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Supporting Information for

Gold-Catalyzed Efficient Synthesis of 2,4-Disubstituted Furans from Aryloxy-enynes

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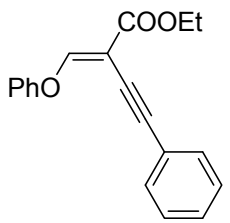
Experimental section

General Methods. All reactions were carried out under argon or nitrogen. Dioxane, THF was distilled from sodium/benzophenone. DCM was distilled from P_2O_5. AgOTf were used as purchased. AgOTf was used as a 0.04 M solution in THF. Unless noted, all commercial reagents were used without further purification.

^{1}H NMR spectra was recorded at 300 or 400 MHz, ^{13}C NMR spectra was recorded at 75 or 100 MHz, and in $CDCl_3$ (containing 0.03% TMS) solutions. ^{1}H NMR spectra was recorded with tetramethylsilane (δ = 0.00 ppm) as internal reference; ^{13}C NMR spectra was recorded with $CDCl_3$ (δ = 77.00 ppm) as internal reference. High-resolution mass spectra was obtained by using Waters Micromass GCT mass spectrometer. Single crystal X-ray diffraction data was collected in Bruker SMART APEX diffractometers with molybdenum cathodes.

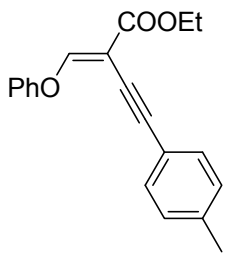
A typical procedure for the Pd-catalyzed Coupling Reaction to (*E*)-ethyl 2-(phenoxymethylene)-4-phenylbut-3-ynoate:

(*Z*)-ethyl 2-bromo-3-phenoxyacrylate **1a** (922 mg, 3.4 mmol), $Pd(PPh_3)_4$ (196 mg, 0.17 mmol, 5 mol %), CuI (65mg, 0.34 mmol, 10 mol %), and Et_3N (34 mL) were added to a Schlenk tube under nitrogen, then phenylacetylene (0.75 mL, 6.8 mmol) was added to the resulted solution, the mixture was stirred at 70 ^{o}C. After the reaction was complete as monitored by thin-layer chromatography, Then the mixture was quenched with saturated NH_4Cl, extracted with ethyl acetate, washed with saturated NaCl solution and dried over Na_2SO_4. The solvent was evaporated under the reduced pressure and the residue was purified by chromatography on silica gel to afford the (*E*)-ethyl 2-(phenoxymethylene)-4-phenylbut-3-ynoate **3a** (874 mg, 88%) as a yellow oil.



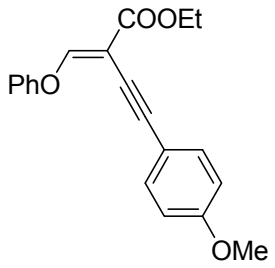
3a

(*E*)-Ethyl 2-(phenoxymethylene)-4-phenylbut-3-ynoate (3a) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 50:1) afforded the title product **3a** in 88% isolated yield as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$, Me_4Si) δ 1.34 (t, *J* = 7.2 Hz, 3H), 4.29 (q, *J* = 7.2 Hz, 2H), 7.13-7.21 (m, 3H), 7.30-7.33 (m, 3H), 7.35-7.39 (m, 2H), 7.52-7.55 (m, 2H), 8.09 (s, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, Me_4Si) δ 14.17, 61.11, 80.05, 97.03, 99.39, 117.50, 123.11, 125.10, 128.11, 128.20, 129.85, 131.46, 156.47, 160.27, 165.27; HRMS (EI) calcd for $C_{19}H_{16}O_3$ 292.1099, found 292.1095.



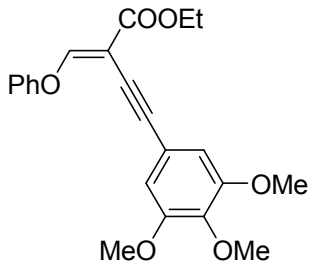
3b

(*E*)-Ethyl 2-(phenoxymethylene)-4-*p*-tolylbut-3-ynoate (3b) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 50:1) afforded the title product **3b** in 86% isolated yield as a yellow oil. ^{1}H NMR (300 MHz, $CDCl_3$, Me_4Si) δ 1.35 (t, *J* = 6.9 Hz, 3H), 2.34 (s, 3H) 4.29 (q, *J* = 7.2 Hz, 2H), 7.11-7.22 (m, 5H), 7.35-7.44 (m, 4H), 8.07 (s, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, Me_4Si) δ 14.15, 21.34, 61.06, 79.36, 97.23, 99.54, 117.48, 120.06, 125.02, 128.86, 129.82, 131.35, 138.28, 156.49, 159.93, 165.32; HRMS (EI) for calcd $C_{20}H_{18}O_3$ 306.1256, found 306.1261.



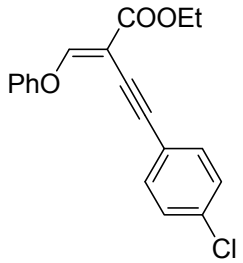
3c

(*E*)-Ethyl 4-(4-methoxyphenyl)-2-(phenoxymethylene)but-3-ynoate (3c) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 50:1) afforded the title product **3c** in 92% isolated yield as a yellow oil. ^{1}H NMR (300 MHz, $CDCl_3$, Me_4Si) δ 1.36 (t, *J* = 7.2 Hz, 3H), 3.81 (s, 3H), 4.30 (q, *J* = 6.9 Hz, 2H), 6.86 (d, *J* = 8.4 Hz, 2H), 7.15-7.23 (m, 3H), 7.37-7.42 (m, 2H), 7.48 (d, *J* = 8.4 Hz, 2H), 8.06 (s, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, Me_4Si) δ 14.26, 55.22, 61.17, 78.73, 97.12, 99.72, 113.82, 115.34, 117.63, 125.09, 129.91, 133.06, 156.63, 159.61, 159.82, 165.51; HRMS (EI) calcd for $C_{20}H_{18}O_4$ 322.1205, found 322.1202.



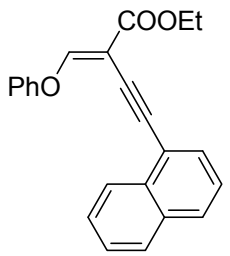
3d

(*E*)-Ethyl 2-(phenoxymethylene)-4-(3,4,5-trimethoxyphenyl)but-3-ynoate (3d) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 10:1) afforded the title product **3d** in 92% isolated yield as a yellow solid. ^{1}H NMR (300 MHz, $CDCl_3$, Me_4Si) δ 1.36 (t, J = 6.9 Hz, 3H), 3.87 (s, 9H), 4.31 (q, J = 7.2 Hz, 2H), 6.78 (s, 2H), 7.17-7.25 (m, 3H) 7.38-7.44 (m, 2H), 8.09 (s, 1H); ^{13}C NMR (75.5 MHz, $CDCl_3$, Me_4Si) δ 14.25, 56.07, 60.90, 61.22, 79.13, 97.03, 99.33, 108.75, 117.67, 118.17, 125.23, 129.94, 138.76, 152.91, 156.58, 160.40, 165.31; HRMS (EI) calcd for $C_{22}H_{22}O_6$ 382.1416, found 382.1415.



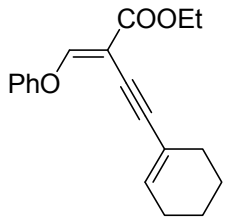
3e

(*E*)-Ethyl 4-(4-chlorophenyl)-2-(phenoxymethylene)but-3-ynoate (3e) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 50:1) afforded the title product **3e** in 89% isolated yield as a yellow oil. ^{1}H NMR (300 MHz, $CDCl_3$, Me_4Si) δ 1.35 (t, J = 6.9 Hz, 3H), 4.30 (q, J = 6.9 Hz, 2H), 7.15-7.25 (m, 3H), 7.28-7.31 (m, 2H), 7.38-7.42 (m, 2H), 7.44-7.47 (m, 2H), 8.09 (s, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, Me_4Si) δ 14.24, 61.25, 81.12, 95.92, 99.24, 117.62, 121.73, 125.27, 128.52, 129.95, 132.77, 134.24, 156.53, 160.66, 165.21; HRMS (EI) calcd for $C_{19}H_{15}O_3Cl$ 326.0710, found 326.0714.



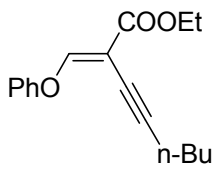
3f

(*E*)-Ethyl 4-(naphthalen-1-yl)-2-(phenoxymethylene)but-3-ynoate (3f) Column chromatography on sillica gel (eluent: petroleum ether / ethyl acetate = 50:1) afforded the title product **3f** in 54% isolated yield as a yellow oil. ^{1}H NMR (300 MHz, $CDCl_3$, Me_4Si) δ 1.44 (t, *J* = 7.2 Hz, 3H), 4.37 (q, *J* = 6.9 Hz, 2H), 7.21-7.26 (m, 3H), 7.41-7.47 (m, 3H), 7.52-7.57 (m, 2H), 7.77 (d, *J* = 7.2 Hz, 1H), 7.84 (t, *J* = 6.9 Hz, 2H), 8.19 (s, 1H), 8.59 (d, *J* = 8.4 Hz, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, Me_4Si) δ 14.32, 61.35, 85.33, 95.65, 99.80, 117.55, 120.93, 125.20, 125.23, 126.35, 126.50, 126.71, 128.16, 128.75, 129.96, 130.03, 133.13, 133.34, 156.62, 160.19, 165.51; HRMS (EI) calcd for $C_{23}H_{18}O_3$ 342.1256, found 342.1252.



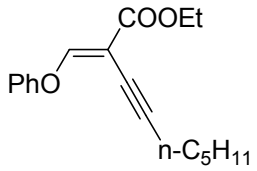
3g

(*E*)-Ethyl 4-cyclohexenyl-2-(phenoxymethylene)but-3-ynoate (3g) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 50:1) afforded the title product **3g** in 78% isolated yield as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$, Me_4Si) δ 1.33 (t, *J* = 7.2 Hz, 3H), 1.59-1.68 (m, 4H), 2.13-2.14 (m, 2H), 2.22-2.24 (m, 2H), 4.26 (q, *J* = 6.8 Hz, 2H), 6.22-6.23 (m, 1H), 7.13-7.15 (m, 2H), 7.20-7.22 (m, 1H), 7.36-7.40 (m, 2H), 8.00 (s, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, Me_4Si) δ 14.23, 21.45, 22.26, 25.71, 29.03, 61.11, 77.27, 99.07, 99.77, 117.64, 120.67, 125.00, 129.87, 135.43, 156.66, 159.50, 165.56; HRMS (EI) calcd for $C_{19}H_{20}O_3$ 296.1412, found 296.1408.



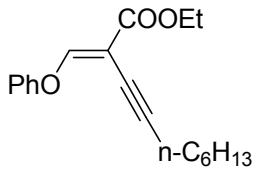
3h

(*E*)-Ethyl 2-(phenoxymethylene)oct-3-ynoate (3h) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 50:1) afforded the title product **3h** in 43% isolated yield as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$, Me_4Si) δ 0.94 (t, *J* = 7.2 Hz, 3H), 1.33 (t, *J* = 7.2 Hz, 3H), 1.48-1.54 (m, 2H), 1.57-1.62 (m, 2H), 2.47 (t, *J* = 7.2 Hz, 2H), 4.26 (q, *J* = 7.2 Hz, 2H), 7.12-7.14 (m, 2H), 7.18-7.21 (m, 1H), 7.36-7.40 (m, 2H), 8.00 (s, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, Me_4Si) δ 13.58, 14.22, 19.51, 21.81, 30.63, 61.05, 71.01, 98.68, 99.90, 117.57, 124.95, 129.87, 156.65, 159.68, 165.82; HRMS (EI) calcd for $C_{17}H_{20}O_3$ 272.1412, found 272.1411.



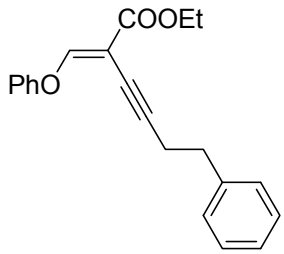
3i

(*E*)-Ethyl 2-(phenoxymethylene)non-3-ynoate (3i) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 50:1) afforded the title product **3i** in 68% isolated yield as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$, Me_4Si) δ 0.91 (t, *J* = 6.8 Hz, 3H), 1.30-1.38 (m, 5H), 1.43-1.48 (m, 2H), 1.58-1.64 (m, 2H), 2.46 (t, *J* = 7.2 Hz, 2H), 4.25 (q, *J* = 7.2 Hz, 2H), 7.11-7.13 (m, 2H), 7.16-7.20 (m, 1H), 7.35-7.40 (m, 2H), 8.00 (s, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, Me_4Si) δ 13.85, 14.11, 19.67, 22.07, 28.14, 30.80, 60.89, 70.95, 98.56, 99.81, 117.41, 124.83, 129.76, 156.52, 159.57, 165.64; HRMS (EI) calcd for $C_{18}H_{22}O_3$ 286.1569, found 286.1563.



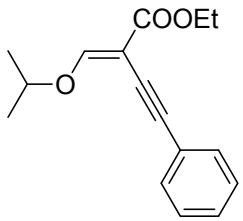
3j

(*E*)-Ethyl 2-(phenoxymethylene)dec-3-ynoate (3j) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 50:1) afforded the title product **3j** in 60% isolated yield as a yellow oil. ^{1}H NMR (300 MHz, $CDCl_3$, Me_4Si) δ 0.89 (t, *J* = 6.9 Hz, 3H), 1.26-1.35 (m, 7H), 1.45-1.50 (m, 2H), 1.56-1.64 (m, 2H), 2.46 (t, *J* = 6.9 Hz, 2H), 4.26 (q, *J* = 7.2 Hz, 2H), 7.11-7.14 (m, 2H), 7.17-7.21 (m, 1H), 7.35-7.40 (m, 2H), 8.00 (s, 1H); ^{13}C NMR (75.5 MHz, $CDCl_3$, Me_4Si) δ 14.00, 14.20, 19.80, 22.51, 28.38, 28.50, 31.29, 61.02, 70.98, 98.69, 99.86, 117.55, 124.92, 129.84, 156.62, 159.72, 165.79; HRMS (EI) calcd for $C_{19}H_{24}O_3$ 300.1725, found 300.1720.



3k

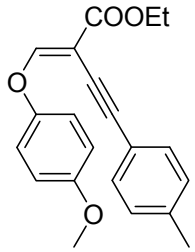
(*E*)-Ethyl 2-(phenoxymethylene)-6-phenylhex-3-ynoate (3k) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 50:1) afforded the title product **3k** in 89% isolated yield as a yellow oil. ^{1}H NMR (300 MHz, $CDCl_3$, Me_4Si) δ 1.33 (t, *J* = 2.4 Hz, 3H), 2.75 (t, *J* = 7.5 Hz, 2H), 2.94 (t, *J* = 7.5 Hz, 2H), 4.26 (q, *J* = 6.9 Hz, 2H), 7.12-7.15 (m, 2H), 7.21-7.29 (m, 6H), 7.37-7.42 (m, 2H), 8.01 (s, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, Me_4Si) δ 14.29, 22.13, 35.01, 61.09, 71.68, 97.66, 99.72, 117.65, 125.04, 126.19, 128.26, 128.29, 128.56, 129.90, 140.68, 156.64, 160.12, 165.72; HRMS (EI) calcd for $C_{21}H_{20}O_3$ 320.1412, found 320.1411.



3l

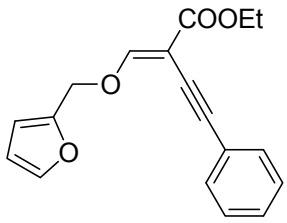
(*E*)-Ethyl 2-(isopropoxymethylene)-4-phenylbut-3-ynoate (3l) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 50:1) afforded

the title product **3l** in 29% isolated yield as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$, Me_4Si) δ 1.33 (t, *J* = 7.2 Hz, 3H), 1.38 (d, *J* = 6 Hz, 6H), 4.25 (q, *J* = 7.2 Hz, 2H), 4.31-4.37 (m, 1H), 7.27-7.33 (m, 3H) 7.47-7.50 (m, 2H), 7.84 (s, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, Me_4Si) δ 14.23, 22.37, 60.69, 79.13, 80.95, 95.03, 95.58, 123.67, 127.76, 128.03, 131.31, 164.17, 166.24; HRMS (EI) calcd for $C_{16}H_{18}O_3$ 258.1256, found 258.1259.



3m

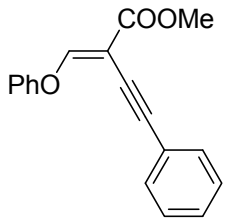
(*E*)-Ethyl 2-((4-methoxyphenoxy)methylene)-4-*p*-tolylbut-3-ynoate (3m) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 10:1) afforded the title product **3m** in 71% isolated yield as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$, Me_4Si) δ 1.34 (t, *J* = 6.8 Hz, 3H), 2.33 (s, 3H), 3.77 (s, 3H), 4.28 (q, *J* = 6.8 Hz, 2H), 6.88 (dd, *J* = 2.4, 6.8 Hz, 2H), 7.08 (dd, J =2.4, 7.2 Hz, 2H), 7.12 (d, *J* = 7.6 Hz, 2H), 7.42 (d, *J* = 8 Hz, 2H), 8.00 (s, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, Me_4Si) δ 14.20, 21.39, 55.52, 61.06, 79.45, 97.04, 98.76, 114.71, 118.71, 120.13, 128.89, 131.38, 138.27, 150.64, 156.82, 161.14, 165.51; HRMS (EI) calcd for $C_{21}H_{20}O_4$ 336.1362, found 336.1359.



3n

(*E*)-Ethyl 2-((furan-2-ylmethoxy)methylene)-4-phenylbut-3-ynoate (3n) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 50:1) afforded the title product **3n** in 73% isolated yield as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$,

Me_4Si) δ 1.32 (t, J = 7.2 Hz, 3H), 4.24 (q, J = 7.2 Hz, 2H), 5.06 (s, 2H), 6.37-6.38 (m, 1H), 6.48-6.49 (m, 1H), 7.27-7.30 (m, 3H), 7.45-7.49 (m, 3H), 7.90 (s, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, Me_4Si) δ 14.20, 60.88, 67.99, 80.49, 96.13, 96.34, 110.64, 111.64, 123.38, 127.97, 128.06, 131.43, 144.03, 148.60, 164.05, 165.79; HRMS (EI) calcd for $C_{18}H_{16}O_4$ 296.1049, found 296.1044.

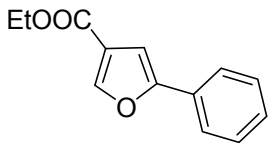


3o

(*E*)-Methyl 2-(phenoxymethylene)-4-phenylbut-3-ynoate (3o) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 50:1) afforded the title product **3o** in 94% isolated yield as a yellow oil. ^1H NMR (400 MHz, $CDCl_3$, Me_4Si) δ 3.83 (s, 3H), 7.14-7.17 (m, 2H) 7.17-7.21 (m, 1H), 7.29-7.33 (m, 3H), 7.36-7.40 (m, 2H), 7.53-7.55 (m, 2H), 8.10 (s, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, Me_4Si) δ 52.22, 79.90, 97.11, 99.10, 117.54, 123.10, 125.18, 128.15, 128.29, 129.91, 131.56, 156.51, 160.56, 165.81; HRMS (EI) calcd for $C_{18}H_{14}O_3$ 278.0943, found 278.0940.

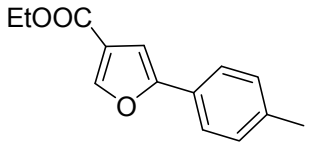
A typical procedure for the Au-catalyzed formation of ethyl 5-phenylfuran-3-carboxylate:

(*E*)-ethyl 2-(phenoxymethylene)-4-phenylbut-3-ynoate (117 mg, 0.4 mmol), THF (2 mL), PPh_3AuCl (4.0 mg, 2 mol %), AgOTf (0.2 mL, 0.04 M solution in THF, 2 mol %) were added to a Schlenk tube. The resulted solution was stirred at room temperature. After the reaction was complete as monitored by thin-layer chromatography, the solvent was evaporated under the reduced pressure and the residue was purified by chromatography on silica gel to afford the 2,4-disubstituted furan derivatives **4a** (79 mg, 91%) as a yellow solid.



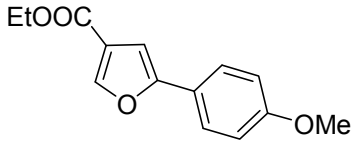
4a

Ethyl 5-phenylfuran-3-carboxylate (4a) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 50:1) afforded the title product **4a** in 91% isolated yield as a yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$, Me_4Si) δ 1.36 (t, J = 6.8 Hz, 3H), 4.33 (q, J = 7.2 Hz, 2H), 6.97 (s, 1H), 7.30-7.32 (m, 1H), 7.37-7.41 (m, 2H), 7.66-7.68 (m, 2H), 8.02 (s, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, Me_4Si) δ 14.28, 60.49, 104.44, 121.24, 123.97, 128.09, 128.73, 129.82, 146.67, 155.08, 163.10; HRMS (EI) calcd for $C_{13}H_{12}O_3$ 216.0786, found 216.0787.



4b

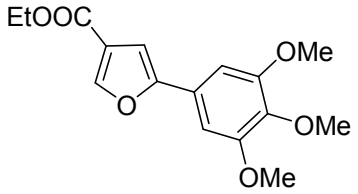
Ethyl 5-*p*-tolylfuran-3-carboxylate (4b) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 50:1) afforded the title product **4b** in 77% isolated yield as a yellow solid. M.p. = 37-55°C; ^{1}H NMR (300 MHz, $CDCl_3$, Me_4Si) δ 1.36 (t, J = 6.9 Hz, 3H), 2.36 (s, 3H), 4.32 (q, J = 6.9 Hz, 2H), 6.91 (s, 1H), 7.19 (d, J = 7.8 Hz, 2H), 7.56 (d, J = 8.4 Hz, 2H), 7.99 (s, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, Me_4Si) δ 14.28, 21.23, 60.43, 103.71, 121.18, 123.95, 127.16, 129.41, 138.06, 146.35, 155.32, 163.18; HRMS (EI) calcd for $C_{14}H_{14}O_3$ 230.0943, found 230.0941.



4c

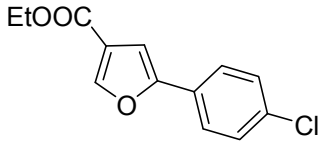
Ethyl 5-(4-methoxyphenyl)furan-3-carboxylate (4c) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 50:1) afforded the title product **4c** in 85% isolated yield as a white solid. ^{1}H NMR (300 MHz, $CDCl_3$, Me_4Si) δ 1.37 (t, J = 7.2 Hz, 3H), 3.84 (s, 3H), 4.32 (q, J = 6.9 Hz, 2H), 6.83 (s, 1H), 6.93 (d, J = 8.7 Hz,

2H), 7.60 (d, J = 8.7 Hz, 2H), 7.98 (s, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, Me_4Si) δ 14.32, 55.32, 60.46, 102.87, 114.21, 121.20, 122.87, 125.51, 146.14, 155.19, 159.59, 163.27; HRMS (EI) calcd for $C_{14}H_{14}O_4$ 246.0892, found 246.0895.



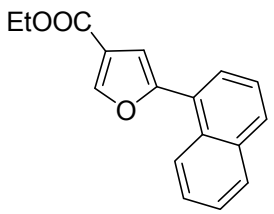
4d

Ethyl 5-(3,4,5-trimethoxyphenyl)furan-3-carboxylate (4d) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 10:1) afforded the title product **4d** in 72% isolated yield as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$, Me_4Si) δ 1.38 (t, J = 7.2 Hz, 3H), 3.88 (s, 3H), 3.92 (s, 6H), 4.33 (q, J = 6.8 Hz, 2H), 6.90 (s, 2H), 6.91 (s, 1H), 8.00 (s, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, Me_4Si) δ 14.22, 56.03, 60.46, 60.82, 101.23, 104.07, 121.24, 125.35, 138.14, 146.35, 153.48, 154.84, 162.97; HRMS (EI) calcd for $C_{16}H_{18}O_6$ 306.1103, found 306.1105.



