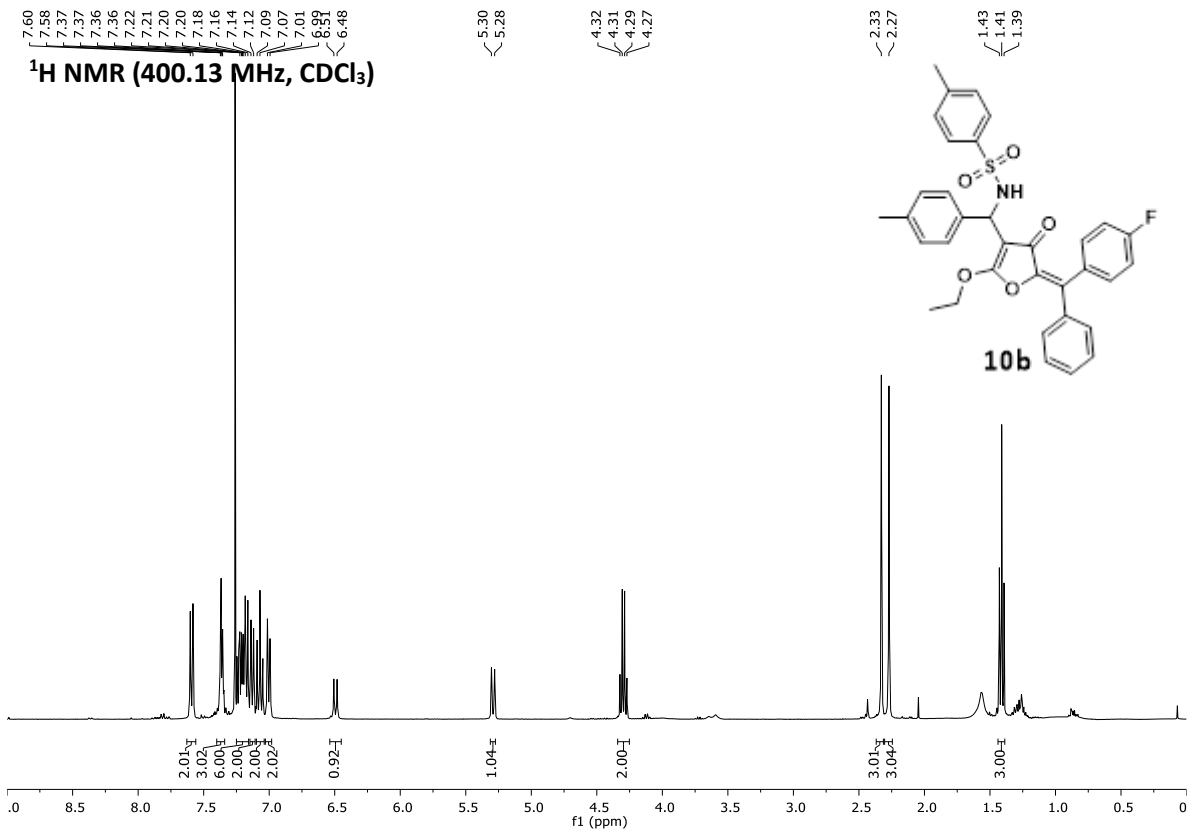


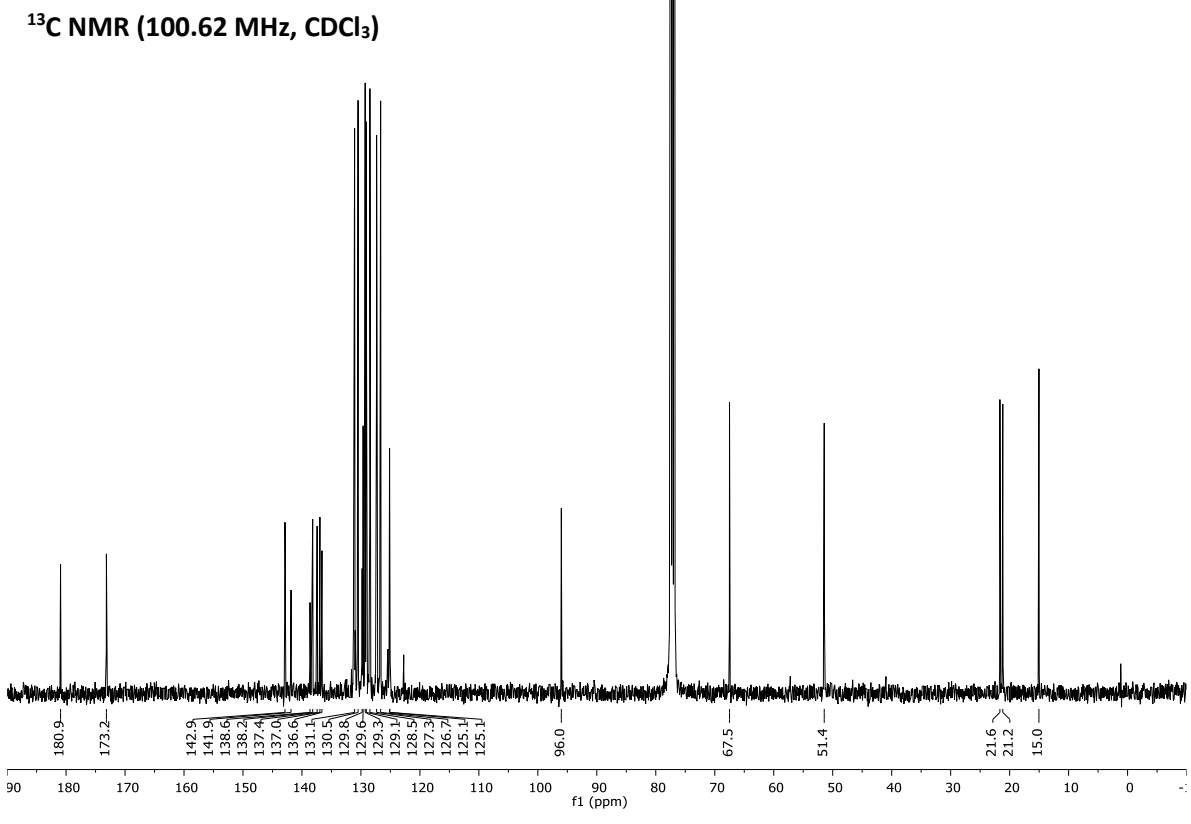
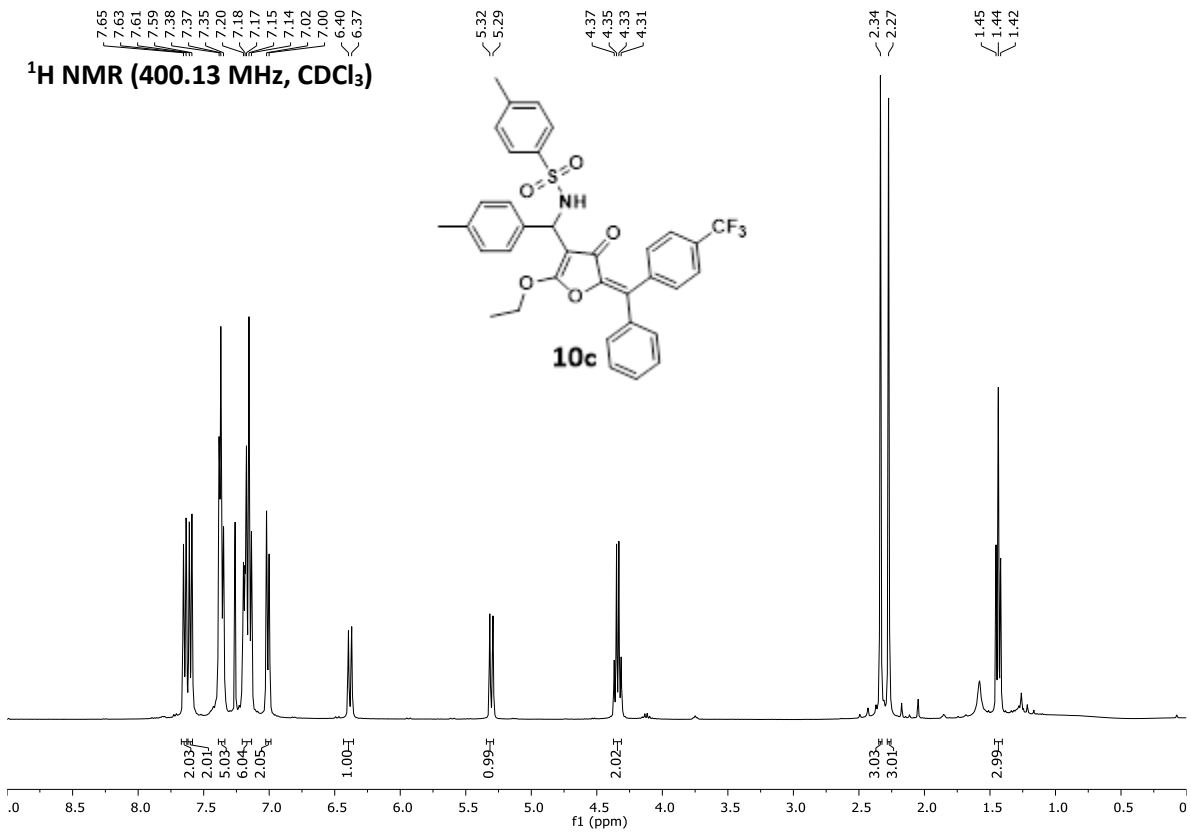
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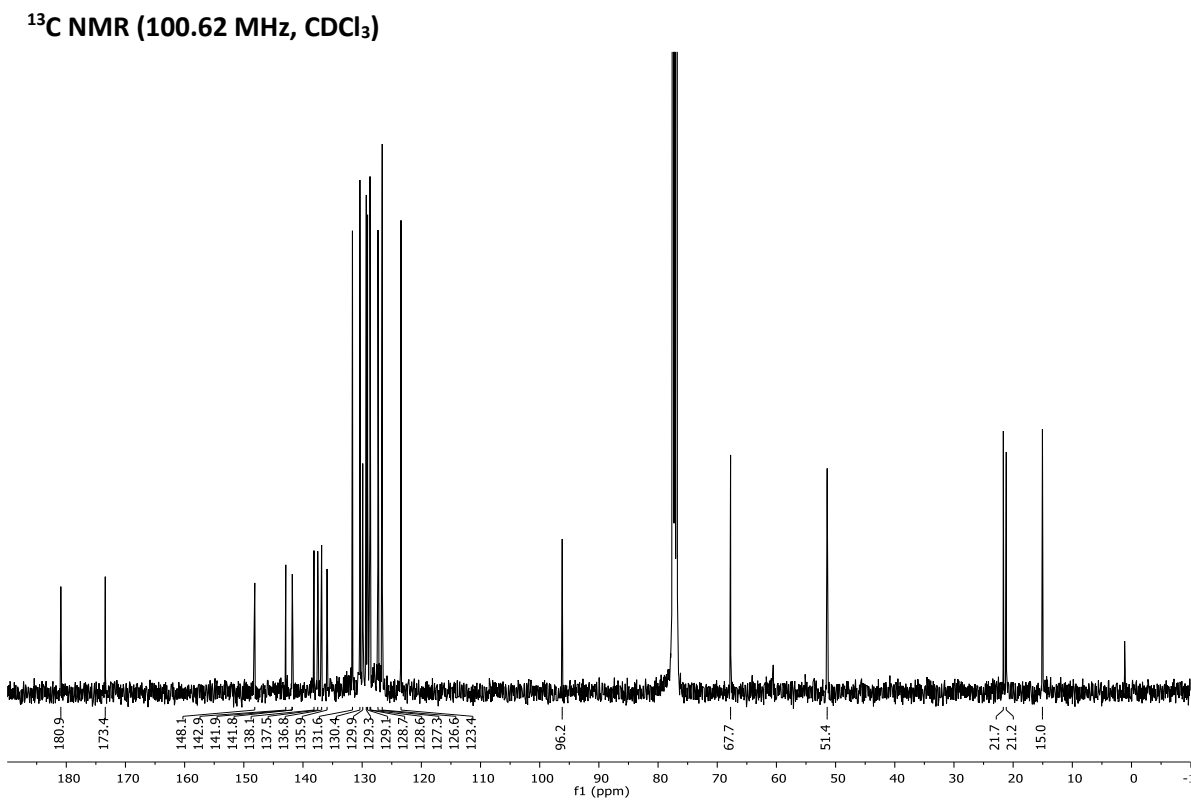
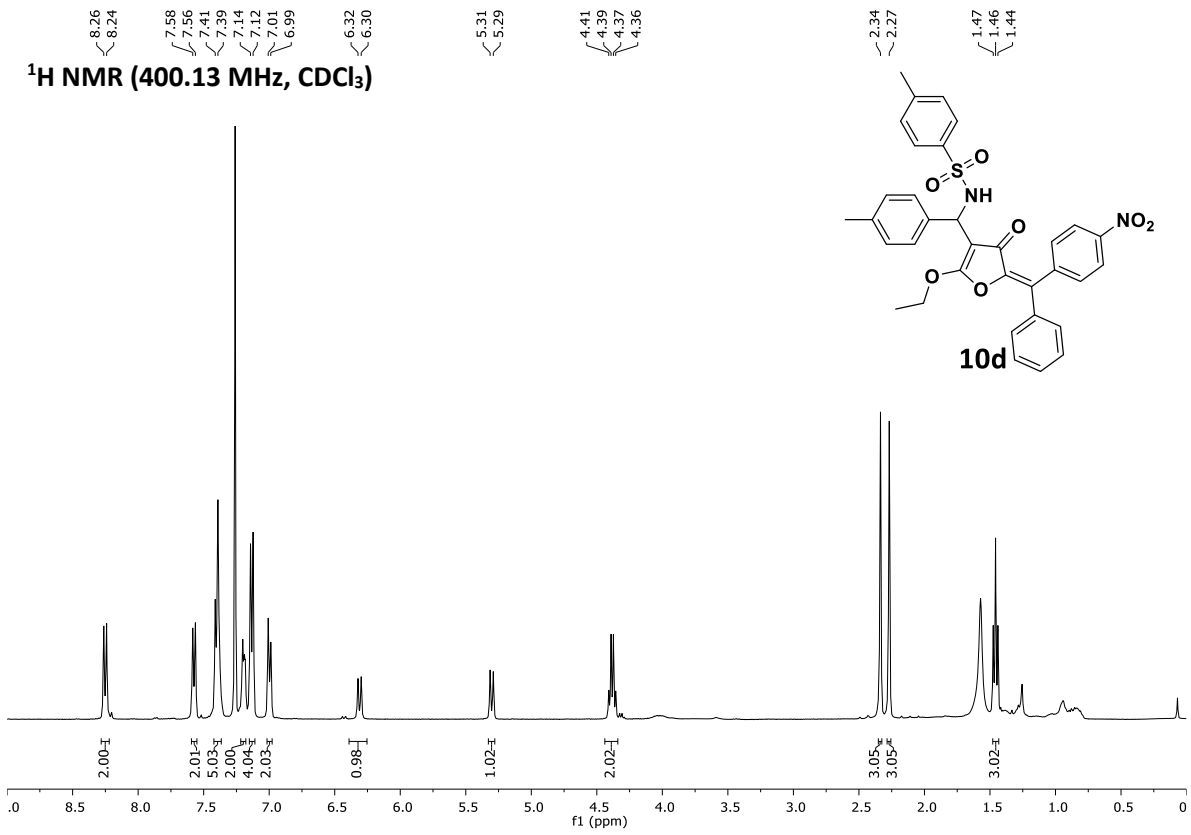


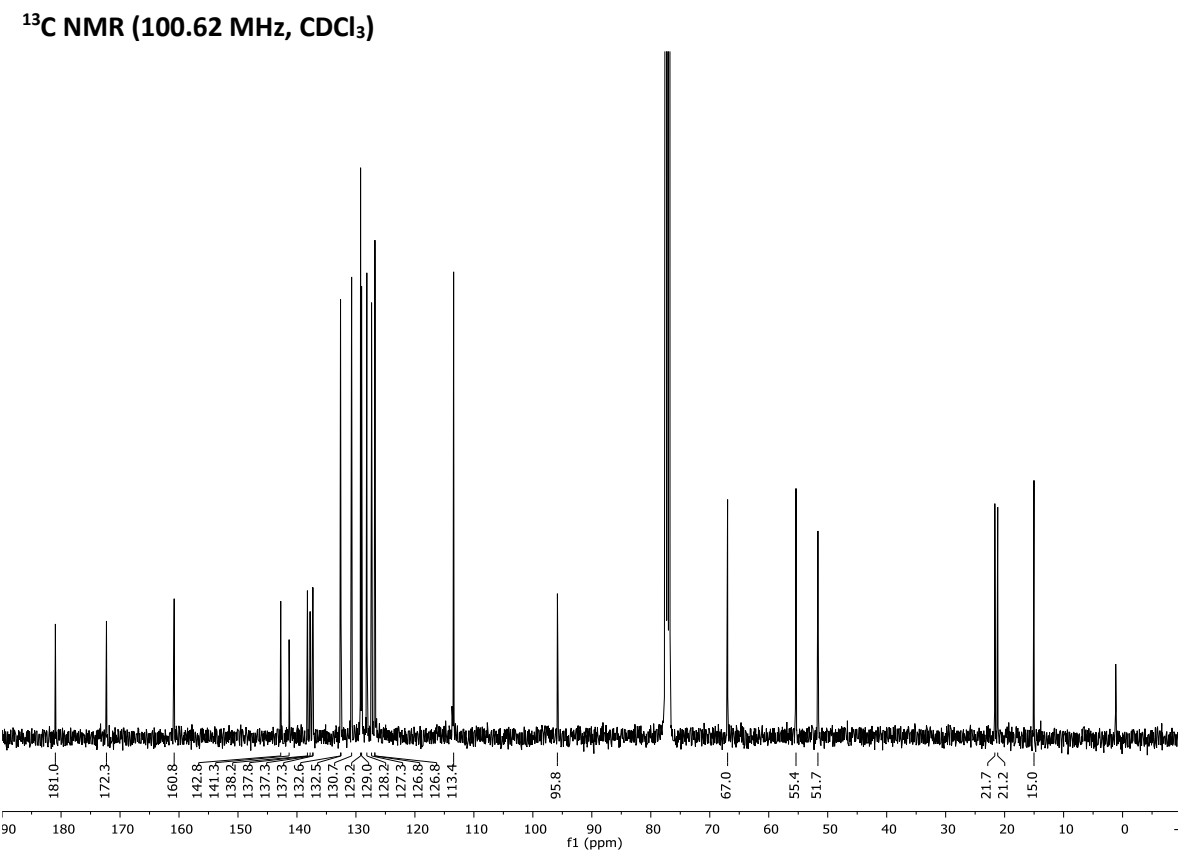
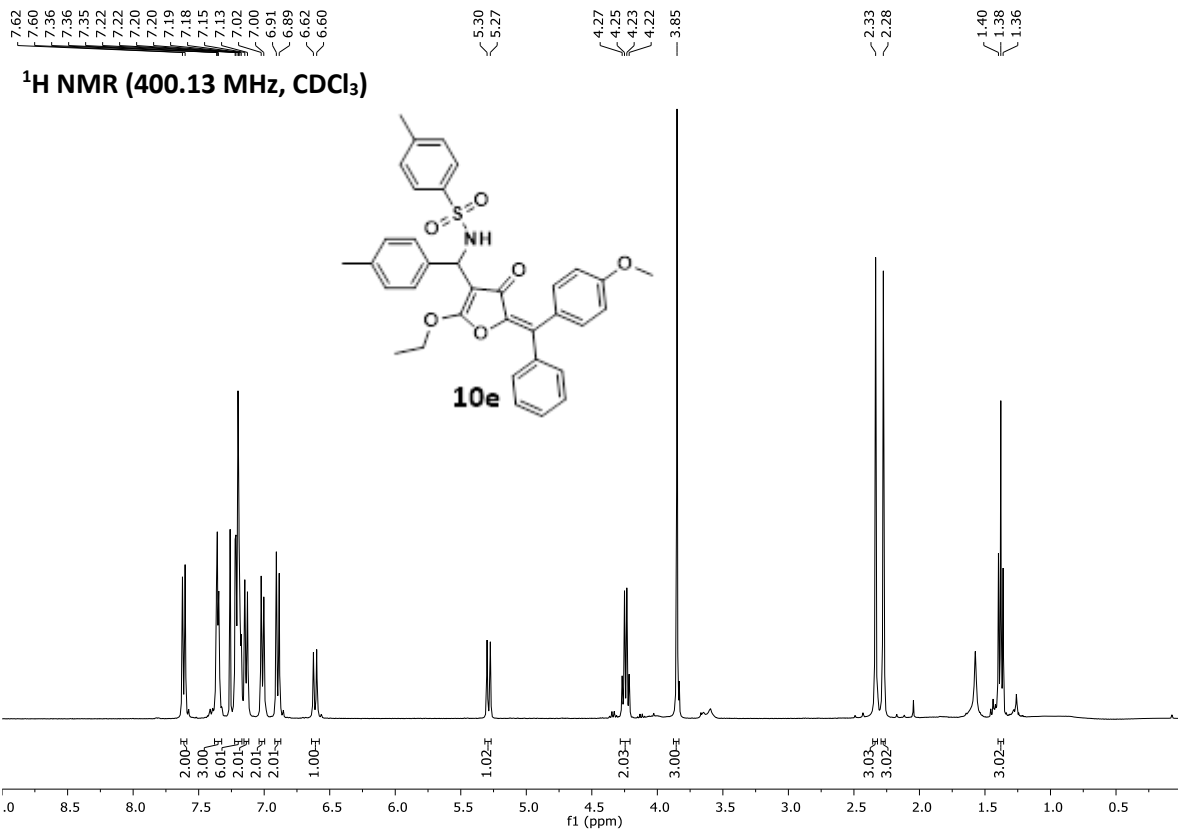
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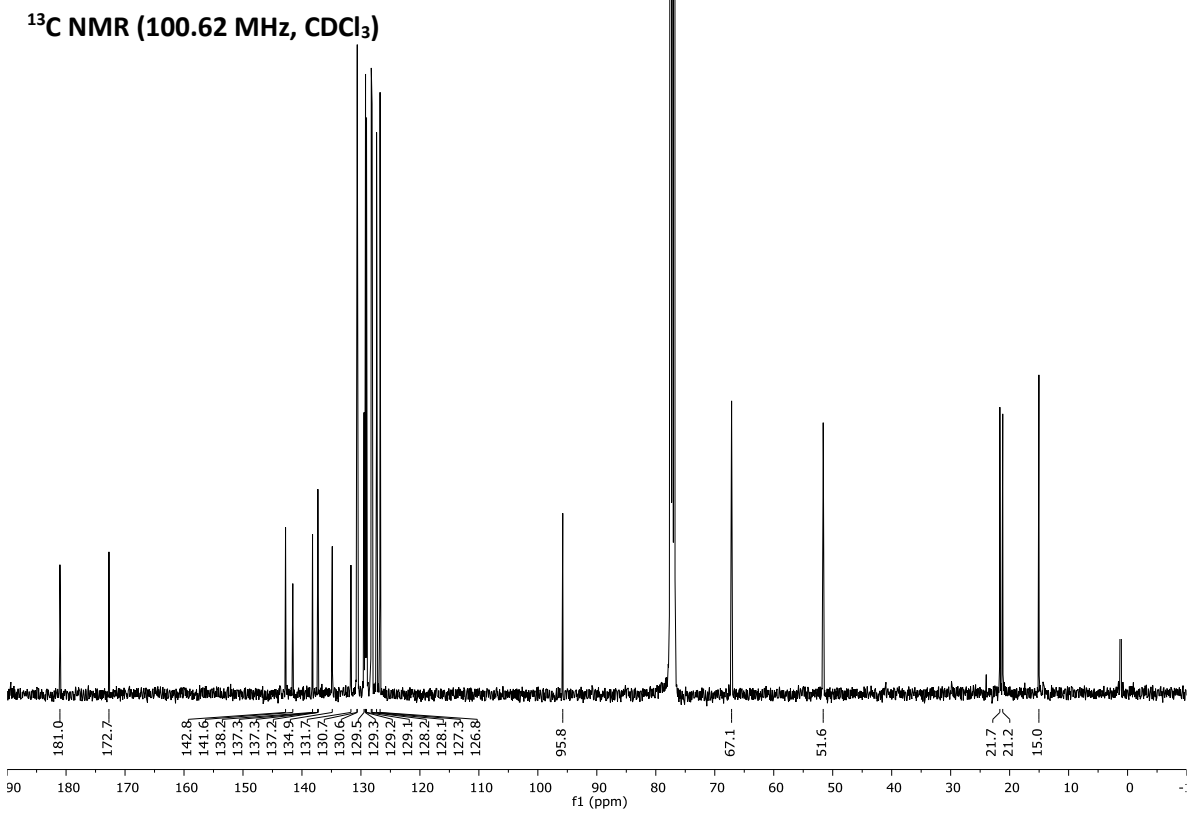
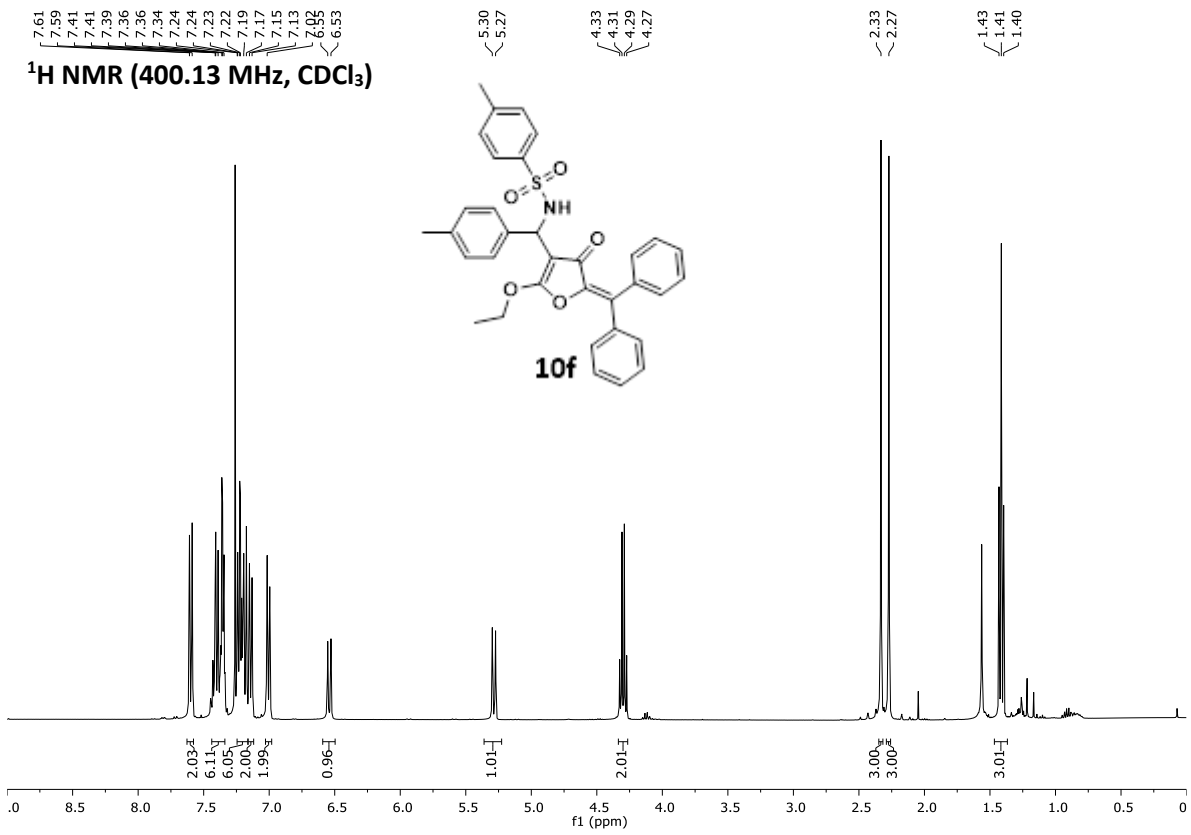




