Bismuth Acetate as a Catalyst for the Sequential Protodeboronation of Di- and Triborylated Indoles

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Supporting Information

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I. General Methods

Unless otherwise stated, the reported yields refer to chromatograph-ically and spectroscopically pure compounds. Pinacolborane (HBpin) and B_2pin_2 were generously supplied by BoroPharm, Inc. and used as received. Bis(η^4-1,5-cyclooctadiene)-di-μ-methoxy-diiridium(I) ([Ir(OMe)(cod)]$_2$), was prepared per a literature procedures.[1] 4,4′-Di-*t*-butyl-2,2′-bipyridine (dtbpy) was purchased from Aldrich. $IrCl_3•(H_2O)_x$ was purchased from Pressure Chemical Co. 2,7-Bis(Bpin)-*N*-Boc-L-tryptophan methyl ester was prepared according to a literature procedure.[2] All borylated starting substrates were purified by column chromatography prior to use. For all Ir-catalyzed reactions, tetrahydrofuran (THF) was obtained from a dry still packed with activated alumina and degassed before use. For all Bi-catalyzed deboronations, THF was reagent grade and used as received. Bismuth(III) acetate was purchased from Aldrich and used as received except where otherwise noted. Acetonitrile (MeCN), triethylamine (NEt_3), and dichloromethane (DCM) were reagent grade. Silica gel was (230-400 Mesh).

Reactions were monitored by thin layer chromatography on precoated silica gel plates (Merck), using UV light or phosphomolybdic acid stain for visualization. Column chromatography was performed on 60 Å silica gel (230–400 mesh). NMR spectra were recorded on Varian VXR-500, Varian Unity-500-Plus (499.74 MHz for ^{1}H and 125.67 MHz for ^{13}C) and Bruker 500 (500.13 MHz for ^{1}H and 125.77 MHz for ^{13}C) spectrometer. ^{1}H and ^{13}C chemical shifts (in ppm) were referenced to the residual protonated or natural abundance solvent signals.[3] ^{11}B spectra were recorded at 160.32 MHz. All coupling constants are apparent *J* values measured at the indicated field strengths. Melting points are uncorrected. High-resolution mass spectrum was acquired at the MSU Mass Spectrometry facility using a Waters GCT Premier GC/TOF instrument (in ESI mode) (Waters Milford, MA) and at Merck (Rahway, NJ) using a Waters

Xevo G2 QTof instrument (in ESI mode). Low-resolution mass spectra were performed at the Molecular Metabolism and Disease Collaborative Mass Spectrometry Core facility at MSU on a Thermo Scientific LTQ-Orbitap Velos using the Ion Trap analyzer in positive ionization mode by nano-ESI.

II. General procedures

General borylation procedure with $[Ir(OMe)(COD)]_2$ and d^{t}bpy. In a glove box, a 20 mL reaction vial, equipped with a magnetic stirring bar, was charged with the substrate. Two separate test tubes were charged with $[Ir(OMe)(COD)]_2$ (1 mol% Ir) and d^{t}bpy (1 mol%). THF (2 × 200 μL) was added to the d^{t}bpy containing test tube in order to dissolve the dtbpy. The dtbpy solution was then mixed with the $[Ir(OMe)(cod)]_2$ and HBpin (2.8 x Ir mol %). After mixing for one minute, the resulting solution was transferred to the reaction vial. Additional THF (3 × 200 μL) was used to wash the test tubes and the washings were transferred to the reaction vial. The reaction vial was sealed, brought out of the glove box and the reaction was carried out at the specified temperature. After completion of the reaction, the mixture was passed through a silica plug to remove the dark brown red color. After further elution with DCM, the volatile materials were removed by rotary evaporation. The crude material was further purified by column chromatography.

General deboronation procedure with $Bi(OAc)_3$ and MeOH. A reaction vial equipped with a magnetic stirring bar was charged with substrate and $Bi(OAc)_3$ (20 mol %). The described MeOH and THF solvent mixture was added to the vial. The reaction vial was sealed and the reaction was carried out at the 80 °C. After completion of the reaction as judged by TLC, the crude mixture was passed through a plug of celite and washed three times by ethyl acetate. After

the volatile materials were removed by rotary evaporation the crude material was purified by column chromatography.

General deboronation procedure with $[Ir(OMe)(COD)]_2$ and MeOH.[4] A Schlenk flask equipped with a magnetic stirring bar was charged with substrate (1.0 mmol, 1.0 equiv) and $[Ir(OMe)(COD)]_2$ (10 mg, 0.015 mmol, 3 mol % Ir). The Schlenk flask was then evacuated and backfilled with nitrogen (this sequence was carried out two times). The solvent mixture (methanol/dichloromethane 2:1, 5 mL) was degassed by a freeze-pump-thaw method then added to the Schlenk flask and flushed under nitrogen twice as mentioned previously. The Schlenk flask was sealed and the reaction was carried out at the 60 °C. After completion of the reaction as judged by TLC, the volatile materials were removed by rotary evaporation. The crude material was purified by column chromatography.

III. Experimental Details and Spectroscopic Data

7-Bpin-L-tryptophan methyl ester (3) via Scheme 3: 7-Bpin-Boc-L-tryptophan methyl ester **2** (330 mg, 0.75 mmol, 1 equiv) was suspended in acetonitrile (10 mL) and water (0.2 mL), and then the containing flask was sealed and placed in an oil bath at 60 ºC in order to provide a homogenous solution. $BiCl_3$ (142 mg, 0.45 mmol, 0.6 equiv) was added into the flask, the mixture was stirred at that temperature for 1 h. An additional $BiCl_3$ (142 mg, 0.45 mmol, 0.6 equiv) was then added and the mixture stirred for a further 1 h. After completion of the reaction as judged by TLC, the volatiles were removed by rotary evaporation. The crude material was suspended in MeOH (5 mL) and placed on a celite bed followed by washing with MeOH (2 x 15 mL). The filtrate was dried over anhydrous $MgSO_4$, filtered, and evaporated to give **3** and trace amounts of **4**. For **3**: ^{1}H NMR (CD_3OD, 500 MHz) δ 7.65 (d, J = 7.8 Hz, 1 H), 7.51 (d, J = 6.9 Hz, 1 H), 7.31 (s, 1 H), 7.05 (t, J = 7.3 Hz, 1 H), 4.37 (m, 1 H), 3.71 (s, 3 H), 3.42 (m, 2 H), 1.35

(s, 9), 1.16 (d, J = 9.8 Hz, 3 H); ^{13}C NMR (CD_3OD, 125 MHz) δ 170.7 (C=O), 142.4, 130.3, 127.4, 126.2, 122.7, 119.9, 107.3, 85.1, 54.7 , 53.7, 31.1, 28.8, 27.31, 25.2; ^{11}B NMR (CD_3OD, 160 MHz) δ 29.8; HRMS (ESI): *m/z* calculated for $C_{18}H_{26}BN_2O_4$ $[M+H]^+$ 345.1986, found 345.1992.

7-Bpin-Boc-L-tryptophan methyl ester (2) via Scheme 3. The general Bi-catalyzed deboronation procedure was applied to 2,7-bis(Bpin)-Boc-L-tryptophan methyl ester **1** (39 mg, 0.068 mmol) and $Bi(OAc)_3$ (5.3 mg, 0.0137 mmol, 20 mol%) with a MeOH /THF solvent mixture (0.34 mL / 0.27 mL) at 80 °C for 7 h. The crude material was concentrated and purified by column chromatography (20% ethyl acetate/hexanes) on silica gel. The product (**2**) was isolated as white solid (27 mg, 90%, mp 177 °C). ^{1}H NMR (CD_3OD, 500 MHz) δ 9.13 (br s, 1 H), 7.67 (d, J = 7.8 Hz, 1 H), 7.64 (d, J = 6.8 Hz, 1 H), 7.13 (t, J = 7.6 Hz, 1 H), 7.06 (s, 1 H), 5.06 (d, J = 7.8, 1 H), 4.64 (m, 1 H), 3.67 (s, 3 H), 3.31 (d, J = 4.9, 2 H), 1.43 (s, 9), 1.39 (s, 12 H); ^{13}C NMR (CD_3OD, 125 MHz) δ 172.9, 155.4, 141.4, 129.6, 126.8, 122.9, 122.5, 119.3, 109.7, 84.0, 79.9, 54.4, 52.3, 28.5, 28.1, 25.2. The spectral data were in accordance with literature values.[4]

Borylation Details for Table 1

Table 1, entry 1. 2,7-Bis(Bpin)-indole (6). The borylation was carried out neat with indole **5** (585 mg, 5 mmol, 1 equiv), B_2pin_2 (2.54 mg, 10 mmol, 2 equiv), HBpin (210 μL, 1.4 mmol, 0.28 equiv), $[Ir(OMe)(COD)]_2$ (17 mg, 0.025 mmol, 1 mol % Ir) and d^{t}bpy (13 mg, 0.05 mmol, 1 mol %) at 80 °C for 48 h and worked up as described in the general borylation procedure. The crude material was concentrated and purified by column chromatography (10% ethyl acetate/hexanes) on silica gel. The product was isolated as a white solid (1.9 g, 77%, mp 147 °C). ^{1}H NMR ($CDCl_3$, 500 MHz) δ 9.35 (br s, 1 H), 7.79 (d, J = 7.8 Hz, 1 H), 7.72 (dd, J =

6.9, 1.0 Hz, 1 H), 7.12 (m, 2 H), 1.42 (s, 12 H, 4 CH_3 of Bpin), 1.39 (s, 12 H, 4 CH_3 of Bpin); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 143.3, 131.4, 127.5, 125.3, 119.5, 114.0, 84.1(2 C), 84.0 (2 C), 25.1 (4 CH_3 of Bpin), 25.0 (4 CH_3 of Bpin). The spectral data were in accordance with literature values.[5]

Table 1, entry 2. 2,4,7-Tri(Bpin)-indole (7). The borylation step was carried out neat with 2,7-bis(Bpin)-indole **6** (554 mg, 1.5 mmol, 1 equiv), B_2pin_2 (381 mg, 1.5 mmol, 1 equiv), HBpin (63 μL, 0.42 mmol, 0.28 equiv), $[Ir(OMe)(COD)]_2$ (5 mg, 0.0075 mmol, 1 mol % Ir) and d^{t}bpy (4 mg, 0.0075 mmol, 1 mol %) at 80 °C for 12 h and worked up as described in the general procedure. The crude material was purified by column chromatography (10% ethyl acetate/hexanes) on silica gel to afford **7** as white powder (713 mg, 96%, mp 255°C). ^{1}H NMR ($CDCl_3$, 500 MHz) δ 9.38 (br s, 1 H), 7.70 (d, J = 6.9 Hz, 1 H), 7.62 (d, J = 6.9 Hz, 1 H), 7.59 (d, J = 2.1 Hz, 1 H), 1.42 (s, 12 H, 4 CH_3 of Bpin), 1.39 (s, 24 H, 4 CH_3 of Bpin), 1.39 (s, 24 H, 4 CH_3 of Bpin); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 142.5, 131.6, 130.2, 127.2, 115.4, 84.0(2 C), 83.9 (2 C), 83.5 (2 C), 25.0 (8 CH_3 of Bpin), 24.9 (4 CH_3 of Bpin); ^{11}B NMR ($CDCl_3$, 160MHz): δ 30.6; FT-IR (neat) $\tilde{\nu}_{max}$: 3461, 2979, 1538, 1372, 1327, 1292, 1137, 973, 855, 693 cm^{-1}; LRMS (ESI): *m/z* calculated for $C_{26}H_{41}B_3NO_6$ $[M+H]^+$ 496.31, found 496.3.).

Formation of 2,4,7-tri(Bpin)-indole (7) from indole. In a glove box, a 20 mL vial, equipped with a magnetic stirring bar, was charged with indole **5** (585 mg, 5 mmol, 1 equiv) and B_2pin_2 (3.81 g, 10 mmol, 3 equiv). Two separate test tubes were charged with $[Ir(OMe)(COD)]_2$ (100 mg, 0.15 mmol, 6 mol % Ir) and d^{t}bpy (80 mg, 0.3 mmol, 6 mol %). HBpin (210 μL, 1.4 mmol, 0.28 equiv) was added to the $[Ir(OMe)(COD)]_2$ test tube. THF (2 mL) was added to the d^{t}bpy containing test tube in order to dissolve the d^{t}bpy. The d^{t}bpy solution was then mixed with the $[Ir(OMe)(COD)]_2$ and HBpin mixture. After mixing for 1 min, the resulting solution was

transferred to the vial containing the indole substrate. Additional THF (3 mL) was used to wash the test tubes and the washings were transferred to the vial. The vial was well sealed, brought out of the glove box and stirred at 70 °C. After 48 h, the reaction mixture was passed through a silica plug to remove the dark brown red color. After further elution with DCM, the volatile materials were removed by rotary evaporation. The crude residue was purified by column chromatography (10% ethyl acetate/hexanes) on silica gel. Indole **7** was isolated as a white solid (1.5 g, 60%, mp 255°C).

Table 1, entry 3. 2,7-Di(Bpin)-6-fluoroindole (9). The borylation step was carried out neat with 6-fluoroindole **8** (675 mg, 5 mmol, 1 equiv), B_2pin_2 (2.54 g, 10 mmol, 2 equiv), HBpin (210 μL, 1.4 mmol, 0.28 equiv), $[Ir(OMe)(COD)]_2$ (17 mg, 0.025 mmol, 1 mol % Ir) and d^{t}bpy (13 mg, 0.05 mmol, 1 mol%) at 80 °C for 24 h and worked up as described in the general procedure. The crude material was concentrated and purified by column (5% ethyl acetate/hexanes) on silica gel. Product **9** was afforded as a foamy solid (1.59 g, 82%, mp 117-119 °C). ^{1}H NMR ($CDCl_3$, 500 MHz) δ 9.52 (br s, 1 H, NH), 7.71 (dd, *J* = 8.3, 5.4 Hz, 1 H), 7.10 (d, *J* = 2.0 Hz, 1 H), 6.86 (dd, *J* = 10.3, 8.8 Hz, 1 H), 1.44 (s, 12 H, 4 C*H*$_3$ of Bpin), 1.38 (s, 12 H, 4 C*H*$_3$ of Bpin); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 166.2 (d, *J* = 247 Hz), 143.2 (d, *J* = 13.4 Hz), 126.3 (d, *J* = 11.4 Hz), 124.0, 113.8, 108.8 (d, *J* = 27.7 Hz), 84.1 (2 C), 83.8 (2 C), 25.0 (4 CH_3 of Bpin), 24.8 (4 CH_3 of Bpin); ^{11}B NMR ($CDCl_3$, 160MHz): δ 30.5; FT-IR (neat) $\tilde{\nu}_{max}$: 3445, 2980, 1569, 1540, 1387, 1418, 1288, 1235, 1166, 1020, 966, 852, 701 cm^{-1}; LRMS (ESI): *m/z* calculated for $C_{20}H_{29}B_2FNO_4$ $[M+H]^+$ 387.22, found 388.3.

Table 1, entry 4. 2,4,7-Tri(Bpin)-6-fluoroindole (10). The borylation step was carried out neat with 2,7-bis(Bpin)-6-fluoroindole **9** (1.48 g, 3.82 mmol, 1 equiv), B_2pin_2 (970 mg, 3.82 mmol, 1 equiv), HBpin (160 μL, 1.1 mmol, 0.28 equiv), $[Ir(OMe)(COD)]_2$ (12.7 mg, 0.019

mmol, 1 mol % Ir) and d^{t}bpy (10 mg, 0.038 mmol, 1 mol %) at 80 °C for 12 h and worked up as described in the general procedure. The crude material was purified by silica gel chromatography (10% ethyl acetate/hexanes) on silica gel to afford **10** as white powder (1.82 g, 92%, mp 278 °C). ^{1}H NMR ($CDCl_3$, 500 MHz) δ 9.50 (br s, 1 H, NH), 7.54 (d, *J* = 2.1 Hz, 1 H), 7.32 (d, *J* = 10.3 Hz, 1 H), 1.43 (s, 12 H, 4 C*H*$_3$ of Bpin), 1.38 (s, 24 H, 8 C*H*$_3$ of Bpin); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 165.4 (d, *J* = 247 Hz), 143.0 (d, *J* = 12.4 Hz), 128.6, 115.9 (d, *J* = 25.8 Hz), 115.5, 84.1 (2 C), 84.0 (2 C), 84.0 (2 C), 25.1 (8 CH_3 of Bpin), 25.0 (4 CH_3 of Bpin); ^{11}B NMR ($CDCl_3$, 160 MHz): δ 30.1; FT-IR (neat) $\tilde{\nu}_{max}$: 3455, 2979, 1540, 1510, 1387, 1323, 1292, 1235, 1137, 1042, 966, 852, 702 cm^{-1}; LRMS (ESI): *m/z* calculated for $C_{26}H_{40}B_3FNO_6$ $[M+H]^+$ 514.30, found 514.3.).

Formation of 2,4,7-Tri(Bpin)-6-fluoroindole (10) from 6-fluoroindole. In a glove box, a 20 mL vial, equipped with a magnetic stirring bar, was charged with 6-fluoroindole **8** (675 mg, 5 mmol, 1 equiv) and B_2pin_2 (3.81 g, 15 mmol, 3 equiv). Two separate test tubes were charged with $[Ir(OMe)(COD)]_2$ (100 mg, 0.15 mmol, 6 mol % Ir) and d^{t}bpy (80 mg, 0.3 mmol, 6 mol %). HBpin (210 μL, 1.4 mmol, 0.28 equiv) was added to the $[Ir(OMe)(COD)]_2$ test tube. THF (2 mL) was added to the d^{t}bpy containing test tube in order to dissolve the d^{t}bpy. The d^{t}bpy solution was then mixed with the $[Ir(OMe)(COD)]_2$ and HBpin mixture. After mixing for 1 min, the resulting solution was transferred to the vial containing the indole substrate. Additional THF (3 mL) was used to wash the test tubes and the washings were transferred to the vial. The vial was well sealed, brought out of the glove box and stirred at 70 °C. After 24 h, the reaction mixture was passed through a silica plug to remove the dark brown red color. After further elution with DCM, the volatile materials were removed by rotary evaporation. The crude residue was purified by

column chromatography (10% ethyl acetate/hexanes) on silica gel. Indole **10** was crystallized from MeOH as white crystals (1.59 g, 62%, mp 278 °C).

Table 1, entry 5. 4,7-Bis(Bpin)-2-carboethoxy-indole (12). The borylation step was carried out neat with 7-Bpin-2-fluoroindole **11** (189 mg, 1 mmol, 1 equiv), B_2pin_2 (508 mg, 2 mmol, 2 equiv), HBpin (42 μL, 0.28 mmol, 0.28 equiv), $[Ir(OMe)(COD)]_2$ (3.3 mg, 0.005 mmol, 1 mol % Ir) and d′bpy (2.6 mg, 0.01 mmol, 1 mol %) at 80 °C for 12 h and worked up as described in the general procedure. The crude material was purified by column chromatography (5% ethyl acetate/hexanes) on silica gel to afford **12** as a white powder (146 mg, 84%, mp 163 °C). ^{1}H NMR ($CDCl_3$, 500 MHz) δ 9.72 (br s, 1 H), 7.78 (d, J = 6.9 Hz, 1 H), 7.68 (d, J = 7.0 Hz, 1 H), 7.67 (s, 1 H), 4.45 (q, J = 7.1 Hz, 2 H, CH_2CH_3), 1.46 (t, J = 7.1 Hz, 3 H, CH_2CH_3), 1.41 (s, 12 H, 4 CH_3 of Bpin), 1.41 (s, 12 H, 4 CH_3 of Bpin); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 162.4 (C=O), 141.2, 131.9, 130.9, 128.3, 127.7, 110.2, 84.3 (2 C), 83.8 (2 C), 61.0 (CH_2), 25.1 (8 CH_3 of Bpin), 14.6 (CH_3); ^{11}B NMR ($CDCl_3$, 160 MHz): δ 31.3; FT-IR (neat) $\tilde{\nu}_{max}$: 3448, 2978, 1721, 1512, 1385, 1347, 1292, 1136, 973, 855, 763, 695 cm^{-1}; LRMS (ESI): *m/z* calculated for $C_{23}H_{34}B_2NO_6$ $[M+H]^+$ 442.25, found 442.3.[6]

Table 1, entry 6. 4,7-Bis(Bpin)-3-methyl-indole (14). The borylation step was carried out neat with 2-methylindole **13** (131 mg, 1 mmol, 1 equiv), B_2pin_2 (508 mg, 2 mmol, 2 equiv), HBpin (42 μL, 0.28 mmol, 0.28 equiv), $[Ir(OMe)(COD)]_2$ (3.3 mg, 0.005 mmol, 1 mol % Ir) and d′bpy (2.6 mg, 0.01 mmol, 1 mol %) at 80 °C for 24 h and worked up as described in the general procedure. The crude material was purified by column chromatography (20% ethyl acetate/hexanes) on silica gel to afford **14** as a white powder (271 mg, 71%, mp 353 °C). ^{1}H NMR ($CDCl_3$, 500 MHz) δ 8.87 (br s, 1 H), 7.56 (d, J = 6.9 Hz, 1 H), 7.54 (d, J = 6.9 Hz, 1 H), 6.69 (s, 1 H), 2.51 (s, 3 H), 1.40 (s, 12 H, 4 CH_3 of Bpin), 1.39 (s, 12 H, 4 CH_3 of Bpin); ^{13}C

NMR ($CDCl_3$, 125 MHz) δ 140.9, 135.8, 133.0, 127.2, 126.7, 101.9, 84.0 (2 C), 83.5 (2 C), 25.1 (8 CH_3 of Bpin), 14.2 (CH_3); ^{11}B NMR ($CDCl_3$, 160 MHz): δ 30.5; FT-IR (neat) $\tilde{\nu}_{max}$: 3449, 2976, 1610, 1511, 1372, 1332, 1304, 1167, 1136, 968, 856, 697 cm^{-1}; LRMS (ESI): *m/z* calculated for $C_{21}H_{32}B_2NO_4$ $[M+H]^+$ 384.24, found 384.3.

Table 1, entry 7. 3,5-Bis(Bpin)-6-fluoro-indole (15). In a glove box, a 20 mL reaction vial, equipped with a magnetic stirring bar. The 6-fluoroindole **8** (54 mg, 0.4 mmol, 1 equiv) was stirred in HBpin (240 μL, 1.6 mmol, 4 equiv) at rt for 1 h at which time B_2pin_2 (2.54 g, 10 mmol, 2 equiv) was added to the reaction vial. Two separate test tubes were charged with $[Ir(OMe)(COD)]_2$ (100 mg, 0.15 mmol, 6 mol % Ir) and d*t*bpy (80 mg, 0.3 mmol, 6 mol %). HBpin (210 μL, 1.4 mmol, 0.28 equiv) was added to the $[Ir(OMe)(COD)]_2$ test tube. THF (1 mL) was added to the d*t*bpy containing test tube in order to dissolve the d*t*bpy. The d*t*bpy solution was then mixed with the $[Ir(OMe)(COD)]_2$ and HBpin mixture. After mixing for 1 min, the resulting solution was transferred to the vial containing the indole substrate. Additional THF (1 mL) was used to wash the test tubes and the washings were transferred to the vial. The vial was well sealed, brought out of the glove box and stirred at 80 °C. After 5 h, the reaction mixture was passed through a silica plug to remove the dark brown red color. After further elution with DCM, the volatile materials were removed by rotary evaporation. The crude residue was purified by column chromatography (30% ethyl acetate/hexanes) on silica gel. Indole **15** was isolated as a colorless oil (112 mg, 90%). ^1H NMR ($CDCl_3$, 500 MHz) δ 8.56 (br s, 1 H), 8.33 (d, J = 5.4 Hz, 1 H), 7.61 (d, J = 2.5 Hz, 1 H), 7.02 (d, J = 10.3 Hz, 1 H), 1.39 (s, 12 H, 4 CH_3 of Bpin); 1.37 (s, 12 H, 4 CH_3 of Bpin) ^{13}C NMR ($CDCl_3$, 125 MHz) δ 164.4 (d, J = 242 Hz), 139.4 (d, J = 13.4 Hz), 134.8 (d, J = 2.9 Hz), 131.1 (d, J = 9.5 Hz), 127.9, 97.3 (d, J = 29.6 Hz), 83.6 (2 C), 83.2 (2 C), 25.0 (4 CH_3 of Bpin), 25.0 (4 CH_3 of Bpin); ^{11}B NMR ($CDCl_3$, 160 MHz): 30.7; FT-IR (neat)

$\tilde{\nu}_{max}$: 3423, 2980, 1625, 1475, 1373, 1145, 982, 851, 674 cm^{-1}; LRMS (ESI): *m/z* calculated for $C_{20}H_{29}B_2FNO_4$ $[M+H]^+$ 387.22, found 388.3.

