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Supplementary information

Domino transformation of isoxazoles to 2,4-dicarbonylpyrroles under Fe/Ni relay catalysis

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General methods

Melting points were determined on a capillary melting point apparatus Stuart® SMP30. ^{1}H (300 MHz, 400 MHz) and ^{13}C (75 MHz, 100 MHz) NMR spectra were determined in $CDCl_3$ and DMSO-d_6 with Bruker DPX 300 and Bruker AVANCE III 400. Chemical shifts (δ) are reported in parts per million downfield from tetramethylsilane (TMS δ = 0.00); ^{1}H NMR spectra were calibrated according to the residual peak of $CDCl_3$ (7.26 ppm) or DMSO-d_6 (2.50 ppm). For all new compounds ^{13}C{^{1}H}and ^{13}C DEPT135 were recorded and calibrated according to the peak of $CDCl_3$ (77.00 ppm) or DMSO-d_6 (39.51 ppm). Mass spectra were recorded on a Bruker maXis HRMS-ESI-QTOF, electrospray ionization, positive mode. IR-spectra were recorded on a Bruker FT-IR spectrometer Tensor 27 for tablets in KBr, only characteristic absorption is indicated. Thin-layer chromatography (TLC) was conducted on aluminium sheets with 0.2 mm silica gel (fluorescent indicator, Macherey-Nagel).

The starting isoxazoles were synthesized as follows: (1) 3-substituted isoxazol-5(4*H*)-ones were obtained from alkyl 3-oxopropanoates and hydroxylamine hydrochloride according to the literature procedure [1], isoxazol-5(4*H*)-ones were then converted to 3-substituted 5-chloroisoxazoles with phosphorous oxychloride [2], and isoxazoles **1a**, **1b**, **1c** were prepared by nucleophilic substitution of chlorine; (2) the corresponding isoxazole-5(4*H*)-ones were treated with diazomethane solution to give isoxazoles **1d**, **1e**, **1f**, **1g**, **1h** [3]. The spectral and physical data for known compounds corresponds to published data: **1a** [3], **1b** [4], **1d** [2], **1f** [5], **1g** [2], **1h** [6]. Commercial pentane-2,4-dione, 5,5-dimethylcyclohexane-1,3-dione, ethyl 3-oxobutanoate, ethyl 3-oxo-3-phenylpropanoate and 3-oxo-*N*-phenylbutanamide were used without any purification.

Synthesis of starting materials

3-(4-(Dimethylamino)phenyl)isoxazol-5(4*H*)-one. The mixture of ethyl 3-(4-(dimethylamino)phenyl)-3-oxopropanoate (2.35 g, 0.01 mol) and hydroxylamine hydrochloride (2.10 g, 0.03mol) was stirred and heated to reflux in water (70 mL). The mixture was refluxed for 10 minutes and EtOH (100 mL) was added to the reaction. Reaction was stirred under reflux for 1 hour, then was cooled to ambient temperature and neutralized by 4% $NaHCO_3$. The residue formed was filtered off, washed with water, EtOH, and dried on air. Pale yellow solid, 1.80 g (88%), mp 185-187 °C (dec.) (methanol). Product (in DMSO) is a mixture of 2 isomers: (3-(4-(dimethylamino)phenyl)isoxazol-5(4*H*)-one and 5-hydroxy-3-(4-(dimethylamino)phenyl-isoxazole at 1/1 ratio. ^{1}H NMR (DMSO-d_6): δ = 2.99 (s, 12H), 4.22 (s, 2H), 5.52 (s, 1H), 6.77 (d, J=7.5 Hz, 4H), 7.51 (d, J=4.4 Hz, 4H), 12.41 (br s, 1H). ^{13}C NMR (DMSO-d_6): δ = 34.5 (CH_2), 39.6 (CH_3), 111.5 (CH), 114.3 (C) 127.6 (CH), 127.9 (CH), 152.3 (C), 164.2 (C), 172.4 (C), 176.6 (C). ESI/HRMS (m/z): 227.0791 calcd for $C_{11}H_{12}N_2NaO_2$ $[M+Na]^+$, found 227.0783. IR (KBr, cm^{-1}): ν 1795, 1605, 1531, 1165.

3-(4-(Dimethylamino)phenyl)-5-methoxyisoxazole (1e). To a stirred suspension 3-(4-(dimethylamino)phenyl)isoxazol-5(4*H*)-one (1.02 g, 5 mmol) in ether (20 mL) diazomethane, prepared from *N*-nitroso-*N*-methylurea (1.55 g, 15 mmol), in ether (30 mL) was added. The mixture was stirred for 1 day, and the solvent was evaporated. The residue was recrystallized from methanol (hot solution was decanted and the residue was thrown off). Pale yellow solid, 0.31g (28%), mp 119-121 °C (methanol). ^{1}H NMR ($CDCl_3$): δ = 3.00 (s, 6H), 4.01 (s, 3H), 5.44 (s, 1H), 6.72 (d, J=8.5 Hz, 2H), 7.62 (d, J=8.5 Hz, 2H). ^{13}C NMR (DMSO-d_6): δ = 40.2 (CH_3), 58.6 (CH_3), 74.7 (CH), 111.9 (CH), 117.0 (C), 127.4 (CH), 151.5 (C), 164.2 (C), 174.0 (C). ESI/HRMS (m/z): 241.0947 calcd for $C_{12}H_{14}N_2NaO_2$ $[M+Na]^+$, found 241.0944. IR (KBr, cm^{-1}): ν 1633, 1491, 1355, 1161.

3-Phenyl-5-(pyrrolidin-1-yl)isoxazole (1c). The suspension of 5-chloro-3-phenylisoxazole (1.45 g, 8.1 mmol), pyrrolidine (1.15 g, 1.4 mL, 16.2 mmol) and potassium carbonate (3.60 g, 26 mmol) were stirred in DMF (15 ml) for 5 days at room temperature (monitored by TLC). The reaction mixture was poured into water, the residue was filtered off, washed with water and recrystallized from methanol. Colorless solid, 1.00 g (58%), mp 110-112 °C (methanol). ^{1}H NMR ($CDCl_3$): δ = 1.97-2.03 (m, 4H), 3.42-3.47 (m, 4H), 5.13 (s, 1H), 7.39-7.43 (m, 3H), 7.74-7.77 (m, 2H). ^{13}C NMR (DMSO-d_6): δ = 25.5 (CH_2), 47.8 (CH_2), 74.1 (CH_3), 126.6(CH), 128.5 (CH), 129.4 (CH), 130.3 (C), 163.5 (C), 169.2 (C). ESI/HRMS (m/z): 237.0998 calcd for $C_{13}H_{14}N_2NaO$ $[M+Na]^+$, found 237.0994. IR (KBr, cm^{-1}): ν 1608, 1440, 1366, 1172.

General procedure for synthesis of pyrrole derivatives by reaction of isoxazoles with 1,3-dicarbonyl compounds.

Isoxazole (1.0 mmol) and 1,3-dicarbonyl compound (1.0-1.05 mmol) were dissolved in MeCN (5 mL) in a thick-wall tube (15 mL) with screw cap, $FeCl_2 \cdot 4H_2O$ (10% mol) and $NiCl_2 \cdot 6H_2O$ (10% mol) was added, and the suspension obtained was stirred under conditions indicated in table 2-4 to completion of the reaction (monitoring by TLC). MeCN was removed on a rotary evaporator, the residue was dissolved in CH_2Cl_2 or $CHCl_3$ (3 mL) and filtered throw 10 cm layer of silica using light petroleum/ethyl acetate mixture as eluent. The solvents were evaporated, the residue was washed with hexane or hexane/ether mixture and dried to give usually analytically

pure compound. If needed pyrroles were then recrystallized from an appropriate solvent. If two products were formed in the reaction, they were separated by column chromatography on silica using light petroleum/ethyl acetate mixture as eluent.

Ethyl 4-acetyl-5-methyl-3-phenyl-1*H*-pyrrole-2-carboxylate (4a). Ethyl 3-phenyl-2*H*-azirine-2-carboxylate **3a** (123 mg, 0.65 mmol) and pentane-2,4-dione **2a** (66 mg, 0.66 mmol) were dissolved in acetonitrile (5 mL) in a thick-wall screwcap 15 mL tube, and $NiCl_2 \cdot 6H_2O$ (8 mg, 0.03 mmol, 5% mol) was added, and the suspension obtained was stirred at room temperature for 24 hours. After the reaction completion (monitored by TLC), the reaction mixture was poured into water (50 mL). The resulting precipitate was filtered off and dried on air, then washed with hexane and dried once again. Colorless solid, 137 mg (77%), mp 126-128°C (hexane) (lit. mp 128 °C (aq. ethanol) [7]). R_f = 0.27 (light petroleum/ethyl acetate 5:2). ^{1}H NMR data for **4a** corresponds to published data [8]: ^{1}H NMR ($CDCl_3$) δ = 1.00 (t, J=7.2 Hz, 3H), 1.81 (s, 3H), 2.57 (s, 3H), 4.08 (q, J=7.2, 2H), 7.28-7-30 (m, 2H), 7.35-7.38 (m, 3H), 9.82 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ = 13.7 (CH_3), 14.4 (CH_3), 30.7 (CH_3), 60.3 (CH_2), 117.9 (C), 123.5 (C), 127.4 (CH), 127.7 (CH), 129.9 (CH), 132.5 (C), 135.5 (C), 138.6 (C), 161.5 (C), 196.7 (C). ESI/HRMS (m/z): 272.1281 calcd for $C_{16}H_{18}NO_3$ $[M+H]^+$, found 272.1291; 294.1101 calcd for $C_{16}H_{17}NaNO_3$ $[M+Na]^+$, found 294.1114. IR (KBr, cm^{-1}): ν 3282, 1673, 1655.

Methyl 4-acetyl-5-methyl-3-phenyl-1*H*-pyrrole-2-carboxylate (4b). Compound **4b** (120 mg, 82%) was obtained from 5-methoxy-3-phenylisoxazole **1a** (100 mg, 0.57 mmol), pentane-2,4-dione **2a** (58 mg, 0.58 mmol), $FeCl_2 \cdot 4H_2O$ (12 mg, 0.06 mmol, 10% mol) and $NiCl_2 \cdot 6H_2O$ (14 mg, 0.06 mmol, 10% mol) according to the general procedure under conditions indicated in table 2. Colorless solid, R_f = 0.21 (light petroleum/ethyl acetate 5:2), mp 149-151 °C (hexane) (lit. mp 150.5 °C (CCl_4) [9]). Both ^{1}H and ^{13}C NMR spectra corresponds to published data [9, 10]. ^{1}H NMR ($CDCl_3$): δ = 1.80 (s, 3H), 2.57 (s, 3H), 3.62 (s, 3H), 7.28-7.30 (m, 2H), 7.35-7.40 (m, 3H), 9.99 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ = 14.3 (CH_3), 30.6 (CH_3), 51.4 (CH_3), 117.4 (C), 123.7 (C), 127.5 (CH), 127.8 (CH), 129.9 (CH), 132.6 (C), 135.2 (C), 138.8 (C), 161.7 (C), 196.7 (C). ESI/HRMS (m/z): 280.0944 calcd for $C_{15}H_{15}NNaO_3$ $[M+Na]^+$, found 280.0933. IR (KBr, cm^{-1}): ν 3300, 1671, 1655.

Methyl 5-methyl-3-phenyl-1*H*-pyrrole-2-carboxylate (5). Compound **5** (32 mg, 17%), along with compound **4b** (56%), was obtained from 5-methoxy-3-phenylisoxazole **1a** (150 mg, 0.86 mmol), pentane-2,4-dione **2a** (87 mg, 0.87 mmol), $FeCl_2 \cdot 4H_2O$ (36 mg, 0.18 mmol, 20% mol), according to the general procedure under conditions indicated in table 1. Colorless solid, R_f = 0.37 (light petroleum/ethyl acetate 5:2), mp 173-175 °C (hexane).^{1}H NMR ($CDCl_3$): δ = 2.33 (s, 3H), 3.75 (s, 3H), 6.07 (d, J=2.9 Hz, 1H), 7.27-7.31 (m, 1H), 7.34-7.38 (m, 2H), 7.53-7.55 (m, 2H), 8.92 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ = 13.0 (CH_3), 51.1 (CH_3), 111.2 (CH), 116.2 (C), 126.9 (CH), 127.7 (CH), 129.3(CH), 132.6 (C), 133.1 (C), 135.3 (C), 161.5 (C). ESI/HRMS (m/z): 238.0838 calcd for $C_{13}H_{13}NNaO_2$ $[M+Na]^+$, found 238.0844. IR (KBr, cm^{-1}): ν 3304, 1664.

***tert*-Butyl 4-acetyl-5-methyl-3-phenyl-1*H*-pyrrole-2-carboxylate (4c).** Compound **4c** (111 mg, 81%) was obtained from 5-*tert*-butoxy-3-phenylisoxazole **1b** (100 mg, 0.46 mmol), pentane-2,4-dione **2a** (47 mg, 0.47 mmol), $FeCl_2 \cdot 4H_2O$ (10 mg, 0.05 mmol, 10% mol), and $NiCl_2 \cdot 6H_2O$ (12 mg, 0.05 mmol, 10% mol), according to the general procedure under conditions indicated in table 2. Colorless solid, R_f = 0.33 (light petroleum/ethyl acetate 5:2), mp 185-186 °C (hexane). ^{1}H NMR ($CDCl_3$): δ = 1.22 (s, 9H), 1.79 (s, 3H), 2.57 (s, 3H), 7.25-7.27 (m, 2H), 7.32-7.38 (m, 3H), 9.76 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ = 14.5 (CH_3), 27.9 (CH_3), 30.7 (CH_3), 81.0 (C), 119.4 (C), 123.3 (C), 127.2 (CH), 127.7 (CH), 129.9 (CH), 131.6 (C), 136.2 (C), 138.1 (C), 161.0 (C), 196.7 (C). ESI/HRMS (m/z): 322.1414 calcd for $C_{18}H_{21}NNaO_3$ $[M+Na]^+$, found 322.1412. IR (KBr, cm^{-1}): ν 3287, 1661, 1651.

1-(2-Methyl-4-phenyl-5-(pyrrolidine-1-carbonyl)-1*H*-pyrrol-3-yl)ethanone (4d). Compound **4d** (99 mg, 71%) was obtained from 3-phenyl-5-(pyrrolidin-1-yl)isoxazole **1c** (100 mg, 0.47 mmol), pentane-2,4-dione **2a** (50 mg, 0.50 mmol), $FeCl_2 \cdot 4H_2O$ (10 mg, 0.05 mmol, 10% mol), and $NiCl_2 \cdot 6H_2O$ (12 mg, 0.05 mmol, 10% mol), according to the general procedure under conditions indicated in table 2. Colorless solid, R_f = 0.35 (dichloromethane/triethylamine 800:3), mp 182-183 °C (hexane/ether 10/1).^{1}H NMR ($CDCl_3$): δ = 1.51 (br s, 2H), 1.62 (br s, 2H), 1.92 (s, 3H), 2.45 (br s, 2H), 2.49 (s, 3H), 3.47 (br s, 2H), 7.29-7.40. (m, 5H), 10.60 (br s, 1H)^{13}C NMR ($CDCl_3$): δ = 13.7 (CH_3), 24.0 (br s, CH_2), 25.8 (br s, CH_2), 30.7 (CH_3), 46.2 (br s, CH_2), 48.1 (br s, CH_2), 122.1 (C) 122.2 (C), 126.3 (C), 127.5 (CH), 128.5 (CH), 130.0 (CH), 135.8 (C), 136.3 (C), 163.2 (C), 197.4 (C). ESI/HRMS (m/z): 297.1598 calcd for $C_{18}H_{21}N_2O_2$ $[M+H]^+$, found 297.1604; 319.1417 calcd for $C_{18}H_{20}N_2NaO_3$ $[M+Na]^+$, found 319.1424. IR (KBr, cm^{-1}): ν 3192, 1654, 1586.

Methyl 4-acetyl-3-(4-chlorophenyl)-5-methyl-1*H*-pyrrole-2-carboxylate (4e). Compound **4e** (128 mg, 92%) was obtained from 3-(4-chlorophenyl)-5-methoxyisoxazole **1d** (100 mg, 0.48 mmol), pentane-2,4-dione **2a** (50 mg, 0.50 mmol), $FeCl_2 \cdot 4H_2O$ (10 mg, 0.05 mmol, 10% mol), and $NiCl_2 \cdot 6H_2O$ (12 mg, 0.05 mmol, 10% mol), according to the general procedure under conditions indicated in table 2. Colorless solid, R_f = 0.21 (light petroleum/ethyl acetate 5:2), mp 171-173 °C (hexane). ^{1}H NMR ($CDCl_3$): δ = 1.83 (s, 3H), 2.56 (s, 3H), 3.65 (s, 3H), 7.24 (d, J=8.4 Hz, 2H), 7.37 (d, J=8.4 Hz, 2H), 9.73 (br s, 1H).^{13}C NMR ($CDCl_3$): δ = 14.4 (CH_3), 30.8 (CH_3), 51.5 (CH_3), 117.6 (C), 123.7 (C), 128.1 (CH), 131.1 (C), 131.3 (CH), 133.6 (C), 133.7 (C), 138.7 (C), 161.4 (C), 196.2 (C). ESI/HRMS (m/z): 292.0735 calcd for $C_{15}H_{15}ClNO_3$ $[M+H]^+$, found 292.0749; 314.0555 calcd for $C_{15}H_{14}ClNNaO_3$ $[M+Na]^+$, found 314.0568. IR (KBr, cm^{-1}): ν 3391, 1671, 1657.

Methyl 4-acetyl-3-(4-(dimethylamino)phenyl)-5-methyl-1*H*-pyrrole-2-carboxylate (4f). Compound **4f** (32 mg, 23%) was obtained from 3-(4-(dimethylamino)phenyl)-5-methoxyisoxazole **1e** (100 mg, 0.46 mmol), ethyl pentane-2,4-dione **2a** (50 mg, 0.50 mmol), $FeCl_2 \cdot 4H_2O$ (10 mg, 0.05 mmol, 10% mol), and $NiCl_2 \cdot 6H_2O$ (12 mg, 0.05 mmol, 10% mol), according to the general procedure under conditions indicated in table 2. Colorless solid, R_f = 0.21 (light petroleum/ethyl acetate 2:1), mp 184-186 °C (hexane/ether 10/1). ^{1}H NMR ($CDCl_3$): δ = 1.87 (s, 3H), 2.54 (s, 3H), 3.00 (s, 6H), 3.68 (s, 3H), 6.75 (d, J=8.8 Hz, 2H), 7.15 (d, J=8.8 Hz, 2H), 9.20 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ = 14.4 (CH_3), 30.6 (CH_3), 40.5 (CH_3), 51.4 (CH_3), 111.7 (CH), 117.1 (C), 122.2 (C), 124.1 (C), 130.7 (CH), 133.4 (C), 137.8 (C), 149.9 (C), 161.4 (C), 197.4. ESI/HRMS (m/z): 301.1547 calcd for $C_{17}H_{21}N_2O_3$ $[M+H]^+$, found 301.1551; 323.1367 calcd for $C_{17}H_{20}N_2NaO_3$ $[M+Na]^+$; found 323.1371. IR (KBr, cm^{-1}): ν 3303, 3213, 1691, 1674.

Methyl 4-benzoyl-3,5-diphenyl-1*H*-pyrrole-2-carboxylate (4g). Compound **4g** (196 mg, 90%) was obtained from 5-methoxy-3-phenylisoxazole **1a** (100 mg, 0.57 mmol), ethyl 1,3-diphenylpropan-1,3-dione **2b** (128 mg, 0.57 mmol), $FeCl_2 \cdot 4H_2O$ (12 mg, 0.06 mmol, 10% mol), and $NiCl_2 \cdot 6H_2O$ (14 mg, 0.06 mmol, 10% mol), according to the general procedure under conditions indicated in table 2. Colorless solid, R_f = 0.33 (light petroleum/ethyl acetate 5:2), mp 173-174 °C (hexane/ether 10/1) (lit. mp 168-169 °C (EtOH) [11]). Both ^{1}H and ^{13}C NMR spectra corresponds to published data [11]. ^{1}H NMR ($CDCl_3$): δ =3.74 (s, 3H), 7.13-7.20 (m, 5H), 7.29-7.31 (m, 6H), 7.44-7.46 (m, 2H), 7.65 (m, 2H), 9.49-9.52 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ =51.6 (CH_3), 118.6 (C), 123.3 (C), 127.2 (CH), 127.4 (CH), 127.9 (CH), 128.8 (CH), 129.7 (CH), 130.3 (CH), 130.4 (C), 132.5 (CH), 132.9 (C), 133.0 (C), 136.6 (C), 138.1 (C), 161.4 (C), 193.8 (C). ESI/HRMS (m/z): 382.1438 calcd for $C_{25}H_{20}NO_3$ $[M+H]^+$, found 382.1444; 404.1258 calcd for $C_{25}H_{19}NNaO_3$ $[M+Na]^+$, found 404.1274. IR (KBr, cm^{-1}): ν 3273, 1687, 1644.

Methyl 4-benzoyl-3-(4-bromophenyl)-5-phenyl-1*H*-pyrrole-2-carboxylate (4h). Compound **4h** (147 mg, 64%) was obtained from 3-(4-bromophenyl)-5-methoxyisoxazole **1f** (127 mg, 0.50 mmol), ethyl 1,3-diphenylpropan-1,3-dione **2b** (112 mg, 0.50 mmol), $FeCl_2 \cdot 4H_2O$ (10 mg, 0.05 mmol, 10% mol), and $NiCl_2 \cdot 6H_2O$ (12 mg, 0.05 mmol, 10% mol)), according to the general procedure under conditions indicated in table 2. Colorless solid, R_f = 0.42 (light petroleum/ethyl acetate 5:2), mp 237-240 °C (hexane/ether 1/1). ^{1}H NMR (DMSO-d_6): δ= 3.68 (s, 3H), 7.14-7.16 (m, 2H), 7-21-7.29 (m, 5H), 7.37-7.40 (m, 5H), 7.53-7.55 (m, 2H), 12.63 (br s, 1H). ^{13}C NMR (DMSO-d_6): δ = 51.2 (CH_3), 118.9 (C), 120.2 (C), 122.4 (C), 128.1 (CH), 128.16 (C), 128.22 (C), 128.5 (CH), 129.2 (CH), 130.07 (CH), 130.14 (C), 130.4 (C), 132.2 (CH), 132.8 (CH), 132.9 (C), 136.7 (C), 137.8 (C), 160.4 (C), 193.3 (C). ESI/HRMS (m/z): 460.0498 calcd for $C_{25}H_{19}BrNO_3$ $[M+H]^+$, found 460.0553; 482.0363 calcd for $C_{25}H_{18}BrNNaO_3$ $[M+Na]^+$, found 482.0372. IR (KBr, cm^{-1}): ν 3287, 1681, 1644.

Methyl 4-benzoyl-3-(4-methoxyphenyl)-5-phenyl-1*H*-pyrrole-2-carboxylate (4i). Compound **4i** (144 mg, 72%) was obtained from 5-methoxy-3-(4-methoxyphenyl)isoxazole **1g** (100 mg, 0.49 mmol), ethyl 1,3-diphenylpropan-1,3-dione **2b** (112 mg, 0.50 mmol), $FeCl_2 \cdot 4H_2O$ (10 mg, 0.05 mmol, 10% mol), and $NiCl_2 \cdot 6H_2O$ (12 mg, 0.05 mmol, 10% mol), according to the general procedure under conditions indicated in table 2. Colorless solid, R_f = 0.22 (light petroleum/ethyl acetate 5:2). Colorless solid, mp 211-212 °C (hexane/ether 1/1). ^{1}H NMR (DMSO-d_6): δ= 3.67 (s, 3H), 3.68 (s, 3H), 6.73-6.76 (m, 2H), 7.11-7.15 (m, 2H), 7.22-7.30 (m, 5H), 7.36-7.42 (m, 3H), 7.54-7.56 (m, 2H), 12.46 (s, 1H). ^{13}C NMR (DMSO-d_6): δ = 51.0 (CH_3), 54.9 (CH_3), 112.6 (CH), 118.6 (C), 122.6 (C), 125.6 (C), 128.08 (CH), 128.12 (CH), 128.15 (CH), 128.4 (CH), 129.1 (CH), 130.3 (C), 131.2 (CH), 131.4 (C), 132.7 (CH), 136.0 (C), 137.9 (C), 158.1 (C), 160.6 (C), 193.8 (C). ESI/HRMS (m/z): 412.1544 calcd for $C_{26}H_{22}NO_4$ $[M+H]^+$, found 412.1564; 434.1363 calcd for $C_{26}H_{22}NNaO_3$ $[M+Na]^+$, found 434.1378. IR (KBr, cm^{-1}): ν 3296, 1679, 1649.

Methyl 4-acetyl-3,5-dimethyl-1*H*-pyrrole-2-carboxylate (4k). Compound **4k** (149 mg, 87%) was obtained from 5-methoxy-3-methylisoxazole **1h** (100 mg, 0.89 mmol), pentane-2,4-dione **2a** (90 mg, 0.90 mmol), $FeCl_2 \cdot 4H_2O$ (18 mg, 0.09 mmol, 10% mol), and $NiCl_2 \cdot 6H_2O$ (21 mg, 0.09 mmol, 10% mol), according to the general procedure under conditions indicated in table 2. Colorless solid, R_f = 0.20 (light petroleum/ethyl acetate 5:2), mp 163-165 °C (hexane) (lit. mp 160 °C (MeOH) [12]). ^{1}H NMR ($CDCl_3$): δ = 2.45 (s, 3H), 2.52 (s, 3H), 2.58 (s, 3H), 3.86 (s, 3H), 9.09 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ = 12.7 (CH_3), 15.2 (CH_3), 31.3 (CH_3), 51.4 (CH_3), 117.7 (C), 123.6 (C), 129.5 (C), 138.2 (C), 161.9 (C), 195.5 (C). ESI/HRMS (m/z): 218.0788 calcd for $C_{10}H_{13}NNaO_3$ $[M+Na]^+$, found 218.0788. IR (KBr, cm^{-1}): ν 3308, 1682, 1651.

Methyl 6,6-dimethyl-4-oxo-3-phenyl-4,5,6,7-tetrahydro-1*H*-indole-2-carboxylate (7a). Compound **7a** (220 mg, 86%) was obtained from 5-methoxy-3-phenylisoxazole **1a** (150 mg, 0.86 mmol), 5,5-dimethylcyclohexane-1,3-dione **6** (120 mg, 0.86 mmol), $FeCl_2 \cdot 4H_2O$ (18 mg, 0.09 mmol, 10% mol), and $NiCl_2 \cdot 6H_2O$ (21 mg, 0.09 mmol, 10% mol), according to the general procedure under conditions indicated in table 3. Colorless solid, R_f = 0.18 (light petroleum/ethyl acetate 5:2), mp. > 220 °C (dec.) (hexane/ether 5/1). ^{1}H NMR ($CDCl_3$): δ = 1.14 (s, 6H), 2.36 (s, 2H), 2.73 (s, 2H), 3.69 (s, 3H), 7.30-7.37 (m, 3H), 7.40-7.42 (m, 2H), 9.30 (br s, 1H).^{13}C NMR ($CDCl_3$): δ = 28.4 (CH_3), 35.1 (C), 37.0 (CH_2), 51.5 (CH_3), 53.1 (CH_2), 118.5 (C), 119.4 (C), 127.0 (CH), 127.4 (CH), 130.3 (CH), 130.7 (C), 132.6 (C), 144.4 (C), 161.7 (C), 193.0 (C). ESI/HRMS (m/z): 298.1438 calcd for $C_{18}H_{20}NO_3$ $[M+H]^+$, found 298.1432; 320.1257 calcd for $C_{18}H_{19}NNaO_3$ $[M+Na]^+$; found 320.1260. IR (KBr, cm^{-1}): ν 3152, 2959, 1697, 1641.

Methyl 3-(4-chlorophenyl)-6,6-dimethyl-4-oxo-4,5,6,7-tetrahydro-1*H*-indole-2-carboxylate (7b). Compound **7b** (112 mg, 70%) was obtained from 3-(4-chlorophenyl)-5-methoxyisoxazole **1d** (100 mg, 0.48 mmol), 5,5-dimethylcyclohexane-1,3-dione **6** (70 mg, 0.50 mmol),

$FeCl_2 \cdot 4H_2O$ (10 mg, 0.05 mmol, 10% mol), and $NiCl_2 \cdot 6H_2O$ (12 mg, 0.05 mmol, 10% mol), according to the general procedure under conditions indicated in table 3. Colorless solid, R_f = 0.16 (light petroleum/ethyl acetate 5:2), mp 252-254 °C (dec.) (hexane/ether 5/1). ^{1}H NMR ($CDCl_3$): δ = 1.14 (s, 6H), 2.36 (s, 2H), 2.72 (s, 2H), 3.71 (s, 3H), 7.31 (d, J=8.5 Hz, 2H), 7.35 (d, J=8.5 Hz, 2H), 9.33 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ = 28.4 (CH_3), 35.2 (C), 37.0 (CH_2), 51.6 (CH_3), 53.1 (CH_2), 118.5 (C), 119.5 (C), 127.3 (CH), 129.3 (C), 131.0 (C), 131.8 (CH), 133.4 (C), 144.4 (C), 161.4 (C), 193.0 (C). ESI/HRMS (m/z): 332.1048 calcd for $C_{18}H_{19}ClNO_3$ $[M+H]^+$, found 332.1061; 354.0868 calcd for $C_{18}H_{18}ClNNaO_3$ $[M+Na]^+$; found 354.0880. IR (KBr, cm^{-1}): ν 3155, 1696, 1640.

Methyl 3-(4-bromophenyl)-6,6-dimethyl-4-oxo-4,5,6,7-tetrahydro-1*H*-indole-2-carboxylate (7c). Compound **7c** (131 mg, 70%) was obtained from 3-(4-bromophenyl)-5-methoxyisoxazole **1f** (127 mg, 0.50 mmol), 5,5-dimethylcyclohexane-1,3-dione **6** (70 mg, 0.50 mmol), $FeCl_2 \cdot 4H_2O$ (10 mg, 0.05 mmol, 10% mol), and $NiCl_2 \cdot 6H_2O$ (12 mg, 0.05 mmol, 10% mol), according to the general procedure under conditions indicated in table 3. Colorless solid, R_f = 0.18 (light petroleum/ethyl acetate 5:2), mp 245-247 °C (dec.) (hexane/ether 5/1).^{1}H NMR ($CDCl_3$): δ =1.13 (s, 6H), 2.36 (s, 2H), 2.72 (s, 2H), 3.70 (s, 3H), 7.29 (d, J=8.4 Hz, 2H), 7.46 (d, J=8.4 Hz, 2H), 9.38 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ = 28.4 (CH_3), 35.2 (C), 37.0 (CH_2), 51.6 (CH_3), 53.1 (CH_2), 118.4 (C), 119.4 (C), 121.7 (C), 129.3 (C), 130.2 (CH), 131.5 (C), 132.1 (CH), 144.4 (C), 161.4 (C), 193.0 (C). ESI/HRMS (m/z): 398.0363 calcd for $C_{18}H_{18}BrNO_3$ $[M+Na]^+$; found 398.0377. IR (KBr, cm^{-1}): ν 3153, 2958, 1699, 1637.

Methyl 6,6-dimethyl-3-(4-methoxyphenyl)-4-oxo-4,5,6,7-tetrahydro-1*H*-indole-2-carboxylate (7d). Compound **7d** (120 mg, 76%) was obtained from 5-methoxy-3-(4-methoxyphenyl)isoxazole **1g** (100 mg, 0.49 mmol), 5,5-dimethylcyclohexane-1,3-dione **6** (70 mg, 0.50 mmol), $FeCl_2 \cdot 4H_2O$ (10 mg, 0.05 mmol, 10% mol), and $NiCl_2 \cdot 6H_2O$ (12 mg, 0.05 mmol, 10% mol), according to the general procedure under conditions indicated in table 3. Colorless solid, R_f = 0.15 (light petroleum/ethyl acetate 5:2), mp 204-206 °C (hexane/ether 5/1). ^{1}H NMR ($CDCl_3$): δ = 1.13 (s, 6H), 2.36 (s, 2H), 2.71 (s, 2H), 3.71 (s, 3H), 3.83 (s, 3H), 6.89 (d, J=8.9 Hz, 2H), 7.37 (d, J=8.9 Hz, 2H), 9.42 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ = 28.4 (CH_3), 35.0 (C), 37.0 (CH_2), 51.4 (CH_3), 53.2 (CH_2), 55.1 (CH_2), 112.5 (CH), 118.3 (C), 119.1 (C), 124.7 (C), 130.7 (C), 131.7 (CH), 144.7 (C), 158.9 (C), 167.8 (C), 193.2 (C).ESI/HRMS (m/z): 328.1544 calcd for $C_{19}H_{22}NO_4$ $[M+H]^+$, found 328.1555; 350.1363 calcd for $C_{19}H_{21}NNaO_4$ $[M+Na]^+$; found 350.1376. IR (KBr, cm^{-1}): ν 3192, 2962, 1680, 1652.

