ELECTRONIC SUPPORTING INFORMATION FOR

# In situ generation of imines by Staudinger/aza-Wittig tandem combined with thermally induced Wolff rearrangement for one-pot three-component lactam synthesis

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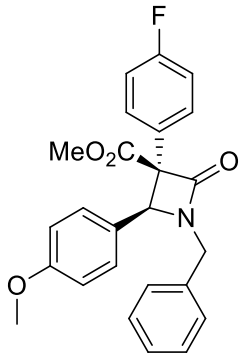
## General information

NMR spectra were acquired with 400 MHz Bruker Avance III spectrometer (400.13 MHz for $^{1}H$, 100.61 MHz for $^{13}C$ and 376.50 MHz for $^{19}F$) in $CDCl_3$ or DMSO-$d_6$ and were referenced to residual solvent proton signals ($\delta_H$ = 7.26 and 2.50, respectively) and solvent carbon signals ($\delta_C$ = 77.16 and 39.52, respectively). Melting points were determined with RD-MP (REACH Devices) melting point apparatus in open capillary tubes. Mass spectra were acquired with HRMS-ESI-qTOF spectrometer Nexera LCMS-9030 or MaXis II Bruker Daltonic GmbH (electrospray ionization mode, positive ions detection). TLC was performed on aluminium-backed pre-coated plates (0.25 mm) with silica gel 60 F254 with a suitable solvent system and was visualized using UV fluorescence. Preparative HPLC was carried out on compact preparative system ECOM ECS28P00, equipped with spectrophotometric detector. Column: YMC-Pack SIL-06, 5 µm, 250×20 mm. Some compounds were additionally purified by RP HPLC on Shimadzu LC-20AP. Column: Agilent Zorbax prepHT XDB-C18, 5 µm, 21.2 × 150 mm. Toluene was dried over molecular sieves 4Å (>24h). Aldehydes, $PPh_3$ and other solvents were obtained from commercial sources and were used without further purification. All diazo reagents were prepared *via* "SAFE" protocol [1]. All azides except new ones were synthesized *via* known literature protocols [2,3] and their NMR spectra are in accordance with the literature. Azides **7b-i** are new and have been fully characterized (*vide infra*).

## General procedure for preparation of *beta*-lactams 4 and dihydro-1,3-oxazines 5 and their analytical data

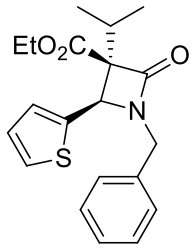
In a screw-cap vial equipped with a magnetic stir bar azide **1** (0.5 mmol) and $PPh_3$ (0.5 mmol) were mixed in 1 mL of toluene. Then corresponding aldehyde **2** (0.5 mmol) was added. The resulting mixture was placed in a pre-heated to 110 °C oil bath or melt heating block for 2 hours. After this time diazo reagent **3** (0.5; 0.75 or 1 mmol) was added and the mixture was stirred for additional 3 hours at 130 °C. After that the solvent was evaporated. Obtained oils were purified by column chromatography eluting with Hexane/Acetone (linear gradient 5-50% of acetone, total volume 500 mL) to give pure compounds **4a-g, 4j or 5a,b,b'**. *Beta*-lactams **4h,i** were additionally purified by RP-HPLC (ACN-water + 0.1% TFA; gradient 5-50% of ACN in 20 min, then 50-95% of ACN in 40 min; 45 °C; 12 mL/min).

**(2*RS*,3*RS*)-Methyl 1-benzyl-3-(4-fluorophenyl)-2-(4-methoxyphenyl)-4-oxoazetidine-3-carboxylate (4a)**



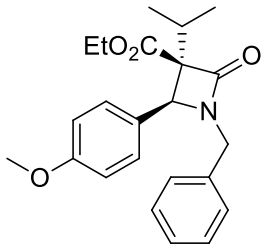

Yield 126 mg, 60% with 0.5 mmol of diazo reagent; 160 mg, 76% with 0.75 mmol of diazo reagent; 193 mg, 92% with 1 mmol of diazo reagent; light yellow oil. $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.68 – 7.60 (m, 2H), 7.29 – 7.18 (m, 5H), 7.10 – 7.01 (m, 4H), 6.94 (d, *J* = 8.7 Hz, 2H), 4.97 (d, *J* = 15.0 Hz, 1H), 4.66 (s, 1H), 3.96 (d, *J* = 15.0 Hz, 1H), 3.82 (s, 3H), 3.37 (s, 3H). $^{13}$C{$^{1}$H} NMR (101 MHz, $CDCl_3$) δ 167.7, 164.9, 162.7 (d, *J* = 247.6 Hz), 160.4, 134.8, 130.7 (d, *J* = 3.3 Hz), 129.4 (d, *J* = 8.2 Hz), 128.9, 128.5, 128.4, 128.0, 125.5, 115.7 (d, *J* = 21.5 Hz), 114.34, 73.4, 66.1, 55.4, 52.4, 44.6. $^{19}$F{$^{1}$H} NMR (376 MHz, $CDCl_3$) δ -113.4. HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{25}H_{23}FNO_4^+$ 420.1606; Found 420.1605.

**(2*RS*,3*RS*)-Ethyl 1-benzyl-3-isopropyl-2-oxo-4-(thiophen-2-yl)azetidine-3-carboxylate (4b)**



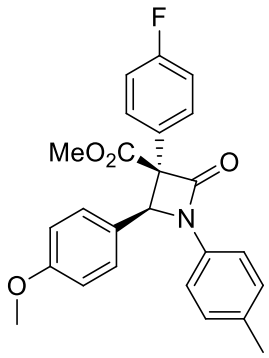

Yield 143 mg, 80% with 0.75 mmol of diazo reagent; light yellow oil. $^{1}$H NMR (400 MHz, $CDCl_3$ + DMSO-$d_6$) δ 7.31 – 7.23 (m, 4H), 7.16 – 7.10 (m, 2H), 7.01 – 6.96 (m, 1H), 6.96 – 6.92 (m, 1H), 4.86 (d, *J* = 14.8 Hz, 1H), 4.55 (s, 1H), 3.90 (d, *J* = 14.7 Hz, 1H), 3.84 (q, *J* = 7.1 Hz, 2H), 2.37 – 2.19 (m, 1H), 1.07 (d, *J* = 6.9 Hz, 3H), 1.03 – 0.95 (m, 6H). $^{13}$C{$^{1}$H} NMR (101 MHz, $CDCl_3$ + DMSO-$d_6$) δ 167.6, 165.1, 137.8, 134.7, 128.6, 127.7, 127.0, 126.2, 125.6, 75.5, 60.6, 56.7, 44.0, 30.5, 18.9, 17.2, 13.5. HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{20}H_{24}NO_3S^+$ 358.1471; Found 358.1471.

**(2*RS*,3*RS*)-Ethyl 1-benzyl-3-isopropyl-2-(4-methoxyphenyl)-4-oxoazetidine-3-carboxylate (4c)**



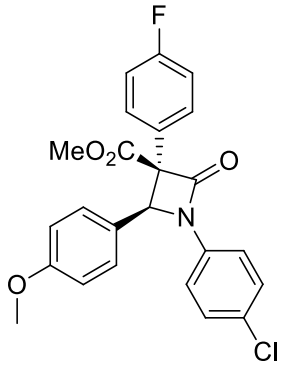

Yield 143 mg, 75% with 0.75 mmol of diazo reagent; light yellow oil. $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.33 – 7.23 (m, 3H), 7.19 – 7.09 (m, 4H), 6.87 (d, *J* = 8.7 Hz, 2H), 4.94 (d, *J* = 14.6 Hz, 1H), 4.28 (s, 1H), 3.80 (s, 3H), 3.84 – 3.73 (m, 3H), 2.30 (hept, *J* = 6.8 Hz, 1H), 1.10 (d, *J* = 6.8 Hz, 3H), 1.02 (d, *J* = 6.8 Hz, 3H), 0.97 (t, *J* = 7.2 Hz, 3H). $^{13}$C{$^{1}$H} NMR (101 MHz, $CDCl_3$) δ 168.3, 166.0, 160.0, 135.4, 129.1, 128.9, 128.5, 128.0, 126.7, 114.1, 75.5, 61.0, 60.9, 55.4, 44.4, 31.1, 19.5, 17.7, 14.0. HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{23}H_{28}NO_4^+$ 382.2013; Found 382.2013.

**(2*RS*,3*RS*)-Methyl 3-(4-fluorophenyl)-2-(4-methoxyphenyl)-4-oxo-1-(*p*-tolyl)azetidine-3-carboxylate (4d)**



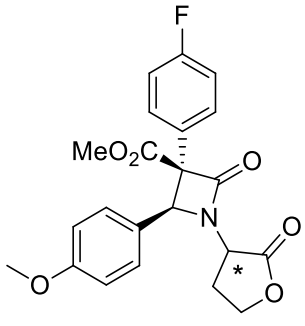
Yield 96 mg, 46% with 0.5 mmol of diazo reagent; 126 mg, 60% with 0.75 mmol of diazo reagent; light yellow solid; m.p. 165-167 °C. $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.81 – 7.70 (m, 1H), 7.34 (d, *J* = 8.7 Hz, 1H), 7.23 (d, *J* = 8.5 Hz, 1H), 7.11 (t, *J* = 8.7 Hz, 1H), 7.06 (d, *J* = 8.2 Hz, 1H), 6.92 (d, *J* = 8.8 Hz, 1H), 5.28 (s, 0H), 3.81 (s, 2H), 3.35 (s, 2H), 2.27 (s, 2H). $^{13}$C{$^{1}$H} NMR (101 MHz, $CDCl_3$) δ 167.5, 162.83 (d, *J* = 247.9 Hz), 161.7, 160.4, 134.7, 134.3, 130.7 (d, *J* = 3.3 Hz), 129.7, 129.6 (d, *J* = 8.2 Hz), 128.4, 125.4, 117.5, 115.80 (d, *J* = 21.6 Hz), 114.4, 72.5, 66.4, 55.4, 52.5, 21.0. $^{19}$F{$^{1}$H} NMR (376 MHz, $CDCl_3$) δ -113.1. HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{25}H_{22}FNO_4Na^+$ 422.1425; Found 422.1426.

**(2*RS*,3*RS*)-Methyl 1-(4-chlorophenyl)-3-(4-fluorophenyl)-2-(4-methoxyphenyl)-4-oxoazetidine-3-carboxylate (4e)**



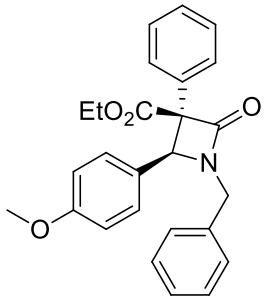
Yield 86 mg, 39% with 0.5 mmol of diazo reagent; 125 mg, 57% with 0.75 mmol of diazo reagent; light yellow solid; m.p. 195-197 °C. $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.83 – 7.67 (m, 2H), 7.36 – 7.19 (m, 6H), 7.12 (t, *J* = 8.6 Hz, 2H), 6.93 (d, *J* = 8.7 Hz, 2H), 5.29 (s, 1H), 3.82 (s, 3H), 3.36 (s, 3H). $^{13}$C{$^{1}$H} NMR (101 MHz, $CDCl_3$) δ 167.2, δ 162.9 (d, *J* = 248.4 Hz), 161.9, 160.5, 135.6, 130.4 (d, *J* = 3.3 Hz), 129.8, 129.5 (d, *J* = 8.2 Hz), 129.3, 128.3, 124.8, 118.8, 115.9 (d, *J* = 21.6 Hz), 114.6, 72.8, 66.5, 55.4, 52.6. $^{19}$F{$^{1}$H} NMR (376 MHz, $CDCl_3$) δ -112.8. HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{24}H_{19}ClFNO_4Na^+$ 462.0879; Found 462.0877.

**(2RS,3RS)-Methyl 3-(4-fluorophenyl)-2-(4-methoxyphenyl)-4-oxo-1-(2-oxotetrahydrofuran-3-yl)azetidine-3-carboxylate (4f)**



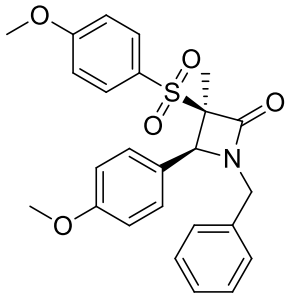
Yield 136 mg, 66% with 0.5 mmol of diazo reagent; 65% with 0.75 mmol of diazo reagent, *dr* 86:14; light yellow oil. Signals of major isomer: $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.67 – 7.60 (m, 2H), 7.33 (d, *J* = 8.7 Hz, 2H), 7.08 (t, *J* = 8.7 Hz, 2H), 6.96 (d, *J* = 8.8 Hz, 2H), 5.18 (s, 1H), 4.51 (td, *J* = 8.9, 2.8 Hz, 1H), 4.27 – 4.17 (m, 1H), 3.97 (t, *J* = 10.5, 9.1 Hz, 1H), 3.82 (s, 3H), 3.38 (s, 3H), 3.17 – 3.02 (m, 1H), 2.68 – 2.55 (m, 1H). $^{13}$C{$^{1}$H} NMR (101 MHz, $CDCl_3$) δ 172.8, 167.4, 165.0, 162.8 (d, *J* = 248.1 Hz), 160.7, 130.1 (d, *J* = 3.2 Hz), 129.4 (d, *J* = 8.2 Hz), 128.6, 125.3, 115.8 (d, *J* = 21.6 Hz), 114.6, 73.5, 67.7, 66.2, 55.5, 52.6, 51.4, 26.7. $^{19}$F{$^{1}$H} NMR (376 MHz, $CDCl_3$) δ -113.27. HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{22}H_{20}FNO_6Na^+$ 436.1167; Found 436.1165.

**(2*RS*,3*RS*)-Ethyl 1-benzyl-2-(4-methoxyphenyl)-4-oxo-3-phenylazetidine-3-carboxylate (4g)**



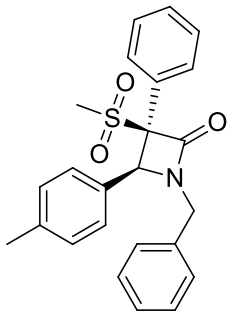
Yield 110 mg, 53% with 0.5 mmol of diazo reagent; light yellow oil. $^1$H NMR (400 MHz, $CDCl_3$) δ 7.64 (d, *J* = 6.8 Hz, 2H), 7.41 – 7.30 (m, 5H), 7.27 (d, *J* = 8.9 Hz, 2H), 7.24 – 7.17 (m, 3H), 7.10 – 7.02 (m, 2H), 6.92 (d, *J* = 8.7 Hz, 2H), 4.96 (d, *J* = 15.0 Hz, 1H), 4.74 (s, 1H), 3.96 (d, *J* = 15.0 Hz, 1H), 3.83 (s, 3H), 3.79 – 3.76 (m, 2H), 0.93 (t, *J* = 7.1 Hz, 3H). $^{13}$C{$^1$H} NMR (101 MHz, $CDCl_3$) δ 167.3, 165.2, 160.3, 135.1, 128.9, 128.7, 128.7, 128.5, 128.2, 127.9, 127.6, 126.0, 114.3, 74.1, 65.8, 61.6, 55.5, 44.6, 13.8. HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{26}H_{25}NO_4Na^+$ 438.1674; Found 438.1674.

**(3*RS*,4*RS*)-1-Benzyl-4-(4-methoxyphenyl)-3-((4-methoxyphenyl)sulfonyl)-3-methylazetidin-2-one (4h)**



Yield 70 mg, 31% with 0.5 mmol of diazo reagent, 122 mg, 54% with 0.75 mmol of diazo reagent, 135 mg; white solid; m.p. 172-174 °C. $^1$H NMR (400 MHz, $CDCl_3$) δ 7.59 (d, *J* = 8.9 Hz, 2H), 7.30 – 7.23 (m, 5H), 7.13 – 7.06 (m, 2H), 6.92 – 6.84 (m, 4H), 4.95 (d, *J* = 14.8 Hz, 1H), 4.38 (s, 1H), 4.01 (d, *J* = 14.8 Hz, 1H), 3.83 (s, 3H), 3.82 (s, 3H), 1.53 (s, 3H). $^{13}$C{$^1$H} NMR (101 MHz, $CDCl_3$) δ 164.3, 163.9, 160.1, 134.6, 131.7, 130.2, 129.1, 129.0, 128.5, 128.1, 123.2, 114.0, 113.6, 79.1, 77.4, 77.1, 76.7, 65.8, 55.6, 55.3, 45.0, 17.7. HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{25}H_{25}NO_5SNa^+$ 474.1346; Found 474.1346.

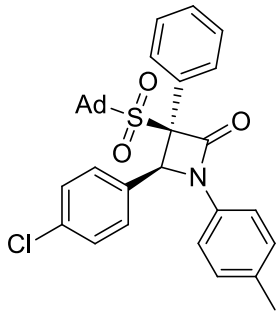
**(3*RS*,4*RS*)-1-Benzyl-3-(methylsulfonyl)-3-phenyl-4-(*p*-tolyl)azetidin-2-one (4i)**



Yield 109 mg, 54 % with 0.75 mmol of diazo reagent; light yellow oil. $^1$H NMR (400 MHz, $CDCl_3$) δ 7.70 – 7.54 (m, 2H), 7.32 – 7.20 (m, 5H), 7.10 – 7.02 (m, 3H), 7.03 – 6.96 (m, 2H), 6.91 – 6.80 (m, 2H), 4.83 (d, *J* = 15.1 Hz, 1H), 4.66 (s, 1H), 3.96 (d, *J* = 15.1 Hz, 1H), 2.39 (s, 3H), 2.19 (s, 3H). $^{13}$C{$^1$H} NMR (101 MHz, $CDCl_3$) δ 162.5, 139.4, 134.2, 132.0, 129.8, 129.2, 129.2, 129.0, 128.9, 128.5, 128.3, 128.1, 127.3, 83.9, 67.1, 45.2, 40.1, 21.4. HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{24}H_{23}NO_3SNa^+$ 428.1291; Found 428.1296.

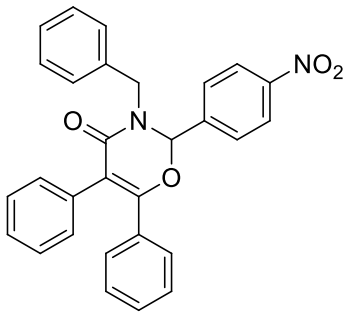
**(3*RS*,4*RS*)-3-(Adamantan-1-ylsulfonyl)-4-(4-chlorophenyl)-3-phenyl-1-(*p*-tolyl)azetidin-2-one (4j)**

Yield 124 mg, 45 % with 0.75 mmol of diazo reagent; light yellow oil. $^1$H NMR (400 MHz, $CDCl_3$) δ 8.04 – 7.95 (m, 2H), 7.56 (d, *J* = 8.2 Hz, 2H), 7.52 – 7.41 (m, 3H), 7.37 (d, *J* = 8.1 Hz, 2H), 7.16 (d, *J* = 8.5 Hz, 2H), 7.07 (d, *J* = 8.4 Hz, 2H), 5.28 (s, 1H), 2.27 (s, 3H), 2.10 – 2.01 (m, 3H), 1.99



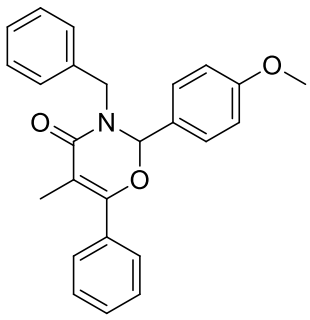
– 1.90 (m, 3H), 1.55 (d, *J* = 13.5 Hz, 4H), 1.51 – 1.41 (m, 6H). $^{13}C\{^{1}H\}$ NMR (101 MHz, $CDCl_3$) δ 158.6, 135.2, 134.8, 134.1, 132.6, 131.1, 130.0, 129.8, 129.6, 128.8, 128.4, 117.8, 85.8, 77.4, 69.8, 69.6, 35.7, 35.2, 28.8, 21.0. HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{32}H_{32}ClNO_3SNa^+$ 568.1684; Found 568.1661.

**3-Benzyl-2-(4-nitrophenyl)-5,6-diphenyl-2*H*-1,3-oxazin-4(3*H*)-one (5a)**



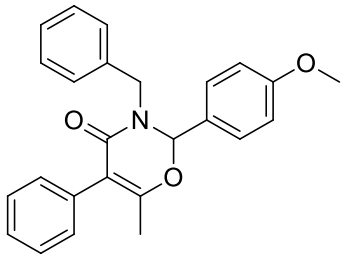
Yield 105 mg, 48% with 0.75 mmol of diazo reagent; light yellow solid; m.p. 162-164 °C. $^{1}H$ NMR (400 MHz, $CDCl_3$) δ 8.24 (d, *J* = 8.8 Hz, 2H), 7.62 (d, *J* = 8.7 Hz, 2H), 7.32 – 7.27 (m, 5H), 7.25 – 7.19 (m, 5H), 7.16 – 7.09 (m, 5H), 6.43 (s, 1H), 5.32 (d, *J* = 15.3 Hz, 1H), 4.24 (d, *J* = 15.4 Hz, 1H). $^{13}C\{^{1}H\}$ NMR (101 MHz, $CDCl_3$) δ 163.1, 158.0, 148.7, 142.9, 136.2, 132.9, 132.2, 131.4, 130.3, 129.8, 128.9, 128.5, 128.1, 128.0, 127.9, 127.5, 123.8, 113.9, 86.3, 47.8. HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{29}H_{23}N_2O_4^+$ 463.1652; Found 463.1655.

**3-Benzyl-2-(4-methoxyphenyl)-5-methyl-6-phenyl-2*H*-1,3-oxazin-4(3*H*)-one (5b)**



Yield 51 mg, 26% with 0.5 mmol of diazo reagent; yellow oil. $^{1}H$ NMR (400 MHz, $CDCl_3$) δ 7.37 – 7.31 (m, 2H), 7.31 – 7.22 (m, 8H), 7.20 – 7.15 (m, 2H), 6.89 (d, *J* = 8.7 Hz, 2H), 6.11 (s, 1H), 5.30 (d, *J* = 15.3 Hz, 1H), 3.91 (d, *J* = 15.3 Hz, 1H), 3.84 (s, 3H), 1.80 (s, 3H). $^{13}C\{^{1}H\}$ NMR (101 MHz, $CDCl_3$) δ 163.4, 161.2, 160.6, 137.1, 133.7, 130.9, 129.0, 128.5, 128.1, 128.0, 127.8, 127.4, 127.2, 113.9, 113.6, 87.2, 55.4, 46.8, 18.5. HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{25}H_{24}NO_3^+$ 386.1751; Found 386.1748.

**3-Benzyl-2-(4-methoxyphenyl)-6-methyl-5-phenyl-2*H*-1,3-oxazin-4(3*H*)-one (5b')**

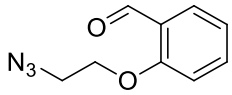


Yield 71 mg, 38% with 0.5 mmol of diazo reagent; yellow oil. $^{1}H$ NMR (400 MHz, $CDCl_3$) δ 7.39 – 7.30 (m, 5H), 7.30 – 7.20 (m, 5H), 7.20 – 7.15 (m, 2H), 6.87 (d, *J* = 8.7 Hz, 2H), 6.13 (s, 1H), 5.32 (d, *J* = 15.4 Hz, 1H), 3.91 (d, *J* = 15.4 Hz, 1H), 3.79 (s, 3H), 1.98 (s, 3H). $^{13}C\{^{1}H\}$ NMR (101 MHz, $CDCl_3$) δ 165.6, 160.6, 157.1, 137.1, 133.3, 130.0, 129.2, 129.1, 128.6, 128.2, 127.9, 127.6, 127.5, 114.0, 106.9, 87.1, 55.4, 46.8, 12.2. HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{25}H_{24}NO_3^+$ 386.1751; Found 386.1757.

**General procedure for preparation of azides 7a-g and their analytical data**

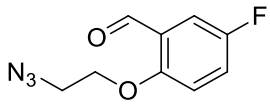
Corresponding salicylic aldehyde (1.05 mmol), 2-azidoethyl methanesulfonate (1 mmol) and $K_2CO_3$ (1.05 mmol) were mixed in DMF (3 mL) and stirred at 50 °C. Reaction progress was controlled by TLC. Solvent of the resulting mixture was evaporated, residue was diluted with water and extracted with DCM. Combined organic layers were washed with NaOH (3%), water, brine, dried over anhydrous $Na_2SO_4$ and solvent was removed under reduced pressure to give pure compounds **7a-g**.

**2-(2-Azidoethoxy)benzaldehyde (7a)**



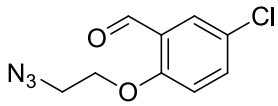
Yield 168 mg, 88%; yellow amorphous solid. $^1$H NMR (400 MHz, $CDCl_3$) δ 10.52 (s, 1H), 7.91 – 7.81 (m, 1H), 7.63 – 7.48 (m, 1H), 7.08 (t, *J* = 7.5 Hz, 1H), 6.97 (d, *J* = 8.4 Hz, 1H), 4.27 (t, *J* = 4.9 Hz, 2H), 3.68 (t, *J* = 4.9 Hz, 2H). $^{13}$C{$^1$H} NMR (101 MHz, $CDCl_3$) δ 189.4, 160.5, 136.0, 128.7, 125.2, 121.6, 112.5, 67.6, 50.3. HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_9H_{10}N_3O_2$ 192.0773; Found 192.0772.

**2-(2-Azidoethoxy)-5-fluorobenzaldehyde (7b)**



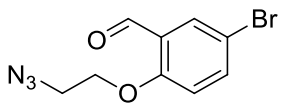
Yield 184 mg, 88%; brown amorphous solid. $^1$H NMR (400 MHz, $CDCl_3$) δ 10.45 (d, *J* = 3.1 Hz, 1H), 7.58 – 7.47 (m, 1H), 7.31 – 7.19 (m, 1H), 7.00 – 6.91 (m, 1H), 4.25 (t, 2H), 3.68 (t, 2H). $^{13}$C{$^1$H} NMR (101 MHz, $CDCl_3$) δ 188.4, 188.3, 158.7, 156.8, 156.8, 156.2, 126.1, 126.0, 122.7, 122.4, 114.5, 114.3, 114.2, 68.3, 50.3. $^{19}$F{$^1$H} NMR (376.5 MHz, $CDCl_3$) δ -121.32. HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_9H_8N_3O_2FNa$ 232.0498; Found 232.0495.

**2-(2-Azidoethoxy)-5-chlorobenzaldehyde (7c)**



Yield 210 mg, 93%; yellow amorphous solid. $^1$H NMR (400 MHz, CDCl3) δ 10.43 (s, 1H), 7.81 (d, J = 2.7 Hz, 1H), 7.49 (dd, J = 8.9, 2.7 Hz, 1H), 6.93 (d, J = 8.9 Hz, 1H), 4.25 (t, J = 4.9 Hz, 2H), 3.68 (t, J = 4.9 Hz, 2H). $^{13}$C{$^1$H} NMR (101 MHz, CDCl3) δ 188.1, 159.0, 135.5, 128.3, 127.4, 126.1, 114.2, 68.1, 50.3. HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_9H_8ClN_3NaO_2$ 248.0197/250.0168; Found 248.0196/250.0168.

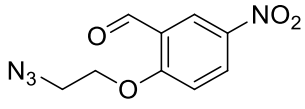
**2-(2-Azidoethoxy)-5-bromobenzaldehyde (7d)**



Yield 250 mg, 93%; yellow amorphous solid. $^1$H NMR (400 MHz, $CDCl_3$) δ 10.42 (s, 1H), 7.96 (d, *J* = 2.6 Hz, 1H), 7.64 (dd, *J* = 8.8, 2.6 Hz, 1H), 6.88 (d, *J* = 8.8 Hz, 1H), 4.43 – 3.97 (m, 2H), 3.69 (t, *J* = 4.9 Hz, 2H). $^{13}$C{$^1$H} NMR (101 MHz,

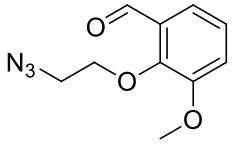
$CDCl_3$) δ 188.0, 159.4, 138.4, 131.4, 126.5, 114.6, 114.5, 68.0, 50.3. HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_9H_9N_3O_2Br$ 269.9873/271.9853; Found 269.9878/271.9859.

**2-(2-Azidoethoxy)-5-nitrobenzaldehyde (7e)**



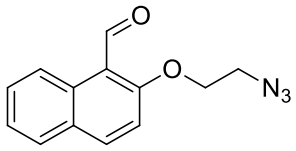
Yield 187 mg, 79%; yellow amorphous solid. $^1$H NMR (400 MHz, $CDCl_3$) δ 10.42 (s, 1H), 7.96 (d, *J* = 2.6 Hz, 1H), 7.64 (dd, *J* = 8.8, 2.6 Hz, 1H), 6.88 (d, *J* = 8.8 Hz, 1H), 4.35 – 4.18 (m, 2H), 3.69 (t, *J* = 4.9 Hz, 2H). $^{13}C\{^1H\}$ NMR (101 MHz, $CDCl_3$) δ 188.0, 159.4, 138.4, 131.4, 126.5, 114.6, 68.0, 50.3. HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_9H_9N_4O_4$ 237.0618; Found 237.0624.

**2-(2-azidoethoxy)-3-methoxybenzaldehyde (7f)**



Yield: 186 mg, 84%; brown oil. $^1$H NMR (400 MHz, $CDCl_3$) δ 10.48 (s, 1H), 8.72 (d, *J* = 2.9 Hz, 1H), 8.44 (dd, *J* = 9.2, 2.9 Hz, 1H), 7.12 (d, *J* = 9.2 Hz, 1H), 4.40 (t, *J* = 4.9 Hz, 2H), 3.77 (t, *J* = 4.9 Hz, 2H). $^{13}C\{^1H\}$ NMR (101 MHz, $CDCl_3$) δ 187.1, 164.2, 142.3, 130.7, 124.8, 113.0, 68.7, 50.1. HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{10}H_{12}N_3O_3$ 222.0873; Found 222.0877.

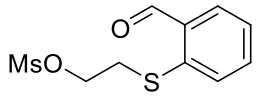
**2-(2-Azidoethoxy)-1-naphthaldehyde (7g)**



Yield 219 mg, 99%; reddish amorphous solid. $^1$H NMR (400 MHz, $CDCl_3$) δ 10.93 (s, 1H), 9.27 (d, *J* = 8.7 Hz, 1H), 8.06 (d, *J* = 9.1 Hz, 1H), 7.78 (d, *J* = 7.5 Hz, 1H), 7.63 (t, *J* = 7.8 Hz, 1H), 7.44 (t, *J* = 7.5 Hz, 1H), 7.29 – 7.17 (m, 1H), 4.38 (t, *J* = 5.0 Hz, 2H), 3.72 (t, *J* = 5.0 Hz, 2H). $^{13}C\{^1H\}$ NMR (101 MHz, $CDCl_3$) δ 191.8, 162.6, 137.6, 131.6, 130.1, 129.1, 128.4, 125.2, 125.2, 117.4, 113.4, 68.5, 50.5. HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{13}H_{12}N_3O_2$ 242.0930; Found 242.0926.

**Preparation of azide 7h**

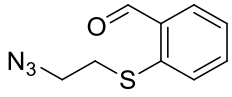
**2-((2-Formylphenyl)thio)ethyl methanesulfonate**



Mesyl chloride (1.87 mmol) was added to a solution of 2-((2-hydroxyethyl)thio)benzaldehyde (synthesized *via* known literature protocol [4]) and triethylamine (2.21 mmol) in DCM (6 mL) at 0 °C. 1 Volume of saturated $NaHCO_3$ solution was added and mixture was stirred for 30 min. Organic layer was separated, aqueous layer was extracted with DCM. Combined organic layers were washed with brine, dried over anhydrous $Na_2SO_4$ and solvent was removed under reduced pressure to give 2-((2-formylphenyl)thio)ethyl

methanesulfonate (237 mg, 91%) as a crude product that was used in a next stage directly without purification.

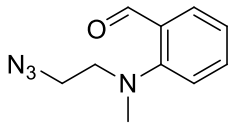
**2-((2-Azidoethyl)thio)benzaldehyde (7h)**



Sodium azide (2.33 mmol) was added to a solution of 2-((2-formylphenyl)thio)ethyl methanesulfonate (1.55 mmol) in DMF (4 mL). Mixture was stirred overnight at room temperature. The reaction solution was diluted with water and extracted with chloroform. Combined organic layers were washed with water, brine and dried over anhydrous $Na_2SO_4$. The solvent was removed under reduced pressure to give 2-((2-azidoethyl)thio)benzaldehyde (310 mg, 96%) as a yellow oil. $^1$H NMR (400 MHz, $CDCl_3$) δ 10.40 (s, 1H), 7.93 – 7.78 (m, 1H), 7.59 – 7.51 (m, 1H), 7.46 (d, *J* = 7.8 Hz, 1H), 7.36 (t, *J* = 7.4 Hz, 1H), 3.52 (t, *J* = 6.9 Hz, 2H), 3.14 (t, *J* = 7.0 Hz, 2H). $^{13}$C{$^1$H} NMR (101 MHz, $CDCl_3$) δ 191.4, 139.7, 134.9, 134.2, 132.1, 129.3, 126.5, 50.0, 32.9. HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_9H_9N_3OSNa$ 230.0359; Found 230.0362.

**Preparation of azide 7i**

**2-((2-Azidoethyl)(methyl)amino)benzaldehyde (7i)**



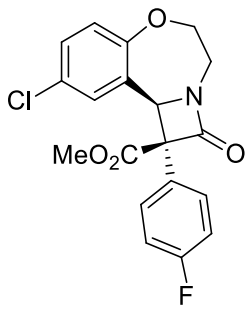
2-Azido-N-methyl ethan-1-amine (2.66 mmol) was added to a solution of 2-fluorobenzaldehyde (2.42 mmol) and $K_2CO_3$ (2.66 mmol) in 2 mL of DMF and mixture was stirred for 16 h at 110 °C. The reaction solution was diluted with water and extracted with chloroform. Combined organic layers were washed with water, brine and dried over anhydrous $Na_2SO_4$. The solvent was removed under reduced pressure to give 2-((2-azidoethyl)(methyl)amino)benzaldehyde (251 mg, 50%) as a brown oil. $^1$H NMR (400 MHz, $CDCl_3$) δ 10.31 (s, 1H), 7.80 (dd, *J* = 7.7, 1.6 Hz, 1H), 7.55 – 7.45 (m, 1H), 7.12 (dd, *J* = 17.3, 8.0 Hz, 2H), 3.46 (t, *J* = 6.0 Hz, 2H), 3.35 (t, *J* = 6.0 Hz,2), 2.94 (s, 3H). $^{13}$C{$^1$H} NMR (101 MHz, $CDCl_3$) δ 191.4, 154.9, 134.8, 130.7, 129.1, 122.6, 119.9, 56.3, 49.0, 43.6. HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{10}H_{12}N_4ONa$ 227.0903; Found 227.0905.

**General procedure for preparation of annelated *beta*-lactams 9 and their analytical data**

In a screw-cap vial equipped with a magnetic stir bar azide **7** (0.5 mmol) and $PPh_3$ (0.5 mmol) were mixed in 1 mL of toluene. The resulting mixture was placed in a pre-heated to 110 °C oil bath or melt heating block for 1 hour. After this time diazo reagent **3** (0.75 or 1 mmol) was added and the mixture was stirred for additional 3 hours at 110 °C. After that the solvent was evaporated.

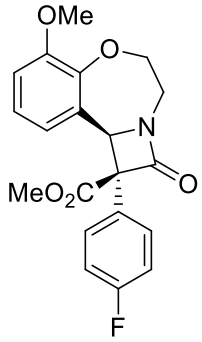
Obtained oils were purified by column chromatography eluting with Hexane/Acetone (linear gradient 5-50% of acetone, total volume 500 mL) to give pure compounds **9a-k**.

**(1*RS*,10*bRS*)-Methyl 9-chloro-1-(4-fluorophenyl)-2-oxo-2,4,5,10*b*-tetrahydro-1*H*-azeto[1,2-d]benzo[*f*][1,4]oxazepine-1-carboxylate (9a)**



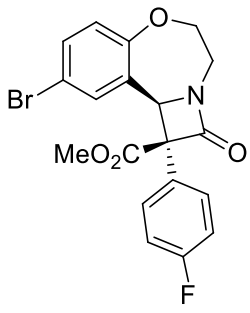

Yield 66 mg, 35% with 0.75 mmol of diazo reagent; 143 mg, 76% with 1 mmol of diazo reagent; yellow oil. $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.68 – 7.60 (m, 2H), 7.21 – 7.10 (m, 4H), 6.99 (d, *J* = 8.7 Hz, 1H), 5.26 (s, 1H), 4.37 – 4.16 (m, 3H), 3.36 (s, 3H), 3.35 – 3.29 (m, 1H). $^{13}$C{$^{1}$H} NMR (101 MHz, $CDCl_3$) δ 167.9, 163.3, 162.8 (d, *J* = 248.1 Hz), 157.5, 129.92 (d, *J* = 8.1 Hz), 129.2, 128.4, 127.5, 127.3, 123.4, 115.88 (d, *J* = 21.7 Hz), 73.8, 70.4, 63.3, 52.8, 43.1. $^{19}$F{$^{1}$H} NMR (376 MHz, $CDCl_3$) δ -113.0. HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{19}H_{16}ClFNO_4^+$ 376.0746; Found 376.0745.

