Supplementary Information

Hypoiodite-Catalyzed Oxidative Cyclisation of Michael Adducts of Chalcones with 1,3-Dicarbonyl compounds: A Facile and Versatile Approach to Substituted Furans and Cyclopropanes

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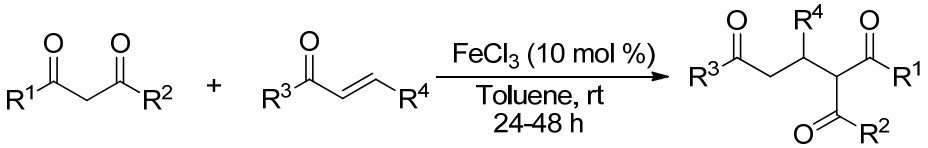
General Information

^{1}H NMR spectra were recorded at 600 MHz or 400 MHz and ^{13}C NMR spectra were measured at 150MHz or 100 MHz using Bruker AVANCE III NMR spectrometers with $CDCl_3$ as the solvent. Chemical shifts (δ) were measured in ppm and referenced to the deuterated chloroform (^{1}H: δ = 7.26 ppm, ^{13}C: δ = 77.00 ppm). The multiplicities of signals were described using the following abbreviations: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, dd = doublet of doublets, tt = triplet of triplets. High-resolution mass spectrometry (HRMS) was performed on a micrOTOF-Q II instrument with an ESI source. Melting points were measured with a RD-II type melting point apparatus. Fluorescence excitation and emission spectra were recorded by Cary Eclipse fluorescence spectrophotometer (Varian, America) with C = 1.5 x 10^{-5} mol/L. The known compounds were identified by the comparison of their NMR spectra with reported data in literatures; the new compounds were characterized by NMR, HRMS and melting point for solid samples. Unless otherwise noted, reagents obtained from commercial sources were directly used without further purification; all solvents were obtained from commercial sources and were purified according to standard procedures. Petroleum ether (PE), where used, has the boiling point range 60-90 ^{o}C. Column chromatography was performed on silica gel (200-300 mesh).

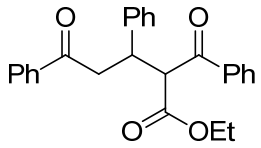
Preparation of Michael Adducts

General procedure:[S1]



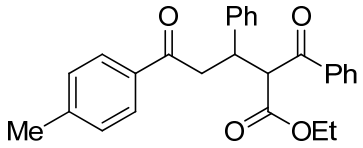
To a solution of chalcone (7.5 mmol) and 1,3-dicarbonyl compounds (5 mmol) in freshly distilled toluene (5 mL) was added $FeCl_3$ (0.5 mmol). After stirring at room temperature for 24-48 h, the mixture was diluted with H_2O (10 mL) and extracted with EtOAc (3 × 20 mL). The combined organic layers were dried (Na_2SO_4), concentrated in vacuo, and purified by column chromatography to gain Michael adducts **1**or **4**. All products were known compounds and structures have been confirmed by ^{1}H NMR.

Ethyl 2-benzoyl-5-oxo-3,5-diphenylpentanoate (1a)[S2]



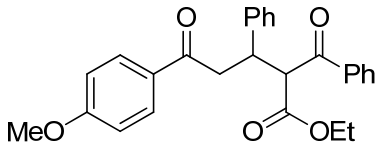
Yield: 55%; white solid; m.p. 139-141 ^{o}C;^{1}H NMR ($CDCl_3$, 400 MHz, two isomers ratio 1:1): δ 8.09 (d, 1H, J = 8.0 Hz), 7.90-7.82 (m, 3H), 7.60 (t, 0.5H, J = 7.2 Hz), 7.55-7.37 (m, 5.5H), 7.31 (d, 1H, J = 8.0 Hz), 7.26-7.21 (m, 2H), 7.19-7.11 (m, 1.5H), 7.06 (t, 0.5H, J = 7.2 Hz), 4.92 (dd, 1H, J = 9.6, 4.0 Hz), 4.45-4.35(m, 1H), 4.20-4.10 (m, 1H), 3.87-3.77 (m, 1H),3.62-3.52 (m, 1H), 3.48 (dd, 0.5 H, J = 16.0, 4.0 Hz), 3.31 (dd, 0.5 H, J =16.0, 9.6 Hz), 1.16 (t, 1.5H, J = 7.2 Hz), 0.88 (t, 1.5 H, J =7.2 Hz).

Ethyl 2-benzoyl-5-oxo-3-phenyl-5-(p-tolyl)pentanoate (1b)[S3]



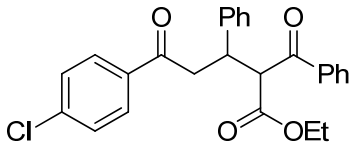
Yield: 60%; white solid; m.p. 87-89 ^{o}C; ^{1}H NMR ($CDCl_3$, 400 MHz, two isomers ratio 1:1): δ 8.09 (d, 1H, J = 8.0 Hz), 7.85 (d, 1H, J = 8.0 Hz), 7.79 (t, 2H, J = 8.8 Hz), 7.60 (t, 0.5H, J = 7.2 Hz), 7.55-7.45 (m, 1.5H), 7.39 (t, 1H, J = 7.6 Hz), 7.30 (d, 1H, J = 7.2 Hz), 7.26-7.18 (m, 4H), 7.16-7.10 (m, 1.5H), 7.08-7.02 (m, 0.5H), 4.93 (dd, 1H, J = 9.6, 4.0 Hz), 4.45-4.35(m, 1H), 4.20-4.10 (m, 1H), 3.87-3.77 (m, 1H),3.45-3.40 (m, 1.5 H), 3.27 (dd, 0.5 H, J = 16.0, 9.6 Hz), 2.38 (s, 3H), 1.16 (t, 1.5H, J = 7.2 Hz), 0.87 (t, 1.5 H, J =7.2 Hz).

Ethyl 2-benzoyl-5-(4-methoxyphenyl)-5-oxo-3-phenylpentanoate (1c)[S3]



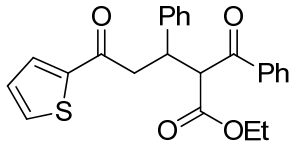
Yield: 60%, white solid; m.p.102-104 ^{o}C; ^{1}H NMR ($CDCl_3$, 400 MHz, two isomers ratio 1:3): δ 8.09 (d, 1.4H, J = 7.2 Hz), 7.90-7.80 (m, 2.4H), 7.60 (t, 0.8H, J = 7.2 Hz), 7.55-7.45 (m, 1.7H), 7.39 (t, 0.7H, J = 7.6 Hz), 7.29 (d, 1.6H, J = 7.6 Hz), 7.23 (t, 2H, J = 7.2 Hz), 7.19-7.10 (m, 1.3H), 7.05 (t, 0.3H, J = 7.2 Hz),6.87 (d, 2H, J = 8.8 Hz) 4.96-4.90 (m, 1H), 4.44-4.32 (m, 0.5H), 3.88-3.78 (m, 4.5H), 3.51-3.40 (m, 1.3H),3.22 (dd, 0.7H, J = 16.0, 9.6 Hz), 1.16 (t, 0.8H, J = 7.2 Hz), 0.88 (t, 2.4 H, J =7.2 Hz).

Ethyl 2-benzoyl-5-(4-chlorophenyl)-5-oxo-3-phenylpentanoate (1d)[S3]



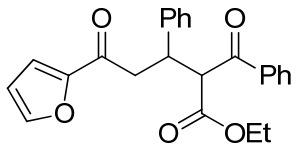
Yield: 44%; white solid; m.p.94-96 °C; ^{1}H NMR ($CDCl_3$, 600 MHz, two isomers ratio 3:2): δ 8.10 (d, 1H, J = 7.2 Hz), 7.87-7.80 (m, 2.8H), 7.59 (t, 0.6H, J = 7.2 Hz), 7.52-7.46 (m, 1.6H), 7.39-7.34 (m, 2.8H), 7.30 (d, 1H, J = 7.2 Hz), 7.26-7.22 (m, 2H), 7.18-7.12 (m, 1.5H), 7.05 (t, 0.5H, J = 7.2 Hz), 4.93 (dd, 1H, J = 12.0, 9.6 Hz), 4.41-4.35(m, 1H), 4.18-4.11 (m, 0.8H), 3.85-3.77 (m, 1.2H),3.59 (dd, 0.4H, J = 10.2, 4.2 Hz), 3.53-3.42 (m, 1 H), 3.28 (dd, 0.6H, J =16.2, 10.2 Hz), 1.15 (t, 1.2H, J = 7.2 Hz), 0.86 (t, 1.8H, J =7.2 Hz).

Ethyl 2-benzoyl-5-oxo-3-phenyl-5-(thiophen-2-yl)pentanoate (1e)[S3]



Yield: 44%; white solid; m.p. 118-120 °C; ^{1}H NMR ($CDCl_3$, 400 MHz, two isomers ratio 3:2): δ 8.10 (d, 1H, J = 8.0 Hz), 7.85 (d, 0.8H, J = 8.4 Hz), 7.76-7.71 (m, 1H), 7.63-7.55 (m, 1.7H), 7.53-7.47 (m, 1.6H), 7.39 (t, 1H, J = 7.6 Hz), 7.31(d, 1.2H, J = 7.6 Hz), 7.23 (d, 1.6H, J = 7.2 Hz), 7.19-7.11 (m, 1.7H), 7.10-7.03 (m, 1.4H), 4.96 (dd, 1H, J = 10.0, 2.8 Hz), 4.42-4.32 (m, 1H), 4.15 (q, 1H, J = 6.8 Hz), 3.88-3.77 (m, 1H), 3.51-3.35 (m, 1.5H), 3.24-3.16 (m, 0.5 H), 1.17 (t, 1.2H, J = 7.2 Hz), 0.87 (t, 1.8 H, J =7.2 Hz).

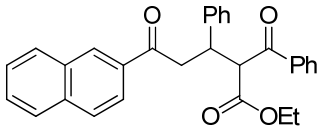
Ethyl 2-benzoyl-5-(furan-2-yl)-5-oxo-3-phenylpentanoate (1f)[S3]



Yield: 59%; white solid; m.p.150-152 °C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.10 (d, 2H, J = 7.6 Hz), 7.60 (t, 1H, J = 7.6 Hz), 7.49 (t, 3H, J = 7.6 Hz), 7.32 (d, 2H, J = 7.2 Hz), 7.23 (d, 2H, J = 7.6 Hz), 7.19-7.13 (m, 2H), 6.47-6.43 (m, 1H), 4.95 (d, 1H, J = 10.4

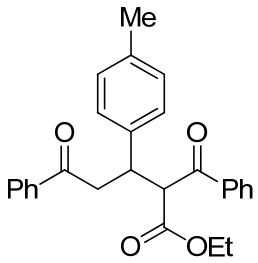
Hz), 4.44-4.32 (m, 1H), 3.87-3.76 (m, 2H), 3.29-3.15 (m, 2H), 0.87 (t, 3H, *J* =7.2 Hz).

Ethyl 2-benzoyl-5-(naphthalen-2-yl)-5-oxo-3-phenylpentanoate (1g)[S3]



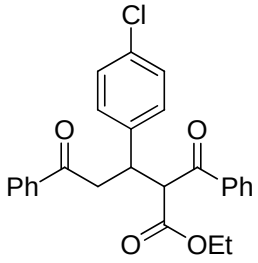
Yield: 59%; white solid; m.p.144-146 ^{o}C; ^{1}H NMR ($CDCl_3$, 400 MHz, two isomers ratio 1:1): δ 8.45 (s, 1H), 8.13 (d, 1H, *J* = 7.2 Hz), 7.97-7.81 (m, 4.8 H), 7.64-7.48 (m, 4H), 7.40 (t, 1H, J = 8.0 Hz), 7.28 (d, 1H, J = 8.0 Hz), 7.23 (d, 1H, J = 7.6 Hz), 7.19-7.11 (m, 1.5H), 7.06 (m, 0.5H), 4.97 (dd, 1H, J = 9.6, 4.80 Hz), 4.54-4.42 (m, 1H), 4.22-4.14 (m, 1H), 3.88-3.79 (m, 1H),3.73-3.58 (m, 1.4H), 3.43 (dd, 0.6 H, J = 15.6, 9.6 Hz), 1.18 (t, 1.2H, J = 7.2 Hz), 0.88 (t, 1.8H, *J* =7.2 Hz).

Ethyl 2-benzoyl-5-oxo-5-phenyl-3-(p-tolyl)pentanoate (1h)[S3]



Yield: 55%; white solid; m.p.113-115 ^{o}C; ^{1}H NMR ($CDCl_3$, 600 MHz, two isomers ratio 1:1): δ 8.09 (d, 1H, *J* = 8.4 Hz), 7.91-7.85 (m, 3H), 7.60 (t, 0.5H, J = 7.8 Hz), 7.54-7.47 (m, 2.5H), 7.44-7.38 (m, 3H), 7.18 (d, 1H, J = 7.8 Hz), 7.12 (d, 1H, J = 7.8 Hz), 7.04 (d, 1H, J = 7.8 Hz), 6.94 (d, 1H, J = 8.4 Hz), 4.90 (dd, 1H, J = 12.0, 9.6 Hz), 4.39-4.31 (m, 1H), 4.19-4.11 (m, 1H), 3.87-3.81 (m, 1H),3.59-3.43 (m, 1H), 3.27 (dd, 0.5 H, J = 15.6, 9.6 Hz), 3.31 (dd, 0.5 H, *J* =16.0, 9.6 Hz), 2.26 (s, 1.5 H), 2.18 (s, 1.5 H) 1.16 (t, 1.5H, J = 7.2 Hz), 0.89 (t, 1.5 H, *J* =7.2 Hz).

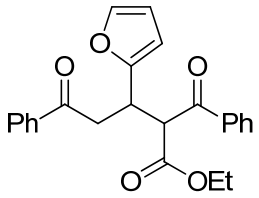
Ethyl 2-benzoyl-3-(4-chlorophenyl)-5-oxo-5-phenylpentanoate (1i)[S3]



Yield: 45%; white solid; m.p.122-124 ^{o}C; ^{1}H NMR ($CDCl_3$, 400 MHz, two isomers

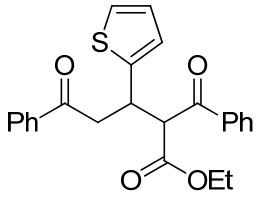
ratio 8:5): δ 8.09 (d, 1.2H, J = 8.0 Hz), 7.90-7.82 (m, 2.7H), 7.62 (t, 0.6H, J = 7.2 Hz), 7.56-7.48 (m, 2.65H), 7.45-7.38 (m, 2.65H), 7.29-7.26 (m, 1H), 7.23-7.17 (m, 2H), 7.11 (d, 0.8H, J = 8.4 Hz), 4.88 (dd, 1H, J = 10.4, 3.2 Hz), 4.43-4.32 (m, 1H), 4.20-4.12 (m, 0.8H), 3.90-3.80 (m, 1.2H),3.59-3.42 (m, 1.4H), 3.27 (dd, 0.6 H, J = 16.0, 4.0 Hz), 3.31 (dd, 0.5 H, J =16.0, 9.6 Hz), 1.16 (t, 1.15H, J = 7.2 Hz), 0.91 (t, 1.85 H, J =7.2 Hz).

Ethyl 2-benzoyl-3-(furan-2-yl)-5-oxo-5-phenylpentanoate (1j)[S3]



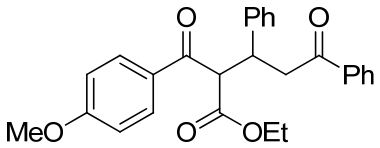
Yield: 35%; white solid; m.p.58-60 ^{o}C; ^{1}H NMR ($CDCl_3$, 600 MHz, two isomers ratio 7:3): δ 8.04 (d, 1.4H, J = 8.4 Hz), 7.96-7.91 (m, 2.6H), 7.59 (t, 0.7H, J = 7.2 Hz), 7.56-7.51 (m, 1.3H), 7.50-7.41 (m, 4H), 7.27 (dd, 0.7H, J = 1.8, 1.2 Hz), 7.13 (dd, 0.3H, J = 1.8, 1.2 Hz), 6.20 (dd, 0.7H, J = 3.6, 1.8 Hz), 6.12 (d, 0.7H, J = 3.0 Hz), 6.09 (dd, 0.3H, J = 3.6, 1.8 Hz), 6.02 (d, 0.3H, J = 3.0 Hz), 5.03 (d, 0.3H, J = 8.4 Hz), 4.98 (d, 0.7H, J = 8.4 Hz), 4.55-4.46 (m, 1H), 4.45-4.35 (m, 1H), 4.18-4.11 (m, 0.6H), 4.04-3.94 (m, 1.4H), 3.63-3.51 (m, 0.6H), 3.49-3.39 (m, 1.4H), 1.16 (t, 0.9H, J = 7.2 Hz), 0.88 (t, 2.1H, J =7.2 Hz).

Ethyl 2-benzoyl-5-oxo-5-phenyl-3-(thiophen-2-yl)pentanoate (1k)[S3]



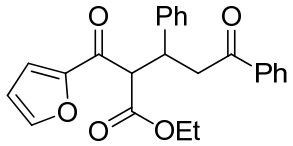
Yield: 36%; brown solid; m.p.74-76^{o}C; ^{1}H NMR ($CDCl_3$, 400 MHz, two isomers ratio 7:5): δ 8.07 (d, 1.2H, J = 7.6 Hz), 7.95-7.88 (m, 2.8H), 7.62-7.48 (m, 3H), 7.47-7.38 (m, 3H), 7.11 (d, 0.56H, J = 5.2 Hz), 7.00 (d, 0.44H, J = 5.2 Hz), 6.92 (d, 0.58H, J = 3.6 Hz), 6.88-6.82 (m, 1H), 6.77-6.72 (m, 0.42H), 5.01 (dd, 1H, J = 14.4, 8.8 Hz), 4.78-4.68 (m, 1H), 4.19-4.08 (m, 1H), 3.98-3.88 (m, 1H),3.64-3.52 (m, 1.4H), 3.46-3.37 (m, 0.6 H), 1.15 (t, 1.25H, J = 7.2 Hz), 0.88 (t, 1.75 H, J =7.2 Hz).

Ethyl 2-(4-methoxybenzoyl)-5-oxo-3,5-diphenylpentanoate (1l)[S3]



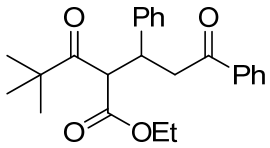
Yield: 54%; white solid; m.p.105-107^{o}C; ^{1}H NMR ($CDCl_3$, 400 MHz, two isomers ratio 2:1): δ 8.09 (d, 0.65H, J = 8.8 Hz), 7.92-7.84 (m, 3.3H), 7.56-7.47 (m, 1H), 7.45-7.37 (m, 2H), 7.29 (d, 0.7H, J = 7.2 Hz), 7.26-7.20 (m, 2H), 7.19-7.11 (m, 1.65H), 7.05 (t, 0.66H, J = 7.2 Hz), 6.96 (d, 0.67H, J = 8.8 Hz), 6.87 (d, 1.33H, J = 8.8 Hz), 4.92-4.84 (m, 1H), 4.44-4.32 (m, 1H), 4.20-4.10 (m, 1.34H), 3.91-3.78 (m, 3.66H), 3.60-3.43 (m, 1.7H), 3.26 (dd, 0.3H, J = 16.0, 10.0 Hz), 1.17 (t, 2H, J = 7.2 Hz), 0.88 (t, 1H, J =7.2 Hz).

Ethyl 2-(furan-2-carbonyl)-5-oxo-3,5-diphenylpentanoate (1m)[S3]



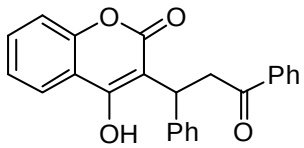
Yield: 59%; white solid; m.p.119-121^{o}C; ^{1}H NMR ($CDCl_3$, 400 MHz, two isomers ratio 3:1): δ 7.88 (m, 2H), 7.63 (s, 0.7H), 7.55-7.48 (m, 1.4H), 7.45-7.35 (m, 2.8H), 7.31-7.26 (m, 1.6H), 7.26-7.20 (m, 1.8H), 7.18-7.12 (t, 1.4H, J = 7.2 Hz), 7.10-7.05 (m, 0.3H), 6.59-6.54 (m, 0.75H), 6.48-6.45 (m, 0.25), 4.71-4.63 (m, 1H), 4.41-4.31 (m, 1H), 4.21-4.12 (m, 0.6H), 3.93-3.83 (m, 1.4H),3.62-3.45 (m, 1.3H), 3.38-3.30 (dd, 0.7 H, J = 16.0, 10.0 Hz), 1.18 (t, 0.8H, J = 7.2 Hz), 0.88 (t, 2.2 H, J =7.2 Hz).

Ethyl 4,4-dimethyl-3-oxo-2-(3-oxo-1,3-diphenylpropyl)pentanoate (1n)[S3]



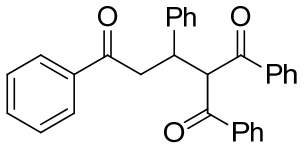
Yield: 47%; colorless oil; ^{1}H NMR ($CDCl_3$, 400 MHz, two isomers ratio 2:1): δ 7.87 (d, 2H, J = 7.2 Hz), 7.52 (t, 1H, J = 7.2 Hz), 7.41 (t, 2H, J = 7.6 Hz), 7.25-7.11 (m, 5.5H), 4.36 (dd, 1H, J = 14.0, 9.6 Hz), 4.28-4.12 (m, 2.5 H), 3.84 (q, 0.6H, J = 7.2 Hz), 1.24 (t, 2H, J = 7.2 Hz), 1.15 (s, 2.5H), 0.93 (t, 1H, J =7.2 Hz), 0.87 (s, 6.5H).

4-Hydroxy-3-(3-oxo-1,3-diphenylpropyl)-2H-chromen-2-one (1o)[S4]



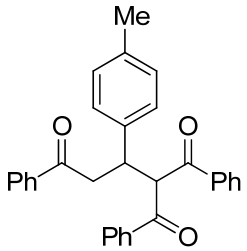
Yield: 56%; white solid; m.p.162-164 ^{o}C; ^{1}H NMR ($CDCl_3$, 600 MHz): δ 9.90 (brs, 1H), 8.09 (dd, 2H, J = 7.6, 1.2 Hz), 7.98 (dd, 1H, J = 7.8, 1.2 Hz), 7.63 (t, 1H, J = 7.2 Hz), 7.52-7.46 (m, 3H), 7.41 (d, 2H, J = 7.8 Hz), 7.33-7.27 (m, 3H), 7.25-7.20 (m, 2H), 4.96 (dd, 1H, J = 10.2, 1.8 Hz), 4.49 (dd, 1H, J = 19.2, 10.2 Hz), 3.80 (dd, 1H, J = 19.2, 2.4 Hz).

2-Benzoyl-1,3,5-triphenylpentane-1,5-dione (1p)[S1]



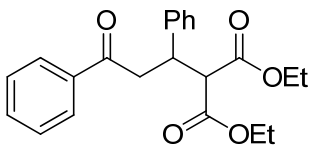
Yield: 65%; white solid; m.p. 154-156 ^{o}C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.97 (d, 2H, *J* = 7.6 Hz), 7.88 (d, 2H, J = 7.6 Hz), 7.80 (d, 2H, J = 7.6 Hz), 7.58-7.40 (m, 7H), 7.34 (t, 2H, J = 7.6 Hz), 7.25 (d, 2H, J = 7.6 Hz), 7.15-7.02 (m, 3H), 5.91 (d, 1H, J = 8.4 Hz), 4.52-4.64 (m, 1H), 3.68-3.54 (m, 2H).

2-Benzoyl-1,5-diphenyl-3-(p-tolyl)pentane-1,5-dione (1q)[S1]



Yield: 44%; white solid; m.p.153-155 ^{o}C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.98 (d, 2H, *J* = 8.8 Hz), 7.88 (d, 2H, *J* = 7.2 Hz), 7.81 (d, 2H, *J* = 7.6 Hz), 7.57-7.40 (m, 7H), 7.34 (t, 2H, *J* = 7.6 Hz), 7.13 (d, 2H, *J* = 8.0 Hz), 6.92 (d, 2H, *J* = 8.0 Hz), 5.88 (d, 1H, *J* = 8.4 Hz), 4.58-4.48 (m, 1H), 3.66-3.51 (m, 2H), 2.18 (s, 3H).

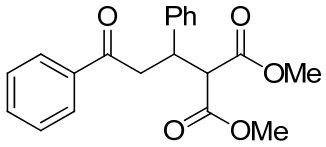
Diethyl 2-(3-oxo-1,3-diphenylpropyl)malonate (4a)[S1]



Yield: 80%; white solid; m.p.62-64 ^{o}C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.90 (d, 2H, *J* = 8.0 Hz), 7.53 (t, 1H, J = 7.2 Hz), 7.42 (t, 2H, J = 7.2 Hz), 7.26-7.21 (m, 4H), 7.19-7.14

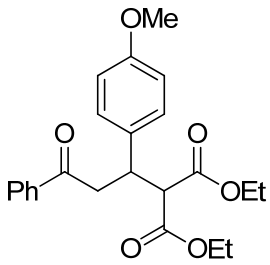
(m, 1H) 4.25-4.14 (m, 3H), 3.95 (q, 2H, J = 7.2 Hz), 3.82 (d, 1H, J = 9.6 Hz), 3.59-3.41 (m, 2H), 1.24 (t, 3H, J = 7.2 Hz), 1.00 (t, 3H, *J* =7.2 Hz).

Dimethyl 2-(3-oxo-1,3-diphenylpropyl)malonate (4b)[S1]



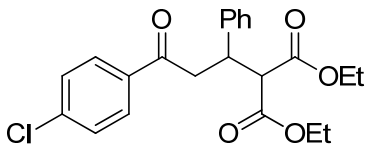
Yield: 75%; white solid; m.p. 103-105 ^{o}C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.90 (d, 2H, *J* = 8.0 Hz), 7.53 (t, 1H, J = 7.2 Hz), 7.42 (t, 2H, J = 7.2 Hz), 7.26-7.21 (m, 4H), 7.19-7.14 (m, 1H) 4.23-4.16 (m, 3H), 3.86 (d, 1H, J = 9.2 Hz), 3.73 (s, 3H), 3.58-3.44 (m, 5H).

Diethyl 2-(1-(4-methoxyphenyl)-3-oxo-3-phenylpropyl)malonate (4c)[S1]



Yield: 72%; white solid; m.p. 71-73 ^{o}C; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.89 (d, 2H, *J* = 8.0 Hz), 7.53 (t, 1H, J = 7.6 Hz), 7.42 (t, 2H, J = 7.2 Hz), 7.17 (d, 2H, J = 8.8 Hz), 6.77 (d, 2H, J = 8.8 Hz), 4.25-4.10 (m, 3H), 3.96 (q, 2H, J = 7.2 Hz), 3.78 (d, 1H, J = 9.6 Hz), 3.73 (s, 3H), 3.51 (d, 1H, J = 14.4, 4.4 Hz), 3.40 (d, 1H, J = 14.4, 9.6 Hz), 1.24 (t, 3H, J = 7.2 Hz), 1.03 (t, 3H, *J* =7.2 Hz).

Diethyl 2-(3-(4-chlorophenyl)-3-oxo-1-phenylpropyl)malonate (4d)[S1]



Yield: 87%; white solid; m.p. 62-65 ^{o}C; ^{1}H NMR ($CDCl_3$, 600 MHz): δ 7.83 (d, 2H, *J* = 8.4 Hz), 7.39 (d, 2H, J = 8.4 Hz), 7.25-7.21 (m, 4H), 7.19-7.14 (m, 1H), 4.24-4.12 (m, 3H), 3.95 (q, 2H, J = 7.2 Hz), 3.80 (d, 1H, J = 9.6 Hz), 3.52 (dd, 1H, J = 16.8, 4.8 Hz), 3.40 (d, 1H, J = 16.8, 9.6 Hz), 1.24 (t, 3H, J = 7.2 Hz), 1.01 (t, 3H, *J* =7.2 Hz).

General Procedure for the Synthesis of 2, 3 and 5

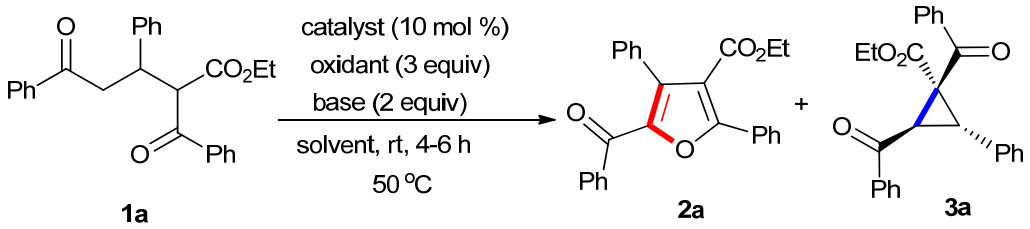
Synthesis of 2a: A 10 mL oven-dried reaction vessel was charged with Michael adduct of ethyl benzoylacetate with chalcone (**1a**, 40 mg, 0.1 mmol), DBU (31 mg, 0.2 mmol), and NIS (2.3 mg, 0.01 mmol) in 1,4-dioxane (2.0 mL) under air. TBHP (70% in water) (39 mg, 0.3 mmol) was added slowly to the sealed reaction vessel by syringe, and the resulting solution was stirred at 50 ^{o}C for 4 h. After the reaction was complete, sat. $Na_2S_2O_3$ aqueous solution (10 mL) was added to quench the reaction, and the mixture was extracted by ethyl acetate (3 × 10 mL). The organic layer was separated and dried over anhydrous Na_2SO_4. After the removal of the solvent under vacuo, the residue was purified by flash column chromatography with PE/EtOAc (95 : 5) to give **2a** as white solid; yield: 26.4 mg (66%); m.p. 114-116 ^{o}C; TLC, R_f = 0.31 (PE:EtOAc = 95:5); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.93-7.90 (m, 2H), 7.86 (d, 2H, J = 7.6 Hz), 7.51-7.45 (m, 4H), 7.40-7.30 (m, 7H), 4.12 (q, 2H, J = 7.2 Hz), 0.97 (t, 3H, J = 7.2 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 183.3, 163.8, 156.6, 146.2, 137.2, 135.9, 132.5, 131.2, 130.3, 129.6, 128.7, 128.6, 128.2, 128.1, 127.8, 117.5, 61.2, 13.5; HRMS (ESI) m/z calcd. for $C_{26}H_{21}O_4$ $[M+H]^+$: 397.1434, found: 397.1438.

Synthesis of 3a: A 10 mL oven-dried reaction vessel was charged with Michael adduct of ethyl benzoylacetate with chalcone (**1a**, 40 mg, 0.1 mmol), TBAI (3.7 mg, 0.01 mmol) in THF (2.0 mL) under air. TBHP (5-6 M in decane) (39 mg, 0.3 mmol) was added slowly to the sealed reaction vessel by syringe, and the resulting solution was stirred at reflux for 2 h. After the reaction was complete, sat. $Na_2S_2O_3$ aqueous solution (10 mL) was added to quench the reaction, and the mixture was extracted by ethyl acetate (3 × 10 mL). The organic layer was separated and dried over anhydrous Na_2SO_4. After the removal of the solvent under vacuo, the residue was purified by flash column chromatography with PE/EtOAc (95 : 5) to give **3a** as white solid; yield: 30.3 mg (76%); m.p. 138-140 ^{o}C; TLC, R_f = 0.29 (PE:EtOAc = 95:5); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.05 (d, 2H, J = 7.2 Hz), 7.94 (d, 2H, J = 7.2 Hz), 7.60 (t, 1H, J = 7.2 Hz), 7.49 (t, 3H, J = 8.0 Hz), 7.46-7.42 (m, 2H), 7.35 (t, 4H, J = 8.0 Hz), 7.32-7.27(m, 1H), 4.56 (d, 1H, J =7.2 Hz), 4.02 (d, 1H, J = 7.2 Hz), 3.91-3.82 (m, 2H), 0.78 (t, 3H, J =7.2 Hz); ^{13}C

NMR ($CDCl_3$, 100 MHz): δ 194.0, 190.6, 166.8, 136.8, 136.6, 133.69, 133.66, 133.0, 128.8, 128.7, 128.52, 128.48, 128.4, 127.7, 62.0, 50.1, 36.8, 36.5, 13.6; HRMS (ESI) m/z calcd. for C26H23O4 [M+H]+: 399.1591, found: 399.1589.

Synthesis of 5a:[S5] A 10 mL oven-dried reaction vessel was charged with Michael adduct of ethyl malonate with chalcone (**4a**, 36.7 mg, 0.1 mmol), DBU (26 mg, 0.2 mmol), and NIS (2.3 mg, 0.01 mmol) in 1,4-dioxane (2.0 mL) under air. TBHP (70% in water) (26 mg, 0.2 mmol) was added slowly to the sealed reaction vessel by syringe, and the resulting solution was run at 50 ^oC for 2 h. After the reaction was complete, sat. $Na_2S_2O_3$ aqueous solution (10 mL) was added to quench the reaction, and the mixture was extracted by ethyl acetate (3 × 10 mL). The organic layer was separated and dried over anhydrous Na_2SO_4. After the removal of the solvent under vacuo, the residue was purified by flash column chromatography with PE/EtOAc (9 : 1) to give **5a** as colorless oil; yield: 29 mg (94%). colorless oil; TLC, R_f = 0.38 (PE:EtOAc = 90:10); ^1H NMR ($CDCl_3$, 400 MHz): δ 8.11 (d, 2H, J = 7.6 Hz), 7.62 (t, 1H, J = 7.2 Hz), 7.51 (t, 2H, J = 7.2 Hz), 7.32-7.26 (m, 5H), 4.17-4.10(m, 3H), 4.00 (q, 2H, J =6.8 Hz),3.80 (d, 1H, J = 7.6 Hz), 1.11 (t, 3H, J =7.2 Hz), 0.98 (t, 3H, J =7.2 Hz).

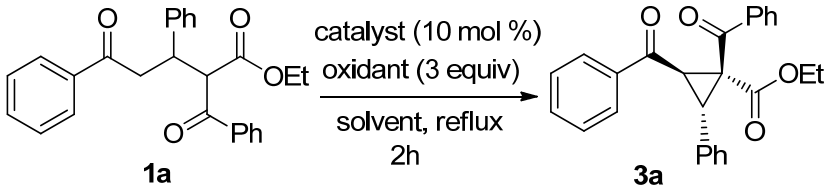
Table S1. Optimization of the reaction conditions for the synthesis of 2a[a]



entry	catalyst	base	oxidant	solvent	yield (%)[b]	
					2a	**3a**
1	NIS	DBU	TBHP	THF	55	42
2	–	DBU	TBHP	THF	0	0
3	NIS	–	TBHP	THF	0	0
4	NIS	DBU	TBHP	EtOAc	47	51
5	NIS	DBU	TBHP	$CHCl_3$	52	46
6	NIS	DBU	TBHP	1,4-dioxane	66	30
7	NIS	DBU	TBHP	1,4-dioxane/H_2O[c]	40	53
8[d]	NIS	DBU	TBHP	1,4-dioxane	63	36
9	I_2	DBU	TBHP	1,4-dioxane	52	41
10	TBAI	DBU	TBHP	1,4-dioxane	46	53
11	DIH	DBU	TBHP	1,4-dioxane	47	52
12	NIS	DBU	H_2O_2	1,4-dioxane	19	17
13	NIS	DBU	CHP[e]	1,4-dioxane	65	33
14	NIS	DABCO	TBHP	1,4-dioxane	trace	19
15	NIS	K_2CO_3	TBHP	1,4-dioxane	0	trace

[a] Reaction condition: **1a** (0.1 mmol), catalyst (0.01 mmol), TBHP (0.3 mmol), base (0.2 mmol), solvent (2 mL), stirred at 50 °C for 4-6 h. [b] Isolated yields. [c] V(1,4-dioxane):V(H_2O) = 3:1. [d] At room temperature, 19 h. [e] CHP = cumene hydrogen peroxide (80%-85% in water).

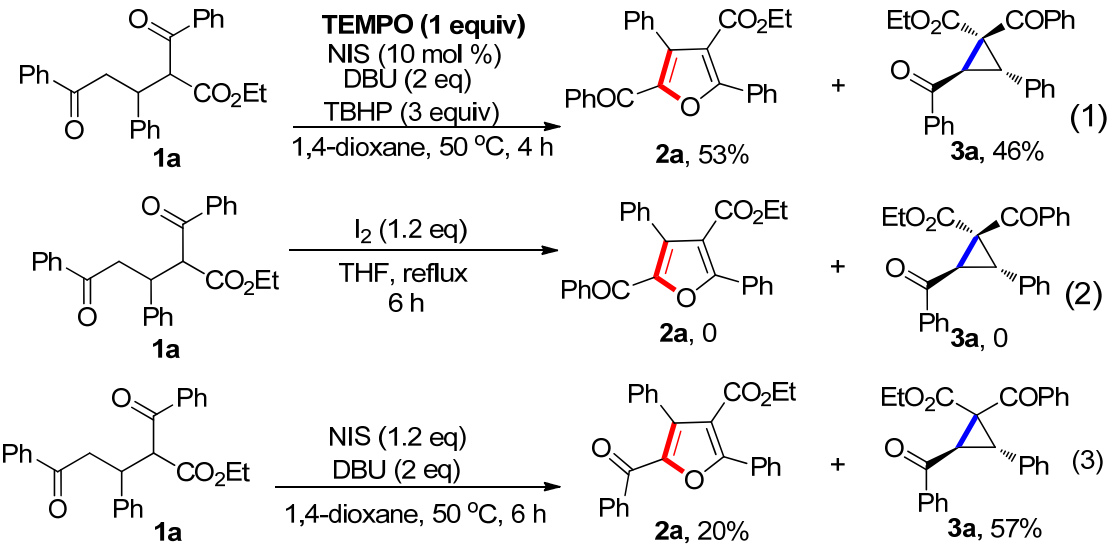
Table S2. Optimization of Reaction Conditions for the Synthesis of 3a[a]



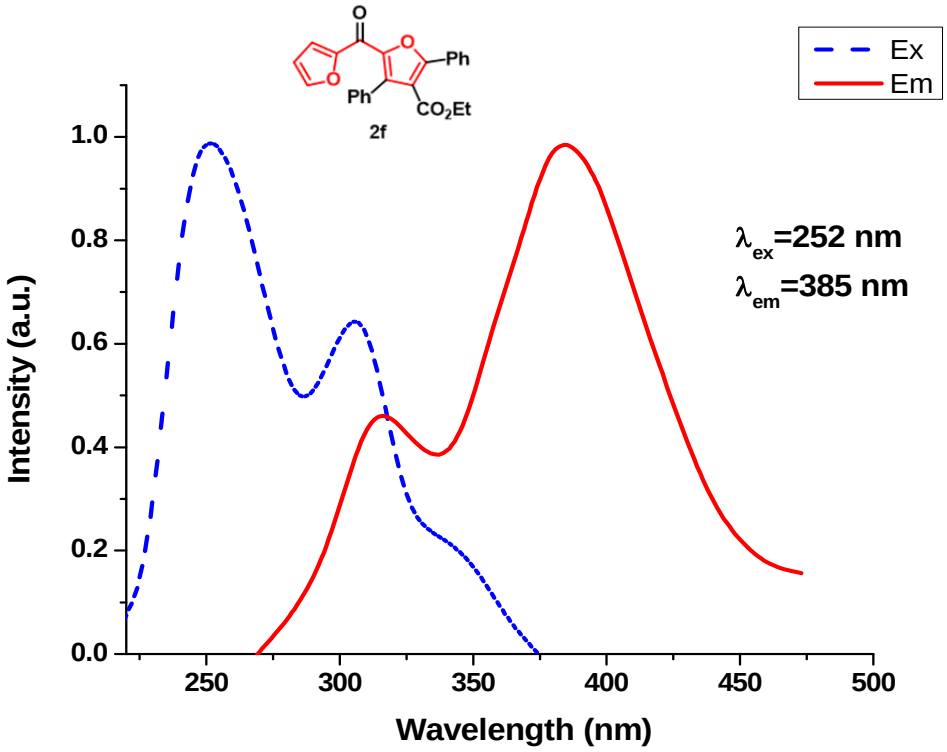
entry	catalyst	oxidant	solvent	yield (%)[b]	dr[c]
1	TBAI	TBHP	1,4-dioxane	45	> 19:1
2	TBAI	TBHP	DME	43	> 19:1
3	TBAI	TBHP	EtOAc	33	> 19:1
4	TBAI	TBHP	CH_3CN	29	> 19:1
5	TBAI	TBHP	DCE	28	> 19:1
6	**TBAI**	**TBHP**	**THF**	**76**	**> 19:1**
7	TBAI	TBPB	THF	N.R.	N.D.
8	TBAI	H_2O_2	THF	trace	N.D.
9[d]	TBAI	TBHP	THF	60	> 19:1
10[e]	TBAI	TBHP	THF	53	> 19:1
11[f]	TBAI	TBHP	THF	49	> 19:1

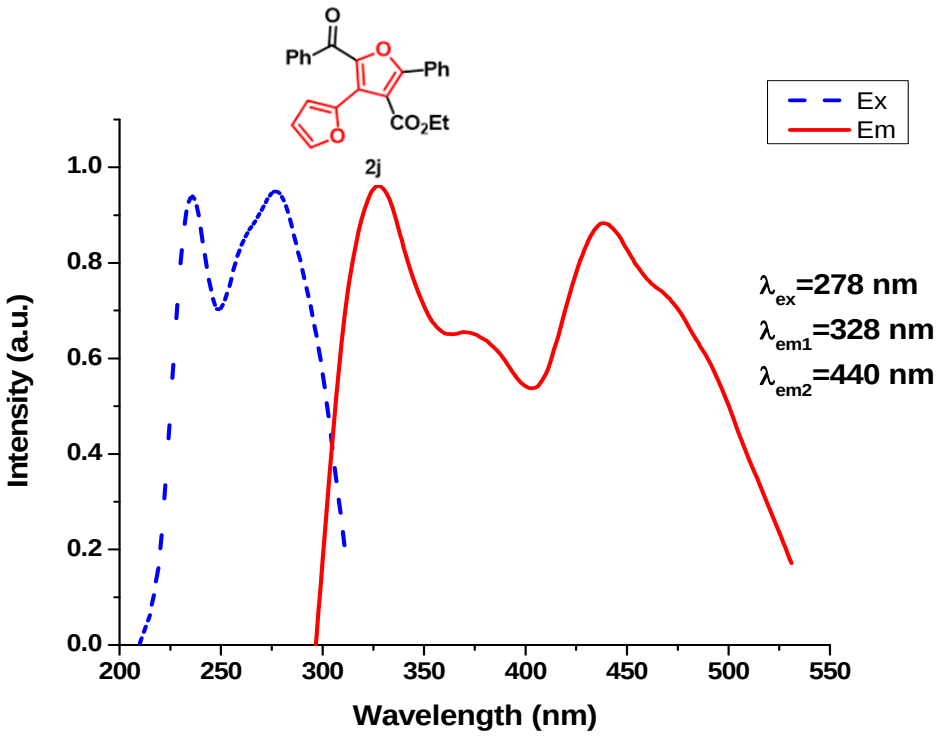
[a] Reaction condition: **1a** (0.1 mmol), catalyst (0.01 mmol), TBHP (0.3 mmol) (5-6 M in decane), solvent (1 mL), stirred at reflux for 2 h. [b] Isolated yields. [c] Determined by ^{1}H NMR. [d] TBHP (70% in water) was used. [e] The reaction was run at 60 °C. [f] The reaction was run at 50 °C.

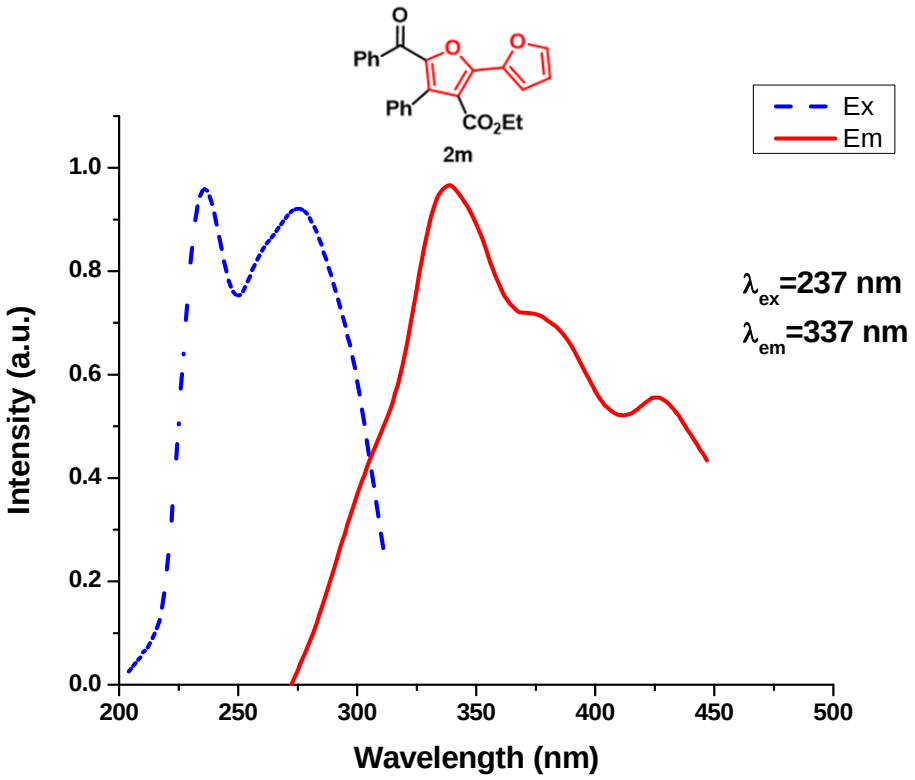
Experiments on Mechanism Study



Fluorescence Spectra of 2f, 2j and 2m

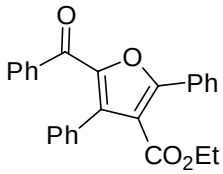






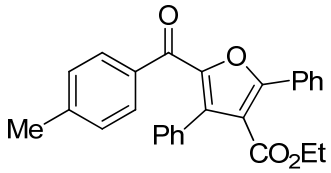
Characterization Data of Products

Ethyl 5-benzoyl-2,4-diphenylfuran-3-carboxylate (2a)



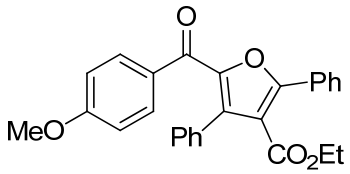
Yield: 26.4 mg (66%); time: 4 h; white solid; m.p. 114-116 ^{o}C; TLC, R_f = 0.31 (PE:EtOAc = 95:5); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.93-7.90 (m, 2H), 7.86 (d, 2H, J = 7.6 Hz), 7.51-7.45 (m, 4H), 7.40-7.30 (m, 7H), 4.12 (q, 2H, J = 7.2 Hz), 0.97 (t, 3H, J = 7.2 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 183.3, 163.8, 156.6, 146.2, 137.2, 135.9, 132.5, 131.2, 130.3, 129.6, 128.7, 128.6, 128.2, 128.1, 127.8, 117.5, 61.2, 13.5; HRMS (ESI) m/z calcd. for $C_{26}H_{21}O_4$ $[M+H]^+$: 397.1434, found: 397.1438.

Ethyl 5-(4-methylbenzoyl)-2,4-diphenylfuran-3-carboxylate (2b)



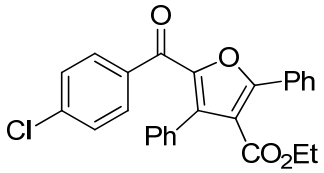
Yield: 25.4 mg (62%); time: 4 h; white solid; m.p. 152-154 ^{o}C; TLC, R_f = 0.33 (PE:EtOAc = 95:5); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.95-7.90 (m, 2H), 7.82 (d, 2H, J = 8.0 Hz), 7.50-7.45 (m, 3H), 7.40-7.36 (m, 2H), 7.35-7.31 (m, 3H), 7.19 (d, 2H, J = 8.4 Hz), 4.12 (q, 2H, J = 7.2 Hz), 2.39(s, 3H), 0.97 (t, 3H, J = 7.2 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 182.8, 163.9, 156.2, 143.4, 135.5, 134.5, 131.3, 130.2, 129.8, 129.5, 128.85, 128.77, 128.5, 128.01, 127.98, 127.7, 117.4, 61.2, 21.6, 13.5; HRMS (ESI) m/z calcd. for $C_{27}H_{23}O_4[M+H]^+$: 411.1591, found: 411.1600.

Ethyl 5-(4-methoxybenzoyl)-2,4-diphenylfuran-3-carboxylate (2c)



Yield: 21.7 mg (51%); time: 4 h; white solid; m.p. 95-97 ^{o}C; TLC, R_f = 0.16 (PE:EtOAc = 95:5); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.96-7.90 (m, 4H), 7.51-7.46 (m, 3H), 7.40-7.32 (m, 5H), 6.88 (d, 2H, J = 9.2 Hz), 4.12 (q, 2H, J = 7.2 Hz) , 3.85(s, 3H), 0.97 (t, 3H, J = 7.2 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 181.7, 163.9, 163.2, 156.1, 146.5, 135.1, 132.1, 131.4, 130.1, 129.8, 129.6, 128.8, 128.5, 128.01, 127.98, 127.8, 117.3, 113.5, 61.1, 55.4, 13.5; HRMS (ESI) m/z calcd. for $C_{27}H_{23}O_5$ $[M+H]^+$: 427.1540, found: 427.1539.

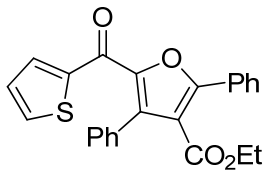
Ethyl 5-(4-chlorobenzoyl)-2,4-diphenylfuran-3-carboxylate (2d)



Yield: 22.8 mg (53%); time: 3 h; white solid; m.p. 79-81 ^{o}C; TLC, R_f = 0.36 (PE:EtOAc

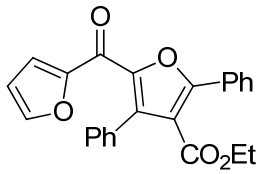
= 95:5); ^{1}H NMR ($CDCl_3$, 600 MHz): δ 7.93-7.89 (m, 2H), 7.82 (d, 2H, J = 8.4 Hz), 7.50-7.46 (m, 3H), 7.37-7.32 (m, 7H), 4.12 (q, 2H, J = 7.2 Hz) , 0.97 (t, 3H, J = 7.2 Hz); ^{13}C NMR ($CDCl_3$, 150 MHz): δ 181.8, 163.7, 156.7, 145.9, 138.9, 136.3, 135.5, 131.0, 130.9, 130.4, 129.5, 128.8, 128.6, 128.5, 128.4, 128.3, 128.0, 127.8, 117.6, 61.2, 13.5; HRMS (ESI) m/z calcd. for $C_{26}H_{20}ClO_4$ $[M+H]^+$: 431.1045, found: 431.1040.

Ethyl 2,4-diphenyl-5-(thiophene-2-carbonyl)furan-3-carboxylate (2e)



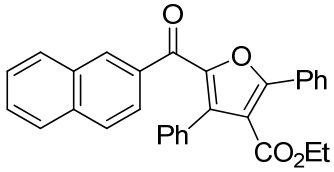
Yield: 25.8 mg (64%); time: 5.5 h; yellow solid; m.p. 101-104 ^{o}C; TLC, R_f = 0.23 (PE:EtOAc = 95:5); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.16 (d, 1H, J = 4.0 Hz), 8.01-7.96 (m, 2H), 7.71 (dd, 1H, J = 4.8, 0.8 Hz), 7.57-7.49 (m, 3H), 7.48-7.39 (m, 5H), 7.19 (t, 1H, J = 4.8 Hz), 4.11 (q, 2H, J = 7.2 Hz), 0.96 (t, 3H, J = 7.2 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 173.3, 163.7, 156.3, 145.5, 142.6, 136.1, 134.3, 134.1, 131.1, 130.3, 129.4, 128.7, 128.67, 128.2, 128.13, 128.10, 127.8, 118.0, 61.2, 13.5; HRMS (ESI) m/z calcd. for $C_{24}H_{19}O_4S$ $[M+H]^+$: 403.0999, found: 403.0998.

Ethyl 5-(furan-2-carbonyl)-2,4-diphenylfuran-3-carboxylate (2f)



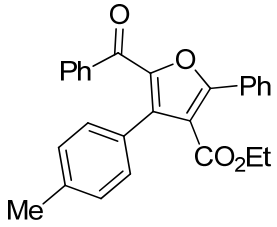
Yield: 23.2 mg (60%); time: 6 h; white solid; m.p. 116-119 ^{o}C; TLC, R_f = 0.25 (PE:EtOAc = 95:5); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.97-7.93 (m, 2H), 7.64 (d, 1H, J = 1.2 Hz), 7.55-7.48 (m, 4H), 7.47-7.36 (m, 5H), 6.58 (dd, 1H, J = 3.6, 1.6 Hz), 4.11 (q, 2H, J = 7.2 Hz), 0.96 (t, 3H, J = 7.2 Hz). ^{13}C NMR ($CDCl_3$, 100 MHz): δ 168.9, 163.7, 156.4, 151.1, 147.2, 145.2, 135.9, 130.9, 130.3, 129.5, 128.8, 128.7, 128.2, 128.0, 127.7, 120.3, 117.8, 112.3, 61.2, 13.5. HRMS (ESI) m/z calcd. for $C_{24}H_{19}O_5$ $[M+H]^+$: 387.1227, found: 387.1224.

Ethyl 5-(2-naphthoyl)-2,4-diphenylfuran-3-carboxylate (2g)



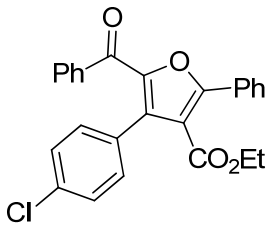
Yield: 24.8 mg (54%); time: 7 h; yellow solid; m.p. 96-99 ^{o}C; TLC, R_f = 0.30 (PE:EtOAc = 95:5); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.44 (s, 1H), 7.98-7.92 (m, 3H), 7.88-7.81 (m, 3H), 7.58 (t, 1H, J = 7.2 Hz), 7.52 (d, 1H, J = 8.0 Hz), 7.50-7.46 (m, 3H), 7.42-7.38 (m, 2H), 7.32-7.22 (m, 3H), 4.14 (q, 2H, J = 7.2 Hz), 0.99 (t, 3H, J = 7.2 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 183.1, 163.9, 156.5, 146.4, 135.8, 135.2, 134.4, 132.2, 131.7, 131.3, 130.3, 129.53, 129.47, 128.7, 128.6, 128.3, 128.1, 127.99, 127.97, 127.8, 127.7, 126.6, 125.2, 117.5, 61.2, 13.5; HRMS (ESI) m/z calcd. for $C_{30}H_{23}O_4$ $[M+H]^+$: 447.1591, found: 447.1597.

Ethyl 5-benzoyl-2-phenyl-4-(p-tolyl)furan-3-carboxylate (2h)



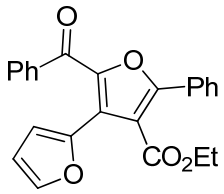
Yield: 21.7 mg (53%); time: 6.5 h; white solid; m.p. 126-128 ^{o}C; TLC, R_f = 0.38 (PE:EtOAc = 95:5); ^{1}H NMR ($CDCl_3$, 600 MHz): δ 7.91-7.87 (m, 4H), 7.52-7.45 (m, 4H), 7.38 (t, 2H, J = 7.8 Hz), 7.27 (d, 2H, J = 7.8 Hz), 7.14 (d, 2H, J = 7.8 Hz), 4.15 (q, 2H, J = 7.2 Hz), 2.36 (s, 3H), 1.03 (t, 3H, J = 7.2 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 183.2, 163.9, 156.3, 146.2, 138.0, 137.3, 136.0, 132.4, 130.2, 129.6, 129.4, 128.8, 128.54, 128.49, 128.1, 128.0, 117.5, 61.2, 21.3, 13.6; HRMS (ESI) m/z calcd. for $C_{27}H_{23}O_4$ $[M+H]^+$: 411.1591, found: 411.1595.

Ethyl 5-benzoyl-4-(4-chlorophenyl)-2-phenylfuran-3-carboxylate (2i)



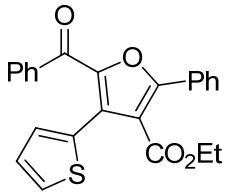
Yield: 29.4 mg (68%); time: 1.5 h; white solid; m.p. 131-133 ^{o}C; TLC, R_f = 0.34 (PE:EtOAc = 95:5); ^{1}H NMR ($CDCl_3$, 600 MHz): δ 7.90 (d, 4H, J = 7.2 Hz), 7.54 (t, 1H, J = 7.2 Hz), 7.49-7.47 (m, 3H), 7.41 (t, 2H, J = 7.8 Hz), 7.33 (s, 4H), 4.14 (q, 2H, J = 7.2 Hz), 1.03 (t, 3H, J = 7.2 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 183.0, 163.5, 156.9, 146.3, 137.0, 134.7, 134.2, 132.7, 131.0, 130.4, 129.7, 129.6, 128.6, 128.2, 128.1, 128.0, 117.2, 61.3, 13.6; HRMS (ESI) m/z calcd. for $C_{26}H_{20}ClO_4$ $[M+H]^+$: 431.1045, found: 431.1047.