Methyl 3,6,6-trimethyl-4-oxo-4,5,6,7-tetrahydro-1*H*-indole-2-carboxylate (7e). Compound **7e** (37 mg, 18%) was obtained from 5-methoxy-3-methylisoxazole **1h** (100 mg, 0.89mmol), 5,5-dimethylcyclohexane-1,3-dione **6** (126 mg, 0.90mmol), $FeCl_2 \cdot 4H_2O$ (18 mg, 0.09 mmol, 10% mol), and $NiCl_2 \cdot 6H_2O$ (21 mg, 0.09 mmol, 10% mol), according to the general procedure under conditions indicated in table 3. Colorless solid, R_f = 0.22 (light petroleum/ethyl acetate 5:2), mp > 185°C (dec.) (hexane/ether 5/1).^{1}H NMR ($CDCl_3$): δ = 1.10 (s, 6H), 2.35 (s, 2H), 2.60 (s, 3H), 2.65 (s, 2H), 3.87 (s, 3H), 8.87 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ = 11.4 (CH_3), 28.4 (CH_3), 35.2 (C), 36.9 (CH_2), 51.5 (CH_3), 52.9 (CH_2), 119.3 (C), 119.7 (C), 128.5 (C), 144.4 (C), 162.4 (C), 194.8 (C). ESI/HRMS (m/z): 258.1101 calcd for $C_{13}H_{17}NNaO_3$ $[M+Na]^+$, found 258.1089. IR (KBr, cm^{-1}): ν 3253, 2957, 1699, 1683, 1636.

4-Ethyl 2-methyl 3,5-diphenyl-1*H*-pyrrole-2,4-dicarboxylate (9a) and methyl 4-benzoyl-5-ethoxy-3phenyl-1*H*-pyrrole-2-carboxylate (10a). Compound **9a** (103 mg, 52%) and compound **10a** (24 mg, 12%) were obtained from 5-methoxy-3-phenylisoxazole **1a** (100 mg, 0.57 mmol), ethyl 3-oxo-3-phenylpropanoate **8a** (120 mg, 0.62 mmol), $FeCl_2 \cdot 4H_2O$ (12 mg, 0.06 mmol, 10% mol), and $NiCl_2 \cdot 6H_2O$ (14 mg, 0.06 mmol, 10% mol), according to the general procedure under conditions indicated in table 4.

Compound **9a**, colorless solid, R_f = 0.39 (light petroleum/ethyl acetate 5:2), mp 175-176 °C (hexane) (lit. mp 161-162 °C (ethyl acetate) [11]). Both ^{1}H and ^{13}C NMR spectra corresponds to published data [11]. ^{1}H NMR ($CDCl_3$): δ = 0.86 (t, J=7.2 Hz, 3H), 3.65 (s, 3H), 3.96 (q, J=7.2 Hz, 2H), 7.35-7.37 (m, 5H), 7.43-7.45 (m, 3H), 7.59-7.62 (m, 2H), 9.37 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ = 13.5 (CH_3), 51.5 (CH_3), 60.0 CH_2), 115.0 (C), 119.2 (C), 127.1 (CH), 127.2 (CH), 128.4 (CH), 128.9 (CH), 129.1 (CH), 129.9 (CH), 131.1 (C), 133.5 (C), 134.2 (C), 138.9 (C), 161.3 (C), 164.5 (C). ESI/HRMS (m/z): 350.1387 calcd for $C_{21}H_{20}NO_4$ $[M+H]^+$, found 350.1395; 372.1207 calcd for $C_{21}H_{19}NNaO_4$ $[M+Na]^+$, found 372.1221. IR (KBr, cm^{-1}): ν 3294, 1717, 1675.

Compound **10a**, colorless solid, R_f = 0.18 (light petroleum/ethyl acetate 5:2), mp 186-187 °C (hexane).^{1}H NMR ($CDCl_3$): δ = 1.24 (t, J=7.0 Hz, 3H), 3.68 (s, 3H), 4.14 (q, J=7.0 Hz, 2H), 7.12-7.15 (m, 3H), 7.21-7.24 (m, 4H), 7.33-7.36 (m, 1H), 7.63-7.65 (m, 2H), 9.10 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ =14.7 (CH_3), 51.4 (CH_3), 69.4 (CH_2), 109.0 (C), 110.6 (C), 127.1 (CH), 127.2 (CH), 127.7 (CH), 129.4 (CH), 130.3 (CH), 131.9 (CH), 132.8 (C), 133.2 (C), 138.9 (C), 149.9 (C), 161.3 (C), 191.3 (C). ESI/HRMS (m/z): 350.1387 calcd for $C_{21}H_{20}NO_4$ $[M+H]^+$, found 350.1396; 372.1207 calcd for $C_{21}H_{19}NNaO_4$ $[M+Na]^+$, found 372.1216. IR (KBr, cm^{-1}): ν 3264, 1663, 1638.

4-Ethyl 2-methyl 3-(4-chlorophenyl)-2-methyl-5-phenyl-1*H*-pyrrole-2,4-dicarboxylate (9b) and methyl 4-benzoyl-3-(4-chlorophenyl)-5-ethoxy-1*H*-pyrrole-2-carboxylate (10b). Compound **9b** (86 mg, 47%) and compound **10b** (31 mg, 17%) were obtained from 3-(4-chlorophenyl)-5-methoxyisoxazole **1d** (100 mg, 0.48 mmol) and 3-oxo-3-phenylpropanoate **8a** (96 mg, 0.50 mmol), $FeCl_2 \cdot 4H_2O$ (10 mg, 0.05 mmol, 10% mol), and $NiCl_2 \cdot 6H_2O$ (12 mg, 0.05 mmol, 10% mol), according to the general procedure under conditions indicated in table 4.

Compound **9b**, colorless solid, R_f = 0.39 (light petroleum/ethyl acetate 5:2), mp 188-190 °C (hexane). ^{1}H NMR ($CDCl_3$): δ= 0.90 (t, J=7.2 Hz, 3H), 3.66-3.67 (m, 3H), 3.88 (q, J=7.2 Hz, 2H), 7.29-7.31 (m, 2H), 7.34-7.36 (m, 2H), 7.41-7.48 (m, 3H), 7.56-7.60 (m, 2H), 9.37 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ = 13.5 (CH_3), 51.6 (CH_3), 60.1 (CH_2), 114.7 (C), 119.3 (C), 127.4 (CH), 128.4 (CH), 128.9 (CH), 129.2 (CH), 131.0 (C), 131.4 (CH), 132.2 (C), 132.7 (C), 133.2 (C), 139.2 (C), 161.1 (C), 164.2 (C). ESI/HRMS (m/z): 384.0998 calcd for $C_{21}H_{19}ClNO_4$ $[M+H]^+$, found 384.0963; 406.0817 calcd for $C_{21}H_{18}ClNNaO_4$ $[M+Na]^+$; found 406.0826. IR (KBr, cm^{-1}): ν 3293, 1715, 1673.

Compound **10b**, colorless solid, R_f = 0.16 (light petroleum/ethyl acetate 5:2), mp 175-177 °C (hexane).^{1}H NMR ($CDCl_3$): δ= 1.23 (t, J=7.0 Hz, 3H), 3.70 (s, 3H), 4.11 (q, J=7.0 Hz, 2H), 7.12-7.18 (m, 4H), 7.25-7.28 (m, 2H), 7.38-7.42 (m, 1H), 7.63-7.65 (m, 2H), 8.91 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ = 14.7 (CH_3), 51.5 (CH_3), 69.5 (CH_2), 108.8 (C), 110.8 (C), 127.5 (CH), 127.8 (H), 129.4 (CH), 131.5 (C), 131.6 (CH), 131.8 (C), 132.2 (CH), 133.2 (C), 138.8 (C), 149.8 (C), 161.0 (C), 191.0 (C). ESI/HRMS (m/z): 384.0998 calcd for $C_{21}H_{19}ClNO_4$ $[M+H]^+$, found 384.1012; 406.0817 calcd for $C_{21}H_{18}ClNNaO_4$ $[M+Na]^+$; found 406.0832. IR (KBr, cm^{-1}): ν 3282, 1666, 1642.

4-Ethyl 2-methyl 3-(4-methoxyphenyl)-5-phenyl-1*H*-pyrrole-2,4-dicarboxylate (9c) and methyl 4-benzoyl-5-ethoxy-3-(4-methoxyphenyl)-1*H*-pyrrole-2-carboxylate (10c). Compound **9c** (30 mg, 33%) and compound **10c** (10 mg, 11%) were obtained from 5-methoxy-3-(4-methoxyphenyl)isoxazole **1g** (50 mg, 0.24 mmol), ethyl 3-oxo-3-phenylpropanoate **8a** (50 mg, 0.26 mmol), $FeCl_2 \cdot 4H_2O$ (6 mg, 0.03 mmol, 10% mol), and $NiCl_2 \cdot 6H_2O$ (7 mg, 0.03mmol, 10% mol), according to the general procedure under conditions indicated in table 4.

Compound **9c**, colorless solid, R_f = 0.27 (light petroleum/ethyl acetate 5:2), mp 174-175 °C (hexane). ^{1}H NMR ($CDCl_3$): δ = 0.91 (t, J=7.1 Hz, 3H), 3.69 (s, 3H), 3.85 (s, 3H), 3.99 (q, J=7.1 Hz, 2H), 6.92 (d, J=8.7 Hz, 2H), 7.30 (d, J=8.7 Hz, 2H), 7.42-7.46 (m, 3H), 7.57-7.59 (m, 2H), 9.28 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ = 13.6 (CH_3), 51.6 (CH_3), 55.2 (CH_3), 60.0 (CH_2), 112.7 (CH), 115.0 (C), 119.1 (C), 126.2 (C), 128.4 (CH), 128.8 (CH), 129.0 (CH), 131.1 (CH), 131.2 (C), 133.4 (C), 138.7 (C), 158.9 (C), 161.2 (C), 164.6 (C). ESI/HRMS (m/z): 402.1312 calcd for $C_{22}H_{21}NNaO_5$ $[M+Na]^+$, found 402.1293. IR (KBr, cm^{-1}): ν 3288, 1716, 1676.

Compound **10c**, colorless solid, R_f = 0.12 (light petroleum/ethyl acetate 5:2), mp 158-159 °C (hexane). ^{1}H NMR ($CDCl_3$): δ = 1.24 (t, J=7.0 Hz, 3H), 3.70 (s, 3H), 3.73 (s, 3H), 4.12 (q, J=7.0 Hz, 2H), 6.70 (d, J=8.7 Hz, 2H), 7.16 (d, J=8.7 Hz, 2H), 7.22-7.26 (m, 2H), 7.34-7.38 (m, 1H), 7.63-7.65 (m, 2H), 8.95 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ = 14.8 (CH_3), 51.4 (CH_3), 55.1 (CH_3), 69.3 (CH_2), 108.9 (C), 110.4 (C), 112.8 (CH), 125.5 (C), 127.7 (CH), 129.5 (CH), 131.5 (CH), 132.0 (CH), 132.7 (C), 138.9 (C), 149.8 (C), 158.7 (C), 161.3 (C), 191.4 (C). ESI/HRMS (m/z): 380.1492 calcd for $C_{22}H_{22}NO_5$ $[M+H]^+$, found 380.1476. IR (KBr, cm^{-1}): ν 3230, 1714, 1632.

2-*tert*-Butyl 4-ethyl 5-methyl-3-phenyl-1*H*-pyrrole-2,4-dicarboxylate (9d). Compound **9d** (51 mg, 34%) was obtained from 5-*tert*-butoxy-3-phenylisoxazole **1b** (100 mg, 0.46 mmol), ethyl 3-oxobutanoate **8b** (61 mg, 0.47 mmol), $FeCl_2 \cdot 4H_2O$ (10 mg, 0.05 mmol, 10% mol), and $NiCl_2 \cdot 6H_2O$ (12 mg, 0.05 mmol, 10% mol), according to the general procedure under conditions indicated in table 4. Colorless solid, R_f = 0.44 (light petroleum/ethyl acetate 5:2), mp 152-154 °C (hexane). ^{1}H NMR ($CDCl_3$): δ = 0.96 (t, J=7.0 Hz, 3H), 1.23 (s, 9H), 2.58 (s, 3H), 4.02 (q, J=7.0 Hz, 2H), 7.21-7.23 (m, 2H), 7.27-7.32 (m, 3H), 9.66 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ =13.7 (CH_3), 13.9 (CH_3), 27.9 (CH_3), 59.3 (CH_2), 81.0 (C), 113.6 (C), 119.6 (C), 126.4 (CH), 126.8 (CH), 129.8 (CH), 132.7 (C), 135.9 (C), 138.2 (C), 161.1 (C), 164.9 (C). ESI/HRMS (m/z): 352.1519 calcd for $C_{19}H_{24}NNaO_4$ $[M+Na]^+$, found 352.1533. IR (KBr, cm^{-1}): ν 3284, 1694, 1662.

4-Ethyl 2-methyl 5-methyl-3-phenyl-1*H*-pyrrole-2,4-dicarboxylate (9e). Compound **9e** (143 mg, 58%) was obtained from 5-methoxy-3-phenylisoxazole **1a** (150 mg, 0.86 mmol) and ethyl 3-oxobutanoate **8b** (112 mg, 0.86 mmol), $FeCl_2 \cdot 4H_2O$ (18 mg, 0.09 mmol, 10% mol), and $NiCl_2 \cdot 6H_2O$ (21 mg, 0.09 mmol, 10% mol), according to the general procedure under conditions indicated in table 4. Colorless solid, R_f = 0.39 (light petroleum/ethyl acetate 5:2), mp 141-143 °C (hexane) (lit. mp 140 (CCl_4) [9]). Both ^{1}H and ^{13}C NMR spectra are in accordance to literature [9, 10]. ^{1}H NMR ($CDCl_3$): δ =0.98 (t, J=7.2 Hz, 3H), 2.59 (s, 3H), 3.64 (s, 3H), 4.03 (q, J=7.2 Hz, 2H), 7.25-7.28 (m, 2H), 7.30-7.33 (m, 3H), 9.48 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ = 13.7 (CH_3), 13.9 (CH_3), 51.4 (CH_3), 59.4 (CH_2), 114.0 (C), 117.7 (C), 126.8 (CH), 126.9 (CH), 129.8 (CH), 133.5 (C), 134.8 (C), 138.7 (C), 161.5 (C), 164.8 (C). ESI/HRMS (m/z): 310.1050 calcd for $C_{16}H_{17}NNaO_4$ $[M+Na]^+$, found 310.1062. IR (KBr, cm^{-1}): ν 3308, 1700, 1670.

4-Ethyl 2-methyl 3-(4-chlorophenyl)-5-methyl-1*H*-pyrrole-2,4-dicarboxylate (9f) and methyl 4-acetyl-3-(4-chlorophenyl)-5-ethoxy-1*H*-pyrrole-2-carboxylate (10d). Compound **9f** (62 mg, 40%) and compound **10d** (13 mg, 4%) were obtained from 3-(4-clorophenyl)-5-methoxyisoxazole **1d** (100 mg, 0.48 mmol) and ethyl 3-oxobutanoate **8b** (65 mg, 0.50 mmol), $FeCl_2 \cdot 4H_2O$ (10 mg, 0.05 mmol, 10% mol), and $NiCl_2 \cdot 6H_2O$ (12 mg, 0.05 mmol, 10% mol), according to the general procedure under conditions indicated in table 4.

Compound **9f**, colorless solid, R_f = 0.39 (light petroleum/ethyl acetate 5:2), mp 150-153 °C (hexane). ^{1}H NMR ($CDCl_3$): δ = 1.04 (t, J=7.1 Hz, 3H), 2.58 (s, 3H), 3.65 (s, 3H), 4.06 (q, J=7.1 Hz, 2H), 7.19-7.22 (m, 2H), 7.30-7.32 (m, 2H), 9.64 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ = 13.8 (CH_3), 13.9 (CH_3), 51.5 (CH_3), 59.6 (CH_2), 113.9 (C), 117.8 (C), 127.2 (CH), 131.3 (CH), 132.2 (C), 132.8 (C), 133.3 (C), 139.0 (C), 161.5 (C), 164.6 (C). ESI/HRMS (m/z): 322.0841 calcd for

$C_{16}H_{17}ClNO_4$ $[M+H]^+$, found 322.0851; 344.0661 calcd for $C_{16}H_{16}ClNNaO_4$ $[M+Na]^+$; found 344.0671. IR (KBr, cm^{-1}): ν 3282, 1701, 1671.

Compound **10d**, colorless solid, R_f = 0.16 (light petroleum/ethyl acetate 5:2), mp 160-162 °C (hexane). ^1H NMR ($CDCl_3$): δ = 1.52 (t, J=7.0 Hz, 3H), 2.21 (s, 3H), 3.62 (s, 3H), 4.32 (q, J=7.0 Hz, 2H), 7.20 (d, J=8.4 Hz, 2H), 7.32 (d, J=8.4 Hz, 2H), 8.96 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ = 14.8 (CH_3), 30.6 (CH_3), 51.5 (CH_3), 68.0 (CH_2), 109.2 (C), 111.6 (C), 127.6 (CH), 131.15 (C), 131.18 (CH), 132.8 (C), 133.2 (C), 151.1 (C), 161.3 (C), 192.7 (C).ESI/HRMS (m/z): 322.0841 calcd for $C_{16}H_{17}ClNO_4$ $[M+H]^+$, found 322.0850; 344.0661 calcd for $C_{16}H_{16}ClNNaO_4$ $[M+Na]^+$; found 344.0675. IR (KBr, cm^{-1}): ν 3072, 2978, 2955, 1720, 1628.

4-Ethyl 2-methyl 3-(4-bromophenyl)-5-methyl-1*H*-pyrrole-2,4-dicarboxylate (9g), methyl 4-acetyl-3-(4-bromophenyl)-5-ethoxy-1*H*-pyrrole-2-carboxylate (10e). Compound **9g** (75 mg, 41%) and compound **10e** (21 mg, 11%) were obtained from 3-(4-bromophenyl)-5-methoxyisoxazole **1f** (127 mg, 0.50mmol), ethyl 3-oxobutanoate **8b** (65 mg, 0.50 mmol), $FeCl_2{\cdot}4H_2O$ (10 mg, 0.05 mmol, 10% mol), and $NiCl_2{\cdot}6H_2O$ (12 mg, 0.05 mmol, 10% mol), according to the general procedure under conditions indicated in table 4.

Compound **9g**, colorless solid, R_f = 0.35 (light petroleum/ethyl acetate 5:2), mp 145-147 °C (hexane).^1H NMR ($CDCl_3$): δ= 1.04 (t, J=7.2 Hz, 3H), 2.58 (s, 3H), 3.66 (s, 3H), 4.06 (q, J=7.2 Hz, 2H), 7.15 (d, J=8.4 Hz, 2H), 7.46 (d, J=8.4 Hz, 2H), 9.29 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ = 13.8 (CH_3), 14.0 (CH_3), 51.5 (CH_3), 59.6 (CH_2), 113.8 (C), 117.8 (C), 121.1 (C), 130.1 (CH), 131.7 (CH), 132.1 (C), 133.8 (C), 138.9 (C), 161.3 (C), 164.5 (C). ESI/HRMS (m/z): 366.0336 calcd for $C_{16}H_{17}BrNO_4$ $[M+H]^+$, found 366.0345; 388.0155 calcd for $C_{16}H_{16}BrNNaO_4$ $[M+Na]^+$; found 388.0164. IR (KBr, cm^{-1}): ν 3296, 1698, 1670.

Compound **10e**, colorless solid, R_f = 0.15 (light petroleum/ethyl acetate 5:2), mp 163-165 °C (hexane). ^1H NMR ($CDCl_3$): δ= 1.53 (t, J=7.0 Hz, 3H), 2.21 (s, 3H), 3.63 (s, 3H), 4.32 (q, J=7.0 Hz, 2H), 7.15 (d, J=8.6 Hz, 2H), 7.47 (d, J=8.6 Hz, 2H), 8.90 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ = 14.8 (CH_3), 30.6 (CH_3), 51.5 (CH_3), 68.0 (CH_2), 109.2 (C), 111.5 (C), 121.5 (C), 130.5 (CH), 131.1 (C), 131.5 (CH), 133.3 (C), 151.0 (C), 161.3 (C), 192.6 (C). ESI/HRMS (m/z): 366.0336 calcd for $C_{16}H_{17}BrNO_4$ $[M+H]^+$, found 366.0348; 388.0155 calcd for $C_{16}H_{16}BrNNaO_4$ $[M+Na]^+$; found 388.0170. IR (KBr, cm^{-1}): ν 3159, 3071, 2976, 1721, 1626.

4-Ethyl 2-methyl 3-(4-(dimethylamino)phenyl)-5-methyl-1*H*-pyrrole-2,4-dicarboxylate (9h). Compound **9h** (54 mg, 36%) was obtained from 3-(4-(dimethylamino)phenyl)-5-methoxyisoxazole **1e** (100 mg, 0.46mmol), ethyl 3-oxobutanoate **8b** (65 mg, 0.50 mmol), $FeCl_2{\cdot}4H_2O$ (10 mg, 0.05 mmol, 10% mol), and $NiCl_2{\cdot}6H_2O$ (12 mg, 0.05 mmol, 10% mol), according to the general procedure under conditions indicated in table 4. Colorless solid, R_f = 0.18 (light petroleum/ethyl acetate 2:1), mp 155-156 °C (hexane). ^1H NMR ($CDCl_3$): δ = 1.09 (t, J=7.1 Hz, 3H), 2.56 (s, 3H), 2.97 (s, 6H), 3.68 (s, 3H), 4.10 (q, J=7.1 Hz, 2H), 6.73 (d, J=8.9 Hz, 2H), 7.18 (d, J=8.9 Hz, 2H), 9.38 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ =14.0 (CH_3), 14.1 (CH_3), 40.7 (CH_3), 51.4 (CH_3), 59.4 (CH_2), 111.3 (CH), 113.9 (C), 117.4 (C), 122.2 (C), 130.9 (CH), 134.2 (C), 138.5 (C), 149.7 (C), 161.6 (C), 165.0 (C). ESI/HRMS (m/z): 331.1653 calcd for $C_{18}H_{23}N_2O_4$ $[M+H]^+$, found 331.1670; 353.1472 calcd for $C_{18}H_{22}N_2NaO_4$ $[M+Na]^+$; found 353.1480. IR (KBr, cm^{-1}): ν 3298, 1699, 1666.

4-Ethyl 2-methyl 3-(4-methoxyphenyl)-5-methyl-1*H* pyrrole-2,4-dicarboxylate (9i). Compound **9i** (79 mg, 51%) was obtained from from 5-methoxy-3-(4-methoxyphenyl)isoxazole **1g** (100 mg, 0.49 mmol), ethyl 3-oxobutanoate **8b** (65 mg, 0.50mmol), $FeCl_2{\cdot}4H_2O$ (10 mg, 0.05 mmol, 10% mol), and $NiCl_2{\cdot}6H_2O$ (12 mg, 0.05 mmol, 10% mol), according to the general procedure under conditions indicated in table 4. Colorless solid, R_f = 0.23 (light petroleum/ethyl

acetate 5:2) mp 148-149 °C (hexane). ^{1}H NMR ($CDCl_3$): δ = 1.06 (t, J=7.2 Hz, 3 H), 2.57 (s, 3H), 3.67 (s, 3H), 3.84 (s, 3H), 4.07 (q, J=7.2 Hz, 2H), 6.89 (d, J=8.7 Hz, 2H), 7.21 (d, J=8.7 Hz, 2H), 9.26 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ = 13.9 (CH_3), 14.1 (CH_3), 51.4 (CH_3), 55.2 (CH_3), 59.5 (CH_2), 112.5 (CH), 114.0 (C), 117.7 (C), 126.7 (C), 131.1 (CH), 133.4 (C), 138.5 (C), 158.7 (C), 161.4 (C), 164.8 (C). ESI/HRMS (m/z): 318.1336 calcd for $C_{17}H_{20}NO_5$ $[M+H]^+$, found 318.1343; 340.1156 calcd for $C_{17}H_{19}NNaO_5$ $[M+Na]^+$, found 340.1166. IR (KBr, cm^{-1}): ν 3297, 1699, 1667.

Methyl 5-methyl-3-phenyl-4-(phenylcarbamoyl)-1*H*-pyrrole-2-carboxylate (9k). Compound **9k** (79 mg, 50%) was obtained from 5-methoxy-3-phenylisoxazole **1a** (83 mg, 0.47mmol), 3-oxo-*N*-phenylbutanamide **8c** (84 mg, 0.47mmol), $FeCl_2 \cdot 4H_2O$ (10 mg, 0.05 mmol, 10% mol), and $NiCl_2 \cdot 6H_2O$ (12 mg, 0.05 mmol, 10% mol), according to the general procedure under conditions indicated in table 4. Colorless solid, R_f= 0.22 (light petroleum/ethyl acetate 2:1), mp 233-234 °C (hexane/ether 10/1). ^{1}H NMR ($CDCl_3$): δ = 2.70 (s, 3H), 3.66 (s, 3H), 6.92-7.03 (m, 4H), 7.15-7.19 (m, 2H), 7.43-7.45 (m, 2H), 7.50-7.52 (m, 3H), 9.50 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ =14.1 (CH_3), 51.4 (CH_3), 116.8 (C), 117.3 (C), 119.2 (CH), 123.5 (CH), 128.5 (CH), 128.7 (CH), 128.8 (CH), 129.6 (C), 130.3 (CH), 133.9 (C), 138.0 (C), 138.8 (C), 161.3 (C), 162.7 (C). ESI/HRMS (m/z): 335.1391 calcd for $C_{20}H_{19}N_2O_3$ $[M+H]^+$, found 335.1389; 357.1210 calcd for $C_{20}H_{18}N_2NaO_3$ $[M+Na]^+$; found 357.1222. IR (KBr, cm^{-1}): ν 3404, 3294, 1661.

Methyl 3-(4-bromophenyl)-5-methyl-4(phenylcarbamoyl)-1*H*-pyrrole-2-carboxylate (9l). Compound **9l** (104 mg, 65%) was obtained from 3-(4-bromophenyl)-5-methoxyisoxazole **1f** (100 mg, 0.39mmol), 3-oxo-N-phenylbutanamide **8c** (70 mg, 0.39mmol), $FeCl_2 \cdot 4H_2O$ (8 mg, 0.04mmol, 10% mol), and $NiCl_2 \cdot 6H_2O$ (10 mg, 0.04mmol, 10% mol), according to the general procedure under conditions indicated in table 4. Colorless solid, R_f= 0.17 (light petroleum/ethyl acetate 2:1), mp 228-230 °C (hexane/ether 10/1). ^{1}H NMR ($CDCl_3$): δ = 2.67 (s, 3H), 3.69 (s, 3H), 6.82 (br s, 1H), 7.00-7.03 (m, 1H), 7.07 (d, J=7.8 Hz, 2H), 7.20-7.24 (m, 2H), 7.32 (d, J=8.4 Hz, 2H), 7.62 (d, J=8.4 Hz, 2H), 9.49 (br s, 1H). ^{13}C NMR ($CDCl_3$): δ = 13.9 (CH_3), 51.6 (CH_3), 116.9 (C), 117.3 (C), 119.3 (CH), 122.8 (C), 123.8 (CH), 128.2 (C), 128.9 (CH), 131.8 (CH), 132.0 (CH), 132.7 (C), 137.8 (C), 138.7 (C), 161.0 (C), 162.5 (C).ESI/HRMS (m/z): 413.0496 calcd for $C_{20}H_{18}BrN_2O_3$ $[M+H]^+$, found 413.0492; 435.0315 calcd for $C_{20}H_{17}BrN_2NaO_3$ $[M+Na]^+$; found 435.0309. IR (KBr, cm^{-1}): ν 3413, 3295, 1677, 1662.

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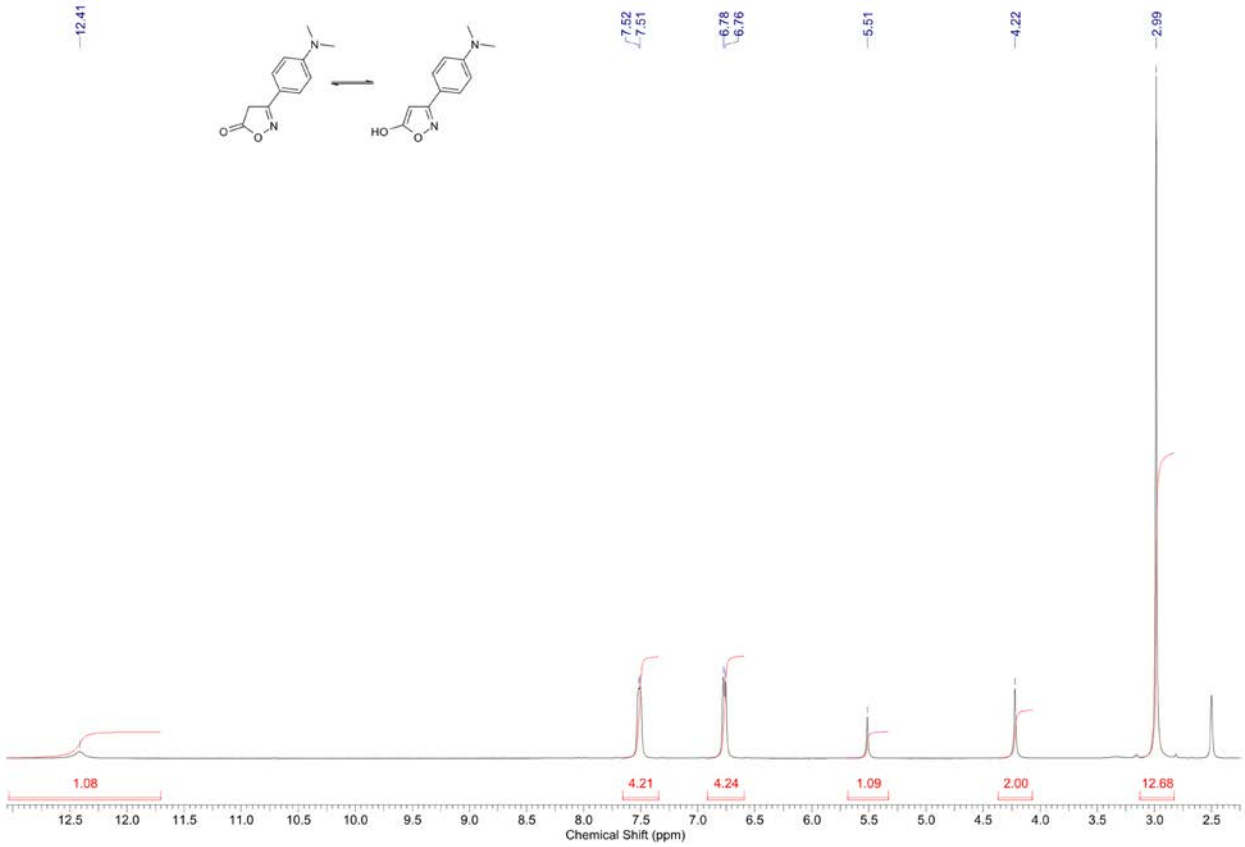
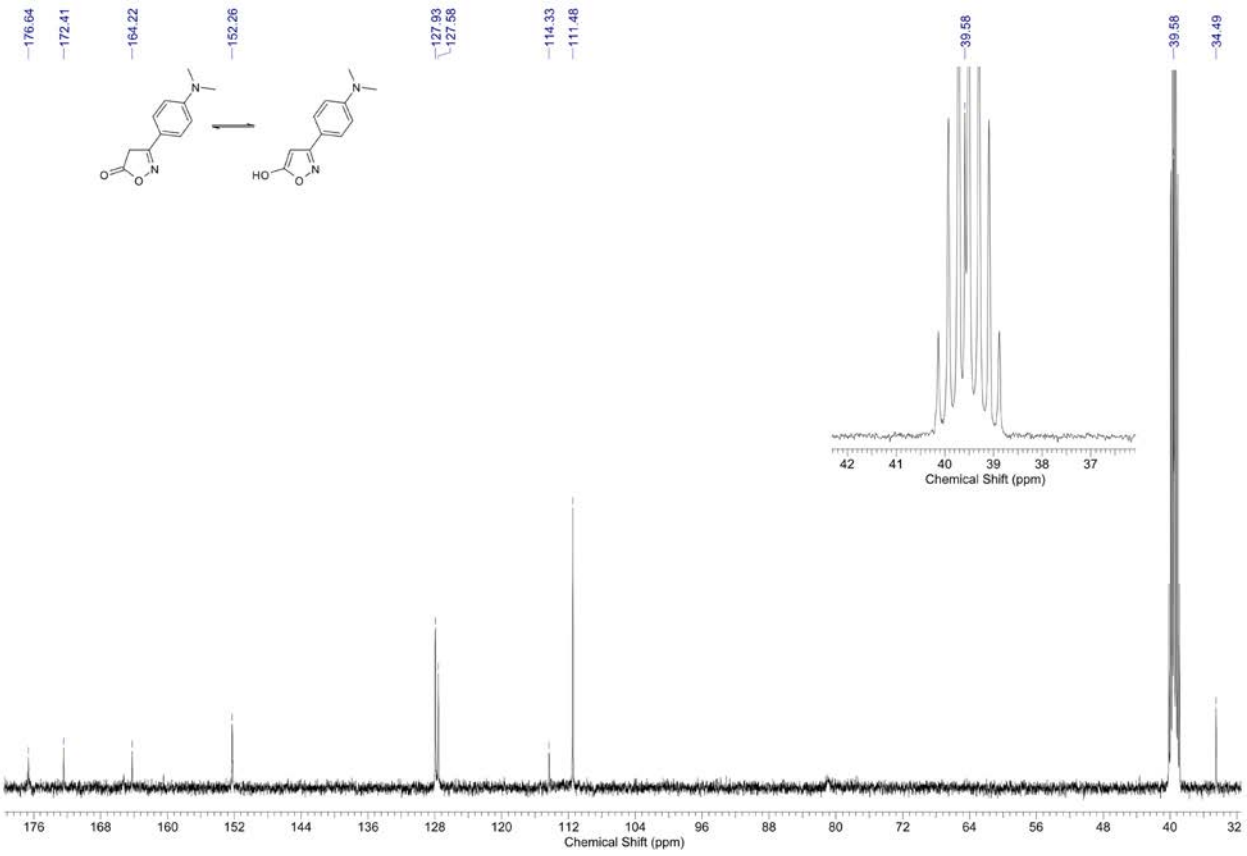
NMR Spectra

