Supporting Information

Indole Synthesis by Palladium-Catalyzed Tandem Allylic Isomerization – Furan Diels-Alder Reaction

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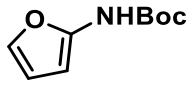
Contents

General Experimental Protocols

All reactions were performed under an N_2 or argon atmosphere and all glassware was dried in an oven at 140 °C for 2 h prior to use. Reactions carried out at -78 °C employed a CO_2/acetone bath. THF was distilled over sodium/benzophenone ketyl, and CH_2Cl_2 was purified using an alumina column filtration system. DMF was dried over 4 Å molecule sieves. Pyridine and Et_3N were dried from KOH. Reactions were monitored by TLC analysis (pre-coated silica gel 60 F_{254} plates) and spots were visualized by UV or with a PMA solution (5 g of phosphomolybdic acid in 100 mL of 95% EtOH), *p*-anisaldehyde solution (2.5 mL of *p*-anisaldehyde, 2 mL of AcOH, and 3.5 mL of conc. H_2SO_4 in 100 mL of 95% EtOH), Vaughn's reagent (4.8 g of $(NH_4)_6Mo_7O_{24}$•4 H_2O and 0.2 g of $Ce(SO_4)_2$ in 100 mL of a 3.5 N H_2SO_4 solution) or a $KMnO_4$ solution (1.5 g of $KMnO_4$ and 1.5 g of K_2CO_3 in 100 mL of a 0.1% NaOH solution). Purifications by chromatography were performed using SiO_2 or an ISCO-Companion flash chromatography system. $^1H/^{13}C$ NMR spectra were recorded on Bruker Avance 300/75 MHz, Bruker Avance 400/100 MHz or Bruker Avance 500/125 MHz instrument. Chemical shifts were reported in parts per million with the residual solvent peak used as the internal standard. Chemical shifts were tabulated as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, q = quarter, dd = doublet of doublet, dt = doublet of triplet, m = multiplet, br = broad, app = apparent), coupling constants, and integration. Mass spectra were obtained on a Micromass Autospec double focusing instrument. IR spectra were obtained on an Identify IR-ATR spectrometer. Microwave reactions were performed using a Biotage Initiator in glass microwave vials (cap sealed) with continuous magnetic stirring and an external surface temperature sensor. LCMS analyses were completed on a Waters MicroMass ZQ with 2525 Binary Gradient Module, 2420 ELSD, 2996 PDA using MeCN/H_2O with 0.1% TFA. Melting points (uncorrected) were determined using a Mel-Temp instrument.

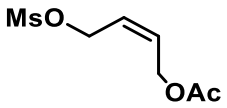
Synthetic Procedures and Spectral Characterization

Preparations of Allylic Acetates



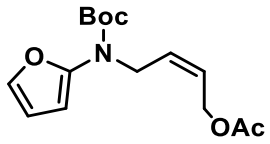
12

***tert*-Butyl furan-2-ylcarbamate (12).**[1] To a stirred solution of 2-furoyl chloride (805 mg, 6.17 mmol) in *t*-BuOH (4.0 mL) was added sodium azide (457 mg, 7.03 mmol) in one portion. The reaction mixture was stirred at rt for 24 h, and then at reflux (ca. 85 °C) for 16 h. The solvent was removed under reduced pressure. The residue was purified by chromatography on SiO_2 (Hexanes : EA = 9 : 1) to give **12** (751 mg, 67%) as a white solid: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.06 (dd, 1 H, *J* = 1.2, 2.0 Hz), 6.58 (br, 1 H), 6.34 (dd, 1 H, *J* = 2.0, 3.2 Hz), 6.04 (br, 1 H), 1.50 (s, 9 H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 151.8, 145.4, 136.1, 111.3, 95.2, 81.3, 28.1.



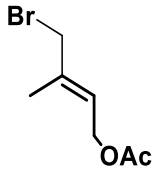
14

(*Z*)-4-((Methylsulfonyl)oxy)but-2-en-1-yl acetate (14). To a cooled (0 °C) solution of (*Z*)-4-hydroxybut-2-en-1-yl acetate[2] (278 mg, 2.14 mmol) and triethylamine (0.90 mL, 6.4 mmol) in anhydrous CH_2Cl_2 (5.0 mL) was added methanesulfonyl chloride (0.21 mL, 2.7 mmol). The reaction mixture was stirred at 0 °C for 45 min, quenched with water (5.0 mL) at 0 °C, extracted with CH_2Cl_2, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The residue was purified by chromatography on SiO_2 (Hexanes : EA = 1 : 1) to give **14** (247 mg, 55%) as a pale yellow liquid: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 5.85 (ttd, 1 H, *J* = 1.2, 6.4, 10.8 Hz), 5.80 (ttd, 1 H, *J* = 1.2, 6.4, 11.2 Hz), 4.85 (d, 2 H, *J* = 6.0 Hz), 4.66 (d, 2 H, *J* = 6.0 Hz), 3.02 (s, 3 H), 2.06 (s, 3 H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 170.6, 130.1, 126.0, 64.8, 59.5, 38.0, 31.5, 20.8.



15

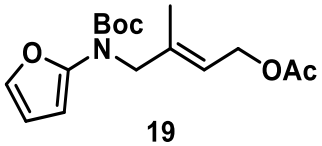
(*Z*)-4-((*tert*-Butoxycarbonyl)(furan-2-yl)amino)but-2-en-1-yl acetate (15). To a solution of **12** (971 mg, 5.30 mmol) in dry DMF (7.0 mL) at 0 °C was added NaH (318 mg, 7.95 mmol, 60 % in mineral oil) in 4 portions. The reaction mixture was stirred at 0 °C for 2 h. Then, **14** (499 mg, 3.36 mmol) was added dropwise over 5 min. The resulting solution was stirred at 0 °C for 2 h and then rt for 2 h, diluted with Et_2O (5 mL), quenched with saturated aqueous NH_4Cl (5 mL), extracted with Et_2O (3 x 15 mL), washed with water and brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The crude product was purified by chromatography on SiO_2 (Hexanes : EA = 15 : 1) to give **15** (939 mg, 60%) as a pale yellow liquid: ATR-IR (neat) 2954, 2922, 2852, 1713, 1685, 1368, 1236, 1206, 1150, 1025 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz) δ 7.17 (dd, 1 H, *J* = 0.8, 2.0 Hz), 6.32 (dd, 1 H, *J* = 2.4, 3.2 Hz), 6.00 (br, 1 H), 5.74 (ttd, 1 H, *J* = 1.2, 6.8, 10.8 Hz), 5.66 (ttd, 1 H, *J* = 1.2, 6.8, 11.2 Hz), 4.59 (d, 2 H, *J* = 6.4 Hz), 4.27 (d, 2 H, *J* = 6.8 Hz), 2.04 (s, 3 H), 1.45 (s, 9 H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 170.2, 153.1, 147.8, 137.8, 129.4, 126.2, 110.6, 100.8, 81.0, 59.5, 45.0, 27.8, 20.5; MS (ESI) *m*/z (rel. intensity) 318 ($[M+Na]^+$, 27), 259 (56), 218 (100), 203 (50), 136 (29); HRMS (EI) *m*/z calcd for $C_{15}H_{21}NO_5Na$ [M+Na] 318.1317, found 318.1328.



18

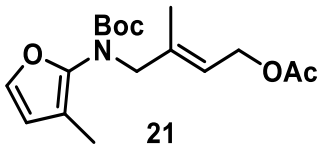
(*E*)-4-Bromo-3-methylbut-2-en-1-yl acetate (18).[3] To a solution of isoprene (1.96 mL, 19.6 mmol) in glacial acetic acid (10.0 mL) was added *N*-bromosuccinimide (2.59 g, 14.6 mmol). The reaction mixture was stirred at rt for 12 h, quenched with

water, extracted with CH_2Cl_2, washed with water, aqueous $NaHCO_3$, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The residue was purified by chromatography on SiO_2 (Hexanes : EA = 32 : 1) to give **18** (1.66 g, 55%) as a colorless liquid: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 5.72 (bt, 1 H, *J* = 6.8 Hz), 4.59 (d, 2 H, *J* = 6.8 Hz), 3.94 (s, 2 H), 2.06 (s, 3 H), 1.84 (td, 3 H, *J* = 0.8, 1.2 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 170.8, 137.2, 124.2, 60.9, 39.4, 20.9, 15.1.



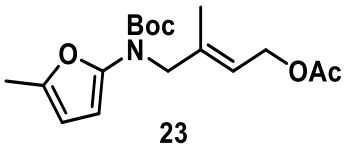
19

(*E*)-4-((*tert*-Butoxycarbonyl)(furan-2-yl)amino)-3-methylbut-2-en-1-yl acetate (19). To a solution of **12** (413 mg, 2.26 mmol) in dry DMF (5.0 mL) at 0 °C was added NaH (135 mg, 3.38 mmol, 60 % in mineral oil) in 4 portions. The reaction mixture was stirred at 0 °C for 1 h. Then, **18** (490 mg, 2.37 mmol) was added dropwise over 5 min. The resulting solution was stirred at 0 °C for 2 h and then rt for 2 h, diluted with Et_2O (5 mL), quenched with saturated aqueous NH_4Cl (5 mL), extracted with Et_2O (3 x 15 mL), washed with water and brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The crude product was purified by chromatography on SiO_2 (Hexanes : EA = 15 : 1) to give **19** (539 mg, 77%) as a pale yellow liquid: ATR-IR (neat) 2973, 2932, 1735, 1709, 1610, 1506, 1504, 1364, 1228, 1158, 1051, 1021, 1003, 857, 766, 736 cm^{-1}; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.15 (dd, 1 H, *J* = 1.0, 2.0 Hz), 6.31 (dd, 1 H, *J* = 2.0, 3.0 Hz), 5.98 (br, 1 H), 5.43 (qt, 1 H, *J* = 1.0, 7.0 Hz), 4.58 (d, 2 H, *J* = 7.0 Hz), 4.11 (s, 2 H), 2.02 (s, 3 H), 1.71 (s, 3 H, *J* = 1.2 Hz), 1.44 (s, 9 H); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 170.6, 153.7, 148.1, 137.9, 137.0, 120.1, 110.6, 100.9, 81.1, 60.5, 55.1, 27.9, 20.7, 14.1; MS (ESI) *m*/z (rel. intensity) 332 ($[M+23]^+$, 100), 276 (42), 232 (90); HRMS (ESI) *m*/z calcd for $C_{16}H_{23}NO_5Na$ [M+Na] 332.1474, found 332.1465.



21

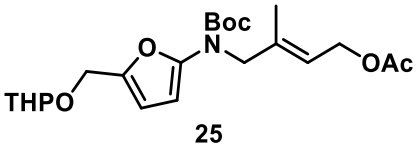
(*E*)-4-((*tert*-Butoxycarbonyl)(3-methylfuran-2-yl)amino)-3-methylbut-2-en-1-yl acetate (21). To a solution of *tert*-butyl (3-methylfuran-2-yl)carbamate[4] (361 mg, 1.83 mmol) in dry DMF (5.0 mL) at 0 °C was added NaH (110 mg, 2.74 mmol, 60 % in mineral oil) in 4 portions. The reaction mixture was stirred at 0 °C for 1 h. Then, **18** (398 mg, 1.92 mmol) was added dropwise over 5 min. The resulting solution was stirred at rt for 2 h, diluted with Et_2O (10 mL), quenched with saturated aqueous NH_4Cl (10 mL), extracted with Et_2O (3 x 10 mL), washed with water and brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The crude product was purified by chromatography on SiO_2 (Hexanes : EA = 15 : 1) to give **21** (320 mg, 54%) as a colorless liquid: ATR-IR (neat) 2977, 2928, 1737, 1709, 1646, 1508, 1364, 1228, 1159, 1094, 1053, 1021, 887, 861, 740 cm^{-1}; ^1H NMR ($CDCl_3$, 500 MHz) δ 7.09 (s, 1 H), 6.16 (s, 1 H), 5.42 (t, 1 H, *J* = 6.5 Hz), 4.55 (d, 2 H, *J* = 6.5 Hz), 4.05 (s, 2 H), 2.01 (s, 3 H), 1.85 (s, 3 H), 1.72 (s, 3 H), 1.39 (bs, 9 H); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 170.8, 154.5, 144.0, 138.2, 137.6, 137.2, 121.1, 112.9, 80.8, 60.8, 55.2, 28.1, 20.9, 14.5, 9.5; HRMS (ESI) *m*/z calcd for $C_{17}H_{25}NO_5Na$ [M+Na] 346.1630, found 346.1616.



23

(*E*)-4-((*tert*-Butoxycarbonyl)(5-methylfuran-2-yl)amino)-3-methylbut-2-en-1-yl acetate (23). To a solution of *tert*-butyl (5-methylfuran-2-yl)carbamate[4] (126 mg, 0.640 mmol) in dry DMF (2.0 mL) at 0 °C was added NaH (38.4 mg, 0.960 mmol, 60 % in mineral oil) in 4 portions. The reaction mixture was stirred at 0 °C for 1 h. Then, **18** (139 mg, 0.672 mmol) was added dropwise over 5 min. The resulting solution was stirred at rt for 2 h, diluted with Et_2O (10 mL), quenched with saturated aqueous NH_4Cl (10 mL), extracted with Et_2O (3 x 10 mL), washed with

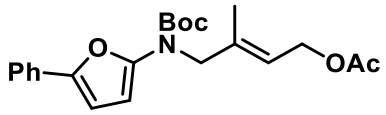
water and brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The crude product was purified by chromatography on SiO_2 (Hexanes : EA = 15 : 1) to give **23** (105 mg, 51%) as a pale yellow liquid: ATR-IR (neat) 2977, 2928, 1737, 1709, 1616, 1571, 1364, 1228, 1159, 1057, 1020, 956, 859, 775, 738 cm^{-1}; ^1H NMR ($CDCl_3$, 500 MHz) δ 5.88 (s, 1 H), 5.84 (br, 1 H), 5.44 (t, 1 H, *J* = 7.0 Hz), 4.59 (d, 2 H, *J* = 6.5 Hz), 4.08 (s, 2 H), 2.22 (s, 3 H), 2.03 (s, 3 H), 1.71 (s, 3 H), 1.44 (bs, 9 H); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 171.0, 154.2, 147.8, 146.3, 137.4, 120.2, 106.4, 102.4, 81.1, 60.9, 60.4, 28.1, 21.0, 14.4, 13.6; HRMS (ESI) *m*/z calcd for $C_{17}H_{25}NO_5Na$ [M+Na] 346.1630, found 346.1613.



25

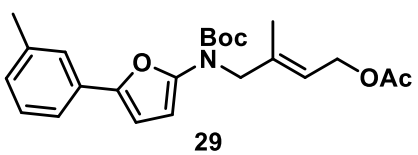
(*E*)-4-((*tert*-Butoxycarbonyl)(5-(((tetrahydro-2*H*-pyran-2-yl)oxy)methyl)furan-2-yl)amino)-3-methylbut-2-en-1-yl acetate (25). To a solution of *tert*-butyl (5-(((tetrahydro-2*H*-pyran-2-yl)oxy)methyl)furan-2-yl)carbamate[4] (298 mg, 1.00 mmol) in dry DMF (2.0 mL) at 0 °C was added NaH (60.0 mg, 1.50 mmol, 60 % in mineral oil) in 4 portions. The reaction mixture was stirred at 0 °C for 1 h. Then, **18** (218 mg, 1.05 mmol) was added dropwise over 5 min. The resulting solution was stirred at rt for 2 h, diluted with Et_2O (10 mL), quenched with saturated aqueous NH_4Cl (10 mL), extracted with Et_2O (3 x 10 mL), washed with water and brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The crude product was purified by chromatography on SiO_2 (Hexanes : EA = 15 : 1) to give **25** (340 mg, 80%) as a yellow liquid: ATR-IR (neat) 2973, 2939, 2868, 1737, 1713, 1620, 1562, 1454, 1441, 1390, 1366, 1228, 1200, 1159, 1133, 1116, 1016, 964, 904, 869, 816, 785 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz) δ 6.25 (d, 1 H, *J* = 3.2 Hz), 5.93 (br, 1 H), 5.43 (qt, 1 H, *J* = 0.8, 6.4 Hz), 4.69 (t, 1 H, *J* = 3.2 Hz), 4.57 (d, 1 H, *J* = 13.2 Hz), 4.56 (d, 2 H, *J* = 6.8 Hz), 4.42 (d, 1 H, *J* = 13.2 Hz), 4.13 (s, 2 H), 3.88 (ddd, 1 H, *J* = 2.8, 8.4, 11.2 Hz), 3.53 (td, 1 H, *J* = 4.4, 10.8 Hz), 2.02

(s, 3 H), 1.86-1.49 (m, 9 H), 1.44 (s, 9 H); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 170.6, 153.5, 148.0,146.7, 137.0, 120.2, 110.4, 101.4, 96.6, 81.1, 61.6, 60.6, 60.4, 54.8, 30.2, 27.9, 25.2, 20.7, 18.9, 14.2; HRMS (ESI) *m*/z calcd for $C_{22}H_{33}NO_7Na$ ([M+Na]$^+$) 446.2155, found 446.2133.



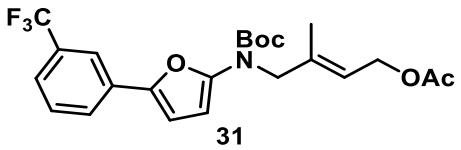
27

(*E*)-4-((*tert*-Butoxycarbonyl)(5-phenylfuran-2-yl)amino)-3-methylbut-2-en-1-yl acetate (27). To a solution of *tert*-butyl (5-phenylfuran-2-yl)carbamate[4] (320 mg, 1.24 mmol) in dry DMF (3.0 mL) at 0 °C was added NaH (74.2 mg, 1.85 mmol, 60 % in mineral oil) in 4 portions. The reaction mixture was stirred at 0 °C for 1 h. Then, **18** (269 mg, 1.30 mmol) was added dropwise over 5 min. The resulting solution was stirred at rt for 2 h, diluted with Et_2O (10 mL), quenched with saturated aqueous NH_4Cl (10 mL), extracted with Et_2O (3 x 10 mL), washed with water and brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The crude product was purified by chromatography on SiO_2 (Hexanes : EA = 15 : 1) to give **27** (328 mg, 69%) as a pale yellow liquid: ATR-IR (neat) 2977, 2930, 1735, 1709, 1597, 1549, 1446, 1390, 1366, 1228, 1156, 1060, 1020, 857, 759, 692 cm^{-1}; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.56 (d, 2 H, *J* = 7.5 Hz), 7.33 (t, 2 H, *J* = 7.5 Hz), 7.19 (t, 1 H, *J* = 7.5 Hz), 6.57 (d, 1 H, *J* = 3.5 Hz), 6.07 (br, 1 H), 5.51 (qt, 1 H, *J* = 1.0, 7.0 Hz), 4.59 (d, 2 H, *J* = 7.0 Hz), 4.22 (s, 2 H), 1.95 (s, 3 H), 1.74 (s, 3 H), 1.46 (s, 9 H); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 170.6, 153.4, 147.6, 137.0, 130.5, 129.2, 128.4, 126.8, 123.0, 120.3, 114.6, 106.0, 81.3, 60.6, 54.8, 28.0, 20.6, 14.2; HRMS (ESI) *m*/z calcd for $C_{22}H_{27}NO_5Na$ [M+Na] 408.1787, found 408.1776.



29

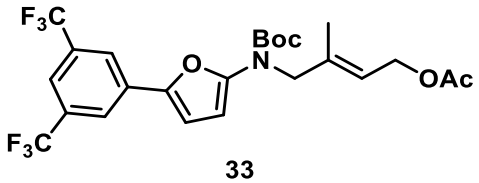
(*E*)-4-((*tert*-Butoxycarbonyl)(5-(*m*-tolyl)furan-2-yl)amino)-3-methylbut-2-en-1-yl acetate (29). To a solution of *tert*-butyl (5-(*m*-tolyl)furan-2-yl)carbamate[4] (170 mg, 0.622 mmol) in dry DMF (2.0 mL) at 0 °C was added NaH (37.3 mg, 1.25 mmol, 60 % in mineral oil) in 4 portions. The reaction mixture was stirred at 0 °C for 1 h. Then, **18** (135 mg, 0.653 mmol) was added dropwise over 5 min. The resulting solution was stirred at rt for 2 h, diluted with Et_2O (10 mL), quenched with saturated aqueous NH_4Cl (10 mL), extracted with Et_2O (3 x 10 mL), washed with water and brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The crude product was purified by chromatography on SiO_2 (Hexanes : EA = 15 : 1) to give **29** (167 mg, 67%) as a yellow liquid: ATR-IR (neat) 2975, 2926, 1735, 1709, 1603, 1549, 1366, 1390, 1228, 1158, 1021, 1060, 949, 857, 779, 692 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz) δ 7.38-7.36 (m, 2 H), 7.22 (t, 1 H, *J* = 7.6 Hz), 7.02 (d, 1 H, *J* =7.2 Hz), 6.55 (d, 1 H, *J* = 3.6 Hz), 6.07 (br, 1 H), 5.50 (qt, 1 H, *J* = 1.6, 7.2 Hz), 4.59 (d, 2 H, *J* = 7.2 Hz), 4.22 (s, 2 H); 2.35 (s, 3 H), 1.95 (s, 3 H), 1.75 (s, 3 H), 1.46 (s, 9 H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 170.6, 153.4, 148.8, 147.4, 138.0, 137.0, 128.4, 127.6, 123.6, 120.3, 120.2, 105.8, 102.5, 81.3, 60.6, 54.8, 27.9, 21.3, 20.6, 14.2; HRMS (ESI) *m*/z calcd for $C_{23}H_{29}NO_5Na$ [M+Na] 422.1943, found 422.1951.



31

((*E*)-4-((*tert*-Butoxycarbonyl)(5-(3-(trifluoromethyl)phenyl)furan-2-yl)amino)-3-methylbut-2-en-1-yl acetate (31). To a solution of *tert*-butyl (5-(3-(trifluoromethyl)phenyl)furan-2-yl)carbamate[4] (362 mg, 1.11 mmol) in dry DMF (4.0 mL) at 0 °C was added NaH (66.3 mg, 1.66 mmol, 60 % in mineral oil) in 4 portions. The reaction mixture was stirred at 0 °C for 1 h. Then, **18** (240 mg, 1.16 mmol) was added dropwise over 5 min. The resulting solution was stirred at rt for 2 h, diluted with Et_2O (10 mL), quenched with saturated aqueous NH_4Cl (10 mL), extracted with Et_2O (3 x 10 mL), washed with water and brine, dried (Na_2SO_4),

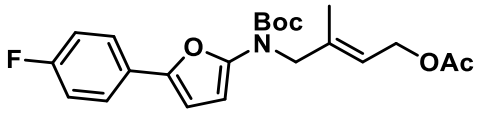
filtered, and concentrated under reduced pressure. The crude product was purified by chromatography on SiO_2 (Hexanes : EA = 15 : 1) to give **31** (333 mg, 66%) as a yellow liquid: ATR-IR (neat) 2978, 2930, 1737, 1713, 1610, 1592, 1551, 1452, 1392, 1366, 1333, 1267, 1230, 1159, 1124, 1098, 1075, 1060, 1021, 857, 796, 783, 697 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz) δ 7.79 (s, 1 H), 7.74-7.72 (m, 1 H), 7.48-7.46 (m, 2 H), 6.68 (d, 1 H, J = 3.6 Hz), 6.12 (br, 1 H), 5.51 (qt, 1 H, J = 1.2, 6.8 Hz), 4.60 (d, 2 H, J = 6.8 Hz), 4.24 (s, 2 H), 1.98 (s, 3 H), 1.76 (s, 3 H), 1.48 (s, 9 H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 170.6, 153.2, 148.5, 147.0, 136.9, 131.3, 131.0 (q, J_{CF} = 32.2 Hz), 129.0, 126.0, 124.9 (q, J_{CF} = 271.0 Hz), 123.2 (q, J_{CF} = 3.6 Hz), 120.5, 119.6 (q, J_{CF} = 3.8 Hz), 107.6, 102.4, 81.6, 60.6, 54.7, 27.9, 20.6, 14.2; HRMS (ESI) m/z calcd for $C_{23}H_{26}NO_5F_3Na$ [M+Na] 476.1661, found 476.1679.



33

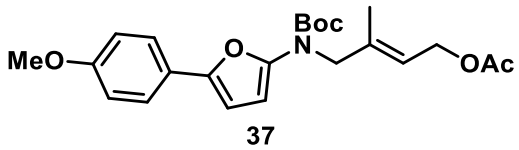
(*E*)-4-((5-(3,5-Bis(trifluoromethyl)phenyl)furan-2-yl)(*tert*-butoxycarbonyl)amino)-3-methylbut-2-en-1-yl acetate (33). To a solution of *tert*-butyl (5-(3,5-bis(trifluoromethyl)phenyl)furan-2-yl)carbamate[4] (148 mg, 0.374 mmol) in dry DMF (2.0 mL) at 0 °C was added NaH (22.4 mg, 0.561 mmol, 60 % in mineral oil) in 4 portions. The reaction mixture was stirred at 0 °C for 1 h. Then, **18** (81.3 mg, 0.393 mmol) was added dropwise over 5 min. The resulting solution was stirred at rt for 2 h, diluted with Et_2O (10 mL), quenched with saturated aqueous NH_4Cl (10 mL), extracted with Et_2O (3 x 10 mL), washed with water and brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The crude product was purified by chromatography on SiO_2 (Hexanes : EA = 15 : 1) to give **33** (170 mg, 87%) as a yellow solid: Mp 70.3–71.8 °C; ATR-IR (neat) 2980, 2928, 2855, 1743, 1720, 1622, 1607, 1549, 1454, 1377, 1370, 1279, 1232, 1172, 1135, 1023, 952, 891, 856, 844, 788, 703, 682 cm^{-1}; ^1H NMR ($CDCl_3$, 500 MHz) δ 7.92 (s, 2 H), 7.66 (s, 1 H),

6.79 (d, 1 H, J = 3.5 Hz), 6.17 (br, 1 H), 5.50 (qt, 1 H, J = 1.0, 7.0 Hz), 4.60 (d, 2 H, J = 7.0 Hz), 4.26 (s, 2 H), 1.96 (s, 3 H), 1.75 (s, 3 H), 1.48 (s, 9 H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 170.8, 153.0, 149.4, 145.4, 136.8, 132.4, 132.1 (q, J_{CF} = 33.0 Hz), 123.2 (q, J_{CF} = 270.0 Hz), 122.6 (q, J_{CF} = 3.8 Hz), 120.6, 119.8 (sp, J_{CF} = 3.8 Hz), 109.4, 102.4, 82.0, 60.6, 54.6, 28.0, 20.7, 14.3; HRMS (ESI) m/z calcd for $C_{24}H_{26}NO_5F_6$ [M+H] 522.1715, found 522.1694.



