Electronic Supplementary Information (ESI)

Direct photochemical intramolecular [4+2] cycloadditions of dehydrosecodine-type substrates for the synthesis of the *iboga*-type scaffold and divergent [2+2] cycloadditions employing micro-flow system

Gavin Tay, Soushi Nishimura, and Hiroki Oguri*

Department of Chemistry, Graduate School of Science, The University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113-0033, Japan.

Email: hirokioguri@g.ecc.u-tokyo.ac.jp

Table of Contents

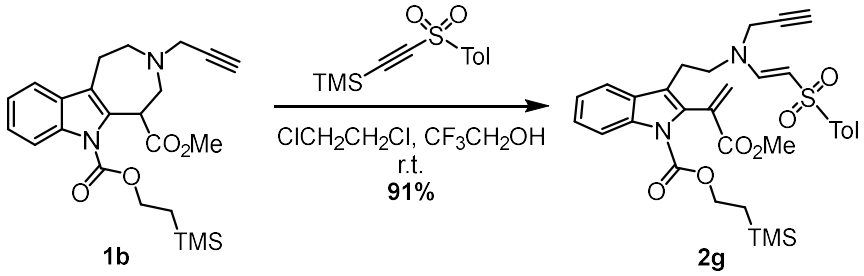
1. General Methods and Materials

All reactions were performed under an inert atmosphere unless otherwise noted. All reactions requiring heating were conducted in a preheated heating mantle, and reaction temperatures are reported as the temperature of the heat transfer medium surrounding the vessel. Microwave reactions were performed using a Biotage Initiator. Photoreactions were carried out with Kessil LED lamps (370 nm, 427 nm, and 456 nm) and CCS UV-LED 8332C lamp (280 nm), set to 75% irradiation intensity (30 W) and placed at a distance of 7.00 cm from the reaction vessel. Flow reactions were conducted using a MiChS-L-1s or MiChS-L1ML photo-flow reactor with a syringe pump or TACMINA Q Smoothflow pump. Reactions were monitored by thin layer chromatography using Merck Millipore TLC Silica gel F254 plates (0.25 mm), which were visualised using UV light, phosphomolybdic acid (PMA) stain, PMS stain, *p*-anisaldehyde stain, basic $KMnO_4$ stain, and ninhydrin spray. Flash column chromatography was performed using Kanto Silica Gel 60N. The medium pressure liquid chromatography (MPLC) purifications were performed on a Biotage® Isolera, or Biotage® Selekt. UV-Vis spectral measurements were conducted on a JASCO V-730 spectrophotometer. Single crystal X-ray diffraction data were collected on Bruker D8 VENTURE diffractometer. NMR spectra were recorded on JEOL ECS 400 (^{1}H/400 MHz, ^{13}C{^{1}H}/100 MHz) or JEOL JNM-ECZ500R/M3 (^{1}H/500 MHz, ^{13}C{^{1}H}/125 MHz) spectrometers. Chemical shifts were quoted in parts per million (ppm) from deuterated chloroform as an internal standard of 7.26 ppm and 77.00 ppm for ^{1}H and ^{13}C{^{1}H} NMR, respectively. Triphenylmethane was used as the internal standard for the determination of NMR yields. Data for ^{1}H NMR were reported as follows: chemical shift (multiplicity, coupling constant, number of hydrogens). Multiplicity is abbreviated as follows: s (singlet), d (doublet), t (triplet), q (quartet), quin (quintet), m (multiplet), br (broad). UPLC-MS analyses were conducted on a Waters ACQUITY UPLC H-Class system. LCMS analyses were conducted on a Shimadzu LCMS-IT-TOF system. ESI-Mass spectra were recorded on Bruker Daltonics micrOTOF-II. DFT computational modelling was performed with Spartan'20 Wavefunction (Win/64b) software[1,2]. All DFT calculations were computed using B3LYP-D3(6-31+G*) level of theory.

Commercial solvents and reagents were used as received unless otherwise stated. All solvents used for photoreaction were degassed by three cycles of freeze-pump-thaw. $[Cu(Xantphos)CH_3CN]^+PF_6^-$ **6**,[3] $[Cu(dppf)(CH_3CN)_2]^+PF_6^-$ **7**,[4] and **S32**[5] were prepared according to reported protocols. Compounds **1b**,[6] **2b**,[6] **2c**,[7] **2d**,[6] **2h**,[6] **S1**,[6] **S19**,[8] and **S25**[8] were synthesised according to the reported procedures.

2. Synthetic procedures of substrates

Synthesis of compound 2g



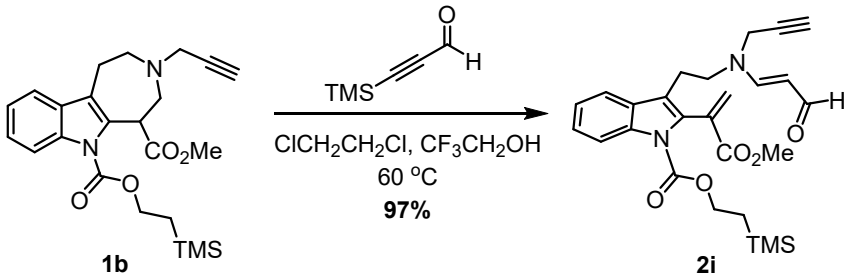
A solution of **1b** (504 mg, 1.18 mmol) and *p*-tolyl[2-(trimethylsilyl)ethynyl]sulfone (451 mg, 1.79 mmol) in 1,2-dichloroethane (3.0 mL) and 2,2,2-trifluoroethanol (3.0 mL) was stirred at r.t. for 75 min. The reaction mixture was then concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **2g** (652 mg, 1.07 mmol, 91%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.14 (d, *J* = 8.2 Hz, 1H), 7.69 (d, *J* = 8.2 Hz, 2H), 7.49 (d, *J* = 7.8 Hz, 1H), 7.35 (ddd, *J* = 8.2, 7.3, 1.4 Hz, 1H), 7.30-7.26 (m, 3H), 7.24-7.23 (m, 1H), 6.52 (br, 1H), 5.73 (s, 1H), 5.03 (d, *J* = 12.8 Hz, 1H), 4.46-4.41 (m, 2H), 3.74 (s, 3H), 3.69 (br, 2H), 3.44 (br, 2H), 2.97 (br, 2H), 2.42 (s, 3H), 2.28 (s, 1H), 1.20-1.15 (m, 2H), 0.08 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 166.2, 151.4, 148.2, 142.4, 141.6, 135.4, 133.8, 132.8, 129.4, 128.9, 128.4, 126.3, 125.3, 123.2, 118.6, 117.6, 116.0, 95.7, 74.1, 66.1, 52.3, 21.4, 17.5, -1.6 ppm.

HRMS (ESI): *m/z* calcd for $C_{32}H_{38}N_2O_6SSi$ $[M + H]^+$: 607.2293; found: 607.2264.

Synthesis of compound 2i



A solution of **1b** (286 mg, 0.670 mmol) and 3-(trimethylsilyl)-2-propyn-1-al (150 mg, 1.01 mmol) in 1,2-dichloroethane (1.7 mL) and 2,2,2-trifluoroethanol (1.7 mL) was stirred at 60 ºC for 15 h. The reaction mixture was then concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **21** (314 mg, 0.654 mmol, 97%).

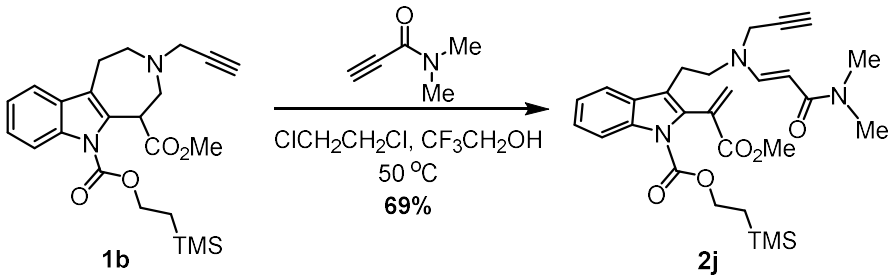
^{1}H NMR (400 MHz, $CDCl_3$) δ 9.08 (br, 1H), 8.16 (d, *J* = 8.2 Hz, 1H), 7.53 (d, *J* = 7.8 Hz, 1H), 7.37 (ddd, *J* = 8.2, 7.3, 1.4, 1H), 7.29 (ddd, *J* = 7.8, 6.9, 0.9 Hz, 1H), 6.94 (br, 1H), 6.60 (d, *J* = 1.4 Hz, 1H), 5.78 (d,

J = 1.4 Hz, 1H), 5.24 (br, 1H), 4.45-4.41 (m, 2H), 3.75 (m, 5H), 3.53 (br, 2H), 3.03 (br, 2H), 2.33 (s, 1H), 1.19-1.15 (m, 2H), 0.07 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 189.5, 166.1, 157.9, 151.4, 135.4, 133.8, 132.9, 128.8, 128.4, 125.4, 123.2, 118.6, 117.4, 116.0, 103.0, 74.4, 66.1, 52.3, 17.5, -1.6 ppm.

HRMS (ESI): *m/z* calcd for $C_{26}H_{32}N_2O_5Si$ [M + Na]$^+$: 503.1973; found: 503.1982.

Synthesis of compound 2j



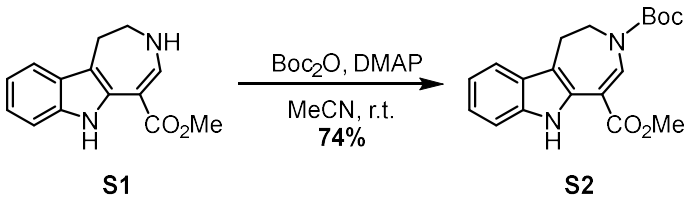
A solution of **1b** (408 mg, 0.956 mmol) and *N,N*-dimethyl propiolamide (186 mg, 1.91 mmol) in 1,2-dichloroethane (2.5 mL) and 2,2,2-trifluoroethanol (2.5 mL) was stirred at 50 °C for 75 h. The reaction mixture was then concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **2j** (345 mg, 0.659 mmol, 69%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.16 (d, *J* = 8.2 Hz, 1H), 7.58 (d, *J* = 7.8 Hz, 1H), 7.45 (d, *J* = 12.8 Hz, 1H), 7.35 (ddd, *J* = 8.8, 6.8, 1.5 Hz, 1H), 7.30-7.26 (m, 1H), 6.61 (d, *J* = 1.4 Hz, 1H), 5.79 (d, *J* = 1.8 Hz, 1H), 4.99 (d, *J* = 12.8 Hz, 1H), 4.45-4.41 (m, 2H), 3.82 (d, *J* = 1.8 Hz, 2H), 3.74 (s, 3H), 3.43 (t, *J* = 7.8 Hz, 2H), 3.04-2.94 (br, 2H), 2.97 (s, 6H), 2.29 (t, *J* = 2.3 Hz, 1H), 1.19-1.15 (m, 2H), 0.07 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 168.9, 166.2, 151.5, 149.2, 135.5, 133.8, 132.5, 129.2, 128.3, 125.2, 123.1, 118.8, 118.2, 115.9, 86.8, 78.1, 73.2, 66.0, 52.2, 51.9, 41.5, 22.9, 17.5, -1.6 ppm.

HRMS (ESI): *m/z* calcd for $C_{28}H_{37}N_3O_5Si$ [M + H]$^+$: 524.5275; found: 524.5272.

Synthesis of compound S2



To a solution of **S1** (2.03 g, 8.38 mmol) and *N,N*-dimethyl-4-aminopyridine (102 mg, 0.838 mmol) in acetonitrile (33.5 mL) was added Boc_2O (2.12 mL, 9.22 mmol) dropwise. After stirring at r.t. for 20 min, the reaction mixture was added sat. NH_4Cl aqueous solution and extracted with dichloromethane. The combined organic extracts were washed with water and brine, dried over anhydrous Na_2SO_4, and

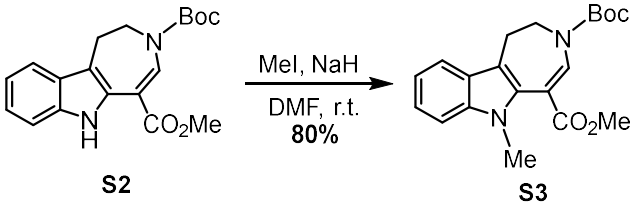
concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **S2** (2.12 g, 6.18 mmol, 74%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 10.53 (s, 1H), 8.41 (s, 1H), 7.49 (d, *J* = 8.2 Hz, 1H), 7.36 (d, *J* = 8.2 Hz, 1H), 7.17 (ddd, *J* = 8.0, 7.2, 1.2 Hz, 1H), 7.09 (ddd, *J* = 8.0, 6.8, 1.2 Hz, 1H), 3.99 (t, *J* = 4.8 Hz, 2H), 3.89 (s, 3H), 3.16 (dd, *J* = 5.7, 3.9 Hz, 2H), 1.58 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 168.9, 152.1, 139.4, 134.6, 128.4, 127.5, 122.1, 119.2, 117.6, 113.6, 111.0, 103.8, 83.4, 52.2, 44.8, 28.1, 26.2 ppm

HRMS (ESI): *m/z* calcd for $C_{19}H_{22}N_2O_4$ $[M + H]^+$: 343.1653; found: 343.1647.

Synthesis of compound S3



S2 **S3**

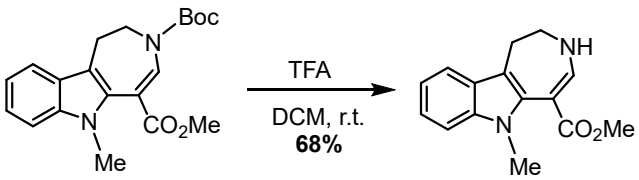
To a solution of NaH (45.8 mg, 1.05 mmol, 55% in immersion oil) in *N*,*N*-dimethylformamide (8.8 mL) stirred at 0 ºC was added **S2** (300 mg, 0.876 mmol) in *N*,*N*-dimethylformamide (8.8 mL) dropwise. After stirring at room temperature for 50 min, methyl iodide (0.0850 mL, 1.37 mmol) was added at 0 ºC. After stirring at room temperature for 20 h, the reaction mixture was quenched with sat. NH_4Cl aqueous solution dropwise, added water, and extracted with ethyl acetate. The combined organic extracts were washed with brine, dried over anhydrous Na_2SO_4, and concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **S3** (250 mg, 0.700 mmol, 80%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.44 (s, 1H), 7.50 (d, *J* = 7.8 Hz, 1H), 7.29 (d, *J* = 8.2 Hz, 1H), 7.21 (ddd, *J* = 8.4, 6.8, 1.6 Hz, 1H), 7.10 (ddd, *J* = 8.4, 6.8, 0.8 Hz, 1H), 4.01-3.98 (m, 2H), 3.85 (s, 3H), 3.56 (s, 3H), 3.10-3.07 (m, 2H), 1.55 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 168.5, 152.5, 138.5, 138.0, 131.1, 126.0, 122.8, 121.9, 119.2, 117.4, 116.2, 109.4, 103.4, 83.4, 52.1, 31.9, 28.0, 23.6 ppm

HRMS (ESI): *m/z* calcd for $C_{20}H_{24}N_2O_4$ $[M + H]^+$: 357.1809; found: 357.1765.

Synthesis of compound S4



S3 **S4**

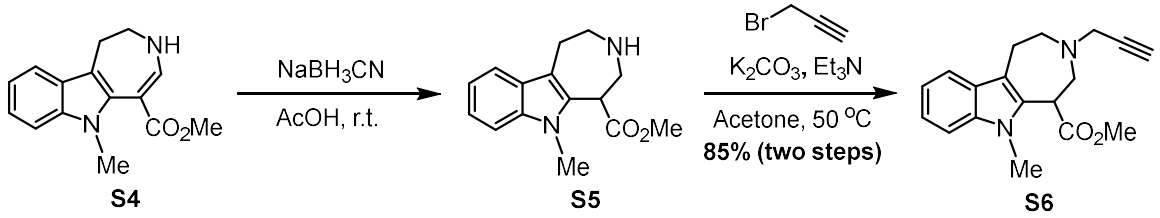
To a solution of **S3** (743 mg, 2.03 mmol) in dichloromethane (8.3 mL) was added trifluoroacetic acid (2.39 mL, 31.3 mmol) dropwisely at 0 °C. After stirring at r.t. for 6.3 h, the reaction mixture was concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **S4** (360 mg, 1.40 mmol, 68%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.72 (d, *J* = 8.2 Hz, 1H), 7.45 (d, *J* = 7.8 Hz, 1H), 7.27 (d, *J* = 8.8 Hz, 1H), 7.16 (ddd, *J* = 8.0, 7.2, 0.8 Hz, 1H), 7.07 (ddd, *J* = 8.0, 6.8, 0.9 Hz, 1H), 5.09 (br, 1H), 3.79 (s, 3H), 3.57-3.54 (m, 5H), 3.11 (t, *J* = 4.4 Hz, 2H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 169.2, 145.4, 138.0, 133.7, 126.6, 120.8, 118.7, 116.5, 113.5, 109.1, 92.4, 51.3, 49.9, 32.1, 25.4 ppm.

HRMS (ESI): *m/z* calcd for $C_{15}H_{16}N_2O_2$ $[M + Na]^+$: 279.1104; found: 279.1050.

Synthesis of compound S6



S4 **S5** **S6**

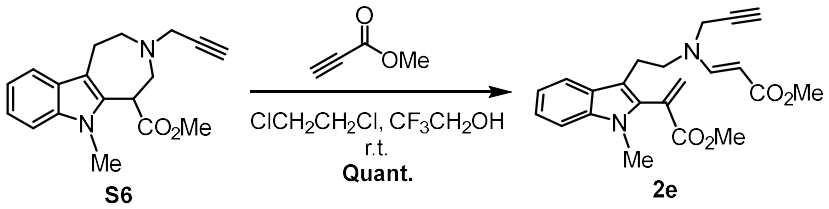
To a solution of **S4** (161 mg, 0.626 mmol) in acetic acid (6.4 mL) was added $NaBH_3CN$ (111 mg, 1.76 mmol) portionwise. After stirring at r.t. for 30 min, the reaction mixture was quenched with 12 M HCl until gas evolution has stopped, basified with 25% NH_3 aqueous solution at 0 °C, and extracted with dichloromethane. The combined organic extracts were washed with sat. $NaHCO_3$ aqueous solution, dried over anhydrous Na_2SO_4, and concentrated *in vacuo*. The resulting residue was used in the next step without further purification. To a solution of crude **S5** and anhydrous K_2CO_3 (171 mg, 1.24 mmol) in acetone (2.7 mL) was added triethylamine (0.0947 mL, 0.680 mmol) and propargyl bromide (0.0610 mL, 0.803 mmol). After stirring at 50 °C for 20 h, the reaction mixture was filtered, concentrated *in vacuo*, added ethyl acetate and water, and extracted with ethyl acetate. The combined organic extracts were washed with sat. NH_4Cl aqueous solution and brine, dried over anhydrous Na_2SO_4 and concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **S6** (156 mg, 0.527 mmol, 85% for two steps).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.53 (d, *J* = 8.2 Hz, 1H), 7.27 (d, *J* = 8.4 Hz, 1H), 7.21 (ddd, *J* = 8.4, 6.8, 1.6 Hz, 1H), 7.11 (ddd, *J* = 8.0, 6.8, 0.8 Hz, 1H), 4.04 (dd, *J* = 4.8, 4.0 Hz, 1H), 3.72-3.63 (m, 7H), 3.58 (t, *J* = 2.1 Hz, 2H), 3.12-3.04 (m, 2H), 2.98-2.90 (m, 2H), 2.74-2.68 (m, 1H), 2.24 (t, *J* = 2.1 Hz, 1H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 171.4, 136.3, 133.8, 127.4, 121.3, 118.9, 118.2, 113.3, 109.0, 79.0, 72.6, 56.8, 55.7, 52.3, 49.9, 44.0, 29.5, 24.9 ppm.

HRMS (ESI): *m/z* calcd for $C_{18}H_{20}N_2O_2$ $[M + H]^+$: 297.1598; found: 297.1601.

Synthesis of compound 2e



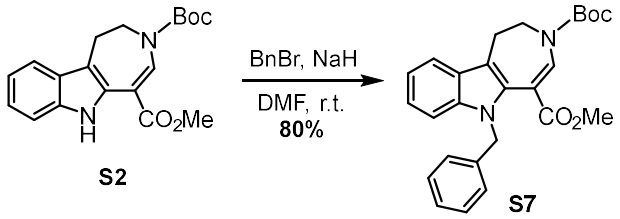
A solution of **S6** (125 mg, 0.422 mmol) in 1,2-dichloroethane (1.1 mL) and 2,2,2-trifluoroethanol (1.1 mL) was added methyl propiolate (0.0880 mL, 0.990 mmol). After stirring at r.t. for 16 h, the reaction mixture was concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **2e** (160 mg, 0.421 mmol, quant.).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.59 (d, *J* = 7.6 Hz, 1H), 7.39 (d, *J* = 12.8 Hz, 1H), 7.32-7.24 (m, 2H), 7.15 (ddd, *J* = 7.6, 7.2, 0.8 Hz, 1H), 6.85 (d, *J* = 1.4 Hz, 1H), 5.94 (d, *J* = 1.8 Hz, 1H), 4.71 (d, *J* = 13.3 Hz, 1H), 3.81 (s, 3H), 3.72 (d, *J* = 2.3 Hz, 2H), 3.68 (s, 3H), 3.57 (s, 3H), 3.44 (t, *J* = 7.6 Hz, 2H), 3.00 (t, *J* = 7.6, 6.6 Hz, 2H), 2.28 (t, *J* = 2.3 Hz, 1H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 169.7, 166.1, 150.5, 136.9, 133.7, 133.6, 131.9, 126.8, 122.4, 119.5, 118.7, 110.3, 109.4, 86.1, 77.8, 73.3, 52.6, 50.6, 30.5 ppm.

HRMS (ESI): *m/z* calcd for $C_{22}H_{24}N_2O_4$ $[M + H]^+$: 381.1809; found: 381.1806.

Synthesis of compound S7



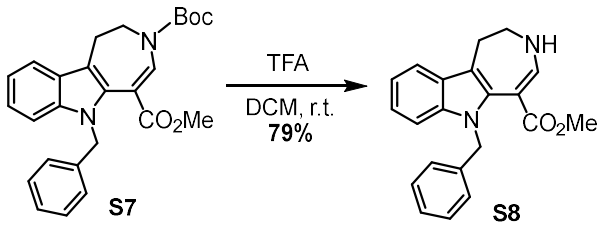
To a solution of NaH (267 mg, 6.12 mmol, 55% in immersion oil) in *N*,*N*-dimethylformamide (20 mL) stirred at 0 °C was added **S2** (1.03 g, 3.01 mmol) in *N*,*N*-dimethylformamide (10 mL) dropwise. After stirring at room temperature for 30 min, benzyl bromide (0.560 mL, 4.71 mmol) was added at 0 °C. After stirring at room temperature for 1 h, the reaction mixture was quenched with sat. NH_4Cl aqueous solution dropwise, added water, and extracted with ethyl acetate. The combined organic extracts were washed with brine, dried over anhydrous Na_2SO_4, and concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **S7** (1.04 g, 2.40 mmol, 80%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.41 (s, 1H), 7.56-7.52 (m, 1H), 7.32-7.19 (m, 3H), 7.11 (ddd, *J* = 7.6, 4.6, 1.8 Hz, 3H), 7.03 (d, *J* = 6.9 Hz, 2H), 5.19 (s, 2H), 4.02-4.00 (m, 2H), 3.37 (s, 3H), 3.14-3.11 (m, 2H), 1.55 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 168.4, 152.4, 138.9, 138.3, 137.8, 131.3, 128.4, 126.9, 126.5, 126.4, 126.3, 122.1, 119.6, 117.5, 117.1, 110.7, 103.3, 83.4, 51.8, 51.6, 48.8, 28.1, 28.0, 23.5 ppm.

HRMS (ESI): *m/z* calcd for $C_{26}H_{28}N_2O_4$ $[M + H]^+$: 433.2122; found: 433.2125.

Synthesis of compound S8



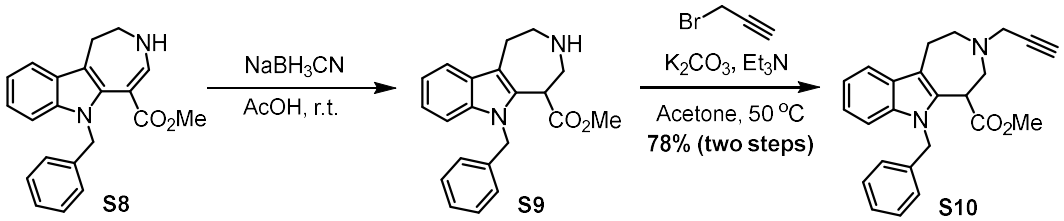
To a solution of **S7** (715 mg, 1.65 mmol) in dichloromethane (6.6 mL) was added trifluoroacetic acid (1.9 mL, 24.8 mmol) dropwise at 0 °C. After stirring at room temperature for 17.5 h, the reaction mixture was concentrated *in vacuo*. The resulting residue was purified by silica gel chromatography to afford **S8** (432 mg, 1.30 mmol, 79%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.71 (d, *J* = 8.7 Hz, 1H), 7.48 (d, *J* = 5.5 Hz, 1H), 7.25-7.17 (m, 3H), 7.09-7.05 (m, 5H), 5.18 (s, 2H), 5.09 (br, 1H), 3.58 (t, *J* = 4.4 Hz, 2H), 3.26 (s, 3H), 3.15 (t, *J* = 4.1 Hz, 2H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 169.2, 145.8, 138.5, 138.3, 133.9, 128.2, 127.2, 126.5, 126.3, 121.1, 119.1, 116.5, 114.5, 110.5, 92.2, 50.7, 49.9, 48.9, 25.3 ppm.

HRMS (ESI): *m/z* calcd for $C_{21}H_{20}N_2O_2$ $[M + H]^+$: 333.1598; found: 333.1620.

Synthesis of compound S10



To a solution of **S8** (389 mg, 1.17 mmol) in acetic acid (12 mL) was added $NaBH_3CN$ (149 mg, 2.37 mmol) portionwise. After stirring at r.t. for 2.5 h, the reaction mixture was quenched with 12 M HCl until gas evolution has stopped, basified with 25% NH_3 aqueous solution at 0 °C, and extracted with dichloromethane. The combined organic extracts were washed with sat. $NaHCO_3$ aqueous solution, dried over anhydrous Na_2SO_4, and concentrated *in vacuo*. The resulting residue was used in the next step without further purification. To a solution of crude **S9** and anhydrous K_2CO_3 (195 mg, 1.41 mmol) in acetone (4.6

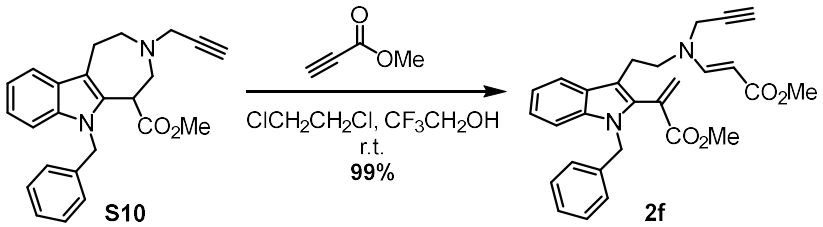
mL) was added triethylamine (0.225 mL, 1.61 mmol) and propargyl bromide (0.115 mL, 1.52 mmol). After stirring at 50 ºC for 27.5 h, the reaction mixture was filtered, concentrated *in vacuo*, added ethyl acetate and water, and extracted with ethyl acetate. The combined organic extracts were washed with sat. NH_4Cl aqueous solution and brine, dried over anhydrous Na_2SO_4 and concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **S10** (332 mg, 0.891 mmol, 78% for two steps).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 (dd, *J* = 6.6, 1.1 Hz, 1H), 7.28-7.20 (m, 4H), 7.18-7.10 (m, 2H), 6.96 (d, *J* = 6.4 Hz, 2H), 5.30 (dd, *J* = 26.6, 17.4 Hz, 2H), 3.87 (dd, *J* = 4.4, 4.4 Hz, 1H), 3.55 (s, 3H), 3.53-3.50 (m, 3H), 3.10-3.06 (m, 2H), 2.98-2.92 (m, 1H), 2.77-2.65 (m, 2H), 2.19 (t, *J* = 2.3 Hz, 1H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 171.2, 137.7, 136.2, 133.9, 128.7, 127.6, 127.4, 125.9, 121.7, 119.2, 118.3, 114.4, 109.3, 78.9, 72.7, 57.2, 55.7, 52.1, 50.1, 46.5, 44.2, 25.0 ppm.

HRMS (ESI): *m/z* calcd for $C_{24}H_{24}N_2O_2$ $[M + H]^+$: 373.1911; found: 373.1906.

Synthesis of compound 2f



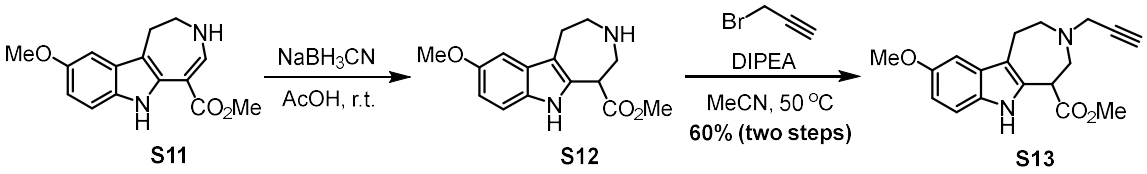
To a solution of **S10** (149 mg, 0.400 mmol) in 1,2-dichloromethane (2.0 mL) and 2,2,2-trifluoroethanol was added methyl propiolate (0.0850 mL, 0.960 mmol). After stirring at room temperature for 18 h, the reaction mixture was concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **2f** (182 mg, 0.398 mmol, 99%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.63-7.61 (m, 1H), 7.39 (d, *J* = 13.3 Hz, 1H), 7.24-7.13 (m, 6H), 6.97-6.95 (m, 2H), 6.75 (d, *J* = 1.6 Hz, 1H), 5.84 (d, *J* = 1.6 Hz, 1H), 5.19 (s, 2H), 4.71 (d, *J* = 13.3 Hz, 1H), 3.74 (d, *J* = 2.4 Hz, 2H), 3.67 (s, 3H), 3.61 (s, 3H), 3.48 (t, *J* = 7.6 Hz, 2H), 3.01 (dd, *J* = 8.0, 8.8 Hz, 2H), 2.28 (t, *J* = 2.5 Hz, 1H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 169.5, 165.9, 150.4, 137.4, 136.6, 134.0, 133.4, 131.7, 128.4, 127.1, 127.0, 126.0, 122.4, 119.7, 118.6, 110.8, 110.2, 85.9, 77.7, 73.3, 52.2, 50.4, 47.5 ppm.

HRMS (ESI): *m/z* calcd for $C_{28}H_{28}N_2O_4$ $[M + H]^+$: 457.2122; found: 457.2118.

Synthesis of compound S13



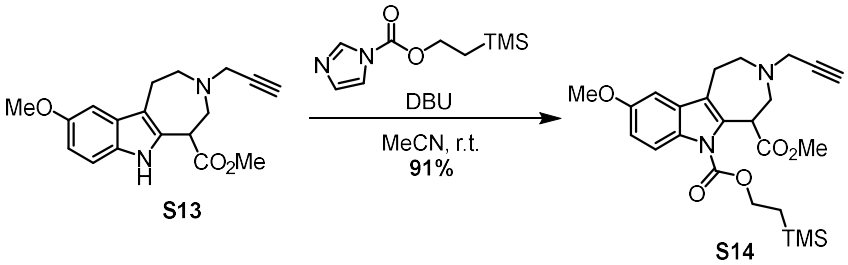
To a solution of **S11** (10.6 g, 38.9 mmol) in acetic acid (86.5 mL) was added $NaBH_3CN$ (5.63 g, 89.5 mmol) portionwise. After stirring at r.t. for 6 h, the reaction mixture was quenched with 12 M HCl until gas evolution has stopped, basified with 25% NH_3 aqueous solution at 0 °C, and extracted with dichloromethane. The combined organic extracts were washed with brine, dried over anhydrous Na_2SO_4, and concentrated *in vacuo*. The resulting residue was used in the next step without further purification. To a solution of crude **S12** in acetonitrile (132 mL) was added *N*,*N*-diisopropylethylamine (13.8 mL, 79.5 mmol) and propargyl bromide (3.61 mL, 47.7 mmol) at 0 °C. After stirring at r.t. for 30 min, the reaction mixture was filtered, concentrated *in vacuo*, added dichloromethane and water, and extracted with dichloromethane. The combined organic extracts were washed with sat. $NaHCO_3$ aqueous solution and brine, dried over anhydrous Na_2SO_4 and concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **S13** (7.50 g, 24.0 mmol, 60% for two steps).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.27 (s, 1H), 7.21-7.17 (m, 1H), 6.94 (d, J = 2.3 Hz, 1H), 6.81 (dd, J = 8.7, 2.3 Hz, 1H), 4.04-4.01 (m, 1H), 3.85 (s, 3H), 3.76 (s, 3H), 3.57 (d, J = 2.4 Hz, 2H), 3.37-3.32 (m, 1H), 3.17-312 (m, 1H), 3.00-2.88 (m, 4H), 2.23 (t, J = 2.3 Hz, 1H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 172.1, 154.1, 132.8, 130.0, 128.8, 113.4, 111.7, 111.5, 100.2, 79.0, 72.9, 56.7, 55.9, 55.4, 52.4, 49.1, 45.8, 24.5 ppm.

HRMS (ESI): *m/z* calcd for $C_{18}H_{20}N_2O_3$ $[M + H]^+$: 313.1547; found: 313.1550.

Synthesis of compound S14



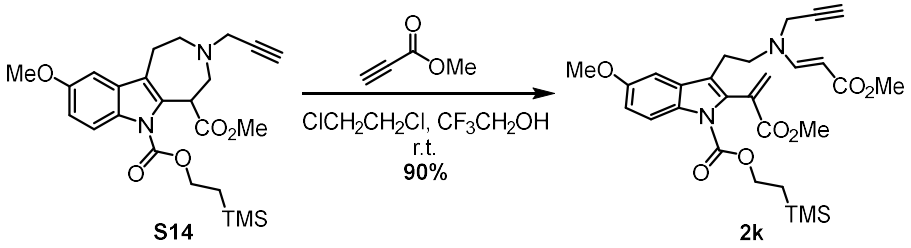
To a solution of **S13** (503 mg, 1.61 mmol) and Teoc-imidazole (511 mg, 2.41 mmol) in acetonitrile (5.3 mL) was added 1,8-diazabicyclo(5.4.0)undec-7-ene (0.120 mL, 0.800 mmol). After stirring at r.t. for 9 h, the reaction mixture was concentrated *in vacuo,* added dichloromethane and sat. NH_4Cl aqueous solution, and extracted with dichloromethane. The combined organic extracts were dried over anhydrous Na_2SO_4 and concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **S14** (697 mg, 1.53 mmol, 91%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.96 (d, *J* = 8.7 Hz, 1H), 6.91-6.87 (m, 2H), 4.98 (dd, *J* = 4.8, 5.2 Hz, 1H), 4.48-4.44 (m, 2H), 3.86 (s, 3H), 3.73 (s, 3H), 3.61 (dd, *J* = 13.1, 5.3 Hz, 1H), 3.51 (d, *J* = 2.3 Hz, 2H), 3.11 (dt, *J* = 8.0, 4.0 Hz, 1H), 3.00-2.94 (m, 2H), 2.87 (m, 1H), 2.73 (ddd, *J* = 13.2, 9.6, 1.8 Hz, 1H), 2.23 (t, *J* = 2.3 Hz, 1H), 1.24-1.19 (m, 2H), 0.09 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 171.9, 156.0, 152.1, 135.0, 130.7, 130.0, 121.4, 116.7, 112.6, 100.9, 79.0, 72.7, 65.6, 56.4, 55.7, 54.1, 52.1, 49.2, 46.0, 23.9, 17.6, -1.6 ppm.

HRMS (ESI): *m/z* calcd for $C_{24}H_{32}N_2O_5Si$ $[M + H]^+$: 457.2153; found: 457.2142.

Synthesis of compound 2k



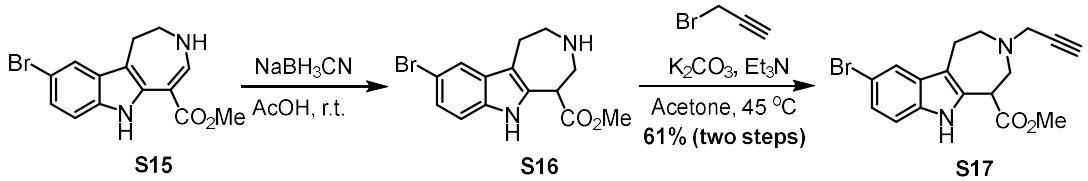
To a solution of **S14** (434 mg, 0.993 mmol) in 1,2-dichloroethane (2.5 mL) and 2,2,2-trifluoroethanol (2.5 mL) was added methyl propiolate (0.165 mL, 1.99 mmol). After stirring at r.t. for 17.5 h, the reaction mixture was then concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **2k** (481 mg, 0.889 mmol, 90%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.04 (d, *J* = 8.7 Hz, 1H), 7.39 (d, *J* = 13.3 Hz, 1H), 6.99-6.95 (m, 2H), 6.60 (d, *J* = 1.8 Hz, 1H), 5.78 (d, *J* = 1.4 Hz, 1H), 4.74 (d, *J* = 13.3 Hz, 1H), 4.44-4.40 (m, 2H), 3.88 (s, 3H), 3.75 (s, 3H), 3.72 (br, 1H), 3.67 (s, 3H), 3.43 (t, *J* = 7.1 Hz, 2H), 2.96 (br, 2H), 2.28 (t, *J* = 2.5 Hz, 1H), 1.19-1.14 (m, 2H), 0.07 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 169.5, 166.2, 156.2, 151.4, 150.4, 133.9, 133.3, 130.1, 130.0, 128.3, 117.8, 116.8, 113.9, 101.3, 86.7, 77.7, 73.5, 66.0, 55.7, 52.3, 50.6, 17.6, -1.6 ppm.

HRMS (ESI): *m/z* calcd for $C_{28}H_{36}N_2O_7Si$ $[M + Na]^+$: 563.2184; found: 563.2146.

Synthesis of compound S17



To a solution of **S15** (2.30 g, 7.16 mmol) in acetic acid (20 mL) was added $NaBH_3CN$ (870 mg, 13.8 mmol) portionwise at 0 °C. After stirring at r.t. for 4.5 h, the reaction mixture was quenched with 1 M HCl aqueous solution, basified with 25% NH_3 aqueous solution at 0 °C, and extracted with dichloromethane.

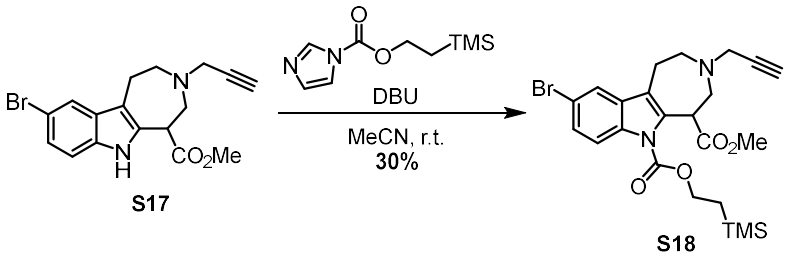
The combined organic extracts were washed with sat. NH_4Cl aqueous solution, dried over anhydrous Na_2SO_4, and concentrated *in vacuo*. The resulting residue was used in the next step without further purification. To a solution of crude **S16** and anhydrous K_2CO_3 (1.17 g, 8.47 mmol) in acetone (17.5 mL) was added triethylamine (1.91 mL, 13.7 mmol) and propargyl bromide (0.540 mL, 7.18 mmol). After stirring at 45 °C for 12 h, the reaction mixture was filtered and extracted with dichloromethane. The combined organic extracts were washed with sat. NH_4Cl aqueous solution, dried over anhydrous Na_2SO_4 and concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **S17** (1.56 g, 4.31 mmol, 61% for two steps).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.51 (s, 1H), 7.60 (d, *J* = 1.8 Hz, 1H), 7.21 (dd, *J*= 8.2, 1.8 Hz, 1H), 7.15 (d, *J* = 8.7 Hz, 1H), 4.05 (m, 1H), 3.77 (s, 3H), 3.57 (d, *J* = 2.3 Hz, 2H), 3.34 (dd, *J* = 12.8, 6.9 Hz, 1H), 3.15 (dd, *J* = 13.6, 2.4. Hz, 1H), 2.95-2.90 (m, 4H), 2.25 (d, *J* = 2.3 Hz, 1H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 171.9, 133.3, 133.3, 130.1, 124.4, 120.7, 113.2, 112.6, 112.2, 78.8, 73.1, 56.6, 55.3, 52.5, 49.1, 45.6, 24.3 ppm.

HRMS (ESI): *m/z* calcd for $C_{17}H_{17}N_2O_2Br$ $[M + H]^+$: 361.0546; found: 361.0525.

Synthesis of compound S18



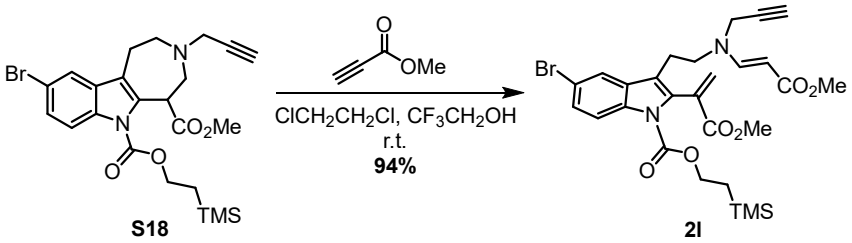
To a solution of **S17** (790 mg, 2.19 mmol) in acetonitrile (7.5 mL) was added Teoc-imidazole (701 mg, 3.30 mmol) and 1,8-diazabicyclo(5.4.0)undec-7-ene (0.160 mL, 1.08 mmol). After stirring at r.t. for 14.5 h, the reaction mixture was concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **S18** (327 mg, 0.647 mmol, 30%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 (d, *J* = 9.2 Hz, 1H), 7.58 (d, *J* = 1.8 Hz, 1H), 7.36 (dd, *J* = 8.9, 2.1 Hz, 1H), 4.96 (br, 1H), 4.51-4.43 (m, 2H), 3.73 (s, 3H), 3.63-3.52 (m, 3H), 3.12-2.73 (m, 4H), 2.24 (s, 1H), 1.25-1.16 (m, 2H), 0.09 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 171.6, 151.9, 134.1, 131.6, 129.0, 128.2, 127.0, 121.0, 120.8, 117.3, 116.2, 72.9, 66.1, 56.2, 53.9, 52.3, 49.2, 46.0, 23.8, 17.7, -1.6 ppm.

HRMS (ESI): *m/z* calcd for $C_{23}H_{29}N_2O_4Br$ $[M + H]^+$: 505.1153; found: 505.1137.

Synthesis of compound 2l



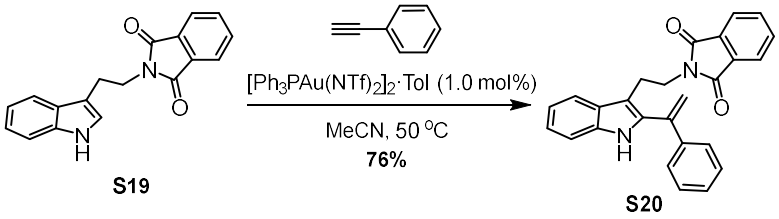
To a solution of **S18** (307 mg, 0.608 mmol) in 1,2-dichloroethane (3.1 mL) and 2,2,2-trifluoroethanol (3.1 mL) was added methyl propiolate (0.101 mL, 1.21 mmol). After stirring at r.t. for 14 h, the reaction mixture was then concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **2l** (338 mg, 0.573 mmol, 94%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.04 (d, *J* = 9.2 Hz, 1H), 7.69 (d, *J* = 2.3 Hz, 1H), 7.45 (dd, *J* = 8.9, 2.1 Hz, 1H), 7.36 (d, *J* = 8.7 Hz, 1H), 6.63 (d, *J* = 1.4 Hz, 1H), 5.80 (d, *J* = 1.4 Hz, 1H), 4.69 (d, *J* = 13.3 Hz, 1H), 4.47-4.38 (m, 2H), 3.76 (m, 5H), 3.68 (s, 3H), 3.43 (t, *J* = 7.1 Hz, 2H), 2.95 (br, 2H), 2.32 (t, *J* = 2.5 Hz, 1H), 1.18-1.13 (m, 2H), 0.07 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 169.5, 166.0, 151.1, 150.3, 134.2, 133.9, 133.5, 130.8, 128.9, 128.1, 121.5, 117.4, 117.2, 116.4, 101.4, 87.0, 77.5, 76.7, 73.8, 66.4, 52.4, 50.7, 17.5, -1.6 ppm.

HRMS (ESI): *m/z* calcd for $C_{27}H_{33}N_2O_6SiBr$ $[M + Na]^+$: 611.1183; found: 611.1134.

Synthesis of compound S20[9]



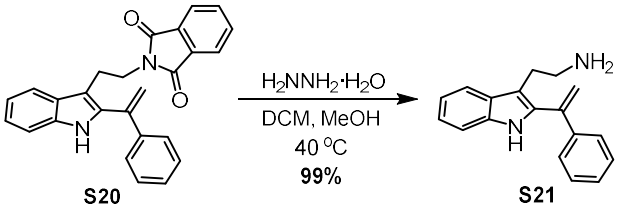
To a solution of **S19** (1.01 g, 3.48 mmol) and $[Ph_3PAu(NTf)_2]_2$·toluene (54.1 mg, 0.0345 mmol) in acetonitrile (10 mL) was added ethynyl benzene (1.12 mL, 10.3 mmol). After stirring at 50 °C for 24 h, the reaction mixture was concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **S20** (1.04 g, 2.65 mmol, 76%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.14 (d, *J* = 8.2 Hz, 1H), 7.55 (d, *J* = 7.8 Hz, 1H), 7.40-7.29 (m, 3H), 6.64 (d, *J* = 1.4 Hz, 1H), 5.80 (d, *J* = 1.4 Hz, 1H), 4.72 (d, *J* = 13.3 Hz, 1H), 3.74 (s, 3H), 3.72 (br, 2H), 3.68 (s, 3H), 3.44 (t, *J* = 7.2 Hz, 2H), 2.99 (br, 2H), 2.28 (t, *J* = 2.3 Hz, 1H), 1.60 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) d 168.2, 140.7, 139.9, 135.3, 134.8, 133.7, 132.2, 128.6, 128.4, 128.3, 127.7, 123.0, 122.5, 119.7, 119.0, 117.0, 111.2, 110.8, 38.3, 24.0 ppm.

HRMS (ESI): *m/z* calcd for $C_{26}H_{20}N_2O_2$ $[M + H]^+$: 393.1598; found: 393.1626.

Synthesis of compound S21



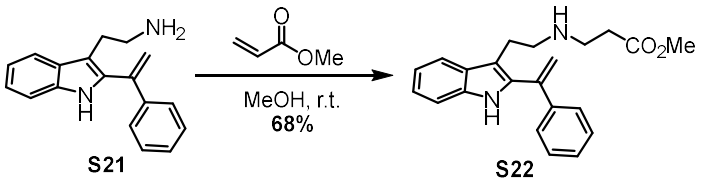
To a solution of **S20** (98.8 mg, 0.252 mmol) in methanol (2.6 mL) and dichloromethane (2.6 mL) was added 79% hydrazine monohydrate (0.185 mL, 3.82 mmol). After stirring at 40 °C for 10 h, the reaction mixture was filtered and concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **S21** (65.3 mg, 0.249 mmol, 99%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.98 (s, 1H), 7.63 (d, *J* = 8.2 Hz, 1H), 7.38-7.29 (m, 6H), 7.20 (ddd, *J* = 8.4, 6.8, 0.8 Hz, 1H), 7.13 (ddd, *J* = 7.6, 6.8, 0.8 Hz, 1H), 5.69 (d, *J* = 0.9 Hz, 1H), 5.55 (d, *J* = 1.4 Hz, 1H), 2.93 (t, *J* = 7.1 Hz, 2H), 2.81 (t, *J* = 6.9 Hz, 2H), 1.34 (br, 2H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 141.3, 140.1, 135.4, 134.7, 128.8, 128.4, 128.3, 127.6, 122.4, 119.4, 119.1, 116.6, 112.6, 110.8, 42.9, 29.1 ppm.

HRMS (ESI): *m/z* calcd for $C_{18}H_{18}N_2$ $[M + H]^+$: 263.1543; found: 263.1565.

Synthesis of compound S22



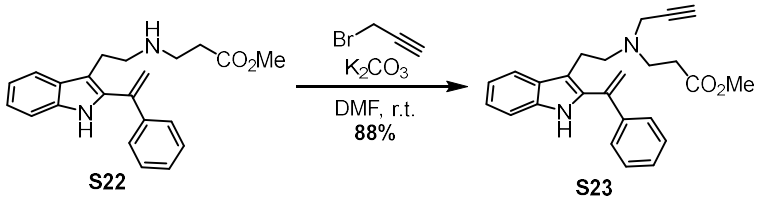
To a solution of **S21** (926 mg, 3.53 mmol) in methanol (7.0 mL) was dropwisely added methyl acrylate (0.318 mL, 3.53 mmol) over 1 h. After stirring at r.t. 8 h, the reaction mixture was filtered and concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **S22** (832 mg, 2.39 mmol, 68%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.84 (s, 1H), 7.64 (d, *J* = 8.2 Hz, 1H), 7.38-7.33 (m, 5H), 7.29 (d, *J* = 7.8 Hz, 1H), 7.19 (ddd, *J* = 8.0, 6.8, 0.8 Hz, 1H), 7.12 (ddd, *J* = 8.0, 7.2, 0.9 Hz, 1H), 5.69 (d, *J* = 1.4 Hz, 1H), 5.55 (d, *J* = 1.4 Hz, 1H), 3.63 (s, 3H), 2.90-2.82 (m, 6H), 2.46-2.43 (m, 2H), 1.50 (br, 1H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 173.1, 141.2, 140.1, 135.4, 134.5, 128.7, 128.4, 128.3, 127.7, 122.5, 119.5, 119.1, 116.7, 112.9, 110.8, 51.5, 50.2, 44.8, 34.7, 25.3 ppm.

HRMS (ESI): *m/z* calcd for $C_{22}H_{24}N_2O_2$ $[M + H]^+$: 349.1911; found: 349.1902.

Synthesis of compound S23



S22 S23

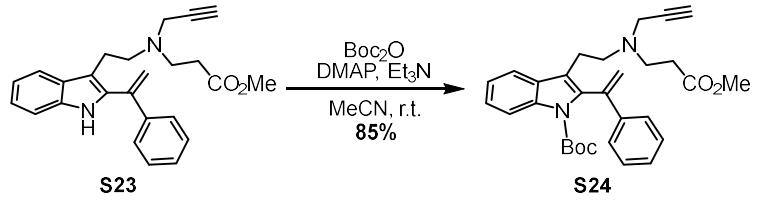
To a solution of **S22** (799 mg, 2.29 mmol) and anhydrous K_2CO_3 (349 mg, 2.52 mmol) in *N*,*N*-dimethylformamide (5.7 mL) was added propargyl bromide (0.185 mL, 2.41 mmol). After stirring at r.t. for 3 h, the reaction mixture was filtered extracted with diethyl ether. The combined organic extracts were washed with sat. NH_4Cl aqueous solution, dried over anhydrous Na_2SO_4, and concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **S23** (779 mg, 2.02 mmol, 88%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.88 (s, 1H), 7.67 (d, *J* = 7.8 Hz, 1H), 7.39-7.35 (m, 5H), 7.28 (d, *J* = 8.2 Hz, 1H), 7.20 (ddd, *J* = 8.0, 6.8, 0.09 Hz, 1H), 7.14 (ddd, *J* = 8.0, 7.2, 0.9 Hz, 1H), 5.70 (d, *J* = 0.9 Hz, 1H), 5.55 (d, *J* = 0.9 Hz, 1H), 3.66 (s, 3H), 3.42 (d, *J* = 2.7 Hz, 2H), 2.91-2.74 (m, 6H), 2.44 (t, *J* = 7.1 Hz, 2H), 2.19 (t, *J* = 2.3 Hz, 1H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 172.8, 141.2, 140.1, 135.4, 134.3, 128.6, 128.4, 128.3, 127.7, 127.2, 122.4, 119.4, 119.0, 116.5, 112.8, 110.7, 78.6, 73.0, 53.9, 51.5, 49.1, 42.0, 32.9, 23.1 ppm.

HRMS (ESI): *m/z* calcd for $C_{25}H_{26}N_2O_2$ $[M + H]^+$: 387.2067; found: 307.2071.

Synthesis of compound 24



S23 S24

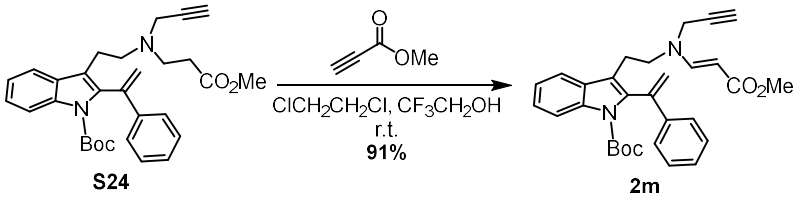
To a solution of **S23** (540 mg, 1.40 mmol) and *N*,*N*-dimethyl-4-aminopyridine (17.8 mg, 0.145 mmol) in acetonitrile (4.7 mL) was added triethylamine (0.235 mL, 1.68 mmol) and Boc_2O (0.389 mL, 1.68 mmol). After stirring at r.t. for 1.5 h, the reaction mixture was concentrated *in vacuo* and extracted with dichloromethane. The combined organic extracts were washed with brine, dried over anhydrous Na_2SO_4, and concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **S24** (575 mg, 1.18 mmol, 85%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.19 (d, *J* = 8.2 Hz, 1H), 7.64 (dd, *J* = 7.6, 0.8 Hz, 2H), 7.38-7.22 (m, 9H), 6.01 (d, *J* = 0.9 Hz, 1H), 5.42 (d, *J* = 0.9 Hz, 1H), 3.64 (s, 3H), 3.43 (d, *J* = 2.5 Hz, 2H), 2.89-2.74 (m, 6H), 2.42 (t, *J* = 6.9 Hz, 2H), 2.15 (t, *J* =2.3 Hz, 1H), 1.31 (s, 9H) ppm.

^{13}C NMR (125 MHz, $CDCl_3$) δ 172.7, 149.7, 140.5, 139.4, 136.1, 135.4, 129.4, 128.2, 127.7, 125.9, 124.5, 122.5, 119.5, 118.9, 115.4, 115.3, 83.6, 78.3, 73.1, 53.5, 51.5, 49.2, 41.8, 32.8, 27.5, 22.9 ppm.

HRMS (ESI): *m/z* calcd for $C_{30}H_{34}N_2O_4$ $[M + H]^+$: 487.2592; found: 487.2605.

Synthesis of compound 2m



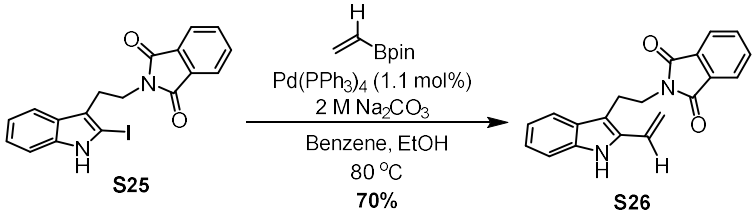
To a solution of **S24** (446 mg, 0.0.917 mmol) in 1,2-dichloroethane (2.3 mL) and 2,2,2-trifluoroethanol (2.3 mL) was added methyl propiolate (0.150 mL, 1.83 mmol). After stirring at r.t. for 5 h, the reaction mixture was then concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **2m** (402 mg, 0.830 mmol, 91%).