**(1*RS*,10*bRS*)-Methyl 1-(4-fluorophenyl)-7-methoxy-2-oxo-2,4,5,10*b*-tetrahydro-1*H*-azeto[1,2-*d*]benzo[*f*][1,4]oxazepine-1-carboxylate (9b)**



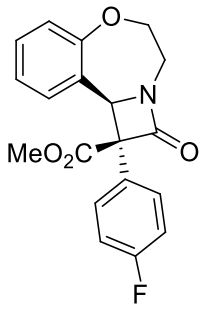

Yield 130 mg, 70% with 0.75 mmol of diazo reagent; yellow oil. $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.69 – 7.59 (m, 2H), 7.10 (t, *J* = 8.7 Hz, 2H), 7.00 (t, *J* = 8.0 Hz, 1H), 6.84 (d, *J* = 6.6 Hz, 1H), 6.73 (d, *J* = 7.8 Hz, 1H), 5.32 (s, 1H), 4.39 – 4.18 (m, 3H), 3.86 (s, 3H), 3.39 – 3.30 (m, 1H), 3.29 (s, 3H). $^{13}$C{$^{1}$H} NMR (101 MHz, $CDCl_3$) δ 168.3, 163.3, 162.7 (d, *J* = 247.8 Hz), 151.8, 148.3, 130.3 (d, *J* = 3.3 Hz), 129.9 (d, *J* = 8.2 Hz), 127.2, 123.4, 118.7, 115.7 (d, *J* = 21.6 Hz), 111.4, 73.3, 70.9, 63.8, 56.2, 52.6, 43.2. $^{19}$F{$^{1}$H} NMR (376 MHz, $CDCl_3$) δ -113.3. HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{21}H_{18}FNO_5^+$ 372.1242; Found 372.1241.

**(1*RS*,10*bRS*)-Methyl 9-bromo-1-(4-fluorophenyl)-2-oxo-2,4,5,10*b*-tetrahydro-1*H*-azeto[1,2-d]benzo[*f*][1,4]oxazepine-1-carboxylate (9c)**



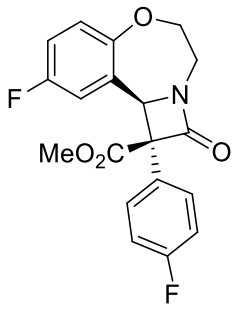

Yield 143 mg, 68% with 0.75 mmol of diazo reagent; orange oil. $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.68 – 7.58 (m, 2H), 7.36 – 7.30 (m, 1H), 7.26 (s, 1H), 7.15 (t, *J* = 8.7 Hz, 2H), 6.93 (d, *J* = 8.6 Hz, 1H), 5.27 (s, 1H), 4.37 – 4.16 (m, 3H), 3.38 (s, 3H), 3.35 – 3.28 (m, 1H). $^{13}$C{$^{1}$H} NMR (101 MHz, $CDCl_3$) δ 167.9, 163.2, 162.8 (d, *J* = 248.3 Hz), 158.0, 132.2, 130.3, 130.0, 129.9 (d, *J* = 8.3 Hz), 129.8, 128.0, 123.8, 116.0, 115.9 (d, *J* = 21.7 Hz), 73.9, 70.4, 63.2, 52.8, 43.1. $^{19}$F{$^{1}$H} NMR (376 MHz, $CDCl_3$) δ -113.0. HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{19}H_{16}BrFNO_4^+$ 420.0241; Found 420.0240.

**(1*RS*,10*bRS*)-Methyl 1-(4-fluorophenyl)-2-oxo-2,4,5,10*b*-tetrahydro-*1H*-azeto[1,2-d]benzo[*f*][1,4]oxazepine-1-carboxylate (9d)**



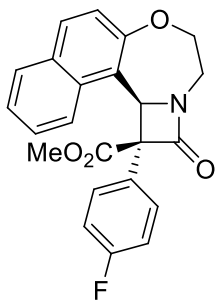
Yield 113 mg, 66% with 0.75 mmol of diazo reagent; yellow oil. $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.73 – 7.57 (m, 2H), 7.25 – 7.18 (m, 1H), 7.18 – 7.10 (m, 3H), 7.10 – 7.03 (m, 2H), 5.32 (s, 1H), 4.40 – 4.11 (m, 3H), 3.37 – 3.29 (m, 1H), 3.26 (s, 3H). $^{13}$C{$^{1}$H} NMR (126 MHz, $CDCl_3$) δ 168.3, 163.5, 162.8 (d, *J* = 247.9 Hz), 158.8, 130.2 (d, *J* = 3.3 Hz), 130.0 (d, *J* = 8.2 Hz), 129.3, 127.7, 125.6, 123.4, 121.9, 115.8 (d, *J* = 21.6 Hz), 73.7, 70.2, 63.9, 52.7, 43.2. $^{19}$F{$^{1}$H} NMR (376 MHz, $CDCl_3$) δ -113.3. HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{19}H_{16}FNO_4Na^+$ 364.0956; Found 364.0960.

**(1*RS*,10*bRS*)-Methyl 9-fluoro-1-(4-fluorophenyl)-2-oxo-2,4,5,10*b*-tetrahydro-1*H*-azeto[1,2-d]benzo[*f*][1,4]oxazepine-1-carboxylate (9e)**



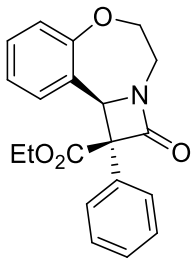
Yield 104 mg, 58% with 1.5 eq of diazo-reagent; orange oil. $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.67 – 7.60 (m, 2H), 7.15 (d, *J* = 8.5 Hz, 2H), 7.06 – 6.99 (m, 1H), 6.96 – 6.90 (m, 1H), 6.89 – 6.84 (m, 1H), 5.25 (s, 1H), 4.33 – 4.16 (m, 3H), 3.37 (s, 3H), 3.35 – 3.28 (m, 1H). $^{13}$C{$^{1}$H} NMR (101 MHz, $CDCl_3$) δ 168.0, 163.3, 162.83 (d, *J* = 248.1 Hz), 158.30 (d, *J* = 243.6 Hz), 155.03 (d, *J* = 2.6 Hz), 130.0, 129.91 (d, *J* = 8.1 Hz), 127.59 (d, *J* = 6.9 Hz), 123.46 (d, *J* = 8.3 Hz), 116.00 (d, *J* = 22.7 Hz), 115.88 (d, *J* = 21.7 Hz), 113.83 (d, *J* = 24.4 Hz), 73.7, 70.6, 63.6, 52.8, 43.2. $^{19}$F{$^{1}$H} NMR (376 MHz, $CDCl_3$) δ -113.0, -119.1. HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{19}H_{16}F_2NO_4^+$ 360.1042; Found 360.1042.

**(1*RS*,12*cRS*)-Methyl 1-(4-fluorophenyl)-2-oxo-2,4,5,12*c*-tetrahydro-1*H*-azeto[1,2-d]naphtho[1,2-*f*][1,4]oxazepine-1-carboxylate (9f)**



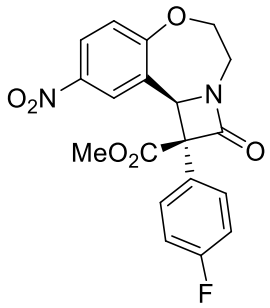
Yield 82 mg, 42% with 0.75 mmol of diazo reagent; orange oil. $^{1}$H NR (400 MHz, $CDCl_3$) δ 7.85 – 7.76 (m, 3H), 7.71 (d, *J* = 8.9 Hz, 1H), 7.61 – 7.51 (m, 1H), 7.44 – 7.34 (m, 2H), 7.23 – 7.11 (m, 3H), 5.81 (s, 1H), 4.71 – 4.54 (m, 1H), 4.51 – 4.36 (m, 1H), 4.18 (td, *J* = 12.3, 4.3 Hz, 1H), 3.37 (dd, *J* = 13.2, 4.3, 1.2 Hz, 1H), 2.97 (s, 3H). $^{13}$C{$^{1}$H} NMR (101 MHz, $CDCl_3$) δ 166.12 (d, *J* = 205.5 Hz), 162.76 (d, *J* = 248.4 Hz), 158.3, 132.3, 130.2, 130.0, 129.78 (d, *J* = 8.1 Hz), 129.65 (d, *J* = 3.5 Hz), 128.6, 126.7, 125.0, 123.6, 122.1, 117.1, 115.97 (d, *J* = 21.5 Hz), 75.4, 70.3, 64.5, 52.1, 41.9. $^{19}$F{$^{1}$H} NMR (376 MHz, $CDCl_3$) δ -113.3. HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{23}H_{19}FNO_4^+$ 392.1293; Found 392.1291.

**(1*RS*,10*bRS*)-Ethyl 2-oxo-1-phenyl-2,4,5,10*b*-tetrahydro-*1H*-azeto[1,2-d]benzo[*f*][1,4]oxazepine-1-carboxylate (9g)**



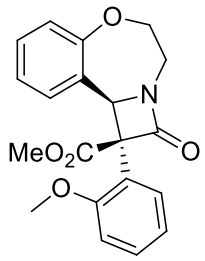
Yield 69 mg, 41% with 0.5 mmol of diazo reagent; yellow oil. $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.72 – 7.67 (m, 2H), 7.49 – 7.42 (m, 2H), 7.41 – 7.35 (m, 1H), 7.25 – 7.19 (m, 2H), 7.10 – 7.01 (m, 2H), 5.38 (s, 1H), 4.36 – 4.18 (m, 3H), 3.85 – 3.75 (m, 1H), 3.73 – 3.61 (m, 1H), 3.38 – 3.18 (m, 1H), 0.79 (t, *J* = 7.2 Hz, 3H). $^{13}$C{$^{1}$H} NMR (101 MHz, $CDCl_3$) δ 167.9, 163.8, 158.9, 134.5, 129.0, 128.7, 128.4, 128.2, 128.0, 126.0, 123.3, 121.8, 74.3, 70.3, 63.6, 61.9, 43.1, 13.5. HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{20}H_{20}NO_4^+$ 338.1387; Found 338.1389.

**(1*RS*,10*bRS*)-Methyl 1-(4-fluorophenyl)-9-nitro-2-oxo-2,4,5,10*b*-tetrahydro-1*H*-azeto[1,2-d]benzo[*f*][1,4]oxazepine-1-carboxylate (9h)**



Yield 110 mg, 57% with 0.75 mmol of diazo reagent; yellow oil. $^{1}$H NMR (400 MHz, $CDCl_3$) δ 8.08 (d, *J* = 7.5 Hz, 2H), 7.73 – 7.59 (m, 2H), 7.21 – 7.05 (m, 3H), 5.36 (s, 1H), 4.55 – 4.39 (m, 1H), 4.36 – 4.19 (m, 2H), 3.43 – 3.33 (m, 1H), 3.31 (s, 3H). $^{13}$C{$^{1}$H} NMR (101 MHz, $CDCl_3$) δ 167.5, 163.8, 162.9, 162.8 (d, *J* = 248.5 Hz), 142.8, 129.8 (d, *J* = 8.3 Hz), 129.4 (d, *J* = 3.4 Hz), 126.1, 124.7, 124.0, 122.7, 116.0 (d, *J* = 21.8 Hz), 74.2, 70.3, 62.9, 52.9, 42.7. $^{19}$F{$^{1}$H} NMR (376 MHz, $CDCl_3$) δ -112.6. HRMS (ESI) m/z: $[M+Na]^+$ Calcd for $C_{19}H_{15}FN_2O_6Na^+$ 409.0806; Found 409.0813.

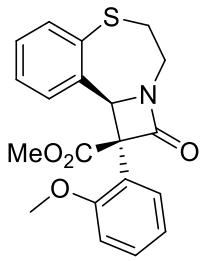
**(1*RS*,10*bRS*)-Methyl 1-(2-methoxyphenyl)-2-oxo-2,4,5,10*b*-tetrahydro-1*H*-azeto[1,2-d]benzo[*f*][1,4]oxazepine-1-carboxylate (9i)**



Yield 138 mg,78% with 0.75 mmol of diazo reagent; yellow oil. $^{1}$H NMR (400 MHz, $CDCl_3$) δ 8.08 – 7.77 (m, 1H), 7.57 (d, *J* = 6.5 Hz, 1H), 7.42 – 7.34 (m, 1H), 7.25 – 7.18 (m, 1H), 7.11 – 6.96 (m, 4H), 5.38 (s, 1H), 4.44 – 4.06 (m, 3H), 3.85 (s, 3H), 3.35 (s, 3H), 3.32 (ddd, *J* = 12.8, 6.1, 3.0 Hz, 1H). $^{13}$C{$^{1}$H} NMR (101 MHz, $CDCl_3$) δ 168.0, 163.9, 159.0, 157.1, 130.1, 128.9, 128.8, 128.3, 128.1, 123.2, 121.9, 121.0, 111.5, 70.8, 70.4, 63.1, 55.3, 52.4, 43.3. HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{21}H_{19}NO_5^+$ 354.1336; Found 354.1333.

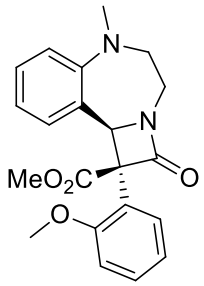
**(1*RS*,10*bRS*)-Methyl 1-(2-methoxyphenyl)-2-oxo-2,4,5,10*b*-tetrahydro-1*H*-azeto[1,2-d]benzo[*f*][1,4]thiazepine-1-carboxylate (9j)**

Yield 74 mg, 40 % with 0.75 mmol of diazo reagent; yellow oil. $^{1}$H NMR (400 MHz, $CDCl_3$) δ 7.88 (dd, *J* = 7.7, 1.7 Hz, 1H), 7.51 (t, *J* = 8.6 Hz, 2H), 7.37 (t, *J* = 8.7 Hz, 1H), 7.29 – 7.20 (m,



1H), 7.21 – 7.14 (m, 1H), 7.06 – 6.96 (m, 2H), 5.44 (s, 1H), 4.36 – 4.24 (m, 1H), 3.79 (s, 3H), 3.40 (s, 3H), 3.39 – 3.32 (m, 1H), 3.11 – 2.96 (m, 2H). $^{13}C\{^{1}H\}$ NMR (101 MHz, $CDCl_3$) δ 168.3, 165.3, 157.4, 138.5, 135.9, 133.6, 130.0, 129.4, 128.7, 127.7, 127.1, 123.5, 121.0, 111.6, 71.5, 66.3, 55.4, 52.4, 44.0, 33.4. HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{20}H_{20}NO_4S^+$ 370.1108; Found 370.1109.

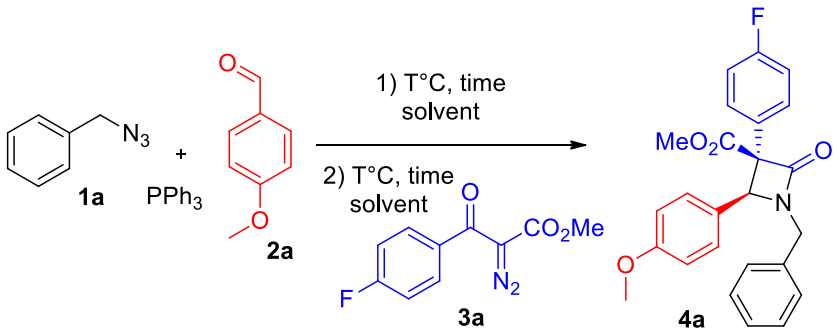
**(1*RS*,10*bRS*)-Methyl 1-(2-methoxyphenyl)-6-methyl-2-oxo-1,2,4,5,6,10*b*-hexahydroazeto[1,2-d]benzo[*f*][1,4]diazepine-1-carboxylate (9k)**



Yield 24 mg, 13% with 0.75 mmol of diazo reagent; yellow oil. $^{1}H$ NMR (400 MHz, $CDCl_3$) δ 7.30 – 7.22 (m, 1H), 7.09 – 6.98 (m, 1H), 6.93 – 6.82 (m, 2H), 6.69 (t, *J* = 7.5 Hz, 1H), 6.61 – 6.52 (m, 2H), 6.50 (d, *J* = 8.2 Hz, 1H), 5.75 (s, 1H), 4.10 – 3.97 (m, 1H), 3.76 (s, 3H), 3.66 (s, 3H), 3.37 – 3.24 (m, 1H), 3.18 – 3.03 (m, 1H), 2.73 (s, 3H). $^{13}C\{^{1}H\}$ NMR (101 MHz, $CDCl_3$) δ 170.1, 166.2, 156.5, 151.1, 130.0, 129.6, 129.1, 128.0, 125.2, 122.5, 120.3, 120.2, 116.6, 109.7, 73.6, 64.2, 54.9, 54.0, 53.0, 40.9, 40.6. HRMS (ESI) m/z: $[M+H]^+$ Calcd for $C_{21}H_{23}N_2O_4^+$ 367.1652; Found 367.1649.

**Table S1**

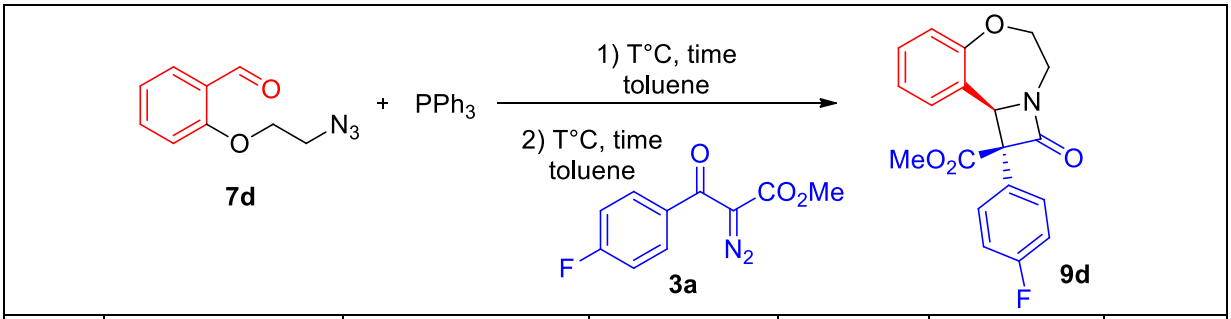
Conditions finding of 2 step *beta*-lactam **4a** synthesis by internal standart-based $^{19}F$ NMR.




| Entry | Solvent | T (1st stage), °C | T (2nd stage), °C | Time 1+2 stages, h | Imine, equiv. | Diazo, equiv. | Yield, % |
|---|---|---|---|---|---|---|---|
| 1 | toluene | 110 | 60 | 2+3 | 1 | 1 | 0 |
| 2 | toluene | 110 | 80 | 2+3 | 1 | 1 | 0 |
| 3 | toluene | 110 | 110 | 2+3 | 1 | 1 | 62 |
| 4 | toluene | 110 | 130 | 2+3 | 1 | 1 | 76 |
| 5 | toluene | 110 | 150 | 2+3 | 1 | 1 | 76 |
| 6 | toluene | 110 | 130 | 1+1 | 1 | 1 | 0 |
| 7 | toluene | 110 | 130 | 1+1 | 1 | 1 | 0 |
| 8 | toluene | 110 | 130 | 3+3 | 1 | 1 | 53 |
| 9 | toluene | 110 | 130 | 16+3 | 1 | 1 | 67 |
| 10 | toluene | 110 | 130 | 3+16 | 1 | 1 | 51 |
| 1 | toluene | 150 | 130 | 1+3 | 1 | 1 | 68 |
| 12 | toluene | 150 | 130 | 2+3 | 1 | 1 | 70 |
| 13 | toluene | 130 | 130 | 2+3 | 1 | 1 | 76 |
| 14 | toluene | 110 | 130 | 2+3 | 1.5 | 1 | 57 |
| 15 | toluene | 110 | 130 | 2+3 | 2 | 1 | 54 |
| 16 | toluene | 110 | 130 | 2+3 | 1 | 1.5 | 77 |
| 17 | toluene | 110 | 130 | 2+3 | 1 | 2 | 69 |
| 18 | DMF | 110 | 130 | 2+3 | 1 | 1 | 0 |
| 19 | *p*-xylene | 110 | 130 | 2+3 | 1 | 1 | 67 |
| 20 | PhCl | 110 | 130 | 2+3 | 1 | 1 | 65 |
| 21 | $PhCF_3$ | 110 | 130 | 2+3 | 1 | 1 | 76 |
| 22 | 1,2-dichlorobenzene | 110 | 130 | 2+3 | 1 | 1 | 75 |
| 23 | | 110 | 130 | 2+3 | 1 | 1 | 75 |

**Table S2**

Conditions finding of 2 step annelated *beta*-lactam **9d** synthesis by internal standart-based $^{19}F$ NMR.




| Entry | T (1st stage), °C | T (2nd stage), °C | Time 1+2 stages, h | Imine, equiv. | Diazo, equiv. | Yield, % |
|---|---|---|---|---|---|---|
| 1 | 110 | 110 | 2+3 | 1 | 1 | 44 |
| 2 | 110 | 130 | 2+3 | 1 | 1 | 35 |
| 3 | 110 | 150 | 2+3 | 1 | 1 | 20 |
| 4 | 130 | 130 | 2+3 | 1 | 1 | 39 |
| 5 | 130 | 150 | 2+3 | 1 | 1 | 15 |
| 6 | 150 | 150 | 2+3 | 1 | 1 | 13 |
| 7 | 110 | 110 | 1+3 | 1 | 1 | 54 |
| 8 | 110 | 110 | 3+3 | 1 | 1 | 44 |
| 9 | 110 | 110 | 1+3 | 1.5 | 1 | 36 |
| 10 | 110 | 110 | 1+3 | 1 | 1.5 | 72 |

## Crystallographic data

X-ray Single Crystal analysis was performed on Agilent Technologies (Oxford Diffraction) SuperNova diffractometer with monochromated CuKα radiation. The crystal was kept at 100 K during data collection. Using Olex2[5], the structures were solved with the SHELXT[6] structure solution program using Intrinsic Phasing and refined with the SHELXL[7] refinement package using Least Squares minimization. CCDC 2208381 **(9g)** contain the supplementary crystallographic data for this paper. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via https://www.ccdc.cam.ac.uk/.

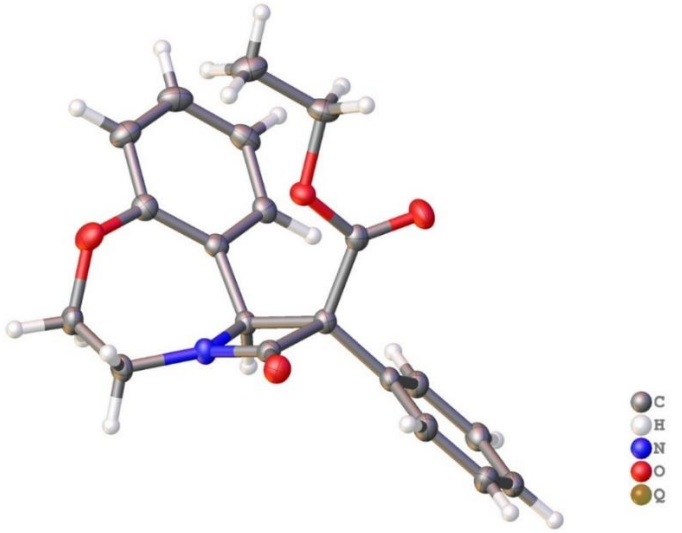



**Figure S1.** Crystal structure of compound 9d (ORTEP plot, 50% probability level)

| **Table 1 Crystal data and structure refinement for 9d.** | |
|---|---|
| Identification code | 2ver0-21974_PPS-192_auto |
| Empirical formula | $C_{20}H_{19}NO_4$ |
| Formula weight | 337.36 |
| Temperature/K | 100.15 |
| Crystal system | monoclinic |
| Space group | $P2_1/n$ |
| a/Å | 13.2559(2) |
| b/Å | 8.60080(10) |
| c/Å | 14.9878(3) |
| α/° | 90 |
| β/° | 104.098(2) |
| γ/° | 90 |
| Volume/Å$^3$ | 1657.31(5) |
| Z | 4 |
| $\rho_{calc}$g/cm$^3$ | 1.352 |
| μ/mm$^{-1}$ | 0.772 |
| F(000) | 712.0 |
| Crystal size/mm$^3$ | ? × ? × ? |
| Radiation | CuKα (λ = 1.54184) |
| 2Θ range for data collection/° | 7.994 to 138.398 |
| Index ranges | -16 ≤ h ≤ 14, -10 ≤ k ≤ 10, -17 ≤ l ≤ 18 |
| Reflections collected | 10828 |

| | |
|---|---|
| Independent reflections | 3086 [$R_{int}$ = 0.0258, $R_{sigma}$ = 0.0278] |
| Data/restraints/parameters | 3086/0/227 |
| Goodness-of-fit on $F^2$ | 1.032 |
| Final R indexes [I>=2σ (I)] | $R_1$ = 0.0341, $wR_2$ = 0.0873 |
| Final R indexes [all data] | $R_1$ = 0.0396, $wR_2$ = 0.0913 |
| Largest diff. peak/hole / e $Å^{-3}$ | 0.20/-0.22 |

## References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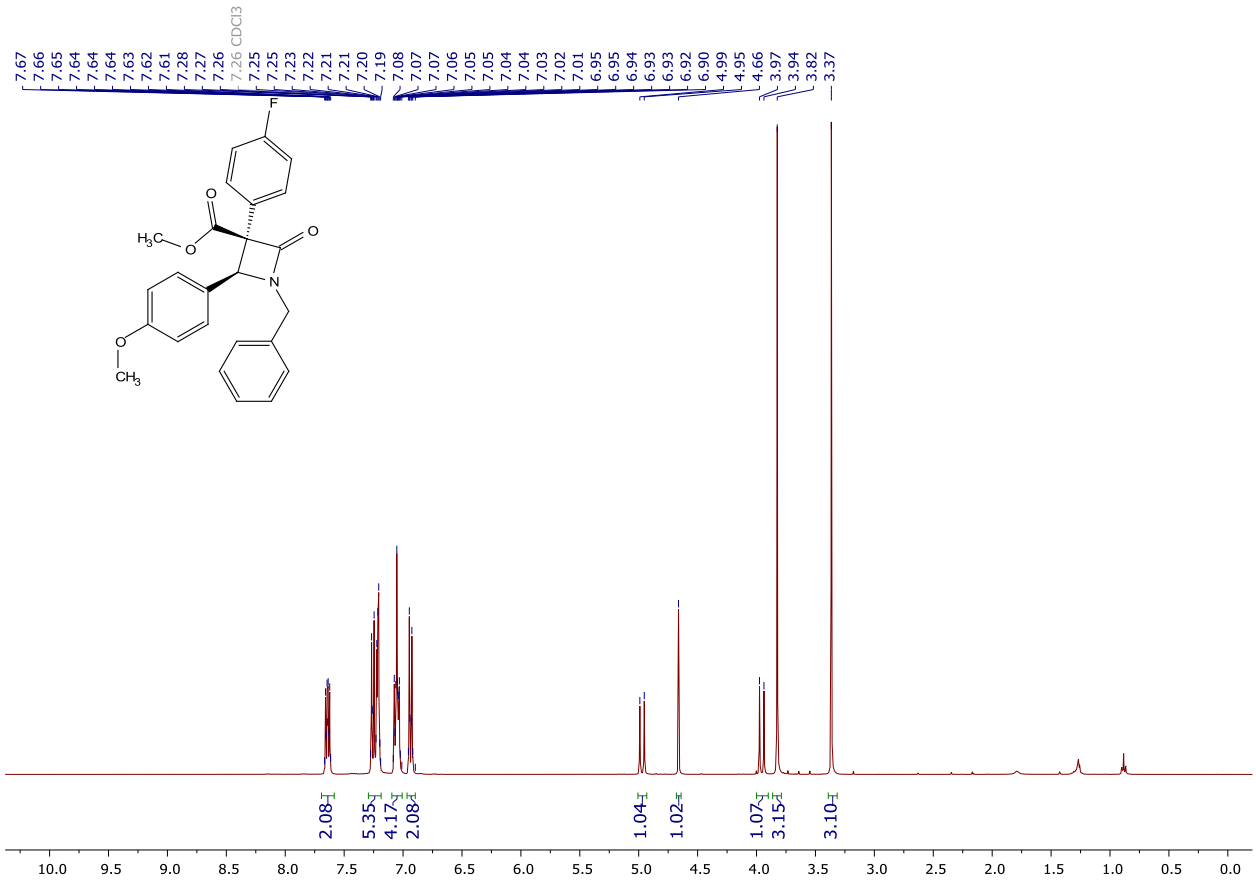
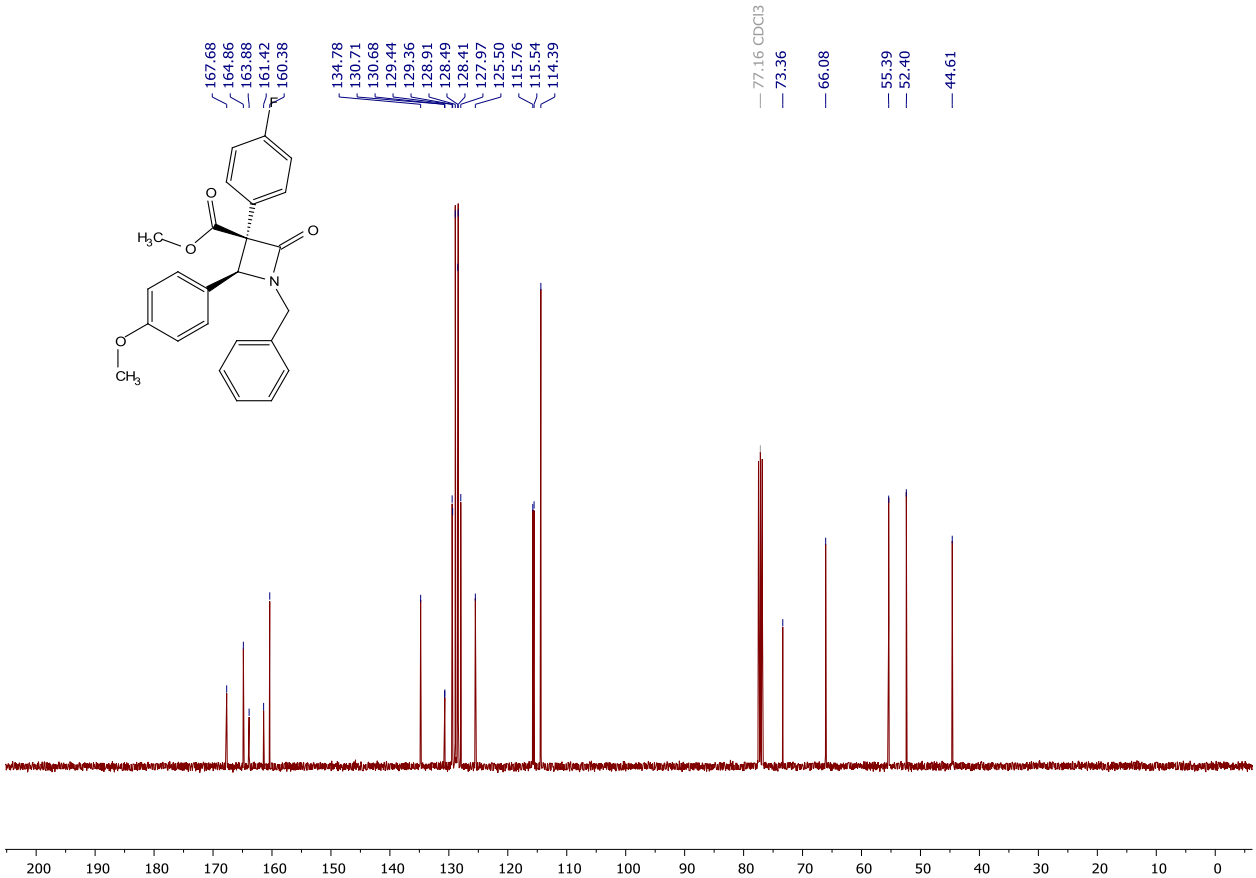
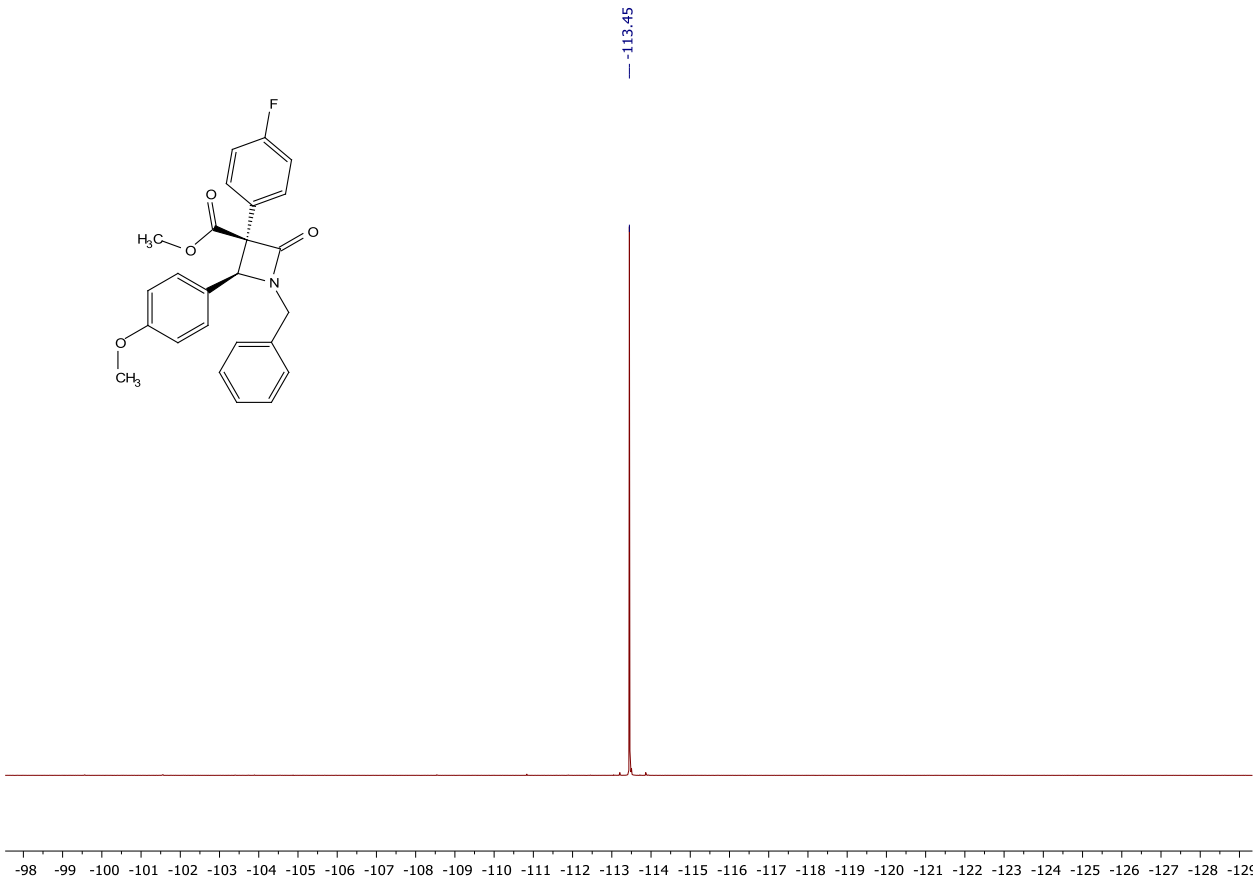
7. Sheldrick, G.M. (2015). Acta Cryst. C71, 3-8.

