Electronic Supplementary Material (ESI) for RSC Advances.

Supporting Information

Regioselective Copper-Diamine-Catalyzed C-H Arylation of 1,2,4-Triazole Ring with Aryl Bromides

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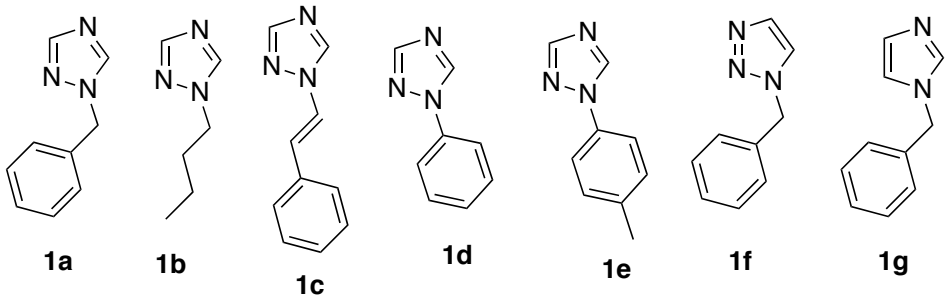
General Considerations

All commercially available chemicals and anhydrous solvents were used directly upon purchase from suppliers. Analytical thin layer chromatography (TLC) was performed using Merck 60 F254 precoated silica gel plates (0.2 mm thickness) and visualized using UV radiation on Spectroline Model ENF-24061/F 254 nm. Flash chromatography was performed using Merck silica gel 60 with AR grade solvents. Columns were packed as a silica gel suspension in hexane prior to elution by the appropriate solvent system (hexane/EtOAc). Melting points were determined using OptiMelt automated melting point system and are uncorrected. Nuclear magnetic resonance (NMR) spectra were recorded on a Bruker Avance DPX 400 spectrophotometer. Chemical shifts for ^{1}H and ^{13}C NMR are reported as δ in units of parts per million (ppm) downfield from $SiMe_4$ and relative to the residual signal of $CDCl_3$ (δ 7.26, singlet for ^{1}H NMR; d 77.06, triplet for ^{13}C NMR). Multiplicities are reported based on apparent multiplicities and coupling constants (*J* values) are reported in unit of Hertz (Hz). Numbers of protons are reported based on the appropriate integration of the signals. IR spectra were recorded using Perkin–Elmer Paragon 100 FT-IR spectrophotometer on KBr plates. Mass spectroscopy was performed using Agilent 1100 series LC/MSD.

Synthesis of Substrates



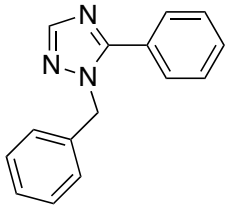
1a was synthesized according to modified literature procedure: To an oven-dried 50-mL RBF equipped with a magnetic stir bar, benzyl bromide (5.0 mmol) and MeCN (20 mL) were added. K_2CO_3 (3.0 equiv.) was then slowly added followed by 1,2,4-triazole (5.0 equiv.). The reaction mixture was then heated at 85 ^oC under N_2 for overnight. Upon cooling to room temperature, the reaction mixture was passed through a pad of celite with EtOAc washing and the filtrate was then concentrated under reduced pressure. The residue was next redissolved in EtOAc and subsequently washed with concentrated aqueous $NaHCO_3$ (3 times), water and brine. The organic layer was then dried Na_2SO_4 and concentrated under reduced pressure to afford the analytically pure **1a** as light yellow viscous oil which slowly solidified to off-white solid in 78% yield (621 mg). **1b**, **1f** and **1g** were also prepared according to the same procedure using the appropriate starting materials. All compounds were used without further purification except **1f** which was further purified by silica gel column chromatography prior to use. **1a**,[1] **1b**,[2] **1f**[1] and **1g**[3] are known compounds whose homogeneity and identify were confirmed by comparing its ^1H NMR spectrum with literature.

1c,[4] **1d**[5] and **1e**[5] are all known compounds which were synthesized according to literature procedures.

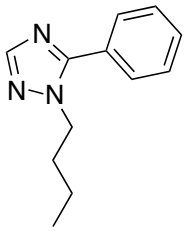
General Procedure for Cu-catalyzed C-H Arylation

To an 8-mL screw-capped reaction vial equipped with a magnetic stir bar, a mixture of CuI (20 mol%), 1,2,4-triazole (0.5 mmol), LiO^tBu (2.0 equiv.), DMEDA (20 mol%) and aryl bromide (3.0 equiv.) was mixed in dioxane (0.5 mL). The reaction mixture was then placed into a pre-heated oil bath at 140 ^oC with vigorous stirring. After 24 h, the reaction mixture was then allowed to cool to room temperature and passed through a short pad of celite with DCM washing. The crude reaction mixture was then dried over Na_2SO_4 and concentrated under reduced pressure. Purification by silica gel chromatography (hexane: EtOAc) then gave the desired arylated product.

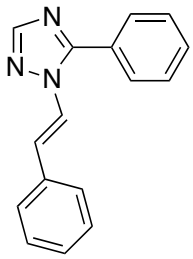
Characterization Data for Arylated Products



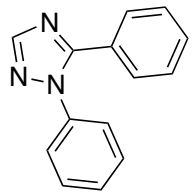
1-benzyl-5-phenyl-1*H*-1,2,4-triazole (**3aa**).[6] Off-white solid (62%, 72.5 mg); R_f (2:1 hexane:EtOAc) = 0.37; m.p 83 – 86 ^oC; ^1H NMR (400 MHz, $CDCl_3$): δ 5.43 (s, 2H), 7.15 – 7.16 (m, 2H), 7.30 – 7.36 (m, 3H), 7.44 – 7.49 (m, 3H), 7.57 – 7.60 (m, 2H), 8.03 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 52.8, 126.9, 127.9, 128.1, 128.8, 128.9, 129.0, 130.3, 135.9, 151.3; ν_{max} (KBr) 3066, 3029, 2959, 1606, 1483, 1454, 1390, 1289, 1234, 1184, 1132, 1074, 1014, 916, 788, 738 cm^{-1}; HRMS (ESI) calcd for $C_{15}H_{14}N_3$ [M+H]: 236.1187, found: 236.1190.



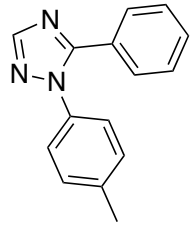
1-butyl-5-phenyl-1*H*-1,2,4-triazole (**3ba**). Light yellow oil (40%, 40.3 mg); R_f (2:1 hexane:EtOAc) = 0.37; ^{1}H NMR (400 MHz, $CDCl_3$): δ 0.88 (t, *J* = 7.5 Hz, 3H), 1.25 – 1.32 (m, 2H), 1.83 – 1.89 (m, 2H), 4.20 (t, *J* = 7.5 Hz, 2H), 7.49 – 7.52 (m, 3H), 7.60 – 7.62 (m, 2H), 7.95 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 13.5, 19.7, 32.0, 49.0, 128.3, 128.7, 128.8, 130.0, 150.7; ν_{max} (KBr) 3068, 2960, 2934, 2874, 1484, 1463, 1442, 1385, 1276, 1161, 1013, 922, 881, 777, 731, 699 cm^{-1}; HRMS (ESI) calcd for $C_{12}H_{16}N_3$ [M+H]: 202.1344, found: 202.1348.



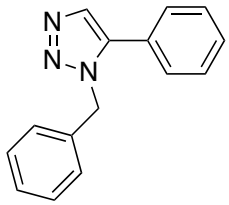
(*E*)-5-phenyl-1-styryl-1*H*-1,2,4-triazole (**3ca**). Yellow solid (50%, 61.7 mg); R_f (2:1 hexane:EtOAc) = 0.50; m.p 123 – 126 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.28 – 7.31 (m, 1H), 7.33 – 7.37 (m, 2H), 7.40 – 7.43 (m, 3H), 7.49 – 7.58 (m, 4H), 7.69 – 7.72 (m, 2H), 8.07 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 121.9, 122.5, 126.7, 127.6, 128.4, 128.9, 129.1, 129.4, 130.6, 134.4, 151.6, 154.4; ν_{max} (KBr) 3054, 1766, 1654, 1596, 1529, 1486, 1450, 1329, 1261, 1131, 1074, 1008, 941, 886, 775, 755 cm^{-1}; HRMS (ESI) calcd for $C_{16}H_{14}N_3$ [M+H]: 248.1187, found: 248.1190.



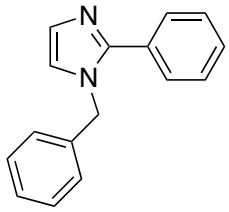
1,5-diphenyl-1*H*-1,2,4-triazole (**3da**). Off-white solid (43%, 47.3 mg); R_f (2:1 hexane:EtOAc) = 0.54; m.p 78 – 81 ^oC; ^1H NMR (400 MHz, $CDCl_3$): δ 7.32 – 7.44 (m, 8H), 7.48 – 7.50 (m, 2H), 8.10 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 125.4, 127.6, 127.8, 128.6, 128.9, 129.0, 129.4, 130.1, 138.2, 151.6; ν_{max} (KBr) 3085, 1598, 1558, 1501, 1440, 1383, 1290, 1200, 1139, 1069, 984, 915, 779, 721 cm^{-1}; HRMS (ESI) calcd for $C_{14}H_{12}N_3$ [M+H]: 222.1031, found: 222.1032.



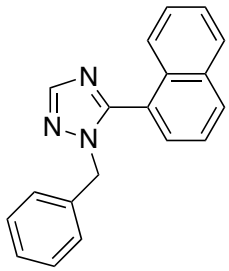
5-phenyl-1-(*p*-tolyl)-1*H*-1,2,4-triazole (**3ea**). Off-white solid (42%, 49.0 mg); R_f (2:1 hexane:EtOAc) = 0.47; m.p 63 – 65 ^oC; ^1H NMR (400 MHz, $CDCl_3$): δ 2.41 (s, 3H), 7.20 – 7.25 (m, 4H), 7.32 – 7.36 (m, 2H), 7.37 – 7.41 (m, 1H), 7.49 – 7.51 (m, 2H), 8.08 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 21.2, 125.2, 127.9, 128.6, 128.9, 129.97, 130.01, 135.8, 139.1, 151.5, 153.8; ν_{max} (KBr) 3037, 2920, 1600, 1560, 1514, 1487, 1455, 1381, 1266, 1203, 1136, 1107, 1065, 985, 897, 823, 781, 721 cm^{-1}; HRMS (ESI) calcd for $C_{15}H_{14}N_3$ [M+H]: 236.1187, found: 236.1190.



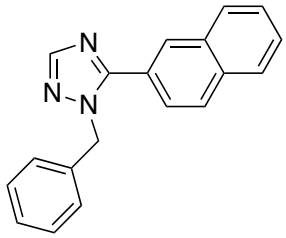
1-benzyl-5-phenyl-1*H*-1,2,3-triazole (**3fa**).[7] Off-white solid (22%, 25.4 mg); R_f (2:1 hexane:EtOAc) = 0.37; m.p 75 – 78 ^oC; ^1H NMR (400 MHz, $CDCl_3$): δ 5.55 (s, 2H), 7.06 – 7.09 (m, 2H), 7.24 – 7.30 (m, 5H), 7.40 – 7.44 (m, 3H), 7.75 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 51.9, 127.0, 127.2, 128.2, 128.9, 128.95, 128.98, 129.5, 133.4, 135.6; ν_{max} (KBr) 3060, 3033, 2962, 1603, 1479, 1453, 1434, 1365, 1233, 1208, 1127, 1113, 1076, 827, 769, 740, 719, 701 cm^{-1}; HRMS (ESI) calcd for $C_{15}H_{14}N_3$ [M+H]: 236.1187, found: 236.1189.



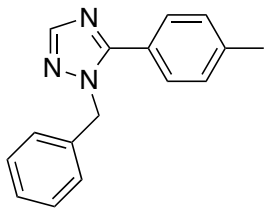
1-benzyl-2-phenyl-1*H*-imidazole (**3ga**). Yellow oil (24%, 28.6 mg); R_f (2:1 hexane:EtOAc) = 0.20; ^1H NMR (400 MHz, $CDCl_3$): δ 5.21 (s, 2H), 6.97 (s, 1H), 7.08 (d, J = 7.2 Hz, 2H), 7.19(s, 1H), 7.28 – 7.40 (m, 6H), 7.54 (s, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 50.4, 121.2, 126.6, 127.9, 128.6, 128.8, 128.9, 129.0, 130.4, 136.9, 148.2; ν_{max} (KBr) 3065, 3033, 2933, 1605, 1498, 1473, 1454, 1417, 1359, 1277, 1128, 1075, 1019, 914, 772, 729, 699 cm^{-1}; HRMS (ESI) calcd for $C_{16}H_{15}N_2$ [M+H]: 235.1235, found: 235.1237.



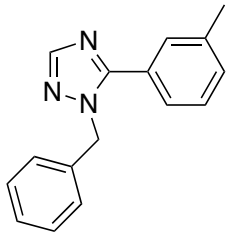
1-benzyl-5-(naphthalene-1-yl)-1*H*-1,2,4-triazole (**3ab**). Light tan solid (65%, 93.4 mg); R_f (2:1 hexane:EtOAc) = 0.46; m.p 60 – 64 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.19 (s, 2H), 6.99 – 7.01 (m, 2H), 7.22 – 7.26 (m, 3H), 7.44 – 7.57 (m, 4H), 7.63 (d, J = 8.4 Hz, 1H), 7.93 (d, J = 8.0 Hz, 1H), 8.01 (d, J = 8.0 Hz, 1H), 8.16 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 52.7, 124.9, 125.0, 125.5, 126.6, 127.4, 127.6, 128.1, 128.46, 128.47, 128.7, 130.8, 131.8, 133.6, 135.5, 151.5, 154.0; ν_{max} (KBr) 3033, 2939, 1594, 1497, 1469, 1455, 1379, 1275, 1177, 1086, 976, 894, 803, 779, 723 cm^{-1}; HRMS (ESI) calcd for $C_{19}H_{16}N_3$ [M+H]: 286.1344, found: 286.1346.



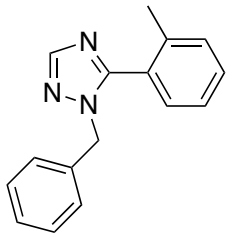
1-benzyl-5-(naphthalene-2-yl)-1*H*-1,2,4-triazole (**3ac**). Off-white solid (74%, 105.9 mg); R_f (2:1 hexane:EtOAc) = 0.43; m.p 124 – 127 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.51 (s, 2H), 7.21 – 7.23 (m, 2H), 7.33 – 7.39 (m, 3H), 7.54 – 7.59 (m, 2H), 7.71 (dd, J_1 = 8.6 Hz, J_2 = 1.8 Hz, 1H), 7.80 – 7.82 (m, 1H), 7.88 – 7.90 (m, 1H), 7.94 (d, J = 8.8 Hz, 1H), 8.05 (s, 1H), 8.08 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 53.0, 125.2, 125.5, 126.9, 127.0, 127.5, 127.9, 128.2, 128.5, 128.8, 128.9, 129.0, 132.8, 133.8, 136.0, 151.4, 155.3; ν_{max} (KBr) 3063, 3028, 2956, 1603, 1498, 1475, 1454, 1430, 1367, 1286, 1183, 1116, 1029, 865, 830, 753, 725 cm^{-1}; HRMS (ESI) calcd for $C_{19}H_{16}N_3$ [M+H]: 286.1344, found: 286.1347.



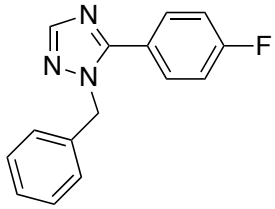
1-benzyl-5-(*p*-tolyl)-1*H*-1,2,4-triazole (**3ad**). Off-white solid (60%, 75.2 mg); R_f (2:1 hexane:EtOAc) = 0.43; m.p 59 – 60 ^oC; ^1H NMR (400 MHz, $CDCl_3$): δ 2.40 (s, 3H), 5.42 (s, 2H), 7.15 – 7.16 (m, 2H), 7.25 – 7.27 (m, 2H), 7.30 – 7.34 (m, 3H), 7.47 – 7.49 (m, 2H), 8.01 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 21.4, 52.7, 125.0, 126.9, 128.1, 128.6, 128.9, 129.6, 136.0, 140.5, 151.3, 155.4; ν_{max} (KBr) 3025, 2919, 1615, 1491, 1462, 1387, 1272, 1232, 1179, 1124, 1080, 1033, 1015, 903, 877, 824, 784, 732, 696 cm^{-1}; HRMS (ESI) calcd for $C_{16}H_{16}N_3$ [M+H]: 250.1344, found: 250.1345.



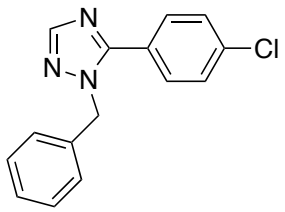
1-benzyl-5-(*m*-tolyl)-1*H*-1,2,4-triazole (**3ae**). Off-white solid (66%, 82.6 mg); R_f (2:1 hexane:EtOAc) = 0.46; m.p 51 – 54 ^oC; ^1H NMR (400 MHz, $CDCl_3$): δ 2.35 (s, 3H), 5.40 (s, 2H), 7.15 – 7.16 (m, 2H), 7.28 – 7.35 (m, 6H), 7.41 (s, 1H), 8.00 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 21.2, 52.7, 125.5, 126.9, 127.7, 128.0, 128.6, 128.8, 129.5, 130.9, 135.9, 138.7, 151.1, 155.3; ν_{max} (KBr) 3108, 3028, 1584, 1524, 1492, 1452, 1372, 1274, 1249, 1184, 1123, 1074, 1035, 919, 896, 806, 741 cm^{-1}; HRMS (ESI) calcd for $C_{16}H_{16}N_3$ [M+H]: 250.1344, found: 250.1347.