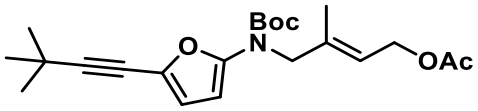
35

(*E*)-4-((*tert*-Butoxycarbonyl)(5-(4-fluorophenyl)furan-2-yl)amino)-3-methylbut-2-en-1-yl acetate (35). To a solution of ***tert*-butyl (5-(4-fluorophenyl)furan-2-yl)carbamate**[4] (231 mg, 0.833 mmol) in dry DMF (3.0 mL) at 0 °C was added NaH (50.0 mg, 1.25 mmol, 60 % in mineral oil) in 4 portions. The reaction mixture was stirred at 0 °C for 1 h. Then, **18** (181 mg, 0.875 mmol) was added dropwise over 5 min. The resulting solution was stirred at rt for 2 h, diluted with Et_2O (10 mL), quenched with saturated aqueous NH_4Cl (10 mL), extracted with Et_2O (3 x 10 mL), washed with water and brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The crude product was purified by chromatography on SiO_2 (Hexanes : EA = 15 : 1) to give **35** (240 mg, 72%) as a yellow liquid: ATR-IR (neat) 2977, 2928, 1737, 1711, 1618, 1594, 1553, 1497, 1392, 1366, 1228, 1156, 1057, 1020, 835, 779 cm^{-1}; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.55-7.52 (m, 2 H), 7.05 (tt, 2 H, J =2.0, 9.0 Hz), 6.50 (d, 1 H, J = 3.5 Hz), 6.06 (br, 1 H), 5.52-5.48 (m, 1 H), 4.60 (d, 2 H, J = 7.0 Hz), 4.21 (s, 2 H), 1.98 (s, 3 H), 1.75 (s, 3 H), 1.47 (s, 9 H); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 170.7, 162.3 (d, J_{CF} = 245.0 Hz), 153.5, 147.7, 137.1, 127.0 (d, J_{CF} = 3.8 Hz), 124.8 (d, J_{CF} = 7.5 Hz), 120.3, 115.5 (d, J_{CF} = 22.5 Hz), 105.6, 102.6, 81.4, 60.6, 55.0, 28.0, 20.7, 14.2; HRMS (ESI) m/z calcd for $C_{22}H_{26}NO_5FNa$ ([M+Na]$^+$) 426.1693, found 426.1703.



37

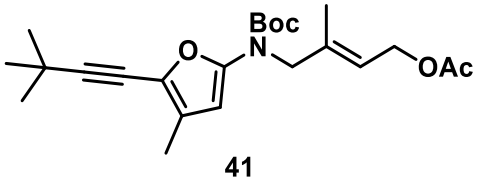
(*E*)-4-((*tert*-Butoxycarbonyl)(5-(4-methoxyphenyl)furan-2-yl)amino)-3-methylbut-2-en-1-yl acetate (37). To a solution of ***tert*-butyl (5-(4-methoxyphenyl)furan-2-yl)carbamate**[4] (371 mg, 1.28 mmol) in dry DMF (3.0 mL) at 0 °C was added NaH (76.8 mg, 1.92 mmol, 60 % in mineral oil) in 4 portions. The reaction mixture was stirred at 0 °C for 1 h. Then, **18** (279 mg, 1.34 mmol) was added dropwise over 5 min. The resulting solution was stirred at rt for 2 h, diluted with Et_2O (10 mL), quenched with saturated aqueous NH_4Cl (10 mL), extracted with Et_2O (3 x 10 mL), washed with water and brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The crude product was purified by chromatography on SiO_2 (Hexanes : EA = 15 : 1) to give **37** (356 mg, 67%) as a yellow liquid: ATR-IR (neat) 2973, 2928, 1735, 1711, 1620, 1605, 1581, 1554, 1498, 1456, 1441, 1392, 1366, 1292, 1273, 1247, 1230, 1159, 1060, 1021, 951, 831, 779 cm^{-1}; ^1H NMR ($CDCl_3$, 500 MHz) δ 7.51 (td, 2 H, *J* = 2.5, 9.5 Hz), 6.90 (td, 2 H, *J* = 2.5, 9.5 Hz), 6.43 (d, 1 H, *J* = 3.0 Hz), 6.04 (br, 1 H), 5.50 (qt, 1 H, *J* = 1.5, 7.0 Hz), 4.60 (d, 2 H, *J* = 7.0 Hz), 4.20 (s, 2 H), 3.82 (s, 3 H), 1.99 (s, 3 H), 1.75 (s, 3 H), 1.47 (s, 9 H); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 170.9, 158.8, 153.8, 149.1, 147.1, 137.3, 124.7, 123.9, 120.4, 114.1, 104.4, 102.8, 81.4, 60.8, 55.3, 55.2, 28.2, 20.9, 14.4; HRMS (ESI) *m*/z calcd for $C_{23}H_{29}NO_6Na$ [M+Na] 438.1893, found 438.1895.



39

(*E*)-4-((*tert*-Butoxycarbonyl)(5-(3,3-dimethylbut-1-yn-1-yl)furan-2-yl)amino)-3-methylbut-2-en-1-yl acetate (39). To a solution of *tert*-butyl (5-(3,3-dimethylbut-1-yn-1-yl)furan-2-yl)carbamate[4] (119 mg, 0.451 mmol) in dry DMF (2.0 mL) at 0 °C was added NaH (27.1 mg, 0.677 mmol, 60 % in mineral oil) in 4

portions. The reaction mixture was stirred at 0 °C for 1 h. Then, **18** (98.1 mg, 0.474 mmol) was added dropwise over 5 min. The resulting solution was stirred at rt for 2 h, diluted with Et_2O (10 mL), quenched with saturated aqueous NH_4Cl (10 mL), extracted with Et_2O (3 x 10 mL), washed with water and brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The crude product was purified by chromatography on SiO_2 (Hexanes : EA = 15 : 1) to give **39** (95.0 mg, 54%) as a yellow liquid: ATR-IR (neat) 2969, 2928, 2865, 1737, 1715, 1607, 1541, 1448, 1472, 1392, 1364, 1271, 1228, 1158, 1062, 1020, 980, 857, 779 cm^{-1}; ^1H NMR ($CDCl_3$, 500 MHz) δ 6.38 (d, 1 H, *J* =3.5 Hz), 5.95 (br, 1 H), 5.42 (qt, 1 H, *J* = 1.0, 6.5 Hz), 4.59 (d, 2 H, *J* = 7.0 Hz), 4.14 (s, 2 H), 2.03 (s, 3 H), 1.70 (s, 3 H), 1.44 (s, 9 H), 1.30 (s, 9 H); ^{13}C NMR($CDCl_3$, 125 MHz)) δ 170.9, 153.4, 147.4, 137.0, 132.7, 120.2, 115.2, 102.0, 101.9, 81.6, 69.5, 60.8, 54.5, 30.7, 28.1, 28.1, 20.9, 14.4; HRMS (ESI) *m*/z calcd for $C_{22}H_{31}NO_5Na$ [M+Na] 412.2100, found 412.2094.

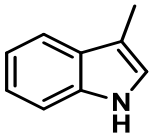


41

(*E*)-4-((*tert*-Butoxycarbonyl)(5-(3,3-dimethylbut-1-yn-1-yl)-4-methylfuran-2-yl)amino)-3-methylbut-2-en-1-yl acetate (41). To a solution of *tert*-butyl (5-(3,3-dimethylbut-1-yn-1-yl)-4-methylfuran-2-yl)carbamate[4] (76.0 mg, 0.274 mmol) in dry DMF (0.5 mL) at 0 °C was added NaH (16.4 mg, 0.411 mmol, 60 % in mineral oil) in 4 portions. The reaction mixture was stirred at 0 °C for 1 h. Then, **18** (59.6 mg, 0.288 mmol) was added dropwise over 5 min. The resulting solution was stirred at rt for 2 h, diluted with Et_2O (10 mL), quenched with saturated aqueous NH_4Cl (10 mL), extracted with Et_2O (3 x 10 mL), washed with water and brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The crude product was purified by chromatography on SiO_2 (Hexanes : EA = 15 : 1) to give **41** (78.0 mg, 71%) as a yellow liquid: ATR-IR (neat) 2971, 2932, 2158, 1737, 1713, 1618, 1581, 1554, 1500, 1456, 1443, 1392, 1364, 1230, 1159, 1060, 1023, 951, 857, 831, 777 cm^{-1}; ^1H NMR

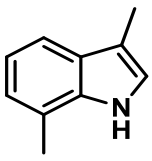
($CDCl_3$, 400 MHz) δ 5.88 (br, 1 H), 5.41 (qt, 1 H, *J* = 1.2, 6.8 Hz), 4.59 (d, 2 H, *J* = 6.8 Hz), 4.13 (s, 2 H), 2.03 (s, 3 H), 2.01 (s, 3 H), 1.69 (s, 3 H), 1.45 (s, 9 H), 1.31 (s, 9 H); ^{13}C NMR($CDCl_3$, 125 MHz)) δ 170.8, 153.3, 146.6, 137.1, 125.8, 119.9, 115.2, 104.4, 101.8, 81.5, 68.7, 60.7, 54.2, 30.8, 28.0, 20.8, 14.4, 10.8; HRMS (ESI) *m*/z calcd for $C_{23}H_{33}NO_5Na$ [M+Na] 426.2256, found 426.2253.

Conversions to Indoles



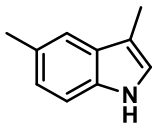
20

3-Methyl-1*H*-indole (20). To a solution of **19** (55.5 mg, 0.179 mmol) and P(O*i*-Pr)$_3$ (7.5 mg, 0.036 mmol) in NMP (1.8 mL) was added $Pd(PPh_3)_4$ (10 mg, 0.0090 mmol). The reaction mixture was stirred under microwave irradiation at 180 °C for 20 min, quenched with ether and water, extracted with ether, washed with brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The residue was purified by chromatography on SiO_2 (Hexanes : EA = 16 : 1) to give **20** (19.5 mg, 83%) as a yellow solid: Mp 89.2–90.6 °C; ATR-IR (neat) 3413, 2921, 736 cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz) δ 7.87 (br, 1 H), 7.60 (d, 1 H, *J* = 7.6 Hz), 7.36 (d, 1 H, *J* = 8.0 Hz), 7.20 (dt, 1 H, *J* = 0.8, 8.0 Hz), 7.14 (dt, 1 H, *J* = 1.2, 8.0 Hz), 6.98 (d, 1 H, *J* = 1.2 Hz), 2.35 (d, 3 H, *J* = 0.8 Hz); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 136.2, 128.3, 121.8, 121.5, 119.1, 118.8, 111.7, 110.9, 9.6; MS (EI) *m*/z (%) 131 ($[M]^+$, 57), 130 (100), 86 (55), 84 (82); HRMS (EI) *m*/z calcd for C_9H_9N [M] 131.0735, found 131.0703. Spectral data are consistent with literature reference.[5]



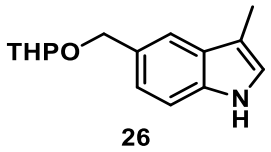
22

3,7-Dimethyl-1*H*-indole (22). To a solution of **21** (46 mg, 0.14 mmol) and P(O*i*-Pr)$_3$ (5.9 mg, 0.028 mmol) in NMP (0.70 mL) was added Pd(PPh$_3$)$_4$ (8.1 mg, 0.0081 mmol). The reaction mixture was stirred under microwave irradiation at 180 °C for 20 min, quenched with ether and water, extracted with ether, washed with brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The residue was purified by chromatography on SiO_2 (Hexanes : EA = 16 : 1) to give **22** (18 mg, 86%) as a yellow solid: Mp 57.3–59.1 °C; ATR-IR (neat) 3417, 2921, 742 cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.81 (br, 1 H), 7.46 (d, 1 H, *J* = 7.6 Hz), 7.07 (t, 1 H, *J* = 7.6 Hz), 7.02–6.98 (m, 2 H), 2.49 (s, 3 H), 2.35 (s, 3 H); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 135.8, 127.8, 122.4, 121.2, 120.0, 119.3, 116.5, 112.2, 16.5, 9.8; HRMS (EI) *m*/z calcd for $C_{10}H_{11}N$ 145.0891, found 145.0909. Spectral data are consistent with literature reference.[6]



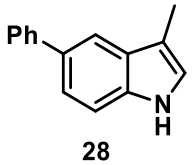
24

3,5-Dimethyl-1*H*-indole (24). To a solution of **23** (33 mg, 0.10 mmol) and P(O*i*-Pr)$_3$ (4.3 mg, 0.021 mmol) in NMP (0.51 mL) was added Pd(PPh$_3$)$_4$ (5.9 mg, 0.0051 mmol). The reaction mixture was stirred under microwave radiation at 180 °C for 20 min, quenched with ether and water, extracted with ether, washed with brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The residue was purified by chromatography on SiO_2 (Hexanes : EA = 16 : 1) to give **24** (13 mg, 84%) as a yellow solid: Mp 70.9–72.6 °C; ATR-IR (neat) 3409, 2919, 742 cm^{-1}; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.78 (br, 1 H), 7.37 (d, 1 H, *J* = 1.0 Hz), 7.24 (d, 1 H, *J* = 8.5 Hz), 7.02 (dd, 1 H, *J* = 1.0, 8.5 Hz), 6.94 (d, 1 H, *J* = 1.0 Hz), 2.47 (s, 3 H), 2.31 (d, 3 H, *J* = 1.0 Hz); ^{13}C NMR (CDCl3, 125 MHz) δ 134.5, 128.5, 128.3, 123.4, 121.7, 118.5, 111.2, 110.6, 21.5, 9.6; HRMS (EI) *m*/z calcd for $C_{10}H_{10}N$ [M-H] 144.0813, found 144.0798. Spectral data are consistent with literature reference.[7]



26

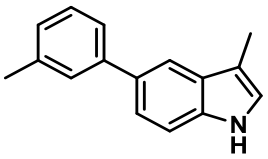
3-Methyl-5-(((tetrahydro-2*H*-pyran-2-yl)oxy)methyl)-1*H*-indole (26). To a solution of **25** (63 mg, 0.15 mmol) and P(O*i*-Pr)$_3$ (6.2 mg, 0.030 mmol) in NMP (0.75 mL) was added Pd(PPh$_3$)$_4$ (8.6 mg, 0.0074 mmol). The reaction mixture was stirred under microwave irradiation at 180 °C for 20 min, quenched with ether and water, extracted with ether, washed with brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The residue was purified by chromatography on SiO_2 (Hexanes : EA = 16 : 1) to give **26** (22 mg, 59%) as a pale yellow liquid: ATR-IR (neat) 3411, 2930, 1116, 1074, 1023, 794 cm^{-1}; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.91 (br, 1 H), 7.58 (s, 1 H), 7.32 (d, 1 H, *J* = 8.0 Hz), 7.22 (dd, 1 H, *J* = 1.0, 8.5 Hz), 6.97 (s, 1 H), 4.90 (d, 1 H, *J* = 11.0 Hz), 4.75 (t, 1 H, *J* = 3.5 Hz), 4.62 (d, 1 H, , *J* = 11.5 Hz), 3.99 (ddd, 1 H, *J* = 3.0, 9.0, 12.0 Hz), 3.58 (td, 1 H, *J* = 5.0 , 11.0 Hz), 2.33 (d, 3 H, *J* = 0.5 Hz), 1.90-1.84 (m, 1 H), 1.76-1.70 (m, 1 H), 1.67-1.51 (m, 4 H); ^{13}C NMR ($CDCl_3$,125 MHz) δ 135.9, 128.8, 128.3, 122.8, 122.0, 119.0, 111.8, 110.8, 97.2, 62.2, 30.7, 25.6, 19.5, 9.6; HRMS (ESI) *m*/z calcd for $C_{15}H_{19}NO_2Na$ [M+Na] 268.1313, found 268.1335.



28

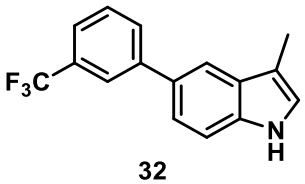
3-Methyl-5-phenyl-1*H*-indole (28). To a solution of **27** (57 mg, 0.15 mmol) and P(O*i*-Pr)$_3$ (6.1 mg, 0.029 mmol) in NMP (0.73 mL) was added Pd(PPh$_3$)$_4$ (8.5 mg, 0.0073 mmol). The reaction mixture was stirred under microwave irradiation at 180 °C for 20 min, quenched with ether and water, extracted with ether, washed with brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The residue was purified by chromatography on SiO_2 (Hexanes : EA = 16 : 1) to give **28** (24 mg, 77%) as a yellow liquid: ATR-IR (neat) 3416, 3062, 2921, 762 cm^{-1}; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.92 (br, 1 H), 7.78 (dd, 1 H, *J* = 1.0, 1.5 Hz), 7.68 (d, 1 H, *J* = 1.5

Hz), 7.67 (d, 1 H, *J* = 1.0 Hz), 7.46-7.40 (m, 4 H), 7.32 (tt, 1 H, *J* = 1.0, 7.5 Hz), 7.01 (d, 1 H, *J* = 1.0 Hz), 2.38 (d, 3 H, *J* = 1.0 Hz); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 142.7, 135.7, 132.8, 128.8, 128.6, 127.4, 126.2, 122.2, 121.7, 117.4, 112.2, 111.1, 9.7; HRMS (EI) *m*/z calcd for $C_{15}H_{13}N$ [M] 207.1048, found 207.1065.



30

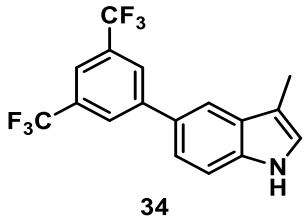
3-Methyl-5-(*m*-tolyl)-1*H*-indole (30). To a solution of **29** (34 mg, 0.085 mmol) and P(O*i*-Pr)$_3$ (3.5 mg, 0.017 mmol) in NMP (0.43 mL) was added $Pd(PPh_3)_4$ (4.9 mg, 0.0043 mmol). The reaction mixture was stirred under microwave irradiation at 180 °C for 20 min, quenched with ether and water, extracted with ether, washed with brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The residue was purified by chromatography on SiO_2 (Hexanes : EA = 16 : 1) to give **30** (16 mg, 87%) as a yellow liquid: ATR-IR (neat) 3417, 3025, 2921, 785 cm^{-1}; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.91 (br, 1 H), 7.77 (s, 1 H), 7.49-7.39 (m, 4 H), 7.34 (t, 1 H, *J* = 8.0 Hz), 7.14 (d, 1 H, *J* = 8.0 Hz), 7.00 (s, 1 H), 2.44 (s, 3 H), 2.38 (d, 3 H, *J* = 0.5 Hz); ^{13}C NMR ($CDCl_3$,125 MHz) δ 142.7, 138.1, 135.7, 132.9, 128.7, 128.5, 128.2, 127.0, 124.5, 122.2, 121.8, 117.4, 112.1, 111.1, 21.6, 9.7; HRMS (EI) *m*/z calcd for $C_{16}H_{15}N$ 221.1204 [M], found 221.1216.



32

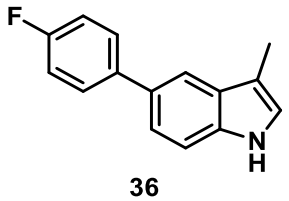
3-Methyl-5-(3-(trifluoromethyl)phenyl)-1*H*-indole (32). To a solution of **31** (47 mg, 0.10 mmol) and P(O*i*-Pr)$_3$ (4.3 mg, 0.021 mmol) in NMP (0.51 mL) was added $Pd(PPh_3)_4$ (6.0 mg, 0.0051 mmol). The reaction mixture was stirred under

microwave irradiation at 180 °C for 20 min, quenched with ether and water, extracted with ether, washed with brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The residue was purified by chromatography on SiO_2 (Hexanes : EA = 16 : 1) to give **32** (12 mg, 41%) as a yellow liquid: ATR-IR (neat) 3418, 2921, 1331, 1070, 792 cm^{-1}; ^1H NMR ($CDCl_3$, 500 MHz) δ 7.96 (br, 1 H), 7.91 (s, 1 H), 7.85 (dd, 1 H, *J* = 1.5, 4.0 Hz), 7.78 (s, 1 H), 7.56-7.55 (m, 2 H), 7.44 (s, 2 H), 7.04 (d, 1 H, *J* = 1.0 Hz), 2.39 (d, 3 H, *J* = 1.0 Hz); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 143.5, 136,1, 132,3, 131.0 (q, J_{CF} = 31.0 Hz), 130.6, 129.0, 128.9, 124.4 (q, J_{CF} = 271.0 Hz), 124.0 (q, J_{CF} = 3.8 Hz), 122.9 (q, J_{CF} = 3.8 Hz), 122.6, 121.5, 117.6, 112.3, 111.4, 9.7; HRMS (EI) *m*/z calcd for $C_{16}H_{12}NF_3$ [M] 275.0922, found 275.0900.



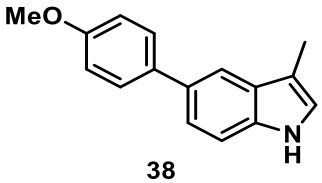
34

5-(3,3-Dimethylbut-1-yn-1-yl)-3-methyl-1*H*-indole (34). To a solution of **33** (88 mg, 0.17 mmol) and P(O*i*-Pr)$_3$ (7.1 mg, 0.034 mmol) in NMP (0.85 mL) was added $Pd(PPh_3)_4$ (9.8 mg, 0.0085 mmol). The reaction mixture was stirred under microwave irradiation at 180 °C for 20 min, quenched with ether and water, extracted with ether, washed with brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The residue was purified by chromatography on SiO_2 (Hexanes : EA = 16 : 1) to give **34** (28 mg, 48%) as a yellow solid: 109.2–110.8 °C; ATR-IR (neat) 3420, 2926, 1376, 1277, 1172, 1131, 798, 684 cm^{-1}; ^1H NMR ($CDCl_3$, 500 MHz) δ 8.08 (s, 1 H), 8.02 (br, 1 H), 7.80 (s, 1 H), 7.79 (d, 1 H, *J* = 0.5 Hz), 7.46 (d, 1 H, *J* = 8.0 Hz), 7.44 (dd, 1 H, *J* = 1.5, 8.5 Hz), 7.06 (q, 1 H, *J* = 1.0 Hz), 2.41 (d, 3 H, *J* = 1.0 Hz); ^{13}C NMR ($CDCl_3$,125 MHz) δ 144.8, 136.4, 131.8 (q, J_{CF} = 32.5 Hz), 129.7, 129.0, 127.3(q, J_{CF} = 2.9 Hz), 123.6 (q, J_{CF} = 270.0 Hz), 122.9, 121.3, 119.7 (sp, J_{CF} = 3.8 Hz); 117.8, 112.5, 111.7, 9.7; HRMS (EI) *m*/z calcd for $C_{17}H_{11}NF_6$ [M] 343.0796, found 343.0815.



36

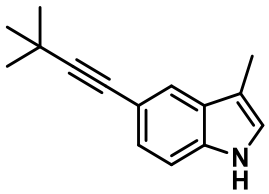
5-(4-Fluorophenyl)-3-methyl-1*H*-indole (36). To a solution of **35** (48 mg, 0.12 mmol) and P(O*i*-Pr)$_3$ (4.9 mg, 0.024 mmol) in NMP (0.60 mL) was added Pd(PPh$_3$)$_4$ (6.8 mg, 0.0059 mmol). The reaction mixture was stirred under microwave irradiation at 180 °C for 20 min, quenched with ether and water, extracted with ether, washed with brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The residue was purified by chromatography on SiO_2 (Hexanes : EA = 16 : 1) to give **36** (18 mg, 66%) as a yellow solid: Mp 82.9–84.1 °C; ATR-IR (neat) 3413, 2923, 839, 814 cm^{-1}; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.93 (br, 1 H), 7.72 (s, 1 H), 7.61 (dd, 2 H, J = 5.5, 8.5 Hz), 7.39 (dd, 2 H, J = 8.0, 11.0 Hz), 7.13 (dd, 2 H, J = 8.5, 8.5 Hz), 7.02 (s, 1 H), 2.37 (s, 3 H); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 161.9 (d, J_{CF} = 243.0 Hz), 138.8 (d, J_{CF} = 3.0 Hz), 135.7, 131.8, 128.8 (d, J_{CF} = 7.7 Hz), 128.8, 122.4, 121.6, 117.3, 115.4 (d, J_{CF} = 21.1 Hz), 112.2, 111.2, 9.7; HRMS (ESI) m/z calcd for $C_{15}H_{13}NF$ [M+H] 226.1032, found 226.1018.



38

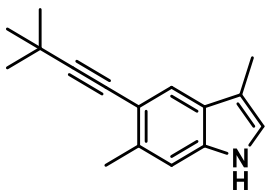
5-(4-Methoxyphenyl)-3-methyl-1*H*-indole (38). To a solution of **37** (53 mg, 0.13 mmol) and P(O*i*-Pr)$_3$ (5.3 mg, 0.025 mmol) in NMP (0.64 mL) was added Pd(PPh$_3$)$_4$ (7.4 mg, 0.0063 mmol). The reaction mixture was stirred under microwave irradiation at 180 °C for 20 min, quenched with ether and water, extracted with ether, washed with brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The residue was purified by chromatography on SiO_2 (Hexanes : EA = 16 :

1) to give **38** (19 mg, 64%) as a yellow solid: Mp 130.2–133.0 °C; ATR-IR (neat) 3410, 2919, 1240 cm^{-1}; ^1H NMR ($CDCl_3$, 500 MHz) δ 7.89 (br, 1 H), 7.73-7.72 (m, 1 H), 7.60 (td, 2 H, *J* = 2.5, 9.0 Hz), 7.40 (dd, 1 H, *J* = 2.0, 8.0 Hz), 7.38 (dd, 1 H, *J* = 0.5, 8.5 Hz), 7.01–6.98 (m, 3 H), 3.86 (s, 3 H), 2.37 (d, 3 H, *J* = 1.0 Hz); ^{13}C NMR ($CDCl_3$,100 MHz) δ 158.4, 135.5, 135.4, 132.5, 128.8, 128.3, 122.2, 121.5, 116.9, 114.1, 112.0, 111.1, 55.4, 9.7; HRMS (ESI) *m*/z calcd for $C_{16}H_{16}NO$ [M+H] 238.1232, found 238.1257.



40

5-(3,3-Dimethylbut-1-yn-1-yl)-3-methyl-1*H*-indole (40). To a solution of **39** (51 mg, 0.13 mmol) and P(O*i*-Pr)$_3$ (5.5 mg, 0.026 mmol) in NMP (0.65 mL) was added $Pd(PPh_3)_4$ (7.6 mg, 0.0065 mmol). The reaction mixture was stirred under microwave irradiation at 180 °C for 20 min, quenched with ether and water, extracted with ether, washed with brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The residue was purified by chromatography on SiO_2 (Hexanes : EA = 16 : 1) to give **40** (15 mg, 52%) as a pale yellow liquid: ATR-IR (neat) 3415, 2922, 2166, 796 cm^{-1}; ^1H NMR ($CDCl_3$, 500 MHz) δ 7.88 (br, 1 H), 7.65 (s, 1 H), 7.22 (br, 2 H), 6.95 (s, 1 H), 2.30 (s, 3 H), 1.34 (s, 9 H); ^{13}C NMR ($CDCl_3$,125 MHz) δ 135.5, 128.2, 125.6, 122.5, 122.1, 114.5, 111.9, 110.7, 95.6, 80.2, 31.3, 27.9, 9.6; HRMS (EI) *m*/z calcd for $C_{15}H_{17}N$ [M] 211.1360, found 211.1350.



42

5-(3,3-Dimethylbut-1-yn-1-yl)-3,6-dimethyl-1*H*-indole (42). To a solution of **41** (54 mg, 0.13 mmol) and P(O*i*-Pr)$_3$ (5.6 mg, 0.027 mmol) in NMP (0.67 mL) was added Pd(PPh$_3$)$_4$ (7.8 mg, 0.0067 mmol). The reaction mixture was stirred under microwave irradiation at 180 °C for 20 min, quenched with ether and water, extracted with ether, washed with brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. The residue was purified by chromatography on SiO_2 (Hexanes : EA = 16 : 1) to give **42** (8.3 mg, 27%) as a pale yellow liquid: ATR-IR (neat) 3396, 2922, 2166, 1277, 1124, 1072, 796 cm^{-1}; ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.72 (br, 1 H), 7.61 (s, 1 H), 7.13 (s, 1 H), 6.87 (s, 1 H), 2.49 (s, 3 H), 2.28 (d, 3 H, *J* = 1.0 Hz), 1.36 (s, 9 H); HRMS (EI) *m*/z calcd for $C_{16}H_{19}N$ 225.1517, found 225.1503.