3-(4-(Dimethylamino)phenyl)isoxazol-5(4*H*)-one





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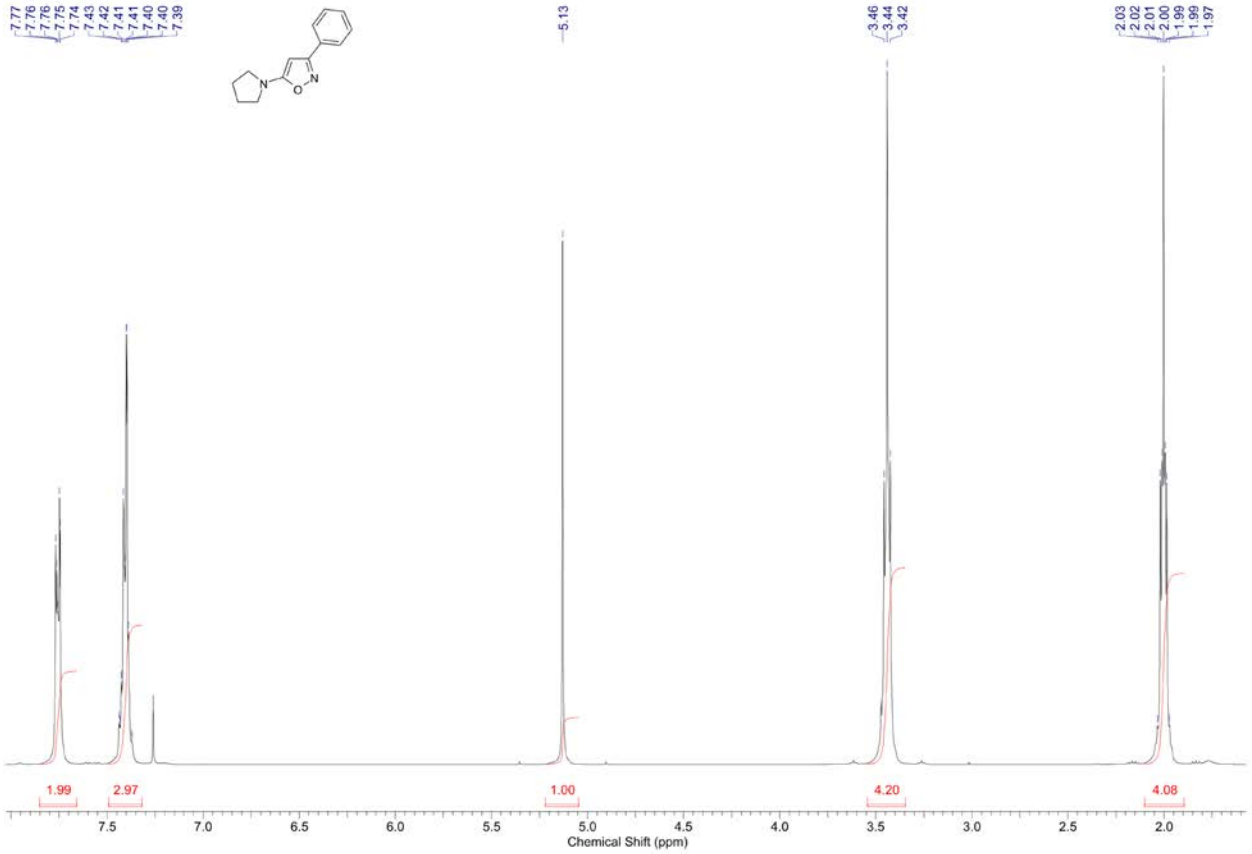

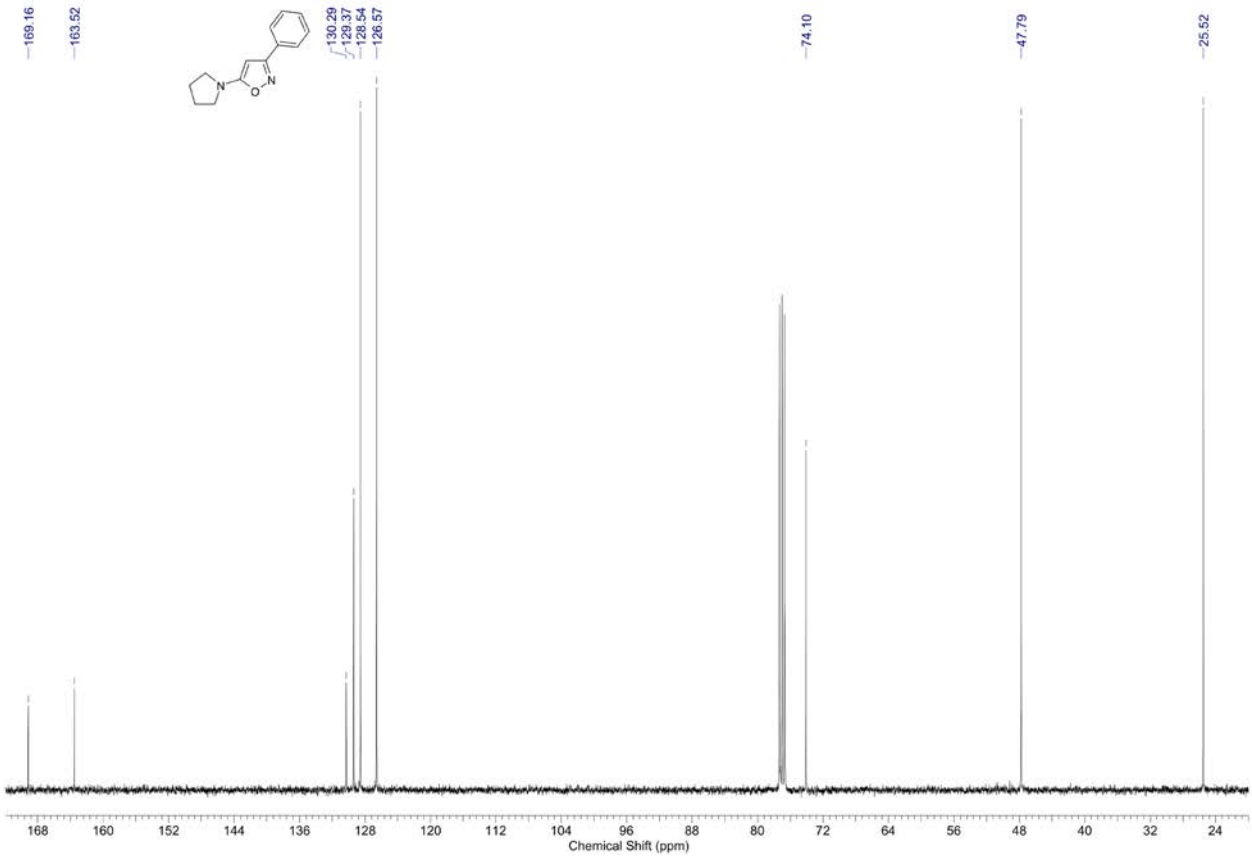

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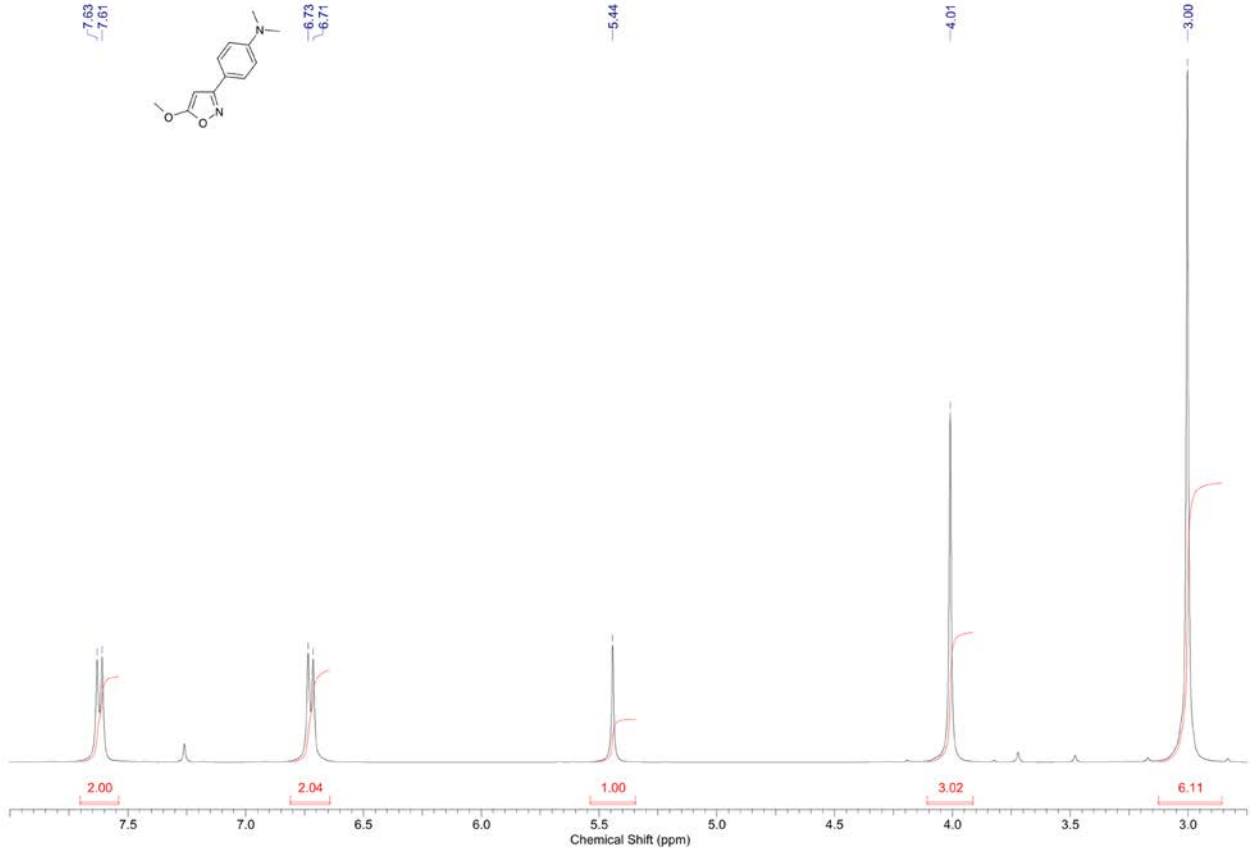

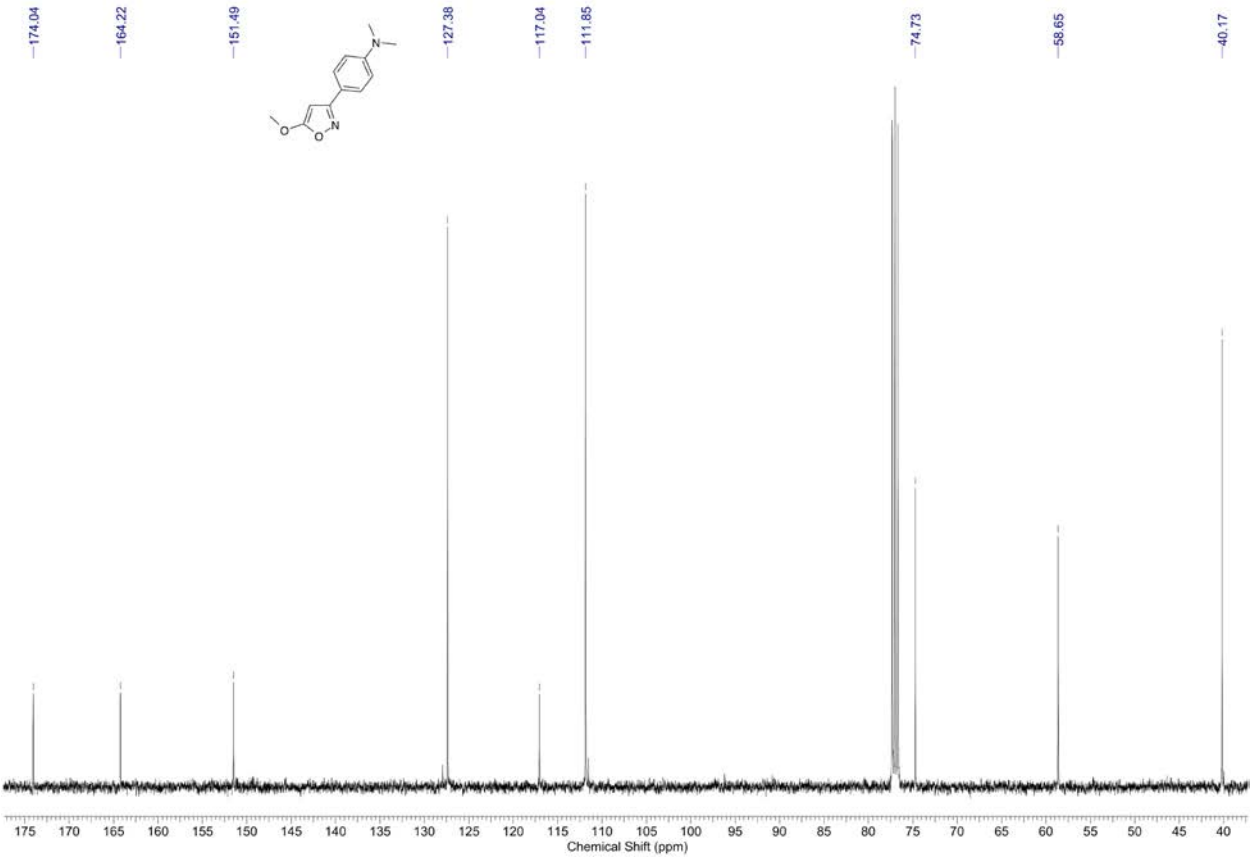

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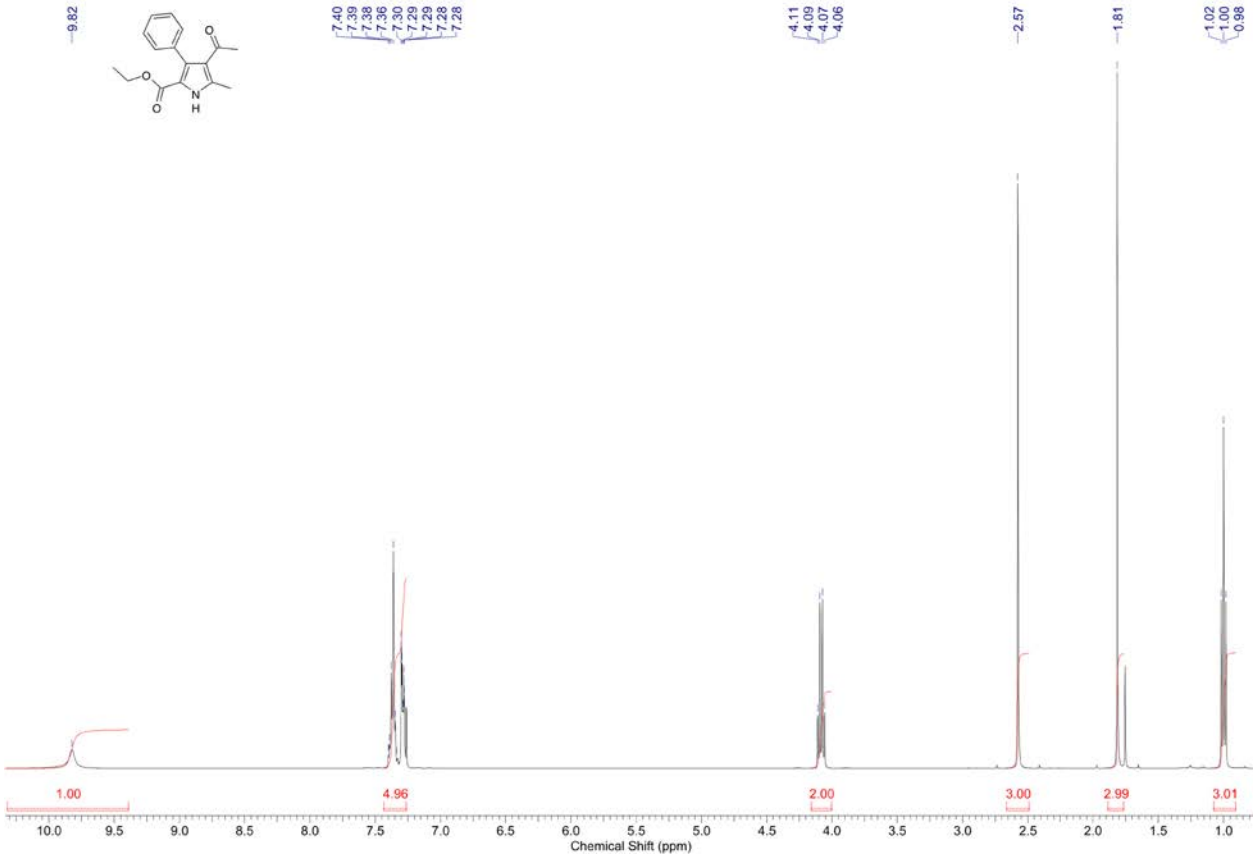

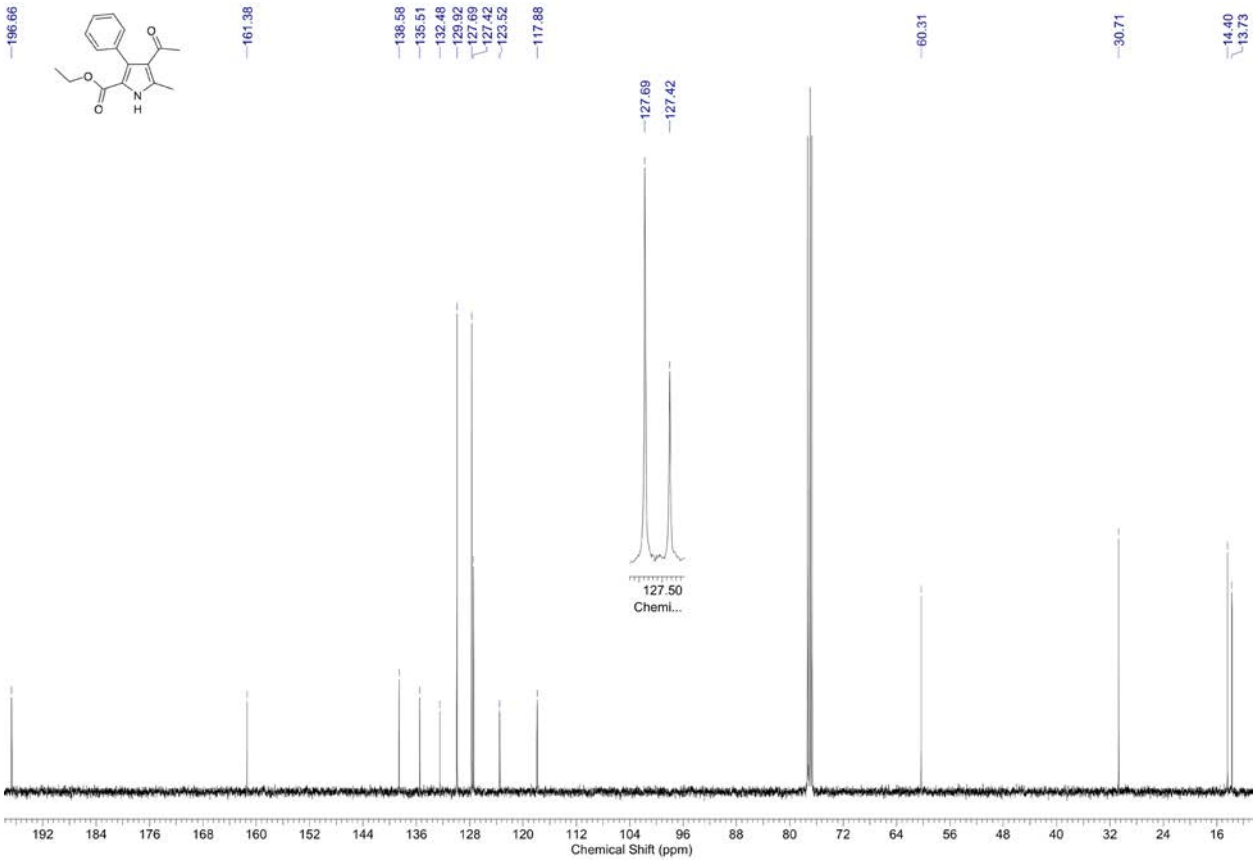

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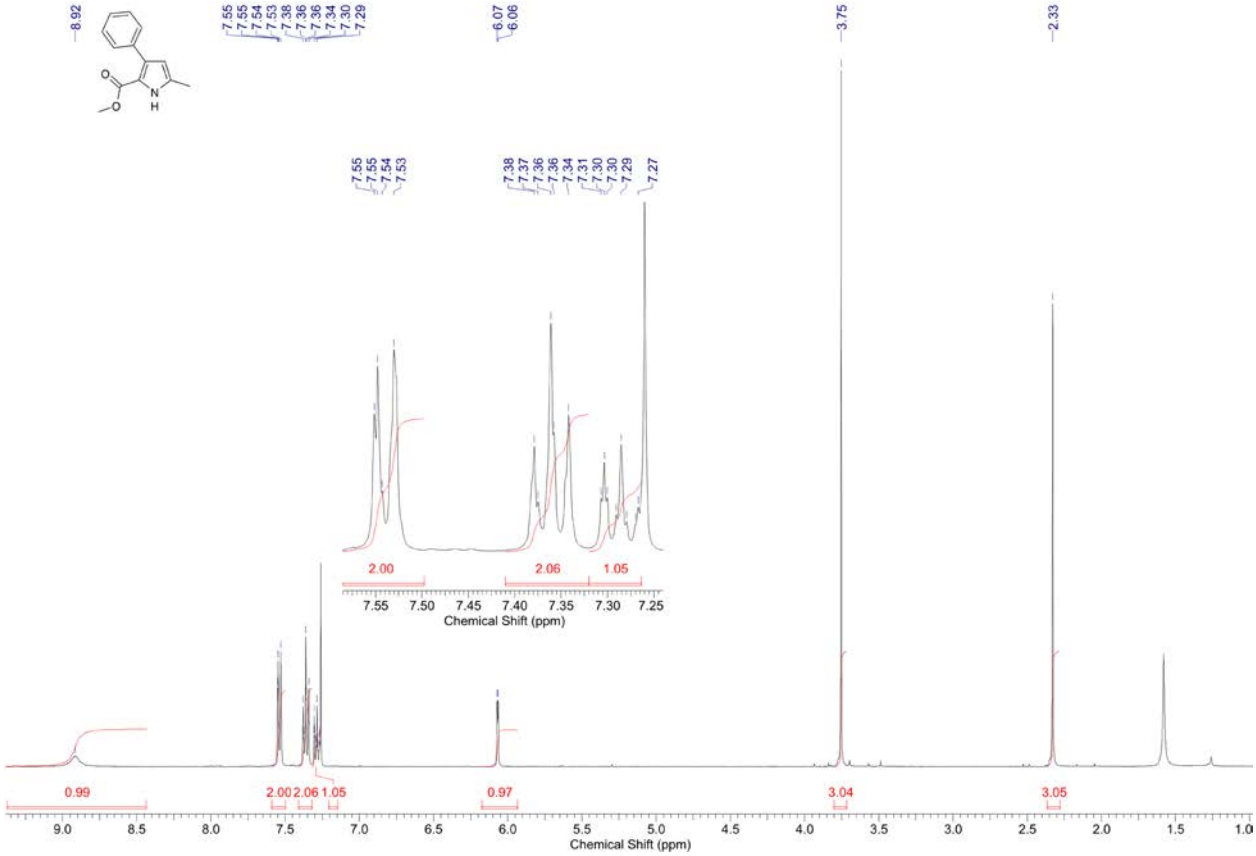

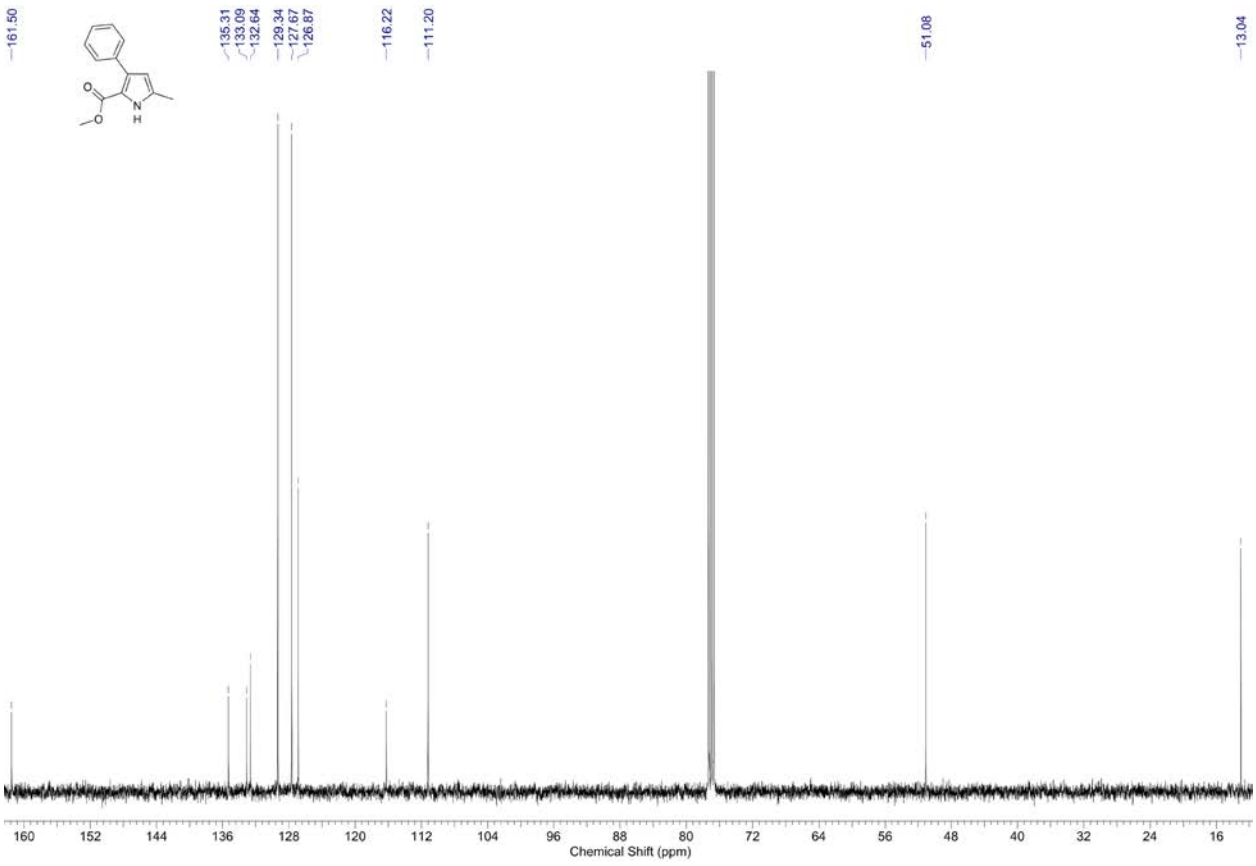

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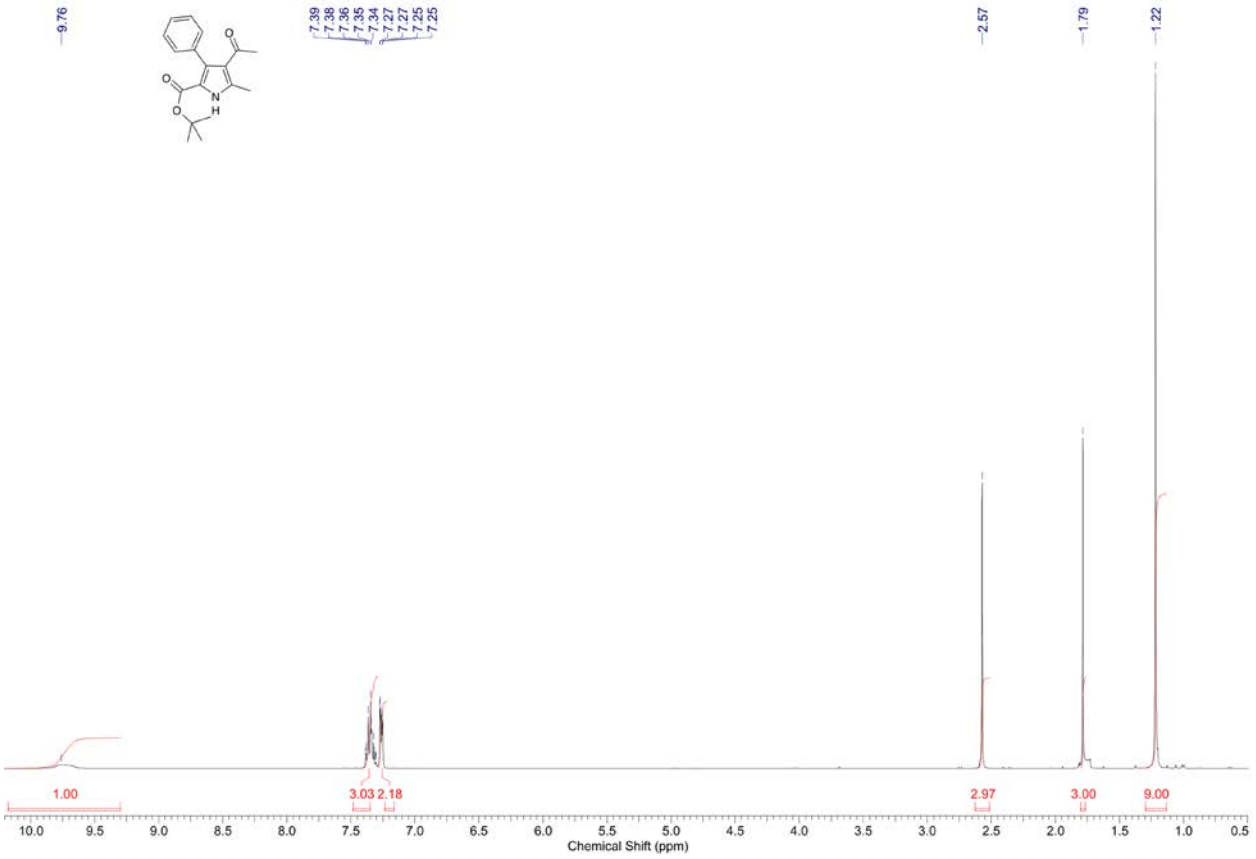

