Supporting Information

Base-Catalyzed and DMSO-Promoted Intramolecular Hydroalkoxylation to Prepare Pentacyclic Chromeno[4,3-b]indolines

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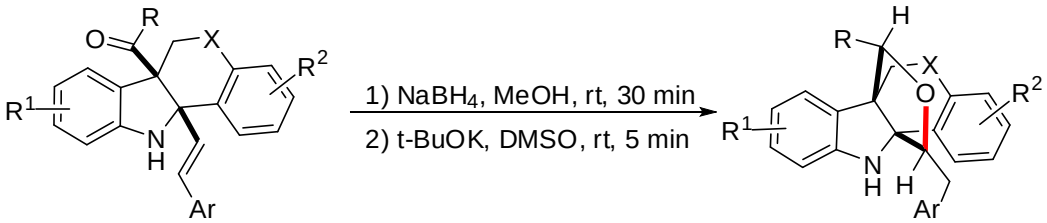
Contents

1. General Experimental Information:

^{1}H NMR and ^{13}C NMR spectra were recorded at ambient temperature using 400 MHz, 600 MHz spectrometers. The data are reported as follows: chemical shift in ppm from internal tetramethylsilane on the δ scale, multiplicity (br = broad, s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet), coupling constants (Hz), and integration. High resolution mass spectra were acquired on an LTQ FT spectrometer, and were obtained by peak matching. Melting points are reported uncorrected. Analytical thin layer chromatography was performed on 0.25 mm extra hard silica gel plates with UV254 fluorescent indicator. Chromatography was performed using with 300-400 mesh silica gel (SiO_2). Unless otherwise noted, all reagents and solvents were obtained from commercial sources and, where appropriate, purified prior to use. All reagents and solvents were obtained from commercial sources and, where appropriate, purified prior to use. Indoline **1a-1y**[1] were known compounds and prepared according to literature methods, and their spectral data matched literature values.

2. One-pot synthesis of chromeno[4,3-b]indolines 3a-3y



1, X = O, NMe

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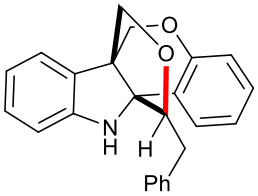
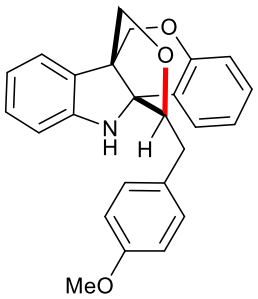
General procedure A: In a round-bottle flask was charged with indoline **1** (0.2 mmol) and MeOH (2 mL). And $NaBH_4$ (0.4 mmol, 2.0 equiv.) was then added. The reaction mixture was stirred vigorously at room temperature for 30 min until the substrate **1** disappeared (monitored by TLC). At this time, the reaction was diluted with H_2O (10 mL) and extracted with Et_2O (10 mL). The combined organic layers were washed with brine (10 mL), dried over Na_2SO_4, and filtered. The solvent was removed under reduced pressure to give crude alcohol.

In a 25 mL reaction flask was charged with the above crude alcohol, t-BuONa (0.04 mmol, 20 mol%), and DMSO (2.0 mL). The reaction was stirred for 5 min at room temperature until the indoline alcohol was completely consumed (monitored by TLC). At this time, the reaction was quenched with water (10 mL) and extracted with EtOAc (10 mL). The combined organic layers were washed with brine (10 mL), dried over Na_2SO_4, and filtered. The solvent was removed under reduced pressure and the crude product was purified by flash column chromatography (PE/EtOAc = 30:1) to afford compounds **3a-3y**.



3a

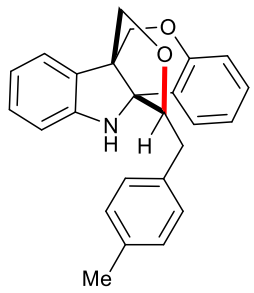
12-Benzyl-6H,11H-6a,11a-(methanooxymethano)chromeno[4,3-b]indole (**3a**). A white solid, 0.057 g, 81% yield. Mp: 181−182 ℃; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.28−7.24 (m, 2H), 7.22−7.18 (m, 4H), 7.14−7.06 (m, 2H), 7.05−6.99 (m, 2H), 6.97 (d, J = 8.0 Hz, 1H), 6.79−6.76 (m, 1H), 6.67 (d, J = 7.6 Hz, 1H), 4.33 (d, J = 11.6 Hz, 2H), 4.23 (d, J = 8.8 Hz, 1H), 4.07 (d, J = 8.8 Hz, 1H), 3.92 (d, J = 11.2 Hz, 1H), 3.83 (t, J = 6.4 Hz, 1H), 3.13 (d, J = 6.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 153.5, 149.9, 138.7, 130.6, 129.1, 128.9, 128.4, 128.1, 126.3, 125.7, 122.9, 122.7, 119.5, 118.1, 109.7, 90.9, 75.3, 72.0, 69.3, 60.1, 36.0; IR (thin film): 3342, 3030, 2928, 2856, 1608, 1491, 1038, 746 cm^{-1}; HRMS (ESI) m/z calcd for $C_{24}H_{22}NO_2$ $[M+H]^+$: 356.1651, found 356.1643.



3b

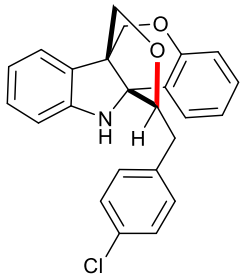
12-(4-Methoxybenzyl)-6H,11H-6a,11a-(methanooxymethano)chromeno[4,3-b]ind

ole (**3b**)**.** A white solid, 0.008 g, 10% yield. Mp: 174−175 ℃; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.22−7.18 (m, 1H), 7.15−7.08 (m, 4H), 7.05−7.00 (m, 2H), 6.97 (d, J = 8.0 Hz, 1H), 6.81−6.79 (m, 2H), 6.77 (d, J = 7.2 Hz, 1H), 6.69 (d, J = 8.0 Hz, 1H), 4.32 (d, J = 11.2 Hz, 2H), 4.22 (d, J = 8.8 Hz, 1H), 4.06 (d, J = 8.8 Hz, 1H), 3.92 (d, J = 11.2 Hz, 1H), 3.81−3.76 (m, 4H), 3.07 (d, J = 6.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 158.1, 153.6, 149.9, 130.7, 130.6, 130.0, 128.9, 128.4, 128.2, 125.6, 122.9, 122.7, 119.5, 118.1, 113.8, 109.7, 91.1, 75.3, 72.0, 69.3, 60.1, 55.2, 35.1; IR (thin film): 3470, 3028, 2926, 2857, 1609, 1492, 1087, 762 cm^{-1}; HRMS (ESI) m/z calcd for $C_{25}H_{24}NO_3$ $[M+H]^+$: 386.1756, found 386.1747.



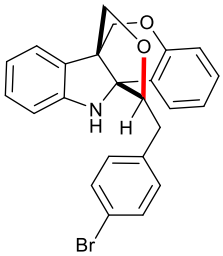
3c

12-(4-Methylbenzyl)-6H,11H-6a,11a-(methanooxymethano)chromeno[4,3-b]indol e (**3c**)**.** A white solid, 0.037 g, 50% yield. Mp: 182−183 ℃; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.21−7.17 (m, 1H), 7.15 (d, J = 7.2 Hz, 1H), 7.11−7.05 (m, 5H), 7.04−6.99 (m, 2H), 6.97 (d, J = 8.0 Hz, 1H), 6.78−6.75 (m, 1H), 6.69 (d, J = 7.6 Hz, 1H), 4.34 (s, 1H), 4.32 (d, J = 11.6 Hz, 1H), 4.21 (d, J = 8.8 Hz, 1H), 4.05 (d, J = 8.8 Hz, 1H), 3.92 (d, J = 11.6 Hz, 1H), 3.80 (t, J = 6.4 Hz, 1H), 3.08 (d, J = 6.0 Hz, 2H), 2.29 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 153.6, 150.0, 135.9, 135.5, 130.7, 129.1, 129.0, 128.9, 128.4, 128.2, 125.8, 122.9, 122.7, 119.5, 118.1, 109.7, 91.0, 75.3, 72.0, 69.3, 60.1, 35.6, 21.0; IR (thin film): 3343, 3021, 2925, 2856, 1608, 1490, 1263, 1039, 794, 686 cm^{-1}; HRMS (ESI) m/z calcd for $C_{25}H_{24}NO_2$ $[M+H]^+$: 370.1802, found 370.1800.



3d

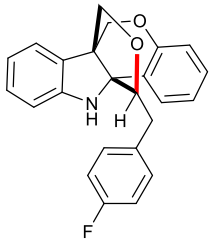
12-(4-Chlorobenzyl)-6H,11H-6a,11a-(methanooxymethano)chromeno[4,3-b]indole (3d). A white solid, 0.051 g, 65% yield. Mp: 197−198 ℃; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.23−7.16 (m, 4H), 7.13−7.07 (m, 3H), 7.05−7.01 (m, 2H), 6.97 (d, J = 7.6 Hz, 1H), 6.79 (t, J = 7.2 Hz, 1H), 6.69 (d, J = 7.6 Hz, 1H), 4.31 (d, J = 11.2 Hz, 2H), 4.21 (d, J = 8.8 Hz, 1H), 4.02 (d, J = 9.2 Hz, 1H), 3.89 (d, J = 11.2 Hz, 1H), 3.74 (dd, J = 4.4 Hz, 8.0 Hz, 1H), 3.08 (d, J = 8.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 153.5, 149.9, 137.2, 132.1, 130.7, 130.5, 128.9, 128.5, 128.4, 127.9, 125.4, 122.8, 122.7, 119.7, 118.2, 109.9, 90.7, 75.3, 73.9, 69.1, 60.1, 35.3; IR (thin film): 3371, 3031, 2913, 2356, 1607, 1487, 1299, 1048, 766, 693 cm^{-1}; HRMS (ESI) m/z calcd for $C_{24}H_{21}ClNO_2$ $[M+H]^+$: 390.1255, found 390.1254.



3e

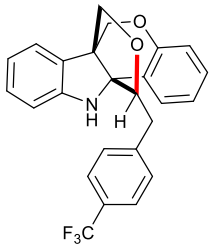
12-(4-Bromobenzyl)-6H,11H-6a,11a-(methanooxymethano)chromeno[4,3-b]indole (3e). A white solid, 0.044 g, 51% yield. Mp: 198−199 ℃; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.37−7.35 (m, 2H), 7.24−7.21 (m, 1H), 7.19 (d, J = 8.0 Hz, 1H), 7.12−7.02 (m, 5H), 6.98 (d, J = 8.0 Hz, 1H), 6.80−6.76 (m, 1H), 6.69 (d, J = 7.6 Hz, 1H), 4.32 (d, J = 12.0 Hz, 2H), 4.22 (d, J = 9.2 Hz, 1H), 4.05 (d, J = 8.8 Hz, 1H), 3.90 (d, J = 11.6 Hz, 1H), 3.74 (dd, J = 4.0 Hz, 8.8 Hz, 1H), 3.08 (d, J = 8.8 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 153.6, 150.0, 137.7, 131.4, 130.9, 130.7, 129.0, 128.6, 127.9, 125.4, 122.9, 122.8, 120.2, 119.7, 118.2, 109.9, 90.6, 75.3, 71.9, 69.3, 60.1, 35.4; IR (thin

film): 3353, 3015, 2925, 2855, 1608, 1490, 1206, 1040, 761, 686 cm^{-1}; HRMS (ESI) m/z calcd for $C_{24}H_{21}BrNO_2$ $[M+H]^+$: 434.0750, found 434.0749.



3f

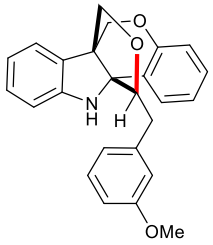
12-(4-Fluorobenzyl)-6H,11H-6a,11a-(methanooxymethano)chromeno[4,3-b]indole (3f). A white solid, 0.054 g, 73% yield. Mp: 186−187 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.24−7.20 (m, 1H), 7.18−7.14 (m, 3H), 7.12−7.08 (m, 1H), 7.05−7.01 (m, 2H), 6.98 (d, J = 8.4 Hz, 1H), 6.95−6.91 (m, 2H), 6.80−6.76 (m, 1H), 6.70 (d, J = 8.0 Hz, 1H), 4.33 (d, J = 11.2 Hz, 2H), 4.22 (d, J = 8.8 Hz, 1H), 4.06 (d, J = 9.2 Hz, 1H), 3.91 (d, J = 11.2 Hz, 1H), 3.76 (t, J = 6.0 Hz, 1H), 3.09 (d, J = 6.0 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 162.7 (d, J = 242.1 Hz), 153.6, 144.9, 134.4 (d, J = 2.9 Hz), 130.7, 130.5, 130.4, 128.9, 128.5, 128.0, 125.5, 122.9 (d, J = 12.4 Hz), 119.6, 118.2, 115.2 (d, J = 21.1 Hz), 109.8, 90.9, 75.3, 71.9, 69.3, 60.1, 35.1; ^{19}F NMR (376 MHz, $CDCl_3$): δ -111.4; IR (thin film): 3330, 3043, 2929, 2849, 1606, 1489, 1216, 1062, 747, 693 cm^{-1}; HRMS (ESI) m/z calcd for $C_{24}H_{21}FNO_2$ $[M+H]^+$: 374.1551, found 374.1545.



3g

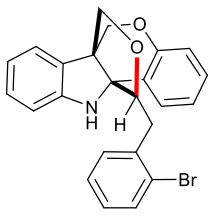
12-(4-(Trifluoromethyl)benzyl)-6H,11H-6a,11a-(methanooxymethano)chromeno[4,3-b]indole (3g). A white solid, 0.061 g, 73% yield. Mp: 163−164 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.50−7.48 (m, 2H), 7.31−7.29 (m, 2H), 7.23−7.18 (m, 2H), 7.12−7.09 (m, 1H), 7.06−7.03 (m, 2H), 6.99 (d, J = 8.4 Hz, 1H), 6.81−6.77 (m, 1H), 6.70 (d, J = 7.6 Hz, 1H), 4.33 (d, J = 11.2 Hz, 2H), 4.23 (d, J = 9.2 Hz, 1H), 4.05 (d, J

= 8.8 Hz, 1H), 3.90 (d, *J* = 11.6 Hz, 1H), 3.77 (dd, *J* = 3.2 Hz, 8.8 Hz, 1H), 3.22−3.12 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): *δ* 153.6, 150.0, 143.0, 130.8, 129.5, 129.1 (q, *J* = 32.1 Hz), 129.0, 128.6, 128.3 (q, *J* = 270.6 Hz), 127.9, 125.3, 125.2 (q, *J* = 3.6 Hz), 122.9, 122.8, 119.8, 118.2, 110.0, 90.5, 75.4, 72.0, 69.4, 60.2, 35.8; ^{19}F NMR (376 MHz, $CDCl_3$): *δ* -62.3; IR (thin film): 3353, 3040, 2924, 2854, 1611, 1491, 1208, 1038, 747, 687 cm^{-1}; HRMS (ESI) m/z calcd for $C_{25}H_{21}F_3NO_2$ $[M+H]^+$: 424.1519, found 424.1521.



3h

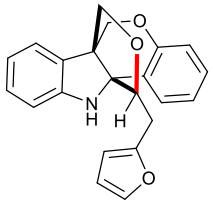
12-(3-Methoxybenzyl)-6H,11H-6a,11a-(methanooxymethano)chromeno[4,3-b]indole (**3h**)**.** A white solid, 0.038 g, 49% yield. Mp: 231−232 ℃; ^{1}H NMR (400 MHz, $CDCl_3$): *δ* 7.22−7.16 (m, 2H), 7.14−7.08 (m, 2H), 7.05−6.99 (m, 2H), 6.97 (d, *J* = 8.0 Hz, 1H), 6.81 (d, *J* = 6.8 Hz, 1H), 6.77−6.73 (m, 3H), 6.70 (d, *J* = 8.0 Hz, 1H), 4.33 (d, *J* = 11.6 Hz, 2H), 4.23 (d, *J* = 8.8 Hz, 1H), 4.07 (d, *J* = 9.2 Hz, 1H), 3.92 (d, *J* = 11.2 Hz, 1H), 3.83−3.79 (m, 1H), 3.75 (s, 3H), 3.11 (d, *J* = 6.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): *δ* 159.6, 153.6, 149.9, 140.3, 130.7, 129.4, 128.9, 128.4, 128.1, 125.7, 122.9, 122.7, 121.5, 119.5, 118.1, 114.9, 111.8, 109.7, 90.8, 75.3, 72.1, 69.3, 60.0, 54.9, 36.1; IR (thin film): 3416, 3028, 2920, 2852, 1619, 1490, 1264, 1022, 737, 692 cm^{-1}; HRMS (ESI) m/z calcd for $C_{25}H_{24}NO_3$ $[M+H]^+$: 386.1751, found 386.1748.



3i

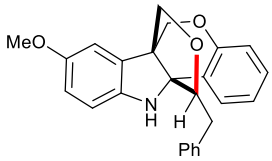
12-(2-Bromobenzyl)-6H,11H-6a,11a-(methanooxymethano)chromeno[4,3-b]indole (**3i**)**.** A white solid, 0.065 g, 75% yield. Mp: 272−273 ℃; ^{1}H NMR (400 MHz, $CDCl_3$): *δ* 7.49 (d, *J* = 8.0 Hz, 1H), 7.37 (d, *J* = 7.6 Hz, 1H), 7.32 (d, *J* = 7.2 Hz, 1H),

7.22−7.18 (m, 2H), 7.13−7.09 (m, 1H), 7.06−7.03 (m, 3H), 6.96 (d, *J* = 8.0 Hz, 1H), 6.80−6.77 (m, 1H), 6.71 (d, *J* = 7.6 Hz, 1H), 4.36 (s, 1H), 4.32 (d, *J* = 11.6 Hz, 1H), 4.22 (d, *J* = 8.8 Hz, 1H), 4.05 (d, *J* = 9.2 Hz, 1H), 3.96−3.89 (m, 2H), 3.42−3.39 (m, 1H), 3.15 (dd, *J* = 10.0 Hz, 14.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): *δ* 153.5, 150.0, 138.1, 132.7, 131.8, 130.6, 128.9, 128.5, 128.1, 127.7, 127.3, 126.1, 124.5, 122.9, 122.7, 119.6, 118.0, 109.9, 88.8, 75.3, 72.2, 69.3, 60.1, 36.5; IR (thin film): 3470, 3030, 2919, 2850, 1632, 1490, 1227, 1047, 761, 685 cm^{-1}; HRMS (ESI) m/z calcd for $C_{24}H_{21}BrNO_2$ $[M+H]^+$: 434.0750, found 434.0749.



3j

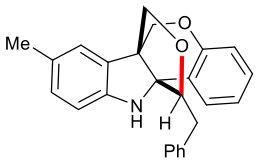
12-(Furan-2-ylmethyl)-6H,11H-6a,11a-(methanooxymethano)chromeno[4,3-b]indole (3j). A white solid, 0.048 g, 70% yield. Mp: 167−168 ℃; ^{1}H NMR (400 MHz, $CDCl_3$): *δ* 7.31 (s, 1H), 7.18−7.15 (m, 1H), 7.10−7.06 (m, 1H), 7.04 (d, *J* = 7.2 Hz, 1H), 6.97−6.93 (m, 2H), 6.88 (d, *J* = 7.2 Hz, 1H), 6.78−6.74 (m, 1H), 6.67 (d, *J* = 7.6 Hz, 1H), 6.31 (s, 1H), 6.14 (d, *J* = 2.4 Hz, 1H), 4.39 (s, 1H), 4.31 (d, *J* = 11.2 Hz, 1H), 4.23 (d, *J* = 9.2 Hz, 1H), 4.11 (d, *J* = 8.8 Hz, 1H), 3.99 (t, *J* = 6.4 Hz, 1H), 3.90 (d, *J* = 11.6 Hz, 1H), 3.18 (d, *J* = 6.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): *δ* 153.4, 152.2, 149.8, 141.3, 130.3, 129.0, 128.4, 127.9, 125.9, 122.9, 122.7, 119.5, 118.0, 110.5, 109.7, 107.0, 88.4, 74.9, 71.8, 69.0, 60.1, 29.1; IR (thin film): 3339, 3036, 2925, 2856, 1609, 1490, 1208, 1039, 747, 689 cm^{-1}; HRMS (ESI) m/z calcd for $C_{22}H_{20}NO_3$ $[M+H]^+$: 346.1438, found 346.1434.



3k

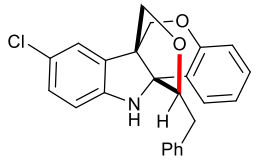
12-Benzyl-8-methoxy-6H,11H-6a,11a-(methanooxymethano)chromeno[4,3-b]indole (3k). A white solid, 0.041 g, 54% yield. Mp: 145−146 ℃; ^{1}H NMR (400 MHz, $CDCl_3$): *δ* 7.27−7.17 (m, 6H), 7.16 (d, *J* = 8.4 Hz, 1H), 7.02−6.98 (m, 1H), 6.96 (d, *J*

= 8.0 Hz, 1H), 6.69−6.65 (m, 3H), 4.30 (d, *J* = 11.6 Hz, 1H), 4.22 (d, *J* = 8.8 Hz, 1H), 4.03 (d, *J* = 8.8 Hz, 1H), 3.91 (d, *J* = 11.6 Hz, 1H), 3.81 (s, 1H), 3.75 (s, 3H), 3.17−3.08 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): *δ* 154.3, 153.4, 143.8, 138.8, 132.5, 129.1, 128.4, 128.3, 126.3, 125.8, 122.7, 118.0, 114.1, 111.1, 109.4, 91.1, 74.9, 72.5, 69.0, 60.3, 55.9, 36.2; IR (thin film): 3337, 3023, 2939, 2846, 1600, 1495, 1226, 1032, 765, 664 cm^{-1}; HRMS (ESI) m/z calcd for $C_{25}H_{24}NO_3$ $[M+H]^+$: 386.1751, found 386.1748.



3l

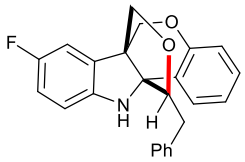
12-Benzyl-8-methyl-6H,11H-6a,11a-(methanooxymethano)chromeno[4,3-b]indole (3l). A white solid, 0.047 g, 64% yield. Mp: 189−190 °C; ^{1}H NMR (400 MHz, $CDCl_3$): *δ* 7.25−7.16 (m, 6H), 7.12 (d, *J* = 6.8 Hz, 1H), 7.01−6.94 (m, 2H), 6.92 (d, *J* = 7.6 Hz, 1H), 6.85 (s, 1H), 6.61 (d, *J* = 7.6 Hz, 1H), 4.29 (d, *J* = 11.2 Hz, 1H), 4.21 (d, *J* = 8.8 Hz, 2H), 4.03 (d, *J* = 9.2 Hz, 1H), 3.90 (d, *J* = 11.6 Hz, 1H), 3.83 (t, *J* = 6.8 Hz, 1H), 3.12 (d, *J* = 6.0 Hz, 2H), 2.26 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): *δ* 153.4, 147.6, 138.8, 131.0, 129.4, 129.1, 129.0, 128.4, 128.3, 126.3, 125.8, 123.5, 122.7, 118.0, 109.9, 91.0, 75.0, 72.2, 69.2, 60.0, 36.2, 20.8; IR (thin film): 3321, 3022, 2927, 2859, 1615, 1497, 1227, 1074, 758, 697 cm^{-1}; HRMS (ESI) m/z calcd for $C_{25}H_{24}NO_2$ $[M+H]^+$: 370.1802, found 370.1800.



3m

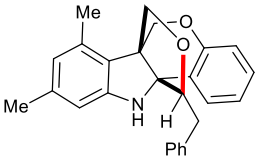
12-Benzyl-8-chloro-6H,11H-6a,11a-(methanooxymethano)chromeno[4,3-b]indole (3m). A yellow solid, 0.055 g, 71% yield. Mp: 233−234 °C; ^{1}H NMR (400 MHz, $CDCl_3$): *δ* 7.27−7.24 (m, 2H), 7.21−7.19 (m, 4H), 7.10 (d, *J* = 7.2 Hz, 1H), 7.05−7.01 (m, 2H), 6.99−6.95 (m, 2H), 6.59 (d, *J* = 8.0 Hz, 1H), 4.32 (s, 1H), 4.28 (d, *J* = 11.6 Hz, 1H), 4.19 (d, *J* = 8.8 Hz, 1H), 4.02 (d, *J* = 8.8 Hz, 1H), 3.89 (d, *J* = 11.6 Hz, 1H),

3.82 (t, J = 6.4 Hz, 1H), 3.11 (d, J = 6.0 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 153.4, 148.5, 138.4, 132.4, 129.1, 128.8, 128.6, 128.4, 127.6, 126.4, 125.6, 123.9, 123.2, 122.8, 118.2, 110.5, 90.8, 75.1, 72.6, 68.9, 60.2, 36.0; IR (thin film): 3343, 3029, 2923, 2857, 1603, 1486, 1207, 1031, 770, 683 cm^{-1}; HRMS (ESI) m/z calcd for $C_{24}H_{21}ClNO_2$ $[M+H]^+$: 390.1255, found 390.1250.



3n

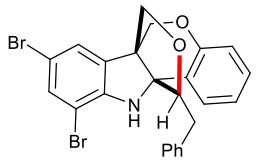
12-Benzyl-8-fluoro-6H,11H-6a,11a-(methanooxymethano)chromeno[4,3-b]indole (3n). A white solid, 0.045 g, 61% yield. Mp: 209−210 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.27−7.21 (m, 6H), 7.14 (d, J = 7.6 Hz, 1H), 7.03−7.00 (m, 1H), 6.97 (d, J = 8.0 Hz, 1H), 6.82−6.75 (m, 2H), 6.62 (dd, J = 4.4 Hz, 8.4 Hz, 1H), 4.28 (d, J = 11.2 Hz, 1H), 4.19 (d, J = 8.8 Hz, 2H), 4.03 (d, J = 9.2 Hz, 1H), 3.91 (d, J = 11.2 Hz, 1H), 3.83 (dd, J = 5.2 Hz, 7.2 Hz, 1H), 3.13 (d, J = 4.8 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 158.7 (d, J = 235.5 Hz), 153.4, 146.0, 138.6, 132.3 (d, J = 7.3 Hz), 129.1, 128.6, 128.4, 127.9, 126.4, 125.6, 122.8, 118.1, 115.3 (d, J = 22.6 Hz), 110.6 (d, J = 8.0 Hz), 110.3 (d, J = 24.1 Hz), 90.9, 75.0, 72.8, 68.9, 60.3, 36.1; ^{19}F NMR (376 MHz, $CDCl_3$): δ -124.3; IR (thin film): 3339, 3027, 2923, 2856, 1604, 1490, 1225, 1030, 773, 651 cm^{-1}; HRMS (ESI) m/z calcd for $C_{24}H_{21}FNO_2$ $[M+H]^+$: 374.1551, found 374.1548.



3o

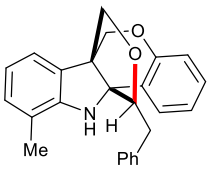
12-Benzyl-7,9-dimethyl-6H,11H-6a,11a-(methanooxymethano)chromeno[4,3-b]indole (3o). A white solid, 0.057 g, 75% yield. Mp: 163−164 °C; ^{1}H NMR (400 MHz, DMSO-d_6): δ 7.57 (d, J = 7.2 Hz, 1H), 7.20−7.18 (m, 3H), 7.15 (d, J = 6.8 Hz, 1H), 7.08−06 (m, 2H), 6.95 (d, J = 8.0 Hz, 1H), 6.72 (s, 1H), 6.17−6.14 (m, 2H), 4.62 (d, J = 11.6 Hz, 1H), 4.20 (d, J = 8.8 Hz, 1H), 3.92 (d, J = 8.8 Hz, 1H), 3.68 (d, J = 11.2 Hz,

2H), 3.03 (d, *J* = 14.4 Hz, 1H), 2.85 (dd, *J* = 10.4 Hz, 14.0 Hz, 1H), 2.13 (s, 6H); ^{13}C NMR (100 MHz, DMSO-d_6): δ 153.8, 151.7, 139.7, 138.3, 133.5, 129.4, 129.3, 128.7, 128.6, 127.4, 126.5, 124.9, 122.9, 120.2, 117.7, 106.2, 91.5, 74.4, 72.6, 70.0, 60.3, 35.3, 21.6, 18.8; IR (thin film): 3432, 3029, 2918, 2855, 1654, 1489, 1228, 1027, 764, 697 cm^{-1}; HRMS (ESI) m/z calcd for $C_{26}H_{26}NO_2$ $[M+H]^+$: 384.1958, found 384.1956.



3p

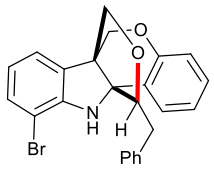
12-Benzyl-8,10-dibromo-6H,11H-6a,11a-(methanooxymethano)chromeno[4,3-b]indole (3p). A white solid, 0.054 g, 53% yield. Mp: 179−180 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.38 (s, 1H), 7.30−7.22 (m, 6H), 7.06 (s, 1H), 7.01−7.00 (m, 2H), 6.98 (d, *J* = 8.0 Hz, 1H), 4.55 (s, 1H), 4.27 (d, *J* = 11.2 Hz, 1H), 4.19 (d, *J* = 9.2 Hz, 1H), 4.04 (d, *J* = 8.8 Hz, 1H), 3.88 (d, *J* = 11.2 Hz, 1H), 3.83 (t, *J* = 6.4 Hz, 1H), 3.12 (d, *J* = 6.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 153.3, 147.6, 137.9, 133.4, 132.9, 129.2, 128.8, 128.5, 126.9, 126.6, 125.8, 125.0, 123.0, 118.2, 110.2, 102.9, 90.8, 75.0, 72.1, 68.7, 61.6, 35.9; IR (thin film): 3444, 3021, 2920, 2851, 1630, 1493, 1227, 1026, 764, 693 cm^{-1}; HRMS (ESI) m/z calcd for $C_{24}H_{20}Br_2NO_2$ $[M+H]^+$: 511.9855, found 511.9855.



3q

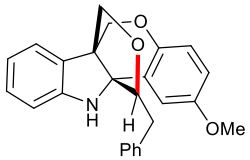
12-Benzyl-10-methyl-6H,11H-6a,11a-(methanooxymethano)chromeno[4,3-b]indole (3q). A white solid, 0.051 g, 70% yield. Mp: 233−234 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.28−7.18 (m, 6H), 7.16 (d, *J* = 7.6 Hz, 1H), 7.02−7.00 (m, 1H), 6.97−6.93 (m, 2H), 6.91 (d, *J* = 7.2 Hz, 1H), 6.74−6.71 (m, 1H), 4.32 (d, *J* = 11.2 Hz, 1H), 4.22 (d, *J* = 8.8 Hz, 1H), 4.06 (d, *J* = 9.2 Hz, 1H), 4.03 (s, 1H), 3.90 (d, *J* = 11.6 Hz, 1H), 3.84 (dd, *J* = 4.4 Hz, 7.6 Hz, 1H), 3.18 (m, 2H), 2.19 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 153.6, 148.5, 138.7, 130.1, 129.8, 129.2, 128.4, 126.3, 125.8, 122.7, 120.2,

119.9, 119.3, 118.1, 91.0, 75.3, 71.8, 69.4, 60.5, 36.1, 17.0; IR (thin film): 3322, 3028, 2926, 2860, 1602, 1485, 1263, 1039, 752, 699 cm^{-1}; HRMS (ESI) m/z calcd for $C_{25}H_{24}NO_2$ $[M+H]^+$: 370.1802, found 370.1801.



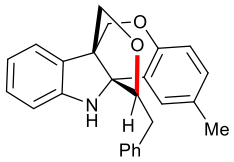
3r

12-Benzyl-10-bromo-6H,11H-6a,11a-(methanooxymethano)chromeno[4,3-b]indole (3r). A white solid, 0.067 g, 78% yield. Mp: 202−203 ℃; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.29−7.19 (m, 7H), 7.04−7.00 (m, 2H), 6.97−6.95 (m, 2H), 6.65−6.61 (m, 1H), 4.56 (s, 1H), 4.31 (d, J = 11.2 Hz, 1H), 4.22 (d, J = 9.2 Hz, 1H), 4.07 (d, J = 9.2 Hz, 1H), 3.89 (d, J = 11.2 Hz, 1H), 3.84 (t, J = 6.0 Hz, 1H), 3.15 (d, J = 6.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 153.4, 148.3, 138.2, 131.5, 131.4, 129.2, 128.6, 128.5, 127.4, 126.5, 125.9, 122.8, 121.7, 120.3, 118.1, 102.7, 90.9, 75.1, 71.6, 69.0, 61.5, 36.0; IR (thin film): 3316, 3028, 2924, 2855, 1601, 1486, 1225, 1044, 761, 656 cm^{-1}; HRMS (ESI) m/z calcd for $C_{24}H_{21}BrNO_2$ $[M+H]^+$: 434.0750, found 434.0750.



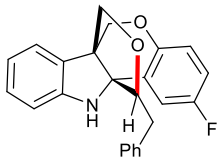
3s

12-Benzyl-2-methoxy-6H,11H-6a,11a-(methanooxymethano)chromeno[4,3-b]indole (3s). A pink solid, 0.040 g, 52% yield. Mp: 157−158 ℃; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.28−7.19 (m, 5H), 7.12−7.08(m, 1H), 7.03 (d, J = 7.2 Hz, 1H), 6.91 (d, J = 8.8 Hz, 1H), 6.79−6.73 (m, 2H), 6.70 (d, J = 7.6 Hz, 1H), 6.64 (s, 1H), 4.33 (s, 1H), 4.29 (d, J = 11.2 Hz, 1H), 4.22 (d, J = 8.8 Hz, 1H), 4.06 (d, J = 9.6 Hz, 1H), 3.84−3.82 (m, 2H), 3.73 (s, 3H), 3.12 (d, J = 6.4 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.9, 149.9, 147.5, 138.6, 130.7, 129.1, 128.9, 128.8, 128.4, 126.4, 122.9, 119.6, 118.7, 113.7, 111.0, 109.7, 90.8, 75.2, 72.3, 69.5, 60.1, 55.7, 36.1; IR (thin film): 3351, 3030, 2926, 2857, 1606, 1496, 1206, 1039, 745, 698 cm^{-1}; HRMS (ESI) m/z calcd for $C_{25}H_{24}NO_3$ $[M+H]^+$: 386.1751, found 386.1748.



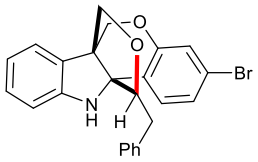
3t

12-Benzyl-2-methyl-6H,11H-6a,11a-(methanooxymethano)chromeno[4,3-b]indole (3t). A white solid, 0.045 g, 61% yield. Mp: 199−200 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.28−7.23 (m, 5H), 7.11−7.08 (m, 1H), 7.04 (d, J = 7.2 Hz, 1H), 6.98 (d, J = 8.0 Hz, 1H), 6.84 (d, J = 8.0 Hz, 1H), 6.78−6.73 (m, 2H), 6.70 (d, J = 7.6 Hz, 1H), 4.33 (s, 1H), 4.29 (d, J = 11.2 Hz, 1H), 4.22 (d, J = 8.8 Hz, 1H), 4.07 (d, J = 8.8 Hz, 1H), 3.87−3.83 (m, 2H), 3.14 (d, J = 6.0 Hz, 2H), 2.23 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 151.3, 149.9, 138.6, 131.9, 130.7, 129.2, 129.0, 128.9, 128.4, 127.7, 126.4, 126.2, 122.8, 119.5, 117.7, 109.7, 90.9, 75.1, 72.1, 69.3, 60.2, 36.2, 20.9; IR (thin film): 3351, 3024, 2925, 2861, 1603, 1498, 1215, 1028, 790, 683 cm^{-1}; HRMS (ESI) m/z calcd for $C_{25}H_{24}NO_2$ $[M+H]^+$: 370.1802, found: 370.1798.



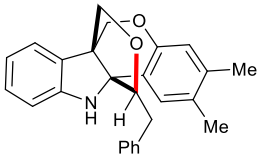
3u

12-Benzyl-2-fluoro-6H,11H-6a,11a-(methanooxymethano)chromeno[4,3-b]indole (3u). A white solid, 0.049 g, 66% yield. Mp: 189−190 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.29−7.21 (m, 5H), 7.13−7.09 (m, 1H), 7.03 (d, J = 7.2 Hz, 1H), 6.93−6.85 (m, 2H), 6.79−6.76 (m, 1H), 6.70−6.68 (m, 2H), 4.31 (d, J = 11.2 Hz, 2H), 4.22 (d, J = 8.8 Hz, 1H), 4.06 (d, J = 8.8 Hz, 1H), 3.83−3.78 (m, 2H), 3.14−3.03 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 159.1 (d, J = 239.1 Hz), 149.7, 149.6 (d, J = 2.2 Hz), 138.2, 130.4, 129.4 (d, J = 7.3 Hz), 129.1, 129.0, 128.5, 126.6, 122.9, 119.7, 119.3 (d, J = 8.0 Hz), 115.3 (d, J = 23.3 Hz), 112.5 (d, J = 23.3 Hz), 109.7, 90.8, 75.3, 72.2, 69.6, 60.2, 35.9; ^{19}F NMR (376 MHz, $CDCl_3$): δ -119.6; IR (thin film): 3378, 3030, 2926, 2856, 1605, 1490, 1258, 1016, 732, 698 cm^{-1}; HRMS (ESI) m/z calcd for $C_{24}H_{21}FNO_2$ $[M+H]^+$: 374.1551, found 374.1547.



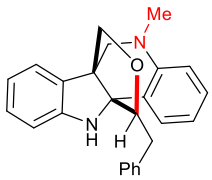
3v

12-Benzyl-3-bromo-6H,11H-6a,11a-(methanooxymethano)chromeno[4,3-b]indole (3v). A white solid, 0.061 g, 71% yield. Mp: 183−184 ℃; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.29−7.25 (m, 2H), 7.21−7.19 (m, 3H), 7.12−7.09 (m, 3H), 7.03 (d, J = 7.2 Hz, 1H), 6.88 (d, J = 8.0 Hz, 1H), 6.80−6.76 (m, 1H), 6.70 (d, J = 8.0 Hz, 1H), 4.31 (d, J = 11.2 Hz, 2H), 4.21 (d, J = 8.8 Hz, 1H), 4.03 (d, J = 8.8 Hz, 1H), 3.89 (d, J = 11.6 Hz, 1H), 3.80 (dd, J = 4.4 Hz, 8.0 Hz, 1H), 3.14−3.03 (m, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.3, 149.7, 138.3, 130.2, 129.1, 129.0, 128.5, 127.3, 127.2, 126.5, 125.7, 122.9, 121.3, 121.2, 119.7, 109.8, 90.8, 75.1, 71.9, 69.3, 60.0, 36.1; IR (thin film): 3347, 3028, 2921, 2860, 1607, 1489, 1262, 1010, 743, 696 cm^{-1}; HRMS (ESI) m/z calcd for $C_{24}H_{21}BrNO_2$ $[M+H]^+$: 434.0750, found 434.0749.