## Copies of $^{1}H$, $^{13}C$ and $^{19}F$ NMR spectra

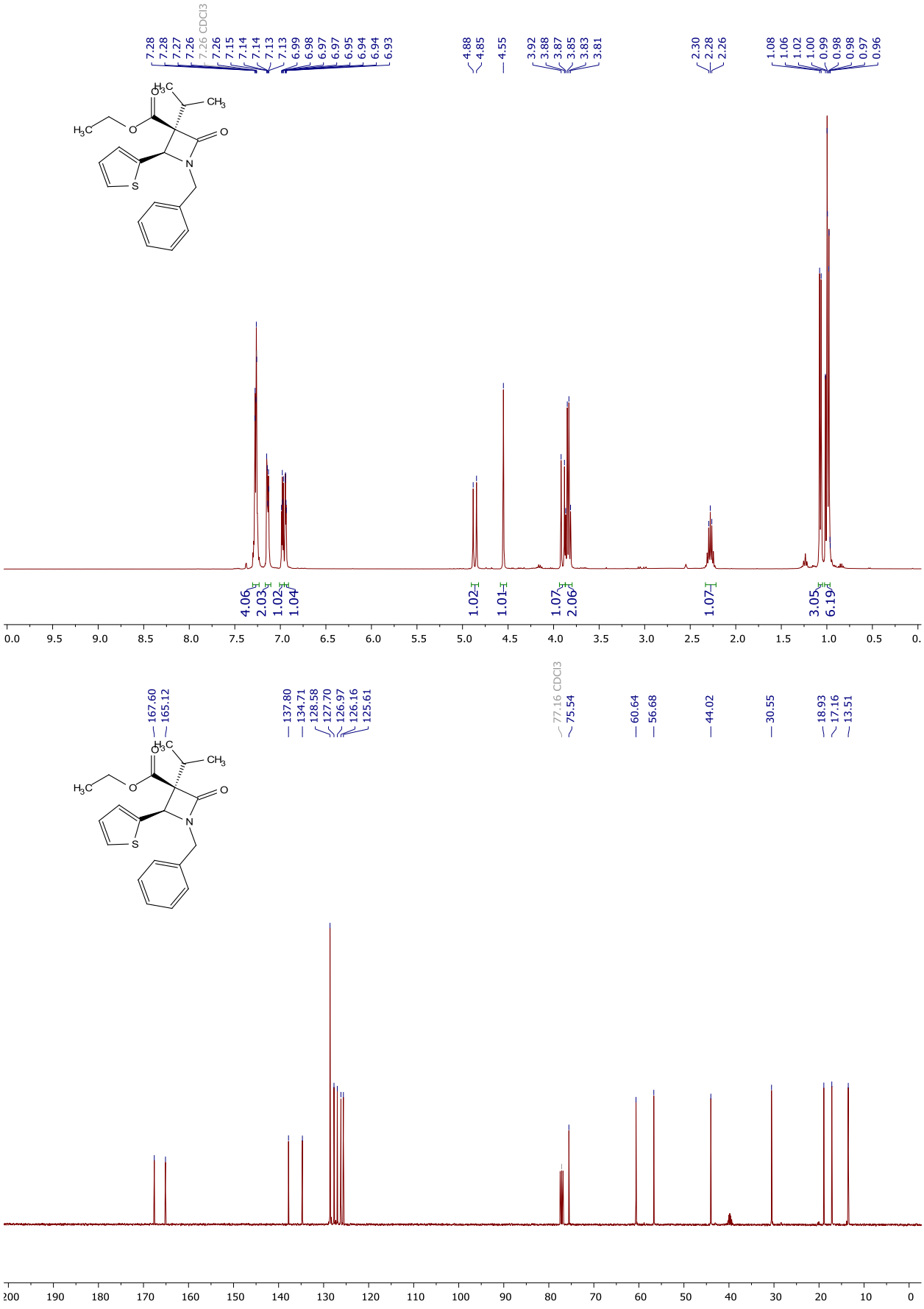
$^{1}H$, $^{13}C$ and $^{19}F$ NMR spectra of compound **4a**



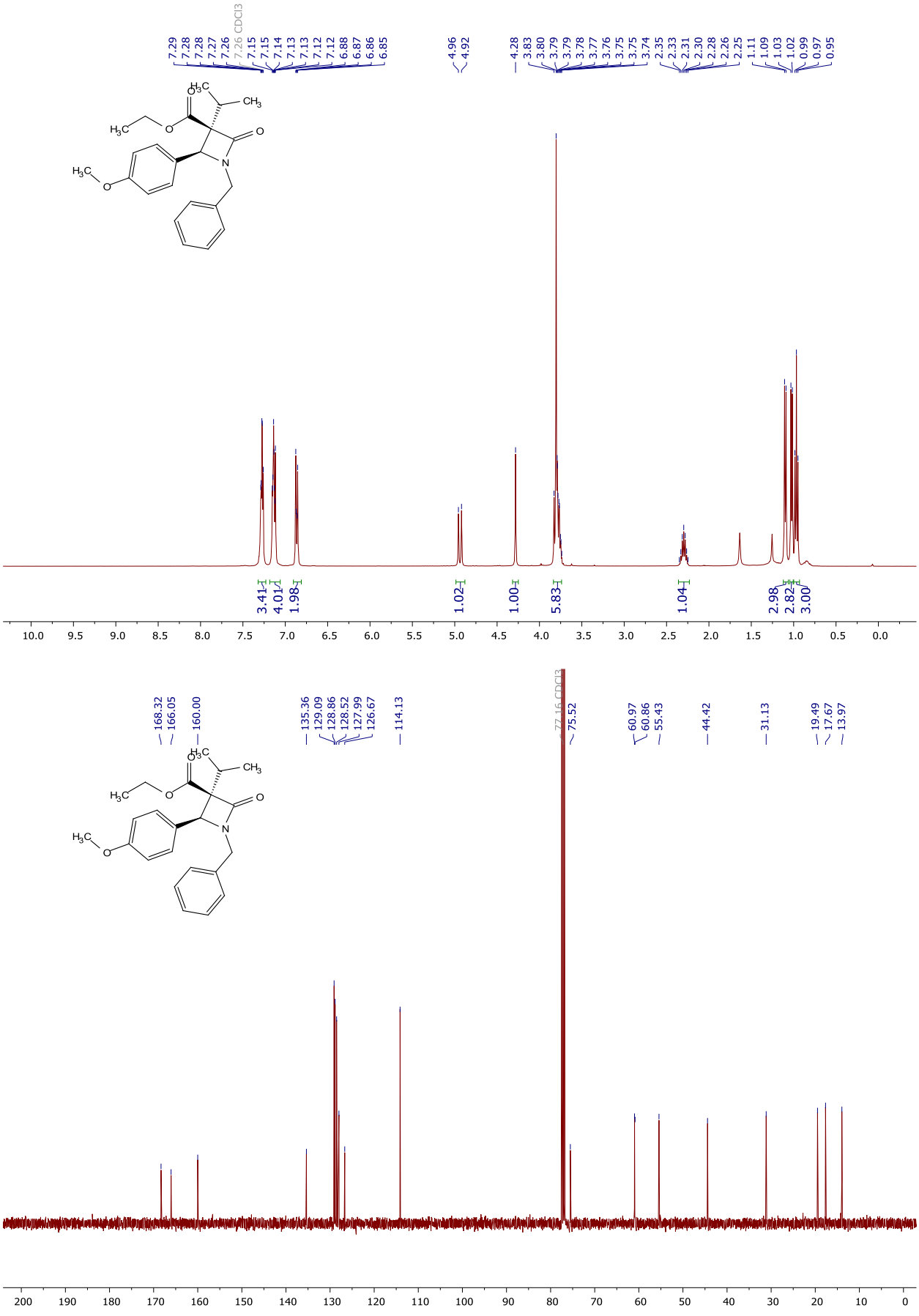




-113.45
F
O
O
$H_3C$
O
N
O
$CH_3$
-98 -99 -100 -101 -102 -103 -104 -105 -106 -107 -108 -109 -110 -111 -112 -113 -114 -115 -116 -117 -118 -119 -120 -121 -122 -123 -124 -125 -126 -127 -128

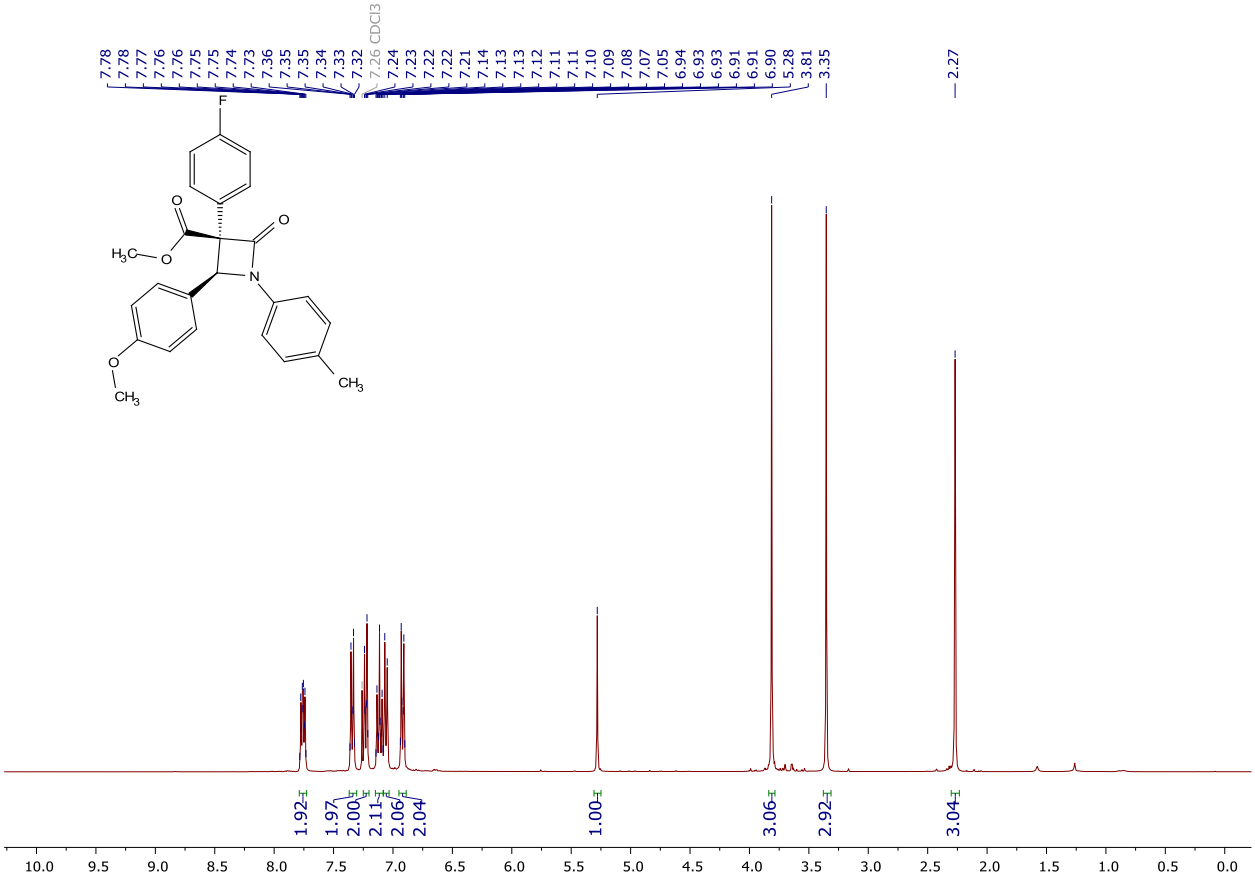
$^{1}H$ and $^{13}C$ NMR spectra of compound **4b**

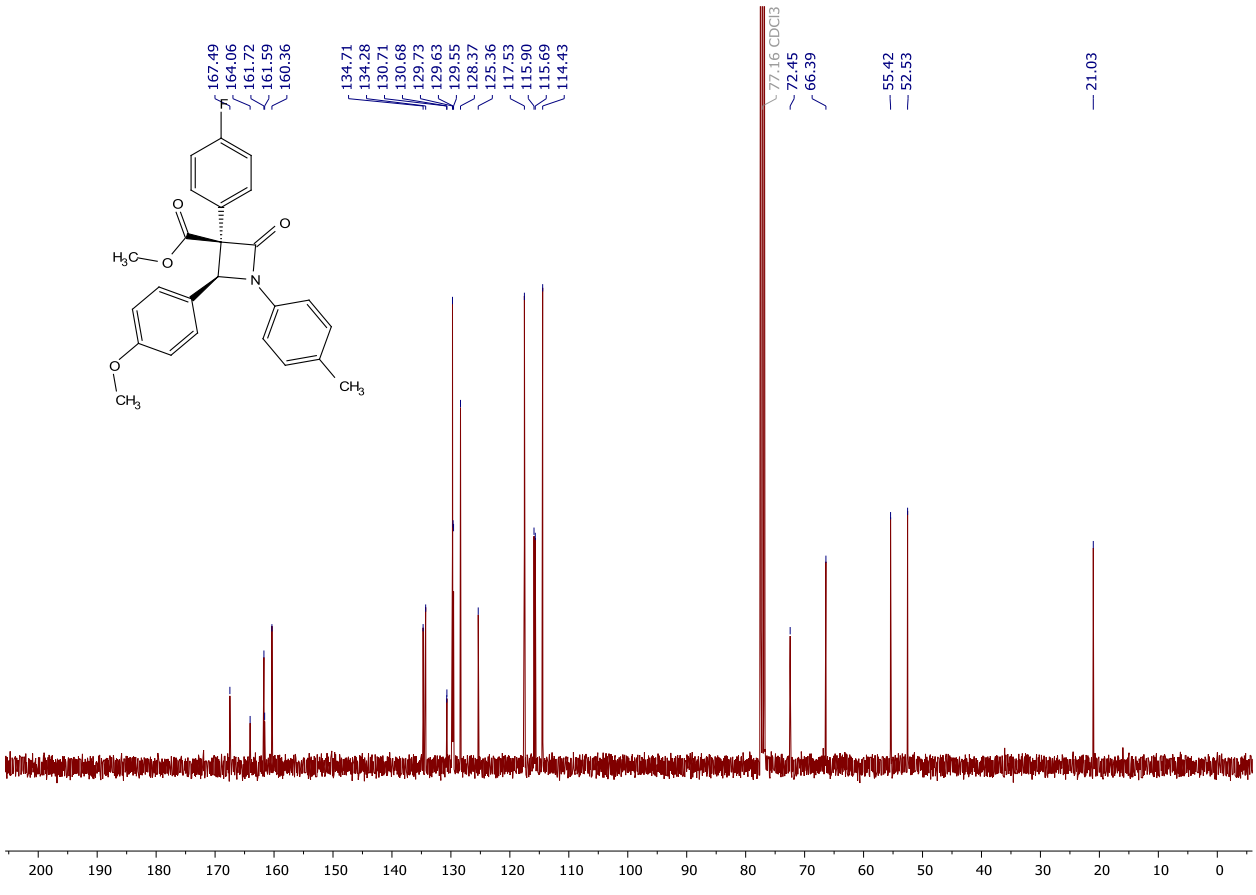


$^{1}H$ and $^{13}C$ NMR spectra of compound **4c**



$^{1}H$, $^{13}C$ and $^{19}F$ NMR spectra of compound **4d**

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164.06
161.72
161.59
160.36
134.71
134.28
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129.73
129.63
129.55
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125.36
117.53
115.90
115.69
114.43
77.16 CDCl3
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66.39
55.42
52.53
21.03
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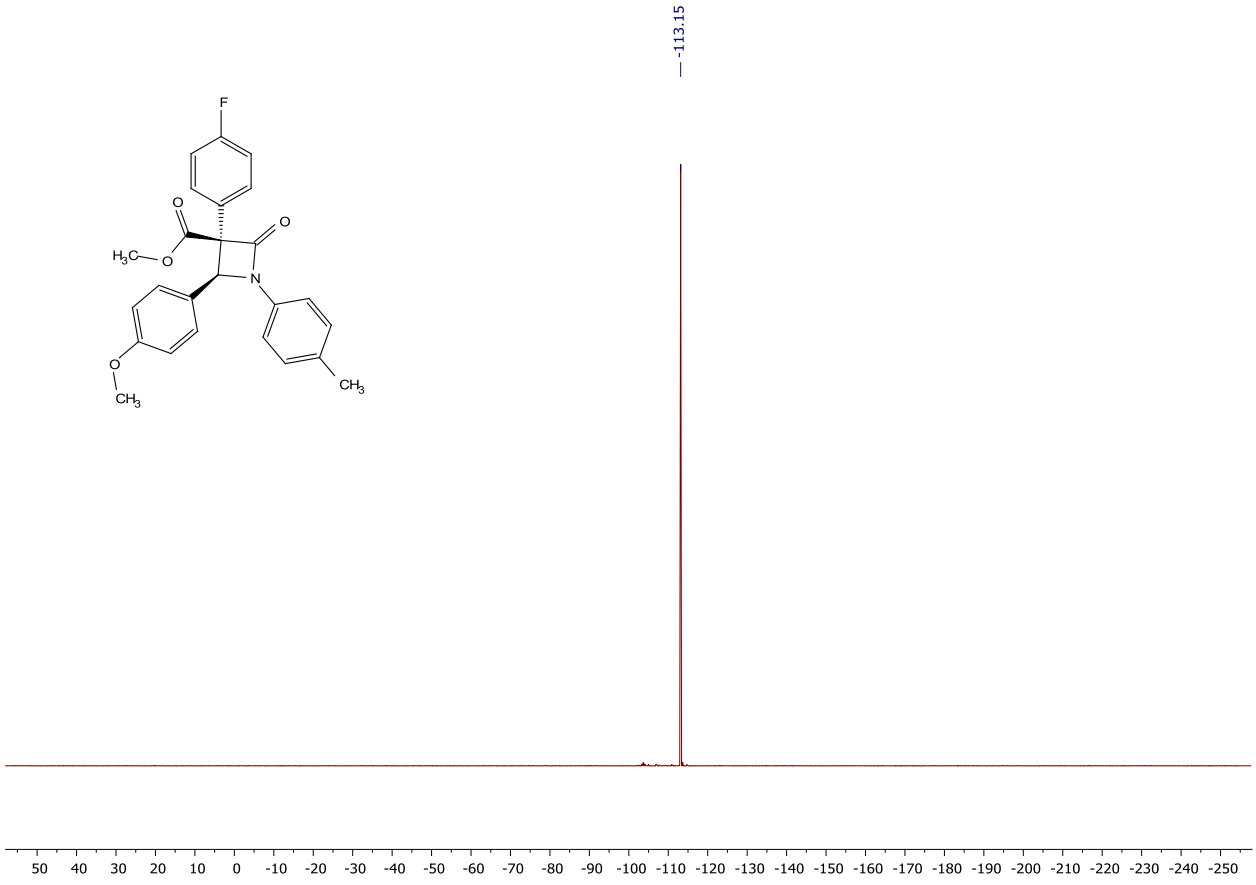
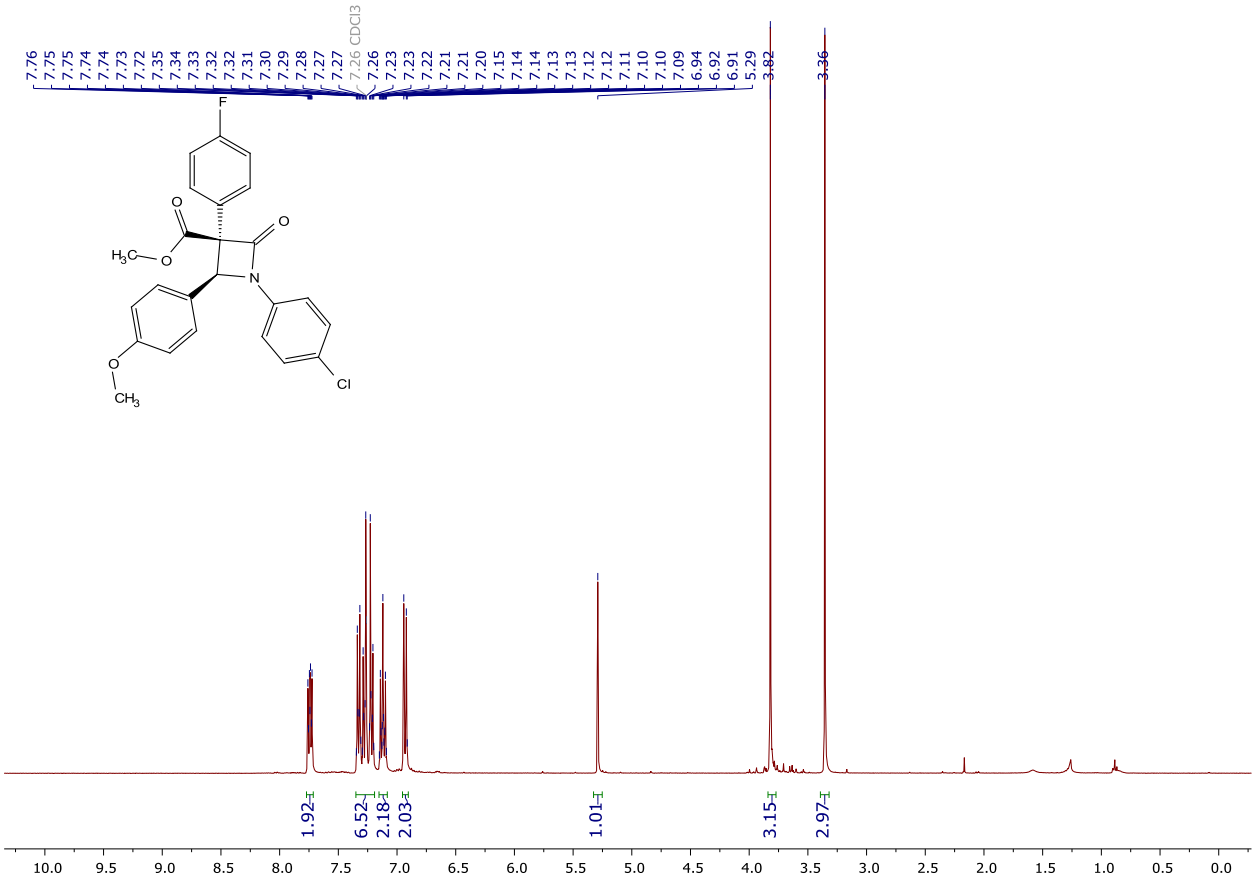
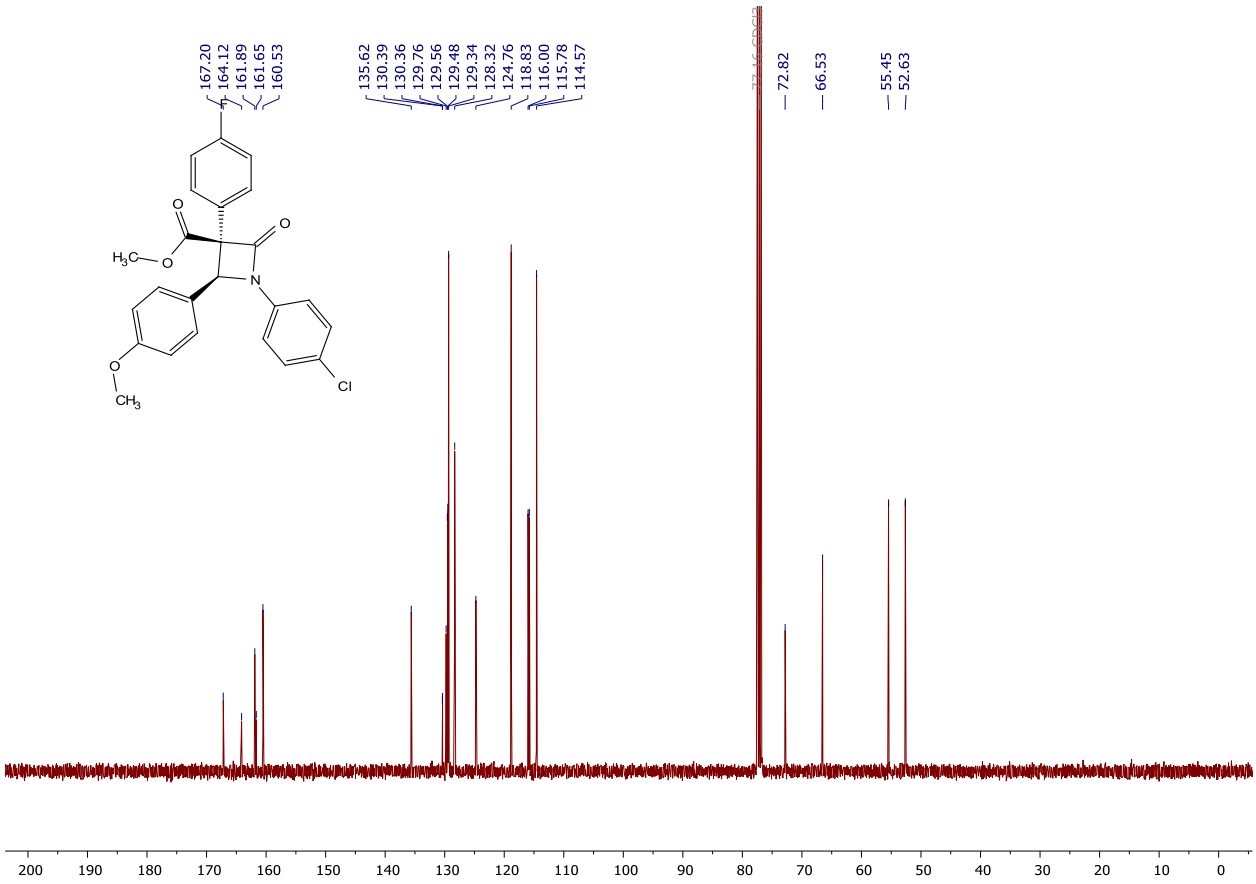

-113.15
50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220 -230 -240 -250

$^{1}H$, $^{13}C$ and $^{19}F$ NMR spectra of compound **4e**

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124.76
118.83
116.00
115.78
114.57
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CH3
Cl
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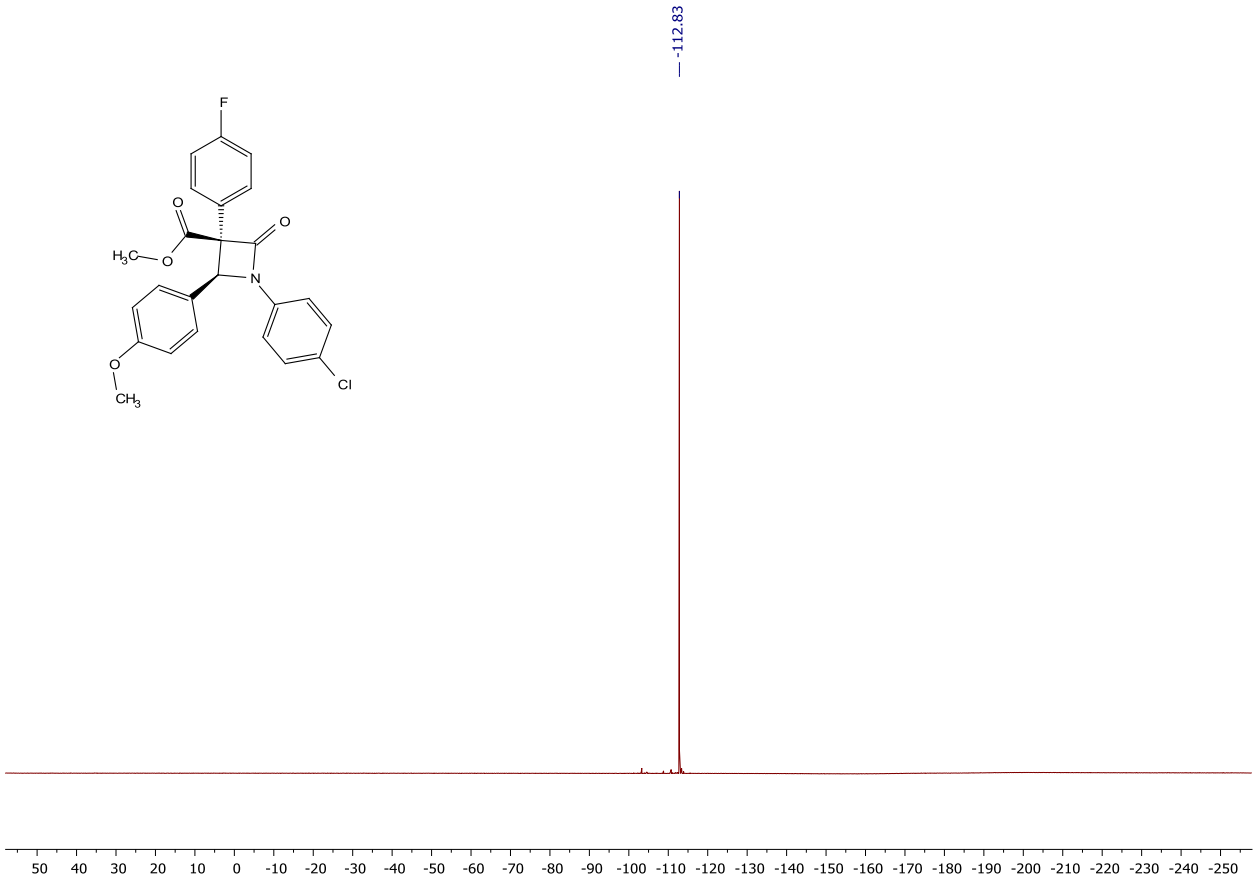
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F
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O
O
H3C
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N
O
CH3
Cl
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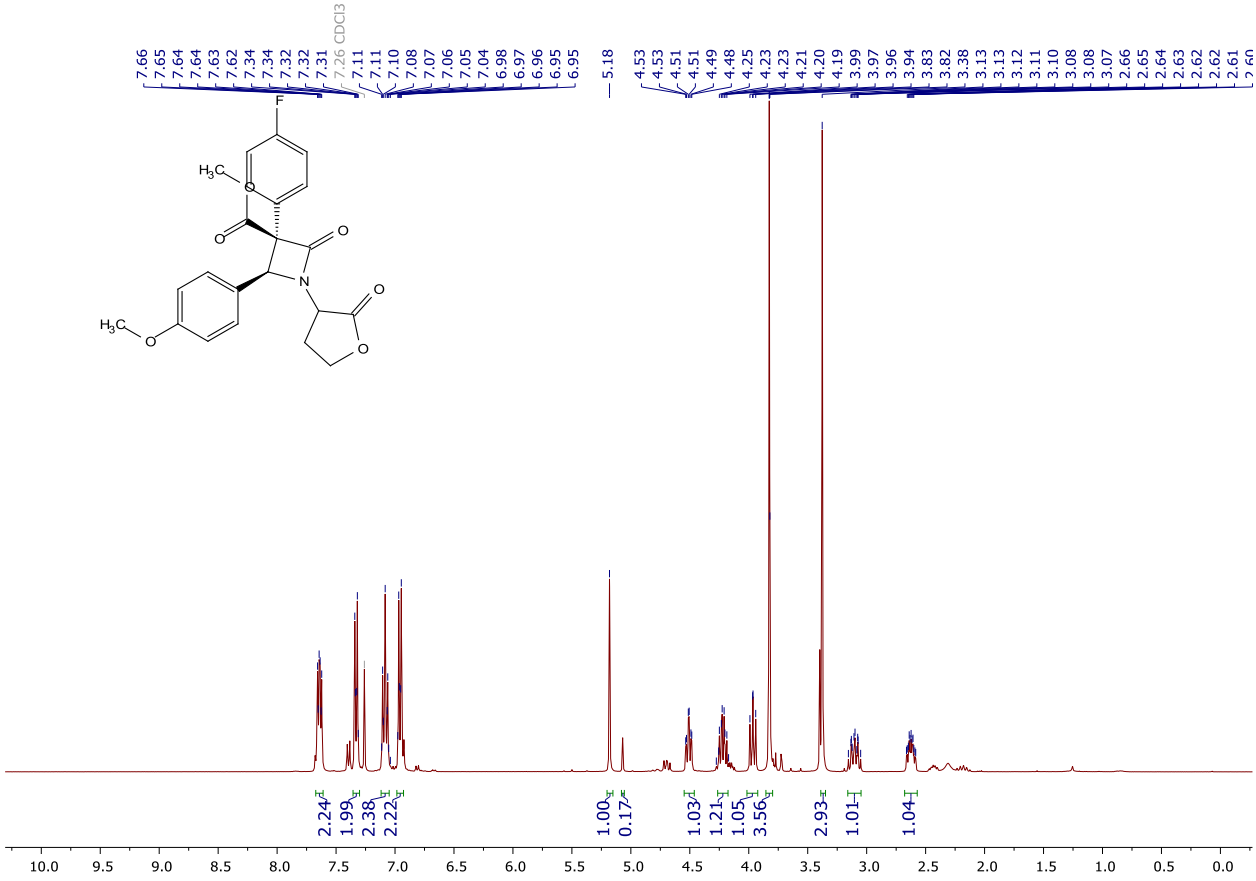
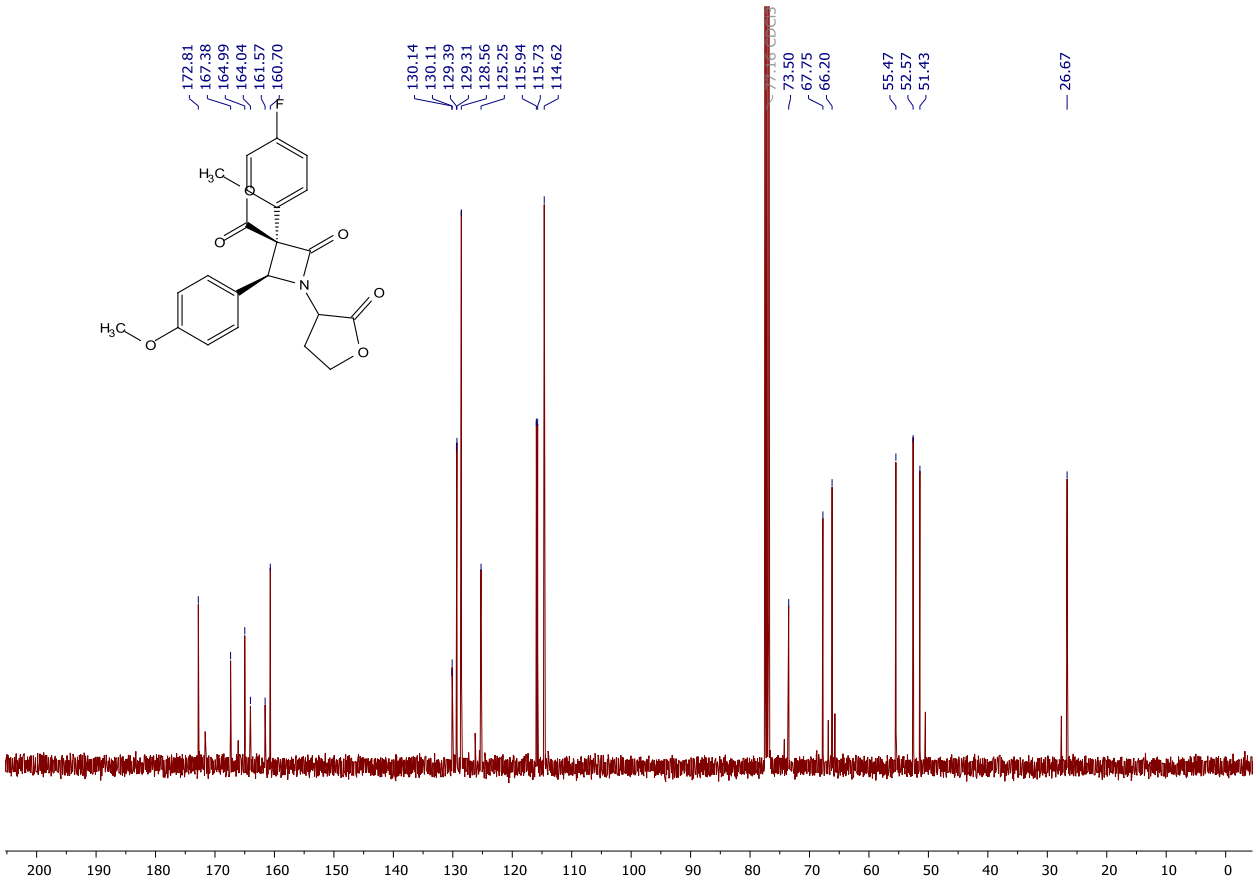
$^{1}H$, $^{13}C$ and $^{19}F$ spectra of compound **4f**