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.21 (d, *J* = 8.3 Hz, 1H), 7.59 (d, *J* = 7.7 Hz, 1H), 7.37-7.29 (m, 4H), 7.26-7.23 (m, 4H), 6.07 (s, 1H), 5.38 (s, 1H), 4.69 (d, *J* = 13.3 Hz, 1H), 3.75 (d, *J* = 2.3 Hz, 2H), 3.67 (s, 3H), 3.40 (t, *J* = 7.8 Hz, 2H), 3.01-2.99 (m, 2H), 2.24 (t, *J* = 2.4 Hz, 1H), 1.31 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 169.6, 150.5, 149.6, 140.6, 139.0, 136.1, 136.1, 129.0, 128.4, 128.1, 125.9, 124.8, 122.9, 118.5, 117.4, 115.6, 115.5, 86.6, 84.0, 77.6, 73.5, 50.6, 27.5 ppm.

HRMS (ESI): *m/z* calcd for $C_{30}H_{32}N_2O_4$ $[M + Na]^+$: 507.2254; found: 507.2257.

Synthesis of compound S26[10]



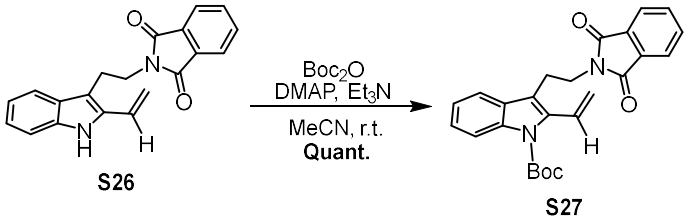
To a solution of **S25**[8] (748 mg, 1.80 mmol) and $Pd(PPh_3)_4$ (23.4 mg, 0.0202 mmol) in benzene (15 mL) and ethanol (4.5 mL) was added 2 M Na_2CO_3 aqueous solution (0.90 mL) and vinyl pinacolborane (0.370 mL, 2.17 mmol) and the solution was bubbled under argon gas for 10 min. After stirring at 80 °C under reflux for 17 h, the reaction mixture was cooled to r.t., added sat. $NaHCO_3$ aqueous solution, and extracted with ethyl acetate. The combined organic extracts were washed with brine, dried over anhydrous Na_2SO_4, and concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **S26** (396 mg, 1.25 mmol, 70%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.06 (s, 1H), 7.85-7.81 (m, 2H), 7.72-7.69 (m, 3H), 7.29 (d, *J* = 7.8 Hz, 1H), 7.18 (ddd, *J* = 8.0, 7.2, 0.9 Hz, 1H), 7.10 (ddd *J* = 8.0, 7.2, 1.2 Hz, 1H), 6.89 (dd, *J* = 17.6, 11.2 Hz, 1H), 5.46 (d, *J* = 17.4 Hz, 1H), 5.24 (d, *J* = 11.4 Hz, 1H), 3.93-3.89 (m, 2H), 3.18-3.14 (m, 2H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 168.3, 136.1, 133.8, 133.0, 132.2, 128.6, 125.1, 123.2, 123.1, 119.9, 119.0, 111.9, 111.8, 110.6, 38.5, 23.2 ppm.

HRMS (ESI): *m/z* calcd for $C_{20}H_{16}N_2O_2$ $[M + Na]^+$: 339.1104; found: 339.1114.

Synthesis of compound S27



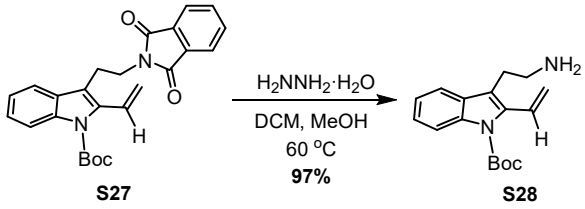
To a solution of **S26** (151 mg, 0.362 mmol) and *N*,*N*-dimethyl-4-aminopyridine (4.61 mg, 0.0377 mmol) in acetonitrile (1.45 mL) was added triethylamine (0.0610 mL, 0.438 mmol) and Boc_2O (0.113 mL, 0.467 mmol). After stirring at r.t. for 30 min, the reaction mixture was concentrated *in vacuo.* The resulting residue was purified by silica-gel chromatography to afford **S27** (187 mg, 0.362 mmol, quant.).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.09-8.07 (m, 1H), 7.87-7.83 (m, 2H), 7.77-7.69 (m, 3H), 7.31-7.24 (m, 2H), 6.93 (dd, *J* = 17.9, 11.4 Hz, 1H), 5.63 (dd, *J* = 17.9, 1.4 Hz, 1H), 5.54 (dd, *J* = 11.4, 1.4 Hz, 1H), 3.94-3.90 (m, 2H), 3.14-3.10 (m, 2H), 1.66 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 168.2, 150.5, 135.9, 135.5, 133.9, 132.2, 129.8, 128.6, 124.6, 123.2, 122.9, 118.9, 117.7, 116.1, 115.5, 84.1, 38.0, 28.2, 24.2 ppm.

HRMS (ESI): *m/z* calcd for $C_{25}H_{24}N_2O_4$ $[M + Na]^+$: 439.1628; found: 439.1629.

Synthesis of compound S28



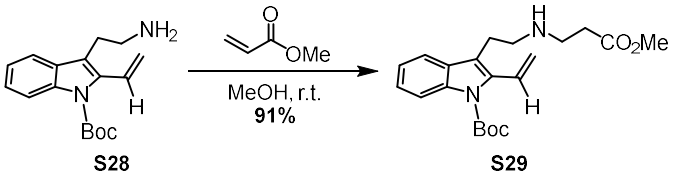
To a solution of **S27** (273 mg, 0.0655 mmol) in methanol (6.55 mL) and dichloromethane (6.55 mL) was added hydrazine monohydrate (0.160 mL, 3.28 mmol). After stirring at 60 ºC under reflux for 21 h, the reaction mixture was cooled to r.t., filtered, concentrated *in vacuo*, dissolved in dichloromethane and sat. $NaHCO_3$ aqueous solution, and extracted with dichloromethane. The combined organic extracts were dried with anhydrous Na_2SO_4 and concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **S28** (182 mg, 0.636 mmol, 97%)

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.10 (d, *J* = 8.2 Hz, 1H), 7.55 (d, *J* = 7.8 Hz, 1H), 7.31-7.27 (m, 1H), 7.23 (ddd, *J* = 7.6, 6.0, 1.1 Hz, 1H), 6.95 (dd, *J* = 17.4, 11.4 Hz, 1H), 5.49-5.48 (m, 1H), 5.45 (dd, *J* = 9.6, 1.8 Hz, 1H), 3.03-2.92 (m, 4H), 1.67 (s, 9H), 1.31 (s, 2H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 150.5, 135.5, 130.2, 129.1, 124.4, 122.5, 118.9, 117.9, 117.3, 115.5, 83.9, 42.8, 28.9, 28.2 ppm.

HRMS (ESI): *m/z* calcd for $C_{17}H_{22}N_2O_2$ $[M + H]^+$: 287.1754; found: 287.1714.

Synthesis of compound S29



S28 S29

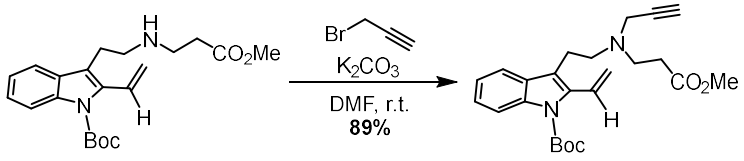
To a solution of **S28** (280 mg, 0.978 mmol) in methanol (2.0 mL) was dropwisely added methyl acrylate (0.0950 mL, 1.03 mmol) in methanol (2.9 mL) over 1 h. After stirring at r.t. for 3 h, the reaction mixture was concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **S29** (331 mg, 0.889 mmol, 91%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.10-8.08 (m, 1H), 7.55 (d, *J* = 7.3 Hz, 1H), 7.29 (ddd, *J* = 8.8, 6.4, 1.2 Hz, 1H), 7.23 (ddd, *J* = 8.8, 6.4, 1.1 Hz, 1H), 6.97-6.90 (m, 1H), 5.48 (m, 1H), 5.45 (dd, *J* = 5.5, 1.8 Hz, 1H), 3.66 (s, 3H), 3.00-2.89 (m, 6H), 2.53-2.50 (m, 2H), 1.67 (s, 9H), 1.57 (s, 1H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 173.1, 150.5, 135.5, 135.4, 130.1, 129.0, 124.4, 122.6, 118.9, 117.9, 117.4, 115.5, 83.9, 51.5, 50.0, 45.0, 34.6, 28.2, 25.4 ppm.

HRMS (ESI): *m/z* calcd for $C_{21}H_{28}N_2O_4$ $[M + Na]^+$: 395.1941; found: 395.1980.

Synthesis of compound S30



S29 S30

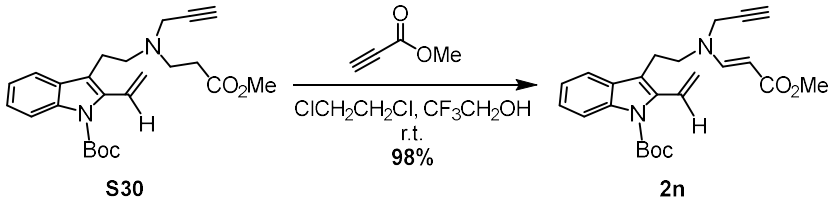
To a solution of **S29** (177 mg, 0.475 mmol) and anhydrous K_2CO_3 (73.0 mg, 0.528 mmol) in *N*,*N*-dimethylformamide (1.2 mL) was added propargyl bromide (0.0378 mL, 0.499 mmol). After stirring at r.t. for 2 h, the reaction mixture was filtered, added water, and extracted with ethyl acetate. The combined organic extracts were washed with brine, dried over anhydrous Na_2SO_4, and concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **S30** (173 mg, 0.421 mmol, 89%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.09 (d, *J* = 7.8 Hz, 1H), 7.57-7.55 (m, 1H), 7.29 (ddd, *J* = 8.4, 7.2, 1.4 Hz, 1H), 7.24 (ddd, *J* = 8.4, 6.4, 1.4 Hz, 1H), 6.94 (dd, *J* = 17.4, 11.4 Hz, 1H), 5.48 (d, *J* = 0.9 Hz, 1H), 5.45 (dd, *J* = 8.2, 1.8 Hz, 1H), 3.68 (s, 3H), 3.54 (d, *J* = 2.3 Hz, 2H), 2.95-2.90 (m, 4H), 2.81-2.77 (m, 2H), 2.50 (t, *J* = 7.3 Hz, 2H), 2.22 (t, *J* = 2.3 Hz, 1H), 1.67 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 172.7, 150.5, 135.6, 135.2, 130.1, 129.0, 124.4, 122.6, 118.8, 117.9, 117.2, 115.5, 83.9, 78.3, 73.3, 53.6, 51.6, 49.4, 42.0, 33.0, 28.2, 23.3 ppm.

HRMS (ESI): *m/z* calcd for $C_{24}H_{30}N_2O_4$ $[M + Na]^+$: 433.2098; found: 433.2135.

Synthesis of compound 2n



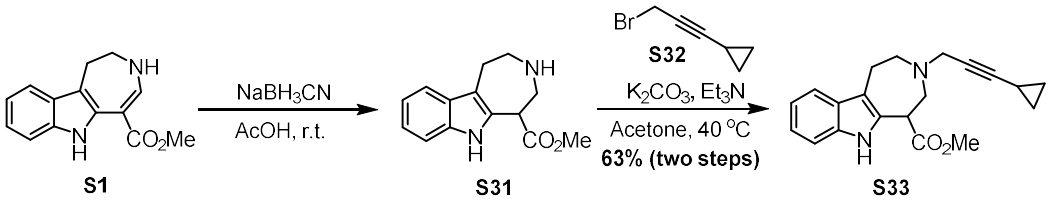
To a solution of **S30** (161 mg, 0.392 mmol) in 1,2-dichloroethane (1.0 mL) and 2,2,2-trifluoroethanol (1.0 mL) was added methyl propiolate (0.0350 mL, 0.392 mmol). After stirring at r.t. for 6 h, the reaction mixture was then concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **2n** (157 mg, 0.386 mmol, 98%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.11-8.09 (m, 1H), 7.53-7.51 (m, 1H), 7.44 (d, *J* = 13.3 Hz, 1H), 7.31 (ddd, *J* = 8.8, 6.4, 1.5 Hz, 1H), 7.26 (ddd, *J* = 8.8, 7.2, 1.2 Hz, 1H), 6.93 (dd, *J* = 17.6, 11.2 Hz, 1H), 5.52 (dd, *J* = 11.2, 1.6 Hz, 1H), 5.42 (dd, *J* = 17.6, 1.6 Hz, 1H), 4.79 (d, *J* = 13.3 Hz, 1H), 3.86 (d, *J* = 2.3 Hz, 2H), 3.69 (s, 3H), 3.50-3.46 (m, 2H), 3.12-3.08 (m, 2H), 2.33 (t, *J* = 2.5 Hz, 1H), 1.67 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 169.6, 150.5, 150.3, 135.8, 135.5, 129.5, 129.2, 124.7, 122.9, 118.4, 117.6, 116.0, 115.7, 86.7, 84.2, 77.6, 73.6, 50.7, 28.2 ppm.

HRMS (ESI): *m/z* calcd for $C_{24}H_{28}N_2O_4$ $[M + Na]^+$: 431.1941; found: 431.1938.

Synthesis of compound S33



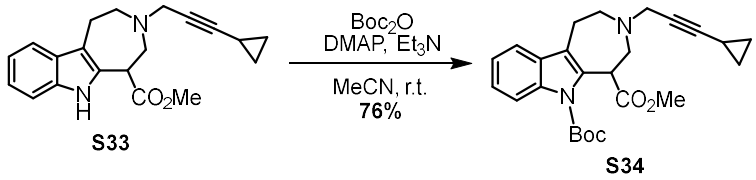
To a solution of **S1** (244 mg, 1.01 mmol) in acetic acid (3.4 mL) was added $NaBH_3CN$ (133 mg, 2.12 mmol) portionwise. After stirring at r.t. for 2.5 h, the reaction mixture was quenched with 12 M HCl until gas evolution has stopped, basified with 25% NH_3 aqueous solution at 0 °C, and extracted with dichloromethane. The combined organic extracts were washed with sat. $NaHCO_3$ aqueous solution, dried over anhydrous Na_2SO_4, and concentrated *in vacuo*. The resulting residue was used in the next step without further purification. To a solution of crude **S31** and anhydrous K_2CO_3 (167 mg, 1.20 mmol) in acetone (4.0 mL) was added triethylamine (0.195 mL, 1.40 mmol) and cyclopropane propargyl bromide **S32** (0.200 mL, 1.30 mmol). After stirring at 40 °C for 1 h, the reaction mixture was filtered, concentrated *in vacuo*, added ethyl acetate and water, and extracted with ethyl acetate. The combined organic extracts were washed with sat. NH_4Cl aqueous solution and brine, dried over anhydrous Na_2SO_4 and concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **S33** (202 mg, 0.627 mmol, 63% for two steps).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.42 (s, 1H), 7.50 (d, *J* = 7.8 Hz, 1H), 7.31 (d, *J* = 8.2 Hz, 1H), 7.15 (ddd, *J* = 8.4, 6.4, 1.6 Hz, 1H), 7.10 (ddd, *J* = 8.8, 5.6, 0.9 Hz, 1H), 4.08 (d, *J* = 5.0 Hz, 1H), 3.78 (s, 3H), 3.51 (s, 2H), 3.33-3.16 (m, 2H), 2.98-2.92 (m, 4H), 1.28-1.20 (m, 1H), 0.78-0.62 (m, 4H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 172.3, 134.8, 132.0, 128.4, 121.6, 119.3, 118.0, 113.7, 110.7, 56.7, 55.3, 52.4, 49.2, 45.8, 45.5, 24.3, 8.2, -0.6 ppm.

HRMS (ESI): *m/z* calcd for $C_{20}H_{22}N_2O_2$ $[M + H]^+$: 323.1754; found: 323.1723.

Synthesis of compound S34



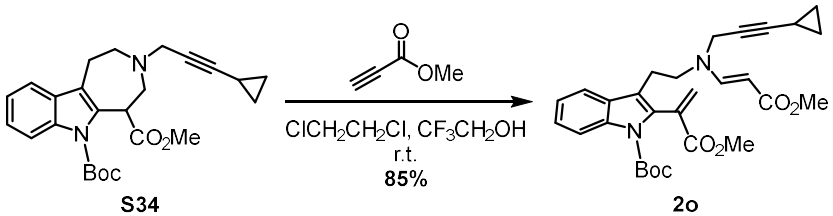
To a solution of **S33** (184 mg, 0.571 mmol) and *N*,*N*-dimethyl-4-aminopyridine (8.25 mg, 0.0675 mmol) in acetonitrile (2.3 mL) was added triethylamine (0.095 mL, 0.685 mmol) and Boc_2O (0.160 mL, 0.685 mmol). After stirring at r.t. for 1 h, the reaction mixture was concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **S34** (182 mg, 0.431 mmol, 76%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.04 (dd, *J* = 7.3, 1.4 Hz, 1H), 7.47-7.45 (m, 1H), 7.30-7.22 (m, 2H), 4.94 (dd, *J* = 5.2, 4.8 Hz, 1H), 3.72 (s, 3H), 3.63-3.58 (m, 1H), 3.44 (d, *J* = 0.9 Hz, 2H), 3.09-2.98 (m, 2H), 2.91-2.83 (m, 2H), 2.65 (ddd, *J* = 14.0, 9.2, 2.1 Hz, 1H), 1.64 (s, 9H), 1.24-1.19 (m, 1H), 0.77-0.62 (m, 4H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 172.0, 150.7, 135.5, 134.5, 129.7, 124.0, 122.4, 121.2, 118.0, 115.6, 88.3, 84.0, 70.3, 56.6, 54.2, 52.0, 49.7, 46.0, 28.2, 23.9, 8.2, -0.6 ppm

HRMS (ESI): *m/z* calcd for $C_{25}H_{30}N_2O_4$ $[M + H]^+$: 423.2279; found: 423.2256.

Synthesis of compound 2o



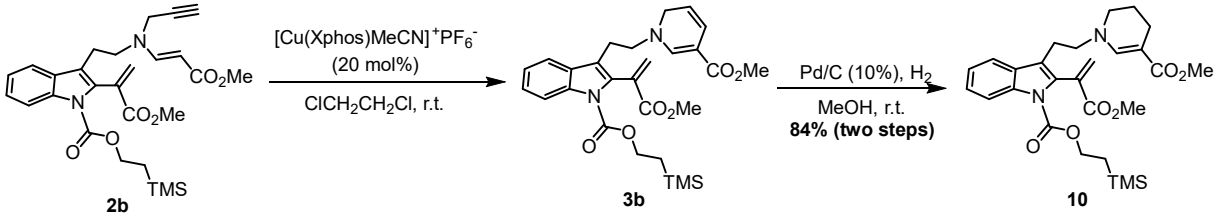
To a solution of **S34** (161 mg, 0.381 mmol) in 1,2-dichloroethane (1.0 mL) and 2,2,2-trifluoroethanol (1.0 mL) was added methyl propiolate (0.0780 mL, 0.876 mmol). After stirring at r.t. for 3.5 h, the reaction mixture was then concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **2o** (164 mg, 0.324 mmol, 85%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.14 (d, *J* = 8.2 Hz, 1H), 7.58 (d, *J* = 7.8 Hz, 1H), 7.41-7.28 (m, 3H), 6.65 (d, *J* = 1.4 Hz, 1H), 5.80 (d, *J* = 1.4 Hz, 1H), 4.68 (d, *J* = 13.3 Hz, 1H), 3.73 (t, *J* = 7.6 Hz, 5H), 3.68 (s, 3H), 3.41 (t, *J* = 7.6 Hz, 2H), 2.97 (br, 2H), 1.60 (s, 9H), 1.23-1.18 (m, 1H), 0.78-0.73 (m, 2H), 0.66-0.62 (m, 2H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 169.8, 166.1, 150.6, 150.0, 135.6, 133.9, 132.6, 129.0, 128.0, 125.1, 124.5, 122.9, 118.8, 117.7, 115.8, 103.3, 89.2, 85.9, 84.5, 68.9, 52.2, 50.6, 28.2, 28.0, 8.1, -0.6 ppm.

HRMS (ESI): *m/z* calcd for $C_{29}H_{34}N_2O_6$ $[M + H]^+$: 507.2490; found: 507.2459.

Synthesis of compound 10



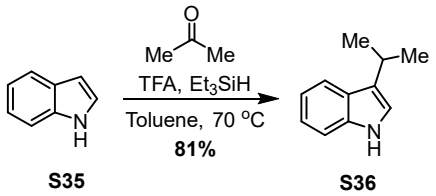
To a solution of **2b** (100 mg, 0.196 mmol) in 1,2-dichloroethane (2.0 mL) was added $[Cu(xantphos)CH_3CN)]^+PF_6^-$ (32.6 mg, 0.0393 mmol). After stirring at r.t. for 2 h, the reaction mixture was concentrated *in vacuo*. The resulting residue was used in the next step without further purification. To crude **3b** was added Pd/C (55.0 mg, 0.0517 mmol, 10% w/w), methanol (2.5 mL), and purged with H_2 gas. After stirring at r.t. for 6 h, the reaction mixture was filtered through a pad of celite and concentrated *in vacuo.* The resulting residue was purified by silica-gel chromatography to afford **10** (84.0 mg, 0.164 mmol, 84% for two steps).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.17 (d, *J* = 8.2 Hz, 1H), 7.53 (d, *J* = 7.3 Hz, 1H), 7.38-7.34 (m, 1H), 7.29 (t, *J* = 7.3 Hz, 2H), 6.62 (d, *J* = 1.4 Hz, 1H), 5.78 (d, *J* = 1.4 Hz, 1H), 4.46-4.41 (m, 2H), 3.74 (s, 3H), 3.66 (s, 3H), 3.32 (t, *J* = 7.3 Hz, 2H), 3.06 (t, *J* = 5.7 Hz, 2H), 2.91 (br, 2H), 2.23 (t, *J* = 6.2 Hz, 2H), 1.78-1.72 (m, 2H), 1.20-1.15 (m, 2H), 0.07 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 168.9, 166.2, 151.5, 145.4, 135.5, 133.9, 132.5, 129.2, 128.1, 125.2, 123.0, 118.8, 118.2, 115.9, 94.5, 77.3, 77.0, 76.7, 66.0, 55.9, 52.2, 50.5, 46.3, 24.3, 21.2, 19.9, 17.5, -1.6 ppm.

HRMS (ESI): *m/z* calcd for $C_{27}H_{36}N_2O_6Si$ $[M+H^+]$: 513.2416; found: 513.2371.

Synthesis of compound S36



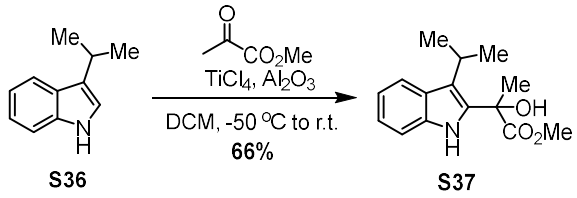
To a solution of trifluoroacetic acid (1.46 mL, 19.2 mmol) and triethylsilane (6.10 mL, 38.4 mmol) in toluene (8.0 mL) warmed to 70 °C, a solution of indole **S35** (1.51 g, 12.9 mmol) and acetone (1.4 mL, 19.2 mmol) in toluene (5.0 mL) was slowly added. After stirring at 70 °C for 1 h, the reaction mixture was cooled to 0 °C, added sat. $NaHCO_3$ aqueous solution, and extracted with ethyl acetate. The combined organic extracts were washed with brine, dried over anhydrous Na_2SO_4, and concentrated *in vacuo*. The resulting residue was purified by silica-gel chromatography to afford **S36** (1.65 g, 10.4 mmol, 81%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.78 (br, 1H), 7.75 (d, *J* = 7.8 Hz, 1H), 7.37 (d, *J* = 7.8 Hz, 1H), 7.26 (t, *J* = 7.2, 1H), 7.19 (t, *J* = 8.0 Hz, 1H), 6.96 (s, 1H), 3.34-3.24 (m, 1H), 1.45 (d, *J* = 6.9 Hz, 6H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 136.6, 126.8, 124.0, 121.8, 119.4, 119.2, 119.0, 111.1, 25.5, 23.3 ppm.

HRMS (ESI): *m/z* calcd for $C_{11}H_{13}N$ $[M + Na]^+$: 182.0940; found: 182.0956.

Synthesis of compound S37[11]



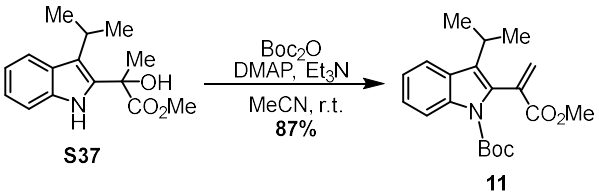
To a solution of methyl pyruvate (0.290 mL, 3.14 mmol) in dichloromethane (15 mL) cooled to -50 °C was added $TiCl_4$ (0.350 mL, 3.14 mmol) and stirred for 1 h. The resulting mixture was then added to a solution of **S36** (508 mg, 3.19 mmol) and Al_2O_3 (1.29 g, 12.6 mmol) in dichloromethane (16 mL) at -50 °C over 10 min. After stirring at -50 °C for 1 h, the reaction mixture was quenched with sat. NH_4Cl aqueous solution, warmed to r.t., filtered, and extracted with dichloromethane. The combined organic extracts were dried over anhydrous Na_2SO_4 and concentrated *in vacuo.* The resulting residue was purified by silica-gel chromatography to afford **S37** (540 mg, 2.07 mmol, 66%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.46 (s, 1H), 7.77 (d, *J* = 7.3 Hz, 1H), 7.34 (d, *J* = 8.2 Hz, 1H), 7.16 (ddd, *J* = 8.4, 6.8, 1.2 Hz, 1H), 7.07 (ddd, *J* = 8.0, 6.8, 1.3 Hz, 1H), 3.95 (s, 1H), 3.83 (s, 3H), 3.55-3.44 (m, 1H), 1.90 (s, 3H), 1.44 (dd, *J* = 8.0, 7.1 Hz, 6H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 175.1, 134.6, 131.7, 127.5, 121.7, 121.2, 118.8, 118.5, 111.3, 73.2, 53.6, 26.4, 25.9, 22.8, 22.4 ppm.

HRMS (ESI): *m/z* calcd for $C_{15}H_{19}NO_3$ $[M + Na]^+$: 284.1257; found: 284.1216.

Synthesis of compound 11



To a solution of **S37** (411 mg, 1.57 mmol) in acetonitrile (16 mL) was added *N*,*N*-dimethyl-4-aminopyridine (18.8 mg, 0.154 mmol), triethylamine (0.660 mL, 4.72 mmol), and Boc_2O (1.10 mL, 4.72 mmol). After stirring at r.t. for 19.5 h, the reaction mixture was concentrated *in vacuo.* The resulting residue was purified by silica-gel chromatography to afford **11** (467 mg, 1.36 mmol, 87%).

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.17 (d, *J* = 8.2 Hz, 1H), 7.75 (d, *J* = 8.2 Hz, 1H), 7.31 (ddd, *J* =8.0, 7.6, 0.8 Hz, 1H), 7.22 (t, *J* = 7.3 Hz, 1H), 6.63 (d, *J* = 1.8 Hz, 1H), 5.72 (d, *J* = 1.8 Hz, 1H), 3.73 (s, 3H), 3.20-3.09 (m, 1H), 1.59 (s, 9H), 1.40 (d, *J* = 6.9 Hz, 6H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 166.5, 150.2, 136.2, 134.3, 130.1, 128.2, 128.1, 127.0, 124.3, 122.1, 120.8, 115.8, 84.1, 52.1, 28.0, 26.0, 22.4 ppm.

HRMS (ESI): *m/z* calcd for $C_{15}H_{17}NO_2$ $[M + Na]^+$: 366.1676; found: 366.1626.

3. Optimisation of photoreaction conditions

3.1 Batch conditions

Representative procedure (Table S5, entry 1)

A solution of **2b** (10.0 mg, 19.6 μmol) and $[Cu(dppf)(CH_3CN)_2]^+PF_6^-$ (3.80 mg, 0.00392 mmol) in degassed 1,2-dichloroethane (0.49 mL) was stirred at r.t. for 3 h. Then, the reaction mixture was concentrated *in vacuo* and the resulting residue of **3b** was immediately dissolved in degassed toluene (0.49 mL). After irradiating the reaction solution with 370 nm Kessil lamp (30 W, distance: 7.0 cm) for 90 min, the reaction mixture was concentrated *in vacuo*. The NMR yield was determined using triphenylmethane as an internal standard.

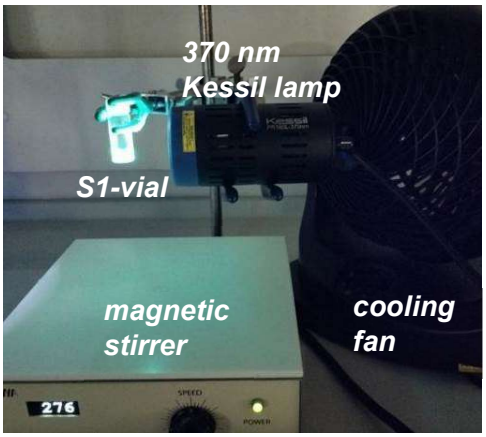
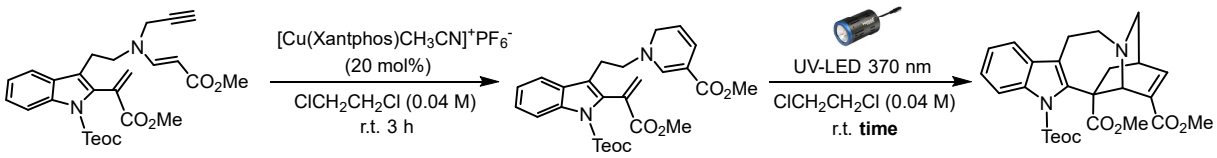


Figure S1. Batch photoreaction setup.

Table S1. Optimisation of reaction time

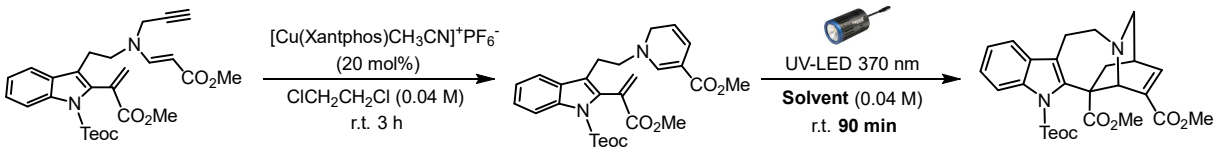


2b **3b** **5b**

Entry	Reaction time	Yield of **5b**[a]
1	60 min	37%
2	**90 min**	**42% (41%)**[b]
3	120 min	40%
4	180 min	32%
5	240 min	30%[b]

[a] Yield of **5b** was determined as a two-step yield by ^{1}H NMR spectroscopic analyses using triphenylmethane as an internal standard. [b] Isolated yield over two steps.

Table S2. Optimisation of reaction solvent

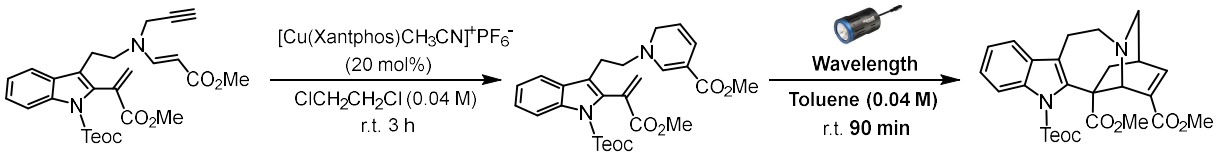


2b **3b** **5b**

Entry	Solvent	Yield of **5b**[a]
1	1,2-dichloroethane	42%
2	acetonitrile	27%
3	**toluene**	**43%**
4	benzene	41%
5	tetrahydrofuran	37%
6	methanol	37%
7	dichloromethane	39%

[a] Yield of **5b** was determined as a two-step yield by ^{1}H NMR spectroscopic analyses using triphenylmethane as an internal standard.

Table S3. Optimisation of irradiation wavelength

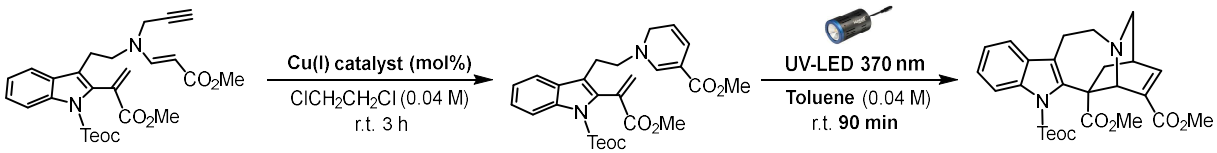


2b **3b** **5b**

Entry	Wavelength	Yield of **5b**[a]
1[b]	280 nm	4%
2	**370 nm**	**43%**
3	427 nm	30%
4	456 nm	trace

[a] Yield of **5b** was determined as a two-step yield by ^{1}H NMR spectroscopic analyses using triphenylmethane as an internal standard. [b] Reaction was irradiated for 3 h.

Table S4. Optimisation of Cu(I) catalyst

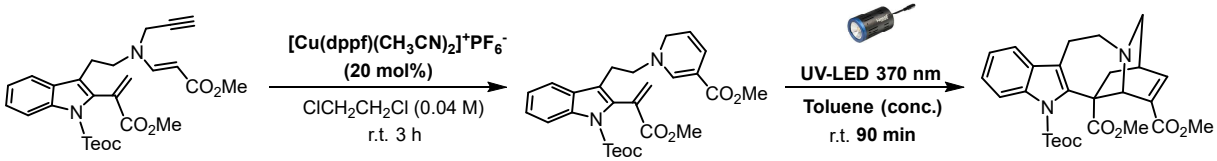


2b **3b** **5b**

Entry	Cu(I) catalyst	Yield of **5b**[a]
1	$[Cu(Xantphos)CH_3CN]^+PF_6^-$ (20 mol%)	41%
2	**$[Cu(dppf)(CH_3CN)_2]^+PF_6^-$ (20 mol%)**	**55% (49%)**[b]
3	$[Cu(dppf)(CH_3CN)_2]^+PF_6^-$ (10 mol%)	54%
4	$[Cu(dppf)(CH_3CN)_2]^+PF_6^-$ (50 mol%)	54%

[a] Yield of **5b** was determined as a two-step yield by ^{1}H NMR spectroscopic analyses using triphenylmethane as an internal standard. [b] Isolated yield over two steps.

Table S5. Optimisation of reaction solvent concentration



2b **3b** **5b**

Entry	Concentration	Yield of **5b**[a]
1	**0.04 M**	**55%**
2	0.01 M	48%
3	0.005 M	51%

[a] Yield of **5b** was determined as a two-step yield by ^{1}H NMR spectroscopic analyses using triphenylmethane as an internal standard.

3.2 Flow conditions

Representative procedure

A solution of **2** (1.0 equiv.) and $[Cu(dppf)(CH_3CN)_2]^+PF_6^-$ (0.2 equiv.) in degassed 1,2-dichloroethane (0.04 M) was stirred at r.t. for 3 h. Then, an additional amount of 1,2-dichloroethane (total 0.01 M) was added. The reaction mixture of **3** was drawn into a gastight syringe and eluted through a photo-flow reactor using a syringe pump under 370 nm irradiation (30 W, distance: 7.0 cm) with a residence time of 25 min (Figure S2). The resulting solution was concentrated *in vacuo* and purified by silica-gel chromatography to afford **5**.

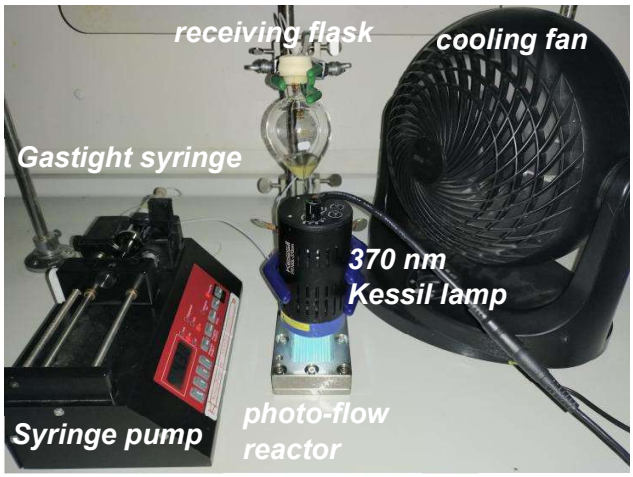
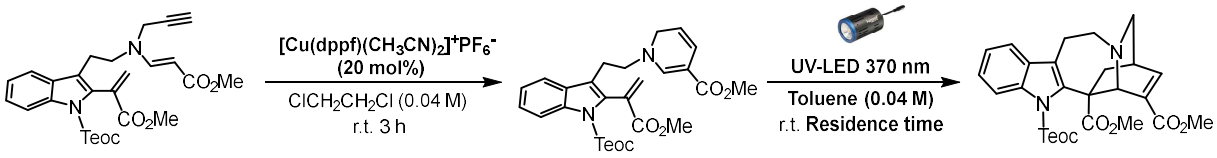


Figure S2. Photo-flow reaction setup.

Table S6. Optimisation of photoreaction under flow conditions



2b **3b** **5b**

Entry	Variations from batch	Residence time	Yield of **5b**[a]
1	none	15 min	24%
2	none	20 min	41%
3	none	25 min	35%
4	0.01 M	15 min	53%
5[b]	0.01 M	20 min	55%
6	0.01 M	25 min	61% (51%)[c]
7	**0.01 M of $ClCH_2CH_2Cl$**	**25 min**	**74% (72%)[c]**

[a] Yield of **5b** was determined as a two-step yield by ^1H NMR spectroscopic analyses using triphenylmethane as an internal standard. [b] Reaction was irradiated for 3 h.
[c] Isolated yield over two steps.

Scale-up reaction under flow conditions

A solution of **2b** (316 mg, 0.619 mmol) and $[Cu(dppf)(CH_3CN)_2]^+PF_6^-$ (115 mg, 0.123 mmol) in degassed 1,2-dichloroethane (15.5 mL) was stirred at r.t. for 3 h. Then, an additional amount of 1,2-dichloroethane (46.4 mL) was added. The reaction mixture of **3b** was eluted through a photo-flow reactor using a TACMINA Q Smoothflow pump under 370 nm irradiation (30 W, distance: 7.0 cm) with a residence time of 25 min. The resulting solution was concentrated *in vacuo* and purified by silica-gel chromatography to afford **5b** (213 mg, 0.417 mmol, 68%).

4. List of ene-yne substrates

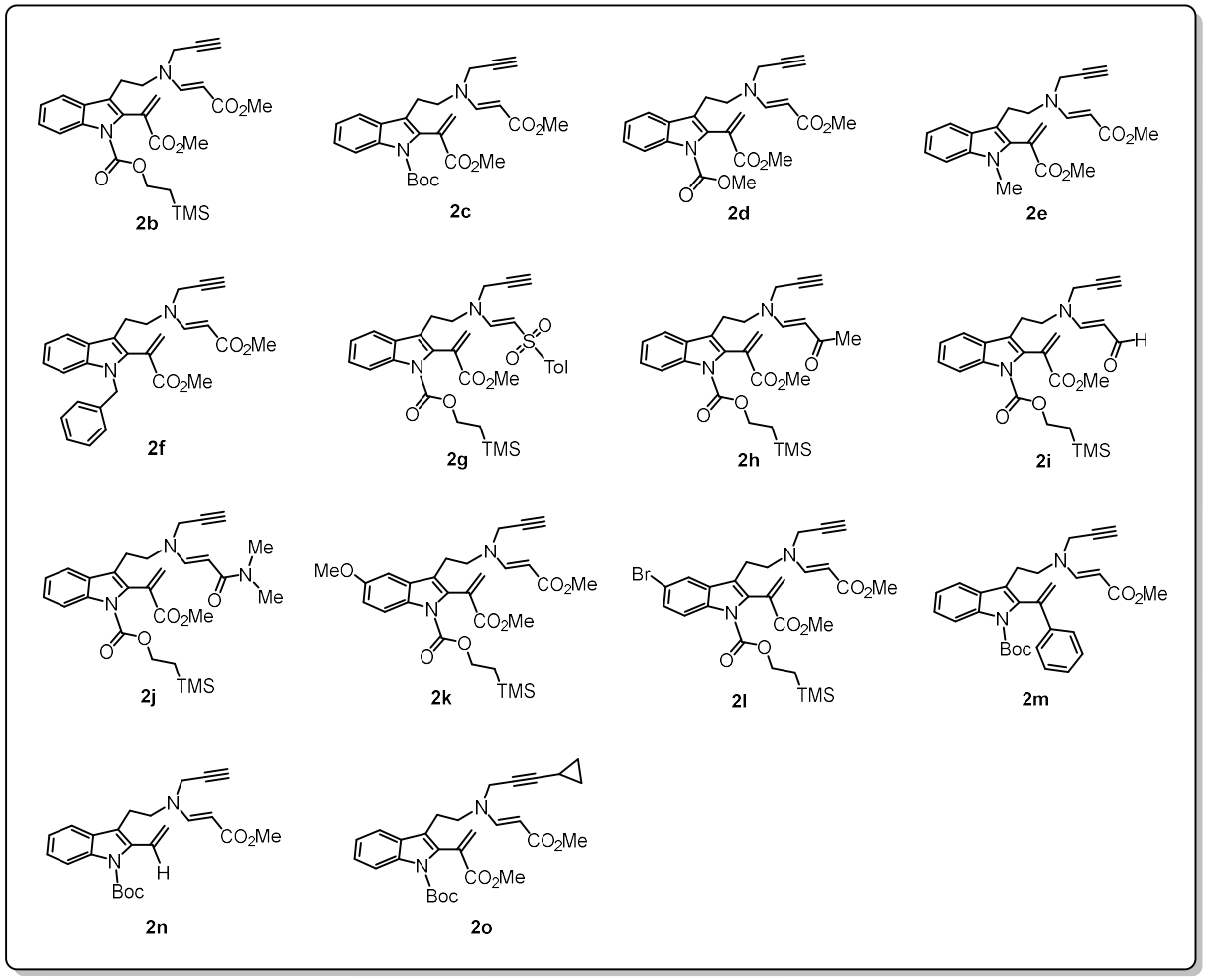


Figure S3. List of prepared ene-yne substrates for Cu(I)-catalysed DHP-formation followed by photo-mediated cyclisation reaction.

5. Representative photoreaction procedures

5.1 Photoreaction from substrate 2b under flow conditions

A solution of **2c** (50.0 mg, 0.0979 mmol) and $[Cu(dppf)(CH_3CN)_2]^+PF_6^-$ (18.7 mg, 0.0197 mmol) in degassed 1,2-dichloroethane (2.45 mL) was stirred at r.t. for 3 h. Then, an additional amount of 1,2-dichloroethane (7.34 mL) was added. The reaction mixture of **3b** was drawn into a gastight syringe and eluted through a photo-flow reactor using a syringe pump under 370 nm irradiation (30 W, distance: 7.0 cm) with a residence time of 25 min. The resulting solution was concentrated *in vacuo* and purified by silica-gel chromatography to afford **5b** (33.5 mg, 0.0656 mmol, 72%).

5.2 Photoreaction from substrate 2d under flow conditions

A solution of **2d** (27.7 mg, 0.0647 mmol) and $[Cu(dppf)(CH_3CN)_2]^+PF_6^-$ (12.9 mg, 0.0134 mmol) in degassed 1,2-dichloroethane (1.62 mL) was stirred at r.t. for 3 h. Then, an additional amount of 1,2-dichloroethane (4.85 mL) was added. The reaction mixture of **3d** was drawn into a gastight syringe and eluted through a photo-flow reactor using a syringe pump under 370 nm irradiation (30 W, distance: 7.0 cm) with a residence time of 25 min. The resulting solution was concentrated *in vacuo* and purified by silica-gel chromatography to afford **5d** (21.2 mg, 0.045 mmol, 77%).

5.3 Photoreaction from substrate 2n under flow conditions

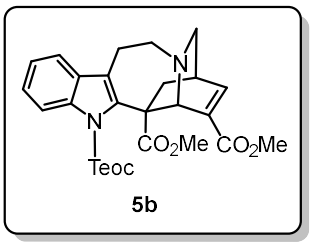
A solution of **2n** (113 mg, 0.277 mmol) and $[Cu(dppf)(CH_3CN)_2]^+PF_6^-$ (54.0 mg, 0.563 mmol) in degassed 1,2-dichloroethane (6.92 mL) was stirred at r.t. for 3 h. Then, an additional amount of 1,2-dichloroethane (20.8 mL) was added. The reaction mixture of **3n** was drawn into a gastight syringe and eluted through a photo-flow reactor using a syringe pump under 370 nm irradiation (30 W, distance: 7.0 cm) with a residence time of 25 min. The resulting solution was concentrated *in vacuo* and purified by silica-gel chromatography to afford **5n** (9.80 mg, 0.0240 mmol, 9%), **8n** (55.8 mg, 0.136 mmol), and **9n** (43.0 mg, 0.105 mmol, 38%).

5.4 Re-analysis of photoreaction from substrate 2c under flow conditions

A solution of **2c** (143 mg, 0.307 mmol) and $[Cu(dppf)(CH_3CN)_2]^+PF_6^-$ (60.4 mg, 0.629 mmol) in degassed 1,2-dichloroethane (7.60 mL) was stirred at r.t. for 3 h. Then, an additional amount of 1,2-dichloroethane (23.1 mL) was added. The reaction mixture of **3c** was drawn into a gastight syringe and eluted through a photo-flow reactor using a syringe pump under 370 nm irradiation (30 W, distance: 7.0 cm) with a residence time of 25 min. The resulting solution was concentrated *in vacuo* and purified by silica-gel chromatography to afford **5c** (7.00 mg, 0.0150 mmol, 5%), **9c** (101 mg, 0.216 mmol, 71%)

6. Physical data of *iboga*- and *unnatural*-type scaffolds

Product 5b



5b

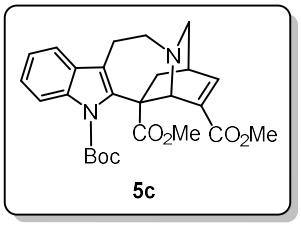
Isolated yield: 72%

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.11 (d, *J* = 8.2 Hz, 1H), 7.50 (d, *J* = 7.3 Hz, 1H), 7.40 (d, *J* = 6.4 Hz, 1H), 7.32-7.28 (m, 1H), 7.24 (s, 1H), 5.03 (s, 1H), 4.38 (m, 2H), 3.75 (s, 3H), 3.63-3.60 (m, 1H), 3.49 (s, 3H), 3.37-3.29 (m, 1H), 3.05-2.97 (m, 2H), 2.90-2.83 (m, 2H), 2.71 (dt, *J* = 13.3, 2.5 Hz, 1H), 2.54 (d, *J* = 8.2 Hz, 1H), 1.81 (dd, *J* = 13.3, 2.7 Hz, 1H), 1.21-1.15 (m, 2H), 0.06 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 172.7, 164.1, 151.6, 143.4, 138.1, 138.0, 135.8, 129.5, 124.5, 122.7, 119.0, 118.3, 115.8, 65.7, 55.7, 53.5, 53.0, 52.2, 52.0, 51.6, 37.9, 32.9, 21.9, 17.7, -1.6 ppm.

HRMS (ESI): *m/z* calcd for $C_{27}H_{34}N_2O_6Si$ $[M + H]^+$: 511.2259; found: 511.2254.

Product 5c



5c

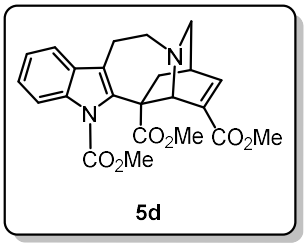
Isolated yield: 71%

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.94 (dd, *J* = 6.9, 1.8 Hz, 1H), 7.52-7.50 (m, 1H), 7.41 (d, *J* = 6.4 Hz, 1H), 7.30-7.23 (m, 2H), 5.02 (s, 1H), 3.76 (s, 3H), 3.67-3.63 (m, 1H), 3.48 (s, 3H), 3.38-3.29 (m, 1H), 3.06-2.77 (m, 5H), 2.57 (d, *J* = 8.2 Hz, 1H), 1.82 (dd, *J* = 13.5, 2.5 Hz, 1H), 1.63 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 172.4, 164.1, 150.4, 143.4, 138.5, 138.0, 135.2, 129.5, 124.2, 122.3, 118.3, 115.6, 84.1, 55.5, 53.6, 53.1, 52.3, 52.1, 51.6, 37.9, 32.9, 28.1, 21.8 ppm.

HRMS (ESI): *m/z* calcd for $C_{26}H_{30}N_2O_6$ $[M + H]^+$: 467.2177; found: 467.2168.

Product 5d



5d

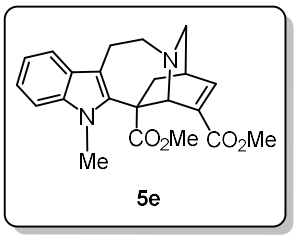
Isolated yield: 77%

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.12 (dd, *J* = 7.3, 0.9 Hz, 1H), 7.53-7.51 (m, 1H), 7.41 (dd, *J* = 6.8, 0.8 Hz, 1H), 7.35-7.27 (m, 2H), 5.05 (s, 1H), 3.88 (s, 3H), 3.76 (s, 3H), 3.65-3.61 (m, 1H), 3.50 (s, 3H), 3.39-3.31 (m, 1H), 3.08-2.85 (m, 4H), 2.67 (dt, *J* = 13.3, 2.7 Hz, 1H), 2.56 (d, *J* = 8.2 Hz, 1H), 1.82 (dd, *J* = 13.3, 2.7 Hz, 1H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 172.8, 164.1, 151.8, 143.4, 138.1, 137.8, 135.9, 129.5, 124.8, 122.9, 119.4, 118.3, 115.6, 55.8, 53.5, 53.1, 53.0, 52.3, 52.0, 51.7, 37.7, 32.9, 21.9 ppm.

HRMS (ESI): *m/z* calcd for $C_{23}H_{24}N_2O_6$ $[M + H]^+$: 425.1707; found: 425.1700.

Product 5e



5e

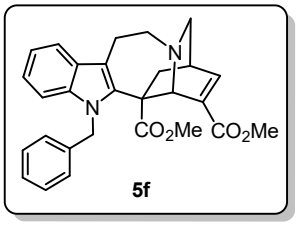
Isolated yield: 32%

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.56 (dd, *J* = 8.0, 0.8 Hz, 1H), 7.44 (dd, *J* = 6.4, 0.9 Hz, 1H), 7.23-7.20 (m, 2H), 7.16-7.12 (m, 1H), 5.25 (s, 1H), 3.76 (s, 3H), 3.73-3.69 (m, 1H), 3.54 (s, 3H), 3.48 (s, 3H), 3.42-3.33 (m, 1H), 3.12-3.04 (m, 2H), 2.96-2.90 (m, 3H), 2.58 (d, *J* = 7.8 Hz, 1H), 1.82 (dd, *J* = 13.3, 3.7 Hz, 1H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 173.3, 163.9, 144.8, 138.2, 137.3, 136.9, 127.3, 121.6, 119.1, 118.4, 111.7, 108.7, 54.6, 54.2, 53.0, 52.6, 51.7, 35.6, 32.7, 30.9, 21.9 ppm.

HRMS (ESI): *m/z* calcd for $C_{22}H_{24}N_2O_4$ $[M + Na]^+$: 403.1628; found: 403.1627.

Product 5f



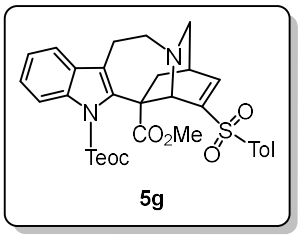
Isolated yield: 36%

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.61 (dd, *J* = 6.9, 1.8 Hz, 1H), 7.39 (dd, *J* = 6.8, 1.2 Hz, 1H), 7.24-7.09 (m, 5H), 6.99 (dd, *J* = 6.9, 1.4 Hz, 1H), 6.81-6.78 (m, 2H), 5.30 (s, 1H), 5.28-5.09 (m, 2H), 3.75-3.70 (m, 4H), 3.67-3.58 (m, 1H), 3.49-3.40 (m, 1H), 3.15-3.08 (m, 2H), 3.02 (s, 3H), 2.97-2.89 (m, 3H), 2.57 (d, *J* = 8.7 Hz, 1H), 1.81-1.77 (m, 1H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 172.4, 163.7, 145.0, 136.9, 136.8, 128.7, 128.5, 128.3, 127.5, 126.9, 125.8, 122.0, 119.4, 118.4, 112.4, 110.0, 55.0, 54.4, 53.9, 53.0, 52.1, 51.7, 47.6, 35.4, 32.6, 21.9 ppm.

HRMS (ESI): *m/z* calcd for $C_{28}H_{28}N_2O_4$ $[M + Na]^+$: 479.1941; found: 479.1944.

Product 5g



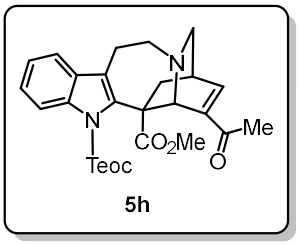
Isolated yield: 52%

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.10 (d, *J* = 7.3 Hz, 1H), 7.86 (d, *J* = 8.2 Hz, 2H), 7.49 (d, *J* = 6.9 Hz, 1H), 7.35-7.25 (m, 4H), 6.99 (d, *J* = 6.0 Hz, 1H), 4.91 (s, 1H), 4.41 (t, *J* = 8.9 Hz, 2H), 3.59 (s, 3H), 3.39 (dd, *J* = 11.7, 3.9 Hz, 1H), 3.23-3.14 (m, 1H), 3.01-2.95 (m, 2H), 2.88-2.75 (m, 3H), 2.51 (d, *J* = 8.2 Hz, 1H), 2.45 (s, 3H), 1.82 (dd, *J* = 13.3, 2.7 Hz, 1H), 1.23-1.18 (m, 2H), 0.08 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 171.8, 151.6, 146.0, 144.2, 140.8, 137.8, 136.4, 135.6, 129.6, 129.4, 128.4, 124.7, 122.7, 118.7, 118.3, 115.9, 65.9, 56.3, 53.3, 52.7, 51.3, 37.5, 33.0, 22.0, 21.6, 17.7, -1.5 ppm.

HRMS (ESI): *m/z* calcd for $C_{32}H_{38}N_2O_6SSi$ $[M + H]^+$: 607.2293; found: 607.2275.

Product 5h



5h

*cyclisation of the 1,6-DHP ring (**2h→3h**) required gentle heating at 45 °C.