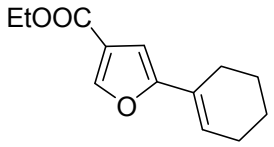
4e

Ethyl 5-(4-chlorophenyl)furan-3-carboxylate (4e) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 50:1) afforded the title product **4e** in 84% isolated yield as a yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$, Me_4Si) δ 1.36 (t, J = 6.8 Hz, 3H), 4.32 (q, J = 7.2 Hz, 2H), 6.94 (s, 1H), 7.35 (d, J = 8.0 Hz, 2H), 7.57 (d, J =8.0 Hz, 2H), 8.00 (s, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, Me_4Si) δ 14.25, 60.54, 104.89, 121.36, 125.17, 128.26, 128.94, 133.84, 146.80, 153.96, 162.86; HRMS (EI) calcd for $C_{13}H_{11}O_3Cl$ 250.0397, found 250.0400.



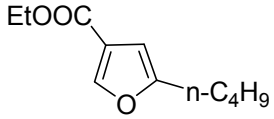
4f

Ethyl 5-(naphthalen-1-yl)furan-3-carboxylate (4f) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 50:1) afforded the title product **4f** in 71% isolated yield as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$, Me_4Si) δ 1.38 (t, *J* = 7.2 Hz, 3H), 4.35 (q, *J* = 7.2 Hz, 2H), 7.06 (s, 1H), 7.49-7.54 (m, 3H), 7.70-7.72 (m, 1H), 7.84-7.88 (m, 2H), 8.16 (s, 1H), 8.32 (d, *J* = 8.0 Hz, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, Me_4Si) δ 14.31, 60.54, 108.75, 121.01, 125.15, 126.05, 126.51, 126.82, 127.34, 128.56, 129.27, 130.16, 133.79, 147.09, 154.50, 163.21; HRMS (EI) calcd for $C_{17}H_{14}O_3$ 266.0943, found 266.0942.



4g

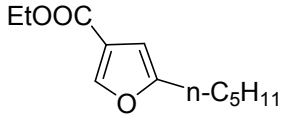
Ethyl 5-cyclohexenylfuran-3-carboxylate (4g) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 50:1) afforded the title product **4g** in 44% isolated yield as a light yellow oil. ^{1}H NMR (300 MHz, $CDCl_3$, Me_4Si) δ 1.34 (t, *J* = 6.6 Hz, 3H), 1.63-1.76 (m, 4H), 2.20-2.27 (m, 4H), 4.29 (q, *J* = 7.5 Hz, 2H), 6.34 (t, *J* = 3.9 Hz, 1H), 6.46 (s, 1H), 7.88 (s, 1H); ^{13}C NMR (75.5 MHz, $CDCl_3$, Me_4Si) δ 14.30, 22.01, 22.16, 24.72, 25.10, 60.36, 102.90, 120.44, 124.09, 126.58, 145.93, 156.63, 163.43; HRMS (EI) calcd for $C_{13}H_{16}O_3$ 220.1099, found 220.1101.



4h

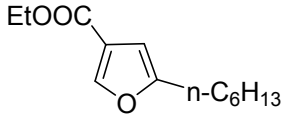
Ethyl 5-butylfuran-3-carboxylate (4h) Column chromatography on sillica gel

(eluent: petroleum ether / ethyl acetate = 50:1) afforded the title product **4h** in 76% isolated yield as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$, Me_4Si) δ 0.93 (t, *J* = 7.2 Hz, 3H), 1.26-1.39 (m, 5H), 1.58-1.66 (m, 2H), 2.61 (t, *J* = 8 Hz, 2H), 4.28 (q, *J* = 7.2 Hz, 2H), 6.33 (s, 1H), 7.87 (s, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, Me_4Si) δ 13.69, 14.29, 22.06, 27.44, 29.74, 60.19, 104.68, 119.87, 145.93, 157.93, 163.49; HRMS (EI) calcd for $C_{11}H_{16}O_3$ 196.1099, found 196.1102.



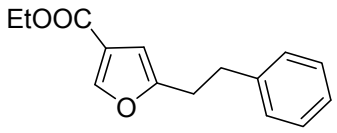
4i

Ethyl 5-pentylfuran-3-carboxylate (4i) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 50:1) afforded the title product **4i** in 87% isolated yield as a white oil. ^{1}H NMR (300 MHz, $CDCl_3$, Me_4Si) δ 0.90 (t, *J* = 6.6 Hz, 3H), 1.30-1.36 (m, 7H), 1.61-1.66 (m, 2H), 2.61 (t, *J* = 7.8 Hz, 2H), 4.28 (q, *J* = 7.2 Hz, 2H), 6.33 (s, 1H), 7.87 (s, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, Me_4Si) δ 13.90, 14.28, 22.31, 27.33, 27.72, 31.16, 60.18, 104.67, 119.87, 145.92, 157.95, 163.47; HRMS (EI) calcd for $C_{12}H_{18}O_3$ 210.1256, found 210.1254.



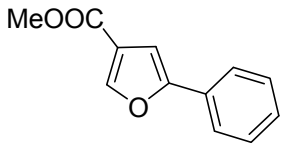
4j

Ethyl 5-hexylfuran-3-carboxylate (4j) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 50:1) afforded the title product **4j** in 90% isolated yield as a light yellow oil. ^{1}H NMR (300 MHz, $CDCl_3$, Me_4Si) δ 0.88 (t, *J* = 6.6 Hz, 3H), 1.31-1.36 (m, 9H), 1.60-1.65 (m, 2H), 2.61 (t, *J* = 7.8 Hz, 2H), 4.28 (q, *J* = 7.2 Hz, 2H), 6.33 (s, 1H), 7.87 (s, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, Me_4Si) δ 13.98, 14.27, 22.49, 27.59, 27.74, 28.65, 31.46, 60.17, 104.64, 119.81, 145.91, 157.93, 163.46; HRMS (EI) calcd for $C_{13}H_{20}O_3$ 224.1412, found 224.1413.



4k

Ethyl 5-phenethylfuran-3-carboxylate (4k) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 50:1) afforded the title product **4k** in 82% isolated yield as a white oil. ^{1}H NMR (300 MHz, $CDCl_3$, Me_4Si) δ 1.32 (t, *J* = 6.9 Hz, 3H), 2.94 (s, 4H), 4.27 (q, *J* = 6.9 Hz, 2H), 6.33 (s, 1H), 7.15-7.22 (m, 3H), 7.25-7.28 (m, 2H), 7.88 (s, 1H); ^{13}C NMR (75.5 MHz, $CDCl_3$, Me_4Si) δ 14.26, 29.66, 33.93, 60.23, 105.28, 119.92, 126.16, 128.23, 128.39, 140.59, 146.10, 156.69, 163.34; HRMS (EI) calcd for $C_{15}H_{16}O_3$ 244.1099, found 244.1102.



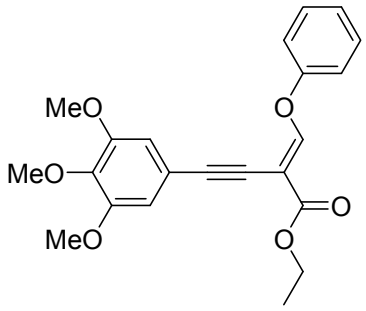
4l

Methyl 5-phenylfuran-3-carboxylate (4l) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 50:1) afforded the title product **4l** in 90% isolated yield as a white solid. ^{1}H NMR (400 MHz, $CDCl_3$, Me_4Si) δ 3.77 (s, 3H), 6.88 (s, 1H), 7.22-7.24 (m, 1H), 7.29-7.33 (m, 2H), 7.57-7.59 (m, 2H), 7.93 (s, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, Me_4Si) δ 51.60, 104.37, 120.86, 123.97, 128.14, 128.74, 129.74, 146.75, 155.15, 163.50; HRMS (EI) calcd for $C_{12}H_{10}O_3$ 202.0630, found 202.0631.

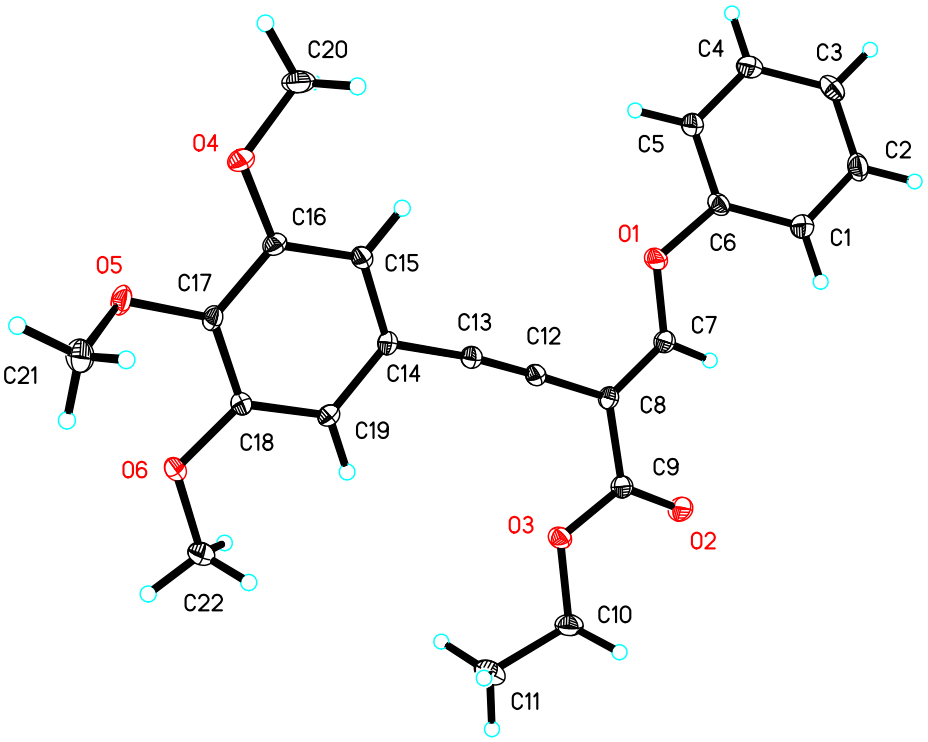
Ethyl 2-(phenoxymethylene)-4-phenylbut-3-ynoate (*E:Z*=1:1) Column chromatography on silica gel (eluent: petroleum ether / ethyl acetate = 50:1) afforded the title product in 83% isolated yield as a yellow oil. ^{1}H NMR (400 MHz, $CDCl_3$, Me_4Si), two isomers: δ 1.34-1.39 (m, 6H), 4.27-4.35 (m, 4H), 7.14-7.18 (m, 4H), 7.20-7.21 (m, 2H), 7.30-7.33 (m, 6H), 7.36-7.41 (m, 4H), 7.45 (s, 1H), 7.46-7.48 (m, 2H), 7.53-7.55 (m, 2H), 8.09 (s, 1H); ^{13}C NMR (100.6 MHz, $CDCl_3$, Me_4Si), two isomers: δ 14.19, 14.24, 61.00, 61.19, 117.59, 117.61, 125.10, 125.16, 128.07, 128.16,

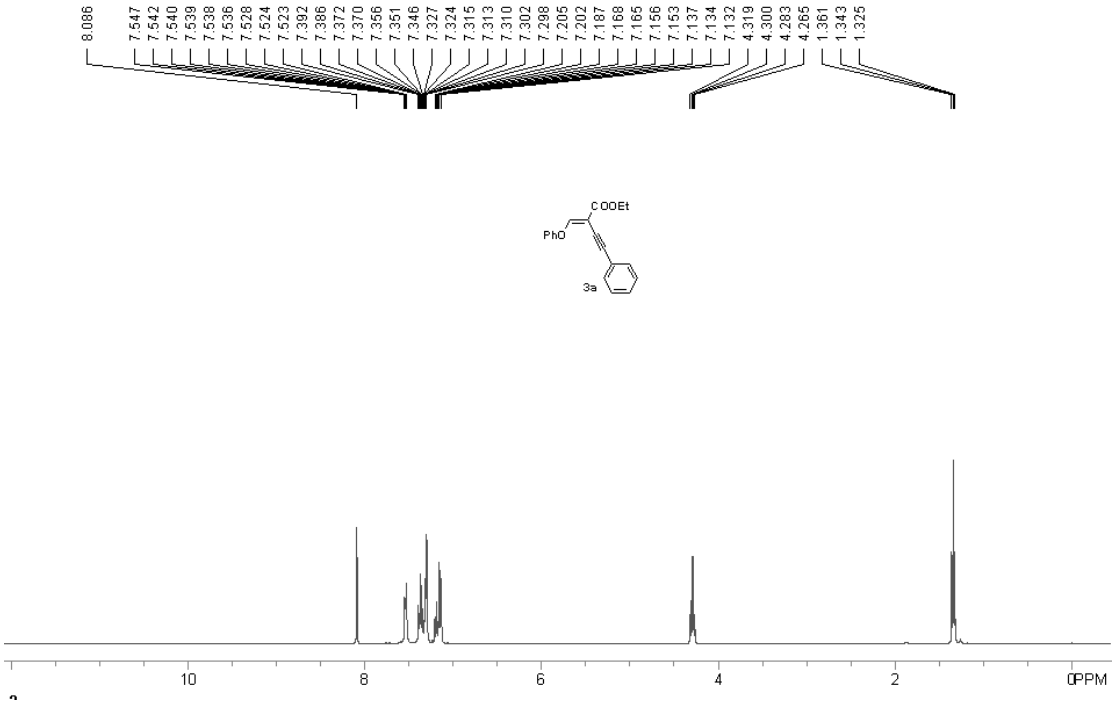
128.22, 128.25, 129.91, 129.92, 131.33, 131.56, 158.38, 160.34.