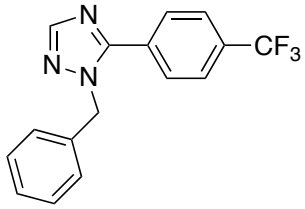
1-benzyl-5-(*o*-tolyl)-1*H*-1,2,4-triazole (**3af**). Off-white solid (60%, 74.2 mg); R_f (2:1 hexane:EtOAc) = 0.46; m.p 40 – 44 ^oC; ^1H NMR (400 MHz, $CDCl_3$): δ 2.09 (s, 3H), 5.17 (s, 2H), 7.03 – 7.06 (m, 2H), 7.19 – 7.31 (m, 6H), 7.38 – 7.42 (m, 1H), 8.03 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 19.5, 52.5, 125.9, 127.7, 127.8, 128.2, 128.7, 129.7, 130.3, 130.7, 135.5, 138.2, 151.1, 154.7; ν_{max} (KBr) 3030, 1605, 1530, 1453, 1385, 1364, 1273, 1229, 1184, 1136, 1113, 1075, 1015, 917, 885, 774, 749, 716 cm^{-1}; HRMS (ESI) calcd for $C_{16}H_{16}N_3$ [M+H]: 250.1344, found: 250.1347.



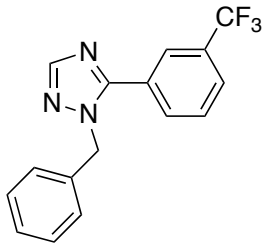
1-benzyl-5-(2-methoxyphenyl)-1*H*-1,2,4-triazole (**3ag**). Light yellow oil (60%, 75.4 mg); R_f (2:1 hexane:EtOAc) = 0.40; ^1H NMR (400 MHz, $CDCl_3$): δ 5.39 (s, 2H), 7.10 – 7.14 (m, 4H), 7.28 – 7.34 (m, 3H), 7.53 – 7.56 (m, 2H), 7.99 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 52.7, 116.0 (d, J = 21.7 Hz), 123.9 (d, J = 3.3 Hz), 126.7, 128.1, 128.9, 130.8 (d, J = 6.8 Hz), 135.6, 151.1, 154.2, 163.7 (d, J = 249.8 Hz); ν_{max} (KBr) 3066, 3034, 2939, 1609, 1486, 1463, 1381, 1275, 1229, 1160, 1123, 1028, 1013, 844, 729 cm^{-1}; HRMS (ESI) calcd for $C_{15}H_{13}FN_3$ [M+H]: 254.1093, found: 254.1095.



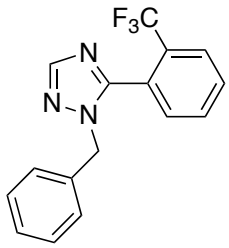
1-benzyl-5-(4-chlorophenyl)-1*H*-1,2,4-triazole (**3ah**). Light yellow solid (63%, 84.9 mg); R_f (2:1 hexane:EtOAc) = 0.41; m.p 75 – 78 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.42 (s, 2H), 7.13 – 7.15 (m, 2H), 7.31 – 7.37 (m, 3H), 7.42 – 7.44 (m, 2H), 7.50 – 7.53 (m, 2H), 8.02 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 52.9, 126.3, 126.8, 128.3, 129.1, 129.2, 130.1, 135.6, 136.2, 151.4, 154.2; ν_{max} (KBr) 3070, 3011, 2934, 1601, 1488, 1457, 1409, 1375, 1286, 1245, 1186, 1094, 1010, 905, 835, 732, 696 cm^{-1}; HRMS (ESI) calcd for $C_{15}H_{13}ClN_3$ [M+H]: 270.0798, found: 270.0797.



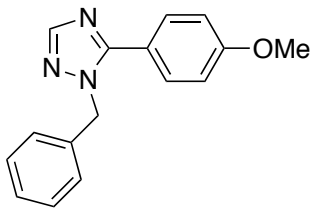
1-benzyl-5-(4-(trifluoromethyl)phenyl)-1*H*-1,2,4-triazole (**3ai**). Off-white solid (46%, 70.4 mg); R_f (2:1 hexane:EtOAc) = 0.51; m.p 44 – 46 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.45 (s, 2H), 7.14 – 7.16 (m, 2H), 7.32 – 7.38 (m, 3H), 7.72 (s, 4H), 8.07 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 53.0, 122.3, 125.0, 125.9 (q, J = 3.7 Hz), 126.8, 127.8, 128.4, 129.1, 129.2, 131.4, 132.2 (q, J = 32.8 Hz), 135.5, 151.5; ν_{max} (KBr) 3069, 3033, 2963, 1622, 1544, 1455, 1440, 1384, 1328, 1241, 1131, 1071, 1030, 900, 846, 754, 720 cm^{-1}; HRMS (ESI) calcd for $C_{16}H_{13}F_3N_3$ [M+H]: 304.1061, found: 304.1063.



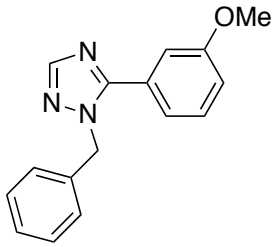
1-benzyl-5-(3-(trifluoromethyl)phenyl)-1*H*-1,2,4-triazole (**3aj**). Off-white solid (55%, 83.9 mg); R_f (2:1 hexane:EtOAc) = 0.43; m.p 50 – 52 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.43 (s, 2H), 7.17 – 7.19 (m, 2H), 7.32 – 7.38 (m, 3H), 7.59 (t, *J* = 7.8 Hz, 1H), 7.73 – 7.78 (m, 2H), 7.85 (s, 1H), 8.06 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 53.1, 122.3, 124.9, 125.8 (q, *J* = 3.8 Hz), 126.9, 127.0, 128.4, 128.8, 129.1, 129.5, 131.3, 131.7, 132.0, 135.4, 151.4, 153.8; ν_{max} (KBr) 3073, 2934, 1622, 1498, 1457, 1375, 1323, 1276,1130, 1034, 916, 889, 815, 771, 743, 724 cm^{-1}; HRMS (ESI) calcd for $C_{16}H_{13}F_3N_3$ [M+H]: 304.1061, found: 304.1063.



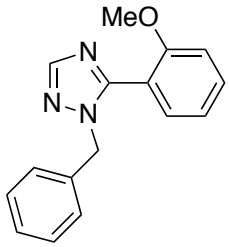
1-benzyl-5-(2-(trifluoromethyl)phenyl)-1*H*-1,2,4-triazole (**3ak**). Yellow solid (31%, 47.1 mg); R_f (2:1 hexane:EtOAc) = 0.38; m.p 86 – 89 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.13 (s, 2H), 7.04 – 7.06 (m, 2H), 7.25 – 7.29 (m, 4H), 7.59 (t, *J* = 7.4 Hz, 1H), 7.66 (t, *J* = 7.6 Hz, 1H), 7.84 (d, *J* = 7.6 Hz, 1H), 8.04 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 52.8, 121.9, 124.7, 126.9 (q, *J* = 4.8 Hz), 127.8, 128.3, 128.8, 130.1, 130.4, 130.7, 131.8, 132.0, 135.0, 151.2; ν_{max} (KBr) 3068, 3030, 2988, 1605, 1478, 1464, 1362, 1315, 1274, 1229, 1169, 1131, 1065, 1033, 980, 875, 780, 726 cm^{-1}; HRMS (ESI) calcd for $C_{16}H_{13}F_3N_3$ [M+H]: 304.1061, found: 304.1062.



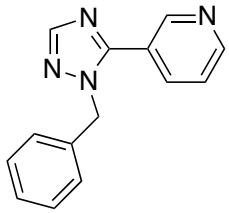
1-benzyl-5-(4-methoxyphenyl)-1*H*-1,2,4-triazole (**3al**). Light tan solid (56%, 74.8 mg); R_f (2:1 hexane:EtOAc) = 0.26; m.p 79 – 82 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.84 (s, 3H), 5.42 (s, 2H), 6.95 – 6.97 (m, 2H), 7.15 – 7.16 (m, 2H), 7.30 – 7.37 (m, 3H), 7.51 – 7.53 (m, 2H), 8.00 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 52.7, 55.4, 114.3, 120.2, 126.8, 128.1, 129.0, 130.2, 136.0, 151.2, 155.2, 161.1; ν_{max} (KBr) 3065, 3034, 3005, 2957, 2833, 1611, 1577, 1540, 1472, 1378, 1254, 1178, 1124, 1022, 899, 834, 751, 713 cm^{-1}; HRMS (ESI) calcd for $C_{16}H_{16}N_3O$ [M+H]: 266.1293, found: 266.1292.



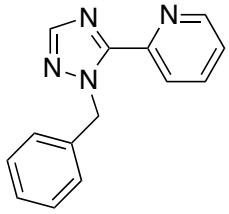
1-benzyl-5-(3-methoxyphenyl)-1*H*-1,2,4-triazole (**3am**). Yellow oil (61%, 81.2 mg); R_f (2:1 hexane:EtOAc) = 0.37; ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.73 (s, 3H), 5.43 (s, 2H), 7.00 – 7.02 (m, 1H), 7.11 – 7.16 (m, 4H), 7.29 – 7.36 (m, 4H), 8.02 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 52.7, 55.3, 113.7, 116.6, 120.8, 126.8, 128.0, 128.9, 129.0, 129.9, 135.9, 151.2, 155.1, 159.8; ν_{max} (KBr) 3065, 3032, 2939, 2836, 1607, 1584, 1496, 1377, 1288, 1262, 1221, 1181, 1123, 1049, 1028, 864, 792, 739, 728 cm^{-1}; HRMS (ESI) calcd for $C_{16}H_{16}N_3O$ [M+H]: 266.1293, found: 266.1294.



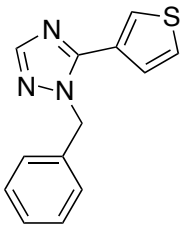
1-benzyl-5-(2-methoxyphenyl)-1*H*-1,2,4-triazole (**3an**). Off-white solid (43%, 56.7 mg); R_f (2:1 hexane:EtOAc) = 0.28; m.p 68 – 71 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 3.69 (s, 3H), 5.21 (s, 2H), 6.98 (d, J = 8.4 Hz, 1H), 7.02 – 7.08 (m, 3H), 7.24 – 7.29 (m, 3H), 7.37 (dd, J_1 = 7.6 Hz, J_2 = 1.6 Hz, 1H), 7.45 – 7.49 (m, 1H), 8.02 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 42.8, 55.4, 111.2, 117.4, 121.0, 127.6, 127.8, 128.6, 131.8, 132.0, 135.9, 151.5, 152.9, 157.1; ν_{max} (KBr) 3014, 2968, 2936, 1781, 1583, 1449, 1381, 1251, 1182, 1104, 1010, 893, 804, 766, 730 cm^{-1}; HRMS (ESI) calcd for $C_{16}H_{16}N_3O$ [M+H]: 266.1293, found: 266.1294.



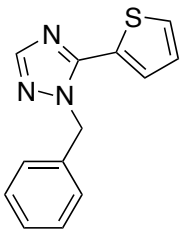
3-(1-benzyl-1*H*-1,2,4-triazol-5-yl)pyridine (**3ao**). Yellow solid (34%, 40.7 mg); R_f (1:1 hexane:EtOAc) = 0.18; m.p 54 – 57 ^{o}C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.45 (s, 2H), 7.13 – 7.15 (m, 2H), 7.31 – 7.36 (m, 3H), 7.38 – 7.42 (m, 1H), 7.90 (dt, J_1 = 8.0 Hz, J_2 = 2.0 Hz, 1H), 8.07 (s, 1H), 8.72 (d, J = 3.6 Hz, 1H), 8.84 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 53.1, 123.6, 124.4, 126.8, 128.4, 129.1, 135.4, 136.2, 149.2, 151.2, 151.6, 152.5; ν_{max} (KBr) 3065, 3027, 2976, 2935, 1598, 1570, 1489, 1456, 1420, 1379, 1307, 1281, 1196, 1127, 1015, 897, 813, 732, 704 cm^{-1}; HRMS (ESI) calcd for $C_{14}H_{13}N_4$ [M+H]: 237.1140, found: 237.1143.



2-(1-benzyl-1*H*-1,2,4-triazol-5-yl)pyridine (**3ap**). Off-white solid (71%, 83.4 mg); R_f (2:1 hexane:EtOAc) = 0.39; m.p 65 – 67 ^oC; ^1H NMR (400 MHz, $CDCl_3$): δ 6.13 (s, 2H), 7.22 – 7.36 (m, 6H), 7.82 (td, J_1 = 7.8 Hz, J_2 = 1.6 Hz, 1H), 7.98 (s, 1H), 8.23 (d, J = 8.0 Hz, 1H), 8.69 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 54.1, 123.9, 124.3, 127.8, 128.0, 128.6, 136.7, 137.1, 147.9, 148.8, 150.8, 151.5; ν_{max} (KBr) 3098, 2961, 1604, 1585, 1453, 1418, 1320, 1278, 1191, 1139, 1090, 1030, 996, 920, 796, 703 cm^{-1}; HRMS (ESI) calcd for $C_{14}H_{13}N_4$ [M+H]: 237.1140, found: 237.1142.



1-benzyl-5-(thiophen-3-yl)-1*H*-1,2,4-triazole (**3aq**). Light tan oil (45%, 53.8 mg); R_f (2:1 hexane:EtOAc) = 0.43; ^1H NMR (400 MHz, $CDCl_3$): δ 5.50 (s, 2H), 7.11 – 7.15 (m, 2H), 7.30 – 7.37 (m, 3H), 7.39 – 7.41 (m, 2H), 7.56 – 7.57 (m, 1H), 7.99 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 52. 8, 126.48, 126.52, 126.9, 127.5, 128.1, 128.3, 129.1, 135.7, 150.9, 151.1; ν_{max} (KBr) 3104, 3032, 2953, 1571, 1496, 1454, 1409, 1341, 1307, 1272, 1183, 1121, 1076, 1030, 975, 893, 861, 793, 727 cm^{-1}; HRMS (ESI) calcd for $C_{13}H_{12}N_3S$ [M+H]: 242.0752, found: 242.0754.



1-benzyl-5-(thiophen-2-yl)-1*H*-1,2,4-triazole (**3ar**). Light yellow oil (56%, 67.3 mg); R_f (2:1 hexane:EtOAc) = 0.47; ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.57 (s, 2H), 7.06 – 7.08 (m, 1H), 7.15 – 7.17 (m, 2H), 7.29 – 7.37 (m, 4H), 7.46 – 7.48 (m, 1H), 7.98 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 53.0, 126.6, 127.9, 128.1, 128.3, 128.9, 129.0, 135.4, 149.5, 151.2; ν_{max} (KBr) 3107, 3033, 2937, 1605, 1568, 1455, 1474, 1386, 1330, 1279, 1231, 1180, 1114, 982, 853, 729 cm^{-1}; HRMS (ESI) calcd for $C_{13}H_{12}N_3S$ [M+H]: 242.0752, found: 242.0754.

