BEILSTEIN JOURNAL OF ORGANIC CHEMISTRY

Supporting Information

for

Direct C(sp^3)–H allylation of 2-alkylpyridines with Morita–Baylis–Hillman carbonates via a tandem nucleophilic substitution/aza-Cope rearrangement

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Experimental details, characterization data and copies of NMR spectra of new compounds

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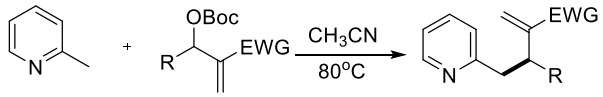
I. General experimental protocols

Acetonitrile was dried by refluxing with CaH_2 and then evaporation; other solvents and commercial reagents were used as received without additional purification. The Morita–Baylis–Hillman carbonates **2a–i** were prepared following the known procedure.[1-2] Flash column chromatography was performed using silica gel G (200–300 mesh). Reactions were monitored by thin-layer chromatography (TLC) (silica gel 60 F_{254}) and visualized using UV or $KMnO_4$. Melting points were measured on a SGW X-4 apparatus and were uncorrected.

^1H (and ^{13}C NMR) spectra were measured on a Varian spectrometer at 300 (or 75) MHz, respectively. Chemical shifts are reported in ppm (δ) with TMS as the internal standard and $CDCl_3$ or DMSO-d_6 as solvents. Multiplicities are indicated as the following: s = singlet, d = doublet, dd = doublet of doublets, t = triplet, q = quartet, m = multiplet and br s = broad singlet. Coupling constants (*J* values) are noted in Hertz. ^{13}C NMR spectra are determined with complete proton decoupling and reported in ppm.

II. Preparation procedures and characterization data.

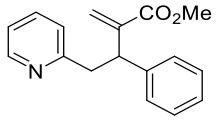
*General experimental procedure for the synthesis of compound **3***



1a **2** **3**

2-Picoline (**1a**, 1.0 mmol) and Morita–Baylis–Hillman carbonates **2** (0.5 mmol) were dissolved in anhydrous CH_3CN (2.0 mL), and the mixture was stirred and heated in an oil bath at 80 °C under nitrogen atmosphere until the completion of the starting material **2** (monitored by TLC). After removing the solvent under vacuum, the residue was directly loaded on a silica gel column and purified by flash chromatography (eluting with petroleum ether/EtOAc), to provide the desired products **3**.

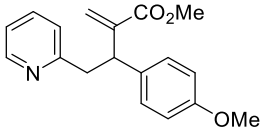
Methyl 2-methylene-3-phenyl-4-(pyridin-2-yl) butanoate (3a) [3]



Eluting with petroleum ether/EtOAc = 5:1 (v/v). Colorless oil, yield 91%.

^{1}H NMR (300 MHz, Chloroform-*d*): *δ* 8.52– 8.49 (m, 1H), 7.47 (td, *J* = 7.8 Hz, 1.8 Hz, 1H), 7.25–7.11 (m, 5H), 7.05 (dd, *J* = 7.5 Hz, 4.8Hz, 1H), 6.93 (d, *J* = 7.8 Hz, 1H), 6.31(s, 1H), 5.76 (s, 1H), 4.51 (t, *J* = 7.8 Hz, 1H), 3.63 (s, 3H), 3.40 (dd, *J* = 13.8Hz, 7.5 Hz, 1H), 3.24 (dd, *J* = 13.5Hz, 8.4 Hz, 1H).

Methyl 3-(4-methoxyphenyl)-2-methylene-4-(pyridin-2-yl) butanoate (3b)



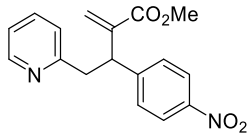
Eluting with petroleum ether/EtOAc = 8:1 (v/v). Pale yellow oil, yield 47%.

^{1}H NMR (300 MHz, Chloroform-*d*) *δ* 8.50 (ddd, *J* = 5.1Hz, 1.8Hz, 0.9Hz, 1H), 7.47 (td, *J* = 7.5Hz, 1.8Hz, 1H), 7.11–7.02 (m, 3H), 6.93(d, *J* = 7.8Hz, 1H), 6.78–6.73 (m, 2H), 6.28

(s, 1H), 5.74–5.72 (m, 1H), 4.45 (t, *J* = 8.1 Hz, 1H), 3.75 (s, 3H), 3.64 (s, 3H), 3.37 (dd, *J* = 13.8 Hz, 7.2 Hz, 1H), 3.19 (dd, *J* = 13.5 Hz, 8.7 Hz, 1H).

^{13}C NMR (75 MHz, Chloroform-*d*) *δ* 167.3, 159.8, 158.2, 149.3, 143.3, 136.1, 134.0, 129.1, 124.5, 123.6, 121.3, 113.7, 55.2, 51.9, 45.8, 43.3.

Methyl 2-methylene-3-(4-nitrophenyl)-4-(pyridin-2-yl) butanoate (3c)

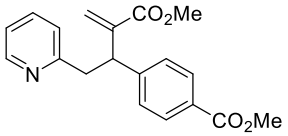


Eluting with petroleum ether/EtOAc = 5:1 (v/v). Yellow oil, yield 69%.

^{1}H NMR (300 MHz, Chloroform-*d*) *δ* 8.51 (ddd, *J* = 4.8, 1.8, 0.9 Hz, 1H), 8.06 (d, *J* = 8.7 Hz, 2H), 7.50 (td, *J* = 7.5 Hz, 1.8 Hz, 1H), 7.32 (d, *J* = 8.7 Hz, 2H), 7.09 (ddd, *J* = 7.8 Hz, 5.1 Hz, 1.2 Hz, 1H), 6.93 (dt, *J* = 7.8 Hz, 0.9 Hz, 1H), 6.41 (s, 1H), 5.87–5.85 (m, 1H), 4.65 (t, *J* = 7.8 Hz, 1H), 3.65 (s, 3H), 3.45 (A of AB, *J* = 13.8 Hz, 6.6 Hz, 1H), 3.22 (B of AB, *J* = 13.8 Hz, 9.3 Hz, 1H);

^{13}C NMR (75 MHz, Chloroform-*d*) *δ* 166.6, 158.5, 150.0, 149.6, 146.7, 141.8, 136.4, 129.0, 126.0, 123.6, 123.6, 121.7, 52.1, 46.5, 42.6.

Methyl 4-(3-(methoxycarbonyl)-1-(pyridin-2-yl) but-3-en-2-yl) benzoate (3d)

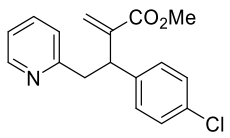


Eluting with petroleum ether/EtOAc = 10:1 (v/v). Colorless oil, yield 71%.

^{1}H NMR (300 MHz, Chloroform-*d*) *δ* 8.51 (ddd, *J* = 4.8, 1.8, 0.9 Hz, 1H), 7.88 (d, *J* = 8.4 Hz, 2H), 7.46 (td, *J* = 7.8, 1.8 Hz, 1H), 7.23 (d, *J* = 8.4 Hz, 2H), 7.06 (ddd, *J* = 7.5, 4.8, 0.9 Hz, 1H), 6.89 (d, *J* = 7.8 Hz, 1H), 6.36 (s, 1H), 5.80 (d, *J* = 0.6 Hz, 1H), 4.58 (t, *J* = 7.8 Hz, 1H), 3.87 (s, 3H), 3.63 (s, 3H), 3.41 (dd, *J* = 13.5 Hz, 6.9 Hz, 1H), 3.21 (dd, *J* = 13.5, 9.0 Hz, 1H);

^{13}C NMR (75 MHz, Chloroform-*d*) *δ* 167.1, 166.9, 159.1, 149.4, 147.5, 142.4, 136.2, 129.7, 128.5, 128.2, 125.5, 123.6, 121.5, 52.1, 52.0, 46.6, 42.9.

Methyl 3-(4-chlorophenyl)-2-methylene-4-(pyridin-2-yl) butanoate (3e)

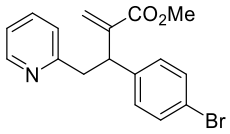


Eluted with petroleum ether/EtOAc = 14:1 (v/v). Pale yellow oil, yield 78%.

^{1}H NMR (300 MHz, Chloroform-*d*) *δ* 8.51 (ddd, *J* = 5.1Hz,1.8Hz,0.9Hz, 1H), 7.49 (td, *J* = 7.5Hz, 1.8Hz, 1H), 7.20–7.15 (m, 2H), 7.12–7.05 (m, 3H), 6.93 (d, *J* = 7.8Hz, 1H), 6.32 (t, *J* = 0.6Hz, 1H), 5.76 (dd, *J* = 1.2Hz, 0.6Hz,1H), 4.49 (t, *J* = 7.8Hz, 1H), 3.64 (s, 3H), 3.39 (dd, *J* = 13.8Hz, 6.9Hz, 1H), 3.19 (dd, *J* = 13.8Hz, 9.0Hz, 1H);

^{13}C NMR (75 MHz, Chloroform-*d*) *δ* 167.0, 159.2, 149.4, 142.7, 140.6, 136.2, 132.3, 129.5, 128.5, 125.1, 123.7, 121.4, 52.0, 46.0, 43.0.

Methyl 3-(4-bromophenyl)-2-methylene-4-(pyridin-2-yl) butanoate (3f)

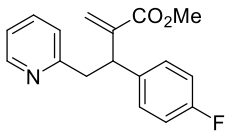


Eluting with petroleum ether/EtOAc = 14:1 (v/v). Colorless oil, yield 74%.

^{1}H NMR (300 MHz, Chloroform-*d*) *δ* 8.51 (ddd, *J* = 5.1, 1.5, 0.6 Hz, 1H), 7.49 (td, *J* = 7.8, 1.8 Hz, 1H), 7.36 – 7.30 (m, 2H), 7.10 – 7.00 (m, 3H), 6.92 (d, *J* = 7.8 Hz, 1H), 6.33 (s, 1H), 5.77 (s, 1H), 4.51 – 4.44 (m, 1H), 3.65 (s, 3H), 3.38 (dd, *J* = 13.5 Hz, 7.2 Hz, 1H), 3.17 (dd, *J* = 14.1 Hz, 9.3 Hz, 1H);

^{13}C NMR (75 MHz, Chloroform-*d*) *δ* 167.0, 159.2, 149.4, 142.6, 141.1, 136.3, 131.5, 129.9, 125.2, 123.7, 121.5, 120.5, 52.0, 46.1, 43.0.

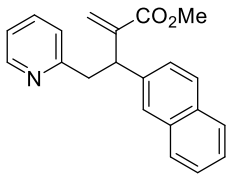
Methyl 3-(4-fluorophenyl)-2-methylene-4-(pyridin-2-yl) butanoate (3g)



Eluting with petroleum ether/EtOAc = 14:1 (v/v). Colorless oil, yield 69%.

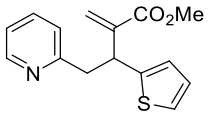
^{1}H NMR (300 MHz, Chloroform-*d*) *δ* 8.53 – 8.49 (m, 1H), 7.48 (td, *J* = 7.5 Hz, 1.8 Hz, 1H), 7.15 – 7.03 (m, 3H), 6.94 – 6.86 (m, 3H), 6.32 (s, 1H), 5.76 (s, 1H), 4.53 – 4.45 (m, 1H), 3.65 (s, 3H), 3.39 (dd, *J* = 13.5 Hz, 6.6 Hz, 1H), 3.18 (dd, *J* = 13.5 Hz, 9.0 Hz, 1H);
^{13}C NMR (75 MHz, Chloroform-*d*) *δ* 167.1, 161.5 (d, *J* = 243 Hz), 159.3, 149.4, 142.9, 137.6 (d, *J* = 3 Hz), 136.1, 129.6 (d, *J* = 7.5 Hz), 124.8, 123.6, 121.3, 115.1 (d, *J* = 21 Hz), 51.9, 45.9, 43.2.

Methyl 2-methylene-3-(naphthalen-2-yl)-4-(pyridin-2-yl) butanoate (3h)



Eluting with petroleum ether/EtOAc = 14:1 (v/v). Colorless oil, yield 65%.
^{1}H NMR (300 MHz, Chloroform-*d*) *δ* 8.51 (ddd, *J* = 5.1 Hz, 1.8 Hz, 0.9 Hz, 1H), 7.79 – 7.72 (m, 2H), 7.71 (d, *J* = 8.4 Hz, 1H), 7.62 (dd, *J* = 1.2 Hz, 0.3 Hz, 1H), 7.46 – 7.37 (m, 3H), 7.31 (dd, *J* = 8.7Hz, 1.8 Hz, 1H), 7.04 (ddd, *J* = 7.5 Hz, 4.8 Hz, 1.2 Hz, 1H), 6.93 (dt, *J* = 7.8 Hz, 0.9 Hz, 1H), 6.36 (s, 1H), 5.83 – 5.81 (m, 1H), 4.70 (t, *J* = 7.8 Hz, 1H), 3.62 (s, 3H), 3.48 (dd, *J* = 13.8 Hz, 7.2 Hz, 1H), 3.33 (dd, *J* = 13.5 Hz, 8.4 Hz, 1H);
^{13}C NMR (75 MHz, Chloroform-*d*) *δ* 167.3, 159.6, 149.4, 143.0, 139.6, 136.2, 133.5, 132.4, 128.0, 127.9, 127.6, 126.7, 125.9, 125.6, 125.2, 125.2, 123.6, 121.3, 52.0, 46.6, 43.2.

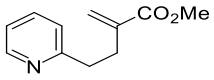
Methyl 2-methylene-4-(pyridin-2-yl)-3-(thiophen-2-yl) butanoate (3i)



Eluted with petroleum ether/EtOAc = 16:1 (v/v). Pale yellow oil, yield 26%.
^{1}H NMR (300 MHz, Chloroform-*d*) *δ* 8.55 – 8.50 (m, 1H), 7.52 (td, *J* = 7.8 Hz, 1.8 Hz, 1H), 7.13 – 7.06 (m, 2H), 7.04 (d, *J* = 7.8 Hz, 1H), 6.86 (dd, *J* = 5.1 Hz, 3.3 Hz, 1H), 6.82 – 6.78 (m, 1H), 6.28 (s, 1H), 5.75 (s, 1H), 4.81 (t, *J* = 8.1 Hz, 1H), 3.70 (s, 3H), 3.45 (dd, *J* = 13.8 Hz, 7.5 Hz, 1H), 3.35 (dd, *J* = 13.5 Hz, 8.4 Hz, 1H);

^{13}C NMR (75 MHz, Chloroform-*d*) *δ* 167.0, 159.2, 149.4, 145.9, 142.8, 136.2, 126.7, 125.7, 125.0, 123.8, 123.7, 121.5, 52.1, 44.1, 42.1.

Methyl 2-methylene-4-(pyridin-2-yl) butanoate (3j)

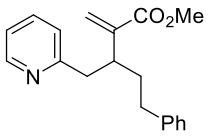


Eluting with petroleum ether/EtOAc = 14:1 (v/v). Colorless oil, yield 84%.

^{1}H NMR (300 MHz, Chloroform-*d*) *δ* 8.54 (ddd, *J* = 4.8 Hz, 1.5 Hz, 0.9 Hz, 1H), 7.59 (td, *J* = 7.8 Hz, 1.8 Hz, 1H), 7.17 – 7.08 (m, 2H), 6.17 – 6.14 (m, 1H), 5.54 (q, *J* = 1.5 Hz, 1H), 3.77 (s, 3H), 3.01 – 2.95 (m, 2H), 2.80 – 2.71 (m, 2H);

^{13}C NMR (75 MHz, Chloroform-*d*) *δ* 167.6, 161.0, 149.4, 139.7, 136.4, 125.8, 123.1, 121.3, 52.0, 37.2, 32.1.

Methyl 2-methylene-5-phenyl-3-(pyridin-2-ylmethyl) pentanoate (3k)

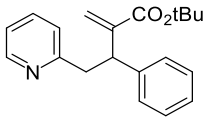


Eluting with petroleum ether/EtOAc = 16:1 (v/v). Colorless oil, yield 38%.