X-ray crystal structure of 3d



3d

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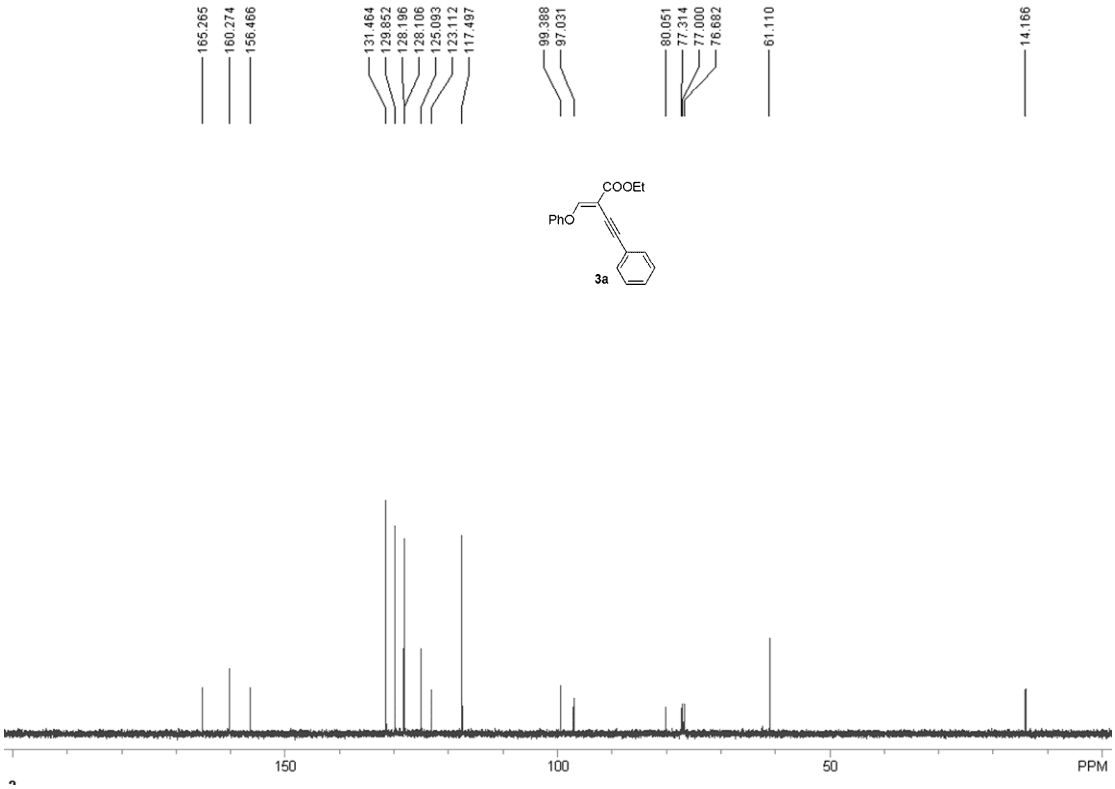
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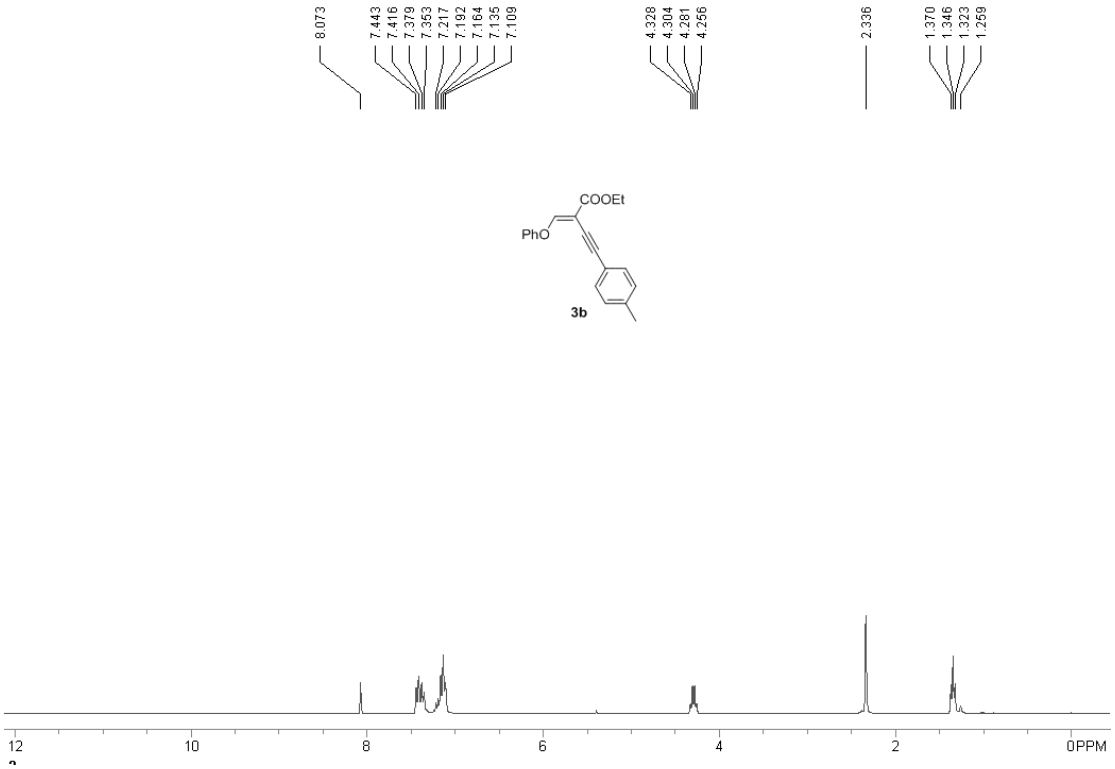
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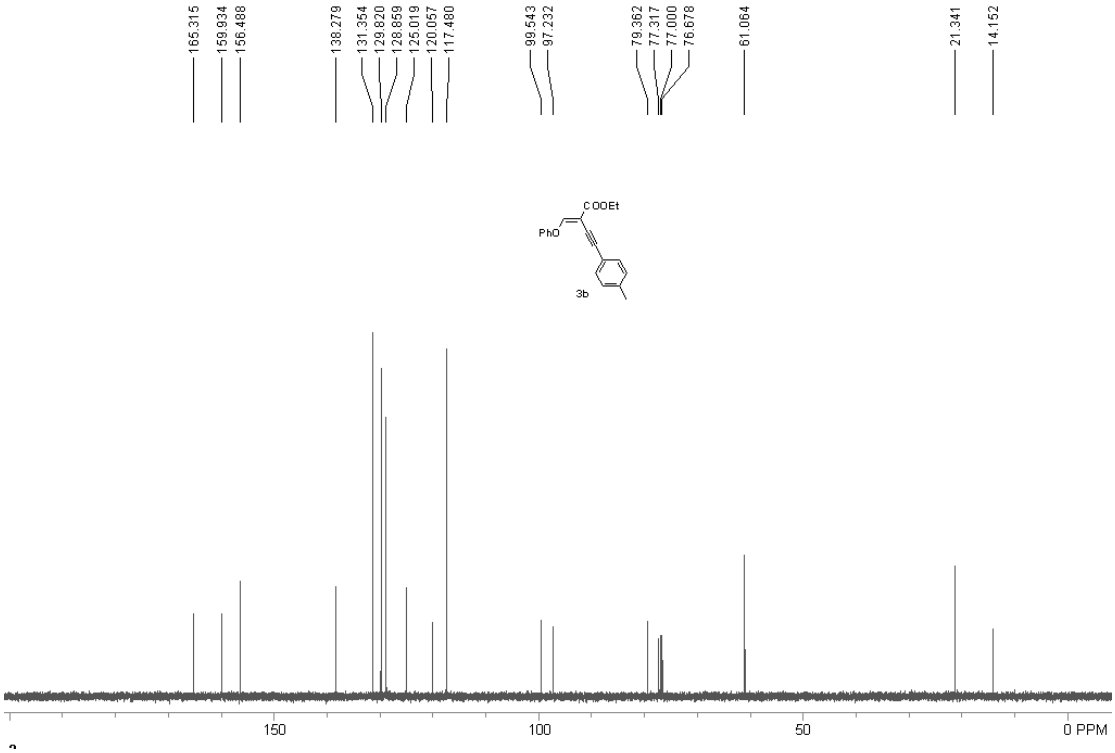
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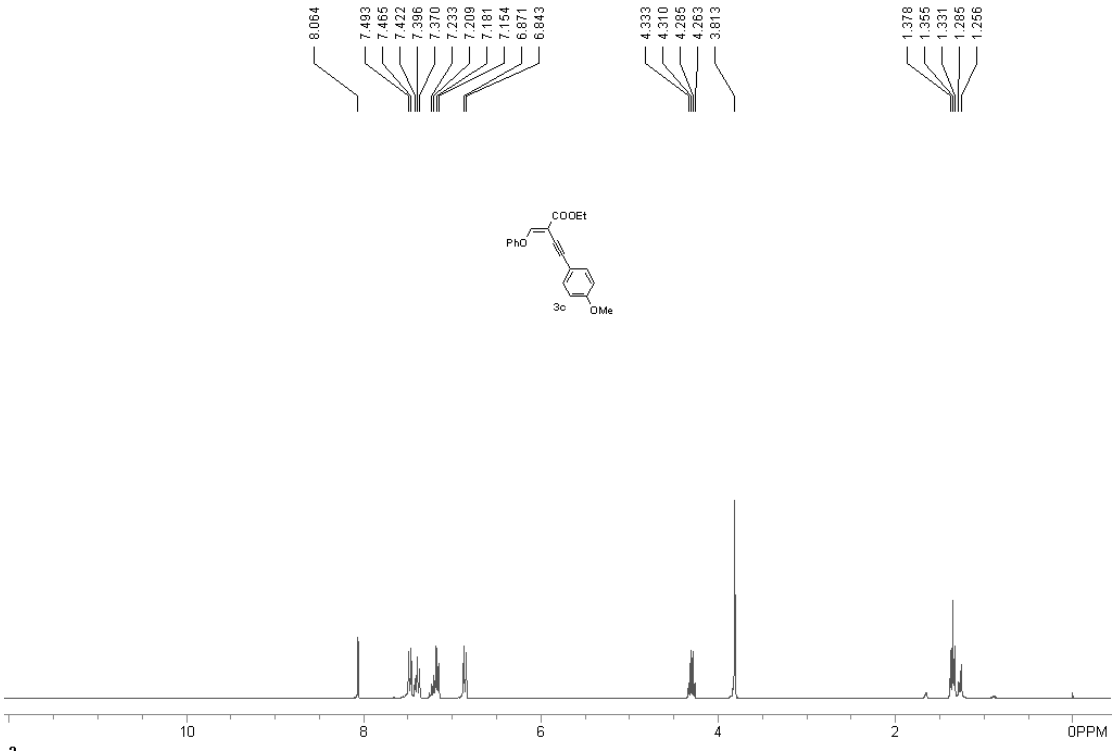
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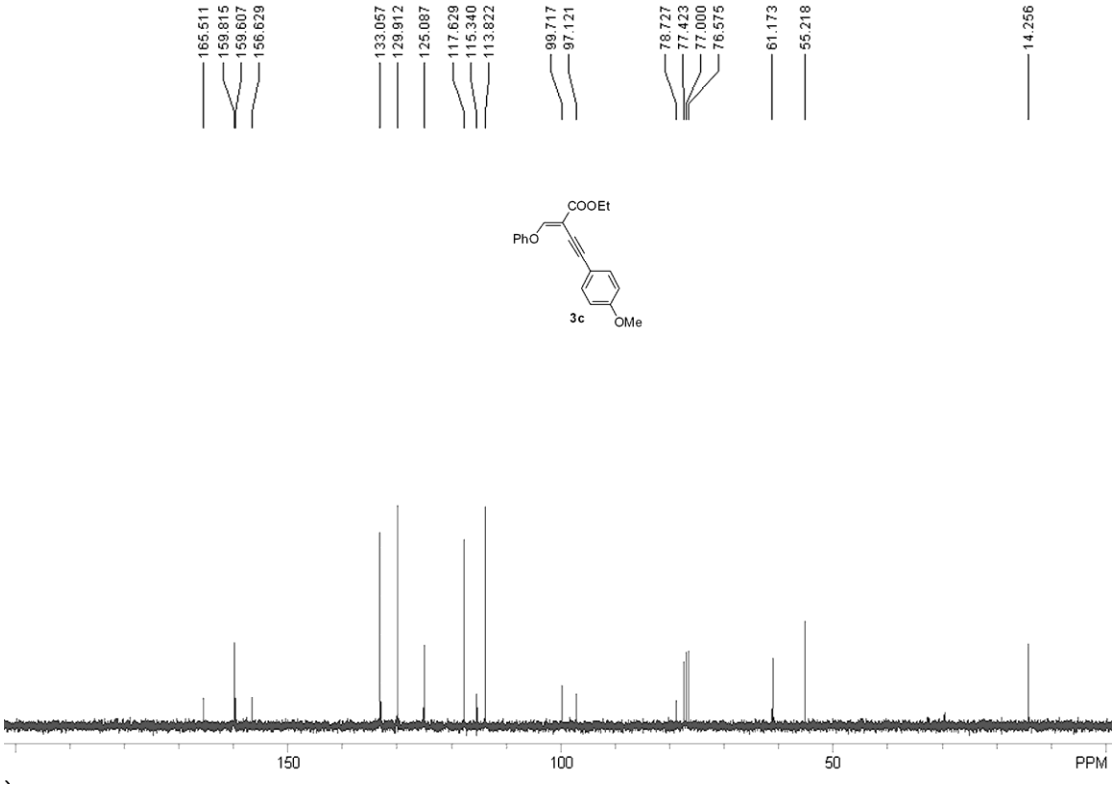
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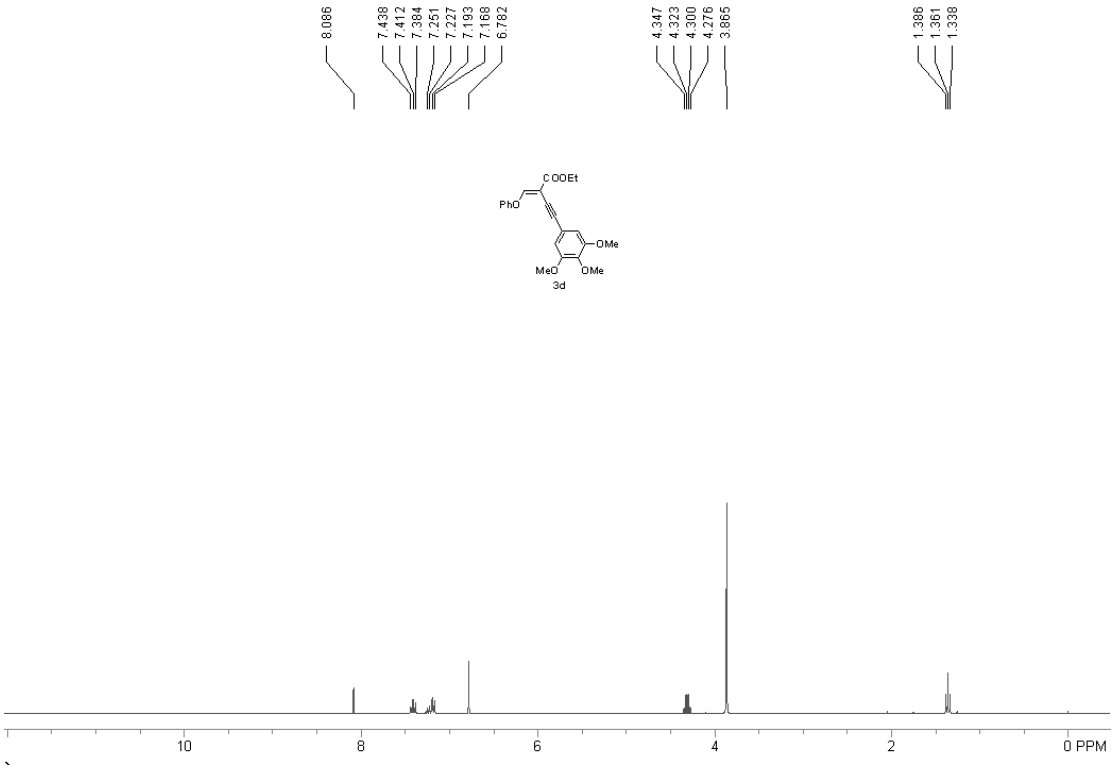
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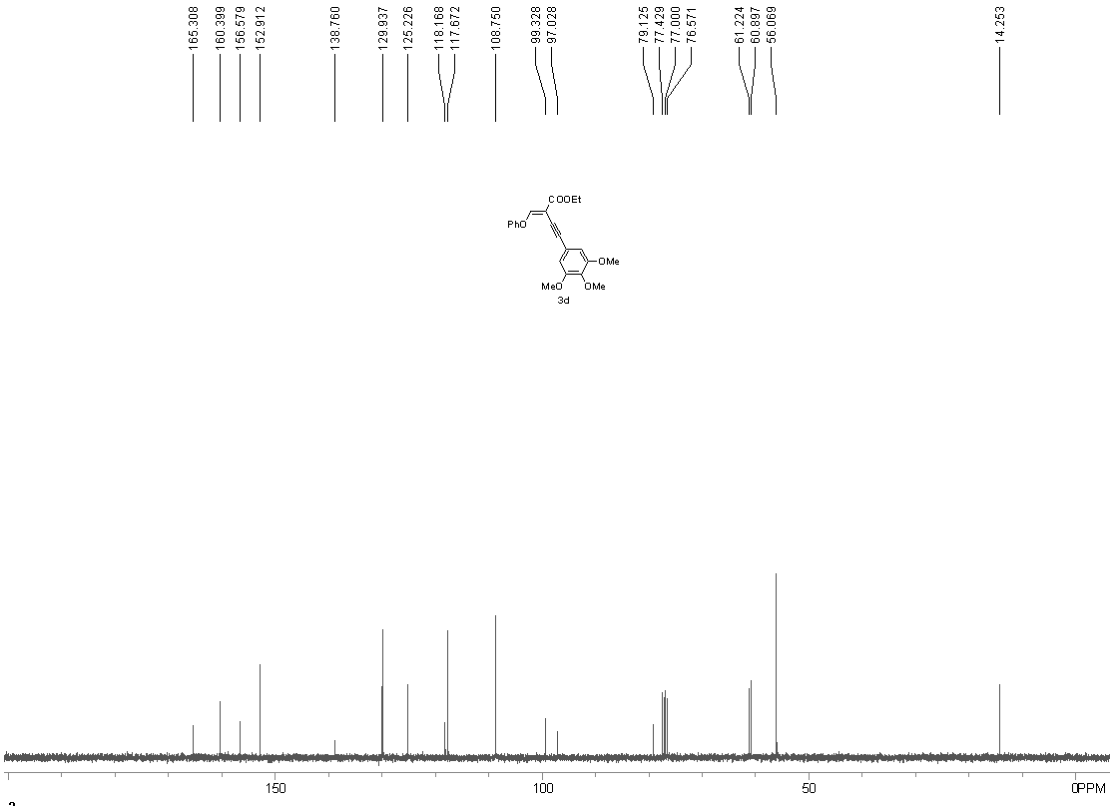
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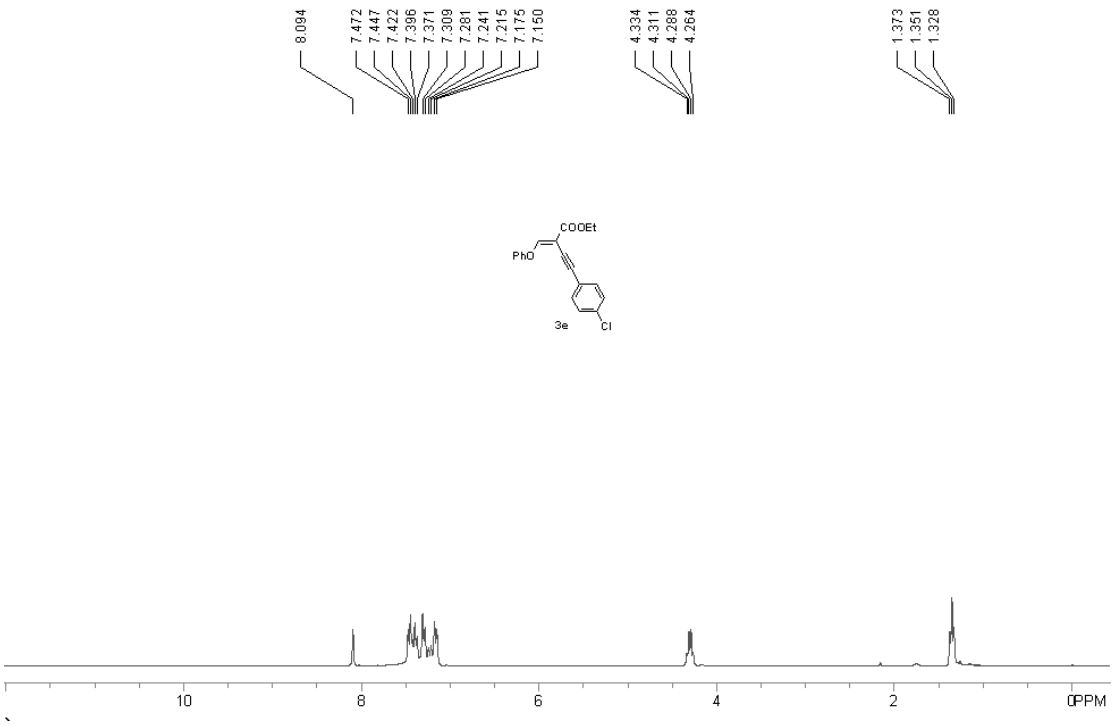
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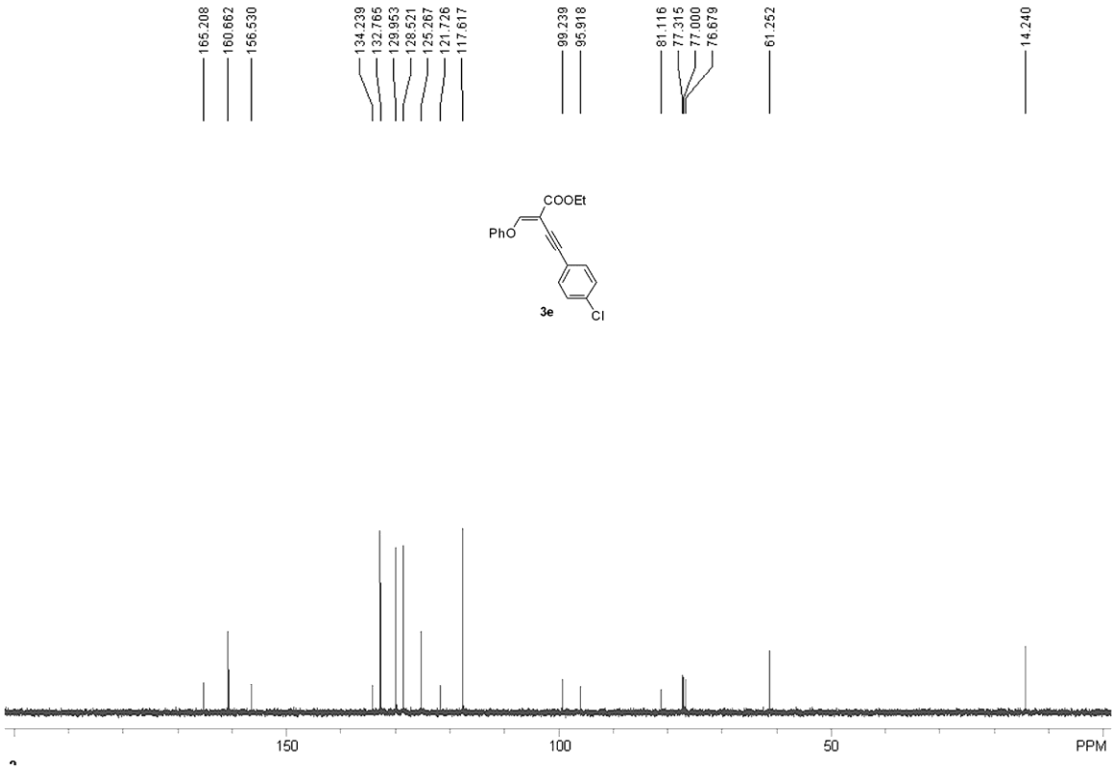
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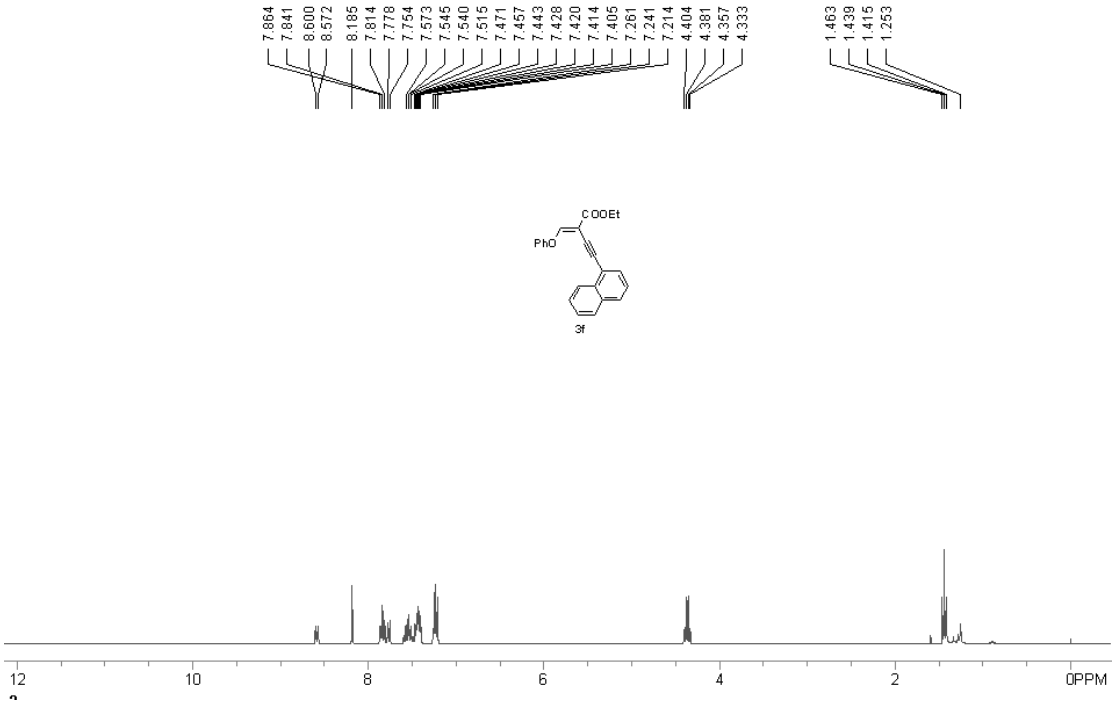
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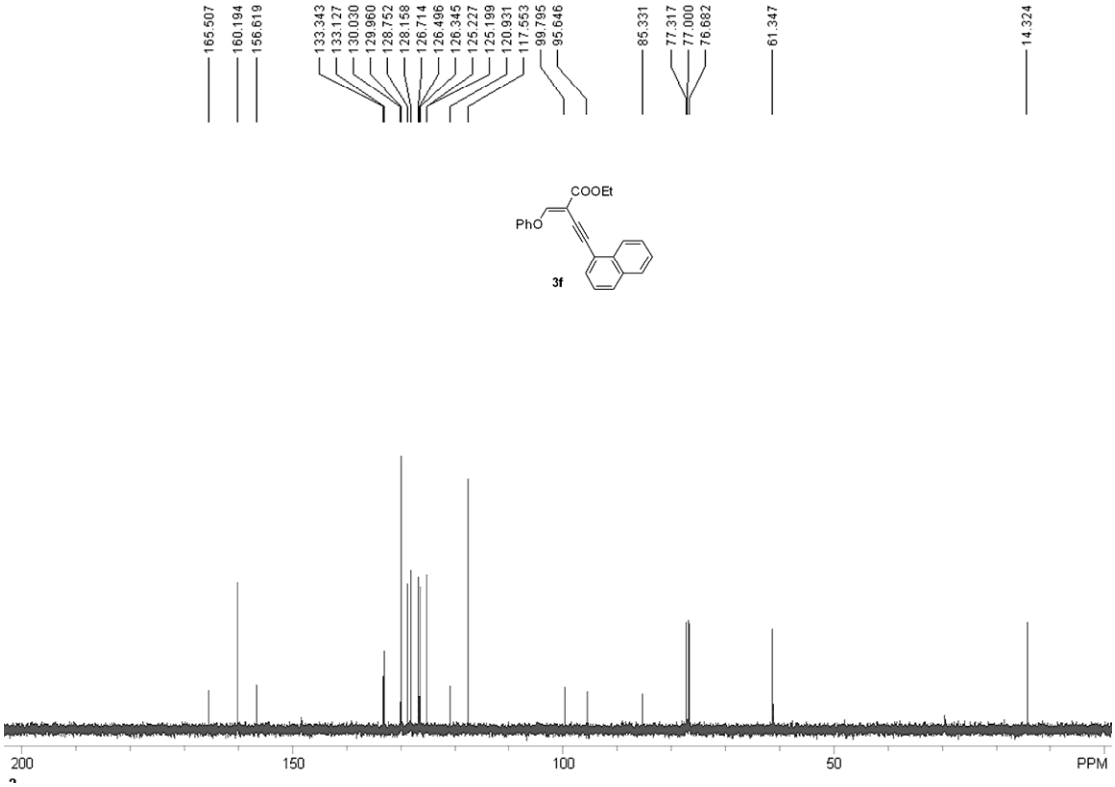
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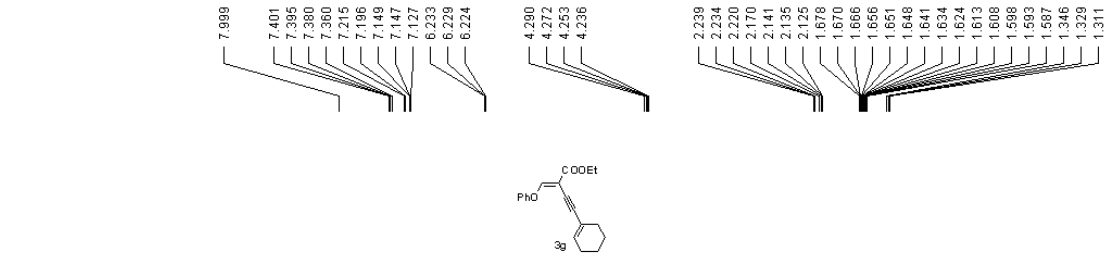
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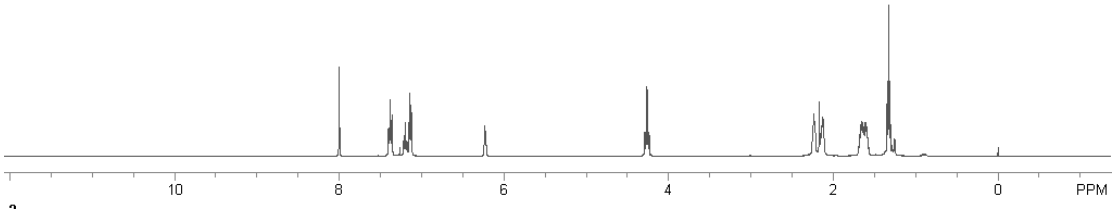
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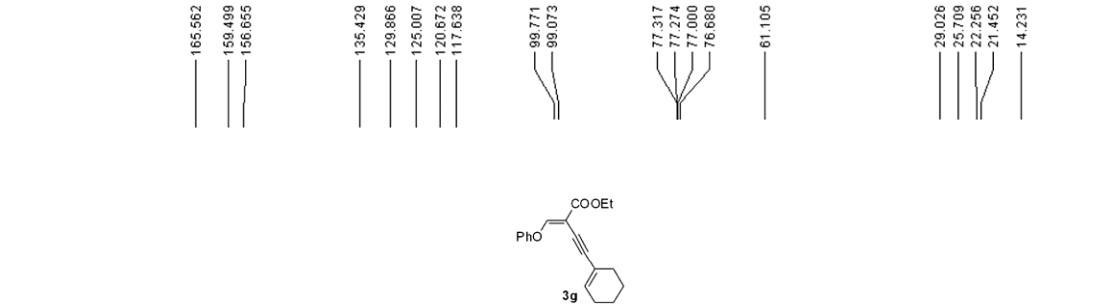
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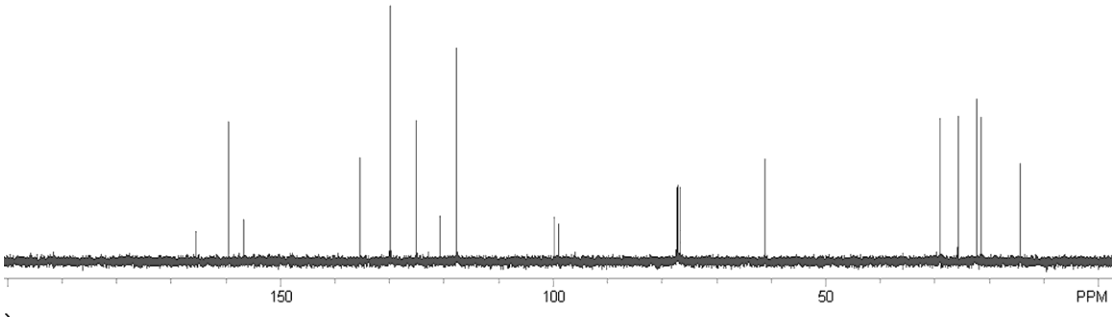
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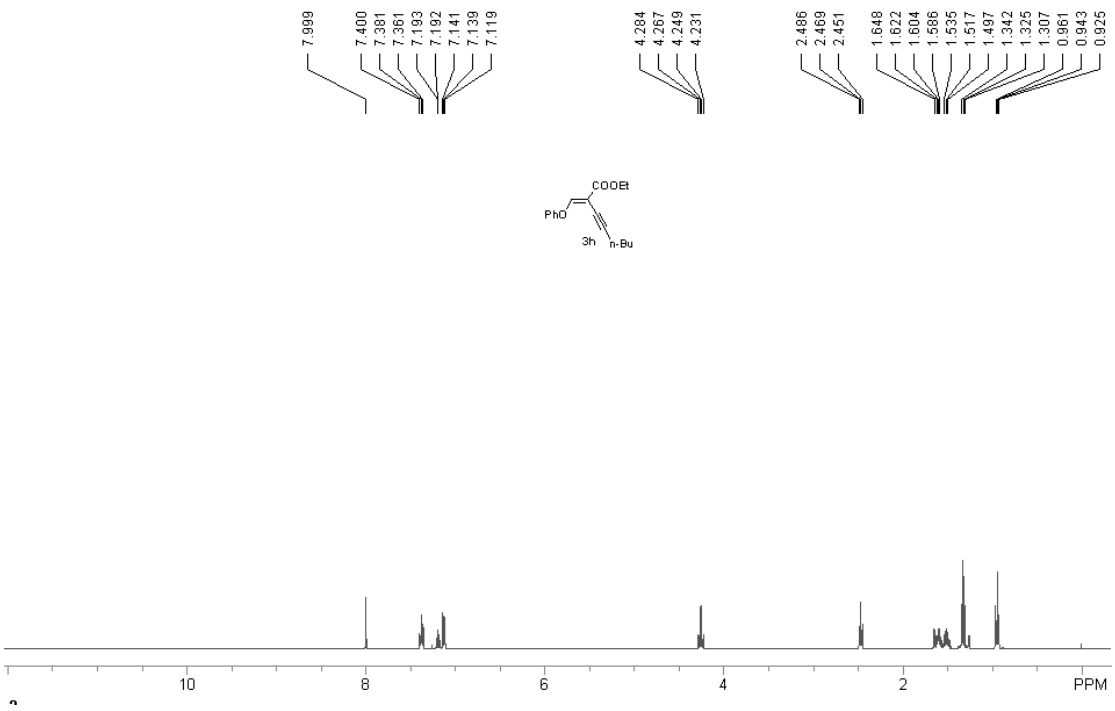
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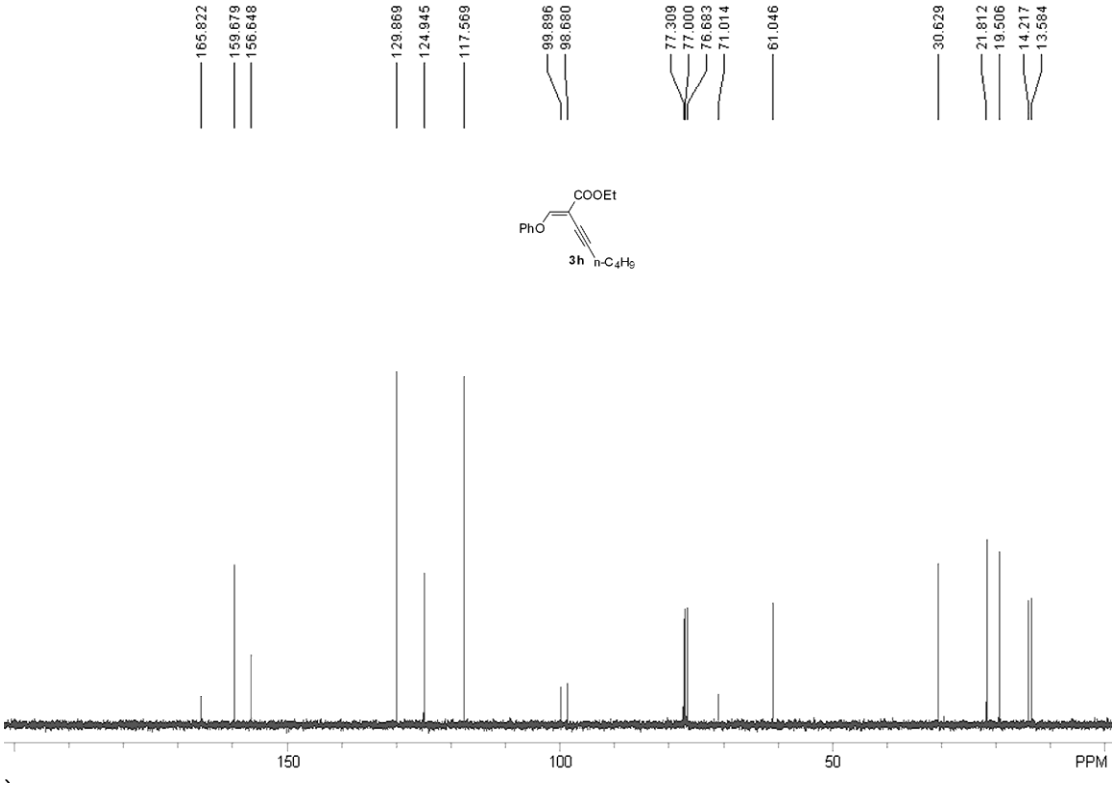
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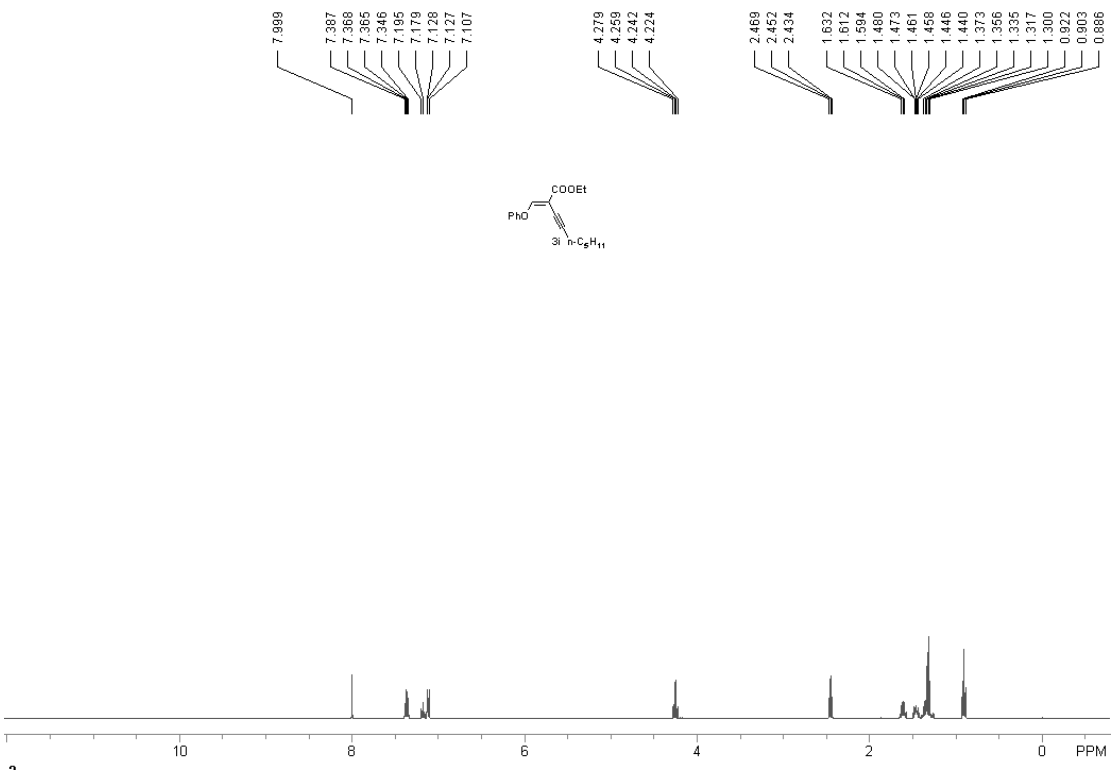
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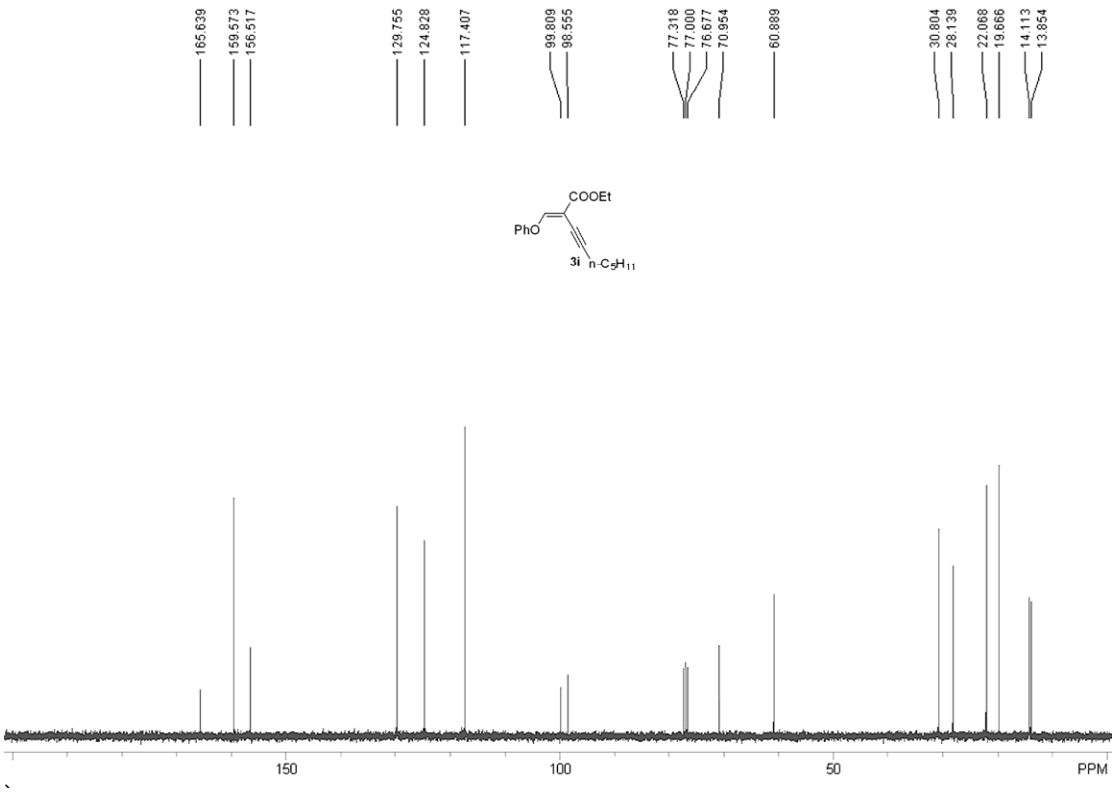
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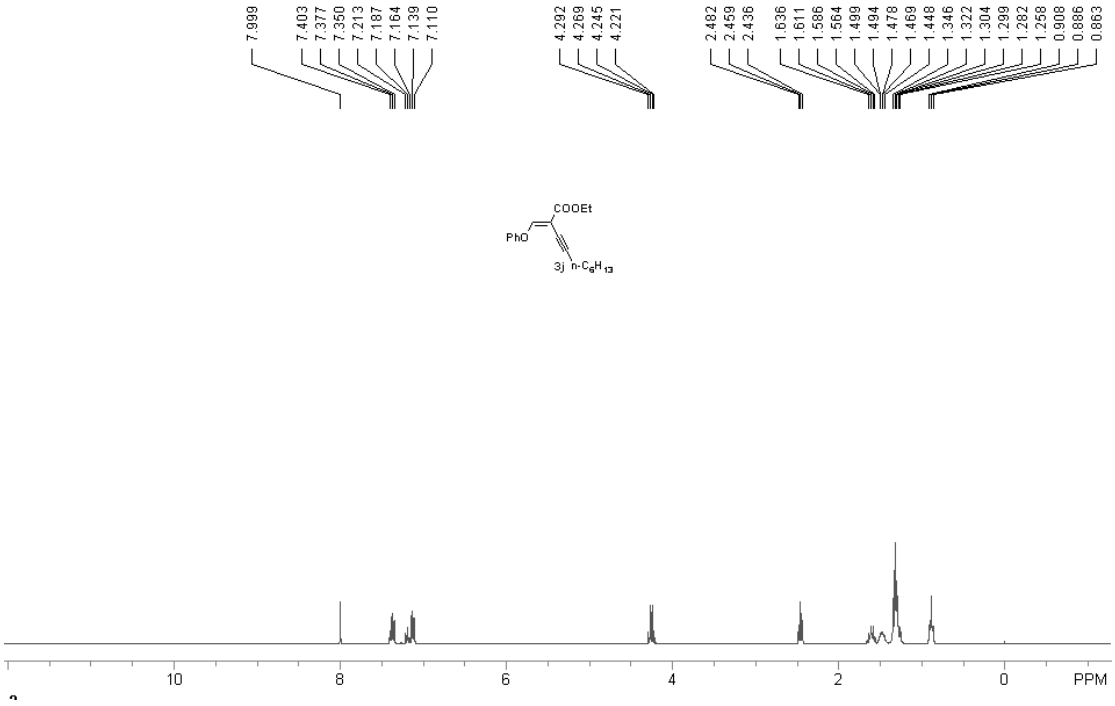
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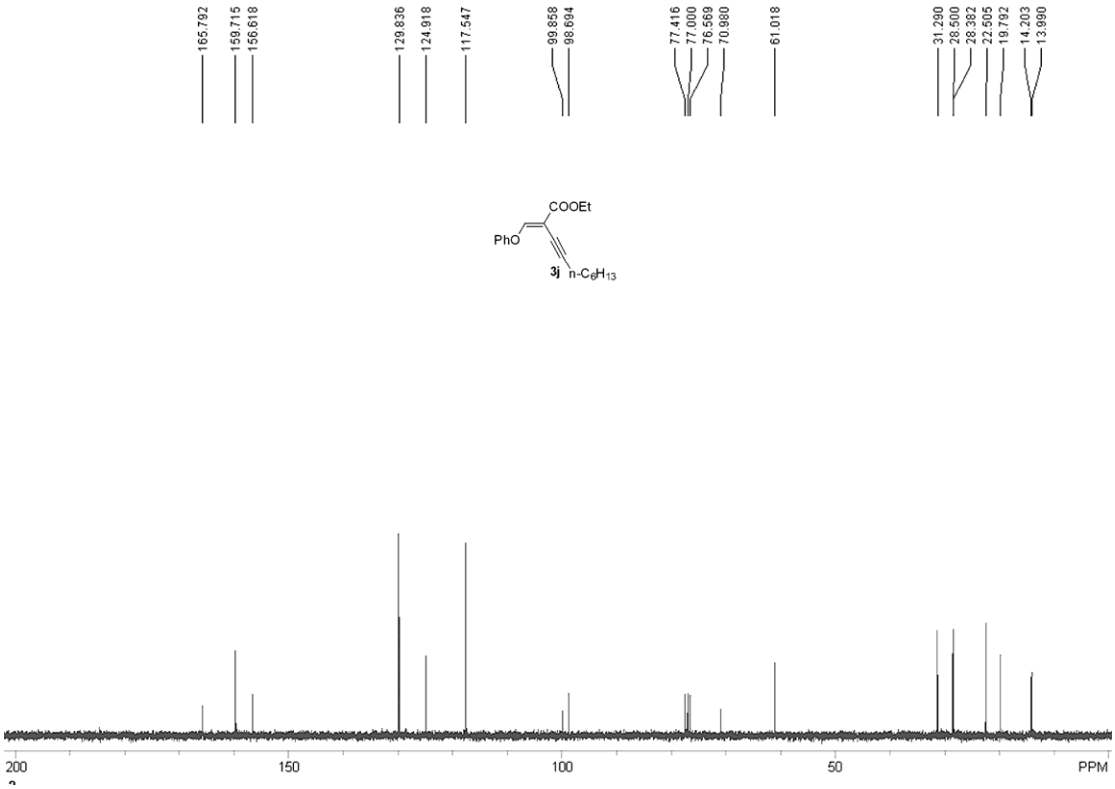