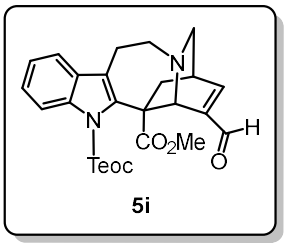
Isolated yield: 60%

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.11 (d, *J* = 7.3 Hz, 1H), 7.52 (d, *J* = 6.9 Hz, 1H), 7.34-7.27 (m, 3H), 5.22 (s, 1H), 4.42-4.37 (m, 2H), 3.64-3.59 (m, 1H), 3.45 (s, 3H), 3.43-3.34 (m, 1H), 3.10 (dt, *J* = 5.6, 2.7 Hz, 1H), 3.00 (dq, *J* = 15.9, 2.2 Hz, 1H), 2.90-2.83 (m, 2H), 2.72 (dt, *J* = 13.1, 2.9 Hz, 1H), 2.58 (d, *J* = 7.8 Hz, 1H), 2.34 (s, 3H), 1.83 (dd, *J* = 13.1, 3.0 Hz, 1H), 1.22-1.16 (m, 2H), 0.07 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 193.7, 172.7, 151.6, 146.6, 143.4, 138.1, 135.7, 129.5, 124.5, 122.7, 119.0, 118.3, 115.9, 65.7, 55.3, 53.7, 52.3, 52.0, 50.8, 38.1, 33.0, 24.3, 21.8, 17.7, -1.5 ppm.

HRMS (ESI): *m/z* calcd for $C_{27}H_{34}N_2O_5Si$ $[M + H]^+$: 495.2310; found: 495.2310.

Product 5i



5i

*cyclisation of the 1,6-DHP ring (**2i→3i**) required gentle heating at 60 °C.

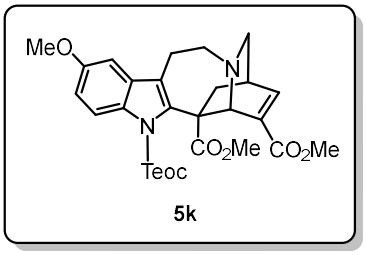
Isolated yield: 15%

^{1}H NMR (400 MHz, $CDCl_3$) δ 9.48 (s, 1H), 8.11 (d, *J* = 8.2 Hz, 1H), 7.52 (dd, *J* = 7.3, 0.9 Hz, 1H), 7.39 (d, *J* = 6.9 Hz, 1H), 7.31 (m, 2H), 5.12 (s, 1H), 4.42-4.38 (m, 2H), 3.65-3.62 (m, 1H), 3.47 (s, 3H), 3.41-3.33 (m, 1H), 3.15-2.77 (m, 5H), 2.63 (d, *J* = 7.3 Hz, 1H), 1.89 (dd, *J* = 13.5, 3.0 Hz, 1H), 1.26 (d, *J* = 5.0 Hz, 1H), 1.22-1.16 (m, 2H), 0.07 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 187.4, 172.5, 151.7, 151.3, 137.7, 135.7, 129.4, 124.7, 122.8, 119.1, 118.4, 115.9, 65.9, 55.3, 53.9, 52.4, 52.0, 50.2, 38.1, 33.4, 29.4, 21.7, 17.7, -1.5 ppm.

HRMS (ESI): *m/z* calcd for $C_{26}H_{32}N_2O_5Si$ $[M + H]^+$: 481.2153; found: 481.2117.

Product 5k



5k

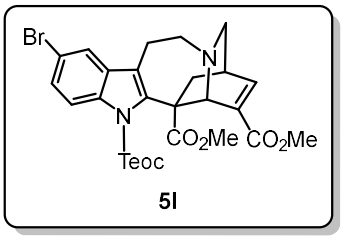
Isolated yield: 60%

^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (d, *J* = 9.2 Hz, 1H), 7.41 (d, *J* = 6.4 Hz, 1H), 7.00-6.90 (m, 2H), 5.04 (s, 1H), 4.38 (t, *J* = 8.7 Hz, 2H), 3.88 (s, 3H), 3.76 (s, 3H), 3.66-3.63 (m, 1H), 3.50 (s, 3H), 3.38-3.30 (m, 1H) 3.07 (d, *J* = 8.8 Hz, 1H), 2.90-2.85 (m, 3H), 2.72 (d, *J* = 13.2 Hz, 1H) 2.56 (d, *J* = 8.4 Hz, 1H), 1.82 (d, *J* = 13.3 Hz, 1H), 1.22-1.15 (m, 2H), 0.07 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 172.6, 164.1, 156.0, 151.5, 143.4, 138.6, 137.9, 130.3, 130.3, 118.9, 116.8, 113.0, 101.2, 65.6, 55.7, 55.6, 53.7, 52.9, 52.2, 52.1, 51.6, 37.8, 32.8, 29.6, 21.9, 17.7, -1.6 ppm.

HRMS (ESI): *m/z* calcd for $C_{28}H_{36}N_2O_7Si$ $[M + H]^+$: 541.2365; found: 541.2351.

Product 5l



5l

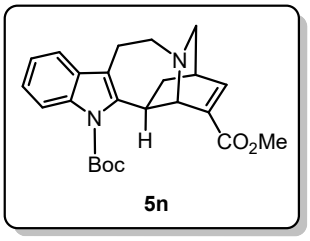
Isolated yield: 41%

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.99 (d, *J* = 8.7 Hz, 1H), 7.63 (d, *J* = 1.8 Hz, 1H), 7.41-7.37 (m, 2H), 5.02 (s, 1H), 4.41-4.36 (m, 2H), 3.76 (s, 3H), 3.65-3.62 (m, 1H), 3.50 (s, 3H), 3.36-3.28 (m, 1H), 3.06 (s, 1H), 2.93-2.86 (m, 3H), 2.71 (d, *J* = 13.3 Hz, 1H), 2.54 (d, *J* = 8.2 Hz, 1H), 1.82-1.78 (m, 1H), 1.21-1.15 (m, 2H), 0.06 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 172.4, 164.0, 151.3, 143.3, 139.2, 137.9, 134.5, 131.3, 127.3, 121.1, 118.3, 117.3, 116.1, 66.1, 55.6, 53.5, 52.9, 52.3, 51.9, 51.7, 37.8, 32.8, 21.8, 17.7, -1.6 ppm.

HRMS (ESI): *m/z* calcd for $C_{27}H_{33}N_2O_6SiBr$ $[M + H]^+$: 589.1364; found: 589.1324.

Product 5n



5n

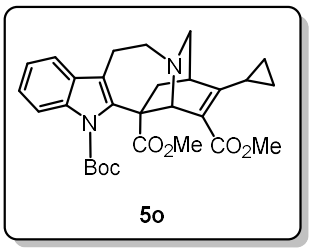
Isolated yield: 9%

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97-7.94 (m, 1H), 7.43-7.41 (m, 1H), 7.33 (d, *J* = 6.0 Hz, 1H), 7.24-7.20 (m, 2H), 4.30 (s, 1H), 3.76 (s, 3H), 3.66-3.63 (m, 1H), 3.49-3.28 (m, 3H), 3.09 (d, *J* = 8.8 Hz, 1H), 2.96-2.91 (m, 2H), 2.75 (dt, *J* = 15.9, 3.1 Hz, 1H), 2.26-2.18 (m, 1H), 1.73-1.65 (m, 1H), 1.64 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 164.0, 150.4, 142.7, 141.3, 140.8, 135.1, 130.1, 123.5, 122.3, 117.7, 117.4, 115.1, 83.8, 55.6, 52.4, 51.6, 48.2, 38.3, 31.9, 31.8, 28.3, 20.1 ppm.

HRMS (ESI): *m/z* calcd for $C_{24}H_{28}N_2O_4$ $[M + H]^+$: 409.2122; found: 409.2140.

Product 5o



5o

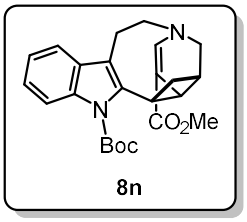
Isolated yield: 15%

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 (dd, *J* = 5.2, 1.2 Hz, 1H), 7.50 (dd, *J* = 6.6, 2.0 Hz, 1H), 7.30-7.24 (m, 2H), 5.04 (s, 1H), 3.74 (s, 3H), 3.67-3.63 (m, 1H), 3.48 (s, 3H), 3.33-3.25 (m, 1H), 3.15-3.08 (m, 1H), 3.02-2.97 (m, 2H), 2.82 (ddd, *J* = 13.2, 12.0, 3.2 Hz, 1H), 2.70 (dt, *J* = 13.3, 2.7 Hz, 1H), 2.52 (d, *J* = 7.3 Hz, 1H), 2.17 (br, 1H), 1.76 (dd, *J* = 13.7, 2.7 Hz, 1H), 1.63 (s, 9H), 0.96-0.93 (m, 2H), 0.91-0.85 (m, 1H), 0.66-0.63 (m, 1H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 172.5, 165.4, 160.9, 150.4, 138.9, 135.2, 129.6, 128.8, 124.1, 122.3, 118.6, 118.3, 115.7, 84.0, 56.0, 55.3, 54.4, 52.8, 52.0, 51.1, 37.8, 31.4, 28.1, 21.8, 11.7, 6.8, 6.0 ppm.

HRMS (ESI): *m/z* calcd for $C_{29}H_{34}N_2O_6$ $[M + H]^+$: 507.2490; found: 507.2449.

Product 8n



8n

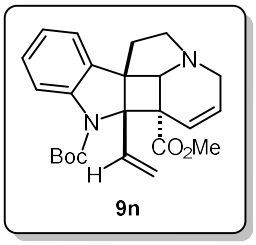
Isolated yield: 49%

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.92-7.90 (m, 1H), 7.47-7.44 (m, 1H), 7.23-7.17 (m, 2H), 6.88 (s, 1H), 5.36-5.30 (m, 1H), 4.28 (t, *J* = 8.8 Hz, 1H), 3.58-3.54 (m, 1H), 3.49 (s, 3H), 3.24-2.92 (m, 5H), 2.76 (d, *J* = 12.8 Hz, 1H), 2.63-2.55 (m, 1H), 2.14 (dt, *J* = 13.7, 3.0 Hz, 1H), 1.67 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 167.4, 151.0, 150.3, 138.9, 136.0, 129.6, 123.8, 122.1, 117.0, 116.5, 115.6, 106.4, 83.7, 55.4, 50.4, 49.7, 44.2, 41.0, 38.9, 28.2, 25.6, 22.5 ppm.

HRMS (ESI): *m/z* calcd for $C_{24}H_{28}N_2O_4$ $[M + Na]^+$: 431.1941; found: 431.1955.

Product 9n



9n

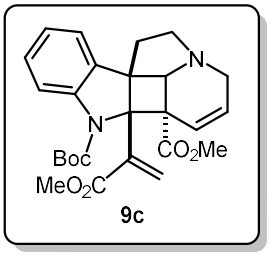
Isolated yield: 38%

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.93 (d, *J* = 7.8 Hz, 1H), 7.24 (t, *J* = 7.3 Hz, 1H), 7.17 (d, *J* = 6.9 Hz, 1H), 7.01 (t, *J* = 7.6 Hz, 1H), 6.31 (dd, *J* = 17.4, 11.0 Hz, 1H), 6.21-6.10 (m, 2H), 5.29 (d, *J* = 11.0 Hz, 1H), 5.14 (d, *J* = 17.4 Hz, 1H), 4.04 (s, 1H), 3.52 (s, 3H), 3.40 (d, *J* = 17.4 Hz, 1H), 3.24-3.16 (m, 2H), 3.03-2.99 (m, 1H), 2.25-2.16 (m, 1H), 2.05-2.00 (m, 1H), 1.44 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 171.5, 151.0, 145.9, 133.3, 131.3, 128.6, 128.1, 125.7, 122.9, 122.8, 116.6, 113.9, 81.2, 74.1, 66.5, 61.8, 53.0, 52.0, 49.7, 44.2, 32.3, 28.0 ppm.

HRMS (ESI): *m/z* calcd for $C_{24}H_{28}N_2O_4$ $[M + Na]^+$: 431.1941; found: 431.1987.

Product 9c



9c

Isolated yield: 5%

^{1}H NMR (400 MHz, $CDCl_3$) δ 7.79 (br, 1H), 7.22-7.16 (m, 2H), 7.00 (ddd, *J* = 8.0, 7.2, 0.9 Hz, 1H), 6.58-6.57 (m, 2H), 6.31 (s, 1H), 6.05 (m, 1H), 4.19 (s, 1H), 3.55 (s, 3H), 3.45 (s, 3H), 3.41 (t, *J* = 2.1 Hz, 1H), 3.27 (d, *J* = 5.0 Hz, 1H), 3.23-3.17 (m, 2H), 2.42-2.34 (m, 1H), 2.09-2.04 (m, 1H), 1.48 (s, 9H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 171.2, 166.8, 132.8, 128.2, 128.2, 126.0, 125.6, 122.7, 121.5, 114.3, 81.9, 75.3, 66.2, 53.8, 52.3, 51.8, 51.5, 44.5, 31.7, 29.7, 27.9 ppm.

HRMS (ESI): *m/z* calcd for $C_{26}H_{30}N_2O_6$ $[M + H]^+$: 467.2177; found: 467.2157.

7. X-ray crystallographic analysis

7.1 Crystallographic data of 5h

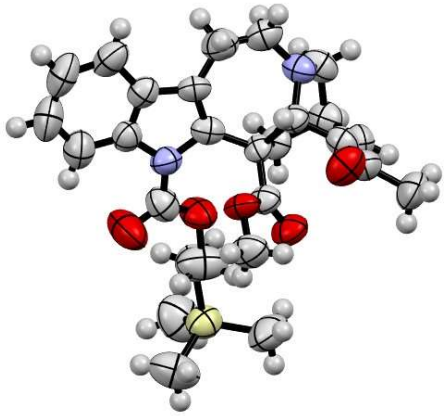


Figure S4. X-ray crystallographic structure of **5h** (ellipsoids set at 50% probability).

Table S7. Crystallographic data of **5h**.

Empirical formula	$C_{27}H_{34}N_2O_5Si$
Formula weight	494.65
Temperature/K	300.00
Crystal system	monoclinic
Space group	$P2_1/n$
a/Å	21.073(6)
b/Å	6.658(2)
c/Å	21.467(6)
α /°	90
β /°	117.635(6)
g /°	90
Volume/Å^3	2668.5(14)
Z	4
Calculated density (g·cm^{-3})	1.231
Absorption coefficient (mm^{-1})	0.126
F(000)	1056.0

Crystal size/mm^3	0.509 x 0.11 x 0.048
Radiation	MoKα (λ = 0.71073)
2q range for data collection/°	3.698 to 52.286
Index ranges	$-26 \le h \le 26$, $-6 \le k \le 8$, $-25 \le l \le 26$
Reflections collected	24702
Independent reflections	5304 [R_{int} = 0.1940, R_{sigma} = 0.2084]
Data / restraints / parameters	5304 / 0 / 321
Final R indices [$I \ge 2s\ (I)$]	R_1 = 0.0879, wR_2 = 0.2275
Final R indexes [all data]	R_1 = 0.2993, wR_2 = 0.3378
Largest diff. Peak/hole / e Å^{-3}	0.23/-0.33
Deposit number CCDC	2333565

7.2 Crystallographic data of 8n

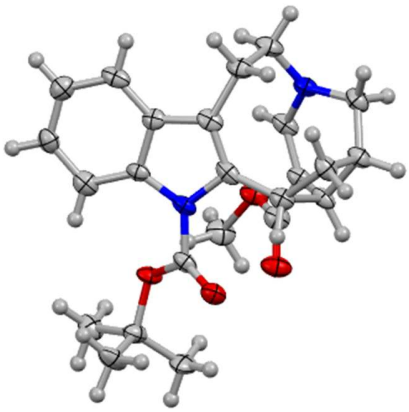


Figure S5. X-ray crystallographic structure of **8n** (ellipsoids set at 50% probability).

Table S8. Crystallographic data of **8n**.

Empirical formula	$C_{24}H_{28}N_2O_4$
Formula weight	408.08
Temperature/K	109.0
Crystal system	monoclinic
Space group	$P2_1/c$
a/Å	10.4706(18)
b/Å	11.081(2)
c/Å	18.106(3)
α /°	90
β /°	97.388(4)
g /°	90
Volume/Å^3	2083.3(7)
Z	4
Calculated density (g·cm^{-3})	1.302
Absorption coefficient (mm^{-1})	0.089
F(000)	872.0
Crystal size/mm^3	0.9 x 0.097 x 0.100

Radiation	MoKα (λ = 0.71073)
2q range for data collection/°	3.922 to 50.812
Index ranges	$-12 \le h \le 12$, $-12 \le k \le 13$, $-21 \le l \le 21$
Reflections collected	19090
Independent reflections	3845 [R_{int} = 0.1843, R_{sigma} = 0.1745]
Data / restraints / parameters	3845 / 0 / 275
Final *R* indices [$I \ge 2s(I)$]	R_1 = 0.0793, wR_2 = 0.1727
Final *R* indexes [all data]	R_1 = 0.1995, wR_2 = 0.2507
Largest diff. Peak/hole / e Å^{-3}	0.44/-0.32
Deposit number CCDC	2375152

7.3 Crystallographic data of 9n

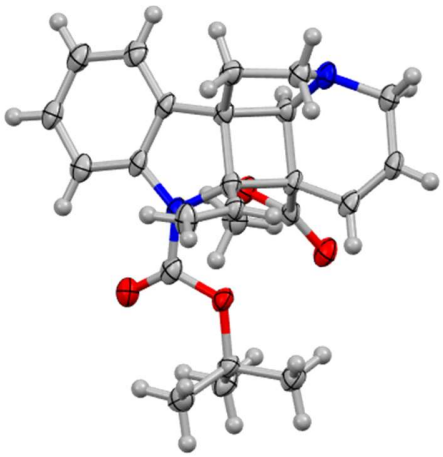


Figure S6. X-ray crystallographic structure of **9n** (ellipsoids set at 50% probability).

Table S9. Crystallographic data of **9n**.

Empirical formula	$C_{24}H_{28}N_2O_4$
Formula weight	408.08
Temperature/K	109.0
Crystal system	triclinic
Space group	P-1
a/Å	8.7113(16)
b/Å	11.4041(19)
c/Å	11.531(2)
α /°	77.946(5)
β /°	70.288(4)
g /°	71.509(4)
Volume/Å^3	1016.0(3)
Z	2
Calculated density (g·cm^{-3})	1.335
Absorption coefficient (mm^{-1})	0.091
F(000)	436.0
Crystal size/mm^3	0.037 x 0.064 x 0.131

Radiation	MoKα (λ = 0.71073)
2q range for data collection/°	3.776 to 50.906
Index ranges	$-10 \le h \le 10$, $-13 \le k \le 12$, $-13 \le l \le 13$
Reflections collected	23135
Independent reflections	3765 [R_{int} = 0.1533, R_{sigma} = 0.1236]
Data / restraints / parameters	3765 / 0 / 281
Final *R* indices [$I \ge 2s(I)$]	R_1 = 0.0747, wR_2 = 0.1643
Final *R* indexes [all data]	R_1 = 0.1577, wR_2 = 0.2156
Largest diff. Peak/hole / e Å^{-3}	0.34/-0.52
Deposit number CCDC	2375172

8. DFT computational modelling

Conformational search was carried out using Conformer Distribution (MMFF) and preliminarily refined by Semi-Empirical (PM6) method of calculation. Then, the ten lowest energy conformers were optimised by Hartree-Fock method using 6-31G* basis set. Finally, the three lowest energy conformers were optimised using DFT B3LYP-D3 (6-31+G*) level of theory to determine the lowest energy structure.

8.1 Calculated structure of compound 3d

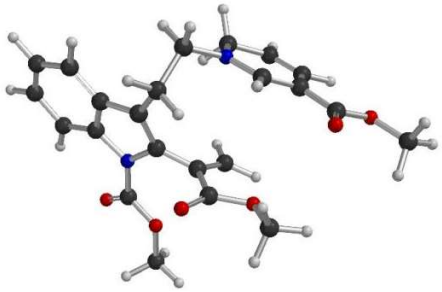


Figure S7. DFT computational model (B3LYP-D3, 6-31+G*) of **3d**.

Cartesian Coordinates (Angstroms)

	Atom	X	Y	Z
1	H1	0.1602698	-1.7758792	-4.4722039
2	C1	0.1761713	-2.5593642	-3.7199006
3	C4	0.2179038	-4.6126097	-1.8091168
4	C2	0.5051323	-3.8640021	-4.0936794
5	C6	-0.1265021	-2.2631424	-2.3719177
6	C5	-0.1107652	-3.2940051	-1.4295991
7	C3	0.5292984	-4.8765308	-3.1458592
8	H2	0.2270467	-5.4287935	-1.0917842
9	H3	0.7402040	-4.0859075	-5.1314374
10	H6	0.7820046	-5.8914255	-3.4445919
11	N1	-0.5238234	-2.7620973	-0.1951765
12	C8	-0.5783477	-1.3663395	-0.3432059
13	C9	-0.4652151	-1.0577013	-1.6939190
14	C7	-0.6319082	0.2919991	-2.3402642
15	H5	-1.1510896	0.1439262	-3.2965857
16	H7	-1.3040609	0.9163796	-1.7423320
17	C10	0.6783987	1.0379733	-2.6227477

18	H9	1.3679624	0.3913033	-3.1795788
19	H11	0.4639647	1.8908309	-3.2791306
20	N2	1.3242629	1.5477043	-1.4046176
21	C12	3.1756107	1.4958285	0.2225012
22	C13	1.3185821	3.0353133	0.5027316
23	C14	2.5850349	2.4705220	0.9358850
24	C15	0.7697610	2.5643878	-0.6308579
25	C16	2.6028721	0.9149122	-1.0455266
26	H12	4.1230742	1.0865517	0.5582000
27	H16	3.0479456	2.8482111	1.8411788
28	H19	-0.1754128	2.9500561	-1.0076632
29	H20	3.3238006	1.0638755	-1.8575522
30	H21	2.4597102	-0.1627797	-0.9103856
31	C11	-0.7252738	-0.4978692	0.7831367
32	C17	0.2999594	-0.3978222	1.6496333
33	H4	1.2223035	-0.9525836	1.5126710
34	H24	0.2602726	0.2587971	2.5126125
35	C18	-1.9795993	0.3089533	0.9416446
36	O3	-3.0052172	0.1041553	0.3062886
37	O4	-1.8079365	1.3038618	1.8532359
38	C21	-2.9217601	2.1892869	1.9640543
39	H10	-3.8013003	1.6525786	2.3328140
40	H27	-3.1320992	2.6657023	1.0012572
41	H28	-2.6635919	2.9691993	2.6858009
42	C22	0.5792724	4.0920495	1.2509663
43	O5	-0.5024855	4.5549012	0.9140541
44	O6	1.2723004	4.4614332	2.3618649
45	C25	0.6252600	5.4679305	3.1401910
46	H29	1.2594837	5.6885336	4.0032399
47	H33	0.5038647	6.3858296	2.5564804
48	H34	-0.3421220	5.1082821	3.5048998
49	C26	-0.8273486	-3.5496450	0.9486437
50	O1	-0.5432047	-4.7374159	1.0156091
51	O2	-1.4910429	-2.8310346	1.8905428
52	C29	-1.8684561	-3.5891792	3.0387233
53	H13	-2.3941597	-2.9219456	3.7273081
54	H35	-0.9822917	-3.9825582	3.5465345
55	H36	-2.5467130	-4.4006380	2.7569303

8.2 Calculated structure of compound 3n

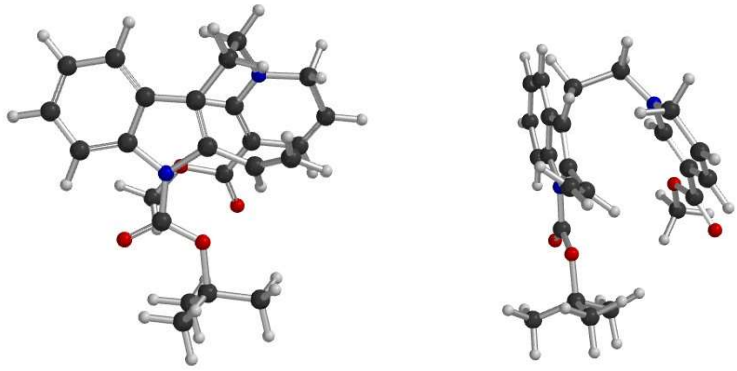


Figure S8. DFT computational model (B3LYP-D3, 6-31+G*) of **3n**.

Cartesian Coordinates (Angstroms)

	Atom	X	Y	Z
1	H1	1.6667628	1.7045377	-4.2878929
2	C1	1.3810381	2.2275784	-3.3788686
3	C4	0.6229427	3.5862787	-0.9936594
4	C2	1.0871907	3.5886222	-3.4003819
5	C6	1.2978555	1.5376378	-2.1600908
6	C5	0.9083962	2.2160974	-0.9821437
7	C3	0.7171852	4.2559945	-2.2174120
8	H2	0.3330432	4.1095510	-0.0940207
9	H3	1.1430470	4.1386425	-4.3363984
10	H6	0.4925271	5.3185878	-2.2531156
11	N1	0.8817670	1.2583964	0.0525240
12	C8	1.2694612	-0.0023305	-0.4892746
13	C9	1.5206212	0.1499491	-1.8319746
14	C10	0.5543834	1.5680009	1.3778382
15	O2	0.2136592	2.6891935	1.7199930
16	O1	0.6683803	0.5032811	2.1636084
17	C12	0.3625919	0.5570946	3.6189268
18	C13	1.3600591	1.4900053	4.3061115
19	H5	1.2361259	1.4067646	5.3915395
20	H16	2.3859690	1.1997786	4.0535123
21	H17	1.2010149	2.5304290	4.0143957
22	C14	-1.0933041	0.9737267	3.8283428
23	H14	-1.3491726	0.8419460	4.8857391

24	H18	-1.7573581	0.3397452	3.2310643
25	H19	-1.2554087	2.0177310	3.5552053
26	C15	0.5806271	-0.8953278	4.0433188
27	H15	-0.1057133	-1.5596958	3.5073209
28	H20	0.3955376	-0.9907245	5.1182676
29	H21	1.6086024	-1.2091966	3.8333506
30	C7	1.7649797	-0.9376565	-2.8448905
31	H7	2.2912937	-1.7842030	-2.4009972
32	H8	2.4017277	-0.5620929	-3.6553902
33	C11	0.4532653	-1.4550927	-3.4991628
34	H11	-0.0756415	-0.6293744	-3.9850924
35	H35	0.6984519	-2.1956776	-4.2682477
36	N2	-0.4495774	-2.0829157	-2.5353911
37	C17	-1.0429071	-3.9873819	-1.0658783
38	C18	-2.0142065	-1.7735147	-0.7377147
39	C19	-1.8653122	-3.1784123	-0.3758707
40	C20	-1.2818759	-1.3161642	-1.8141362
41	C21	-0.2120141	-3.5113361	-2.2323310
42	H9	-0.9265287	-5.0337189	-0.7946536
43	H23	-2.4344671	-3.5546174	0.4694592
44	H26	-1.3437754	-0.2817486	-2.1306326
45	H27	0.8600090	-3.6505253	-2.0208405
46	H28	-0.4258524	-4.0960825	-3.1412283
47	C16	-2.8195647	-0.8812998	0.0648352
48	O3	-3.4613598	-1.2147696	1.0667221
49	O4	-2.7975237	0.4141191	-0.3682374
50	C22	-3.5450258	1.3663070	0.4081276
51	H4	-3.4094989	2.3212186	-0.1014668
52	H12	-4.6050796	1.0971171	0.4360728
53	H13	-3.1528473	1.4210763	1.4274643
54	C25	1.2403873	-1.2656422	0.2609792
55	H22	0.3265442	-1.4777276	0.8080848
56	C23	2.2252580	-2.1737946	0.2510579
57	H10	3.1709414	-2.0025112	-0.2577804
58	H29	2.1023680	-3.1258738	0.7613138

9. Representative UV-Vis spectra

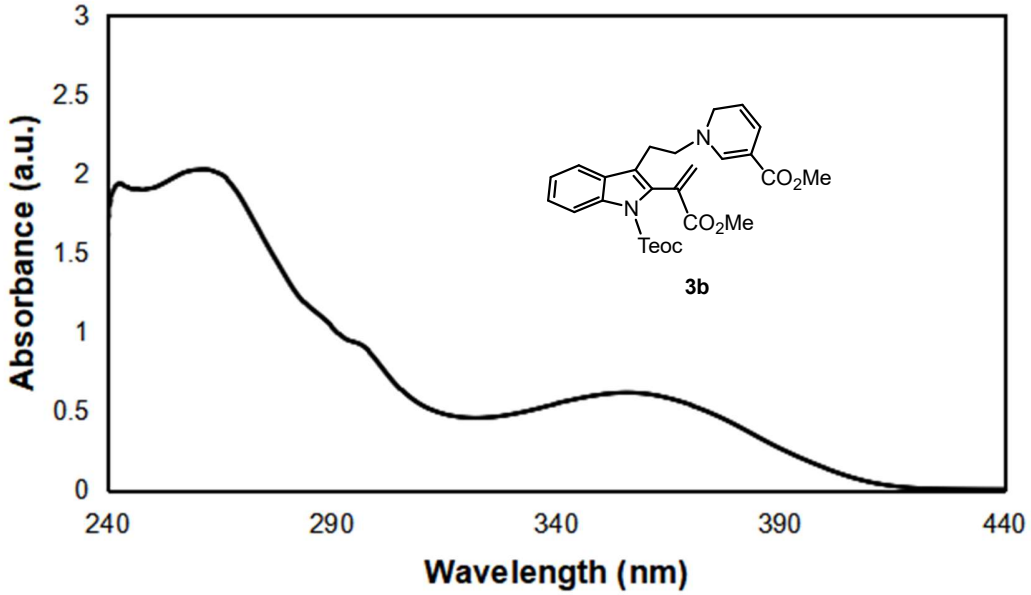


Figure S9. UV-Vis spectrum of **3b**. Characteristic UV-Vis absorption can be observed at 356 nm. Concentration = 0.100 mM in $CHCl_3$. $\varepsilon = 6.16 \times 10^3\ M^{-1}\ cm^{-1}$.

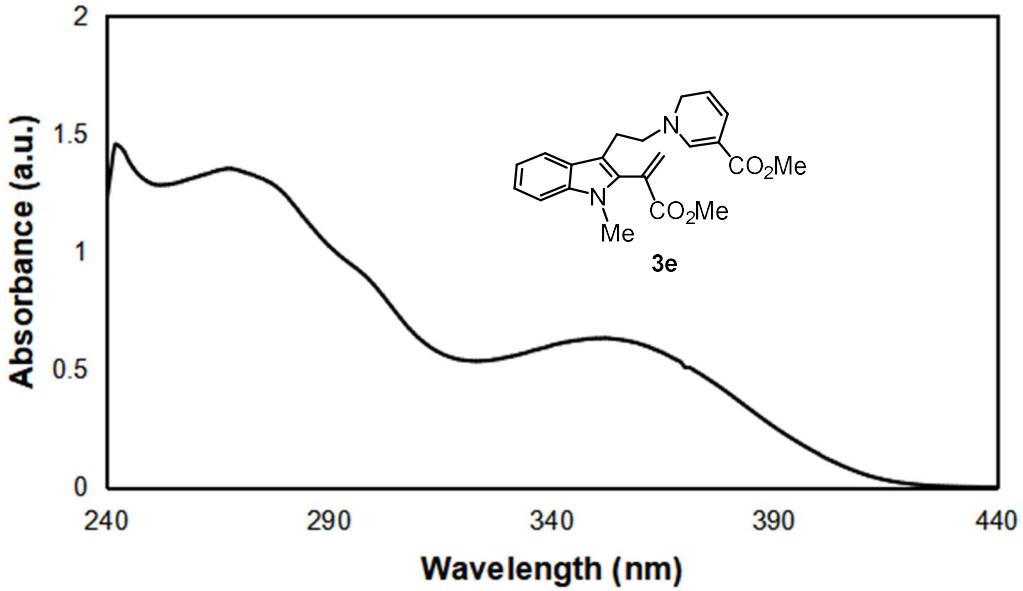


Figure S10. UV-Vis spectrum of **3e**. Characteristic UV-Vis absorption can be observed at 352 nm. Concentration = 0.100 mM in $CHCl_3$. $\varepsilon = 6.32 \times 10^3\ M^{-1}\ cm^{-1}$.

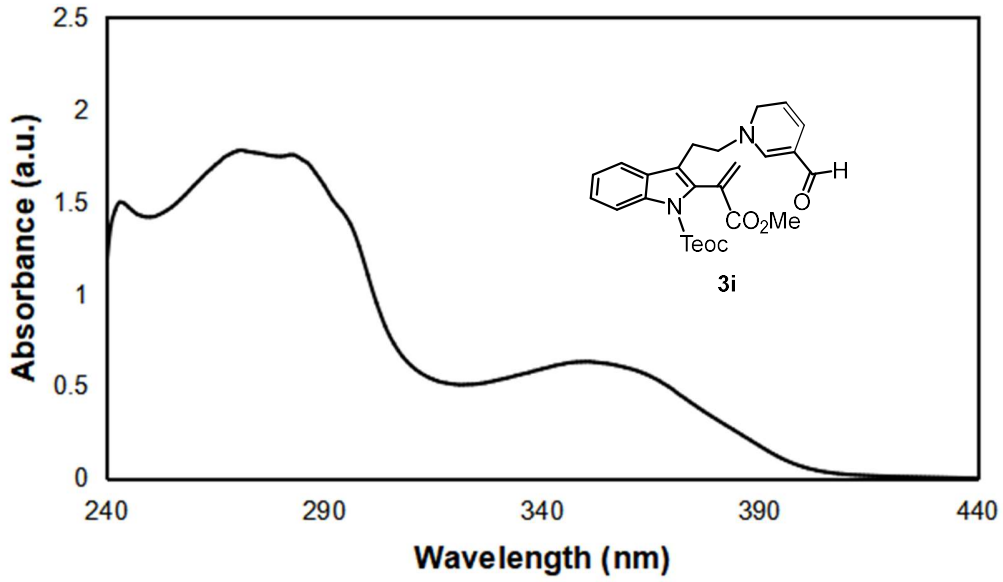


Figure S11. UV-Vis spectrum of **3i**. Characteristic UV-Vis absorption can be observed at 351 nm. Concentration = 0.100 mM in $CHCl_3$. $\varepsilon = 6.31 \times 10^3\ M^{-1}\ cm^{-1}$.

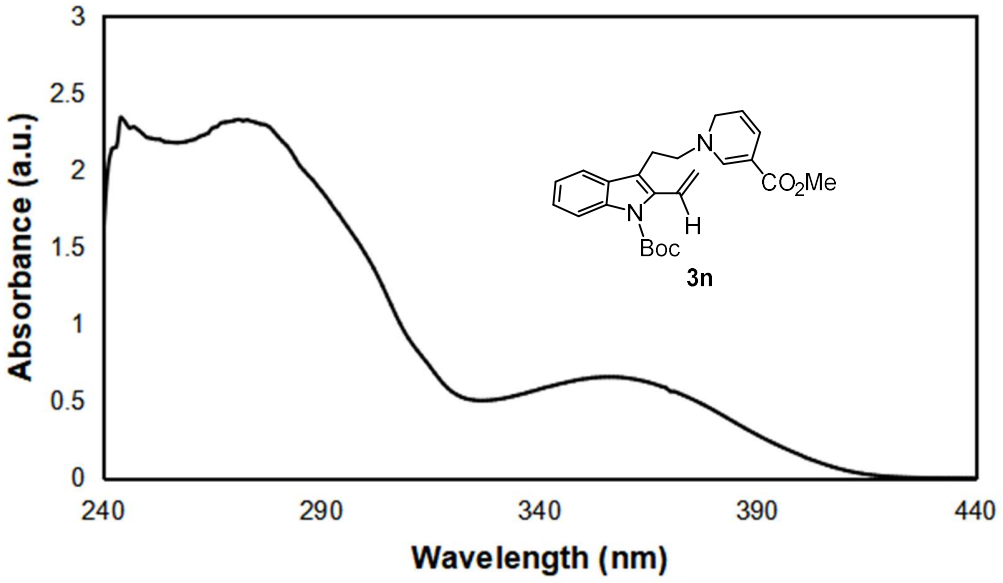


Figure S12. UV-Vis spectrum of **3n**. Characteristic UV-Vis absorption can be observed at 357 nm. Concentration = 0.100 mM in $CHCl_3$. $\varepsilon = 6.56 \times 10^3\ M^{-1}\ cm^{-1}$.

10. Mechanistic studies

10.1 UV-Vis spectral data

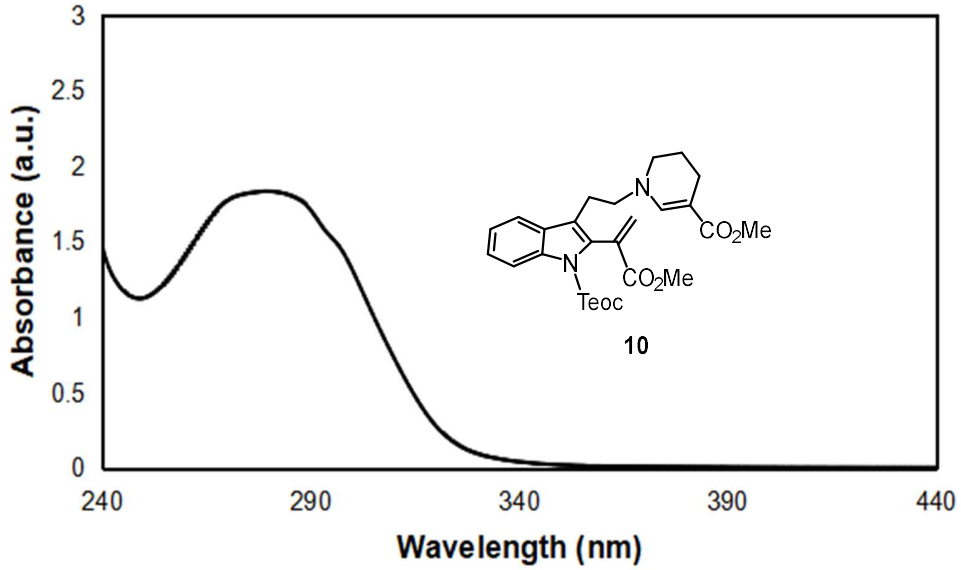


Figure S13. UV-Vis spectrum of **10**. The tetrahydropyridine (THP) unit does not exhibit UV-Vis absorption at around 360 nm. This strongly suggests that the characteristic absorption at around 360 nm is derived from the conjugated system of the 1,6-DHP ring. Concentration = 0.100 mM in $CHCl_3$.

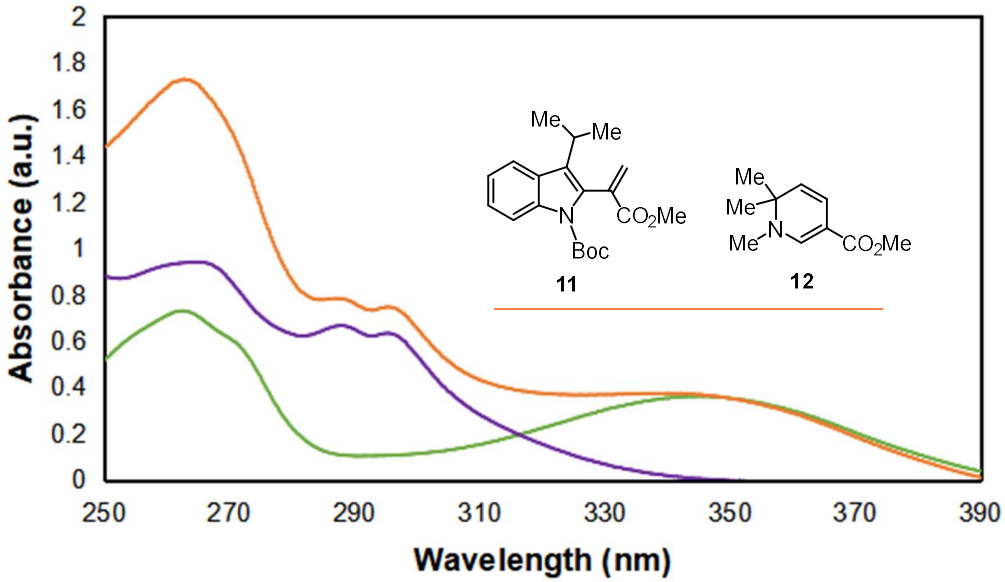


Figure S14. UV-Vis spectrum of **11** (purple), **12** (green), and mixture of **11** and **12** (orange). The lack of a shift in the UV absorption between substrates **11** and **12**, as well as their mixture, indicates that this reaction is unlikely to involve the formation of either an electron donor-acceptor (EDA) complex or a charge-transfer (CT) complex. Concentration = 0.075 mM in $CHCl_3$.

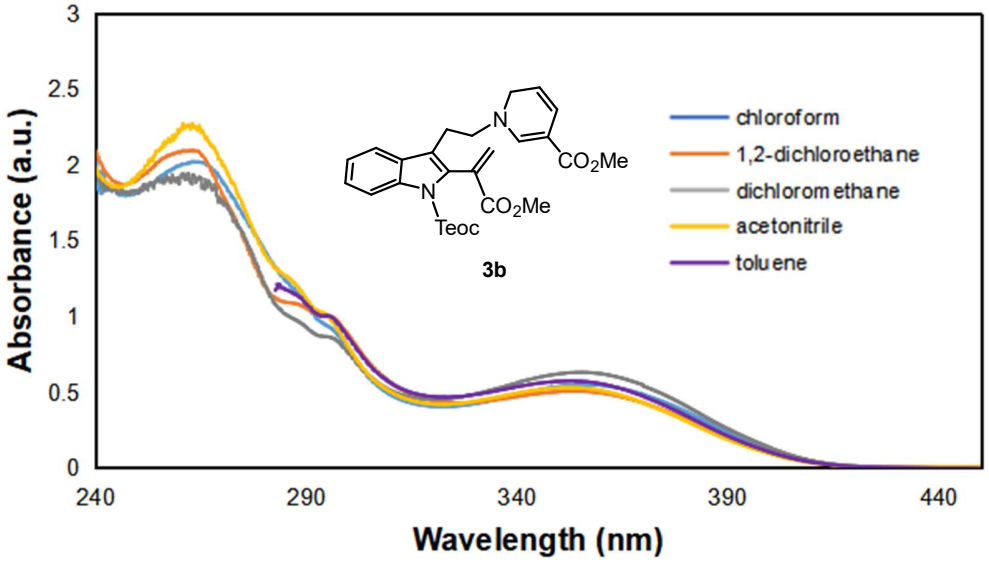


Figure S15. UV-Vis spectrum of **5b** in different solvents. The lack of a shift in the UV absorption indicates that there is no solvent dependency, and thus, it is unlikely to involve the formation of an EDA complex. Concentration = 0.100 mM.

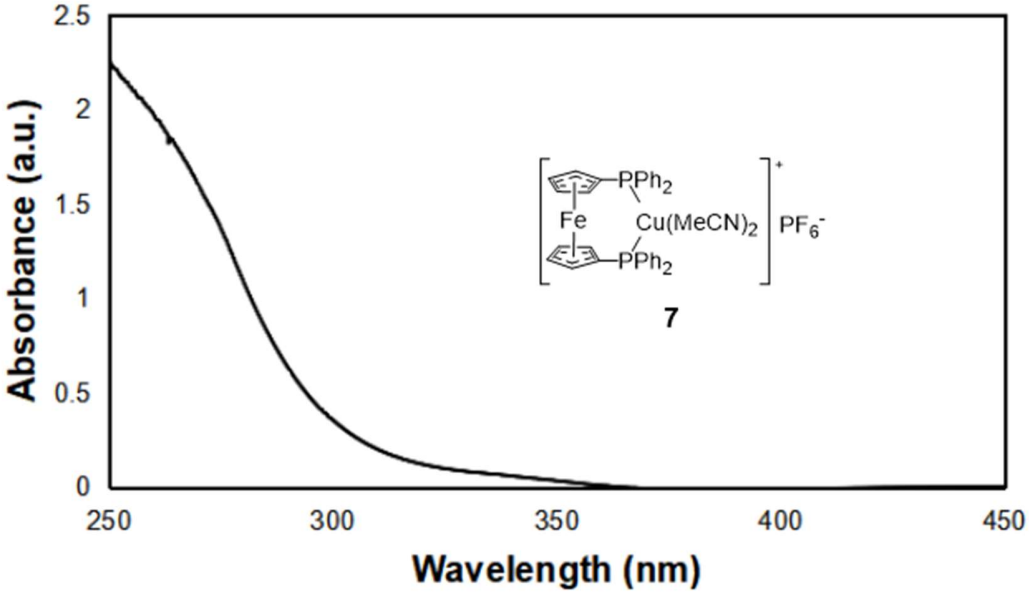
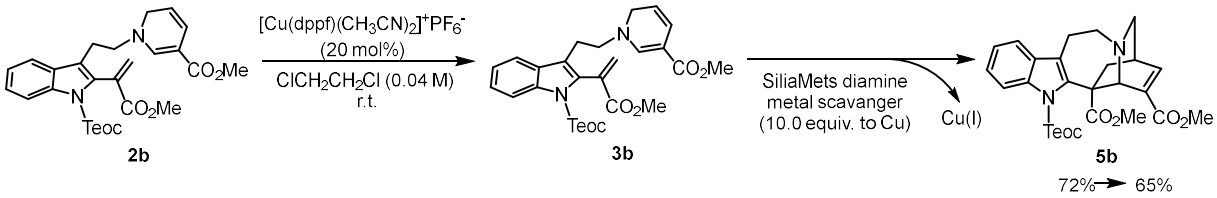


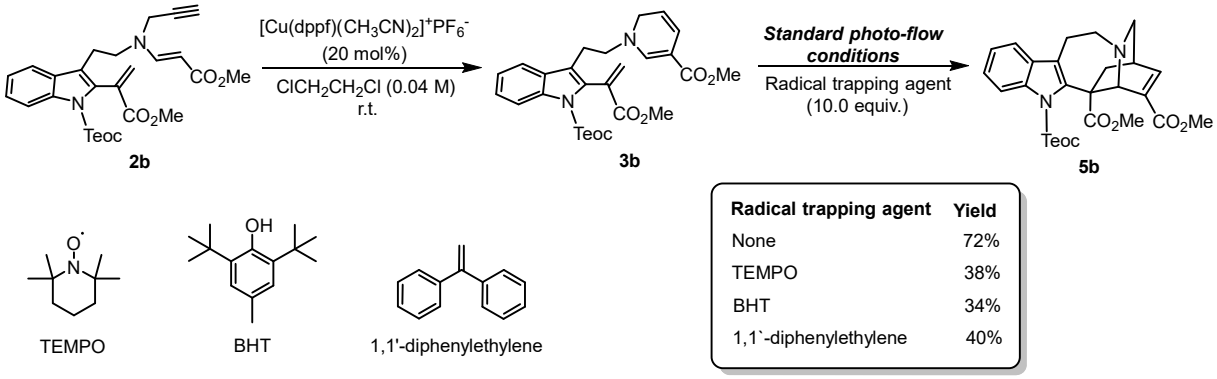
Figure S16. UV-Vis spectrum of $[Cu(dppf)(CH_3CN)_2]^+PF_6^-$ (**7**). The lack of UV-Vis absorption at around 370 nm indicates that the Cu(I) catalyst is not photoactivated upon 370 nm irradiation and does not act as a photocatalyst for the [4+2] cycloaddition. Concentration = 0.075 mM in $CHCl_3$.

10.2 Removal of Cu(I) species



A solution of **2b** (54.5 mg, 0.107 mmol) and $[Cu(dppf)(CH_3CN)_2]^+PF_6^-$ (20.6 mg, 0.0210 mmol) in degassed 1,2-dichloroethane (2.65 mL) was stirred at r.t. for 1.5 h. Then, SiliaMetS Diamine scavenger (159 mg, 1.32 mmol/g, 10.0 equiv. to Cu) was added. After stirring at r.t. for 1 h, the reaction mixture was filtered through a short pad of silica, and an additional amount of 1,2-dichloroethane (8.05 mL) was added. The crude mixture of **3b** was drawn into a gastight syringe and eluted through a photo-flow reactor using a syringe pump under 370 nm irradiation (30 W, distance: 7.0 cm) with a residence time of 25 min. The resulting solution was concentrated *in vacuo* and purified by silica-gel chromatography to afford **5b** (35.4 mg, 0.0693 mmol, 65%).

10.3 Radical trapping studies



Radical trapping agent	Yield
None	72%
TEMPO	38%
BHT	34%
1,1`-diphenylethylene	40%

Representative procedure

A solution of **2b** (20.0 mg, 0.0391 mmol) and $[Cu(dppf)(CH_3CN)_2]^+PF_6^-$ (3.81 mg, 0.00389 mmol) in degassed 1,2-dichloroethane (0.98 mL) was stirred at r.t. for 5 h. Then, an additional amount of 1,2-dichloroethane (2.94 mL) was added, followed by the radical trapping agent (10.0 equiv.). The reaction mixture of **3b** was drawn into a gastight syringe and eluted through a photo-flow reactor using a syringe pump under 370 nm irradiation (30 W, distance: 7.0 cm) with a residence time of 25 min. The resulting solution was concentrated *in vacuo* and purified by silica-gel chromatography to afford **5b**. The crude reaction mixture was also analysed by LCMS-IT-TOF.

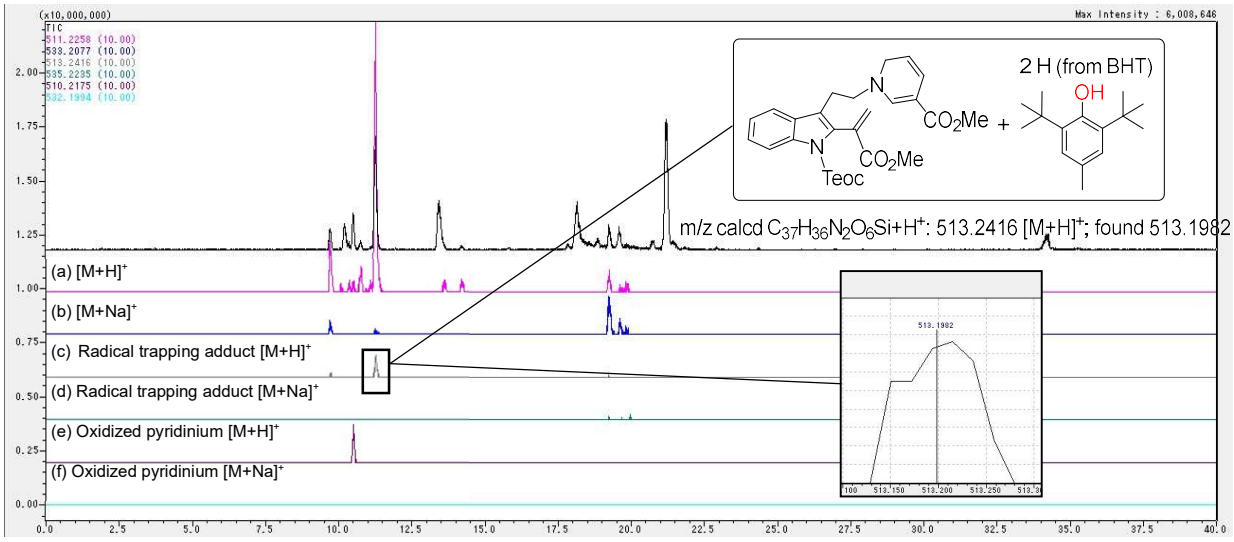


Figure S17. LCMS-IT-TOF analysis of crude radical trapping reaction mixture with BHT.

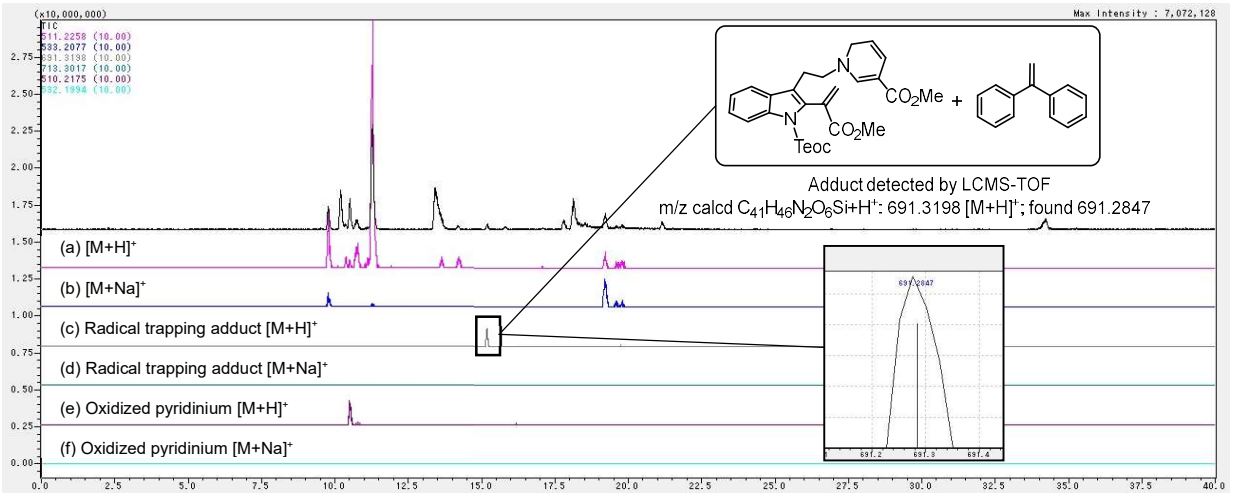
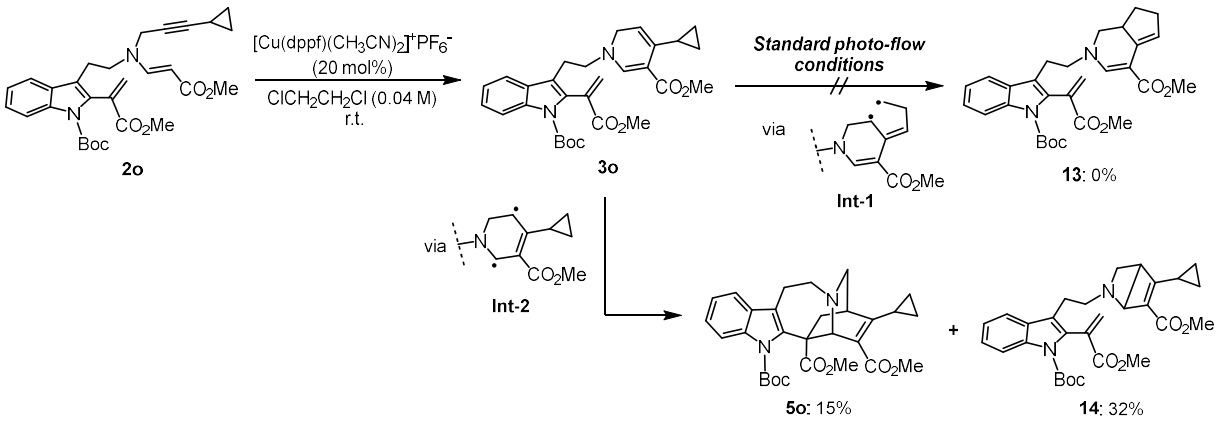


Figure S18. LCMS-IT-TOF analysis of crude radical trapping reaction mixture with 1,1'-diphenylethylene.

10.4 Radical clock experiment



A solution of **2o** (107 mg, 0.211 mmol) and $[Cu(dppf)(CH_3CN)_2]^+PF_6^-$ (41.3 mg, 0.0421 mmol) in degassed 1,2-dichloroethane (5.4 mL) was stirred at r.t. for 2 h. Then, an additional amount of 1,2-dichloroethane (15.7 mL) was added. The reaction mixture of **3o** was drawn into a gastight syringe and eluted through a photo-flow reactor using a syringe pump under 370 nm irradiation (30 W, distance: 7.0 cm) with a residence time of 25 min. The resulting solution was concentrated *in vacuo* and purified by silica-gel chromatography to afford **5o** (15.6 mg, 0.0308 mmol, 15%) and **14** (34.2 mg, 0.0675 mmol, 32%).