^{1}H NMR (300 MHz, Chloroform-*d*) *δ* 8.52 (ddd, *J* = 4.8 Hz, 1.8 Hz, 0.9 Hz, 1H), 7.55 (td, *J* = 7.5 Hz, 1.8 Hz, 1H), 7.26 – 7.20 (m, 2H), 7.19 – 7.04 (m, 5H), 6.20 (d, *J* = 0.9 Hz, 1H), 5.54 – 5.52 (m, 1H), 3.73 (s, 3H), 3.24 – 3.09 (m, 1H), 3.09 – 2.96 (m, 2H), 2.67 – 2.44 (m, 2H), 2.02 – 1.77 (m, 2H);

^{13}C NMR (75 MHz, Chloroform-*d*) *δ* 167.6, 160.3, 149.3, 142.6, 142.3, 136.2, 128.4, 128.4, 126.0, 125.8, 123.7, 121.2, 51.9, 43.3, 42.3, 35.4, 33.7.

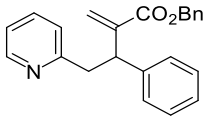
tert-Butyl 2-methylene-3-phenyl-4-(pyridin-2-yl) butanoate (3l)



Eluting with petroleum ether/EtOAc = 17:1 (v/v). Colorless oil, yield 39%.

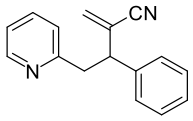
^{1}H NMR (300 MHz, Chloroform-*d*) *δ* 8.51 (ddd, *J* = 5.1 Hz, 1.8 Hz, 0.9 Hz, 1H), 7.44 (td, *J* = 7.8 Hz, 1.8 Hz, 1H), 7.23 – 7.01 (m, 6H), 6.87 (dt, *J* = 7.8 Hz, 0.9 Hz, 1H), 6.25 (t, *J* = 0.9 Hz, 1H), 5.65 (t, *J* = 1.2 Hz, 1H), 4.41 (t, *J* = 7.8 Hz, 1H),3.39 (dd, *J* = 13.5, 6.9 Hz, 1H), 3.16 (dd, *J* = 13.5, 9.0 Hz, 1H), 1.30 (s, 9H);
^{13}C NMR (75 MHz, Chloroform-*d*) *δ* 166.1, 159.8, 149.3, 144.8, 142.4, 136.0, 128.2, 126.4, 123.7, 121.2, 80.8, 46.7, 43.3, 28.0.

Benzyl 2-methylene-3-phenyl-4-(pyridin-2-yl) butanoate (3m)



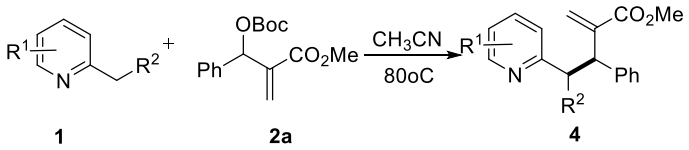
Eluting with petroleum ether/EtOAc = 16:1 (v/v). Colorless oil, yield 48%.
^{1}H NMR (300 MHz, Chloroform-*d*) *δ* 8.49 (ddd, *J* = 4.8 Hz, 1.5 Hz, 0.6 Hz, 1H), 7.44 (td, *J* = 7.5, 1.8 Hz, 1H), 7.32 – 7.26 (m, 3H), 7.24 – 7.11 (m, 7H), 7.04 (ddd, *J* = 7.2 Hz, 4.8 Hz, 0.9 Hz, 1H), 6.89 (d, *J* = 7.8 Hz, 1H), 6.37 (s, 1H), 5.80 – 5.77 (m, 1H), 5.11 (A of AB, *J* = 12.6 Hz, 1H), 5.03 (B of AB, *J* = 12.6 Hz, 1H), 4.52 (t, *J* = 7.8 Hz, 1H), 3.40 (dd, *J* = 13.8 Hz, 7.2 Hz, 1H), 3.22 (dd, *J* = 13.8 Hz, 8.7 Hz, 1H);
^{13}C NMR (75 MHz, Chloroform-*d*) *δ* 166.6, 159.6, 149.3, 142.9, 142.0, 136.1, 136.0, 128.5, 128.4, 128.2, 128.1, 128.1, 126.6, 125.3, 123.6, 121.3, 66.6, 46.6, 43.2.

2-Methylene-3-phenyl-4-(pyridin-2-yl) butanenitrile (3n) [3]



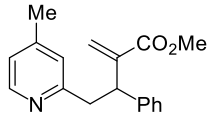
Eluting with petroleum ether/EtOAc = 10:1 (v/v). Colorless oil, yield 53%.
^{1}H NMR (300 MHz, Chloroform-*d*) δ 8.55 (ddd, *J* = 4.8 Hz, 1.8 Hz, 0.9 Hz, 1H), 7.54 (td, *J* = 7.8 Hz, 1.8 Hz, 1H), 7.36 – 7.21 (m, 5H), 7.14 – 7.05 (m, 2H), 5.81 (s, 1H), 5.74 (d, *J* = 0.9 Hz, 1H), 4.23 (t, *J* = 7.8 Hz, 1H), 3.43 (dd, *J* = 13.8 Hz, 8.4 Hz, 1H), 3.31 (dd, *J* = 13.8 Hz, 7.2 Hz, 1H).

General experimental procedure for the synthesis of compounds 4



Similar to the procedure for the synthesis of compounds **3**, the picoline derivative **1** (1.0 mmol) and Morita–Baylis–Hillman carbonate **2a** (0.5 mmol) were dissolved in anhydrous CH_3CN (2.0 mL) and then stirred and heated in an oil bath at 80 °C (or 100 °C as indicated) until the completion of **2a**. After removing the solvent under vacuum, the residue wad directly purified by flash chromatography on silica gel column (eluting with petroleum ether/EtOAc), to provide the desired products **4**.

Methyl 2-methylene-4-(4-methylpyridin-2-yl)-3-phenylbutanoate (4a)

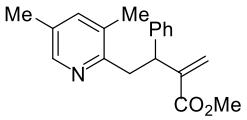


Eluting with petroleum ether/EtOAc = 5:1 (v/v). Colorless oil, yield 39%.

^{1}H NMR (300 MHz, Chloroform-*d*) *δ* 8.35 (d, *J* = 5.1 Hz, 1H), 7.24–7.13 (m, 5H), 6.89 (d, *J* = 4.8 Hz, 1H), 6.79 (s, 1H), 6.31(s, 1H), 5.77 (s, 1H), 4.51 (t, *J* = 7.8 Hz, 1H), 3.64 (s, 3H), 3.36 (A of AB, *J* = 13.8, 7.5 Hz, 1H), 3.20 (B of AB, *J* = 13.8, 8.4 Hz, 1H), 2.24 (s, 3H);

^{13}C NMR (75 MHz, Chloroform-*d*) *δ* 167.4, 159.3, 148.7,147.6, 143.1, 142.2, 128.4, 128.2, 126.6, 125.0, 124.6, 122.5, 51.9, 46.6, 42.9, 21.1.

Methyl 4-(3,5-dimethylpyridin-2-yl)-2-methylene-3-phenylbutanoate (4b)

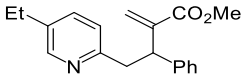


Eluting with petroleum ether/EtOAc = 5:1 (v/v). Pale yellow oil, yield 83%.

^{1}H NMR (300 MHz, Chloroform-*d*) *δ* 8.18 (s, 1H), 7.23–7.10 (m, 6H), 6.34 (s, 1H), 5.77 (s, 1H), 4.56 (t, *J* = 7.8 Hz, 1H), 3.61 (s, 3H), 3.31–3.14 (m, 2H), 2.23 (s, 3H), 1.99 (s, 3H);

^{13}C NMR (75 MHz, Chloroform-*d*) *δ* 167.4, 154.8, 147.1, 143.4, 142.4, 138.3, 131.1, 130.5, 128.2, 128.1, 126.5, 124.6, 51.9, 45.9, 39.6, 18.6, 18.0.

Methyl 4-(5-ethylpyridin-2-yl)-2-methylene-3-phenylbutanoate (4c)[3]

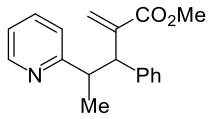


Eluting with petroleum ether/EtOAc = 10:1 (v/v). Colorless oil, yield 71%.

^{1}H NMR (300 MHz, Chloroform-*d*) *δ* 8.34 (d, *J* = 2.1Hz, 1H), 7.30 (dd, *J* = 8.1Hz, 2.4Hz, 1H), 7.26–7.11 (m, 5H), 6.86 (d, *J* = 7.8 Hz, 1H), 6.31 (s, 1H), 5.76 (t, *J* = 0.9 Hz,1H), 4.50 (t, *J* = 8.1 Hz, 1H), 3.63 (s, 3H), 3.36 (A of AB, *J* = 13.8, 7.5 Hz, 1H), 3.20 (B of AB, *J* = 13.8, 8.4 Hz, 1H), 2.58 (q, *J* = 7.8 Hz, 2H), 1.21 (t, *J* = 7.8 Hz, 3H);

^{13}C NMR (75 MHz, Chloroform-*d*) *δ* 167.3, 156.8, 148.9, 143.0, 142.2, 136.7, 135.6, 128.3, 128.2, 126.5, 125.0, 123.1, 51.9, 46.5, 42.7, 25.8, 15.3.

Methyl 2-methylene-3-phenyl-4-(pyridin-2-yl) pentanoate (4d)

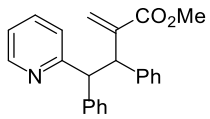


Eluting with petroleum ether/EtOAc = 10:1 (v/v). Colorless oil, yield 61%.

^{1}H NMR (300 MHz, Chloroform-*d*) *δ* 8.56–8.52 (m, 1H), 7.65 (t, *J* = 7.8Hz, 1H), 7.41–7.29 (m, 5H), 7.26–7.20 (m, 1H), 7.14 (t, *J* = 6.9Hz, 1H), 6.07 (s, 1H), 5.76 (s, 1H), 4.38 (d, *J* = 12.0Hz, 1H), 3.71–3.61(m, 1H), 3.58 (s, 3H), 1.09 (d, *J* = 6.9 Hz, 3H);

^{13}C NMR (75 MHz, Chloroform-*d*) *δ* 167.3, 165.1, 149.2, 142.5, 141.6, 136.7, 128.9, 128.5, 126.8, 125.5, 122.2, 121.4, 51.9, 51.9, 45.5, 21.2.

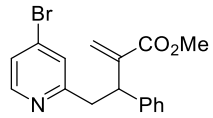
Methyl 2-methylene-3,4-diphenyl-4-(pyridin-2-yl) butanoate (4e)[3]



Eluting with petroleum ether/EtOAc = 10:1 (v/v). White solid, m. p.: 165-167^{o}C, yield 71%.

^{1}H NMR (300 MHz, Chloroform-*d*) *δ* 8.54 (ddd, *J* = 4.8 Hz, 1.8 Hz, 0.9 Hz, 1H), 7.56 (td, *J* = 7.8 Hz, 2.1 Hz, 1H), 7.30 (d, *J* = 7.8 Hz, 1H), 7.21-6.95 (m, 11H), 6.16 (s, 1H), 5.73 (s, 1H), 5.06 (d, *J* = 12.6 Hz, 1H), 4.73 (d, *J* = 12.6 Hz, 1H), 3.63 (s, 3H).

Methyl 4-(4-bromopyridin-2-yl)-2-methylene-3-phenylbutanoate(4f)

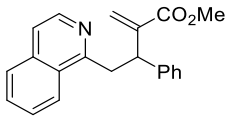


The reaction was performed at 100 °C for 16h. Eluting with petroleum ether/EtOAc = 10:1 (v/v). Colorless oil, yield 32%.

^{1}H NMR (300 MHz, Chloroform-*d*) *δ* 8.31 (d, *J* = 5.1 Hz, 1H), 7.26–7.13 (m, 7H), 6.32 (s, 1H), 5.73 (s, 1H), 4.49 (t, *J* = 7.8 Hz, 1H), 3.65 (s, 3H), 3.38 (dd, *J* = 13.8Hz, 7.5 Hz, 1H), 3.20 (dd, *J* = 13.8 Hz, 8.7 Hz, 1H);

^{13}C NMR (75 MHz, Chloroform-*d*) *δ* 167.2, 161.3, 150.0, 142.7, 141.6, 132.9, 128.5, 128.1, 127.0, 126.8, 125.2, 124.8, 52.0, 46.4, 42.8.

Methyl 4-(isoquinolin-1-yl)-2-methylene-3-phenylbutanoate (4g)



The reaction was performed at 100 °C for 4h. Eluting with petroleum ether/EtOAc = 10:1 (v/v). Pale yellow oil, yield 39%.

^{1}H NMR (300 MHz, Chloroform-*d*) *δ* 8.38 (d, *J* = 5.7 Hz, 1H), 8.13 (d, *J* = 8.4 Hz, 1H), 7.79 – 7.76 (m, 1H), 7.66 –7.60 (m, 1H), 7.57-7.51 (m, 1H), 7.46 (d, *J* = 5.7 Hz, 1H), 7.22 – 7.11 (m, 5H), 6.31 (s, 1H), 5.78 – 5.77 (m, 1H), 4.79 (td, *J* = 6.9 Hz, 0.9 Hz, 1H), 3.91 (dd, *J* = 14.1Hz, 7.5 Hz, 1H), 3.76 (dd, *J* = 14.1, 7.8 Hz, 1H), 3.62 (s, 3H).

^{13}C NMR (75 MHz, Chloroform-*d*) *δ* 167.4, 159.3, 143.1, 142.2, 141.8, 136.2, 129.8, 128.4, 128.1, 127.5, 127.1, 126.6, 125.2, 125.1, 119.5, 51.9, 46.2, 39.8.

III. References

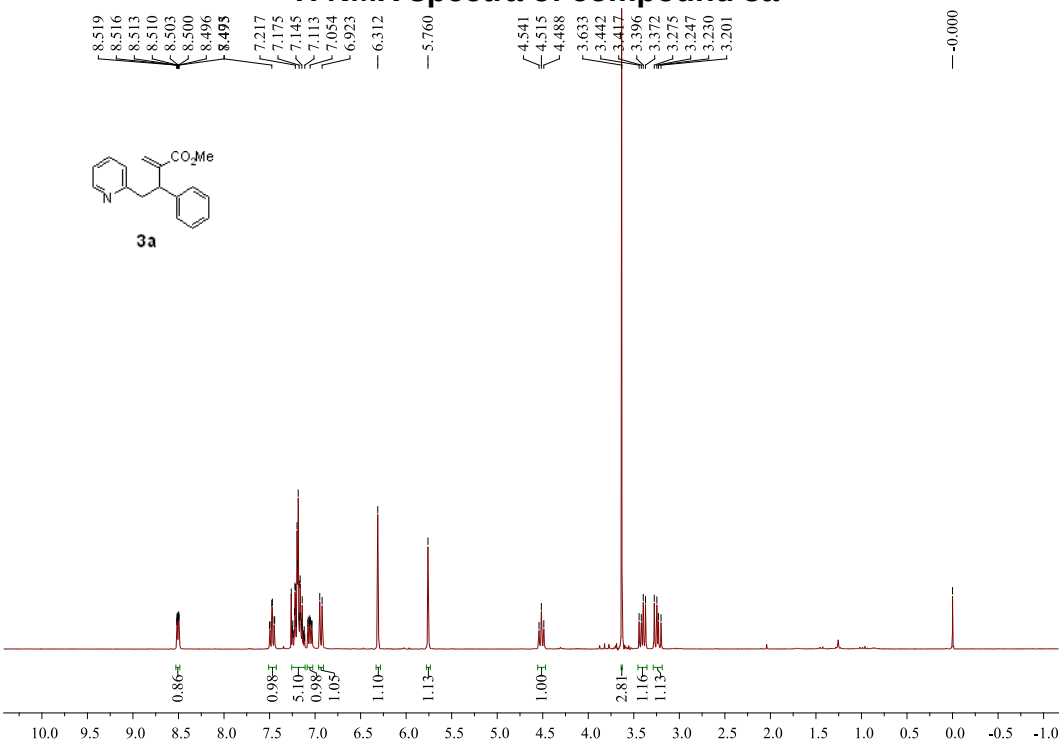
1、Yang, X. -H.; Li, J. -P.; Wang, D. -C.; Xie, M. -S.; Qu, G. -R.; Guo, H. -M. *Chem.Commun.* **2019,** *55,* 9144-9147. doi: 10.1039/c9cc04542b

