Electronic Supplementary Material (ESI) for Chemical Communications

PPh_3-Mediated Intramolecular Conjugating of Alkyl Halide with Electron-deficient Olefins: Facile Synthesis of Chromans and Relevant Analogues.

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Supporting Information

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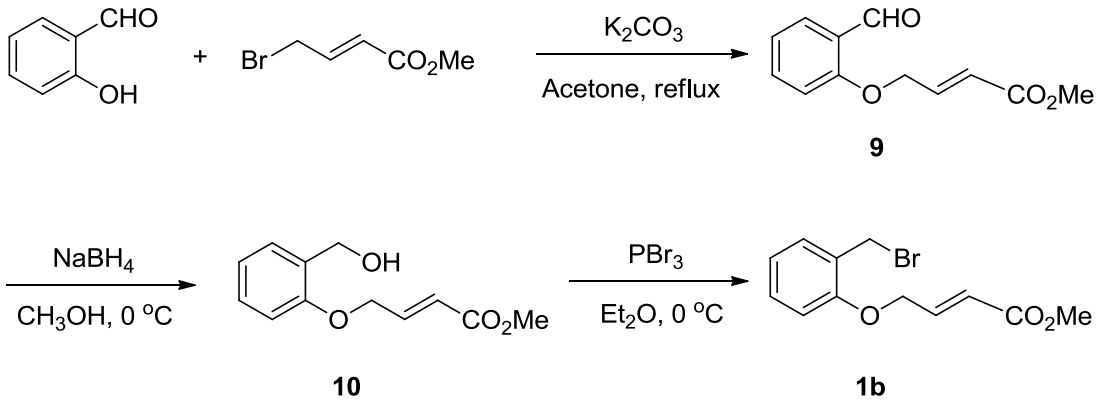
1. General Information

All reactions were carried out under N_2 unless otherwise noted. All compounds and solvents were purified according to standard methods unless otherwise noted.

^{1}H NMR spectra were recorded on a VARIAN Mercury 300 MHz or VARIAN Mercury 400 MHz spectrometer in chloroform-d. All signals are reported in ppm with the internal TMS signal at 0.0 ppm or chloroform signal at 7.26 ppm as a standard. The data are reported as (s = singlet, d = doublet, t = triplet, q = quadruplet, m = multiplet or unresolved, coupling constant(s) in Hz, integration). ^{13}C NMR spectra were recorded on a VARIAN Mercury 75 MHz or 100 MHz spectrometer in chloroform-d. All signals are reported in ppm with the internal chloroform signal at 77.0 ppm as a standard. IR spectra were recorded on a Perkin–Elmer 983, Digital FT–IR spectrometer or Bruker–Tensor 27; frequencies are given in reciprocal centimeters (cm^{-1}) and only selected absorbance is reported; Mass spectra were determined on an Agilent 5973N MSD (EI) and Shimadzu LCMS-2010EV (ESI) mass spectrometer or Agilent G6100 LC/MSD (ESI) single Quand mass spectrometer. High resolution mass spectra were recorded on Waters Micromass GCT Premier (EI) and Bruker Daltonics, Inc. APEXIII 7.0TESLA FTMS (ESI) mass spectrometers.

2. Synthesis of Substrates

1b as an example:[1]

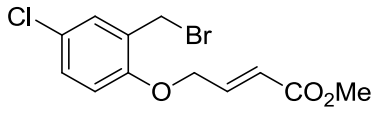


A mixture of salicylaldehyde (2.44 g, 20 mmol), methyl 4-bromocrotonate (4.65 g, 26 mmol), K_2CO_3 (3.59 g, 26 mmol), and acetone (60 mL) was stirred for 15 min, and then warmed to reflux. After the completion of the reaction (monitored by TLC), the resulting mixture was cooled to room temperature, filtered rapidly through a funnel with a thin layer of silica gel and eluted with DCM. The filtrate was concentrated and the residue was purified by chromatography on silica gel (PE/EA = 5/1) to afford the desired product **9** (3.6 g, 82% yield) as a pale yellow solid. ^{1}H NMR (300 MHz, $CDCl_3$, TMS): δ 10.55 (s, 1H), 7.86 (dd, *J* = 8.1 and 2.1 Hz, 1H), 7.58-7.52 (m, 1H), 7.16-7.05 (m. 2H), 6.95 (d, *J* = 8.7 Hz, 1H), 6.23 (dt, *J* = 15.6 and 2.1 Hz, 1H), 4.85-4.83 (m, 2H), 3.78 (s, 3H).

A solution of the aldehyde **9** (3 g, 13.6 mmol) in MeOH (30 mL) was cooled to 0 ℃, and then $NaBH_4$ (0.126 g, 4.54 mmol) was added in one portion. After the completion of the reaction (monitored by TLC, in half an hour), saturated NH_4Cl solution was added and the solution was extracted with EtOAc and dried with anhydrous Na_2SO_4. The solution was filtered and concentrated. The crude product **10** was pure enough for the next step without the need of further purification.

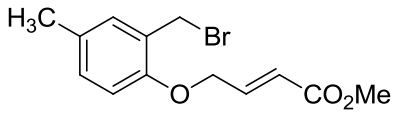
The crude product **10** (3 g, 13.6 mmol) was then dissolved in dry Et_2O and cooled to 0℃, and to this solution PBr_3 (0.52 mL, 5.44mmol) was added dropwise. After completion of the reaction (monitored by TLC, in half an hour), saturated aq.

$NaHCO_3$ was added and the solution was extracted with Et_2O and dried with anhydrous Na_2SO_4. The solution was filtered and concentrated. The residue was purified by column chromatography on silica gel (PE/EA = 10/1) to give substrate **1b** (70 % yield) as a white solid. ^{1}H NMR (300 MHz, $CDCl_3$, TMS): δ 7.37-7.28 (m, 2H), 7.13 (dt, *J* = 15.6 and 4.0 Hz, 1H), 6.99-6.94 (m, 1H), 6.83 (d, *J* = 8.1 Hz, 1H), 6.31 (dt, *J* = 15.6 and 2.1 Hz, 1H), 4.81-4.79 (m, 2H), 4.60 (s, 2H), 3.78 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.4, 155.7, 142.2, 131.0, 130.1, 126.3, 121.5, 121.3, 111.8, 66.4, 51.7, 28.7.



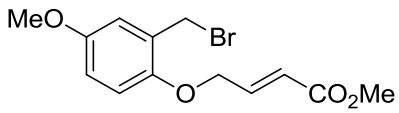
1a

1a, white solid; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.33 (d, *J* = 2.4 Hz, 1H), 7.23 (dd, *J* = 8.8 and 2.4 Hz, 1H), 7.10 (dt, *J* = 15.6 and 4.0 Hz, 1H), 6.75 (d, *J* = 8.8 Hz, 1H), 6.26 (dt, *J* = 15.6 and 2.2 Hz, 1H), 4.78-4.76 (m, 2H), 4.51 (s, 2H), 3.77 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.3, 154.3, 141.7, 130.7, 129.7, 128.1, 126.1, 121.8, 113.1, 66.9, 51.7, 27.4; IR ν/ cm^{-1} 2951 (w), 1718 (m), 1490 (m), 1256 (m), 1019 (m), 808 (m); MS (EI, m/z, rel. intensity) 318 (10.2, M^+), 140 (100.0), 112 (58.1), 77 (44.6); Anal. Calcd for $C_{12}H_{12}ClBrO_3$: C, 45.10; H, 3.78. Found: C, 45.08; H, 3.75.



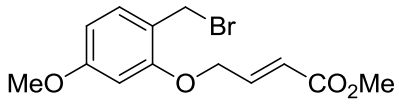
1c

1c, white solid; ^{1}H NMR (300 MHz, $CDCl_3$, TMS): δ 7.16-7.06 (m, 3H), 6.72 (d, *J* = 8.4 Hz, 1H), 6.28 (d, *J* = 15.6 Hz, 1H), 4.77-4.76 (m, 2H), 4.56 (s, 2H), 3.77 (s, 3H), 2.28 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.5, 153.6, 142.5, 131.5, 130.6, 130.5, 126.0, 121.3, 111.8, 66.6, 51.6, 28.9, 20.2; IR ν/ cm^{-1} 2951 (w), 1722 (m), 1502 (m), 1258 (m), 1020 (m), 735 (m); MS (EI, m/z, rel. intensity) 298 (12.5, M^+), 219 (22.1), 91 (100.0); Anal. Calcd for $C_{13}H_{15}BrO_3$: C, 52.19; H, 5.05. Found: C, 52.11; H, 4.99.



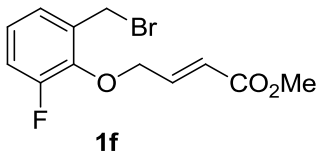
1d

1d, white solid; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.11 (dt, *J* = 15.6 and 4.0 Hz, 1H), 6.91 (d, *J* = 3.2 Hz, 1H), 6.82-6.75 (m, 2H), 6.28 (dt, *J* = 15.6 and 2.0 Hz, 1H), 4.74-4.73 (m, 2H), 4.55 (s, 2H), 3.78 (s, 3H), 3.77 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.5, 153.8, 149.9, 142.7, 127.4, 121.4, 116.4, 114.9, 113.3, 67.3, 55.7, 51.7, 28.6; IR ν/ cm^{-1} 2950 (w), 1715 (m), 1505 (m), 1207(m), 1041 (m), 739 (m); MS (EI, m/z, rel. intensity) 314 (88.1, M^+), 236 (26.2), 162 (100.0); Anal. Calcd for $C_{13}H_{15}BrO_4$: C, 49.54; H, 4.80. Found: C, 49.75; H, 4.81.



1e

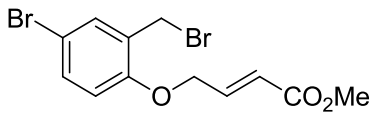
1e, white solid; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.27-7.25 (m, 1H), 7.11 (dt, *J* = 15.6 and 3.8 Hz, 1H), 6.48 (dd, *J* = 8.0 and 2.0 Hz, 1H), 6.38 (d, *J* = 2.0 Hz, 1H), 6.30 (dt, *J* = 15.6 and 1.8 Hz, 1H), 4.76(3)-4.75(5) (m, 2H), 4.59 (s, 2H), 3.79 (s, 3H), 3.77 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.5, 161.5, 156.9, 142.1, 131.8, 121.6, 118.9, 105.2, 99.8, 66.6, 55.4, 51.7, 29.5; IR ν/ cm^{-1} 2951 (w), 1722 (m), 1508 (m), 1167(m), 1020 (m), 737 (m); HRMS (positive ESI) calcd for $C_{13}H_{15}O_4H^{+1}$ ($[M-Br+H]^+$): 236.1043; Found: 236.0997.



1f

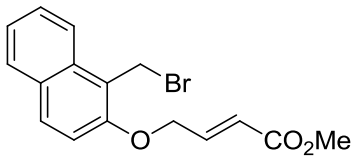
1f, colorless oil; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.15-6.99 (m, 4H), 6.29 (dt, *J* = 15.6 and 2.0 Hz, 1H), 4.89-4.87 (m, 2H), 4.53 (s, 2H), 3.78 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.5, 155.0 (d, $J_{C\text{-}F}$ = 245.7 Hz), 144.2 (d, $J_{C\text{-}F}$ = 10.8 Hz), 142.6 (d, $J_{C\text{-}F}$ = 1.3 Hz), 132.6 (d, $J_{C\text{-}F}$ = 2.6 Hz), 126.0 (d, $J_{C\text{-}F}$ = 3.1 Hz), 124.1 (d, $J_{C\text{-}F}$ = 7.7 Hz), 121.6, 117.5 (d, $J_{C\text{-}F}$ = 19.4 Hz), 71.7 (d, $J_{C\text{-}F}$ = 7.0 Hz), 61.7, 27.2 (d, $J_{C\text{-}F}$ = 3.0 Hz); IR ν/ cm^{-1} 2951 (w), 1726 (m), 1478 (m), 1275 (m), 1016 (m), 789 (m); MS (EI,

m/z, rel. intensity) 302 (2.9, M^+), 124 (100.0), 99 (34.4); HRMS (EI) calcd for $C_{12}H_{12}BrFO_3$ (M^+): 301.9954; Found: 301.9957.



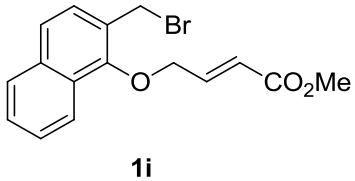
1g

1g, white solid; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.47 (d, *J* = 2.4 Hz, 1H), 7.37 (dd, *J* = 8.8 and 2.4 Hz, 1H), 7.09 (dt, *J* = 15.6 and 3.8 Hz, 1H), 6.71 (d, *J* = 8.4 Hz, 1H), 6.28-6.24 (m, 1H), 4.78-4.76 (m, 2H), 4.50 (s, 2H), 3.77 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.3, 154.8, 141.6, 133.5, 132.7, 128.5, 121.8, 113.5, 113.2, 66.8, 51.7, 27.3; IR ν/ cm^{-1} 2950 (w), 1719 (m), 1490 (m), 1258 (m), 1021 (m), 739 (m); MS (EI, m/z, rel. intensity) 362 (11.1, M^+), 99 (100.0), 77 (84.2); Anal. Calcd for $C_{12}H_{12}Br_2O_3$: C, 39.59; H, 3.32. Found: C, 39.66; H, 3.62.



1h

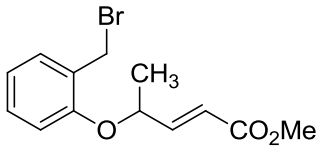
1h, white solid; ^{1}H NMR (300 MHz, $CDCl_3$, TMS): δ 8.04 (d, *J* = 9.0 Hz, 1H), 7.85-7.80 (m, 2H), 7.64-7.59 (m, 1H), 7.44-7.39 (m, 1H), 7.21-7.13 (m, 2H), 6.30 (dt, *J* = 15.9 and 2.1 Hz, 1H), 5.11 (s, 2H), 4.94-4.92 (m, 2H), 3.77 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.4, 153.4, 142.4, 132.1, 131.0, 129.3, 128.5, 127.4, 124.2, 122.6, 121.7, 118.8, 113.7, 67.5, 51.7, 24.7; IR ν/ cm^{-1} 2951 (w), 1720 (m), 1434 (m), 1225 (m), 1019 (m), 804 (m); MS (EI, m/z, rel. intensity) 256 (81.8, $[M-Br]^+$), 182 (67.2), 128 (42.1), 99 (100.0); Anal. Calcd for $C_{16}H_{15}BrO_3$: C, 57.33; H, 4.51. Found: C, 57.23; H, 4.50.



1i

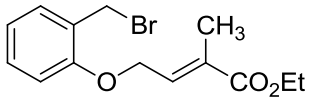
1i, white solid; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 8.02-7.99 (m, 1H), 7.85-7.83 (m, 1H), 7.65 (d, *J* = 8.0 Hz, 1H), 7.54-7.50 (m, 2H), 7.46 (d, *J* = 8.4 Hz, 1H), 7.26-7.20 (m, 1H), 6.50 (dt, *J* = 16.0 and 2.0 Hz, 1H), 4.85-4.84 (m, 2H), 4.74 (s,

2H), 3.82 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 166.6, 152.6, 142.9, 135.0, 128.2, 127.8, 127.7, 127.0, 126.6(7), 126.6(6), 125.2, 122.0, 121.2, 72.6, 51.8, 28.2; IR ν/ cm^{-1} 2949 (w), 1719 (m), 1434 (m), 1215 (m), 815 (m), 750 (m); MS (EI, m/z, rel. intensity) 334 (98.2, M^+), 181 (94.8), 128 (100.0); Anal. Calcd for $C_{16}H_{15}BrO_3$: C, 57.33; H, 4.51. Found: C, 57.37; H, 4.69.



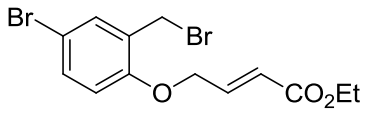
1j

1j, white solid; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.35-7.32 (m, 1H), 7.25-7.21 (m, 1H), 7.05 (dd, *J* = 15.6 and 4.4 Hz, 1H), 6.94-6.90 (m, 1H), 6.77 (d, *J* = 8.4 Hz, 1H), 6.11 (dd, *J* = 15.6 and 1.6 Hz, 1H), 5.06-5.00 (m, 1H), 4.58 (s, 2H), 3.74 (s, 3H), 1.54 (d, *J* = 7.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.6, 155.2, 147.7, 131.0, 130.0, 126.7, 121.1, 120.8, 113.0, 72.7, 51.7, 29.0, 20.6; IR ν/ cm^{-1} 2984 (w), 1723(m), 1491 (m), 1245(m), 752 (m); MS (EI, m/z, rel. intensity) 298 (1.3, M^+), 219 (2.5), 107 (100.0); HRMS (EI) calcd for $C_{13}H_{15}BrO_3$ (M^+): 298.0205; Found: 298.0211.



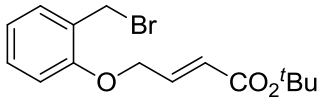
1k

1k, white solid; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.35 (dd, *J* = 7.6 and 1.6 Hz, 1H), 7.30-7.26 (m, 1H), 6.98-6.93 (m, 2H), 6.83 (d, *J* = 8.4 Hz, 1H), 4.80 (dd, *J* = 5.6 and 0.8 Hz, 2H), 4.58 (s, 2H), 4.23 (q, *J* = 7.2 Hz, 2H), 1.94 (d, *J* = 1.2 Hz, 3H), 1.32 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 167.2, 156.1, 136.2, 131.1, 130.1(1), 130.1(0), 126.5, 121.2, 111.9, 65.3, 60.9, 28.8, 14.2, 13.1; IR ν/ cm^{-1} 2979 (w), 1710 (m), 1492 (m), 1246 (m), 1019 (m), 751 (m); MS (EI, m/z, rel. intensity) 312 (1.3, M^+), 233 (7.5), 107 (100.0); Anal. Calcd for $C_{14}H_{17}BrO_3$: C, 53.69; H, 5.47. Found: C, 53.64; H, 5.75.



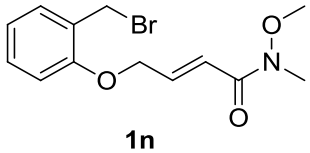
1l

1l, white solid; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.47 (d, *J* = 2.4 Hz, 1H), 7.37 (dd, *J* = 8.8 and 2.4 Hz, 1H), 7.08 (dt, *J* = 16.0 and 4.0 Hz, 1H), 6.71 (d, *J* = 8.4 Hz, 1H), 6.23 (dt, *J* = 16.0 and 1.6 Hz, 1H), 4.77-4.75 (m, 2H), 4.51 (s, 2H), 4.23 (q, *J* = 7.2 Hz, 2H), 1.31 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 165.9, 154.8, 141.3, 133.6, 132.7, 128.5, 122.3, 113.6, 113.2, 66.9, 60.7, 27.3, 14.2; IR ν/ cm^{-1} 2962 (w), 1707 (m), 1490 (m), 1259 (m), 1019 (m), 800 (m); MS (EI, m/z, rel. intensity) 376 (14.3, M^+), 184 (100.0), 77 (74.3); HRMS (EI) calcd for $C_{13}H_{14}Br_2O_3$ (M^+): 375.9310; Found: 375.9309.



1m

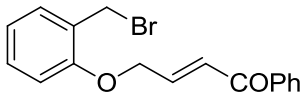
1m, white solid; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.37-7.34 (m, 1H), 7.30-7.26 (m, 1H), 7.04-6.94 (m, 2H), 6.83 (d, *J* = 8.4 Hz, 1H), 6.17 (dt, *J* = 15.6 and 2.0 Hz, 1H), 4.77-4.76 (m, 2H), 4.60 (s, 2H), 1.50 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 165.3, 155.8, 140.7, 130.9, 130.1, 126.3, 123.7, 121.2, 111.9, 80.6, 66.7, 28.7, 28.0; IR ν/ cm^{-1} 2965 (m), 1711 (w), 1258 (m), 1020 (m), 800 (m), 750 (m); MS (EI, m/z, rel. intensity) 326 (5.11, M^+), 191 (100.0), 145 (58.2), 107 (77.8); HRMS (EI) calcd for $C_{15}H_{19}BrO_3$ (M^+): 326.0518; Found: 326.0512.



1n

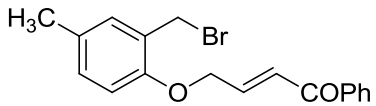
1n, white solid; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.36-7.33 (m, 1H), 7.31-7.26 (m, 1H), 7.13 (dt, *J* = 15.2 and 3.6 Hz, 1H), 6.96-6.92 (m, 2H), 6.85 (d, *J* = 8.0 Hz, 1H), 4.83-4.82 (m, 2H), 4.62 (s, 2H), 3.69 (s, 3H), 3.27 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.2, 155.9, 140.2, 130.9, 130.2, 126.2, 121.1, 119.4, 111.8, 66.7, 62.0, 32.3, 29.0; IR ν/ cm^{-1} 3052 (w), 2936 (w), 1738 (m), 1381 (m), 1009 (m), 735

(m); MS (ESI, positive mode, m/z) 313.9 ($[M+H]^+$). HRMS (positive ESI) calcd for $C_{13}H_{16}BrNO_3H^{+1}$ ($[M+H]^+$): 314.0386; Found: 314.0385.



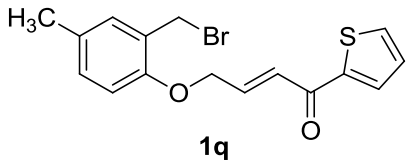
1o

1o, pale yellow solid; ^{1}H NMR (300 MHz, $CDCl_3$, TMS): δ 8.03-8.01 (m, 2H), 7.61-7.46 (m, 4H), 7.38-7.19 (m, 3H), 7.00-6.95 (m, 1H), 6.88 (d, *J* = 8.7 Hz, 1H), 4.91-4.90 (m, 2H), 4.66 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 189.7, 155.8, 141.7, 137.4, 133.0, 130.9, 130.3, 128.6(4), 128.6(0), 126.2, 125.2, 121.2, 111.8, 66.8, 29.2; IR ν/ cm^{-1} 2960 (m), 1674 (m), 1493 (m), 1102 (m), 752 (s); MS (EI, m/z, rel. intensity) 252 (5.3, $[M-Br]^+$), 145 (53.8), 132 (100.0), 77 (48.8); Anal. Calcd for $C_{17}H_{15}BrO_2$: C, 61.65; H, 4.56. Found: C, 61.87; H, 4.56.



1p

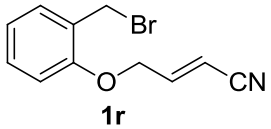
1p, pale yellow solid; ^{1}H NMR (300 MHz, $CDCl_3$, TMS): δ 8.03-8.01 (m, 2H), 7.60-7.46 (m, 4H), 7.26-7.18 (m, 2H), 7.09 (d, *J* = 8.7 Hz, 1H), 6.77 (d, *J* = 8.1 Hz, 1H), 4.88-4.87 (m, 2H), 4.63 (s, 2H), 2.29 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 189.8, 153.8, 142.0, 137.4, 133.0, 131.6, 137.7(0), 136.6(7), 128.7, 128.6, 126.0, 125.2, 111.9, 67.0, 29.4, 20.3; IR ν/ cm^{-1} 2912 (m), 1672 (m), 1414 (m), 1179 (m), 672 (m); HRMS (positive ESI) calcd for $C_{18}H_{17}BrO_2H^{+1}$ ($[M+H]^+$): 345.0485; Found: 345.0472.



1q

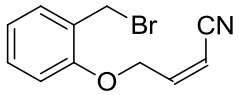
1q, pale yellow solid; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.86 (d, *J* = 3.6 Hz, 1H), 7.68 (d, *J* = 3.6 Hz, 1H), 7.45-7.36 (m, 2H), 7.33-7.22 (m, 2H), 7.17-7.15 (m, 1H), 6.99-6.95 (m, 1H), 6.87 (d, *J* = 8.0 Hz, 1H), 4.91-4.89 (m, 2H), 4.67 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 181.6, 155.8, 145.0, 141.0, 134.4, 132.6, 131.0,

130.4, 128.3, 126.1, 124.9, 121.3, 111.7, 66.6, 26.3; IR ν/ cm^{-1} 3085 (m), 2972 (m), 1622 (m), 1413 (m), 1252 (m), 813.5 (m), 775 (m); HRMS (positive ESI) calcd for $C_{15}H_{13}BrO_2SH^{+1}$ ($[M+H]^+$): 336.9892; Found: 336.9884.



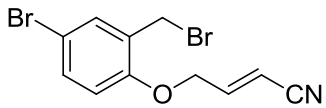
1r

1r, white solid; ^{1}H NMR (300 MHz, $CDCl_3$, TMS): δ 7.37-7.28 (m, 2H), 7.02-6.97 (m, 1H), 6.91 (dt, *J* = 16.2 and 3.5 Hz, 1H), 6.81 (d, *J* = 8.4 Hz, 1H), 5.97 (dt, *J* = 16.2 and 2.4 Hz, 1H), 4.78 (dd, *J* = 4.8 and 2.4 Hz, 2H), 4.56 (s, 2H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 155.3, 148.2, 131.1, 130.3, 126.3, 121.8, 116.9, 111.7, 100.8, 66.1, 28.7; IR ν/ cm^{-1} 2963 (m), 2222 (w), 1258 (m), 1015 (m), 795 (s); MS (EI, m/z, rel. intensity) 251 (6.7, M^+), 172 (97.7), 91 (26.3), 78 (100.0); Anal. Calcd for $C_{11}H_{10}BrNO$: C, 52.41; H, 4.00; N, 5.56. Found: C, 52.89; H, 3.93; N, 5.40.



1r'

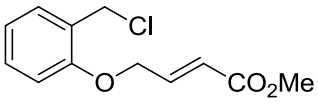
1r', white solid; ^{1}H NMR (300 MHz, $CDCl_3$, TMS): δ 7.37-7.29 (m, 2H), 7.01-6.96 (m, 1H), 6.88 (d, *J* = 8.4 Hz, 1H), 6.83-6.75 (m, 1H), 5.59 (d, *J* = 11.1 Hz, 1H), 4.96 (dd, *J* = 6.0 and 1.5 Hz, 2H), 4.59 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 155.5, 149.0, 131.1, 130.2, 126.6, 121.7, 114.8, 112.0, 101.4, 66.2, 28.7; IR ν/ cm^{-1} 2963 (m), 2222 (w), 1492 (m), 1258 (m), 793 (s); MS (EI, m/z, rel. intensity) 251 (5.7, M^+), 172 (100.0), 91 (28.9), 78 (74.8); Anal. Calcd for $C_{11}H_{10}BrNO$: C, 52.41; H, 4.00; N, 5.56. Found: C,52.29; H, 3.96; N, 5.50.



1s

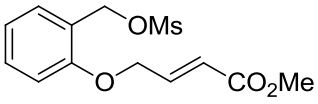
1s, white solid; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.47 (d, *J* = 2.4 Hz, 1H), 7.40 (dd, *J* = 8.8 and 2.8 Hz, 1H), 6.88 (dt, *J* = 16.4 and 2.8 Hz, 1H), 6.69 (d, *J* = 8.8 Hz, 1H), 5.92 (dt, *J* = 16.4 and 2.4 Hz, 1H), 4.75-4.74 (m, 2H), 4.74 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.4, 147.6, 133.7, 132.9, 128.5, 116.7, 113.8, 113.5, 101.1,

66.4, 27.2; IR ν/ cm^{-1} 2963 (m), 2225 (m), 1491 (m), 1257 (m), 1077 (m), 804 (m); MS (EI, m/z, rel. intensity) 329 (16.3, M^+), 171 (65.4), 77 (100.0); HRMS (EI) calcd for $C_{11}H_9Br_2NO$ (M^+): 328.9051; Found: 328.9054.



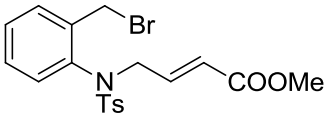
1t

1t, white solid; ^1H NMR (400 MHz, $CDCl_3$, TMS): δ 7.37 (d, *J* = 8.8 Hz, 1H), 7.31-7.26 (m, 1H), 7.11 (dt, *J* = 15.6 and 4.0 Hz, 1H), 6.99-6.95 (m, 1H), 6.83 (d, *J* = 8.4 Hz, 1H), 6.26 (dt, *J* = 15.6 and 2.0 Hz, 1H), 4.76-4.75(m, 2H), 4.68 (s, 2H), 3.76 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.4, 155.6, 142.3, 130.7, 130.0, 126.0, 121.4, 121.3, 111.7, 66.4, 51.6, 41.5; IR ν/ cm^{-1} 2963 (m), 1260 (m), 1089 (m), 1018 (m), 798 (m); MS (EI, m/z, rel. intensity) 240 (15.3, M^+), 106 (100.0), 78 (71.1); HRMS (EI) calcd for $C_{12}H_{13}O_3Cl$ (M^+): 240.0553; Found: 240.0556.



1u

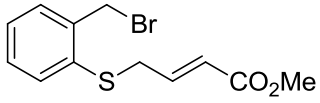
1u, white solid; ^1H NMR (400 MHz, $CDCl_3$, TMS): δ 7.42 (dd, *J* = 7.6 and 2.0 Hz, 1H), 7.39-7.35 (m, 1H), 7.10 (dt, *J* = 16.0 and 4.4 Hz, 1H), 7.05-7.01 (m, 1H), 6.87 (d, *J* = 8.0 Hz, 1H), 6.22 (dt, *J* = 16.0 and 2.0 Hz, 1H), 5.35 (s, 2H), 4.79-4.77 (m, 2H), 3.77 (s, 3H), 2.98 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.3, 156.1, 142.0, 131.2, 131.1, 122.0, 121.9, 121.4, 111.6, 67.2, 66.6, 51.8, 38.0; IR ν/ cm^{-1} 2953 (m), 1718 (m), 1170 (m), 1018 (m), 752 (m); MS (EI, m/z, rel. intensity) 300(1.1, M^+), 96 (90.4), 79 (100.0); HRMS (positive ESI) calcd for $C_{13}H_{16}O_6SNH_4^{+1}$ ($[M+NH_4]^+$): 318.1011; Found: 318.1022.



4a

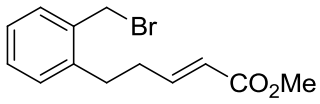
4a, white solid; ^1H NMR (400 MHz, $CDCl_3$, TMS): δ 7.57 (dd, *J* = 7.6 and 1.2 Hz, 1H), 7.52-7.50 (m, 2H), 7.35-7.29 (m, 3H), 7.18-7.14 (m, 1H), 6.92 (dt, *J* = 15.6 and

6.8 Hz, 1H), 6.57 (d, *J* = 8.0 Hz, 1H), 5.81 (dt, *J* = 15.6 and 1.2 Hz, 1H), 4.96-4.93 (m, 1H), 4.54-4.42 (m, 2H), 4.17-4.11 (m, 1H), 3.68 (s, 3H), 2.45 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 165.8, 144.2, 141.7, 139.3, 137.2, 134.6, 132.2, 129.7, 129.3, 129.0, 128.4, 128.0, 124.4, 52.6, 51.6, 29.1, 21.6; IR ν/ cm^{-1} 2956 (w), 1722 (m), 1436 (m), 1160 (m), 728 (m); MS (EI, m/z, rel. intensity) 437 (2.0, M^+), 358 (11.3), 91 (100.0); Anal. Calcd for $C_{19}H_{20}BrNO_4S$: C, 52.06; H, 4.60; N, 3.2. Found: C, 51.96; H, 4.87; N, 2.86.



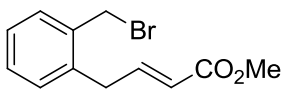
4b

4b, white solid; ^{1}H NMR (300 MHz, $CDCl_3$, TMS): δ 7.43-7.37 (m, 2H), 7.30-7.22 (m, 2H), 7.00-6.90 (m, 1H), 5.79 (d, *J* = 15.9 Hz, 1H), 4.71 (s, 2H), 3.74-3.66 (m, 5H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.2, 142.6, 139.0, 134.4, 132.3, 130.8, 129.2, 127.9, 123.1, 51.6, 35.8, 31.9; IR ν/ cm^{-1} 2951 (w), 1721 (m), 1436 (m), 1199 (m), 738 (m); MS (EI, m/z, rel. intensity) 300 (13.6, M^+), 221 (11.0), 121 (100.0); Anal. Calcd for $C_{12}H_{13}BrO_2S$: C, 47.85; H, 4.35. Found: C, 48.07; H, 4.48



4c

4c, pale yellow solid; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.35-7.33 (m, 1H), 7.29-7.26 (m, 1H), 7.22-7.18 (m, 2H), 7.05 (dt, *J* = 15.6 and 6.8 Hz, 1H), 5.92-5.88 (m, 1H), 4.53 (s, 2H), 3.74 (s, 3H), 2.92-2.88 (m, 2H), 2.62-2.56 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.8, 147.9, 139.6, 135.3, 130.6, 129.5, 129.1, 126.8, 121.6, 51.4, 32.9, 31.4, 30.5; IR ν/ cm^{-1} 2963 (w), 1719 (m), 1435 (m), 1261 (m), 1018 (m), 798 (m); MS (EI, m/z, rel. intensity) 202 (25.1, $[M\text{-}Br]^+$), 143 (100.0), 104 (95.3); HRMS (EI) calcd for $C_{13}H_{15}BrO_2$ (M^+): 282.0255; Found: 282.0254.

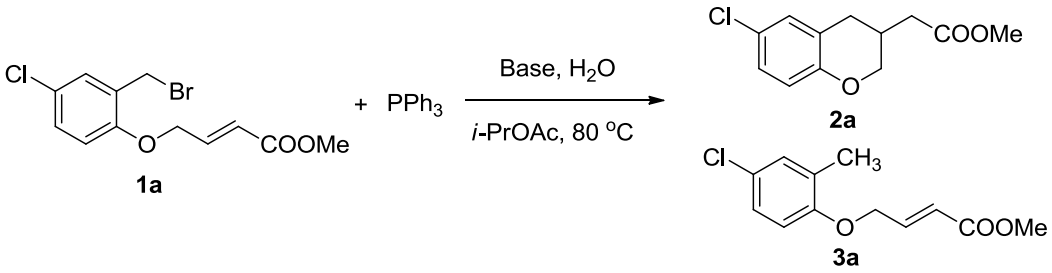


4d

4d, white solid; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.36-7.34 (m, 1H), 7.31-7.22 (m, 2H), 7.19-7.12 (m, 2H), 5.76 (dt, *J* = 15.6 and 1.8 Hz, 1H), 4.47 (s, 2H), 3.72 (s, 3H), 3.68 (dd, *J* = 6.4 and 2.0 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 166.6, 146.6, 136.6, 135.7, 130.6, 130.4, 129.3, 127.5, 122.2, 51.4, 34.9, 31.3.

3. Reaction Optimization

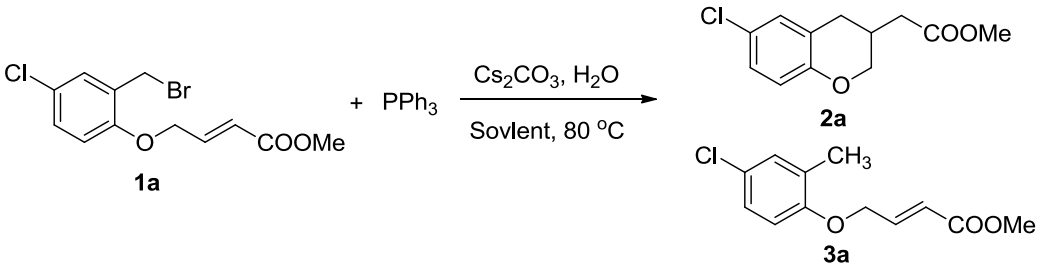
3.1 Base effect:



A mixture of substrate **1a** (0.3 mmol), PPh_3 (0.36 mmol), base (0.9 mmol), H_2O (0.75 mmol), and *i*-PrOAc (4 mL) was stirred under a nitrogen atmosphere at 80 °C until **1a** completely consumed (monitored by TLC). After the reaction was completed, the resulting mixture was filtered rapidly through a funnel with a thin layer of silica gel and eluted with EA. The filtrate was concentrated and the residue was purified by chromatography on silica gel (PE/EA=25/1) to afford the desired product.

Entry	Time (h)	Base	Yield [%] 2a/3a
1	28	Na_2CO_3	20/20
2	15	K_2CO_3	65/16
3	28	Cs_2CO_3	75/trace
4	18	*t*-BuONa	13/7
5	24	*t*-BuOK	trace
6	24	NaOH	54/14
7	18	KOH	50/20
8	24	DMAP	trace
9	24	DBU	trace
10	24	$K_3PO_4{\cdot}3H_2O$	51/40
11	22	K_2HPO_4	60/10

3.2 Solvent and temperature effect:



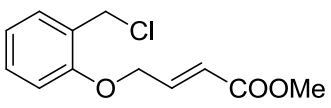
A mixture of substrate **1a** (0.3 mmol), PPh_3 (0.36 mmol), Cs_2CO_3 (0.9 mmol),

H_2O (0.75 mmol), and solvent (4 mL) was stirred under a nitrogen atmosphere at 80 ^oC until **1a** completely consumed monitored by TLC. After the reaction was completed, the resulting mixture was filtered rapidly through a funnel with a thin layer of silica gel and eluted with EA. The filtrate was concentrated and the residue was purified by chromatography on silica gel (PE/EA=25/1) to afford the desired product.

Entry	Time (h)	Slovent	Yield[a] (%) 2a/3a
1	21	DCE	53/13
2	24	CH_3Ph	74/7
3	24	CH_3CN	39/trace
4	21	*t*-BuOH	trace
5	24	1,4-dioxane	46/51
6	45	THF[b]	68/trace
7	28	*i*-PrOAc	75/trace
8	24	EtOAc (80 ℃)	84/trace
9	41	EtOAc (40 ℃)	38/32
10	40	EtOAc (60 ℃)	67/4
11	24	*n*-BuOAc	71/trace
12	24	*i*-BuOAc	66/trace
13	48	1,4-dioxane	43/50
14[c]	24	EtOAc (80 ℃)	78/trace

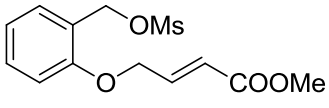
[a] Isolated yield. [b] 65 °C. [c] Using AR-grade EtOAc, with **1b**, no water was added.

3.3 Results with the Corresponding Chloride and Mesylate under Standard Conditions (Quaternerazation at 80 °C).



1t

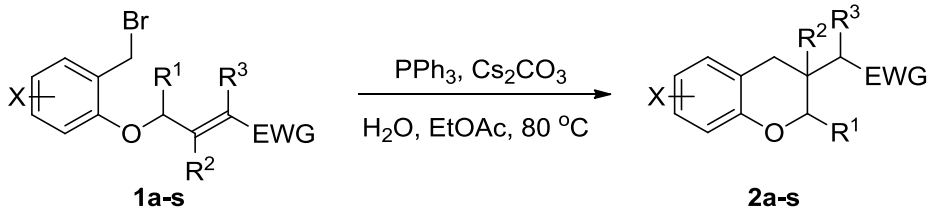
80 °C, TBAI (15 mol%), 3d+25 h, 75% yield



1u

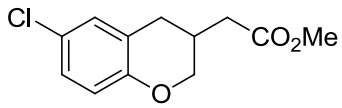
80 °C, 24 + 25 h, 86% yield

4. General Procedure for the Phosphine-Mediated Coupling Reactions



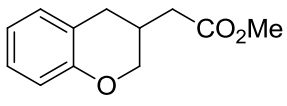
1a-s **2a-s**

A mixture of substrate **1** (0.3 mmol), PPh_3 (0.45 mmol), and EA (4 mL) was stirred under a nitrogen atmosphere at 60 °C until **1** was completely consumed (monitored by TLC). Cs_2CO_3 (0.9 mmol), H_2O (0.75 mmol), and EA (2 mL) were added and then warmed to 80 °C for another 25 h. After the reaction was completed, the resulting mixture was filtered rapidly through a funnel with a thin layer of silica gel and eluted with EA. The filtrate was concentrated and the residue was purified by chromatography on silica gel to afford the desired product.



2a

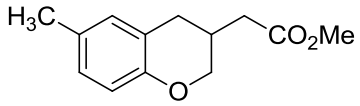
2a, white solid, 87% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.04 (dd, *J* = 8.8 and 2.8 Hz, 1H), 7.00 (d, *J* = 2.8 Hz, 1H), 6.73 (d, *J* = 8.8 Hz, 1H), 4.22-4.19 (m, 1H), 3.91-3.86 (m, 1H), 3.71 (s, 3H), 2.97-2.90 (m, 1H), 2.57-2.49 (m, 2H), 2.46-2.32 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.2, 152.8, 129.4, 127.4, 125.1, 122.2, 117.8, 69.5, 51.8, 35.8, 30.7, 28.6; IR ν/ cm^{-1} 2961 (w), 1734 (m), 1484 (m), 1260 (m), 1024 (m), 811 (m); MS (EI, m/z, rel. intensity) 240 (24.0, M^+), 99 (100.0), 77 (14.4); HRMS (EI) calcd for $C_{12}H_{13}ClO_3$ (M^+): 240.0553; Found: 240.0550.



2b

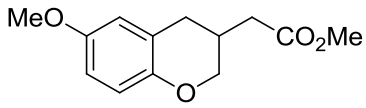
2b, colorless oil, 96% yield; ^{1}H NMR (300 MHz, $CDCl_3$, TMS): δ 7.15-7.02 (m, 2H), 6.87-6.79 (m, 2H), 4.25-4.20 (m, 1H), 3.92-3.86 (m, 1H), 3.71 (s, 3H), 3.02-2.93 (m, 1H), 2.63-2.33 (m, 4H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 172.4, 154.1, 129.9, 127.3,

120.6, 120.5, 116.5, 69.4, 51.7, 35.9, 30.8, 28.9; IR ν/ cm^{-1} 2952 (w), 1733 (m), 1490 (m), 1244 (m), 1021 (m), 753 (m); MS (EI, m/z, rel. intensity) 206 (20.7, M^+), 131 (100.0), 99 (52.3); HRMS (EI) calcd for $C_{12}H_{14}O_3$ (M^+): 206.0943; Found: 206.0942.



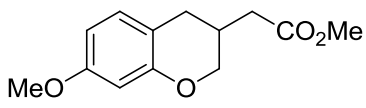
2c

2c, white solid, 93% yield; ^{1}H NMR (300 MHz, $CDCl_3$, TMS): δ 6.90 (d, *J* = 8.1 Hz, 1H), 6.84 (s, 1H), 6.71 (d, *J* = 8.1 Hz, 1H), 4.20-4.17 (m, 1H), 3.90-3.84 (m, 1H), 3.71 (s, 3H), 2.97-2.88 (m, 1H), 2.58-2.32 (m, 4H), 2.25 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.4, 151.9, 130.2, 129.6, 128.0, 120.2, 116.2, 69.4, 51.7, 35.7, 30.8, 29.1, 20.4; IR ν/ cm^{-1} 2953 (m), 1735 (m), 1500 (m), 1220 (m), 814 (m); MS (EI, m/z, rel. intensity) 220 (29.8, M^+), 145 (66.9), 99 (100.0); HRMS (EI) calcd for $C_{13}H_{16}O_3$ (M^+): 220.1099; Found: 220.1098.



2d

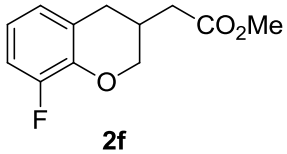
2d, white solid, 92% yield; ^{1}H NMR (300 MHz, $CDCl_3$, TMS): δ 6.76-6.66 (m, 2H), 6.57 (d, *J* = 2.7 Hz, 1H), 4.19-4.15 (m, 1H), 3.88-3.82 (m, 1H), 3.74 (s, 3H), 3.71 (s, 3H), 3.00-2.91 (m, 1H), 2.57-2.32 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.4, 153.4, 148.1, 121.1, 117.0, 114.3, 113.4, 69.3, 55.6, 51.6, 35.9, 31.0, 29.0; IR ν/ cm^{-1} 2923 (m), 1738 (m), 1502 (m), 1220 (m), 815 (m); MS (EI, m/z, rel. intensity) 236 (65.6, M^+), 162 (51.9), 99 (100.0); HRMS (EI) calcd for $C_{13}H_{16}O_4$ (M^+): 236.1049; Found: 236.1048.



2e

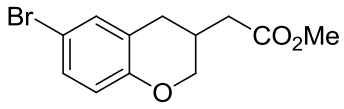
2e, colorless oil, 72% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 6.91 (d, *J* = 8.4 Hz, 1H), 6.45 (dd, *J* = 8.4 and 2.4 Hz, 1H), 6.37 (d, *J* = 2.4 Hz, 1H), 4.21-4.18 (m, 1H), 3.89-3.84 (m, 1H), 3.74 (s, 3H), 3.70 (s, 3H), 2.91-2.86 (m, 1H), 2.56-2.32 (m,

4H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.4, 159.0, 154.8, 130.3, 112.6, 107.4, 101.3, 69.5, 55.2, 51.7, 35.9, 30.1, 29.1; IR ν/ cm^{-1} 2937 (m), 1736 (m), 1620 (m), 1156 (m), 736 (m); MS (EI, m/z, rel. intensity) 236 (44.3, M^+), 163 (100.0), 99 (56.4); HRMS (EI) calcd for $C_{13}H_{16}O_4$ (M^+): 236.1049; Found: 236.1052.



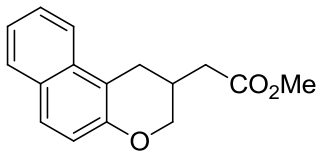
2f

2f, colorless oil, 92% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 6.93-6.88 (m, 1H), 6.82-6.74 (m, 2H), 4.32-4.28 (m, 1H), 3.99-3.89 (m, 1H), 3.71 (s, 3H), 3.03-2.96 (m, 1H), 2.63-2.54 (m, 2H), 2.49-2.33 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.2, 151.4 (d, $J_{C\text{-}F}$ = 243.8 Hz), 142.4 (d, $J_{C\text{-}F}$ = 10.9 Hz), 124.8 (d, $J_{C\text{-}F}$ = 3.1 Hz), 123.2, 119.9 (d, $J_{C\text{-}F}$ = 7.3 Hz), 113.8 (d, $J_{C\text{-}F}$ = 17.9 Hz), 69.7, 51.7, 35.8, 30.4 (d, $J_{C\text{-}F}$ = 2.3 Hz), 28.7; IR ν/ cm^{-1} 2955 (w), 1737 (m), 1487 (m), 1260 (m), 1029 (m), 795 (m); MS (EI, m/z, rel. intensity) 224 (37.1, M^+), 150 (100.0), 99 (73.1); HRMS (EI) calcd for $C_{12}H_{13}FO_3$ (M^+): 224.0849; Found: 224.0851.



2g

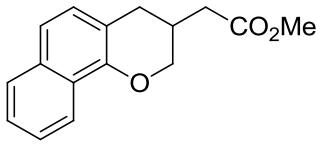
2g, white solid, 83% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.19-7.15 (m, 2H), 6.69 (d, *J* = 8.8 Hz, 1H), 4.22-4.19 (m, 1H), 3.91-3.86 (m, 1H), 3.71 (s, 3H), 2.98-2.91 (m, 1H), 2.57-2.32 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.2, 153.3, 132.3, 130.2, 122.8, 118.3, 112.4, 69.5, 51.7, 35.8, 30.6, 28.6; IR ν/ cm^{-1} 2953 (w), 1730 (s), 1483 (m), 1256 (m), 1025(m), 811 (m); MS (EI, m/z, rel. intensity) 284 (19.7, M^+), 99 (100.0), 77 (17.5); HRMS (EI) calcd for $C_{12}H_{13}BrO_3$ (M^+): 284.0048; Found: 284.0052.



2h

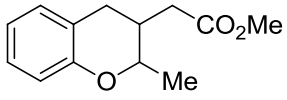
2h, colorless oil, 63% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.78-7.75 (m, 2H), 7.62 (d, *J* = 9.2 Hz, 1H), 7.50-7.46 (m, 1H), 7.37-7.33 (m, 1H), 7.05 (d, *J* = 8.8 Hz,

1H), 4.31-4.27 (m, 1H), 3.99-3.94 (m, 1H), 3.72 (s, 3H), 3.29-3.23 (m, 1H), 2.81-2.68 (m, 2H), 2.56-2.44 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.5, 151.9, 133.1, 129.0, 128.4, 127.8, 126.4, 123.4, 121.7, 118.7, 112.4, 69.2, 51.8, 36.3, 28.9, 27.5; IR ν/ cm^{-1}3061 (w), 2952 (w), 1733 (m), 1230 (m), 1025 (m), 810 (m), 745 (m); MS (EI, m/z, rel. intensity) 256 (69.6, M^+), 182 (100.0), 99 (59.1); HRMS (EI) calcd for $C_{16}H_{16}O_3$ (M^+): 256.1099; Found: 256.1095.



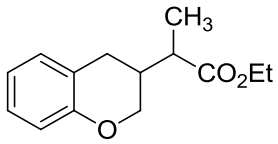
2i

2i, white solid, 97% yield; ^{1}H NMR (300 MHz, $CDCl_3$, TMS): δ 8.16-8.13 (m, 1H), 7.76-7.73 (m, 1H), 7.47-7.41 (m, 2H), 7.35 (d, *J* = 7.8 Hz, 1H), 7.12 (d, *J* = 8.1 Hz, 1H), 4.43-4.40 (m, 1H), 4.10-4.04 (m, 1H), 3.72 (s, 3H), 3.13-3.04 (m, 1H), 2.70-2.62 (m, 2H), 2.55-2.39 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.5, 149.1, 133.2, 127.8, 127.3, 125.6, 125.2, 124.9, 121.4, 119.8, 114.2, 69.6, 51.6, 36.0, 30.9, 29.0; IR ν/ cm^{-1} 3053 (w), 2930 (w), 1736 (m), 1262 (m), 1104 (m), 802 (m), 738 (m); MS (EI, m/z, rel. intensity) 256 (44.8, M^+), 181 (42.4), 99 (100.0); HRMS (EI) calcd for $C_{16}H_{16}O_3$ (M^+): 256.1099; Found: 256.1100.



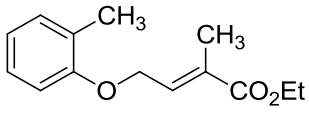
2j

2j, on 0.2 mmol scale, colorless oil, 96% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.11-7.02 (m, 2H), 6.87-6.77 (m, 2H), 4.30 (dq, *J* = 6.4 and 2.0 Hz, 0.43H), 4.07-4.01 (m, 0.57H), 3.71 (s, 1.71H), 3.68 (s, 1.29H), 3.04-2.90 (m, 1H), 3.65-2.17 (m, 4H), 1.37 (d, *J* = 6.4 Hz, 1.71H), 1.31 (d, *J* = 6.4 Hz, 1.29H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 173.4, 172.6, 154.0, 153.7, 130.1, 129.6, 127.4, 127.3, 120.6, 120.4, 120.2, 119.9, 116.6(0), 116.5(8), 74.8, 73.4, 51.7, 36.9, 34.3, 32.4(7), 32.4(6), 30.3, 29.3, 19.1, 17.1; IR ν/ cm^{-1} 2919 (m), 1734 (m), 1488 (m), 1244 (m), 1119 (m), 752 (m); MS (EI, m/z, rel. intensity) 222 (40.4, M^+), 146 (57.8), 131 (100.0); HRMS (EI) calcd for $C_{13}H_{16}O_3$ (M^+): 220.1099; Found: 220.1133.



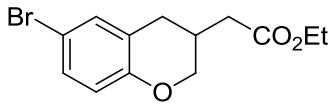
2k

2k, with PMe_3, colorless oil, 79% yield. ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.11-7.01 (m, 2H), 6.86-6.79 (m, 2H), 4.29-4.14 (m, 3H), 3.94-3.89 (m, 0.6H), 3.84-3.79 (m, 0.4H), 2.87-2.82 (m, 1H), 2.65-2.57 (m, 1H), 2.52-2.41 (m, 1H), 2.37-2.25 (m, 1H), 1.30-1.24 (m, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 175.2, 154.4, 130.0, 129.8, 127.4, 127.3, 121.1, 121.0, 120.5, 120.4, 116.5, 116.4, 68.8, 68.0, 60.6, 60.5, 40.9(4), 40.9(2), 35.1, 34.9, 29.3, 28.5, 14.8, 14.4, 14.2; IR ν/ cm^{-1} 2926 (m), 1729 (m), 1490 (m), 1227 (m), 1016 (m), 752 (m); MS (EI, m/z, rel. intensity) 234 (39.8, M^+), 132 (77.6), 102 (100.0); HRMS (EI) calcd for $C_{14}H_{18}O_3$ (M^+): 234.1256; Found: 234.1254.



3k

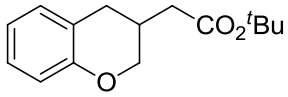
3k, white solid, 87% yield. ^{1}H NMR (300 MHz, $CDCl_3$, TMS): δ 7.18-7.13 (m, 2H), 6.97-6.86 (m, 2H), 6.80-6.77 (m, 1H), 4.72 (d, *J* = 4.8 Hz, 2H), 4.23 (q, *J* = 7.2 Hz, 2H), 2.25 (s, 3H), 1.93 (s, 3H), 1.32 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 167.3, 156.4, 136.9, 130.8, 129.6, 127.0, 126.7, 120.7, 110.9, 64.9, 60.8, 16.2, 14.2, 13.0; IR ν/ cm^{-1} 2964 (m), 2902 (w), 1712 (m), 1261 (m), 1019 (m), 800 (m); MS (EI, m/z, rel. intensity) 234 (4.0, M^+), 189 (6.0), 108 (100.0), 91 (5.9); HRMS (EI) calcd for $C_{14}H_{18}O_3$ (M^+): 234.1256; Found: 234.1254



2l

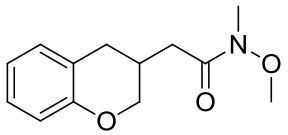
2l, white solid, 79% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.19-7.15 (m, 2H), 6.69 (d, *J* = 8.8 Hz, 1H), 4.23-4.14 (m, 3H), 3.90-3.85 (m, 1H), 2.97-2.90 (m, 1H), 2.57-2.49 (m, 2H), 2.44- 2.30 (m, 2H), 1.27 (t, *J* = 7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 171.7, 153.3, 132.3, 130.2, 122.8, 118.3, 112.4, 69.5, 60.6, 36.0, 30.6, 28.6, 14.2; IR ν/ cm^{-1} 2963 (m), 1730 (m), 1481 (m), 1157 (m), 1018 (m), 810 (m);

MS (EI, m/z, rel. intensity) 298 (42.7, M^+), 210 (87.8), 113 (100.0); HRMS (EI) calcd for $C_{13}H_{15}BrO_3$ (M^+): 298.0205; Found: 298.0203.



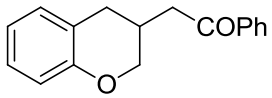
2m

2m, white solid, 90% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.11-7.01 (m, 2H), 6.86-6.79 (m, 2H), 4.23-4.20 (m, 1H), 3.87-3.82 (m, 1H), 2.96-2.91 (m, 1H), 2.57-2.48 (m, 2H), 2.35-2.23 (m, 2H), 1.46 (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 171.2, 154.2, 129.9, 127.3, 120.9, 120.4, 116.4, 80.7, 69.6, 37.7, 30.9, 29.2, 28.1; IR ν/ cm^{-1} 2974 (m), 1725 (m), 1490 (m), 1146 (m), 1018 (m), 752 (m); MS (EI, m/z, rel. intensity) 248 (16.8, M^+), 192 (92.7), 132 (100.0); HRMS (EI) calcd for $C_{15}H_{20}O_3$ (M^+): 248.1412; Found: 248.1409.



2n

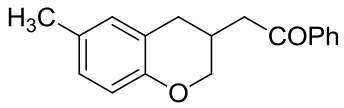
2n, on 0.2 mmol scale, white solid, 83% yield. ^{1}H NMR (300 MHz, $CDCl_3$, TMS): δ 7.11-7.02 (m, 2H), 6.87-6.79 (m, 2H), 4.24-4.21 (m, 1H), 3.97-3.91 (m, 1H), 3.63 (s, 3H), 3.20 (s, 3H), 3.05-2.98 (m, 1H), 2.68-2.42 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.6, 154.3, 130.0, 127.2, 121.0, 120.4, 116.5, 69.8, 61.2, 33.5, 32.1, 31.0, 28.4; IR ν/ cm^{-1} 2931 (m), 1738 (m), 1655 (m), 998 (m), 753 (m); MS (EI, m/z, rel. intensity) 235 (26.4, M^+), 128 (76.6), 103 (100.0); HRMS (EI) calcd for $C_{13}H_{17}NO_3$ (M^+): 235.1208; Found: 235.1204.



2o

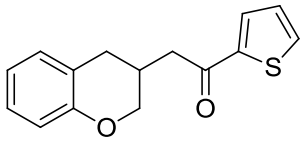
A mixture of substrate **1o** (0.3 mmol), PPh_3 (0.45 mmol), and EA (4 mL) was stirred under a nitrogen atmosphere at 60 °C until **1o** was completely consumed (29 h, monitored by TLC), and then cooled to 40 °C. Cs_2CO_3 (0.9 mmol), H_2O (6.0 mmol), and EA (2 mL) were added and stirred for another 30 h at 40 °C. After the reaction was completed, the resulting mixture was filtered rapidly through a funnel with a thin

layer of silica gel and eluted with EA. The filtrate was concentrated and the residue was purified by chromatography on silica gel to afford the product **2o** in 82% yield as a white solid. ^{1}H NMR (300 MHz, $CDCl_3$, TMS): δ 7.97-7.94 (m, 2H), 7.59-7.54 (m, 1H), 7.48-7.43 (m, 2H), 7.13-7.08 (m, 1H), 7.04-7.01 (m, 1H), 6.88-6.81 (m, 2H), 4.28-4.24 (m, 1H), 4.03-3.97 (m, 1H), 3.17-2.96 (m, 3H), 2.85-2.78 (m, 1H), 2.62-2.55 (m, 1H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 198.4, 154.2, 136.8, 133.2, 130.1, 128.6, 128.0, 127.3, 120.8, 120.5, 116.5, 69.7, 40.0, 30.9, 28.0; IR ν/ cm^{-1}2963 (m), 1682 (m), 1260 (m), 1017 (m), 799 (m); MS (EI, m/z, rel. intensity) 252 (5.4, M^+), 145 (59.8), 132 (100.0); HRMS (EI) calcd for $C_{17}H_{16}O_2$ (M^+): 252.1150; Found: 252.1148.



2p

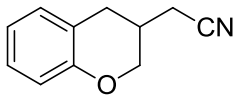
According to the procedure as **2o**, **2p,** white solid; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.96-7.94 (m, 2H), 7.58-7.54 (m, 1H), 7.47-7.43 (m, 2H), 7.92-7.89 (m, 1H), 6.83 (s, 1H), 6.72 (d, *J* = 8.4 Hz, 1H), 4.24-4.20 (m, 1H), 4.00-3.96 (m, 1H), 3.16-2.97 (m, 3H), 2.82-2.77 (m, 1H), 2.57-2.52 (m, 1H), 2.24 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 198.4, 152.0, 136.8, 133.2, 130.4, 129.6, 128.5, 128.0, 127.9, 120.4, 116.2, 69.6, 39.9, 30.9, 28.0, 20.4; IR ν/ cm^{-1} 2923 (m), 1683 (m), 1450 (m), 1218 (m), 1027 (m), 813 (m), 689 (m); HRMS (positive ESI) calcd for $C_{18}H_{18}O_2H^{+1}$ ($[M+H]^+$): 267.1380; Found: 267.1376.