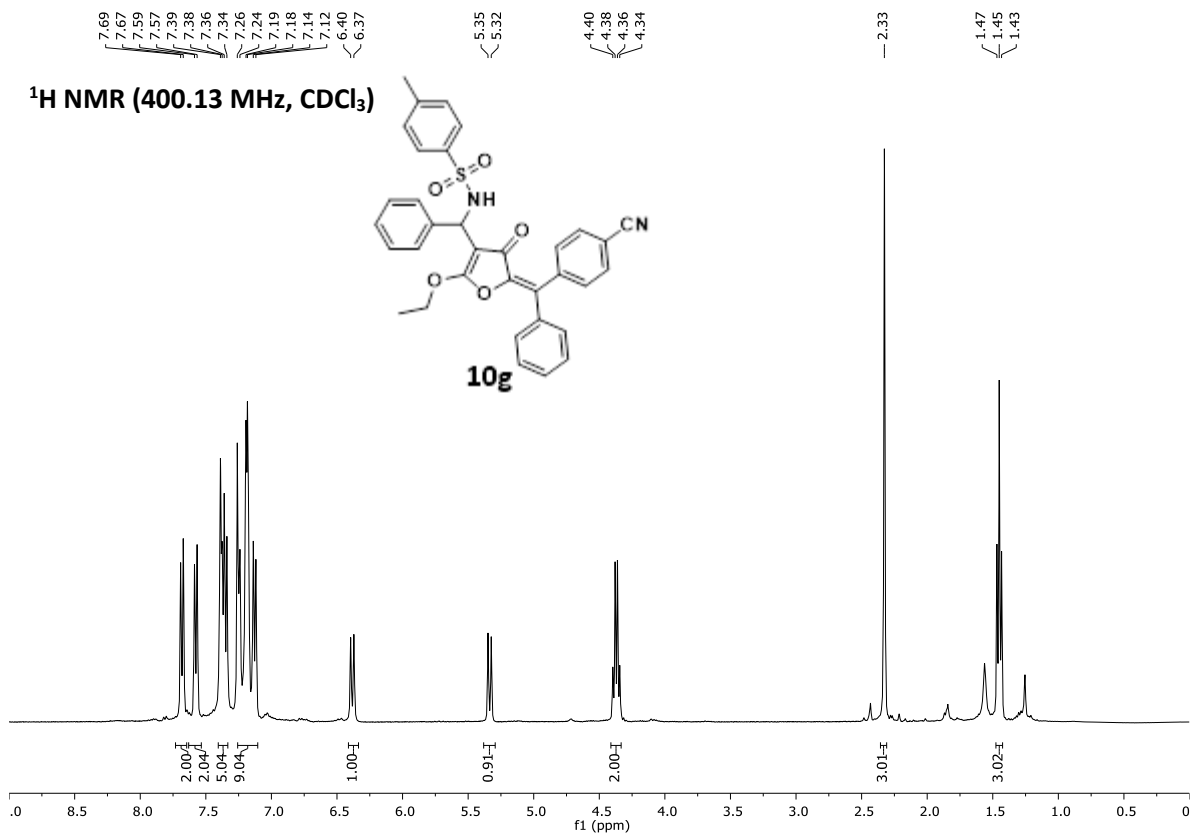




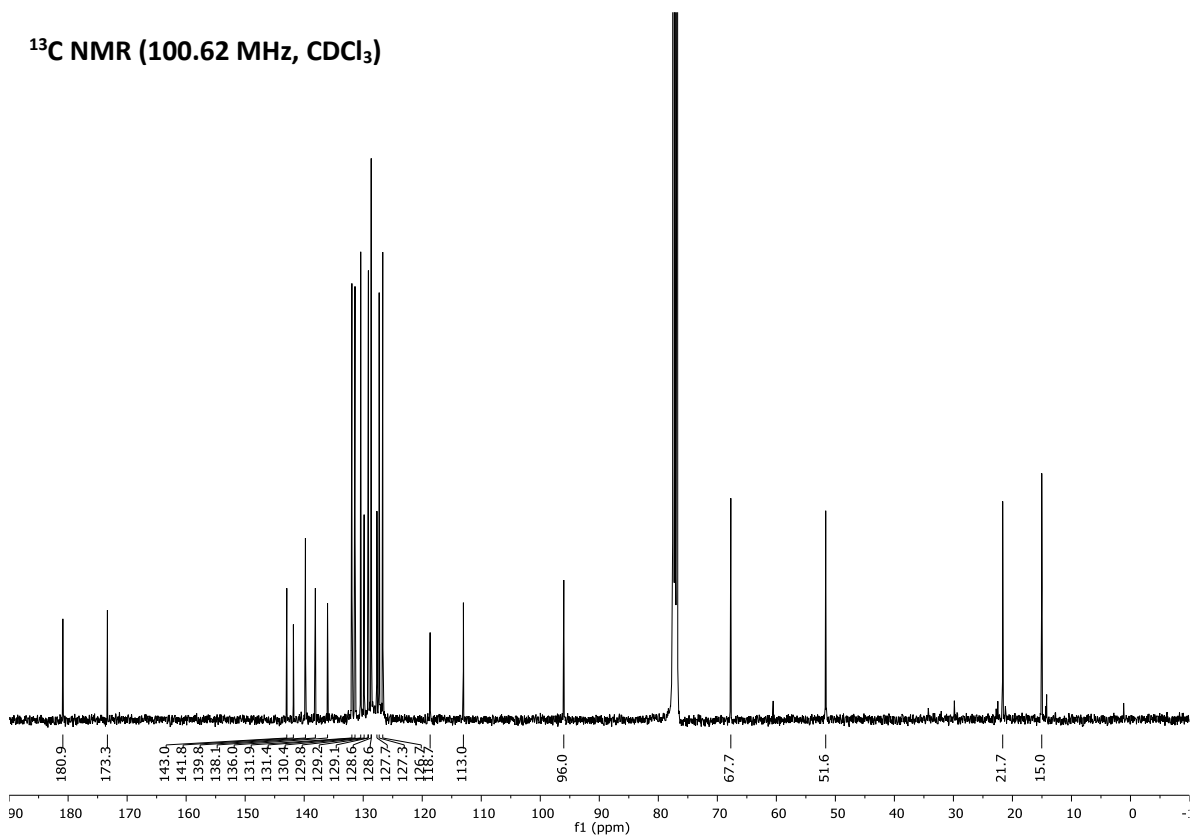


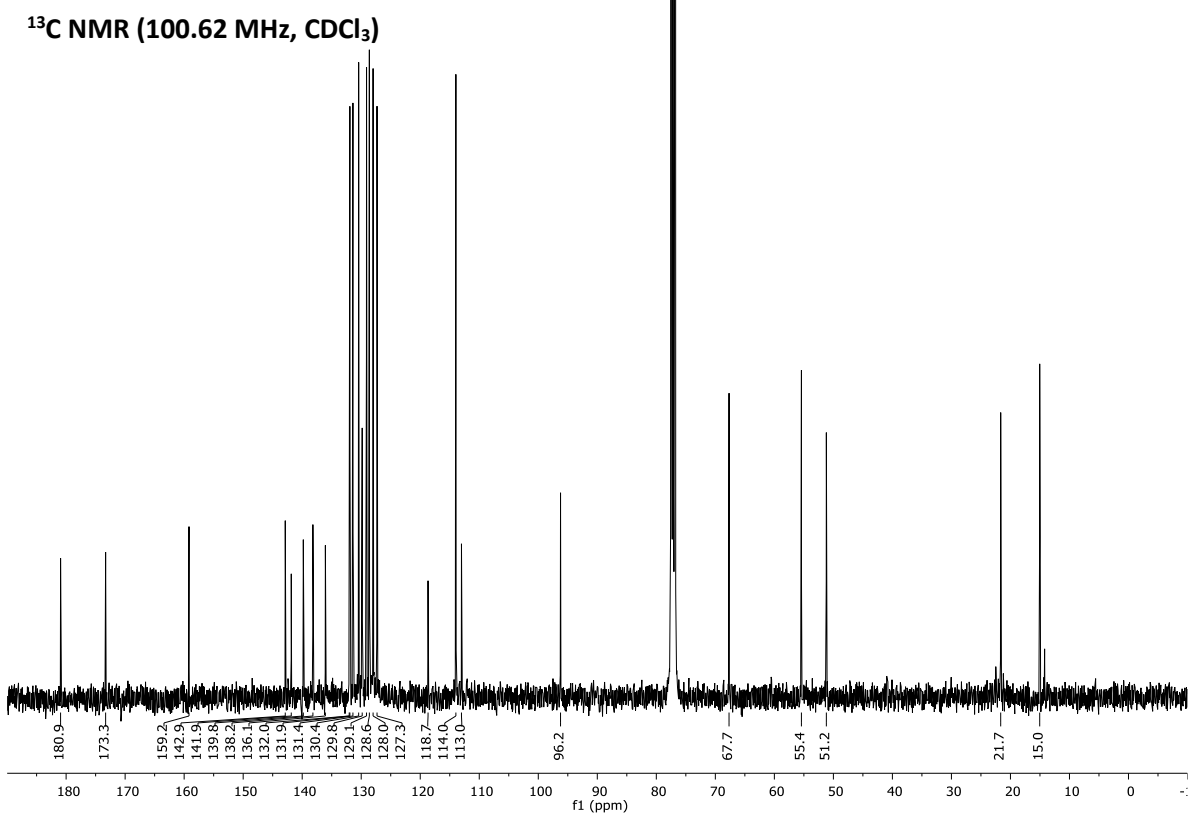
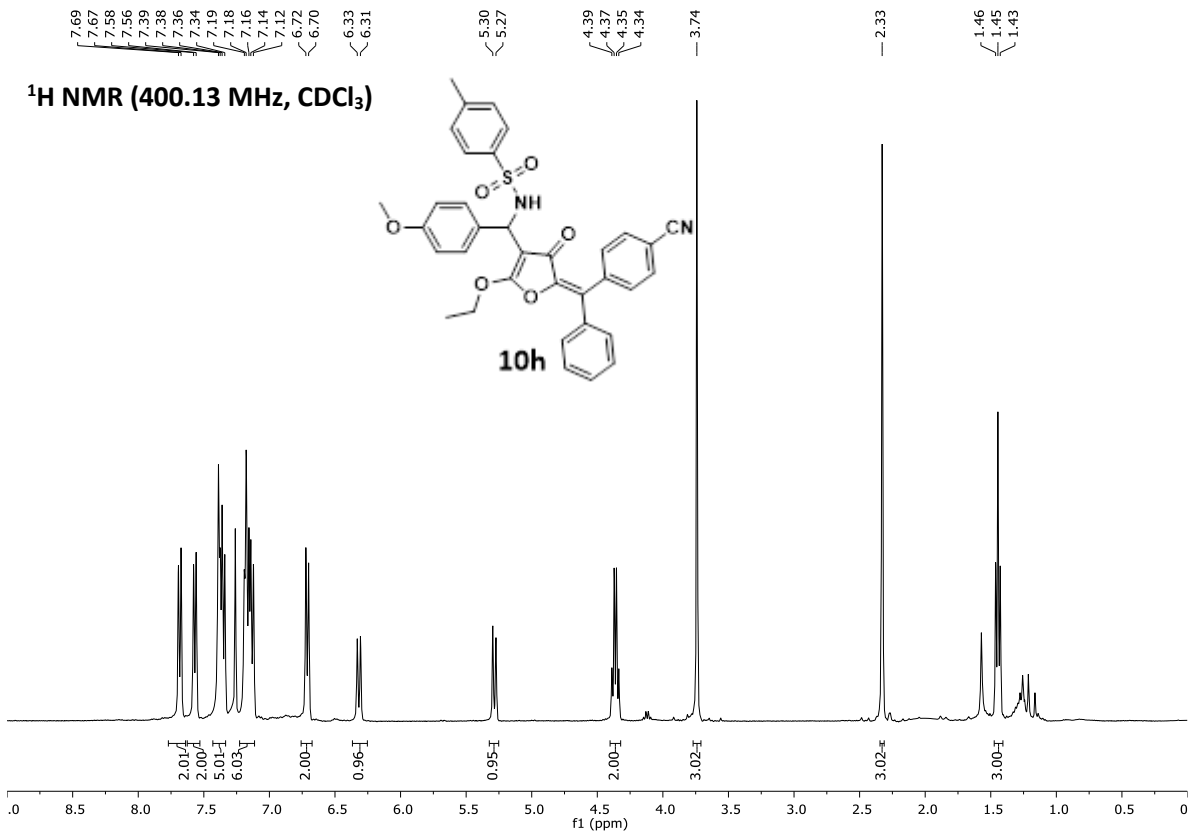