References

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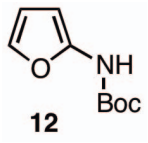
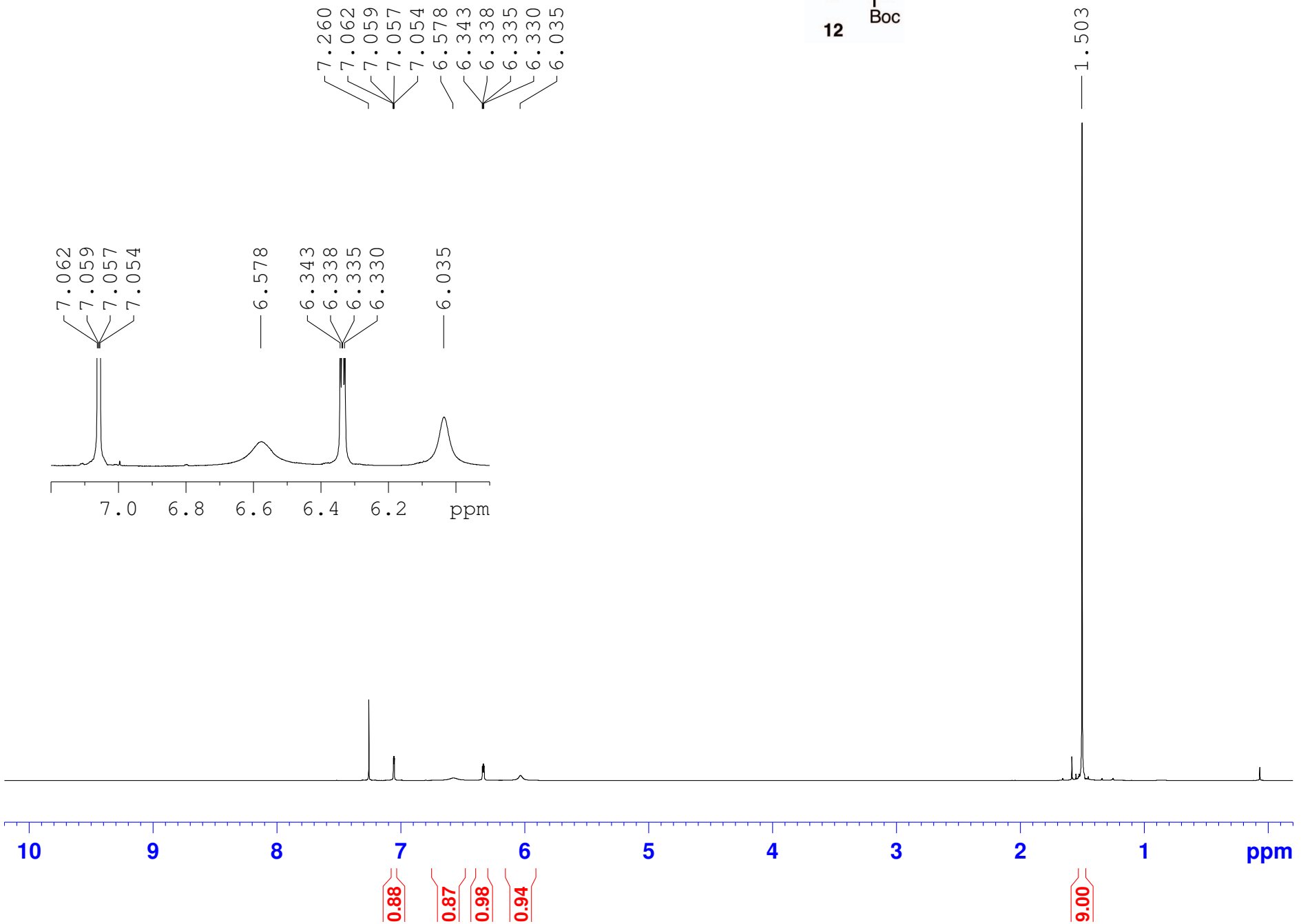
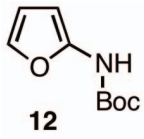
jix-290-008 400HNMR(400a) 071210





jix-290-008 100CNMR(400a) 071210



151.83
145.37
136.10
111.29
95.17
81.32
77.32
77.00
76.68

200 180 160 140 120 100 80 60 40 20 0 ppm

jix-290-021 400HNMR(400a) 072910

7.260
5.886
5.884
5.882
5.870
5.868
5.859
5.856
5.854
5.842
5.840
5.826
5.811
5.809
5.798
5.795
5.792
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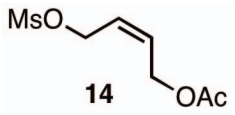
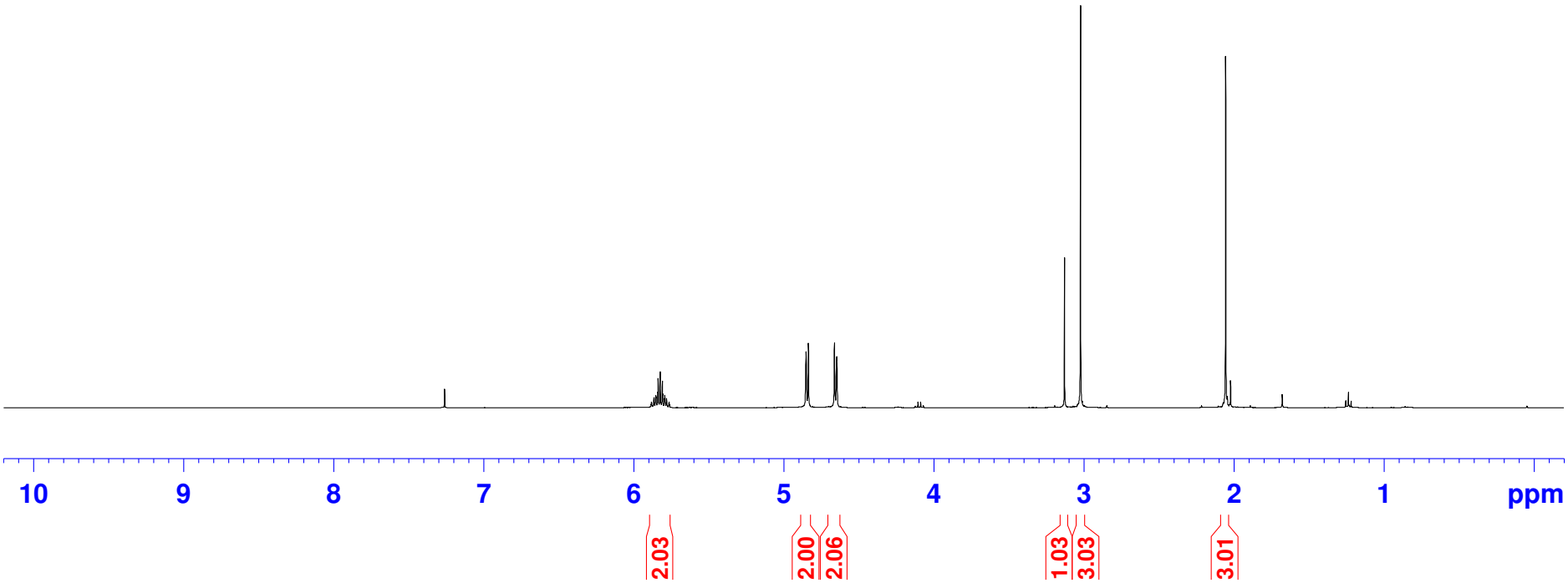
4.839
4.665
4.650
3.132
3.025
2.058





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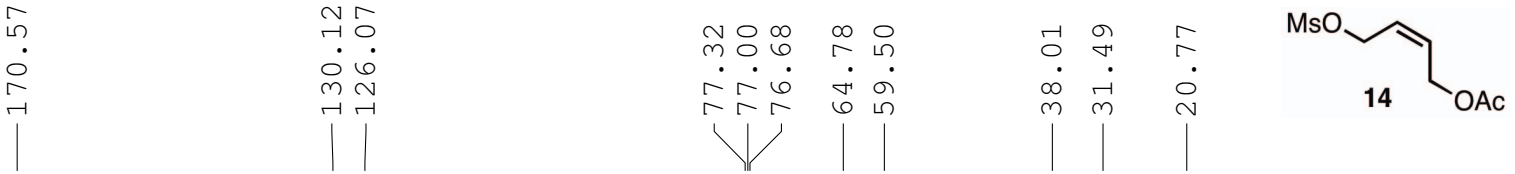

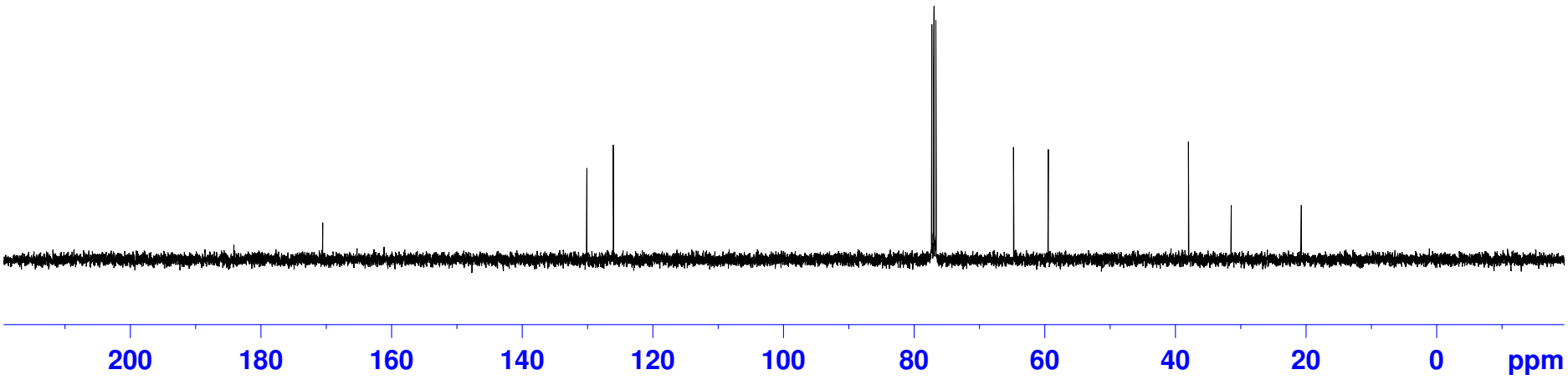

jix-290-007 400HNMR(400a) 071410

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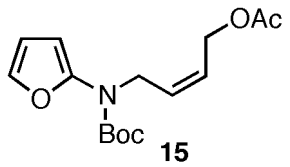

15

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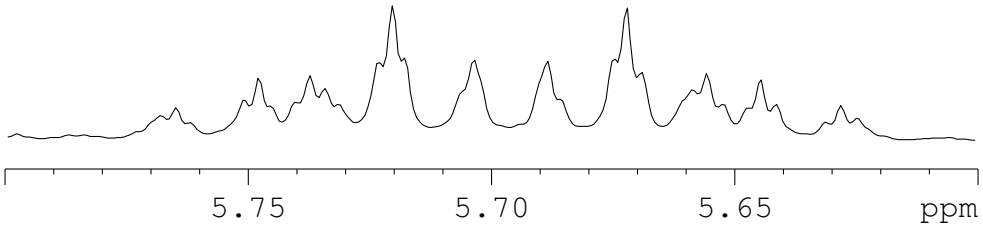
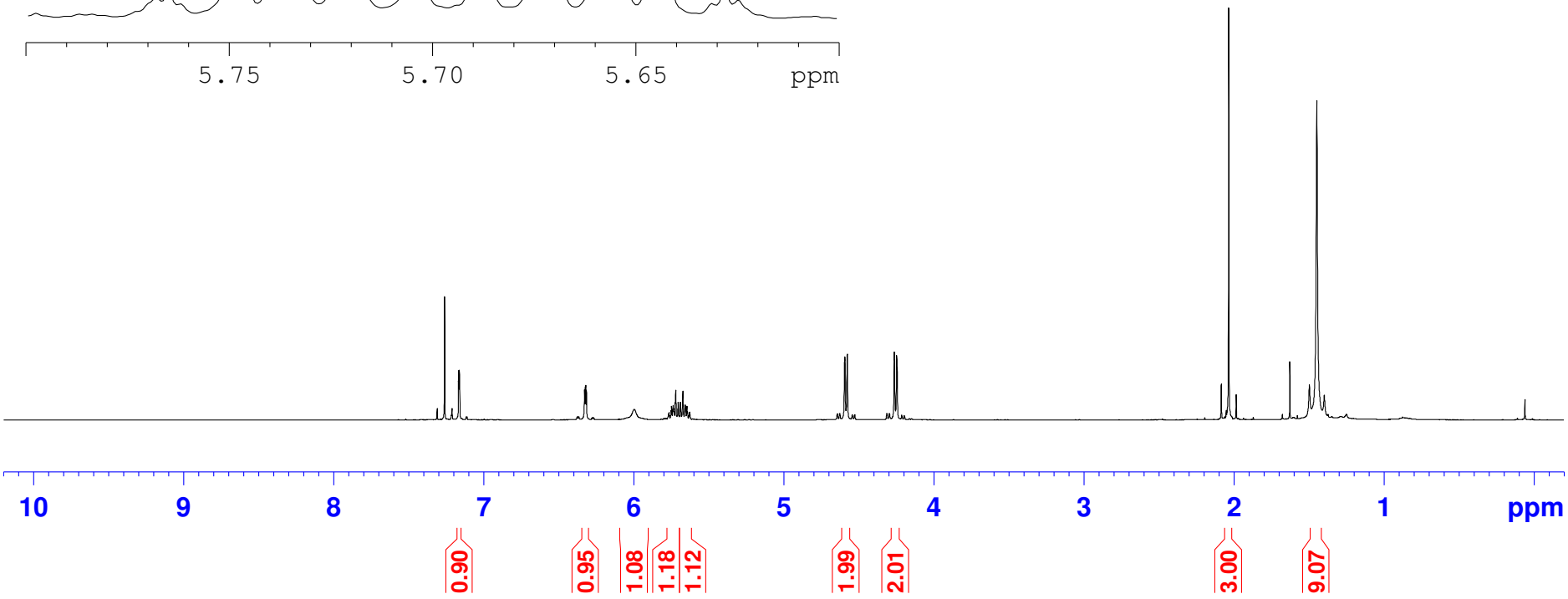
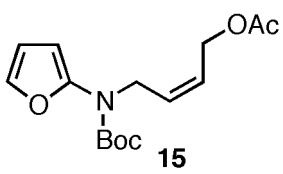




jix-290-007 100CNMR(400a) 071410



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153.08
147.80
137.81
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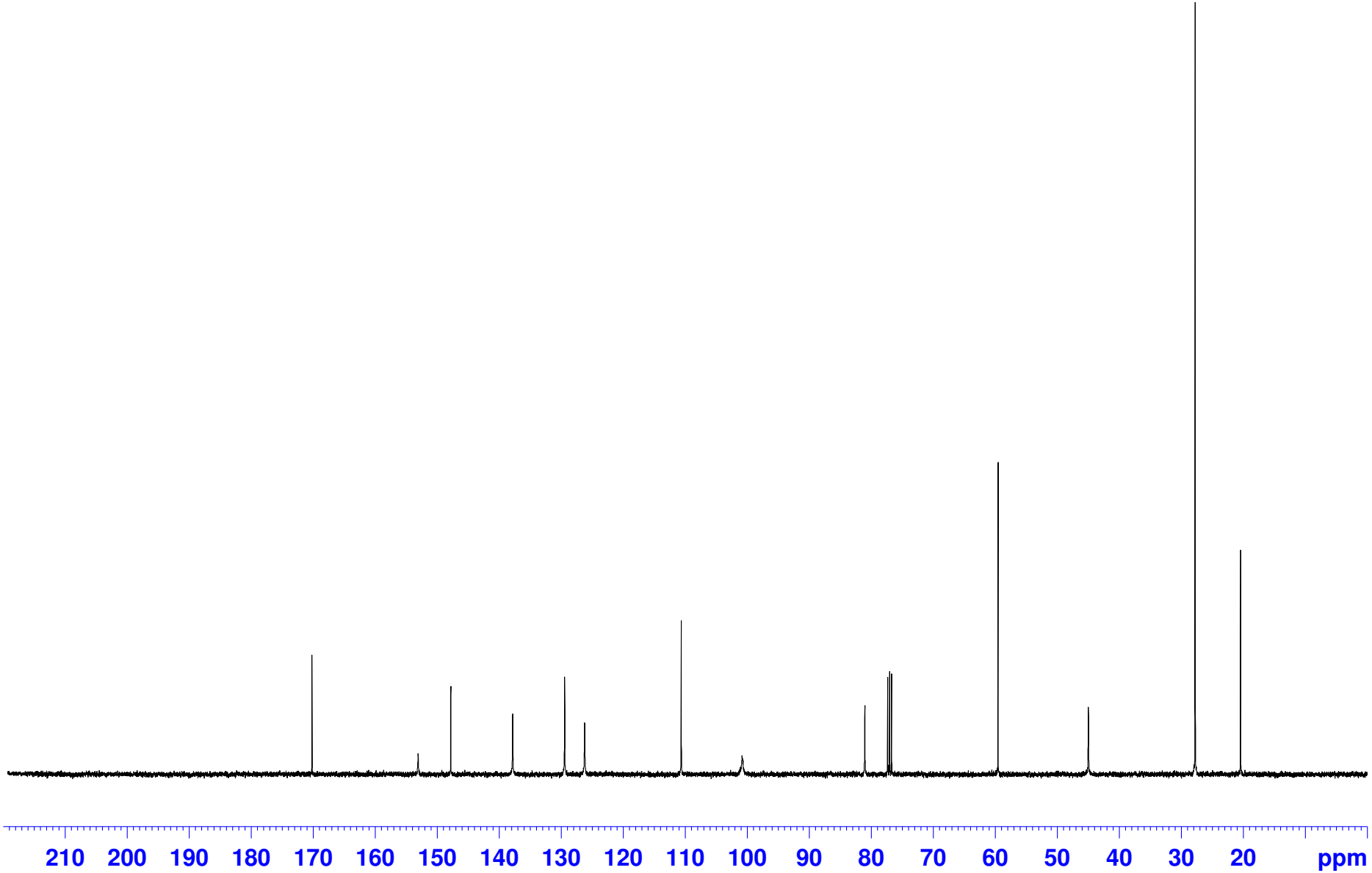
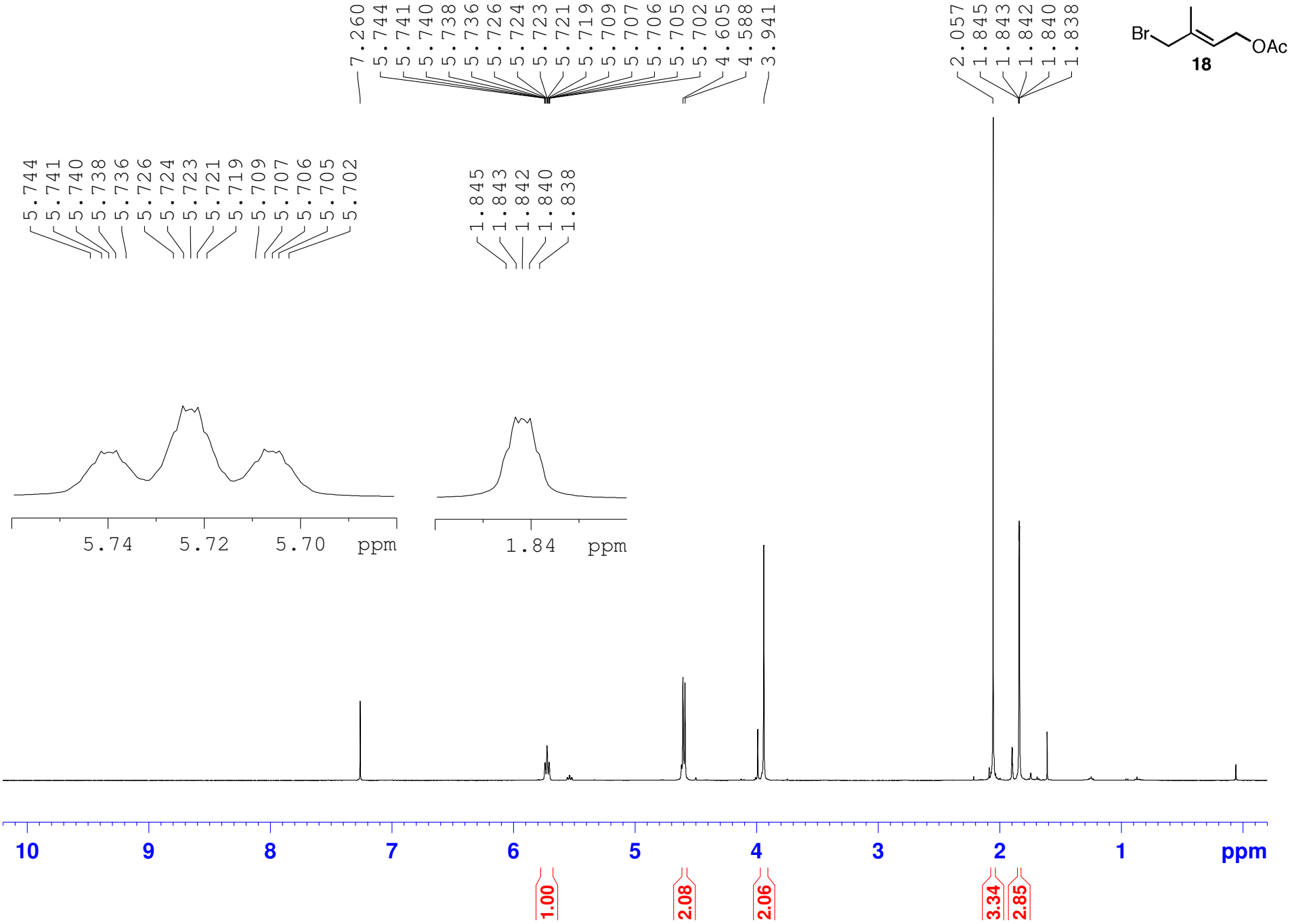
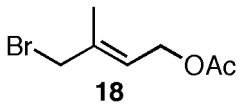
27.77
20.45



jix-290-034-2 1H NMR(400a) 090110



jix-290-034-2 13C NMR(400a) 090110



18

170.82
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77.00
76.68
60.91
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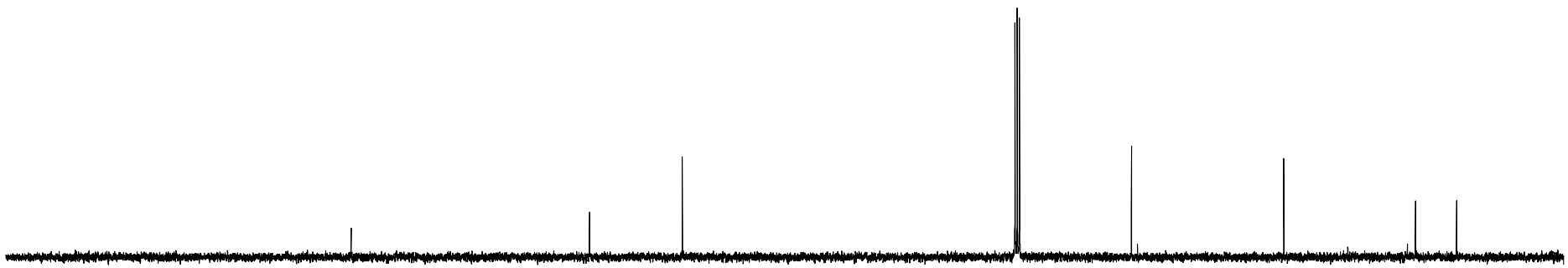
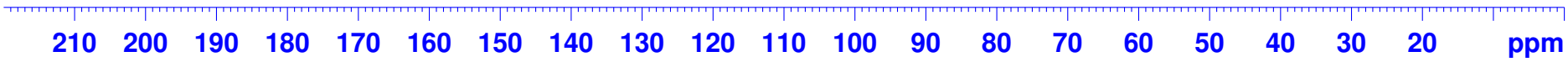
20.88
15.09





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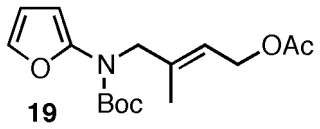

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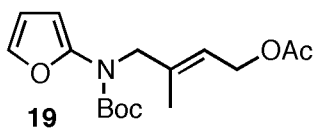

19

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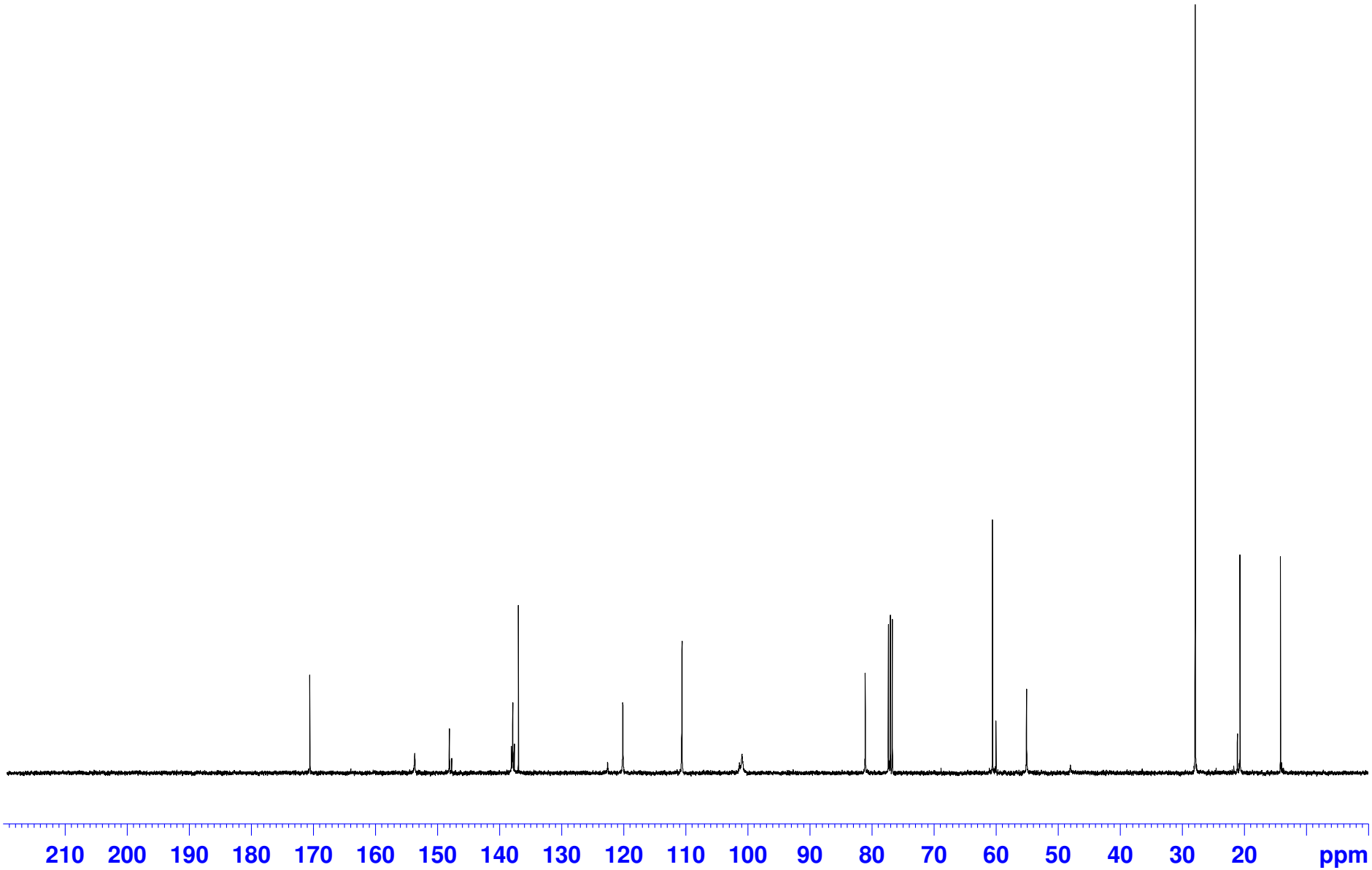