2q

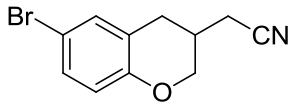
According to the procedure as **2o**, **2q,** white solid; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.68-7.64 (m, 2H), 7.13-7.09 (m, 2H), 7.03-7.01 (m, 1H), 6.87-6.81 (m, 2H), 4.26-4.23 (m, 1H), 4.02-3.97 (m, 1H), 3.08-2.91 (m, 3H), 2.84-2.76 (m, 1H), 2.62-2.56 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 191.4, 154.2, 144.2, 133.9, 132.1, 130.0, 128.1, 127.3, 120.7, 120.5, 116.5, 69.5, 40.6, 30.8, 28.4; IR ν/ cm^{-1}

3095 (m), 2925 (m), 1656 (m), 1456 (m), 1227 (m), 743 (m); HRMS (positive ESI) calcd for $C_{15}H_{14}O_2SH^{+1}$ ($[M+H]^+$): 259.0787; Found: 259.0779.



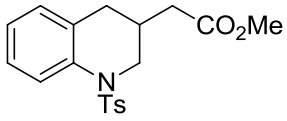
2r

According to the general procedure, **2r,** white solid, 93% yield; ^{1}H NMR (300 MHz, $CDCl_3$, TMS): δ 7.15-7.05 (m, 2H), 6.92-6.81 (m, 2H), 4.25-4.21 (m, 1H), 4.06-4.01 (m, 1H), 3.11-3.05 (m, 1H), 2.72-2.66 (m, 1H), 2.54-2.43 (m, 3H); ^{13}C NMR (75 MHz, $CDCl_3$): δ 153.6, 130.0, 127.8, 121.0, 119.1, 118.0, 116.7, 68.1, 29.9, 29.4, 19.4; IR ν/ cm^{-1} 2923 (w), 2244 (m), 1490 (m), 1245 (m), 1022 (m), 762 (m), 737 (m); MS (EI, m/z, rel. intensity) 173 (63.3, M^+), 131 (100.0), 105 (55.3); HRMS (EI) calcd for $C_{11}H_{11}NO$ (M^+): 173.0841; Found: 173.0839.



2s

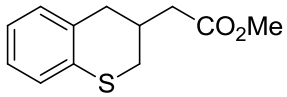
According to the general procedure, **2s,** white solid, 86% yield; ^{1}H NMR (300 MHz, $CDCl_3$, TMS): δ 7.22-7.18 (m, 2H), 6.71 (d, *J* = 8.7 Hz, 1H), 4.23-4.20 (m, 1H), 4.06-4.00 (m, 1H), 3.07-3.02 (m, 1H), 2.70-2.63 (m, 1H), 2.53- 2.42 (m, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 152.8, 132.4, 130.7, 121.3, 118.5, 117.7, 113.0, 68.1, 29.7, 29.0, 19.3; IR ν/ cm^{-1} 2963 (m), 2241 (w), 1479 (m), 1231 (m), 1027 (m), 822 (m); MS (EI, m/z, rel. intensity) 251 (100.0, M^+), 132 (49.2), 77 (41.5); HRMS (EI) calcd for $C_{11}H_{10}BrNO$ (M^+): 250.9946; Found: 250.9949.



5a

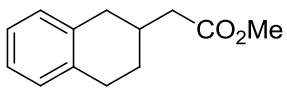
A mixture of substrate **4a** (0.3 mmol), PPh_3 (0.45 mmol), and EA (4 mL) was stirred under a nitrogen atmosphere at 80 ^{o}C until **4a** was completely consumed (monitored by TLC, 2 d). Cs_2CO_3 (0.9 mmol), H_2O (0.75 mmol), and EA (2 mL) were then added and stirred for another 25 h. After the reaction was completed, the resulting mixture was filtered rapidly through a funnel with a thin layer of silica gel

and eluted with EA. The filtrate was concentrated and the residue was purified by chromatography on silica gel to afford the product **5a** as a white solid in 88% yield. ^{1}H NMR (300 MHz, $CDCl_3$, TMS): δ 7.80 (d, *J* = 8.1 Hz, 1H), 7.54-7.51 (m, 2H), 7.22-7.16 (m, 3H), 7.09-6.98 (m, 2H), 4.28-4.22 (m, 1H), 3.70 (s, 3H), 3.23-3.15 (m, 1H), 2.67-2.60 (m, 1H), 2.38 (s, 3H), 2.28-2.10 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 171.7, 143.5, 136.4, 136.2, 129.5, 129.1, 128.8, 127.0, 126.5, 124.8, 123.9, 51.6, 50.6, 37.8, 32.9, 28.8, 21.4; IR ν/ cm^{-1}3056 (w), 2939 (w), 1736 (m), 1350 (m), 1164 (m), 736 (m), 664 (m); MS (EI, m/z, rel. intensity) 359 (5.5, M^+), 144 (90.9), 130 (100.0); HRMS (EI) calcd for $C_{19}H_{21}NO_4S$ (M^+): 359.1191; Found: 359.1195.



5b

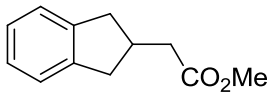
A mixture of substrate **4b** (0.3 mmol), PPh_3 (0.45 mmol), and EA (4 mL) was stirred under a nitrogen atmosphere at 60 °C until **4b** was completely consumed (10h, monitored by TLC). Cs_2CO_3 (0.9 mmol), H_2O (0.75 mmol), and EA (2 mL) were added and then warmed to 80 °C for another 11 h. After the reaction was completed, the resulting mixture was filtered rapidly through a funnel with a thin layer of silica gel and eluted with EA. The filtrate was concentrated and the residue was purified by chromatography on silica gel to afford the desired product **5b** as a pale yellow oil in 71% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.10-7.04 (m, 2H), 7.01-6.95 (m, 2H), 3.70 (s, 3H), 3.10-3.07 (m, 1H), 2.94-2.83 (m, 2H), 2.67-2.59 (m, 2H), 2.54-2.40 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 172.5, 132.2, 132.0, 130.4, 126.5, 126.2, 124.1, 51.6, 38.7, 35.3, 31.8, 29.6; IR ν/ cm^{-1} 2924 (w), 1737 (m), 1438 (m), 1206 (m), 1006 (m), 739 (s); MS (EI, m/z, rel. intensity) 222 (79.1, M^+), 123 (72.4), 99 (100.0); HRMS (EI) calcd for $C_{12}H_{14}O_2S$ (M^+): 222.0715; Found: 222.0717.



5c

According to the general procedure, **5c,** white solid, 89% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.11-7.04 (m, 4H), 3.70 (s, 3H), 2.92-2.82 (m, 3H), 2.53-2.47 (m,

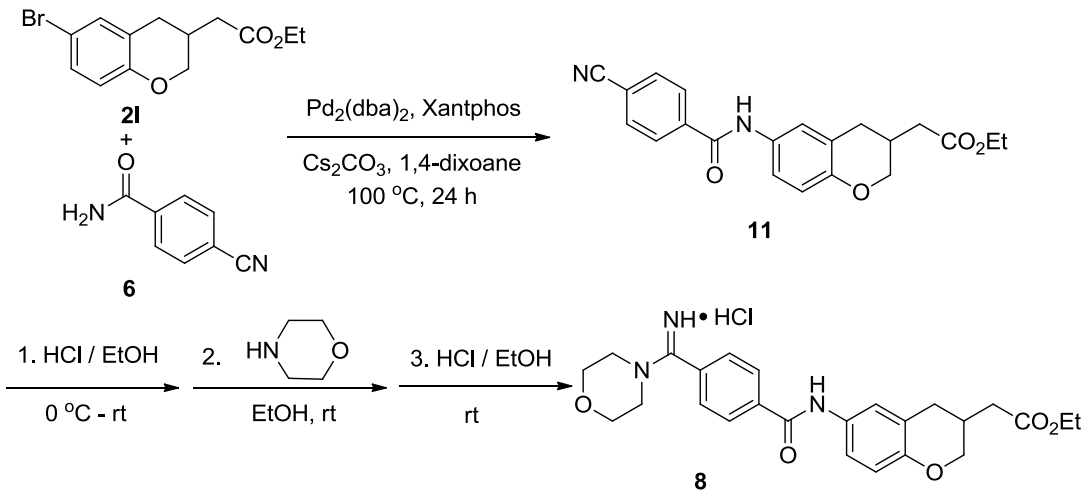
1H), 2.39-2.38 (m, 2H), 2.31-2.25 (m, 1H), 1.99-1.94 (m, 1H), 1.53-1.43 (m, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 173.2, 136.2, 135.7, 129.1, 128.8, 125.7, 125.6, 51.5, 40.8, 35.6, 31.4, 29.1, 28.7; IR ν/ cm^{-1} 2916 (w), 1734 (m), 1435 (m), 1152 (m), 1014 (m), 800 (m), 743 (m); MS (EI, m/z, rel. intensity) 204 (9.6, M^+), 130 (100.0); HRMS (EI) calcd for $C_{13}H_{16}O_2$ (M^+): 204.1150; Found: 204.1147.



5d

According to the general procedure, **5d,** white solid, 95% yield; ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.23-7.16 (m, 2H), 7.15-7.11 (m, 2H), 3.69 (s, 3H), 3.13 (dd, *J* = 15.2 and 7.6 Hz, 2H), 2.92-2.84 (m, 1H), 2.64 (dd, *J* = 15.6 and 7.2 Hz, 2H), 2.49 (d, *J* = 7.2 Hz, 2H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 173.3, 142.6, 126.2, 124.4, 51.5, 39.7, 38.9, 36.0.

5. Synthesis of Glycoprotein IIb-IIIa Antagonist 8.[2]



A flame-dried resealable Schlenk tube was charged with **2l** (149.6 mg, 0.5 mmol), **6** (109.6 mg, 0.75 mmol), $Pd_2(dba)_3$ (45.8 mg, 0.05 mmol), Xantphos (86.8 mg, 0.15 mmol), and Cs_2CO_3 (439.8 mg, 1.35 mmol). The Schlenk tube was evacuated and backfilled with N_2 three times, and then the 1,4-dioxane (5 mL) was added. The mixture was stirred at 100 °C until the starting aryl halide **2l** had been completely consumed monitored by TLC for 27 h. The resulting mixture was then cooled to room temperature, and filtered rapidly through a funnel with a thin layer of silica gel and eluted with EA. The filtrate was concentrated and the residue was purified by chromatography on silica gel to afford the product **11** (129.9 mg, 71% yield) as pale yellow solid. ^{1}H NMR (400 MHz, $CDCl_3$, TMS): δ 7.95 (d, *J* = 8.0 Hz, 2H), 7.88 (s, 1H), 7.76 (d, *J* = 8.4 Hz, 2H), 7.42 (s, 1H), 7.20 (dd, *J* = 7.8 and 2.4 Hz, 1H), 6.80 (dd, *J* = 8.4 and 2.4 Hz, 1H), 4.24-4.14 (m, 3H), 3.92-3.87 (m, 1H), 3.00-2.93 (m, 1H), 2.57-2.52 (m, 2H), 2.45-2.32 (m, 2H), 1.28 (t, *J* = 7.2 Hz, 3H).

Anhydrous HCl was bubbled into an ice-cooled suspension of **11** (36.4 mg, 0.1 mmol) in EtOH (2 mL) for 1.5 h. The mixture was stirred for 4 h at room temerature and concentrated in vacuo. The resulting solid was triturated with Et_2O, dried under reduced pressure and dissovled in EtOH (2 mL), to this solution morpholine (0.6 mmol) was added, and the mixture was stirred for 20 h at room temerature,

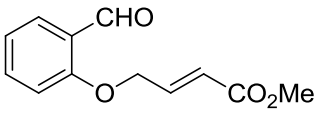
concentrated in vacuo, The resulting solid was triturated with Et_2O, dried under reduced pressure and treated with ethanolic HCl to afford product **8** (42.3 mg, 87% yield) as a pale yellow solid. ^{1}H NMR (400 MHz, DMSO-d_6, TMS): δ 10.38 (s, 1H), 9.75-9.72 (m, 2H), 8.18 (d, *J* = 8.4 Hz, 2H), 7.77 (d, *J* = 8.0 Hz, 2H), 7.53 (s, 1H), 7.48 (d, *J* = 8.4 Hz, 1H), 6.76 (d, *J* = 8.4 Hz, 1H), 4.18 (d, *J* = 10.0 Hz, 1H), 4.11 (q, *J* = 7.2 Hz, 2H), 3.87-3.79 (m, 5H), 3.70-3.62 (m, 2H), 3.41-3.29 (m, 2H), 2.91-2.84 (m, 1H), 2.56-2.33 (m, 4H), 1.21 (t, *J* = 7.2 Hz, 3H).

6. References

1 (a) L.-W. Ye, X.-L. Sun, C.-Y. Li, Y. Tang, *J. Org. Chem.* 2007, **72**, 1335; (b) M. P. Oude Wolbers, F. C. J. M. van Veggel, B. H. M. Snellink-Ruël, J. W. Hofstraat, F. A. J. Geurts, D. N. Reinboudt, *J. Am. Chem. Soc.* 1997, **119**, 138.

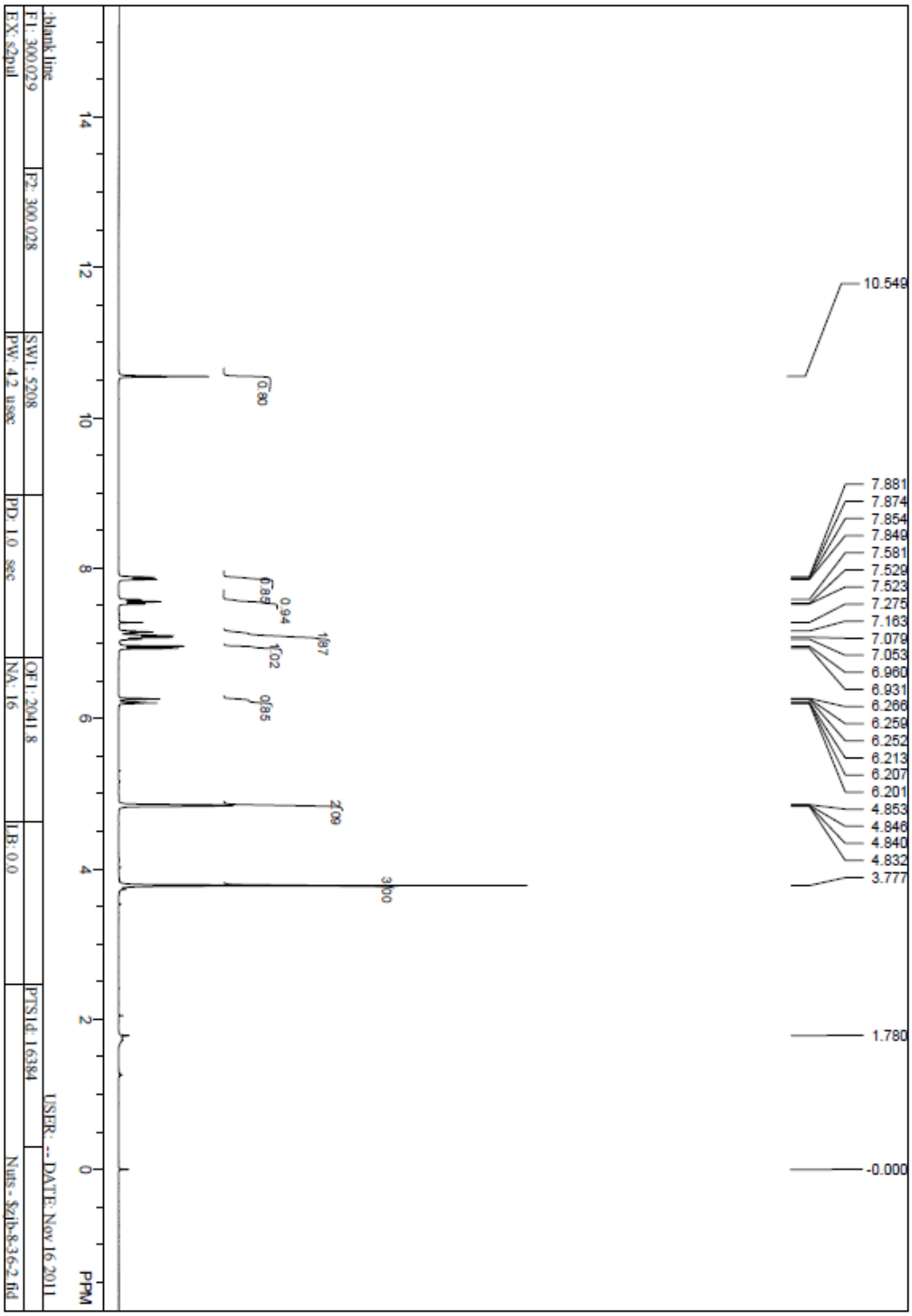
2 (a) J.-J. Yin, S. L. Buchwald, *J. Am. Chem. Soc.* 2002, **124**, 6043; (b) K. Okumura, T. Shimazaki, Y. Aoki, H. Yamashita, *J. Med. Chem.* 1998, **41**, 4036.

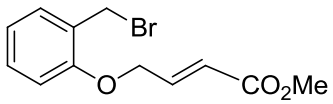
7. NMR Spectra



9

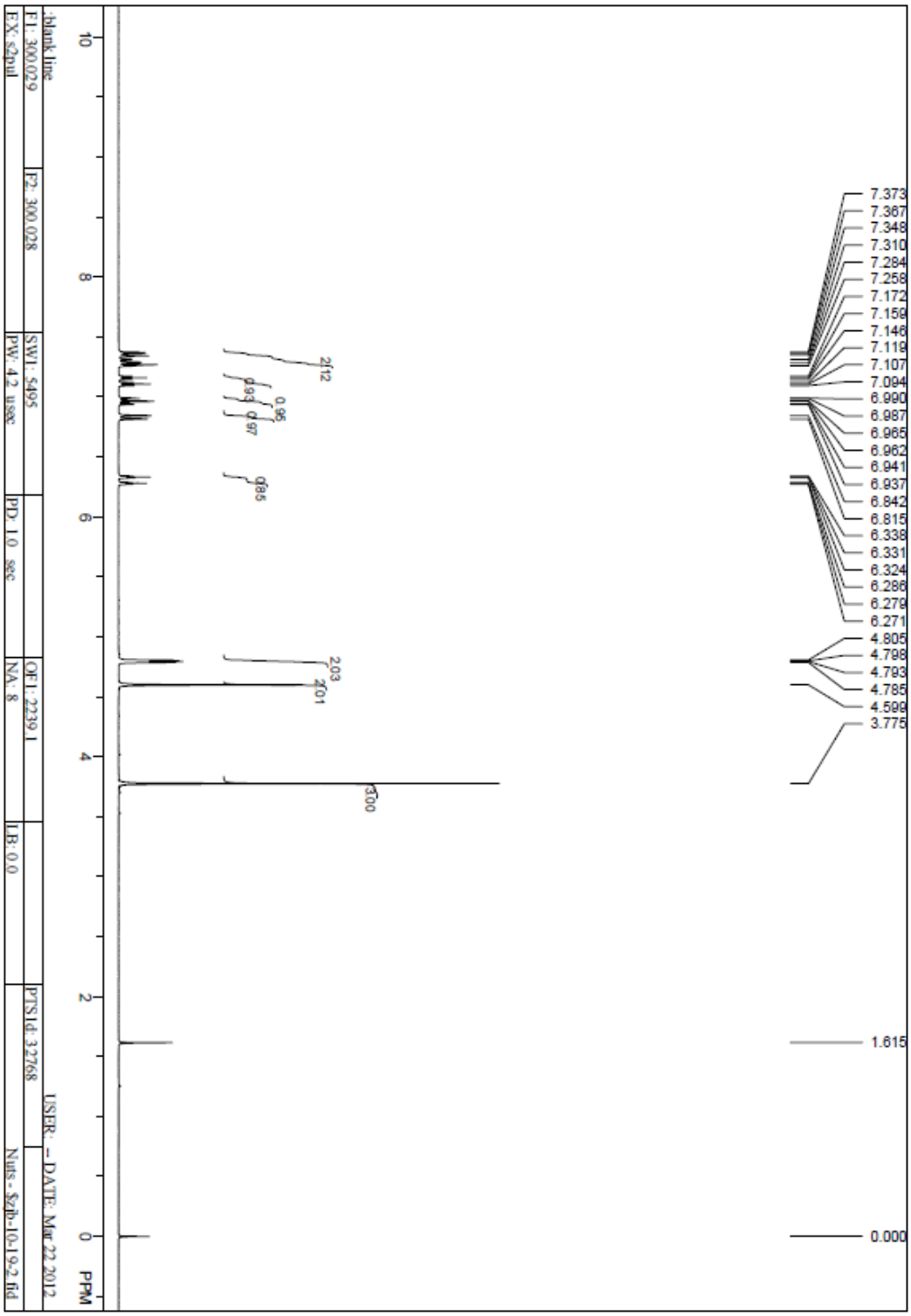
^{1}H NMR (300 M Hz in $CDCl_3$)

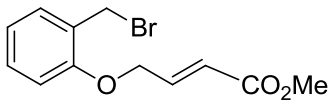




1b

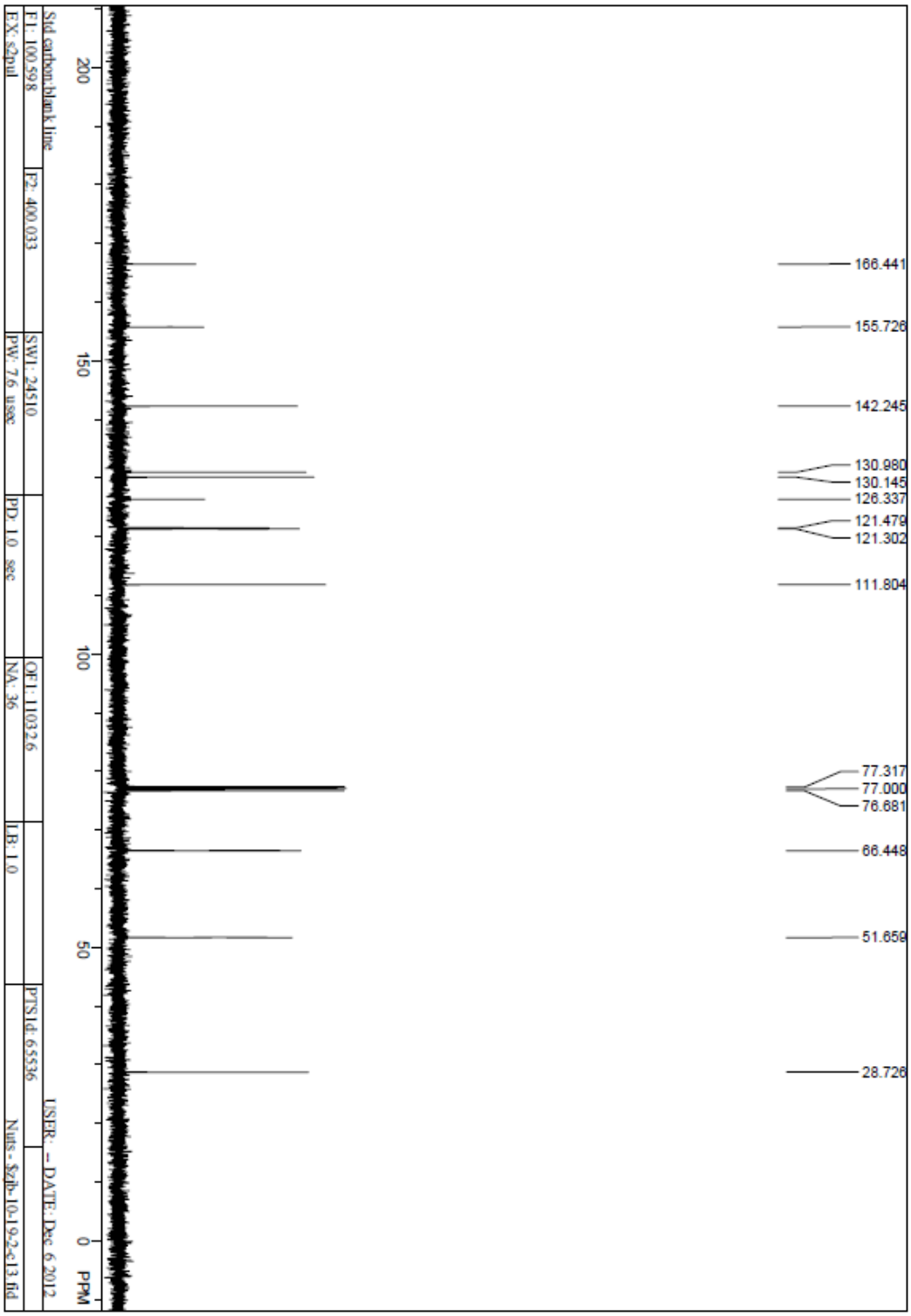
^{1}H NMR (300 M Hz in $CDCl_3$)

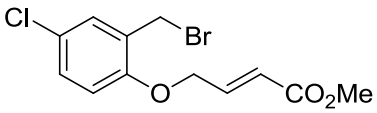




1b

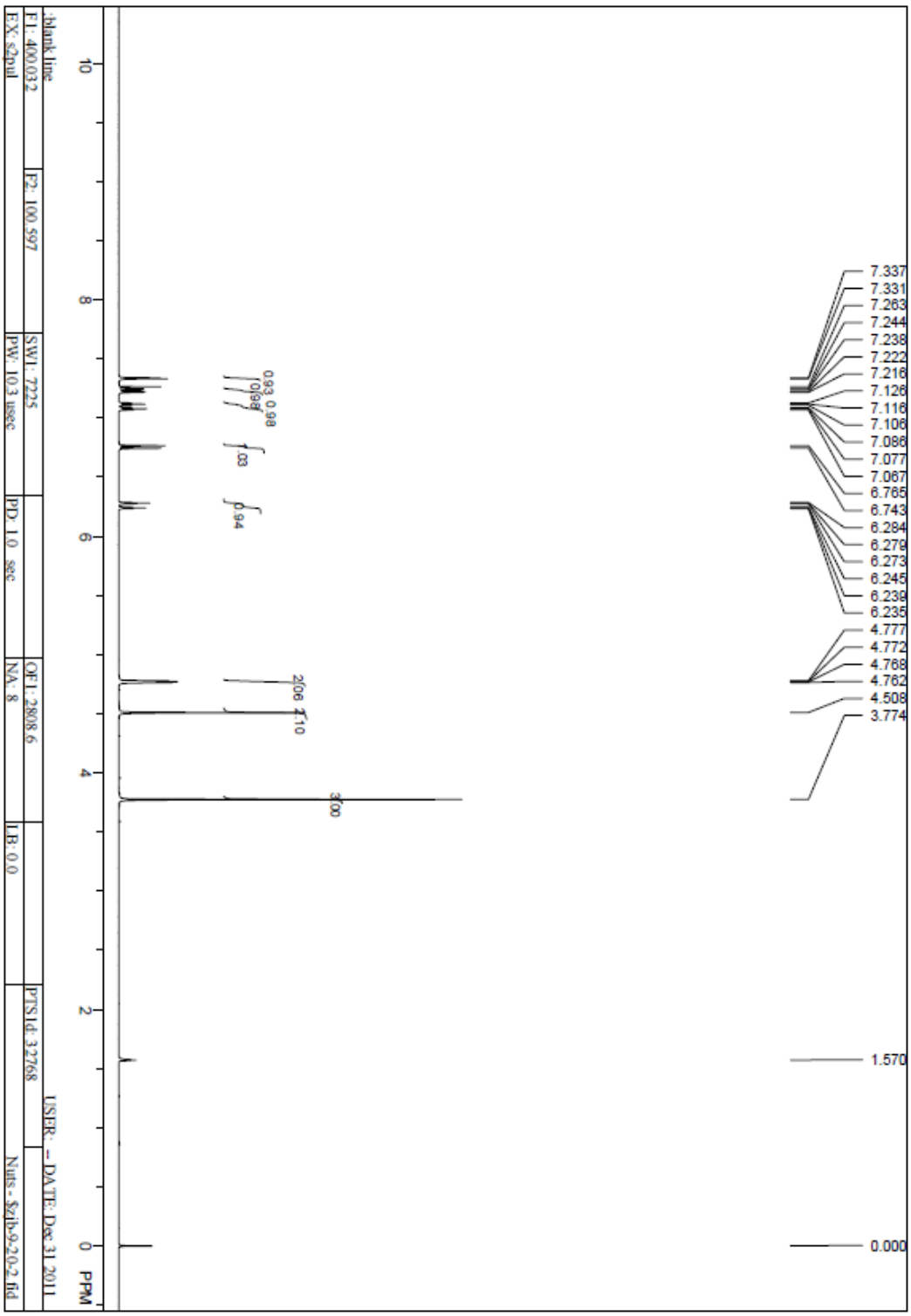
^{13}C NMR (100 M Hz in $CDCl_3$)

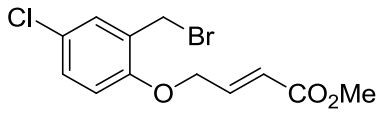




1a

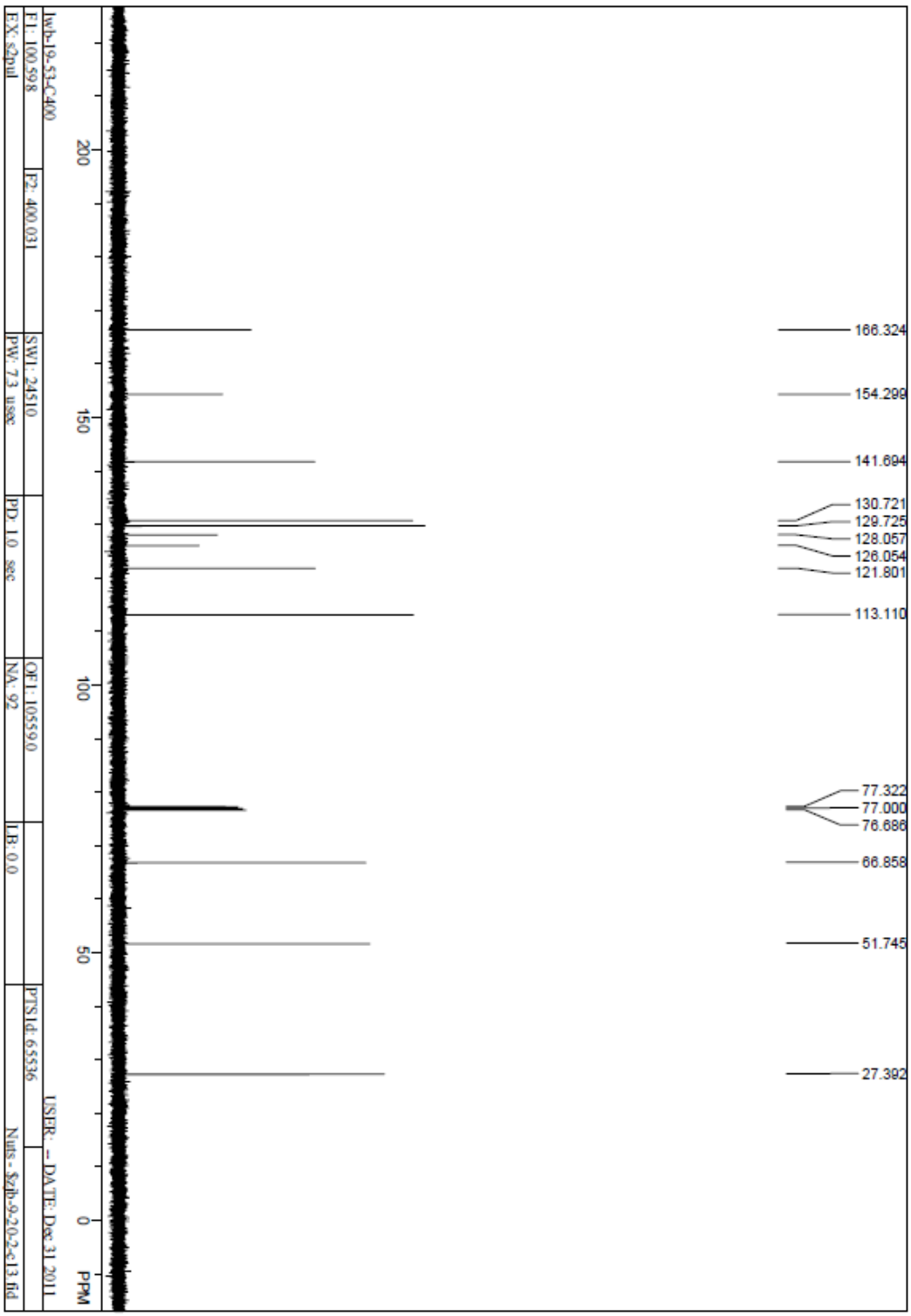
^{1}H NMR (400 M Hz in $CDCl_3$)

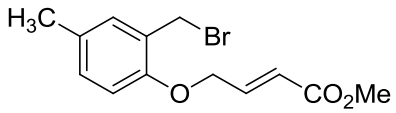




1a

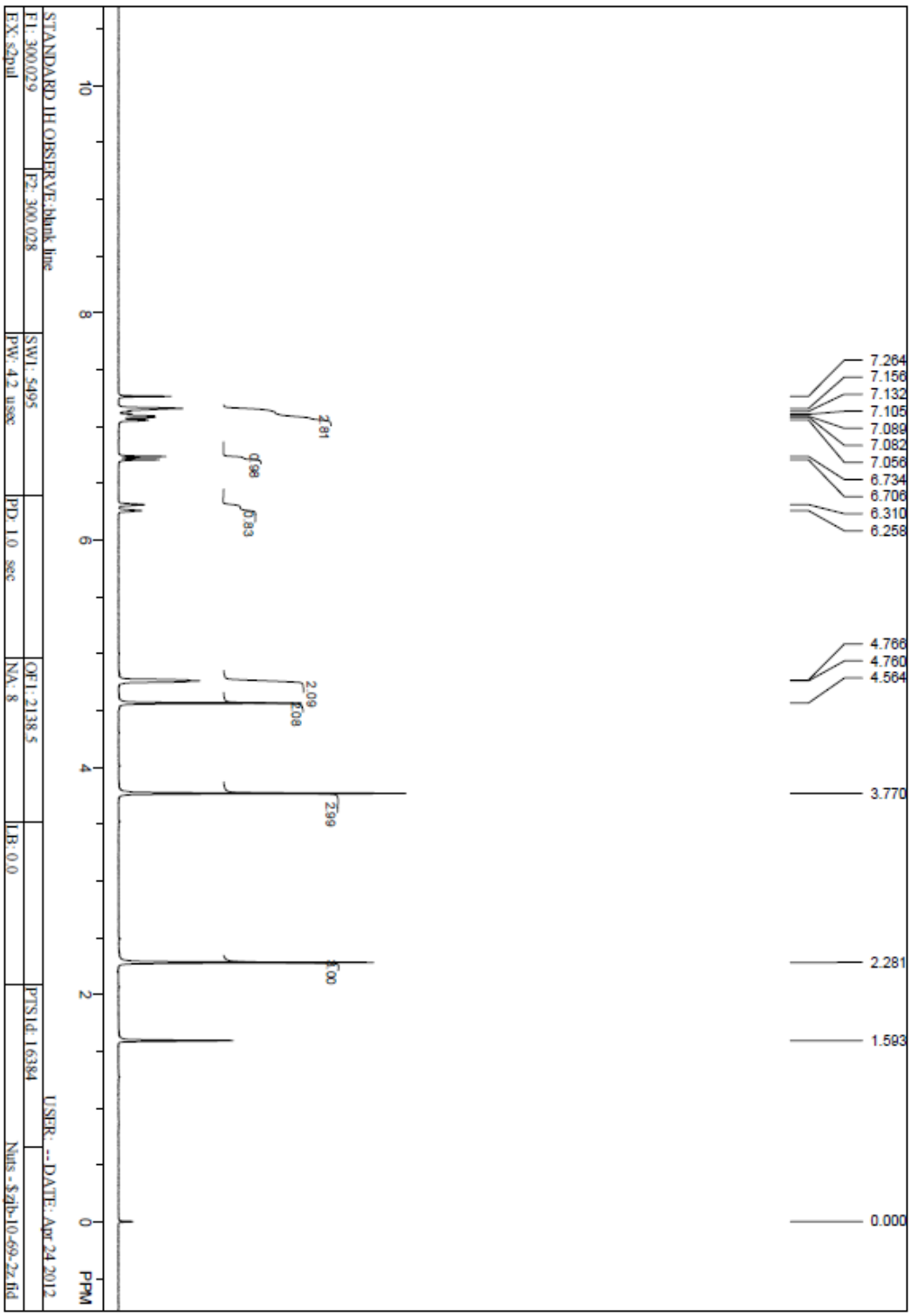
^{13}C NMR (100 M Hz in $CDCl_3$)

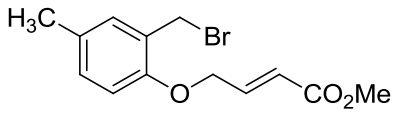




1c

^{1}H NMR (300 M Hz in $CDCl_3$)





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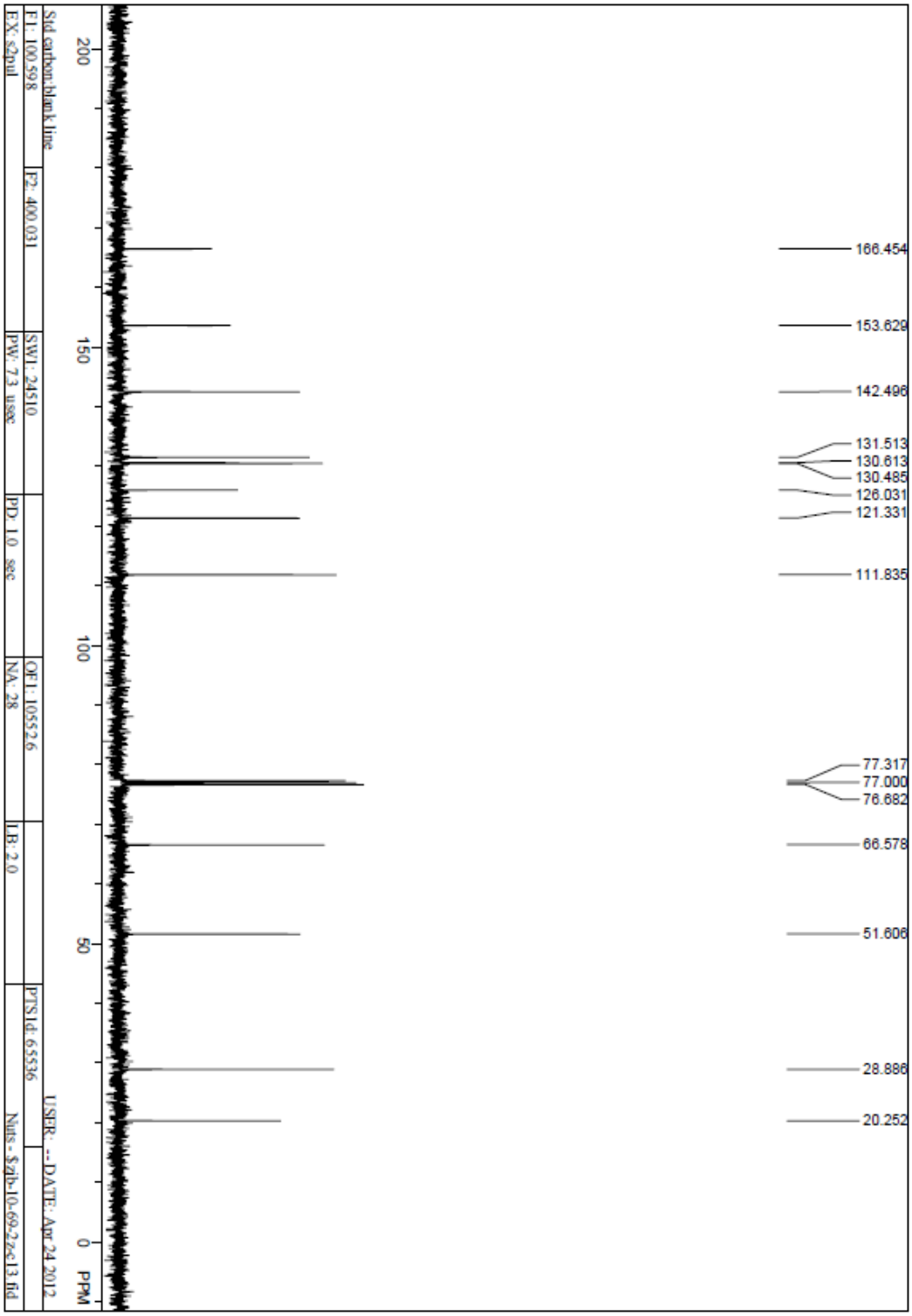

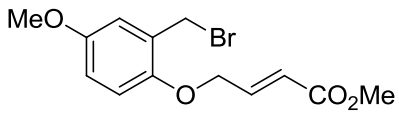

1d

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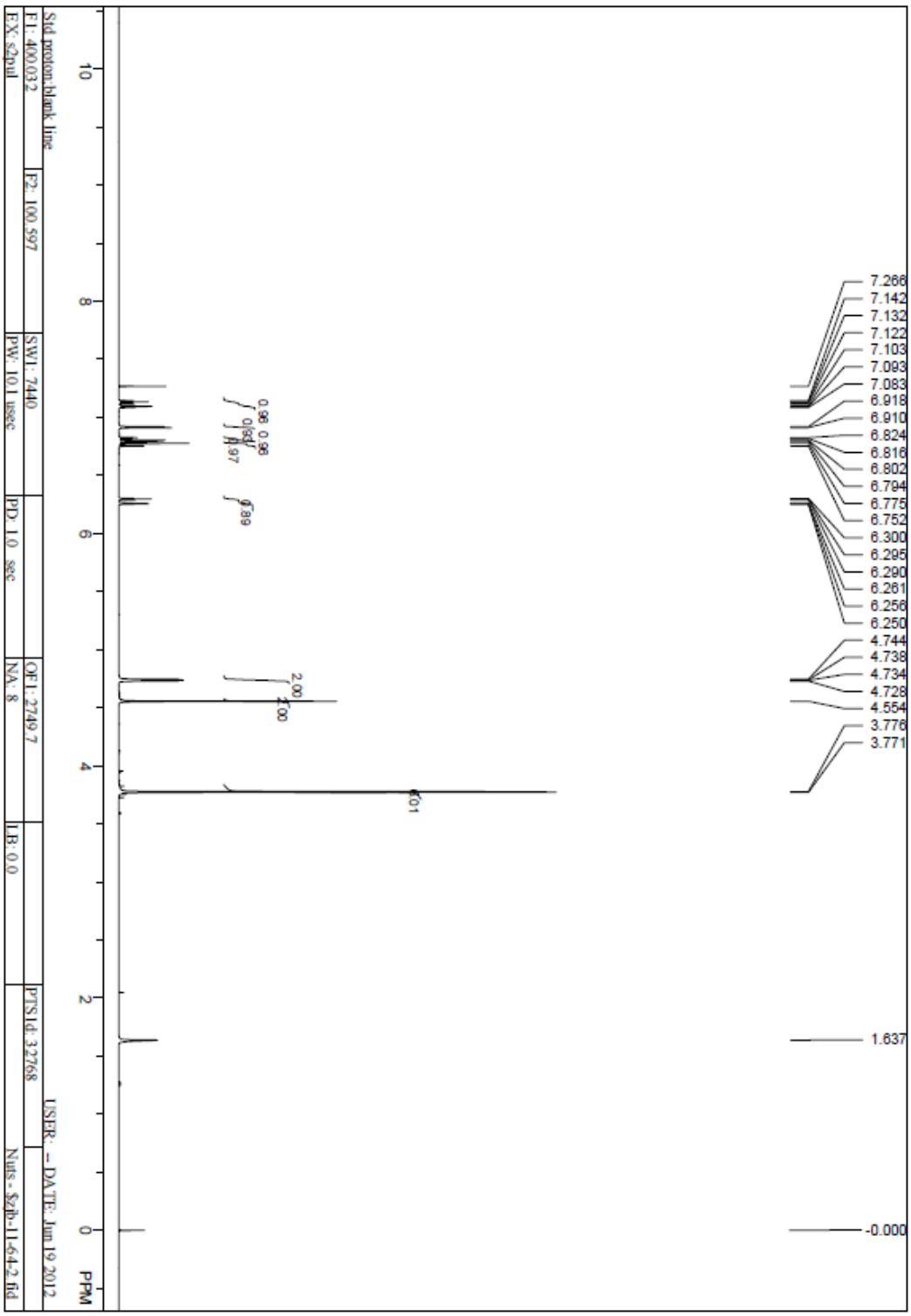
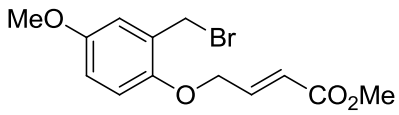
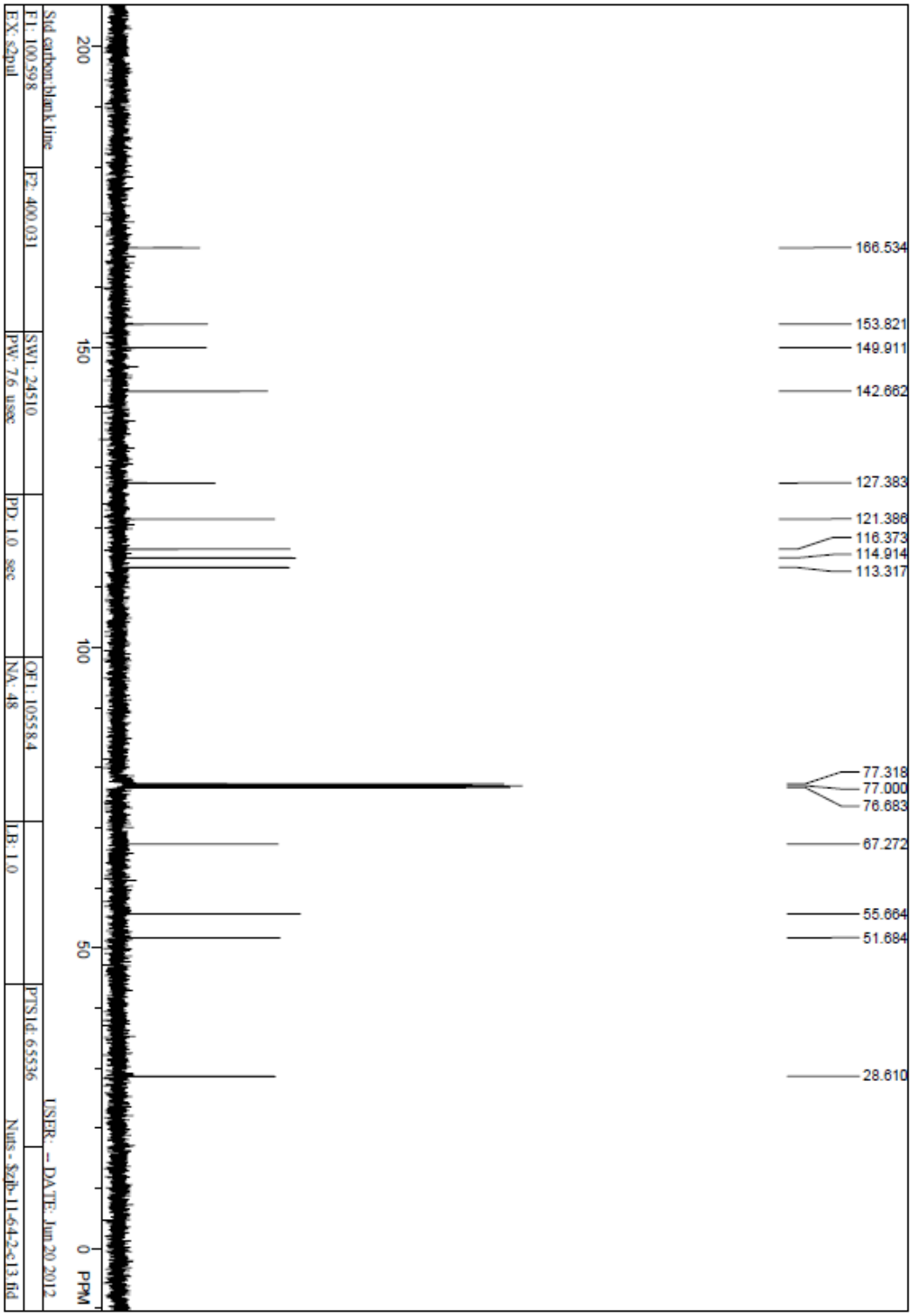
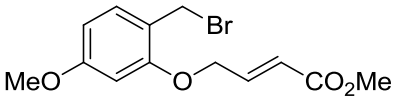




1d

^{13}C NMR (100 M Hz in $CDCl_3$)





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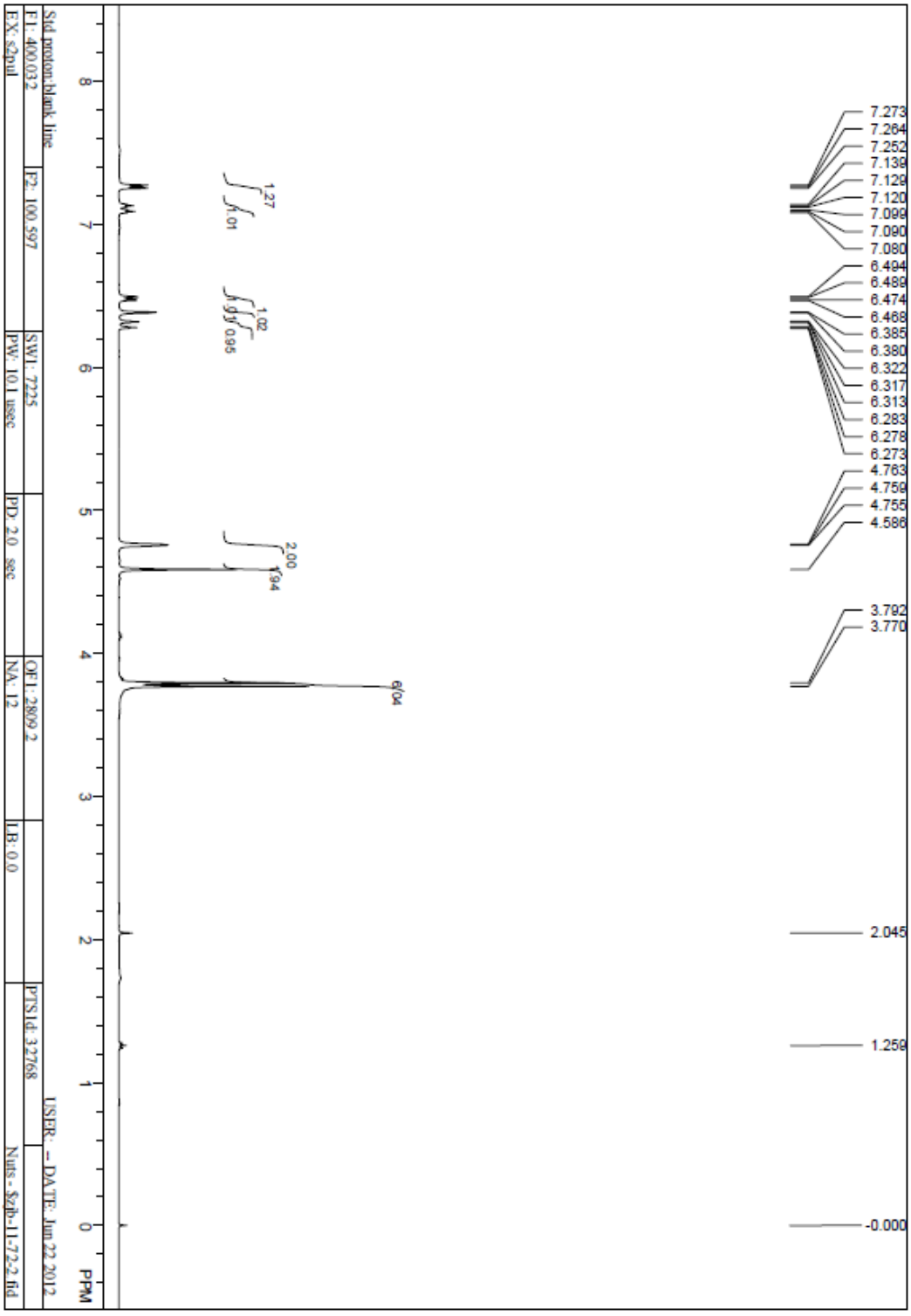

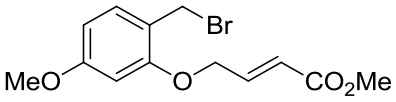

1e

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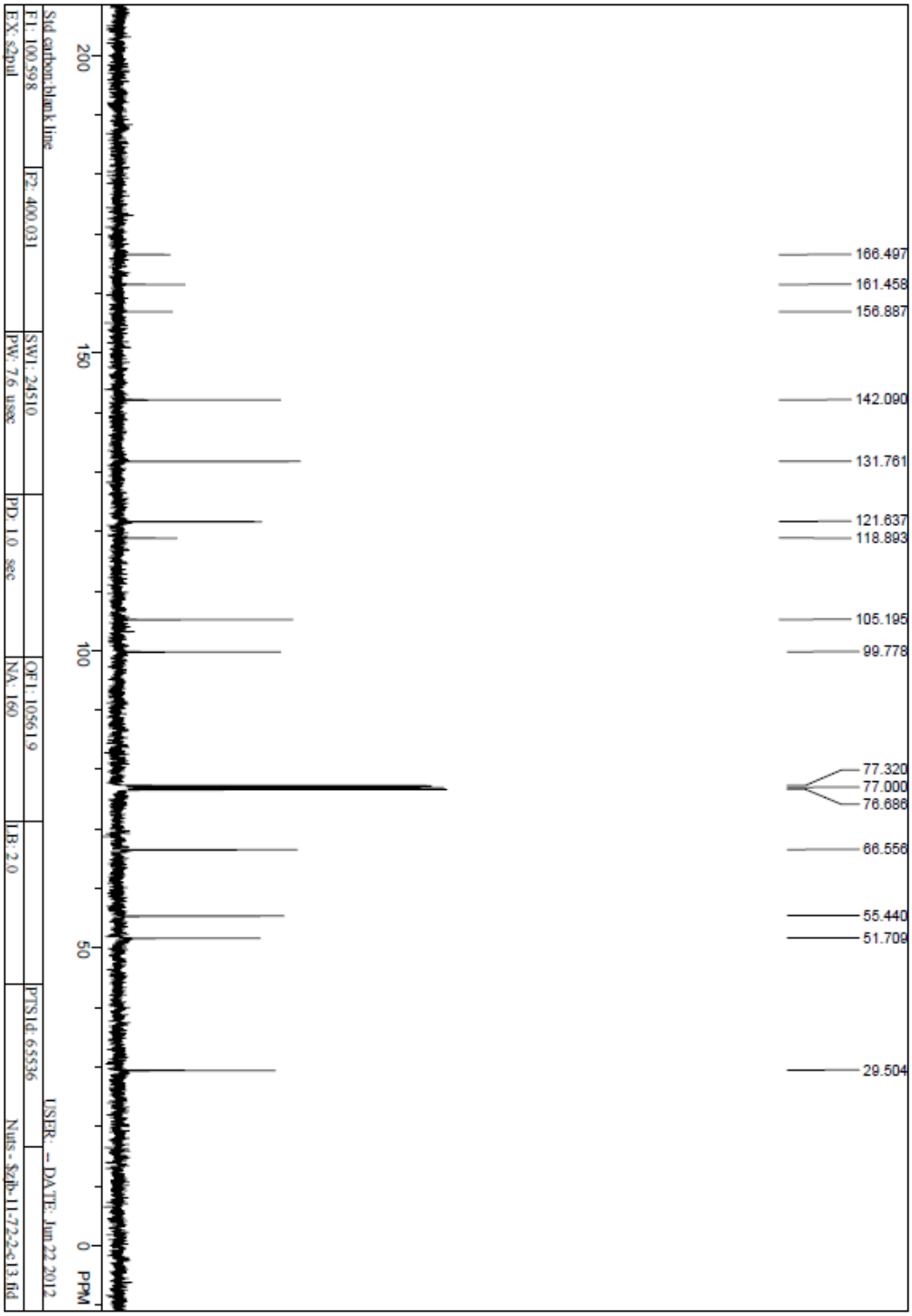
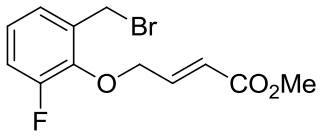
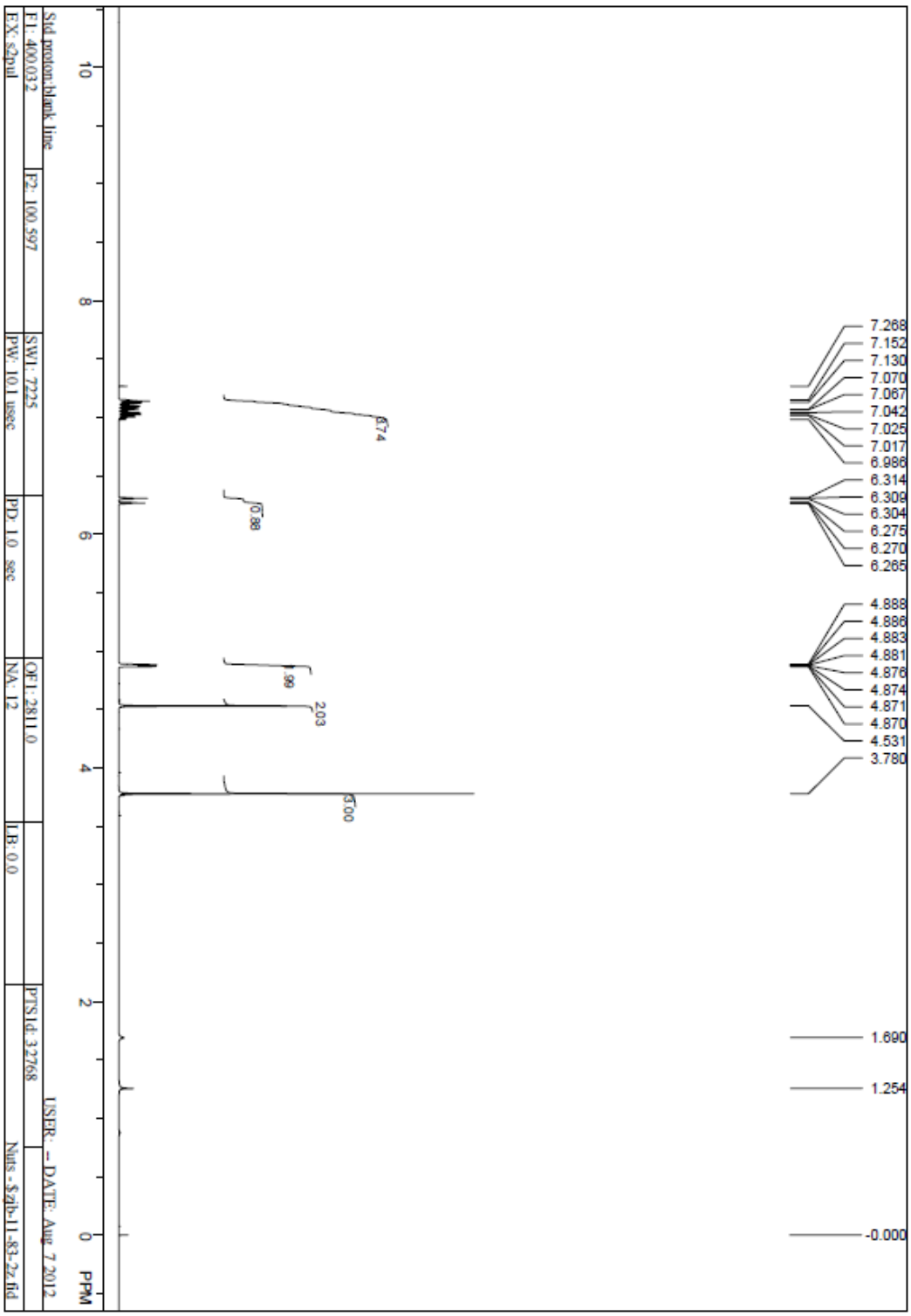
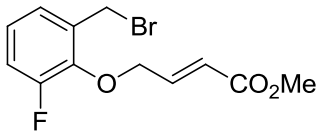