Product 14

^{1}H NMR (500 MHz, $CDCl_3$) δ 8.11 (d, *J* = 8.3 Hz, 1H), 7.56 (d, *J* = 7.4 Hz, 1H), 7.32 (ddd, *J* = 8.0, 7.5, 1.0 Hz, 1H), 7.25-7.22 (m, 1H), 6.62 (d, *J* = 1.7 Hz, 1H), 5.84 (s, 1H), 4.51 (dd, *J* = 3.0, 1.5 Hz, 1H), 3.74 (s, 3H), 3.72 (s, 3H), 3.63 (t, *J* = 7.5 Hz, 1H), 2.98 (br, 1H), 2.90-2.87 (m, 1H), 2.83 (br, 1H), 2.66 (br, 1H), 2.51-2.46 (m, 2H), 2.33-2.28 (m, 1H), 1.59 (s, 9H), 1.00-0.98 (m, 2H), 0.74-0.66 (m, 2H) ppm.

^{13}C NMR (100 MHz, $CDCl_3$) δ 171.4, 166.5, 163.9, 150.2, 135.6, 133.8, 132.0, 129.6, 128.7, 128.0, 124.6, 122.4, 119.7, 119.4, 115.5, 84.1, 61.6, 54.4, 53.9, 52.0, 51.0, 32.8, 28.0, 23.4, 11.0, 8.3, 7.2 ppm.

HRMS (ESI): *m/z* calcd for $C_{29}H_{34}N_2O_6Si$ $[M + H]^+$: 507.2490; found: 507.2490.

11. References

1 B. J. Deppmeier, A. J. Driessen, W. J. Hehre, T. S. Hehre, J. A. Johnson and S. Ohlinger, P. E. Klunzinger, *Spartan 20 Wavefunction Inc.*, 2020, Irvine CA.

2 Y. Shao et al., *Mol. Phys.*, 2015, **113**, 184–215.

3 M. F. Cain, R. P. Hughes, D. S. Glueck, J. A. Golen, C. E. Moore and A. L. Rheingold, *Inorg. Chem.*, 2010, **49**, 7650–7662.

4 H.-S. Kim, J.-W. Kim, S.-C. Kwon, S.-C. Shim and T.-J. Kim, *J. Organometallic Chem.*, 1997, **545-546**, 337–344.

5 J. Zhu, J. Li, L. Zhang, S. Sun, L. Yang, J. Fu, H. Sun, M. Cheng, B. Lin and Y. Liu, *J. Org. Chem.*, 2023, **88**, 10586–10598.

6 H. Mizoguchi, H. Oikawa and H. Oguri, *Nat. Chem.*, 2014, **6**, 57–64.

7 G. Tay, T. Wayama, H. Takezawa, S. Yoshida, S. Sato, M. Fujita and H. Oguri, *Angew. Chem. Int. Ed.*, 2023, **62**, e202305122.

8 F. Kolundzic, M. N. Noshi, M. Tjandra, M. Movassaghi and S. J. Miller, *J. Am. Chem. Soc.*, 2011, **133**, 9104–9111.

9 J. Zhu, J. Li, L. Zhang, S. Sun, Z. Wang, X. Li, L. Yang, M. Cheng, B. Lin and Y. Liu, *J. Org. Chem.*, 2023, **88**, 5483–5496.

10 A. Ueno, T. Kitawaki and N. Chida, *Org. Lett.*, 2008, **10**, 1999–2002.

11 Y.-G. Si, J. Chen, F. Li, J.-H. Li, Y.-J. Qin and B. Jiang, *Adv. Synth. Catal.*, 2006, **348**, 898–904.

11. NMR spectral data

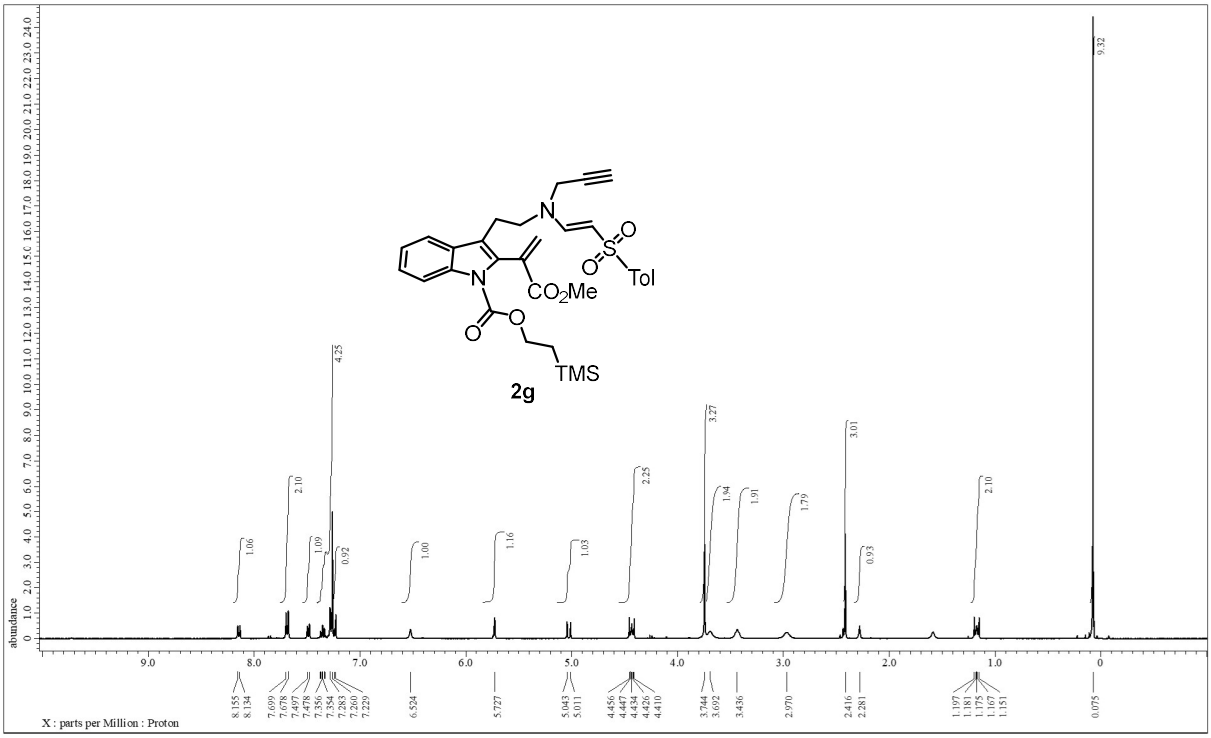


Figure S19. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **2g**.

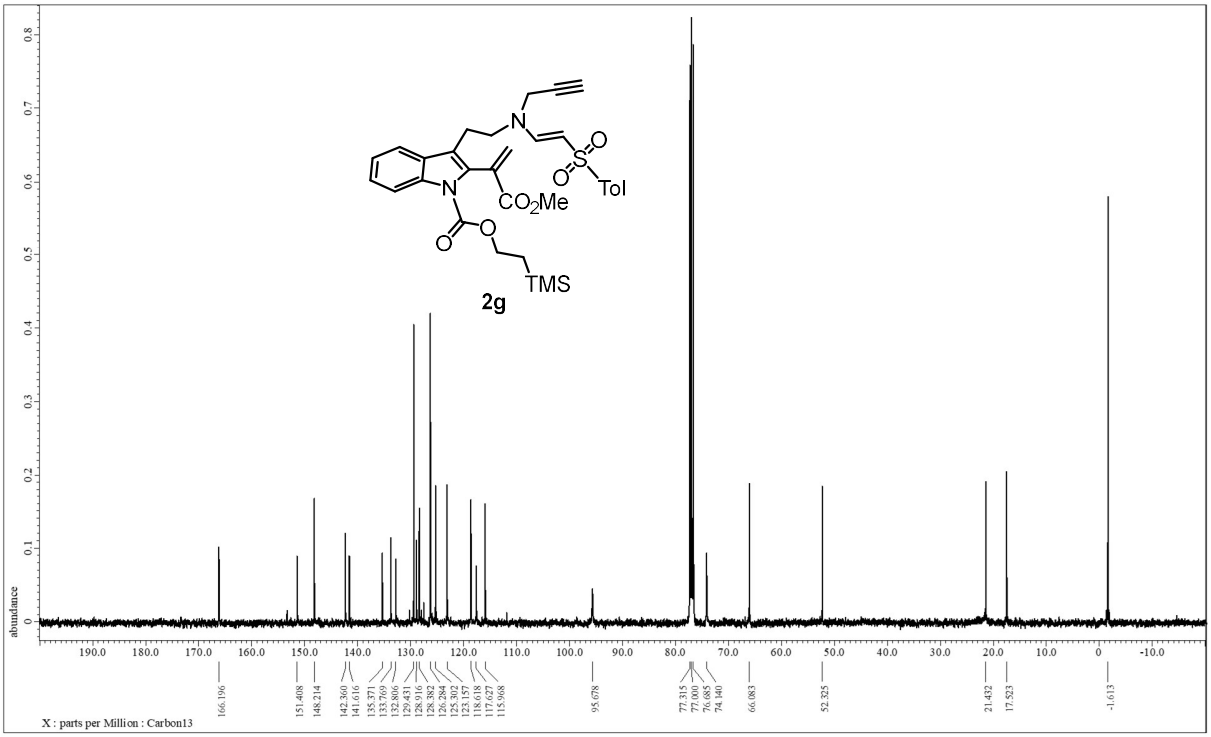


Figure S20. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **2g**.

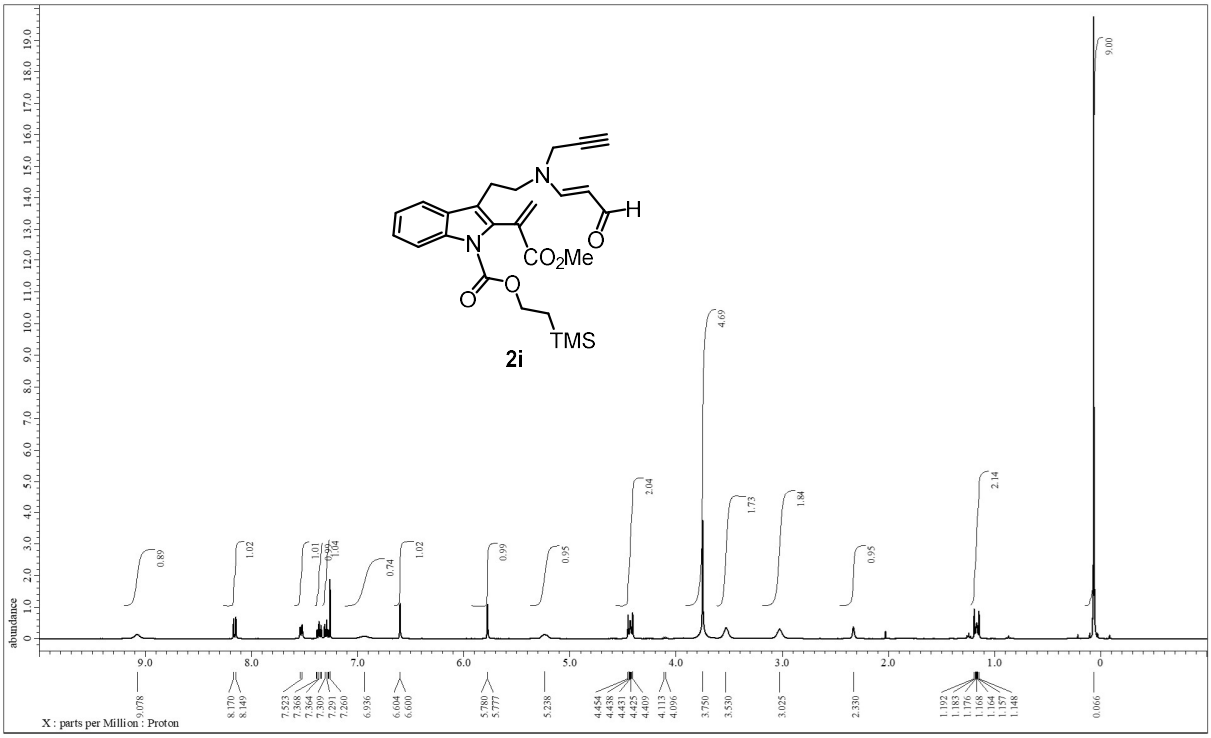


Figure S21. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **2i**.

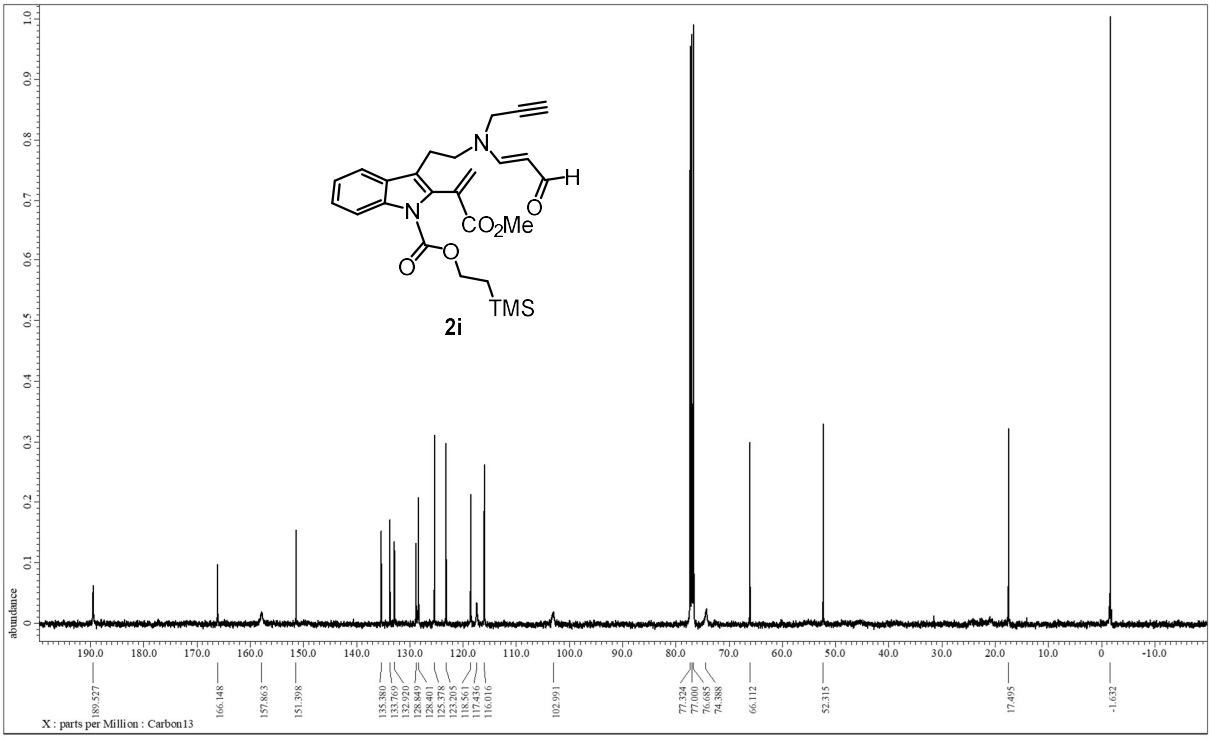


Figure S22. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **2i**.

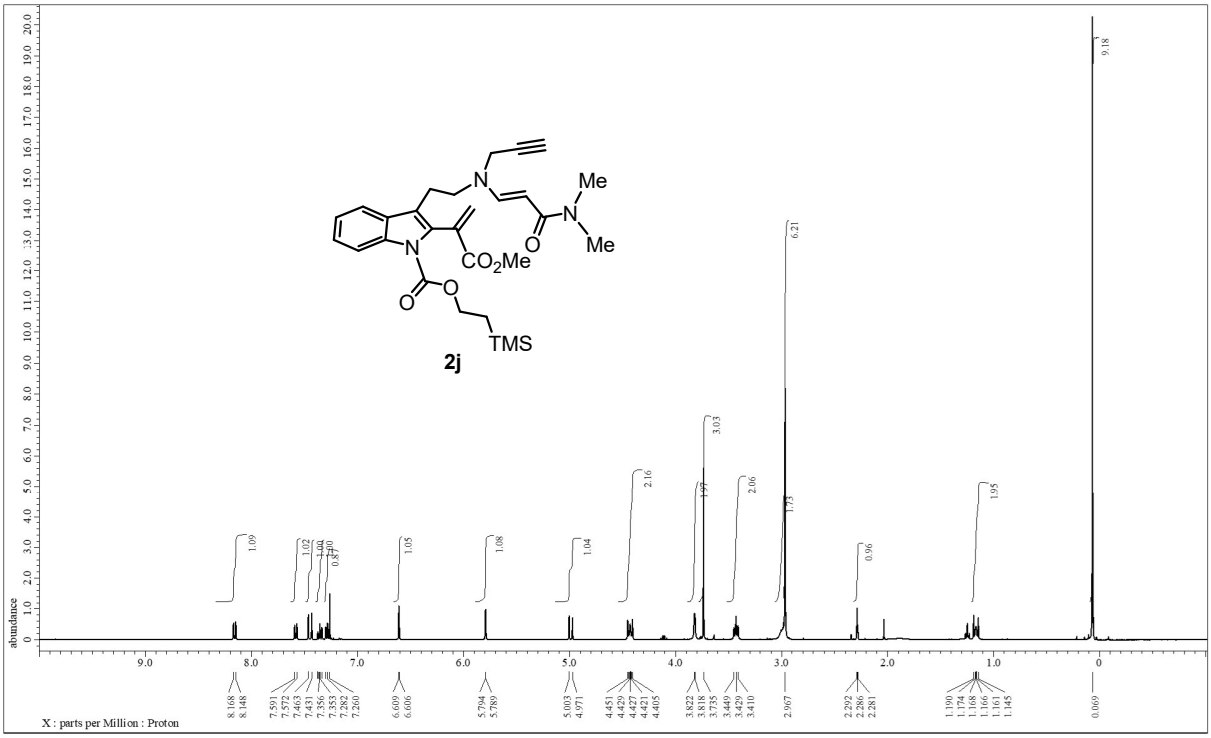


Figure S23. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **2j**.

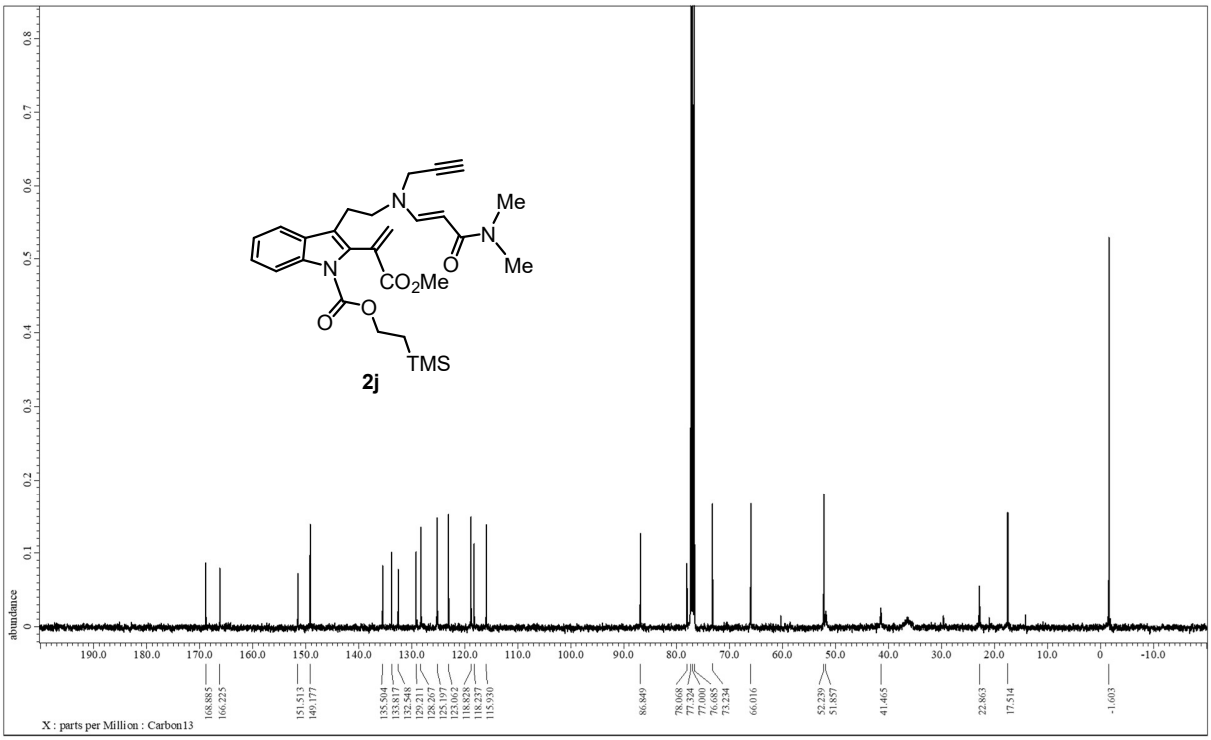


Figure S24. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **2j**.

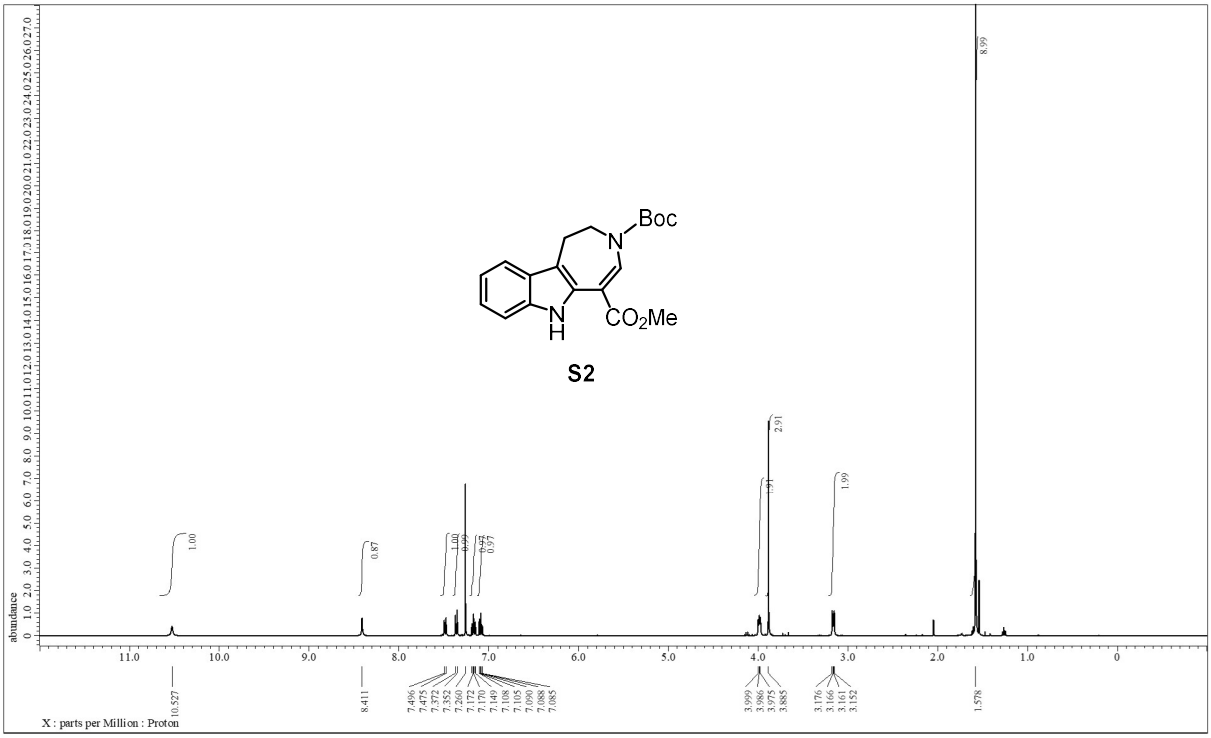


Figure S25. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **S2**.

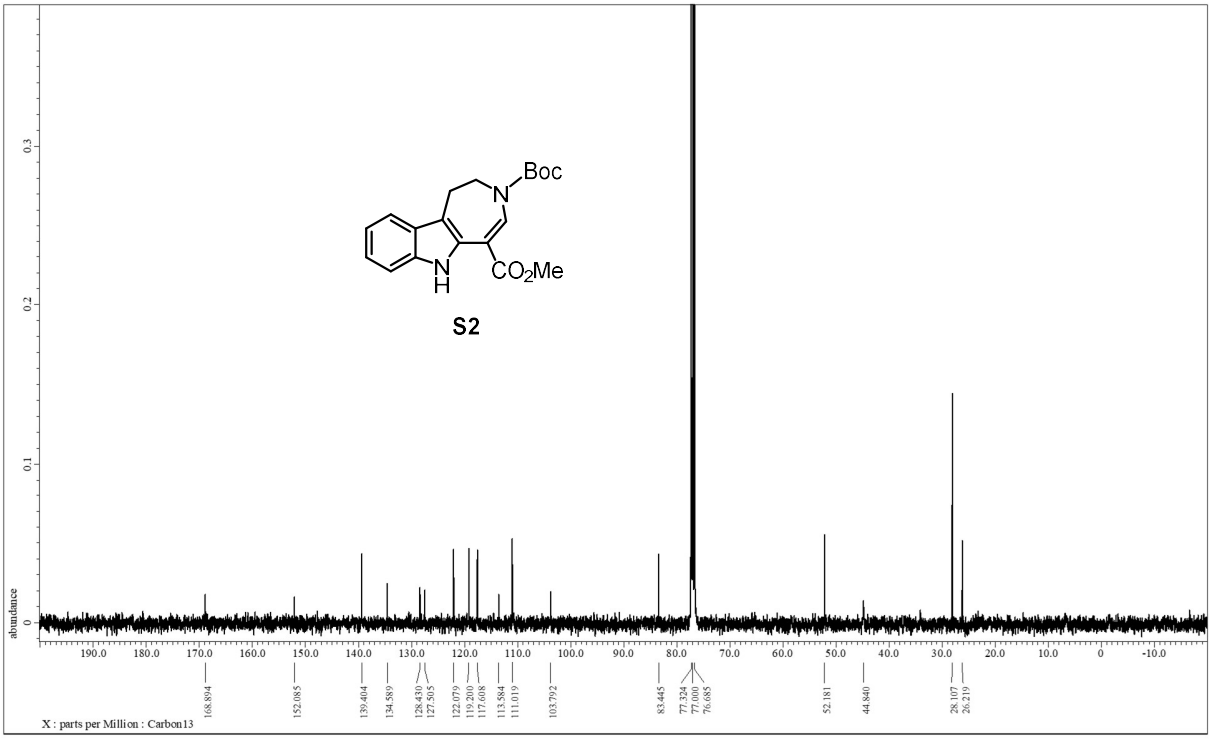


Figure S26. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **S2**.

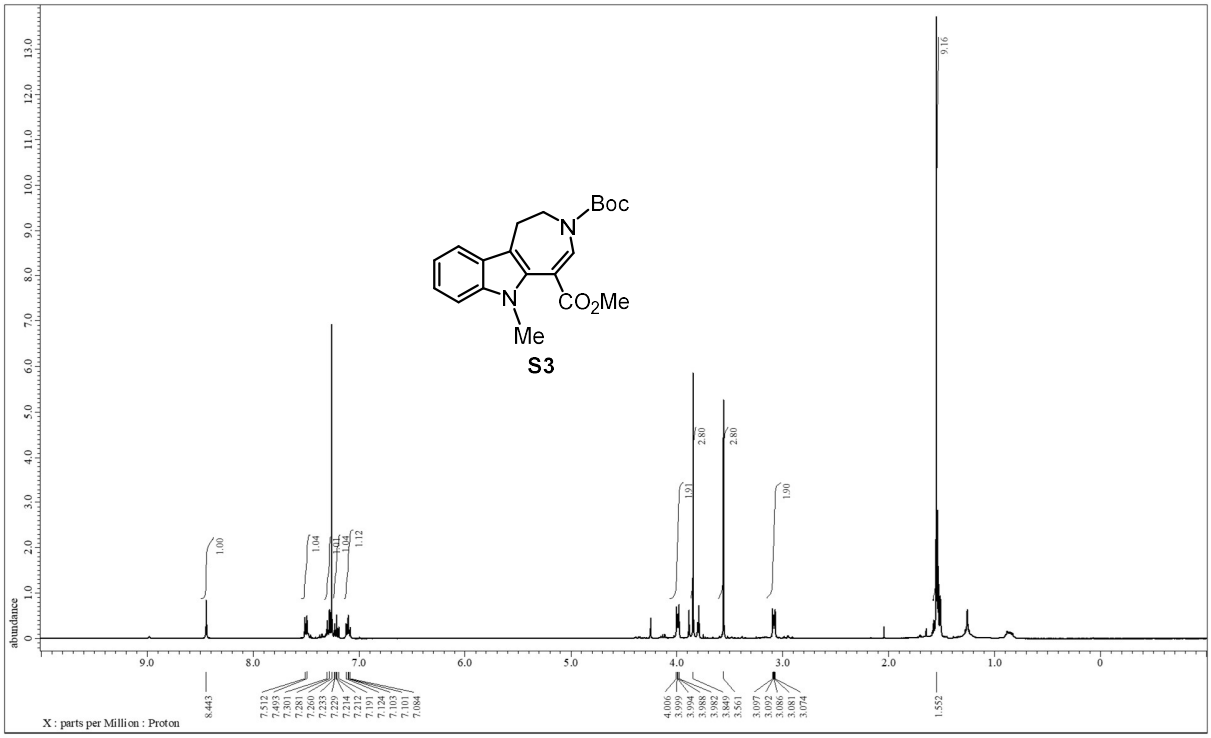


Figure S27. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **S3**.

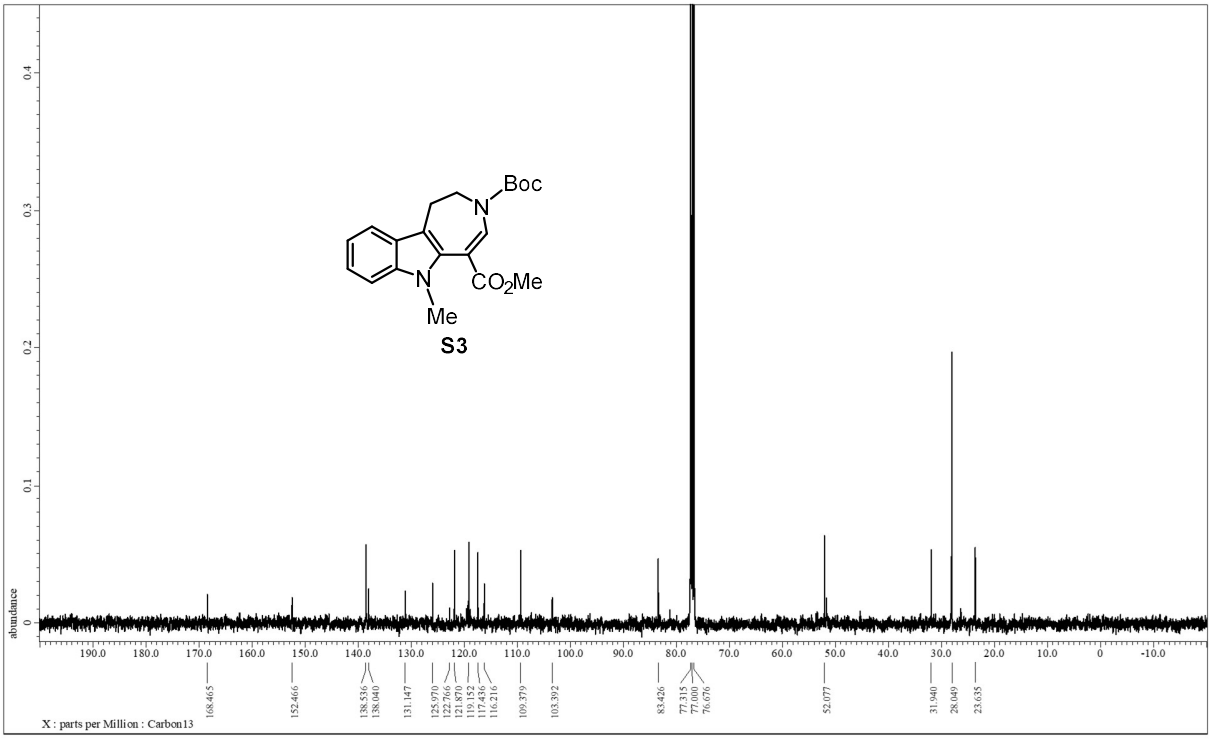


Figure S28. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **S3**.

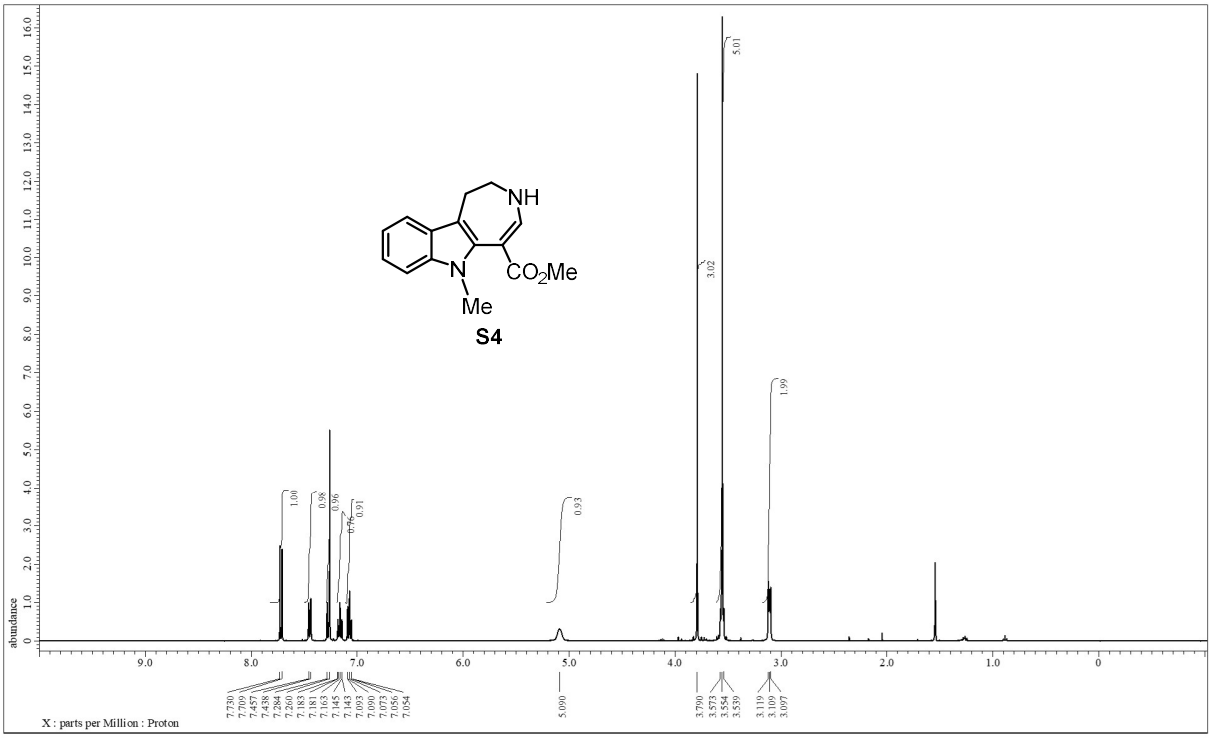


Figure S29. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **S4**.

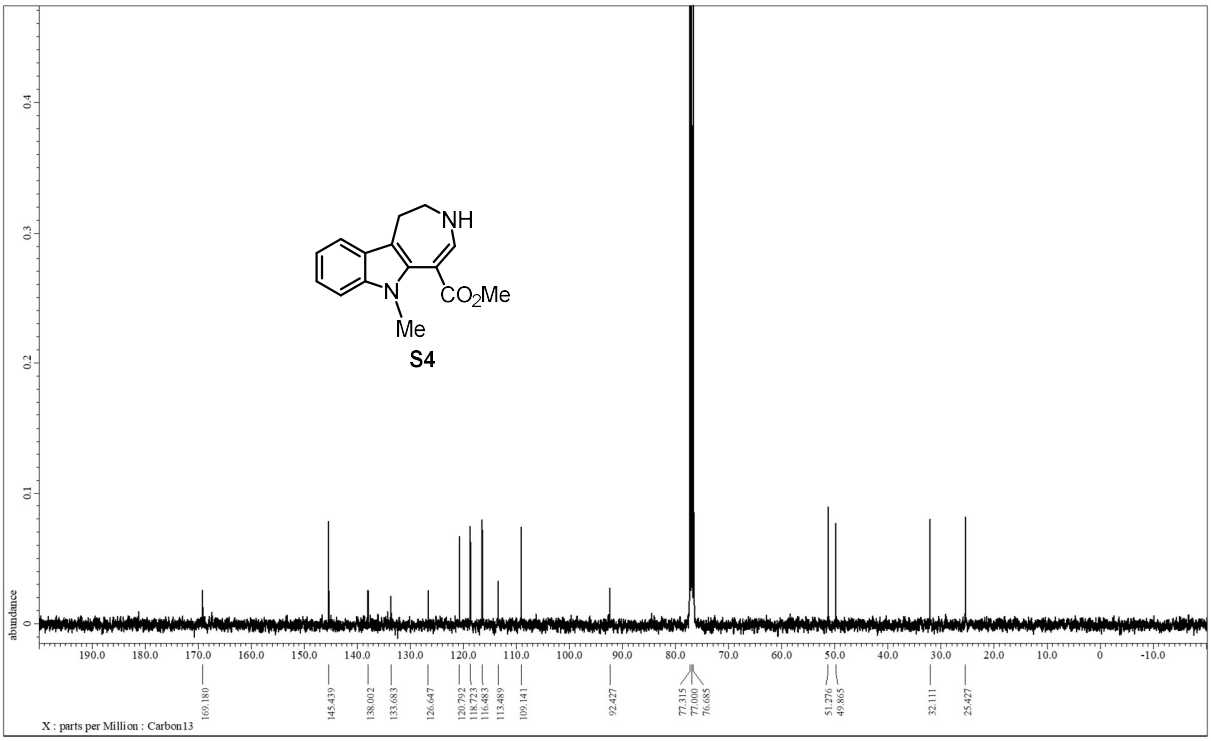


Figure S30. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **S4**.

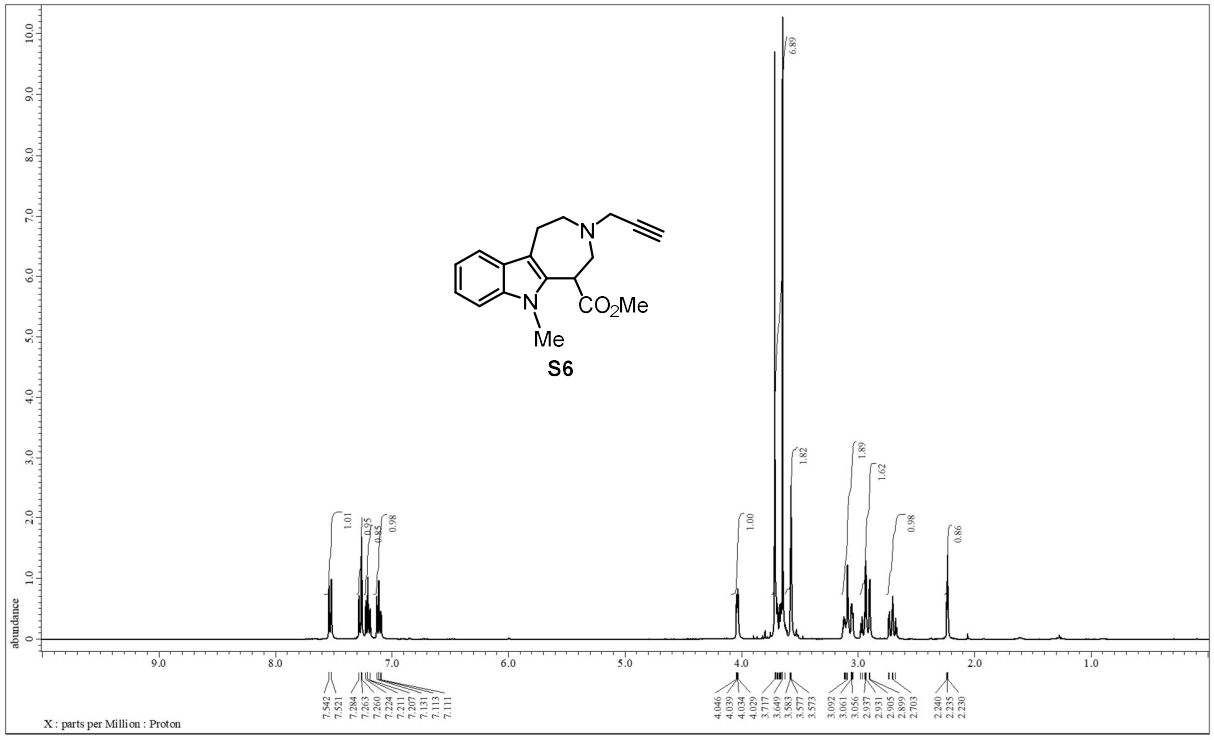


Figure S31. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **S6**.

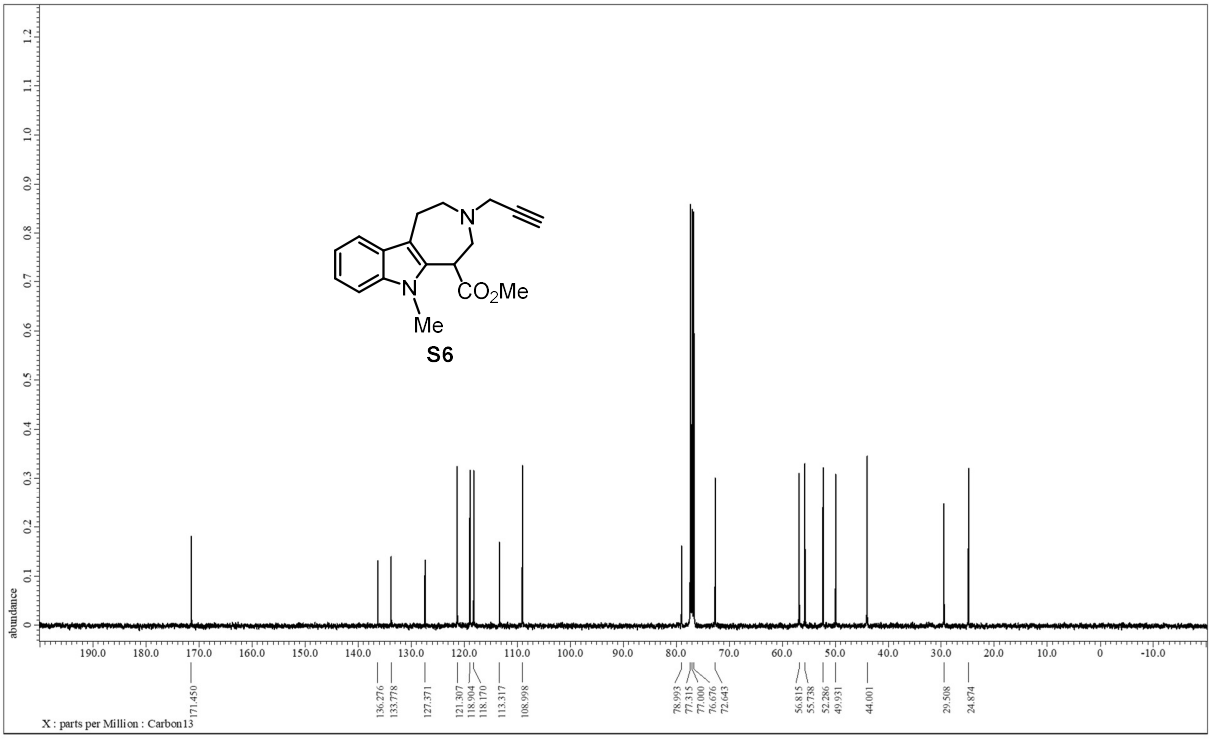


Figure S32. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **S6**.

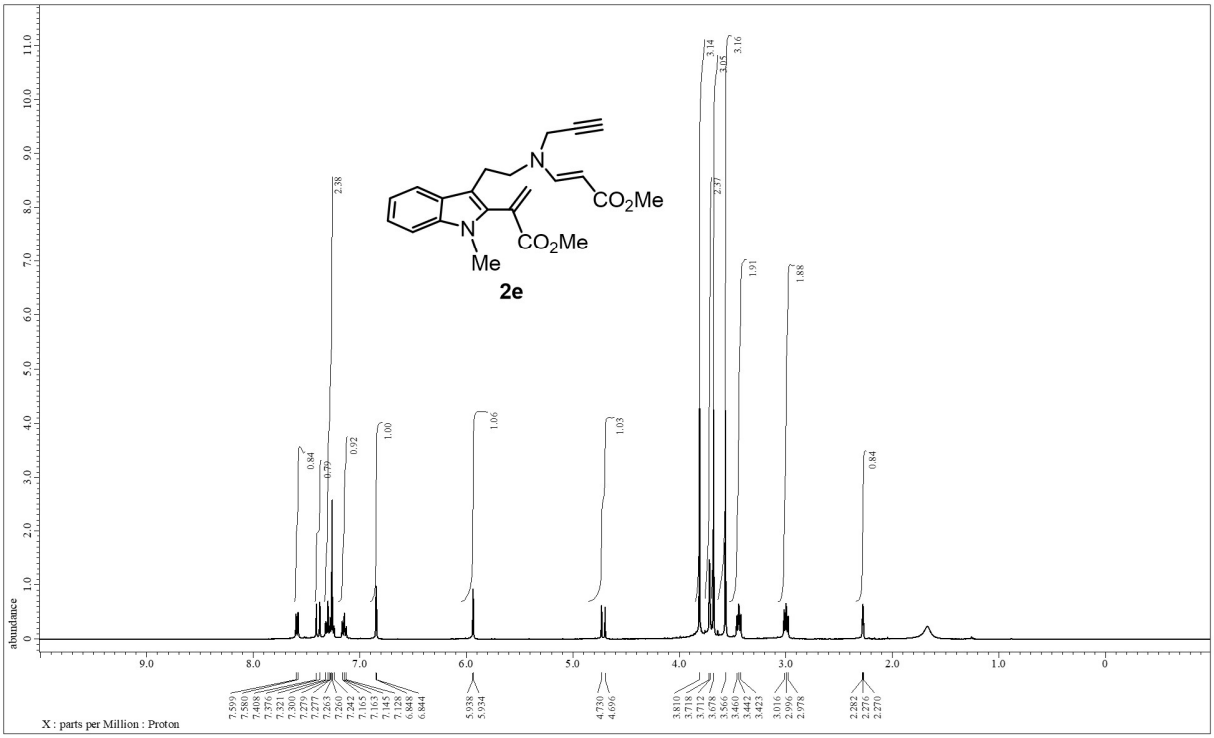


Figure S33. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **2e**.

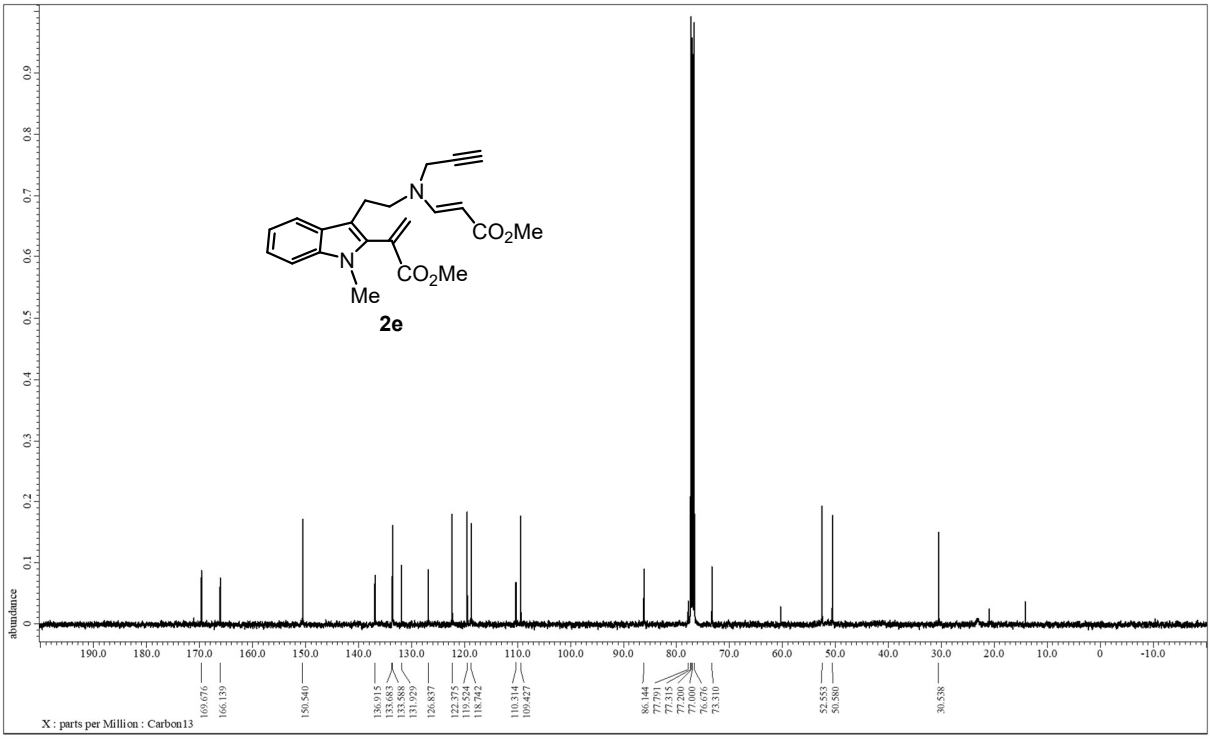


Figure S34. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **2e**.

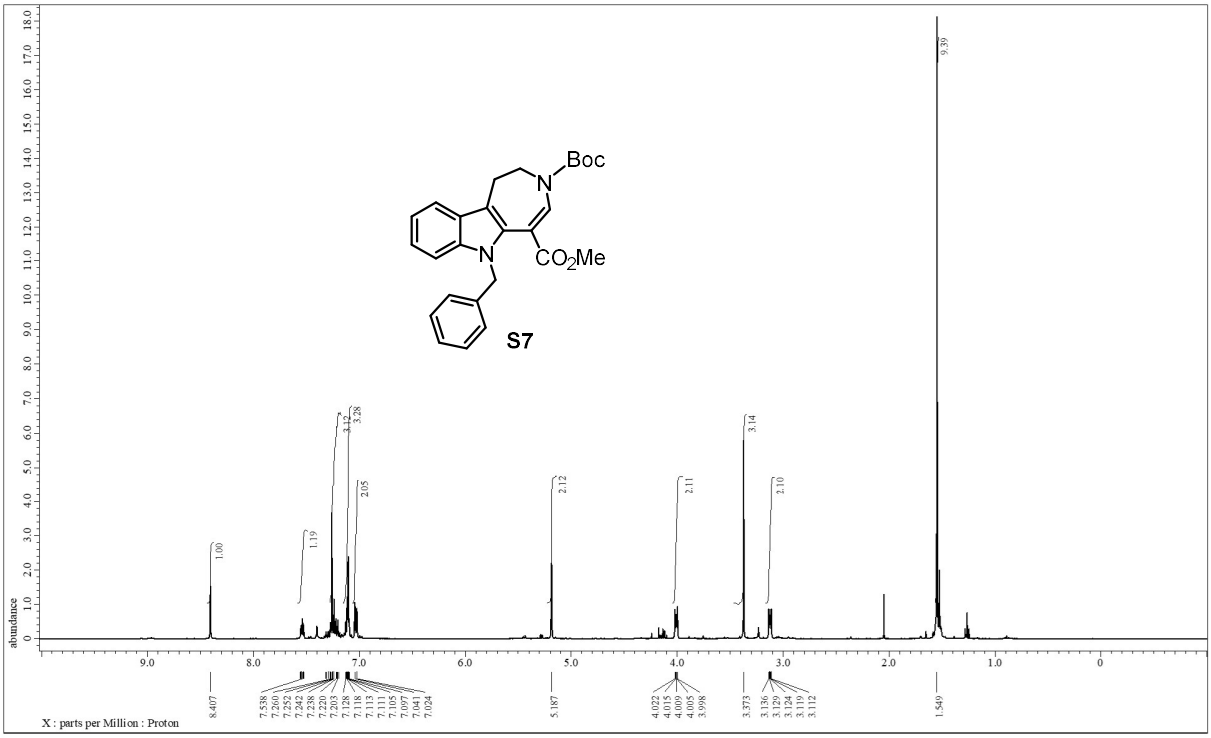


Figure S35. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **S7**.

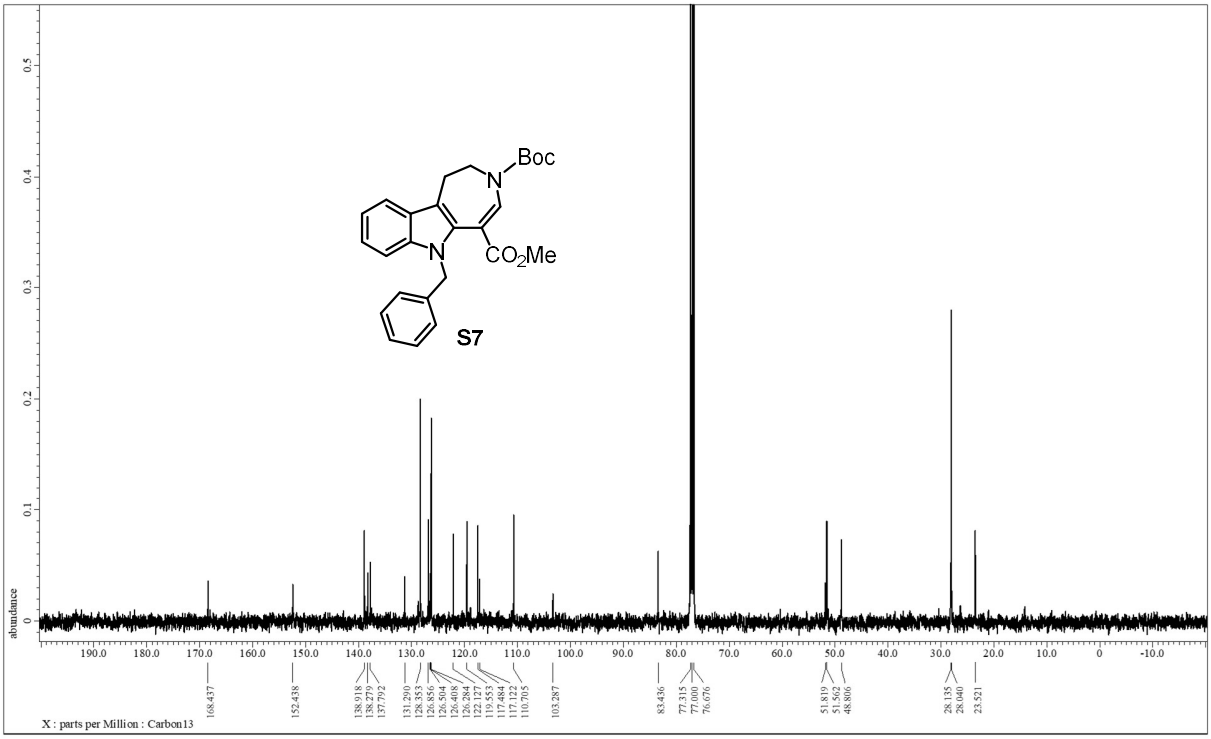


Figure S36. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **S7**.