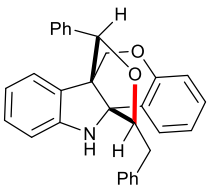
3w

12-Benzyl-2,3-dimethyl-6H,11H-6a,11a-(methanooxymethano)chromeno[4,3-b]indole (3w). A white solid, 0.060 g, 78% yield. Mp: 197−198 ℃; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.30−7.19 (m, 5H), 7.10−7.06 (m, 1H), 7.03 (d, J = 7.2 Hz, 1H), 6.78 (d, J = 7.6 Hz, 1H), 6.74−6.72 (m, 1H), 6.69−6.67 (m, 2H), 4.28 (s, 1H), 4.26 (d, J = 11.2 Hz, 1H), 4.20 (d, J = 8.8 Hz, 1H), 4.04 (d, J = 8.8 Hz, 1H), 3.89−3.85 (m, 2H), 3.15 (d, J = 6.0 Hz, 2H), 2.18 (s, 3H), 2.13 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 151.3, 150.0, 138.7, 137.0, 130.7, 130.6, 129.3, 128.8, 128.4, 126.7, 126.4, 125.1, 122.8, 119.4, 118.7, 109.7, 90.9, 75.0, 71.9, 69.1, 59.9, 36.4, 19.5, 19.2; IR (thin film): 3335, 3026, 2925, 2855, 1605, 1492, 1262, 1033, 739, 681 cm^{-1}; HRMS (ESI) m/z calcd for $C_{26}H_{26}NO_2$ $[M+H]^+$: 384.1958, found 384.1953.



3x

12-Benzyl-5-methyl-5,6-dihydro-11H-6a,11a-(methanooxymethano)indolo[3,2-c]quinoline (**3x**)**.** A white solid, 0.038 g, 52% yield. Mp: 187−188 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.22−7.15 (m, 7H), 7.08−7.04 (m, 1H), 6.99 (d, J = 6.8 Hz, 1H), 6.89−6.85 (m, 1H), 6.78 (d, J = 8.4 Hz, 1H), 6.74−6.71 (m, 1H), 6.67 (d, J = 7.6 Hz, 1H), 4.42 (s, 1H), 4.17 (d, J = 8.4 Hz, 1H), 4.10 (d, J = 8.8 Hz, 1H), 3.65 (dd, J = 3.6 Hz, 8.4 Hz, 1H), 3.25 (d, J = 11.2 Hz, 1H), 3.10−3.01 (m, 2H), 2.93 (d, J = 11.2 Hz, 1H), 2.84 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 149.9, 146.5, 139.2, 133.2, 129.0, 128.7, 128.4, 128.2, 127.9, 126.1, 125.1, 122.6, 119.1, 119.0, 112.6, 109.3, 90.7, 77.2, 73.1, 61.6, 57.7, 39.8, 35.3; IR (thin film): 3362, 3029, 2923, 2853, 1608, 1497, 1255, 1034, 761, 693 cm^{-1}; HRMS (ESI) m/z calcd for $C_{25}H_{25}N_2O$ $[M+H]^+$: 369.1961, found 369.1957.

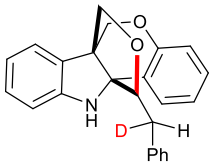


3y

12-Benzyl-14-phenyl-6H,11H-6a,11a-(methanooxymethano)chromeno[4,3-b]indole (**3y**, dr > 20:1)**.** A white solid, 0.066 g, 77% yield. Mp: 100-101 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.42−7.40 (m, 2H), 7.36−7.26 (m, 8H), 7.13 (t, J = 7.2 Hz 1H), 7.05−7.01 (m, 2H), 6.84 (dd, J = 7.6 Hz, 12.0 Hz, 2H), 6.73−6.71 (m, 2H), 6.66 (d, J = 7.6 Hz, 1H), 5.18 (s, 1H), 4.90 (d, J = 6.8 Hz, 1H), 4.16 (s, 1H), 3.93 (dd, J = 12.0 Hz, 15.6 Hz, 2H), 3.41 (d, J = 6.0 Hz, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 152.8, 149.1, 138.9, 136.4, 129.6, 128.9, 128.5, 128.3, 128.2, 128.2, 127.9, 127.7, 126.4, 126.1, 123.4, 122.1, 119.3, 117.6, 110.6, 88.7, 85.3, 76.7, 65.1, 59.3, 38.9; IR (thin film): 3365, 2961, 2926, 2856, 1609, 1490, 1261, 1092, 1017, 804, 764, 689 cm^{-1}; HRMS (ESI) m/z calcd for $C_{30}H_{26}NO_2$ $[M+H]^+$: 432.1958, found 432.1948.

3. Synthesis of chromeno[4,3-b]indoline D-3a

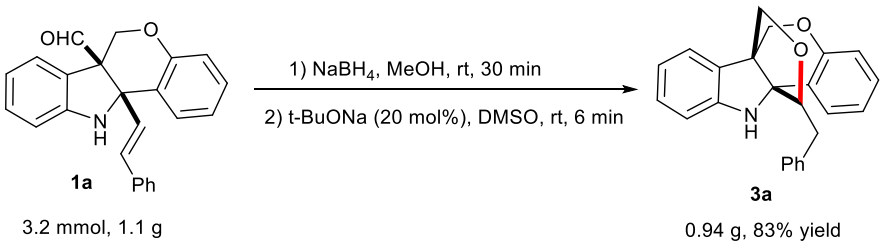
In a 25 mL reaction flask was charged with **2a** (71 mg, 0.2 mmol), *t*-BuONa (3.8 mg, 0.04 mmol, 20 mol%), and DMSO-d_6 (2.0 mL). The reaction was stirred for 5 min at room temperature until **2a** was completely consumed (monitored by TLC). At this time, the reaction was quenched with water (10 mL) and extracted with EtOAc (10 mL). The combined organic layers were washed with brine (10 mL), dried over Na_2SO_4, and filtered. The solvent was removed under reduced pressure and the crude product was purified by flash column chromatography (PE/EtOAc = 30:1) to afford compound **D-3a**.



D-3a

12-(Phenylmethyl-d)-6H,11H-6a,11a-(methanooxymethano)chromeno[4,3-b]indole (**D-3a**). A white solid, 0.056 g, 79% yield. Mp: 184−185 ℃; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.28−7.24 (m, 2H), 7.21−7.17 (m, 4H), 7.12−7.08 (m, 2H), 7.04−6.98 (m, 2H), 6.97 (d, J = 8.0 Hz, 1H), 6.79−6.75 (m, 1H), 6.70 (d, J = 7.6 Hz, 1H), 4.34 (s, 1H), 4.32 (d, J = 11.6 Hz, 1H), 4.23 (d, J = 8.8 Hz, 1H), 4.06 (d, J = 9.2 Hz, 1H), 3.91 (d, J = 11.6 Hz, 1H), 3.82 (d, J = 9.6 Hz, 1H), 3.11 (d, J = 8.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 153.5, 149.9, 138.6, 130.6, 129.1, 128.9, 128.4, 128.1, 126.4, 125.7, 122.9, 122.7, 119.5, 118.1, 109.7, 90.9, 75.3, 72.0, 69.3, 60.1, 35.9 (t, J = 18.9 Hz); IR (thin film): 3343, 3032, 2925, 2862, 1606, 1495, 1209, 1039, 750, 688 cm^{-1}; HRMS (ESI) m/z calcd for $C_{24}H_{21}DNO_2$ $[M+H]^+$: 357.1708, found 357.1703.

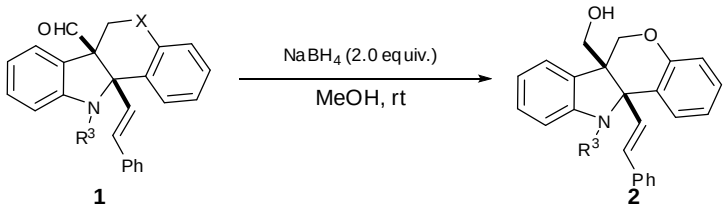
4. Gram-scalable preparation of 3a



In a 100 mL-round-bottle flask was charged with **1a** (1.1 g, 3.2 mmol) and MeOH (30 mL). $NaBH_4$ (243 mg, 6.4 mmol, 2.0 equiv.) was then added in three portions. The reaction mixture was stirred vigorously at room temperature for 30 min until the substrate **1** disappeared (monitored by TLC). At this time, the reaction was diluted with H_2O (30 mL), and exacted with Et_2O (100 mL). The combined organic layers were washed with brine (30 mL), dried over Na_2SO_4, and filtered. The solvent was removed under reduced pressure to give crude alcohol.

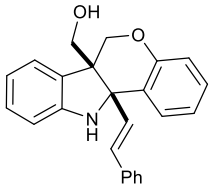
In a 100 mL-round-bottle flask was charged with the above alcohol, t-BuONa (0.64 mmol, 20 mol%), and DMSO (30.0 mL). The reaction was stirred at room temperature for 6 min until the alcohol was completely consumed (monitored by TLC). At this time, the reaction was quenched with water (50 mL) to precipitate solid. Finally, the solid was recrystallized with petroleum ether to afford **3a** (0.94 g, 83% yield) as a white solid.

5. Synthesis of chromeno[4,3-*b*]indolylmethanol 2a and 2aa



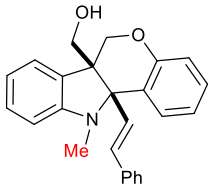
General procedure B: In a 25 mL round-bottle flask was charged with **1** (1.0 mmol) and MeOH (10 mL). $NaBH_4$ (2.0 mmol, 2.0 equiv.) was added. Then, the reaction mixture was stirred vigorously at room temperature for 30 min until the substrate **1** disappeared (monitored by TLC). At this time, the reaction was diluted with H_2O (20 mL) and exacted with Et_2O (30 mL). The combined organic layers were washed with

brine (20 mL), dried over Na_2SO_4, and filtered. The solvent was removed the reduced pressure and the crude product was purified by column chromatography (1/20 to 1/6, ethyl acetate / petroleum ether) to afford **2**.



2a

11a-((*E*)-styryl)-11,11a-dihydrochromeno[4,3-b]indol-6a(6H)-yl)methanol (**2a**)**.** A canary yellow solid, 0.3540 g, 99% yield. Mp: 87−88 ℃; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.47 (d, J = 7.6 Hz, 1H), 7.33−7.27 (m, 3H), 7.25−7.20 (m, 3H), 7.17−7.13 (m, 3H), 7.10 (t, J = 7.2 Hz, 1H), 7.01 (d, J = 8.4 Hz, 1H), 6.92 (t, J = 7.6 Hz, 1H), 6.72 (d, J = 4.0 Hz, 1H), 4.63 (d, J = 12.4 Hz, 1H), 3.92 (dd, J = 11.6 Hz, 16.8 Hz, 2H), 3.76 (d, J = 11.2 Hz, 1H), 2.55 (d, J = 13.6 Hz, 1H), 2.21 (t, J = 12.4 Hz, 1H), 1.26 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 154.7, 148.7, 136.2, 131.2, 130.3, 128.9, 128.7, 128.3, 128.2, 127.9, 127.5, 126.6, 124.3, 121.8, 119.6, 117.4, 110.3, 68.9, 66.0, 64.1, 52.9; IR (thin film): 3595, 3355, 3051, 2933, 2862, 1608, 1486, 1223, 1024, 761, 745, 693 cm^{-1}; HRMS (ESI) m/z calcd for $C_{24}H_{22}NO_2$ $[M+H]^+$: 356.1645, found 356.1659.

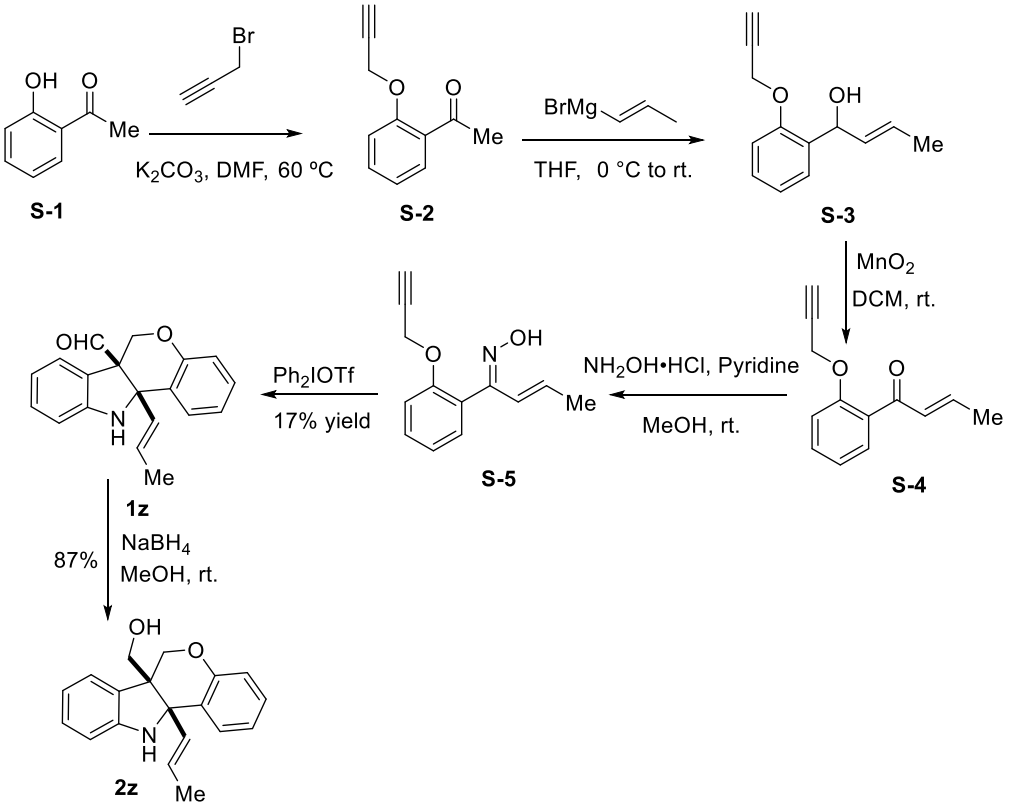


2aa

11-Methyl-11a-((E)-styryl)-11,11a-dihydrochromeno[4,3-b]indol-6a(6H)-yl)methanol (**2aa**). A white solid, 0.360 g, 98% yield. Mp: 155−156 ℃; ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.26−7.23 (m, 5H), 7.18−7.17 (m, 2H), 7.16−7.06 (m, 2H), 6.90−6.83 (m, 2H), 6.67 (t, J = 7.2 Hz, 1H), 6.37−6.27 (m, 3H), 4.29 (d, J = 11.2 Hz, 1H), 4.12 (d, J = 11.2 Hz, 1H), 3.87 (d, J = 11.2 Hz, 1H), 3.74 (d, J = 11.2 Hz, 1H), 2.79 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ 155.6, 150.5, 136.1, 134.7, 131.0, 129.0, 128.9, 128.6, 128.0, 126.6, 123.9, 122.1, 120.4, 117.8 117.7, 106.3, 73.2, 66.8, 63.7, 52.9, 29.8; IR

(thin film): 3588, 3032, 2919, 2878, 1606, 1488, 1223, 1024, 766, 743 cm^{-1}; HRMS (ESI) m/z calcd for $C_{25}H_{24}NO_2$ $[M+H]^+$: 370.1802, found 370.1795.

6. Synthesis of chromeno[4,3-*b*]indolylmethanol 2z



Synthetic procedure:

To a well stirred solution of anhydrous DMF (25 mL) was added **S-1** (10.0 mmol), K_2CO_3 (1.67 g, 12.0 mmol, 1.2 equiv.) and allylbromide (0.93 mL, 12.0 mmol, 1.2 equiv.). The reaction mixture was stirred at 60 °C for 12 h (monitored by TLC) before it was slowly poured into water. Extracted with Et_2O (30 mL), then the combined organic layers were washed with brine (30 mL), dried over Na_2SO_4, and filtered. The solvent was removed under reduced pressure to give product **S-2** as a yellow solid, which was used directly without purification for the next step.

To a solution of **S-2** (10.0 mmol) in THF (10 mL) at 0 °C was added slowly a solution of Grignard reagent magnesium bromide (20.0 mmol, 2.0 equiv.). The resulting mixture was allowed to warm to room temperature and stirred for 2 h. Upon completion, the reaction mixture was quenched by addition of an aqueous saturated

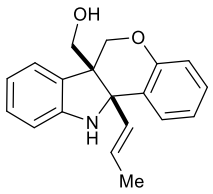
solution of NH_4Cl (30 mL) and extracted with ethyl acetate (3×50 mL)., The combined organic layers were washed with brine (30 mL), dried over Na_2SO_4 and filtered. The solvent was removed under reduced pressure and the crude product was purified by flash column chromatography (1/30 to 1/10, dichloromethane/petroleum ether) to afford **S-3** (74%, 1.48 g) as yellow oil.

The yellow oil **S-3** (7.4 mmol, 1.48 g) was dissolved in DCM (15mL) and MnO_2 (6.5 g, 74.0 mmol, 10.0 equiv.) was added under vigorous stirring. After complete conversion (TLC analysis), the mixture was filtered through a Celite pad washing with DCM. The solvent was removed under reduced pressure and the crude product was purified by flash column chromatography (1/30 to 1/10, dichloromethane/petroleum ether) to afford **S-4** (28%, 0.82g) as yellow oil.

To a solution of **S-4** (2.0 mmol, 0.82g) in MeOH (10 mL) was added hydroxylamine hydrochloride (0.21g, 3.0 mmol, 1.5 equiv.) and pyridine (0.4 mL, 5.0 mmol, 2.5 equiv.). The reaction mixture was then stirred at room temperature until the S-6 was consumed. The solvent was evaporated and the residue was diluted with water (10 mL) and extracted with ethyl acetate (3×10 mL). The combined organic layers were washed with brine (10 mL), dried over Na_2SO_4, and concentrated. Purification of the crude product by flash column chromatography (1/20 to 1/6, ethyl acetate/petroleum ether) afforded the corresponding oxime **S-5** (17%, 0.072 g) as yellow oil. *One isomer:* ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.38–7.37 (m, 1H), 7.26–7.21 (m, 1H), 7.08–7.07 (m, 2H), 7.00 (d, J = 6.8 Hz, 1H), 5.81–5.76 (m, 1H), 4.69 (d, J = 2.0 Hz, 2H), 2.45 (s, 1H), 1.84 (d, J = 6.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$):δ 156.6, 134.6, 129.9, 129.6, 124.9, 121.6, 120.5, 113.5, 78.7, 75.4, 56.4, 18.7; *another isomer:* ^{1}H NMR (400 MHz, $CDCl_3$): δ, 7.35–7.30 (m, 1H), 7.15–7.13 (m, 1H), 7.05–7.02 (m, 2H), 6.38 (d, J = 14.8 Hz, 1H), 5.64–5.58 (m, 1H), 4.67 (d, J = 2.4 Hz, 2H), 2.44 (s, 1H), 1.78 (d, J = 6.0 Hz, 3H); ^{13}C NMR (100MHz, $CDCl_3$): δ 156.6, 131.3, 129.8, 128.0, 122.4, 121.5, 120.5, 113.1,78.6, 75.4, 56.1, 18.3; IR (thin film) 3281, 3072, 2862, 1600, 1498, 1329, 968, 756 cm^{-1}HRMS (ESI) m/z calcd for $C_{13}H_{14}NO_2$ $[M + H]^+$: 216.1019, found: 216.1017.

In a round-bottle flask was charged with **S-5** (0.34 mmol, 0.072 g), diphenyliodonium triflate (0.68 mmol, 0.2914 g, 2.0 equiv.), KOH (0.68 mmol, 0.038 g, 2.0 equiv.) and CCl_4 (4 mL). And then, the reaction mixture was stirred vigorously at room temperature for 3 h until the substrate **S-5** disappeared (monitored by TLC). Then heating at 80 °C for 6 h. At this time, the solvent was removed under reduced pressure to give the crude product **1z** as yellow solid.

In a round-bottle flask charged with the above crude **1z** (0.1 mmol, 0.029 g) and MeOH (1 mL), $NaBH_4$ (0.2 mmol, 0.014 g 2.0 equiv.) was added. Then, the reaction mixture was stirred vigorously atroom temperature for 0.5 h until the substrate **1z** disappeared (monitored by TLC). At this time, the reaction was diluted with H_2O (10 mL) and exacted with Et_2O (20 mL). The combined organic layers were washed with brine (10 mL), dried over $Na_2SO_4$and filtered. Purification of the crude product by flash column chromatography (1/10 to 1/6, ethyl acetate/petroleum ether) afforded indoline **2z**.

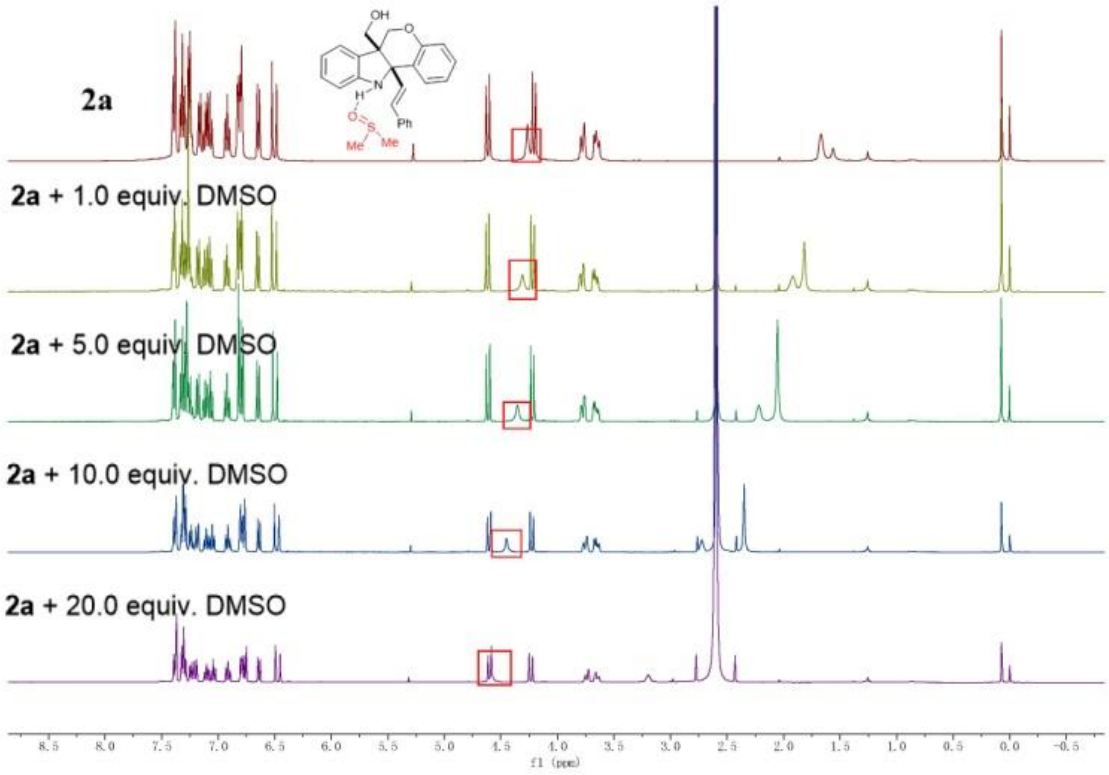


2z

(11a-(Prop-1-en-1-yl)-11,11a-dihydrochromeno[4,3-b]indol-6a(6H)-yl)methanol(2z). A yellow solid, 0.026 g, 87% yield. Mp: 112−113℃; ^{1}H NMR (400 MHz, $CDCl_3$): δ7.25−7.23 (m, 1H), 7.14−7.03 (m, 3H), 6.94 (t, *J* = 7.2 Hz, 1H), 6.80−6.75 (m, 2H), 6.60 (d, *J* = 7.6 Hz, 1H), 5.89−5.74 (m, 2H), 4.56 (d, *J* = 11.6 Hz, 1H), 4.19 (s, 1H), 4.14 (d, *J* = 11.2 Hz, 1H), 3.76 (d, *J* = 11.2 Hz, 1H), 3.63 (d, *J* = 9.6 Hz, 1H), 1.79 (d, *J* = 6.0 Hz, 3H), 1.69 (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ154.7, 148.9, 131.8, 128.7, 128.4, 128.3, 128.0, 127.8, 124.2, 121.6, 119.4, 117.2, 110.1, 68.5,65.8, 64.1, 52.3, 17.8; IR (thin film): 3589, 3029, 2920, 2868, 1605, 1485, 1213, 1034, 765, 743 cm^{-1}; HRMS (ESI) m/z calcd for $C_{19}H_{20}NO_2[M+H]^+$ 294.1489, found 294.1489.

7. Continuous ^{1}H NMR experiments between 2a and DMSO

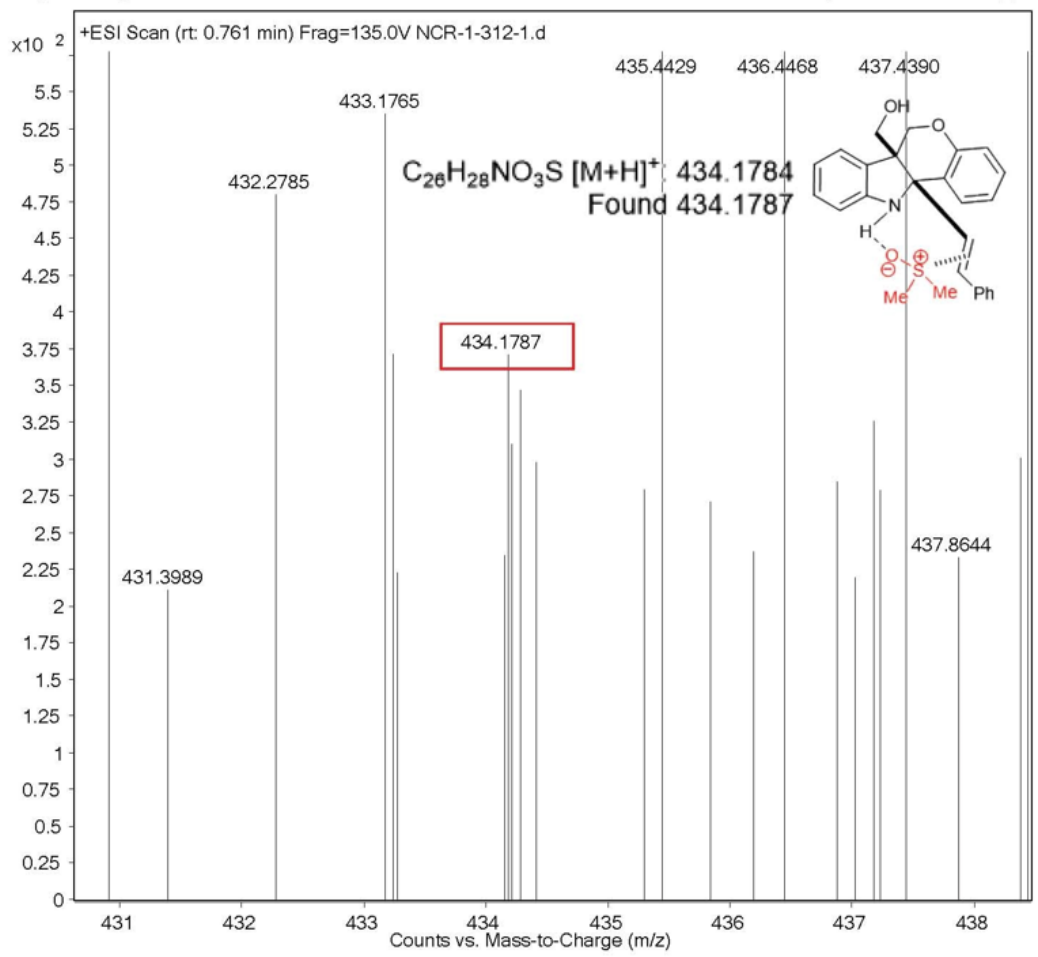
The interaction between indoline **2a** with DMSO was examined by continuous ^{1}H NMR experiments. When **2a** was dissolved in $CDCl_3$, a broad single peak corresponding to N-H of indoline appeared at 4.26 ppm. The N-H peak was shifted to 4.31 ppm after the addition of 1.0 equiv of DMSO to **2a**. Interestingly, further increasing the amounts of DMSO to 5.0, 10.0, and 20.0 equiv. to **2a** in $CDCl_3$ obviously showed that the N-H peak was shifted from 4.31 ppm to 4.58 ppm. These results revealed that the DMSO interacted with **2a** might be through hydrogen-bonding actvation.



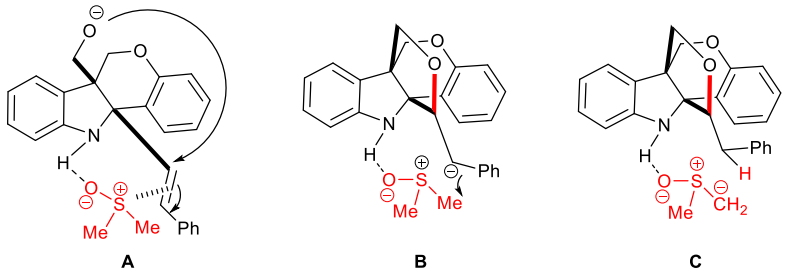
8. Intermediates A, B, or C detected by HRMS (ESI).

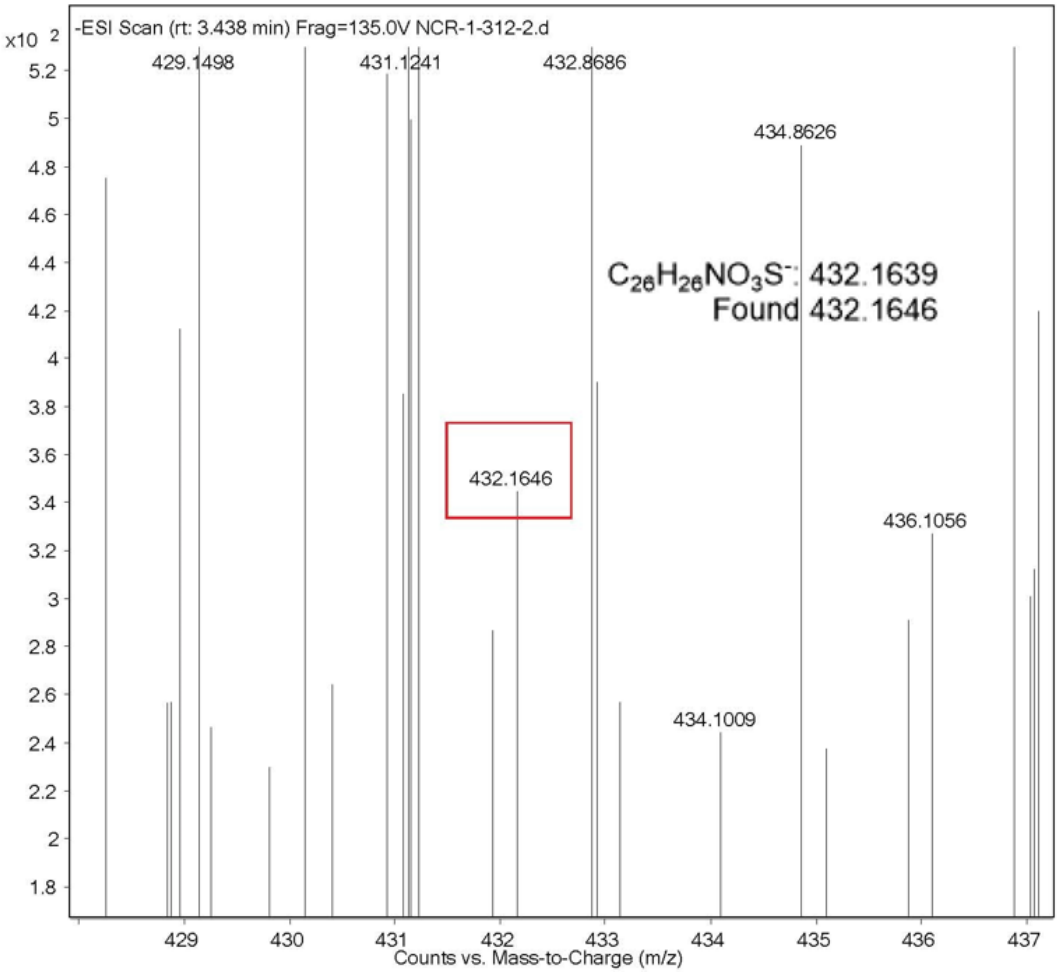
1) When **2a** (0.1 mmol) were added in DMSO (1.0 mL), and the reaction mixture stirred for 3 min. The reaction mixture was directly detected by HRMS (ESI, diluted

with MeOH). The HRMS for intermediate calculated for $C_{26}H_{28}NO_3S$ $[M+H]^+$: 434.1784; found 434.1787.



2) When *t*-BuONa (20 mol%) and **2a** (0.1 mmol), were added in DMSO (1.0 mL), and the reaction mixture stirred for 3 min. The reaction mixture was directly detected by HRMS (ESI, diluted with MeOH). The HRMS (ESI) calculated for $C_{26}H_{26}NO_3S^-$: 432.1639; found 432.1646. However, we cannot confirm that the peak we found belongs to which intermediates **A**, **B**, or **C** owing to the same molecular weight of **A**, **B** or **C**.

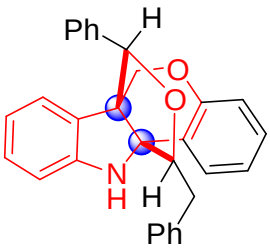




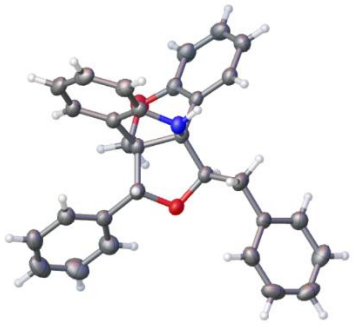
9. References

[1]. Ma, X.-P.; Li, K.; Wu, S.-Y.; Liang, C.; Su, G.-F.; Mo, D.-L. *Green Chem.*, **2017**, *19*, 5761-5766.

10. X-ray structure for compound 3y



3y

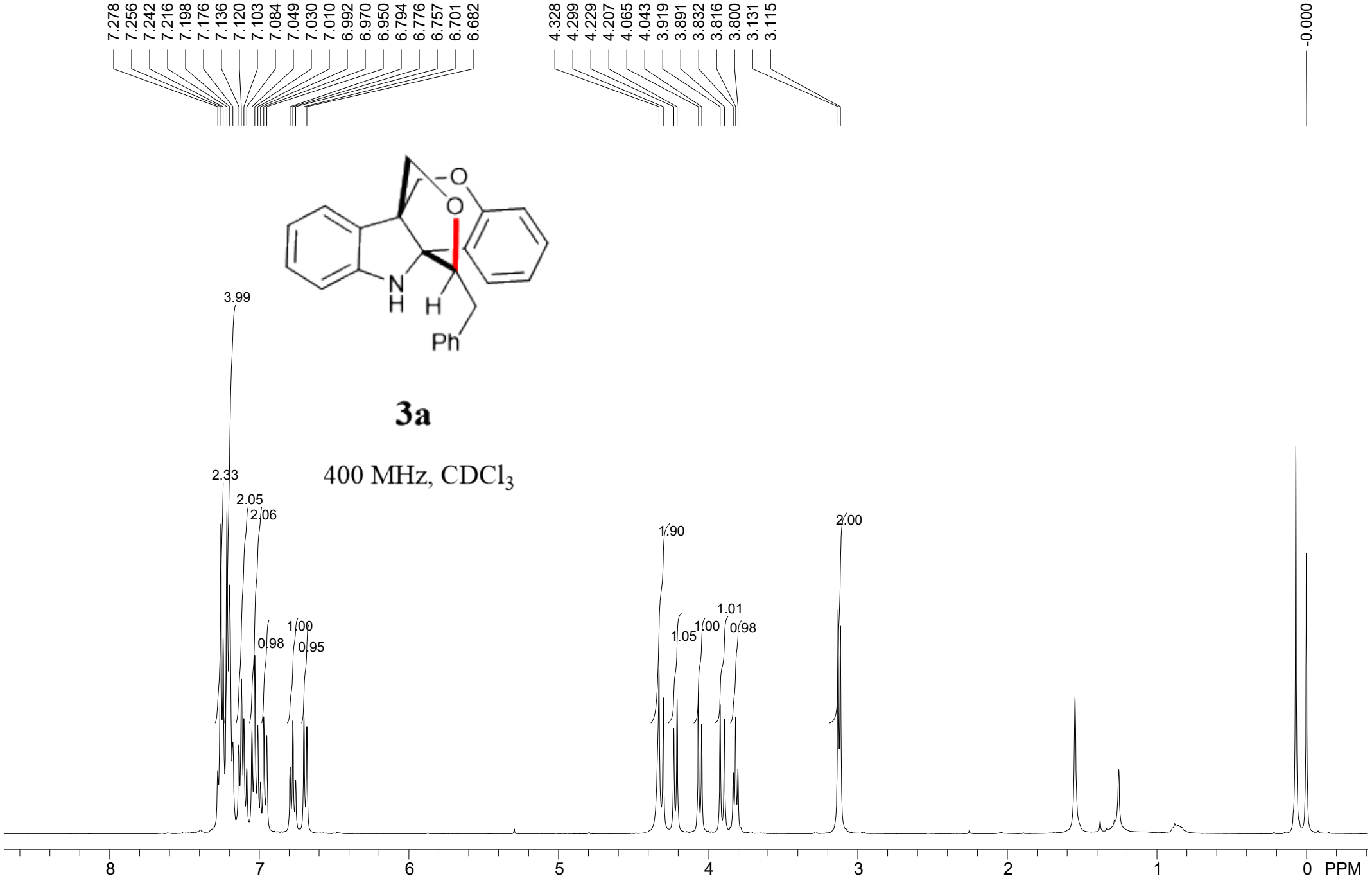


Crystal data and structure refinement details for compound 3y

Crystallographic data and structure refinement parameters for compound 3y	
Empirical formula	$C_{30}H_{25}NO_2$
Formula weight (*M*)	37.53
Crystal system	Triclinic
Space group	P-1
a (Å)	9.206(3)
b (Å)	10.088 (3)
c (Å)	13.161 (4)
α (°)	99.033 (4)
β (°)	97.884(4)
γ (°)	107.657(4)
V/(Å^3)	1127.8(5)
Z	23
D_c(Mg cm^{-3})	1.271
F(000)	456.2
2θ range for data collection (°)	3.2–53.56
Reflections collected / unique	4768/298
	[*R*(int) =0.0310]
Goodness-of-fit on F^2	1.044
Final *R* indices [$I > 2\sigma(I)$]	R_1=0.0417
	ωR_2 = 0.1158