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67.75
66.20
55.47
52.57
51.43
26.67
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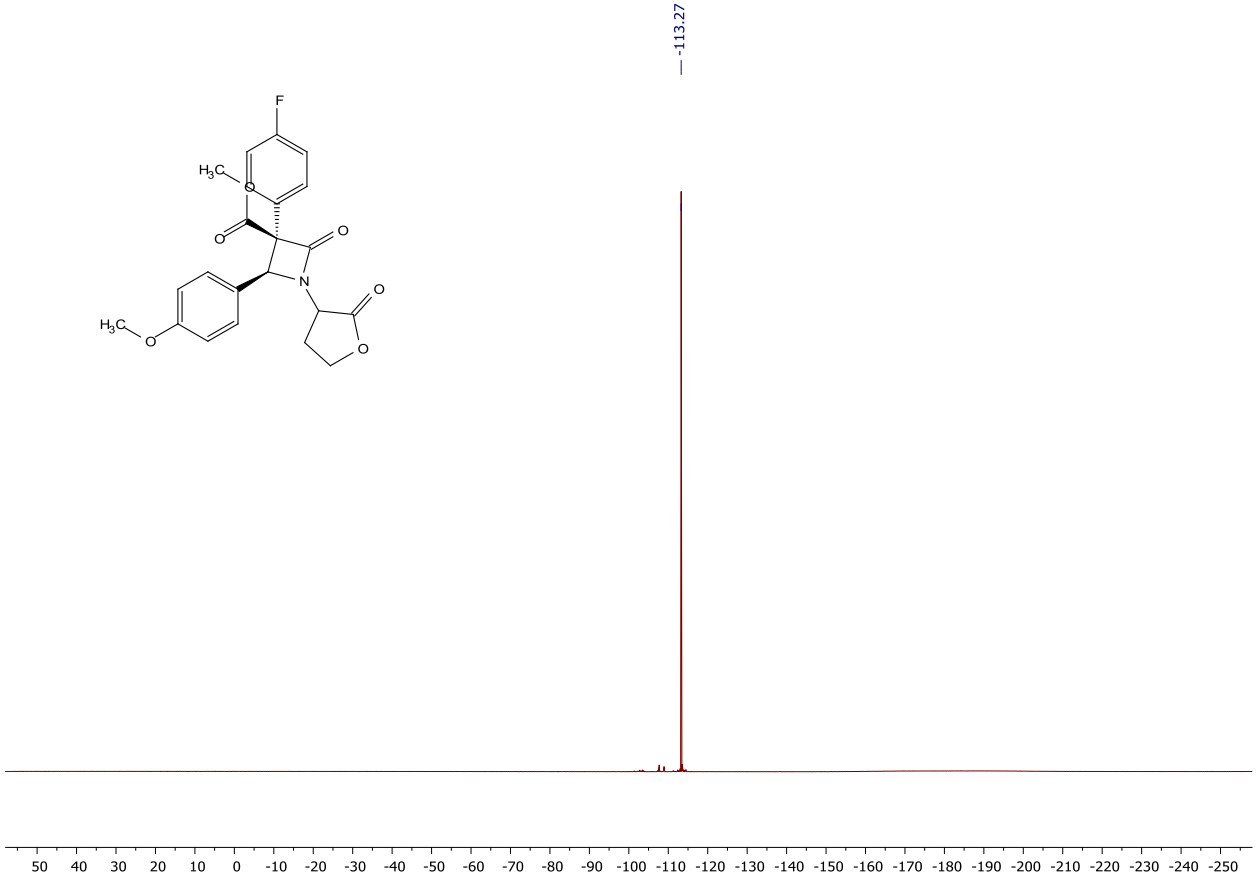
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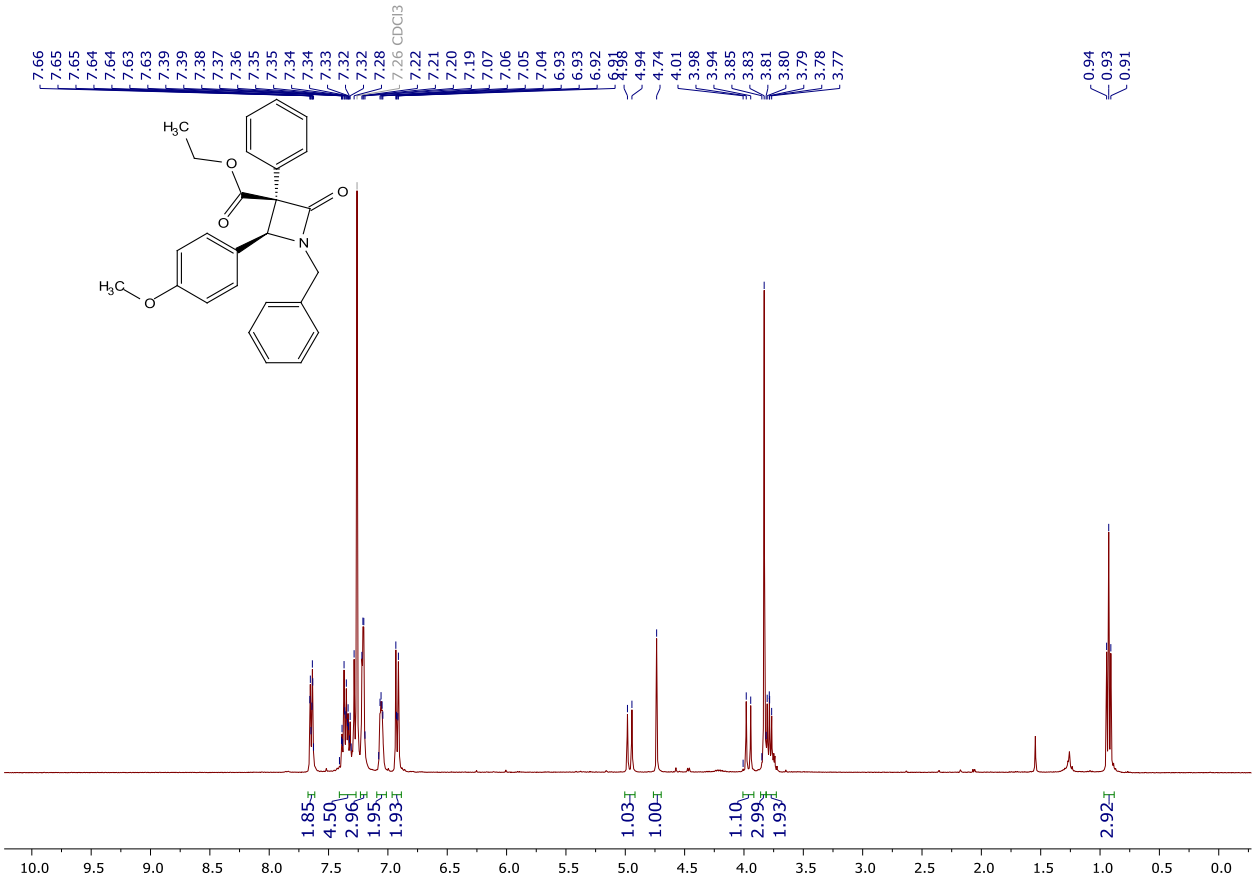
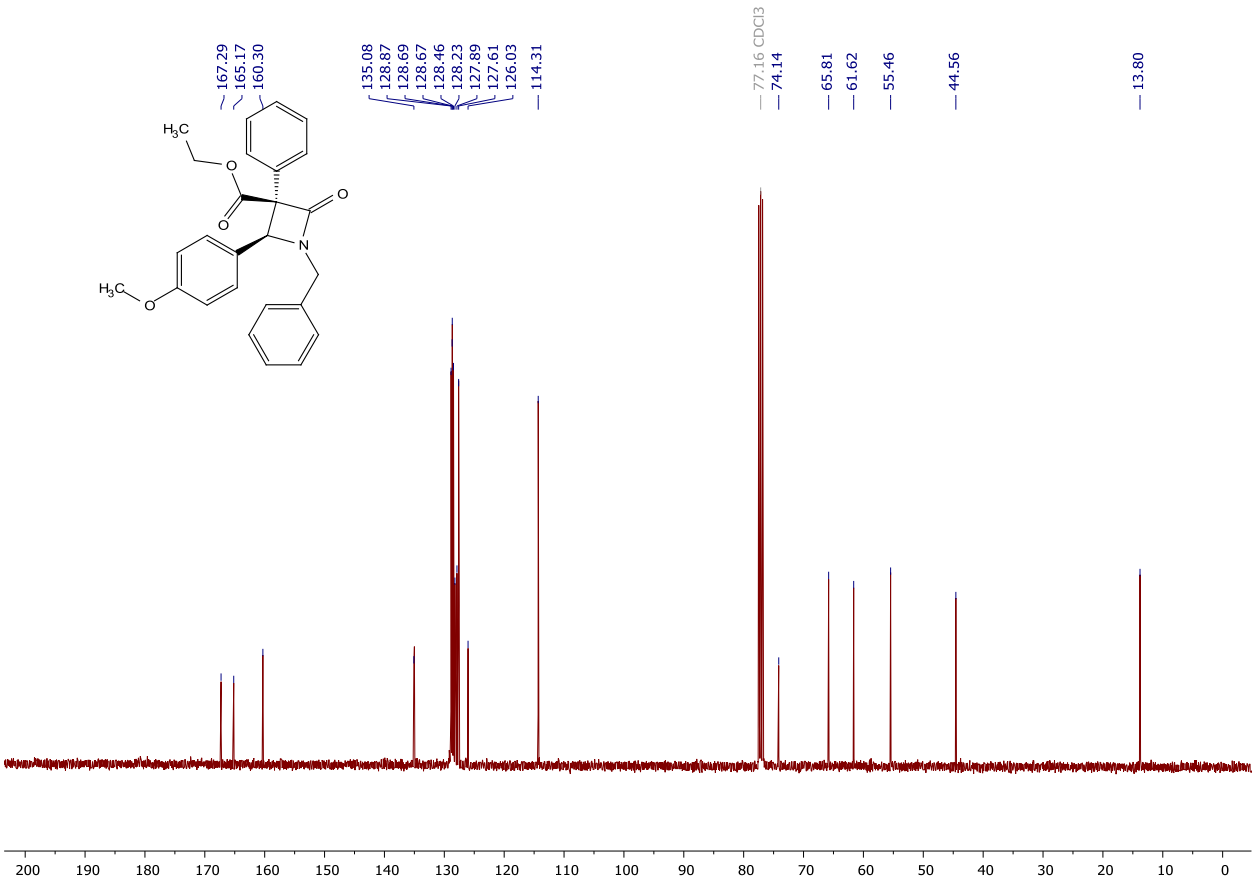
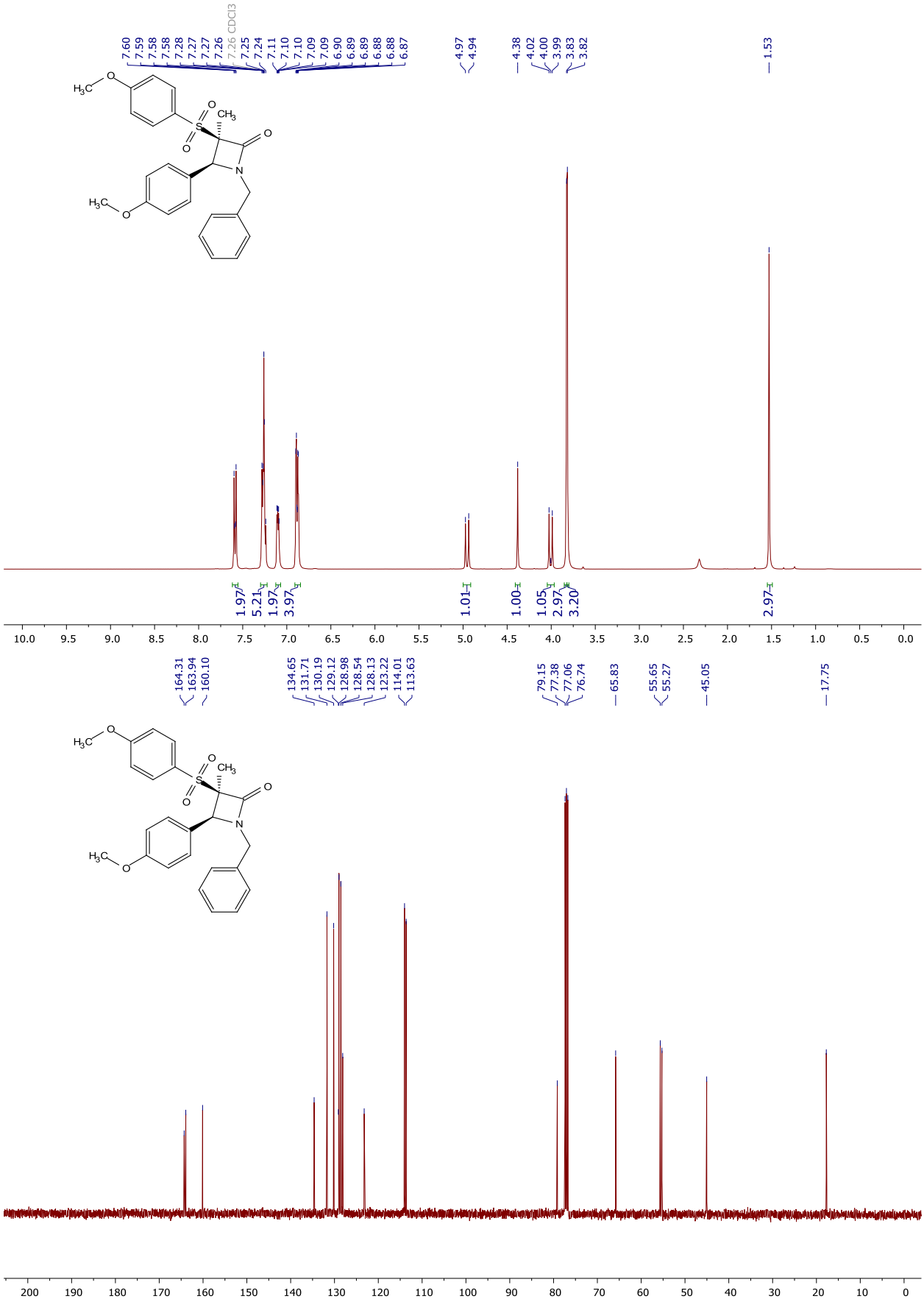
50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220 -230 -240 -250

$^{1}H$ and $^{13}C$ NMR spectra of compound **4g**

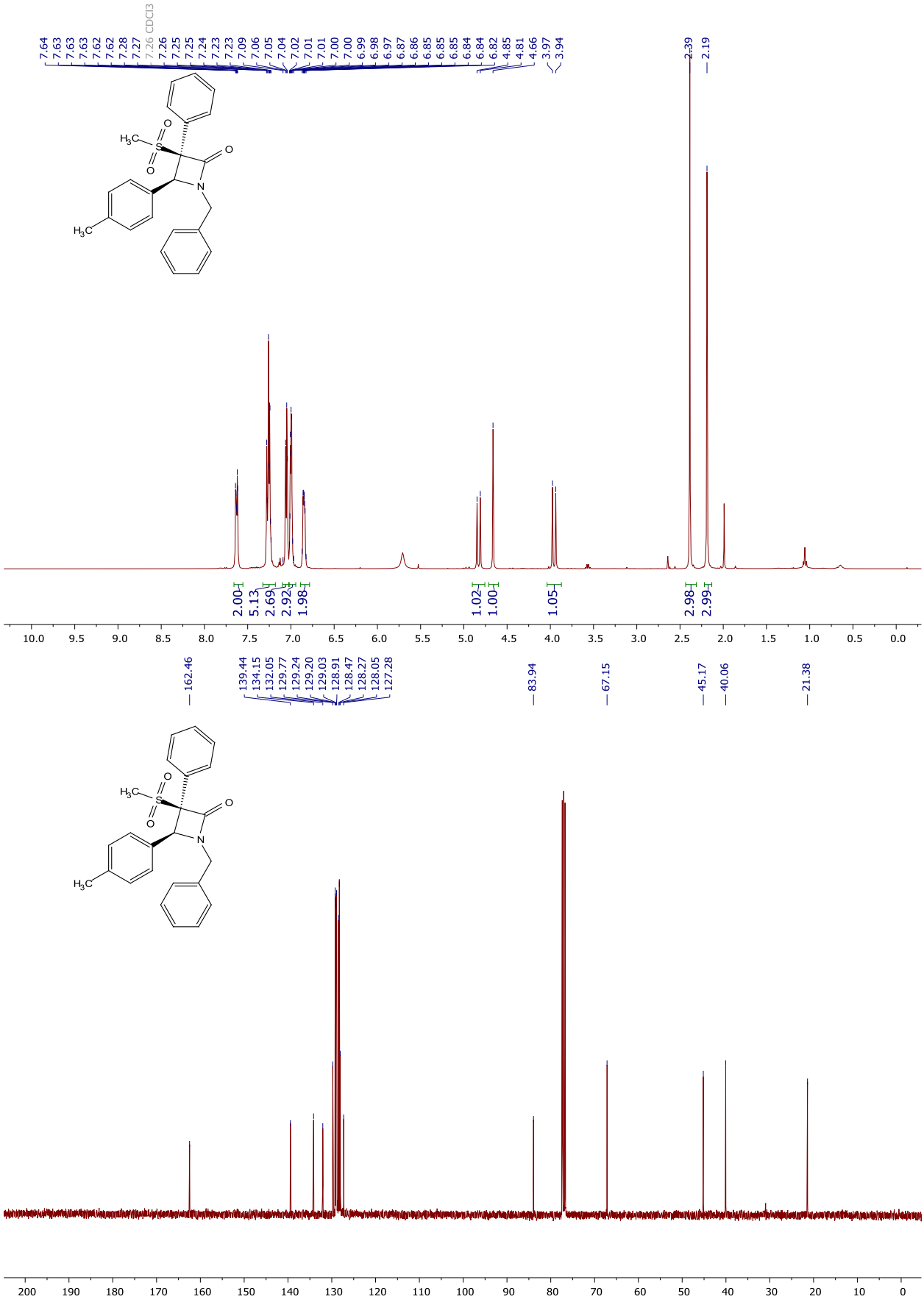


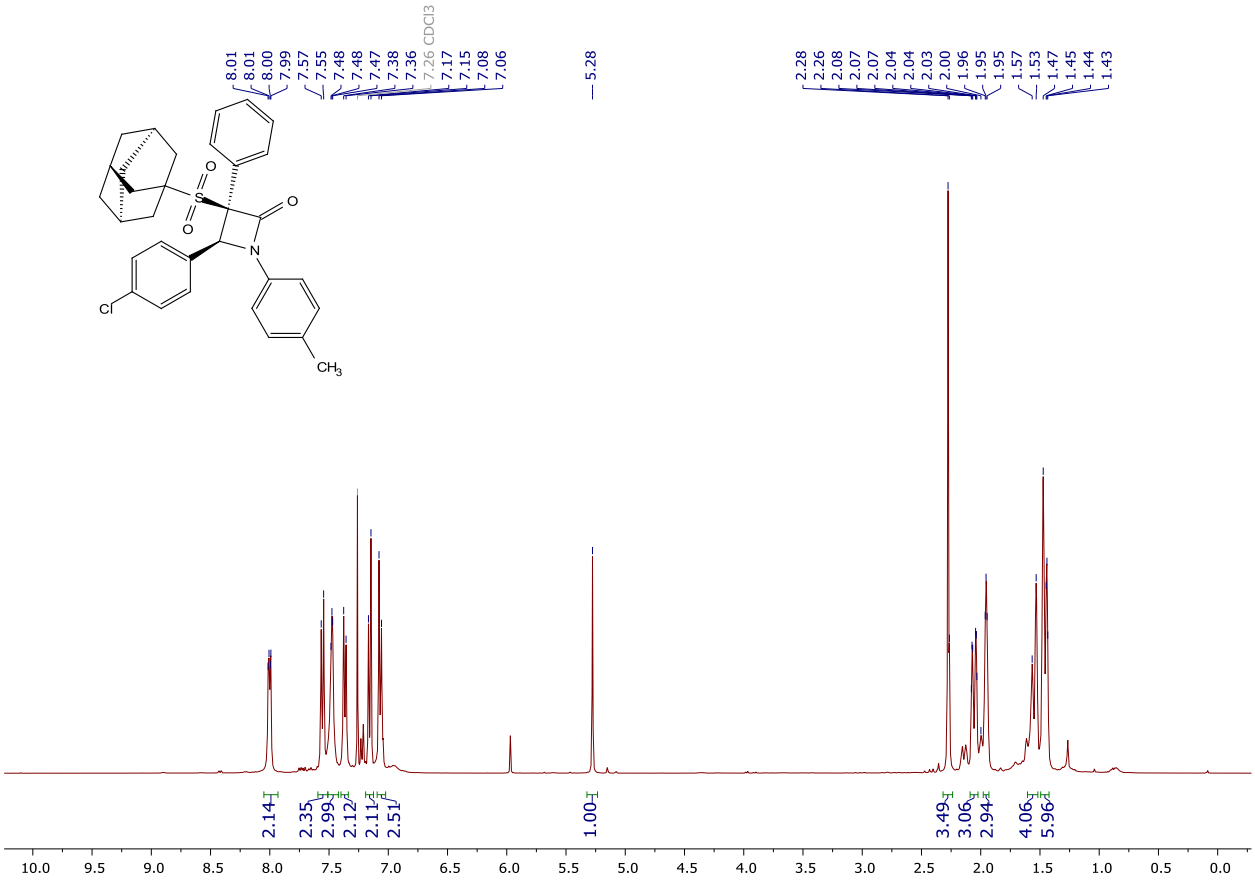
$^{1}$H and $^{13}$C NMR spectra of compound **4h**

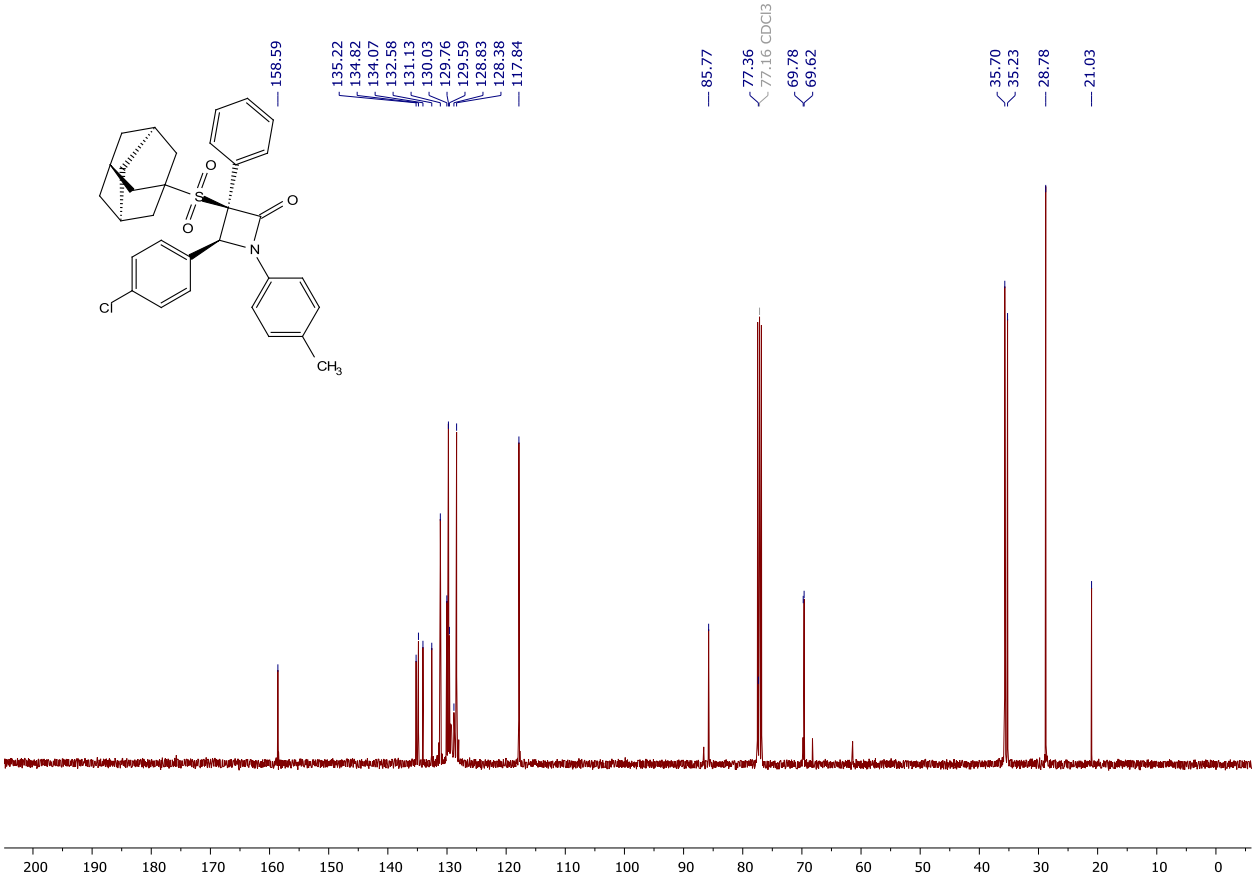


$^{1}$H and $^{13}$C NMR spectra of compound **4i**

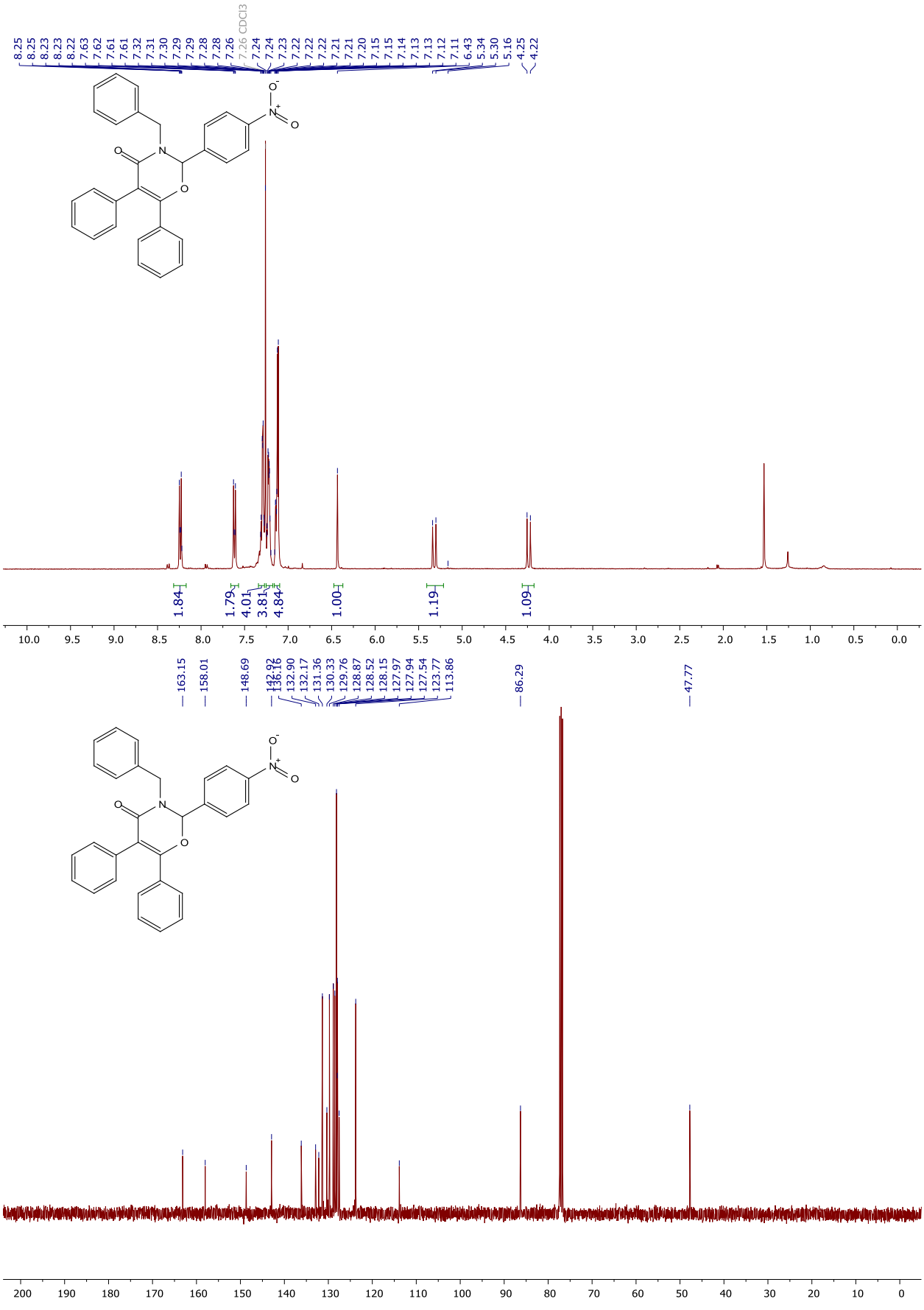


$^{1}H$ and $^{13}C$ NMR spectra of compound **4j**

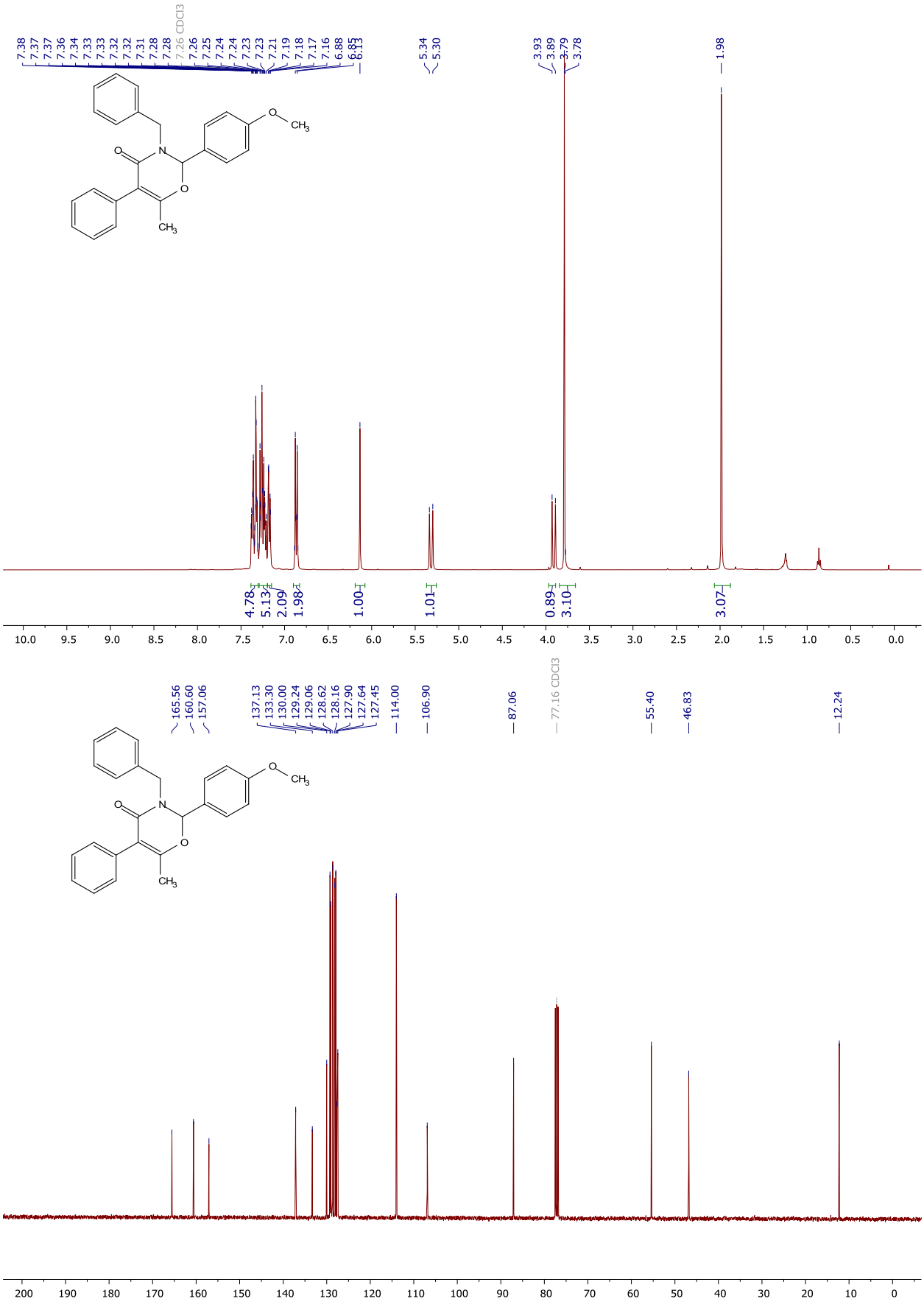


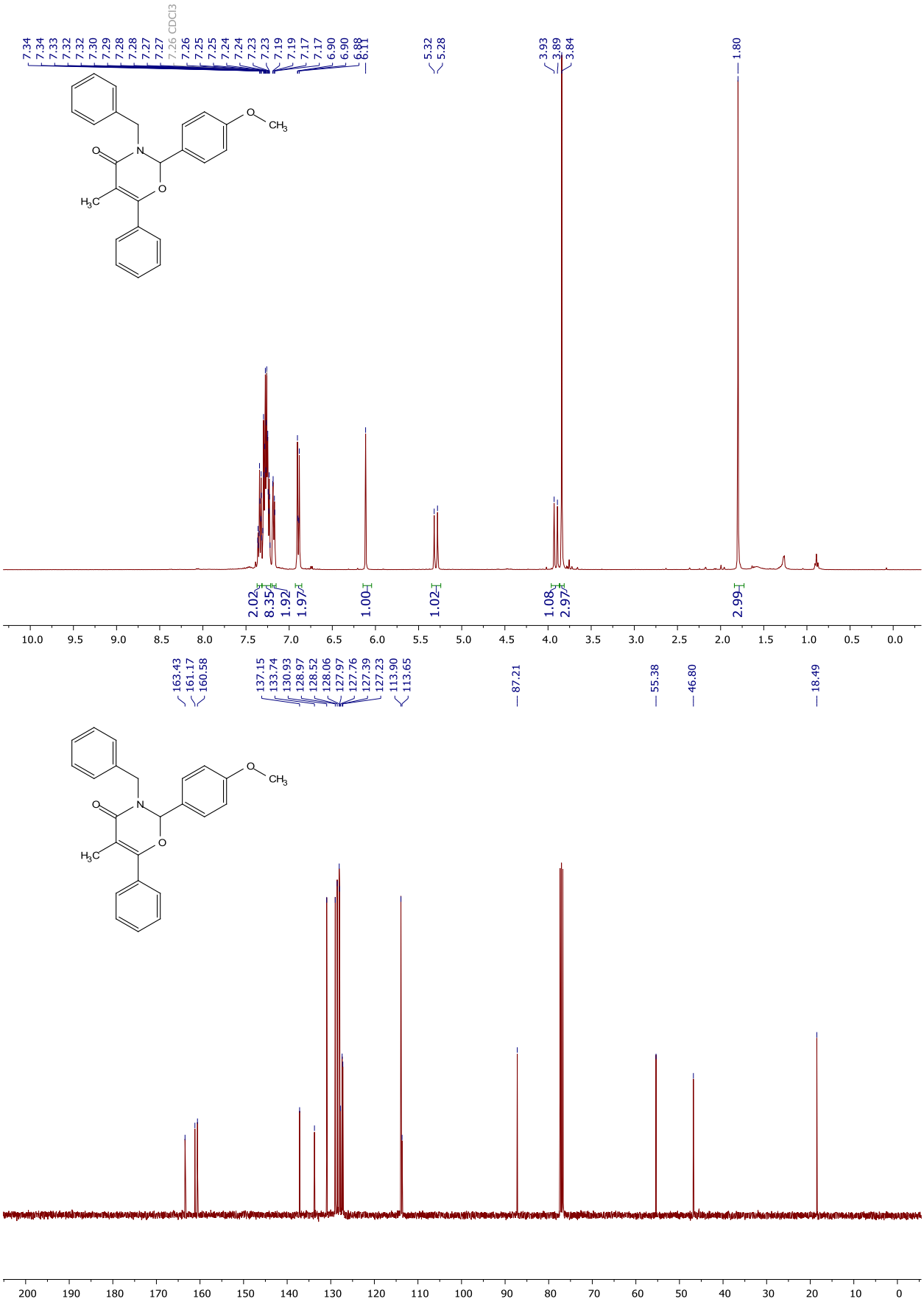
$^{1}H$ and $^{13}C$ NMR spectra of compound **5a**



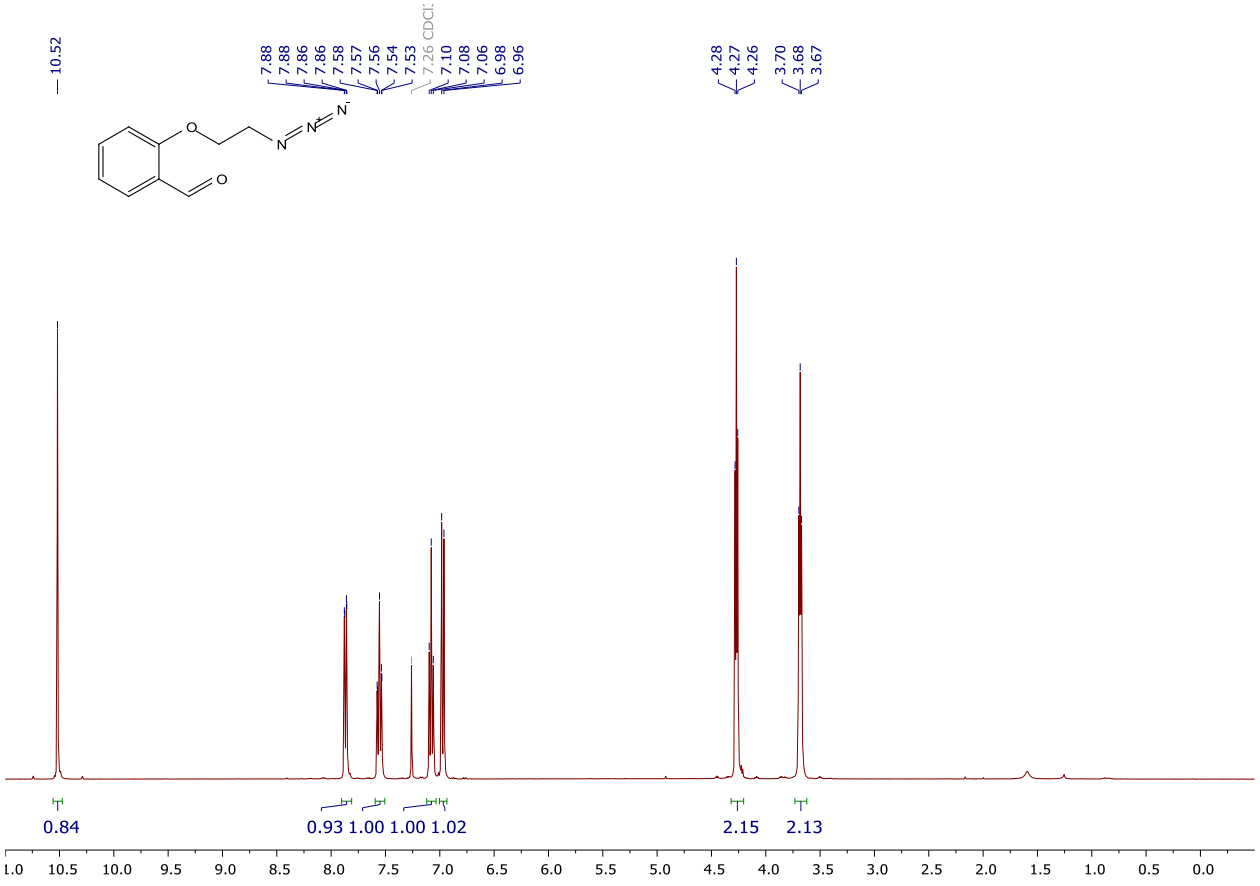
$^{1}$H and $^{13}$C NMR spectra of compound **5b**