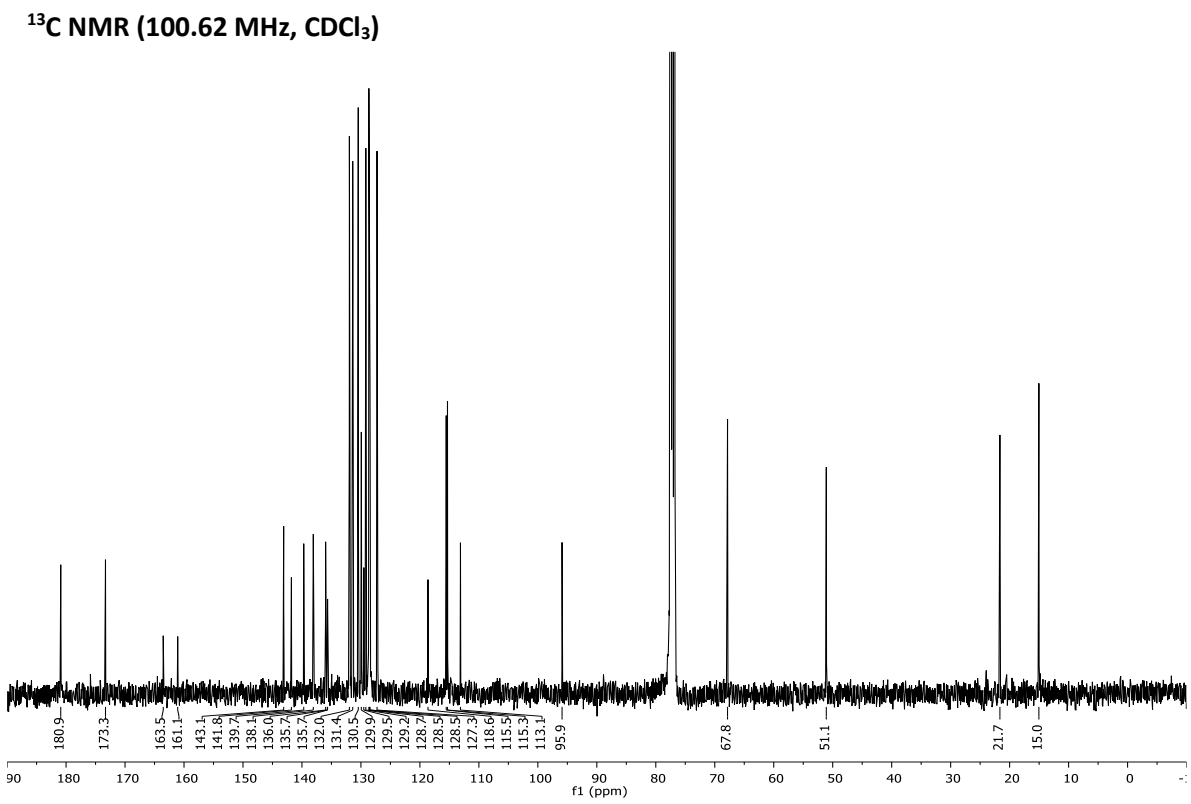
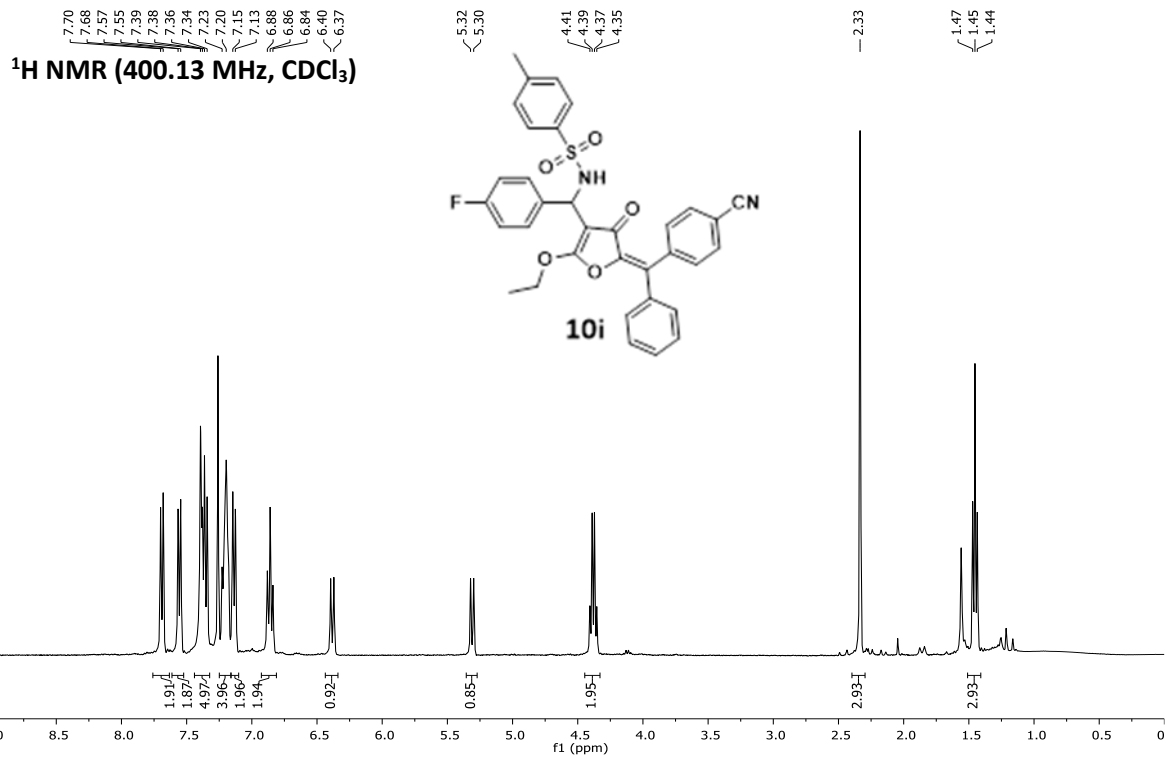
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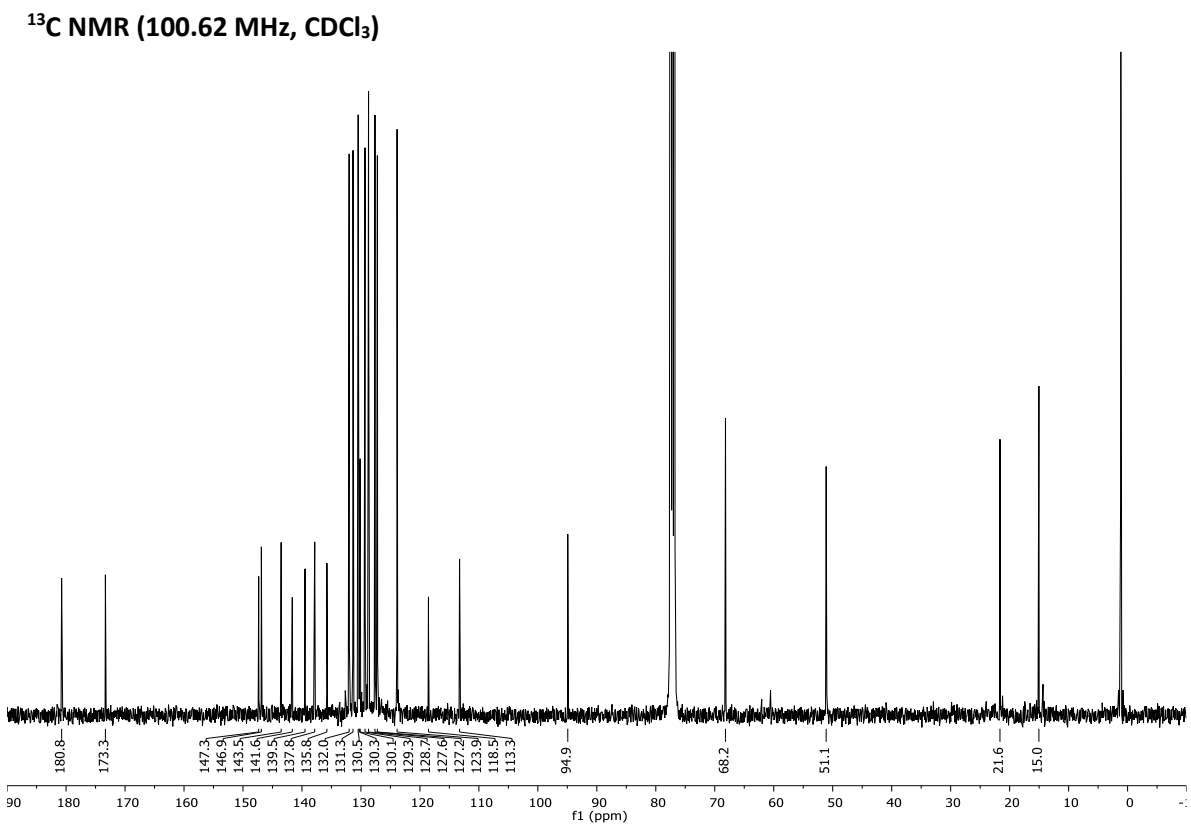
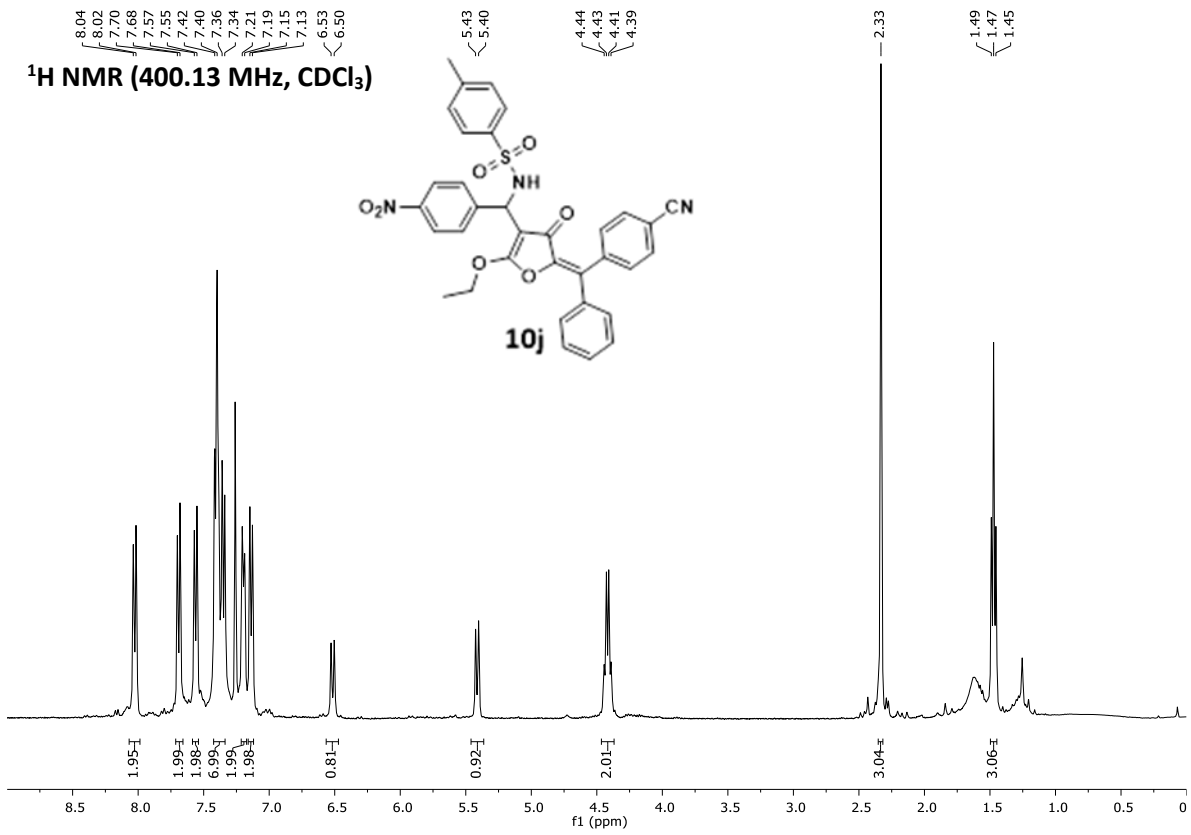


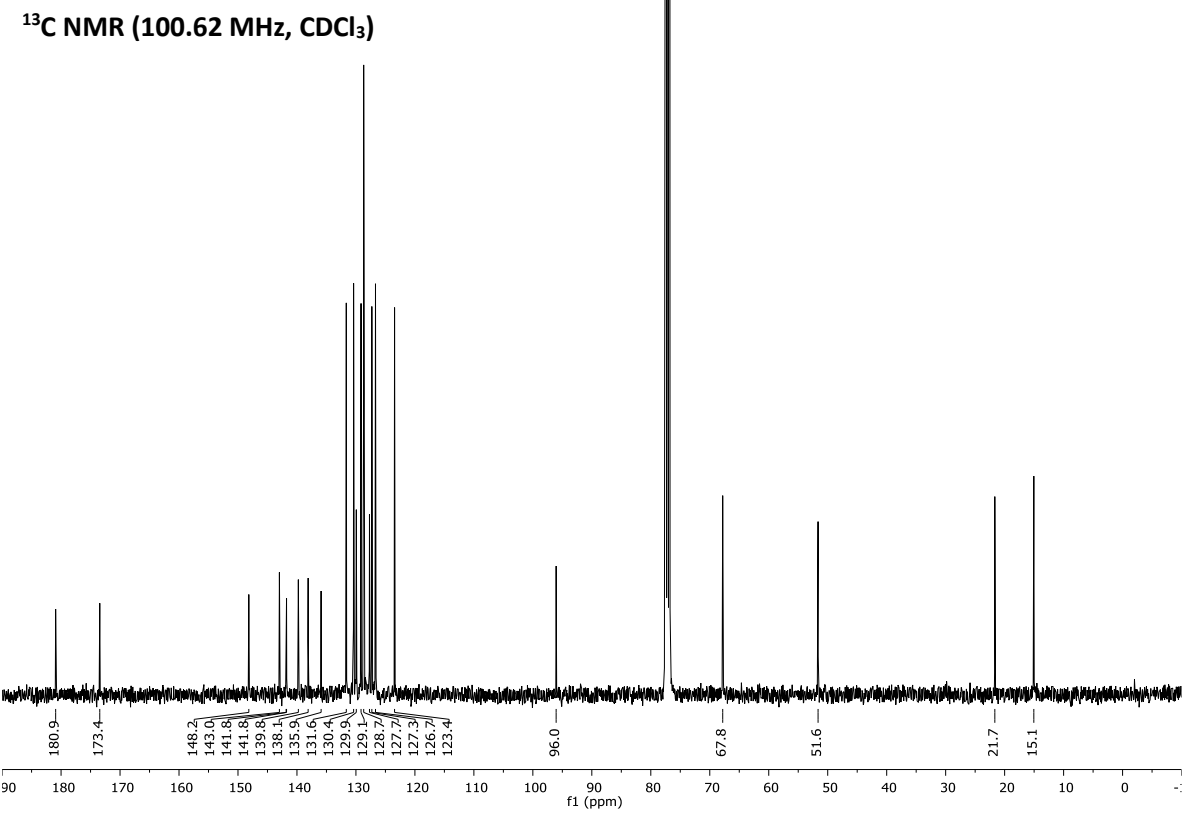
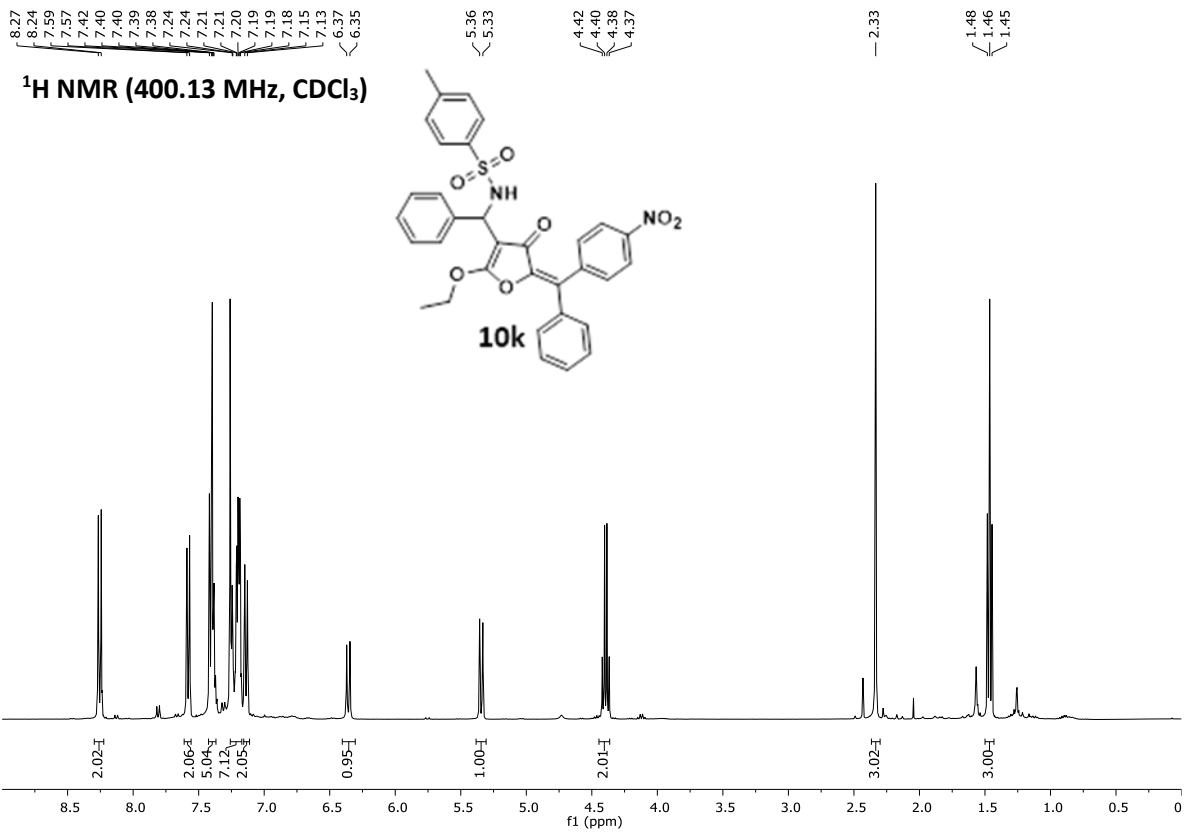
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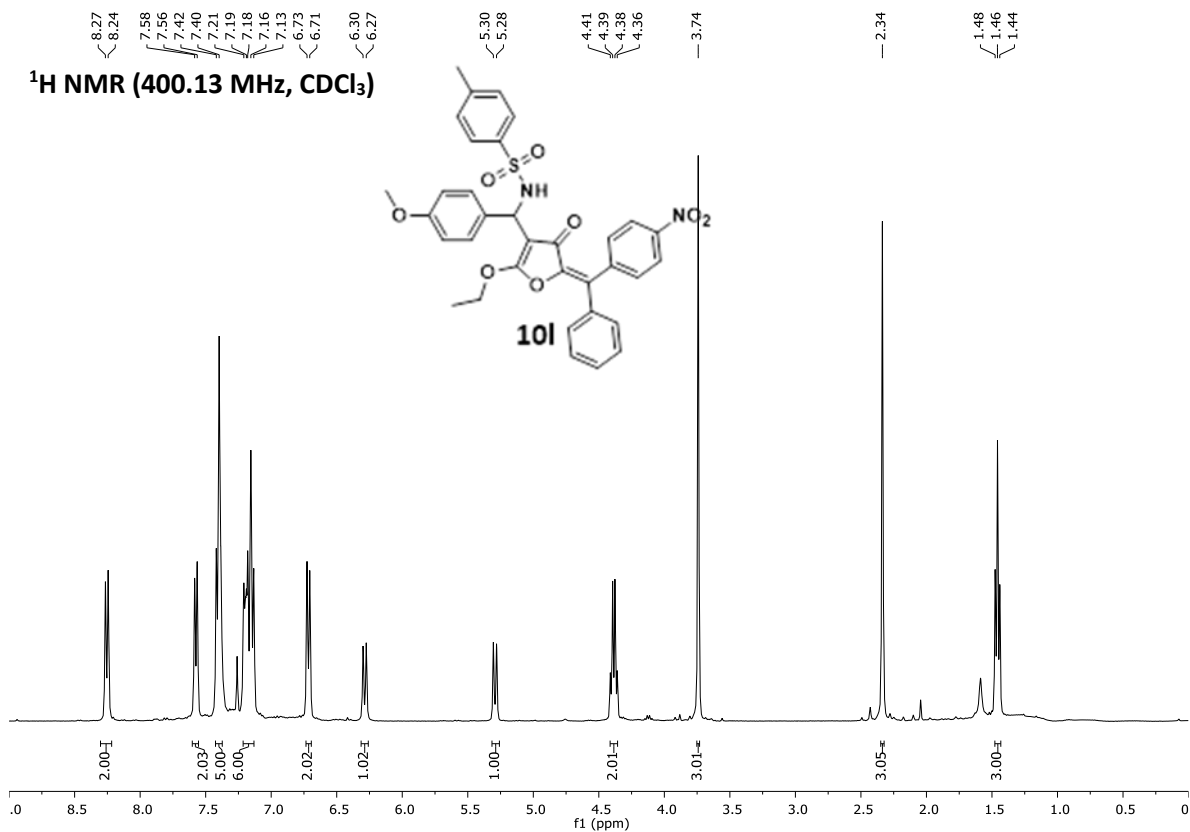