Table 1, entry 8. 3,5-Bis(Bpin)-N-Boc-indole (17). In a glove box, a 20 mL reaction vial, equipped with a magnetic stirring bar, was charged with N-Boc-6-fluoroindole **16** (471 mg, 2 mmol, 1 equiv) and B_2Pin_2 (1.0 g, 4 mmol, 2 equiv). Two separate test tubes were charged with $[Ir(OMe)(COD)]_2$ (40 mg, 0.06 mmol, 6 mol % Ir) and d^{t}bpy (32 mg, 0.12 mmol, 6 mol %). HBpin (84 μL, 0.56 mmol, 0.28 equiv) was added to the $[Ir(OMe)(COD)]_2$ test tube. THF (1 mL) was added to the d^{t}bpy containing test tube in order to dissolve the d^{t}bpy. The d^{t}bpy solution was then mixed with the $[Ir(OMe)(COD)]_2$ and HBpin mixture. After mixing for 1 min, the resulting solution was transferred to the vial containing the indole substrate. Additional THF (3 mL) was used to wash the test tubes and the washings were transferred to the vial. The vial was well sealed, brought out of the glove box and stirred at 80 °C. After 3 h, the reaction mixture was passed through a silica plug to remove the dark brown red color. After further elution with DCM, the volatile materials were removed by rotary evaporation. The crude residue was purified by column chromatography (10% ethyl acetate/hexanes) on silica gel. Indole **17** was isolated as a white solid (780 mg, 80%, mp 163°C). ^{1}H NMR ($CDCl_3$, 500 MHz) δ 8.23 (d, *J* = 5.9 Hz, 1 H), 7.95 (s, 1 H), 7.85 (d, *J* = 10.8 Hz, 1 H), 1.65 (s, 9 H, 3 C*H*$_3$ of Boc), 1.39 (s, 12 H, 4 C*H*$_3$ of Bpin); 1.38 (s, 12 H, 4 C*H*$_3$ of Bpin) ^{13}C NMR ($CDCl_3$, 125 MHz) δ 165.4 (d, *J* = 244 Hz), 149.2, 135.8, 130.5 (d, *J* = 9.5 Hz), 129.4, 102.2 (d, *J* = 31.5 Hz), 84.5 (C), 83.8 (2 C), 83.7 (2 C), 28.3 (3 CH_3 of Boc), 25.0 (4 CH_3 of Bpin), 25.0 (4 CH_3 of Bpin); ^{11}B NMR ($CDCl_3$, 160 MHz): 29.8; FT-IR (neat) $\tilde{\nu}_{max}$: 3447, 2978, 1740, 1636, 1559, 1443, 1363, 1322, 1255, 1139, 1063, 853, 668 cm^{-1}; LRMS (ESI): *m/z* calculated for $C_{25}H_{37}B_2FNO_6$ $[M+H]^+$ 488.27, found 488.3.

Deboronation Details for Table 2

Table 2, entry 1. 7-Bpin-indole (18). The general Bi-catalyzed deboronation procedure was applied to 2,7-bis(Bpin)-indole **6** (36.9 mg, 0.1 mmol, 1 equiv) and $Bi(OAc)_3$ (7.72 mg, 0.02 mmol, 20 mol%) with a solvent mixture of MeOH /THF (0.5 mL /0.4 mL) at 80 °C for 17 h. The crude material was concentrated and purified by column chromatography (5% ethyl acetate/hexanes) on silica gel. Indole **18** was isolated as a white solid (20 mg, 82%). ^{1}H NMR ($CDCl_3$, 500 MHz): δ 9.26 (br s, 1 H), 7.79 (d, J = 7.9 Hz, 1 H), 7.68 (d, J = 7.0 Hz, 1 H), 7.28 (dd, J = 2.8, 2.8 Hz, 1 H), 7.15 (dd, J = 7.5, 7.5 Hz, 1 H), 6.57 (dd, J = 2.8, 2.8 Hz, 1 H), 1.41 (s, 12 H, 4 CH_3 of Bpin); ^{13}C NMR ($CDCl_3$,125 MHz): δ 141.1 (C), 129.4 (CH), 126.9 (C), 124.4 (CH), 124.2 (CH), 119.4 (CH), 102.1 (CH), 83.9 (2 C), 25.2 (4 CH_3 of Bpin); ^{11}B NMR ($CDCl_3$, 160 MHz): 30.8. The spectral data were in accordance with literature values.[5]

Table 2, entry 2. 7-Bpin-indole-2d (18-d_1). A vial equipped with a magnetic stirring bar was charged with 2,7-bis(Bpin)-indole **6** (185 mg, 0.5 mmol, 1 equiv) and $Bi(OAc)_3$ (38.6 mg, 0.1 mmol, 0.2 equiv). A solvent mixture of CD_3OD (810 μL, 20 mmol, 40 equiv) and THF (2 mL) was added to the vial. The vial was sealed and the reaction was carried out at rt. After completion of the reaction as judged by TLC, the crude material was passed through a plug of celite. The celite was washed three times with ethyl acetate. After the volatiles were removed by a rotary evaporation, the crude material was purified by column chromatography (5% ethyl acetate/hexanes) on silica gel. Indole **18-d_1** was isolated as a white solid (101 mg, 83%, mp 87–88 °C). ^{1}H NMR ($CDCl_3$, 500 MHz) δ 9.31 (br s, 1 H), 7.84 (d, J = 7.8 Hz, 1 H), 7.74 (d, J = 6.9 Hz, 1 H), 7.31 (t, J = 2.9 Hz, 0.13 H), 7.20 (t, J = 7.8 Hz, 1 H), 6.61 (d, J = 2.0 Hz, 1 H), 1.45 (s, 12 H, 4 CH_3 of Bpin); ^{13}C NMR ($CDCl_3$,125 MHz): δ 141.0, 129.3, 126.9, 124.4, 124.0 (t, J = 25.8 Hz), 119.4, 102.1, 101.9, 83.9 (2 C), 25.1 (4 CH_3 of Bpin); ^{11}B NMR ($CDCl_3$, 160 MHz): 31.2; FT-IR (neat) $\tilde{\nu}_{max}$: 3457, 2977, 1592, 1503, 1367, 1314, 1130, 978, 845, 805, 753, 678 cm^{-}

[1]; LRMS (ESI): *m/z* calculated for $C_{14}H_{18}DBNO_2$ $[M+H]^+$ 245.15, found 245.1. Percent deuterium incorporation (based on quantitative ^1H NMR): 92%

Table 2, entry 3. 4,7-Bis(Bpin)-indole (19). The general Bi-catalyzed deboronation procedure was applied to 2,4,7-tri(Bpin)-indole **7** (100 mg, 0.2 mmol, 1 equiv) and $Bi(OAc)_3$ (15.4 mg, 0.04 mmol, 20 mol%) with a solvent mixture of MeOH /THF (1 mL /0.8 mL) at 80 °C for 17 h. The crude material was concentrated and purified by column chromatography (5% ethyl acetate/hexanes) on silica gel. Indole **19** was isolated as a white solid (55.4 mg, 75%, mp 225°C). ^1H NMR ($CDCl_3$, 500 MHz) δ 9.24 (br s, 1 H), 7.64 (d, *J* = 7.3 Hz, 1 H), 7.63 (d, *J* = 7.3 Hz, 1 H), 7.31 (dd, *J* = 5.4, 2.9 Hz, 1 H), 7.03 (dd, *J* = 4.9, 2.9 Hz, 1 H), 1.40 (s, 12 H, 4 C*H*$_3$ of Bpin), 1.40 (s, 12 H, 4 C*H*$_3$ of Bpin); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 140.5, 131.6, 128.4, 127.0, 124.5, 104.0, 84.0 (2 C), 83.6 (2 C), 25.2 (8 CH_3 of Bpin); ^{11}B NMR ($CDCl_3$, 160 MHz): δ 31.6; FT-IR (neat) $\tilde{\nu}_{max}$: 3426, 2978, 1400, 1325, 1137, 1067, 968, 856 cm^{-1}; LRMS (ESI): *m/z* calculated for $C_{20}H_{30}B_2NO_4$ $[M+H]^+$ 370.23, found 370.3.

Table 2, entry 4. 4-Bpin-6-fluoro-indole (20). The general Bi-catalyzed deboronation procedure was applied to 2,4,7-tri(Bpin)-6-fluoroindole **10** (513 mg, 1 mmol, 1 equiv) and $Bi(OAc)_3$ (77.2 mg, 0.2 mmol, 20 mol%) with a solvent mixture of MeOH /THF (10 mL /4 mL) at 80 °C for 15 h. The crude material was concentrated and purified by column (10% ethyl acetate/hexanes) on silica gel. Indole **20** was isolated as white solid (205 mg, 80%, mp 114°C). ^1H NMR ($CDCl_3$, 500 MHz) δ 8.27 (br s, 1 H), 7.46 (dd, *J* = 10.3, 2.5 Hz, 1 H), 7.18 (dd, *J* = 2.9, 2.9 Hz, 1 H), 7.14 (dd, *J* = 9.3, 1.5 Hz, 1 H), 7.07 (dd, *J* = 2.5, 2.5 Hz, 1 H), 1.43 (s, 12 H, 4 C*H*$_3$ of Bpin); ^{13}C NMR ($CDCl_3$,125 MHz): δ 159.5 (d, *J* = 237.0 Hz), 135.5 (d, *J* = 11.5 Hz), 129.3, 125.3 (d, *J* = 3.8 Hz), 115.5 (d, *J* = 22.9 Hz), 104.4, 100.4 (d, *J* = 25.8 Hz), 83.9 (2 C), 25.0 (4 CH_3 of Bpin); ^{11}B NMR ($CDCl_3$, 160 MHz): 31.3; FT-IR (neat) $\tilde{\nu}_{max}$: 3344, 2979, 1612, 1384,

1264, 1137, 1064, 966, 849, 782, 682 cm^{-1}; LRMS (ESI): *m/z* calculated for $C_{14}H_{18}BFNO_2$ $[M+H]^+$ 261.13, found 262.1.

Table 2, entry 5. 4,7-Bis(Bpin)-6-fluoro-indole (21). The general Bi-catalyzed deboronation procedure was applied to 2,4,7-tri(Bpin)-6-fluoroindole **10** (513 mg, 1 mmol, 1 equiv) and $Bi(OAc)_3$ (77.2 mg, 0.2 mmol, 20 mol%) with a solvent mixture of MeOH /THF (2.5 mL /4 mL) at 80 °C for 5 h. The crude material was concentrated and purified by column (5% ethyl acetate/hexanes) on silica gel. Indole **21** was isolated as white solid (259 mg, 67%, mp 185°C). ^{1}H NMR ($CDCl_3$, 500 MHz) δ 9.34 (br s, 1 H), 7.33 (d, *J* = 10.3 Hz, 1 H), 7.27 (dd, *J* = 2.9, 2.0 Hz, 1 H), 6.98 (dd, *J* = 2.9, 2.0 Hz, 1 H), 1.42 (s, 12 H, 4 C*H*$_3$ of Bpin), 1.39 (s, 12 H, 4 C*H*$_3$ of Bpin); ^{13}C NMR ($CDCl_3$, 125 MHz): δ 164.5 (d, *J* = 246.0 Hz), 140.5, 128.2, 124.8 (d, *J* = 3.8 Hz), 115.0 (d, *J* = 25.8 Hz), 104.0, 84.1 (2 C), 83.9 (2 C), 25.1 (8 CH_3 of Bpin); ^{11}B NMR ($CDCl_3$, 160 MHz): 30.4; FT-IR (neat) $\tilde{\nu}_{max}$: 3125, 2923, 1559, 1401, 1256, 1139, 1063, 853 cm^{-1}; LRMS (ESI): *m/z* calculated for $C_{20}H_{29}B_2FNO_4$ $[M+H]^+$ 387.22, found 388.3.

Table 2, entry 6 (Ir). 4-Bpin-2-carboethoxy-indole (22). The deboronation step was carried out neat with 4,7-bis(Bpin)-2-ethyl ester-indole **12** (220.5 mg, 0.5 mmol), $[Ir(OMe)(COD)]_2$ (10 mg, 0.015 mmol, 6 mol % Ir) in MeOH (800 μL, 20 mmol, 40 equiv) and THF (5 mL) at rt for 12 h and worked up as described in the general Ir-catalyzed deboronation procedure. The crude material consisting of a 3:1 mixture of **22** and **11** was concentrated by rotary evaporation and purified by column chromatography (5% ethylacetate/hexanes) on silica gel. Indole **22** was isolated as a white solid (85 mg, 54%, mp 139 °C) along with **11** (12 mg, 13%). For **22**: ^{1}H NMR ($CDCl_3$, 500 MHz) δ 9.14 (br s, 1 H), 7.70 (m, 1 H), 7.68 (dd, *J* = 6.9, 1.0 Hz, 1 H), 7.54 (d, *J* = 8.3 Hz, 1 H), 7.34 (dd, *J* = 8.3, 7.3 Hz, 1 H), 4.45 (q, *J* = 6.9 Hz, 2 H, *CH*$_2$CH$_3$), 1.45 (t, *J* = 7.3 Hz, 3 H, CH$_2$*CH*$_3$), 1.41 (s, 12 H, 4 C*H*$_3$ of Bpin); ^{13}C NMR ($CDCl_3$,

125 MHz) δ 162.4 (C=O), 136.4, 131.9, 129.1, 127.8, 124.8 (C), 114.9, 110.7, 83.8 (2 C), 61.2 (CH_2), 25.1 (4 CH_3 of Bpin), 14.6 (CH_3); ^{11}B NMR ($CDCl_3$, 160 MHz): δ 30.8; FT-IR (neat) $\tilde{\nu}_{max}$: 3331, 2979, 1686, 1521, 1250, 1146, 1022, 980, 852, 769, 681 cm^{-1}; LRMS (ESI): *m/z* calculated for $C_{17}H_{23}BNO_4$ $[M+H]^+$ 316.16, found 316.2.

Table 2, entry 7 (Ir). 4-Bpin-2-methyl-indole (23). The deborylation step was carried out neat with 4,7-Bpin-2-methylindole **14** (38 mg, 0.1 mmol, 1 equiv), $[Ir(OMe)(COD)]_2$ (1 mg, 0.0015 mmol, 3 mol % Ir) in MeOH and DCM (2:1, 0.5 mL) at 60 °C for 2 h and worked up as described in the general Ir-catalyzed deboronation procedure. The crude material was purified by silica gel chromatography (5% ethyl acetate/hexanes) on silica gel to afford **23** as a white solid (20 mg, 74%, mp 157–160 °C). ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.88 (br s, 1 H), 7.58 (d, *J* = 6.9 Hz, 1 H), 7.38 (d, *J* = 7.8 Hz, 1 H), 7.11 (t, *J* = 7.8 Hz, 1 H), 6.71 (s, 1 H), 2.47 (s, 3 H), 1.39 (s, 12 H, 4 C*H*$_3$ of Bpin); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 135.9, 135.5, 134.1, 127.7, 120.4, 113.2, 102.5, 83.4 (C), 25.1 (4 CH_3 of Bpin), 14.0 (CH_3); ^{11}B NMR ($CDCl_3$, 160 MHz): δ 30.9; FT-IR (neat) $\tilde{\nu}_{max}$: 3436, 2976, 1549, 1371, 1269, 1130, 1064, 973, 858, 637 cm^{-1}; LRMS (ESI): *m/z* calculated for $C_{15}H_{21}BNO_2$ $[M+H]^+$ 258.16, found 258.2.

Table 2, entry 8 (Bi). 5-Bpin-6-fluoro-indole (24). The general Bi-catalyzed deboronation procedure was applied to 3,5-bis(Bpin)-6-fluoro-indole **15** (77 mg, 0.2 mmol, 1 equiv) and $Bi(OAc)_3$ (15.4 mg, 0.04 mmol, 20 mol%) with a solvent mixture of MeOH /THF (0.8 mL /0.4 mL) at 80 °C for 3 h. The crude material was concentrated and purified by column (5% ethyl acetate/hexanes) on silica gel. Indole **24** was isolated as a white solid (46 mg, 88%, mp 159-162°C). ^{1}H NMR ($CDCl_3$, 500 MHz) δ 8.18 (br s, 1 H), 8.05 (d, *J* = 5.4 Hz, 1 H), 7.17 (dd, *J* = 3.4, 2.5 Hz, 1 H), 7.04 (d, *J* = 10.3 Hz, 1 H), 6.53 (m, 1 H), 1.38 (s, 12 H, 4 C*H*$_3$ of Bpin); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 164.3 (d, *J* = 242 Hz), 138.4 (d, *J* = 13.4 Hz), 129.6 (d, *J* = 10.5 Hz),

128.5, 124.8 (d, J = 3.8 Hz), 103.3, 97.2 (d, J = 29.6 Hz), 83.7 (2 C), 25.0 (4 CH_3 of Bpin); ^{11}B NMR ($CDCl_3$, 160 MHz): 30.7; FT-IR (neat) $\tilde{\nu}_{max}$: cm^{-1}; LRMS (ESI): *m/z* calculated for $C_{14}H_{18}BFNO_2$ $[M+H]^+$ 261.13, found 262.1.

Table 2, entry 8 (Ir). 5-Bpin-6-fluoro-indole (24). The deboronation step was carried out neat with 3,5-bis(Bpin)-6-fluoro-indole **15** (193 mg, 0.5 mmol, 1 equiv), $[Ir(OMe)(COD)]_2$ (5 mg, 0.0075 mmol, 3 mol % Ir) in MeOH and DCM (2:1, 2.5 mL) at 60 °C for 2 h and worked up as described in the general Ir-catalyzed deboronation procedure. The crude material was purified by silica gel chromatography (30% ethyl acetate/hexanes) on silica gel to afford **24** as white solid (86 mg, 66%).

Table 2, entry 9 (Ir). 5-Bpin-N-Boc-indole (25). The deborylation step was carried out neat with 3,5-bis(Bpin)-N-Boc-indole **17** (195 mg, 0.4 mmol), $[Ir(OMe)(COD)]_2$ (8 mg, 0.012 mmol, 6 mol % Ir) in MeOH (800 μL, 20 mmol, 50 equiv) and THF (4 mL) at rt for 10 h and worked up as described in the general Ir-catalyzed deboronation procedure. The crude material was concentrated by by rotary evaporation and purified by column chromatography (5% ethyl acetate/hexanes) on silica gel. Indole **25** was isolated as a colorless oil (67 mg, 47%). ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.93 (d, J = 5.9 Hz, 1 H), 7.82 (br d, J = 8.3 Hz, 1 H), 7.53 (d, J = 2.9 Hz, 1 H), 6.53 (d, J = 3.9 Hz, 1 H), 1.66 (s, 9 H, 3 CH_3 of Boc), 1.38 (s, 12 H, 4 CH_3 of Bpin); ^{13}C NMR ($CDCl_3$, 125 MHz) δ 165.3 (d, J = 244 Hz), 149.5, 129.3 (d, J = 9.5 Hz), 126.7, 126.4 (d, J = 3.8 Hz), 107.4, 102.4 (d, J = 31.5 Hz), 84.3 (C), 83.9 (2 C), 28.3 (3 CH_3 of Boc), 25.0 (4 CH_3 of Bpin); ^{11}B NMR ($CDCl_3$, 160 MHz): 30.1; FT-IR (neat) $\tilde{\nu}_{max}$: 3443, 2979, 1737, 1622, 1446, 1359, 1257, 1143, 1085, 959, 860, 732 cm^{-1}; LRMS (ESI): *m/z* calculated for $C_{19}H_{26}BFNO_4$ $[M+H]^+$ 362.19, found 362.3.

Preparation of 4,7-bis(Bpin)-6-fluoro-N-Boc-indole (26) via Scheme 4. A round bottom flask equipped with a magnetic stirring bar, a condenser, and an additional funnel was charged with 4,7-bis(Bpin)-6-fluoro-indole **21** (217 mg, 0.56 mmol, 1 equiv). MeCN (1 mL) and NEt_3 (1.6 mL, 11.2 mmol, 20 equiv) were injected into the flask. The resulting mixture was heated at 80 °C for 30 min. DMAP (137 mg, 1.12 mmol, 2 equiv) and Boc_2O (2.4 g, 11.2 mmol, 20 equiv) were weighted together in a vial and diluted with MeCN (1 mL). The resulting mixture was stirred at rt until it became a yellow homogenous solution. This solution was then introduced into an additional funnel and allowed flow flow at the rate of 1 drop per 2 min to the round bottom flask. Upon complete addition the reaction mixture was refluxed at 80 °C for 10 h. At that time the reaction was judged to be complete by TLC. After being concentrated by rotary evaporation the crude material was purified by column chromatography (5% acetone/heptane) on silica gel. Boc-Indole **21** was isolated as white solid (250 mg, 80%, mp 158 °C). ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.41 (d, J = 3.4 Hz, 1 H), 7.37 (d, J = 9.8 Hz, 1 H), 7.01 (d, J = 3.9 Hz, 1 H), 1.63 (s, 9 H, 3 CH_3 of Bpin), 1.46 (s, 12 H, 4 CH_3 of Bpin), 1.37 (s, 12 H, 4 CH_3 of Bpin); ^{13}C NMR ($CDCl_3$,125 MHz): δ 163.8 (d, J = 237 Hz), 150.2, 136.8, 131.1, 125.2 (d, J = 3.8 Hz), 117.4 (d, J = 25.8 Hz), 109.7, 84.0 (2 C), 84.0 (C), 84.0 (2 C), 28.3 (3 CH_3 of Boc), 25.7 (4 CH_3 of Bpin), 25.1 (4 CH_3 of Bpin); ^{11}B NMR ($CDCl_3$, 160 MHz): 29.1; FT-IR (neat) $\tilde{\nu}_{max}$: 3422, 2979, 1723, 1540, 1458, 1039, 1233, 1145, 935, 852, 769, 668 cm^{-1}; LRMS (ESI): *m/z* calculated for $C_{25}H_{37}B_2FNO_6$ $[M+H]^+$ 488.27, found 488.2.

Preparation of 7-Bpin-6-fluoro-N-Boc-indole-4-d (27) via Scheme 4. The deborylation step was carried out neat with 4,7-bis(Bpin)-6-fluoro-N-Boc-indole **26** (76 mg, 0.156 mmol, 1 equiv) and $[Ir(OMe)(COD)]_2$ (0.78 mg, 0.0012 mmol, 1.5 mol % Ir) in CD_3OD (253 μL, 6.24 mmol, 40 equiv) and THF (253 μL) at rt for 10 h and worked up as described in the general Ir-

catalyzed deboronation procedure. The crude material was concentrated by rotary evaporation and purified by column chromatography (10% ethyl acetate/hexanes) on silica gel. Deuterated indole **27** was isolated as a colorless oil (44 mg, 78%). ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.45 (dd, *J* = 8.8, 5.9 Hz, 0.16 H), 7.41 (d, *J* = 3.4 Hz, 1 H), 6.94 (d, *J* = 9.3 Hz, 1 H), 6.49 (d, *J* = 3.4 Hz, 1 H), 1.63 (s, 9 H, 3 C*H*$_3$ of Boc), 1.46 (s, 12 H, 4 C*H*$_3$ of Bpin); ^{13}C NMR ($CDCl_3$, 125 MHz): δ 164.1 (d, *J* = 237 Hz), 150.0, 125.8, 125.0 (d, *J* = 3.8 Hz), 110.7 (d, *J* = 27.7 Hz), 107.7, 84.0 (3 C), 28.2 (3 CH_3 of Boc), 25.6 (4 CH_3 of Bpin); ^{11}B NMR ($CDCl_3$, 160 MHz): 28.4; FT-IR (neat) $\tilde{\nu}_{max}$: 3439, 2978, 1724, 1601, 1541, 1353, 1257, 1151, 1093, 984, 854, 736, 613 cm^{-1}; LRMS (ESI): *m/z* calculated for $C_{19}H_{25}DBFNO_4$ $[M+H]^+$ 363.19, found 363.2. Percent deuterium incorporation (based on quantitative ^{1}H NMR): 84%

Preparation of 1-(3-(2-(dimethylamino)ethyl)-7-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-1H-indol-5-yl)-N-methylmethanesulfonamide (29) via Scheme 5. In a glove box a 20 mL vial equipped with a magnetic stirring bar was charged with sumatriptan **28** (200 mg, 0.677 mmol, 1 equiv) and B_2pin_2 (344 mg, 1.354 mmol, 2 equiv). A separate vial was charged with $[Ir(OMe)(COD)]_2$ (11.2 mg, 0.017 mmol, 5.0 mol % Ir) and dtbpy (9.1 mg, 0.034 mmol, 5.0 mol %). THF (1 mL) was added to the vial containing dtbpy, and after mixing for 1 min the resulting solution was transferred to the vial containing the sumatriptan substrate. Additional THF (5 mL) was used to wash, and the washings were transferred to the sumatriptan substrate vial which was then sealed and stirred at 80°C. After 16 h, the reaction mixture was cooled to room temperature and removed from the glove box. Poly(styrene)-bound bipyridine (70 mg, Sigma-Aldrich; 100-200 mesh, 1.0-2.0 mmol/g loading) was added to the reaction mixture, and the solution was stirred for 30 minutes. The mixture was filtered and concentrated under reduced pressure to give the crude 2,7-bis(Bpin)-sumatriptan.

To the above crude 2,7-bis(Bpin)-sumatriptan, $Bi(OAc)_3$ (53.2 mg, 0.135 mmol, 0.2 equiv) and a solvent mixture of CH_3OH (1.64 mL, 40.6 mmol, 60 equiv) and THF (5.2 mL) were added. The vial was sealed and heated to 50 ^oC for 12 hours. The reaction mixture was cooled to room temperature, filtered, and the volatile materials were removed by rotary evaporation. The solution yield was determined by quantitative HPLC to be 85% compared to a pure reference standard. The crude material was purified by supercritical fluid chromatography (SFC) under isocratic conditions (Chiral ID, 21x250cm, 25% IPA + 0.2% Diethylamine/CO_2, 70mL/min, 35 °C, 100 Bar, 220nm, ~15mg/mL in MeCN). After evaporation of solvents from the pure fractions, **29** was isolated as a solid (80 mg, 28%). ^{1}H NMR (DMSO-d_6, 500 MHz): δ 10.00 (s, 1 H), 7.65 (s, 1 H), 7.44 (s, 1 H), 7.16 (s, 1 H), 6.80 (q, J = 5.3 Hz, 1 H), 4.37 (s, 2 H), 2.81 (t, J = 7.8 Hz, 2 H), 2.54 (d, J = 4.8 Hz, 3 H), 2.49 (m, 2 H), 2.21 (s, 6 H), 1.35 (s, 12 H). ^{13}C NMR (DMSO-d_6, 126 MHz): δ 140.4, 131.7, 127.3, 124.9, 124.3, 120.0, 113.1, 84.1, 60.5, 56.8, 45.6, 29.4, 25.2, 23.5. ^{11}B NMR (DMSO-d_6, 160 MHz): δ 20.0. HRMS (ESI-TOF): *m/z* calculated for $C_{20}H_{33}BN_3O_4S$ $[M+H]^+$ 422.2289, found 422.2296.

