Supporting Information

[3 + 3] Cycloaddition of in Situ Formed Azaoxyallyl Cations with 2-Alkenylindoles: An Approach to Tetrahydro-*β*-carbolinones

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Contents

1. General Information

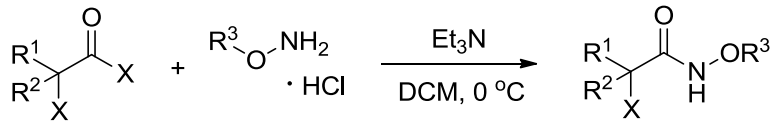
Reagents and Solvents: All solvents were purified and dried according to standard methods. PE refers to petroleum ether (b.p. 60 - 90 ℃), EA refers to ethyl acetate, and DCM refers to dichloromethane.

Chromatography: Flash column chromatography was carried out using commercially available 200-300 mesh under pressure and conducted by eluting with PE/EA , which are listed as volume/volume ratios.

Data Collection: Melting point (m.p.) was measured on a microscopic melting point apparatus. ^{1}H and ^{13}C NMR spectra were collected on BRUKER AV-300 (300 MHz) or BRUKER AV-500 (500 MHz) spectrometer using $CDCl_3$ or DMSO-d_6 as solvent. Chemical shifts of ^{1}H NMR were recorded in parts per million (ppm, δ) relative to tetramethylsilane (δ = 0.00 ppm) with the solvent resonance as an internal standard ($CDCl_3$， δ = 7.26 ppm, DMSO-d_6, δ = 2.50 ppm). Data are reported as follows: chemical shift in ppm (δ), multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, brs = broad singlet, m = multiplet), coupling constant (Hz), and integration. Chemical shifts of ^{13}C NMR were reported in ppm with the solvent as the internal standard ($CDCl_3$, δ = 77.0 ppm, DMSO-d_6, δ = 39.5 ppm). High Resolution Mass measurement was performed on Agilent QTOF 6520 mass spectrometer with electron spray ionization (ESI) as the ion source. Unless otherwise indicated, all other reagents and solvents were obtained from commercial suppliers and used without further purification.

2. General Procedures for the Preparation of *α*-Halohydroxamates

General Procedures[1]



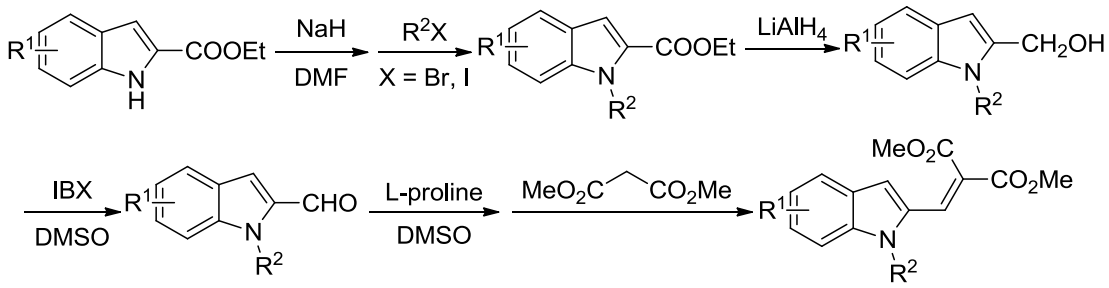
To a suspension of the *O*-alkyloxyamine hydrochloride and triethylamine in DCM (0.25 M) was added dropwise the alpha-haloacid halide at 0 ℃. The reaction mixture was stirred at this temperature until complete consumption of starting material (detected by TLC). The mixture was warmed to room temperature and quenched with water. The organic phase was washed with water (×3), then washed with brine (×1), dried over sodium sulfate, filtered and evaporated. Purification *via* a flash column chromatography (PE/EA = 8/1) provided the *α*-halohydroxamates.

[1] Jeffrey, C. S.; Barnes, K. L.; Eickhoff, J. A.; Carson, C. R. *J. Am. Chem. Soc.* **2011**, *133*, 7688.

3. General Procedures for the Preparation of 2-Alkenylindoles

2-Alkenylindoles were synthesized according to general procedure A, B, C or D. Substrates ***1a*–*f***, ***1j*–*m*** were synthesized according to general procedure A. Substrates ***1g*–*i*** were achieved according to general procedure B. Substrates ***1n*–*r*** and ***1t*** were obtained according to general procedure C and substrate ***1s*** was obtained according to general procedure D.

a) General Procedure A[2,3]



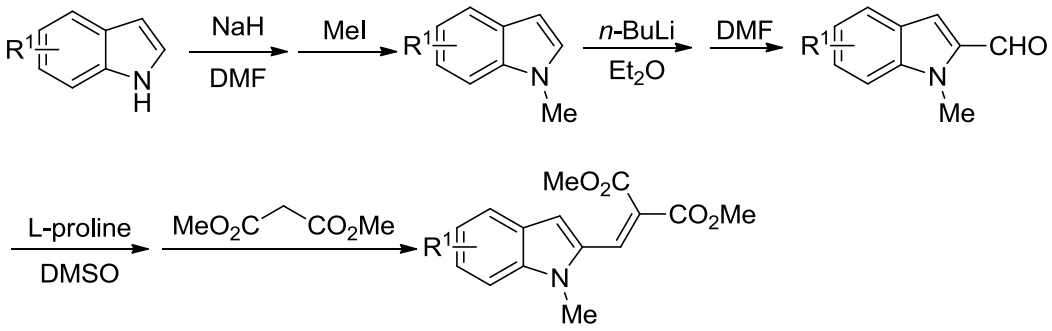
To a DMF (10 mL) solution of ethyl indole-2-carboxylate (5 mmol) was added NaH (60% dispersion in mineral oil, 7.5 mmol) at 0 ^{o}C. The reaction mixture was stirred at the same temperature for 20 min. Then the corresponding alkyl halide (7.5 mmol) was added. The reaction mixture was stirred at room temperature until complete consumption of starting material (detected by TLC). The reaction mixture was quenched with water, extracted with EA (×3). The organic layer was combined, washed with brine, dried over sodium sulfate, filtered and evaporated. Purification *via* a flash column chromatography (PE/EA = 50/1) provided the ethyl 1-alkylindole-2-carboxylate.

To a solution of $LiAlH_4$ (10 mmol) in THF (10 mL) was added dropwise the solution of ethyl 1-alkylindole-2-carboxylate (5 mmol) in THF (10 mL) at 0 ℃. The reaction mixture was stirred at the same temperature for 1 h. Then it was quenched with H_2O (0.38 mL), 10% NaOH (0.76 mL), H_2O (1.14 mL) successively. Then the mixture was filtered and dried over sodium sulfate. The filtrate was evaporated in vacuo and the residue was dissolved in DMSO (10 mL), then IBX (6.5 mmol) was added. The reaction mixture was stirred for 2 hours at room temperature. Then the reaction was quenched by water and filtered. The filtrate was extracted with EA (×3). The organic layer was combined, washed with brine, dried over sodium sulfate, filtered and evaporated. Purification *via* a flash column chromatography (PE/EA = 30/1) provided the 1-alkylindole-2-carbaldehyde.

To a suspension of L-proline (0.6 mmol) in DMSO (4.0 mL), 1-alkylindole-2-carbaldehyde (2.0 mmol) was added at room temperature and the reaction mixture was stirred at the same temperature under argon for 10 minutes. Then dimethyl malonate (2.4 mmol) was added to it dropwise. The reaction mixture was stirred at room temperature for 12 h. Then the reaction was quenched by water (4 mL) and filtered. The mixture was extracted with EA (×3). The organic layer was combined, washed with brine, dried over sodium sulfate, filtered and evaporated. Purification *via* a flash column chromatography (PE/EA = 10/1) provided the 2-alkenylindoles as yellow solid.

[2] Wang, L.; Xie, X. Liu, Y. *Angew. Chem., Int. Ed.* **2013**, *52*, 13302.
[3] Talukdar, R.; Tiwari, D. P.; Saha, A.; Ghorai, M. K. *Org. Lett.* **2014**, *16*, 3954.

b) General Procedure B[3,4]



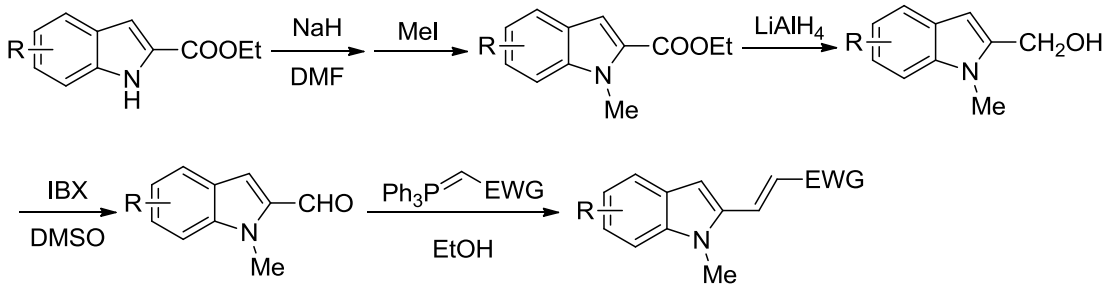
To a DMF (10 mL) solution of indole (5 mmol) was added NaH (60% dispersion in mineral oil, 7.5 mmol) at 0 °C. The reaction mixture was stirred at the same temperature for 20 min. Then iodomethane (7.5 mmol) was added. The reaction mixture was stirred at room temperature until complete consumption of starting material (detected by TLC). The reaction mixture was quenched with water, extracted with EA (×3). The organic layer was combined, washed with brine, dried over sodium sulfate, filtered and evaporated. Purification *via* a flash column chromatography (PE/EA = 80/1) provided the 1-methyl-1*H*-lindole.

Under a argon atmosphere, to a solution of 1-methyl-1*H*-indole (5 mmol) in anhydrous ether (8 mL) was added *n*-BuLi (6 mmol) dropwise at room temperature. The reaction mixture was heated to reflux for 3 h followed by the addition of anhydrous DMF (7.5 mmol) dropwise. The mixture was refluxed for 5 h. Then the reaction was quenched with a saturated solution of ammonium chloride at room temperature. The aqueous layer was extracted with EA (×3). The organic layer was combined, washed with brine, dried over sodium sulfate, filtered and evaporated. Purification *via* a flash column chromatography (PE/EA = 30/1) provided the 1-methylindole-2-carbaldehyde.

To a suspension of L-proline (0.6 mmol) in DMSO (4.0 mL), 1-methylindole-2-carbaldehyde (2.0 mmol) was added at room temperature and the reaction mixture was stirred at the same temperature under argon for 10 minutes. Then dimethyl malonate (2.4 mmol) was added to it dropwise. The reaction mixture was stirred at room temperature for 12 h. Then the reaction was quenched by water (4 mL) and filtered. The mixture was extracted with EA (×3). The organic layer was combined, washed with brine, dried over sodium sulfate, filtered and evaporated. Purification *via* a flash column chromatography (PE/EA = 10/1) provided the 2-alkenylindoles as yellow solid.

[4] Sha, F.; Tao, Y.; Tang, C.-Y.; Zhang, F.; Wu, X.-Y. *J. Org. Chem.* **2015**, *80*, 8122.

c) General Procedure C[2,4]

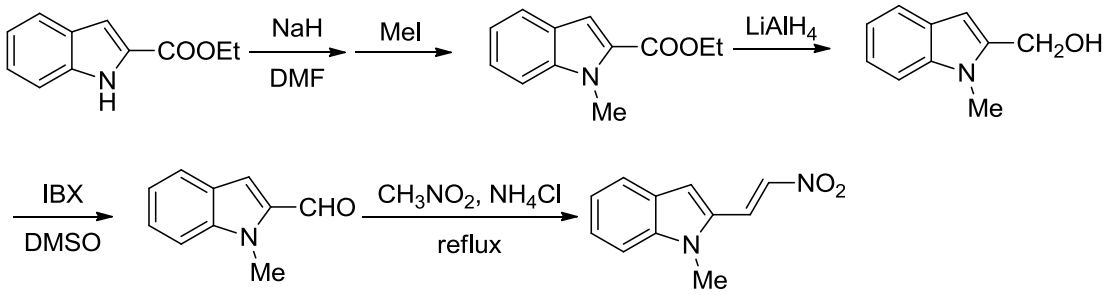


To a DMF (10 mL) solution of ethyl indole-2-carboxylate (5 mmol) was added NaH (60% dispersion in mineral oil, 7.5 mmol) at 0 ^{o}C. The reaction mixture was stirred at the same temperature for 20 min. Then iodomethane (7.5 mmol) was added. The reaction mixture was stirred at room temperature until complete consumption of starting material (detected by TLC). The reaction mixture was quenched with water, extracted with EA (×3). The organic layer was combined, washed with brine, dried over sodium sulfate, filtered and evaporated. Purification *via* a flash column chromatography (PE/EA = 50/1) provided the ethyl 1-methylindole-2-carboxylate.

To a solution of $LiAlH_4$ (10 mmol) in THF (10 mL) was added dropwise the solution of ethyl 1-methylindole-2-carboxylate (5 mmol) in THF (10 mL) at 0 ℃. The reaction mixture was stirred at the same temperature for 1 h. Then it was quenched with H_2O (0.38 mL), 10% NaOH (0.76 mL), H_2O (1.14 mL) successively. Then the mixture was filtered and dried over sodium sulfate. The filtrate was evaporated in vacuo and the residue was dissolved in DMSO (10 mL), then IBX (6.5 mmol) was added. The reaction mixture was stirred for 2 hours at room temperature. Then the reaction was quenched by water and filtered. The filtrate was extracted with EA (×3). The organic layer was combined, washed with brine, dried over sodium sulfate, filtered and evaporated. Purification *via* a flash column chromatography (PE/EA = 30/1) provided the 1-methylindole-2-carbaldehyde.

To a solution of 1-methylindole-2-carbaldehyde (2.0 mmol) in anhydrous EtOH (15 mL) was added phosphorus ylide (2.2 mmol) in one portion at room temperature. The reaction mixture was stirred at the same temperature and monitored by TLC. The mixture was then concentrated under reduced pressure, and the residue was purified *via* a flash column chromatography (PE/EA = 15/1) provided the 2-alkenylindoles as light yellow solid.

d) General Procedure D[2,5]



To a DMF (10 mL) solution of ethyl indole-2-carboxylate (5 mmol) was added NaH (60% dispersion in mineral oil, 7.5 mmol) at 0 ^{o}C. The reaction mixture was stirred at the same temperature for 20 min. Then iodomethane (7.5 mmol) was added. The reaction mixture was stirred at room temperature until complete consumption of starting material (detected by TLC). The reaction mixture was quenched with water, extracted with EA (×3). The organic layer was combined, washed with brine, dried over sodium sulfate, filtered and evaporated. Purification *via* a flash column chromatography (PE/EA = 50/1) provided the ethyl 1-methylindole-2-carboxylate.

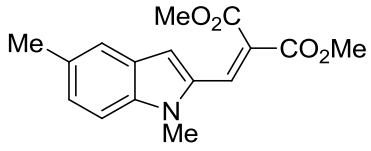
To a solution of $LiAlH_4$ (10 mmol) in THF (10 mL) was added dropwise the solution of ethyl 1-methylindole-2-carboxylate (5 mmol) in THF (10 mL) at 0 ℃. The reaction mixture was stirred at the same temperature for 1 h. Then it was quenched with H_2O (0.38 mL), 10% NaOH (0.76 mL), H_2O (1.14 mL) successively. Then the mixture was filtered and dried over sodium sulfate. The filtrate was evaporated in vacuo and the residue was dissolved in DMSO (10 mL), then IBX (6.5 mmol) was added. The reaction mixture was stirred for 2 hours at room temperature. Then the reaction was quenched by water and filtered. The filtrate was extracted with EA (×3). The organic layer was combined, washed with brine, dried over sodium sulfate, filtered and evaporated. Purification *via* a flash column chromatography (PE/EA = 30/1) provided the 1-methylindole-2-carbaldehyde.

A solution of 1-methylindole-2-carbaldehyde (2.0 mmol) and ammonium acetate (1.0 mmol) in nitromethane (4 mL) was heated at reflux for 4 h under argon. After the mixture cooled to room temperature, ethyl acetate was added. The organic phase was washed with water (×3), then washed with brine (×1), dried over sodium sulfate, filtered and evaporated. Purification *via* a flash column chromatography (PE/EA = 15/1) provided the 2-alkenylindoles as yellow solid.

[5] Yang, W.-L.; Li, C.-Y.; Qin, W.-J.; Tang, F.-F.; Yu, X.; Deng, W.-P. *ACS Catal.* **2016**, *6*, 5685.

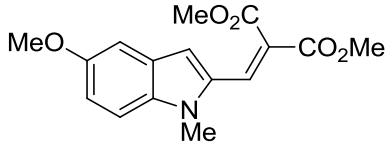
e) Characterization of the Products

dimethyl 2-((1,5-dimethyl-1H-indol-2-yl)methylene)malonate (1b)



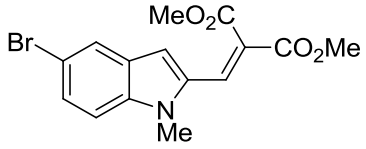
Yellow solid, m. p. 98 – 99 °C; 1H NMR (300 MHz, $CDCl_3$) δ 7.83 (s, 1H), 7.37 (s, 1H), 7.19 (d, *J* = 8.5 Hz, 1H), 7.11 (m, *J* = 8.5, 1.1 Hz, 1H), 6.80 (s, 1H), 3.92 (s, 3H), 3.86 (s, 3H), 3.78 (s, 3H), 2.42 (s, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 167.3, 164.5, 137.3, 130.2, 131.6, 130.0, 127.7, 126.5, 123.2, 121.2, 109.4, 105.8, 52.9, 52.6, 29.8, 21.3 ppm. HRMS(ESI) *m/z* calcd for $[C_{16}H_{17}NO_4+H]^+$ 288.1230, found 288.1228.

dimethyl 2-((5-methoxy-1-methyl-1H-indol-2-yl)methylene)malonate (1c)



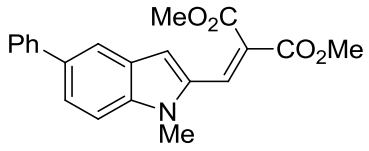
Yellow solid, m. p. 127 – 129 °C; ^1H NMR (300 MHz, $CDCl_3$) δ 7.81 (s, 1H), 7.20 (d, *J* = 8.9 Hz, 1H), 7.02 – 6.91 (m, 2H), 6.80 (s, 1H), 3.93 (s, 3H), 3.86 (s, 3H), 3.83 (s, 3H), 3.78 (s, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 167.3, 164.5, 154.6, 134.4, 131.8, 129.9, 127.7, 123.0, 116.1, 110.7, 105.7, 101.7, 55.6, 52.9, 52.6, 29.9 ppm. HRMS(ESI) *m/z* calcd for $[C_{16}H_{17}NO_5+H]^+$ 304.1179, found 304.1177.

dimethyl 2-((5-bromo-1-methyl-1H-indol-2-yl)methylene)malonate (1e)



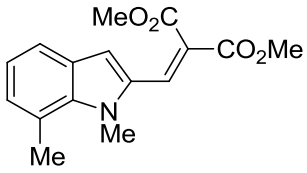
Yellow solid, m. p. 121 – 122 °C; ^1H NMR (300 MHz, $CDCl_3$) δ 7.80 (s, 1H), 7.72 (d, *J* = 1.7 Hz, 1H), 7.34 (dd, *J* = 8.8, 1.8 Hz, 1H), 7.17 (d, *J* = 8.8 Hz, 1H), 6.78 (s, 1H), 3.92 (s, 3H), 3.87 (s, 3H), 3.79 (s, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 166.9, 164.2, 137.2, 132.7, 129.5, 128.9, 127.2, 124.9, 124.1, 113.8, 111.2, 105.3, 53.0, 52.8, 30.0 ppm. HRMS(ESI) *m/z* calcd for $[C_{15}H_{14}BrNO_4+H]^+$ 352.0179, found 352.0187.

dimethyl 2-((1-methyl-5-phenyl-1H-indol-2-yl)methylene)malonate (1f)



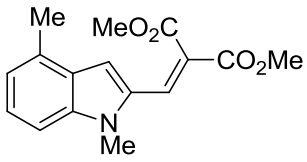
Light yellow solid, m. p. > 250 °C; ^1H NMR (300 MHz, $CDCl_3$) δ 7.79 – 7.65 (m, 2H), 7.52 (d, *J* = 7.4 Hz, 2H), 7.44 (dd, *J* = 8.7, 1.4 Hz, 1H), 7.33 (t, *J* = 7.5 Hz, 2H), 7.28 – 7.17 (m, 2H), 6.83 (s, 1H), 3.84 (s, 3H), 3.76 (s, 3H), 3.69 (s, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 167.1, 164.3, 141.6, 138.2, 134.0, 132.3, 129.8, 128.7, 127.9, 127.1, 126.6, 124.4, 123.9, 120.0, 110.0, 106.6, 52.9, 52.7, 29.9 ppm. HRMS(ESI) *m/z* calcd for $[C_{21}H_{19}NO_4+H]^+$ 372.1206, found 372.1208.

dimethyl 2-((1,7-dimethyl-1H-indol-2-yl)methylene)malonate (1g)



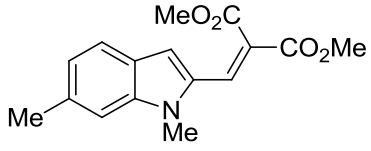
Yellow solid, m. p. 119 – 121 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.84 (s, 1H), 7.46 – 7.37 (m, 1H), 7.02 – 6.90 (m, 2H), 6.83 (s, 1H), 4.04 (s, 3H), 3.90 (s, 3H), 3.86 (s, 3H), 2.75 (s, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 167.2, 164.4, 137.8, 132.3, 130.5, 128.3, 127.4, 123.9, 121.3, 120.6, 120.0, 107.0, 52.9, 52.7, 32.9, 20.5 ppm. HRMS(ESI) *m/z* calcd for $[C_{16}H_{17}NO_4+H]^+$ 288.1230, found 288.1231.

dimethyl 2-((1,4-dimethyl-1H-indol-2-yl)methylene)malonate (1h)



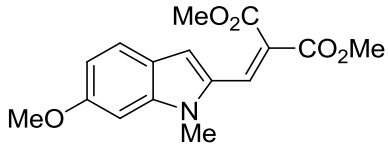
Yellow solid, m. p. 121 – 123 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.86 (s, 1H), 7.28 – 7.08 (m, 2H), 6.95 – 6.82 (m, 2H), 3.92 (s, 3H), 3.86 (s, 3H), 3.79 (s, 3H), 2.51 (s, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 167.3, 164.5, 138.7, 131.5, 131.2, 130.2, 127.7, 124.7, 123.4, 120.6, 107.3, 104.9, 52.9, 52.6, 30.0, 18.5 ppm. HRMS(ESI) *m/z* calcd for $[C_{16}H_{17}NO_4+H]^+$ 288.1230, found 288.1231.

dimethyl 2-((1,6-dimethyl-1H-indol-2-yl)methylene)malonate (1i)



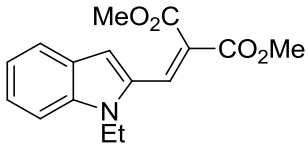
Yellow solid, m. p. 121 – 122 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.83 (s, 1H), 7.47 (d, *J* = 8.2 Hz, 1H), 7.08 (s, 1H), 6.94 (d, *J* = 8.2 Hz, 1H), 6.85 (s, 1H), 3.92 (s, 3H), 3.85 (s, 3H), 3.76 (s, 3H), 2.48 (s, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 167.3, 164.5, 139.3, 134.8, 131.2, 130.1, 125.5, 122.8, 122.7, 121.5, 109.5, 106.5, 52.9, 52.6, 29.7, 22.1 ppm. HRMS(ESI) *m/z* calcd for $[C_{16}H_{17}NO_4+H]^+$ 288.1230, found 288.1233.

dimethyl 2-((6-methoxy-1-methyl-1H-indol-2-yl)methylene)malonate (1j)



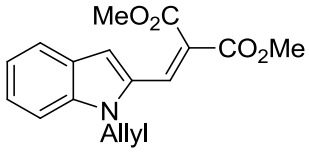
Yellow solid, m. p. 139 – 141 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.81 (s, 1H), 7.46 (d, *J* = 8.8 Hz, 1H), 6.85 (s, 1H), 6.78 (dd, *J* = 8.7, 2.2 Hz, 1H), 6.68 (d, *J* = 1.9 Hz, 1H), 3.93 (s, 3H), 3.87 (s, 3H), 3.85 (s, 3H), 3.75 (s, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 167.5, 164.7, 158.4, 139.9, 130.8, 130.0, 122.8, 122.1, 121.6, 112.0, 107.0, 91.9, 55.5, 52.9, 52.5, 29.8 ppm. HRMS(ESI) *m/z* calcd for $[C_{16}H_{17}NO_5+H]^+$ 304.1179, found 304.1184.

dimethyl 2-((1-ethyl-1H-indol-2-yl)methylene)malonate (1k)



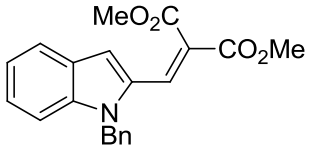
Yellow solid, m. p. 110 – 112 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.83 (s, 1H), 7.60 (d, *J* = 8.0 Hz, 1H), 7.38 – 7.22 (m, 2H), 7.11 (t, *J* = 7.3 Hz, 1H), 6.88 (s, 1H), 4.29 (q, *J* = 7.2 Hz, 2H), 3.92 (s, 3H), 3.86 (s, 3H), 1.38 (t, *J* = 7.2 Hz, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 167.2, 164.4, 137.7, 130.7, 129.9, 127.7, 124.4, 123.9, 122.0, 120.5, 109.7, 106.4, 52.9, 52.7, 38.0, 15.7 ppm. HRMS(ESI) *m/z* calcd for $[C_{16}H_{17}NO_4+H]^+$ 288.1230, found 288.1234.

dimethyl 2-((1-allyl-1H-indol-2-yl)methylene)malonate (1l)



Yellow solid, m. p. 54 – 56 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.77 (s, 1H), 7.61 (d, *J* = 8.0 Hz, 1H), 7.34 – 7.22 (m, 2H), 7.17 – 7.07 (m, 1H), 6.91 (s, 1H), 6.09 – 5.82 (m, 1H), 5.17 (d, *J* = 10.5 Hz, 1H), 4.96 – 4.72 (m, 3H), 3.92 (s, 3H), 3.85 (s, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 167.2, 164.4, 138.2, 132.6, 131.4, 130.1, 127.6, 124.6, 124.0, 121.9, 120.7, 117.0, 109.8, 106.6, 53.0, 52.7, 45.4 ppm. HRMS(ESI) *m/z* calcd for $[C_{17}H_{17}NO_4+H]^+$ 300.1230, found 300.1230.

dimethyl 2-((1-benzyl-1H-indol-2-yl)methylene)malonate (1m)



Yellow solid, m. p. 99 – 100 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.78 (s, 1H), 7.64 (d, *J* = 8.0 Hz, 1H), 7.34 – 7.19 (m, 5H), 7.17 – 7.08 (m, 1H), 7.05 – 6.98 (m, 2H), 6.96 (s, 1H), 5.44 (s, 2H), 3.92 (s, 3H), 3.80 (s, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 167.1, 164.2, 138.5, 136.8, 131.6, 130.0, 128.9, 127.7, 126.0, 124.7, 124.3, 122.0, 120.9, 110.1, 106.9, 53.0, 52.6, 46.7 ppm. HRMS(ESI) *m/z* calcd for $[C_{21}H_{19}NO_4+H]^+$ 350.1387, found 350.1385.

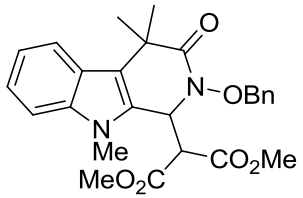
4. General Procedures for [3 + 3] Annulation Reaction

a) General Procedures

In a 10 mL test tube was sequentially added 2-alkenylindoles **1** (0.2 mmol, 1.0 equiv), Na_2CO_3 (0.8 mmol, 4.0 equiv), *α*-halohydroxamates **2** (0.4 mmol, 2.0 equiv) and HFIP (1.0 mL). Then, the tube was sealed and stirred at room temperature. Once the 2-alkenylindoles was complete consumption, the reaction mixture was diluted with EA, filtered through celite and washed with EA. The filtrate was concentrated under reduced pressure and the resulting residue was purified by flash column chromatography (PE/EA = 6/1) on silica gel to afford the pure product.

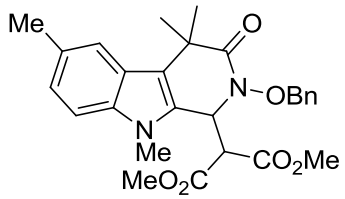
b) Characterization of the Products

dimethyl 2-(2-(benzyloxy)-4,4,9-trimethyl-3-oxo-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl)malonate (3aa)



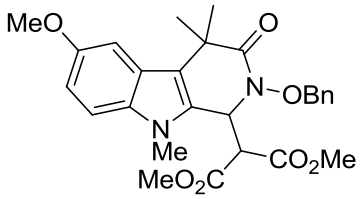
80.2 mg, 86% yield, White solid, m. p. 106 – 108 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.66 (d, *J* = 7.9 Hz, 1H), 7.55 – 7.42 (m, 2H), 7.40 – 7.20 (m, 5H), 7.13 (dd, *J* = 10.7, 3.9 Hz, 1H), 5.75 (d, *J* = 2.8 Hz, 1H), 5.00 (d, *J* = 10.0 Hz, 1H), 4.91 (d, *J* = 10.0 Hz, 1H), 3.83 (d, *J* = 2.8 Hz, 1H), 3.62 (s, 3H), 3.60 (s, 3H), 3.30 (s, 3H), 1.71 (s, 6H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.7, 167.4, 166.8, 138.7, 134.4, 130.1, 128.7, 128.2, 124.9, 124.2, 122.3, 120.0, 119.6, 115.6, 109.6, 75.9, 57.5, 54.7, 52.6, 52.6, 40.8, 30.0, 28.9, 26.1 ppm. HRMS(ESI) *m/z* calcd for $[C_{26}H_{29}N_2O_6+H]^+$ 465.2020, found 465.2024.

dimethyl 2-(2-(benzyloxy)-4,4,6,9-tetramethyl-3-oxo-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl)malonate (3ba)



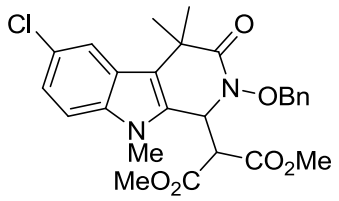
90.2 mg, 94% yield, White solid, m. p. 124 – 125 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.55 – 7.40 (m, 3H), 7.40 – 7.26 (m, 3H), 7.18 (d, *J* = 8.4 Hz, 1H), 7.07 (d, *J* = 8.4 Hz, 1H), 5.72 (d, *J* = 2.9 Hz, 1H), 4.99 (d, *J* = 9.9 Hz, 1H), 4.90 (d, *J* = 10.0 Hz, 1H), 3.81 (d, *J* = 2.9 Hz, 1H), 3.61 (s, 3H), 3.57 (s, 3H), 3.30 (s, 3H), 2.46 (s, 3H), 1.71 (s, 6H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.7, 167.4, 166.8, 137.1, 134.4, 130.1, 128.8, 128.7, 128.2, 124.8, 124.3, 123.8, 119.7, 115.0, 109.3, 75.8, 57.5, 54.7, 52.6, 52.5, 40.8, 30.0, 28.9, 26.0, 21.4 ppm. HRMS(ESI) *m/z* calcd for $[C_{27}H_{30}N_2O_6+H]^+$ 479.2177, found 479.2188.

dimethyl
2-(2-(benzyloxy)-6-methoxy-4,4,9-trimethyl-3-oxo-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl)malonate (3ca)



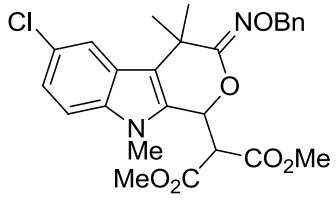
86.0 mg, 87% yield, White solid, m. p. 98 – 100 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.57 – 7.42 (m, 2H), 7.42 – 7.38 (m, 3H), 7.19 (d, *J* = 8.9 Hz, 1H), 7.09 (d, *J* = 2.1 Hz, 1H), 6.91 (dd, *J* = 8.9, 2.3 Hz, 1H), 5.72 (d, *J* = 2.9 Hz, 1H), 5.00 (d, *J* = 9.9 Hz, 1H), 4.90 (d, *J* = 9.9 Hz, 1H), 3.86 (s, 3H), 3.81 (d, *J* = 2.9 Hz, 1H), 3.63 (s, 3H), 3.57 (s, 3H), 3.30 (s, 3H), 1.70 (s, 6H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.8, 167.4, 166.9, 153.8, 134.4, 134.1, 130.1, 128.7, 128.2, 125.5, 124.5, 115.1, 112.0, 110.3, 102.4, 75.9, 57.5, 55.9, 54.8, 52.7, 52.7, 40.8, 30.2, 28.7, 25.9 ppm. HRMS(ESI) *m/z* calcd for $[C_{27}H_{31}N_2O_7+H]^+$ 495.2126, found 495.2124.

dimethyl
2-(2-(benzyloxy)-6-chloro-4,4,9-trimethyl-3-oxo-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl)malonate (3da)



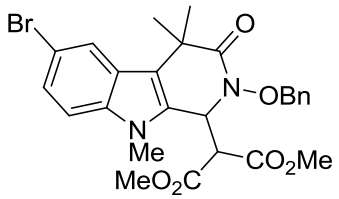
75.8 mg, 76% yield, White solid, m. p. 162 – 164 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.61 (s, 1H), 7.54 – 7.42 (m, 2H), 7.40 – 7.28 (m, 3H), 7.20 (s, 2H), 5.73 (d, *J* = 2.6 Hz, 1H), 5.00 (d, *J* = 10.0 Hz, 1H), 4.90 (d, *J* = 10.0 Hz, 1H), 3.85 (d, *J* = 2.3 Hz, 1H), 3.65 (s, 3H), 3.58 (s, 3H), 3.29 (s, 3H), 1.68 (s, 6H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.5, 167.2, 167.1, 137.2, 134.5, 130.1, 128.8, 128.3, 126.5, 125.4, 125.2, 122.7, 119.5, 110.7, 76.1, 57.5, 55.1, 52.8, 52.7, 40.8, 30.3, 28.9, 26.2 ppm. HRMS(ESI) *m/z* calcd for $[C_{26}H_{27}ClN_2O_6+H]^+$ 499.1630, found 499.1637.

dimethyl
2-(3-((benzyloxy)imino)-6-chloro-4,4,9-trimethyl-1,3,4,9-tetrahydropyrano[3,4-b]indol-1-yl)malonate (4da)



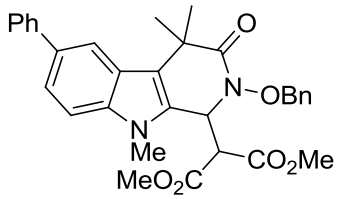
41.9 mg, 42% yield, White solid, m. p. 125– 127 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.52 – 7.32 (m, 5H), 7.22 – 7.09 (m, 2H), 7.05 (s, 1H), 6.34 (d, *J* = 8.4 Hz, 1H), 5.29 (d, *J* = 9.6 Hz, 1H), 4.89 (d, *J* = 9.6 Hz, 1H), 3.83 (s, 1H), 3.79 (s, 3H), 3.23 (s, 3H), 2.83 (s, 3H), 1.37 (s, 3H), 1.31 (s, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 175.2, 164.5, 162.8, 147.7, 144.8, 134.2, 132.1, 129.4, 128.9, 128.6, 128.6, 126.9, 126.3, 123.4, 107.5, 85.8, 77.3, 59.5, 52.9, 52.0, 40.3, 31.0, 28.6, 23.0 ppm. HRMS(ESI) *m/z* calcd for $[C_{26}H_{27}ClN_2O_6+H]^+$ 499.1630, found 499.1634.

dimethyl
2-(2-(benzyloxy)-6-bromo-4,4,9-trimethyl-3-oxo-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl)malonate (3ea)



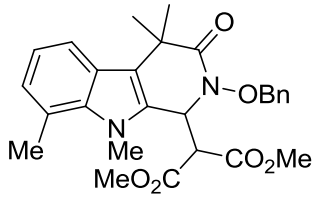
79.0 mg, 73% yield, White solid, m. p. 181 – 183 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.77 (d, *J* = 1.4 Hz, 1H), 7.53 – 7.41 (m, 2H), 7.41 – 7.27 (m, 4H), 7.16 (d, *J* = 8.7 Hz, 1H), 5.74 (d, *J* = 2.8 Hz, 1H), 5.00 (d, *J* = 9.9 Hz, 1H), 4.90 (d, *J* = 10.0 Hz, 1H), 3.84 (d, *J* = 2.8 Hz, 1H), 3.65 (s, 3H), 3.59 (s, 3H), 3.29 (s, 3H), 1.68 (s, 6H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.4, 167.3, 166.9, 137.3, 134.3, 130.1, 128.8, 128.3, 126.3, 125.7, 125.2, 122.5, 115.3, 112.9, 111.1, 76.0, 57.4, 54.8, 52.8, 52.8, 40.7, 30.3, 28.9, 26.1 ppm. HRMS(ESI) *m/z* calcd for $[C_{26}H_{27}BrN_2O_6+H]^+$ 543.1125, found 543.1132.

dimethyl
2-(2-(benzyloxy)-4,4,9-trimethyl-3-oxo-6-phenyl-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl)malonate (3fa)



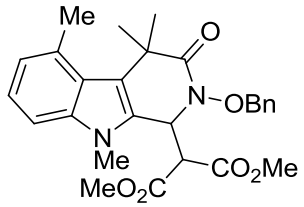
72.2 mg, 67% yield, White solid, m. p. 166 – 168 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.83 (d, *J* = 0.7 Hz, 1H), 7.70 -7.57 (m, 2H), 7.55 – 7.41 (m, 5H), 7.40 – 7.27 (m, 5H), 5.74 (d, *J* = 2.8 Hz, 1H), 5.01 (d, *J* = 10.0 Hz, 1H), 4.92 (d, *J* = 10.0 Hz, 1H), 3.84 (d, *J* = 2.8 Hz, 1H), 3.64 (s, 3H), 3.63 (s, 3H), 3.33 (s, 3H), 1.75 (s, 6H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.7, 167.4, 166.8, 142.1, 138.3, 134.4, 133.3, 130.1, 128.8, 128.7, 128.2, 127.4, 126.6, 125.6, 124.7, 122.2, 118.6, 116.0, 109.9, 76.0, 57.6, 54.7, 52.7, 52.7, 40.9, 30.2, 29.1, 26.1 ppm. HRMS(ESI) *m/z* calcd for $[C_{32}H_{32}N_2O_6+H]^+$ 541.2333, found 541.2343.

dimethyl
2-(2-(benzyloxy)-4,4,8,9-tetramethyl-3-oxo-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl)malonate (3ga)



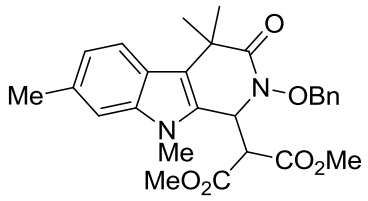
78.2 mg, 82% yield, White solid, m. p. 151 – 153 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.60 – 7.42 (m, 3H), 7.40 – 7.26 (m, 3H), 7.08 – 6.86 (m, 2H), 5.67 (d, *J* = 2.7 Hz, 1H), 5.00 (d, *J* = 10.0 Hz, 1H), 4.91 (d, *J* = 10.0 Hz, 1H), 3.92 – 3.70 (m, 4H), 3.62 (s, 3H), 3.34 (s, 3H), 2.73 (s, 3H), 1.70 (s, 3H), 1.69 (s, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.7, 167.4, 166.7, 138.0, 134.4, 130.1, 128.7, 128.2, 125.6, 125.4, 125.2, 121.7, 119.7, 118.1, 115.8, 75.9, 57.7, 54.7, 52.6, 52.6, 40.7, 33.2, 28.7, 25.7, 20.2 ppm. HRMS(ESI) *m/z* calcd for $[C_{27}H_{30}N_2O_6+H]^+$ 479.2177, found 479.2180.

dimethyl
2-(2-(benzyloxy)-4,4,8,9-tetramethyl-3-oxo-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl)malonate (3ha)



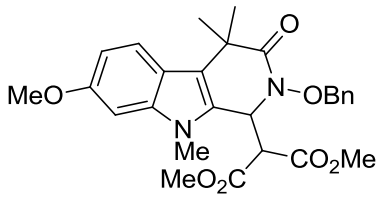
51.4 mg, 54% yield, White solid, m. p. 65 – 67 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.57 – 7.41 (m, 2H), 7.41 – 7.27 (m, 3H), 7.23 – 7.09 (m, 2H), 6.97 (d, *J* = 3.9 Hz, 1H), 5.71 (d, *J* = 2.6 Hz, 1H), 5.01 (d, *J* = 10.1 Hz, 1H), 4.92 (d, *J* = 10.1 Hz, 1H), 3.77 (d, *J* = 2.6 Hz, 1H), 3.63 (s, 3H), 3.58 (s, 3H), 3.30 (s, 3H), 2.78 (s, 3H), 1.80 (s, 3H), 1.72 (s, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 175.9, 167.4, 166.9, 139.5, 134.5, 130.1, 129.6, 128.8, 128.3, 125.3, 124.1, 123.1, 122.5, 116.4, 107.3, 75.9, 57.0, 55.0, 52.7, 52.7, 41.4, 31.3, 30.1, 27.6, 24.5 ppm. HRMS(ESI) *m/z* calcd for $[C_{27}H_{30}N_2O_6+H]^+$ 479.2177, found 479.2175.

dimethyl
2-(2-(benzyloxy)-4,4,7,9-tetramethyl-3-oxo-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl)malonate (3ia)



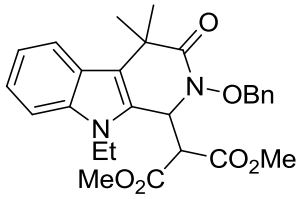
80.5 mg, 84% yield, White solid, m. p. 136 – 138 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.50 (dd, *J* = 18.4, 6.1 Hz, 3H), 7.33 (d, *J* = 4.5 Hz, 3H), 7.09 (s, 1H), 6.97 (d, *J* = 8.0 Hz, 1H), 5.72 (d, *J* = 2.5 Hz, 1H), 4.99 (d, *J* = 9.9 Hz, 1H), 4.90 (d, *J* = 9.9 Hz, 1H), 3.81 (d, *J* = 2.5 Hz, 1H), 3.61 (s, 3H), 3.57 (s, 3H), 3.31 (s, 3H), 2.48 (s, 3H), 1.70 (s, 6H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.7, 167.4, 166.8, 139.1, 134.4, 132.3, 130.1, 128.7, 128.2, 124.1, 122.0, 121.3, 119.6, 115.5, 109.7, 75.9, 57.6, 54.7, 52.6, 52.6, 40.8, 30.0, 28.9, 26.1, 21.7 ppm. HRMS(ESI) *m/z* calcd for $[C_{27}H_{30}N_2O_6+H]^+$ 479.2177, found 479.2183.