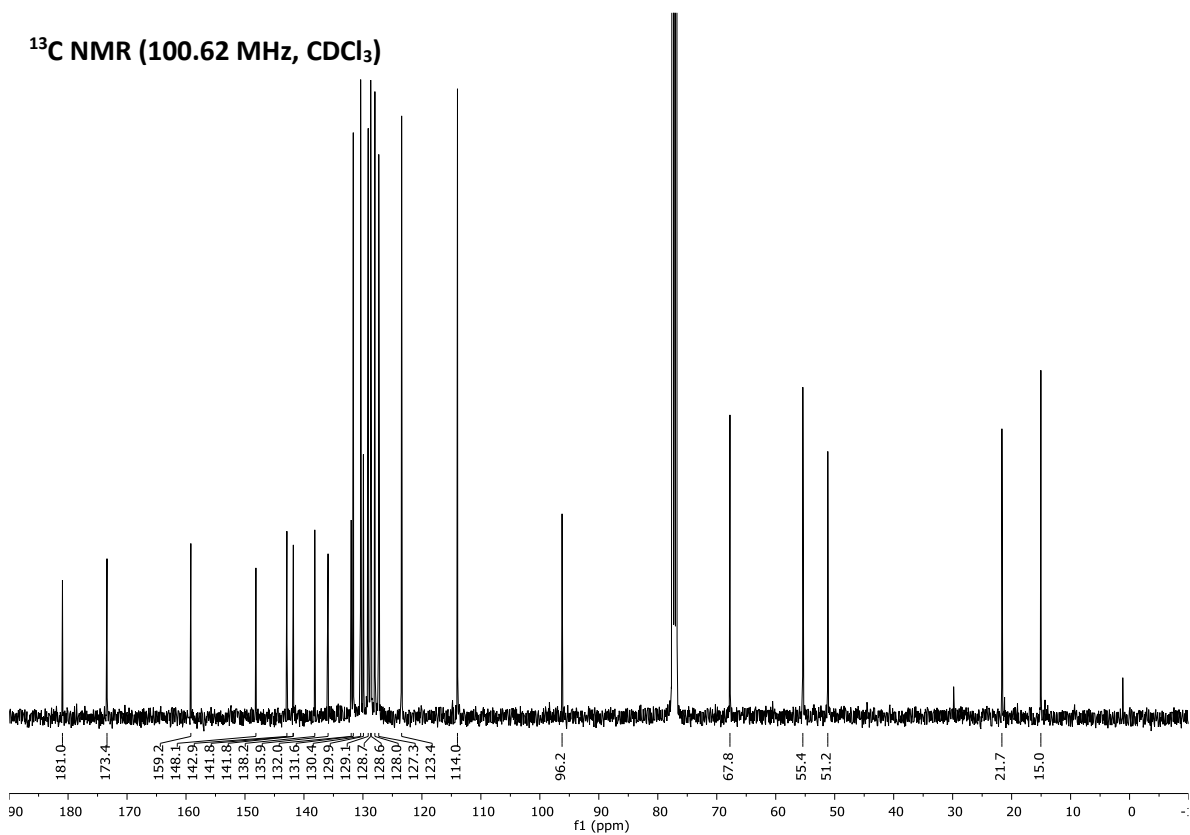


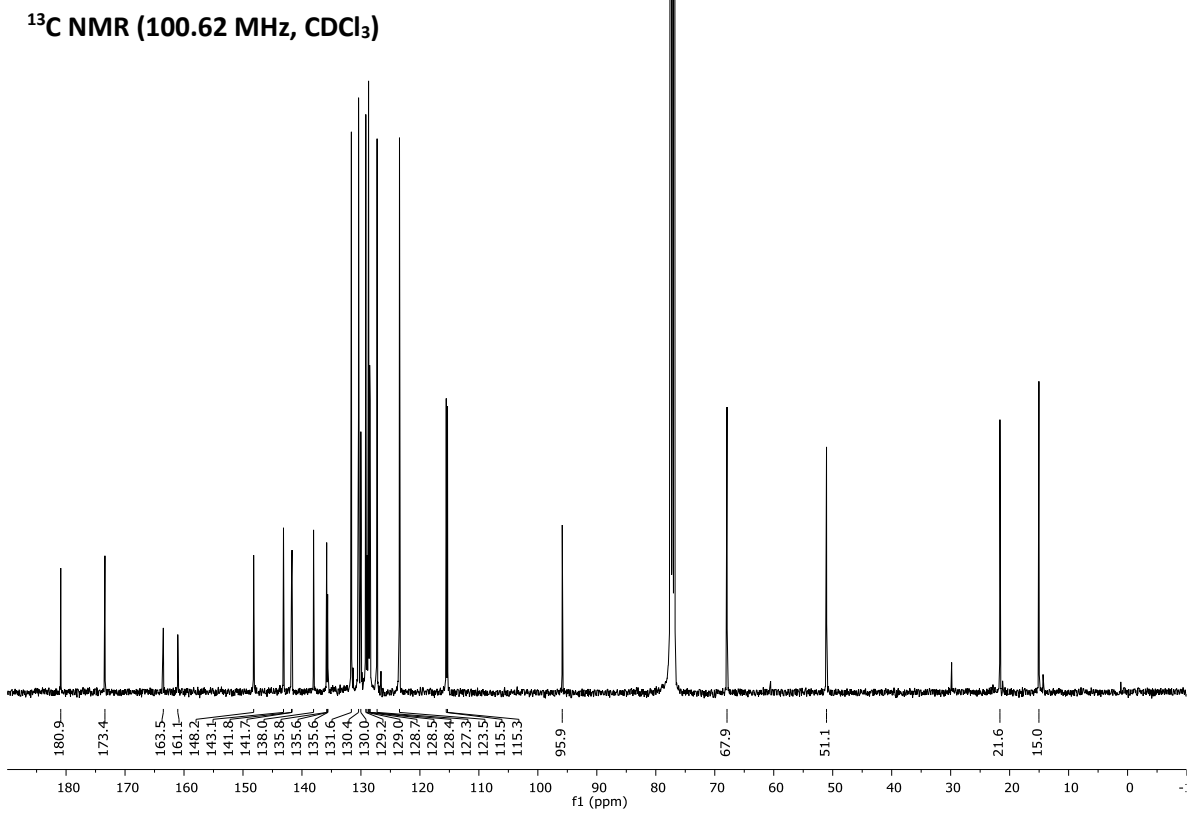
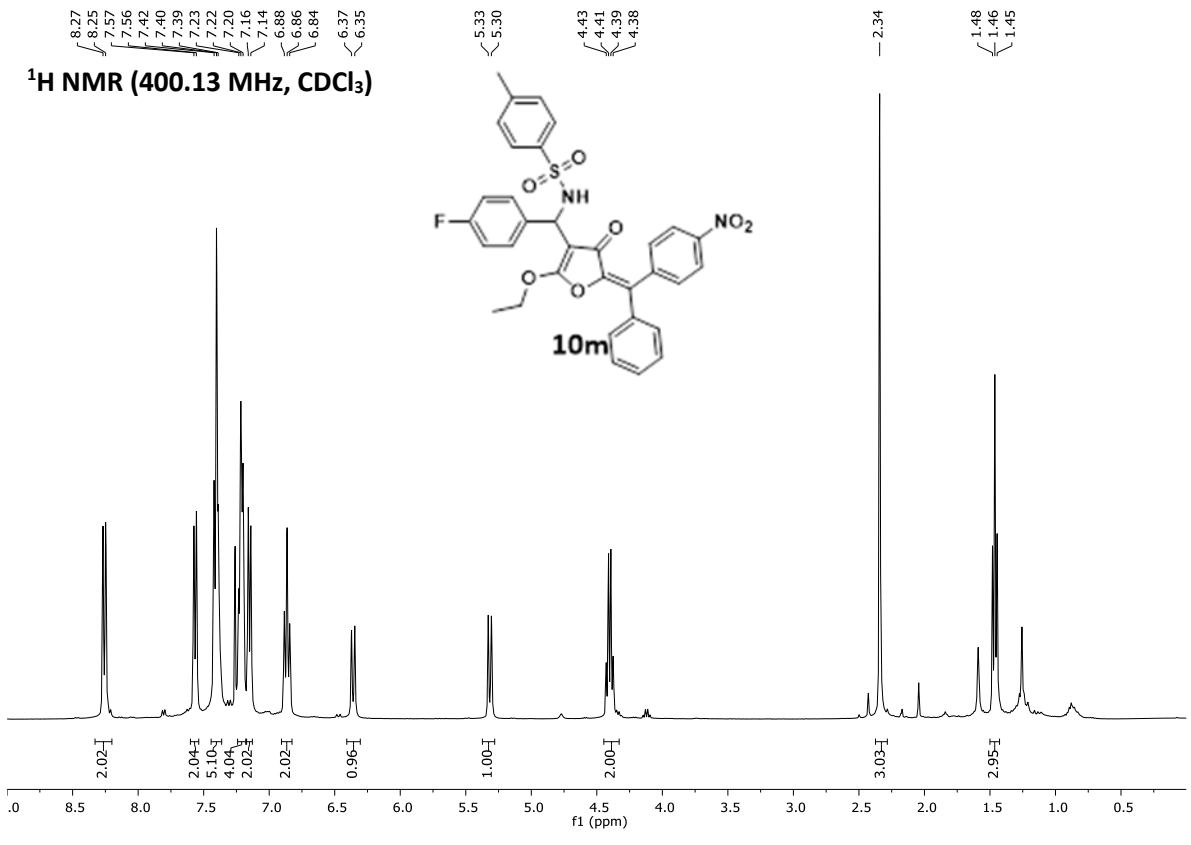


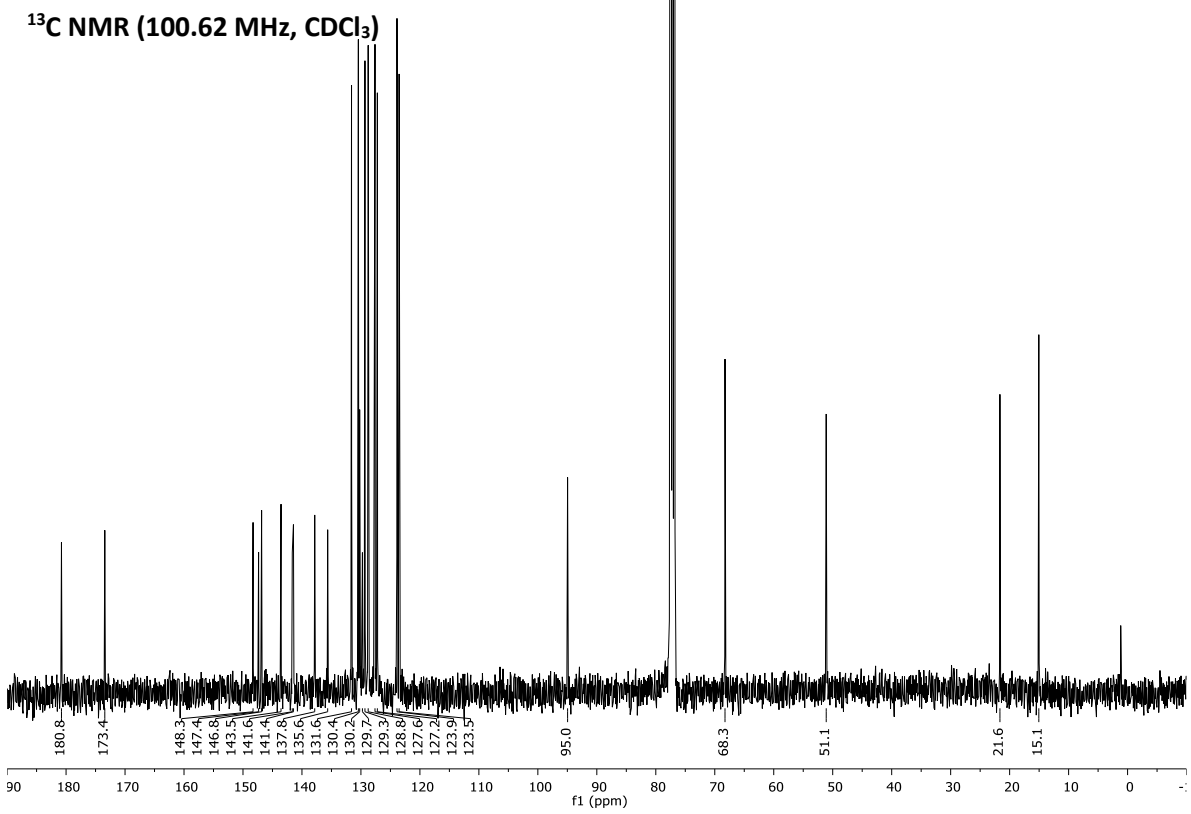
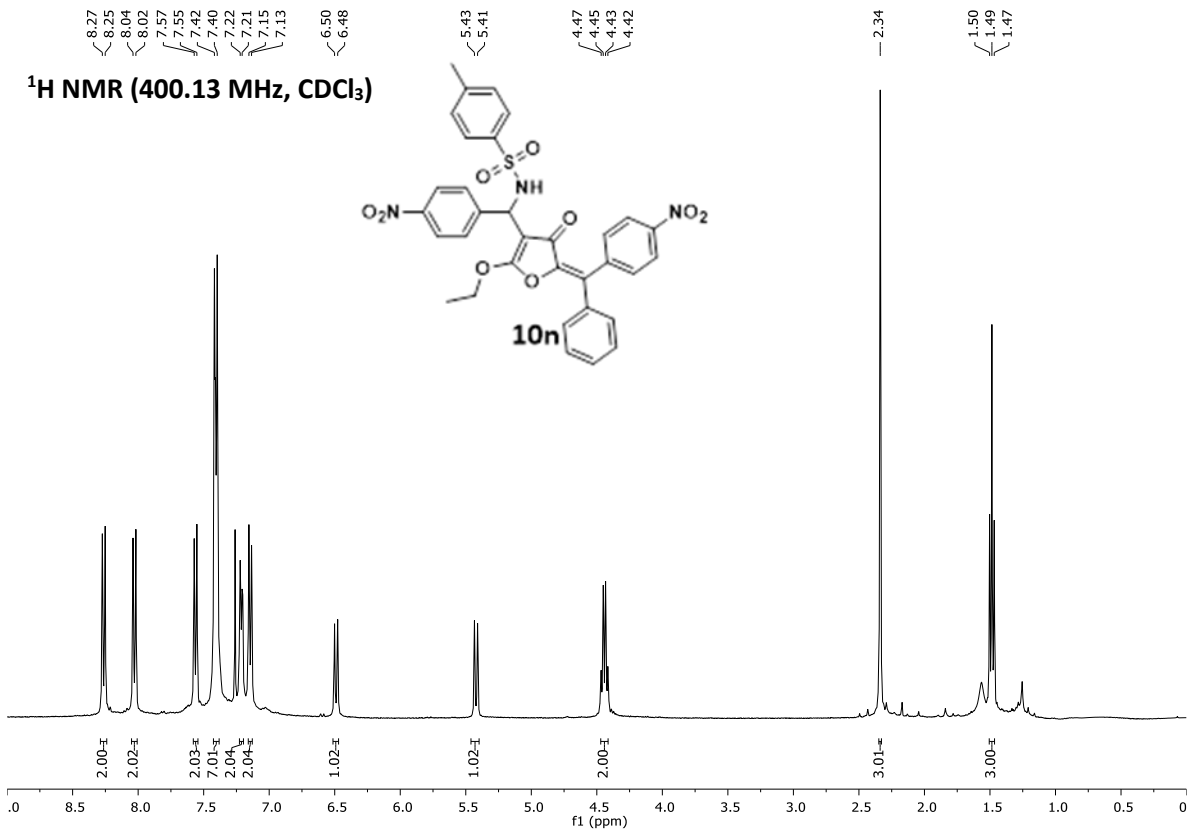
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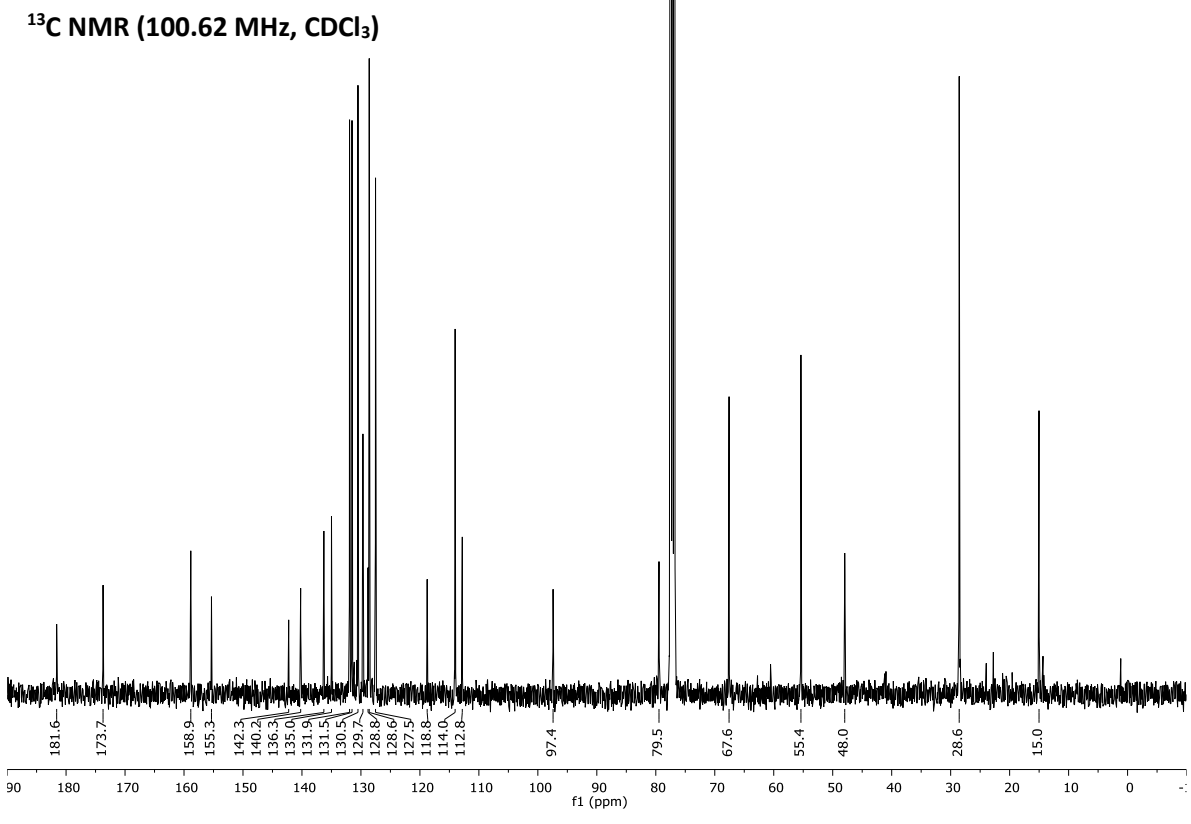
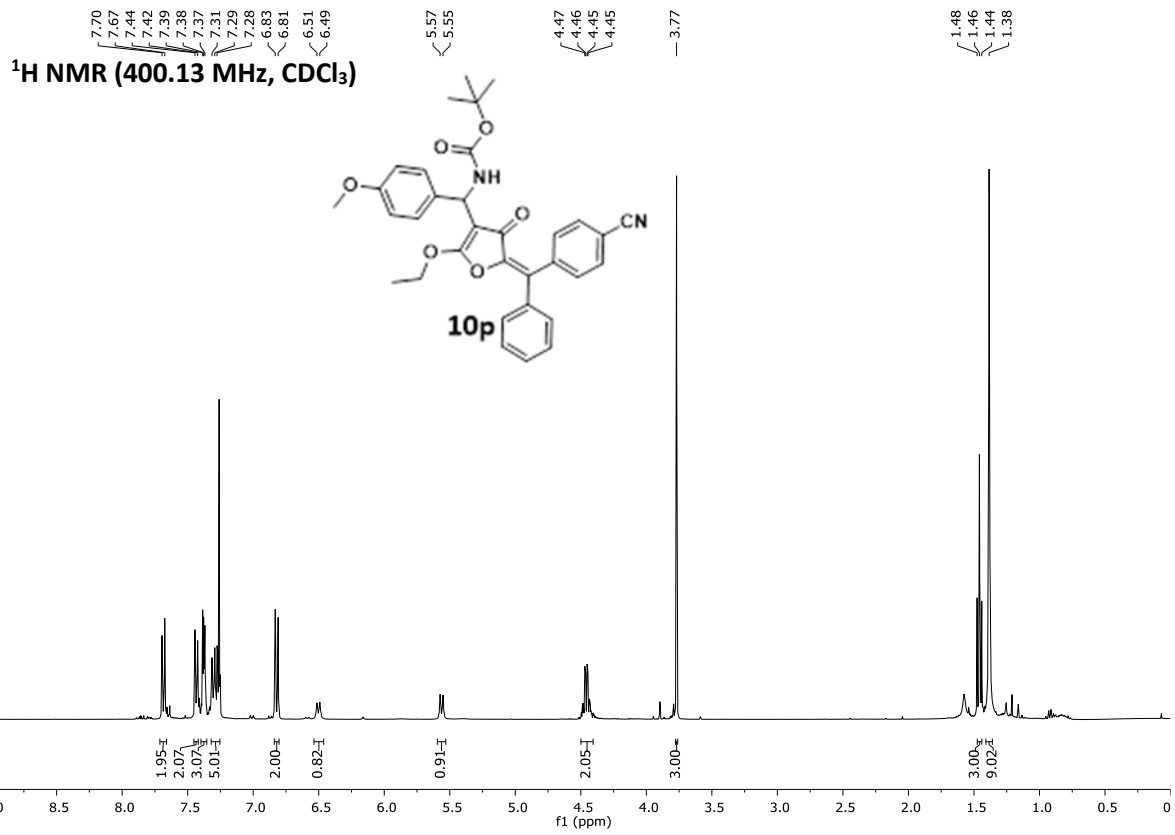


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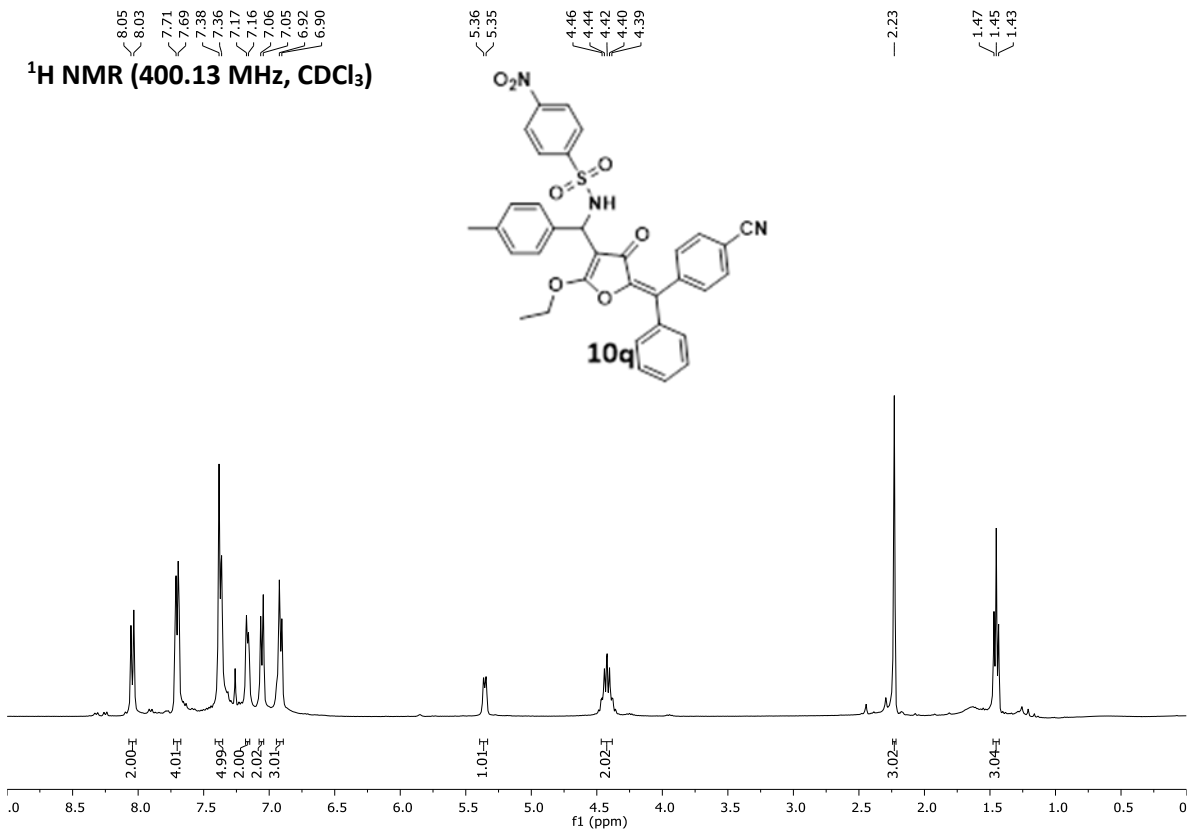