IV. Notes on the grade of the solvents impacting reaction times of Bi-catalyzed deboronations.

During the course of our work we determined that the grade of MeOH used in the deborylation significantly impacts the reaction rate.[7] This issue emerged when we explored the deborylation of **6** to **18**. Experiments initially run at MSU required 17 h at 80 ℃ to complete the monodeboronation of the C-2 Bpin. In contrast the same deboronation run in well plates at Merck was complete in 2 h 45 min at rt (Chart S1). Once the nature of the reaction vessels was ruled out as the cause of the rate difference, we tested for differences in the starting material, $Bi(OAc)_3$, MeOH, and THF being used by Merck vs. MSU. Repeating the deboronation of **6**

with different combinations of the Merck vs. MSU materials revealed that the batch of $Bi(OAc)_3$ has little effect on reaction rates. In contrast, when ACS grade MeOH was exchanged for sure sealed anhydrous 99.8% MeOH that was use at Merck the rate of deboryation showed a marked increase.

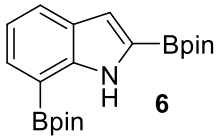
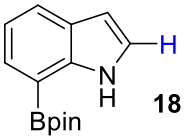
Entry	Starting Indole	Product	Conditions and Yield
1	 **6**	 **18**	MSU: 20 mol % $Bi(OAc)_3$, 125 equiv MeOH, THF, 80 °C, 17 h, 82%[a] Merck: 20 mol % $Bi(OAc)_3$, 40 equiv MeOH, THF, rt, 2 h 45 min

Chart S1. Deboronations of **6** at MSU and Merck

Although not quantified we suspect that common impurities in ACS grade MeOH such as formaldehyde and/ or material that may have leached from the plastic container can slow the reaction. Lastly, while not as pronounced, the rate of deboronation also increased when freshly distilled THF (MSU) was repalced with sure sealed THF (Merck). These results point to $Bi(OAc)_3$ mediated deborylations as being highly dependent upon the quality of the MeOH and somewhat THF dependant.

V. References

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6. Ir-catalyzed borylation of **11** was previously reported to afford **12** and its 5,7-diborylated counterpart in an 85/15 ratio (Lo, W. F.; Kaiser, H. M.; Spannenberg, A.; Beller, M.; Tse, M. K. *Tetrahedron Lett*. **2007**, *48*, 371–375). In our case the 5,7-diborylated product was not observed.

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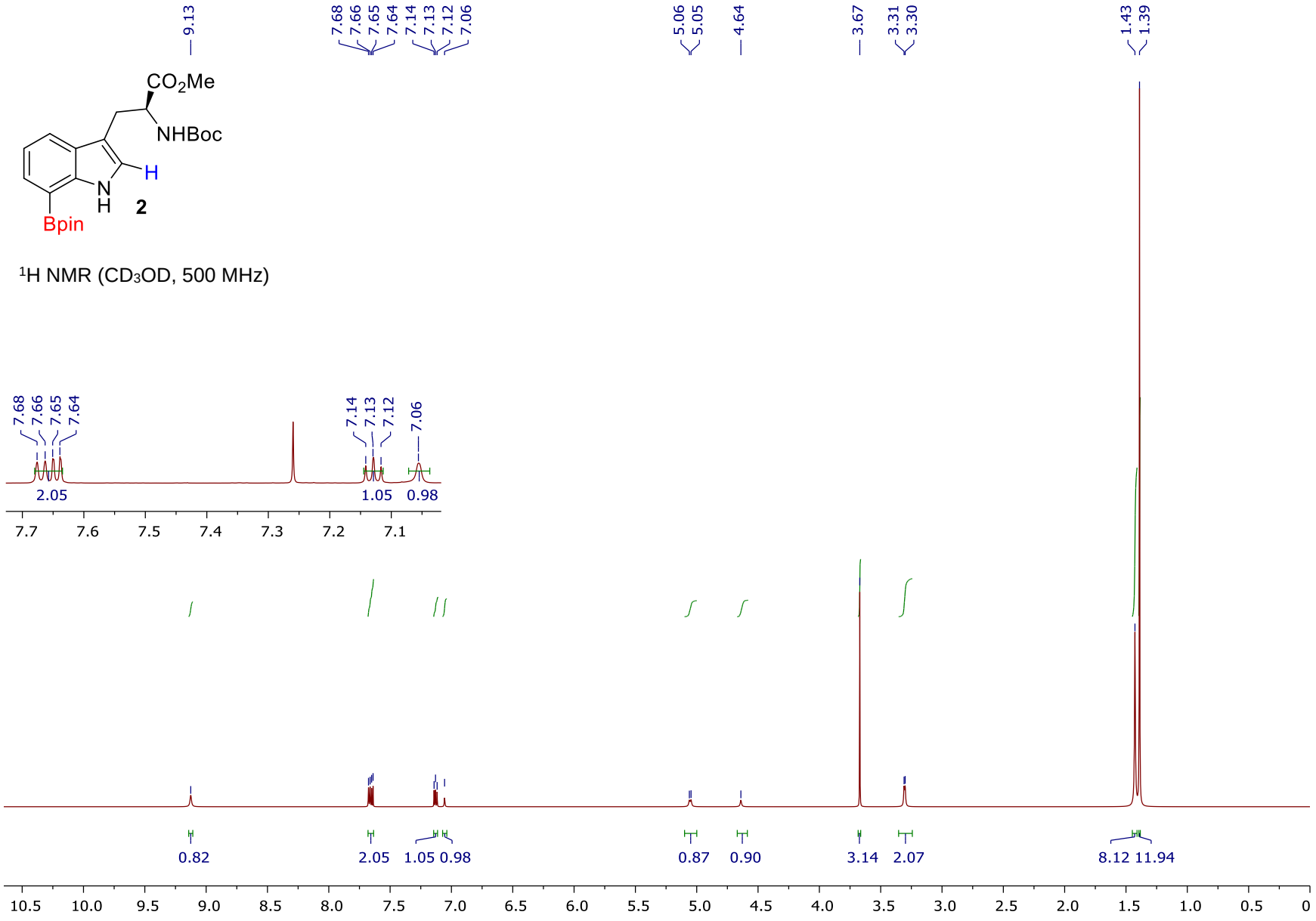
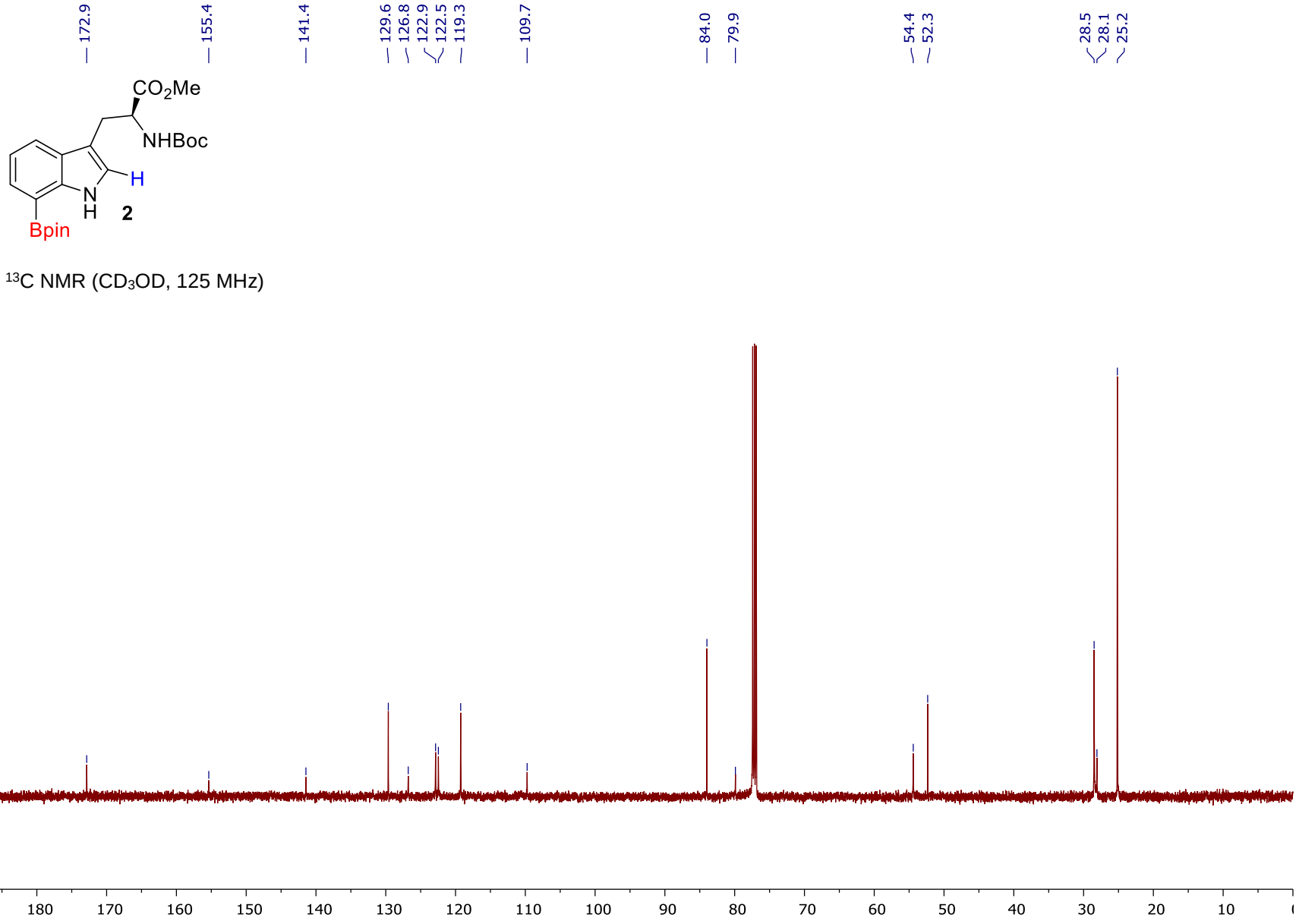
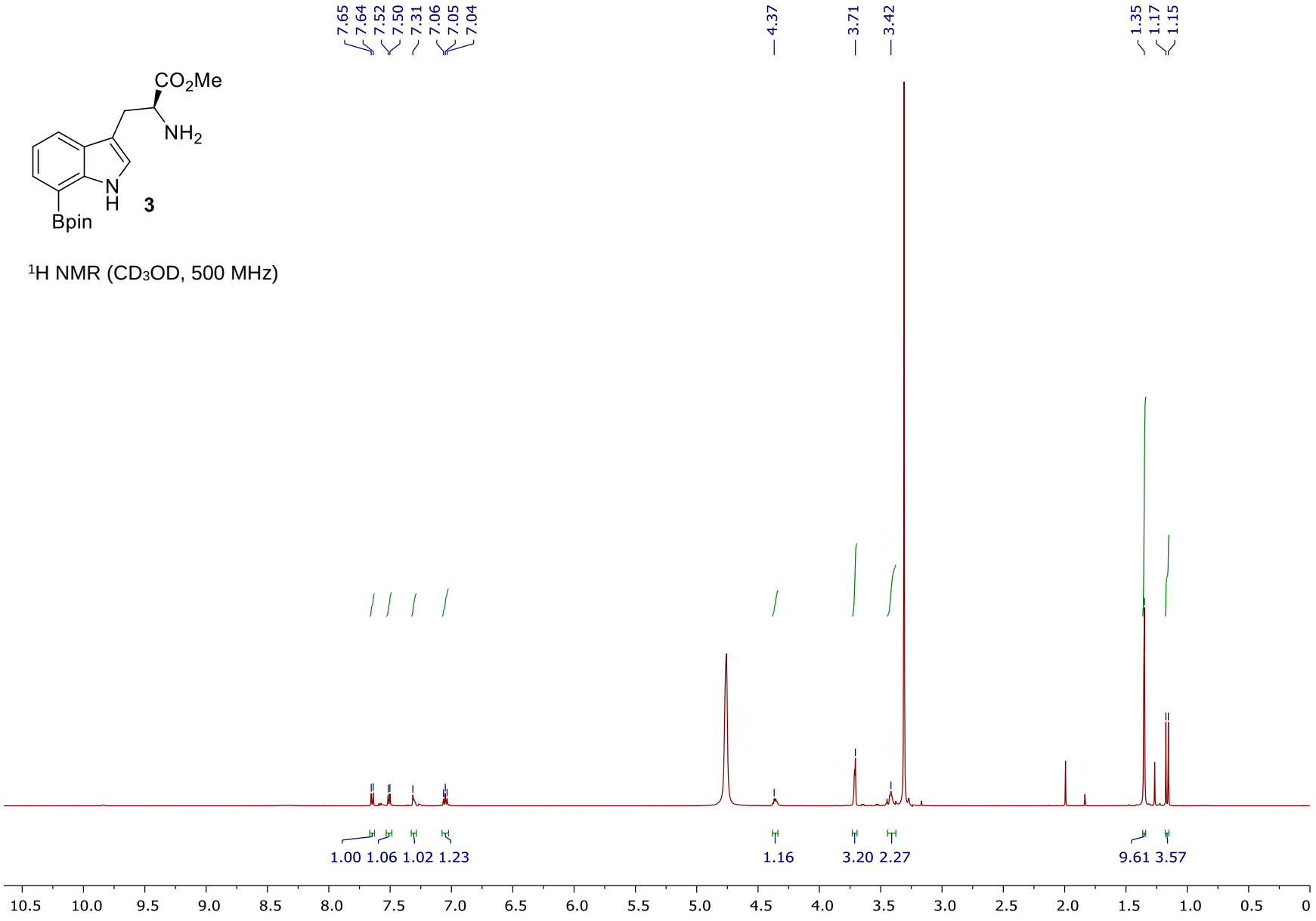
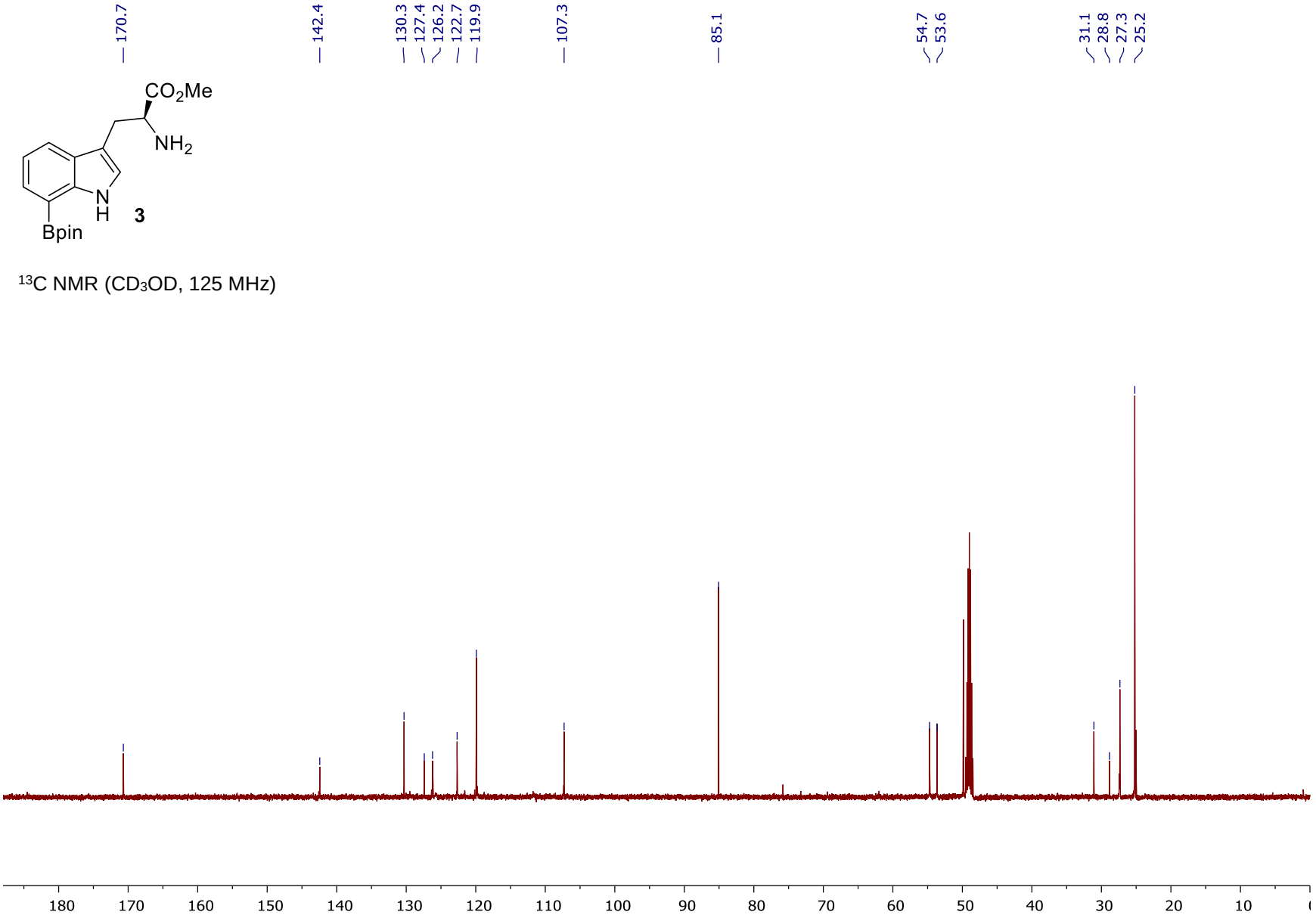
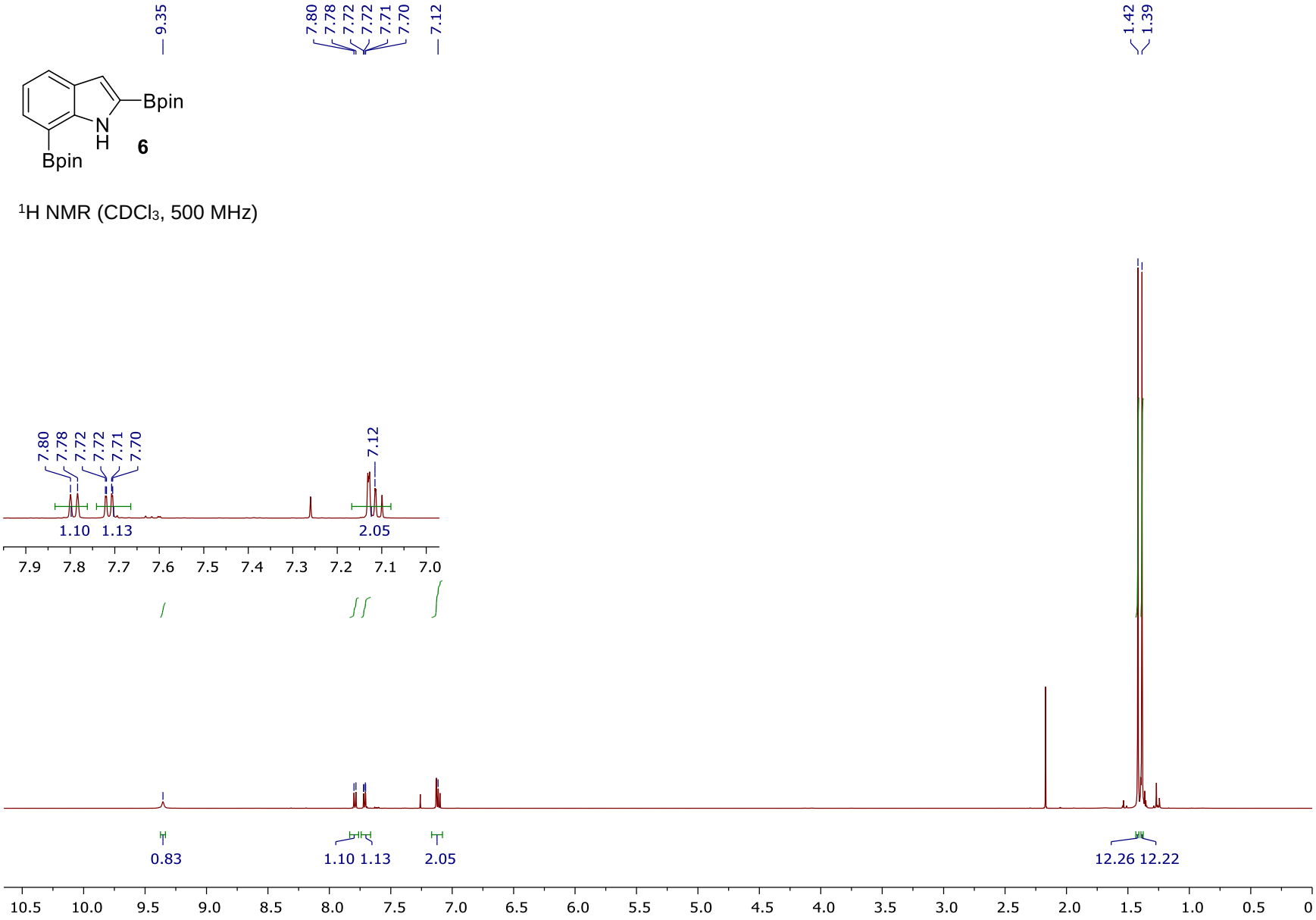

9.13
7.68
7.66
7.65
7.64
7.14
7.13
7.12
7.06
5.06
5.05
4.64
3.67
3.31
3.30
1.43
1.39
CO2Me
NHBoc
H
N
H
2
Bpin
1H NMR (CD3OD, 500 MHz)
2.05
1.05
0.98
0.82
2.05
1.05
0.98
0.87
0.90
3.14
2.07
8.12
11.94


172.9
155.4
141.4
129.6
126.8
122.9
122.5
119.3
109.7
84.0
79.9
54.4
52.3
28.5
28.1
25.2
CO2Me
NHBoc
H
N
H
Bpin
2
13C NMR (CD3OD, 125 MHz)
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10

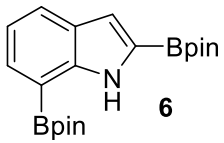

7.65
7.64
7.52
7.50
7.31
7.06
7.05
7.04
4.37
3.71
3.42
1.35
1.17
1.15
CO2Me
NH2
N
H
Bpin
3
1H NMR (CD3OD, 500 MHz)
1.00 1.06 1.02 1.23
1.16
3.20 2.27
9.61 3.57
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0



^{13}C NMR (CD_3OD, 125 MHz)

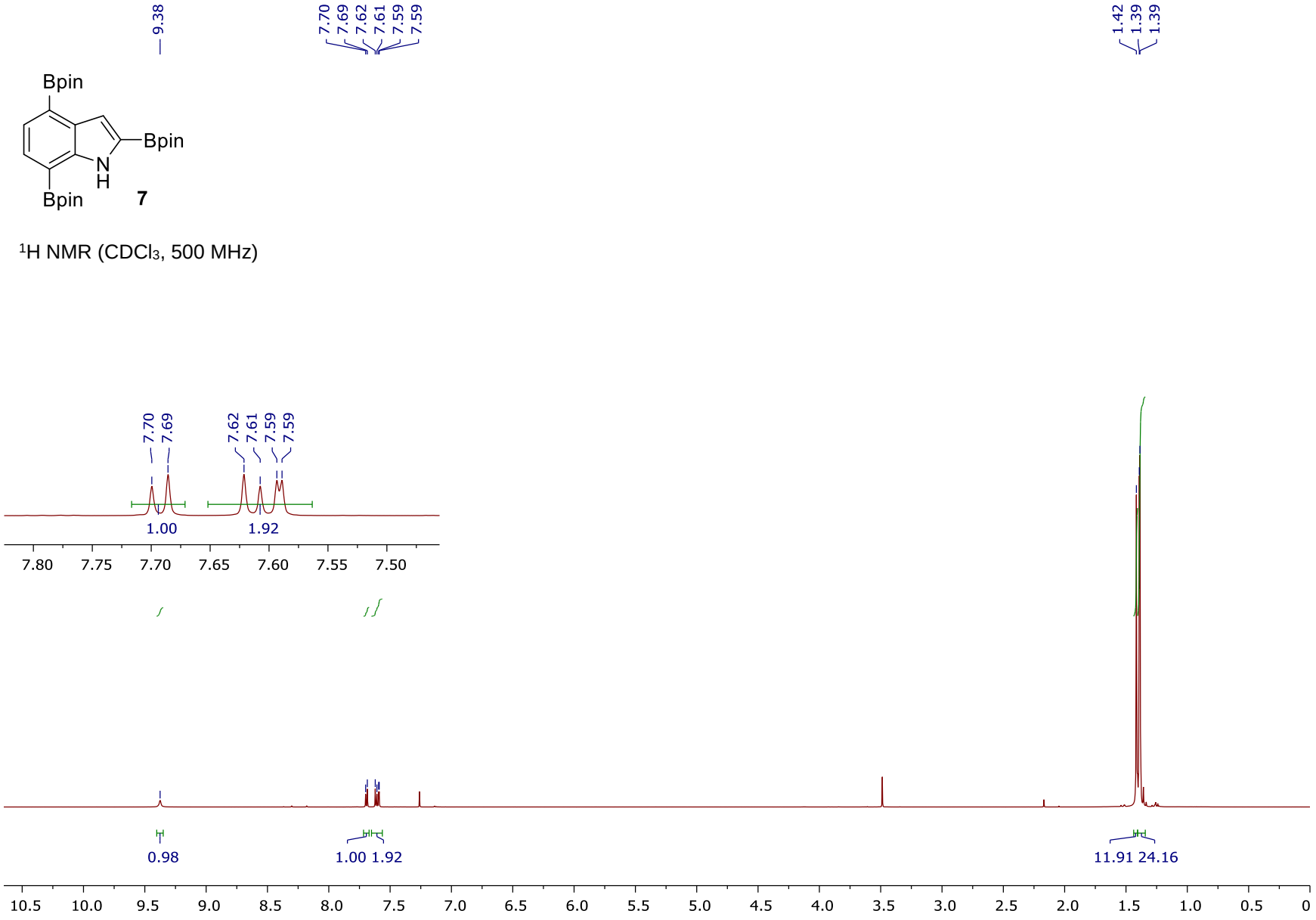


^{1}H NMR ($CDCl_3$, 500 MHz)