dimethyl
2-(2-(benzyloxy)-7-methoxy-4,4,9-trimethyl-3-oxo-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl)malonate (3ja)



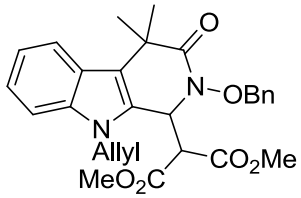
58.8 mg, 59% yield, White solid, m. p. 129 – 130 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.58 – 7.41 (m, 3H), 7.41 – 7.28 (m, 3H), 6.86 – 6.68 (m, 2H), 5.73 (d, *J* = 2.9 Hz, 1H), 4.99 (d, *J* = 9.9 Hz, 1H), 4.90 (d, *J* = 9.9 Hz, 1H), 3.87 (s, 3H), 3.81 (d, *J* = 2.8 Hz, 1H), 3.63 (s, 3H), 3.56 (s, 3H), 3.31 (s, 3H), 1.68 (s, 6H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.7, 167.5, 166.9, 156.6, 139.7, 134.5, 130.1, 128.7, 128.2, 123.5, 120.6, 118.4, 115.7, 109.3, 93.3, 75.9, 57.6, 55.6, 54.9, 52.6, 52.6, 40.8, 30.1, 29.0, 26.2 ppm. HRMS(ESI) *m/z* calcd for $[C_{27}H_{30}N_2O_7+H]^+$ 495.2126, found 495.2127.

dimethyl 2-(2-(benzyloxy)-9-ethyl-4,4-dimethyl-3-oxo-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl)malonate (3ka)



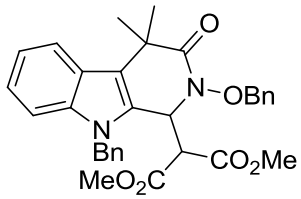
84.0 mg, 88% yield, White solid, m. p. 54 – 56 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.66 (d, *J* = 7.9 Hz, 1H), 7.56 – 7.41 (m, 2H), 7.40 – 7.17 (m, 5H), 7.12 (t, *J* = 7.4 Hz, 1H), 5.56 (d, *J* = 2.7 Hz, 1H), 5.05 – 4.85 (m, 2H), 4.15 – 3.85 (m, 2H), 3.77 (d, *J* = 2.7 Hz, 1H), 3.63 (s, 3H), 3.36 (s, 3H), 1.71 (s, 3H), 1.71 (s, 3H), 1.20 (t, *J* = 7.1 Hz, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.8, 167.5, 166.7, 137.5, 134.5, 130.3, 128.8, 128.2, 124.7, 124.1, 122.2, 120.2, 119.5, 115.9, 110.0, 75.9, 57.9, 54.8, 52.8, 52.7, 40.9, 38.3, 29.1, 25.9, 14.6 ppm. HRMS(ESI) *m/z* calcd for $[C_{27}H_{30}N_2O_6+H]^+$ 479.2177, found 479.2181.

dimethyl 2-(9-allyl-2-(benzyloxy)-4,4-dimethyl-3-oxo-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl)malonate (3la)



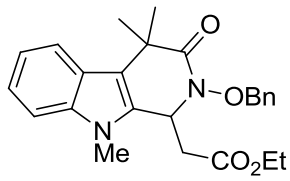
89.2 mg, 91% yield, White solid, m. p. 93 – 95 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.67 (d, *J* = 7.9 Hz, 1H), 7.54 – 7.40 (m, 2H), 7.38 – 7.18 (m, 5H), 7.18 – 7.07 (m, 1H), 7.05 – 7.04 (m, 1H), 5.95 – 5.74 (m, 1H), 5.65 (d, *J* = 2.3 Hz, 1H), 5.15 (d, *J* = 10.4 Hz, 1H), 5.04 – 4.86 (m, *J* = 10.2 Hz, 2H), 4.80 (d, *J* = 17.2 Hz, 1H), 4.70 – 4.53 (m, 2H), 3.81 (d, *J* = 2.3 Hz, 1H), 3.60 (s, 3H), 3.37 (s, 3H), 1.73 (s, 3H), 1.69 (s, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.6, 167.6, 166.4, 138.2, 134.4, 132.1, 130.2, 128.7, 128.1, 124.6, 124.4, 122.4, 120.1, 119.7, 117.2, 116.1, 110.2, 75.8, 57.6, 54.1, 52.7, 52.5, 45.6, 40.8, 29.1, 25.8 ppm. HRMS(ESI) *m/z* calcd for $[C_{28}H_{31}N_2O_6+H]^+$ 491.2177, found 491.2187.

dimethyl 2-(9-benzyl-2-(benzyloxy)-4,4-dimethyl-3-oxo-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl)malonate (3ma)



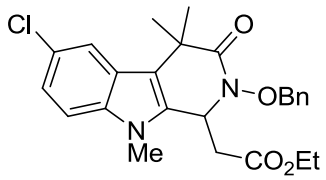
77.9 mg, 72% yield, White solid, m. p. 151 – 152 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.69 (d, *J* = 7.1 Hz, 1H), 7.46 – 7.34 (m, 2H), 7.33 – 7.22 (m, 6H), 7.21 – 7.08 (m, 3H), 6.99 – 6.83 (m, 2H), 5.68 (d, *J* = 2.6 Hz, 1H), 5.25 (s, 2H), 4.90 (d, *J* = 10.2 Hz, 1H), 4.82 (d, *J* = 10.2 Hz, 1H), 3.65 (d, *J* = 2.6 Hz, 1H), 3.58 (s, 3H), 3.31 (s, 3H), 1.75 (s, 3H), 1.69 (s, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.5, 167.4, 166.4, 138.5, 136.4, 134.3, 130.0, 128.8, 128.6, 128.0, 127.5, 125.8, 124.9, 124.5, 122.6, 120.1, 119.8, 116.5, 110.4, 75.6 57.5, 54.4, 52.5, 52.3, 46.9, 40.8, 29.1, 25.8 ppm. HRMS(ESI) *m/z* calcd for $[C_{32}H_{32}N_2O_6+H]^+$ 541.2333, found 541.2343.

ethyl
2-(2-(benzyloxy)-4,4,9-trimethyl-3-oxo-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl)acetate (3na)



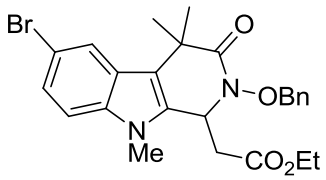
79.8 mg, 95% yield, White solid, m. p. 115 – 116 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.67 (d, *J* = 7.9 Hz, 1H), 7.56 – 7.44 (m, 2H), 7.41 – 7.23 (m, 5H), 7.14 (t, *J* = 7.3 Hz, 1H), 5.52 – 5.35 (m, 1H), 5.02 (d, *J* = 9.7 Hz, 1H), 4.95 (d, *J* = 9.7 Hz, 1H), 4.12 – 3.88 (m, 2H), 3.61 (s, 3H), 2.87 – 2.62 (m, 2H), 1.76 (s, 3H), 1.67 (s, 3H), 1.08 (t, *J* = 7.1 Hz, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.5, 170.5, 138.4, 134.6, 129.9, 128.7, 128.2, 127.5, 124.2, 122.1, 119.9, 119.6, 113.8, 109.5, 75.7, 60.9, 55.1, 41.1, 40.6, 29.6, 27.8, 27.5, 13.8 ppm. HRMS(ESI) *m/z* calcd for $[C_{25}H_{28}N_2O_4+H]^+$ 421.2122, found 421.2133.

ethyl
2-(2-(benzyloxy)-6-chloro-4,4,9-trimethyl-3-oxo-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl)acetate (3oa)



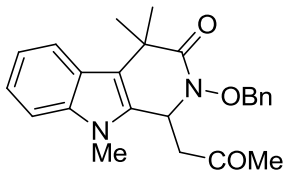
82.5 mg, 91% yield, White solid, m. p. 121 – 123 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.62 (s, 1H), 7.55 – 7.43 (m, 2H), 7.42 – 7.29 (m, 3H), 7.24 – 7.13 (m, 2H), 5.42 (dd, *J* = 5.9, 3.9 Hz, 1H), 5.02 (d, *J* = 9.7 Hz, 1H), 4.94 (d, *J* = 9.7 Hz, 1H), 4.11 – 3.88 (m, 2H), 3.61 (s, 3H), 2.88 – 2.63 (m, 2H), 1.73 (s, 3H), 1.64 (s, 3H), 1.08 (t, *J* = 7.1 Hz, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.2, 170.4, 136.8, 134.5, 129.9, 128.9, 128.7, 128.3, 125.3, 125.1, 122.3, 119.3, 113.7, 110.5, 75.8, 61.0, 55.0, 40.9, 40.4, 29.9, 27.7, 27.5, 13.8 ppm. HRMS(ESI) *m/z* calcd for $[C_{25}H_{27}ClN_2O_4+H]^+$ 455.1732, found 455.1732.

ethyl
2-(2-(benzyloxy)-6-bromo-4,4,9-trimethyl-3-oxo-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl)acetate (3pa)



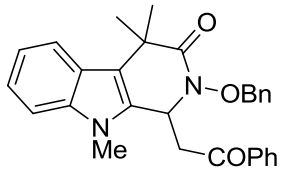
89.7 mg, 90% yield, White solid, m. p. 175 – 176 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.77 (d, *J* = 1.1 Hz, 1H), 7.58 – 7.43 (m, 2H), 7.43 – 7.27 (m, 4H), 7.16 (d, *J* = 8.7 Hz, 1H), 5.43 (dd, *J* = 5.9, 3.9 Hz, 1H), 5.02 (d, *J* = 9.7 Hz, 1H), 4.94 (d, *J* = 9.7 Hz, 1H), 4.10 – 3.88 (m, 2H), 3.61 (s, 3H), 2.84 – 2.64 (m, 2H), 1.73 (s, 3H), 1.64 (s, 3H), 1.08 (t, *J* = 7.1 Hz, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 172.8, 134.0, 133.8, 131.3, 130.7, 130.5, 129.4, 128.8, 128.8, 128.2, 126.7, 126.5, 125.9, 125.0, 123.0, 85.8, 78.2, 78.0, 24.8, 22.7 ppm. HRMS(ESI) *m/z* calcd for $[C_{25}H_{27}BrN_2O_4+H]^+$ 499.1227, found 499.1228.

2-(benzyloxy)-4,4,9-trimethyl-1-(2-oxopropyl)-4,9-dihydro-1H-pyrido[3,4-b]indol-3(2H)-one (3qa)



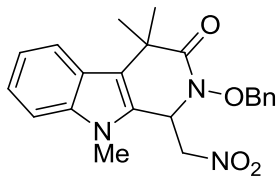
71.1 mg, 91% yield, White solid, m. p. 159 – 161 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.66 (d, *J* = 7.9 Hz, 1H), 7.53 – 7.41 (m, 2H), 7.40 – 7.20 (m, 5H), 7.14 (t, *J* = 7.0 Hz, 1H), 5.63 (dd, *J* = 7.5, 1.6 Hz, 1H), 5.00 – 4.82 (m, 2H), 3.61 (s, 3H), 3.00 (dd, *J* = 16.6, 7.6 Hz, 1H), 2.63 (dd, *J* = 16.6, 1.5 Hz, 1H), 2.16 (s, 3H), 1.75 (s, 3H), 1.68 (s, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 205.5, 173.5, 138.3, 134.1, 130.1, 128.8, 128.4, 127.8, 124.2, 122.1, 119.8, 119.6, 113.5, 109.5, 75.6, 54.2, 49.3, 40.6, 30.9, 29.6, 27.8, 27.6 ppm. HRMS(ESI) *m/z* calcd for $[C_{24}H_{26}N_2O_3+H]^+$ 391.2016, found 391.2012.

2-(benzyloxy)-4,4,9-trimethyl-1-(2-oxo-2-phenylethyl)-4,9-dihydro-1H-pyrido[3,4-b]indol-3(2H)-one (3ra)



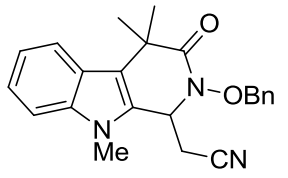
86.7 mg, 96% yield, White solid, m. p. 134 – 136 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.85 (d, *J* = 7.4 Hz, 2H), 7.68 (d, *J* = 7.9 Hz, 1H), 7.51 (t, *J* = 7.3 Hz, 1H), 7.45 – 7.33 (m, 4H), 7.32 – 7.19 (m, 5H), 7.18 – 7.05 (m, 1H), 5.86 (dd, *J* = 6.5, 2.4 Hz, 1H), 4.93 (s, 2H), 3.74 (dd, *J* = 17.0, 6.6 Hz, 1H), 3.61 (s, 3H), 3.06 (dd, *J* = 17.0, 2.4 Hz, 1H), 1.77 (s, 3H), 1.72 (s, 3H) ppm. ^{13}C NMR (126 MHz, $CDCl_3$) δ 196.7, 173.7, 138.5, 136.4, 134.5, 133.3, 129.8, 128.5, 128.5, 128.2, 128.2, 124.4, 122.0, 119.8, 119.6, 113.7, 109.5, 75.6, 54.1, 44.9, 40.7, 29.7, 27.9, 27.6 ppm. HRMS(ESI) *m/z* calcd for $[C_{29}H_{28}N_2O_3+H]^+$ 453.2173, found 453.2179.

2-(benzyloxy)-4,4,9-trimethyl-1-(nitromethyl)-4,9-dihydro-1H-pyrido[3,4-b]indol-3(2H)-one (3sa)



49.3 mg, 63% yield, White solid, m. p. 191 – 192 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.66 (d, *J* = 7.9 Hz, 1H), 7.53 – 7.22 (m, 7H), 7.22 – 7.08 (m, 1H), 5.36 (d, *J* = 2.4 Hz, 1H), 5.13 – 4.91 (m, 2H), 4.81 – 4.58 (m, 2H), 3.56 (s, 3H), 1.76 (s, 3H), 1.67 (s, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.8, 138.8, 134.5, 129.8, 129.0, 128.6, 124.1, 122.9, 122.8, 120.2, 120.0, 116.1, 109.8, 77.3, 76.5, 57.4, 40.9, 29.7, 28.2, 27.5 ppm. HRMS(ESI) *m/z* calcd for $[C_{22}H_{23}N_3O_4+H]^+$ 394.1761, found 394.1767.

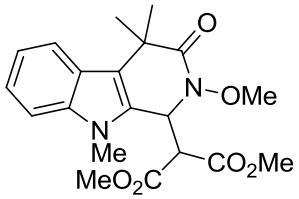
2-(2-(benzyloxy)-4,4,9-trimethyl-3-oxo-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl)acetonitrile (3ta)



70.1 mg, 94% yield, Yellow solid, m. p. 226 – 227 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.69 (d, *J* = 8.0 Hz, 1H), 7.53 – 7.41 (m, 2H), 7.41 – 7.22 (m, 5H), 7.20 – 7.08 (m, 1H), 5.10 (d, *J* = 10.8 Hz, 1H), 5.01 (d, *J* = 10.8 Hz, 1H), 4.73 (dd, *J* = 4.6, 3.6 Hz, 1H), 3.51 (s, 3H), 3.17 (dd, *J* = 17.0, 4.9 Hz, 1H), 2.85 (dd, *J* = 17.0, 3.3 Hz, 1H), 1.82 (s, 3H), 1.78 (s, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.2, 138.8, 134.9, 129.7, 129.0, 128.7, 124.8, 124.1, 122.7, 120.3, 119.9,

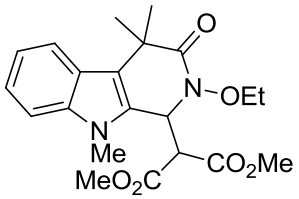
115.6, 115.5, 109.7, 76.6, 55.5, 40.9, 30.0, 28.5, 27.8, 23.7 ppm. HRMS(ESI) *m/z* calcd for $[C_{23}H_{23}N_3O_2+H]^+$ 374.1863, found 374.1865.

dimethyl 2-(2-methoxy-4,4,9-trimethyl-3-oxo-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl) malonate (3ab)



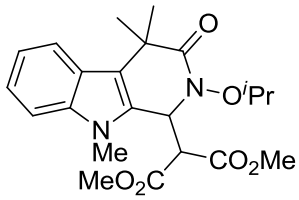
69.8 mg, 90% yield, White solid, m. p. 149 – 151 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.67 (d, *J* = 8.0 Hz, 1H), 7.41 – 7.20 (m, 2H), 7.19 – 7.03 (m, 1H), 5.99 (d, *J* = 2.6 Hz, 1H), 3.86 (d, *J* = 2.6 Hz, 1H), 3.78 (s, 3H), 3.70 (s, 3H), 3.68 (s, 3H), 3.54 (s, 3H), 1.73 (s, 3H), 1.70 (s, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.4, 167.5, 166.7, 138.7, 124.7, 124.1, 122.4, 120.0, 119.6, 115.6, 109.6, 61.2, 56.3, 54.6, 52.8, 52.7, 40.7, 30.1, 28.8, 26.2 ppm. HRMS(ESI) *m/z* calcd for $[C_{20}H_{24}N_2O_6+H]^+$ 389.1707, found 389.1710.

dimethyl 2-(2-ethoxy-4,4,9-trimethyl-3-oxo-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl)malonate (3ac)



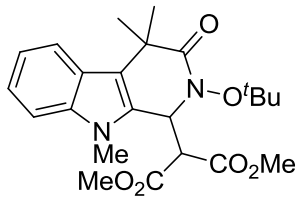
73.3 mg, 91% yield, White solid, m. p. 149 – 151 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.67 (d, *J* = 7.9 Hz, 1H), 7.41 – 7.20 (m, 2H), 7.20 – 7.05 (m, 1H), 5.95 (d, *J* = 2.8 Hz, 1H), 4.15 – 3.90 (m, 2H), 3.86 (d, *J* = 2.8 Hz, 1H), 3.69 (s, 6H), 3.51 (s, 3H), 1.73 (s, 3H), 1.70 (s, 3H), 1.28 (t, *J* = 7.0 Hz, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.8, 167.6, 166.9, 138.8, 124.9, 124.2, 122.4, 120.1, 119.6, 115.8, 109.6, 69.3, 57.0, 54.9, 52.8, 52.7, 40.8, 30.2, 28.9, 26.3, 13.3 ppm. HRMS(ESI) *m/z* calcd for $[C_{21}H_{26}N_2O_6+H]^+$ 403.1864, found 403.1865.

dimethyl 2-(2-isopropoxy-4,4,9-trimethyl-3-oxo-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl)malonate (3ad)



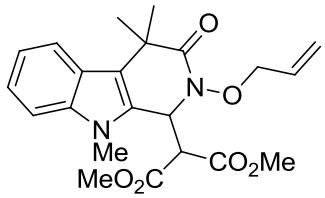
71.1 mg, 85% yield, White solid, m. p. 136 – 138 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.67 (d, *J* = 7.9 Hz, 1H), 7.40 – 7.24 (m, 2H), 7.19 – 7.07 (m, 1H), 5.89 (d, *J* = 3.1 Hz, 1H), 4.42 – 4.22 (m, 1H), 3.88 (d, *J* = 3.1 Hz, 1H), 3.71 (s, 3H), 3.68 (s, 3H), 3.44 (s, 3H), 1.74 (s, 3H), 1.71 (s, 3H), 1.31 – 1.20 (m, 6H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 176.06 (s), 167.5, 167.3, 138.7, 125.2, 124.2, 122.3, 120.0, 119.6, 115.8, 109.7, 76.0, 58.0, 55.2, 52.7, 52.6, 41.1, 30.1, 29.3, 26.0, 20.6, 20.4 ppm. HRMS(ESI) *m/z* calcd for $[C_{22}H_{28}N_2O_6+H]^+$ 417.2020, found 417.2017.

dimethyl
2-(2-(tert-butoxy)-4,4,9-trimethyl-3-oxo-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl)malonate (3ae)



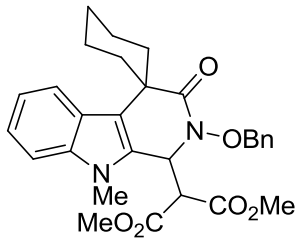
69.1 mg, 80% yield, White solid, m. p. 145 – 147 ^{o}C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.67 (d, *J* = 7.9 Hz, 1H), 7.40 – 7.19 (m, 2H), 7.20 – 7.15 (m, 1H), 5.87 (d, *J* = 3.6 Hz, 1H), 3.90 (d, *J* = 3.6 Hz, 1H), 3.75 (s, 3H), 3.66 (s, 3H), 3.33 (s, 3H), 1.76 (s, 3H), 1.71 (s, 3H), 1.32 (s, 9H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 179.2, 167.9, 167.4, 138.7, 125.7, 124.2, 122.2, 119.8, 119.5, 115.6, 109.7, 83.9, 59.8, 55.7, 52.7, 52.5, 41.7, 30.0, 29.8, 26.8, 25.7 ppm. HRMS(ESI) *m/z* calcd for $[C_{23}H_{30}N_2O_6+H]^+$ 431.2177, found 431.2181.

dimethyl
2-(2-(allyloxy)-4,4,9-trimethyl-3-oxo-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl) malonate (3af)



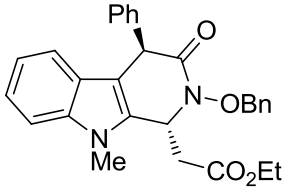
52.2 mg, 63% yield, White solid, m. p. 130 – 132 ^{o}C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.67 (d, *J* = 7.9 Hz, 1H), 7.49 – 7.20 (m, 2H), 7.20 – 7.06 (m, 1H), 6.20 – 5.97 (m, 1H), 5.92 (d, *J* = 2.6 Hz, 1H), 5.47 – 5.17 (m, 2H), 4.57 – 4.30 (m, 2H), 3.86 (d, *J* = 2.6 Hz, 1H), 3.69 (s, 3H), 3.68 (s, 3H), 3.52 (s, 3H), 1.71 (s, 6H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.9, 167.6, 166.8, 138.8, 131.8, 124.8, 124.2, 122.4, 120.9, 120.1, 119.7, 115.7, 109.7, 75.1, 57.6, 54.7, 52.9, 52.7, 40.8, 30.2, 29.2, 26.1 ppm. HRMS(ESI) *m/z* calcd for $[C_{22}H_{26}N_2O_6+H]^+$ 415.1864, found 415.1863.

dimethyl
2-(2'-(benzyloxy)-9'-methyl-3'-oxo-1',2',3',9'-tetrahydrospiro[cyclohexane-1,4'-pyrido[3,4-b]indol]-1'-yl)malonate (3ag)



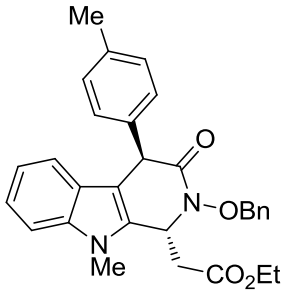
83.6 mg, 83% yield, White solid, m. p. 141– 143 ^{o}C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.76 (d, *J* = 8.0 Hz, 1H), 7.53 – 7.40 (m, 2H), 7.39 – 7.22 (m, 5H), 7.17 – 7.06 (m, 1H), 5.73 (d, *J* = 2.9 Hz, 1H), 4.97 (d, *J* = 10.2 Hz, 1H), 4.86 (d, *J* = 10.2 Hz, 1H), 3.85 (d, *J* = 2.9 Hz, 1H), 3.64 (s, 3H), 3.59 (s, 3H), 3.25 (s, 3H), 2.48 – 2.25 (m, 2H), 2.22 – 2.02 (m, 3H), 1.97 – 1.85 (m, 1H), 1.77 – 1.59 (m, 3H), 1.52 – 1.37 (m, 1H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.1, 167.5, 167.2, 138.8, 134.8, 129.9, 128.6, 128.2, 126.0, 123.8, 122.2, 120.4, 119.3, 116.3, 109.8, 75.8, 57.5, 55.1, 52.7, 52.6, 42.5, 36.8, 33.9, 30.1, 25.4, 22.5 ppm. HRMS(ESI) *m/z* calcd for $[C_{29}H_{32}N_2O_6+H]^+$ 505.2333, found 505.2341.

ethyl
2-(2-(benzyloxy)-9-methyl-3-oxo-4-phenyl-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl)acetate (3nh)



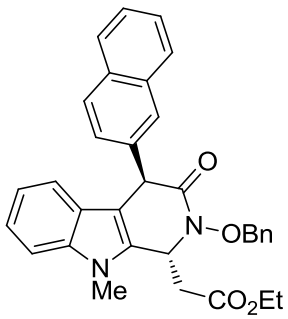
51.5 mg, 55% yield, White solid, m. p. 154– 156 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.48 – 7.37 (m, 2H), 7.35 – 7.24 (m, 9H), 7.21 – 7.12 (m, 1H), 6.96 – 6.78 (m, 2H), 5.40 – 5.27 (m, 1H), 5.04 – 4.81 (m, 3H), 4.10 – 3.90 (m, 2H), 3.64 (s, 3H), 3.00 (dd, *J* = 16.2, 2.7 Hz, 1H), 2.79 (dd, *J* = 16.2, 6.4 Hz, 1H), 1.10 (t, *J* = 7.2 Hz, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.3, 169.0, 139.7, 138.3, 134.8, 130.0, 129.5, 128.7, 128.7, 128.5, 128.3, 127.3, 124.8, 122.3, 119.8, 119.7, 109.1, 108.1, 76.0, 61.0, 56.2, 47.7, 39.2, 30.0, 13.9 ppm. HRMS(ESI) *m/z* calcd for $[C_{29}H_{28}N_2O_4+H]^+$ 469.2122, found 469.2128.

ethyl
2-((1R,4S)-2-(benzyloxy)-9-methyl-3-oxo-4-(p-tolyl)-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl)acetate (3ni)



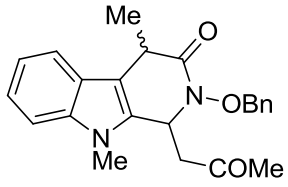
52.0 mg, 54% yield, White solid, m. p. 128– 130 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.49 – 7.28 (m, 5H), 7.27 – 7.21 (m, 1H), 7.20 – 7.03 (m, 5H), 6.96 – 6.80 (m, 2H), 5.39 – 5.26 (m, 1H), 4.91 (q, *J* = 10.4 Hz, 3H), 4.09 – 3.90 (m, 2H), 3.63 (s, 3H), 2.97 (dd, *J* = 16.1, 2.6 Hz, 1H), 2.79 (dd, *J* = 16.1, 6.3 Hz, 1H), 2.32 (s, 3H), 1.08 (t, *J* = 7.1 Hz, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.3, 169.1, 138.4, 136.8, 136.7, 135.0, 129.9, 129.6, 129.2, 128.7, 128.5, 128.3, 124.9, 122.3, 119.8, 119.7, 109.1, 108.3, 76.0, 60.9, 56.3, 47.4, 39.3, 29.9, 21.1, 13.9 ppm. HRMS(ESI) *m/z* calcd for $[C_{30}H_{30}N_2O_4+H]^+$ 483.2278, found 483.2271.

ethyl
2-((1R,4S)-2-(benzyloxy)-9-methyl-4-(naphthalen-2-yl)-3-oxo-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl)acetate (3nj)



59.5 mg, 57% yield, White solid, m. p. 147– 149 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.93 – 7.69 (m, 4H), 7.54 – 7.36 (m, 4H), 7.35 – 7.21 (m, 5H), 7.20 – 7.07 (m, 1H), 6.81 (d, *J* = 3.8 Hz, 2H), 5.43 – 5.33 (m, 1H), 5.15 (d, *J* = 1.5 Hz, 1H), 4.96 (d, *J* = 10.5 Hz, 1H), 4.88 (d, *J* = 10.5 Hz, 1H), 4.12 – 3.93 (m, 2H), 3.66 (s, 3H), 3.02 (dd, *J* = 16.1, 2.7 Hz, 1H), 2.83 (dd, *J* = 16.1, 6.2 Hz, 1H), 1.11 (t, *J* = 7.1 Hz, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.3, 168.9, 138.4, 137.2, 135.0, 133.4, 132.9, 129.9, 129.8, 128.7, 128.4, 128.3, 128.0, 128.0, 127.6, 126.3, 125.9, 125.7, 124.9, 122.3, 119.8, 119.7, 109.1, 108.1, 76.1, 61.0, 56.4, 48.0, 39.3, 30.0, 13.9 ppm. HRMS(ESI) *m/z* calcd for $[C_{33}H_{30}N_2O_4+H]^+$ 519.2278, found 519.2276.

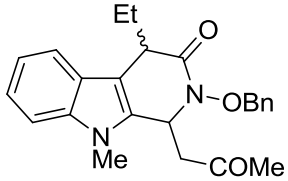
2-(benzyloxy)-4,9-dimethyl-1-(2-oxopropyl)-4,9-dihydro-1H-pyrido[3,4-b]indol-3(2H)-one (3qk)



For the **major diastereomer**: 41.4 mg, 55% yield,Yellow solid, m. p. 149 – 150 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.57 (d, *J* = 7.9 Hz, 1H), 7.52 – 7.42 (m, 2H), 7.42 – 7.30 (m, 5H), 7.20 – 7.05 (m, 1H), 5.60 (d, *J* = 7.3 Hz, 1H), 5.02 – 4.77 (m, 2H), 4.02 – 3.84 (m, 1H), 3.61 (s, 3H), 3.01 (dd, *J* = 16.7, 7.4 Hz, 1H), 2.64 (dd, *J* = 16.7, 1.5 Hz, 1H), 2.15 (s, 3H), 1.70 (d, *J* = 7.2 Hz, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 205.5, 170.8, 138.3, 134.2, 130.1, 128.8, 128.4, 124.8, 122.3, 119.8, 119.2, 109.4, 109.2, 75.8, 54.9, 48.7, 35.9, 30.8, 29.8, 20.1 ppm. HRMS(ESI) *m/z* calcd for $[C_{23}H_{24}N_2O_3+H]^+$ 377.1860, found 377.1853.

For the **minor diastereomer**: 18.0 mg, 24% yield, Yellow solid, m. p. 161 – 162 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.54 (d, *J* = 7.8 Hz, 1H), 7.50 – 7.42 (m, 2H), 7.42 – 7.26 (m, 5H), 7.22 – 7.10 (m, 1H), 5.59 (d, *J* = 7.2 Hz, 1H), 4.97 (d, *J* = 9.3 Hz, 1H), 4.90 (d, *J* = 9.3 Hz, 1H), 3.98 (q, *J* = 7.4 Hz, 1H), 3.63 (s, 3H), 3.04 (dd, *J* = 16.5, 7.4 Hz, 1H), 2.70 (dd, *J* = 16.5, 2.2 Hz, 1H), 2.17 (s, 3H), 1.64 (d, *J* = 7.3 Hz, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 205.6, 169.8, 138.1, 134.2, 130.1, 129.2, 128.9, 128.5, 124.8, 122.4, 119.9, 118.6, 109.9, 109.4, 75.9, 54.1, 49.6, 35.5, 31.1, 29.8, 20.5 ppm. HRMS(ESI) *m/z* calcd for $[C_{23}H_{24}N_2O_3+H]^+$ 377.1860, found 377.1858.

2-(benzyloxy)-4-ethyl-9-methyl-1-(2-oxopropyl)-4,9-dihydro-1H-pyrido[3,4-b]indol-3(2H)-one (3ql)

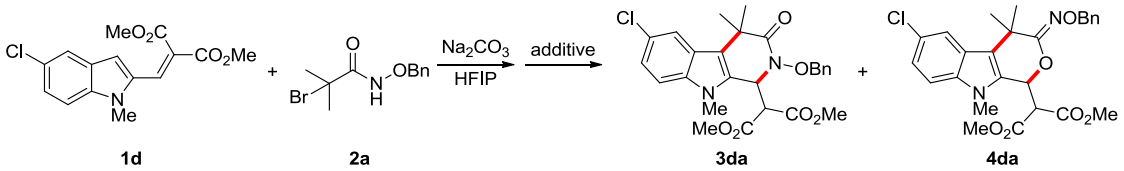


For the **major diastereomer**: 53.2mg, 68% yield, White solid, m. p. 194 – 195 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.56 (d, *J* = 7.9 Hz, 1H), 7.52 – 7.42 (m, 2H), 7.42 – 7.22 (m, 5H), 7.19 – 7.05 (m, 1H), 5.69 (d, *J* = 7.4 Hz, 1H), 4.98 (d, *J* = 9.6 Hz, 1H), 4.88 (d, *J* = 9.6 Hz, 1H), 4.15 – 3.95 (m, 1H), 3.63 (s, 3H), 3.00 (dd, *J* = 16.7, 7.4 Hz, 1H), 2.63 (dd, *J* = 16.7, 1.5 Hz, 1H), 2.51 – 2.19 (m, 2H), 2.14 (s, 3H), 0.66 (t, *J* = 7.4 Hz, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 205.6, 169.6, 138.3, 134.3, 130.3, 130.0, 128.8, 128.4, 124.7, 122.2, 119.7, 119.2, 109.3, 106.8, 76.0, 54.7, 48.9, 41.4, 30.8, 29.9, 25.2, 8.9 ppm. HRMS(ESI) *m/z* calcd for $[C_{24}H_{26}N_2O_3+H]^+$ 391.2016, found 391.2012.

For the **minor diastereomer**: 17.8 mg, 23% yield, White solid, m. p. 198 – 200 °C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.54 (d, *J* = 7.8 Hz, 1H), 7.50 – 7.42 (m, 2H), 7.41 – 7.26 (m, 5H), 7.20 – 7.09 (m, 1H), 5.66 (d, *J* = 7.4 Hz, 1H), 4.95 (d, *J* = 9.2 Hz, 1H), 4.90 (d, *J* = 9.2 Hz, 1H), 4.11 – 3.96 (m, 1H), 3.65 (s, 3H), 3.07 (dd, *J* = 16.7, 7.5 Hz, 1H), 2.72 (dd, *J* = 16.7, 2.0 Hz, 1H), 2.34 – 2.01 (m, 5H), 0.84 (t, *J* = 7.4 Hz, 3H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 205.6, 168.8, 138.1, 134.0, 130.5, 130.2, 128.9, 128.5, 125.0, 122.3, 119.8, 118.9, 109.3, 107.5, 75.8, 53.7, 49.9, 41.6, 31.0, 29.8, 26.3, 10.6 ppm. HRMS(ESI) *m/z* calcd for $[C_{24}H_{26}N_2O_3+H]^+$ 391.2016, found 391.2014.

5. Optimization for the Synthesis of 3da

Table S1 Screening of reaction conditions[a]

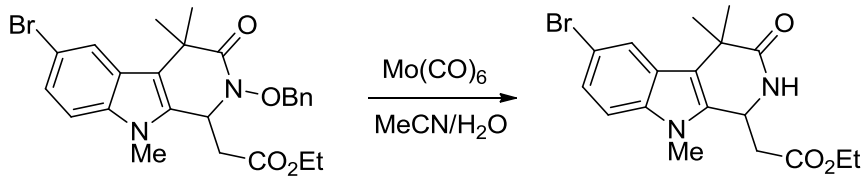


entry	Temperature (^{o}C)	additive	time (h)	yield of **3da** (%)[b]	yield of **4da** (%)[c]
1	rt	/	3	41	42
2	40	/	3	38	27
3	60	/	3	41	< 10
4	80	/	3	41	trace
5[d]	rt	TFA (1 equiv)	3	48	36
6[d]	rt	TFA (2 equiv)	3	55	27
7[d]	rt	TFA (3 equiv)	3	61	25
8[d]	rt	TFA (4 equiv)	3	63	23
9[d]	rt	TFA (5 equiv)	3	67	18
10[d]	rt	TFA (6 equiv)	3	71	10
11[d]	rt	TFA (7 equiv)	3	76	trace
12[d]	rt	TFA (8 equiv)	3	76	trace

[a] Reaction conditions: **1a** (0.2 mmol), **2a** (0.6 mmol), Na_2CO_3 (1.2 mmol) in HFIP (1.5 mL). [b] Isolated yields. [c] Yields were determined by ^{1}H NMR using dibromomethane (δ = 4.80) as an internal standard. [d] TFA was added until **1d** was completely consumed and stirred at room temperature for another 3 h.

6. General Procedure for N−O Bond Cleavage Reaction

a) General Procedure[6]

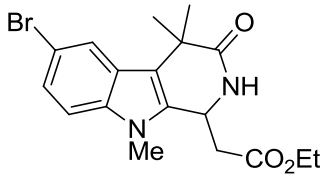


3pa **5pa** 94%

To a solution of tetrahydro-*β*-carbolinone **3pa** (99.6 mg, 0.2 mmol, 1 equiv) in acetonitrile/water (9/1, 2 mL), $Mo(CO)_6$ (63.4 mg, 0.24 mmol, 1.2 equiv) was added. The reaction was stirred at 120 ^oC under argon for 12 h. After cooling to room temperature, the mixture was the filtered through celite and washed with EA. Then, filtrate was concentrated under rotary evaporation, and the resulting residue was purified by silica gel chromatography (PE/EA = 1/1) to afford **5pa** as a white solid (73.5 mg, 94%).

b) Characterization of the Products

ethyl 2-(6-bromo-4,4,9-trimethyl-3-oxo-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl)acetate (5pa)

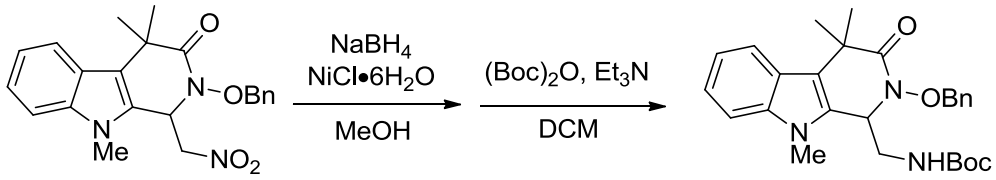


73.5 mg, 94% yield, White solid, m. p. 168 – 170 ^oC; ^1H NMR (300 MHz, DMSO-d_6) δ 7.95 (s, 1H), 7.80 (s, 1H), 7.44 (d, *J* = 8.7 Hz, 1H), 7.28 (d, *J* = 8.7 Hz, 1H), 5.24 – 5.09 (m, 1H), 4.01 – 3.83 (m, 2H), 3.69 (s, 3H), 2.94 (dd, *J* = 15.1, 2.7 Hz, 1H), 2.75 (dd, *J* = 15.1, 6.8 Hz, 1H), 1.52 (d, *J* = 15.8 Hz, 6H), 0.96 (t, *J* = 7.1 Hz, 3H) ppm. ^{13}C NMR (75 MHz, DMSO-d_6) δ 175.4, 169.6, 136.9, 131.0, 125.8, 123.7, 121.4, 113.8, 111.8, 111.5, 60.1, 47.2, 41.7 37.9, 30.0, 27.7, 26.9, 13.7 ppm. HRMS(ESI) *m/z* calcd for $[C_{18}H_{21}BrN_2O_3+H]^+$ 393.0808, found 393.0809.

[6] DiPoto, M. C.; Hughes, R. P.; Wu, J. *J. Am. Chem. Soc.* **2015**, *137*, 14861.

7. General Procedure for Transformations of the Cycloadduct 3sa

a) General Procedure[7]

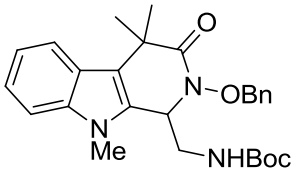


3sa **6sa**

To a suspension of **3sa** (78.6 mg, 0.2 mmol, 1 equiv.), $NiCl_2$ •$6H_2O$ (47.5 mg, 0.2 mmol, 1 equiv.) in THF/MeOH (2/1 3 mL) was carefully added $NaBH_4$ (37.8 mg, 1 mmol, 5 equiv.) at 0 ℃. The reaction mixture was stirred at the same temperature for 1 h. The mixture was then quenched with a saturated solution of ammonium chloride and extracted with DCM (3×20 mL). The combined organic layers were washed with brine and dried over sodium sulfate. The filtrate was evaporated in vacuo and the residue was dissolved in was dissolved in DCM at 0 ℃, followed by adding NEt_3 (40.5 mg, 0.4 mmol, 2 equiv) and Boc anhydride (48.0 mg, 0.22 mmol, 1.1 equiv). After 3 h stirring at room temperature the mixture was quenched by water and extracted with DCM (3×20 mL). The organic layer was washed with brine, dried over sodium sulfate, filtered and evaporated. Purification *via* a flash column chromatography (PE/EA = 3/1) provided **6sa** as a white solid (62.2 mg, 67%).

b) Characterization of the Products

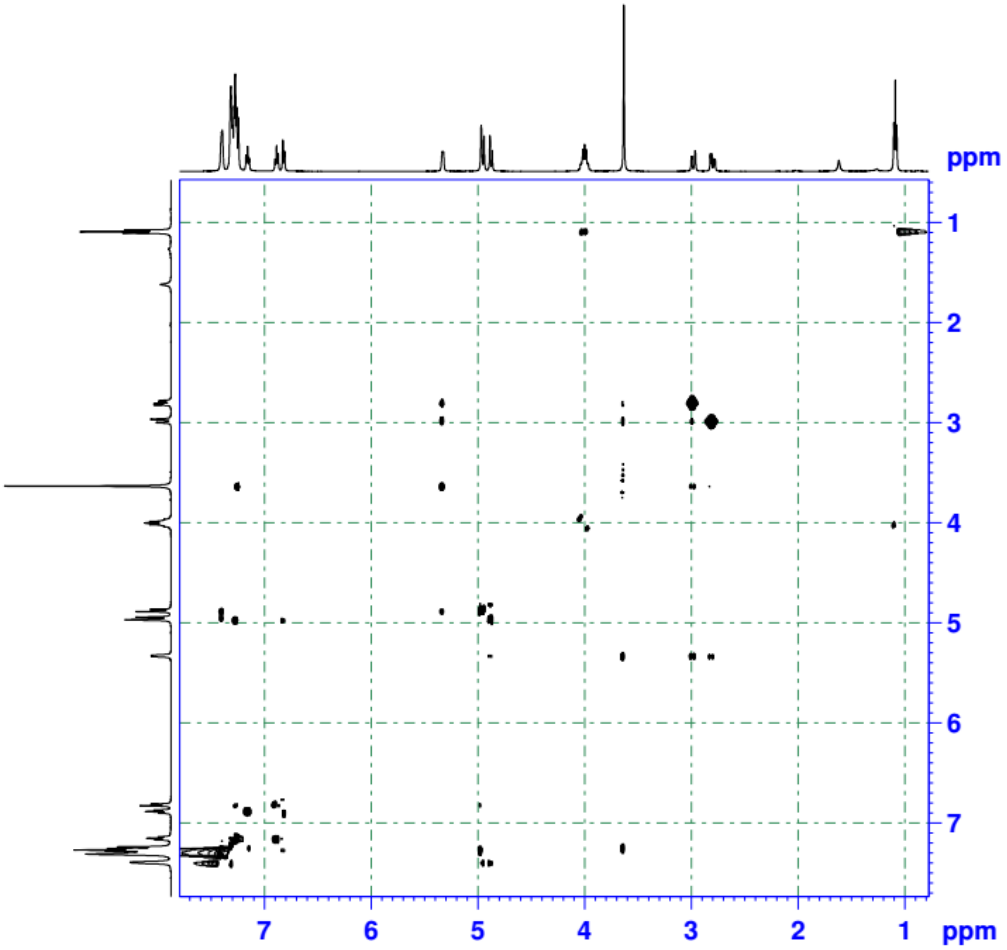
tert-butyl ((2-(benzyloxy)-4,4,9-trimethyl-3-oxo-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indol-1-yl) methyl)carbamate (6sa)

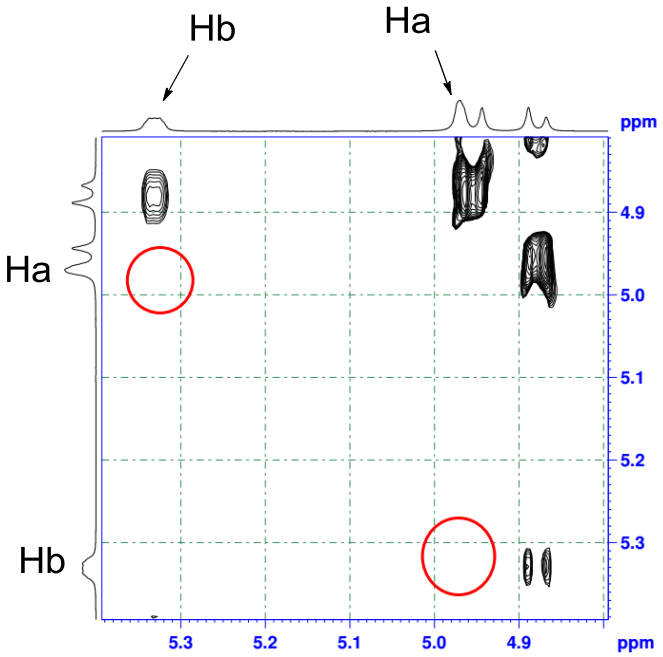


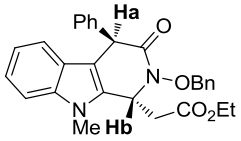
62.2 mg, 67% yield, White solid, m. p. 136 – 137 ^{o}C; ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.63 (d, *J* = 7.9 Hz, 1H), 7.52 – 7.42 (m, 2H), 7.40 – 7.18 (m, 5H), 7.09 (t, *J* = 7.3 Hz, 1H), 5.09 (d, *J* = 10.5 Hz, 1H), 4.96 (d, *J* = 10.5 Hz, 1H), 4.85 – 4.60 (m, 2H), 3.84 – 3.70 (m, 1H), 3.70 – 3.40 (m, 4H), 1.75 (s, 3H), 1.74 (s, 3H), 1.14 (s, 9H) ppm. ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.5, 155.3, 138.3, 135.0, 129.7, 128.8, 128.5, 125.2, 124.0, 121.8, 119.5, 119.2, 114.6, 109.5, 79.5, 76.1, 59.8, 42.4, 40.7, 29.7, 28.7, 27.9, 27.2 ppm. HRMS(ESI) *m/z* calcd for $[C_{27}H_{33}N_3O_4+H]^+$ 464.2544, found 464.2540.