R indices (all data)	R_1=0.0538
	ωR_2 = 0.1270

11. NMR spectra for compounds 3a-3y, 2a, 2aa, 2z, and D-3a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4.043
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N
H
H
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0.98
1.00
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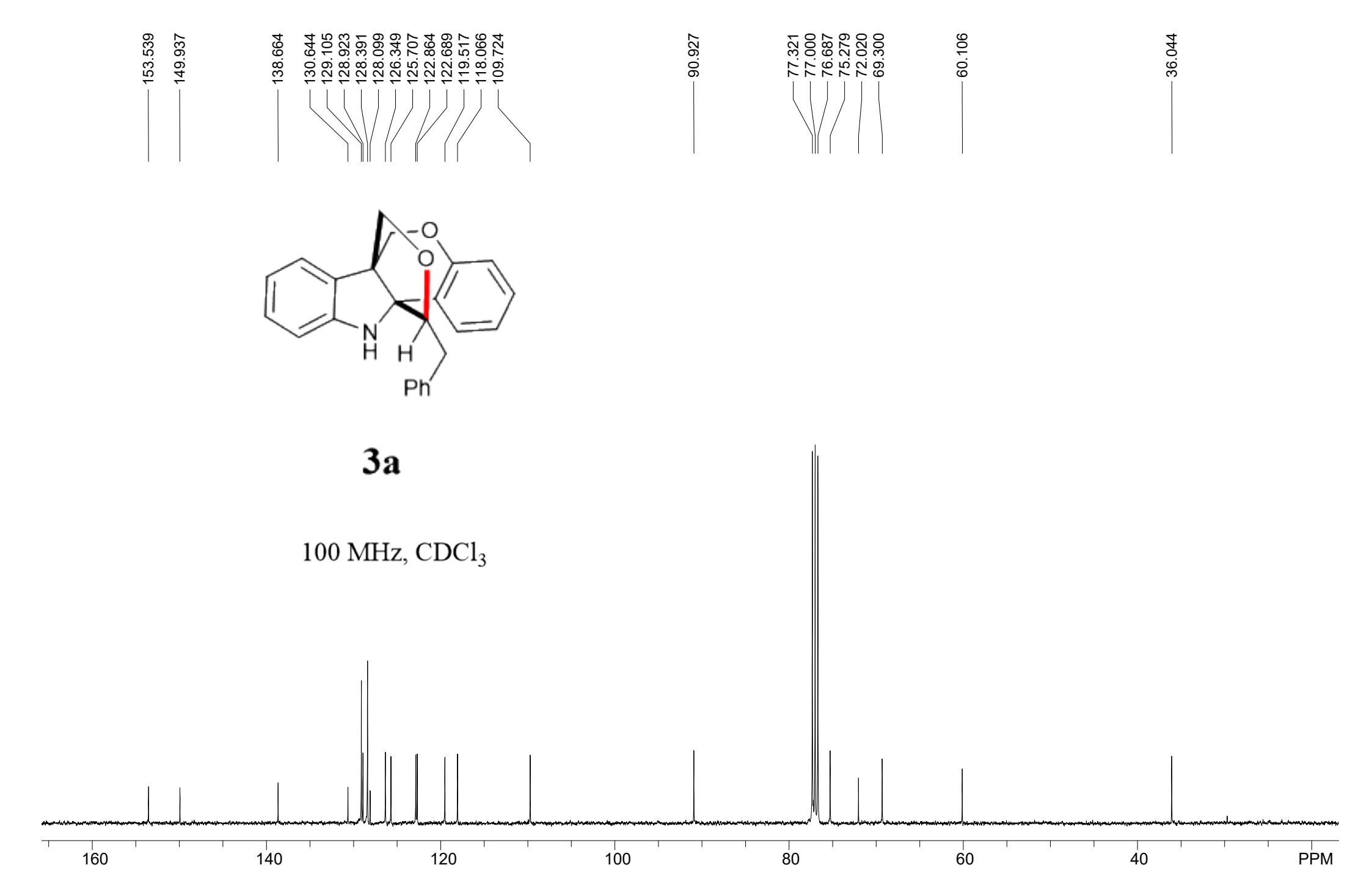
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109.724
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77.321
77.000
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60.106
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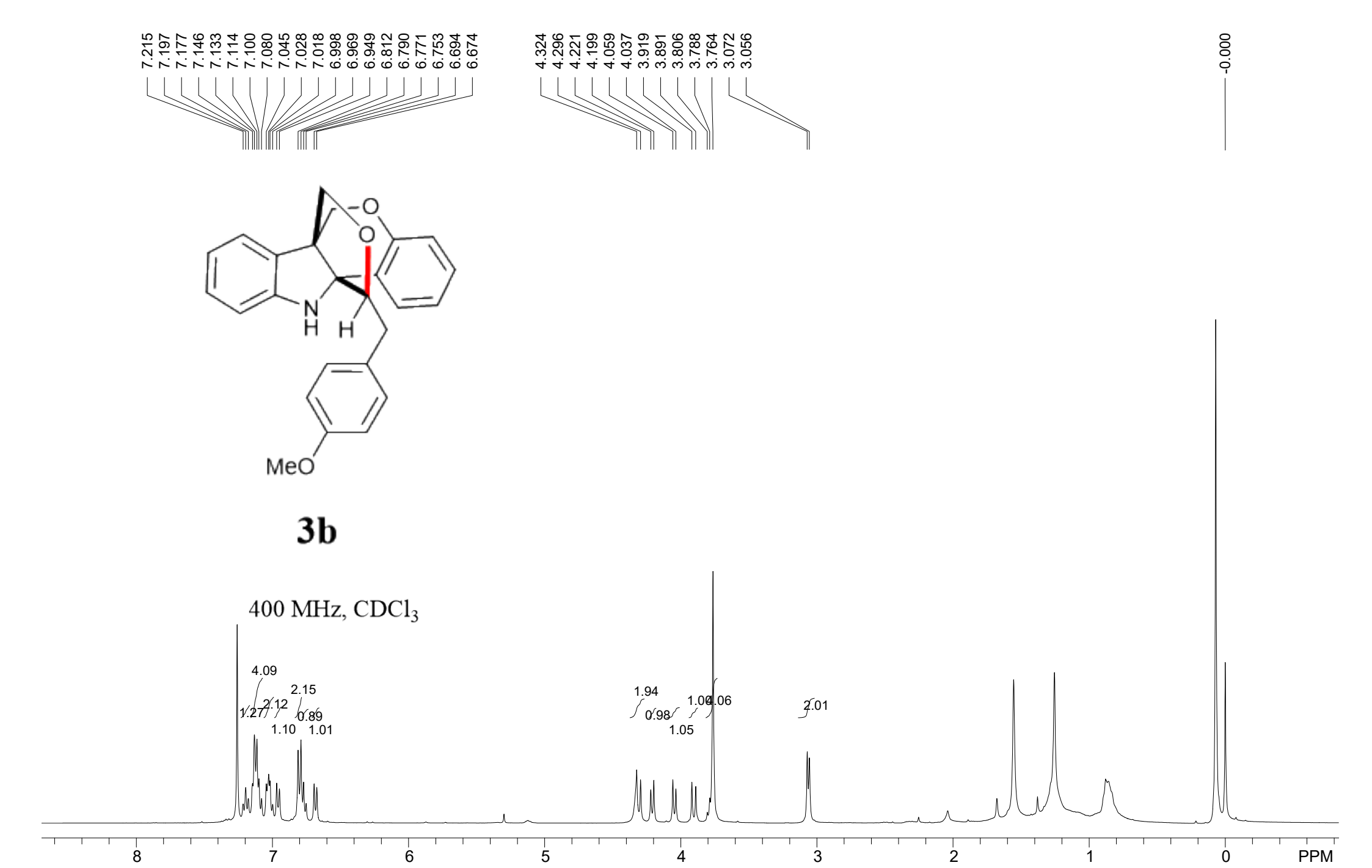
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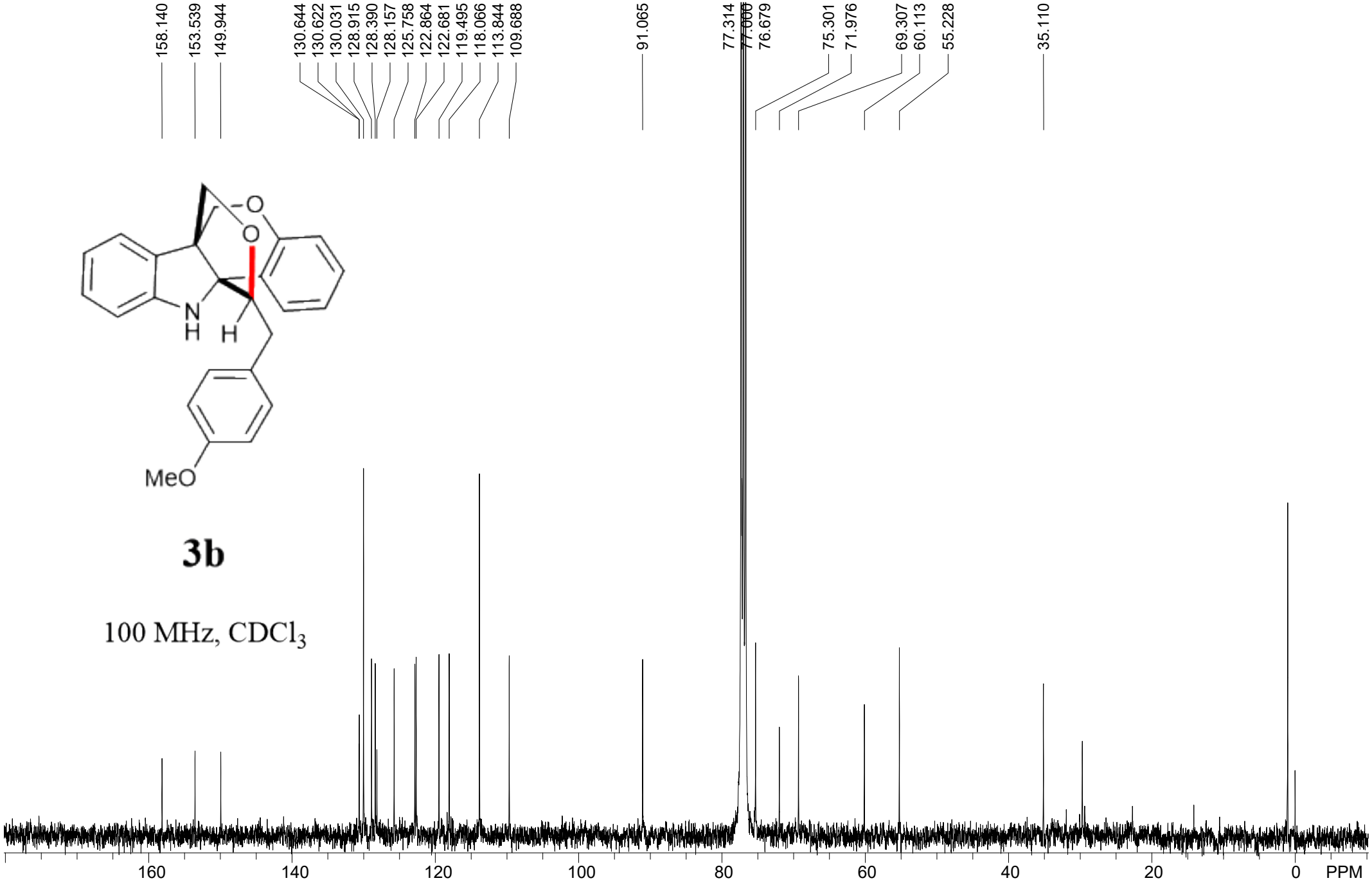
3.891
3.806
3.788
3.764
3.072
3.056
-0.000
O
O
N
H
H
MeO
3b
400 MHz, CDCl3
4.09
2.12
2.15
1.27
0.89
1.10
1.01
1.94
0.98
1.05
1.00
1.06
2.01
8
7
6
5
4
3
2
1
0
PPM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153.539
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130.622
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128.915
128.390
128.157
125.758
122.864
122.681
119.495
118.066
113.844
109.688
91.065
77.314
77.000
76.679
75.301
71.976
69.307
60.113
55.228
35.110
O
O
N
H
H
MeO
3b
100 MHz, CDCl3
160
140
120
100
80
60
40
20
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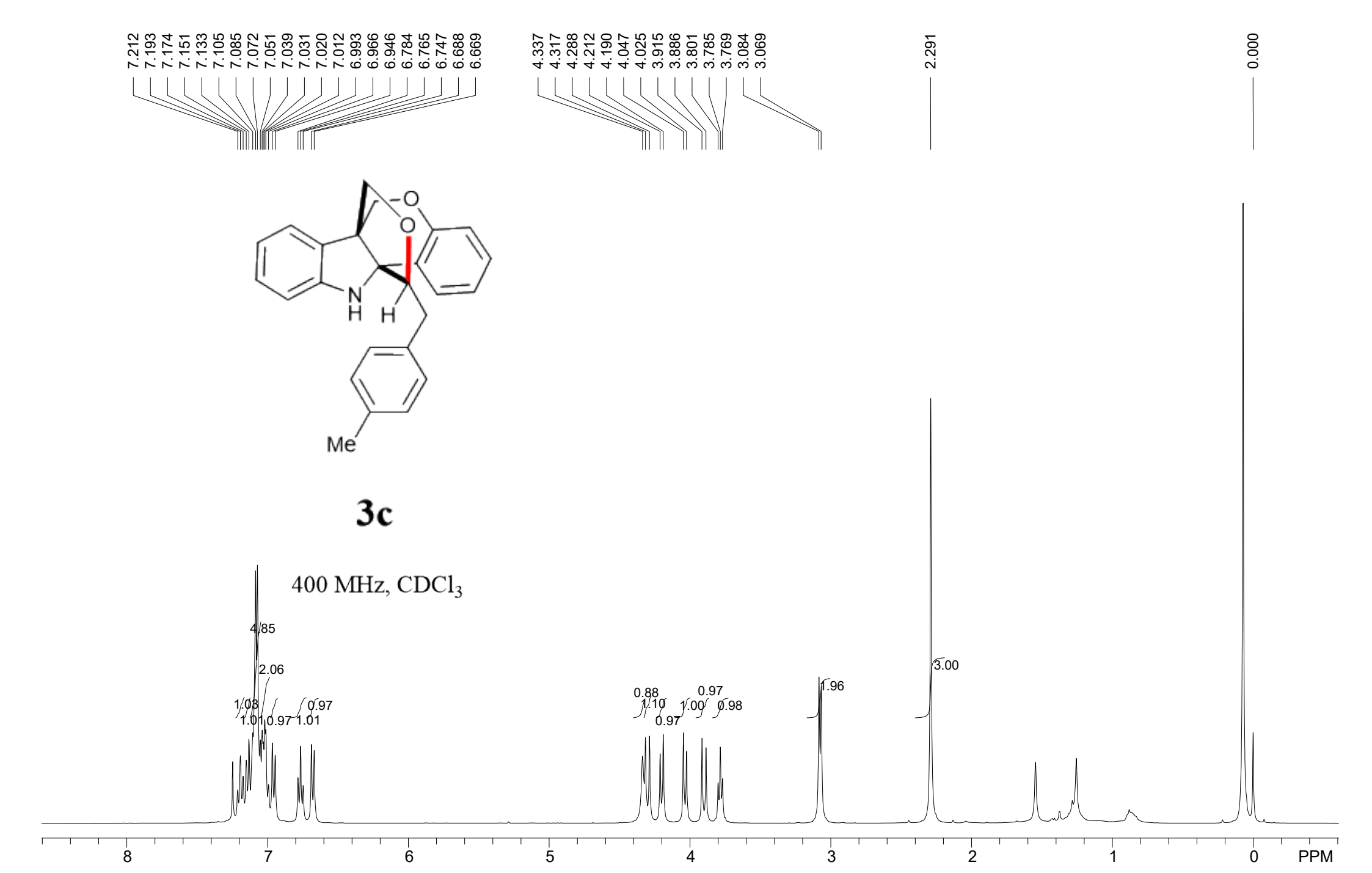
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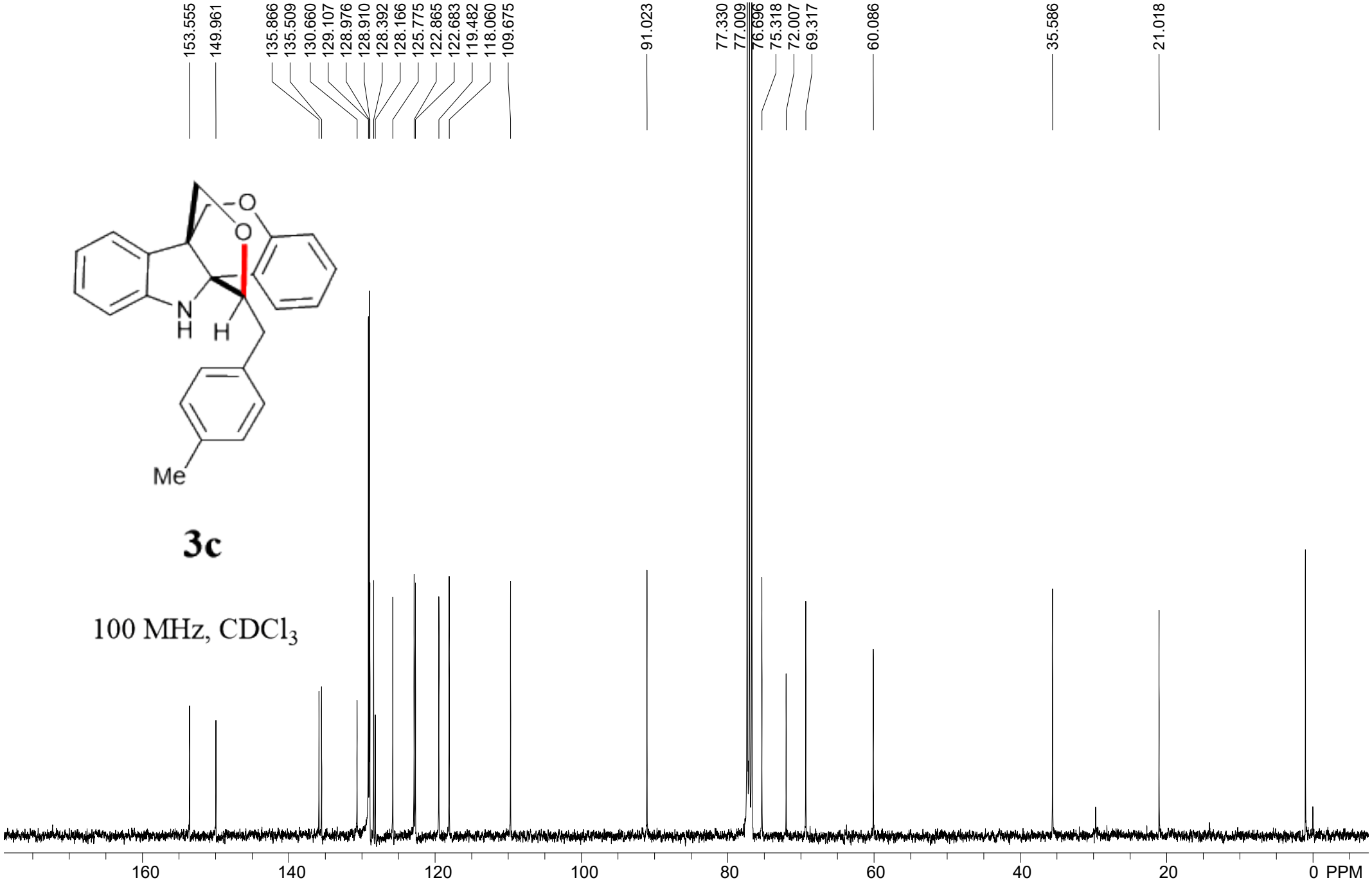
7.193
7.174
7.151
7.133
7.105
7.085
7.072
7.051
7.039
7.031
7.020
7.012
6.993
6.966
6.946
6.784
6.765
6.747
6.688
6.669
4.337
4.317
4.288
4.212
4.190
4.047
4.025
3.915
3.886
3.801
3.785
3.769
3.084
3.069
2.291
0.000
O
O
N
H
H
Me
3c
400 MHz, CDCl3
4.85
2.06
1.03
1.01
0.97
1.01
0.97
0.88
1.10
0.97
1.00
0.97
0.98
1.96
3.00
8
7
6
5
4
3
2
1
0
PPM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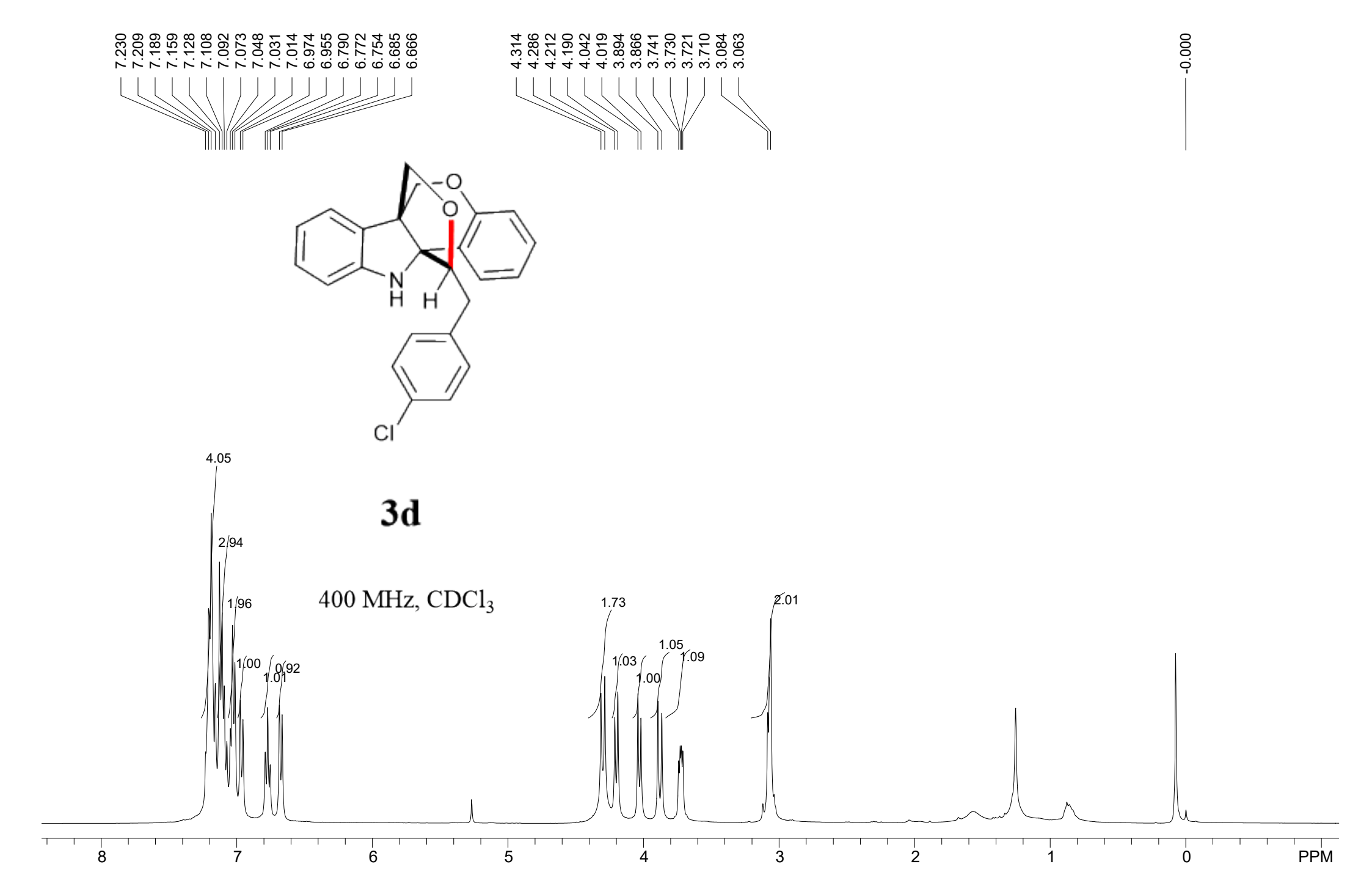
149.961
135.866
135.509
130.660
129.107
128.976
128.910
128.392
128.166
125.775
122.865
122.683
119.482
118.060
109.675
91.023
77.330
77.009
76.696
75.318
72.007
69.317
60.086
35.586
21.018
O
O
N
H
H
Me
3c
100 MHz, CDCl3
160
140
120
100
80
60
40
20
0 PPM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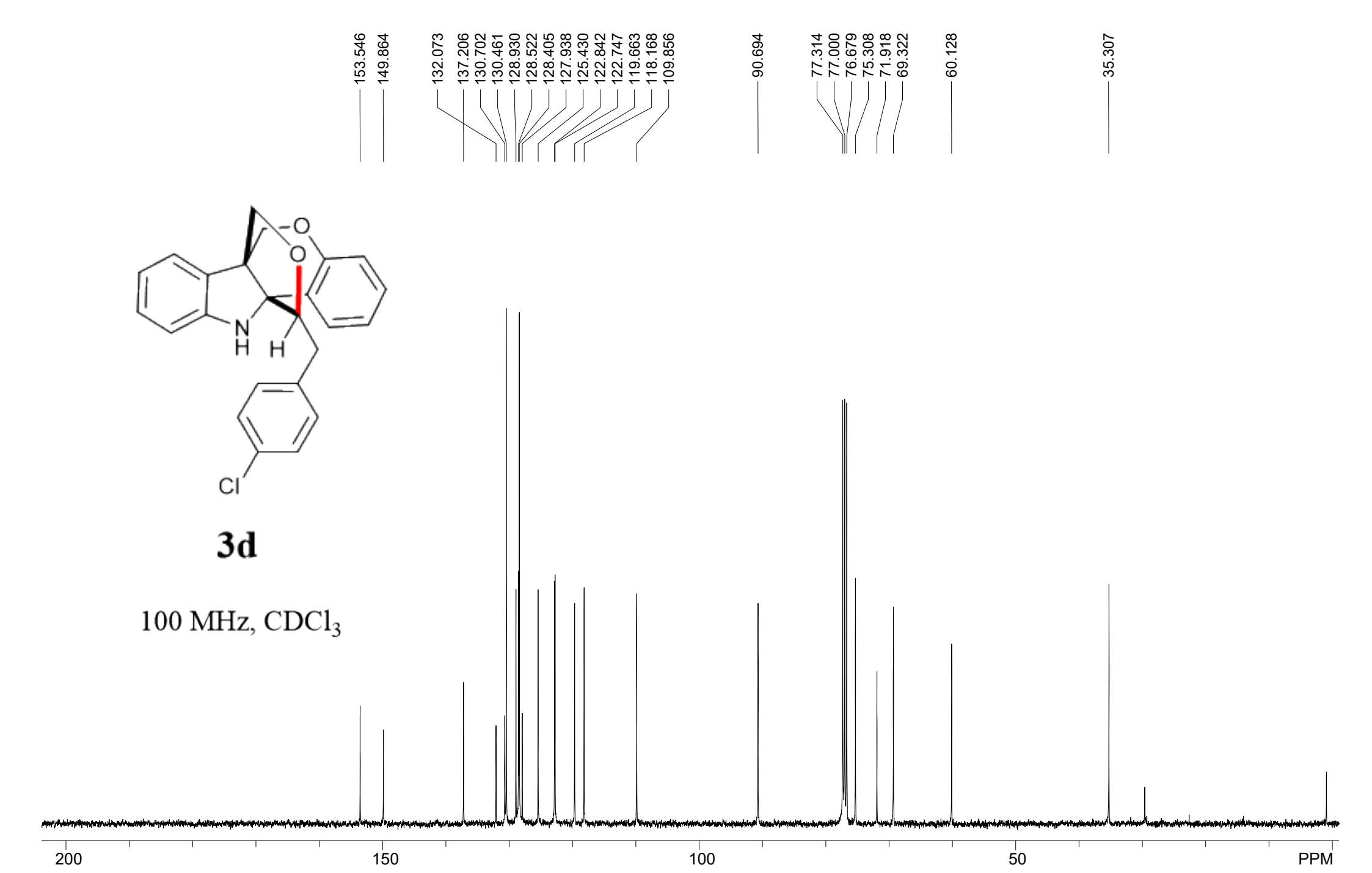
7.209
7.189
7.159
7.128
7.108
7.092
7.073
7.048
7.031
7.014
6.974
6.955
6.790
6.772
6.754
6.685
6.666
4.314
4.286
4.212
4.190
4.042
4.019
3.894
3.866
3.741
3.730
3.721
3.710
3.084
3.063
-0.000
O
O
N
H
H
Cl
3d
400 MHz, CDCl3
4.05
2.94
1.96
1.00
1.01
0.92
1.73
1.03
1.00
1.05
1.09
2.01
8
7
6
5
4
3
2
1
0
PPM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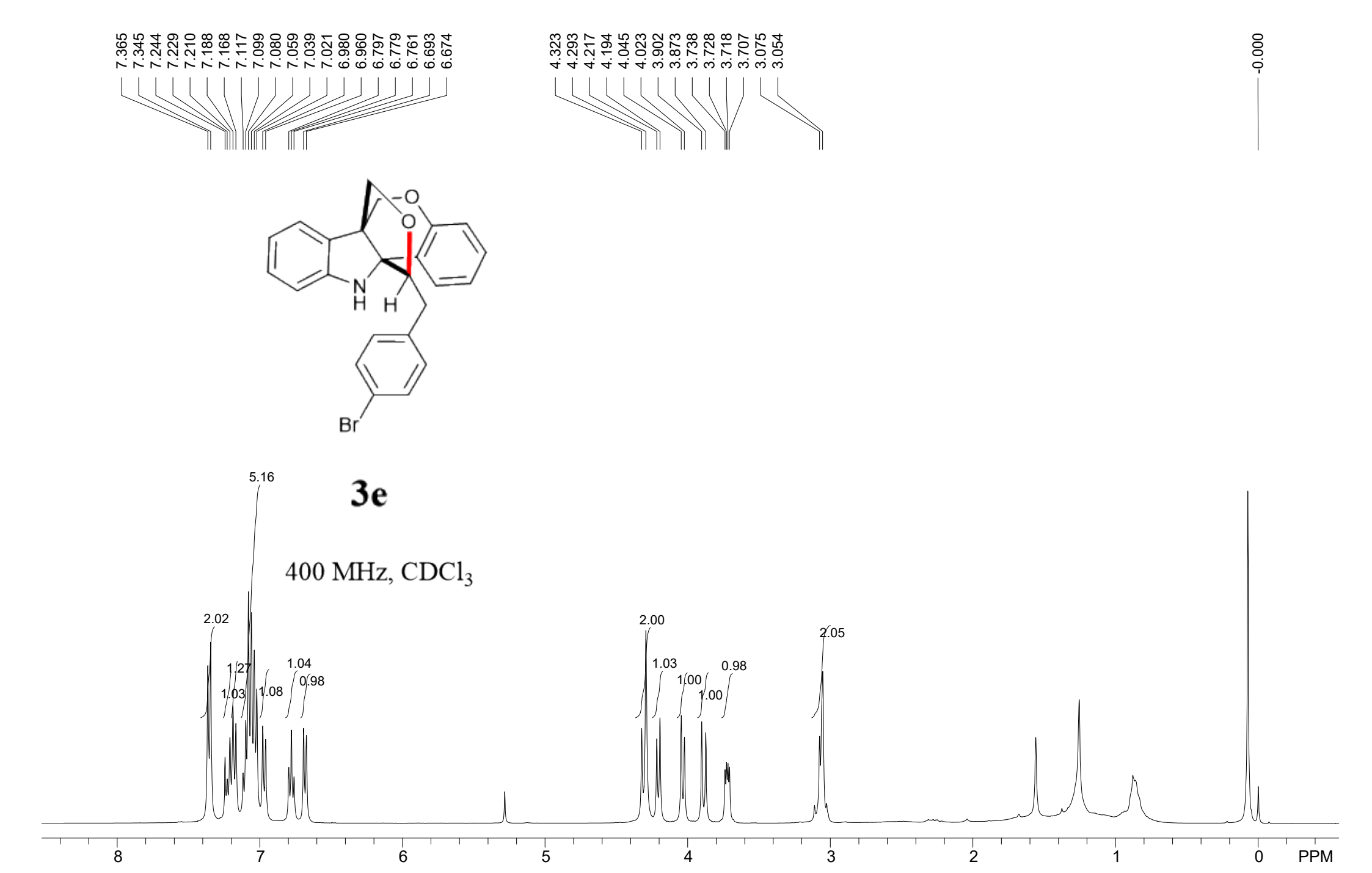
149.864
132.073
137.206
130.702
130.461
128.930
128.522
128.405
127.938
125.430
122.842
122.747
119.663
118.168
109.856
90.694
77.314
77.000
76.679
75.308
71.918
69.322
60.128
35.307
O
O
N
H
H
Cl
3d
100 MHz, CDCl3
200
150
100
50
PPM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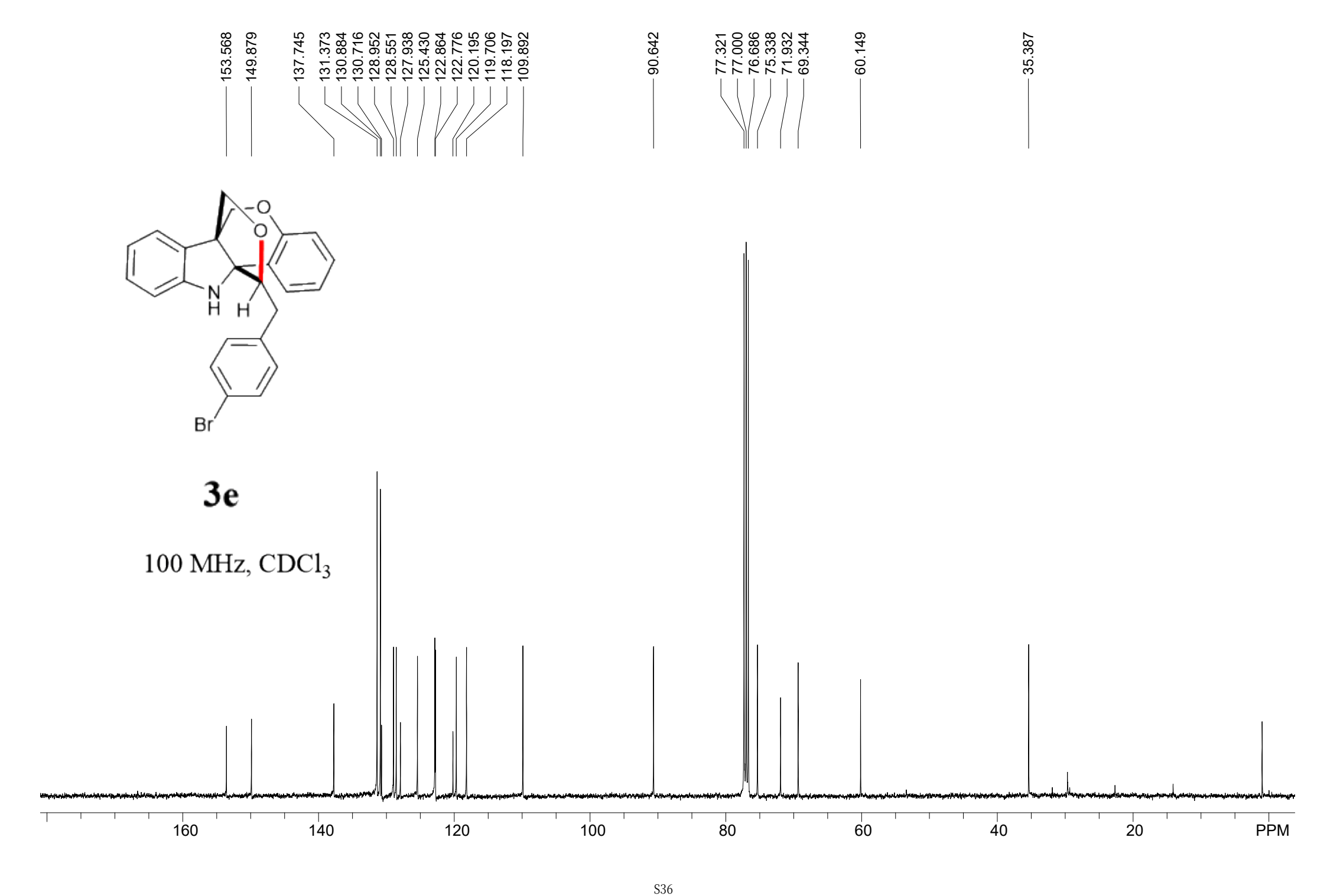
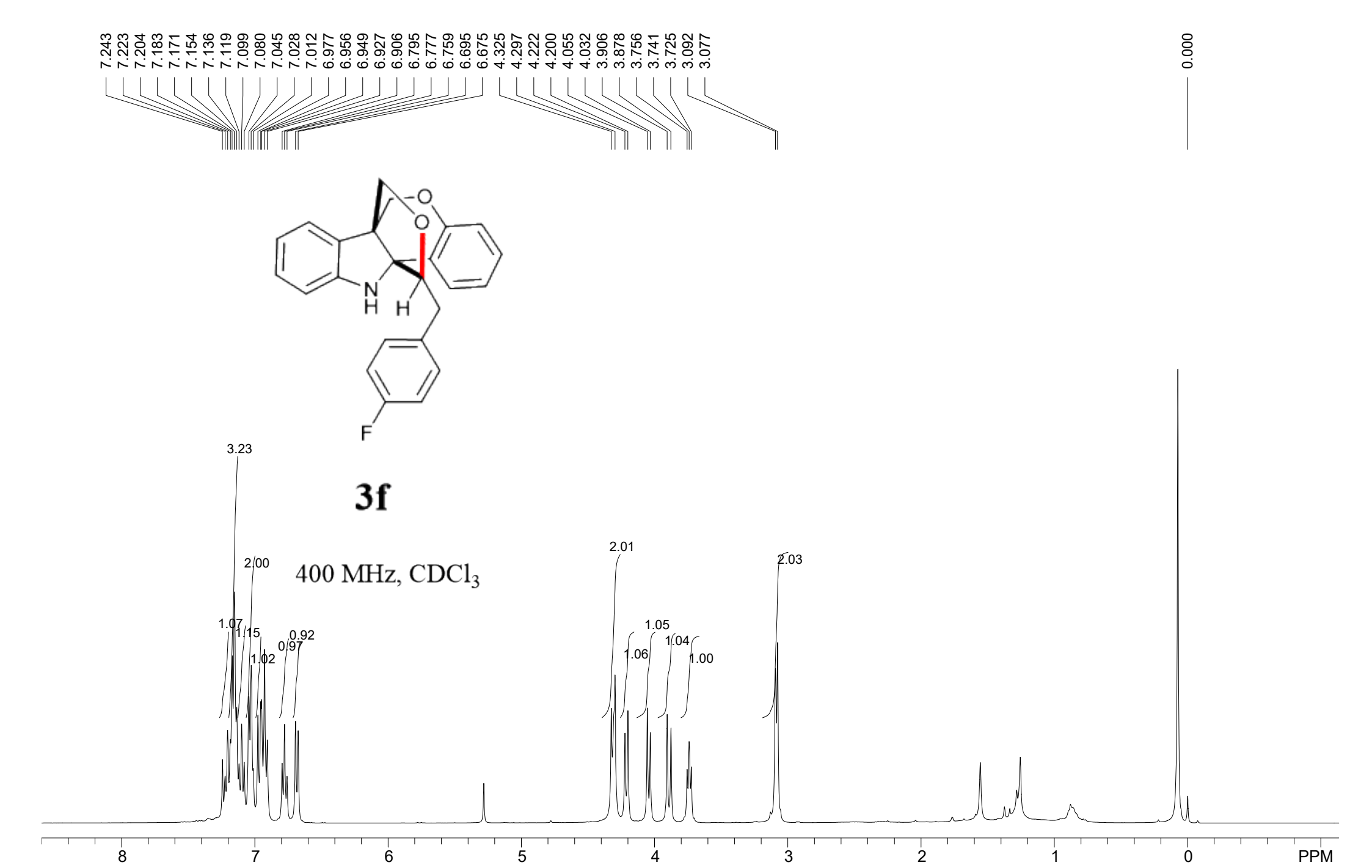
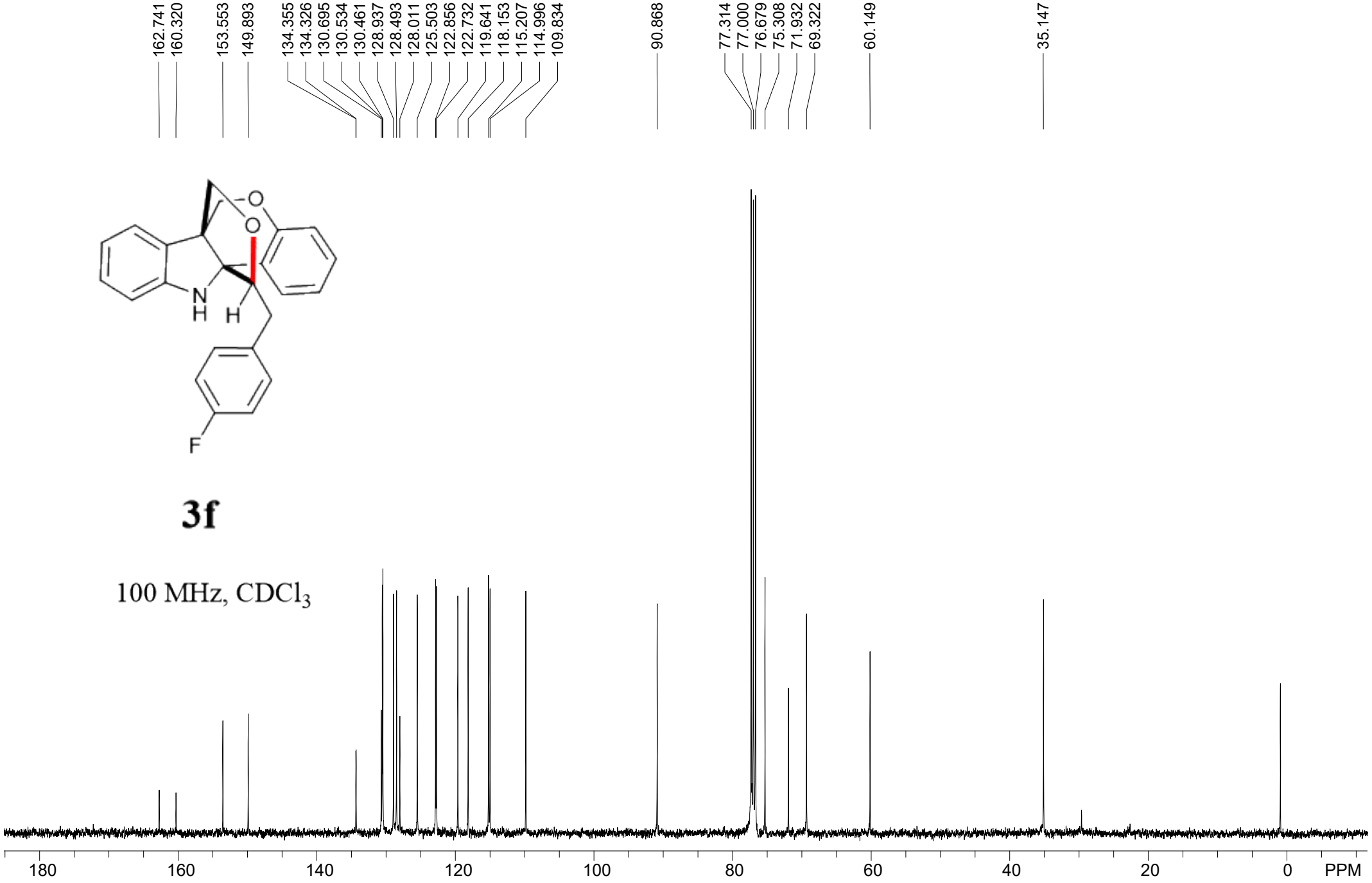
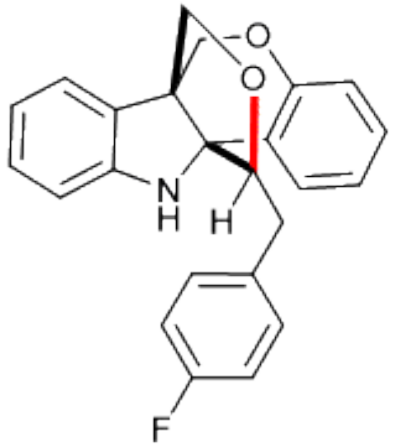
7.345
7.244
7.229
7.210
7.188
7.168
7.117
7.099
7.080
7.059
7.039
7.021
6.980
6.960
6.797
6.779
6.761
6.693
6.674
4.323
4.293
4.217
4.194
4.045
4.023
3.902
3.873
3.738
3.728
3.718
3.707
3.075
3.054
-0.000
O
O
N
H
H
Br
3e
400 MHz, CDCl3
5.16
2.02
1.27
1.03
1.08
1.04
0.98
2.00
1.03
1.00
1.00
0.98
2.05
8
7
6
5
4
3
2
1
0
PPM