2、Pautigny, C.; Jeulin, S.; Ayad, T.; Zhang, Z.; Genet, J.-P.; Ratovelomanana-Vidal, V. *Adv. Synth. Catal.* **2008,** *350,* 2525-2532. doi: 10.1002/adsc.200800504

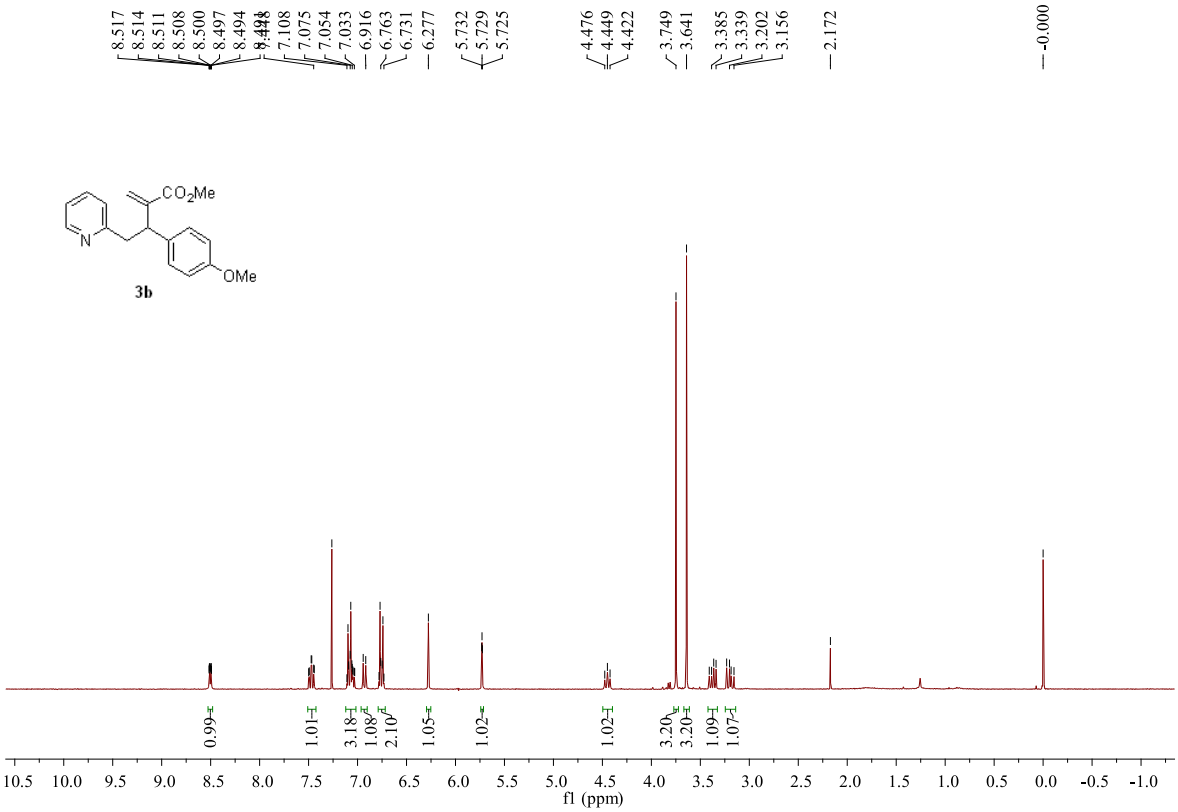
3、Lee, H. S.; Lee, S.; Kim, S. H.; Kim, J. N. *Tetrahedron Lett.* **2011,** *52,* 5039-5042. doi: 10.1016/j.tetlet.2011.07.101