Ethyl 2'-benzoyl-5'-phenyl-[2,3'-bifuran]-4'-carboxylate (2j)



Yield: 20.4 mg (53%); time: 5 h; white solid; m.p. 91-94 ^{o}C; TLC, R_f = 0.32 (PE:EtOAc = 95:5); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.99-7.93 (m, 2H), 7.84-7.79 (m, 2H), 7.57 (t, 1H, J = 7.2 Hz), 7.51-7.43 (m, 6H), 7.41 (dd, 1H, J = 3.2, 0.4 Hz), 6.49 (dd, 1H, J = 3.1, 1.6 Hz), 4.38 (q, 2H, J = 7.2 Hz), 1.28 (t, 3H, J = 7.2 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 182.9, 164.6, 154.7, 145.2, 144.3, 143.2, 137.6, 132.5, 130.2, 129.5, 128.8, 128.4, 128.3, 127.3, 124.8, 116.1, 114.0, 111.8, 61.8, 14.0; HRMS (ESI) m/z calcd. for $C_{24}H_{19}O_5$ $[M+H]^+$: 387.1227, found: 387.1222.

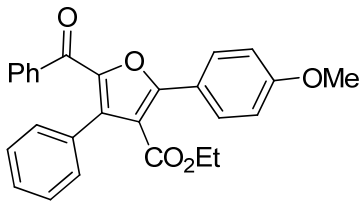
Ethyl 5-benzoyl-2-phenyl-4-(thiophen-2-yl)furan-3-carboxylate (2k)



Yield: 21.5 mg (53%); time: 5 h; yellow solid; m.p. 122-124 ^{o}C; TLC, R_f = 0.31 (PE:EtOAc = 95:5); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.90 (d, 2H, J = 7.2 Hz), 7.88-7.83 (m, 2H), 7.52 (t, 1H, J = 7.6 Hz), 7.49-7.45 (m, 3H), 7.44-7.36 (m, 3H), 7.22 (dd, 1H, J = 3.6, 1.2 Hz), 4.23 (q, 2H, J = 7.2 Hz), 1.13 (t, 3H, J = 7.2 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 183.1, 163.9, 155.9, 146.6, 137.1, 132.6, 130.7, 130.3, 129.6, 129.5, 128.6,

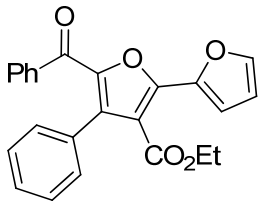
128.5, 128.2, 128.1, 127.8, 127.4, 126.7, 117.7, 61.6, 13.7; HRMS (ESI) m/*z* calcd. for $C_{24}H_{19}O_4S$ $[M+H]^+$: 403.0999, found: 403.0999.

Ethyl 5-benzoyl-2-(4-methoxyphenyl)-4-phenylfuran-3-carboxylate (2l)



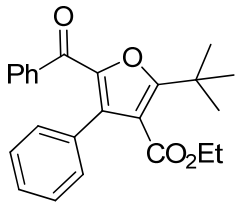
Yield: 23.5 mg (55%); time: 5 h; white solid; m.p. 155-157 ^oC; TLC, R_f = 0.16 (PE:EtOAc = 95:5); ^1H NMR ($CDCl_3$, 600 MHz): δ 7.91 (d, 2H, J = 9.0 Hz), 7.86-7.82 (m, 2H), 7.47 (t, 1H, J = 7.2 Hz), 7.38-7.30 (m, 7H), 6.99 (d, 2H, J = 9.0 Hz), 4.09 (q, 2H, J = 7.2 Hz), 3.87 (s, 3H), 0.95 (t, 3H, J = 7.2 Hz); ^{13}C NMR ($CDCl_3$, 150 MHz): δ 183.2, 164.0, 161.3, 157.1, 145.9, 137.4, 136.1, 132.3, 131.6, 129.8, 129.6, 129.5, 128.04, 127.99, 127.7, 121.4, 116.3, 114.1, 61.0, 55.4, 13.5; HRMS (ESI) m/*z* calcd. for $C_{27}H_{23}O_5$ $[M+H]^+$: 427.1540, found: 427.1534.

Ethyl 5-benzoyl-4-phenyl-[2,2'-bifuran]-3-carboxylate (2m)



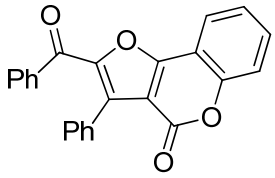
Yield: 20 mg (50%); time: 9 h; yellow oil; TLC, R_f = 0.25 (PE:EtOAc = 95:5); ^1H NMR ($CDCl_3$, 600 MHz): δ 7.89 (d, 2H, J = 7.2 Hz), 7.62 (d, 1H, J = 1.2 Hz), 7.50-7.45 (m, 2H), 7.36 (t, 2H, J = 7.8 Hz), 7.32-7.29 (m, 5H), 6.58 (dd, 1H, J = 3.6, 1.8 Hz), 4.13 (q, 2H, J = 7.2 Hz), 0.98 (t, 3H, J = 7.2 Hz); ^{13}C NMR ($CDCl_3$, 150 MHz): δ 182.9, 162.8, 148.8, 146.1, 144.7, 143.8, 137.1, 135.6, 132.5, 131.3, 129.66, 129.64, 128.1, 128.0, 127.6, 115.6, 114.8, 112.2, 60.9, 13.6; HRMS (ESI) m/*z* calcd. for $C_{24}H_{19}O_5$ $[M+H]^+$: 387.1227, found: 387.1223.

Ethyl 5-benzoyl-2-(tert-butyl)-4-phenylfuran-3-carboxylate (2n)



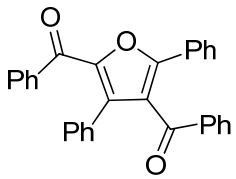
Yield: 15.5 mg (41%); time: 5 h; colorless oil; TLC, R_f = 0.34 (PE:EtOAc = 95:5); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.84 (d, 2H, J = 7.2 Hz), 7.47 (t, 1H, J = 8.4 Hz), 7.35 (t, 2H, J = 7.6 Hz), 7.33-7.26 (m, 5H), 4.09 (q, 2H, J = 7.2 Hz), 1.47 (s, 9H), 1.00 (t, 3H, J = 7.2 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 182.9, 165.8, 164.7, 144.5, 137.3, 135.3, 132.3, 131.4, 129.5, 129.3, 128.0, 127.7, 117.1, 61.1, 34.8, 28.6, 13.6; HRMS (ESI) m/z calcd. for $C_{24}H_{25}O_4[M+H]^+$: 377.1747, found: 377.1748.

2-Benzoyl-3-phenyl-4H-furo[3,2-c]chromen-4-one (2o)



Yield: 26 mg (71%); time: 1.5 h; white solid; m.p. 147-149 ^{o}C; TLC, R_f = 0.08 (PE:EtOAc = 95:5); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.04 (dd, 1H, J = 8.0, 1.2 Hz), 7.75 (d, 2H, J = 7.6 Hz), 7.63 (t, 1H, J = 7.2 Hz), 7.50-7.39 (m, 5H), 7.34-7.27 (m, 5H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 184.0, 158.6, 156.8, 153.7, 147.9, 136.4, 133.1, 132.9, 132.5, 130.5, 129.6, 129.1, 128.14, 128.11, 127.8, 124.8, 122.0, 117.4, 112.0, 110.1; HRMS (ESI) m/z calcd. for $C_{24}H_{15}O_4$ $[M+H]^+$: 367.0965, found: 367.0969.

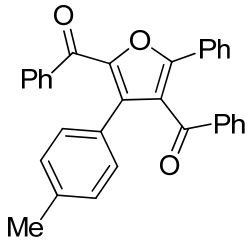
(3,5-Diphenylfuran-2,4-diyl)bis(phenylmethanone) (2p)



Yield: 35 mg (81%); time: 6 h; white solid; m.p. 70-72 ^{o}C; TLC, R_f = 0.41 (PE:EtOAc = 95:5); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.88 (d, 2H, J = 7.6 Hz), 7.77 (d, 2H, J = 8.0 Hz), 7.69-7.64 (m, 2H), 7.47 (t, 1H, J = 7.2 Hz), 7.41 (t, 1H, J = 7.2 Hz), 7.38-7.27 (m, 6H), 7.26-7.21 (m, 3H), 7.12-7.07 (m, 3H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 192.7, 183.5,

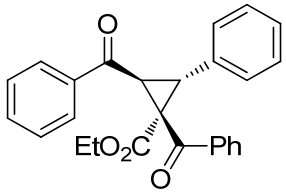
153.9, 145.8, 137.2, 136.8, 136.1, 133.8, 132.5, 130.3, 130.0, 129.71, 129.69, 129.65, 128.8, 128.5, 128.4, 128.3, 128.1, 127.9, 126.9, 123.7; HRMS (ESI) m/*z* calcd. for $C_{30}H_{21}O_3$ $[M+H]^+$: 429.1485, found: 429.1475.

(5-Phenyl-3-(p-tolyl)furan-2,4-diyl)bis(phenylmethanone) (2q)



Yield: 34 mg (77%); time: 4 h; white solid; m.p. 73-75 ^oC; TLC, R_f = 0.36 (PE:EtOAc = 95:5); ^1H NMR ($CDCl_3$, 600 MHz): δ 7.94 (d, 2H, J = 7.2 Hz), 7.82 (t, 2H, J = 7.2 Hz), 7.66 (dd, 2H, J = 6.0, 3.6 Hz), 7.51 (t, 1H, J = 7.2 Hz), 7.45 (t, 1H, J = 7.2 Hz), 7.40 (t, 2H, J = 7.8 Hz), 7.34-7.28 (m, 5H), 7.18 (d, 2H, J = 7.8 Hz), 6.95 (d, 2H, J = 7.8 Hz), 2.21 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz): δ 195.7, 186.3, 156.5, 148.8, 141.0, 140.4, 139.9, 139.1, 136.6, 135.3, 132.7, 132.6, 132.5, 131.7, 131.5, 131.4, 131.0, 130.2, 129.9, 126.8, 24.1; HRMS (ESI) m/*z* calcd. for $C_{31}H_{23}O_3$ $[M+H]^+$: 443.1642, found: 443.1643.

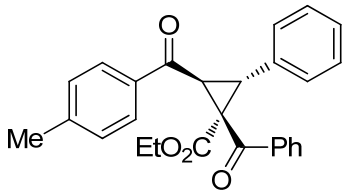
Ethyl 1,2-dibenzoyl-3-phenylcyclopropanecarboxylate (3a)



Yield: 30.3 mg (76%); time: 2 h; white solid; m.p. 138-140 ^oC; TLC, R_f = 0.29 (PE:EtOAc = 95:5); ^1H NMR ($CDCl_3$, 400 MHz): δ 8.05 (d, 2H, J = 7.2 Hz), 7.94 (d, 2H, J = 7.2 Hz), 7.60 (t, 1H, J = 7.2 Hz), 7.49 (t, 3H, J = 8.0 Hz), 7.46-7.42 (m, 2H), 7.35 (t, 4H, J = 8.0 Hz), 7.32-7.27(m, 1H), 4.56 (d, 1H, J =7.2 Hz), 4.02 (d, 1H, J = 7.2 Hz), 3.91-3.82 (m, 2H), 0.78 (t, 3H, J =7.2 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 194.0, 190.6, 166.8, 136.8, 136.6, 133.69, 133.66, 133.0, 128.8, 128.7, 128.52, 128.48, 128.4, 127.7, 62.0, 50.1, 36.8, 36.5, 13.6; HRMS (ESI) m/z calcd. for C26H23O4 [M+H]+: 399.1591, found: 399.1589.

Ethyl 1-benzoyl-2-(4-methylbenzoyl)-3-phenylcyclopropanecarboxylate

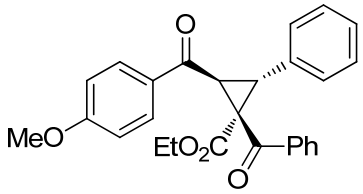
(3b)



Yield: 30.5 mg (74%); time: 2 h; white solid; m.p. 100-102 ^{o}C; TLC, R_f = 0.31 (PE:EtOAc = 95:5); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 7.94 (t, 4H, J = 8.0 Hz), 7.49-7.45 (m, 1H), 7.44-7.41 (m, 2H), 7.35 (t, 4H, J = 8.0 Hz), 7.31-7.27 (m, 3H), 4.54 (d, 1H, J = 7.2 Hz), 4.01 (d, 1H, J = 7.2 Hz), 3.90-3.80 (m, 2H), 2.43 (s, 3H), 0.77 (t, 3H, J =7.2 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 193.5, 190.7, 166.8, 144.6, 136.6, 134.4, 133.8, 133.0, 129.4, 128.7, 128.5, 128.4, 127.6, 62.0, 49.9, 36.7, 36.5, 21.7, 13.6; HRMS (ESI) m/z calcd. for C27H25O4 [M+H]+: 413.1747, found: 413.1739.

Ethyl 1-benzoyl-2-(4-methoxybenzoyl)-3-phenylcyclopropanecarboxylate

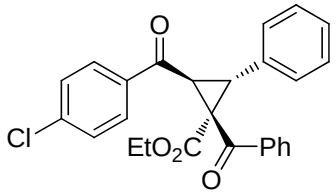
(3c)



Yield: 30 mg (70%); time: 1.5 h; white solid; m.p. 110-112 ^{o}C; TLC, R_f = 0.14 (PE:EtOAc = 95:5); ^{1}H NMR ($CDCl_3$, 600 MHz): δ 8.04 (d, 2H, J = 9.0 Hz), 7.93 (dd, 2H, J = 7.8, 1.8 Hz), 7.46 (tt, 1H, J = 7.2, 1.2 Hz), 7.42 (d, 2H, J = 7.2 Hz), 7.37-7.33 (m, 4H), 7.28 (tt, 1H, J = 7.2, 1.2 Hz), 4.51 (d, 1H, J = 7.8 Hz), 4.01 (d, 1H, J = 7.2 Hz), 3.88 (s, 3H), 3.87-3.84 (m, 2H), 0.77 (t, 3H, J =7.2 Hz); ^{13}C NMR ($CDCl_3$, 150 MHz): δ 192.1, 190.7, 166.9, 164.0, 136.8, 134.0, 132.9, 130.9, 130.0, 128.7, 128.41, 128.39, 128.3, 127.6, 114.0, 61.9, 55.5, 49.9, 36.5, 36.4, 13.5. HRMS (ESI) m/z calcd. for C27H25O5 [M+H]+: 429.1697, found: 429.1687.

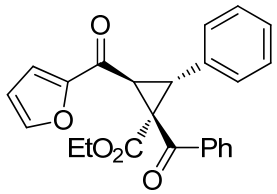
Ethyl 1-benzoyl-2-(4-chlorobenzoyl)-3-phenylcyclopropanecarboxylate

(3d)



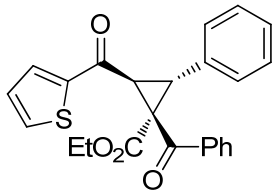
Yield: 30 mg (69%); time: 2 h; white solid; m.p. 151-153 ^{o}C; TLC, R_f = 0.29 (PE:EtOAc = 95:5); ^{1}H NMR ($CDCl_3$, 600 MHz): δ 7.98 (d, 2H, J = 9.0 Hz), 7.92 (d, 2H, J = 7.2 Hz), 7.50-7.45 (m, 3H), 7.41 (d, 2H, J = 7.2 Hz), 7.38-7.34 (m, 4H), 7.30 (t, 1H, J = 7.2 Hz), 4.47 (d, 1H, J = 7.2 Hz), 4.01 (d, 1H, J = 7.8 Hz), 3.90-3.84 (m, 2H), 0.79 (t, 3H, J =7.2 Hz); ^{13}C NMR ($CDCl_3$, 150 MHz): δ 192.8, 190.4, 166.7, 140.3, 136.6, 135.3, 133.6, 133.1, 130.0, 129.1, 128.6, 128.5, 128.45, 128.42, 127.8, 62.1, 50.4, 36.8, 36.4, 13.6. HRMS (ESI) m/z calcd. for $C_{26}H_{22}ClO_4$ $[M+H]^+$: 433.1201, found: 433.1195.

Ethyl 1-benzoyl-2-(furan-2-carbonyl)-3-phenylcyclopropanecarboxylate (3e)



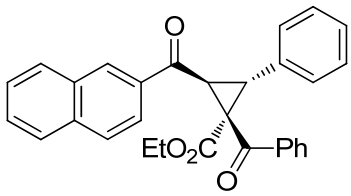
Yield: 23.7 mg (61%); time: 2 h; white solid; m.p. 107-109 ^{o}C; TLC, R_f = 0.23 (PE:EtOAc = 95:5); ^{1}H NMR ($CDCl_3$, 600 MHz): δ 7.92 (dd, 2H, J = 8.4, 1.2 Hz), 7.68 (d, 1H, J = 0.6 Hz), 7.47 (t, 1H, J = 7.2 Hz), 7.42 (d, 2H, J = 7.2 Hz), 7.36 (t, 2H, J = 7.8 Hz), 7.34 (t, 2H, J = 7.8 Hz), 7.30-7.27 (m, 2H), 6.58 (dd, 1H, J =3.6, 1.2 Hz), 4.47 (d, 1H, J = 7.8 Hz), 4.00 (d, 1H, J = 7.8 Hz), 3.91-3.83 (m, 2H), 0.79 (t, 3H, J = 7.2 Hz); ^{13}C NMR ($CDCl_3$, 150 MHz): δ 190.1, 182.4, 166.6, 152.9, 147.1, 136.5, 133.8, 133.0, 128.8, 128.5, 128.4, 128.3, 127.6, 118.0, 112.7, 62.0, 49.8, 36.2, 36.1, 13.6. HRMS (ESI) m/z calcd. for C24H21O5 [M+H]+: 389.1384, found: 389.1375.

Ethyl 1-benzoyl-2-phenyl-3-(thiophene-2-carbonyl)cyclopropane carboxylate (3f)



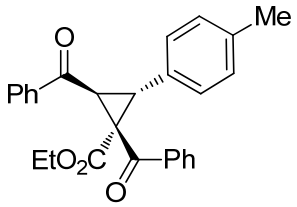
Yield: 23.7 mg (58%); time: 1.5 h; yellow solid; m.p. 86-88 ^{o}C; TLC, R_f = 0.21 (PE:EtOAc = 95:5); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.01 (d, 1H, J = 4.2 Hz), 7.93 (d, 2H, J = 7.8 Hz), 7.69 (d, 1H, J = 5.4 Hz), 7.47 (t, 1H, J = 7.2 Hz), 7.42 (d, 2H, J = 7.2 Hz), 7.38-7.32 (m, 4H), 7.29 (t, 1H, J = 7.2 Hz), 7.20 (t, 1H, J = 4.2 Hz), 4.40 (d, 1H, J = 7.8 Hz), 4.02 (d, 1H, J =7.2 Hz), 3.90-3.83 (m, 2H), 0.79 (t, 3H, J = 7.2 Hz); ^{13}C NMR ($CDCl_3$, 150 MHz): δ 190.2, 186.1, 166.7, 144.1, 136.6, 134.8, 133.7, 133.0, 132.9, 128.7, 128.6, 128.5, 128.4, 127.7, 62.0, 49.8, 37.2, 36.5, 13.6. HRMS (ESI) m/z calcd. for $C_{24}H_{21}O_4S$ [M+H]+: 405.1155, found: 405.1142.

Ethyl 2-(2-naphthoyl)-1-benzoyl-3-phenylcyclopropanecarboxylate (3g)



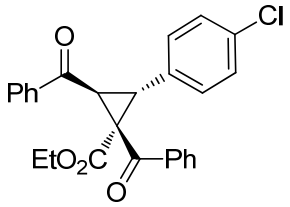
Yield: 27.8 mg (62%); time: 1.5 h; white solid; m.p. 88-90 ^{o}C; TLC, R_f = 0.27 (PE:EtOAc = 95:5); ^{1}H NMR ($CDCl_3$, 600 MHz): δ 8.67 (s, 1H), 8.03 (d, 1H, J = 7.8 Hz), 8.00 (dd, 1H, J = 9.0, 1.2 Hz), 7.96 (d, 2H, J = 7.6 Hz), 7.89 (d, 2H, J = 9.0 Hz), 7.63 (t, 1H, J = 7.2 Hz), 7.59 (t, 1H, J = 7.2 Hz), 7.48 (d, 2H, J = 7.8 Hz), 7.44 (t, 1H, J = 7.2 Hz), 7.38 (t, 2H, J = 7.2 Hz), 7.35-7.30 (m, 3H), 4.72 (d, 1H, J = 7.8 Hz), 4.09 (d, 1H, J = 7.8 Hz), 3.94-3.86 (m, 2H), 0.81 (t, 3H, J =7.2 Hz); ^{13}C NMR ($CDCl_3$, 150 MHz): δ 193.8, 190.6, 166.9, 136.7, 135.9, 134.4, 133.9, 133.0, 132.5, 130.5, 130.0, 128.8, 128.7, 128.6, 128.5, 128.4, 127.8, 127.7, 127.0, 124.0, 62.0, 50.3, 36.9, 36.6, 13.6. HRMS (ESI) m/z calcd. for $C_{30}H_{25}O_4$ $[M+H]^+$: 449.1747, found: 449.1734.

Ethyl 1,2-dibenzoyl-3-(p-tolyl)cyclopropanecarboxylate (3h)



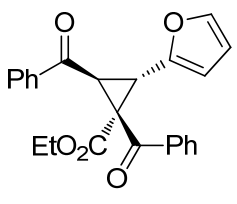
Yield: 32.5 mg (79%); time: 1 h; white solid; m.p. 97-99 ^{o}C; TLC, R_f = 0.36 (PE:EtOAc = 95:5); ^{1}H NMR ($CDCl_3$, 600 MHz): δ 8.04 (dd, 2H, J = 8.4, 1.2 Hz), 7.93 (dd, 2H, J = 8.4, 1.2 Hz), 7.60 (t, 1H, J = 7.2 Hz), 7.50-7.45 (m, 3H), 7.35 (t, 2H, J = 7.8 Hz), 7.31 (d, 2H, J = 8.4 Hz), 7.15 (d, 2H, J = 7.8 Hz), 4.51 (d, 1H, J = 7.2 Hz), 3.98 (d, 1H, J = 7.2 Hz), 3.88 (q, 2H, J = 7.2 Hz), 2.34 (s, 3H), 0.80 (t, 3H, J =7.2 Hz); ^{13}C NMR ($CDCl_3$, 150 MHz): δ 194.0, 190.8, 166.9, 137.4, 137.0, 136.8, 133.6, 132.9, 130.7, 129.1, 128.7, 128.5, 128.4, 61.9, 50.2, 36.8, 36.7, 21.1, 13.6. HRMS (ESI) m/z calcd. for $C_{27}H_{25}O_4$ $[M+H]^+$: 413.1747, found: 417.1730.

Ethyl 1,2-dibenzoyl-3-(4-chlorophenyl)cyclopropanecarboxylate (3i)



Yield: 31.1 mg (72%); time: 1 h; white solid; m.p. 119-121 ^{o}C; TLC, R_f = 0.32 (PE:EtOAc = 95:5); ^{1}H NMR ($CDCl_3$, 600 MHz): δ 8.02 (dd, 2H, J = 7.2, 1.2 Hz), 7.90 (dd, 2H, J = 7.2, 1.2 Hz), 7.61 (tt, 1H, J = 7.2, 1.2 Hz), 7.51-7.45 (m, 3H), 7.38-7.31 (m, 6H), 4.52 (d, 1H, J = 7.8 Hz), 3.98 (d, 1H, J = 7.2 Hz), 3.89 (q, 2H, J = 7.2 Hz), 0.81 (t, 3H, J = 7.2 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 193.6, 190.2, 166.6, 136.7, 136.4, 133.8, 133.6, 133.1, 132.3, 130.0, 128.8, 128.6, 128.5, 128.3, 62.2, 50.1, 36.5, 35.9, 13.6. HRMS (ESI) m/z calcd. for $C_{26}H_{22}ClO_4$ $[M+H]^+$: 433.1201, found: 433.1200.

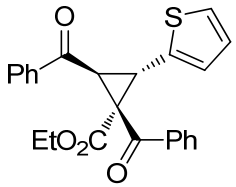
Ethyl 1,2-dibenzoyl-3-(furan-2-yl)cyclopropanecarboxylate (3j)



Yield: 20.2 mg (52%); time: 1 h; yellow oil; TLC, R_f = 0.30 (PE:EtOAc = 95:5); ^{1}H

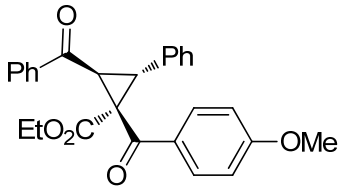
NMR ($CDCl_3$, 600 MHz): δ 8.04 (d, 2H, J = 7.2 Hz), 7.96 (d, 2H, J = 7.8 Hz), 7.60 (t, 1H, J = 7.2 Hz), 7.51-7.47 (m, 3H), 7.41-7.36 (m, 3H), 6.38-6.33 (m, 2H), 4.43 (d, 1H, J = 7.2 Hz), 4.05-3.97 (m, 2H), 3.88 (d, 1H, J = 7.2 Hz), 0.93 (t, 3H, J = 7.2 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 193.3, 190.3, 166.6, 148.4, 142.3, 136.8, 136.6, 133.7, 133.1, 128.74, 128.67, 128.6, 128.5, 110.7, 108.5, 62.2, 49.0, 36.6, 29.5, 13.6. HRMS (ESI) m/z calcd. for $C_{24}H_{21}O_5$ $[M+H]^+$: 389.1384, found: 389.1381.

Ethyl 1,2-dibenzoyl-3-(thiophen-2-yl)cyclopropanecarboxylate (3k)



Yield: 25.4 mg (63%); time: 2 h; white solid; m.p. 151-153 ^{o}C; TLC, R_f = 0.29 (PE:EtOAc = 95:5); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.04 (d, 2H, J = 8.0 Hz), 7.94 (d, 2H, J = 8.0 Hz), 7.61 (t, 1H, J = 7.2 Hz), 7.49 (t, 3H, J = 7.2 Hz), 7.38 (t, 2H, J = 7.2 Hz), 7.24 (d, 1H, J = 5.2 Hz), 7.10-7.05 (m, 1H), 7.01-6.96 (m, 1H), 4.48 (d, 1H, J = 7.2 Hz), 4.05 (d, 1H, J = 7.2 Hz), 3.99-3.91 (m, 2H), 0.87 (t, 3H, J = 7.2 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 193.4, 190.4, 166.5, 136.6, 136.5, 133.8, 133.1, 128.8, 128.6, 128.5, 128.4, 126.9, 126.8, 125.2, 62.2, 50.4, 38.4, 31.6, 13.6. HRMS (ESI) m/z calcd. for $C_{24}H_{21}O_4S$ [M+H]+: 405.1155, found: 405.1156.

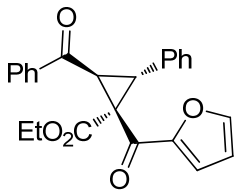
Ethyl 2-benzoyl-1-(4-methoxybenzoyl)-3-phenylcyclopropanecarboxylate (3l)



Yield: 28.2 mg (66%); time: 1.5 h; white solid; m.p. 116-118 ^{o}C; TLC, R_f = 0.14 (PE:EtOAc = 95:15); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.05 (d, 2H, J = 7.2 Hz), 7.92 (dt, 2H, J = 9.2, 2.4 Hz), 7.60 (tt, 1H, J = 7.2, 1.2 Hz), 7.49 (t, 2H, J = 7.2 Hz), 7.42 (d, 2H, J = 6.8 Hz), 7.34 (t, 2H, J = 7.2 Hz), 7.29 (dt, 1H, J = 7.2, 1.2 Hz), 6.82 (d, 2H, J = 8.8 Hz), 4.53 (d, 1H, J = 7.2 Hz), 4.01 (d, 1H, J = 7.2 Hz), 3.92-3.85 (m, 2H), 3.80 (s, 3H),

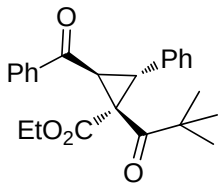
0.81 (t, 3H, J =7.2 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 194.0, 188.9, 167.0, 163.4, 137.0, 133.9, 133.6, 130.7, 129.6, 128.7, 128.66, 128.5, 128.3, 127.6, 113.7, 62.0, 55.4, 50.4, 36.6, 36.0, 13.7. HRMS (ESI) m/z calcd. for $C_{27}H_{25}O_5$ $[M+H]^+$: 429.1697, found: 436.1689.

Ethyl 2-benzoyl-1-(furan-2-carbonyl)-3-phenylcyclopropanecarboxylate (3m)



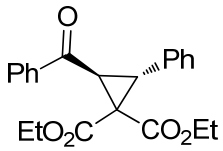
Yield: 19.4 mg (50%); time: 6 h; white solid; m.p. 92-94 ^{o}C; TLC, R_f = 0.23 (PE:EtOAc = 90:10); ^{1}H NMR ($CDCl_3$, 600 MHz): δ 8.06 (dt, 2H, J = 7.8, 1.2 Hz), 7.59 (tt, 1H, J = 9.0, 1.2 Hz), 7.48 (t, 2H, J = 7.8 Hz), 7.42-7.38 (m, 3H), 7.33 (t, 2H, J = 7.2 Hz), 7.28 (t, 1H, J = 7.2 Hz), 7.21 (dd, 1H, J = 3.6, 0.6 Hz), 6.43 (dd, 1H, J = 3.6, 1.8 Hz), 4.44 (d, 1H, J = 7.2 Hz), 4.07 (d, 1H, J = 7.2 Hz), 3.97-3.92 (m, 2H), 0.88 (t, 3H, J = 7.2 Hz); ^{13}C NMR ($CDCl_3$, 150 MHz): δ 193.8, 179.2, 166.2, 152.7, 146.0, 137.0, 133.8, 133.5, 128.8, 128.6, 128.5, 128.3, 127.6, 117.2, 112.4, 61.9, 49.6, 36.2, 35.7, 13.8. HRMS (ESI) m/z calcd. for $C_{24}H_{21}O_5$ $[M+H]^+$: 389.1384, found: 389.1373.

Ethyl 2-benzoyl-3-phenyl-1-pivaloylcyclopropanecarboxylate (3n)



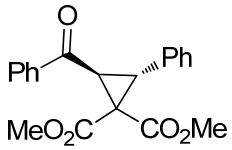
Yield: 20 mg (53%); time: 4 h; colorless oil; TLC, R_f = 0.32 (PE:EtOAc = 95:5); ^{1}H NMR ($CDCl_3$, 600 MHz): δ 8.12 (d, 2H, J = 7.8 Hz), 7.64 (t, 1H, J = 7.2 Hz), 7.54 (t, 2H, J = 7.8 Hz), 7.33-7.28 (m, 4H), 7.26-7.23 (m, 1H), 4.33 (d, 1H, J = 7.2 Hz), 3.99 (d, 1H, J = 7.2 Hz), 3.93-3.88 (m, 2H), 1.18 (s, 9H), 0.97 (t, 3H, J = 7.2 Hz); ^{13}C NMR ($CDCl_3$, 150 MHz): δ 206.2, 194.5, 166.4, 137.1, 133.9, 133.6, 128.9, 128.7, 128.6, 128.2, 127.5, 61.9, 52.4, 45.1, 36.5, 35.4, 28.1, 13.7. HRMS (ESI) m/z calcd. for $C_{24}H_{27}O_4$ $[M+H]^+$: 379.1904 found: 379.1896.

Diethyl 2-benzoyl-3-phenylcyclopropane-1,1-dicarboxylate (5a)[S5]



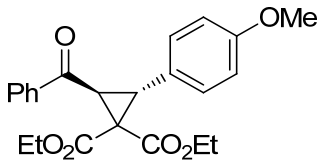
Yield: 34.4 mg (94%); time: 2 h; colorless oil; TLC, R_f = 0.38 (PE:EtOAc = 90:10); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.11 (d, 2H, J = 7.6 Hz), 7.62 (t, 1H, J = 7.2 Hz), 7.51 (t, 2H, J = 7.2 Hz), 7.32-7.26 (m, 5H), 4.17-4.10(m, 3H), 4.00 (q, 2H, J =6.8 Hz),3.80 (d, 1H, J = 7.6 Hz), 1.11 (t, 3H, J =7.2 Hz), 0.98 (t, 3H, J =7.2 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 193.6, 165.9, 165.7, 136.7, 136.6, 133.6, 133.4, 128.7, 128.58, 128.57, 128.3, 127.7, 62.0, 61.9, 46.0, 35.8, 34.9, 13.83, 13.78.

Dimethyl 2-benzoyl-3-phenylcyclopropane-1,1-dicarboxylate (5b)[S5]



Yield: 31.4 mg (93%); time: 1.5 h; colorless oil; TLC, R_f = 0.26 (PE:EtOAc = 90:10); ^{1}H NMR ($CDCl_3$, 600 MHz): δ 8.10 (d, 2H, J = 7.2 Hz), 7.62 (t, 1H, J = 7.2 Hz), 7.52 (t, 2H, J = 7.8 Hz), 7.34-7.26 (m, 5H), 4.14(d, 1H, J = 7.8 Hz), 3.88 (d, 1H, J =7.8 Hz),3.72 (s, 3H), 3.54 (s, 3H); ^{13}C NMR ($CDCl_3$, 150 MHz): δ 193.8, 166.5, 166.1, 136.8, 133.7, 133.4, 128.8, 128.53, 128.49, 128.4, 127.8, 53.0, 52.9, 46.0, 36.6, 35.1;

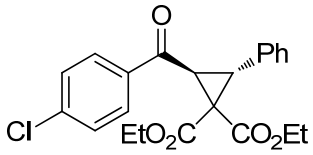
Diethyl 2-benzoyl-3-(4-methoxyphenyl)cyclopropane-1,1-dicarboxylate (5c)[S5]



Yield: 36.8 mg (93%); time: 2 h; colorless oil; TLC, R_f = 0.31 (PE:EtOAc = 90:10); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.10 (d, 2H, J = 7.2 Hz), 7.61 (t, 1H, J = 7.2 Hz), 7.51 (t, 2H, J = 7.6 Hz), 7.23 (d, 2H, J = 8.4 Hz), 6.83 (d, 2H, J = 8.4 Hz), 4.13(q, 2H, J = 7.2 Hz), 4.07 (d, 1H, J =7.6 Hz), 4.05-3.98 (m, 2H), 3.82 (d, 1H, J = 7.6 Hz), 3.79 (s, 3H), 1.11 (t, 3H, J =7.2 Hz), 1.03 (t, 3H, J =7.2 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 193.7,

166.0, 165.8, 159.1, 136.8, 133.6, 129.7, 128.7, 128.6, 125.4, 113.7, 62.0, 61.8, 55.2, 46.1, 35.4, 35.2, 13.88, 13.84.

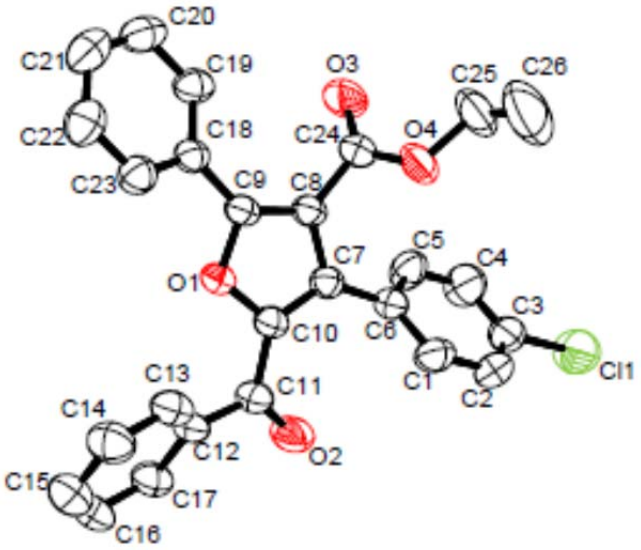
Diethyl 2-(4-chlorobenzoyl)-3-phenylcyclopropane-1,1-dicarboxylate (5d)[S5]



Yield: 38.4 mg (96%); time: 2.5 h; colorless oil; TLC, R_f = 0.45 (PE:EtOAc = 90:10); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 8.01 (d, 2H, J = 8.8 Hz), 7.45 (d, 2H, J = 8.8 Hz), 7.28-7.22 (m, 5H), 4.11 (q, 2H, J = 7.2 Hz), 4.01 (d, 1H, J = 7.6 Hz), 3.97 (q, 2H, J =7.2 Hz), 3.84 (d, 1H, J = 7.6 Hz), 1.08 (t, 3H, J = 7.2 Hz), 0.95 (t, 3H, J =7.2 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 192.3, 165.8, 165.6, 140.2, 135.0, 133.2, 129.9, 129.1, 128.5, 128.3, 127.7, 62.1, 61.9, 46.1, 35.7, 34.9, 13.83, 13.75.

X-Ray structure of 2i and the corresponding data

CCDC 1497561 (**2i**), contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from the Cambridge Crystallographic Data Centre via: www.ccdc.cam.ac.uk/data_request/cif.



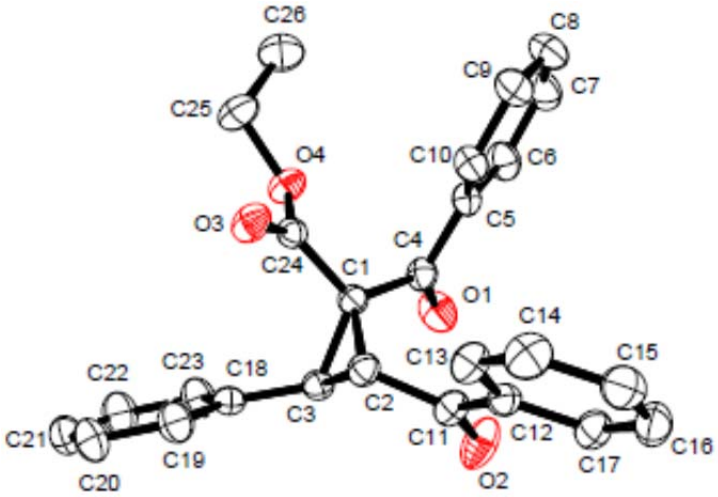
Crystal data	
Chemical formula	$C_{26}H_{19}ClO_4$
M_r	430.86
Crystal system, space group	Triclinic, *P*
Temperature (K)	293
a, *b*, *c* (Å)	8.8081 (4), 9.9881 (5), 12.6194 (6)
α, β, γ (°)	79.9048 (16), 82.4837 (16), 80.2931 (16)
V (Å^3)	1071.49 (9)
Z	2
Radiation type	Mo *K*α
μ (mm^{-1})	0.21
Crystal size (mm)	0.15 × 0.13 × 0.08
Data collection	
Diffractometer	Bruker *APEX*-II CCD

Absorption correction	Multi-scan *SADABS*
No. of measured, independent and observed [$I > 2\sigma(I)$] reflections	14454, 3790, 2661
R_{int}	0.027
$(\sin \theta/\lambda)_{max}$ ($Å^{-1}$)	0.596
Refinement	
$R[F^2 > 2\sigma(F^2)]$, $wR(F^2)$, S	0.051, 0.143, 1.31
No. of reflections	3790
No. of parameters	281
H-atom treatment	H-atom parameters constrained
$\Delta\rho_{max}$, $\Delta\rho_{min}$ (e $Å^{-3}$)	0.21, −0.29

Computer programs: Bruker *APEX2*, Bruker *SAINT*, *SHELXS97* (Sheldrick 2008), *SHELXL2014*/7 (Sheldrick, 2014), Bruker *SHELXTL*.

X-Ray structure of 3a and the corresponding data

CCDC 1497563 (**3a**), contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from the Cambridge Crystallographic Data Centre via: www.ccdc.cam.ac.uk/data_request/cif.



Crystal data	
Chemical formula	$C_{26}H_{22}O_4$
M_r	398.45
Crystal system, space group	Monoclinic, $P2_1/n$
Temperature (K)	299
a, b, c (Å)	8.5852 (6), 15.9050 (12), 15.6721 (12)
β (°)	95.176 (2)
V (Å^3)	2131.3 (3)
Z	63
Radiation type	Mo $K\alpha$
μ (mm^{-1})	0.13
Data collection	
Diffractometer	Bruker *APEX*-II CCD diffractometer
No. of measured, independent and observed [$I > 2\sigma(I)$] reflections	15870, 3759, 2729
R_{int}	0.032
$(\sin \theta/\lambda)_{max}$ (Å^{-1})	0.596
Refinement	
$R[F^2 > 2\sigma(F^2)]$, $wR(F^2)$, S	0.046, 0.126, 1.03
No. of reflections	3759
No. of parameters	272
H-atom treatment	H-atom parameters constrained
$\Delta\rho_{max}$, $\Delta\rho_{min}$ (e Å^{-3})	0.16, −0.19

Computer programs: *SHELXL2014*/7 (Sheldrick, 2014).

References:

[S1] Yang, H.-M.; Gao, Y.-H.; Li, L.; Jiang, Z.-Y.; Lai, G.-Q.; Xia, C.-G.; Xu, L.-W. *Tetrahedron Lett.* **2010**, *51*,3836.

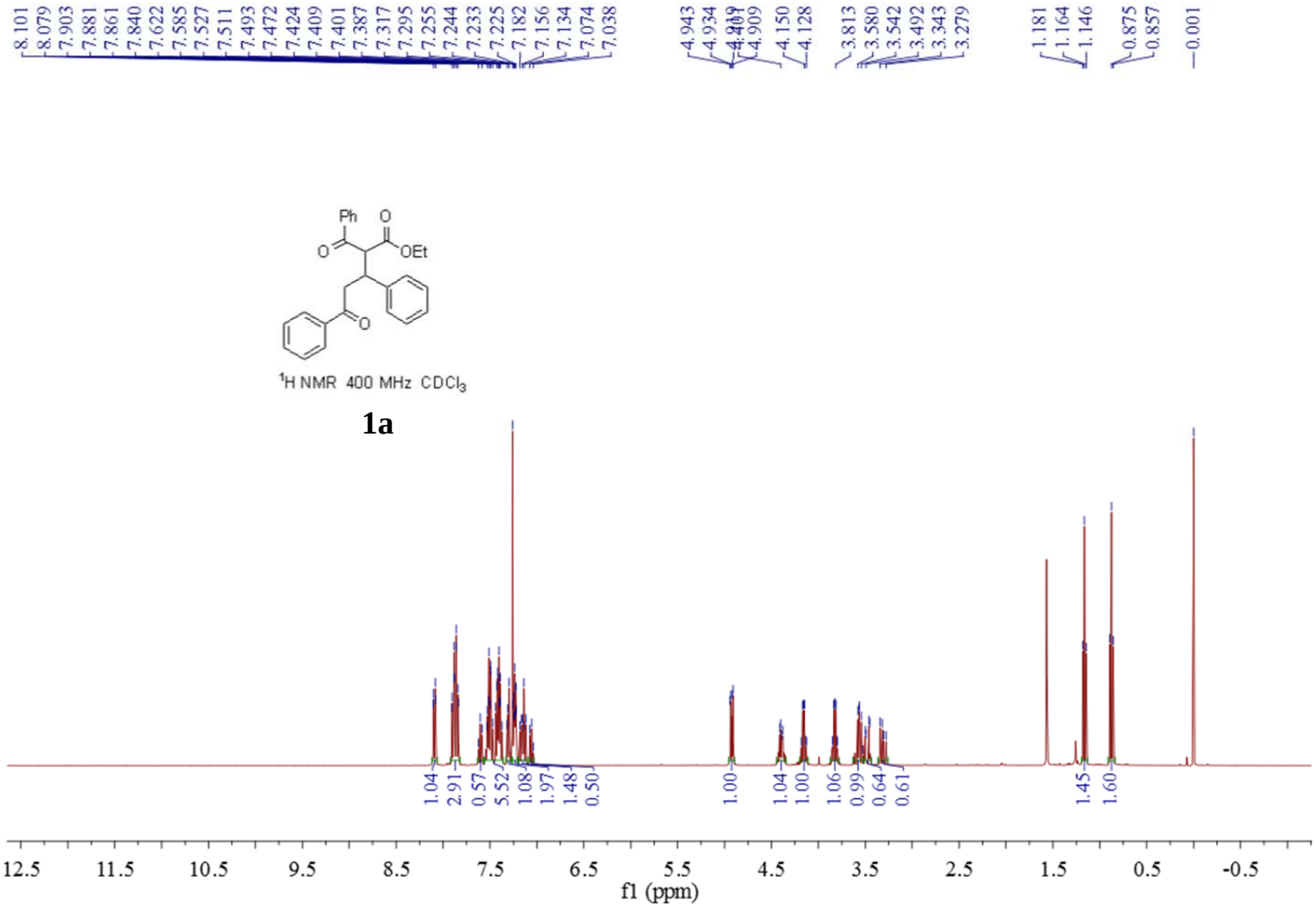
[S2] Christoffers, J. *Chem. Commun.* **1997**, 943.

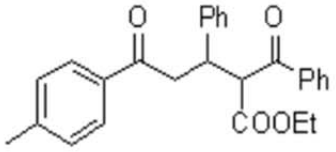
[S3] Sammour, A.; Raouf, A.; Elkasaby, M.; Ibrahim, M. A. *Acta Chimica Academiae Scientiarum Hungaricae* **1973**, *78*, 399.

[S4] Shkel, A. A.; Mazhukina, O. A.; Fedotova, O. V. *Chem. Heterocycl. Compd.* **2011**, *47*, 656.

[S5] Ye, Y.; Zheng, C.; Fan, R. *Org. Lett.* **2009**, *11*, 3156.

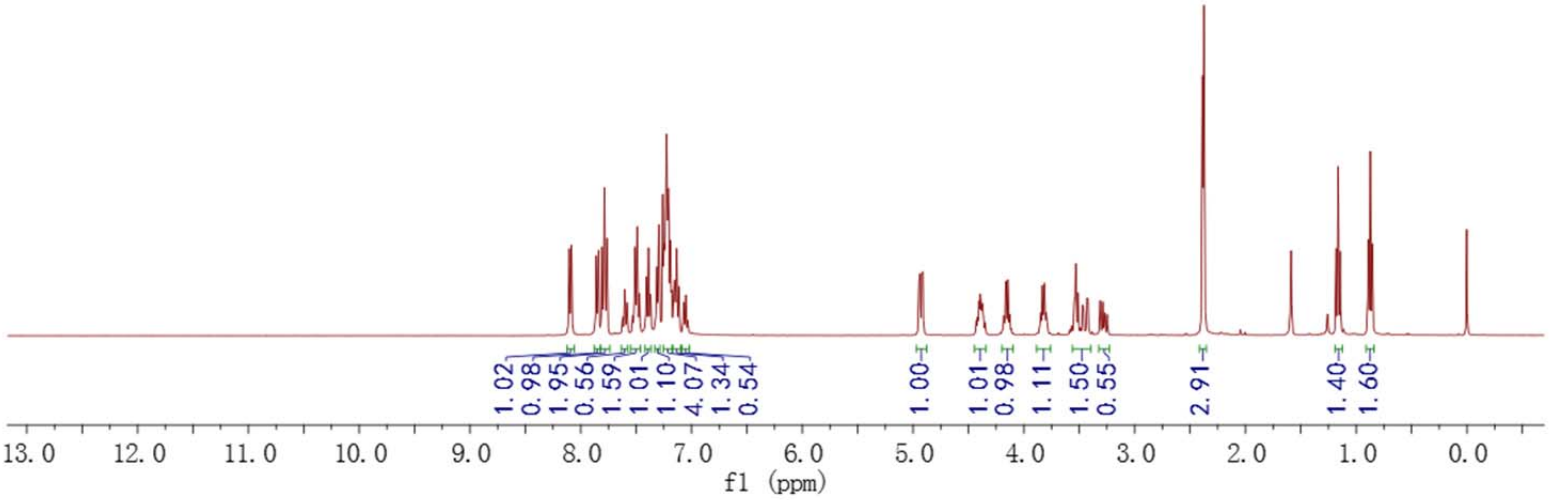
^{1}H NMR Spectra of Michael Adducts

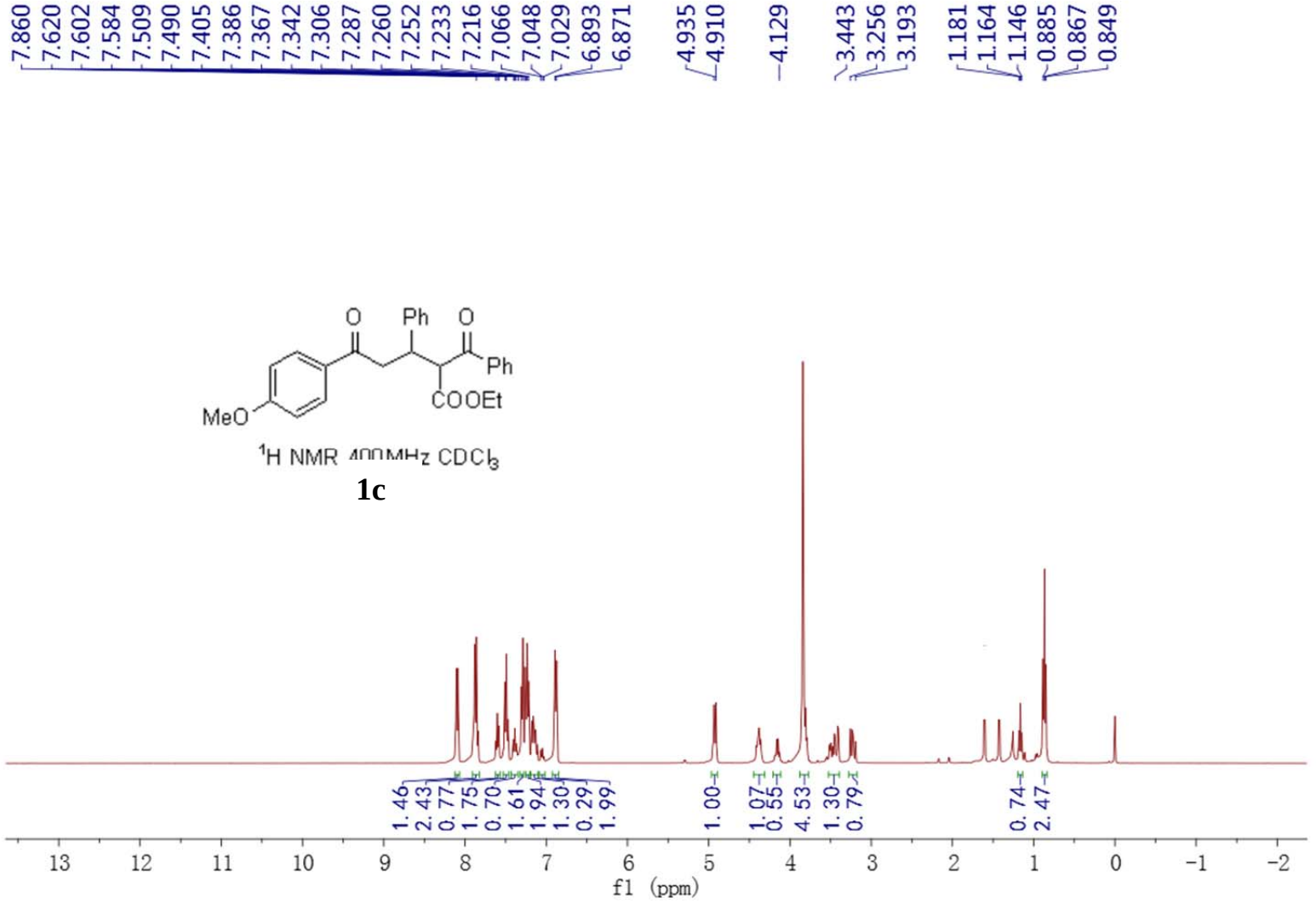




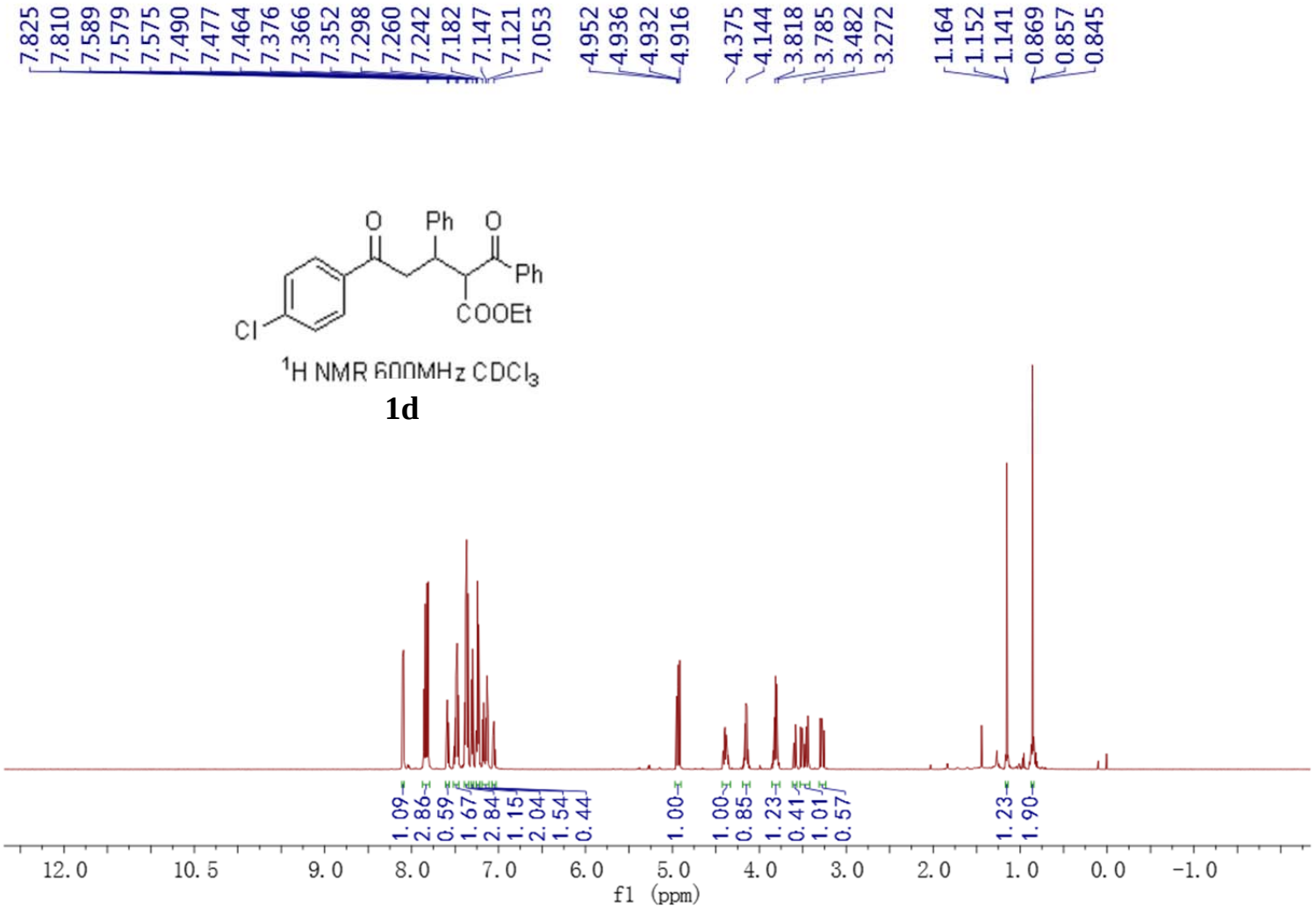
^{1}H NMR 400MHz $CDCl_3$

1b




7.860
7.620
7.602
7.584
7.509
7.490
7.405
7.386
7.367
7.342
7.306
7.287
7.260
7.252
7.233
7.216
7.066
7.048
7.029
6.893
6.871
4.935
4.910
4.129
3.443
3.256
3.193
1.181
1.164
1.146
0.885
0.867
0.849
O
Ph
O
Ph
COOEt
MeO
1H NMR 400MHz CDCl3
1.46
2.43
0.77
1.75
0.70
1.61
1.94
1.30
0.29
1.99
1.00
1.07
0.55
4.53
1.30
0.79
0.74
2.47
13
12
11
10
9
8
7
6
5
4
3
2
1
0
−1
−2
f1 (ppm)