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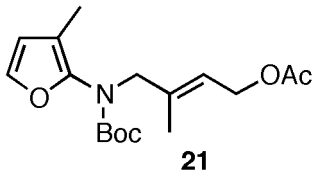

21

7.260
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2.011
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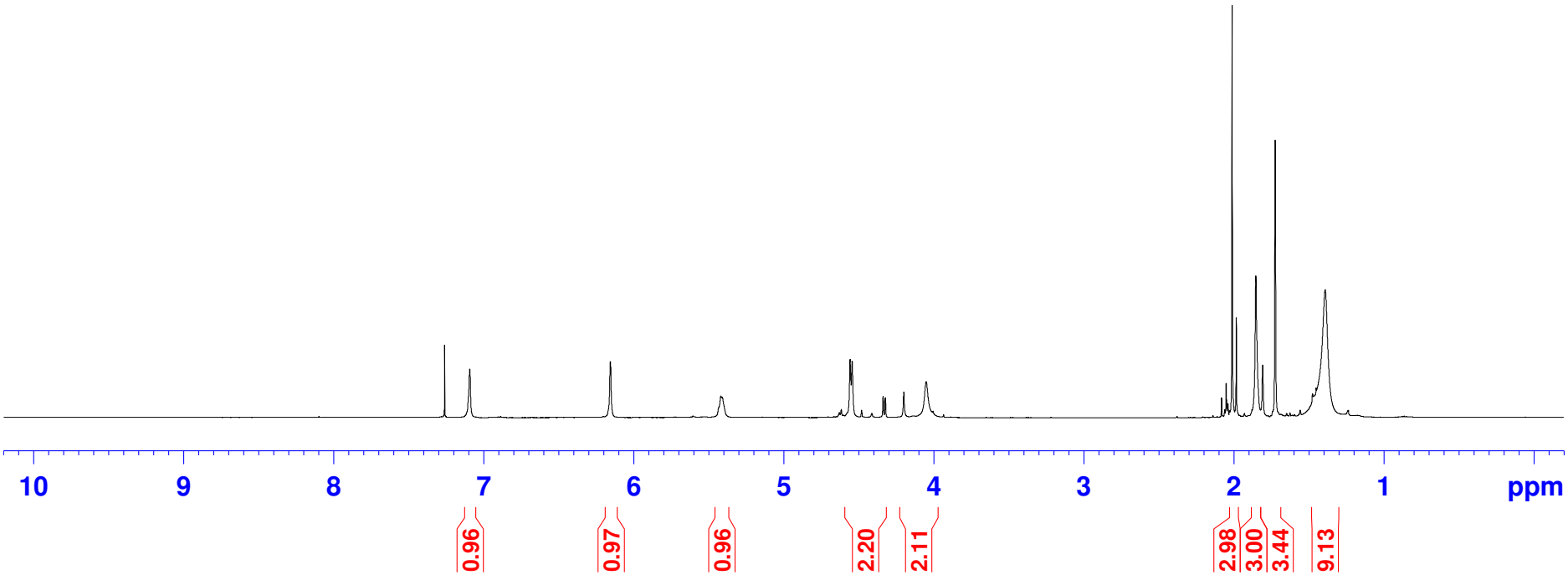
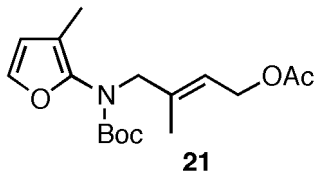
1.391

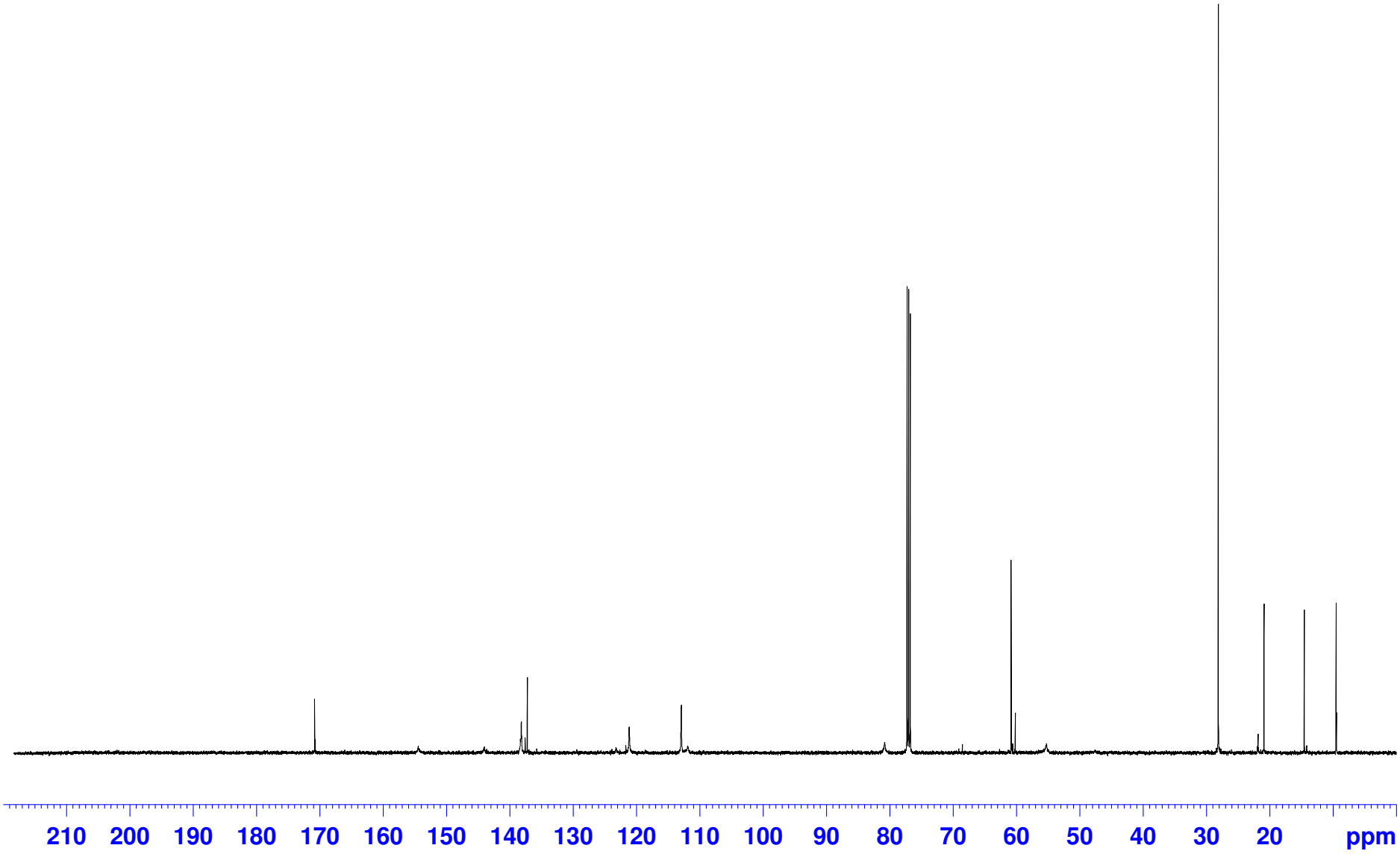


jix-331-055 13C NMR(500) 062611

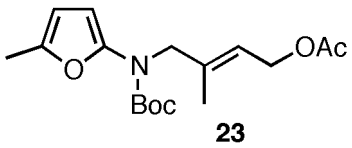


21

170.82
154.46
144.03
138.18
137.58
137.23
121.14
112.90
80.77
77.25
77.00
76.74
60.80
55.23
28.08
20.87
14.50
9.48



jix-315-061 1H NMR(500) 121710



23

7.260

5.877
5.843
5.452
5.438
5.424

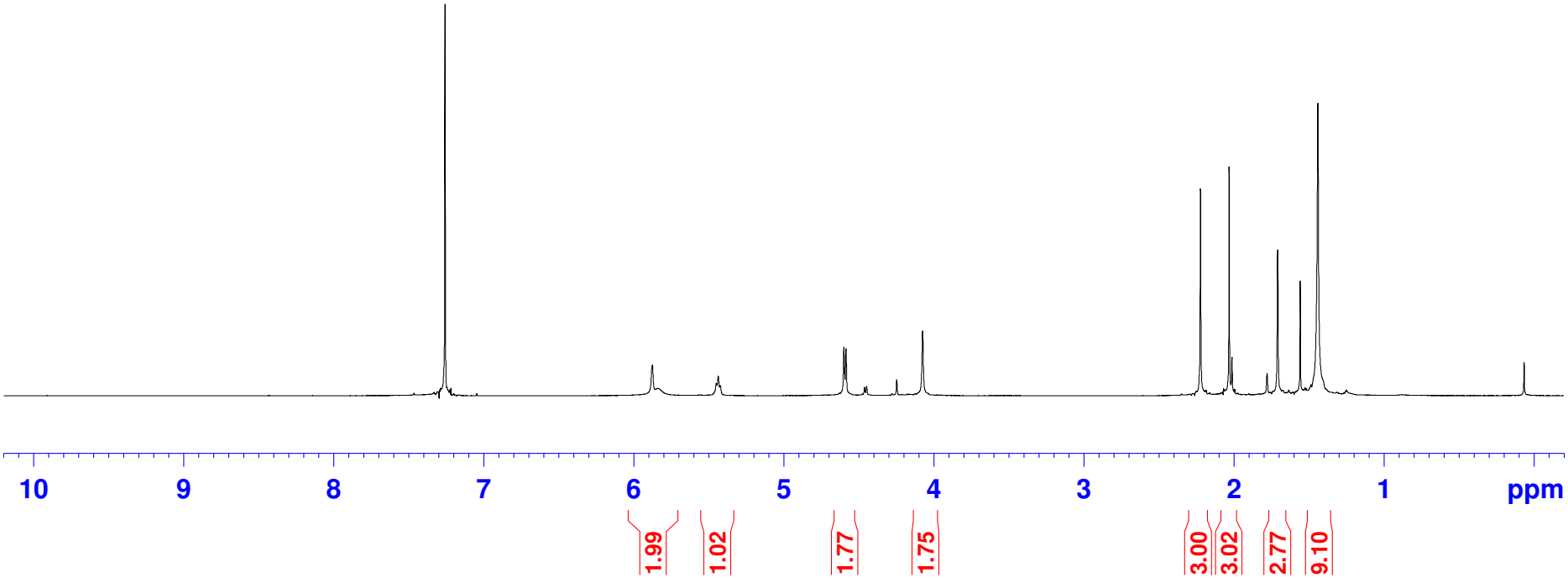
4.600
4.587

4.076

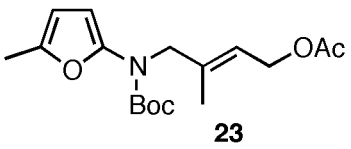
2.223
2.033

1.709

1.441

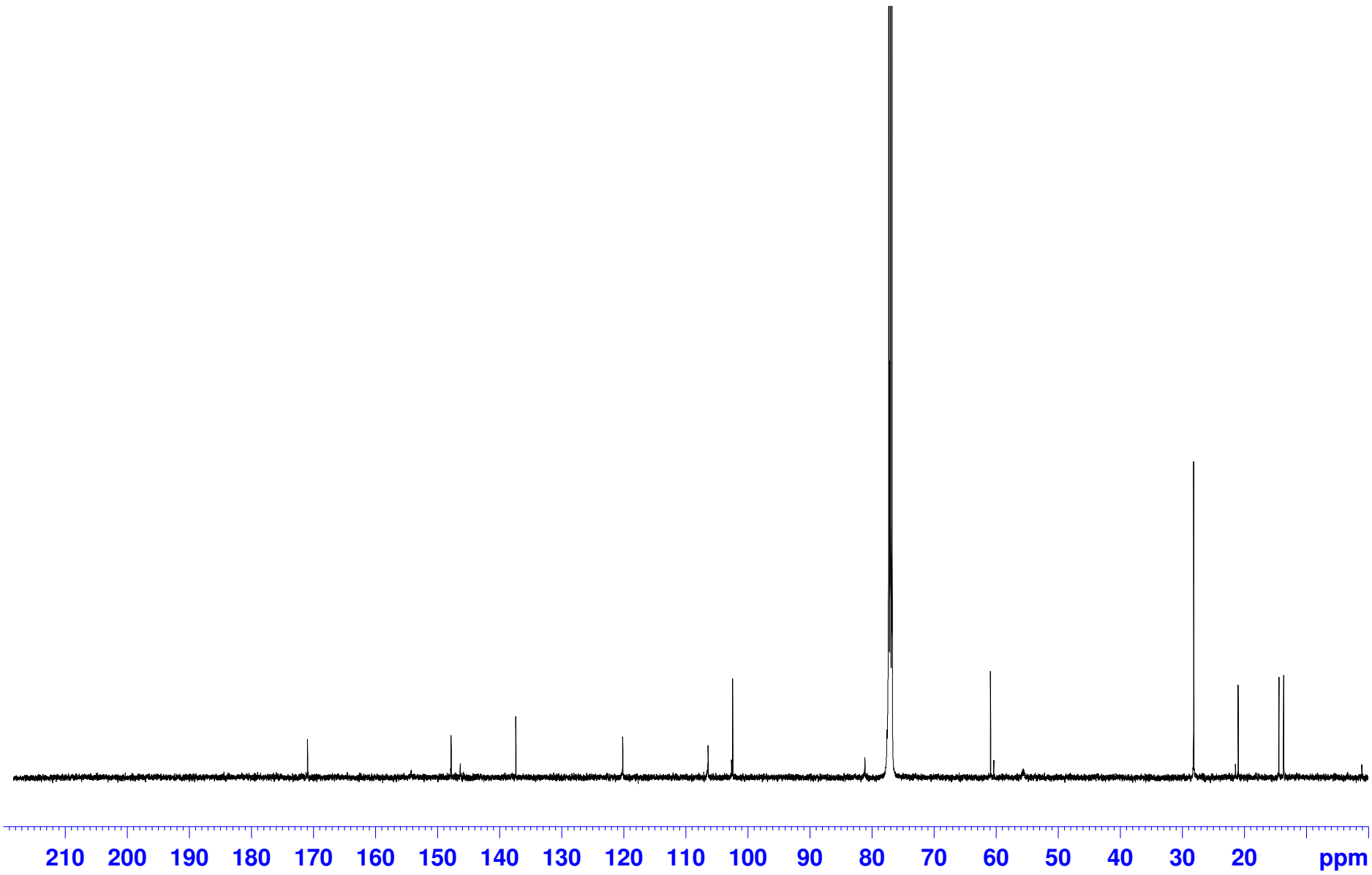


jix-315-061 13C NMR(500) 121710

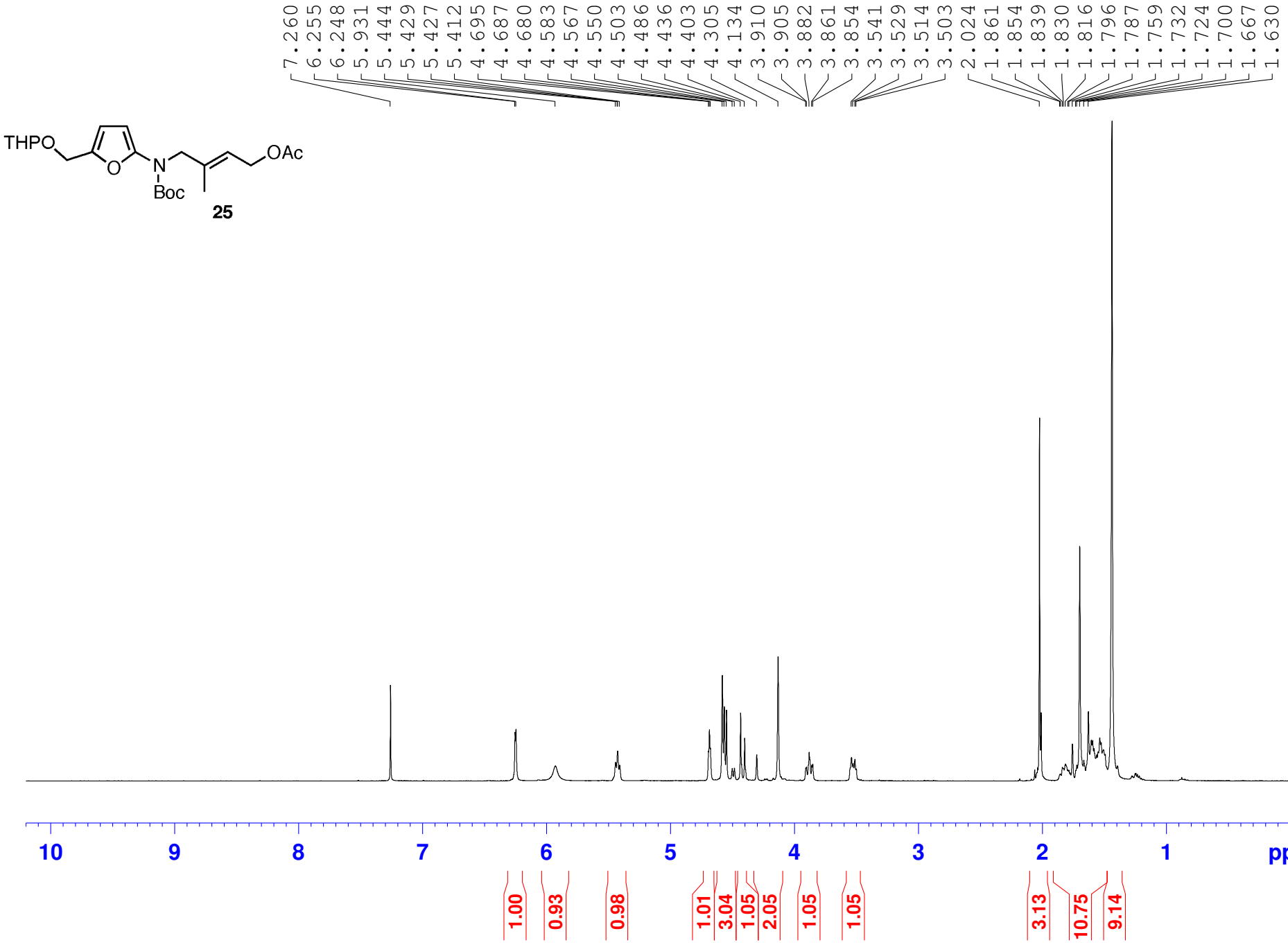


23

170.95
154.24
147.82
146.34
137.38
120.16
106.40
102.44
81.13
77.25
77.00
76.75
60.86
55.61
28.12
20.95
14.39
13.63

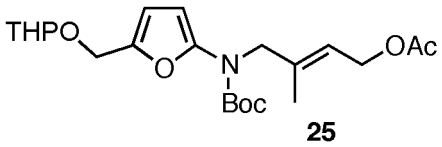


jix-331-096 1H NMR(400a) 043011



jix-331-096 13C NMR(500) 062711

170.59
153.50
148.00
146.73
136.98
120.24
110.42
101.36
96.61
81.10
77.25
77.00
76.74
61.65
60.59
60.36
54.79
30.18
27.91
25.25
20.69
18.94
14.19



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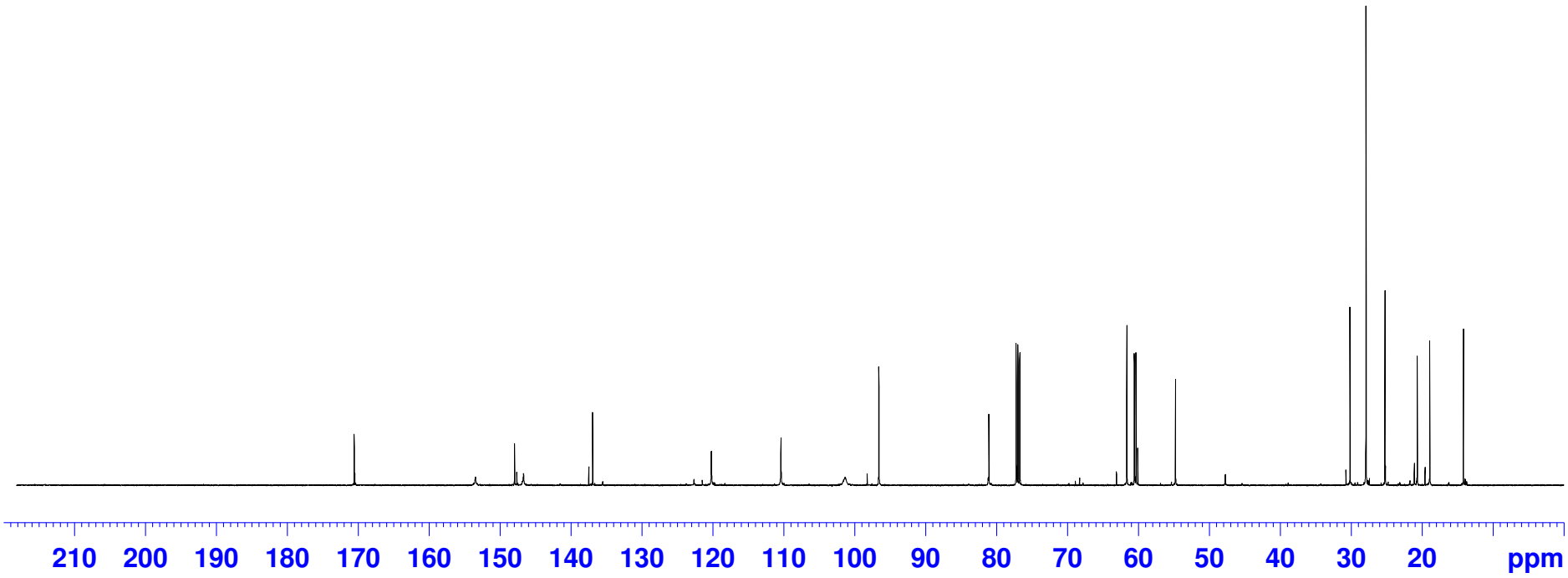
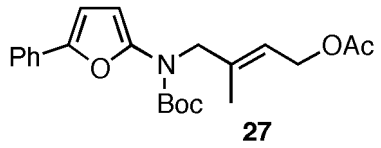
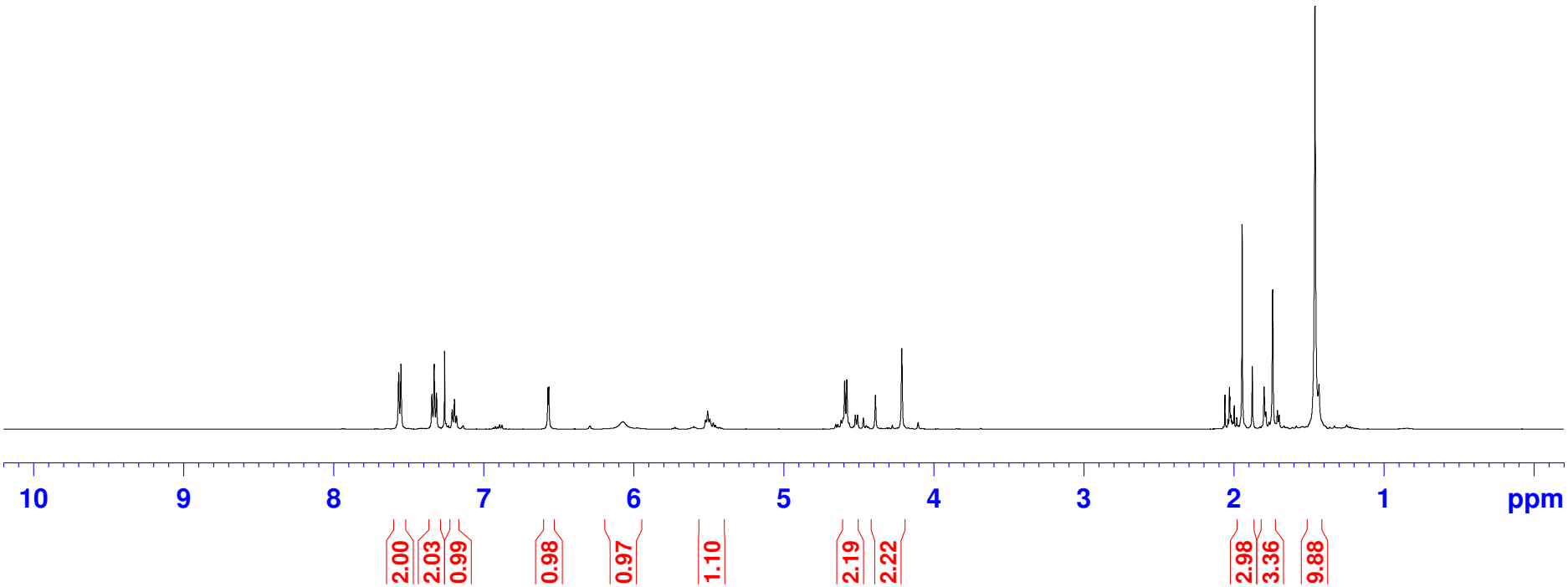


jix-315-092 1H NMR(500) 012711

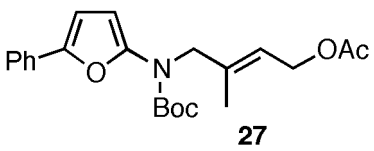
7.566
7.551
7.344
7.329
7.313
7.260
7.209
7.194
7.179
6.572
6.565
6.072
5.522
5.520
5.508
5.506
5.494
5.492
4.596
4.582
4.216
1.947
1.744
1.462