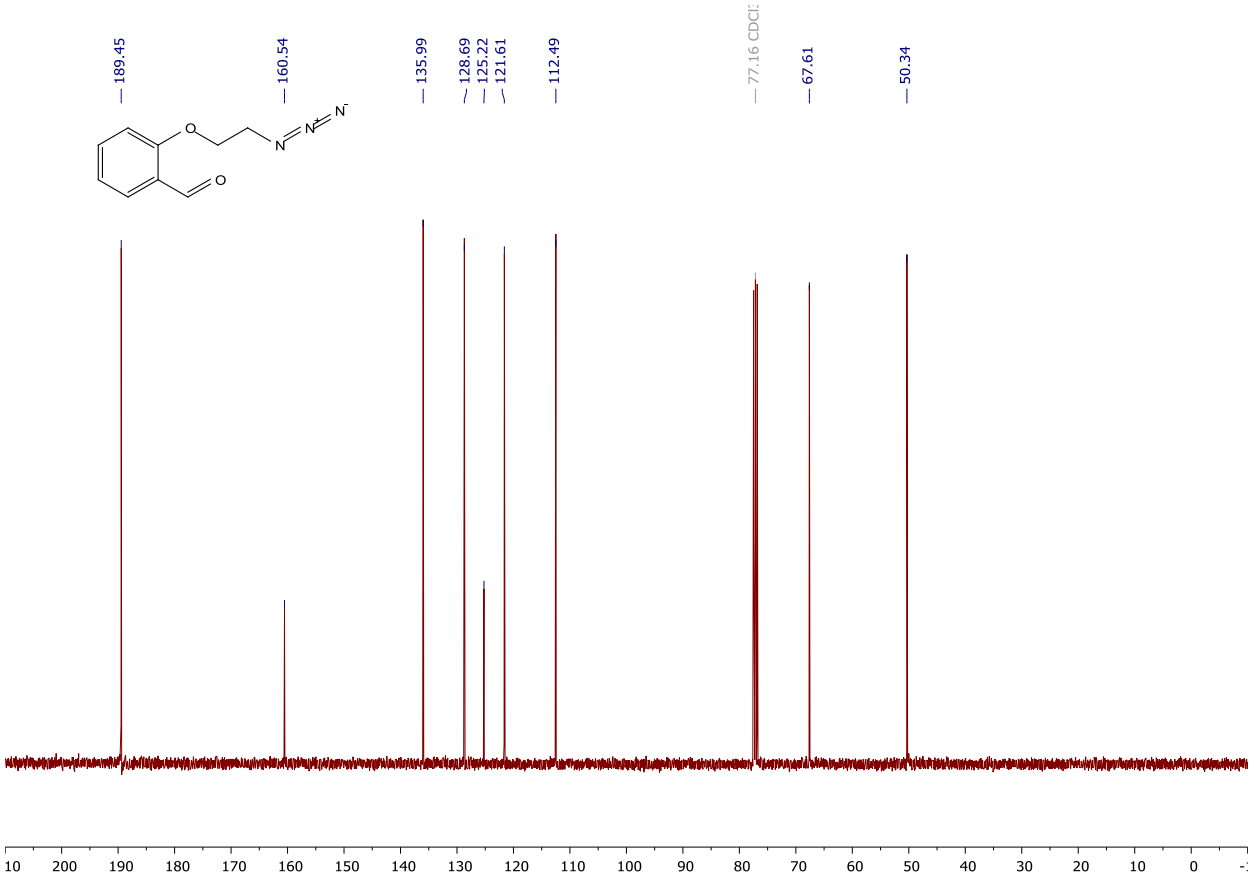


$^{1}H$ and $^{13}C$ NMR spectra of compound **5b'**

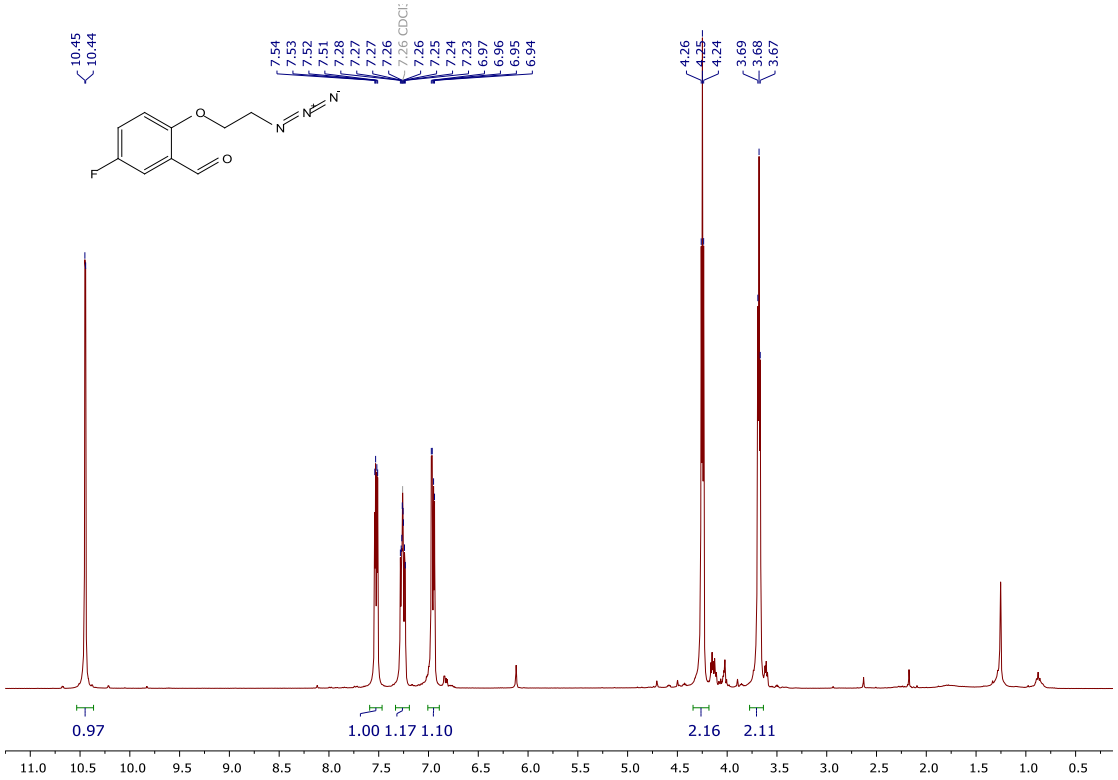


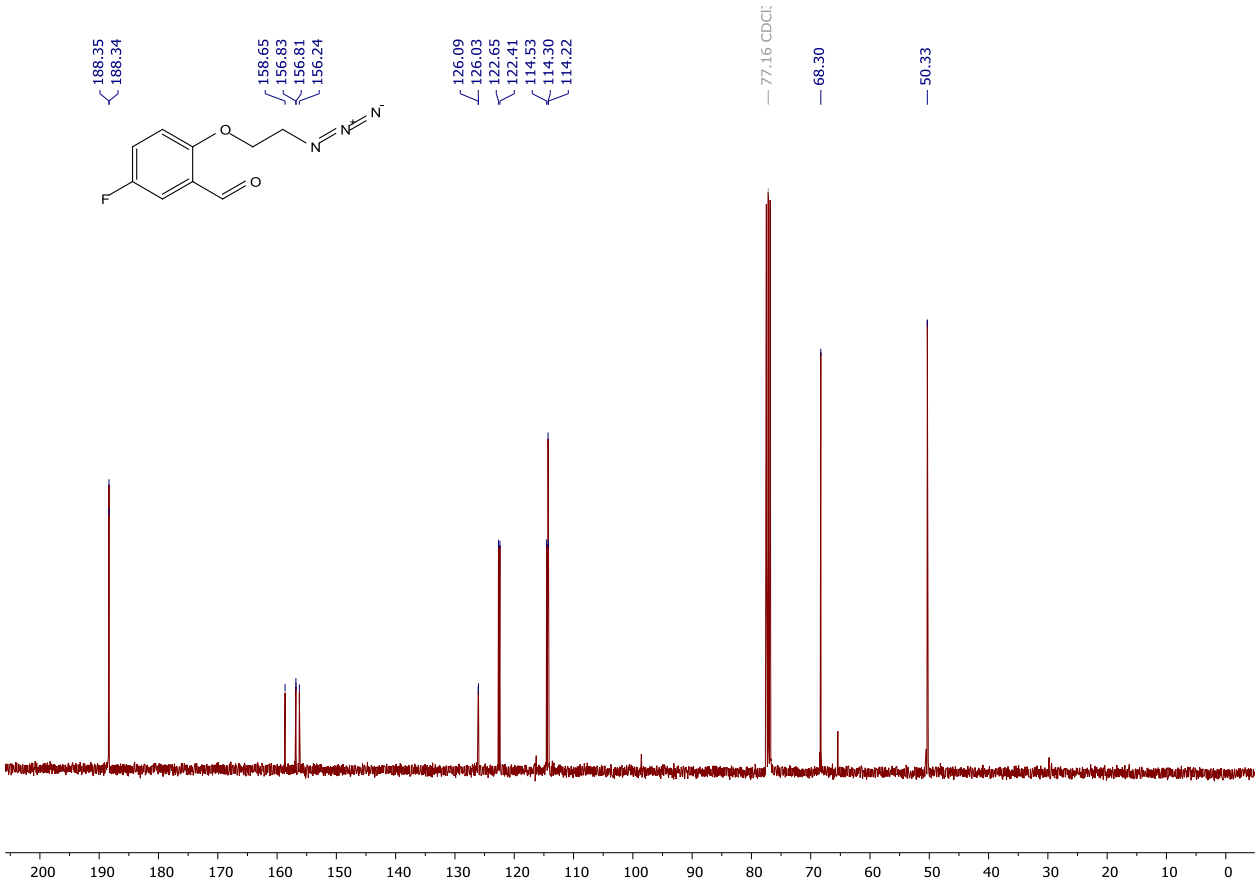
$^{1}H$ and $^{13}C$ NMR spectra of compound **7a**

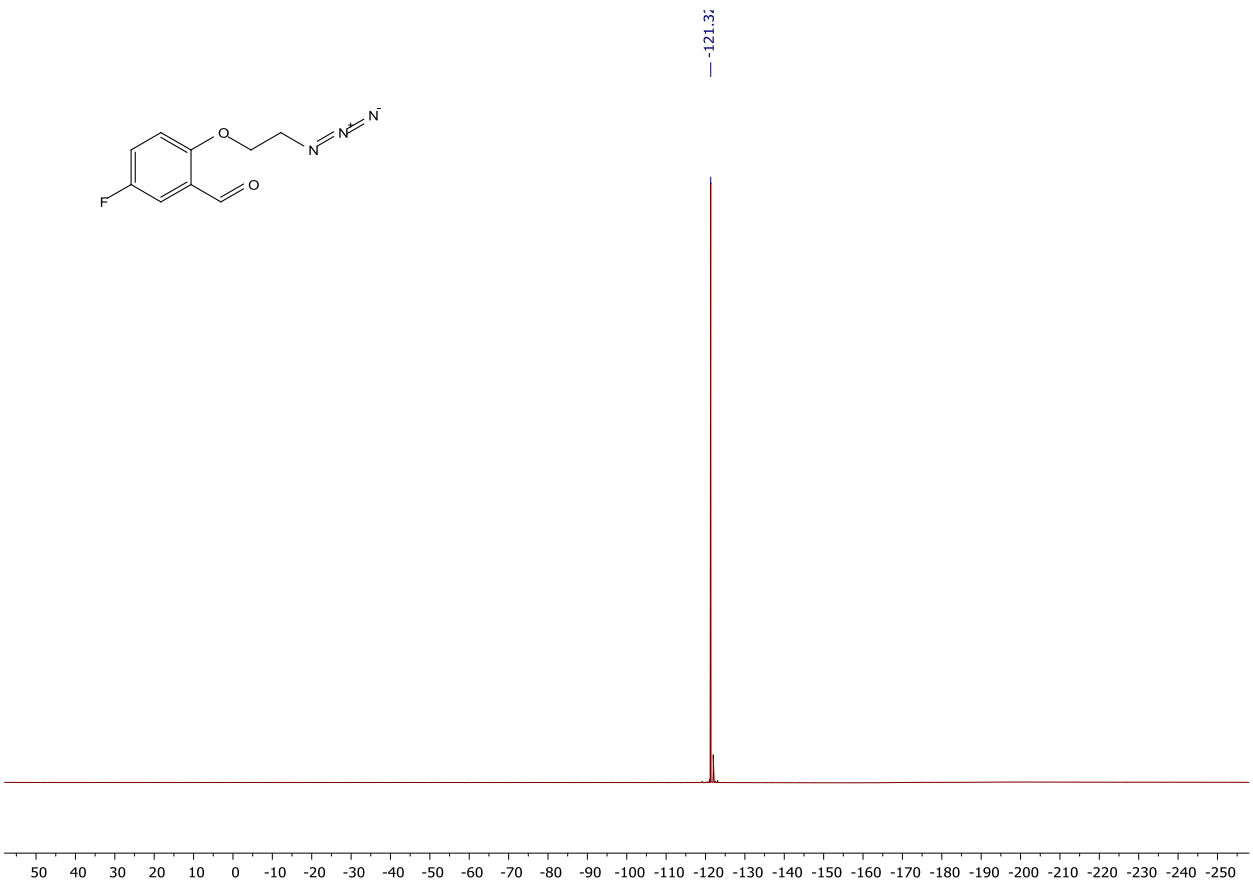


$^{1}H$ and $^{13}C$ NMR spectra of compound **7b**




-121.3
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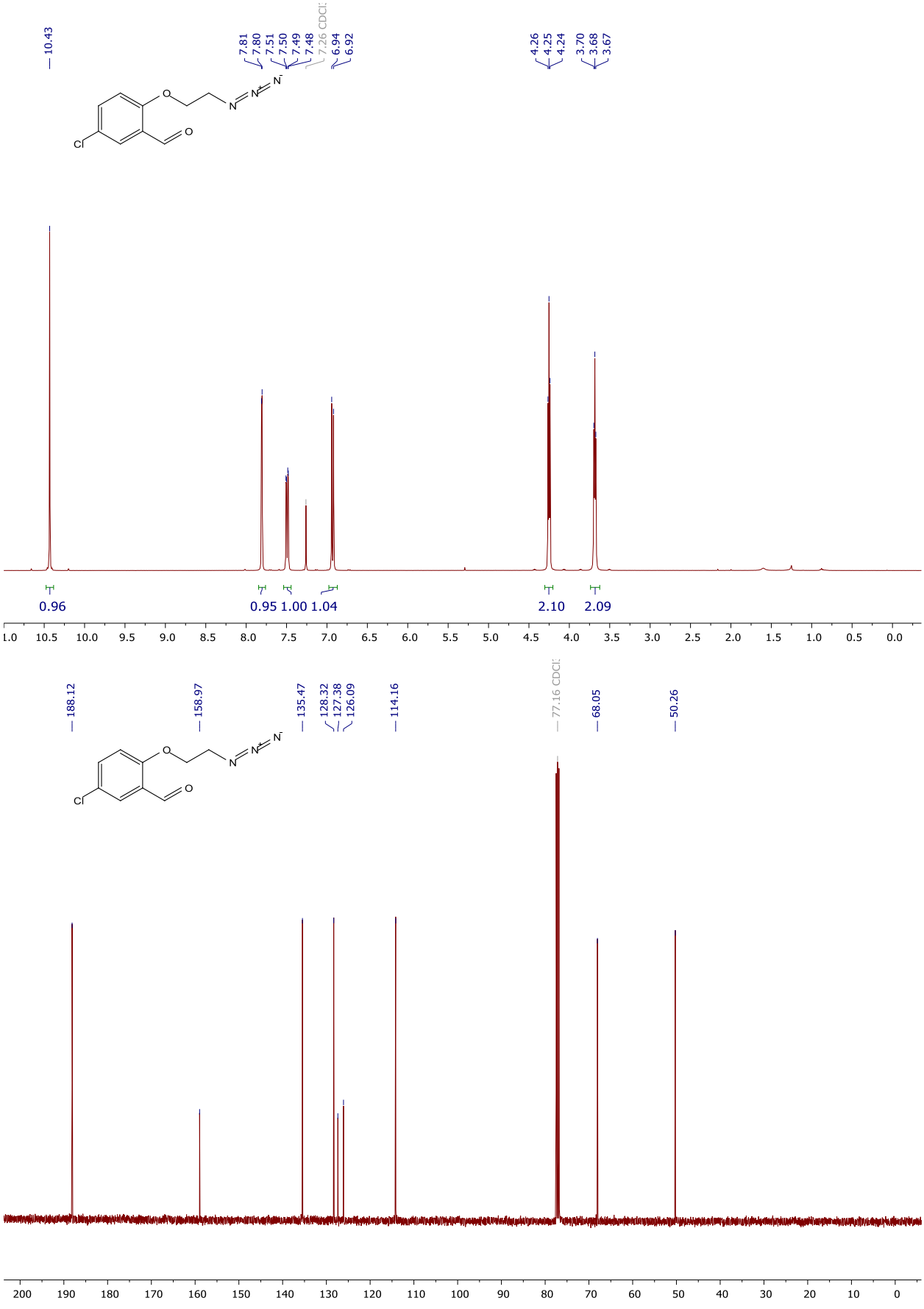
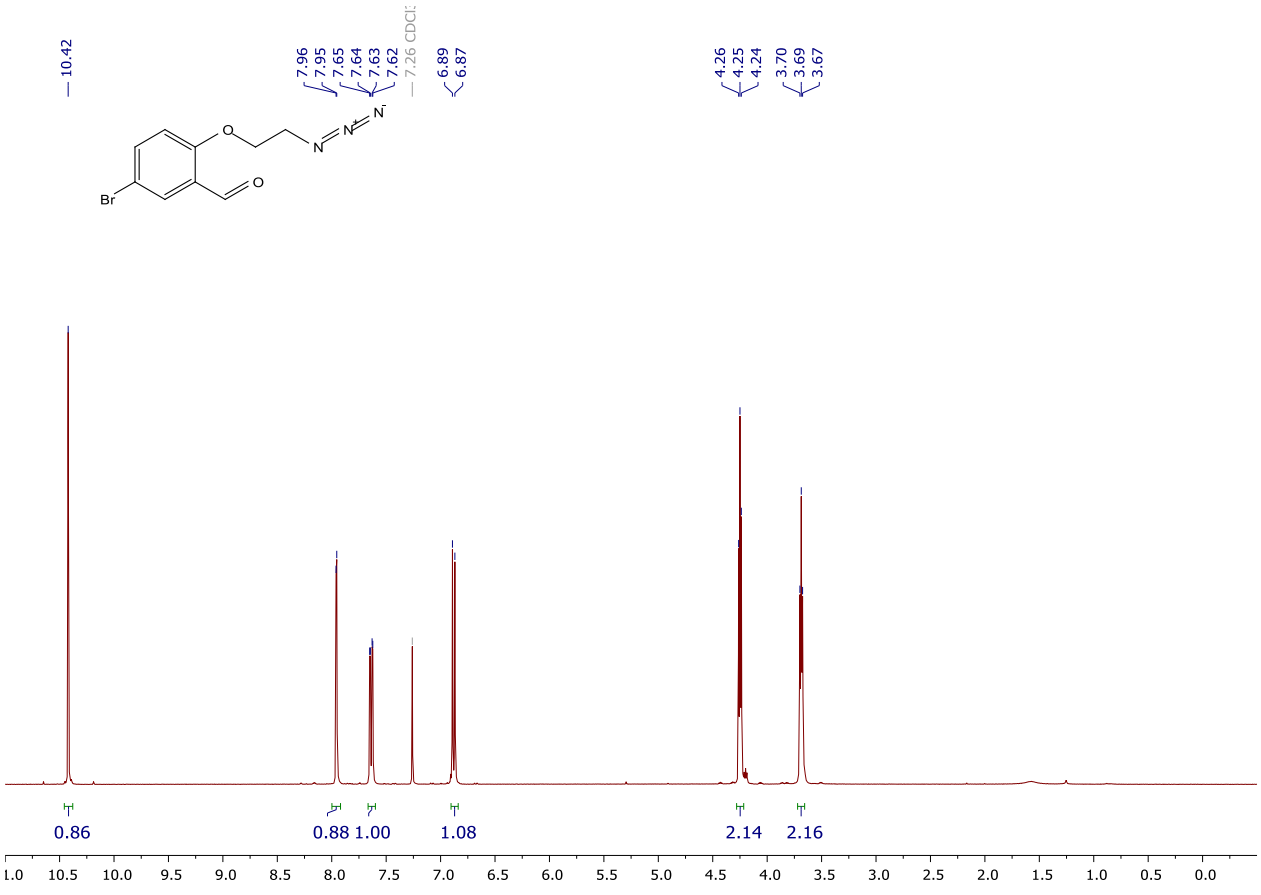
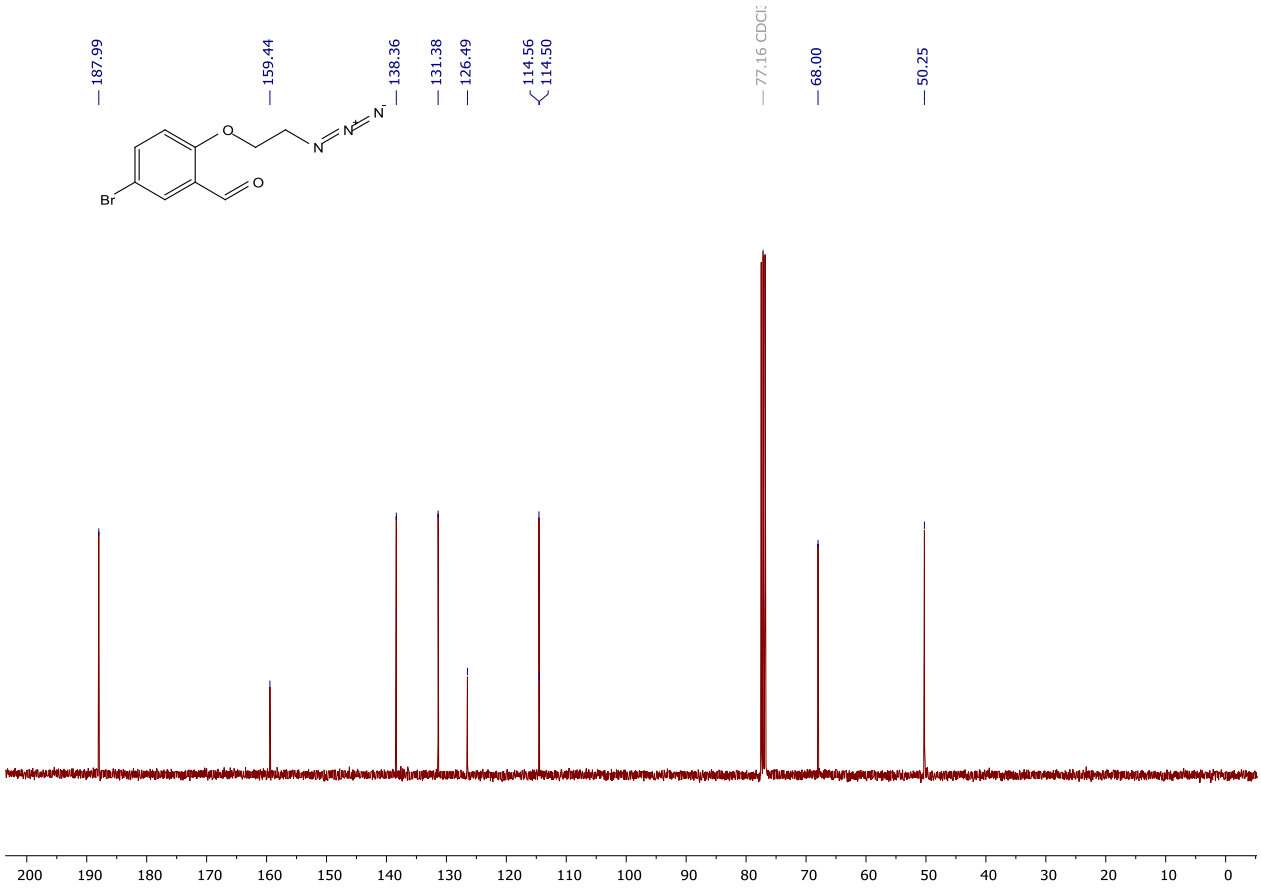
N
N
N
F
O
50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220 -230 -240 -250

$^{1}H$ and $^{13}C$ NMR spectra of compound **7c**

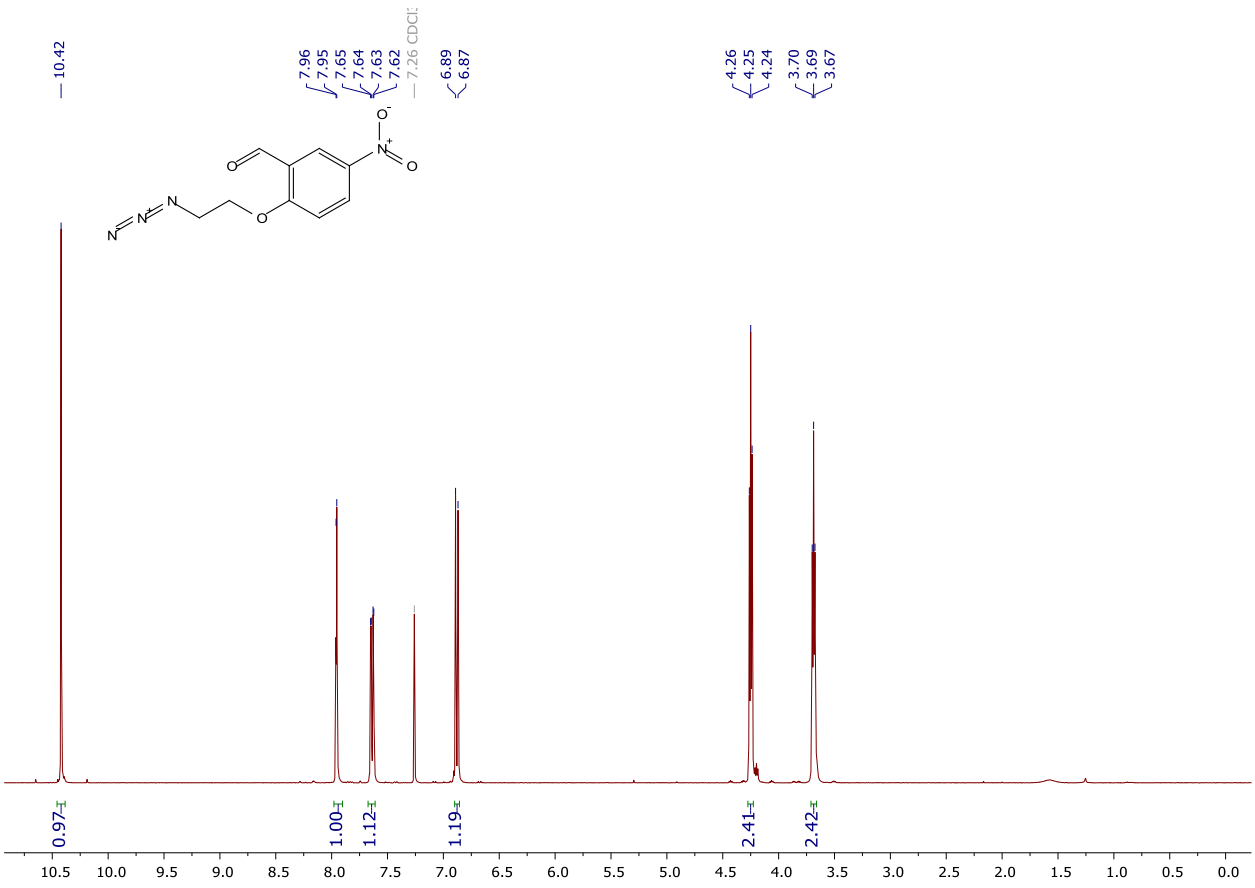


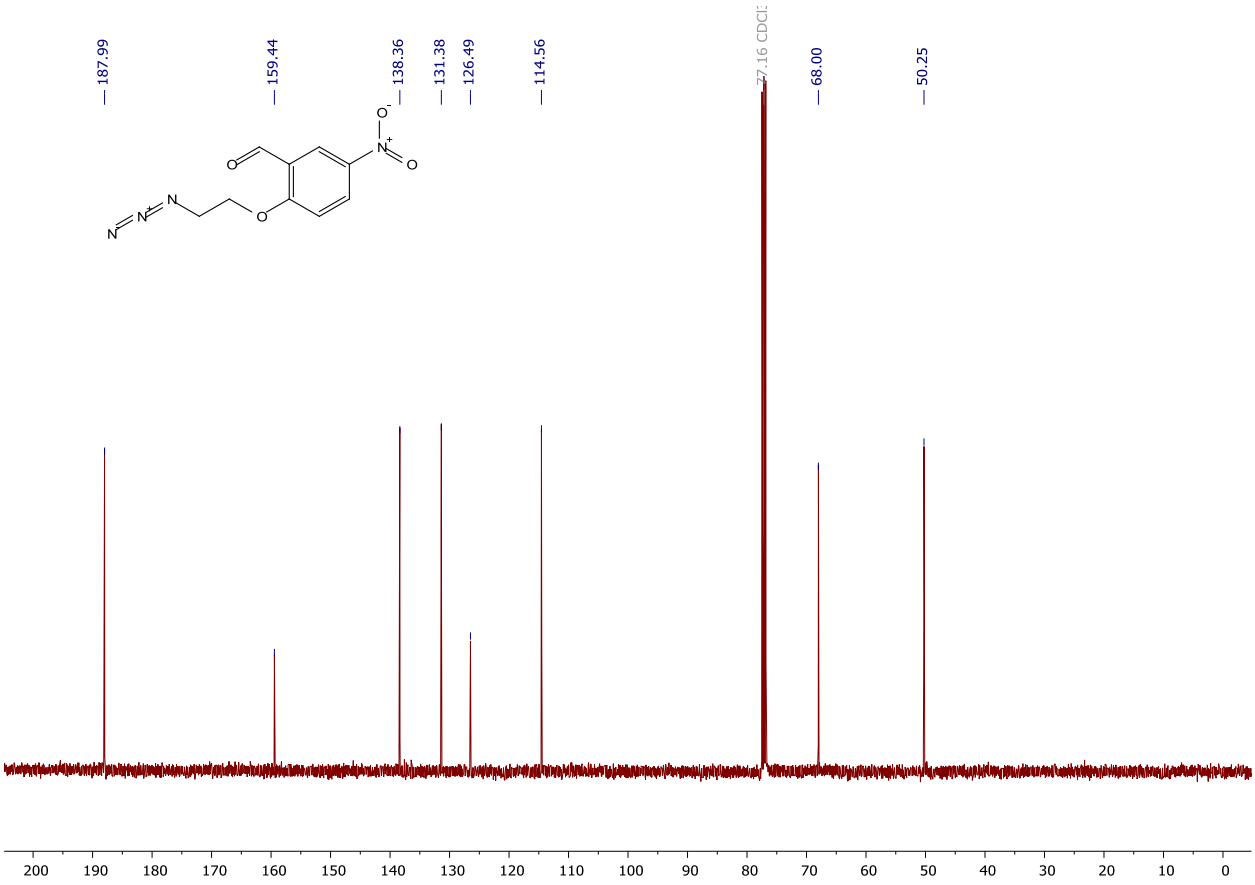
$^{1}H$ and $^{13}C$ NMR spectra of compound **7d**



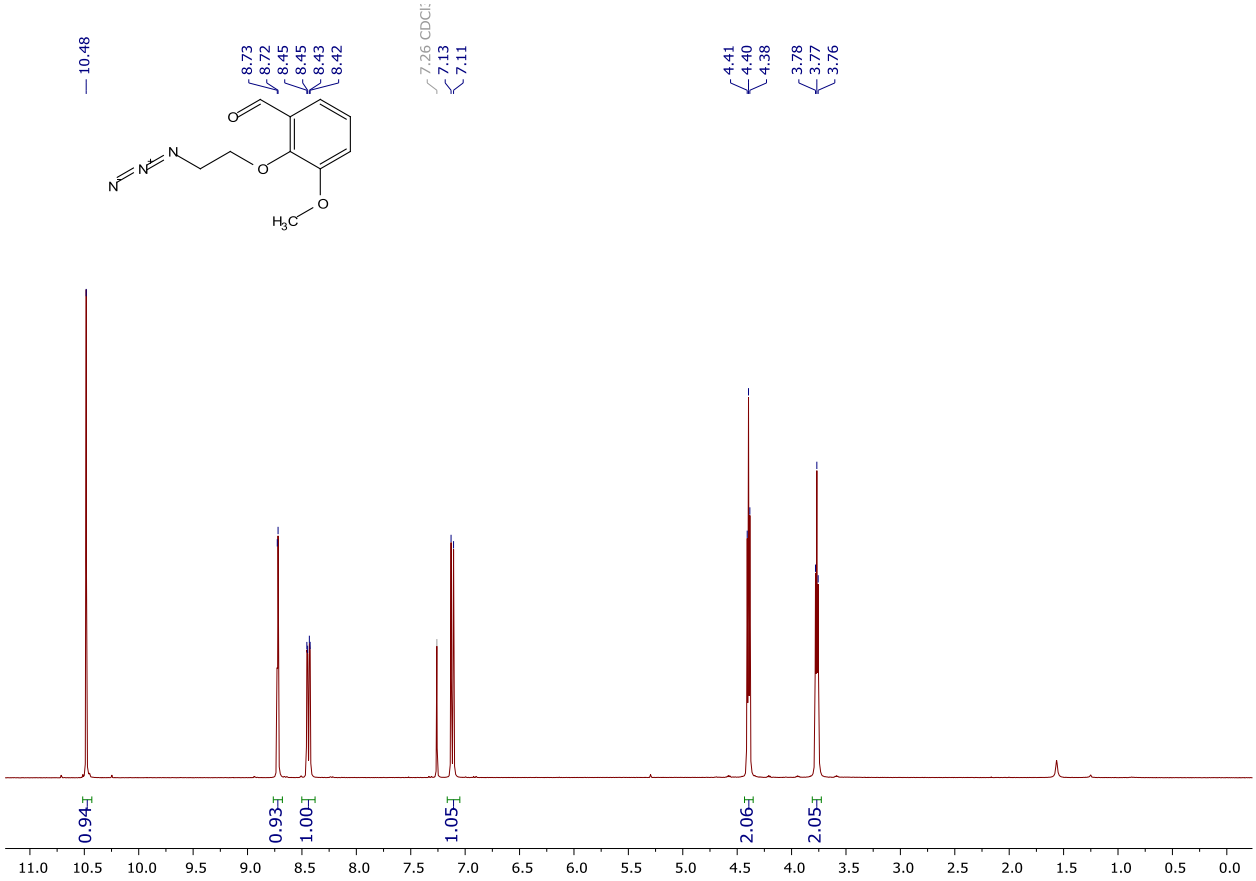



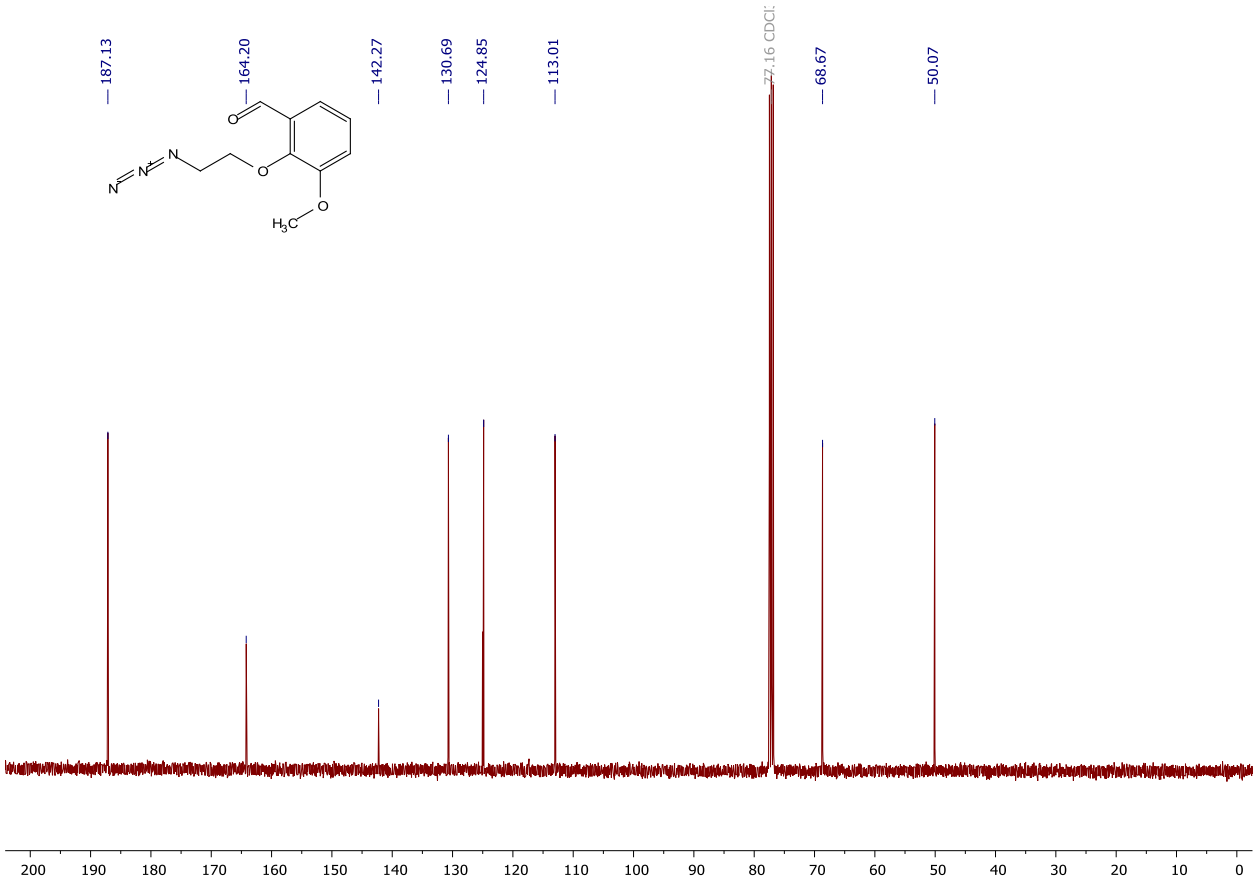
$^{1}H$ and $^{13}C$ NMR spectra of compound **7e**