1f

^{1}H NMR (400 M Hz in $CDCl_3$)





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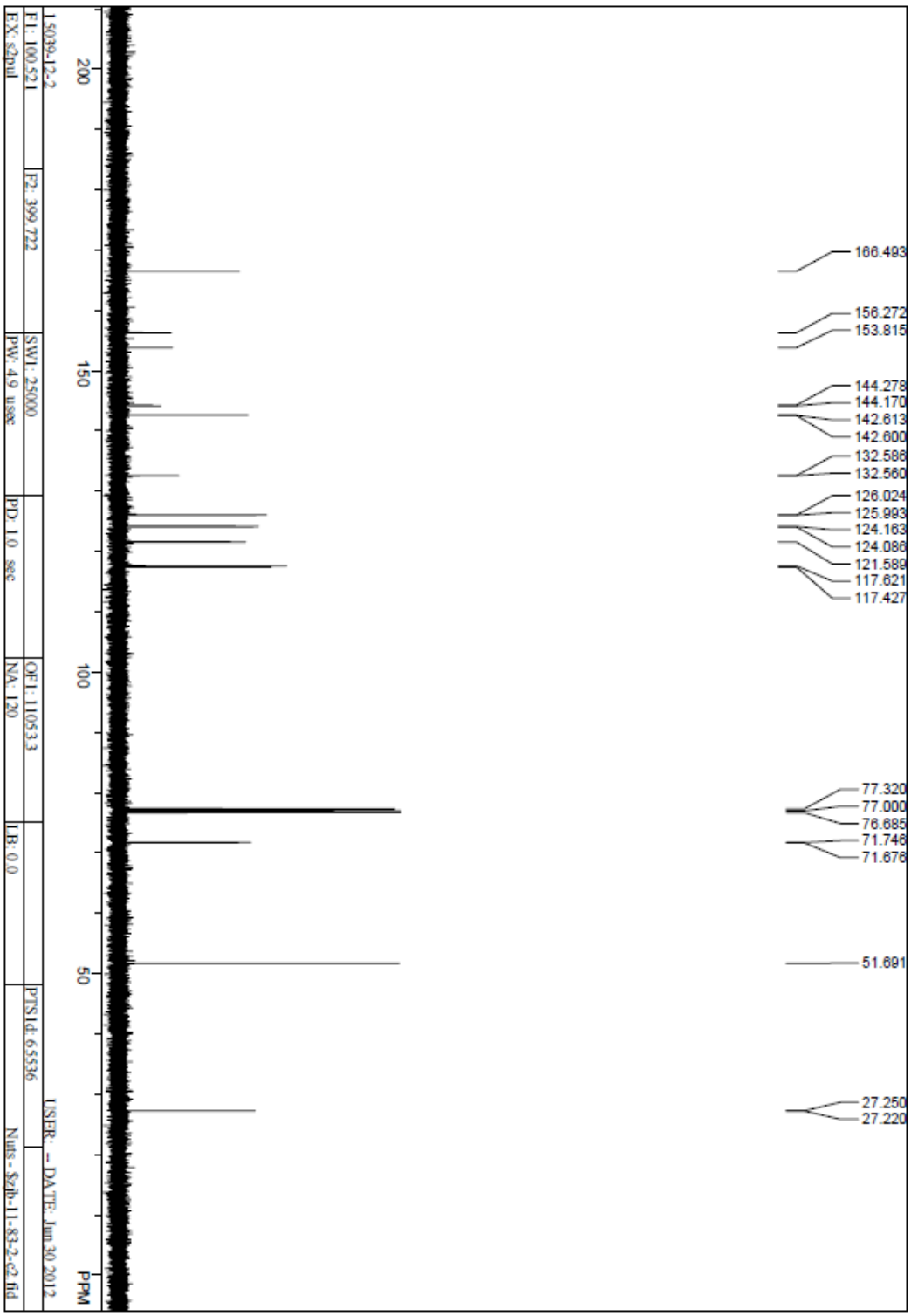
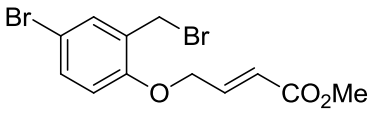
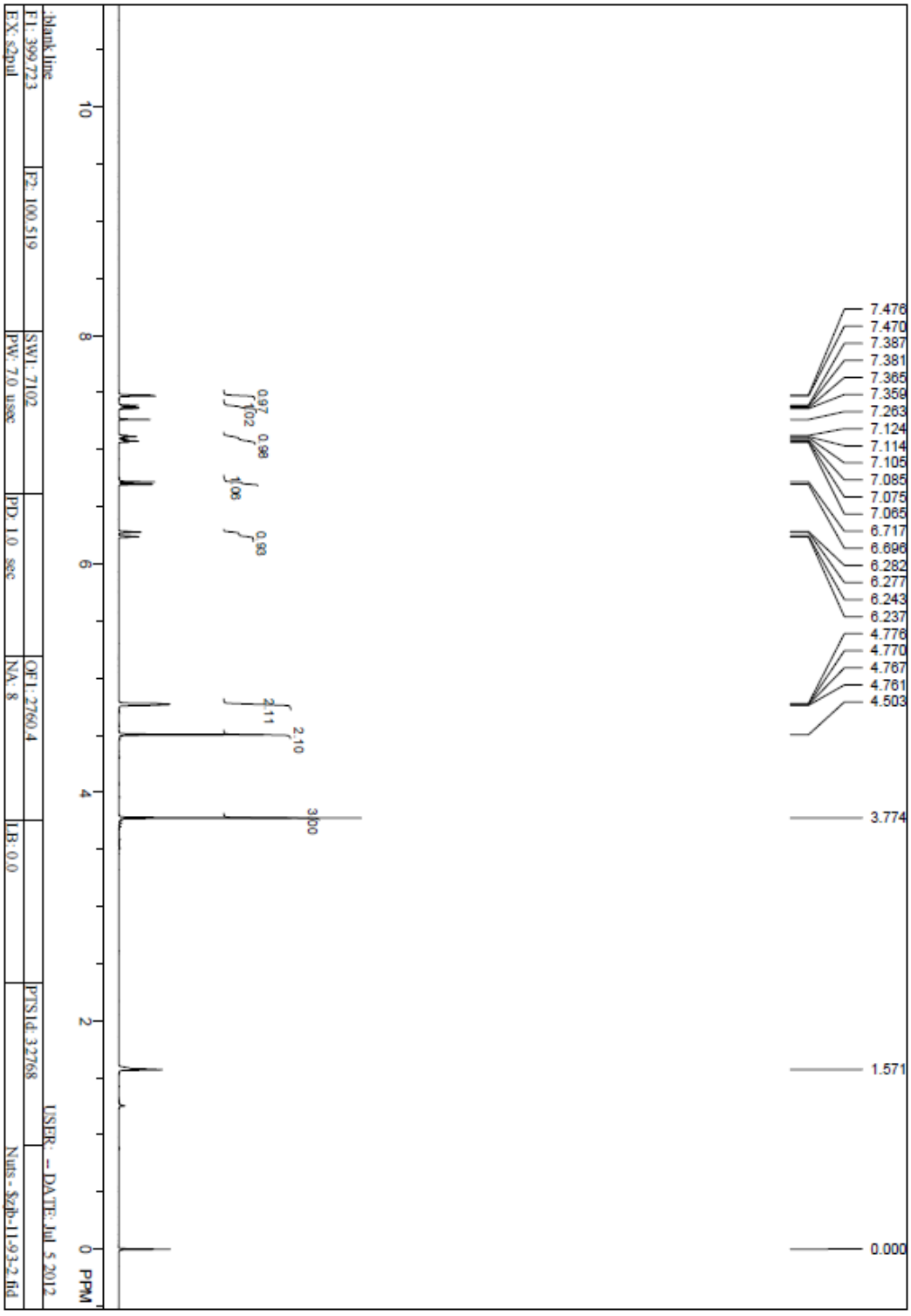
^{13}C NMR (100 M Hz in $CDCl_3$)

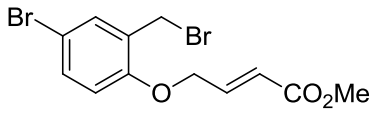




1g

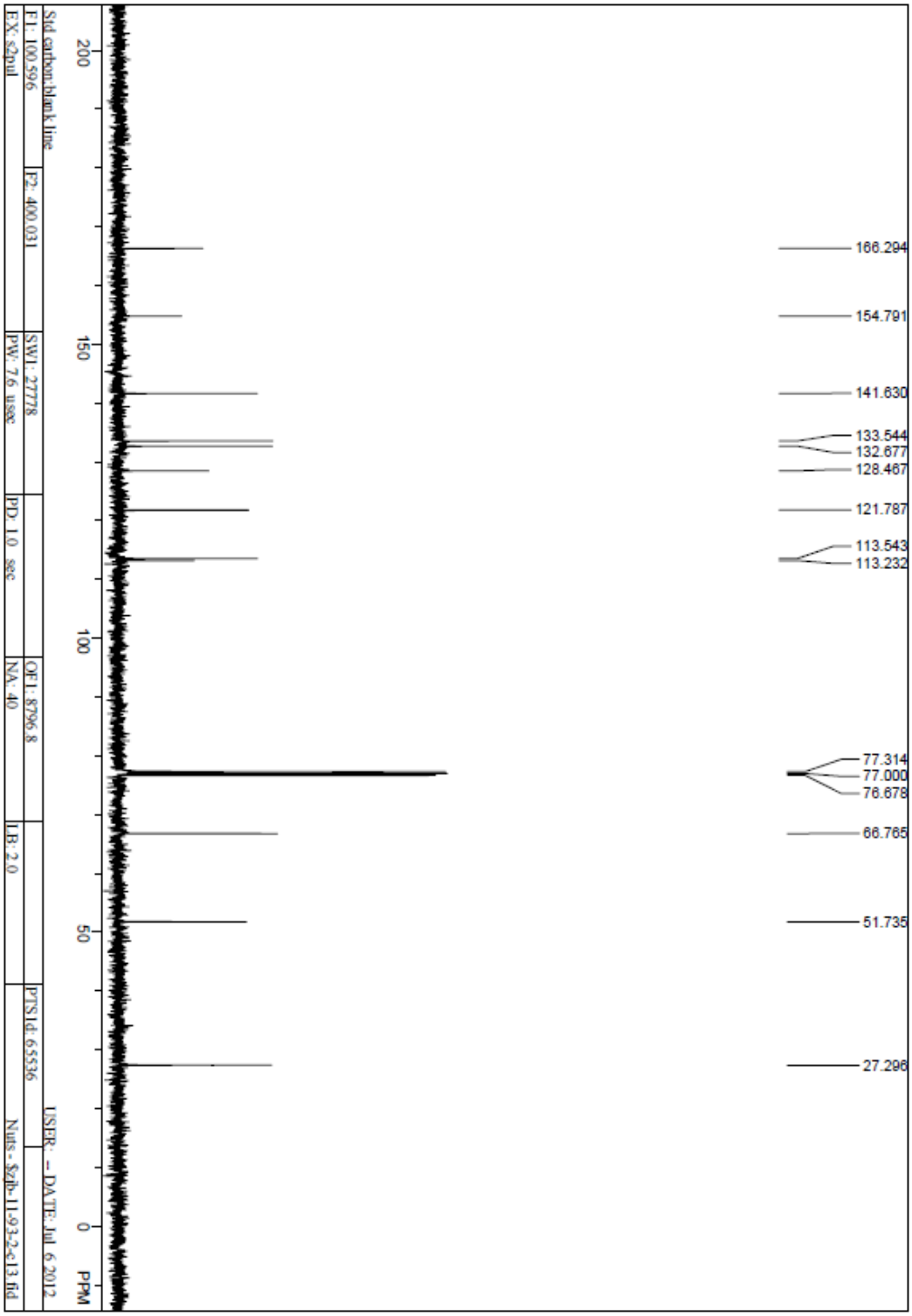
^{1}H NMR (400 M Hz in $CDCl_3$)

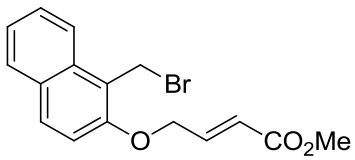




1g

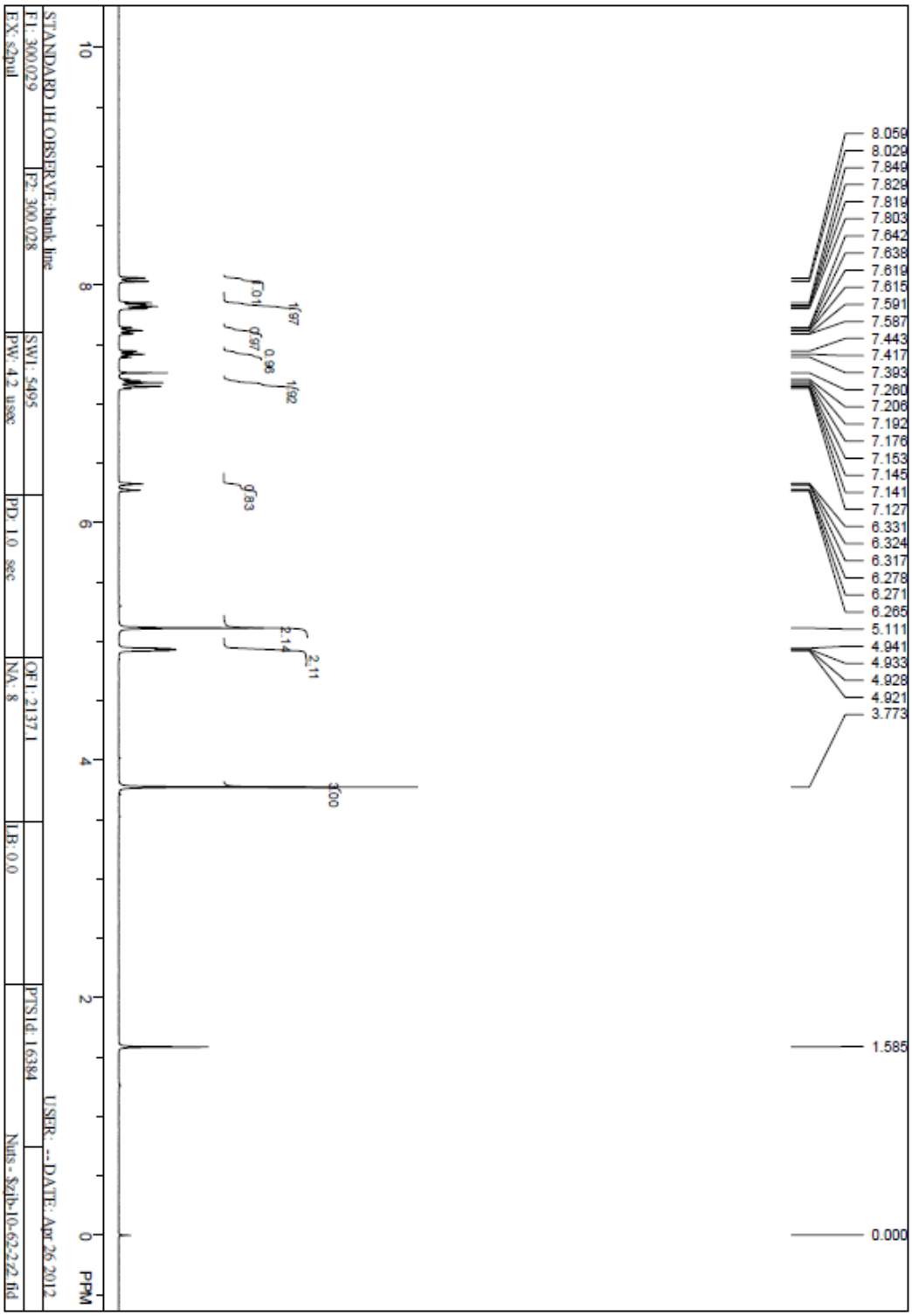
^{13}C NMR (100 M Hz in $CDCl_3$)

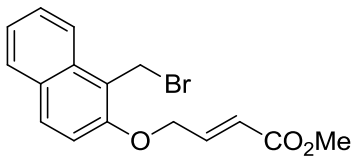




1h

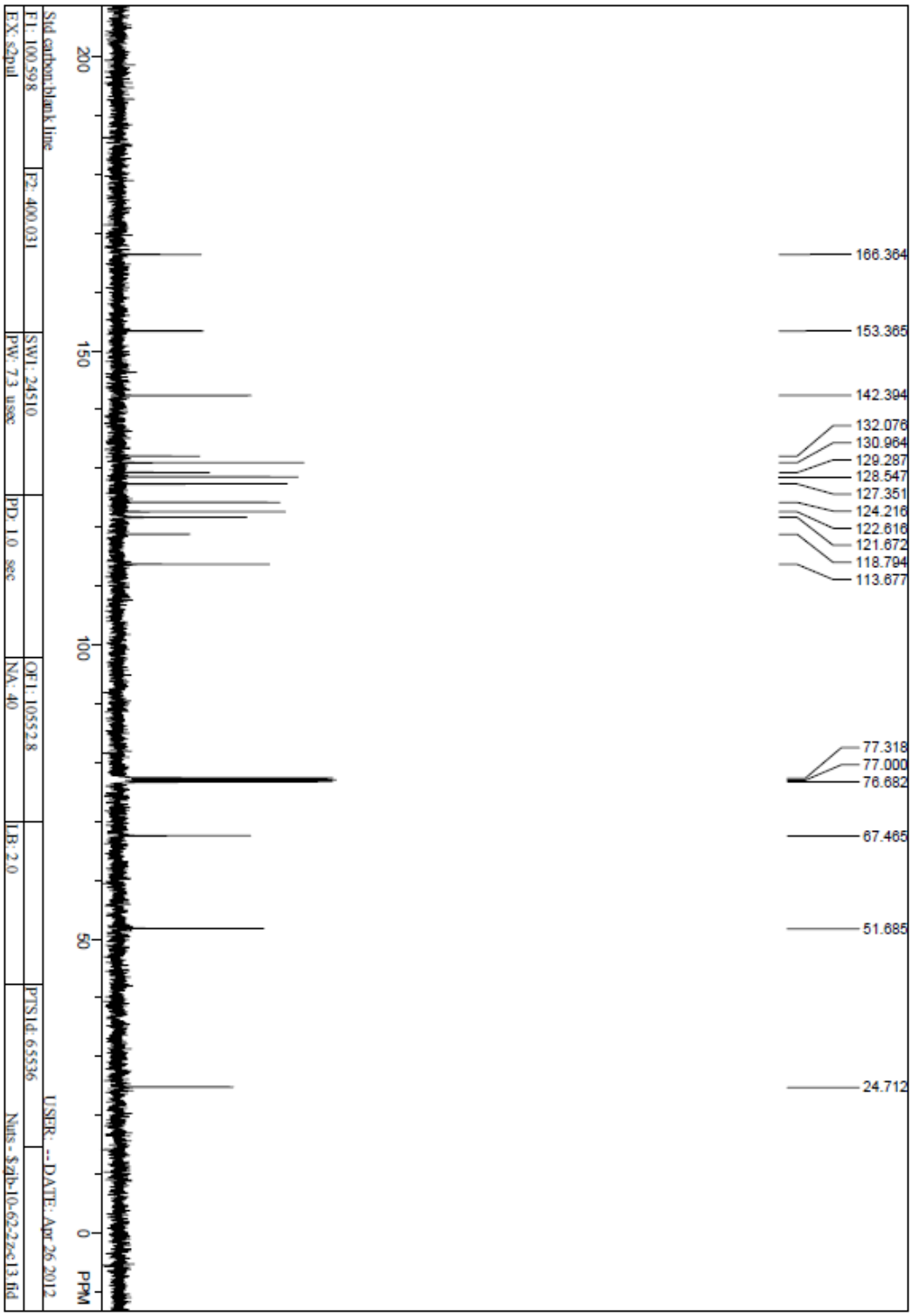
^{1}H NMR (300 M Hz in $CDCl_3$)

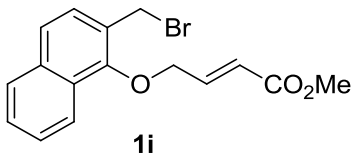




1h

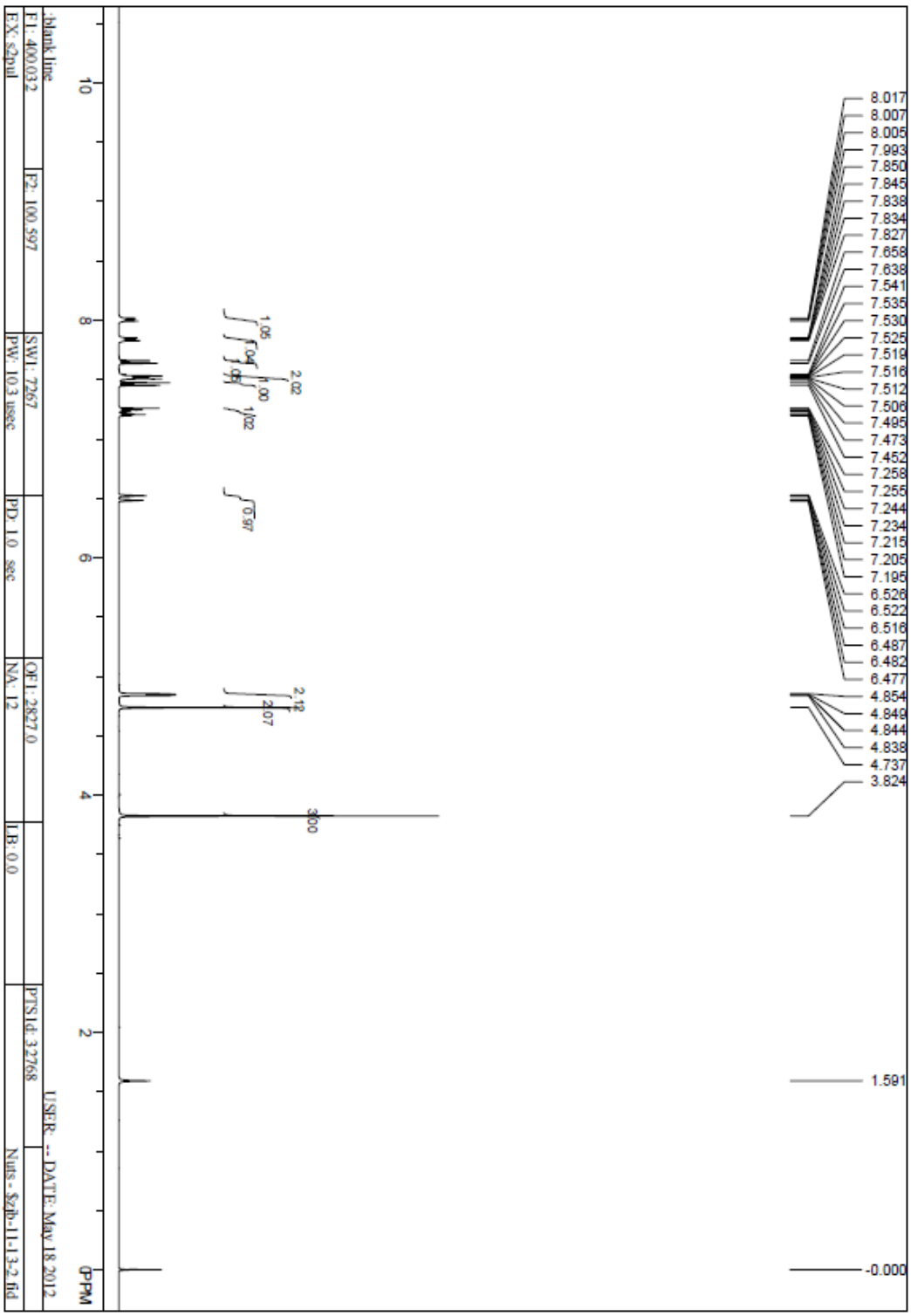
^{13}C NMR (100 M Hz in $CDCl_3$)

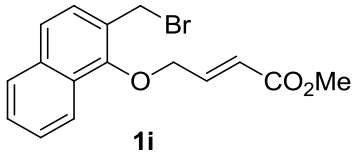




1i

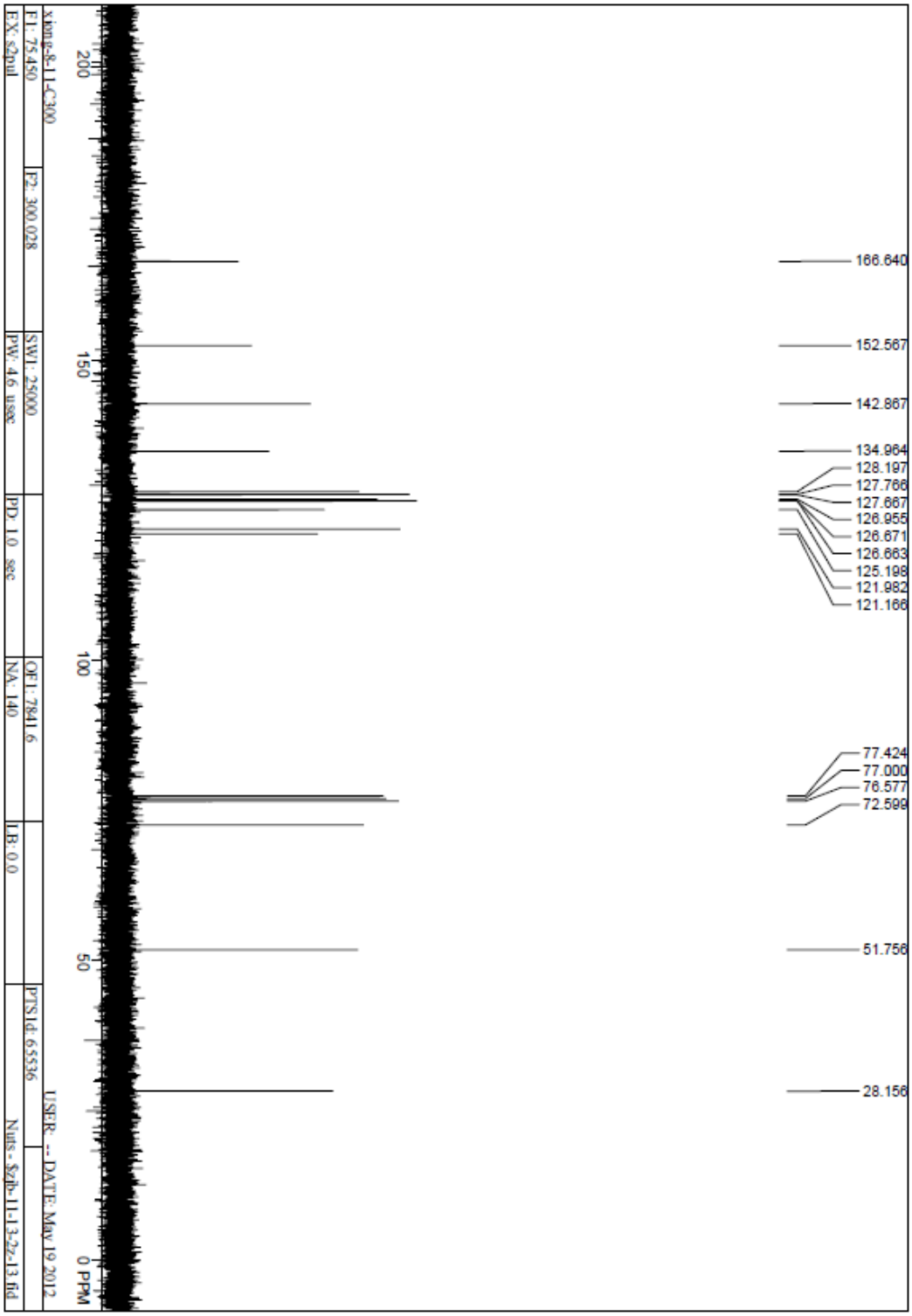
^{1}H NMR (400 M Hz in $CDCl_3$)

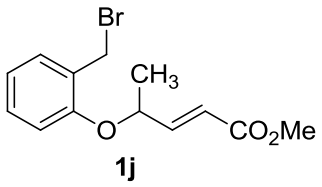




1i

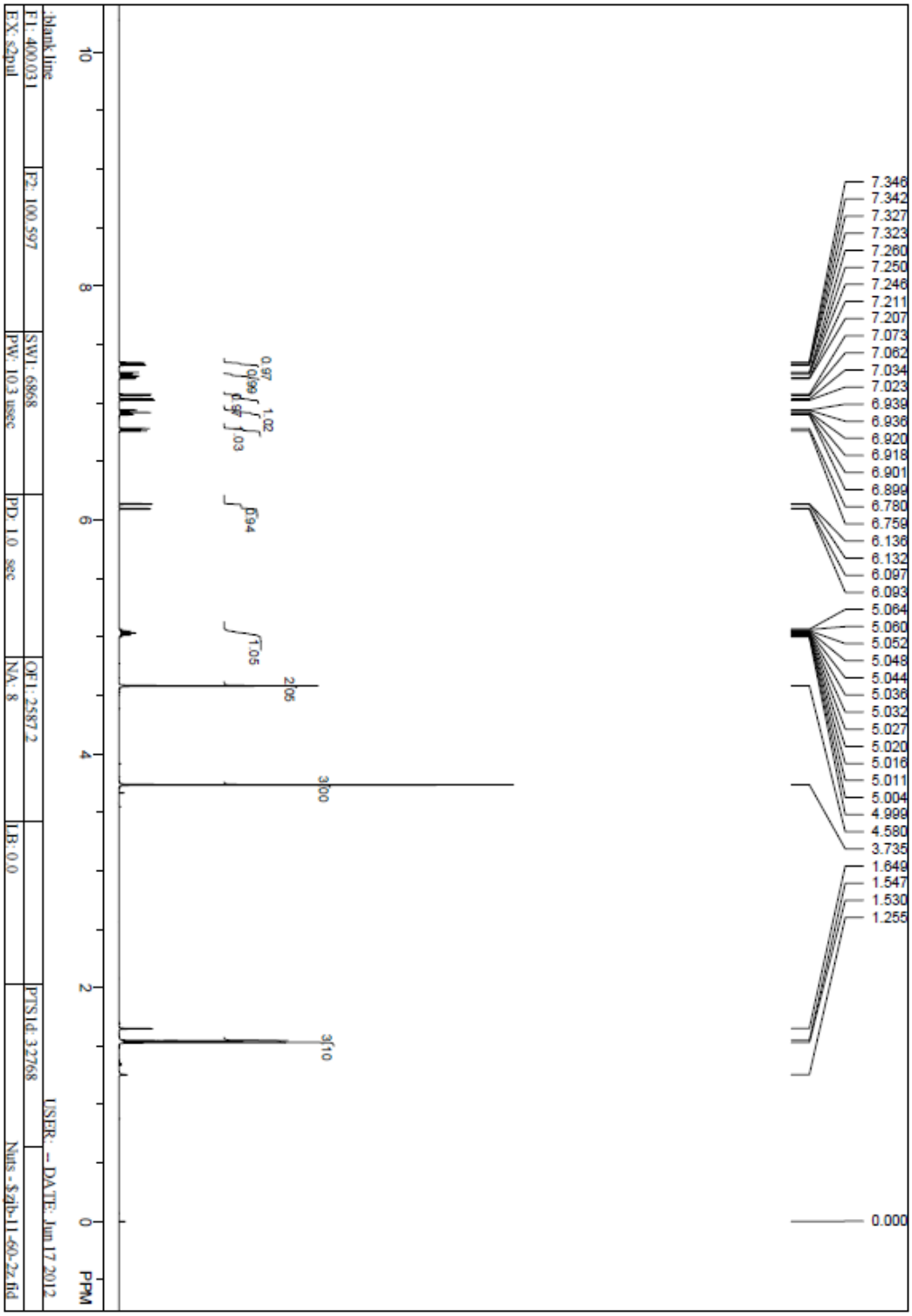
^{13}C NMR (75 M Hz in $CDCl_3$)

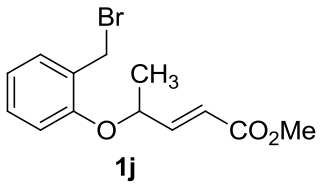




1j

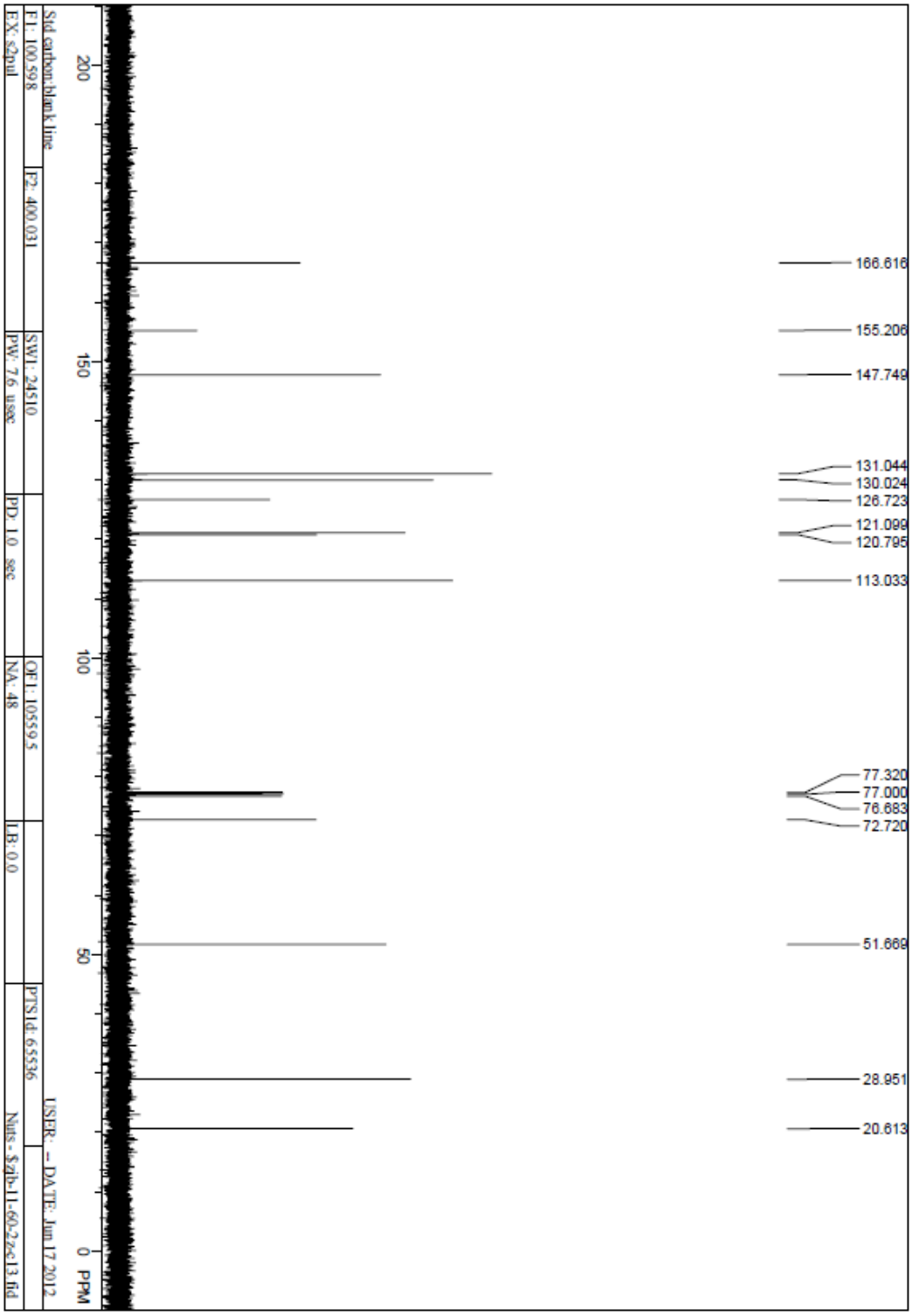
^{1}H NMR (400 M Hz in $CDCl_3$)

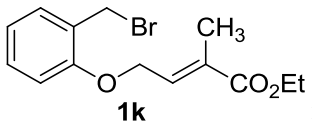




1j

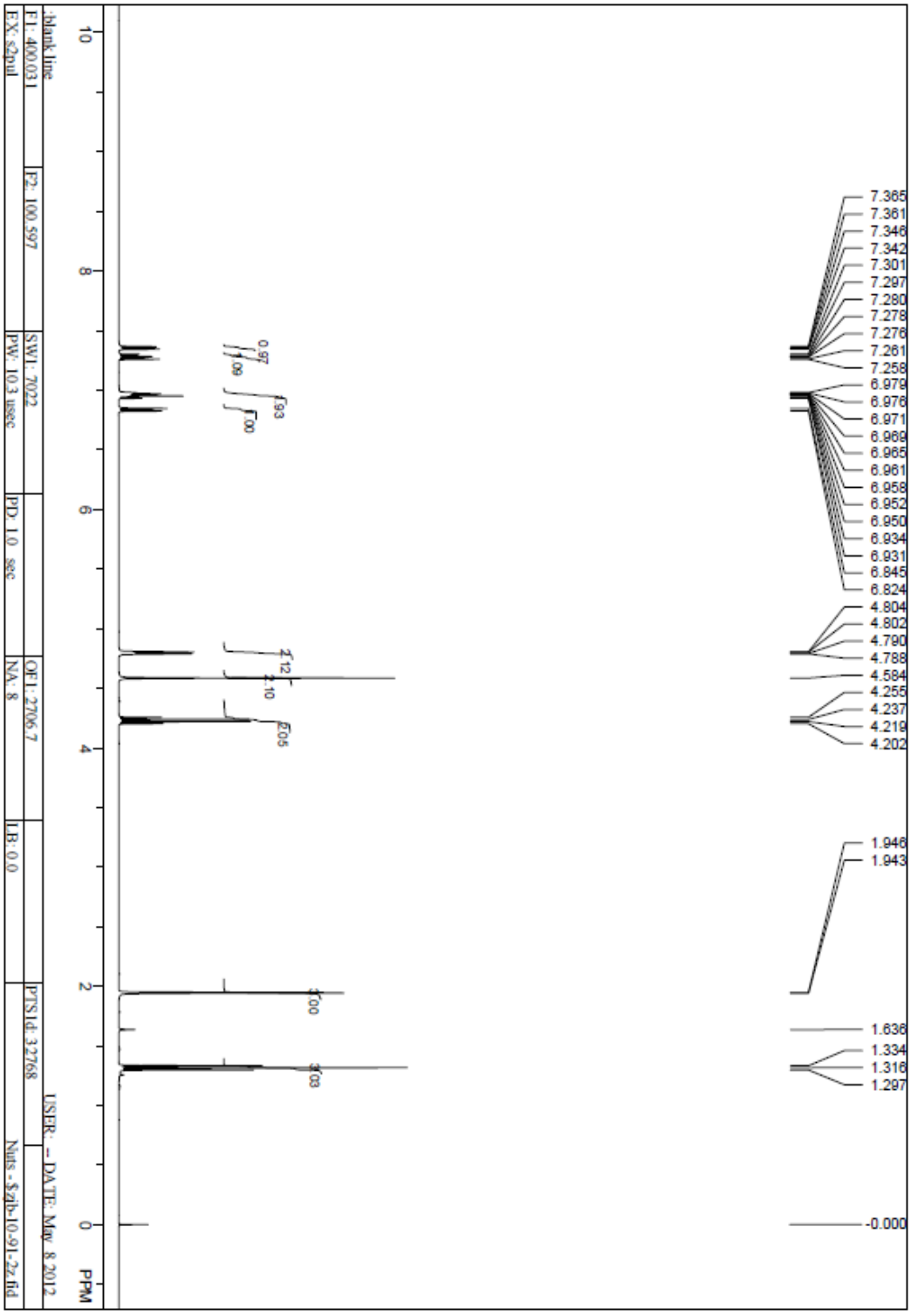
^{13}C NMR (100 M Hz in $CDCl_3$)

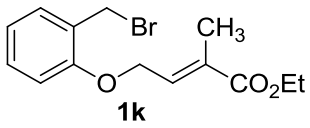




1k

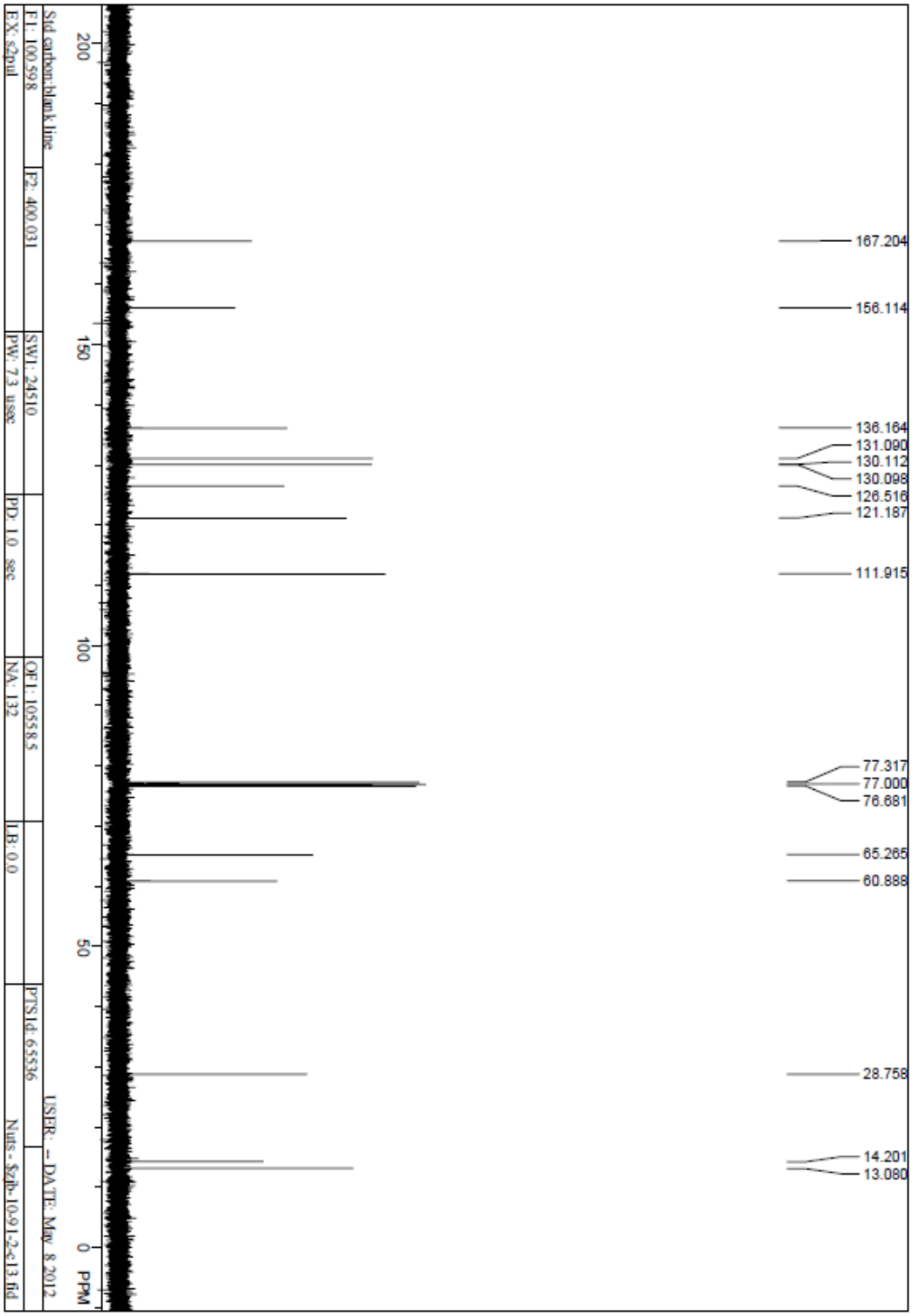
^{1}H NMR (400 M Hz in $CDCl_3$)

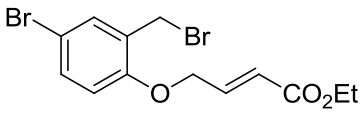




1k

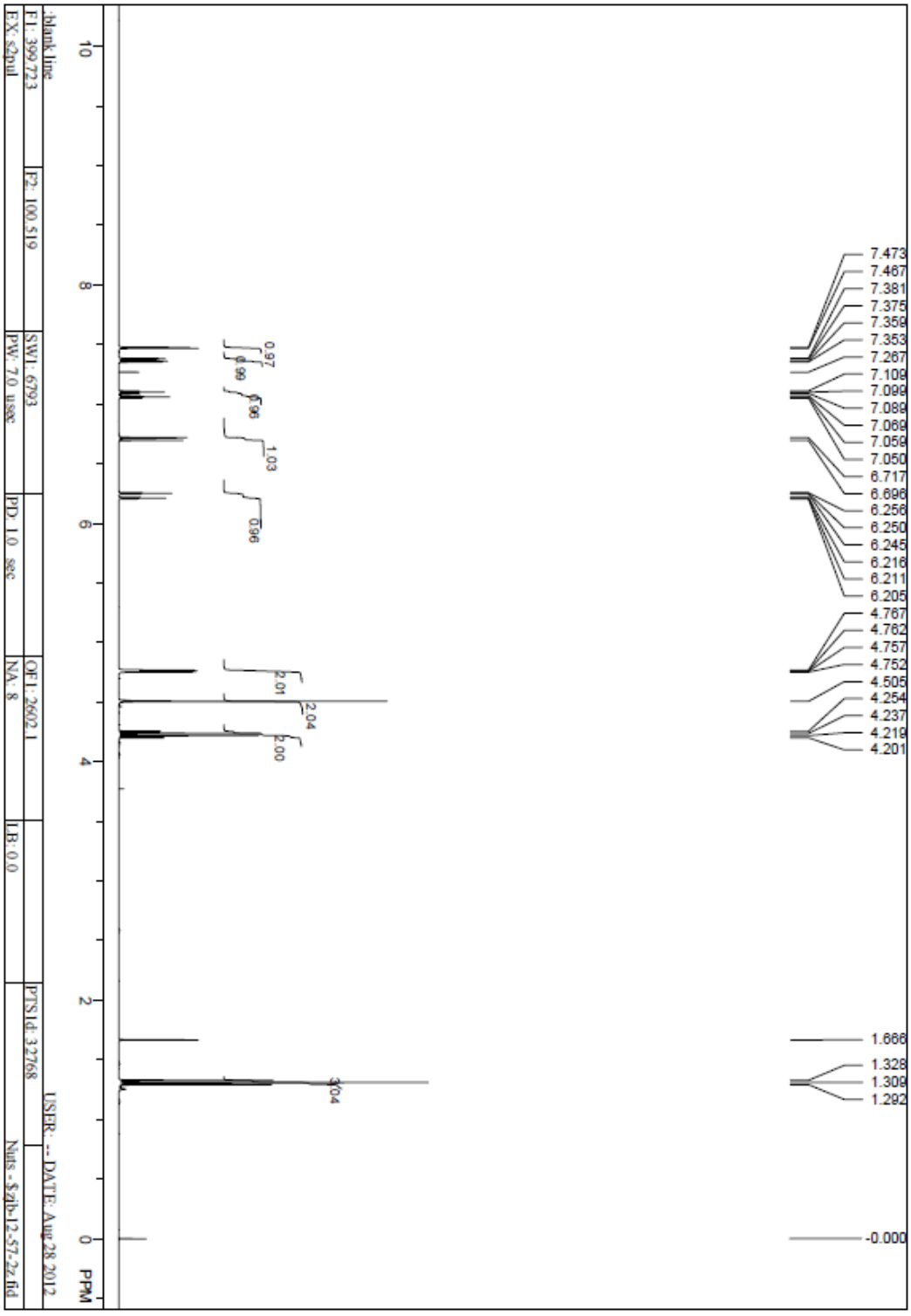
^{13}C NMR (100 M Hz in $CDCl_3$)

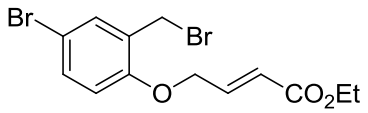




1l

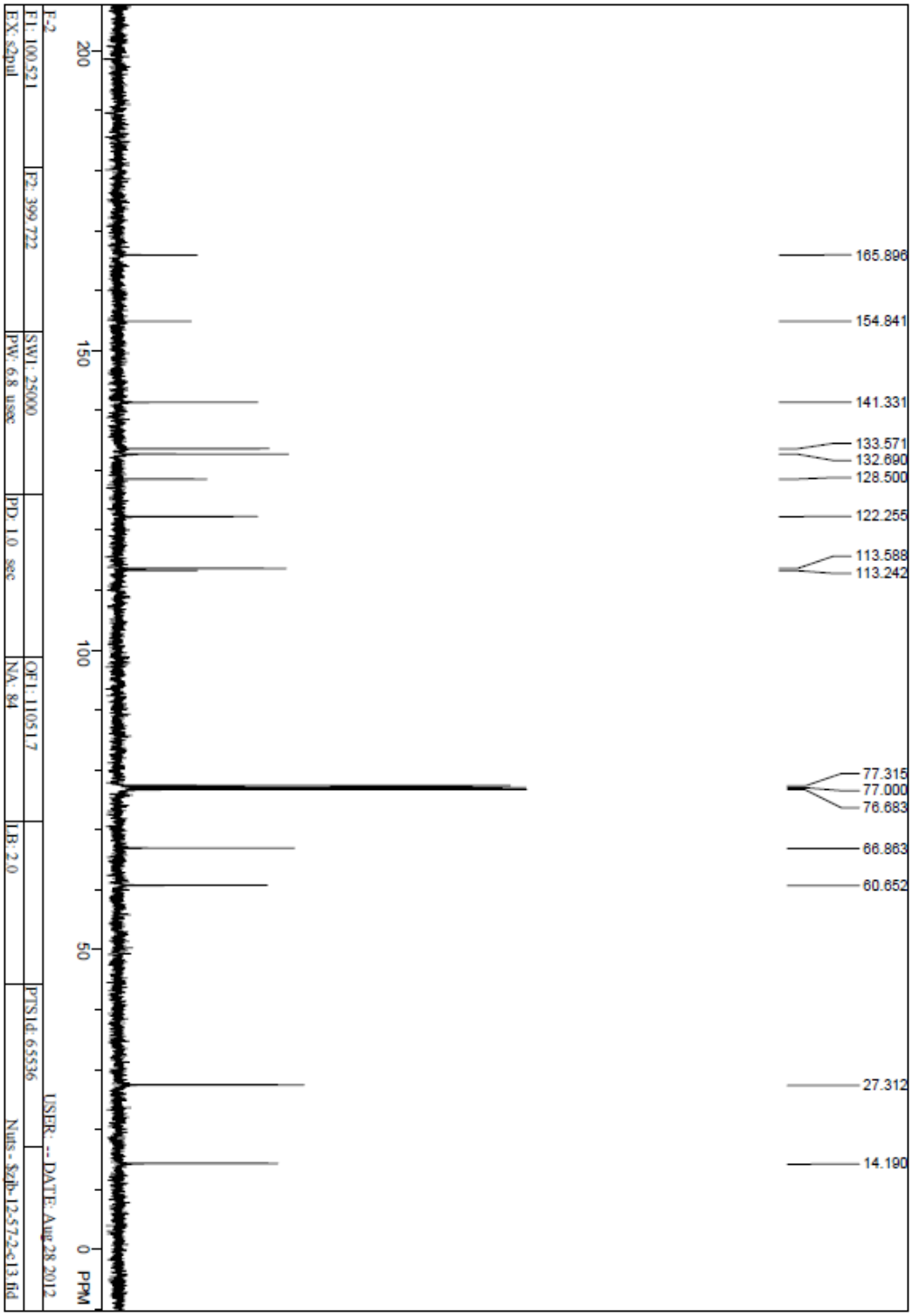
^{1}H NMR (400 M Hz in $CDCl_3$)

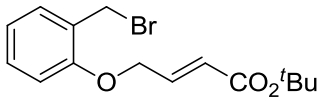




1l

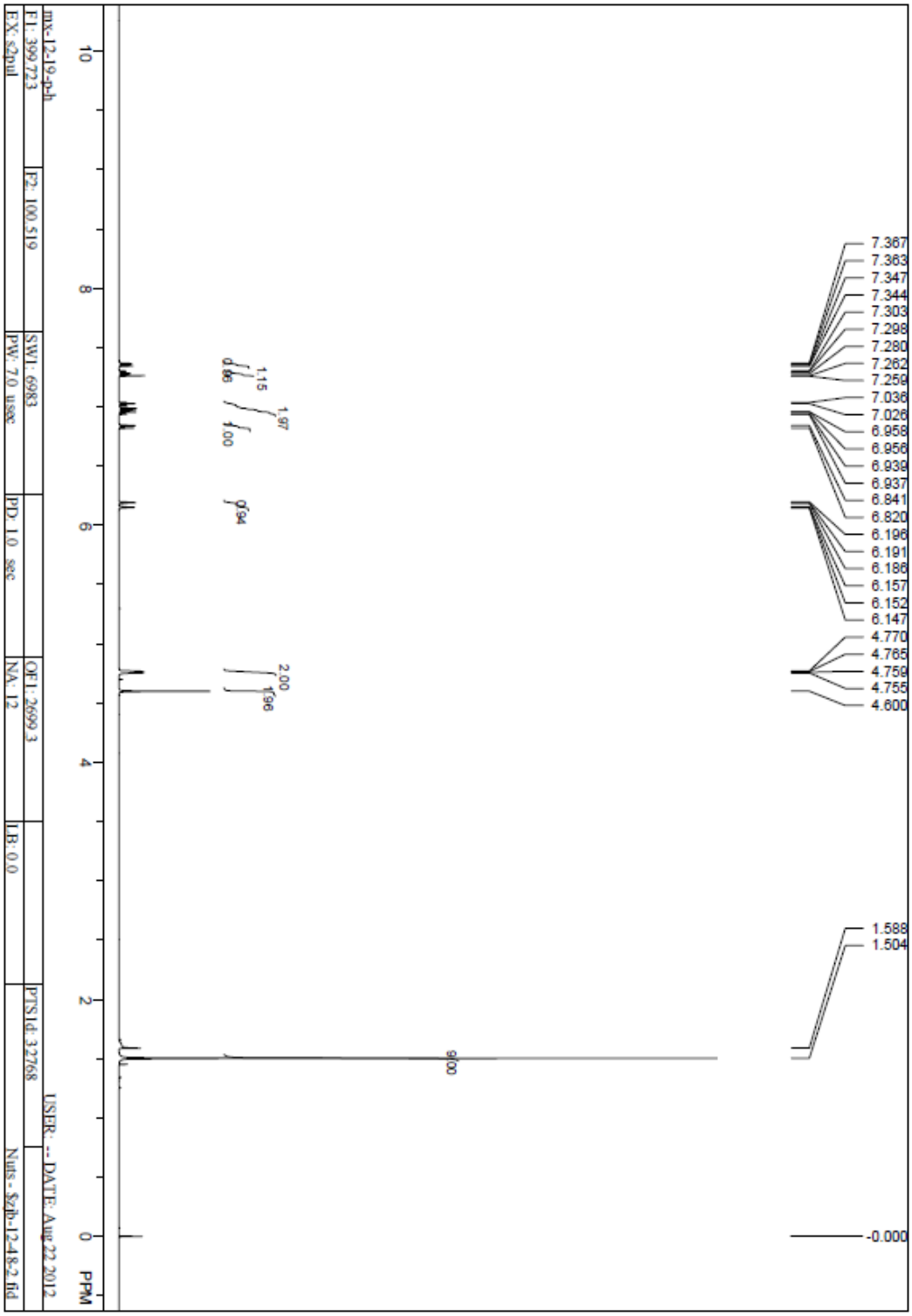
^{13}C NMR (100 M Hz in $CDCl_3$)

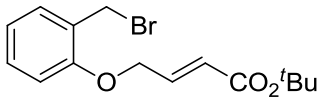




1m

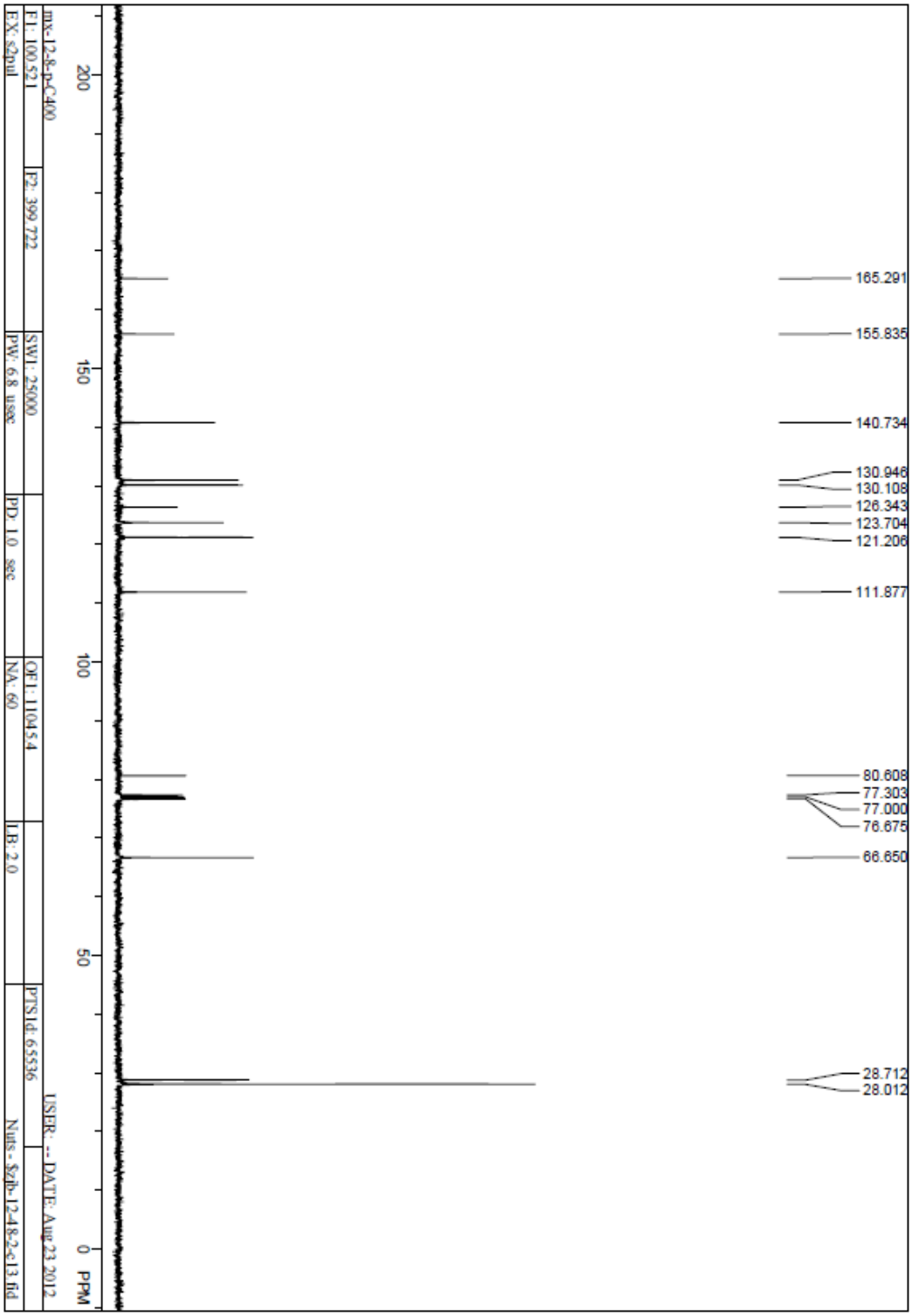
^{1}H NMR (400 M Hz in $CDCl_3$)