153.568
149.879
137.745
131.373
130.884
130.716
128.952
128.551
127.938
125.430
122.864
122.776
120.195
119.706
118.197
109.892
90.642
77.321
77.000
76.686
75.338
71.932
69.344
60.149
35.387
O
O
N
H
H
Br
3e
100 MHz, CDCl3
160
140
120
100
80
60
40
20
PPM

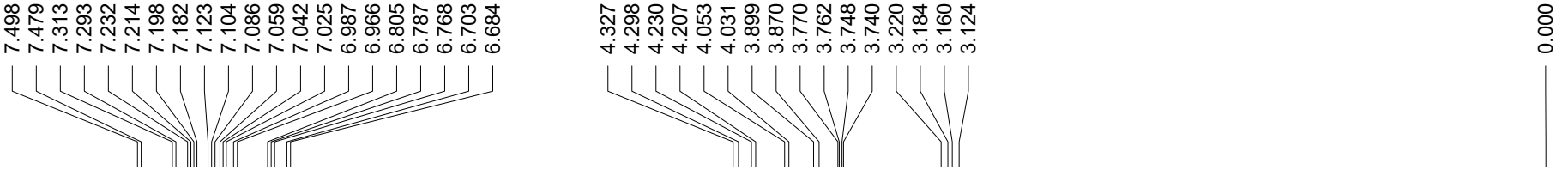

7.243
7.223
7.204
7.183
7.171
7.154
7.136
7.119
7.099
7.080
7.045
7.028
7.012
6.977
6.956
6.949
6.927
6.906
6.795
6.777
6.759
6.695
6.675
4.325
4.297
4.222
4.200
4.055
4.032
3.906
3.878
3.756
3.741
3.725
3.092
3.077
0.000
O
O
N
H
H
F
3f
400 MHz, CDCl3
3.23
2.00
1.07
1.15
1.02
0.97
0.92
2.01
1.06
1.05
1.04
1.00
2.03
8
7
6
5
4
3
2
1
0
PPM

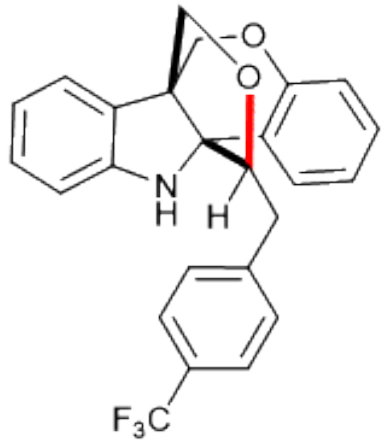

162.741
160.320
153.553
149.893
134.355
134.326
130.695
130.534
130.461
128.937
128.493
128.011
125.503
122.856
122.732
119.641
118.153
115.207
114.996
109.834
90.868
77.314
77.000
76.679
75.308
71.932
69.322
60.149
35.147
O
O
N
H
H
F
3f
100 MHz, CDCl3
180
160
140
120
100
80
60
40
20
0
PPM



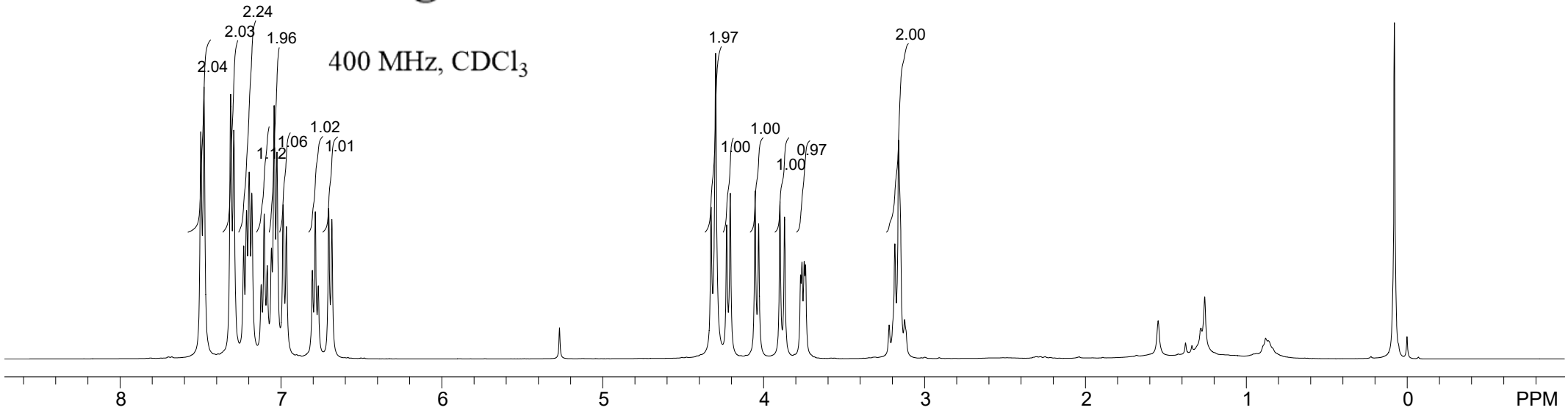
3f

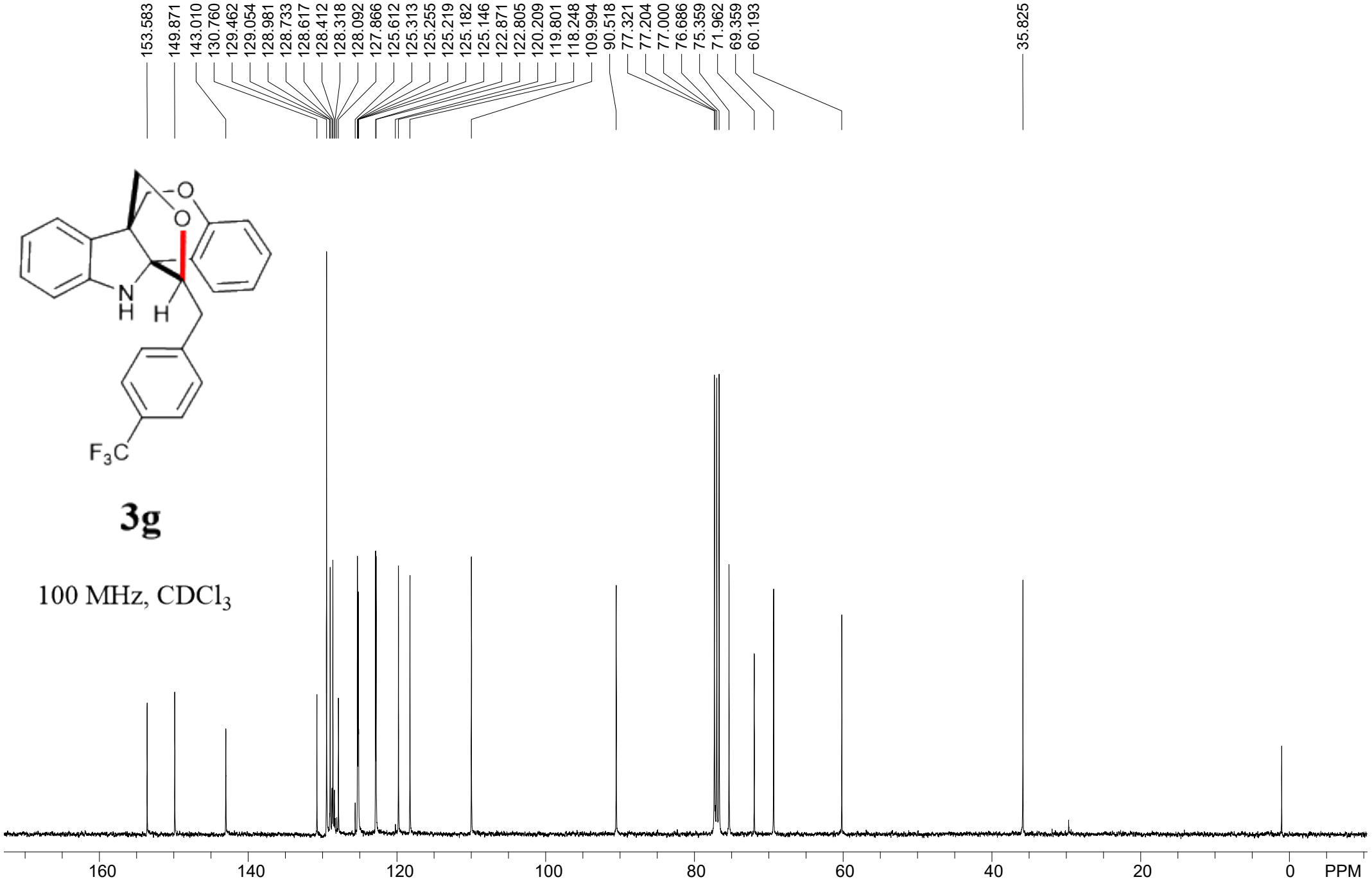
376 MHz, $CDCl_3$

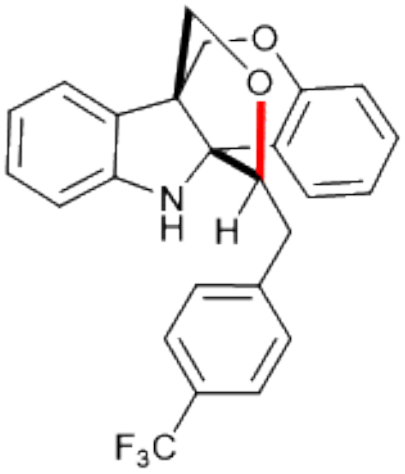

7.498
7.479
7.313
7.293
7.232
7.214
7.198
7.182
7.123
7.104
7.086
7.059
7.042
7.025
6.987
6.966
6.805
6.787
6.768
6.703
6.684
4.327
4.298
4.230
4.207
4.053
4.031
3.899
3.870
3.770
3.762
3.748
3.740
3.220
3.184
3.160
3.124
0.000


O
O
N
H
H
F3C

3g

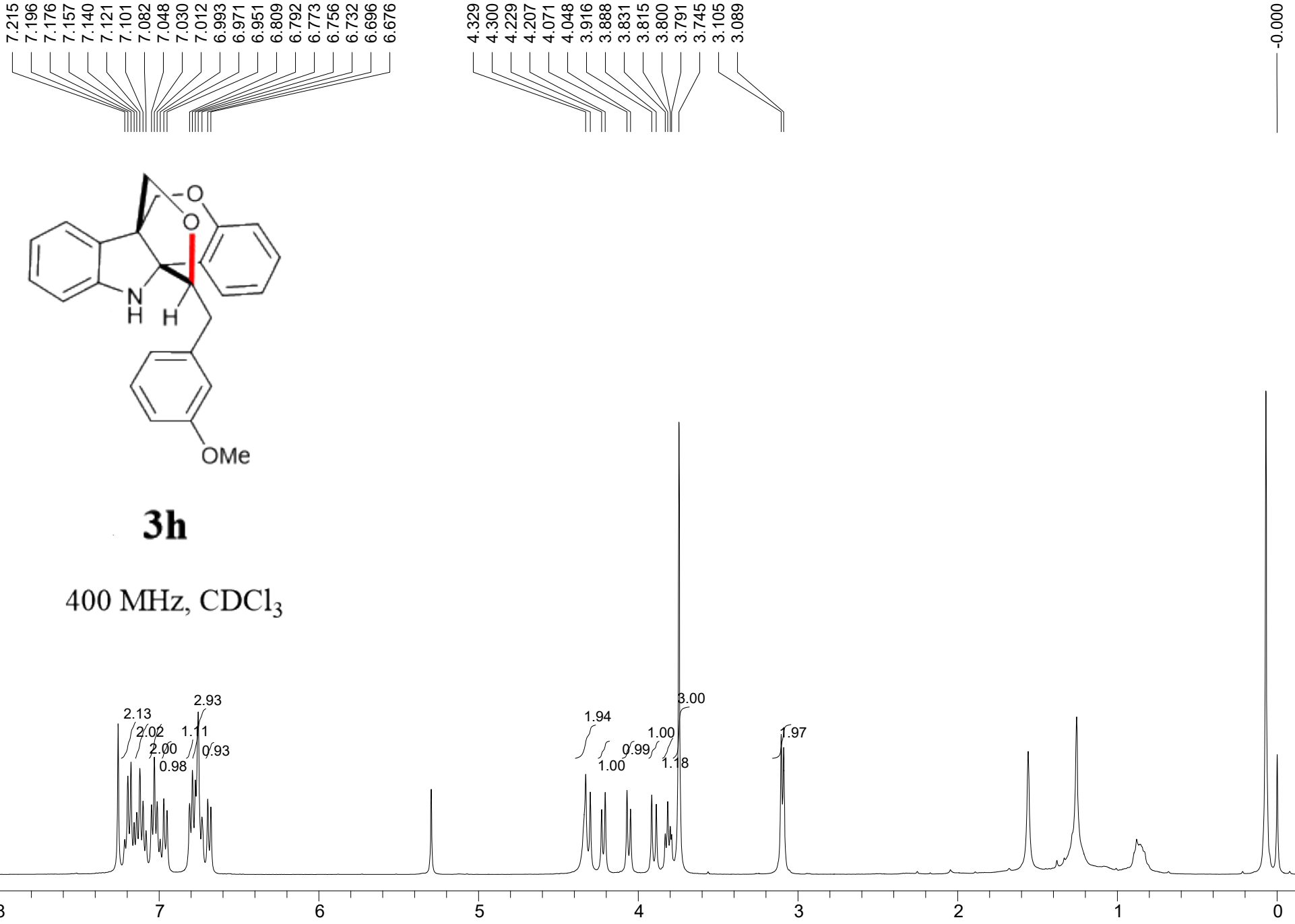

400 MHz, CDCl3
2.24
2.03
1.96
2.04
1.12
1.06
1.02
1.01
1.97
1.00
1.00
1.00
0.97
2.00
8
7
6
5
4
3
2
1
0
PPM

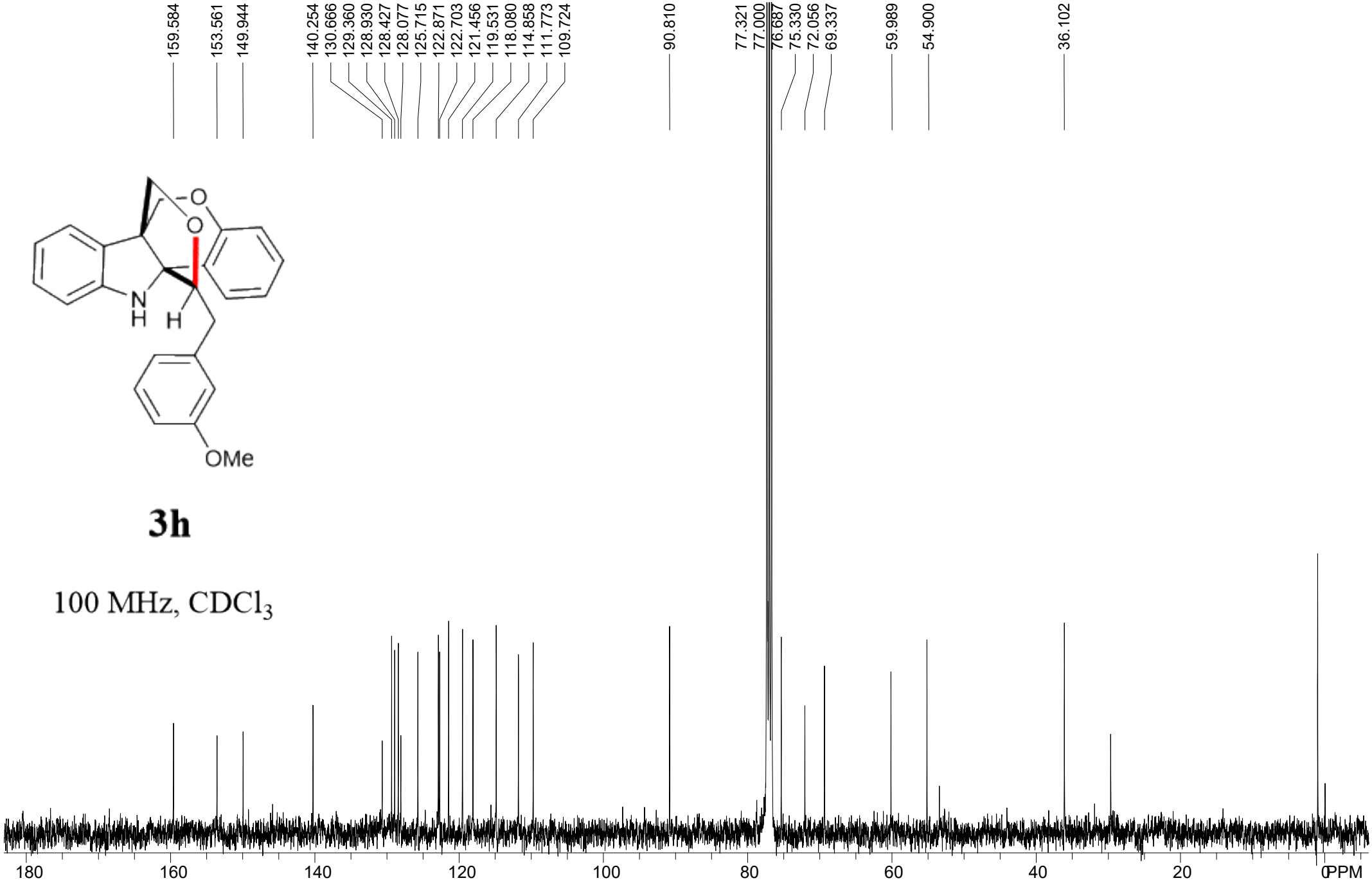

153.583
149.871
143.010
130.760
129.462
129.054
128.981
128.733
128.617
128.412
128.318
128.092
127.866
125.612
125.313
125.255
125.219
125.182
125.146
122.871
122.805
120.209
119.801
118.248
109.994
90.518
77.321
77.204
77.000
76.686
75.359
71.962
69.359
60.193
35.825
O
O
N
H
H
F3C
3g
100 MHz, CDCl3
160
140
120
100
80
60
40
20
0
PPM

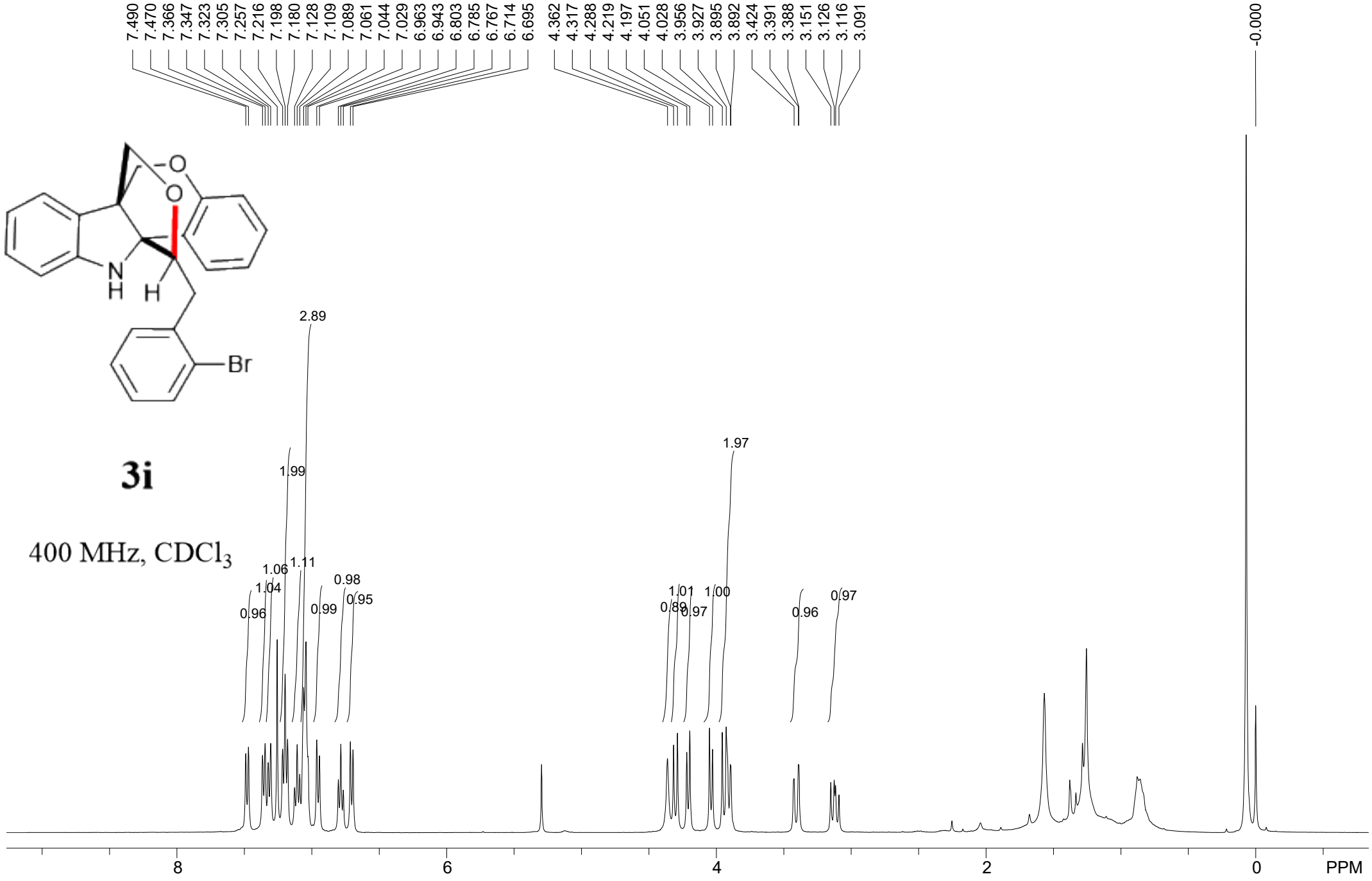


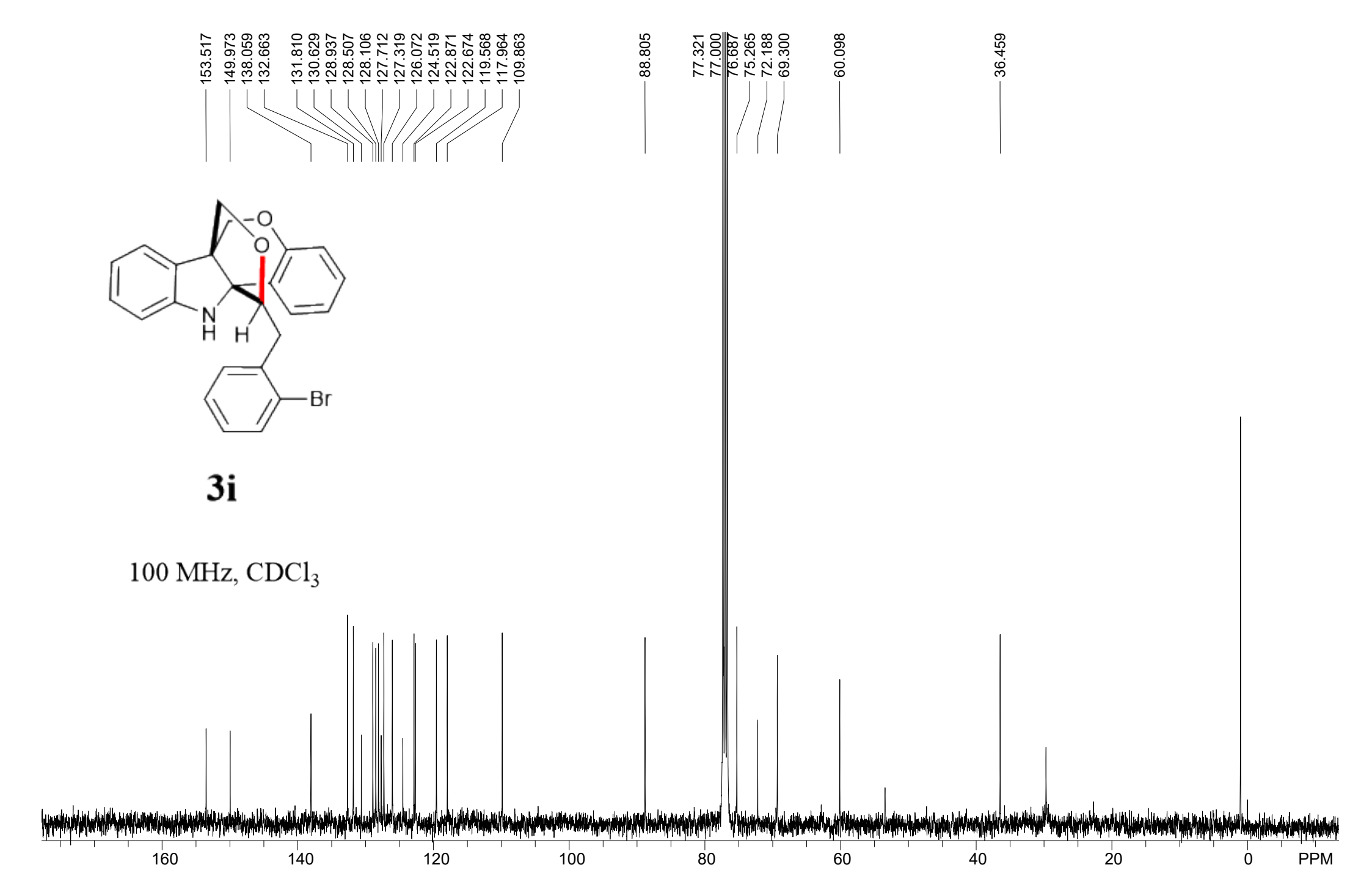
3g

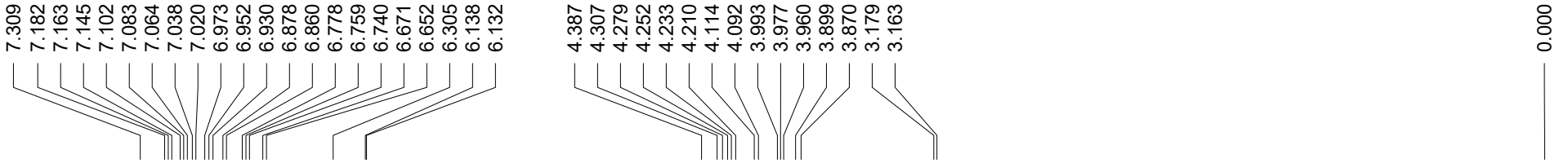
376 MHz, $CDCl_3$

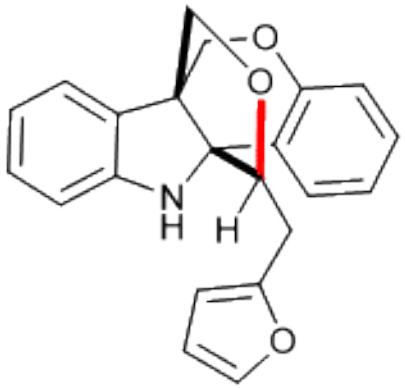

7.215
7.196
7.176
7.157
7.140
7.121
7.101
7.082
7.048
7.030
7.012
6.993
6.971
6.951
6.809
6.792
6.773
6.756
6.732
6.696
6.676
4.329
4.300
4.229
4.207
4.071
4.048
3.916
3.888
3.831
3.815
3.800
3.791
3.745
3.105
3.089
-0.000
O
O
N
H
H
OMe
3h
400 MHz, CDCl3
2.13
2.02
2.00
0.98
1.11
2.93
0.93
1.94
1.00
0.99
1.00
1.18
3.00
1.97
8
7
6
5
4
3
2
1
0
PPM


159.584
153.561
149.944
140.254
130.666
129.360
128.930
128.427
128.077
125.715
122.871
122.703
121.456
119.531
118.080
114.858
111.773
109.724
90.810
77.321
77.000
76.687
75.330
72.056
69.337
59.989
54.900
36.102
O
O
N
H
H
OMe
3h
100 MHz, CDCl3
180
160
140
120
100
80
60
40
20
0
PPM


7.490
7.470
7.366
7.347
7.323
7.305
7.257
7.216
7.198
7.180
7.128
7.109
7.089
7.061
7.044
7.029
6.963
6.943
6.803
6.785
6.767
6.714
6.695
4.362
4.317
4.288
4.219
4.197
4.051
4.028
3.956
3.927
3.895
3.892
3.424
3.391
3.388
3.151
3.126
3.116
3.091
-0.000
O
O
N
H
H
Br
3i
400 MHz, CDCl3
2.89
1.99
1.97
1.06
1.04
1.11
0.98
0.95
0.96
0.99
1.01
1.00
0.89
0.97
0.96
0.97
8
6
4
2
0
PPM

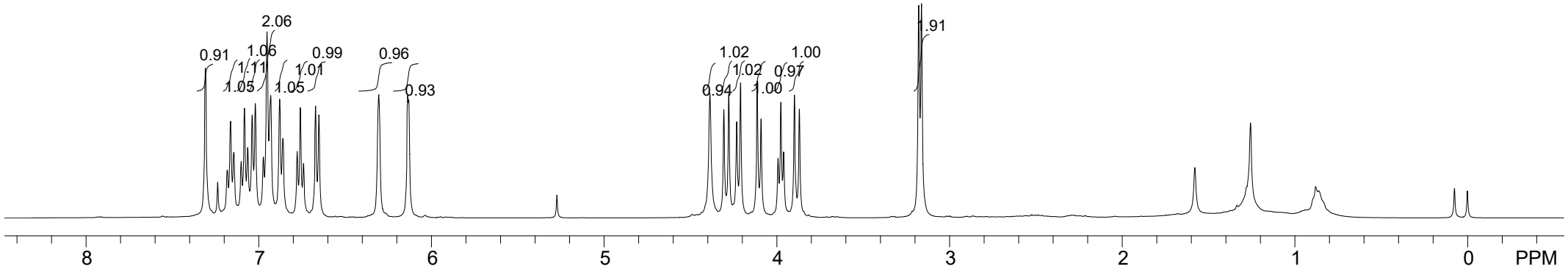

153.517
149.973
138.059
132.663
131.810
130.629
128.937
128.507
128.106
127.712
127.319
126.072
124.519
122.871
122.674
119.568
117.964
109.863
88.805
77.321
77.000
76.687
75.265
72.188
69.300
60.098
36.459
O
O
N
H
H
Br
3i
100 MHz, CDCl3
160
140
120
100
80
60
40
20
0
PPM