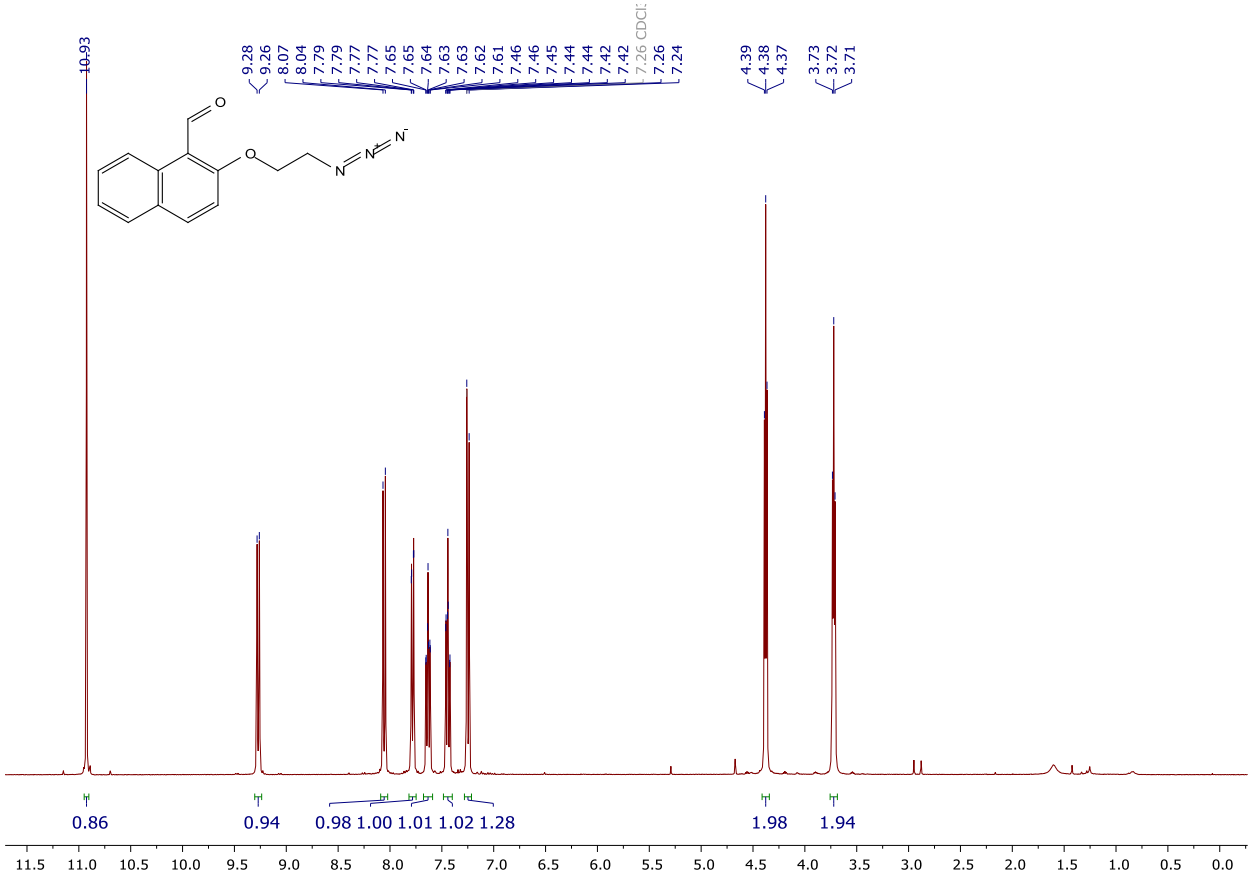



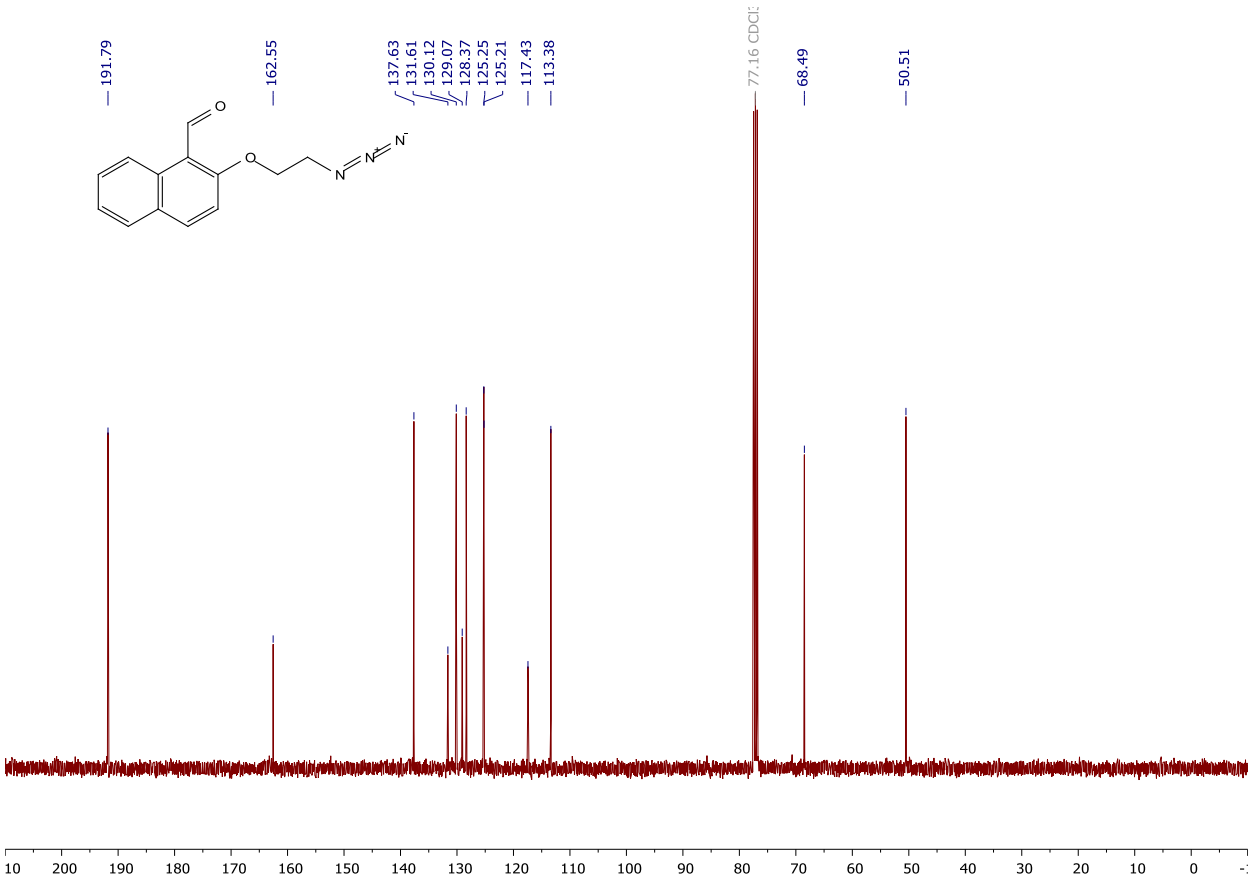
$^{1}H$ and $^{13}C$ NMR spectra of compound **7f**



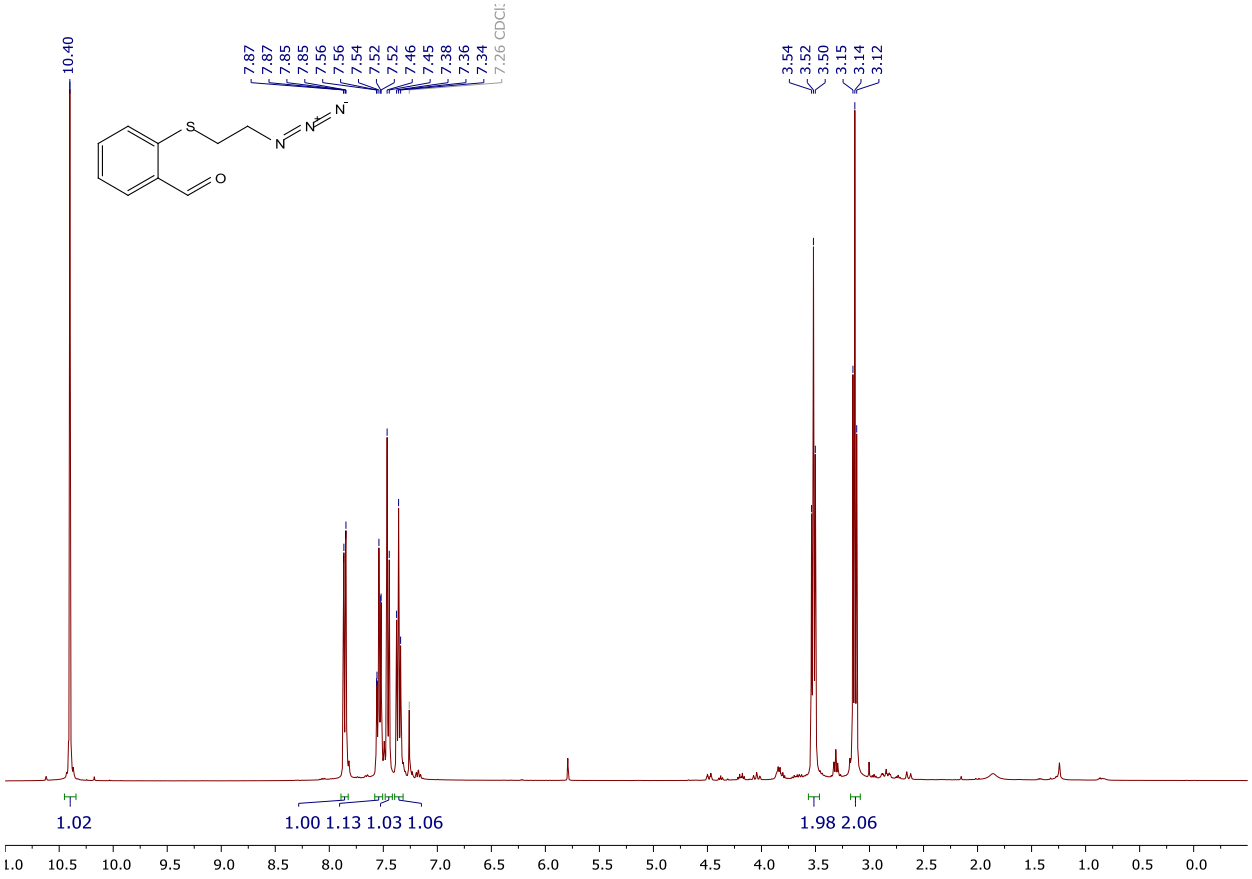



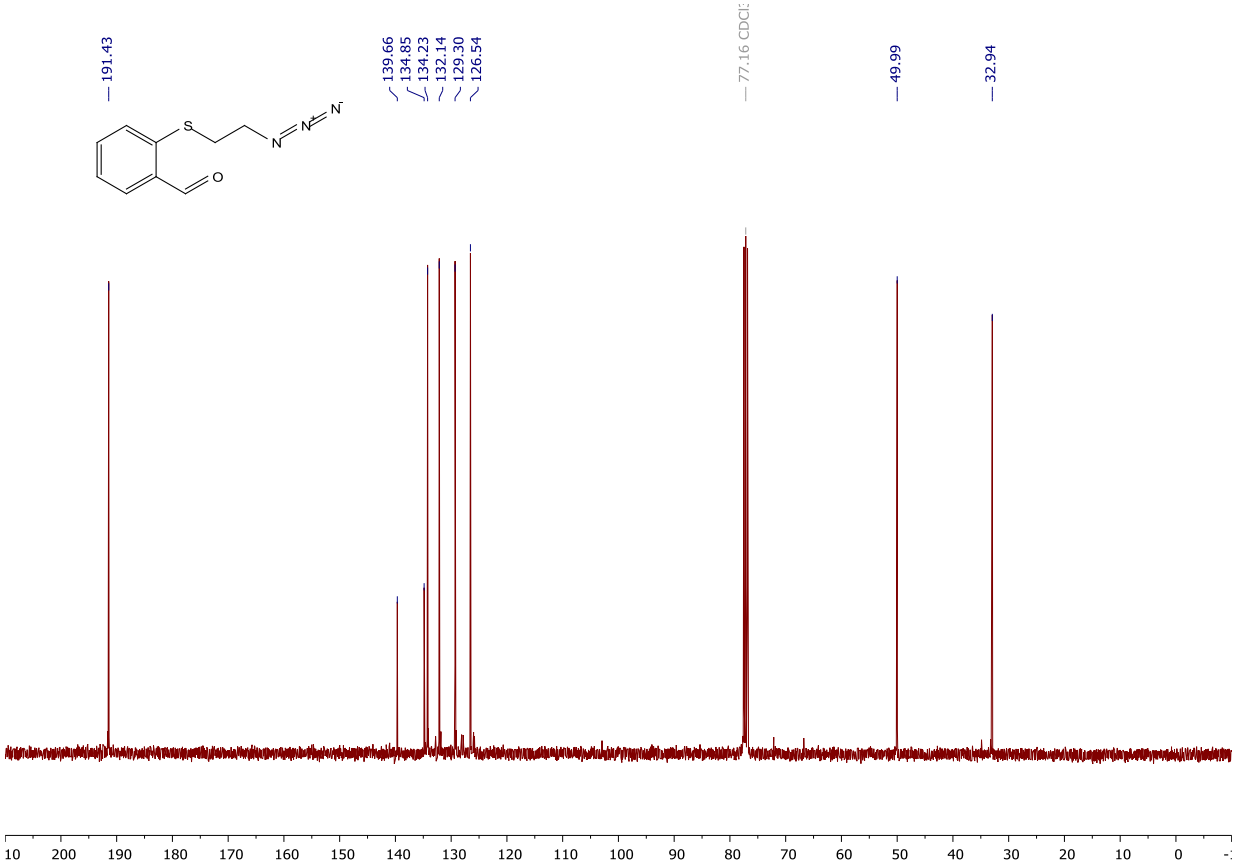
$^{1}H$ and $^{13}C$ NMR spectra of compound **7g**



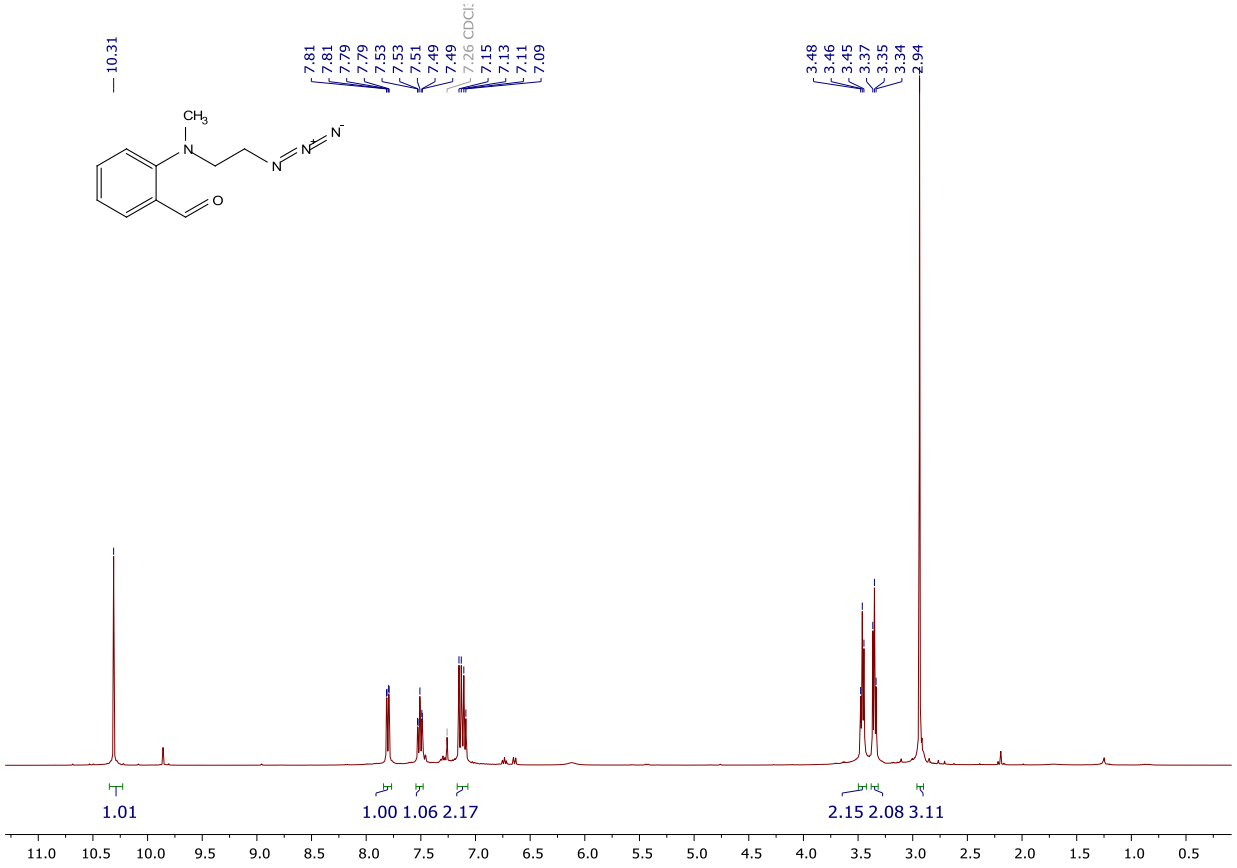



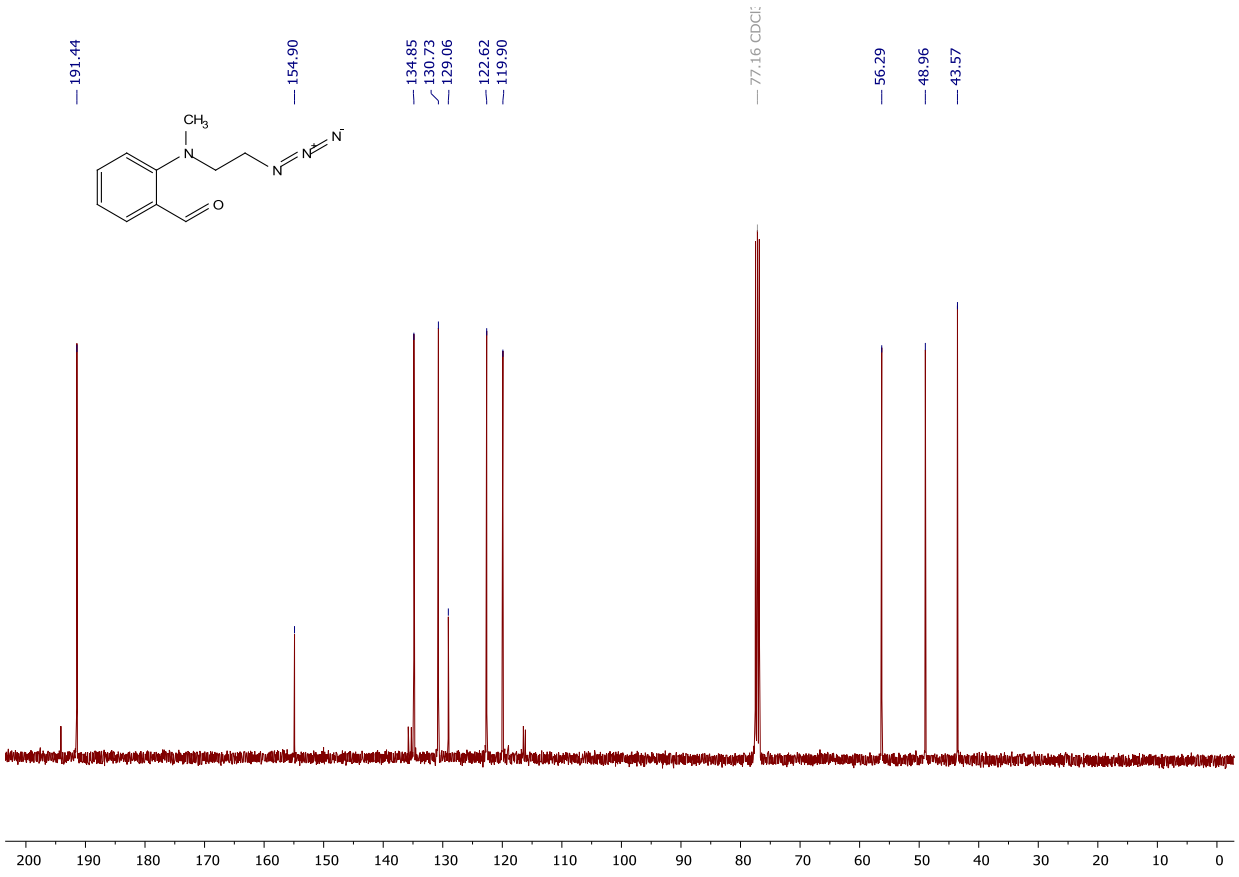
$^{1}H$ and $^{13}C$ NMR spectra of compound **7h**



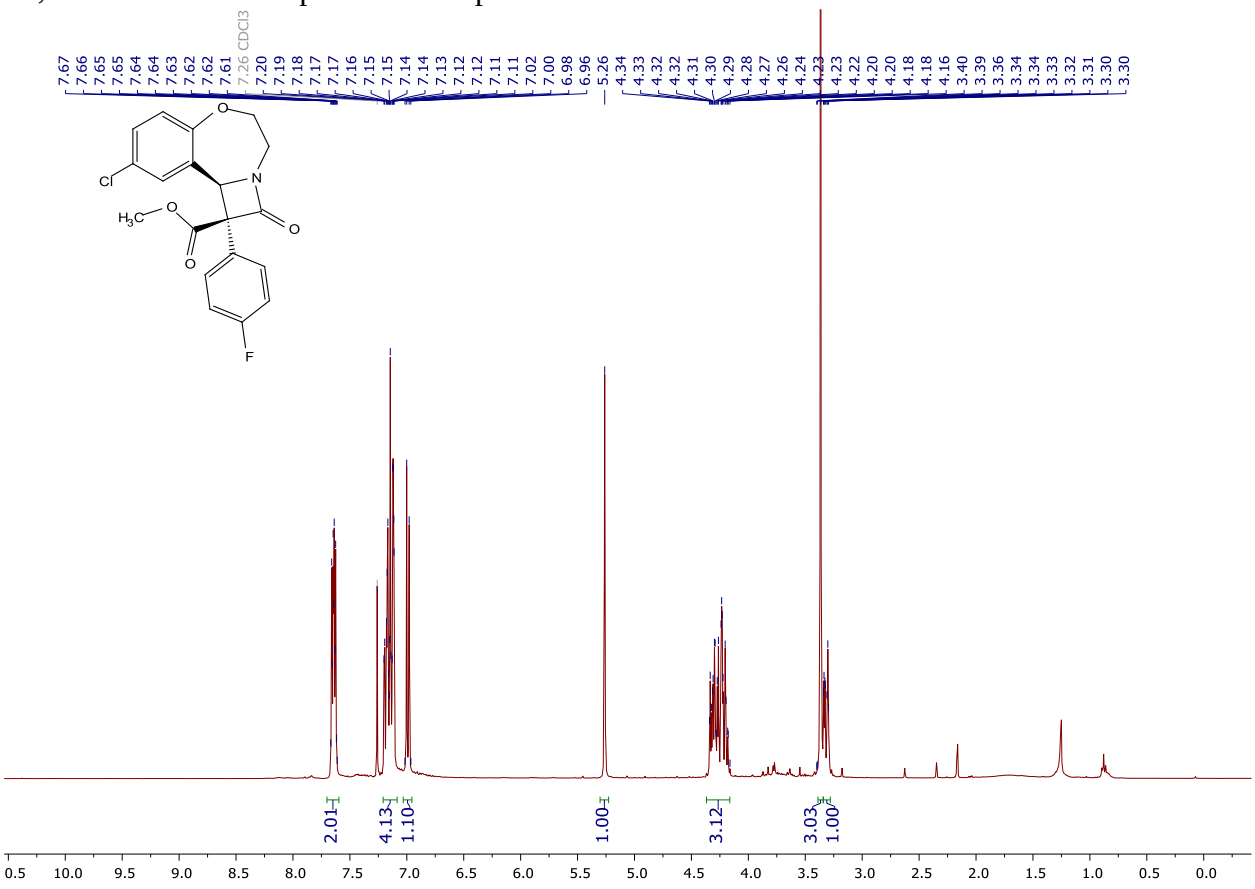



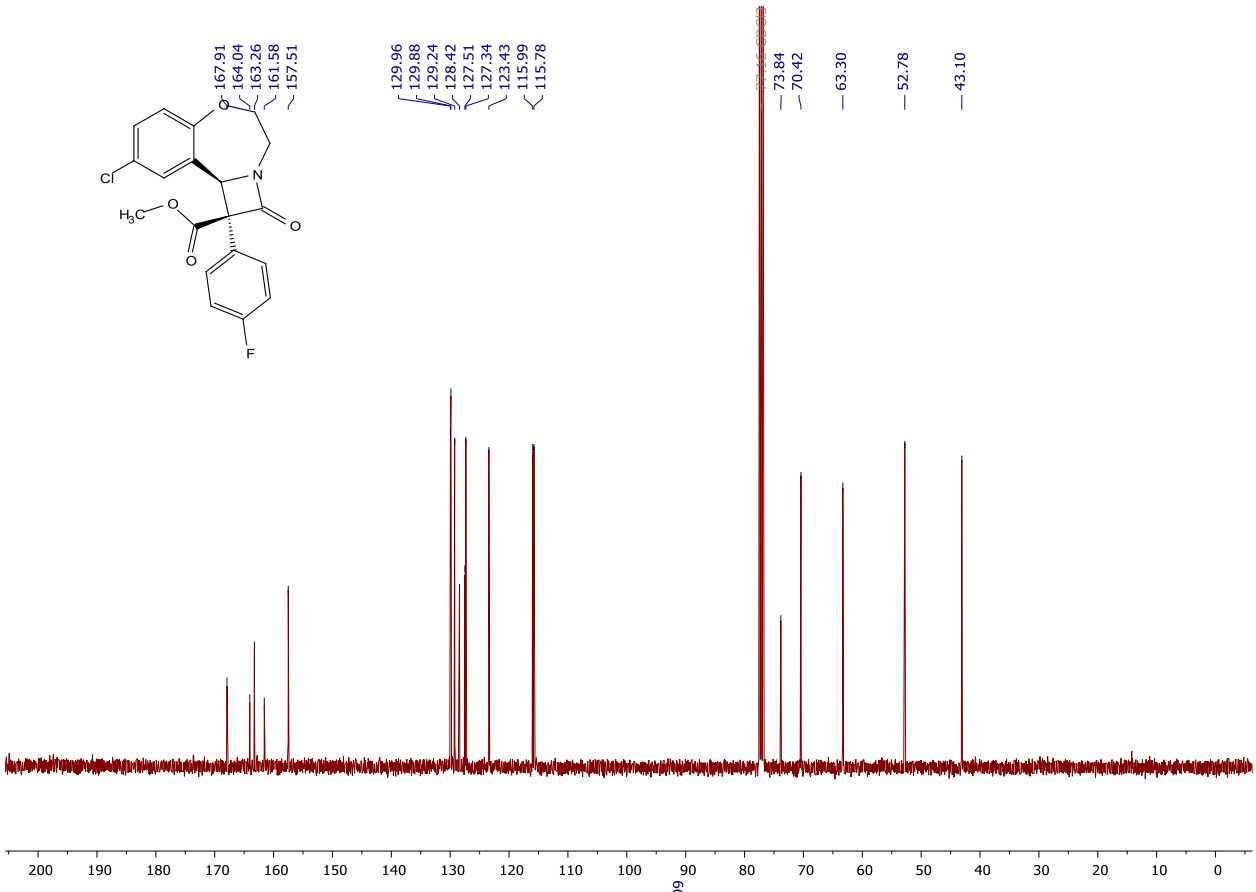
$^{1}H$ and $^{13}C$ NMR spectra of compound **7i**



$^{1}H$, $^{13}C$ and $^{19}F$ NMR spectra of compound **9a**

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129.88
129.24
128.42
127.51
127.34
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115.99
115.78
73.84
70.42
63.30
52.78
43.10
Cl
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N
O
O
O
H3C
F
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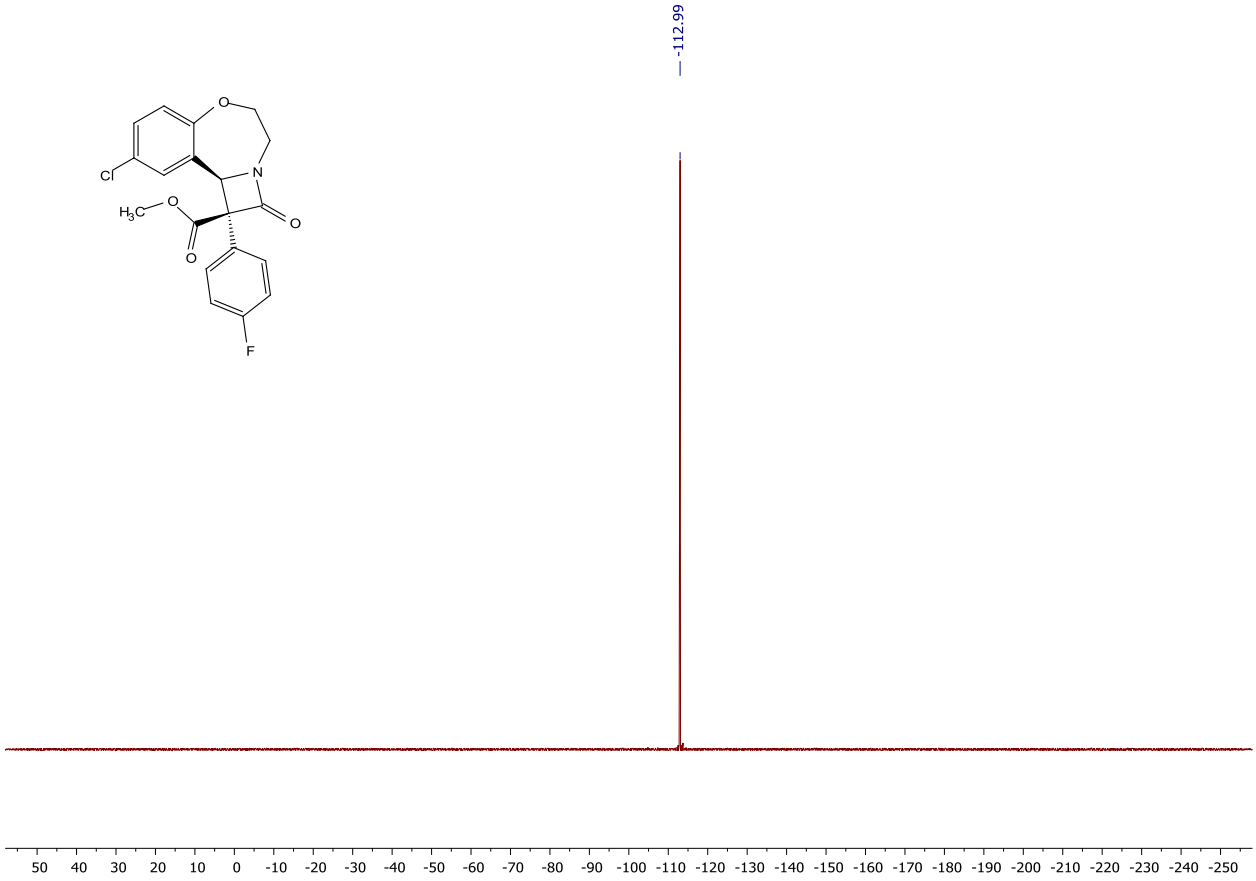
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N
O
O
O
H3C
F
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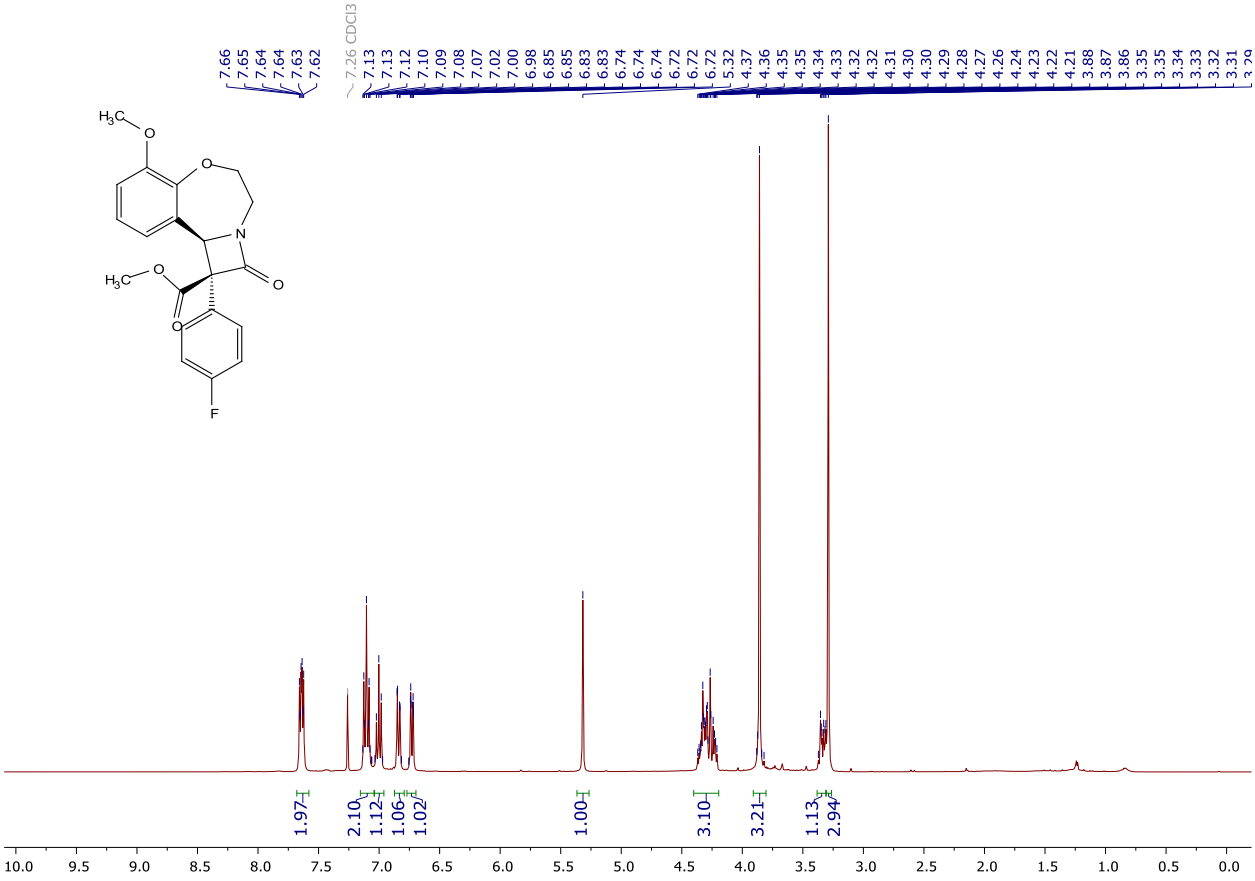
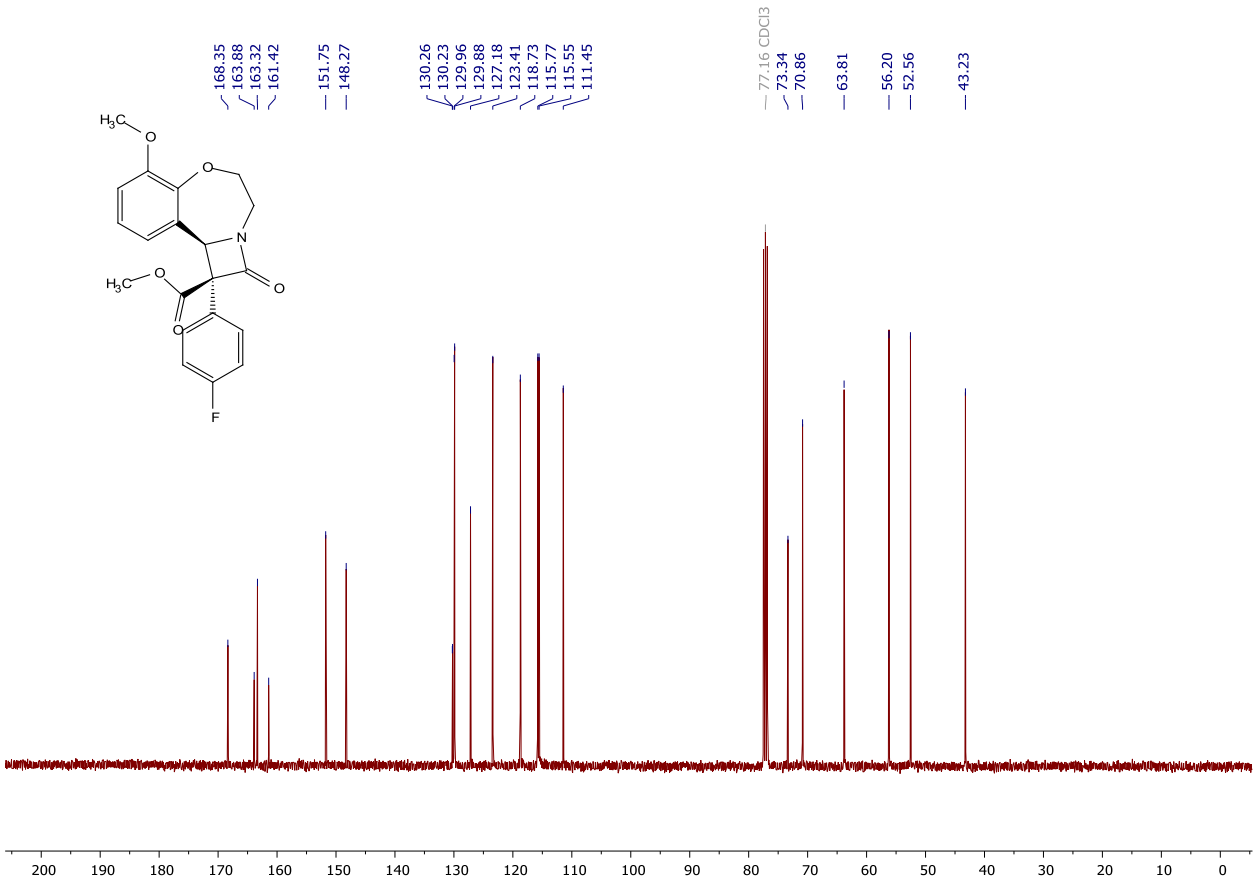
$^{1}H$, $^{13}C$ and $^{19}F$ NMR spectra of compound **9b**