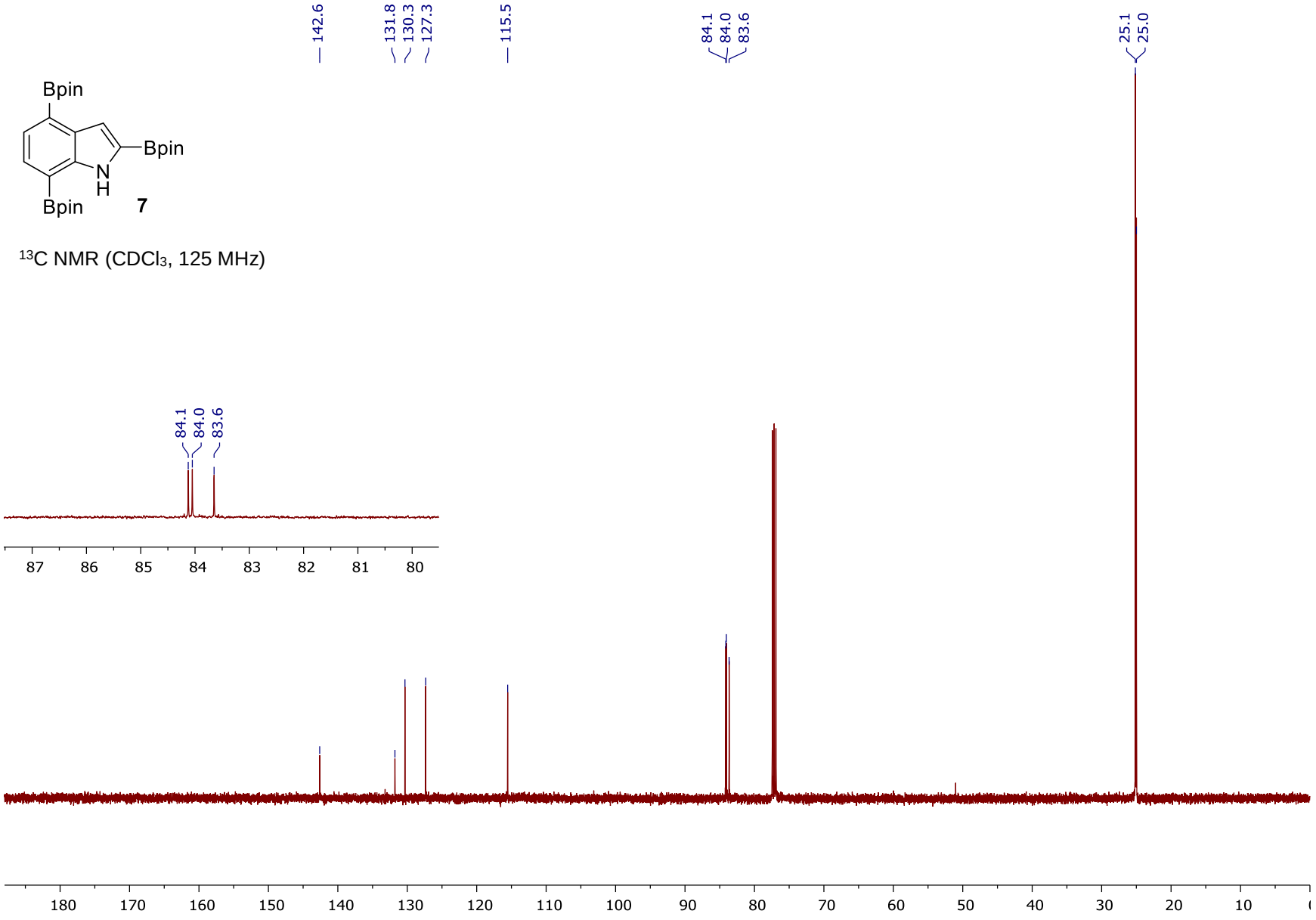


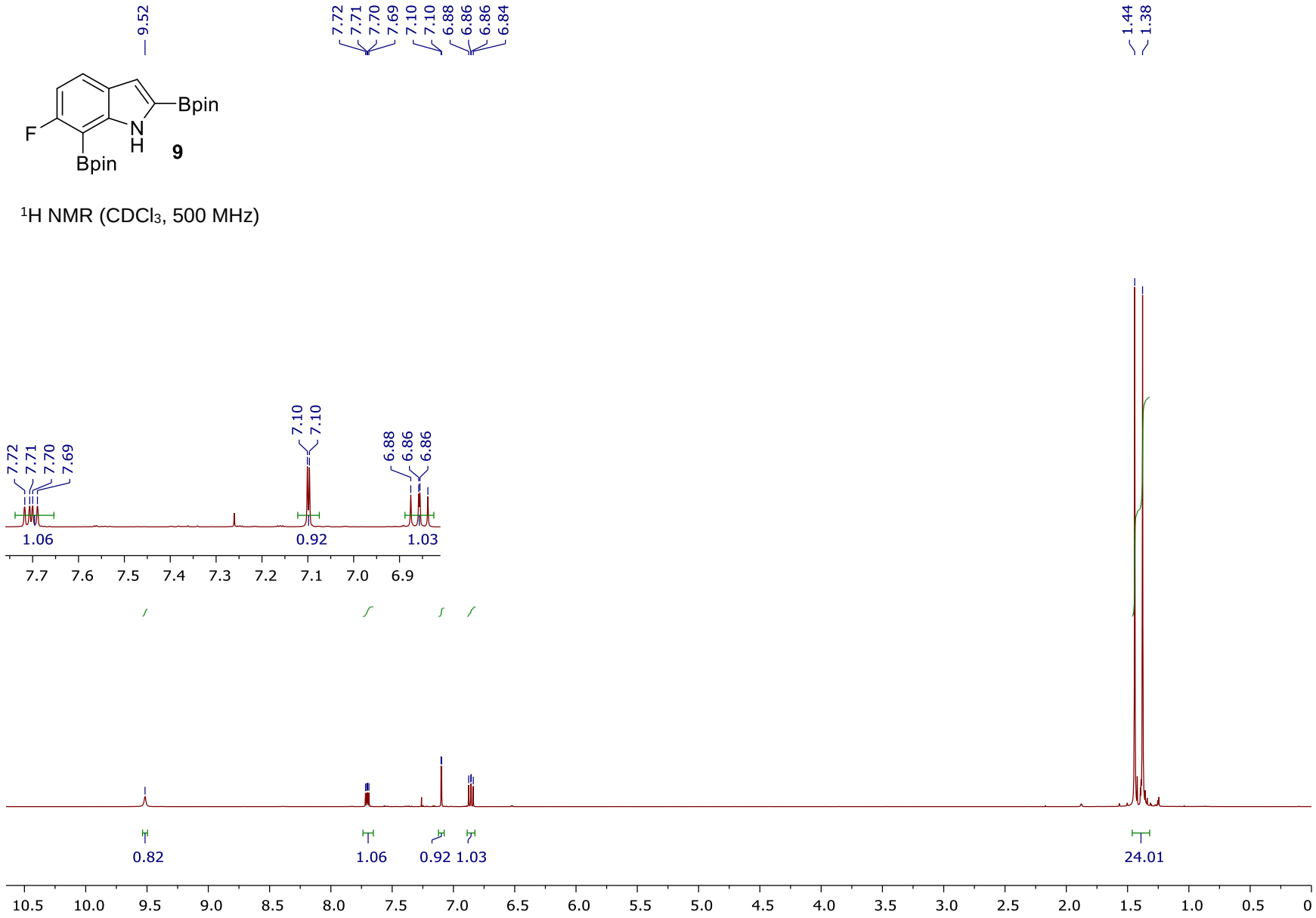
6

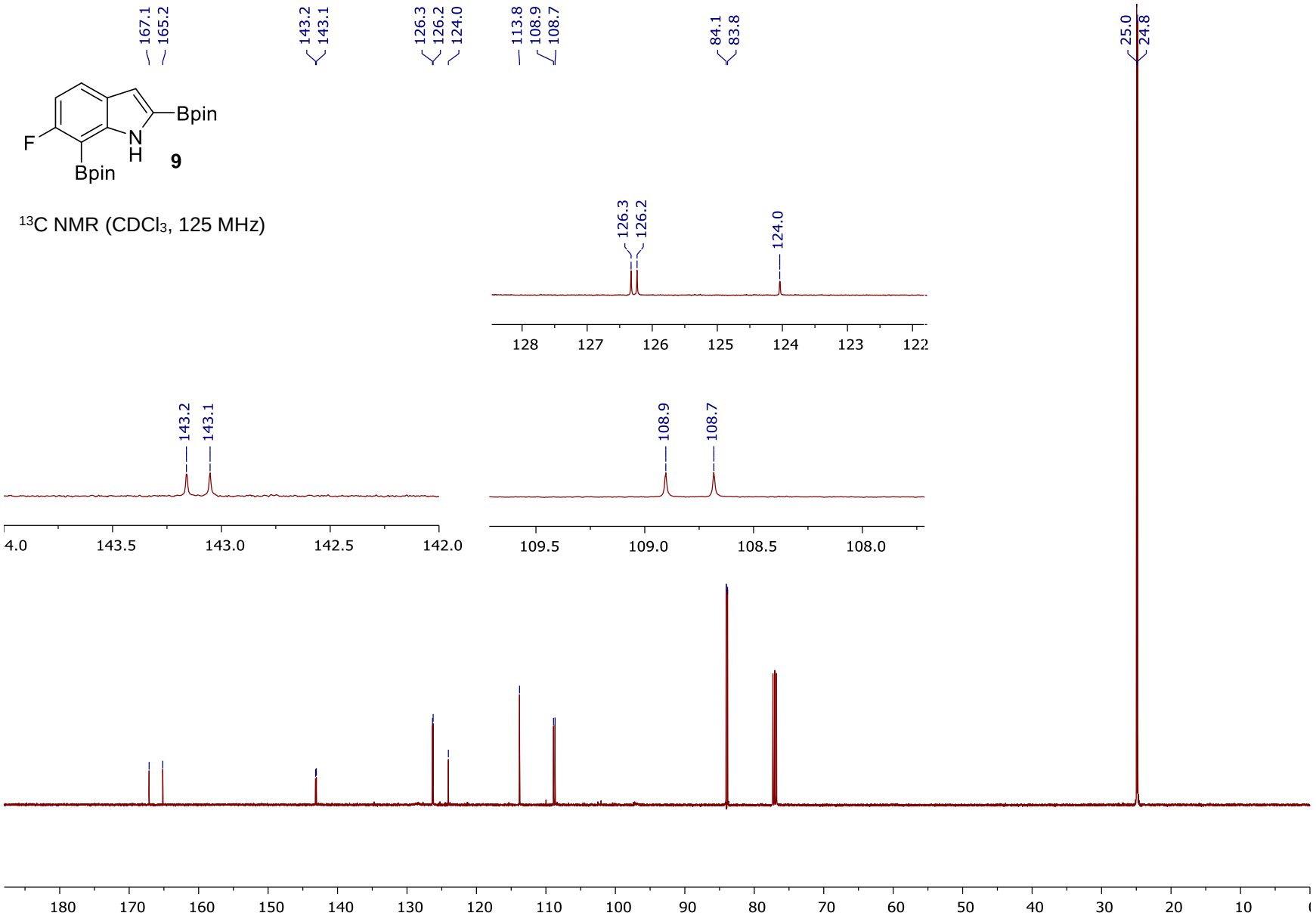
^{13}C NMR ($CDCl_3$, 125 MHz)

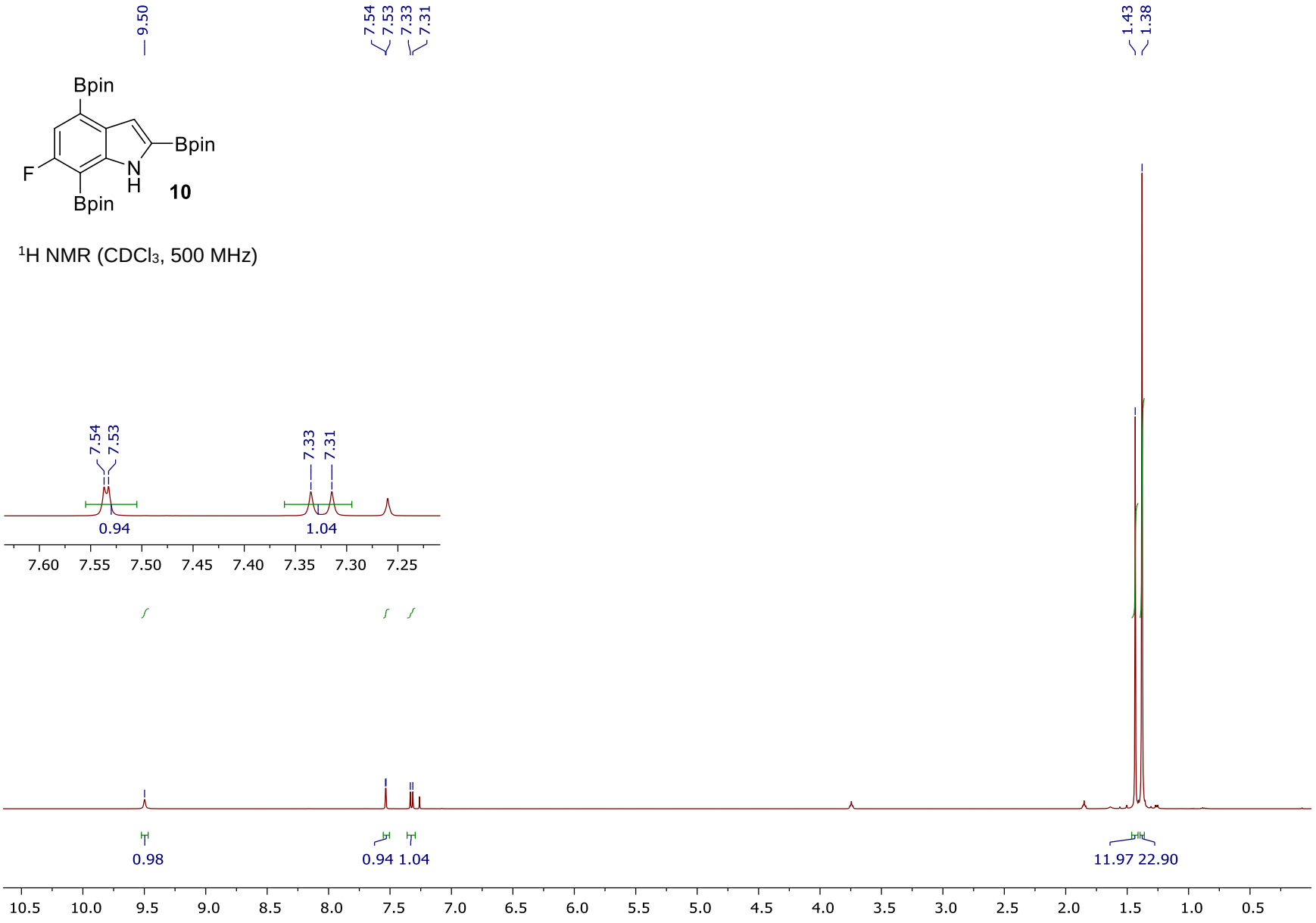


^{1}H NMR ($CDCl_3$, 500 MHz)

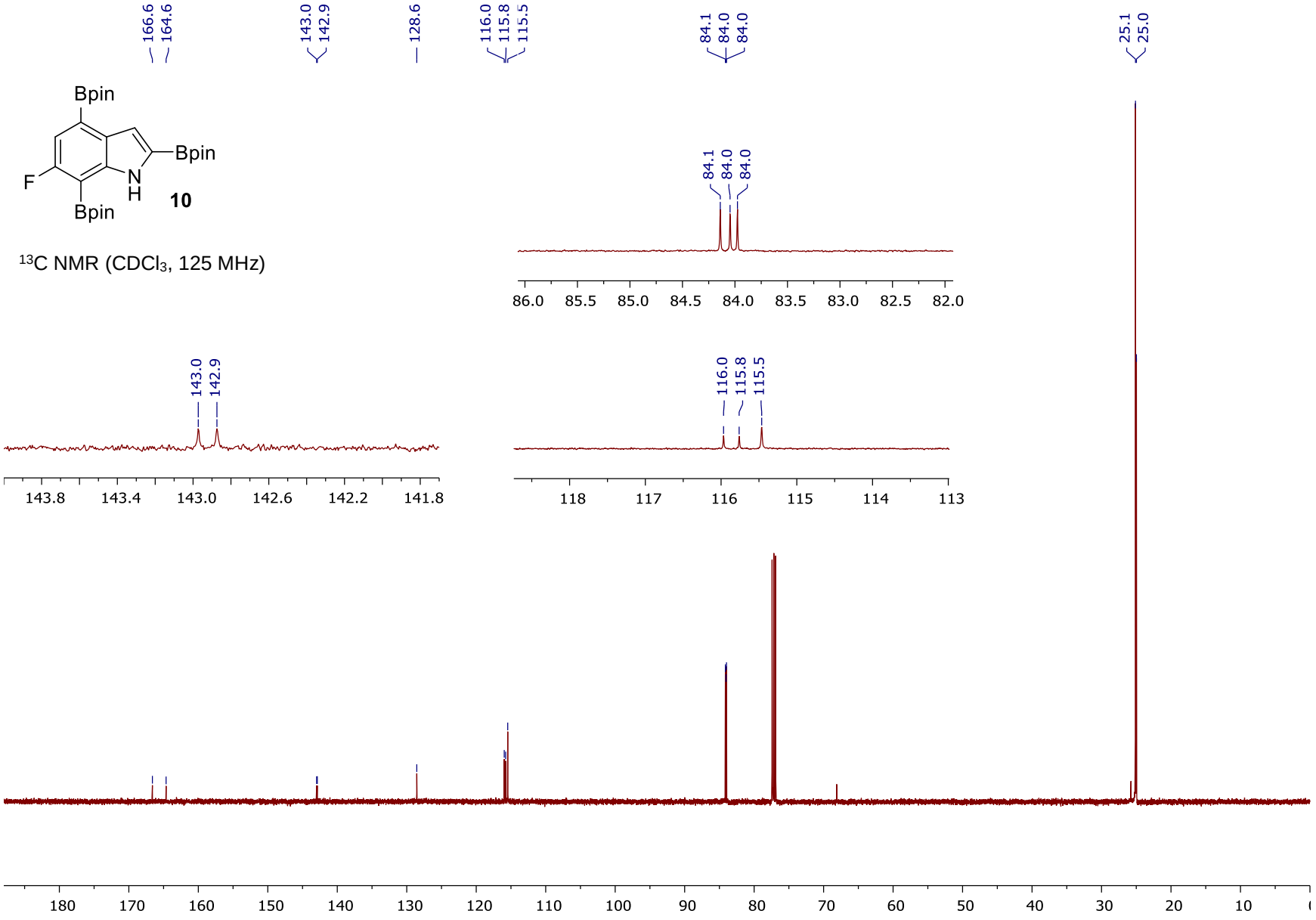

142.6
131.8
130.3
127.3
115.5
84.1
84.0
83.6
25.1
25.0
Bpin
Bpin
Bpin
N
H
7
13C NMR (CDCl3, 125 MHz)
84.1
84.0
83.6
87
86
85
84
83
82
81
80
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10

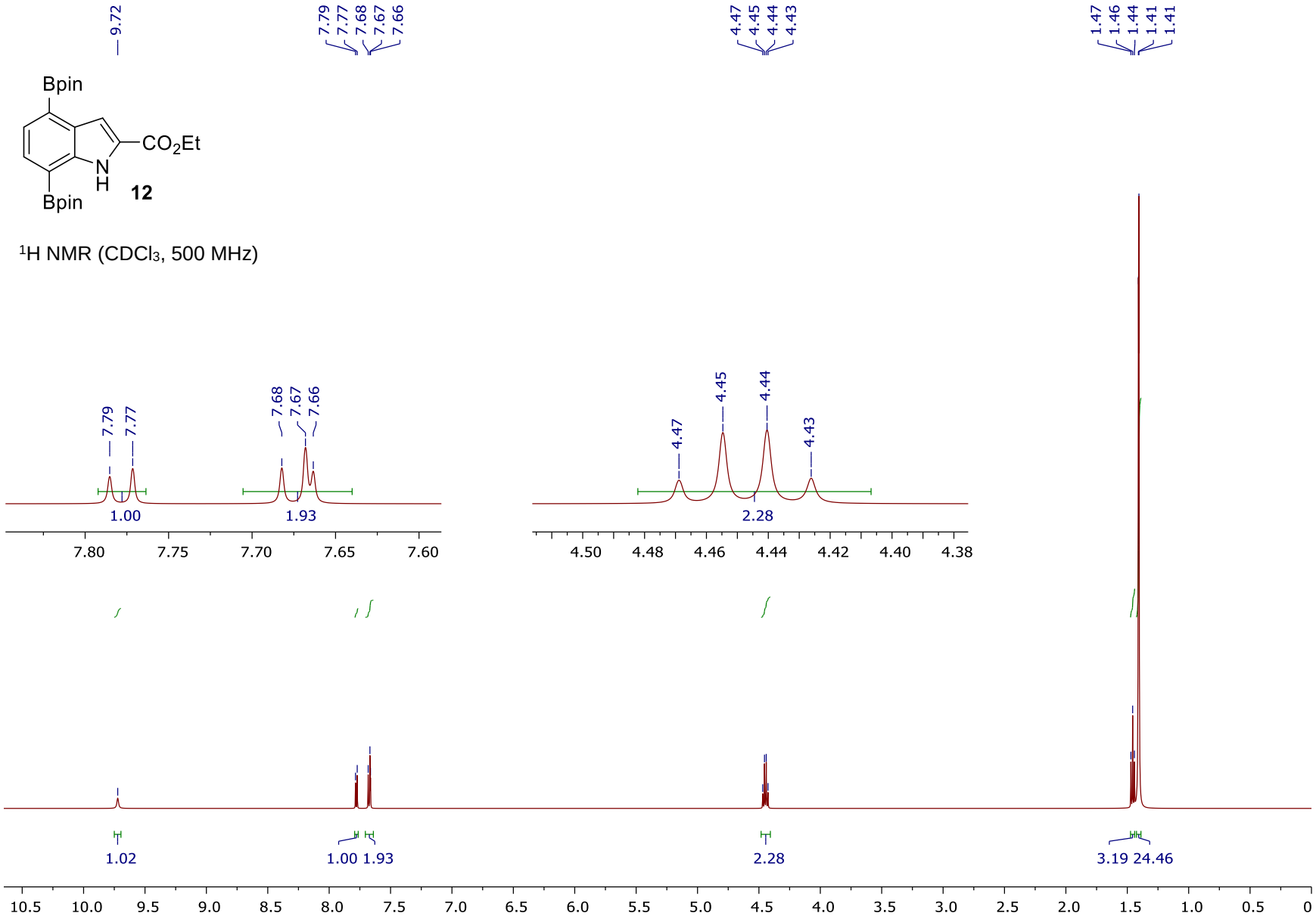

9.52
7.72
7.71
7.70
7.69
7.10
7.10
6.88
6.86
6.86
6.84
1.44
1.38
Bpin
F
N
H
Bpin
9
1H NMR (CDCl3, 500 MHz)
1.06
0.92
1.03
0.82
1.06
0.92
1.03
24.01

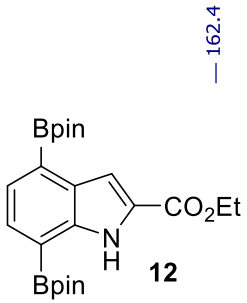

167.1
165.2
143.2
143.1
126.3
126.2
124.0
113.8
108.9
108.7
84.1
83.8
25.0
24.8
F
Bpin
N
H
Bpin
9
^{13}C NMR ($CDCl_3$, 125 MHz)
126.3
126.2
124.0
128
127
126
125
124
123
122
143.2
143.1
143.5
143.0
142.5
142.0
108.9
108.7
109.5
109.0
108.5
108.0
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10



^{1}H NMR ($CDCl_3$, 500 MHz)