1c


7.825
7.810
7.589
7.579
7.575
7.490
7.477
7.464
7.376
7.366
7.352
7.298
7.260
7.242
7.182
7.147
7.121
7.053
4.952
4.936
4.932
4.916
4.375
4.144
3.818
3.785
3.482
3.272
1.164
1.152
1.141
0.869
0.857
0.845
O
Ph
O
Ph
COOEt
Cl
1H NMR 600MHz CDCl3
1d
1.09
2.86
0.59
1.67
2.84
1.15
2.04
1.54
0.44
1.00
1.00
0.85
1.23
0.41
1.01
0.57
1.23
1.90
12.0
10.5
9.0
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6.0
5.0
4.0
3.0
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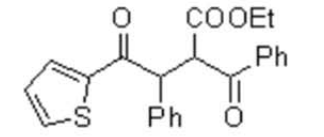
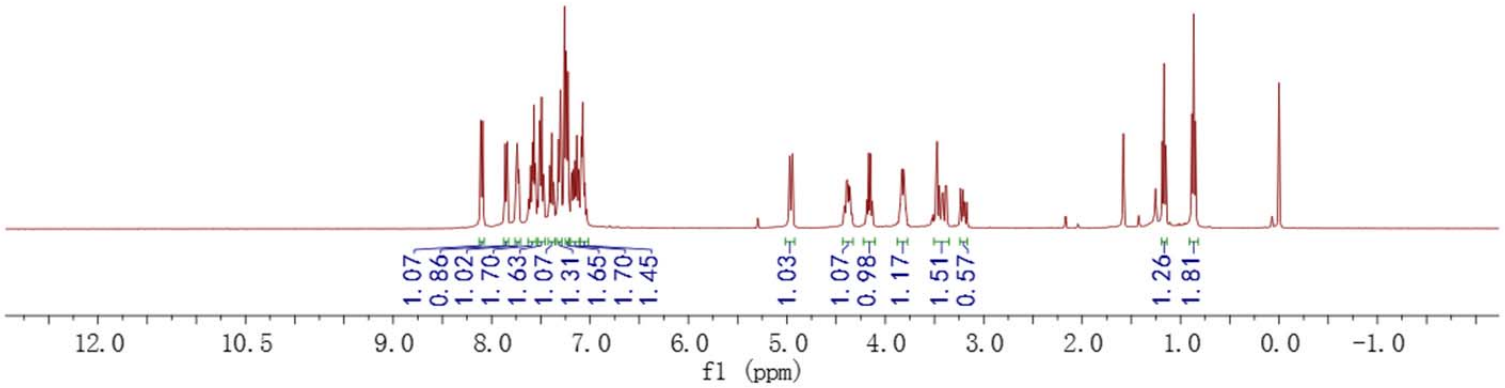
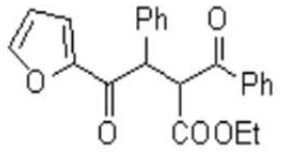
1.0
0.0
-1.0
f1 (ppm)



^{1}H NMR 400 MHz $CDCl_3$

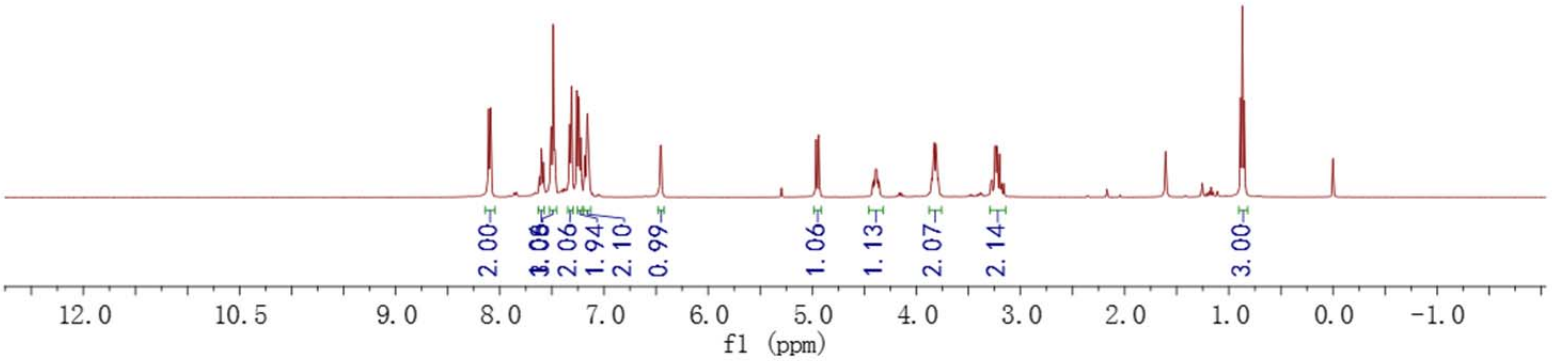
1e

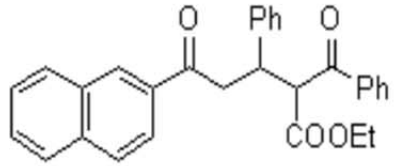




^{1}H NMR 400MHz $CDCl_3$

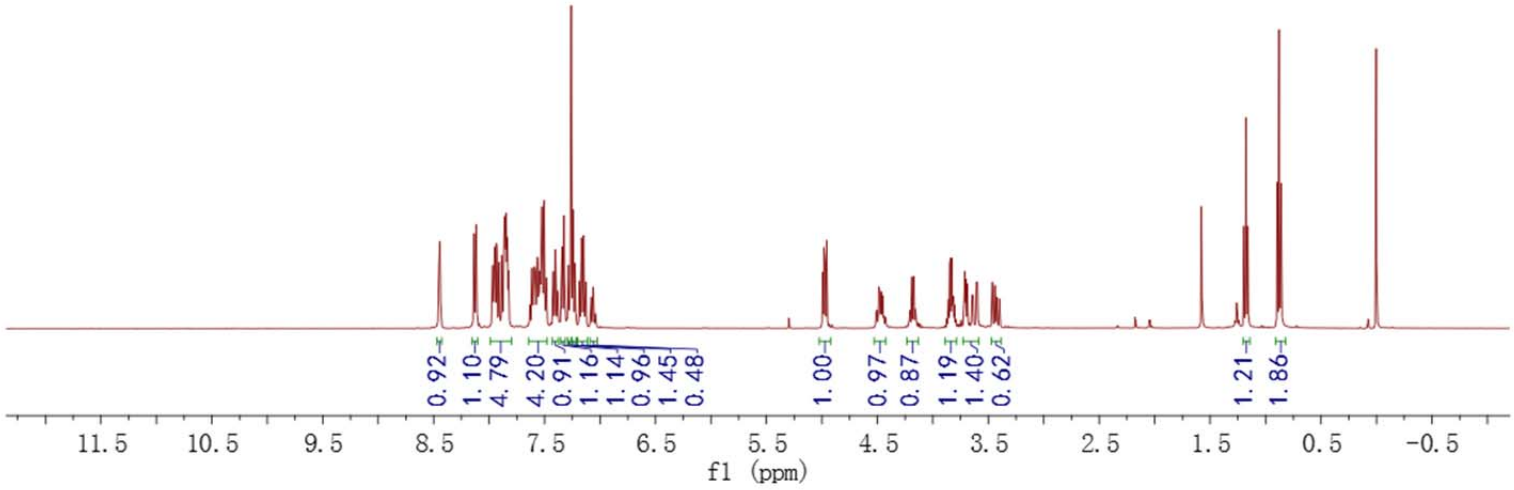
1f

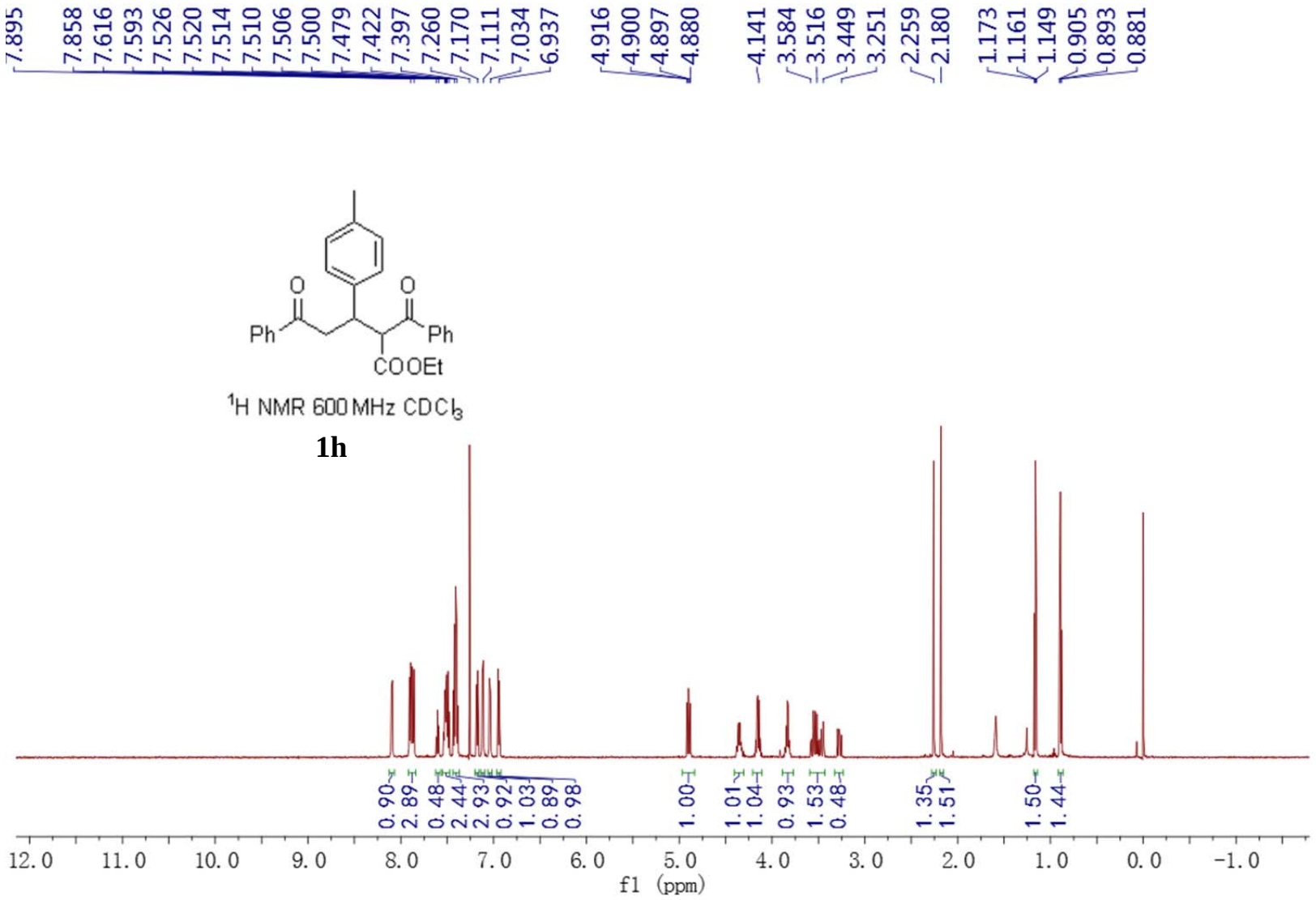


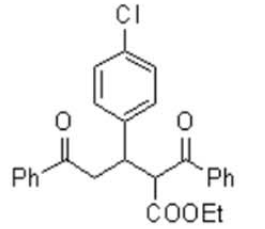


^{1}H NMR 400MHz $CDCl_3$

1g

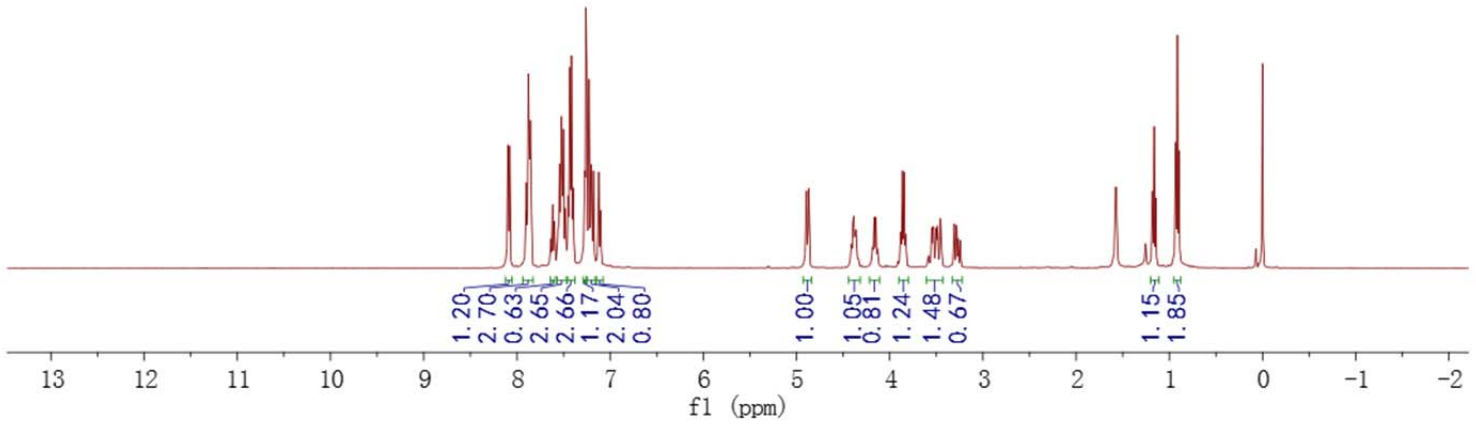


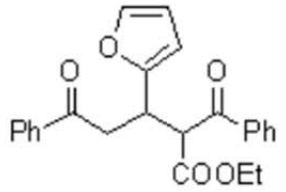

7.895
7.858
7.616
7.593
7.526
7.520
7.514
7.510
7.506
7.500
7.479
7.422
7.397
7.260
7.170
7.111
7.034
6.937
4.916
4.900
4.897
4.880
4.141
3.584
3.516
3.449
3.251
2.259
2.180
1.173
1.161
1.149
0.905
0.893
0.881
O
O
Ph
Ph
COOEt
1H NMR 600 MHz CDCl3
1h
0.90
2.89
0.48
2.44
2.93
0.92
1.03
0.89
0.98
1.00
1.01
1.04
0.93
1.53
0.48
1.35
1.51
1.50
1.44
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
f1 (ppm)



^{1}H NMR 400 MHz $CDCl_3$

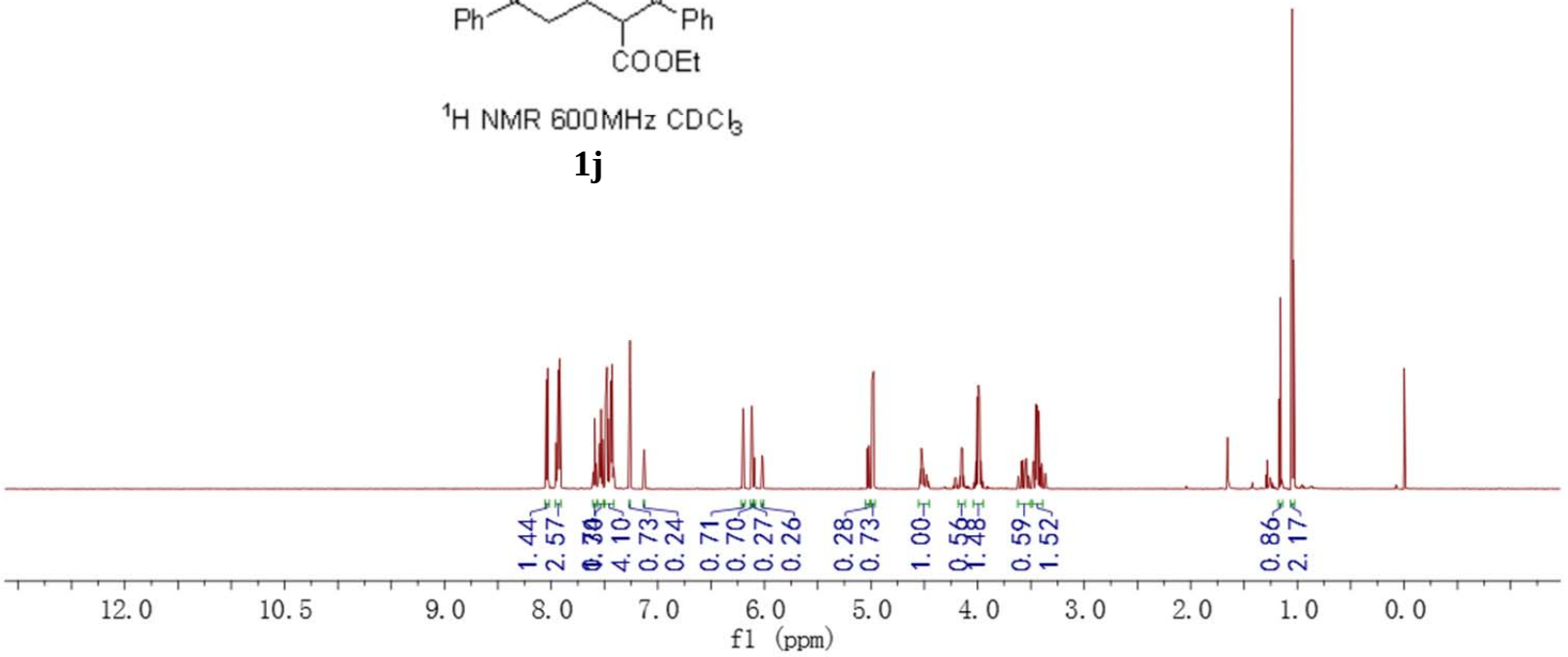
1i

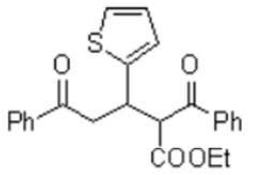




^{1}H NMR 600MHz $CDCl_3$

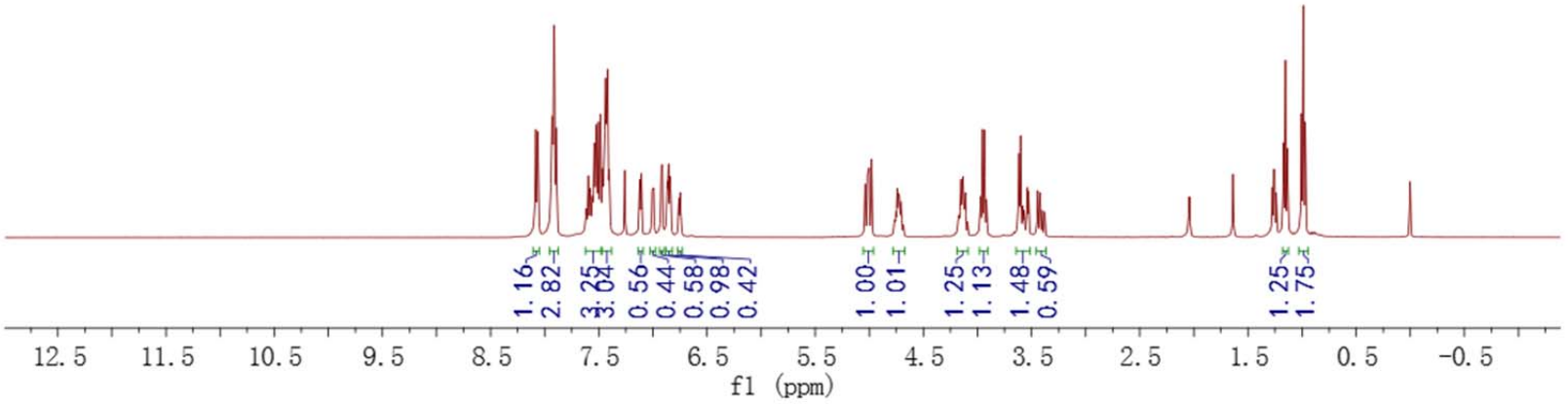
1j

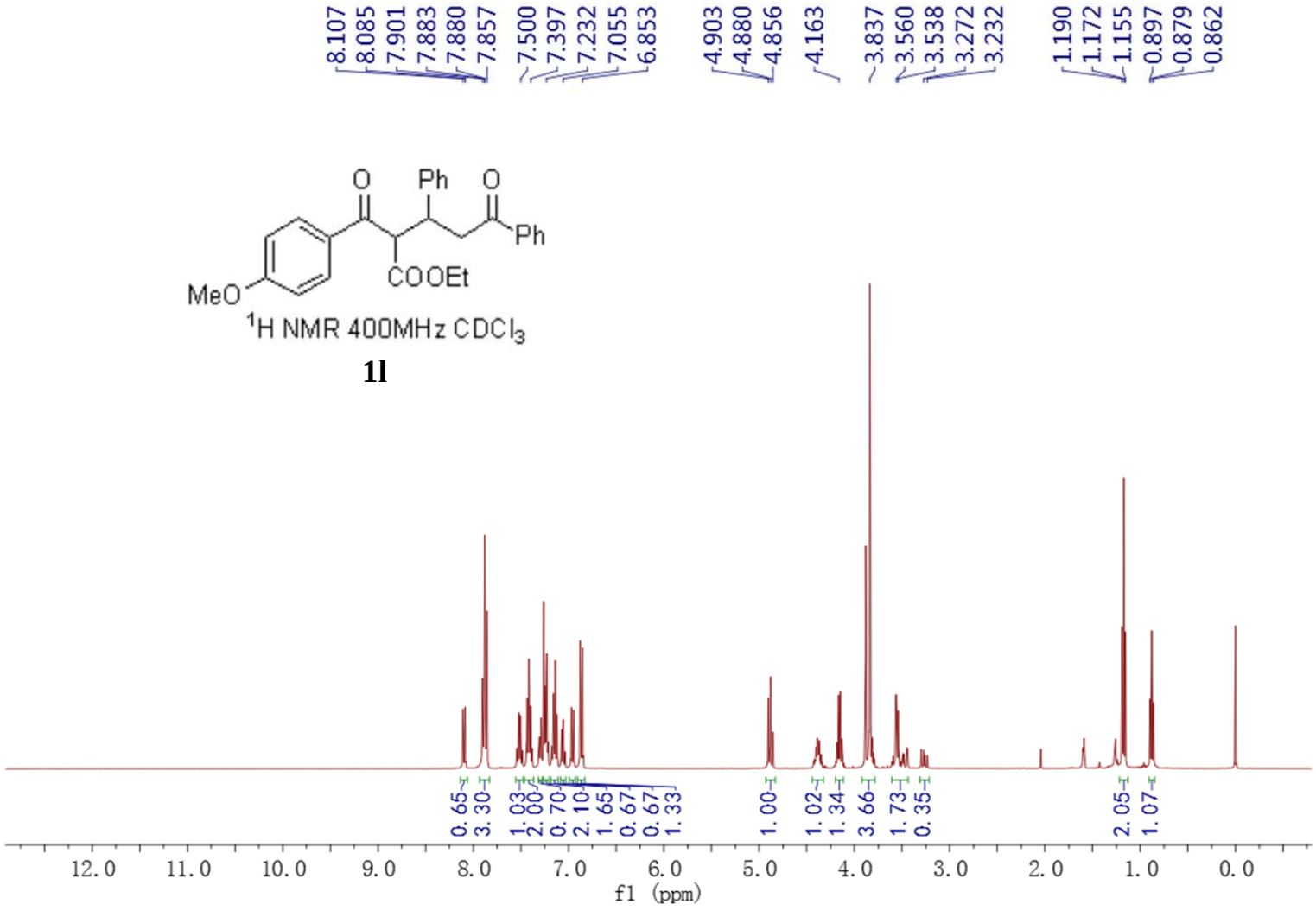




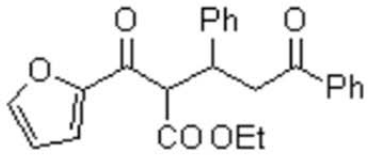
^{1}H NMR 400MHz $CDCl_3$

1k



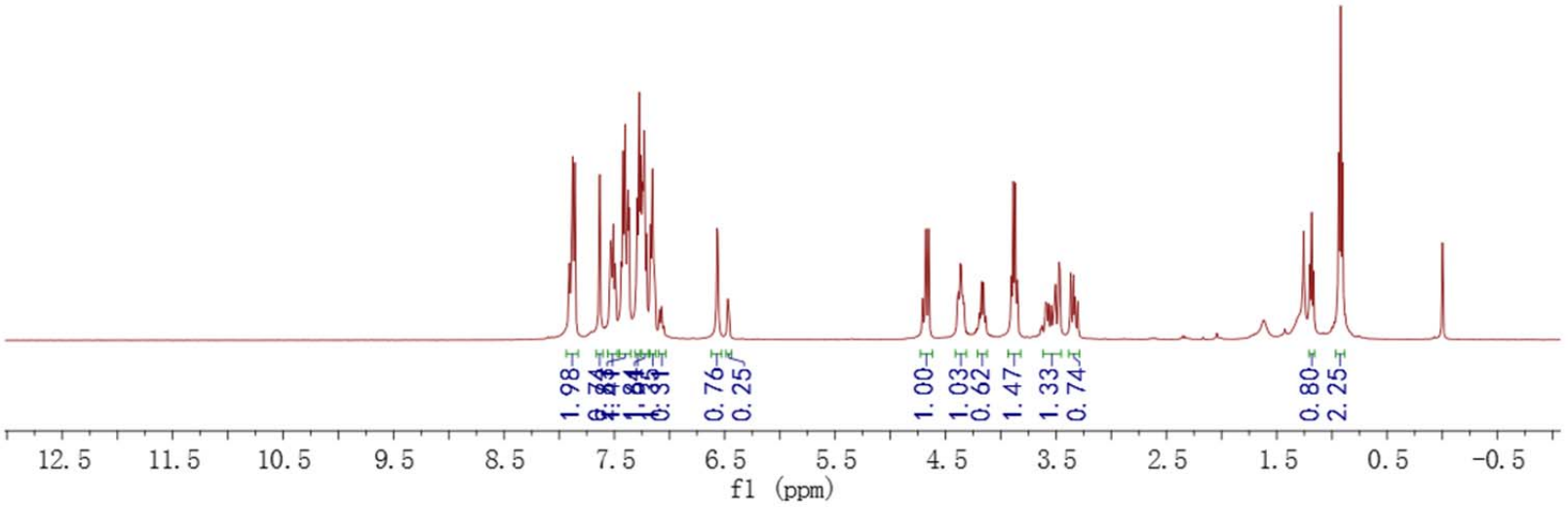

8.107
8.085
7.901
7.883
7.880
7.857
7.500
7.397
7.232
7.055
6.853
4.903
4.880
4.856
4.163
3.837
3.560
3.538
3.272
3.232
1.190
1.172
1.155
0.897
0.879
0.862
O
Ph
O
Ph
COOEt
MeO
^{1}H NMR 400MHz CDCl$_3$
0.65
3.30
1.03
2.00
0.70
2.10
1.65
0.67
0.67
1.33
1.00
1.02
1.34
3.66
1.73
0.35
2.05
1.07
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)

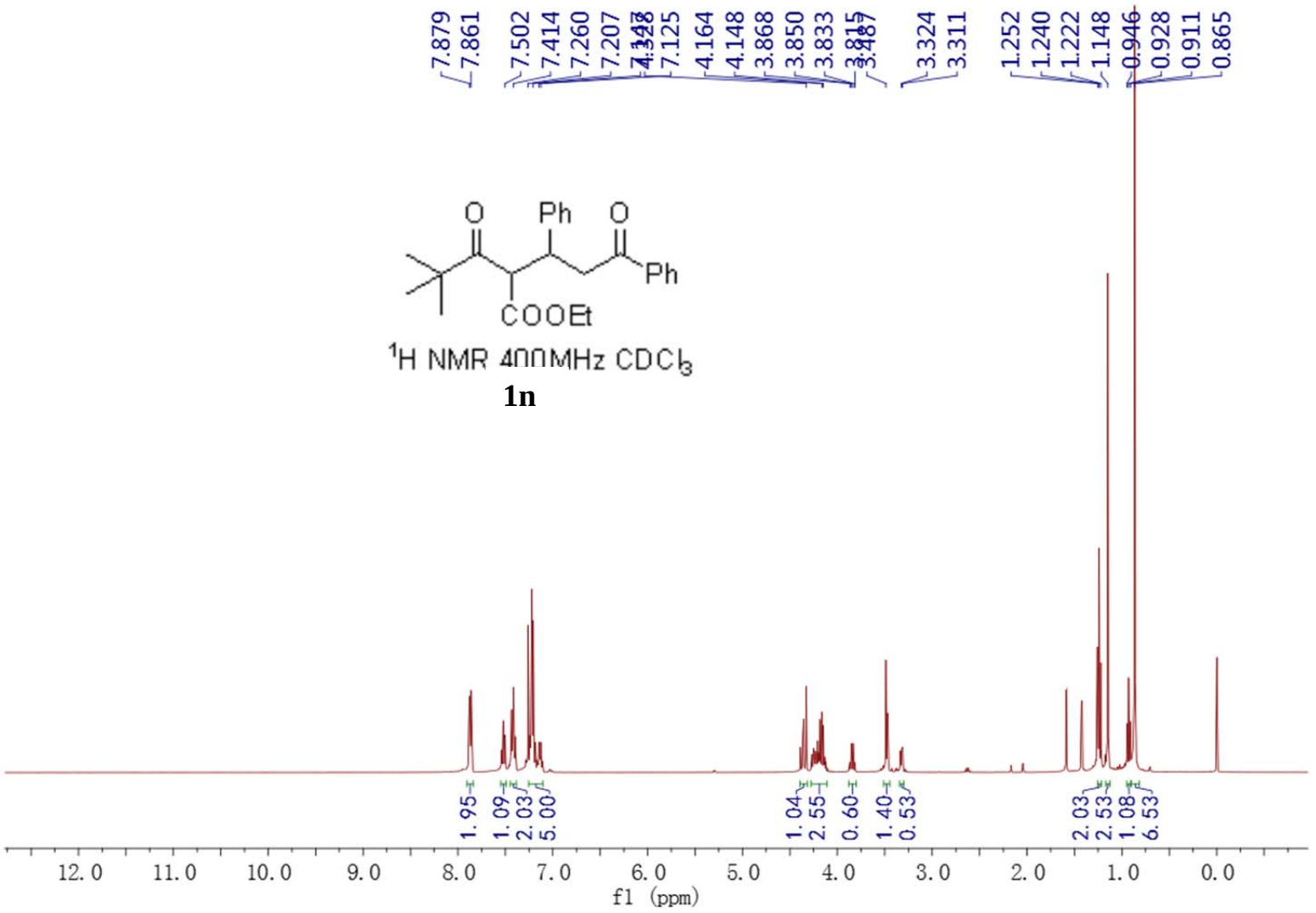
1l



^{1}H NMR 400MHz $CDCl_3$

1m

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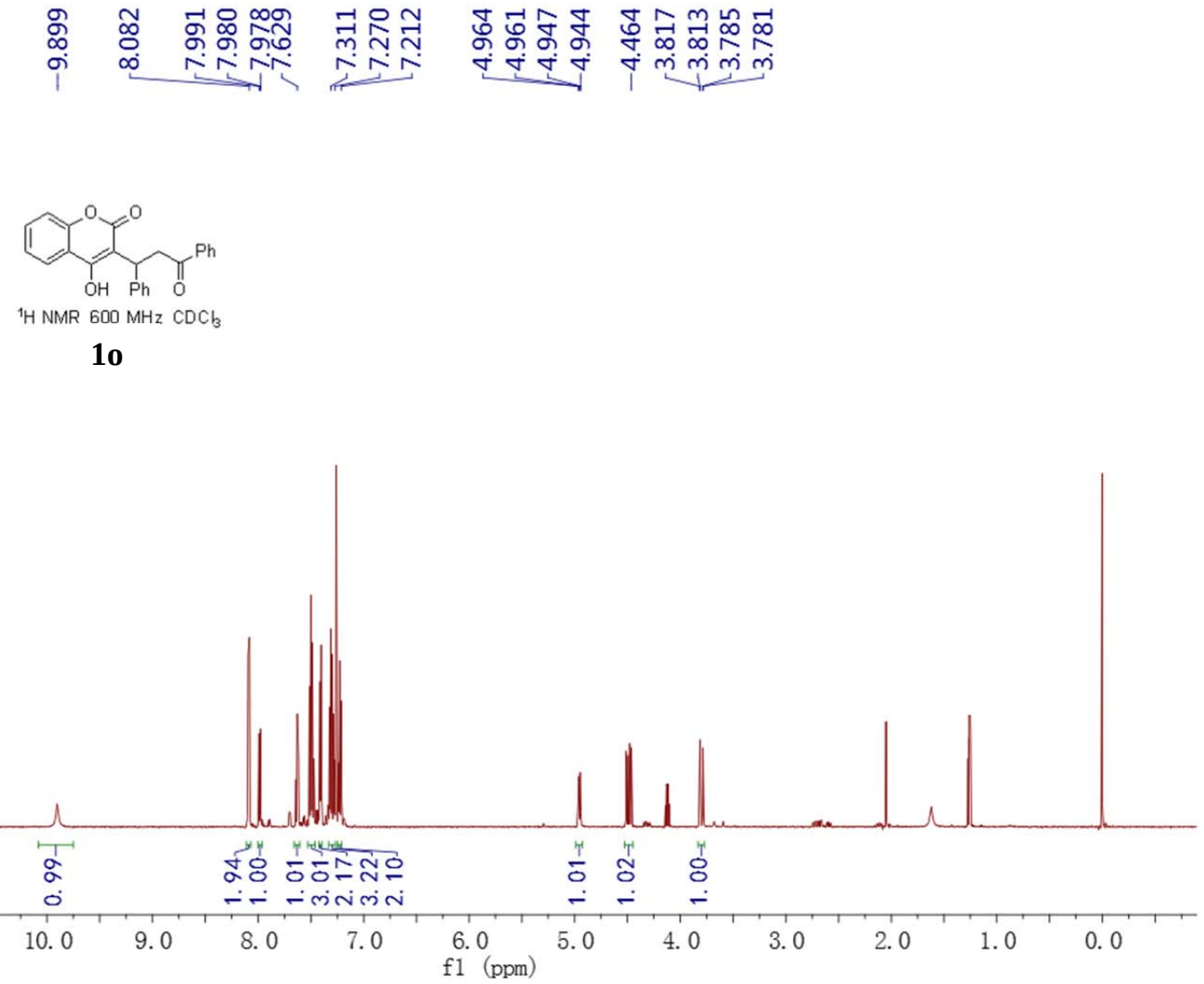
7.260
7.207
7.125
4.164
4.148
3.868
3.850
3.833
3.324
3.311
1.252
1.240
1.222
1.148
0.946
0.928
0.911
0.865
O
Ph
O
Ph
COOEt
1H NMR 400MHz CDCl3
1n
1.95
1.09
2.03
5.00
1.04
2.55
0.60
1.40
0.53
2.03
2.53
1.08
6.53
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)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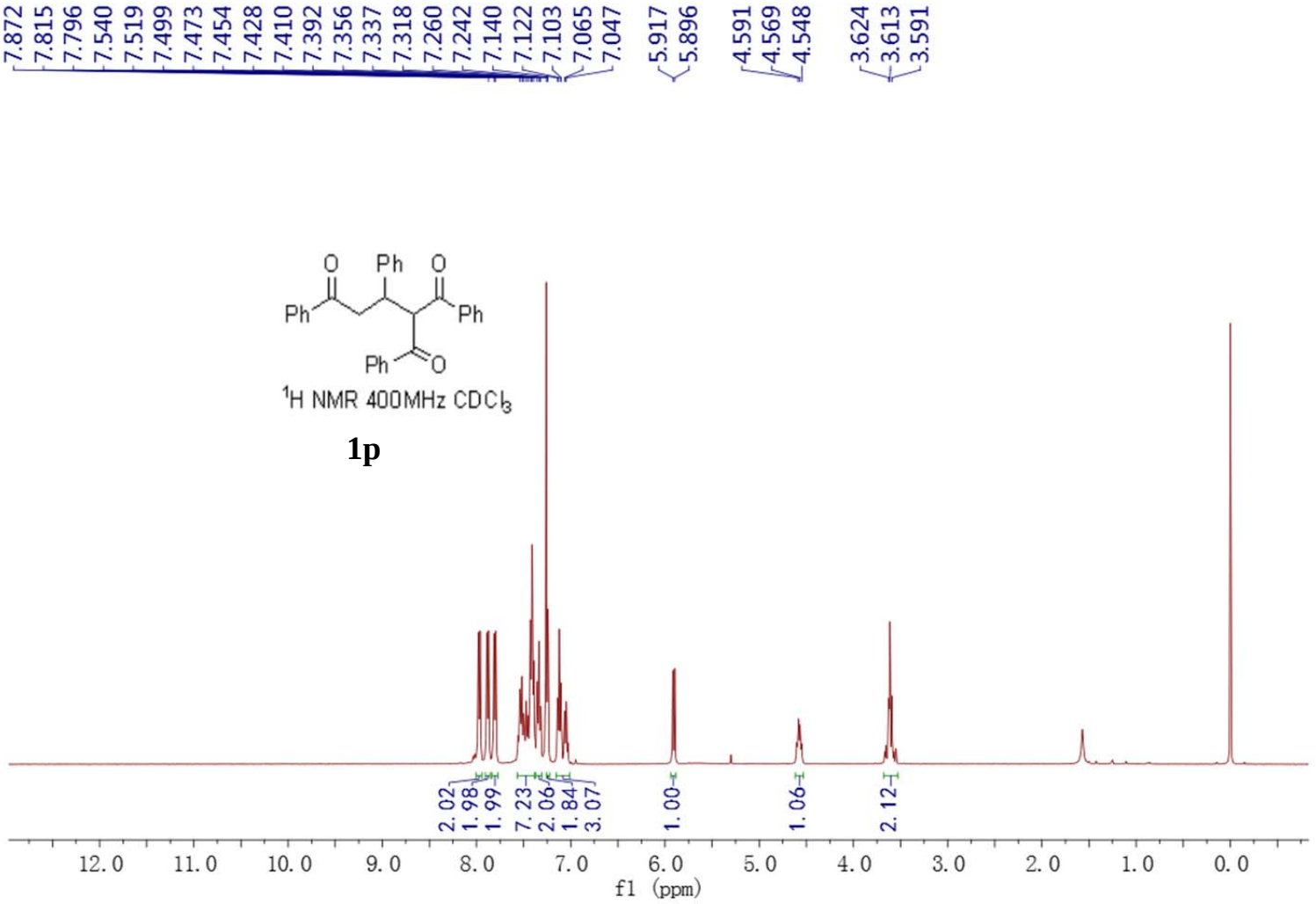
8.082
7.991
7.980
7.978
7.629
7.311
7.270
7.212
4.964
4.961
4.947
4.944
4.464
3.817
3.813
3.785
3.781
O
O
Ph
OH
Ph
O
1H NMR 600 MHz CDCl3
0.99
1.94
1.00
1.01
3.01
2.17
3.22
2.10
1.01
1.02
1.00
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)

1o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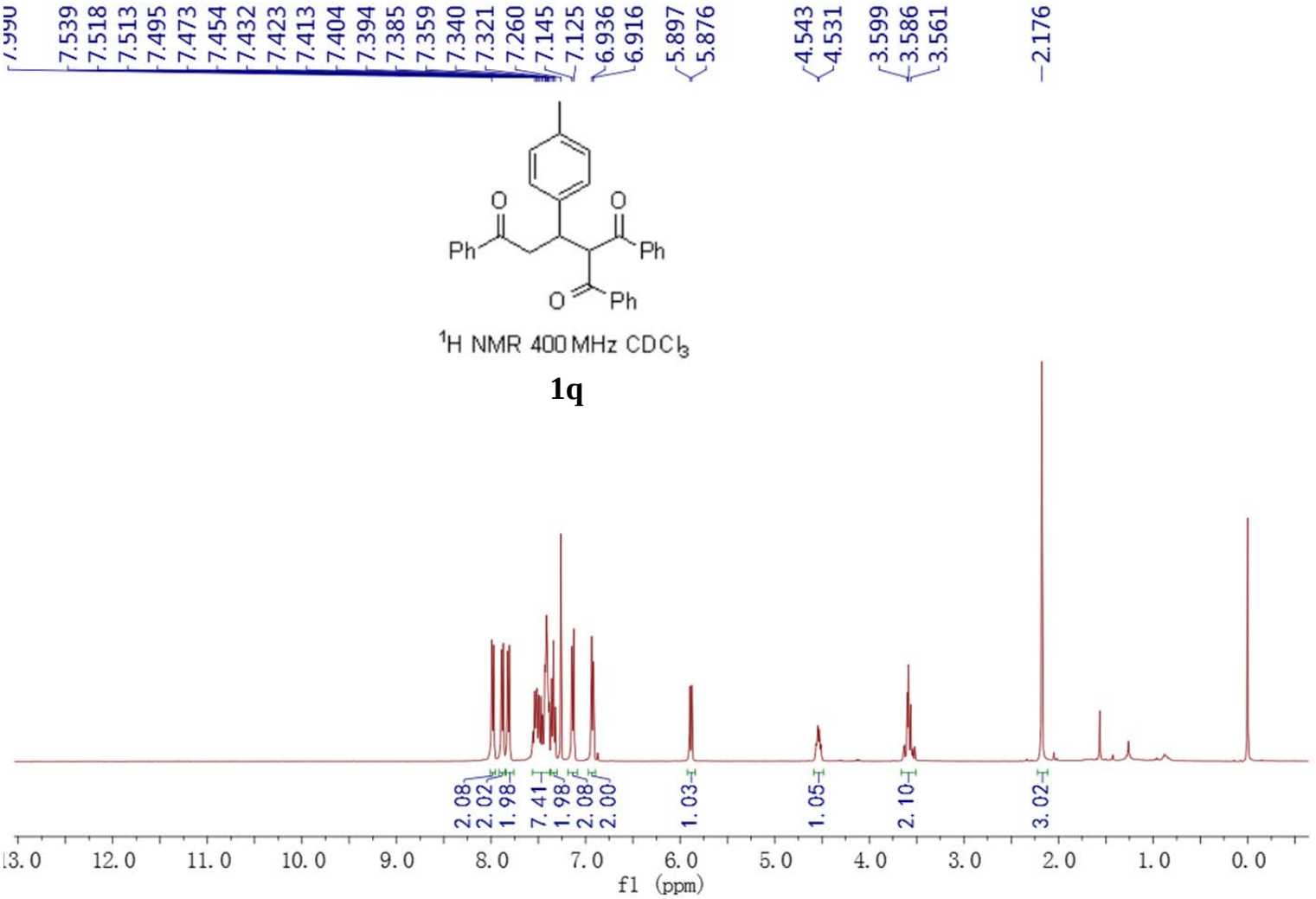
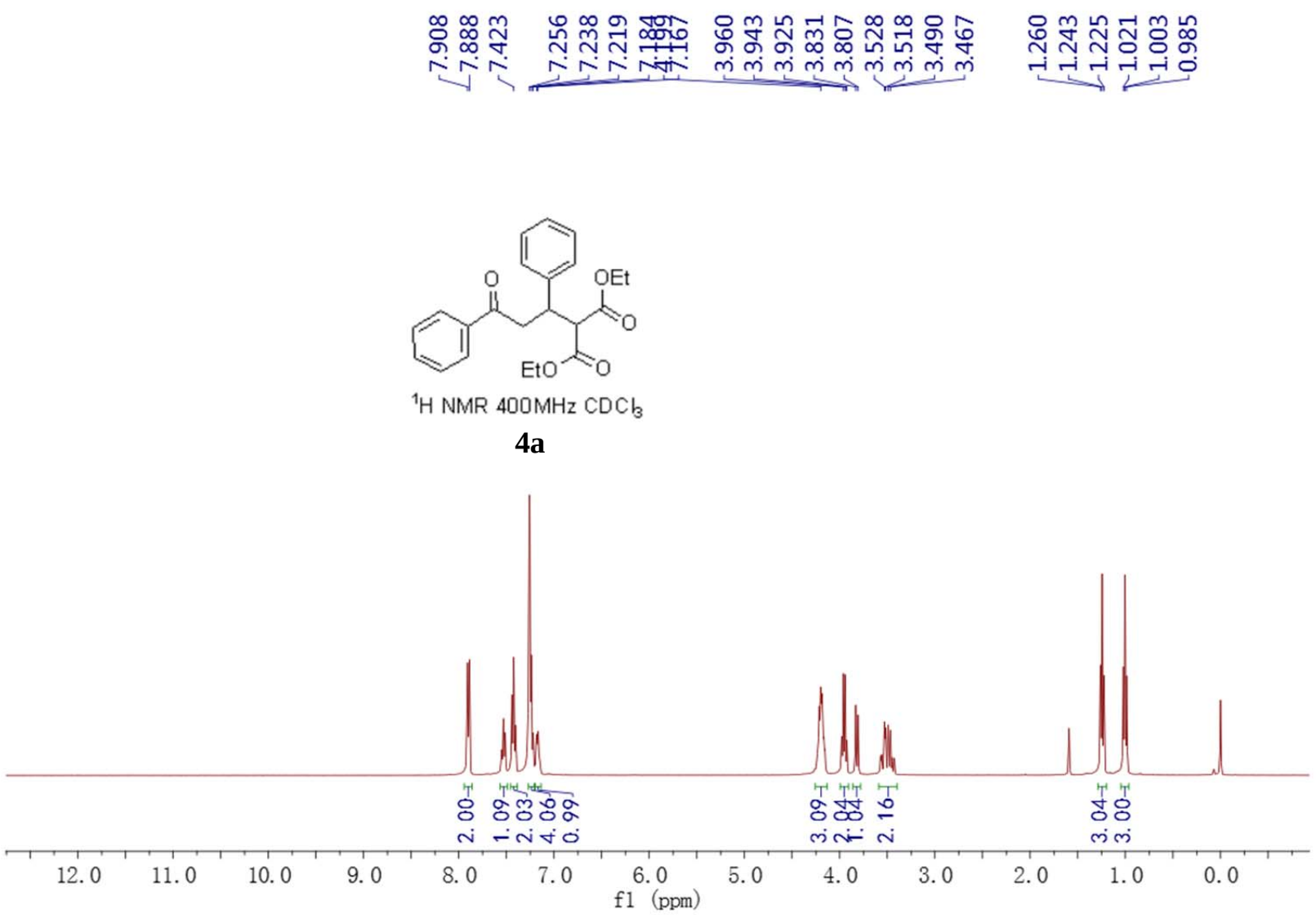
7.540
7.519
7.499
7.473
7.454
7.428
7.410
7.392
7.356
7.337
7.318
7.260
7.242
7.140
7.122
7.103
7.065
7.047
5.917
5.896
4.591
4.569
4.548
3.624
3.613
3.591
O
Ph
O
Ph
Ph
Ph
O
1H NMR 400MHz CDCl3
2.02
1.98
1.99
7.23
2.06
1.84
3.07
1.00
1.06
2.12
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)

1p

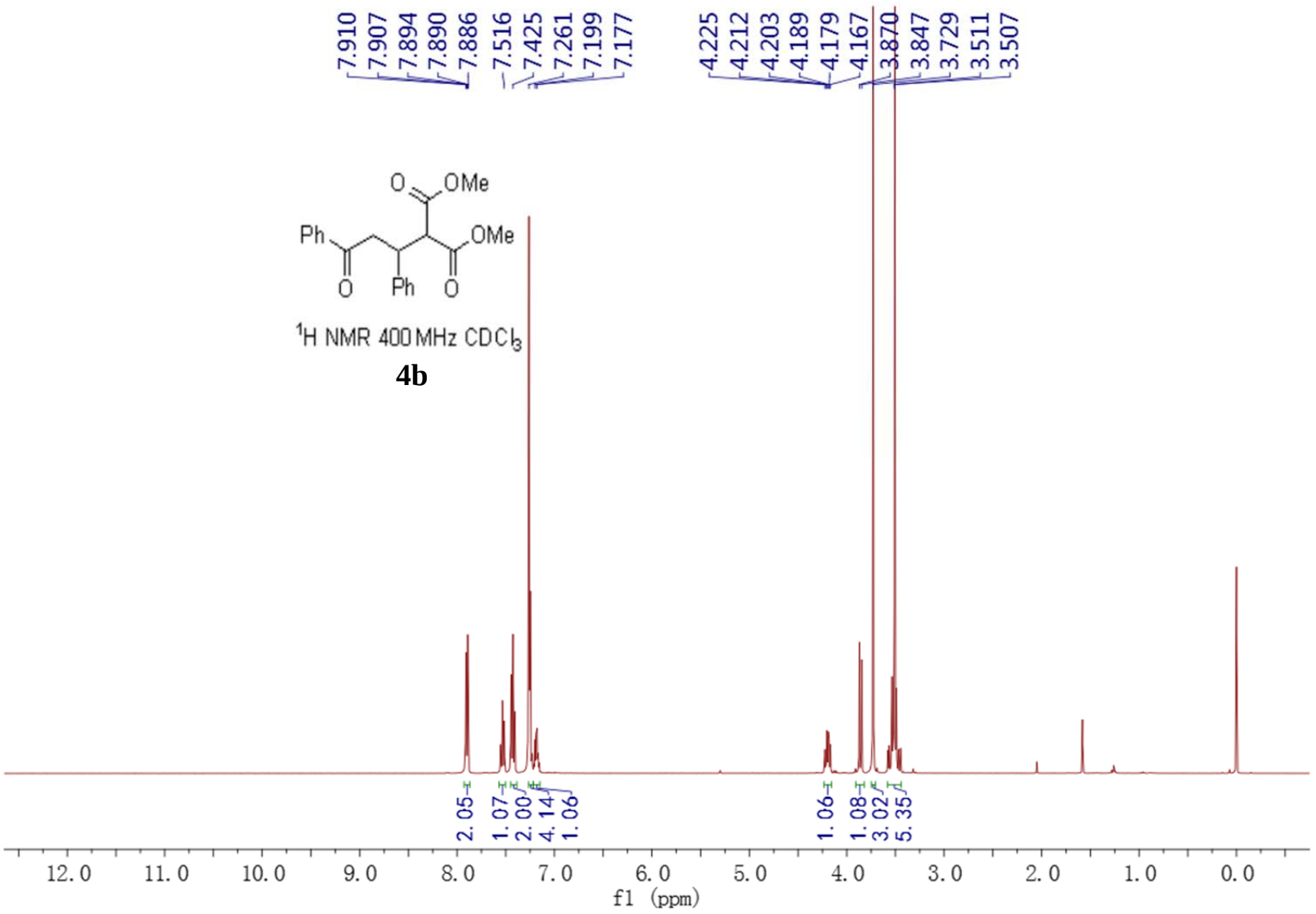

7.990
7.539
7.518
7.513
7.495
7.473
7.454
7.432
7.423
7.413
7.404
7.394
7.385
7.359
7.340
7.321
7.260
7.145
7.125
6.936
6.916
5.897
5.876
4.543
4.531
3.599
3.586
3.561
2.176
O
O
Ph
Ph
O
Ph
1H NMR 400 MHz CDCl3
2.08
2.02
1.98
7.41
1.98
2.08
2.00
1.03
1.05
2.10
3.02
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)

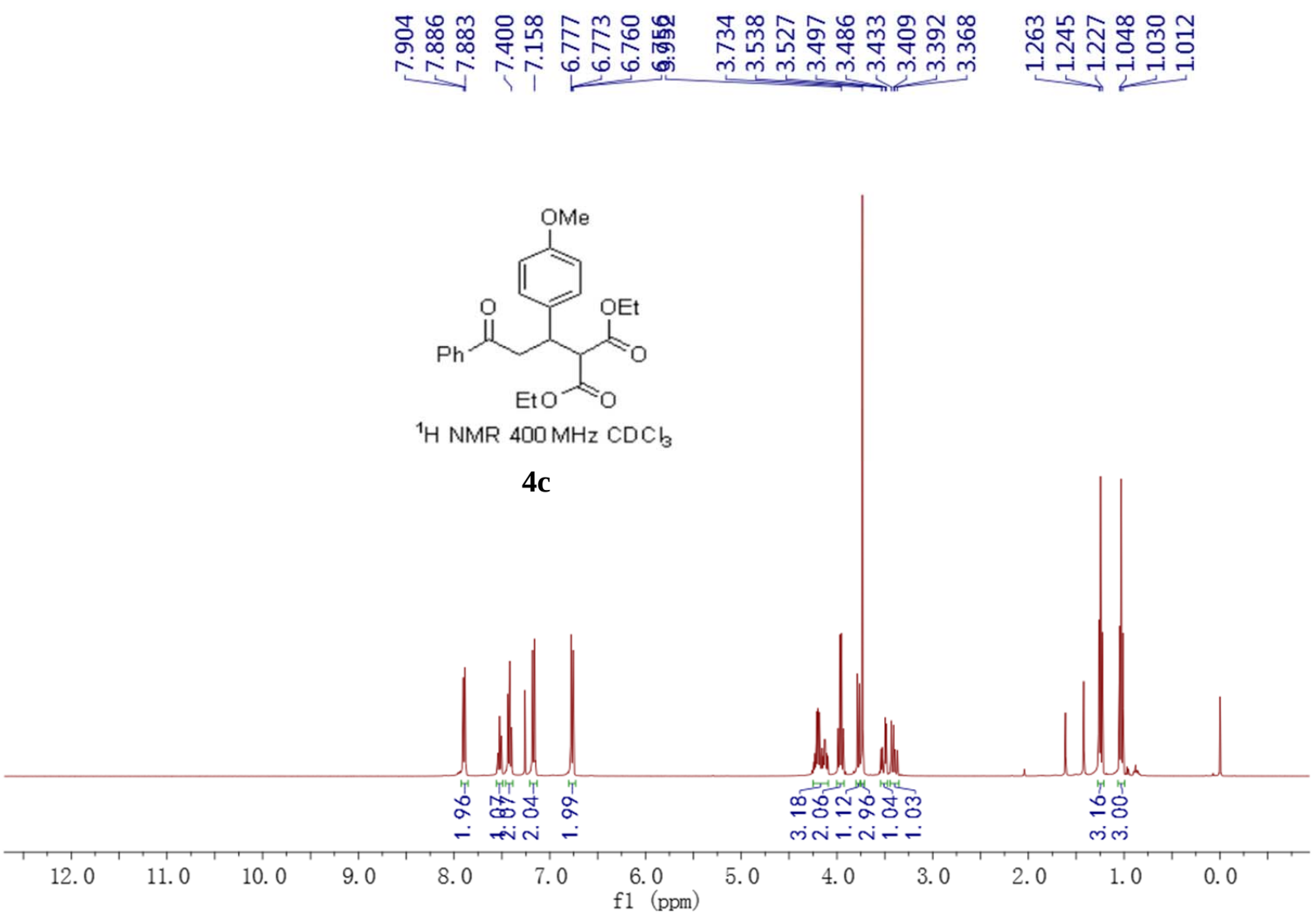
1q



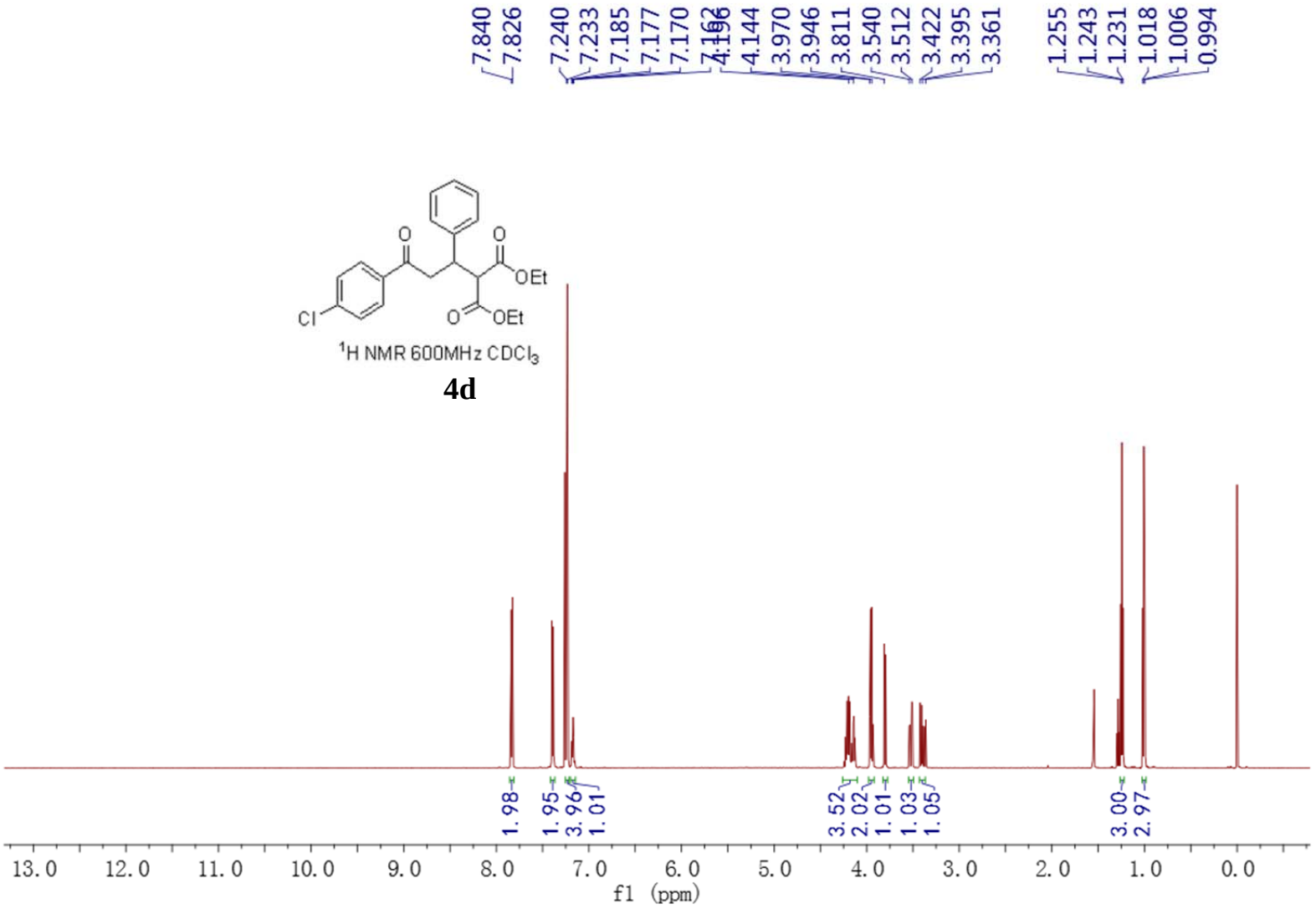
^{1}H NMR 400MHz $CDCl_3$

4a

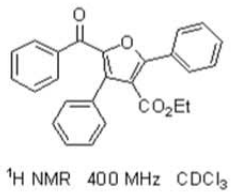

7.910
7.907
7.894
7.890
7.886
7.516
7.425
7.261
7.199
7.177
4.225
4.212
4.203
4.189
4.179
4.167
3.870
3.847
3.729
3.511
3.507
O
OMe
Ph
OMe
O
Ph
O
1H NMR 400 MHz CDCl3
4b
2.05
1.07
2.00
4.14
1.06
1.06
1.08
3.02
5.35
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)