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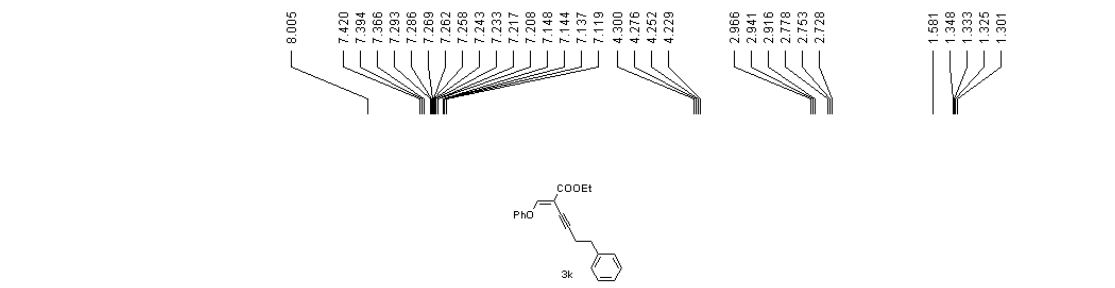
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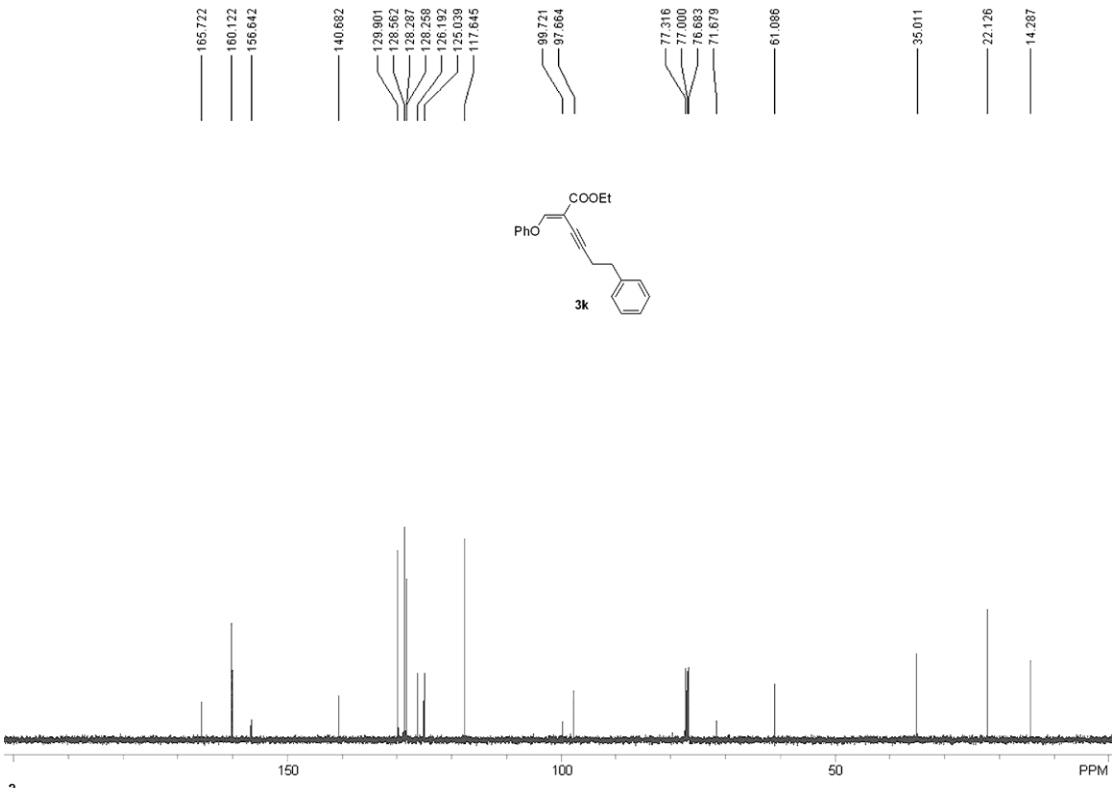
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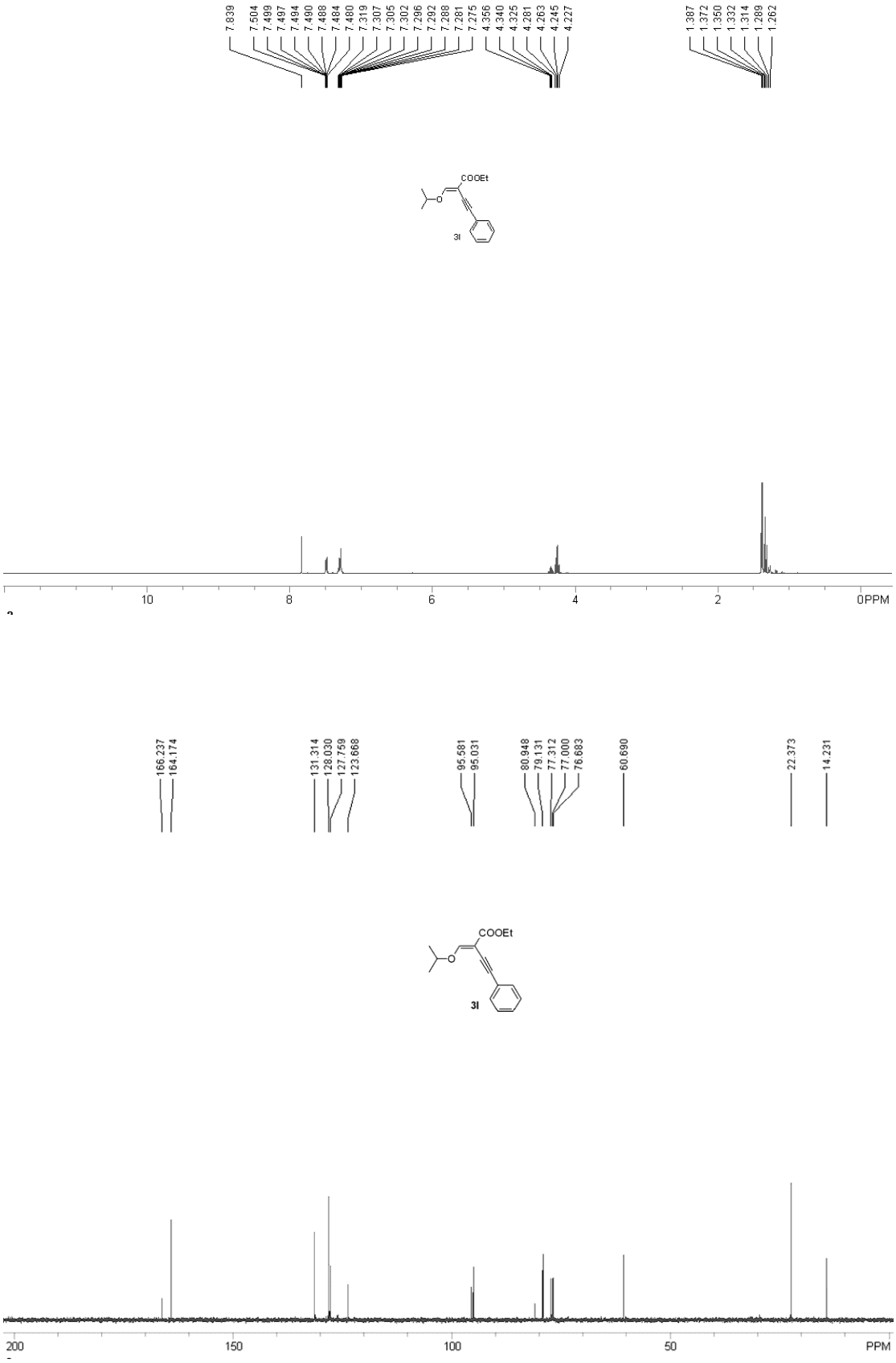
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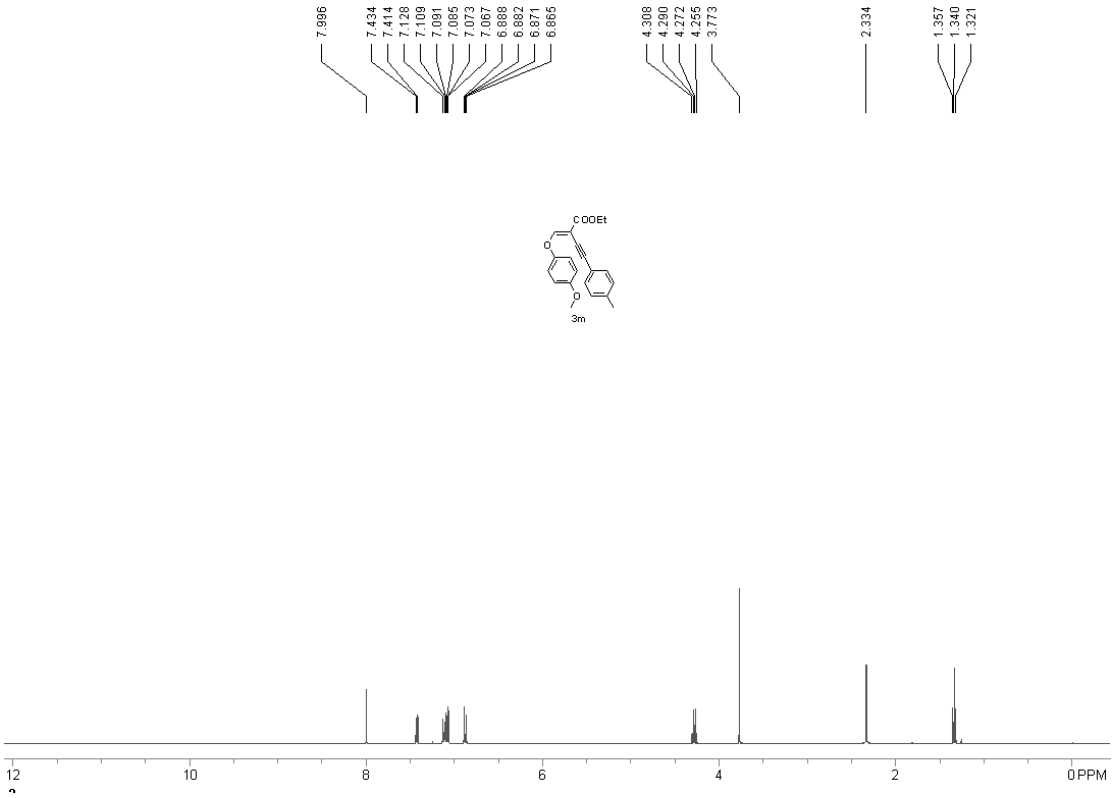
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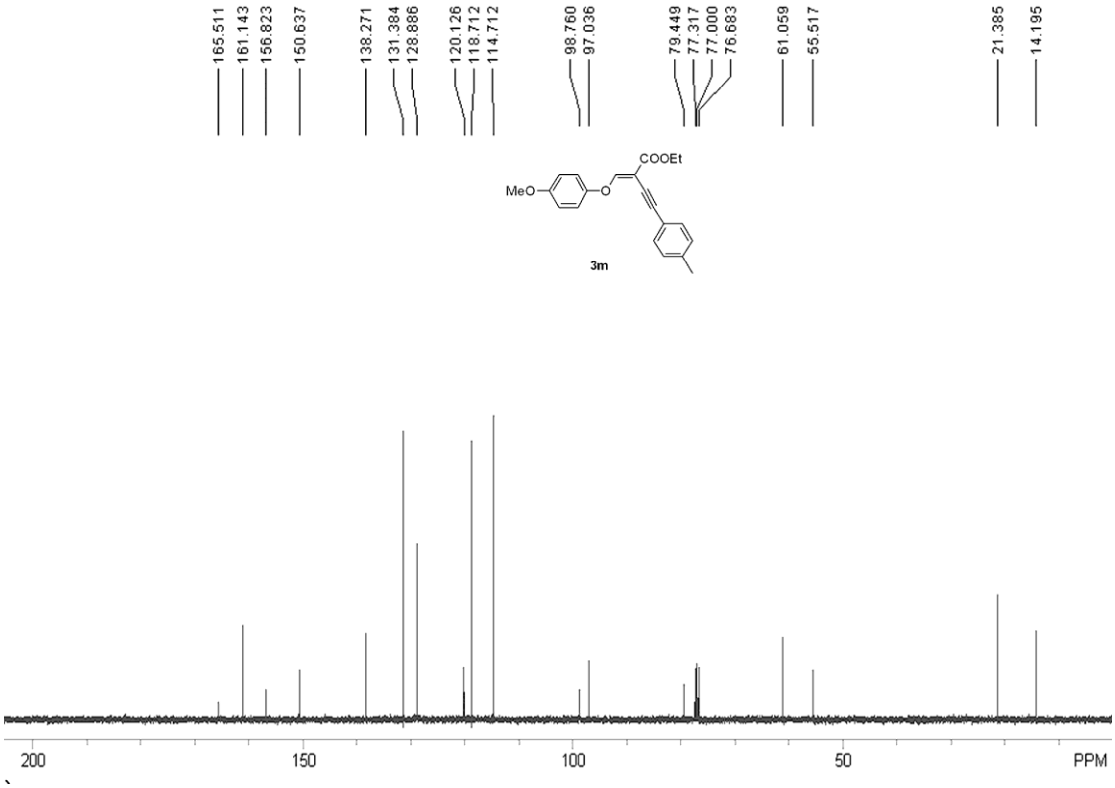
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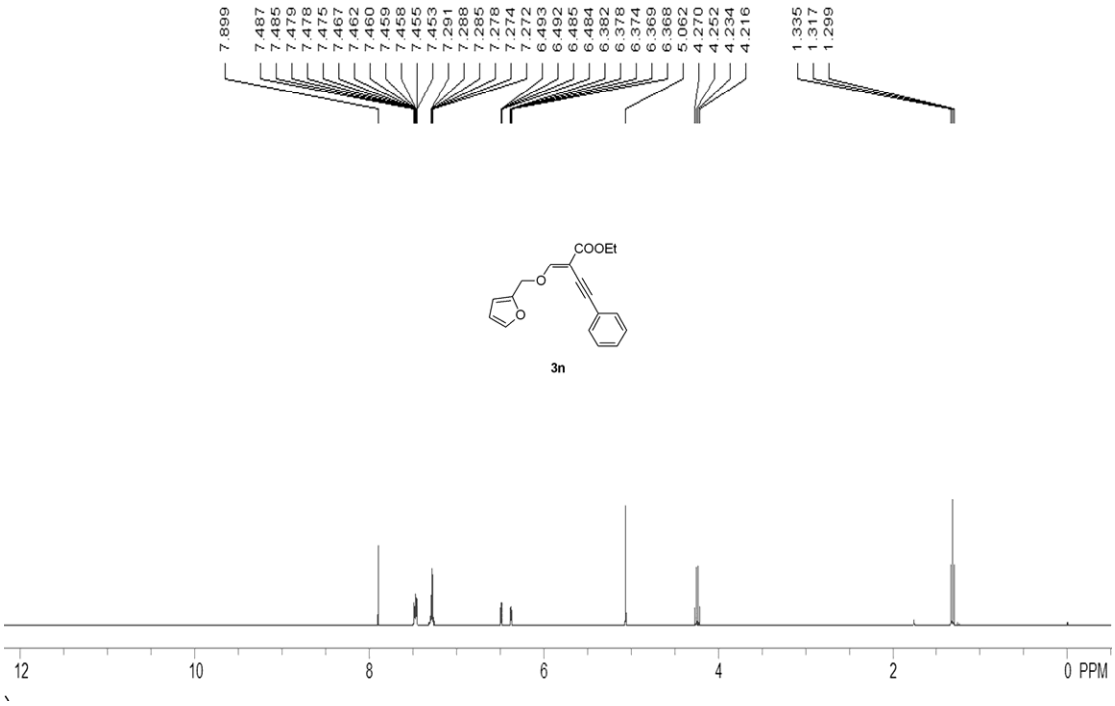
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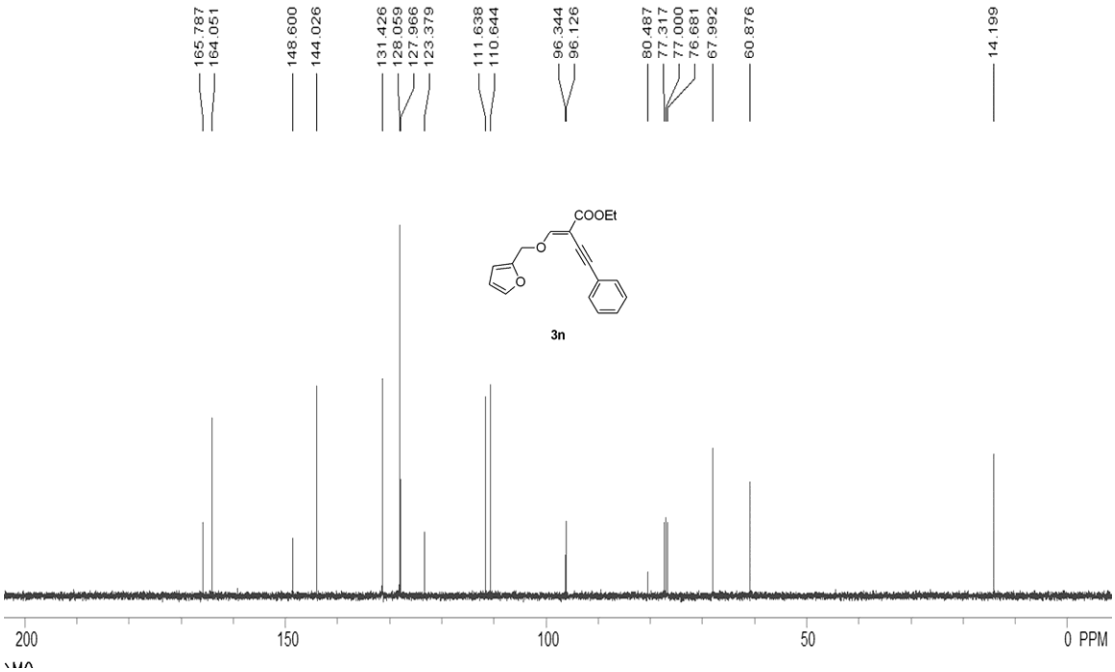
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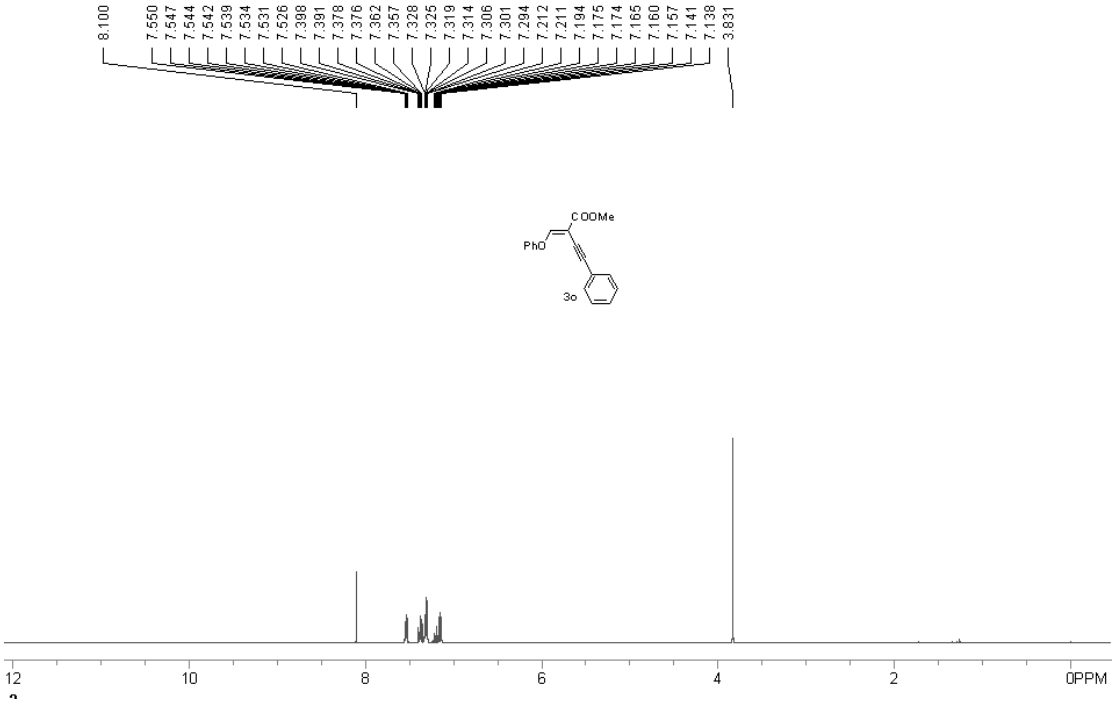
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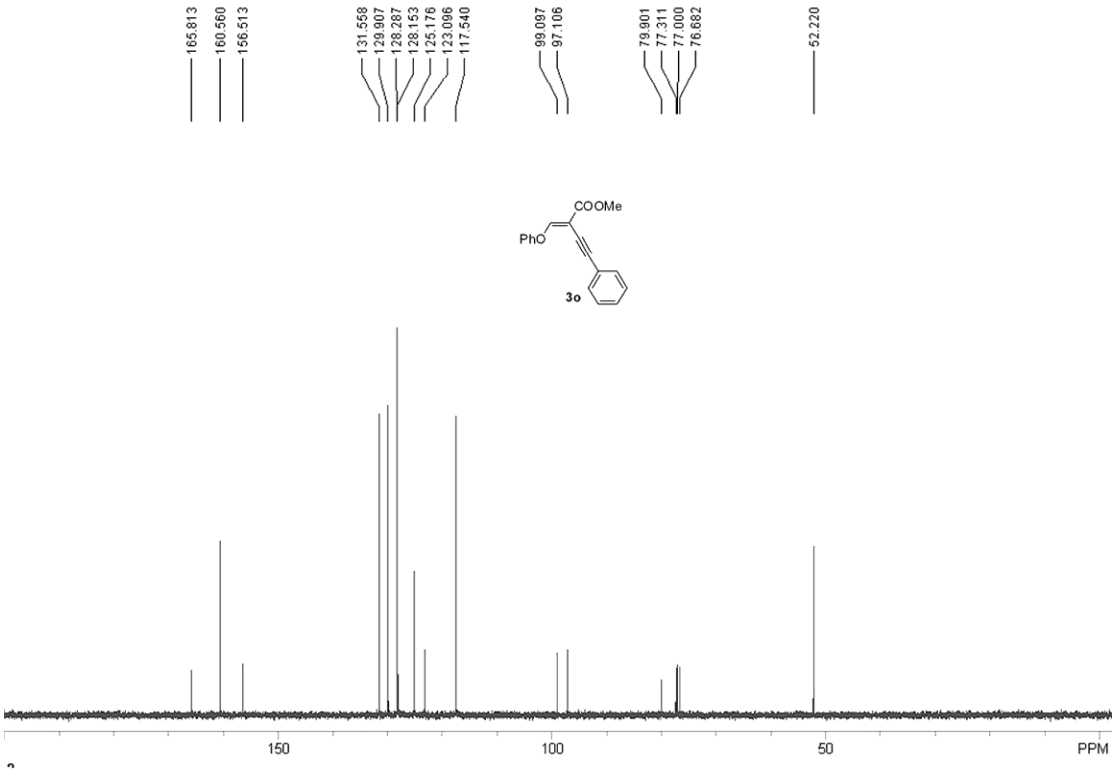
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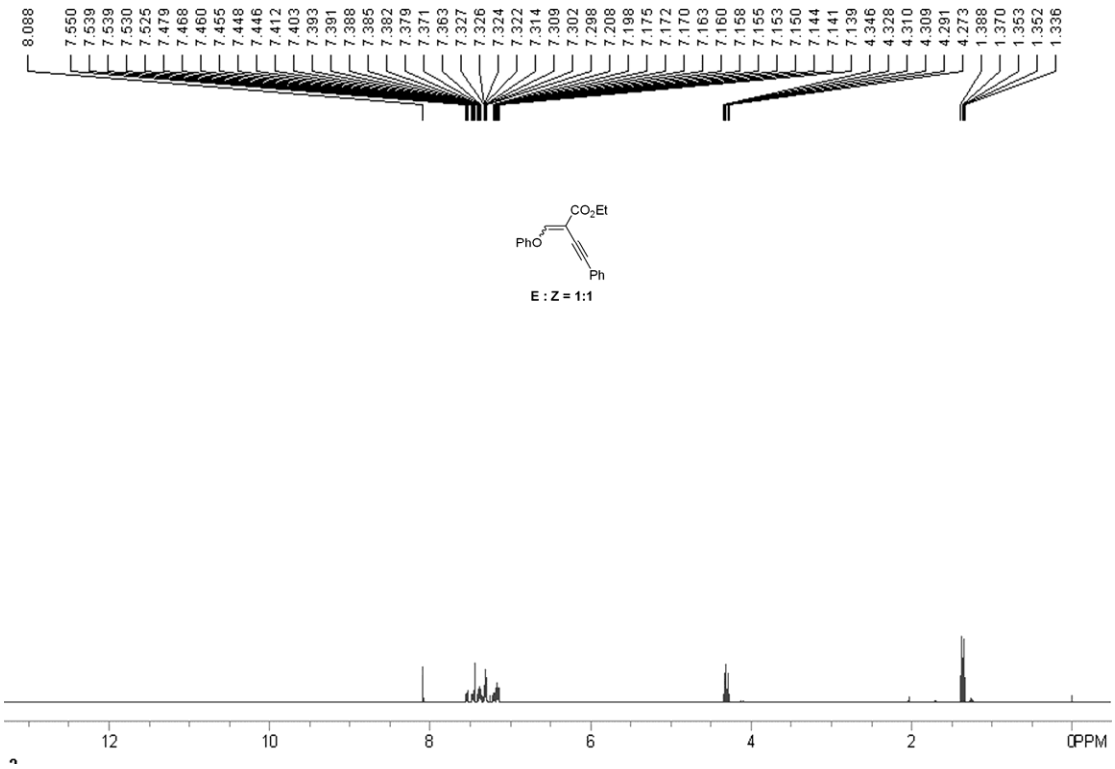
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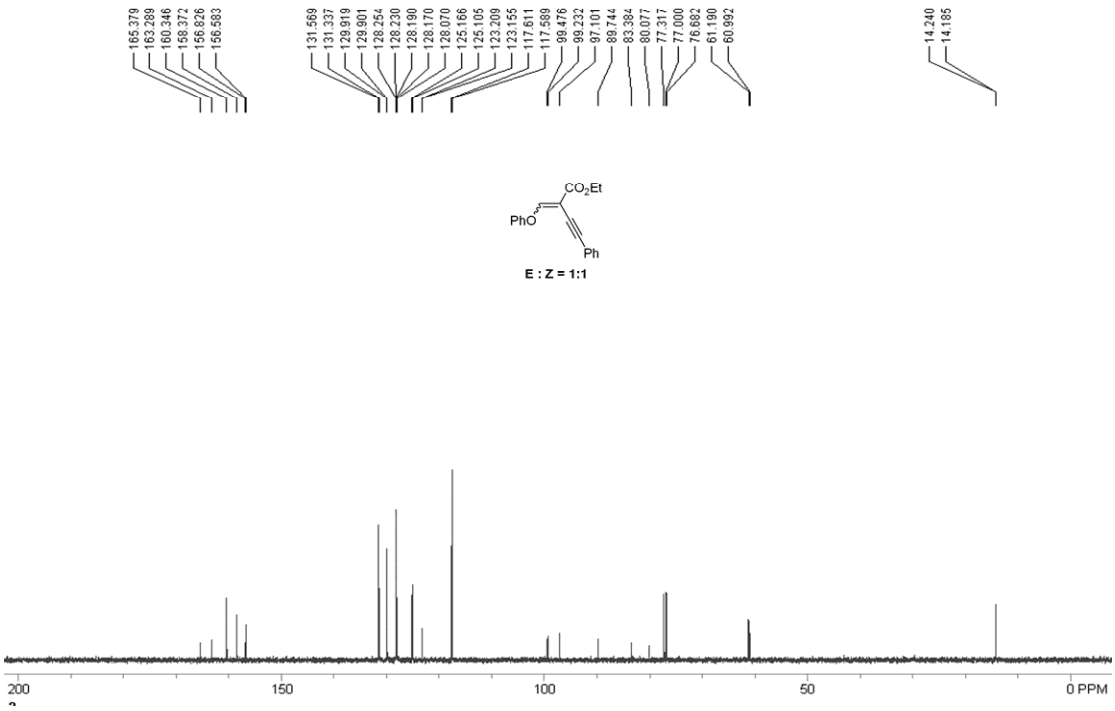
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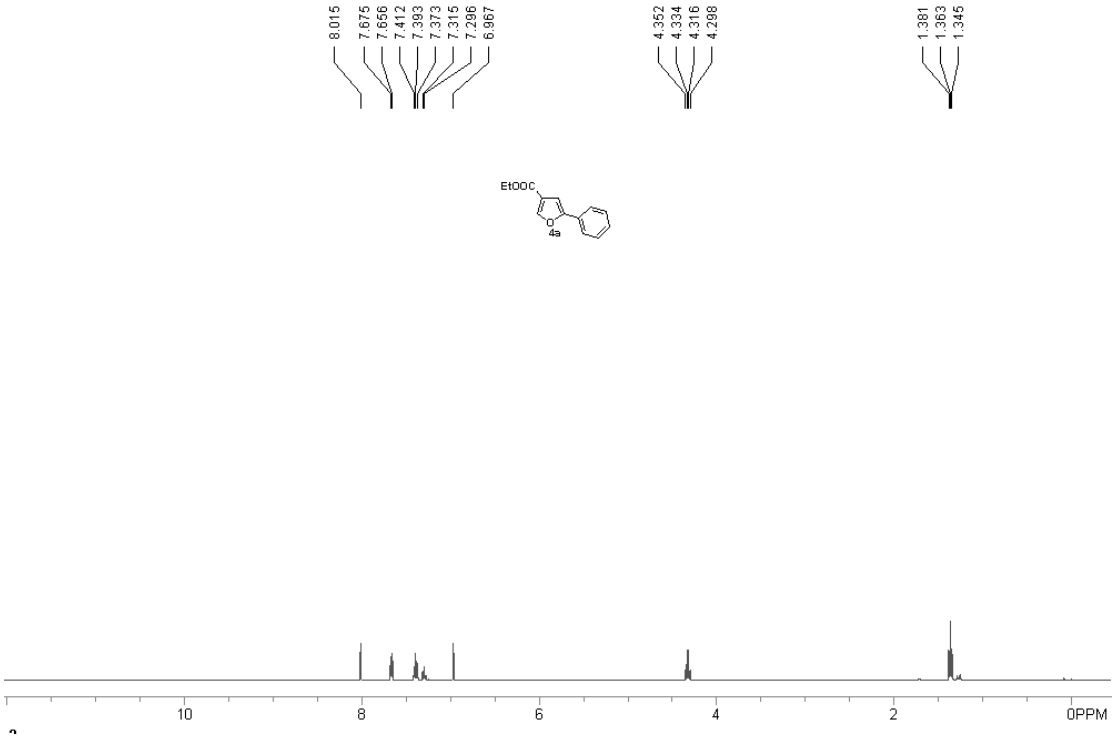
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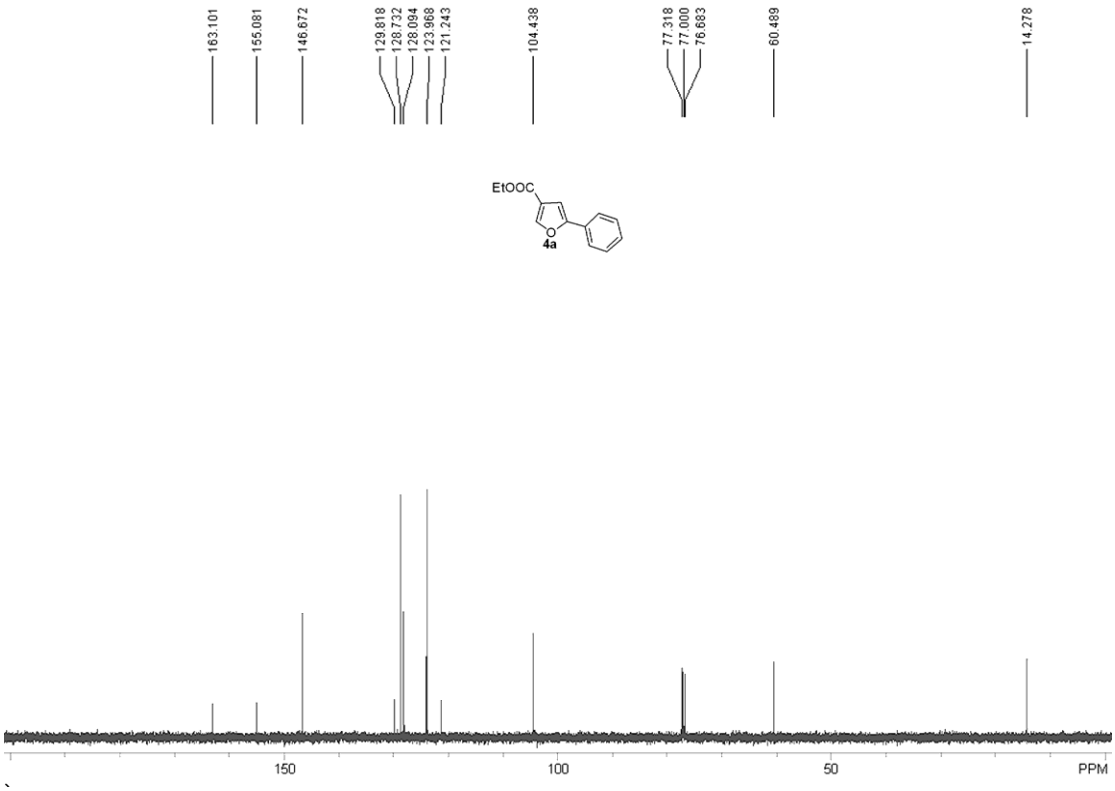
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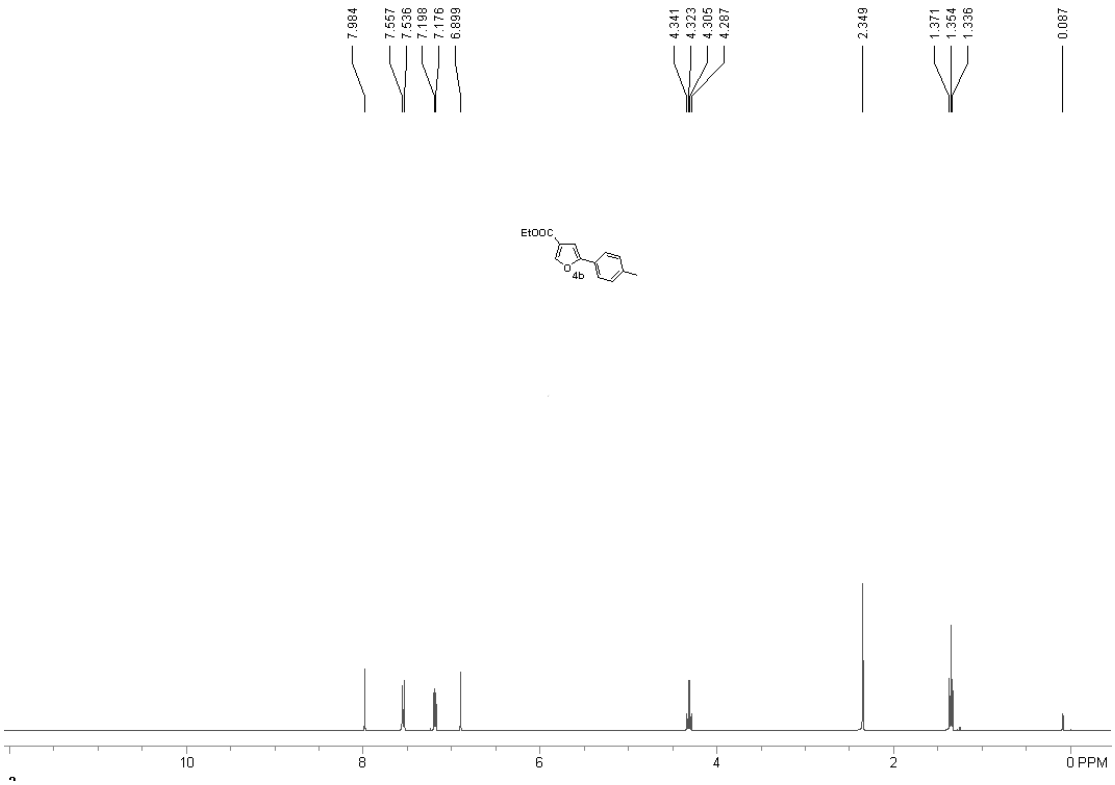
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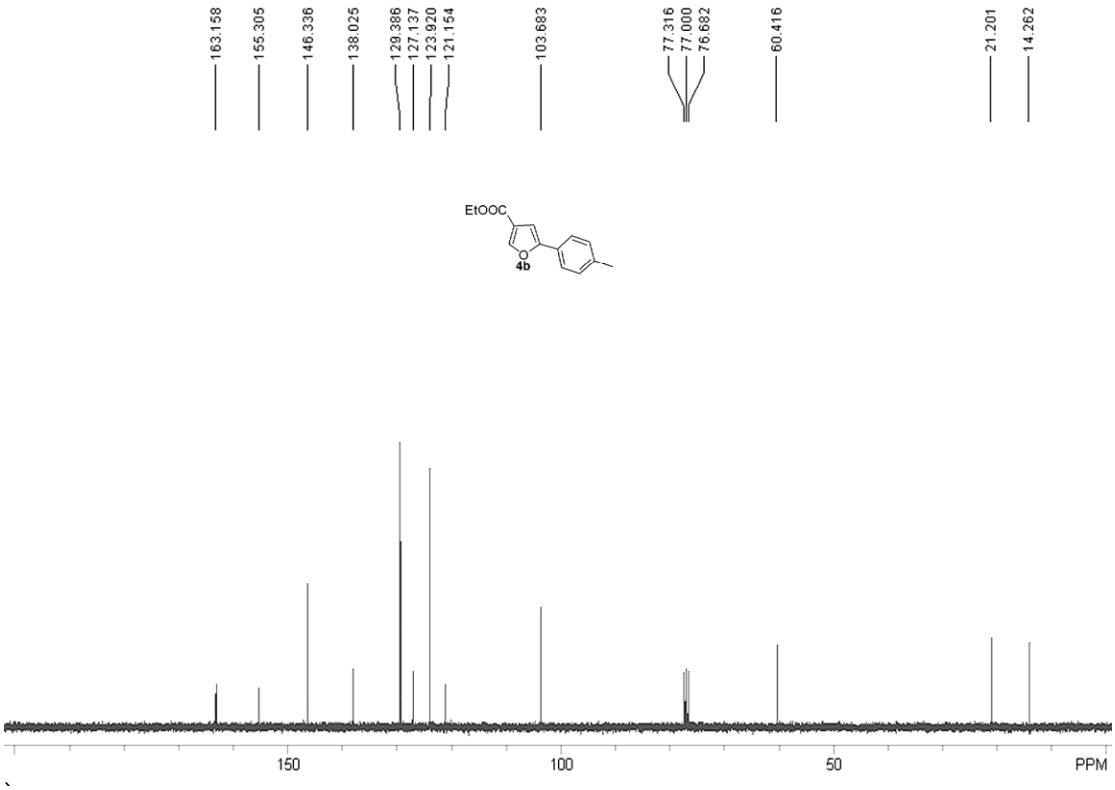
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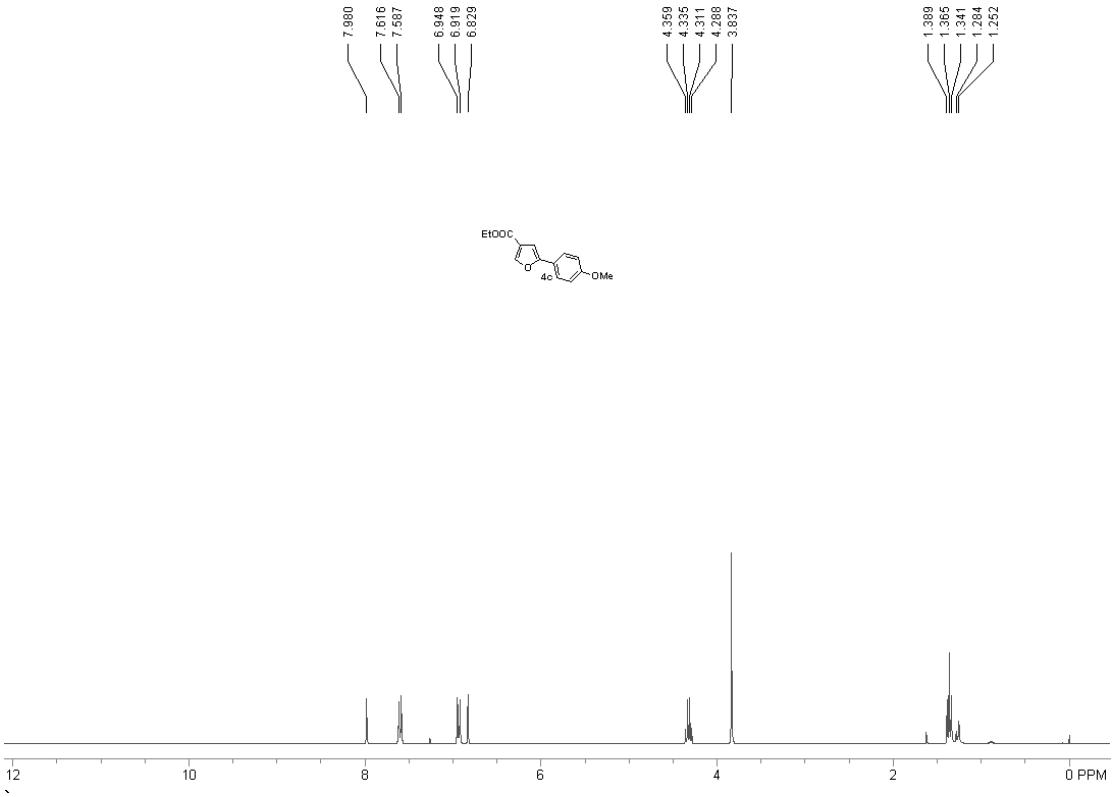
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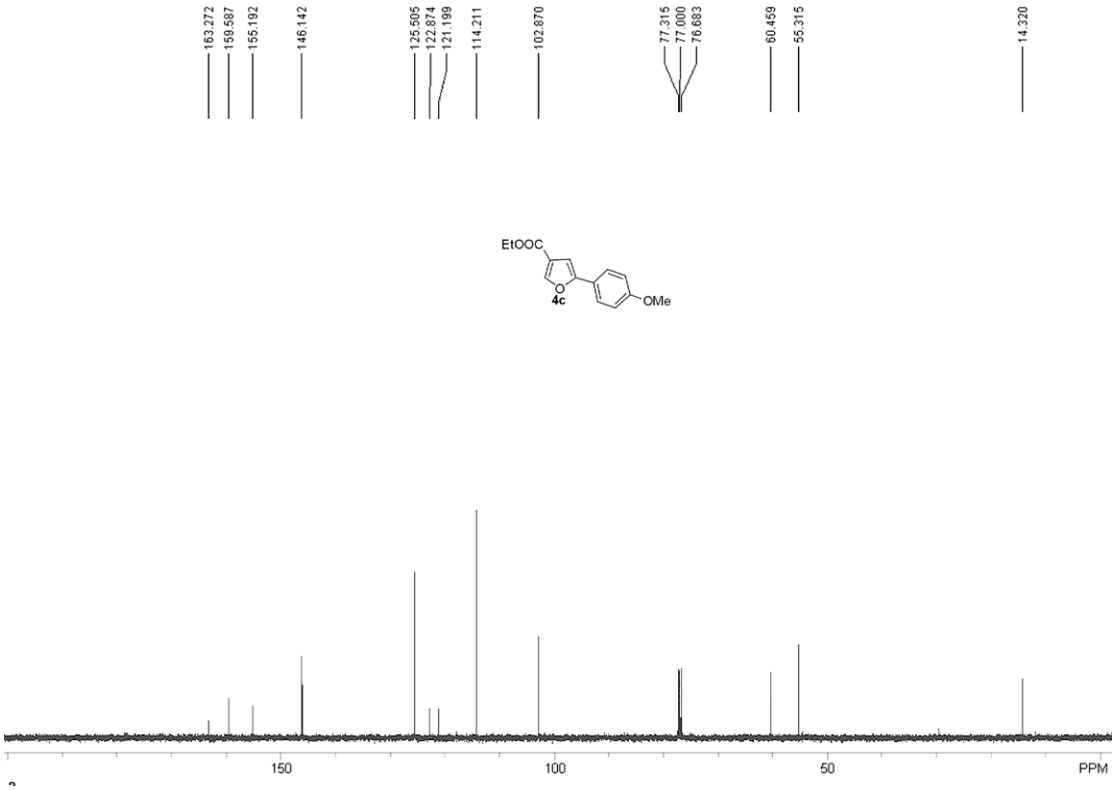
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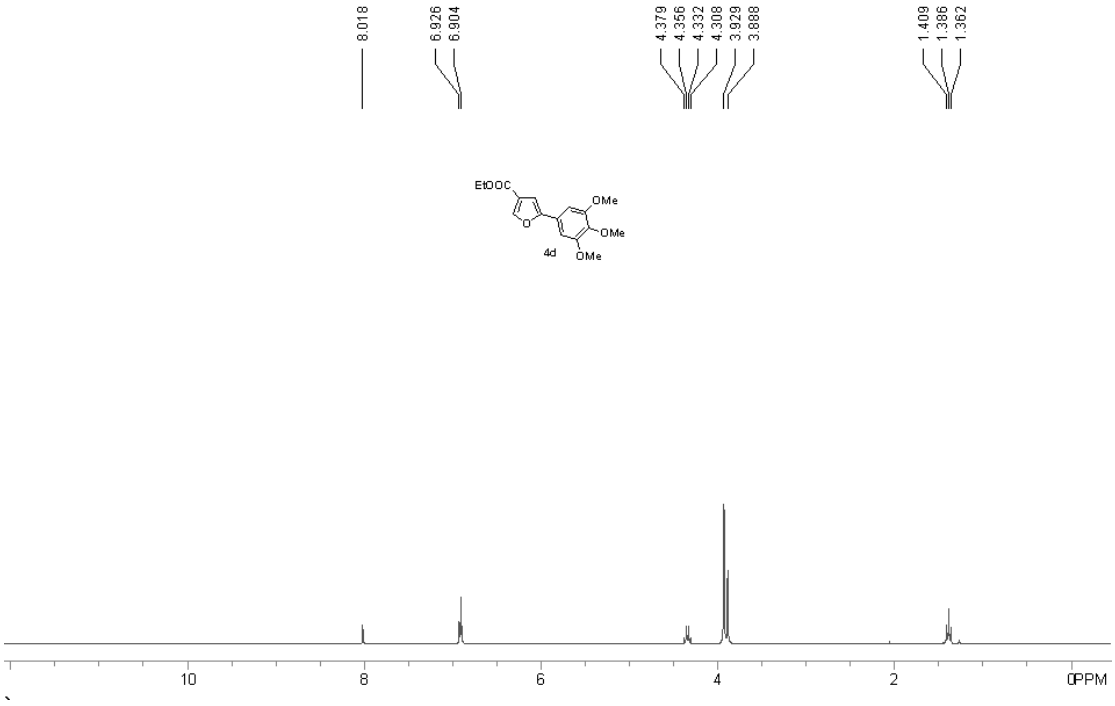
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OMe
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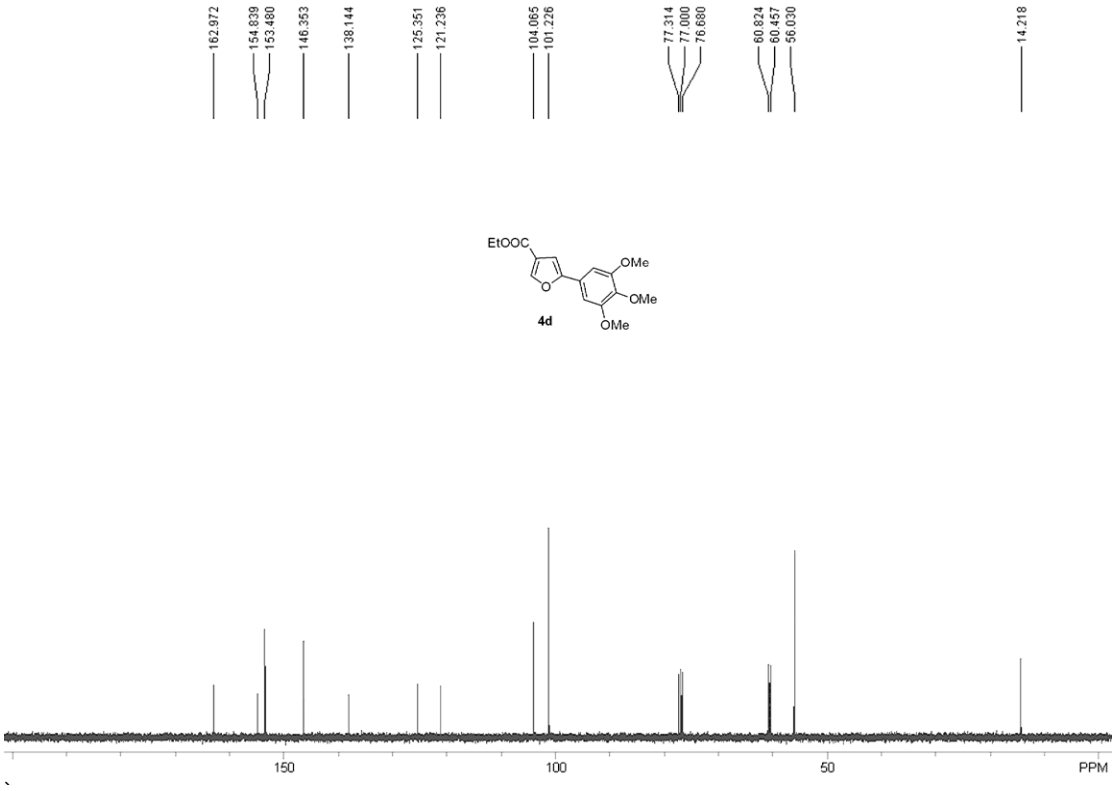
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OMe
OMe
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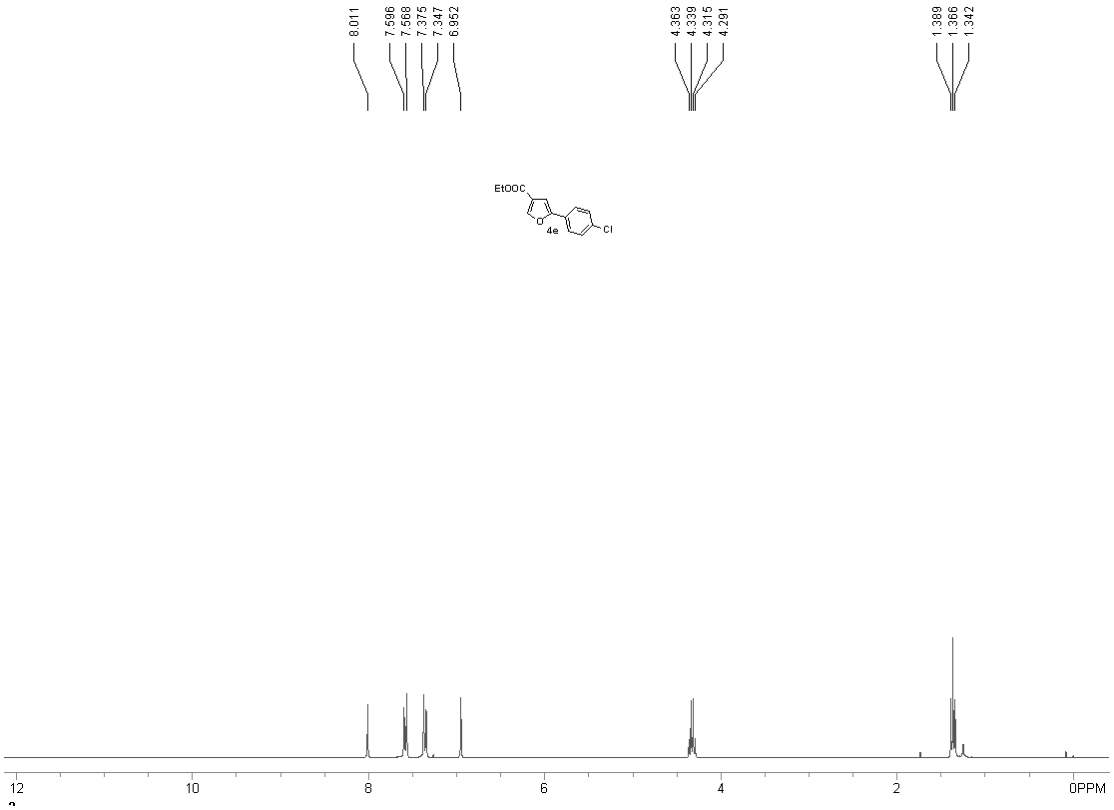