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130.23
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127.18
123.41
118.73
115.77
115.55
111.45
77.16 CDCl3
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70.86
63.81
56.20
52.56
43.23
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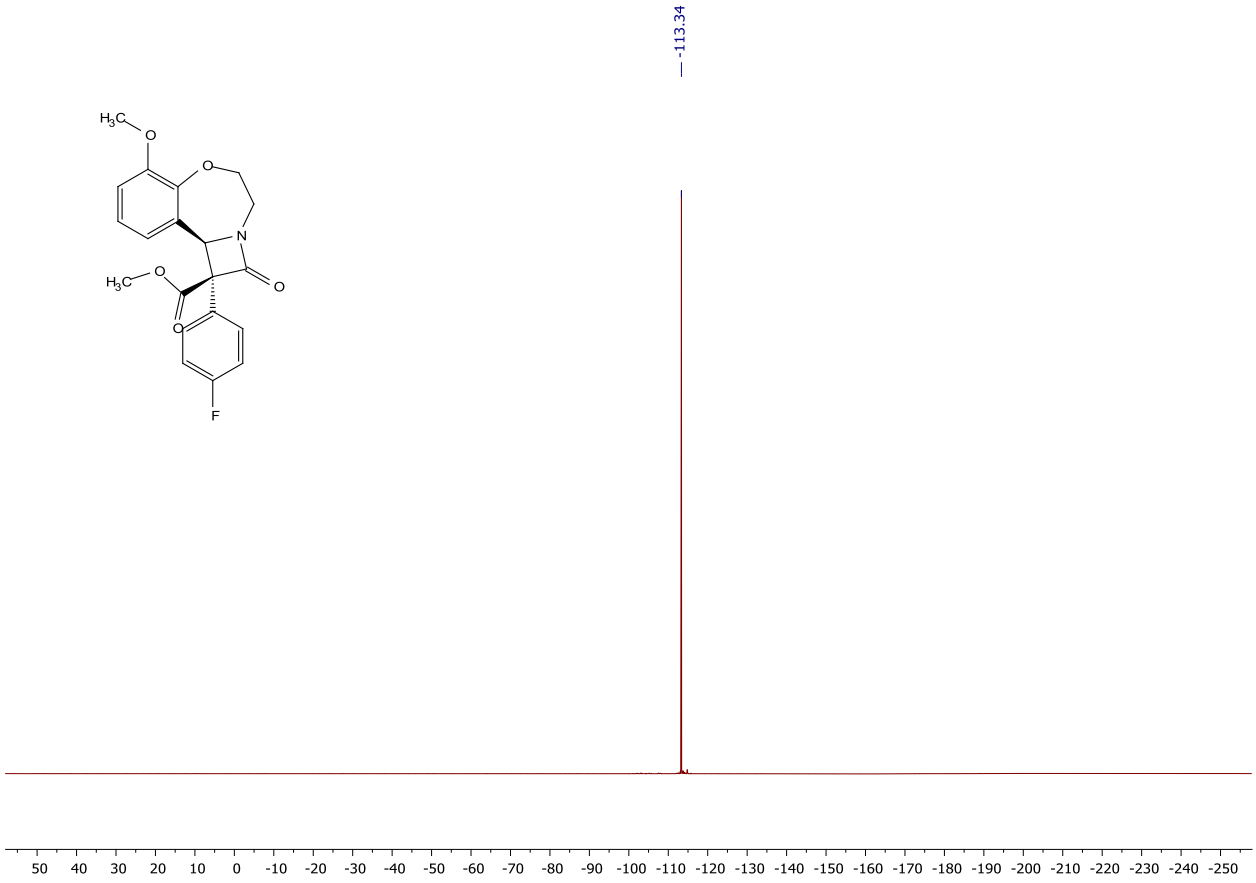
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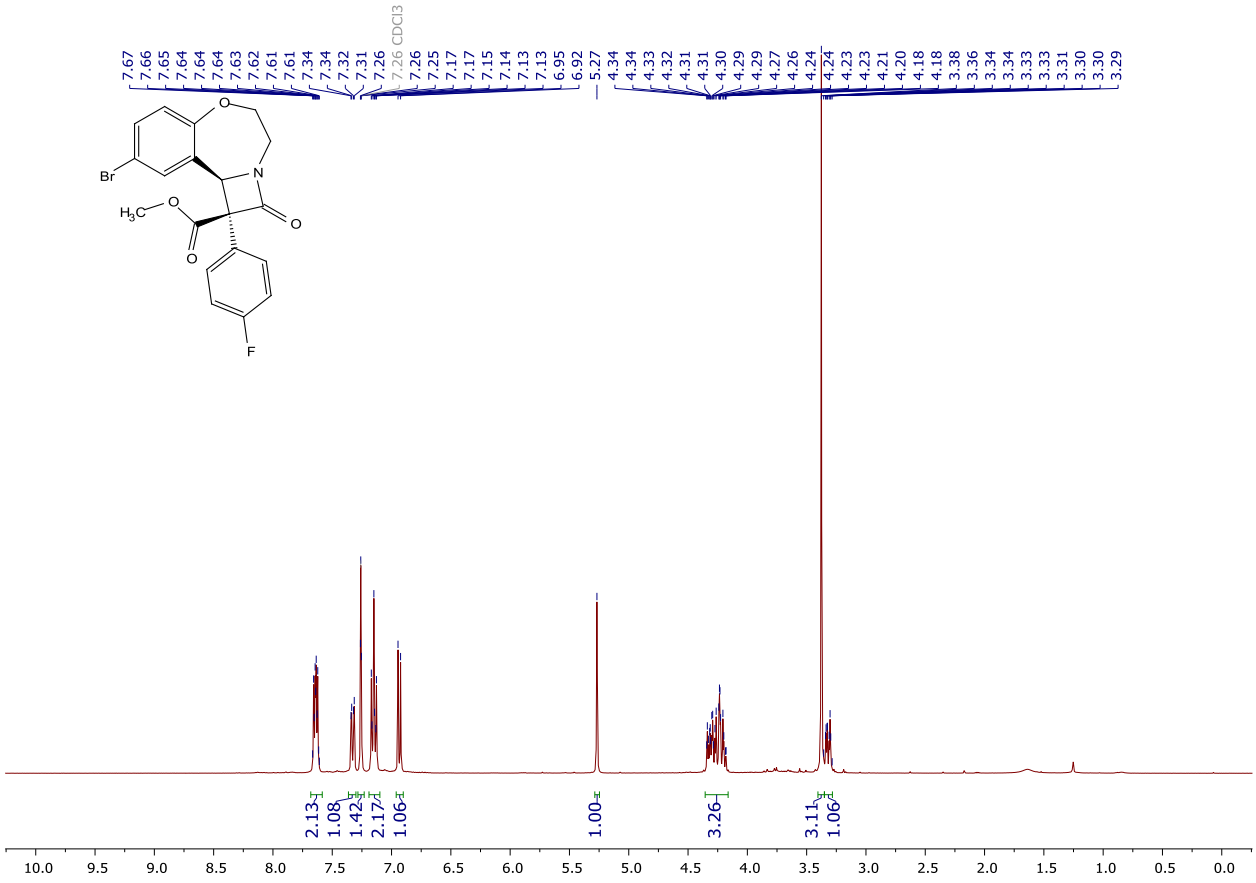
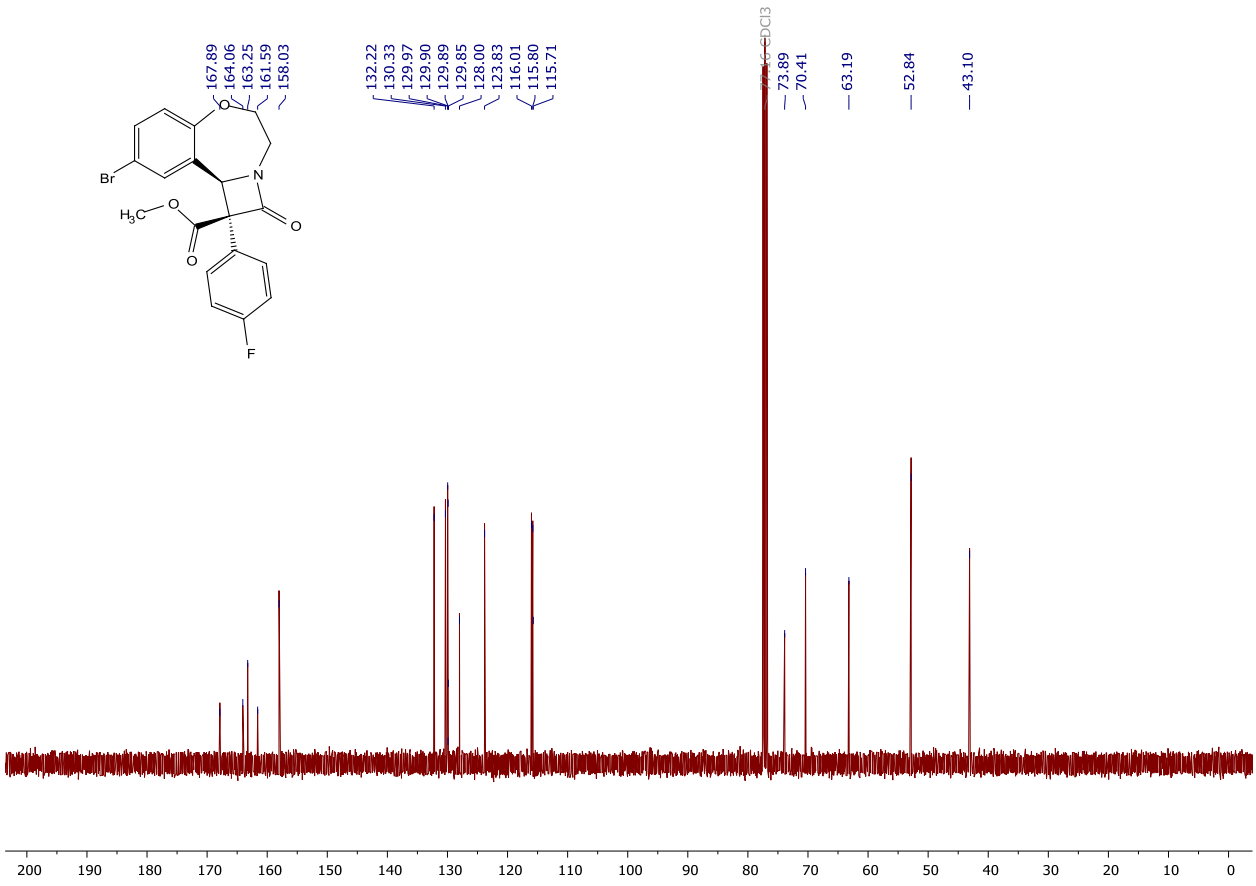
$^{1}H$, $^{13}C$ and $^{19}F$ NMR spectra of compound **9c**

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129.97
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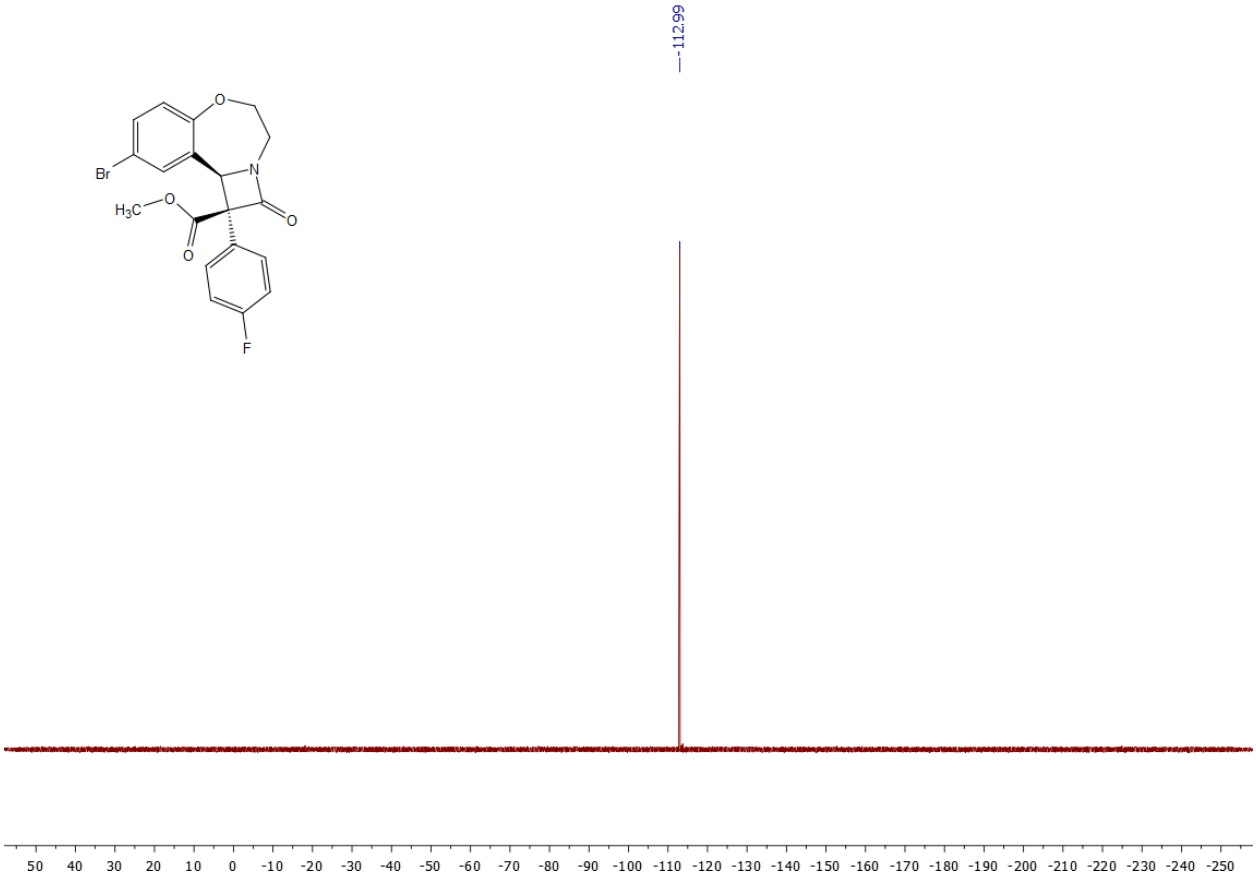
129.89
129.85
128.00
123.83
116.01
115.80
115.71
77.16 CDCl3
73.89
70.41
63.19
52.84
43.10
Br
O
N
O
O
H3C
O
F
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0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N
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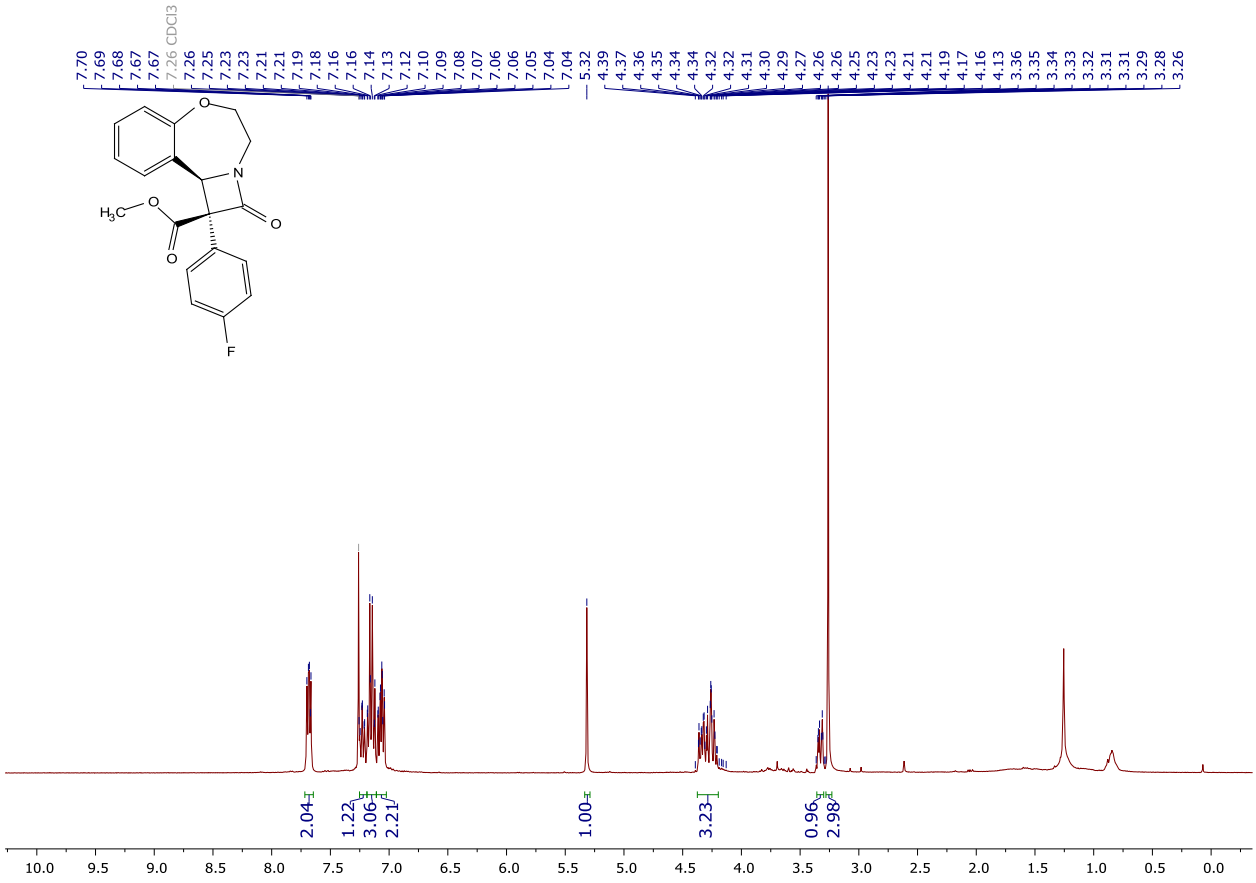
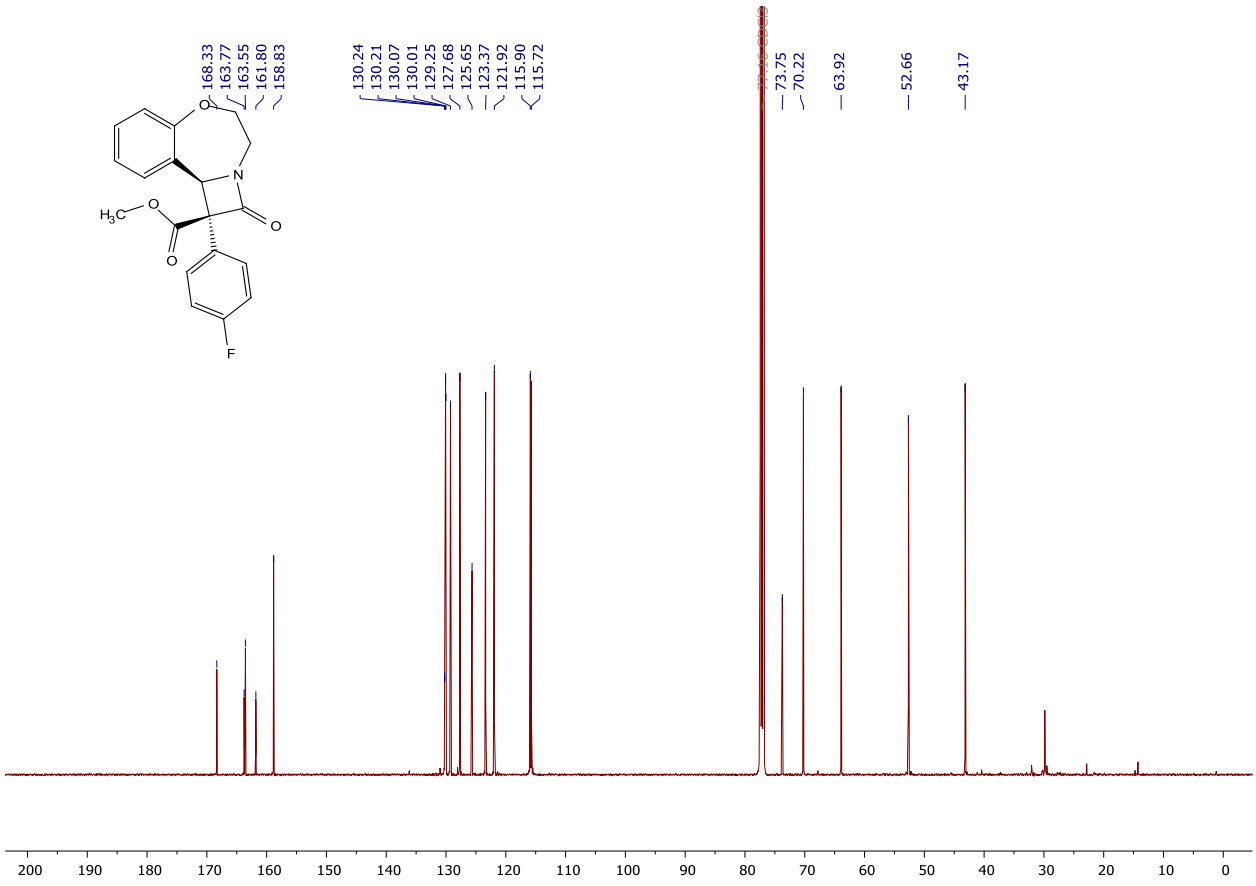
O
H3C
O
F
50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220 -230 -240 -250

$^{1}H$, $^{13}C$ and $^{19}F$ NMR spectra of compound **9d**

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123.37
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115.90
115.72
73.75
70.22
63.92
52.66
43.17
O
N
O
O
O
H3C
F
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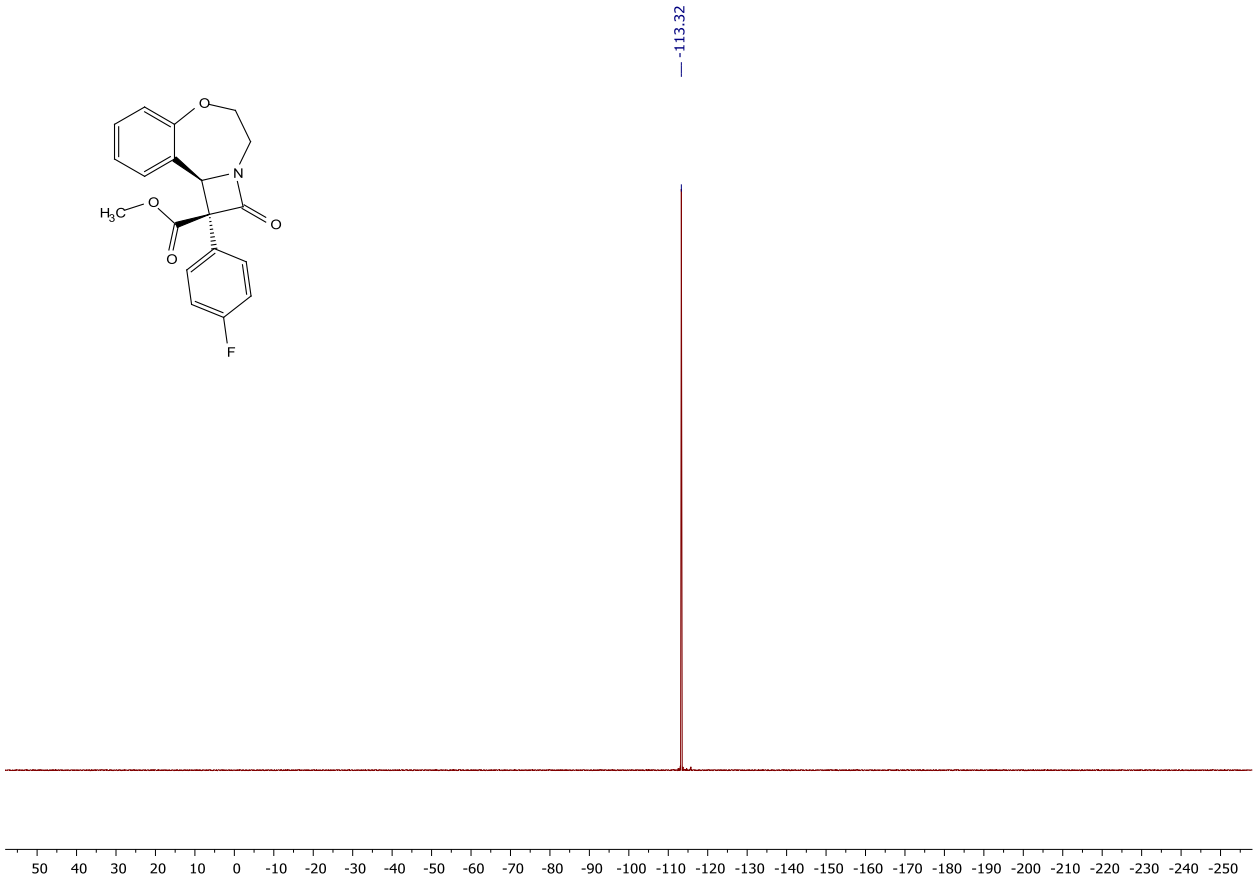
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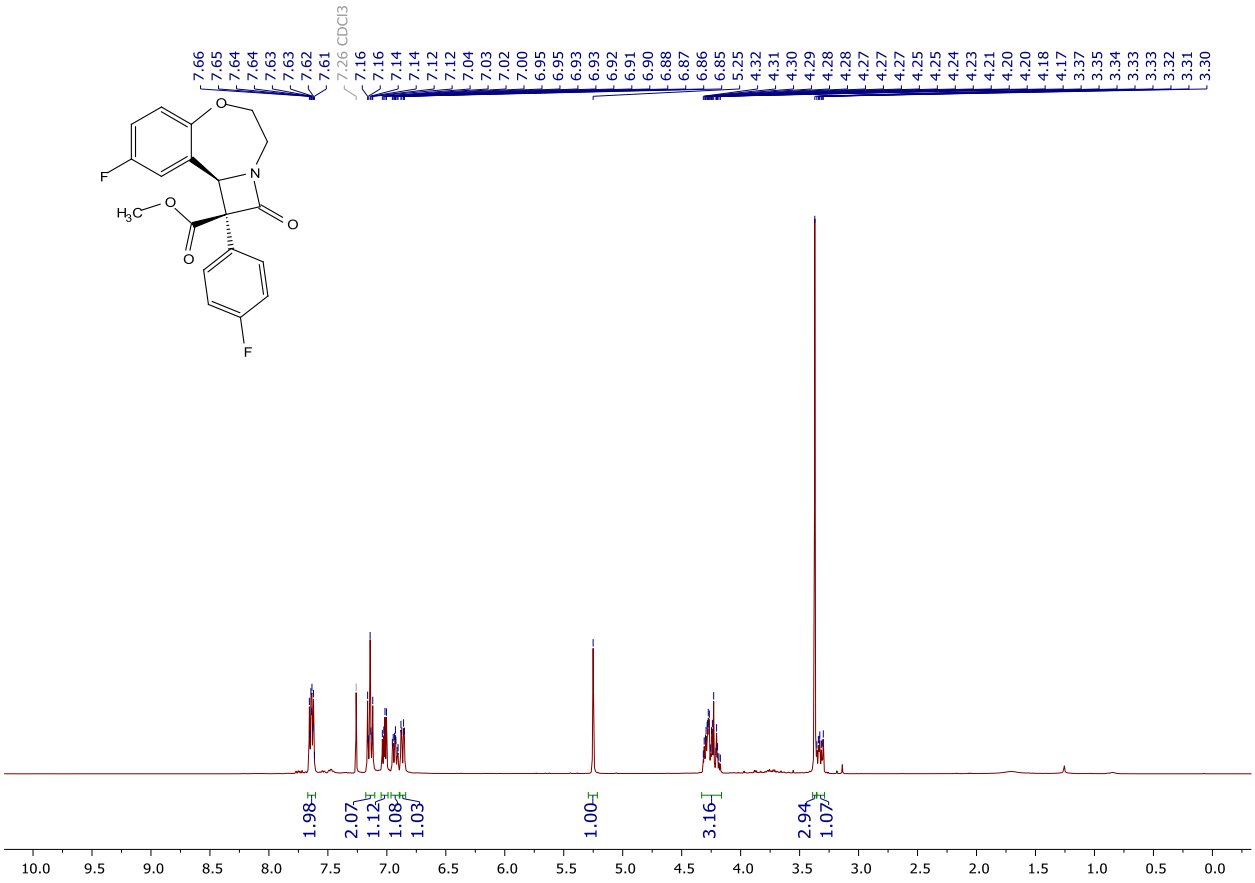
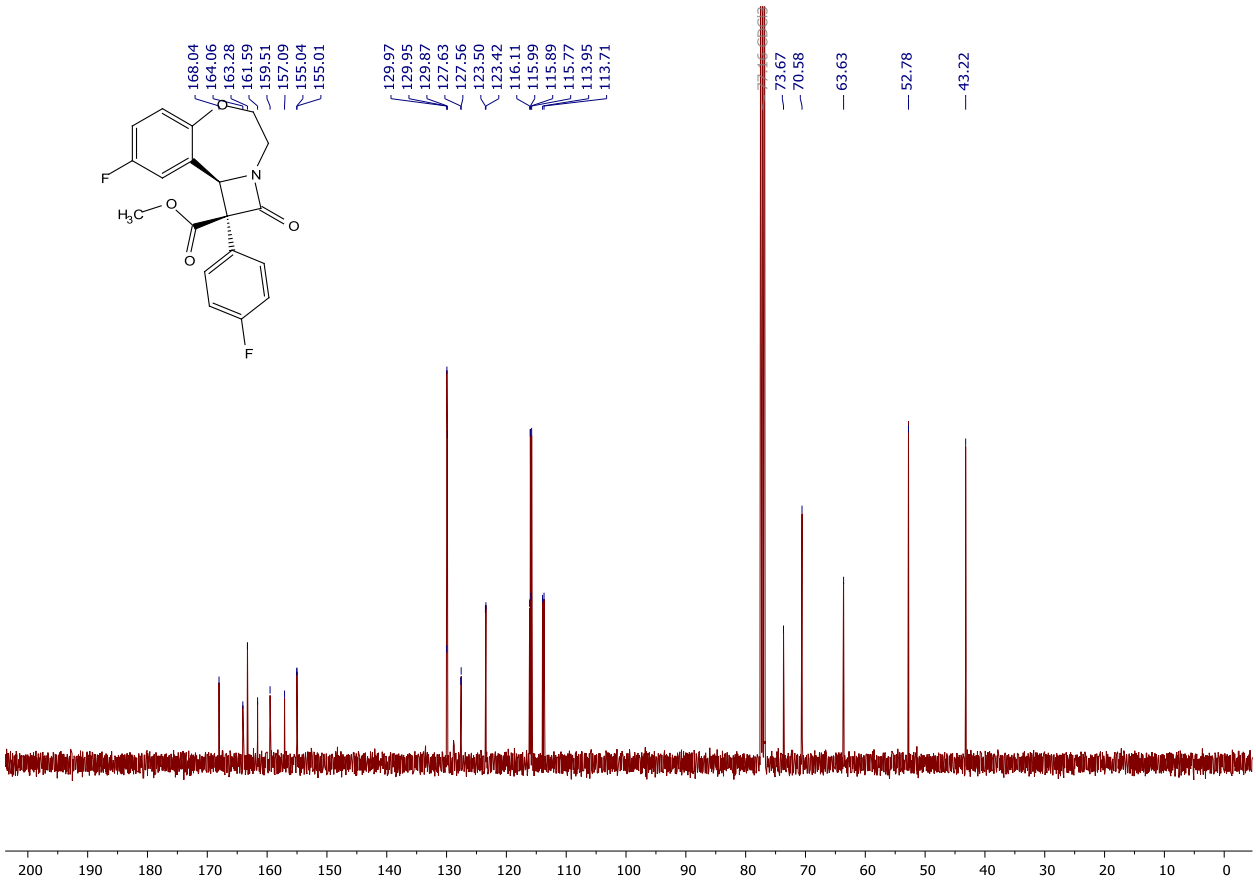
50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220 -230 -240 -250