7.904
7.886
7.883
7.400
7.158
6.777
6.773
6.760
3.734
3.538
3.527
3.497
3.486
3.433
3.409
3.392
3.368
1.263
1.245
1.227
1.048
1.030
1.012
OMe
O
OEt
Ph
O
EtO
O
1H NMR 400 MHz CDCl3
1.96
2.04
1.99
3.18
2.06
1.12
2.96
1.04
1.03
3.16
3.00
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)

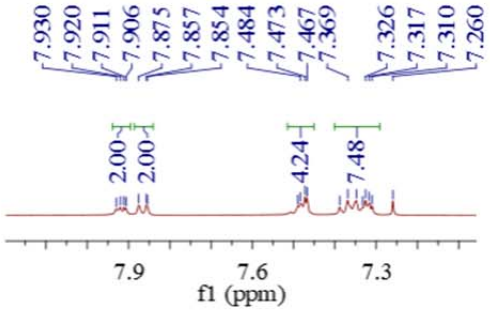
4c

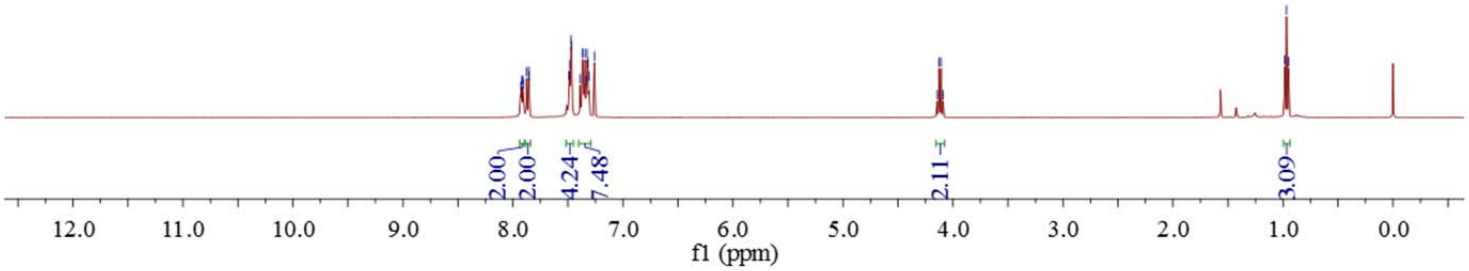

7.840
7.826
7.240
7.233
7.185
7.177
7.170
4.144
3.970
3.946
3.811
3.540
3.512
3.422
3.395
3.361
1.255
1.243
1.231
1.018
1.006
0.994
Cl
O
O
OEt
O
OEt
1H NMR 600MHz CDCl3
4d
1.98
1.95
3.96
1.01
3.52
2.02
1.01
1.03
1.05
3.00
2.97
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)

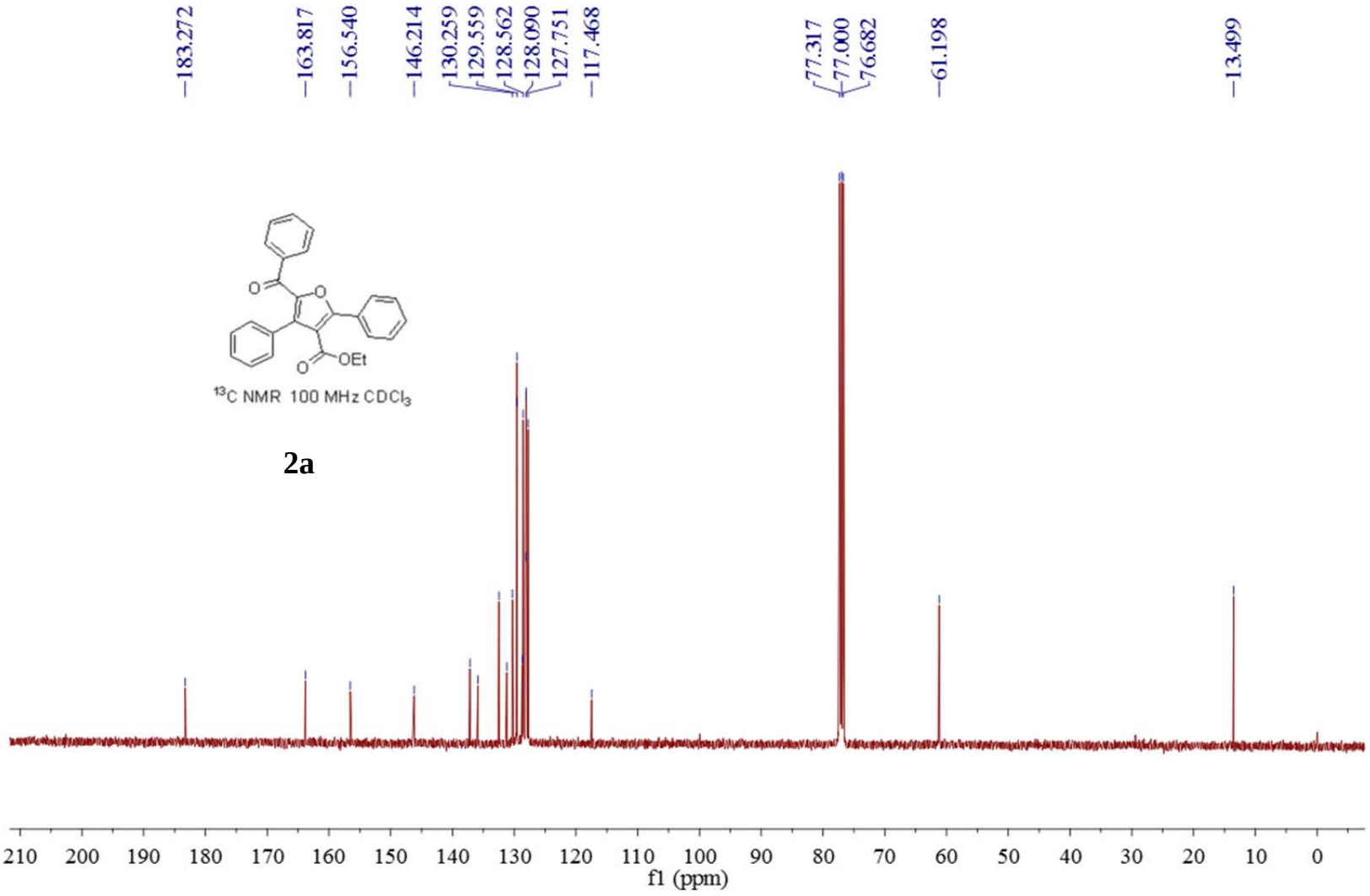
NMR Spectra of Products

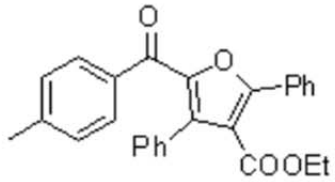


2a



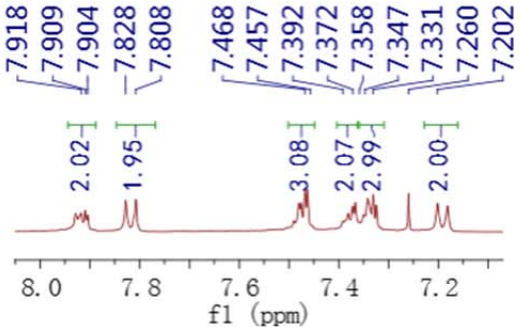


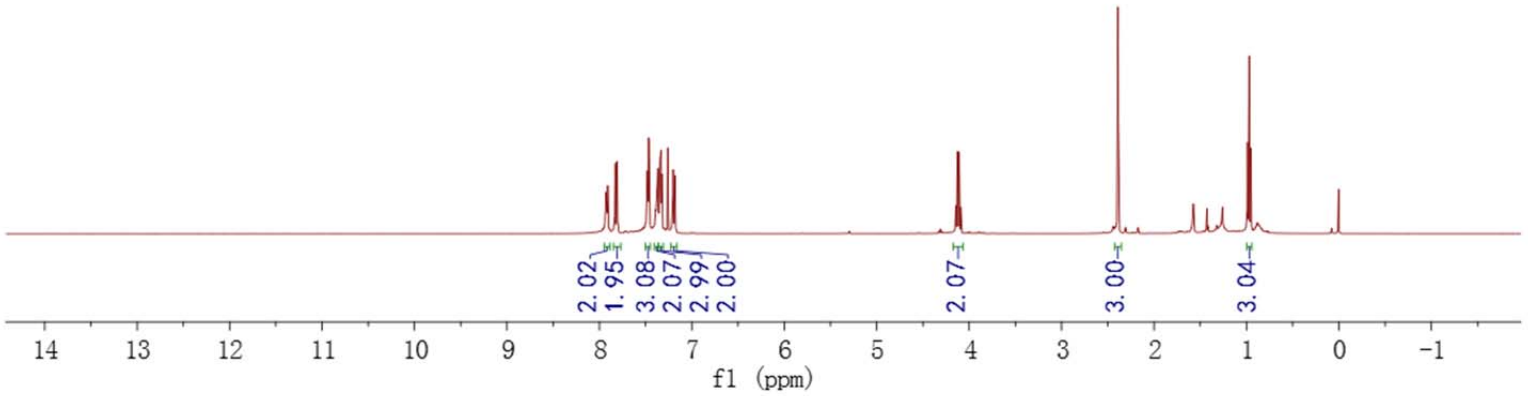

183.272
163.817
156.540
146.214
130.259
129.559
128.562
128.090
127.751
117.468
77.317
77.000
76.682
61.198
13.499
O
O
OEt
O
13C NMR 100 MHz CDCl3
2a
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

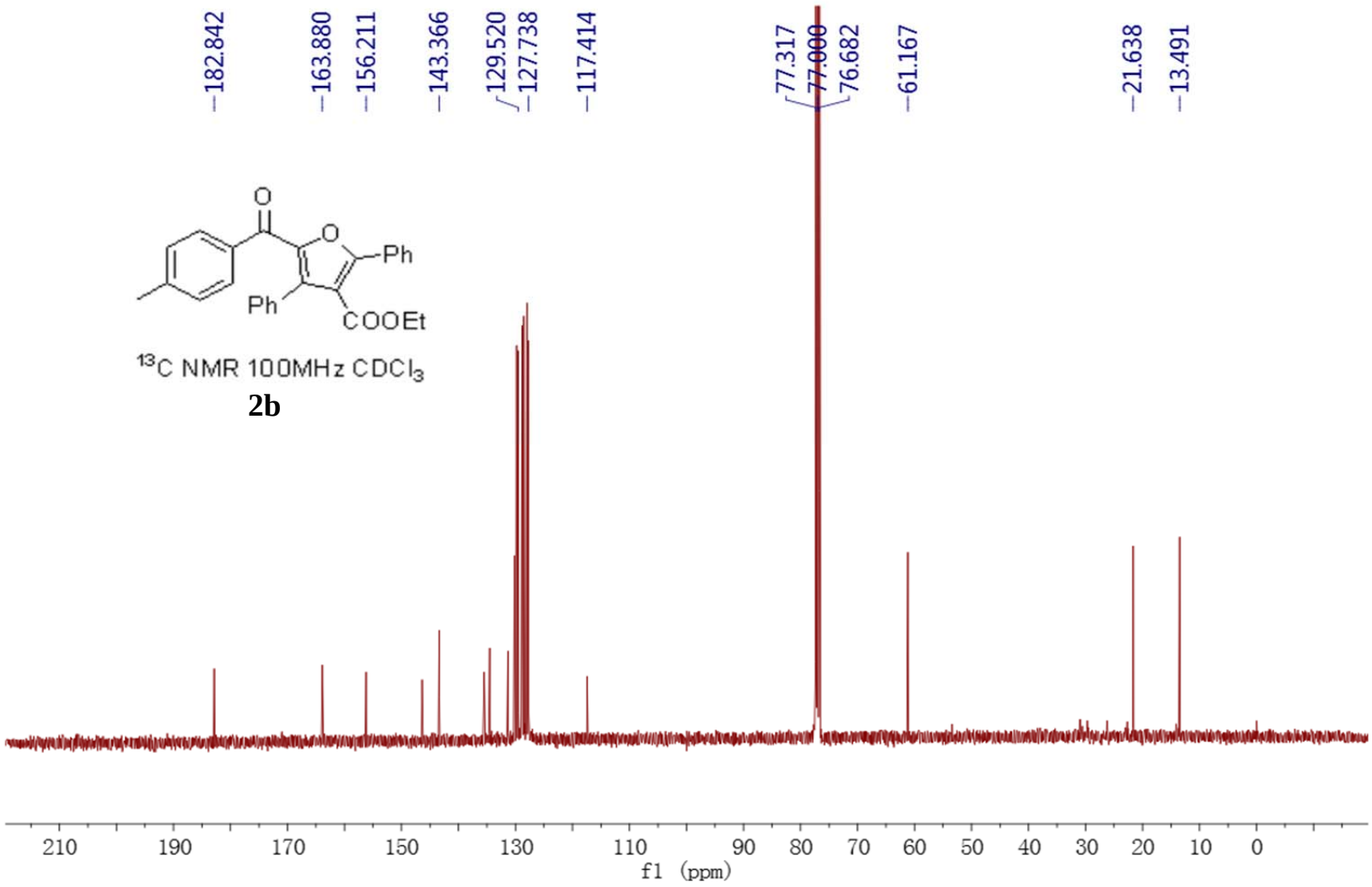


^{1}H NMR 400MHz $CDCl_3$

2b



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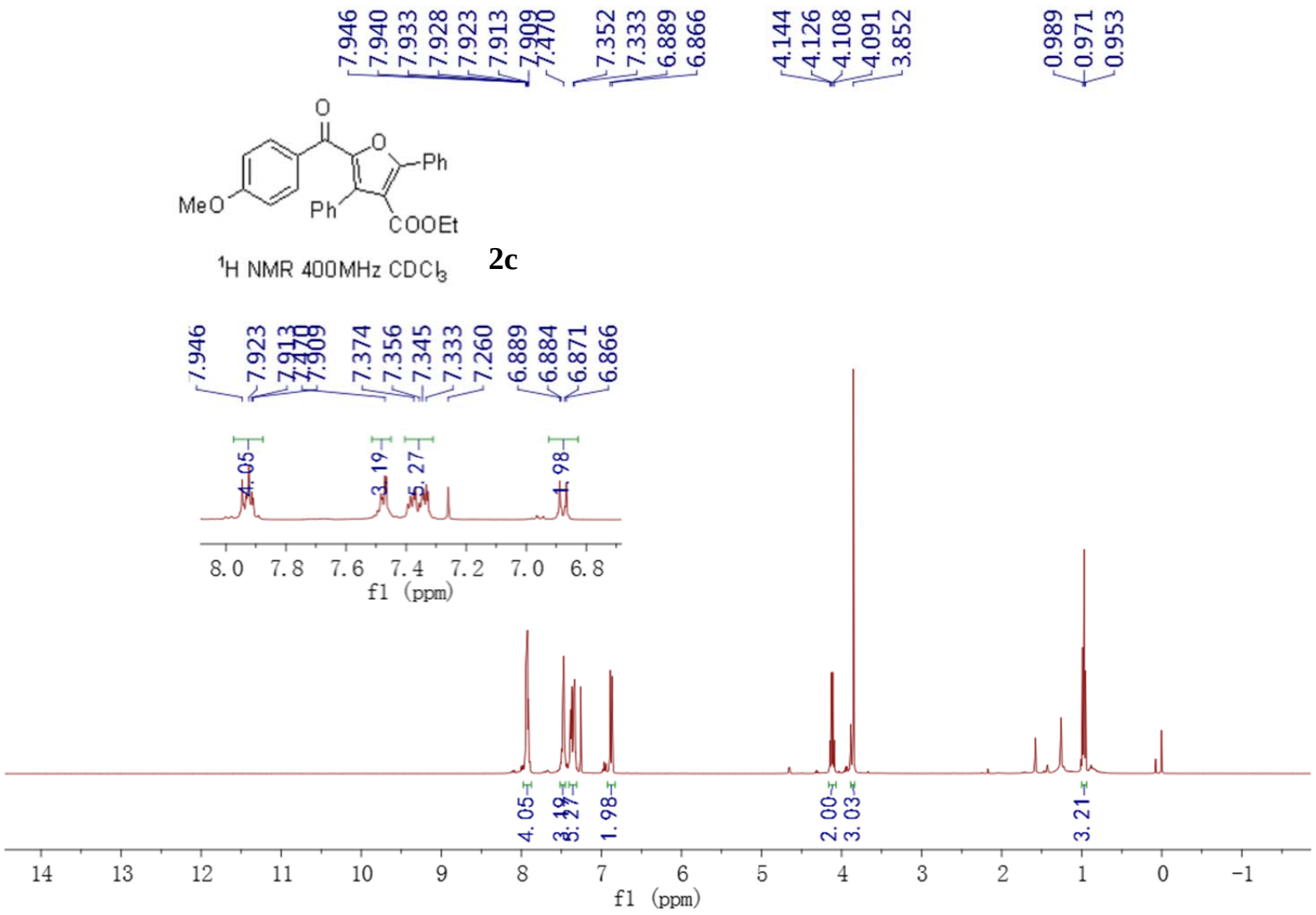
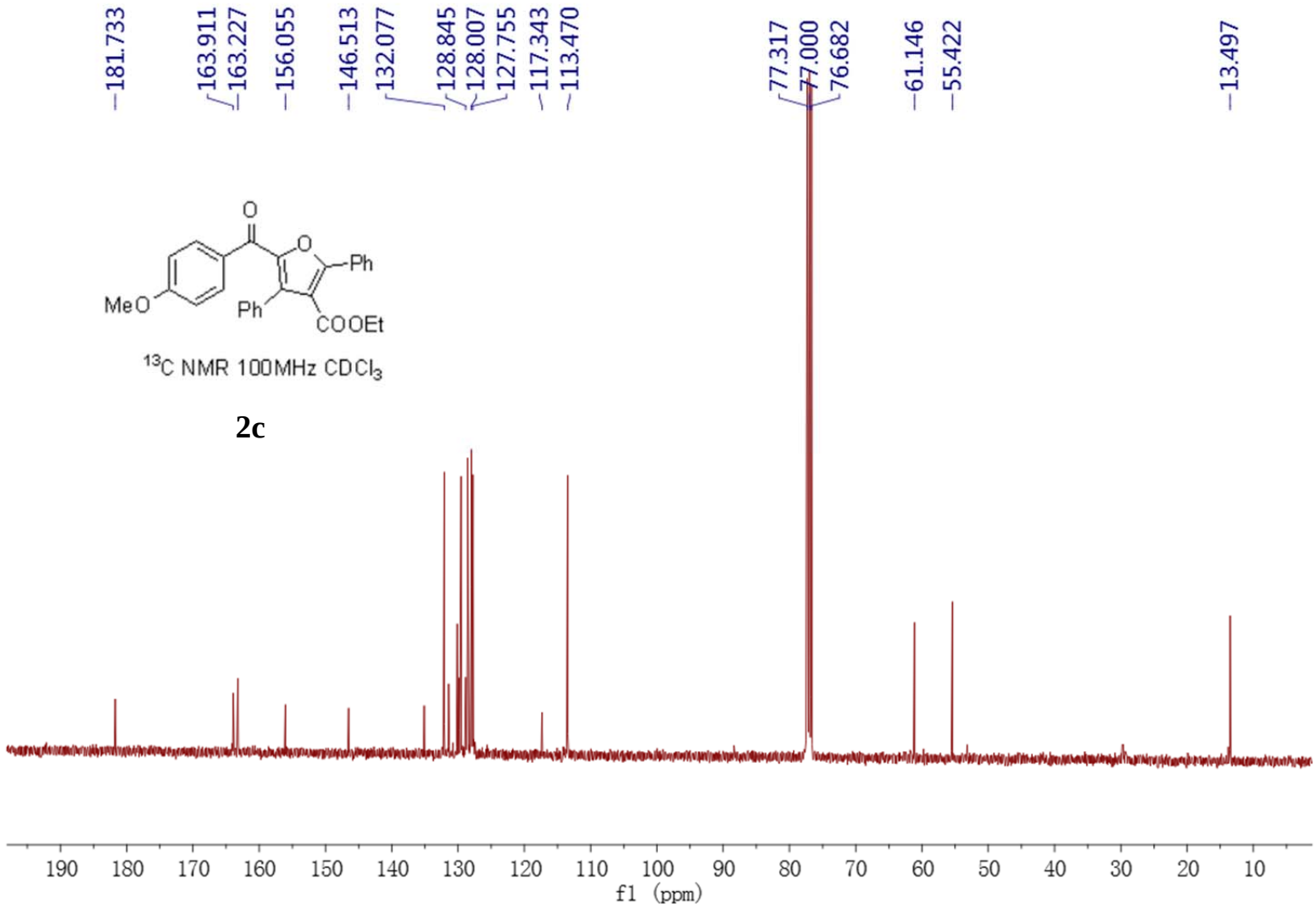
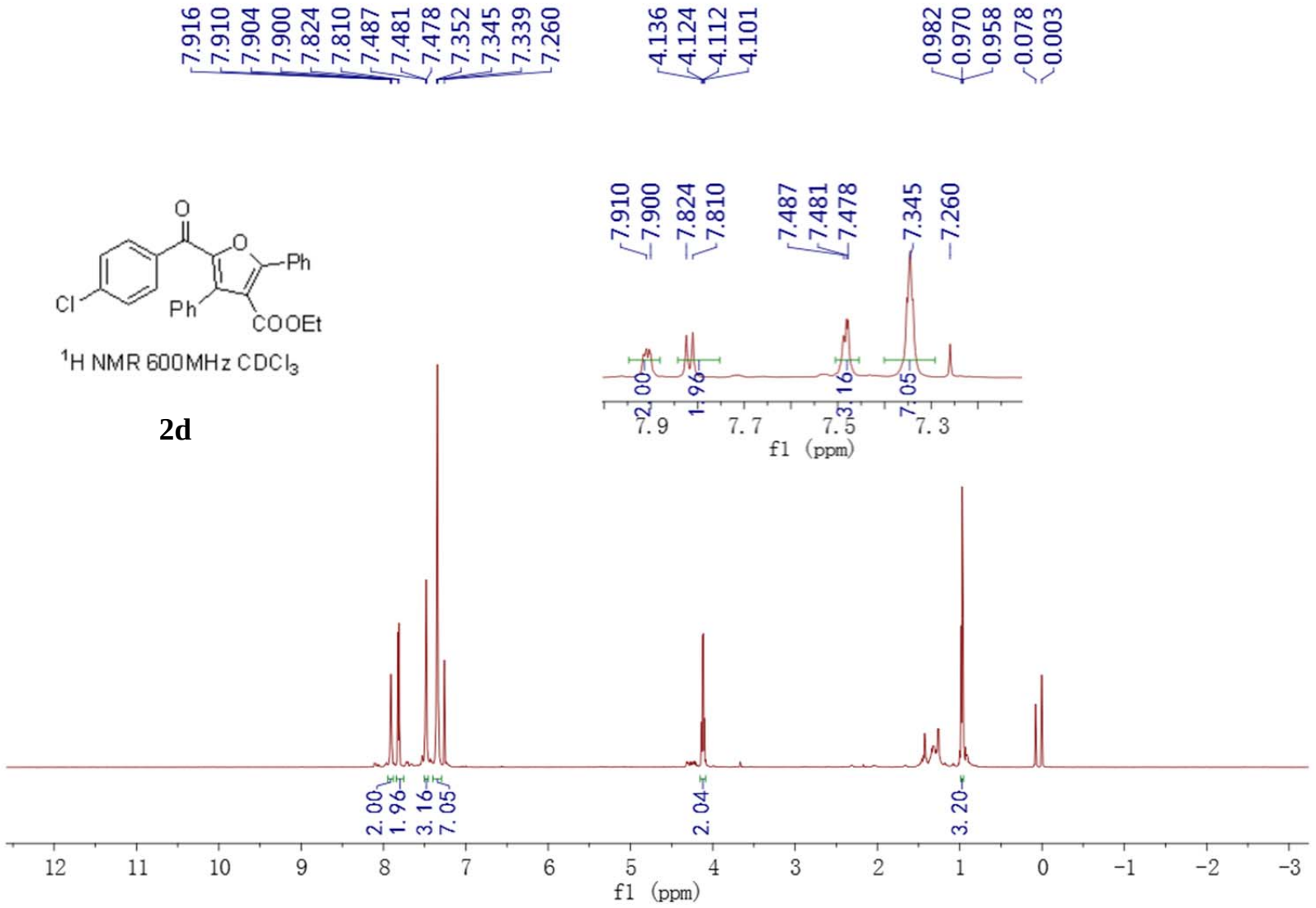
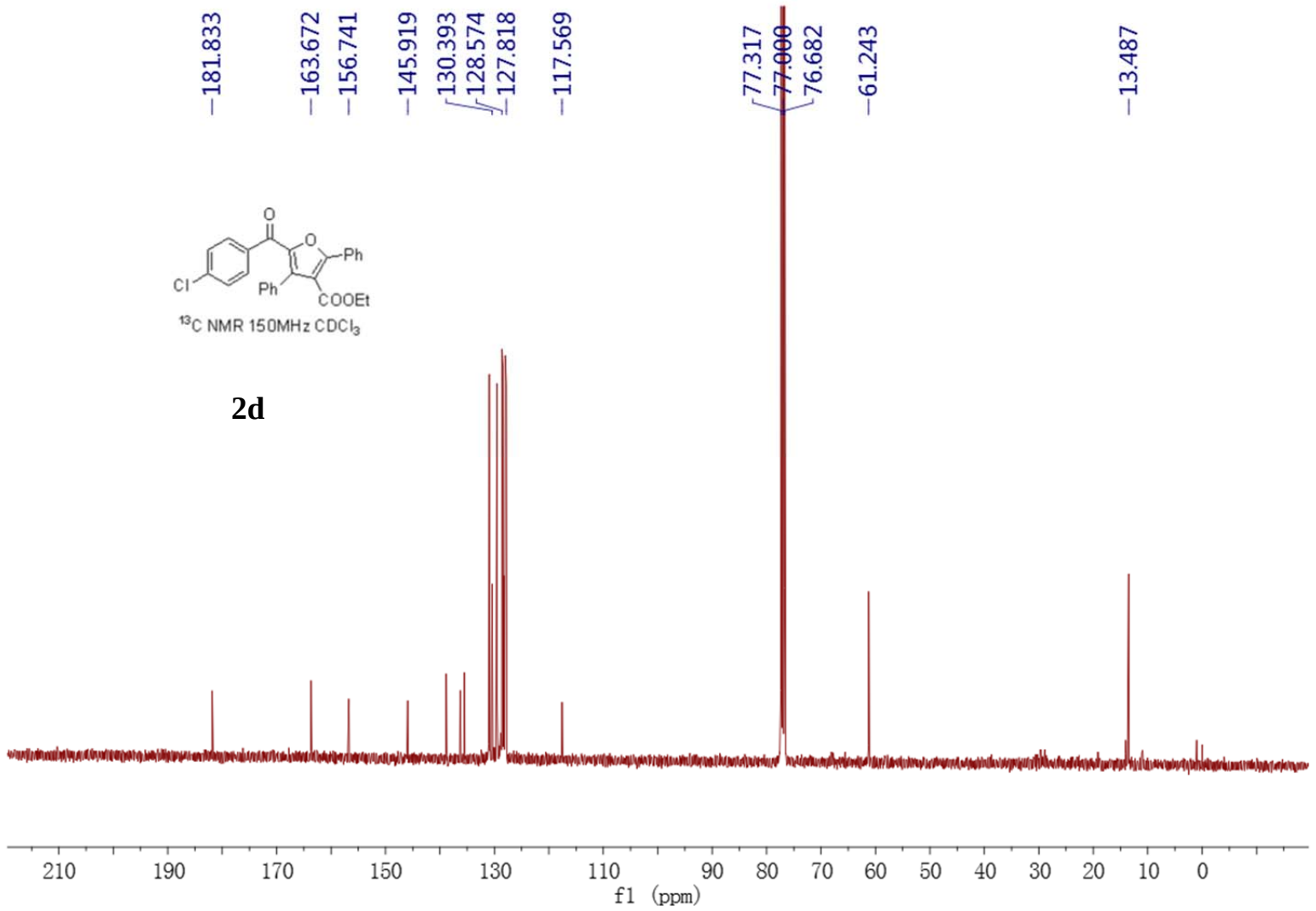
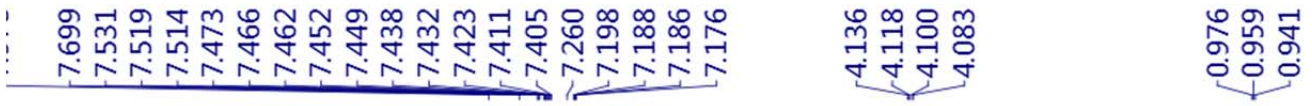
163.880
156.211
143.366
129.520
127.738
117.414
77.317
77.000
76.682
61.167
21.638
13.491
O
O
Ph
Ph
COOEt
13C NMR 100MHz CDCl3
2b
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

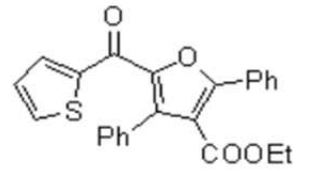

7.946
7.940
7.933
7.928
7.923
7.913
7.909
7.470
7.352
7.333
6.889
6.866
4.144
4.126
4.108
4.091
3.852
0.989
0.971
0.953
O
O
Ph
Ph
MeO
COOEt
1H NMR 400MHz CDCl3
2c
7.946
7.923
7.913
7.909
7.374
7.356
7.345
7.333
7.260
6.889
6.884
6.871
6.866
4.05
3.19
5.27
1.98
8.0 7.8 7.6 7.4 7.2 7.0 6.8
f1 (ppm)
4.05
3.19
5.27
1.98
2.00
3.03
3.21
14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 -1
f1 (ppm)


181.733
163.911
163.227
156.055
146.513
132.077
128.845
128.007
127.755
117.343
113.470
77.317
77.000
76.682
61.146
55.422
13.497
O
O
Ph
MeO
Ph
COOEt
13C NMR 100MHz CDCl3
2c
190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10
f1 (ppm)


7.916
7.910
7.904
7.900
7.824
7.810
7.487
7.481
7.478
7.352
7.345
7.339
7.260
4.136
4.124
4.112
4.101
0.982
0.970
0.958
0.078
0.003
O
O
Ph
Cl
Ph
COOEt
1H NMR 600MHz CDCl3
2d
f1 (ppm)
2.00
1.96
3.16
7.05
2.04
3.20

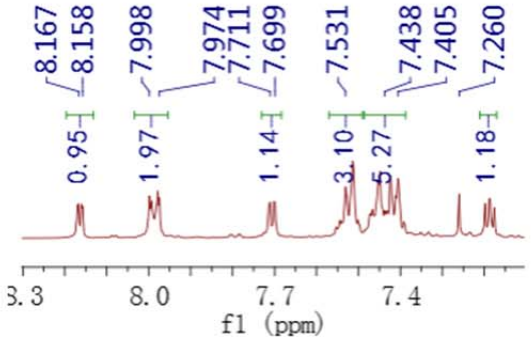

181.833
163.672
156.741
145.919
130.393
128.574
127.818
117.569
77.317
77.000
76.682
61.243
13.487
O
O
Ph
Cl
Ph
COOEt
13C NMR 150MHz CDCl3
2d
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

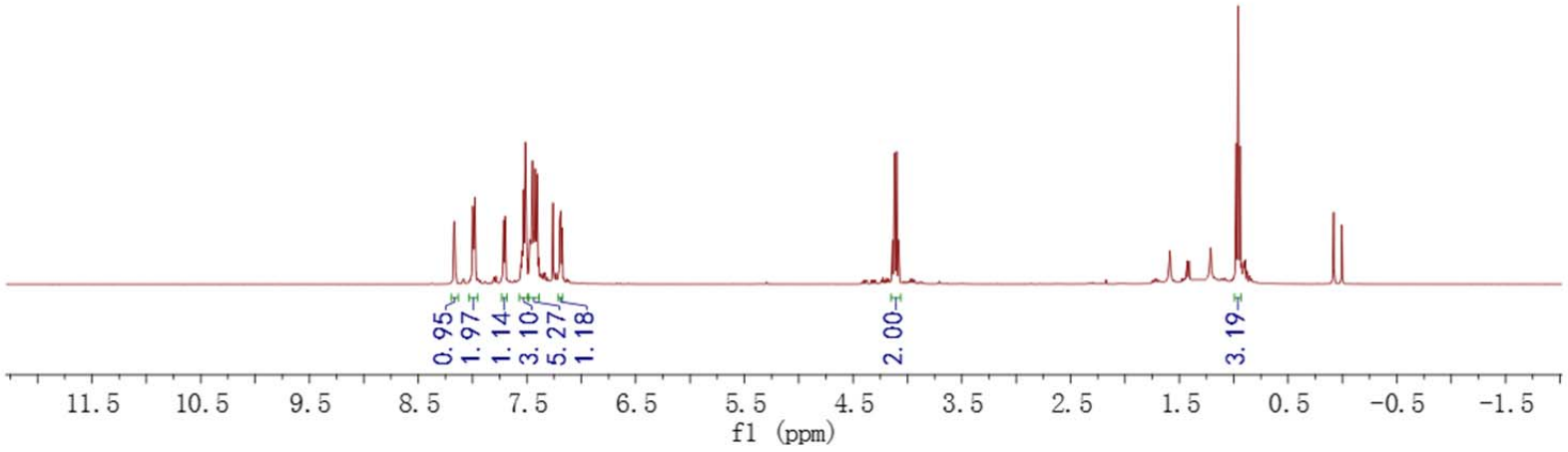


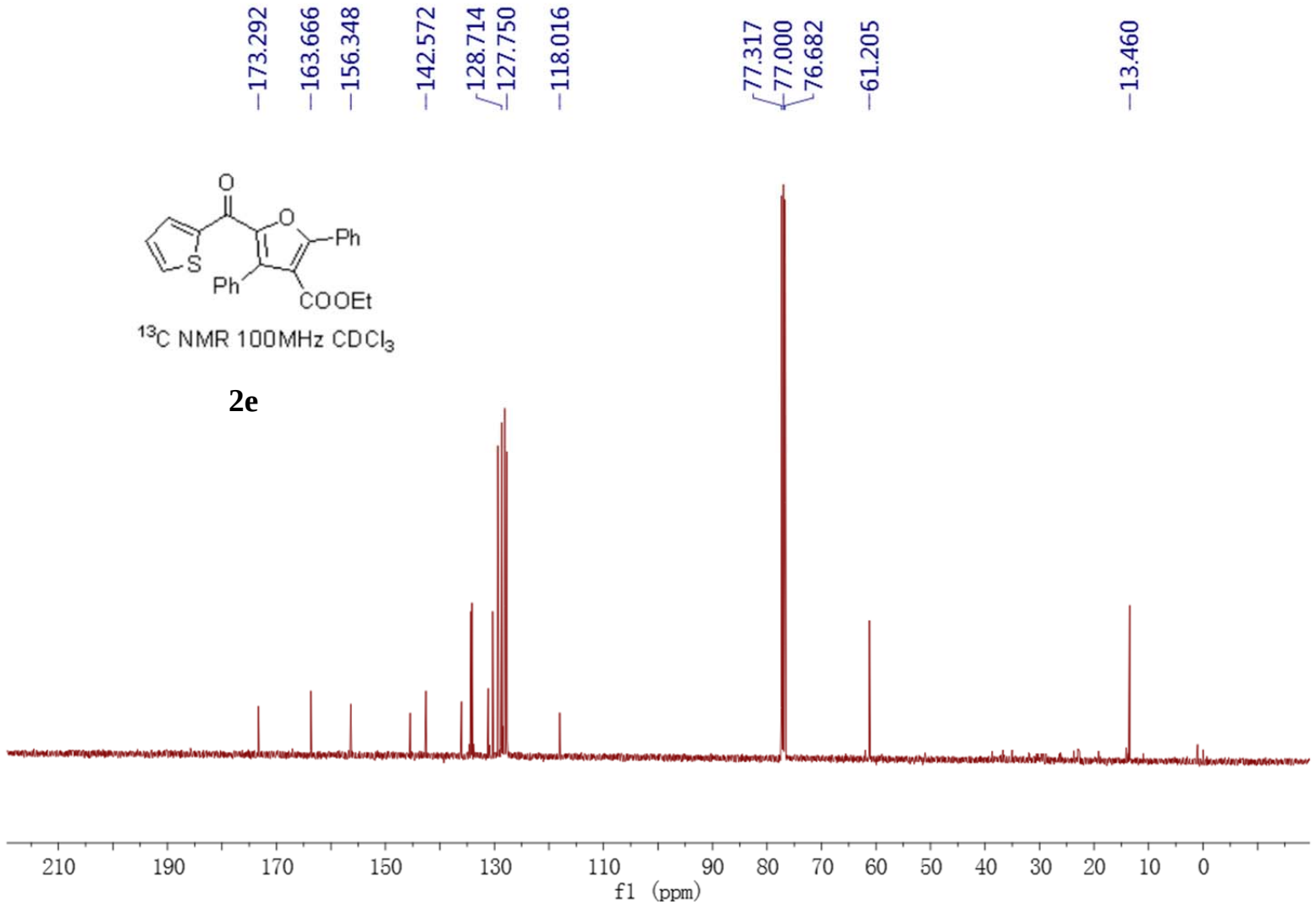


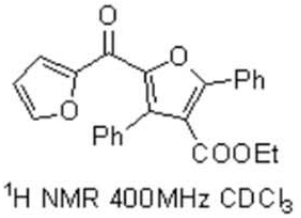
^{1}H NMR 400MHz $CDCl_3$

2e



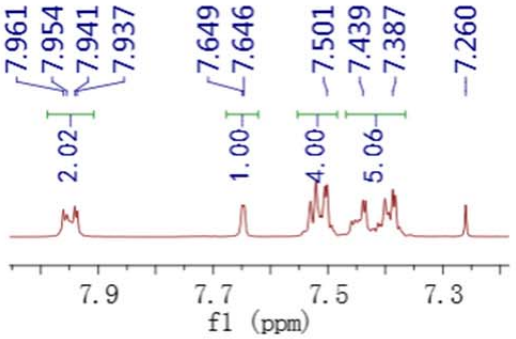


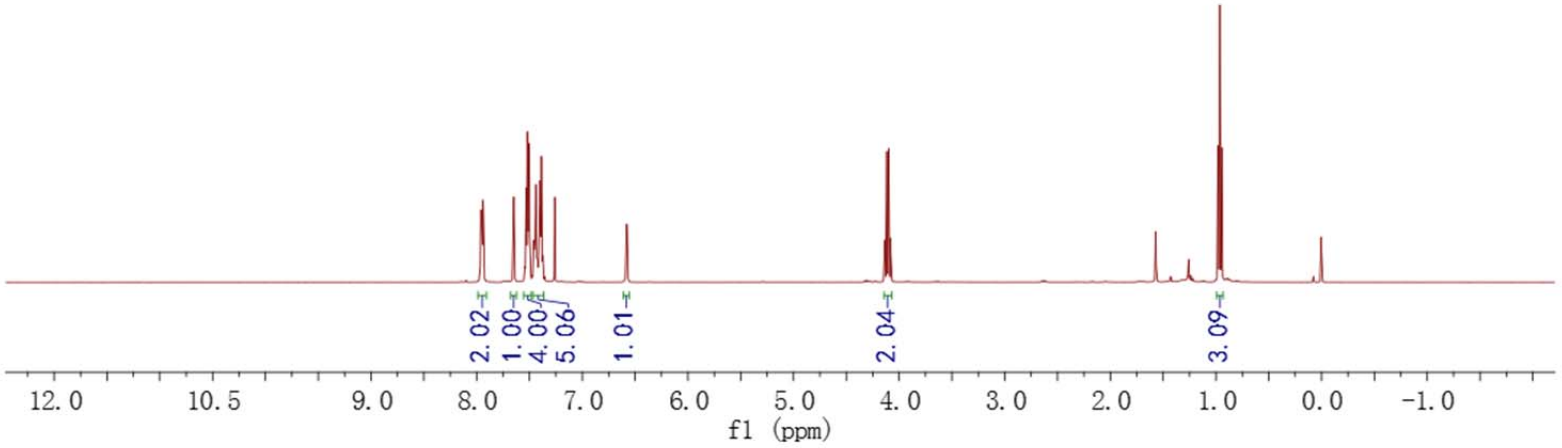

173.292
163.666
156.348
142.572
128.714
127.750
118.016
77.317
77.000
76.682
61.205
13.460
O
O
S
Ph
Ph
COOEt
13C NMR 100MHz CDCl3
2e
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

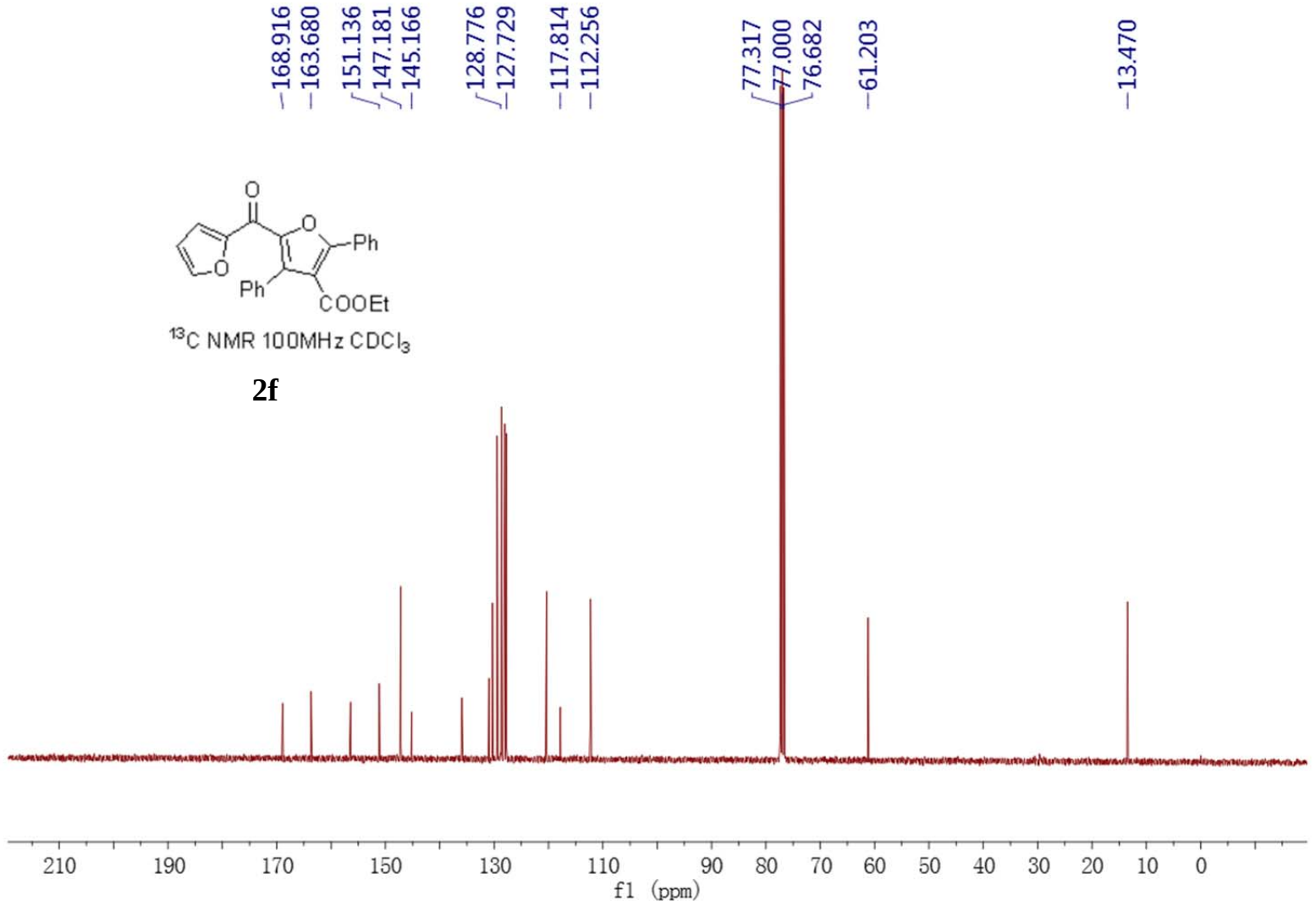


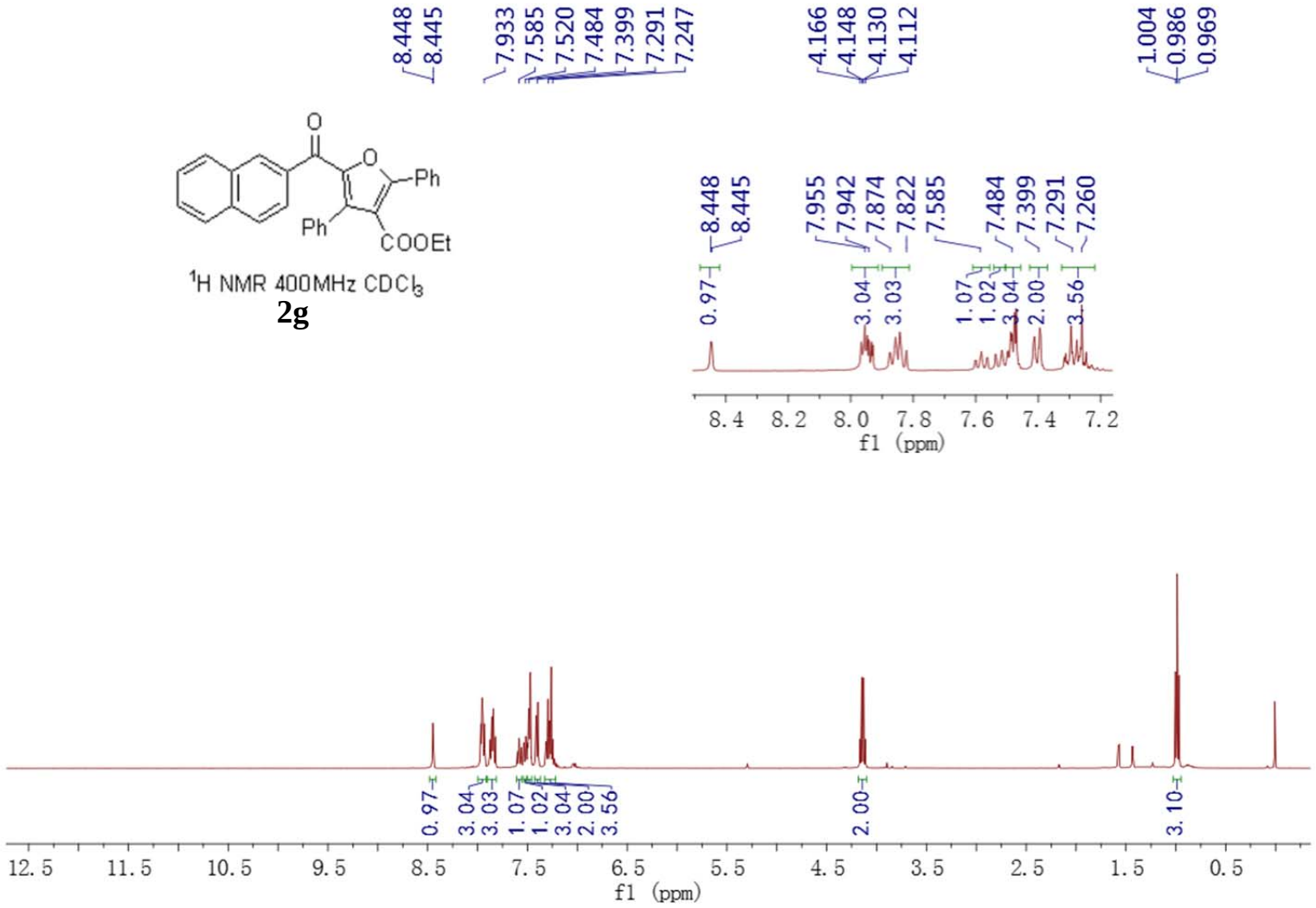
^{1}H NMR 400MHz $CDCl_3$

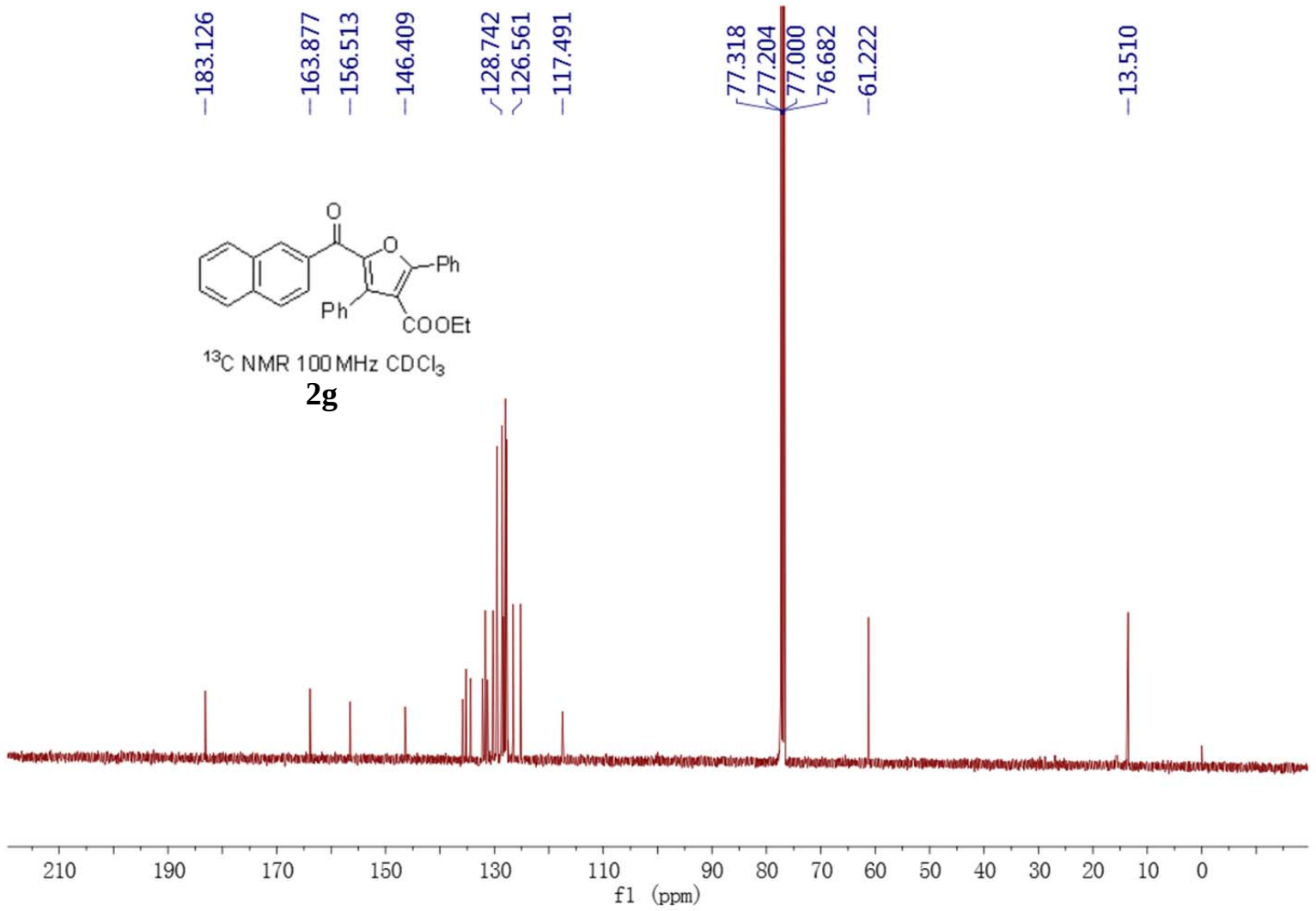
2f






168.916
163.680
151.136
147.181
145.166
128.776
127.729
117.814
112.256
77.317
77.000
76.682
61.203
13.470
O
O
O
Ph
Ph
COOEt
13C NMR 100MHz CDCl3
2f
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.448
8.445
7.933
7.585
7.520
7.484
7.399
7.291
7.247
4.166
4.148
4.130
4.112
1.004
0.986
0.969
O
O
Ph
Ph
COOEt
¹H NMR 400MHz CDCl₃
2g
8.448
8.445
7.955
7.942
7.874
7.822
7.585
7.484
7.399
7.291
7.260
0.97
3.04
3.03
1.07
1.02
3.04
2.00
3.56
8.4
8.2
8.0
7.8
7.6
7.4
7.2
f1 (ppm)
0.97
3.04
3.03
1.07
1.02
3.04
2.00
3.56
2.00
3.10
12.5
11.5
10.5
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
0.5
f1 (ppm)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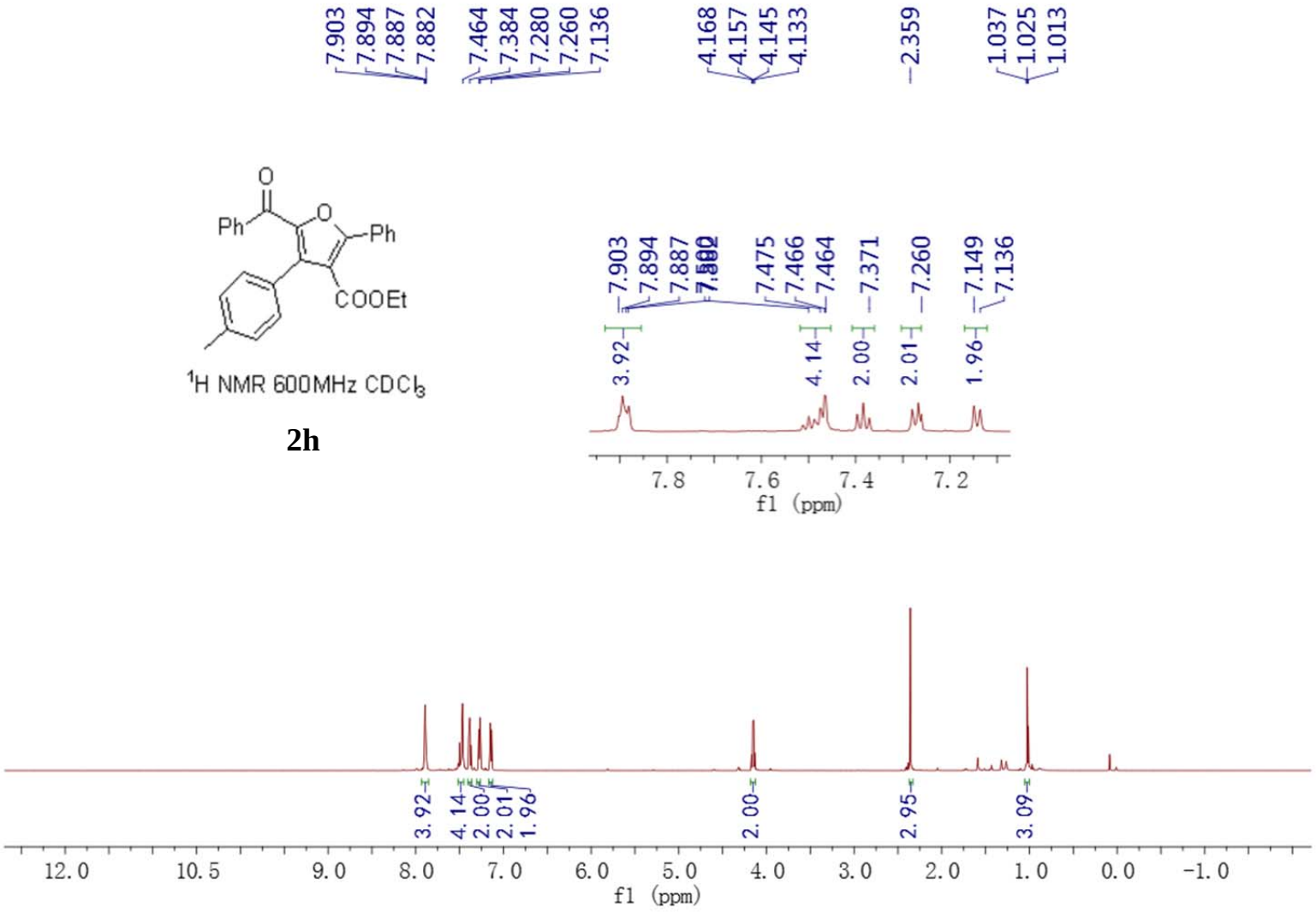
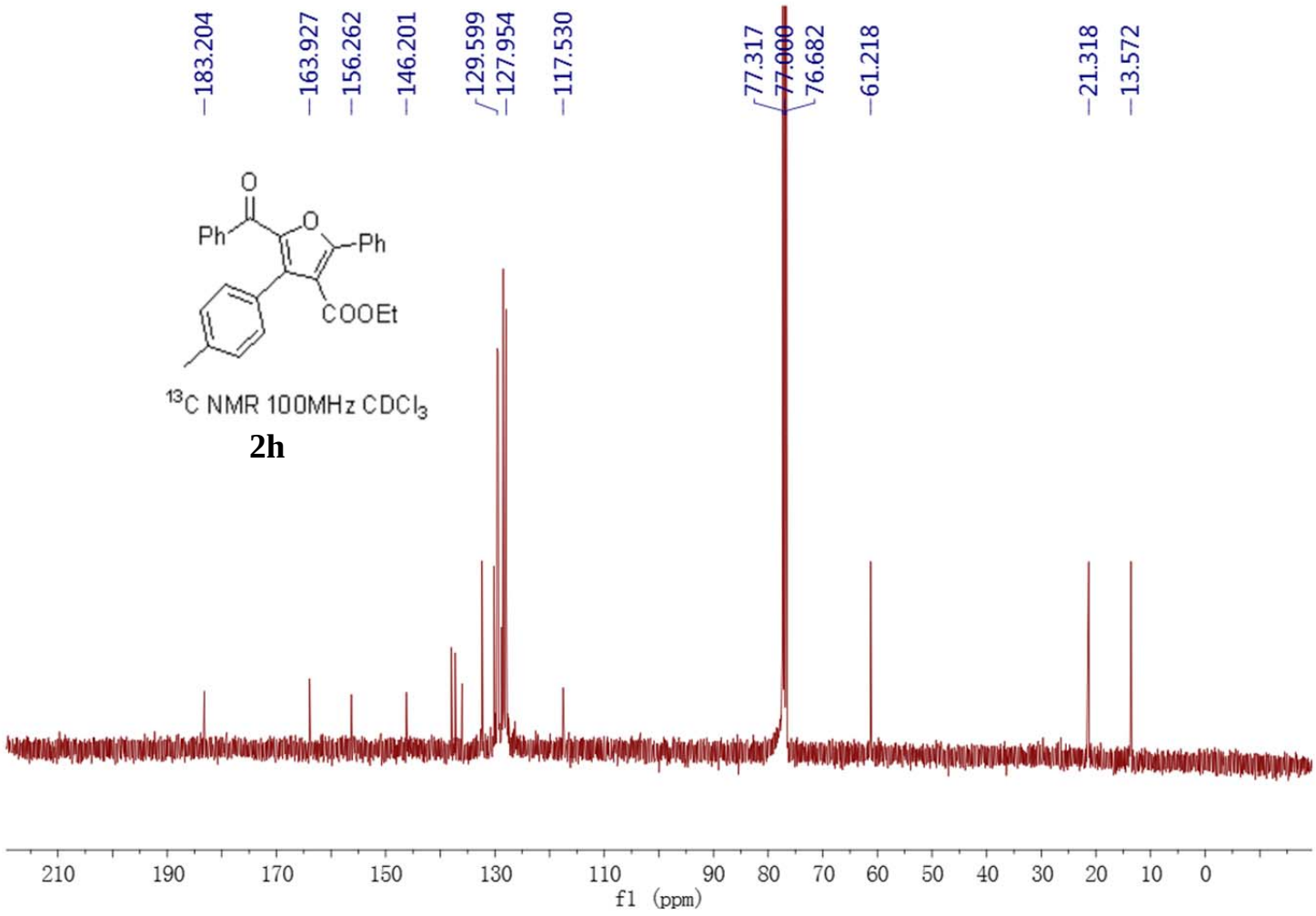
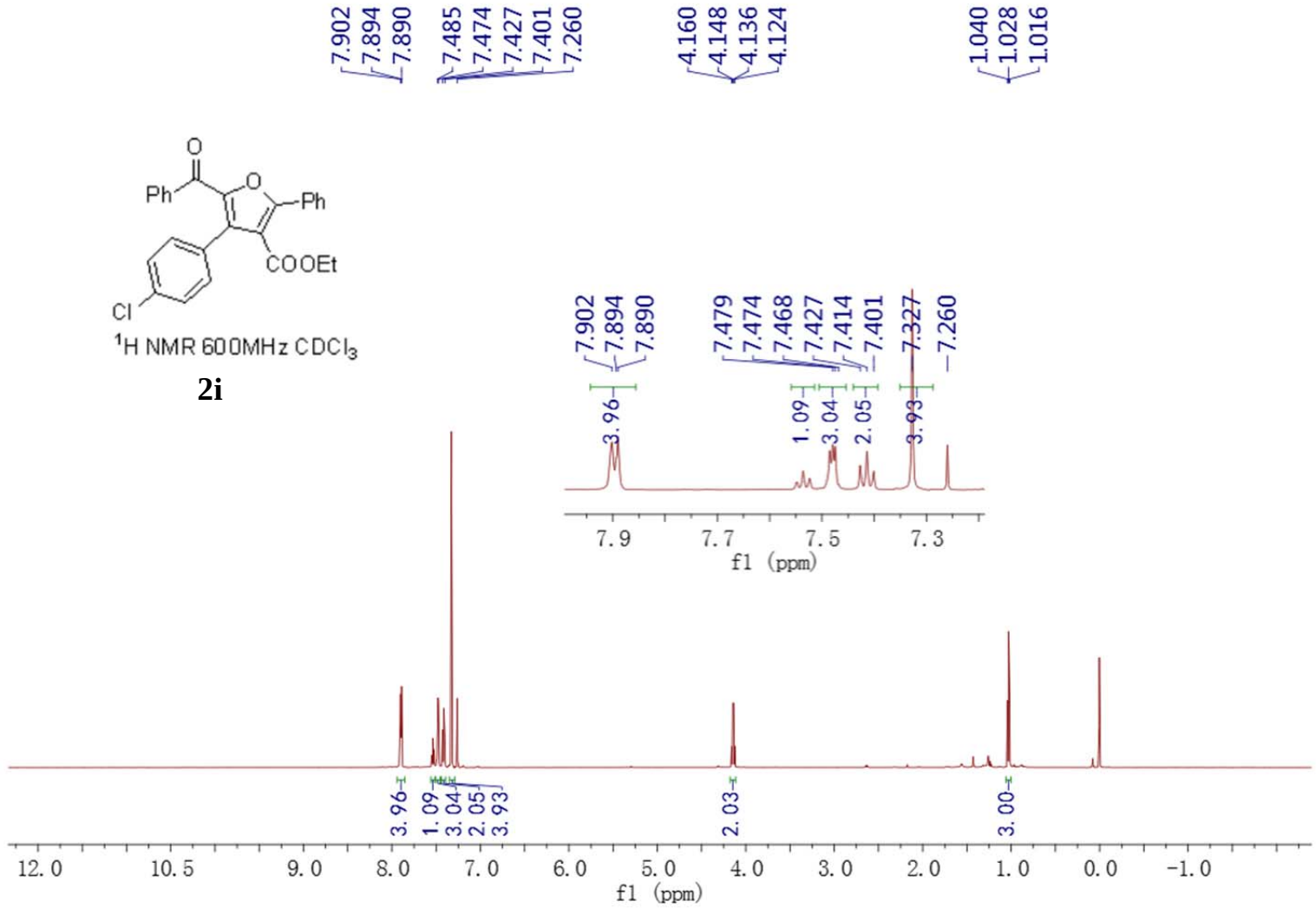
163.877
156.513
146.409
128.742
126.561
117.491
77.318
77.204
77.000
76.682
61.222
13.510
O
O
Ph
Ph
COOEt
13C NMR 100 MHz CDCl3
2g
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