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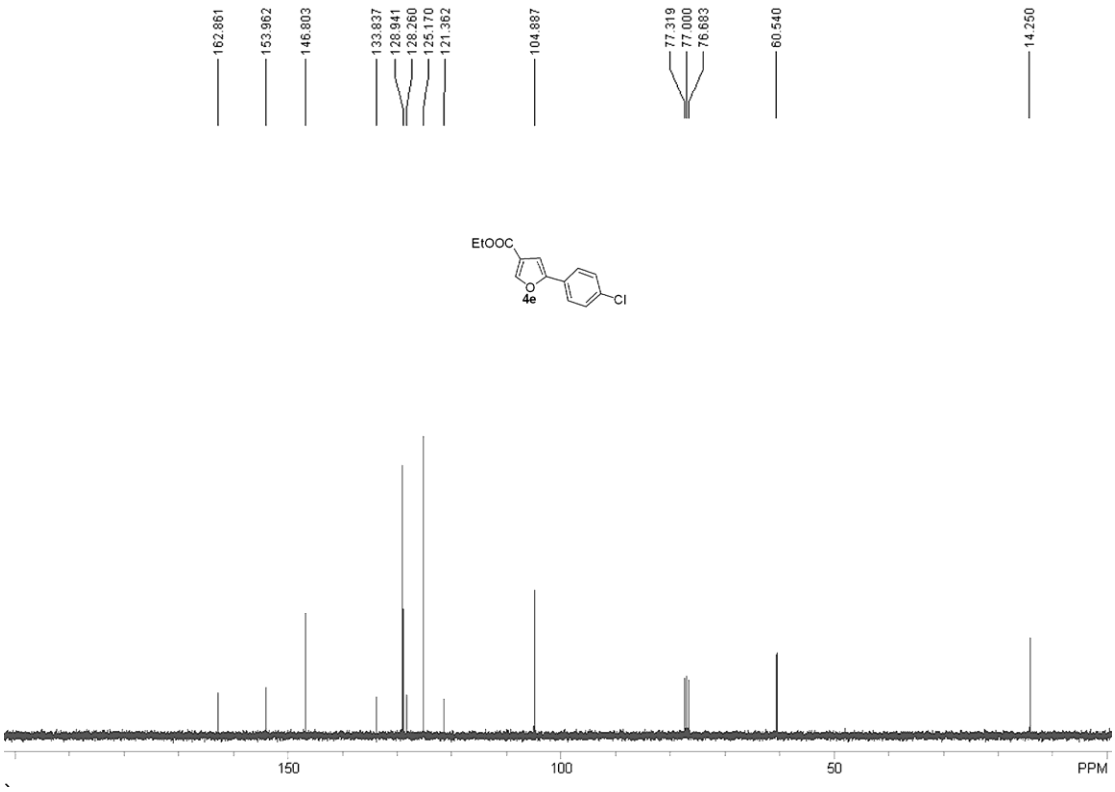
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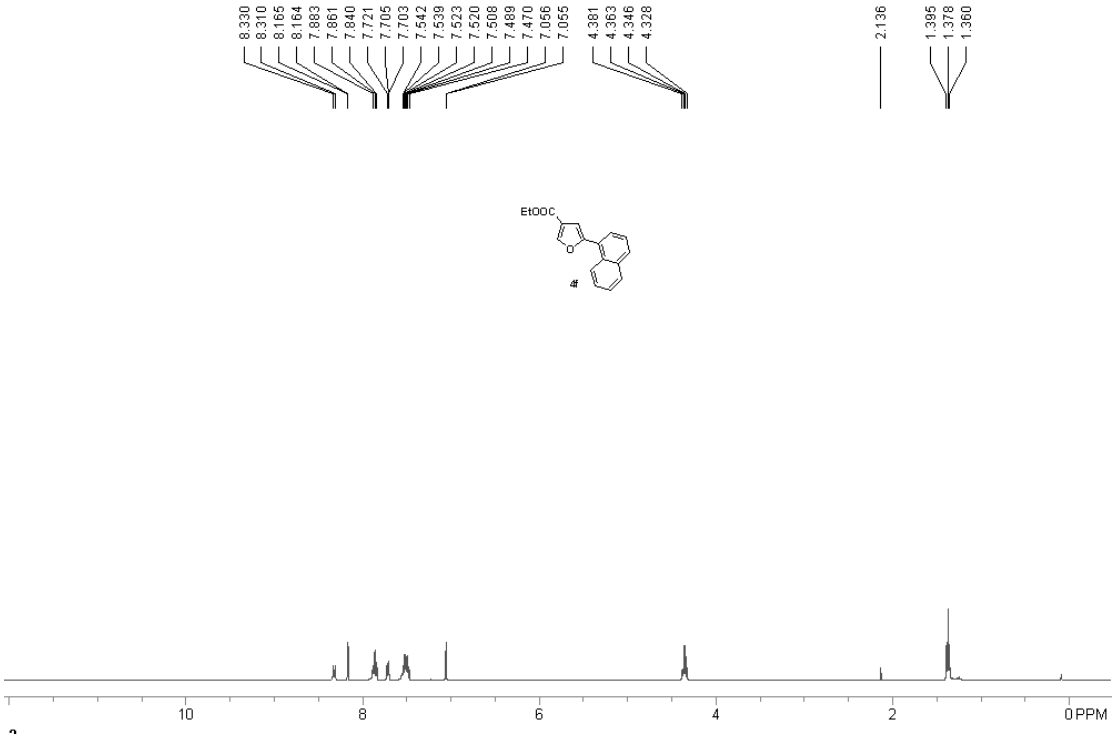
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7.523
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7.055
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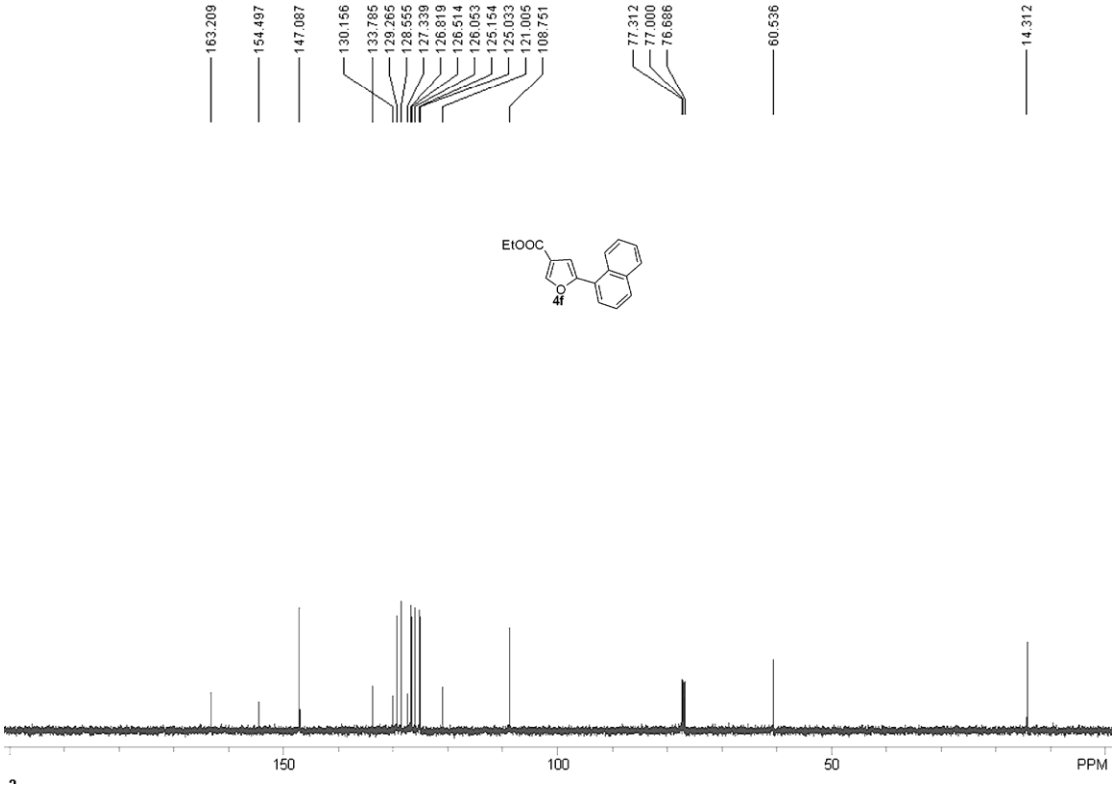
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125.033
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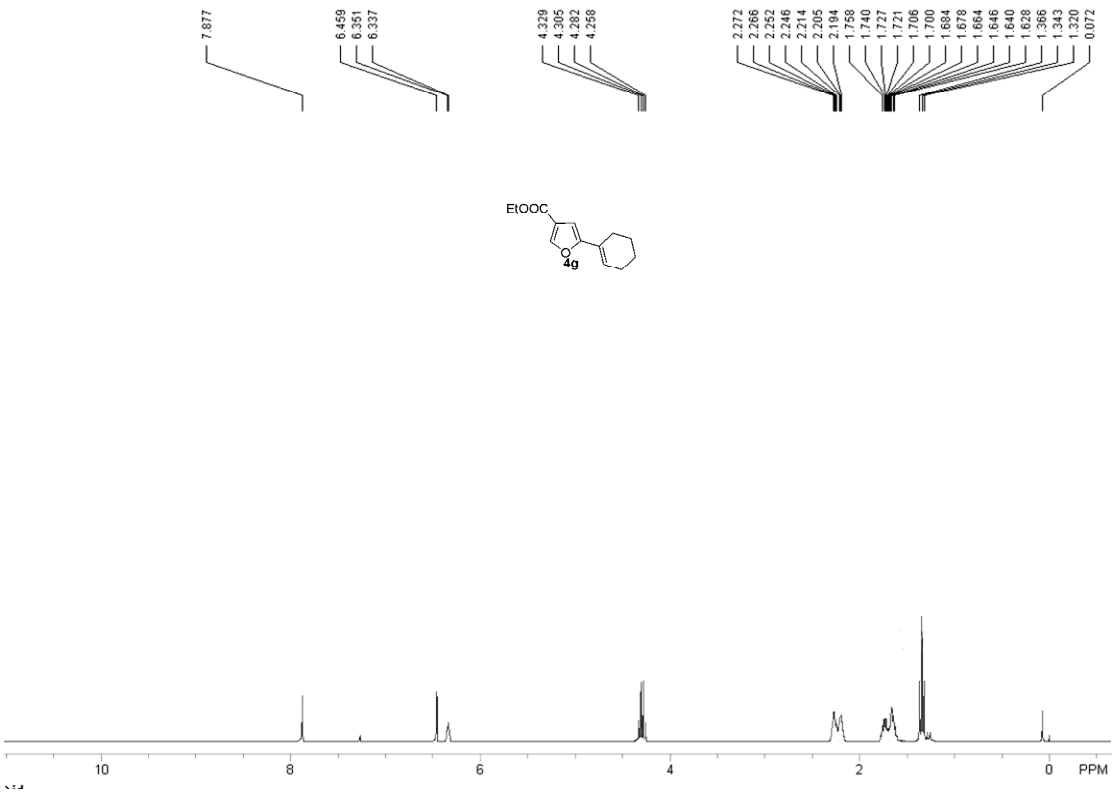
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1.678
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1.646
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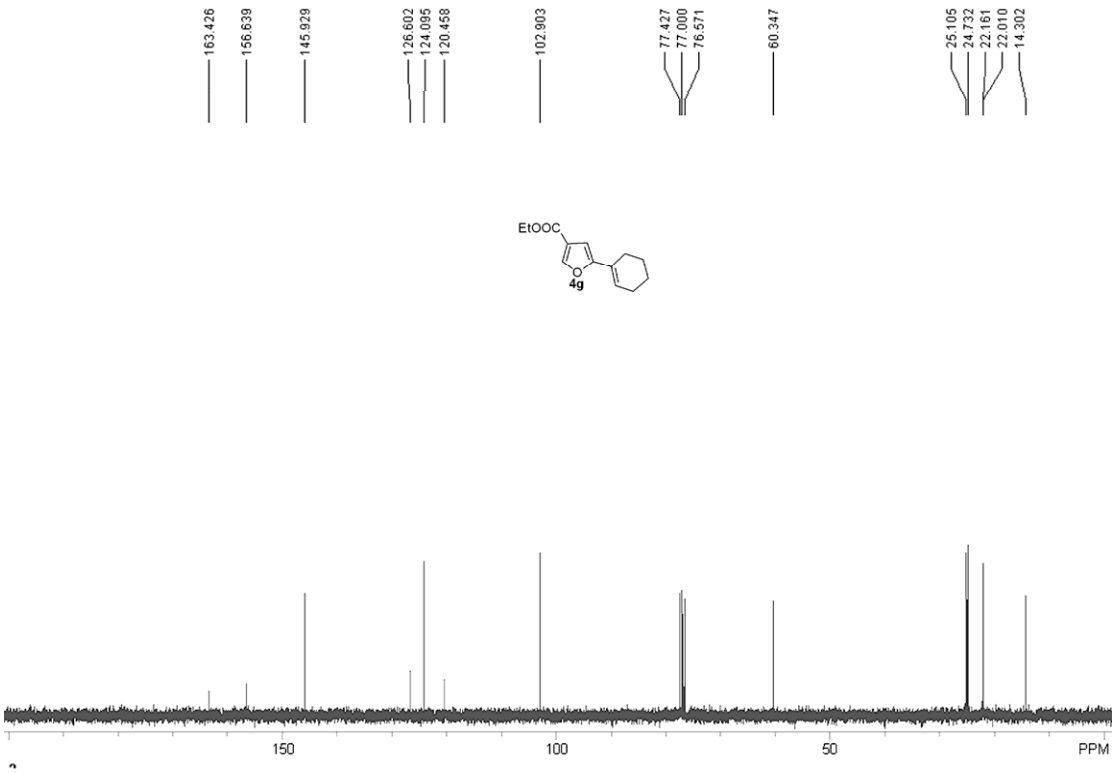
PPM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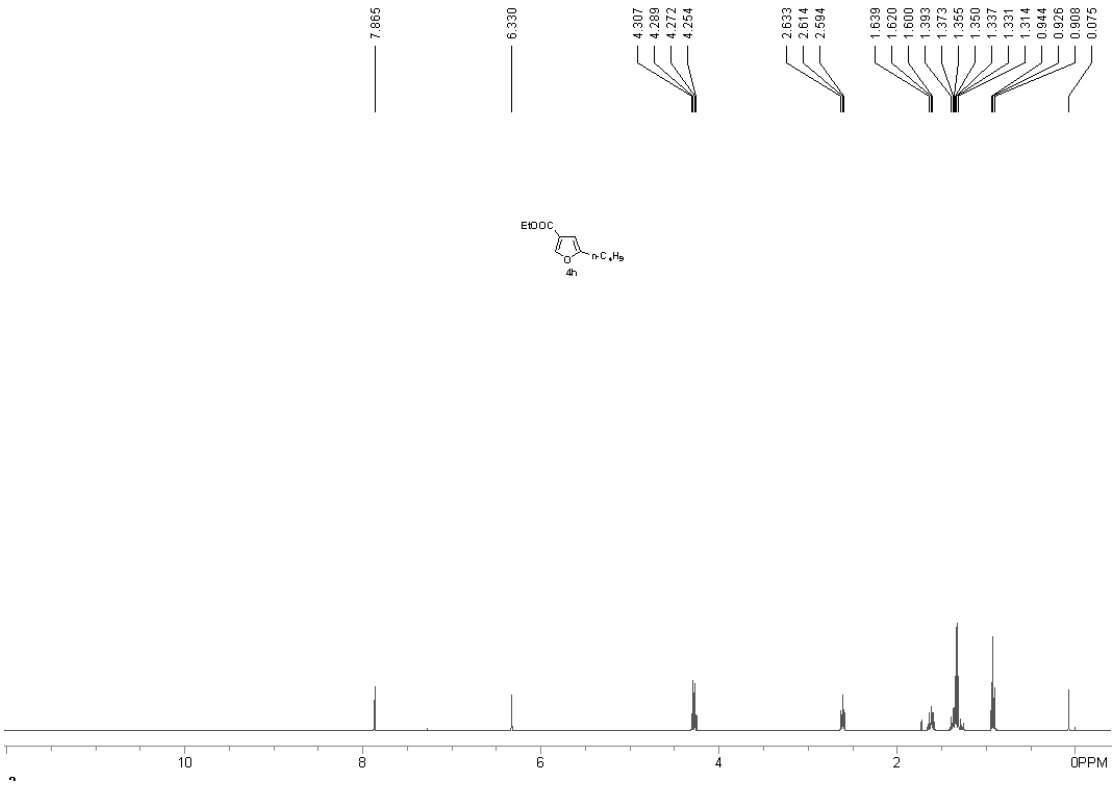
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1.620
1.600
1.393
1.373
1.355
1.350
1.337
1.331
1.314
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0.908
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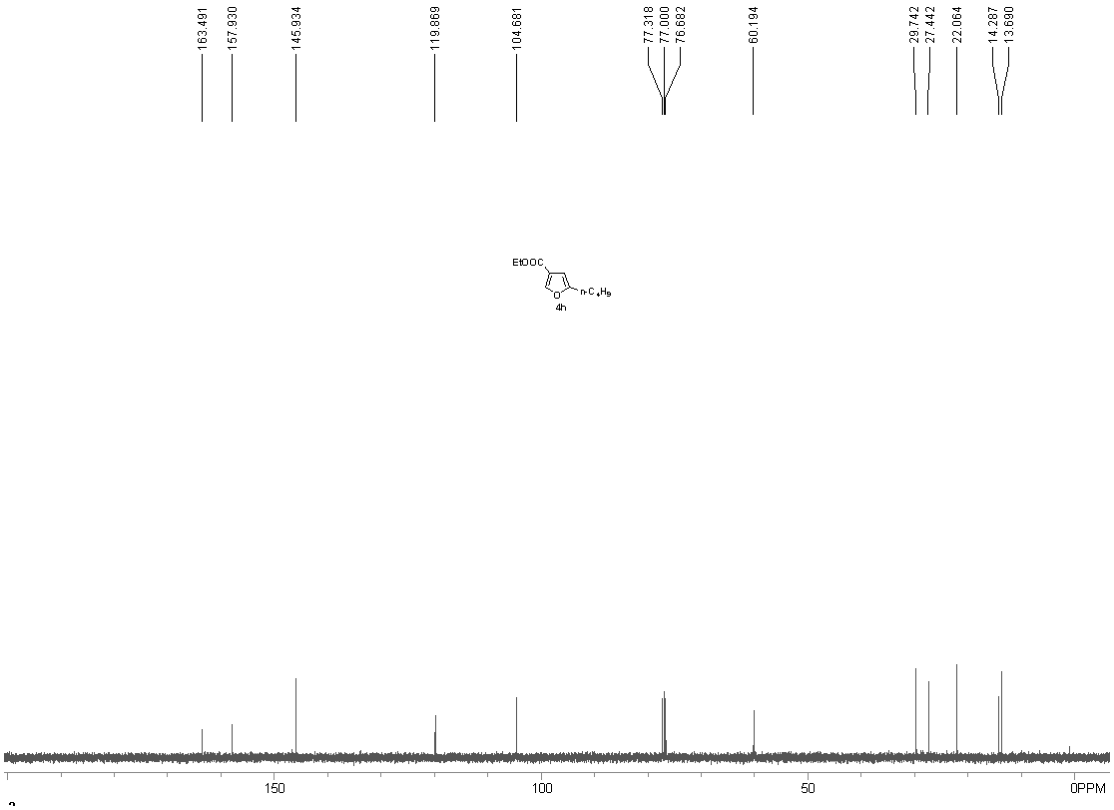
n-C4H9
4h
10
8
6
4
2
0PPM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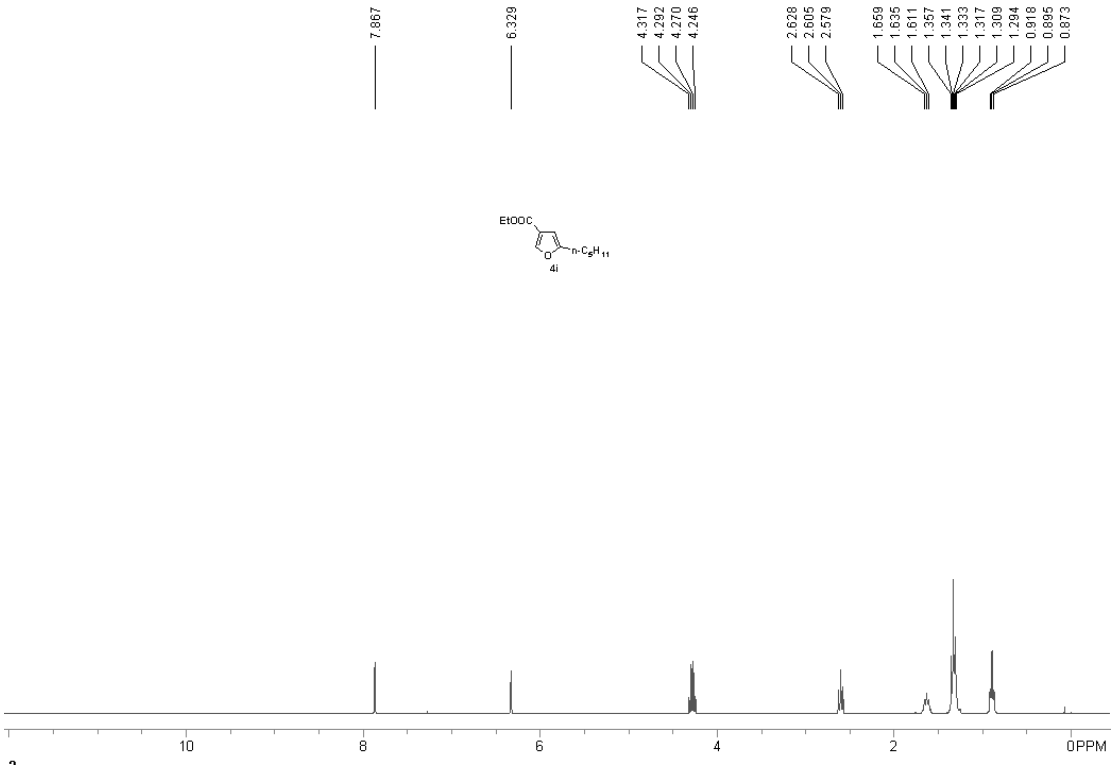
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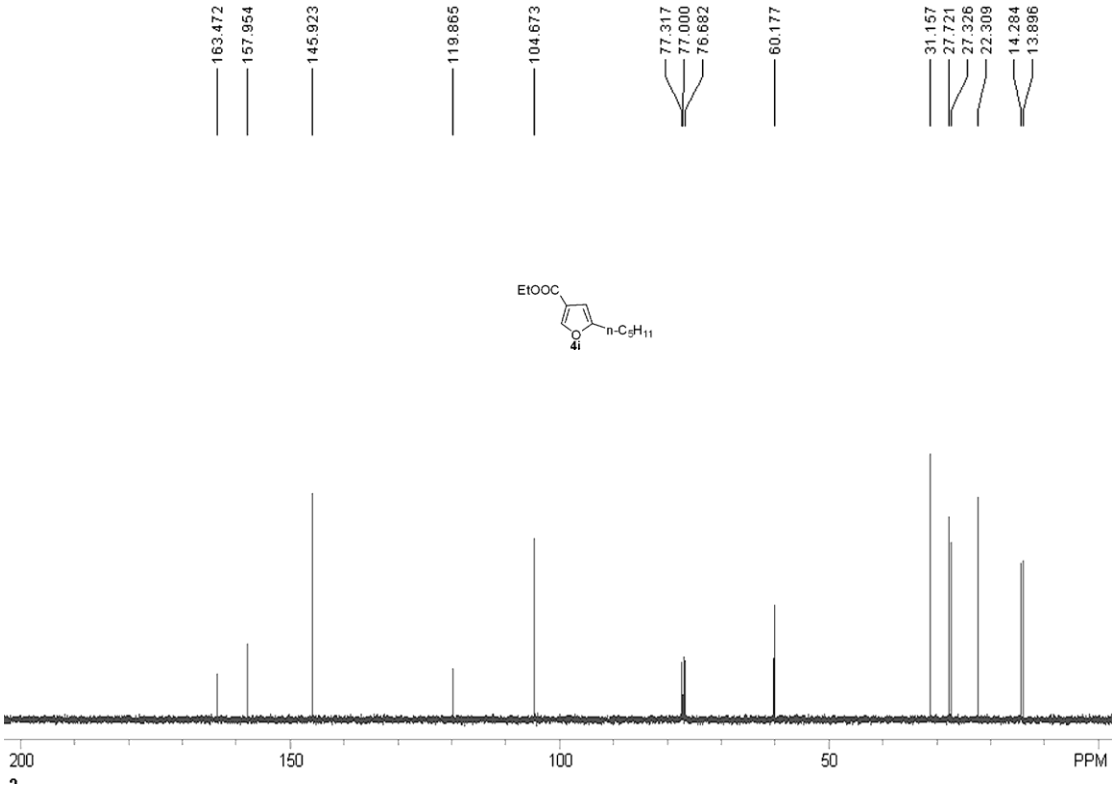
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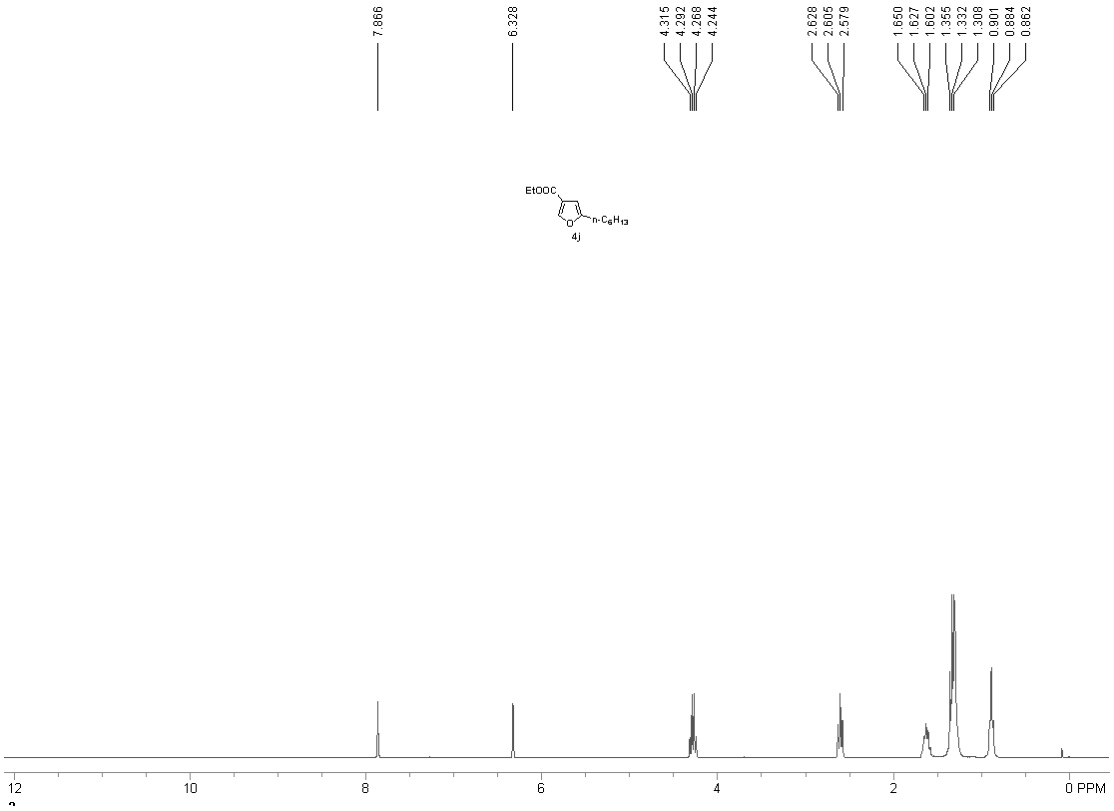
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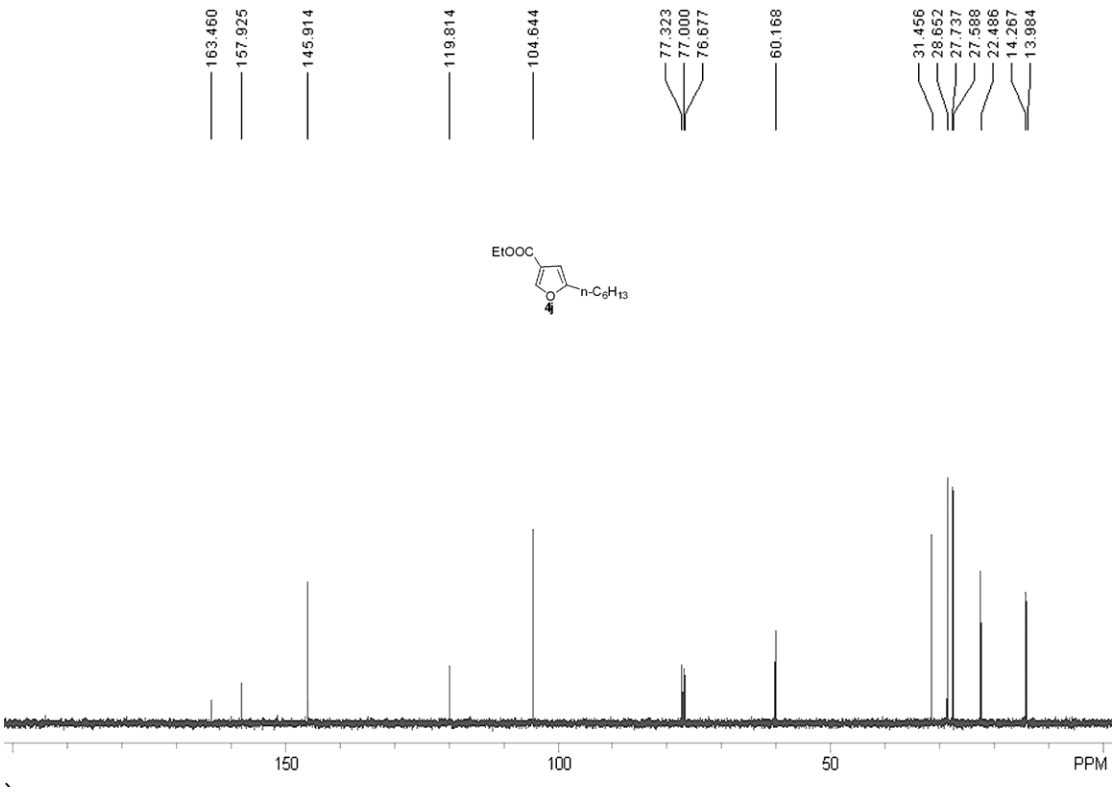
0 PPM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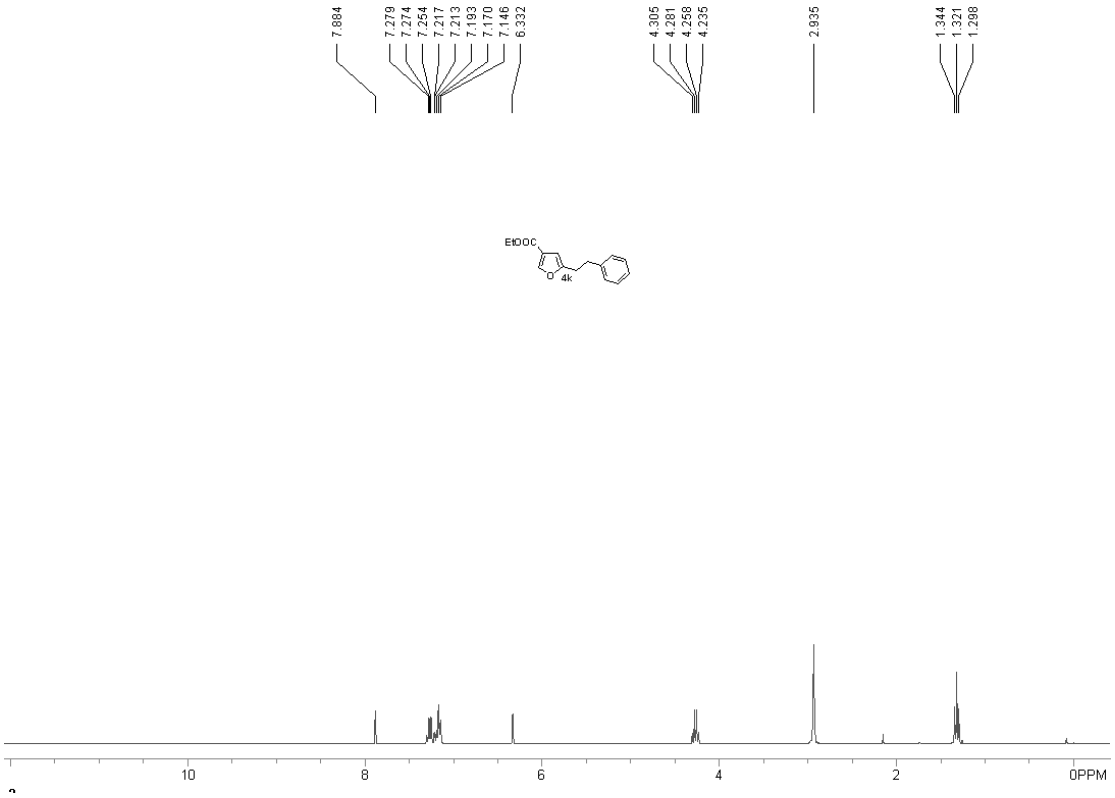
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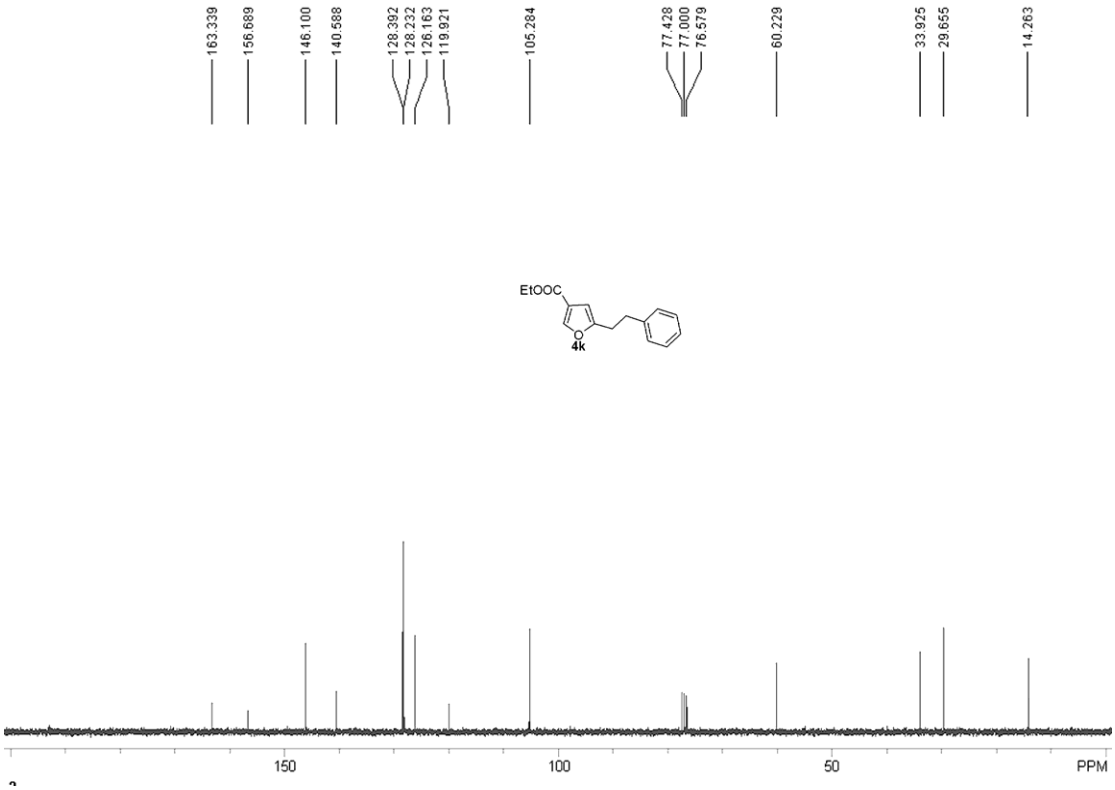
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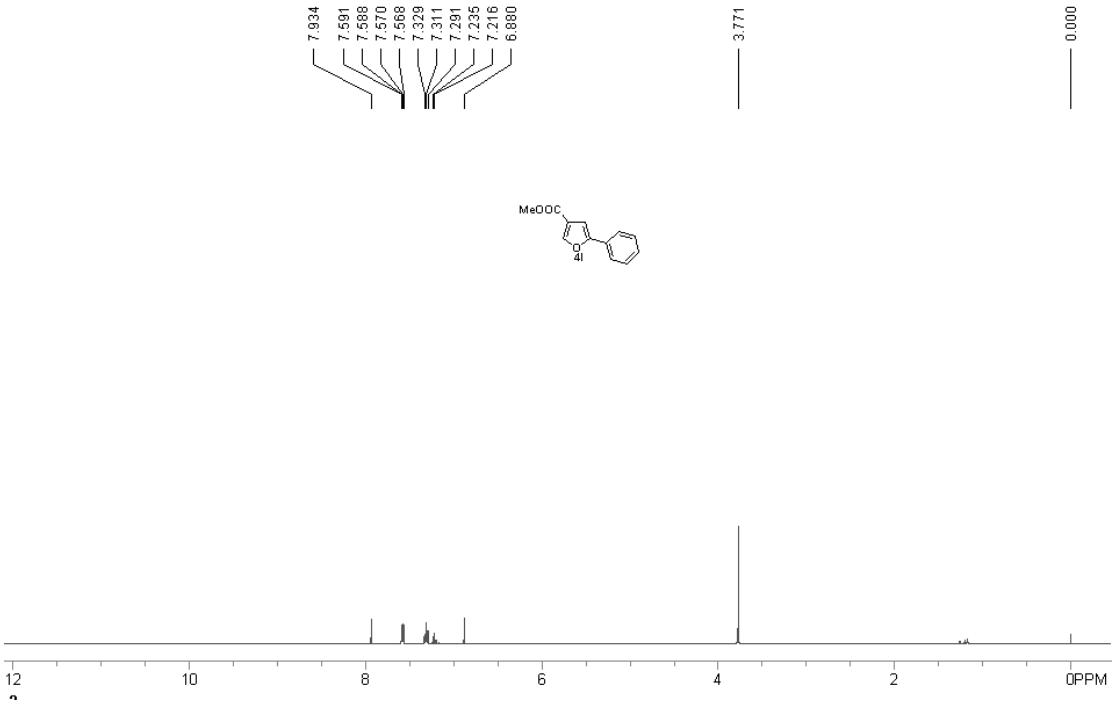
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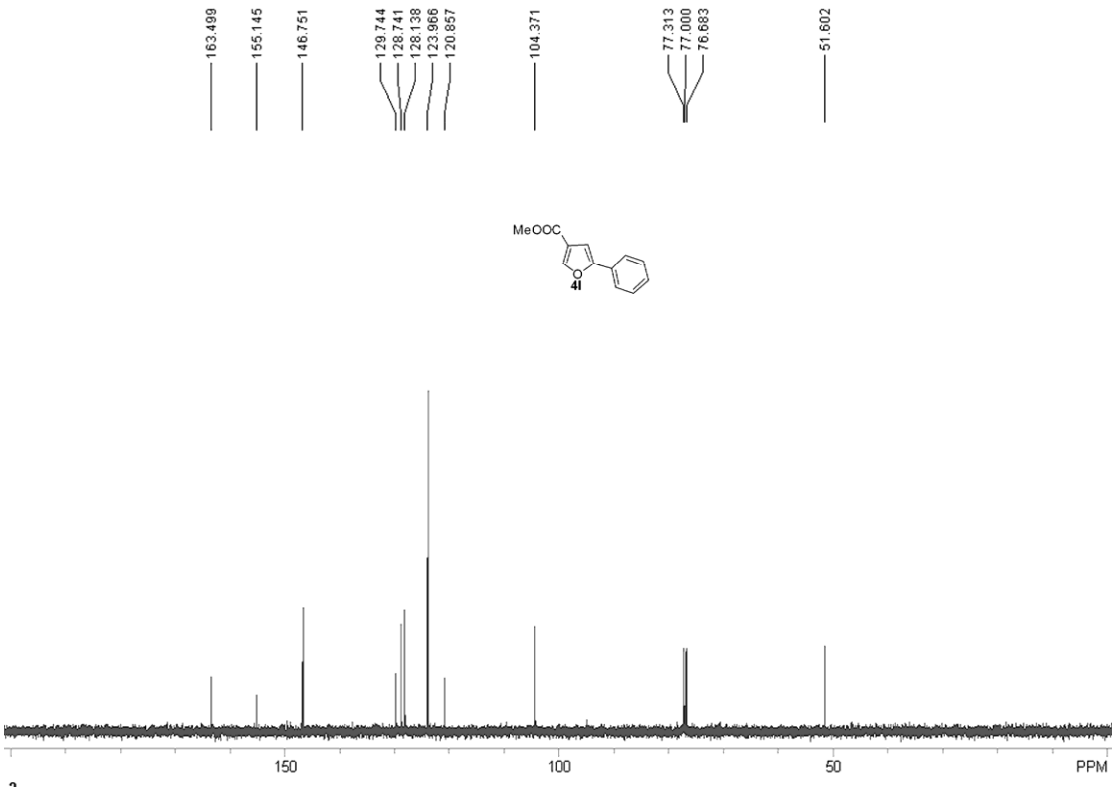
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PPM