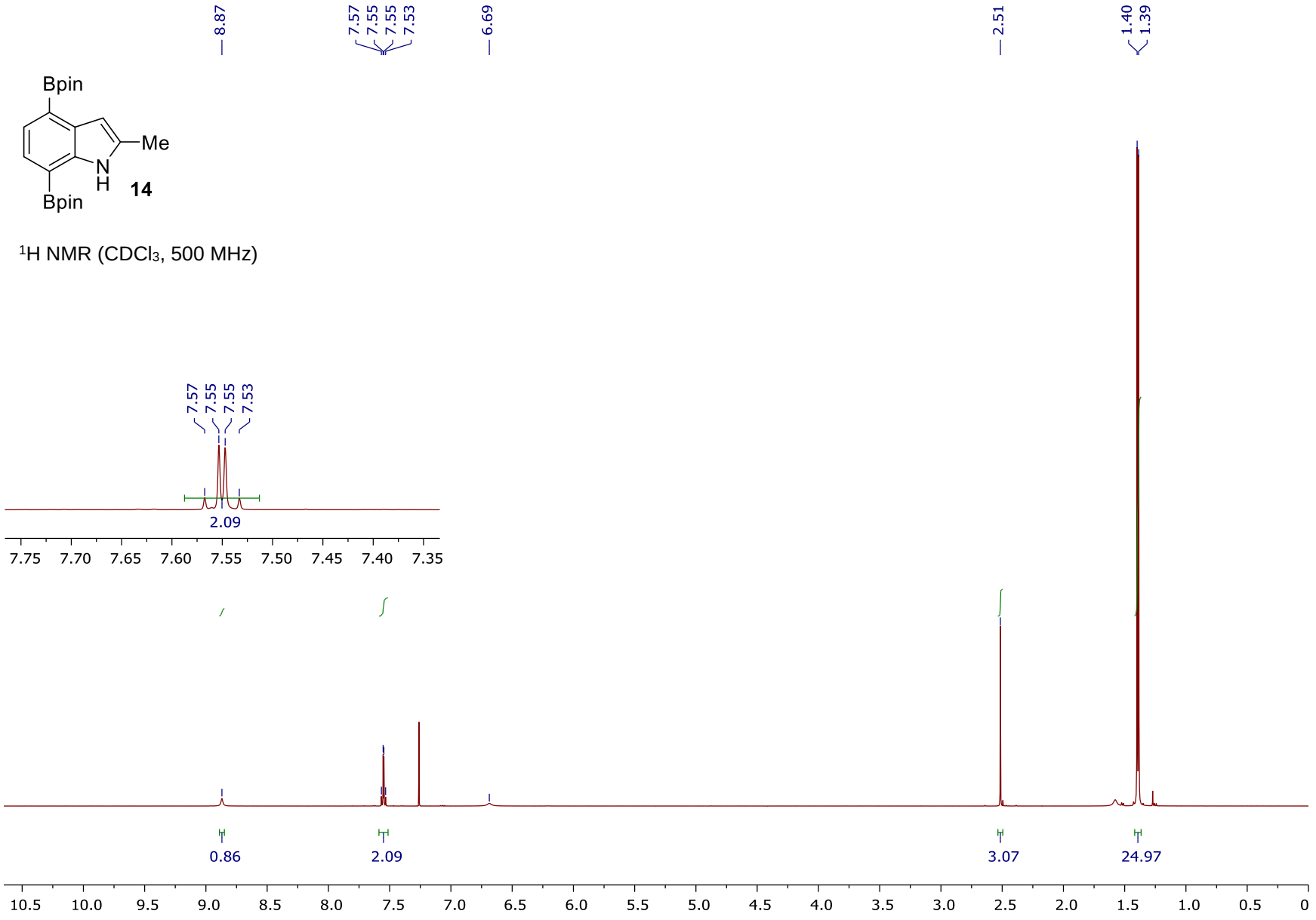

166.6
164.6
143.0
142.9
128.6
116.0
115.8
115.5
84.1
84.0
84.0
25.1
25.0
Bpin
Bpin
F
N
H
Bpin
10
^{13}C NMR ($CDCl_3$, 125 MHz)
84.1
84.0
84.0
86.0
85.5
85.0
84.5
84.0
83.5
83.0
82.5
82.0
143.0
142.9
143.8
143.4
143.0
142.6
142.2
141.8
116.0
115.8
115.5
118
117
116
115
114
113
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10

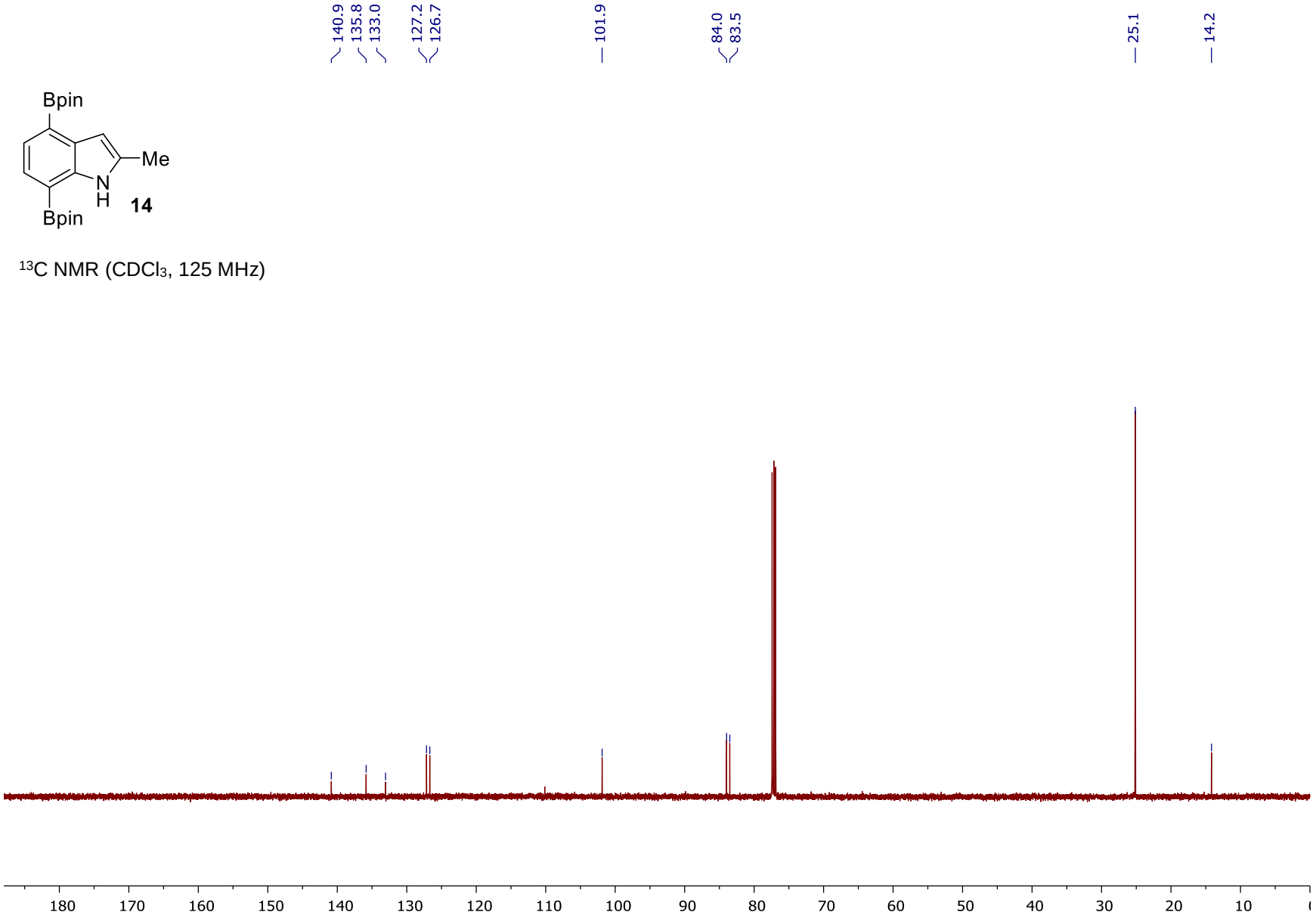

9.72
7.79
7.77
7.68
7.67
7.66
4.47
4.45
4.44
4.43
1.47
1.46
1.44
1.41
1.41
Bpin
CO2Et
N
H
Bpin
12
1H NMR (CDCl3, 500 MHz)
1.00
1.93
2.28
1.02
1.00 1.93
2.28
3.19 24.46



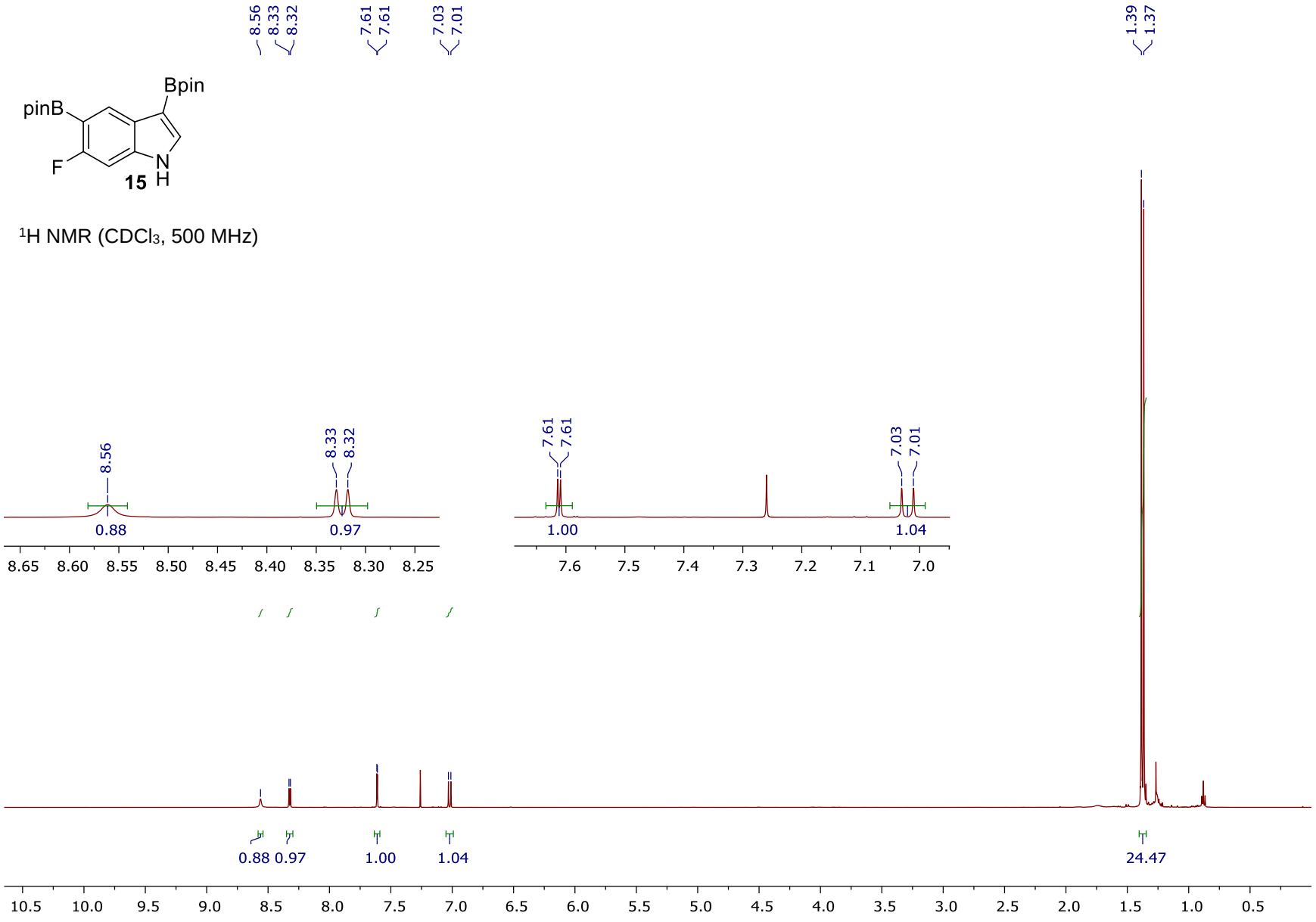
12

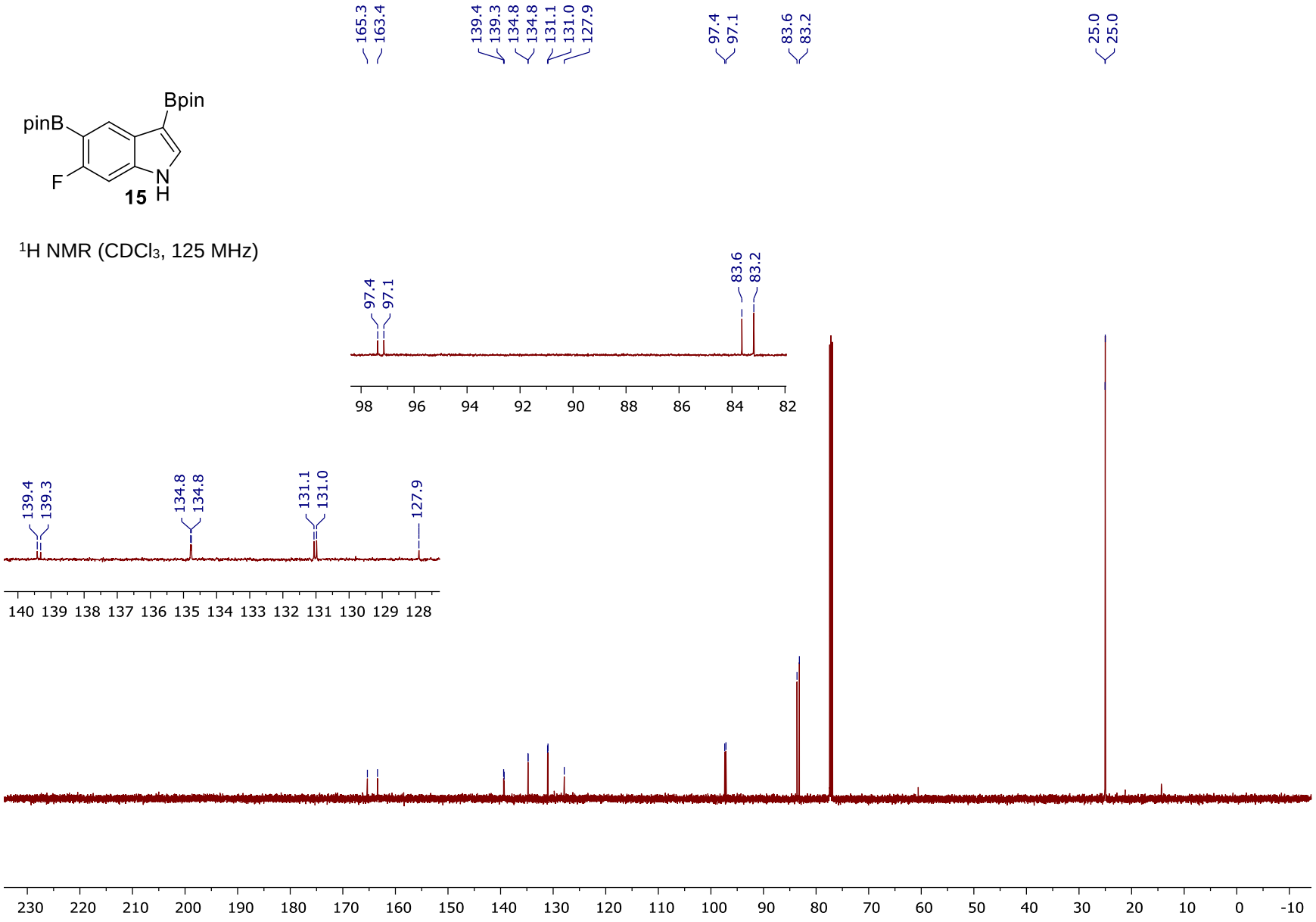
^{13}C NMR ($CDCl_3$, 125 MHz)


8.87
7.57
7.55
7.55
7.53
6.69
2.51
1.40
1.39
Bpin
Me
N
H
Bpin
14
1H NMR (CDCl3, 500 MHz)
2.09
0.86
2.09
3.07
24.97

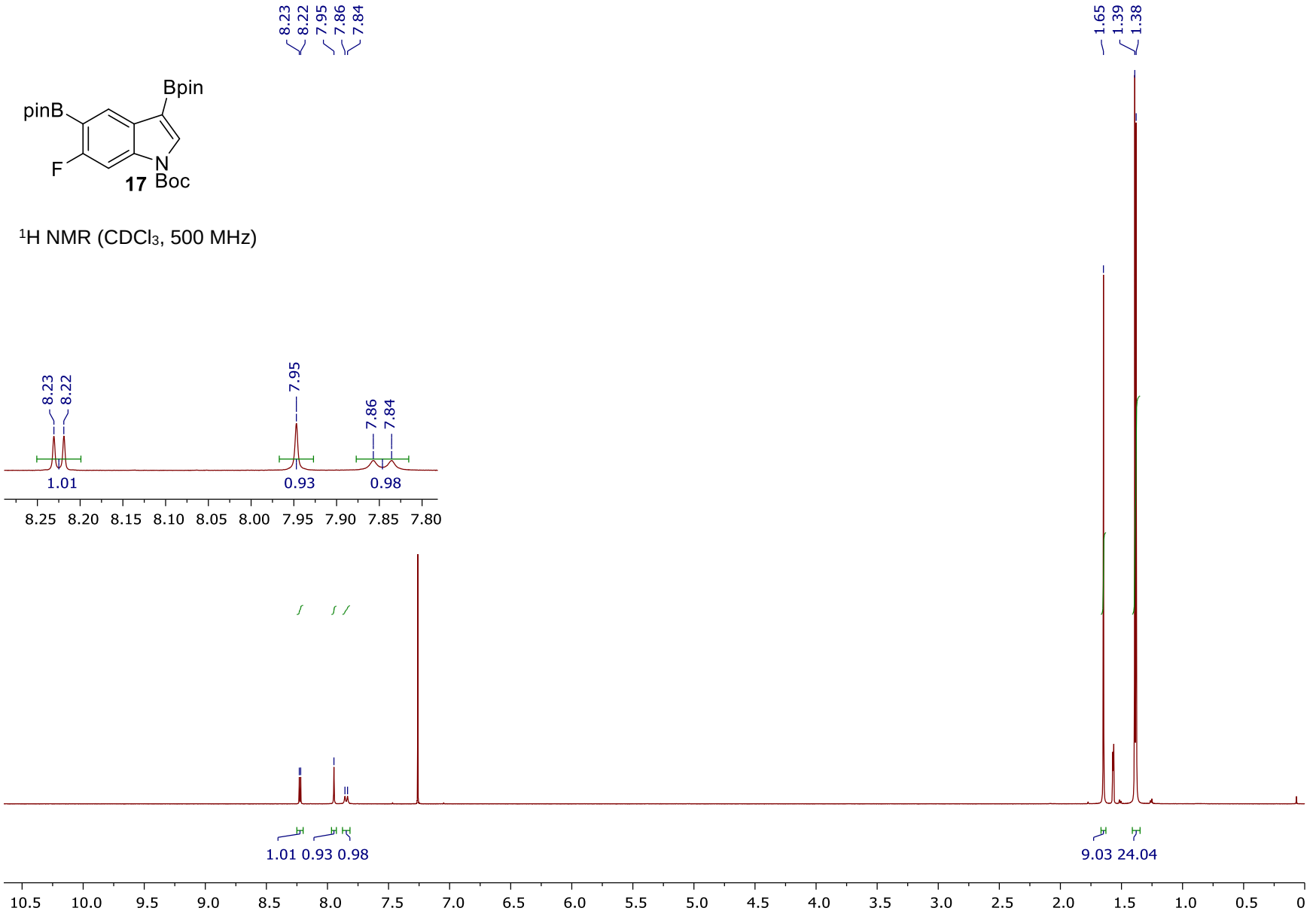


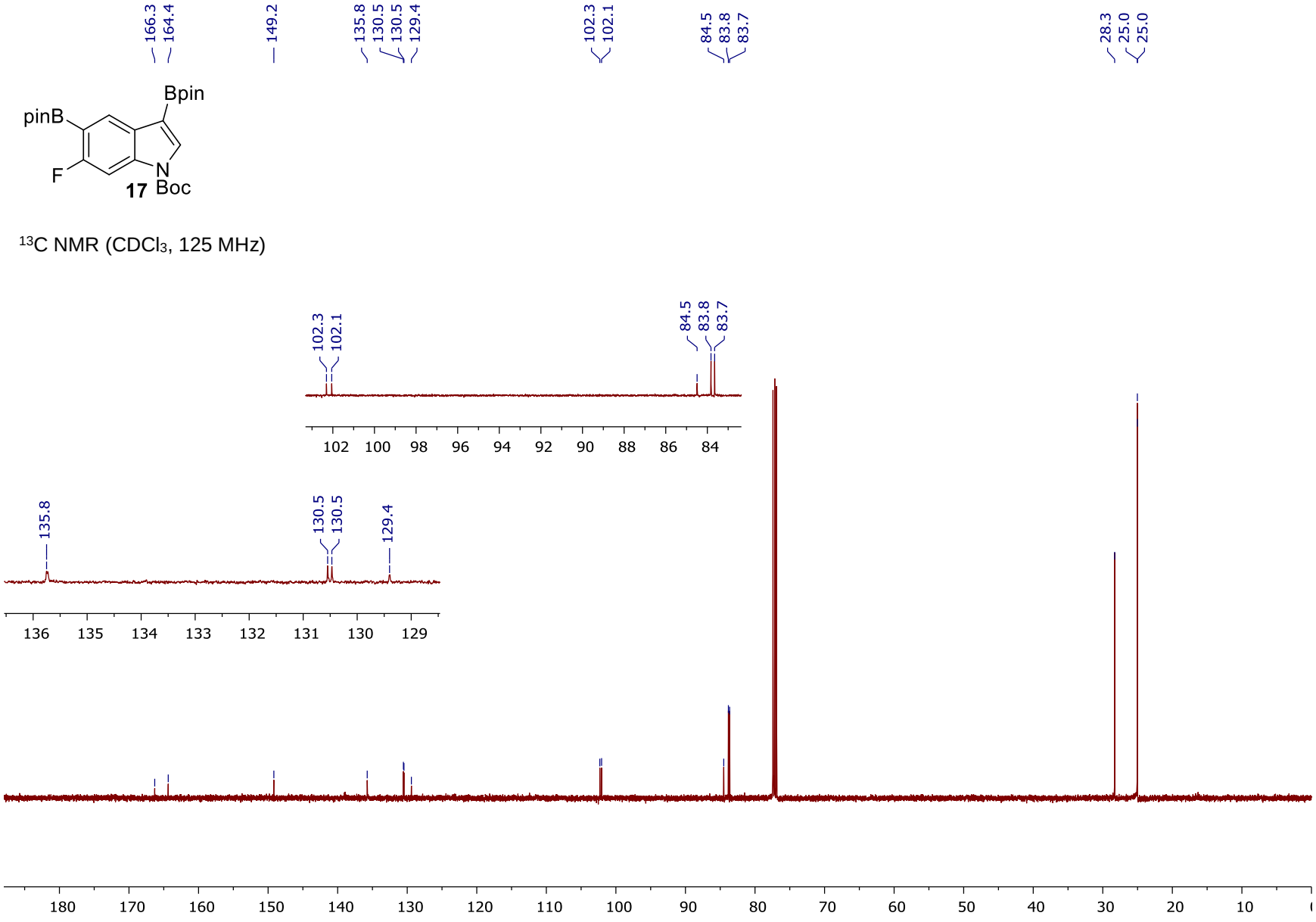
^{13}C NMR ($CDCl_3$, 125 MHz)

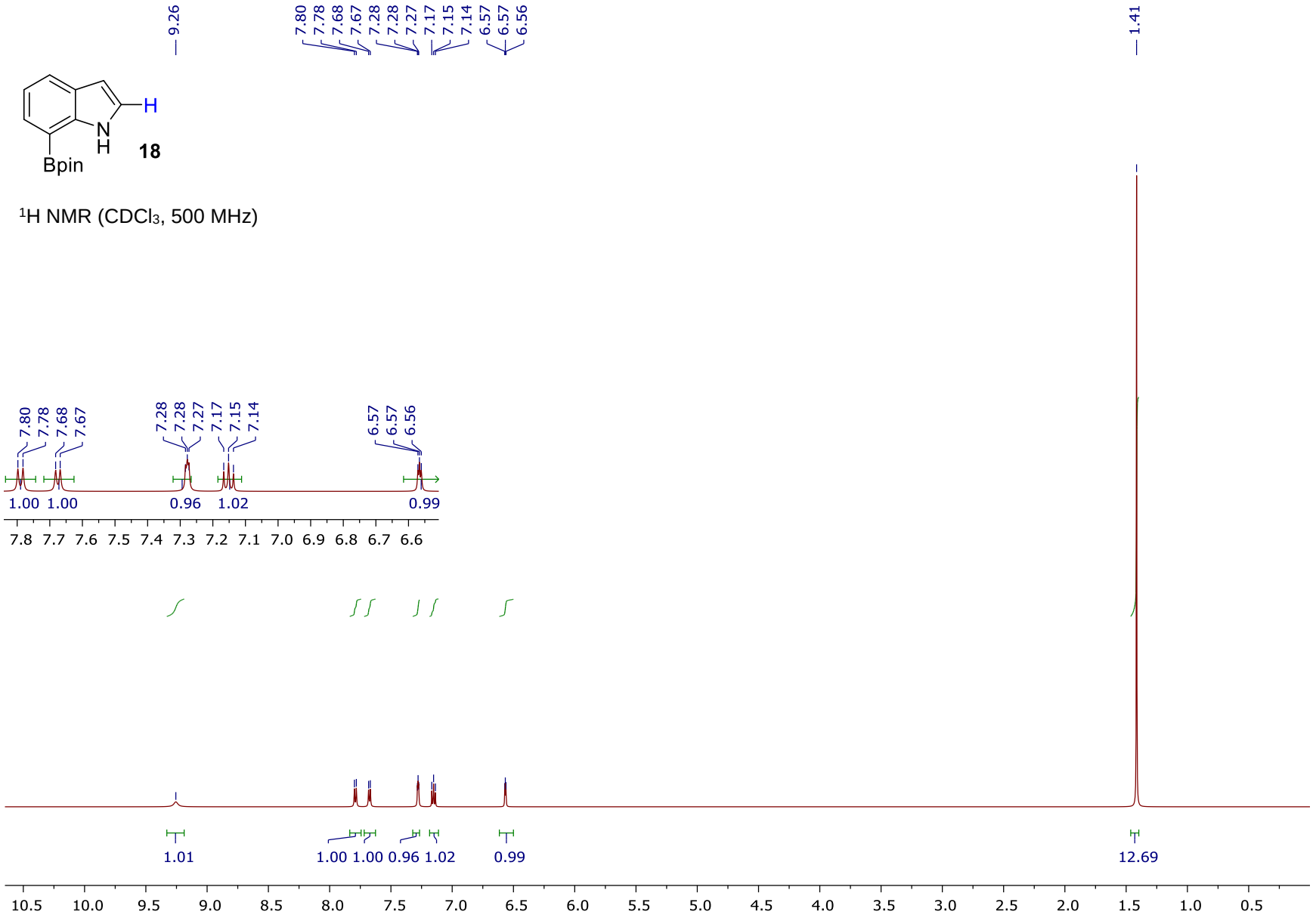

8.56
8.33
8.32
7.61
7.61
7.03
7.01
1.39
1.37
Bpin
pinB
F
N
H
15
1H NMR (CDCl3, 500 MHz)
0.88
0.97
1.00
1.04
24.47