7.903
7.894
7.887
7.882
7.464
7.384
7.280
7.260
7.136
4.168
4.157
4.145
4.133
2.359
1.037
1.025
1.013
O
Ph
O
Ph
COOEt
1H NMR 600MHz CDCl3
2h
7.903
7.894
7.887
7.475
7.466
7.464
7.371
7.260
7.149
7.136
3.92
4.14
2.00
2.01
1.96
7.8
7.6
7.4
7.2
f1 (ppm)
3.92
4.14
2.00
2.01
1.96
2.00
2.95
3.09
12.0
10.5
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
f1 (ppm)


183.204
163.927
156.262
146.201
129.599
127.954
117.530
77.317
77.000
76.682
61.218
21.318
13.572
O
Ph
O
Ph
COOEt
13C NMR 100MHz CDCl3
2h
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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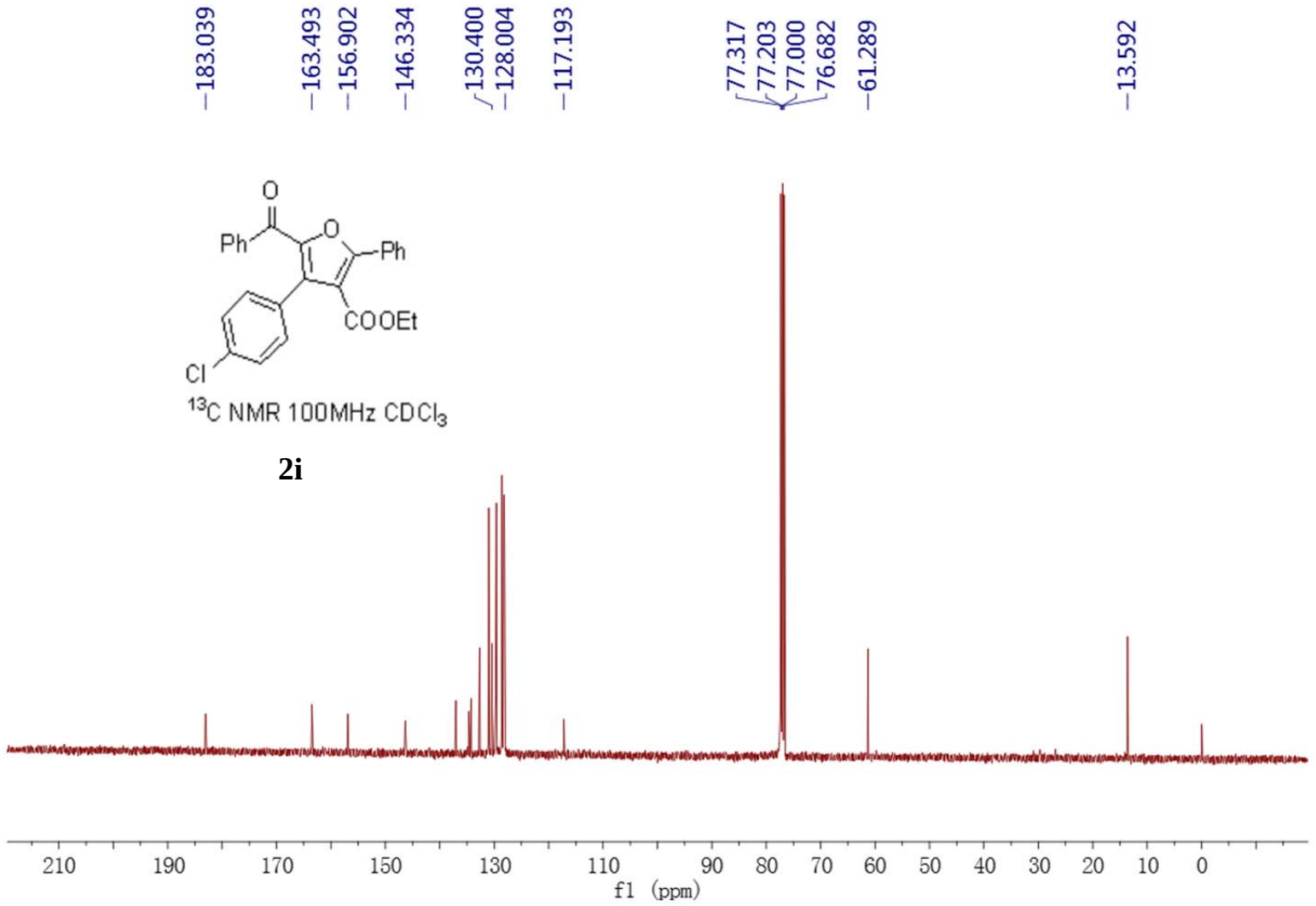
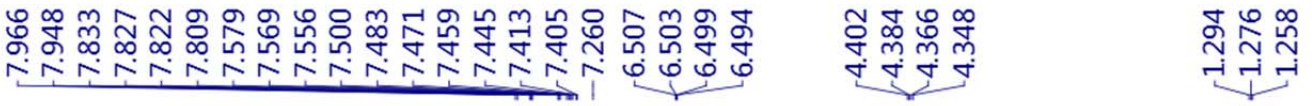
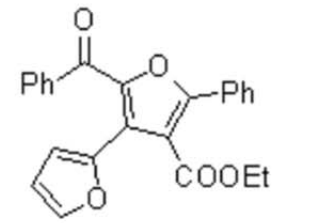
7.894
7.890
7.485
7.474
7.427
7.401
7.260
4.160
4.148
4.136
4.124
1.040
1.028
1.016
O
Ph
O
Ph
COOEt
Cl
1H NMR 600MHz CDCl3
2i
7.902
7.894
7.890
7.479
7.474
7.468
7.427
7.414
7.401
7.327
7.260
3.96
1.09
3.04
2.05
3.93
7.9
7.7
7.5
7.3
f1 (ppm)
3.96
1.09
3.04
2.05
3.93
2.03
3.00
12.0
10.5
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
f1 (ppm)

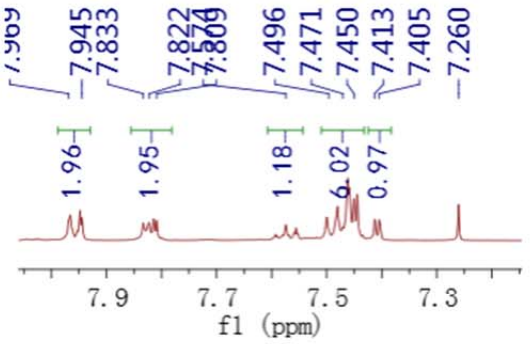

183.039
163.493
156.902
146.334
130.400
128.004
117.193
77.317
77.203
77.000
76.682
61.289
13.592
O
Ph
O
Ph
COOEt
Cl
13C NMR 100MHz CDCl3
2i
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

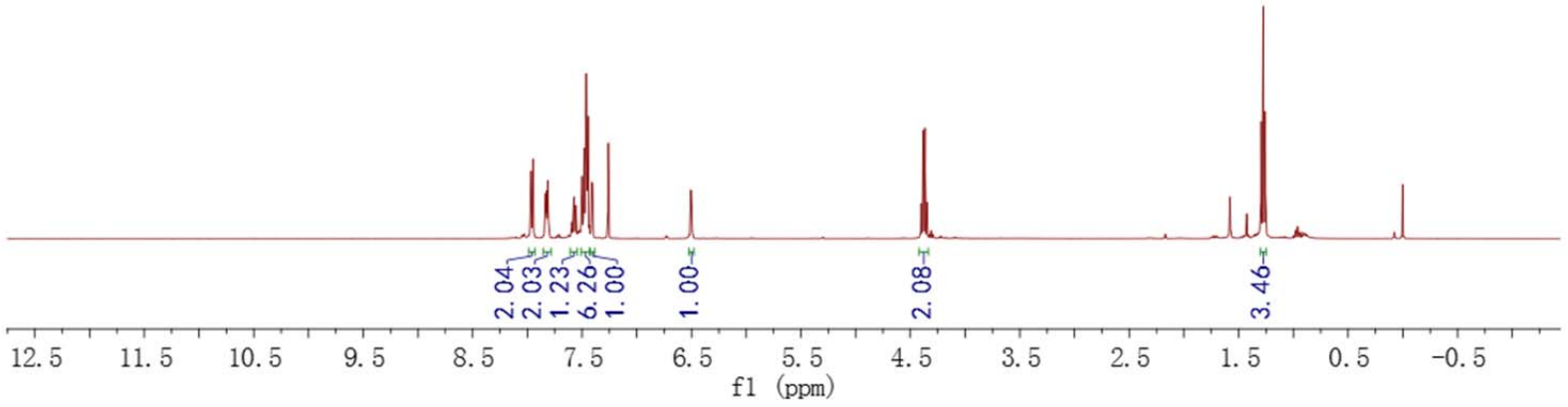


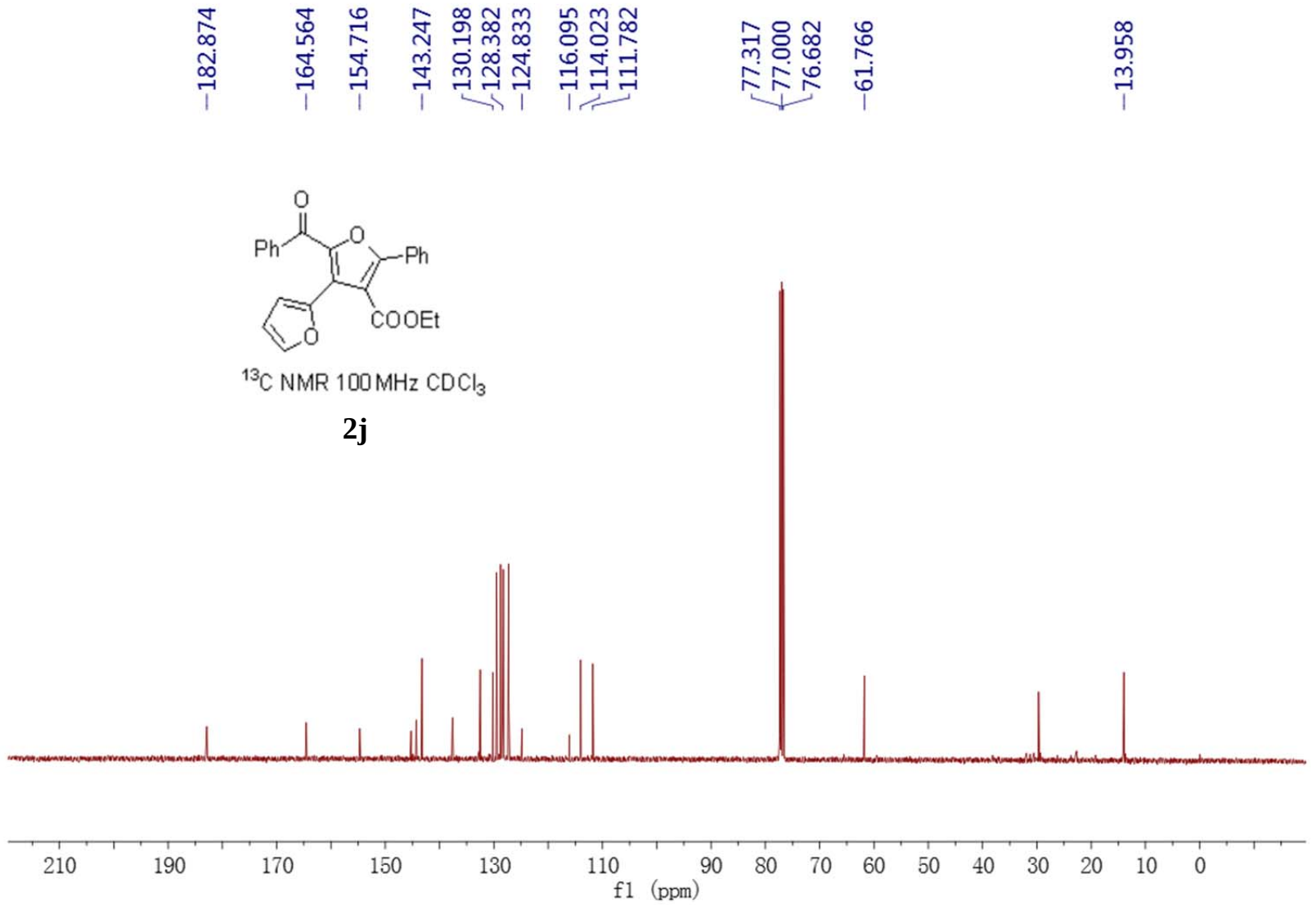


^{1}H NMR 400 MHz $CDCl_3$

2j

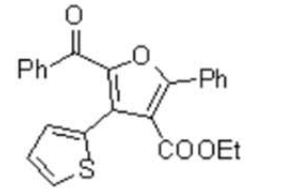






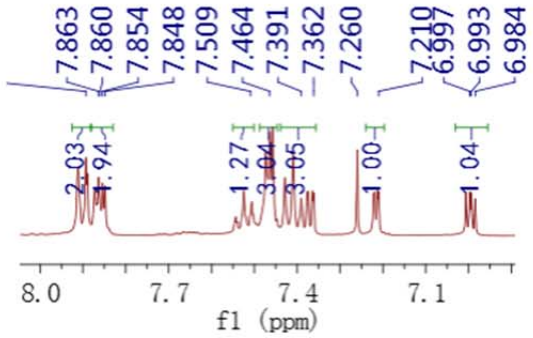
^{13}C NMR 100 MHz $CDCl_3$

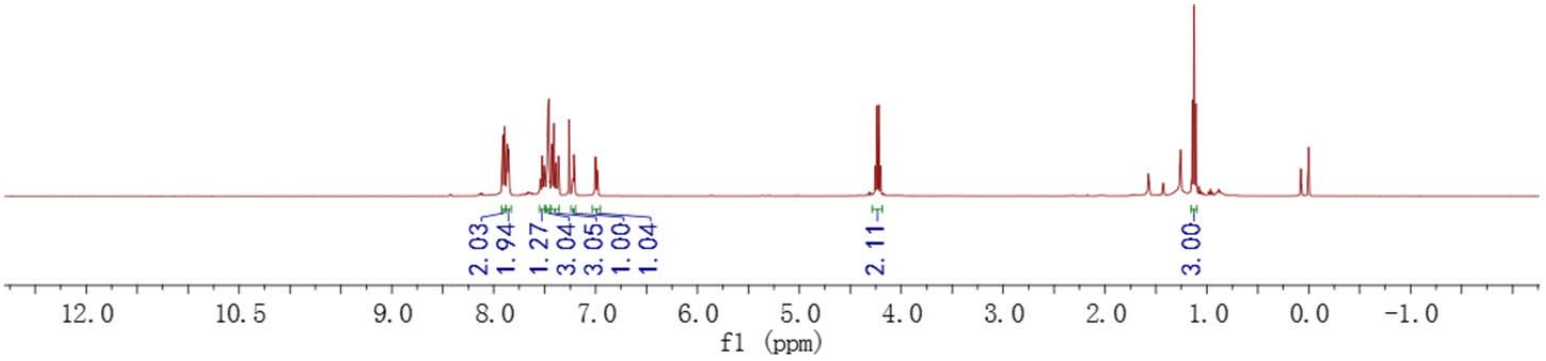
2j

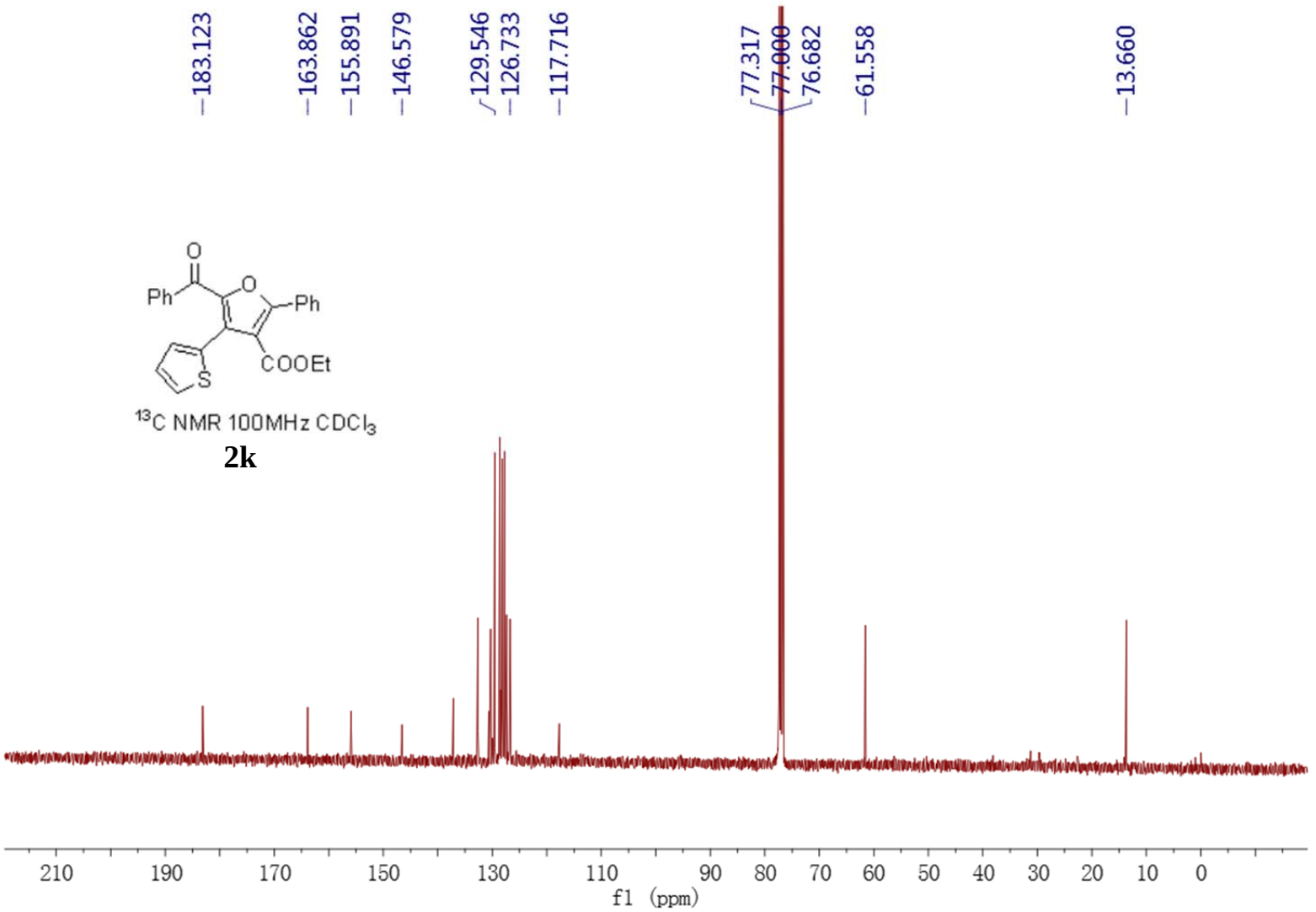


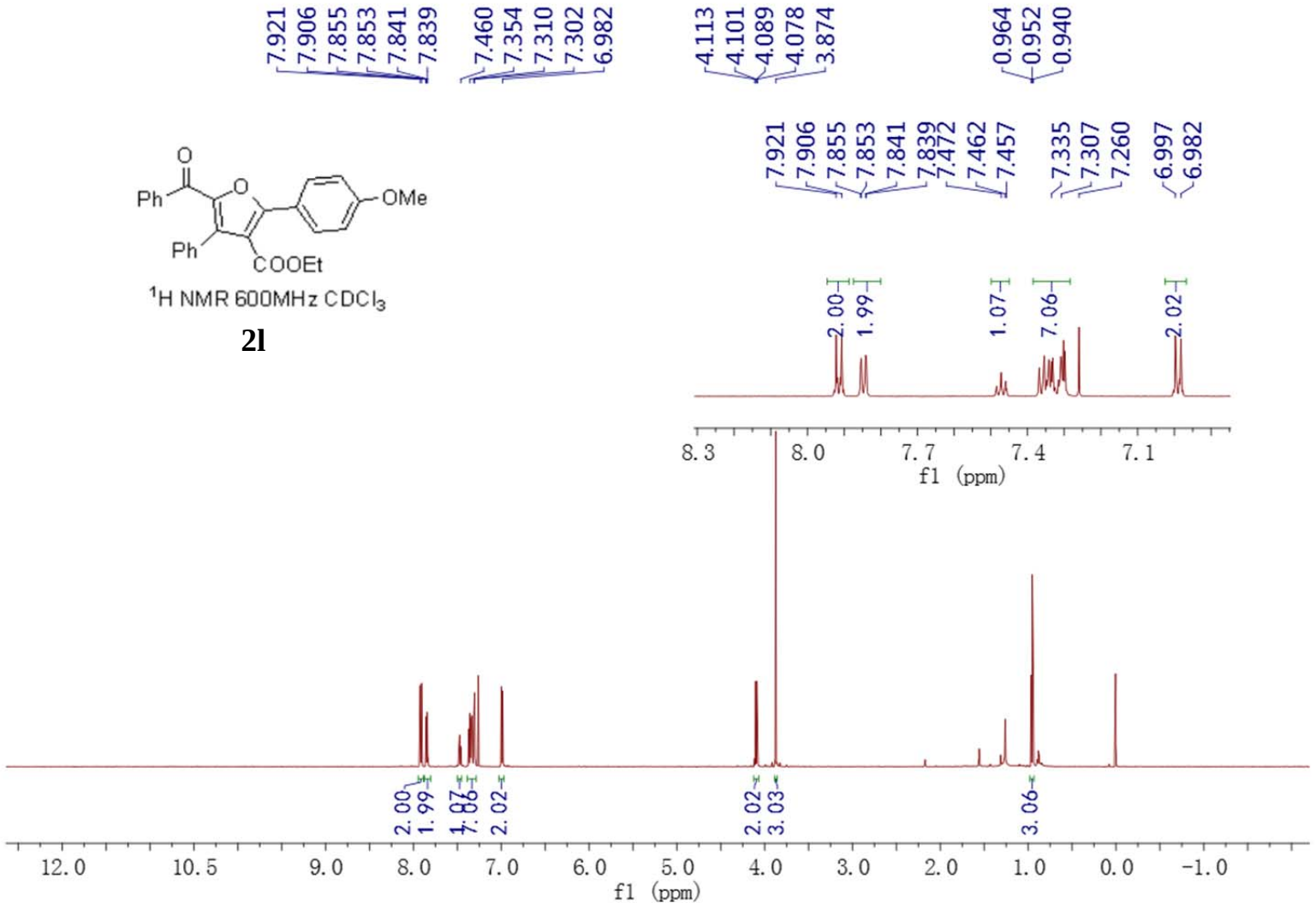
^{1}H NMR 400MHz $CDCl_3$

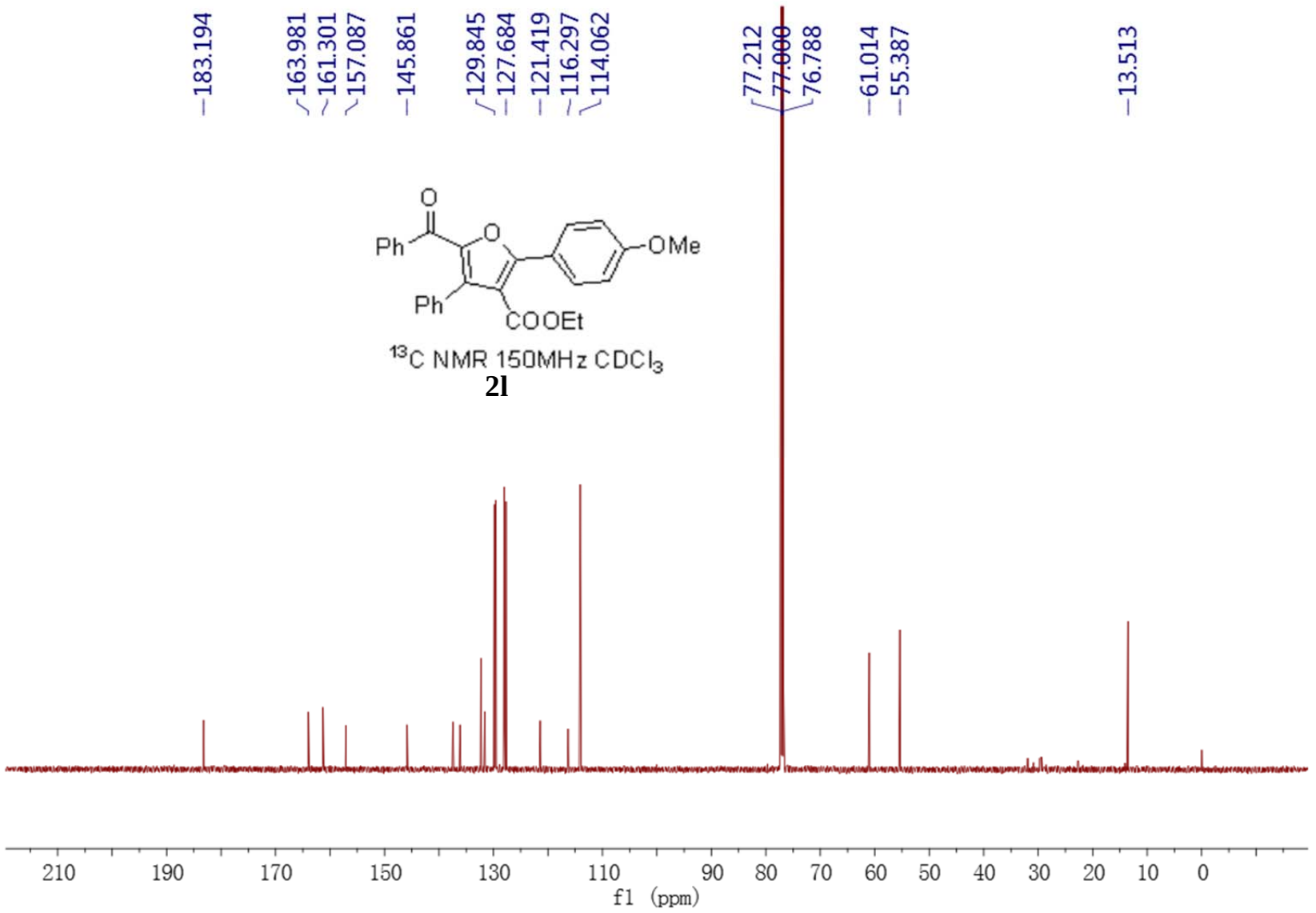
2k



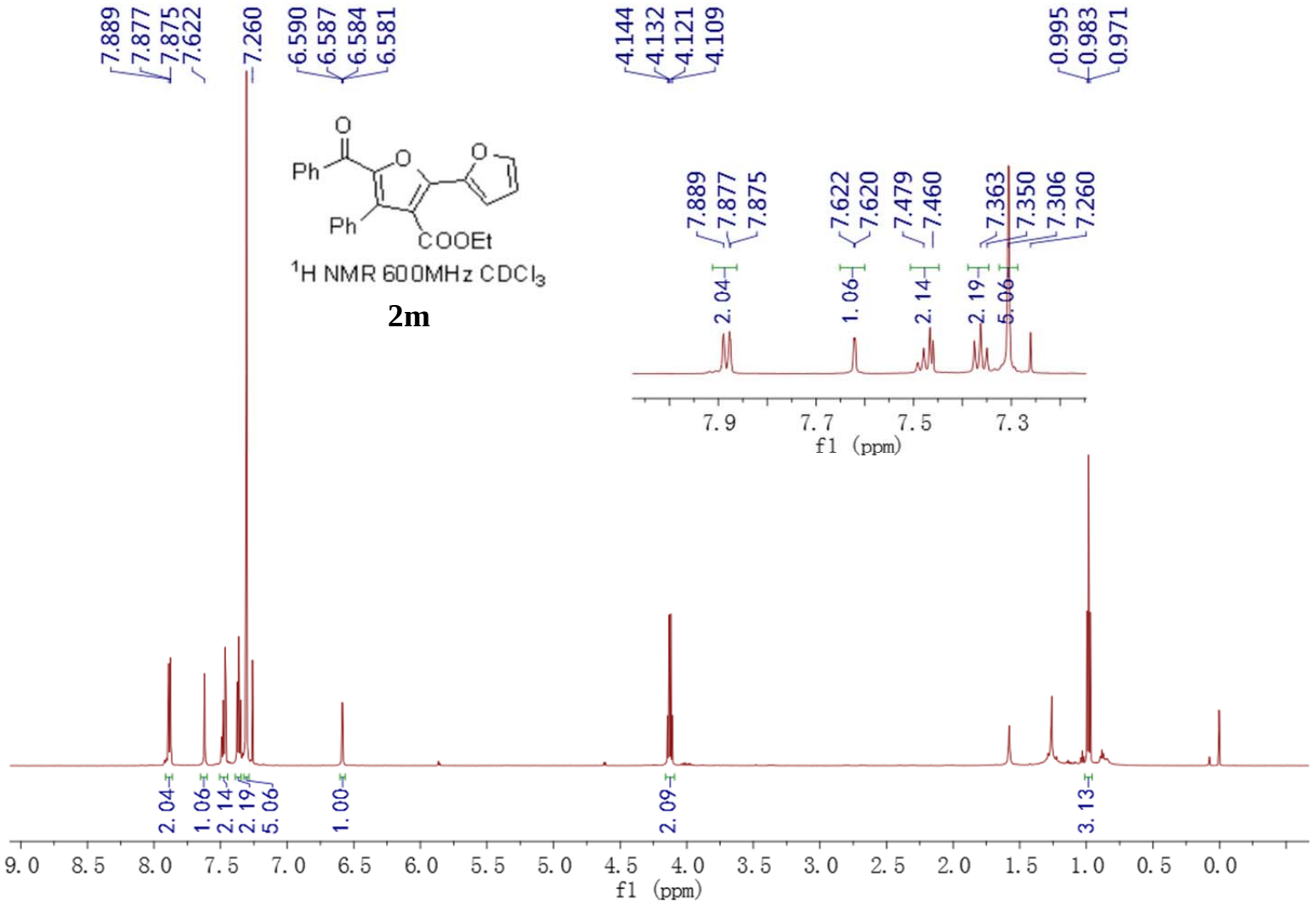


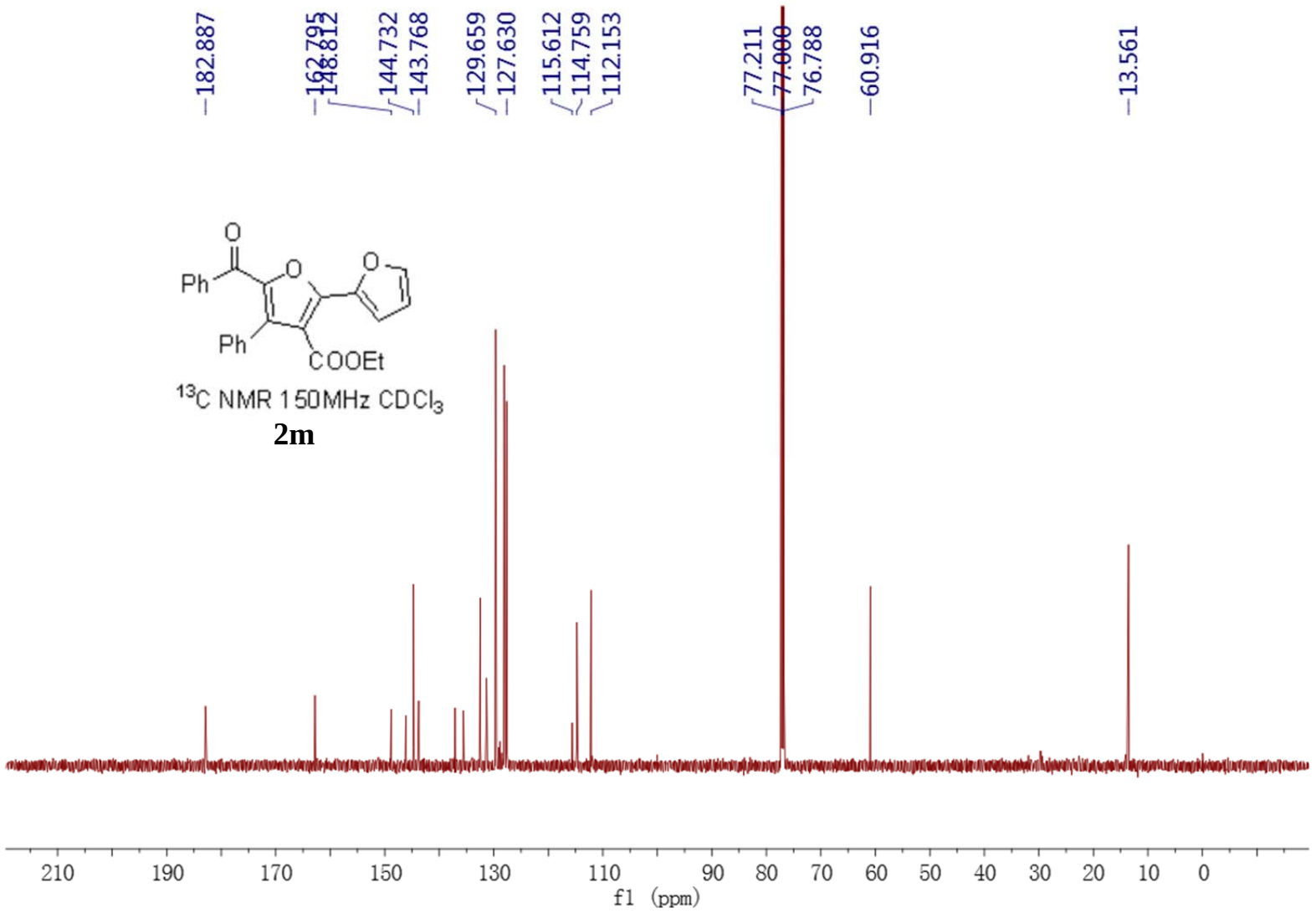

183.123
163.862
155.891
146.579
129.546
126.733
117.716
77.317
77.000
76.682
61.558
13.660
O
Ph
O
Ph
COOEt
S
13C NMR 100MHz CDCl3
2k
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

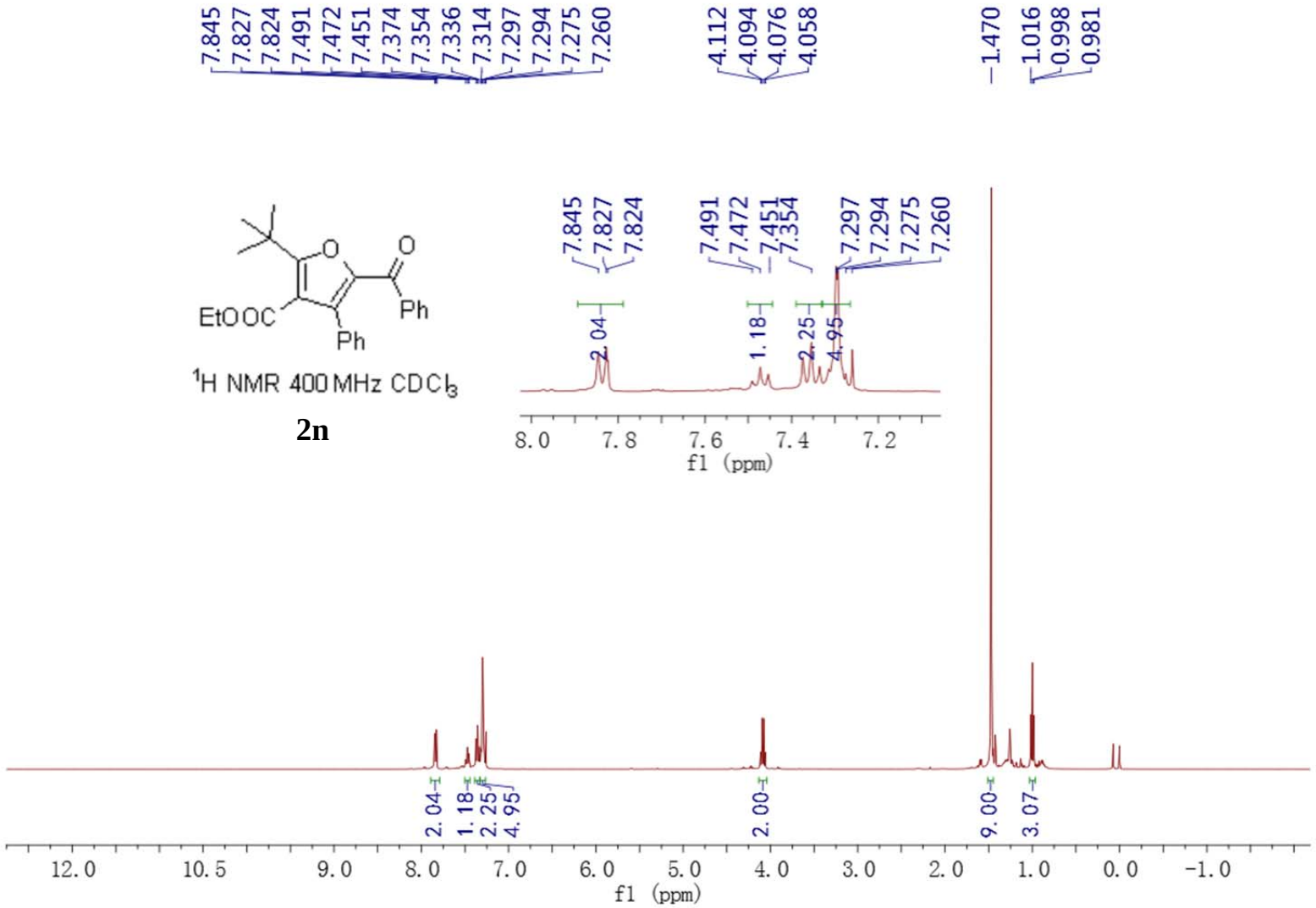

7.921
7.906
7.855
7.853
7.841
7.839
7.460
7.354
7.310
7.302
6.982
4.113
4.101
4.089
4.078
3.874
0.964
0.952
0.940
O
Ph
O
OMe
Ph
COOEt
1H NMR 600MHz CDCl3
2l
2.00
1.99
1.07
7.06
2.02
8.3
8.0
7.7
7.4
7.1
f1 (ppm)
2.00
1.99
2.02
2.02
3.03
3.06
12.0
10.5
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
f1 (ppm)

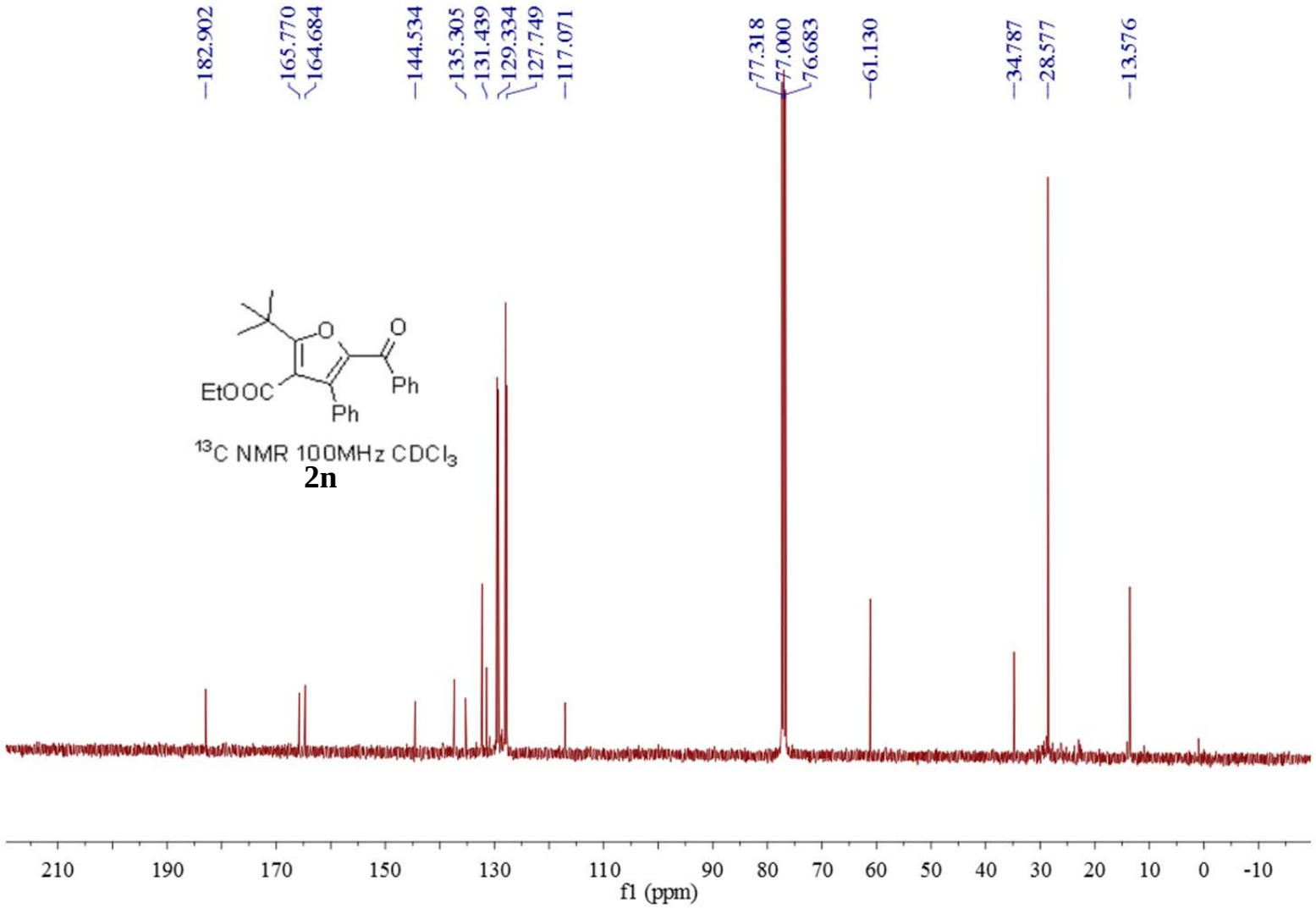

183.194
163.981
161.301
157.087
145.861
129.845
127.684
121.419
116.297
114.062
77.212
77.000
76.788
61.014
55.387
13.513
O
Ph
O
OMe
Ph
COOEt
13C NMR 150MHz CDCl3
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

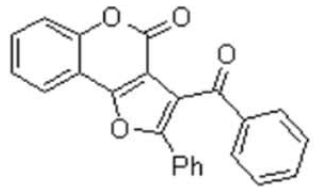
2l


7.889
7.877
7.875
7.622
7.260
6.590
6.587
6.584
6.581
4.144
4.132
4.121
4.109
0.995
0.983
0.971
Ph
Ph
COOEt
1H NMR 600MHz CDCl3
2m
7.889
7.877
7.875
7.622
7.620
7.479
7.460
7.363
7.350
7.306
7.260
2.04
1.06
2.14
2.19
5.06
7.9
7.7
7.5
7.3
f1 (ppm)
2.04
1.06
2.14
2.19
5.06
1.00
2.09
3.13
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


182.887
162.795
148.812
144.732
143.768
129.659
127.630
115.612
114.759
112.153
77.211
77.000
76.788
60.916
13.561
O
Ph
O
O
Ph
COOEt
13C NMR 150MHz CDCl3
2m
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

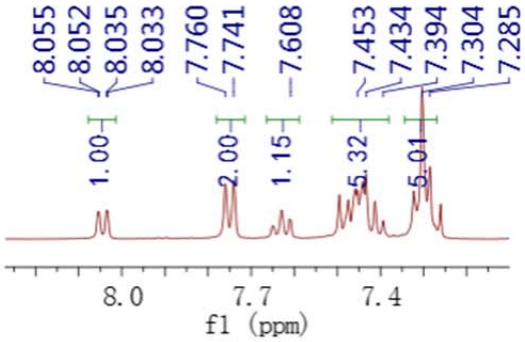

7.845
7.827
7.824
7.491
7.472
7.451
7.374
7.354
7.336
7.314
7.297
7.294
7.275
7.260
4.112
4.094
4.076
4.058
1.470
1.016
0.998
0.981
EtOOC
Ph
Ph
O
O
1H NMR 400 MHz CDCl3
2n
2.04
1.18
2.25
4.95
8.0
7.8
7.6
7.4
7.2
f1 (ppm)
2.04
1.18
2.25
4.95
2.00
9.00
3.07
12.0
10.5
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
f1 (ppm)

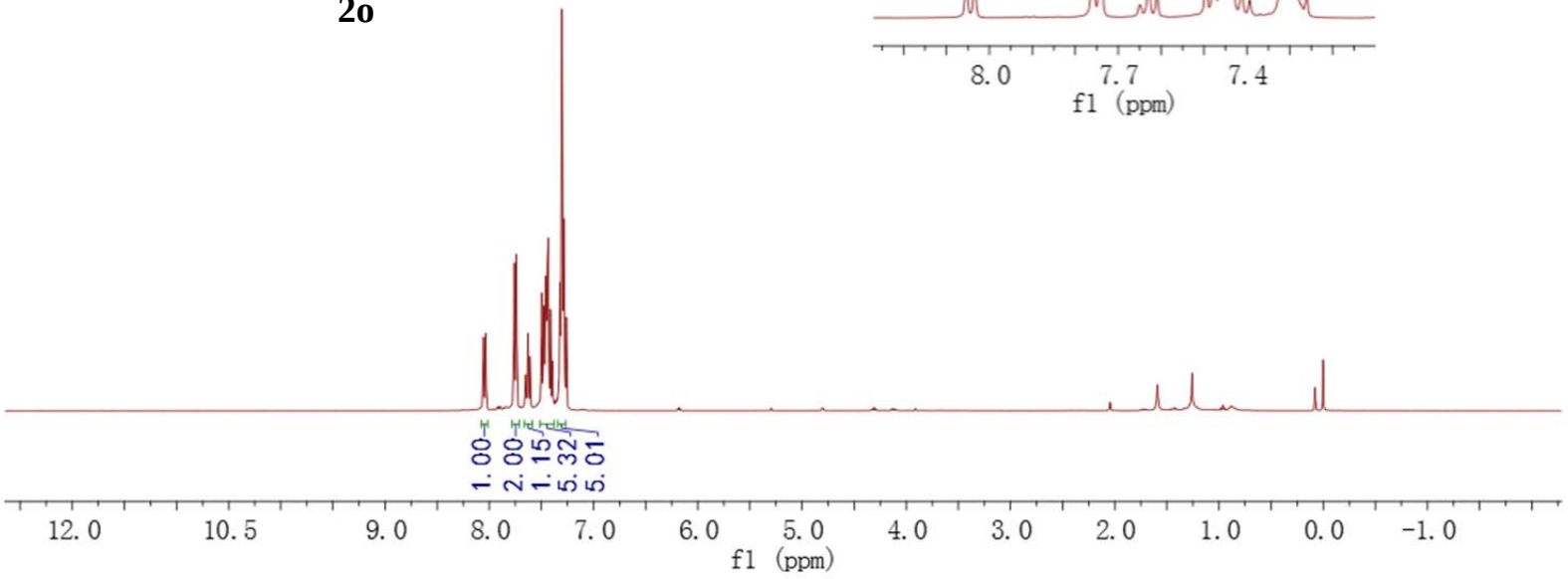

182.902
165.770
164.684
144.534
135.305
131.439
129.334
127.749
117.071
77.318
77.000
76.683
61.130
34.787
28.577
13.576
EtOOC
O
O
Ph
Ph
13C NMR 100MHz CDCl3
2n
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