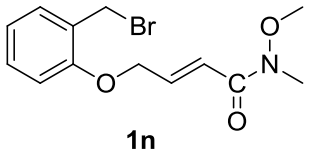




1m

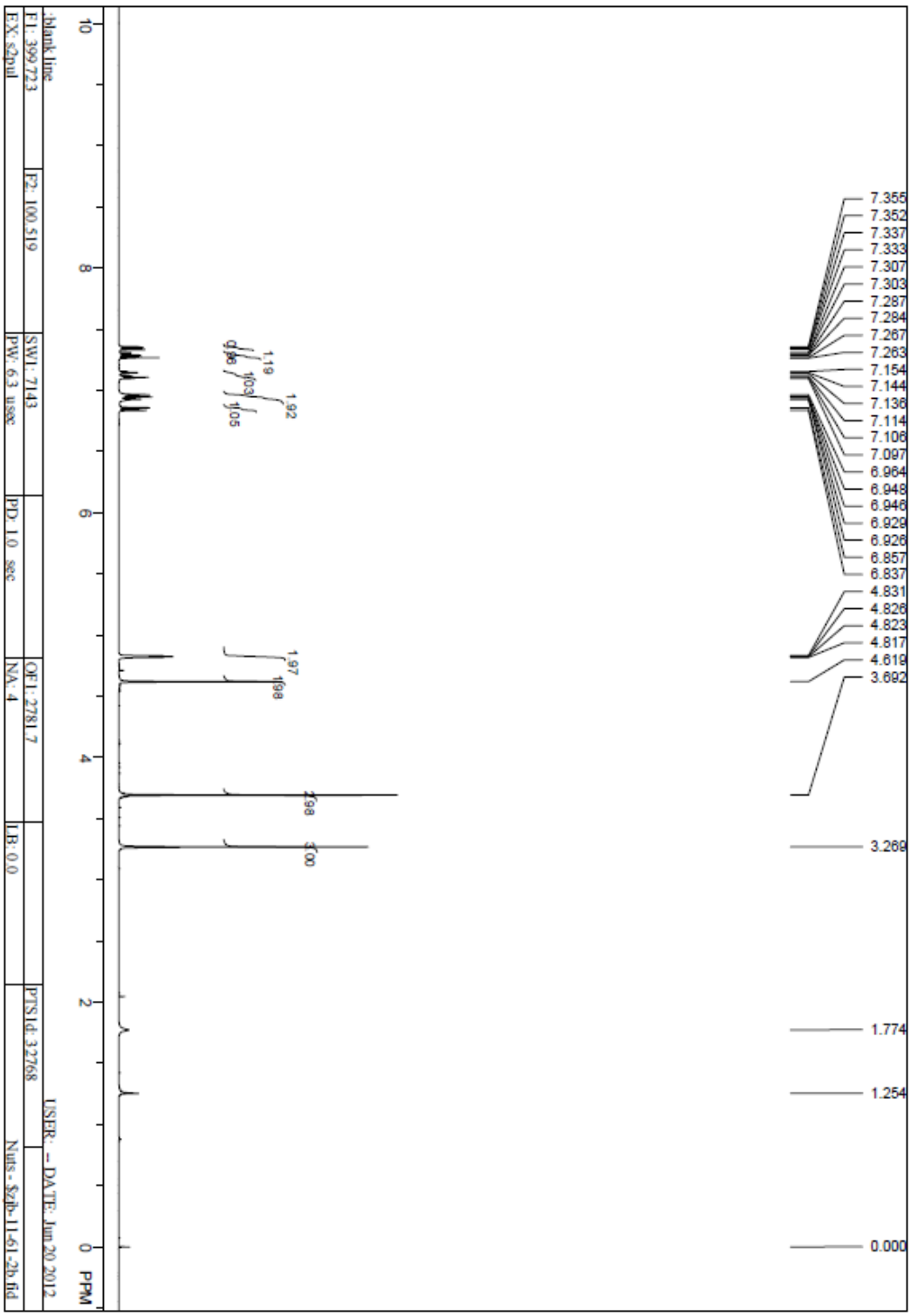
^{13}C NMR (100 M Hz in $CDCl_3$)

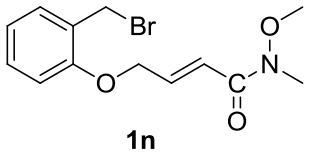




1n

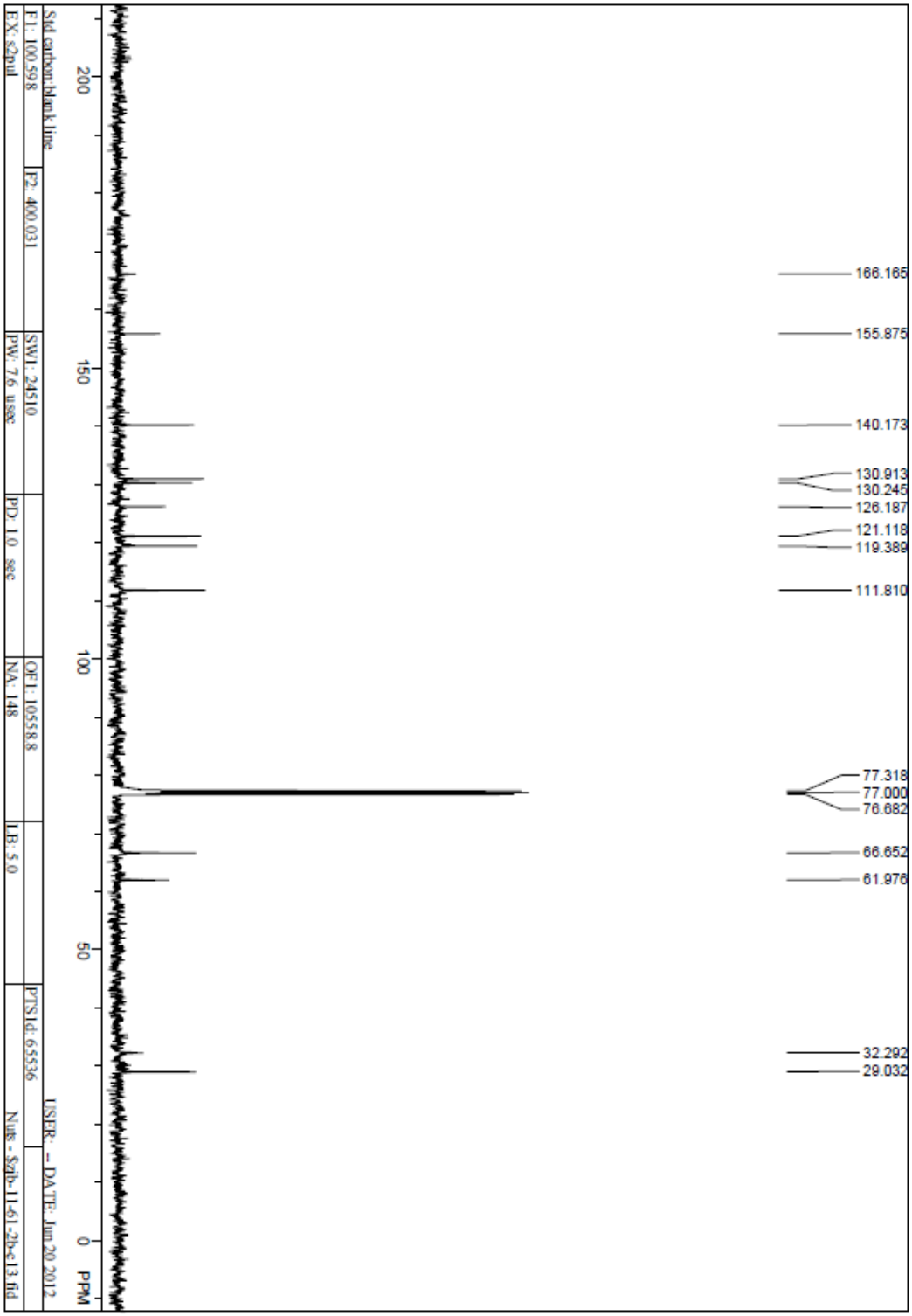
^{1}H NMR (400 M Hz in $CDCl_3$)

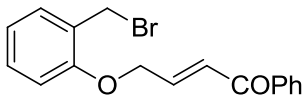




1n

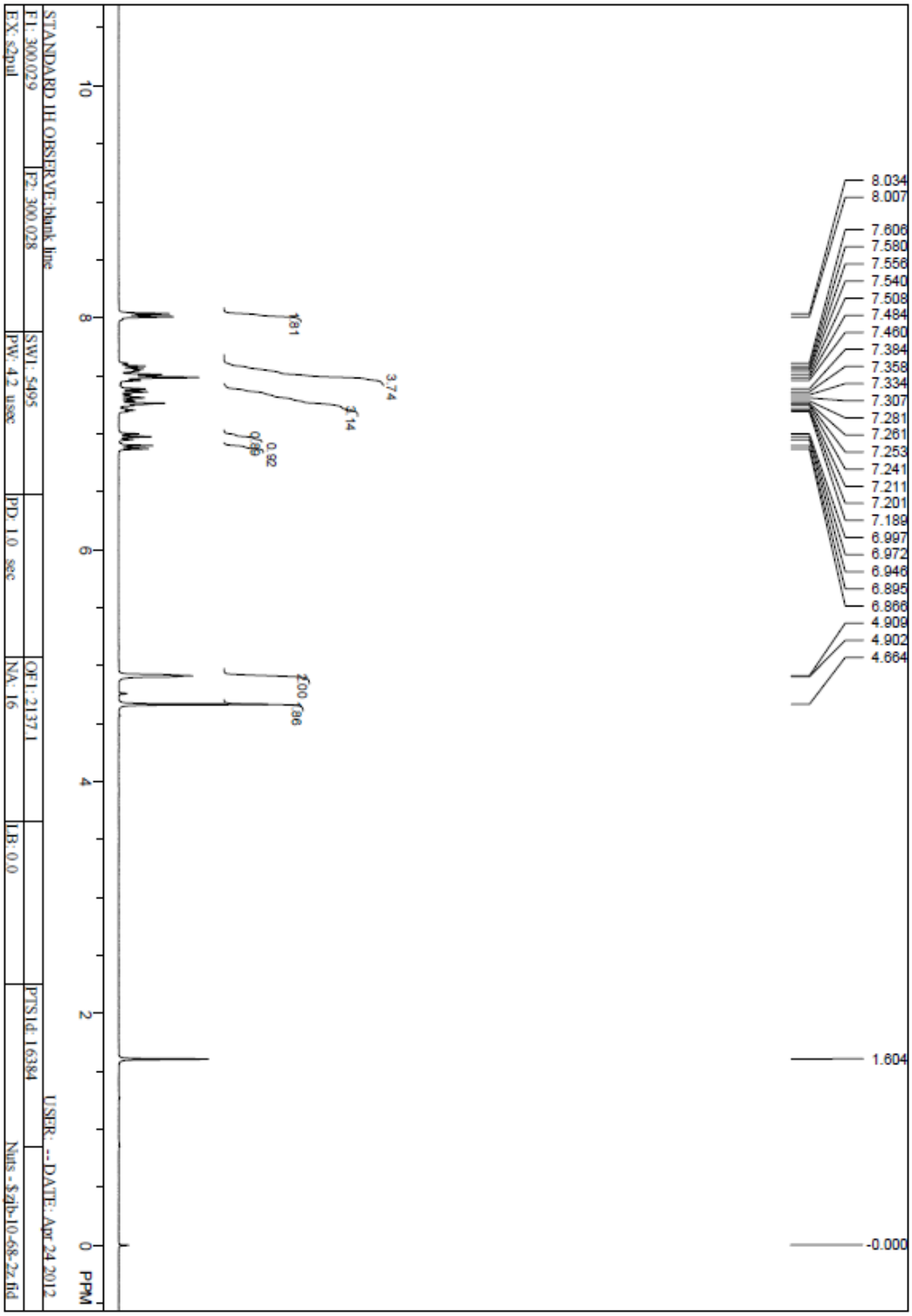
^{13}C NMR (100 M Hz in $CDCl_3$)

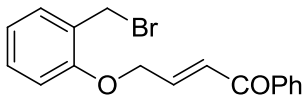




1o

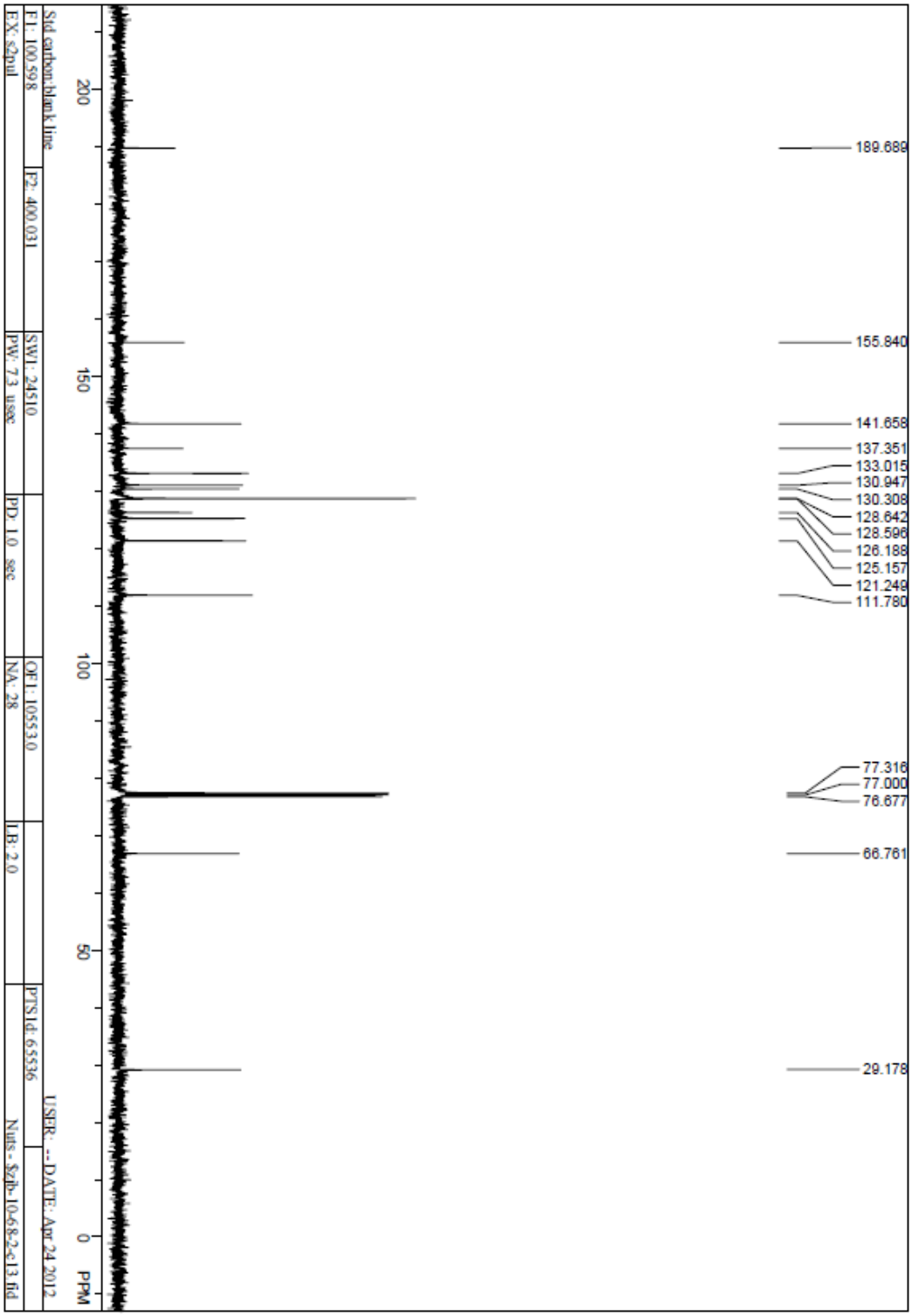
^{1}H NMR (300 M Hz in $CDCl_3$)

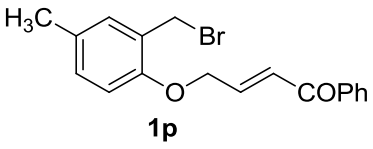




1o

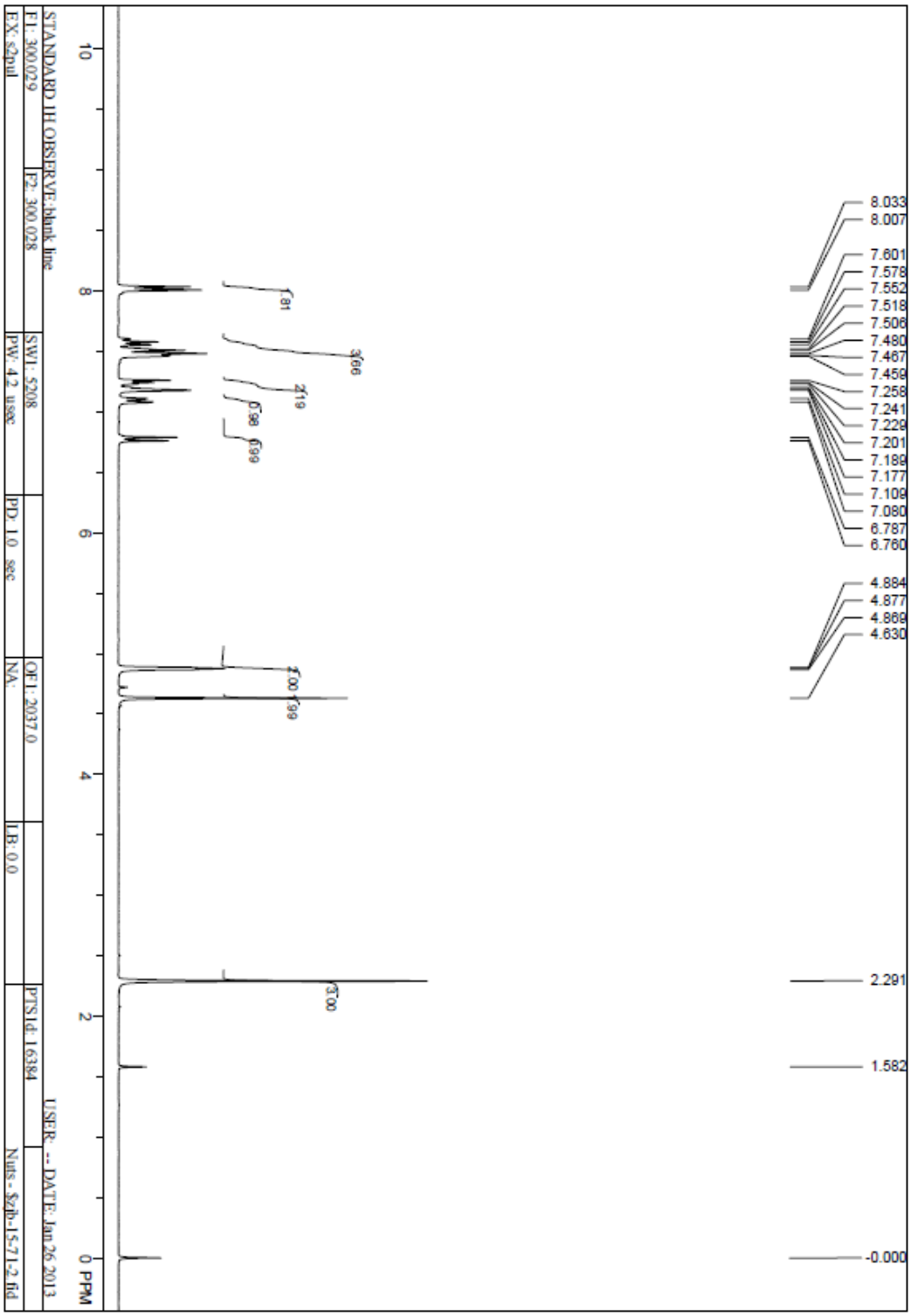
^{13}C NMR (100 M Hz in $CDCl_3$)

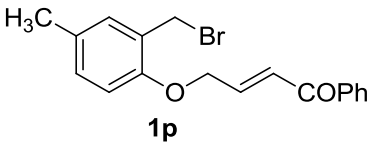




1p

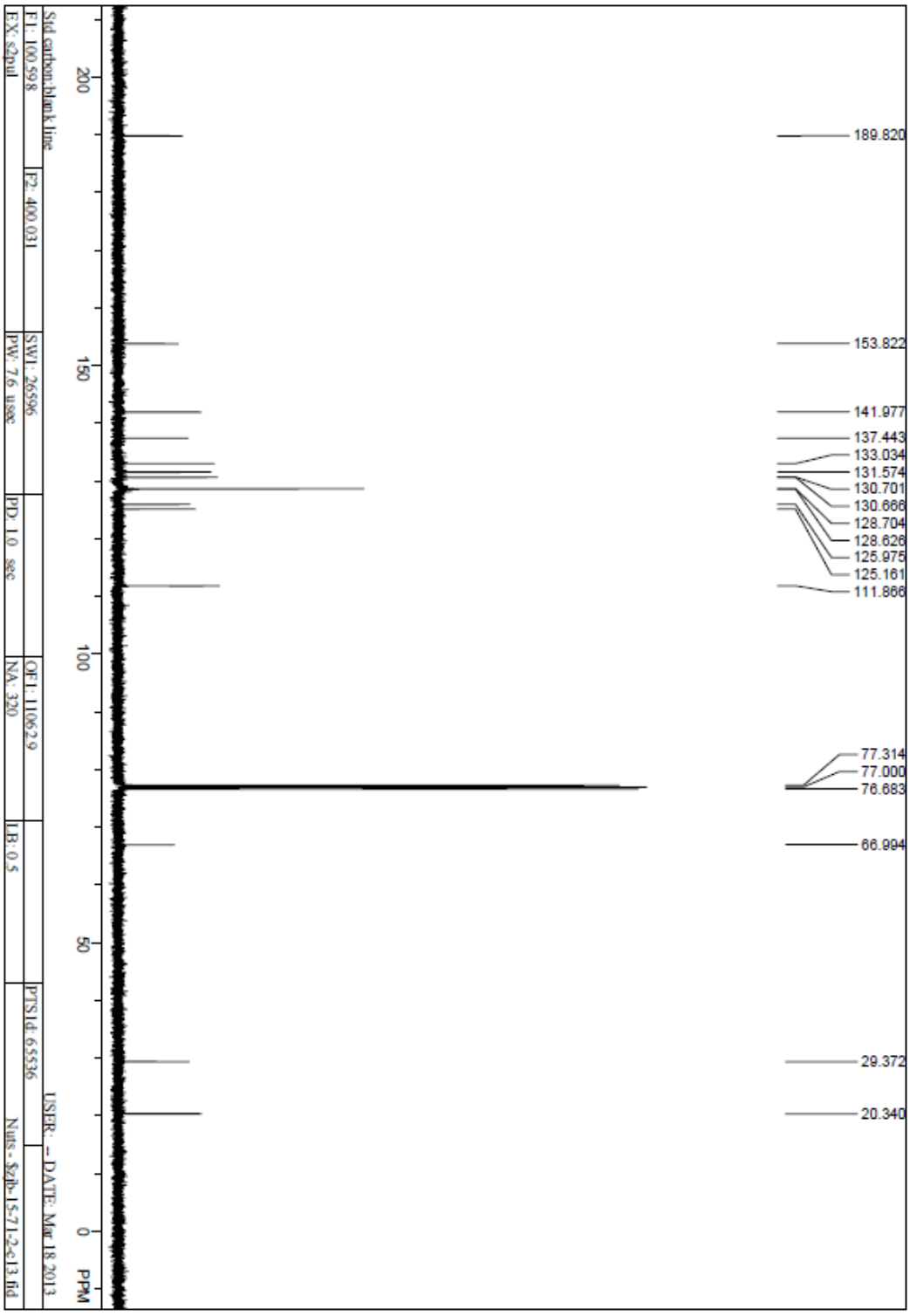
^{1}H NMR (300 M Hz in $CDCl_3$)

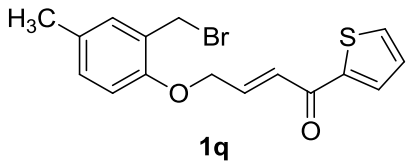




1p

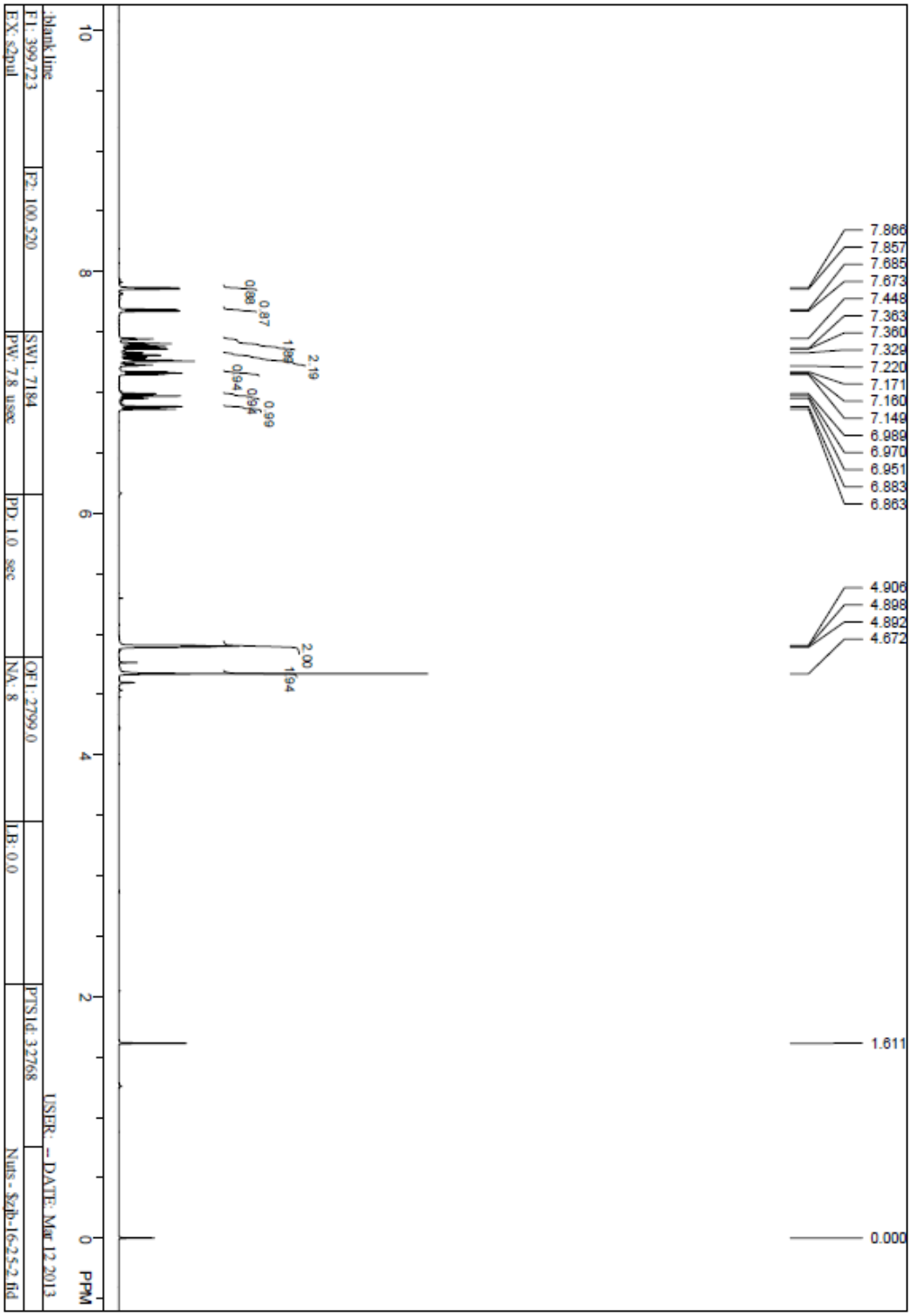
^{13}C NMR (100 M Hz in $CDCl_3$)

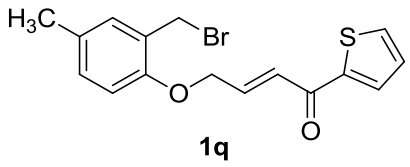




1q

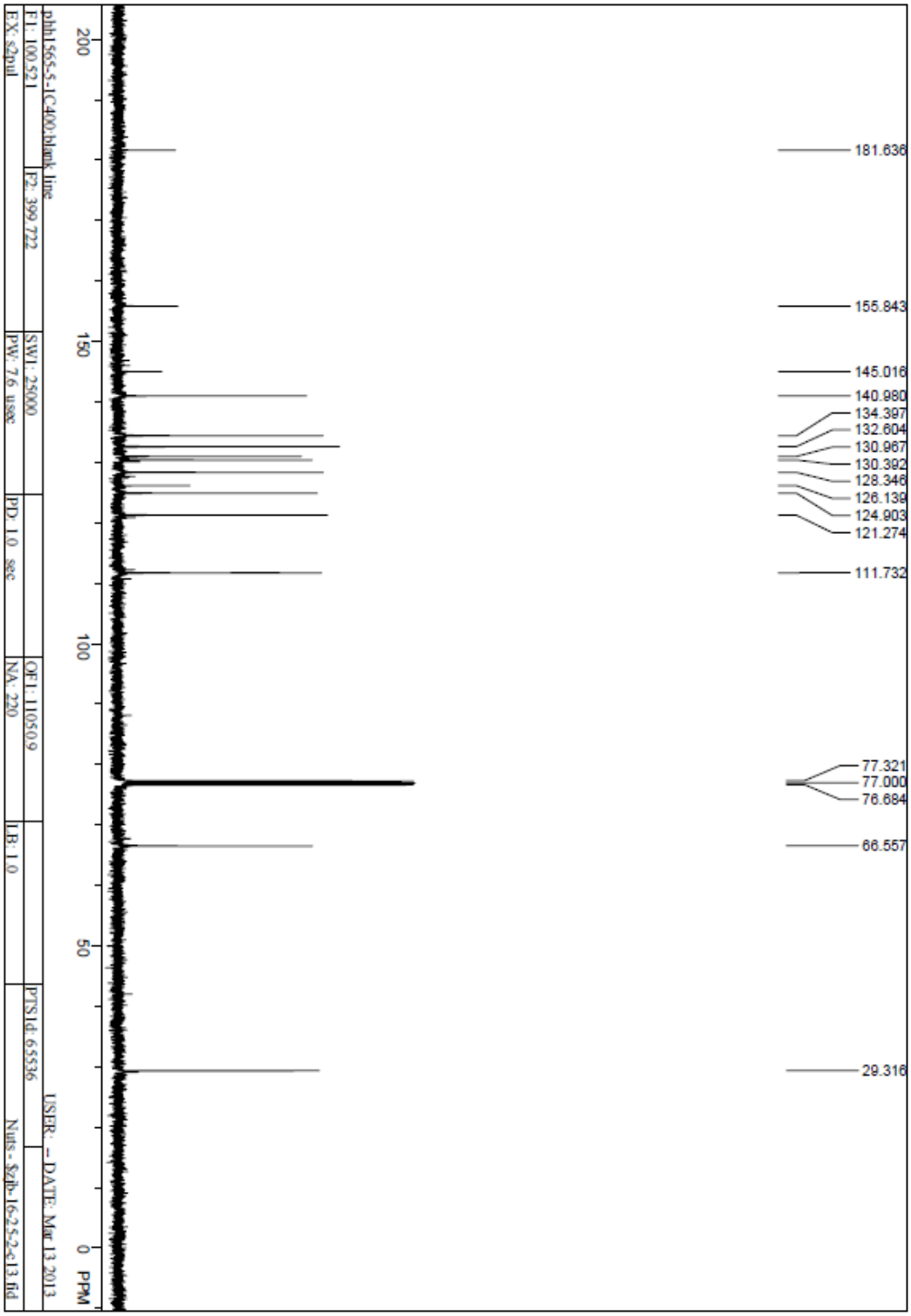
^{1}H NMR (400 M Hz in $CDCl_3$)

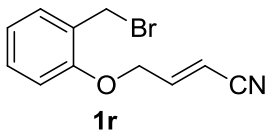




1q

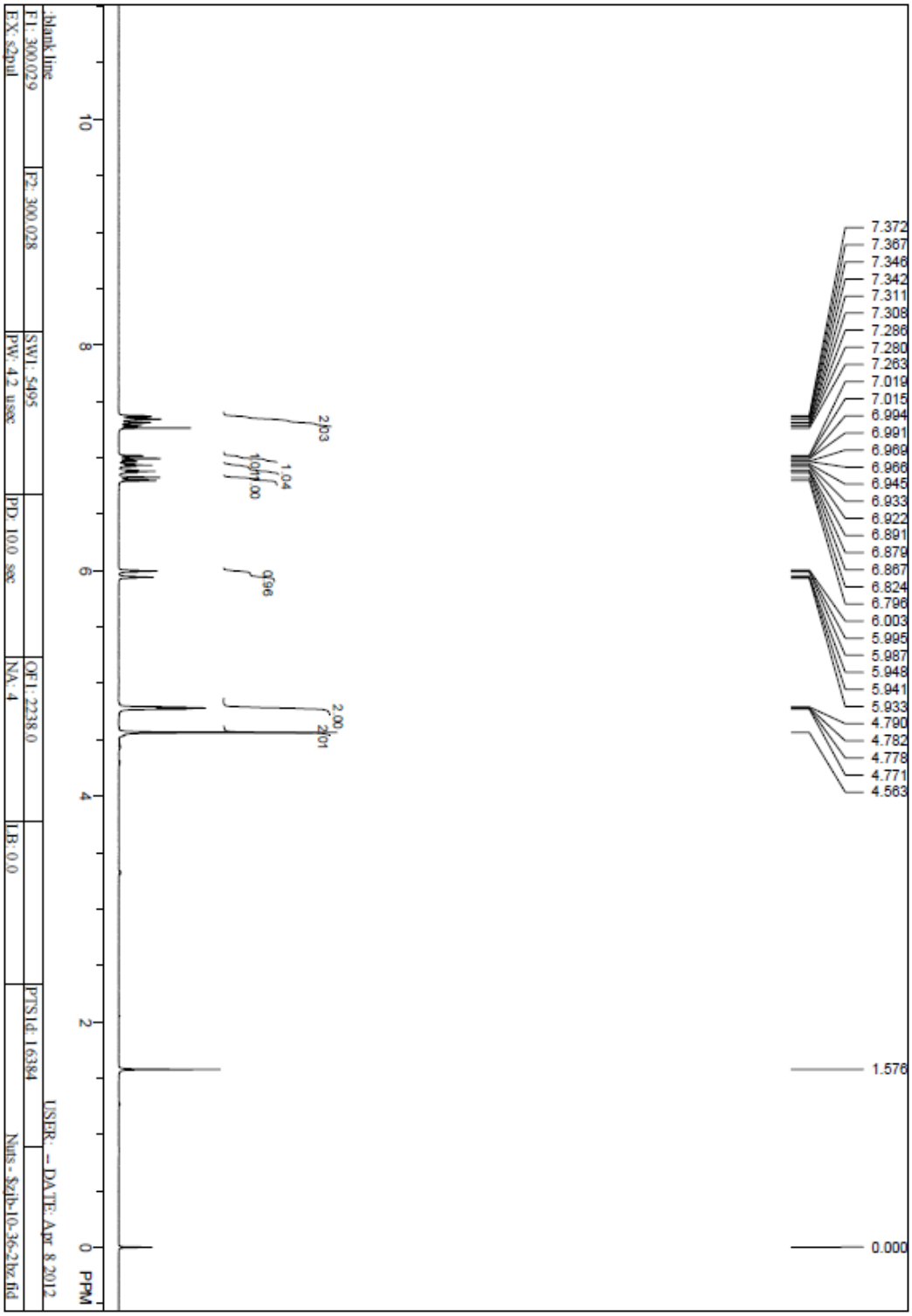
^{13}C NMR (100 M Hz in $CDCl_3$)

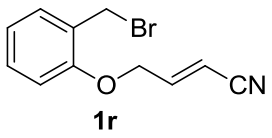




1r

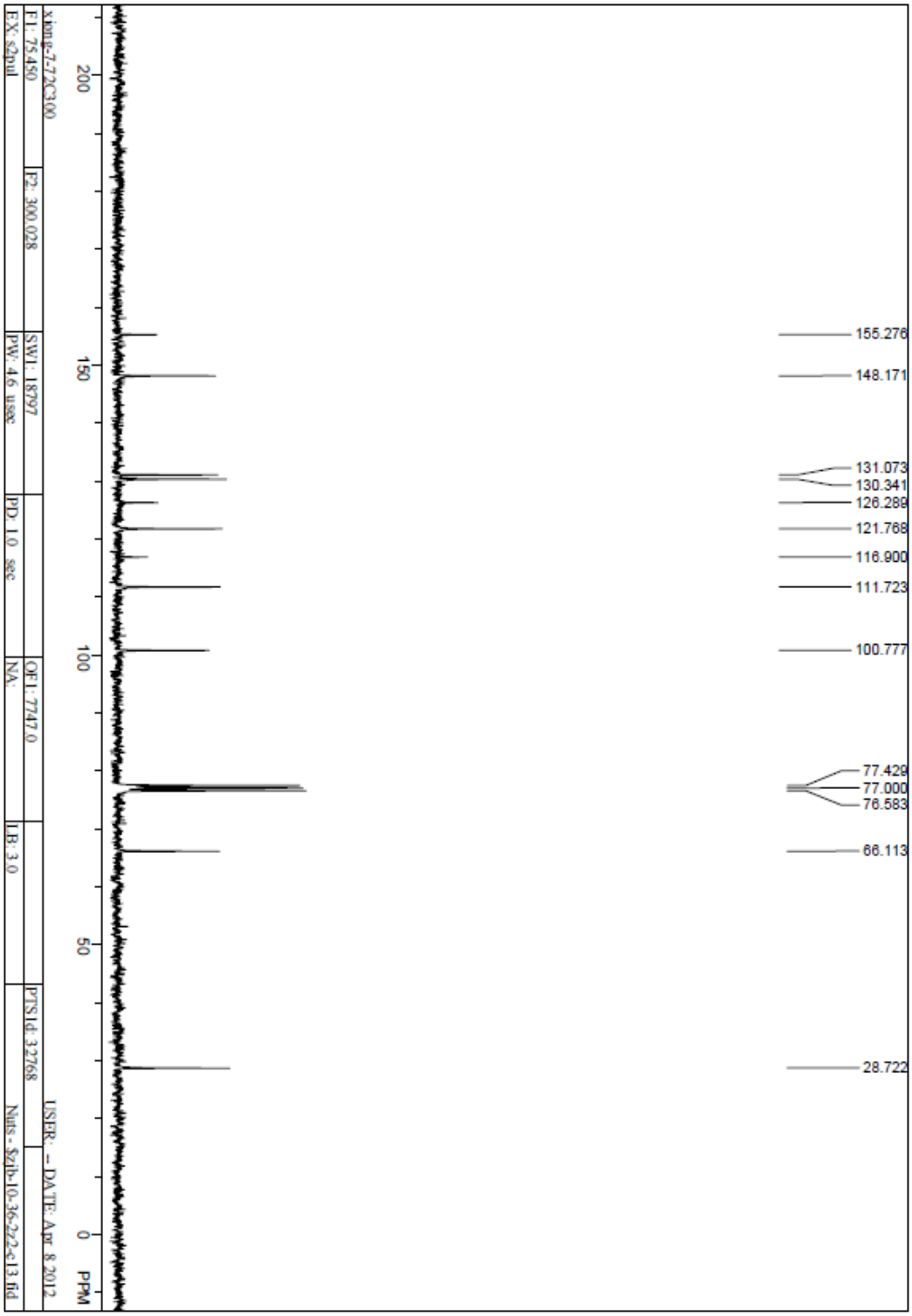
^{1}H NMR (300 M Hz in $CDCl_3$)

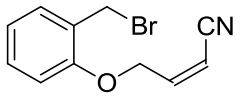




1r

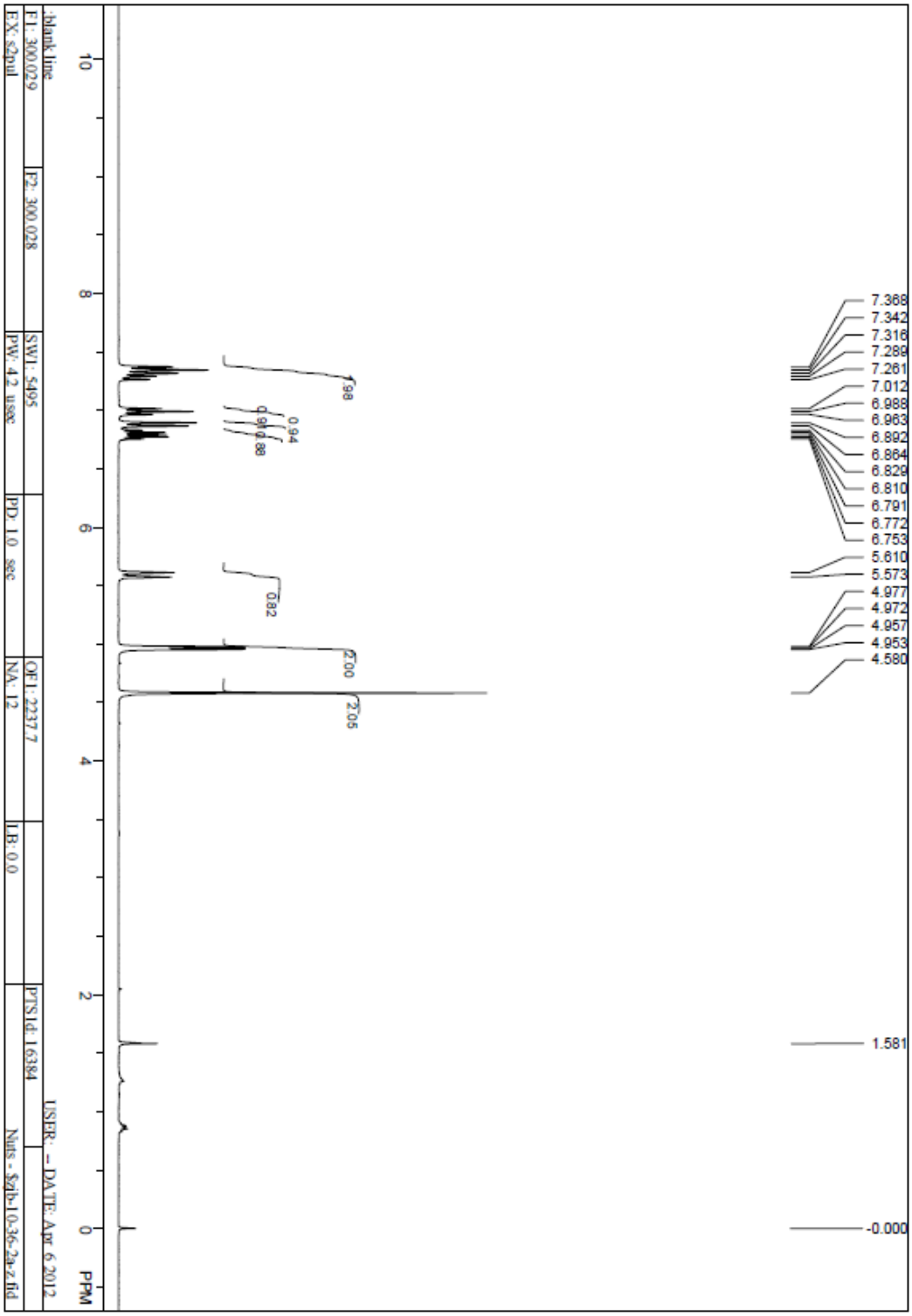
^{13}C NMR (75 M Hz in $CDCl_3$)

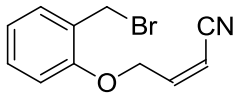




1r'

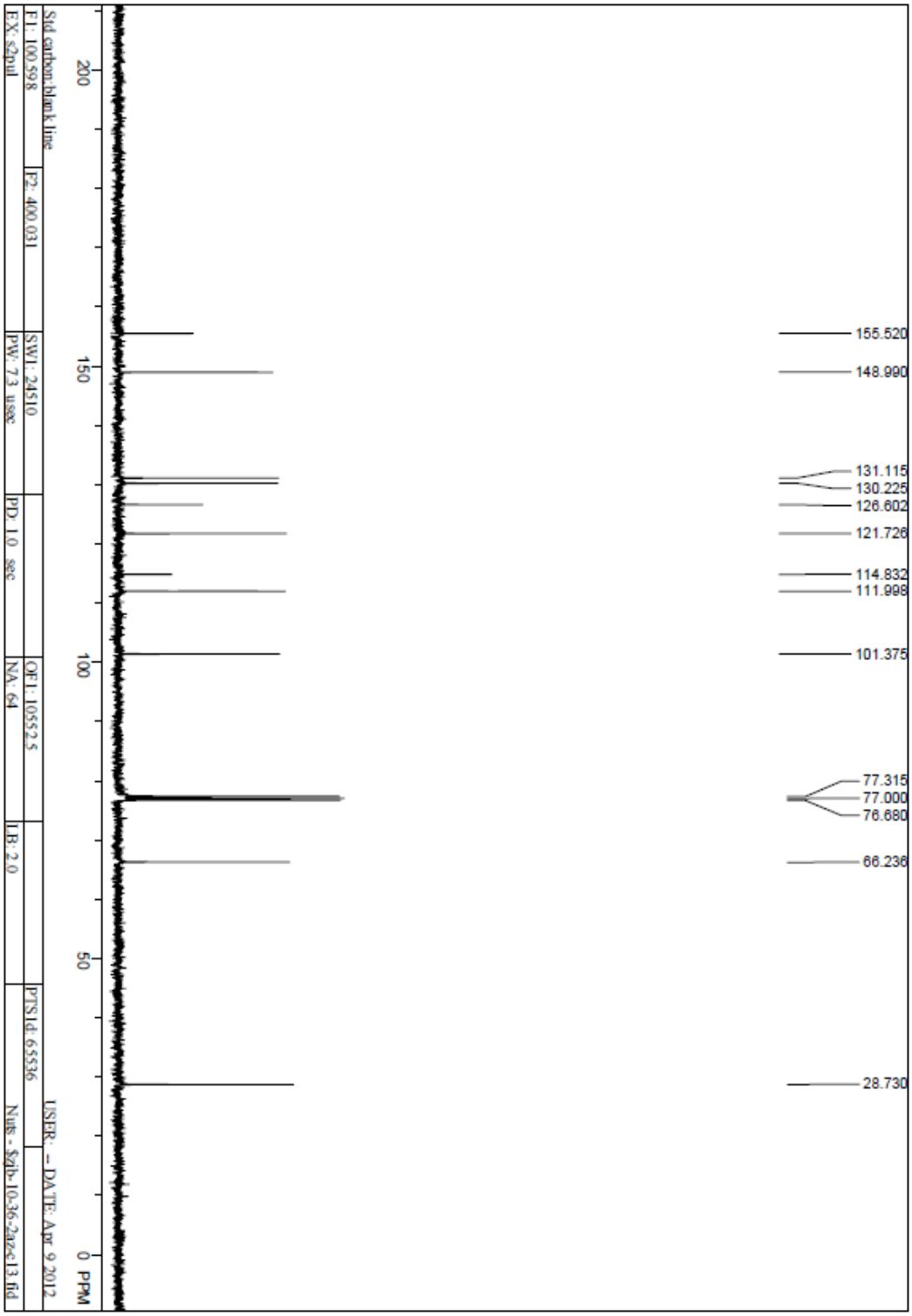
^{1}H NMR (300 M Hz in $CDCl_3$)

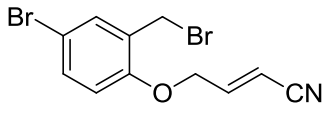




1r'

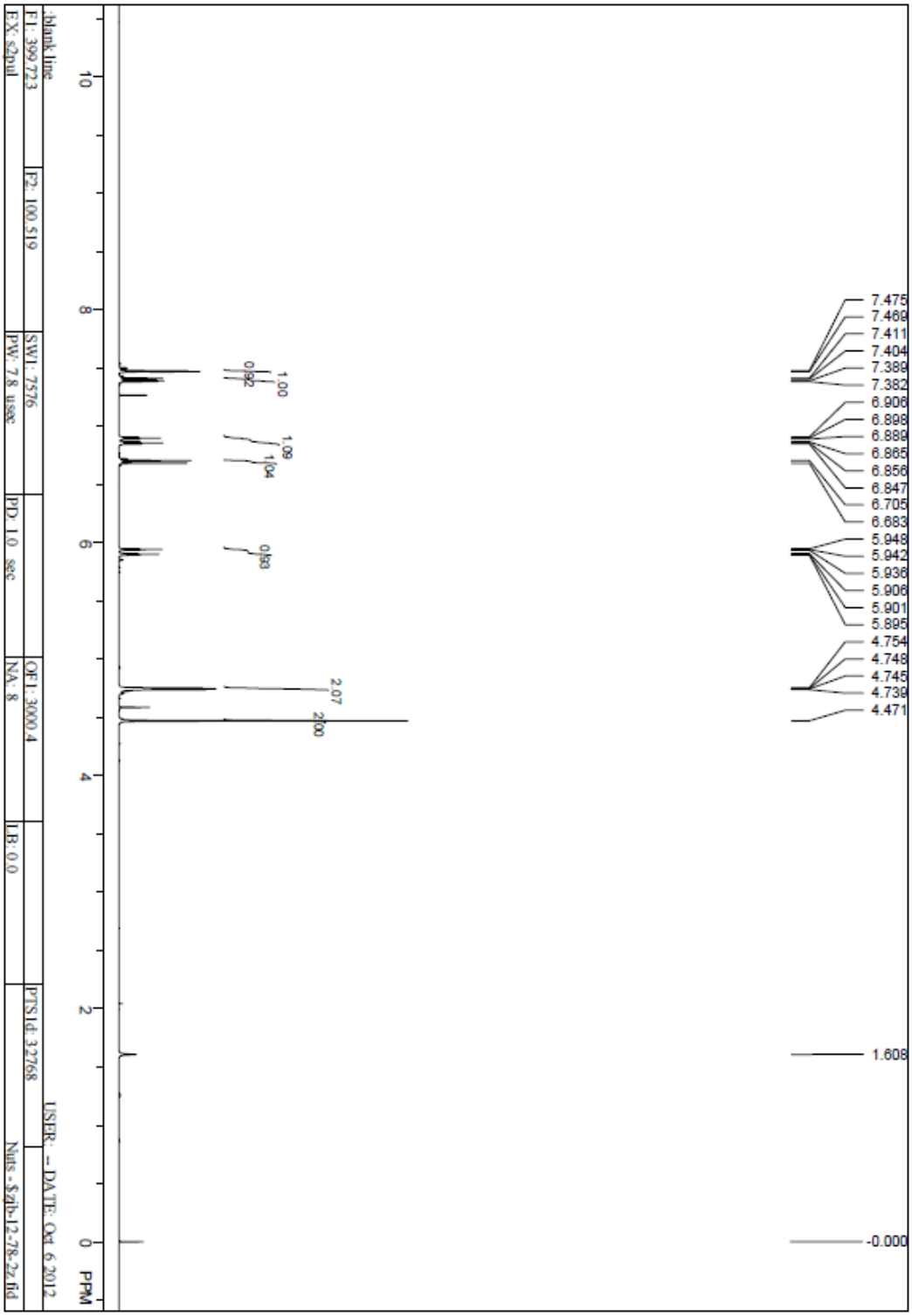
^{13}C NMR (100 M Hz in $CDCl_3$)

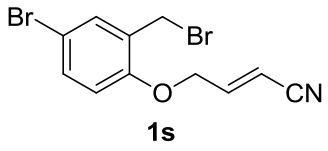




1s

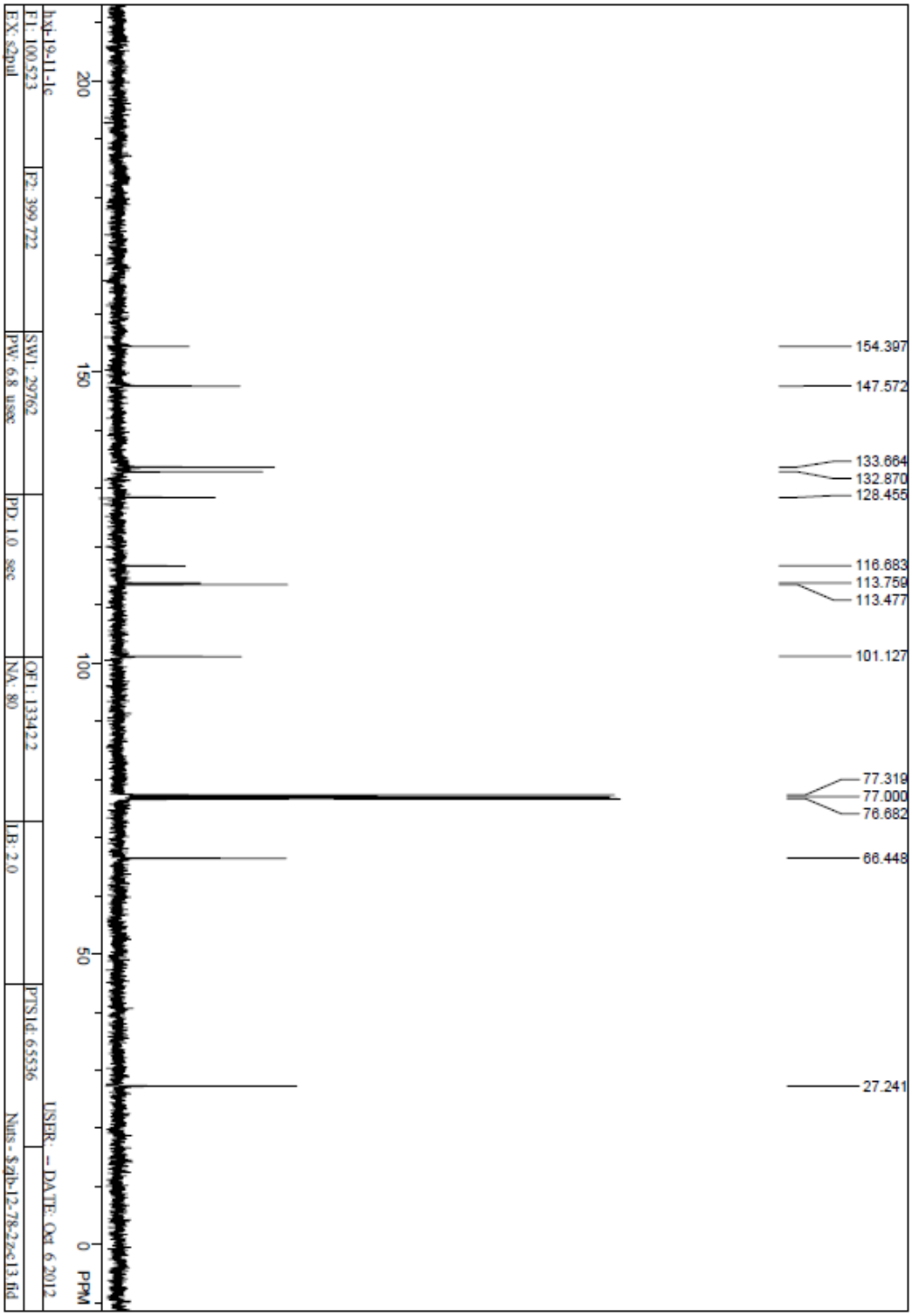
^{1}H NMR (400 M Hz in $CDCl_3$)

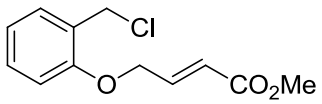




1s

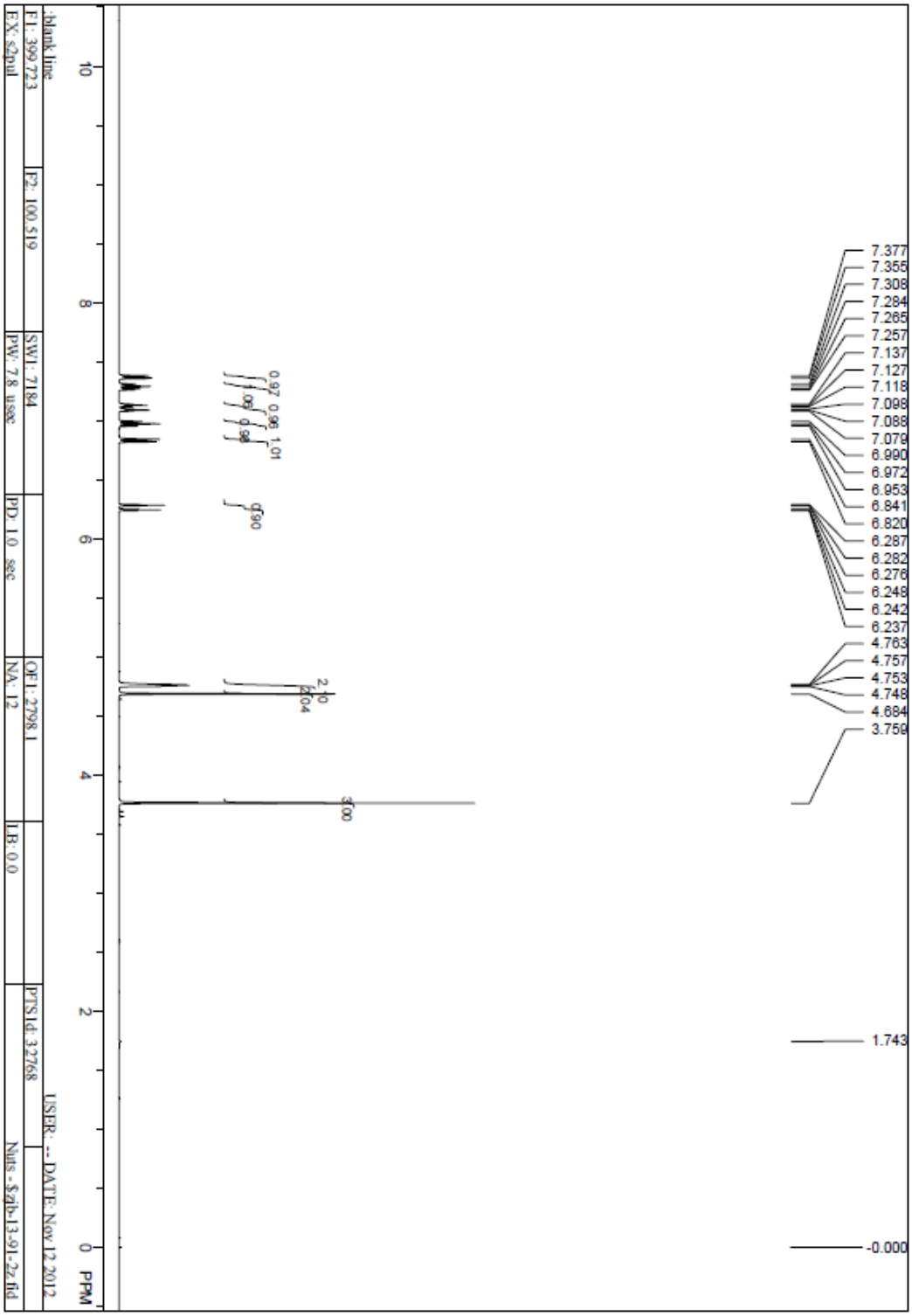
^{13}C NMR (100 M Hz in $CDCl_3$)