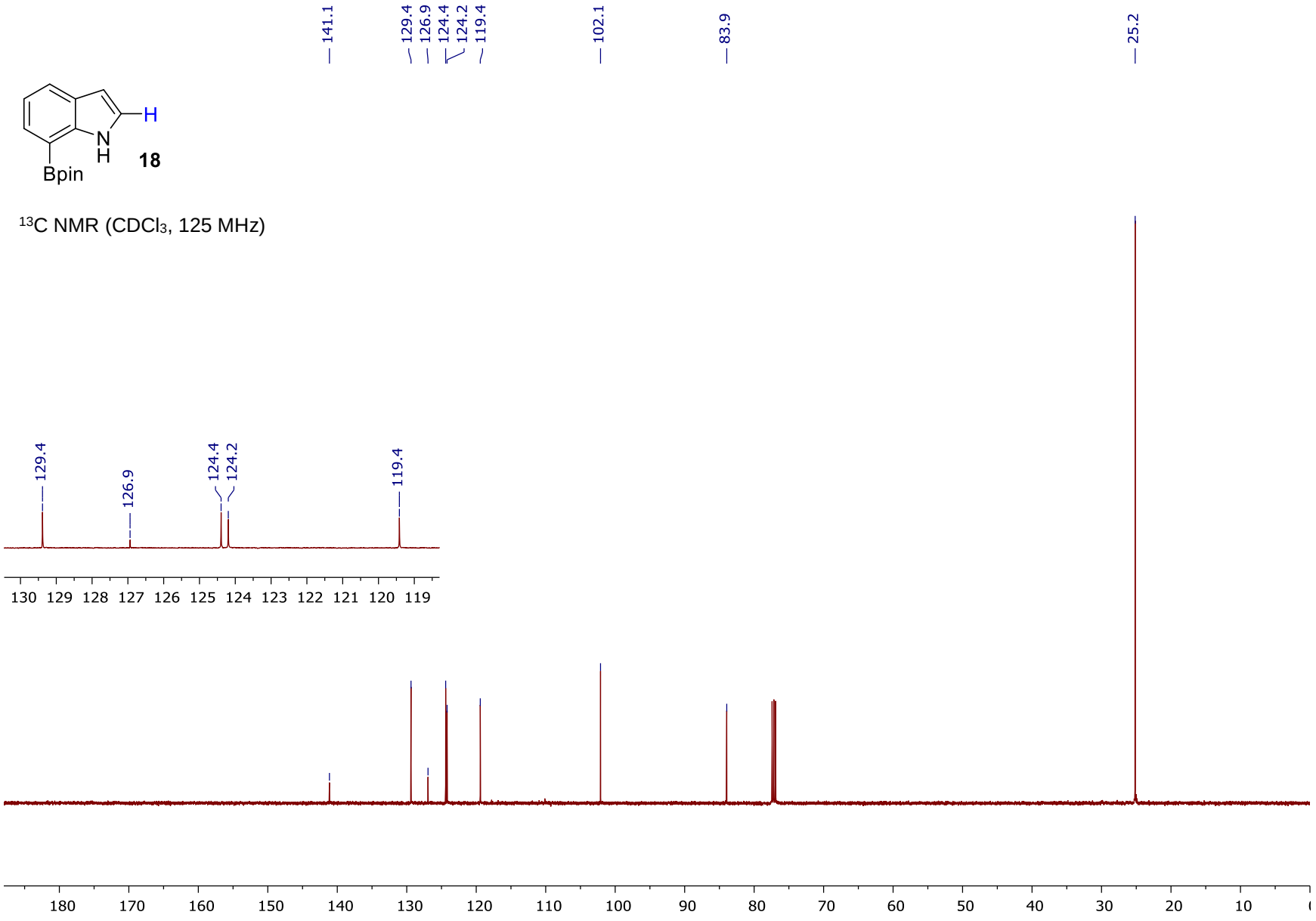


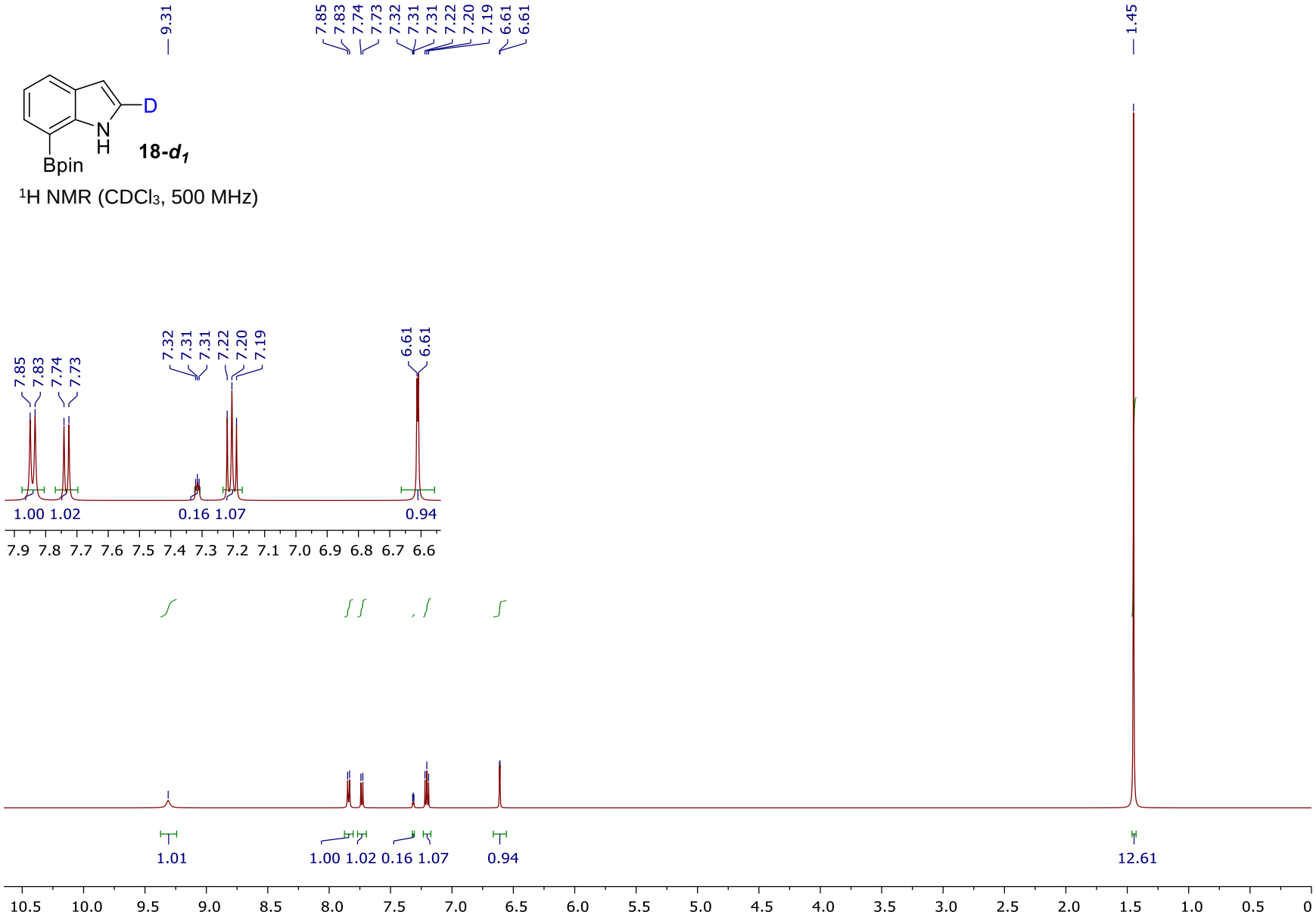
^{1}H NMR ($CDCl_3$, 125 MHz)

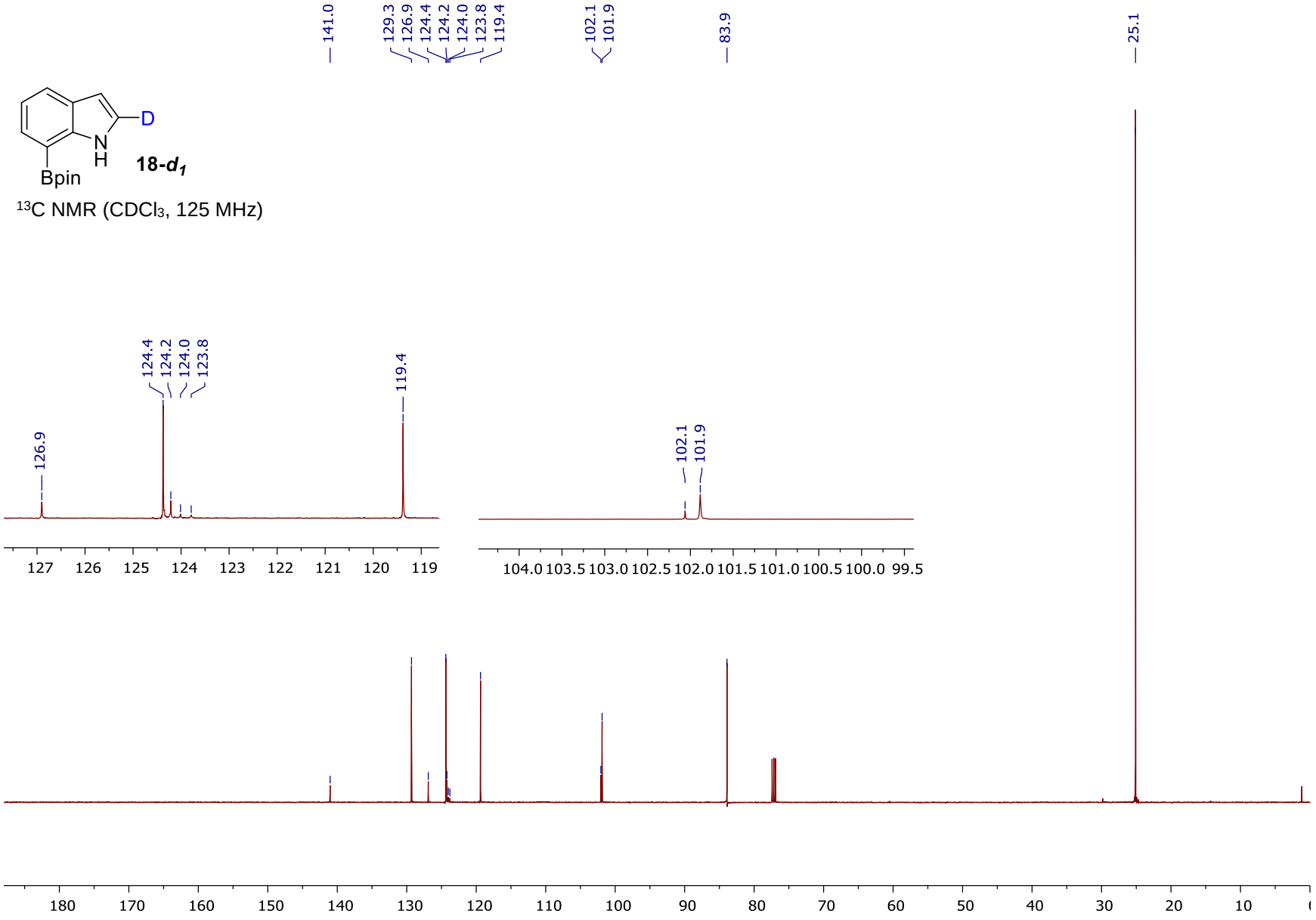

8.23
8.22
7.95
7.86
7.84
1.65
1.39
1.38
Bpin
pinB
F
N
Boc
17
1H NMR (CDCl3, 500 MHz)
1.01
0.93
0.98
9.03
24.04

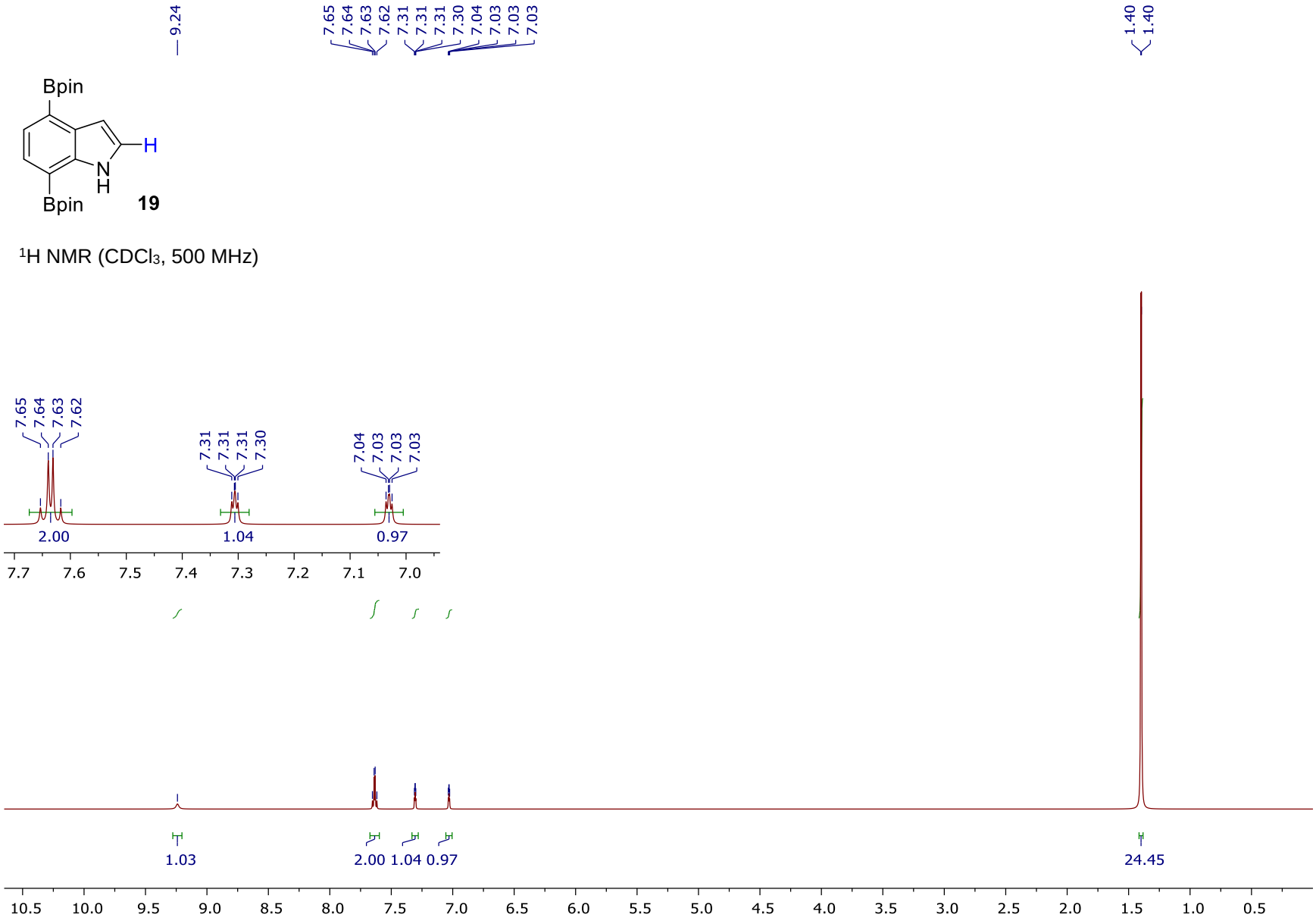

166.3
164.4
149.2
135.8
130.5
130.5
129.4
102.3
102.1
84.5
83.8
83.7
28.3
25.0
25.0
Bpin
pinB
F
N
Boc
17
13C NMR (CDCl3, 125 MHz)
102.3
102.1
84.5
83.8
83.7
135.8
130.5
130.5
129.4

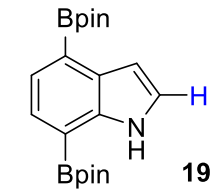

9.26
7.80
7.78
7.68
7.67
7.28
7.28
7.27
7.17
7.15
7.14
6.57
6.57
6.56
1.41
H
N
H
Bpin
18
1H NMR (CDCl3, 500 MHz)
1.00 1.00 0.96 1.02 0.99
1.01 1.00 1.00 0.96 1.02 0.99 12.69


141.1
129.4
126.9
124.4
124.2
119.4
102.1
83.9
25.2
H
N
H
Bpin
18
^{13}C NMR ($CDCl_3$, 125 MHz)
129.4
126.9
124.4
124.2
119.4
130 129 128 127 126 125 124 123 122 121 120 119
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10


9.31
7.85
7.83
7.74
7.73
7.32
7.31
7.31
7.22
7.20
7.19
6.61
6.61
1.45
D
N
H
Bpin
18-d1
1H NMR (CDCl3, 500 MHz)
1.00 1.02
0.16 1.07
0.94
1.01
12.61

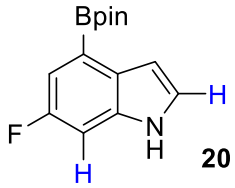

141.0
129.3
126.9
124.4
124.2
124.0
123.8
119.4
102.1
101.9
83.9
25.1
D
N
H
Bpin
18-d_1
^{13}C NMR ($CDCl_3$, 125 MHz)
126.9
124.4
124.2
124.0
123.8
119.4
102.1
101.9
127 126 125 124 123 122 121 120 119
104.0 103.5 103.0 102.5 102.0 101.5 101.0 100.5 100.0 99.5
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10


9.24
7.65
7.64
7.63
7.62
7.31
7.31
7.31
7.30
7.04
7.03
7.03
7.03
1.40
1.40
Bpin
H
N
H
Bpin
19
1H NMR (CDCl3, 500 MHz)
2.00
1.04
0.97
1.03
2.00 1.04 0.97
24.45



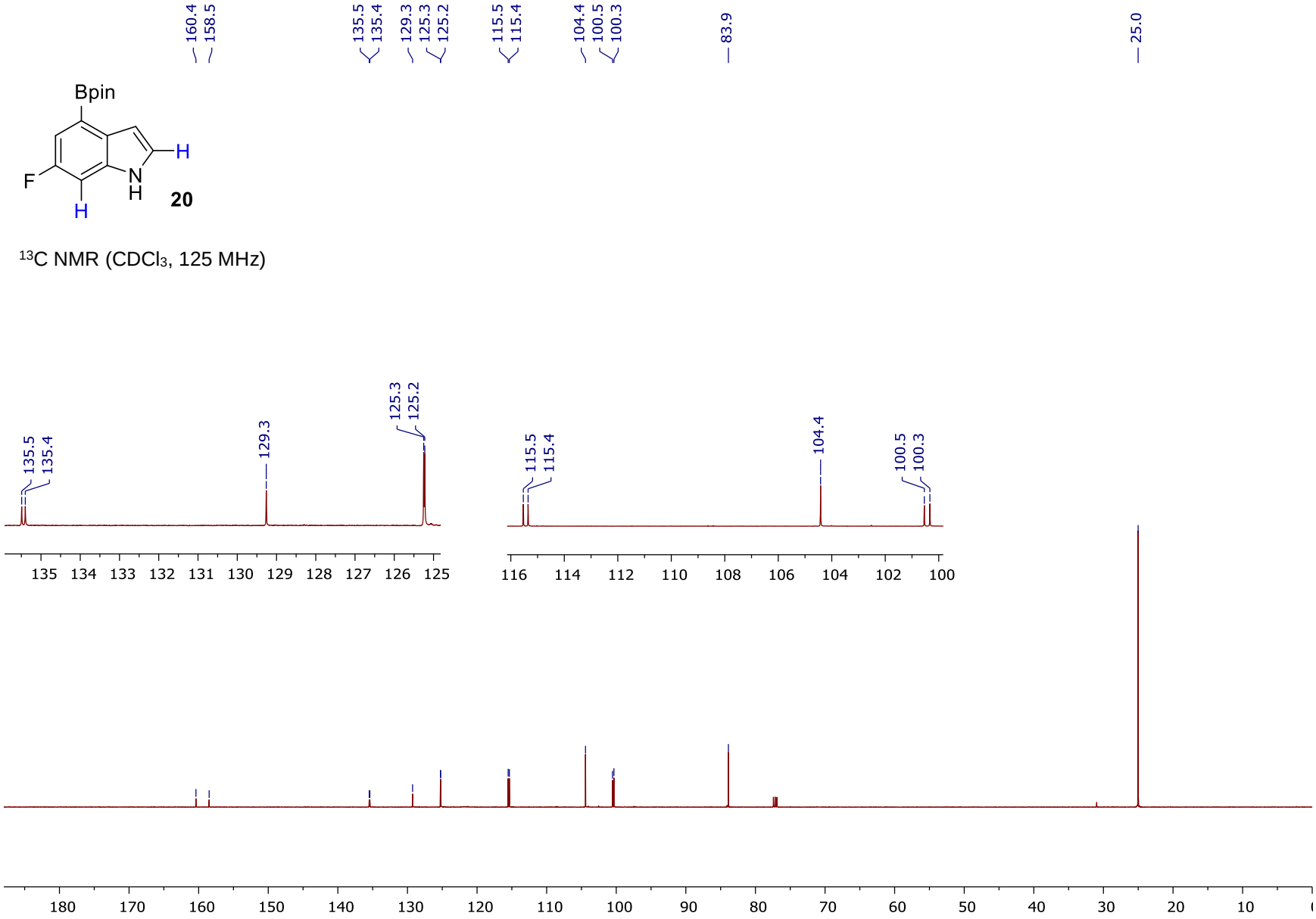
19

^{1}H NMR ($CDCl_3$, 125 MHz)