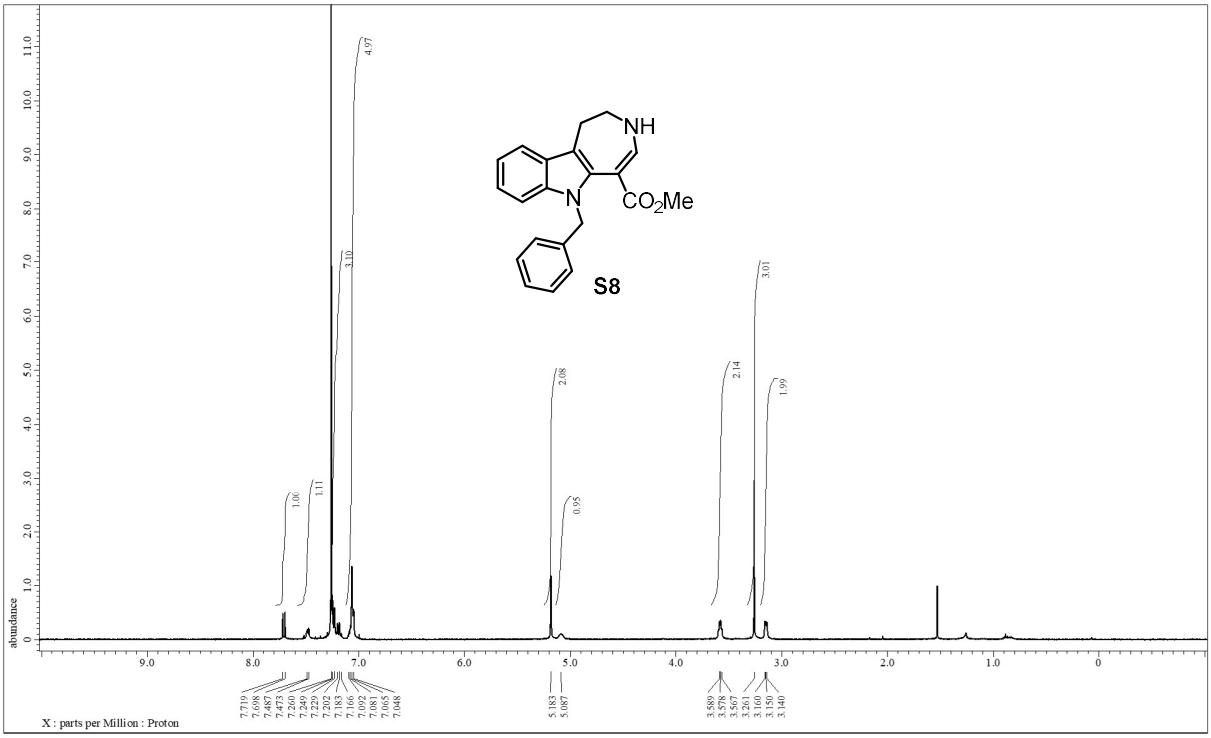


Figure S37. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **S8**.

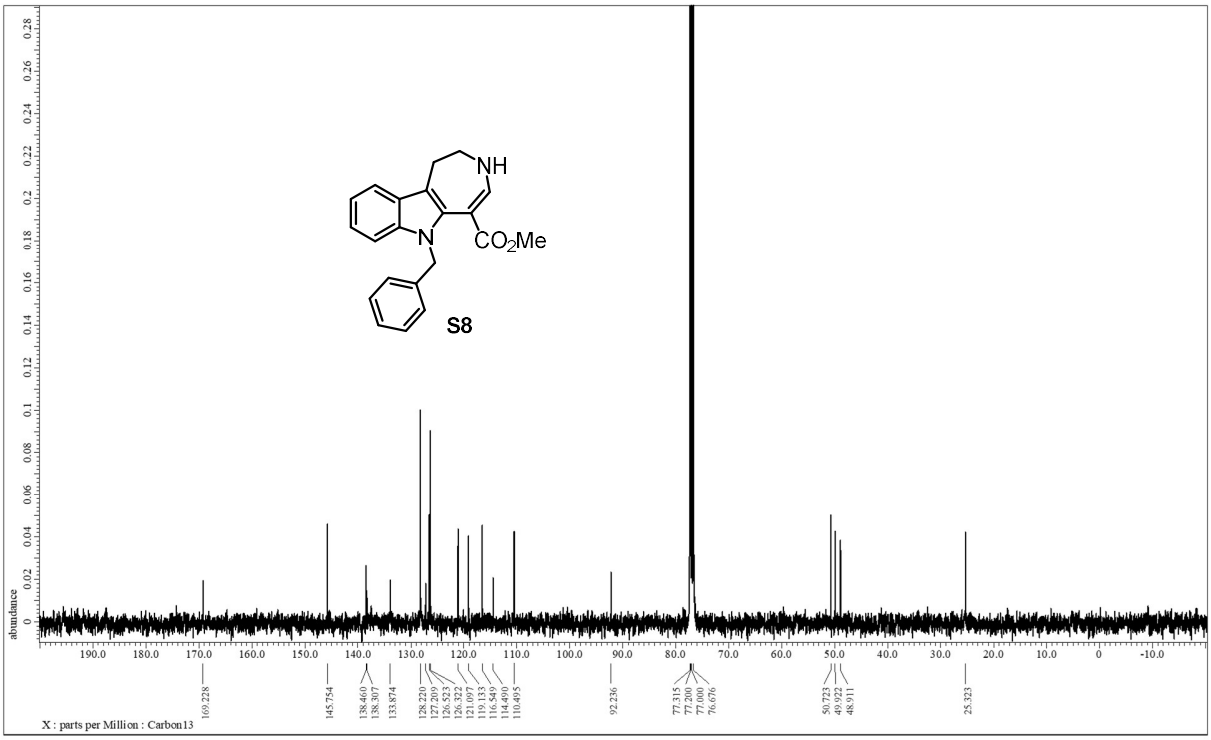


Figure S38. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **S8**.

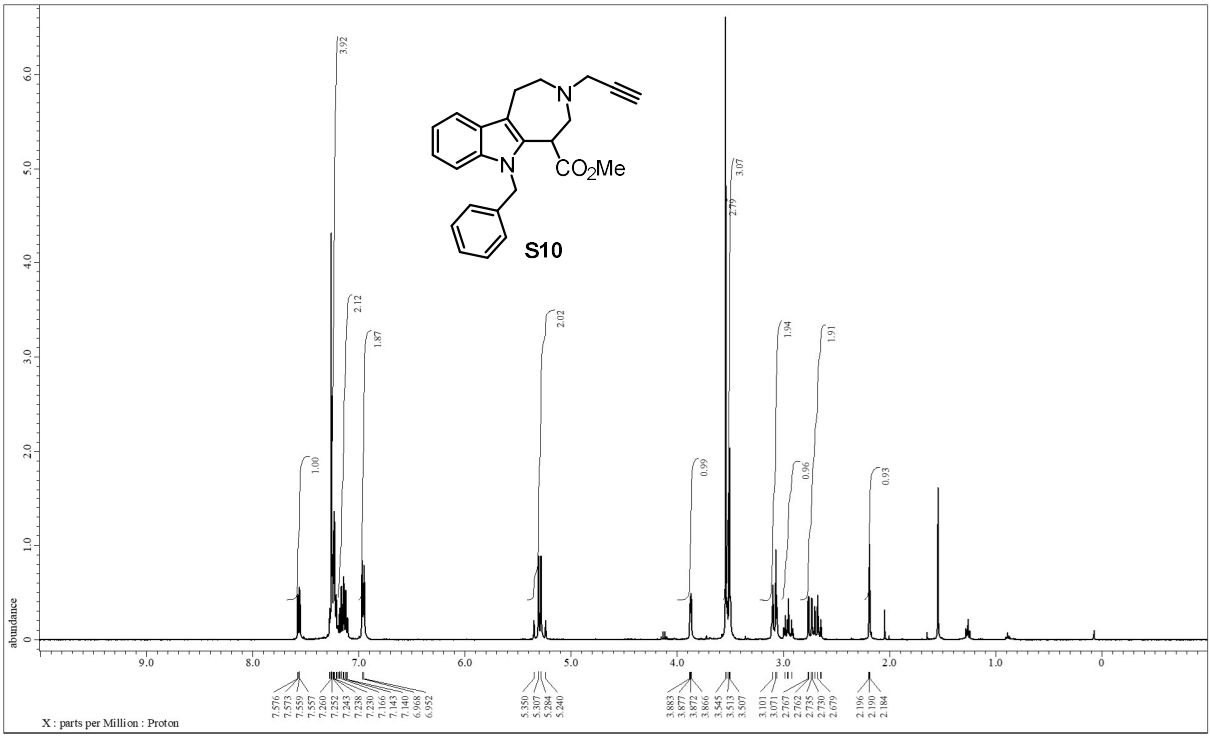


Figure S39. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **S10**.

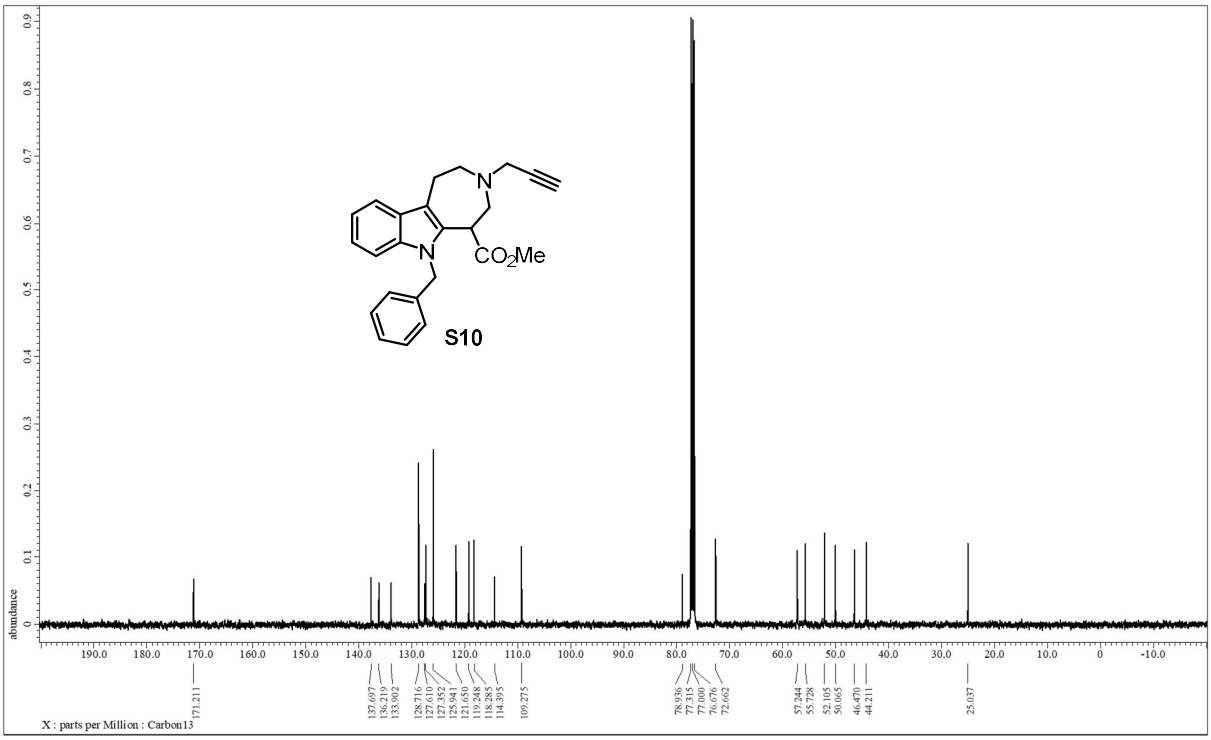


Figure S40. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **S10**.

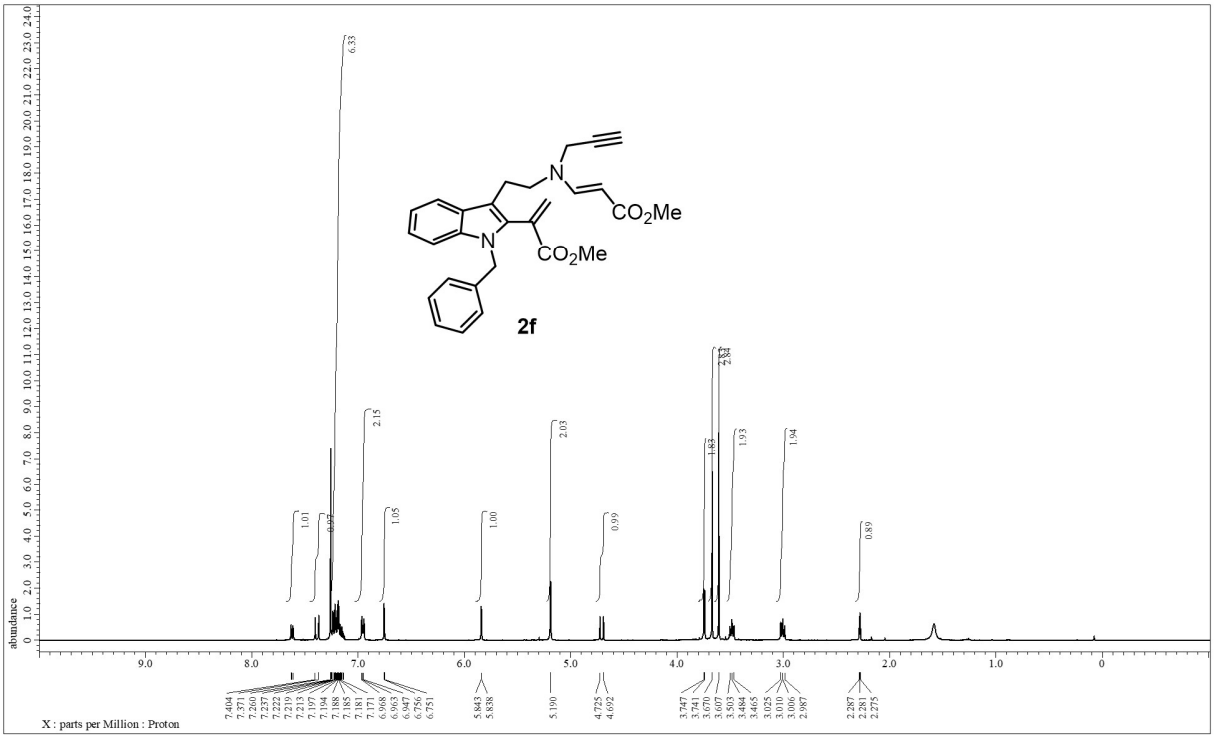


Figure S41. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **2f**.

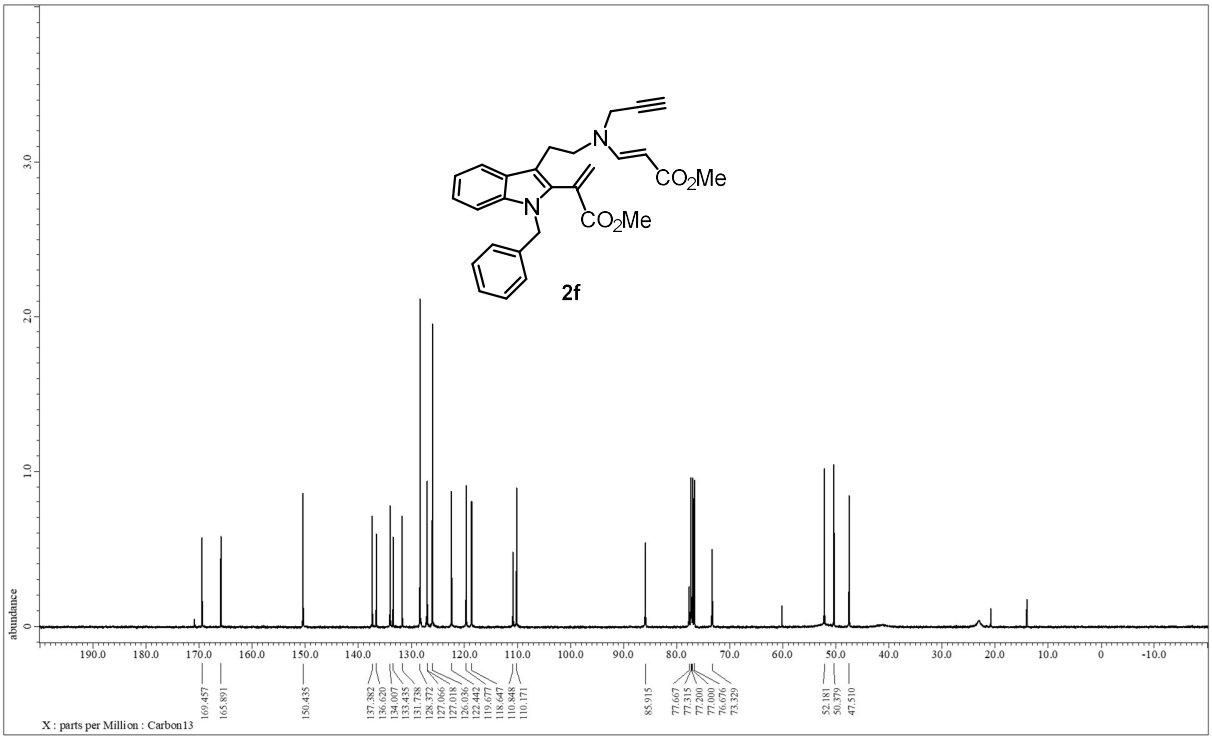


Figure S42. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **2f**.

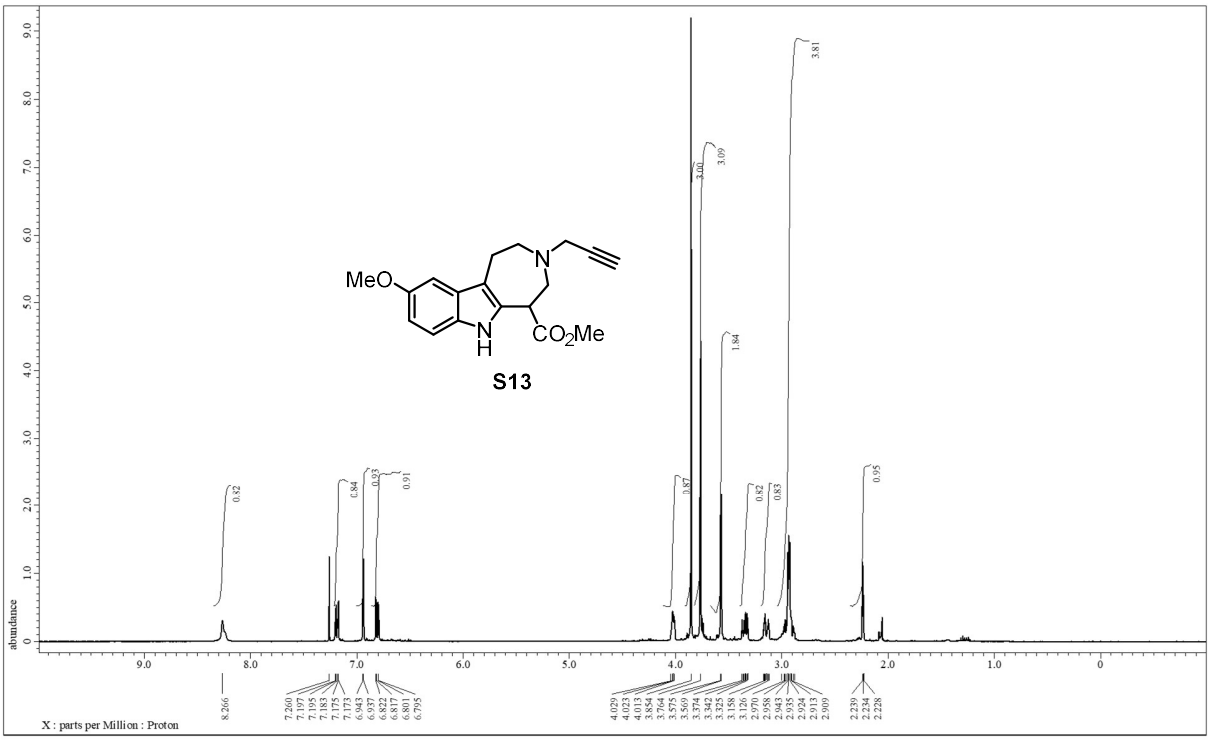


Figure S43. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **S13**.

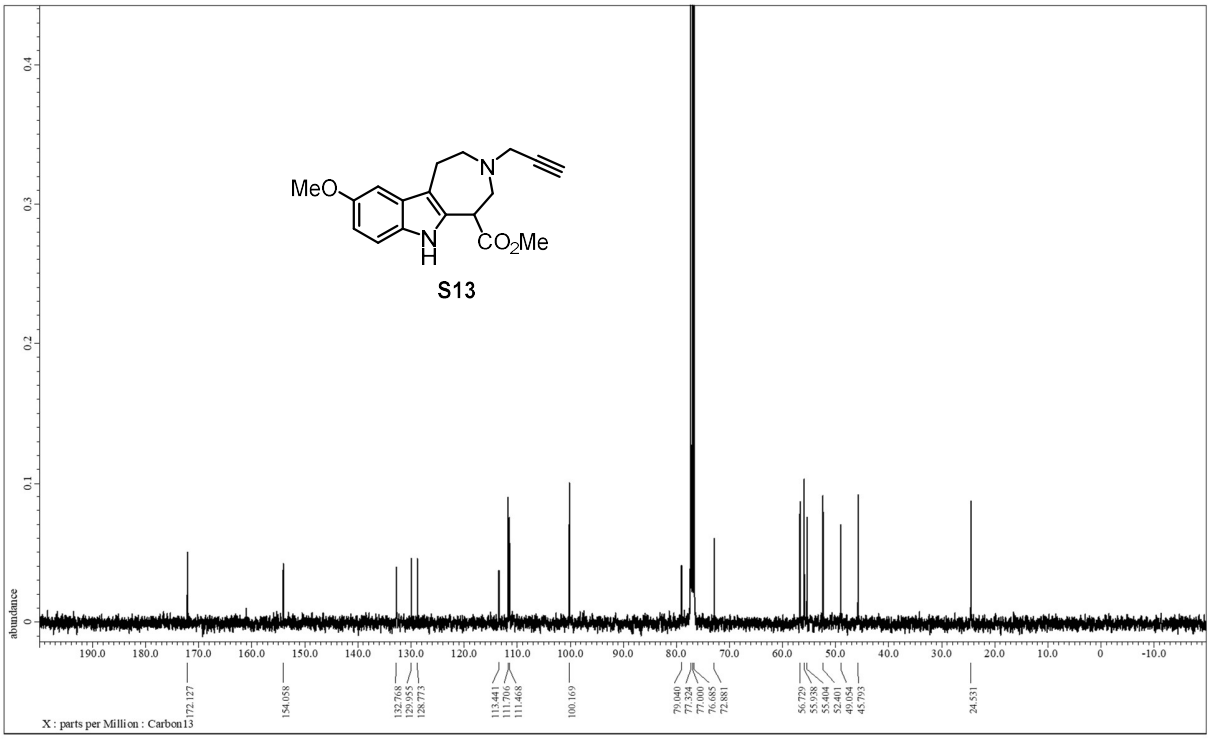


Figure S44. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **S13**.

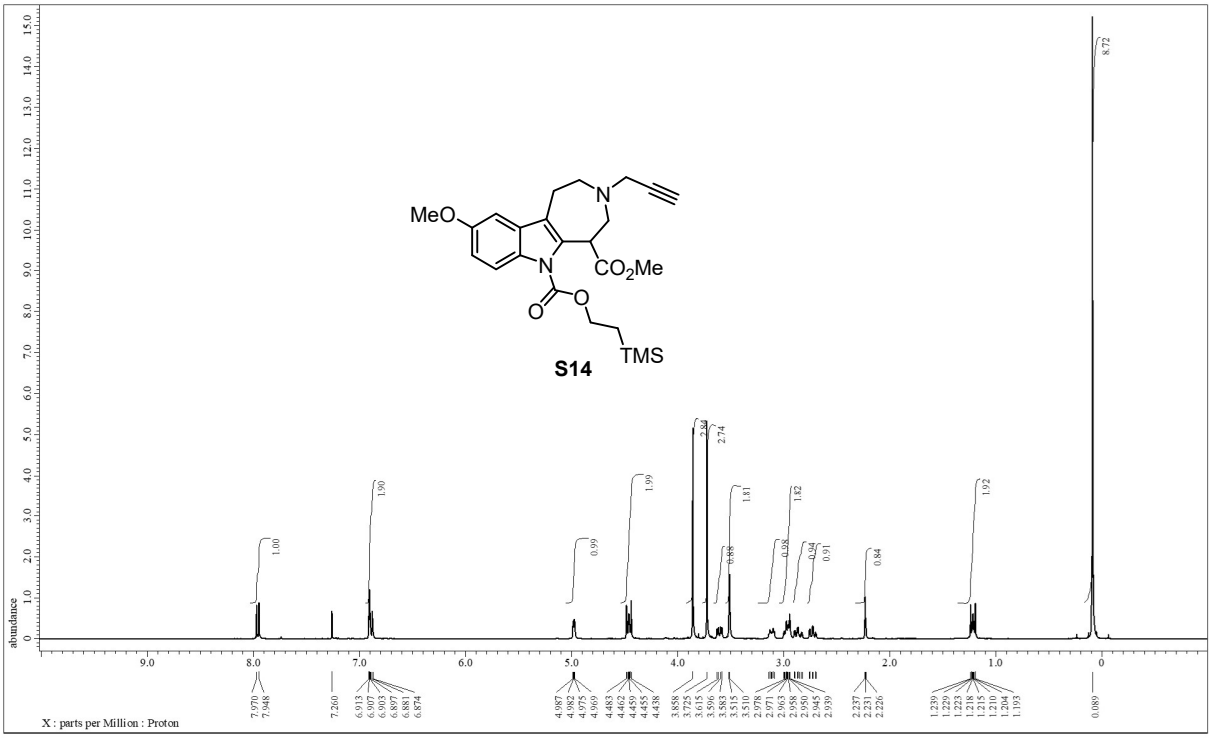


Figure S45. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **S14**.

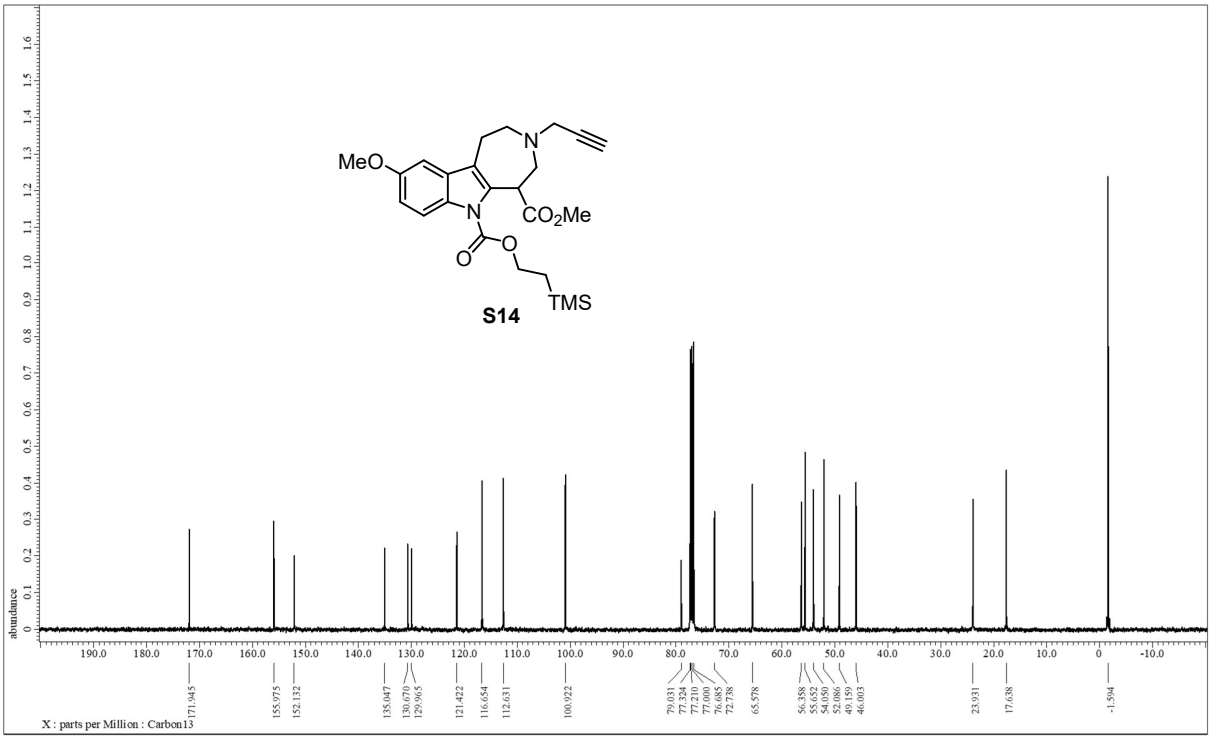


Figure S46. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **S14**.

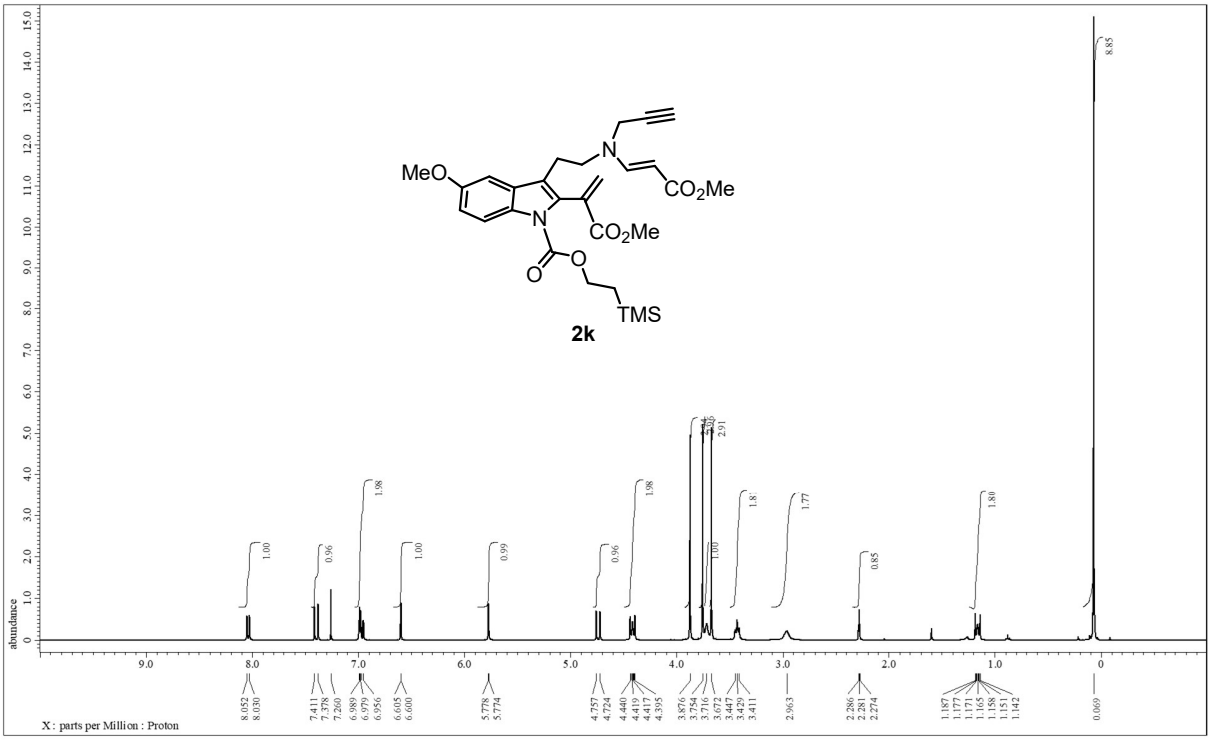


Figure S47. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **2k**.

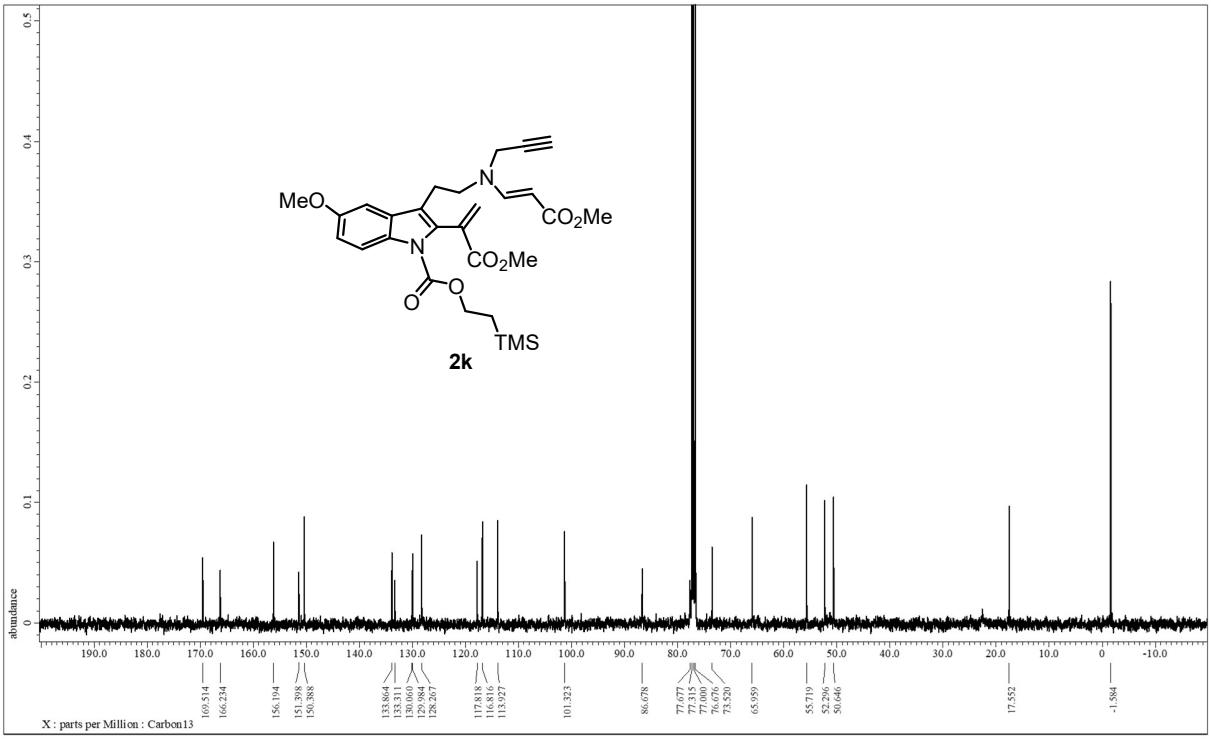


Figure S48. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **2k**.

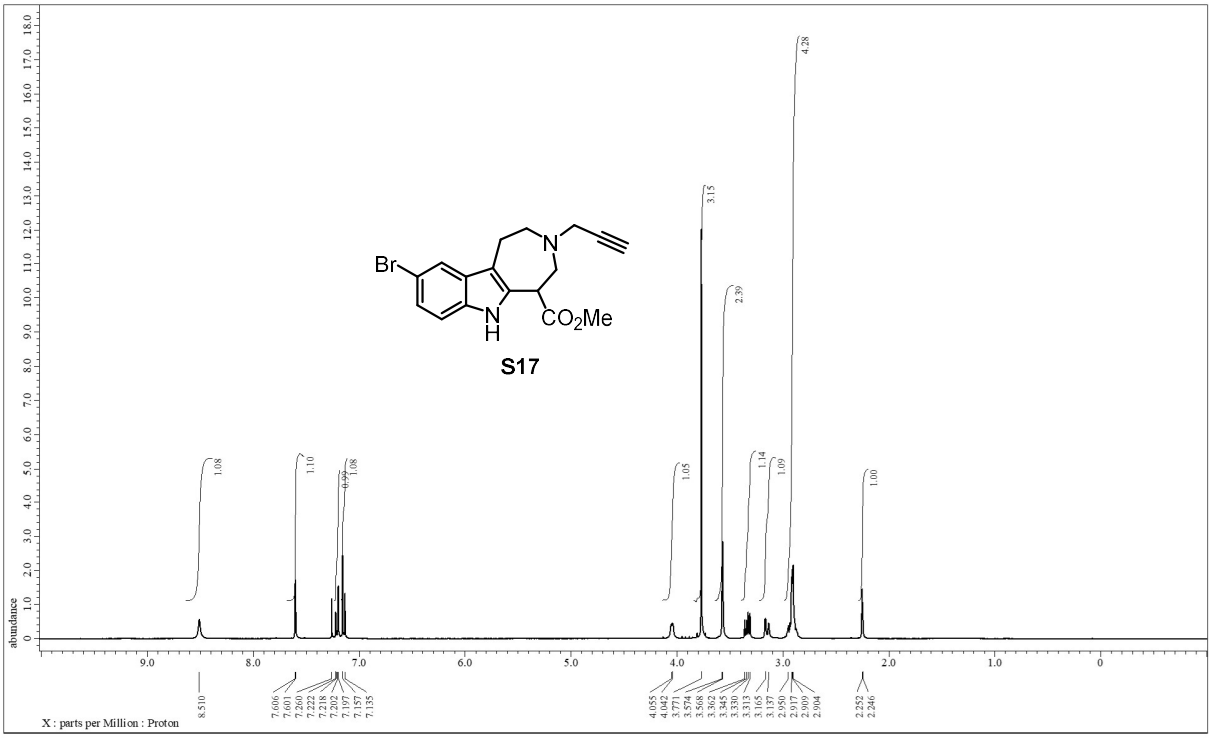


Figure S49. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **S17**.

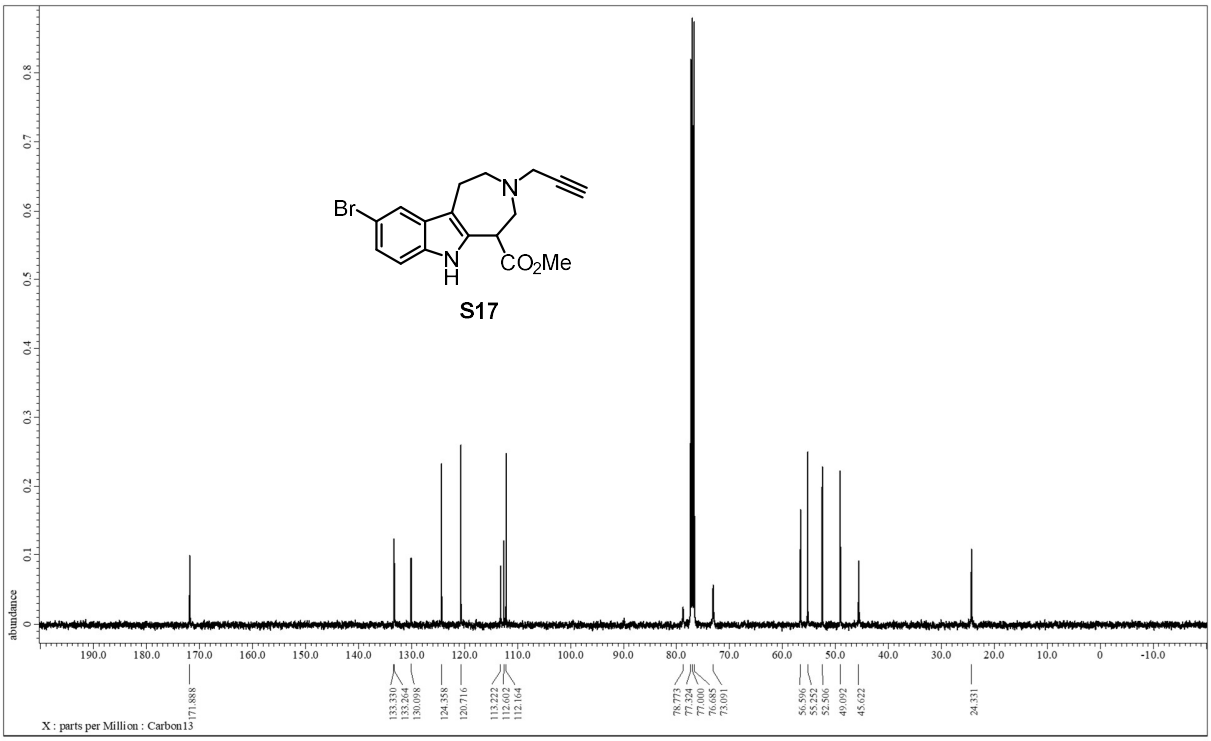


Figure S50. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **S17**.

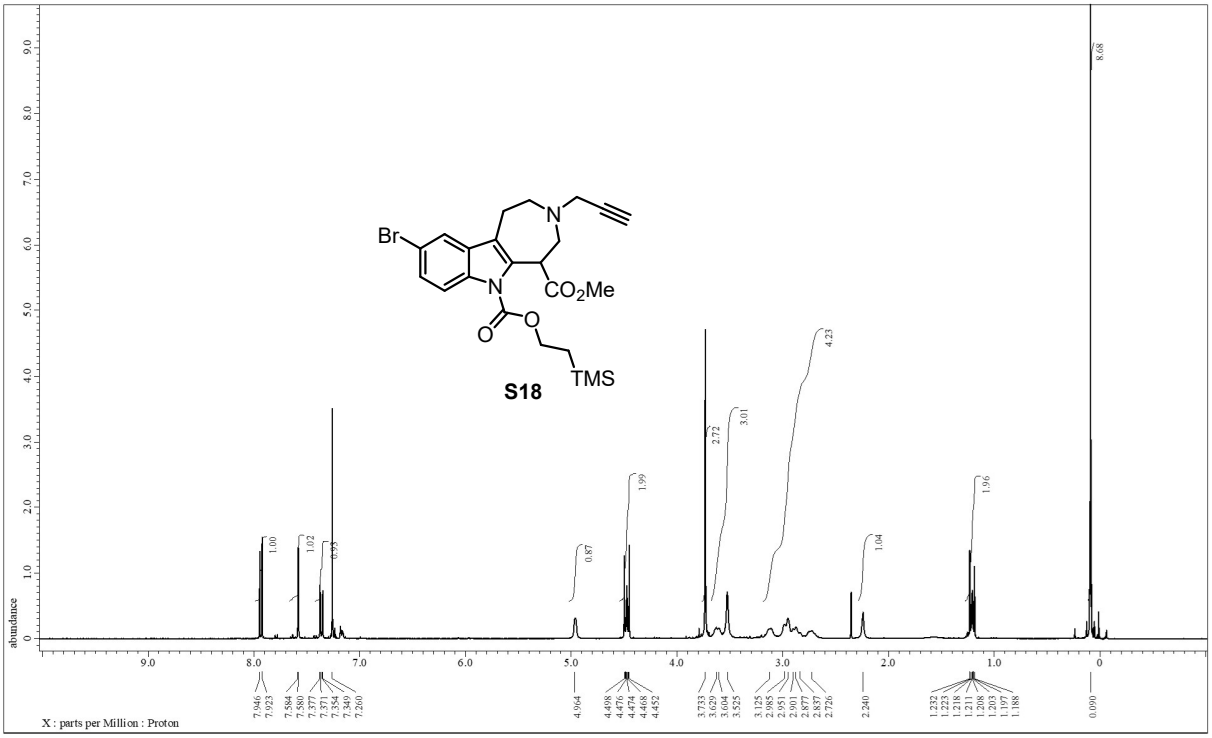


Figure S51. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **S18**.

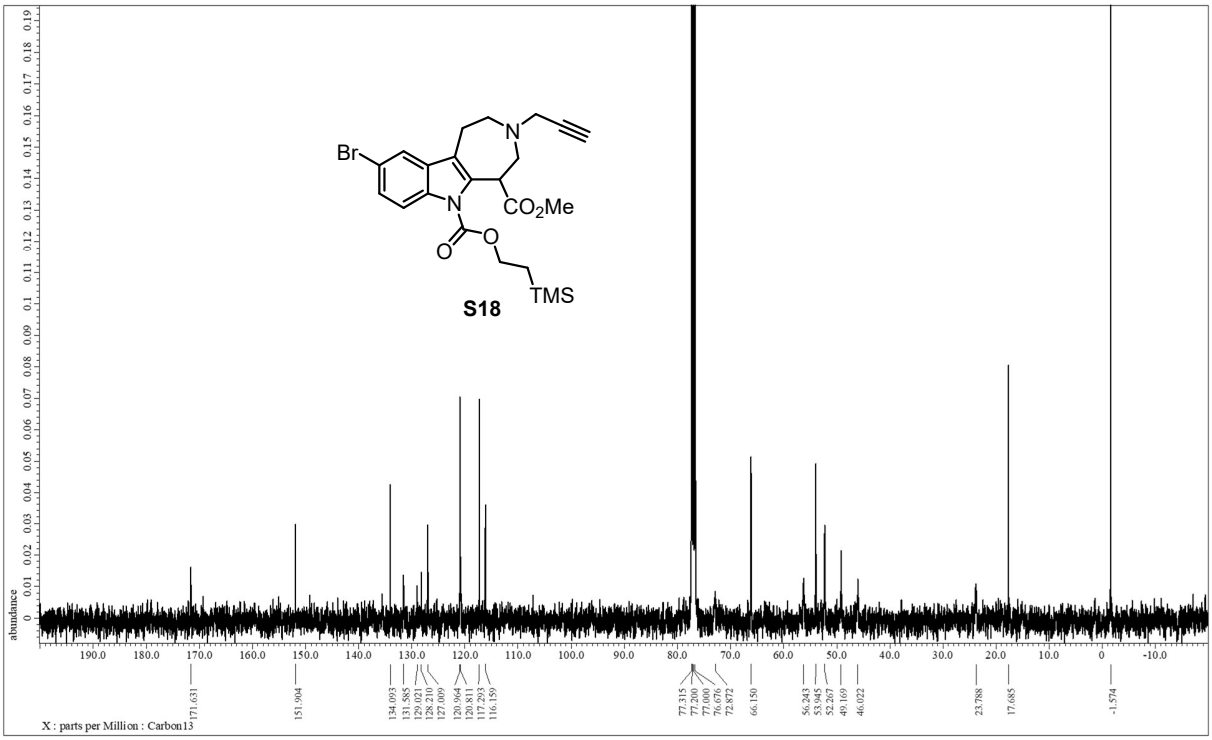


Figure S52. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **S18**.

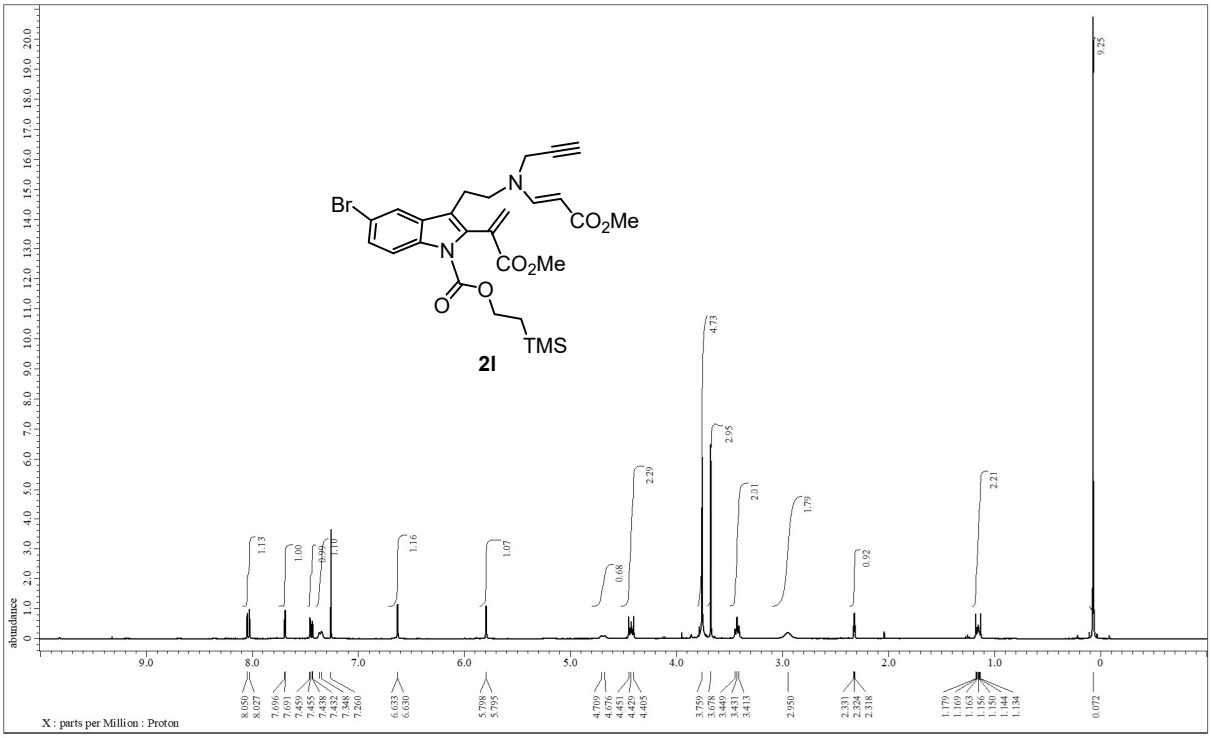


Figure S53. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **2l**.

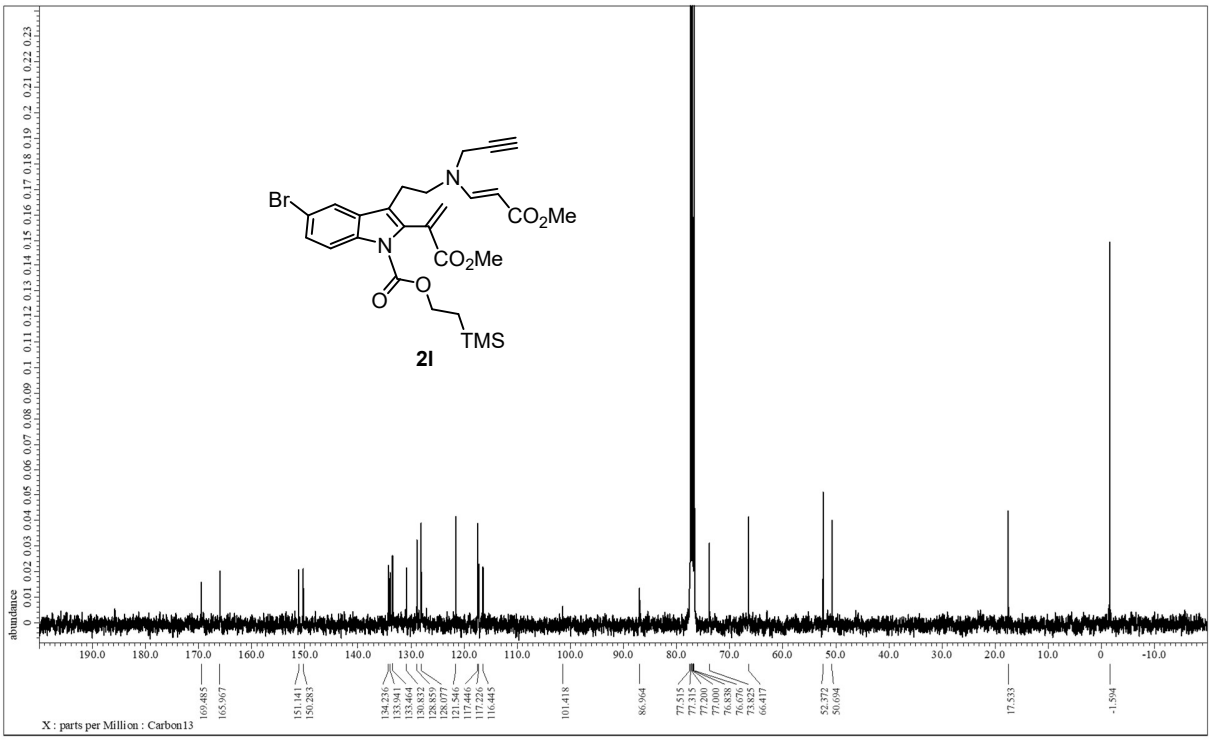


Figure S54. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **2l**.

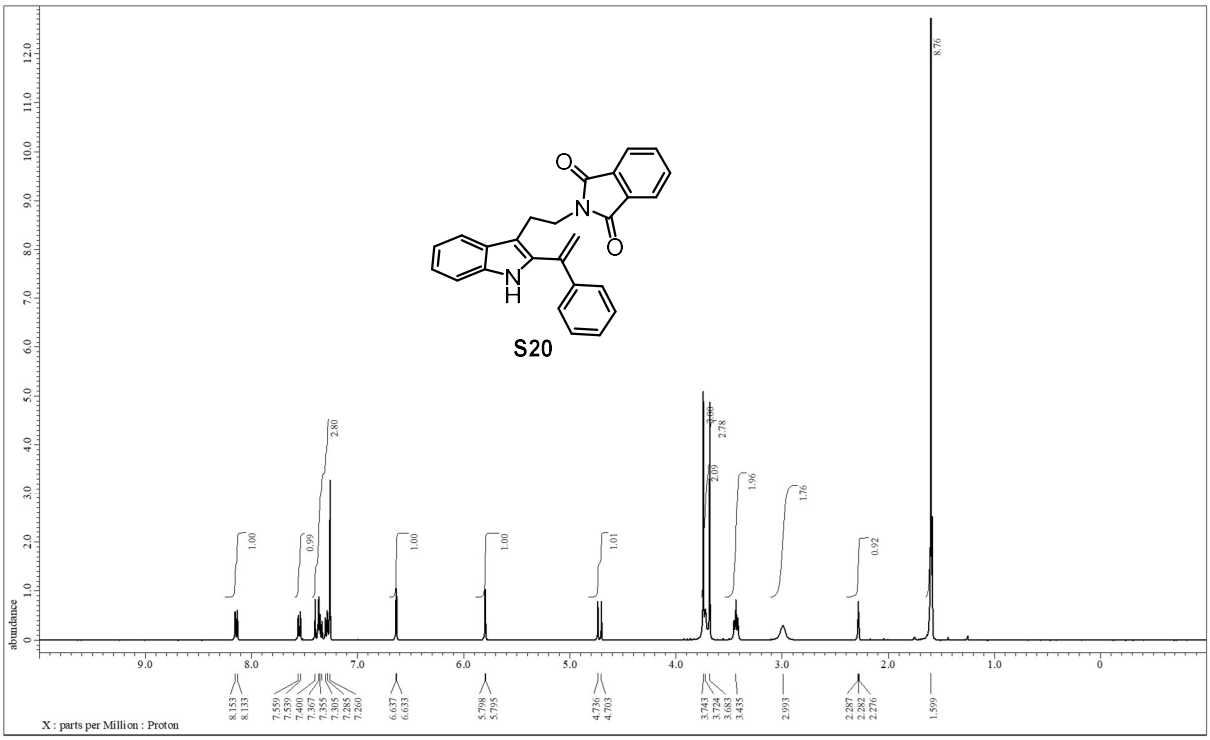


Figure S55. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **S20**.