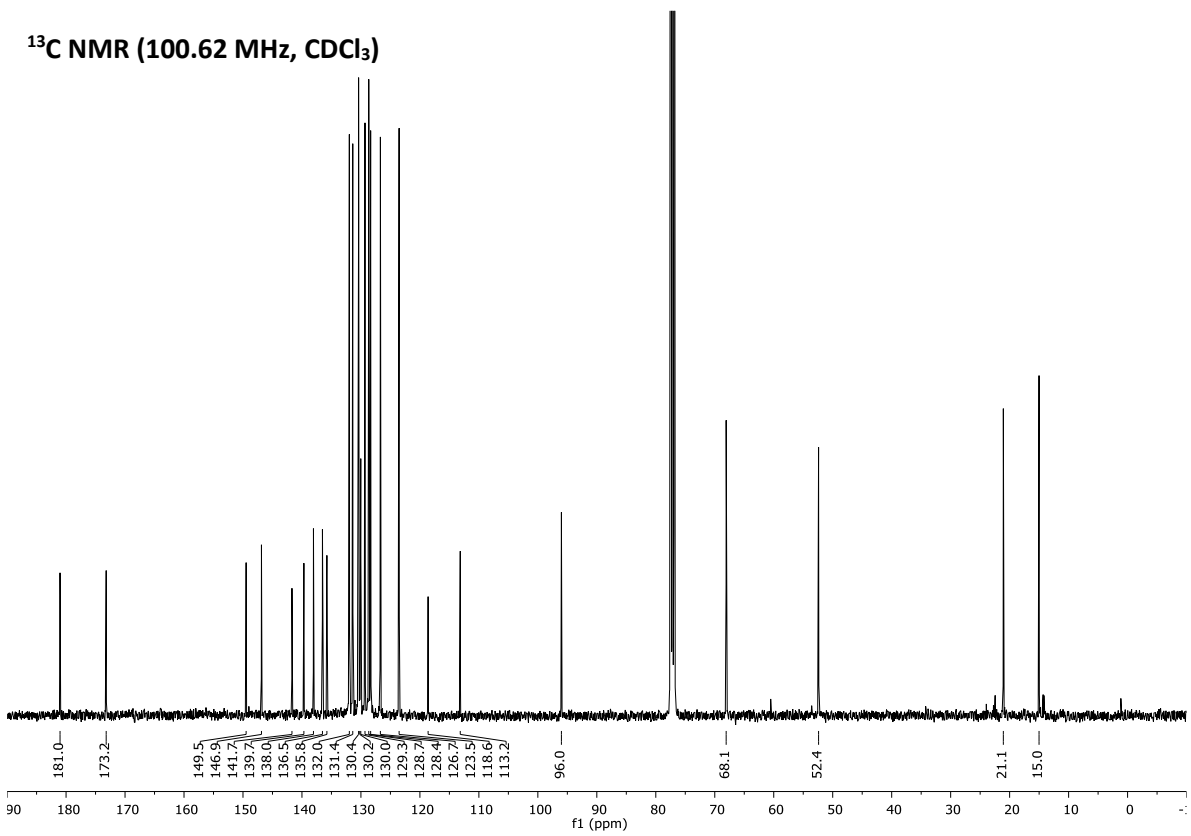


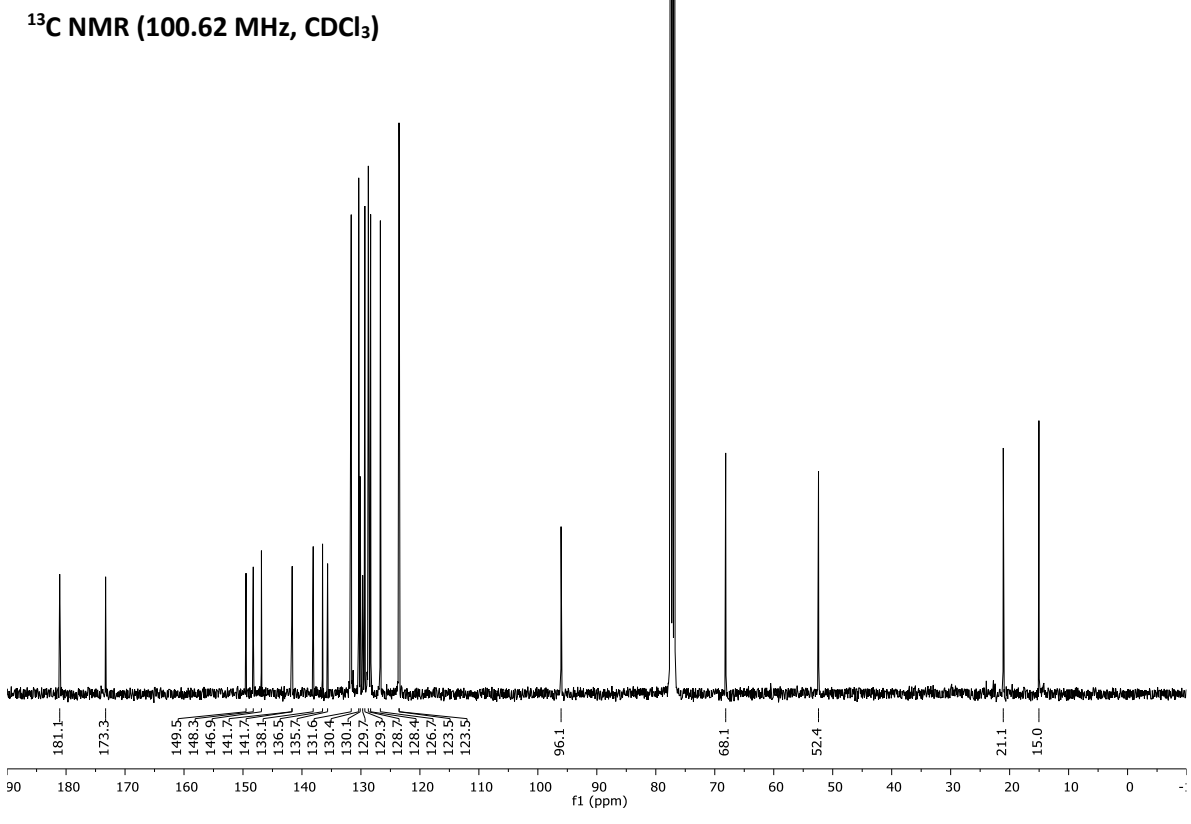
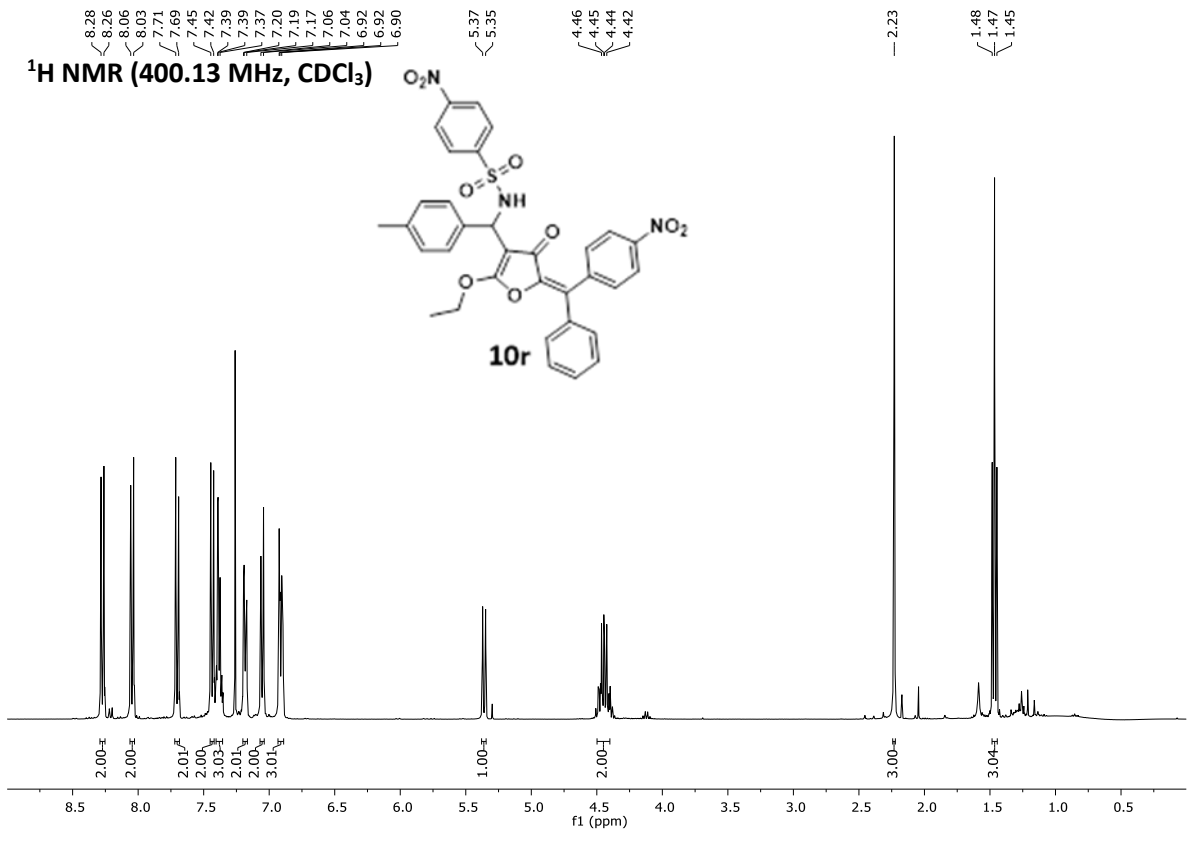


¹H NMR (400.13 MHz, CDCl₃)

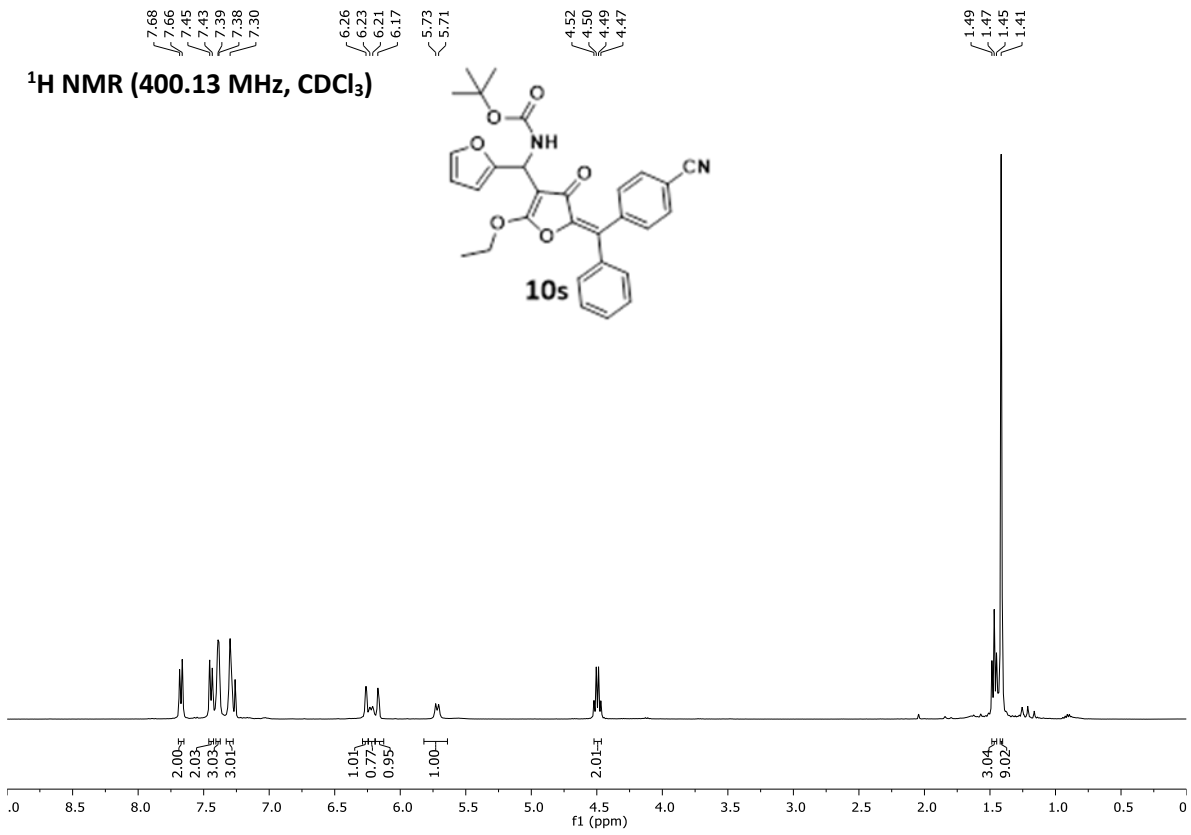


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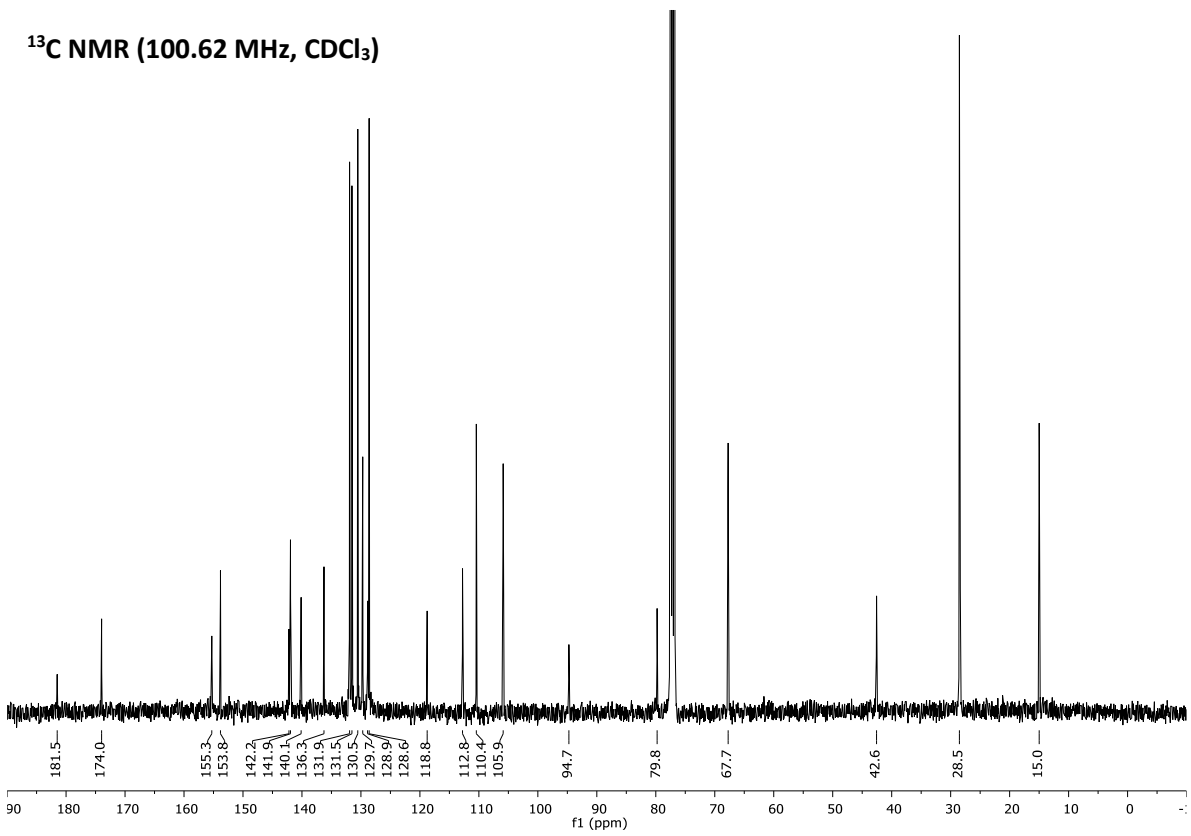


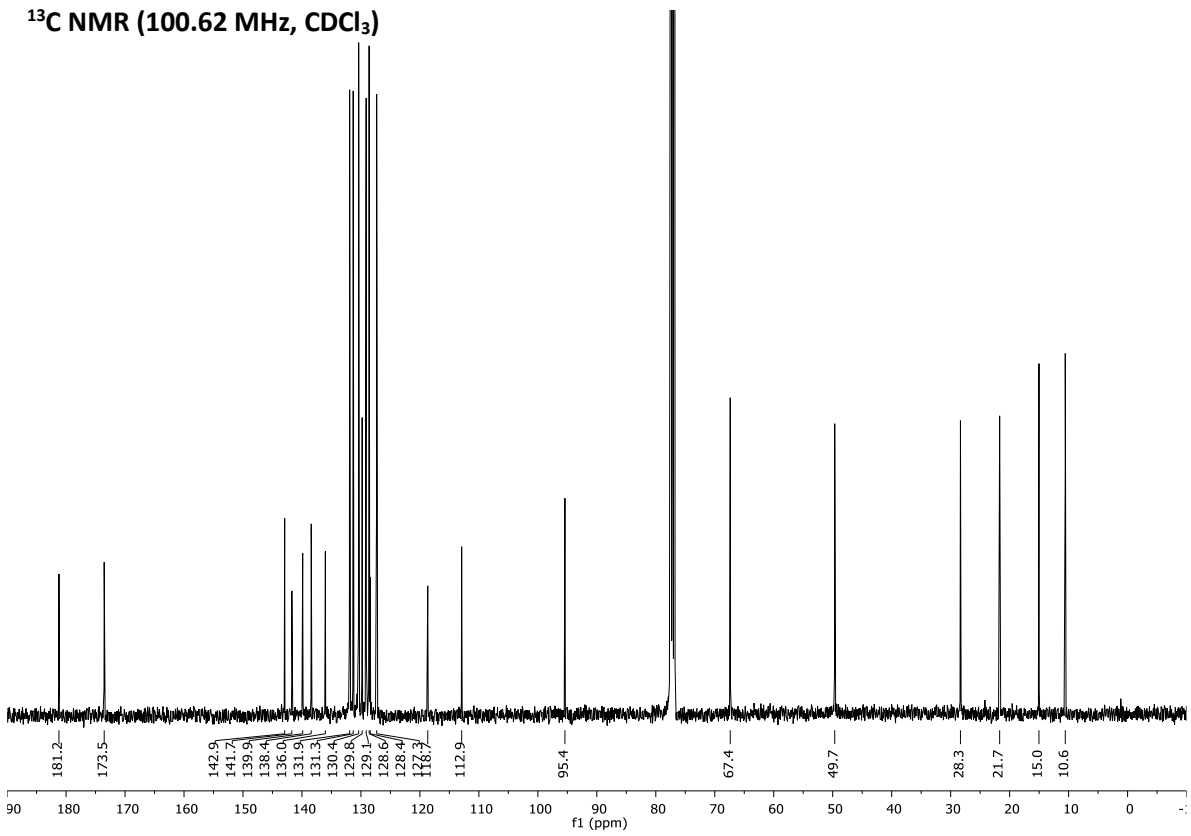
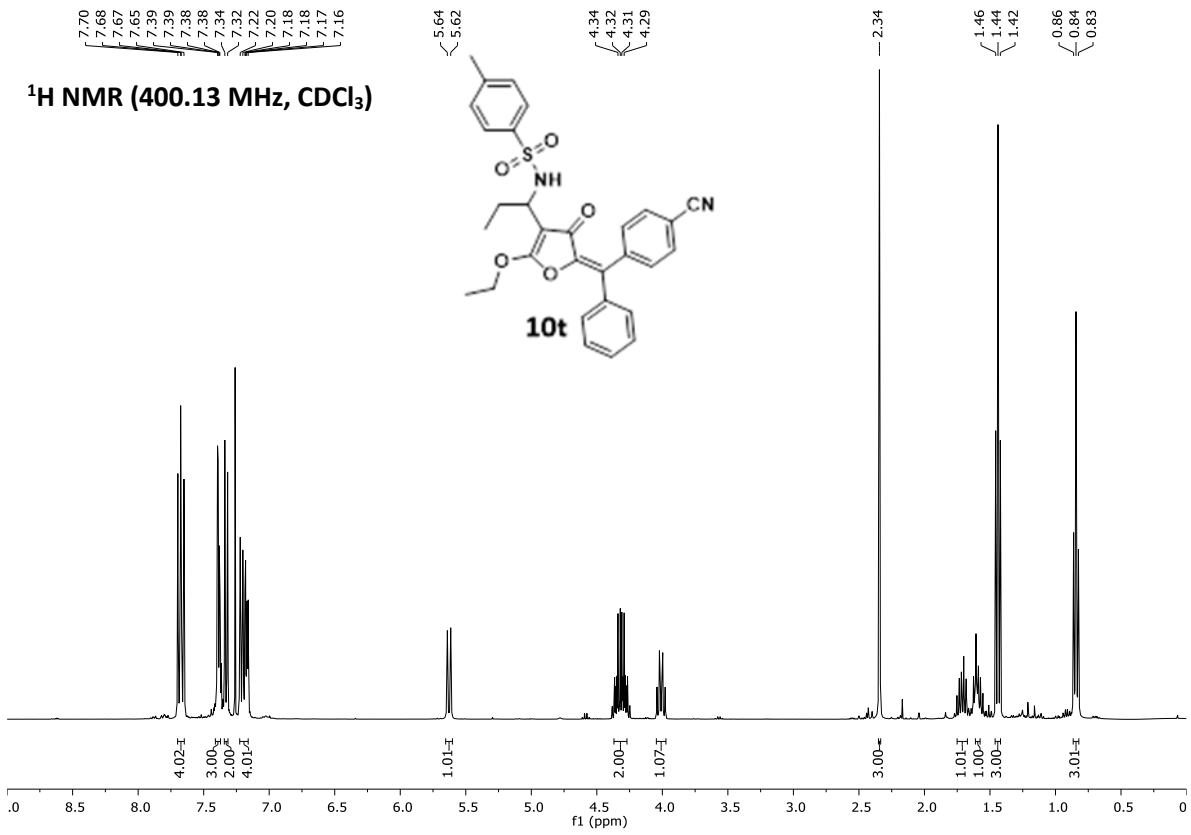