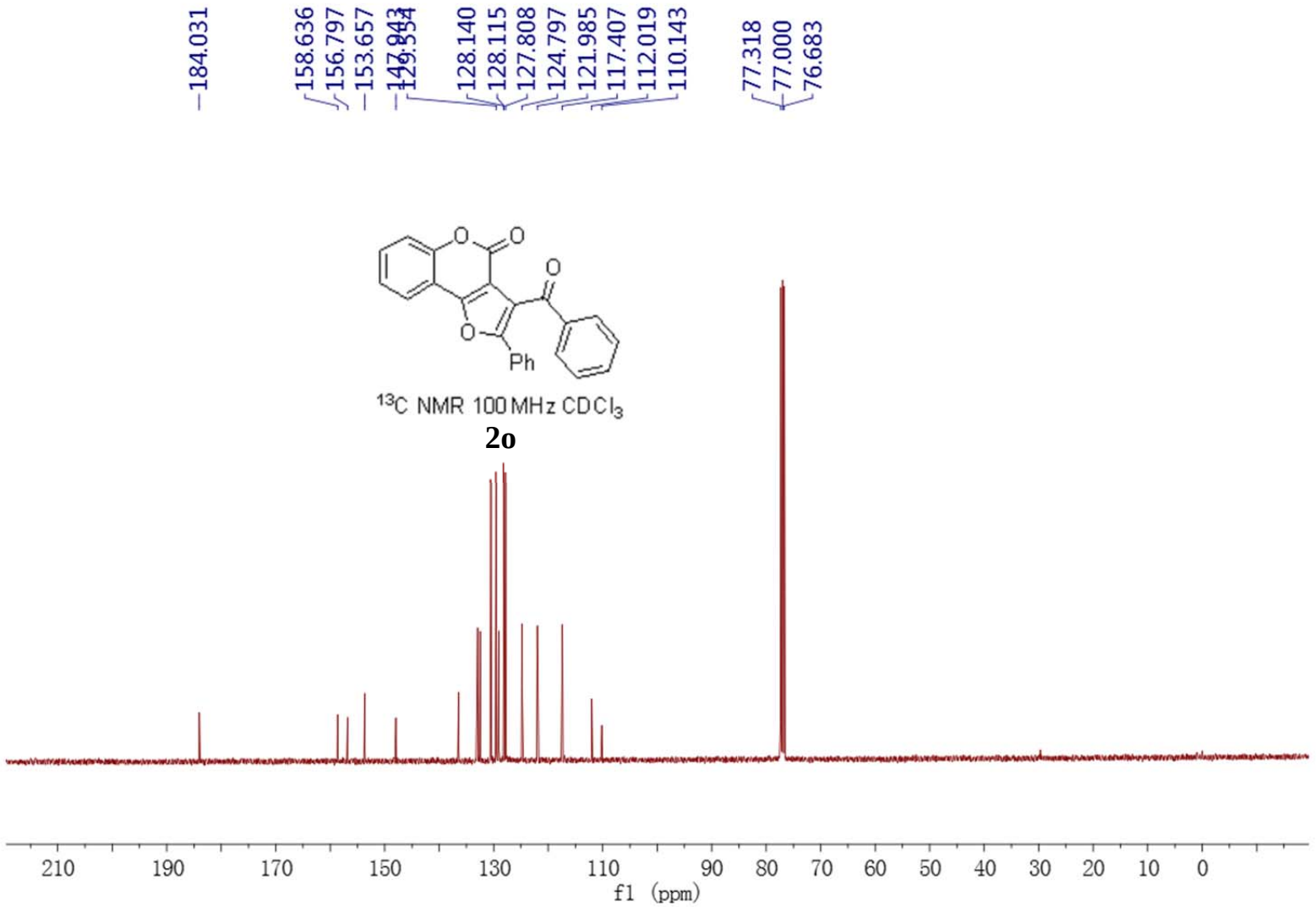


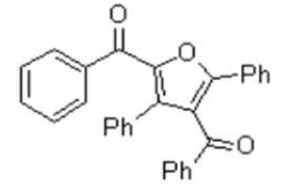
^{1}H NMR 400 MHz $CDCl_3$

2o



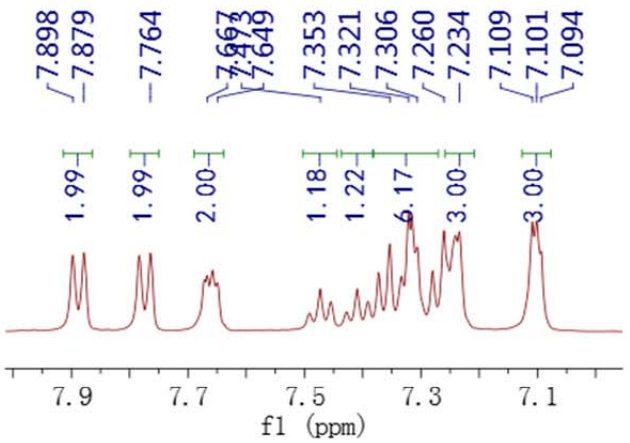


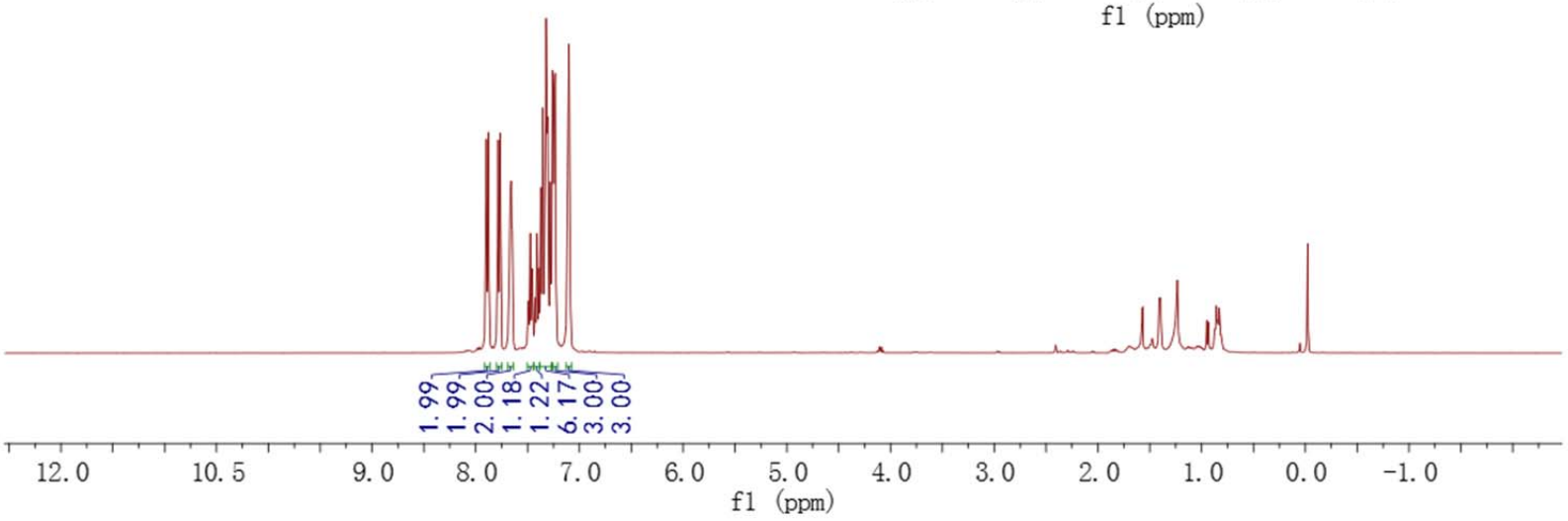

184.031
158.636
156.797
153.657
147.943
129.554
128.140
128.115
127.808
124.797
121.985
117.407
112.019
110.143
77.318
77.000
76.683
O
O
O
O
Ph
13C NMR 100 MHz CDCl3
2o
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

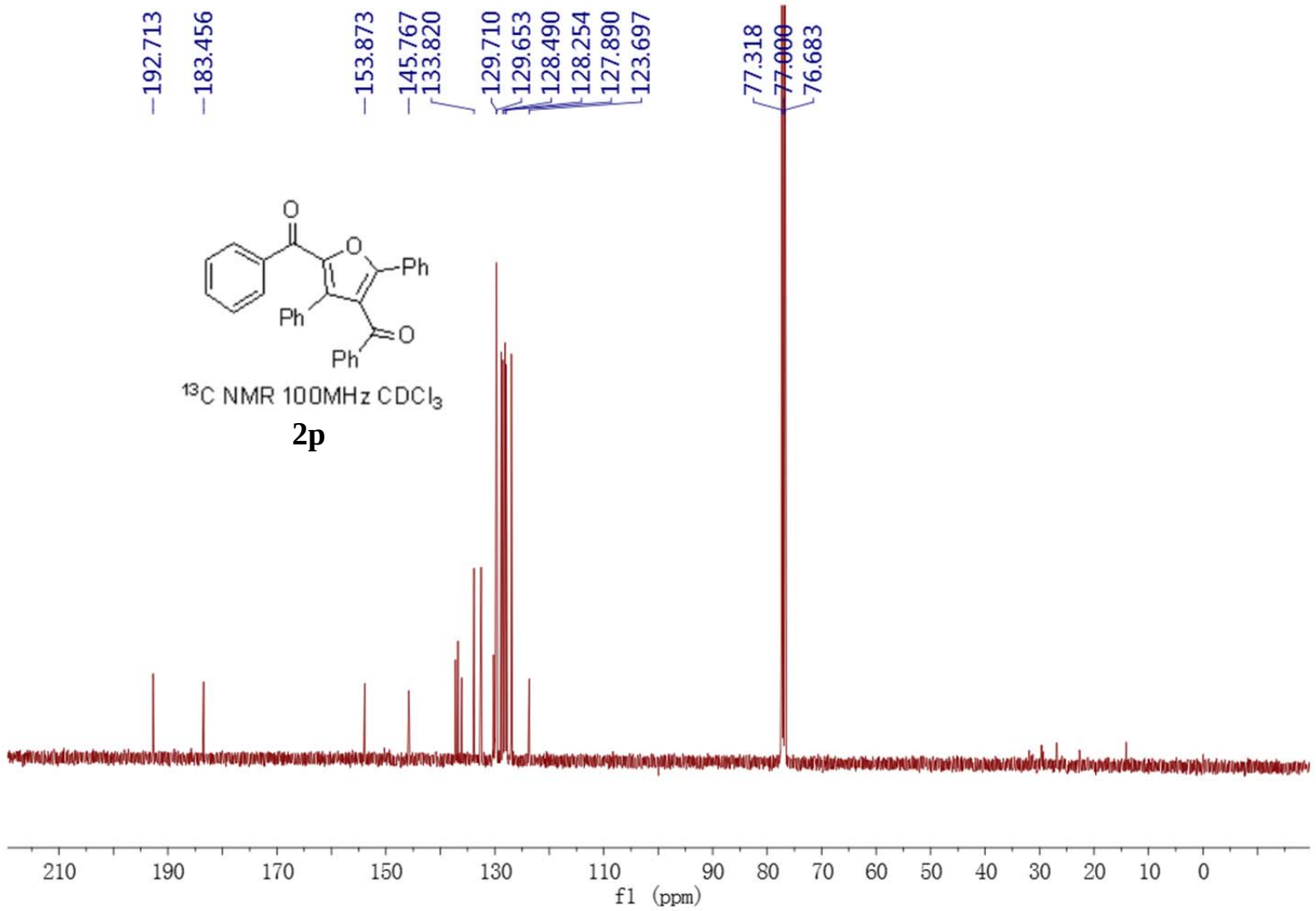


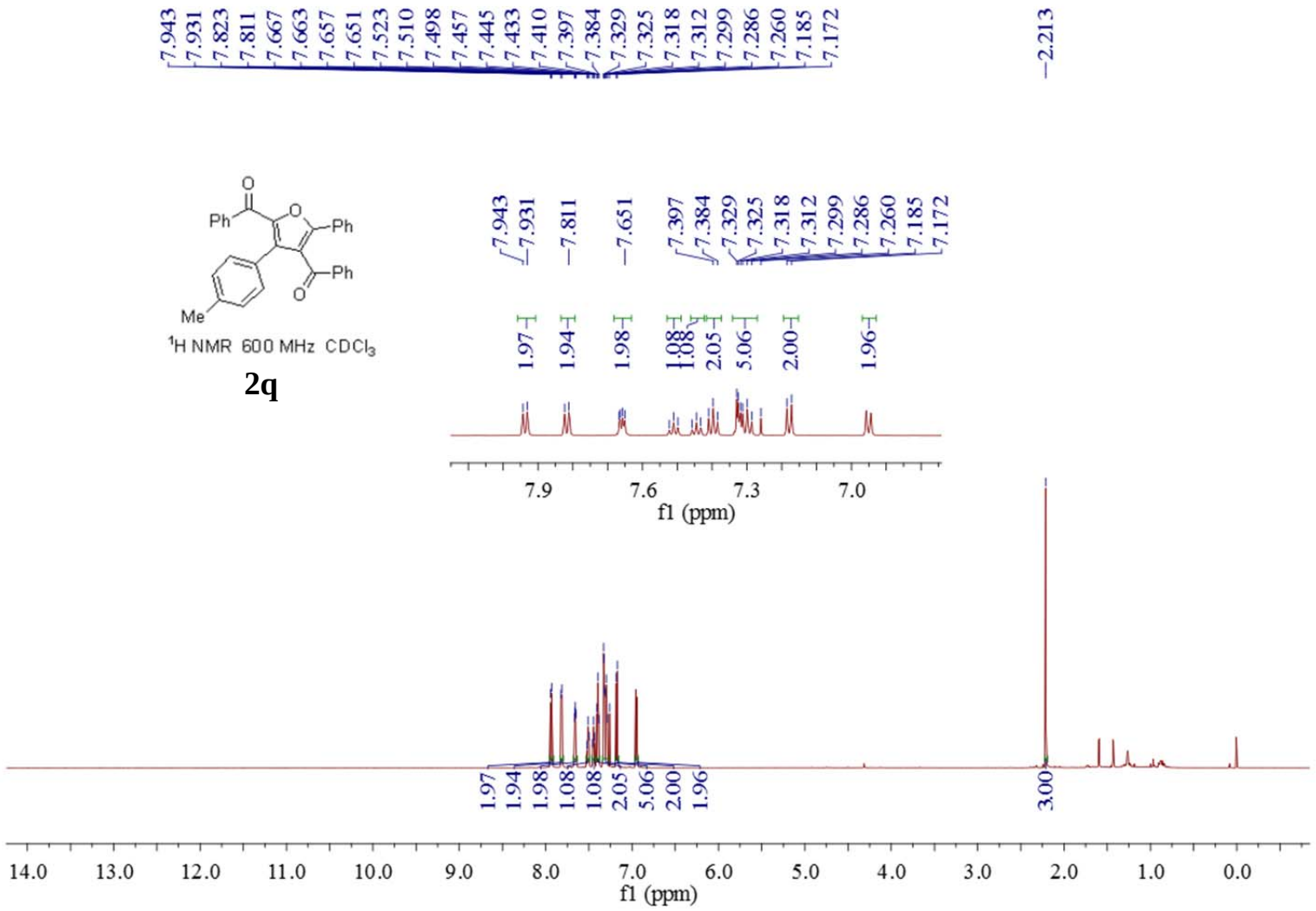
^{1}H NMR 400MHz $CDCl_3$

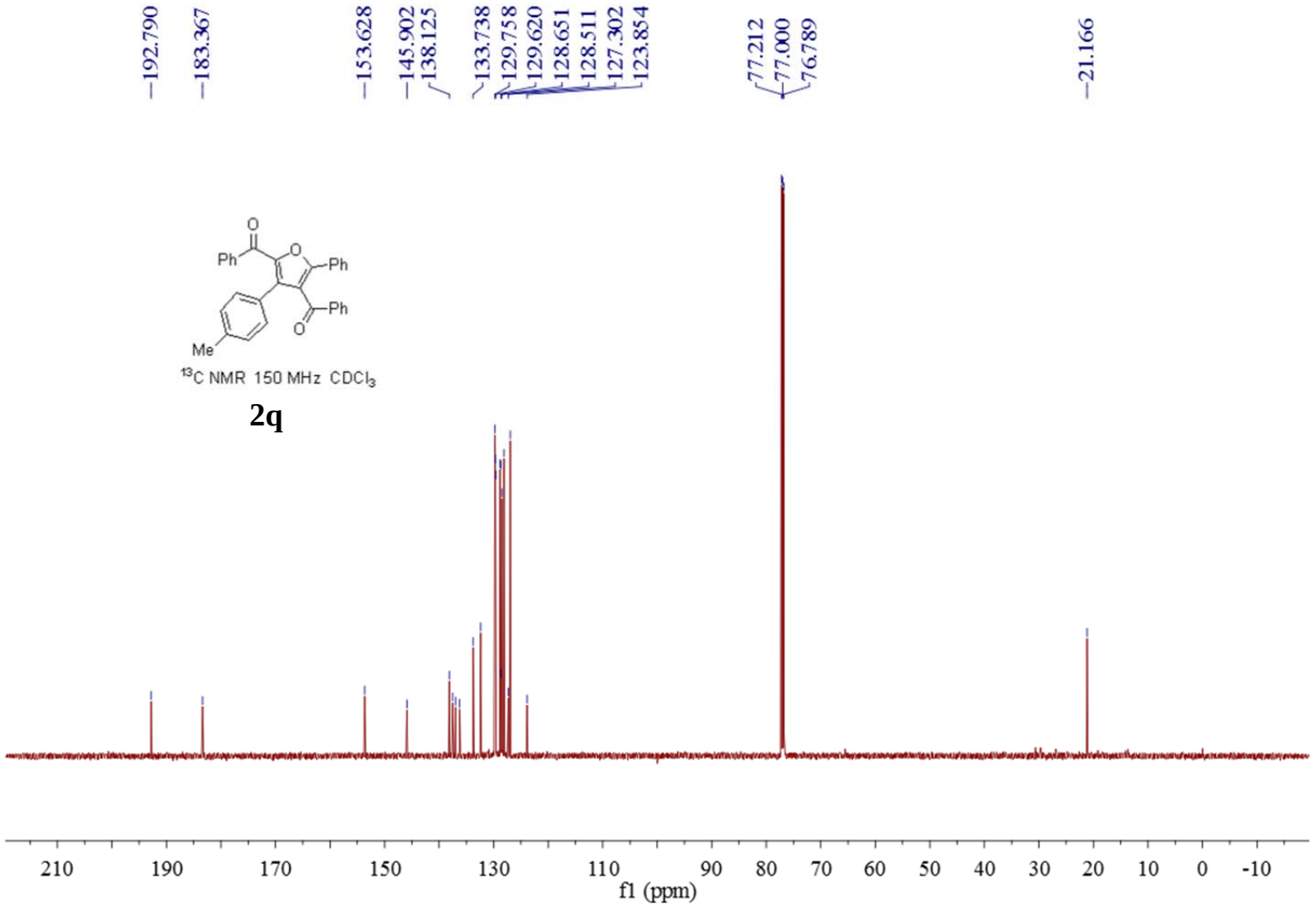
2p

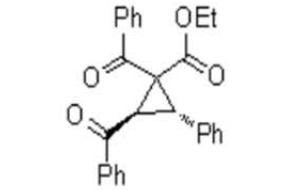





192.713
183.456
153.873
145.767
133.820
129.710
129.653
128.490
128.254
127.890
123.697
77.318
77.000
76.683
O
O
Ph
Ph
O
Ph
13C NMR 100MHz CDCl3
2p
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

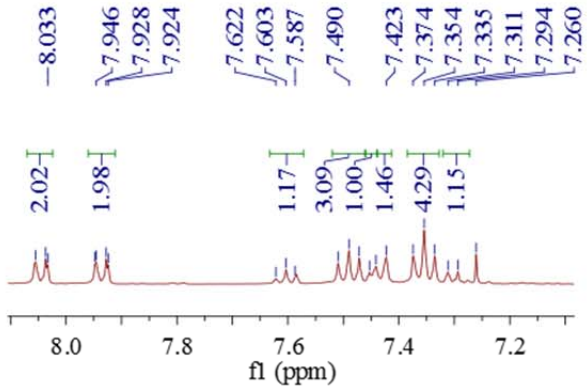

7.943
7.931
7.823
7.811
7.667
7.663
7.657
7.651
7.523
7.510
7.498
7.457
7.445
7.433
7.410
7.397
7.384
7.329
7.325
7.318
7.312
7.299
7.286
7.260
7.185
7.172
2.213
Ph
Ph
Ph
Me
O
O
O
1H NMR 600 MHz CDCl3
2q
1.97
1.94
1.98
1.08
1.08
2.05
5.06
2.00
1.96
3.00
7.9
7.6
7.3
7.0
f1 (ppm)
14.0
13.0
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)

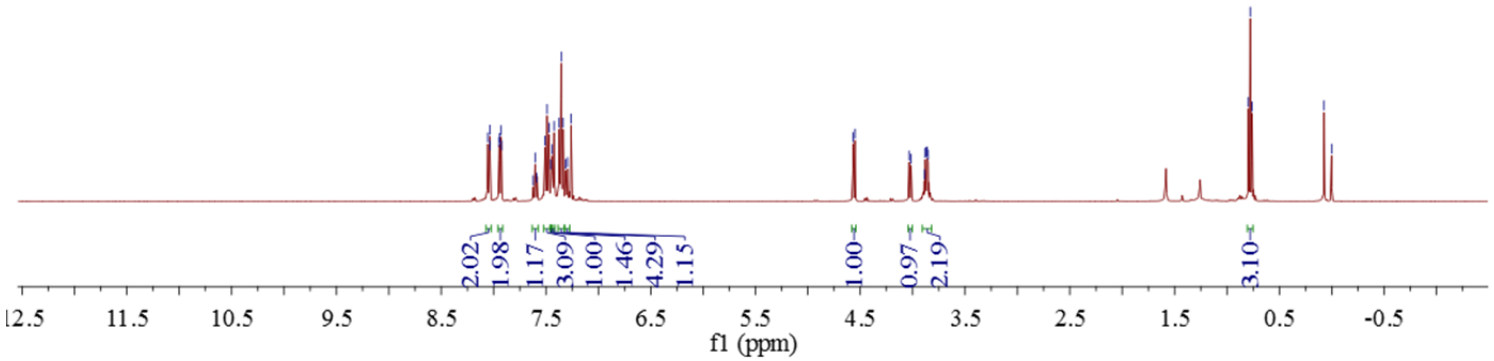

192.790
183.367
153.628
145.902
138.125
133.738
129.758
129.620
128.651
128.511
127.302
123.854
77.212
77.000
76.789
21.166
O
Ph
O
Ph
Ph
O
Me
13C NMR 150 MHz CDCl3
2q
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

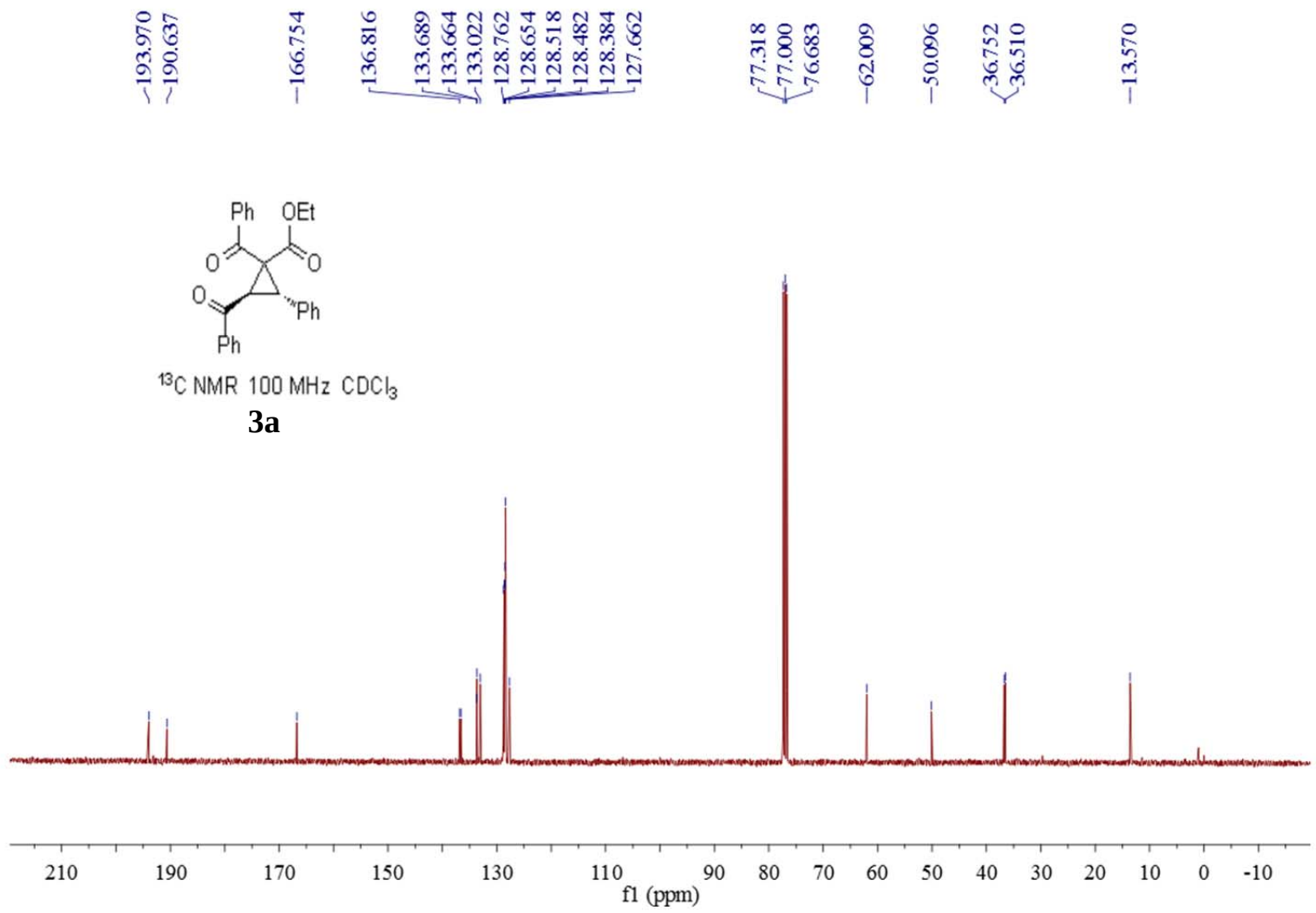


^{1}H NMR 400 MHz $CDCl_3$

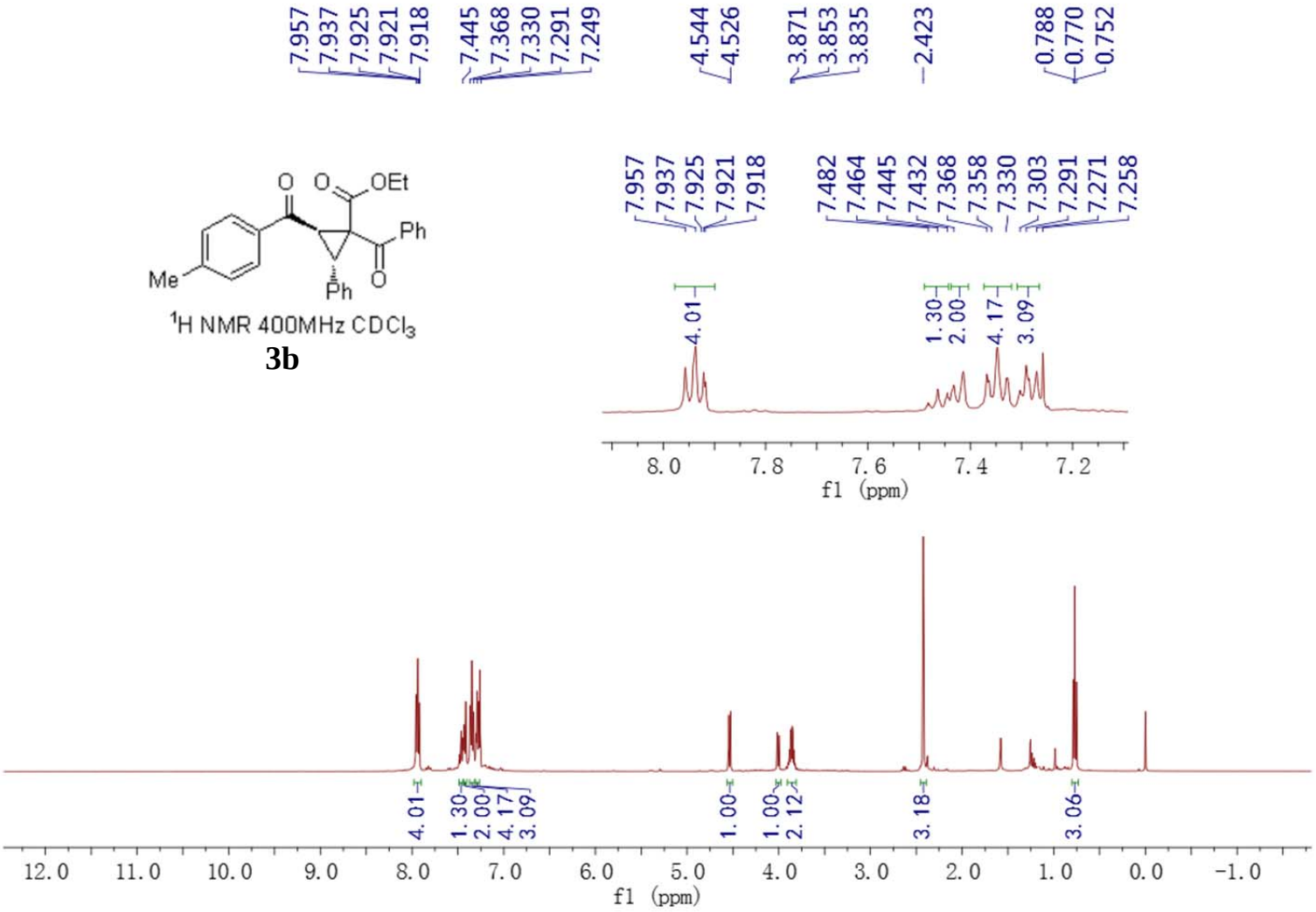
3a

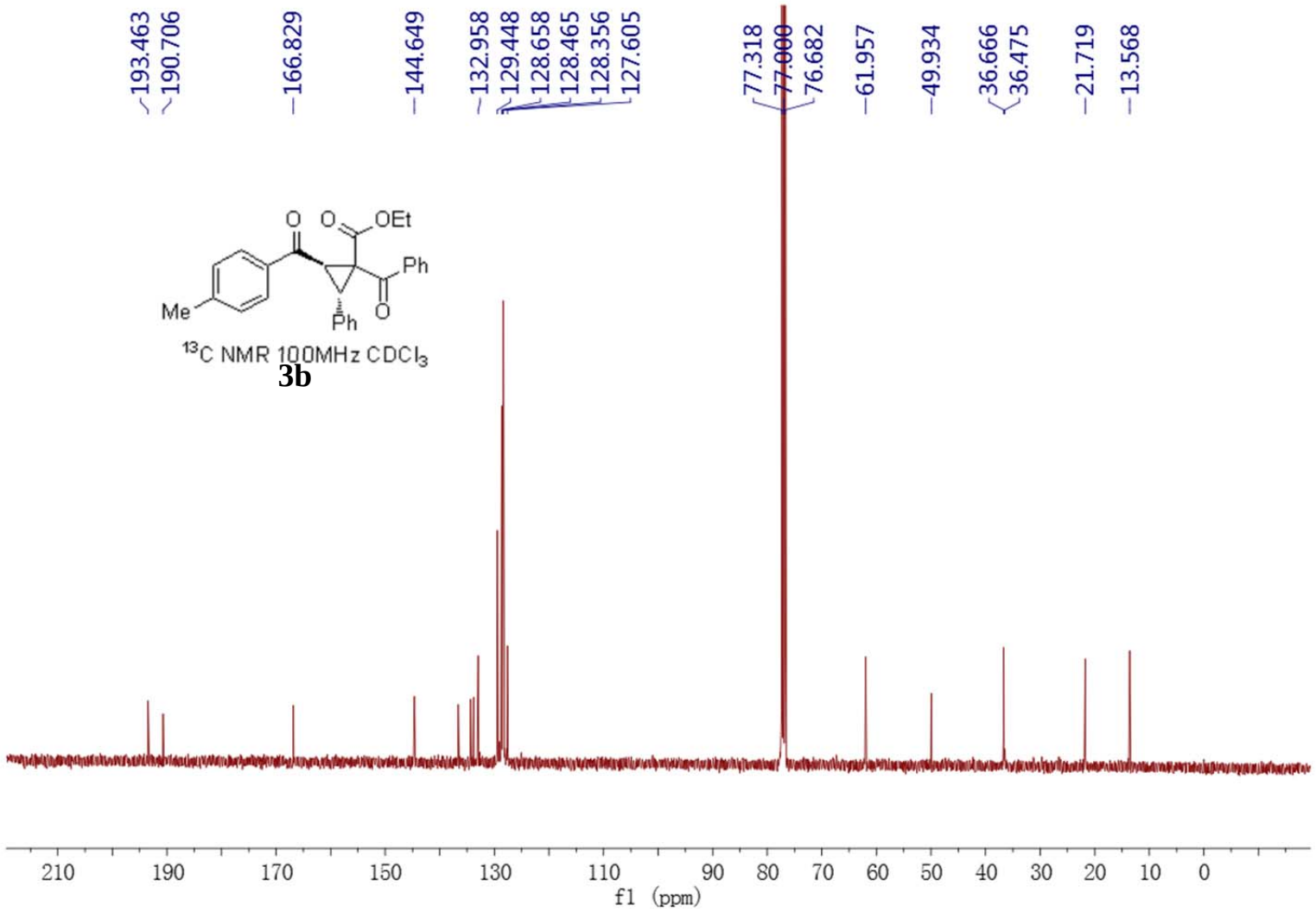


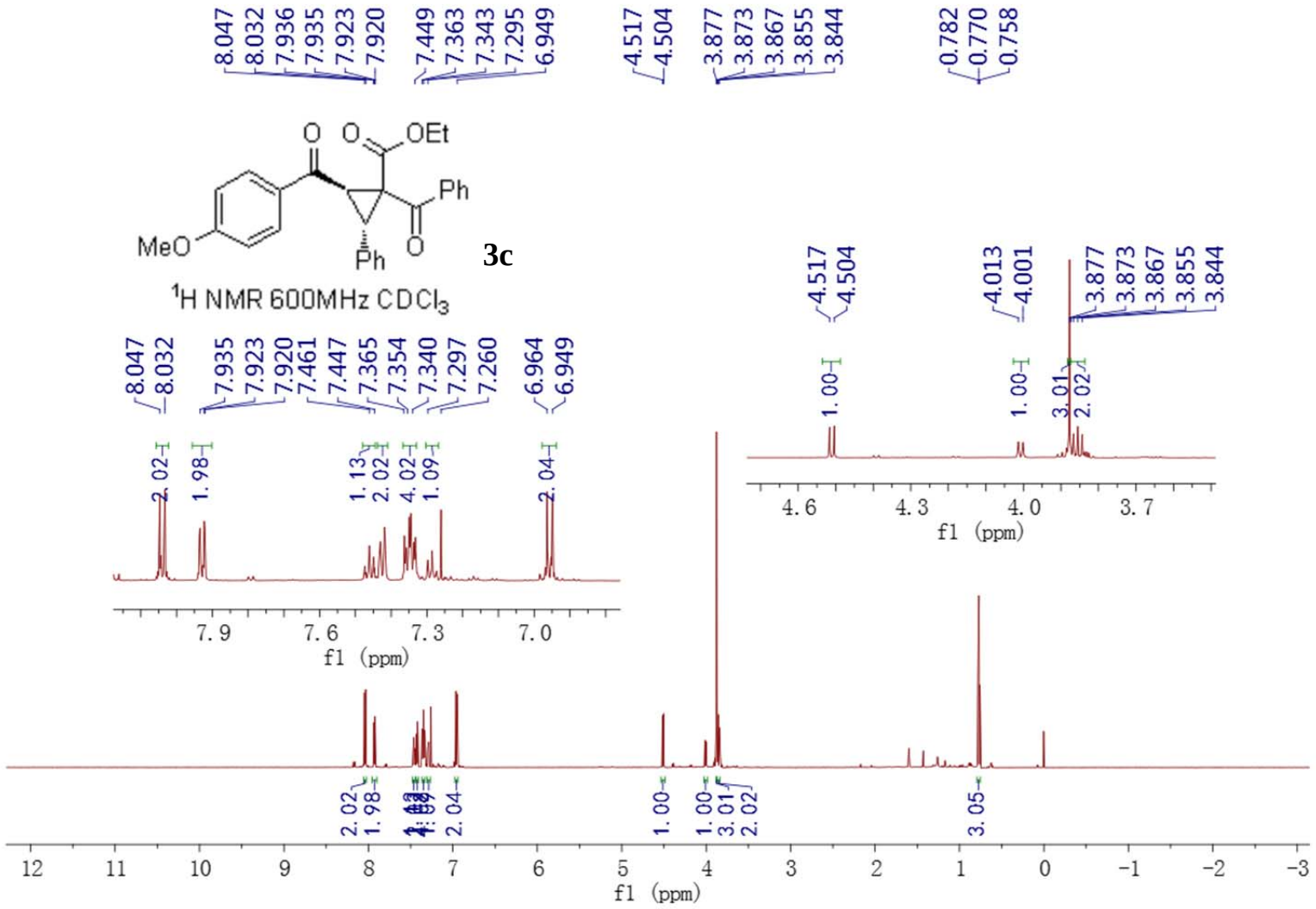


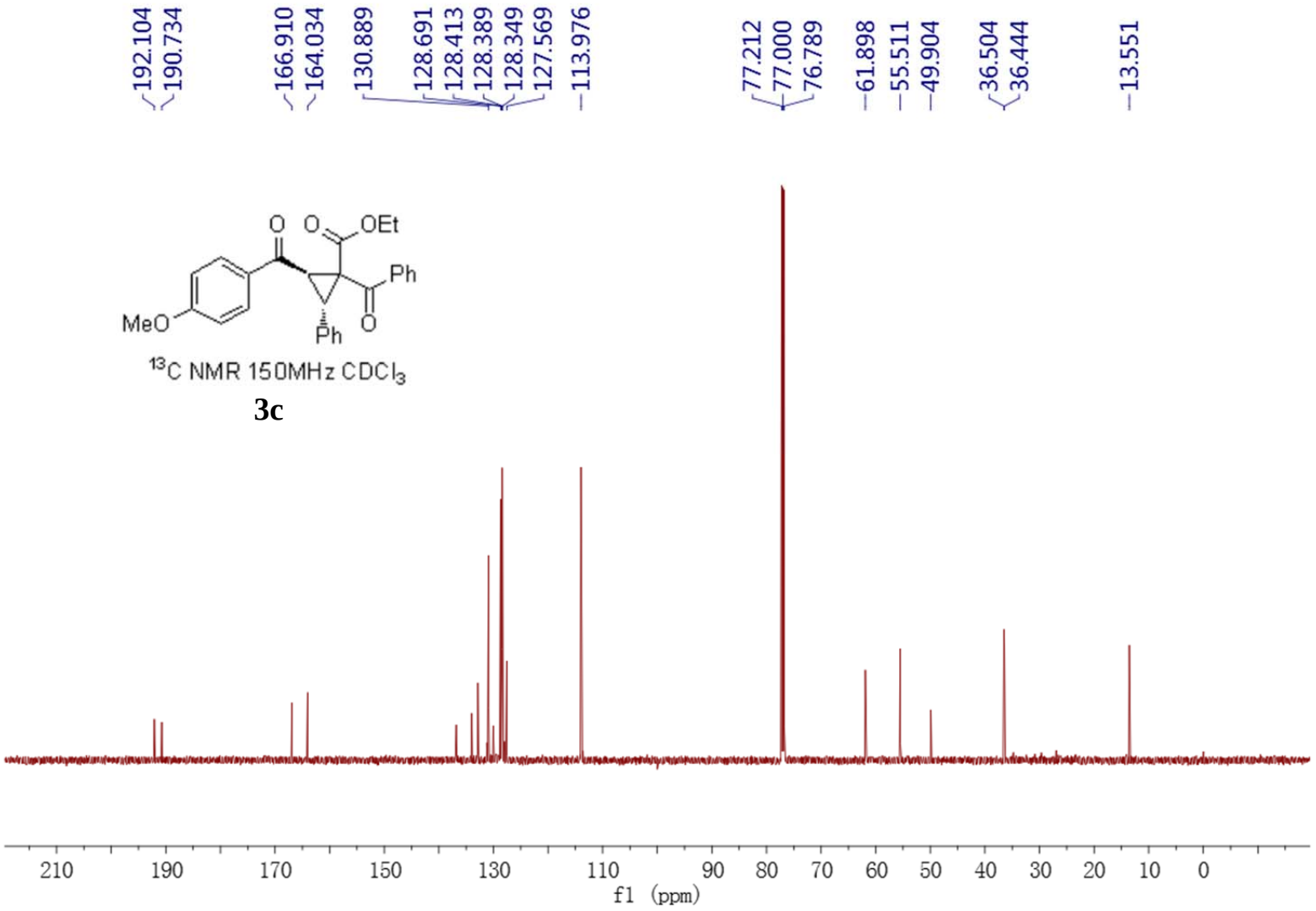

193.970
190.637
166.754
136.816
133.689
133.664
133.022
128.762
128.654
128.518
128.482
128.384
127.662
77.318
77.000
76.683
62.009
50.096
36.752
36.510
13.570
Ph
OEt
O
O
O
Ph
Ph
13C NMR 100 MHz CDCl3
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)

3a


7.957
7.937
7.925
7.921
7.918
7.445
7.368
7.330
7.291
7.249
4.544
4.526
3.871
3.853
3.835
2.423
0.788
0.770
0.752
O
O
OEt
Ph
Me
O
Ph
1H NMR 400MHz CDCl3
3b
7.957
7.937
7.925
7.921
7.918
7.482
7.464
7.445
7.432
7.368
7.358
7.330
7.303
7.291
7.271
7.258
4.01
1.30
2.00
4.17
3.09
8.0
7.8
7.6
7.4
7.2
f1 (ppm)
4.01
1.30
2.00
4.17
3.09
1.00
1.00
2.12
3.18
3.06
12.0
11.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
f1 (ppm)


193.463
190.706
166.829
144.649
132.958
129.448
128.658
128.465
128.356
127.605
77.318
77.000
76.682
61.957
49.934
36.666
36.475
21.719
13.568
O
O
OEt
Ph
Me
Ph
O
13C NMR 100MHz CDCl3
3b
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.047
8.032
7.936
7.935
7.923
7.920
7.449
7.363
7.343
7.295
6.949
4.517
4.504
3.877
3.873
3.867
3.855
3.844
0.782
0.770
0.758
O
O
OEt
Ph
MeO
O
Ph
3c
1H NMR 600MHz CDCl3
8.047
8.032
7.935
7.923
7.920
7.461
7.447
7.365
7.354
7.340
7.297
7.260
6.964
6.949
2.02
1.98
1.13
2.02
4.02
1.09
2.04
7.9
7.6
7.3
7.0
f1 (ppm)
4.517
4.504
4.013
4.001
3.877
3.873
3.867
3.855
3.844
1.00
1.00
3.01
2.02
4.6
4.3
4.0
3.7
f1 (ppm)
2.02
1.98
1.00
1.00
3.01
2.02
3.05
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
f1 (ppm)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190.734
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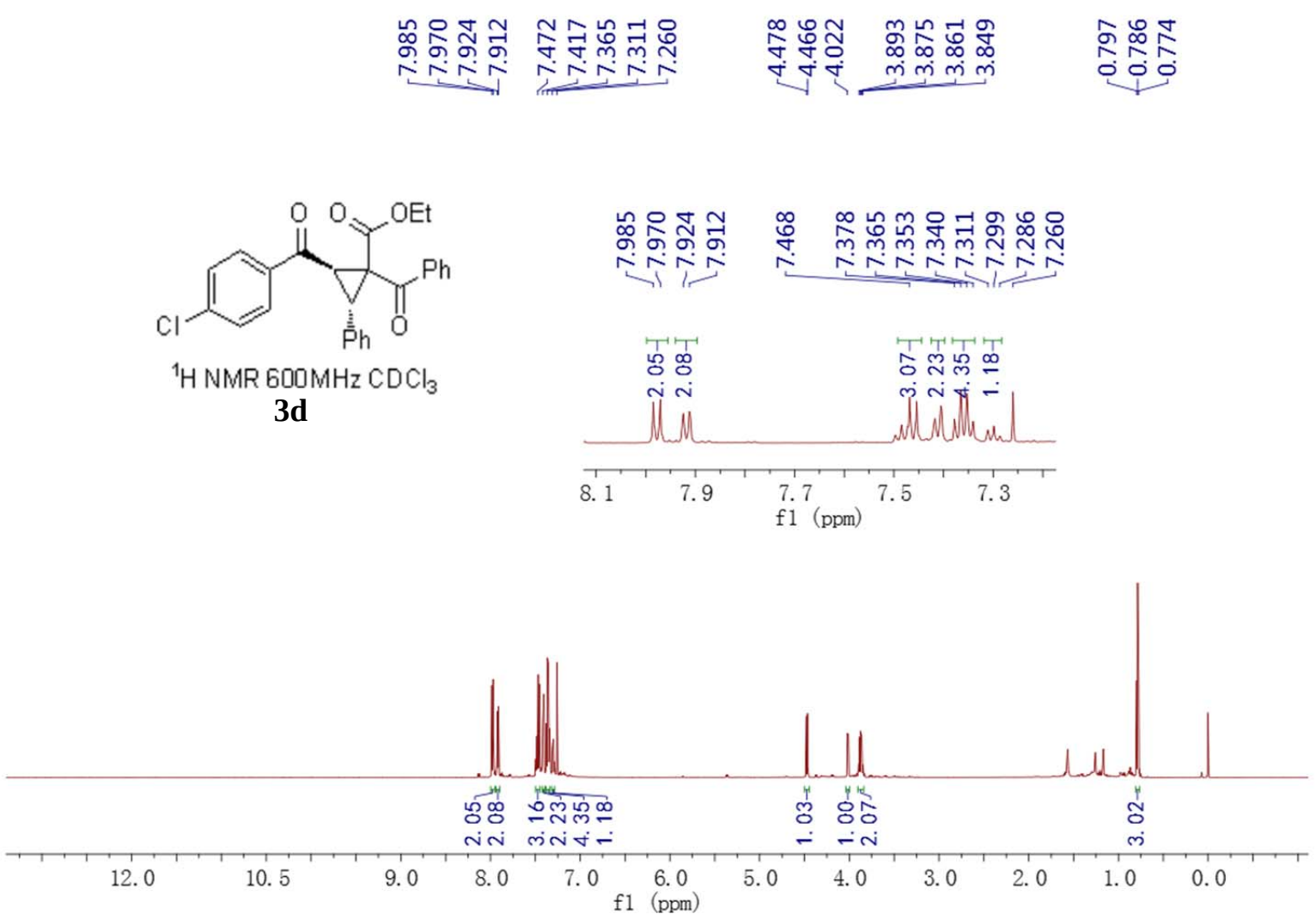
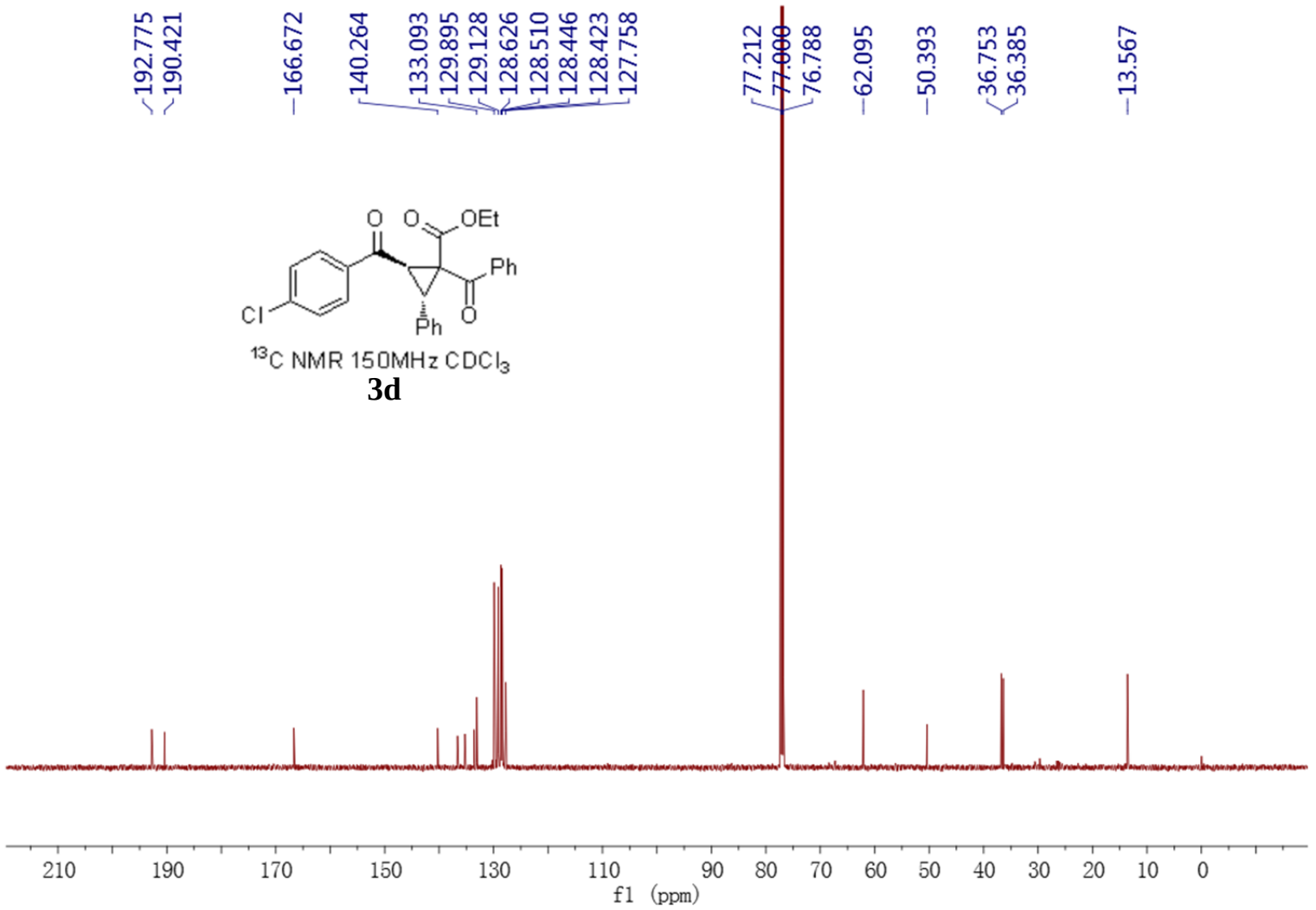
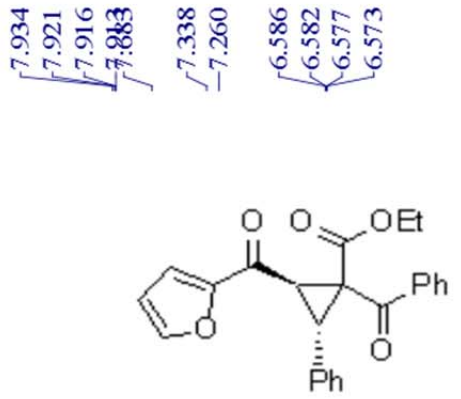
164.034
130.889
128.691
128.413
128.389
128.349
127.569
113.976
77.212
77.000
76.789
61.898
55.511
49.904
36.504
36.444
13.551
O
O
OEt
Ph
MeO
O
Ph
13C NMR 150MHz CDCl3
3c
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


7.985
7.970
7.924
7.912
7.472
7.417
7.365
7.311
7.260
4.478
4.466
4.022
3.893
3.875
3.861
3.849
0.797
0.786
0.774
O
O
OEt
Ph
Cl
O
Ph
1H NMR 600MHz CDCl3
3d
7.985
7.970
7.924
7.912
7.468
7.378
7.365
7.353
7.340
7.311
7.299
7.286
7.260
2.05
2.08
3.07
2.23
4.35
1.18
8.1
7.9
7.7
7.5
7.3
f1 (ppm)
2.05
2.08
3.16
2.23
4.35
1.18
1.03
1.00
2.07
3.02
12.0
10.5
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
f1 (ppm)



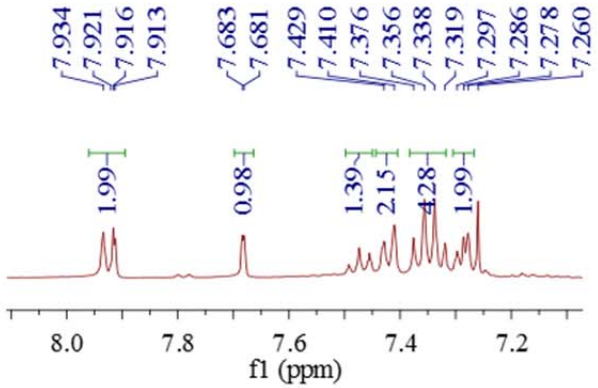
^{13}C NMR 150MHz $CDCl_3$

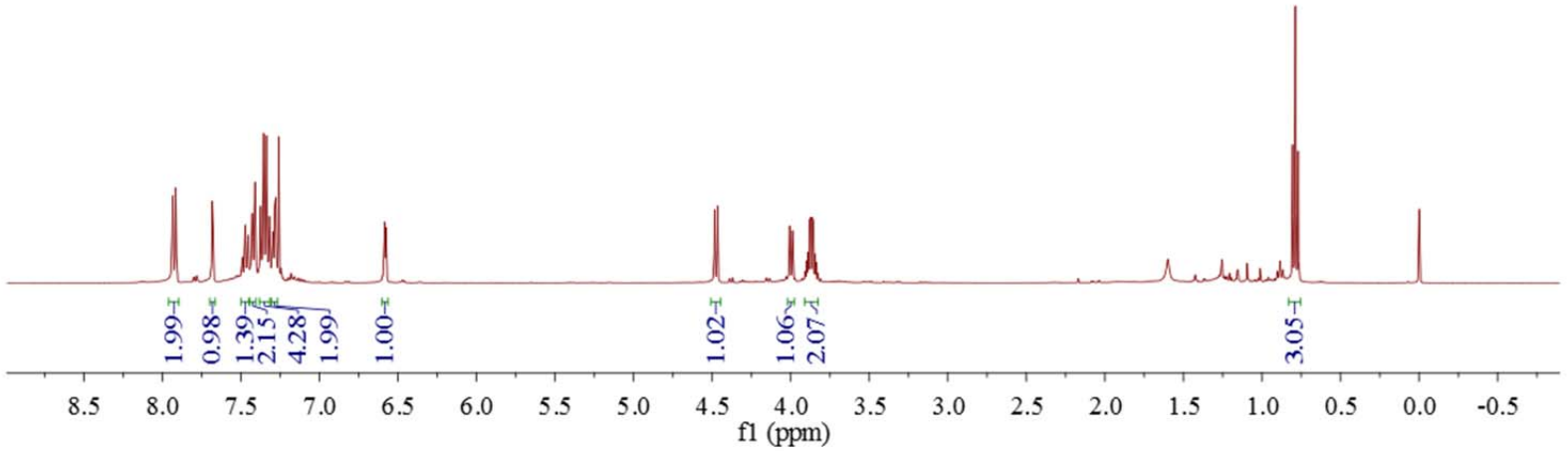
3d

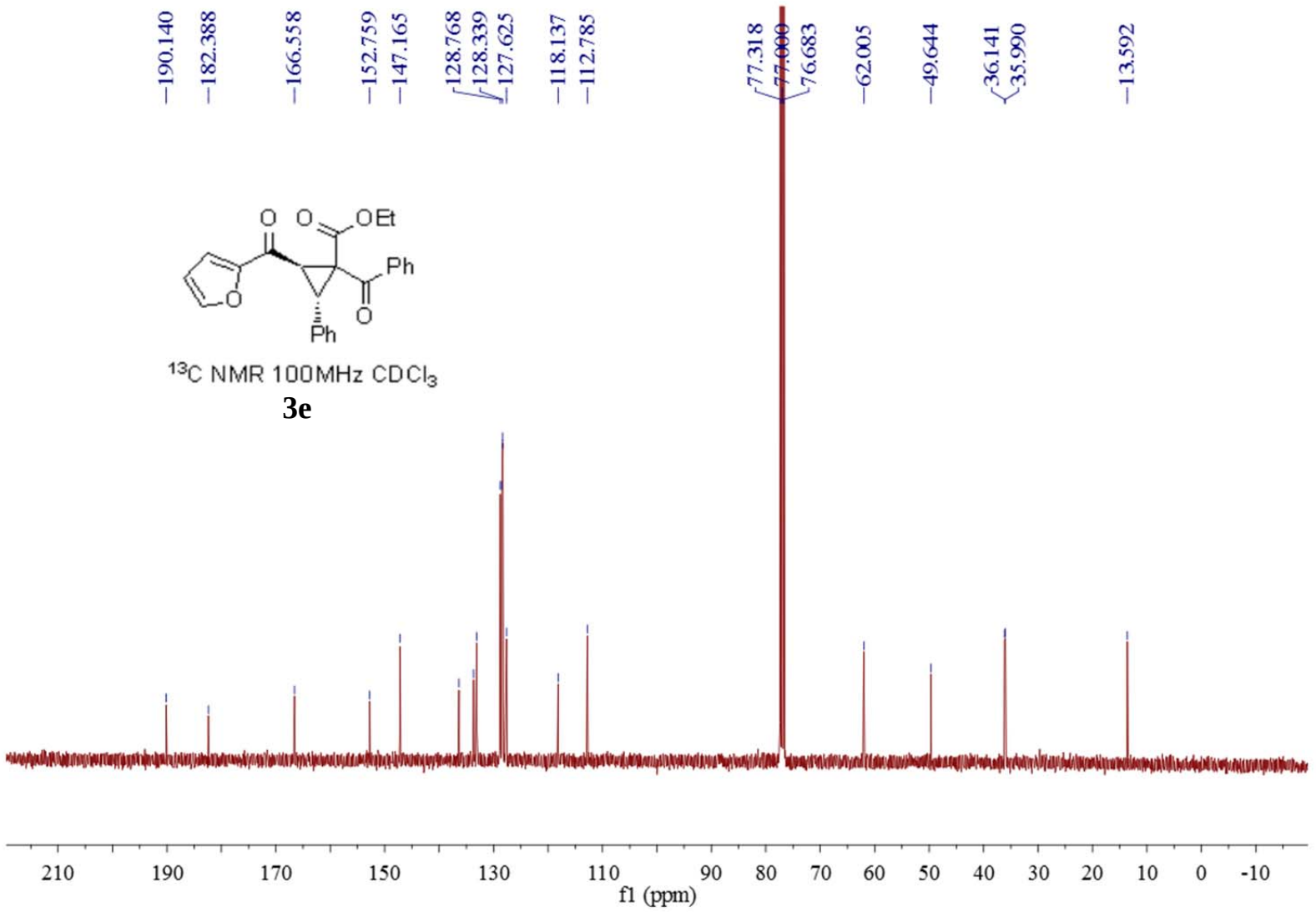


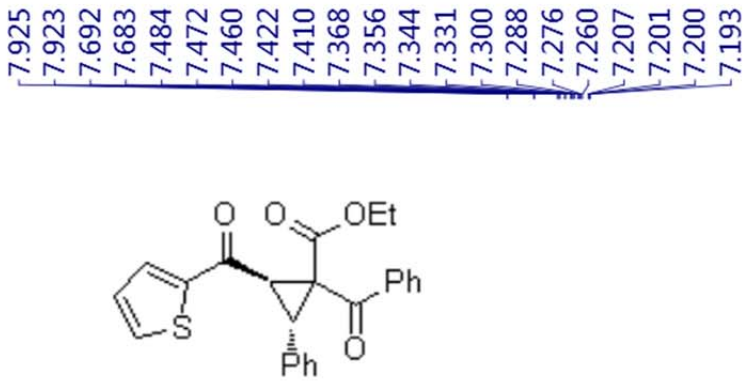
^{1}H NMR 400MHz $CDCl_3$

3e






190.140
182.388
166.558
152.759
147.165
128.768
128.339
127.625
118.137
112.785
77.318
77.000
76.683
62.005
49.644
36.141
35.990
13.592
O
O
OEt
Ph
O
O
Ph
13C NMR 100MHz CDCl3
3e
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)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7.923
7.692
7.683
7.484
7.472
7.460
7.422
7.410
7.368
7.356
7.344
7.331
7.300
7.288
7.276
7.260
7.207
7.201
7.200
7.193
4.405
4.392
3.878
3.866
3.854
3.848
3.843
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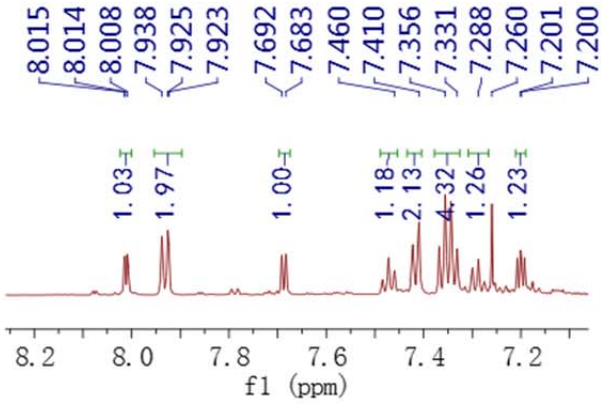
0.786
0.774
O
O
OEt
Ph
S
O
Ph
1H NMR 600MHz CDCl3