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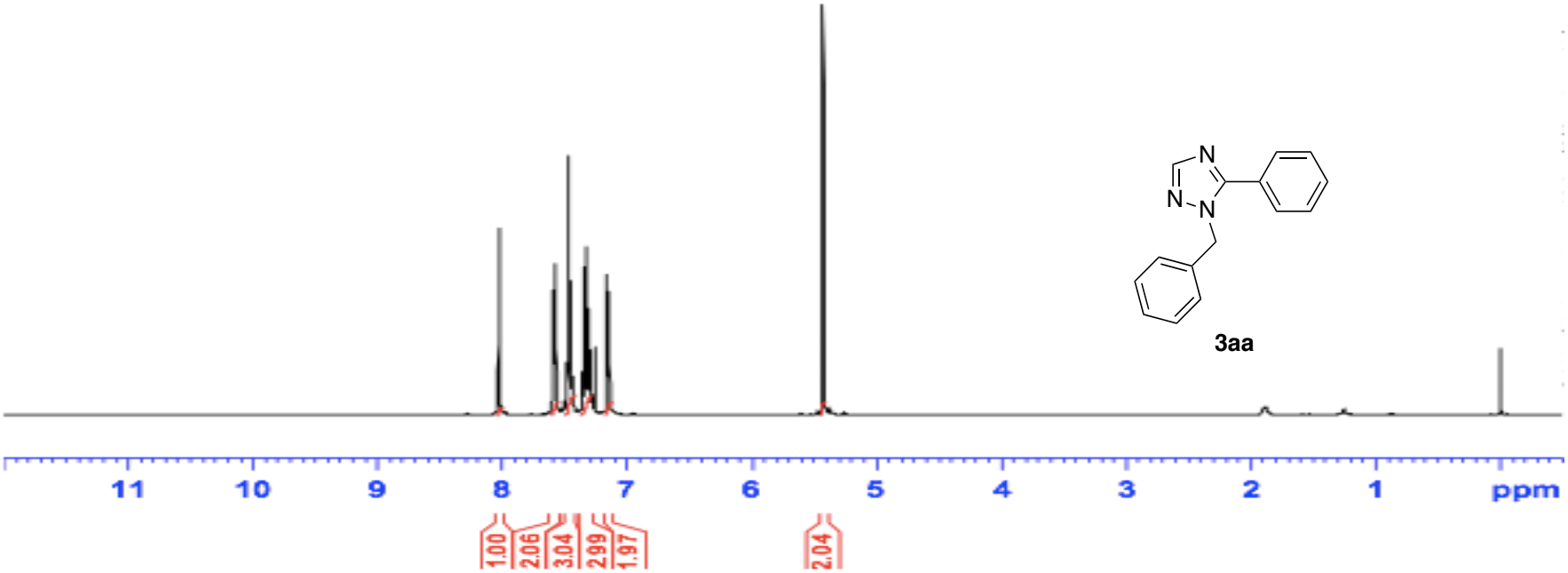
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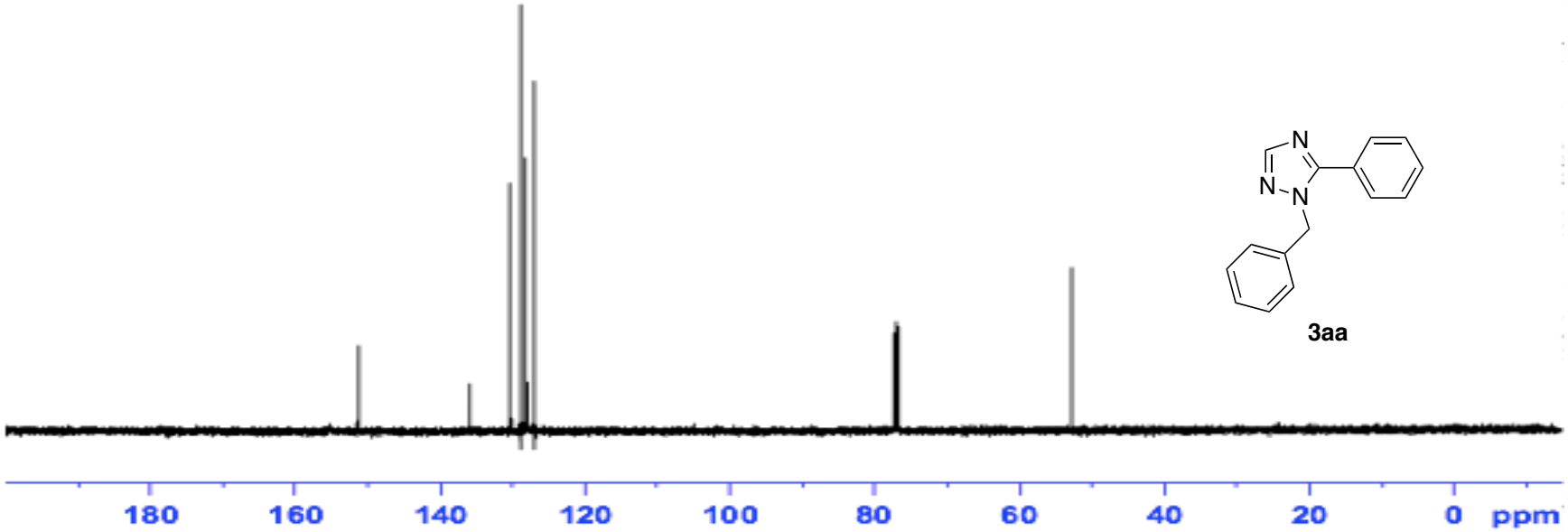
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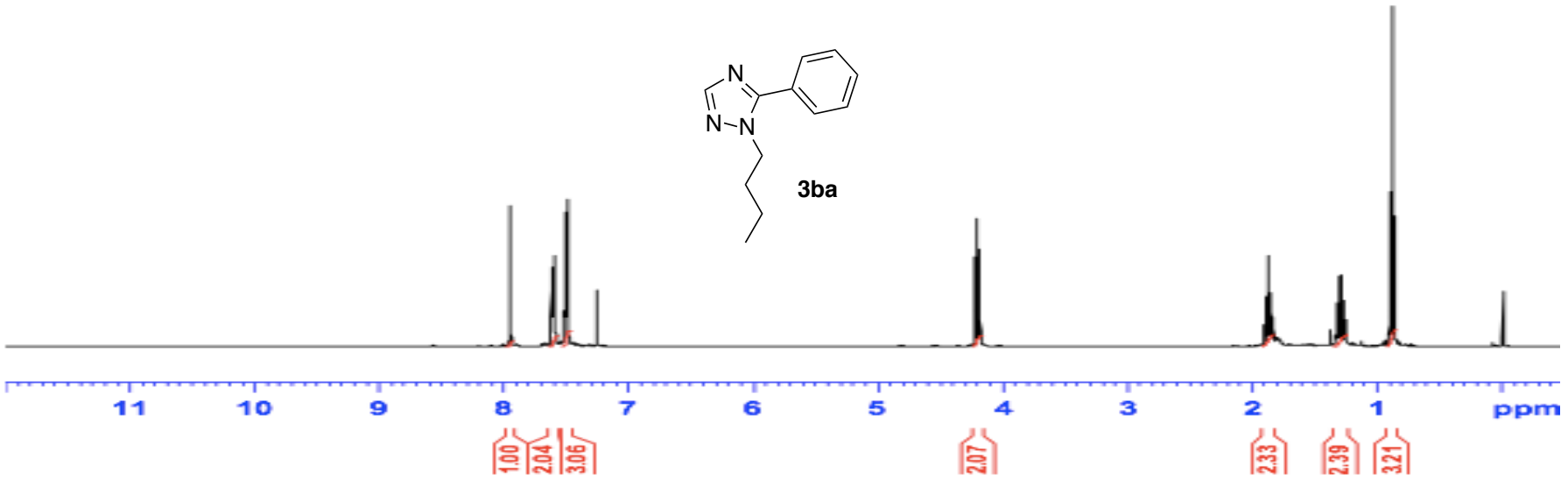
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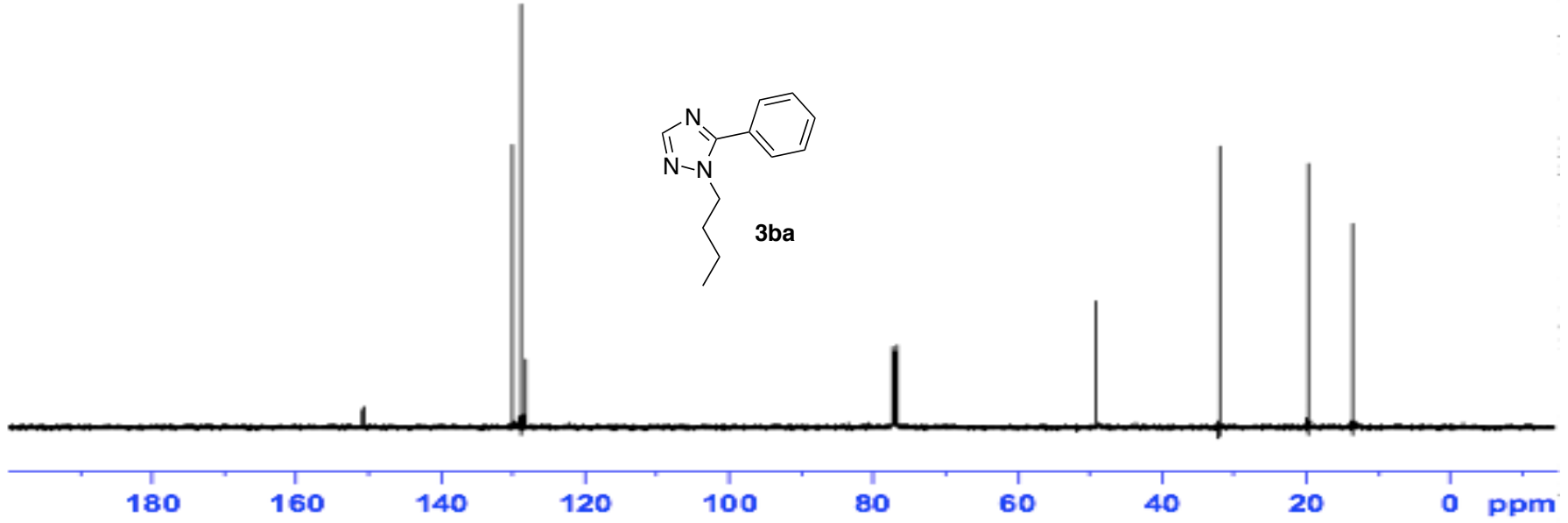
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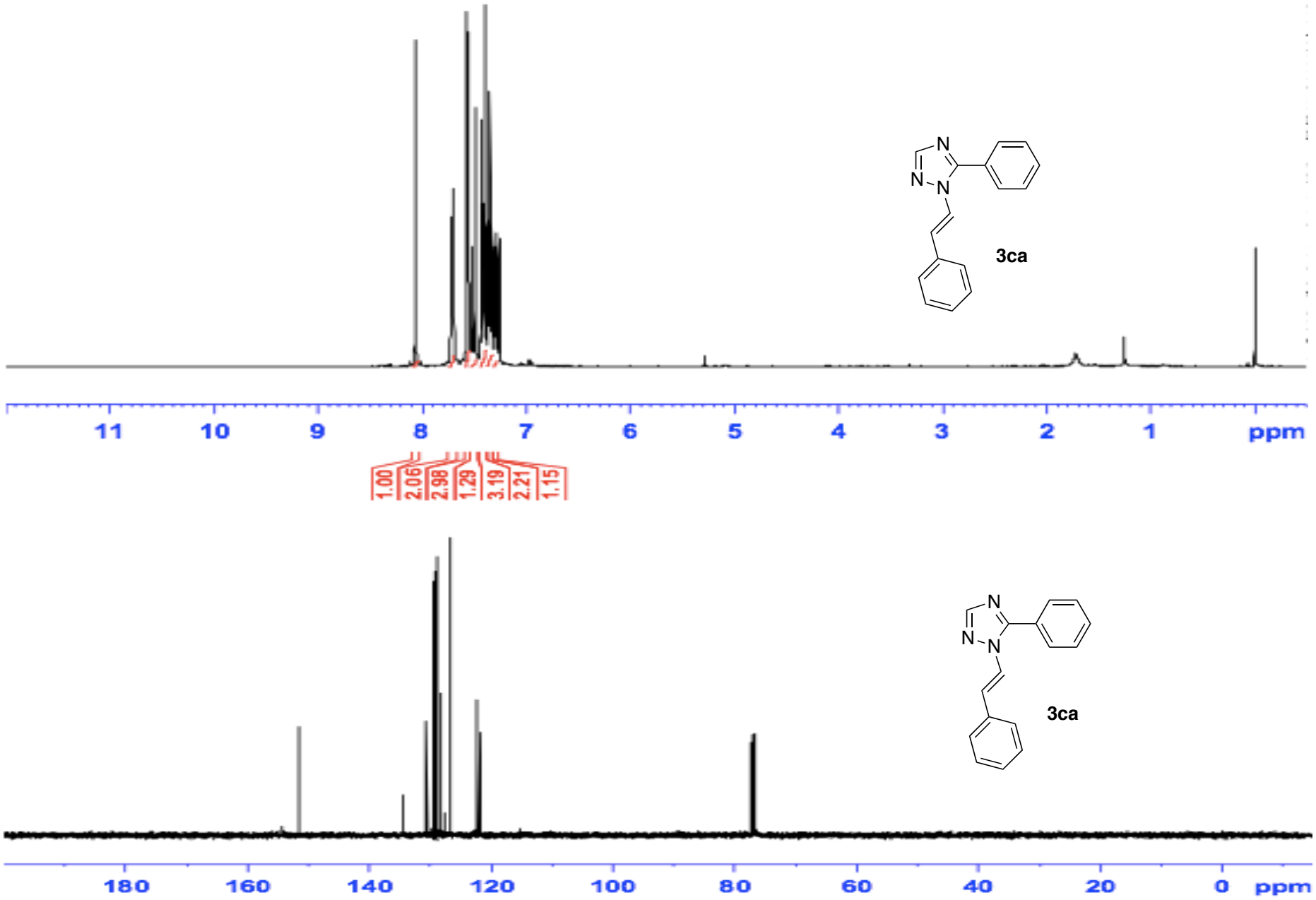
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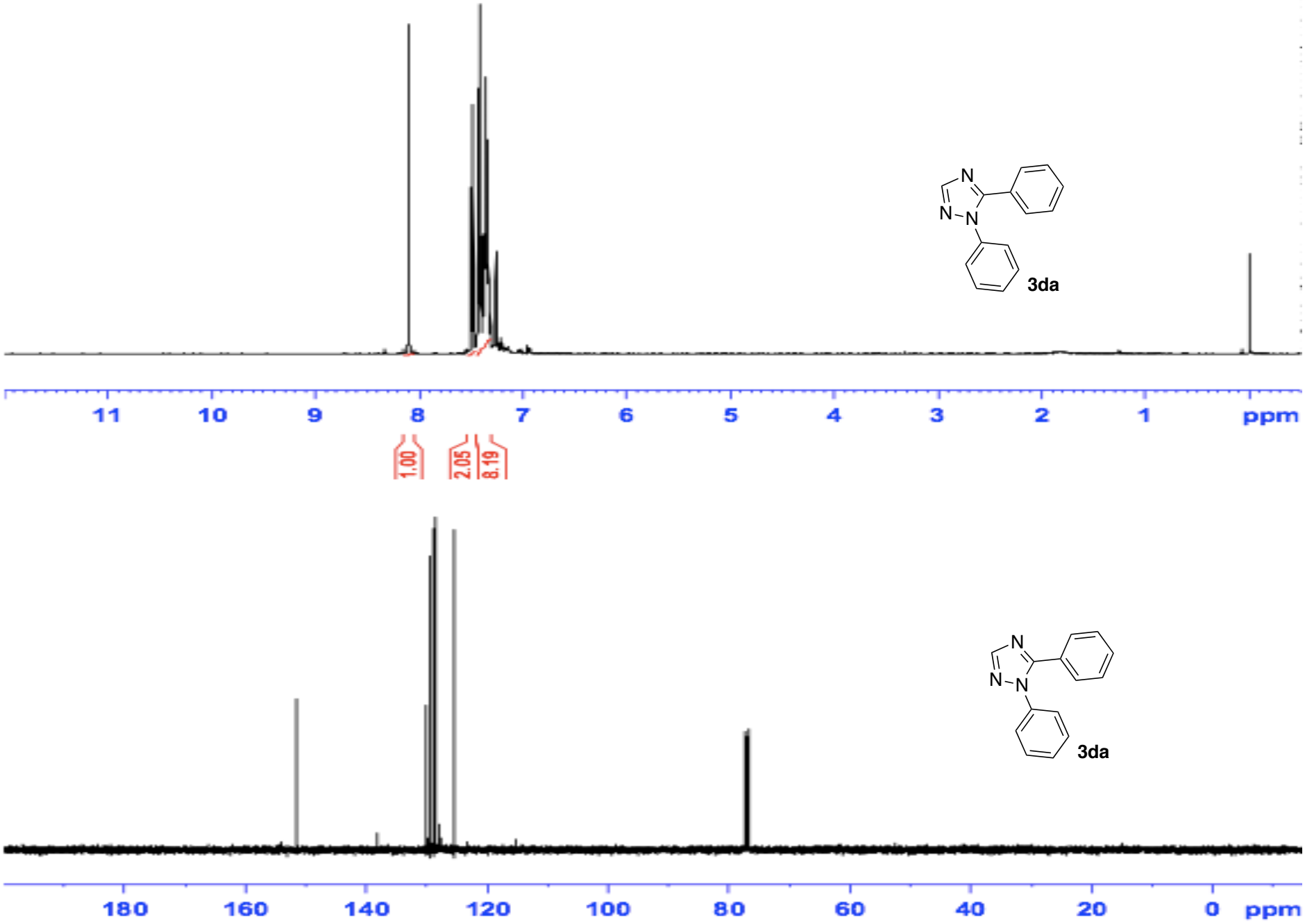
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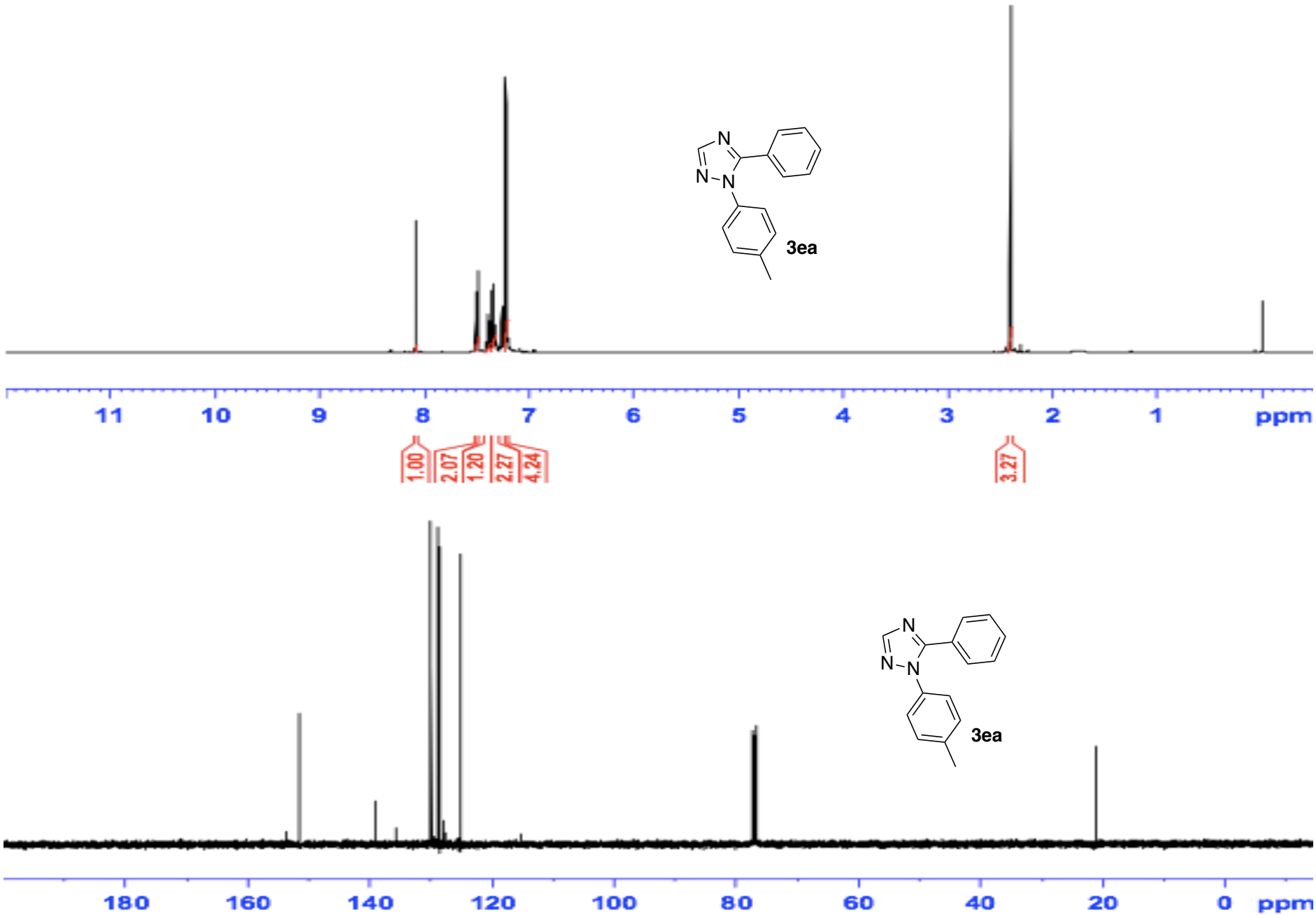
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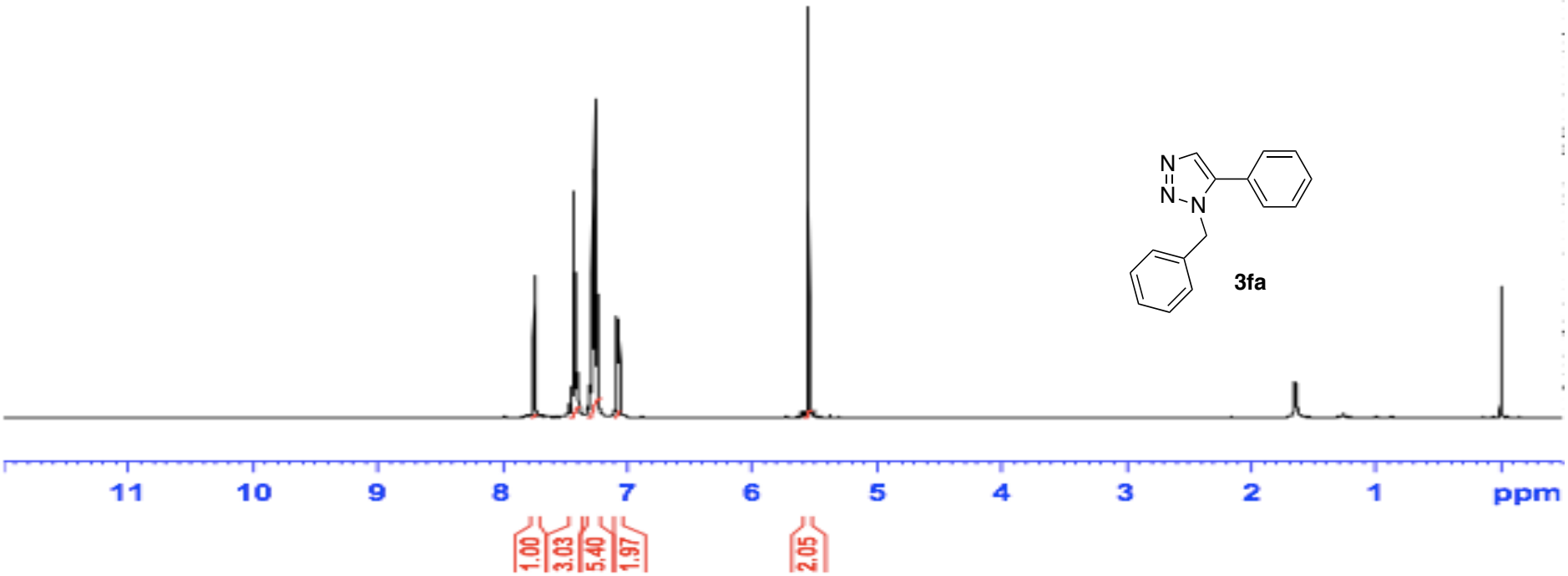
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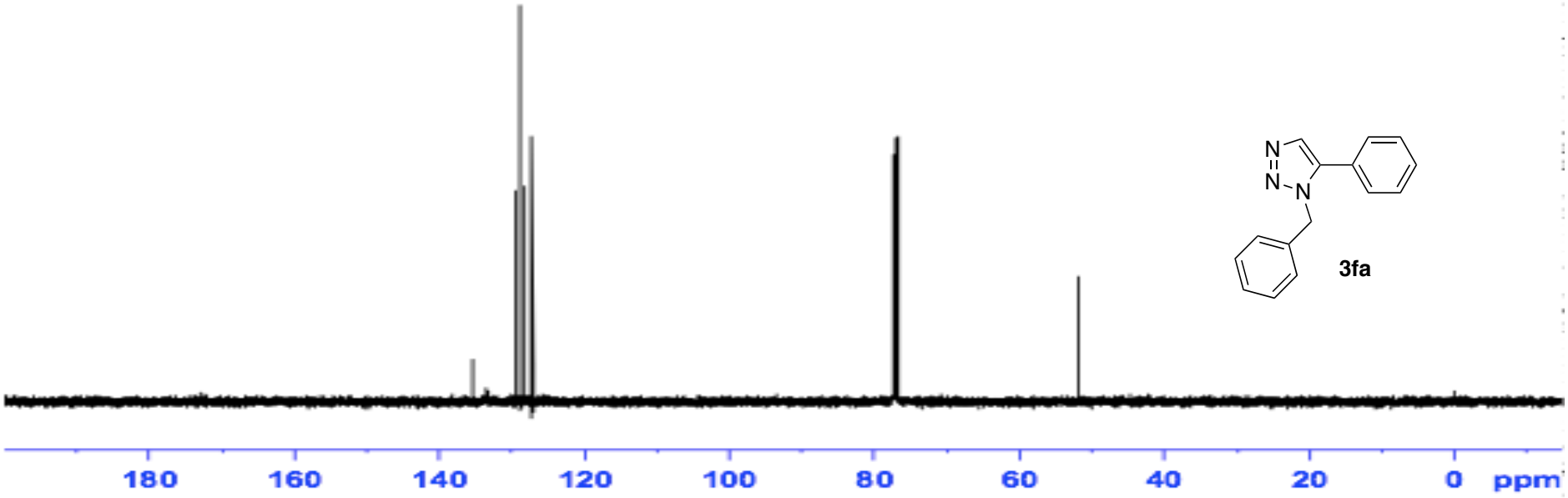
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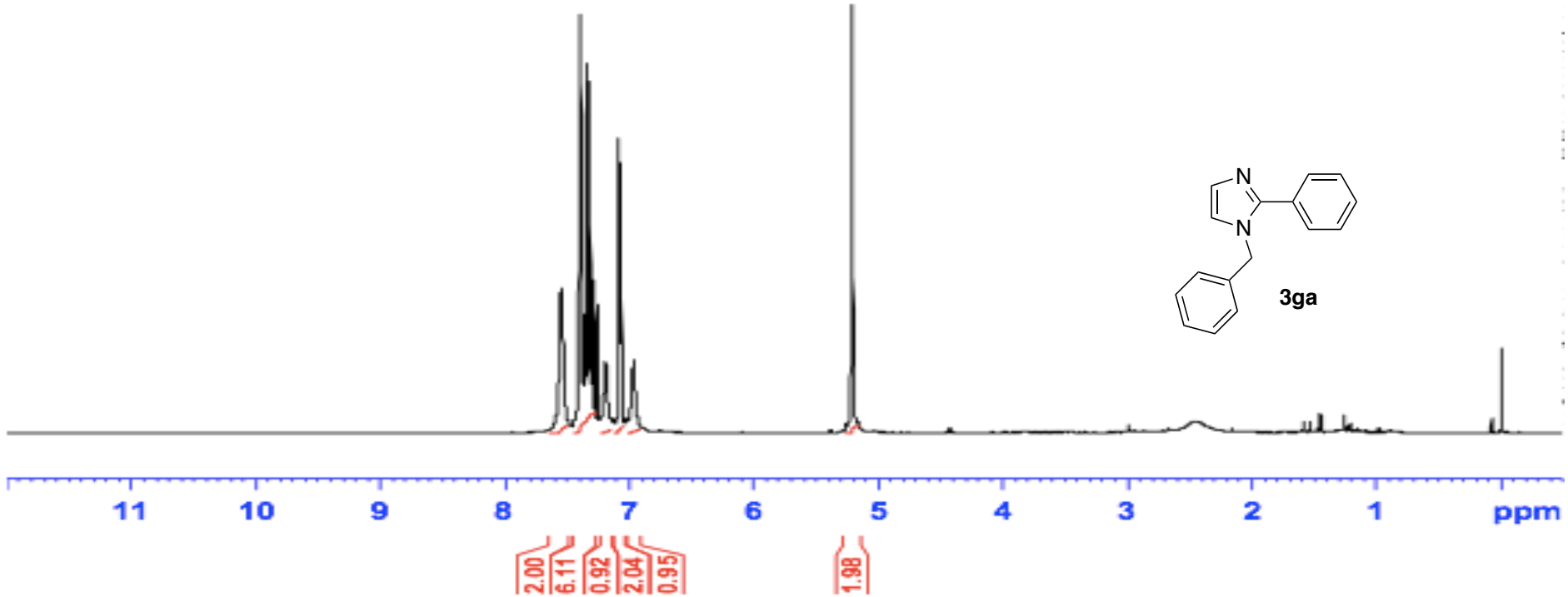
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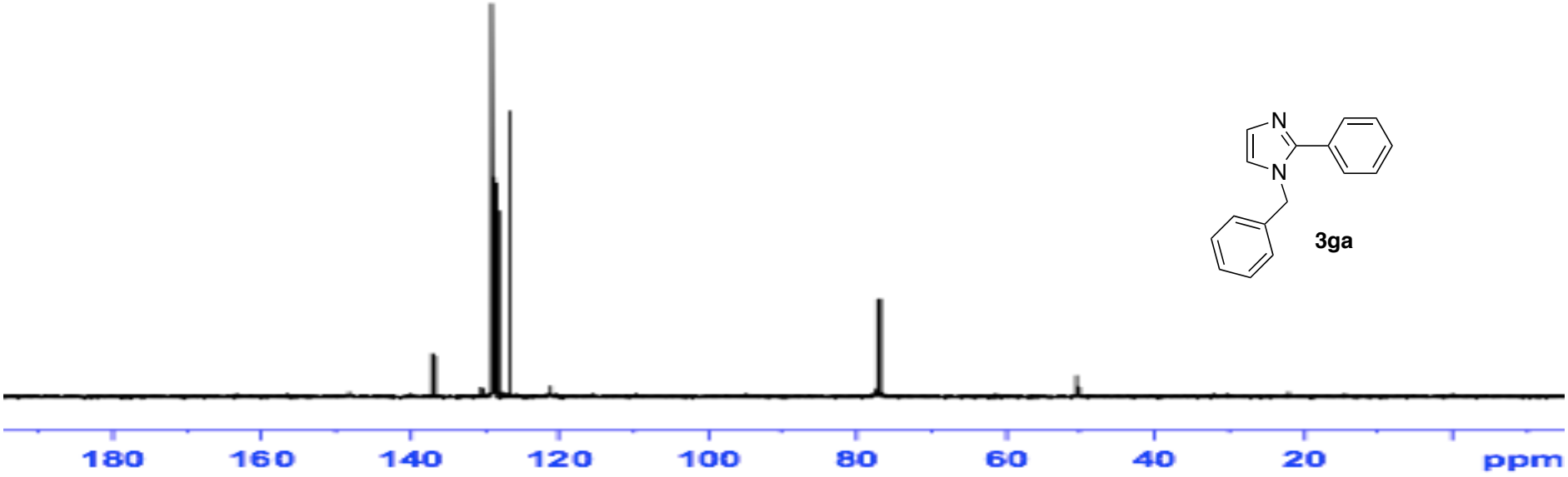
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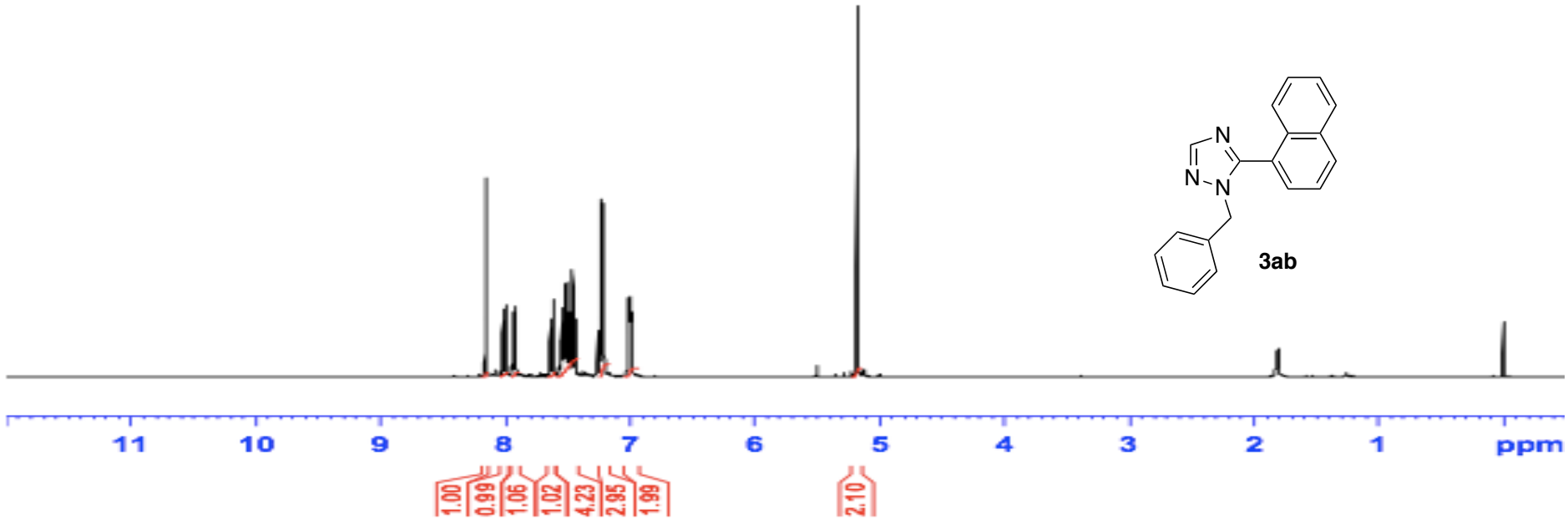
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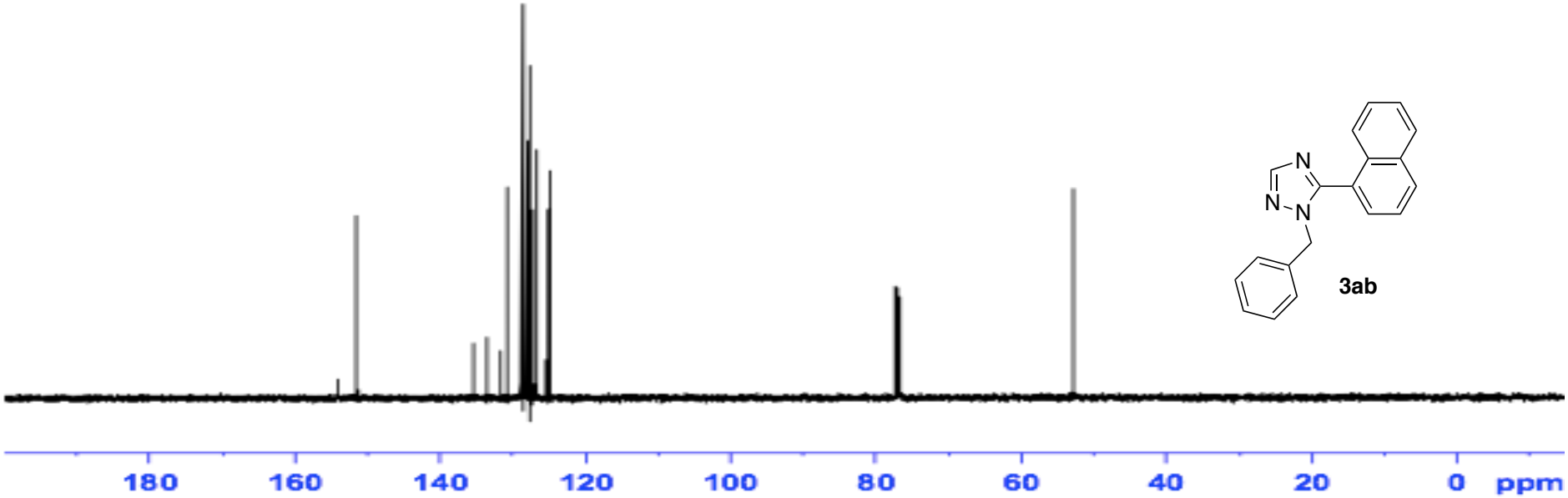
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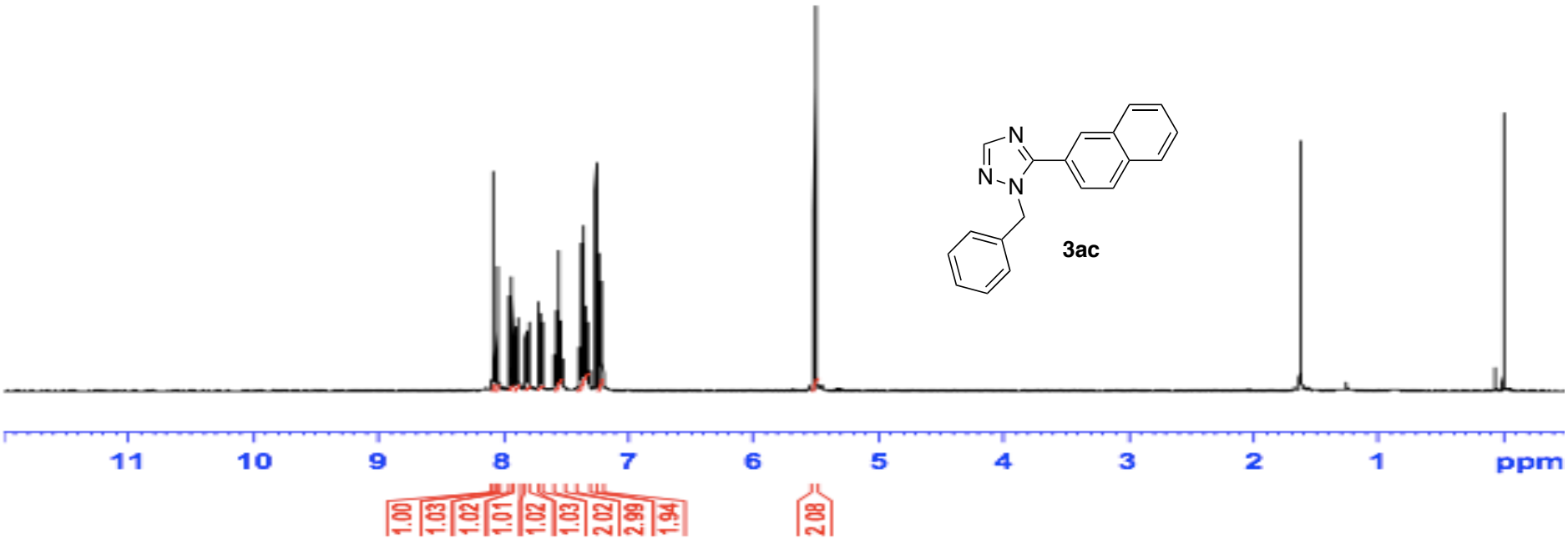