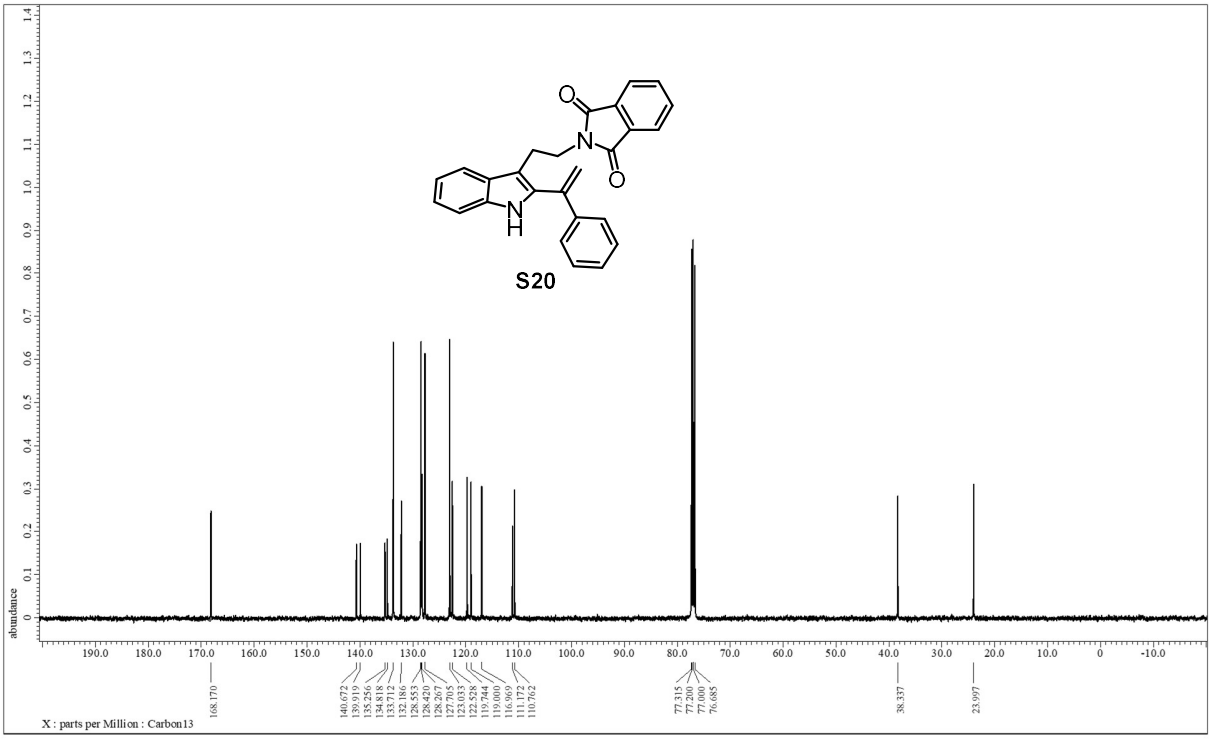


Figure S56. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **S20**.

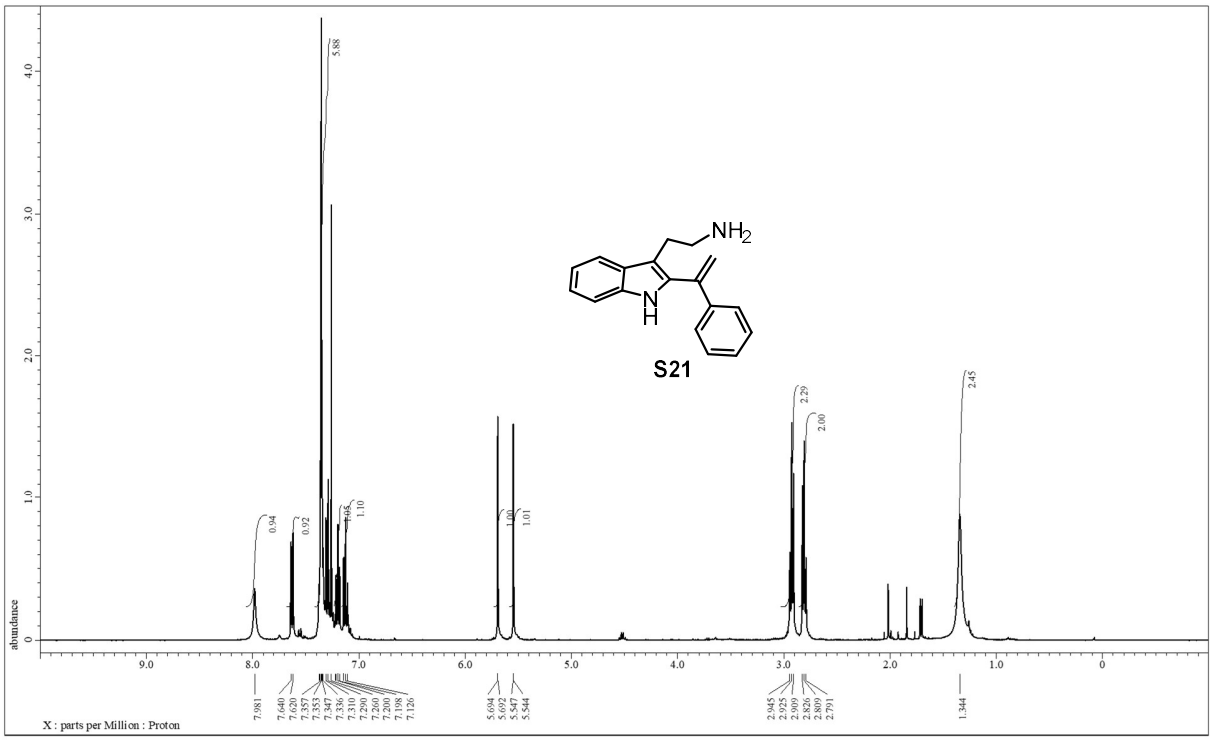


Figure S57. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **S21**.

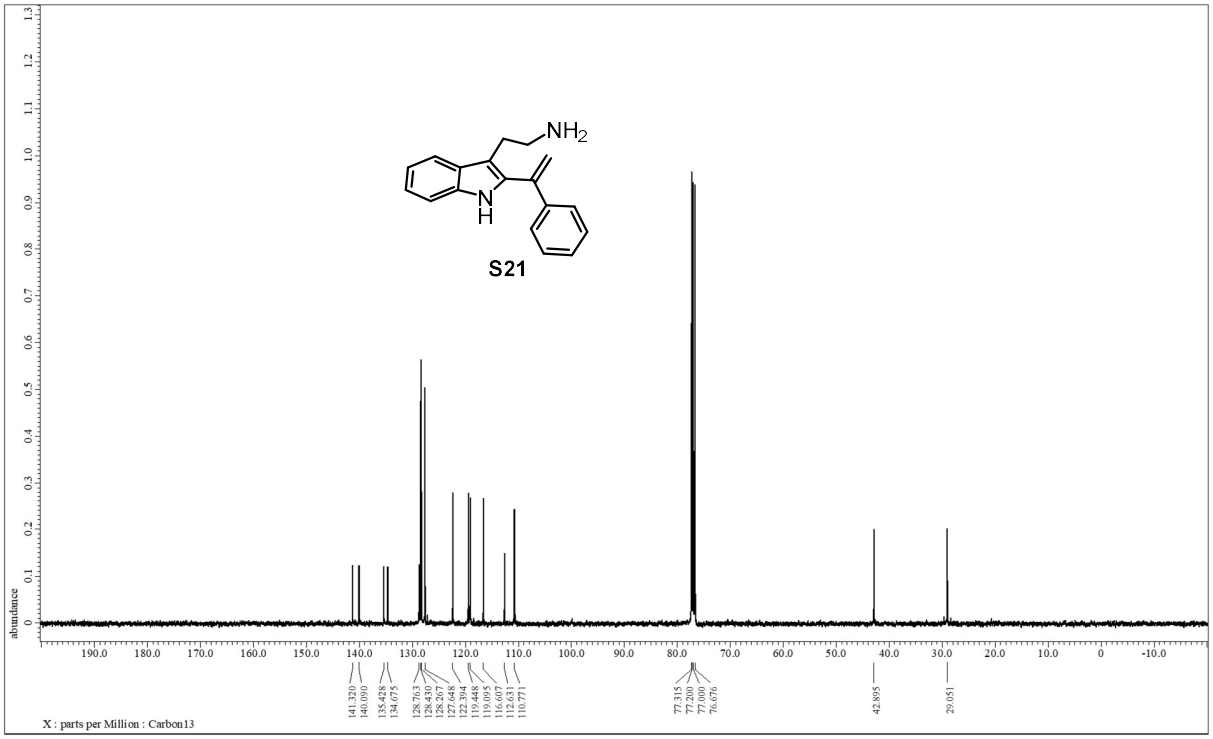


Figure S58. ^{13}C{^{1}H} NMR spectrum (100 MHz, $CDCl_3$) of **S21**.

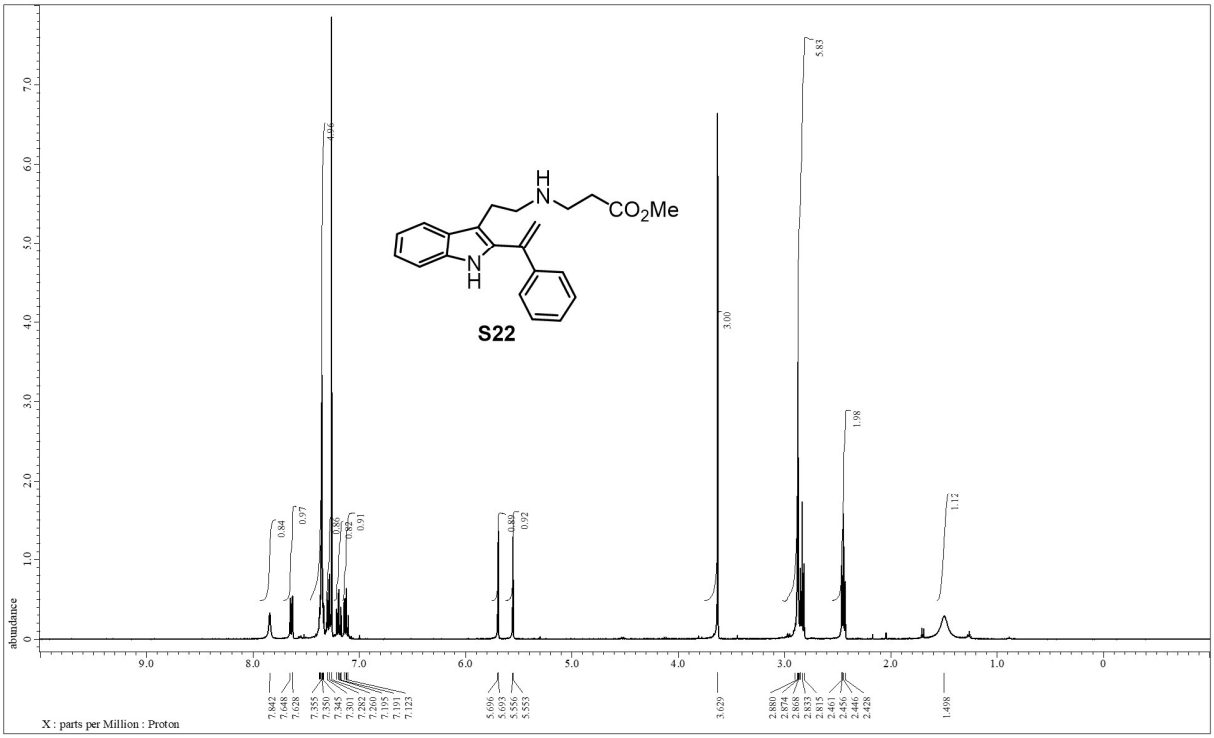


Figure S59. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **S22**.

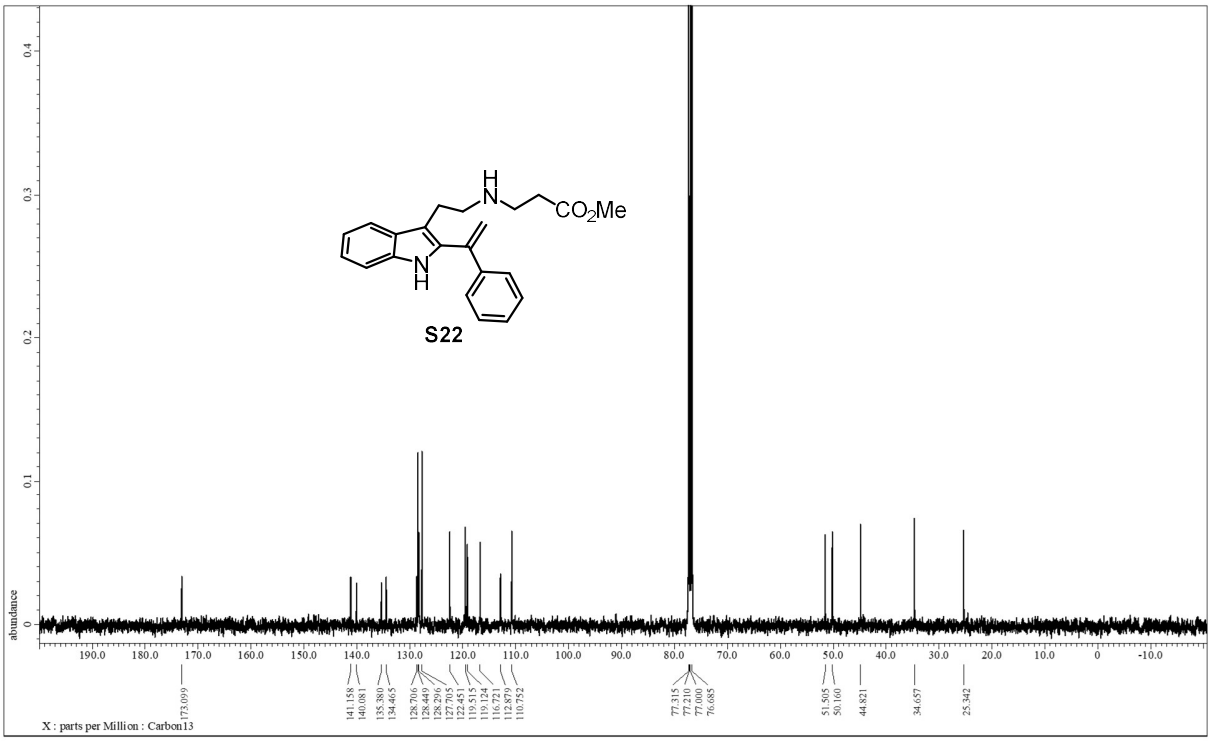


Figure S60. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **S22**.

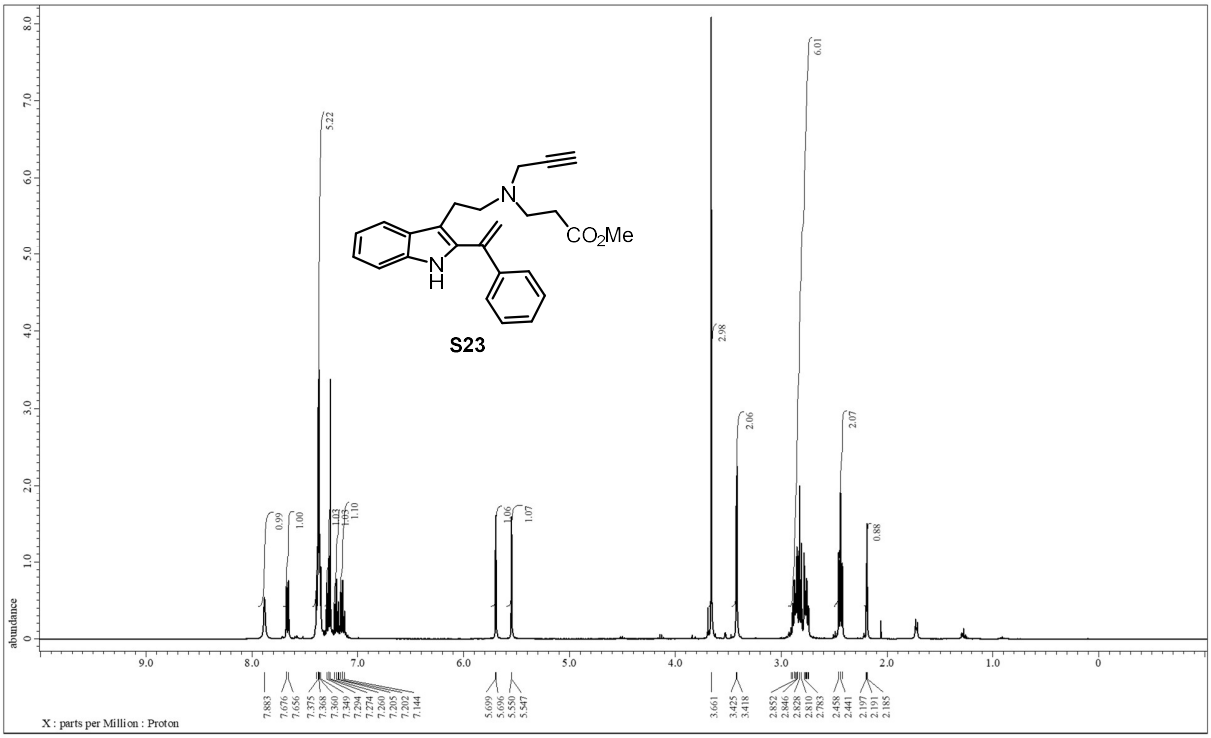


Figure S61. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **S23**.

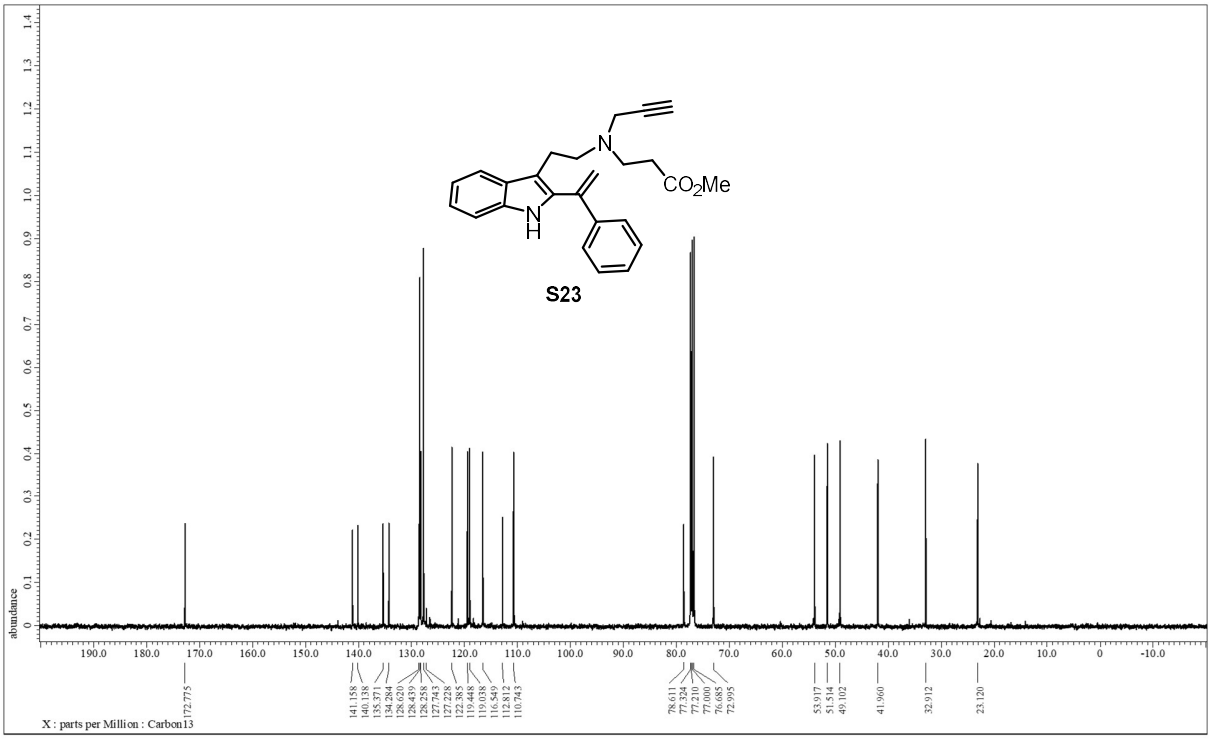


Figure S62. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **S23**.

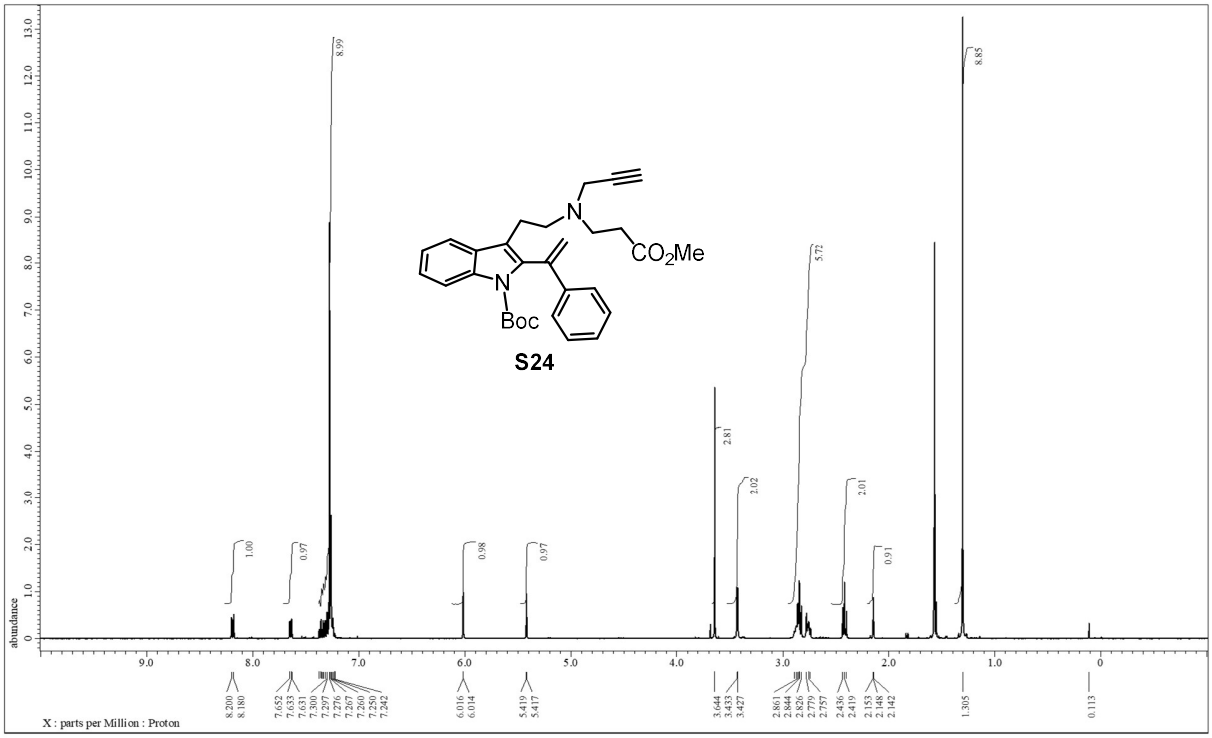


Figure S63. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **S24**.

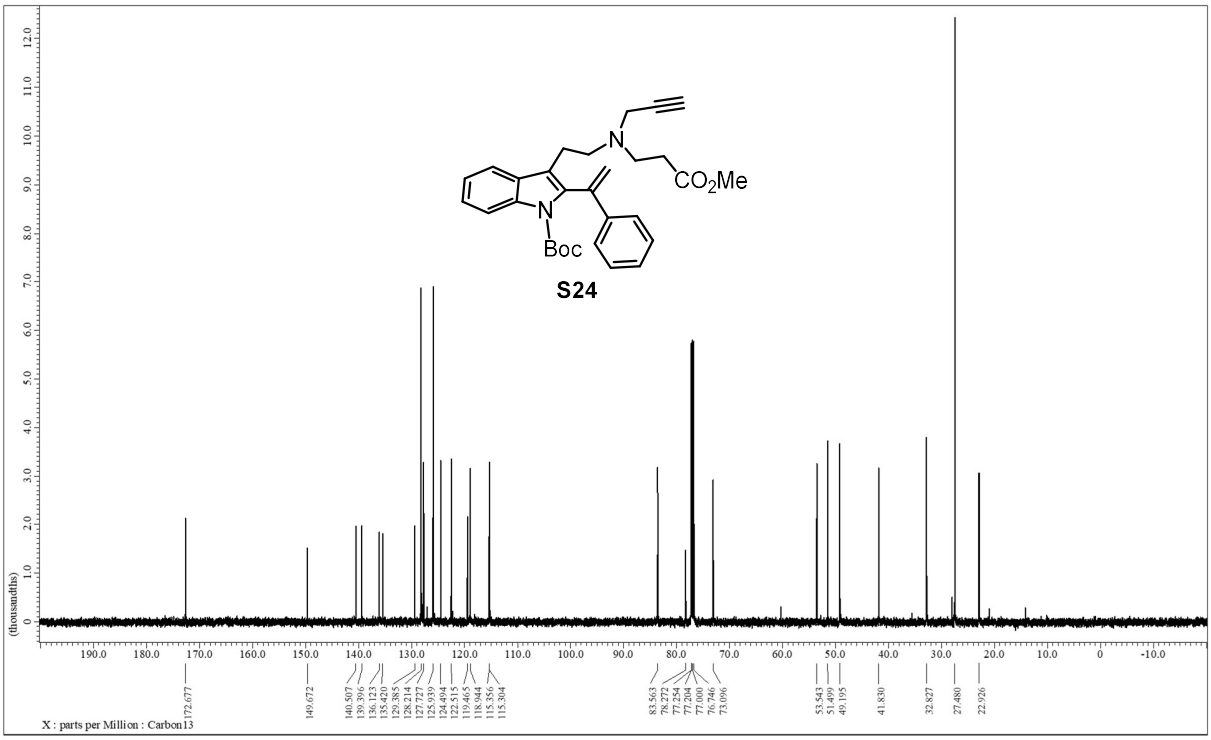


Figure S64. $^{13}C\{^{1}H\}$ NMR spectrum (125 MHz, $CDCl_3$) of **S24**.

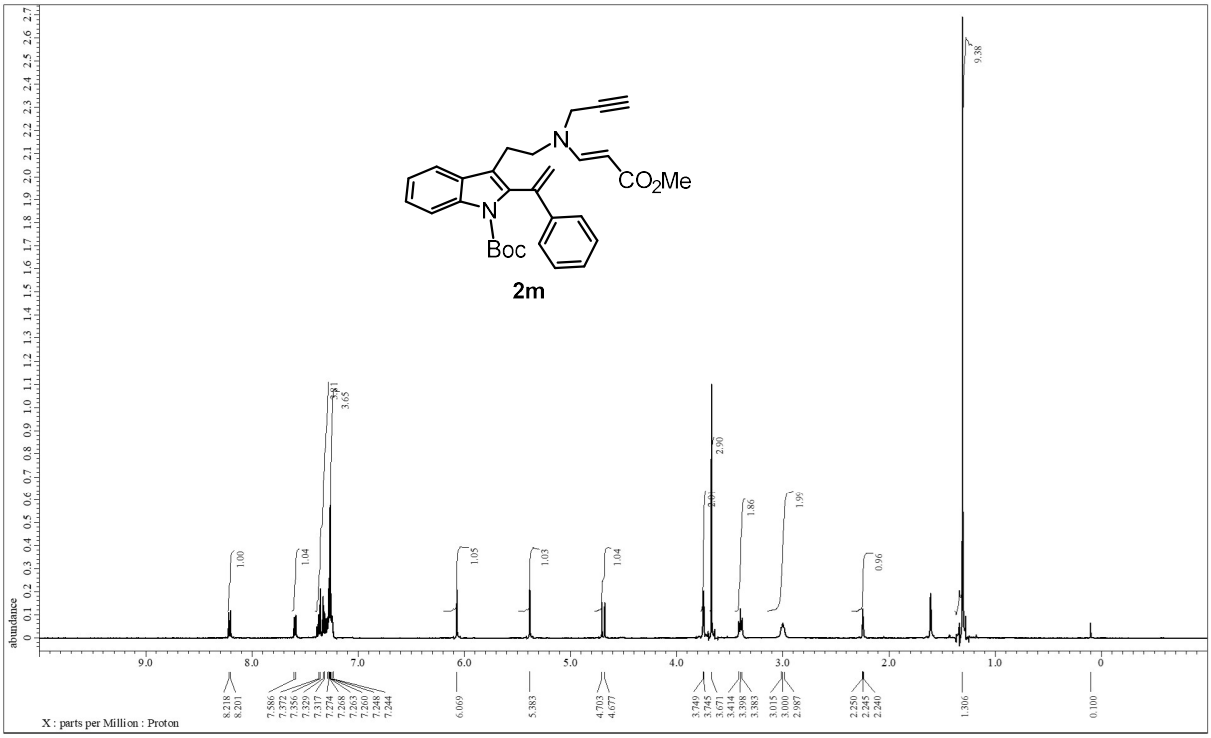


Figure S65. ^{1}H NMR spectrum (500 MHz, $CDCl_3$) of **2m**.

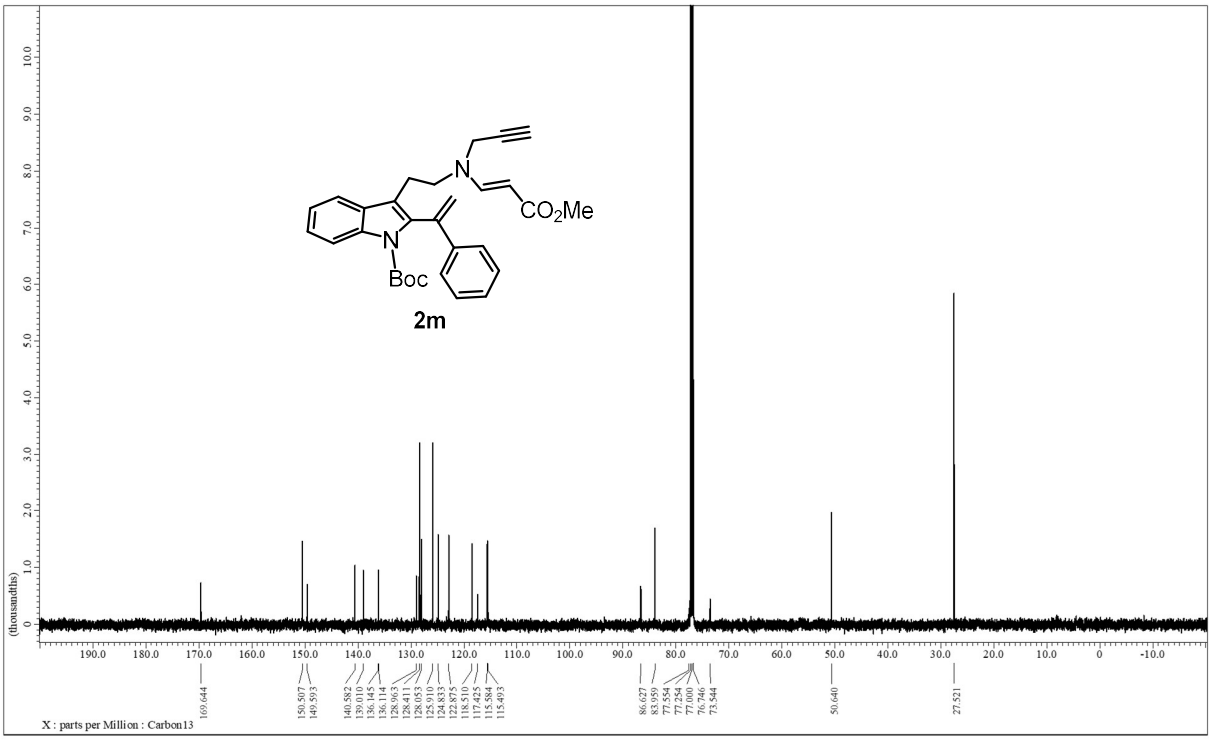


Figure S66. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **2m**.

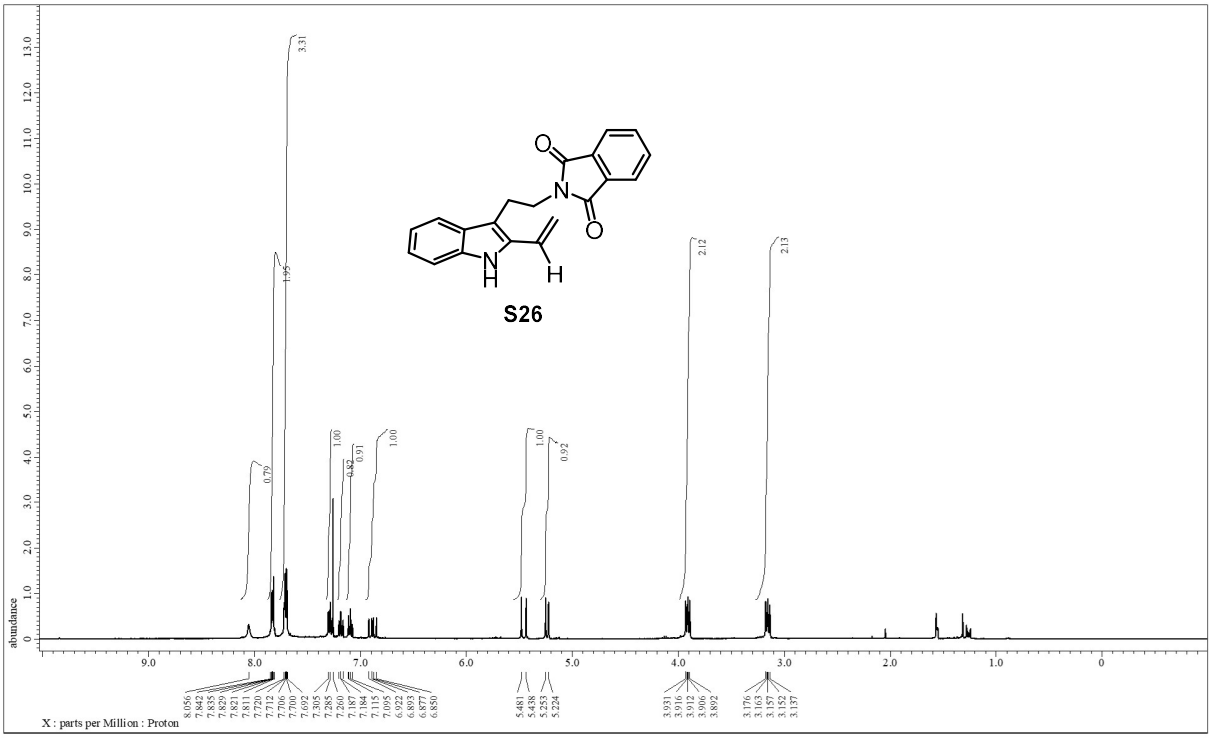


Figure S67. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **S26**.

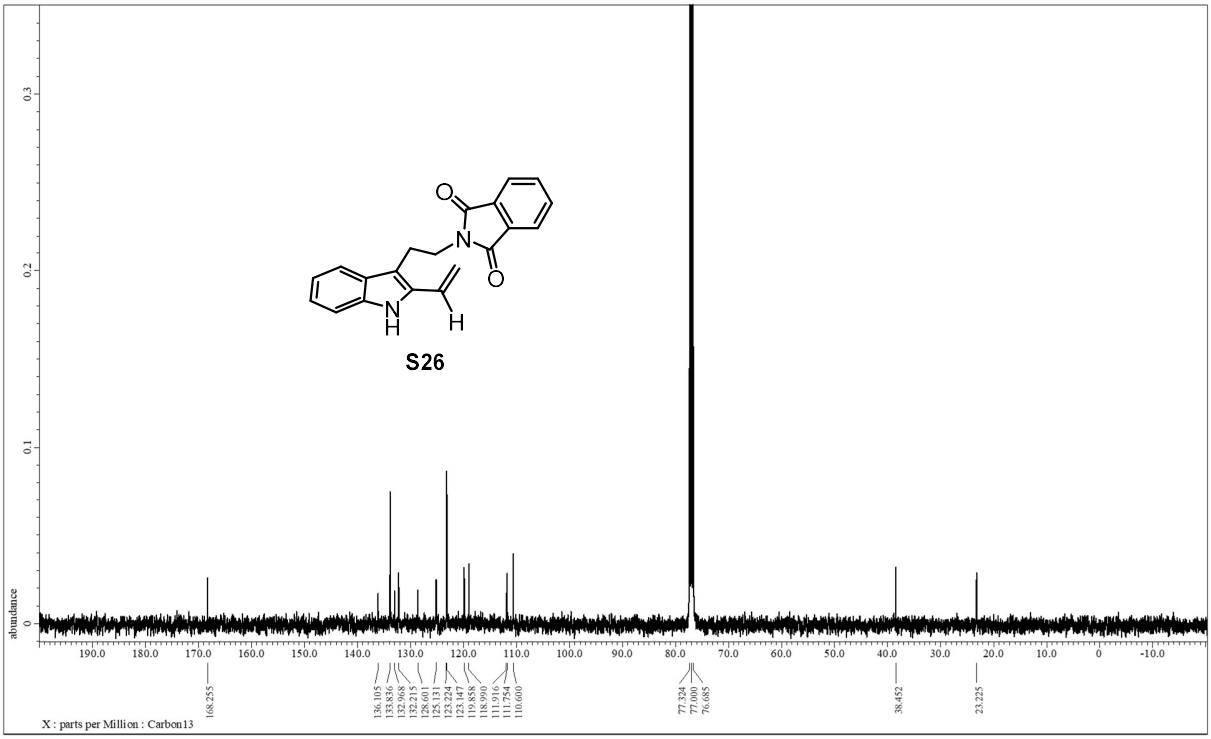


Figure S68. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **S26**.

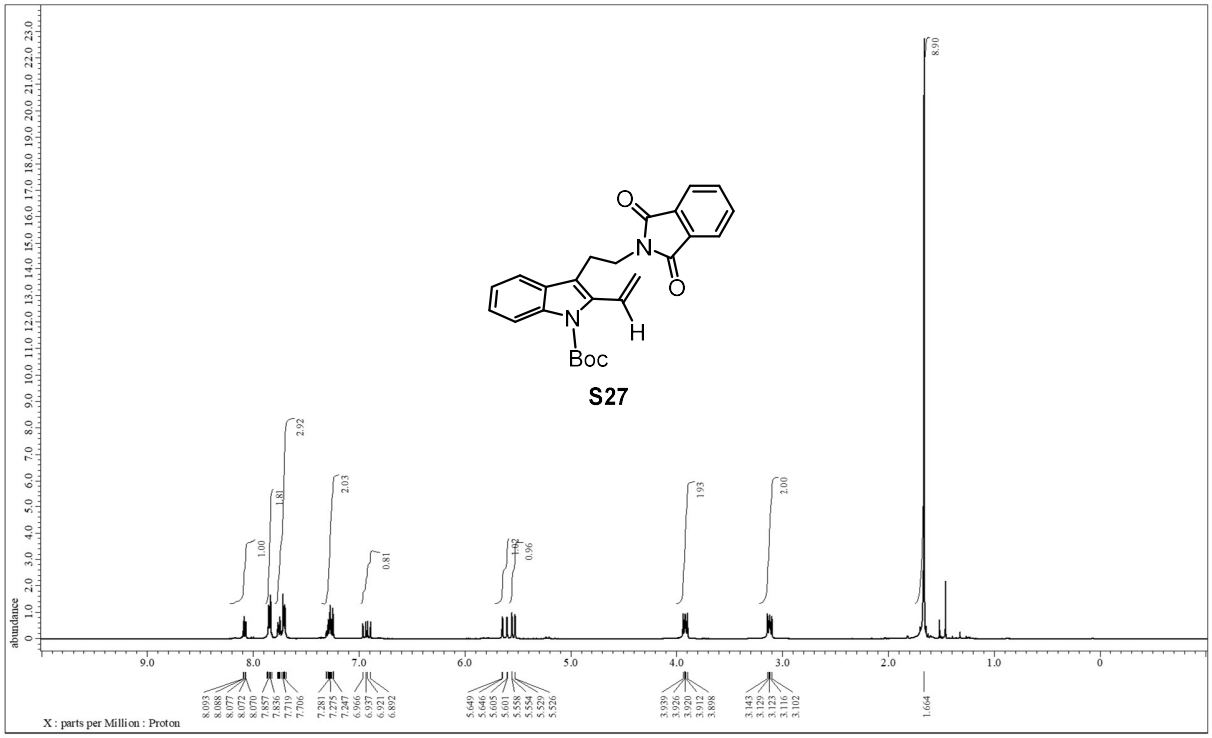


Figure S69. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **S27**.

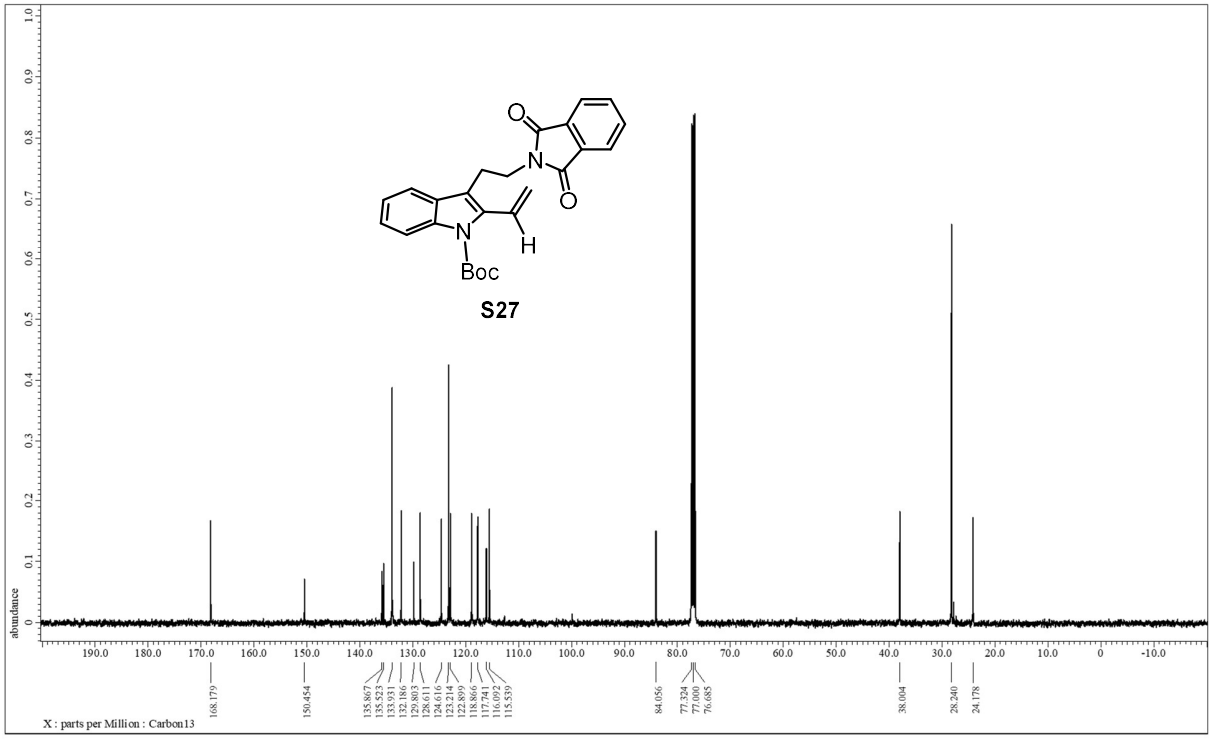


Figure S70. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **S27**.

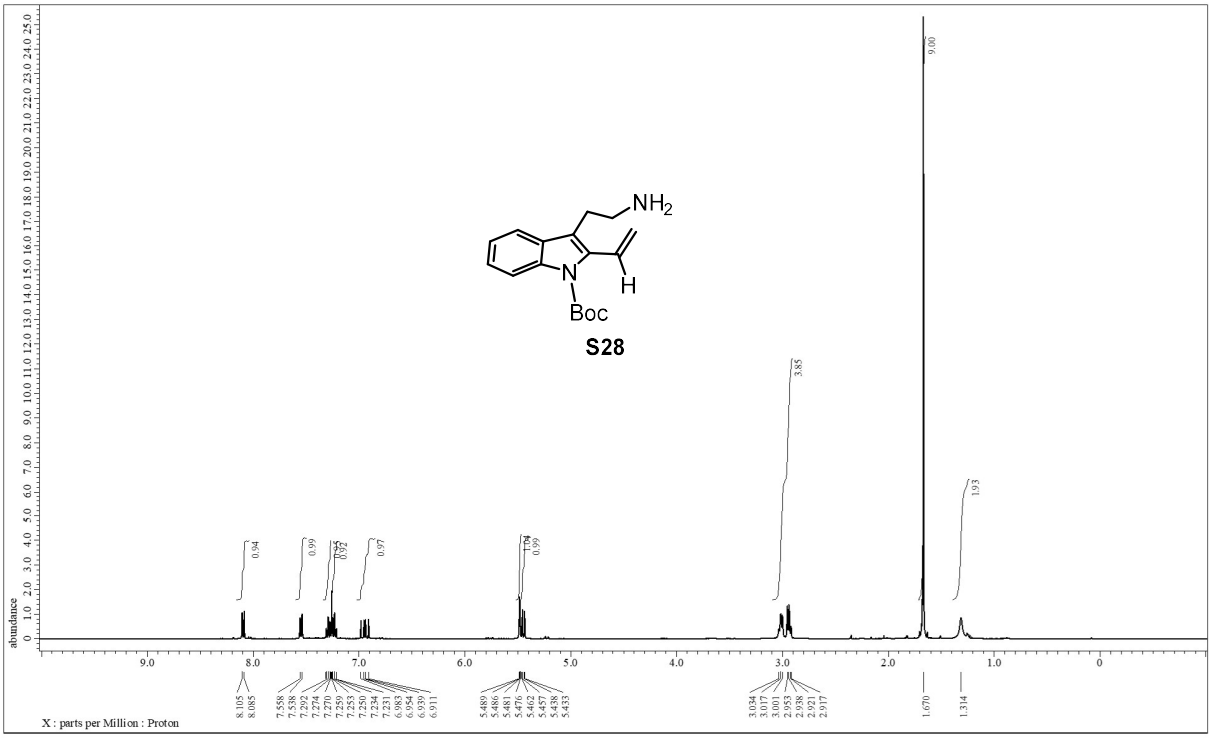


Figure S71. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **S28**.

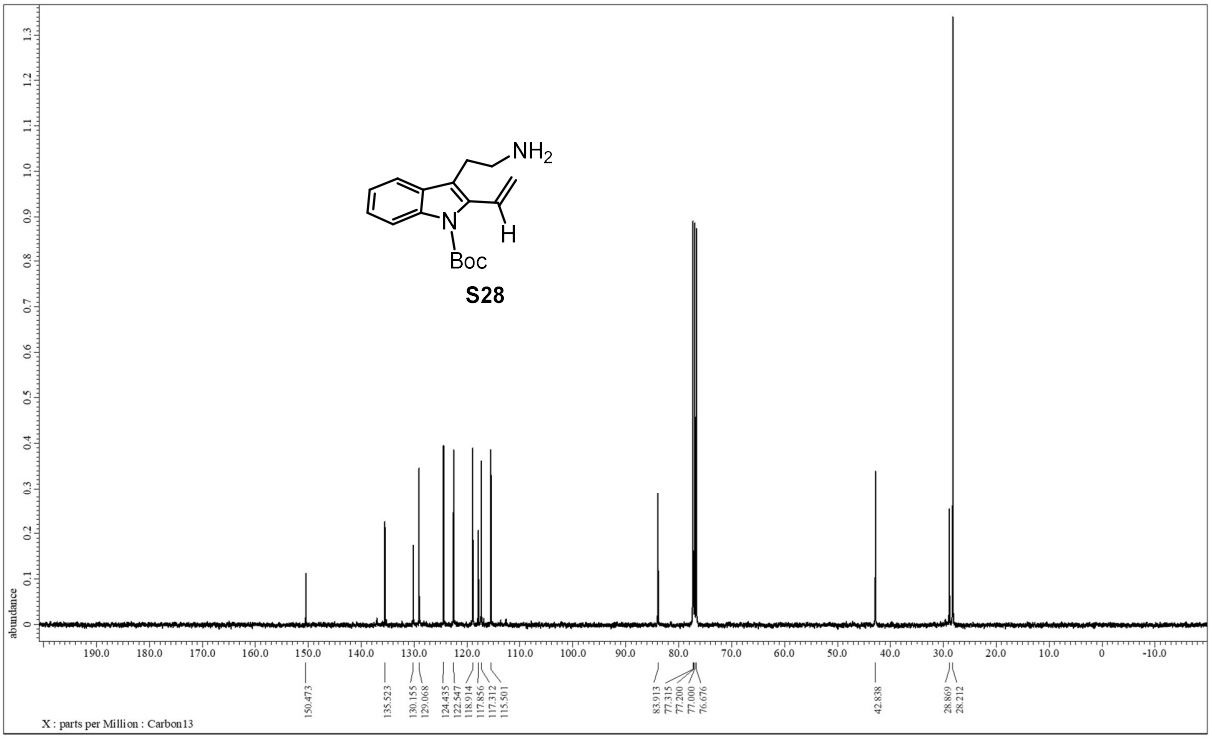


Figure S72. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **S28**.

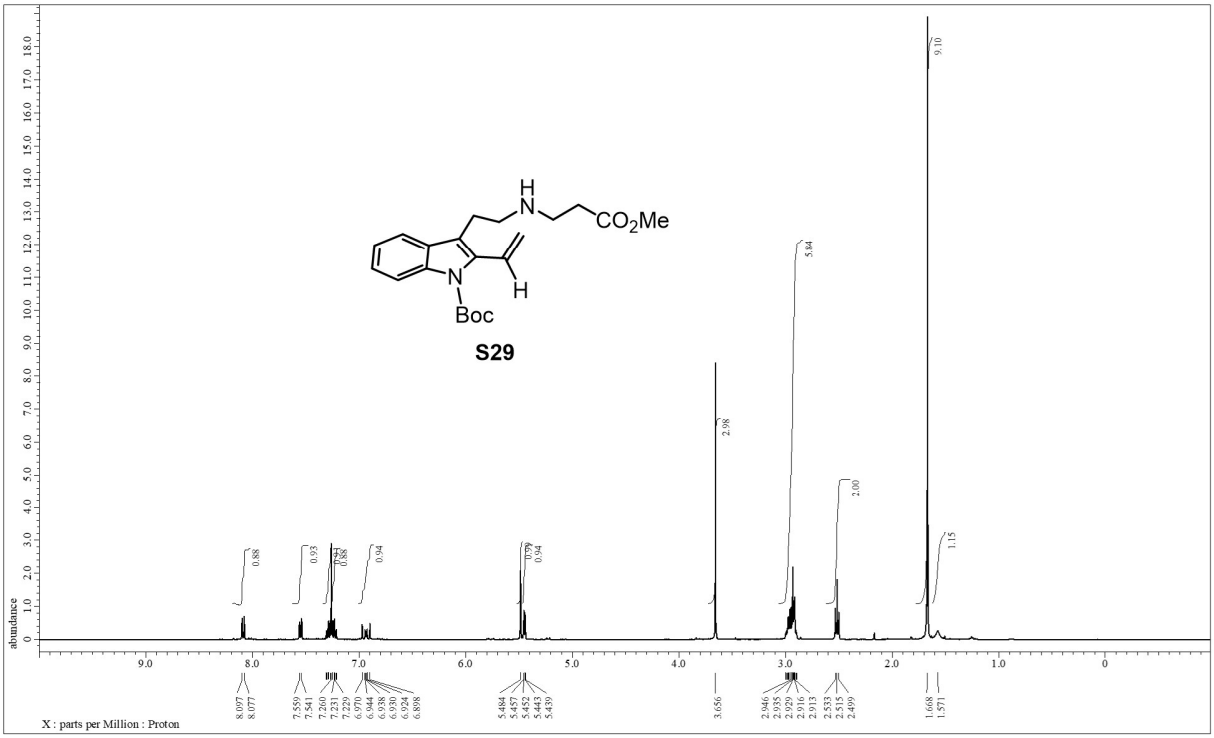


Figure S73. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **S29**.

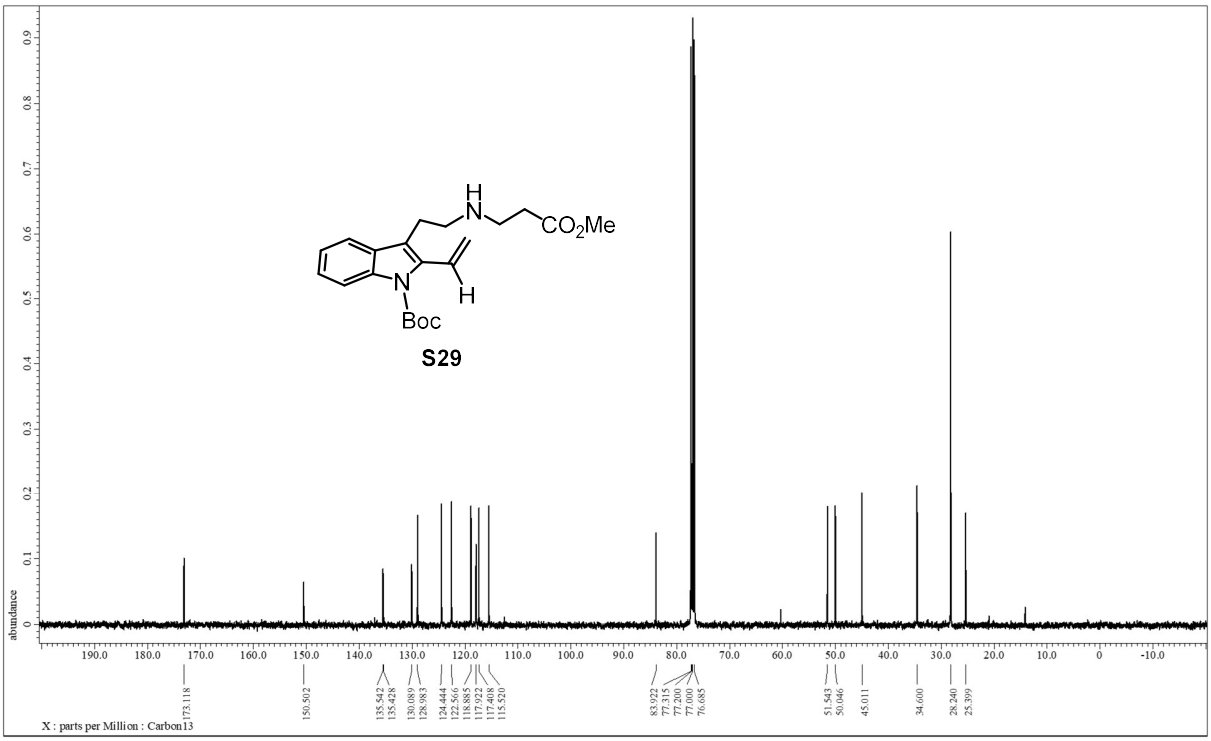


Figure S74. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **S29**.

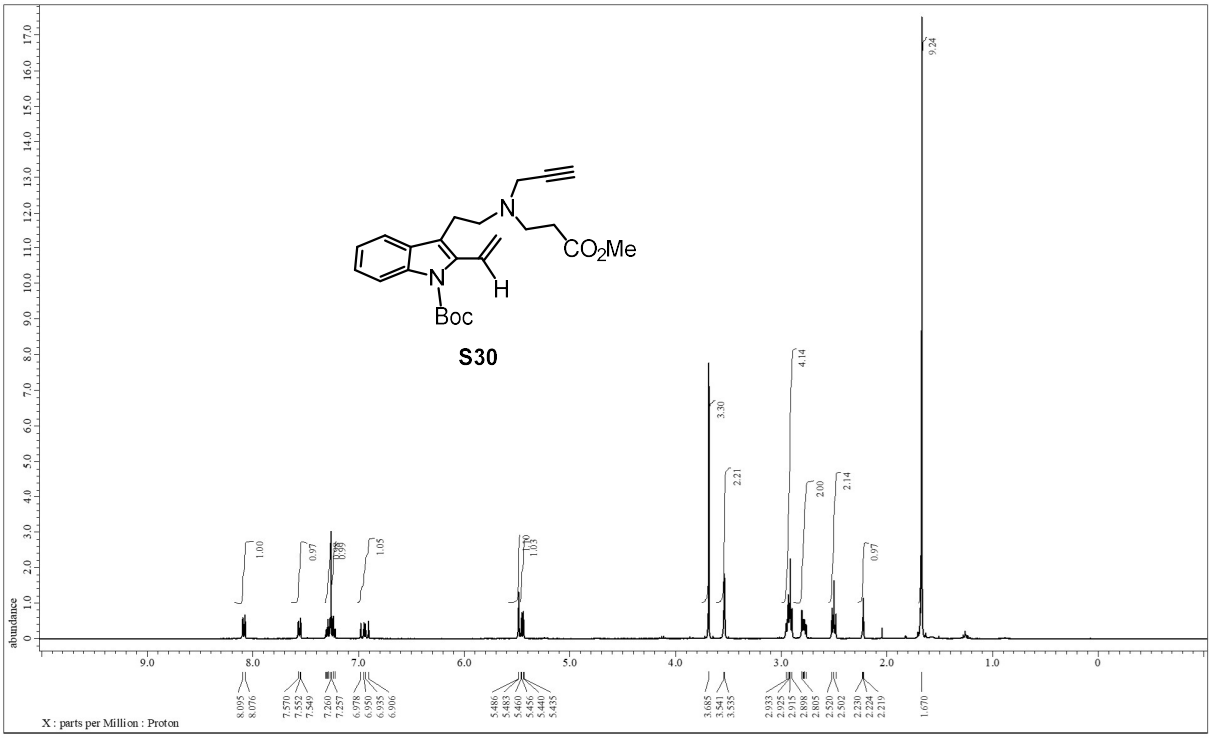


Figure S75. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **S30**.