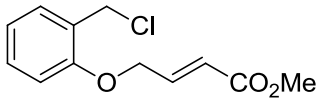




1t

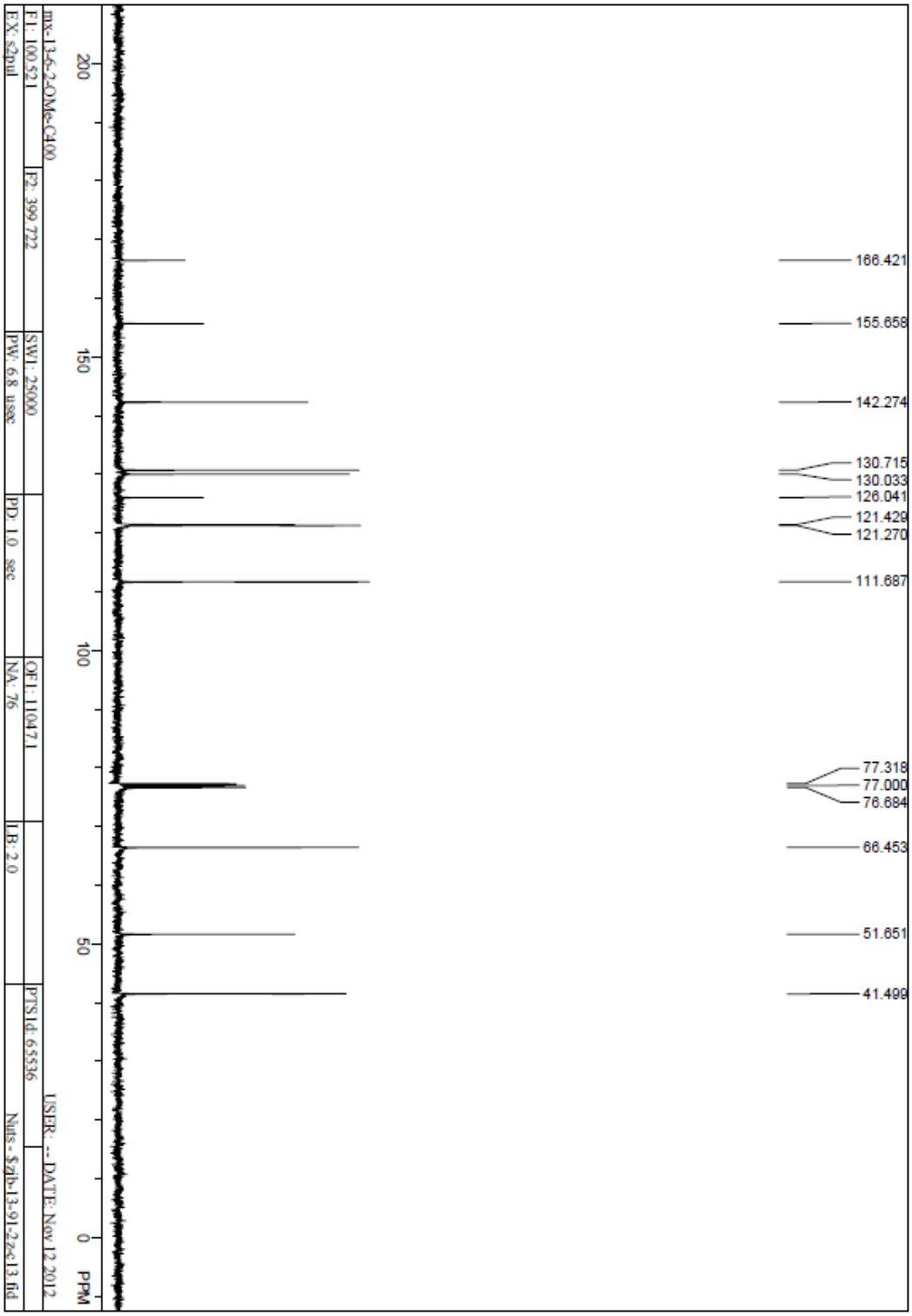
^{1}H NMR (400 M Hz in $CDCl_3$)

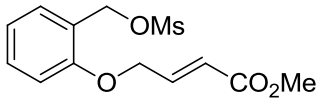




1t

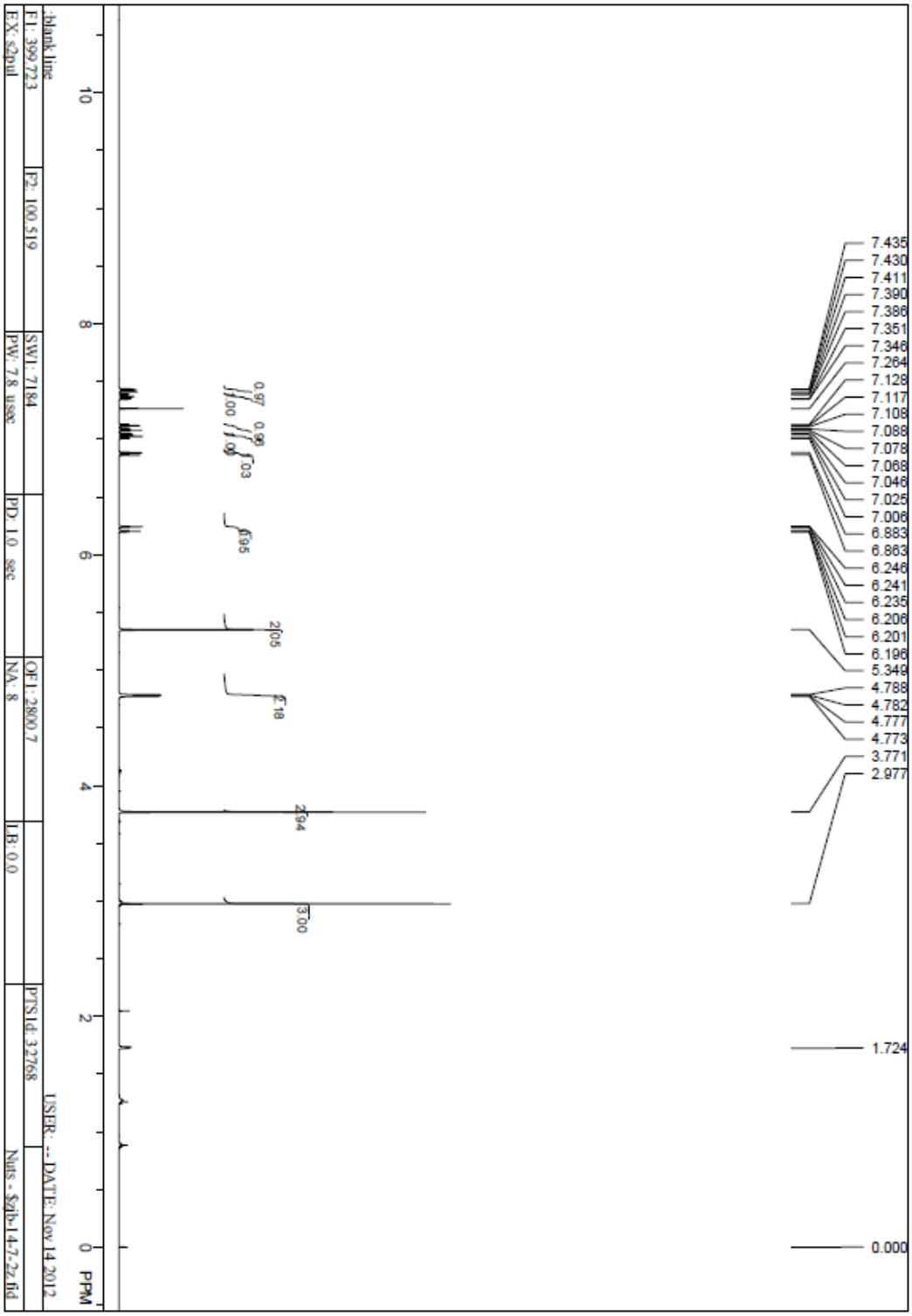
^{13}C NMR (100 M Hz in $CDCl_3$)

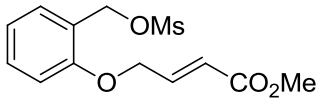




1u

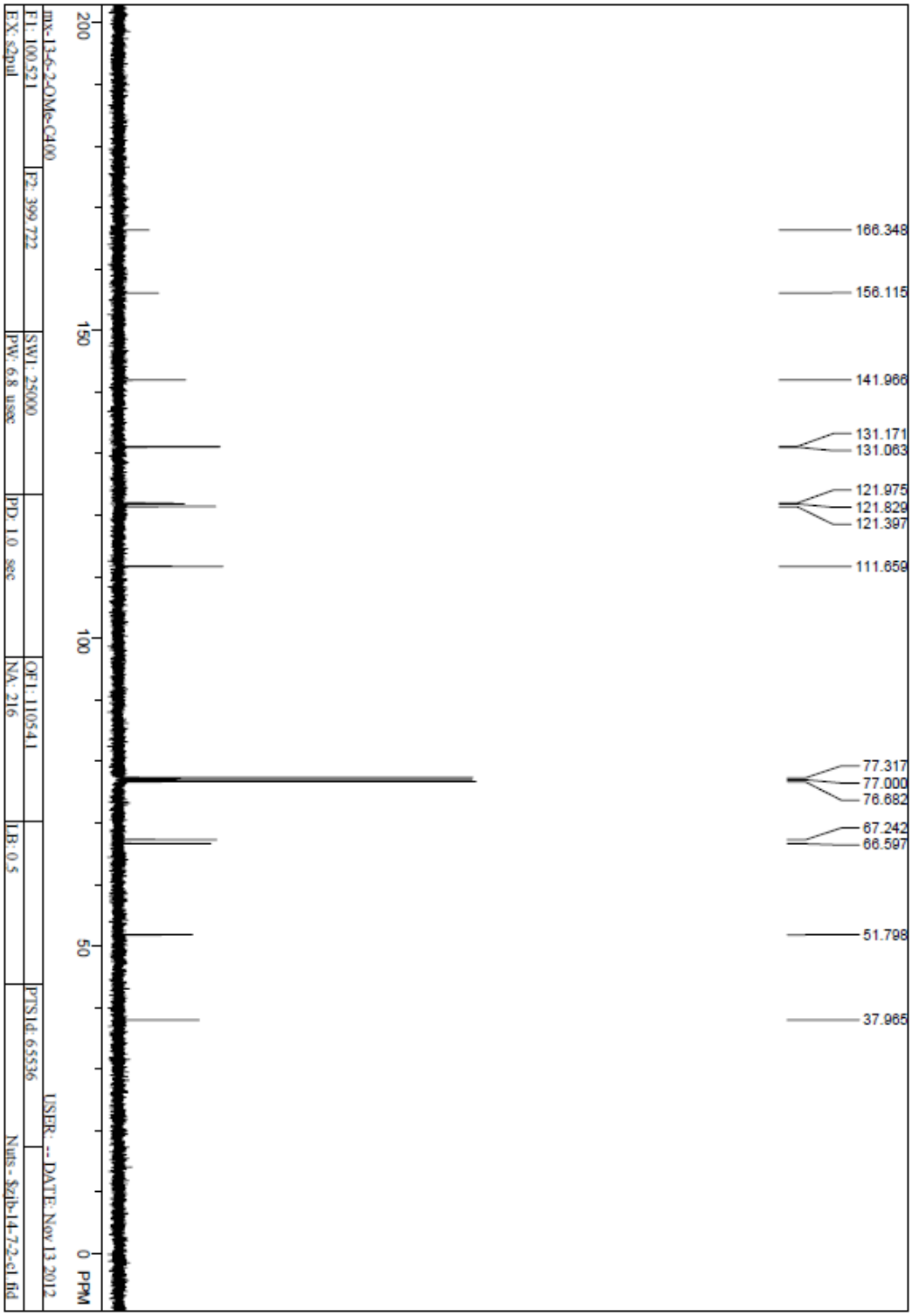
^{1}H NMR (400 M Hz in $CDCl_3$)

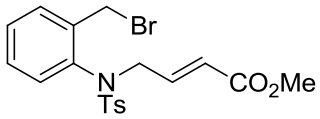




1u

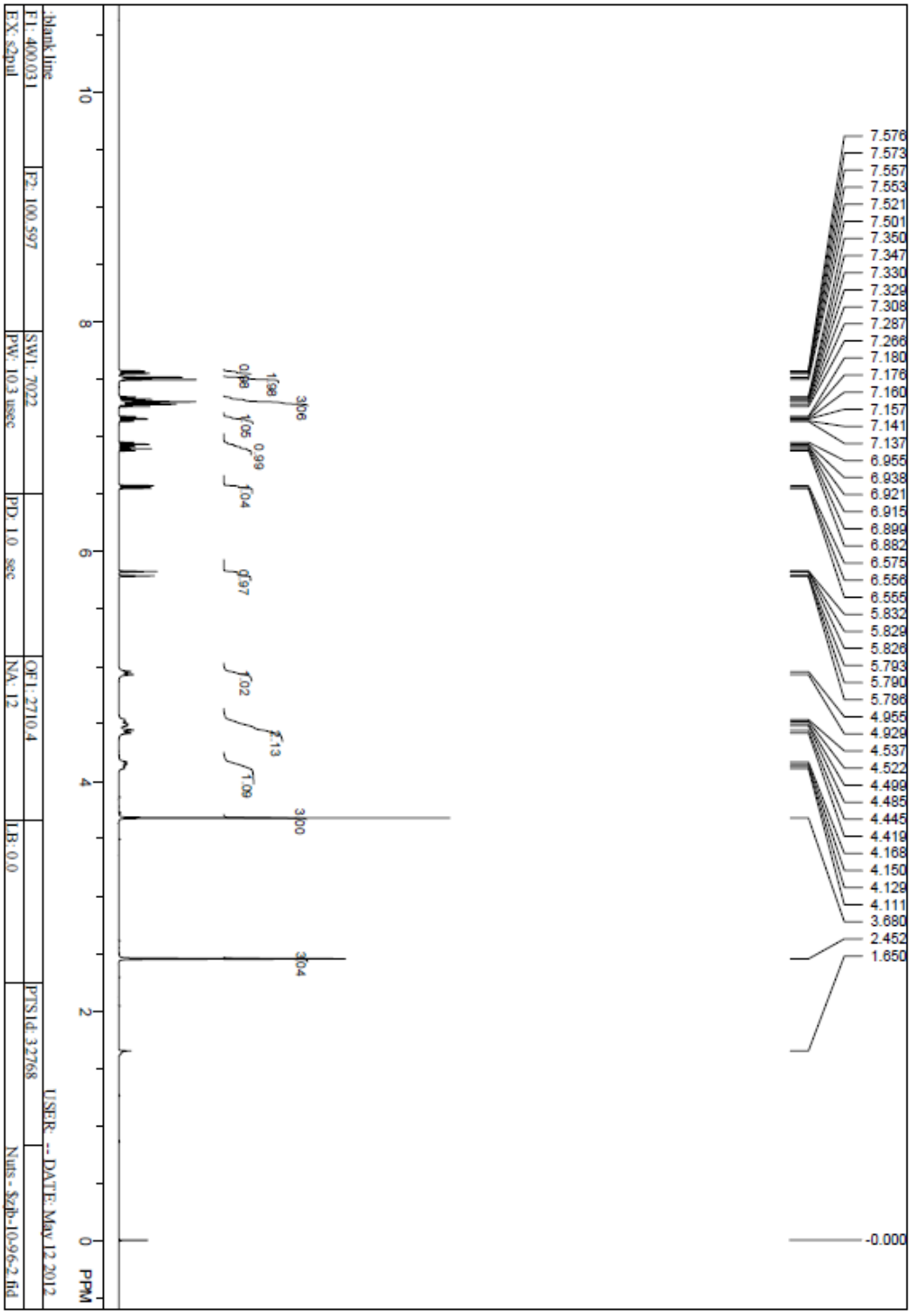
^{13}C NMR (100 M Hz in $CDCl_3$)

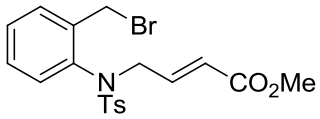




4a

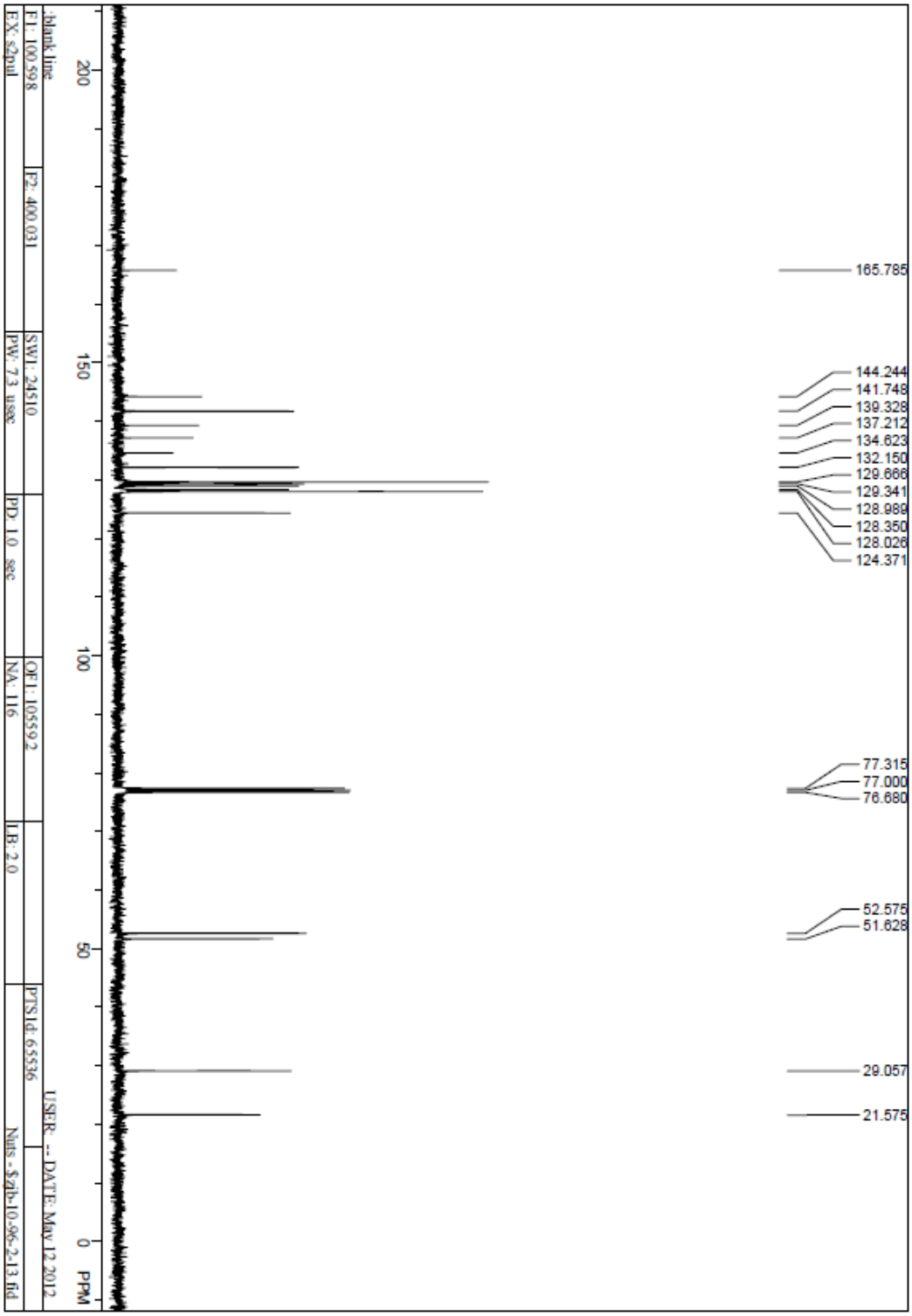
^{1}H NMR (400 M Hz in $CDCl_3$)

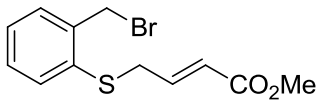




4a

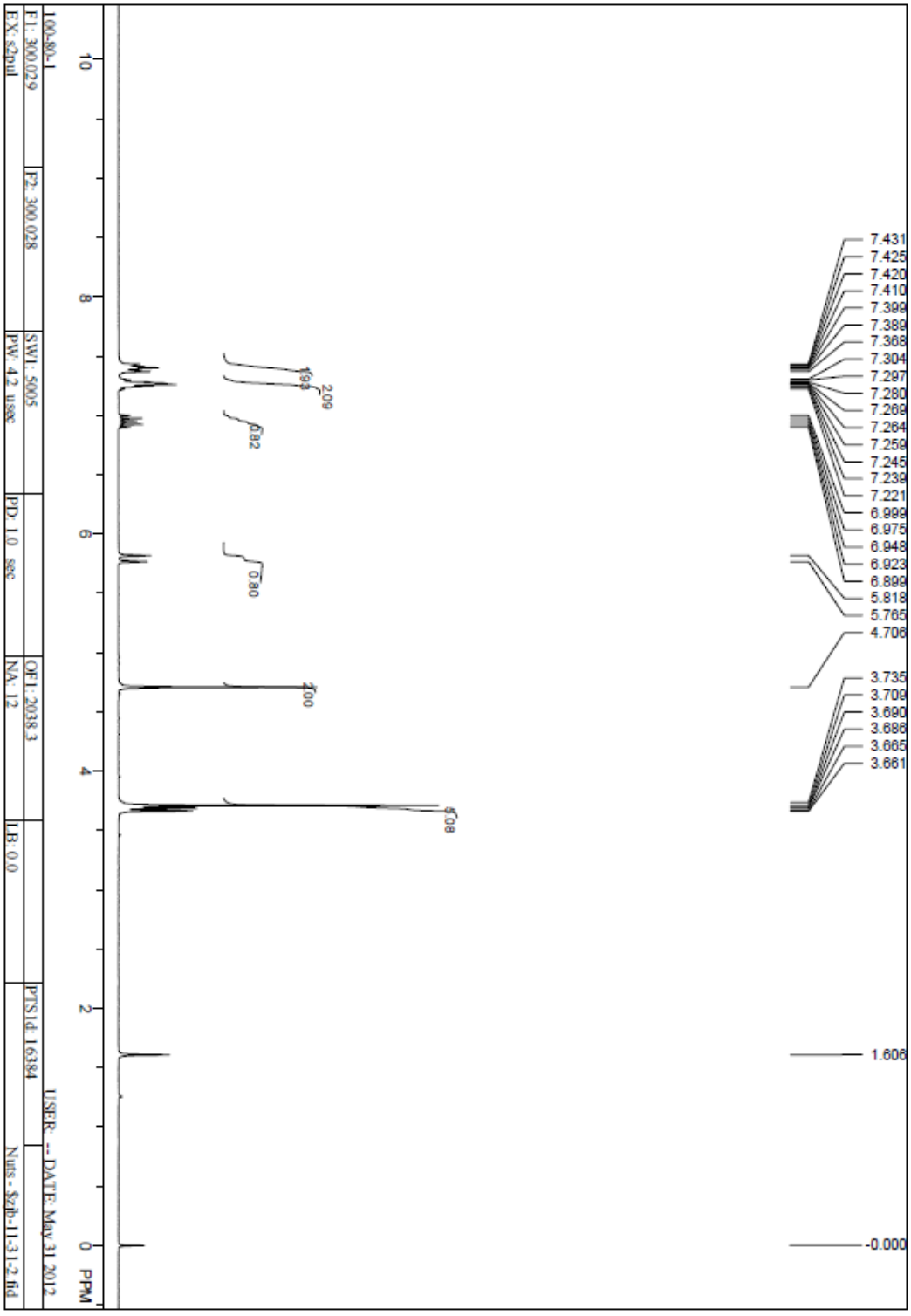
^{13}C NMR (100 M Hz in $CDCl_3$)

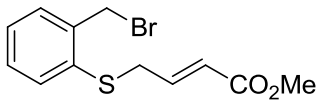




4b

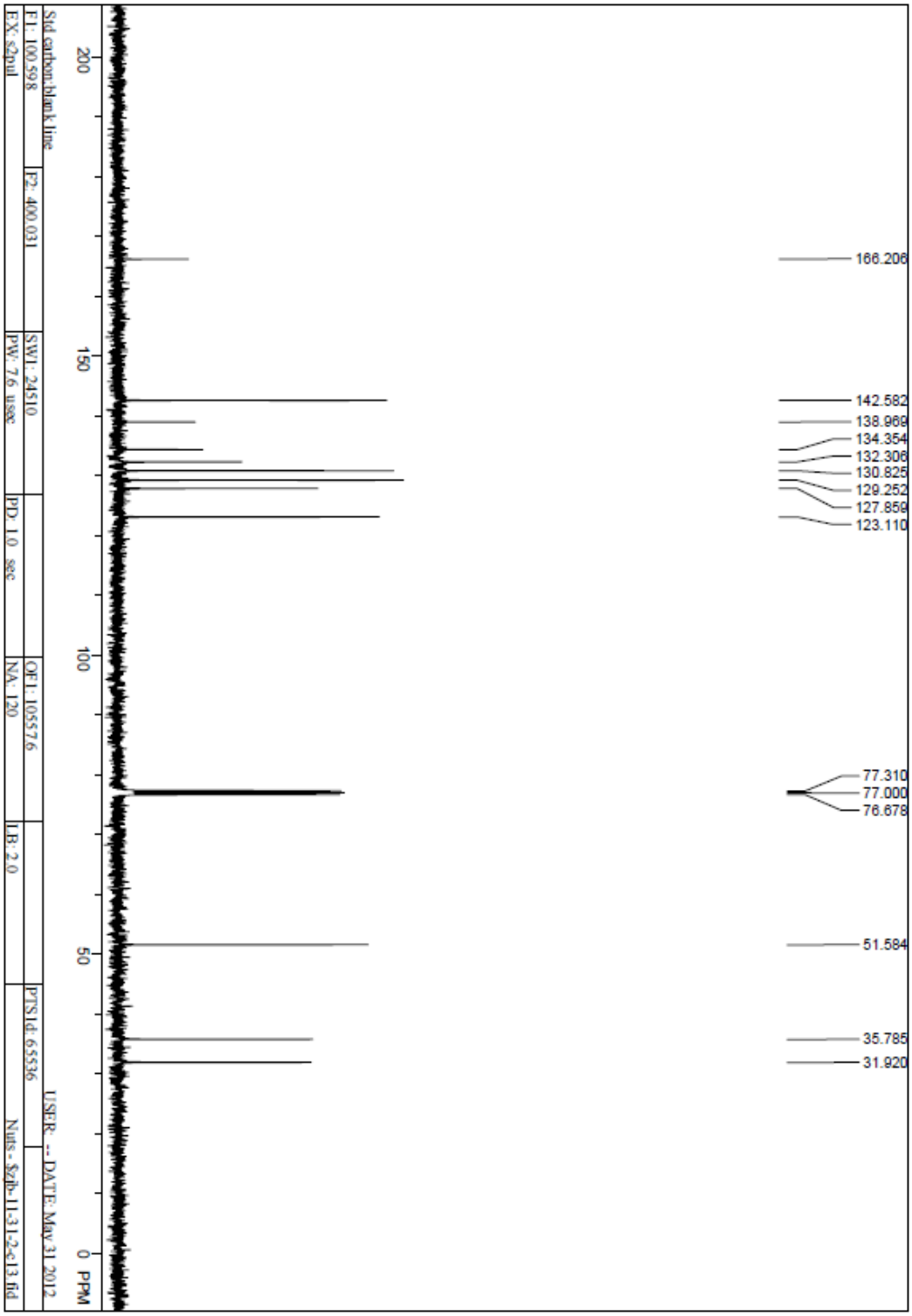
^{1}H NMR (300 M Hz in $CDCl_3$)

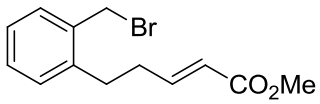




4b

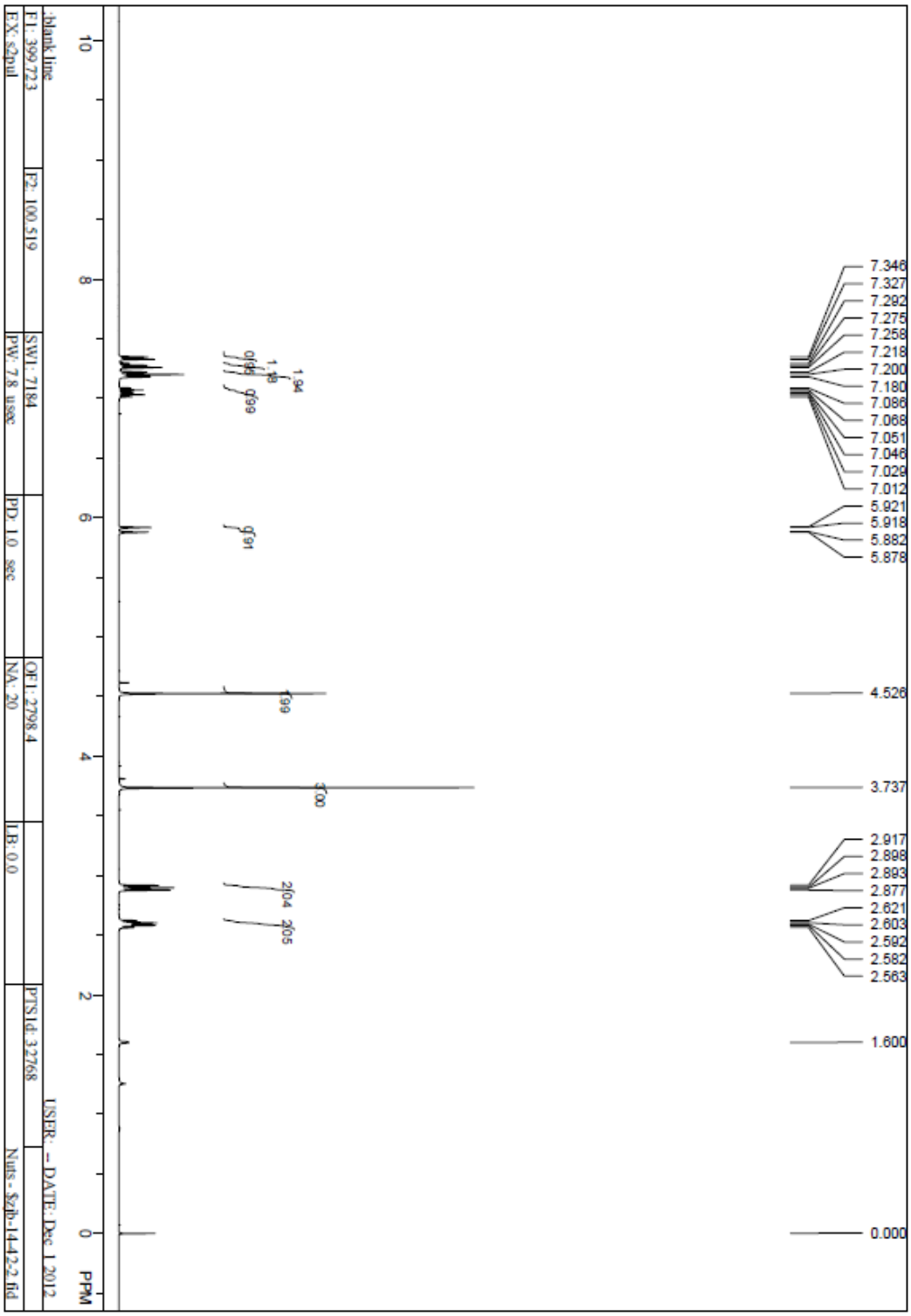
^{13}C NMR (100 M Hz in $CDCl_3$)

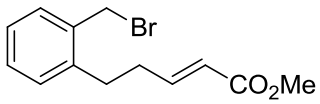




4c

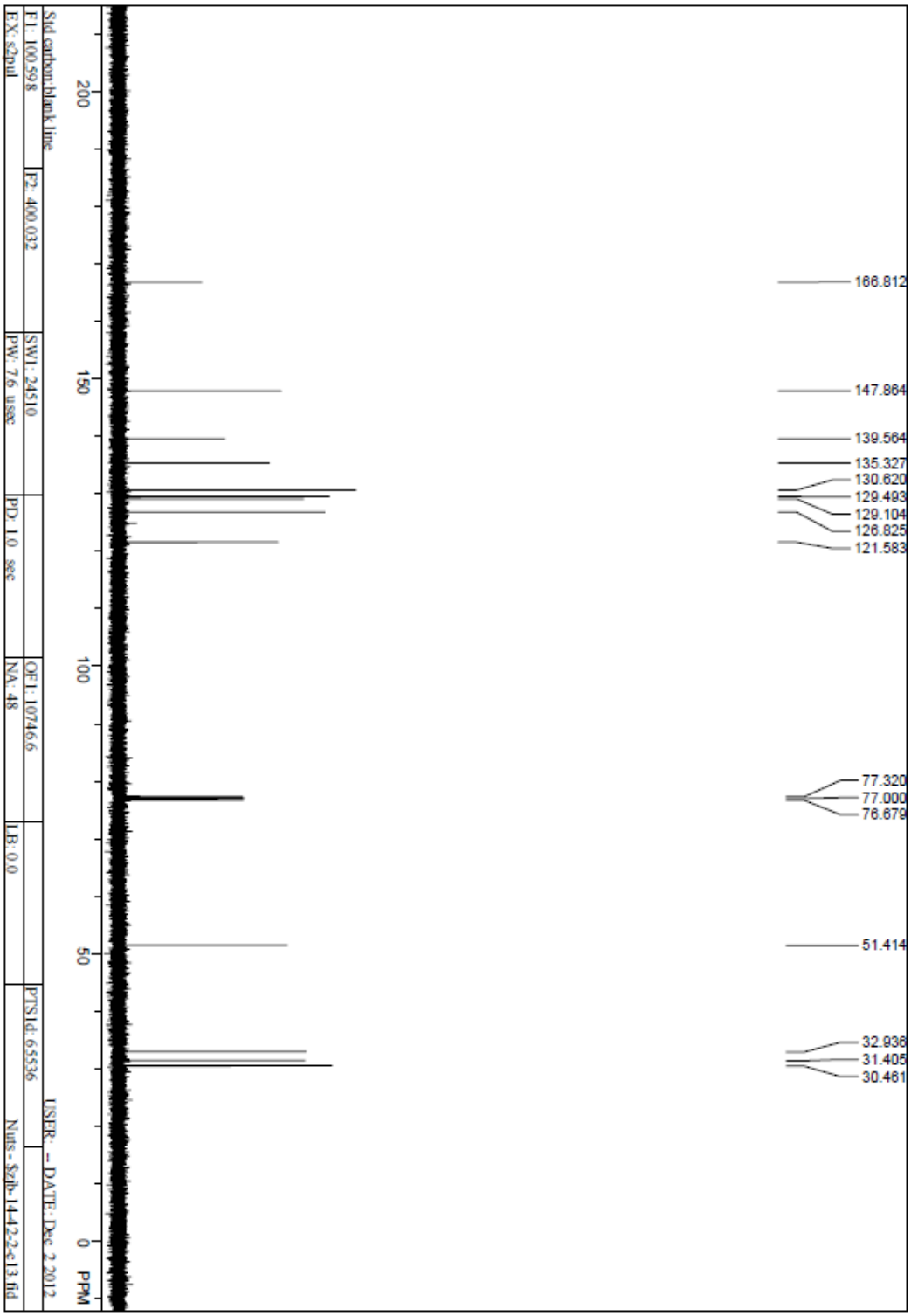
^{1}H NMR (400 M Hz in $CDCl_3$)

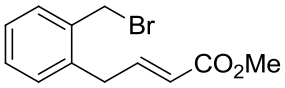




4c

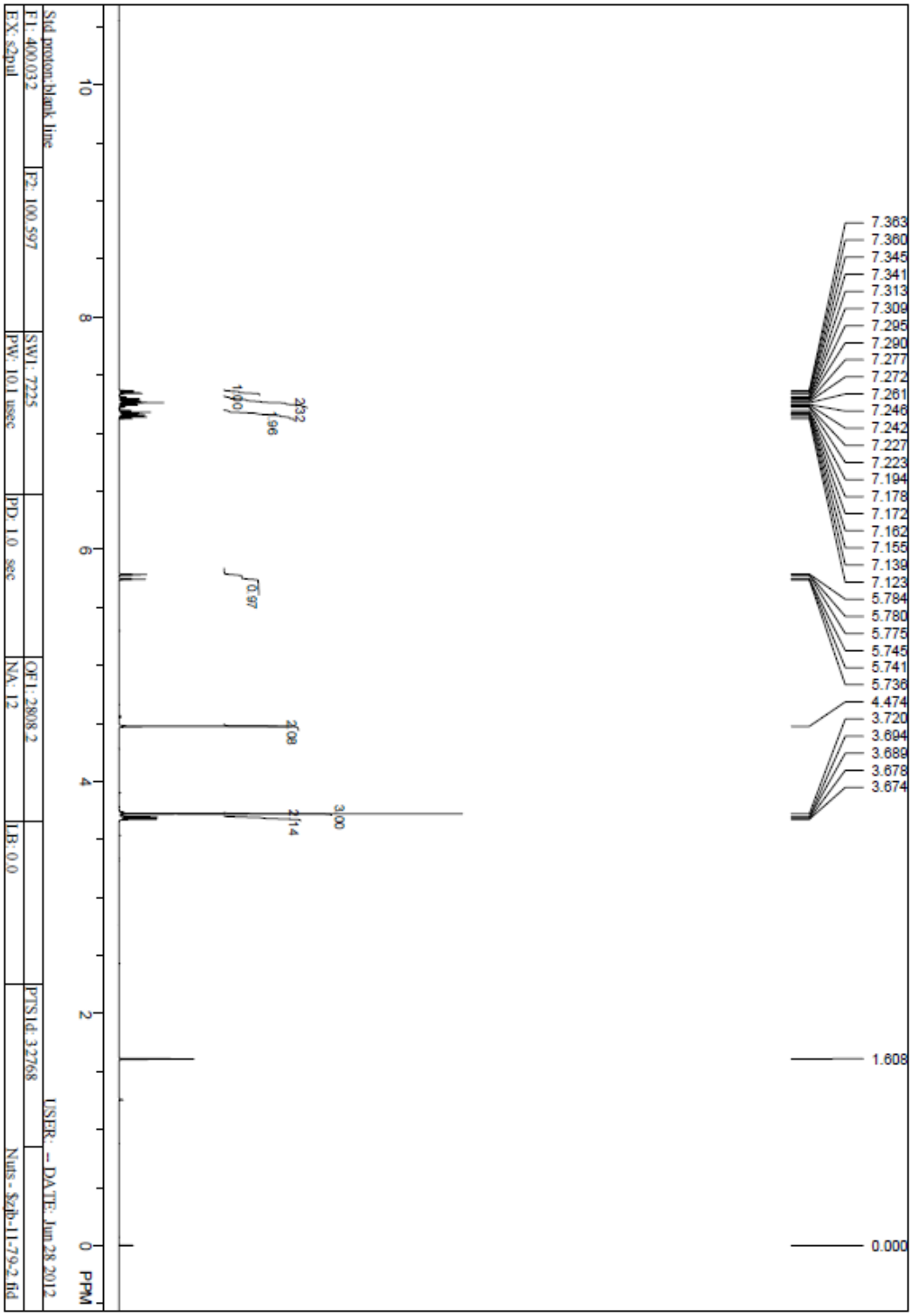
^{13}C NMR (100 M Hz in $CDCl_3$)

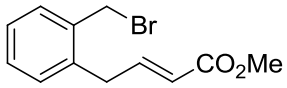




4d

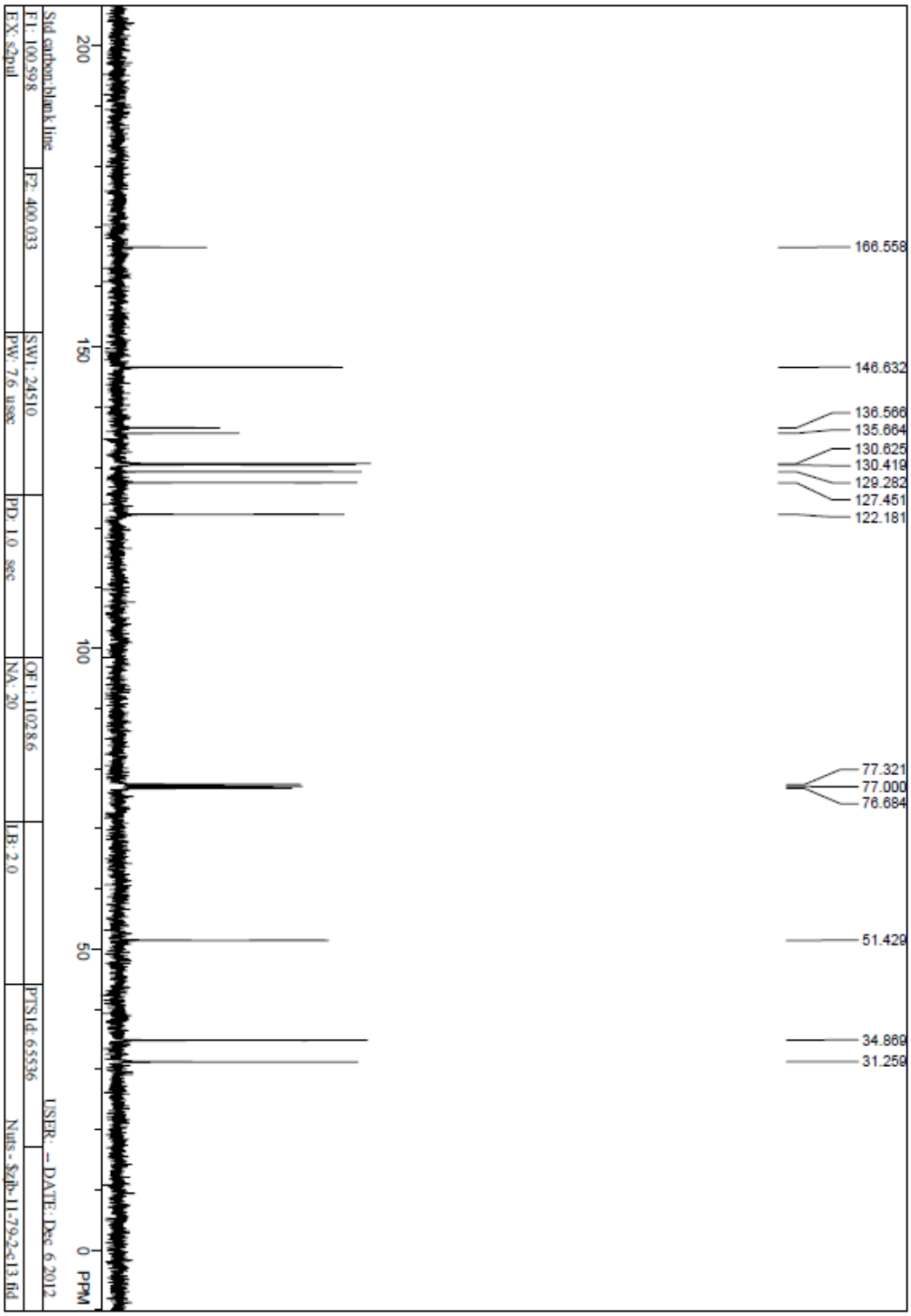
^{1}H NMR (400 M Hz in $CDCl_3$)

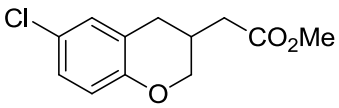




4d

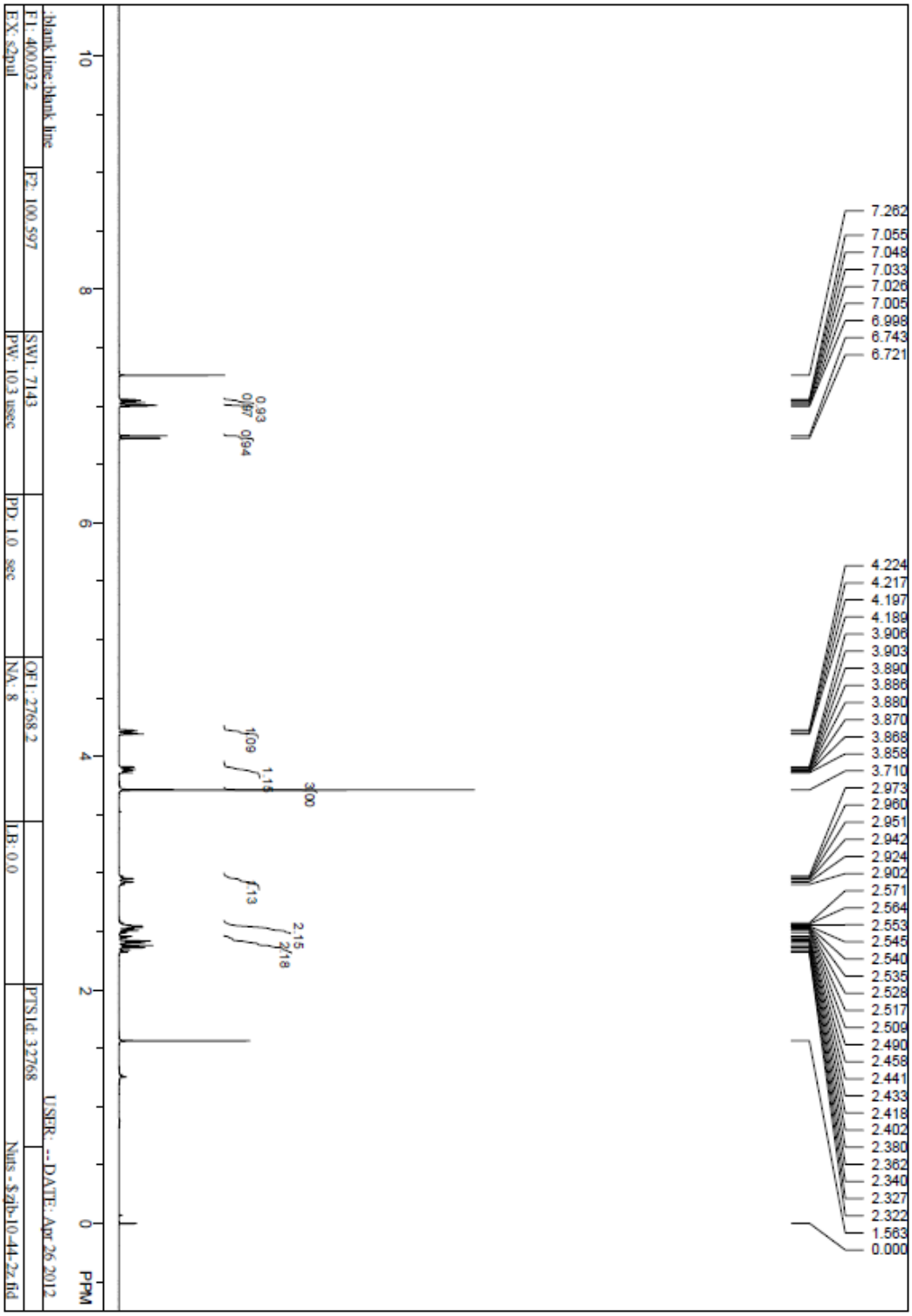
^{13}C NMR (100 M Hz in $CDCl_3$)

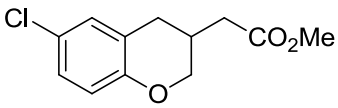




2a

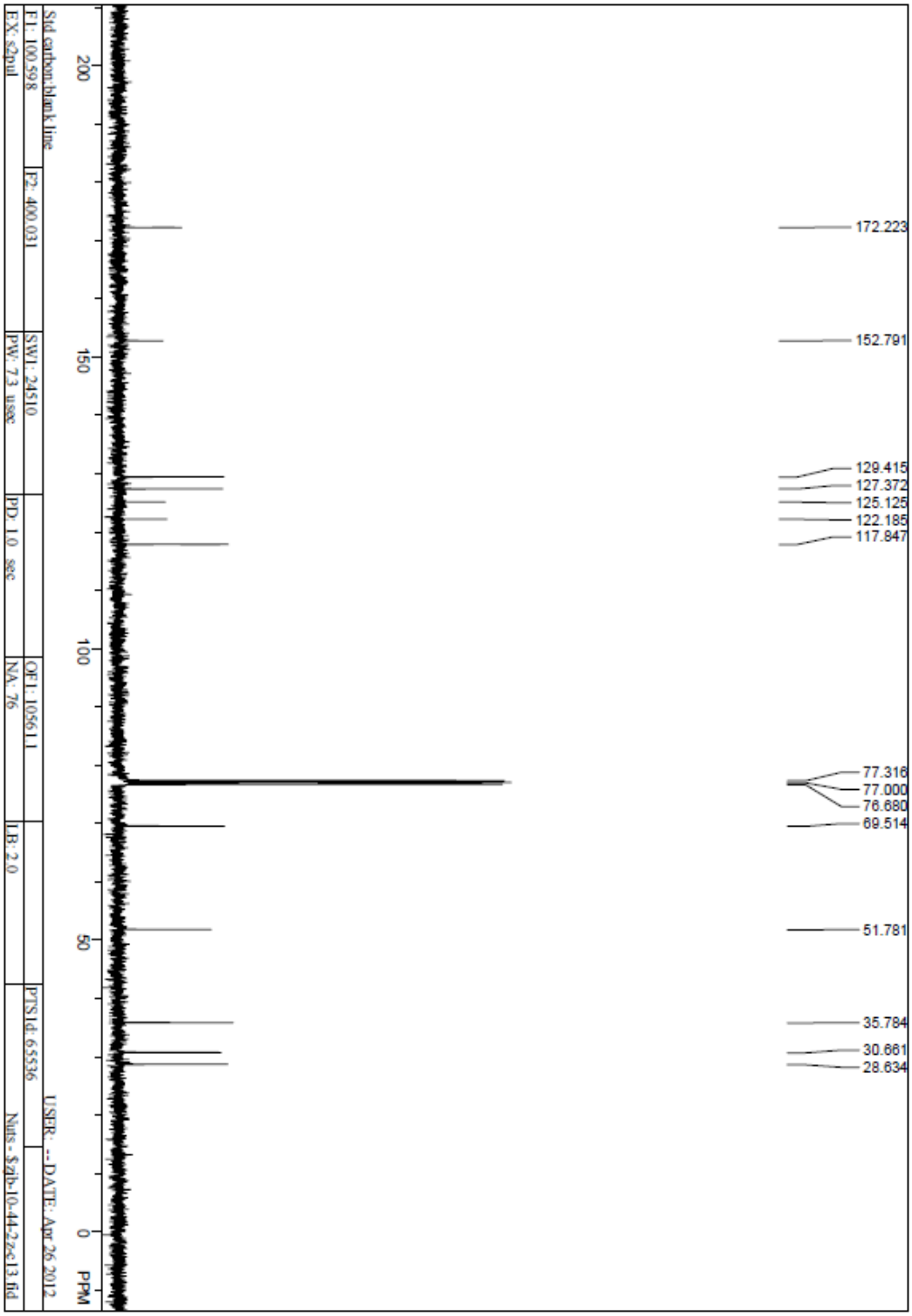
^{1}H NMR (400 M Hz in $CDCl_3$)

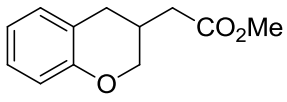




2a

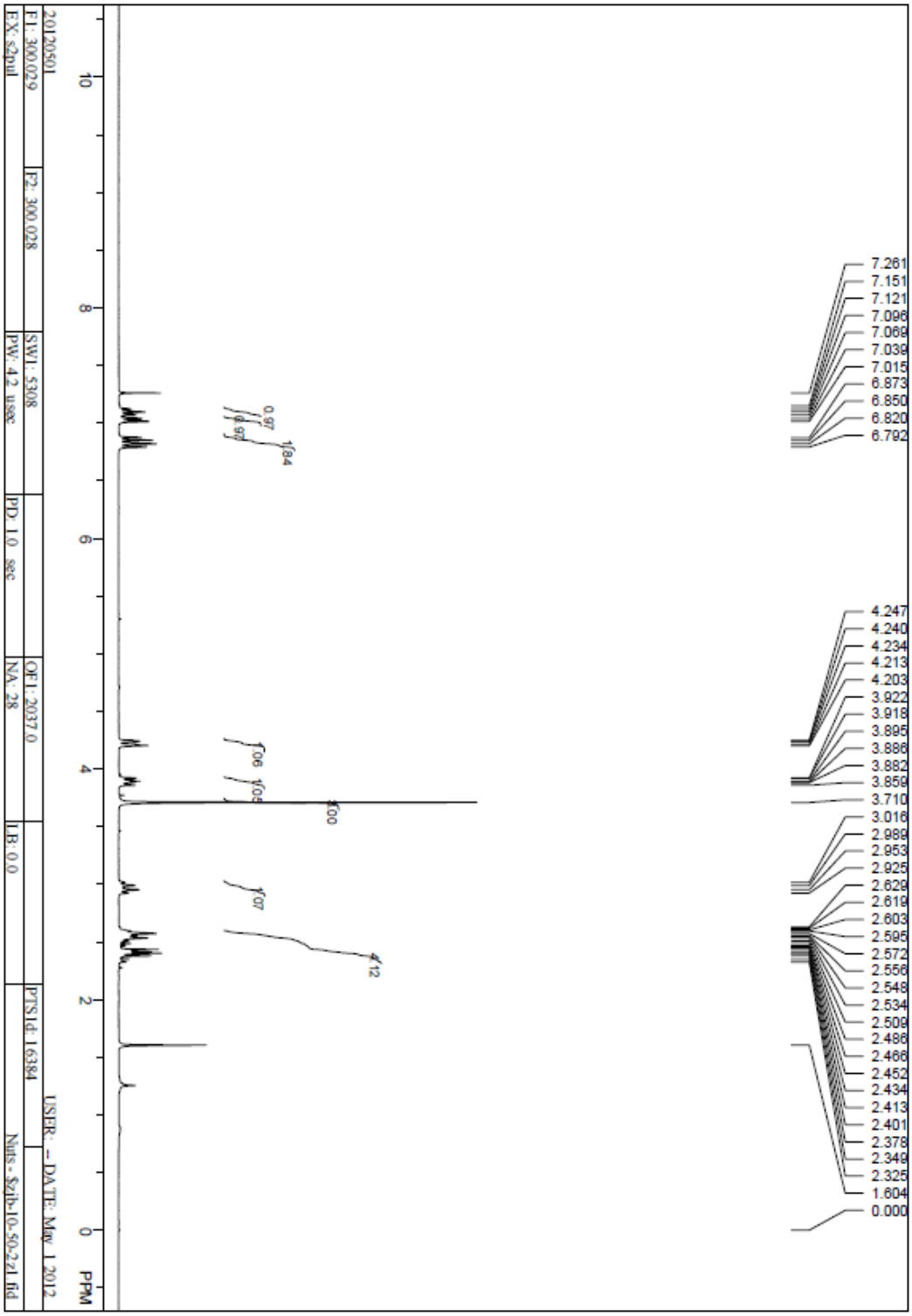
^{13}C NMR (100 M Hz in $CDCl_3$)

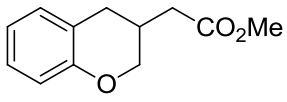




2b

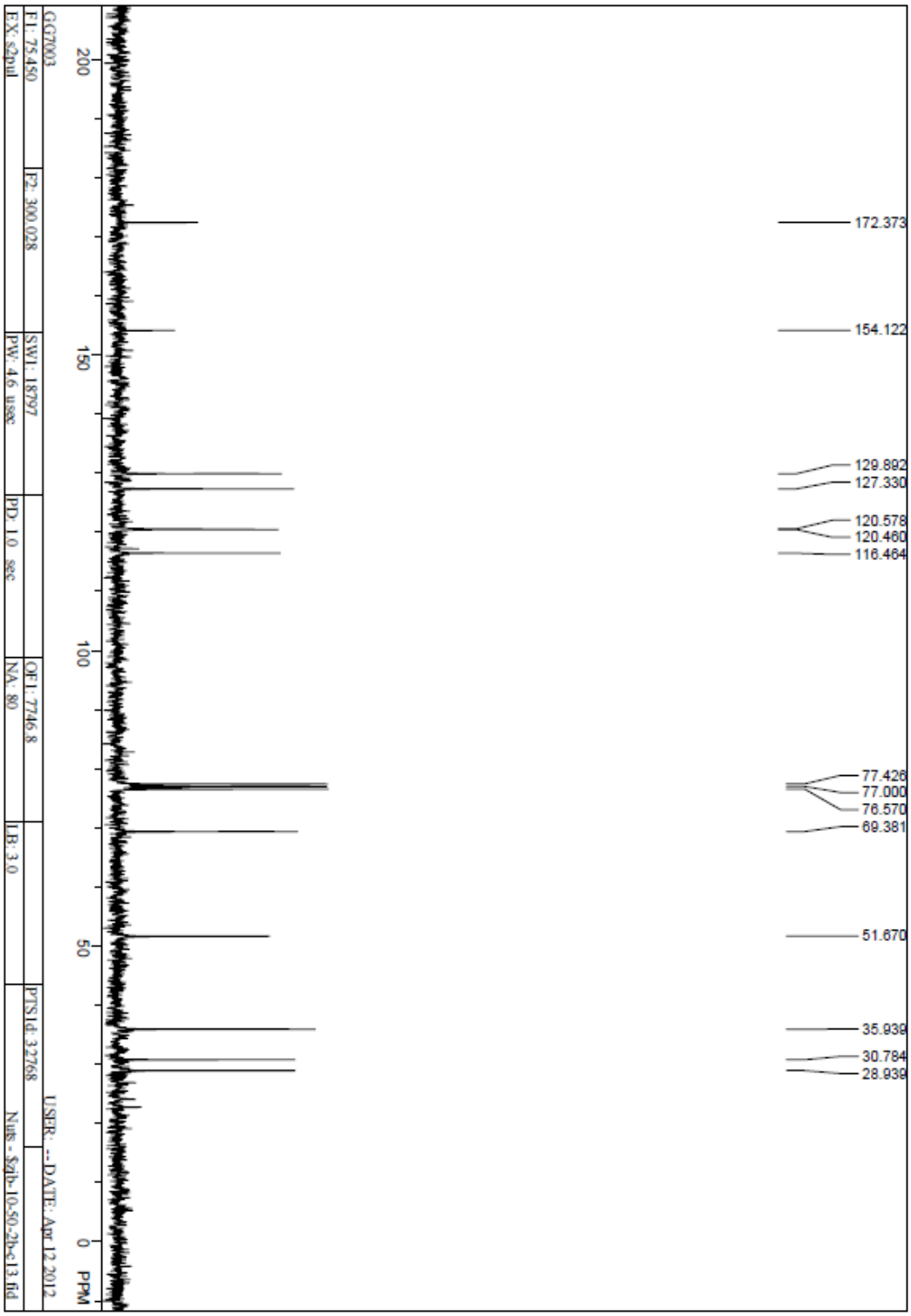
^{1}H NMR (300 M Hz in $CDCl_3$)