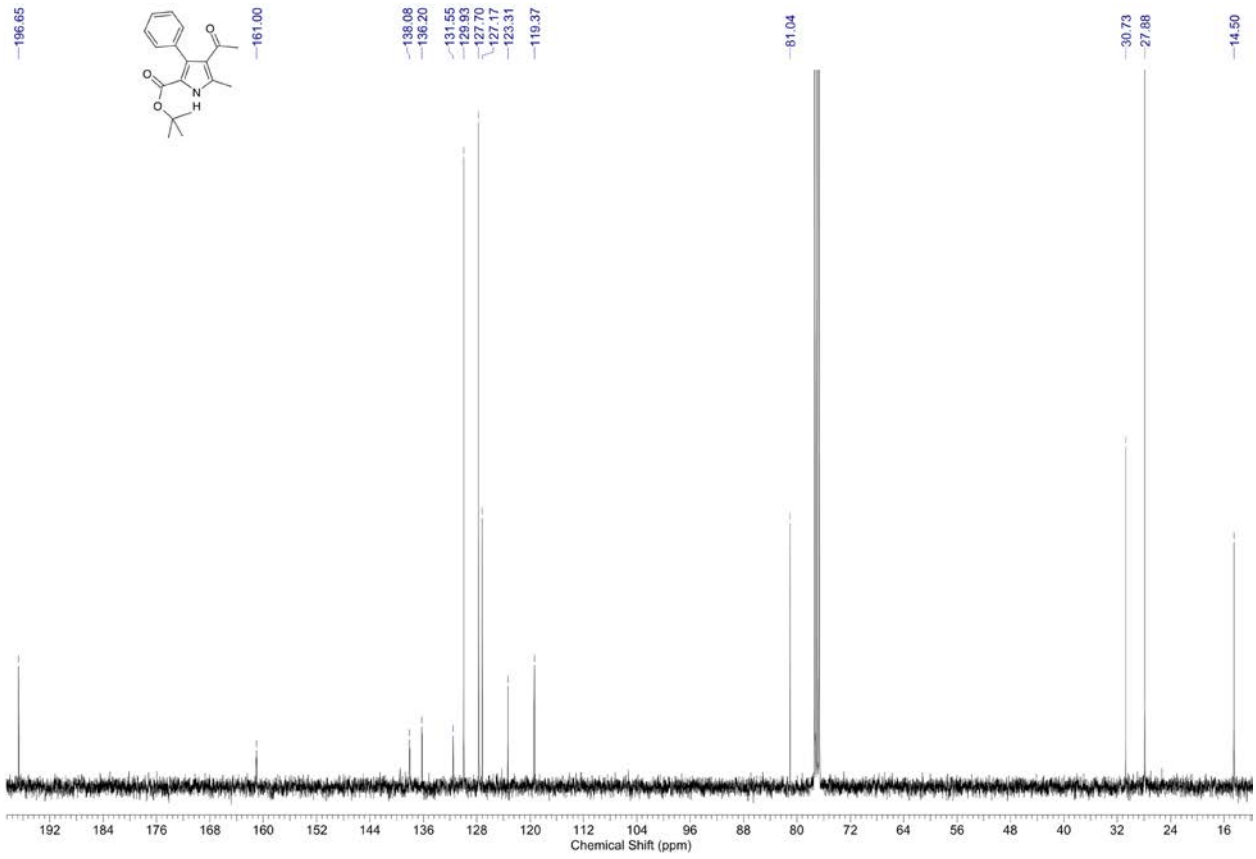

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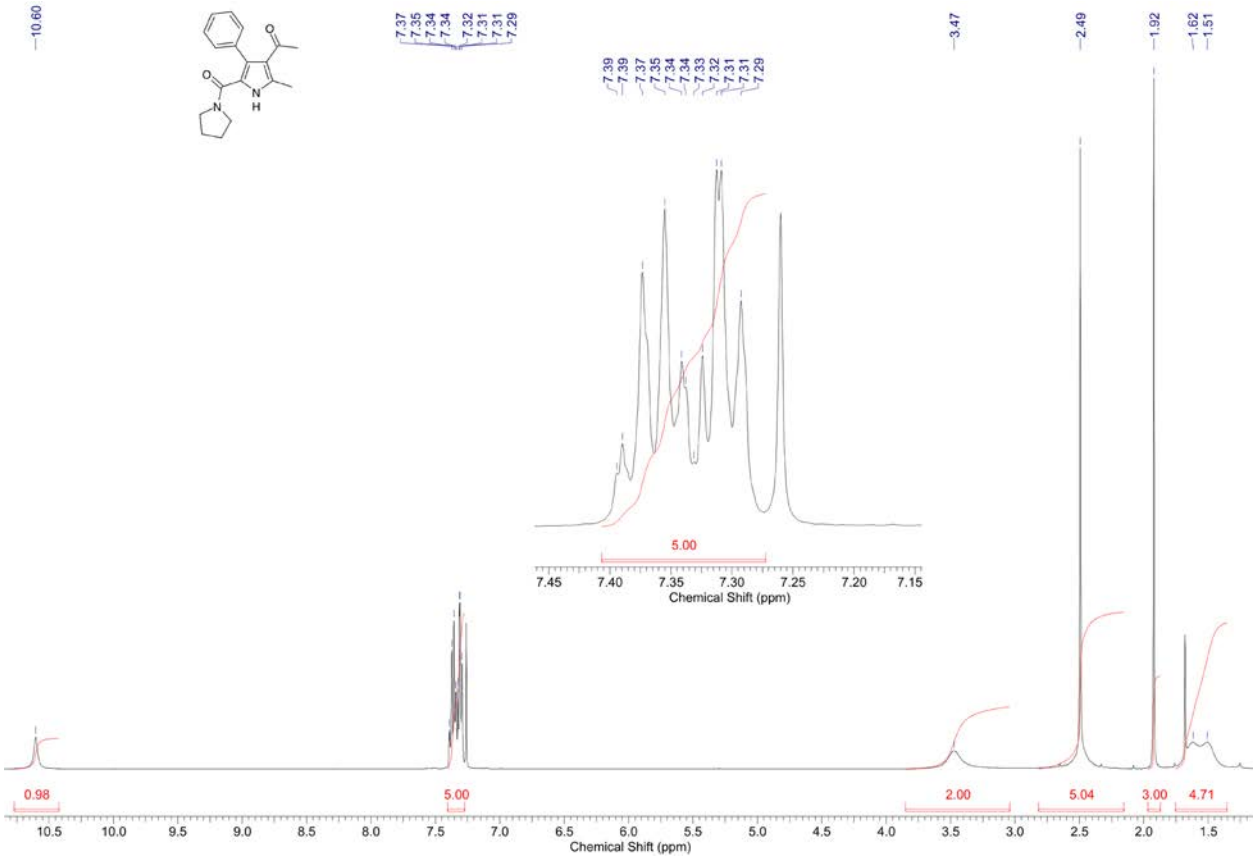

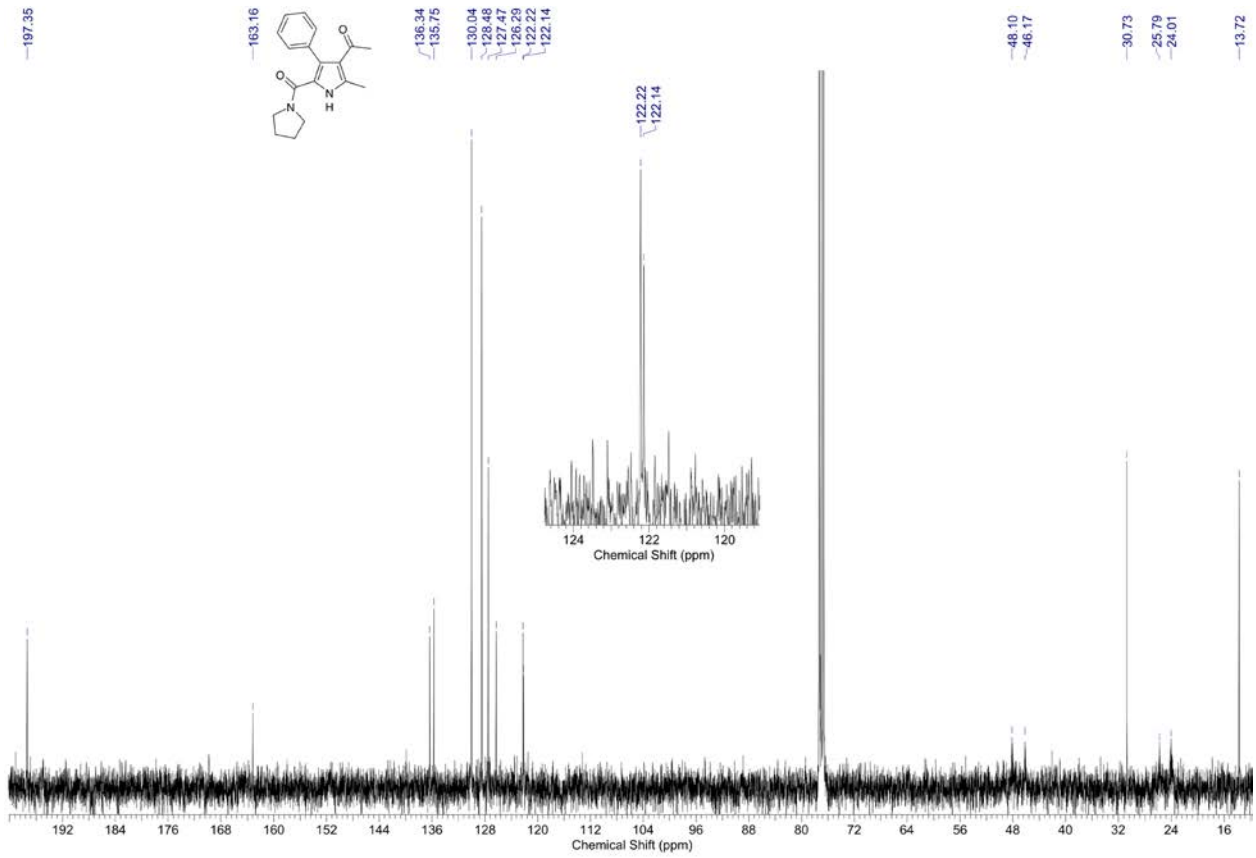

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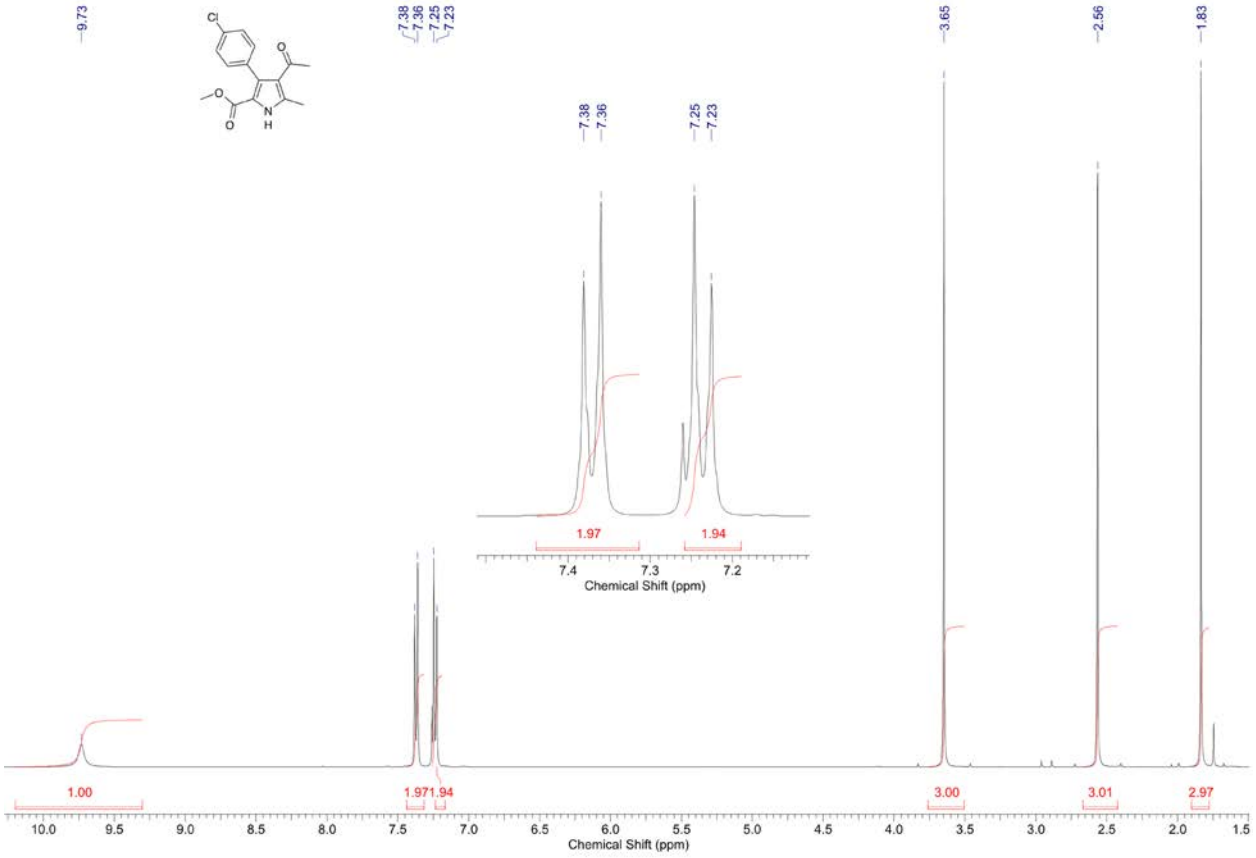

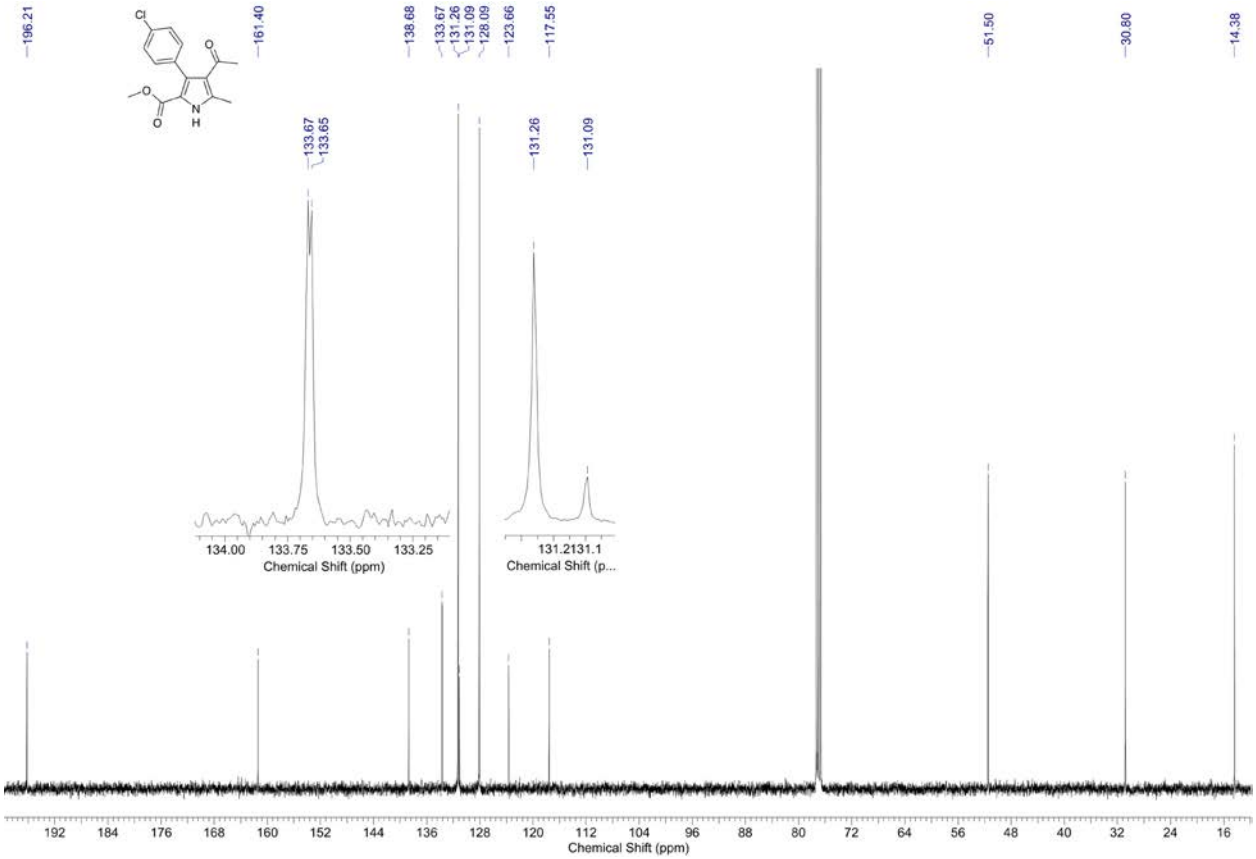

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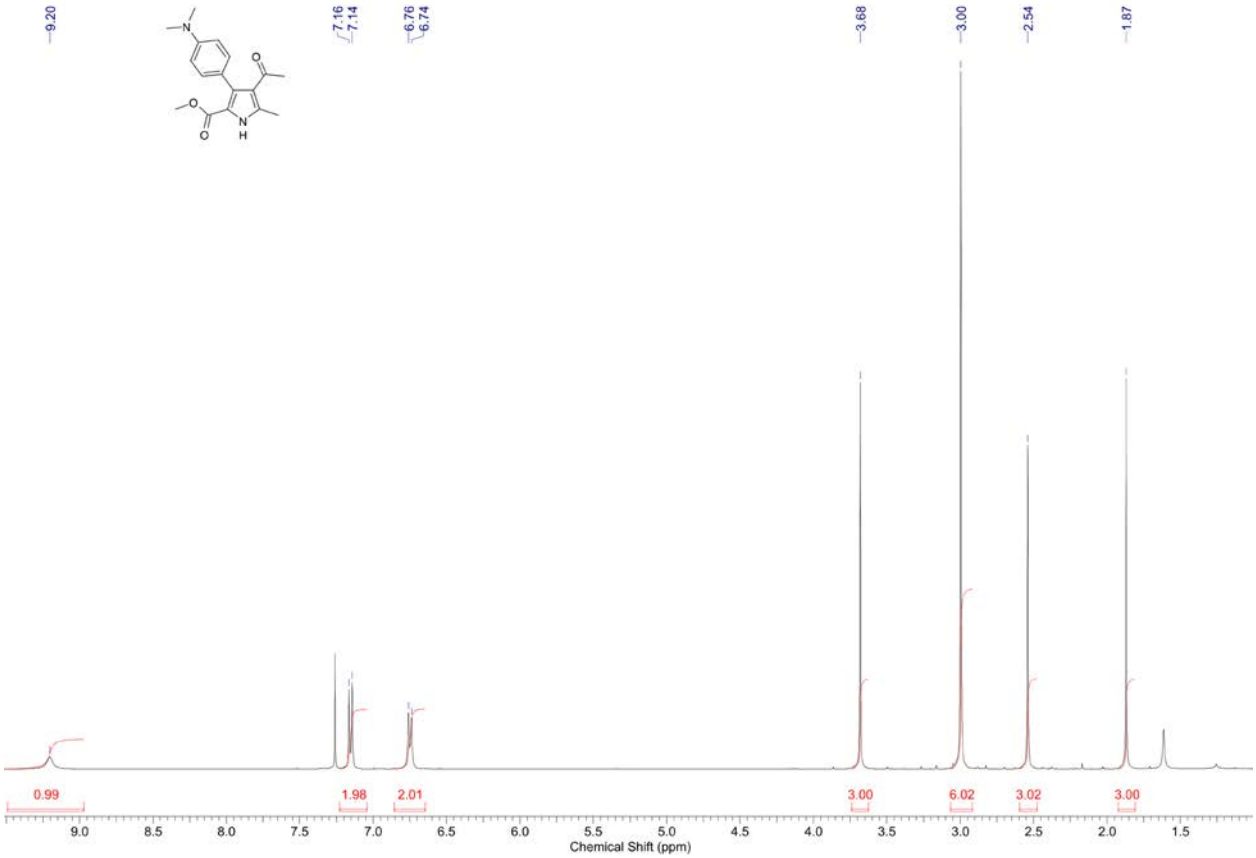

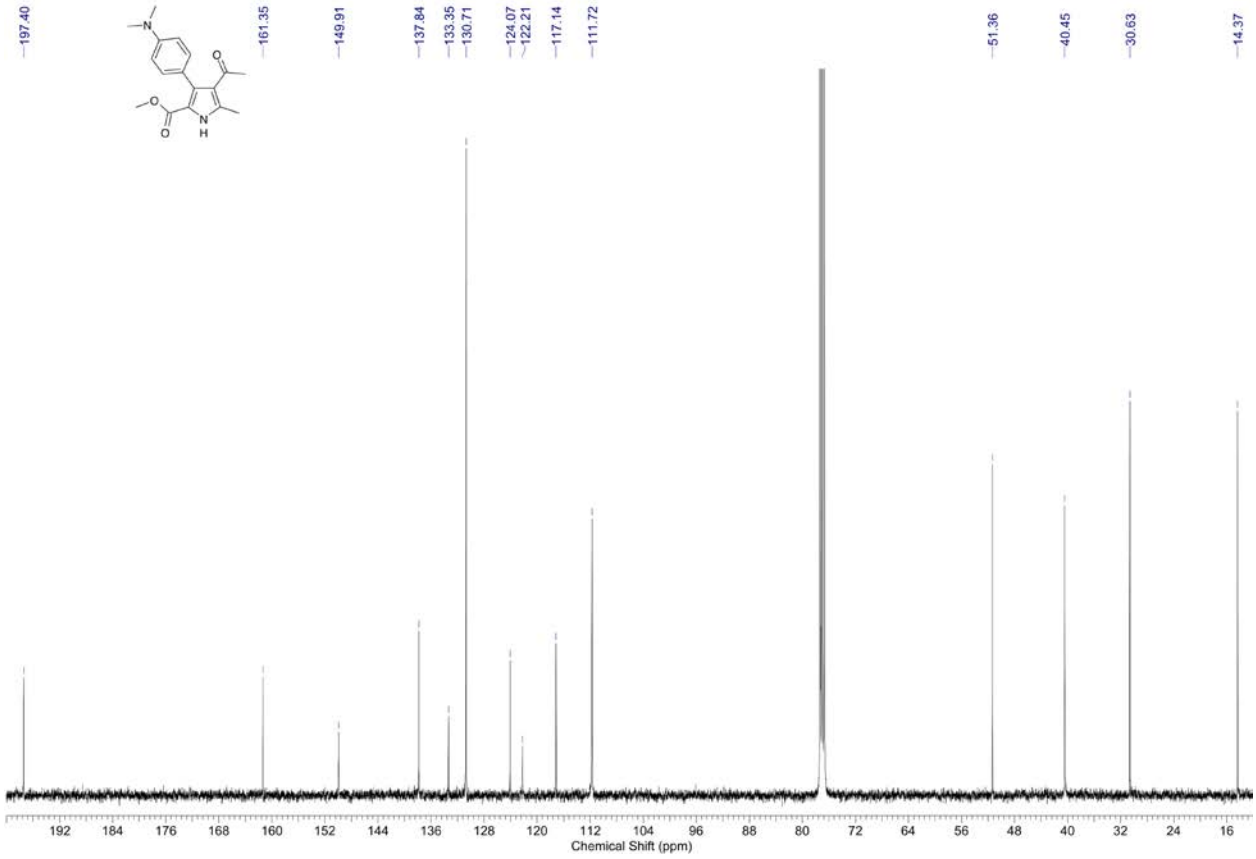

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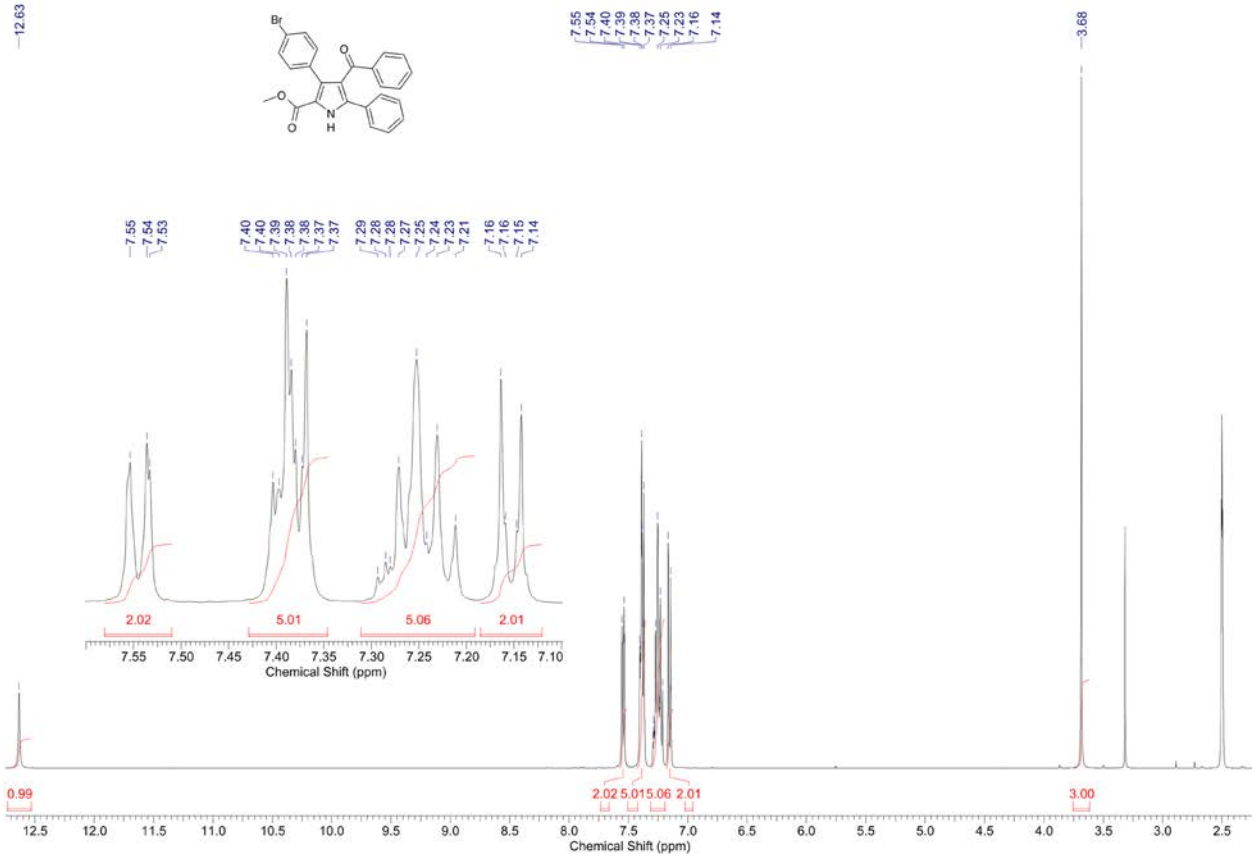

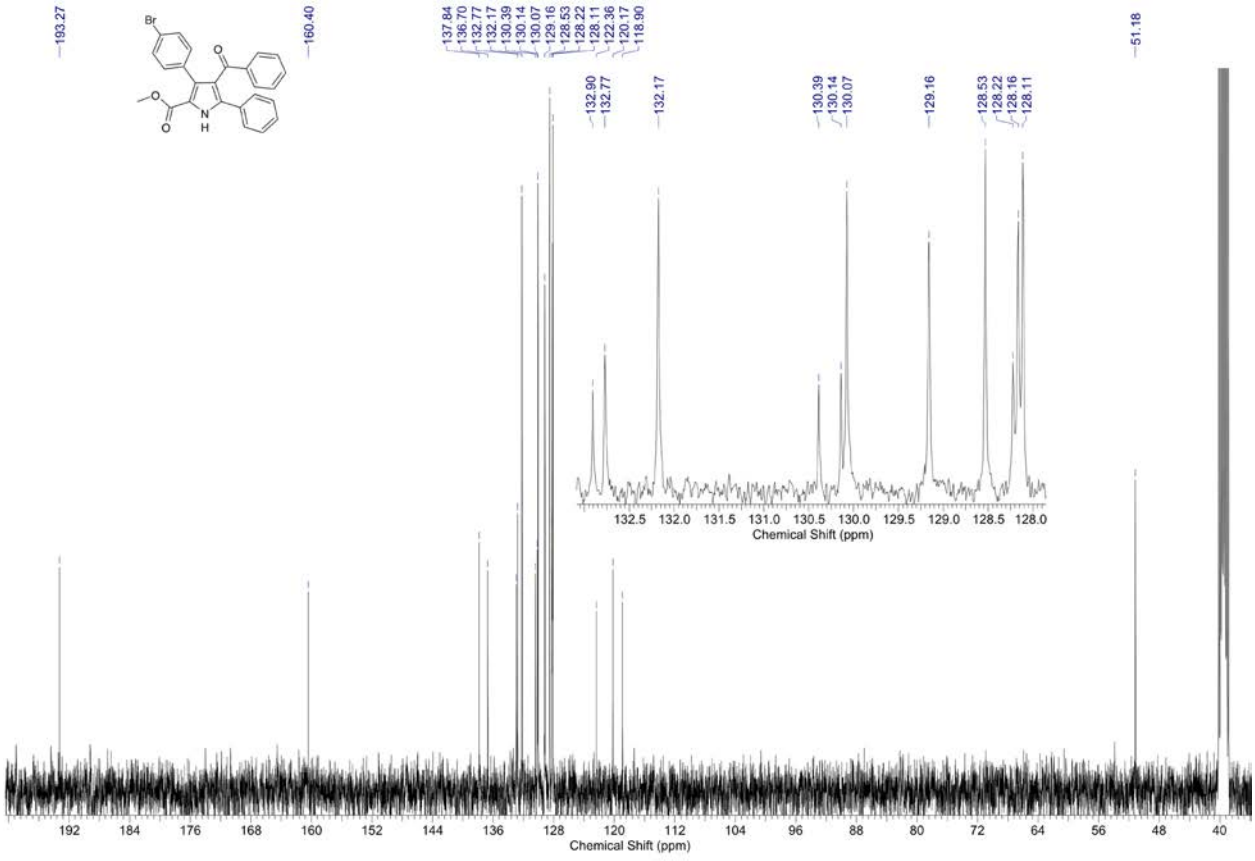

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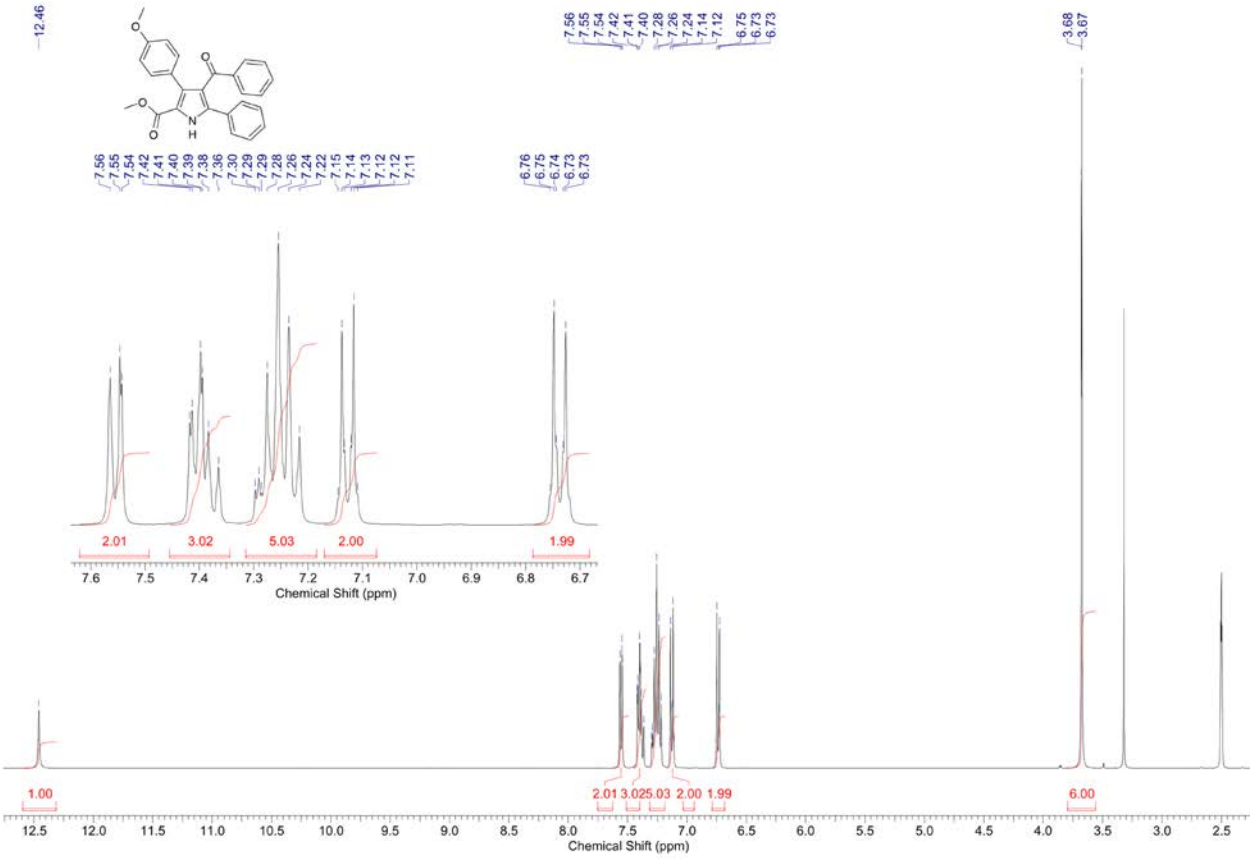