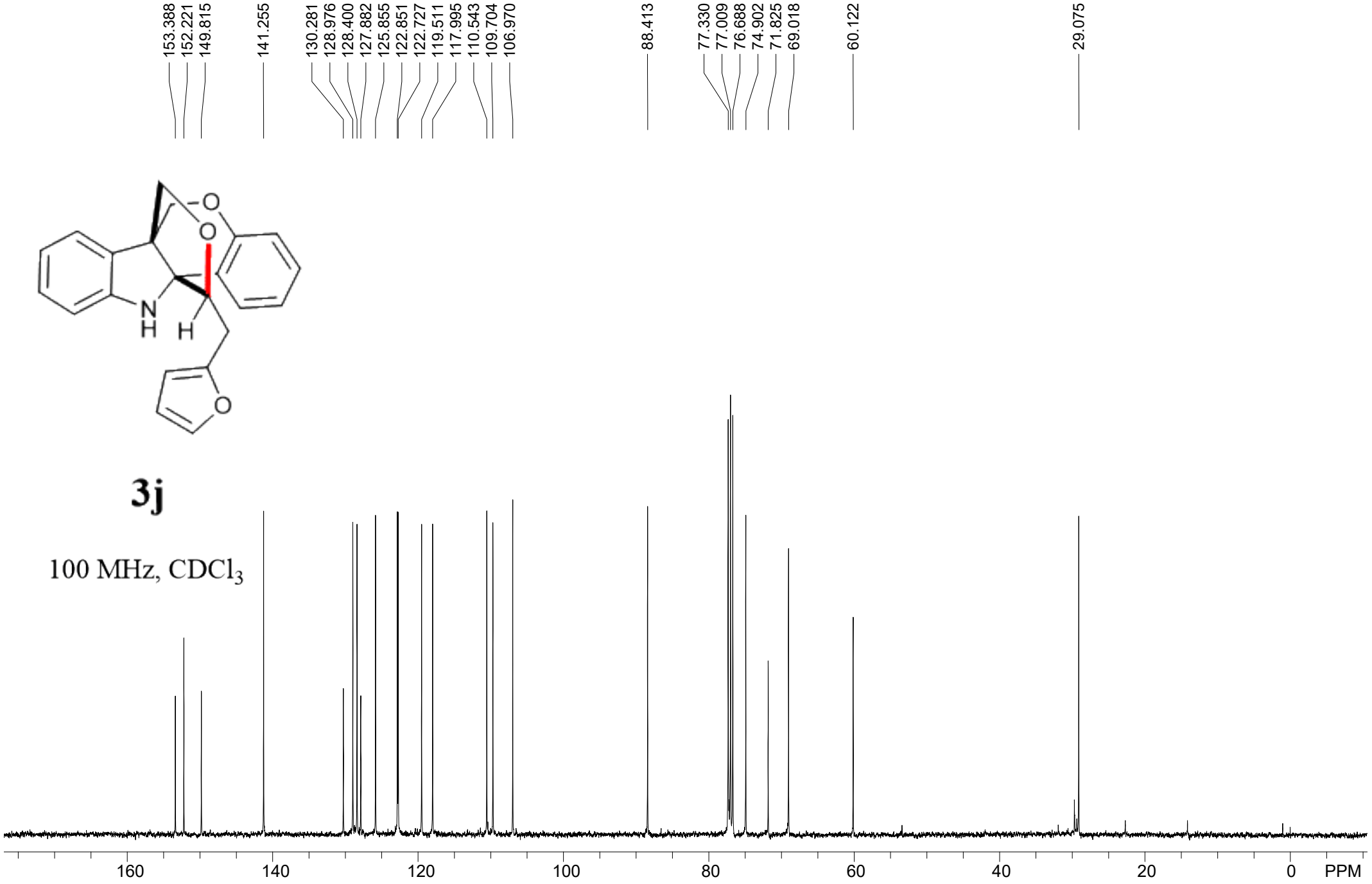


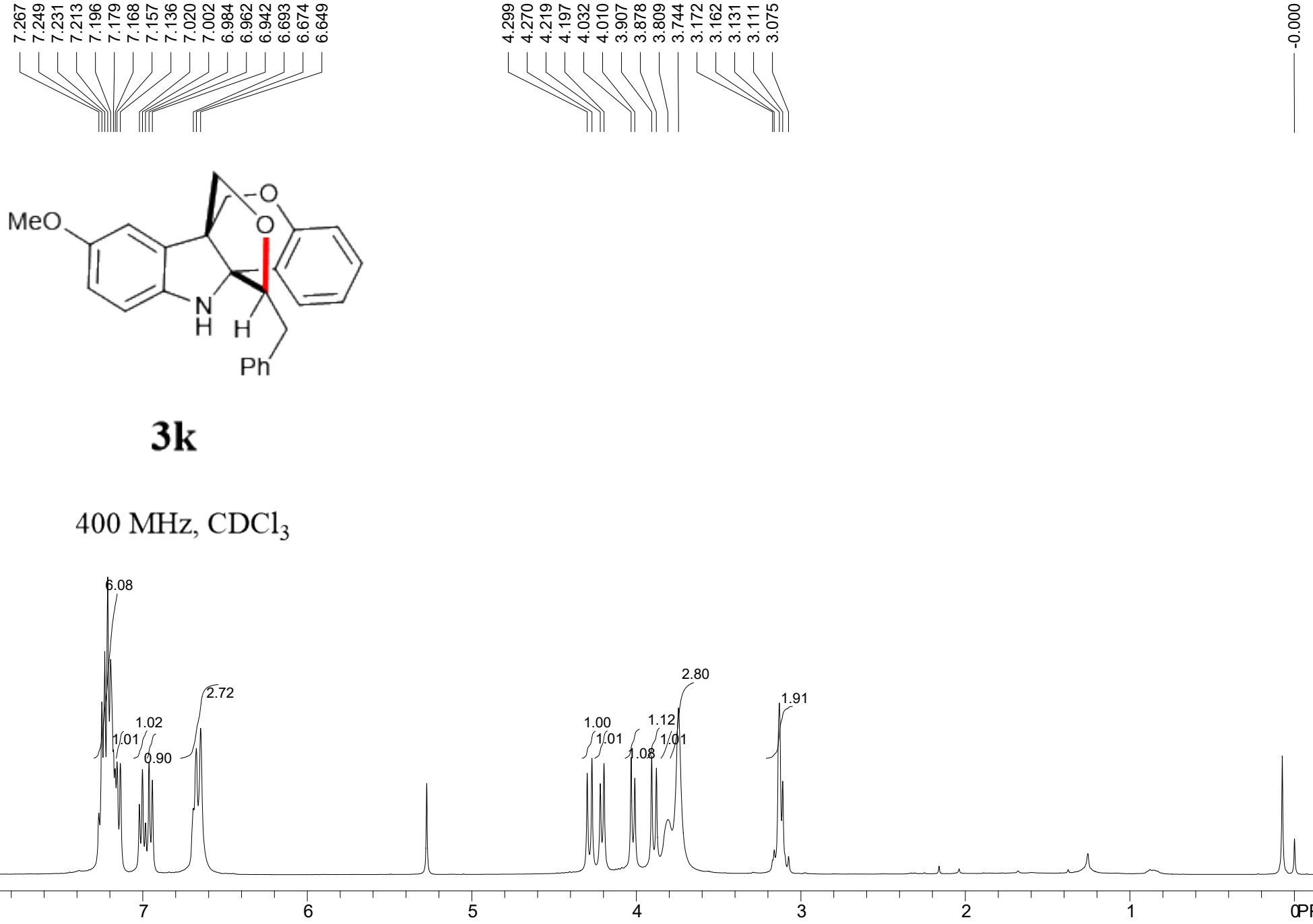


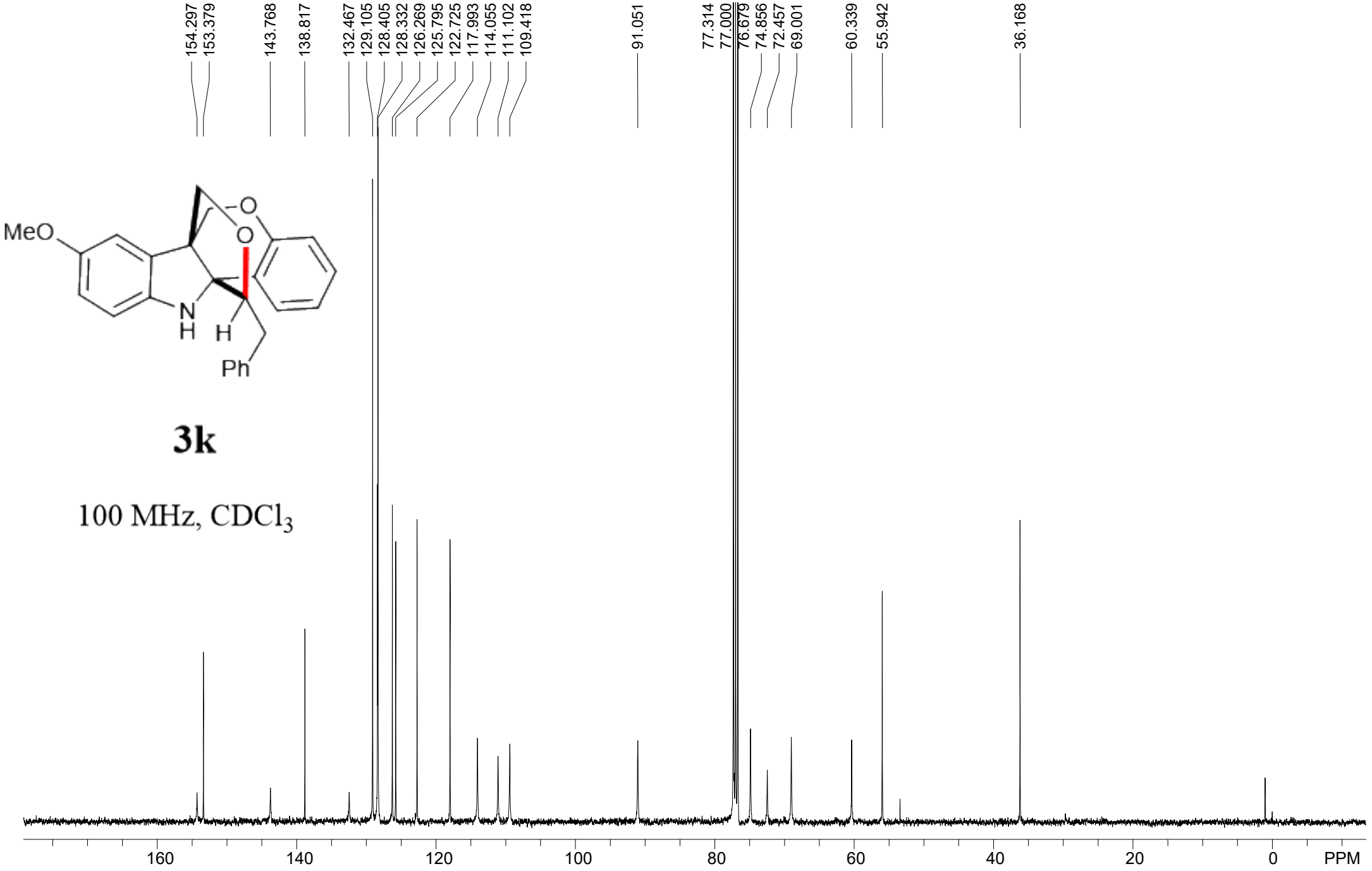
3j

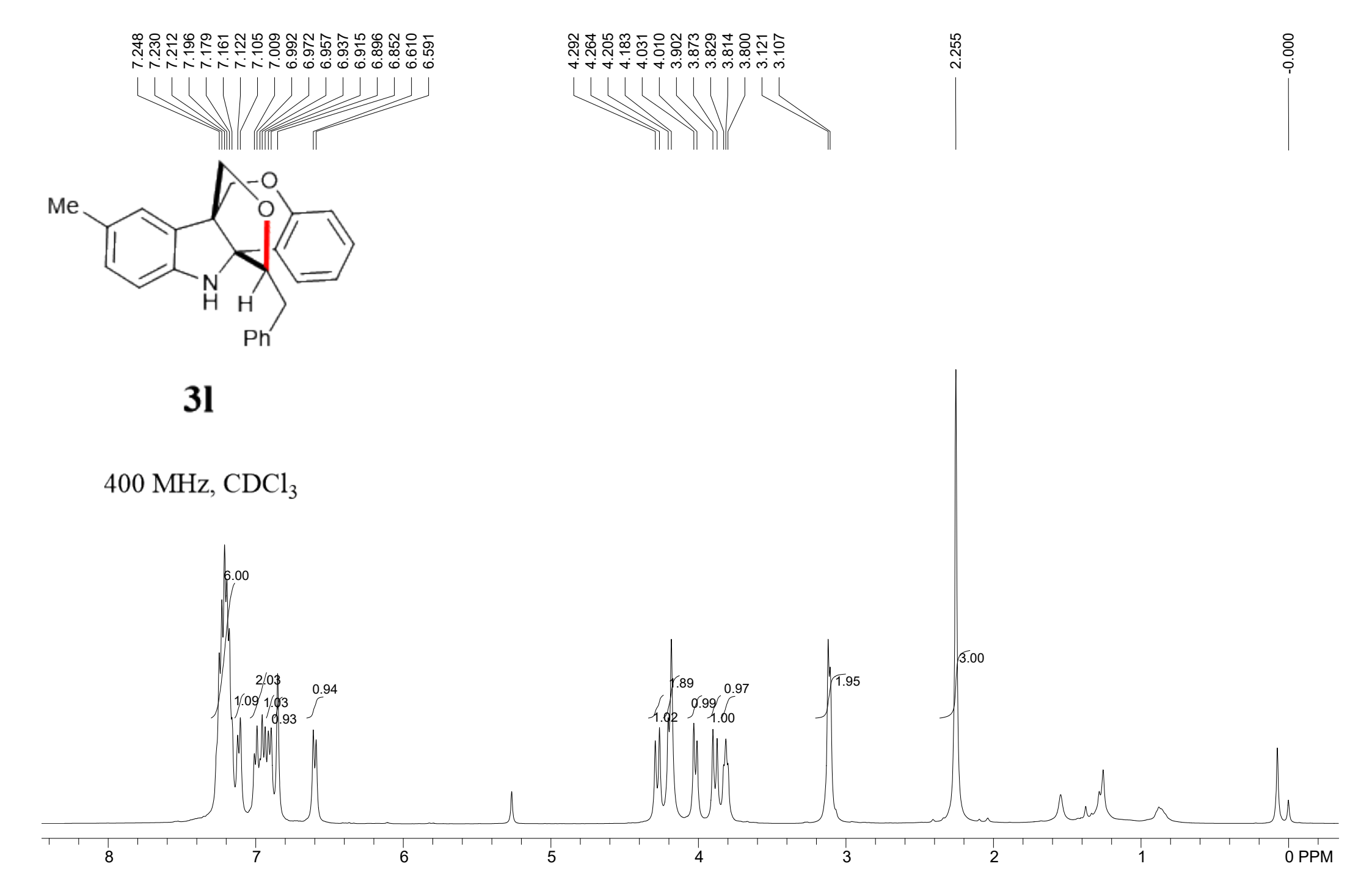
400 MHz, $CDCl_3$

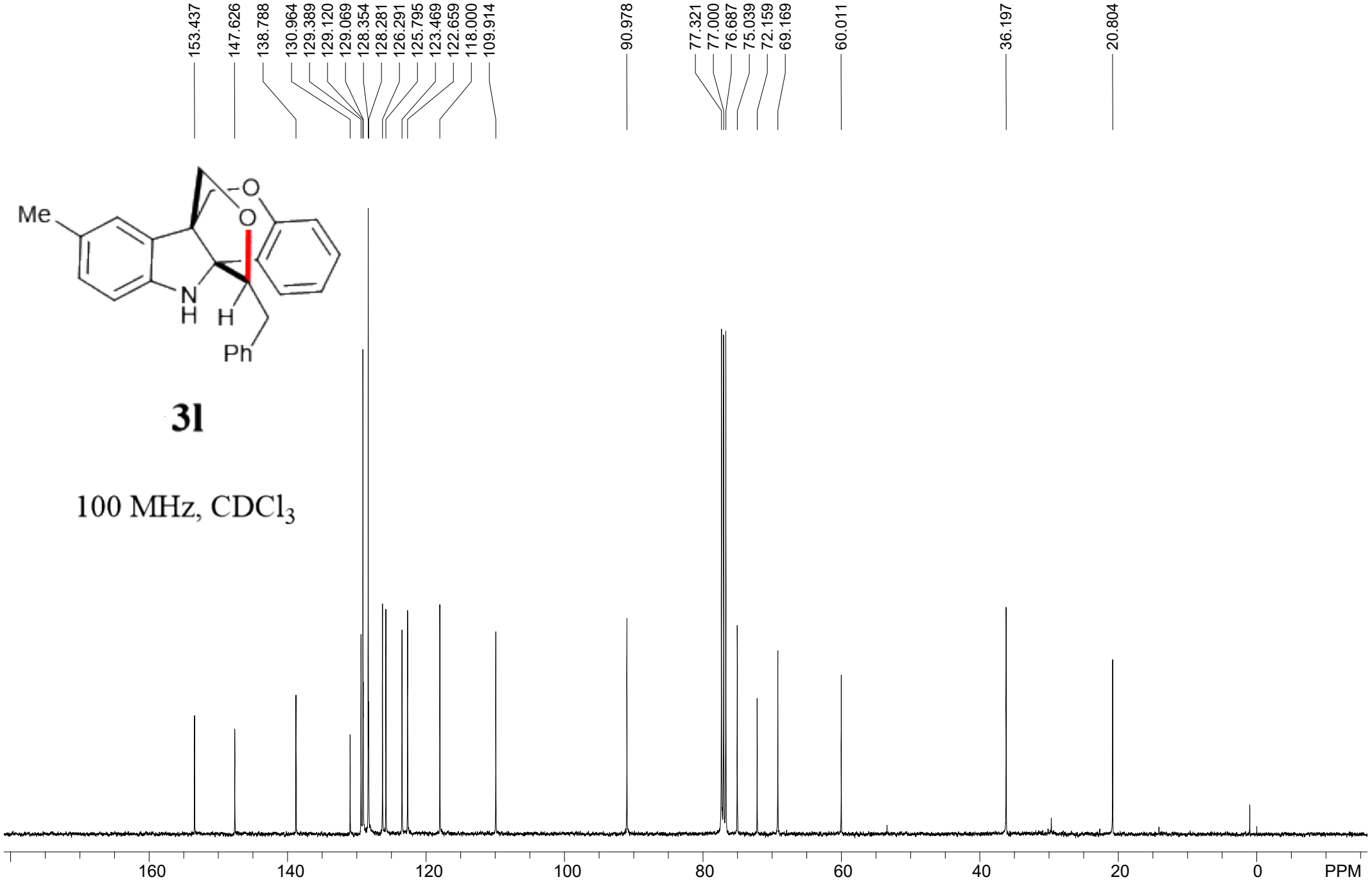


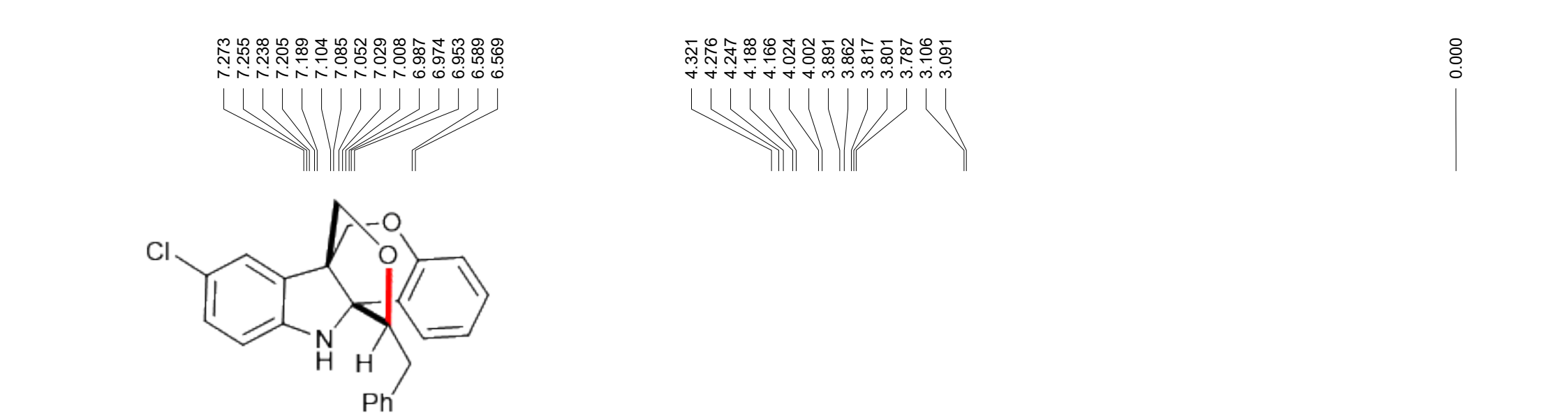

153.388
152.221
149.815
141.255
130.281
128.976
128.400
127.882
125.855
122.851
122.727
119.511
117.995
110.543
109.704
106.970
88.413
77.330
77.009
76.688
74.902
71.825
69.018
60.122
29.075
O
O
N
H
H
O
3j
100 MHz, CDCl3
160
140
120
100
80
60
40
20
0
PPM


7.267
7.249
7.231
7.213
7.196
7.179
7.168
7.157
7.136
7.020
7.002
6.984
6.962
6.942
6.693
6.674
6.649
4.299
4.270
4.219
4.197
4.032
4.010
3.907
3.878
3.809
3.744
3.172
3.162
3.131
3.111
3.075
-0.000
MeO
O
O
N
H
H
Ph
3k
400 MHz, CDCl3
6.08
1.01
1.02
0.90
2.72
1.00
1.01
1.08
1.12
1.01
2.80
1.91
8
7
6
5
4
3
2
1
0
PPM


154.297
153.379
143.768
138.817
132.467
129.105
128.405
128.332
126.269
125.795
122.725
117.993
114.055
111.102
109.418
91.051
77.314
77.000
76.679
74.856
72.457
69.001
60.339
55.942
36.168
MeO
O
O
N
H
H
Ph
3k
100 MHz, CDCl3
160
140
120
100
80
60
40
20
0
PPM

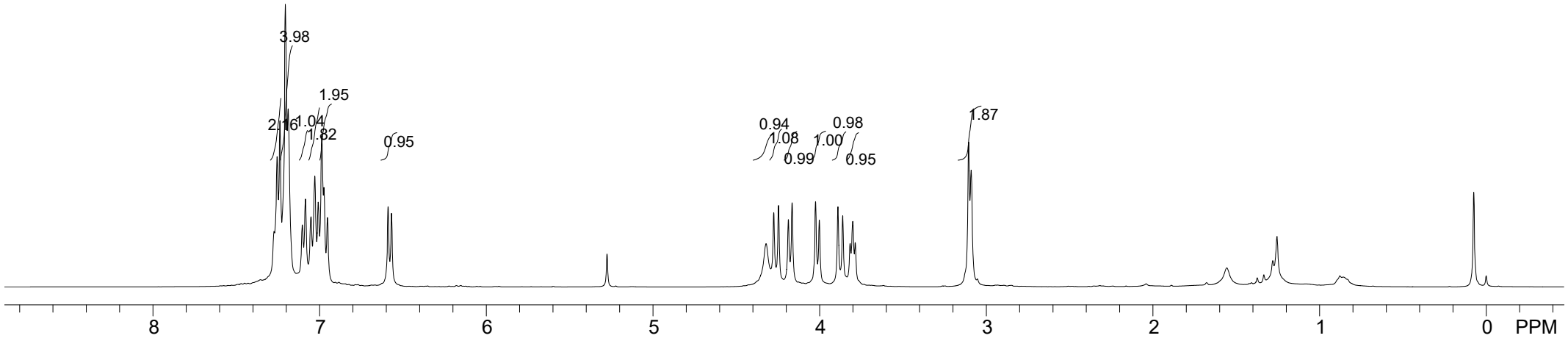

7.248
7.230
7.212
7.196
7.179
7.161
7.122
7.105
7.009
6.992
6.972
6.957
6.937
6.915
6.896
6.852
6.610
6.591
4.292
4.264
4.205
4.183
4.031
4.010
3.902
3.873
3.829
3.814
3.800
3.121
3.107
2.255
-0.000
Me
O
O
N
H
H
Ph
3l
400 MHz, CDCl3
6.00
2.03
1.09
1.03
0.93
0.94
1.89
0.99
0.97
1.02
1.00
1.95
3.00
8
7
6
5
4
3
2
1
0 PPM

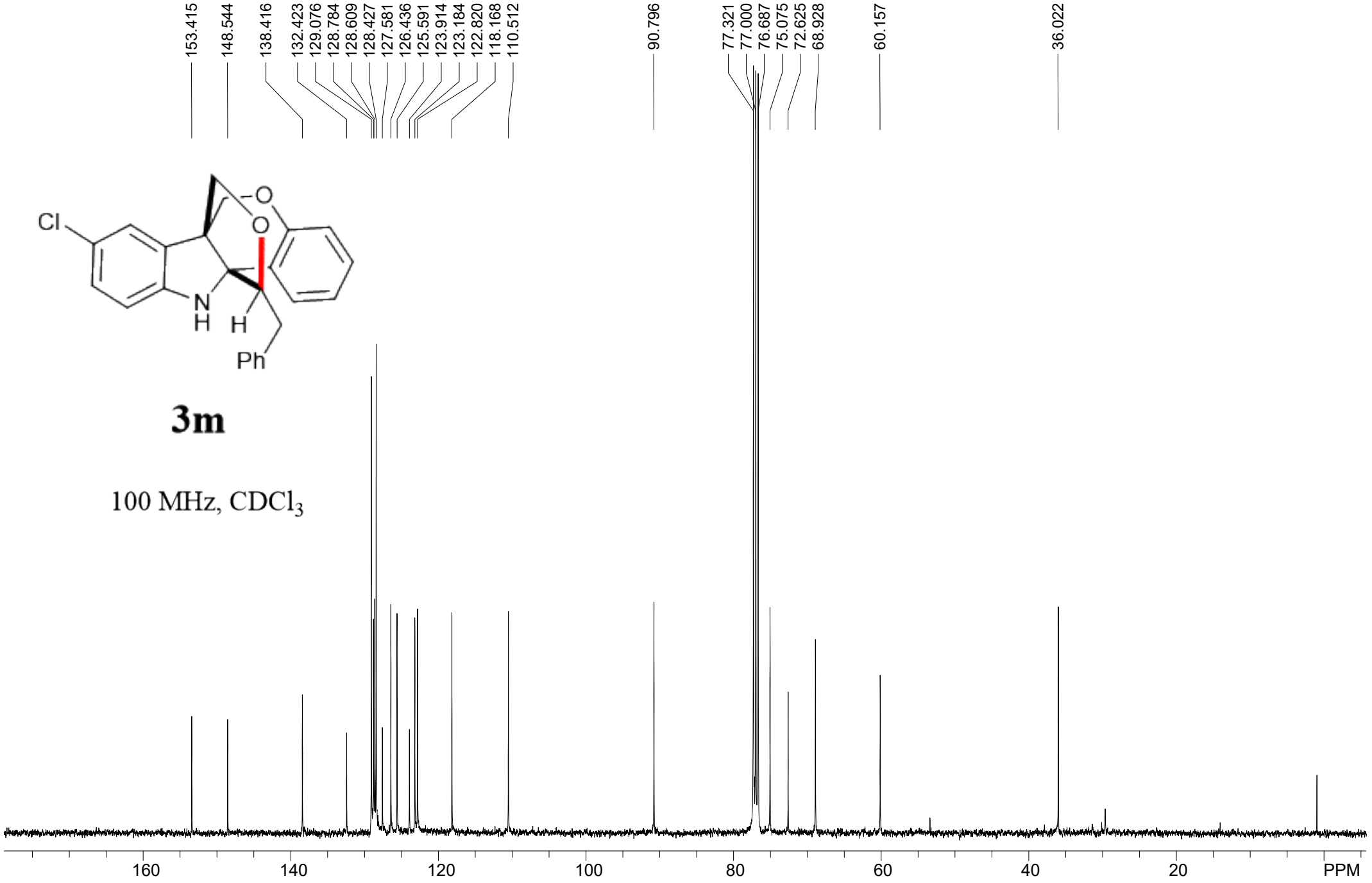

153.437
147.626
138.788
130.964
129.389
129.120
129.069
128.354
128.281
126.291
125.795
123.469
122.659
118.000
109.914
90.978
77.321
77.000
76.687
75.039
72.159
69.169
60.011
36.197
20.804
Me
O
O
N
H
H
Ph
3l
100 MHz, CDCl3
160
140
120
100
80
60
40
20
0
PPM

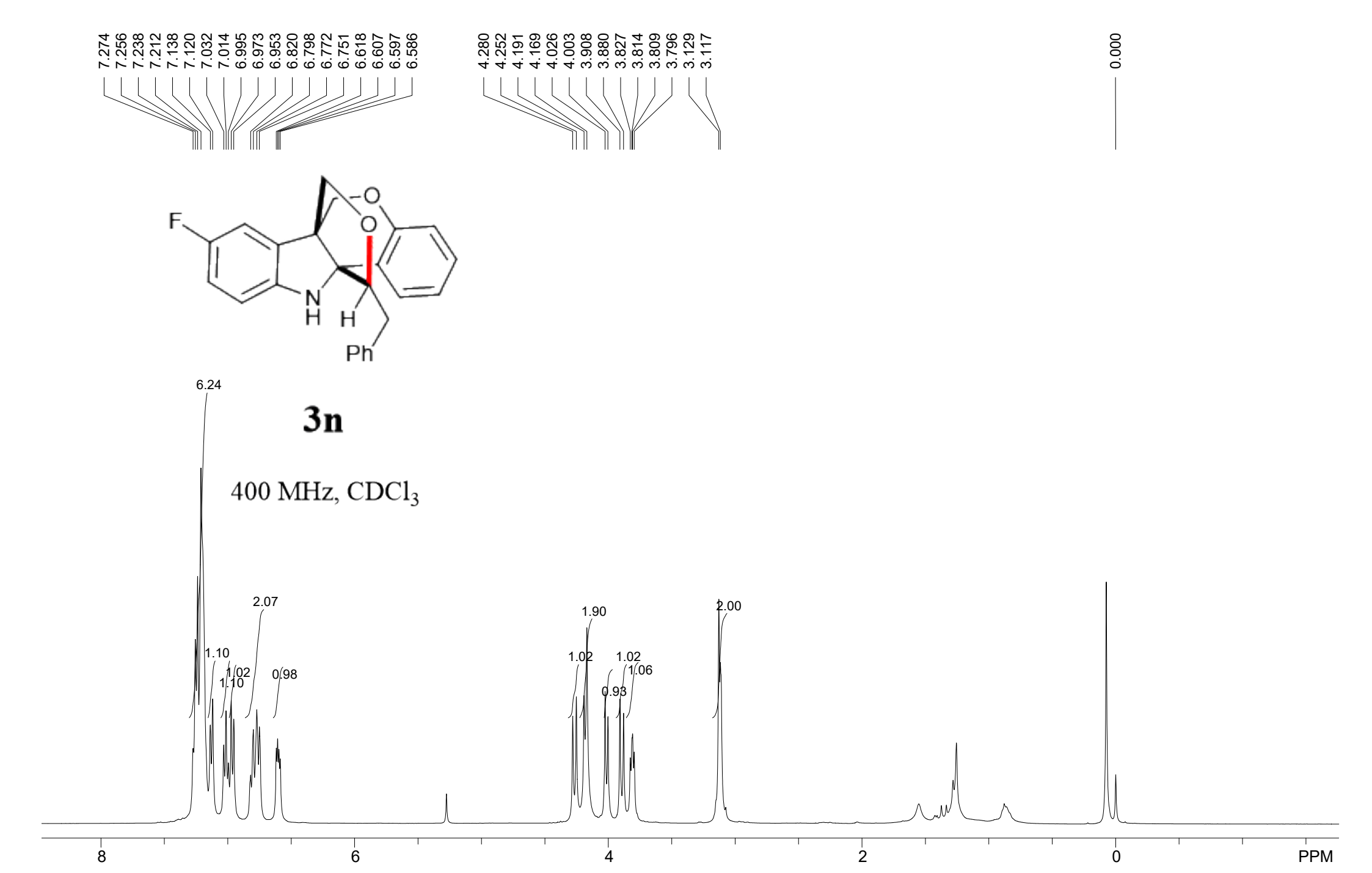


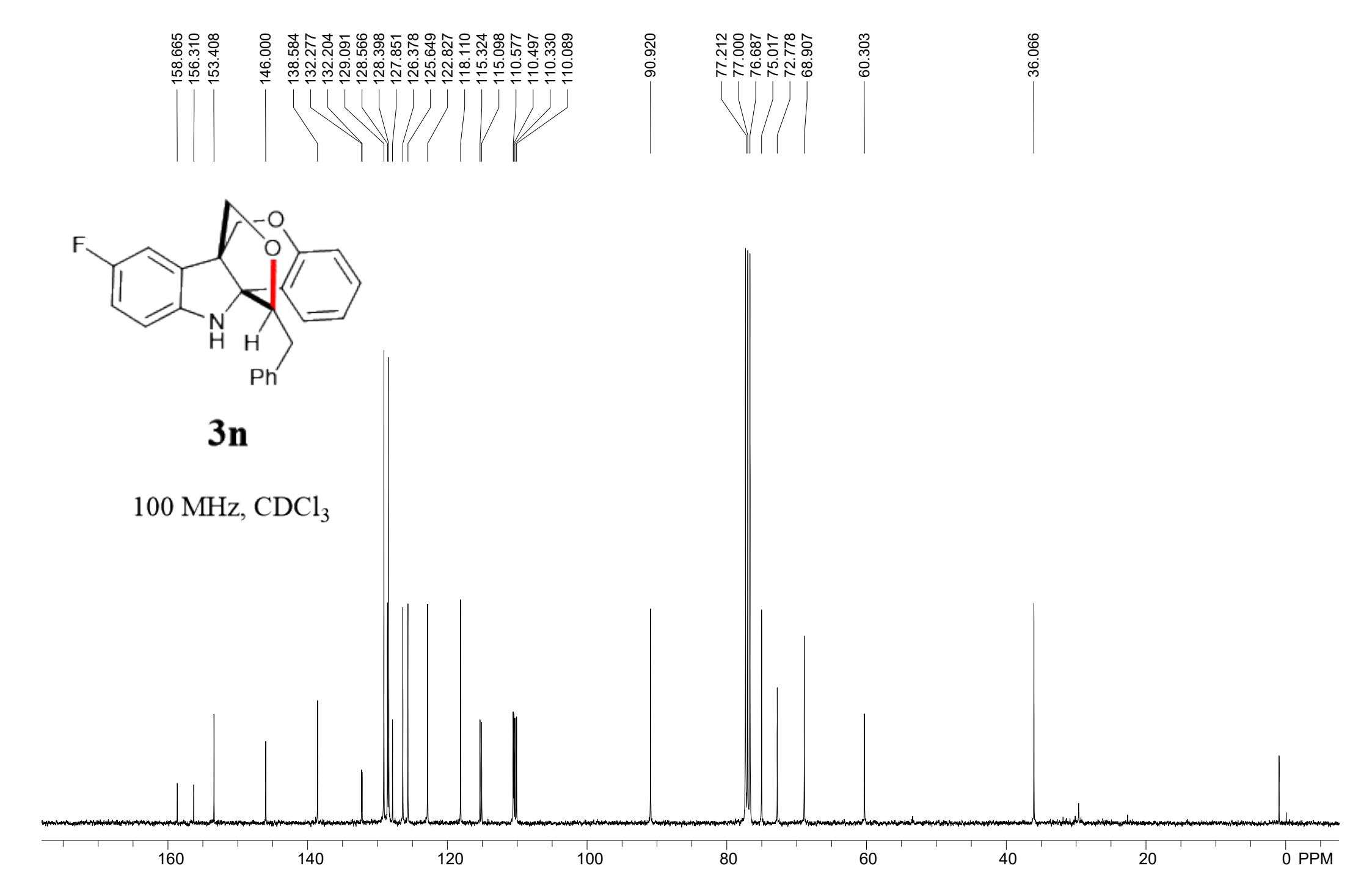
3m

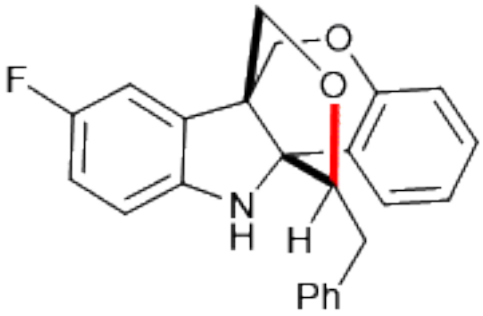
400 MHz, $CDCl_3$




153.415
148.544
138.416
132.423
129.076
128.784
128.609
128.427
127.581
126.436
125.591
123.914
123.184
122.820
118.168
110.512
90.796
77.321
77.000
76.687
75.075
72.625
68.928
60.157
36.022
Cl
O
O
N
H
H
Ph
3m
100 MHz, CDCl3
160
140
120
100
80
60
40
20
PPM

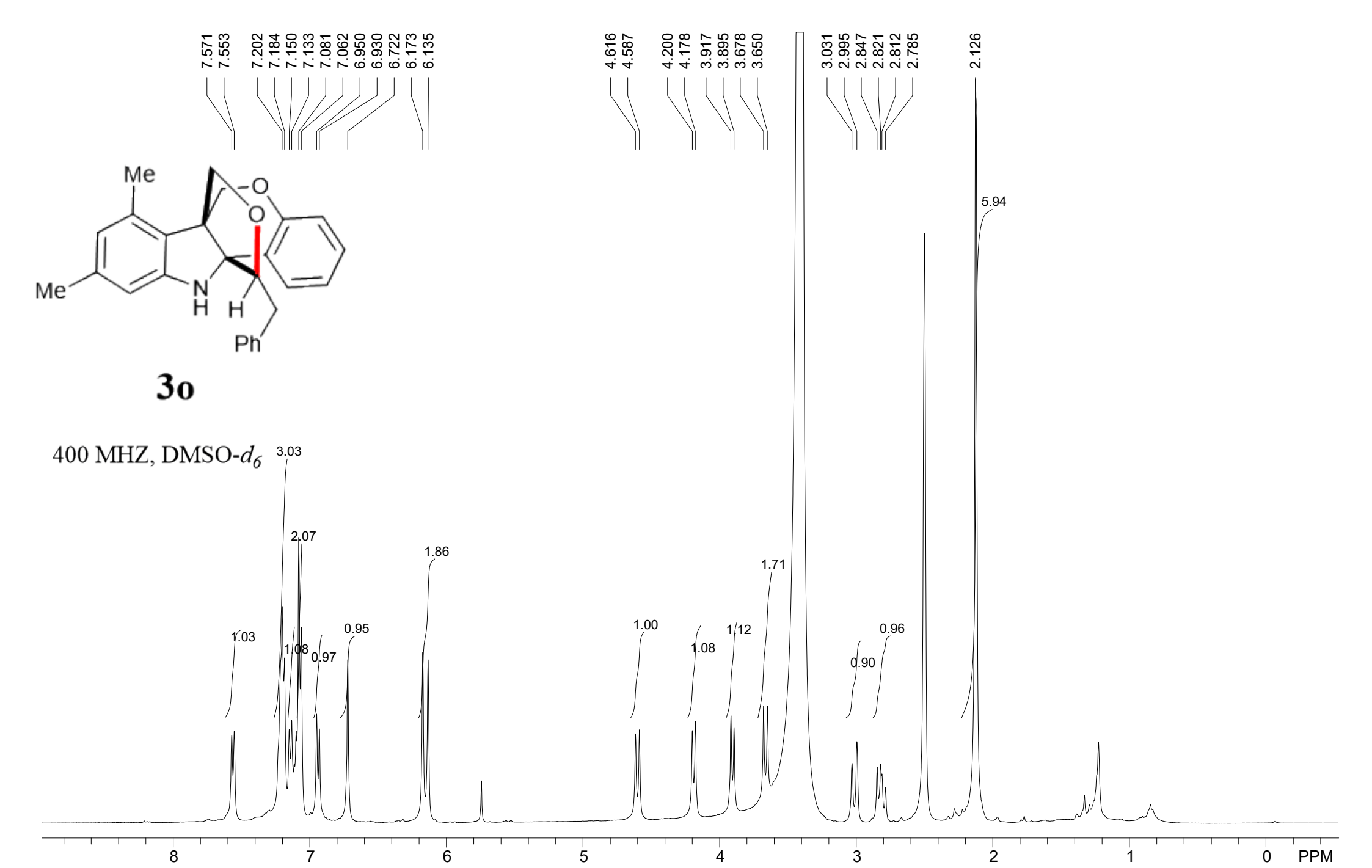

7.274
7.256
7.238
7.212
7.138
7.120
7.032
7.014
6.995
6.973
6.953
6.820
6.798
6.772
6.751
6.618
6.607
6.597
6.586
4.280
4.252
4.191
4.169
4.026
4.003
3.908
3.880
3.827
3.814
3.809
3.796
3.129
3.117
0.000
F
O
O
N
H
H
Ph
3n
400 MHz, CDCl3
6.24
2.07
1.10
1.10
1.02
0.98
1.90
1.02
1.02
1.06
0.93
2.00
8
6
4
2
0
PPM

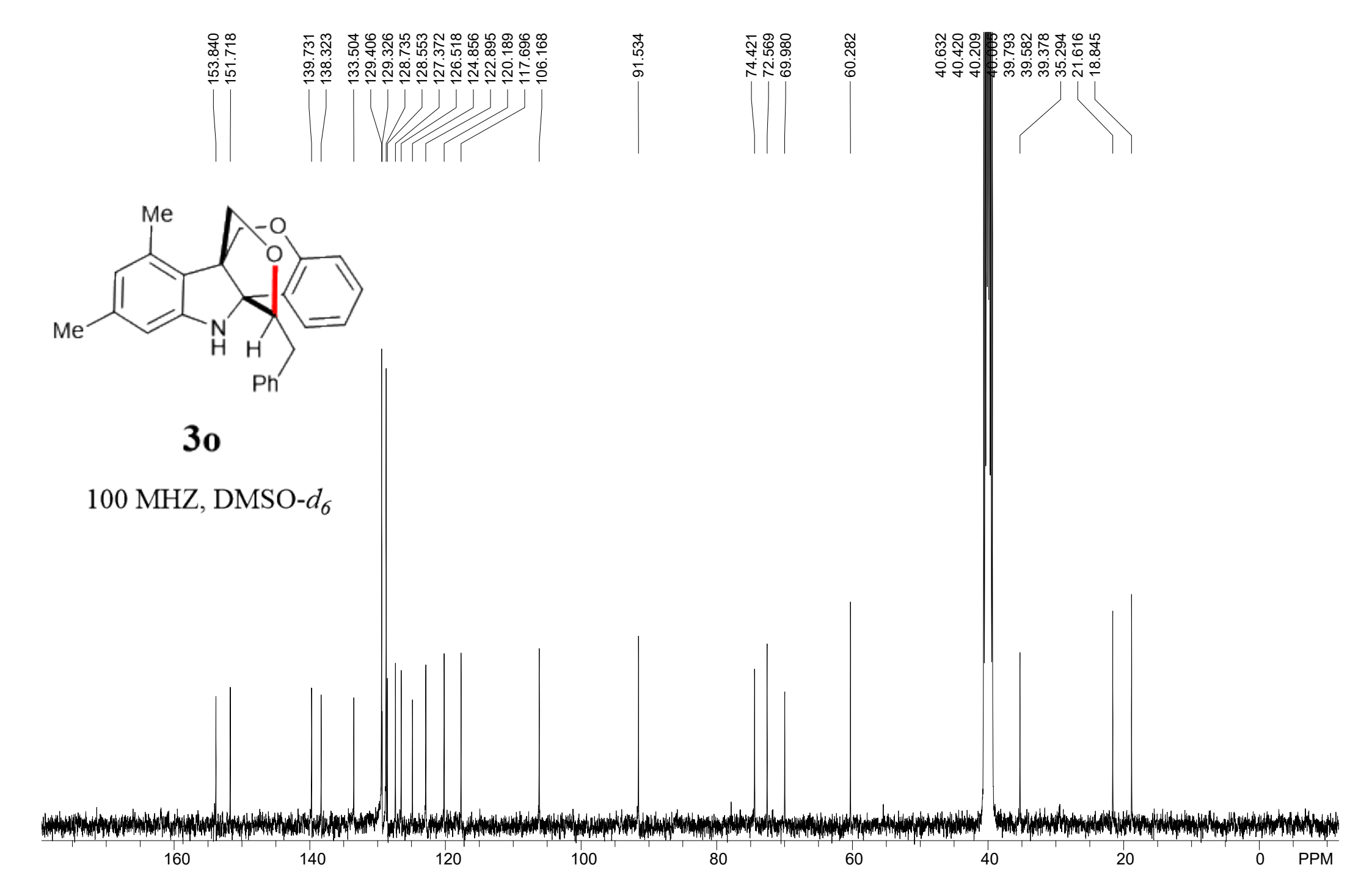

158.665
156.310
153.408
146.000
138.584
132.277
132.204
129.091
128.566
128.398
127.851
126.378
125.649
122.827
118.110
115.324
115.098
110.577
110.497
110.330
110.089
90.920
77.212
77.000
76.687
75.017
72.778
68.907
60.303
36.066
F
O
O
N
H
H
Ph
3n
100 MHz, CDCl3
160
140
120
100
80
60
40
20
0 PPM