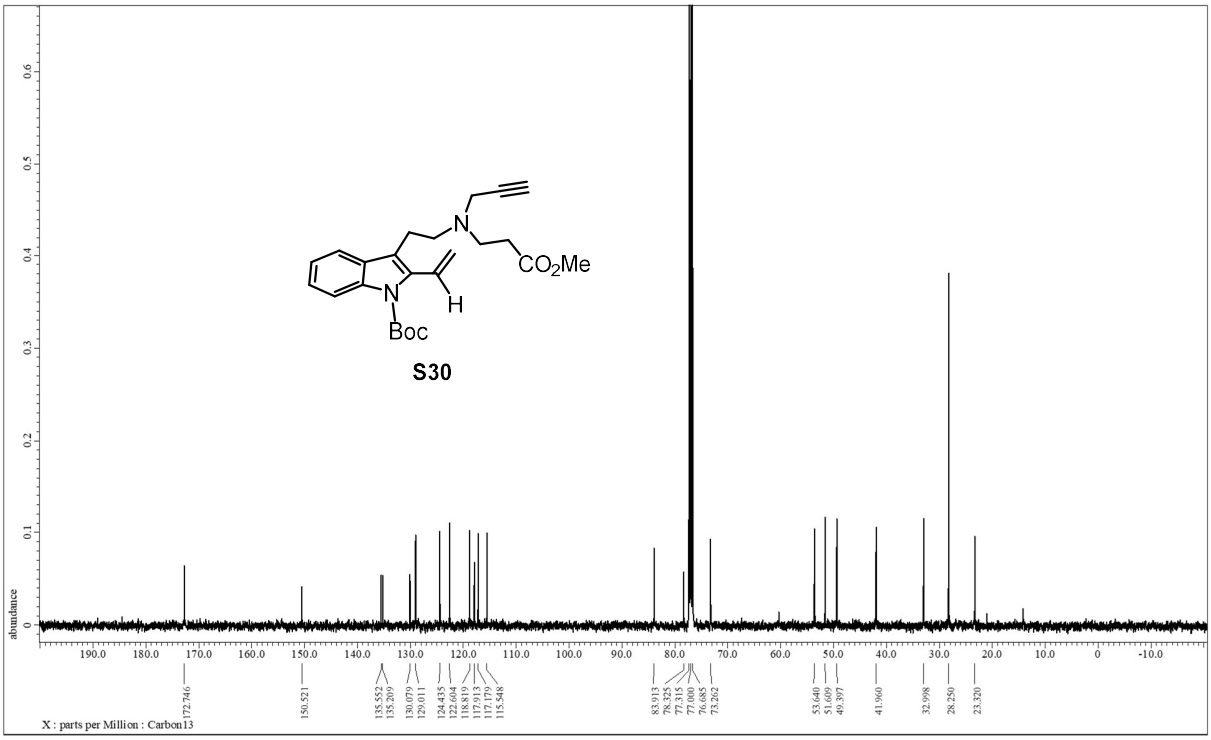


Figure S76. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **S30**.

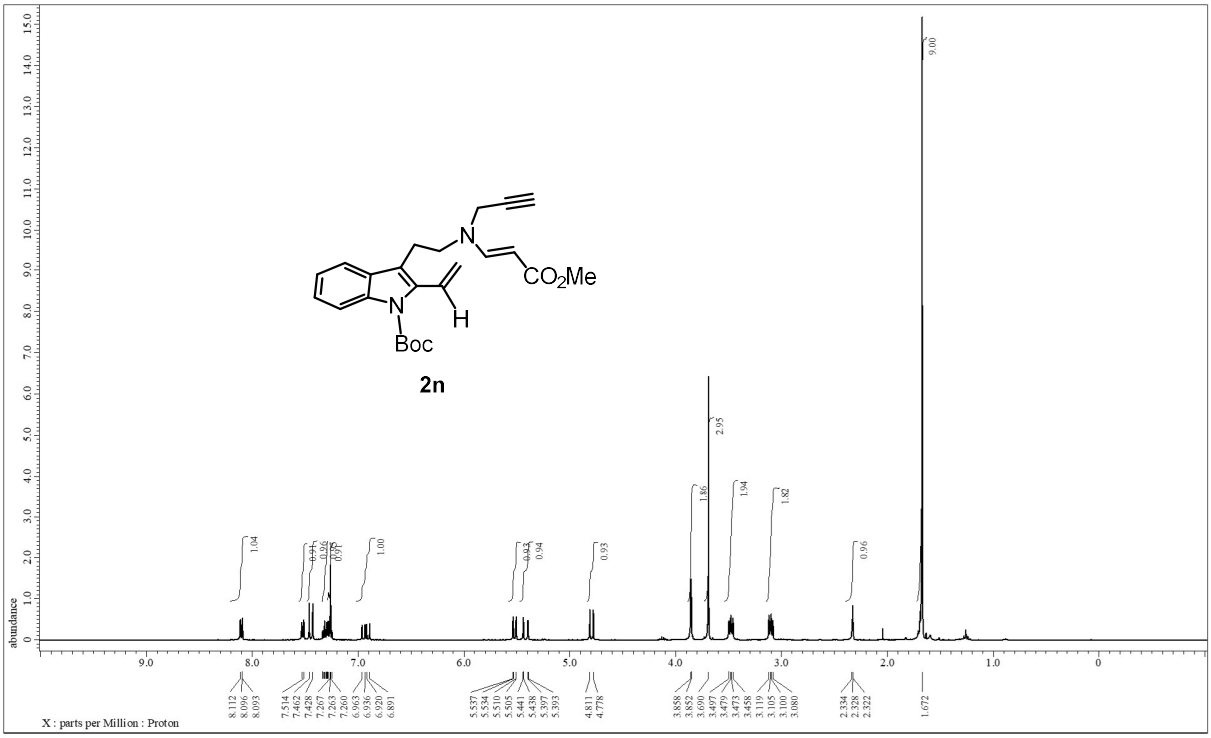


Figure S77. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **2n**.

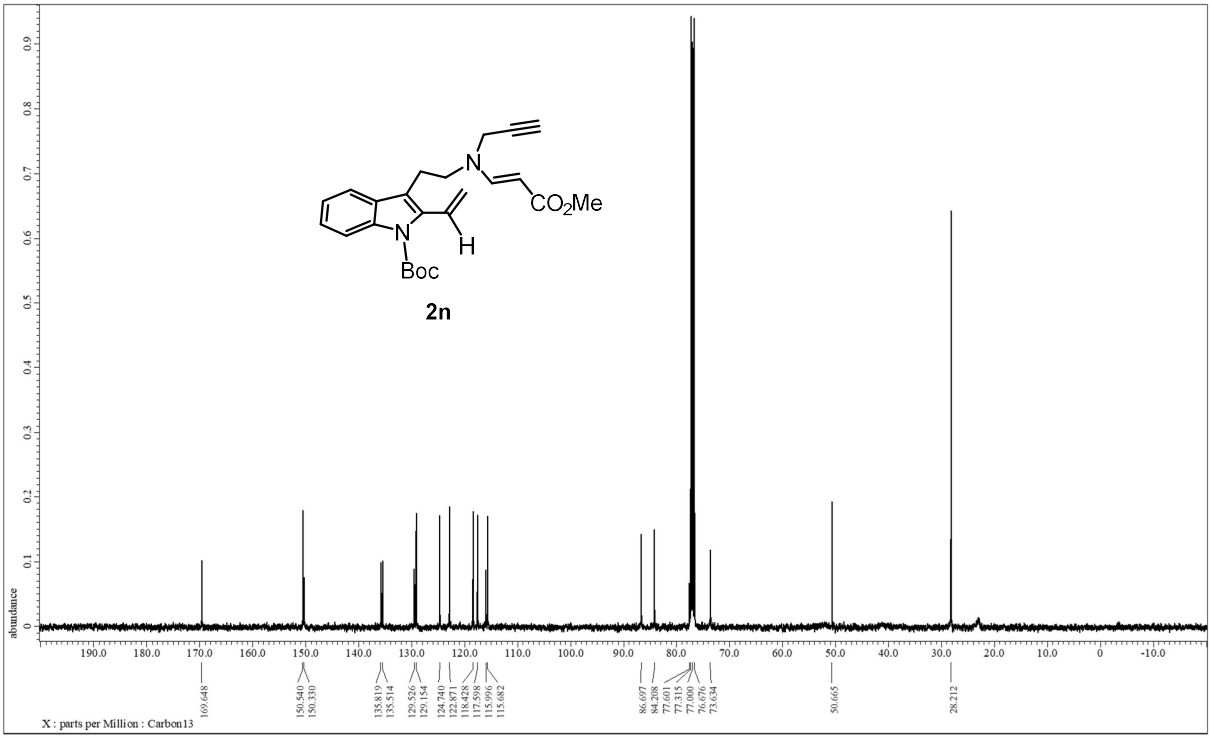


Figure S78. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **2n**.

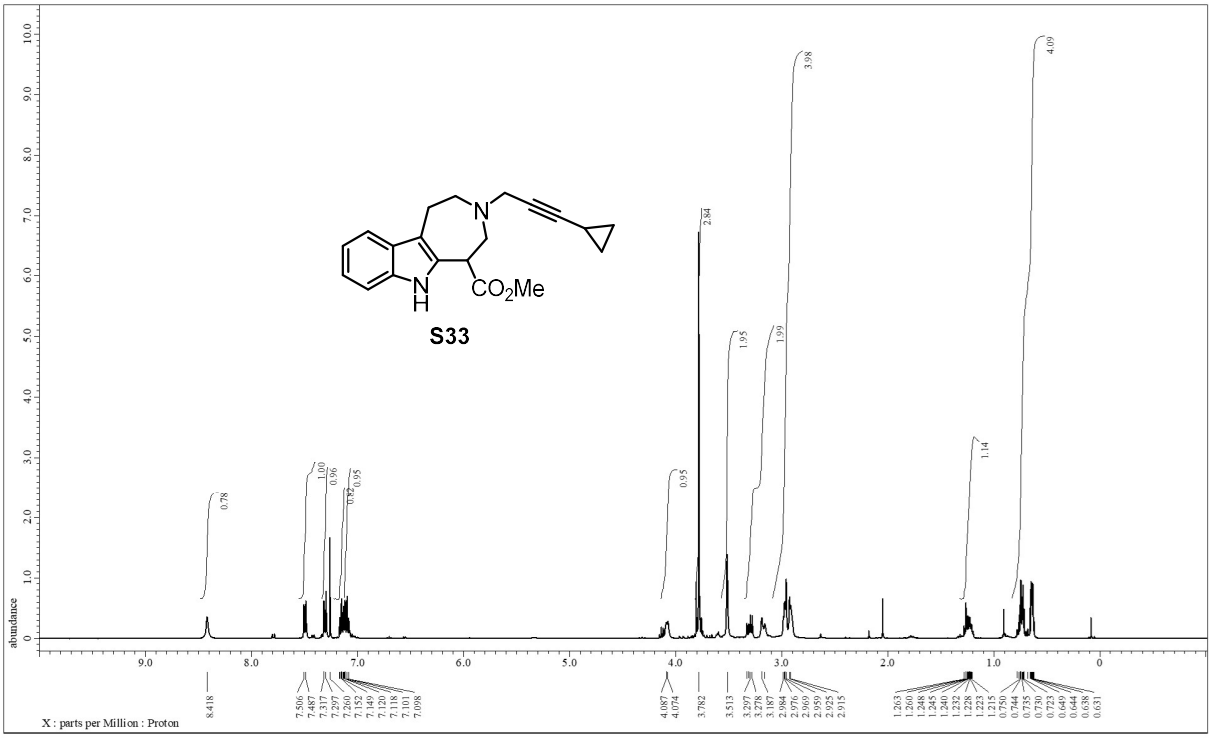


Figure S79. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **S33**.

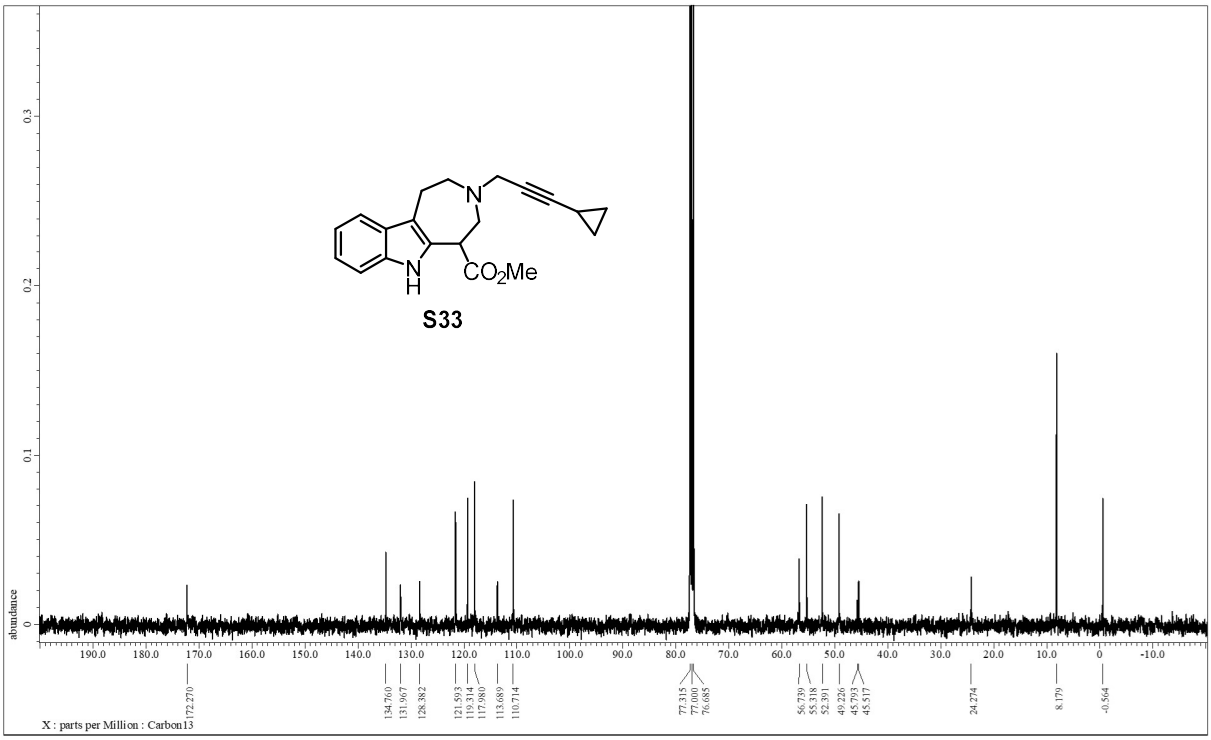


Figure S80. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **S33**.

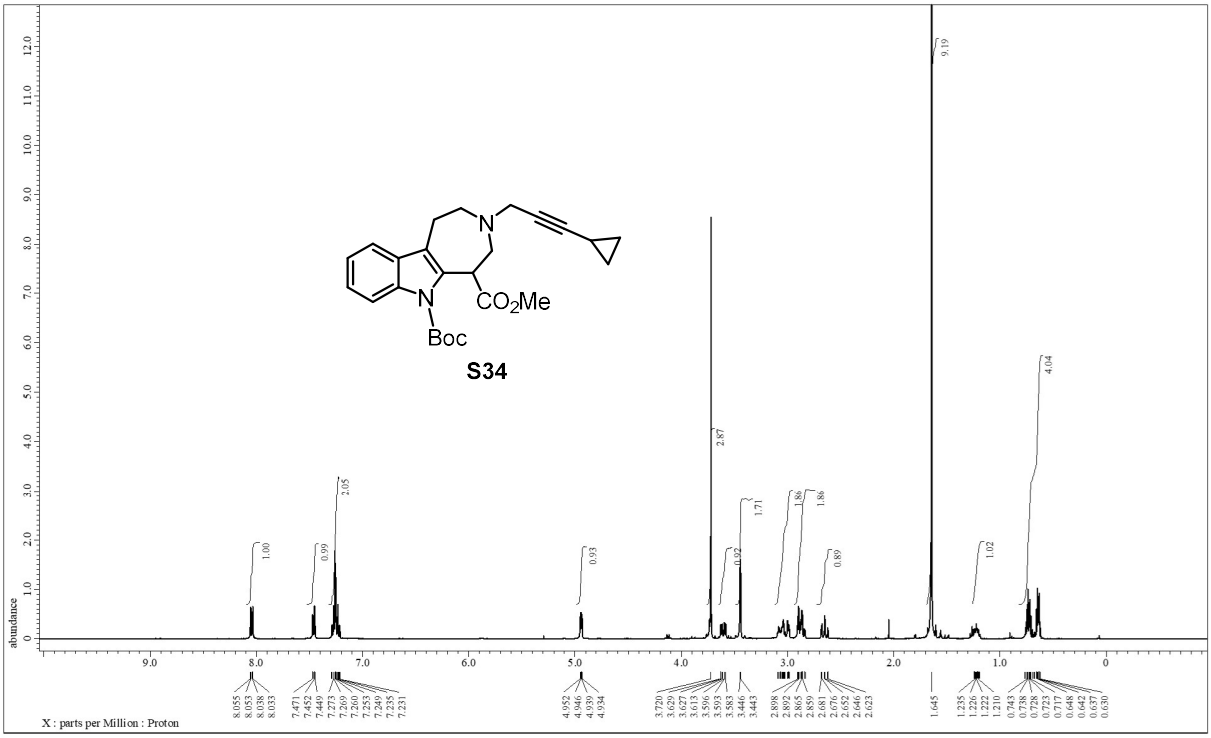


Figure S81. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **S34**.

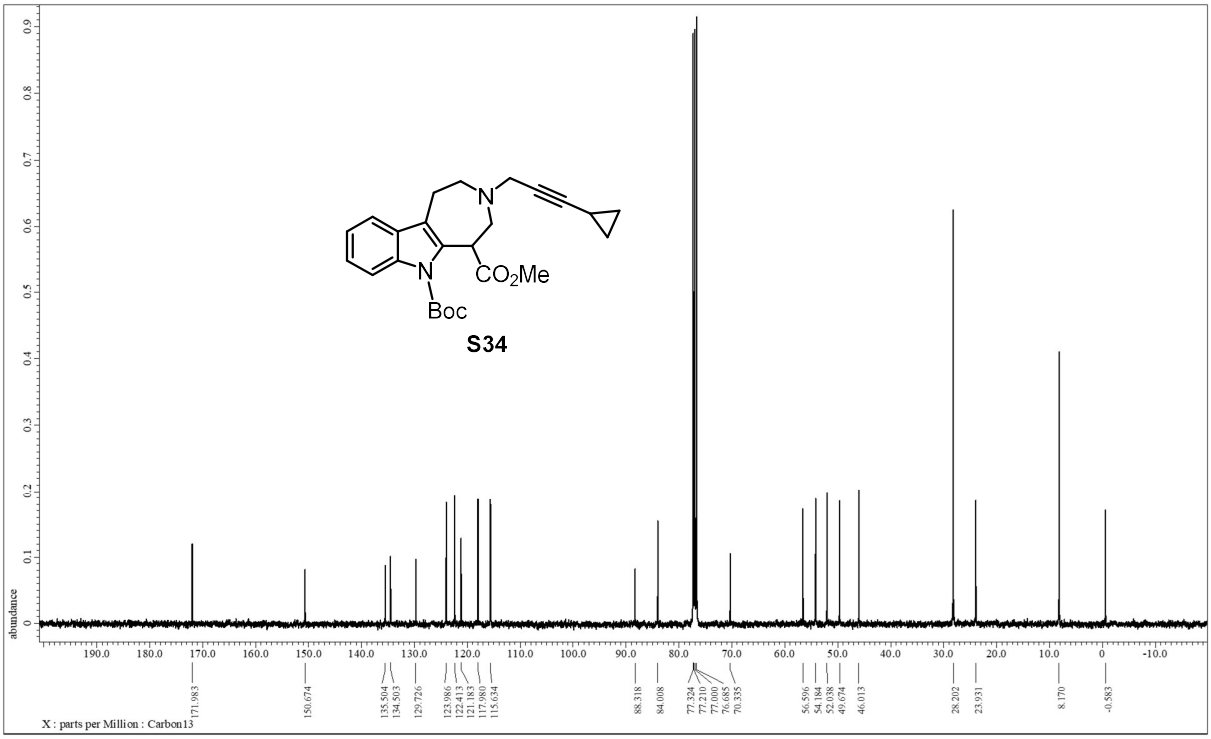


Figure S82. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **S34**.

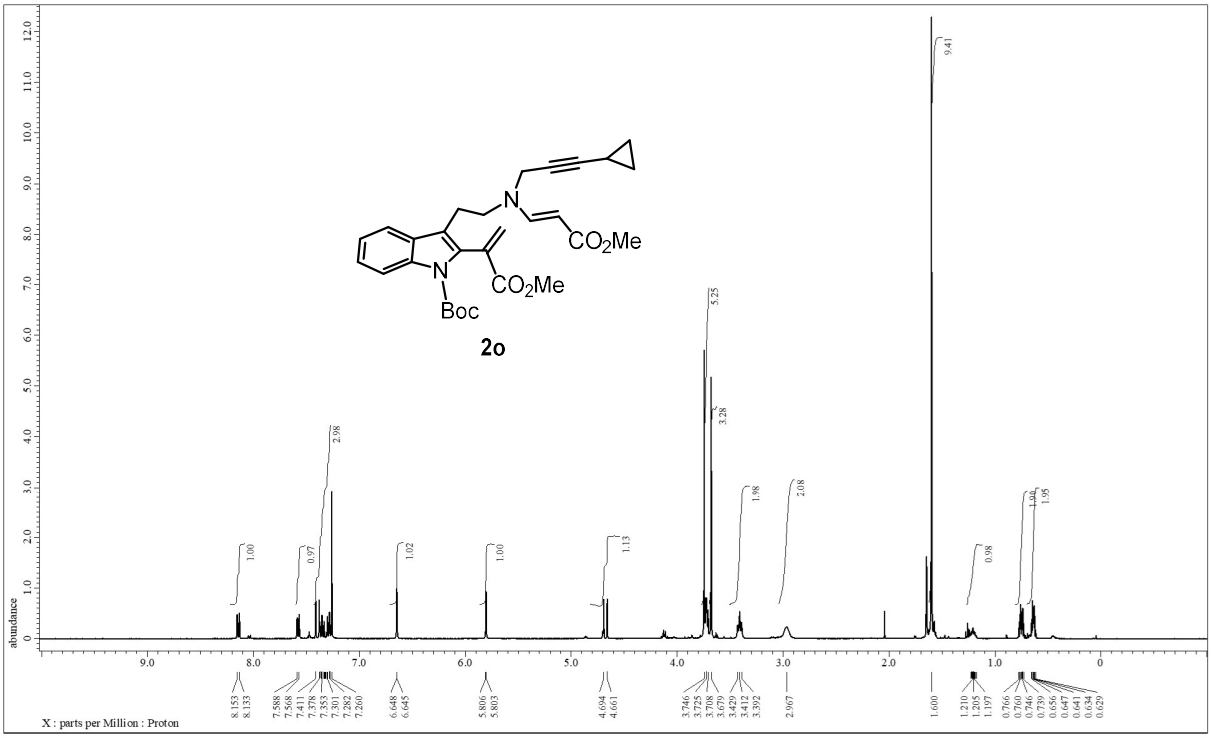


Figure S83. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **2o**.

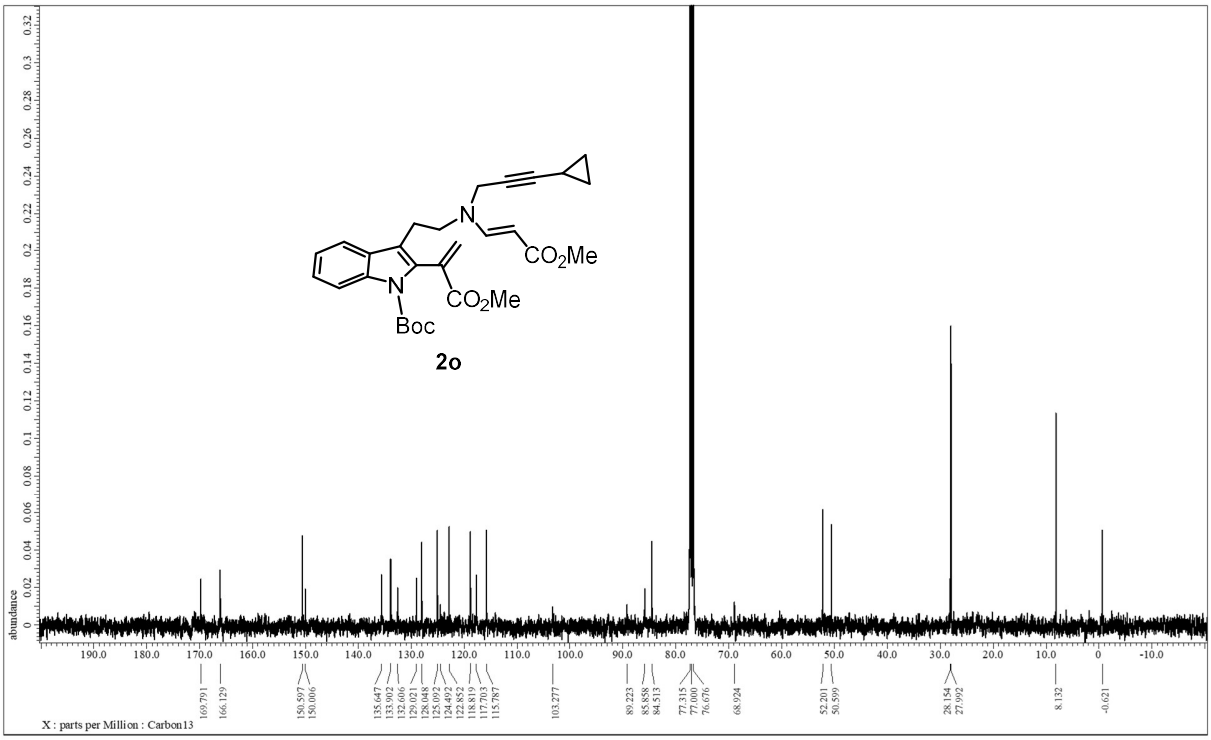


Figure S84. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **2o**.

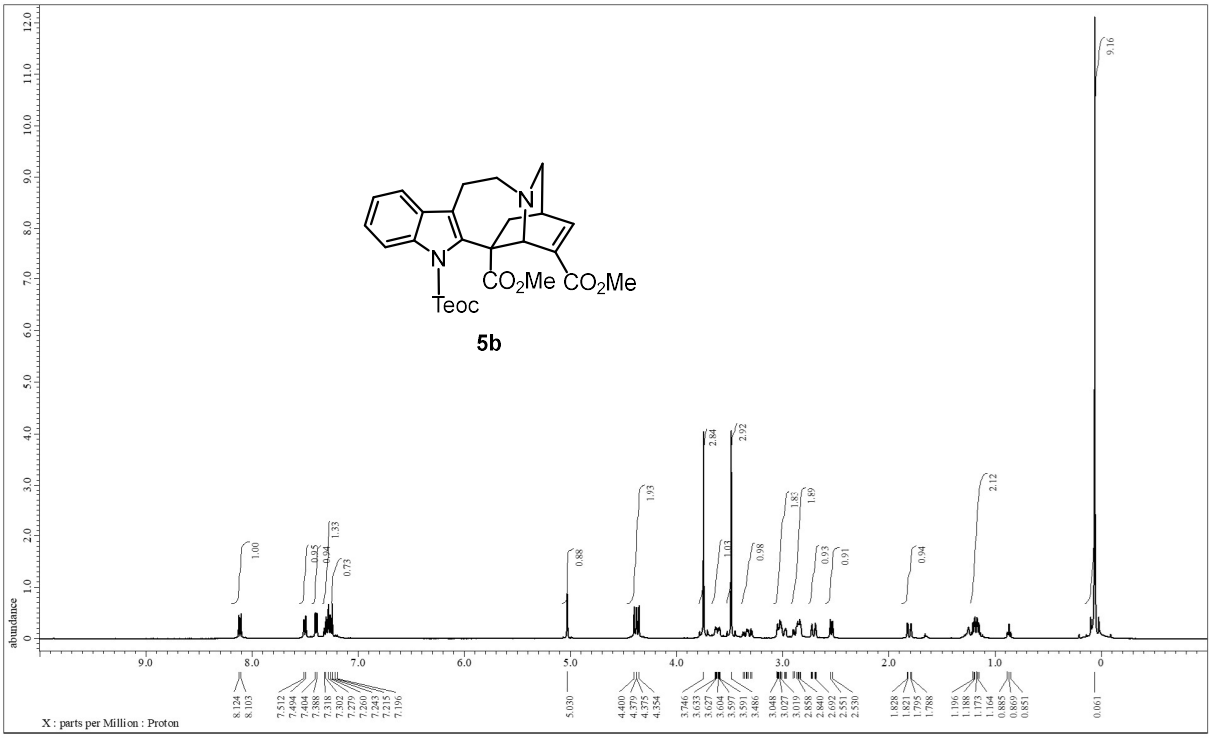


Figure S85. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **5b**.

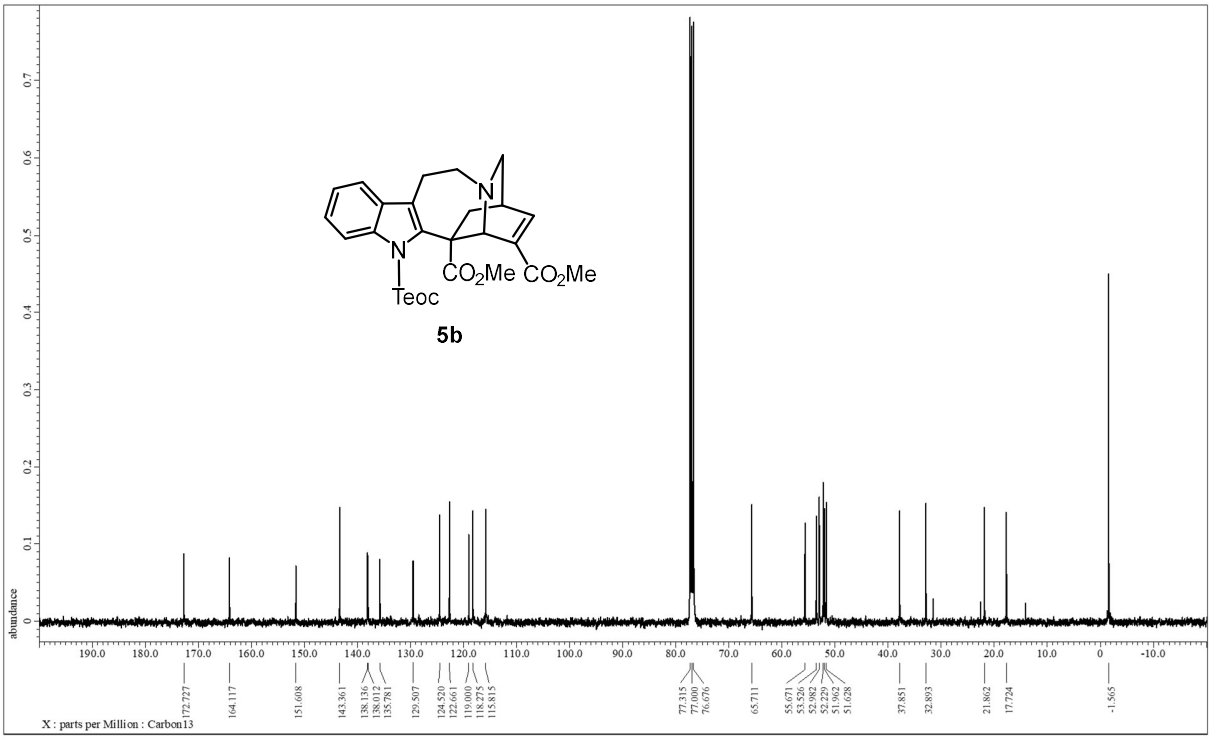


Figure S86. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **5b**.

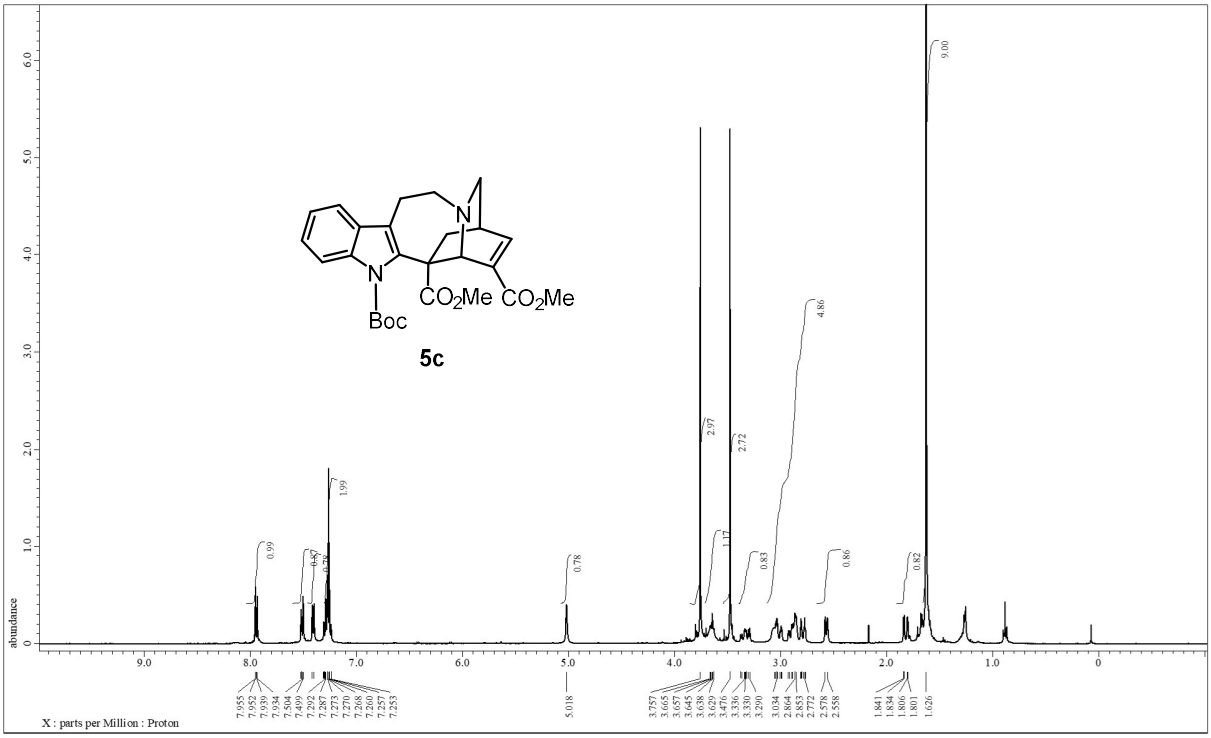


Figure S87. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **5c**.

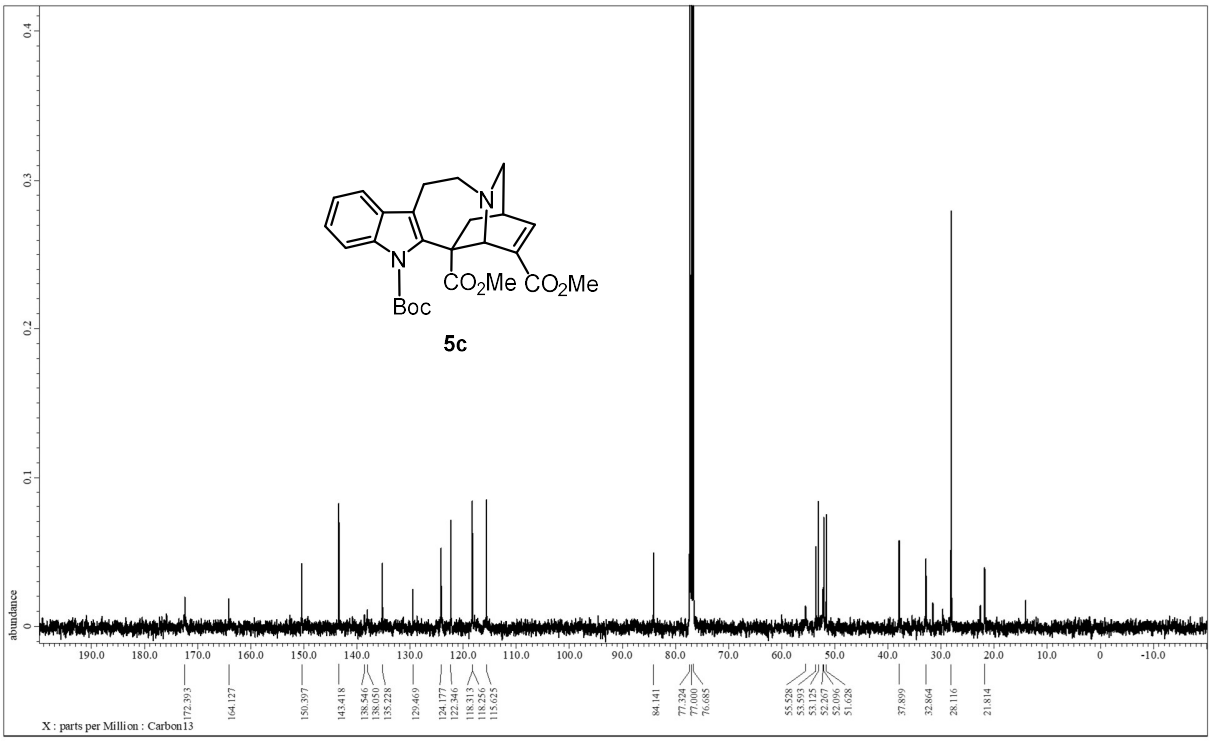


Figure S88. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **5c**.

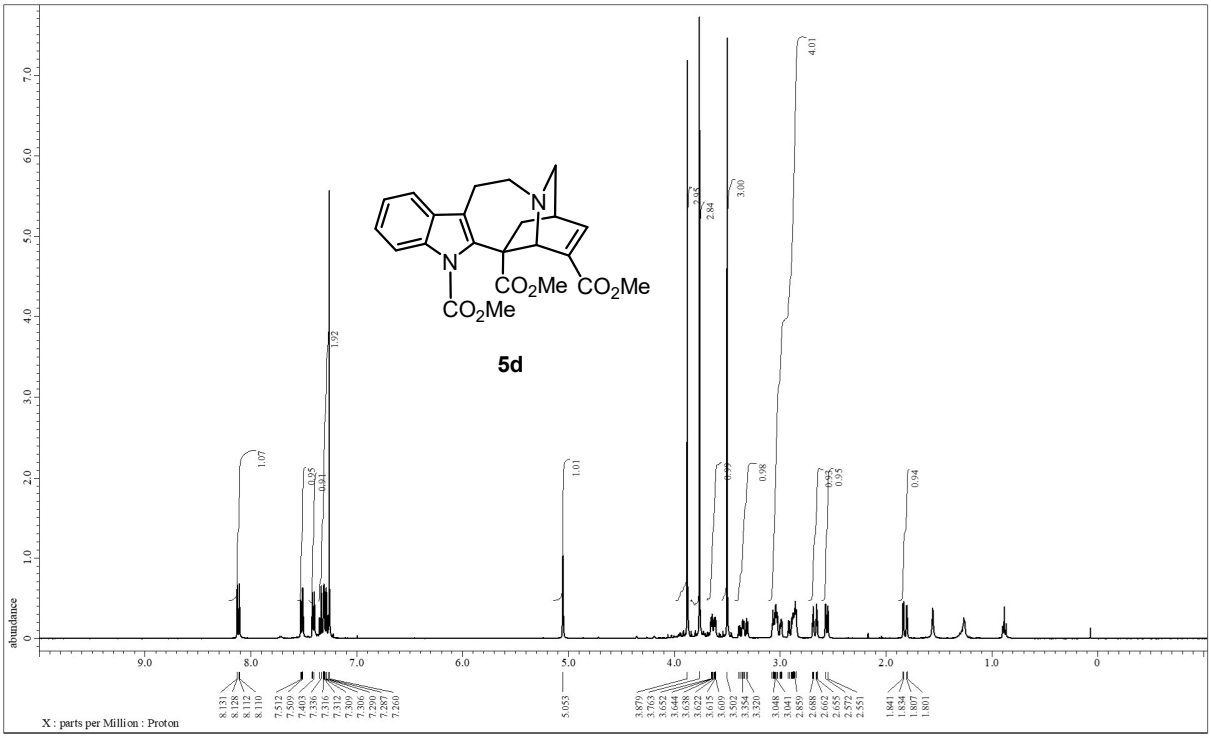


Figure S89. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **5d**.

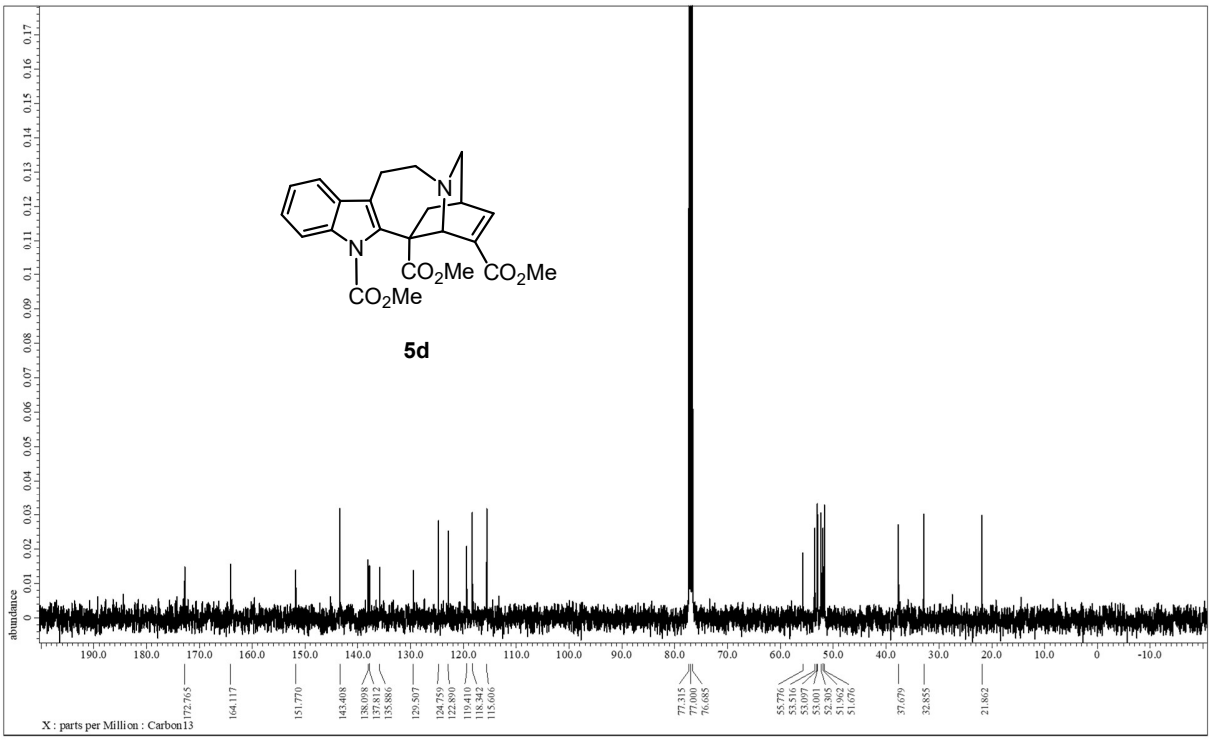


Figure S90. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **5d**.

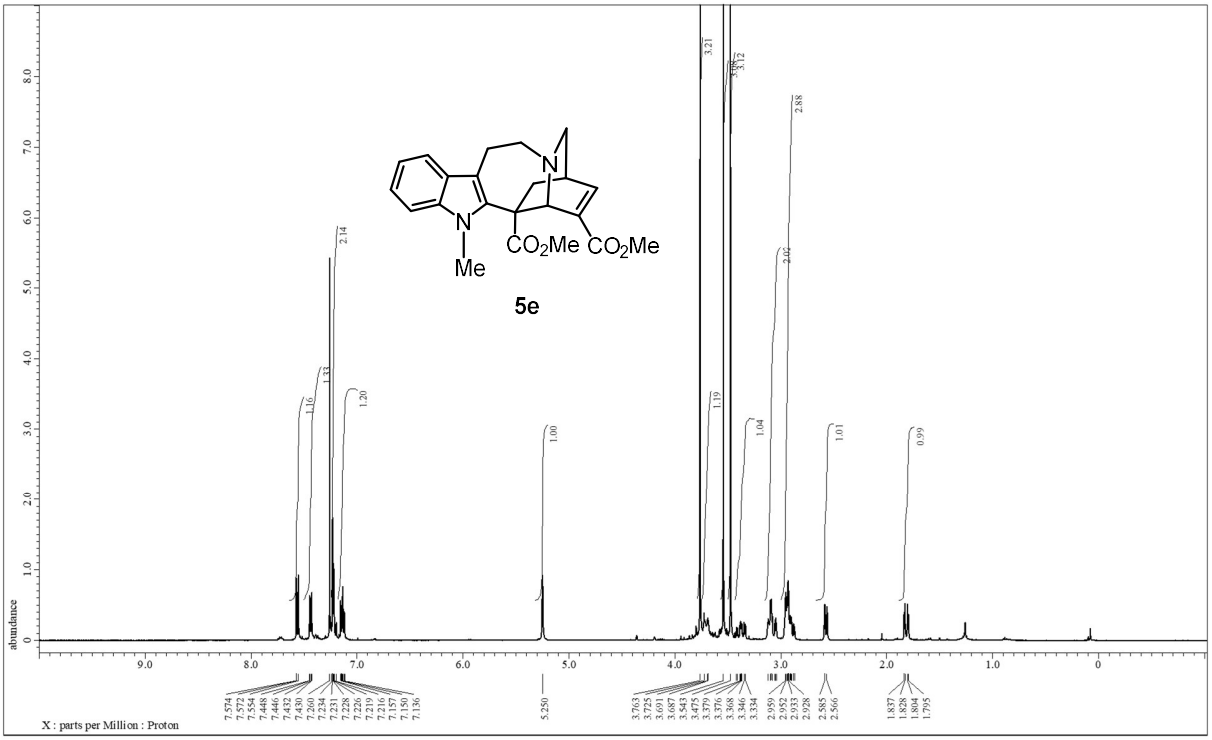


Figure S91. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **5e**.

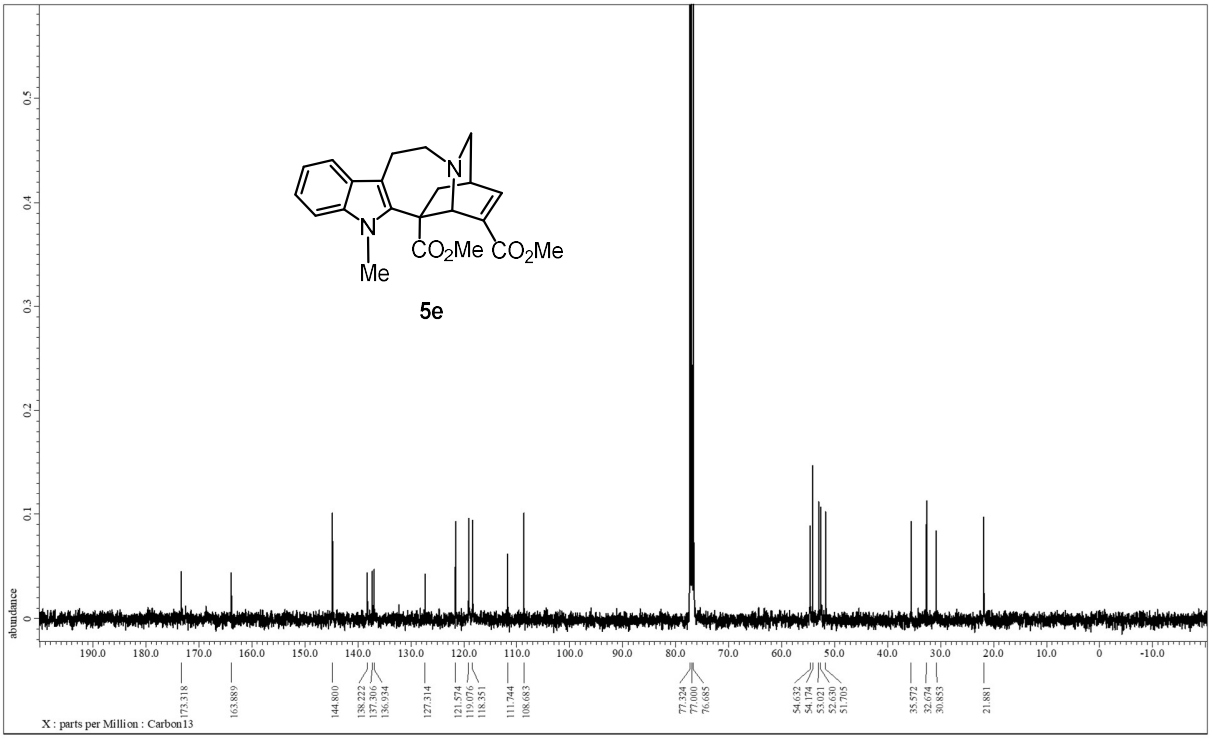


Figure S92. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **5e**.

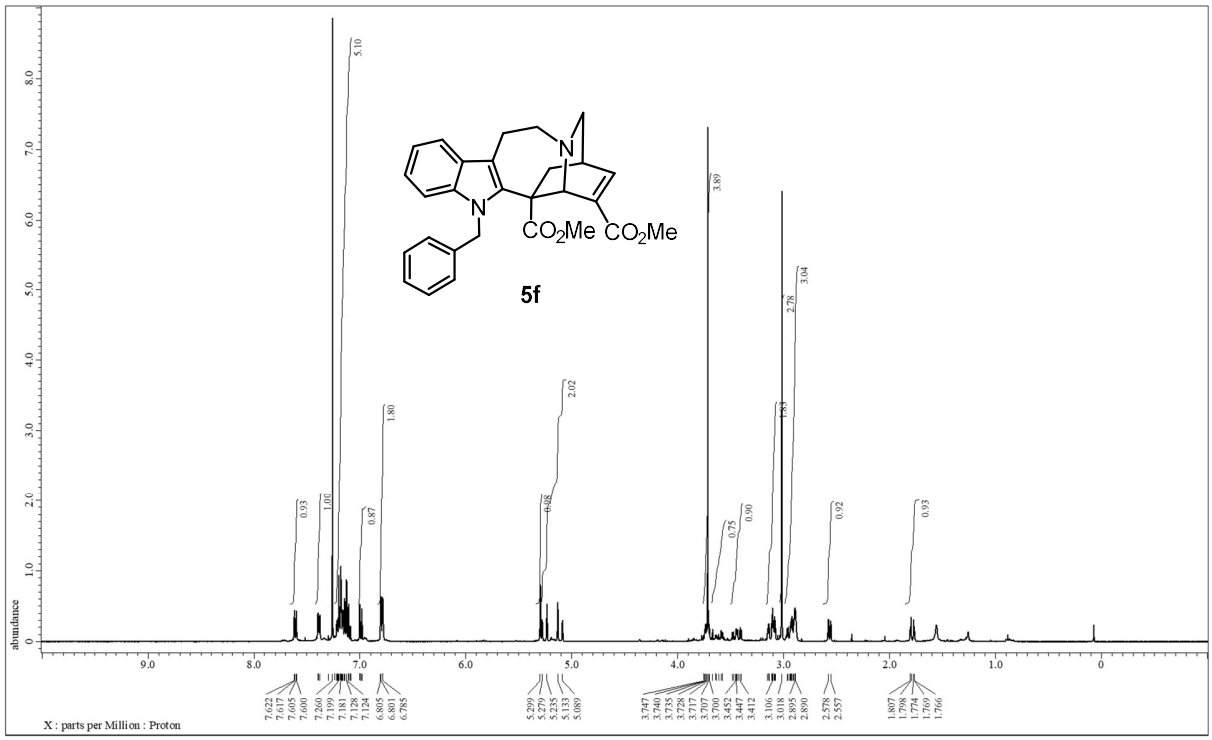


Figure S93. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **5f**.

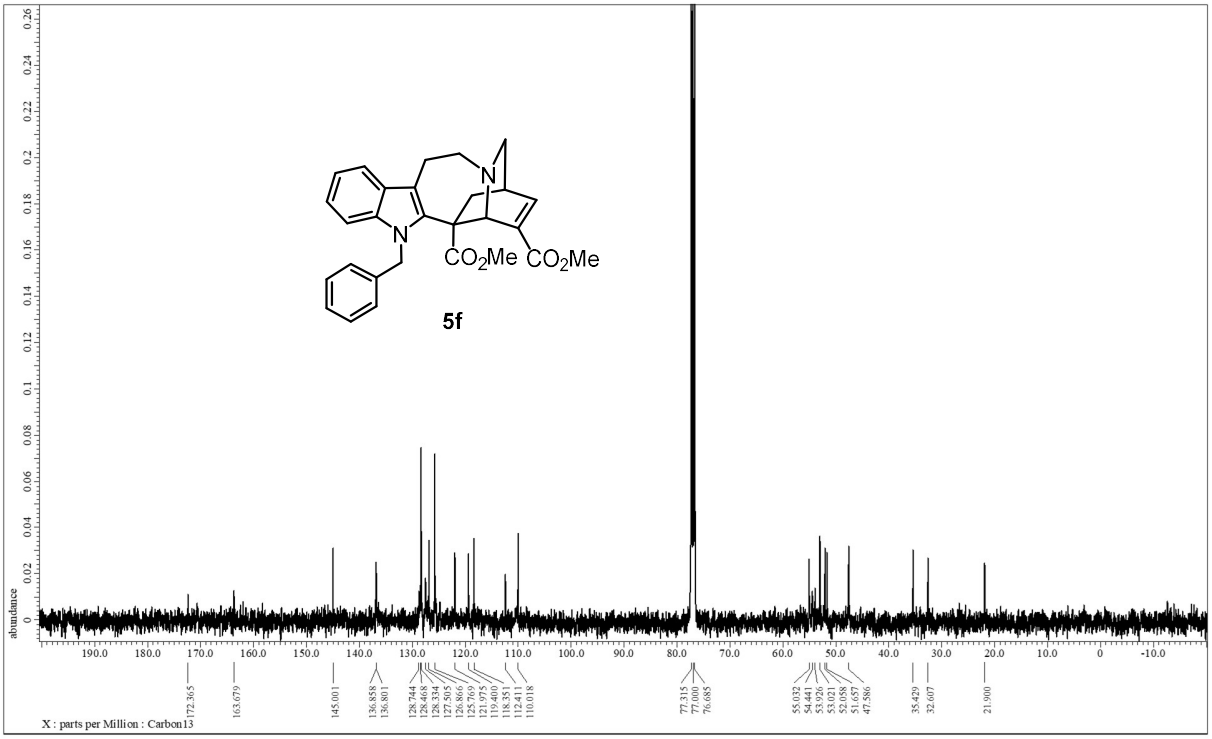


Figure S94. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **5f**.