[7] Ni, Q.; Zhang, H.; Grossmann, A.; Loh, C. C. J.; Merkens, C.; Enders, D. *Angew. Chem., Int. Ed.* **2013**, *52*, 13562.

8. NOE analysis of 3nh

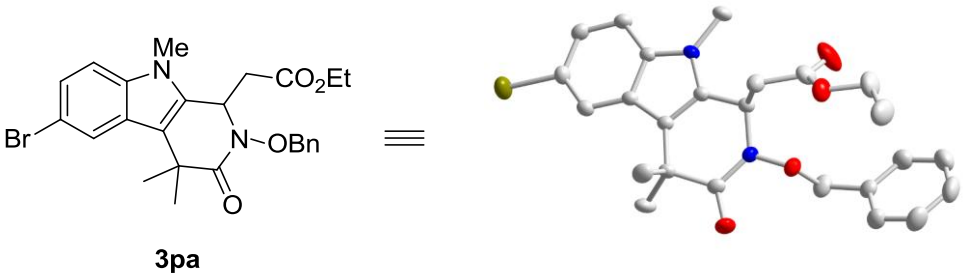






3nh

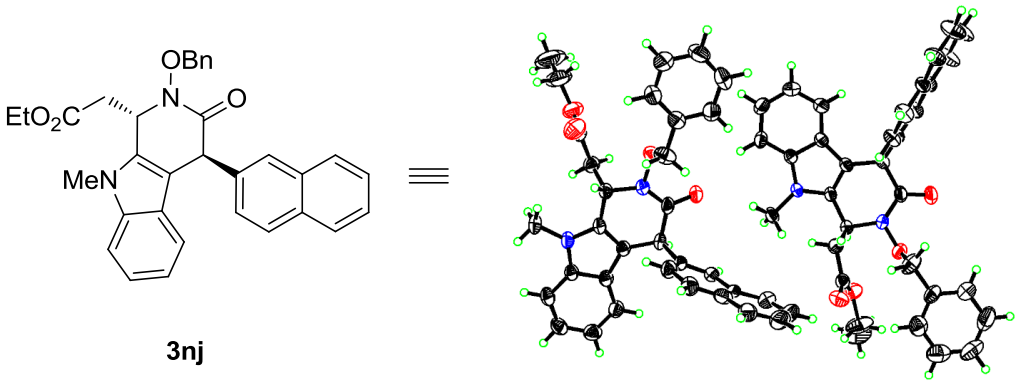
9. X-ray Crastallography Data of 3pa and 3nj



3pa

CCDC−1539525 (**3pa**) contains the supplementary crystallographic data. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.

Bond precision	C-C = 0.0037 A, Wavelength = 0.71073
Unit cell dimensions	a = 13.452(5) Å = 90 ^{o}
	b = 9.374(3) Å = 104.972(4) ^{o}
	c = 19.421(7) Å = 90 ^{o}
Temperature	296 K
Volume	2365.9(15) $Å^3$
Space group	P 21/c
Hall group	-P 2ybc
Sum formula	$C_{25}H_{27}BrN_2O_4$
Mr	499.39
Dx,g cm^{-3}	1.402
Z	4
Mu (mm^{-1})	1.771
F000	1032.0
h, k, lmax	17, 11, 24
Nref	4691
Data completeness	0.918
Theta(max)	26.884
R(reflections)	0.0369(3305)
wR2(reflections)	0.1044(4691)
S	1.025
Npar	294

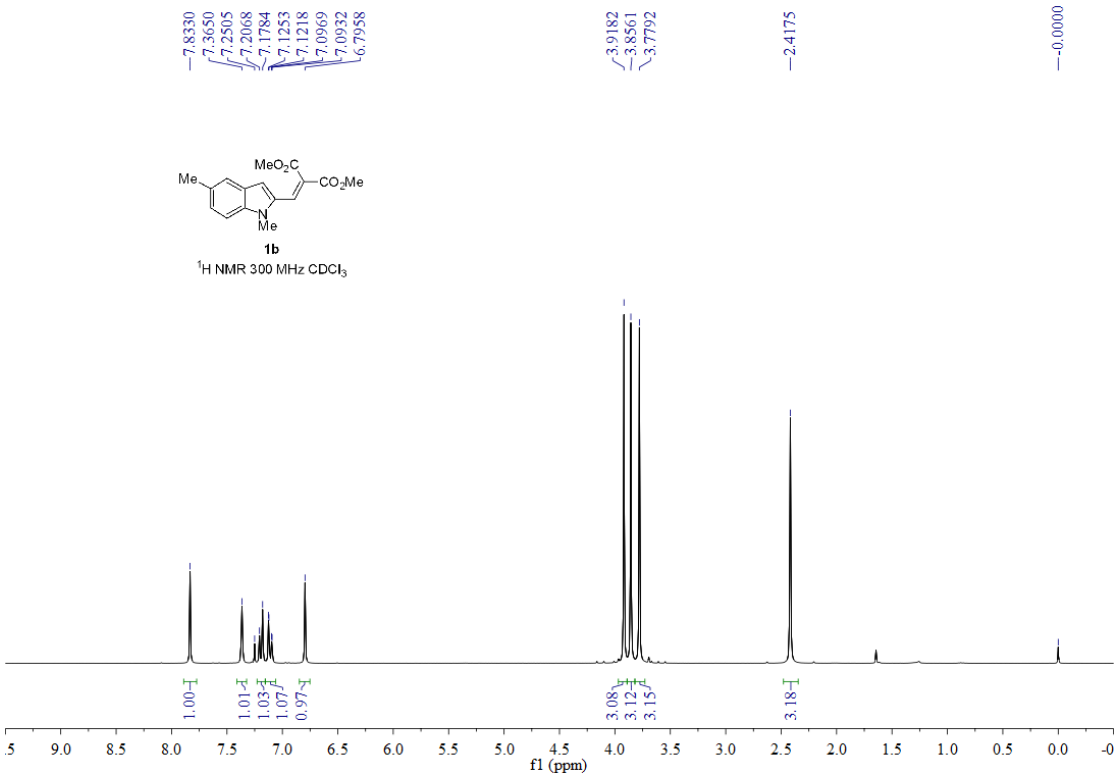


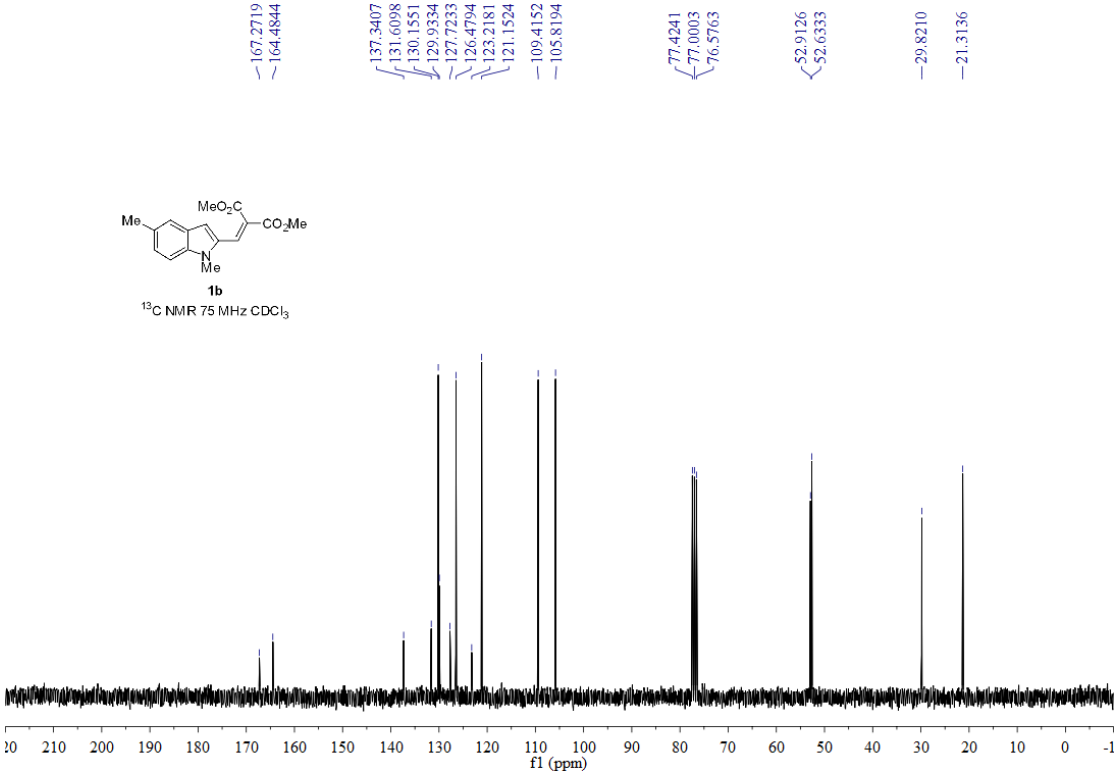
3nj

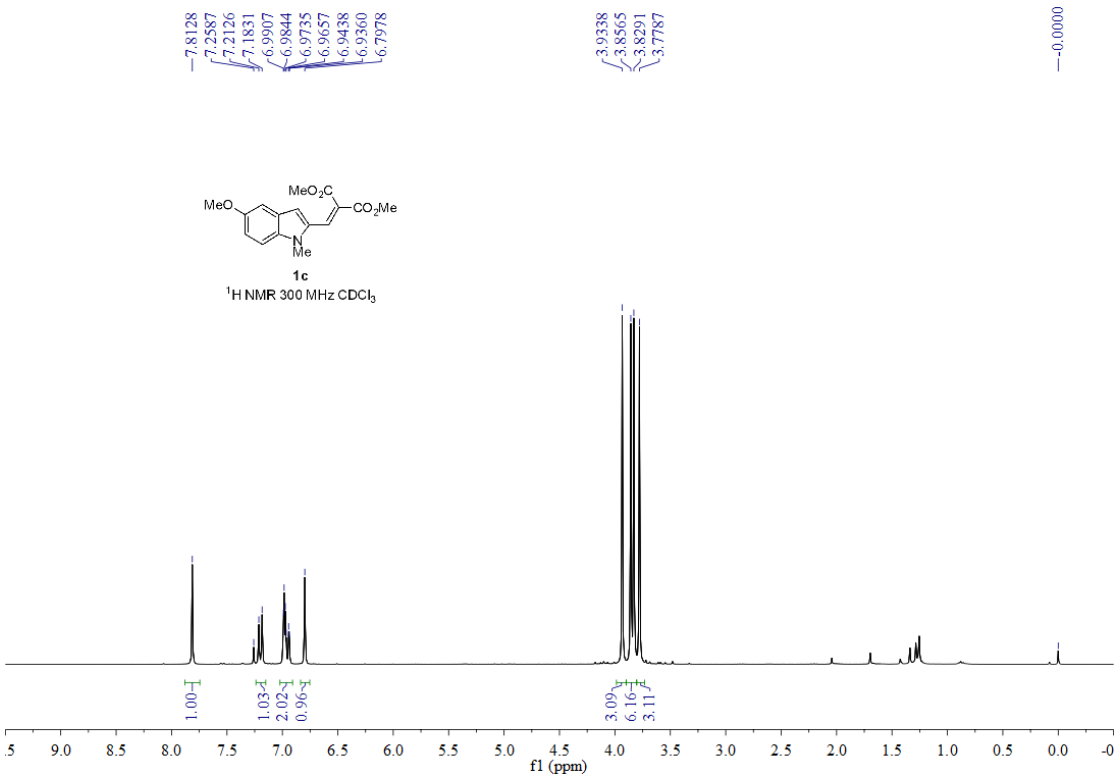
CCDC−1546162 (**3nj**) contains the supplementary crystallographic data. These data can be obtained free of charge from The Cambridge Crystallographic Data Centre via www.ccdc.cam.ac.uk/data_request/cif.

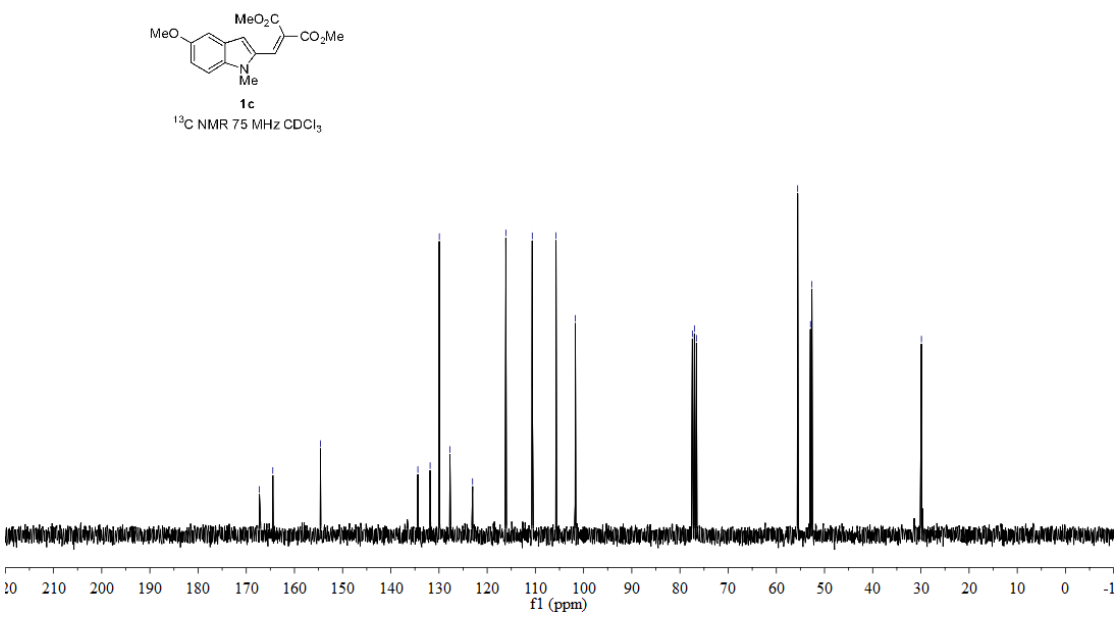
Bond precision	C-C = 0.0053A, Wavelength = 0.71073	
Unit cell dimensions	a = 14.008(3) Å	= 115.266(5) ^{o}
	b = 14.182(4) Å	= 90.430(5) ^{o}
	c = 15.949(4) Å	= 105.169(5) ^{o}
Temperature	173 K	
Volume	2739.7(12) $Å^3$	
Space group	P -1	
Hall group	-P 1	
Sum formula	$C_{33}H_{30}N_2O_4$	
Mr	518.59	
Dx,g cm^{-3}	1.257	
Z	4	
Mu (mm^{-1})	0.083	
F000	1096.0	
h, k, lmax	17, 17, 20	
Nref	11466	
Data completeness	0.979	
Theta(max)	26.802	
R(reflections)	0.0663(5586)	
wR2(reflections)	0.2152(11466)	
S	0.943	
Npar	707	

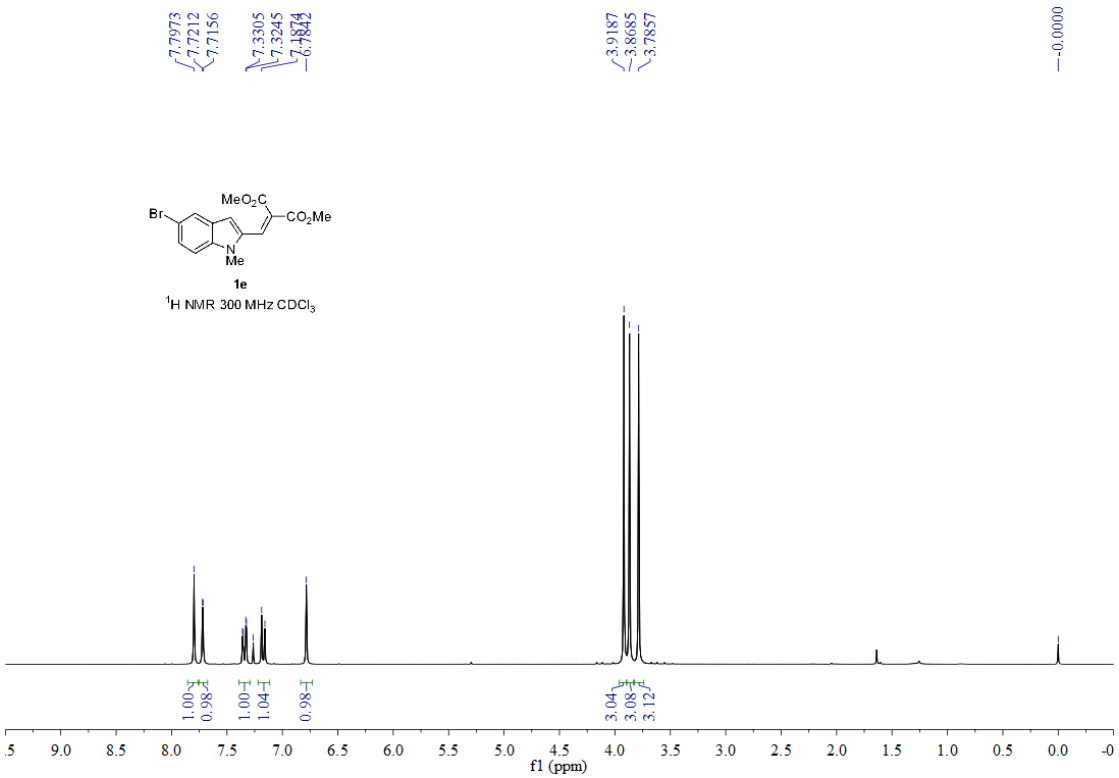
10. Copies of ^{1}H NMR and ^{13}C NMR Spectra of the Titled Compounds

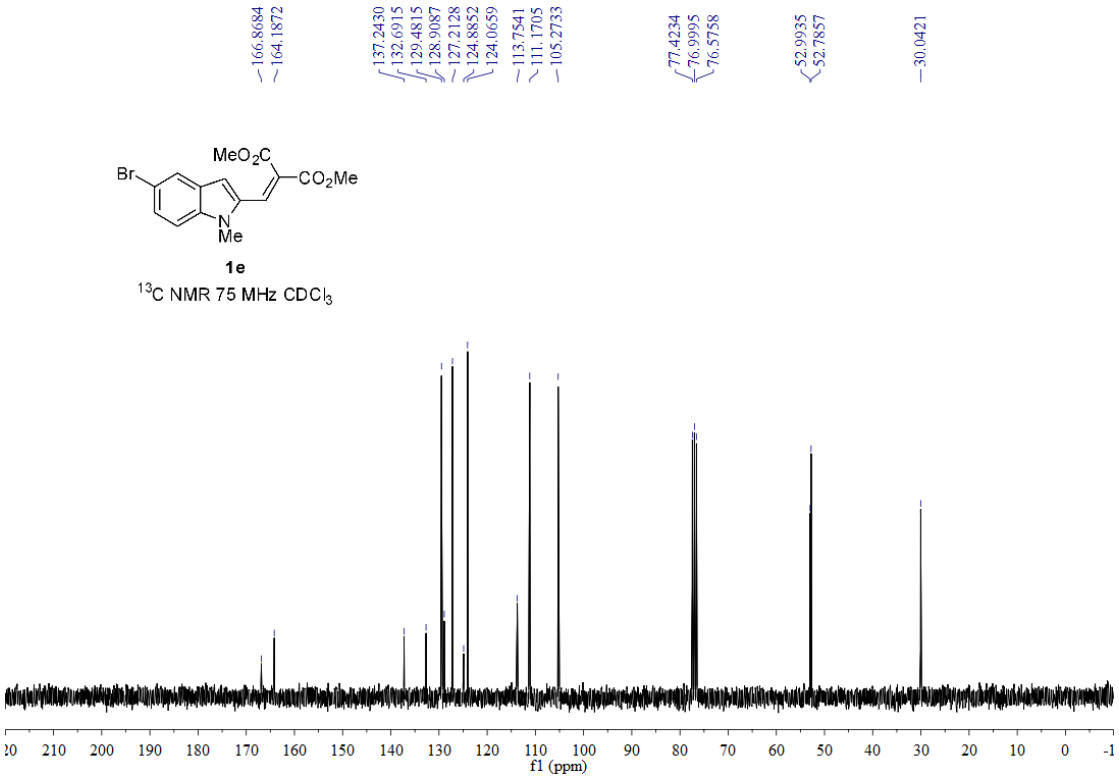





7.8128
7.2587
7.2126
7.1831
6.9907
6.9844
6.9735
6.9657
6.9438
6.9360
6.7978
3.9338
3.8565
3.8291
3.7787
-0.0000
MeO
MeO2C
CO2Me
N
Me
1c
1H NMR 300 MHz CDCl3
1.00
1.03
2.02
0.96
3.09
6.16
3.11
f1 (ppm)


167.2735
164.4914
154.6046
134.3868
131.8419
129.9342
127.7312
123.0376
116.1285
110.6450
105.7162
101.7170
77.4236
76.9997
76.5757
55.5726
52.9078
52.6234
29.8884
MeO
MeO2C
CO2Me
N
Me
1c
13C NMR 75 MHz CDCl3
f1 (ppm)


7.7973
7.7212
7.7156
7.3305
7.3245
7.1842
3.9187
3.8685
3.7857
0.0000
MeO2C
CO2Me
Br
N
Me
1e
1H NMR 300 MHz CDCl3
1.00
0.98
1.00
1.04
0.98
3.04
3.08
3.12
f1 (ppm)


166.8684
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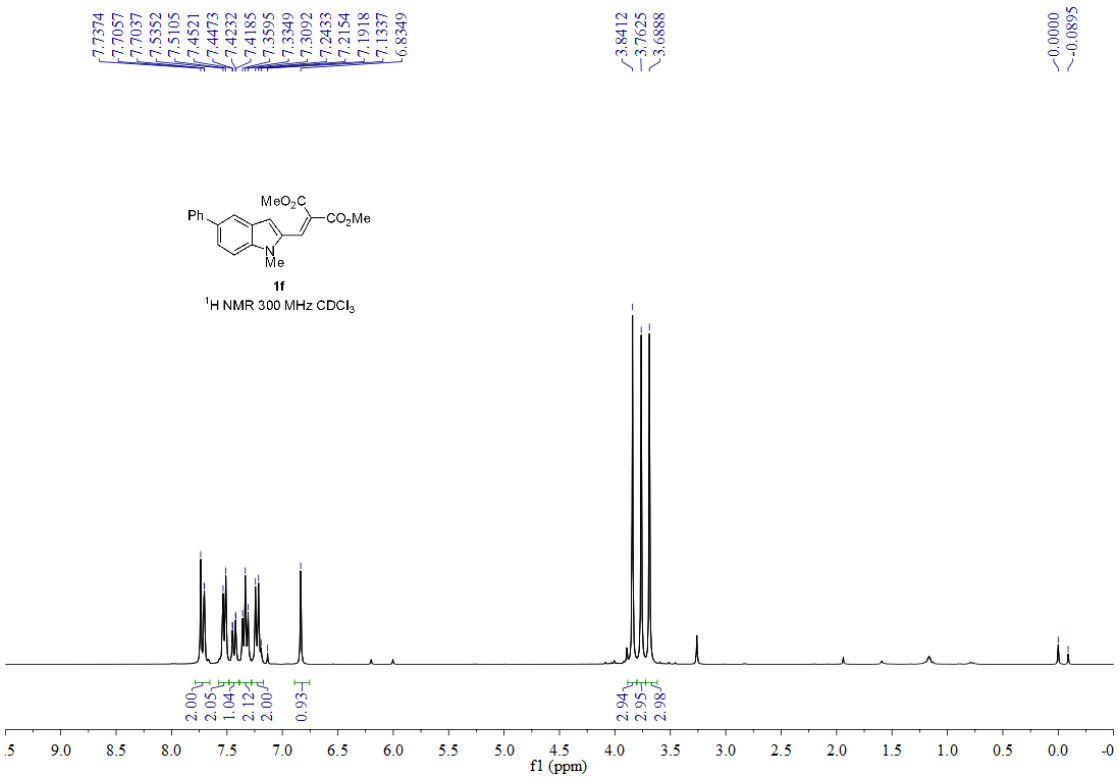
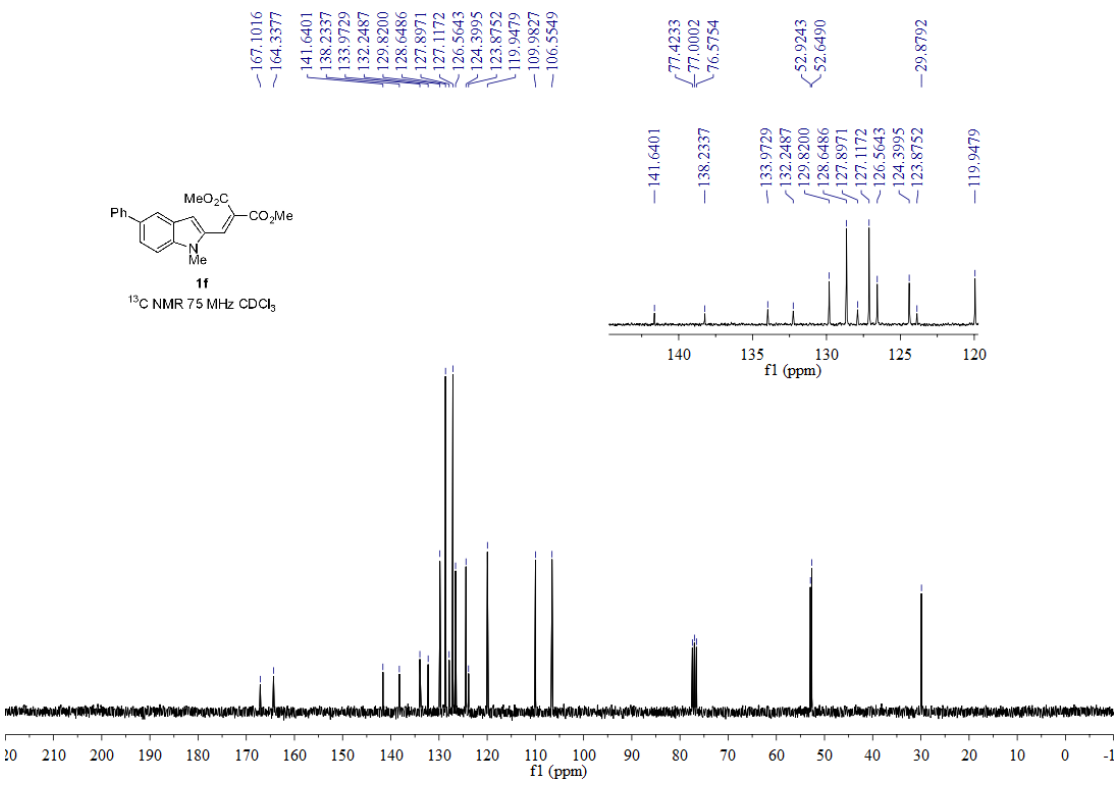
137.2430
132.6915
129.4815
128.9087
127.2128
124.8852
124.0659
113.7541
111.1705
105.2733
77.4234
76.9995
76.5758
52.9935
52.7857
30.0421
MeO2C
CO2Me
Br
N
Me
1e
13C NMR 75 MHz CDCl3
f1 (ppm)