3f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8.008
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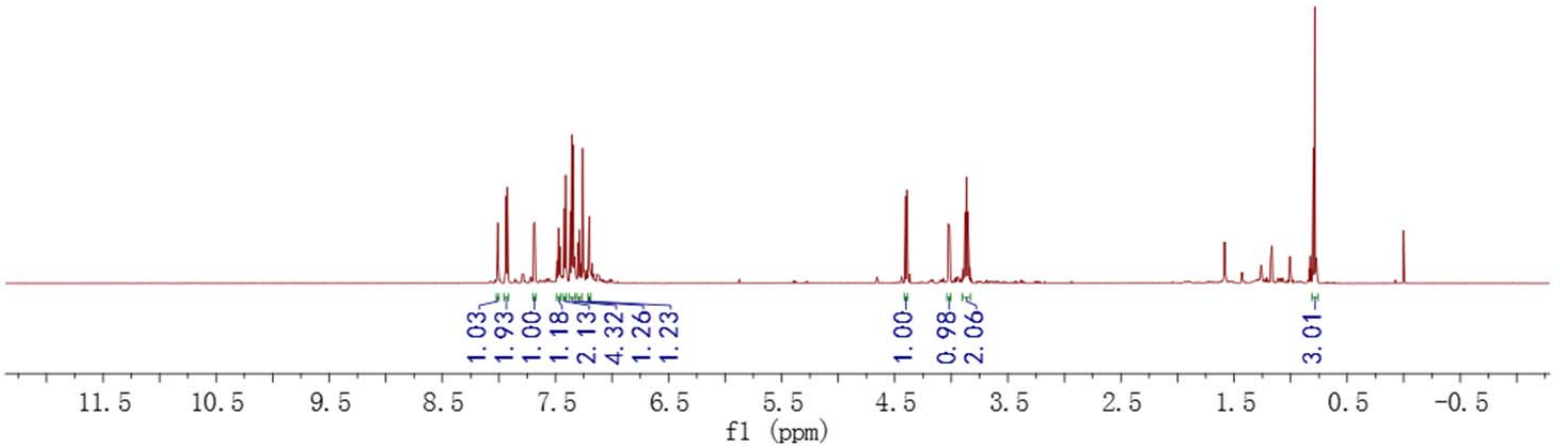
7.683
7.460
7.410
7.356
7.331
7.288
7.260
7.201
7.200
1.03
1.97
1.00
1.18
2.13
4.32
1.26
1.23
8.2
8.0
7.8
7.6
7.4
7.2
f1 (ppm)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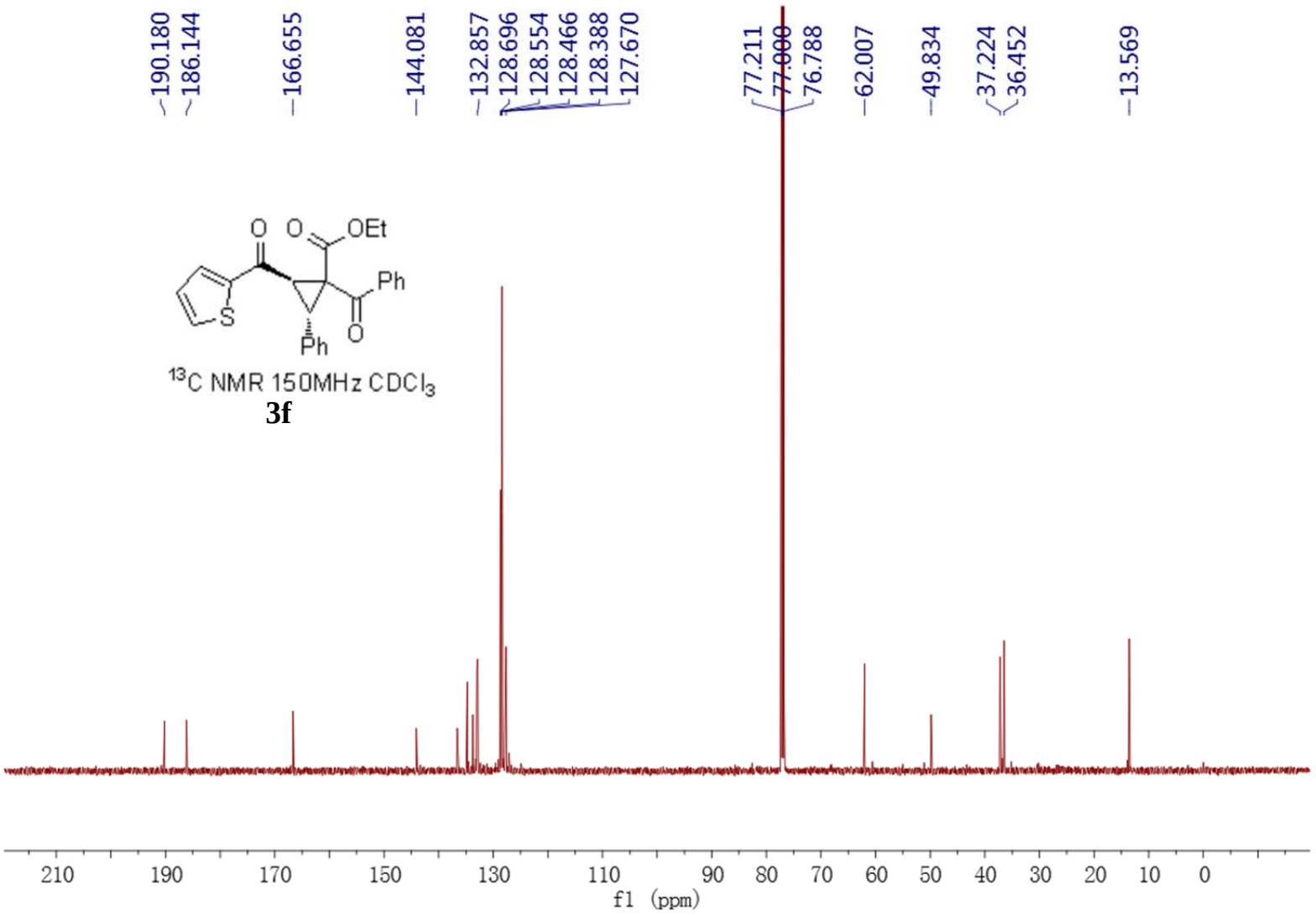
1.93
1.00
1.18
2.13
4.32
1.26
1.23
1.00
0.98
2.06
3.01
11.5
10.5
9.5
8.5
7.5
6.5
5.5
4.5
3.5
2.5
1.5
0.5
-0.5
f1 (ppm)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186.144
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144.081
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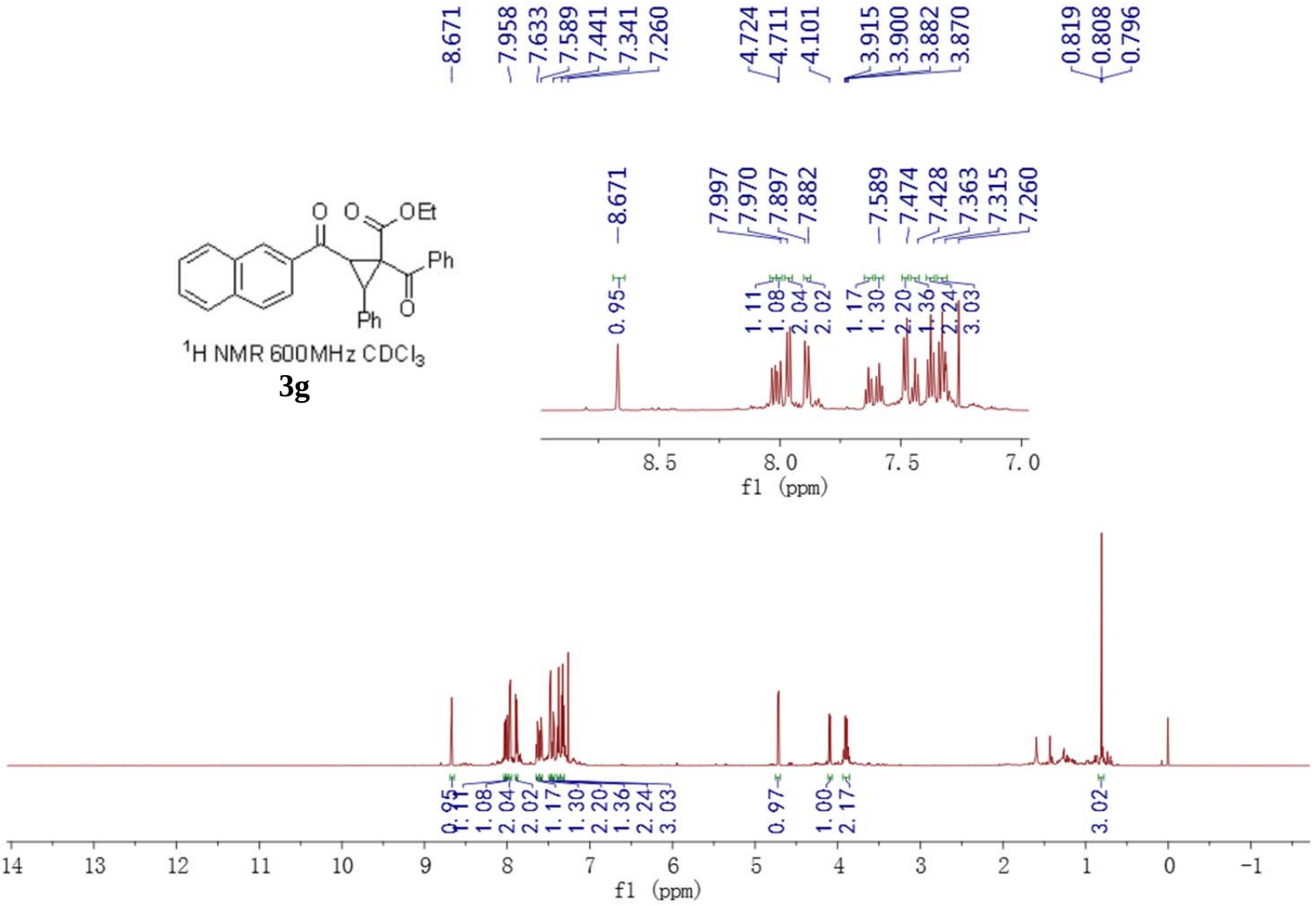
128.696
128.554
128.466
128.388
127.670
77.211
77.000
76.788
62.007
49.834
37.224
36.452
13.569
O
O
OEt
Ph
S
O
Ph
13C NMR 150MHz CDCl3
3f
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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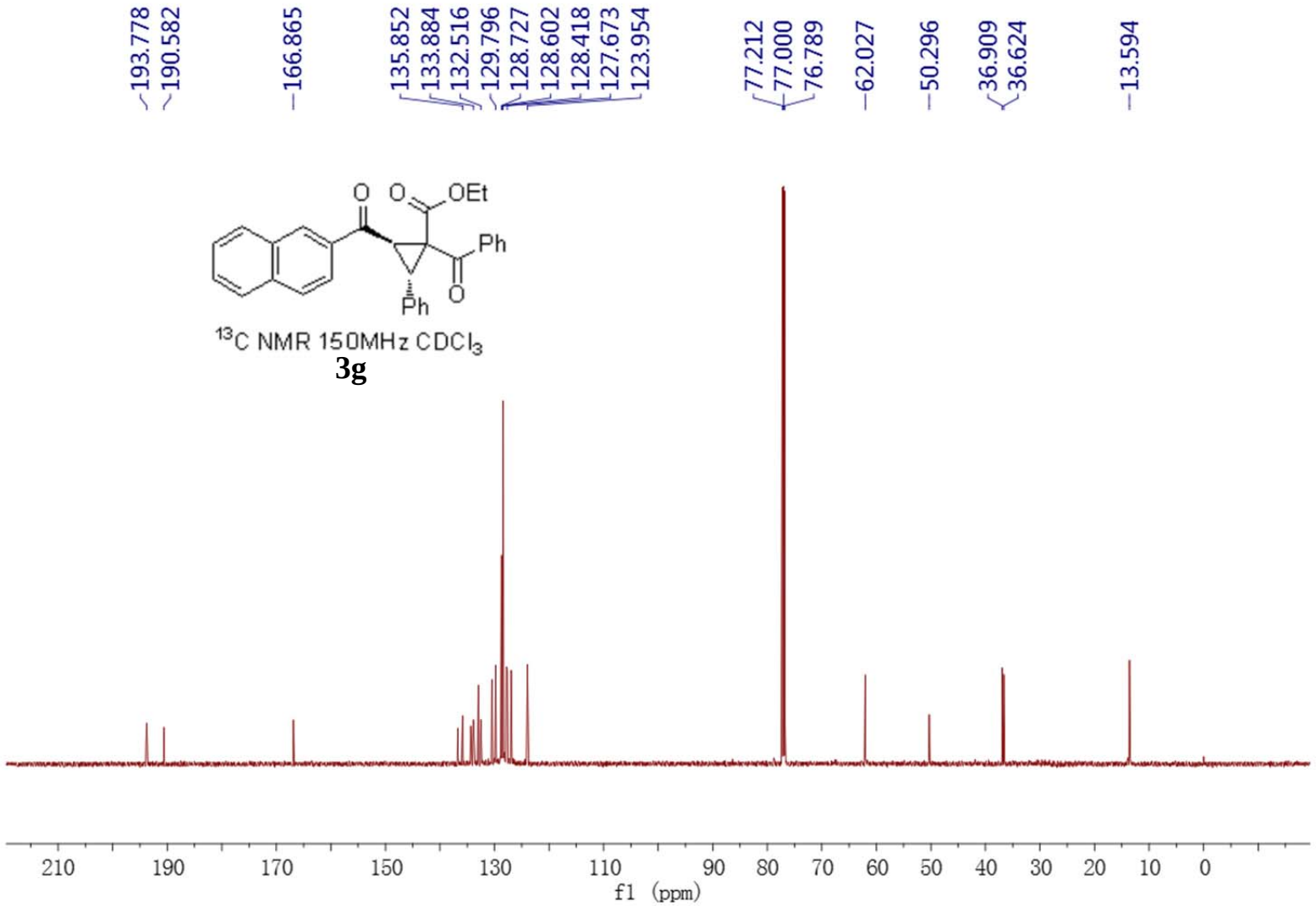
7.958
7.633
7.589
7.441
7.341
7.260
4.724
4.711
4.101
3.915
3.900
3.882
3.870
0.819
0.808
0.796
O
O
OEt
Ph
O
Ph
1H NMR 600MHz CDCl3
3g
f1 (ppm)
f1 (ppm)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190.582
166.865
135.852
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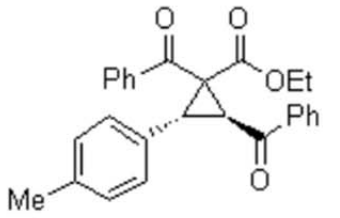
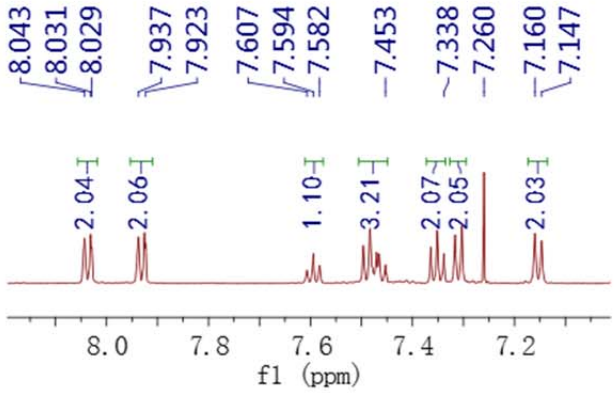
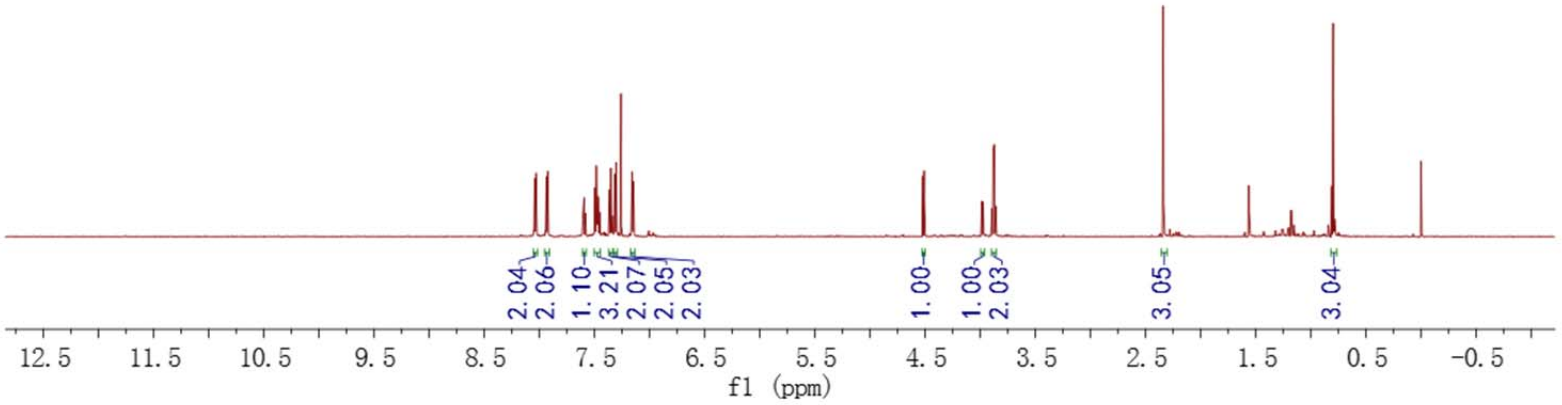
132.516
129.796
128.727
128.602
128.418
127.673
123.954
77.212
77.000
76.789
62.027
50.296
36.909
36.624
13.594
O
O
OEt
Ph
O
Ph
13C NMR 150MHz CDCl3
3g
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

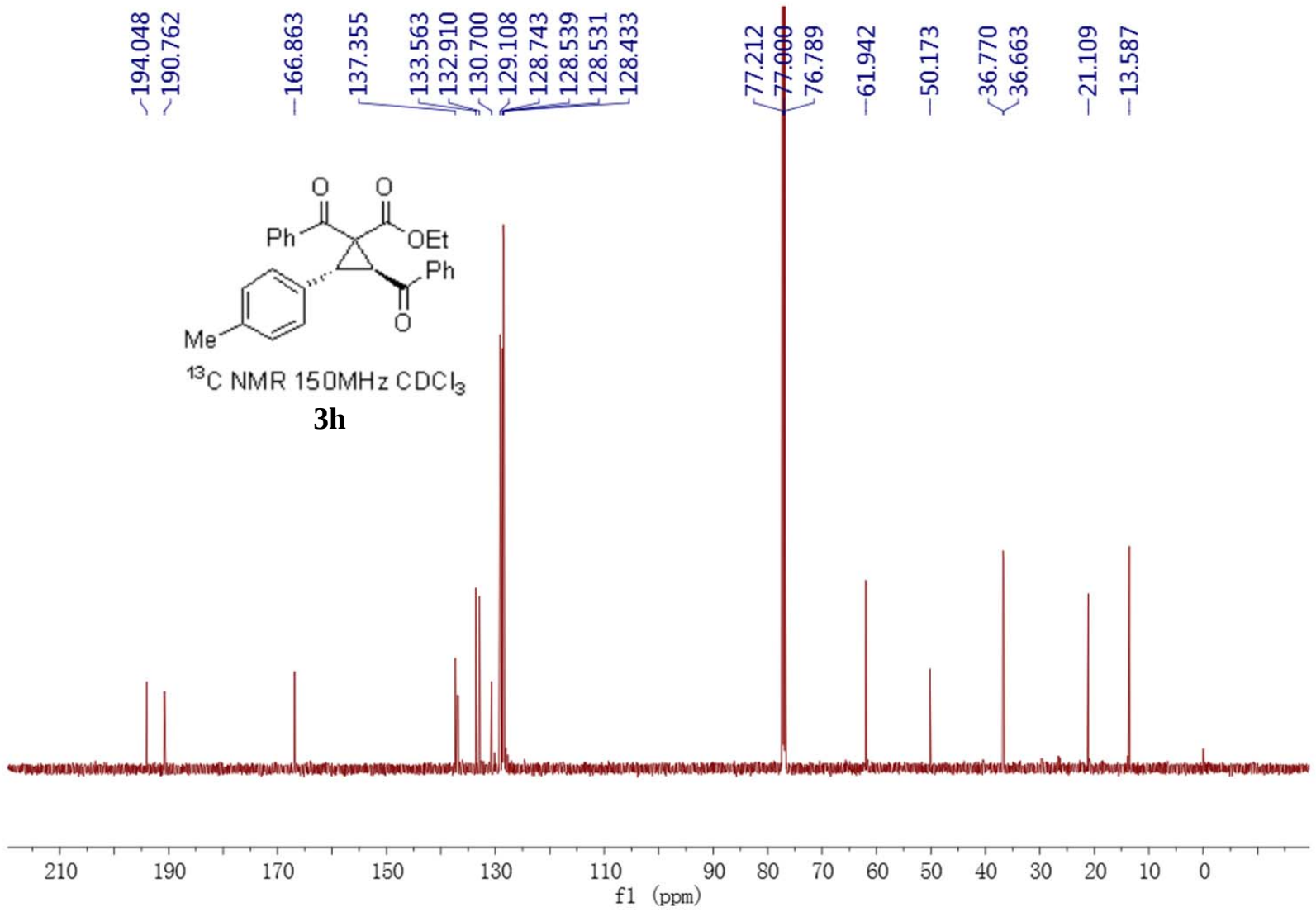


^{1}H NMR 600MHz $CDCl_3$

3h



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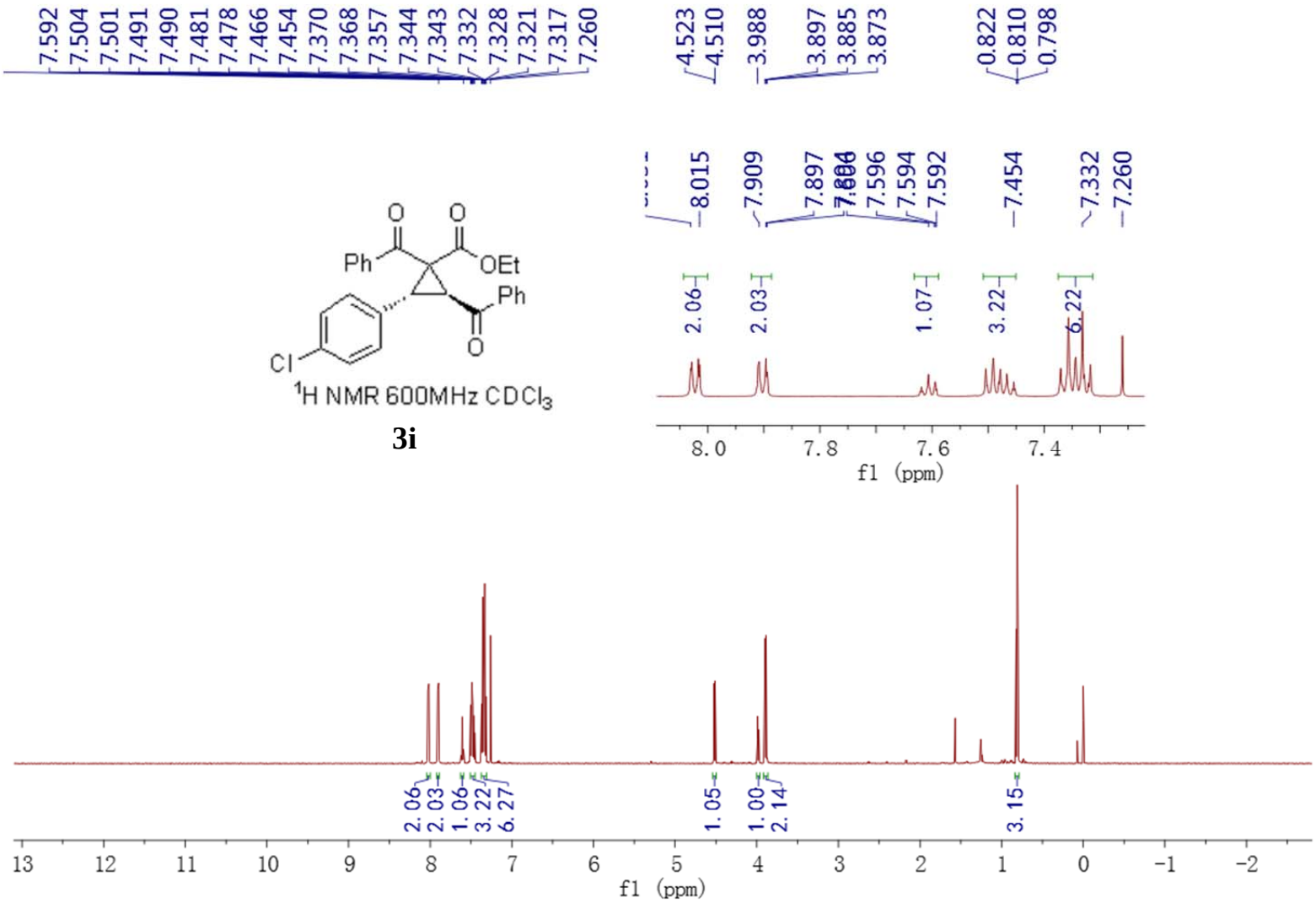
137.355
133.563
132.910
130.700
129.108
128.743
128.539
128.531
128.433
77.212
77.000
76.789
61.942
50.173
36.770
36.663
21.109
13.587
Ph
OEt
Ph
Me
O
O
O
O
13C NMR 150MHz CDCl3
3h
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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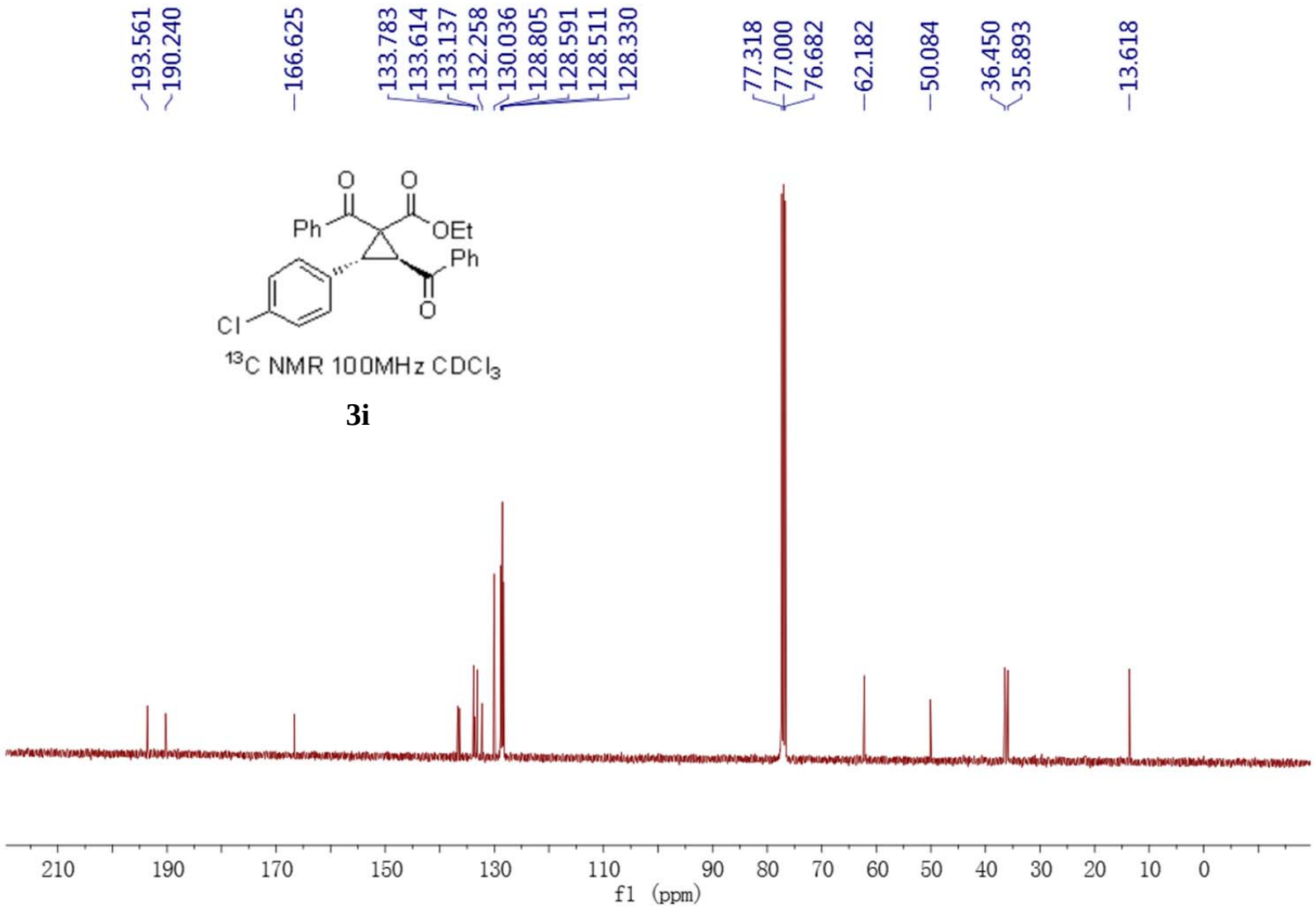
7.504
7.501
7.491
7.490
7.481
7.478
7.466
7.454
7.370
7.368
7.357
7.344
7.343
7.332
7.328
7.321
7.317
7.260
4.523
4.510
3.988
3.897
3.885
3.873
0.822
0.810
0.798
Ph
O
O
OEt
Ph
O
Cl
1H NMR 600MHz CDCl3
3i
8.015
7.909
7.897
7.596
7.594
7.592
7.454
7.332
7.260
2.06
2.03
1.07
3.22
6.22
8.0
7.8
7.6
7.4
f1 (ppm)
2.06
2.03
1.06
3.22
6.27
1.05
1.00
2.14
3.15
13
12
11
10
9
8
7
6
5
4
3
2
1
0
−1
−2
f1 (ppm)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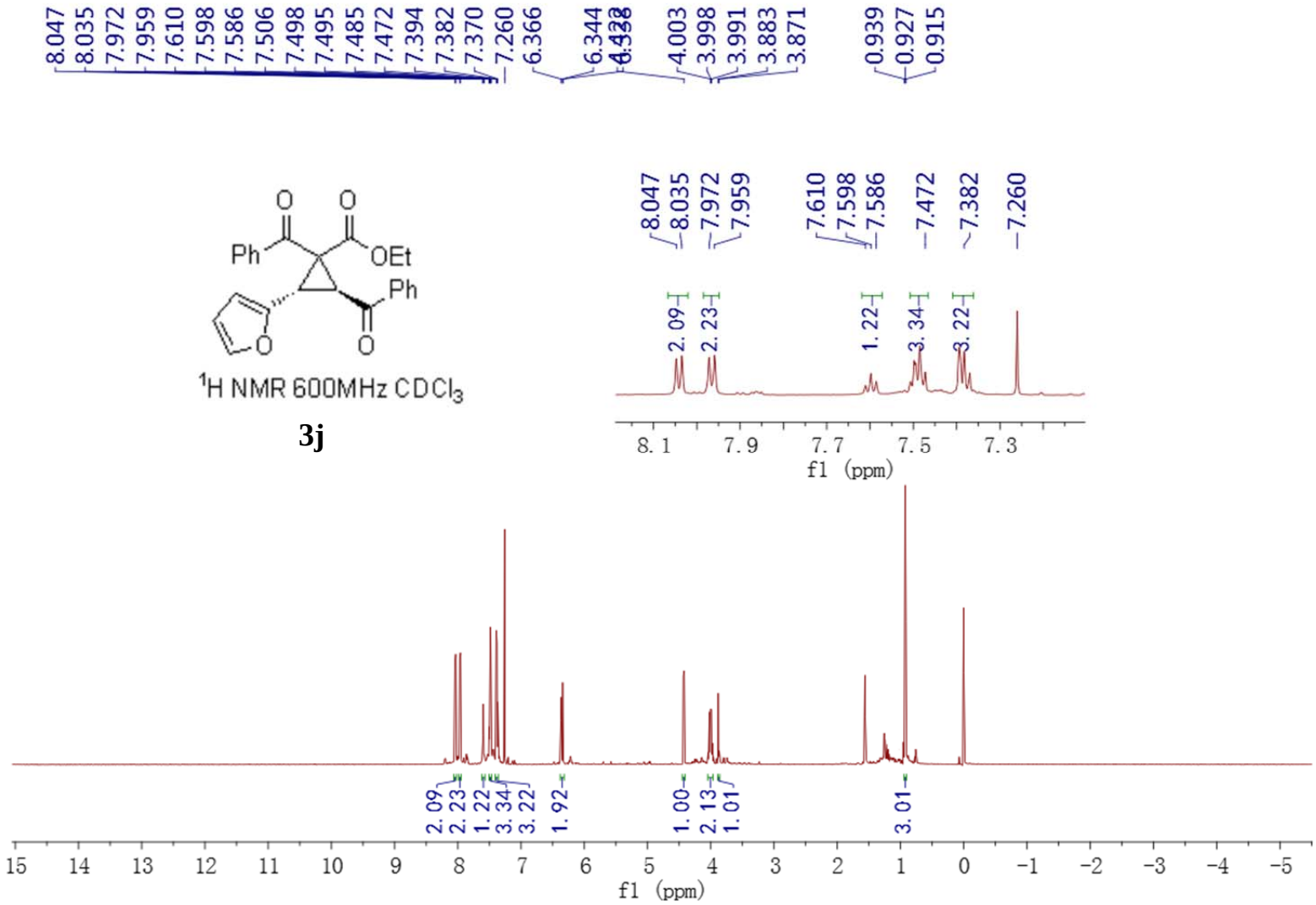
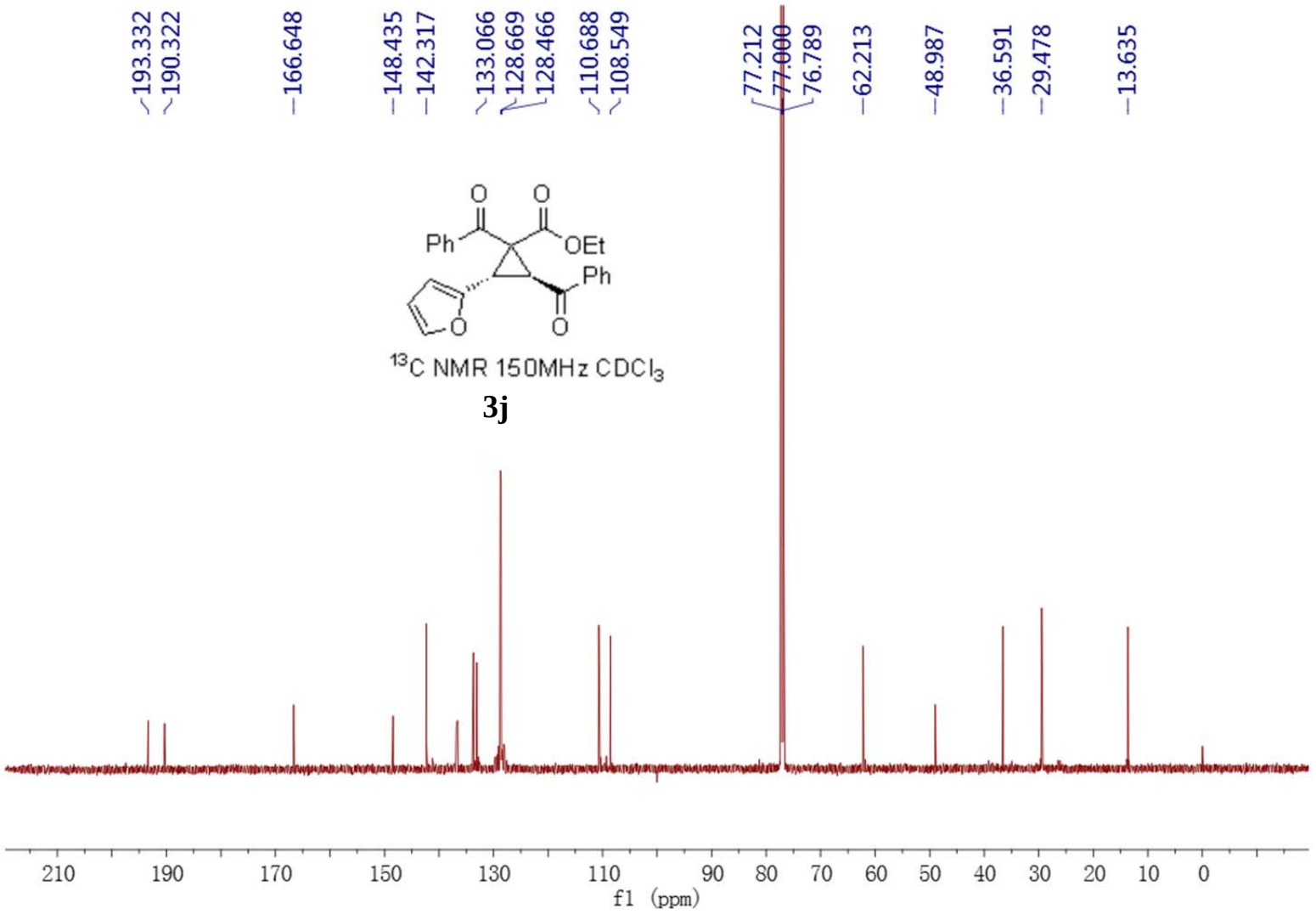
190.240
166.625
133.783
133.614
133.137
132.258
130.036
128.805
128.591
128.511
128.330
77.318
77.000
76.682
62.182
50.084
36.450
35.893
13.618
O
O
Ph
OEt
Ph
O
Cl
13C NMR 100MHz CDCl3
3i
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.047
8.035
7.972
7.959
7.610
7.598
7.586
7.506
7.498
7.495
7.485
7.472
7.394
7.382
7.370
7.260
6.366
6.344
4.003
3.998
3.991
3.883
3.871
0.939
0.927
0.915
Ph
OEt
Ph
O
O
O
O
1H NMR 600MHz CDCl3
3j
2.09
2.23
1.22
3.34
3.22
1.92
1.00
2.13
1.01
3.01
f1 (ppm)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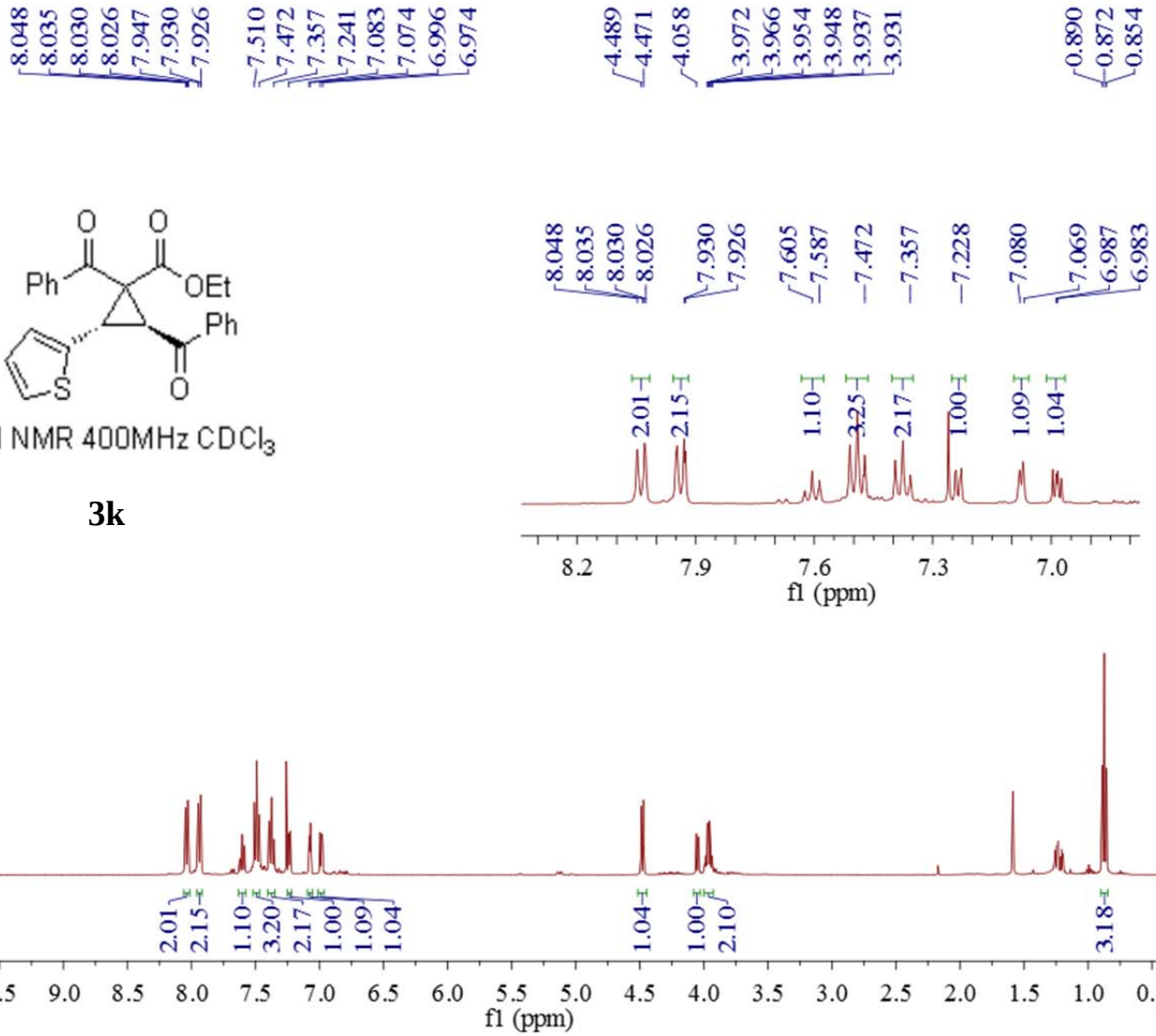
190.322
166.648
148.435
142.317
133.066
128.669
128.466
110.688
108.549
77.212
77.000
76.789
62.213
48.987
36.591
29.478
13.635
Ph
OEt
Ph
O
O
O
O
O
13C NMR 150MHz CDCl3
3j
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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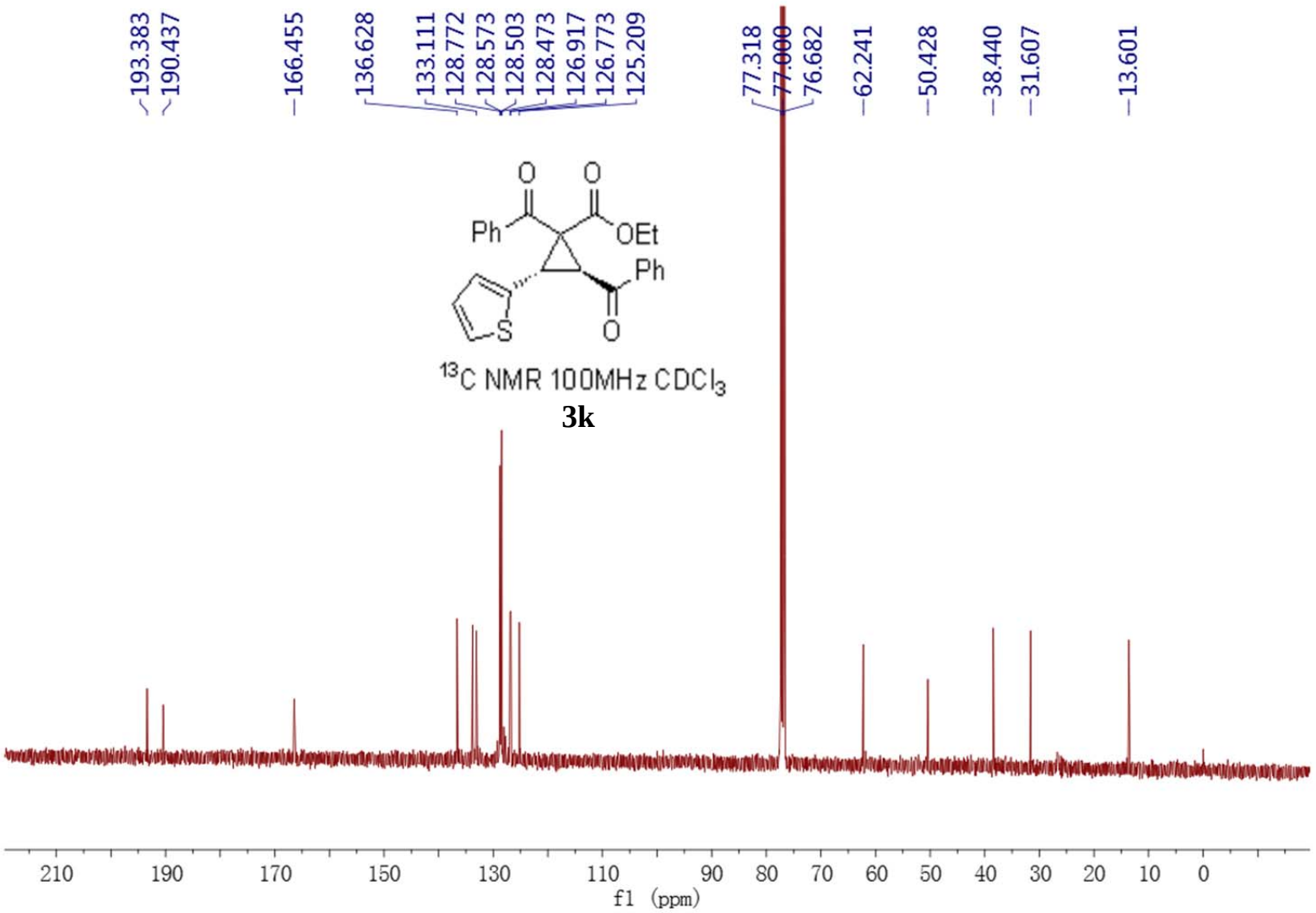
8.035
8.030
8.026
7.947
7.930
7.926
7.510
7.472
7.357
7.241
7.083
7.074
6.996
6.974
4.489
4.471
4.058
3.972
3.966
3.954
3.948
3.937
3.931
0.890
0.872
0.854
Ph
OEt
Ph
O
O
O
S
1H NMR 400MHz CDCl3
3k
8.048
8.035
8.030
8.026
7.930
7.926
7.605
7.587
7.472
7.357
7.228
7.080
7.069
6.987
6.983
2.01
2.15
1.10
3.25
2.17
1.00
1.09
1.04
8.2
7.9
7.6
7.3
7.0
f1 (ppm)
2.01
2.15
1.10
3.20
2.17
1.00
1.09
1.04
1.04
1.00
2.10
3.18
10.5
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)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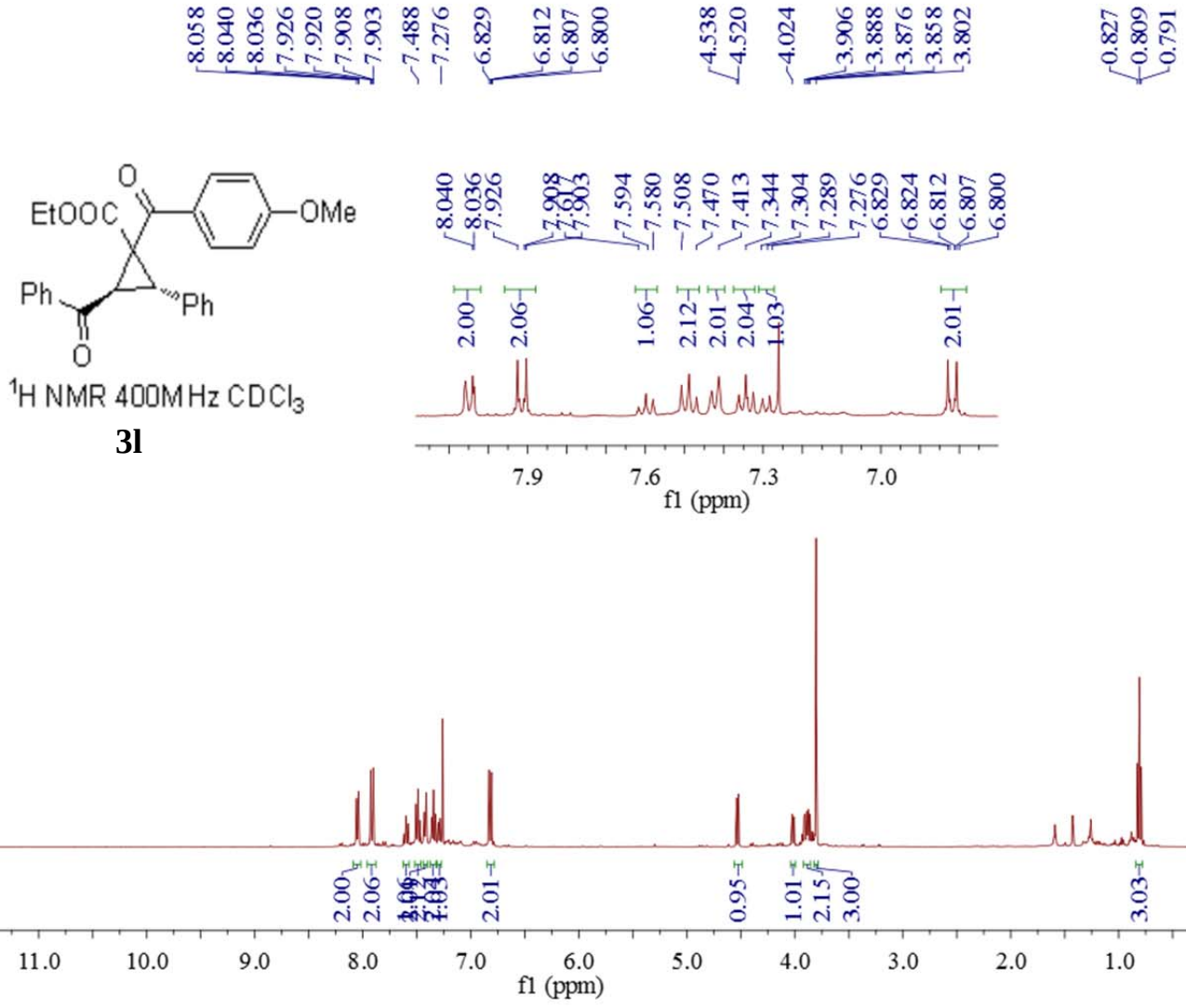
128.573
128.503
128.473
126.917
126.773
125.209
77.318
77.000
76.682
62.241
50.428
38.440
31.607
13.601
O
O
Ph
OEt
Ph
S
O
13C NMR 100MHz CDCl3
3k
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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8.040
8.036
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7.920
7.908
7.903
7.488
7.276
6.829
6.812
6.807
6.800
4.538
4.520
4.024
3.906
3.888
3.876
3.858
3.802
0.827
0.809
0.791
EtOOC
OMe
Ph
Ph
O
O
1H NMR 400MHz CDCl3
3l
8.040
8.036
7.926
7.908
7.903
7.594
7.580
7.508
7.470
7.413
7.344
7.304
7.289
7.276
6.829
6.824
6.812
6.807
6.800
2.00
2.06
1.06
2.12
2.01
2.04
1.03
2.01
7.9
7.6
7.3
7.0
f1 (ppm)
2.00
2.06
2.01
0.95
1.01
2.15
3.00
3.03
12.0
11.0
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7.0
6.0
5.0
4.0
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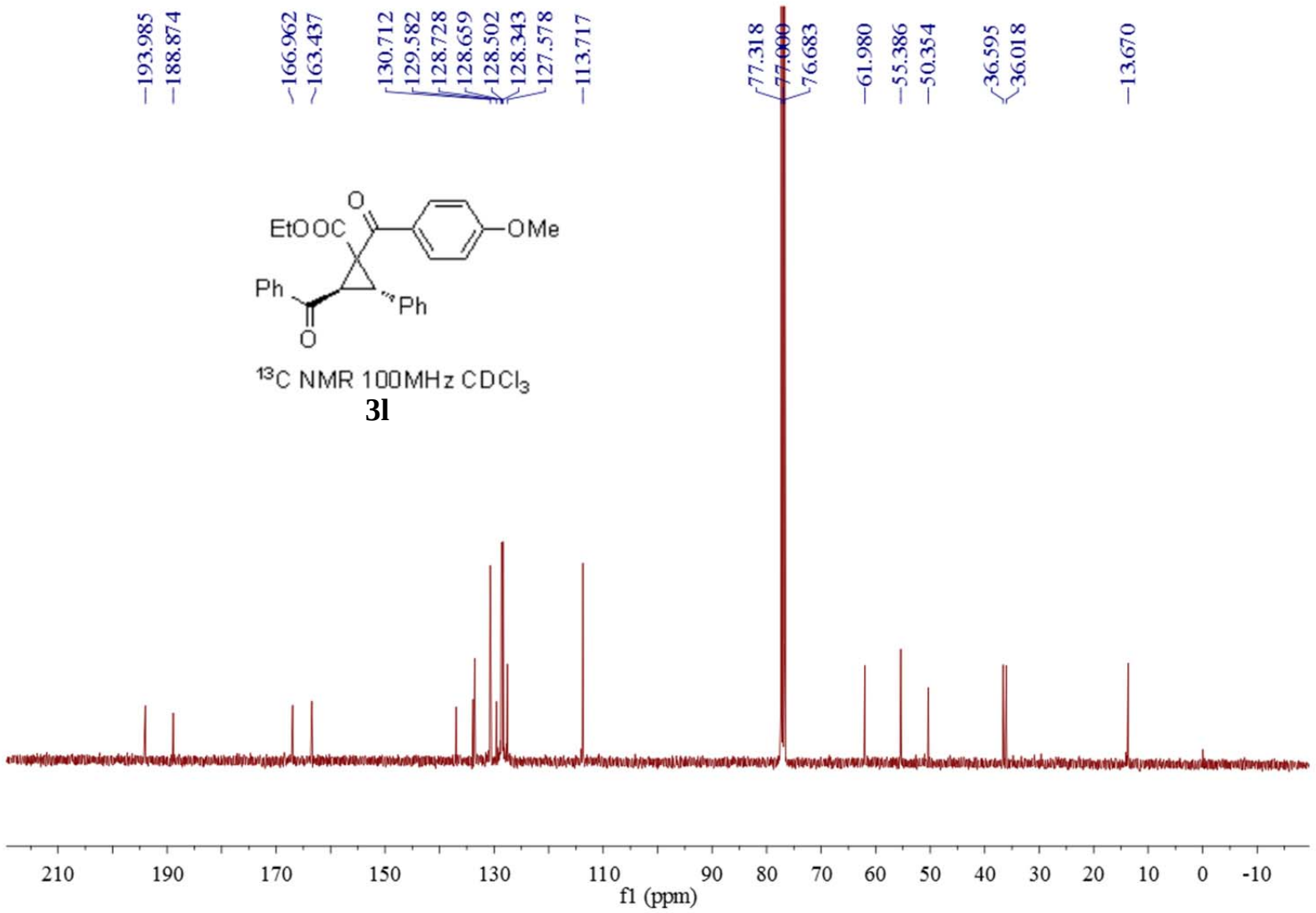
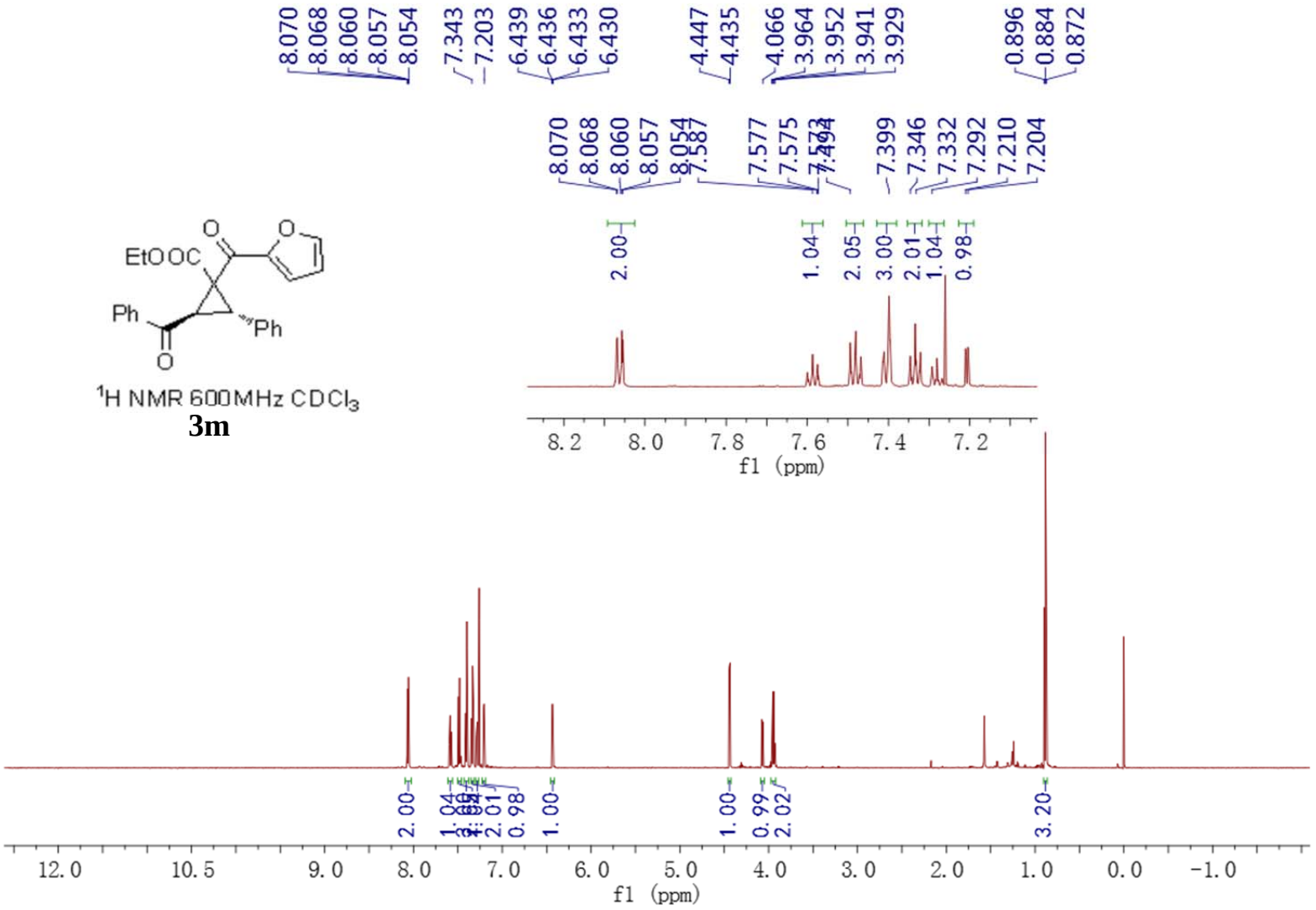
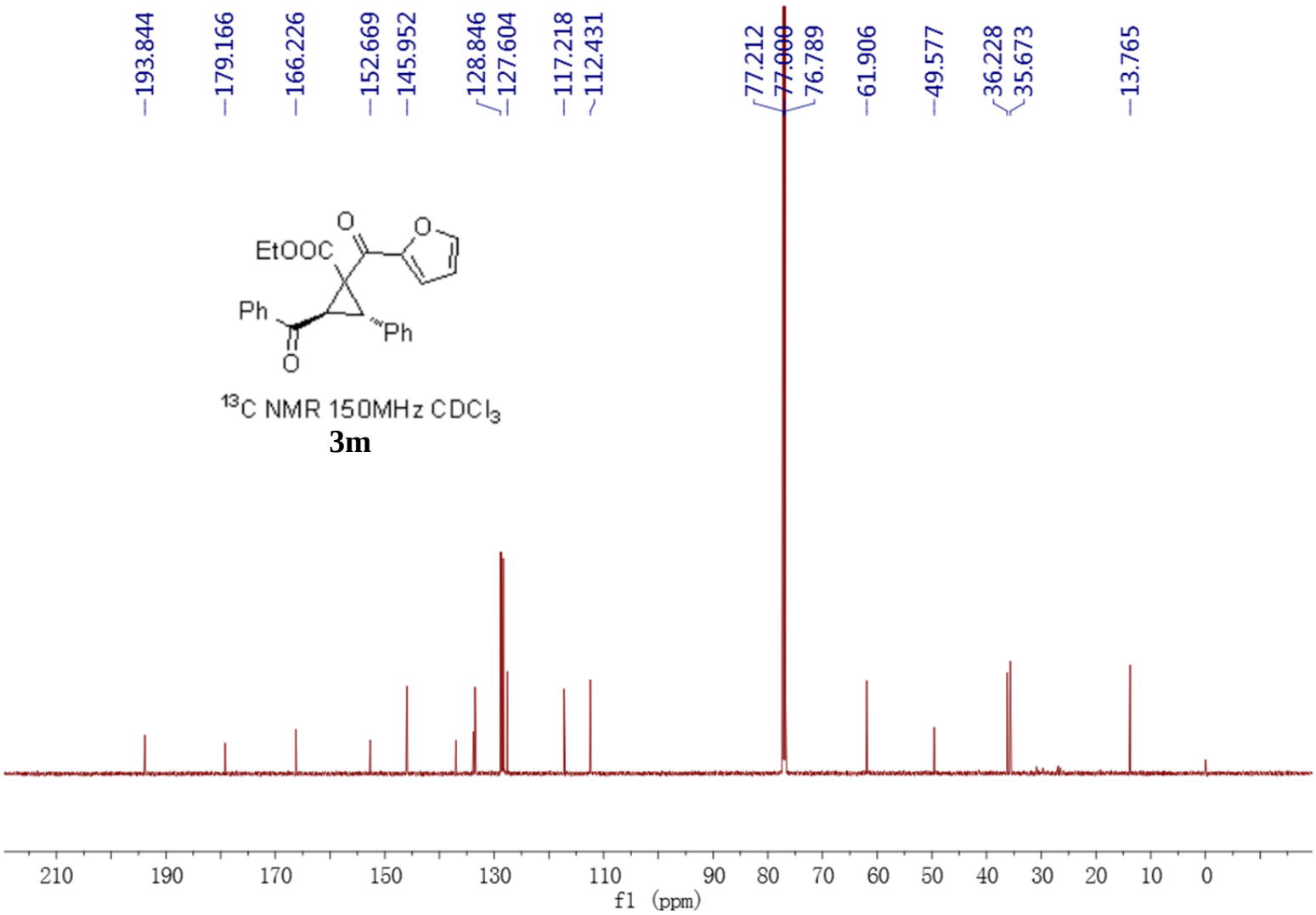
2.0
1.0
0.0
f1 (ppm)