27

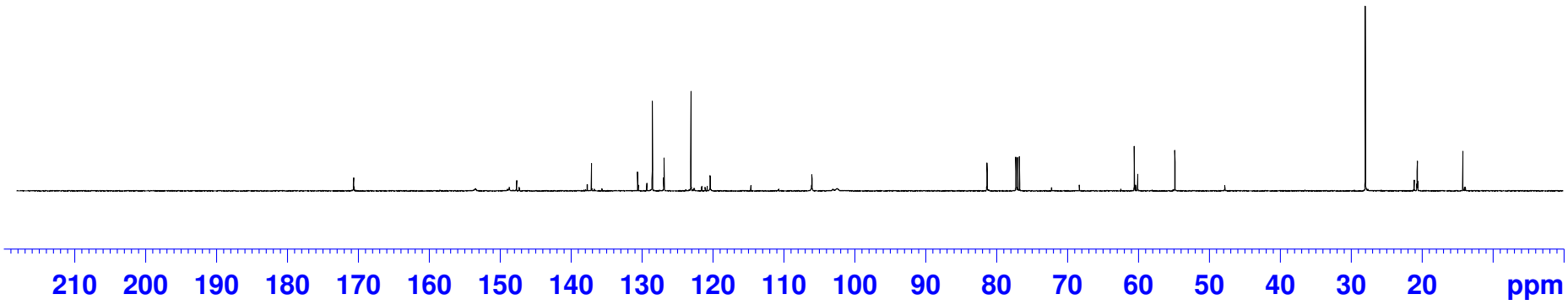


jix-315-092 13C NMR(500) 012711



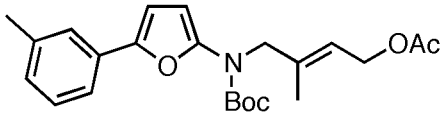
27

170.59
153.42
147.60
137.04
130.54
129.23
128.45
126.80
123.01
120.31
114.56
105.97
81.30
77.26
77.00
76.75
60.55
54.82
27.95
20.63
14.20



jix-331-028 1H NMR(400b) 021711

7.381
7.360
7.260
7.241
7.222
7.203
7.028
7.010
6.555
6.546
6.066
5.523
5.508
5.505
5.490
5.488
4.603
4.585
4.218
2.351
1.954
1.748
1.465



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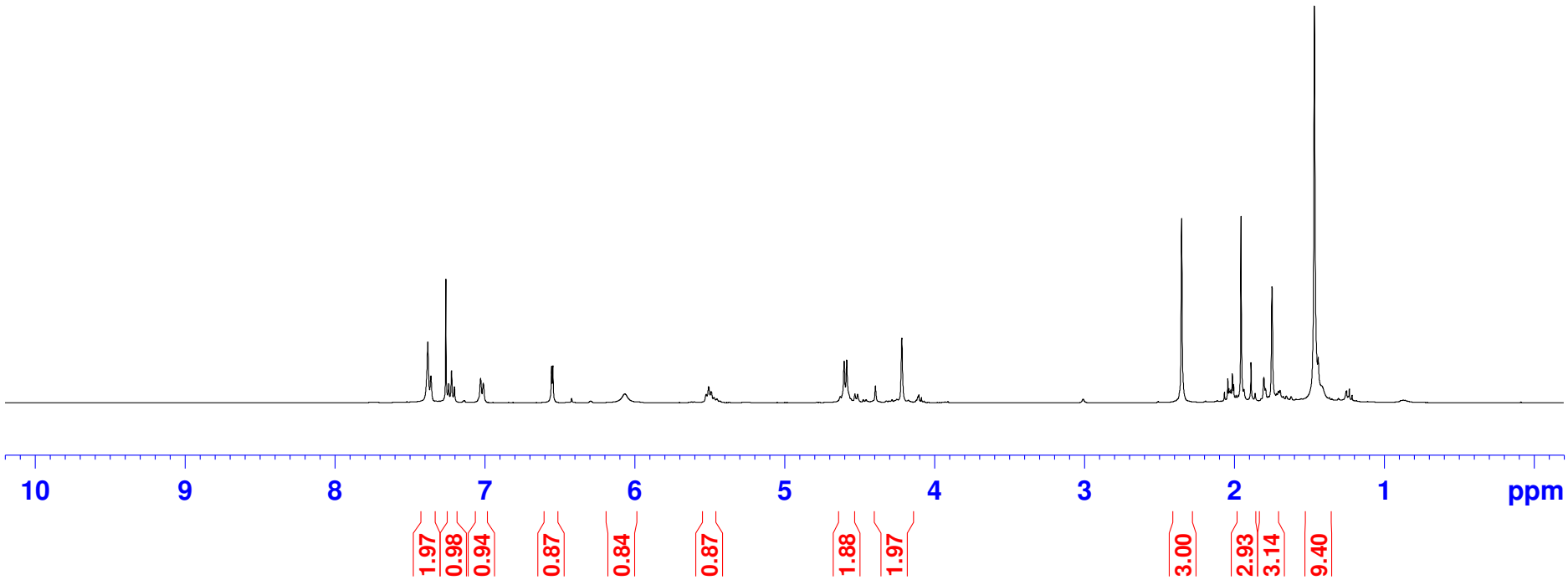
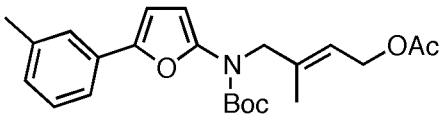


jix-331-028 13C NMR(400b) 021711

170.61
153.41
148.82
147.42
137.97
137.03
130.44
128.37
127.64
123.63
120.29
120.22
105.82
102.46
81.26
77.32
77.00
76.68
60.55
54.81
27.94
21.27
20.62
14.20



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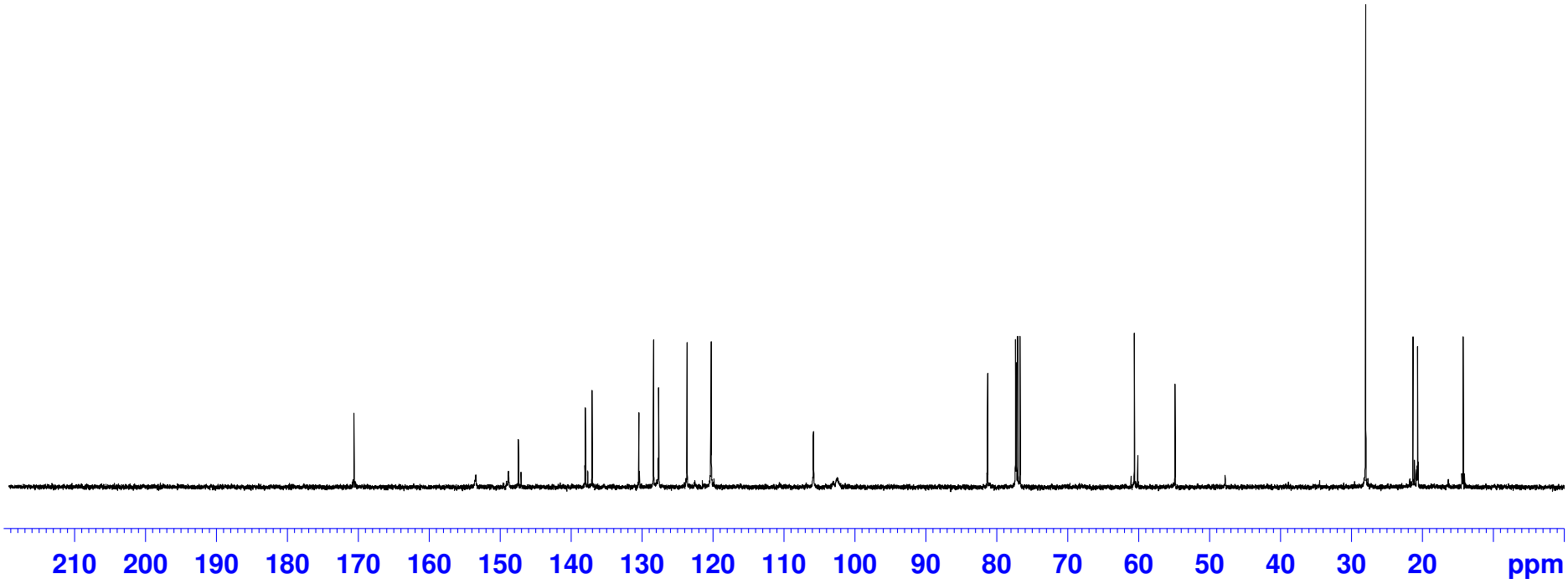
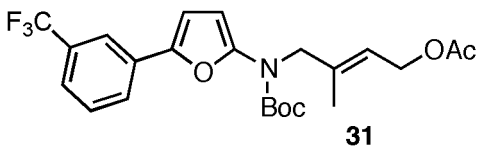


jix-331-019 1H NMR(400a) 021111

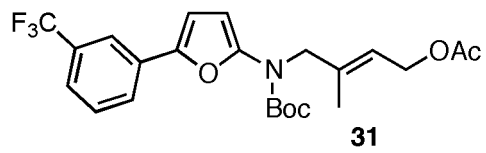


31

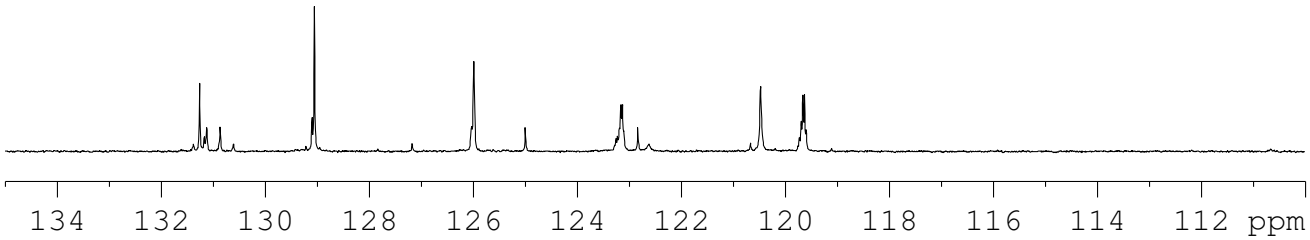
jix-331-019 13C NMR(500) 062711

170.65
153.23
148.46
147.02
136.93
131.26
131.12
130.86
129.05
125.99
125.00
123.20
123.16
123.13
123.10
122.84
120.48
119.69
119.66
119.63
119.60
107.57
102.37
81.63
77.26
77.00
76.75
60.56
54.73
27.94
20.59
14.20

131.257
131.119
130.861
129.048
125.990
125.003
123.195
123.164
123.135
123.105
122.837
120.477
119.694
119.661
119.631
119.602

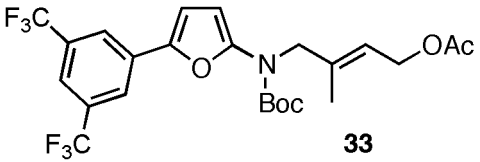


31

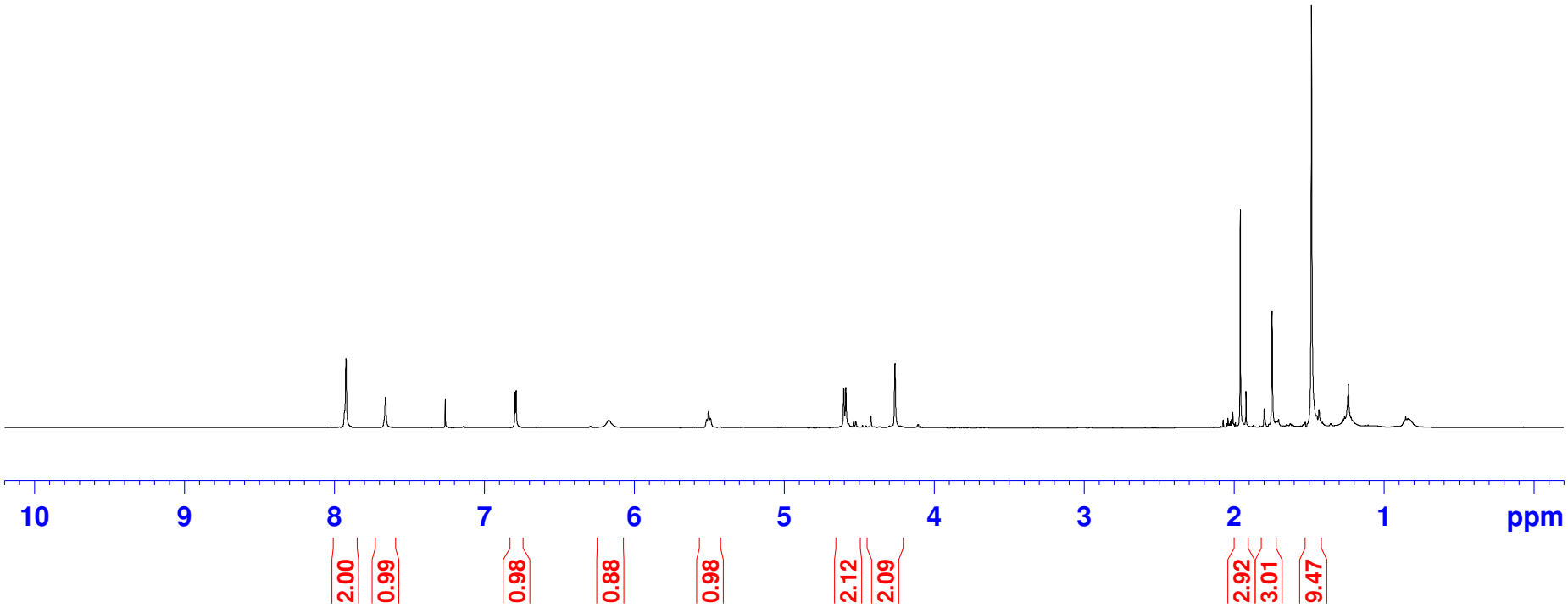


jix-331-036 1H NMR(500) 022411

7.922
7.659
7.260
6.794
6.787
6.169
5.517
5.506
5.504
5.492
5.490
4.603
4.589
4.261
1.958
1.746
1.483

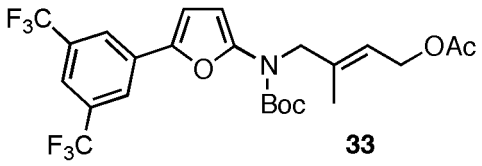


33

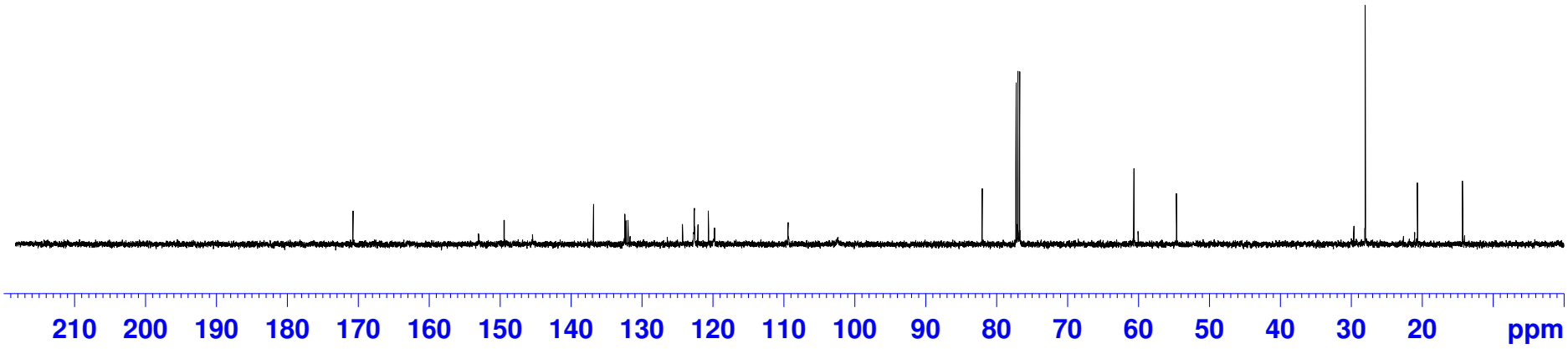


jix-331-036 13C NMR(500) 022411

170.75
153.04
149.43
145.44
136.84
132.40
132.22
131.95
124.27
122.60
122.11
120.63
119.77
109.40
102.36
82.03
77.26
77.00
76.75
60.63
54.63
28.01
20.66
14.29

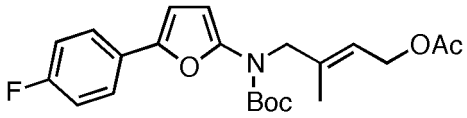


33

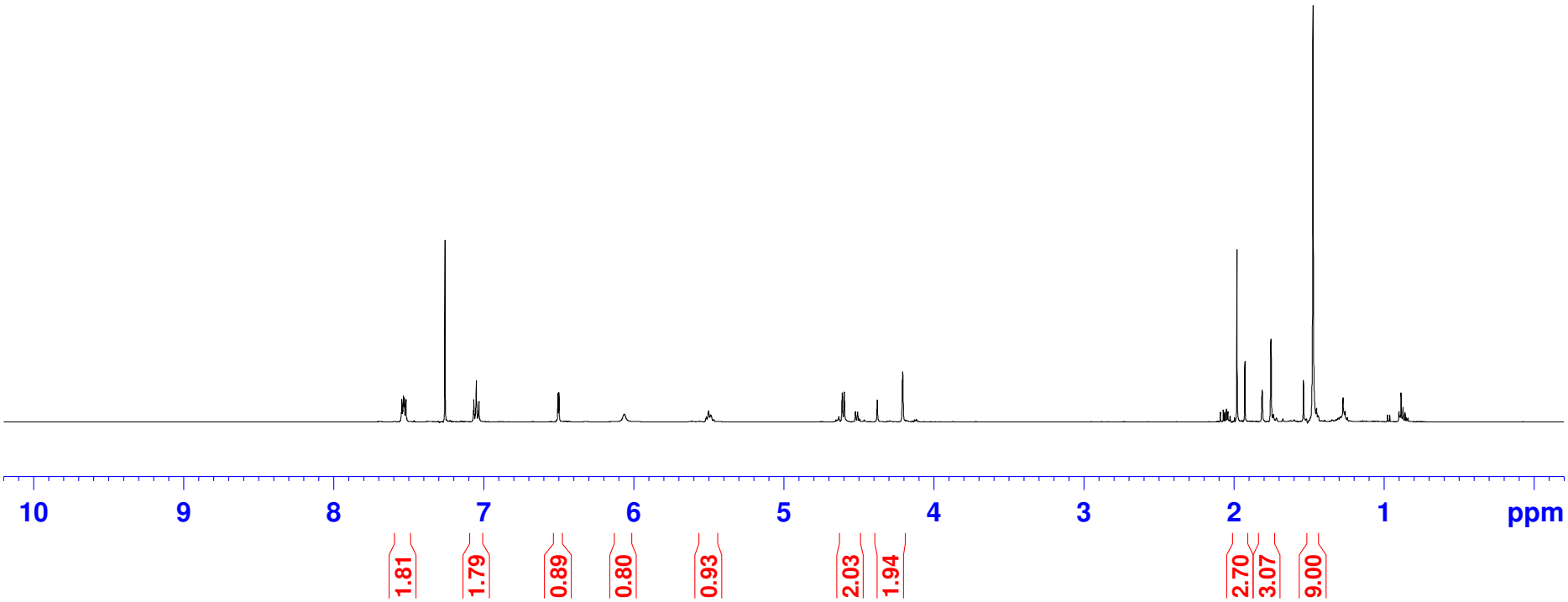


jix-331-013 1H NMR(500) 020711

7.552
7.548
7.544
7.541
7.538
7.534
7.530
7.524
7.520
7.260
7.068
7.064
7.051
7.036
7.033
7.027
6.507
6.500
6.065
5.519
5.516
5.505
5.502
5.500
5.494
5.491
5.488
5.485
5.482
4.612
4.598
4.523
4.509
4.378
4.209
1.980
1.928
1.813
1.812
1.754
1.474

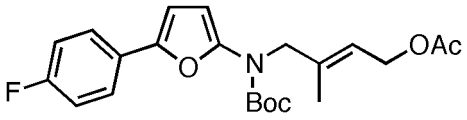


35



jix-331-013 13C NMR(500) 062711

170.67
162.74
160.78
153.48
147.96
147.66
137.07
126.99
126.96
124.85
124.79
120.34
115.59
115.41
105.64
102.62
81.42
77.25
77.00
76.74
60.61
54.95
27.99
20.69
14.24



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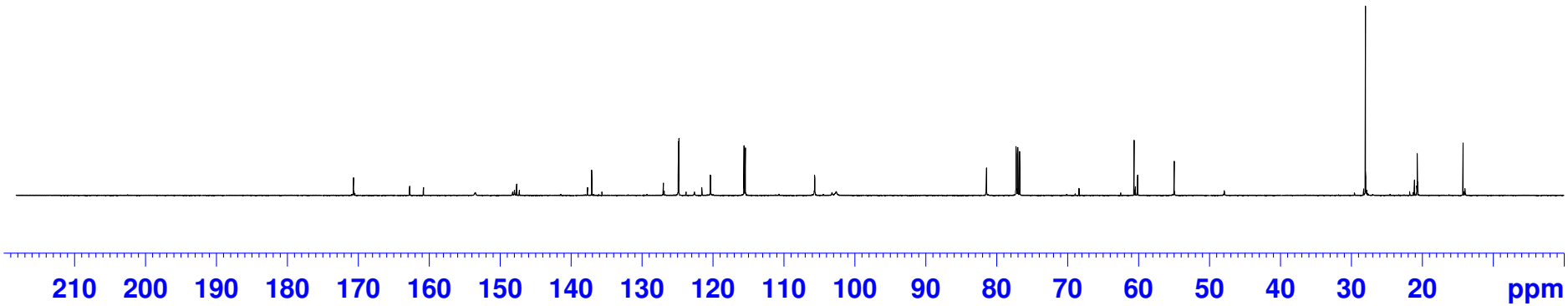
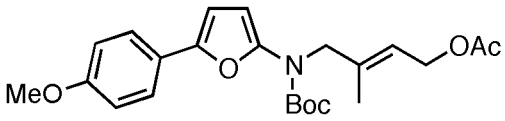
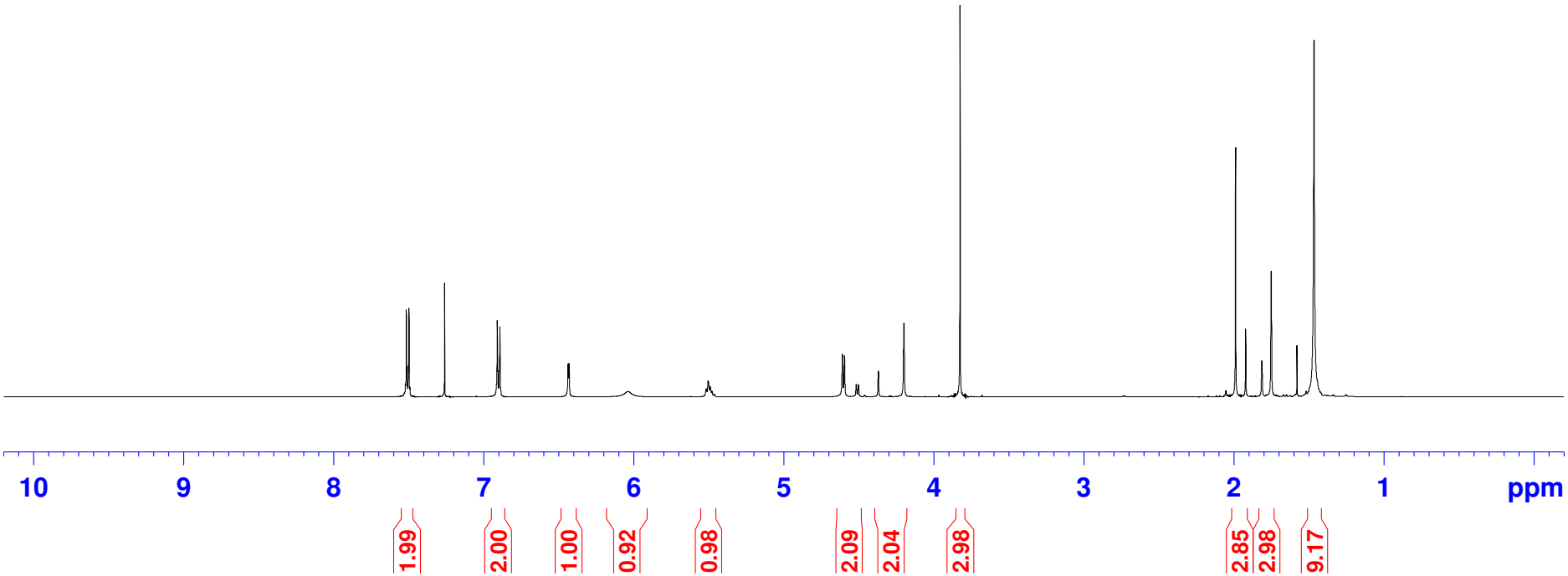


jix-315-093 1H NMR(500) 011211

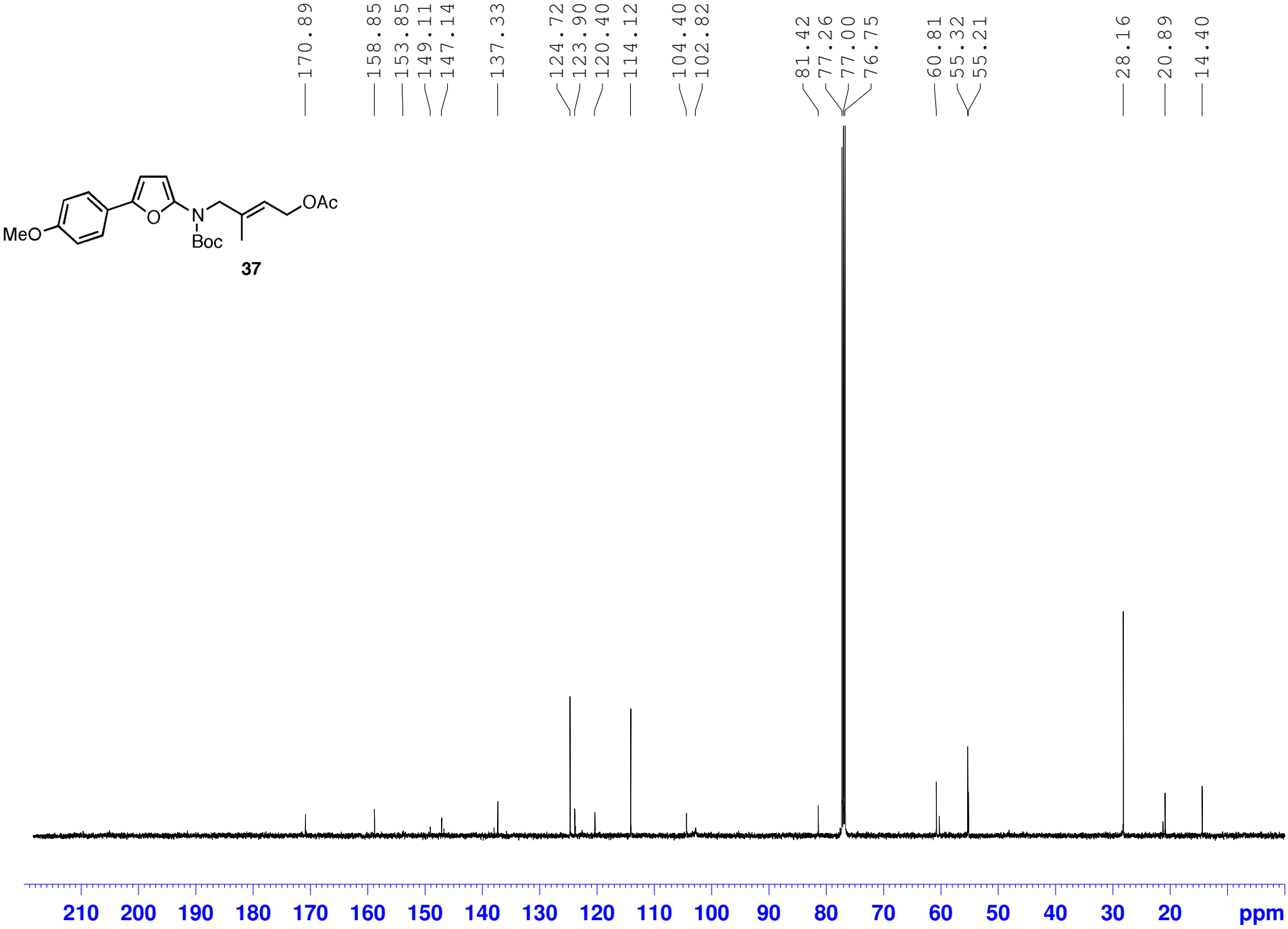
7.521
7.515
7.511
7.501
7.497
7.492
7.260
6.915
6.909
6.905
6.895
6.891
6.886
6.437
6.431
6.038
5.521
5.518
5.516
5.513
5.507
5.504
5.502
5.499
5.493
5.490
5.488
5.485
4.609
4.595
4.516
4.502
4.369
4.199
3.825
1.988
1.921
1.814
1.812
1.751
1.466