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4.214
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4.191
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1.291
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1.247
1.243
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EtO2C
18O
+
EtO2C
16O
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2.00
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3.08
3.12
10
8
6
4
2
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F1: 300.029
F2: 300.028
SW1: 5005
OF1: 2057.2
PTS1d: 16384
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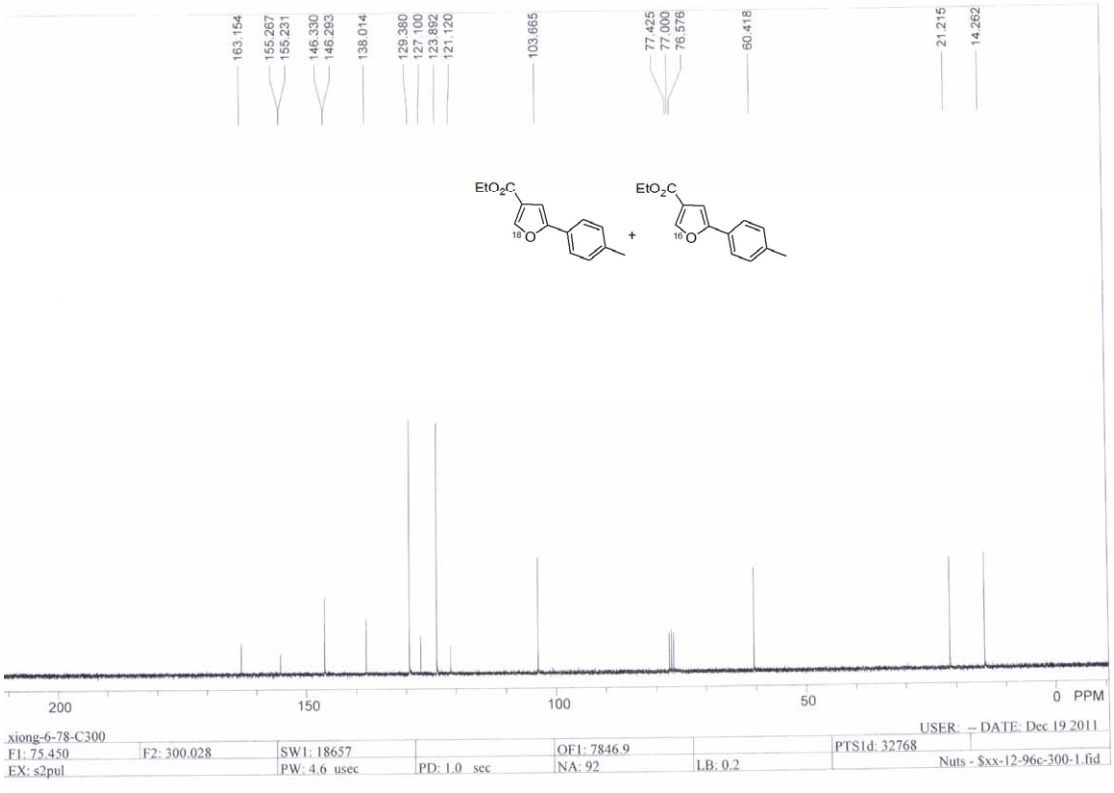
PW: 4.2 usec
PD: 1.0 sec
NA: 12
LB: 0.0
Nuts - $xx-12-96h-300-1.fid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76.576
60.418
21.215
14.262
EtO2C
18O
+
EtO2C
16O
200
150
100
50
0
PPM
xiong-6-78-C300
USER: -- DATE: Dec 19 2011
F1: 75.450
F2: 300.028
SW1: 18657
OF1: 7846.9
PTS1d: 32768
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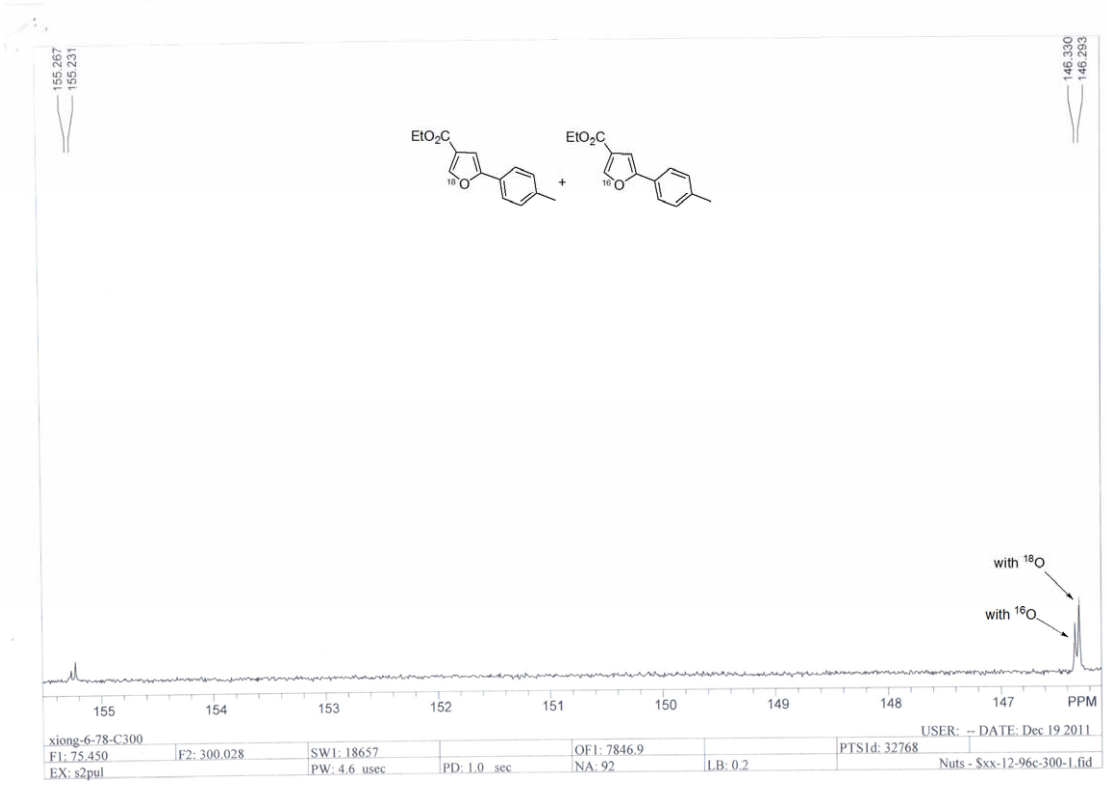
PW: 4.6 usec
PD: 1.0 sec
NA: 92
LB: 0.2
Nuts - $xx-12-96c-300-1.fid