^{13}C NMR 100MHz $CDCl_3$

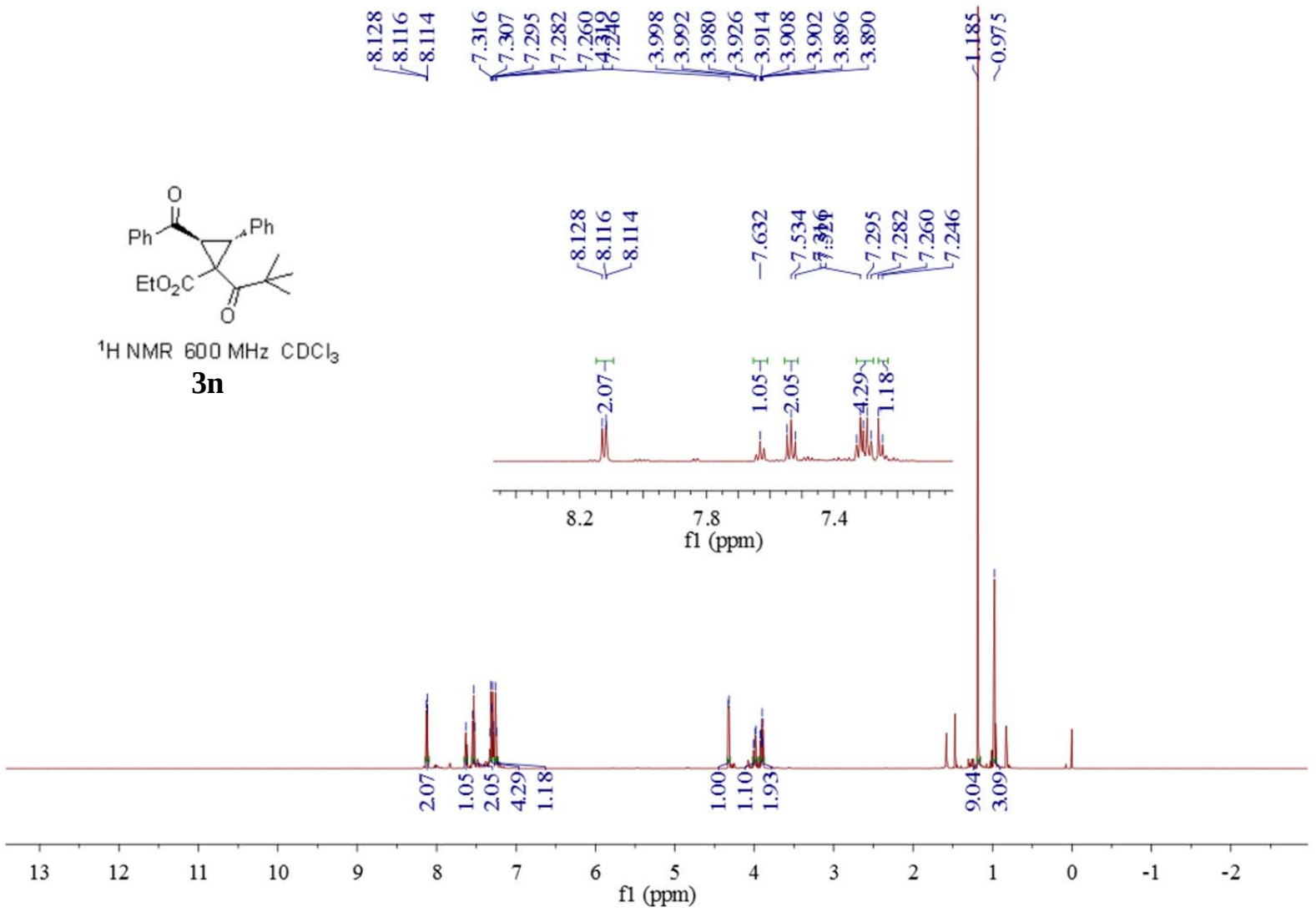
3l

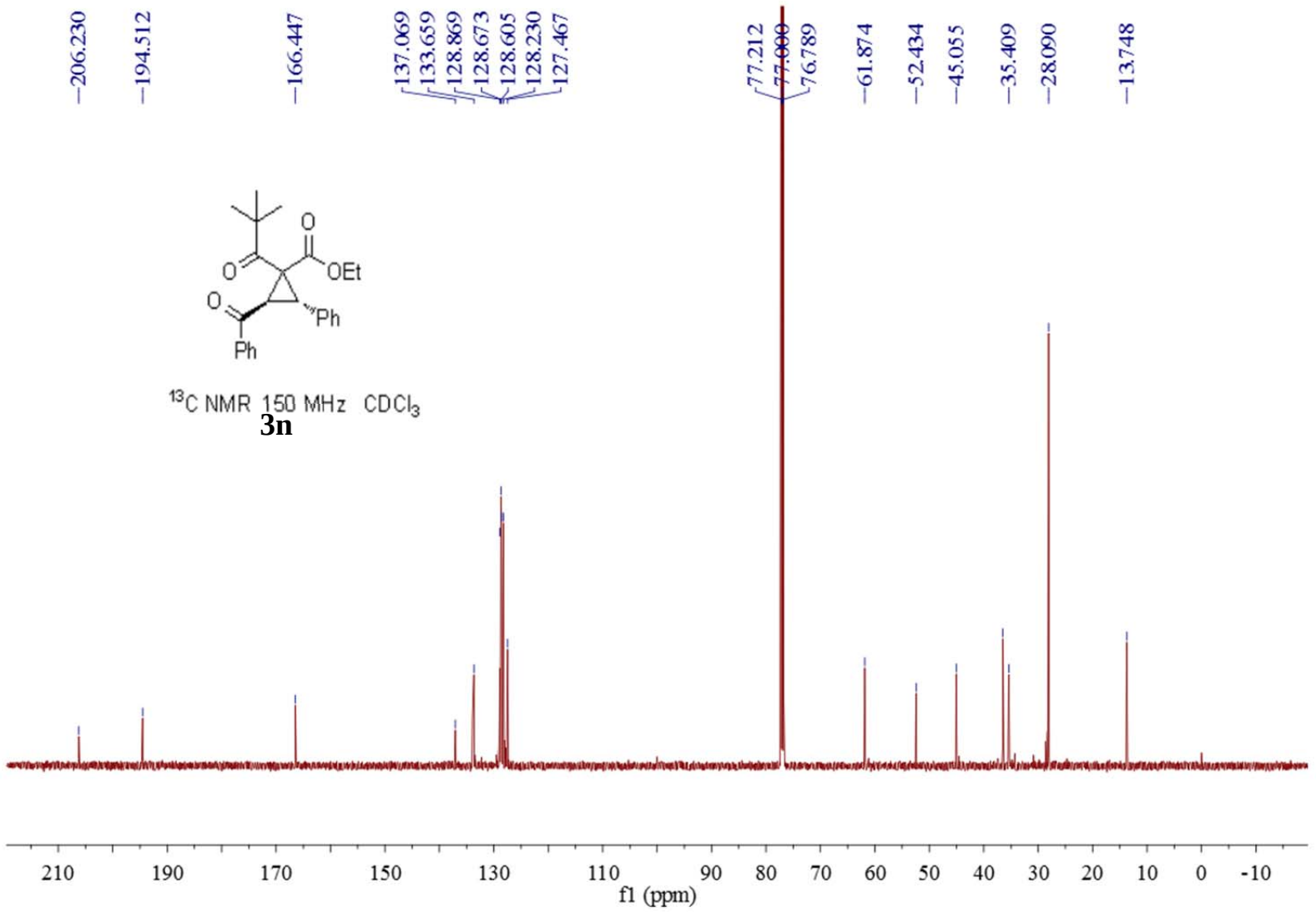

EtOOC
Ph
Ph
^{1}H NMR 600MHz CDCl$_3$
3m
f1 (ppm)

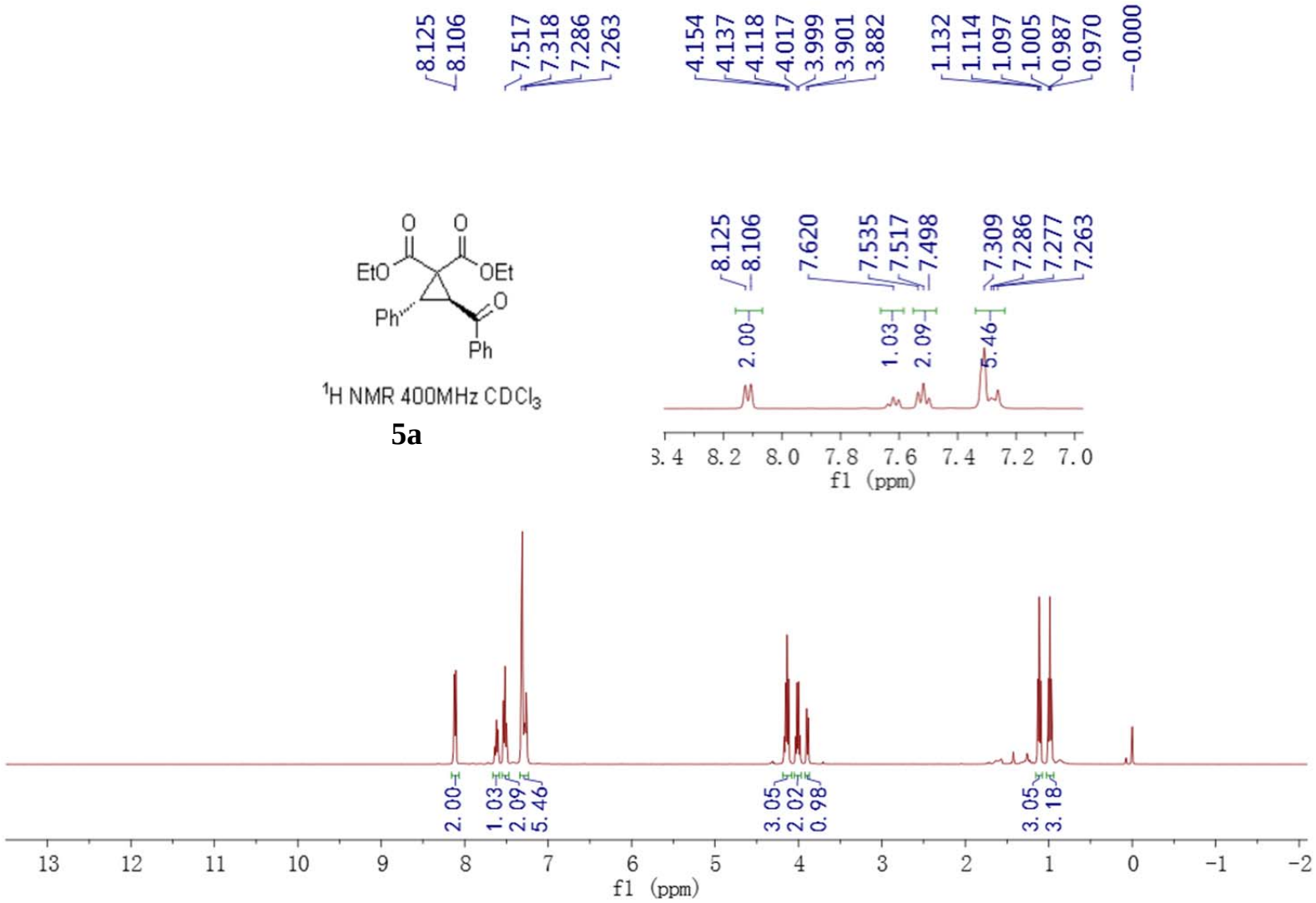


^{13}C NMR 150MHz $CDCl_3$

3m


Ph
Ph
EtO2C
O
O
1H NMR 600 MHz CDCl3
3n
f1 (ppm)


206.230
194.512
166.447
137.069
133.659
128.869
128.673
128.605
128.230
127.467
77.212
77.000
76.789
61.874
52.434
45.055
35.409
28.090
13.748
O
O
OEt
O
Ph
Ph
13C NMR 150 MHz CDCl3
3n
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)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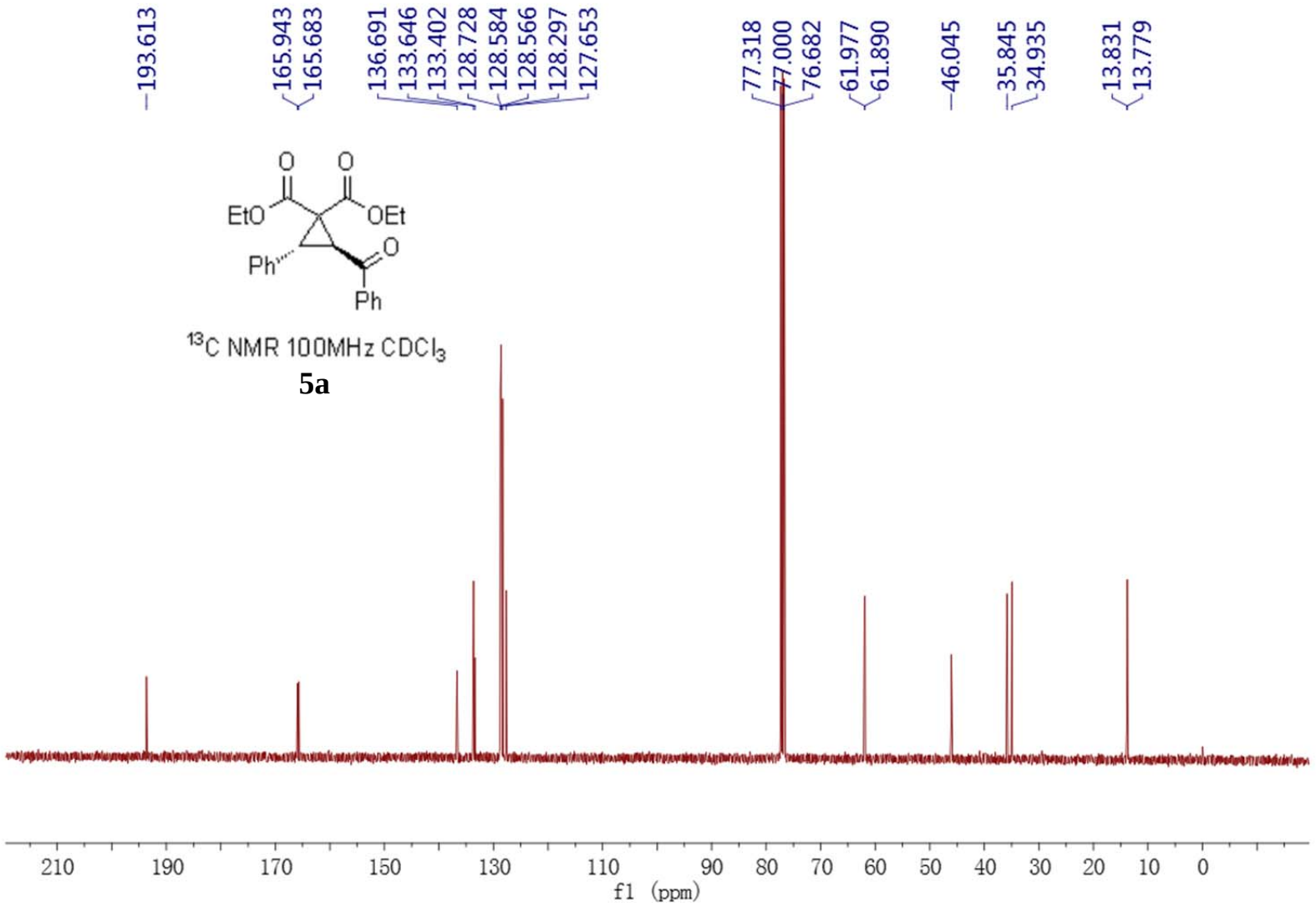
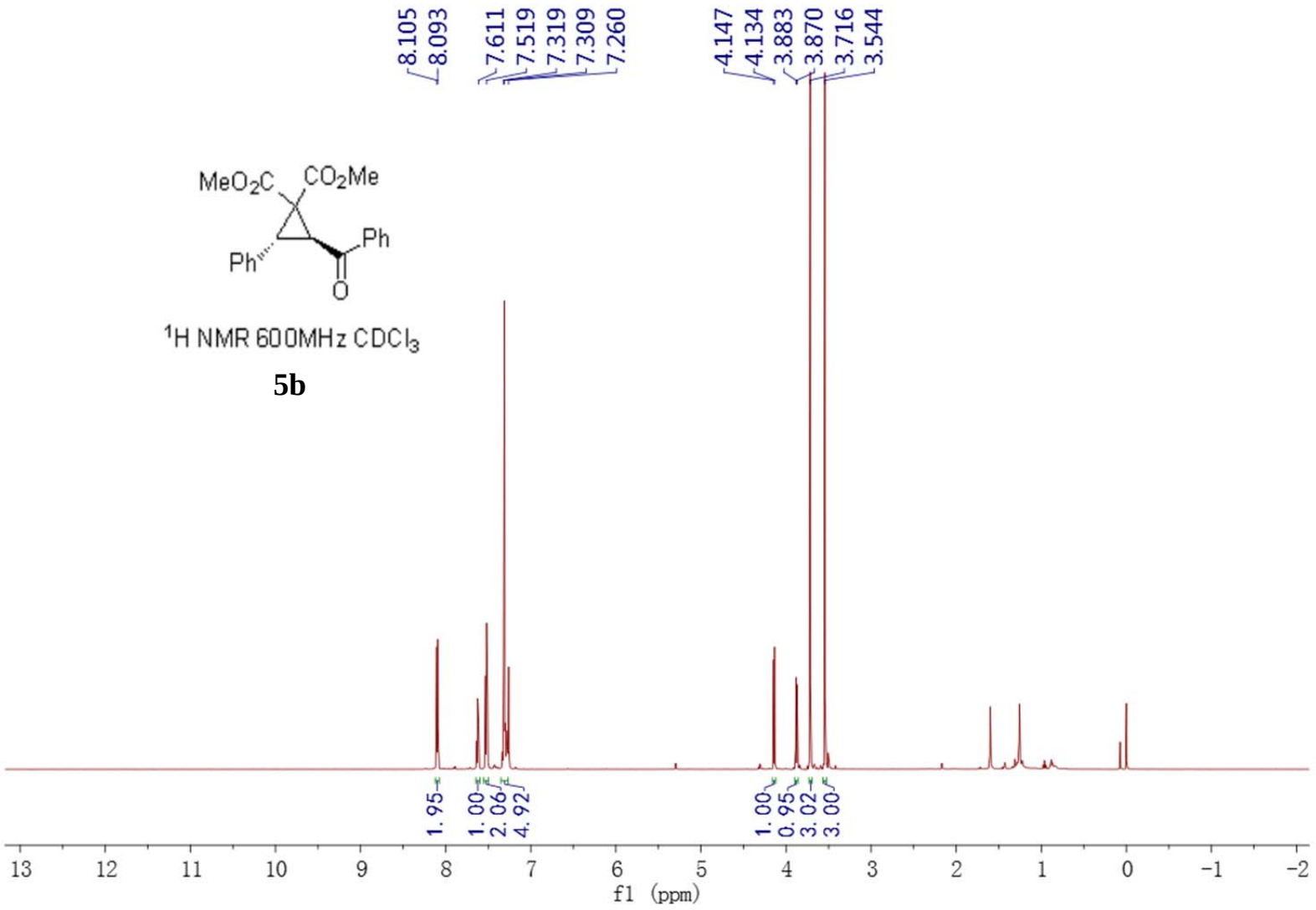
8.106
7.517
7.318
7.286
7.263
4.154
4.137
4.118
4.017
3.999
3.901
3.882
1.132
1.114
1.097
1.005
0.987
0.970
-0.000
EtO
OEt
Ph
Ph
O
O
O
1H NMR 400MHz CDCl3
5a
8.125
8.106
7.620
7.535
7.517
7.498
7.309
7.286
7.277
7.263
2.00
1.03
2.09
5.46
f1 (ppm)
2.00
1.03
2.09
5.46
3.05
2.02
0.98
3.05
3.18
f1 (ppm)


193.613
165.943
165.683
136.691
133.646
133.402
128.728
128.584
128.566
128.297
127.653
77.318
77.000
76.682
61.977
61.890
46.045
35.845
34.935
13.831
13.779
EtO
OEt
Ph
Ph
13C NMR 100MHz CDCl3
5a
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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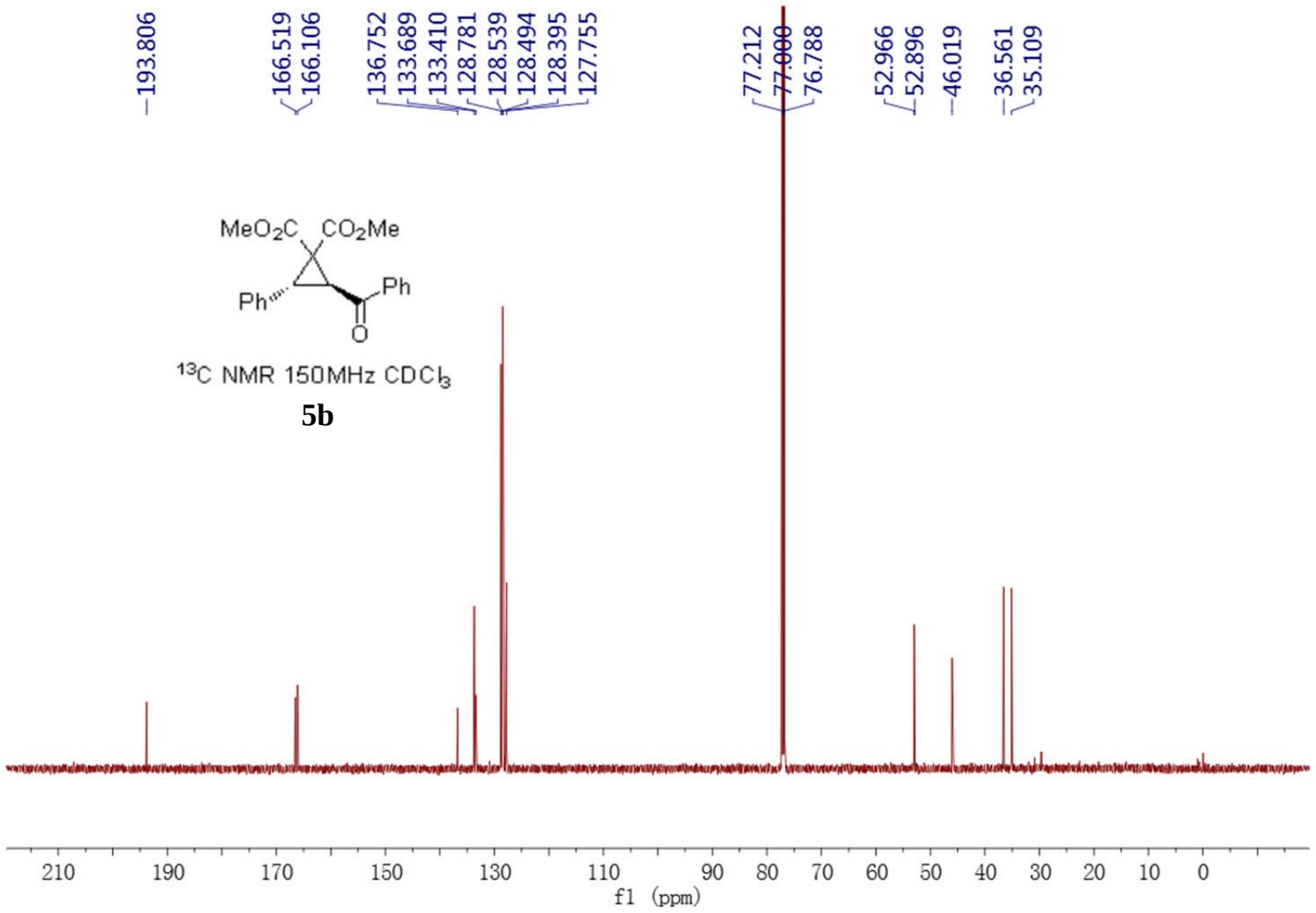
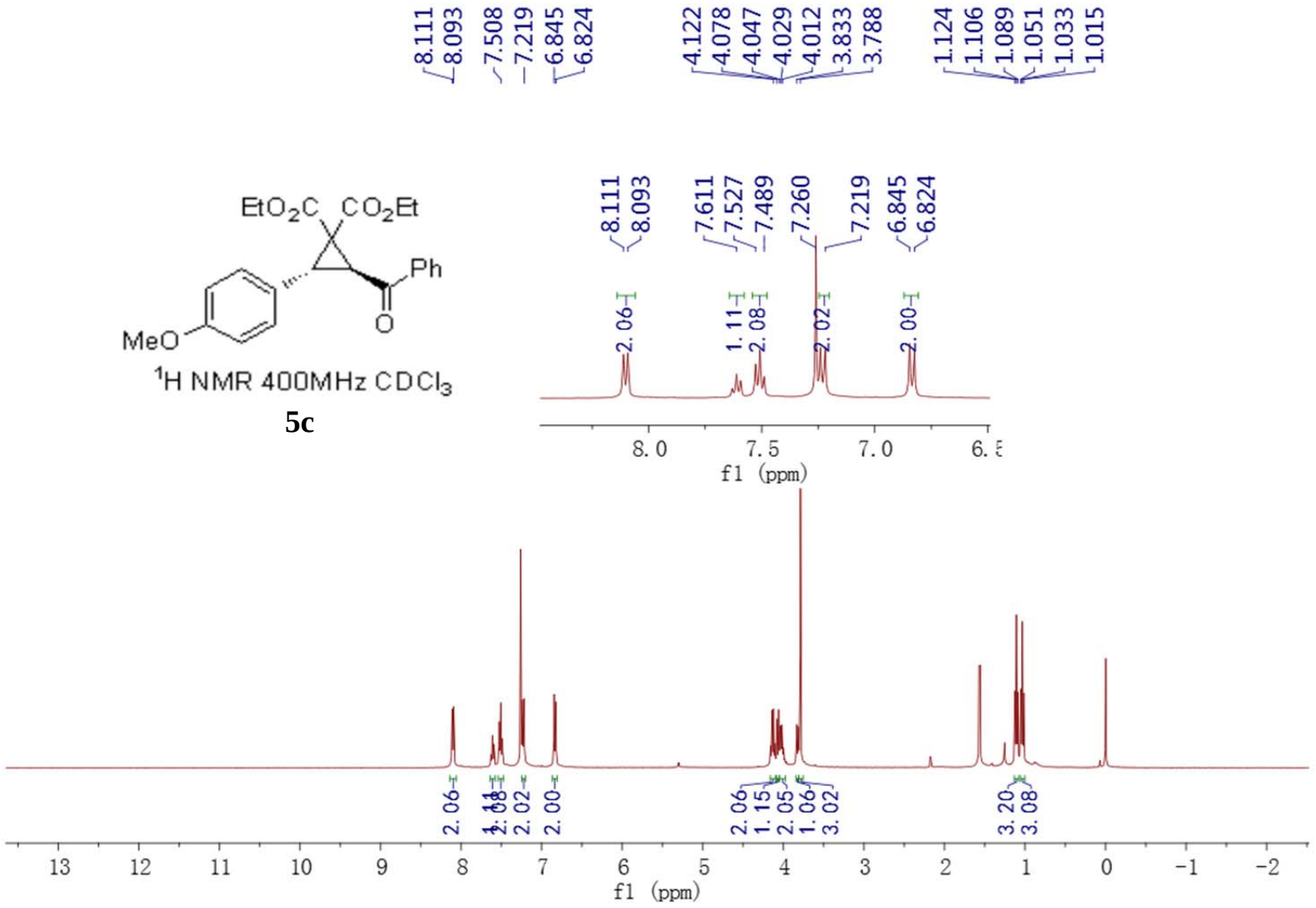
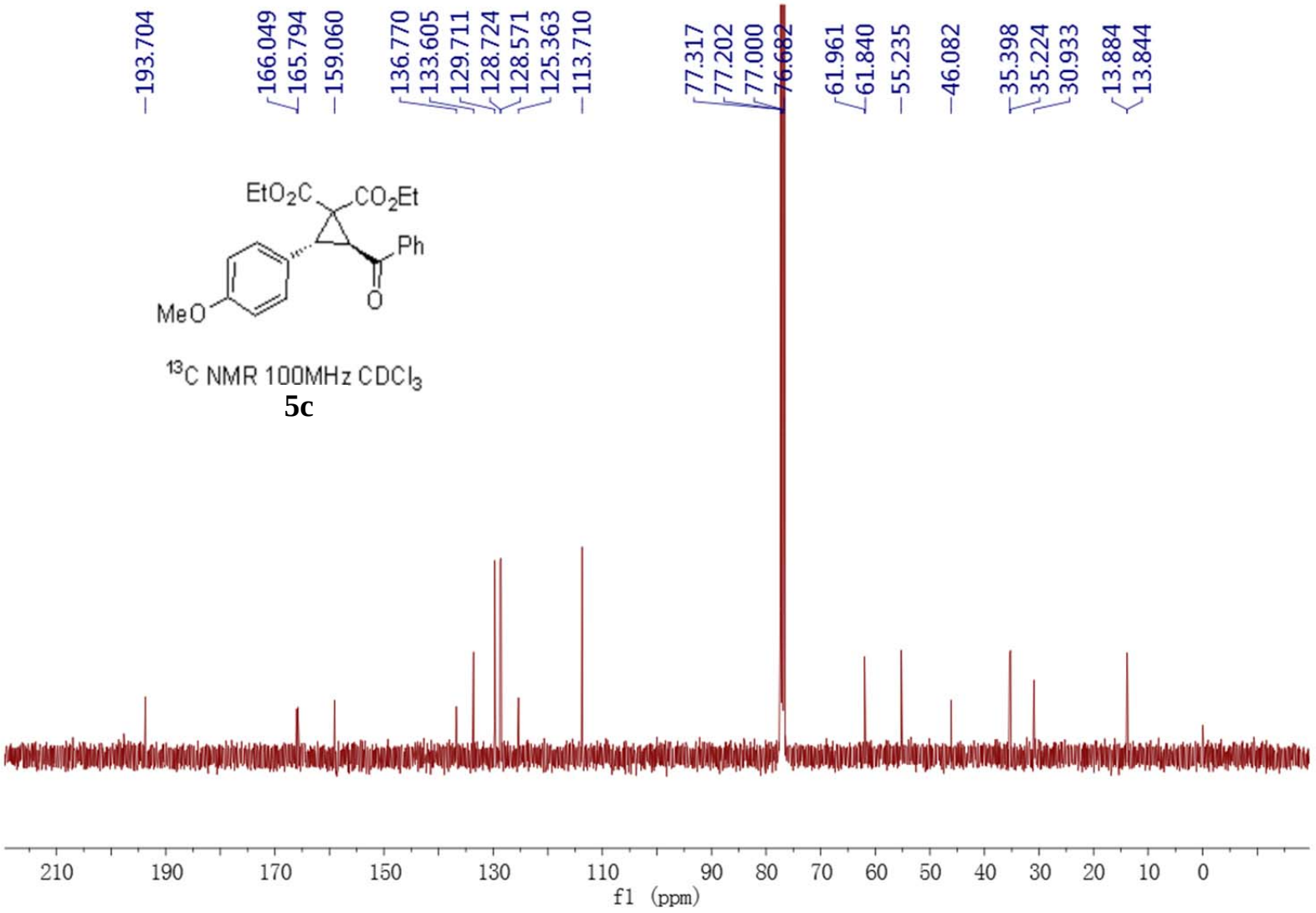
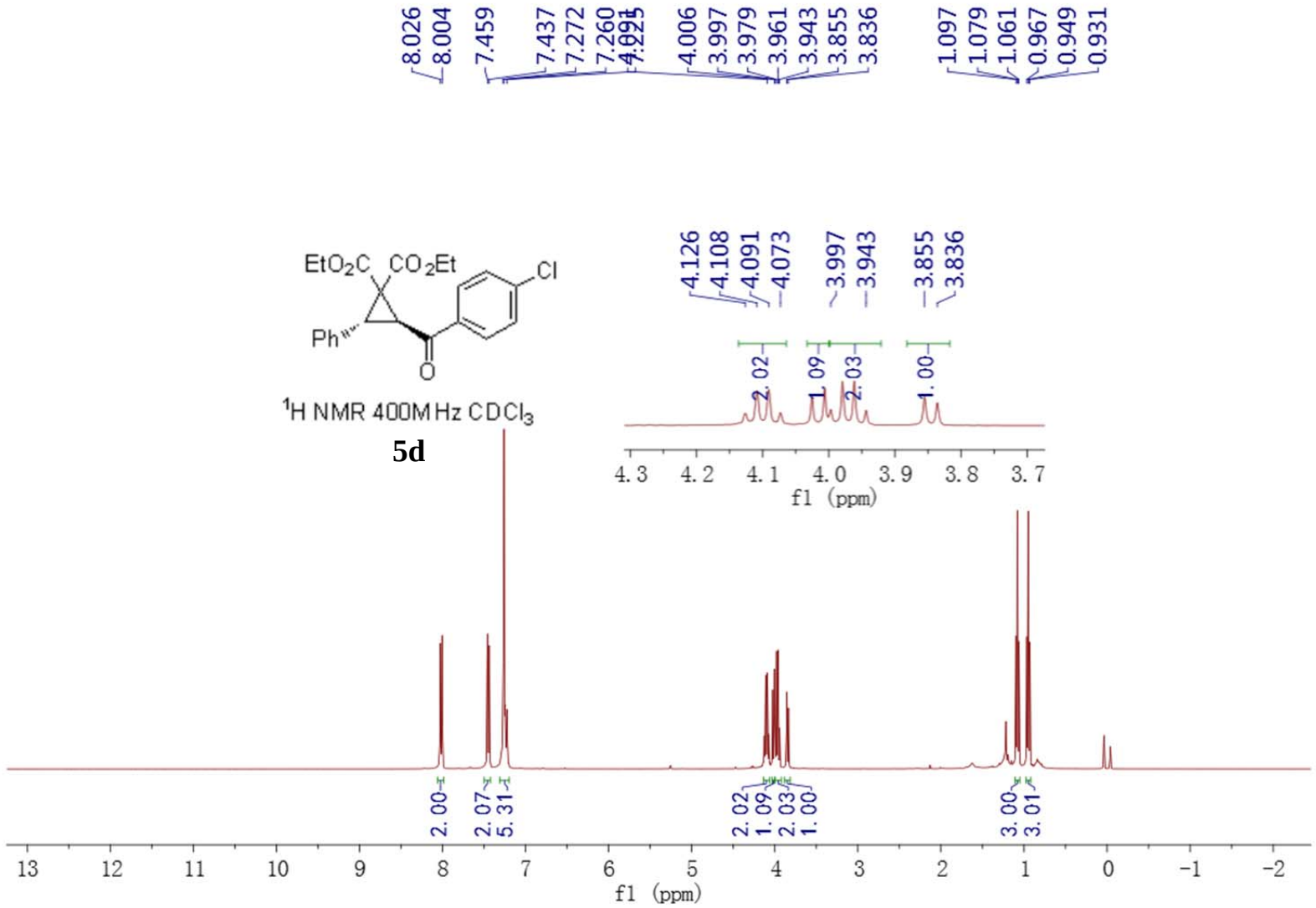
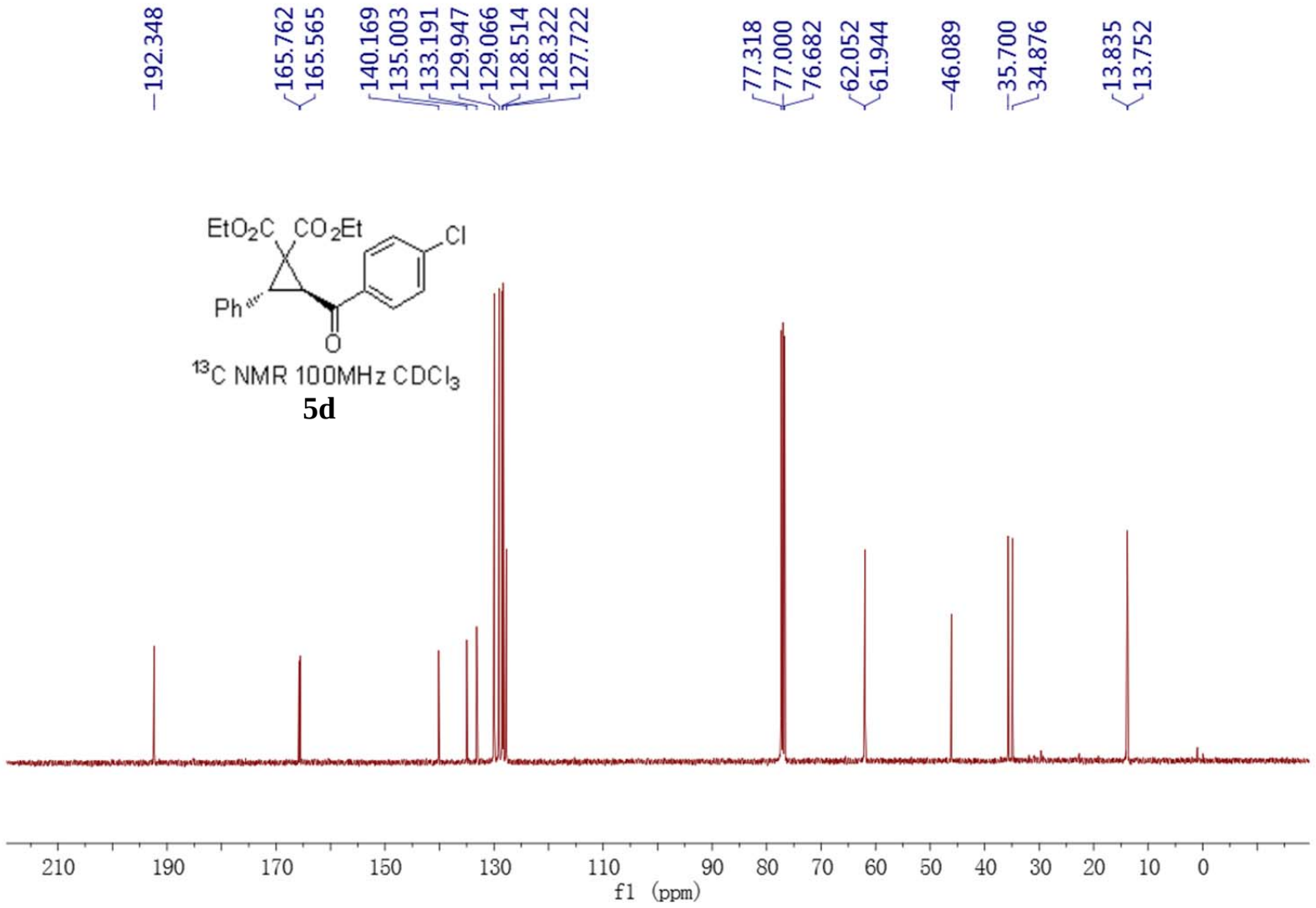
8.093
7.611
7.519
7.319
7.309
7.260
4.147
4.134
3.883
3.870
3.716
3.544
MeO2C
CO2Me
Ph
Ph
O
1H NMR 600MHz CDCl3
5b
1.95
1.00
2.06
4.92
1.00
0.95
3.02
3.00
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
f1 (ppm)

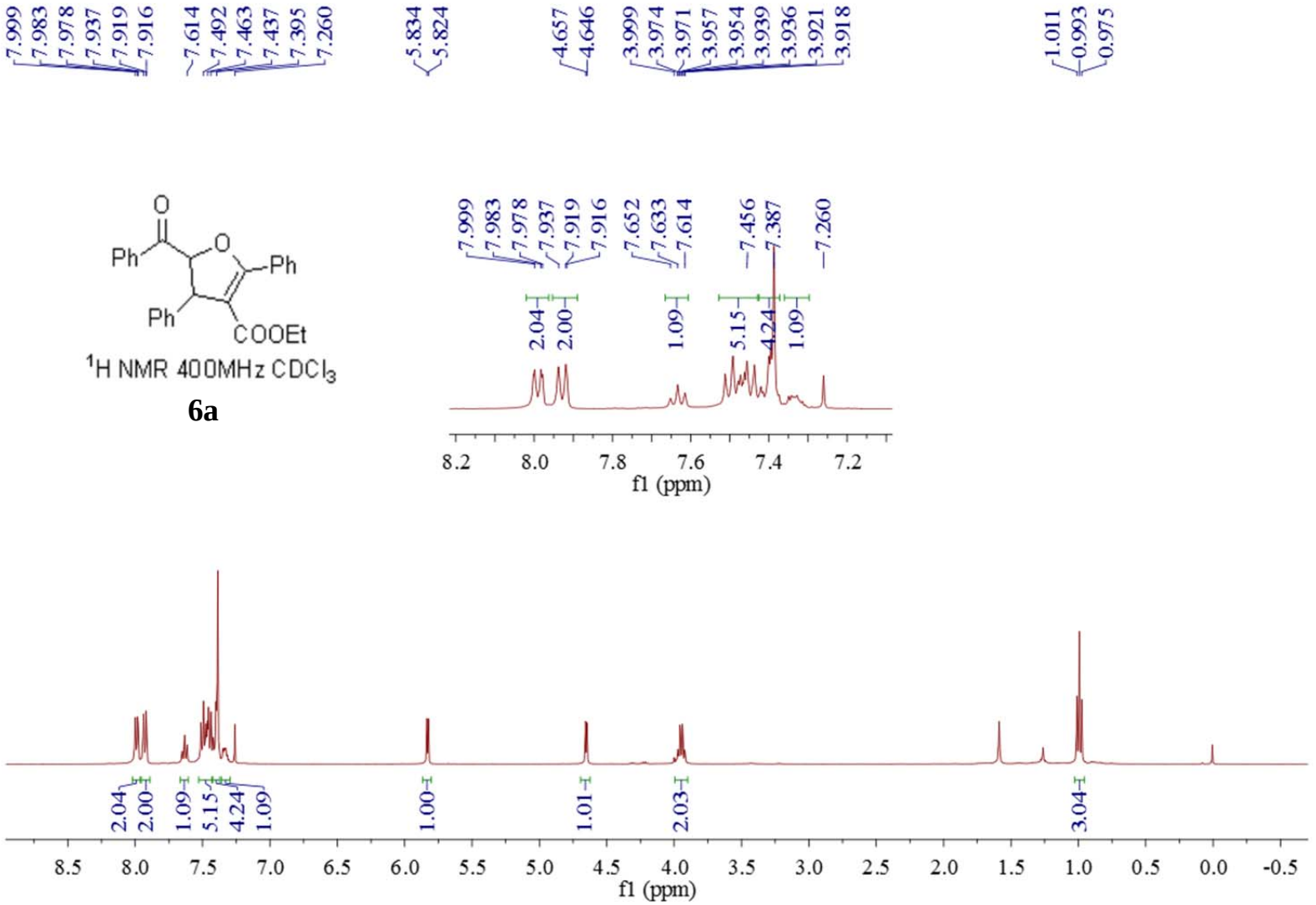

193.806
166.519
166.106
136.752
133.689
133.410
128.781
128.539
128.494
128.395
127.755
77.212
77.000
76.788
52.966
52.896
46.019
36.561
35.109
MeO2C
CO2Me
Ph
Ph
O
13C NMR 150MHz CDCl3
5b
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

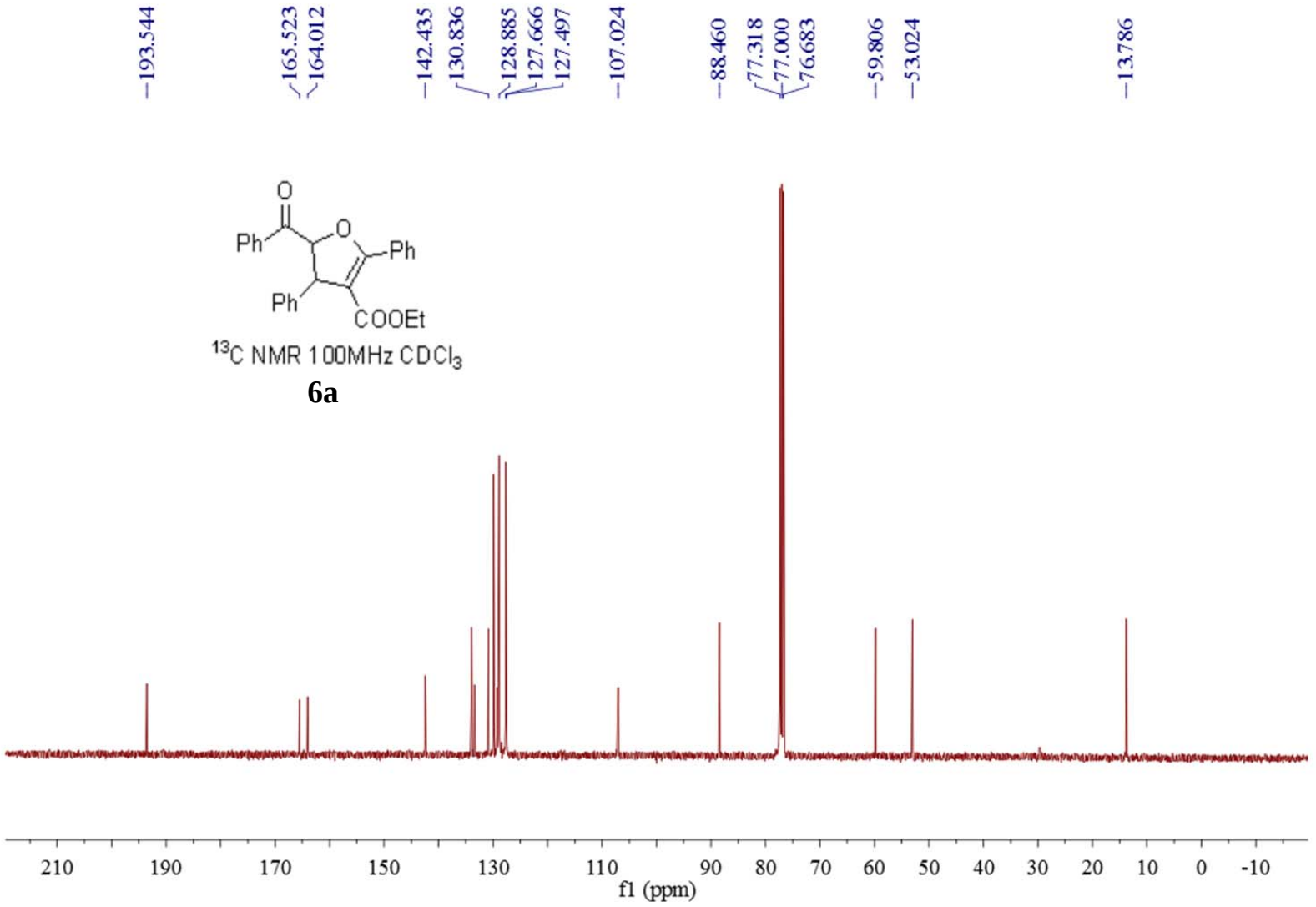

8.111
8.093
7.508
7.219
6.845
6.824
4.122
4.078
4.047
4.029
4.012
3.833
3.788
1.124
1.106
1.089
1.051
1.033
1.015
EtO2C
CO2Et
Ph
O
MeO
1H NMR 400MHz CDCl3
5c
8.111
8.093
7.611
7.527
7.489
7.260
7.219
6.845
6.824
2.06
1.11
2.08
2.02
2.00
8.0
7.5
7.0
f1 (ppm)
2.06
2.02
2.00
2.06
1.15
2.05
1.06
3.02
3.20
3.08
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
f1 (ppm)


193.704
166.049
165.794
159.060
136.770
133.605
129.711
128.724
128.571
125.363
113.710
77.317
77.202
77.000
76.682
61.961
61.840
55.235
46.082
35.398
35.224
30.933
13.884
13.844
EtO2C
CO2Et
Ph
O
MeO
13C NMR 100MHz CDCl3
5c
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


8.026
8.004
7.459
7.437
7.272
7.260
4.006
3.997
3.979
3.961
3.943
3.855
3.836
1.097
1.079
1.061
0.967
0.949
0.931
EtO2C
CO2Et
Cl
Ph
O
1H NMR 400MHz CDCl3
5d
4.126
4.108
4.091
4.073
3.997
3.943
3.855
3.836
2.02
1.09
2.03
1.00
4.3
4.2
4.1
4.0
3.9
3.8
3.7
f1 (ppm)
2.00
2.07
5.31
2.02
1.09
2.03
1.00
3.00
3.01
13
12
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
f1 (ppm)


192.348
165.762
165.565
140.169
135.003
133.191
129.947
129.066
128.514
128.322
127.722
77.318
77.000
76.682
62.052
61.944
46.089
35.700
34.876
13.835
13.752
EtO2C
CO2Et
Cl
Ph
O
13C NMR 100MHz CDCl3
5d
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


7.999
7.983
7.978
7.937
7.919
7.916
7.614
7.492
7.463
7.437
7.395
7.260
5.834
5.824
4.657
4.646
3.999
3.974
3.971
3.957
3.954
3.939
3.936
3.921
3.918
1.011
0.993
0.975
O
Ph
O
Ph
Ph
COOEt
1H NMR 400MHz CDCl3
6a
7.999
7.983
7.978
7.937
7.919
7.916
7.652
7.633
7.614
7.456
7.387
7.260
2.04
2.00
1.09
5.15
4.24
1.09
8.2
8.0
7.8
7.6
7.4
7.2
f1 (ppm)
2.04
2.00
1.09
5.15
4.24
1.09
1.00
1.01
2.03
3.04
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
f1 (ppm)


193.544
165.523
164.012
142.435
130.836
128.885
127.666
127.497
107.024
88.460
77.318
77.000
76.683
59.806
53.024
13.786
O
Ph
O
Ph
Ph
COOEt
13C NMR 100MHz CDCl3
6a
210
190
170
150
130
110
90
80
70
60
50
40
30
20
10
0
-10
f1 (ppm)