37

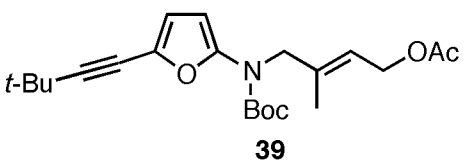


jix-315-093 13C NMR(500) 011211



37

jix-373-017 1H NMR(500) 102011



39

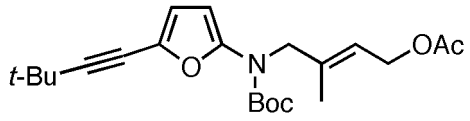
7.260
6.385
6.378
5.944
5.431
5.428
5.426
5.420
5.417
5.414
5.412
5.406
5.403
5.400
4.590
4.577
4.134
2.029
1.697
1.443
1.297

10 9 8 7 6 5 4 3 2 1 ppm

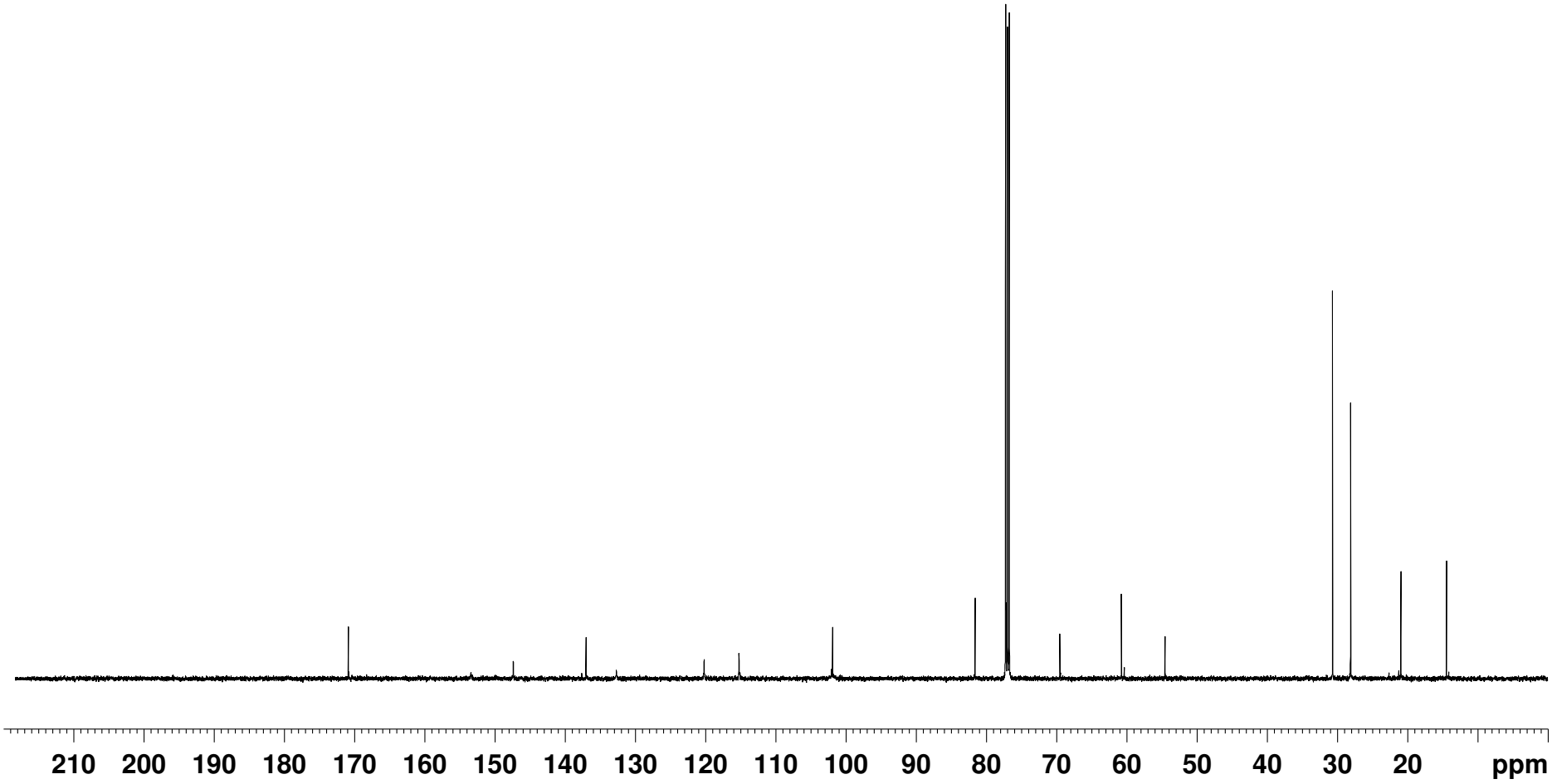
1.00 0.92 0.91 1.94 1.81 3.33 3.22 9.05 9.88

jix-373-017 13C NMR(500) 102011

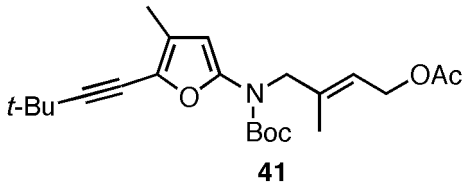
170.90
153.42
147.40
137.03
132.70
120.21
115.24
102.05
101.89
81.60
77.25
77.00
76.74
69.53
60.76
54.53
30.67
28.12
28.08
20.93
14.43



39



jix-344-008 1H NMR(400a) 051211

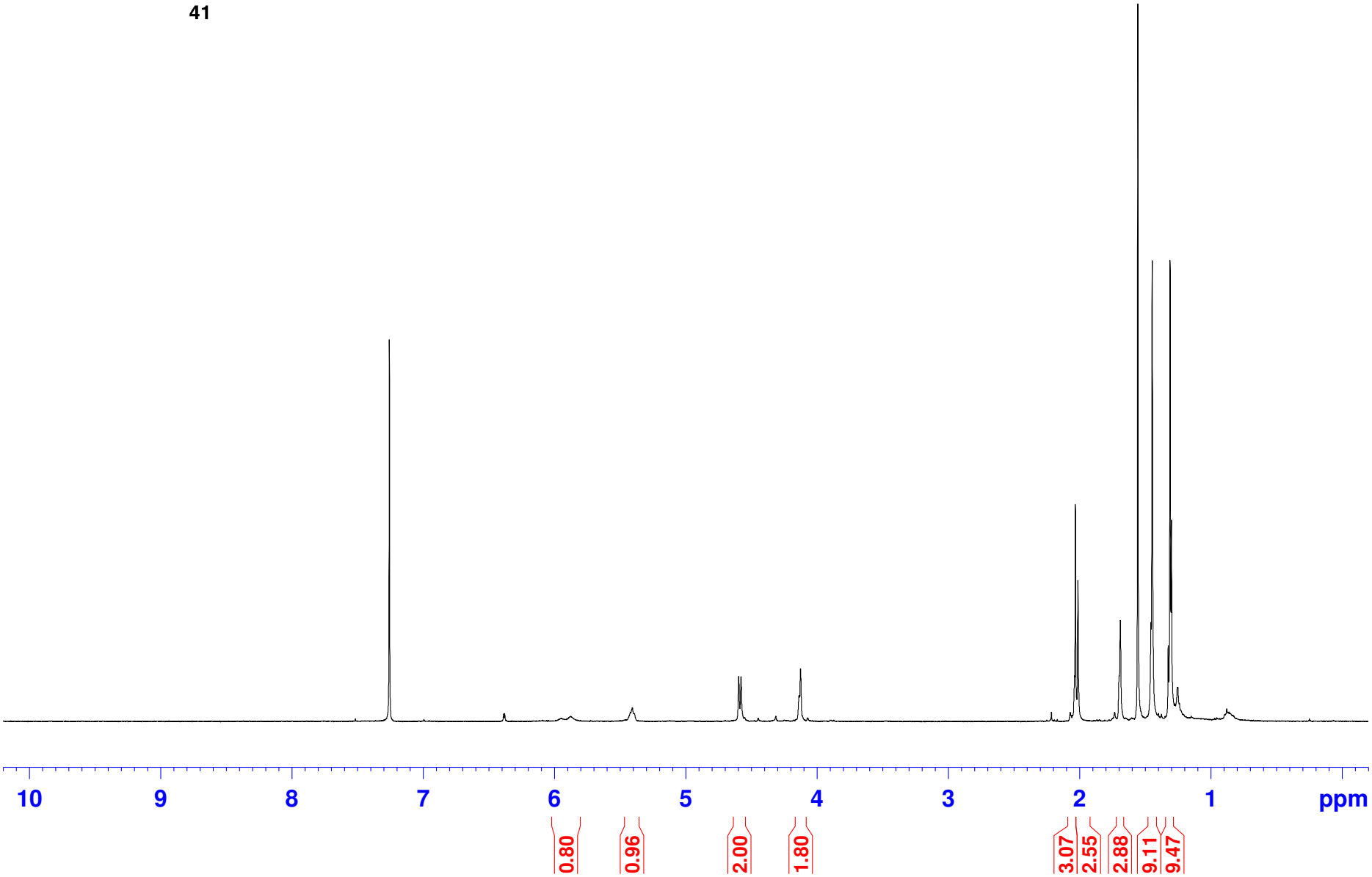


41

7.260

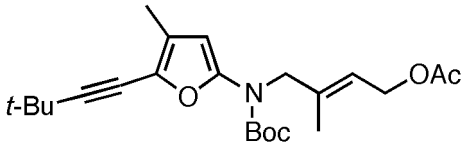
5.878
5.426
5.422
5.411
5.409
5.394
5.391
4.598
4.581
4.128

2.034
2.014
1.691
1.448
1.313

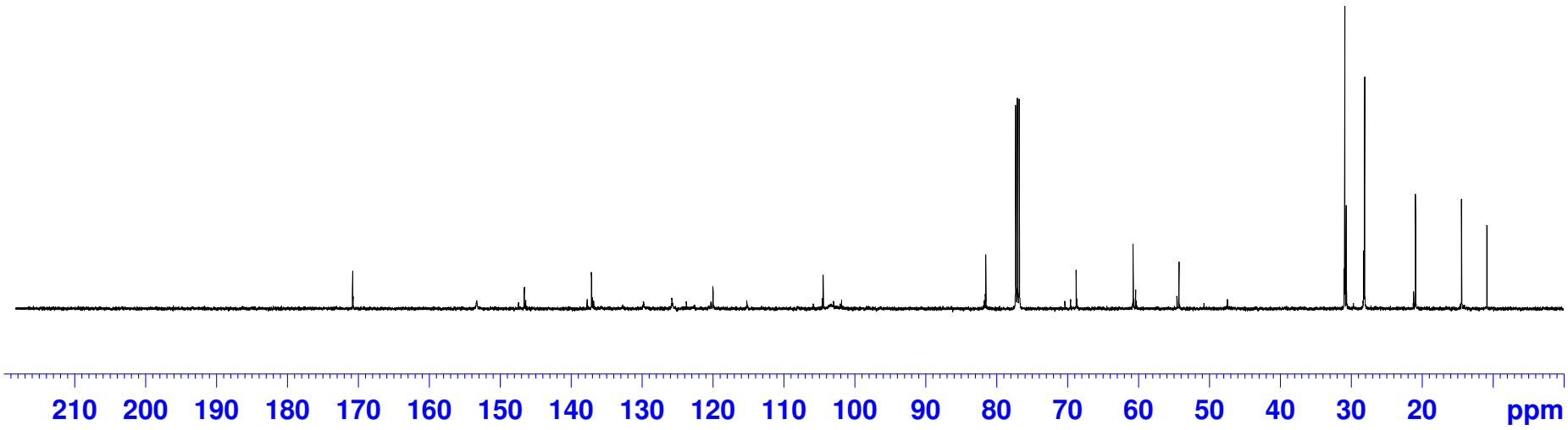


jix-406-039 13C NMR(500) 052212

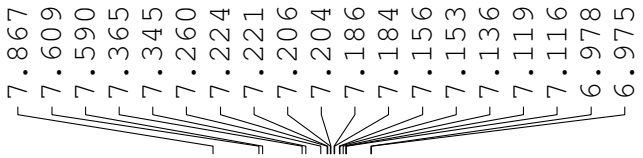
170.77
153.26
146.57
137.08
125.75
119.94
115.17
104.41
101.81
81.46
77.25
77.00
76.75
68.72
60.70
54.21
30.83
28.03
20.84
14.36
10.76

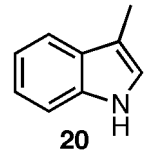


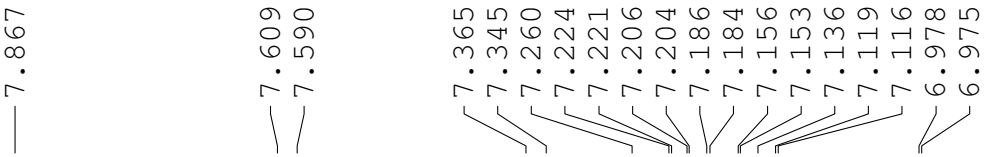
41

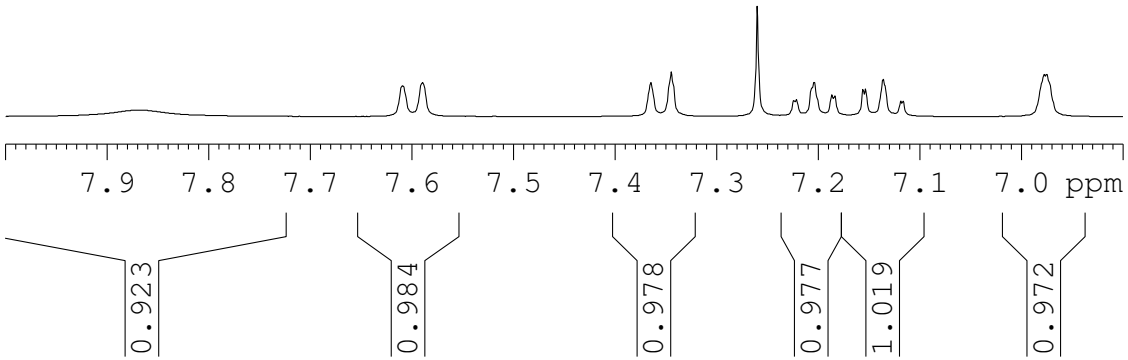


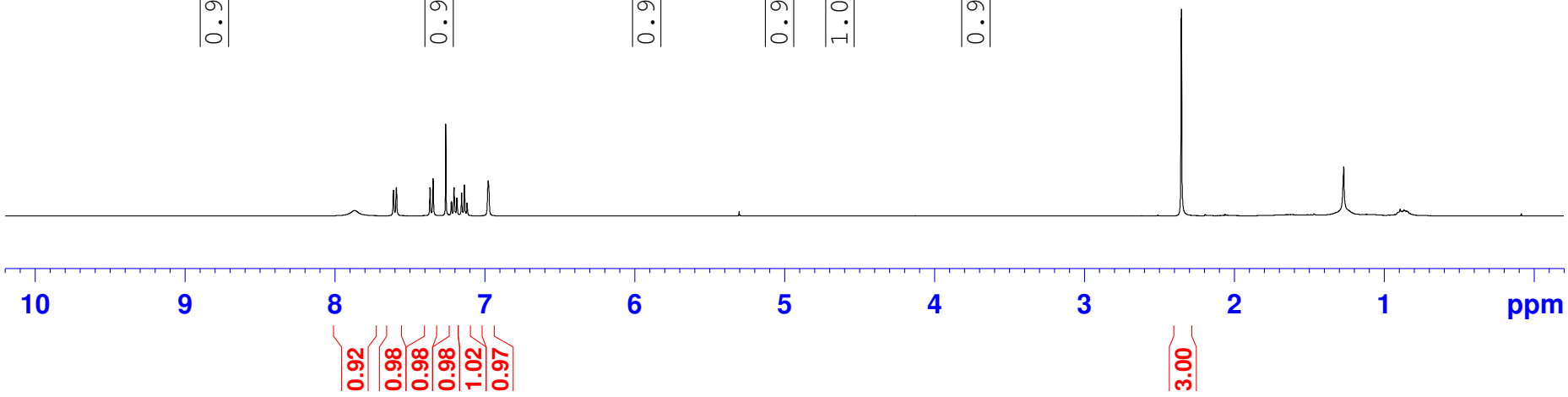
jix-315-009 1H NMR(400b) 062611



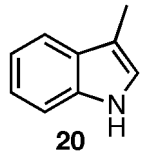






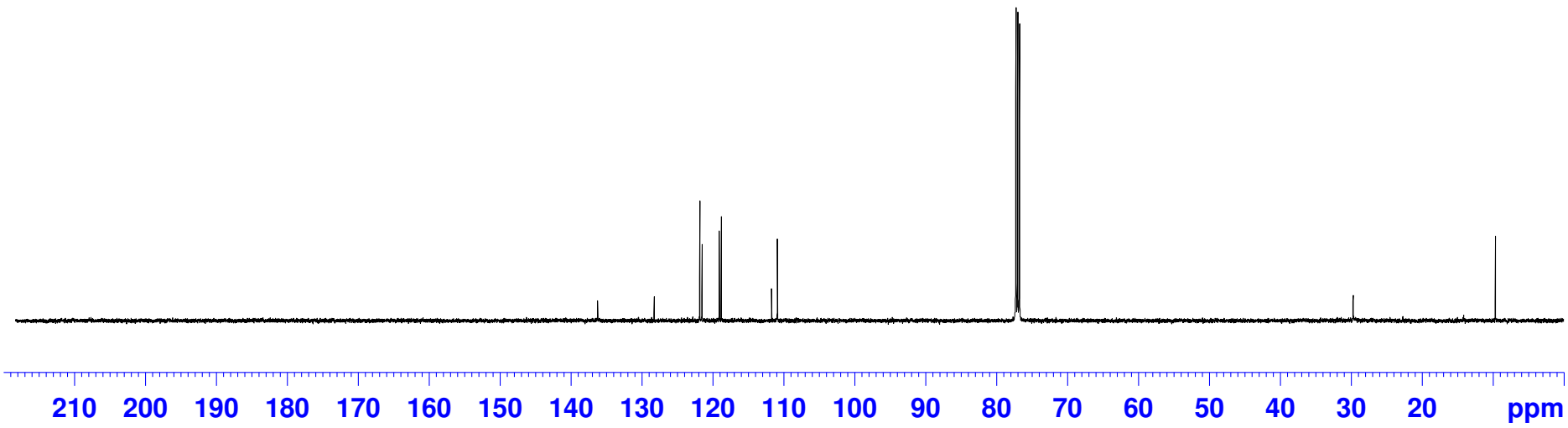


jix-315-009 13C NMR(500) 062711

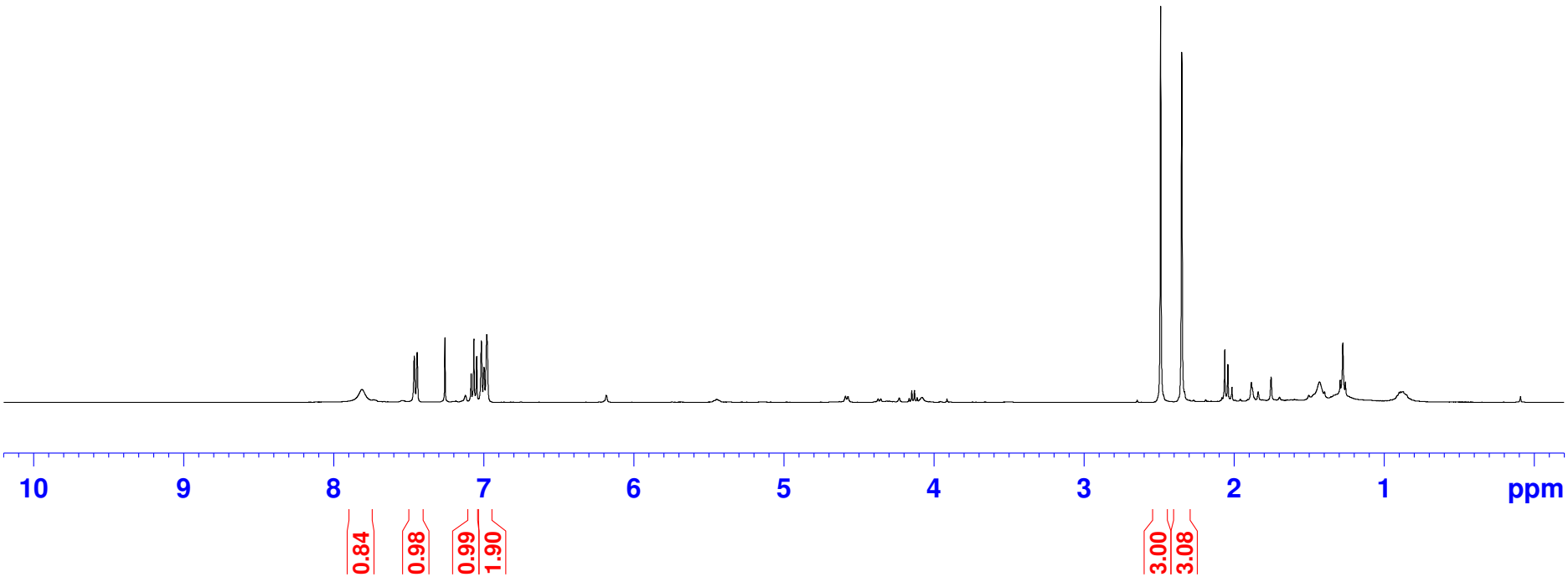


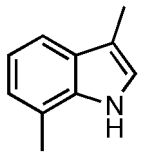
20

136.25
128.27
121.84
121.52
119.09
118.80
111.72
110.90
77.25
77.00
76.74
29.69
9.63



jix-331-056 1H NMR(400b) 031111



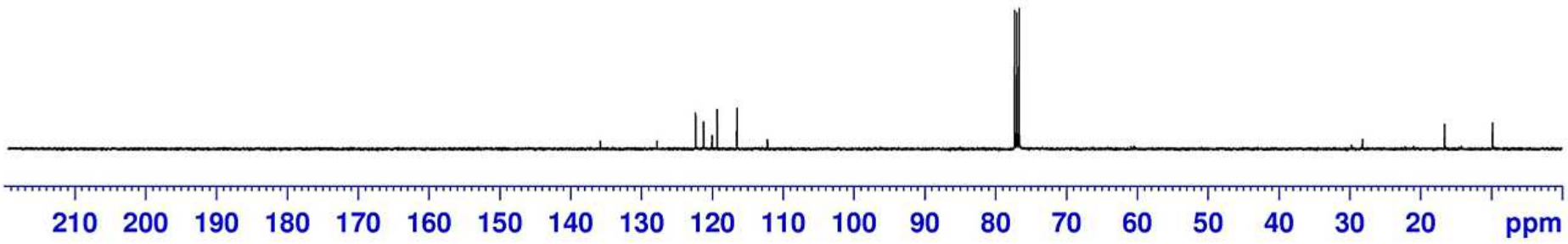


22

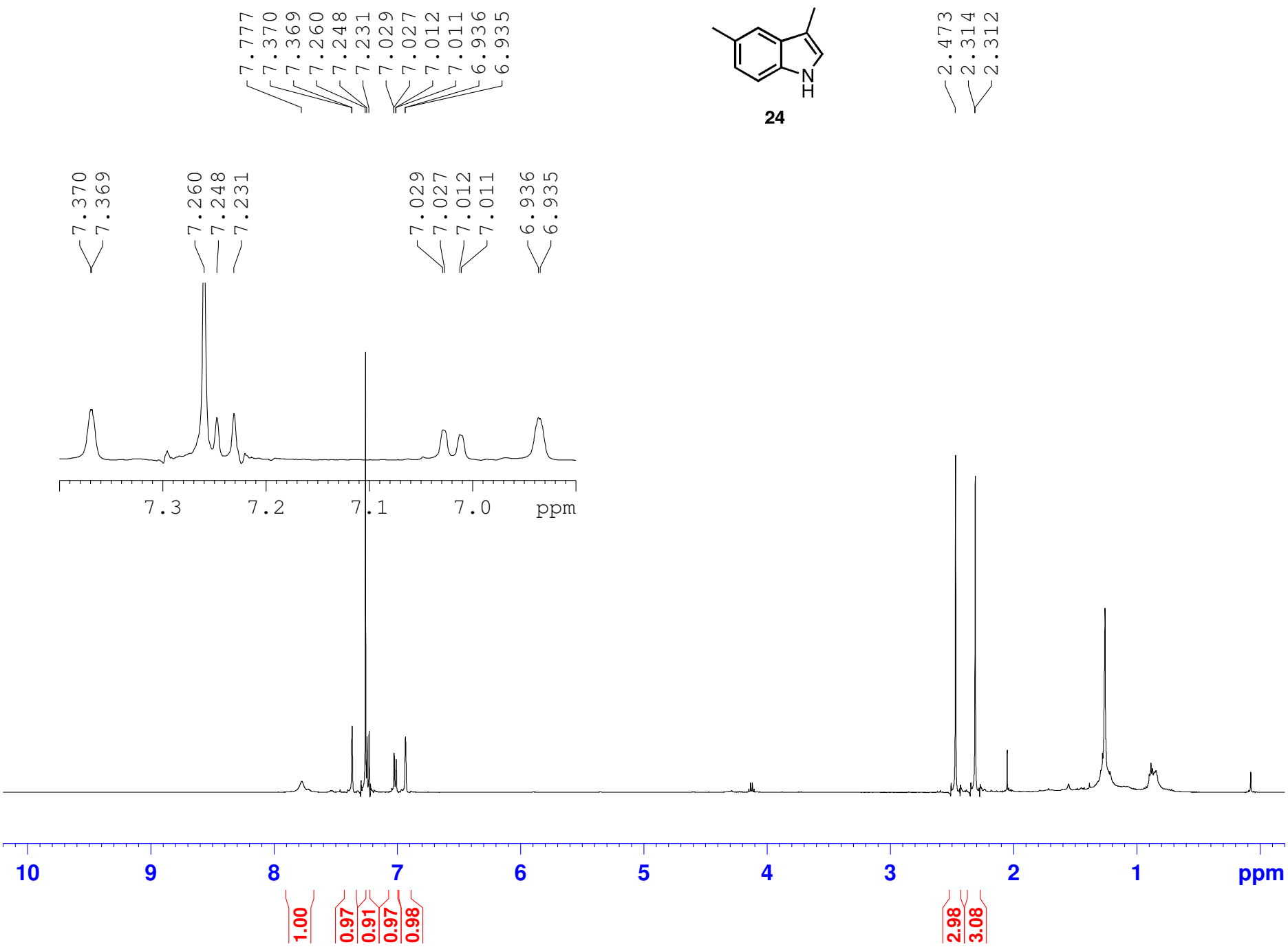
135.84
127.81
122.38
121.24
120.04
119.32
116.53
112.23