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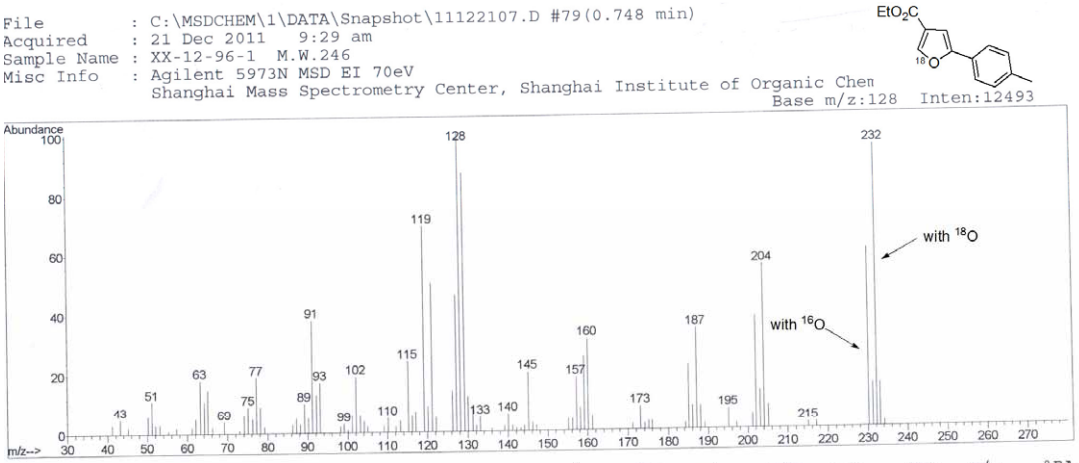
Acquired : 21 Dec 2011 9:29 am
Sample Name : XX-12-96-1 M.W.246
Misc Info : Agilent 5973N MSD EI 70eV
Shanghai Mass Spectrometry Center, Shanghai Institute of Organic Chem
Base m/z:128 Inten:12493