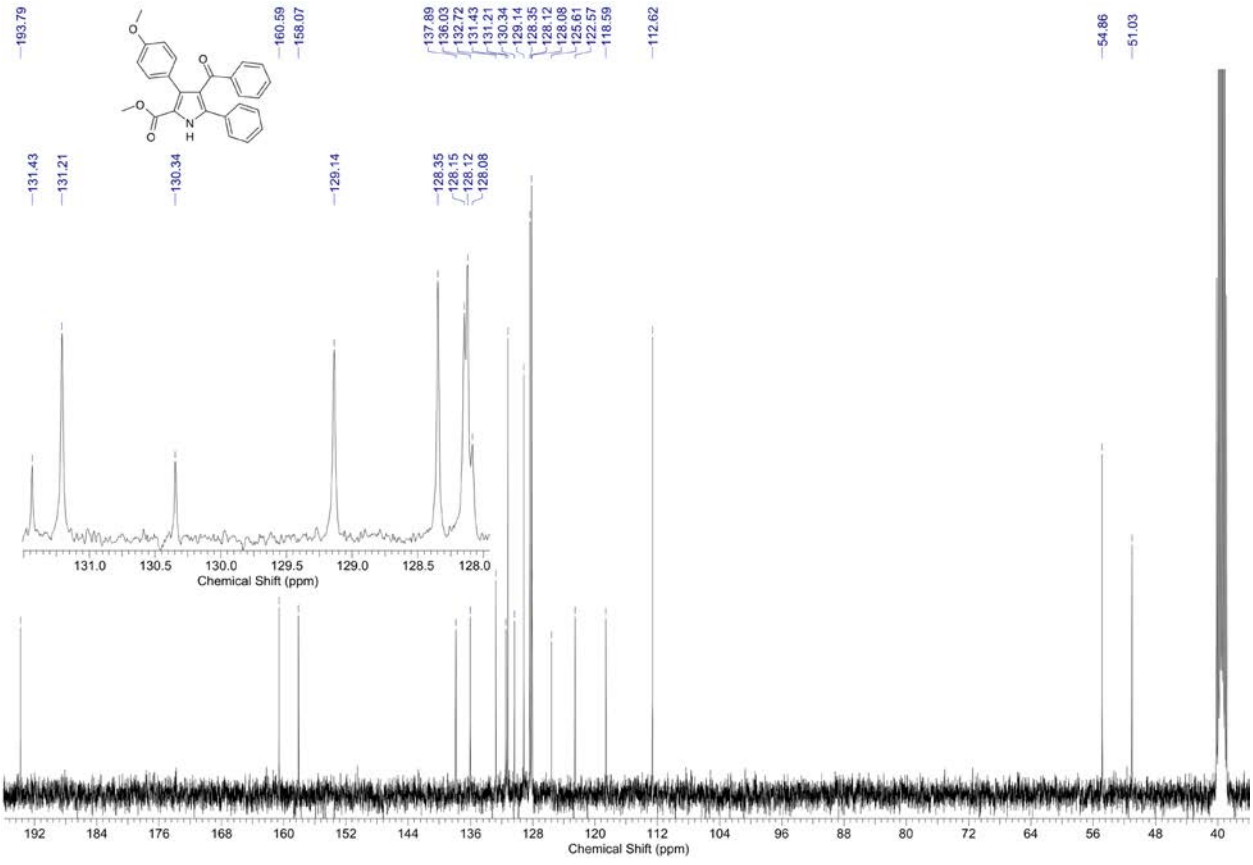

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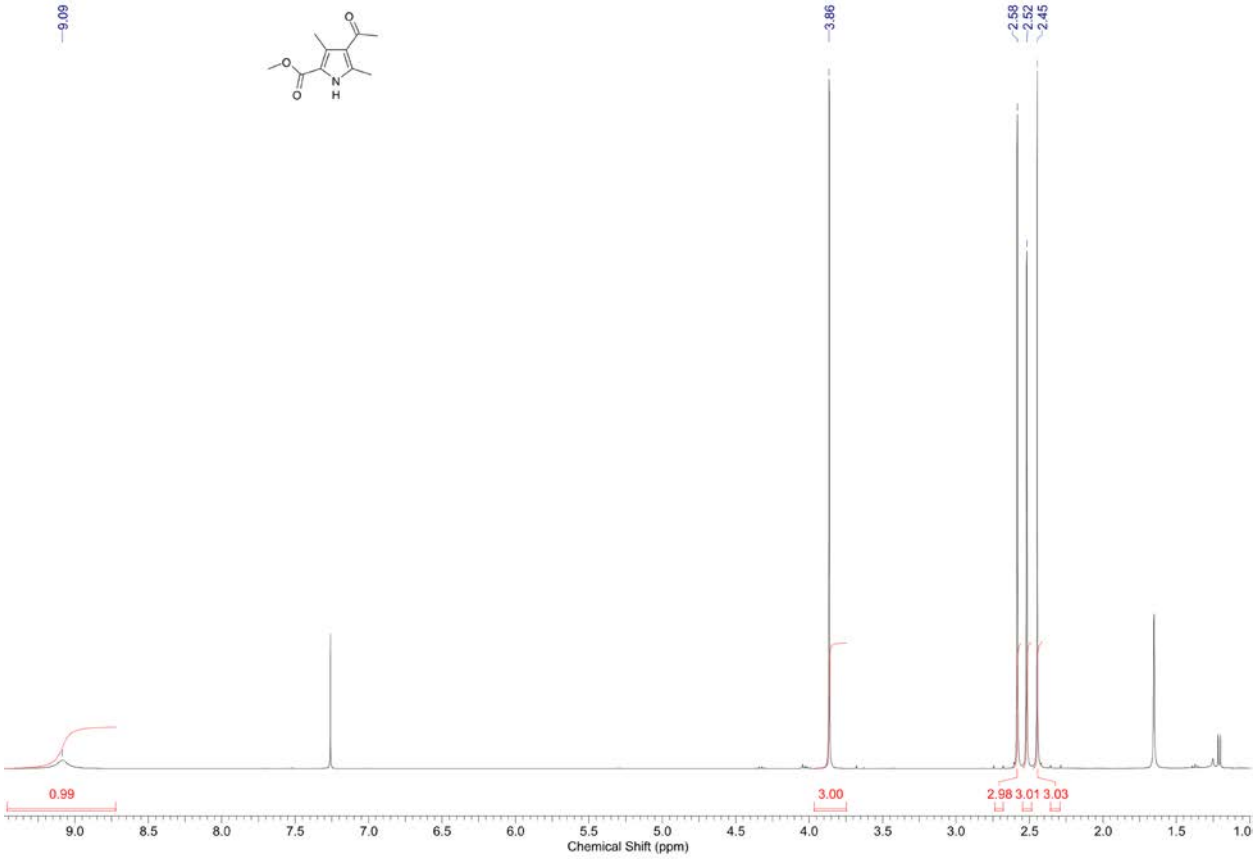

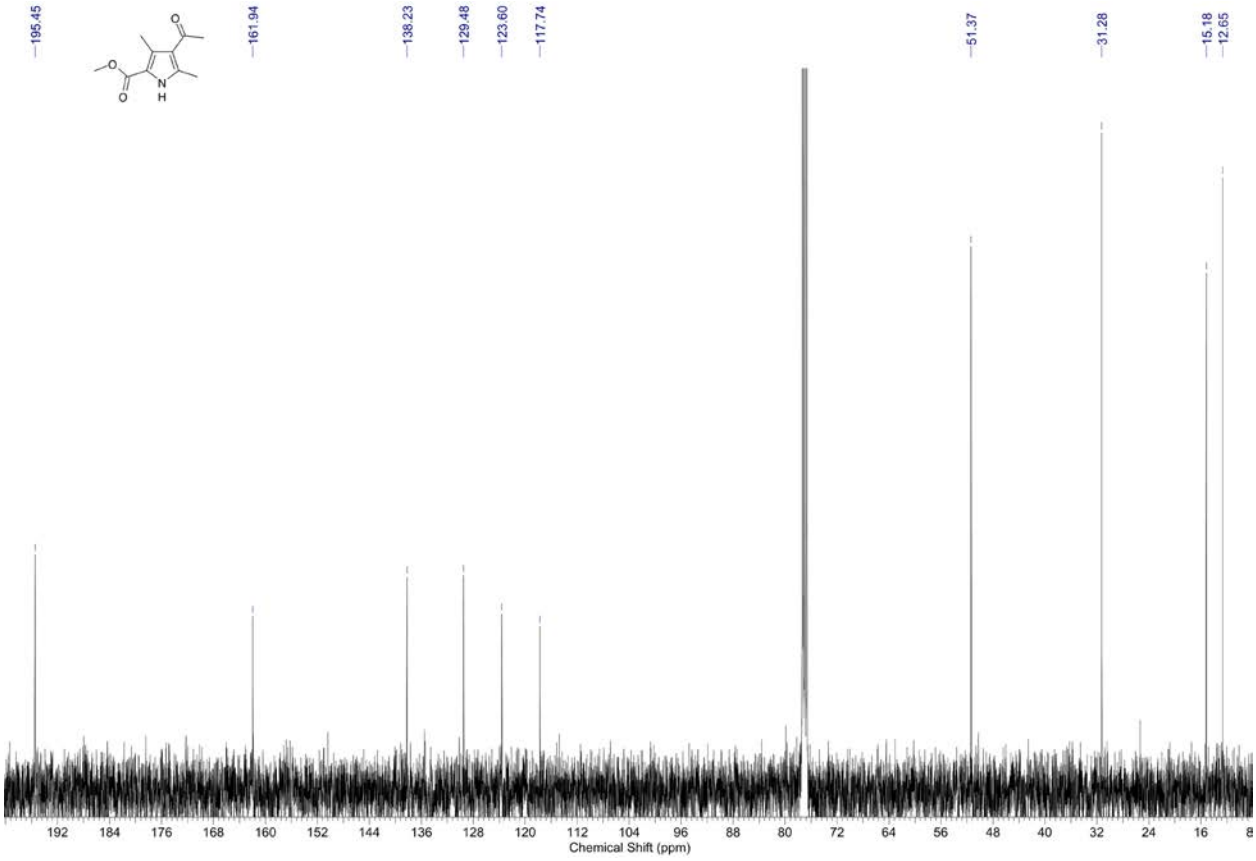

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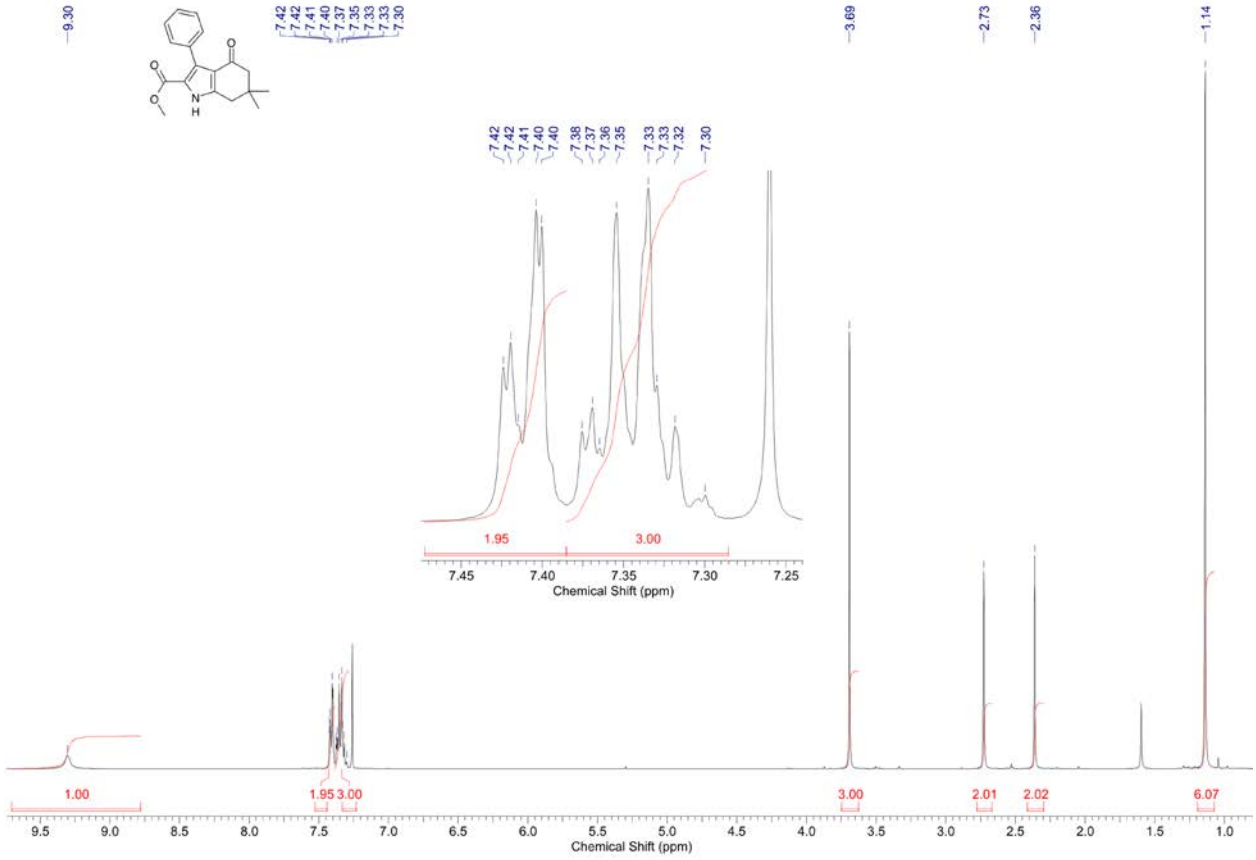

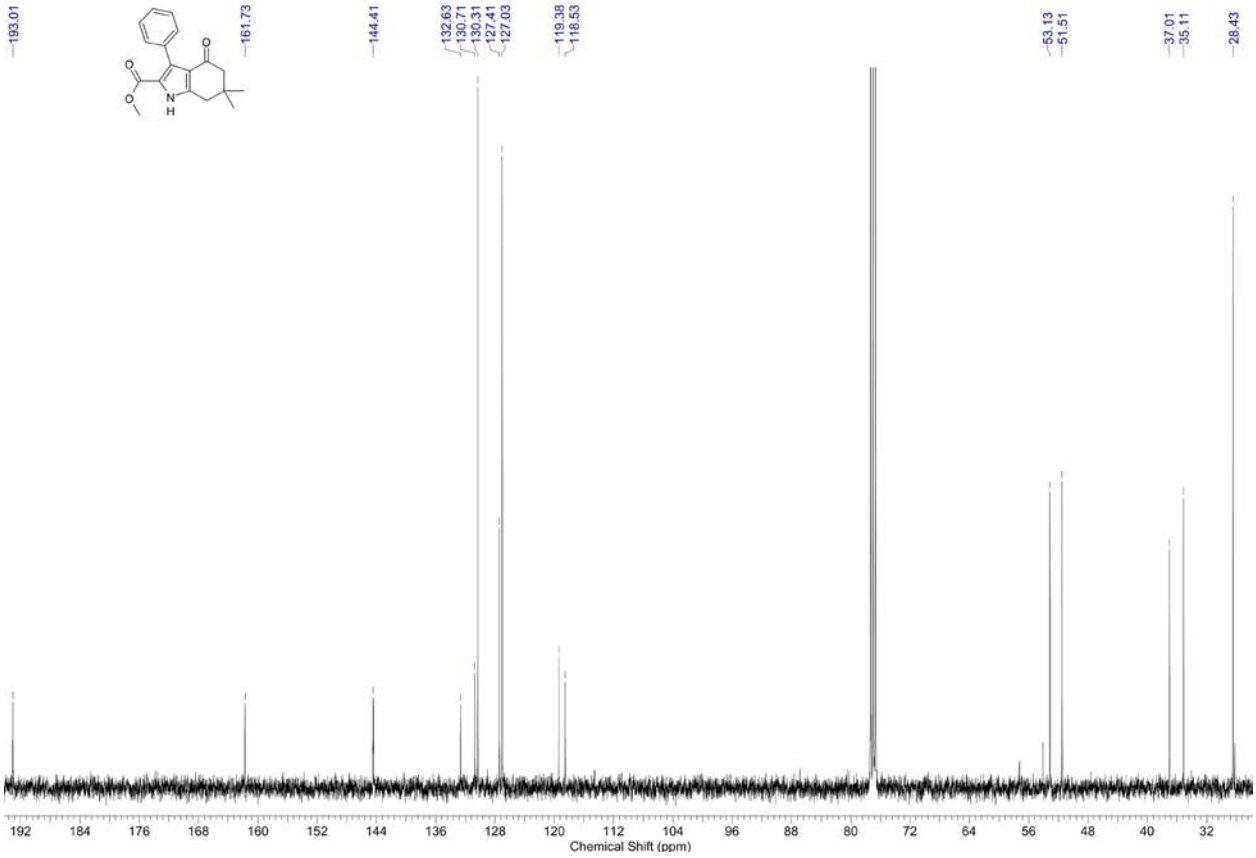

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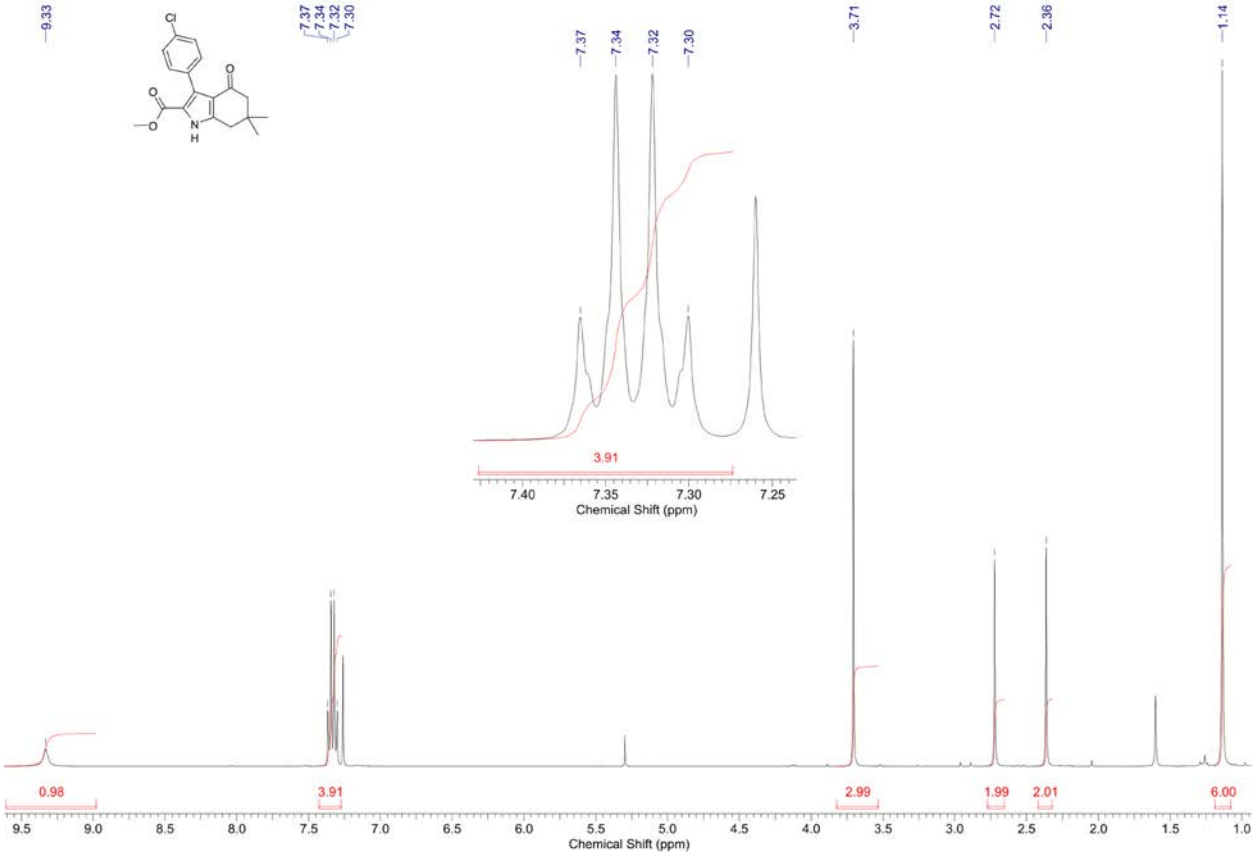

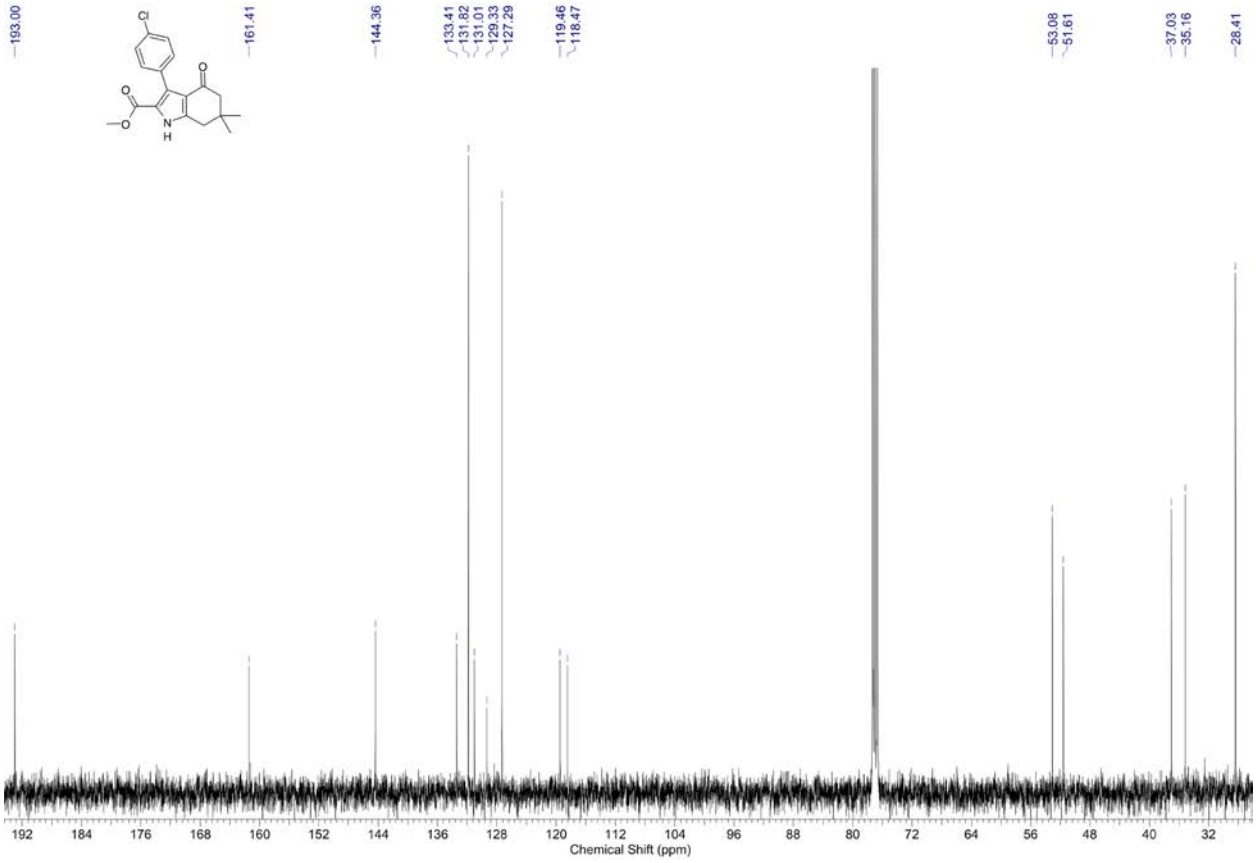

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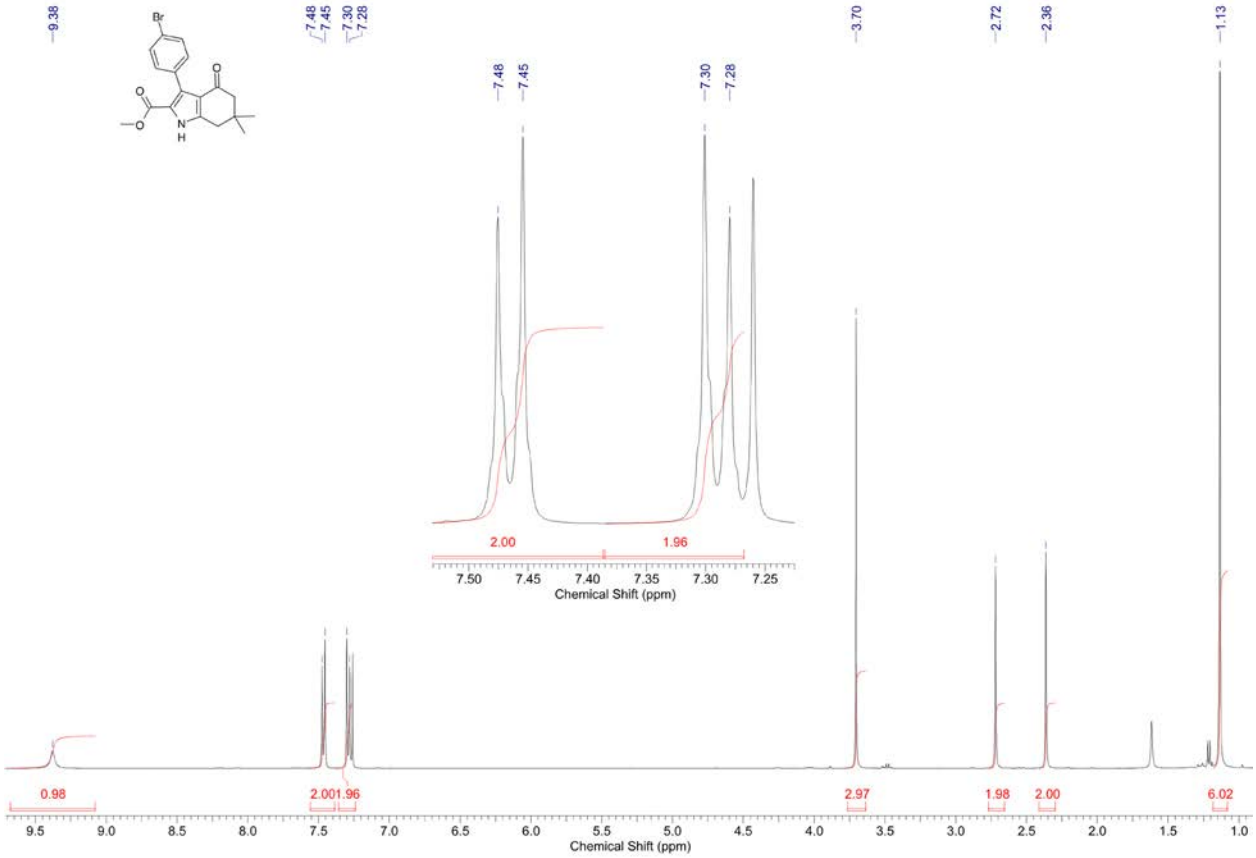

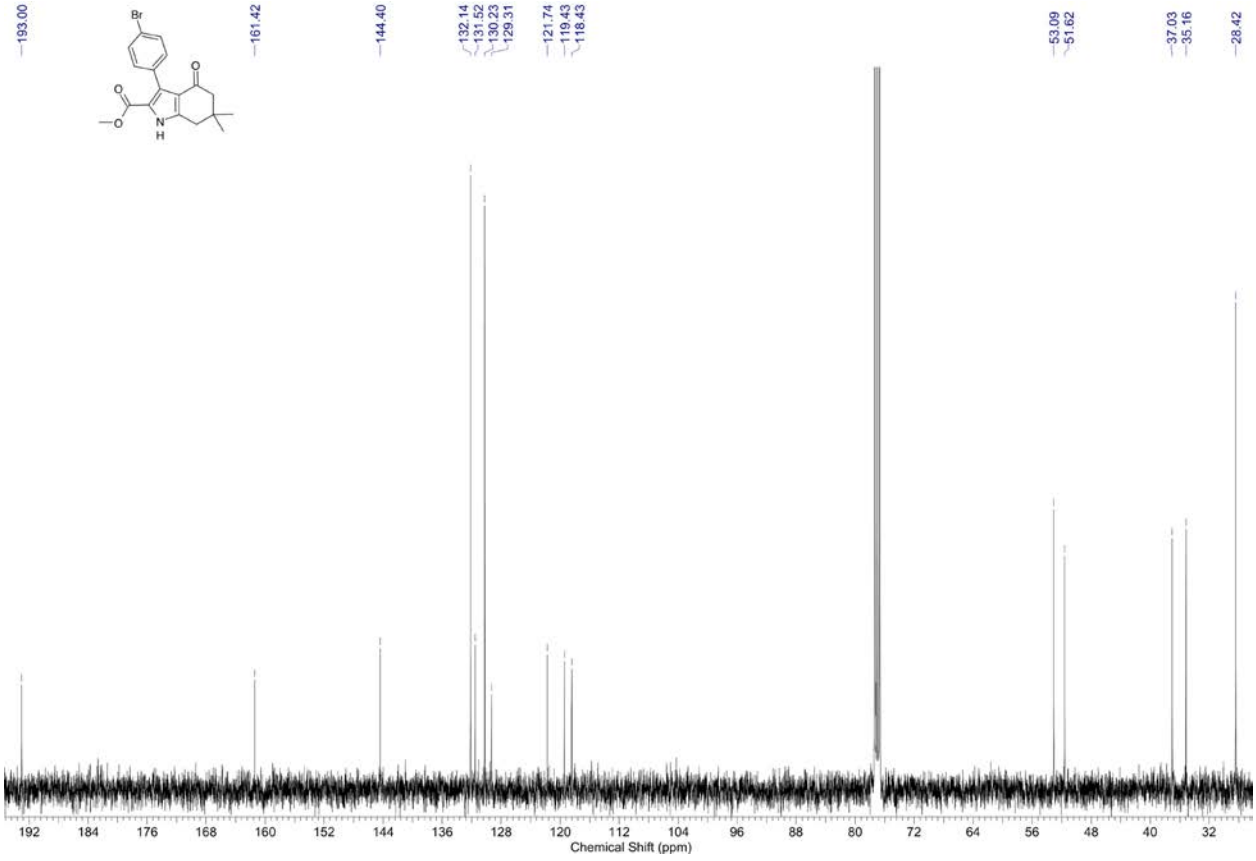

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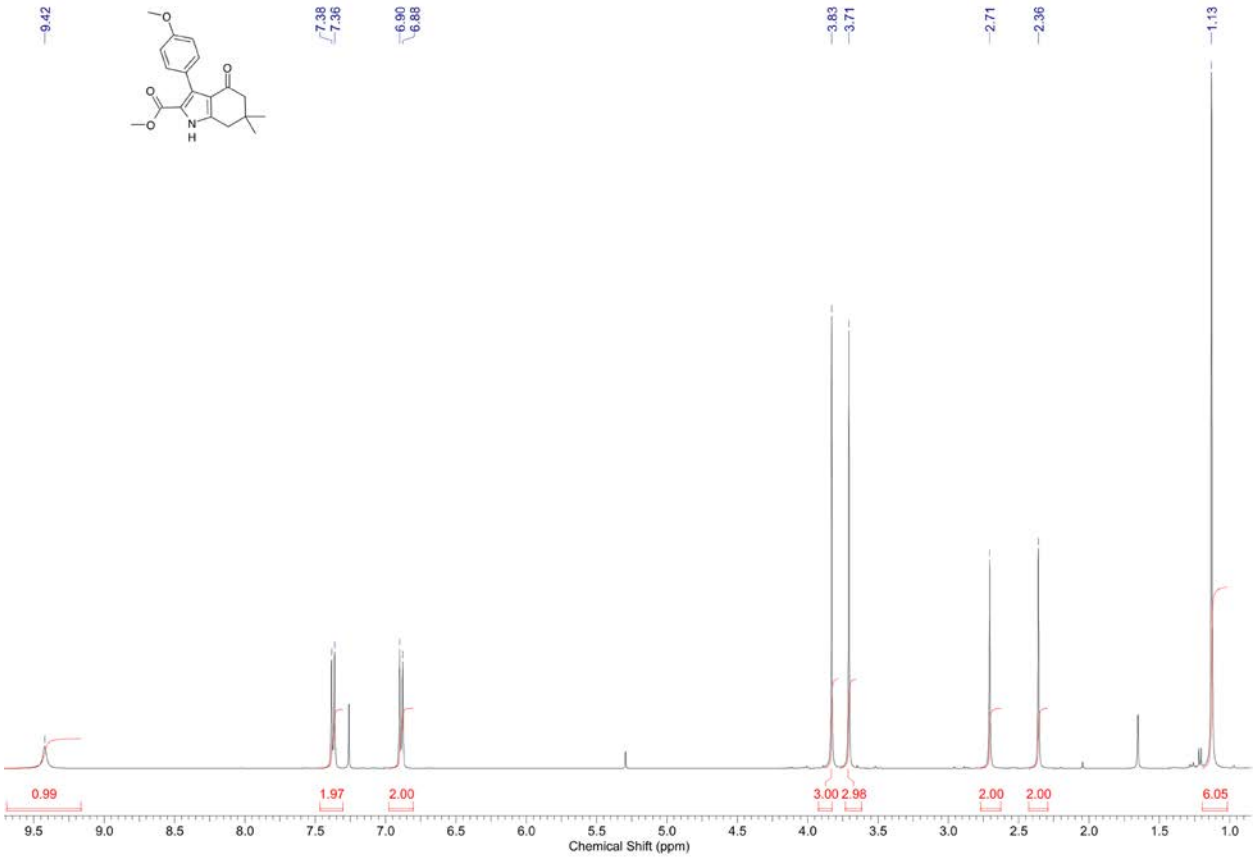