77.32
77.00
76.68

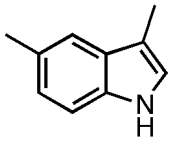
16.53
9.77



jix-315-065 1H NMR(500) 122010



jix-315-065 13C NMR(500) 122010

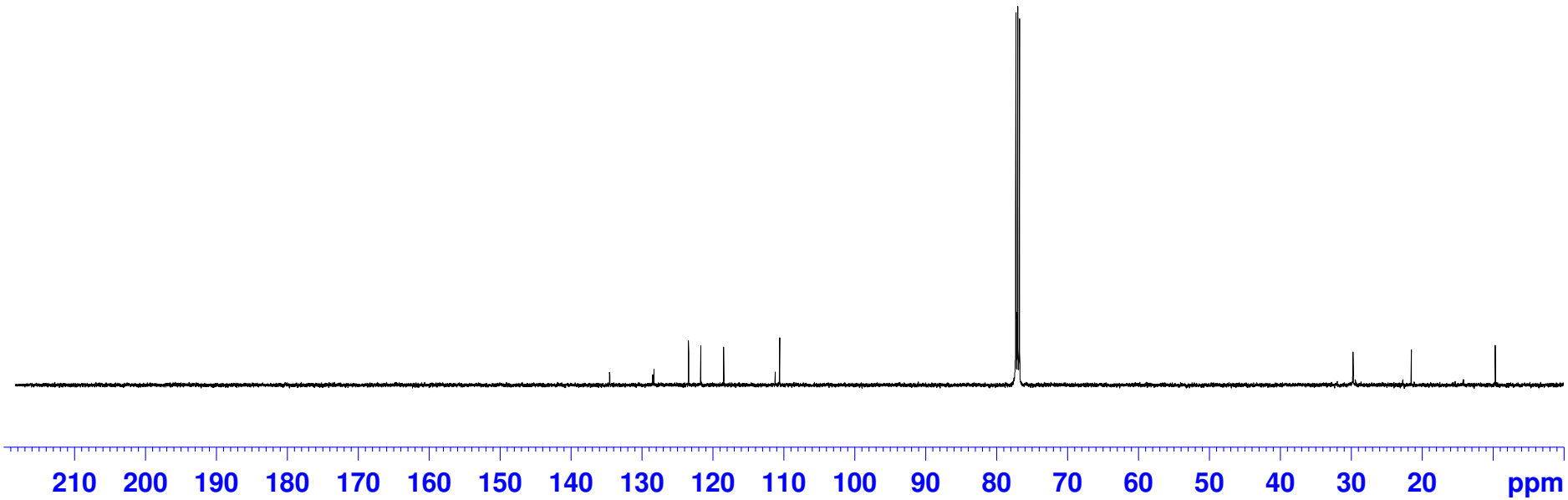


24

134.54
128.47
128.29
123.41
121.68
118.47
111.20
110.56

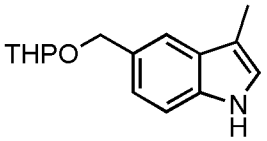
77.25
77.00
76.75

29.70
21.48
9.65

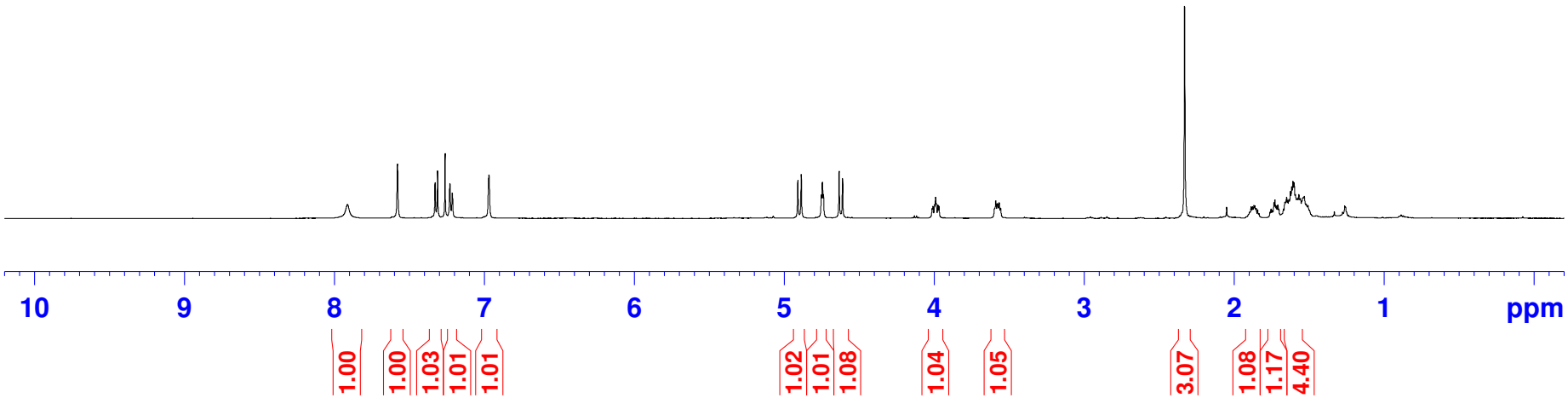


jix-344-012 1H NMR(500) 062211

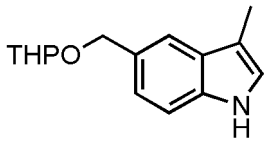
7.911 7.577 7.326 7.310 7.260 7.229 7.227 7.212 7.210 6.968 4.910 4.888 4.753 4.747 4.739 4.635 4.612 4.009 3.998 3.992 3.987 3.976 3.969 3.590 3.579 3.567 2.331 2.330 1.887 1.878 1.869 1.862 1.735 1.728 1.721 1.716 1.709 1.660 1.651 1.644 1.634 1.625 1.617 1.608 1.600 1.592 1.582 1.577 1.569 1.559 1.543 1.533 1.521 1.508



26

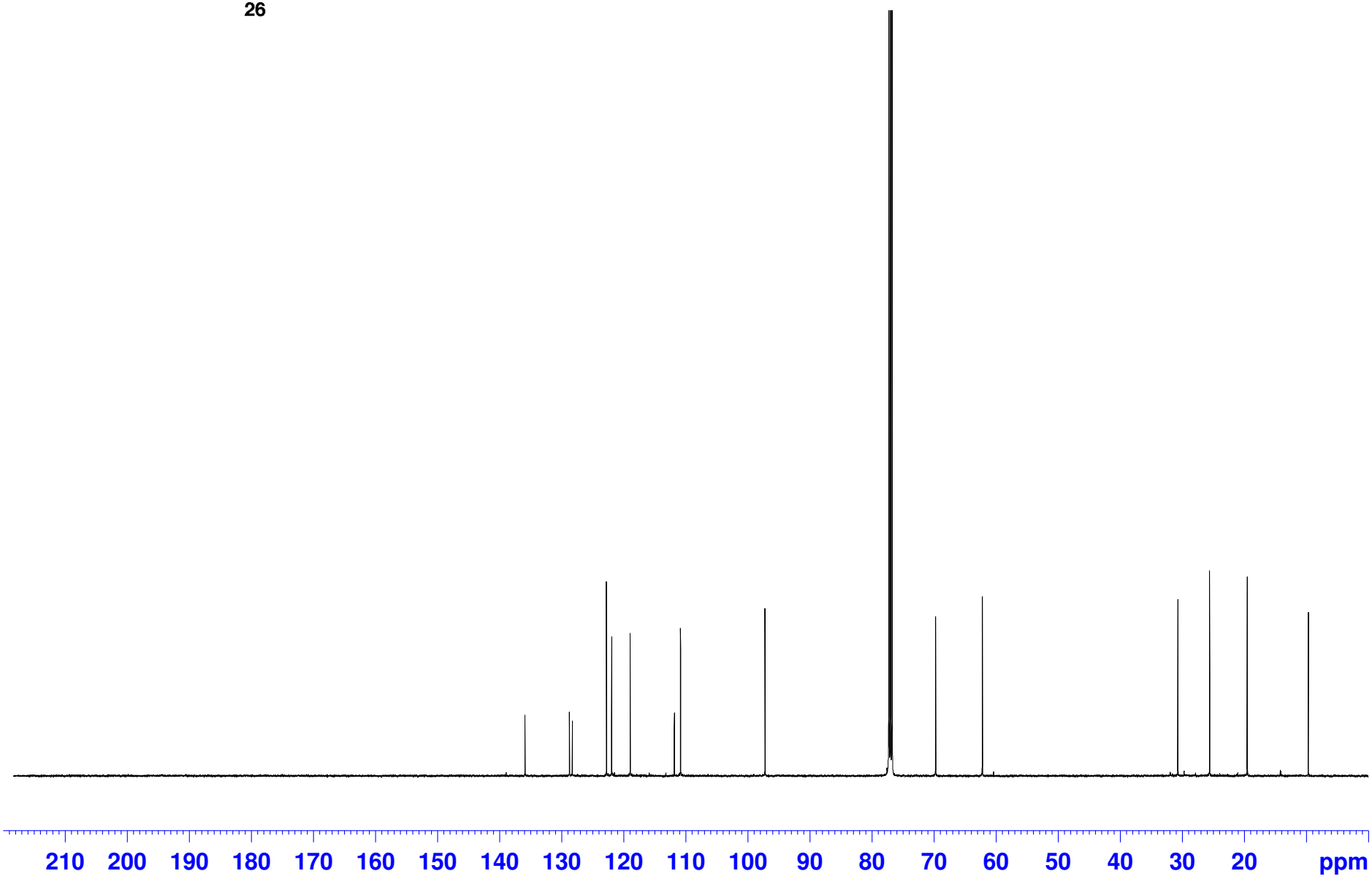


jix-344-012 13C NMR(500) 062211

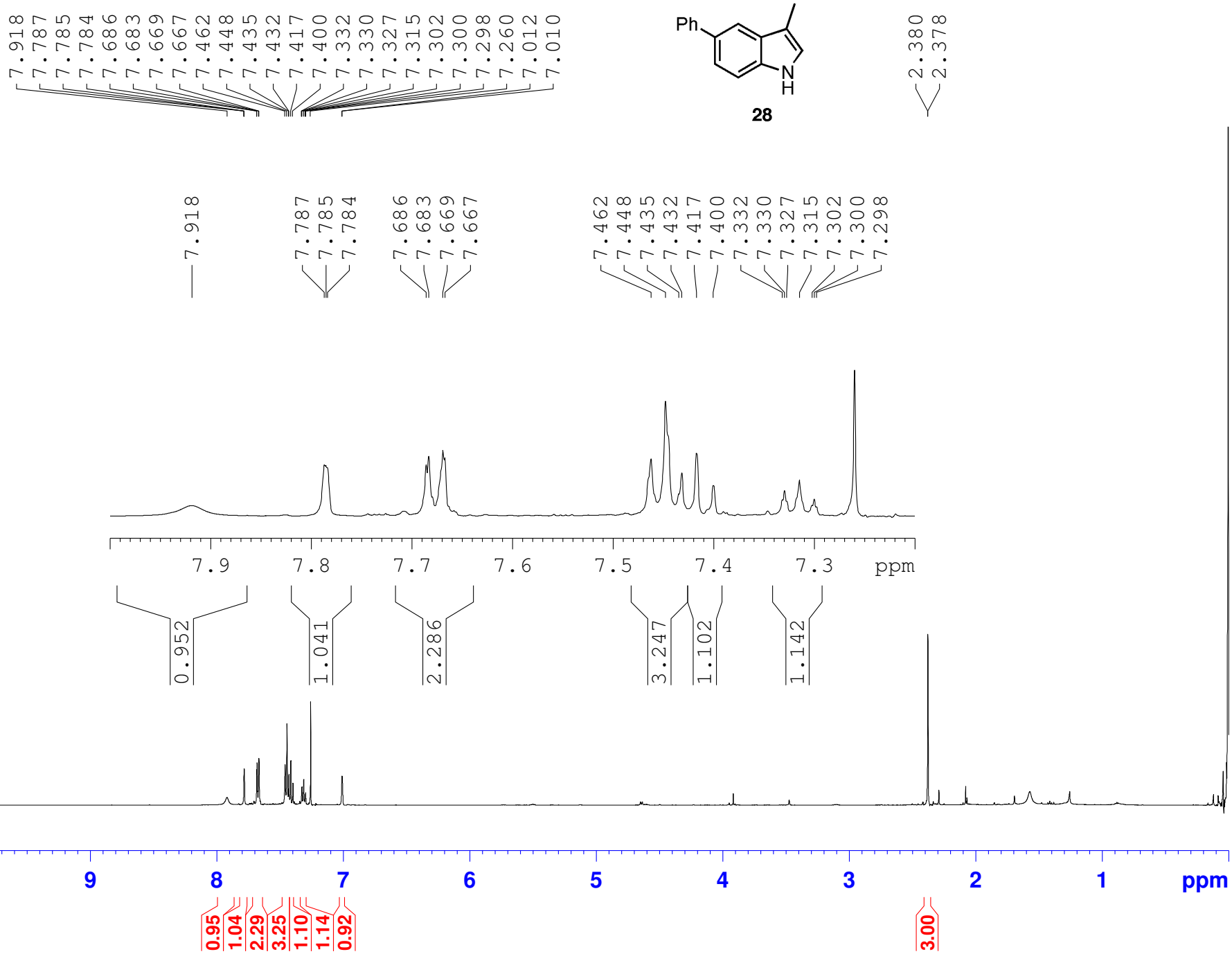


26

135.92
128.75
128.28
122.79
121.95
118.96
111.84
110.84
97.24
77.25
77.00
76.75
69.73
62.20
30.68
25.56
19.50
9.64



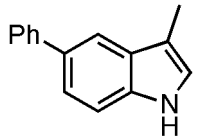
jix-331-008 1H NMR(500) 042011



jix-331-008 13C NMR(500) 042011

142.70
135.74
132.78
128.75
128.60
127.39
126.22
122.24
121.74
117.41
112.15
111.12

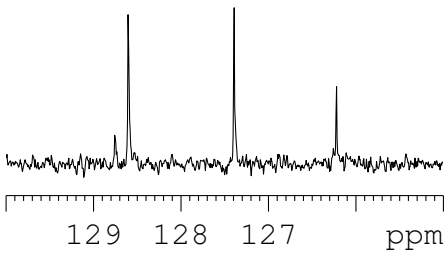
77.25
77.00
76.74



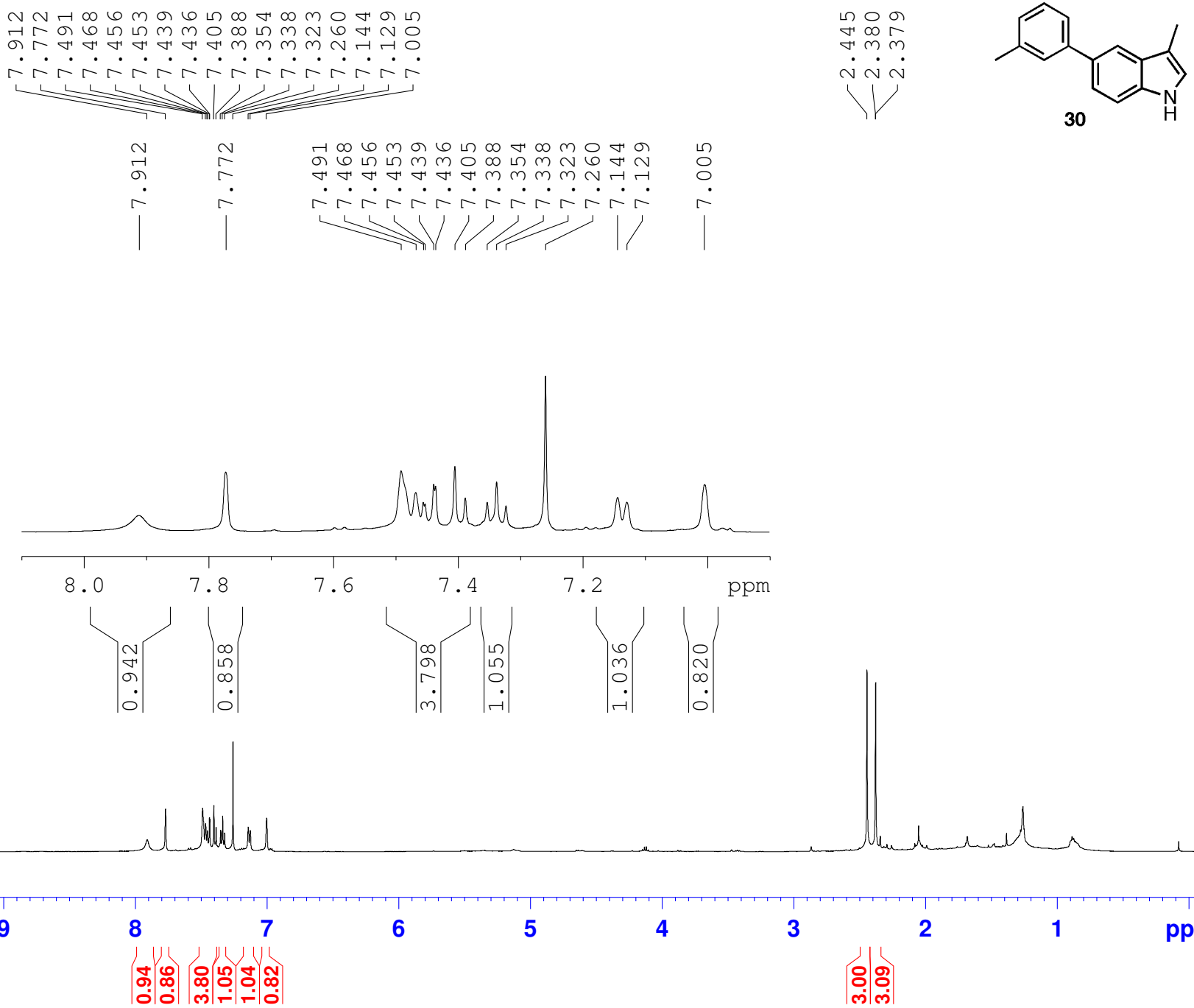
28

9.69

128.751
128.599
127.389
126.219



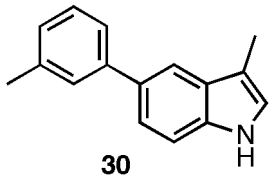
jix-331-029 1H NMR(500) 062011



jix-331-029 13C NMR(500) 062011

142.69
138.12
135.74
132.89
128.74
128.51
128.21
126.98
124.50
122.19
121.79
117.37
112.14
111.06

77.25
77.00
76.74

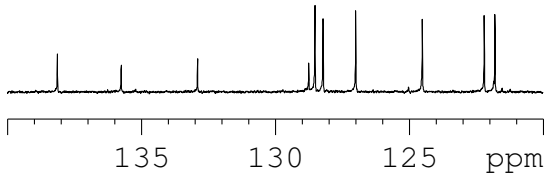


30

21.58

9.68

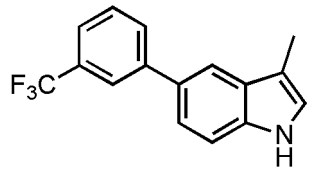
138.119
135.738
132.890
128.740
128.507
128.206
126.984
124.502
122.188
121.789



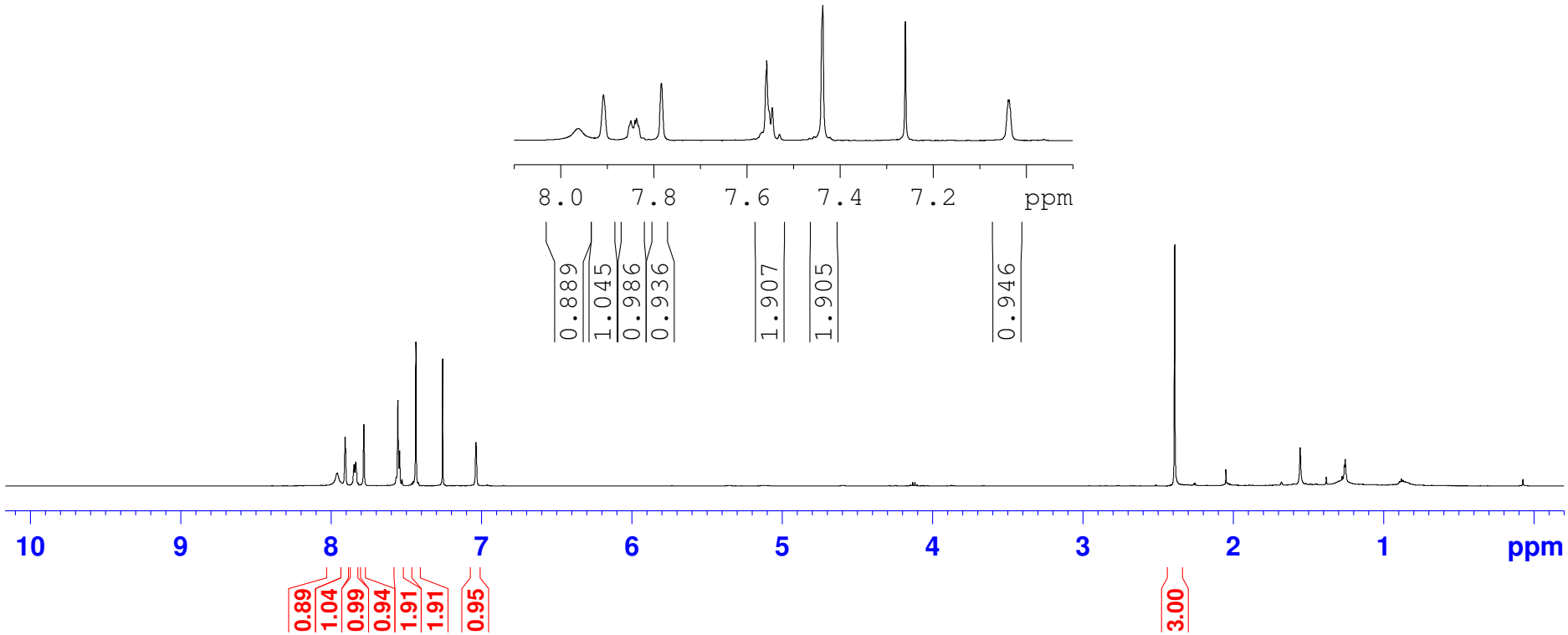
jix-331-023 1H NMR(500) 062411

7.962
7.909
7.853
7.850
7.841
7.838
7.784
7.558
7.546
7.437
7.260
7.039
7.037

2.393
2.391

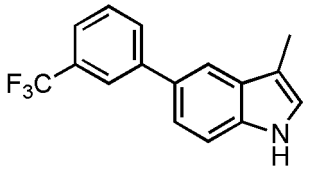


32



jix-331-023 13C NMR(500) 062411

143.48
136.09
131.29
131.08
130.83
130.60
129.01
128.88
125.46
124.09
124.06
124.04
124.00
123.30
122.90
122.87
122.84
122.81
122.56
121.54
117.60
112.32
111.40
77.25
77.00
76.75

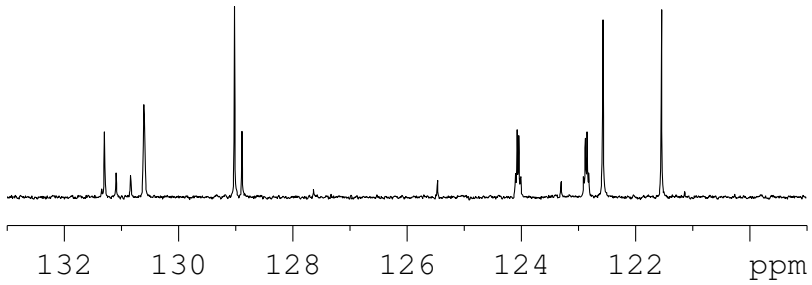


32

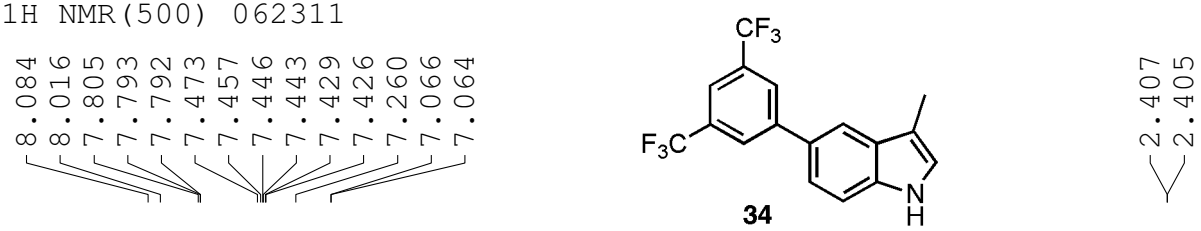
9.67

131.287
131.084
130.831
130.598
129.012
128.882

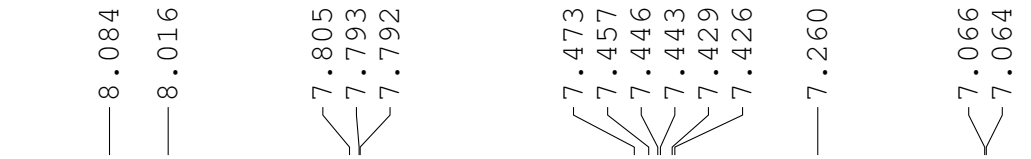
125.460
124.094
124.065
124.035
124.003
123.295
122.900
122.868
122.838
122.809
122.563
121.538

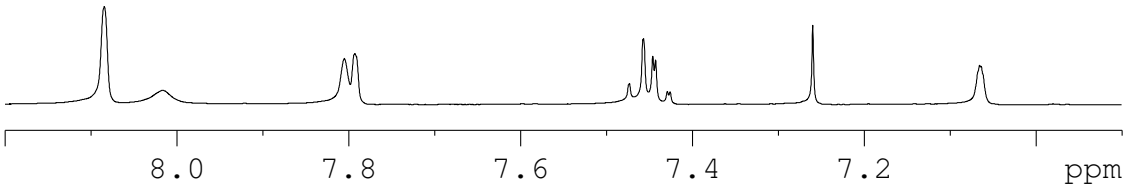


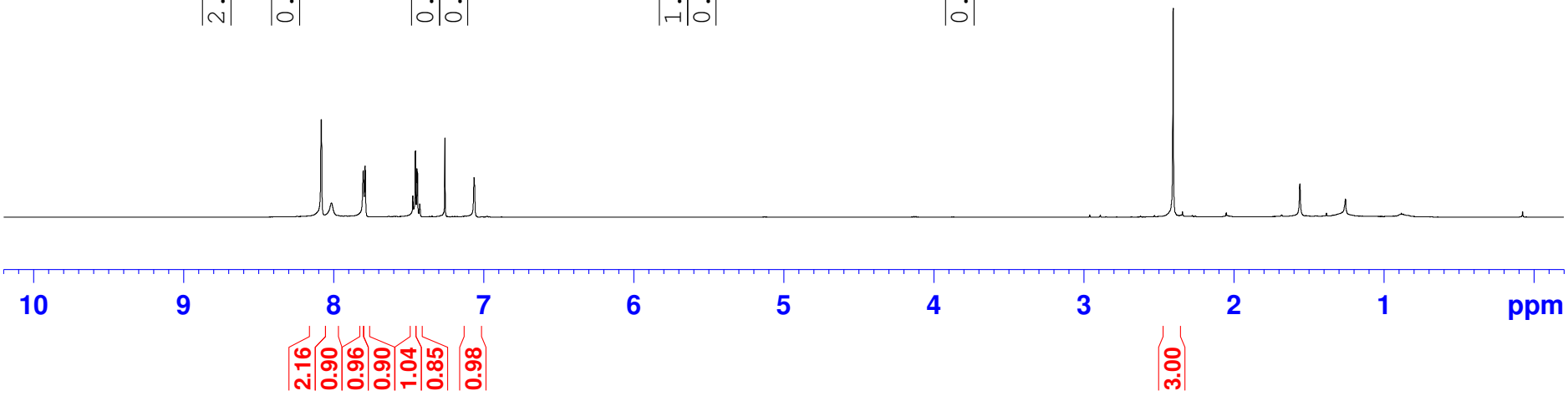
jix-344-016 1H NMR(500) 062311



34





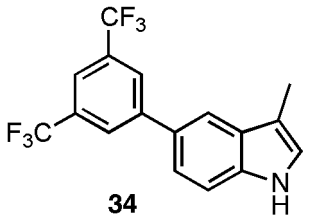


jix-344-016 13C NMR(500) 062311

144.79
136.44
132.24
131.97
131.71
131.45
129.69
129.00
127.26
124.66
122.91
122.50
121.33
119.77
119.74
119.71
117.83
112.49
111.70