3n

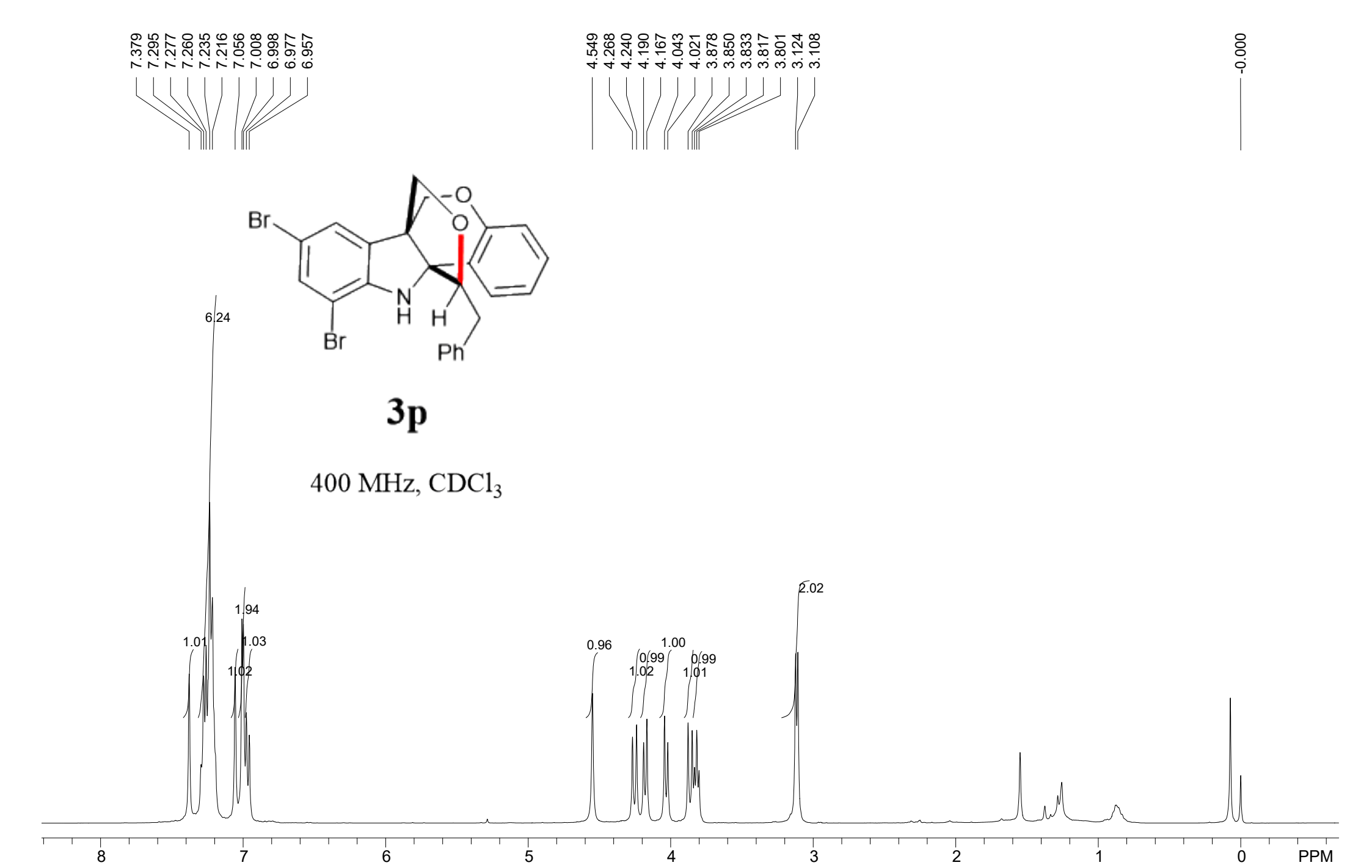
376 MHz, $CDCl_3$

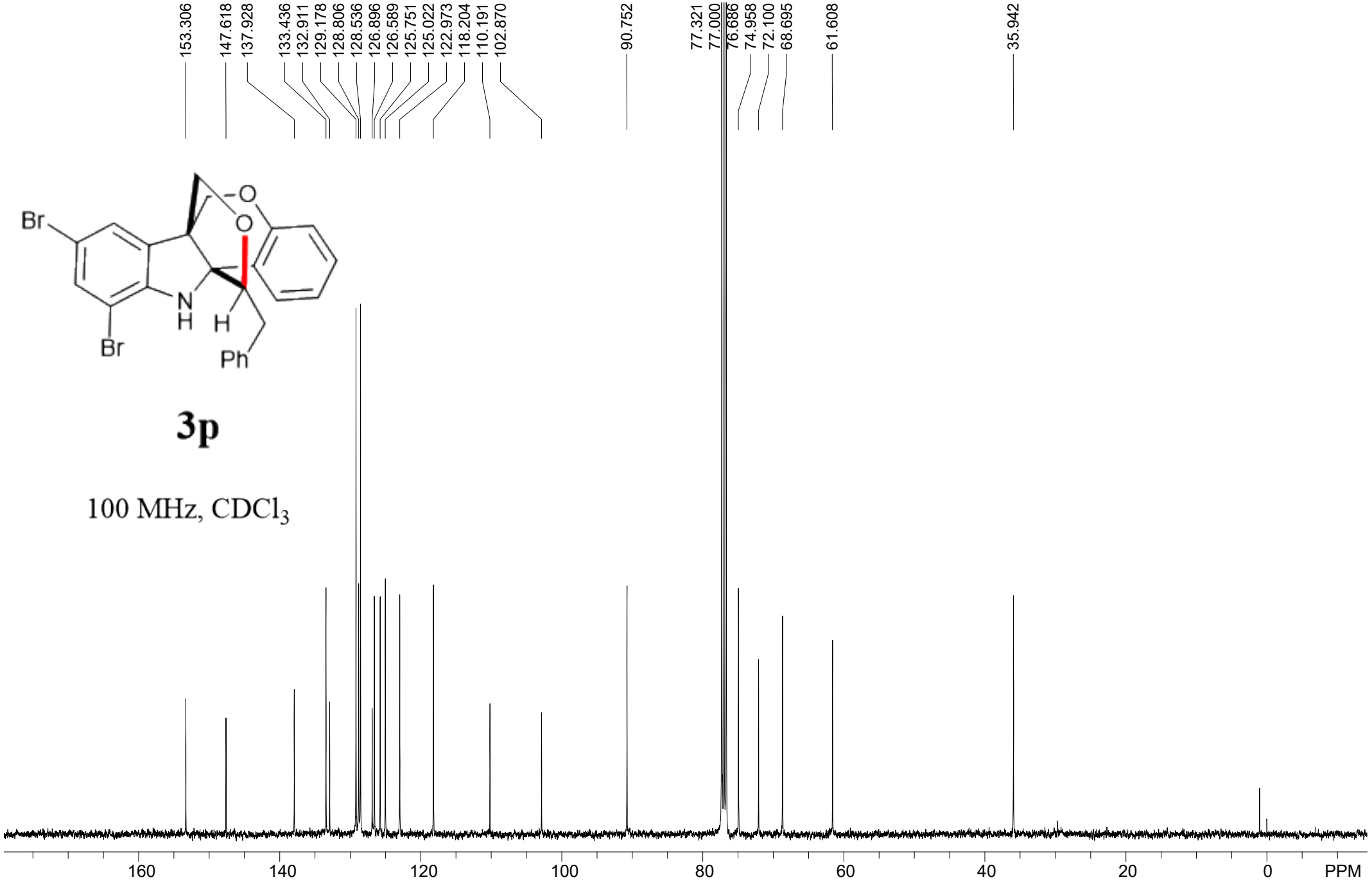

7.571
7.553
7.202
7.184
7.150
7.133
7.081
7.062
6.950
6.930
6.722
6.173
6.135
4.616
4.587
4.200
4.178
3.917
3.895
3.678
3.650
3.031
2.995
2.847
2.821
2.812
2.785
2.126
5.94
Me
O
O
Me
N
H
H
Ph
3o
400 MHZ, DMSO-d_6
3.03
2.07
1.86
1.71
1.03
1.08
0.97
0.95
1.00
1.08
1.12
0.90
0.96
8
7
6
5
4
3
2
1
0
PPM

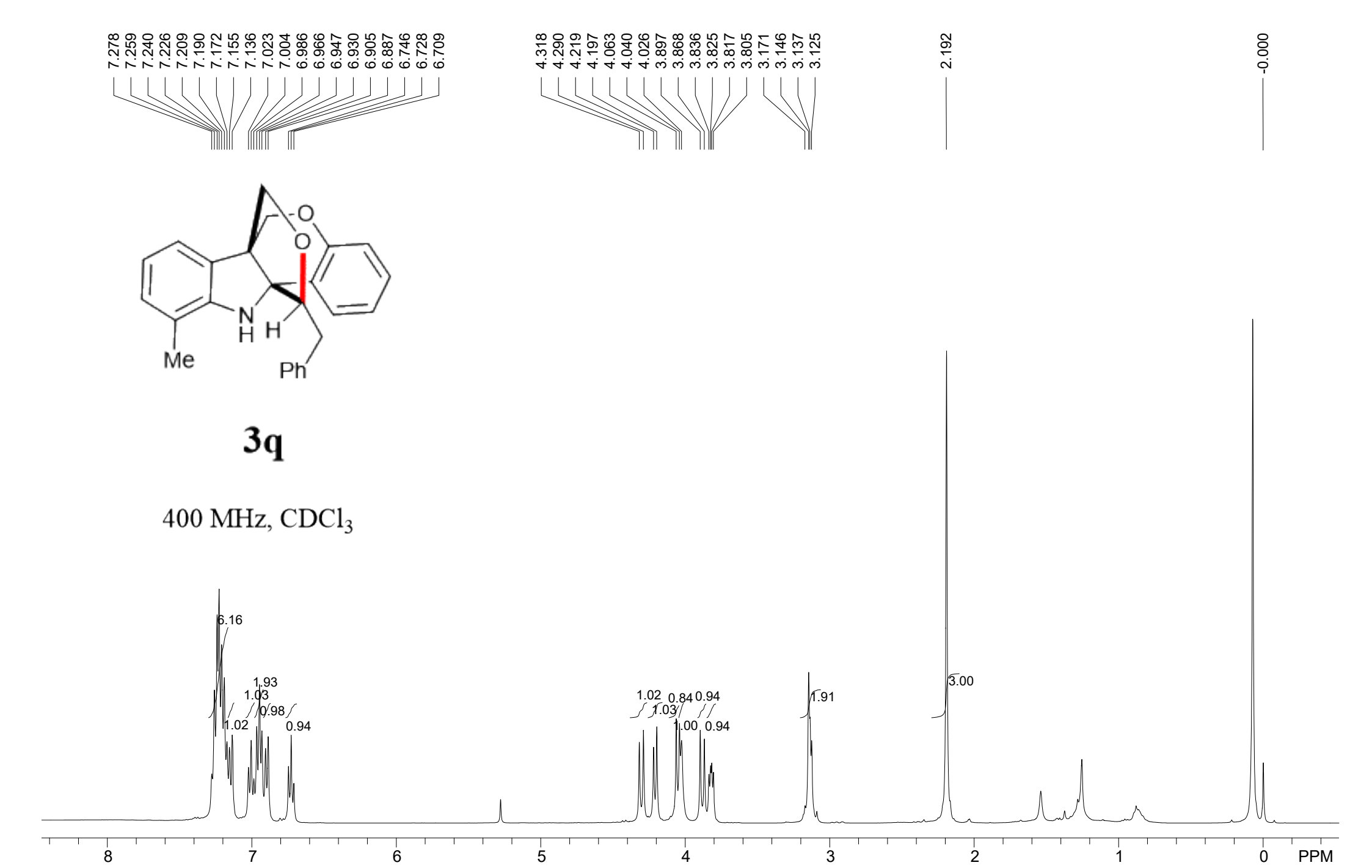


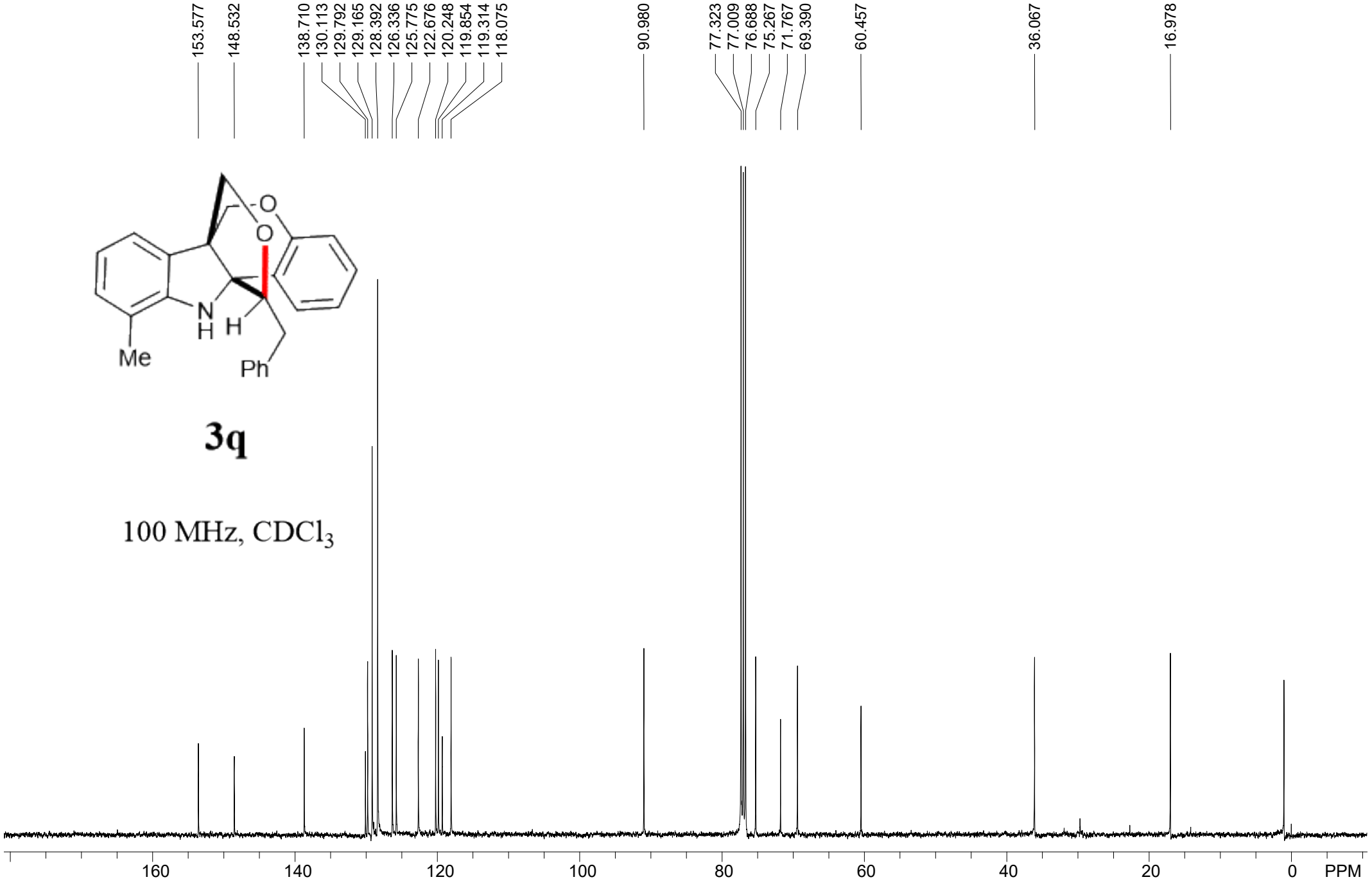
3o

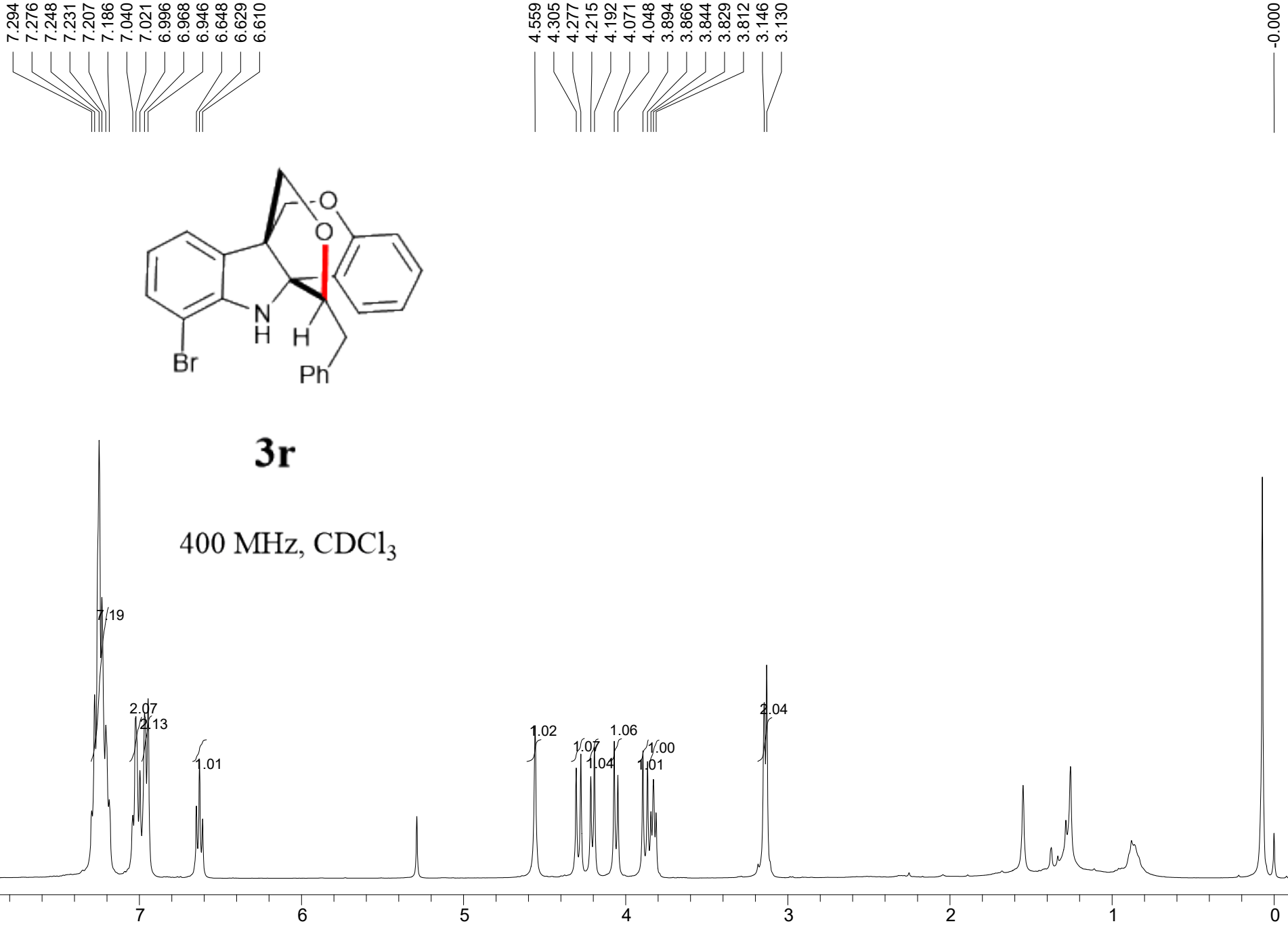
100 MHZ, DMSO-d_6

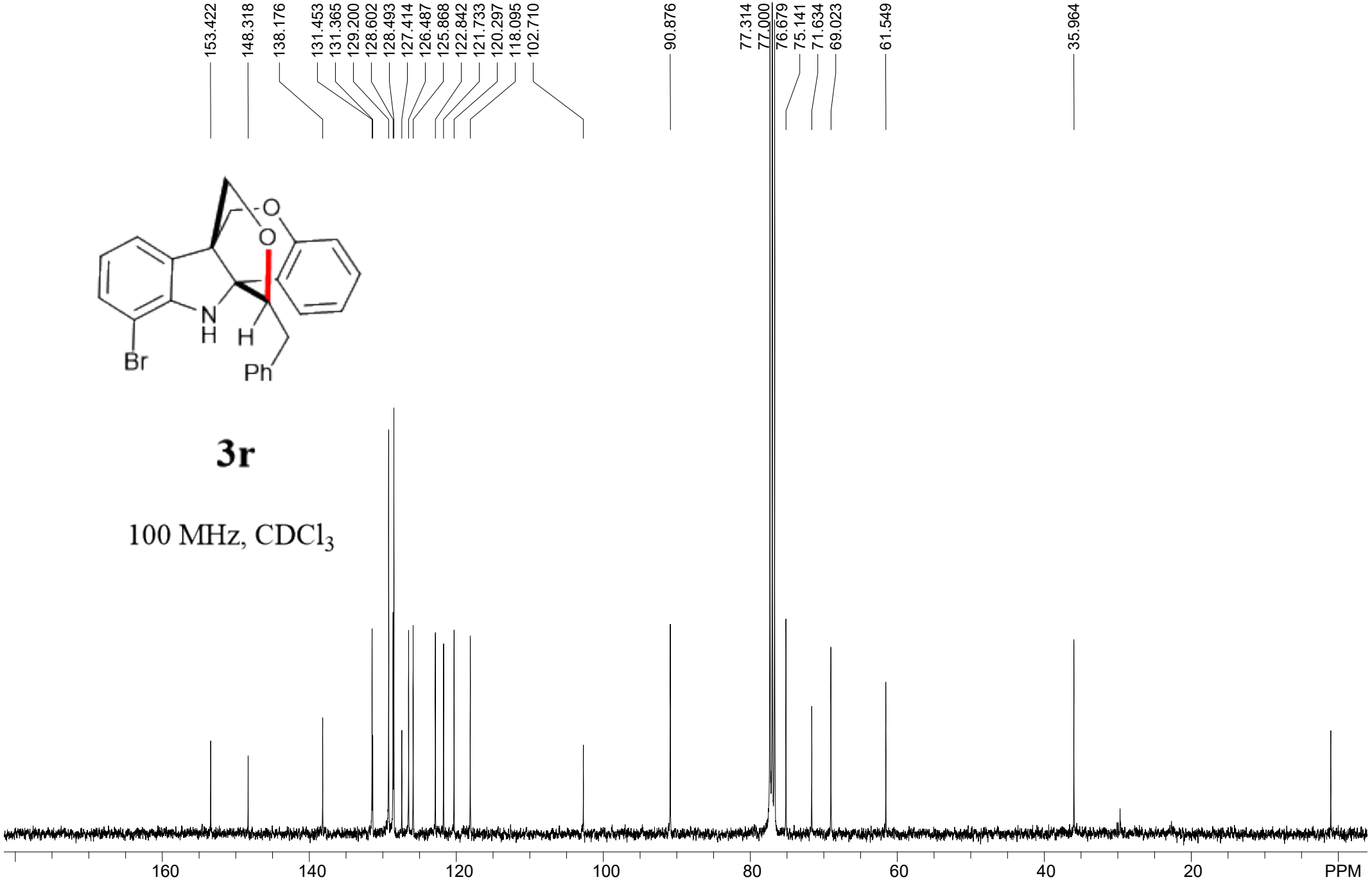

7.379
7.295
7.277
7.260
7.235
7.216
7.056
7.008
6.998
6.977
6.957
4.549
4.268
4.240
4.190
4.167
4.043
4.021
3.878
3.850
3.833
3.817
3.801
3.124
3.108
-0.000
Br
O
O
N
H
H
Br
Ph
3p
400 MHz, CDCl3
6.24
1.01
1.94
1.03
1.02
0.96
1.02
0.99
1.00
1.01
0.99
2.02
8
7
6
5
4
3
2
1
0
PPM


153.306
147.618
137.928
133.436
132.911
129.178
128.806
128.536
126.896
126.589
125.751
125.022
122.973
118.204
110.191
102.870
90.752
77.321
77.000
76.686
74.958
72.100
68.695
61.608
35.942
Br
Br
N
H
O
O
H
Ph
3p
100 MHz, CDCl3
160
140
120
100
80
60
40
20
0
PPM


7.278
7.259
7.240
7.226
7.209
7.190
7.172
7.155
7.136
7.023
7.004
6.986
6.966
6.947
6.930
6.905
6.887
6.746
6.728
6.709
4.318
4.290
4.219
4.197
4.063
4.040
4.026
3.897
3.868
3.836
3.825
3.817
3.805
3.171
3.146
3.137
3.125
2.192
-0.000
O
O
N
H
H
Me
Ph
3q
400 MHz, CDCl3
6.16
1.93
1.03
0.98
1.02
0.94
1.02
1.03
0.84
1.00
0.94
0.94
1.91
3.00
8
7
6
5
4
3
2
1
0
PPM


153.577
148.532
138.710
130.113
129.792
129.165
128.392
126.336
125.775
122.676
120.248
119.854
119.314
118.075
90.980
77.323
77.009
76.688
75.267
71.767
69.390
60.457
36.067
16.978
O
O
N
H
H
Me
Ph
3q
100 MHz, CDCl3
160
140
120
100
80
60
40
20
0
PPM


7.294
7.276
7.248
7.231
7.207
7.186
7.040
7.021
6.996
6.968
6.946
6.648
6.629
6.610
4.559
4.305
4.277
4.215
4.192
4.071
4.048
3.894
3.866
3.844
3.829
3.812
3.146
3.130
-0.000
O
O
N
H
H
Br
Ph
3r
400 MHz, CDCl3
7.19
2.07
2.13
1.01
1.02
1.07
1.04
1.06
1.00
1.01
2.04
8
7
6
5
4
3
2
1
0 PPM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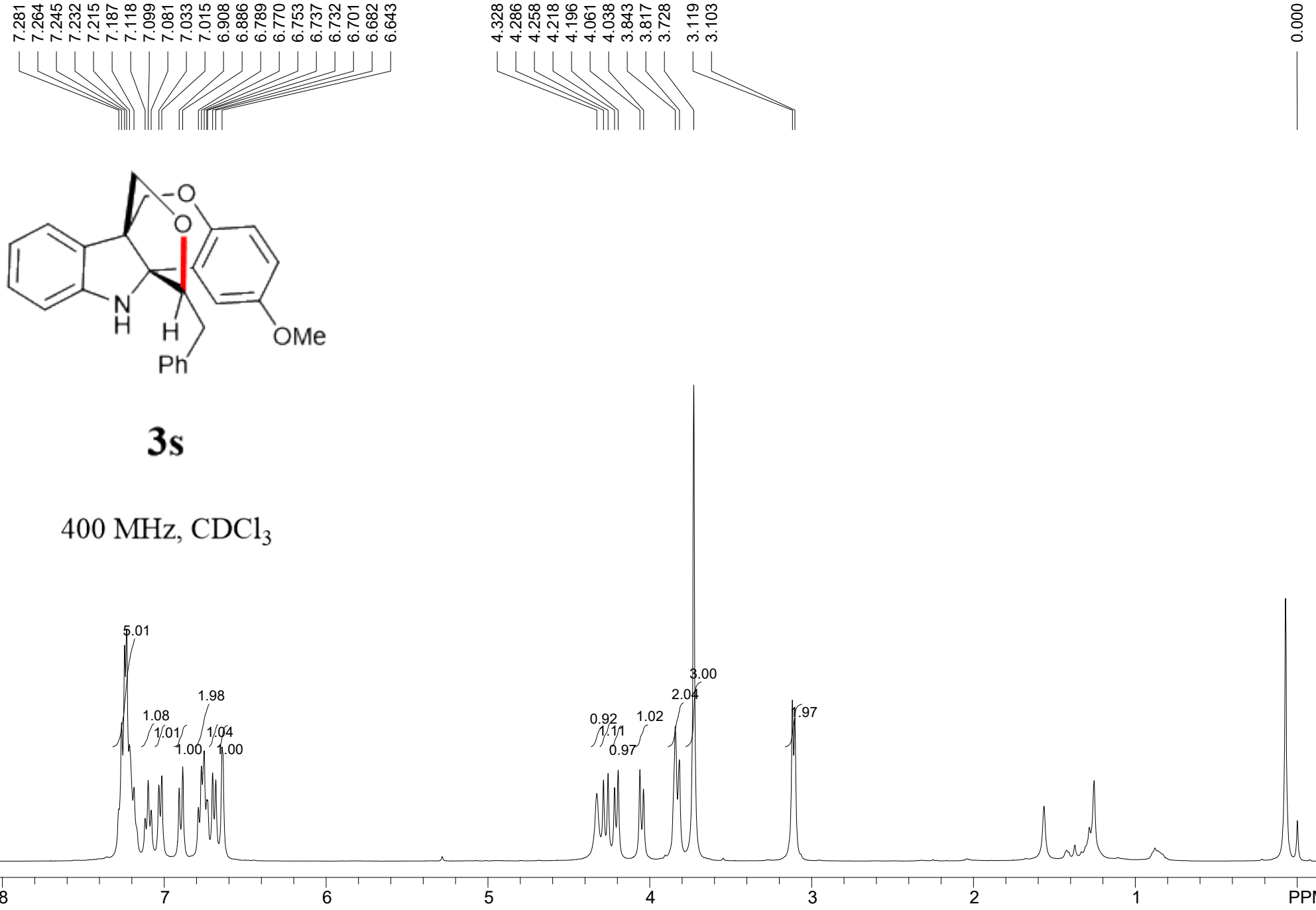
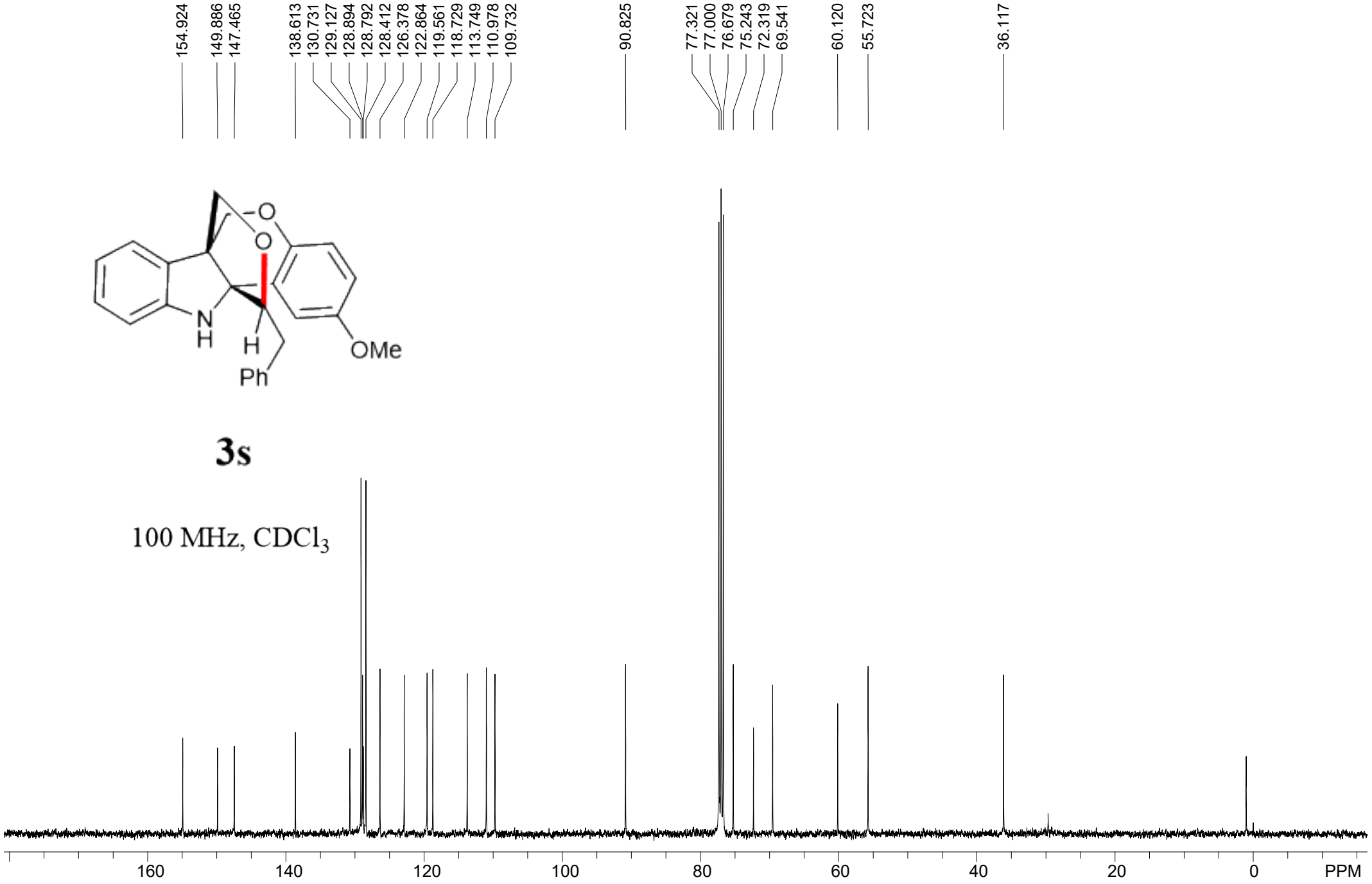
148.318
138.176
131.453
131.365
129.200
128.602
128.493
127.414
126.487
125.868
122.842
121.733
120.297
118.095
102.710
90.876
77.314
77.000
76.679
75.141
71.634
69.023
61.549
35.964
O
O
N
H
H
Br
Ph
3r
100 MHz, CDCl3
160
140
120
100
80
60
40
20
PPM