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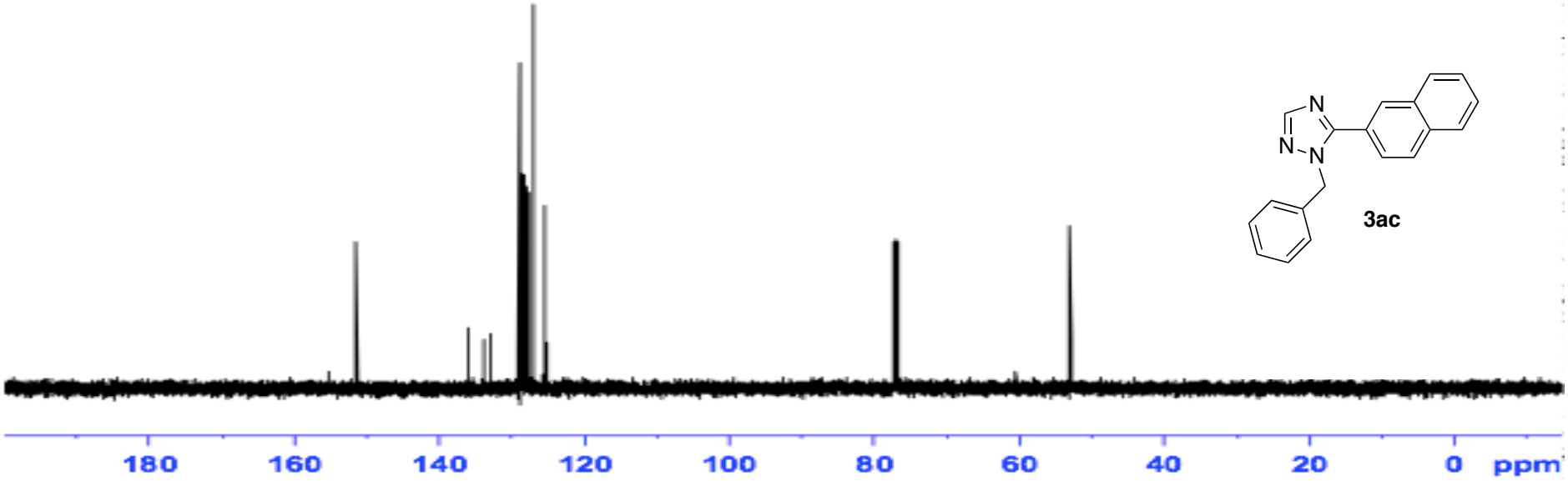
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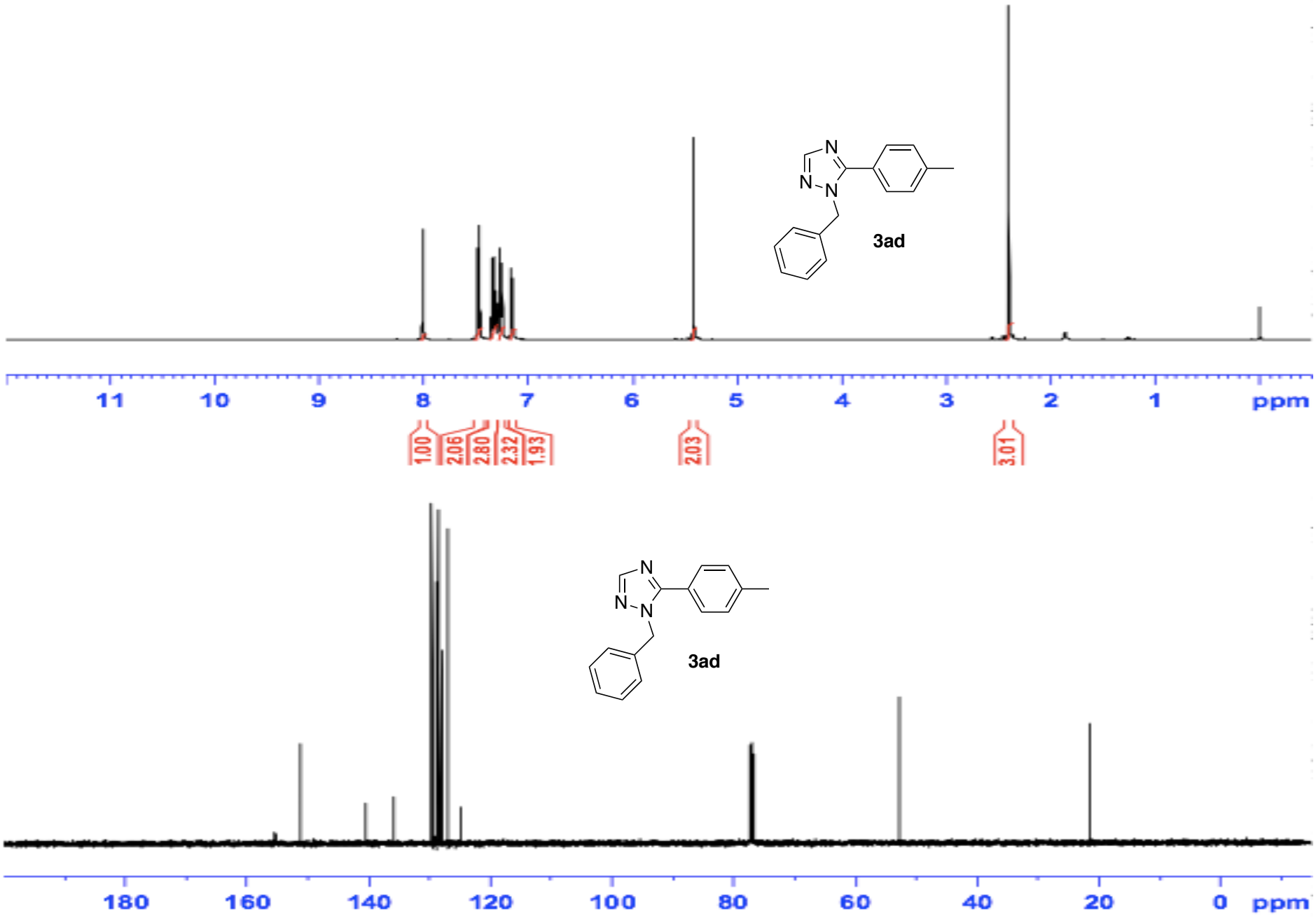
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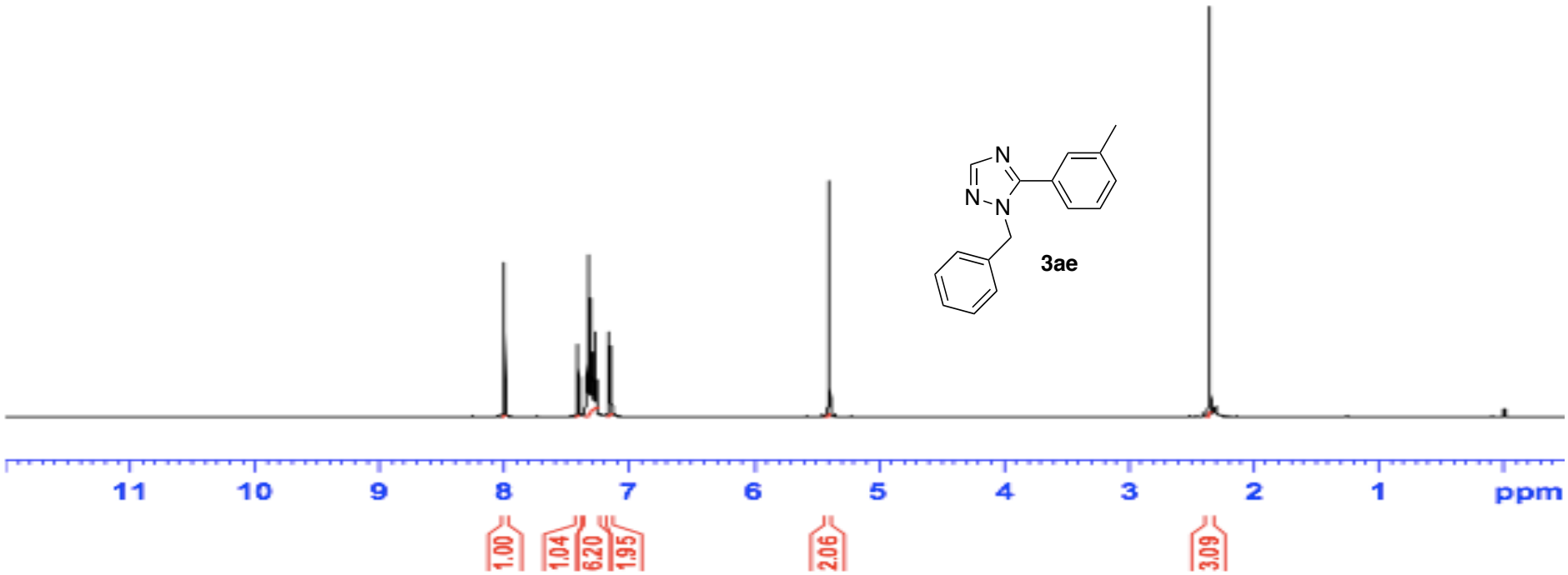
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3
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ppm
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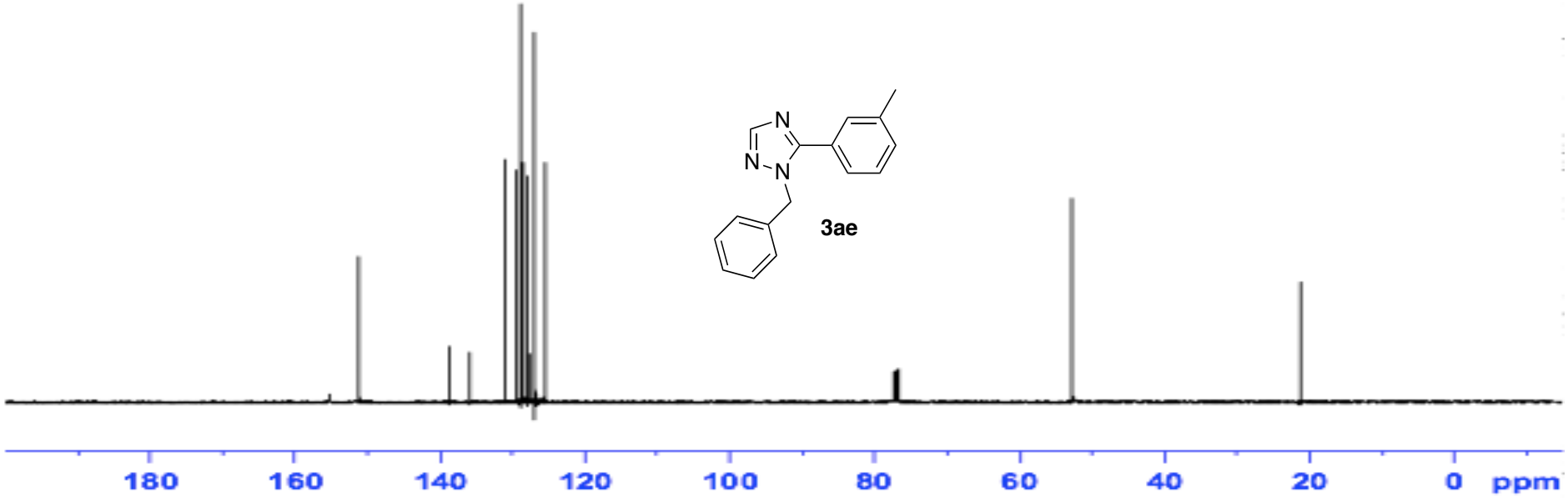
1.95
2.06
3.09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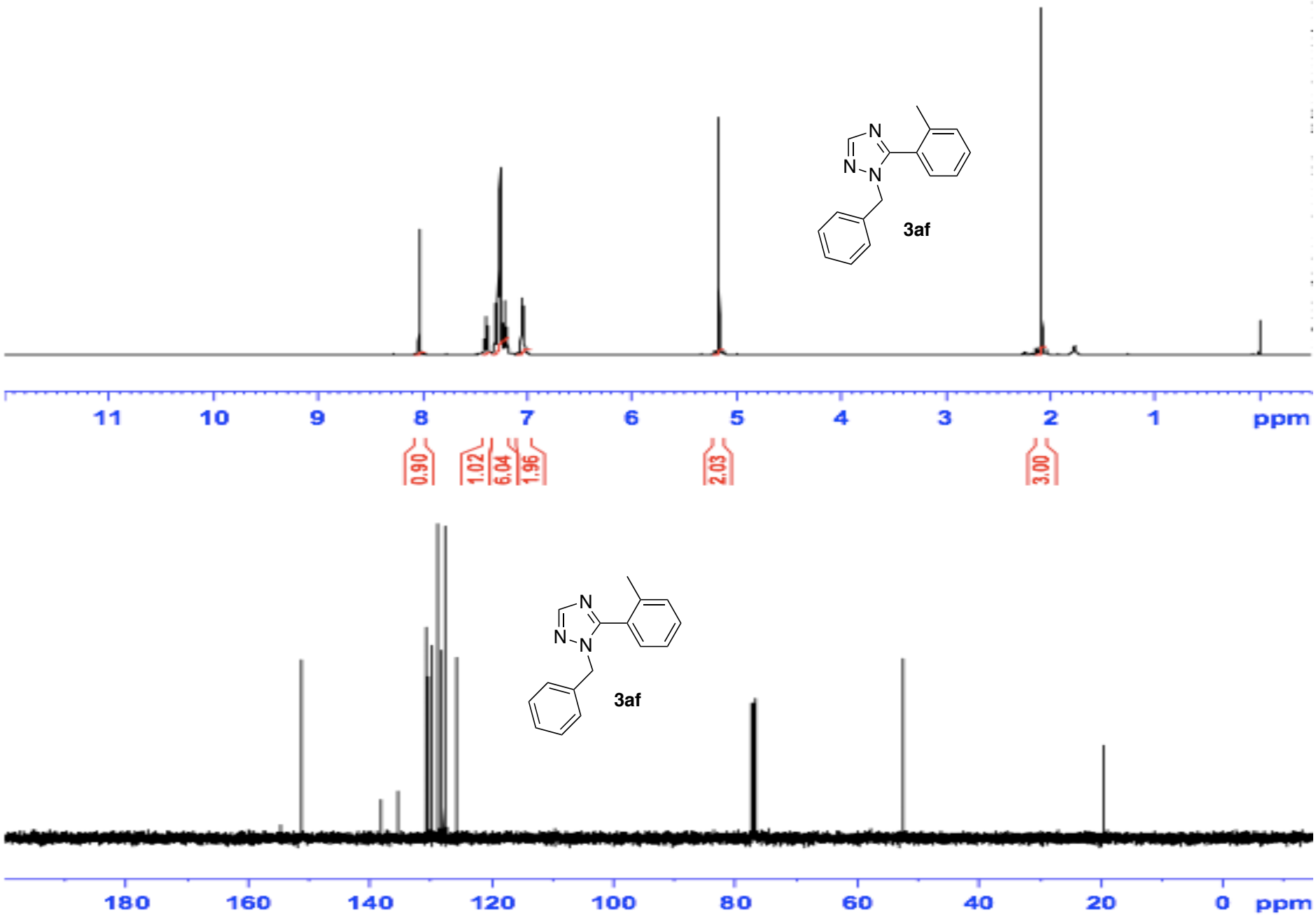
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ppm
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2.03
3.00
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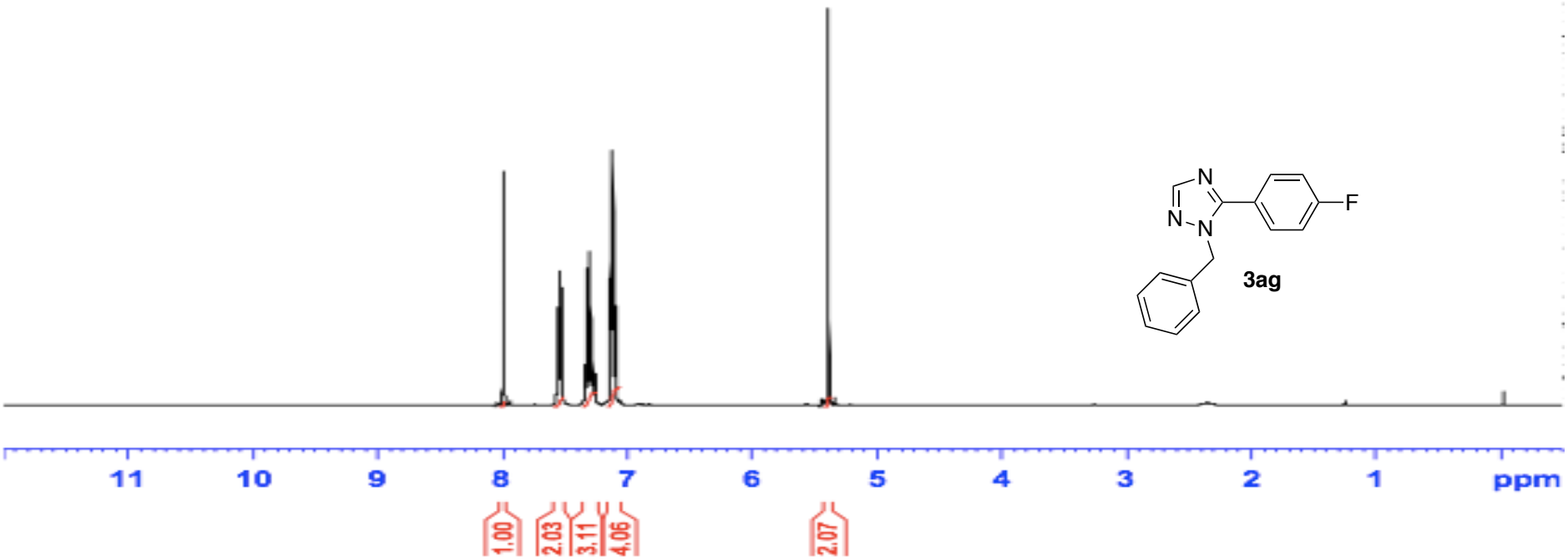
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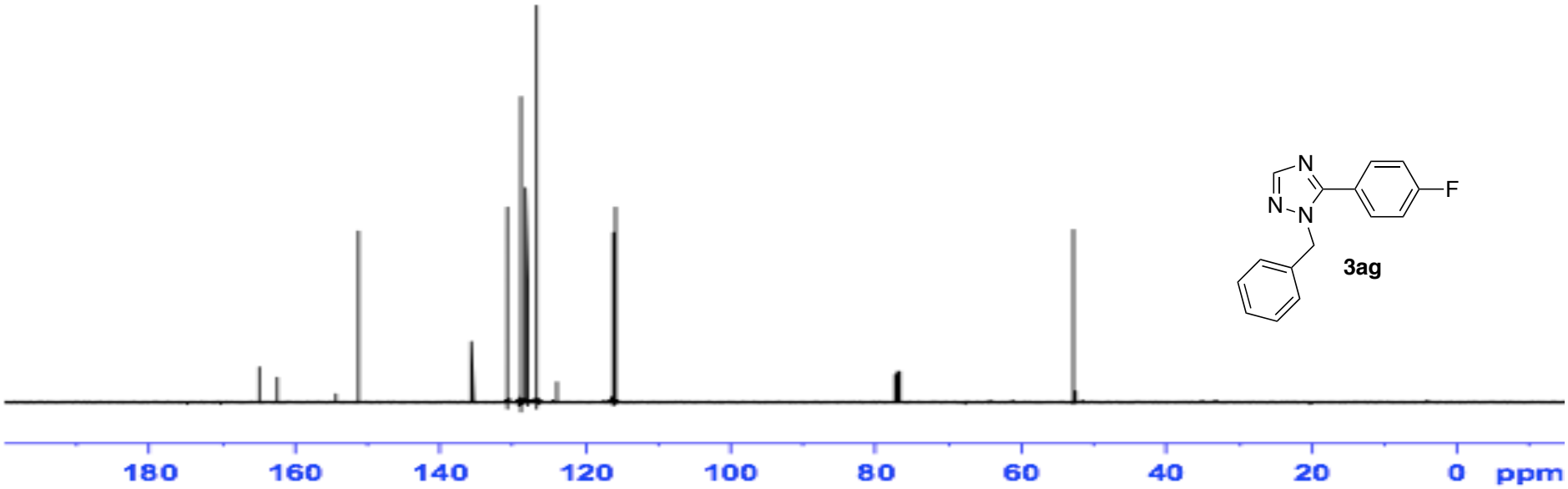
4.06
2.07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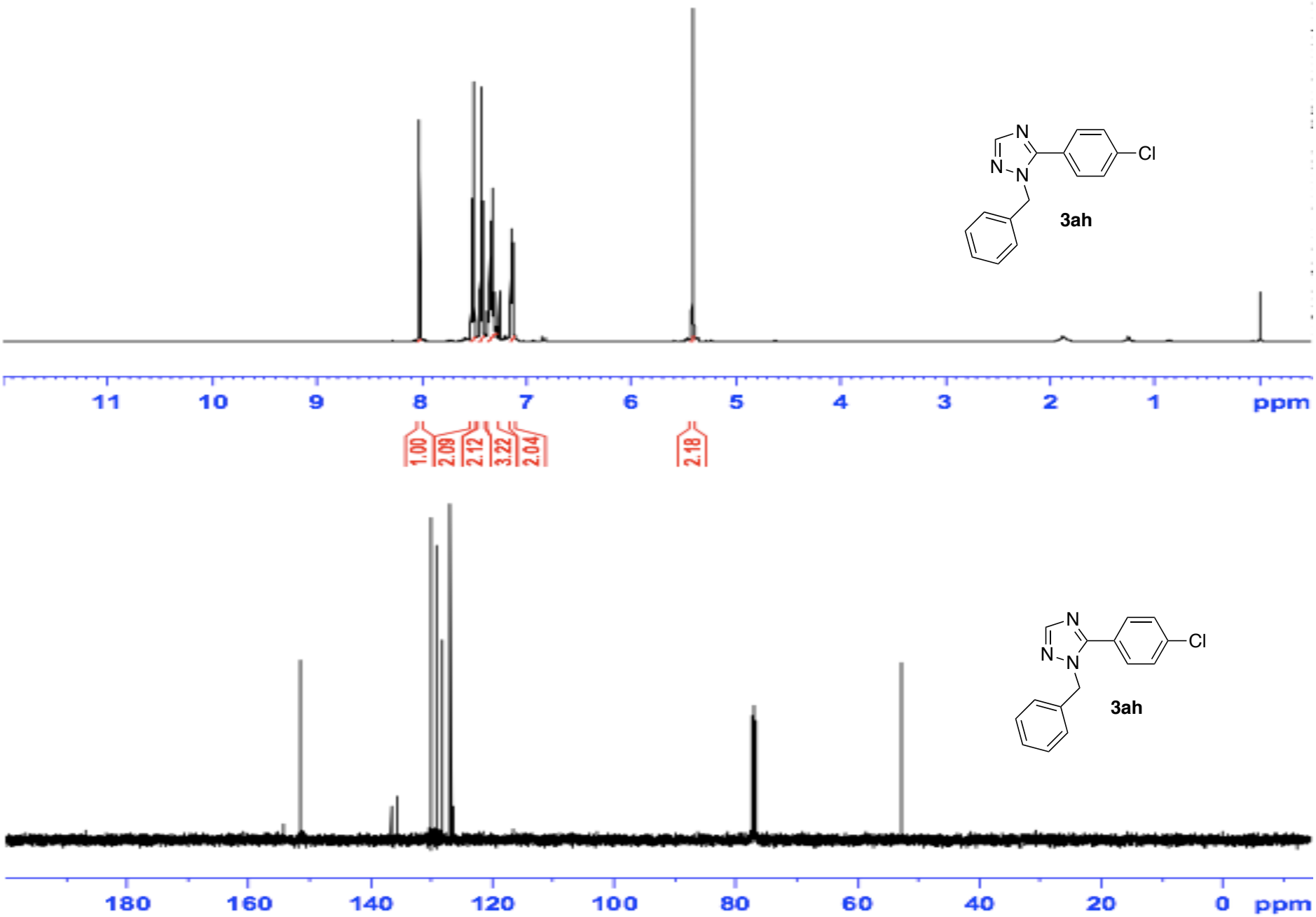
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2.12
3.22
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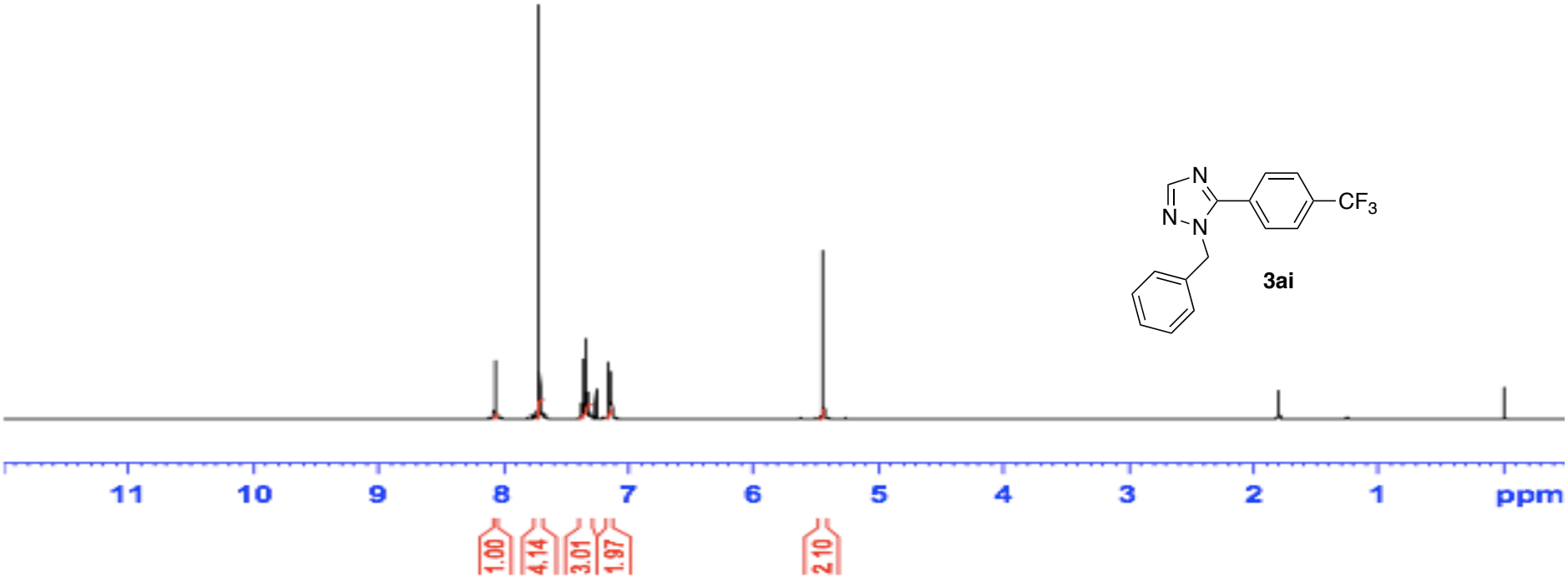
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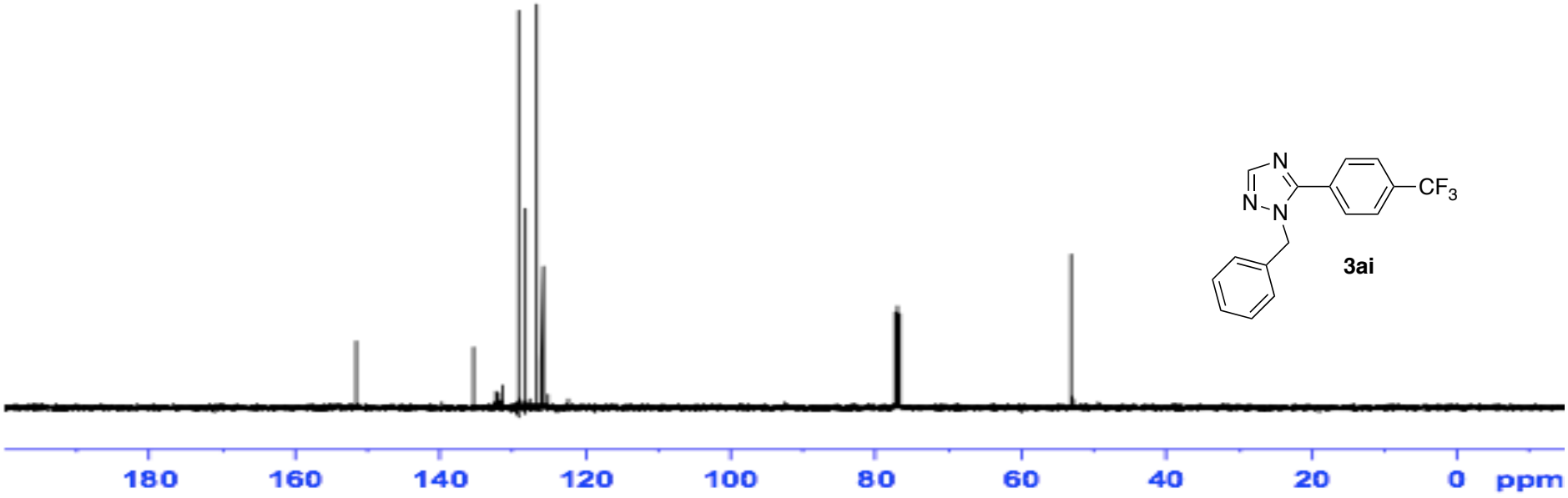