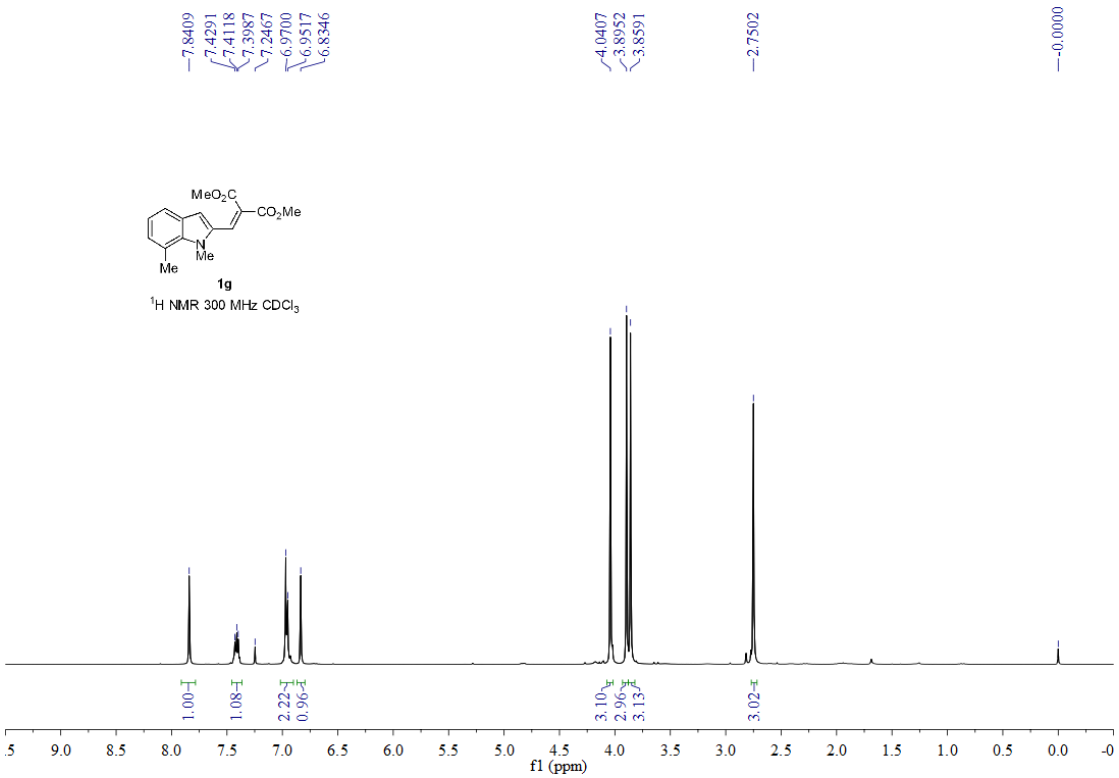
1f

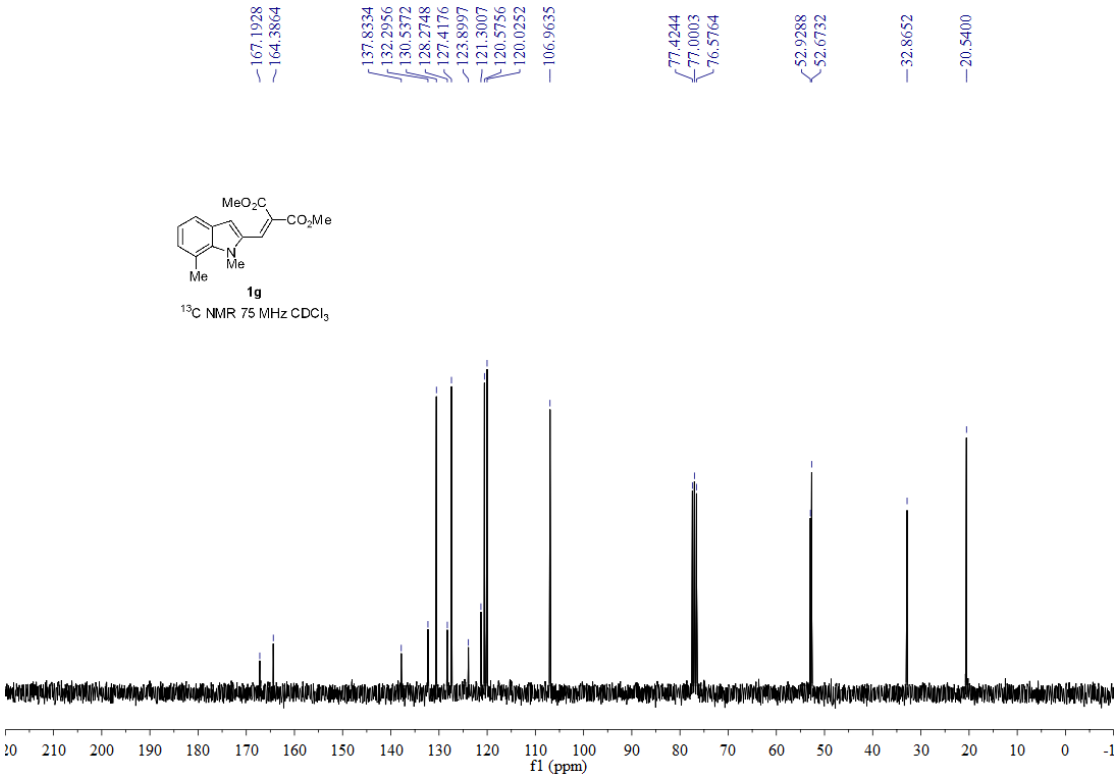
^{1}H NMR 300 MHz $CDCl_3$



1f

^{13}C NMR 75 MHz $CDCl_3$


7.8409
7.4291
7.4118
7.3987
7.2467
6.9700
6.9517
6.8346
4.0407
3.8952
3.8591
2.7502
-0.0000
MeO2C
CO2Me
N
Me
Me
1g
1H NMR 300 MHz CDCl3
1.00
1.08
2.22
0.96
3.10
2.96
3.13
3.02
f1 (ppm)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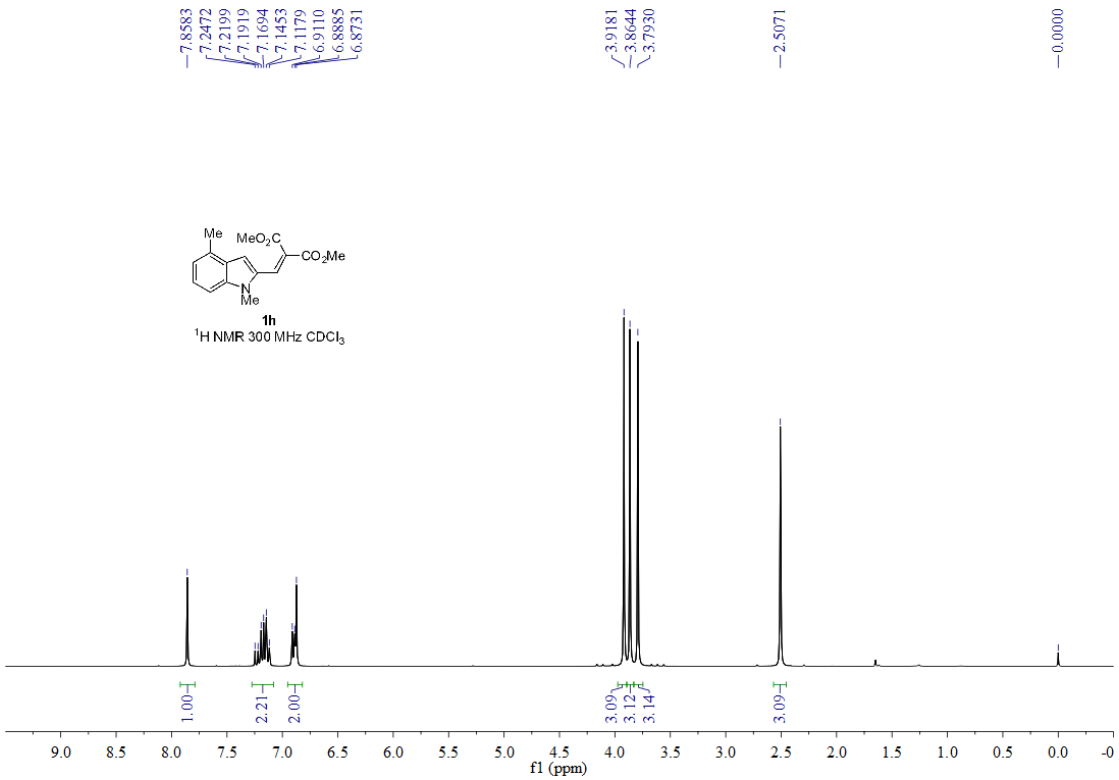
164.3864
137.8334
132.2956
130.5372
128.2748
127.4176
123.8997
121.3007
120.5756
120.0252
106.9635
77.4244
77.0003
76.5764
52.9288
52.6732
32.8652
20.5400
MeO2C
CO2Me
N
Me
Me
1g
13C NMR 75 MHz CDCl3
f1 (ppm)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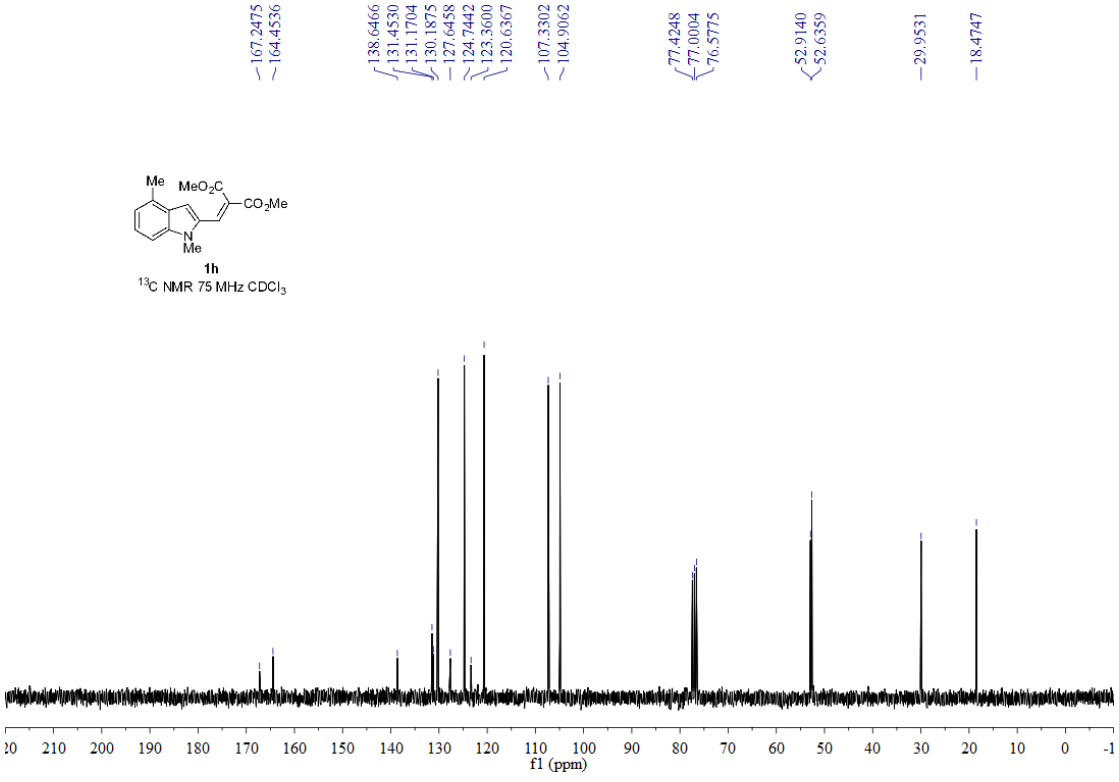
7.2472
7.2199
7.1919
7.1694
7.1453
7.1179
6.9110
6.8885
6.8731
3.9181
3.8644
3.7930
2.5071
0.0000
Me
MeO2C
CO2Me
N
Me
1h
1H NMR 300 MHz CDCl3
1.00
2.21
2.00
3.09
3.12
3.14
3.09
f1 (ppm)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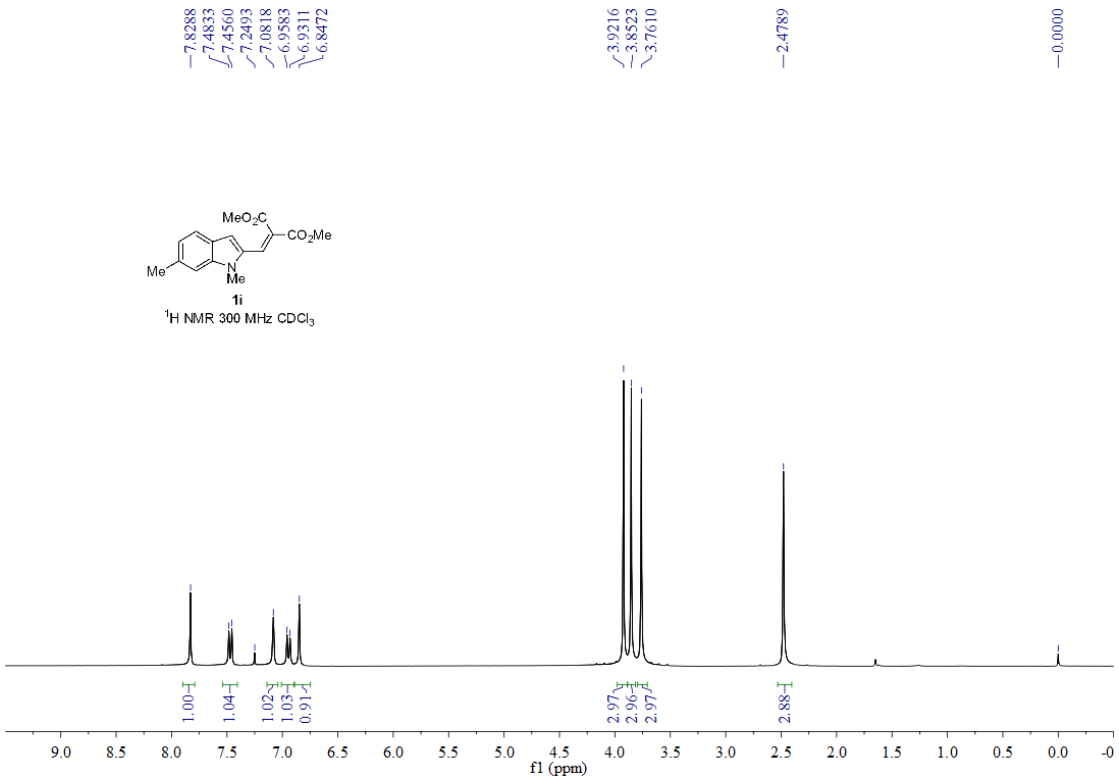
138.6466
131.4530
131.1704
130.1875
127.6458
124.7442
123.3600
120.6367
107.3302
104.9062
77.4248
77.0004
76.5775
52.9140
52.6359
29.9531
18.4747
Me
MeO2C
CO2Me
N
Me
1h
13C NMR 75 MHz CDCl3
f1 (ppm)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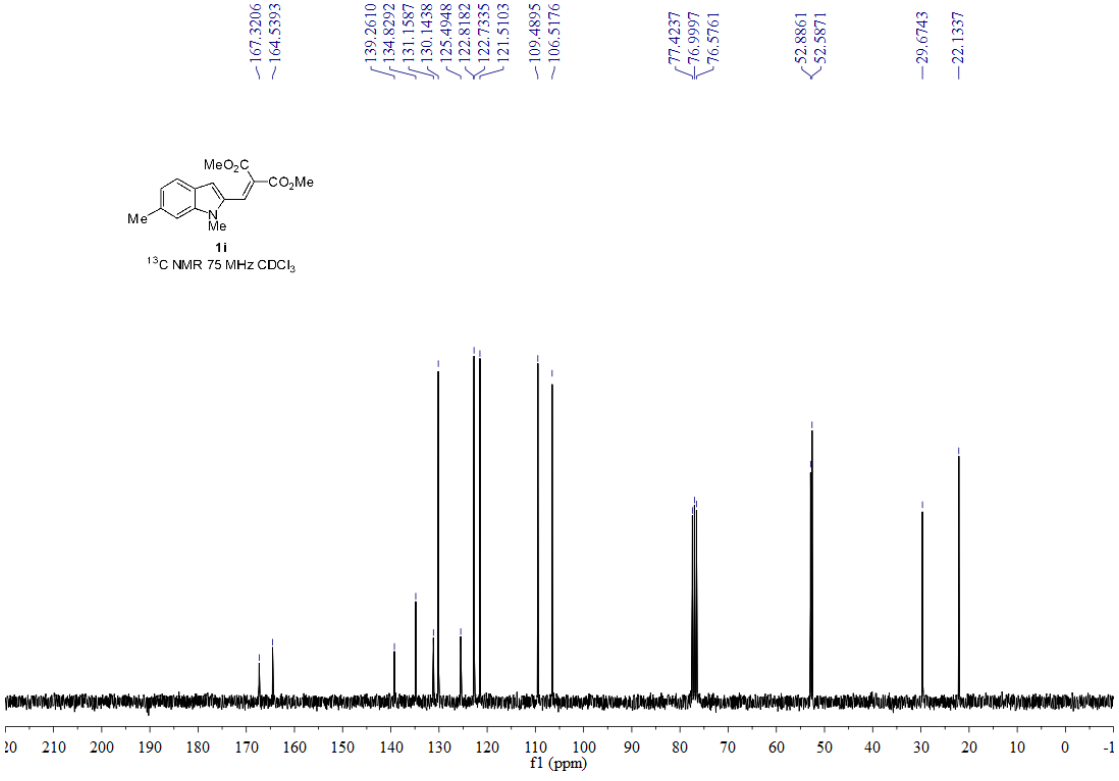
7.4833
7.4560
7.2493
7.0818
6.9583
6.9311
6.8472
3.9216
3.8523
3.7610
2.4789
0.0000
MeO2C
CO2Me
Me
N
Me
1i
1H NMR 300 MHz CDCl3
1.00
1.04
1.02
1.03
0.91
2.97
2.96
2.97
2.88
f1 (ppm)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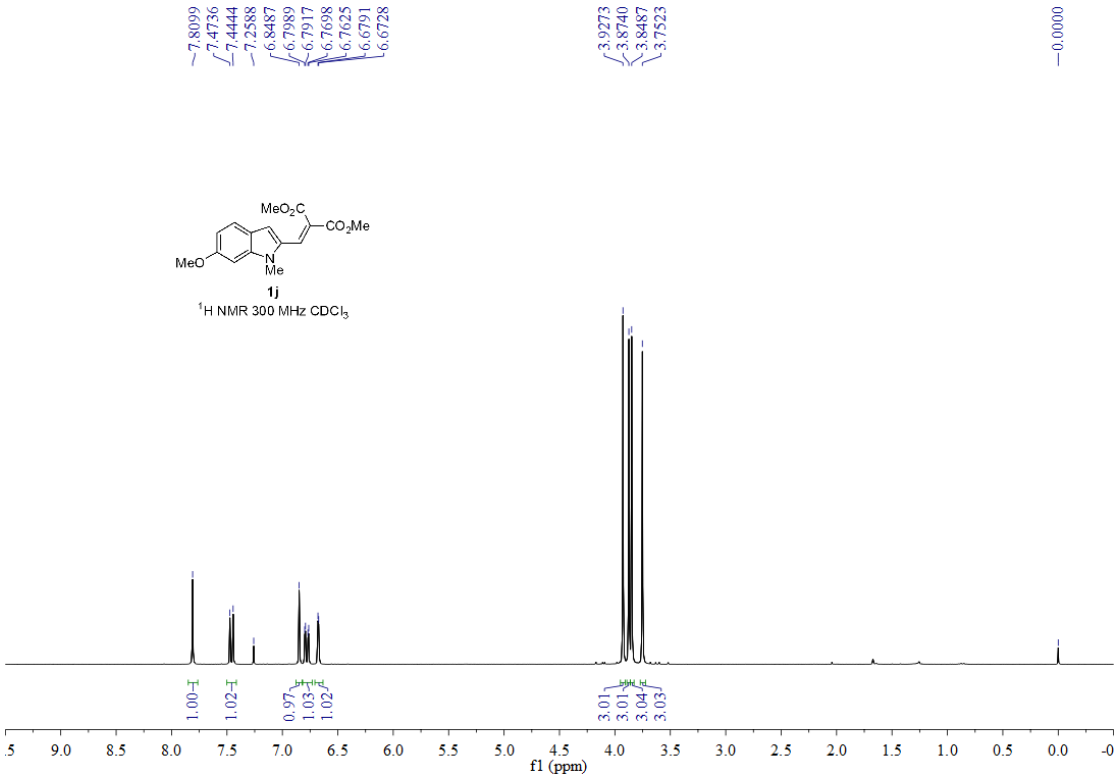
139.2610
134.8292
131.1587
130.1438
125.4948
122.8182
122.7335
121.5103
109.4895
106.5176
77.4237
76.9997
76.5761
52.8861
52.5871
29.6743
22.1337
MeO2C
CO2Me
Me
N
Me
1i
13C NMR 75 MHz CDCl3
f1 (ppm)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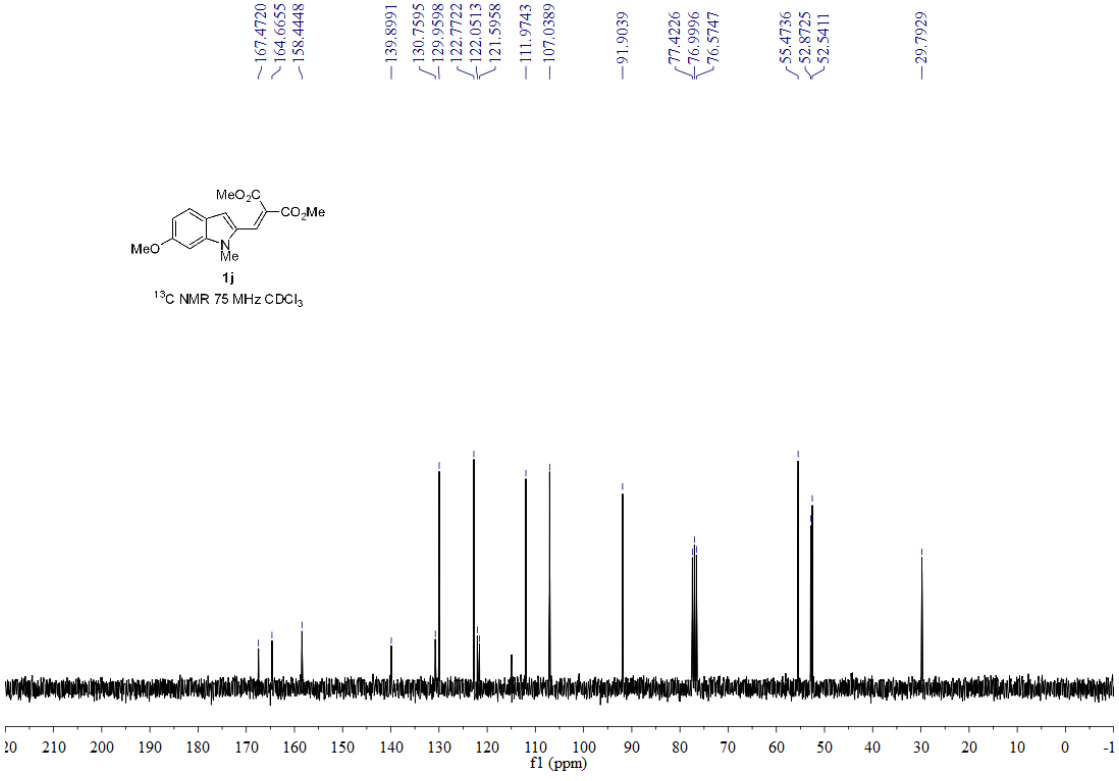
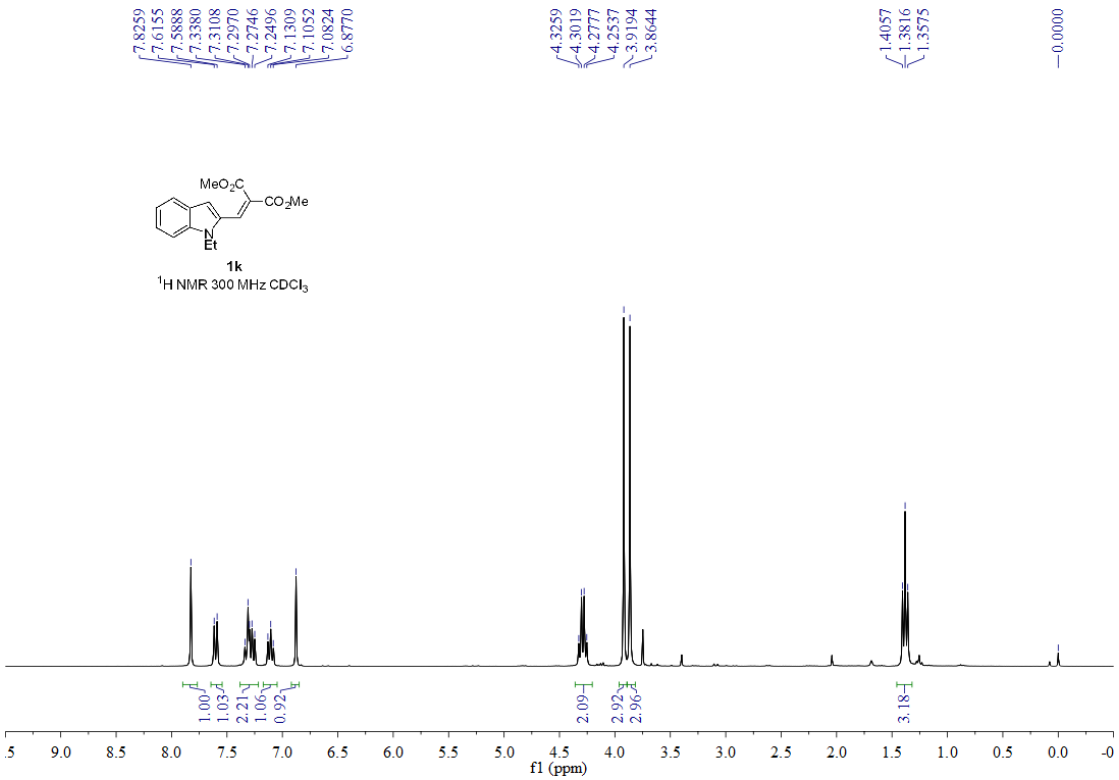
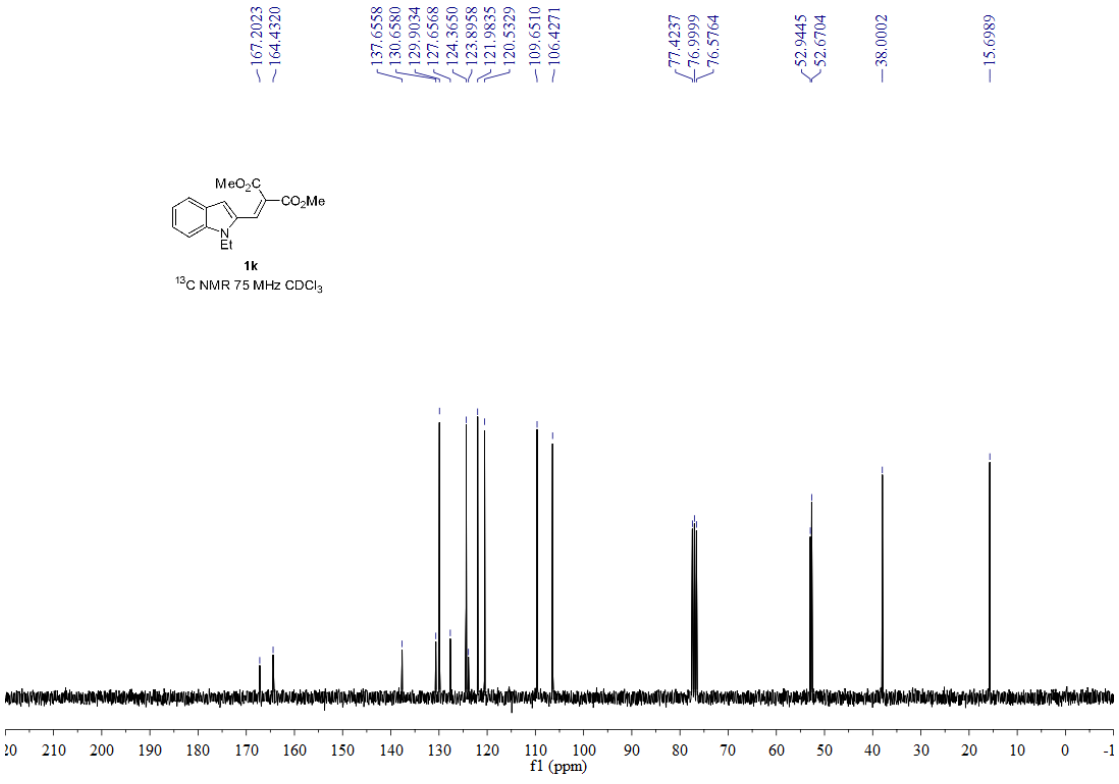
7.4736
7.4444
7.2588
6.8487
6.7989
6.7917
6.7698
6.7625
6.6791
6.6728
3.9273
3.8740
3.8487
3.7523
0.0000
MeO2C
CO2Me
MeO
N
Me
1j
1H NMR 300 MHz CDCl3
1.00
1.02
0.97
1.03
1.02
3.01
3.01
3.04
3.03
f1 (ppm)


167.4720
164.6655
158.4448
139.8991
130.7595
129.9598
122.7722
122.0513
121.5958
111.9743
107.0389
91.9039
77.4226
76.9996
76.5747
55.4736
52.8725
52.5411
29.7929
MeO2C
CO2Me
MeO
N
Me
1j
13C NMR 75 MHz CDCl3
f1 (ppm)



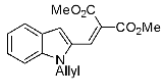
1k

^{1}H NMR 300 MHz $CDCl_3$



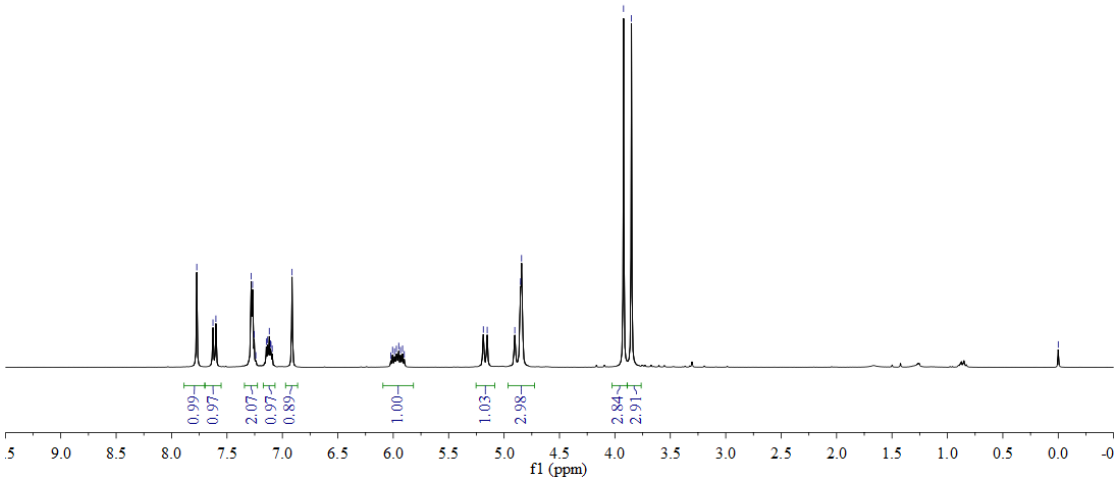
1k

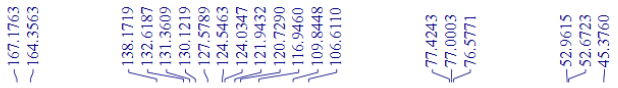
^{13}C NMR 75 MHz $CDCl_3$

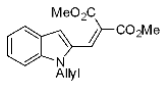


1l

^{1}H NMR 300 MHz $CDCl_3$

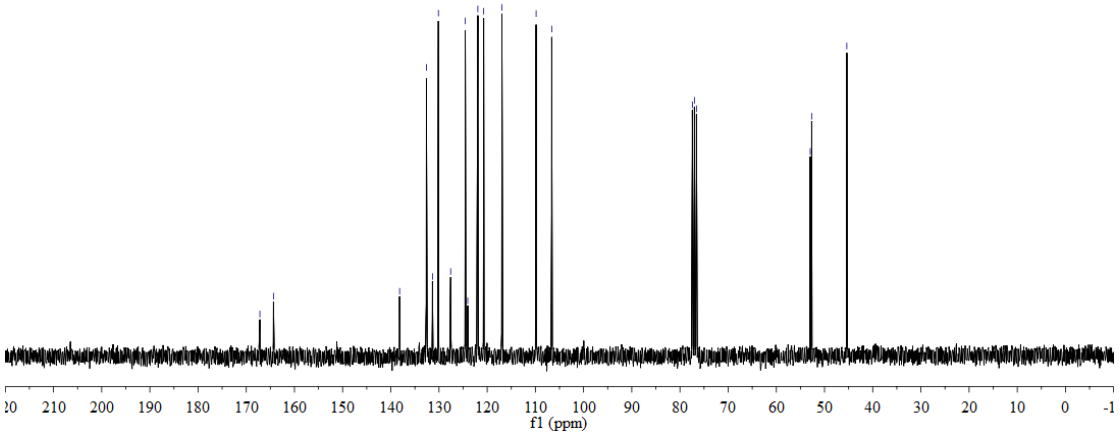


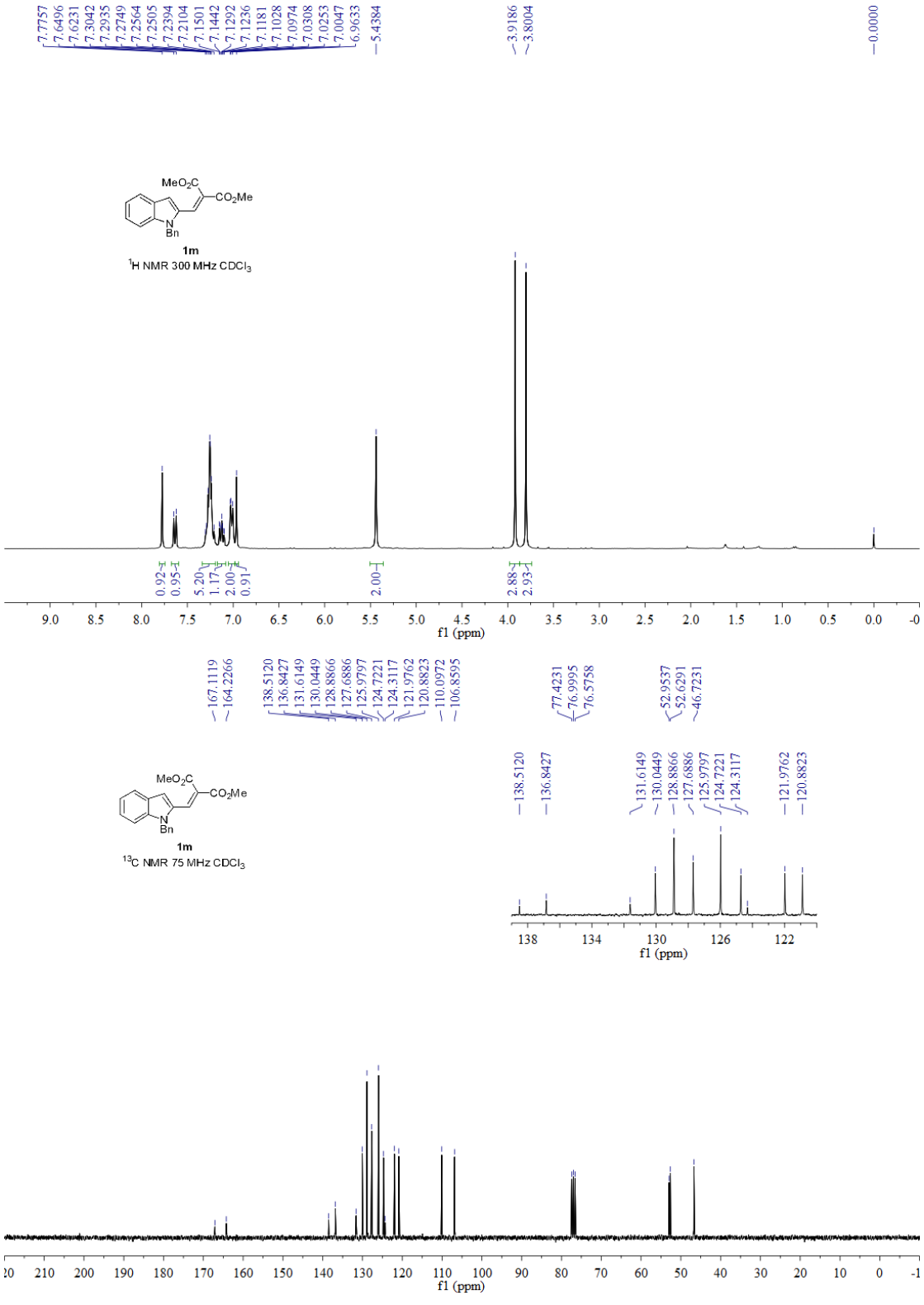




1l

^{13}C NMR 75 MHz $CDCl_3$

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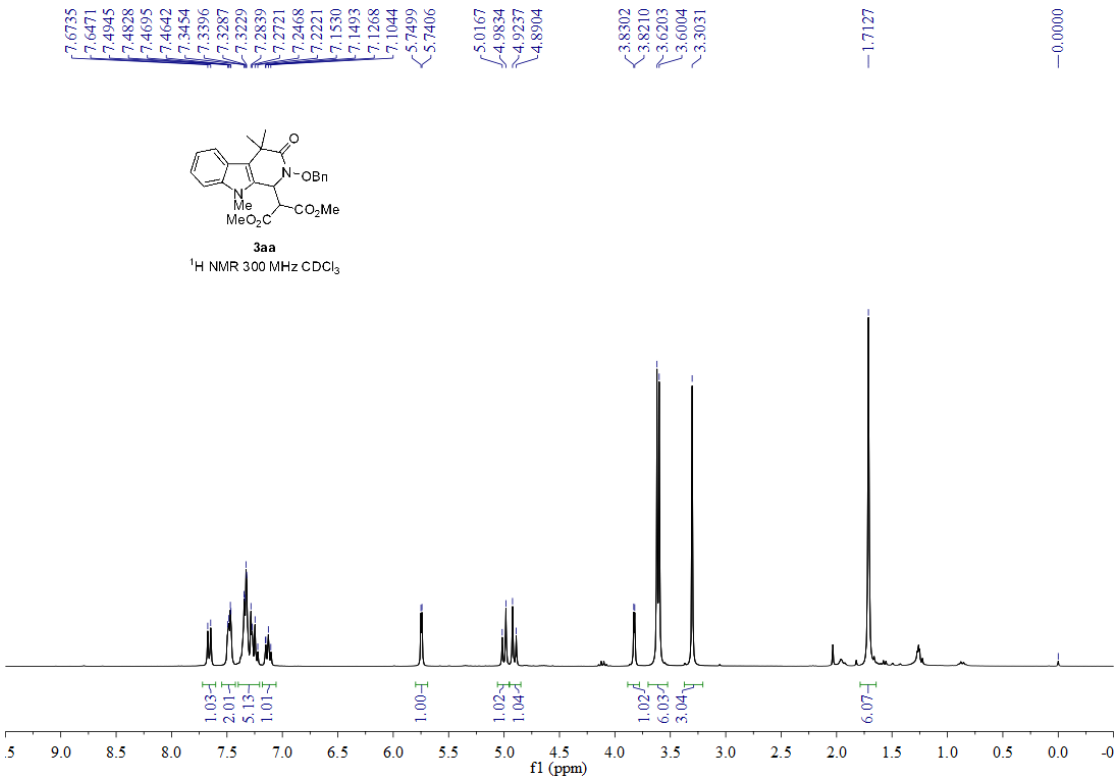
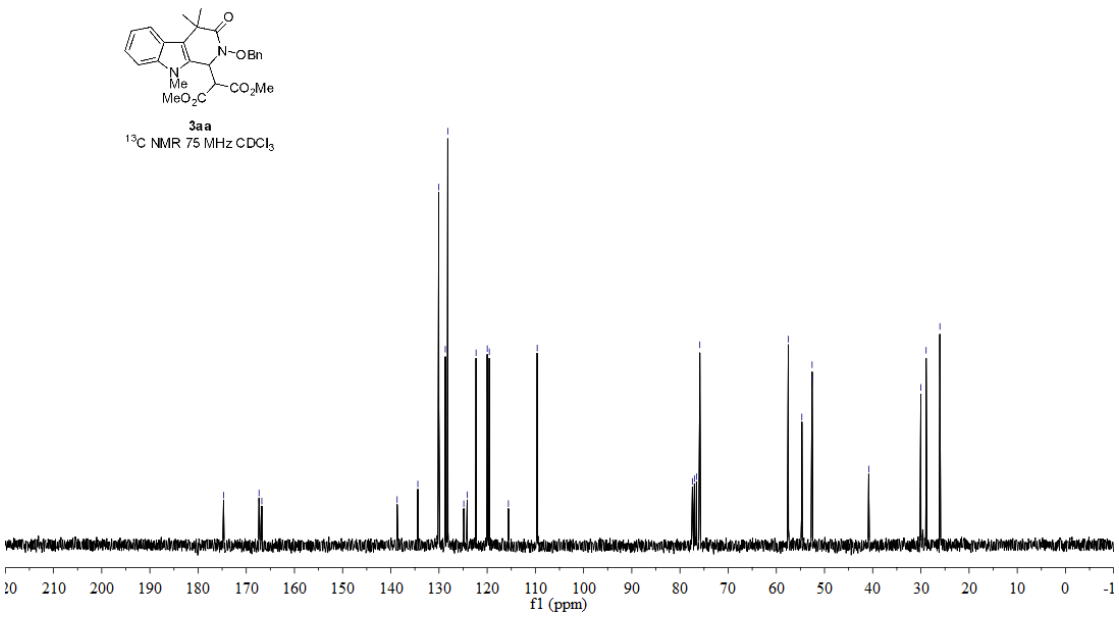
7.6231
7.3042
7.2935
7.2749
7.2564
7.2505
7.2394
7.2104
7.1501
7.1442
7.1292
7.1236
7.1181
7.1028
7.0974
7.0308
7.0253
7.0047
6.9633
5.4384
3.9186
3.8004
0.0000
MeO2C
CO2Me
N
Bn
1m
1H NMR 300 MHz CDCl3
0.92
0.95
5.20
1.17
2.00
0.91
2.00
2.88
2.93
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0
f1 (ppm)
167.1119
164.2266
138.5120
136.8427
131.6149
130.0449
128.8866
127.6886
125.9797
124.7221
124.3117
121.9762
120.8823
110.0972
106.8595
77.4231
76.9995
76.5758
52.9537
52.6291
46.7231
MeO2C
CO2Me
N
Bn
1m
13C NMR 75 MHz CDCl3
138.5120
136.8427
131.6149
130.0449
128.8866
127.6886
125.9797
124.7221
124.3117
121.9762
120.8823
138 134 130 126 122
f1 (ppm)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -1
f1 (ppm)



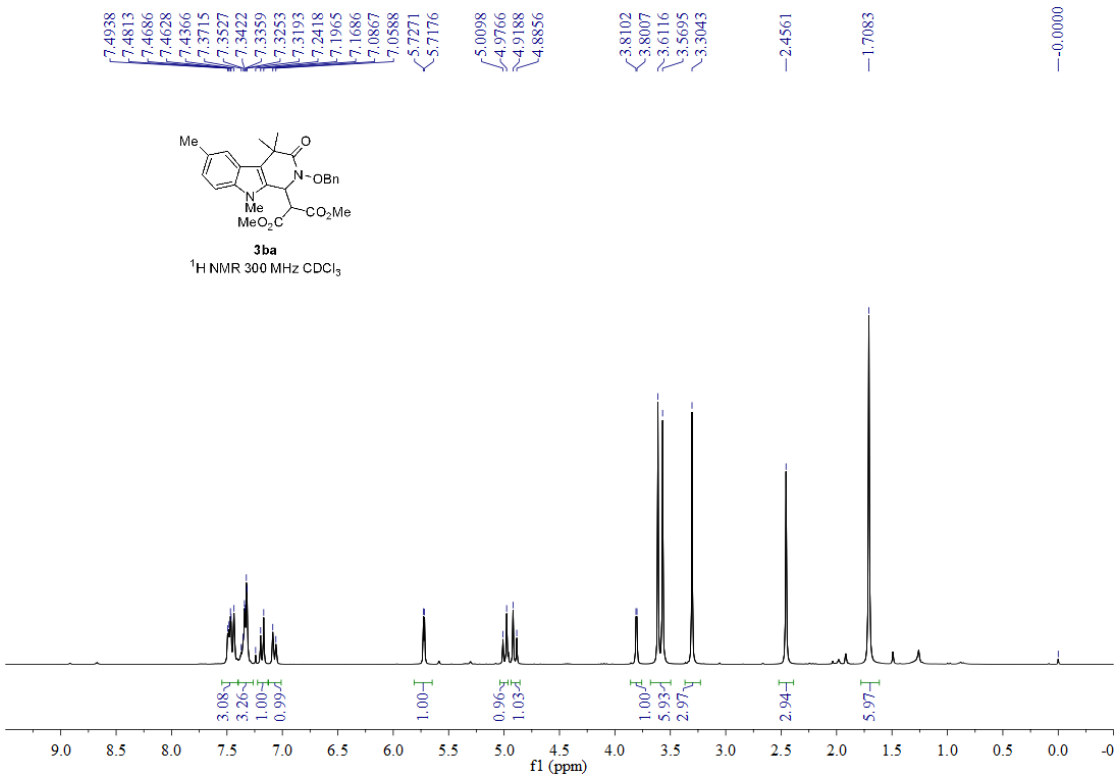
3aa

^{1}H NMR 300 MHz $CDCl_3$



3aa

^{13}C NMR 75 MHz $CDCl_3$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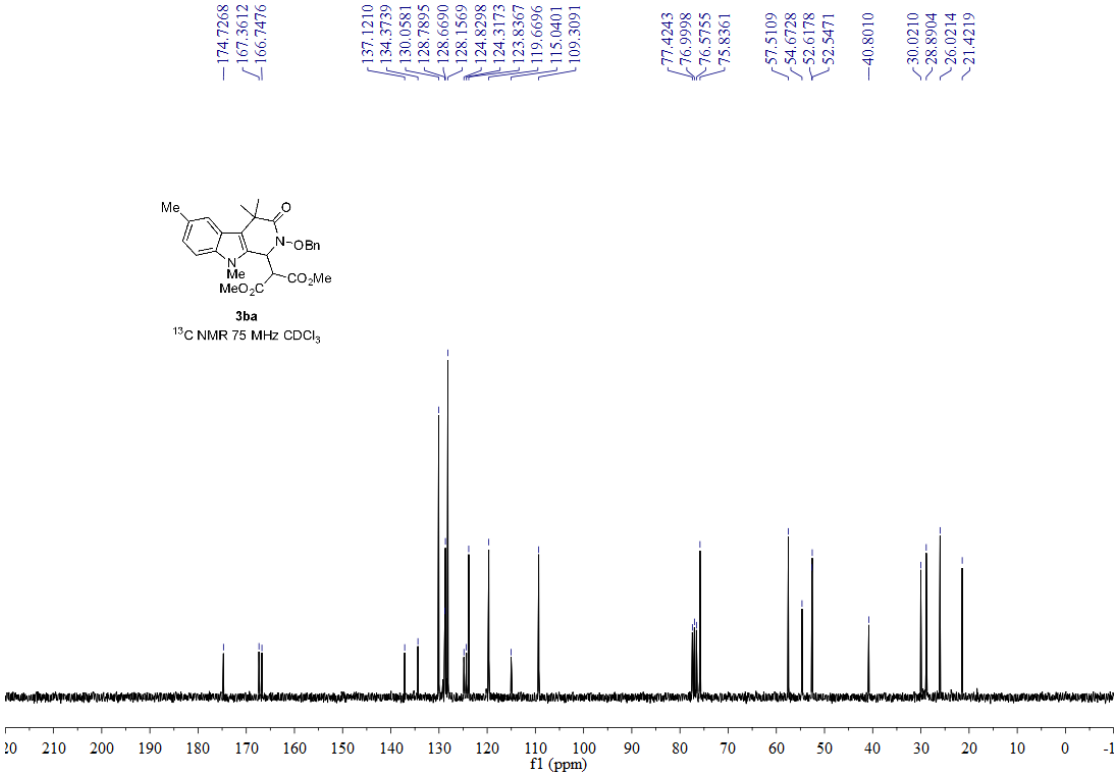
7.4686
7.4628
7.4366
7.3715
7.3527
7.3422
7.3359
7.3253
7.3193
7.2418
7.1965
7.1686
7.0867
7.0588
5.7271
5.7176
5.0098
4.9766
4.9188
4.8856
3.8102
3.8007
3.6116
3.5695
3.3043
2.4561
1.7083
-0.0000
Me
O
N
OBn
Me
MeO2C
CO2Me
3ba
1H NMR 300 MHz CDCl3
3.08
3.26
1.00
0.99
1.00
0.96
1.03
1.00
5.93
2.97
2.94
5.97
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 0.0 -0
f1 (ppm)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134.3739
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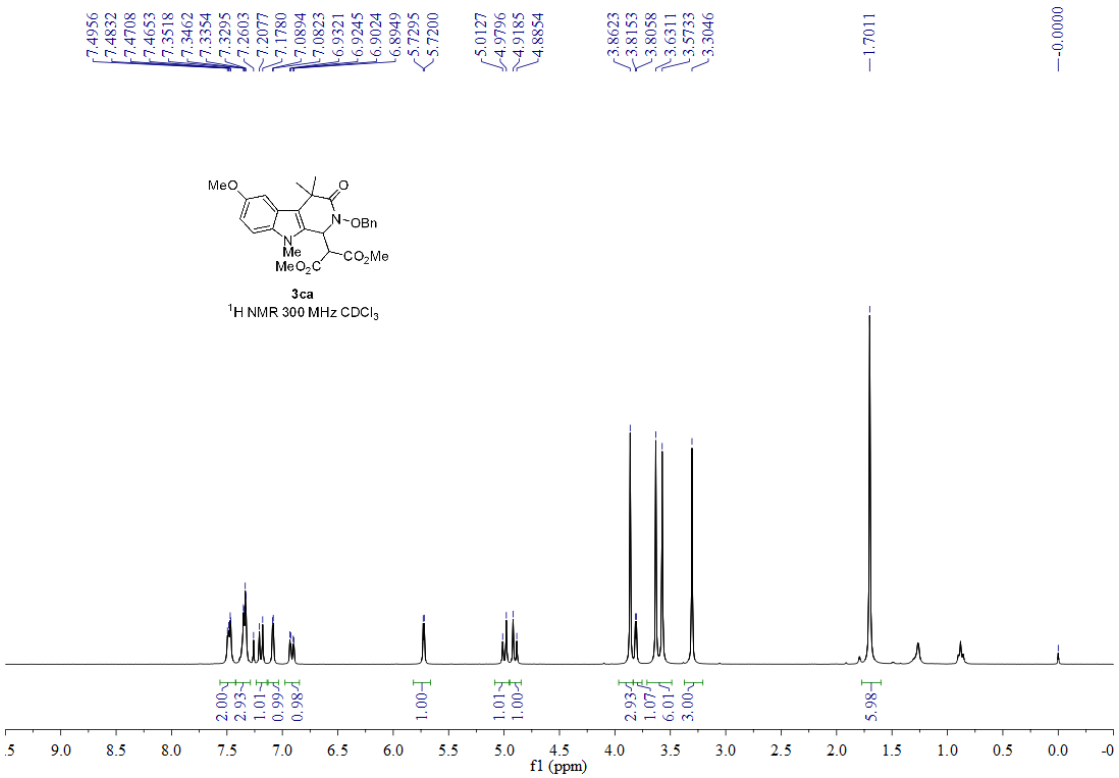
124.3173
123.8367
119.6696
115.0401
109.3091
77.4243
76.9998
76.5755
75.8361
57.5109
54.6728
52.6178
52.5471
40.8010
30.0210
28.8904
26.0214
21.4219
Me
O
N
OBn
Me
MeO2C
CO2Me
3ba
13C NMR 75 MHz CDCl3
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -1
f1 (ppm)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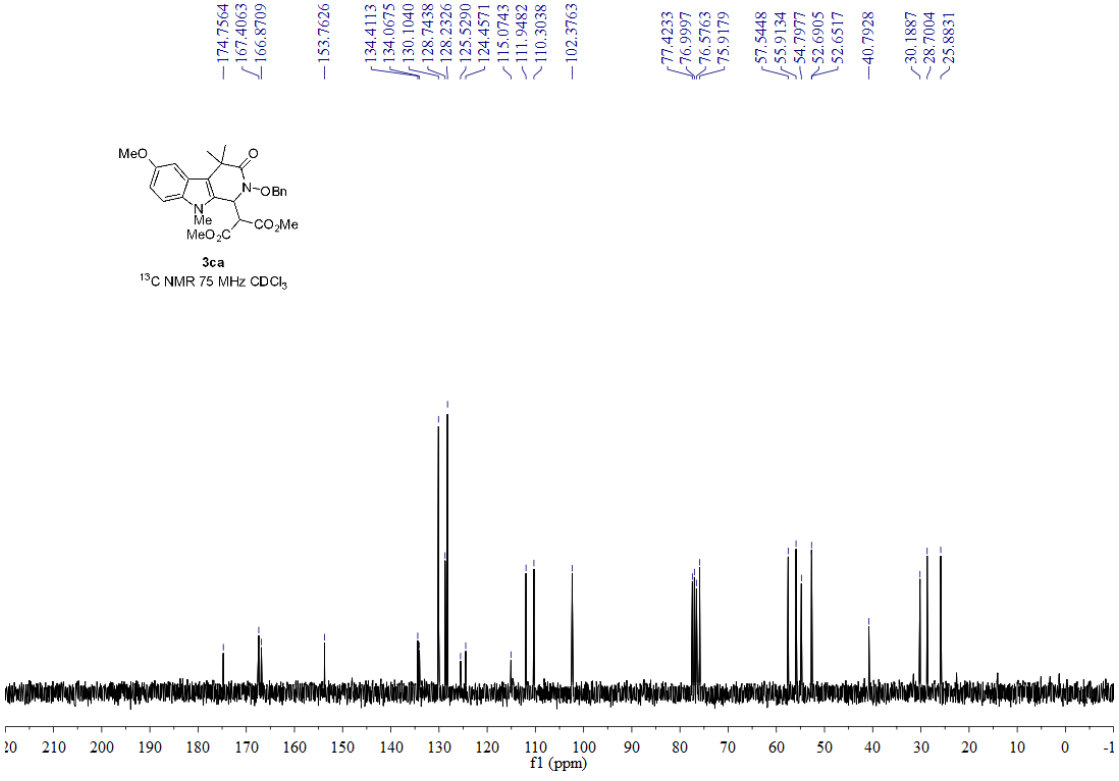
7.4708
7.4653
7.3518
7.3462
7.3354
7.3295
7.2603
7.2077
7.1780
7.0894
7.0823
6.9321
6.9245
6.9024
6.8949
5.7295
5.7200
5.0127
4.9796
4.9185
4.8854
3.8623
3.8153
3.8058
3.6311
3.5733
3.3046
1.7011
0.0000
MeO
O
N
OBn
N
Me
MeO2C
CO2Me
3ca
1H NMR 300 MHz CDCl3
2.00
2.93
1.01
0.99
0.98
1.00
1.01
1.00
2.93
1.07
6.01
3.00
5.98
f1 (ppm)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166.8709
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134.0675
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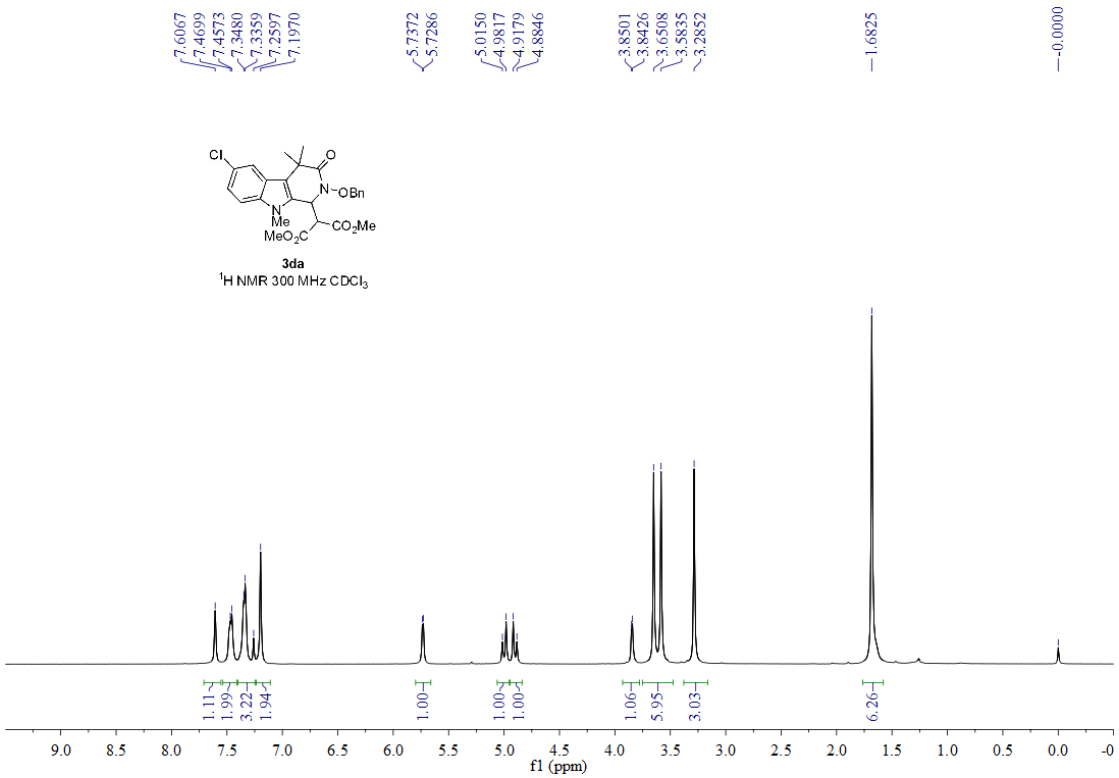
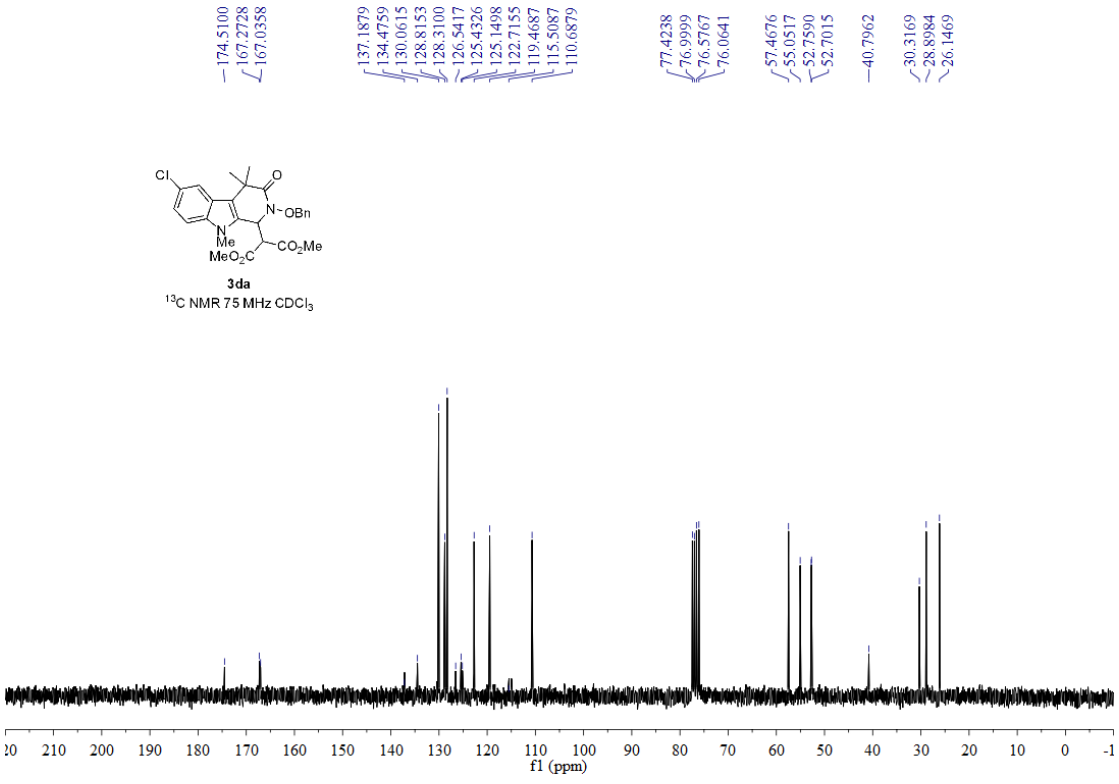
128.2326
125.5290
124.4571
115.0743
111.9482
110.3038
102.3763
77.4233
76.9997
76.5763
75.9179
57.5448
55.9134
54.7977
52.6905
52.6517
40.7928
30.1887
28.7004
25.8831
MeO
O
N
OBn
N
Me
MeO2C
CO2Me
3ca
13C NMR 75 MHz CDCl3
f1 (ppm)