7.281
7.264
7.245
7.232
7.215
7.187
7.118
7.099
7.081
7.033
7.015
6.908
6.886
6.789
6.770
6.753
6.737
6.732
6.701
6.682
6.643
4.328
4.286
4.258
4.218
4.196
4.061
4.038
3.843
3.817
3.728
3.119
3.103
0.000
O
O
N
H
H
Ph
OMe
3s
400 MHz, CDCl3
5.01
1.08
1.01
1.98
1.00
1.04
1.00
0.92
1.11
0.97
1.02
2.04
3.00
1.97
8
7
6
5
4
3
2
1
PPM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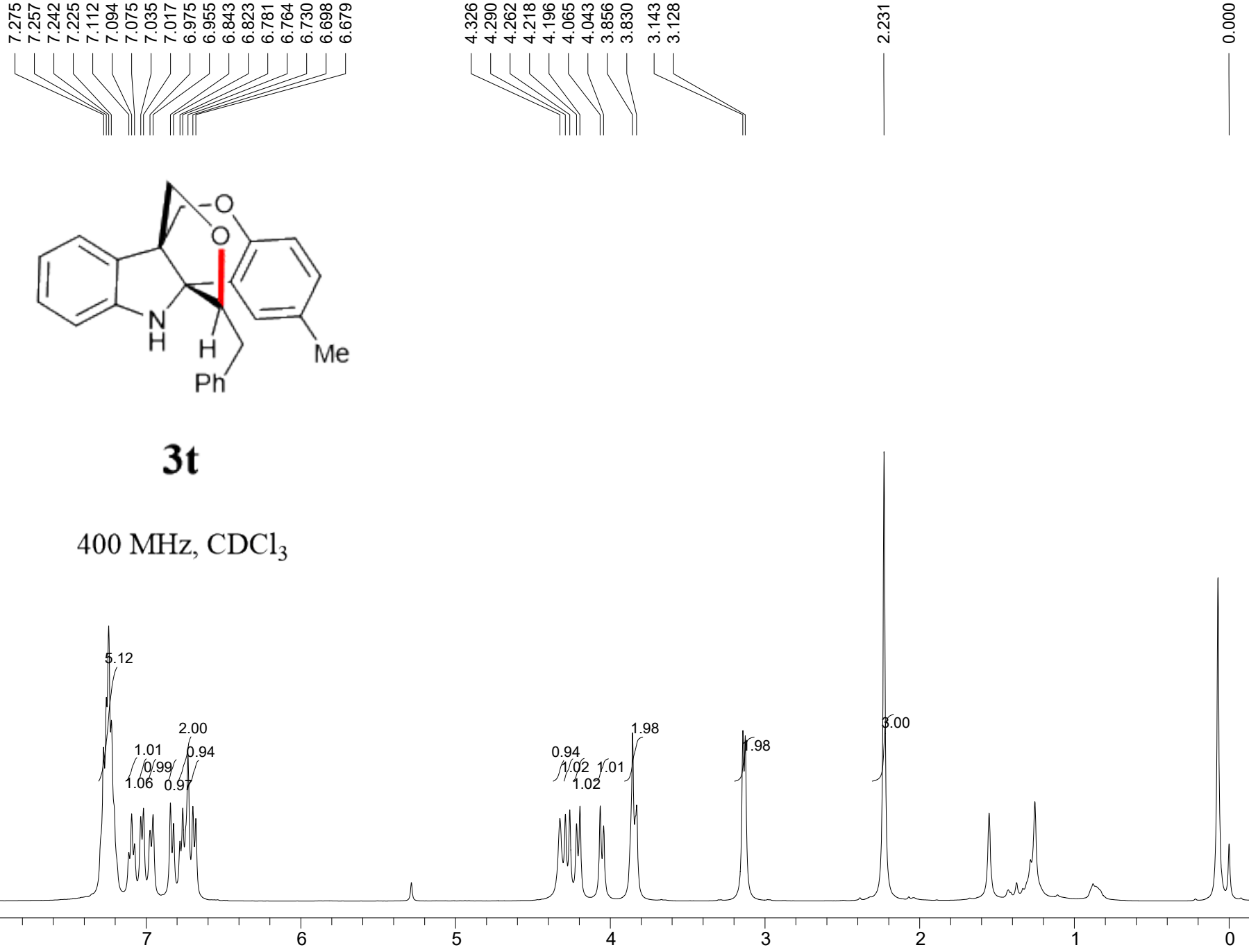
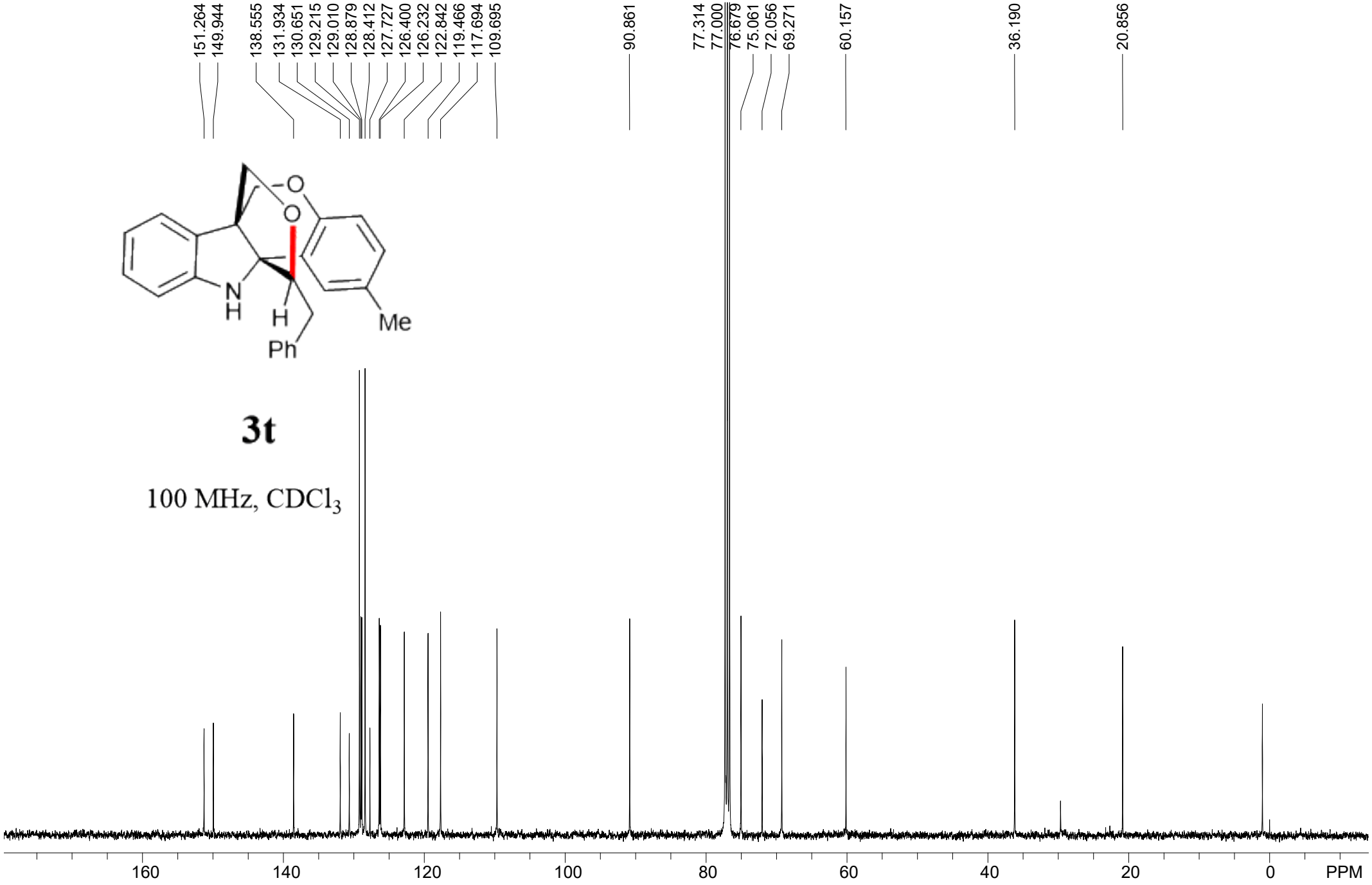
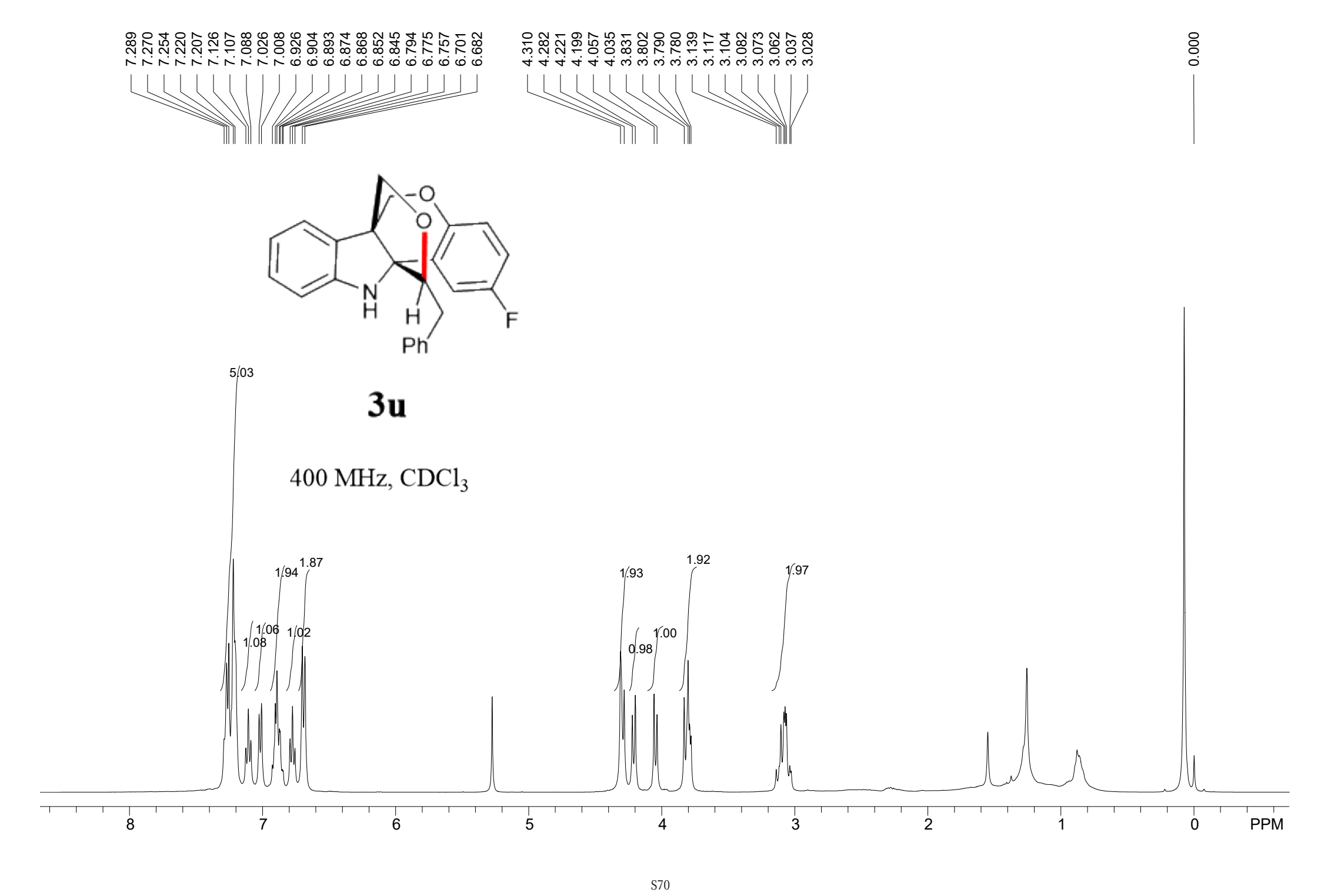
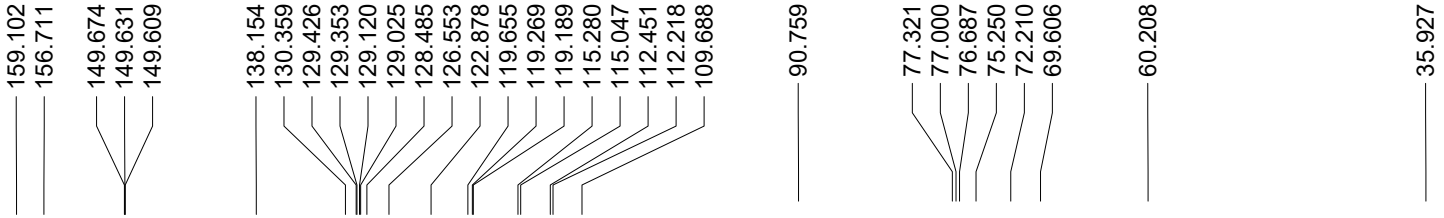
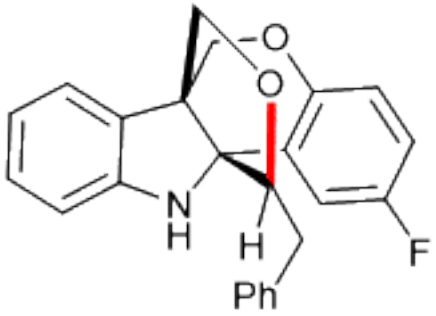
138.613
130.731
129.127
128.894
128.792
128.412
126.378
122.864
119.561
118.729
113.749
110.978
109.732
90.825
77.321
77.000
76.679
75.243
72.319
69.541
60.120
55.723
36.117
O
O
N
H
H
Ph
OMe
3s
100 MHz, CDCl3
160
140
120
100
80
60
40
20
0
PPM


7.275
7.257
7.242
7.225
7.112
7.094
7.075
7.035
7.017
6.975
6.955
6.843
6.823
6.781
6.764
6.730
6.698
6.679
4.326
4.290
4.262
4.218
4.196
4.065
4.043
3.856
3.830
3.143
3.128
2.231
0.000
O
O
N
H
H
Ph
Me
3t
400 MHz, CDCl3
5.12
1.01
0.99
1.06
0.97
2.00
0.94
0.94
1.02
1.02
1.01
1.98
1.98
3.00
8
7
6
5
4
3
2
1
0
PPM


151.264
149.944
138.555
131.934
130.651
129.215
129.010
128.879
128.412
127.727
126.400
126.232
122.842
119.466
117.694
109.695
90.861
77.314
77.000
76.679
75.061
72.056
69.271
60.157
36.190
20.856
O
O
N
H
H
Ph
Me
3t
100 MHz, CDCl3
160
140
120
100
80
60
40
20
0
PPM

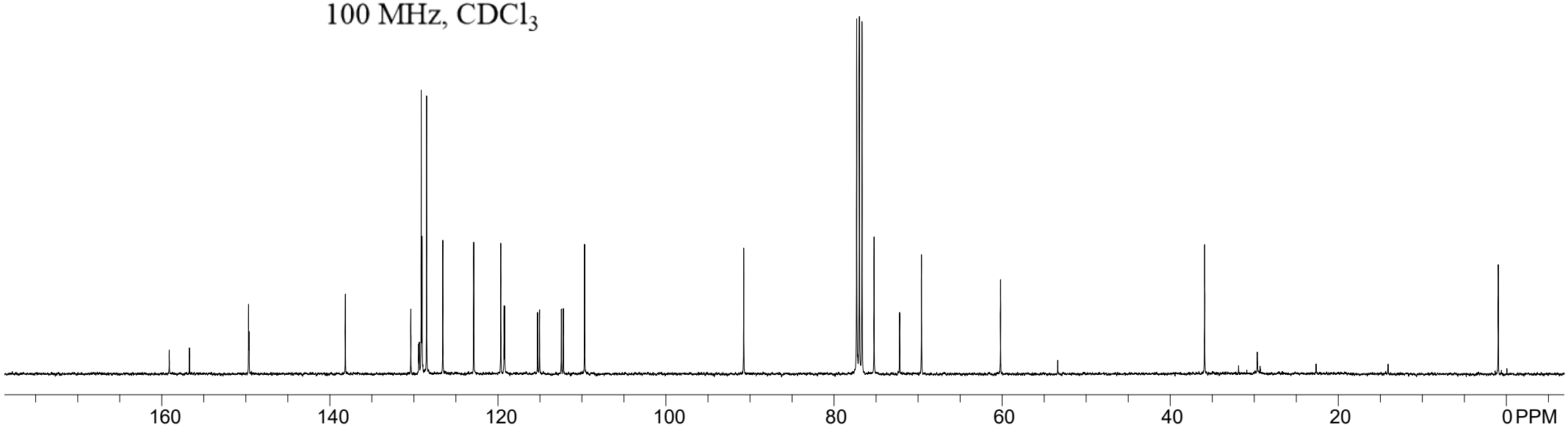

7.289
7.270
7.254
7.220
7.207
7.126
7.107
7.088
7.026
7.008
6.926
6.904
6.893
6.874
6.868
6.852
6.845
6.794
6.775
6.757
6.701
6.682
4.310
4.282
4.221
4.199
4.057
4.035
3.831
3.802
3.790
3.780
3.139
3.117
3.104
3.082
3.073
3.062
3.037
3.028
0.000
O
O
N
H
H
Ph
F
3u
400 MHz, CDCl3
5.03
1.87
1.94
1.06
1.08
1.02
1.93
1.92
1.97
1.00
0.98
8
7
6
5
4
3
2
1
0
PPM

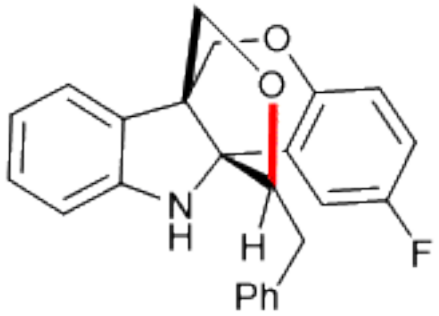




3u

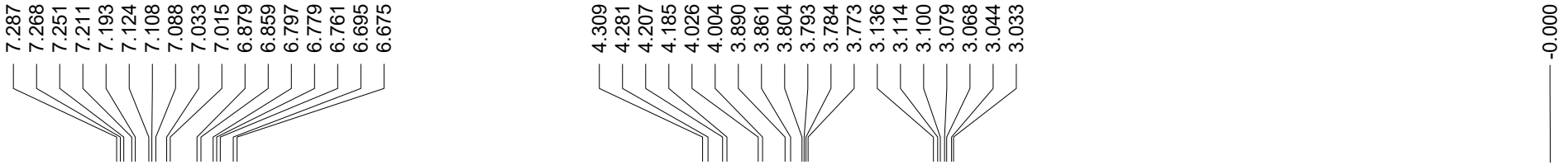
100 MHz, $CDCl_3$

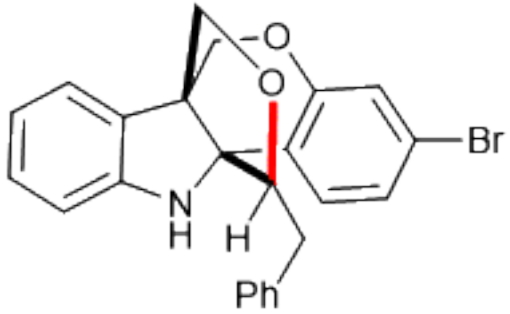




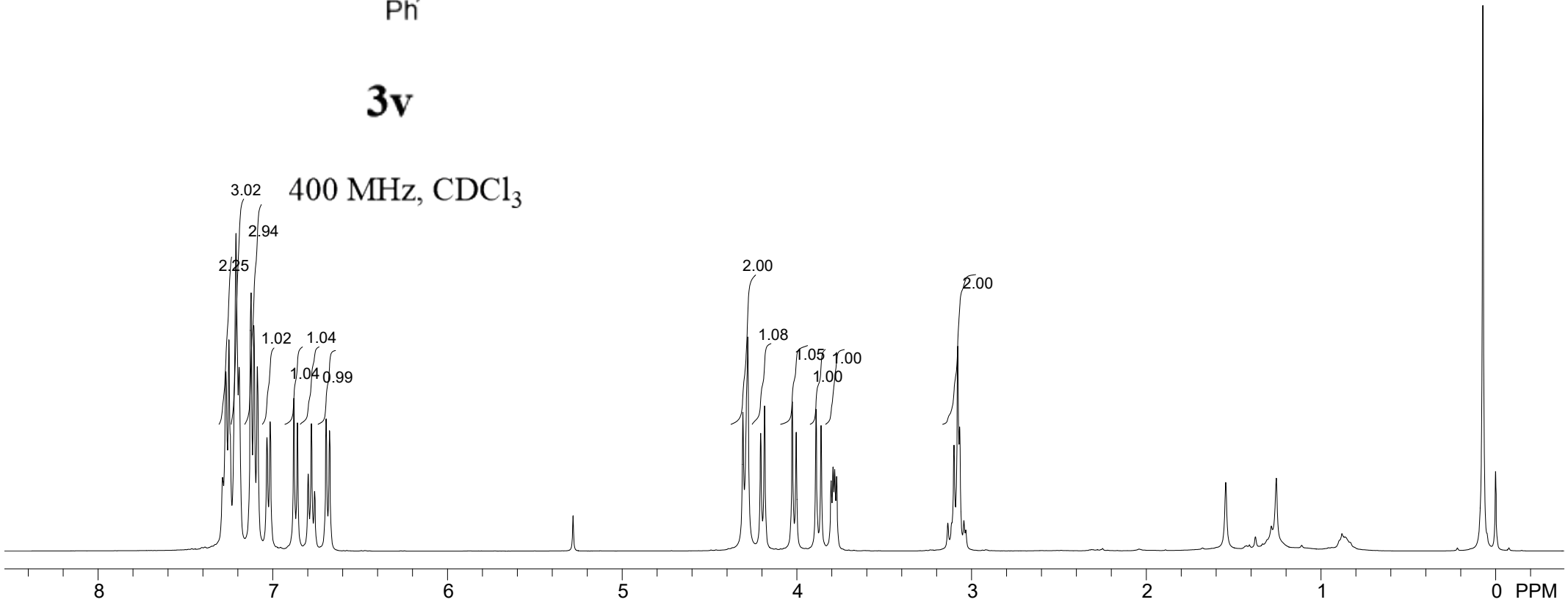
3u

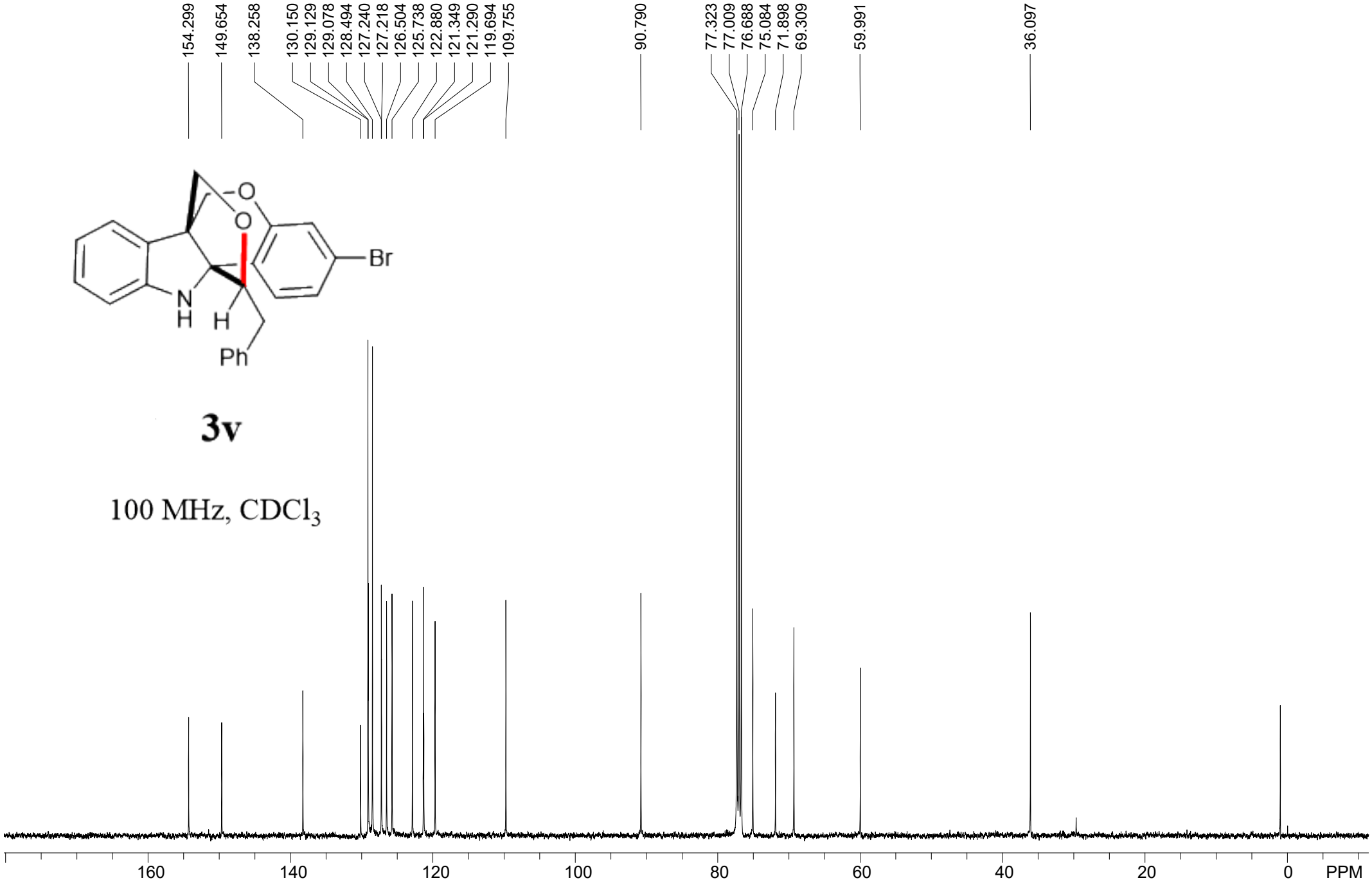
376 MHz, $CDCl_3$

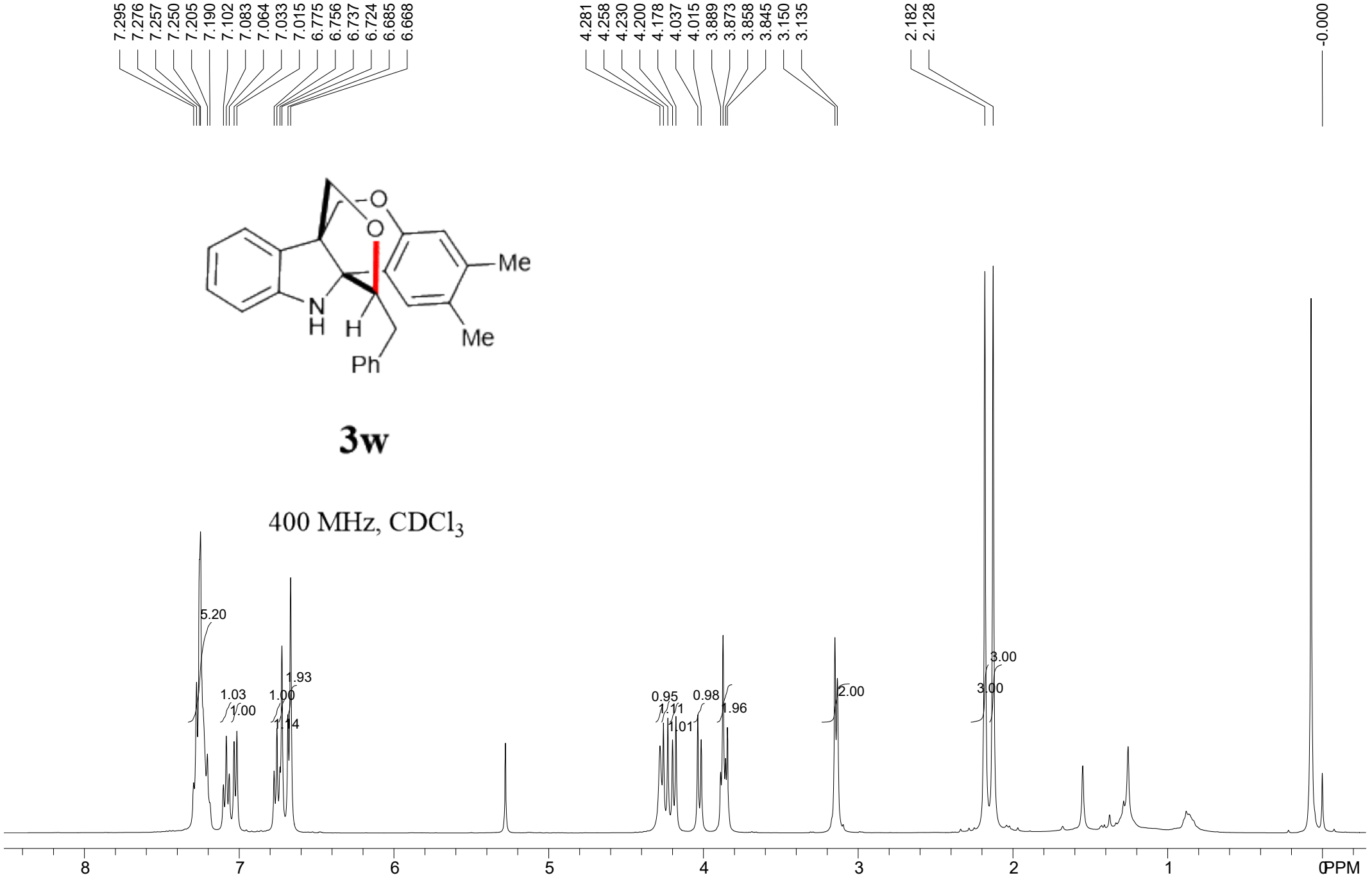

7.287
7.268
7.251
7.211
7.193
7.124
7.108
7.088
7.033
7.015
6.879
6.859
6.797
6.779
6.761
6.695
6.675
4.309
4.281
4.207
4.185
4.026
4.004
3.890
3.861
3.804
3.793
3.784
3.773
3.136
3.114
3.100
3.079
3.068
3.044
3.033
-0.000

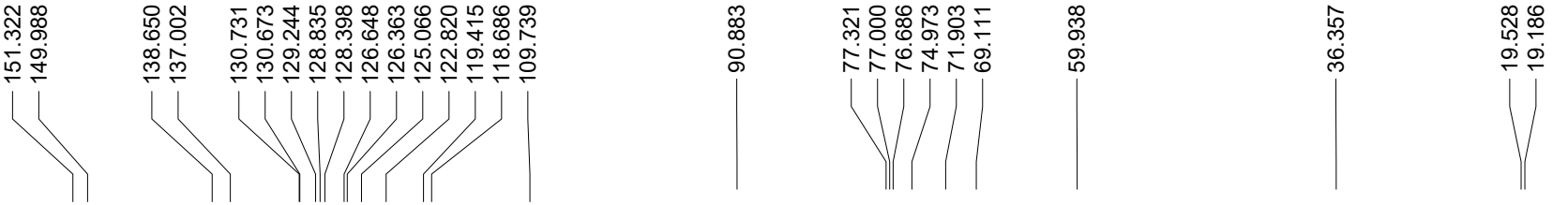

O
O
Br
N
H
H
Ph

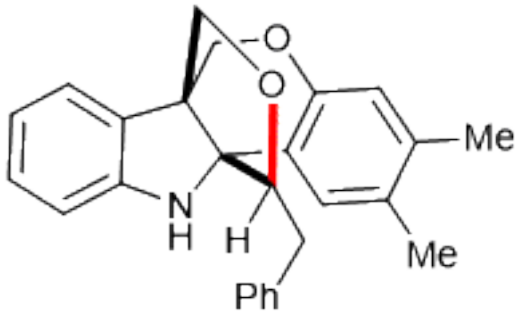
3v


400 MHz, CDCl3
3.02
2.94
2.25
1.02
1.04
1.04
0.99
2.00
1.08
1.05
1.00
1.00
2.00
8
7
6
5
4
3
2
1
0
PPM


154.299
149.654
138.258
130.150
129.129
129.078
128.494
127.240
127.218
126.504
125.738
122.880
121.349
121.290
119.694
109.755
90.790
77.323
77.009
76.688
75.084
71.898
69.309
59.991
36.097
O
O
Br
N
H
H
Ph
3v
100 MHz, CDCl3
160
140
120
100
80
60
40
20
0
PPM

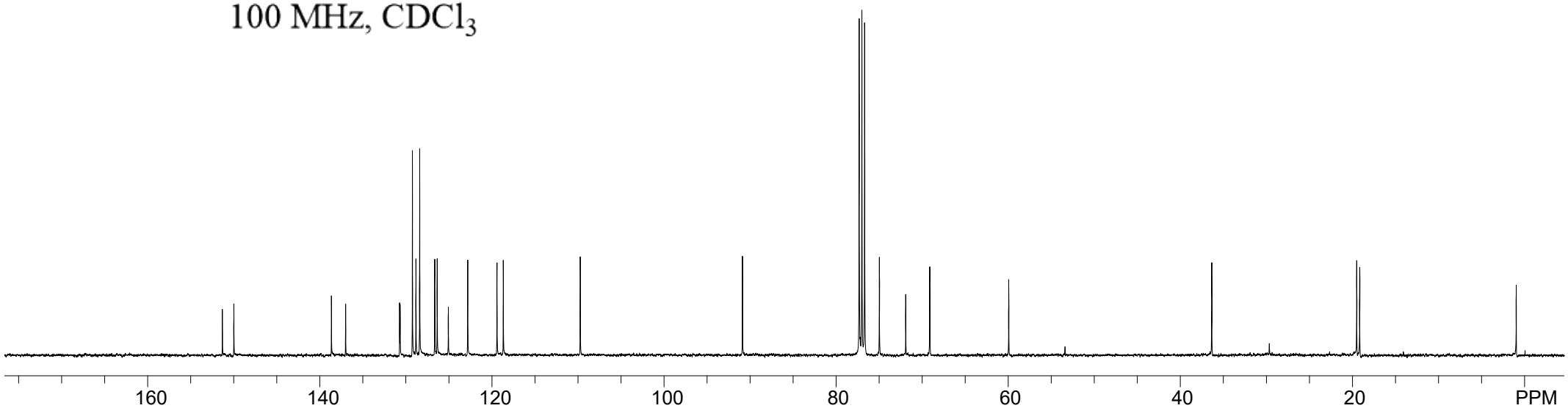

7.295
7.276
7.257
7.250
7.205
7.190
7.102
7.083
7.064
7.033
7.015
6.775
6.756
6.737
6.724
6.685
6.668
4.281
4.258
4.230
4.200
4.178
4.037
4.015
3.889
3.873
3.858
3.845
3.150
3.135
2.182
2.128
-0.000
O
O
N
H
H
Me
Me
Ph
3w
400 MHz, CDCl3
5.20
1.03
1.00
1.00
1.14
1.93
0.95
1.11
1.01
0.98
1.96
2.00
3.00
3.00
8
7
6
5
4
3
2
1
0
PPM

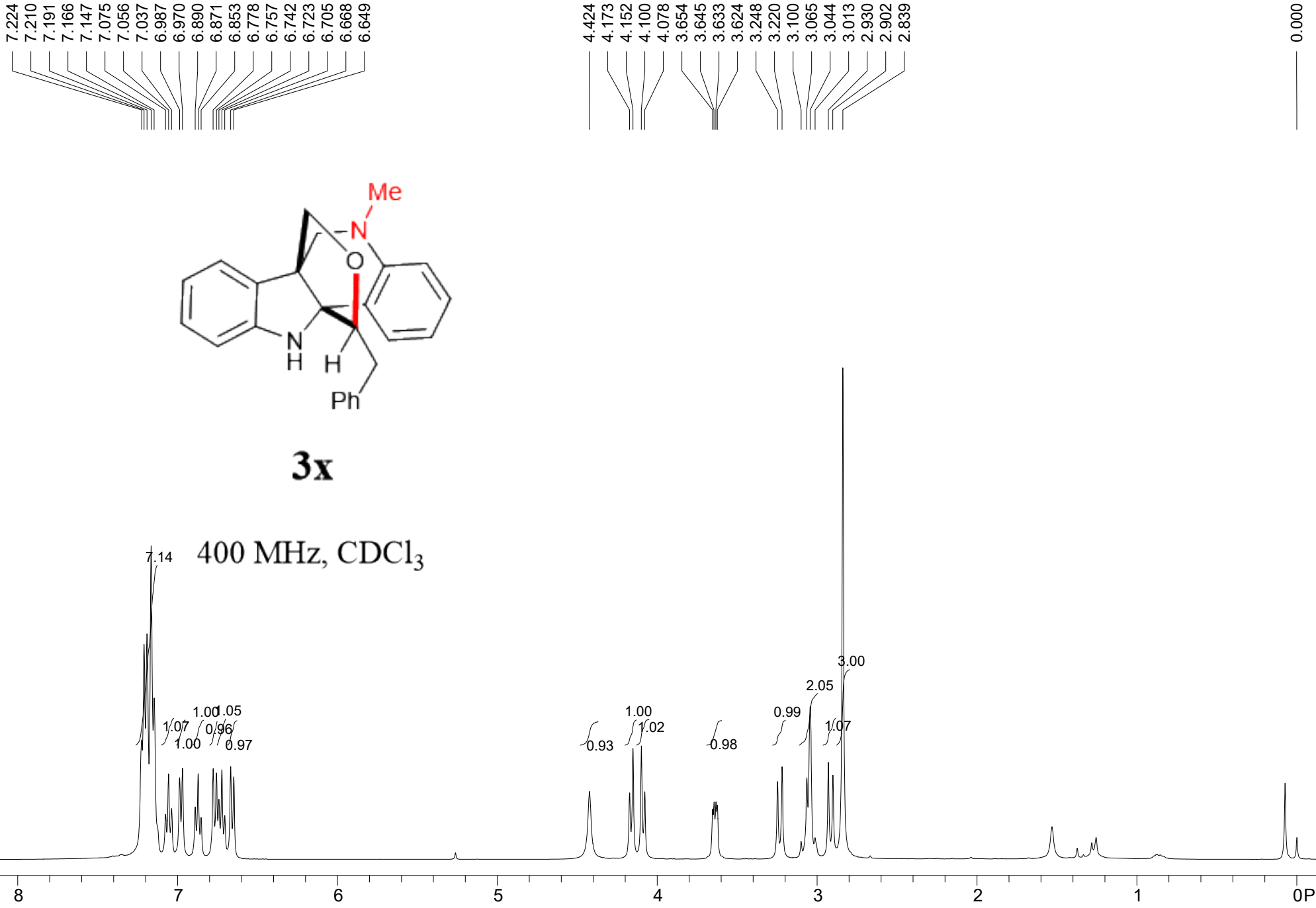


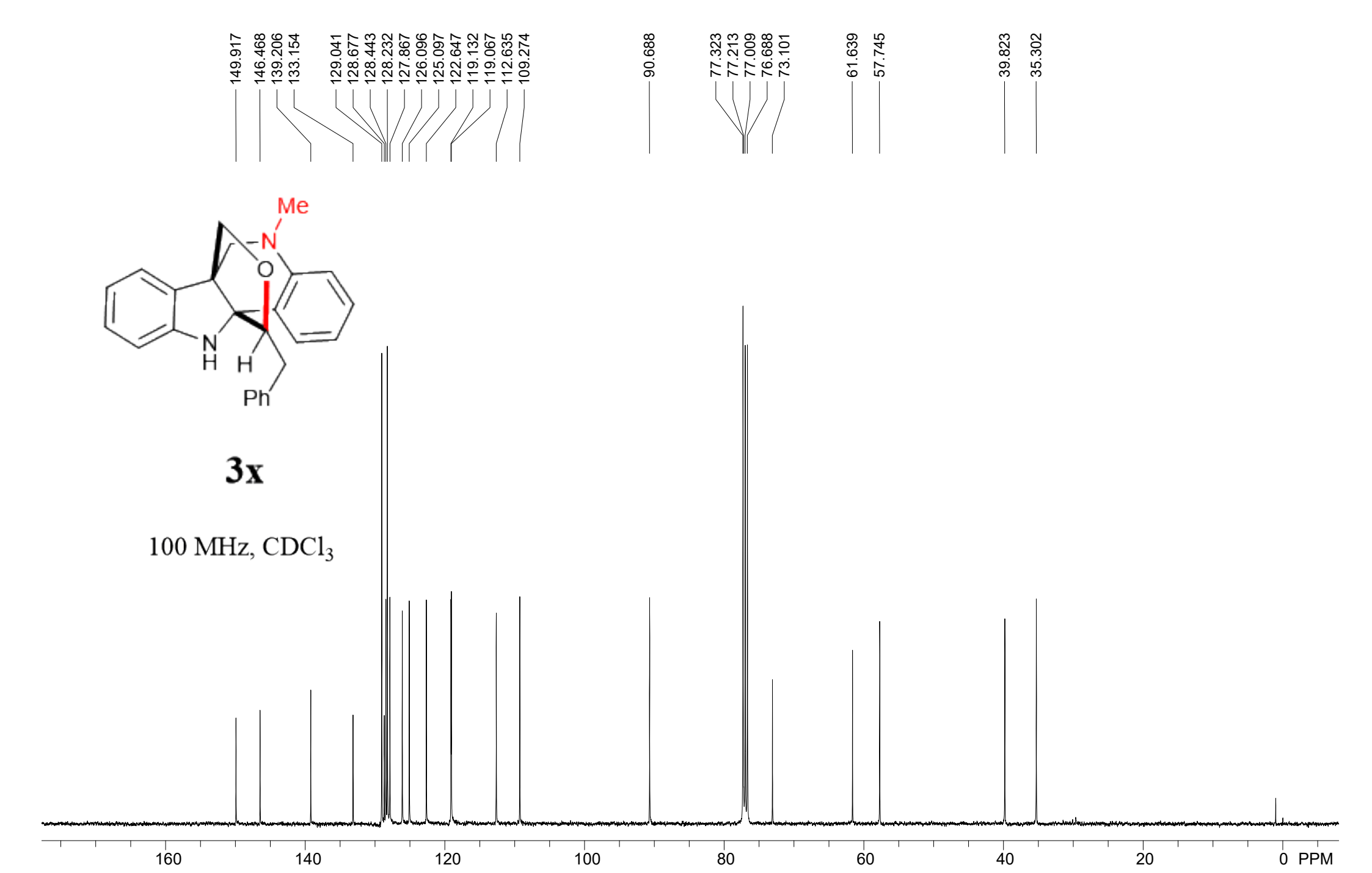


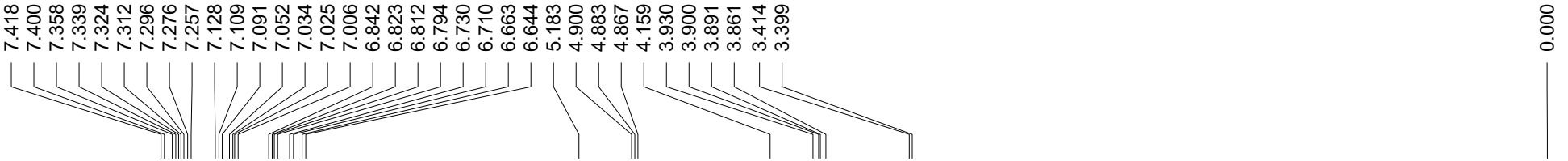
3w

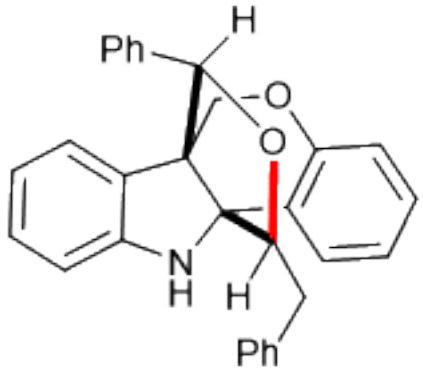
100 MHz, $CDCl_3$



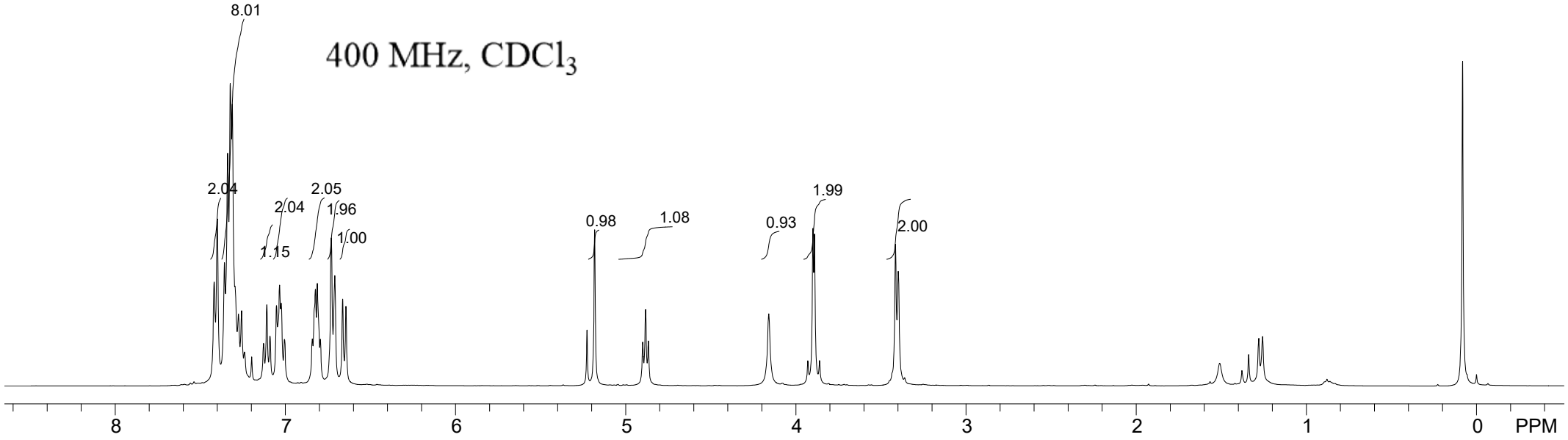

7.224
7.210
7.191
7.166
7.147
7.075
7.056
7.037
6.987
6.970
6.890
6.871
6.853
6.778
6.757
6.742
6.723
6.705
6.668
6.649
4.424
4.173
4.152
4.100
4.078
3.654
3.645
3.633
3.624
3.248
3.220
3.100
3.065
3.044
3.013
2.930
2.902
2.839
0.000
Me
N
O
N
H
H
Ph
3x
400 MHz, CDCl3
7.14
1.07
1.00
1.00
0.96
1.05
0.97
0.93
1.00
1.02
0.98
0.99
2.05
3.00
1.07
8
7
6
5
4
3
2
1
0PPM