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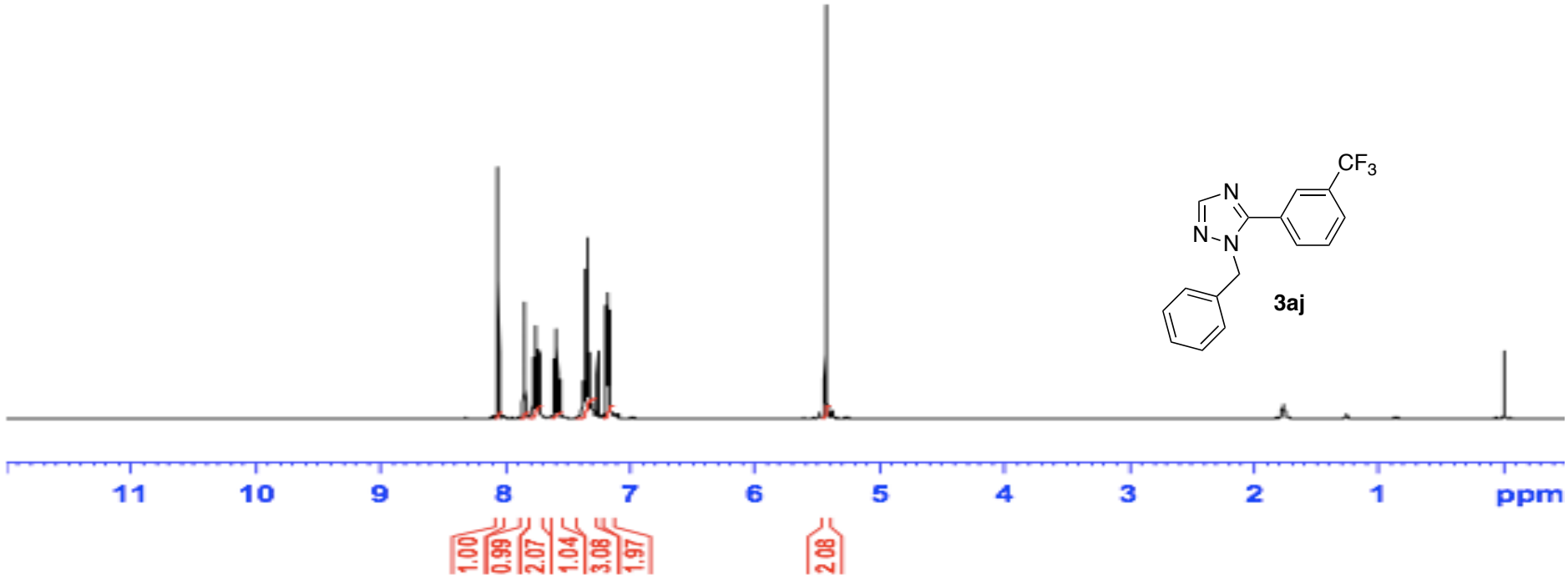
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ppm
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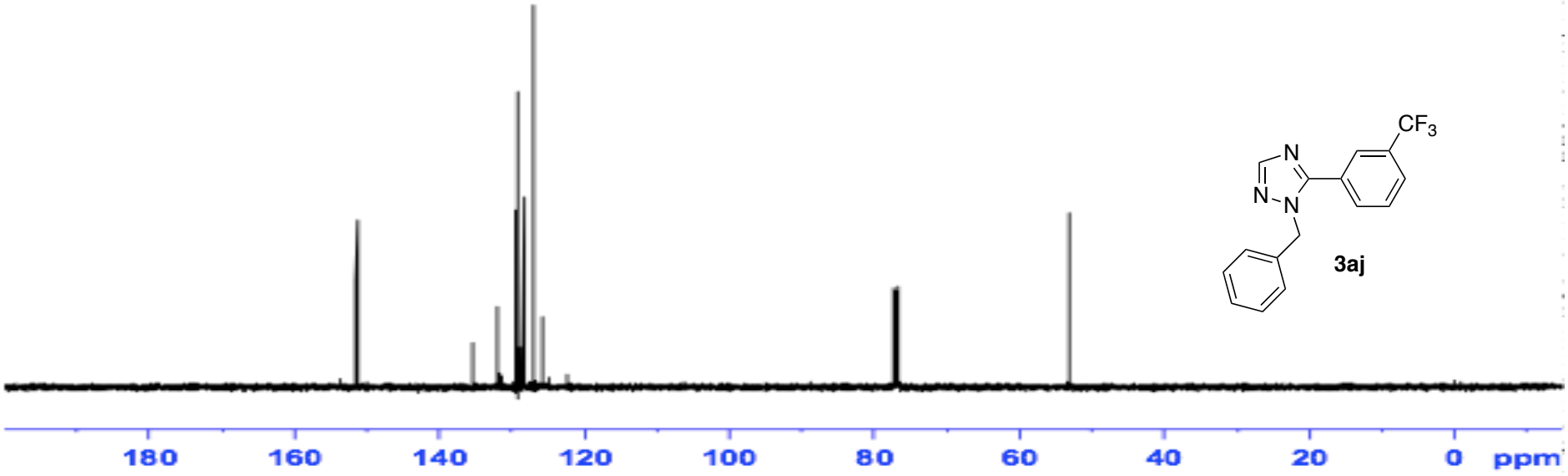
2.08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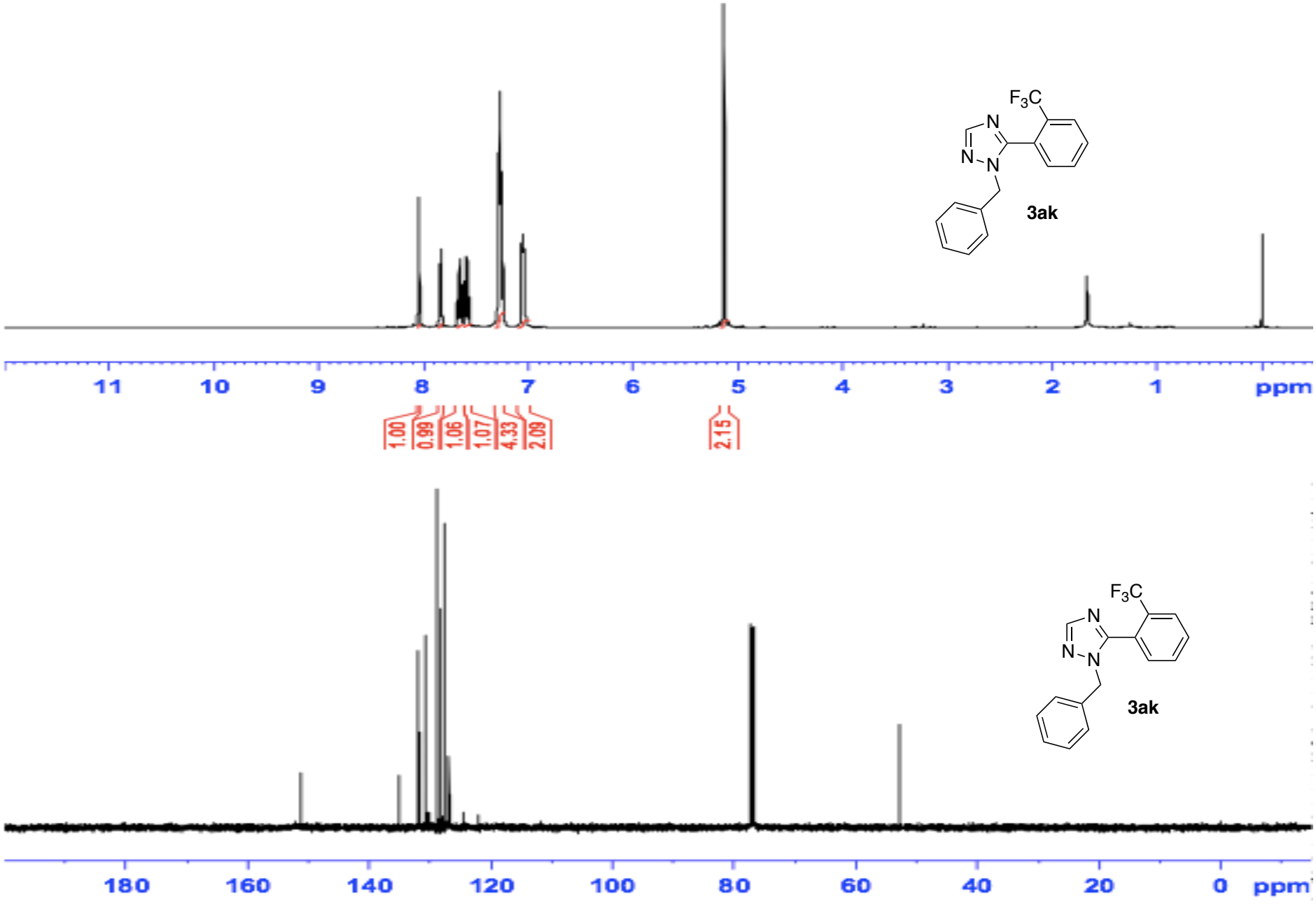
F3C
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3ak
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6
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4
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2
1
ppm
1.00
0.99
1.06
1.07
4.33
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2.15
F3C
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N
N
3ak
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120
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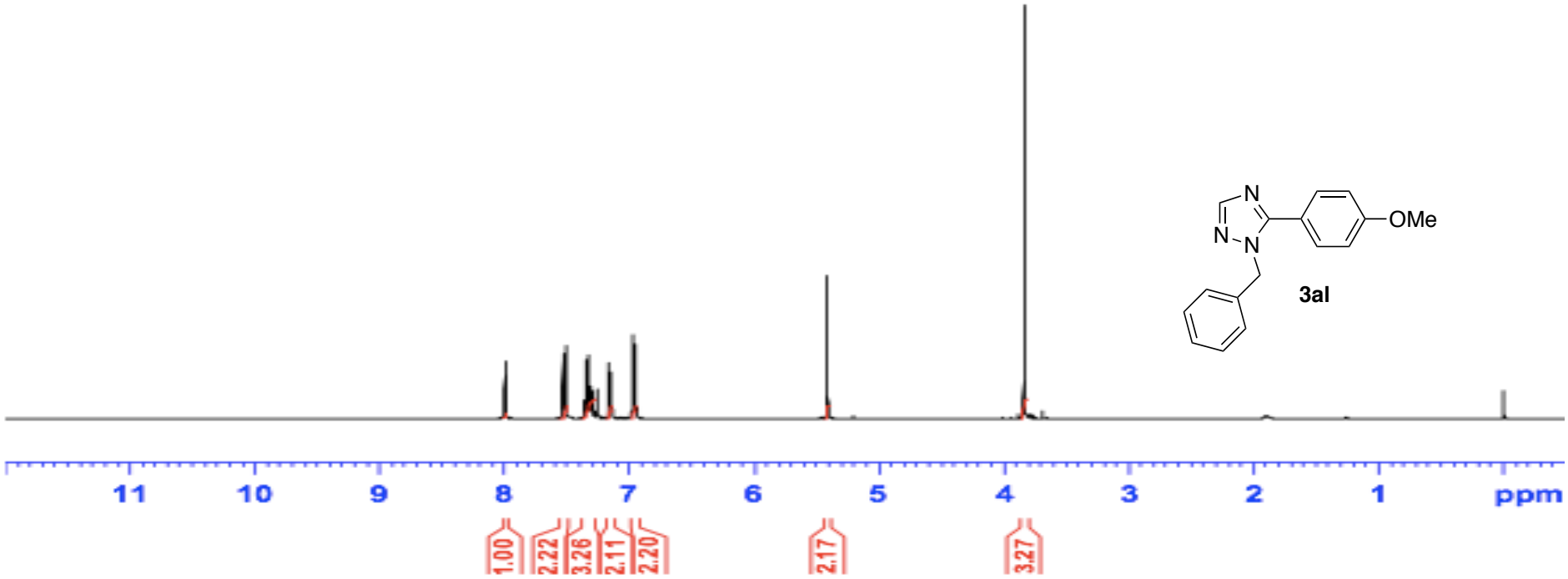
0
ppm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4
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2
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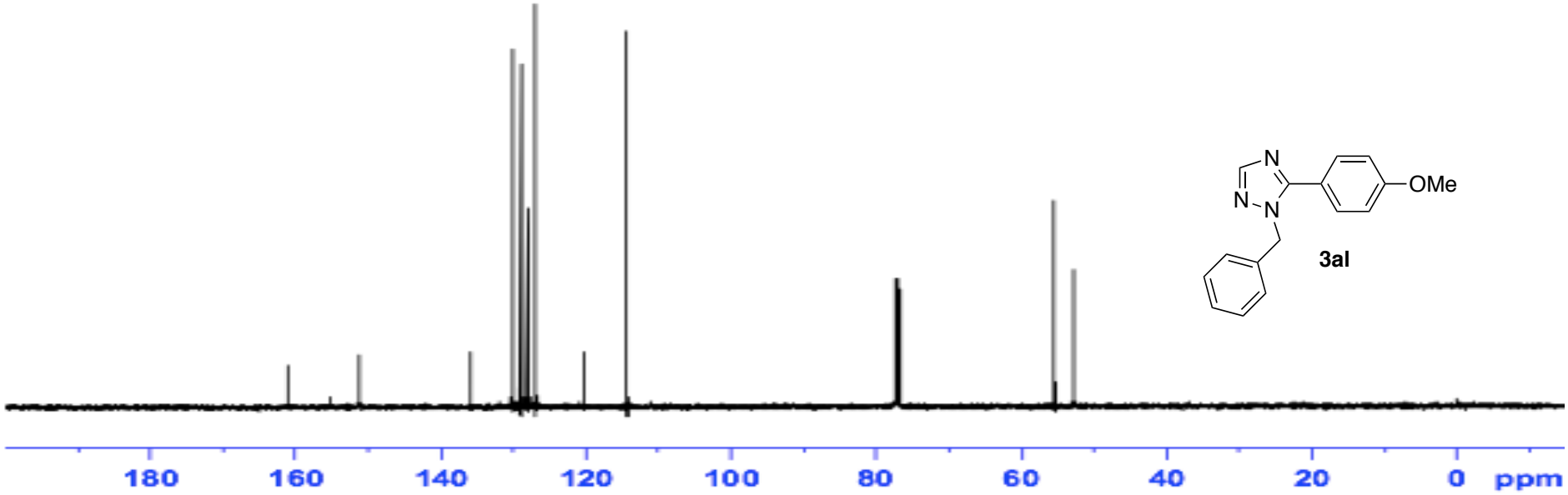
3.26
2.11
2.20
2.17
3.27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OMe
3al
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160
140
120
100
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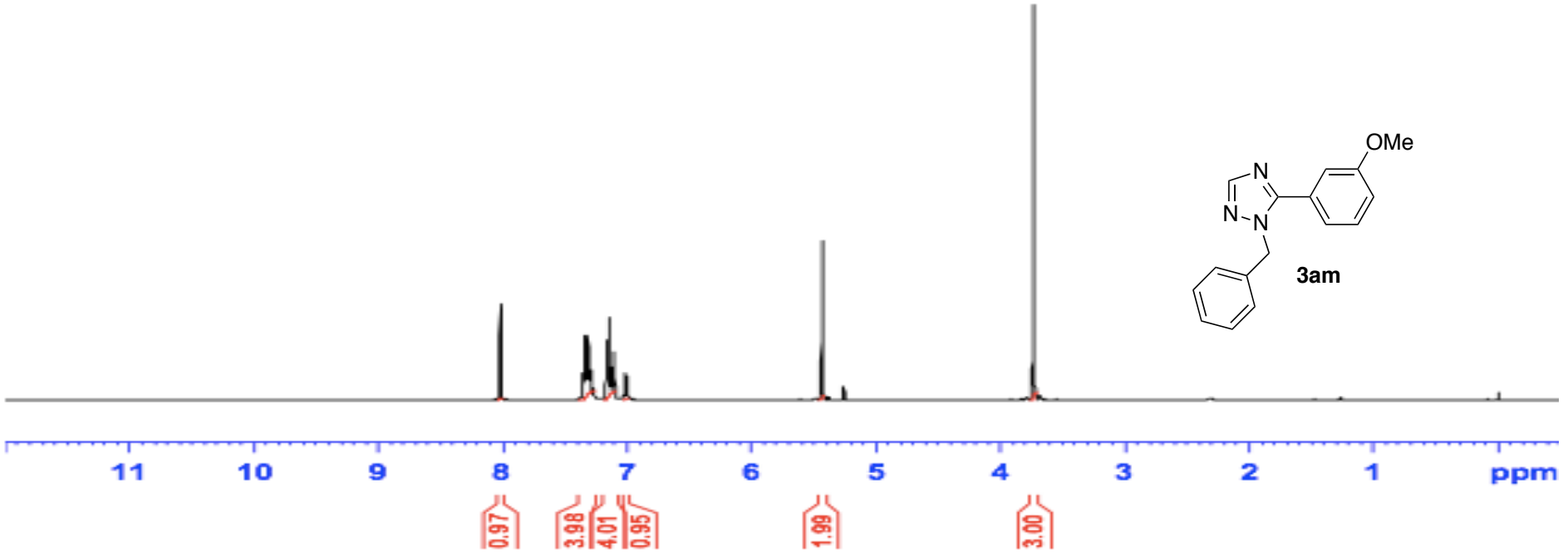
0
ppm