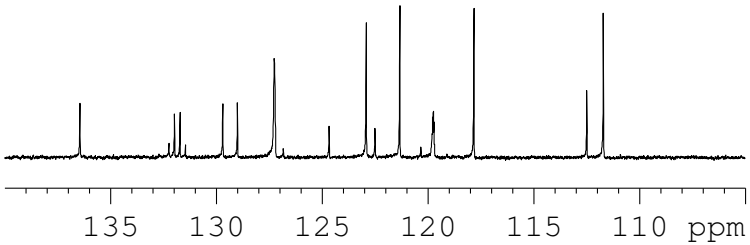
77.25
77.00
76.74

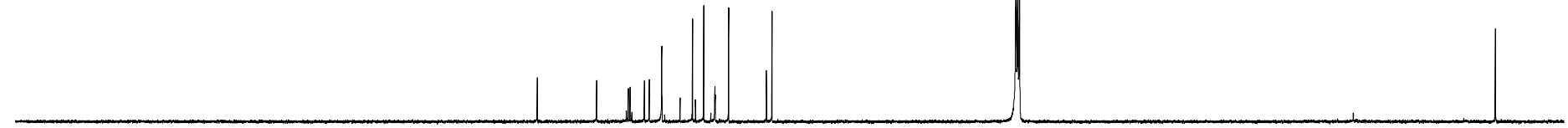
9.67



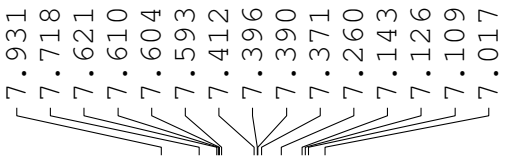
34

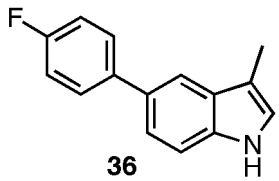
136.438
132.237
131.974
131.713
131.451
129.690
128.998
127.258
124.665
122.912
122.497
121.327
119.773
119.742
119.712
117.826
112.489
111.703



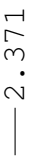


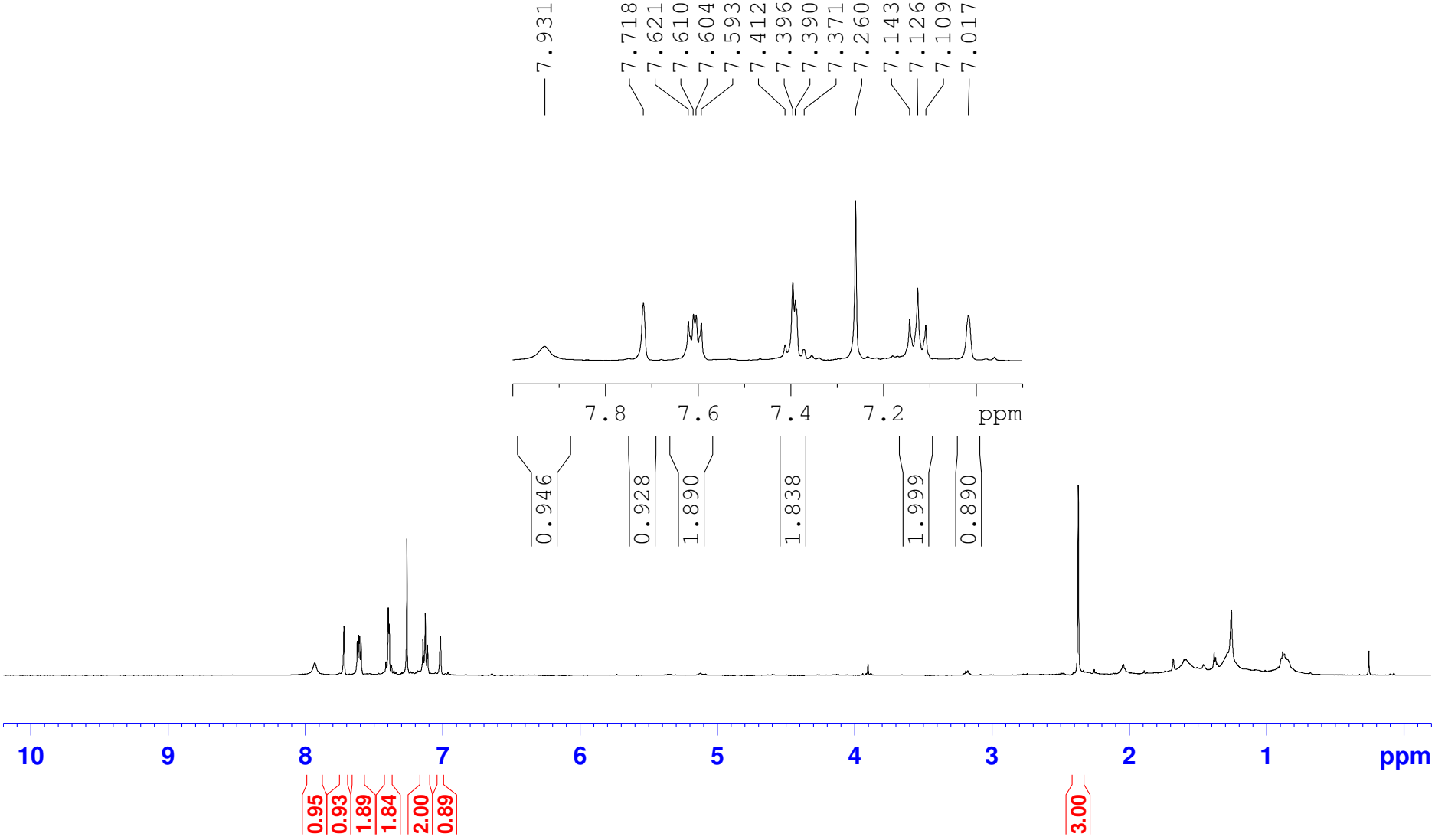
jix-331-014 1H NMR(500) 042111



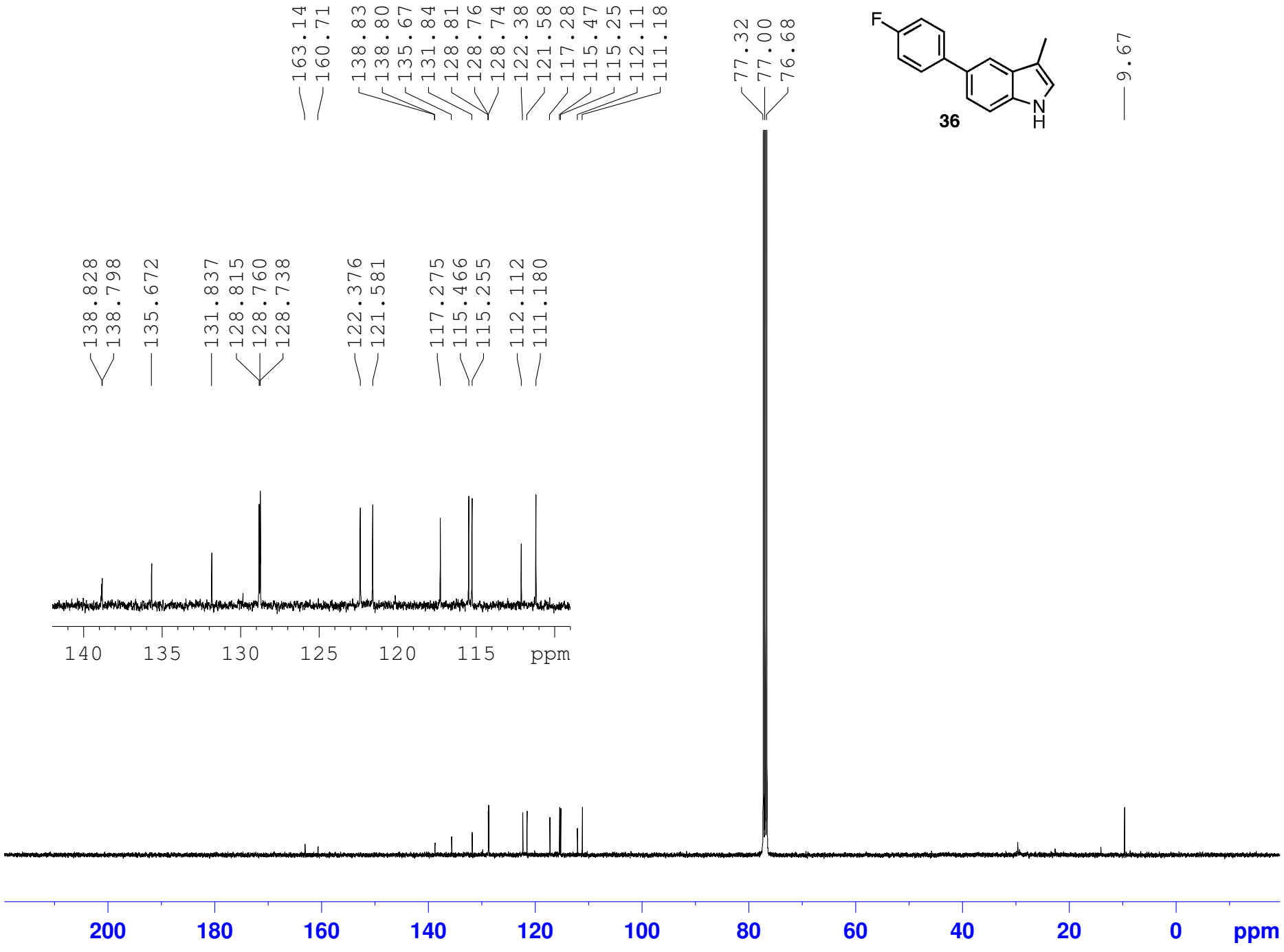


36

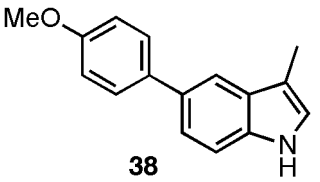




jix-331-014 13C NMR(400b) 042311



jix-344-047 1H NMR(500) 073011

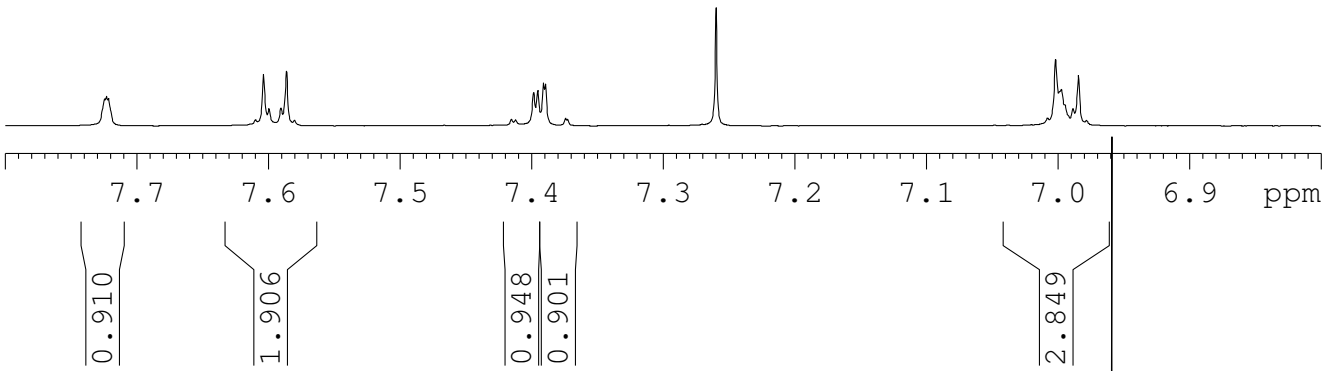


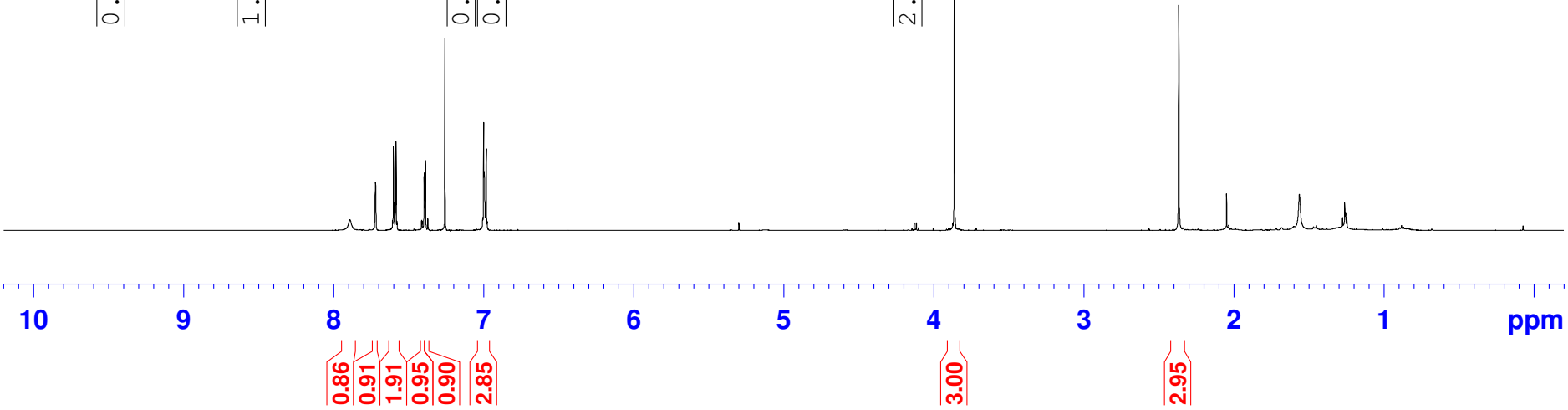
38

7.894 7.726 7.724 7.723 7.721 7.720 7.610 7.604 7.599 7.590 7.586 7.580 7.416 7.412 7.399 7.396 7.391 7.390 7.374 7.373 7.260 7.008 7.002 6.998 6.995 6.989 6.985 6.979

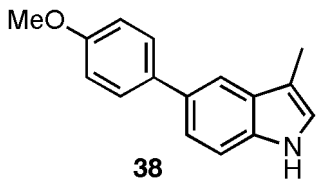
3.864

2.370 2.368



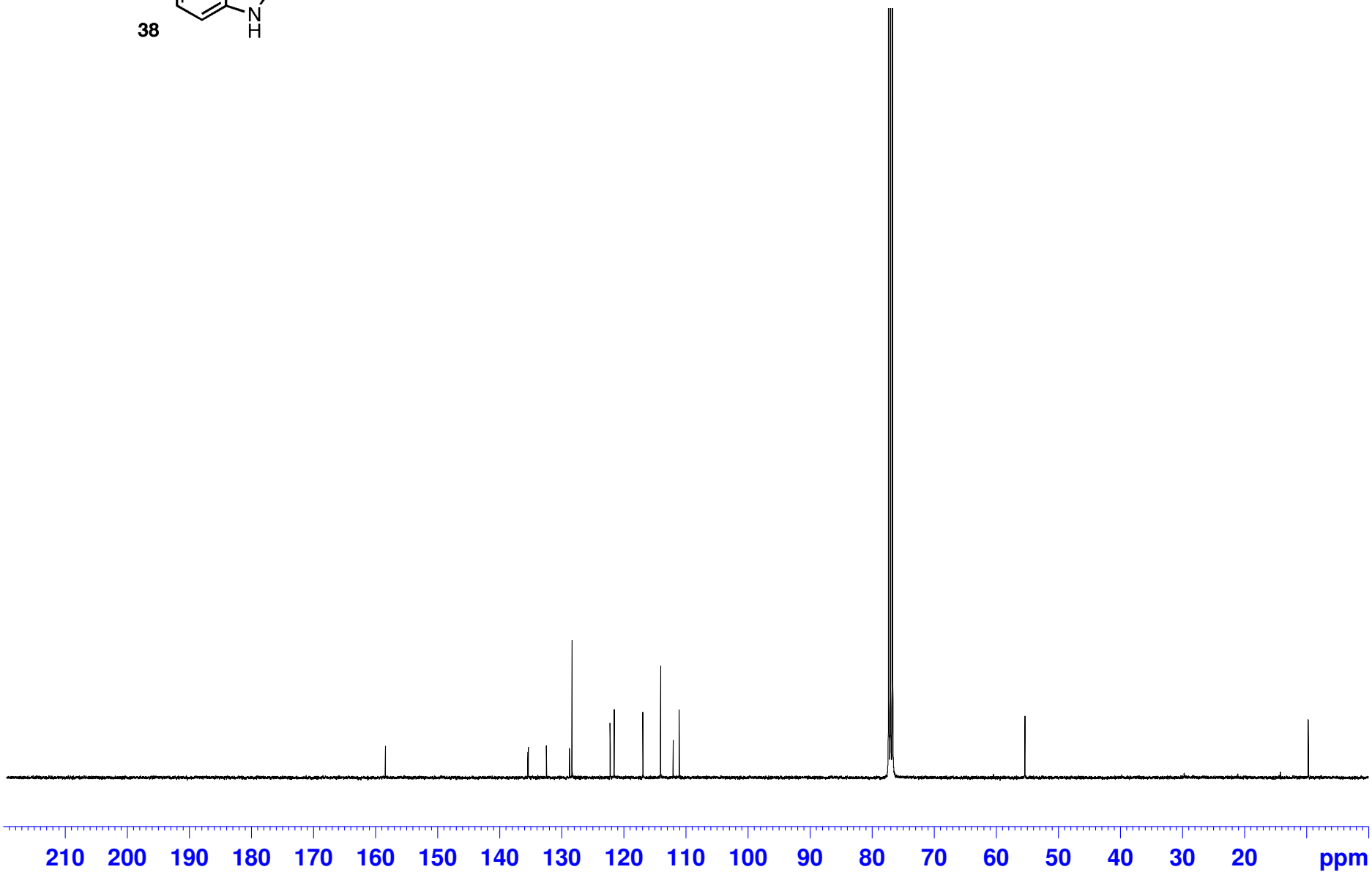


jix-344-047 13C NMR(400b) 072811

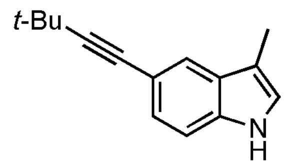


38

158.41
135.45
135.39
132.46
128.76
128.33
122.19
121.54
116.91
114.06
112.04
111.07
77.32
77.00
76.69
55.36
9.69



jix-344-013 1H NMR(500) 062111



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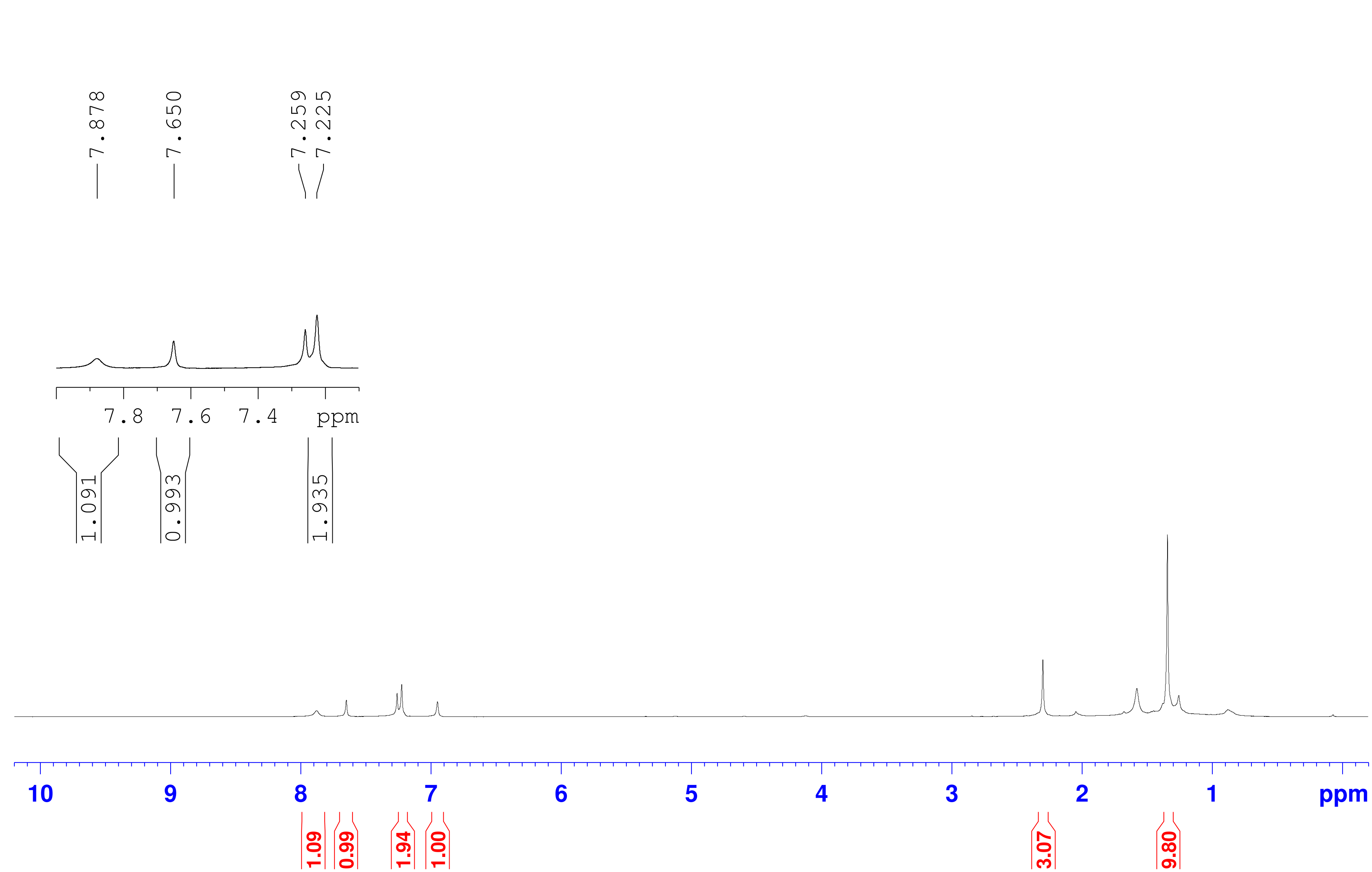
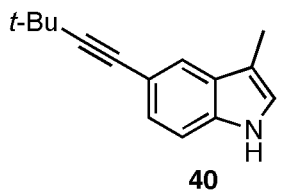


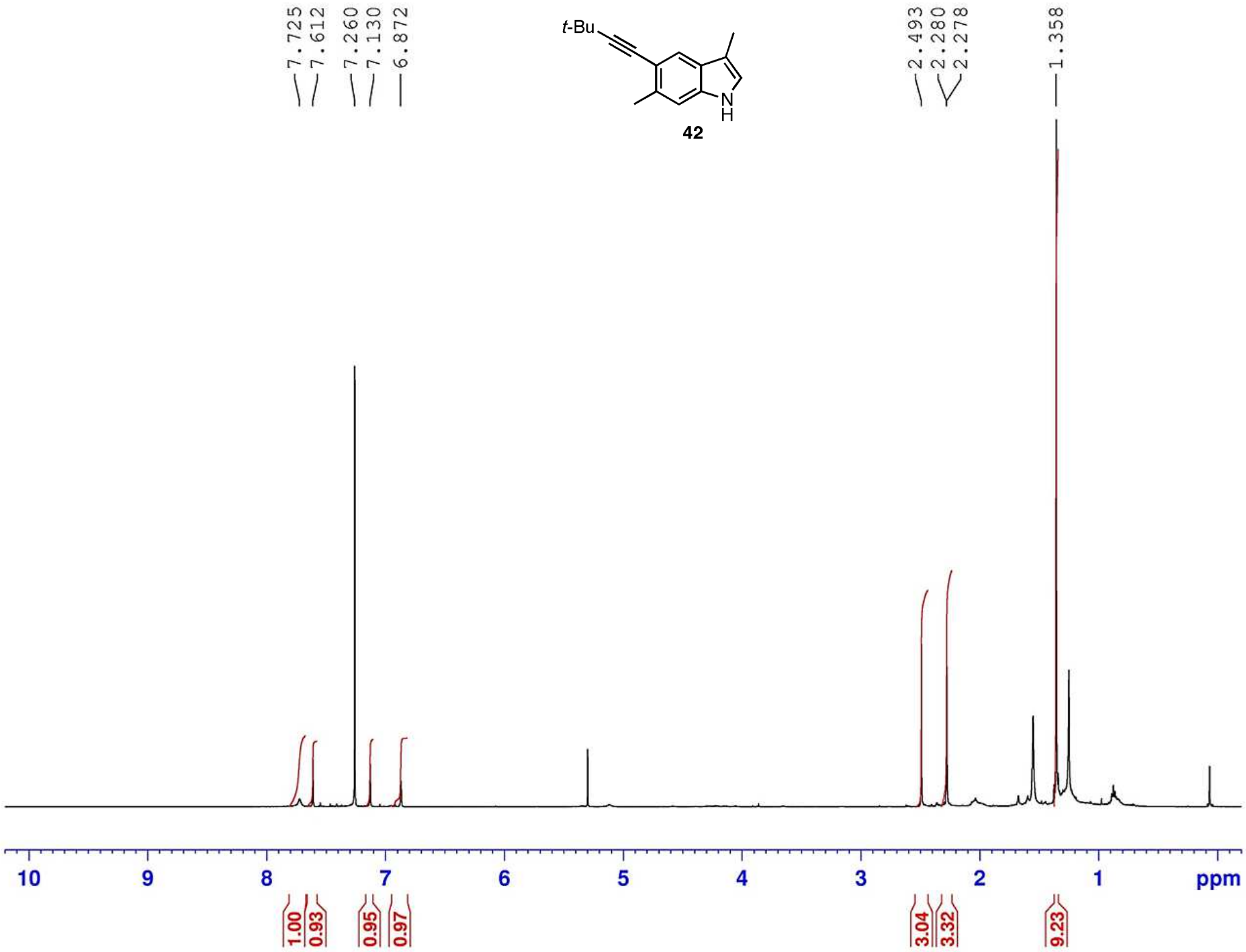
jix-344-013 13C NMR(500) 062111



40

135.50
128.18
125.63
122.50
122.11
114.49
111.89
110.70
95.60
80.21
77.25
77.00
76.74
31.29
27.92
9.56

210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 ppm


7.725
7.612
7.260
7.130
6.872
t-Bu
N
H
42
2.493
2.280
2.278
1.358
10
9
8
7
6
5
4
3
2
1
ppm
1.00
0.93
0.95
0.97
3.04
3.32
9.23