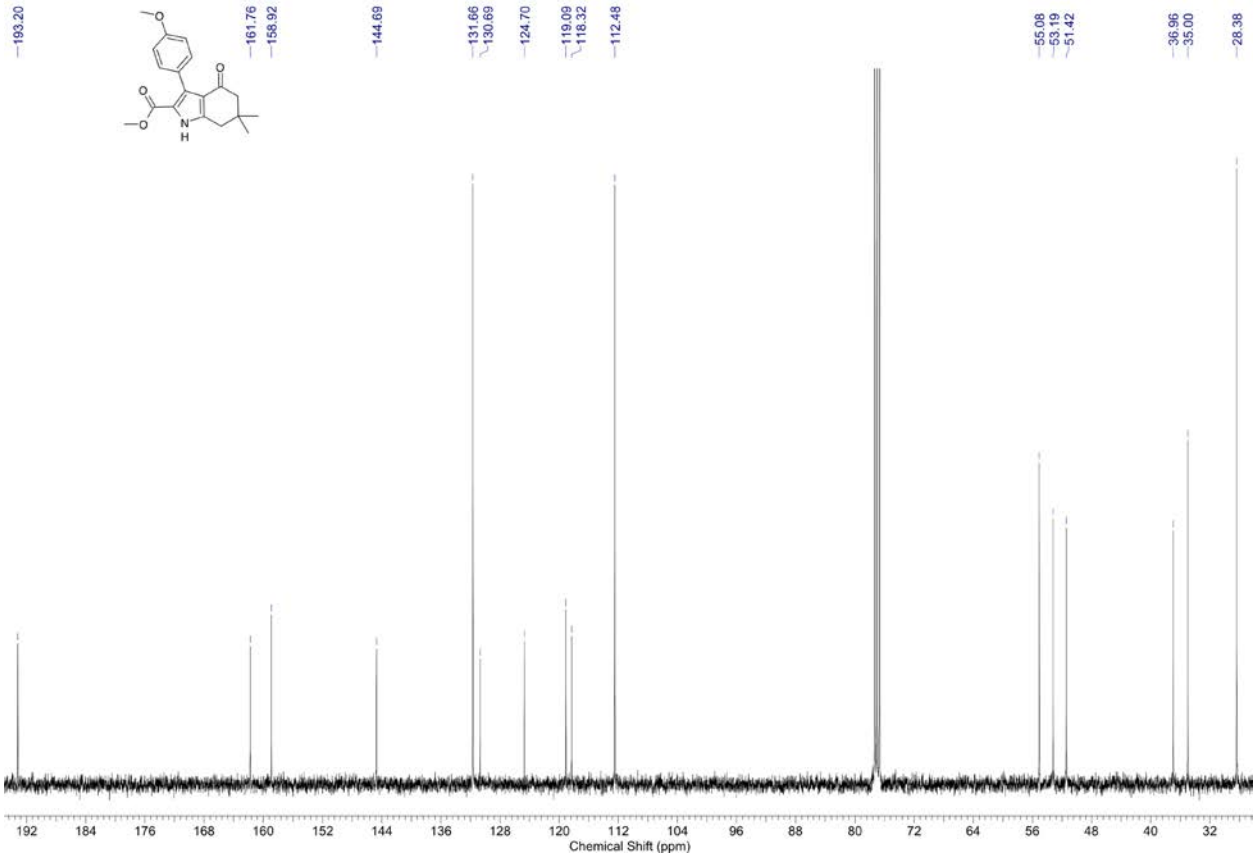

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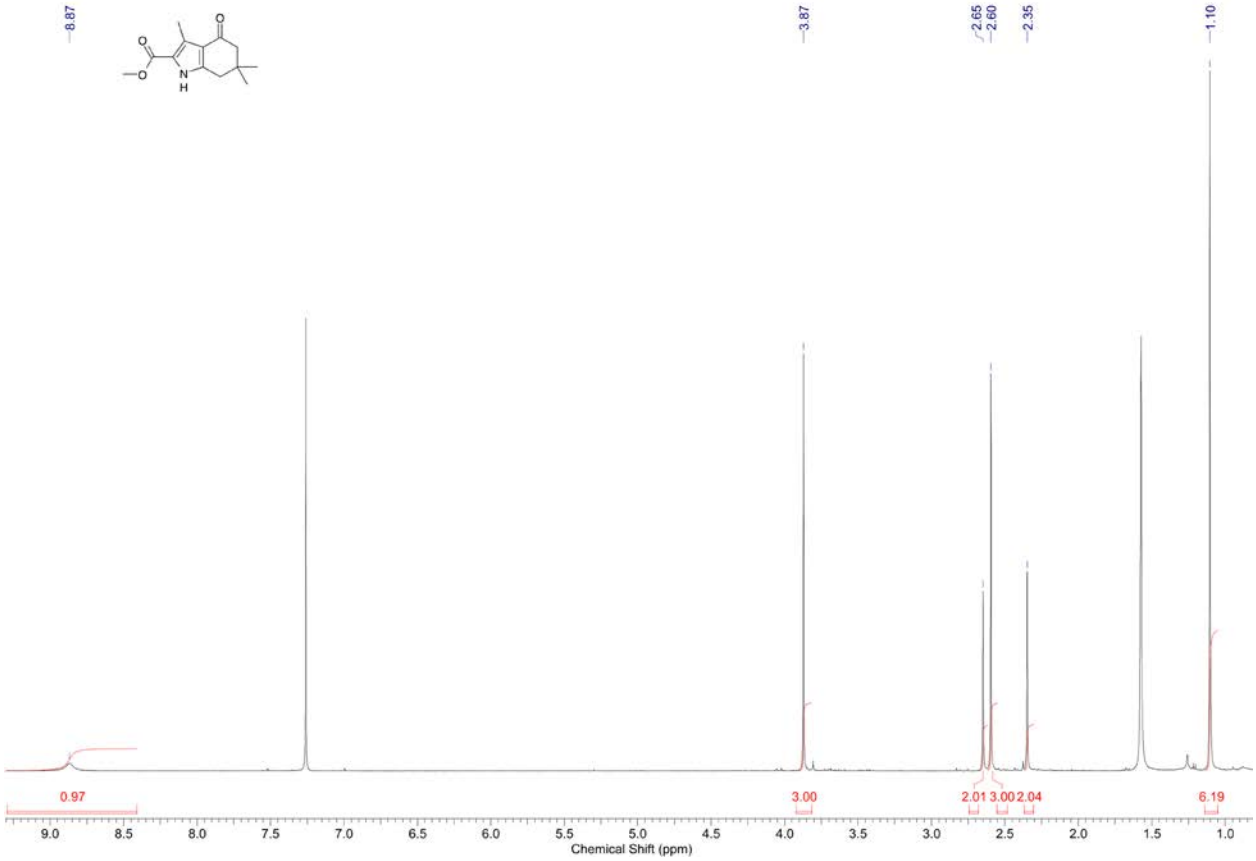
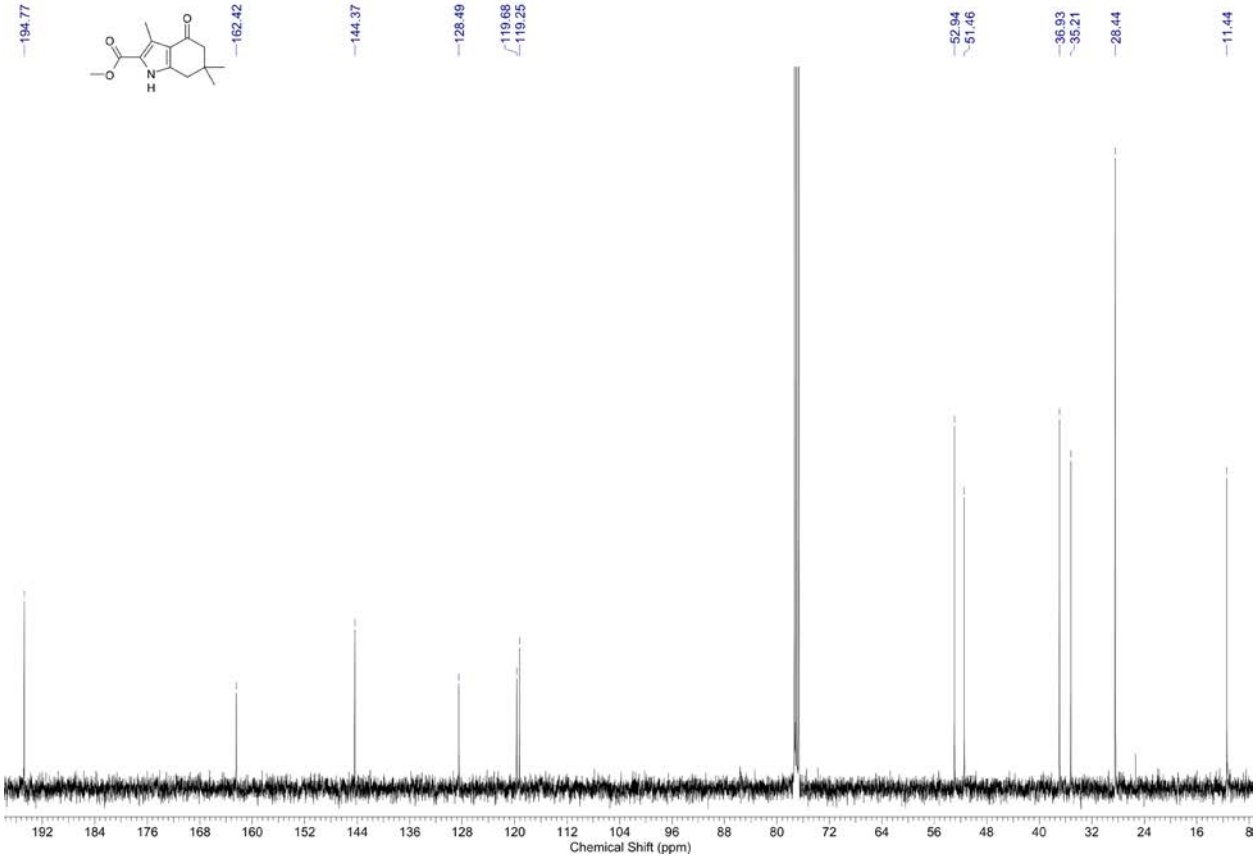
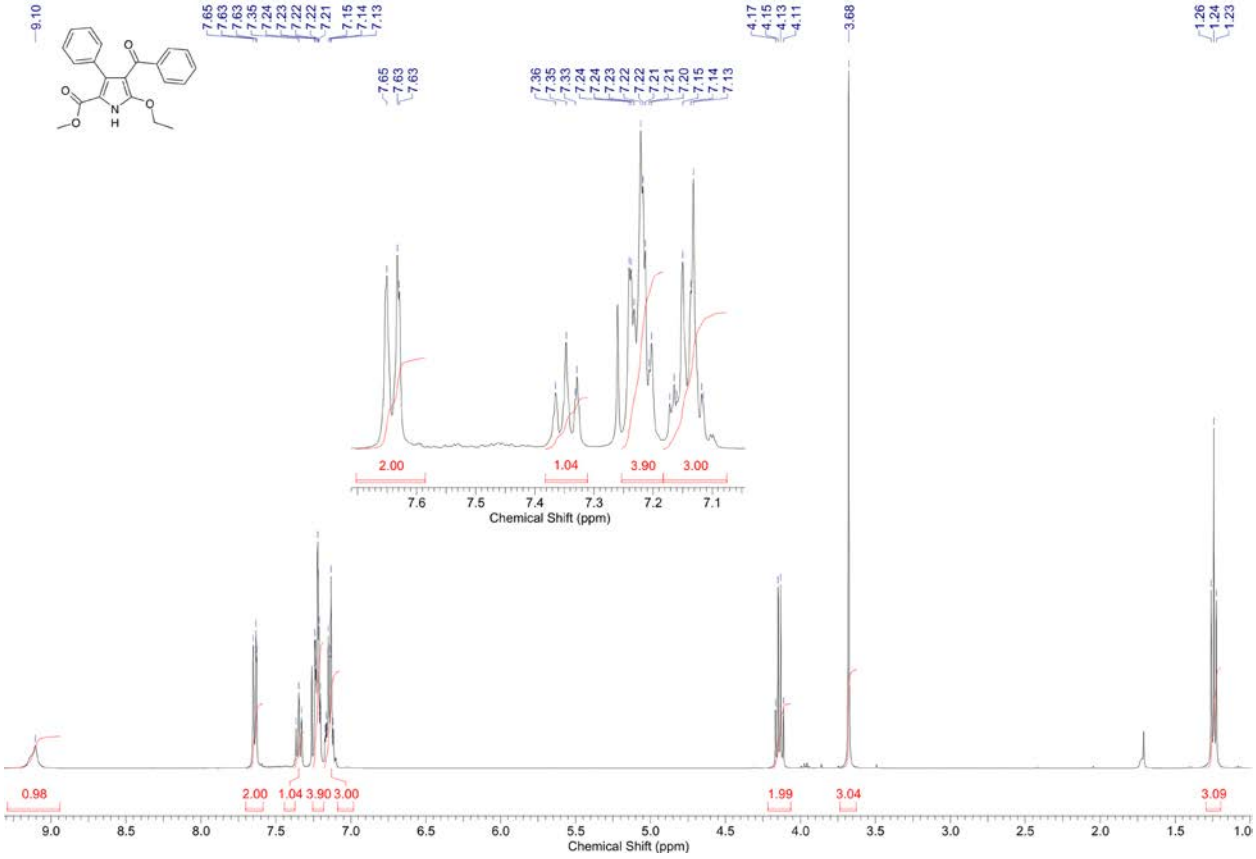
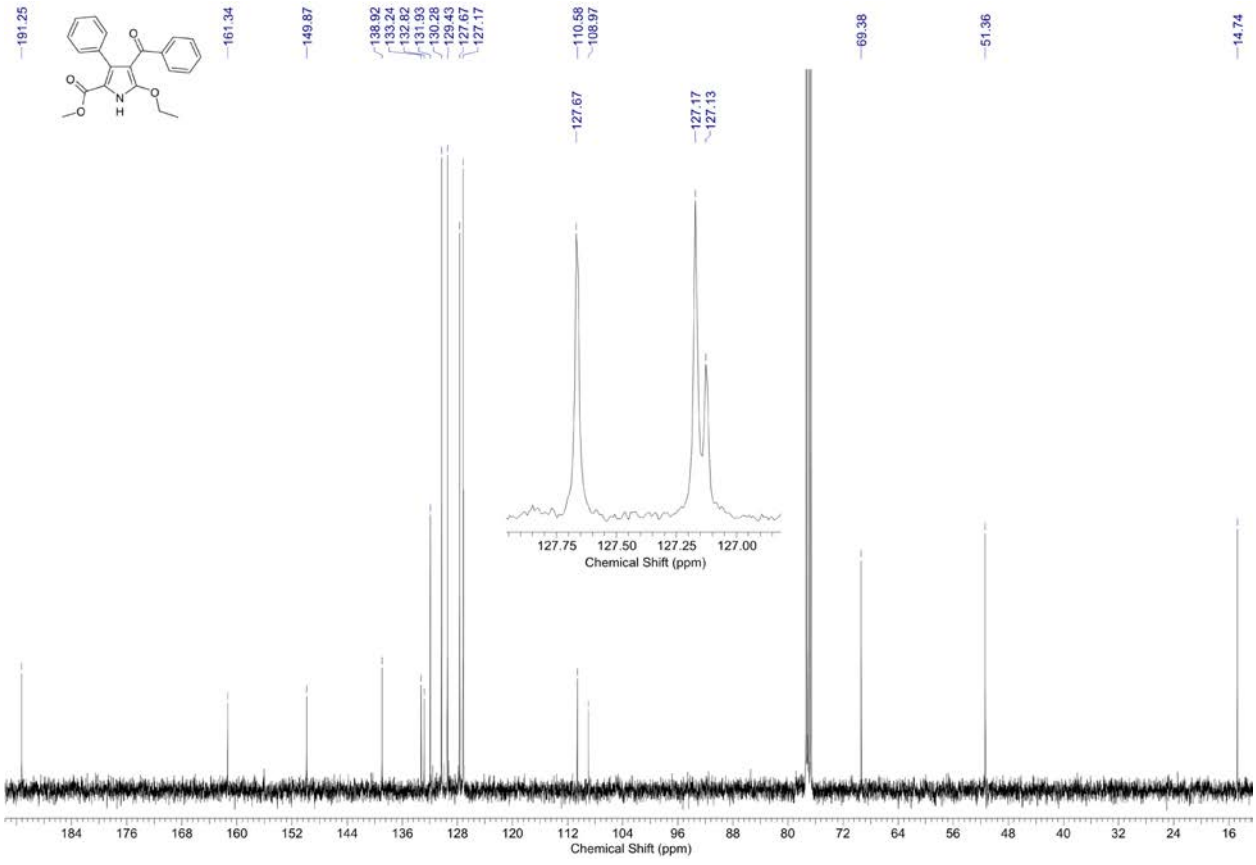


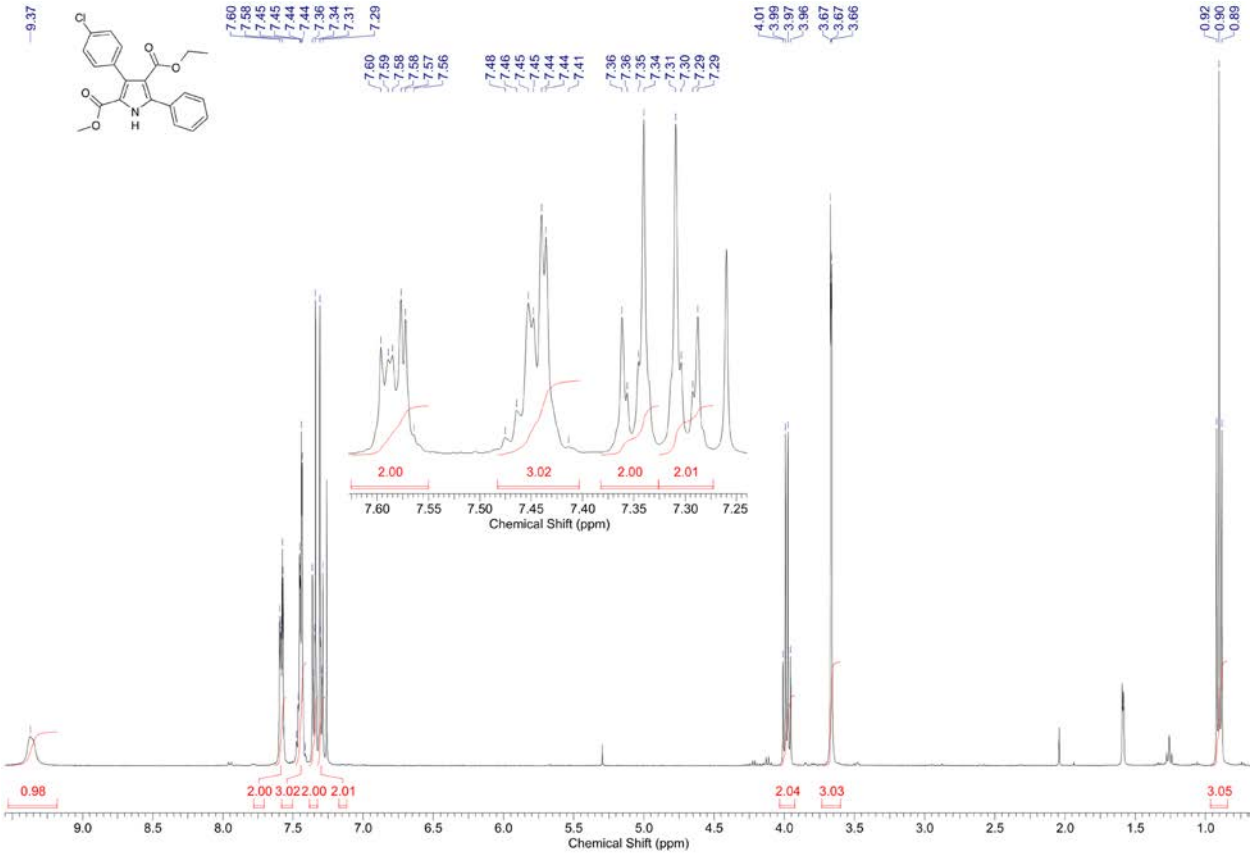


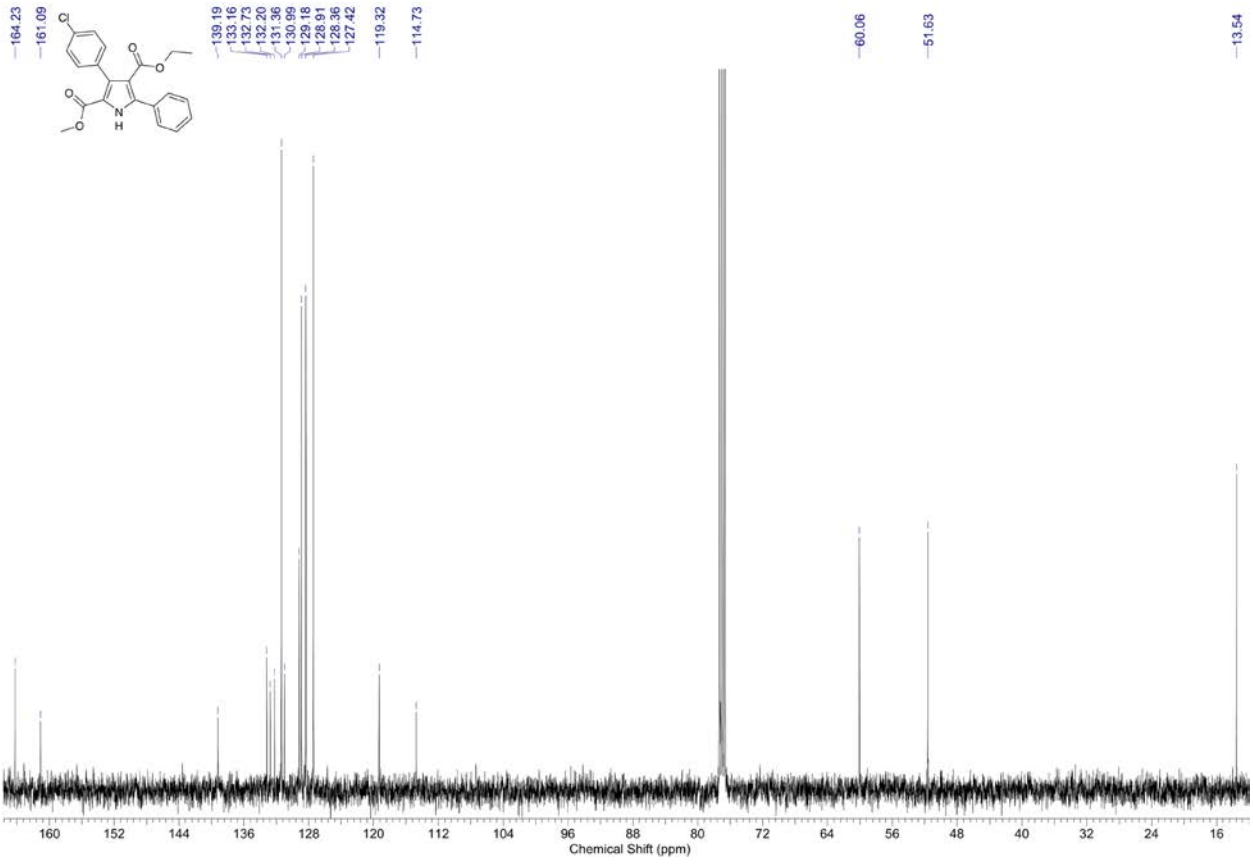
Methyl 4-benzoyl-5-ethoxy-3phenyl-1*H*-pyrrole-2-carboxylate 10a



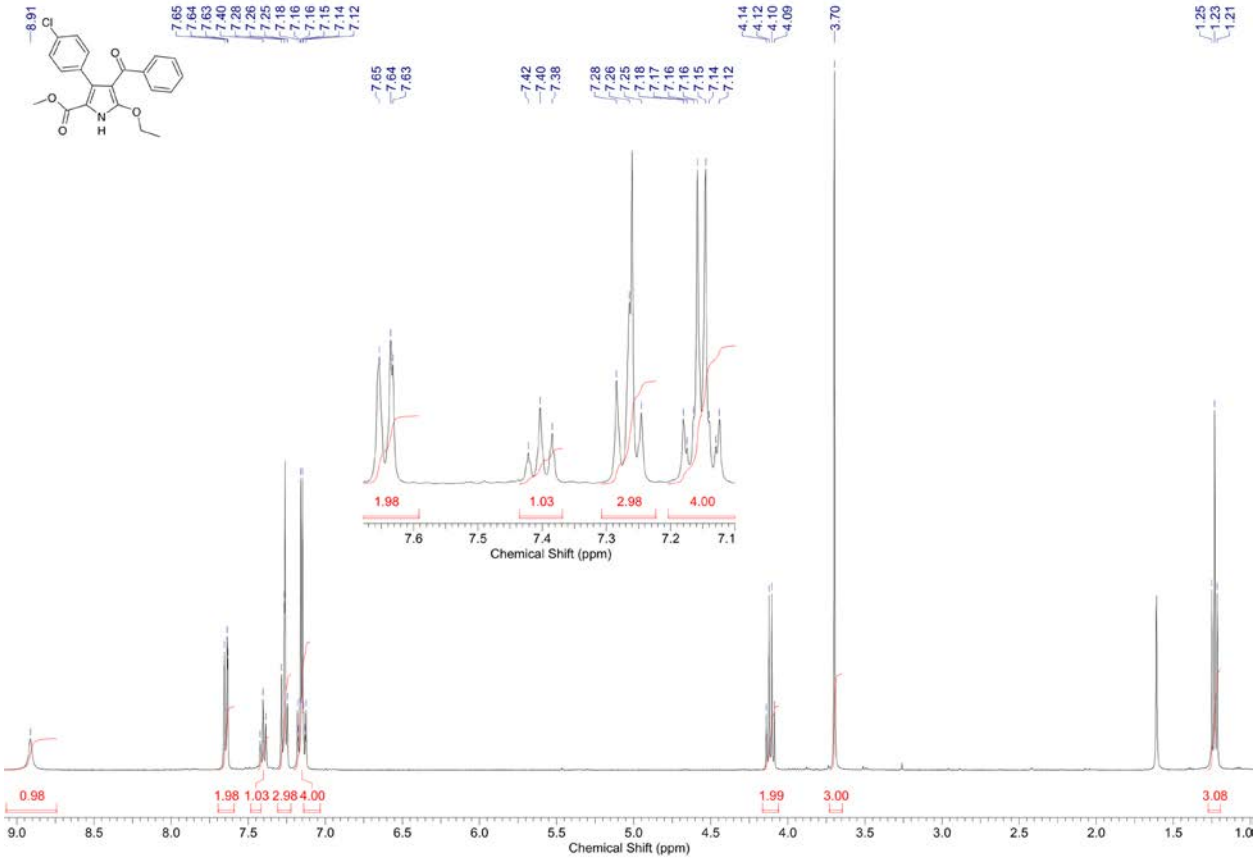


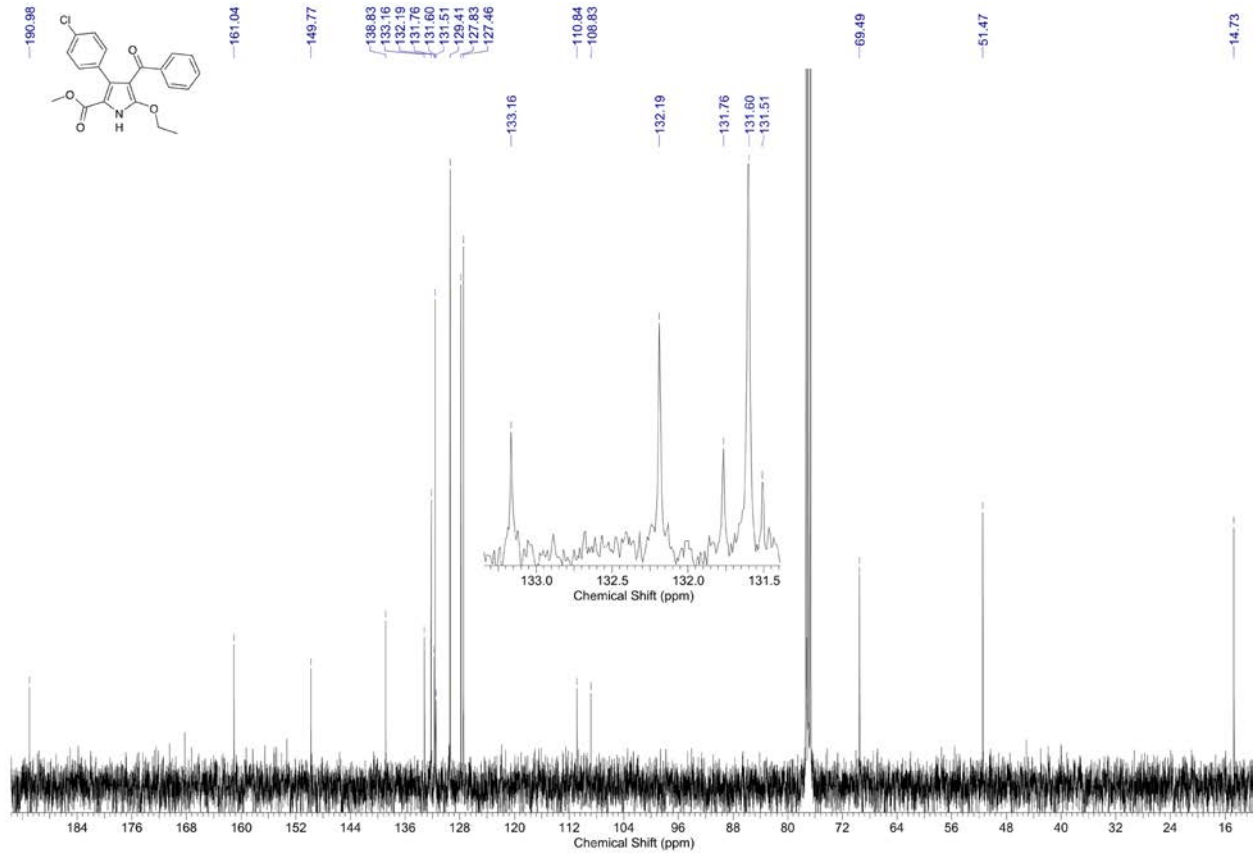
4-Ethyl 2-methyl 3-(4-chlorophenyl)-2-methyl-5-phenyl-1*H*-pyrrole-2,4-dicarboxylate 9b