VI. Copies of ^{1}H, ^{13}C NMR spectra

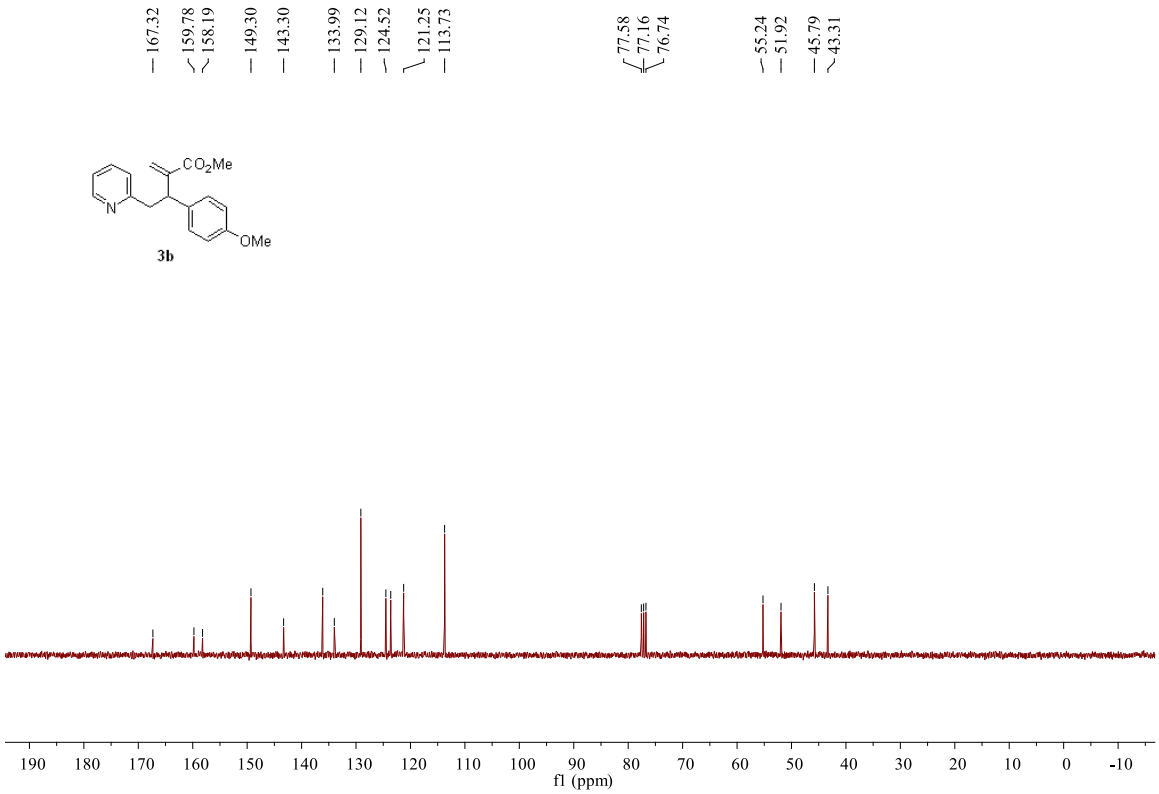
^{1}H NMR spectra of compound 3a



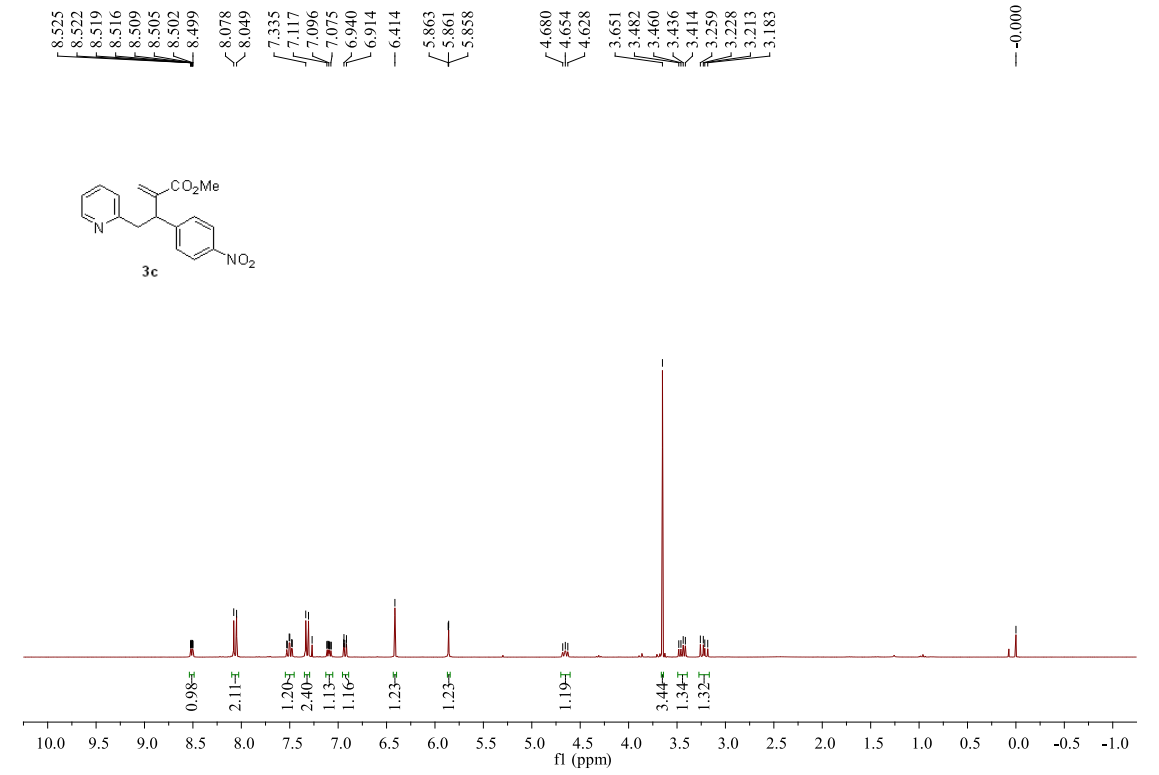
^{1}H NMR spectra of compound 3b



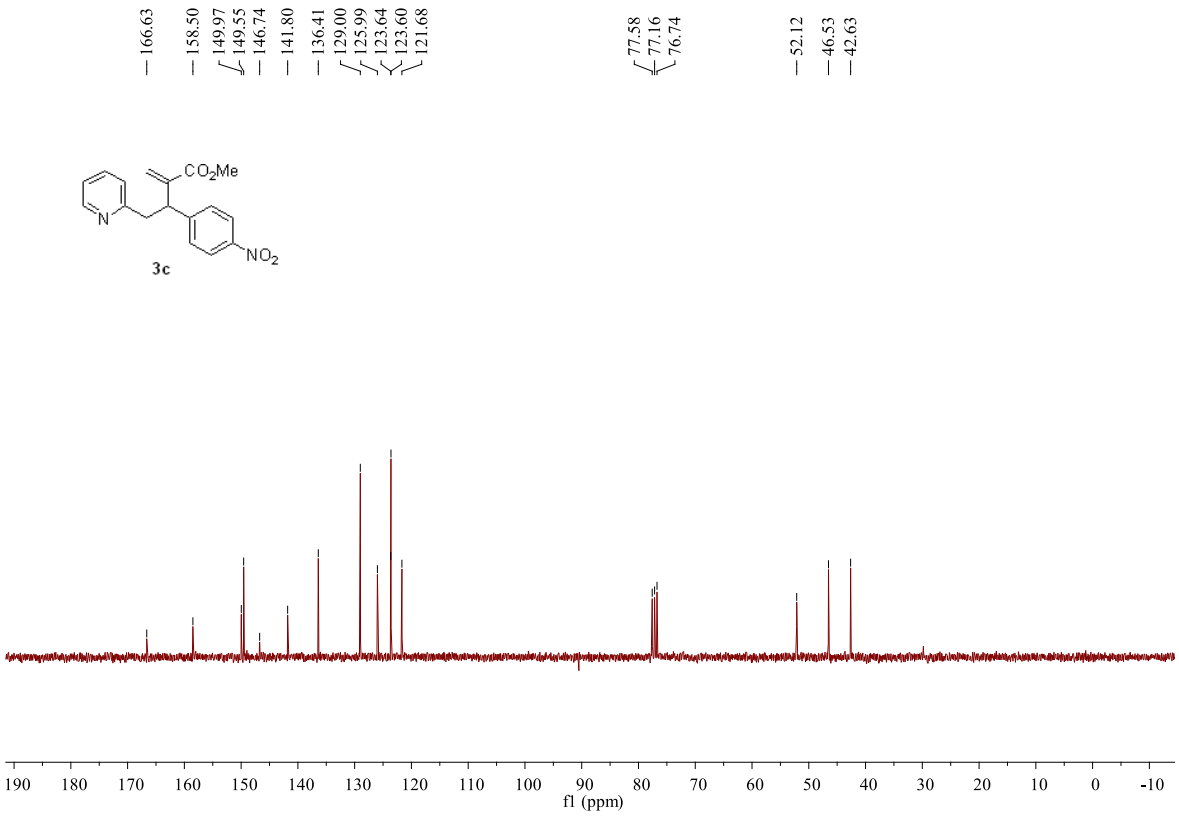
^{13}C NMR spectra of compound 3b



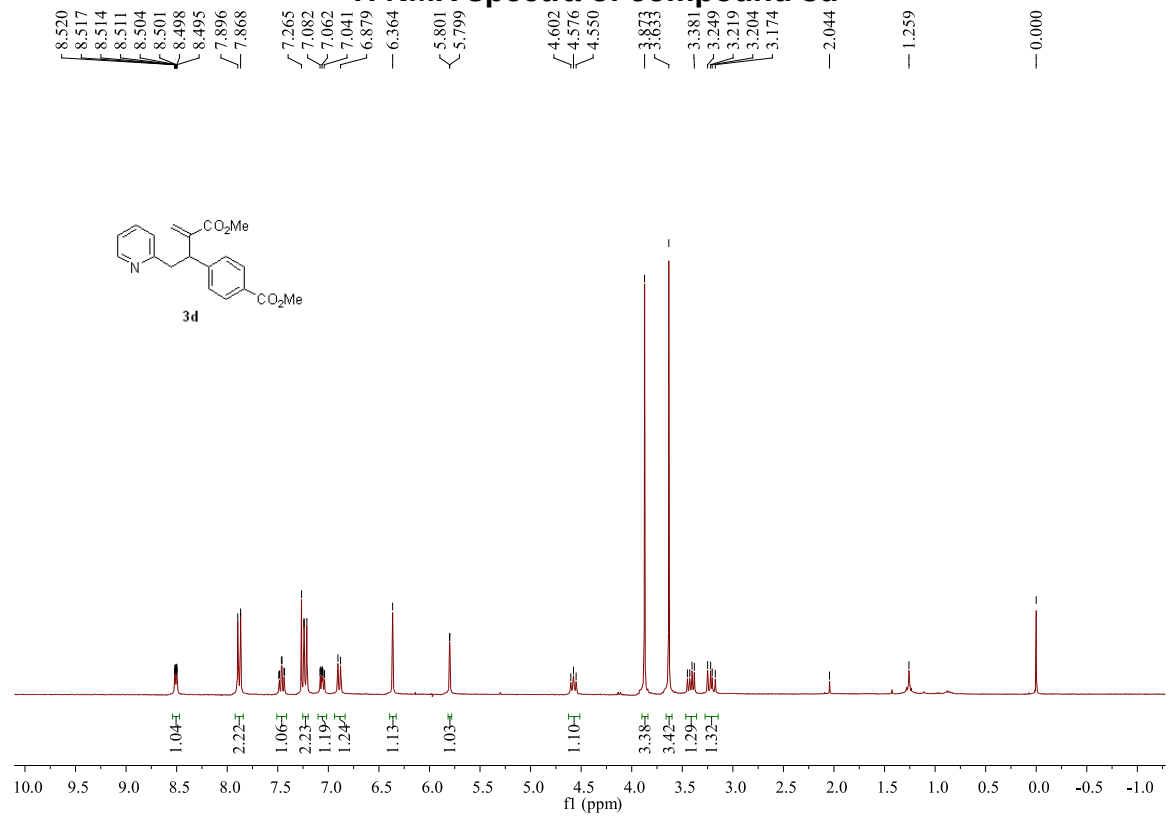
^{1}H NMR spectra of compound 3c



^{13}C NMR spectra of compound 3c



^{1}H NMR spectra of compound 3d



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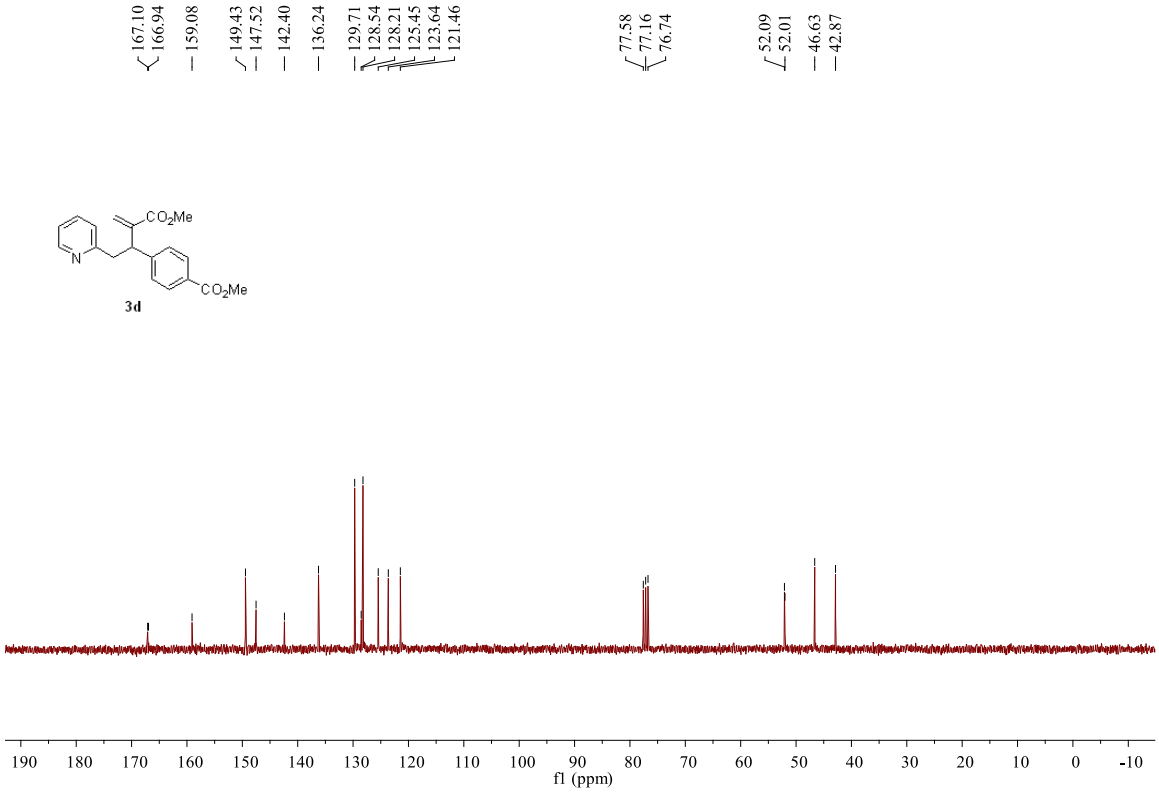
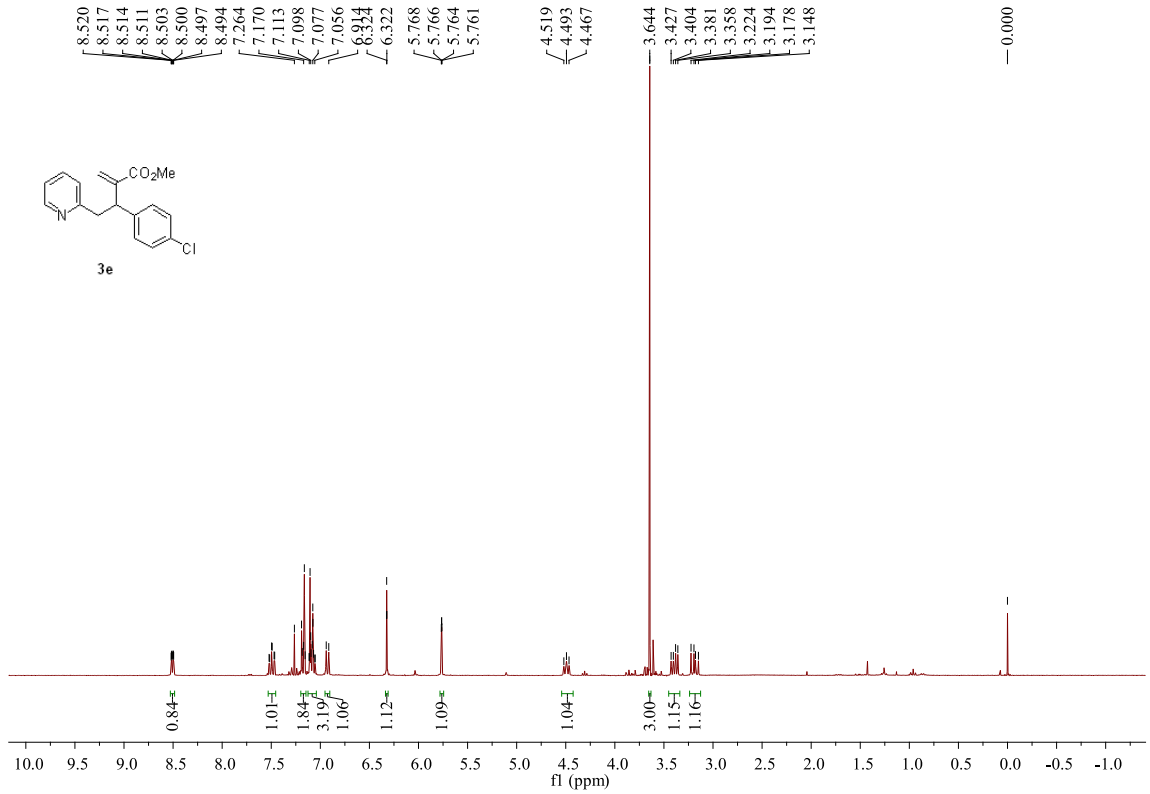
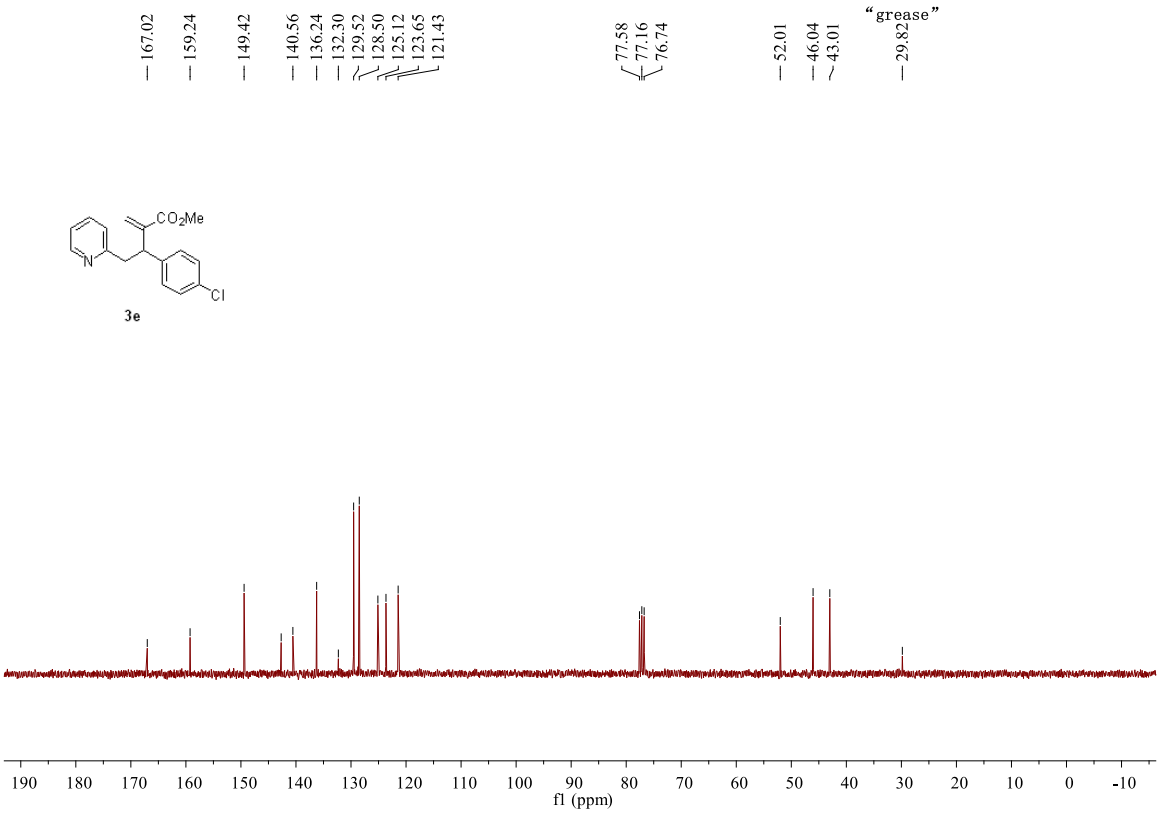