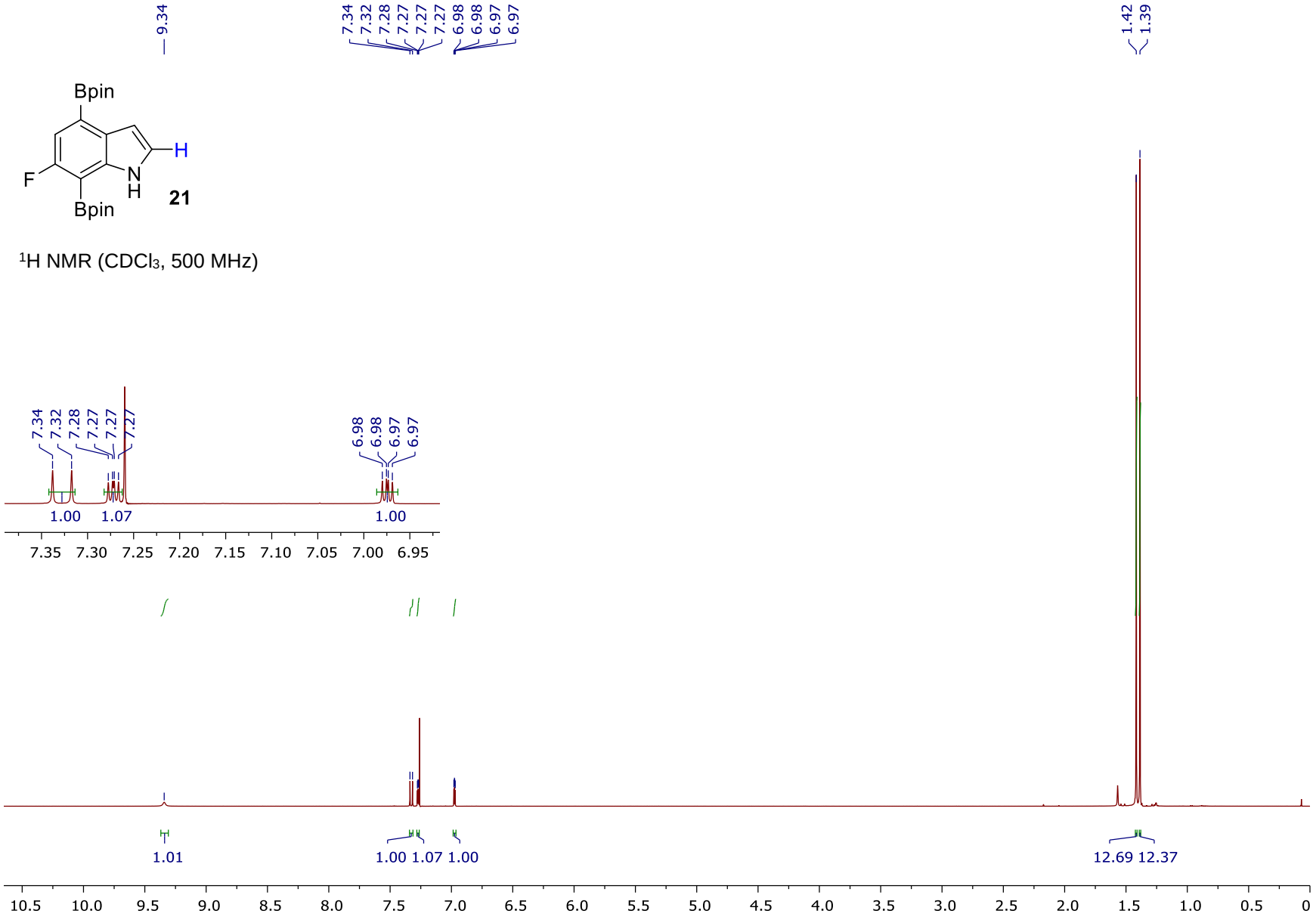


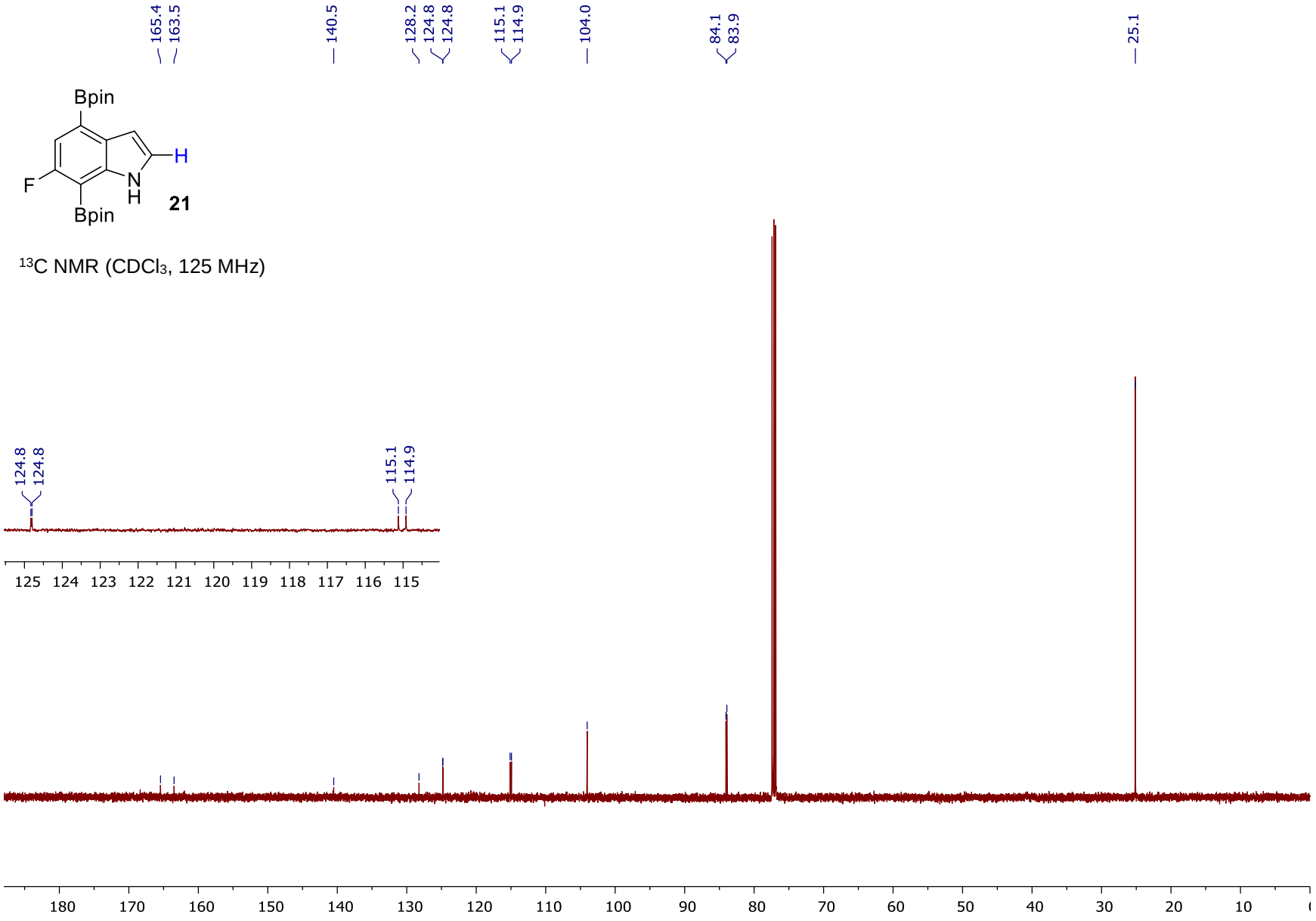
20

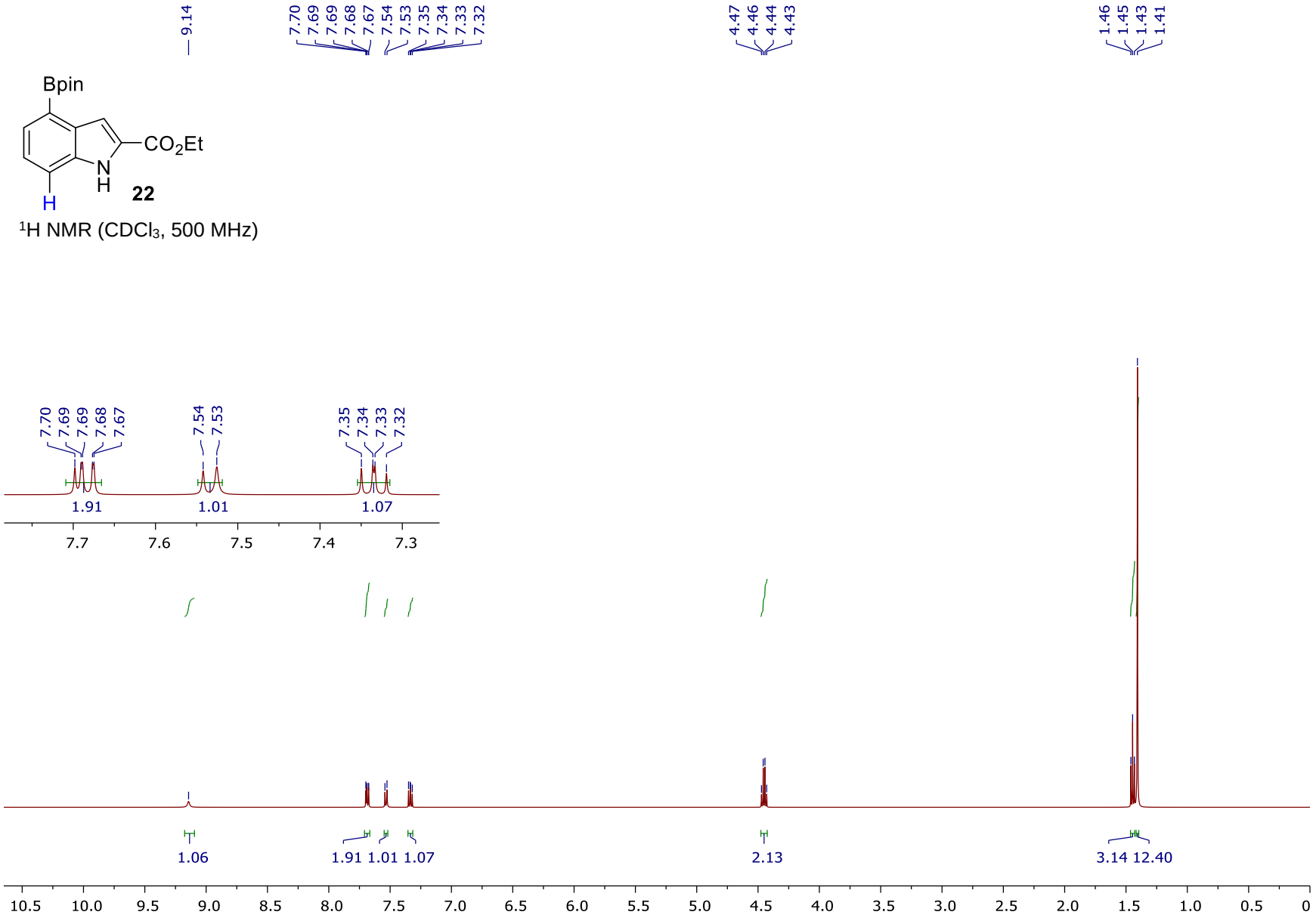
^{1}H NMR ($CDCl_3$, 500 MHz)



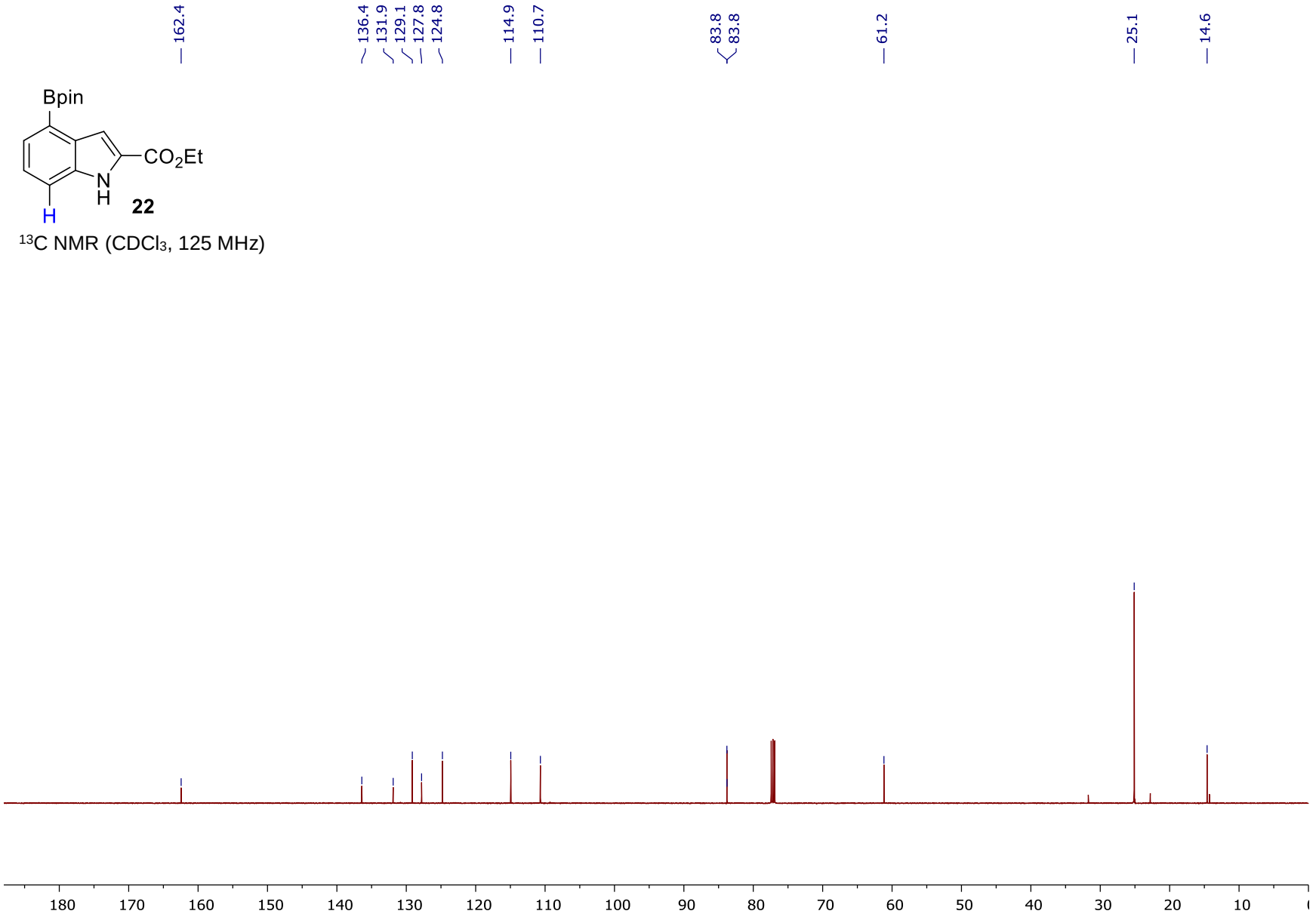
^{13}C NMR ($CDCl_3$, 125 MHz)

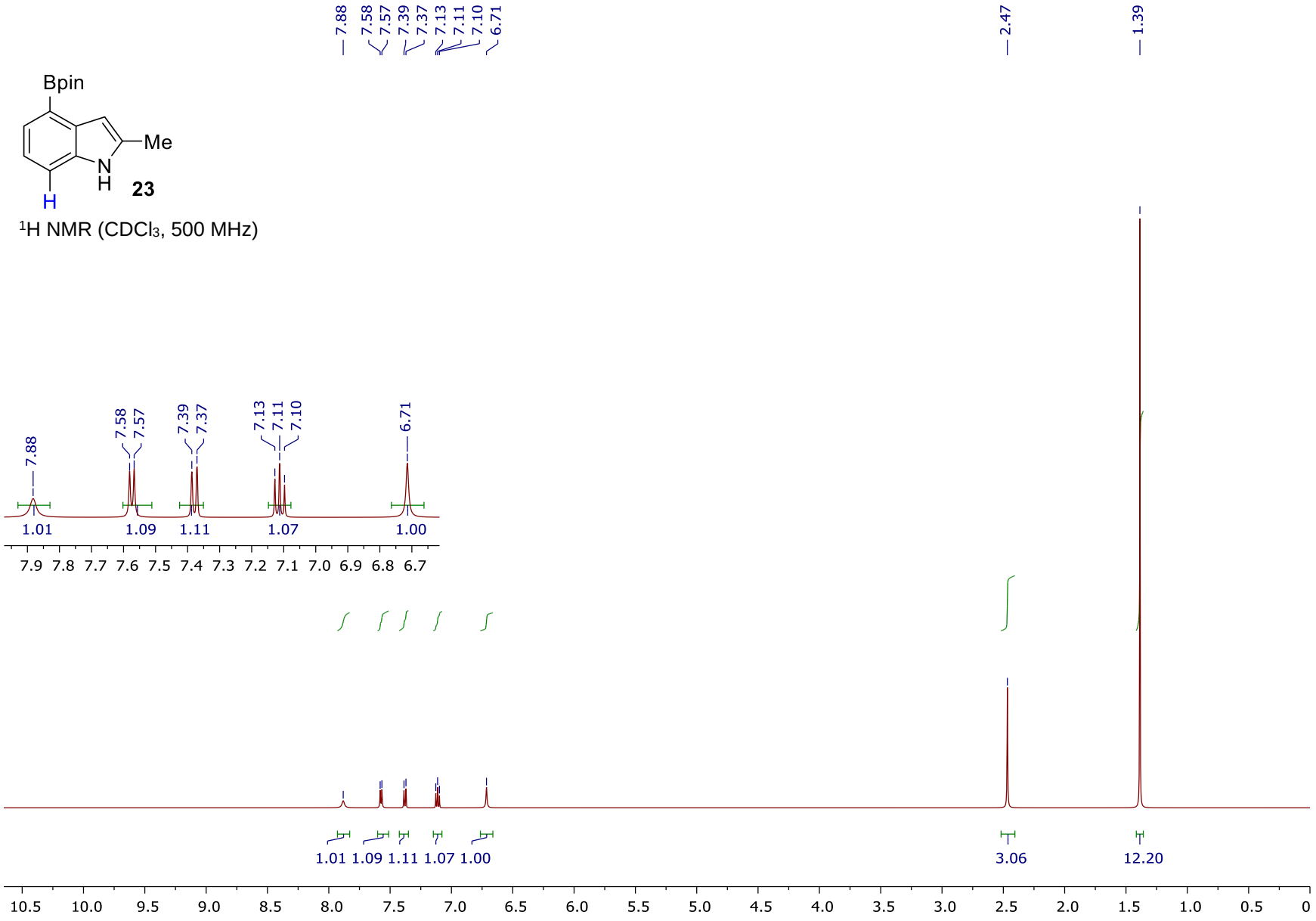

9.34
7.34
7.32
7.28
7.27
7.27
7.27
6.98
6.98
6.97
6.97
1.42
1.39
Bpin
H
F
N
H
Bpin
21
1H NMR (CDCl3, 500 MHz)
1.00
1.07
1.00
7.35 7.30 7.25 7.20 7.15 7.10 7.05 7.00 6.95
1.01
1.00 1.07 1.00
12.69 12.37
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0

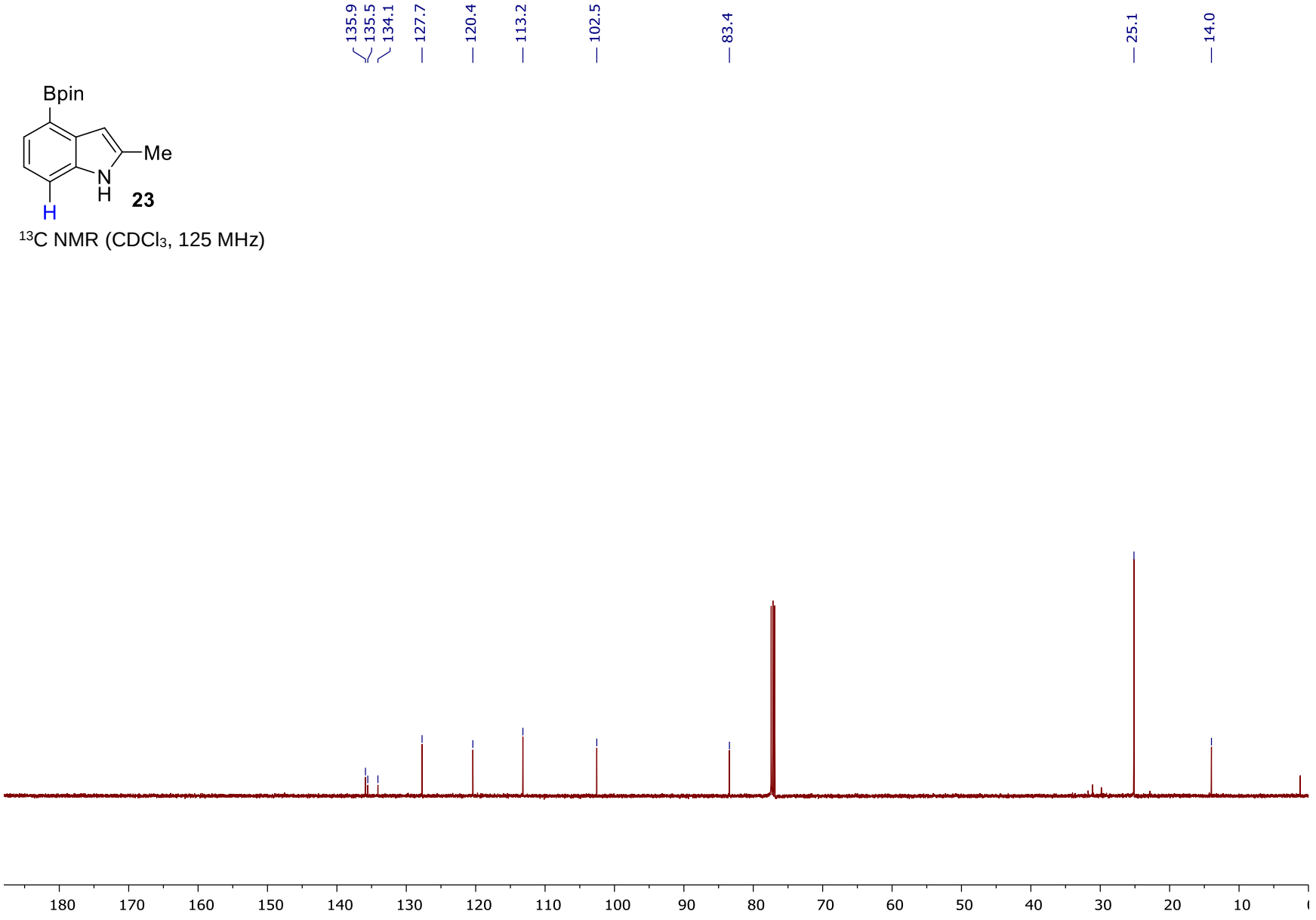

165.4
163.5
140.5
128.2
124.8
124.8
115.1
114.9
104.0
84.1
83.9
25.1
Bpin
H
F
N
H
Bpin
21
^{13}C NMR ($CDCl_3$, 125 MHz)
124.8
124.8
115.1
114.9
125 124 123 122 121 120 119 118 117 116 115
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10

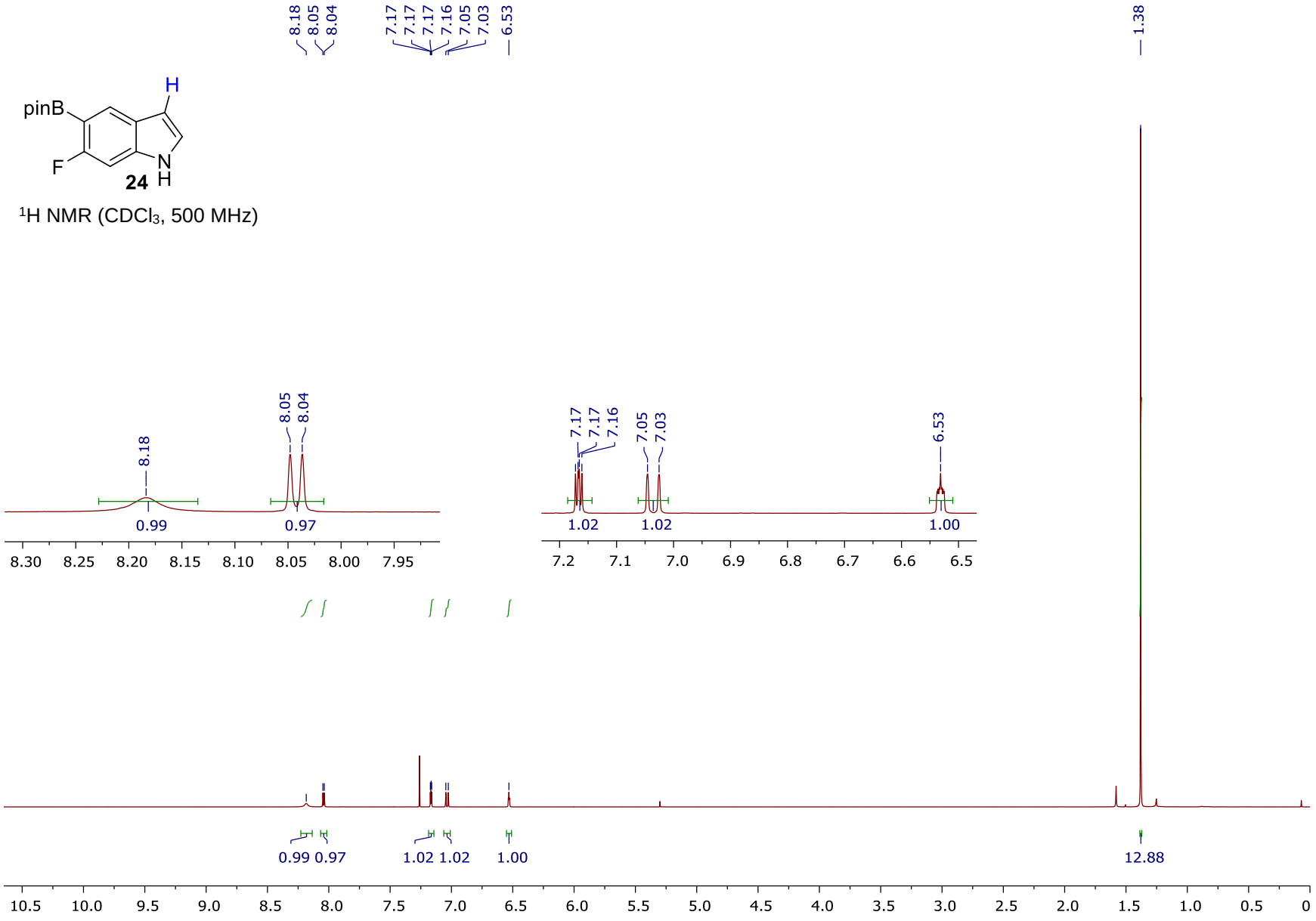


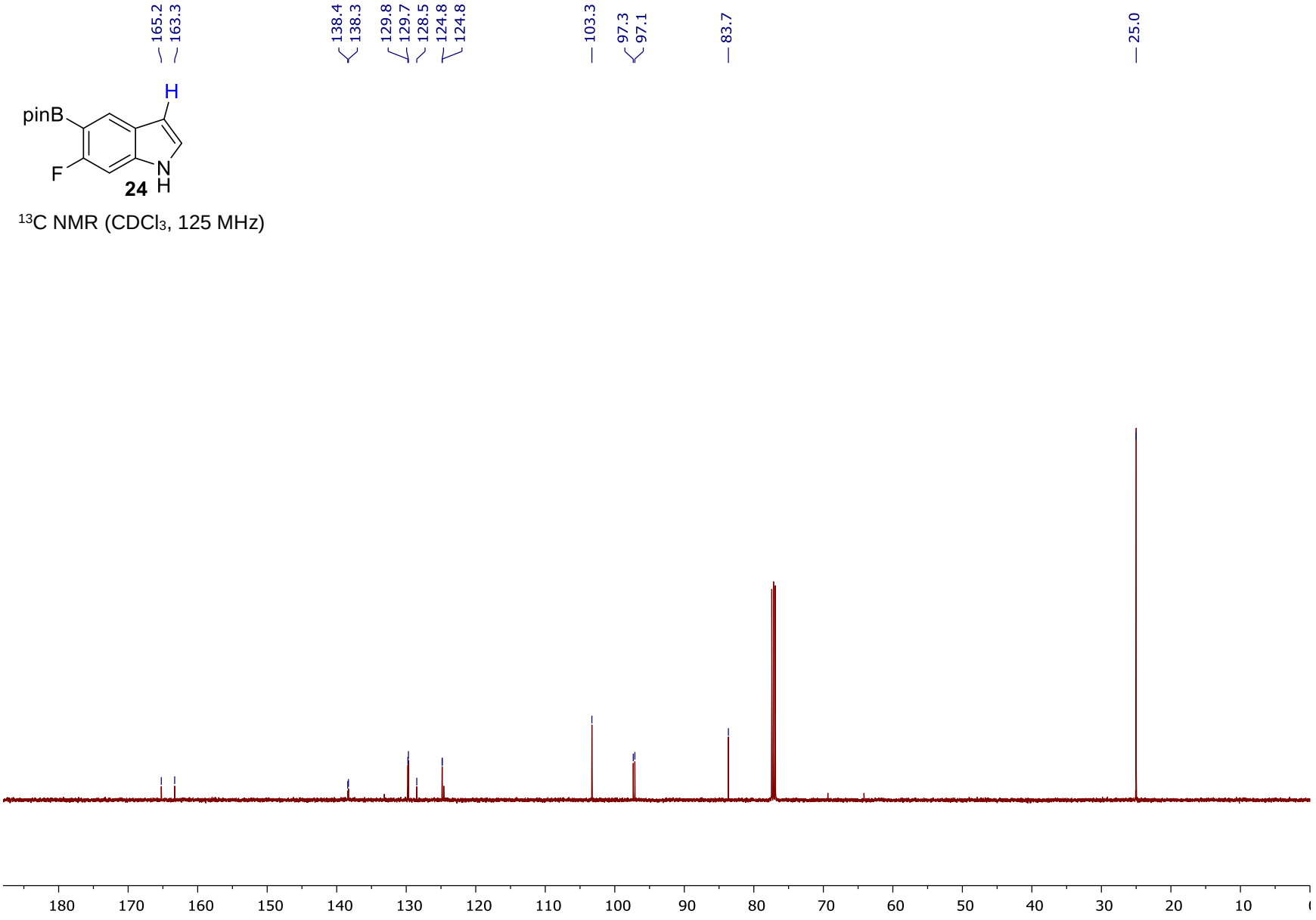
^{1}H NMR ($CDCl_3$, 500 MHz)