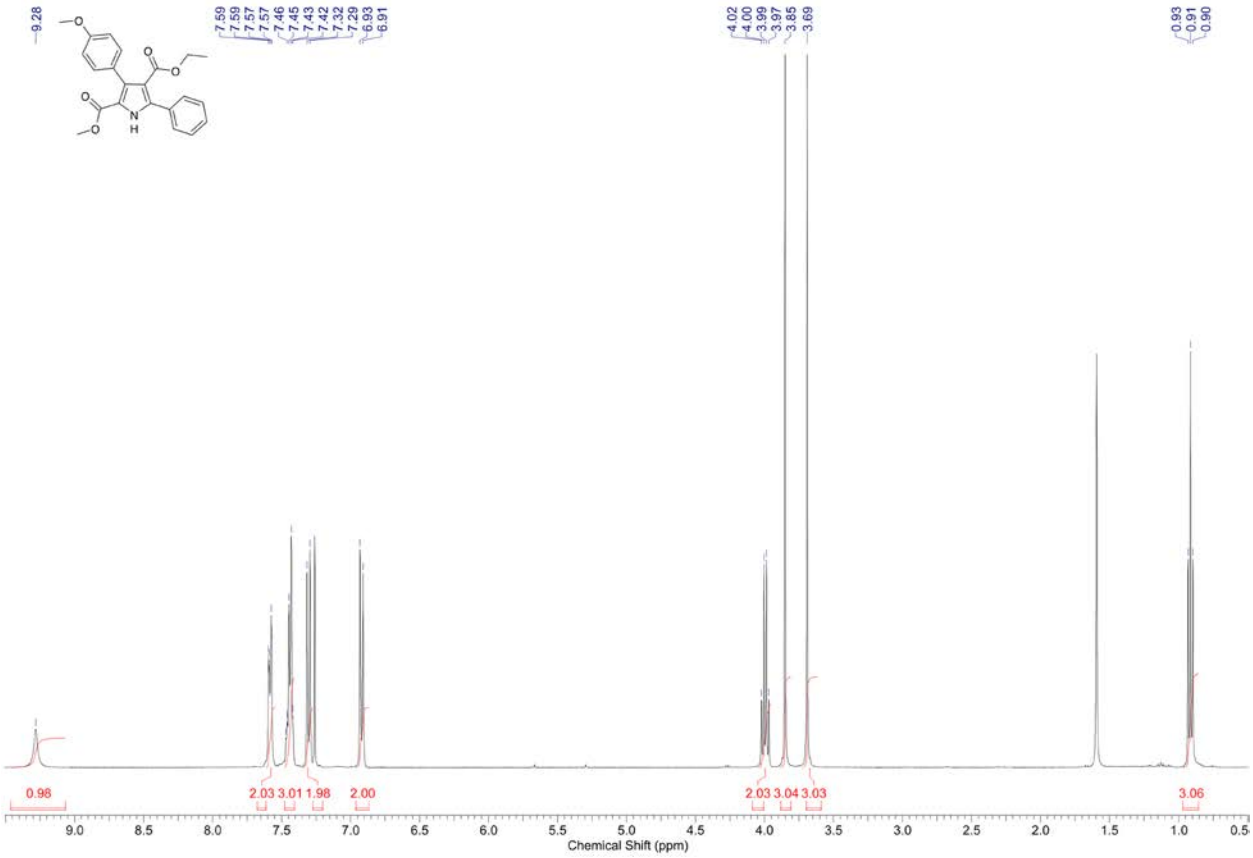


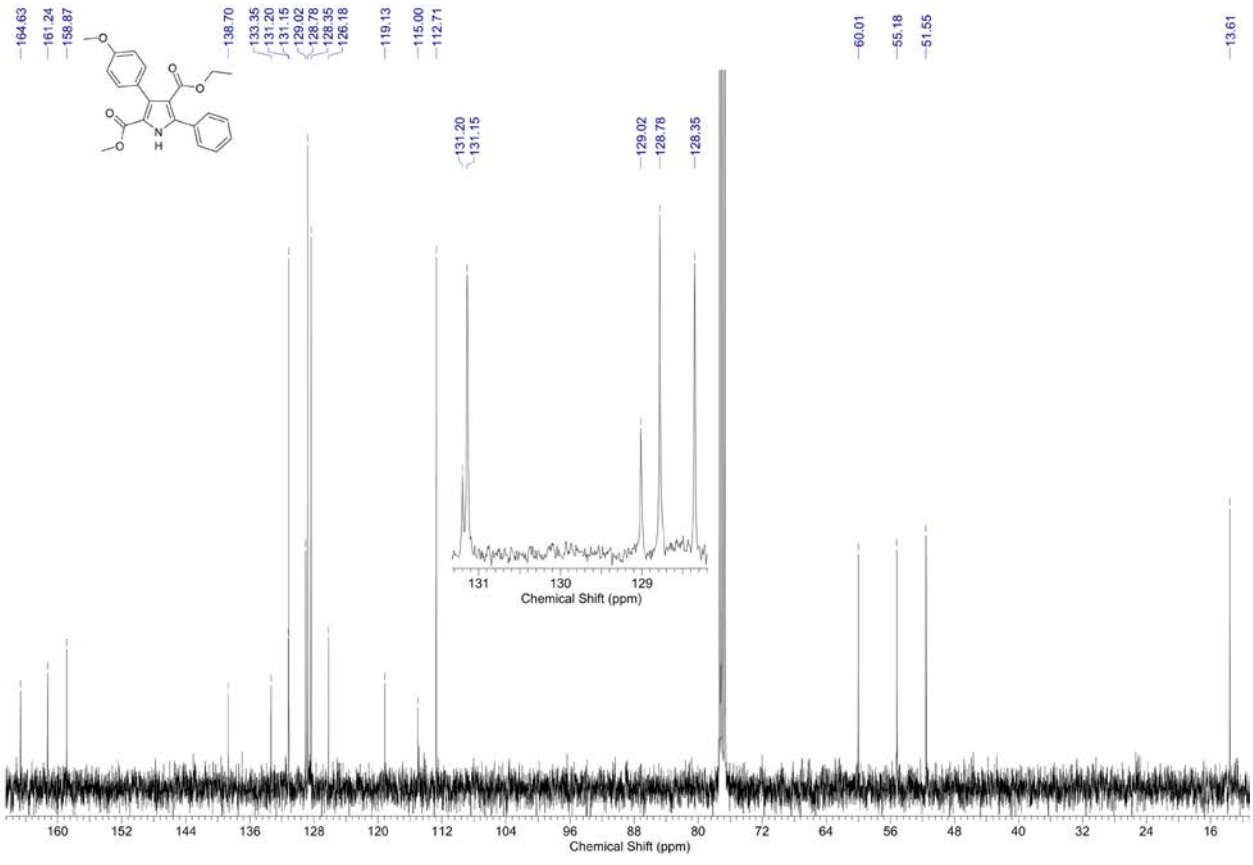
Methyl 4-benzoyl-3-(4-chlorophenyl)-5-ethoxy-1*H*-pyrrole-2-carboxylate 10b



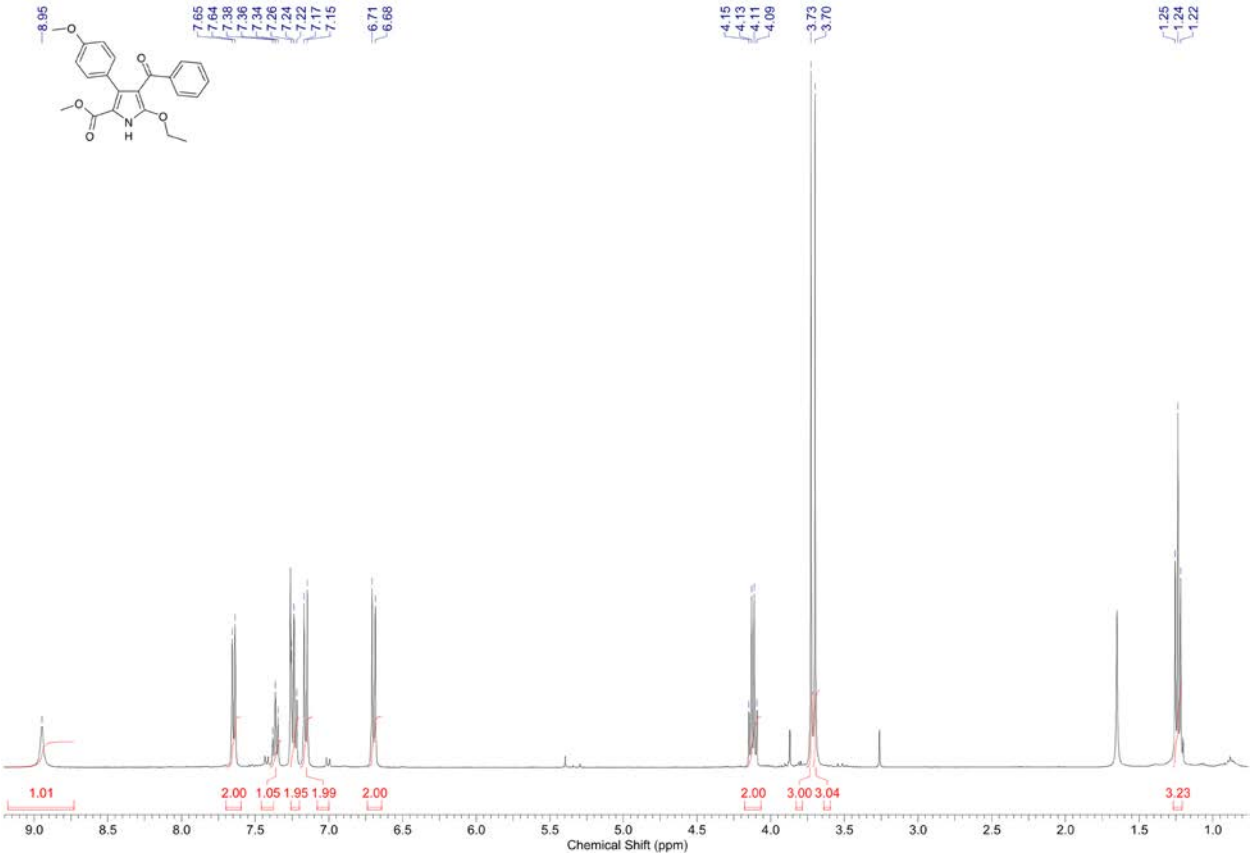


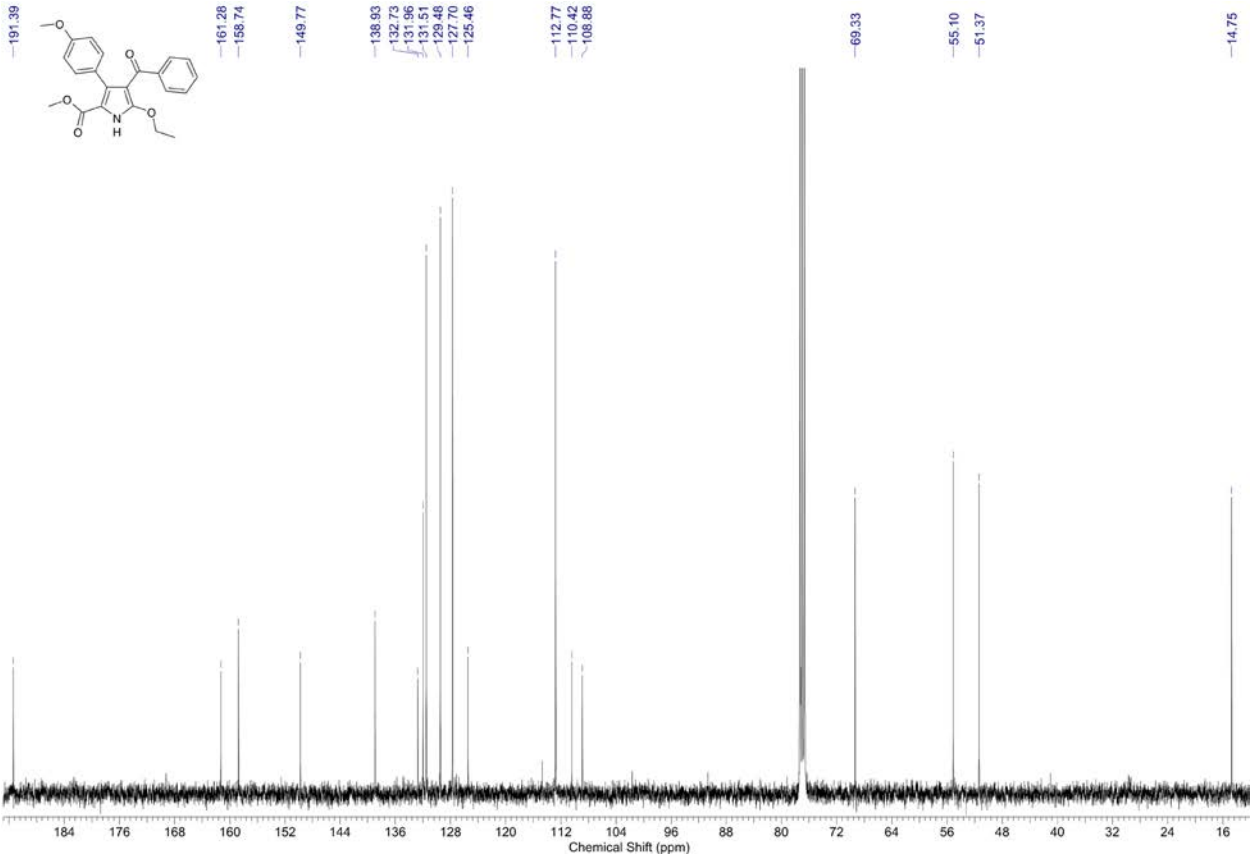
4-Ethyl 2-methyl 3-(4-methoxyphenyl)-5-phenyl-1*H*-pyrrole-2,4-dicarboxylate 9c



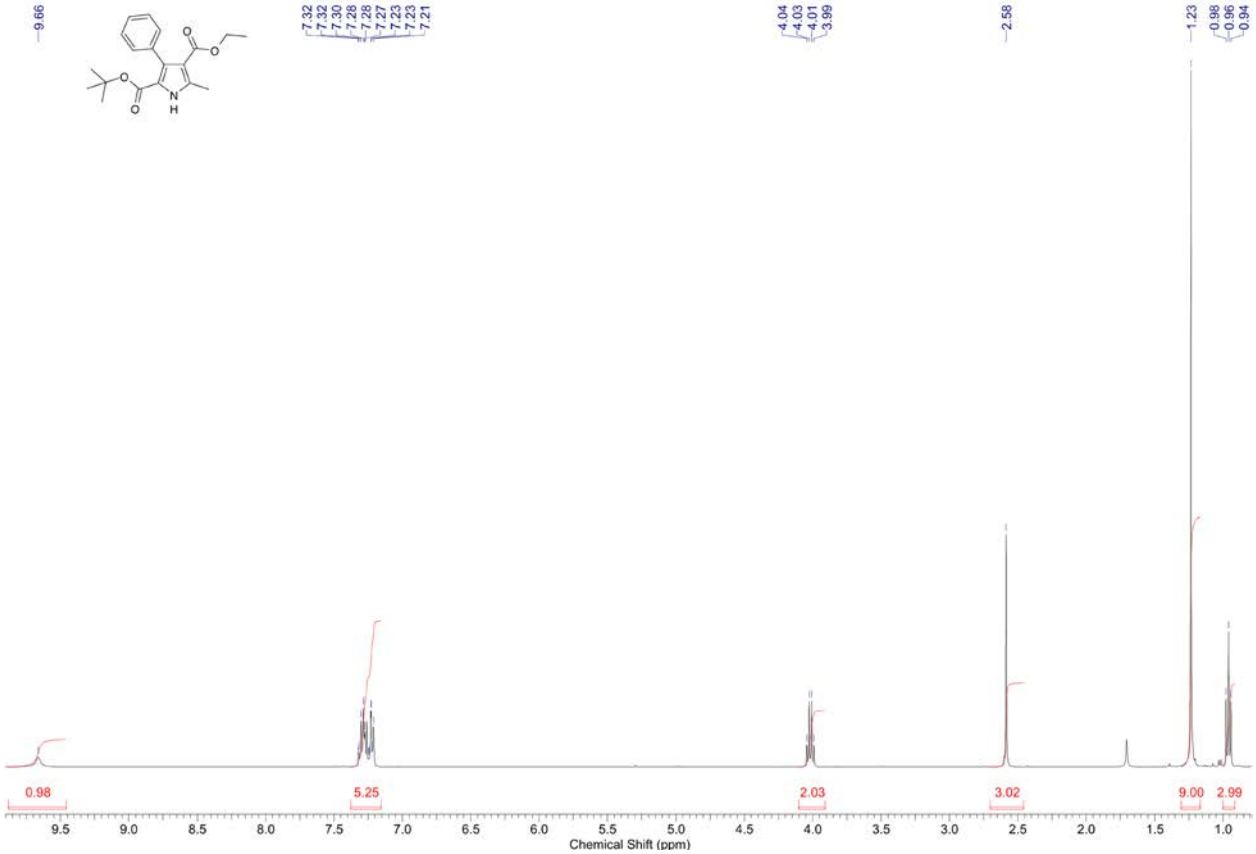


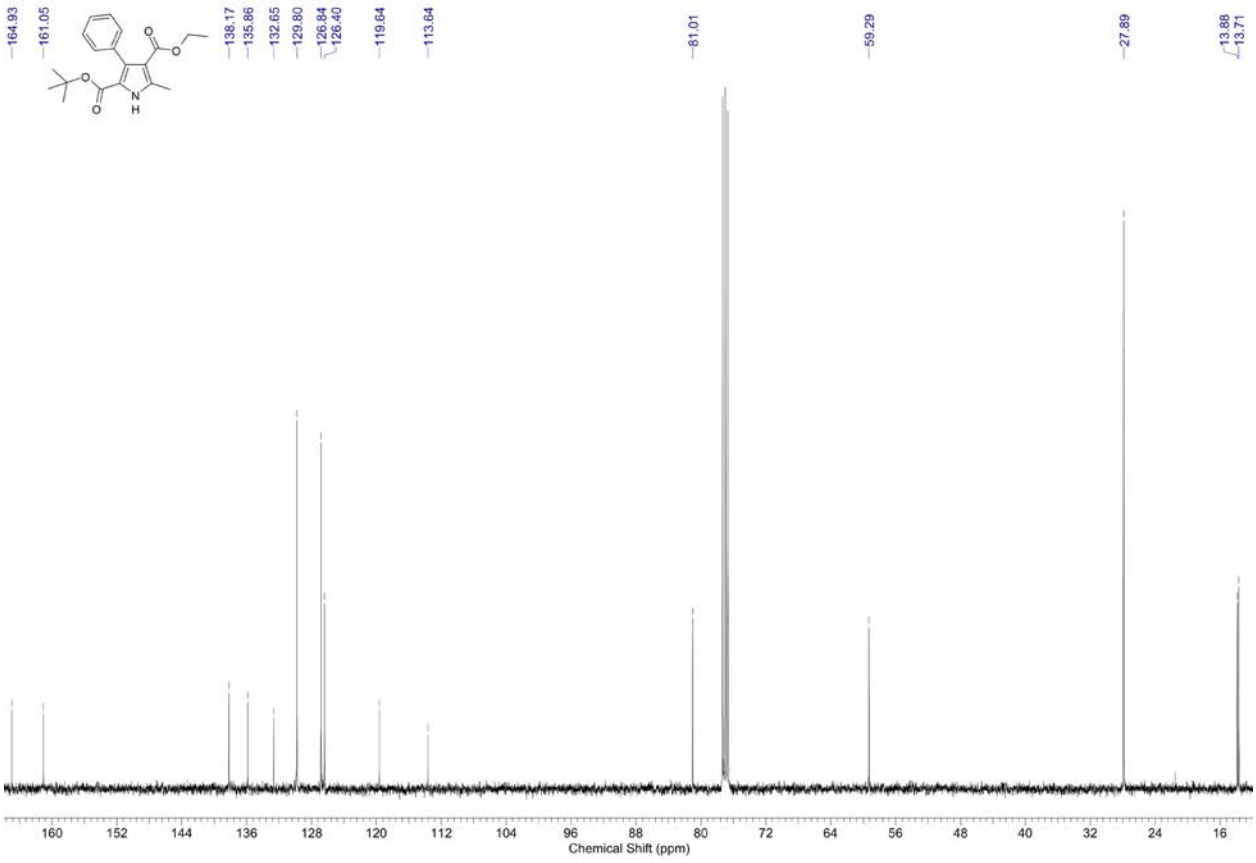
Methyl 4-benzoyl-5-ethoxy-3-(4-methoxyphenyl)-1*H*-pyrrole-2-carboxylate 10c



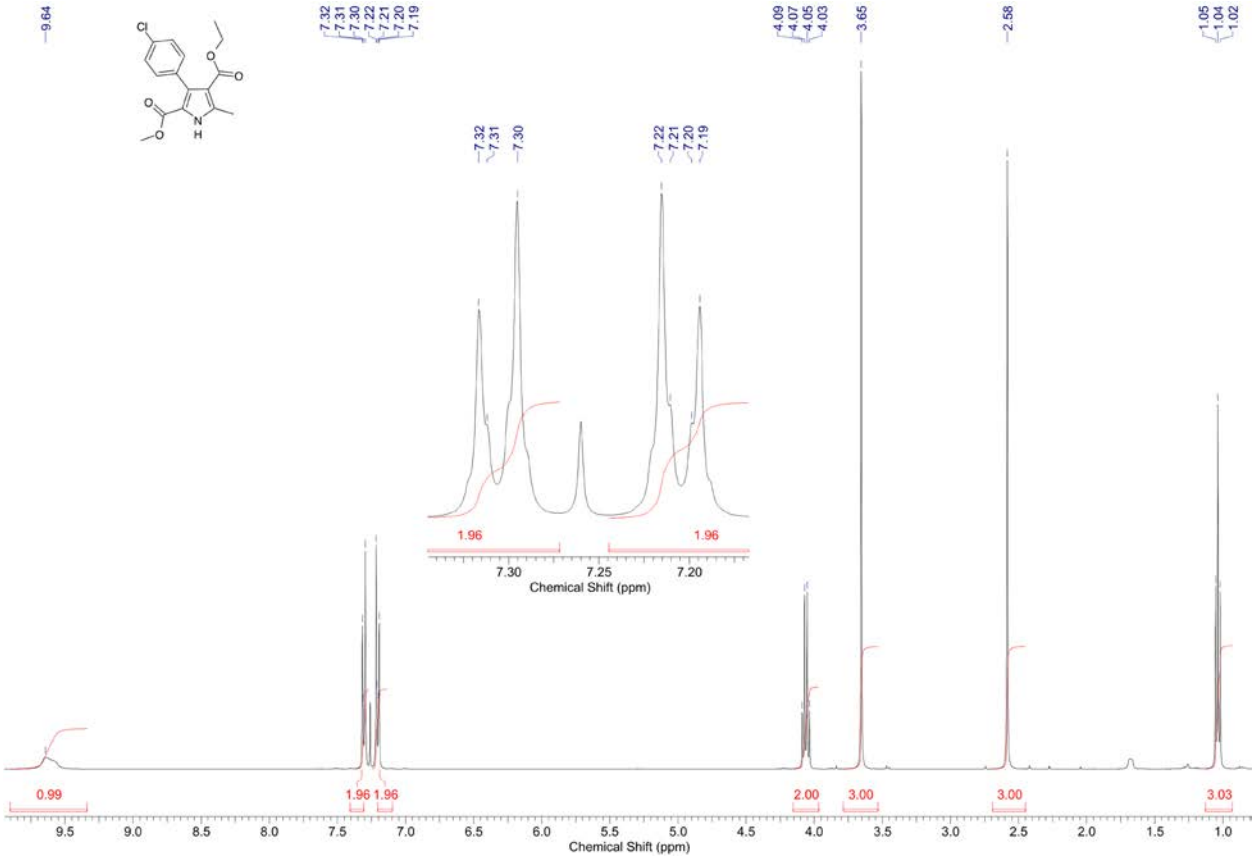


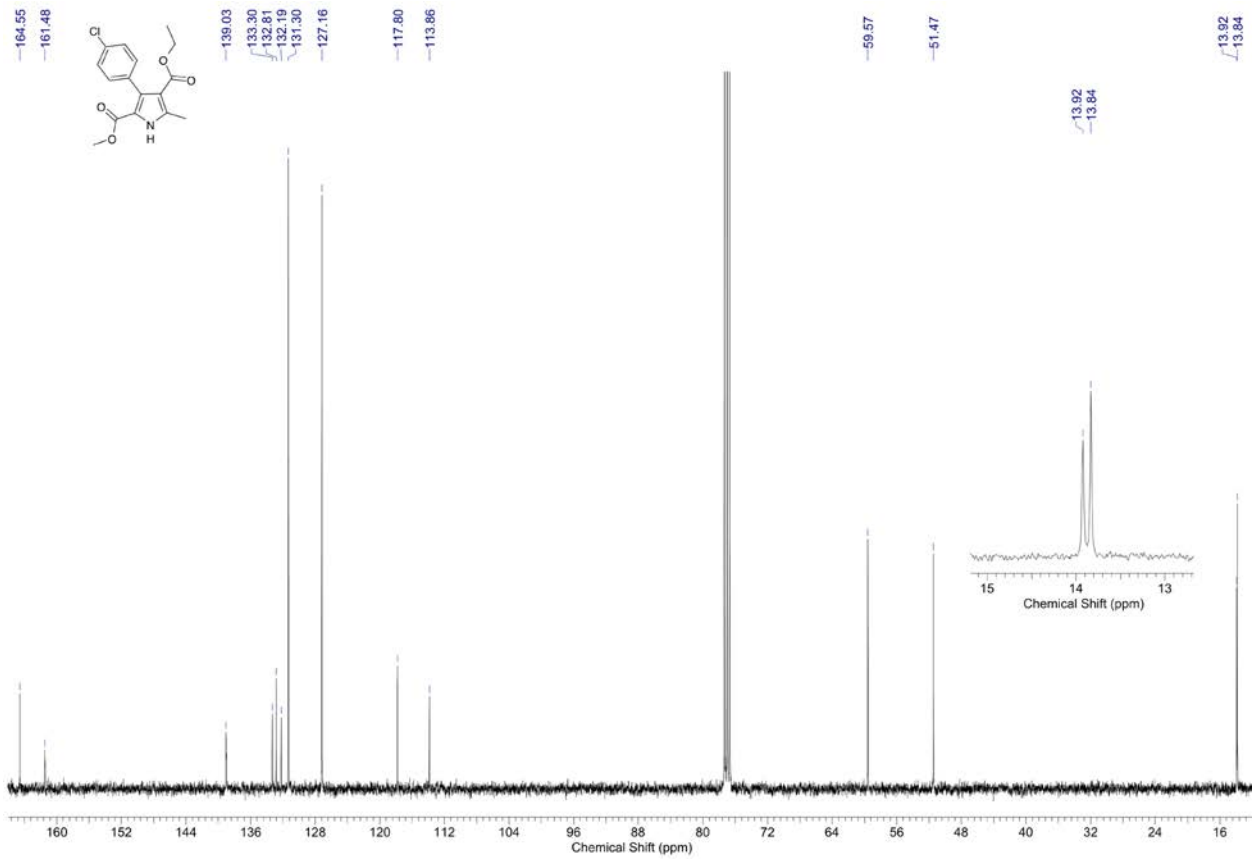
2-*tert*-Butyl 4-ethyl 5-methyl-3-phenyl-1*H*-pyrrole-2,4-dicarboxylate 9d



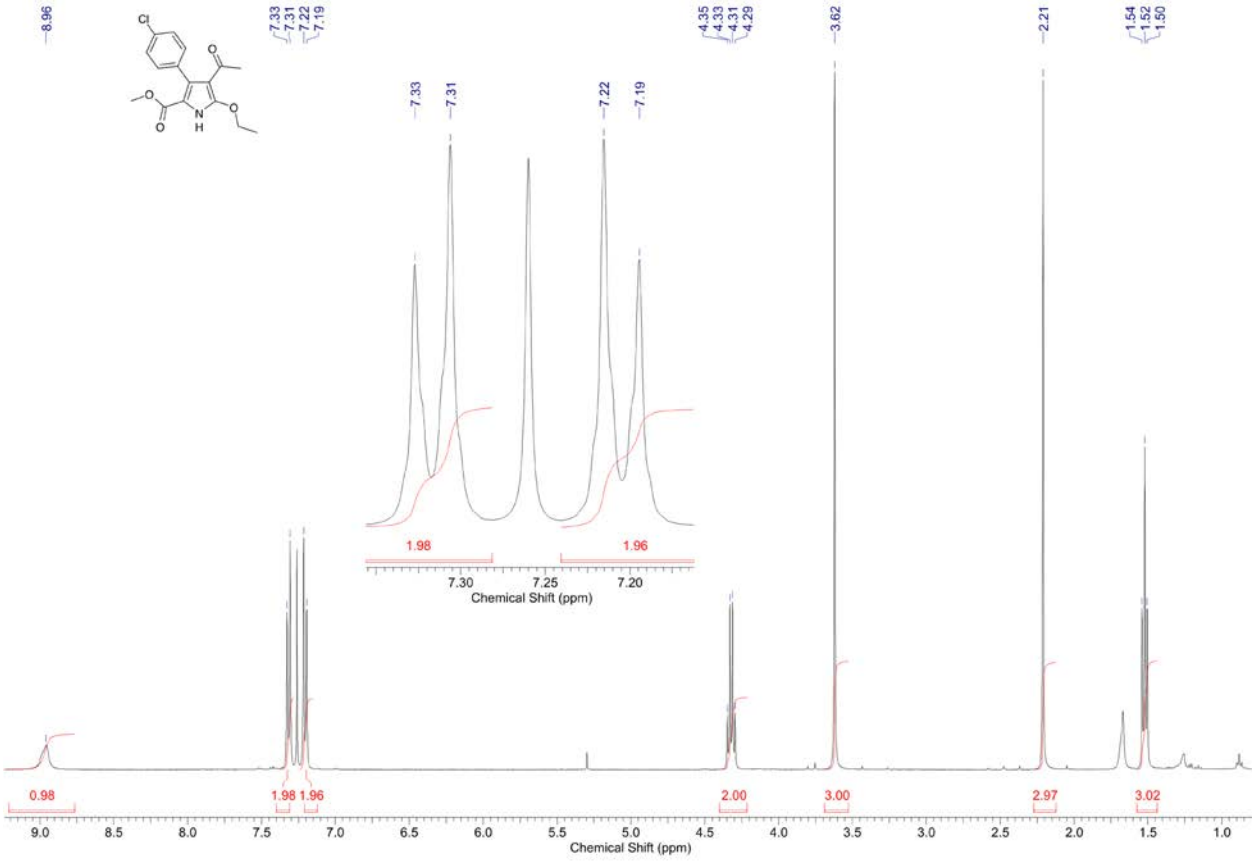


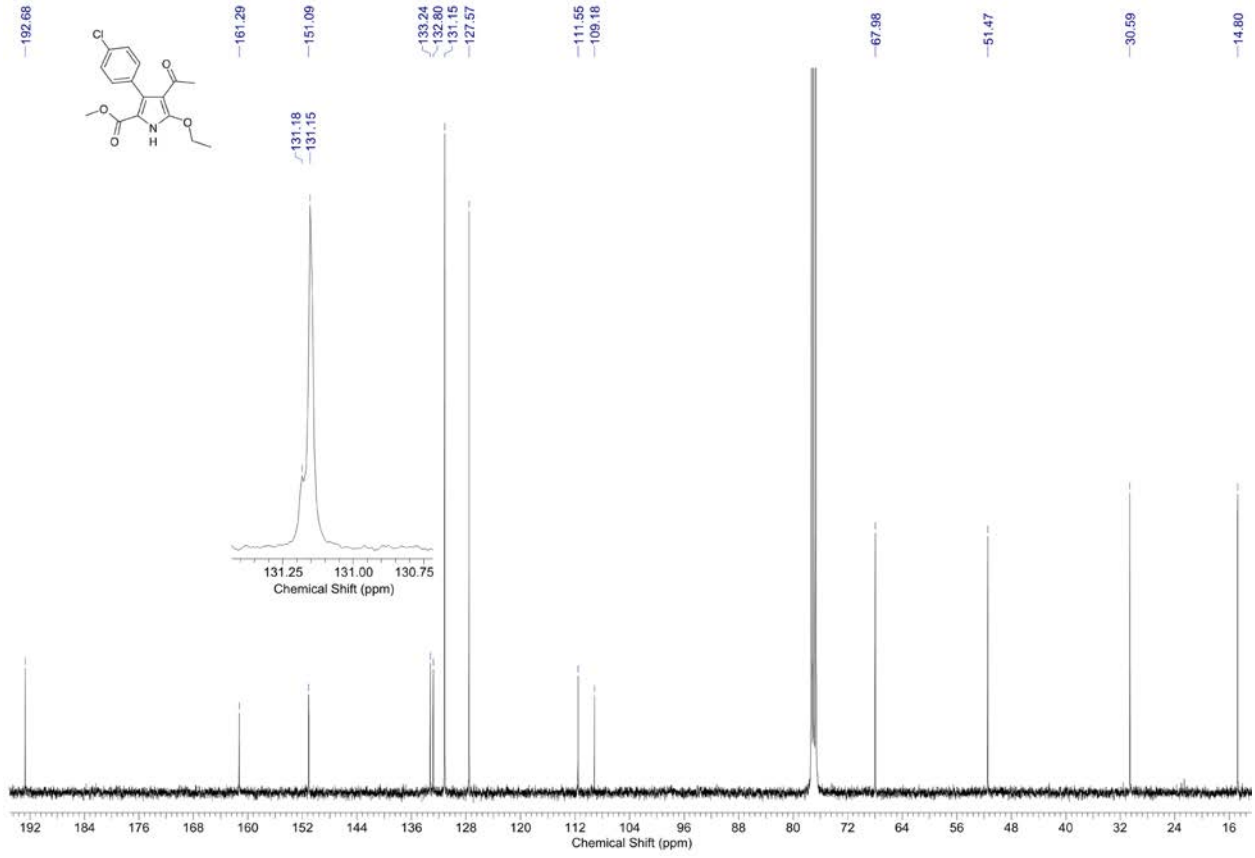
4-Ethyl 2-methyl 3-(4-chlorophenyl)-5-methyl-1*H*-pyrrole-2,4-dicarboxylate 9f