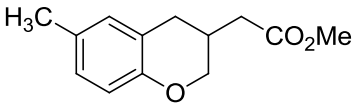




2b

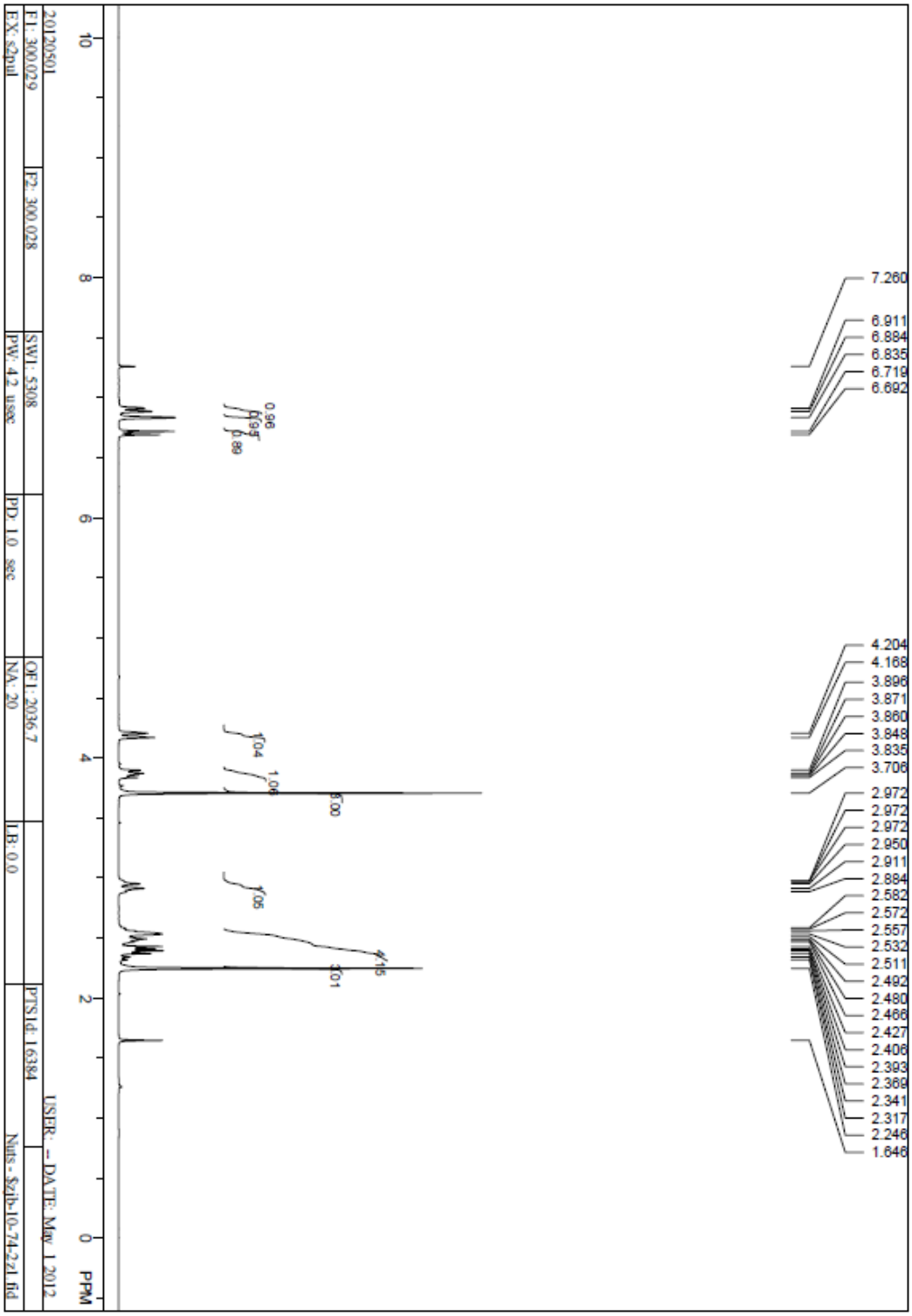
^{13}C NMR (75 M Hz in $CDCl_3$)

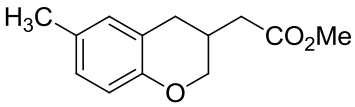




2c

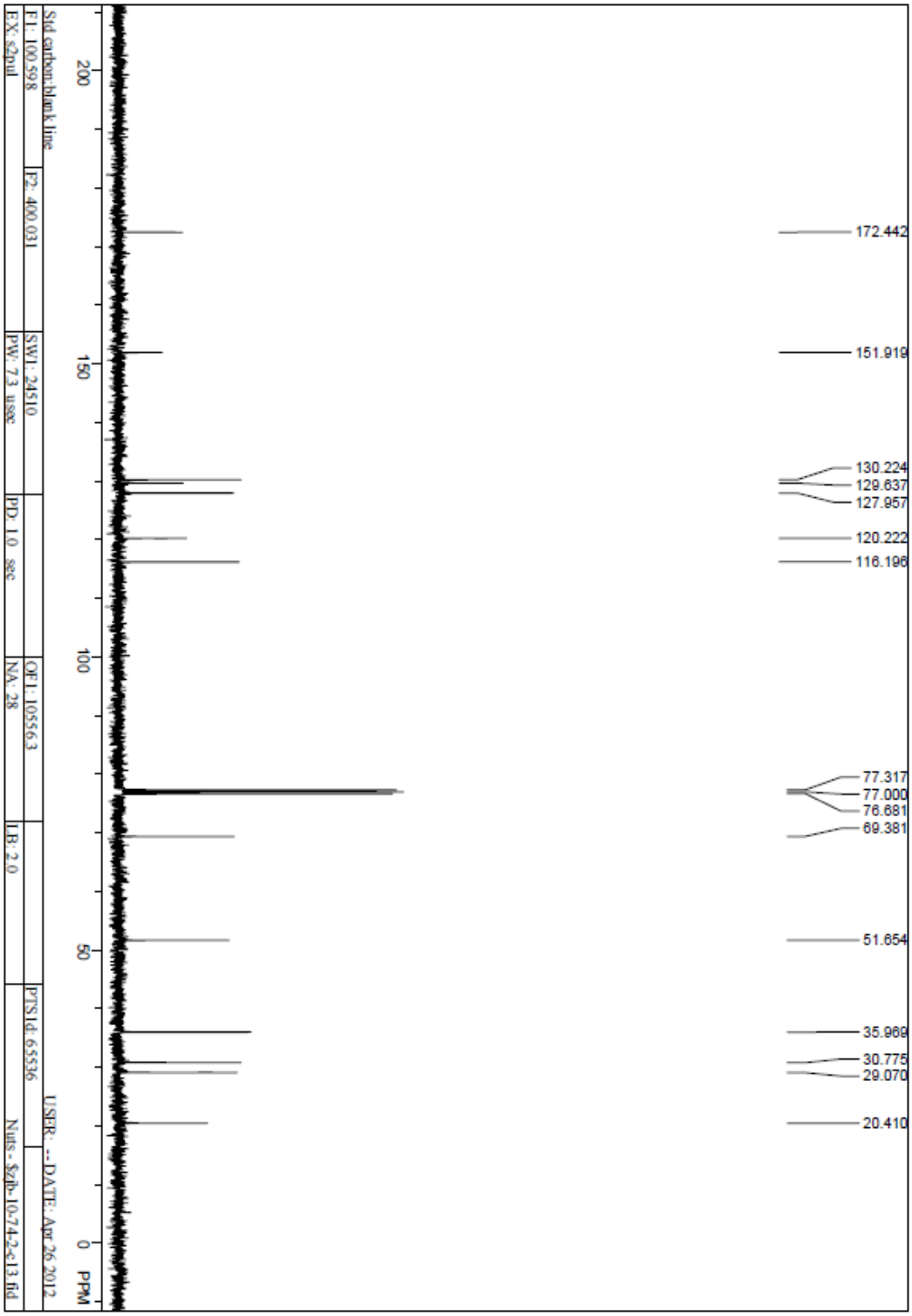
^{1}H NMR (300 M Hz in $CDCl_3$)

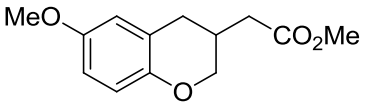




2c

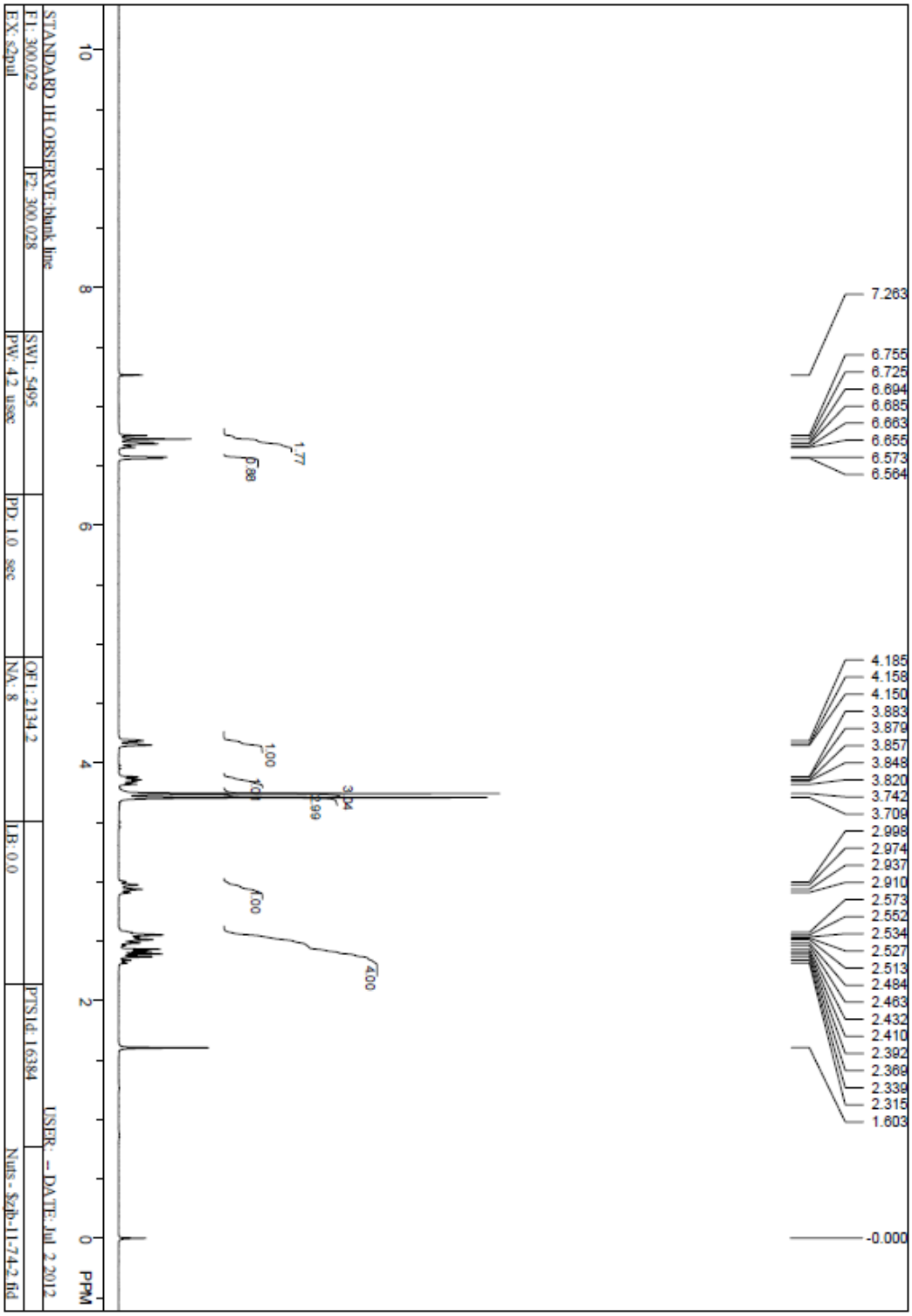
^{13}C NMR (100 M Hz in $CDCl_3$)

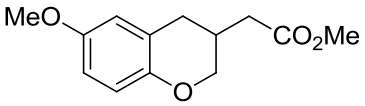




2d

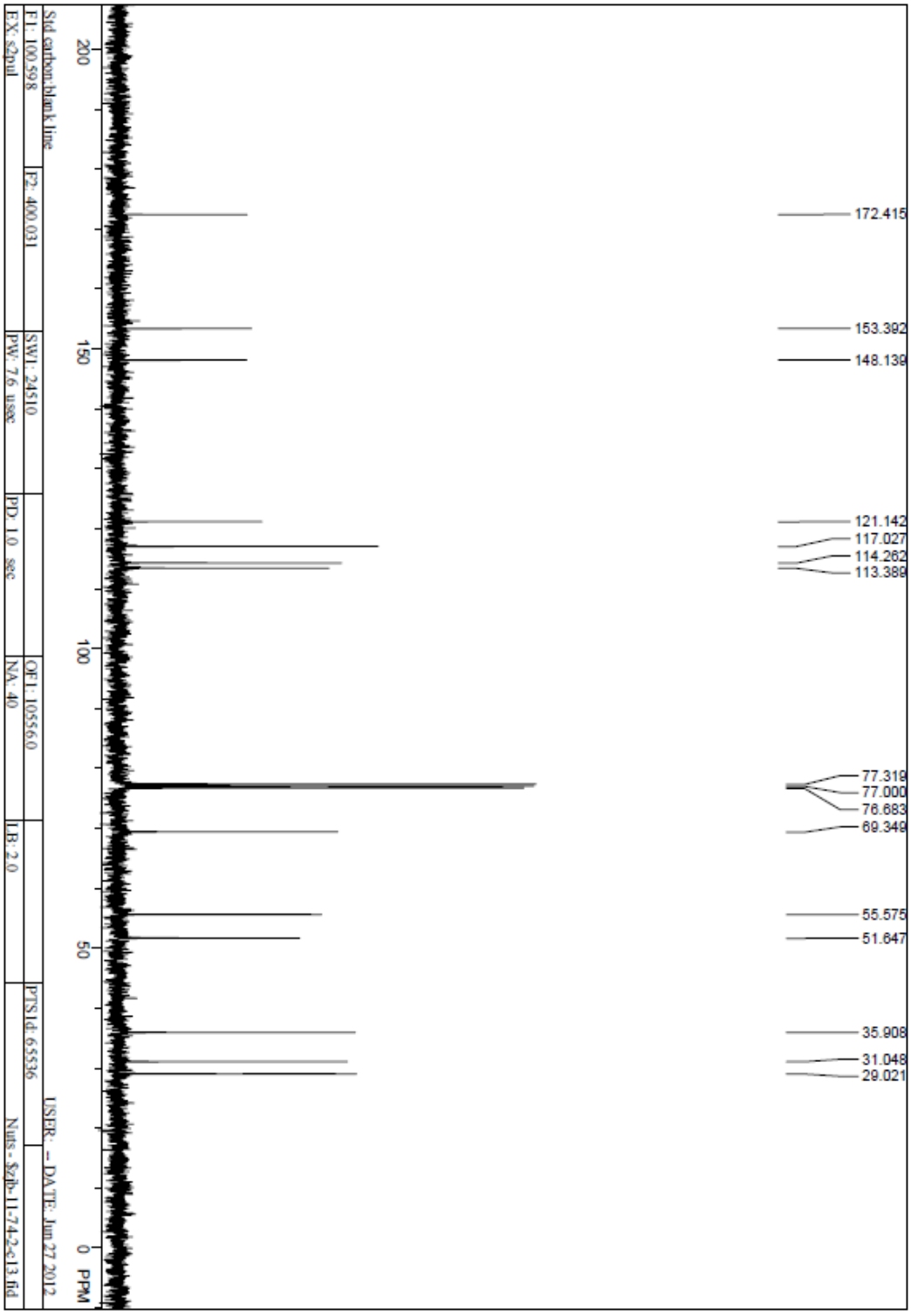
^{1}H NMR (300 M Hz in $CDCl_3$)

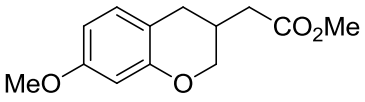




2d

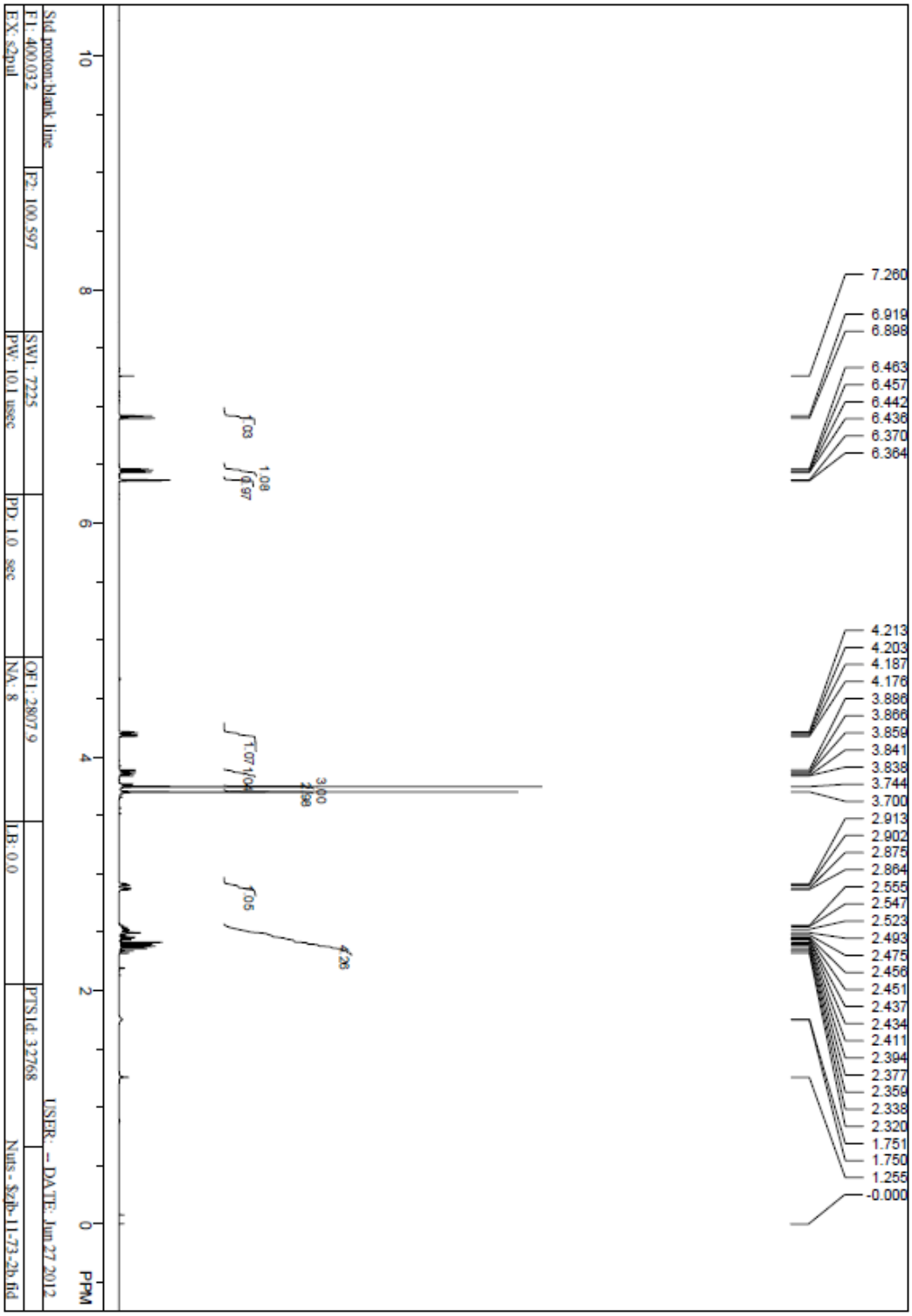
^{13}C NMR (100 M Hz in $CDCl_3$)

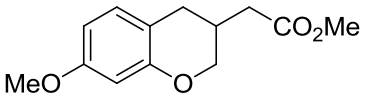




2e

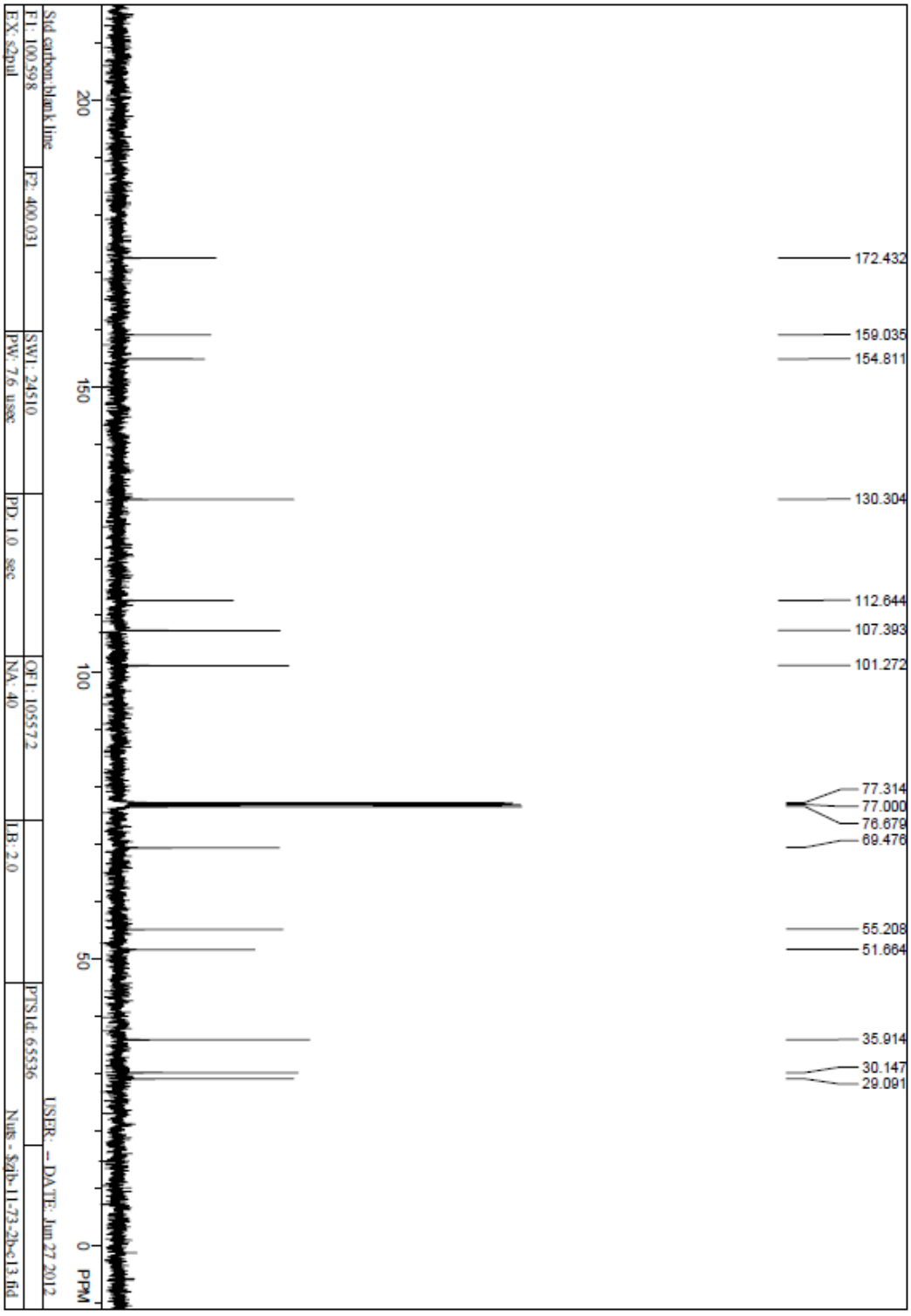
^{1}H NMR (400 M Hz in $CDCl_3$)

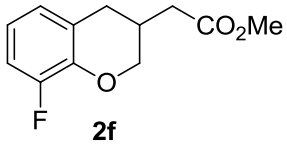




2e

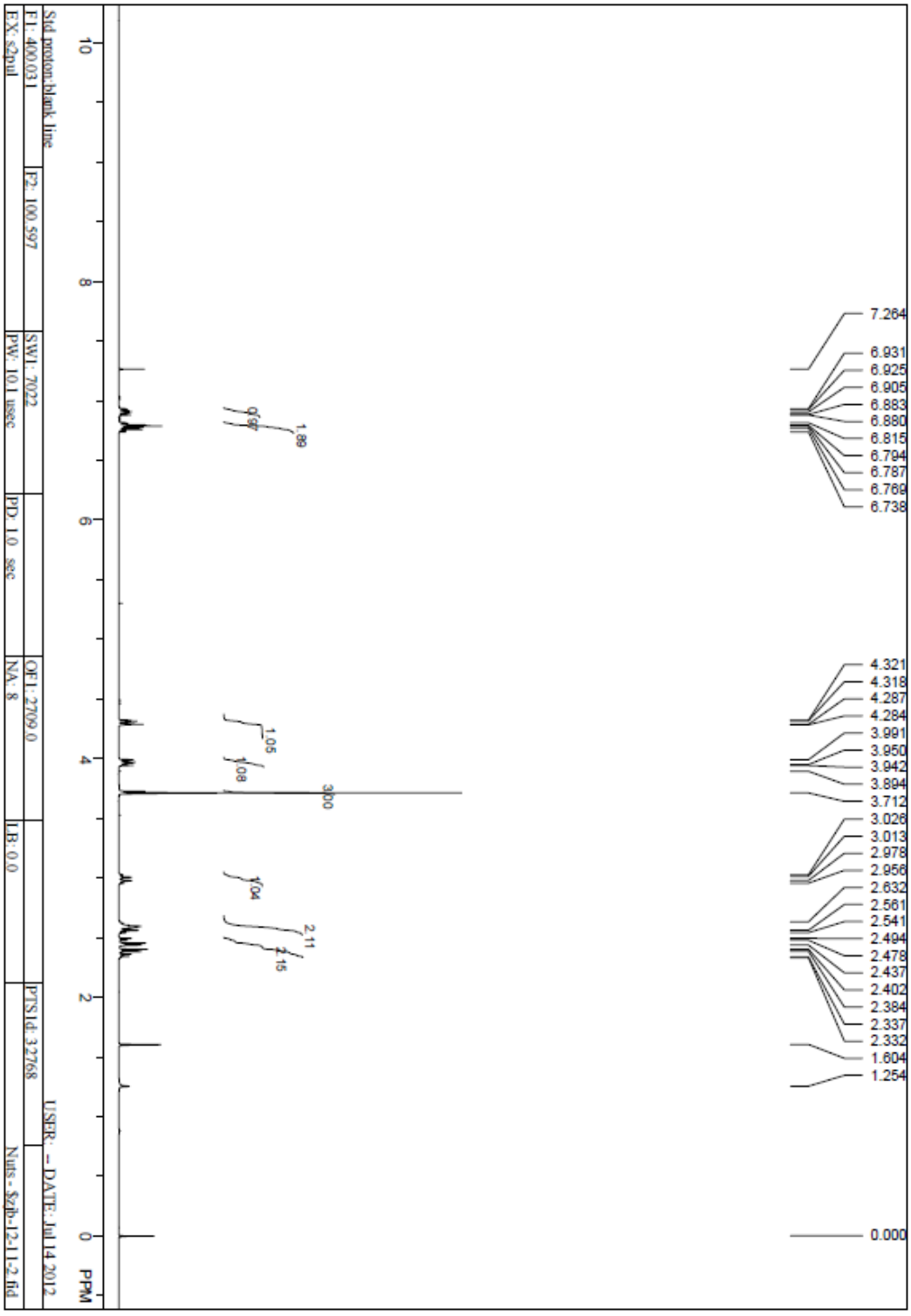
^{13}C NMR (100 M Hz in $CDCl_3$)

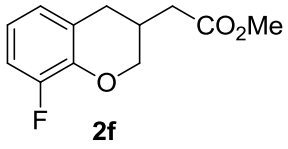




2f

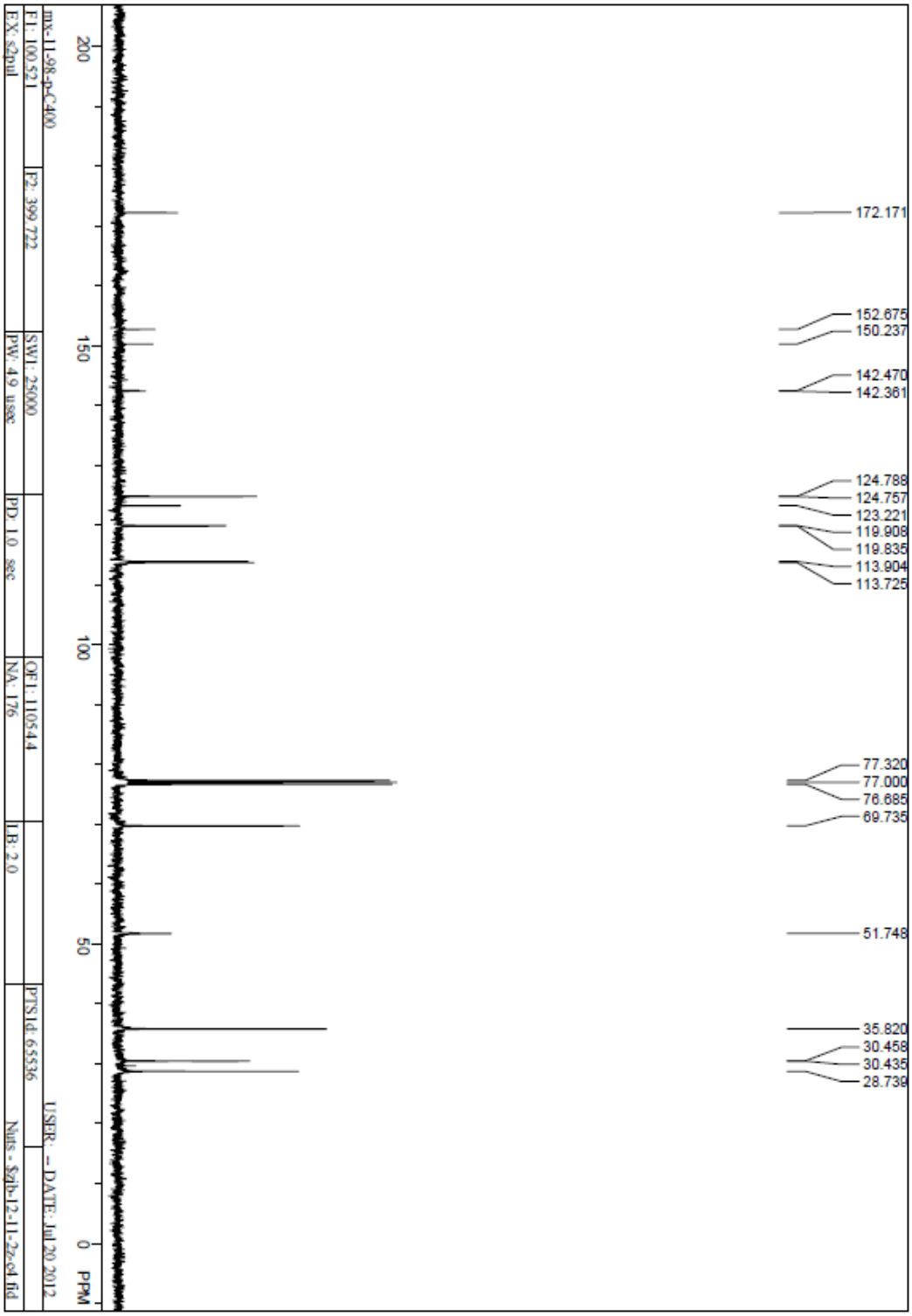
^{1}H NMR (400 M Hz in $CDCl_3$)

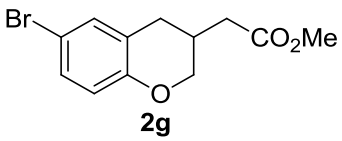




2f

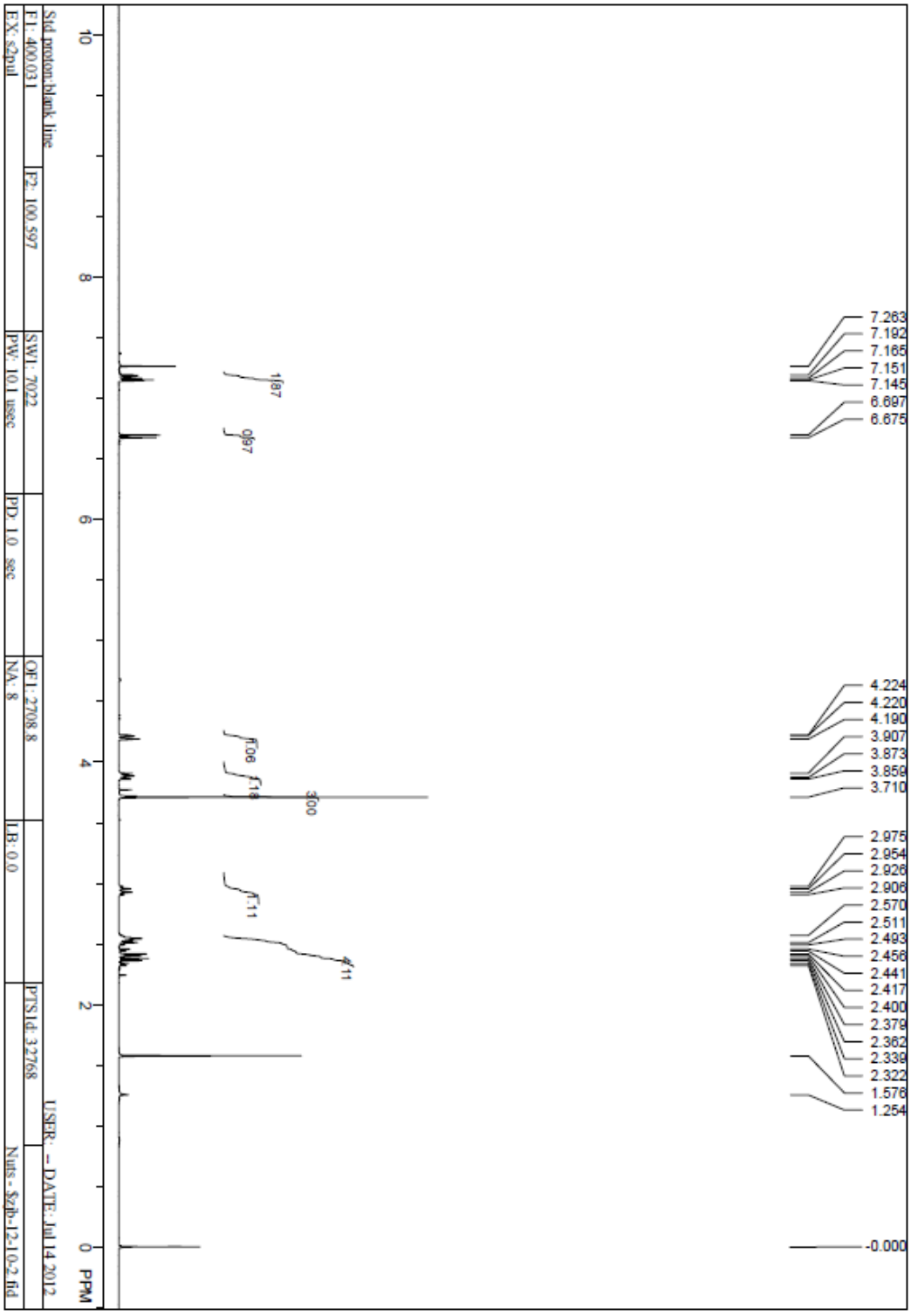
^{13}C NMR (100 M Hz in $CDCl_3$)

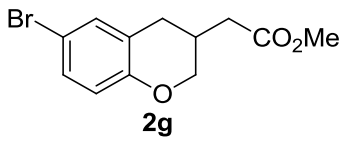




2g

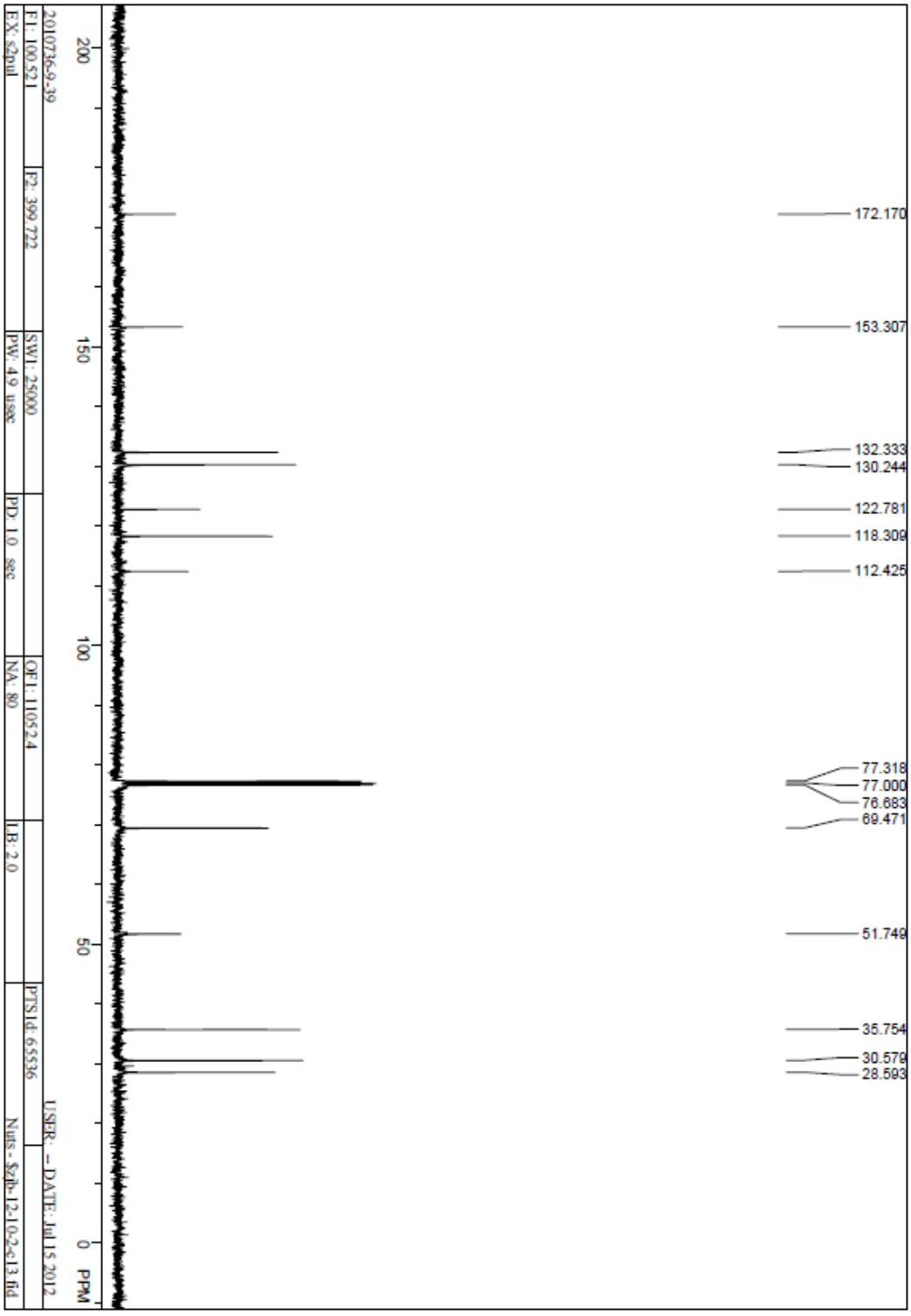
^{1}H NMR (400 M Hz in $CDCl_3$)

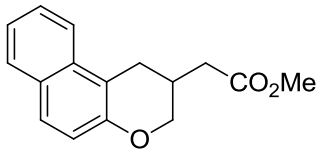




2g

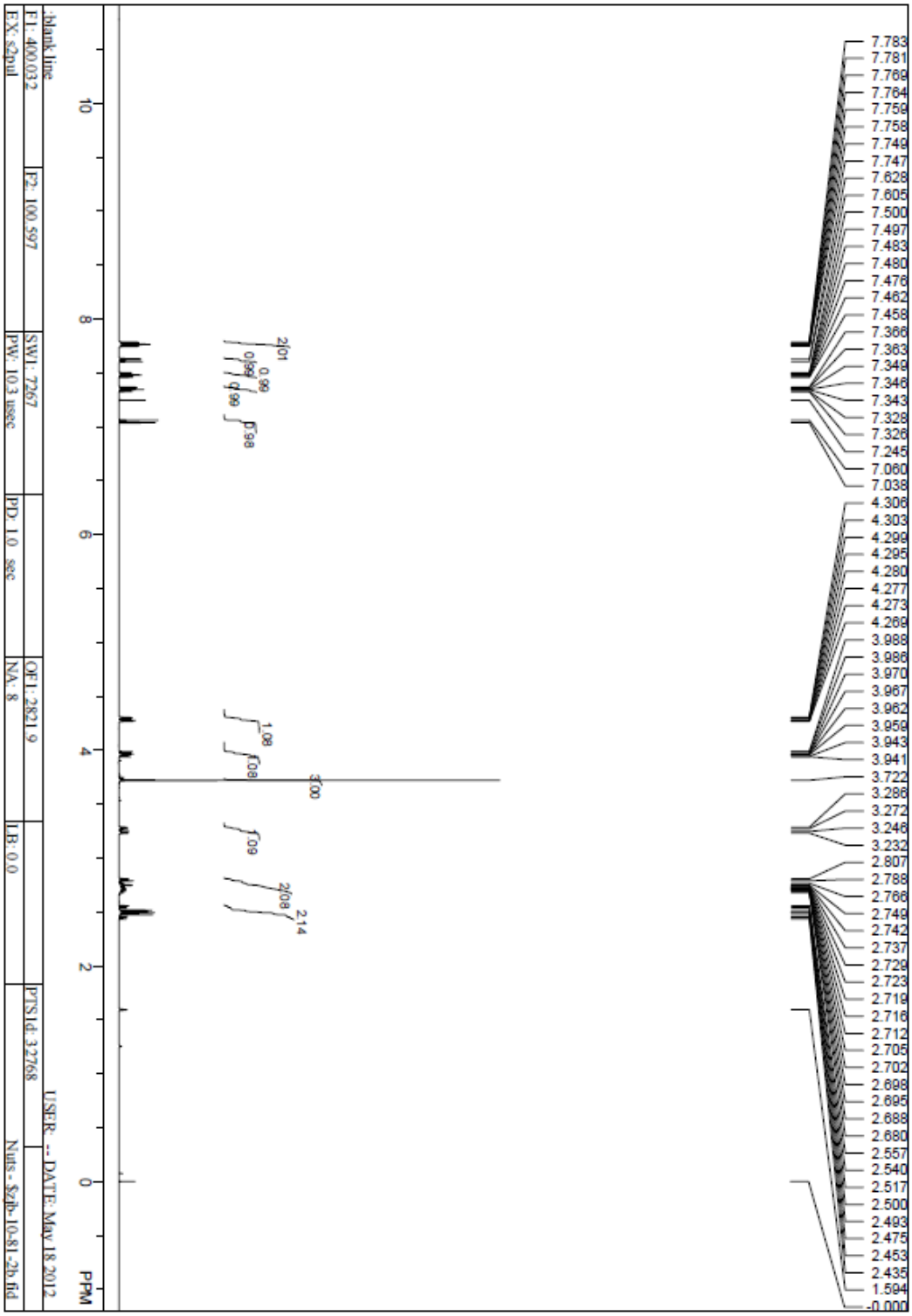
^{13}C NMR (100 M Hz in $CDCl_3$)

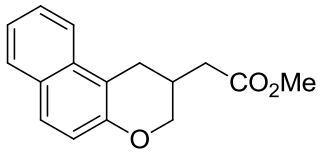




2h

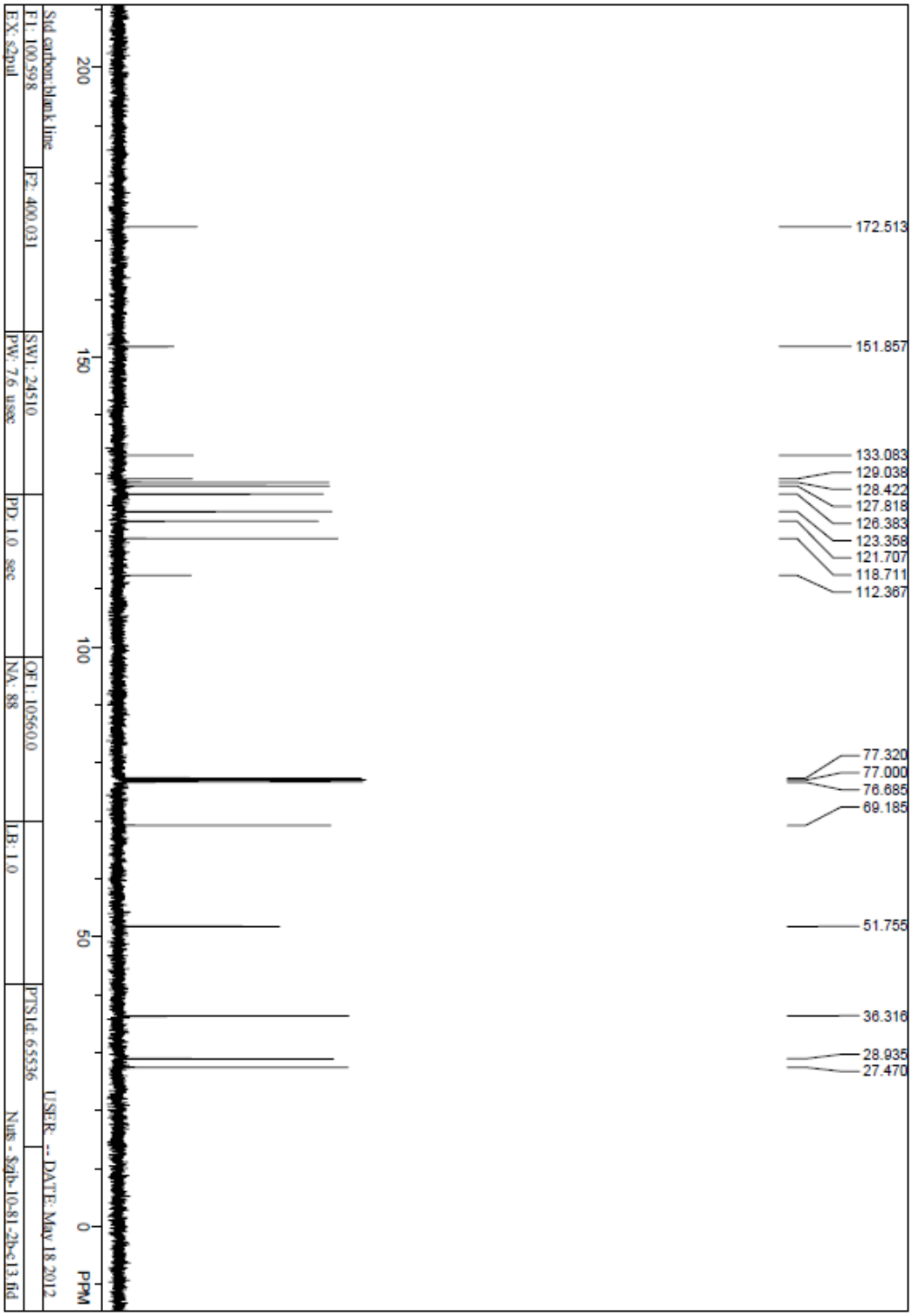
^{1}H NMR (400 M Hz in $CDCl_3$)

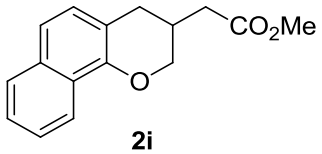




2h

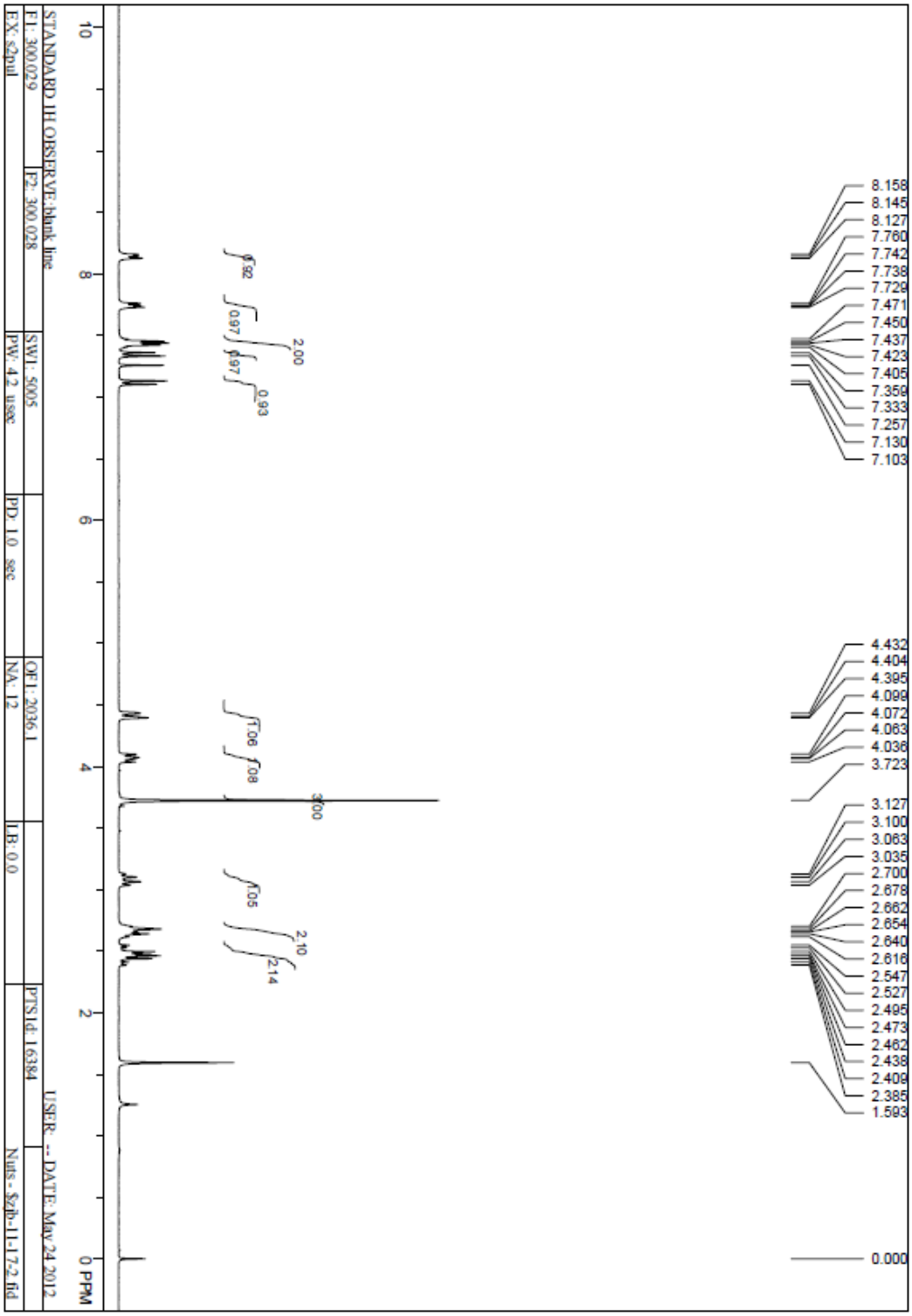
^{13}C NMR (100 M Hz in $CDCl_3$)

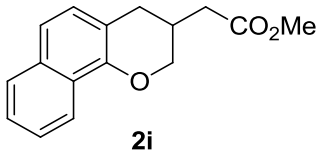




2i

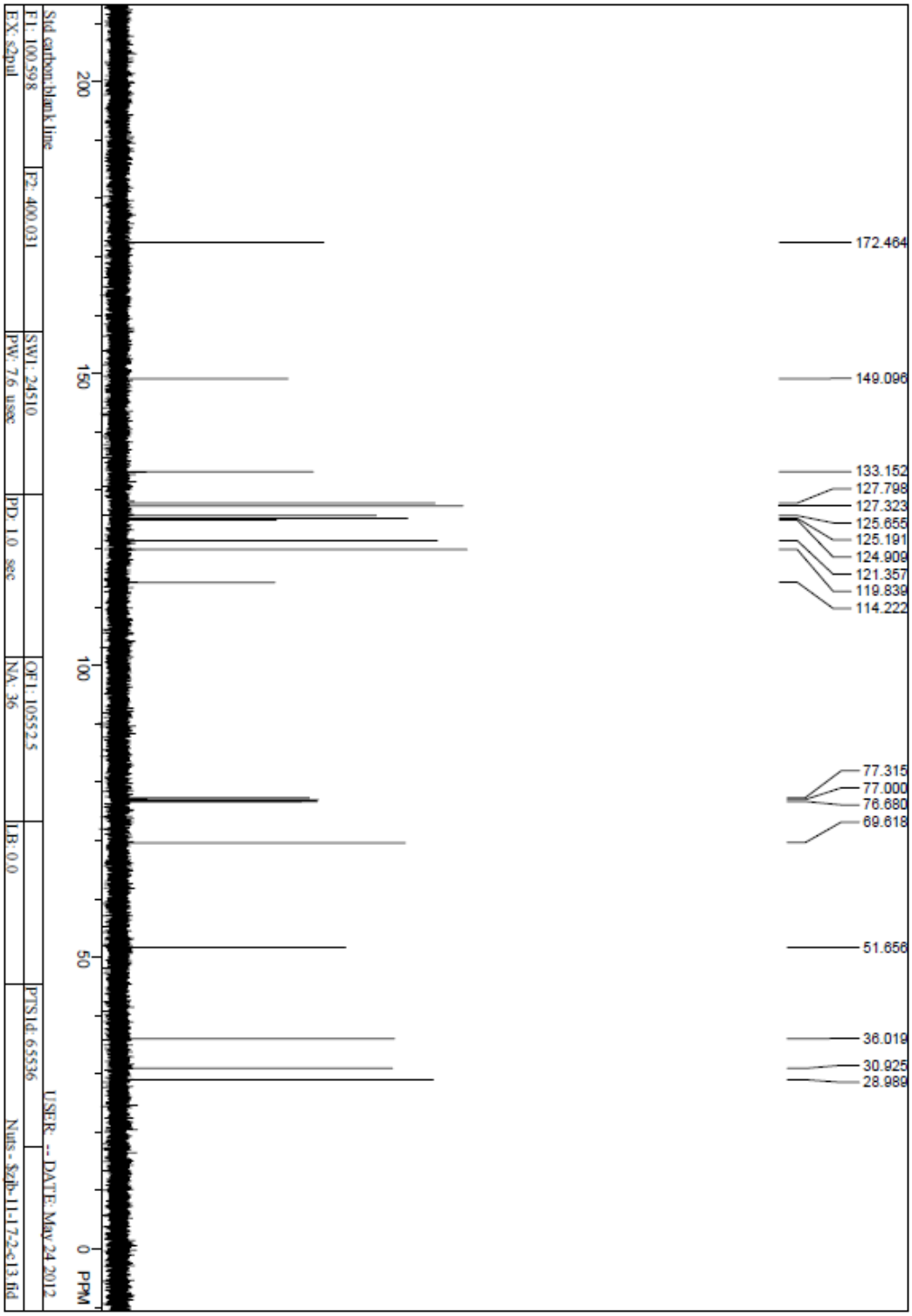
^{1}H NMR (300 M Hz in $CDCl_3$)

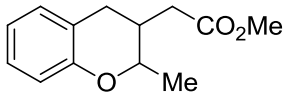




2i

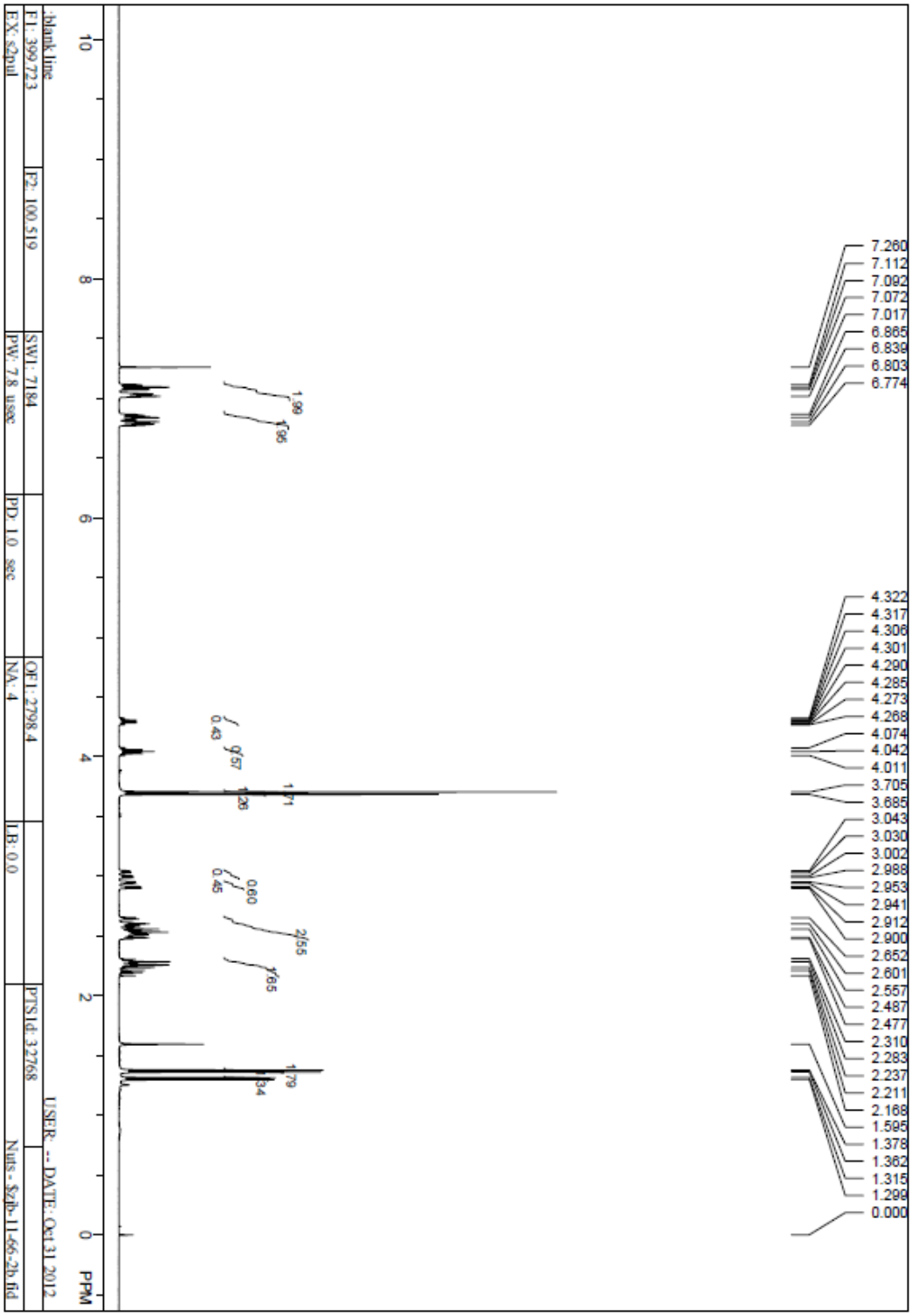
^{13}C NMR (100 M Hz in $CDCl_3$)