$^{1}H$, $^{13}C$ and $^{19}F$ NMR spectra of compound **9e**

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159.51
157.09
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155.01
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129.95
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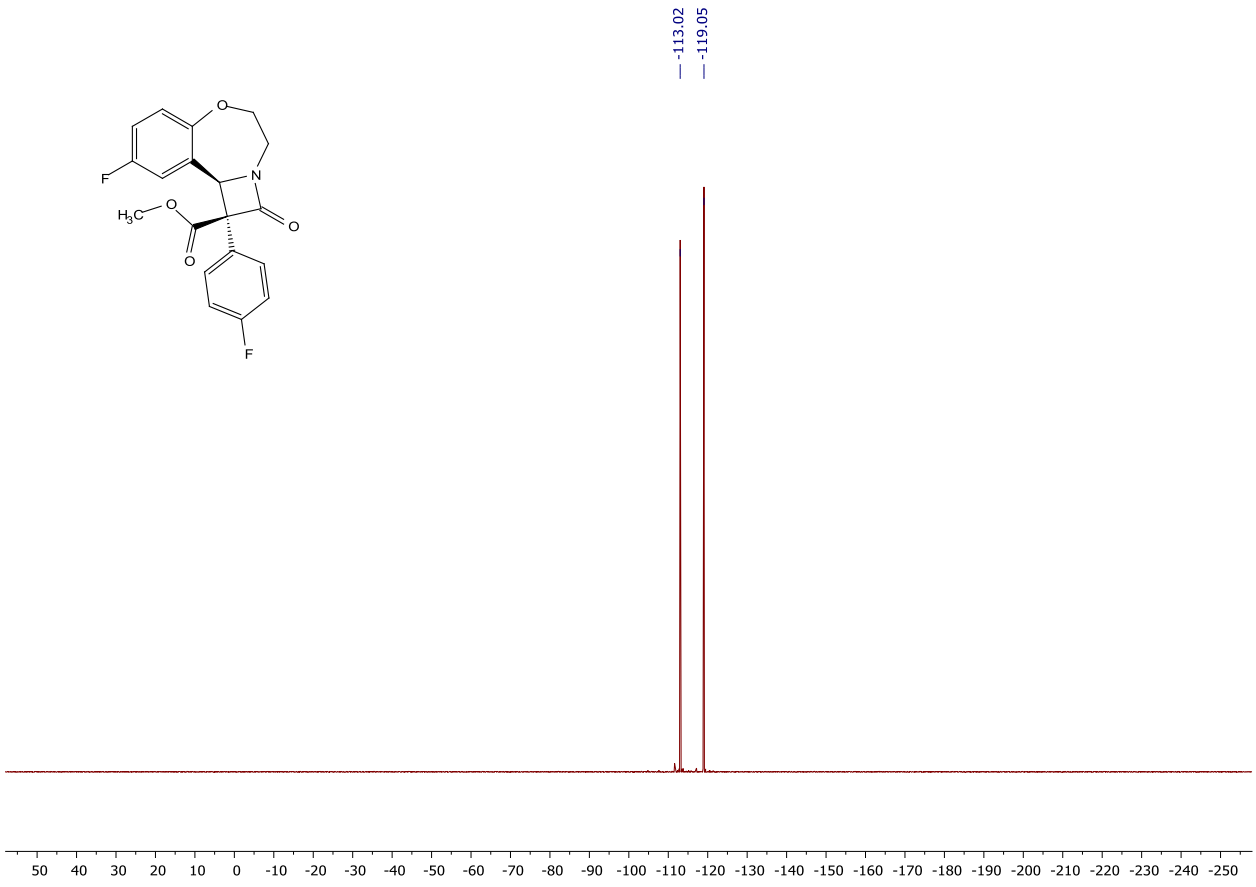
127.63
127.56
123.50
123.42
116.11
115.99
115.89
115.77
113.95
113.71
73.67
70.58
63.63
52.78
43.22
F
O
N
O
O
H3C
O
F
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0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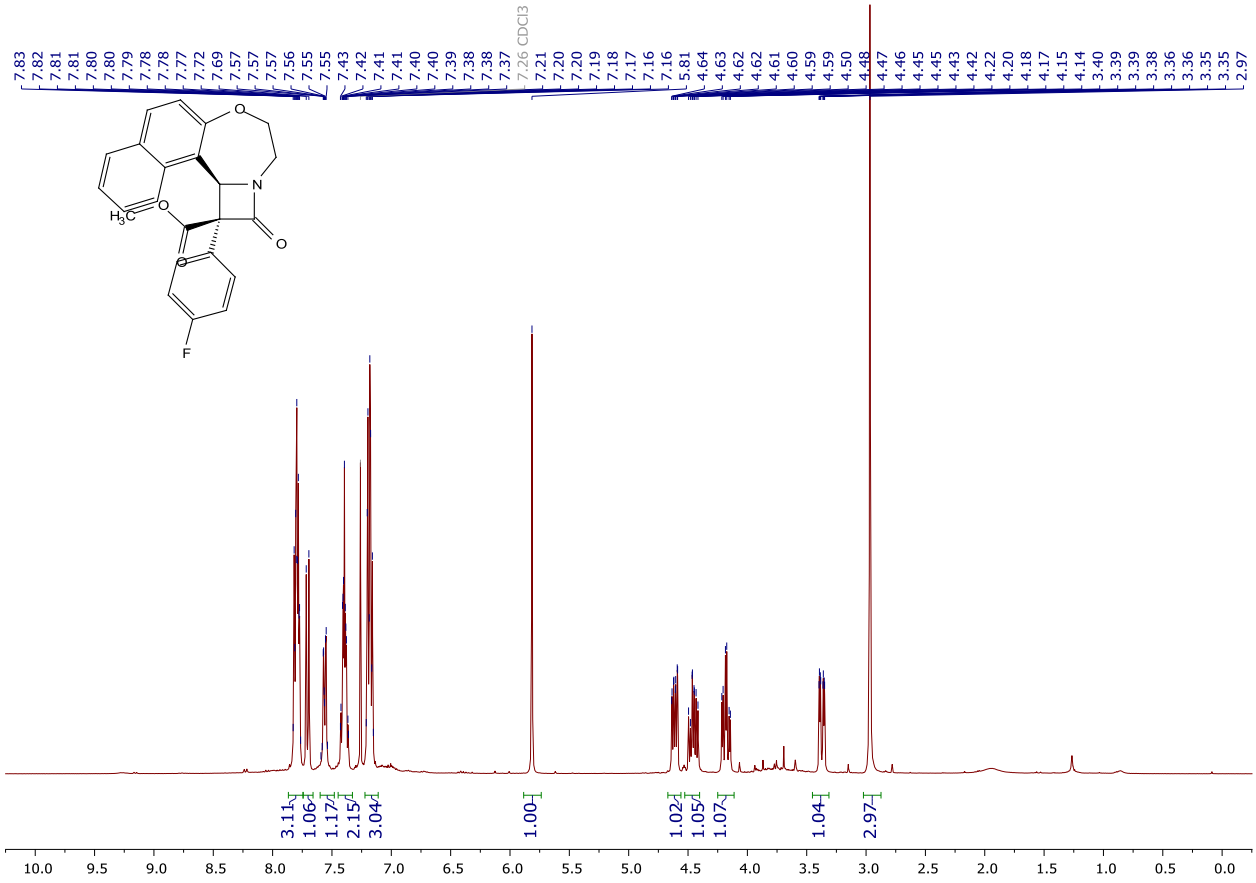
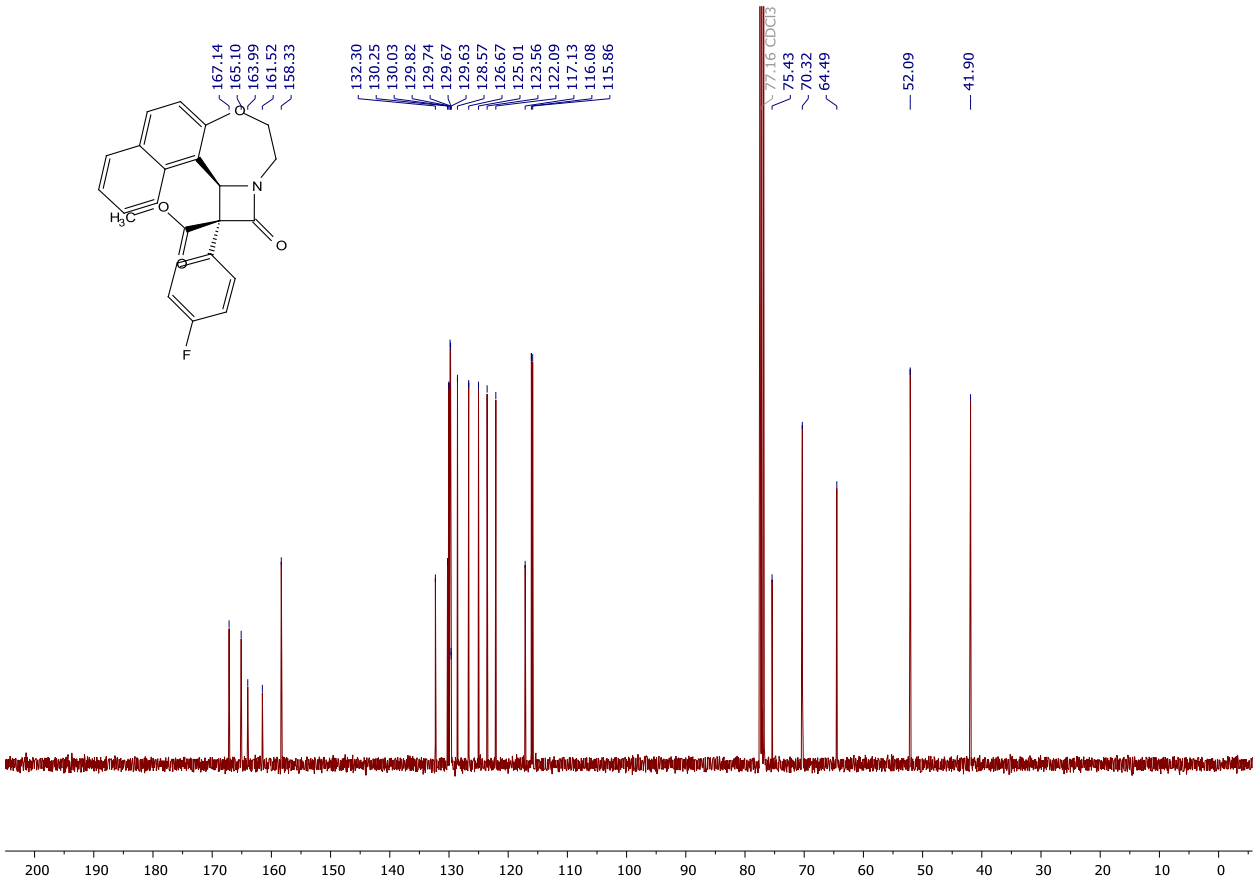
$^{1}H$, $^{13}C$ and $^{19}F$ NMR spectra of compound **9f**



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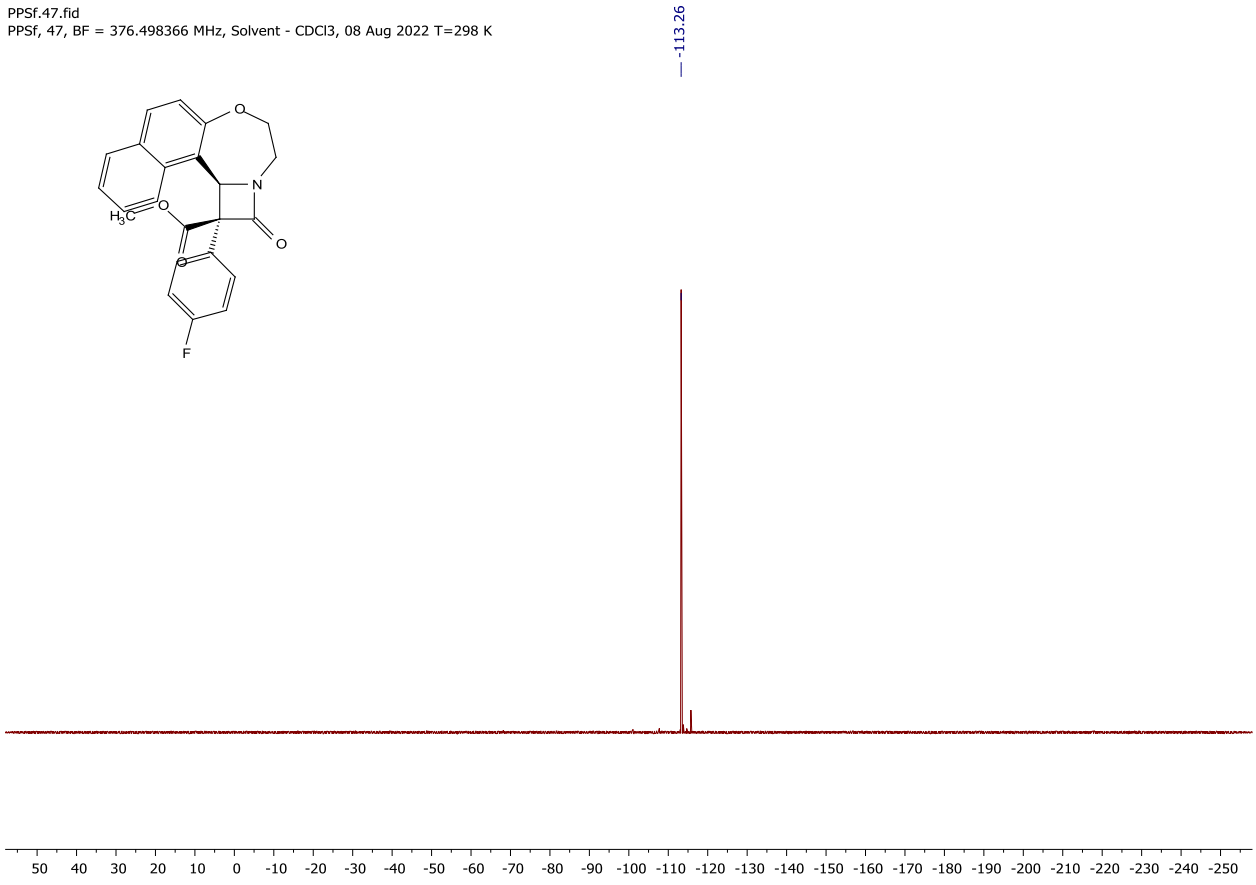
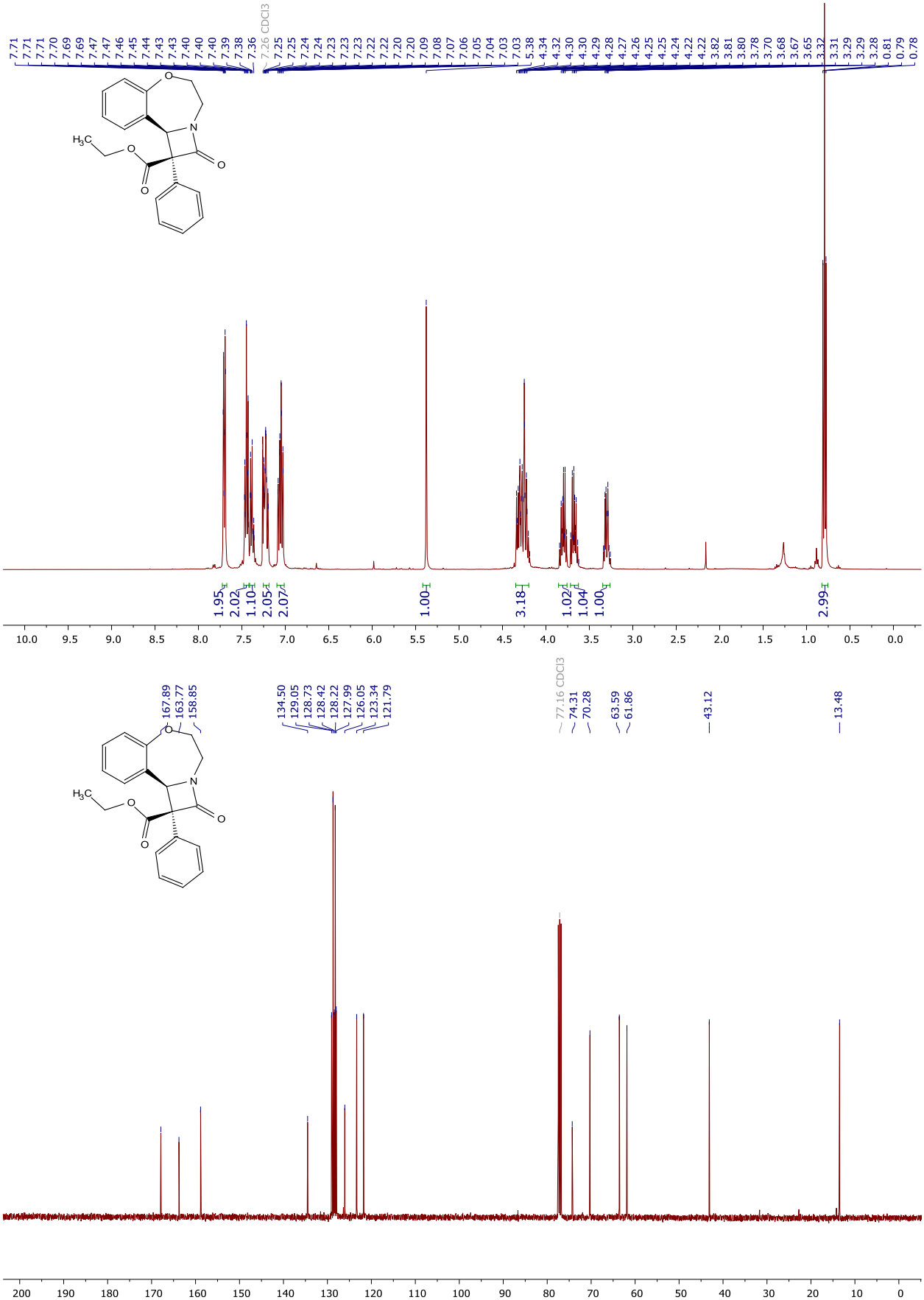
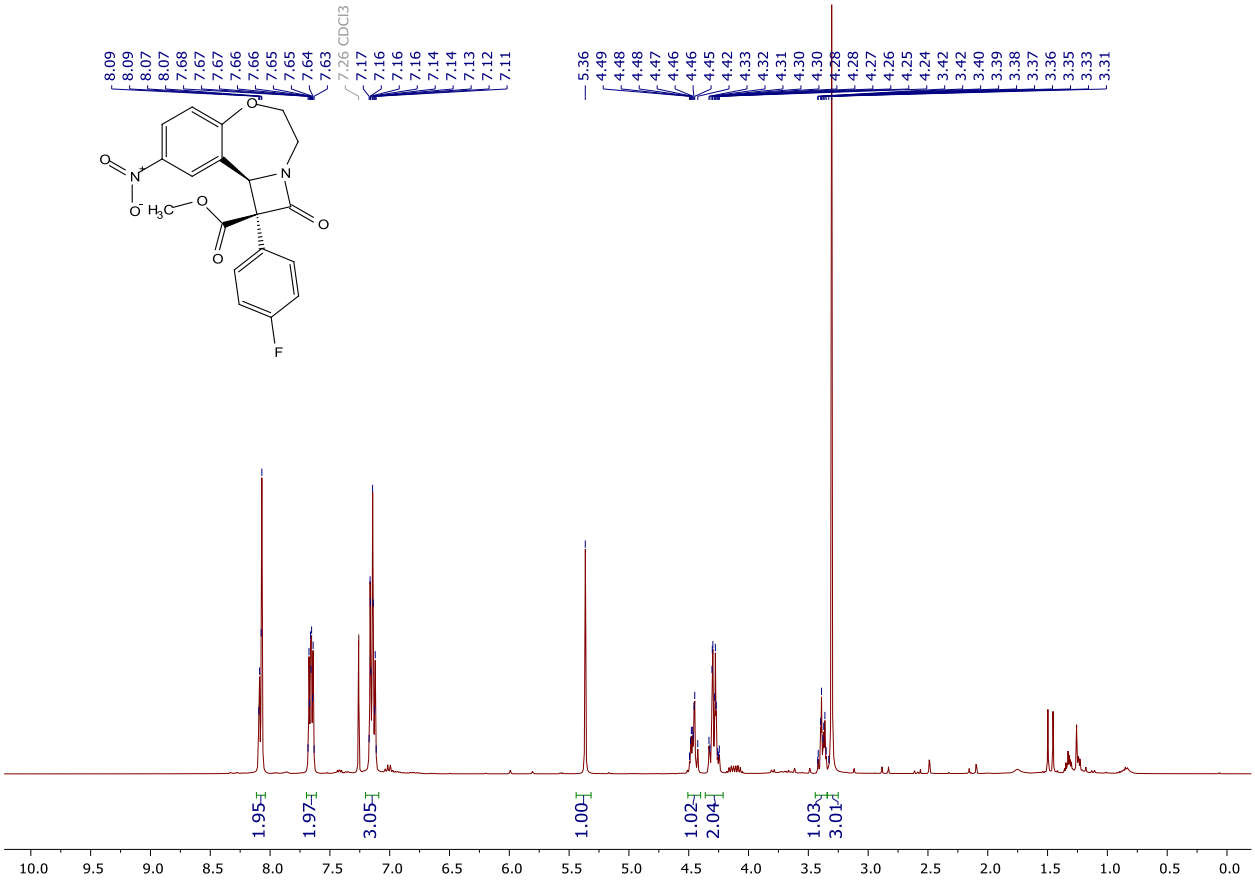
PPSf, 47, BF = 376.498366 MHz, Solvent - CDCl3, 08 Aug 2022 T=298 K

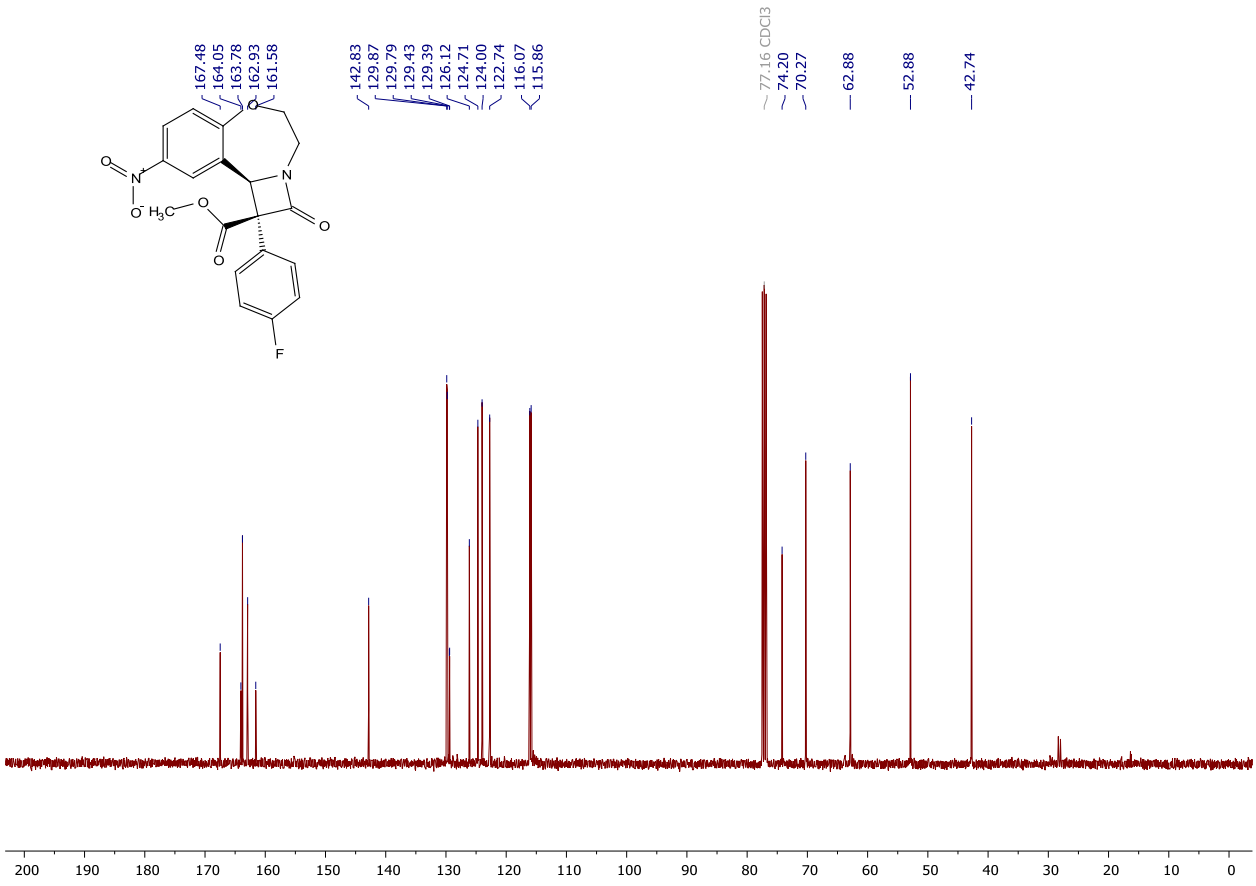


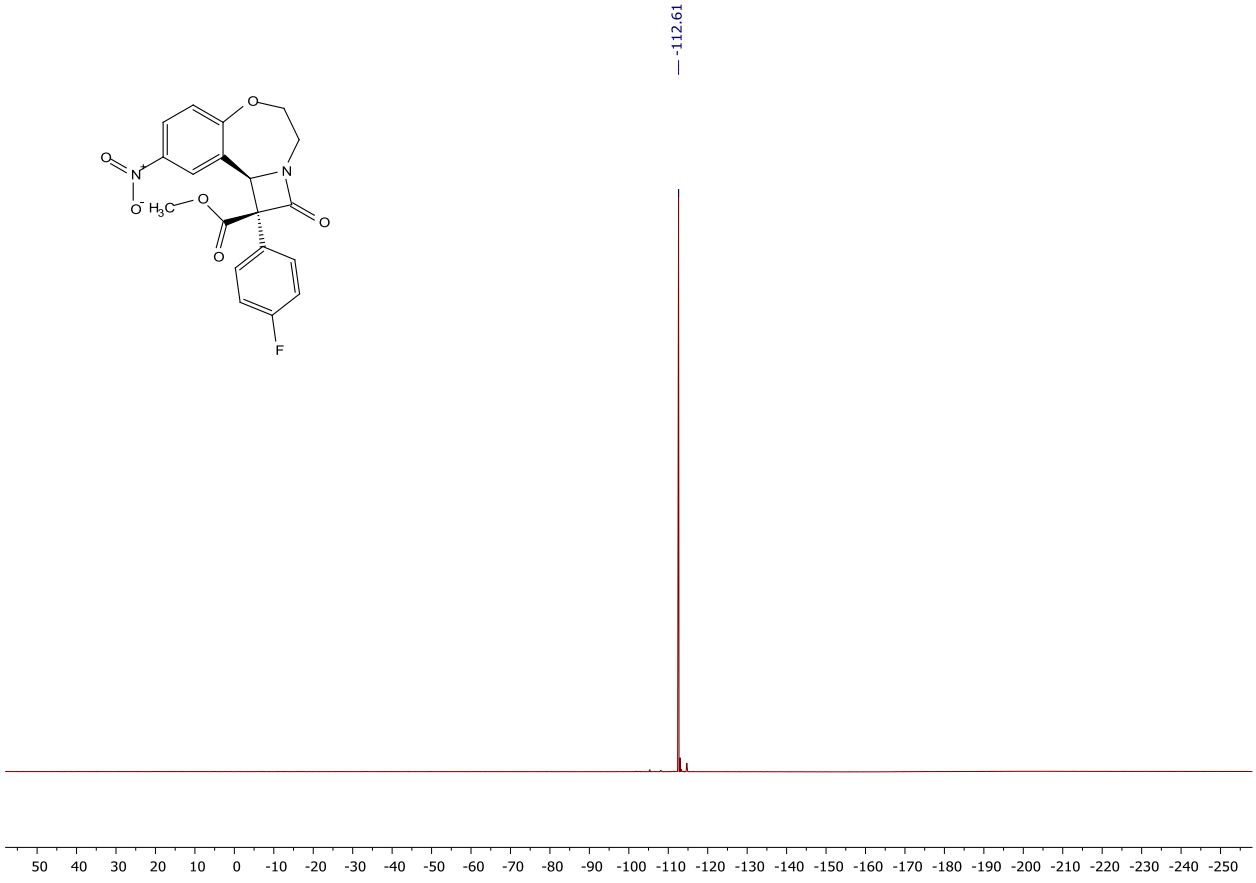
$^{1}H$ and $^{13}C$ NMR spectra of compound **9g**



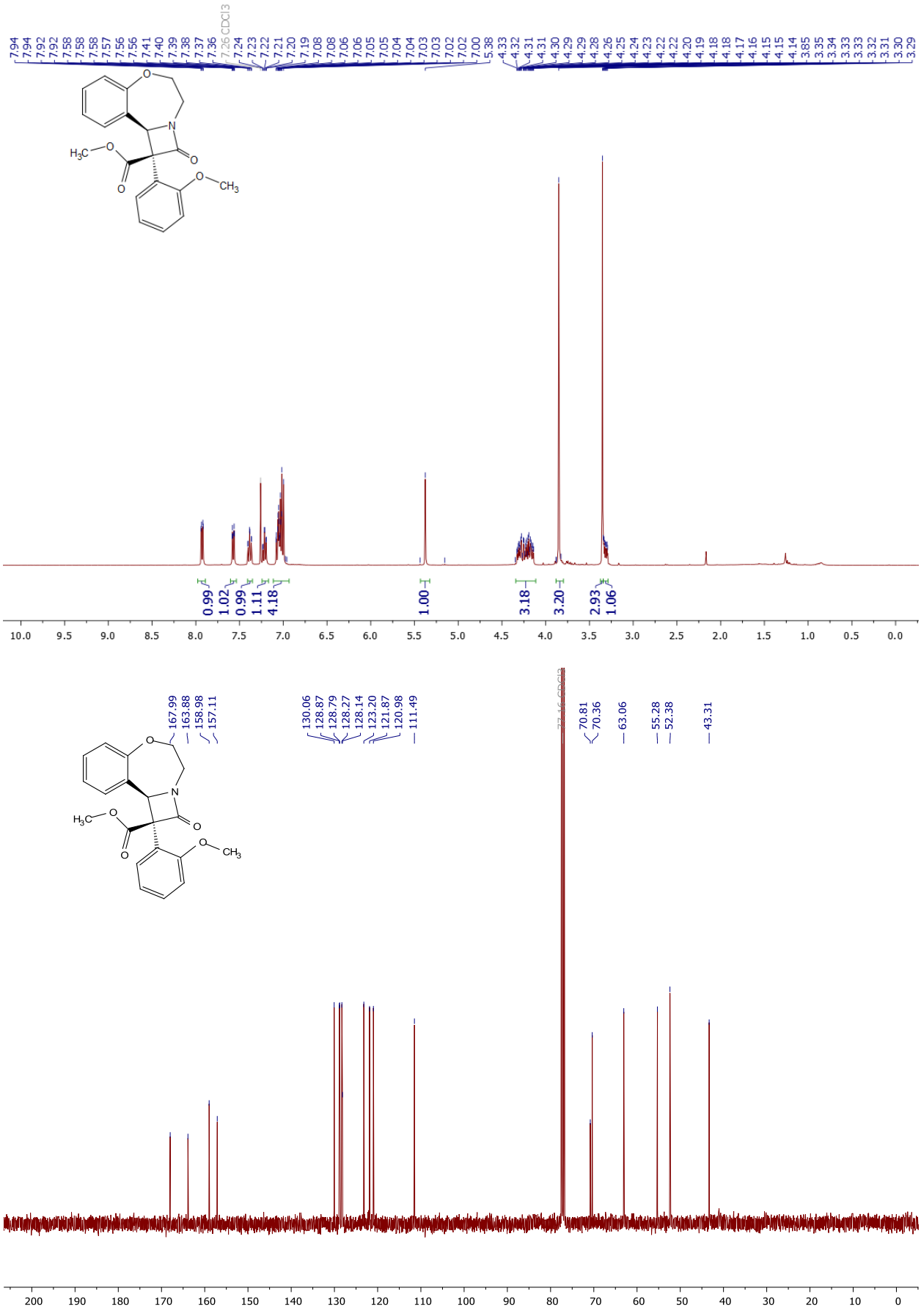
$^{1}H$, $^{13}C$ and $^{19}F$ NMR spectra of compound **9h**



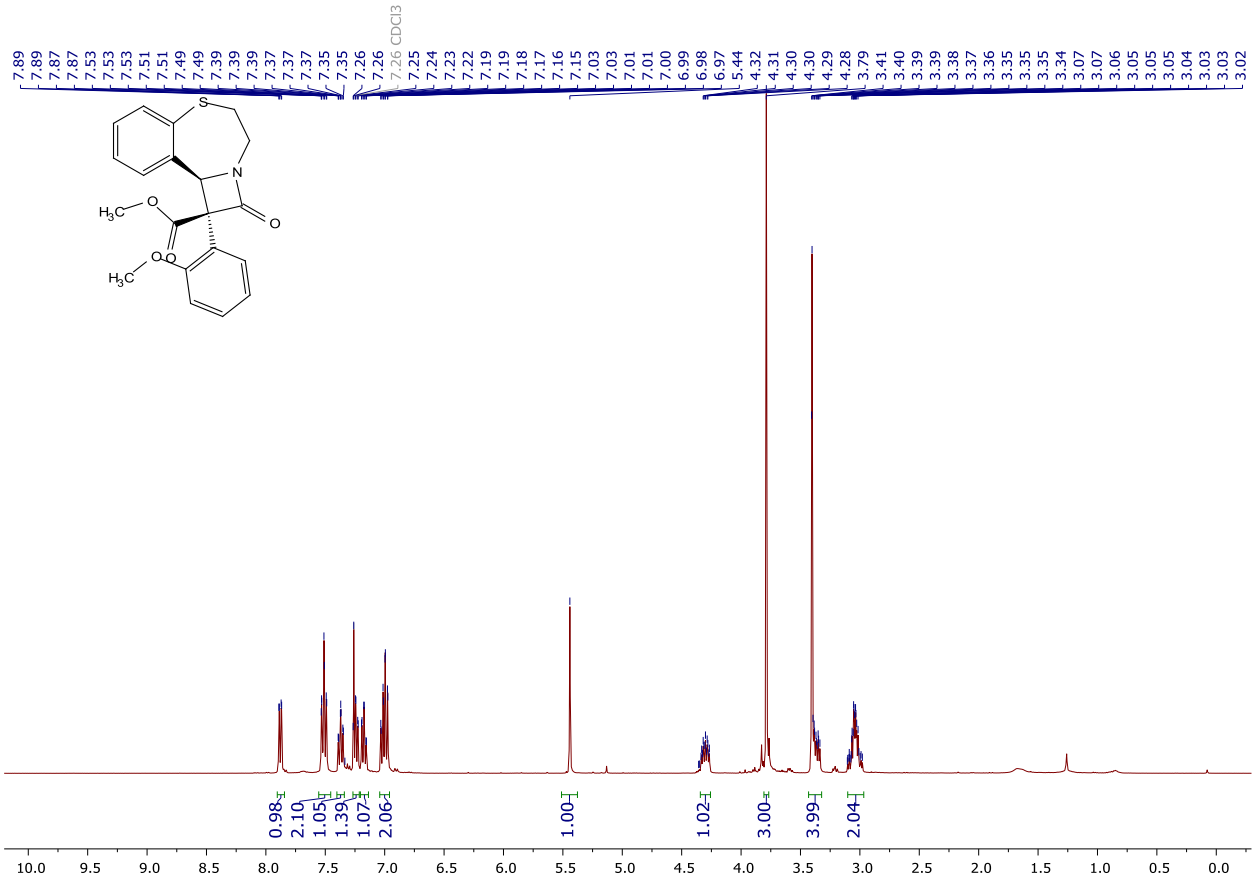

167.48
164.05
163.78
162.93
161.58
142.83
129.87
129.79
129.43
129.39
126.12
124.71
124.00
122.74
116.07
115.86
77.16 CDCl3
74.20
70.27
62.88
52.88
42.74
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0

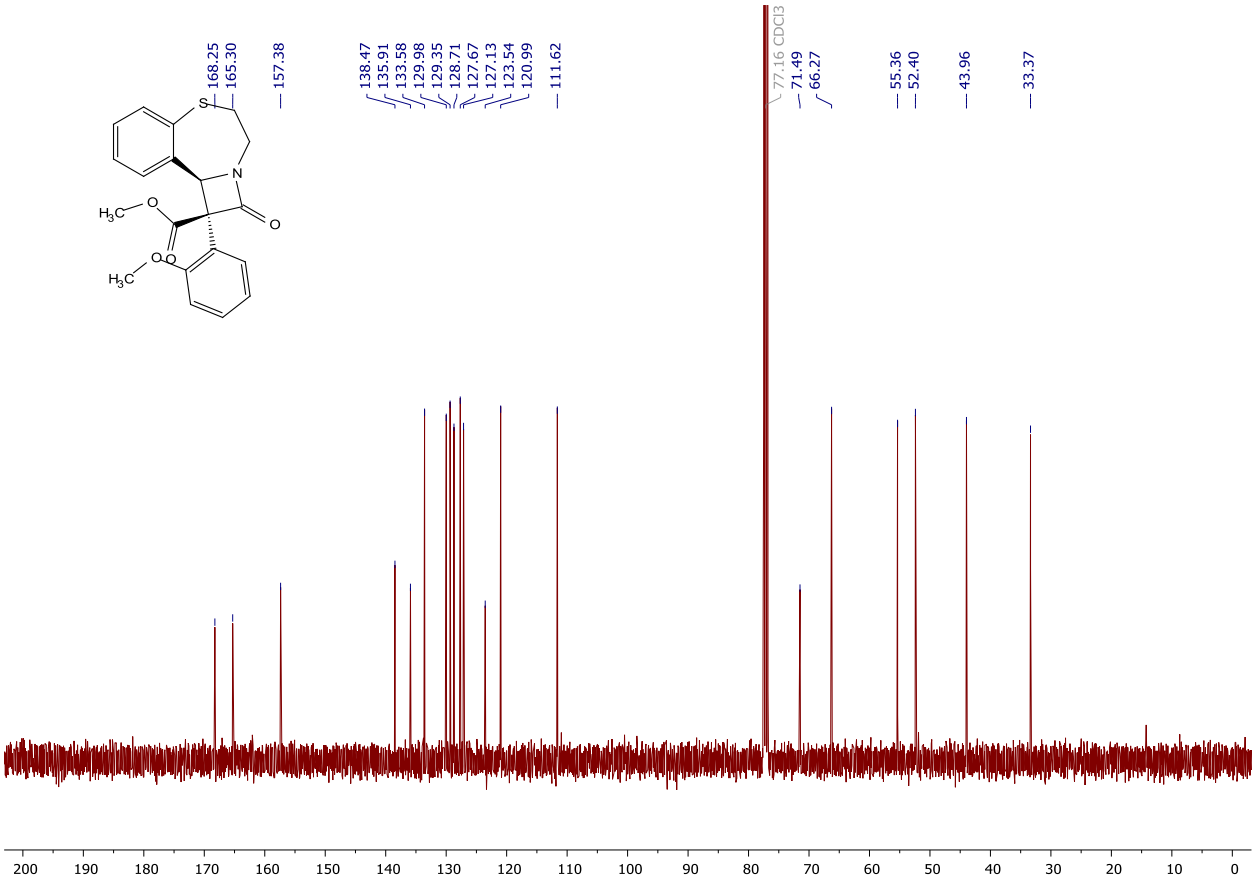

-112.61
50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220 -230 -240 -250

$^{1}$H and $^{13}$C NMR spectra of compound **9i**



$^{1}H$ and $^{13}C$ NMR spectra of compound **9j**



$^{1}H$ and $^{13}C$ NMR spectra of compound **9k**