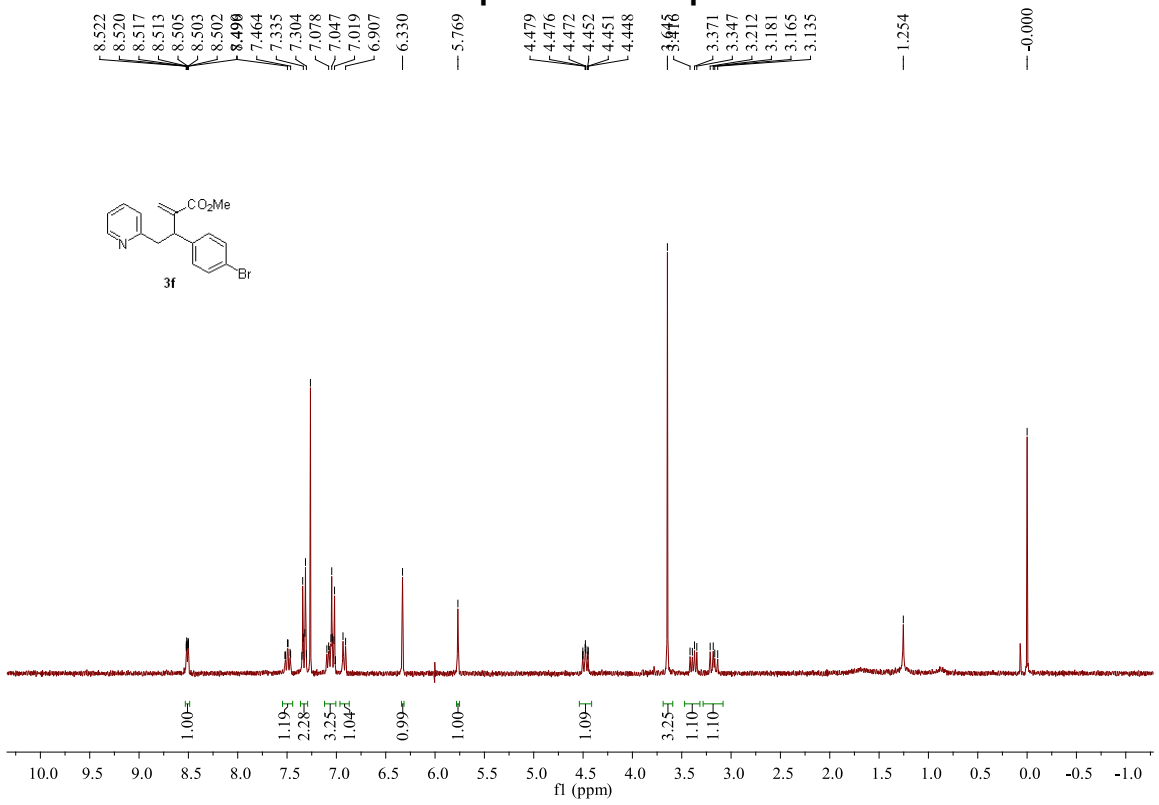
^{1}H NMR spectra of compound 3e



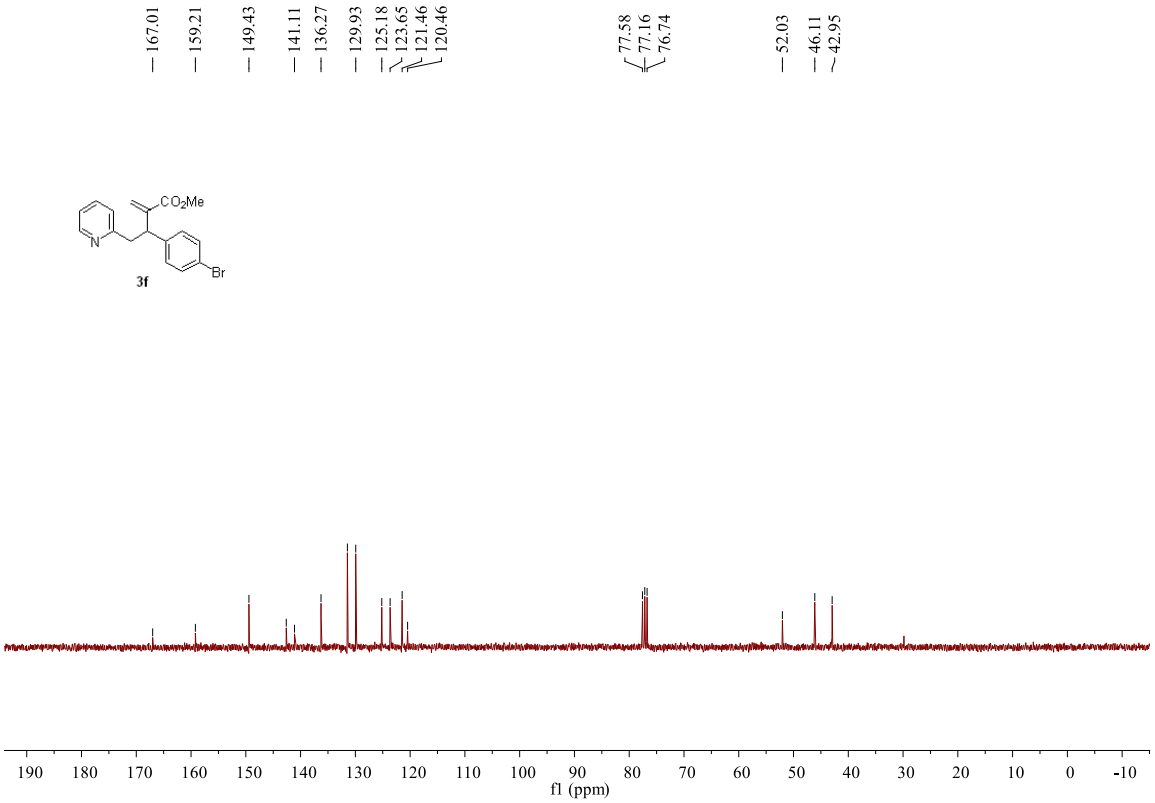
^{13}C NMR spectra of compound 3e



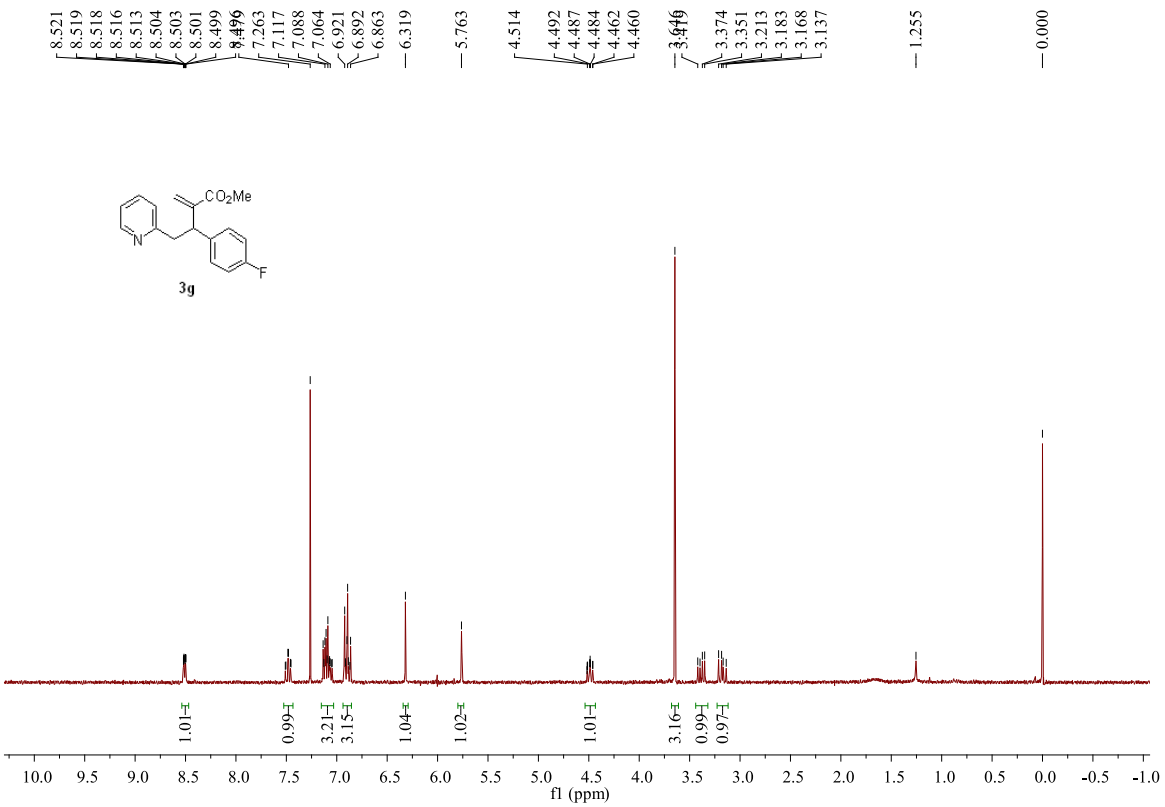
^{1}H NMR spectra of compound 3f



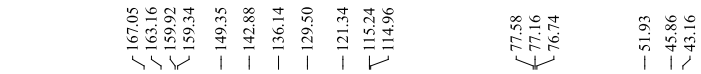
^{13}C NMR spectra of compound 3f

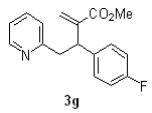


^{1}H NMR spectra of compound 3g

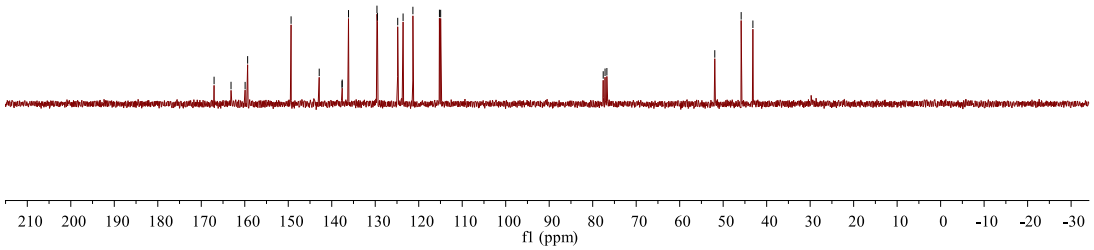


^{13}C NMR spectra of compound 3g

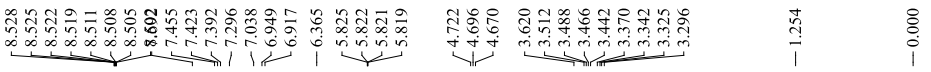


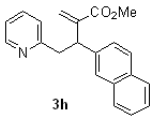


3g

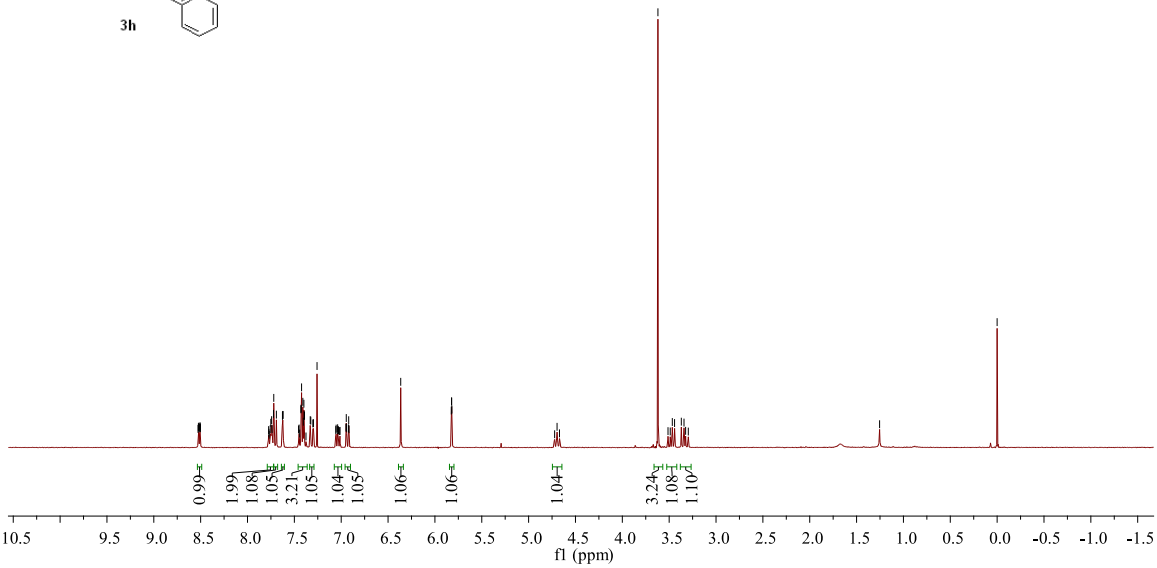


^{1}H NMR spectra of compound 3h

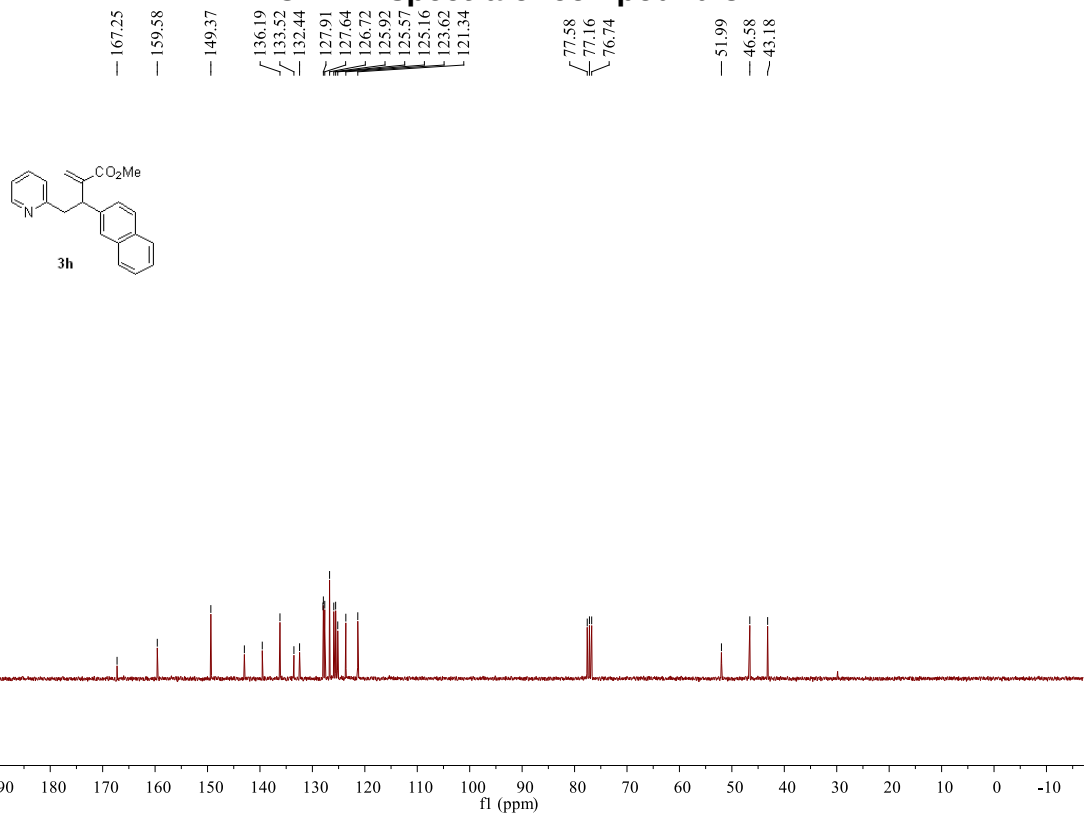




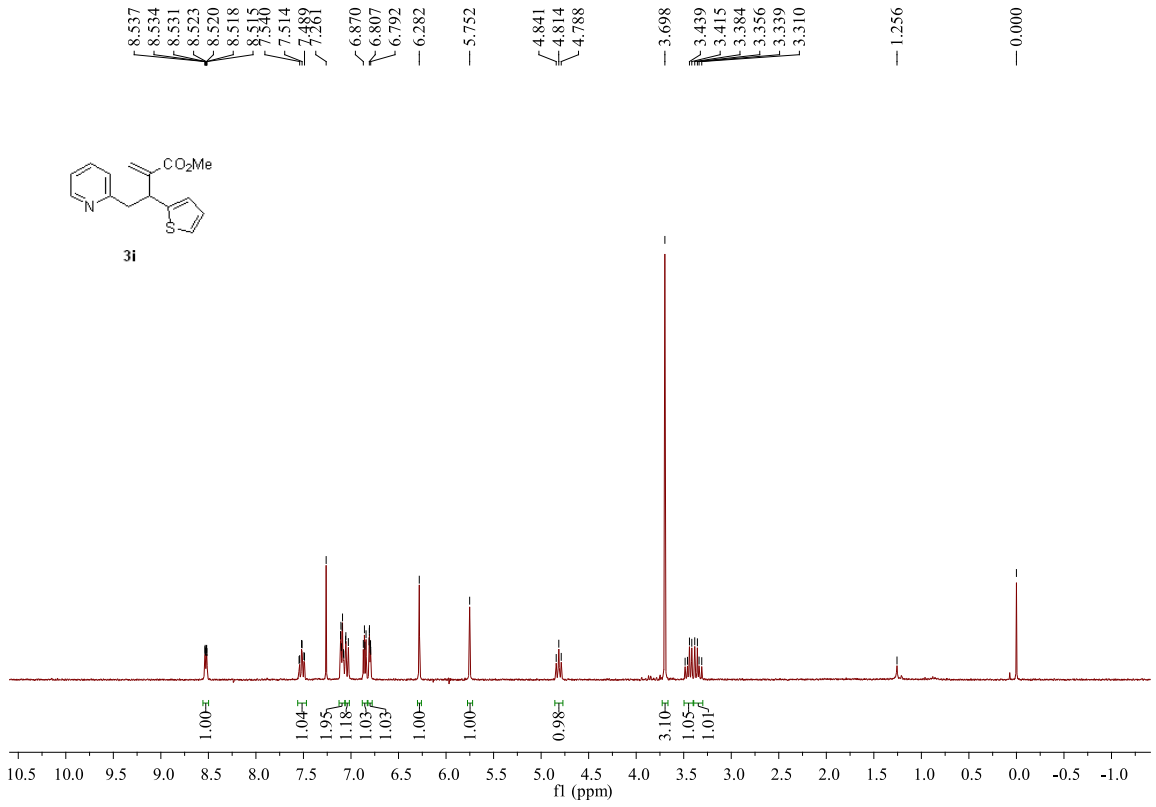
3h



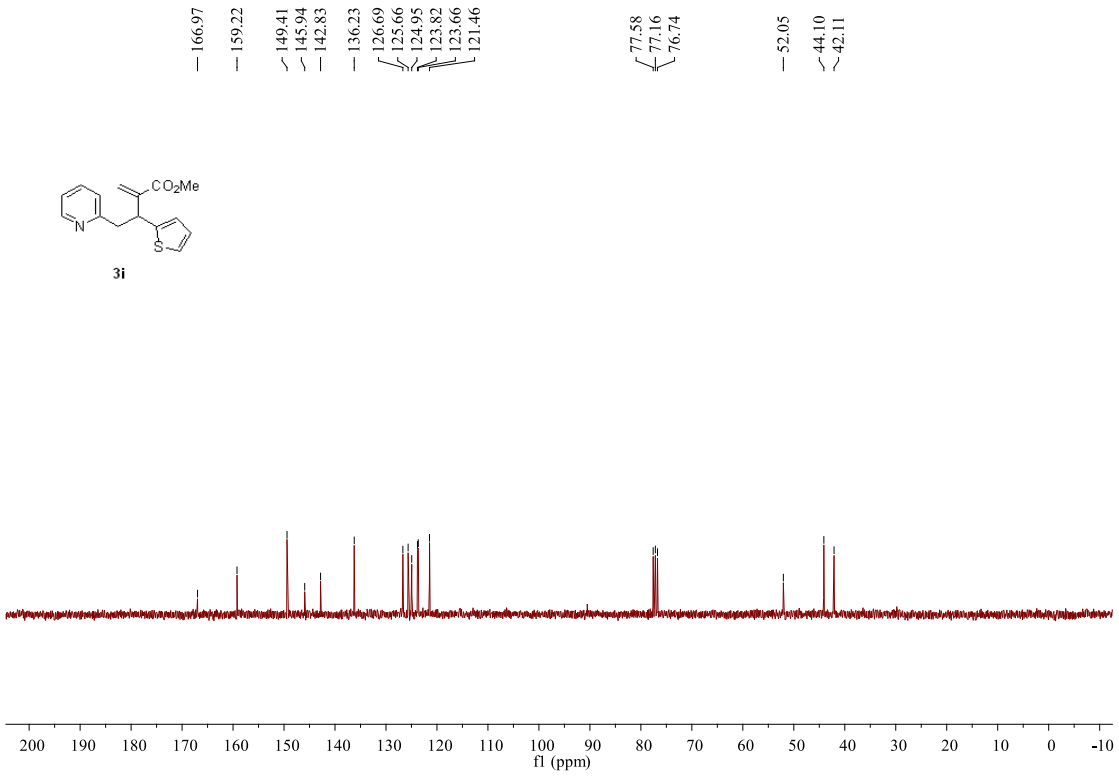
^{13}C NMR spectra of compound 3h



^{1}H NMR spectra of compound 3i



^{13}C NMR spectra of compound 3i



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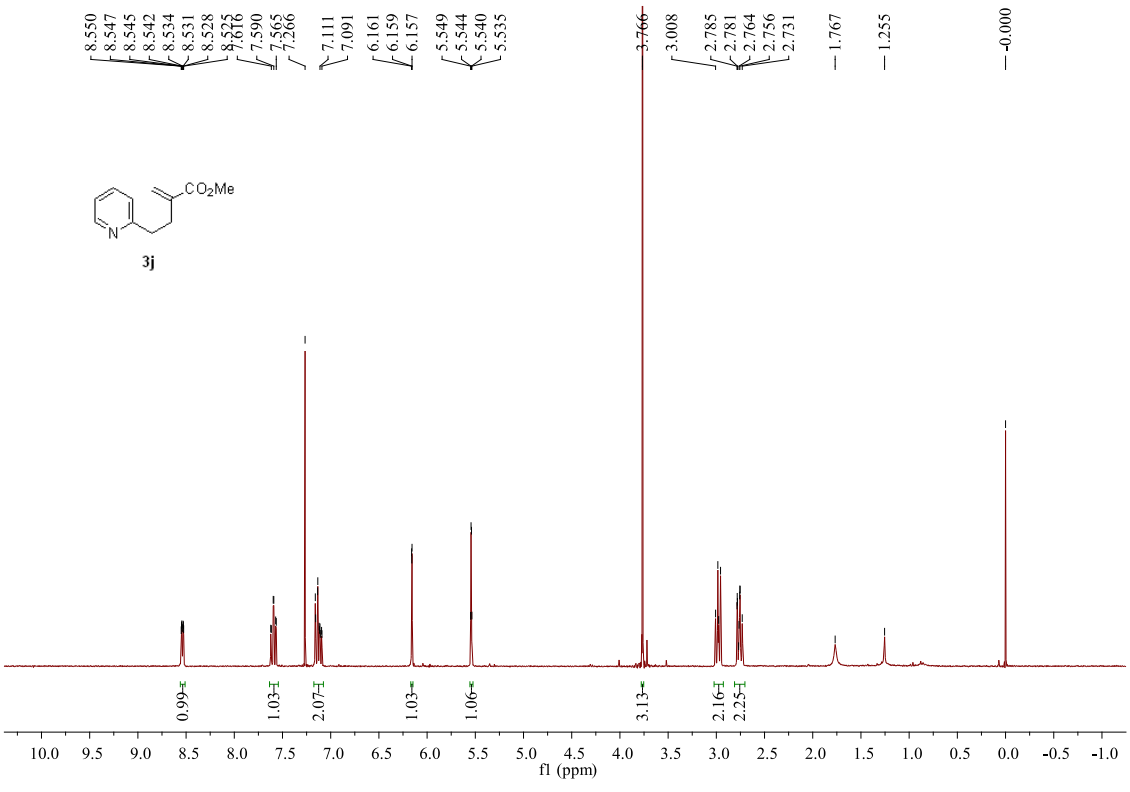