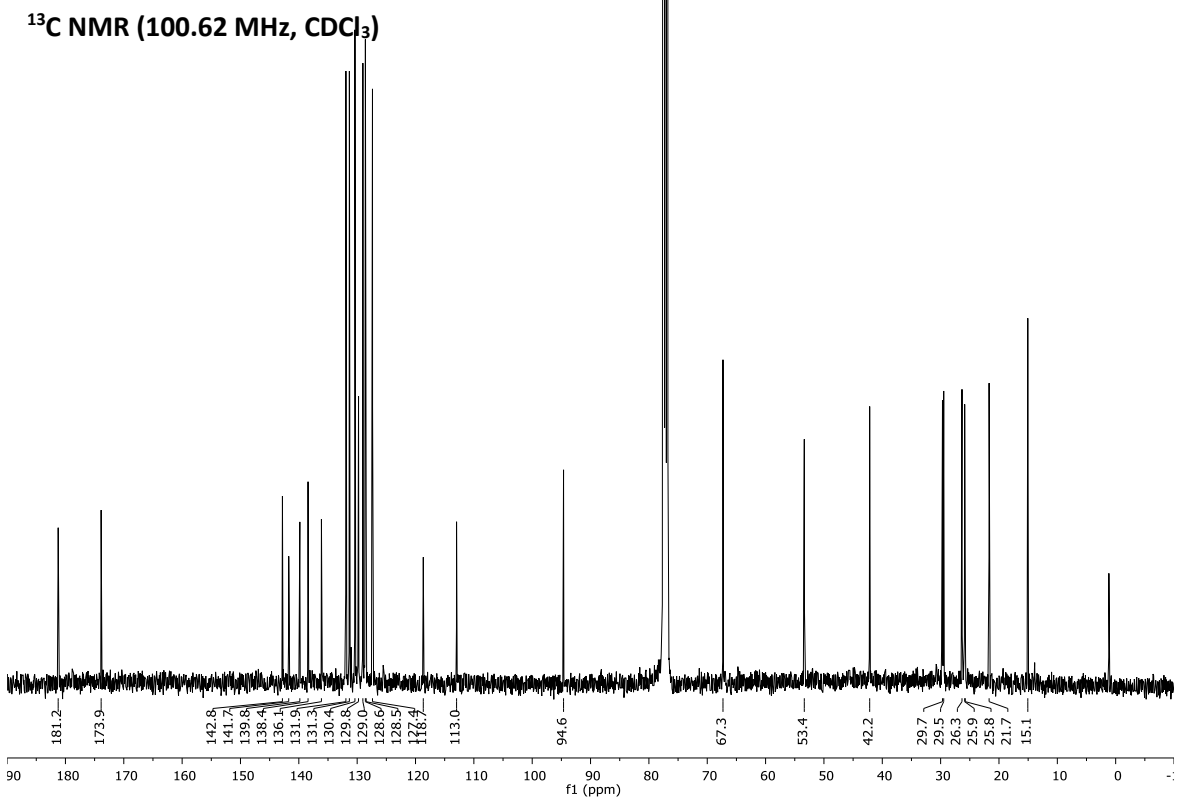
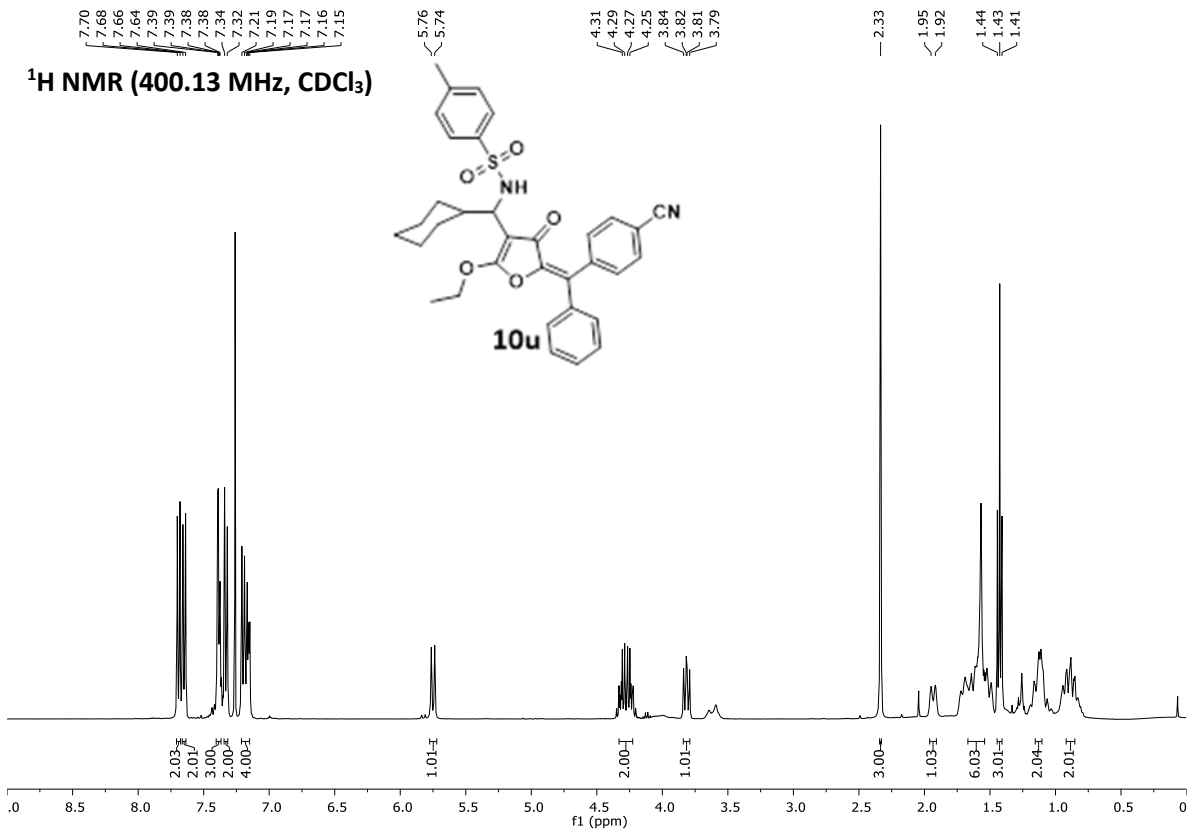
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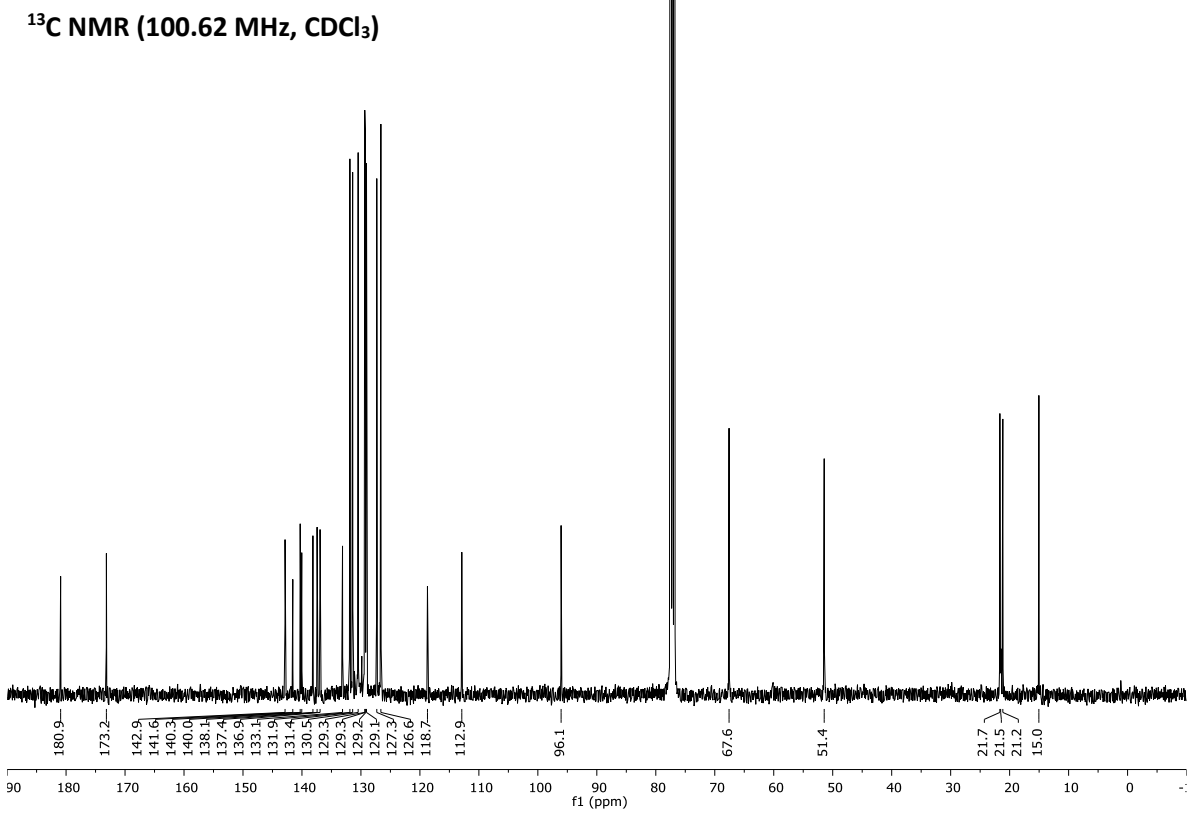
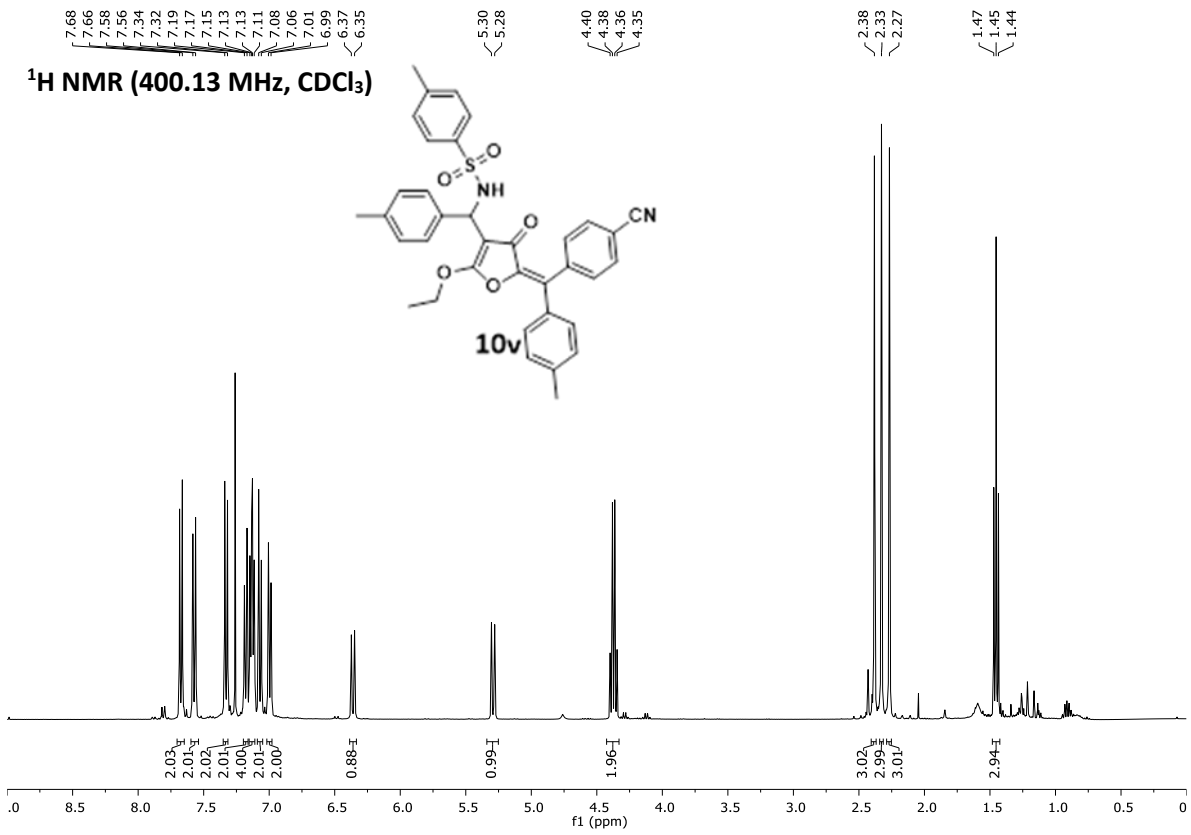


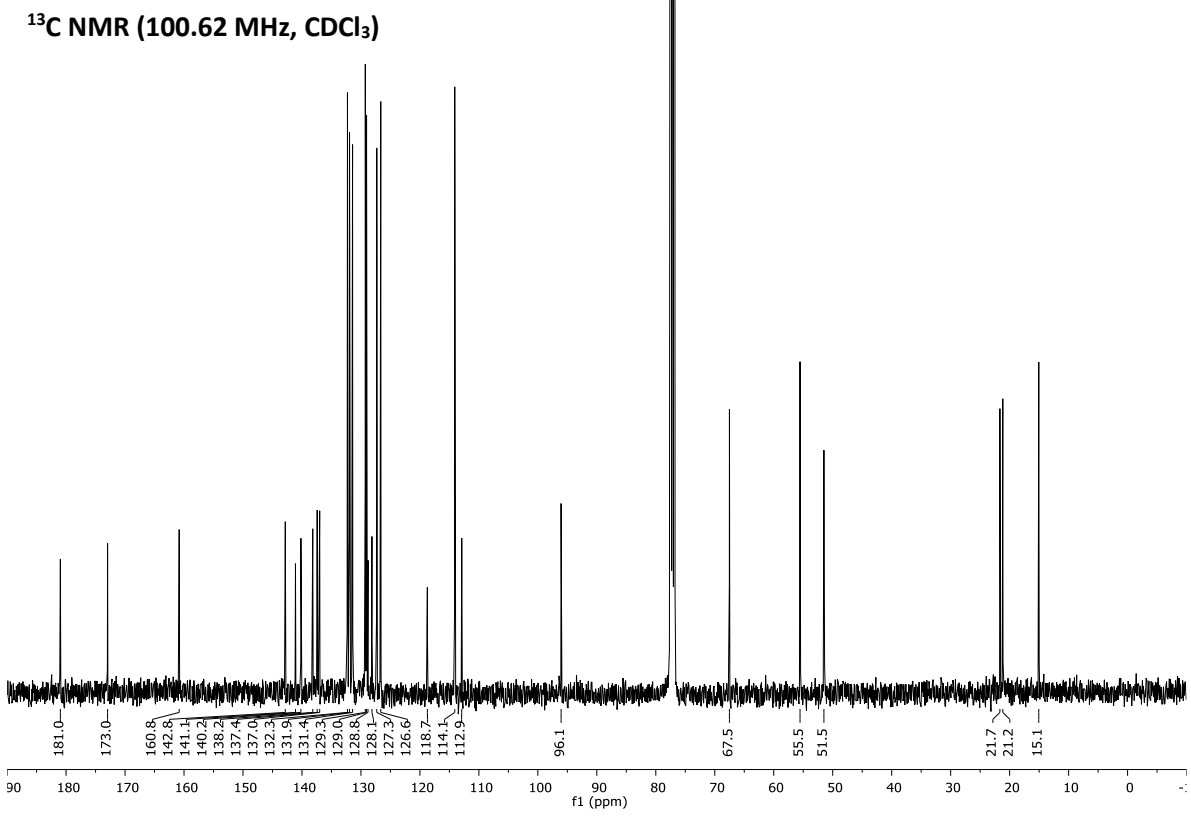
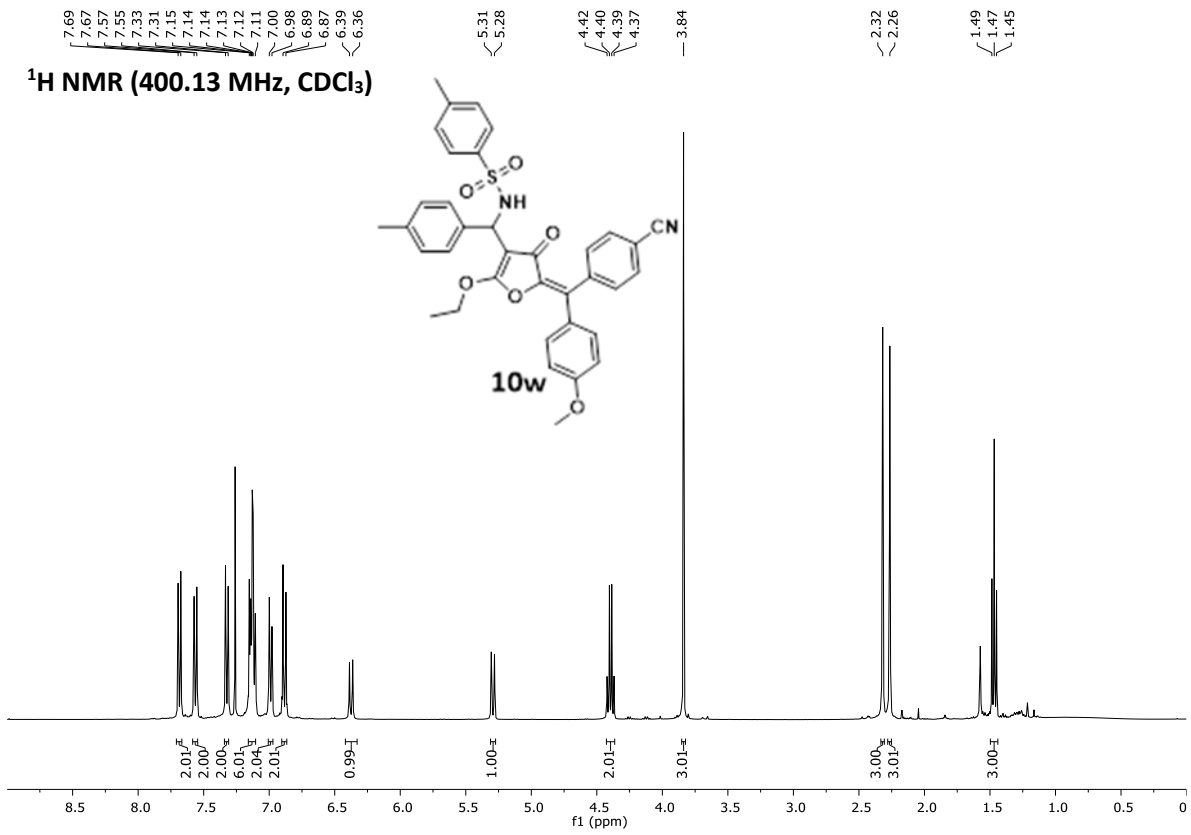
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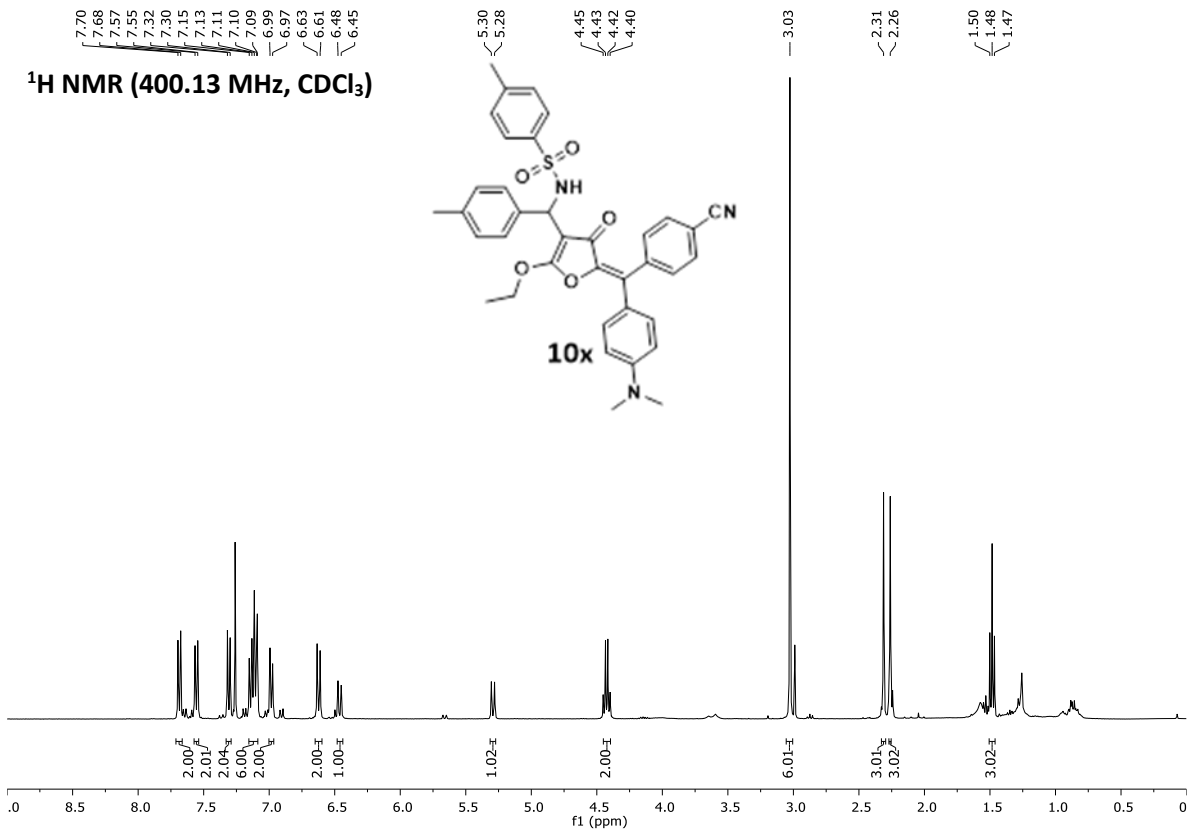