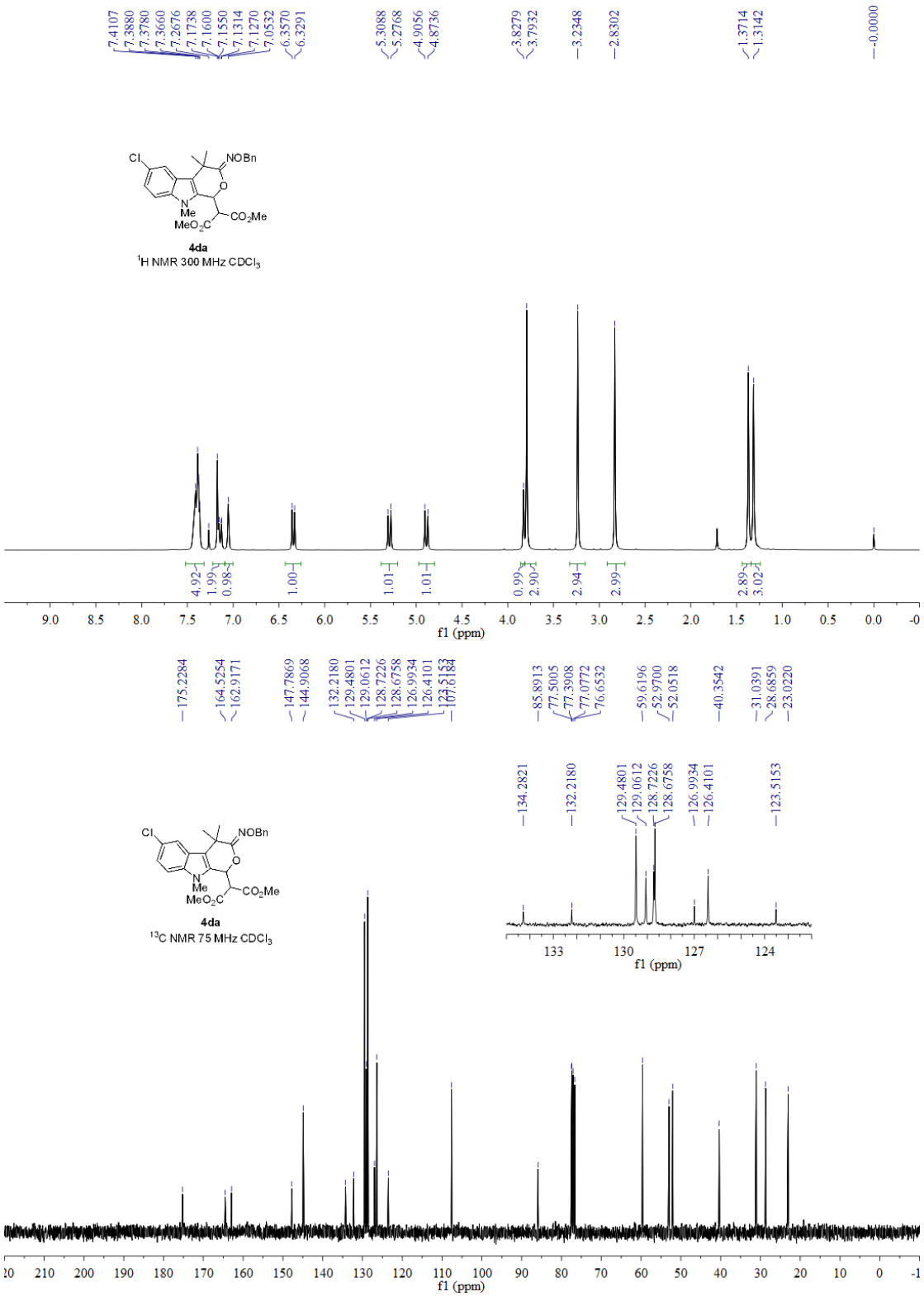
3da

^{1}H NMR 300 MHz $CDCl_3$



3da

^{13}C NMR 75 MHz $CDCl_3$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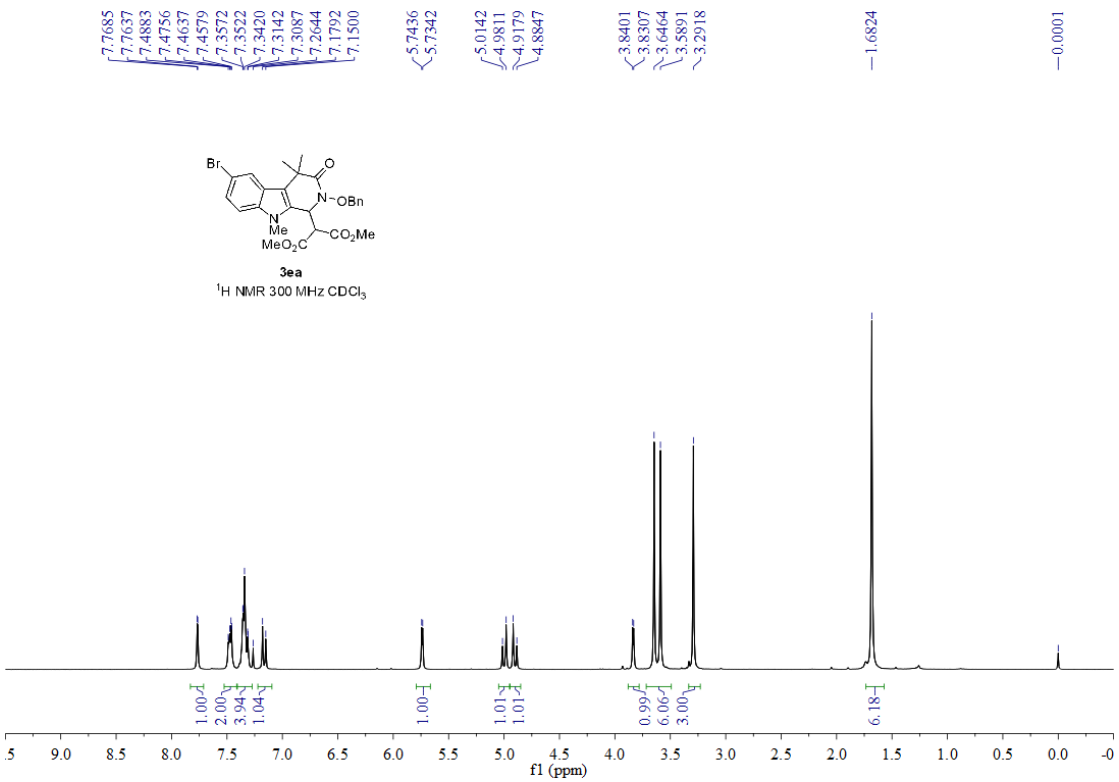
7.3780
7.3660
7.2676
7.1738
7.1600
7.1550
7.1314
7.1270
7.0532
6.3570
6.3291
5.3088
5.2768
4.9056
4.8736
3.8279
3.7932
3.2348
2.8302
1.3714
1.3142
-0.0000
Cl
NOBn
O
N
Me
MeO2C
CO2Me
4da
1H NMR 300 MHz CDCl3
4.92
1.99
0.98
1.00
1.01
1.01
0.99
2.90
2.94
2.99
2.89
3.02
f1 (ppm)
175.2284
164.5254
162.9171
147.7869
144.9068
132.2180
129.4801
129.0612
128.7226
128.6758
126.9934
126.4101
123.5153
107.6184
85.8913
77.5005
77.3908
77.0772
76.6532
59.6196
52.9700
52.0518
40.3542
31.0391
28.6859
23.0220
4da
13C NMR 75 MHz CDCl3
f1 (ppm)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7.4883
7.4756
7.4637
7.4579
7.3572
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7.3087
7.2644
7.1792
7.1500
5.7436
5.7342
5.0142
4.9811
4.9179
4.8847
3.8401
3.8307
3.6464
3.5891
3.2918
1.6824
0.0001
Br
O
N
OBn
N
Me
MeO2C
CO2Me
3ea
1H NMR 300 MHz CDCl3
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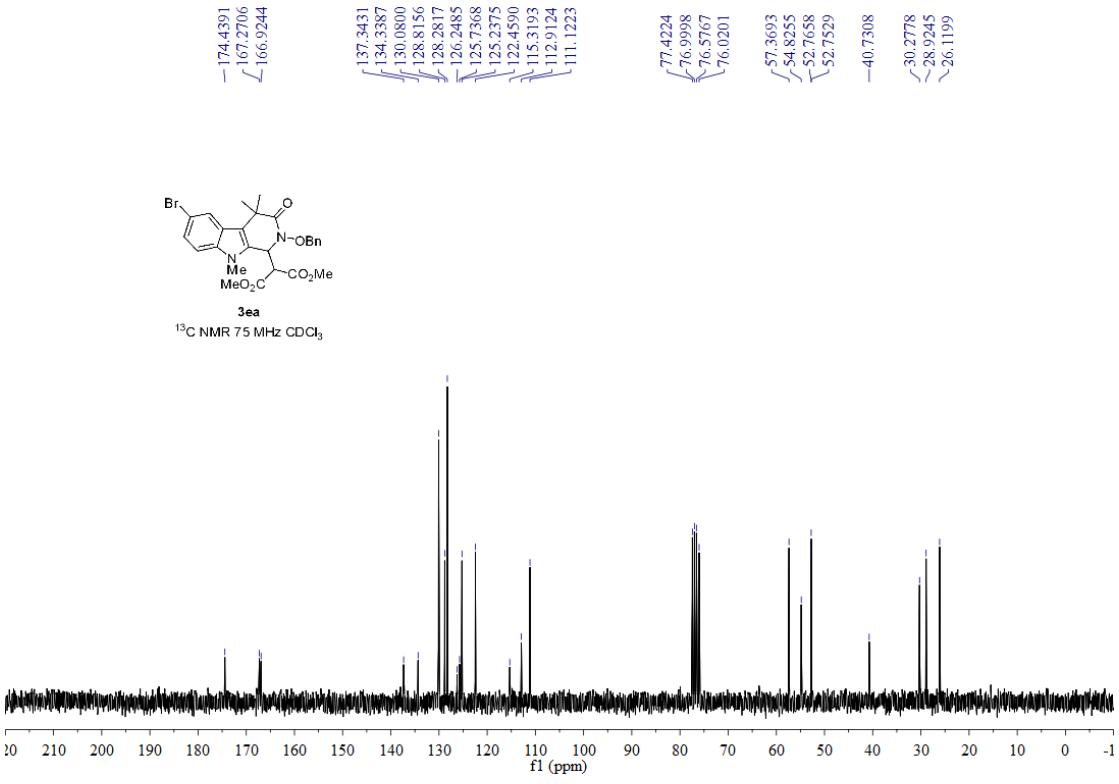
2.00
3.94
1.04
1.00
1.01
1.01
0.99
6.06
3.00
6.18
f1 (ppm)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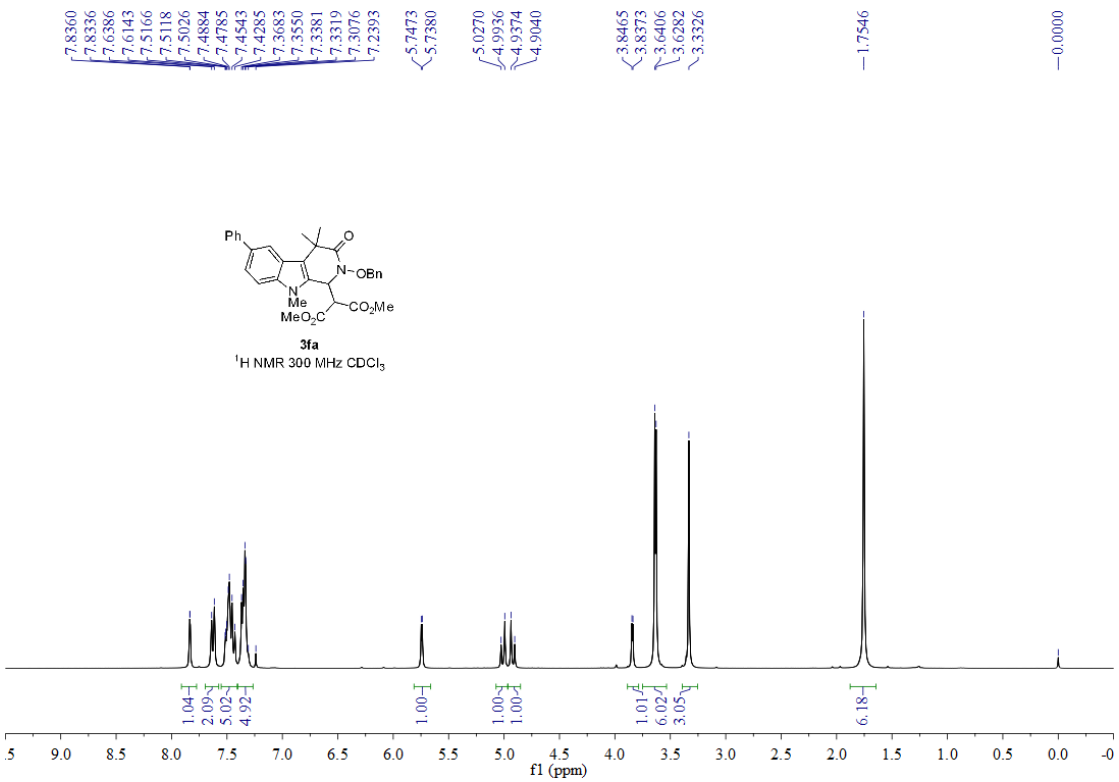
134.3387
130.0800
128.8156
128.2817
126.2485
125.7368
125.2375
122.4590
115.3193
112.9124
111.1223
77.4224
76.9998
76.5767
76.0201
57.3693
54.8255
52.7658
52.7529
40.7308
30.2778
28.9245
26.1199
Br
O
N
OBn
N
Me
MeO2C
CO2Me
3ea
13C NMR 75 MHz CDCl3
f1 (ppm)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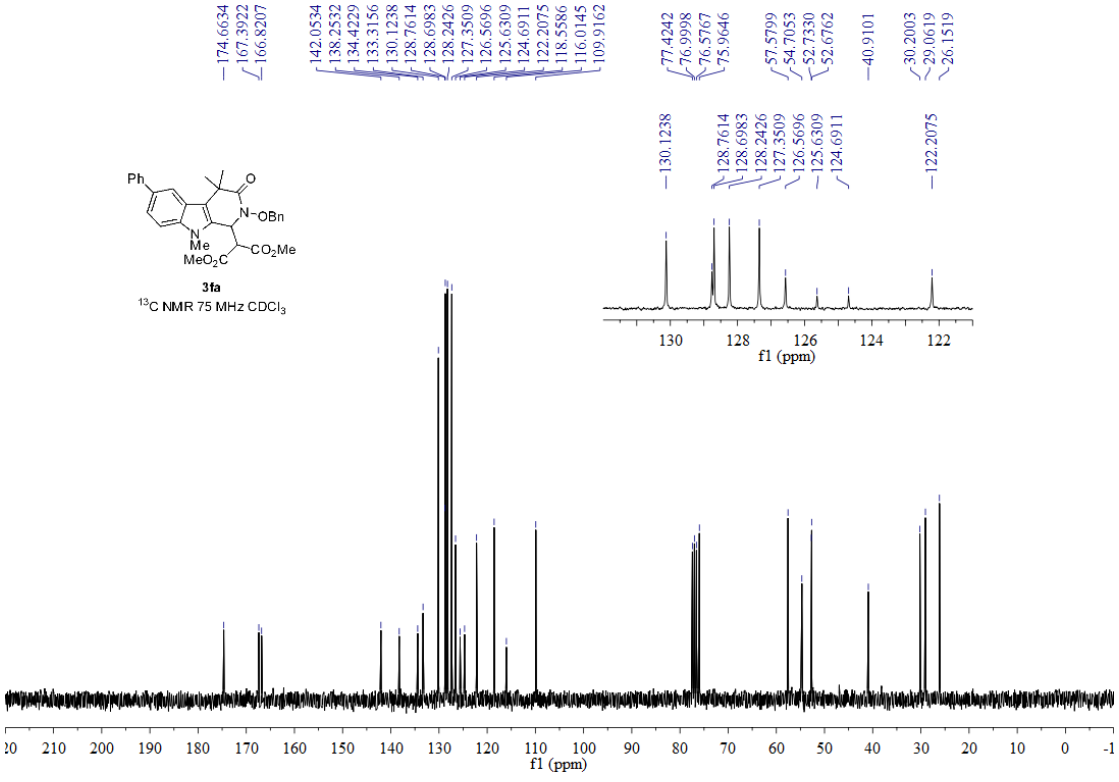
7.8336
7.6386
7.6143
7.5166
7.5118
7.5026
7.4884
7.4785
7.4543
7.4285
7.3683
7.3550
7.3381
7.3319
7.3076
7.2393
5.7473
5.7380
5.0270
4.9936
4.9374
4.9040
3.8465
3.8373
3.6406
3.6282
3.3326
1.7546
0.0000
Ph
O
N
OBn
Me
MeO2C
CO2Me
3fa
1H NMR 300 MHz CDCl3
1.04
2.09
5.02
4.92
1.00
1.00
1.00
1.01
6.02
3.05
6.18
f1 (ppm)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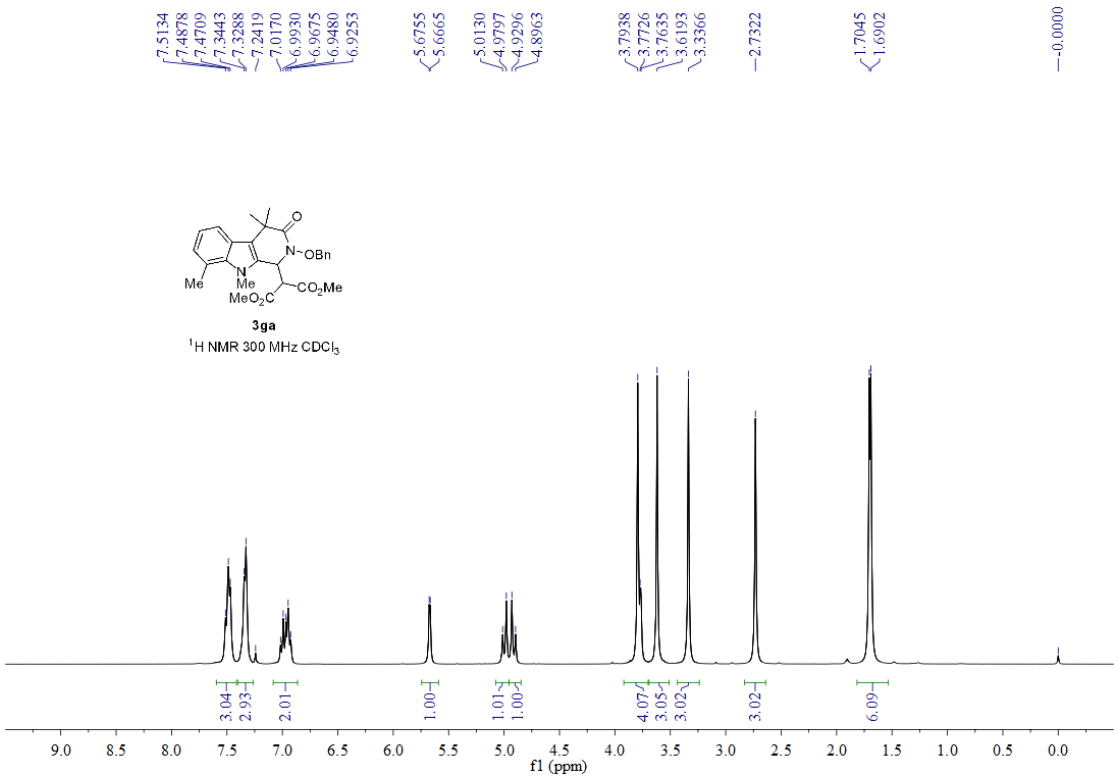
166.8207
142.0534
138.2532
134.4229
133.3156
130.1238
128.7614
128.6983
128.2426
127.3509
126.5696
125.6309
124.6911
122.2075
118.5586
116.0145
109.9162
77.4242
76.9998
76.5767
75.9646
57.5799
54.7053
52.7330
52.6762
40.9101
30.2003
29.0619
26.1519
Ph
O
N
OBn
Me
MeO2C
CO2Me
3fa
13C NMR 75 MHz CDCl3
130.1238
128.7614
128.6983
128.2426
127.3509
126.5696
125.6309
124.6911
122.2075
f1 (ppm)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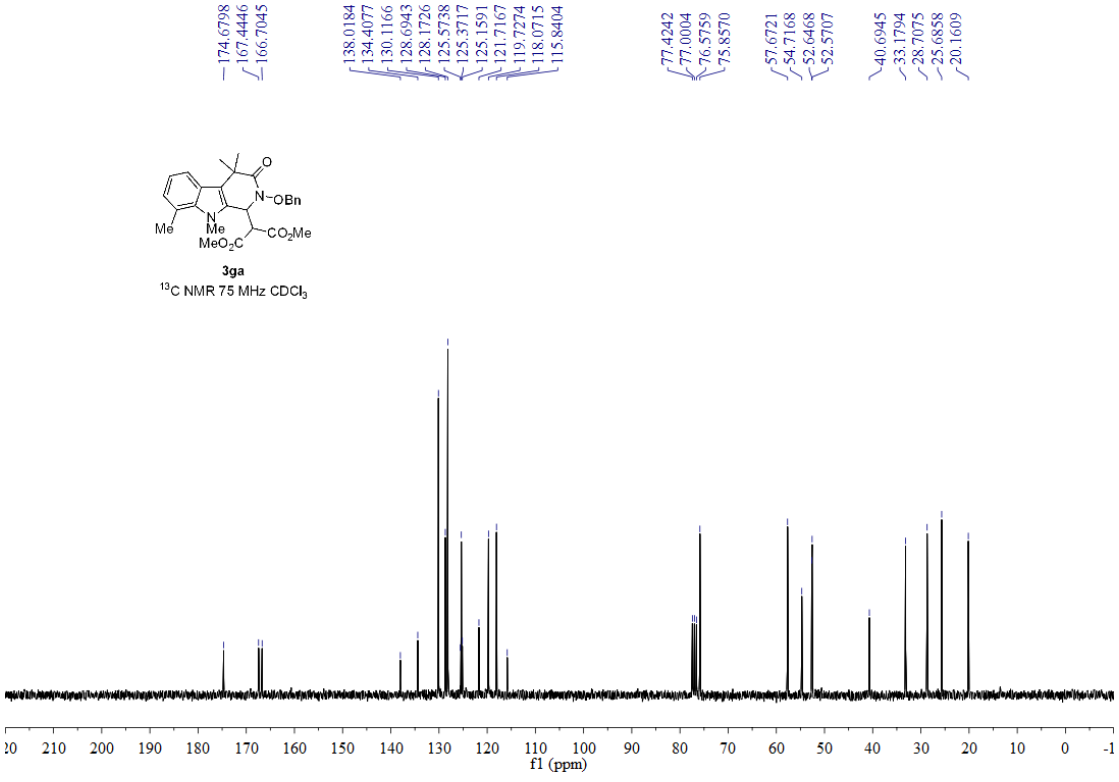
7.4878
7.4709
7.3443
7.3288
7.2419
7.0170
6.9930
6.9675
6.9480
6.9253
5.6755
5.6665
5.0130
4.9797
4.9296
4.8963
3.7938
3.7726
3.7635
3.6193
3.3366
2.7322
1.7045
1.6902
0.0000
OBn
Me
N
Me
MeO2C
CO2Me
3ga
1H NMR 300 MHz CDCl3
3.04
2.93
2.01
1.00
1.01
1.00
4.07
3.05
3.02
3.02
6.09
f1 (ppm)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166.7045
138.0184
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130.1166
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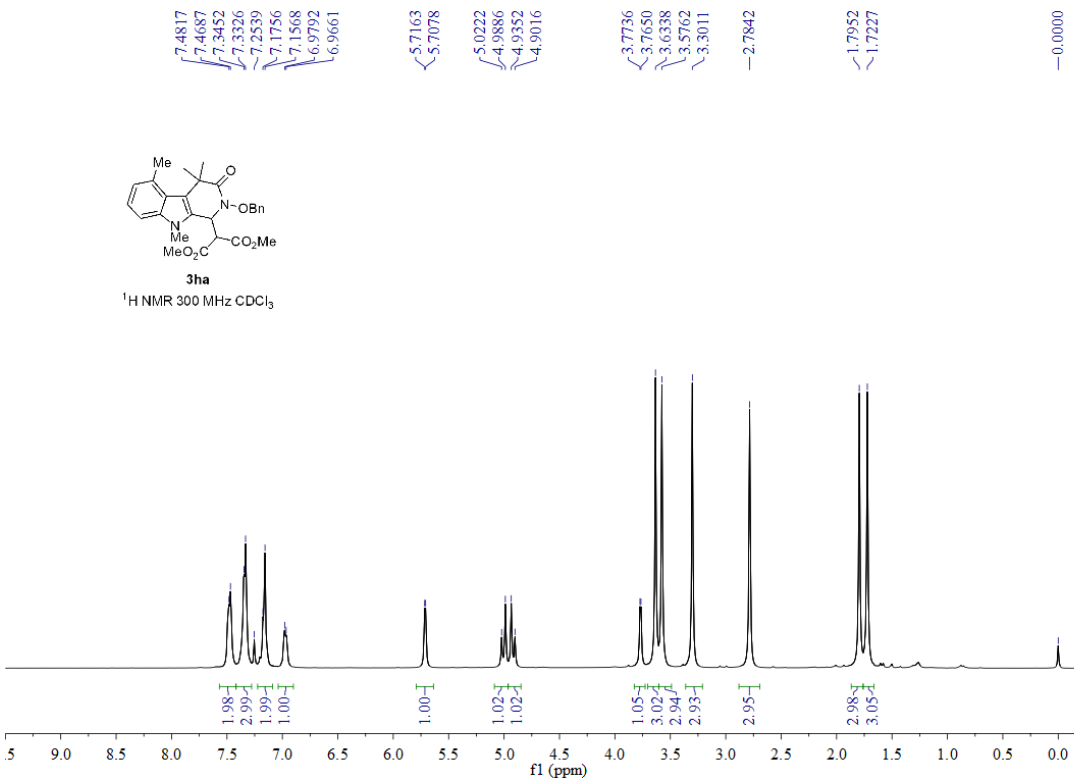
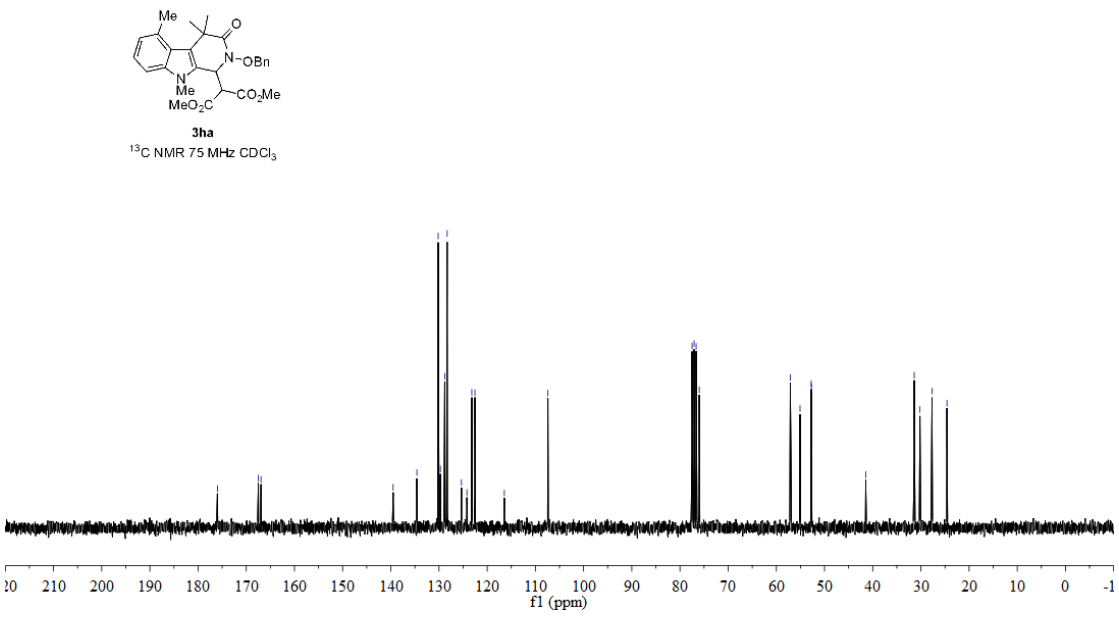
128.1726
125.5738
125.3717
125.1591
121.7167
119.7274
118.0715
115.8404
77.4242
77.0004
76.5759
75.8570
57.6721
54.7168
52.6468
52.5707
40.6945
33.1794
28.7075
25.6858
20.1609
OBn
Me
N
Me
MeO2C
CO2Me
3ga
13C NMR 75 MHz CDCl3
f1 (ppm)