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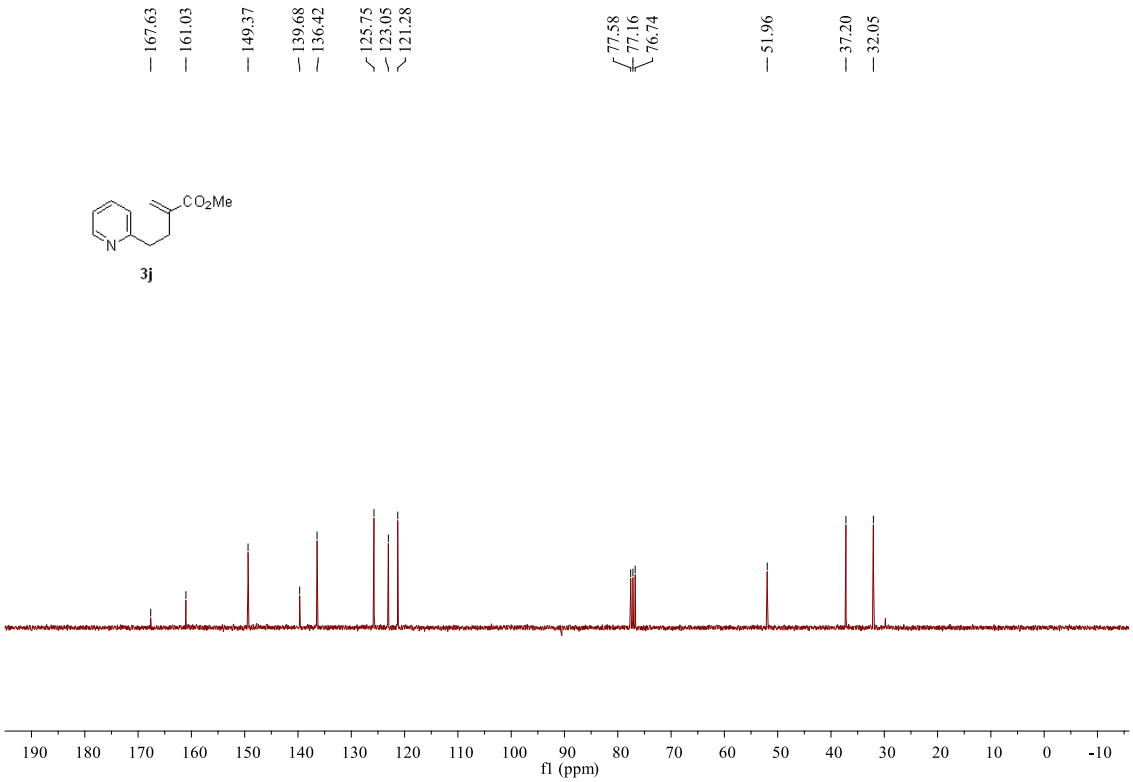
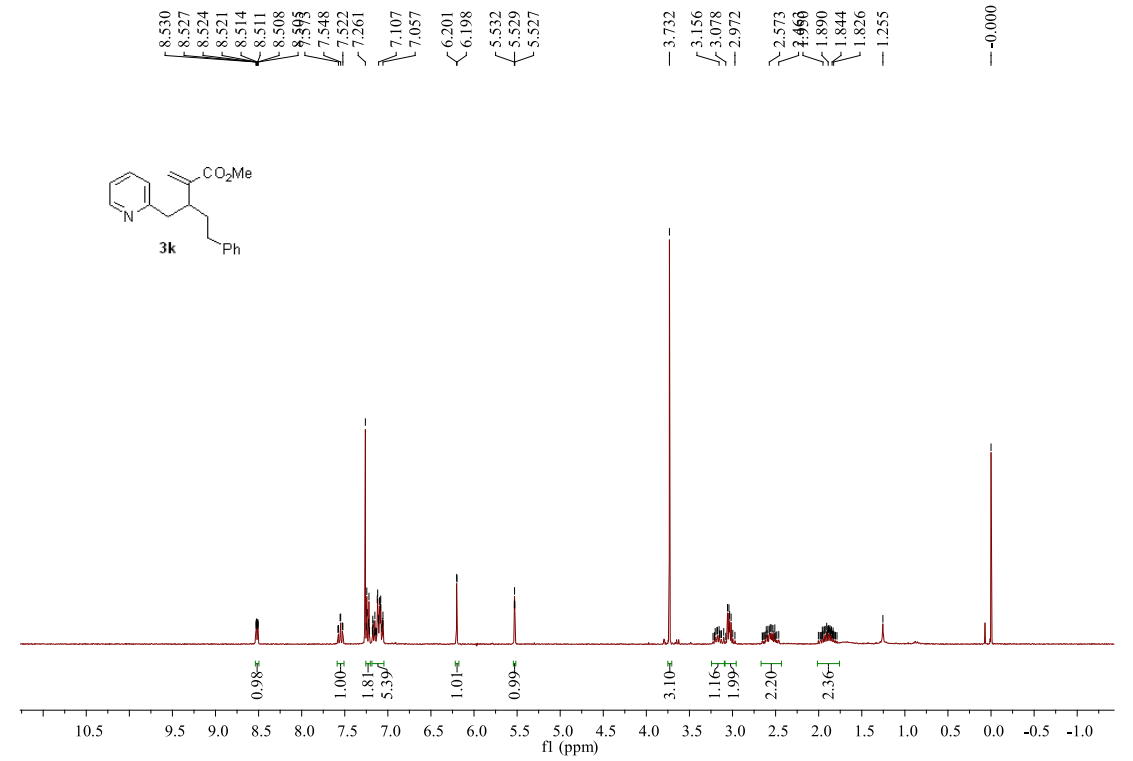
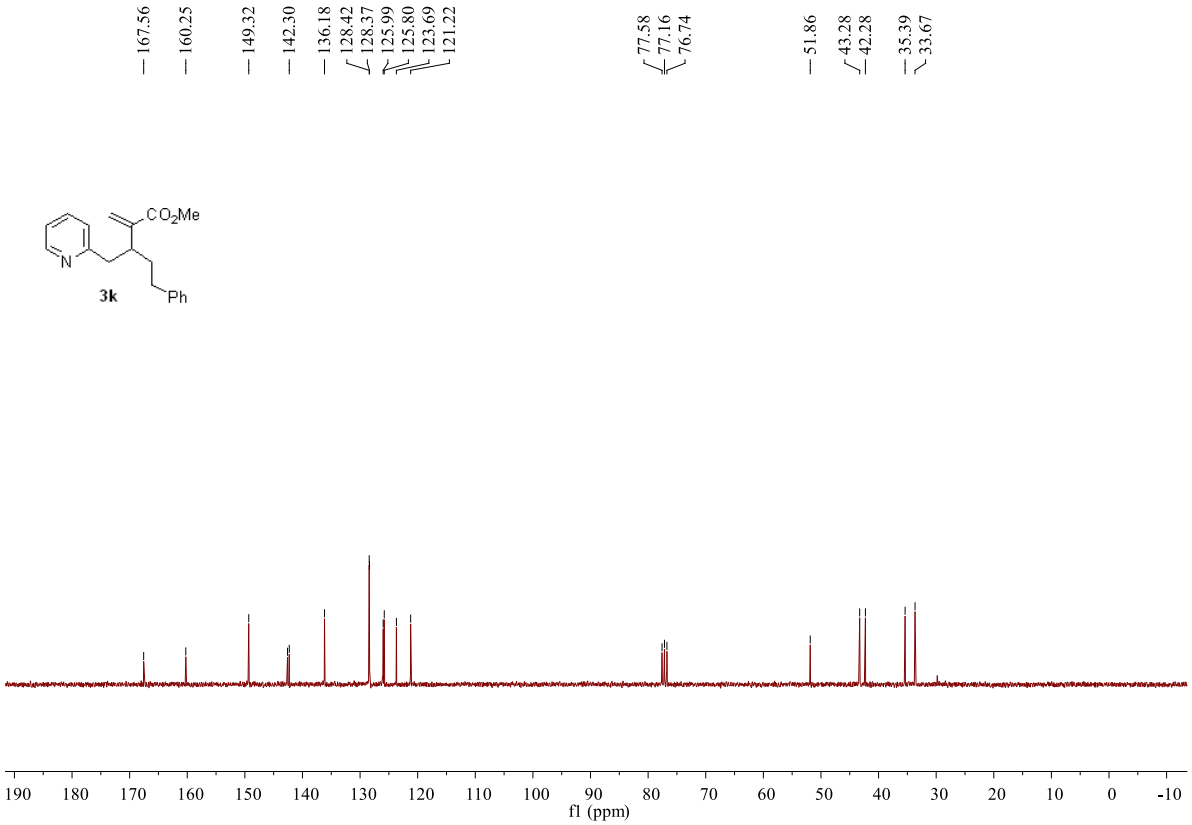


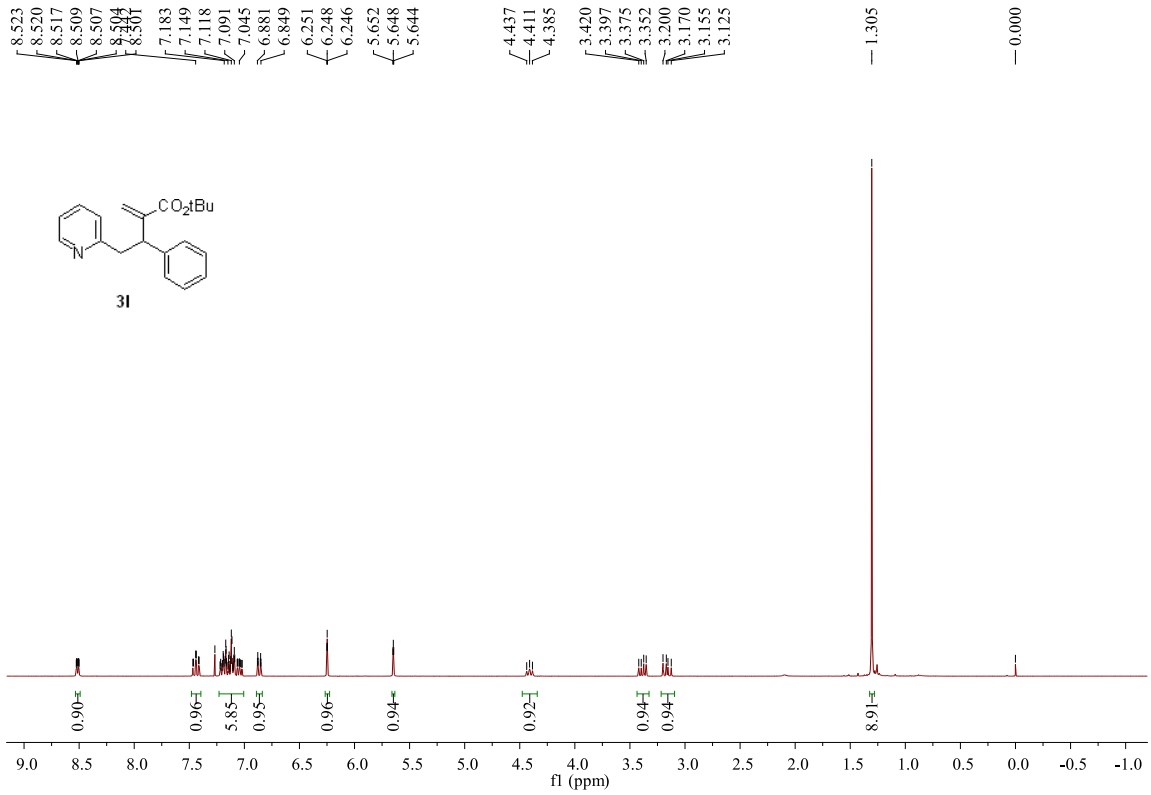
^{1}H NMR spectra of compound 3k



^{13}C NMR spectra of compound 3k



^{1}H NMR spectra of compound 3l



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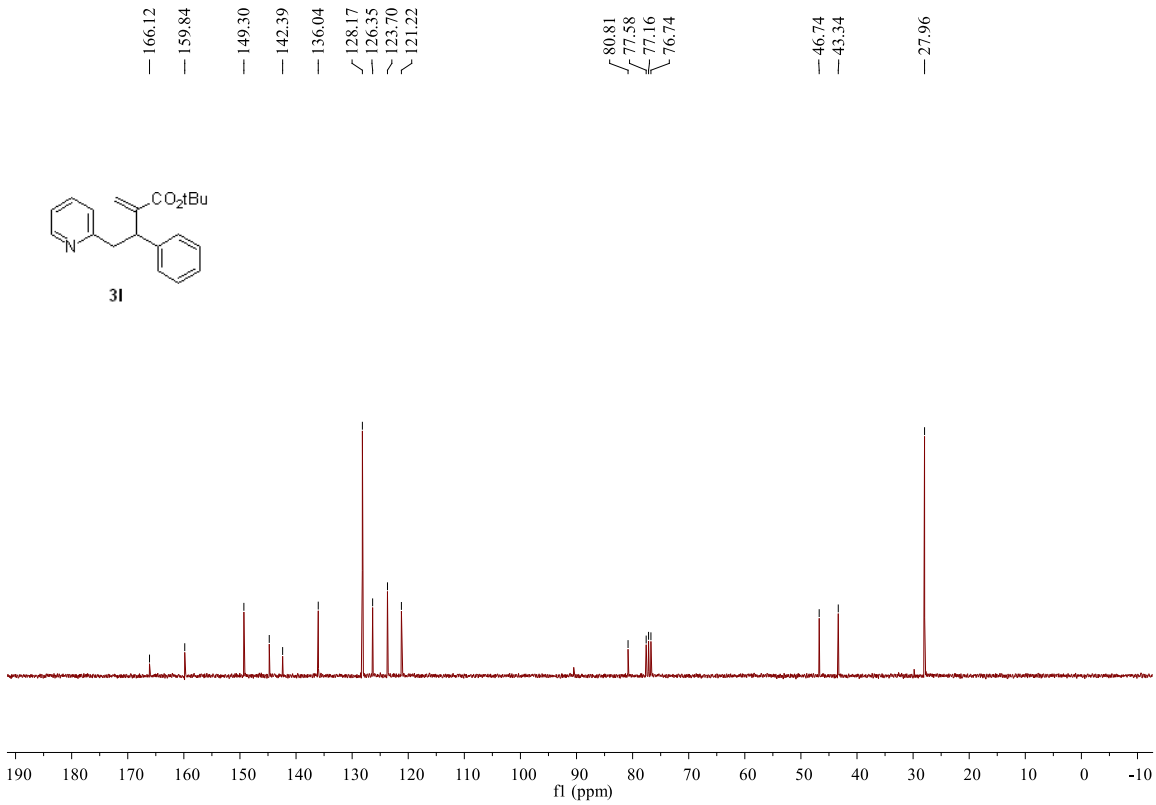
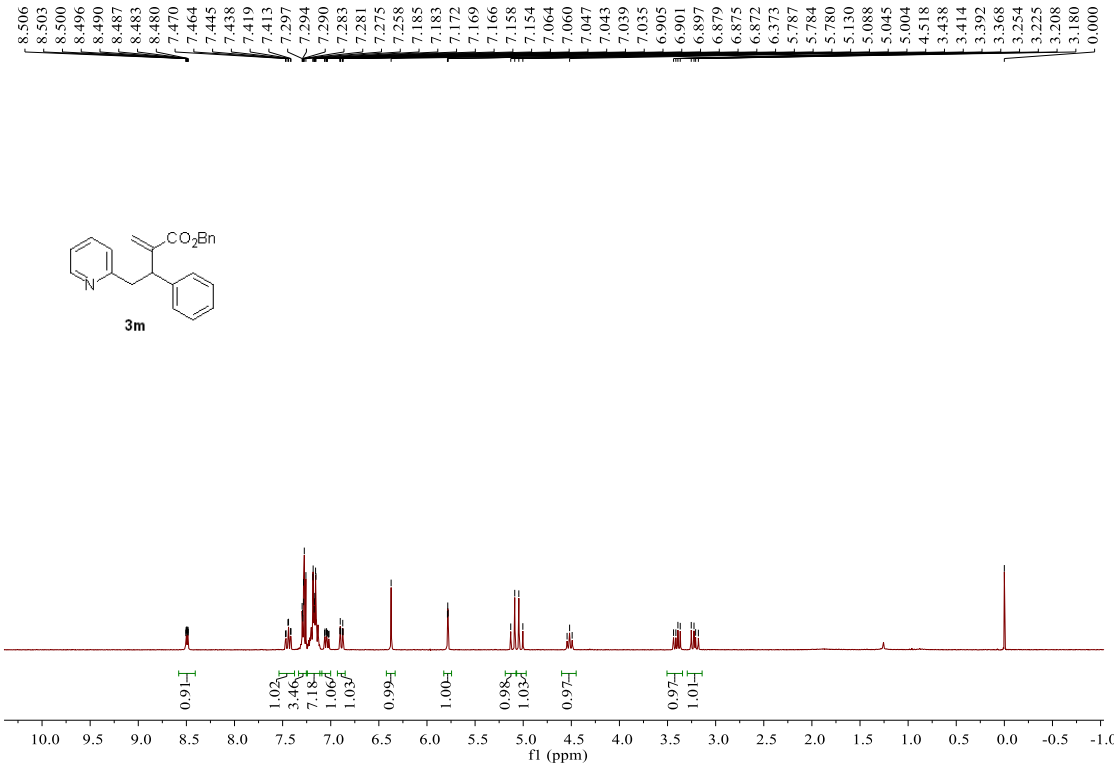