OMe
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N
N
3am
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4
3
2
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ppm
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3.98
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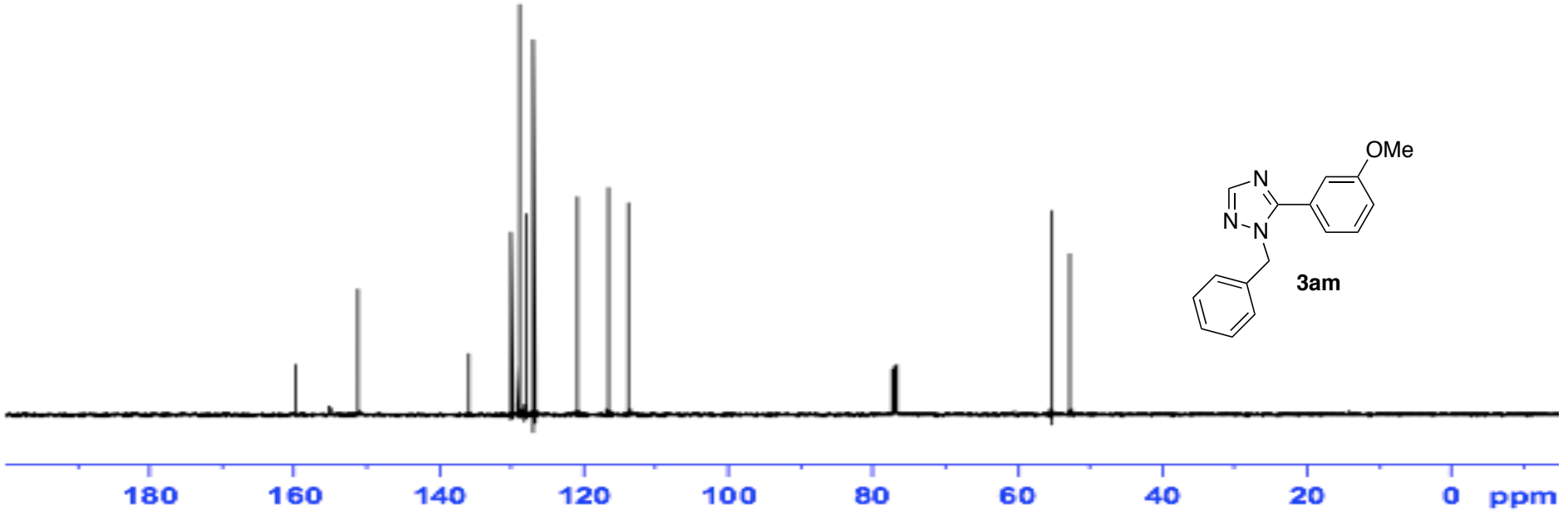
1.99
3.00