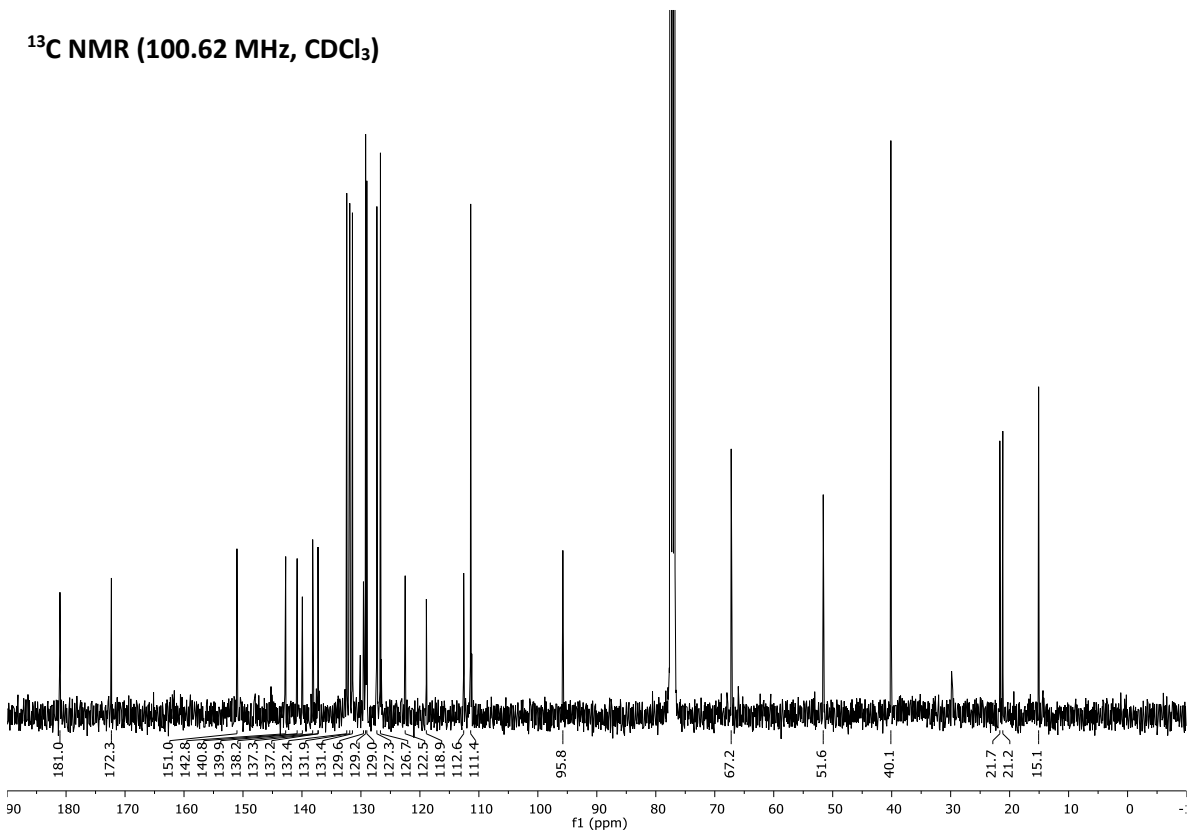


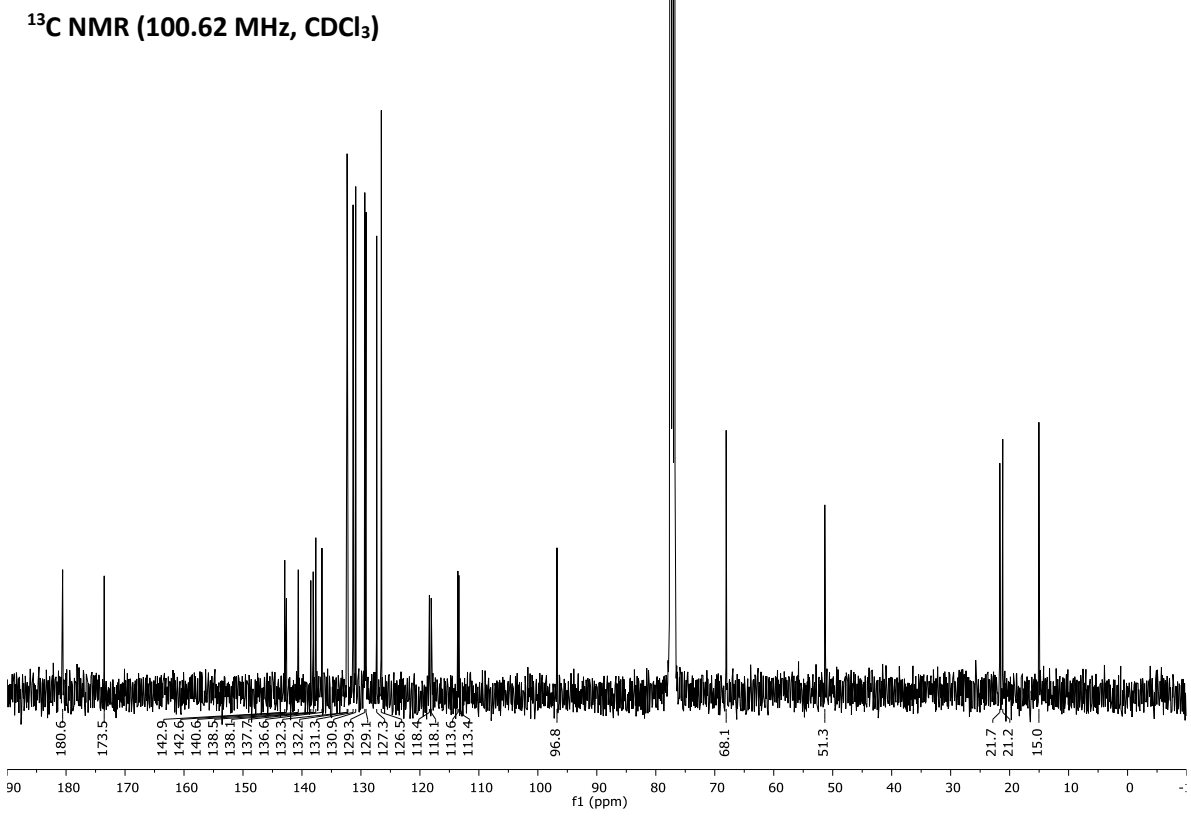
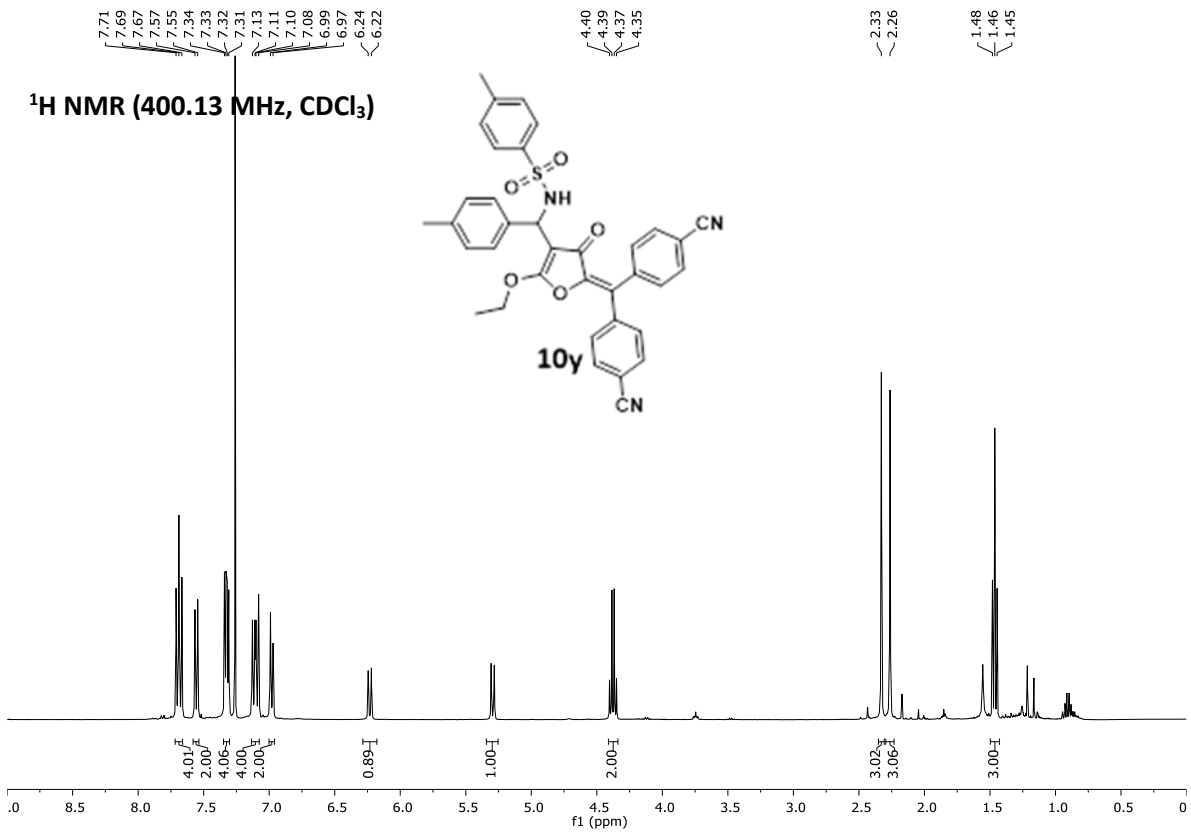


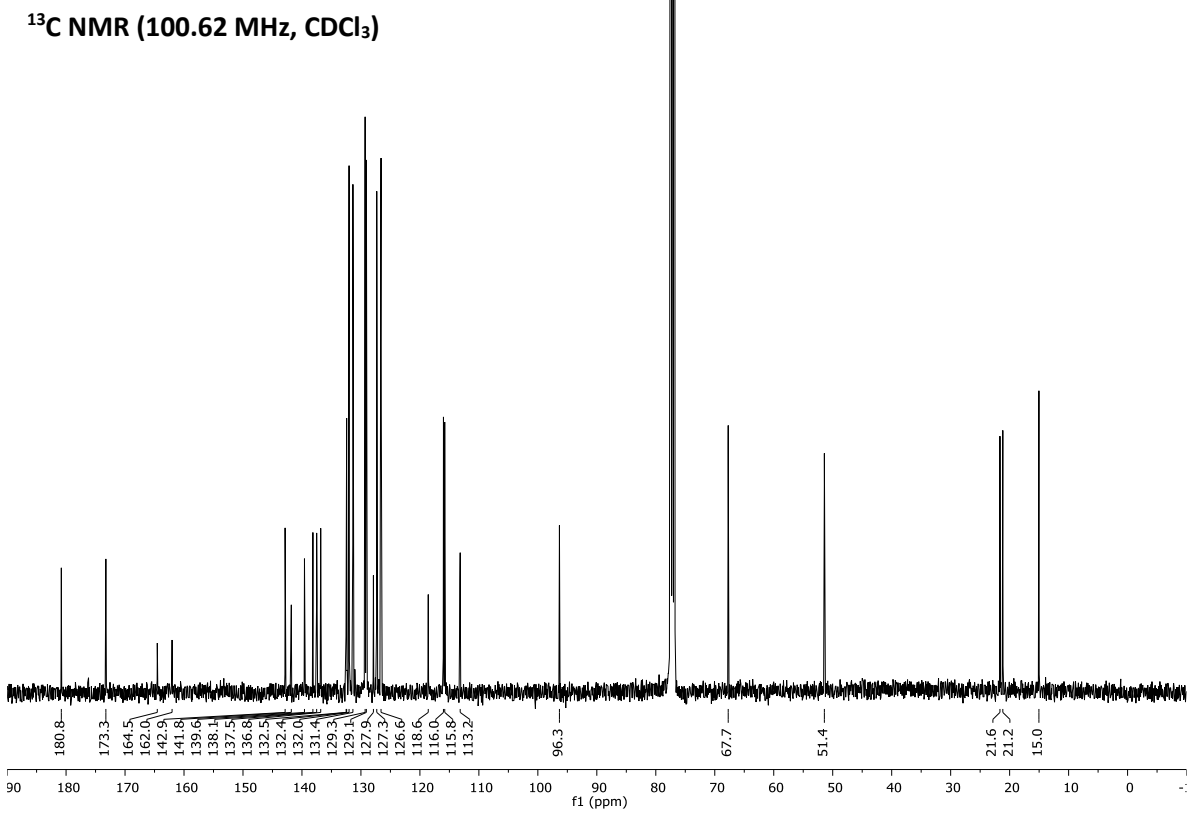
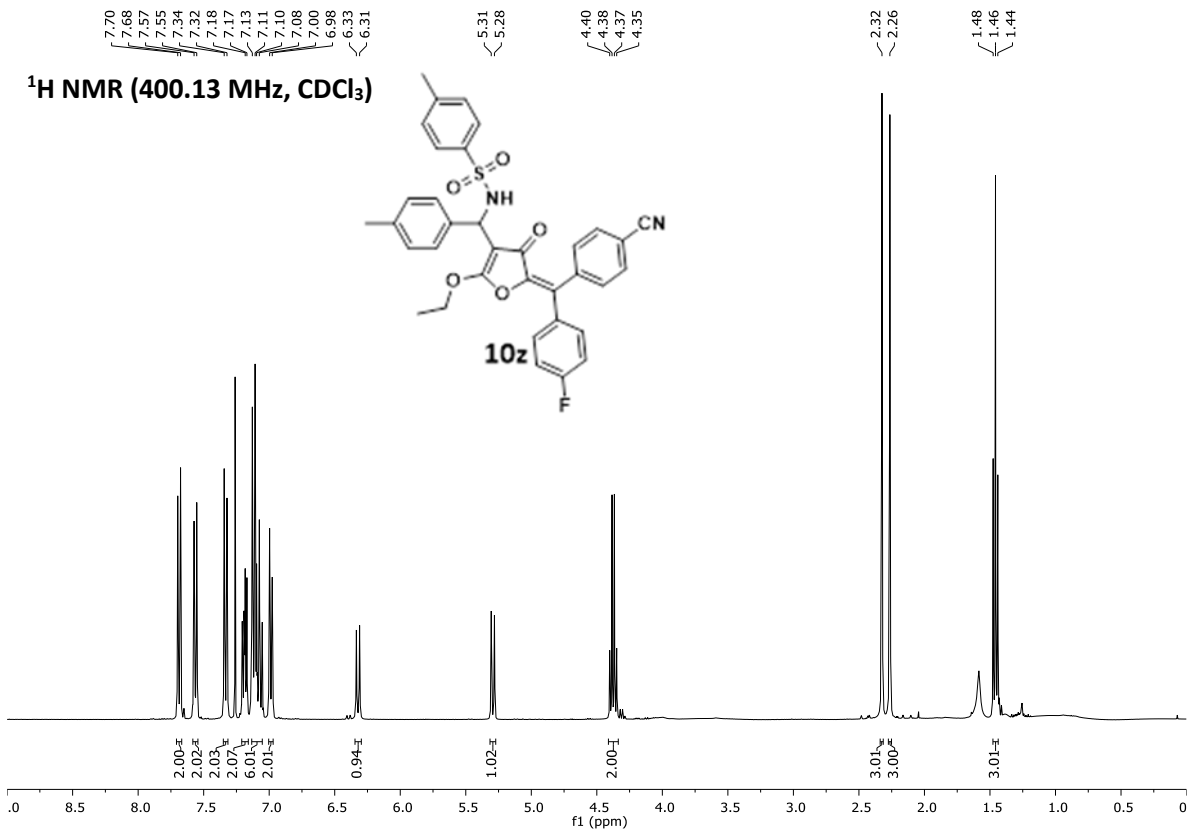
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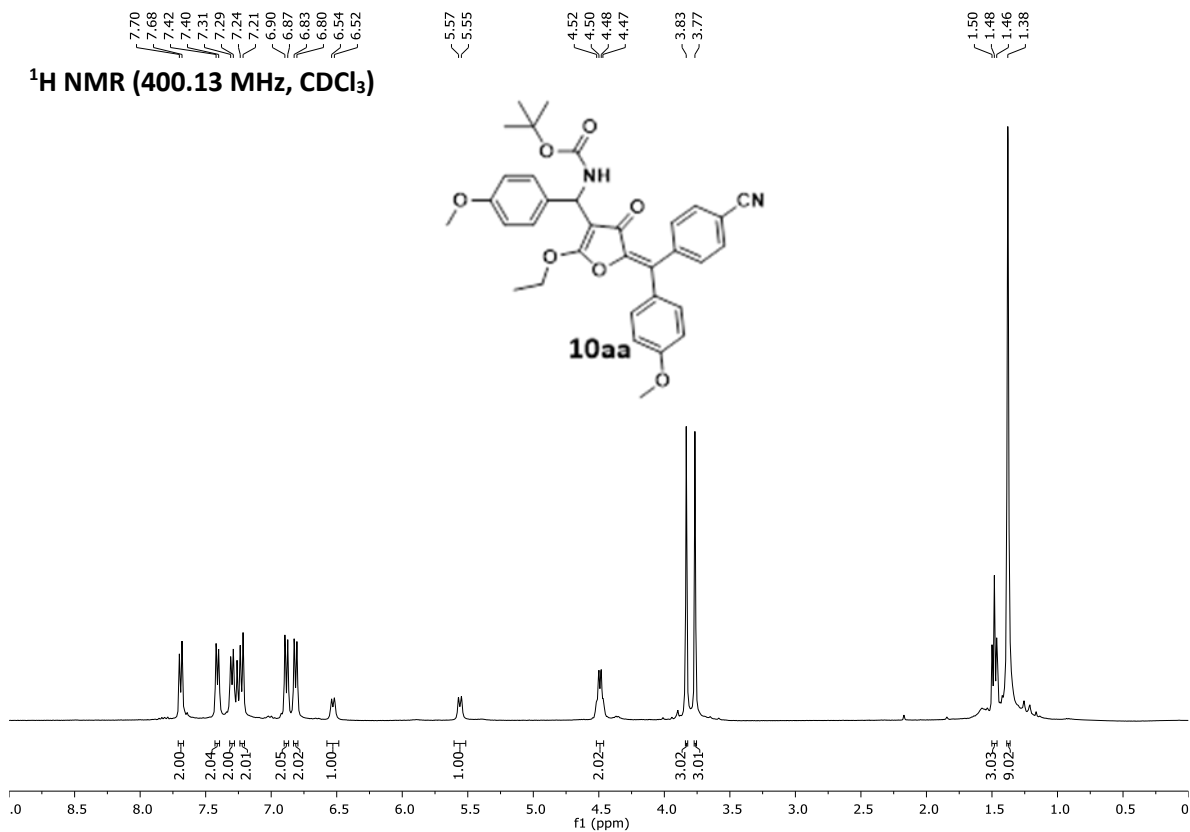
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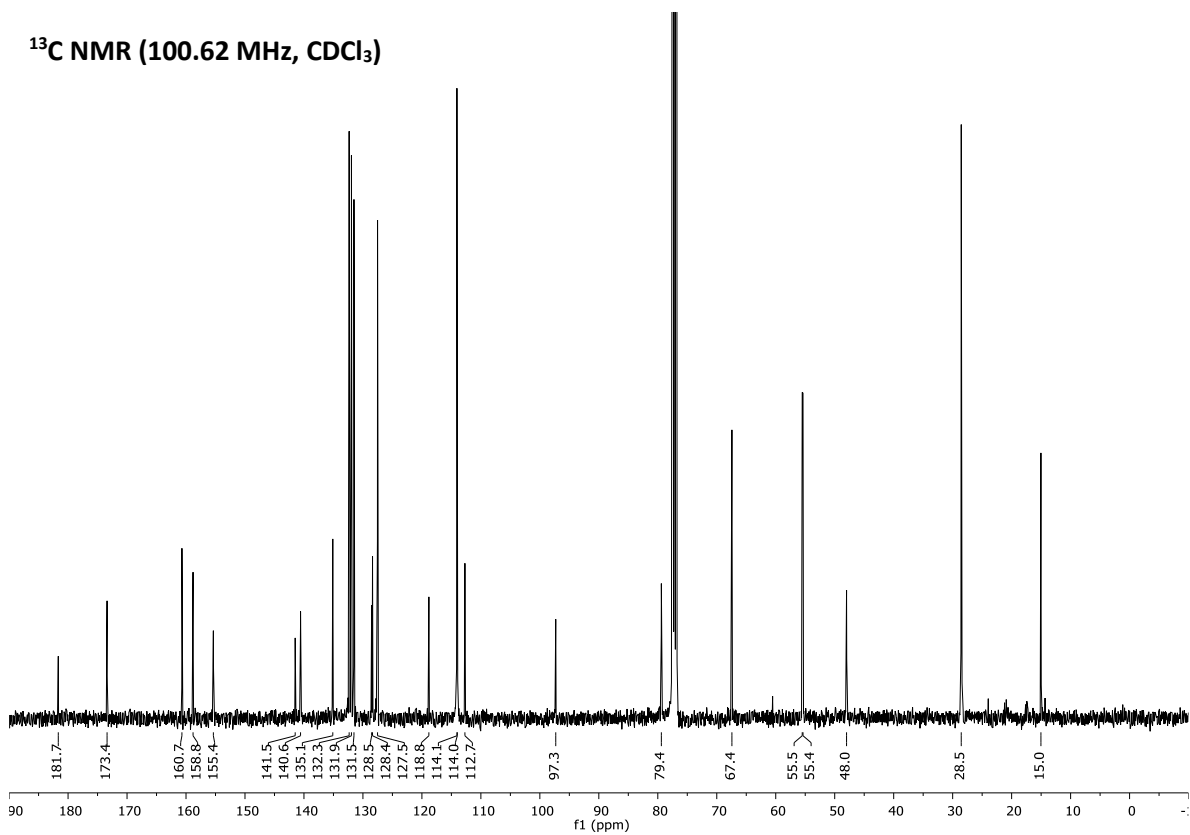