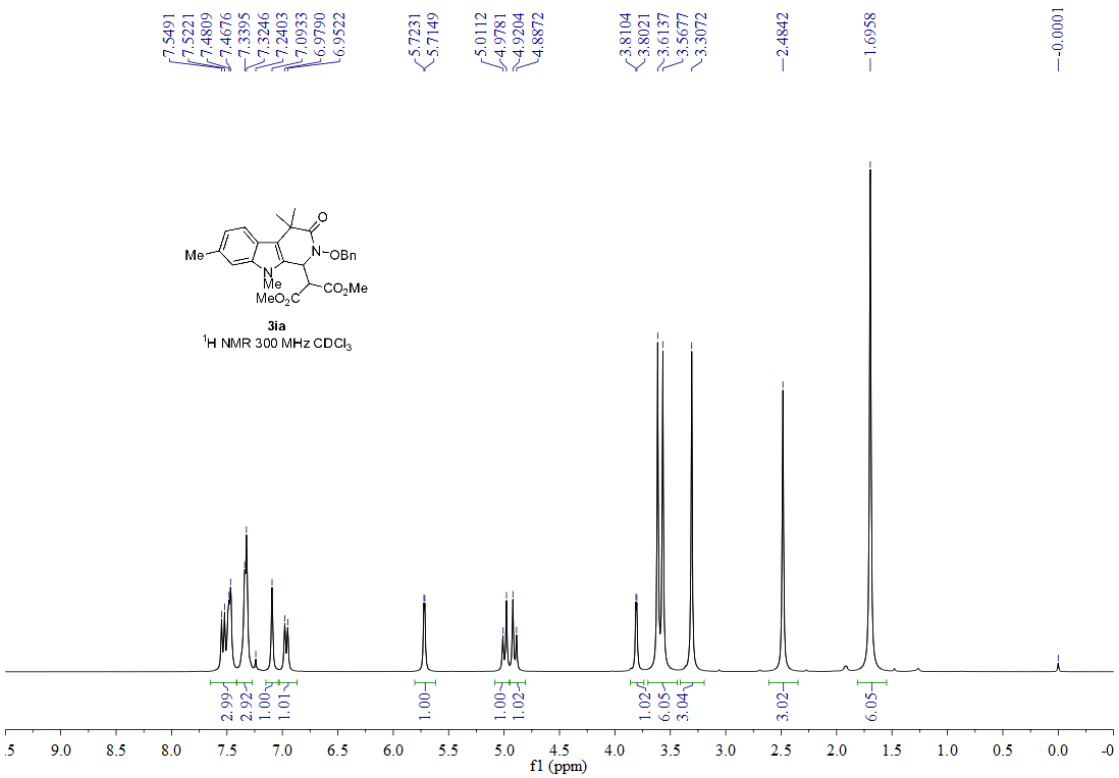
3ha

^{1}H NMR 300 MHz $CDCl_3$



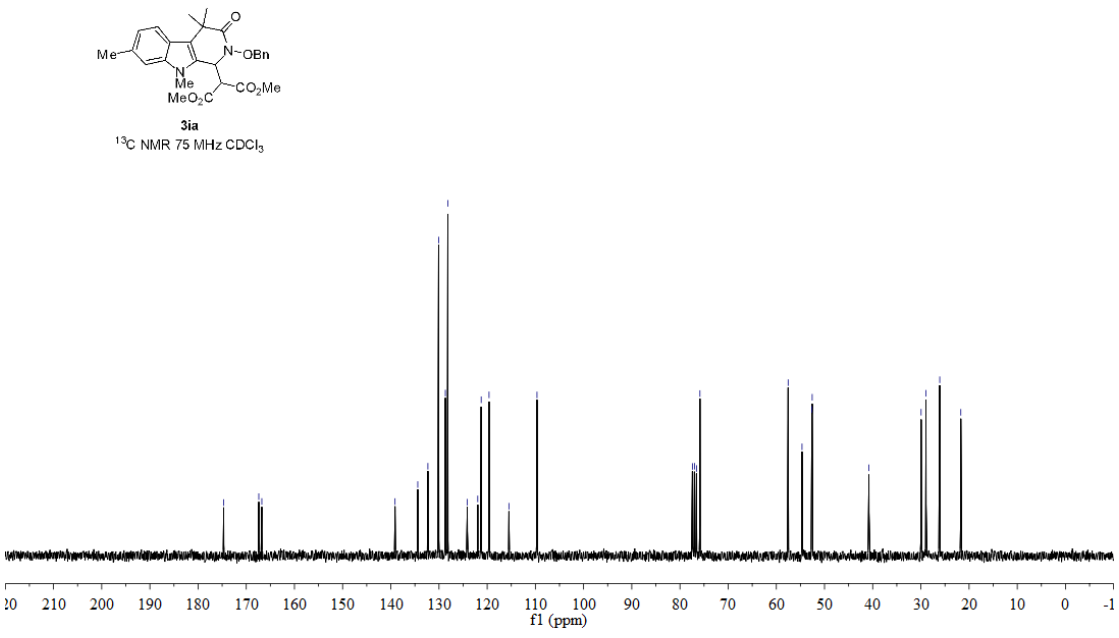
3ha

^{13}C NMR 75 MHz $CDCl_3$



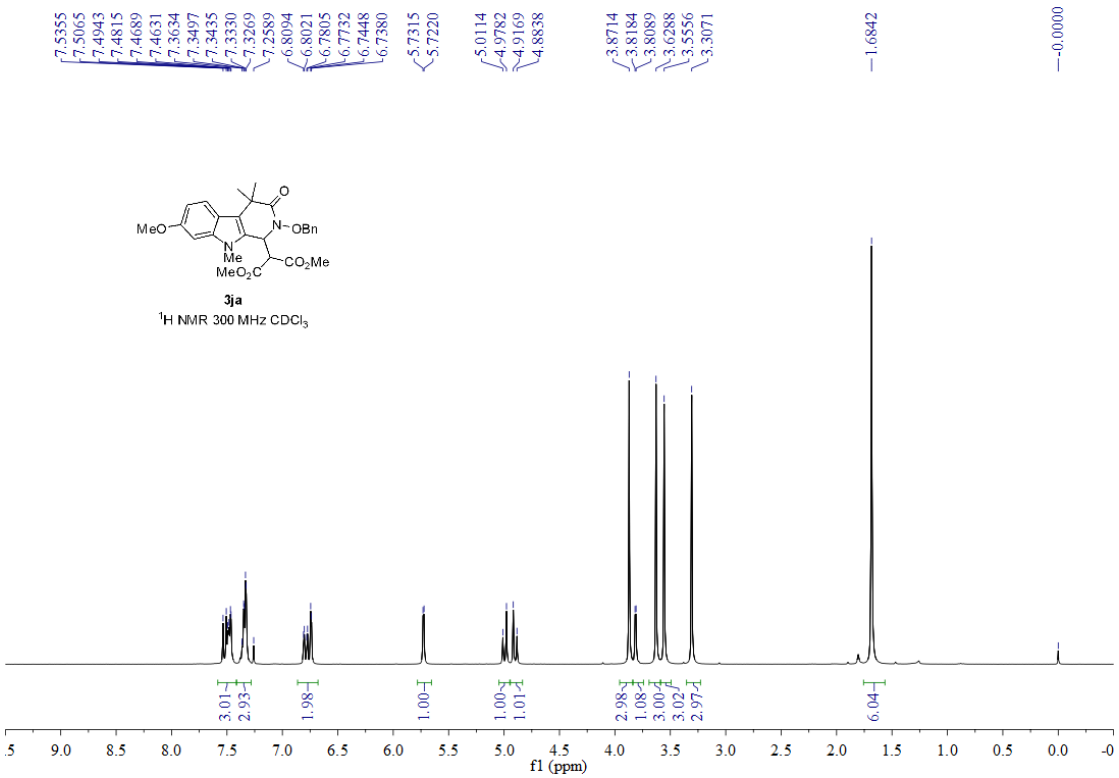
3ia

^{1}H NMR 300 MHz $CDCl_3$



3ia

^{13}C NMR 75 MHz $CDCl_3$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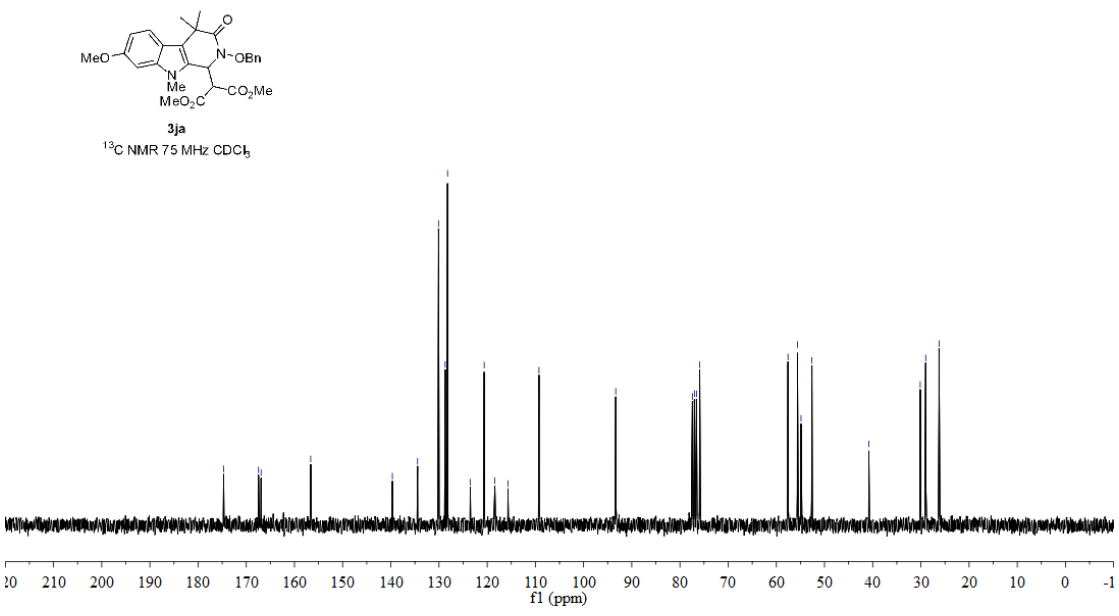
7.4943
7.4815
7.4689
7.4631
7.3634
7.3497
7.3435
7.3330
7.3269
7.2589
6.8094
6.8021
6.7805
6.7732
6.7448
6.7380
5.7315
5.7220
5.0114
4.9782
4.9169
4.8838
3.8714
3.8184
3.8089
3.6288
3.5556
3.3071
1.6842
0.0000
MeO
N
OBn
Me
MeO2C
CO2Me
3ja
1H NMR 300 MHz CDCl3
3.01
2.93
1.98
1.00
1.00
1.01
2.98
1.08
3.00
3.02
2.97
6.04
f1 (ppm)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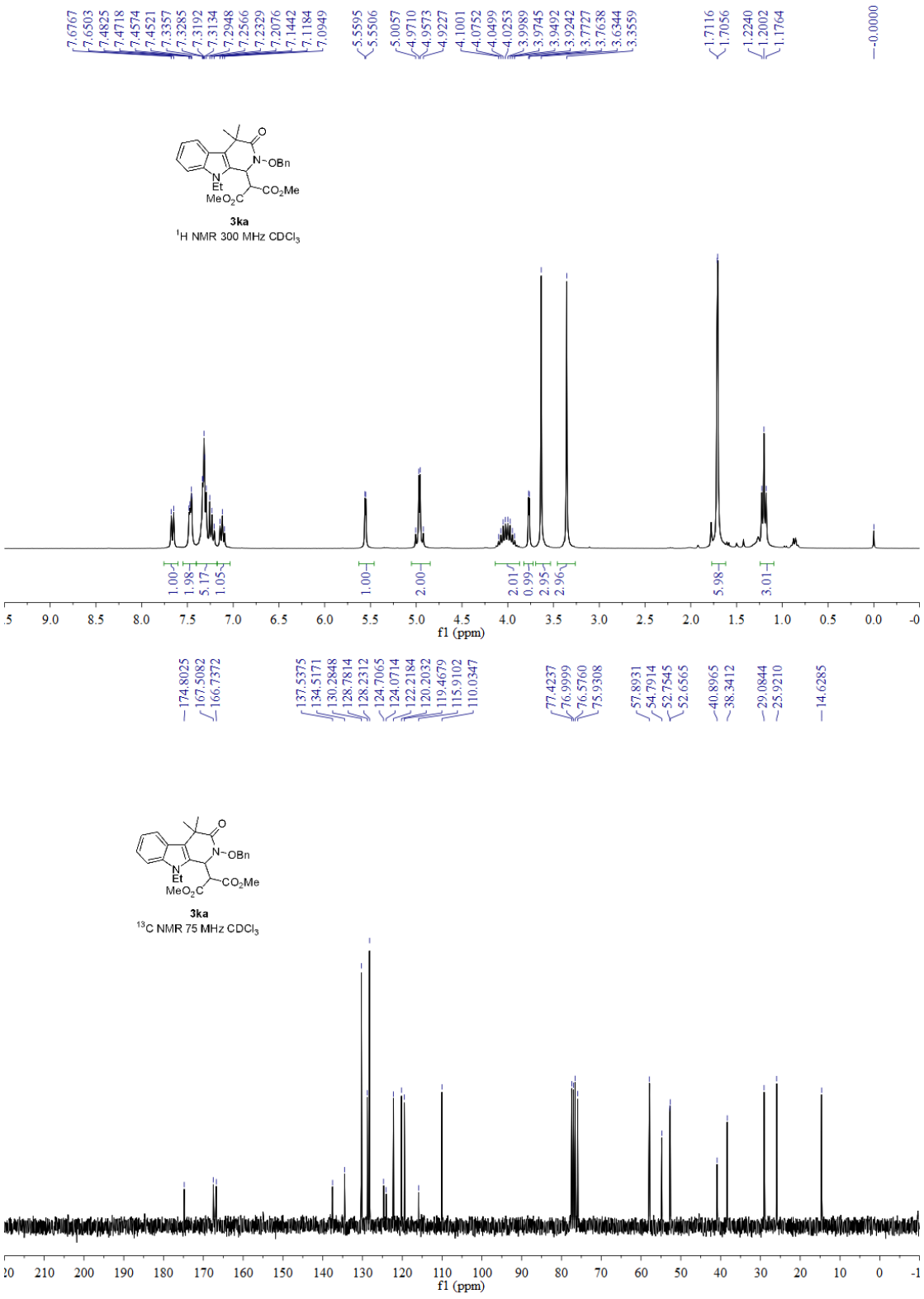
166.9219
156.6284
139.6758
134.4557
130.0917
128.7221
128.2256
123.5089
120.6161
118.4116
115.6931
109.2569
93.3241
77.4238
76.9998
76.5761
75.9034
57.5766
55.6200
54.8735
52.6492
52.6205
40.7988
30.1422
29.0054
26.2327
MeO
N
OBn
Me
MeO2C
CO2Me
3ja
13C NMR 75 MHz CDCl3
f1 (ppm)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7.4574
7.4521
7.3357
7.3285
7.3192
7.3134
7.2948
7.2566
7.2329
7.2076
7.1442
7.1184
7.0949
5.5595
5.5506
5.0057
4.9710
4.9573
4.9227
4.1001
4.0752
4.0499
4.0253
3.9989
3.9745
3.9492
3.9242
3.7727
3.7638
3.6344
3.3559
1.7116
1.7056
1.2240
1.2002
1.1764
-0.0000
N-OBn
Et
MeO2C
CO2Me
3ka
1H NMR 300 MHz CDCl3
1.00
1.98
5.17
1.05
1.00
2.00
2.01
0.99
2.95
2.96
5.98
3.01
f1 (ppm)
174.8025
167.5082
166.7372
137.5375
134.5171
130.2848
128.7814
128.2312
124.7065
124.0714
122.2184
120.2032
119.4679
115.9102
110.0347
77.4237
76.9999
76.5760
75.9308
57.8931
54.7914
52.7545
52.6565
40.8965
38.3412
29.0844
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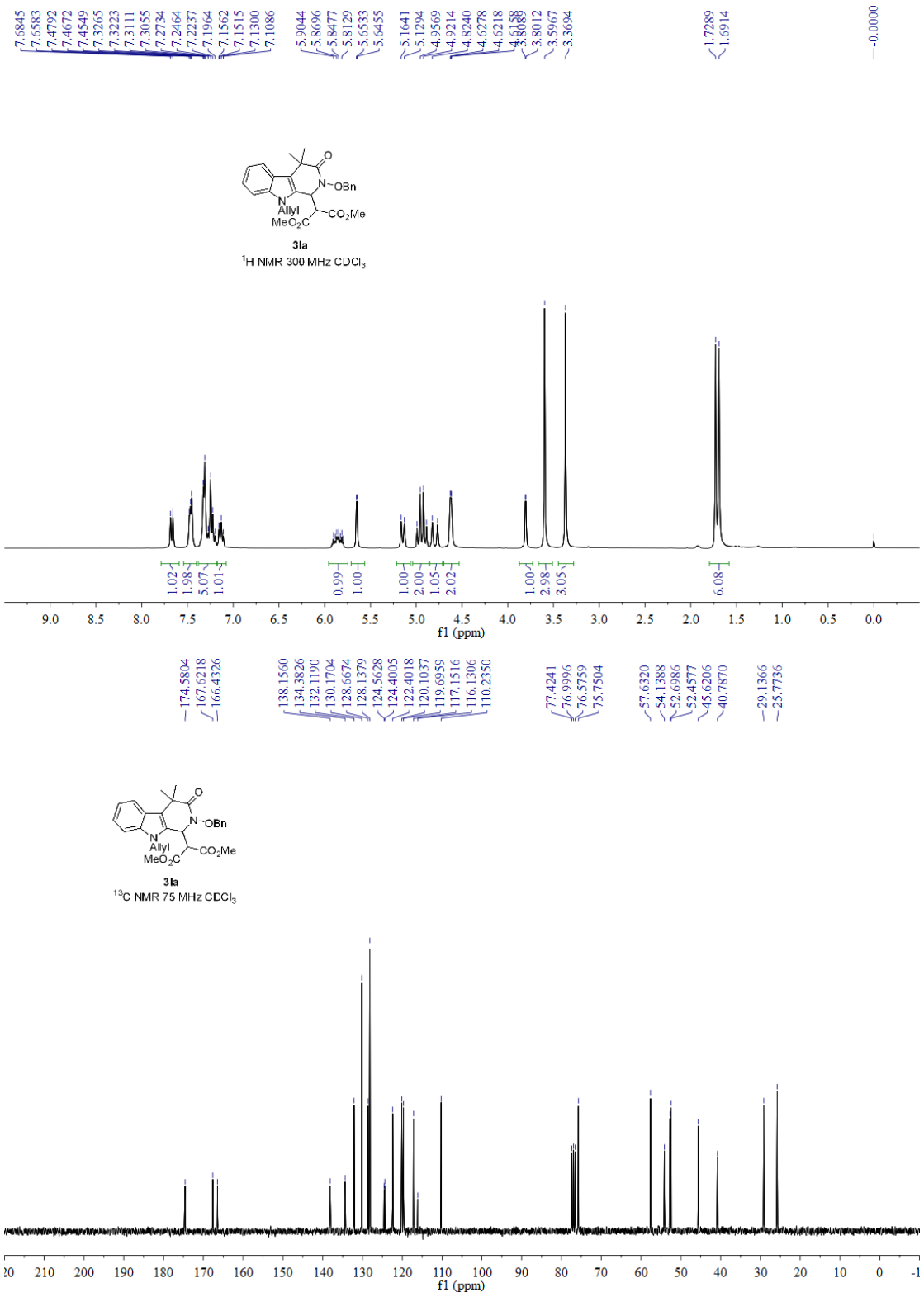
14.6285
N-OBn
Et
MeO2C
CO2Me
3ka
13C NMR 75 MHz CDCl3
f1 (ppm)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7.4792
7.4672
7.4549
7.3265
7.3223
7.3111
7.3055
7.2734
7.2464
7.2237
7.1964
7.1562
7.1515
7.1300
7.1086
5.9044
5.8696
5.8477
5.8129
5.6533
5.6455
5.1641
5.1294
4.9569
4.9214
4.8240
4.6278
4.6218
3.8089
3.8012
3.5967
3.3694
1.7289
1.6914
-0.0000
N-OBn
N
Allyl
MeO2C
CO2Me
3la
1H NMR 300 MHz CDCl3
1.02
1.98
5.07
1.01
0.99
1.00
1.00
2.00
1.05
2.02
1.00
2.98
3.05
6.08
f1 (ppm)
174.5804
167.6218
166.4326
138.1560
134.3826
132.1190
130.1704
128.6674
128.1379
124.5628
124.4005
122.4018
120.1037
119.6959
117.1516
116.1306
110.2350
77.4241
76.9996
76.5759
75.7504
57.6320
54.1388
52.6986
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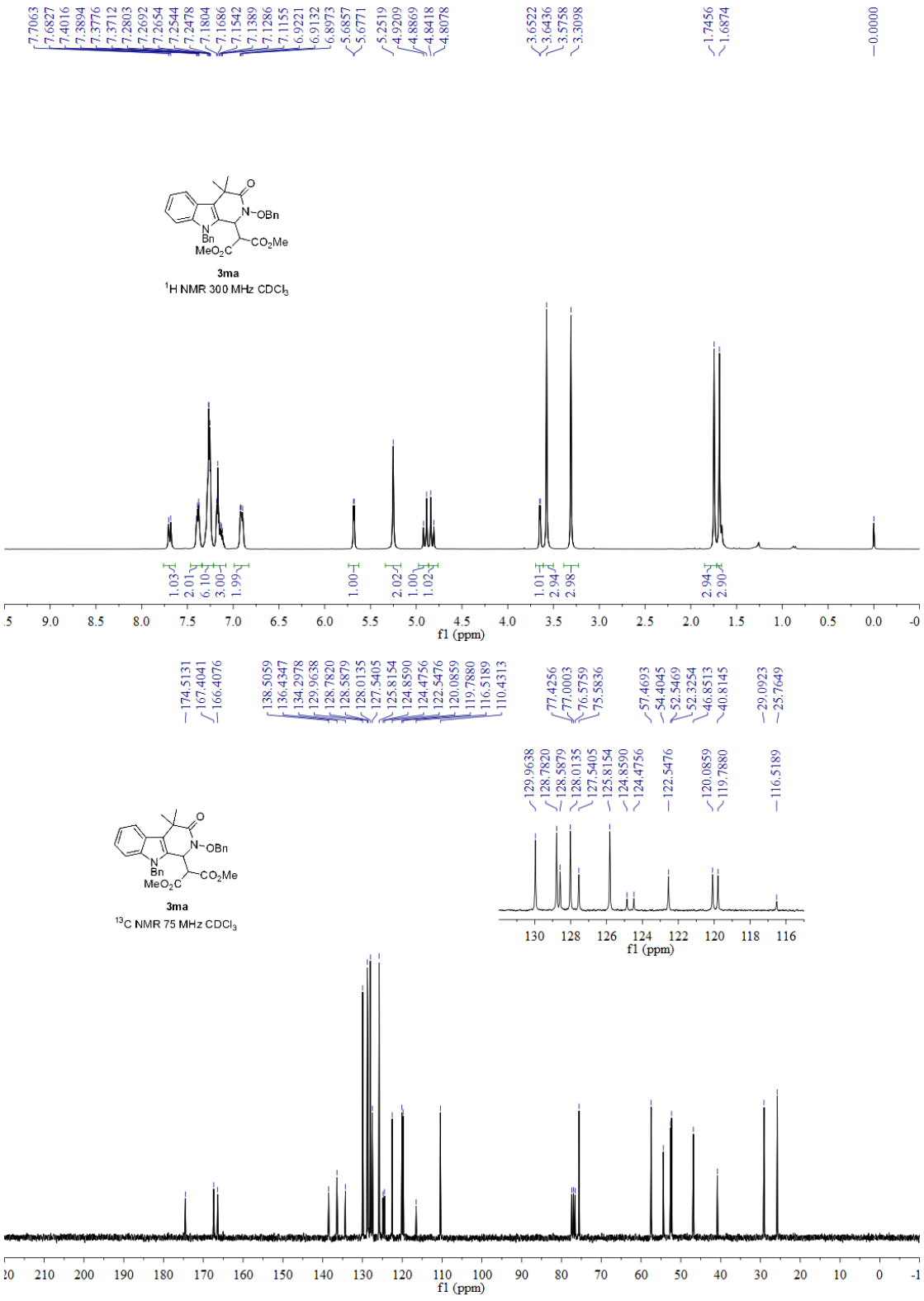
45.6206
40.7870
29.1366
25.7736
3la
13C NMR 75 MHz CDCl3
f1 (ppm)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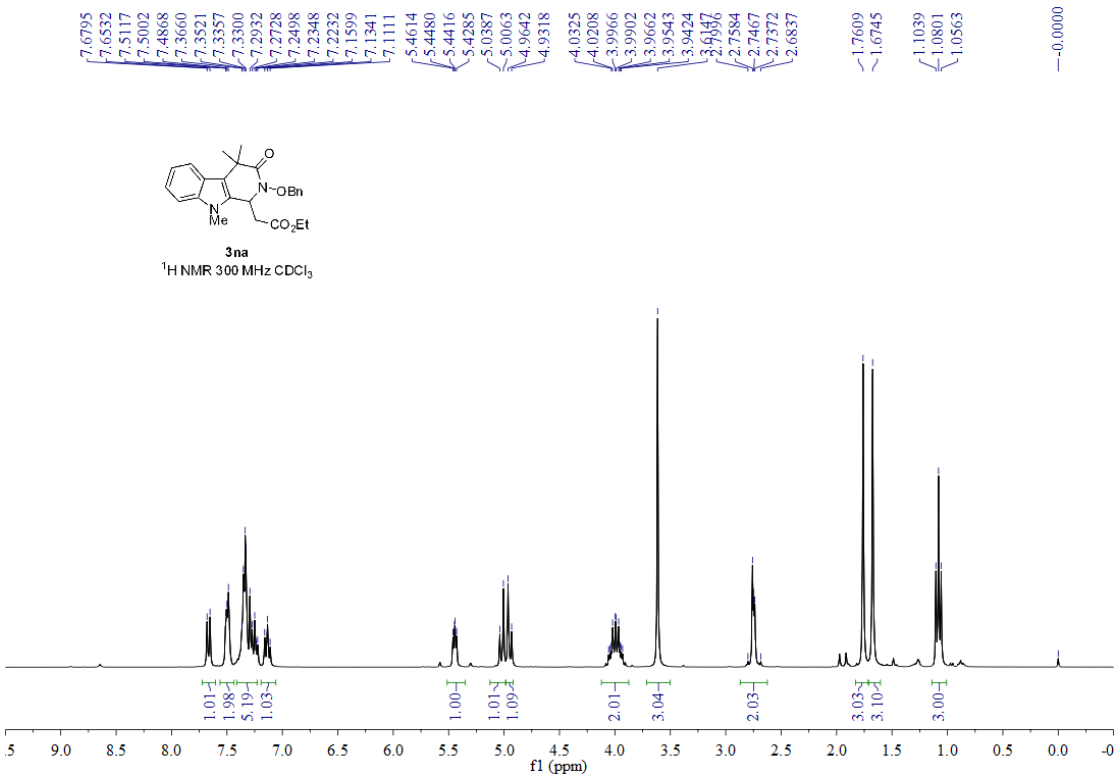
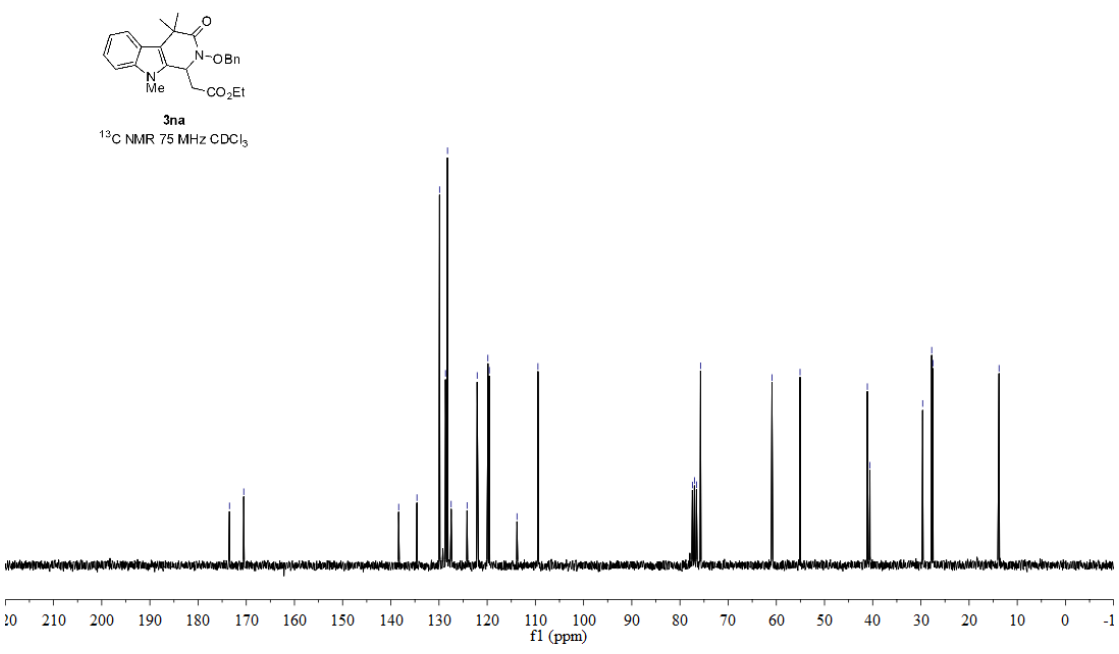
7.2544
7.2478
7.1804
7.1686
7.1542
7.1389
7.1286
7.1155
6.9221
6.9132
6.8973
5.6857
5.6771
5.2519
4.9209
4.8869
4.8418
4.8078
3.6522
3.6436
3.5758
3.3098
1.7456
1.6874
0.0000
N-OBn
Bn
MeO2C
CO2Me
3ma
1H NMR 300 MHz CDCl3
1.03
2.01
6.10
3.00
1.99
1.00
2.02
1.00
1.02
1.01
2.94
2.98
2.94
2.90
f1 (ppm)
174.5131
167.4041
166.4076
138.5059
136.4347
134.2978
129.9638
128.7820
128.5879
128.0135
127.5405
125.8154
124.8590
124.4756
122.5476
120.0859
119.7880
116.5189
110.4313
77.4256
77.0003
76.5759
75.5836
57.4693
54.4045
52.5469
52.3254
46.8513
40.8145
29.0923
25.7649
3ma
13C NMR 75 MHz CDCl3
f1 (ppm)



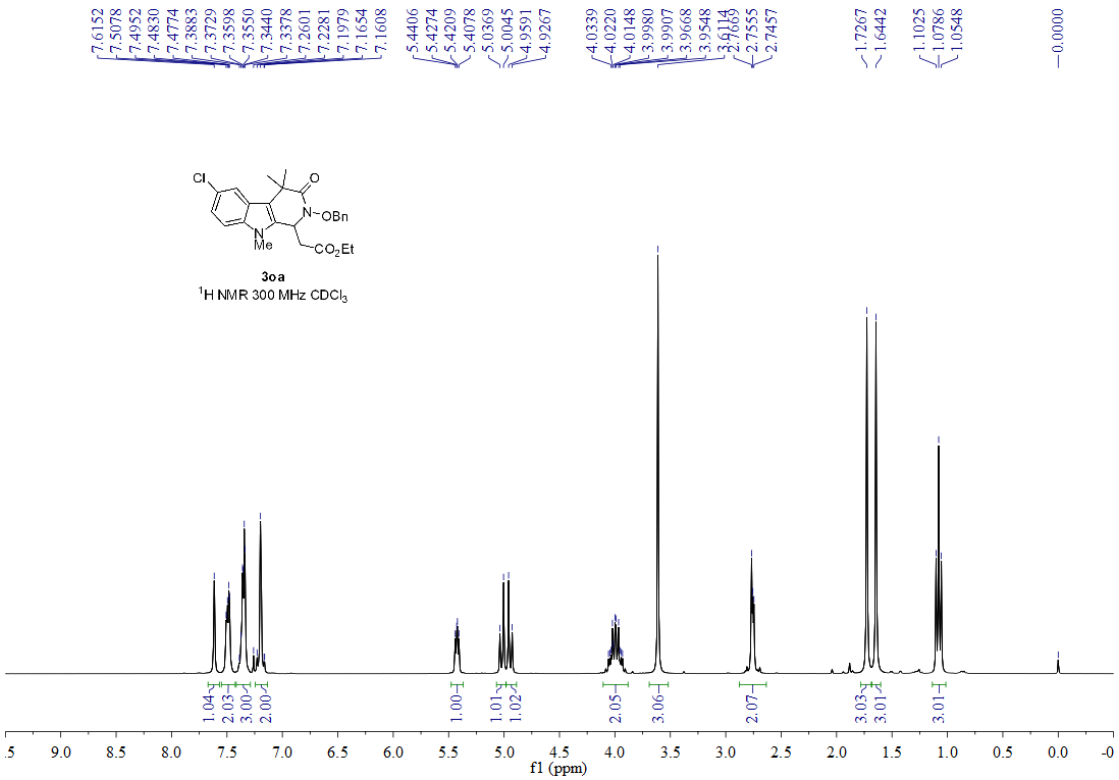
3na

^{1}H NMR 300 MHz $CDCl_3$



3na

^{13}C NMR 75 MHz $CDCl_3$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7.4774
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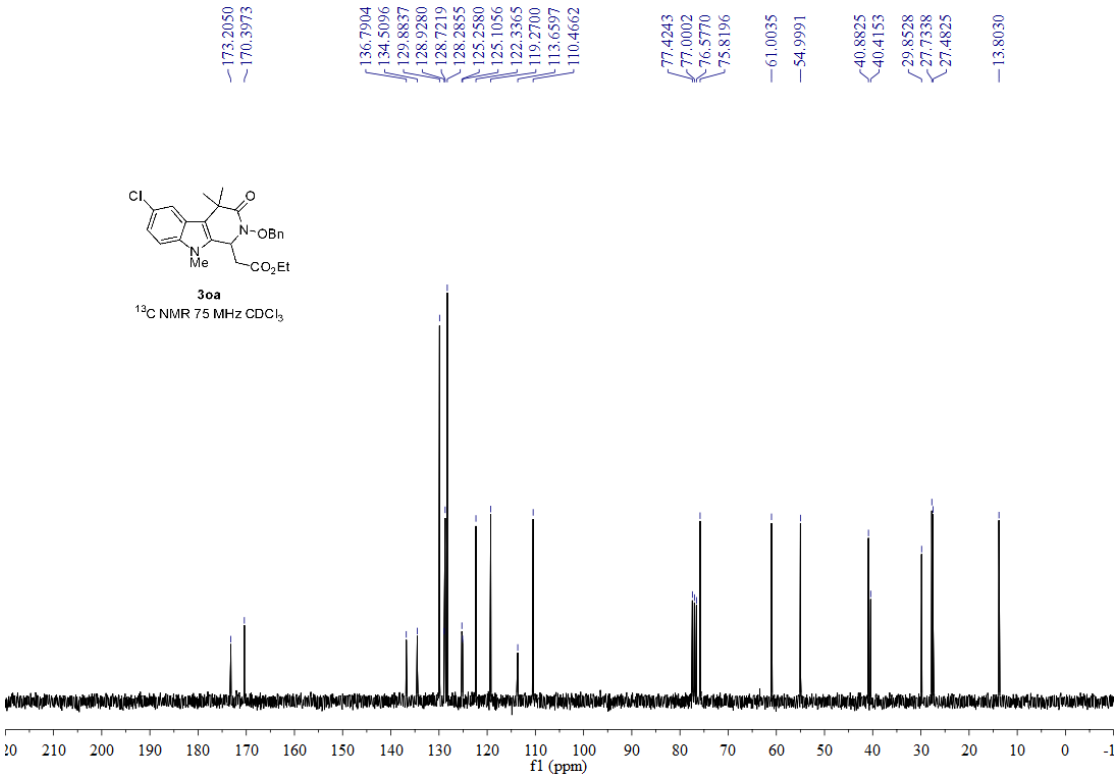
7.3378
7.2601
7.2281
7.1979
7.1654
7.1608
5.4406
5.4274
5.4209
5.4078
5.0369
5.0045
4.9591
4.9267
4.0339
4.0220
4.0148
3.9980
3.9907
3.9668
3.9548
3.6114
2.7663
2.7555
2.7457
1.7267
1.6442
1.1025
1.0786
1.0548
0.0000
Cl
O
N-OBn
N
Me
CO2Et
3oa
1H NMR 300 MHz CDCl3
1.04
2.03
3.00
2.00
1.00
1.01
1.02
2.05
3.06
2.07
3.03
3.01
3.01
f1 (ppm)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134.5096
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128.7219
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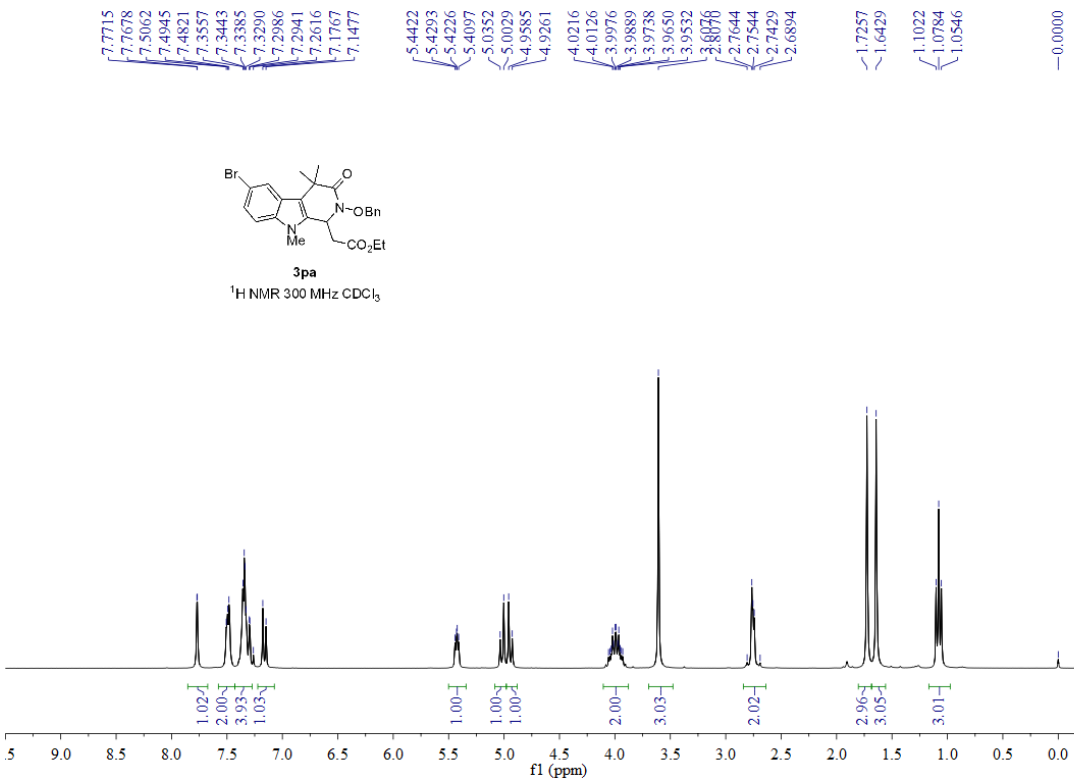
122.3365
119.2700
113.6597
110.4662
77.4243
77.0002
76.5770
75.8196
61.0035
54.9991
40.8825
40.4153
29.8528
27.7338
27.4825
13.8030
Cl
O
N-OBn
N
Me
CO2Et
3oa
13C NMR 75 MHz CDCl3
f1 (ppm)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7.5062
7.4945
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7.3443
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7.3290
7.2986
7.2941
7.2616
7.1767
7.1477
5.4422
5.4293
5.4226
5.4097
5.0352
5.0029
4.9585
4.9261
4.0216
4.0126
3.9976
3.9889
3.9738
3.9650
3.9532
2.7644
2.7544
2.7429
2.6894
1.7257
1.6429
1.1022
1.0784
1.0546
0.0000
Br
O
N
OBn
Me
CO2Et
3pa
1H NMR 300 MHz CDCl3
1.02
2.00
3.93
1.03
1.00
1.00
1.00
2.00
3.03
2.02
2.96
3.05
3.01
f1 (ppm)
173.3077
170.4984
137.1848
134.6289
130.0023
128.9072
128.8457
128.4077
125.9018
125.0279
122.4179
113.7244
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77.5570
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75.9486
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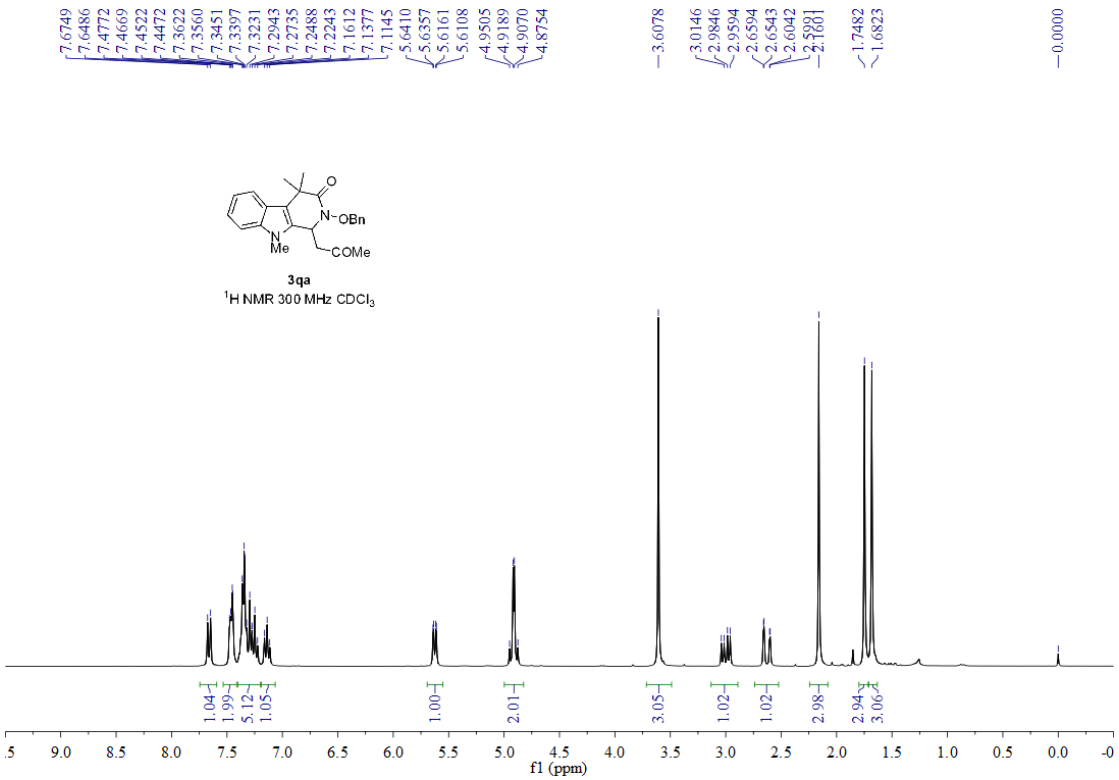
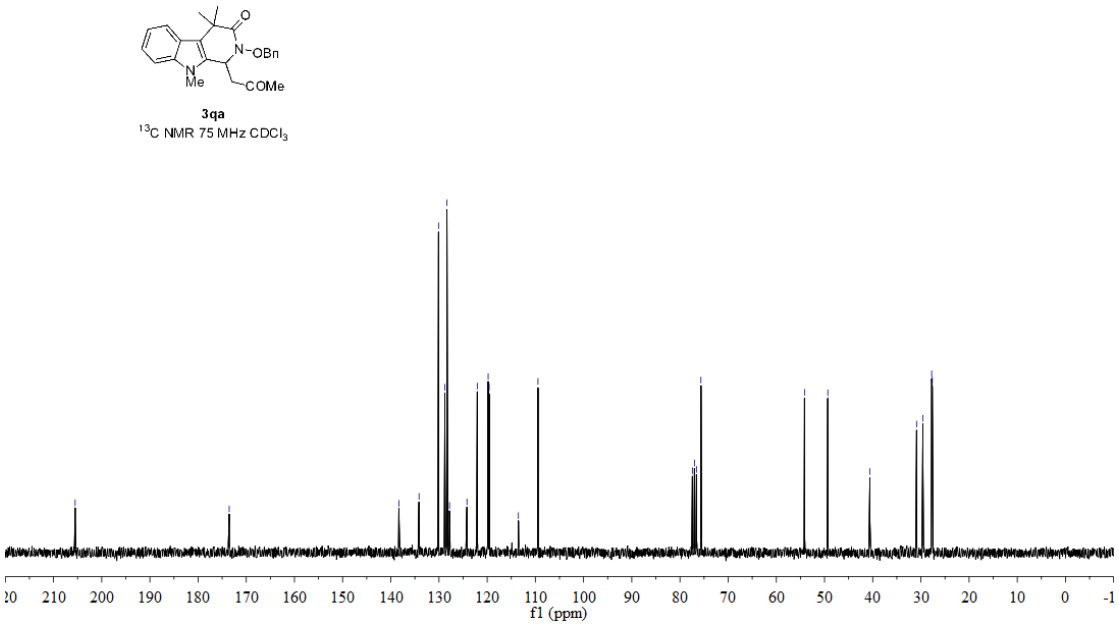
55.0909
40.9894
40.5462
29.9592
27.8983
27.6290
13.9312
Br
O
N
OBn
Me
CO2Et
3pa
13C NMR 75 MHz CDCl3
f1 (ppm)



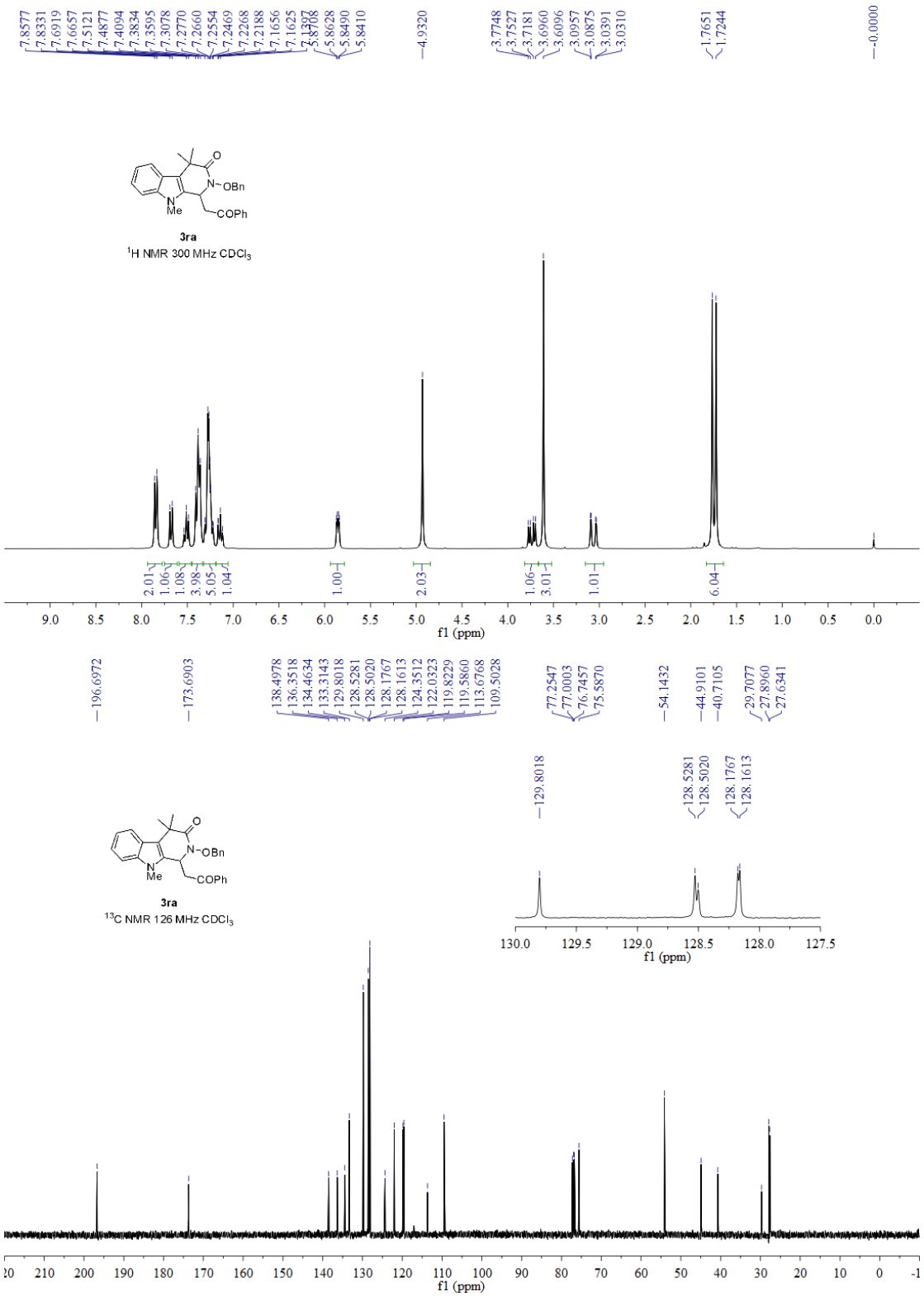
3qa

^{1}H NMR 300 MHz $CDCl_3$



3qa

^{13}C NMR 75 MHz $CDCl_3$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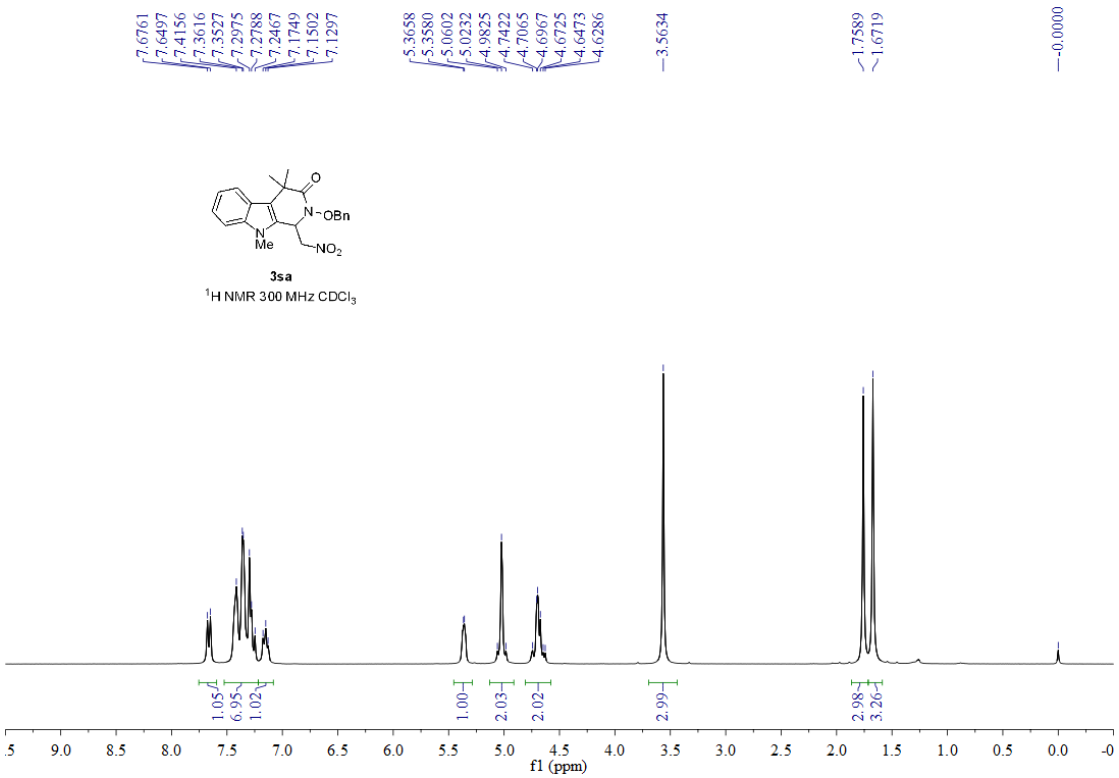
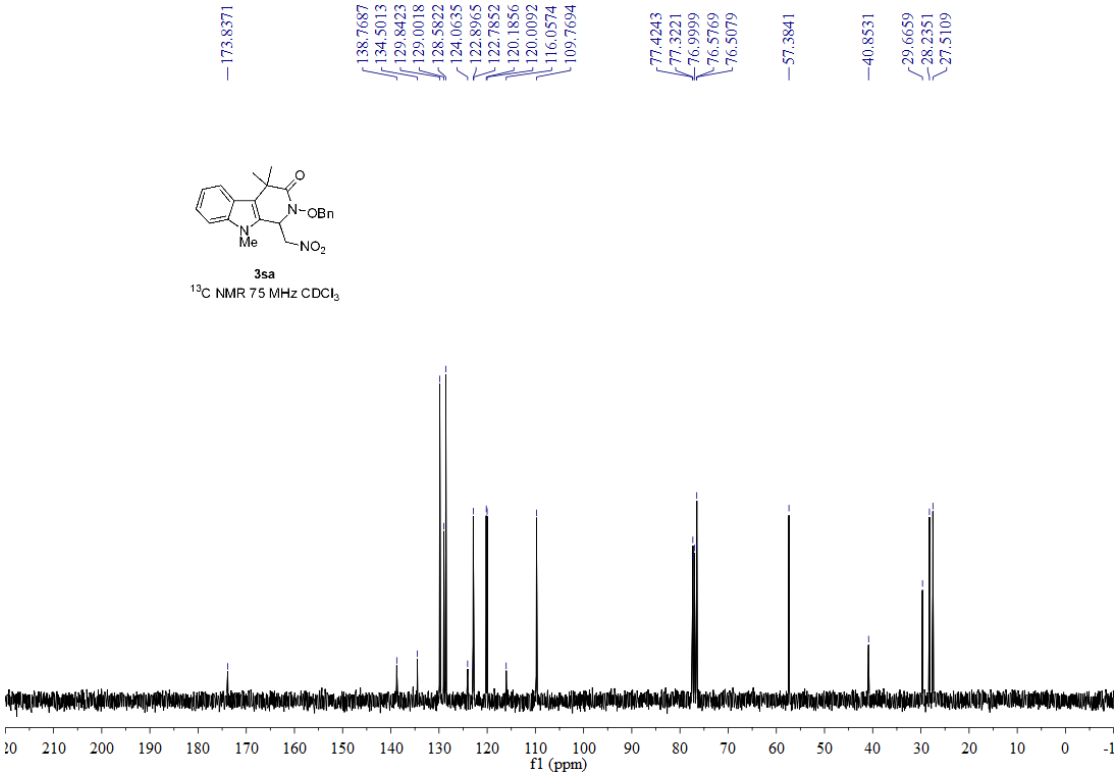
7.6657
7.5121
7.4877
7.4094
7.3834
7.3595
7.3078
7.2770
7.2660
7.2554
7.2469
7.2268
7.2188
7.1656
7.1625
5.8628
5.8490
5.8410
4.9320
3.7748
3.7527
3.7181
3.6960
3.6096
3.0957
3.0875
3.0391
3.0310
1.7651
1.7244
0.0000
O
N
OBn
Me
COPh
3ra
1H NMR 300 MHz CDCl3
2.01
1.06
1.08
3.98
5.05
1.04
1.00
2.03
1.06
3.01
1.01
6.04
f1 (ppm)
196.6972
173.6903
138.4978
136.3518
134.4634
133.3143
129.8018
128.5281
128.5020
128.1767
128.1613
124.3512
122.0323
119.8229
119.5860
113.6768
109.5028
77.2547
77.0003
76.7457
75.5870
54.1432
44.9101
40.7105
29.7077
27.8960
27.6341
3ra
13C NMR 126 MHz CDCl3
f1 (ppm)