m/z	%RA	m/z	%RA	m/z	%RA	m/z	%RA	m/z	%RA	m/z	%RA	m/z	%RA	m/z	%RA
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43	5.01	69	3.47	92	13.05	115	24.05	133	4.55	158	7.76	189	1.74	234	1.76
45	2.02	73	1.34	93	16.66	116	5.80	136	1.47	159	24.41	195	6.74		
50	5.47	74	6.27	98	2.26	117	7.30	139	1.53	160	30.95	197	2.43		
51	11.30	75	8.84	99	2.63	119	68.81	140	6.00	161	4.58	201	4.99		
52	2.96	76	5.27	100	1.22	120	8.58	141	2.05	171	1.64	202	37.77		
53	3.07	77	18.41	101	6.40	121	49.18	142	1.21	173	8.03	203	13.14		
55	1.33	78	8.85	102	19.11	122	4.95	143	1.48	174	1.96	204	54.26		
57	1.58	79	1.61	103	6.16	126	13.63	144	2.17	175	3.19	205	7.75		
61	1.83	86	2.57	104	3.55	127	45.42	145	19.31	176	2.83	215	1.78		
62	5.23	87	5.40	105	1.93	128	100.00	146	3.27	184	2.03	217	2.00		
63	18.31	88	2.59	109	2.15	129	86.34	147	1.54	185	22.27	230	59.50		
64	11.25	89	10.17	110	5.16	130	11.54	155	4.18	186	7.56	231	14.86		
65	15.06	90	5.15	112	1.81	131	9.37	156	3.60	187	33.98	232	94.48		

8 Peak Value:

128	100.00	232	94.48	129	86.34	119	68.81	230	59.50	204	54.26	121	49.18	127	45.42