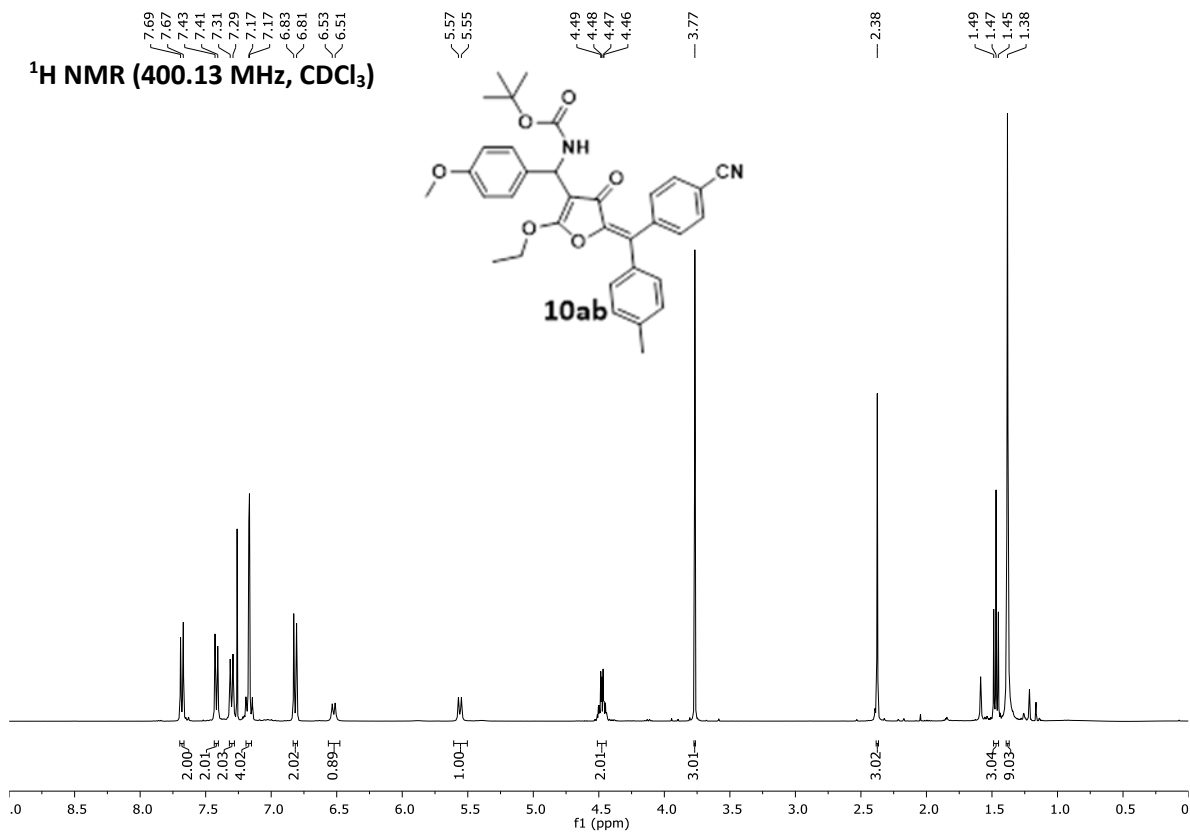
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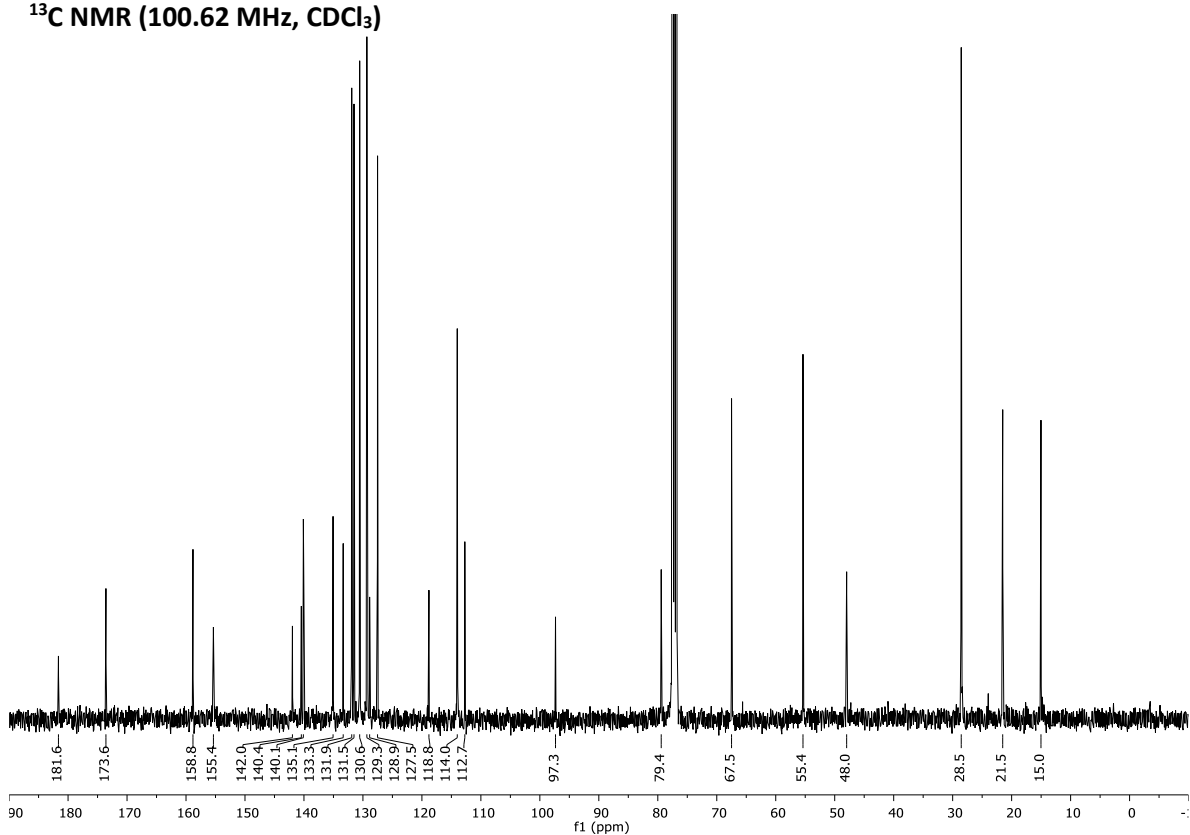
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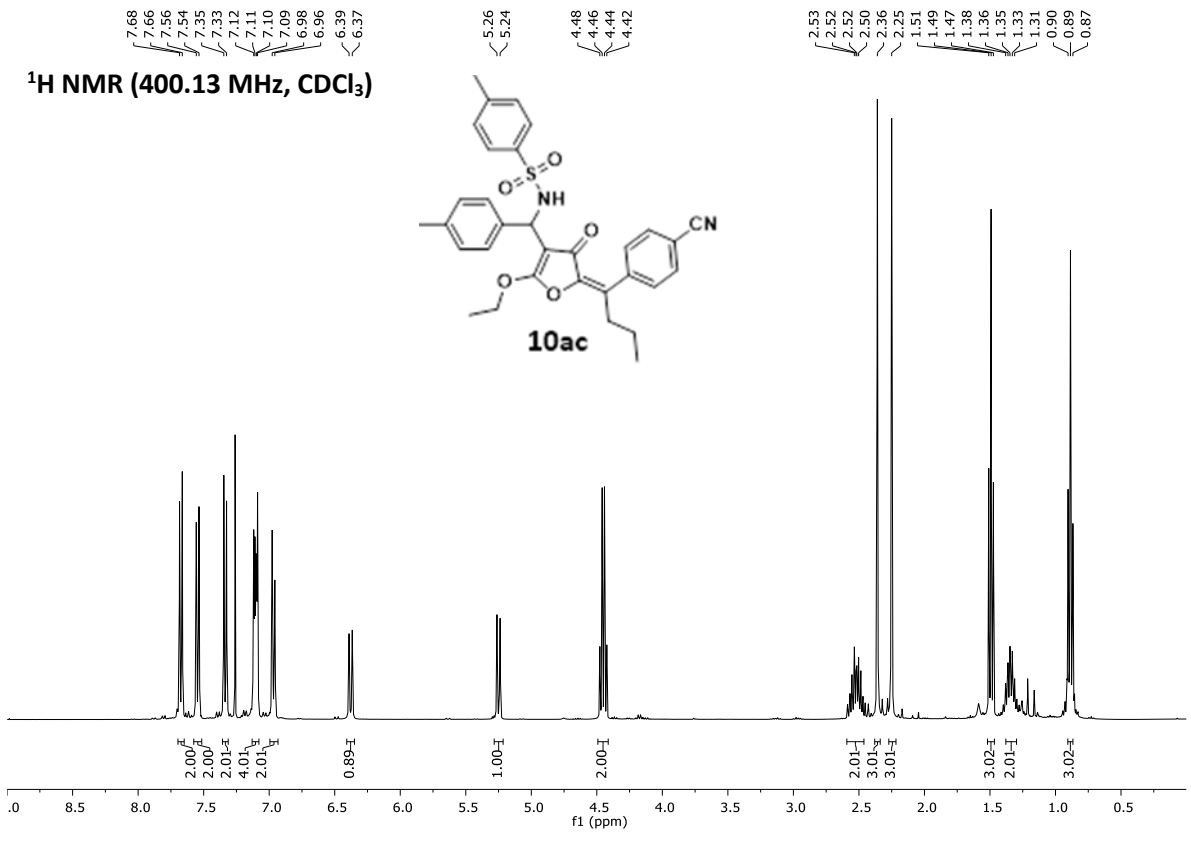
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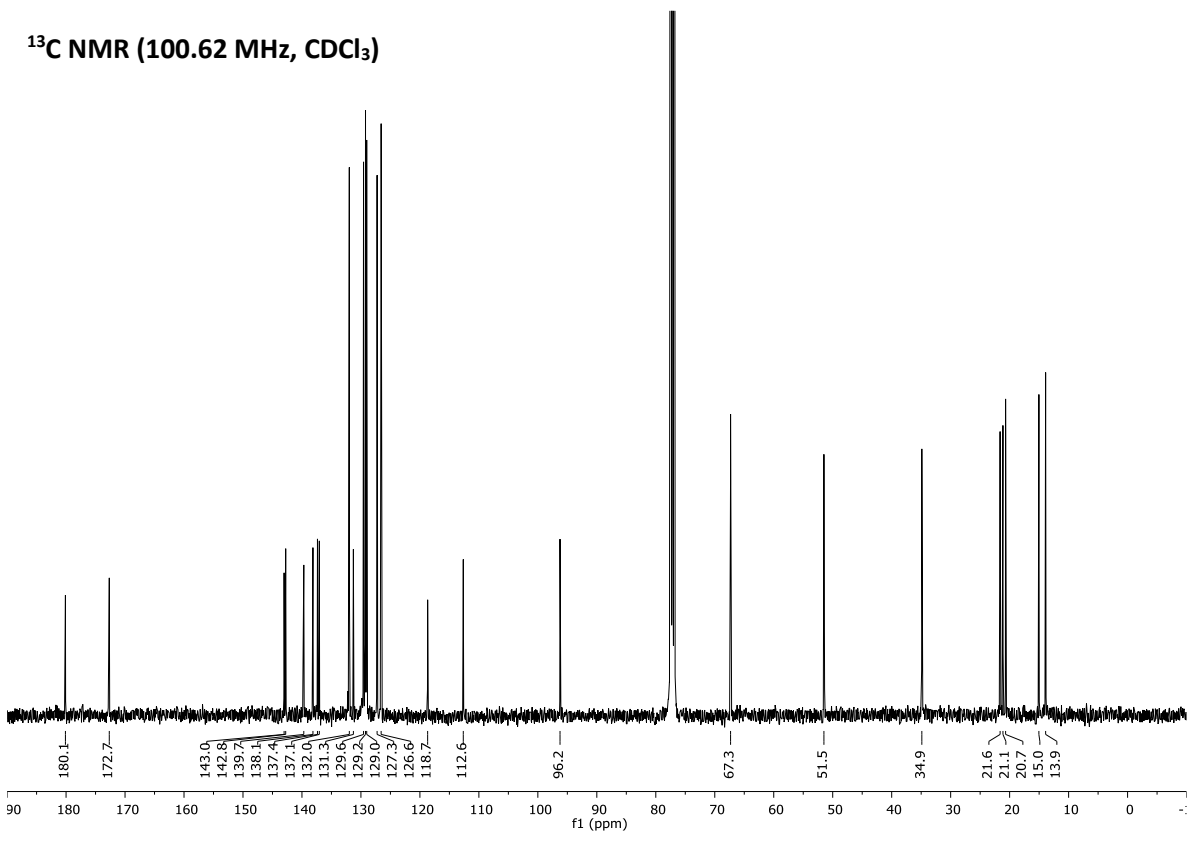
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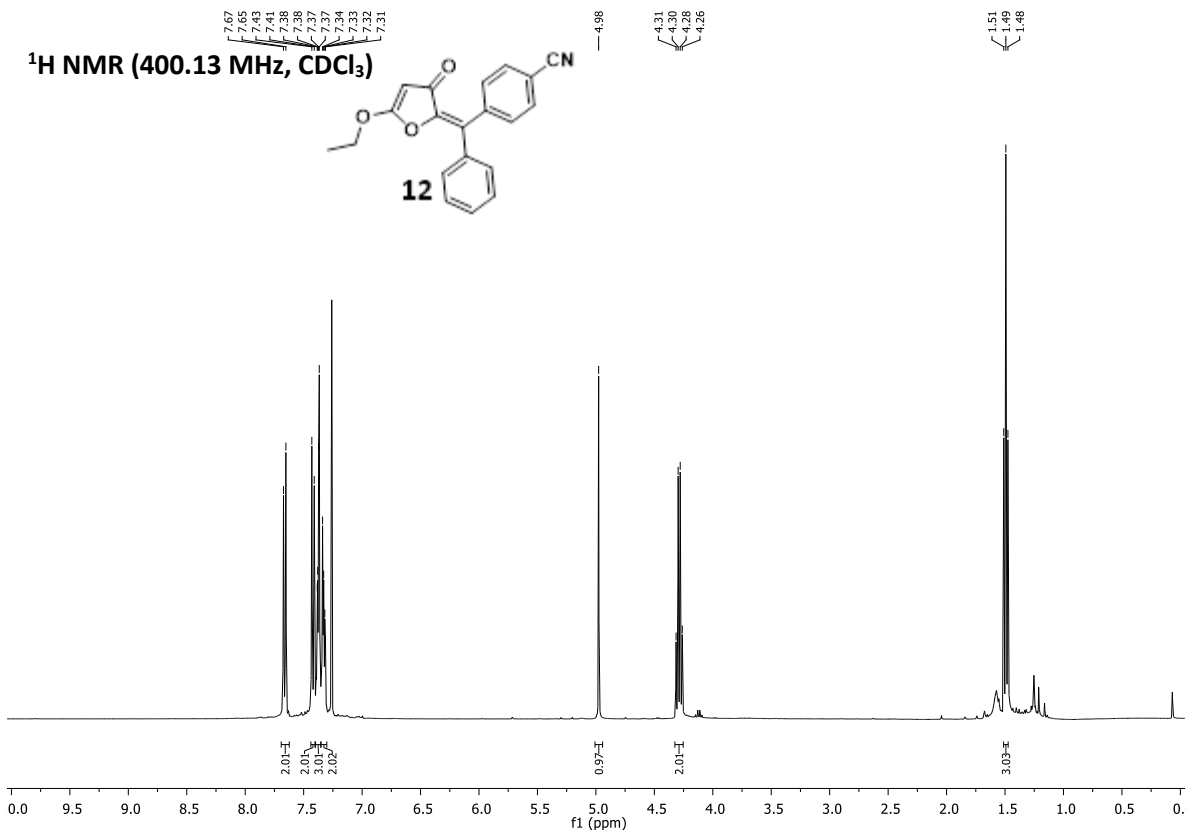
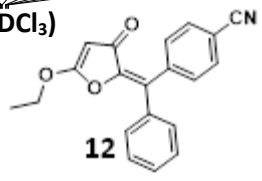
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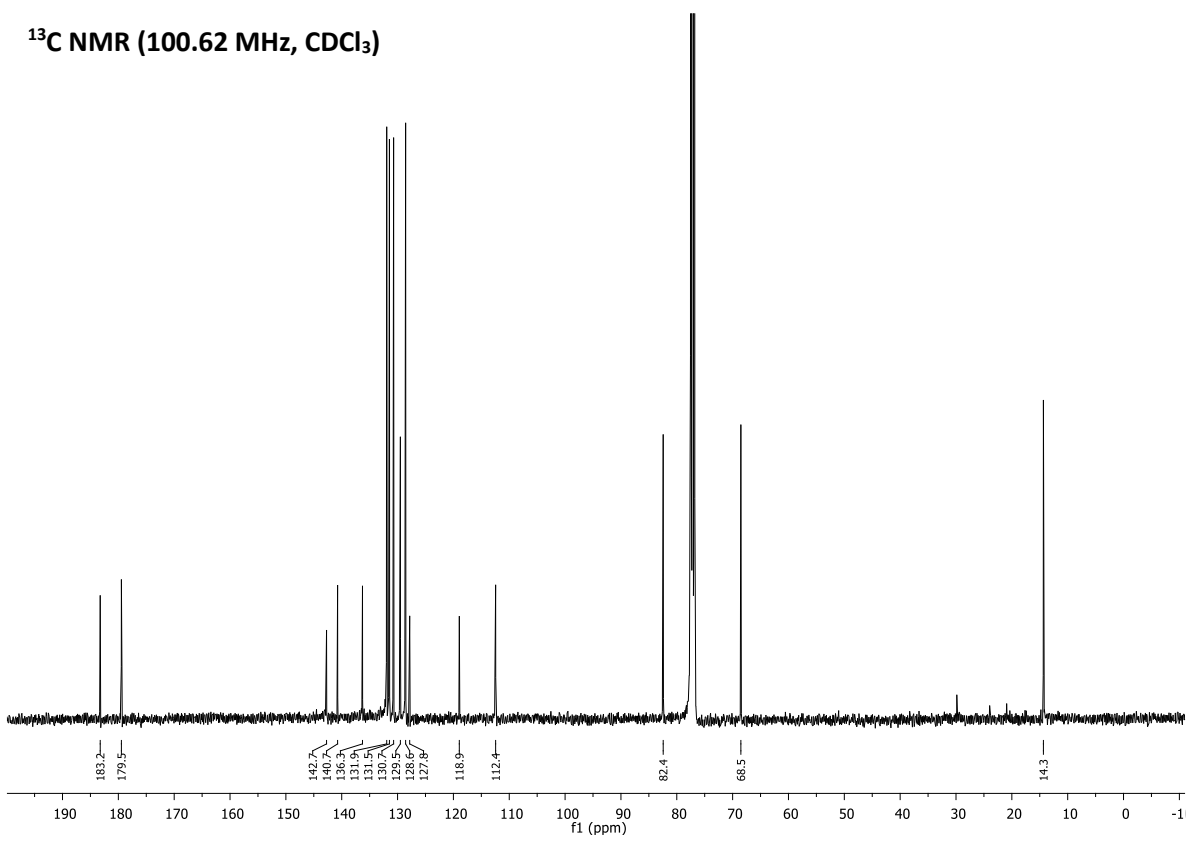
¹³C NMR (100.62 MHz, CDCl₃)



¹H NMR (400.13 MHz, CDCl₃)



¹³C NMR (100.62 MHz, CDCl₃)



Crystallographic data for compound **10a**

The single crystal of **10a** (CCDC 1958641) was prepared by diffusing of petroleum ether into an AcOEt solution of **10a**.

ORTEP drawing of **10a** showing thermal ellipsoids at the 50% probability level (crystal size 0.620 x 0.065 x 0.035 mm³).

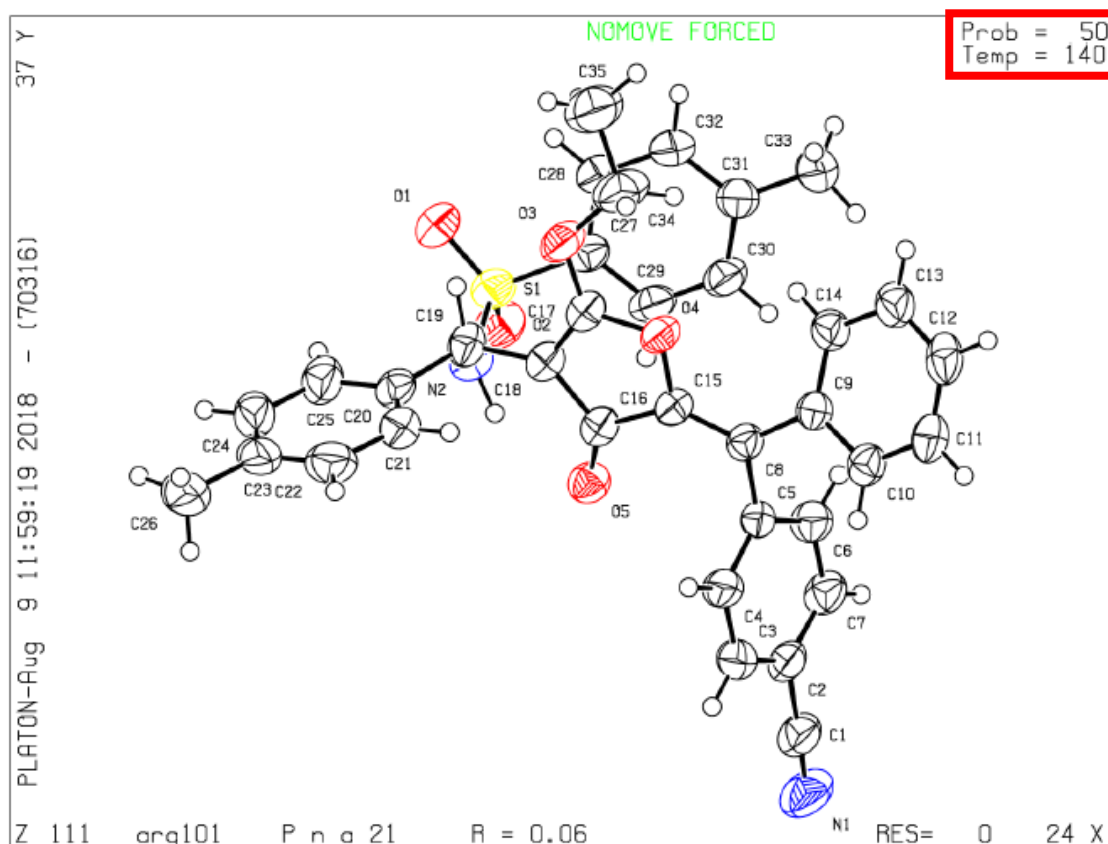


Table 1. Crystal data and structure refinement for **10a**.

Identification code	arg101
Empirical formula	C ₃₅ H ₃₀ N ₂ O ₅ S
Formula weight	590.67
Temperature	140.00(10) K
Wavelength	1.54184 Å
Crystal system	Orthorhombic
Space group	<i>Pna</i> 2 ₁

Unit cell dimensions	a = 21.6768(11) Å	$\alpha = 90^\circ$
	b = 14.8818(6) Å	$\beta = 90^\circ$
	c = 9.1734(4) Å	$\gamma = 90^\circ$
Volume	2959.2(2) Å ³	
Z	4	
Density (calculated)	1.326 Mg/m ³	
Absorption coefficient	1.352 mm ⁻¹	
F(000)	1240	
Crystal size	0.620 x 0.065 x 0.035 mm ³	
Q range for data collection	3.603 to 75.229°	
Index ranges	-27 ≤ h ≤ 26, -18 ≤ k ≤ 18, -10 ≤ l ≤ 11	
Reflections collected	20498	
Independent reflections	5073 [$R_{\text{int}} = 0.0665$]	
Completeness to $\theta = 67.684^\circ$	100.0 %	
Absorption correction	Semi-empirical from equivalents	
Max. and min. transmission	1.00000 and 0.28920	
Refinement method	Full-matrix least-squares on F ²	
Data / restraints / parameters	5073 / 2 / 395	
Goodness-of-fit on F ²	1.050	
Final R indices [$I > 2s(I)$]	$R_1 = 0.0614$, $wR_2 = 0.1529$	
R indices (all data)	$R_1 = 0.0812$, $wR_2 = 0.1676$	
Absolute structure parameter	-0.03(4)	
Largest diff. peak and hole	0.400 and -0.407 e.Å ⁻³	