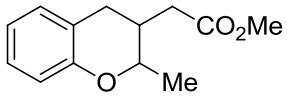




2j

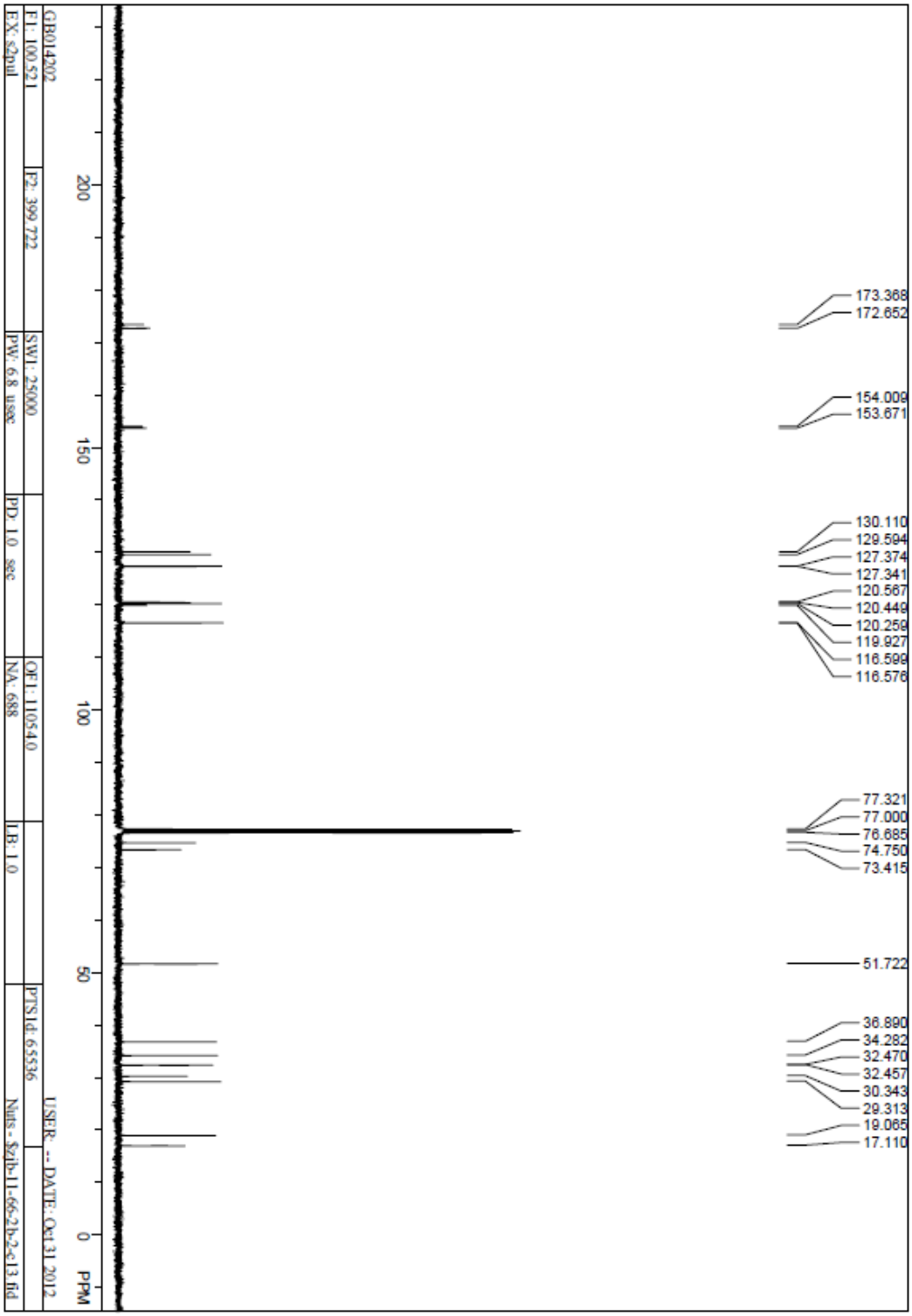
^{1}H NMR (400 M Hz in $CDCl_3$)

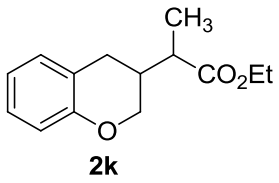




2j

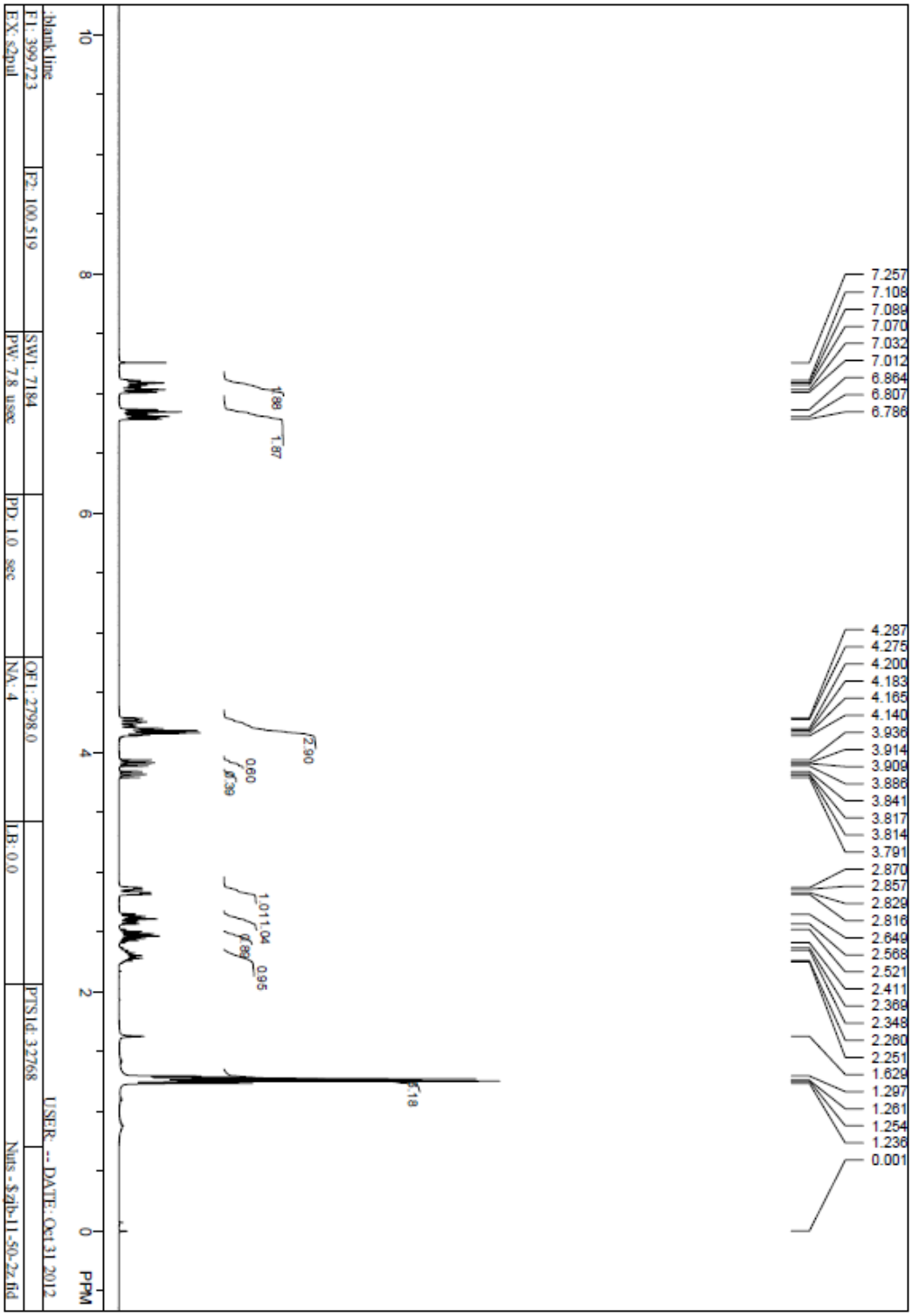
^{13}C NMR (100 M Hz in $CDCl_3$)

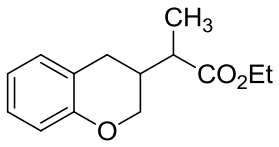




2k

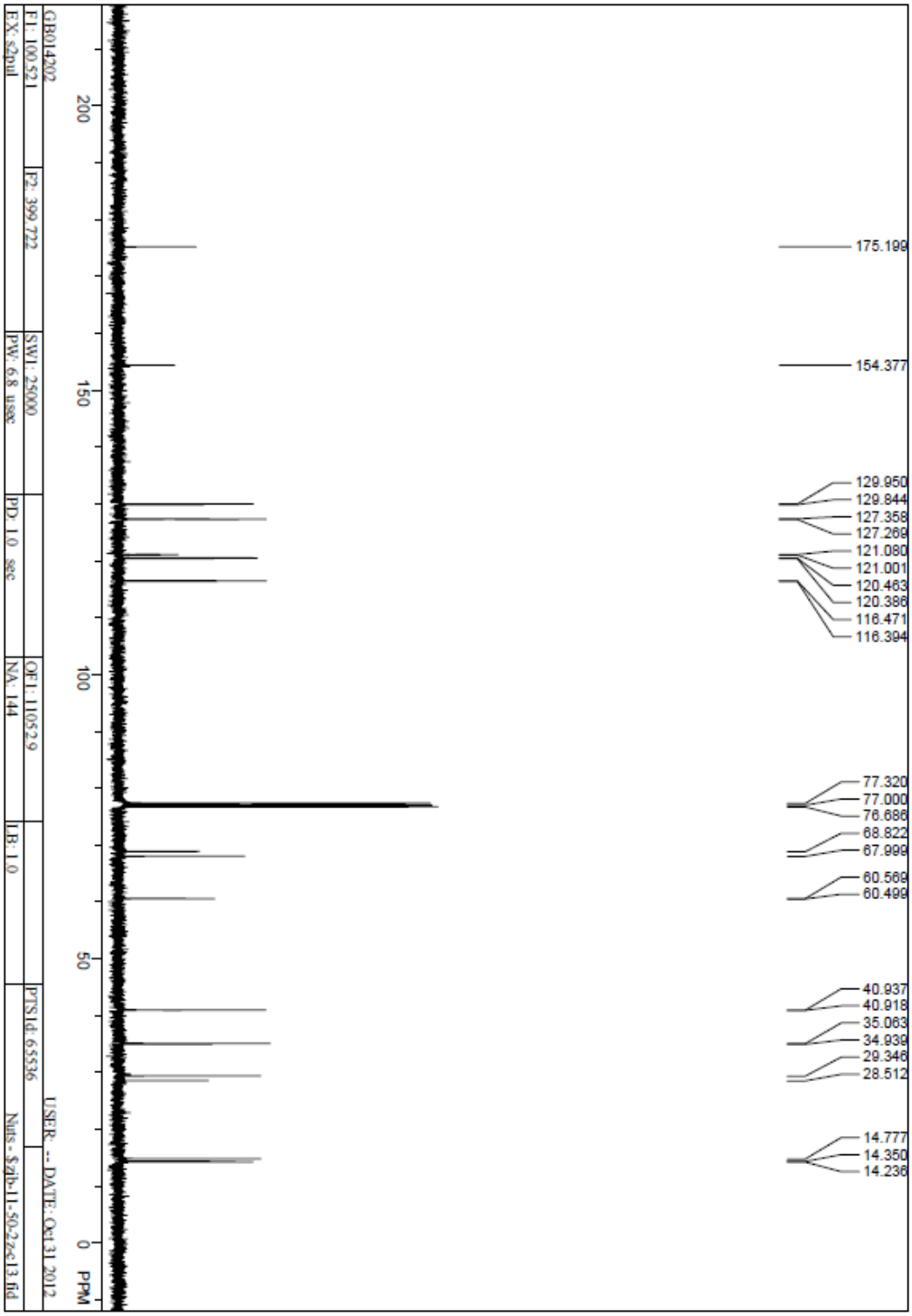
^{1}H NMR (400 M Hz in $CDCl_3$)

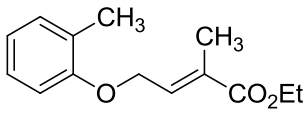




2k

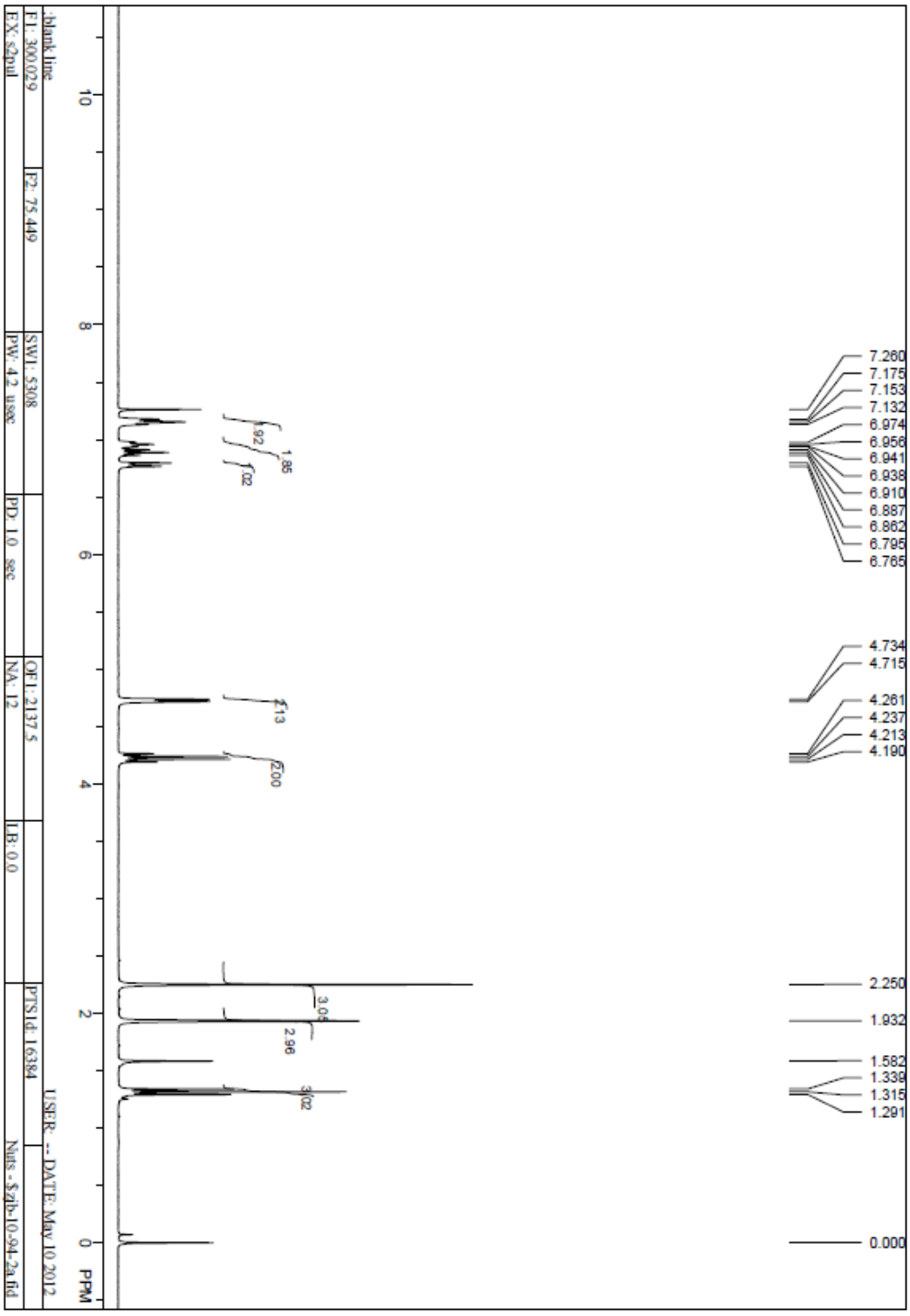
^{13}C NMR (100 M Hz in $CDCl_3$)

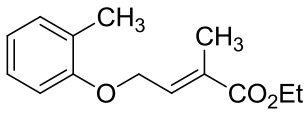




3k

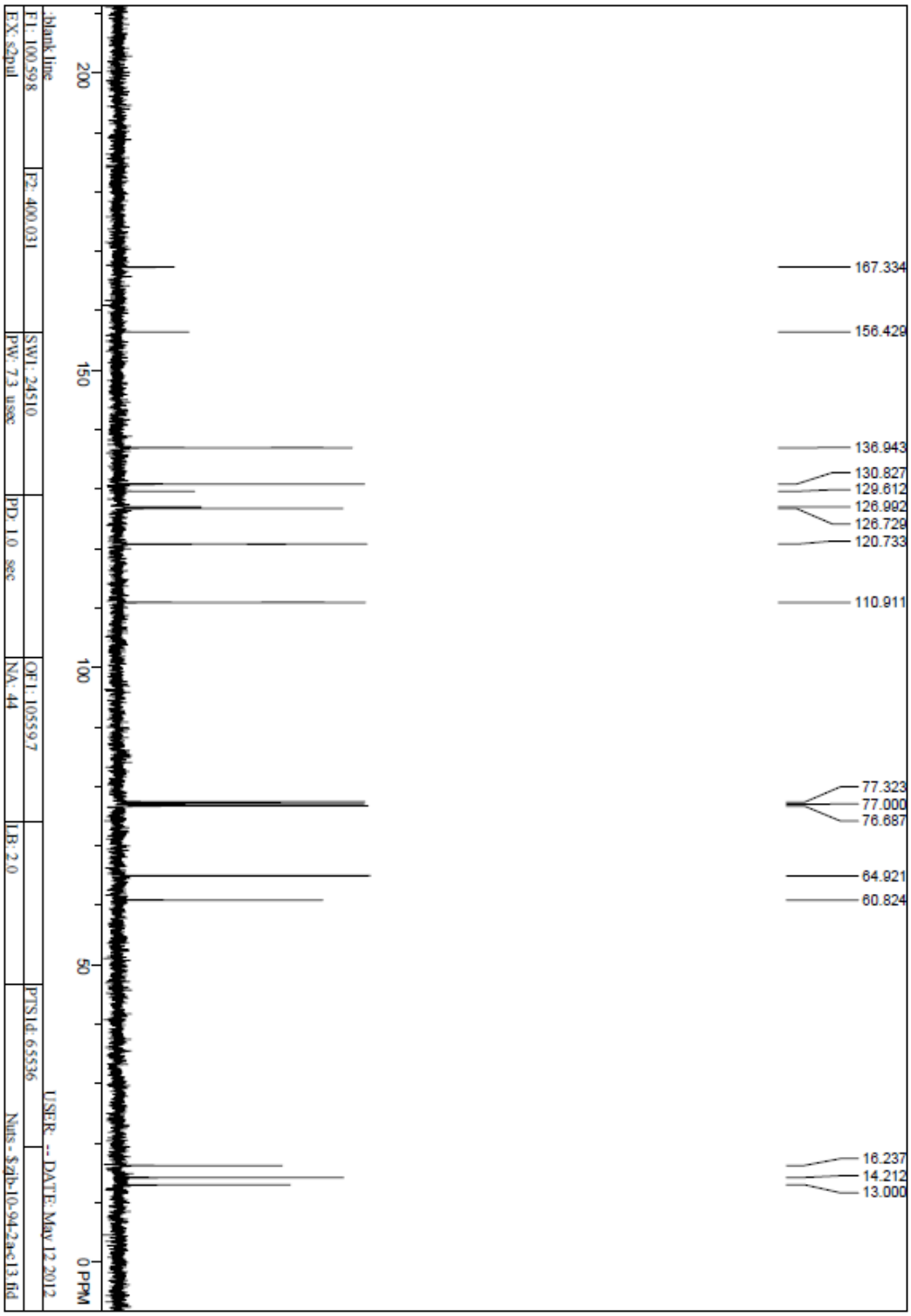
^{1}H NMR (300 M Hz in $CDCl_3$)

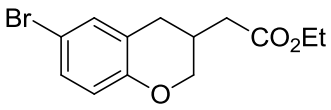




3k

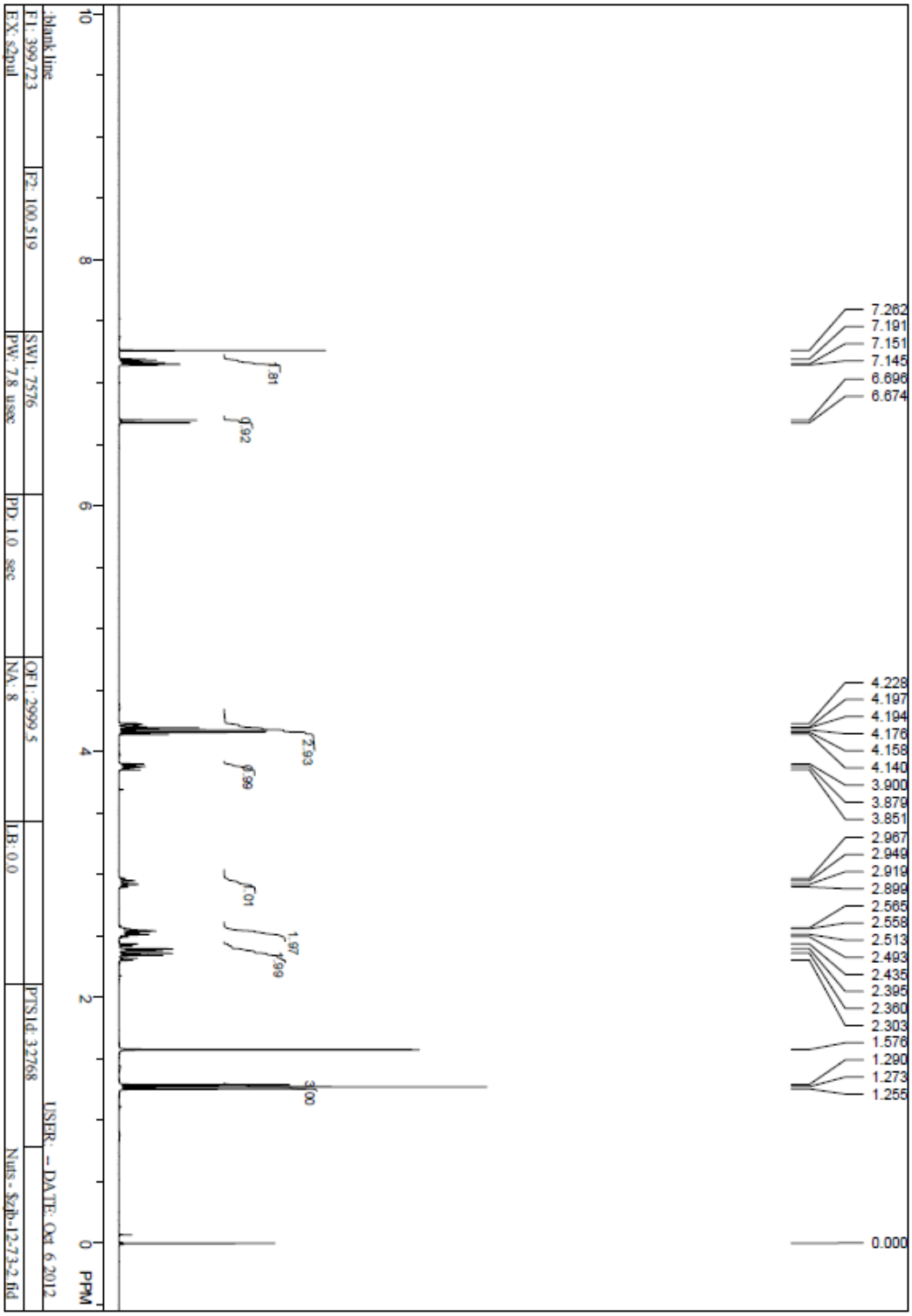
^{13}C NMR (100 M Hz in $CDCl_3$)

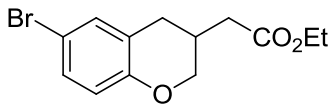




2l

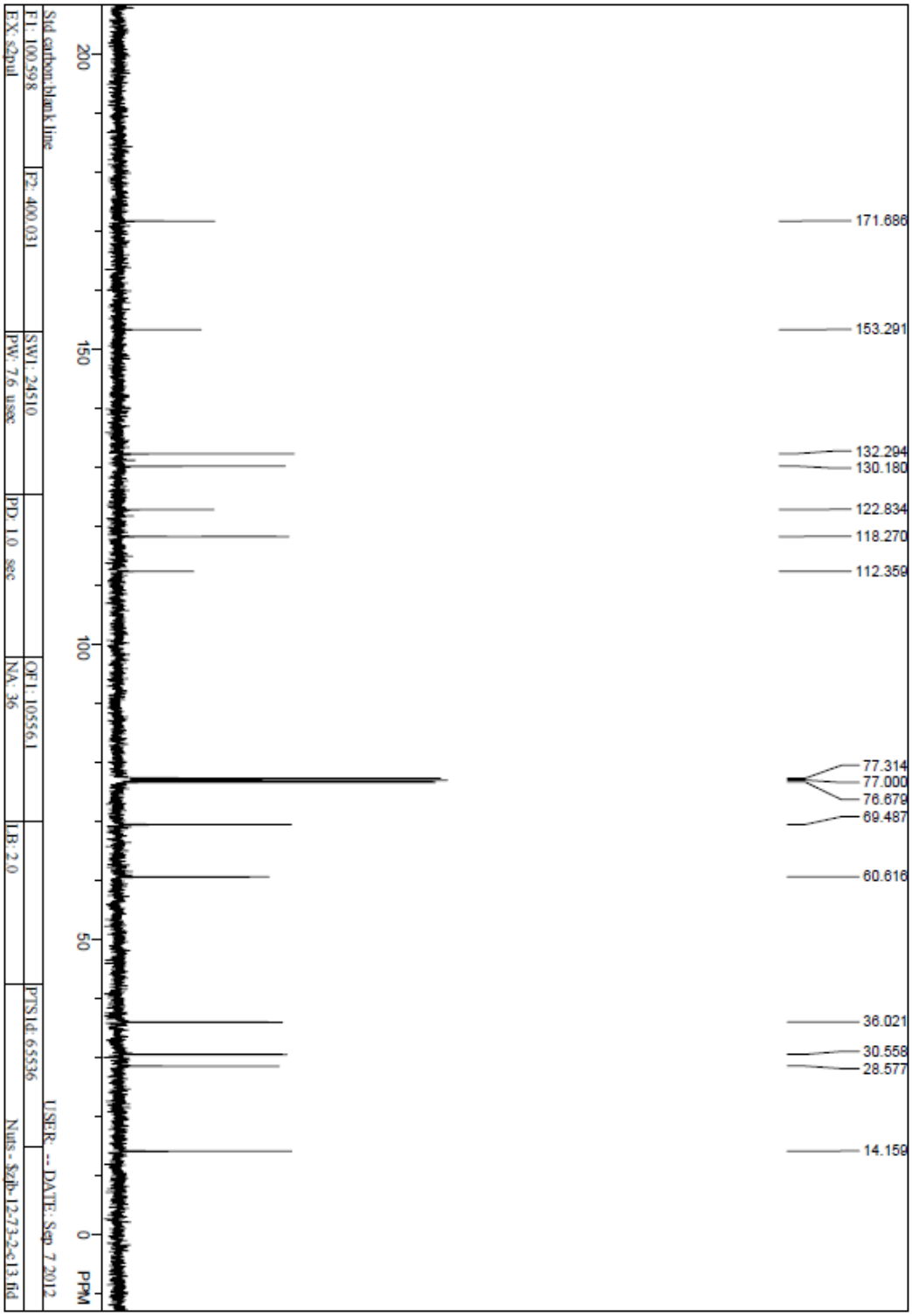
^{1}H NMR (400 M Hz in $CDCl_3$)

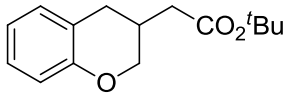




2l

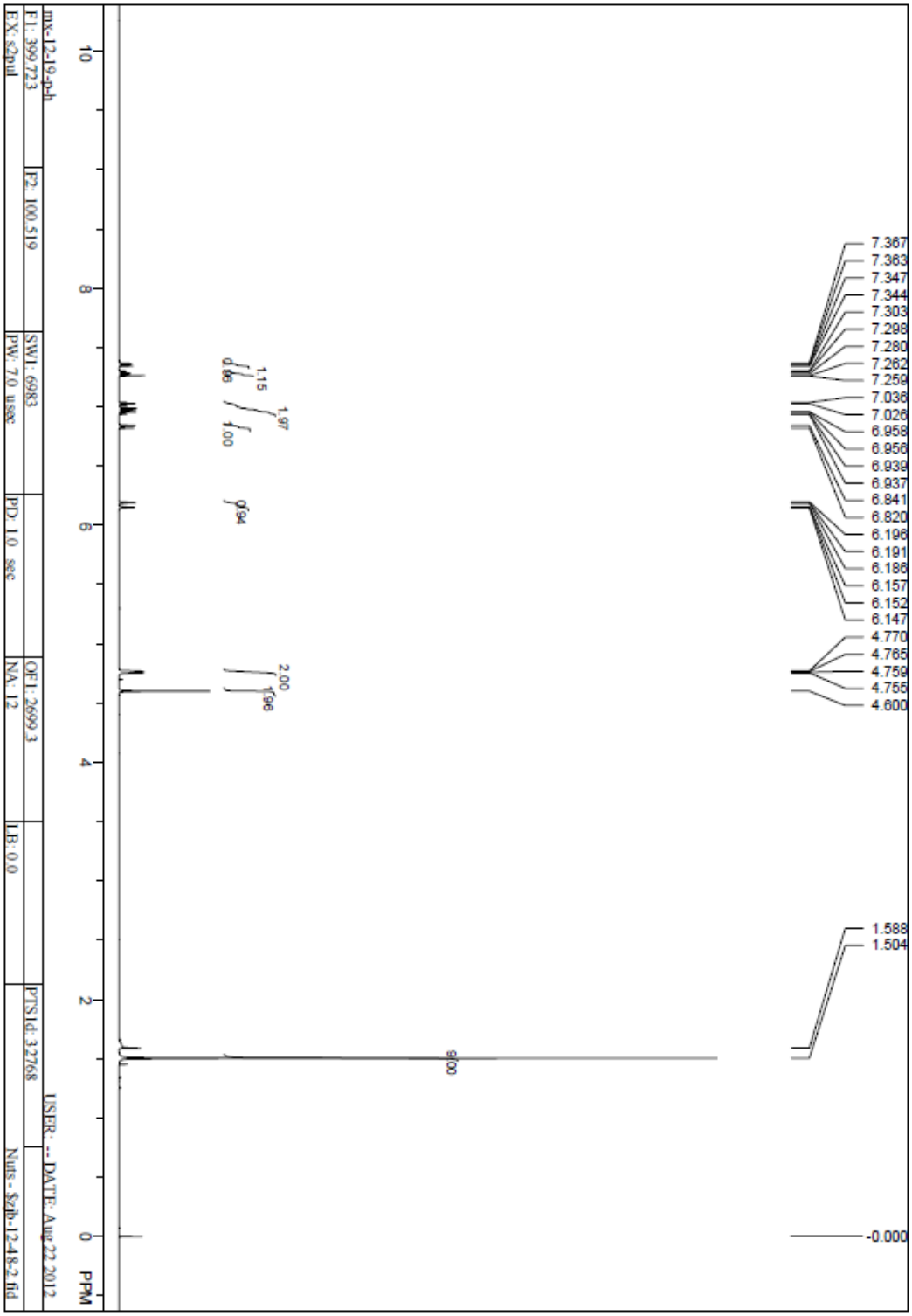
^{13}C NMR (100 M Hz in $CDCl_3$)

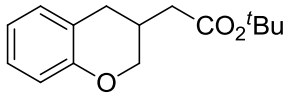




2m

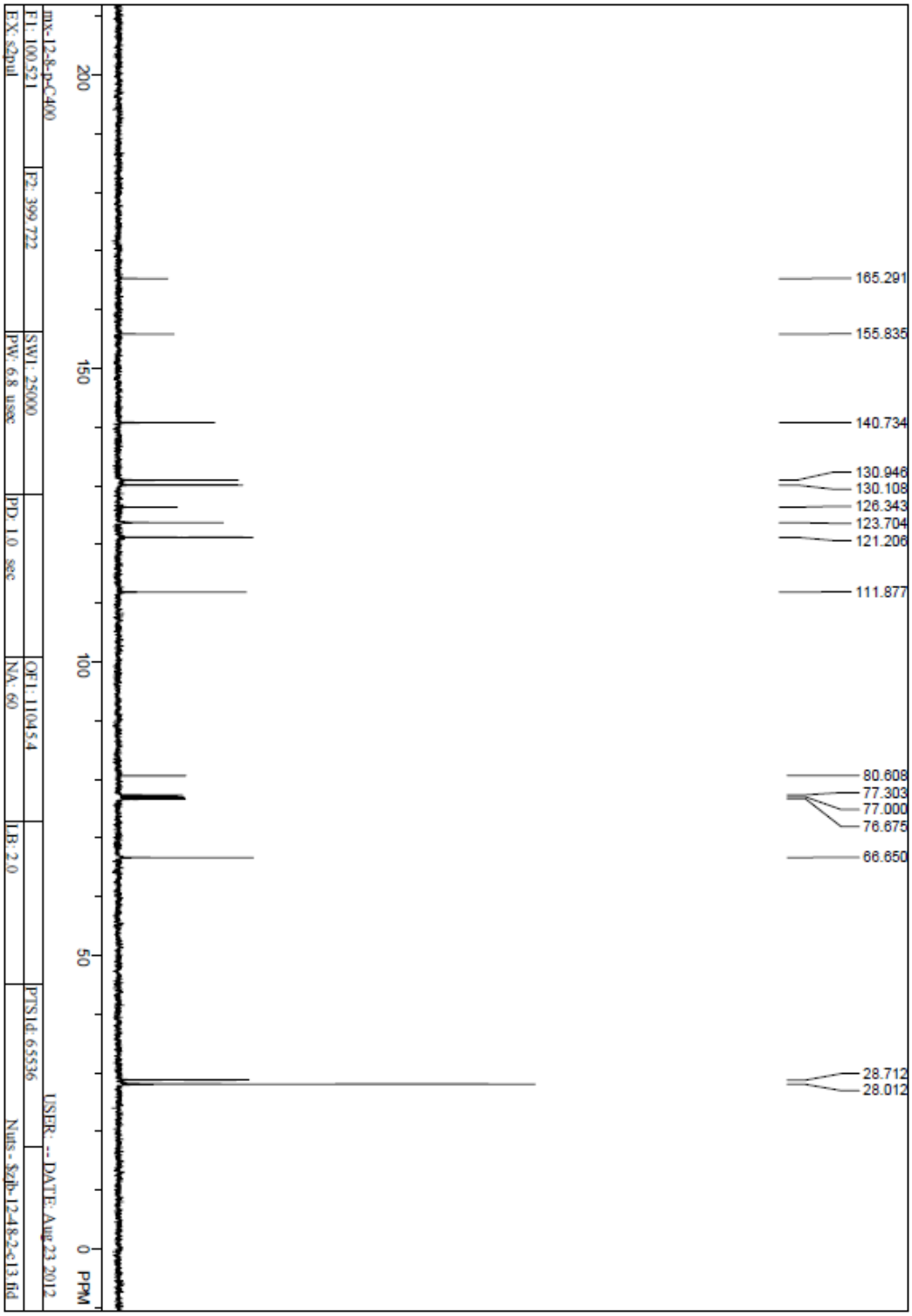
^{1}H NMR (400 M Hz in $CDCl_3$)

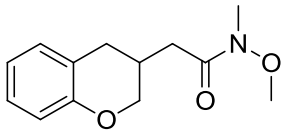




2m

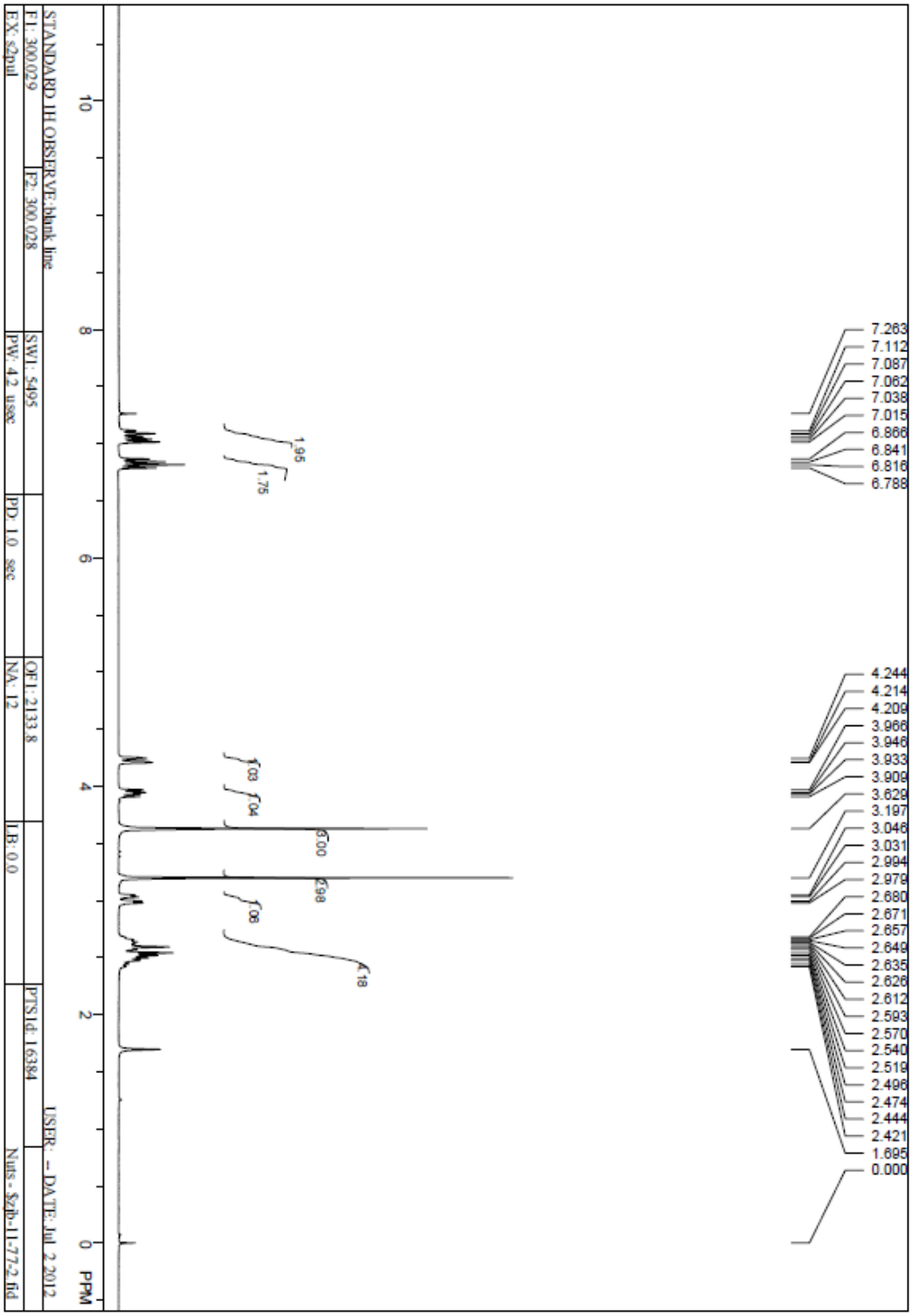
^{13}C NMR (100 M Hz in $CDCl_3$)

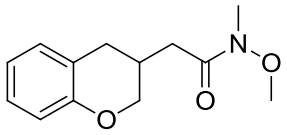




2n

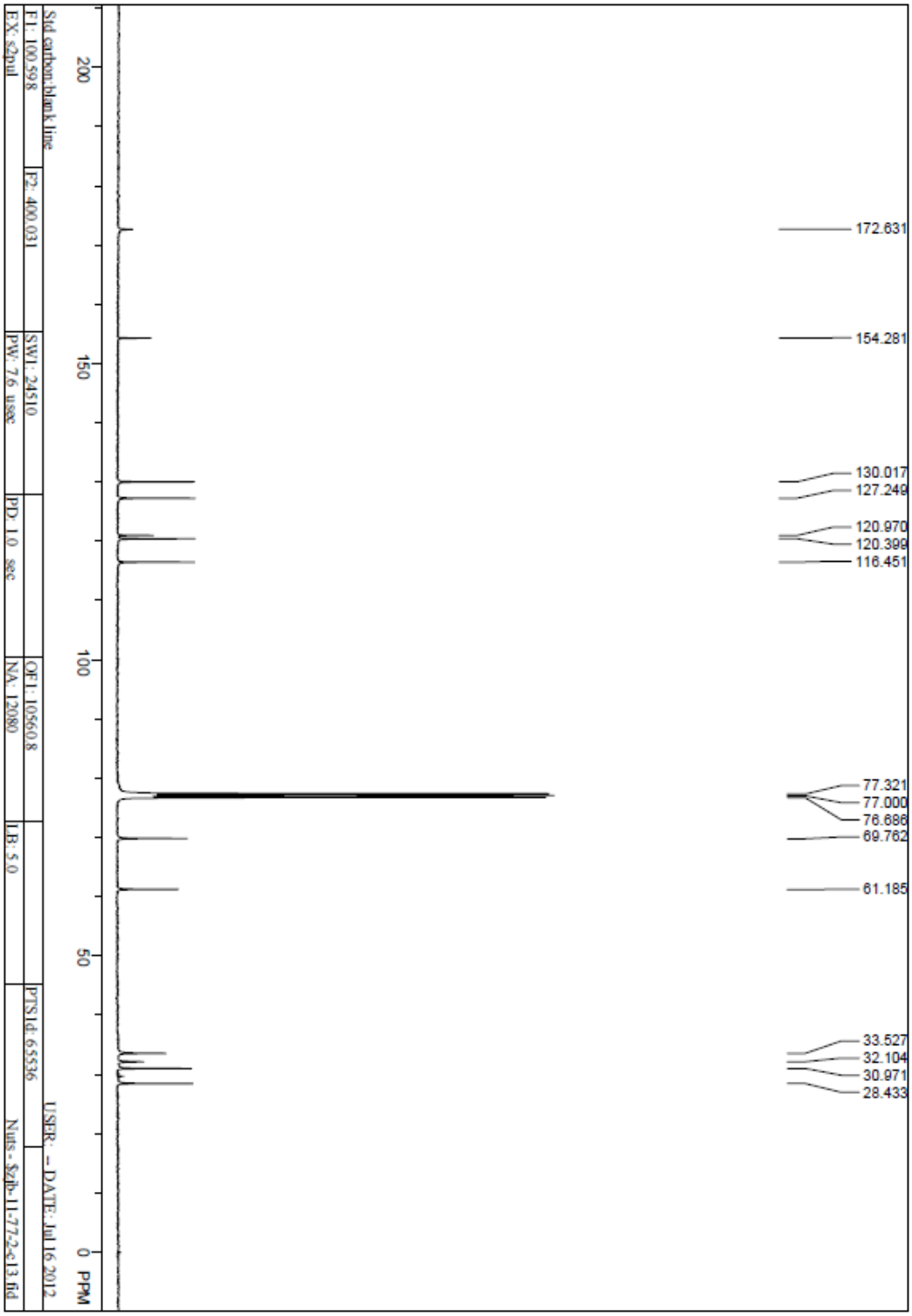
^{1}H NMR (300 M Hz in $CDCl_3$)

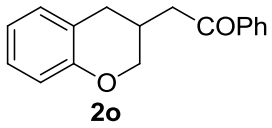




2n

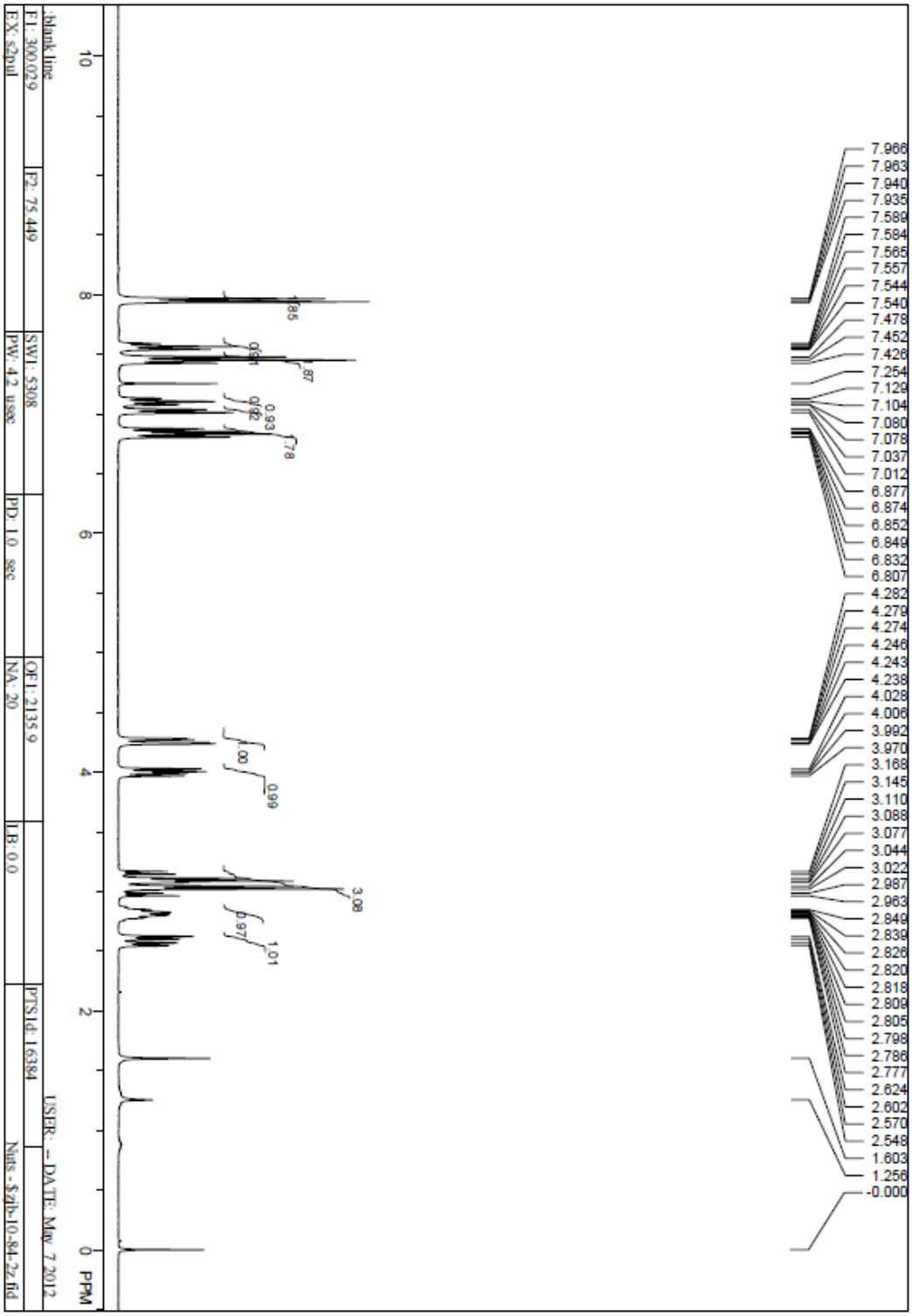
^{13}C NMR (100 M Hz in $CDCl_3$)

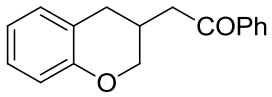




2o

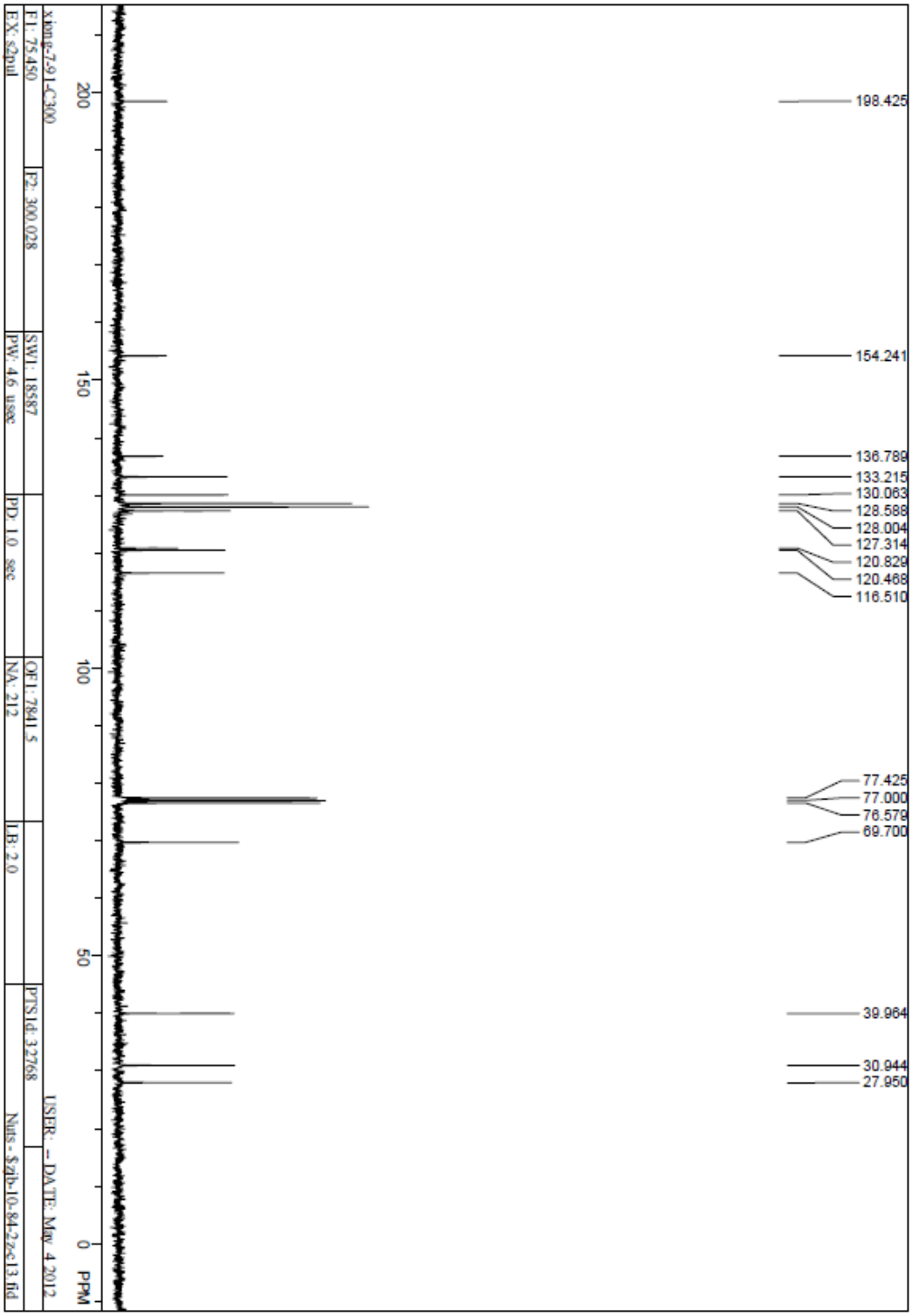
^{1}H NMR (300 M Hz in $CDCl_3$)

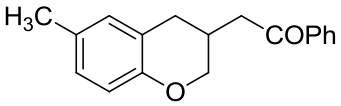




2o

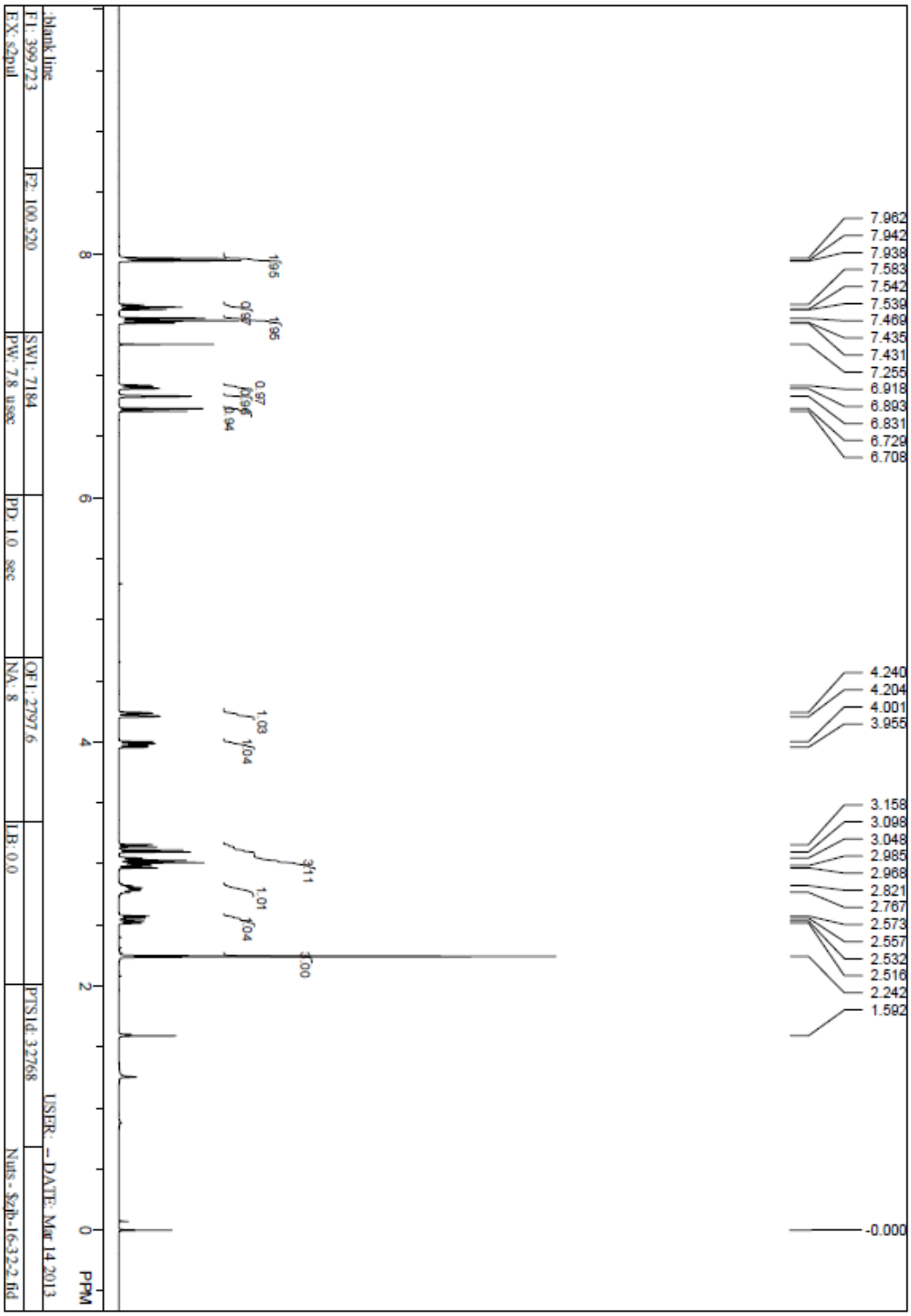
^{13}C NMR (75 M Hz in $CDCl_3$)

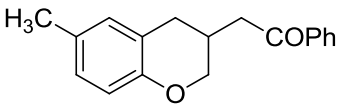




2p

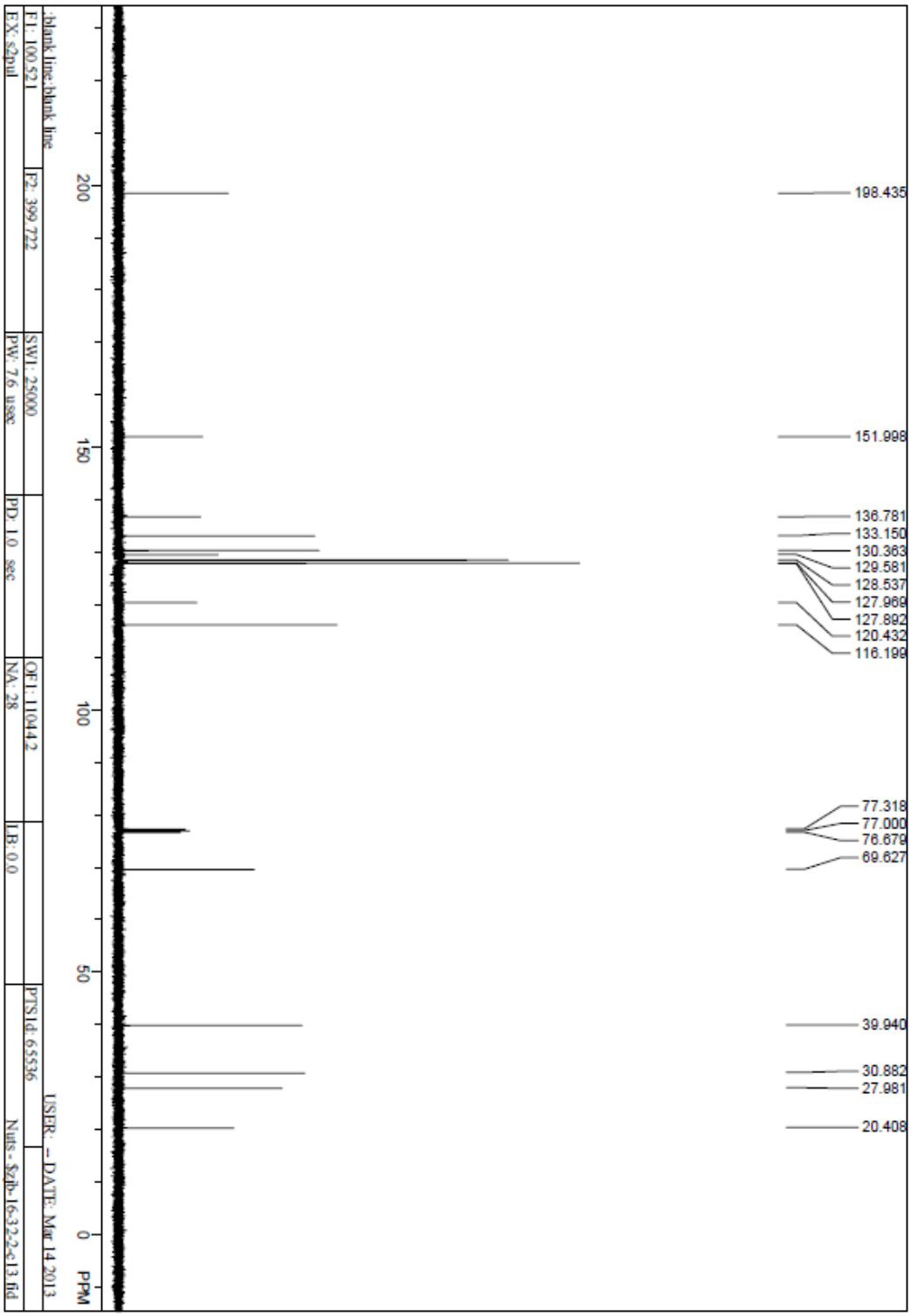
^{1}H NMR (400 M Hz in $CDCl_3$)