OMe
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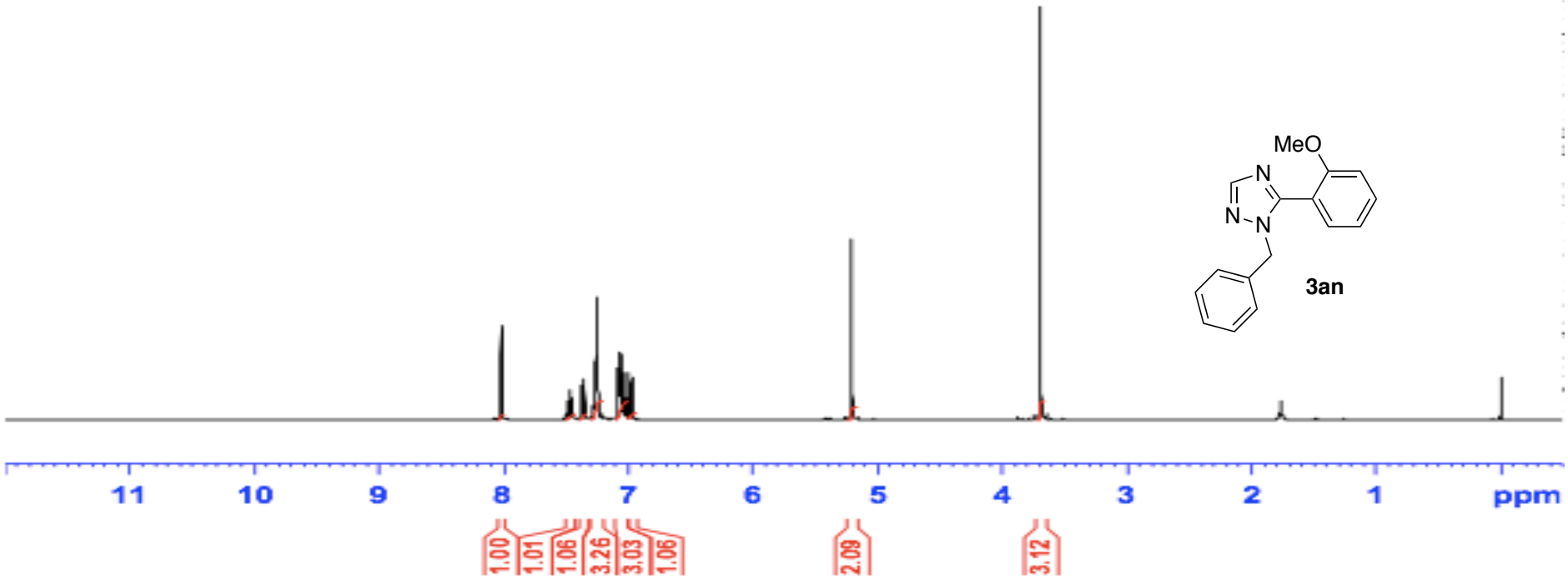
N
N
3am
180
160
140
120
100
80
60
40
20
0
ppm