162.4
136.4
131.9
129.1
127.8
124.8
114.9
110.7
83.8
83.8
61.2
25.1
14.6
Bpin
CO2Et
N
H
H
22
13C NMR (CDCl3, 125 MHz)
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10

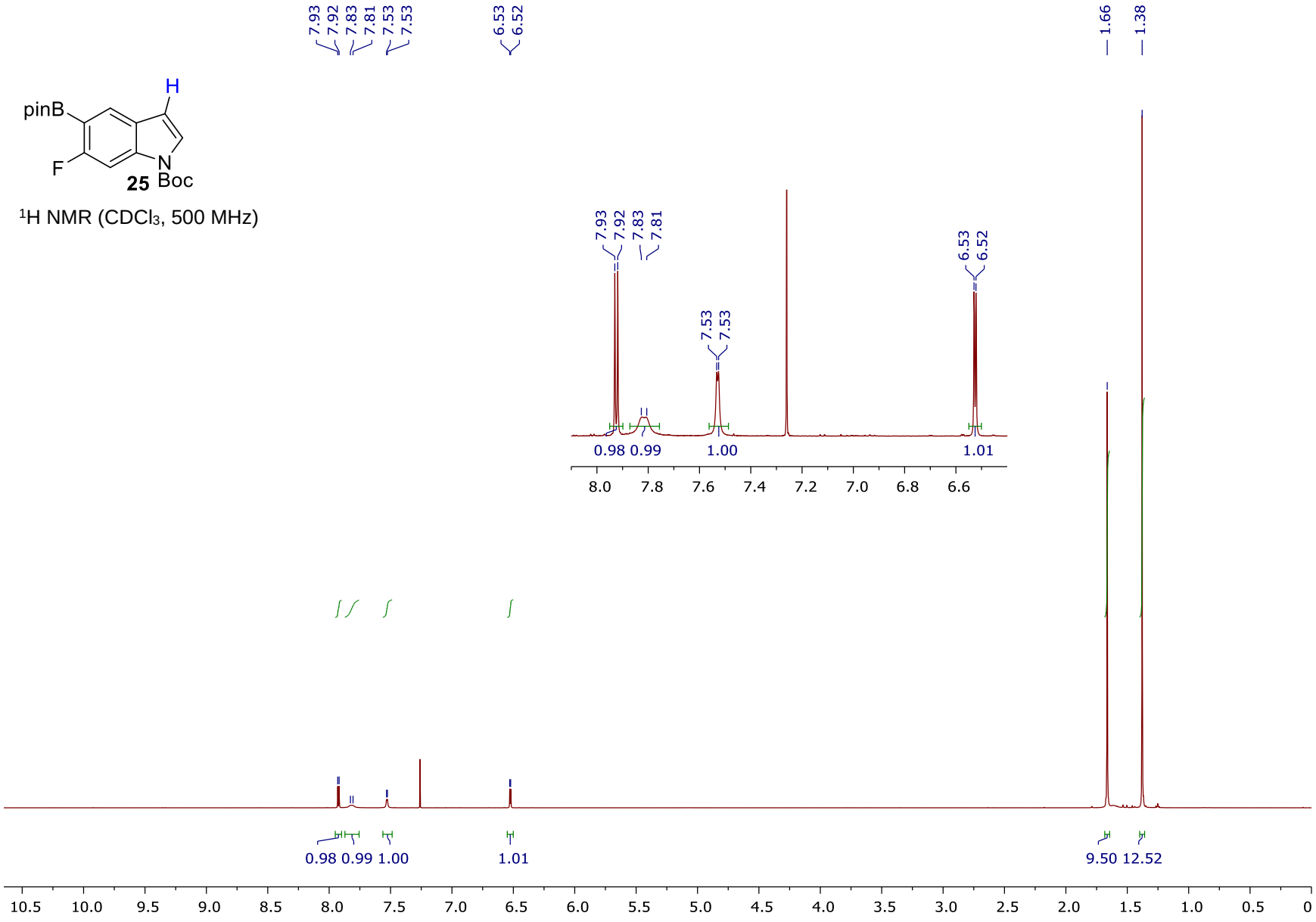

Bpin
Me
N
H
H
23
1H NMR (CDCl3, 500 MHz)
7.88
7.58
7.57
7.39
7.37
7.13
7.11
7.10
6.71
2.47
1.39
1.01
1.09
1.11
1.07
1.00
3.06
12.20

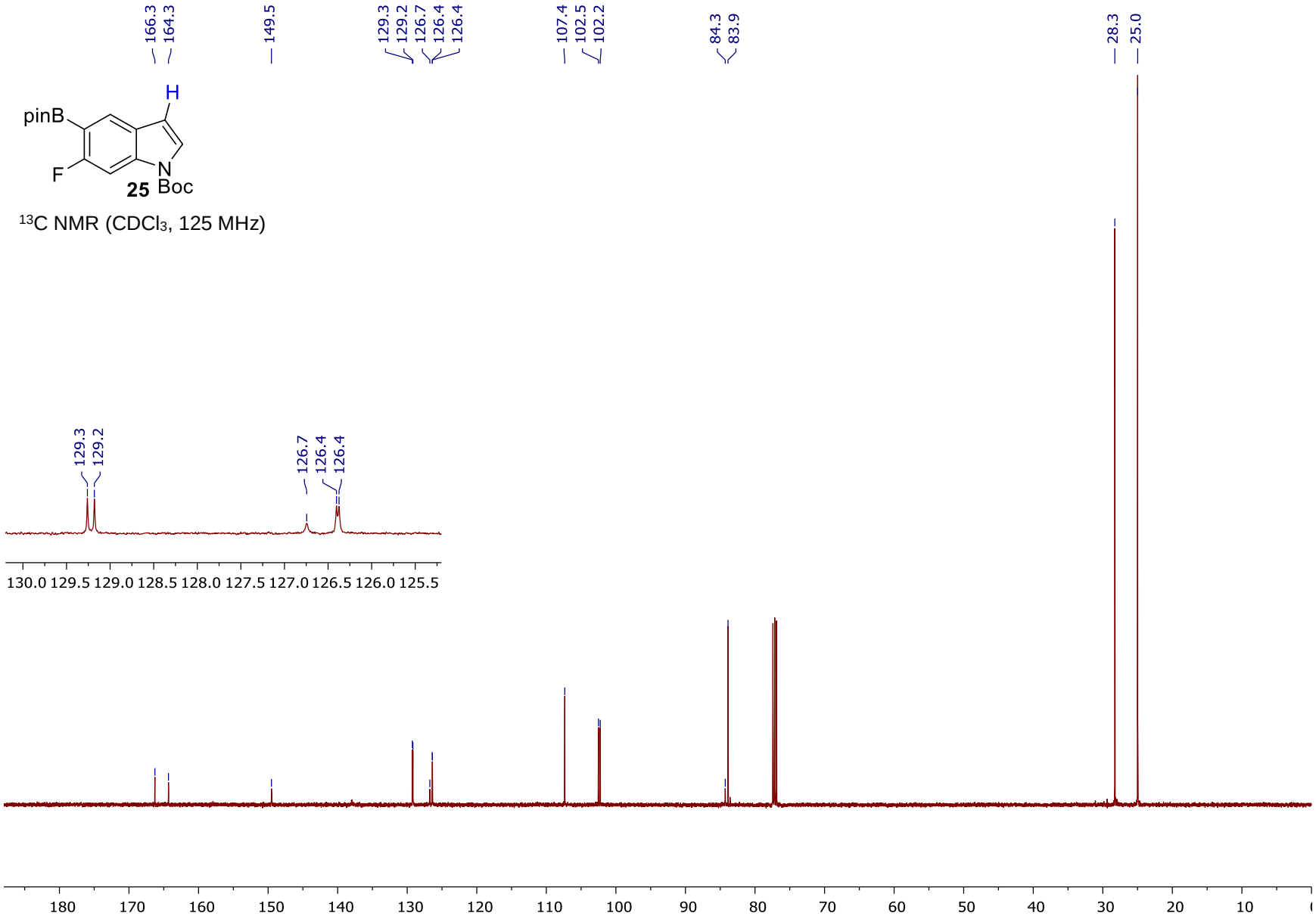

135.9
135.5
134.1
127.7
120.4
113.2
102.5
83.4
25.1
14.0
Bpin
Me
N
H
H
23
^{13}C NMR ($CDCl_3$, 125 MHz)
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10

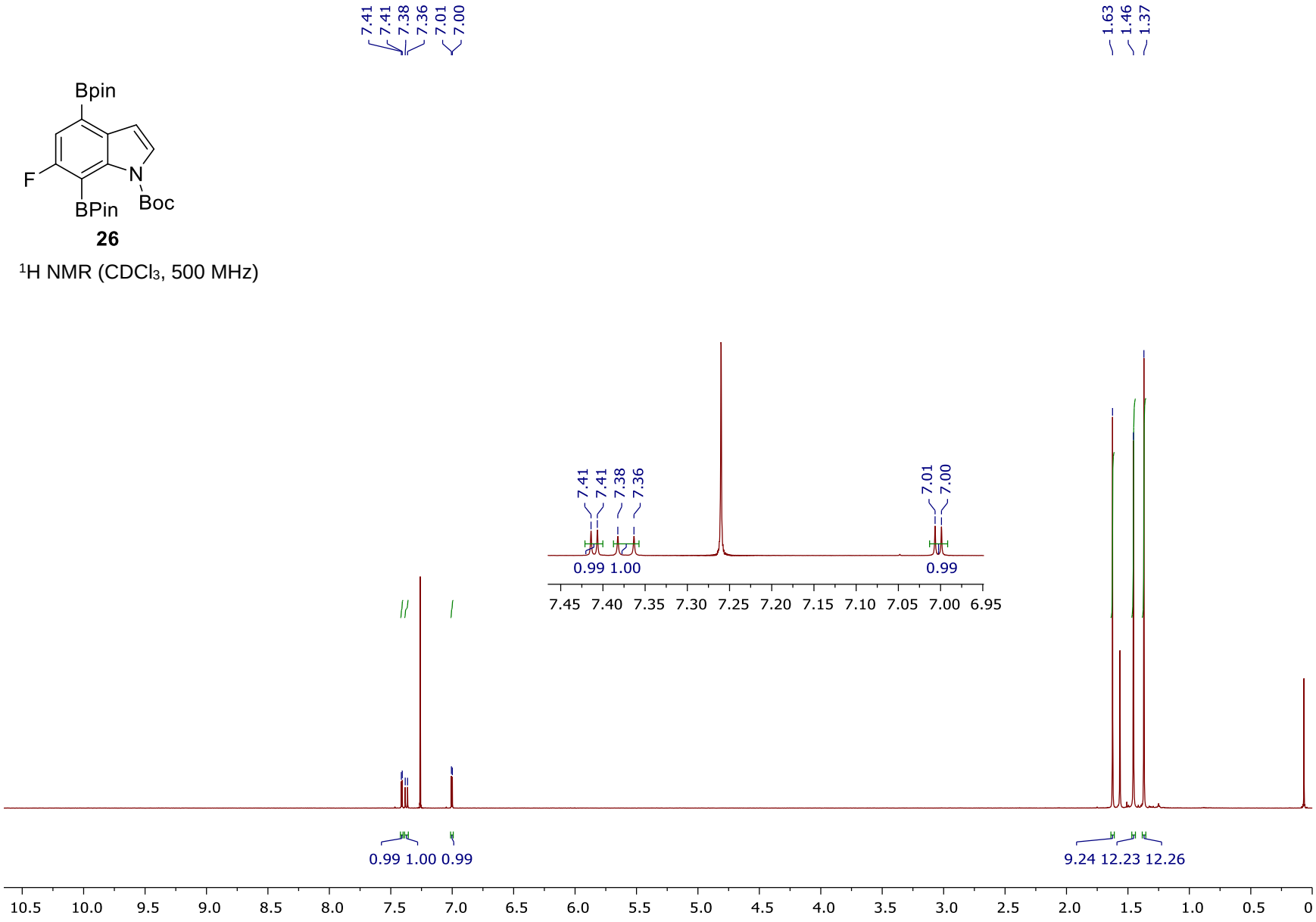

8.18
8.05
8.04
7.17
7.17
7.17
7.16
7.05
7.03
6.53
1.38
pinB
H
F
N
H
24
^{1}H NMR ($CDCl_3$, 500 MHz)
0.99
0.97
1.02
1.02
1.00
12.88



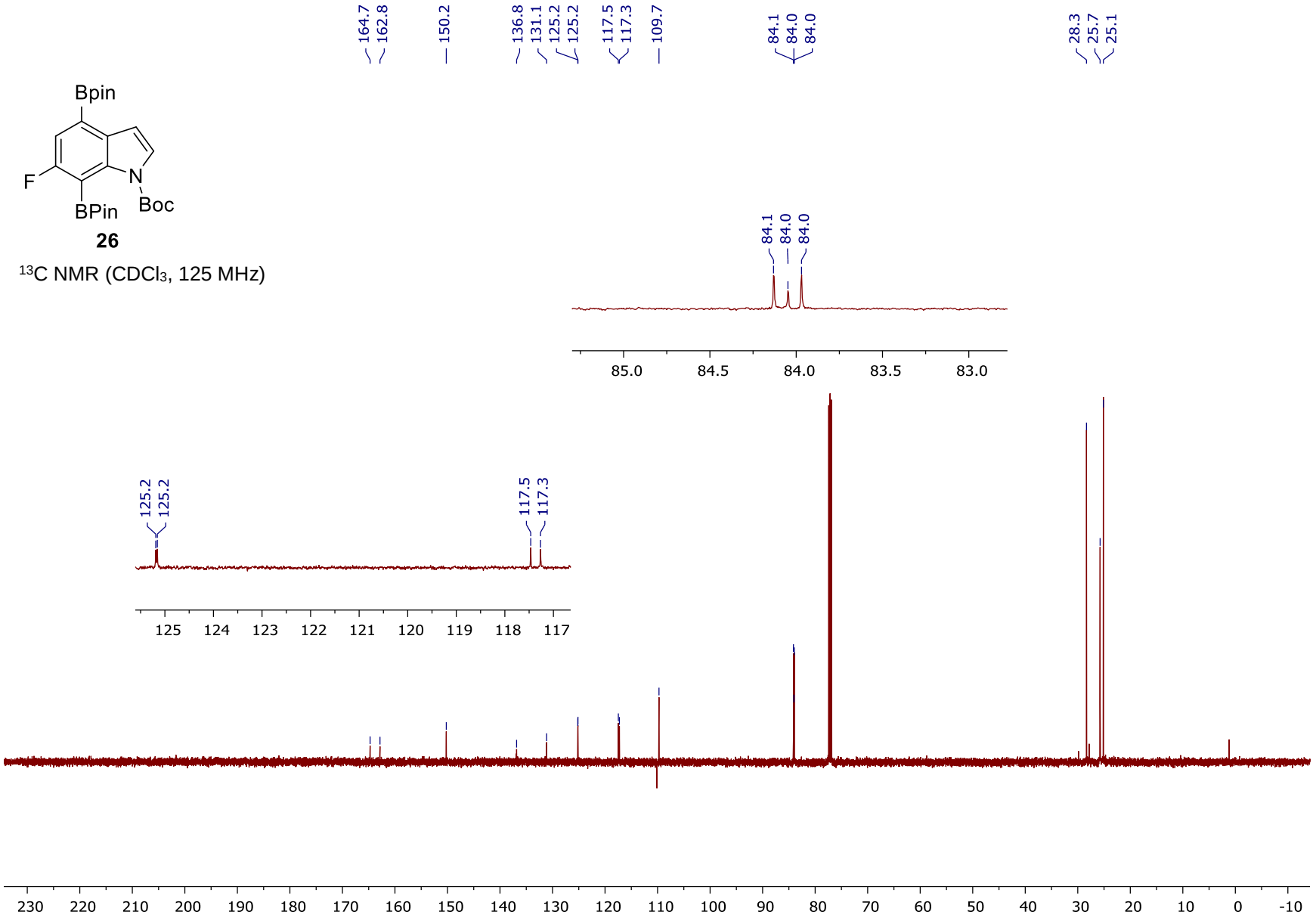
^{13}C NMR ($CDCl_3$, 125 MHz)

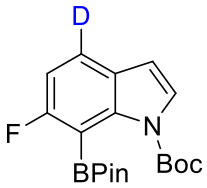

pinB
H
F
N
Boc
25
1H NMR (CDCl3, 500 MHz)
7.93
7.92
7.83
7.81
7.53
7.53
6.53
6.52
1.66
1.38
0.98 0.99 1.00
1.01
9.50 12.52


166.3
164.3
149.5
129.3
129.2
126.7
126.4
126.4
107.4
102.5
102.2
84.3
83.9
28.3
25.0
pinB
H
F
N
Boc
25
^{13}C NMR ($CDCl_3$, 125 MHz)
129.3
129.2
126.7
126.4
126.4
130.0 129.5 129.0 128.5 128.0 127.5 127.0 126.5 126.0 125.5
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10



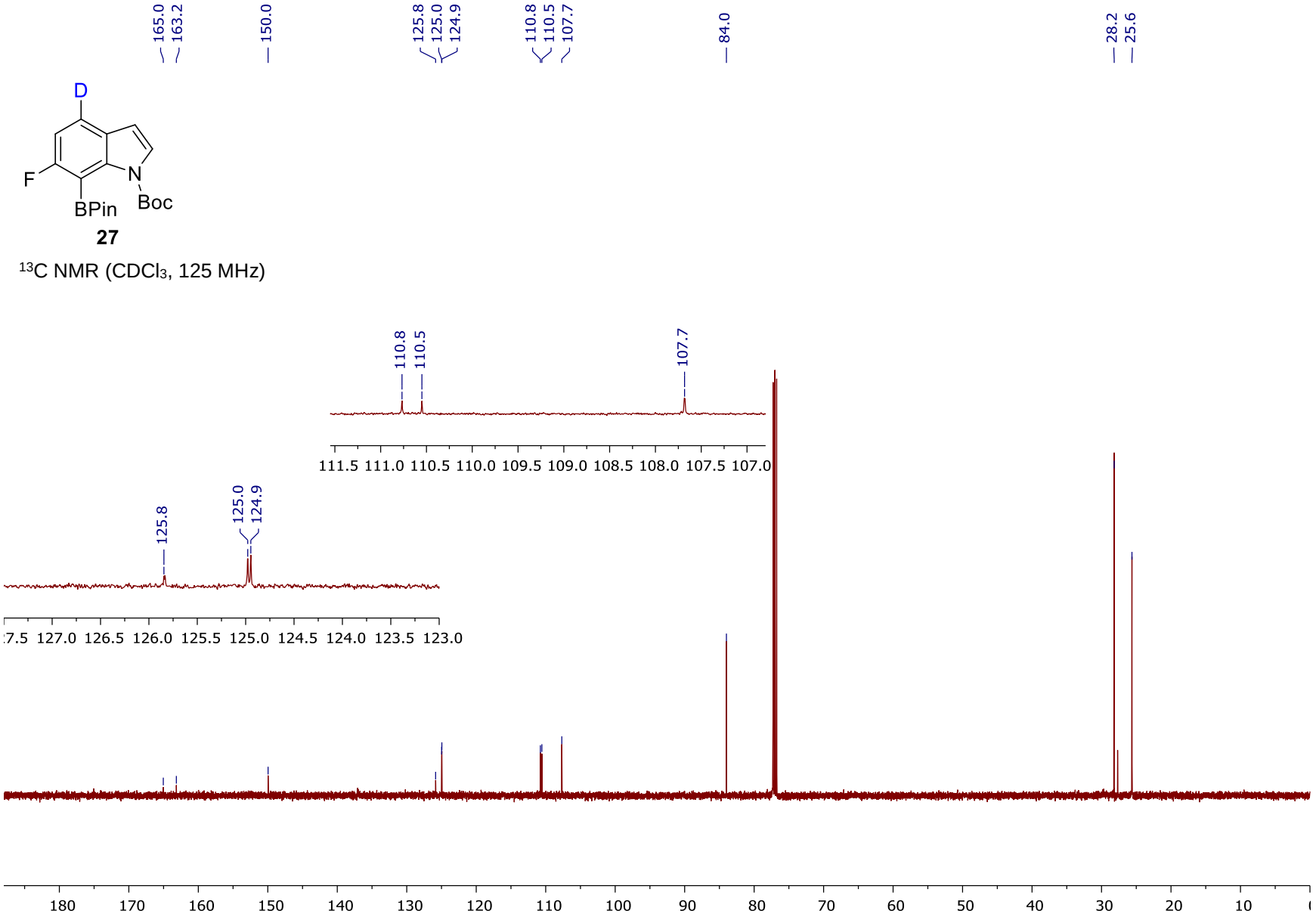
^{1}H NMR ($CDCl_3$, 500 MHz)


Bpin
F
N
Boc
BPin
26
13C NMR (CDCl3, 125 MHz)
164.7
162.8
150.2
136.8
131.1
125.2
125.2
117.5
117.3
109.7
84.1
84.0
84.0
28.3
25.7
25.1
85.0
84.5
84.0
83.5
83.0
125.2
125.2
117.5
117.3
125
124
123
122
121
120
119
118
117
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10

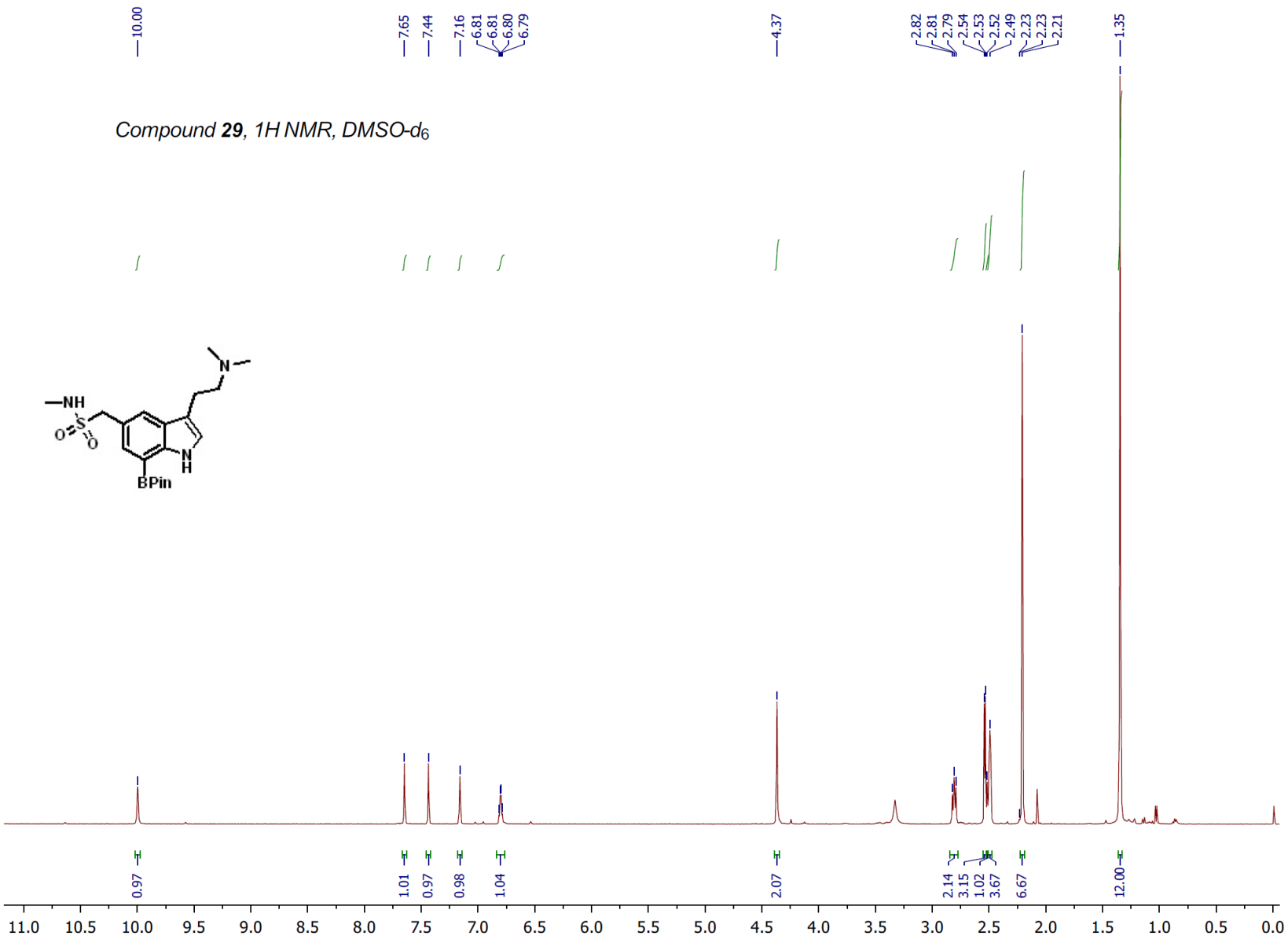


27

^{1}H NMR ($CDCl_3$, 500 MHz)


165.0
163.2
150.0
125.8
125.0
124.9
110.8
110.5
107.7
84.0
28.2
25.6
D
F
N
BPin
Boc
27
13C NMR (CDCl3, 125 MHz)
110.8
110.5
107.7
111.5 111.0 110.5 110.0 109.5 109.0 108.5 108.0 107.5 107.0
125.8
125.0
124.9
127.5 127.0 126.5 126.0 125.5 125.0 124.5 124.0 123.5 123.0
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10

*Compound **29**, 1H NMR, DMSO-d_6*



Compound 29, C-13 NMR, DMSO-d_6