^{1}H NMR spectra of compound 3m



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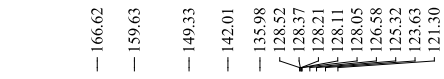
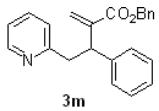
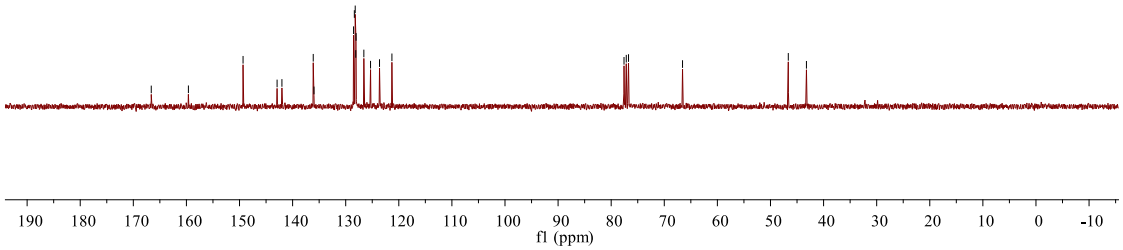
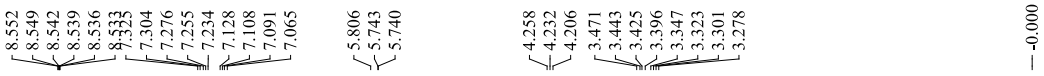