MeO
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N
N
3an
11
10
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8
7
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2
1
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1.01
1.06
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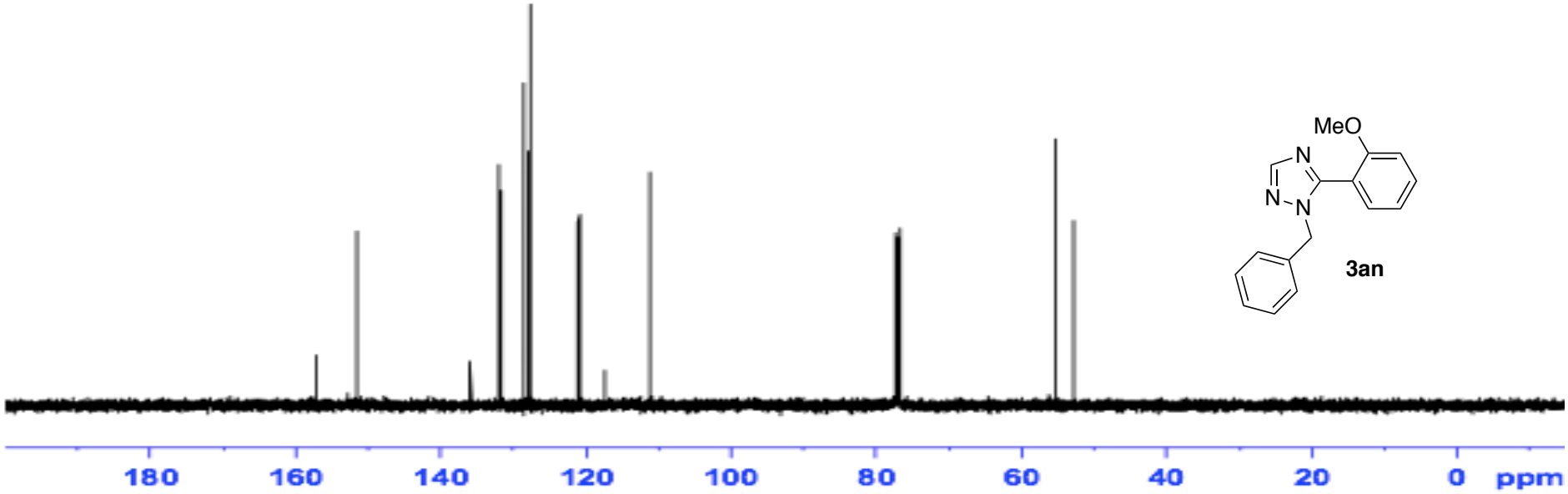
3.12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3an
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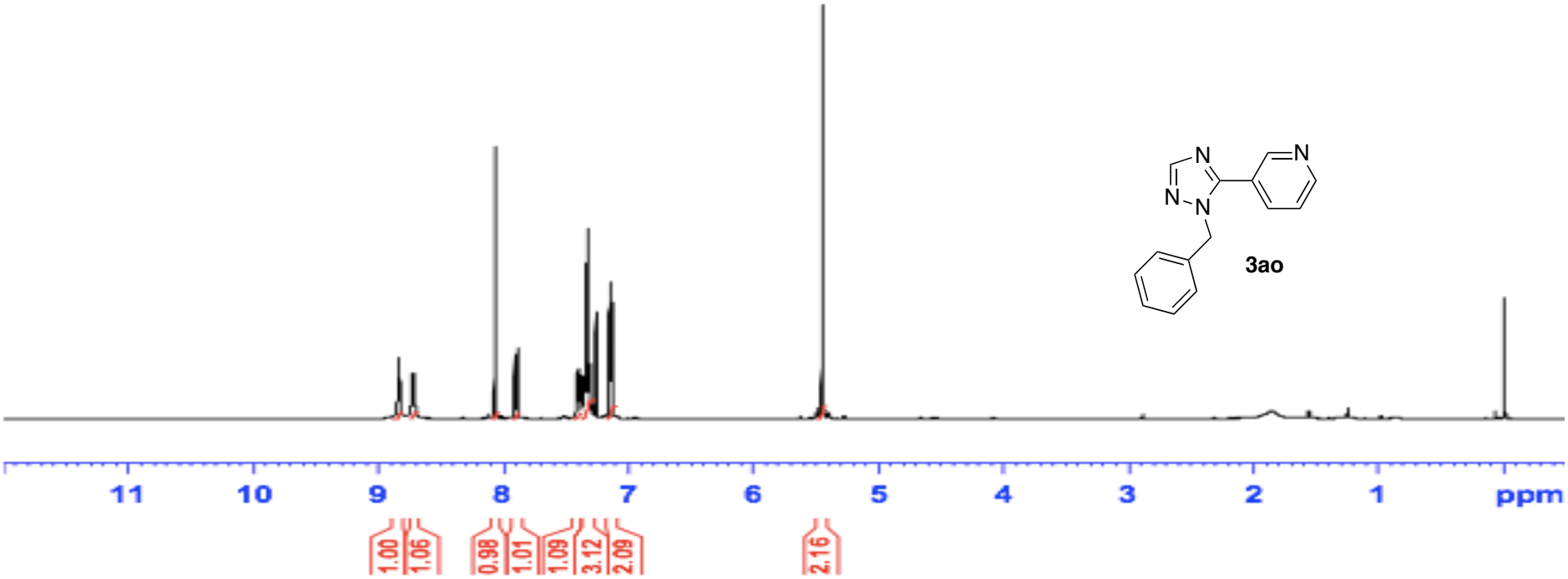
0
ppm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8
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2
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ppm
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1.01
1.09
3.12
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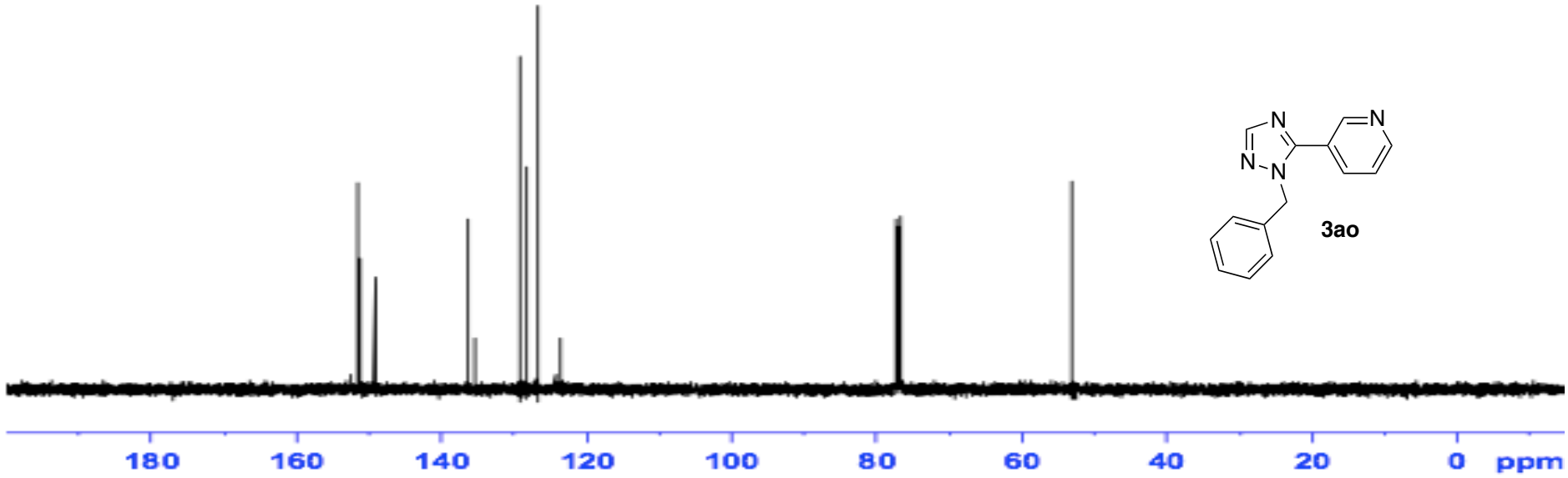
2.16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120
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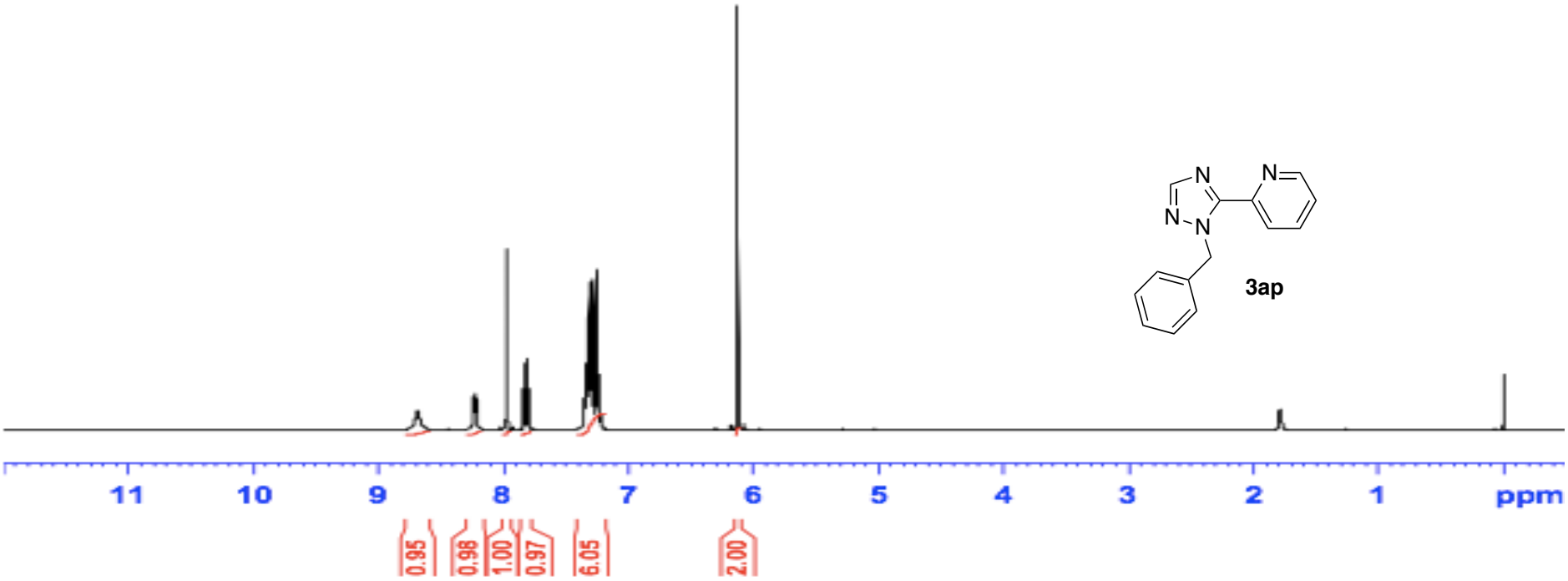
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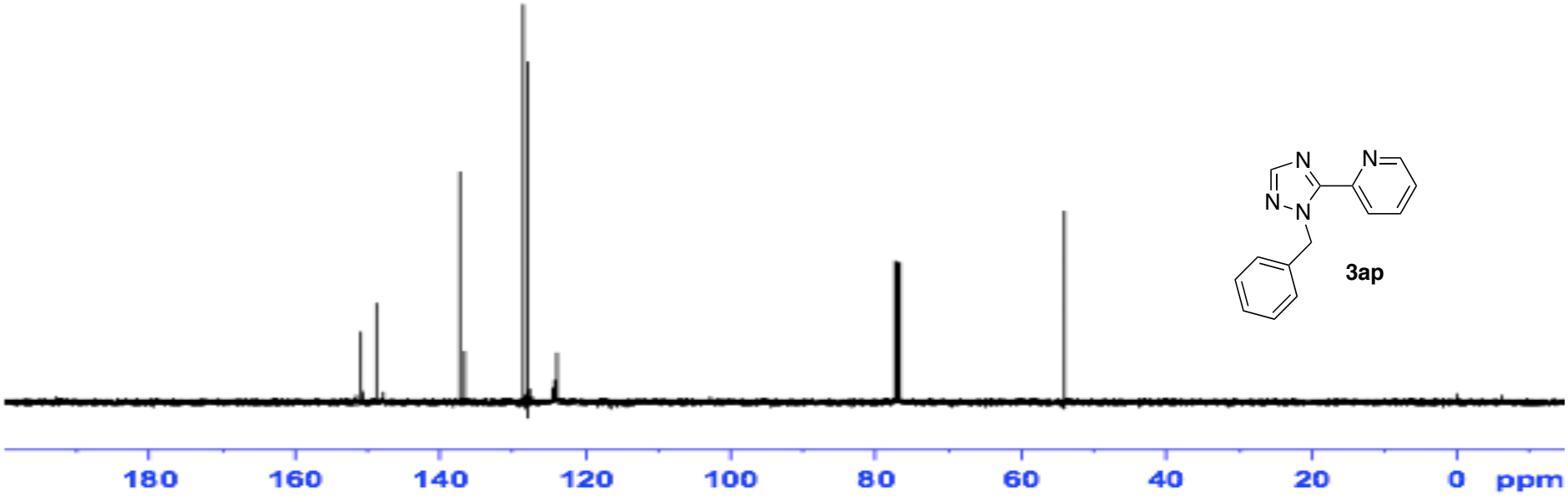
0.97
6.05
2.00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120
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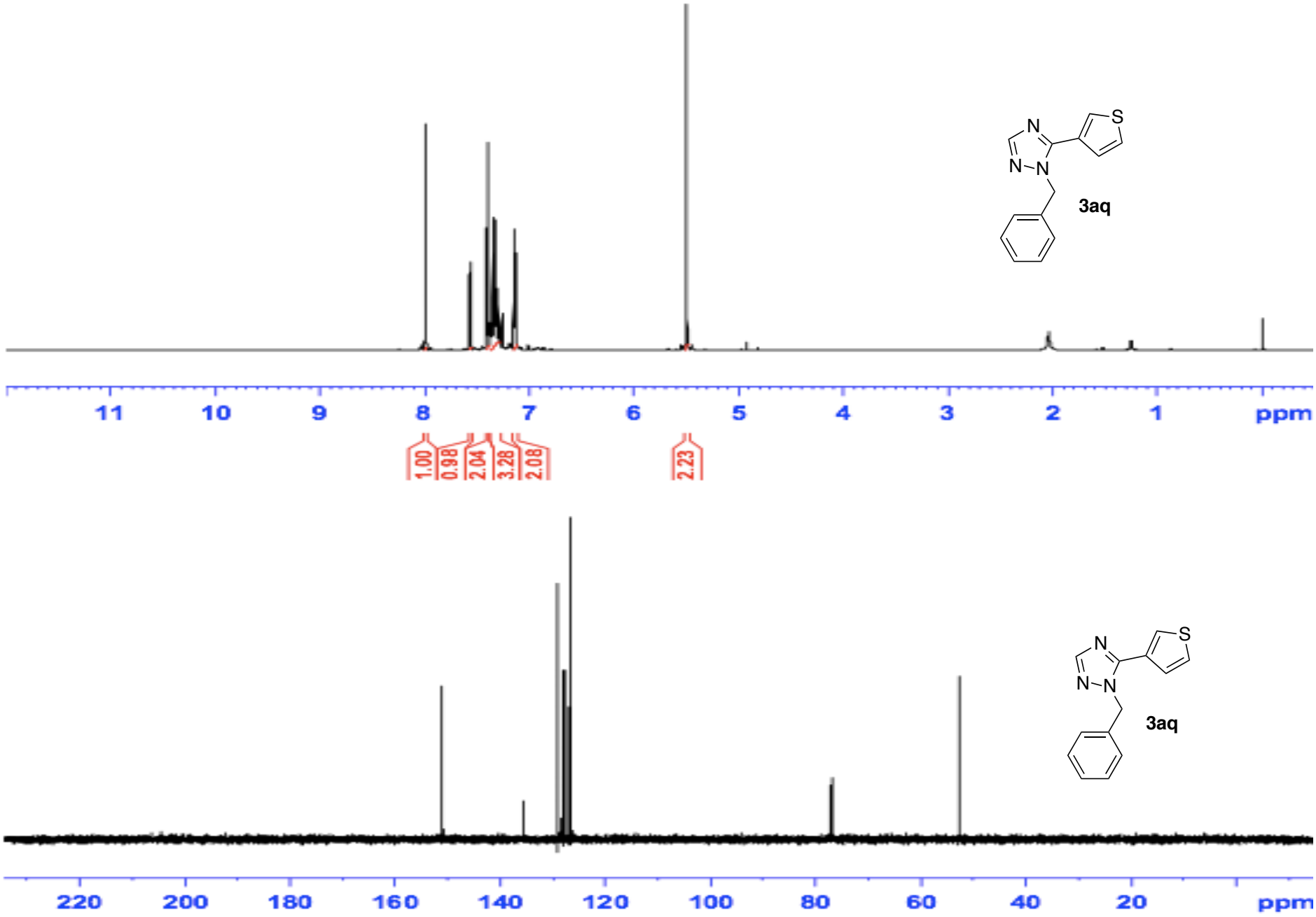
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4
3
2
1
ppm
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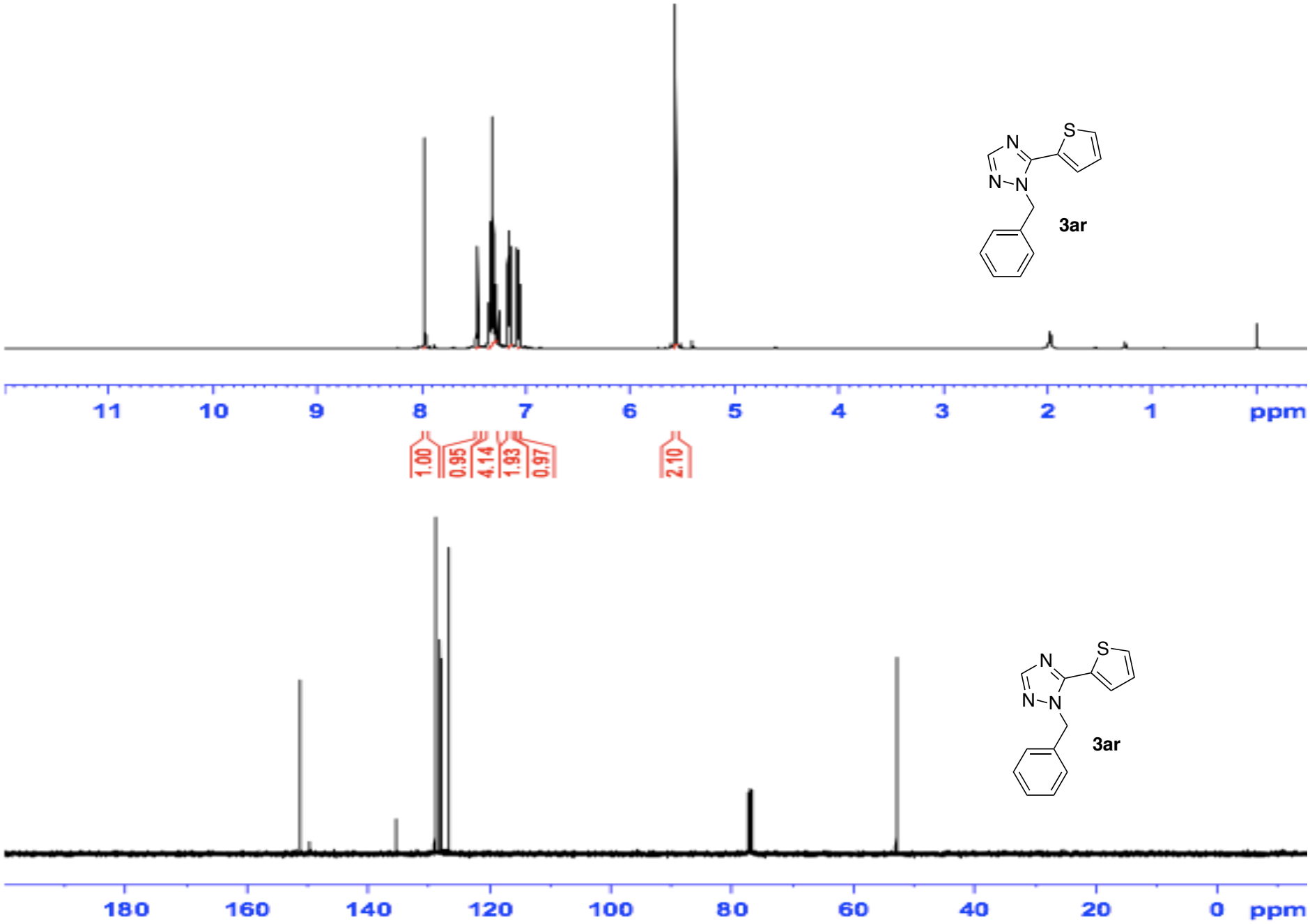
20
ppm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S
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3
2
1
ppm
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0.95
4.14
1.93
0.97
2.10
N
S
N
N
3ar
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160
140
120
100
80
60
40
20
0
ppm