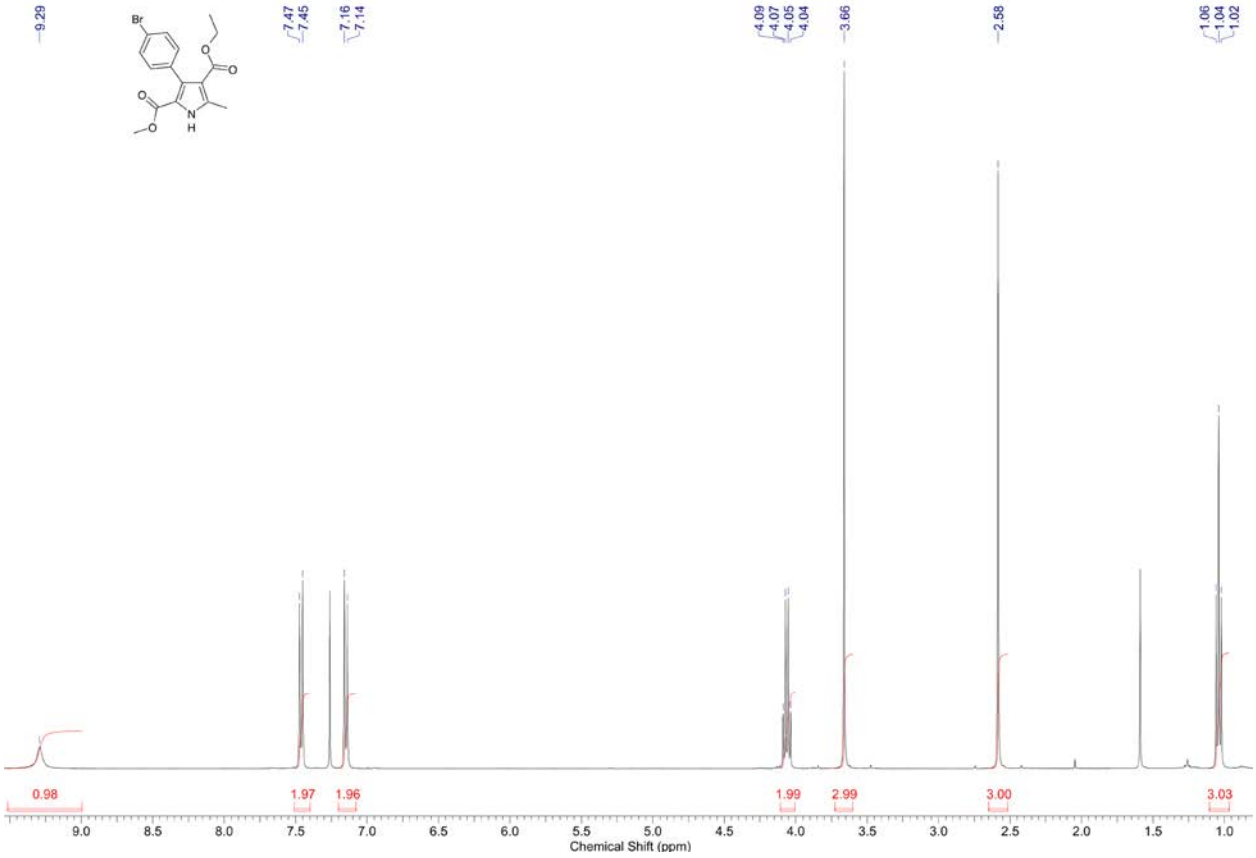


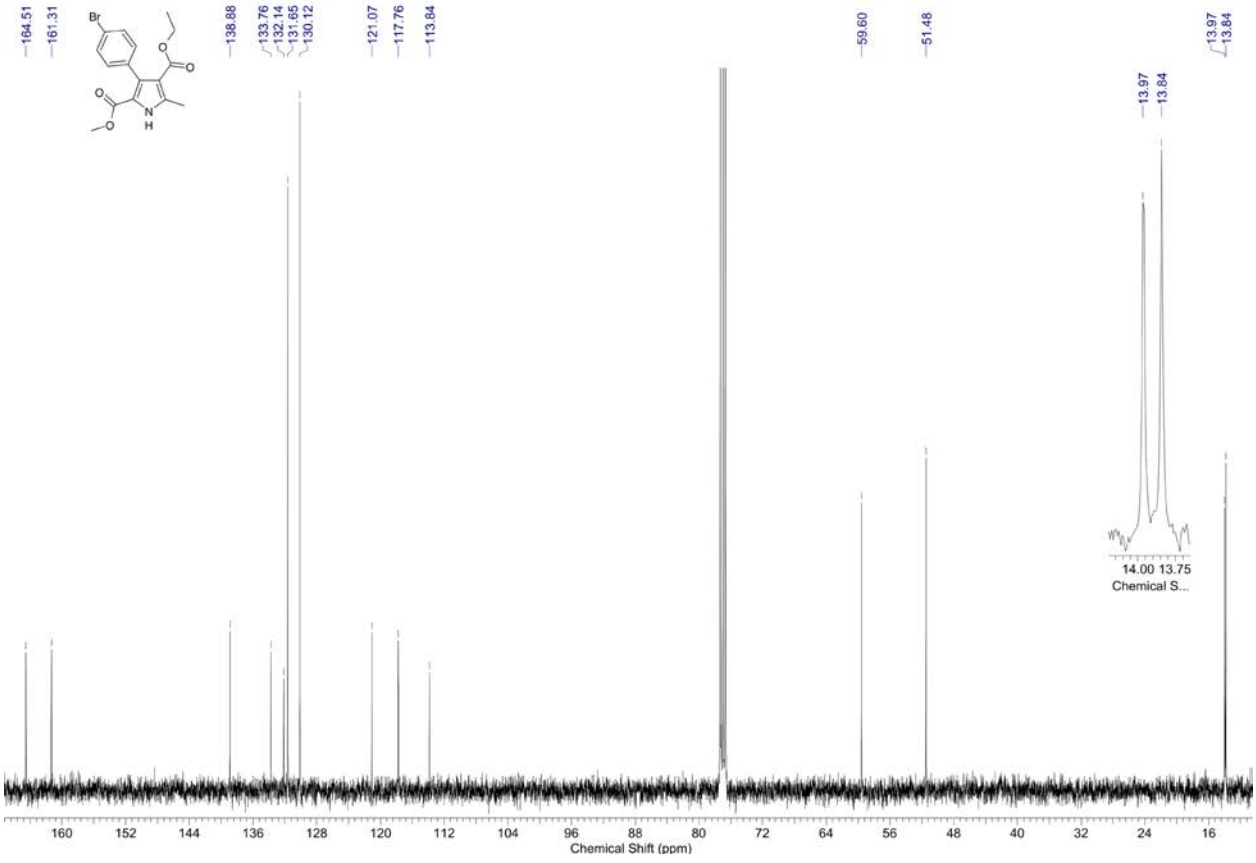
Methyl 4-acetyl-3-(4-chlorophenyl)-5-ethoxy-1*H*-pyrrole-2-carboxylate 10d



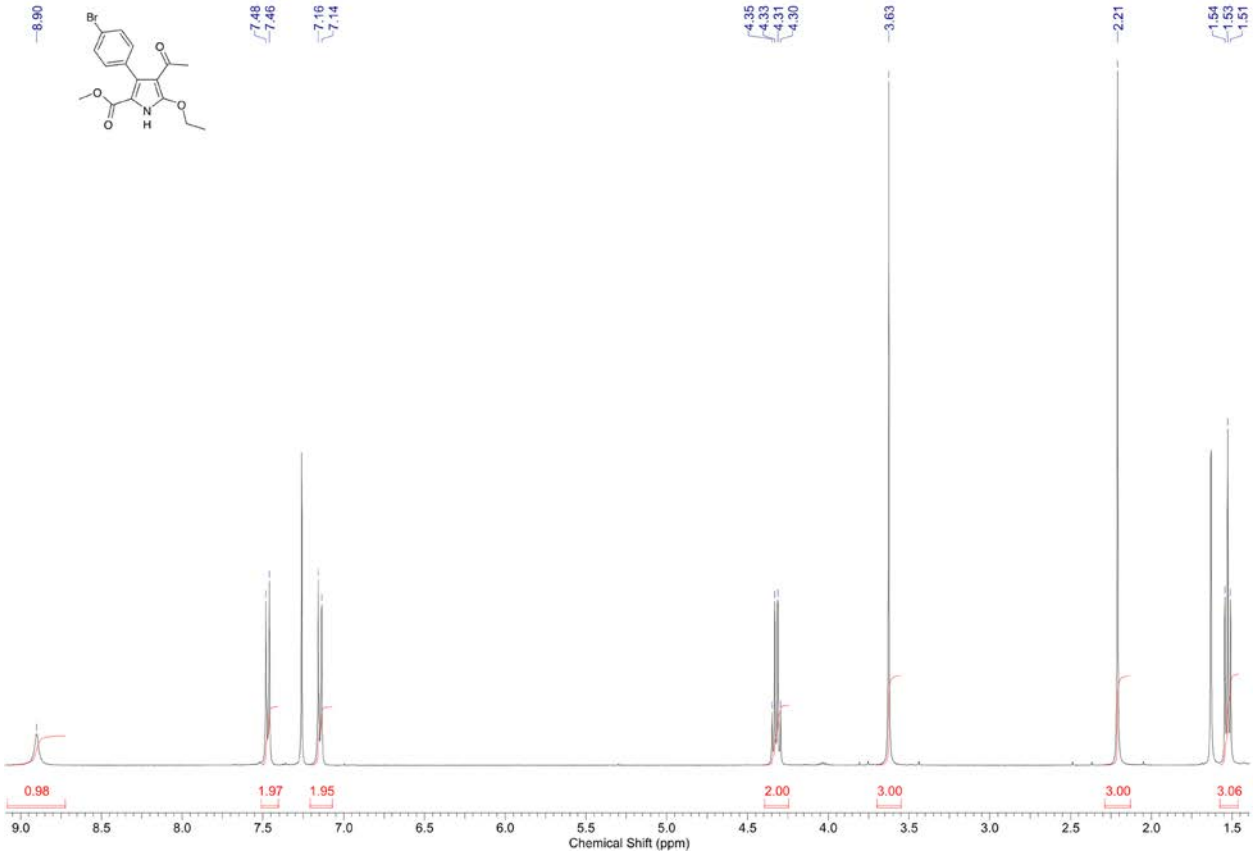


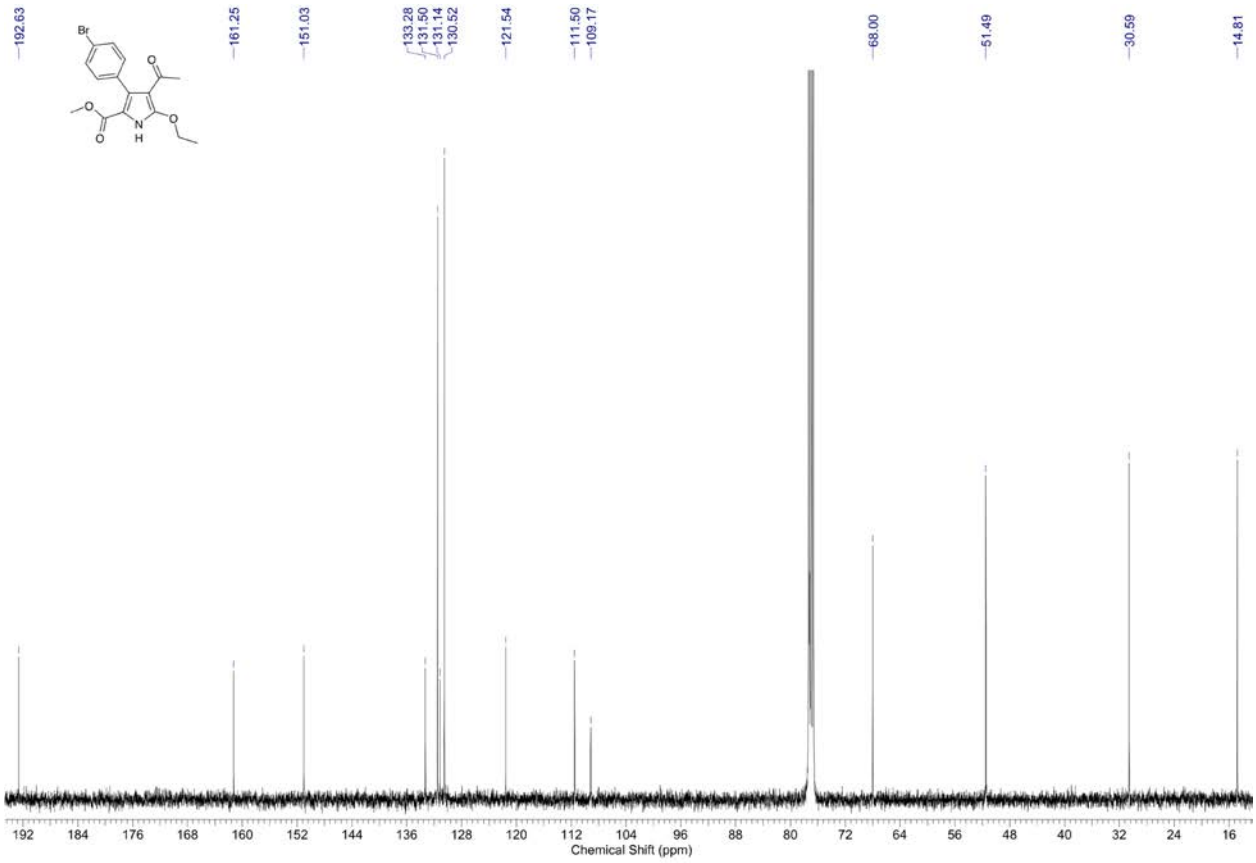
4-Ethyl 2-methyl 3-(4-bromophenyl)-5-methyl-1*H*-pyrrole-2,4-dicarboxylate 9g



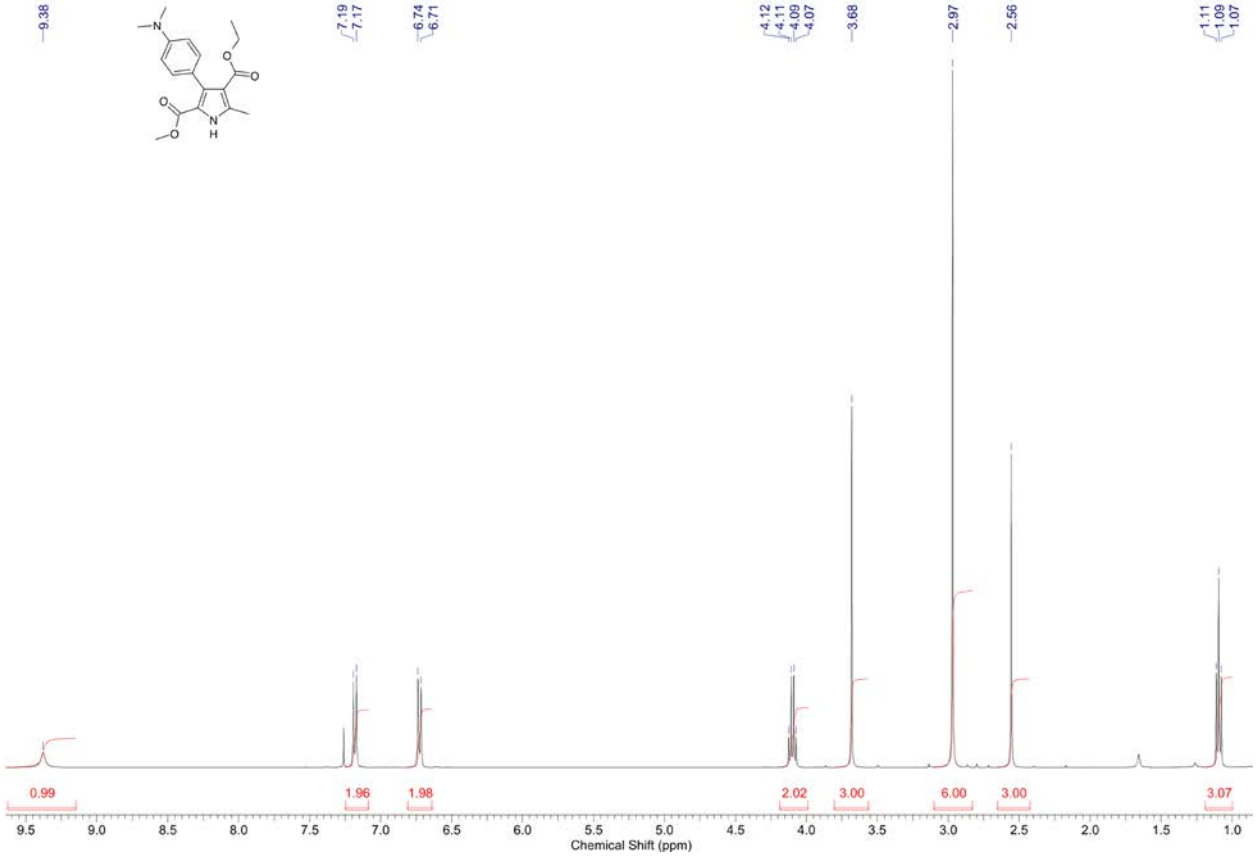


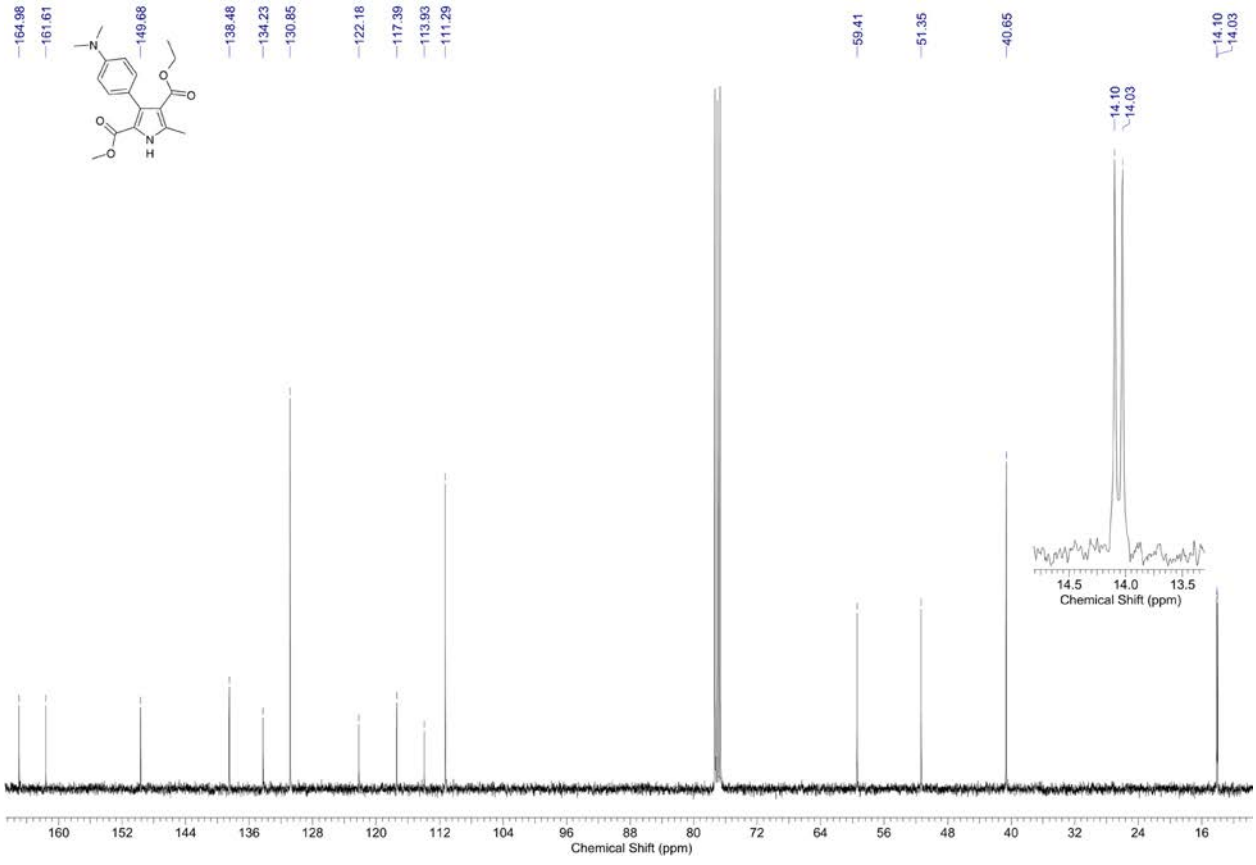
Methyl 4-acetyl-3-(4-bromophenyl)-5-ethoxy-1*H*-pyrrole-2-carboxylate 10e



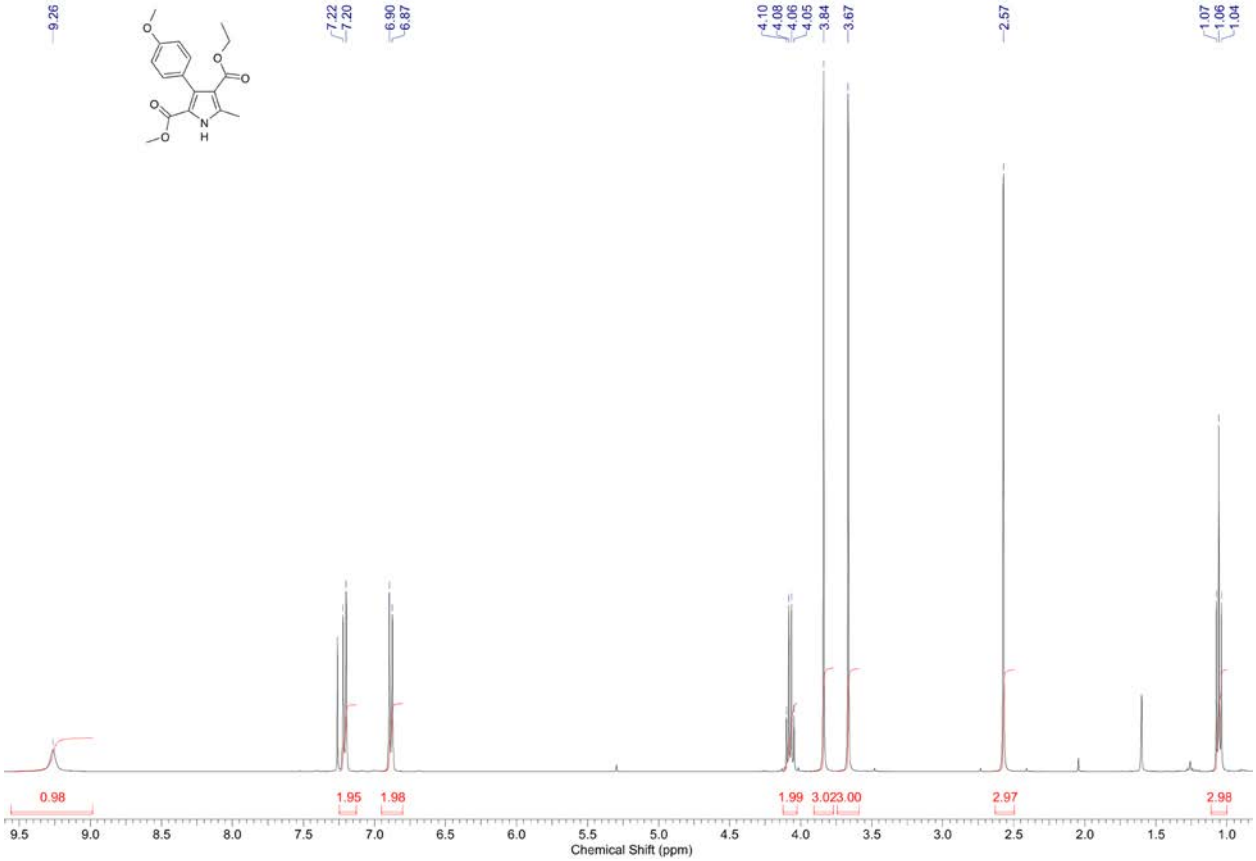


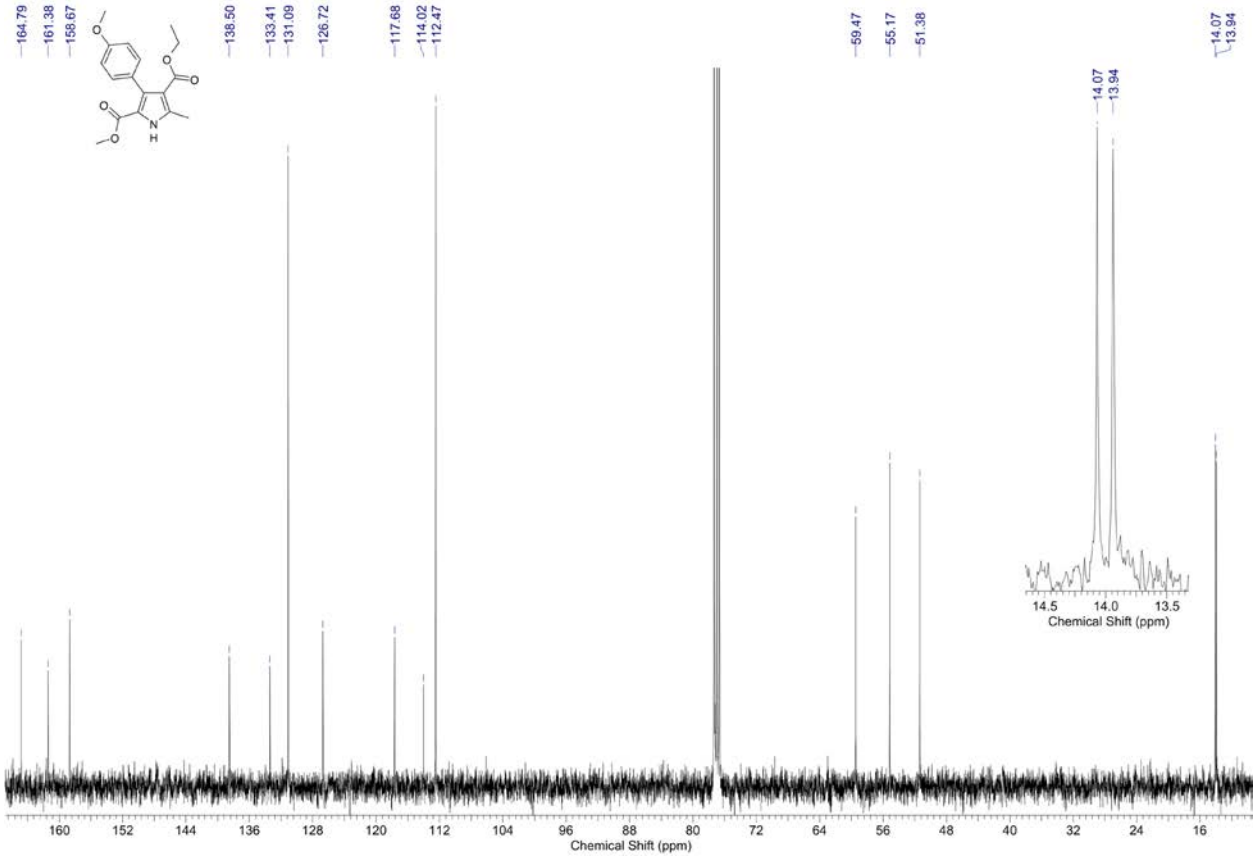
4-Ethyl 2-methyl 3-(4-(dimethylamino)phenyl)-5-methyl-1*H*-pyrrole-2,4-dicarboxylate 9h



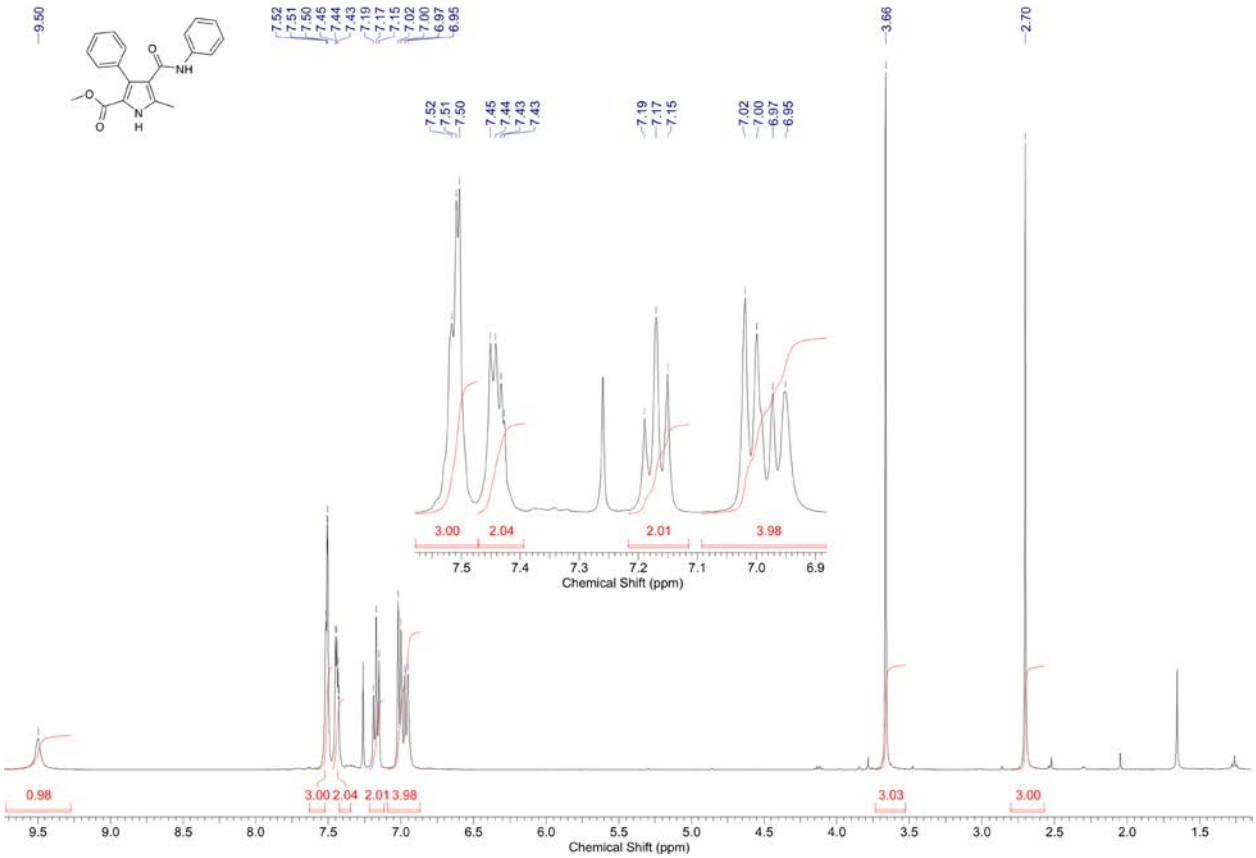


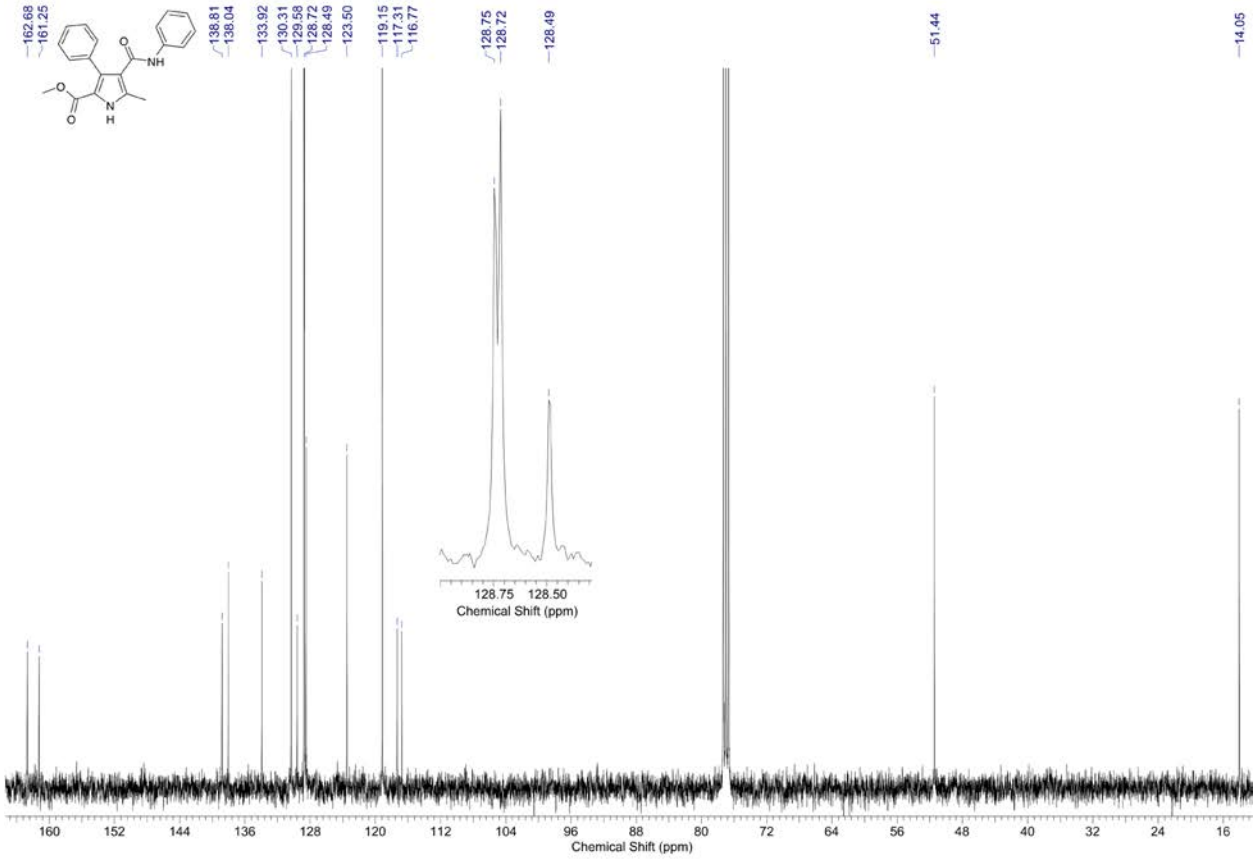
4-Ethyl 2-methyl 3-(4-methoxyphenyl)-5-methyl-1*H*-pyrrole-2,4-dicarboxylate 9i





Methyl 5-methyl-3-phenyl-4-(phenylcarbamoyl)-1*H*-pyrrole-2-carboxylate 9k





Methyl 3-(4-bromophenyl)-5-methyl-4(phenylcarbamoyl)-1*H*-pyrrole-2-carboxylate 9l