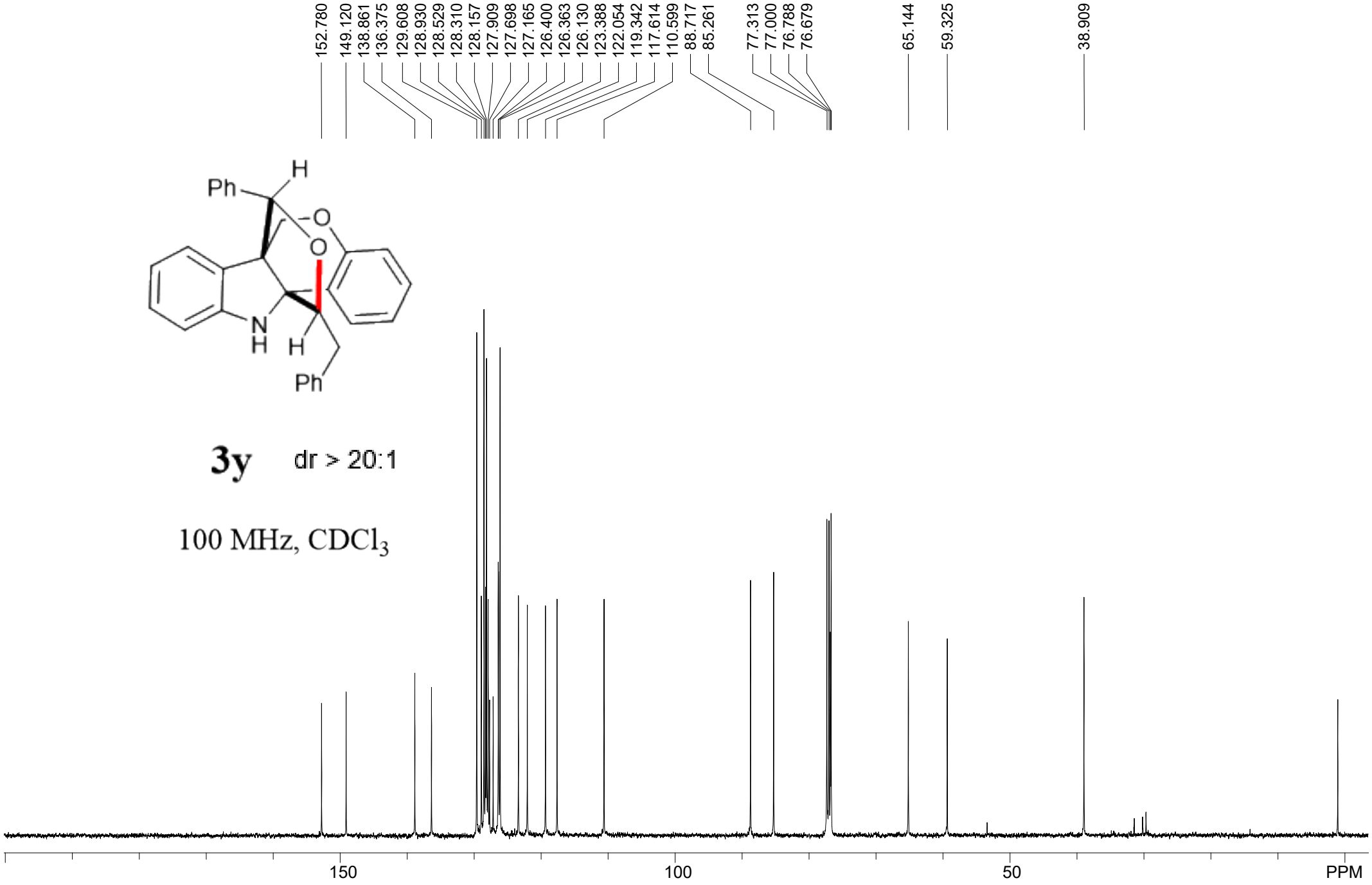

149.917
146.468
139.206
133.154
129.041
128.677
128.443
128.232
127.867
126.096
125.097
122.647
119.132
119.067
112.635
109.274
90.688
77.323
77.213
77.009
76.688
73.101
61.639
57.745
39.823
35.302
Me
N
O
N
H
H
Ph
3x
100 MHz, CDCl3
160
140
120
100
80
60
40
20
0 PPM

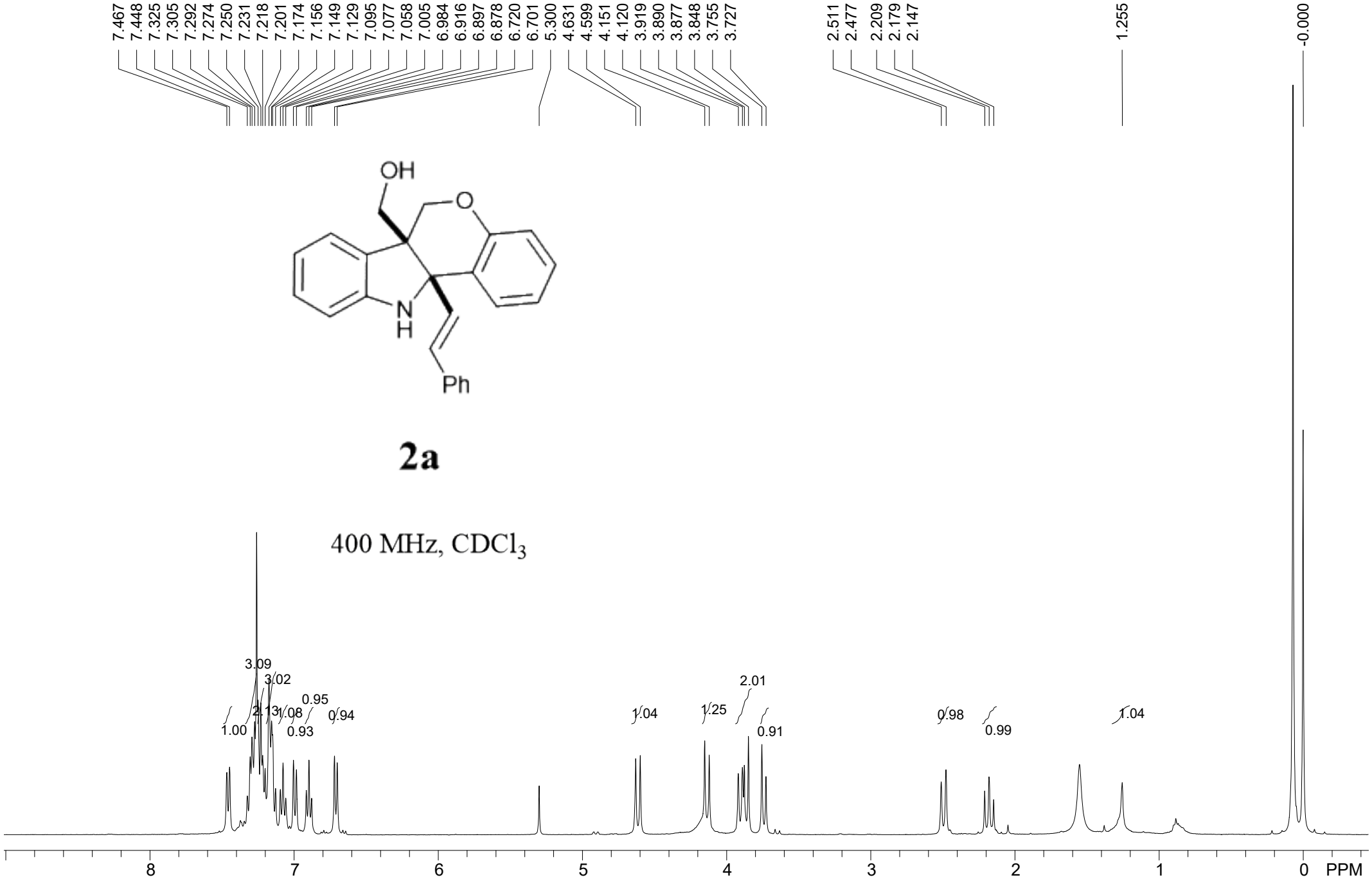

7.418
7.400
7.358
7.339
7.324
7.312
7.296
7.276
7.257
7.128
7.109
7.091
7.052
7.034
7.025
7.006
6.842
6.823
6.812
6.794
6.730
6.710
6.663
6.644
5.183
4.900
4.883
4.867
4.159
3.930
3.900
3.891
3.861
3.414
3.399
0.000

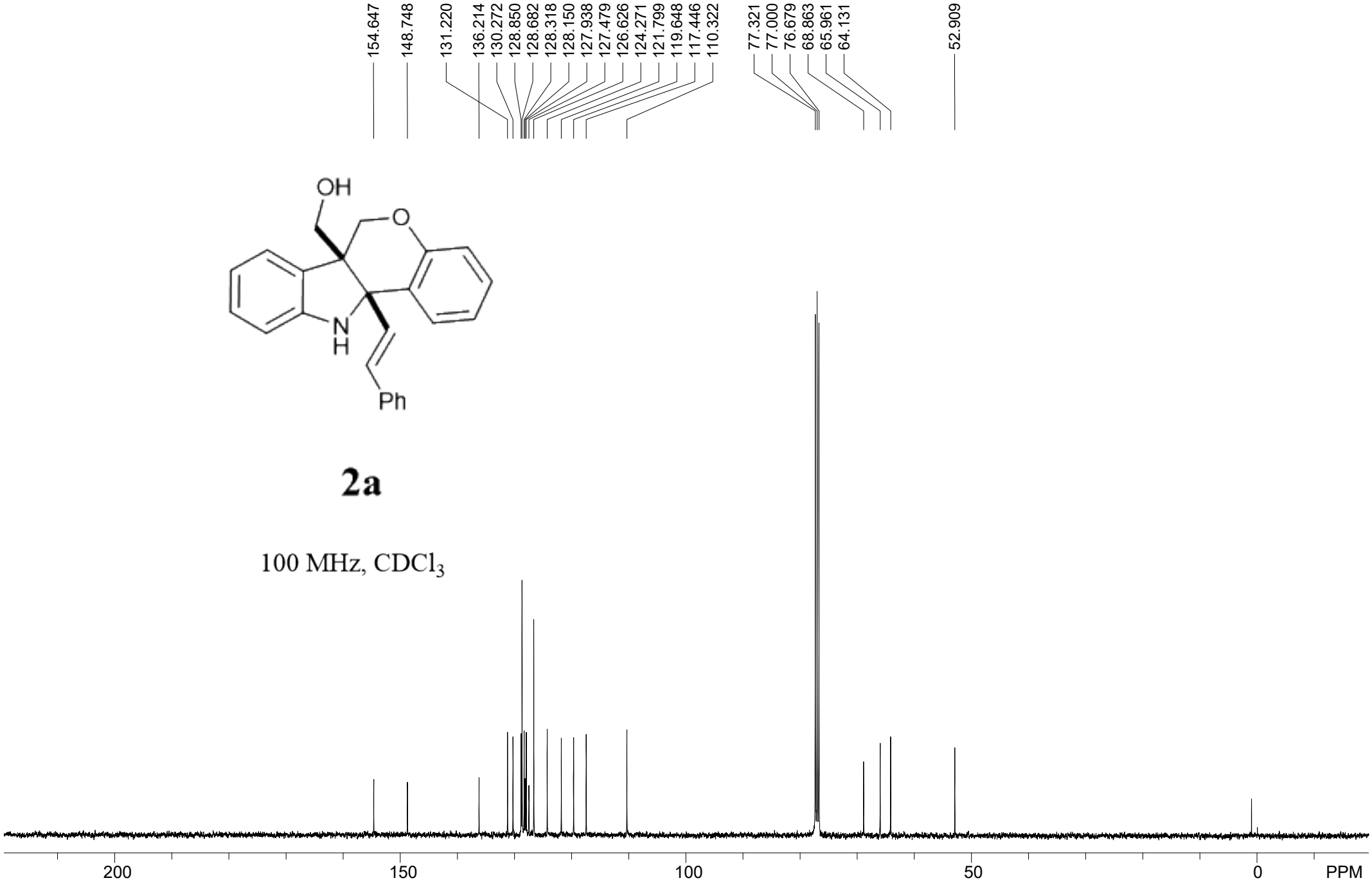

H
Ph
O
O
N
H
H
Ph

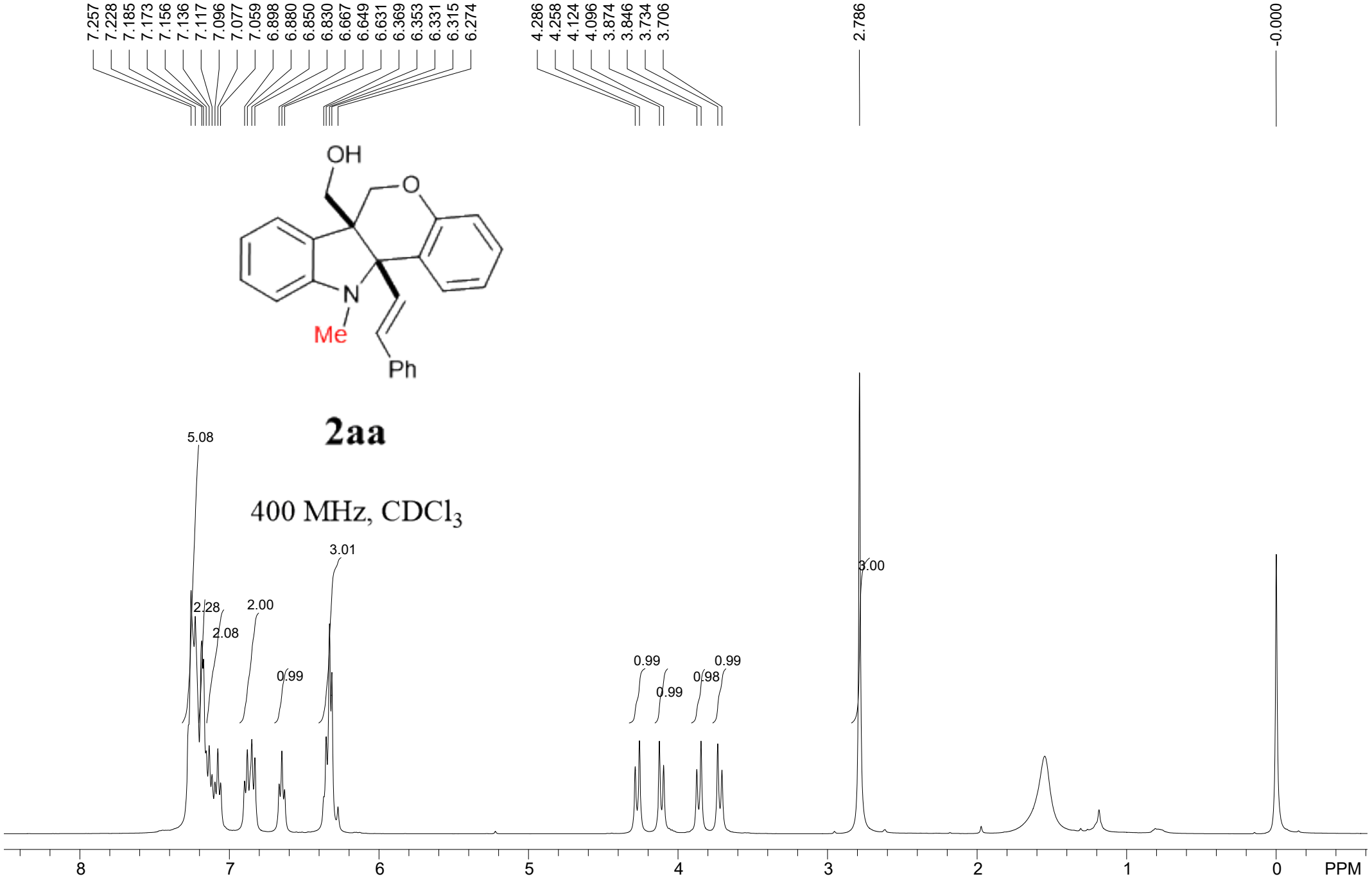
3y dr > 20:1

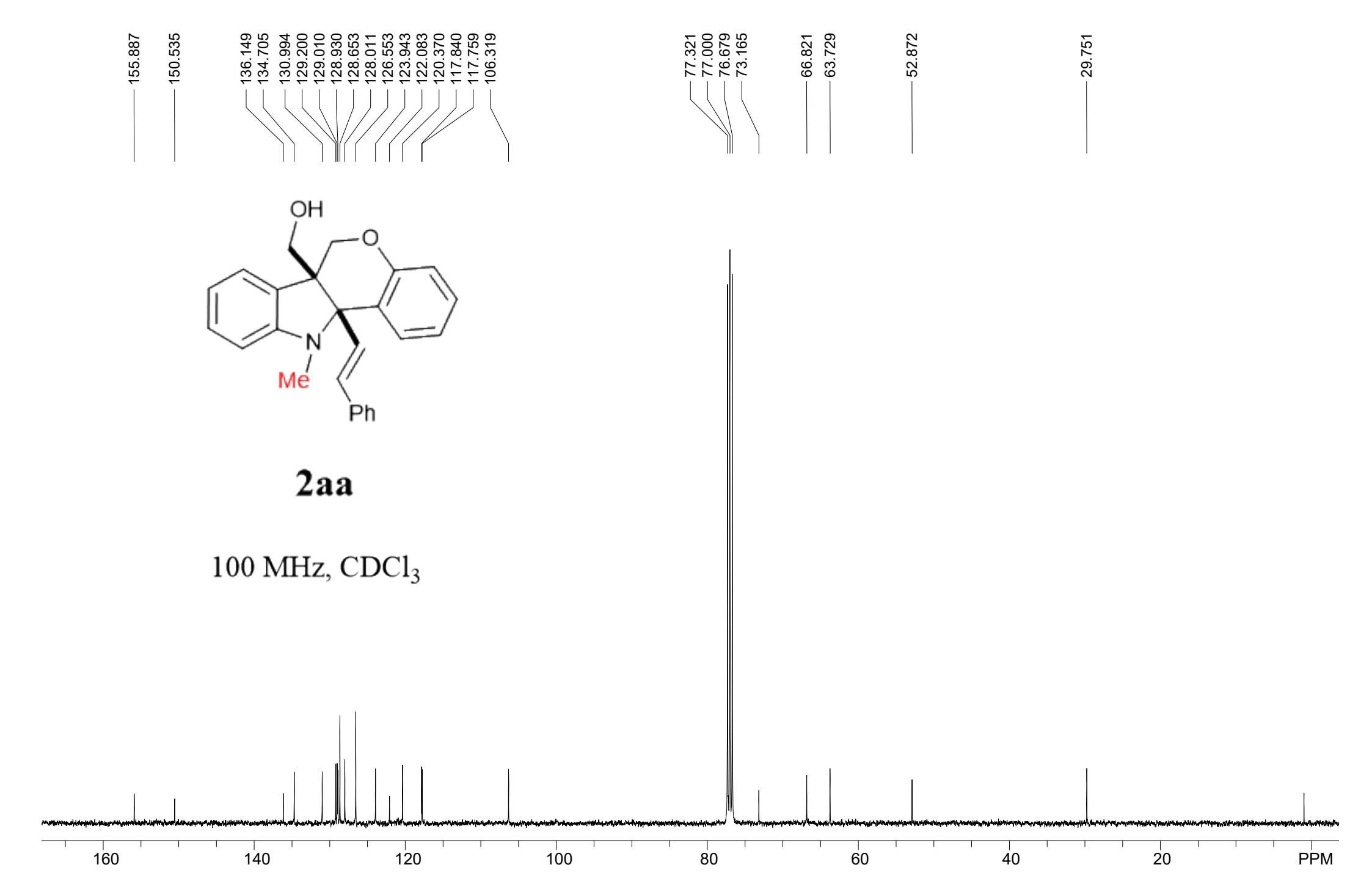

8.01
400 MHz, CDCl3
2.04
2.04
1.15
2.05
1.96
1.00
0.98
1.08
0.93
1.99
2.00
8
7
6
5
4
3
2
1
0
PPM

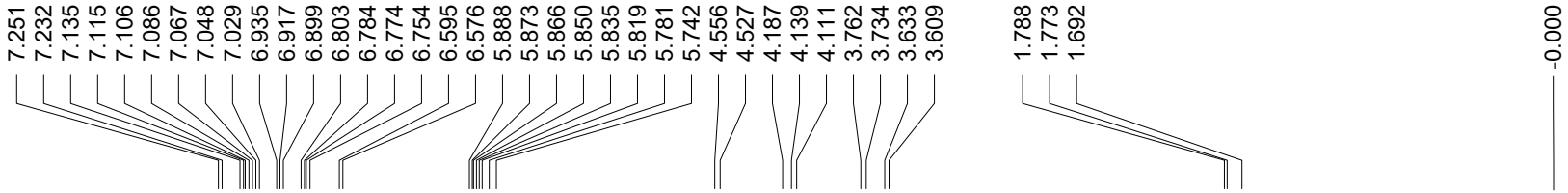

152.780
149.120
138.861
136.375
129.608
128.930
128.529
128.310
128.157
127.909
127.698
127.165
126.400
126.363
126.130
123.388
122.054
119.342
117.614
110.599
88.717
85.261
77.313
77.000
76.788
76.679
65.144
59.325
38.909
Ph
H
O
O
N
H
H
Ph
3y
dr > 20:1
100 MHz, CDCl3
150
100
50
PPM

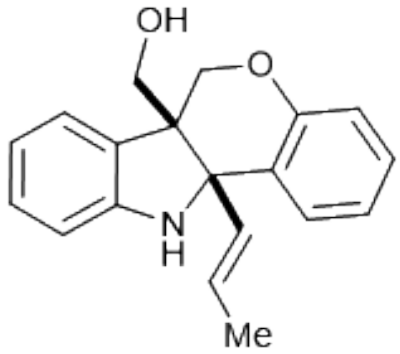

7.467
7.448
7.325
7.305
7.292
7.274
7.250
7.231
7.218
7.201
7.174
7.156
7.149
7.129
7.095
7.077
7.058
7.005
6.984
6.916
6.897
6.878
6.720
6.701
5.300
4.631
4.599
4.151
4.120
3.919
3.890
3.877
3.848
3.755
3.727
2.511
2.477
2.209
2.179
2.147
1.255
-0.000
OH
O
N
H
Ph
2a
400 MHz, CDCl3
1.00
3.09
3.02
2.13
1.08
0.95
0.93
0.94
1.04
1.25
2.01
0.91
0.98
0.99
1.04
8
7
6
5
4
3
2
1
0
PPM


154.647
148.748
131.220
136.214
130.272
128.850
128.682
128.318
128.150
127.938
127.479
126.626
124.271
121.799
119.648
117.446
110.322
77.321
77.000
76.679
68.863
65.961
64.131
52.909
OH
O
N
H
Ph
2a
100 MHz, CDCl3
200
150
100
50
0
PPM

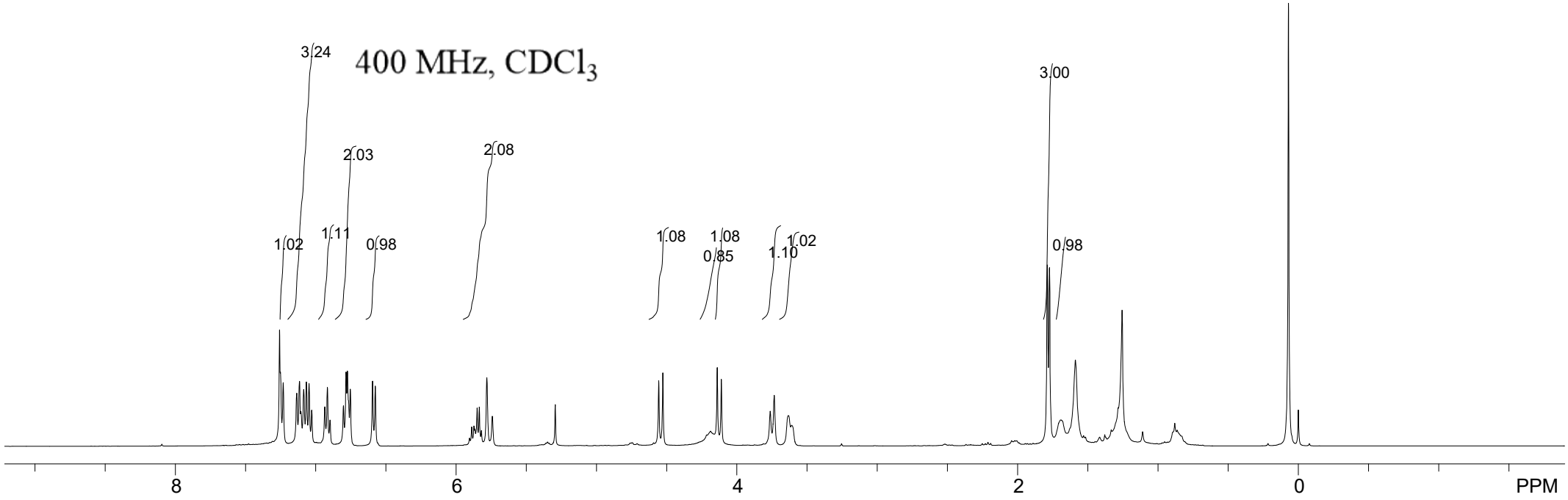

7.257
7.228
7.185
7.173
7.156
7.136
7.117
7.096
7.077
7.059
6.898
6.880
6.850
6.830
6.667
6.649
6.631
6.369
6.353
6.331
6.315
6.274
4.286
4.258
4.124
4.096
3.874
3.846
3.734
3.706
2.786
-0.000
OH
O
N
Me
Ph
2aa
400 MHz, CDCl3
5.08
2.28
2.08
2.00
0.99
3.01
0.99
0.99
0.98
0.99
3.00
8
7
6
5
4
3
2
1
0
PPM

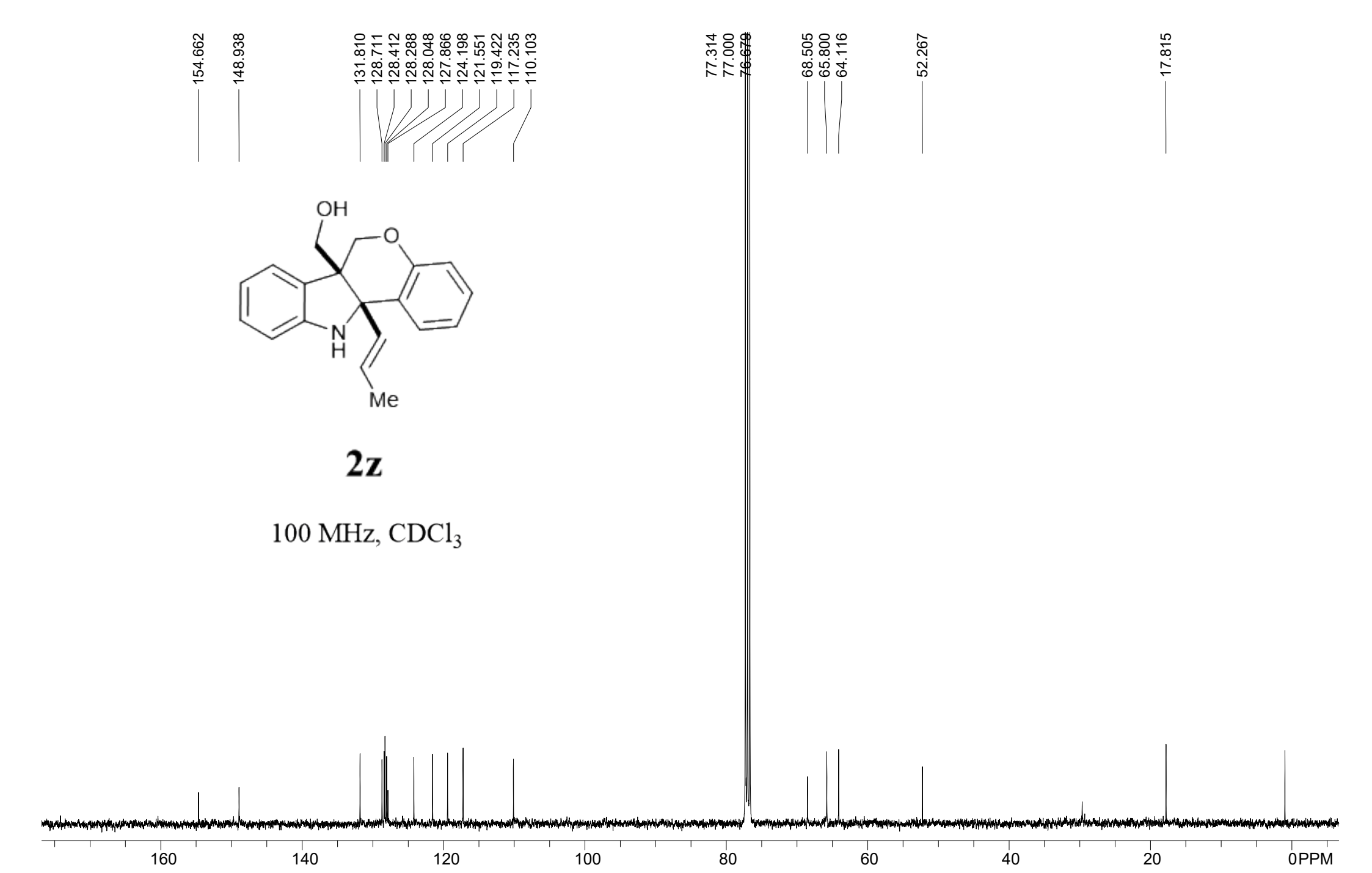

155.887
150.535
136.149
134.705
130.994
129.200
129.010
128.930
128.653
128.011
126.553
123.943
122.083
120.370
117.840
117.759
106.319
77.321
77.000
76.679
73.165
66.821
63.729
52.872
29.751
OH
O
N
Me
Ph
2aa
100 MHz, CDCl3
160
140
120
100
80
60
40
20
PPM


7.251
7.232
7.135
7.115
7.106
7.086
7.067
7.048
7.029
6.935
6.917
6.899
6.803
6.784
6.774
6.754
6.595
6.576
5.888
5.873
5.866
5.850
5.835
5.819
5.781
5.742
4.556
4.527
4.187
4.139
4.111
3.762
3.734
3.633
3.609
1.788
1.773
1.692
-0.000


OH
O
N
H
Me

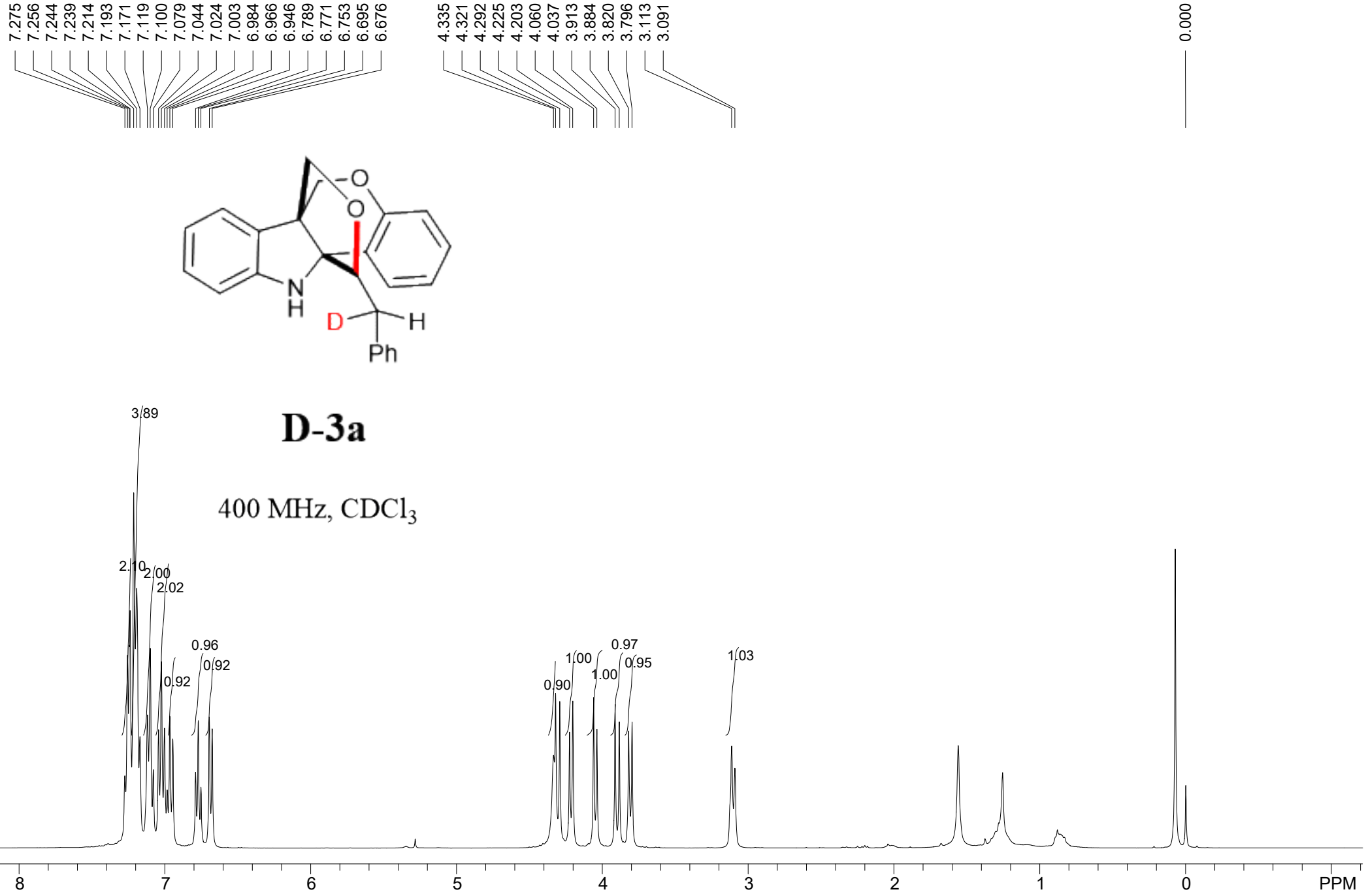
2z

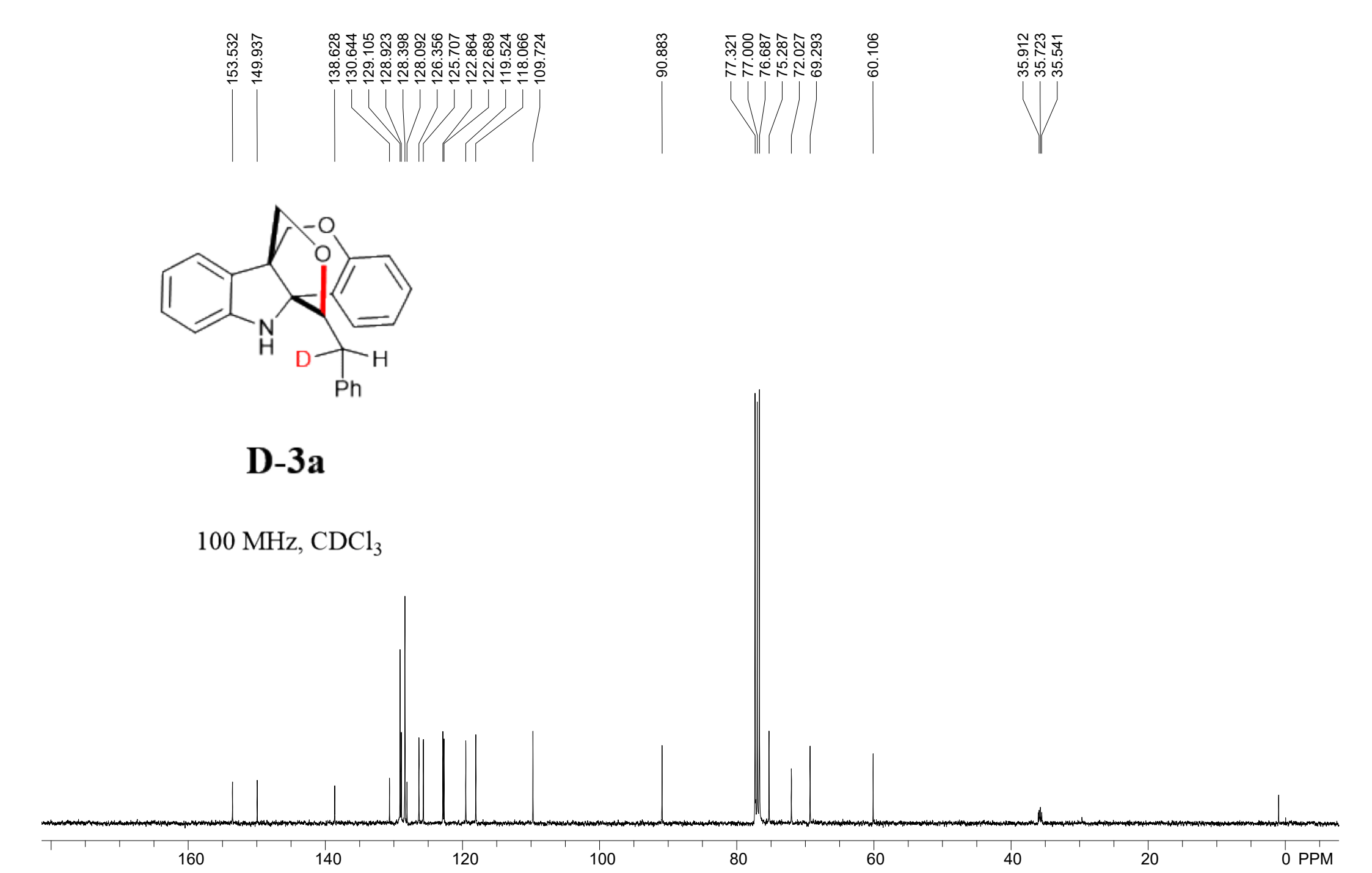

400 MHz, CDCl3
3.24
2.03
2.08
1.02
1.11
0.98
1.08
1.08
0.85
1.10
1.02
3.00
0.98
8
6
4
2
0
PPM



2z

100 MHz, $CDCl_3$


7.275
7.256
7.244
7.239
7.214
7.193
7.171
7.119
7.100
7.079
7.044
7.024
7.003
6.984
6.966
6.946
6.789
6.771
6.753
6.695
6.676
4.335
4.321
4.292
4.225
4.203
4.060
4.037
3.913
3.884
3.820
3.796
3.113
3.091
0.000
O
O
N
H
D
H
Ph
D-3a
400 MHz, CDCl3
3.89
2.10
2.00
2.02
0.92
0.96
0.92
0.90
1.00
1.00
0.97
0.95
1.03
8
7
6
5
4
3
2
1
0
PPM


153.532
149.937
138.628
130.644
129.105
128.923
128.398
128.092
126.356
125.707
122.864
122.689
119.524
118.066
109.724
90.883
77.321
77.000
76.687
75.287
72.027
69.293
60.106
35.912
35.723
35.541
O
O
N
H
D
H
Ph
D-3a
100 MHz, CDCl3
160
140
120
100
80
60
40
20
0 PPM