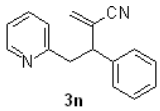


3m

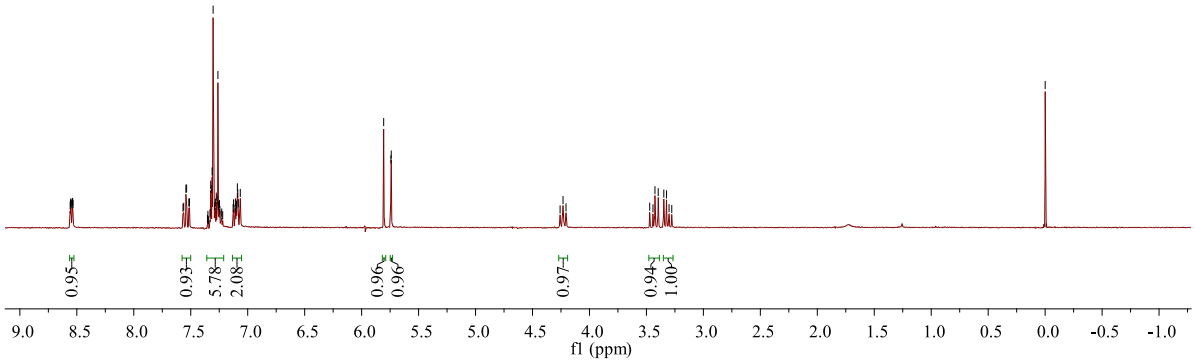


^{1}H NMR spectra of compound 3n

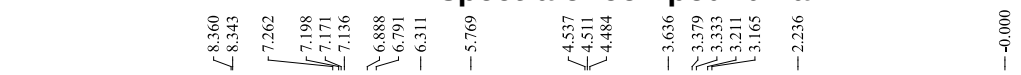


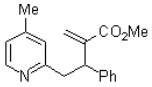


3n

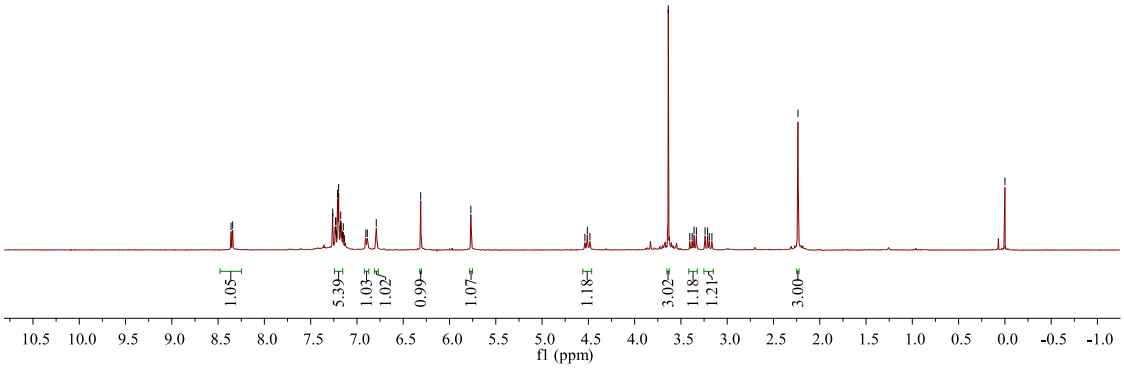


^{1}H NMR spectra of compound 4a

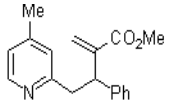




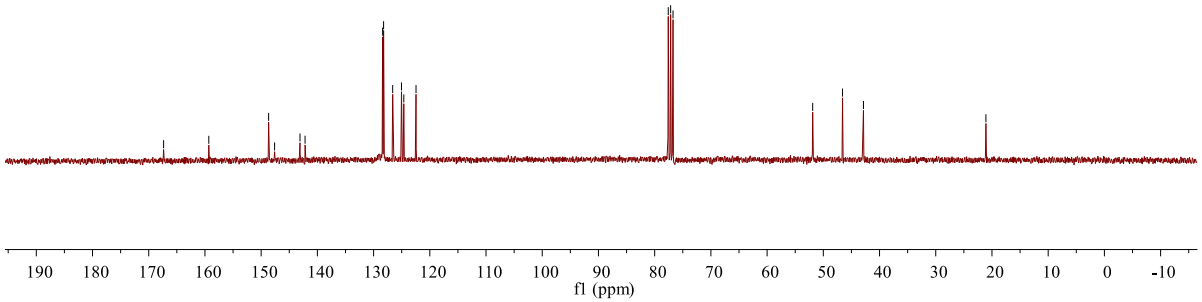
4a



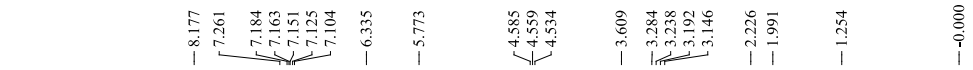
^{13}C NMR spectra of compound 4a

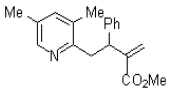


4a

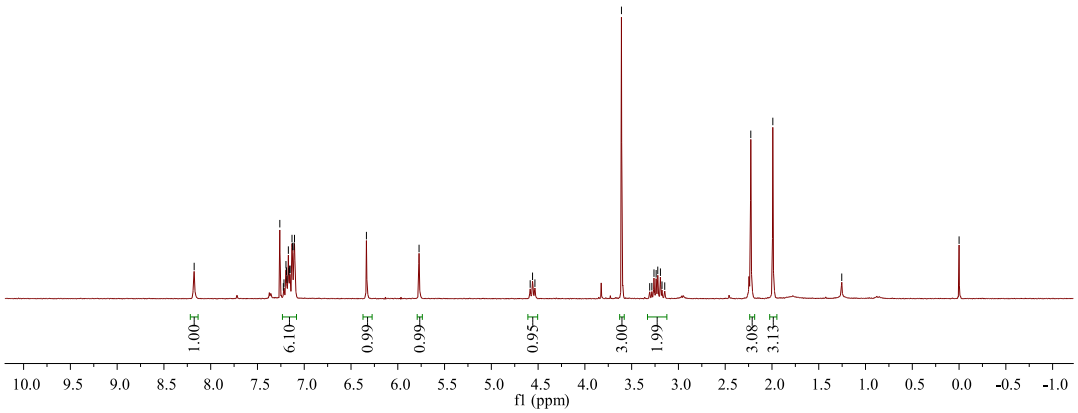


^{1}H NMR spectra of compound 4b

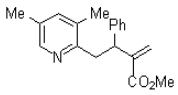




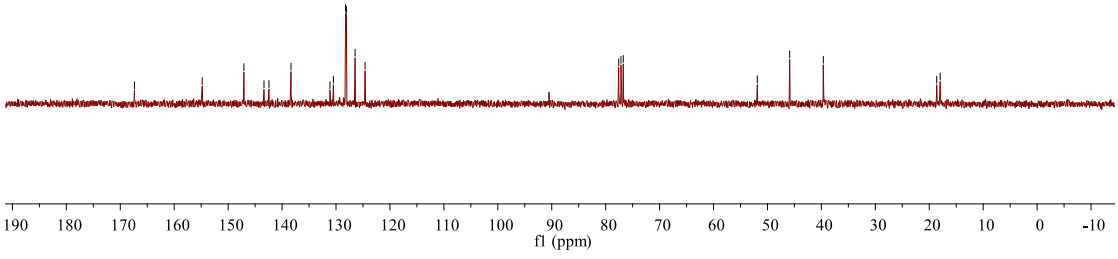
4b



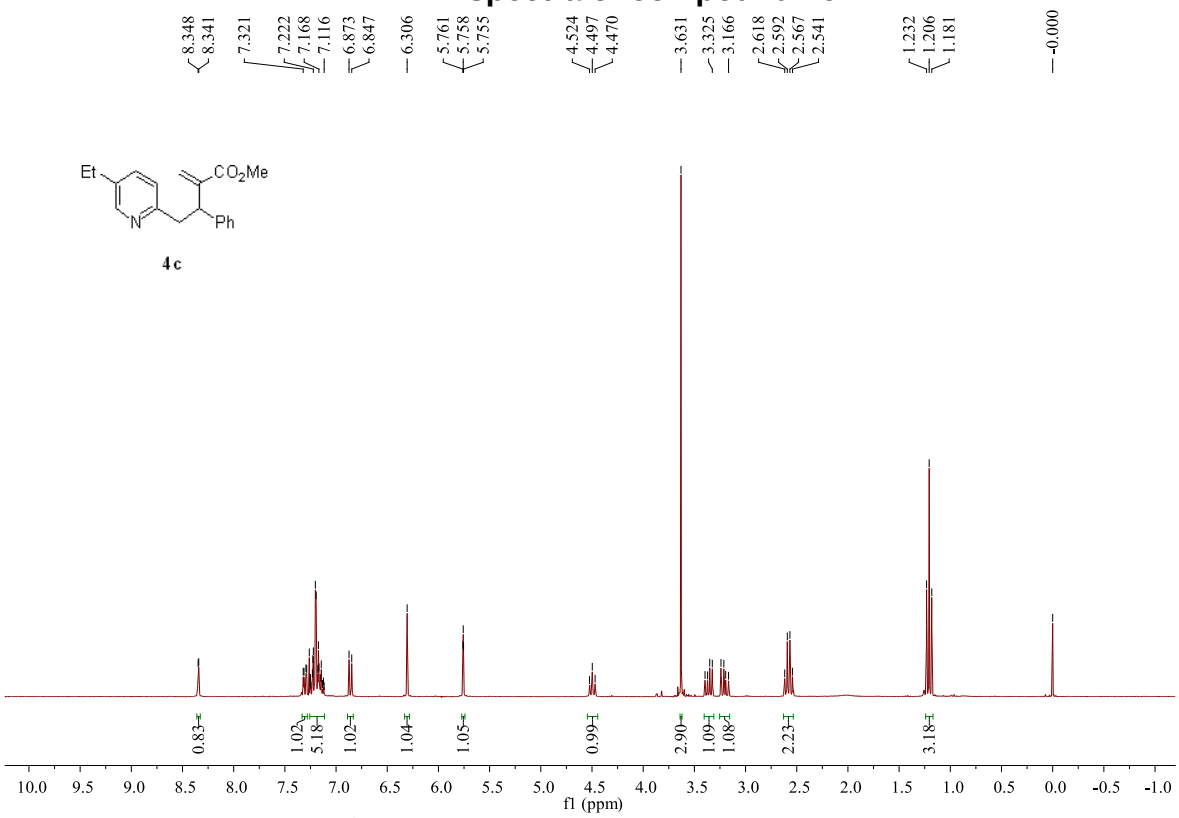
^{13}C NMR spectra of compound 4b



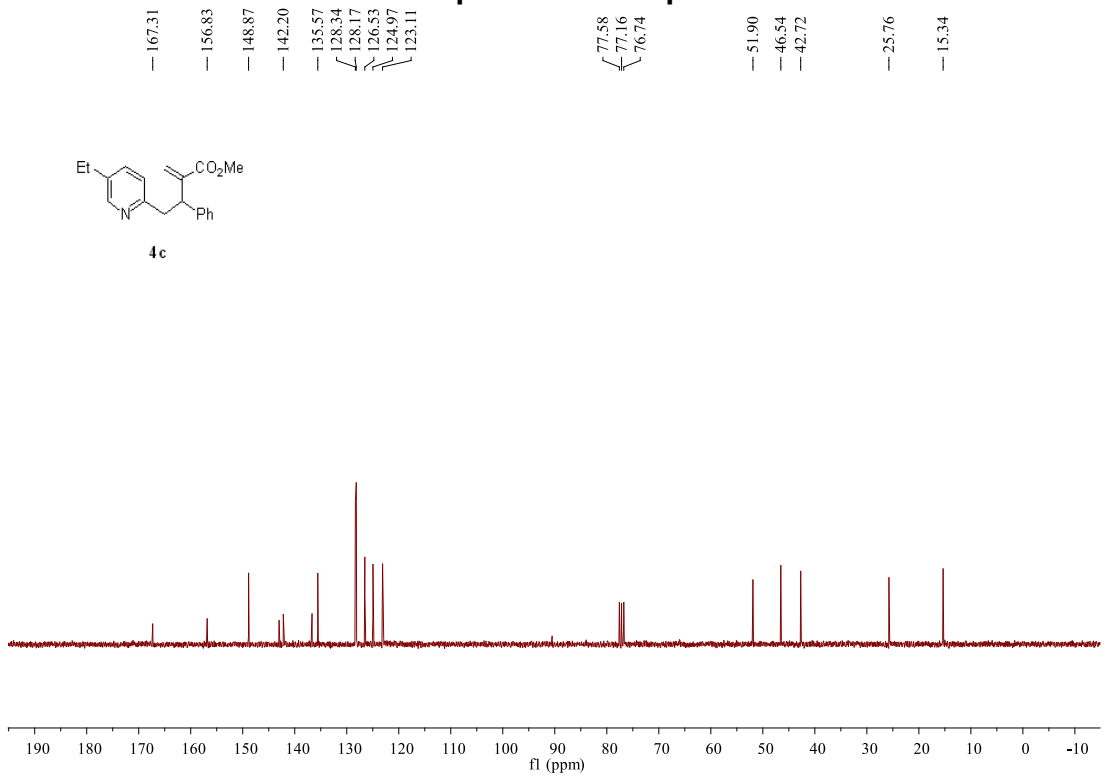
4b



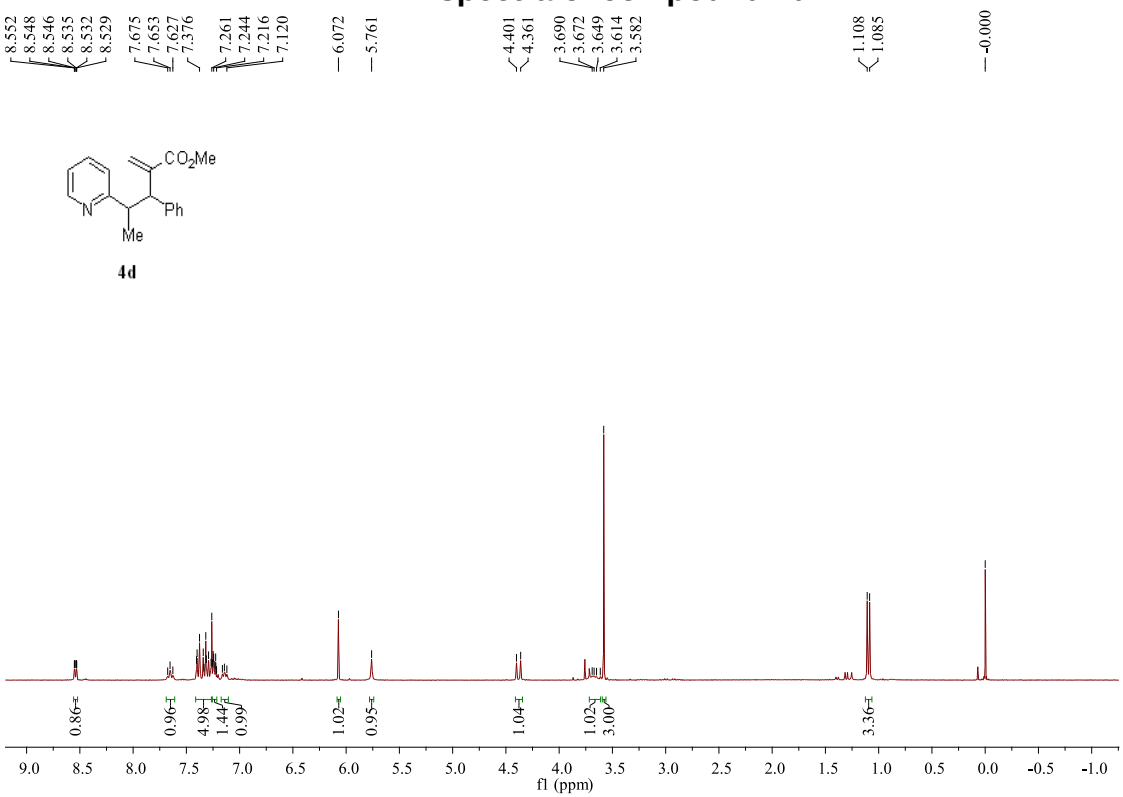
^{1}H NMR spectra of compound 4c



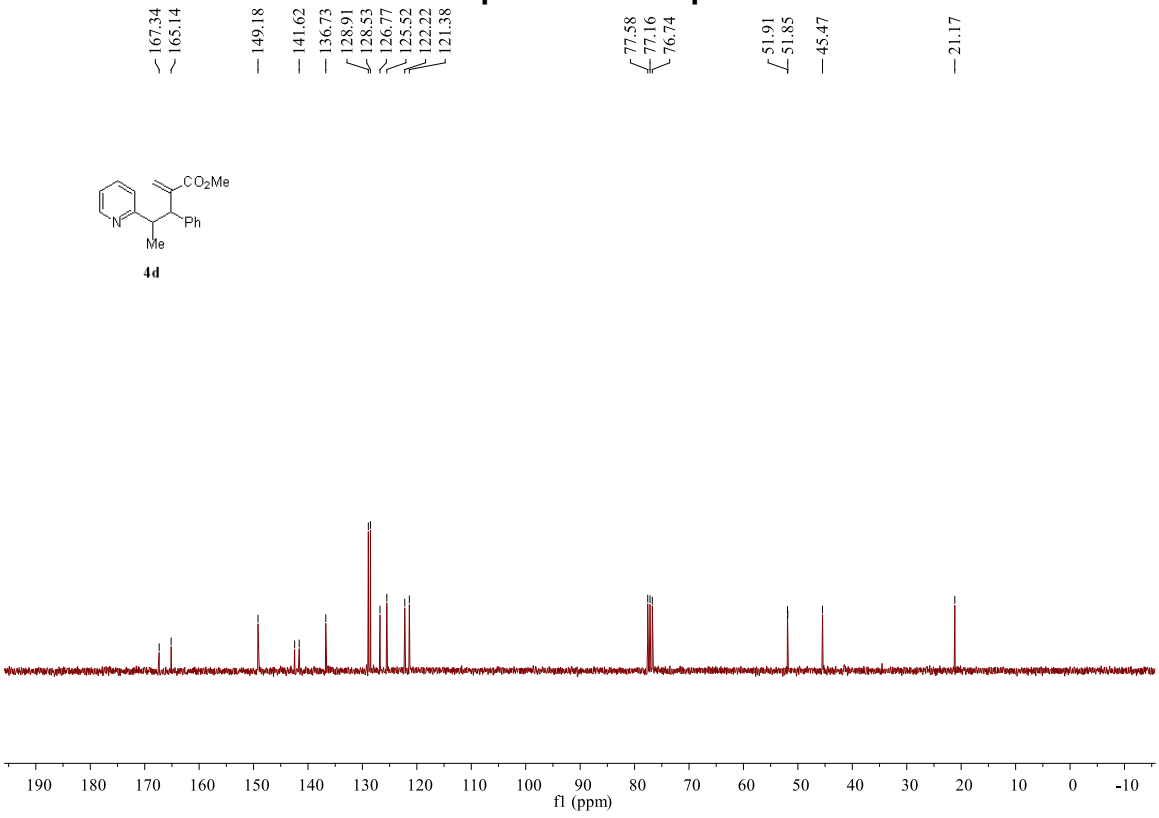
^{13}C NMR spectra of compound 4c



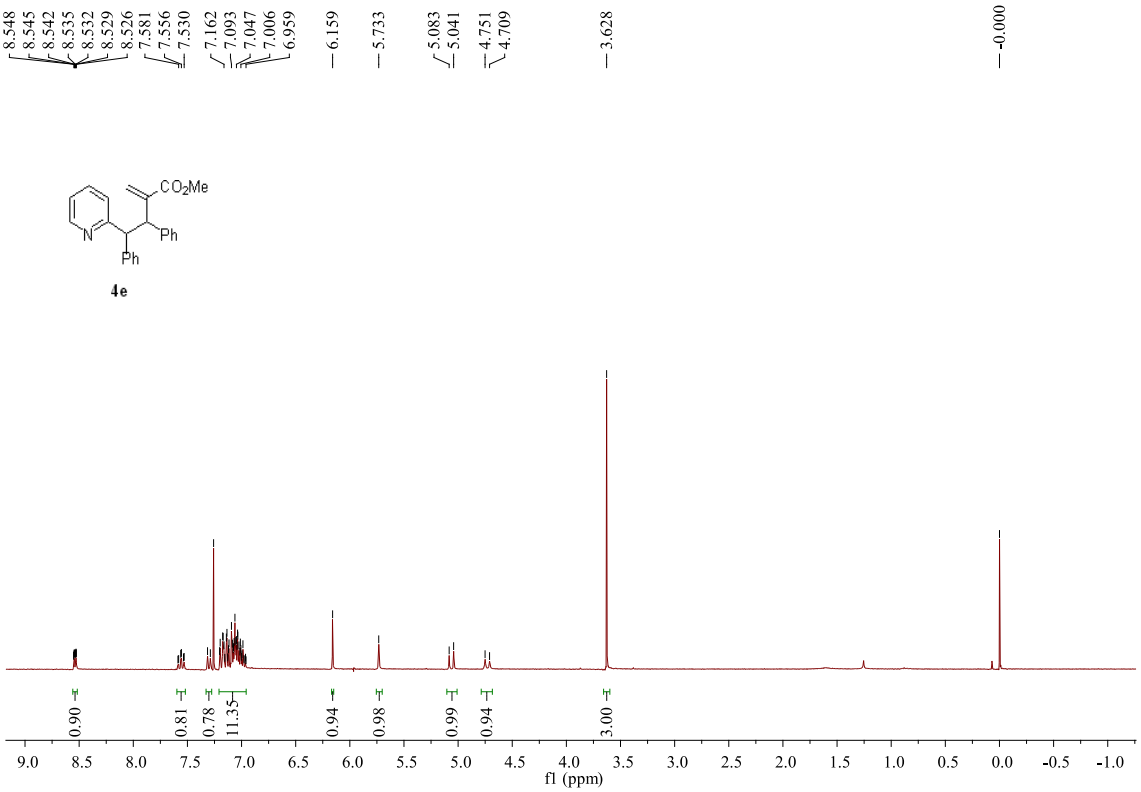
^{1}H NMR spectra of compound 4d



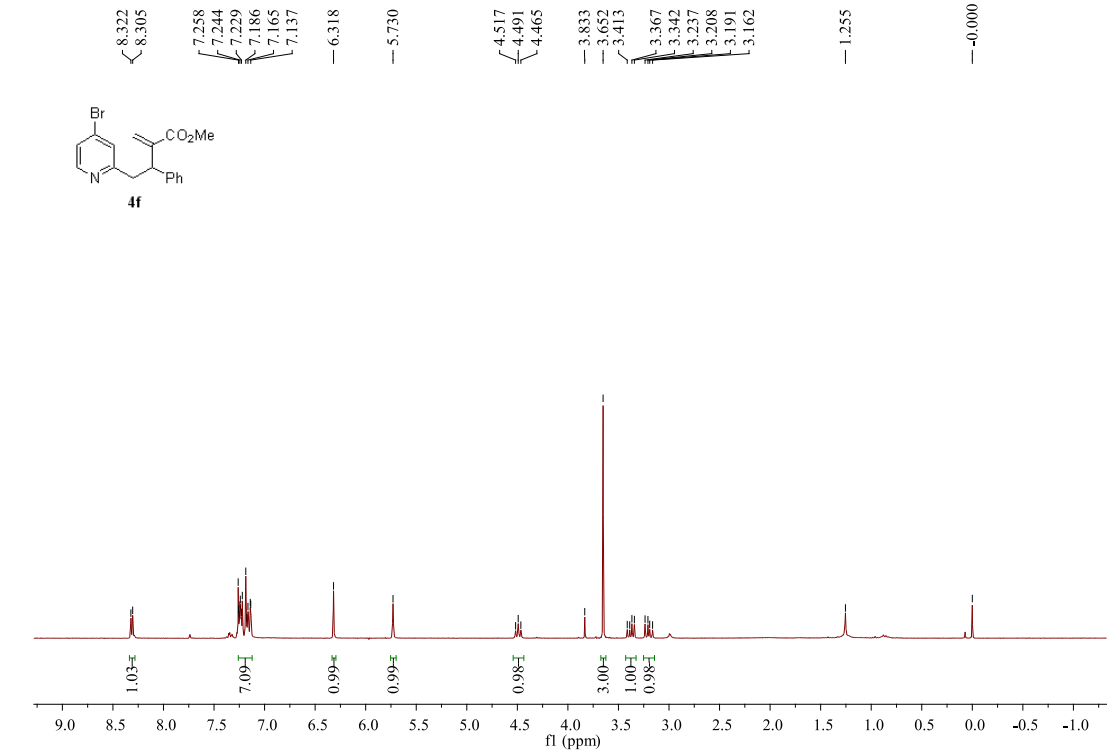
^{13}C NMR spectra of compound 4d



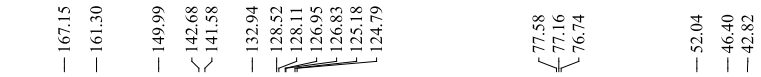
^{1}H NMR spectra of compound 4e

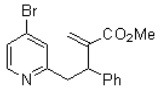


^{1}H NMR spectra of compound 4f

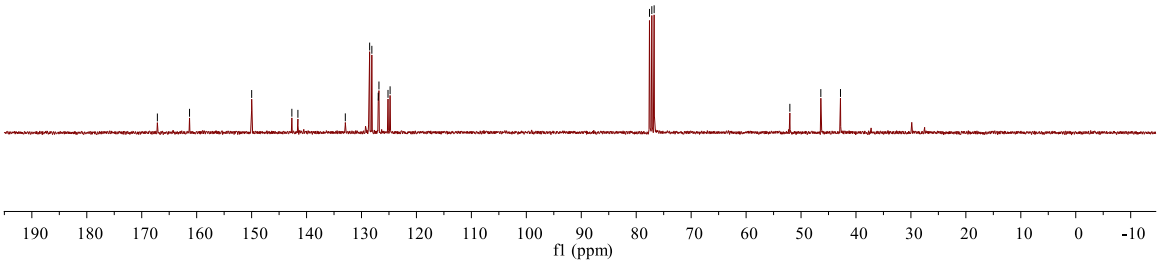


^{13}C NMR spectra of compound 4f

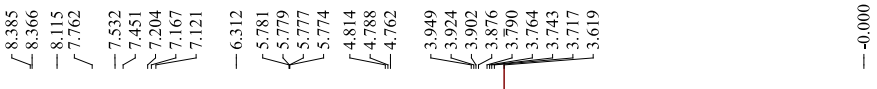


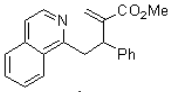


4f

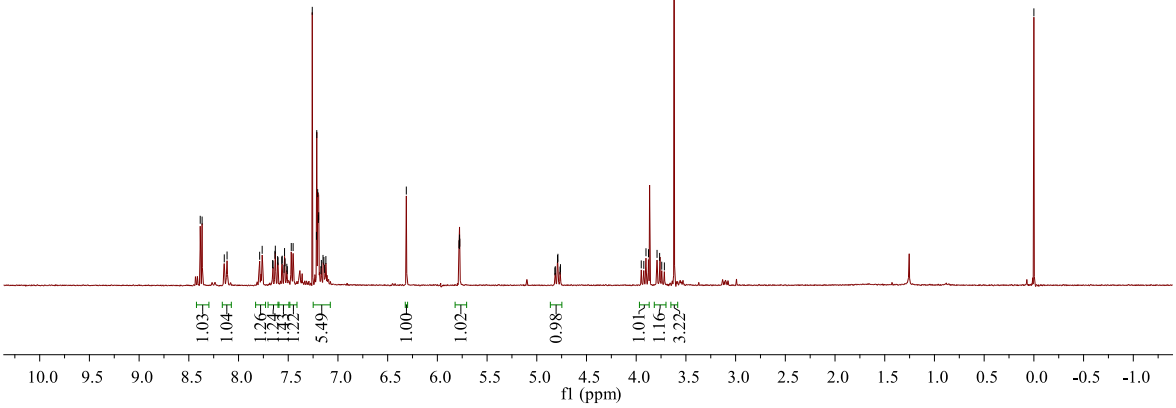


^{1}H NMR spectra of compound 4g





4g



^{13}C NMR spectra of compound 4g