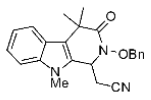
3sa

^{1}H NMR 300 MHz $CDCl_3$



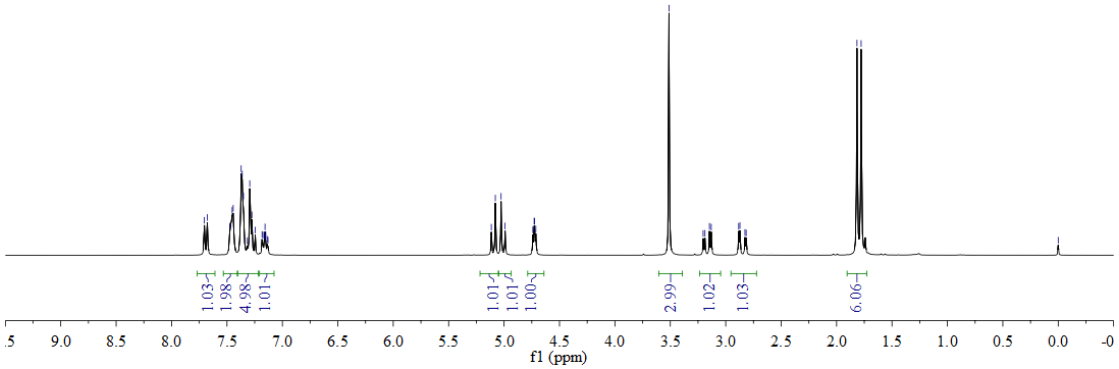
3sa

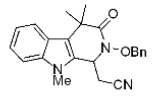
^{13}C NMR 75 MHz $CDCl_3$



3ta

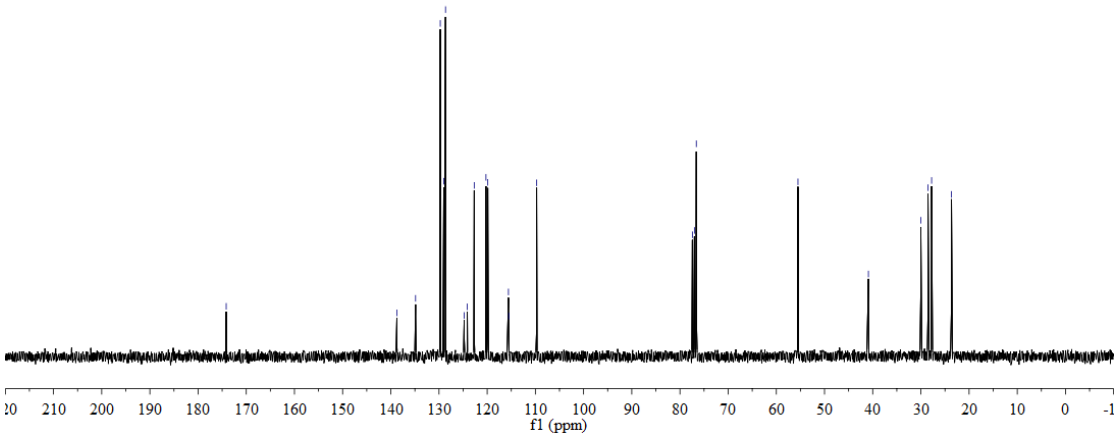
^{1}H NMR 300 MHz $CDCl_3$

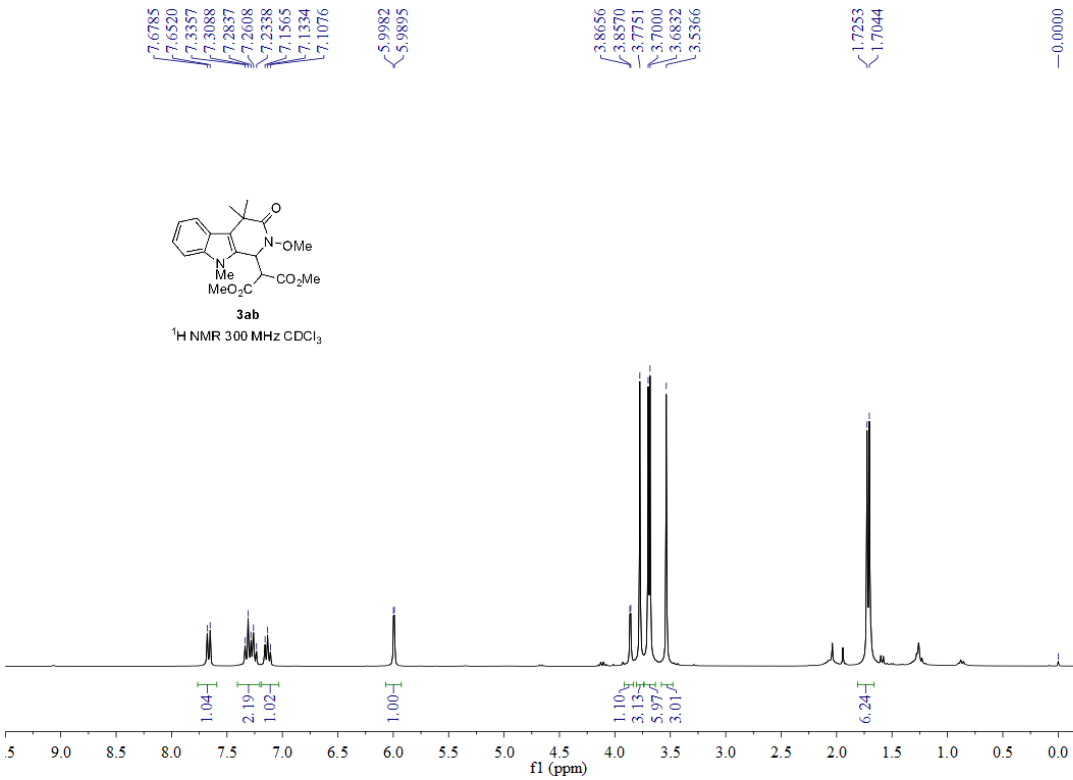




3ta

^{13}C NMR 75 MHz $CDCl_3$

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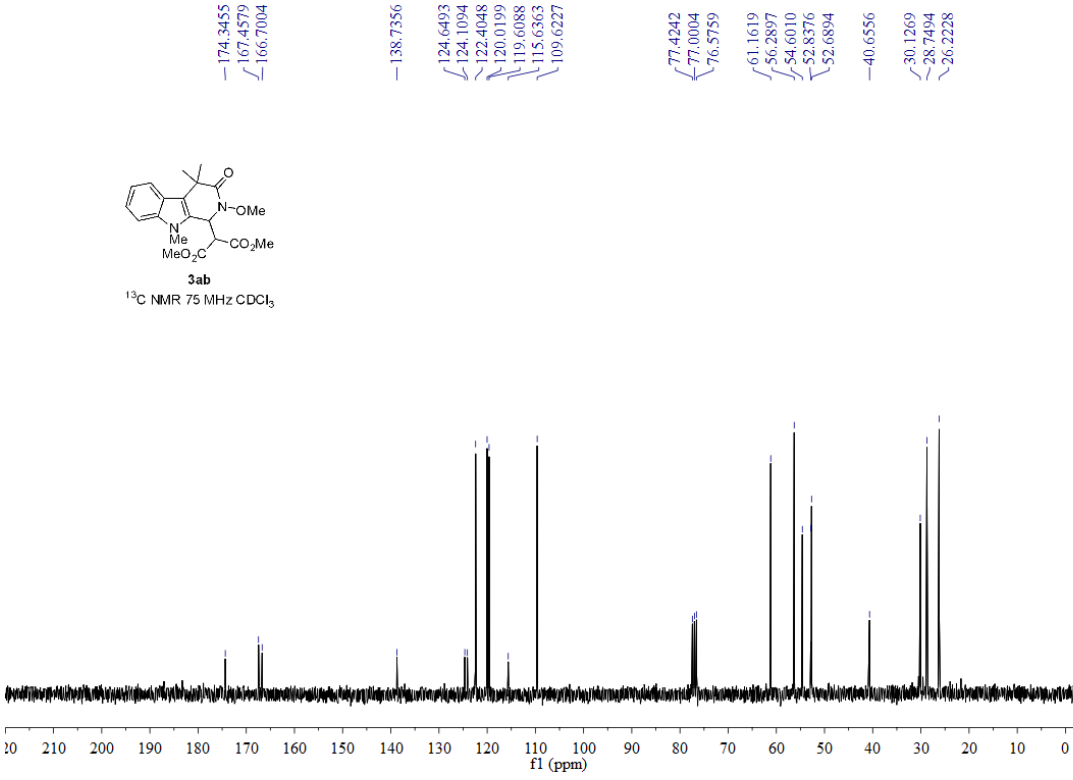
7.6520
7.3357
7.3088
7.2837
7.2608
7.2338
7.1565
7.1334
7.1076
5.9982
5.9895
3.8656
3.8570
3.7751
3.7000
3.6832
3.5366
1.7253
1.7044
0.0000
N-OMe
N
Me
MeO2C
CO2Me
3ab
1H NMR 300 MHz CDCl3
1.04
2.19
1.02
1.00
1.10
3.13
5.97
3.01
6.24
f1 (ppm)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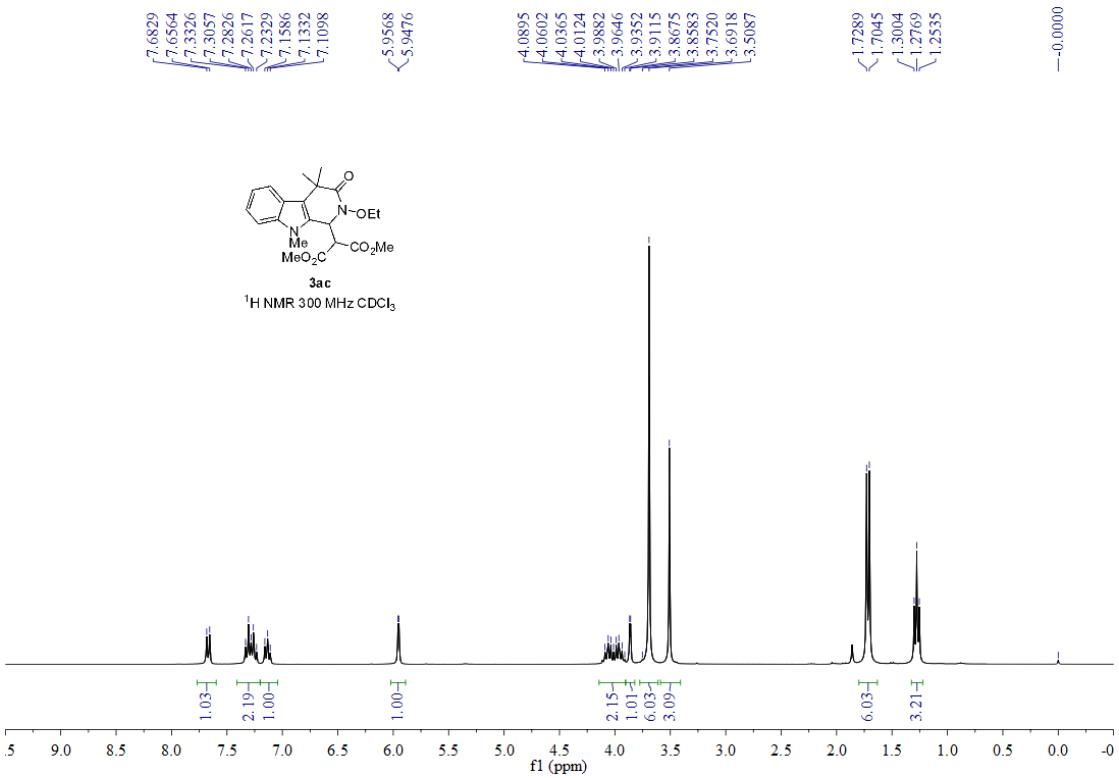
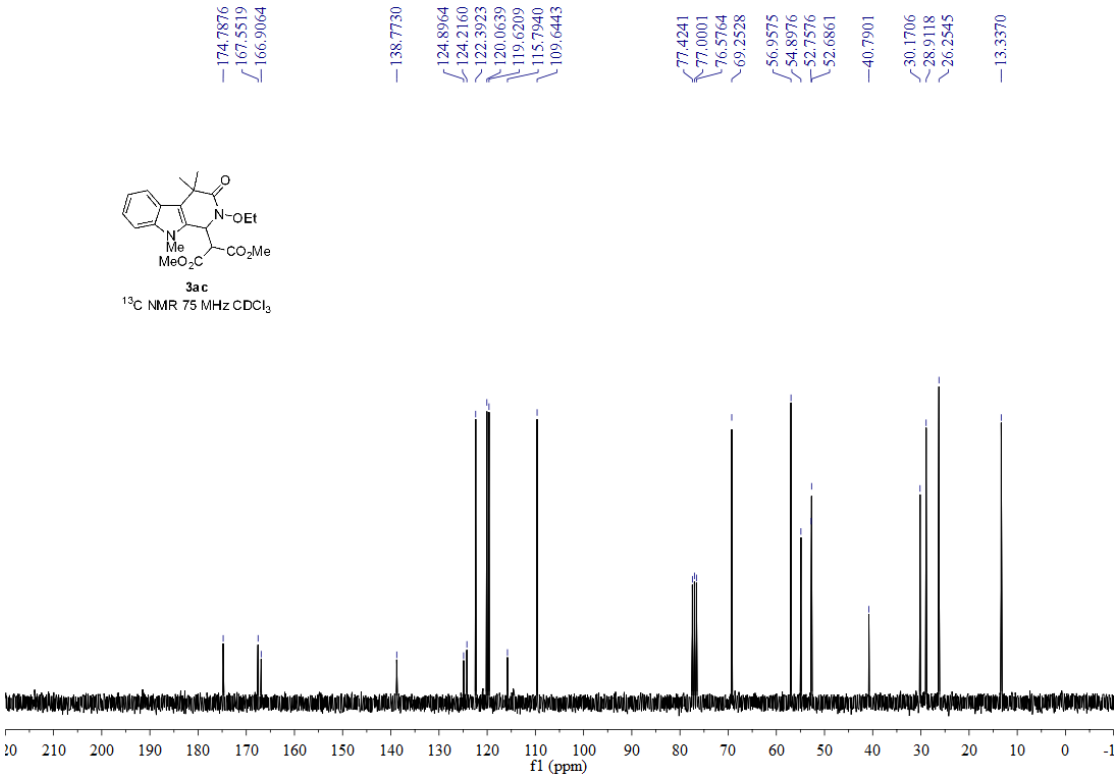
167.4579
166.7004
138.7356
124.6493
124.1094
122.4048
120.0199
119.6088
115.6363
109.6227
77.4242
77.0004
76.5759
61.1619
56.2897
54.6010
52.8376
52.6894
40.6556
30.1269
28.7494
26.2228
N-OMe
N
Me
MeO2C
CO2Me
3ab
13C NMR 75 MHz CDCl3
f1 (ppm)



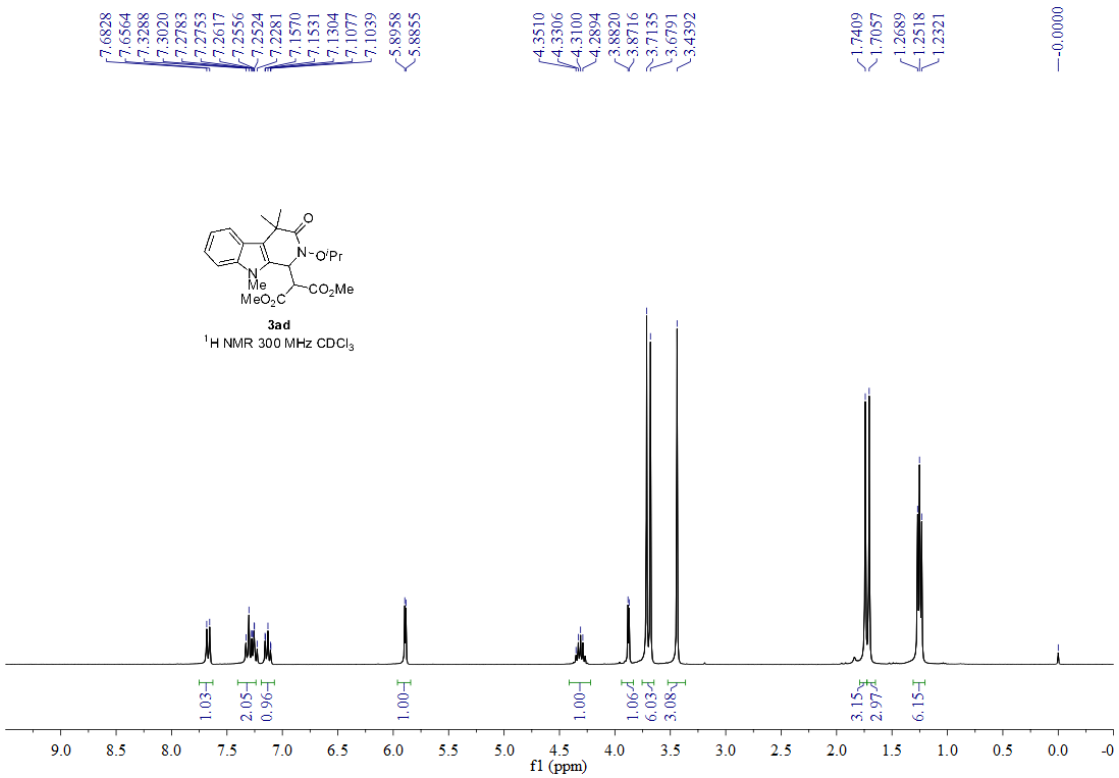
3ac

^{1}H NMR 300 MHz $CDCl_3$



3ac

^{13}C NMR 75 MHz $CDCl_3$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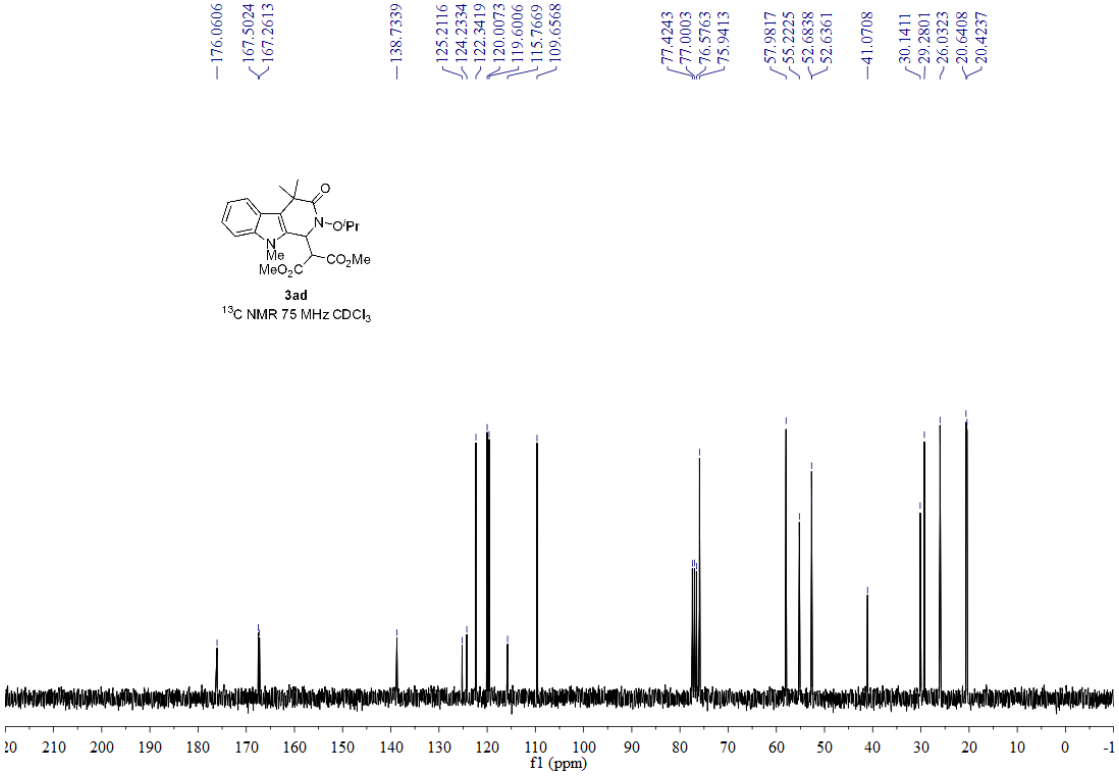
7.6564
7.3288
7.3020
7.2783
7.2753
7.2617
7.2556
7.2524
7.2281
7.1570
7.1531
7.1304
7.1077
7.1039
5.8958
5.8855
4.3510
4.3306
4.3100
4.2894
3.8820
3.8716
3.7135
3.6791
3.4392
1.7409
1.7057
1.2689
1.2518
1.2321
0.0000
O
N-OiPr
N
Me
MeO2C
CO2Me
3ad
1H NMR 300 MHz CDCl3
1.03
2.05
0.96
1.00
1.00
1.06
6.03
3.08
3.15
2.97
6.15
f1 (ppm)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167.5024
167.2613
138.7339
125.2116
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122.3419
120.0073
119.6006
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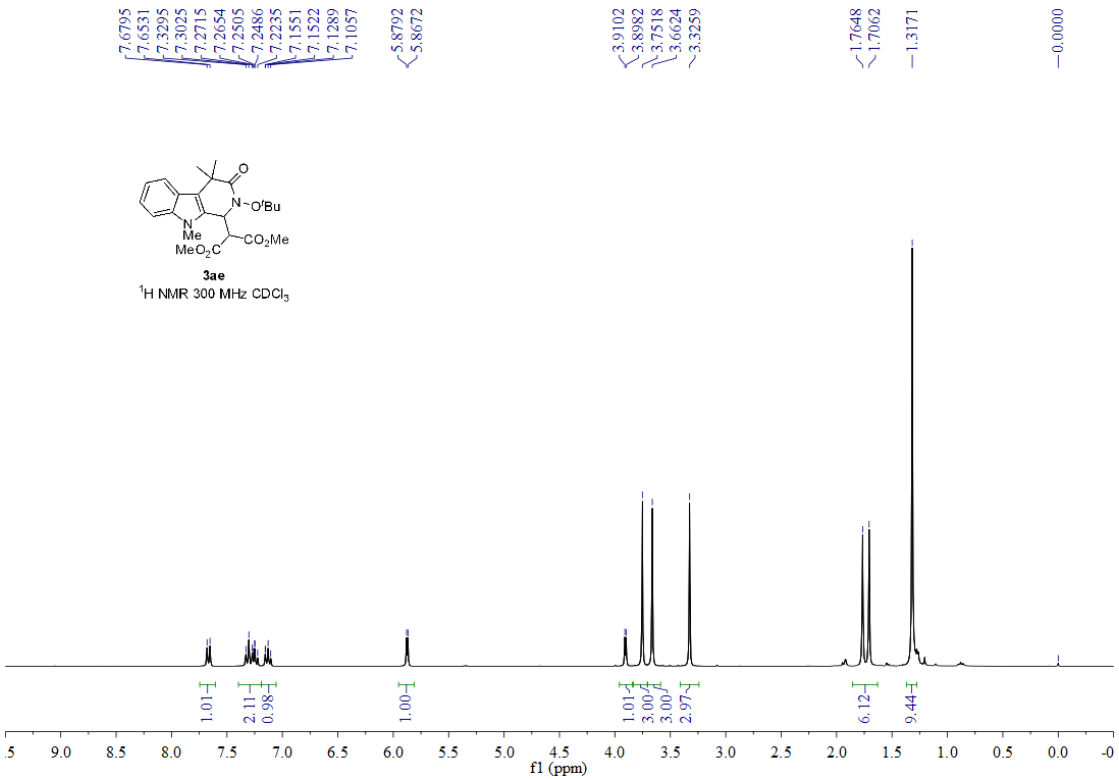
109.6568
77.4243
77.0003
76.5763
75.9413
57.9817
55.2225
52.6838
52.6361
41.0708
30.1411
29.2801
26.0323
20.6408
20.4237
O
N-OiPr
N
Me
MeO2C
CO2Me
3ad
13C NMR 75 MHz CDCl3
f1 (ppm)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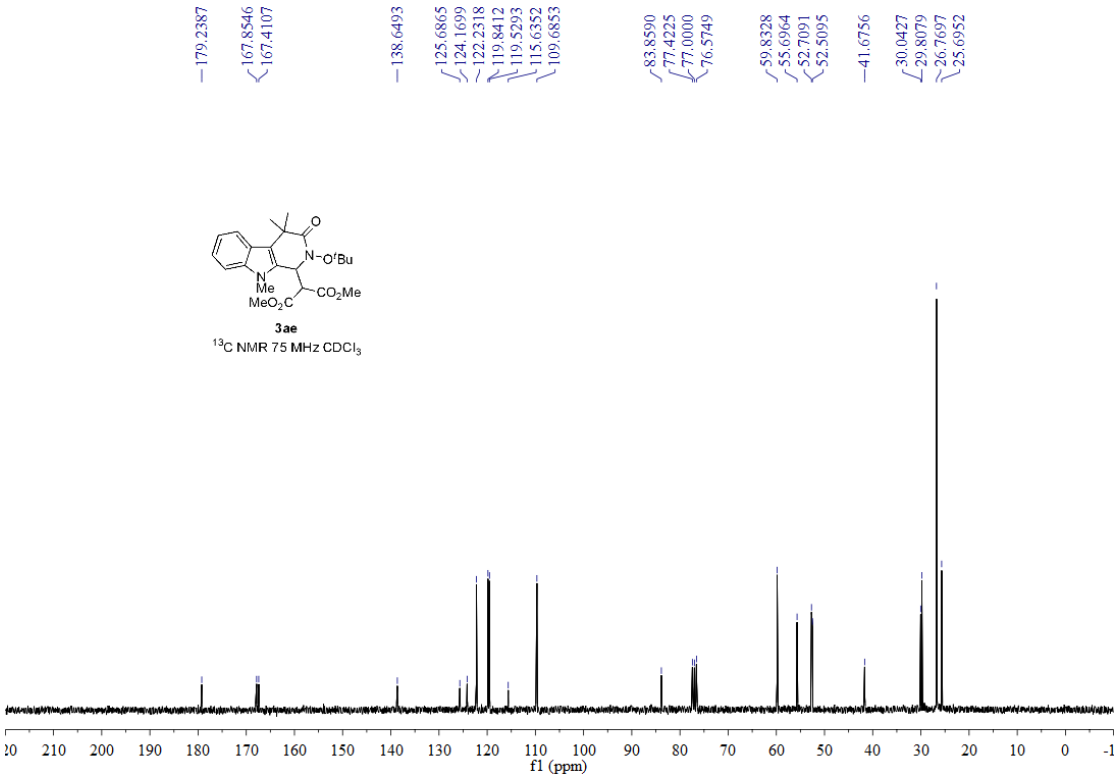
7.6531
7.3295
7.3025
7.2715
7.2654
7.2505
7.2486
7.2235
7.1551
7.1522
7.1289
7.1057
5.8792
5.8672
3.9102
3.8982
3.7518
3.6624
3.3259
1.7648
1.7062
1.3171
0.0000
N-O'Bu
Me
MeO2C
CO2Me
3ae
1H NMR 300 MHz CDCl3
1.01
2.11
0.98
1.00
1.01
3.00
3.00
2.97
6.12
9.44
f1 (ppm)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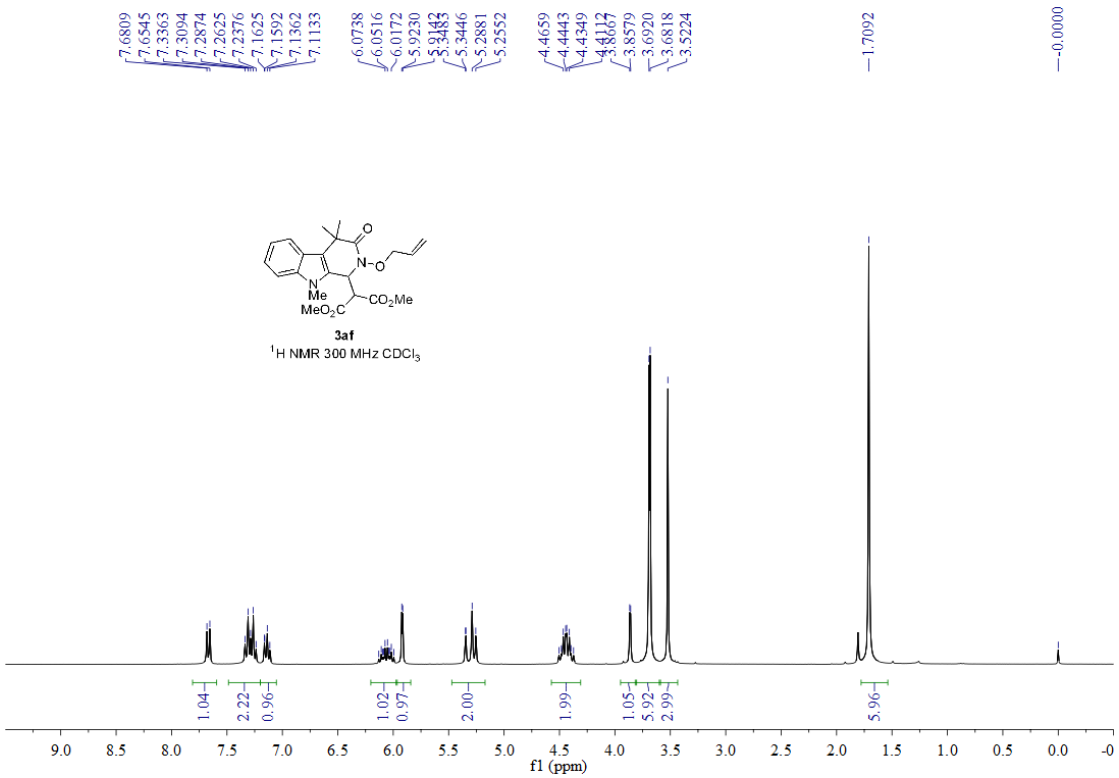
167.8546
167.4107
138.6493
125.6865
124.1699
122.2318
119.8412
119.5293
115.6352
109.6853
83.8590
77.4225
77.0000
76.5749
59.8328
55.6964
52.7091
52.5095
41.6756
30.0427
29.8079
26.7697
25.6952
N-O'Bu
Me
MeO2C
CO2Me
3ae
13C NMR 75 MHz CDCl3
f1 (ppm)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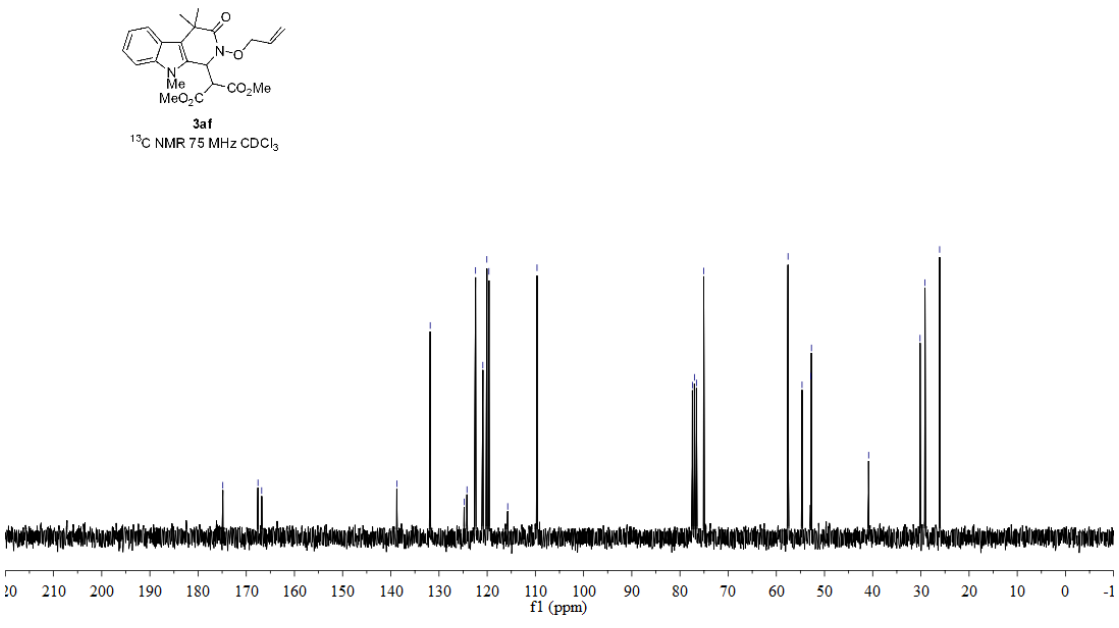
7.6545
7.3363
7.3094
7.2874
7.2625
7.2376
7.1625
7.1592
7.1362
7.1133
6.0738
6.0516
6.0172
5.9230
5.3446
5.2881
5.2552
4.4659
4.4443
4.4349
3.8579
3.6920
3.6818
3.5224
1.7092
0.0000
Me
MeO2C
CO2Me
3af
1H NMR 300 MHz CDCl3
1.04
2.22
0.96
1.02
0.97
2.00
1.99
1.05
5.92
2.99
5.96
f1 (ppm)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166.8042
138.7589
131.8249
124.7943
124.1963
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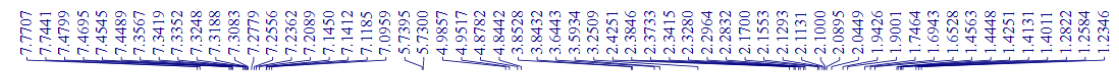
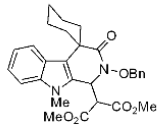
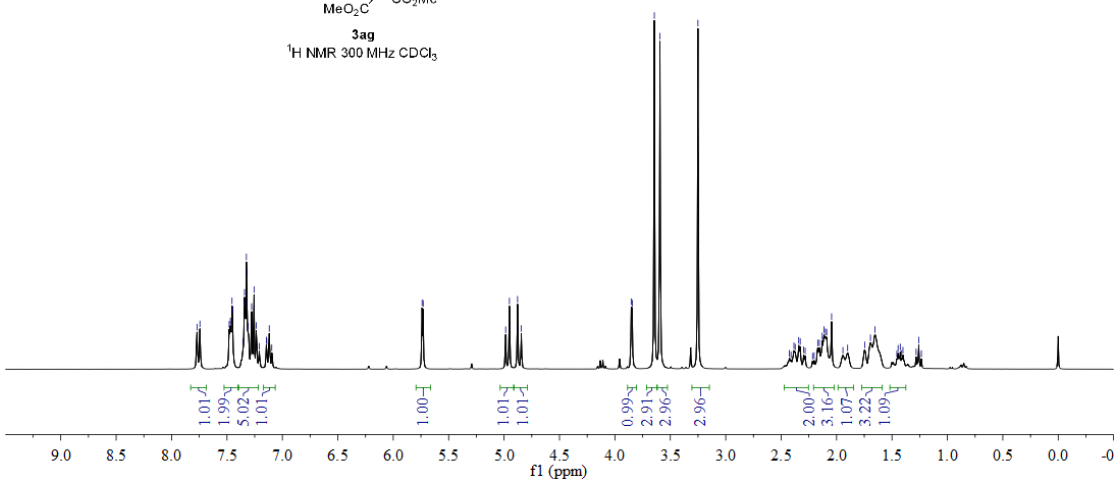
120.9032
120.0714
119.6410
115.7415
109.6616
77.4232
76.9999
76.5762
75.0621
57.5741
54.6677
52.8653
52.7150
40.8431
30.1705
29.1471
26.1133
Me
MeO2C
CO2Me
3af
13C NMR 75 MHz CDCl3
f1 (ppm)