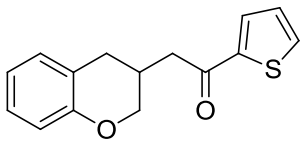




2p

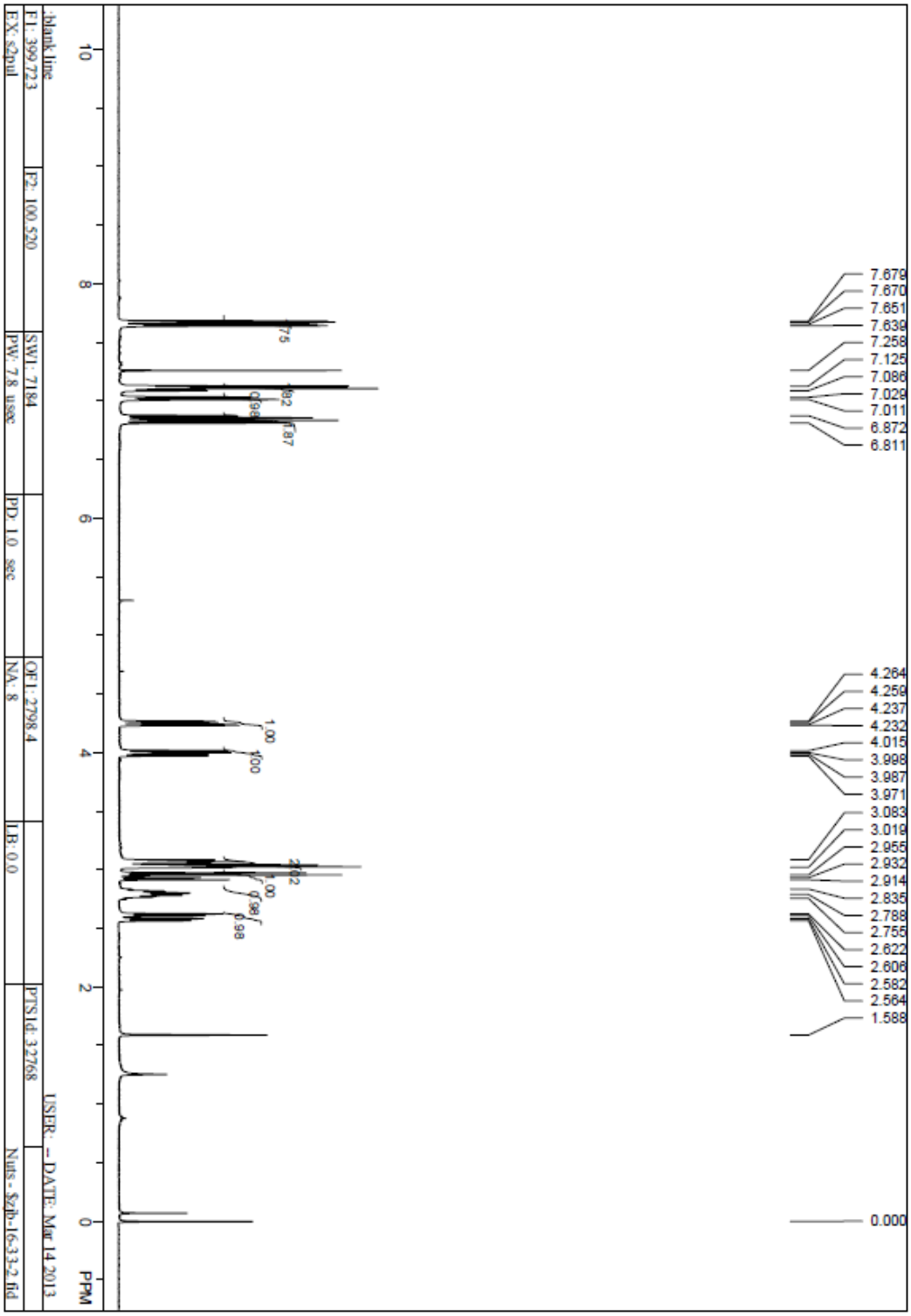
^{13}C NMR (100 M Hz in $CDCl_3$)

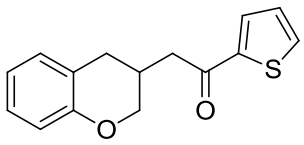




2q

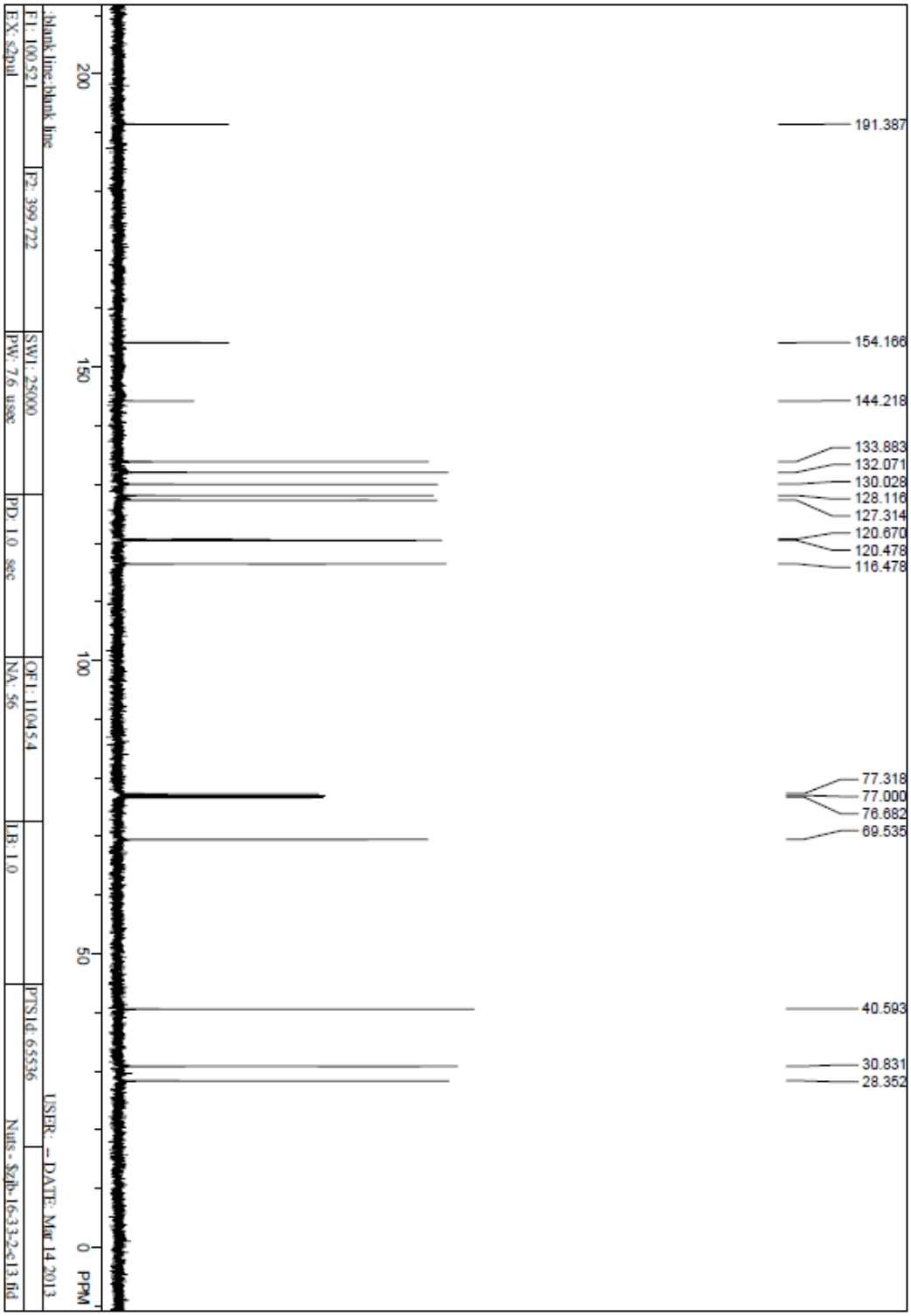
^{1}H NMR (400 M Hz in $CDCl_3$)

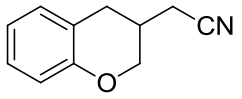




2q

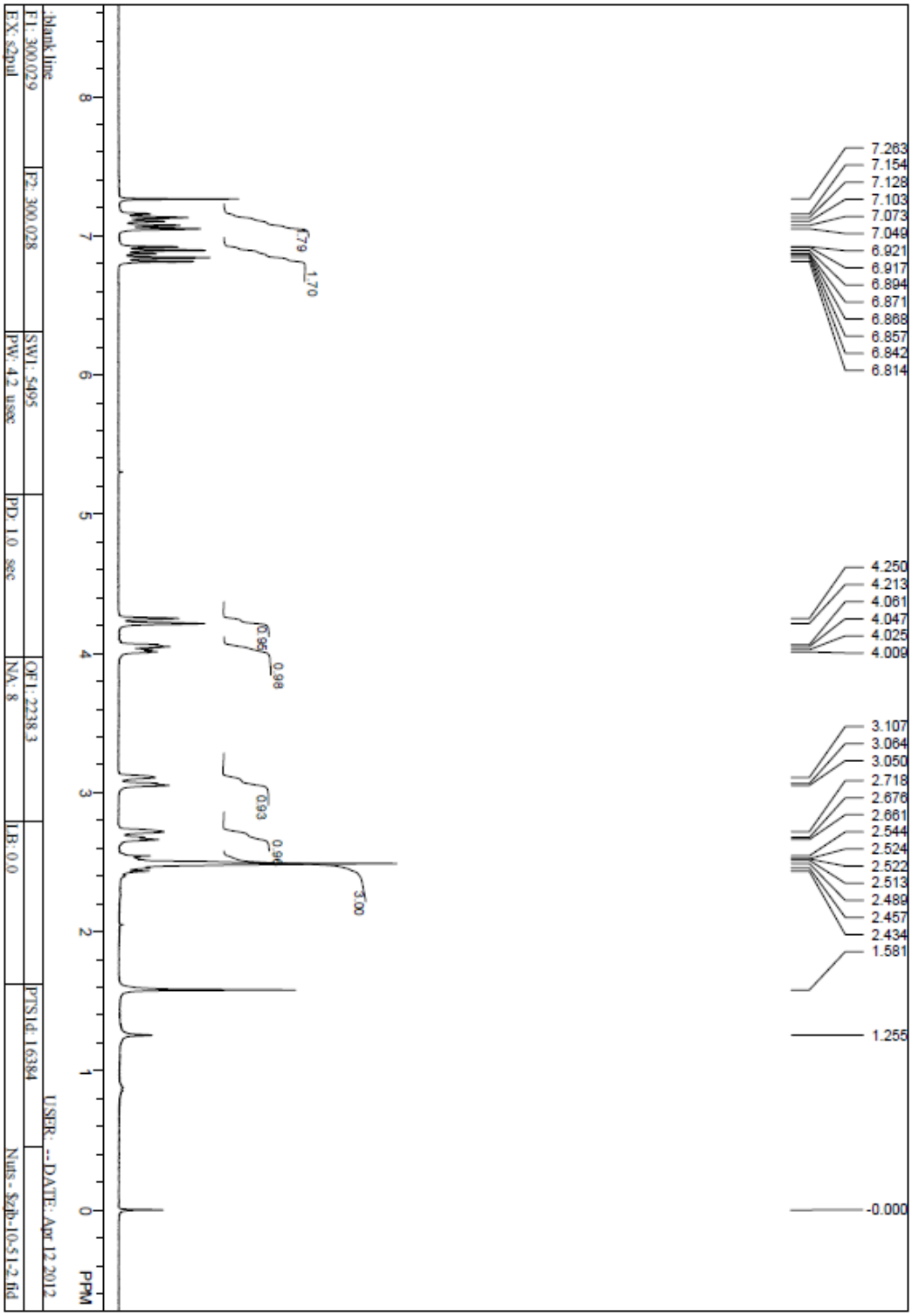
^{13}C NMR (100 M Hz in $CDCl_3$)

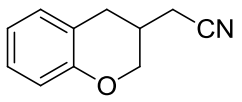




2r

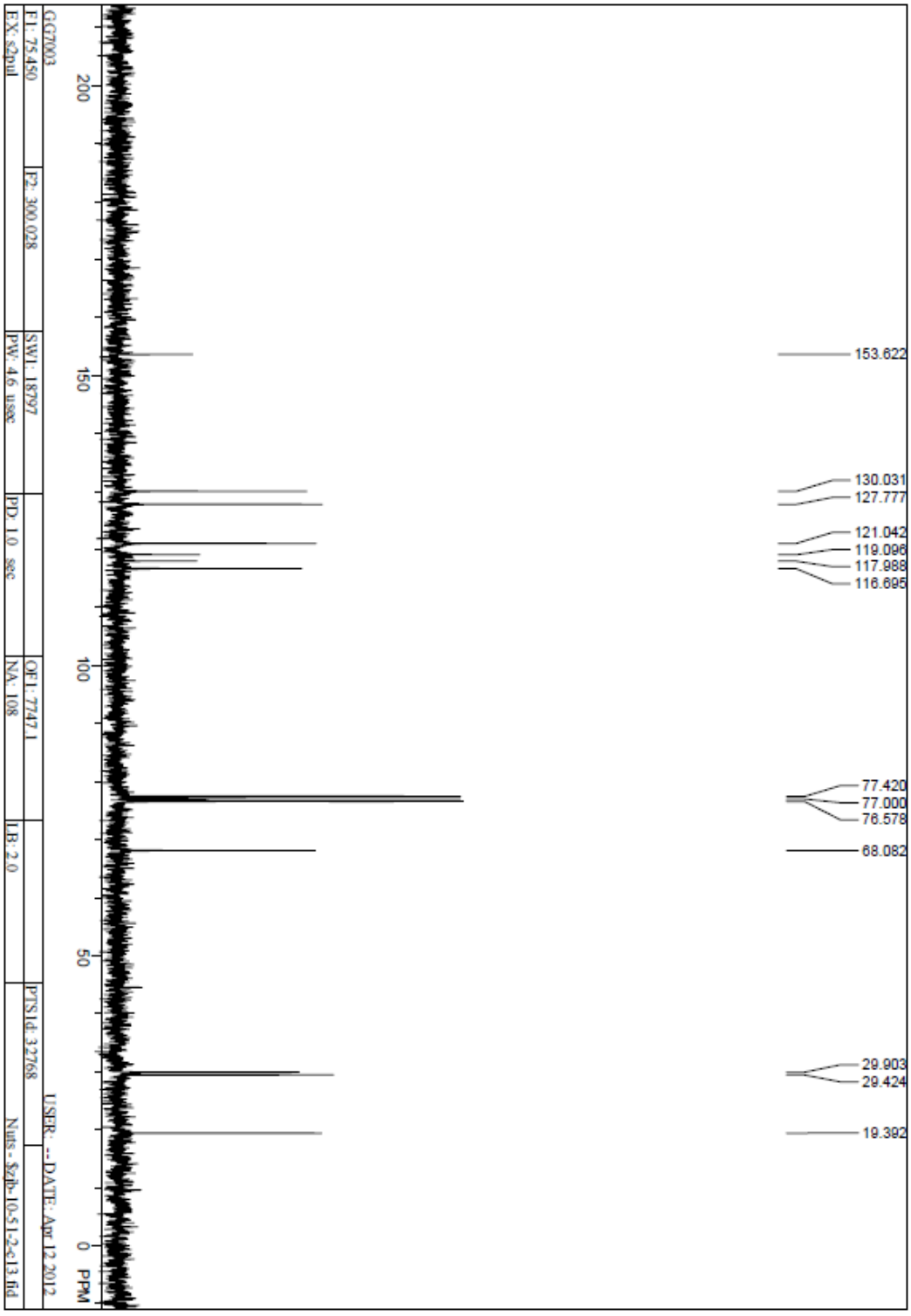
^{1}H NMR (300 M Hz in $CDCl_3$)

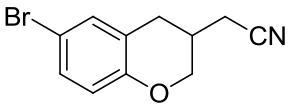




2r

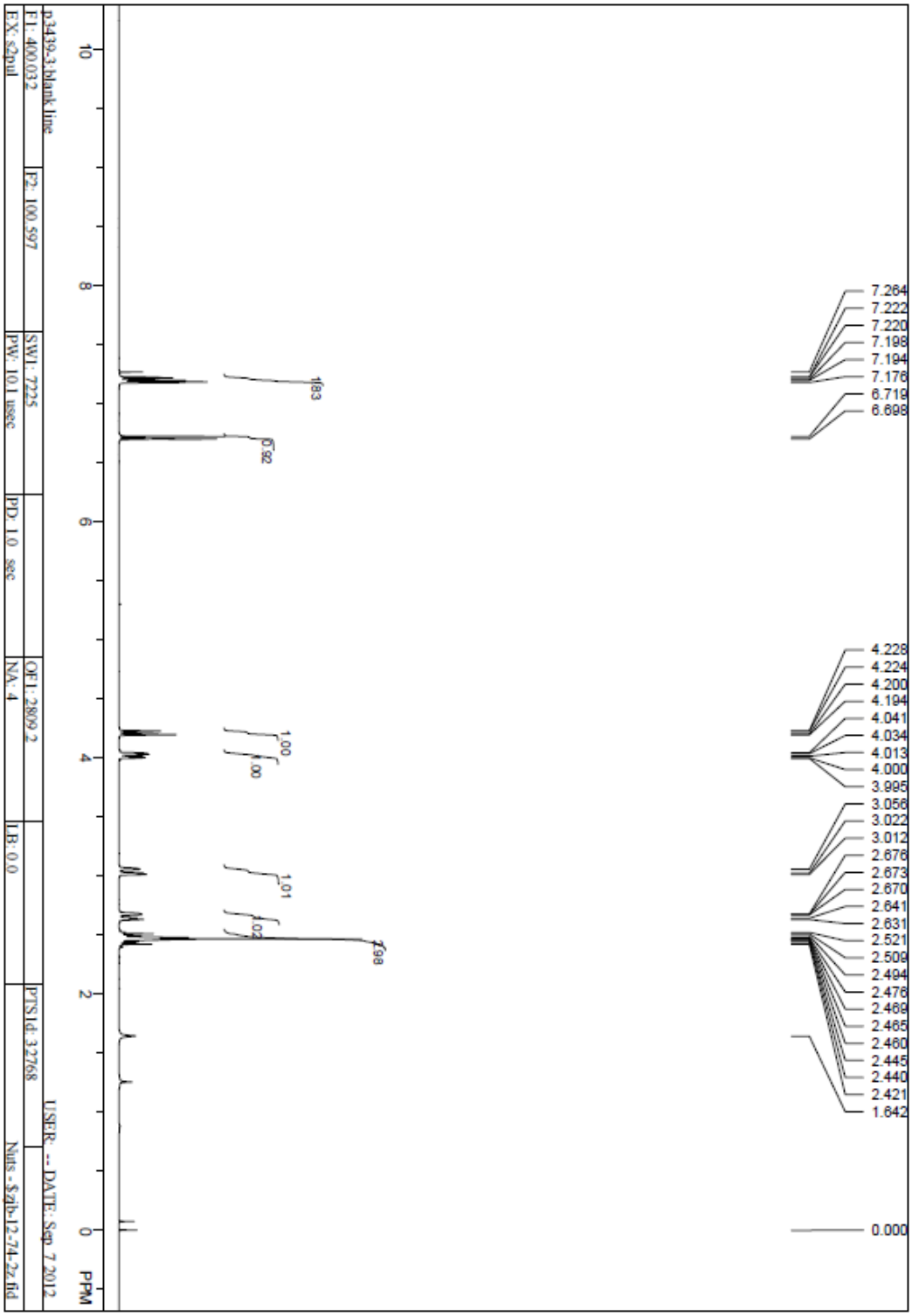
^{13}C NMR (75 M Hz in $CDCl_3$)

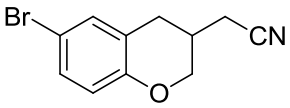




2s

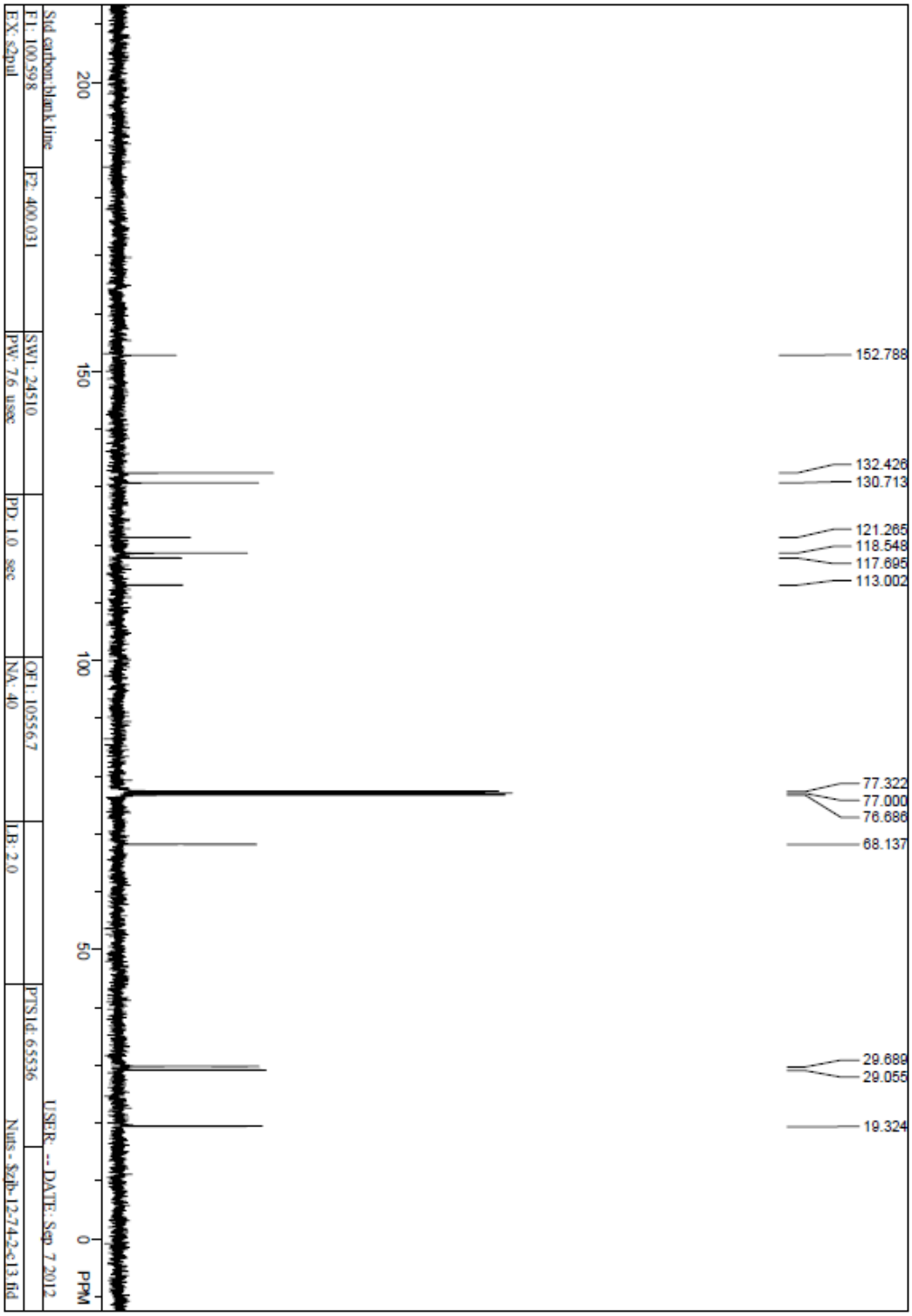
^{1}H NMR (400 M Hz in $CDCl_3$)

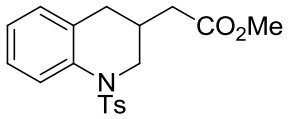




2s

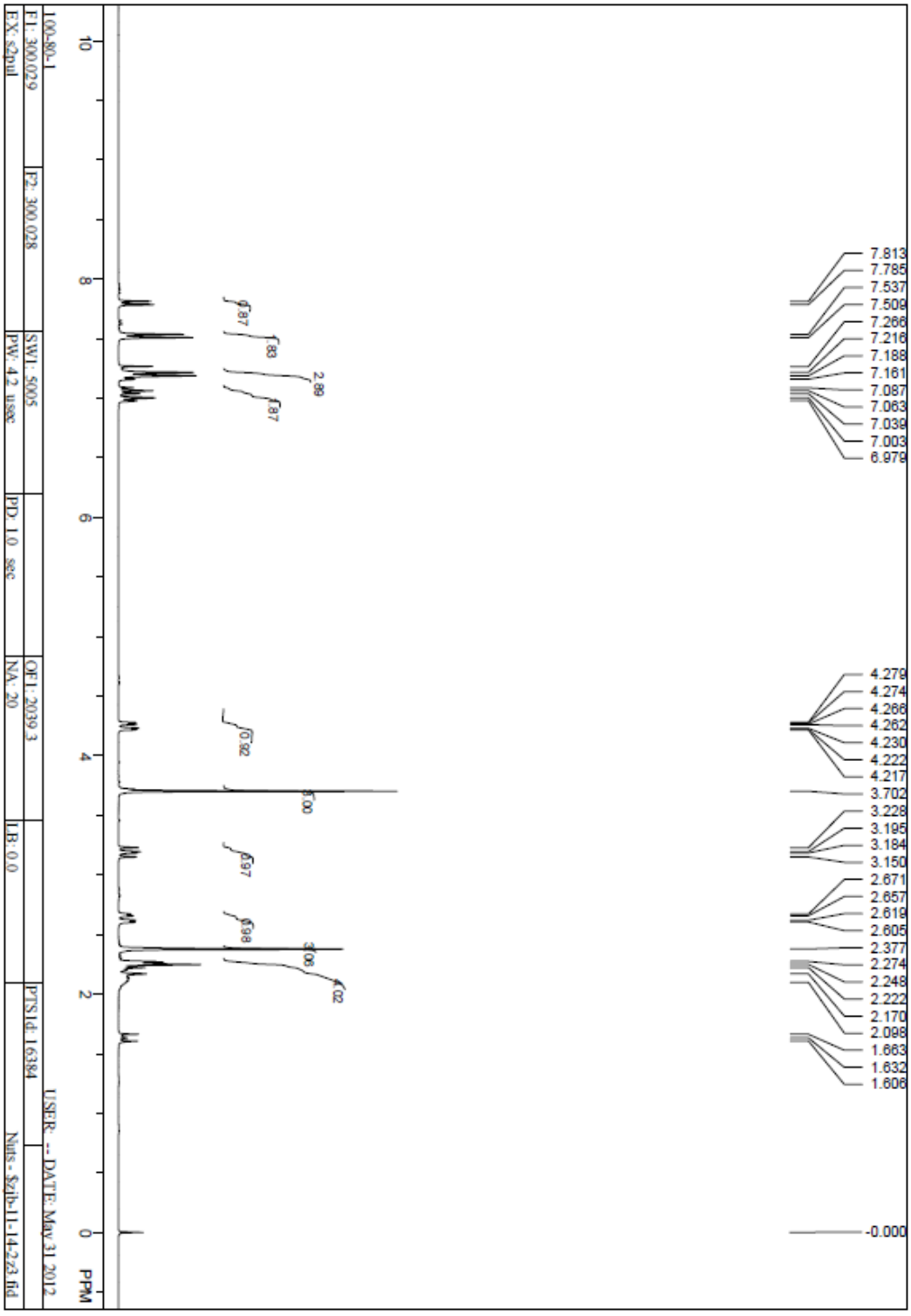
^{13}C NMR (100 M Hz in $CDCl_3$)

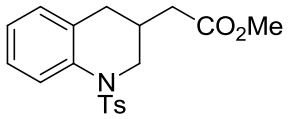




5a

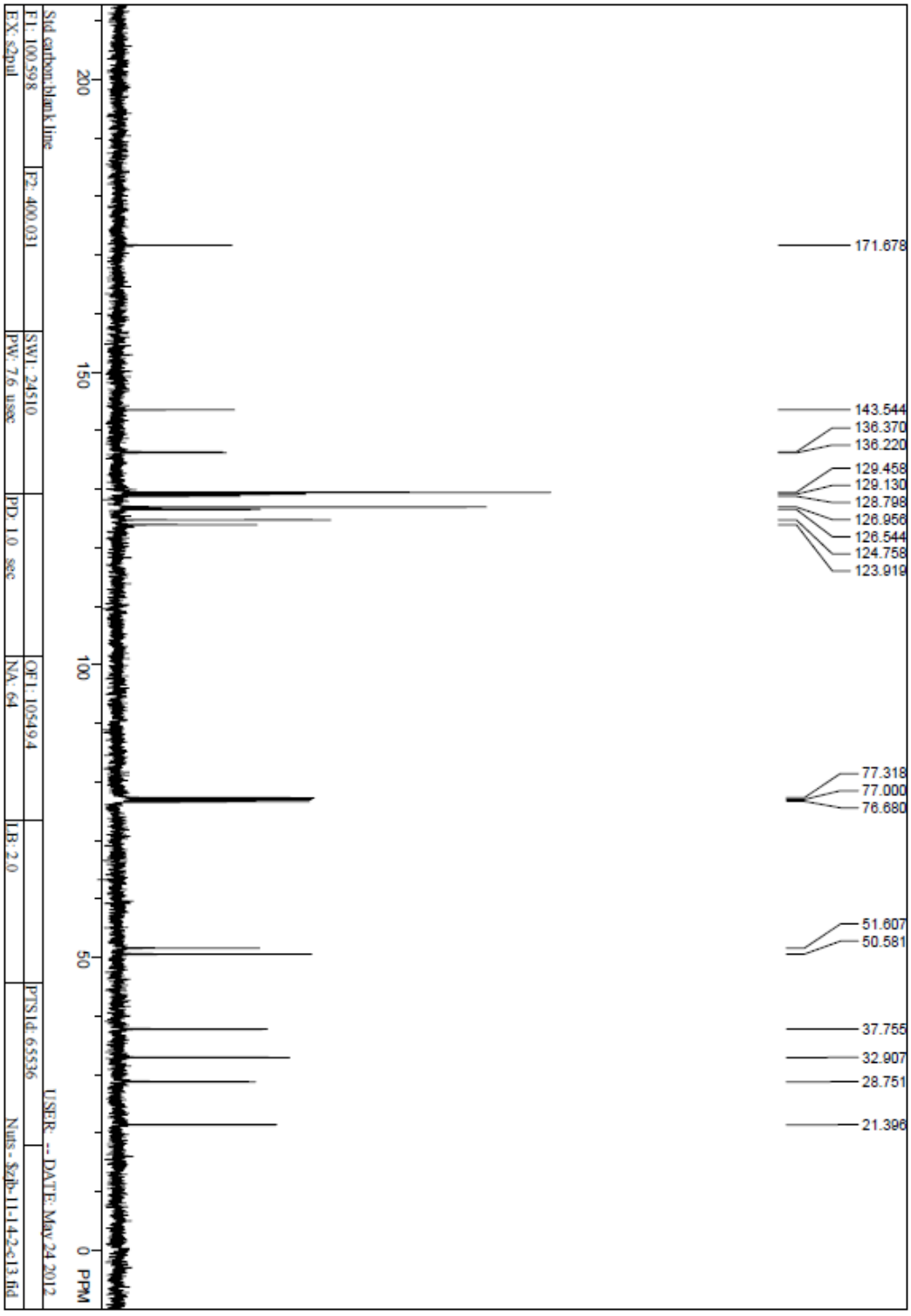
^{1}H NMR (300 M Hz in $CDCl_3$)

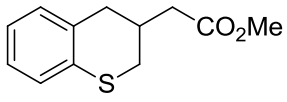




5a

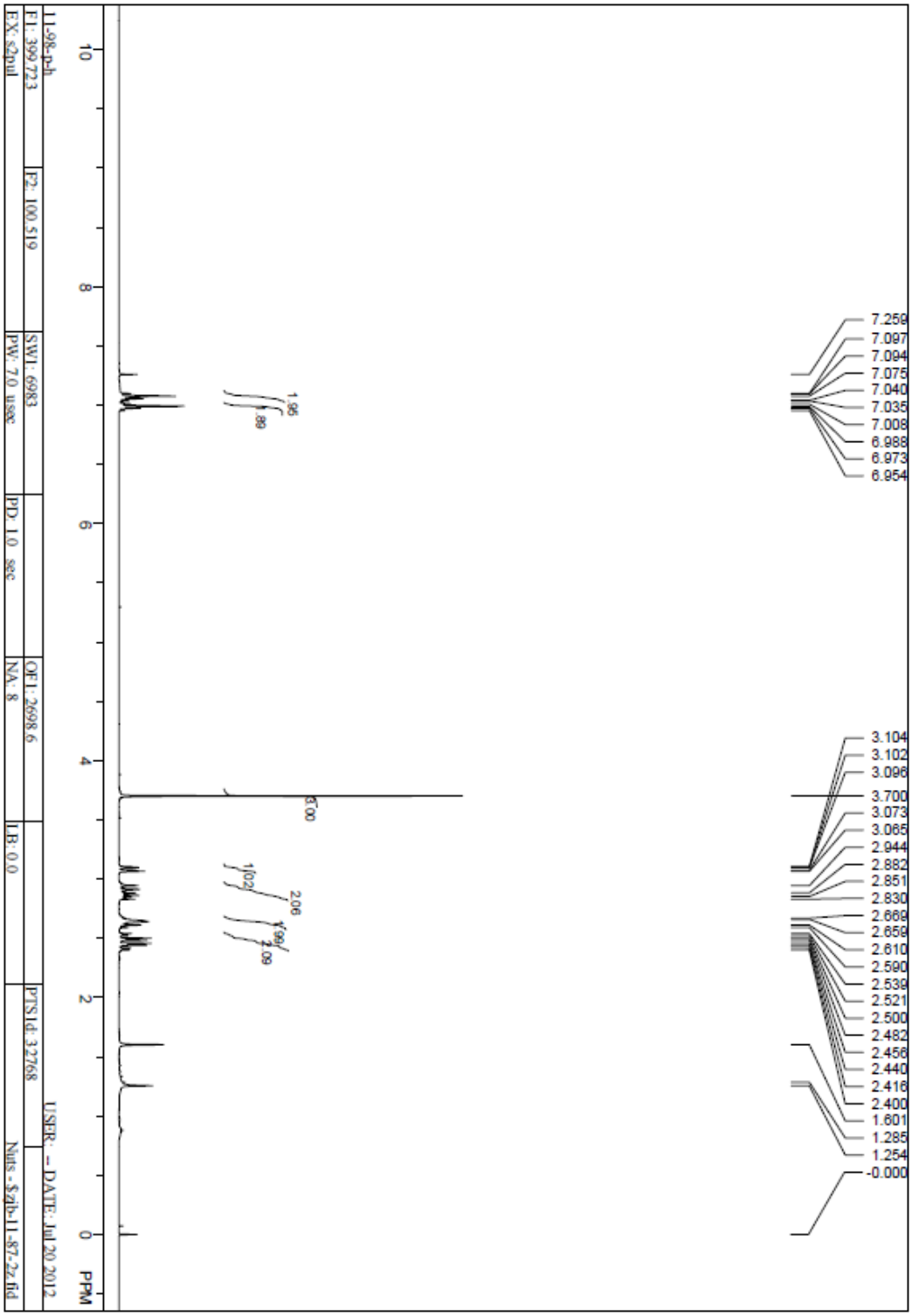
^{13}C NMR (100 M Hz in $CDCl_3$)

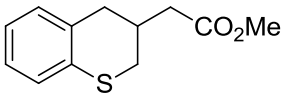




5b

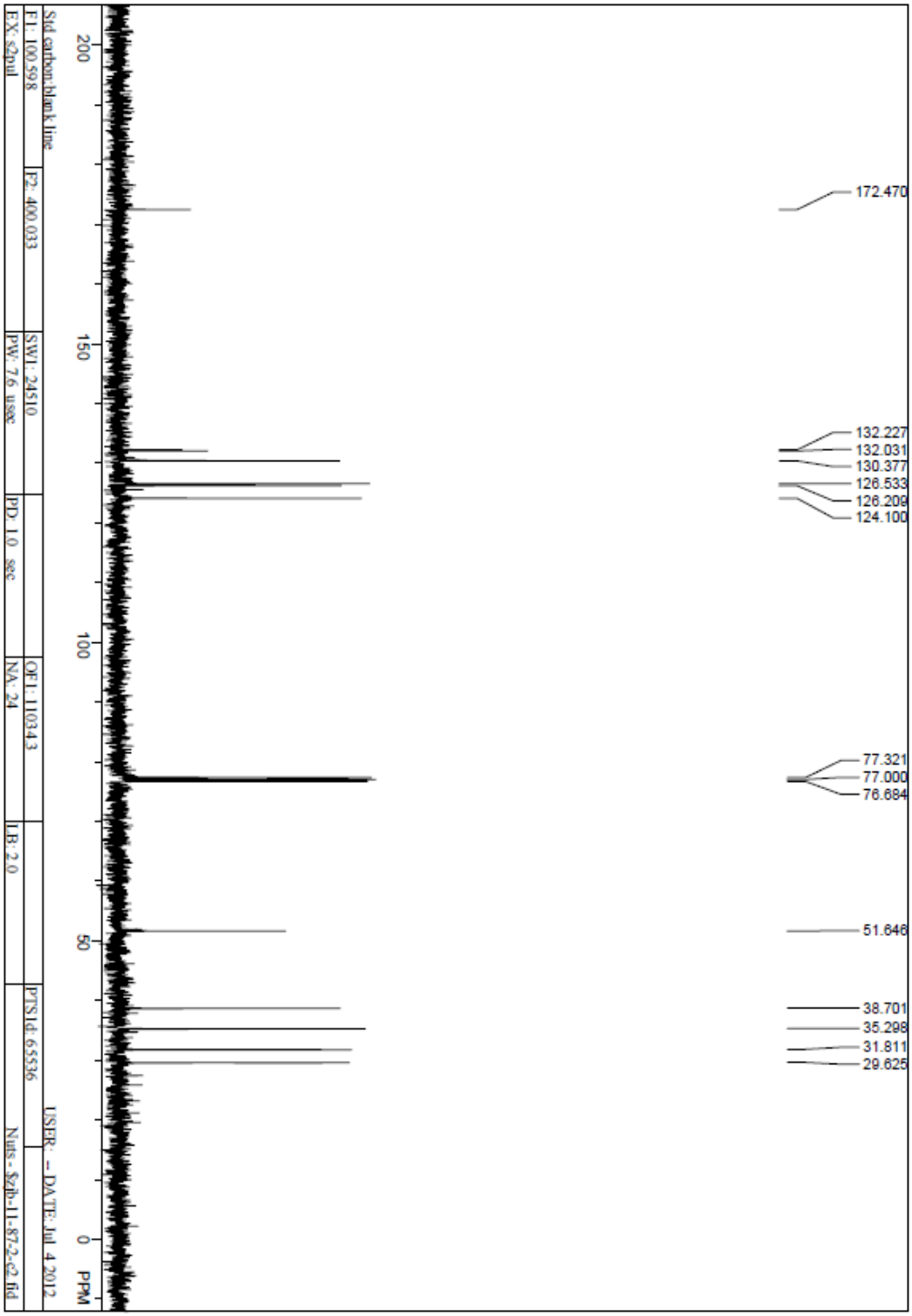
^{1}H NMR (400 M Hz in $CDCl_3$)

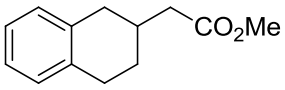




5b

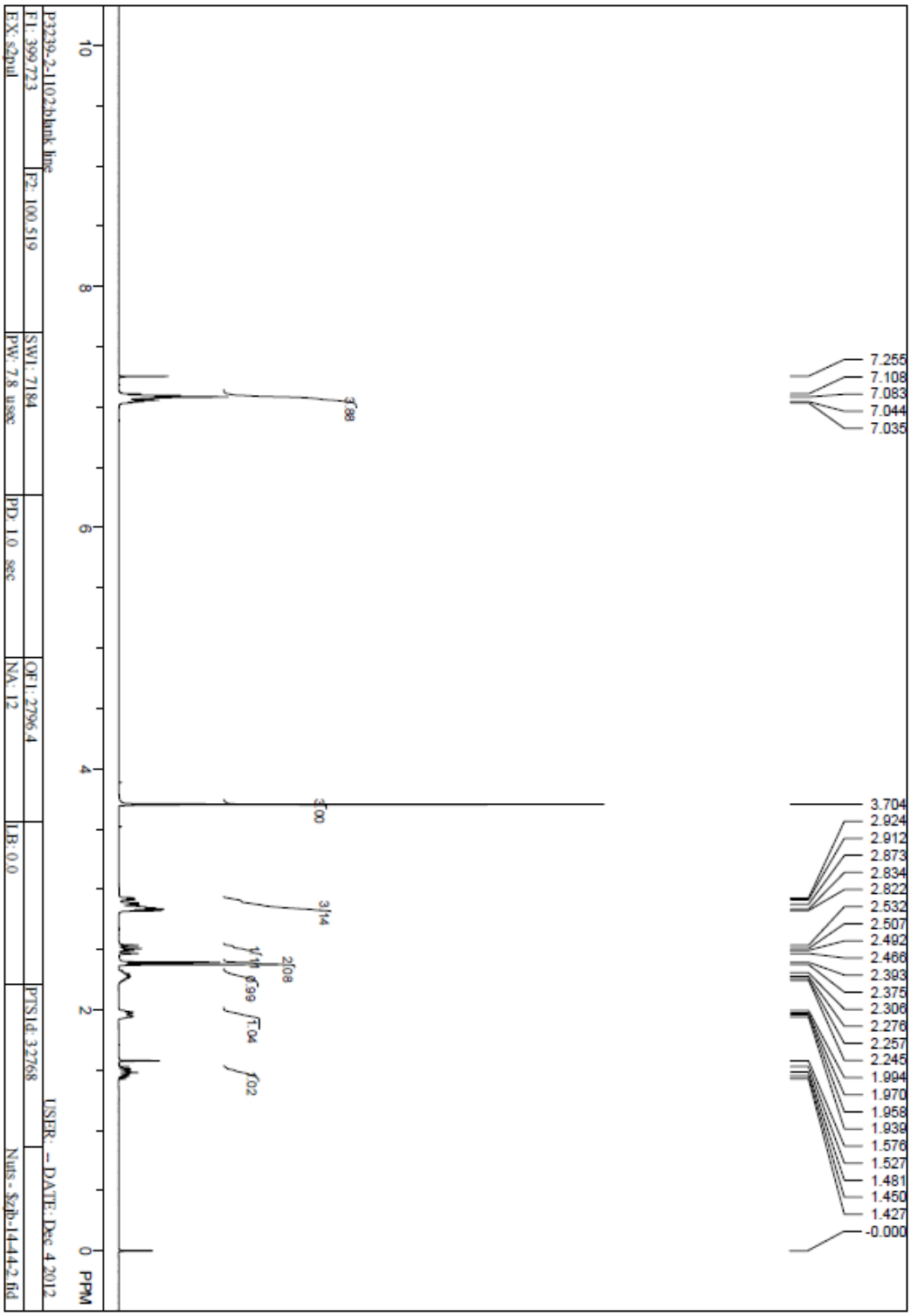
^{13}C NMR (100 M Hz in $CDCl_3$)

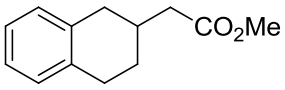




5c

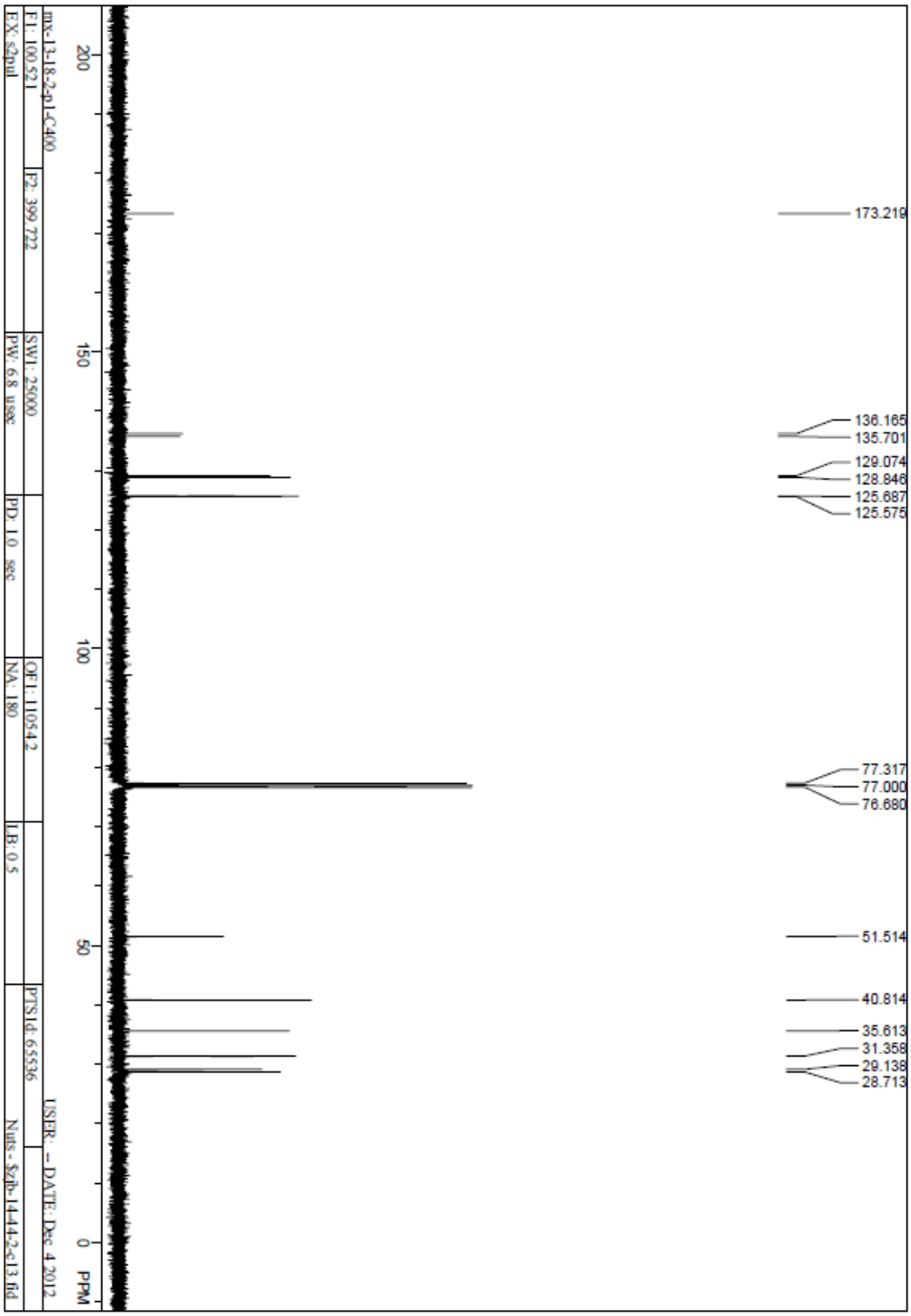
^{1}H NMR (400 M Hz in $CDCl_3$)

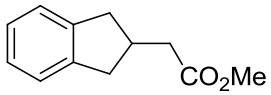




5c

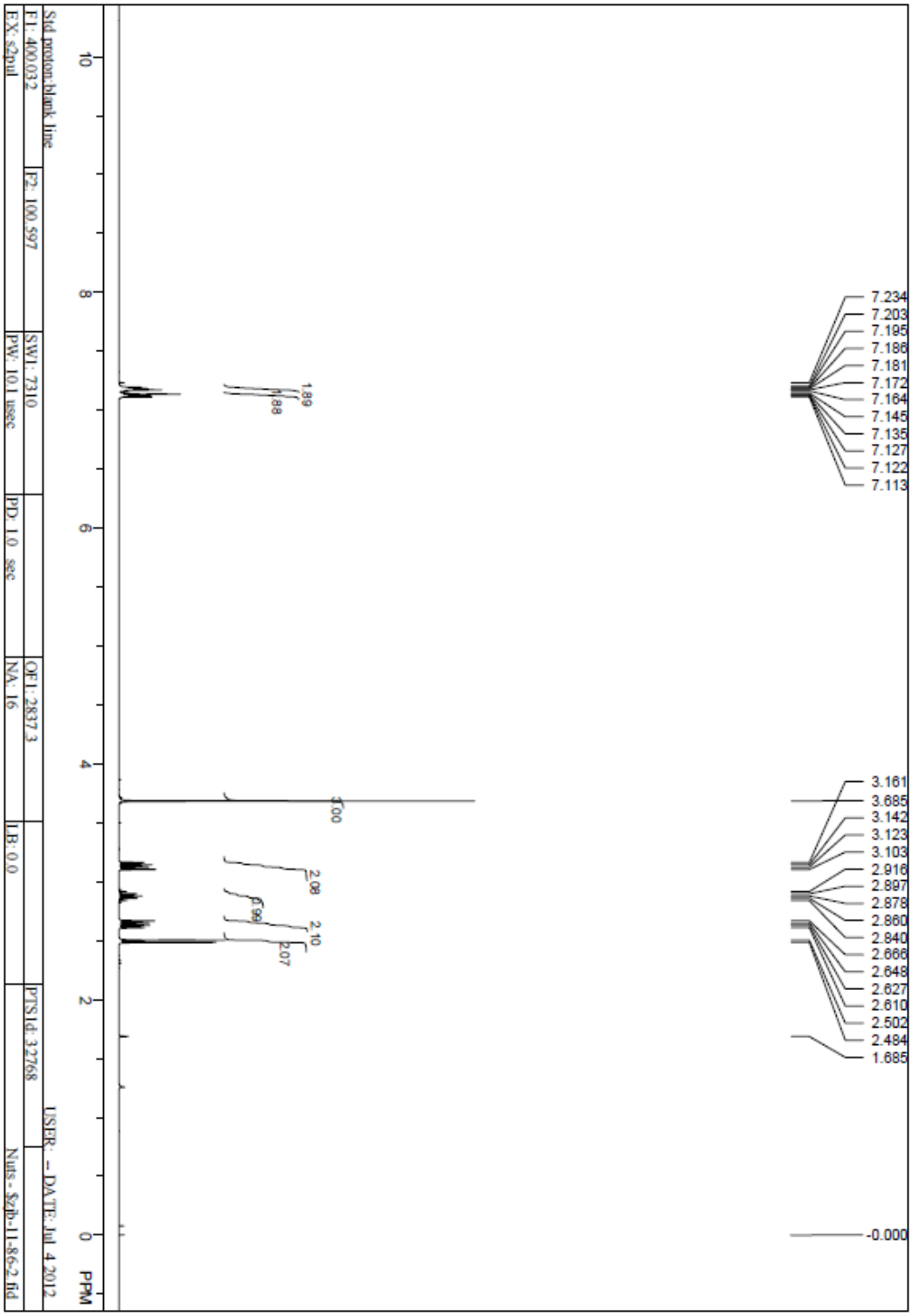
^{13}C NMR (100 M Hz in $CDCl_3$)

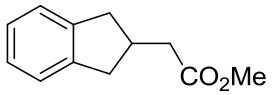




5d

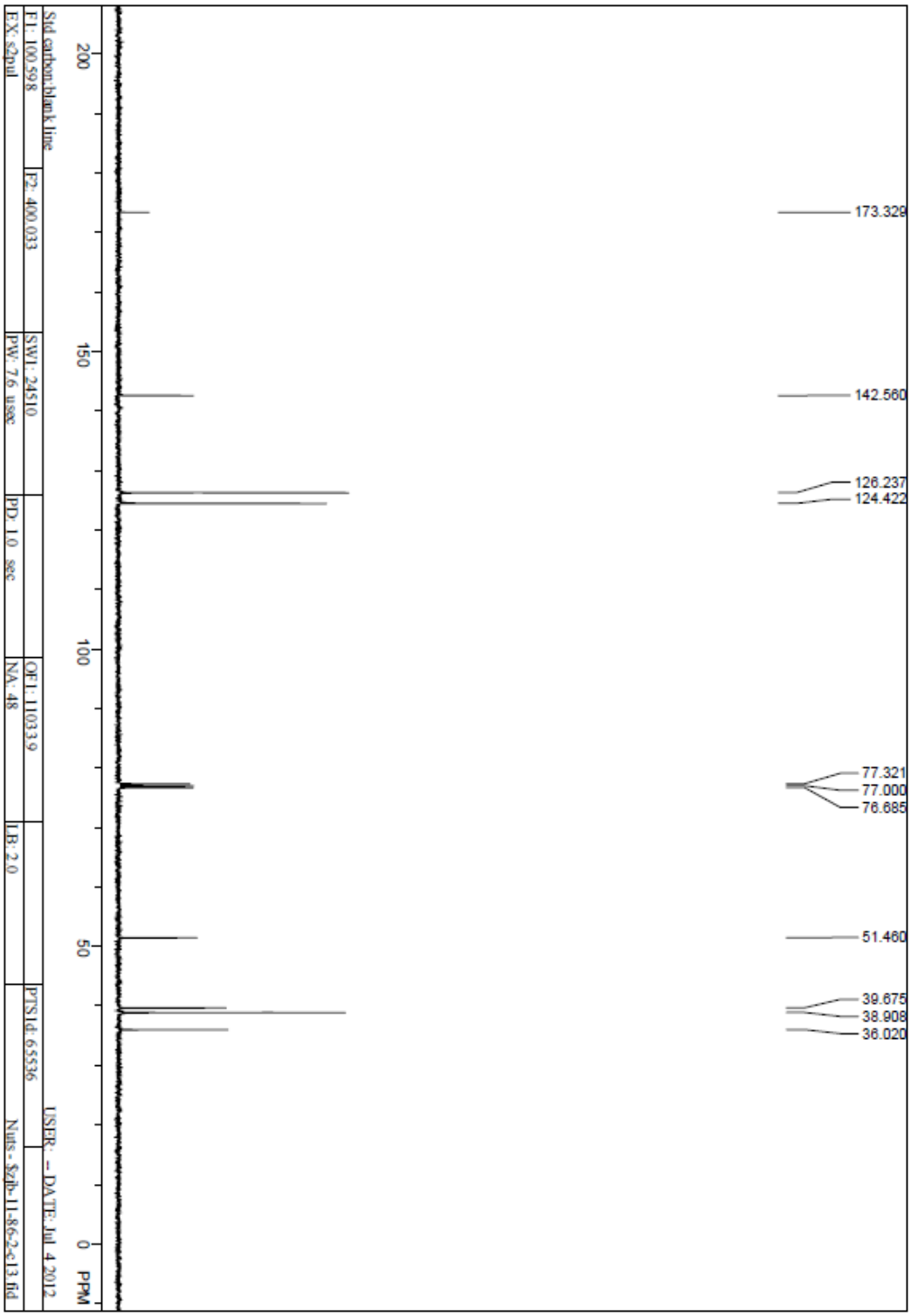
^{1}H NMR (400 M Hz in $CDCl_3$)

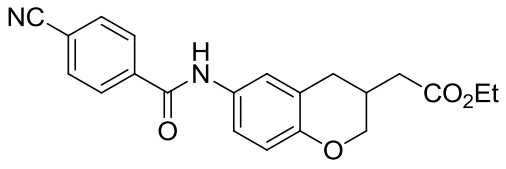




5d

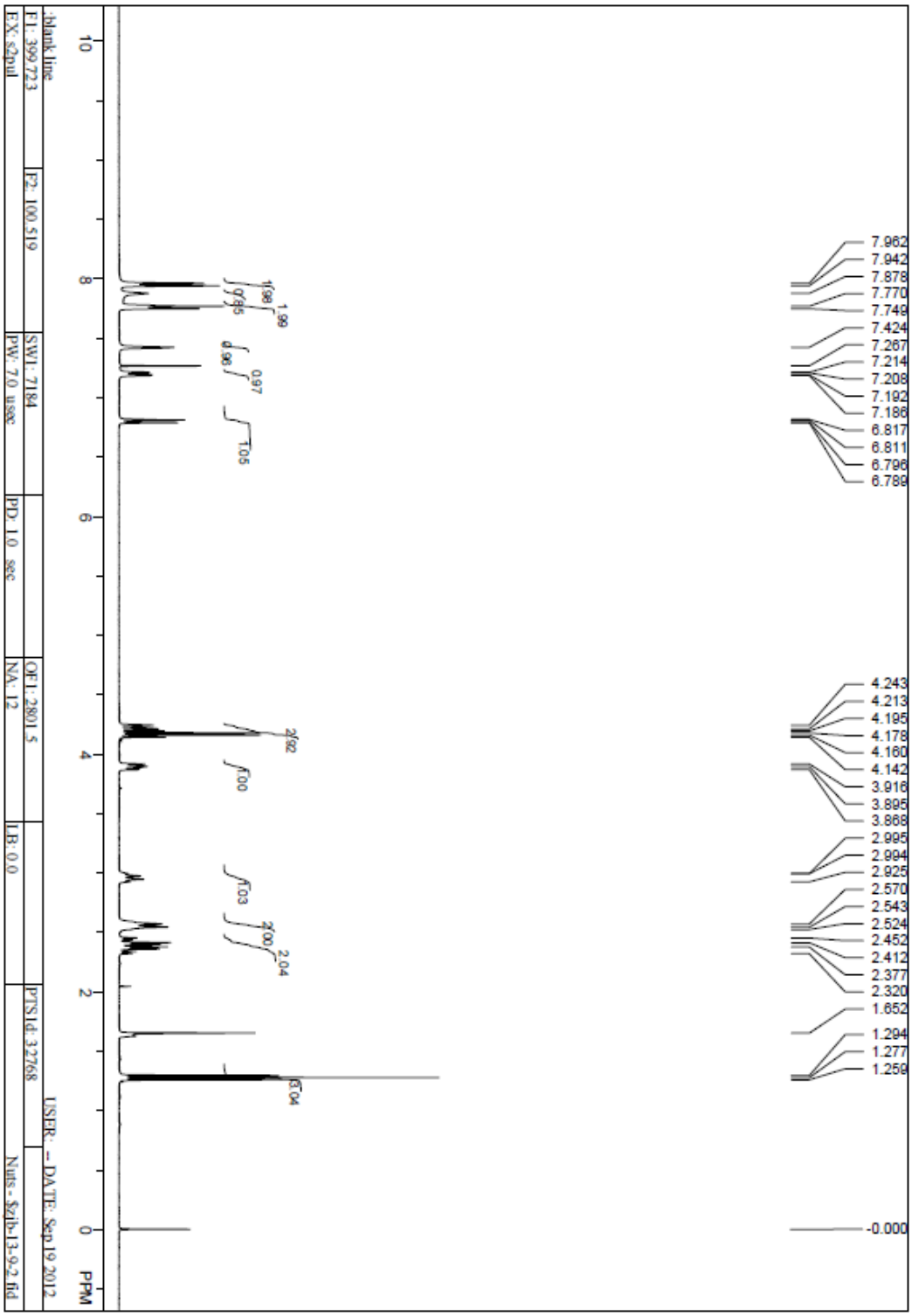
^{13}C NMR (100 M Hz in $CDCl_3$)

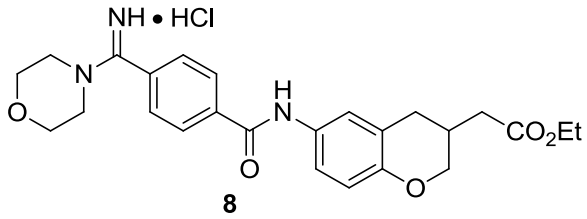




11

^{1}H NMR (400 M Hz in $CDCl_3$)





8

^{1}H NMR (400 M Hz in DMSO-*d*6)