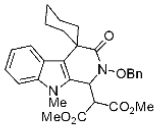




3ag

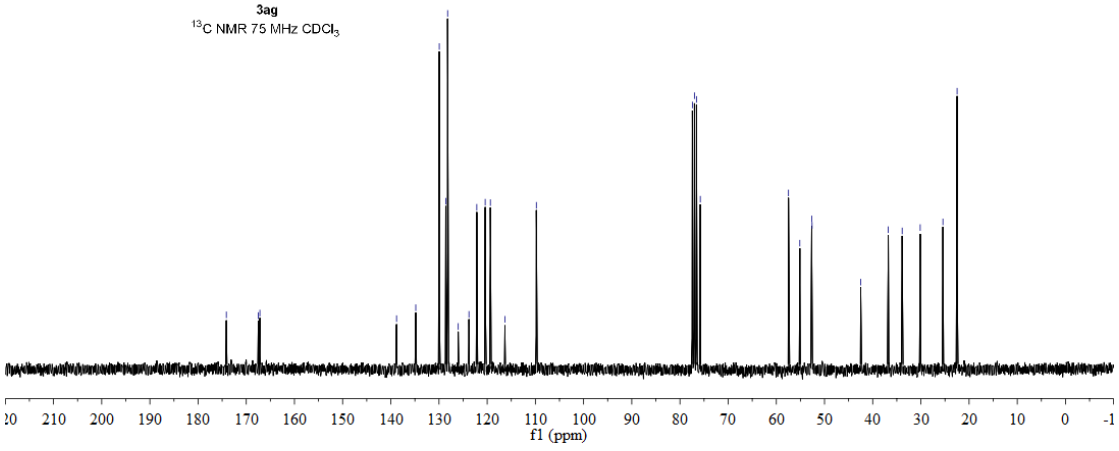
^{1}H NMR 300 MHz $CDCl_3$

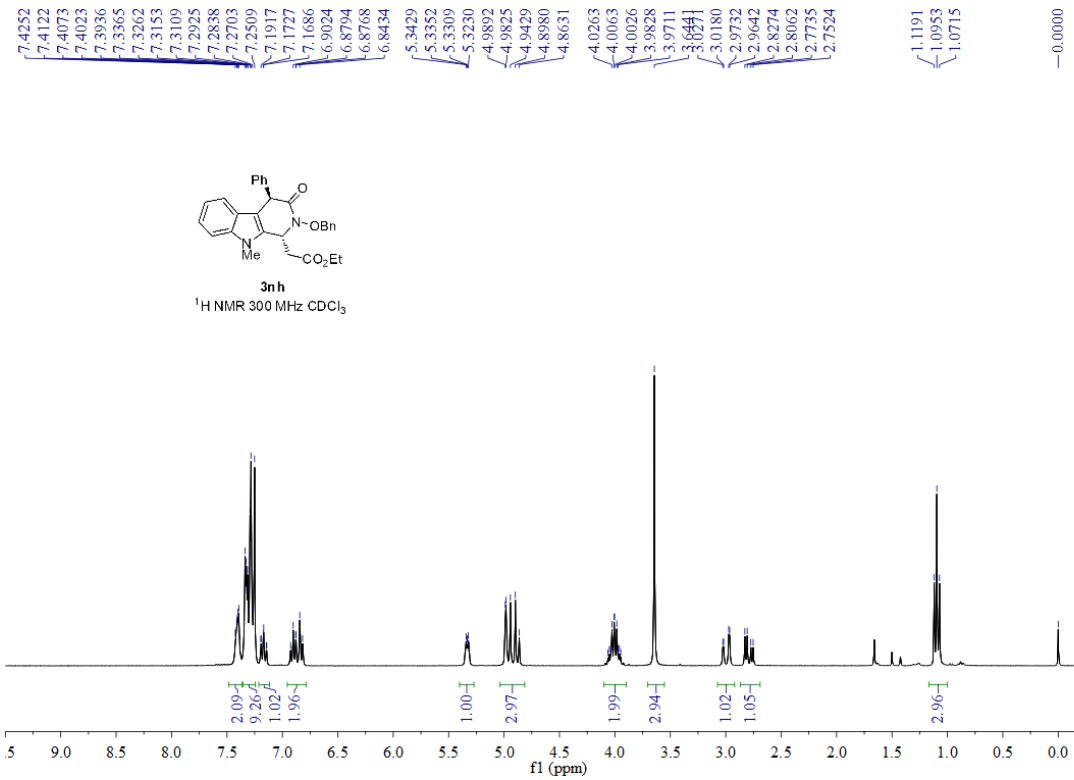




3ag

^{13}C NMR 75 MHz $CDCl_3$

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7.3262
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7.3109
7.2925
7.2838
7.2703
7.2509
7.1917
7.1727
7.1686
6.9024
6.8794
6.8768
6.8434
5.3429
5.3352
5.3309
5.3230
4.9892
4.9825
4.9429
4.8980
4.8631
4.0263
4.0063
4.0026
3.9828
3.9711
3.6441
3.6271
3.0180
2.9732
2.9642
2.8274
2.8062
2.7735
2.7524
1.1191
1.0953
1.0715
0.0000
Ph
O
N
OBn
Me
CO2Et
3nh
1H NMR 300 MHz CDCl3
2.09
9.26
1.02
1.96
1.00
2.97
1.99
2.94
1.02
1.05
2.96
f1 (ppm)
170.2844
168.9900
139.6909
138.3072
134.8439
129.9718
129.5436
128.7387
128.7070
128.5408
128.3042
127.3290
122.2942
119.7589
118.6704
109.1117
108.1339
77.4231
77.0000
76.5769
76.0100
60.9932
56.2318
47.7035
39.2006
29.9516
13.8765
130.0508
129.6226
128.8177
128.7860
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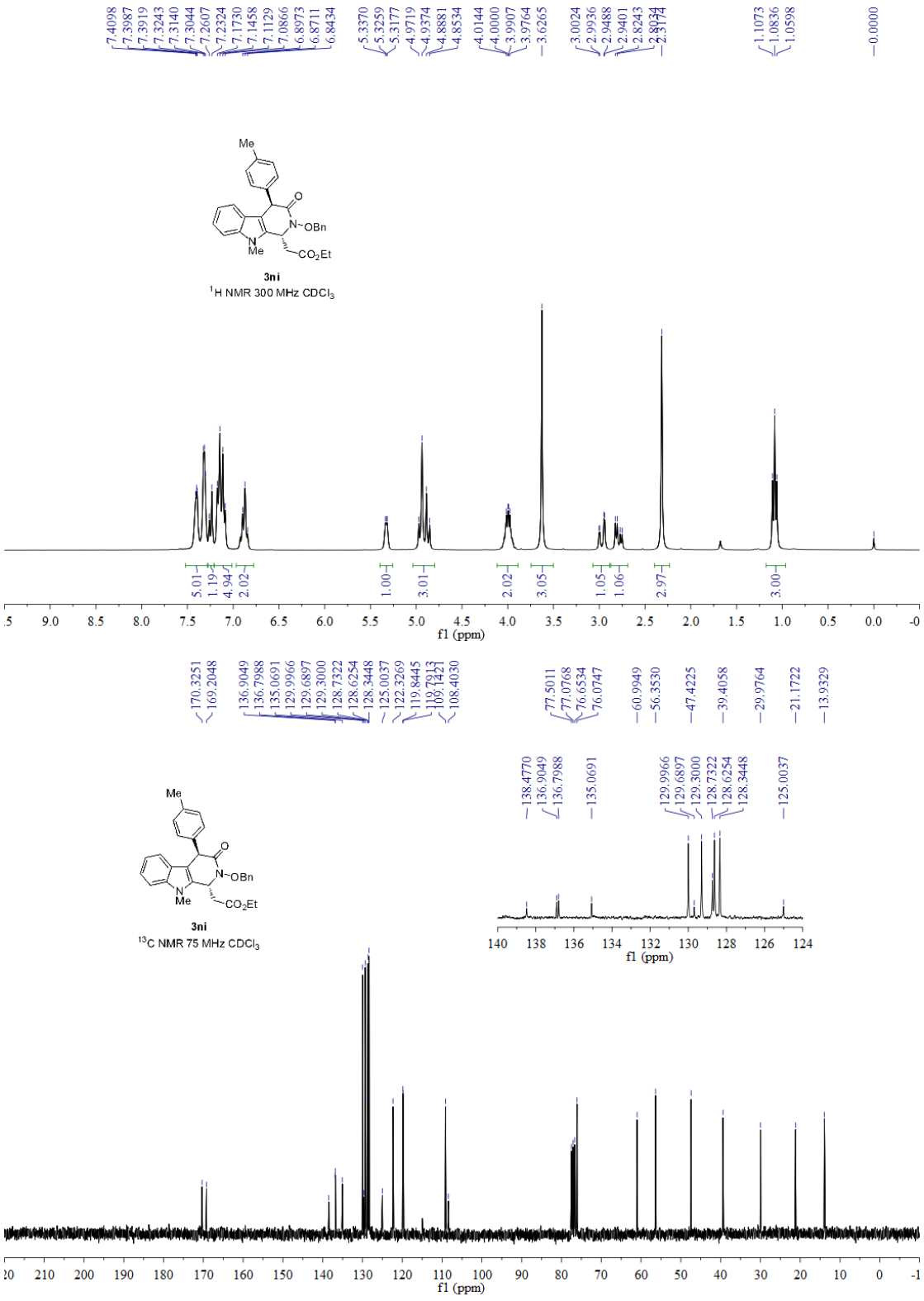
122.3732
119.8379
119.7496
3nh
13C NMR 75 MHz CDCl3
f1 (ppm)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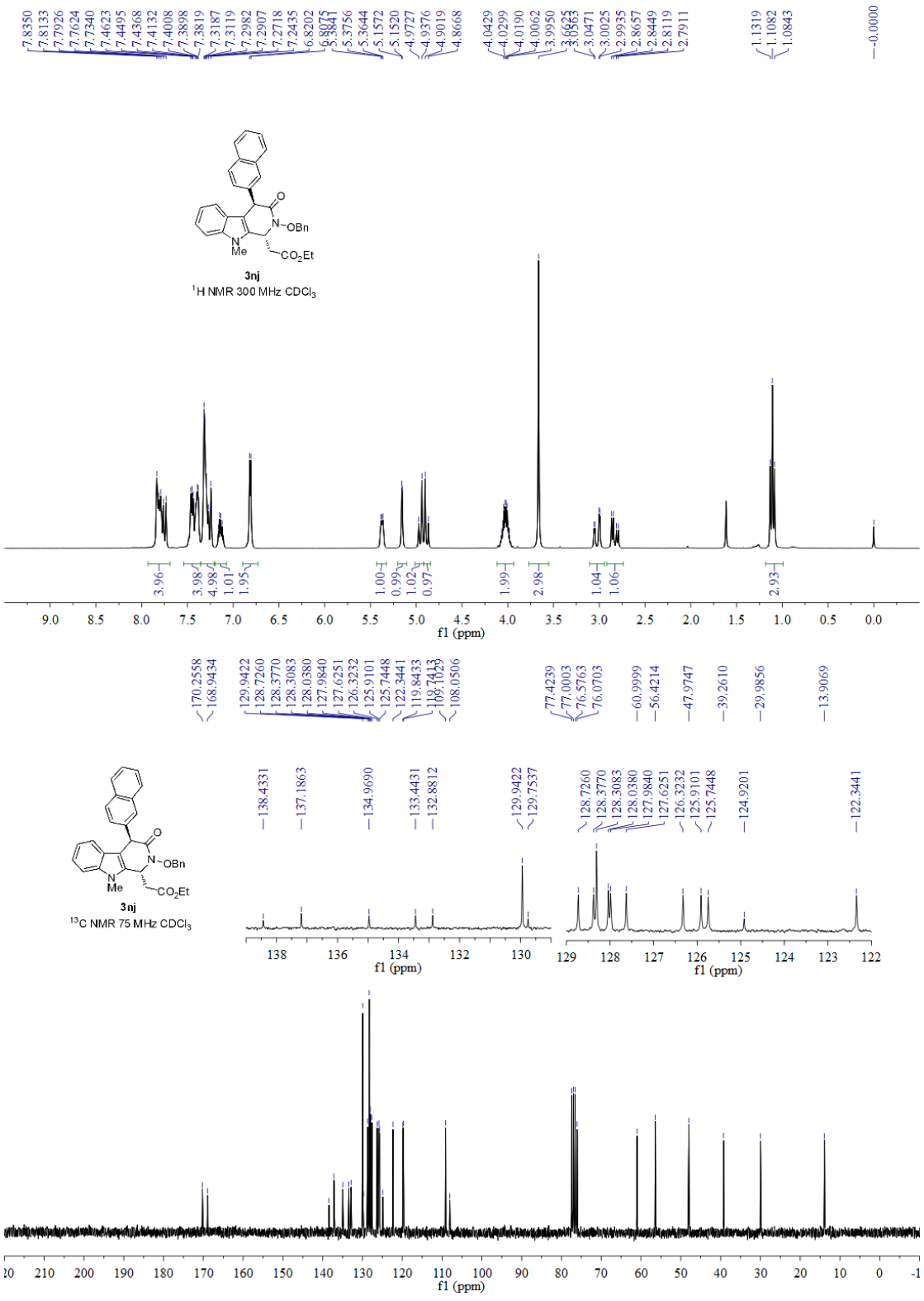
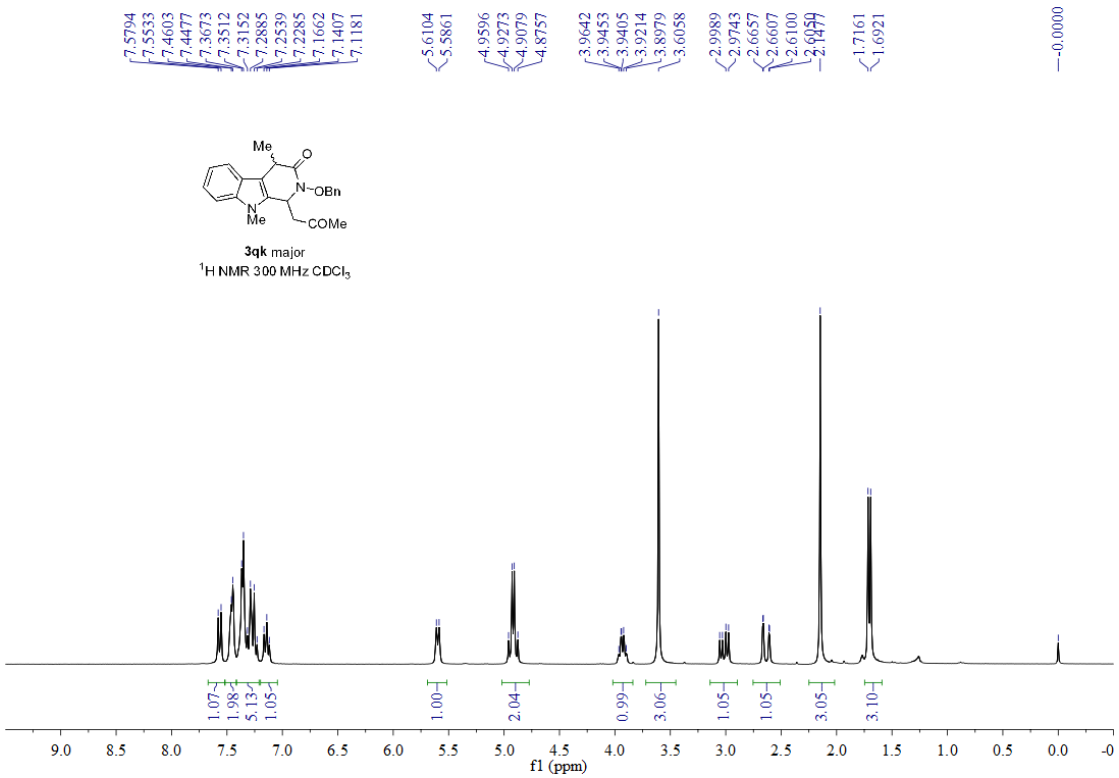
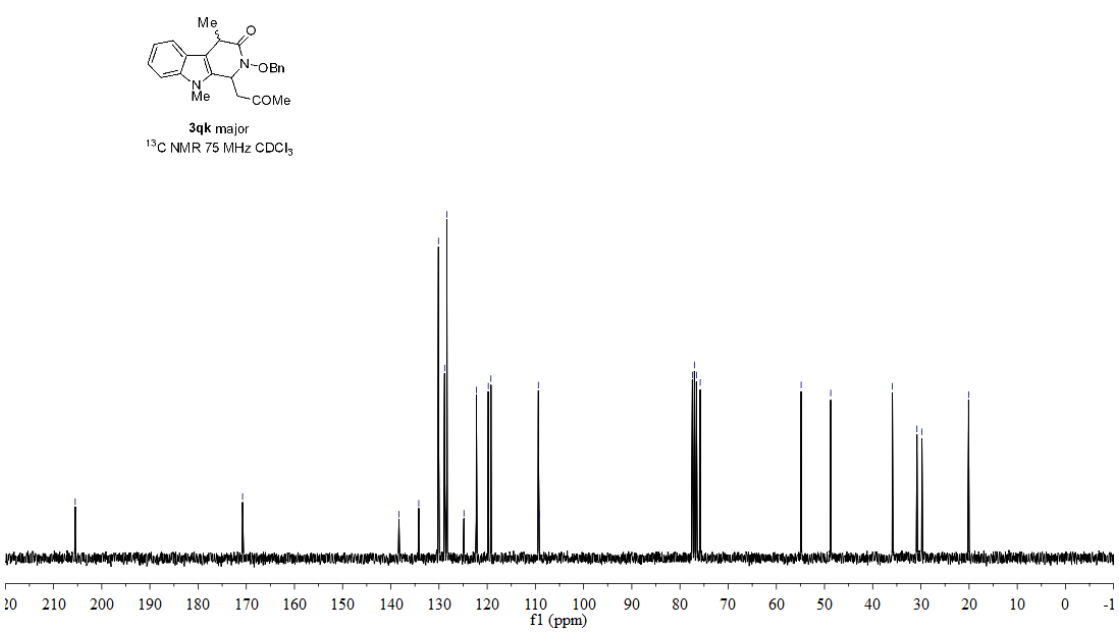
7.3987
7.3919
7.3243
7.3140
7.3044
7.2607
7.2324
7.1730
7.1458
7.1129
7.0866
6.8973
6.8711
6.8434
5.3370
5.3259
5.3177
4.9719
4.9374
4.8881
4.8534
4.0144
4.0000
3.9907
3.9764
3.6265
3.0024
2.9936
2.9488
2.9401
2.8243
2.8034
2.3174
1.1073
1.0836
1.0598
0.0000
Me
O
N-OBn
N
Me
CO2Et
3ni
1H NMR 300 MHz CDCl3
5.01
1.19
4.94
2.02
1.00
3.01
2.02
3.05
1.05
1.06
2.97
3.00
f1 (ppm)
170.3251
169.2048
136.9049
136.7988
135.0691
129.9966
129.6897
129.3000
128.7322
128.6254
128.3448
125.0037
122.3269
119.8445
109.1421
108.4030
77.5011
77.0768
76.6534
76.0747
60.9949
56.3530
47.4225
39.4058
29.9764
21.1722
13.9329
138.4770
136.9049
136.7988
135.0691
129.9966
129.6897
129.3000
128.7322
128.6254
128.3448
125.0037
Me
O
N-OBn
N
Me
CO2Et
3ni
13C NMR 75 MHz CDCl3
f1 (ppm)
f1 (ppm)

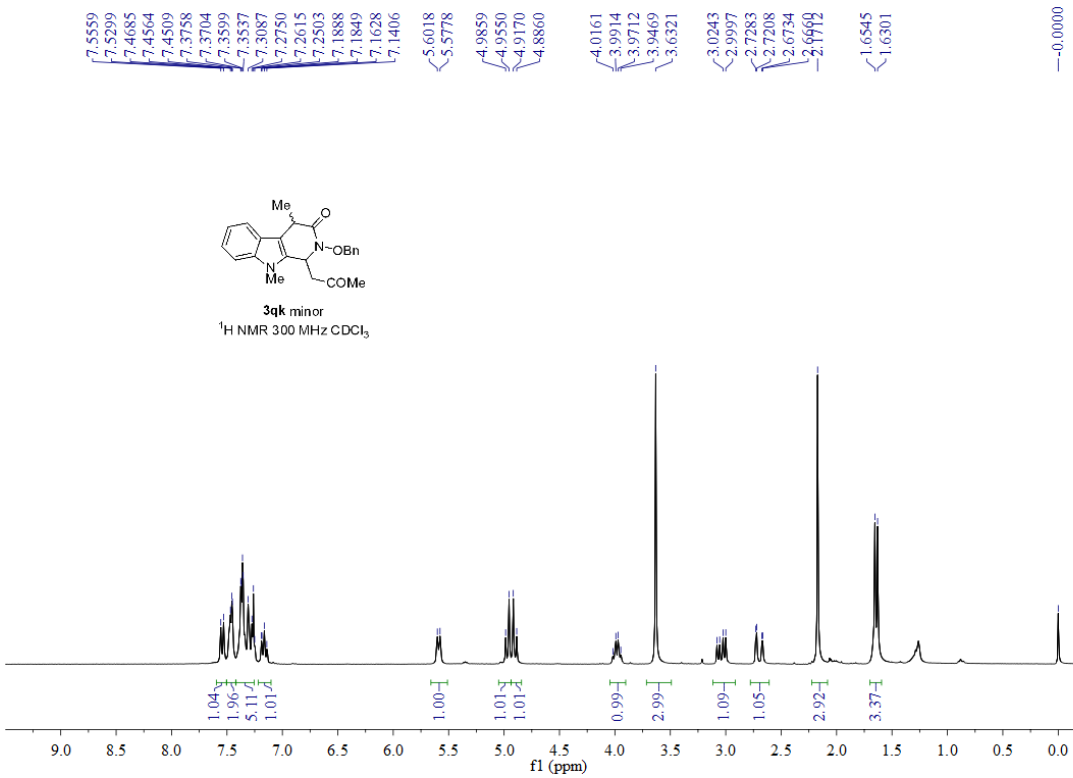

3nj
1H NMR 300 MHz CDCl3
f1 (ppm)
3nj
13C NMR 75 MHz CDCl3
f1 (ppm)
f1 (ppm)



3qk major
^{1}H NMR 300 MHz $CDCl_3$



3qk major
^{13}C NMR 75 MHz $CDCl_3$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7.4685
7.4564
7.4509
7.3758
7.3704
7.3599
7.3537
7.3087
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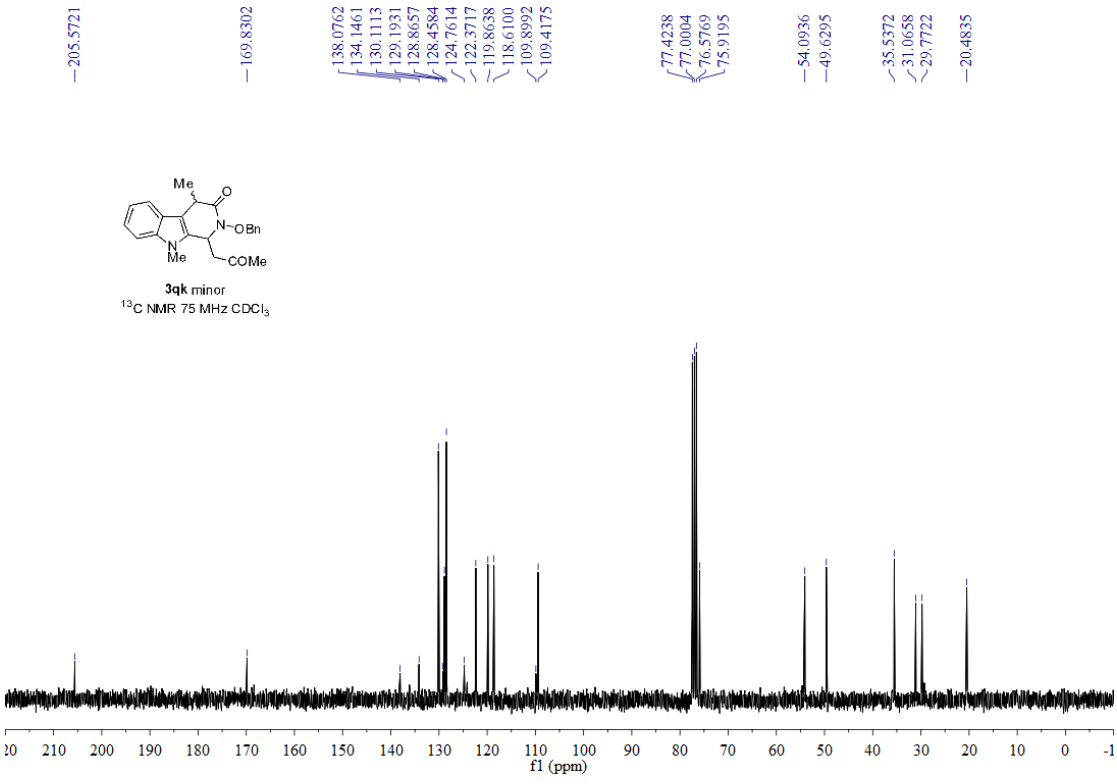
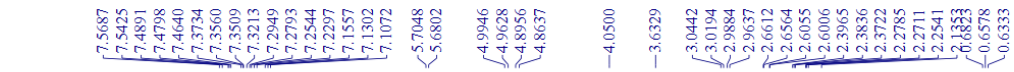
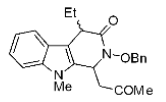
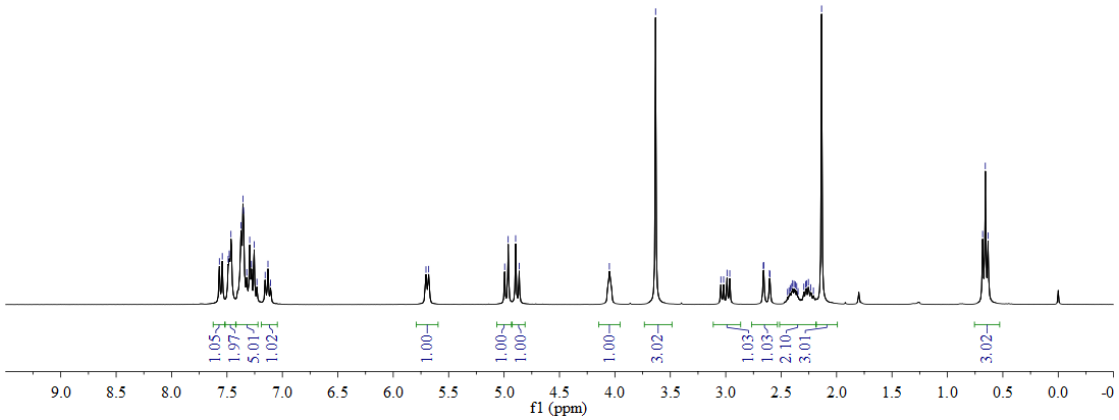
7.2615
7.2503
7.1888
7.1849
7.1628
7.1406
5.6018
5.5778
4.9859
4.9550
4.9170
4.8860
4.0161
3.9914
3.9712
3.9469
3.6321
3.0243
2.9997
2.7283
2.7208
2.6734
2.6660
2.1712
1.6545
1.6301
-0.0000
Me
O
N
OBn
N
Me
COMe
3qk minor
1H NMR 300 MHz CDCl3
1.04
1.96
5.11
1.01
1.00
1.01
1.01
0.99
2.99
1.09
1.05
2.92
3.37
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
0.0
-0
f1 (ppm)

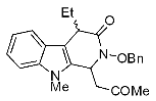

205.5721
169.8302
138.0762
134.1461
130.1113
129.1931
128.8657
128.4584
124.7614
122.3717
119.8638
118.6100
109.8992
109.4175
77.4238
77.0004
76.5769
75.9195
54.0936
49.6295
35.5372
31.0658
29.7722
20.4835
Me
O
N
OBn
N
Me
COMe
3qk minor
13C NMR 75 MHz CDCl3
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-1
f1 (ppm)



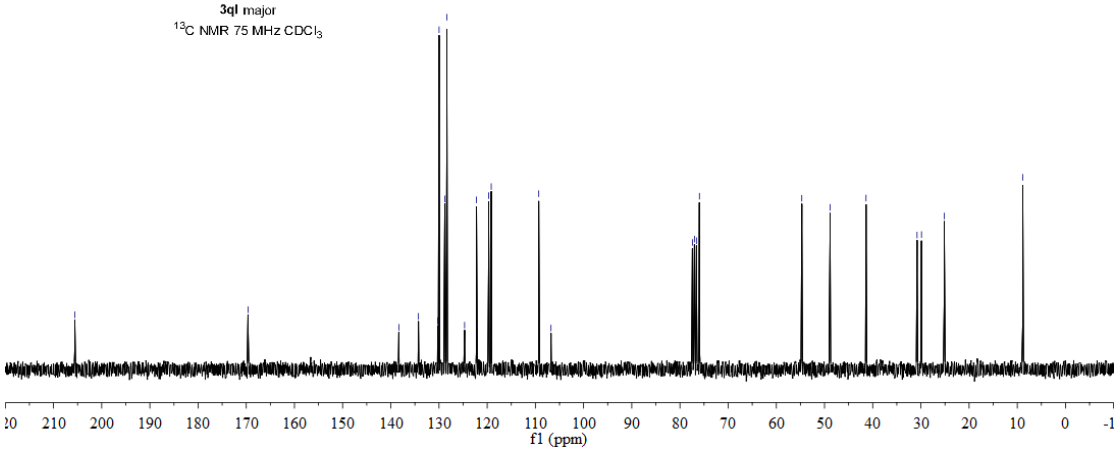


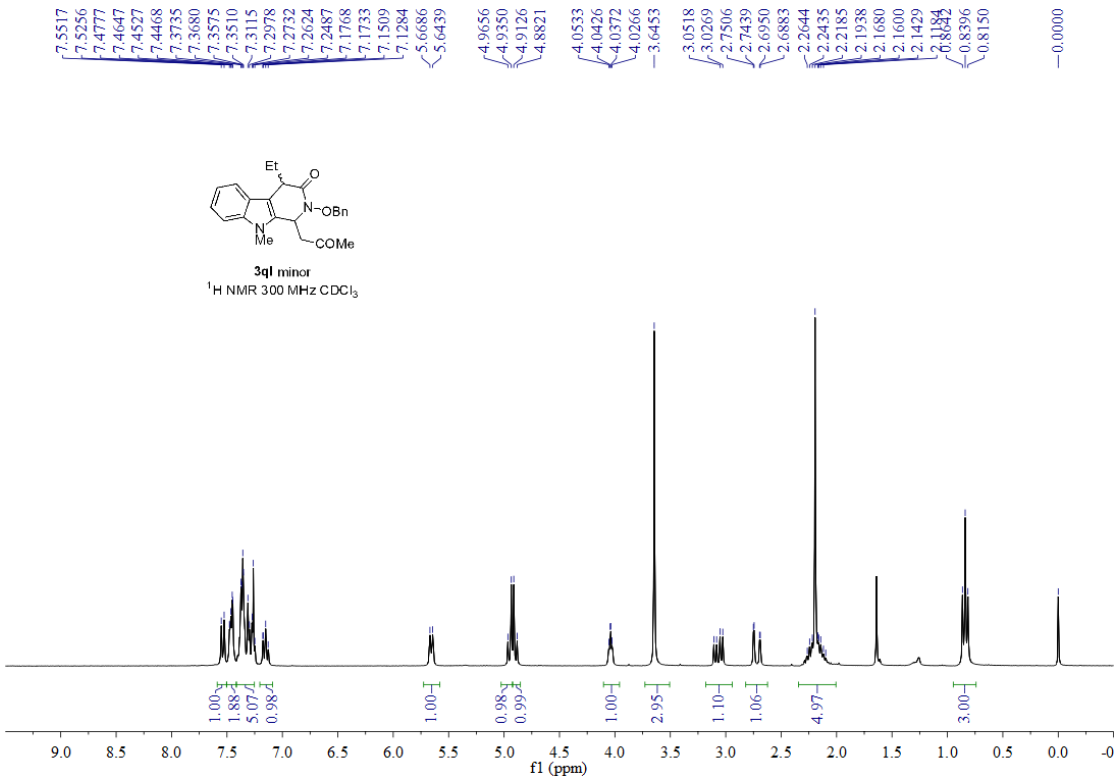
3ql major
^{1}H NMR 300 MHz $CDCl_3$





3ql major
^{13}C NMR 75 MHz $CDCl_3$

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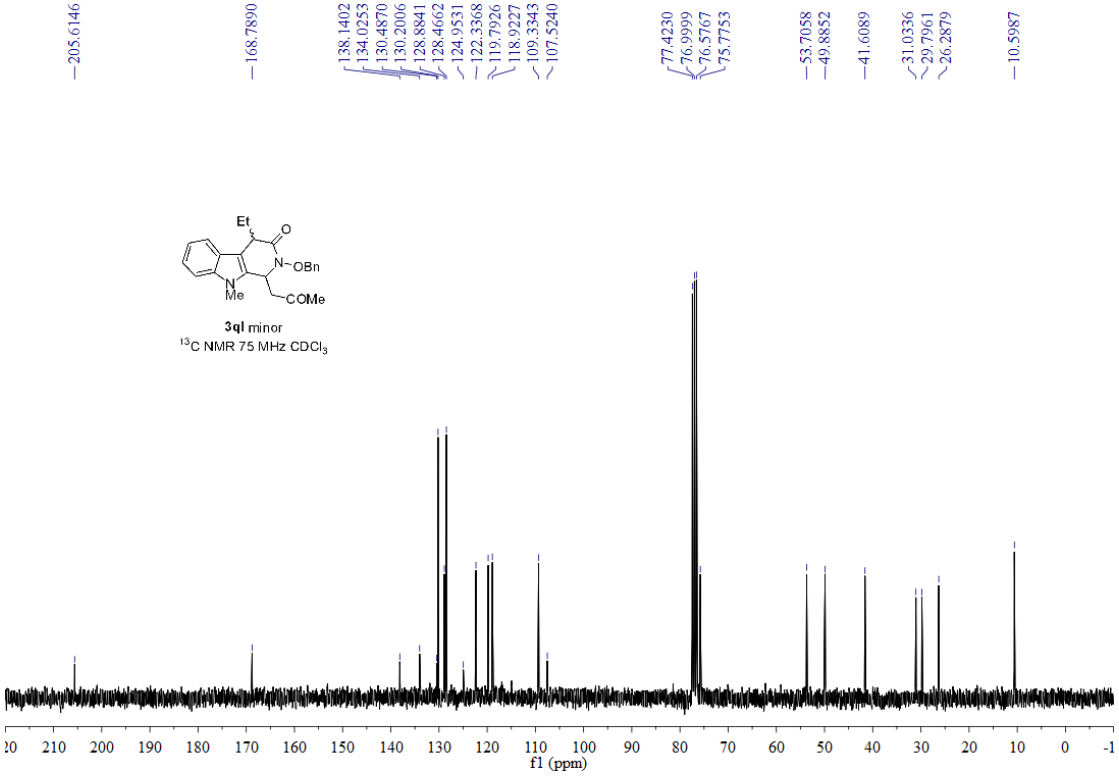
7.5256
7.4777
7.4647
7.4527
7.4468
7.3735
7.3680
7.3575
7.3510
7.3115
7.2978
7.2732
7.2624
7.2487
7.1768
7.1733
7.1509
7.1284
5.6686
5.6439
4.9656
4.9350
4.9126
4.8821
4.0533
4.0426
4.0372
4.0266
3.6453
3.0518
3.0269
2.7506
2.7439
2.6950
2.6883
2.2644
2.2435
2.2185
2.1938
2.1680
2.1600
2.1429
2.1184
0.8642
0.8396
0.8150
0.0000
Et
O
N
OBn
Me
COMe
3ql minor
1H NMR 300 MHz CDCl3
1.00
1.88
5.07
0.98
1.00
0.98
0.99
1.00
2.95
1.10
1.06
4.97
3.00
f1 (ppm)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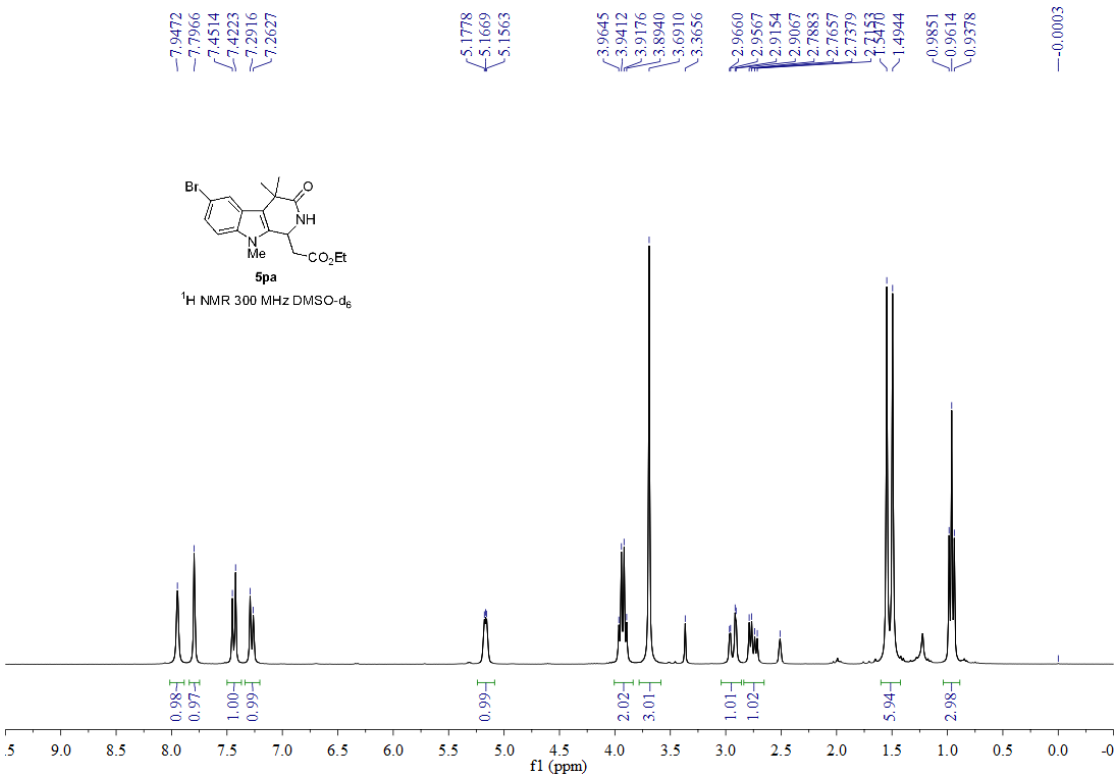
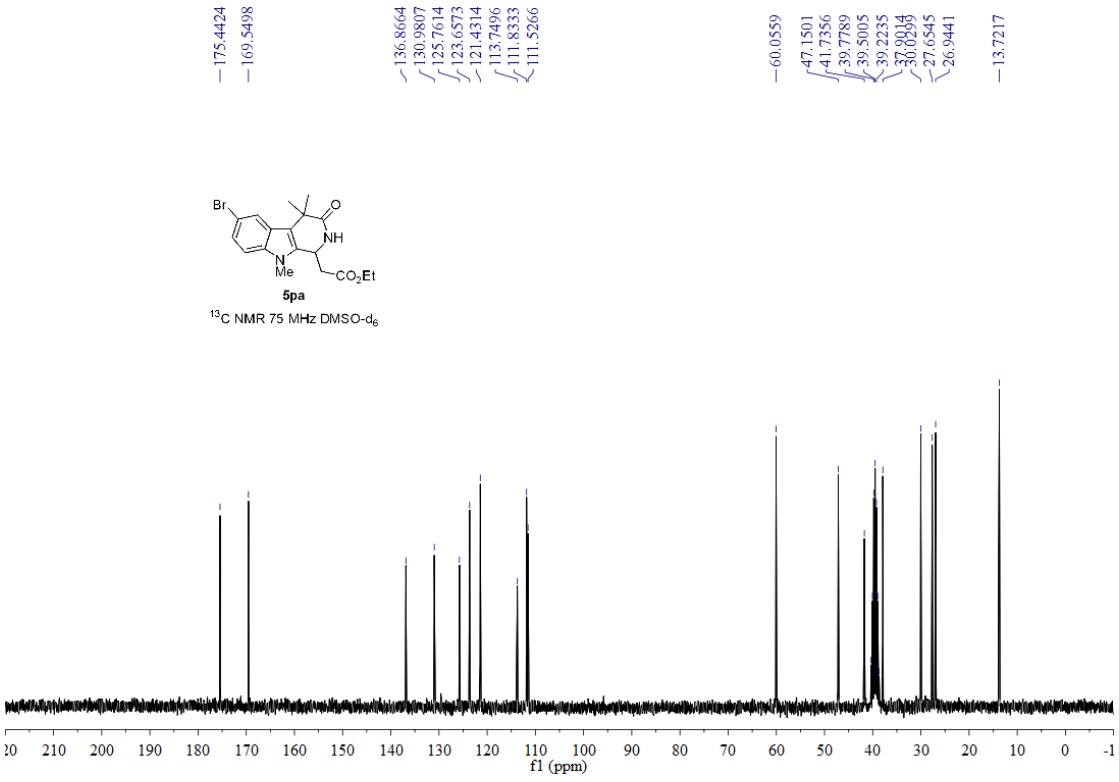
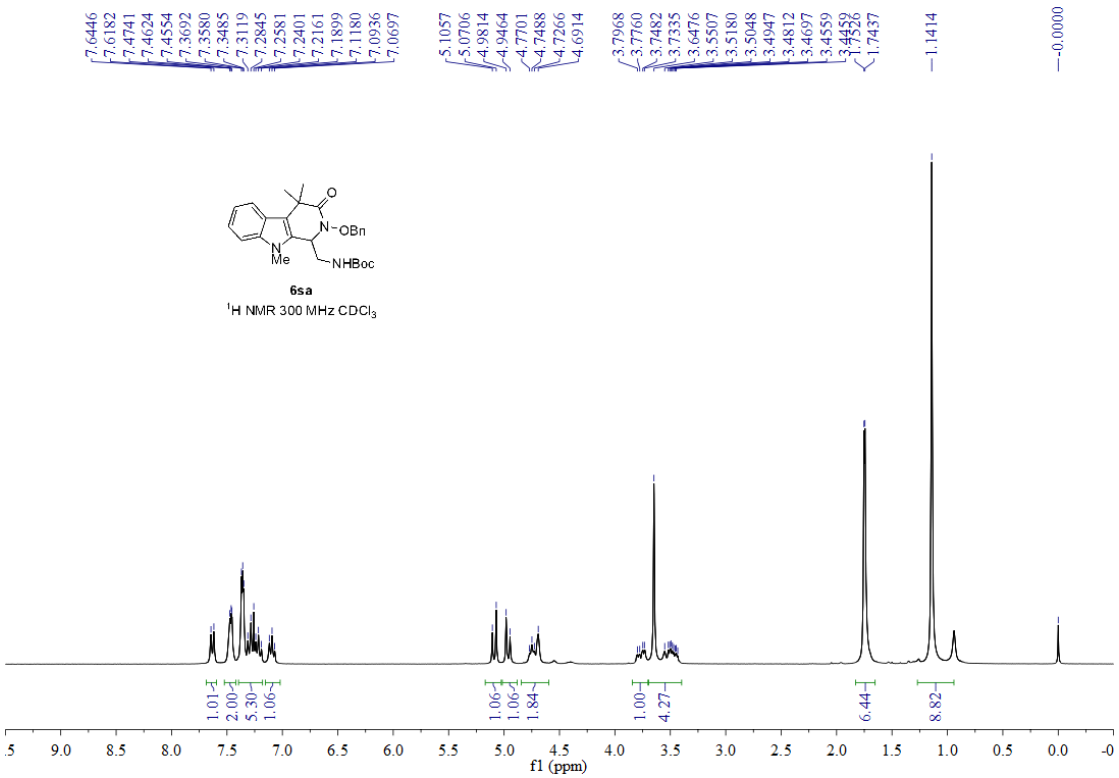
168.7890
138.1402
134.0253
130.4870
130.2006
128.8841
128.4662
124.9531
122.3368
119.7926
118.9227
109.3343
107.5240
77.4230
76.9999
76.5767
75.7753
53.7058
49.8852
41.6089
31.0336
29.7961
26.2879
10.5987
Et
O
N
OBn
Me
COMe
3ql minor
13C NMR 75 MHz CDCl3
f1 (ppm)

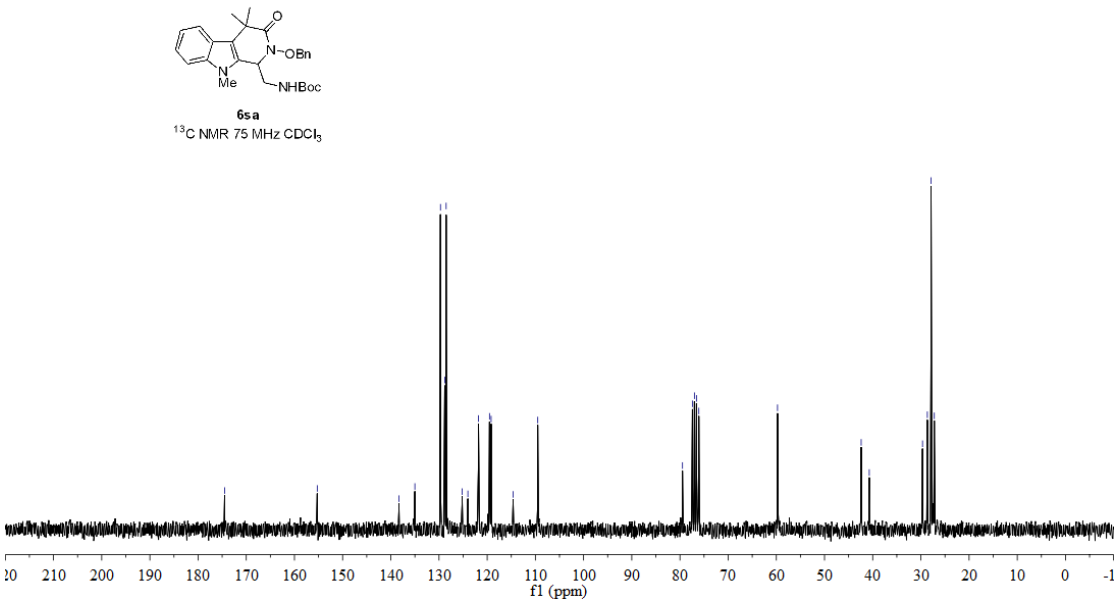

7.9472
7.7966
7.4514
7.4223
7.2916
7.2627
5.1778
5.1669
5.1563
3.9645
3.9412
3.9176
3.8940
3.6910
3.3656
2.9660
2.9567
2.9154
2.9067
2.7883
2.7657
2.7379
1.4944
0.9851
0.9614
0.9378
-0.0003
Br
O
NH
N
Me
CO2Et
5pa
1H NMR 300 MHz DMSO-d6
0.98
0.97
1.00
0.99
0.99
2.02
3.01
1.01
1.02
5.94
2.98
f1 (ppm)


175.4424
169.5498
136.8664
130.9807
125.7614
123.6573
121.4314
113.7496
111.8333
111.5266
60.0559
47.1501
41.7356
39.7789
39.5005
39.2235
37.9014
30.0299
27.6545
26.9441
13.7217
Br
O
NH
N
Me
CO2Et
5pa
13C NMR 75 MHz DMSO-d6
f1 (ppm)



6sa

^{1}H NMR 300 MHz $CDCl_3$



6sa

^{13}C NMR 75 MHz $CDCl_3$