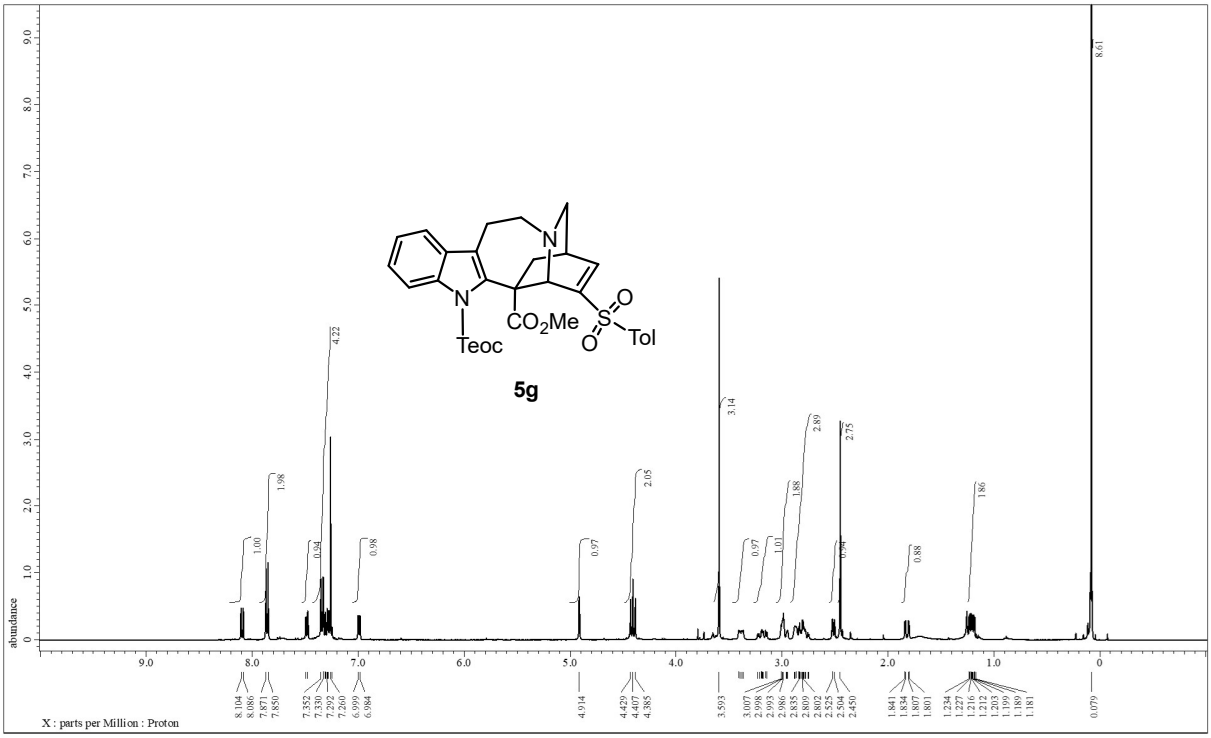


Figure S95. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **5g**.

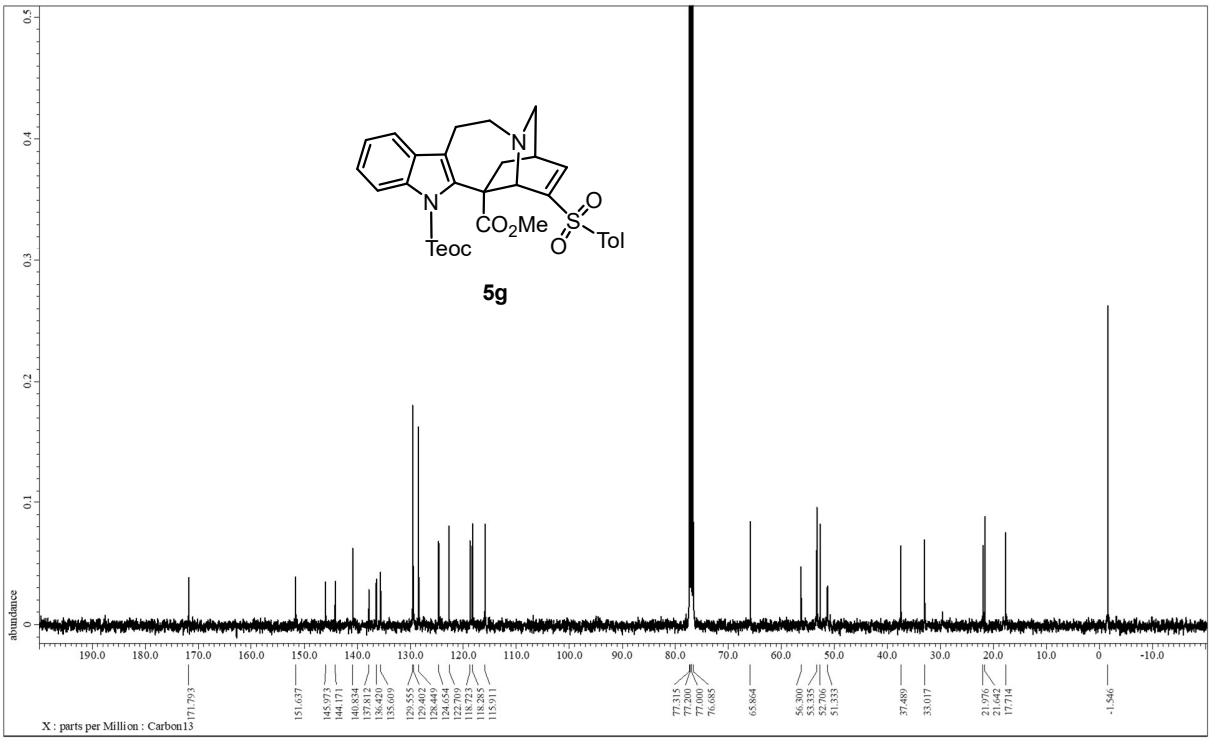


Figure S96. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **5g**.

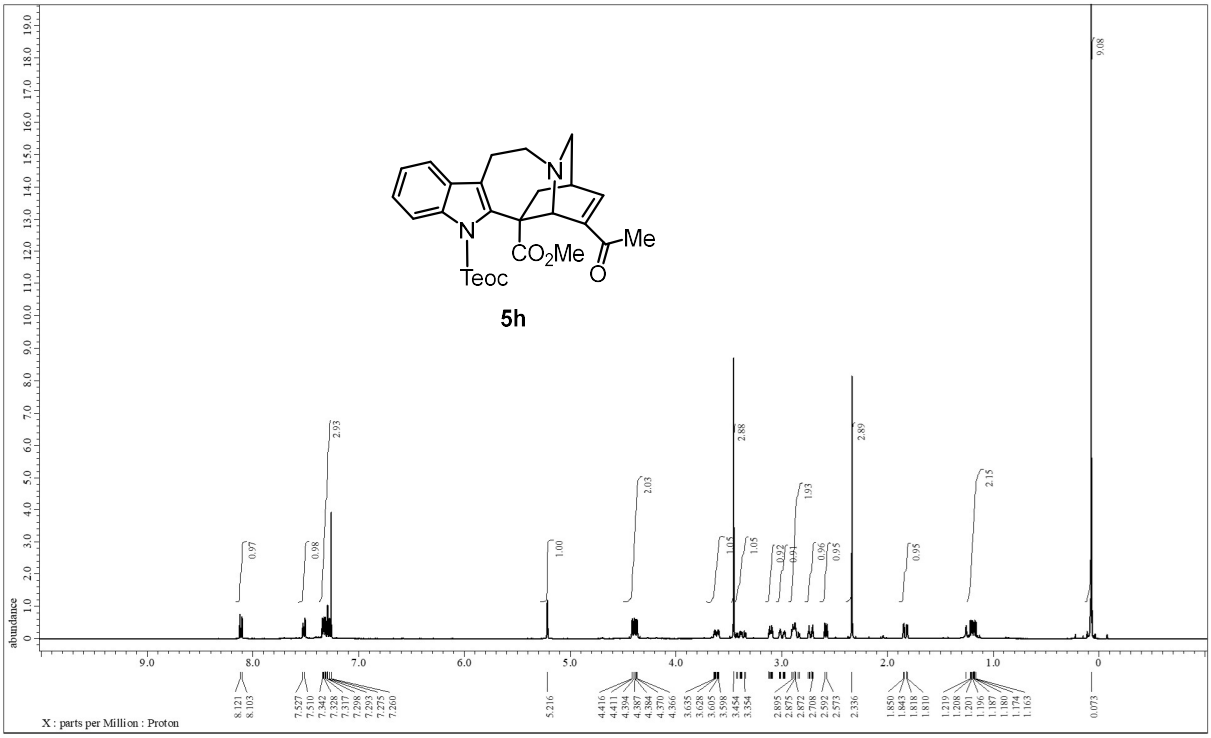


Figure S97. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **5h**.

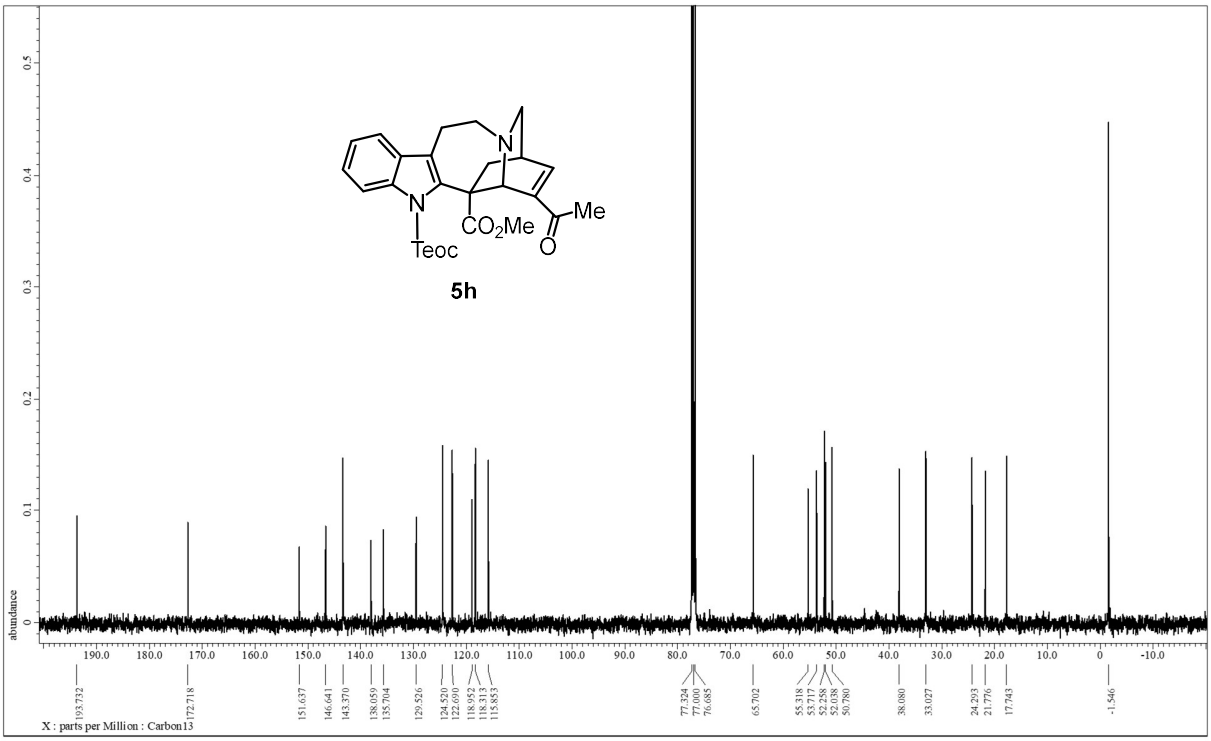


Figure S98. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **5h**.

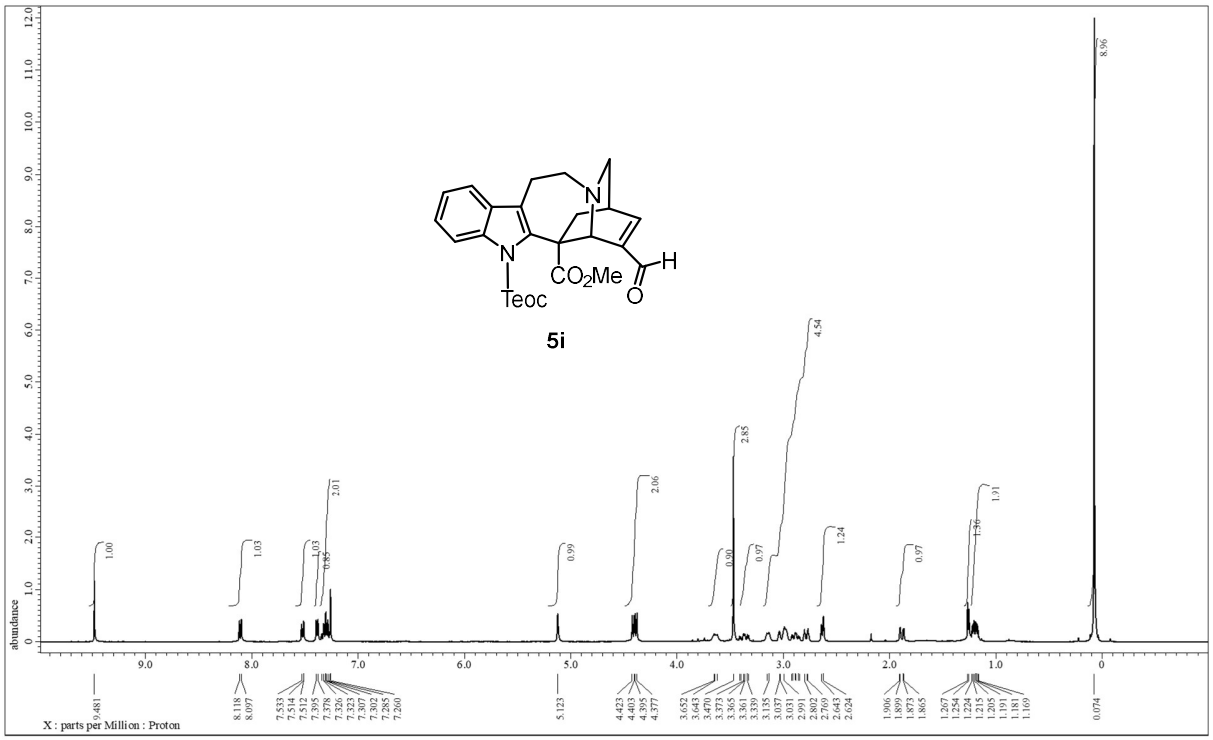


Figure S99. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **5i**.

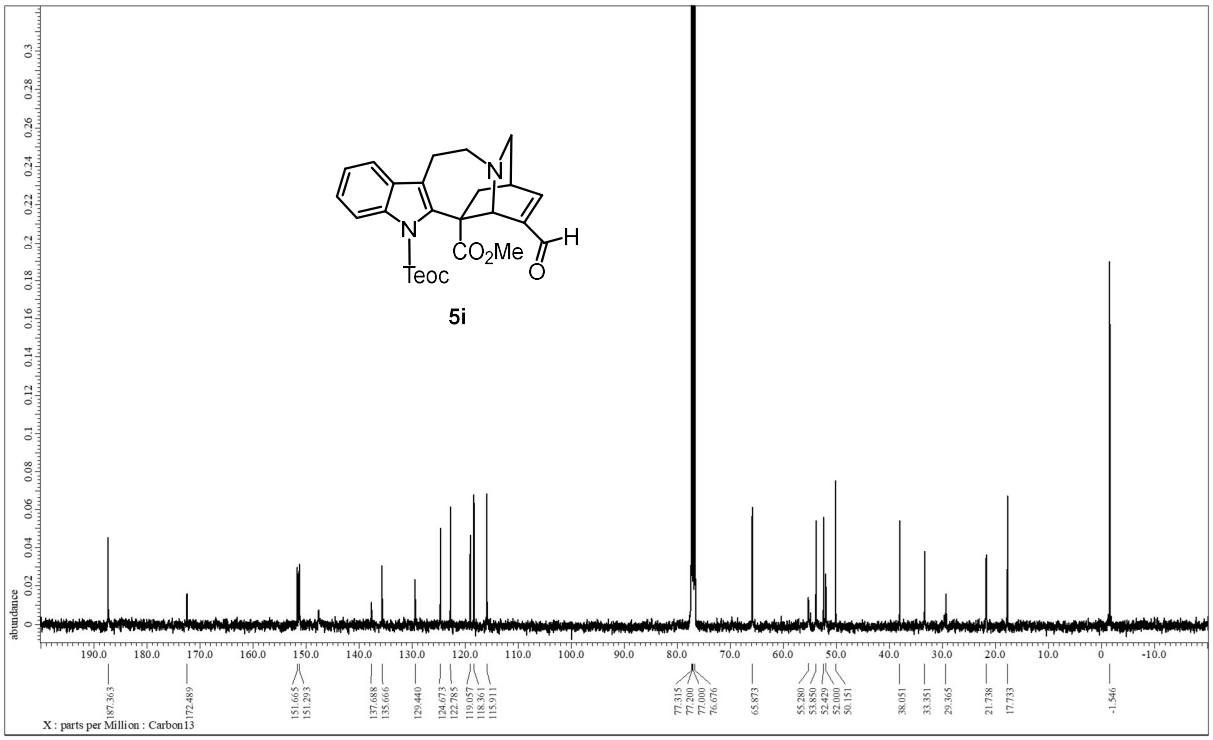


Figure S100. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **5i**.

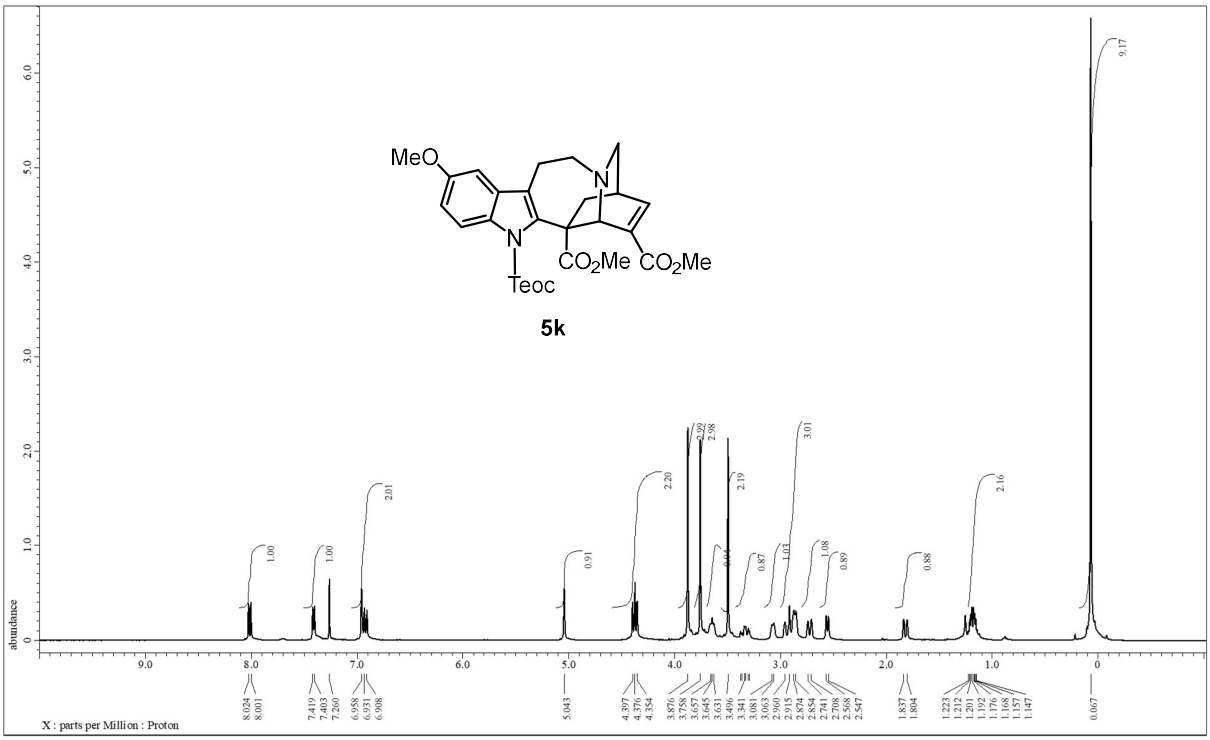


Figure S101. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **5k**.

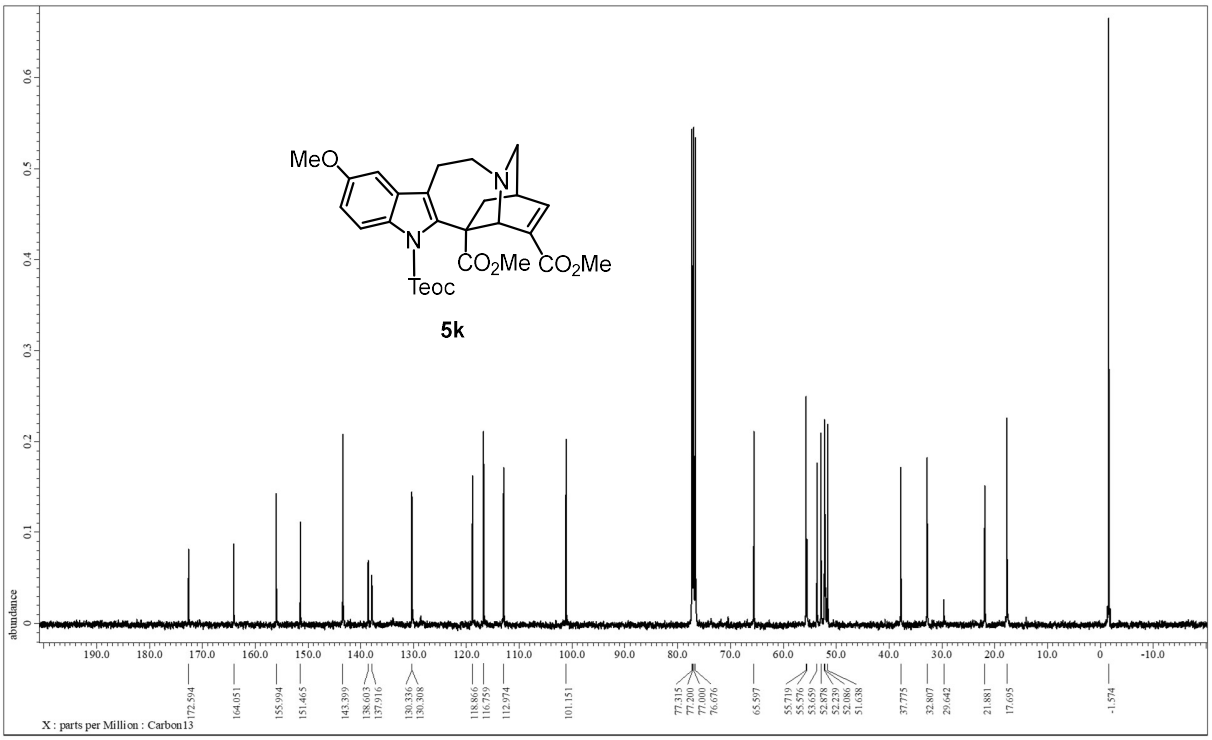


Figure S102. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **5k**.

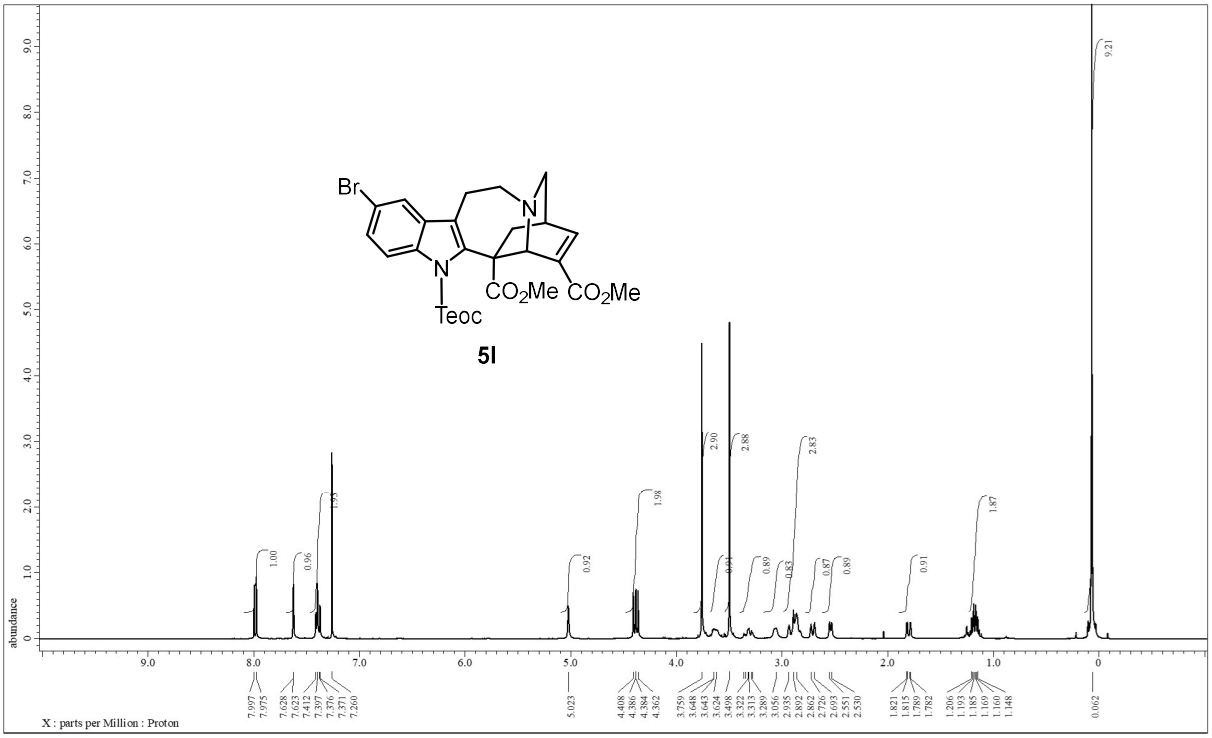


Figure S103. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **5l**.

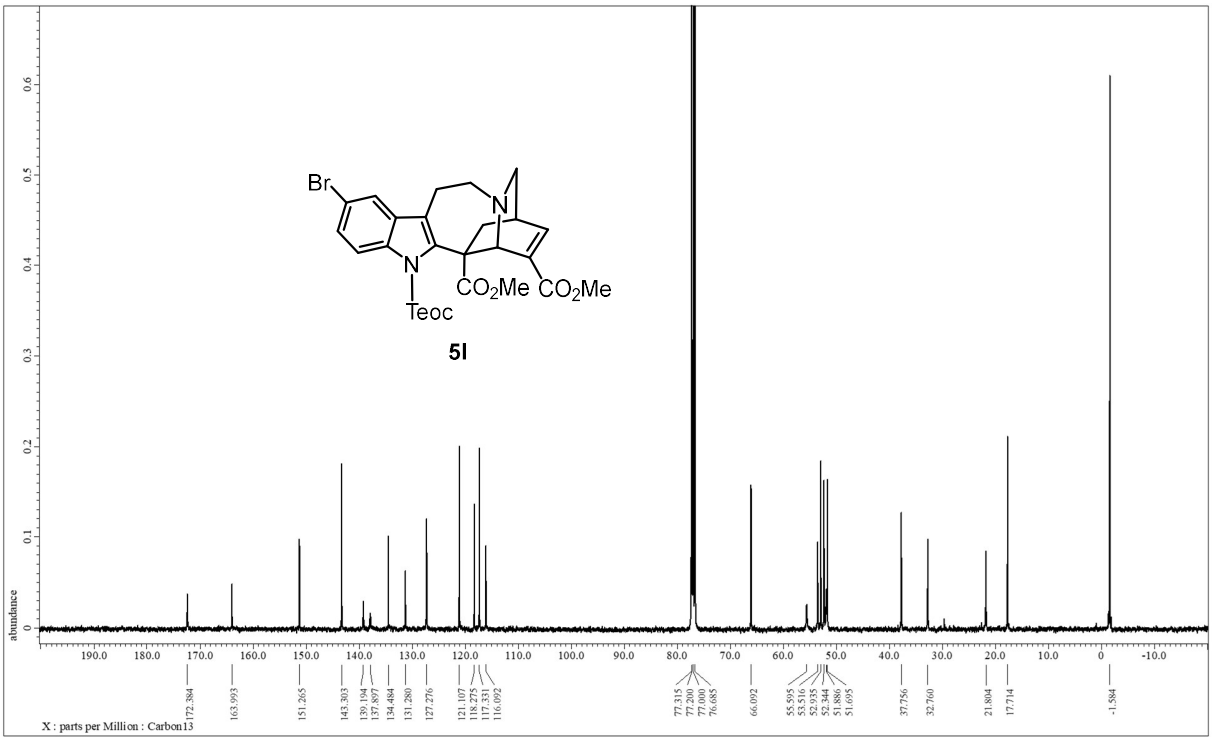


Figure S104. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **5l**.

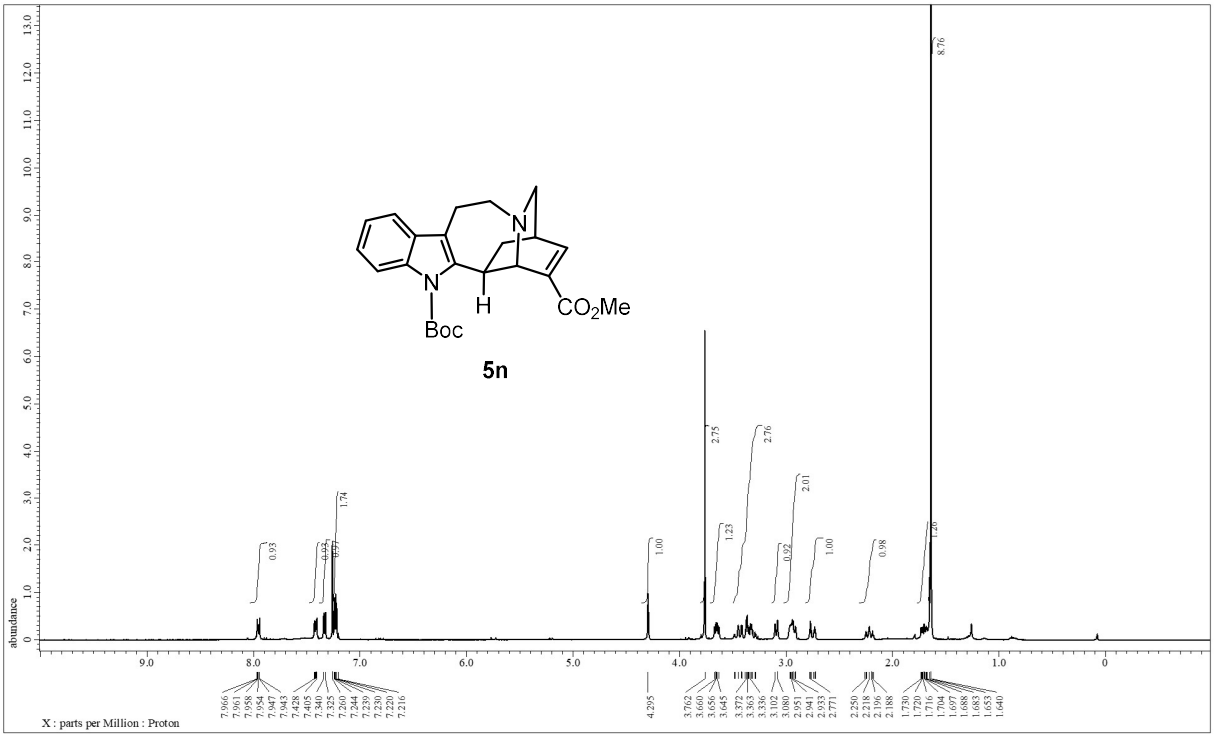


Figure S105. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **5n**.

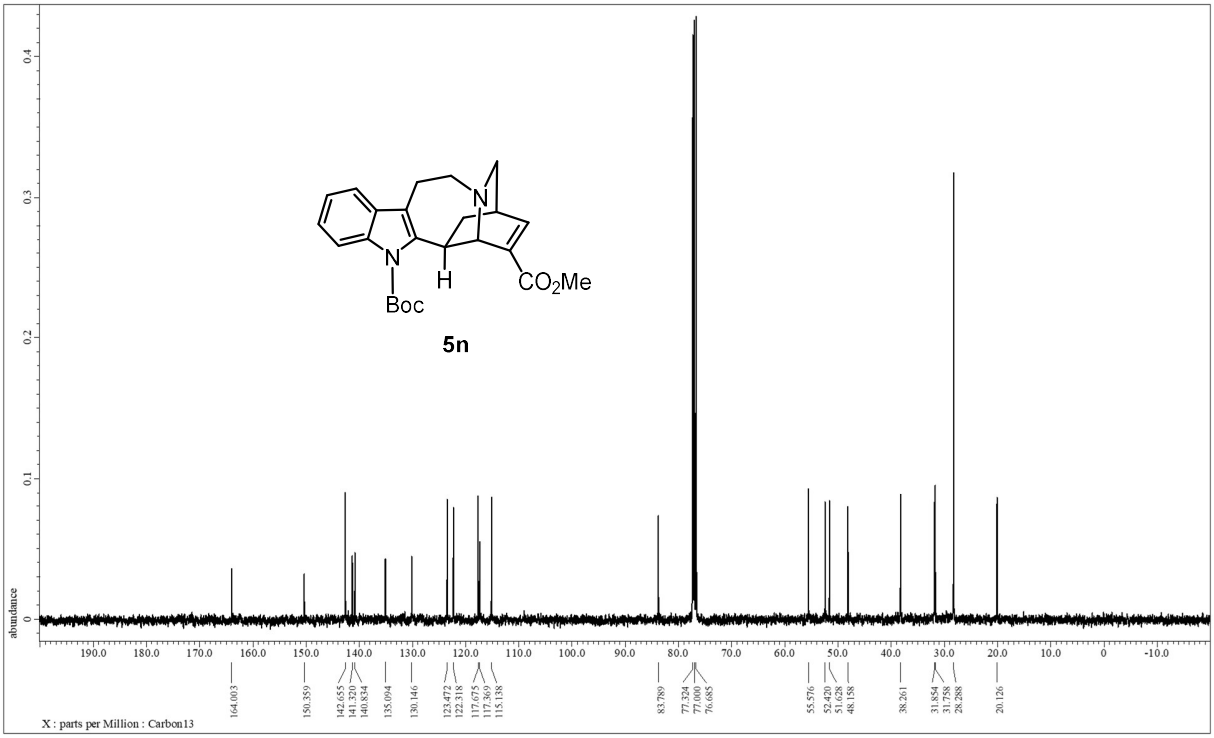


Figure S106. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **5n**.

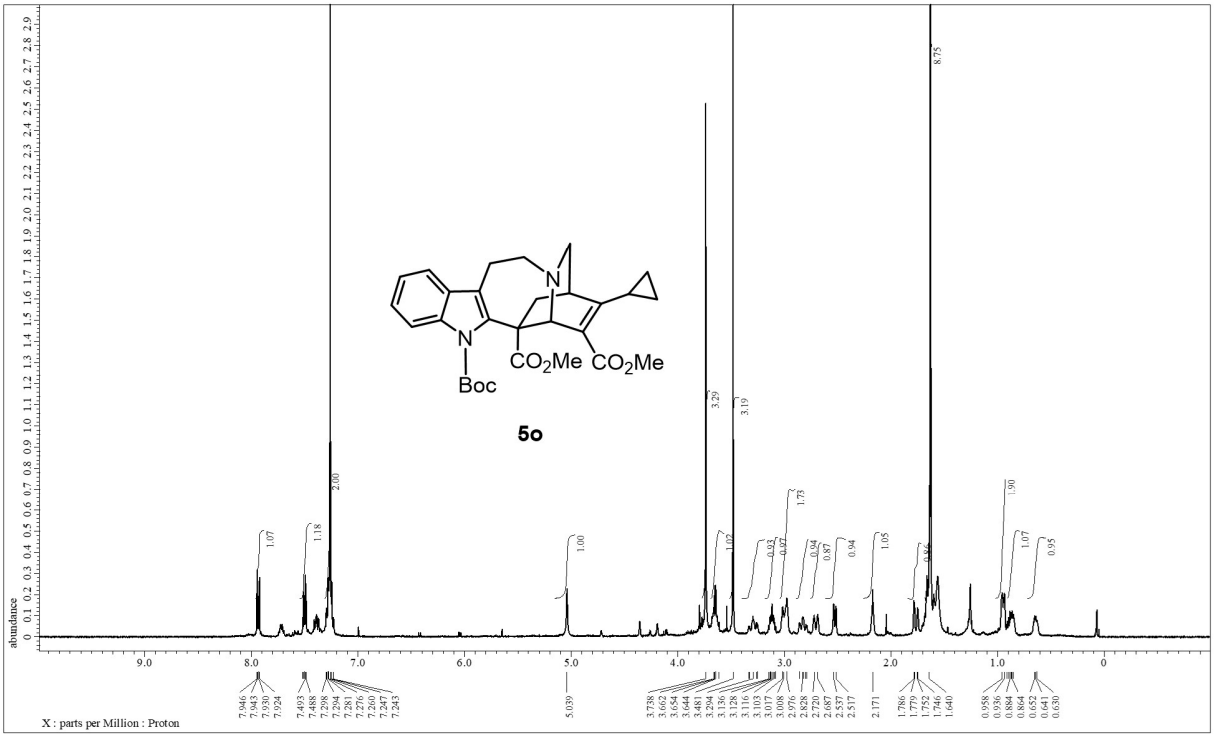


Figure S107. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **5o**.

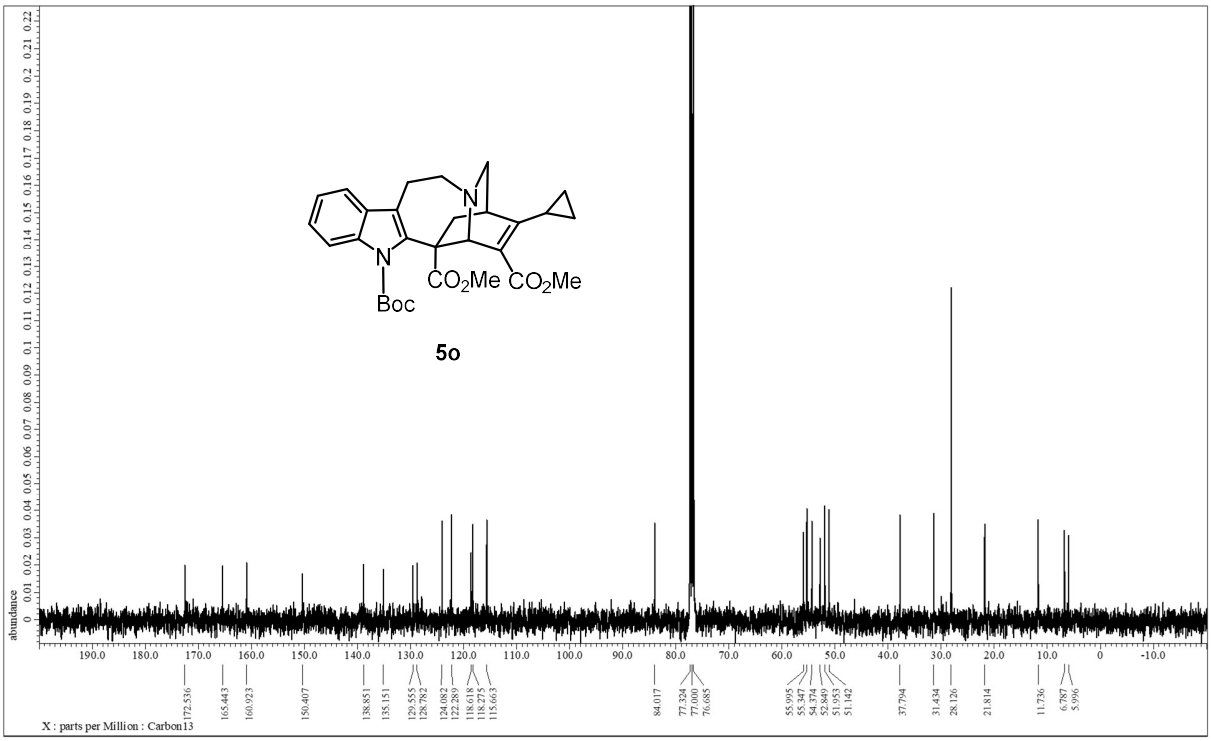


Figure S108. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **5o**.

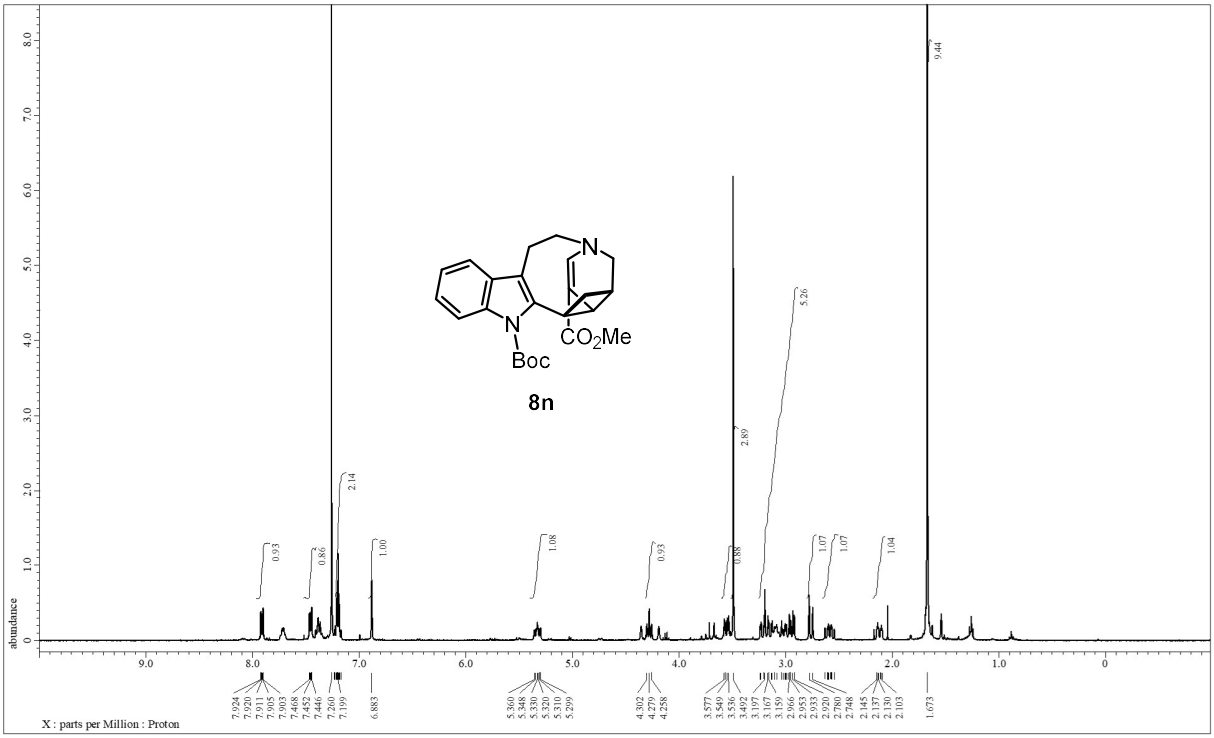


Figure S109. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **8n**.

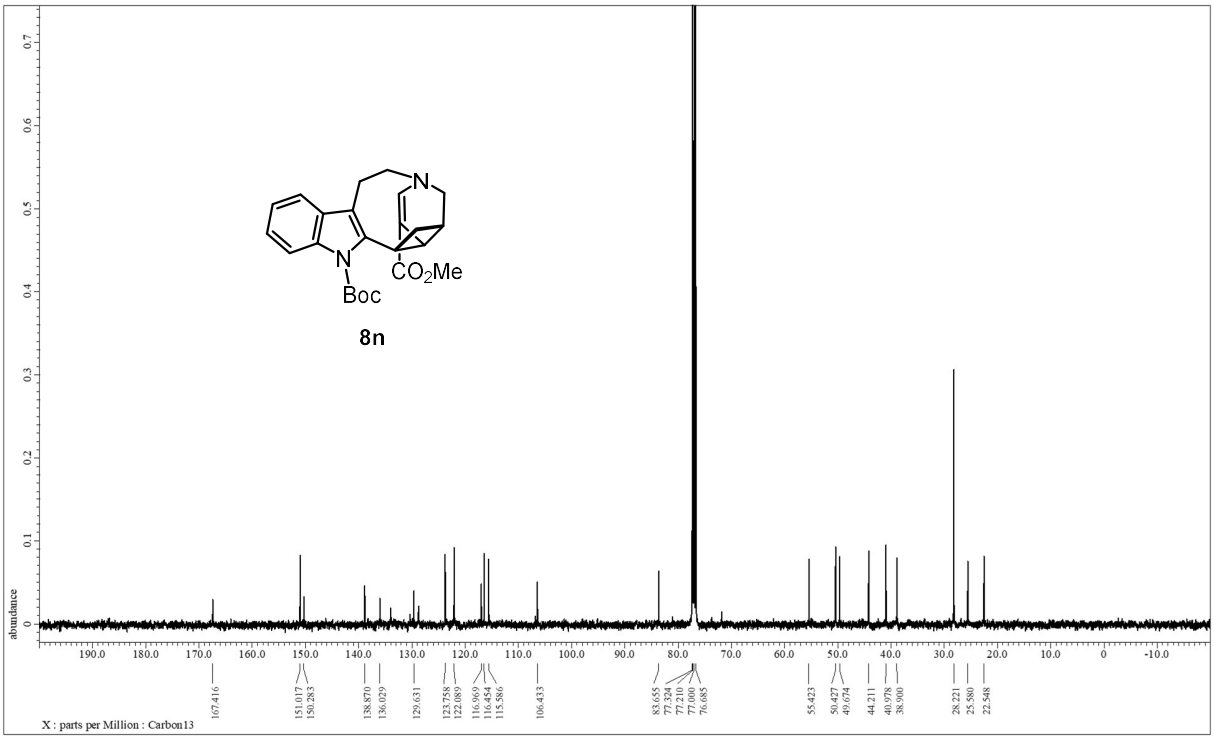


Figure S110. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **8n**.

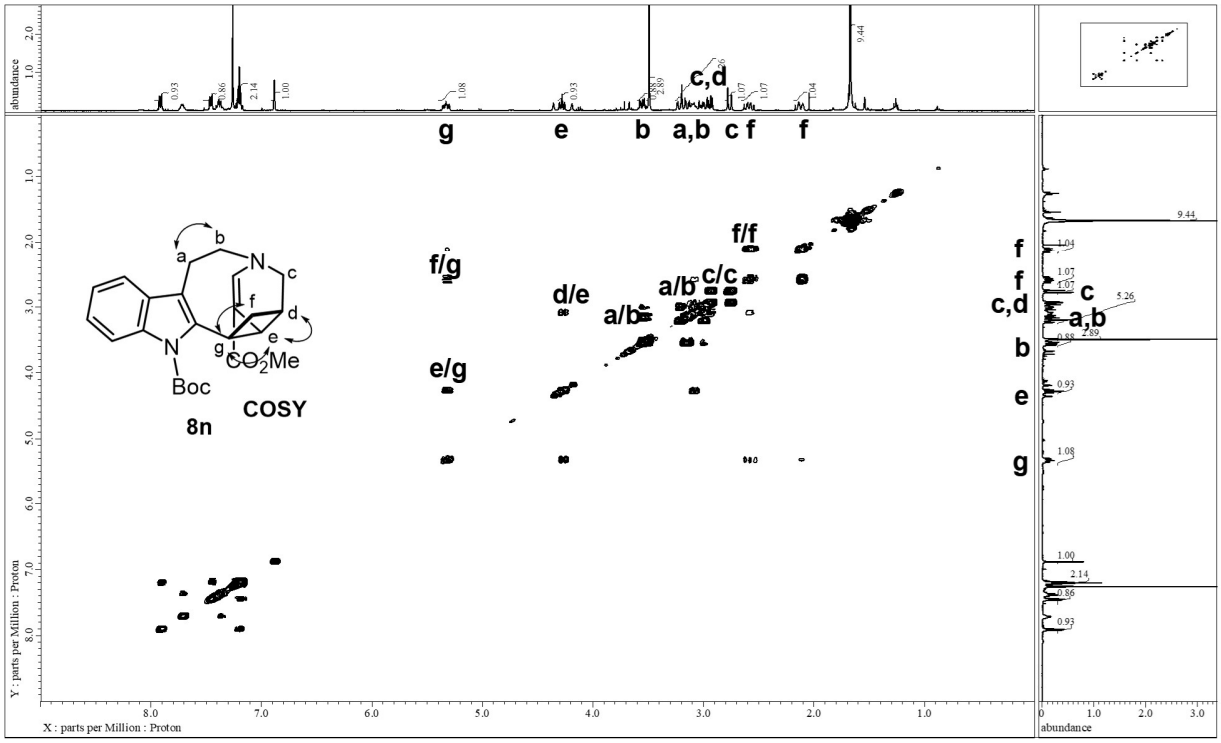


Figure S111. $^{1}H–^{1}H$ COSY spectrum (400 MHz, $CDCl_3$) of **8n**.

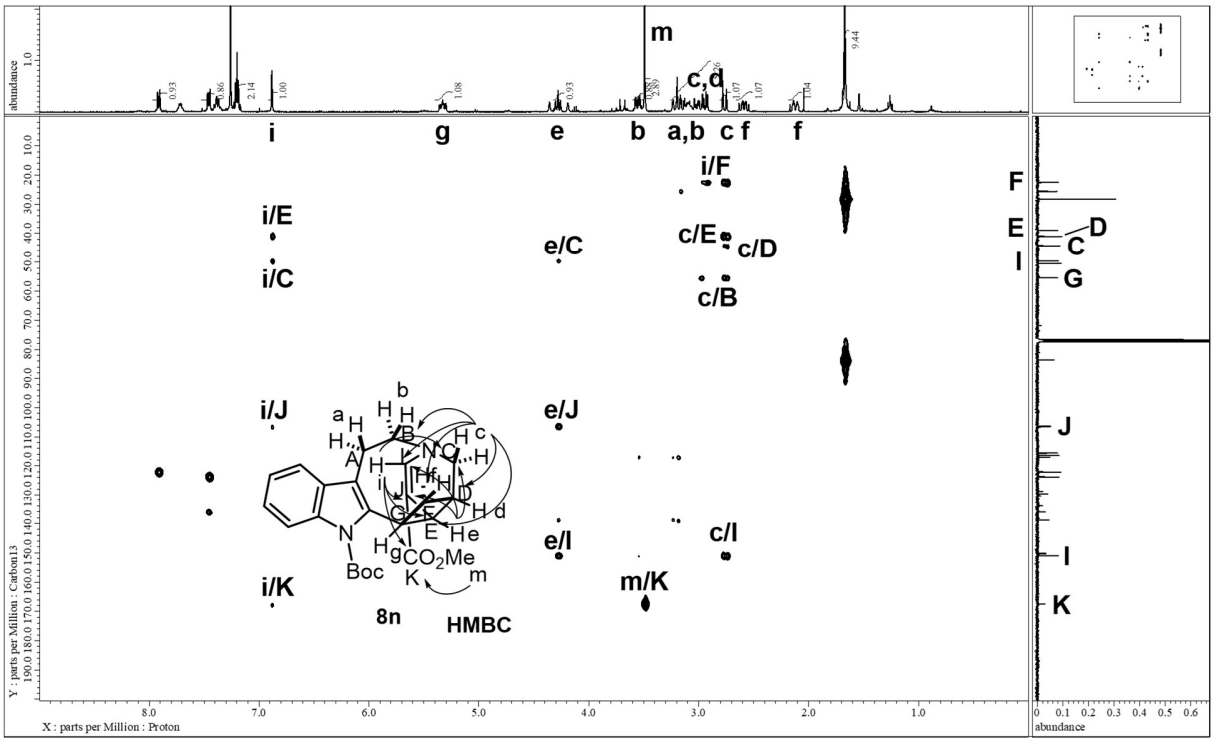


Figure S112. $^{1}H–^{13}C\{^{1}H\}$ HMBC NMR spectrum (100 MHz, $CDCl_3$) of **8n**.

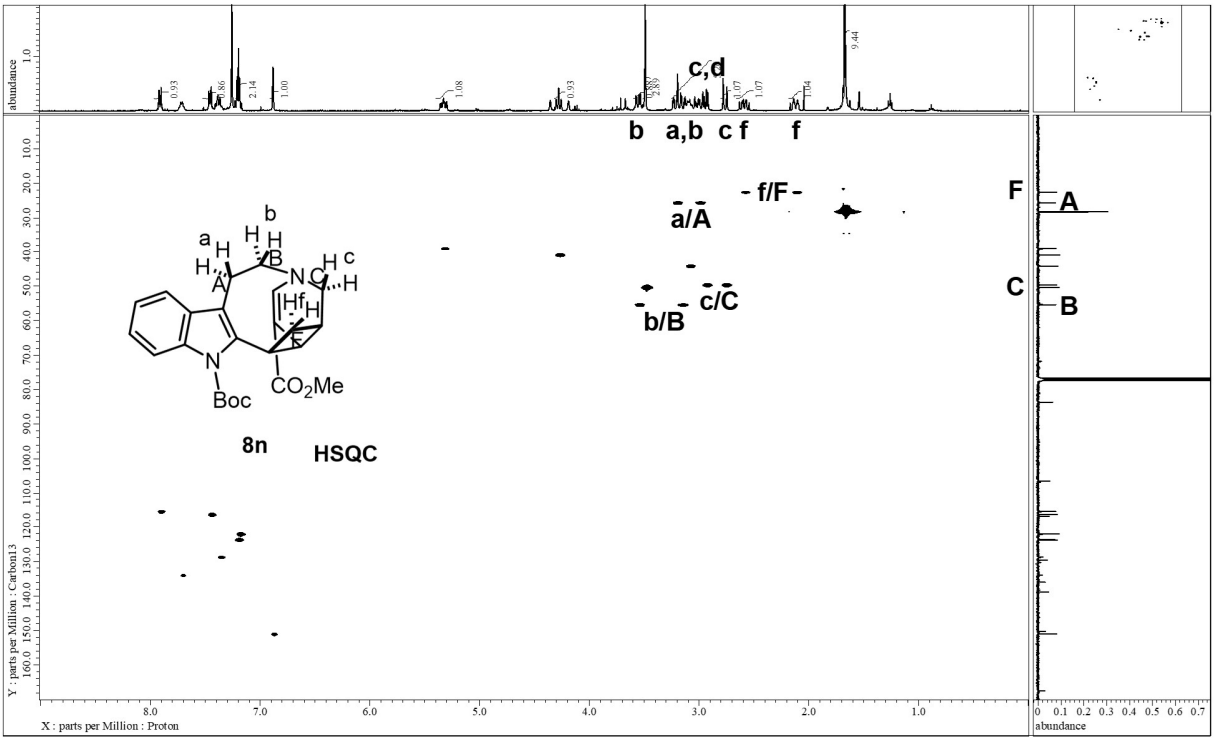


Figure S113. $^{1}H–^{13}C\{^{1}H\}$ HSQC NMR spectrum (100 MHz, $CDCl_3$) of **8n**.

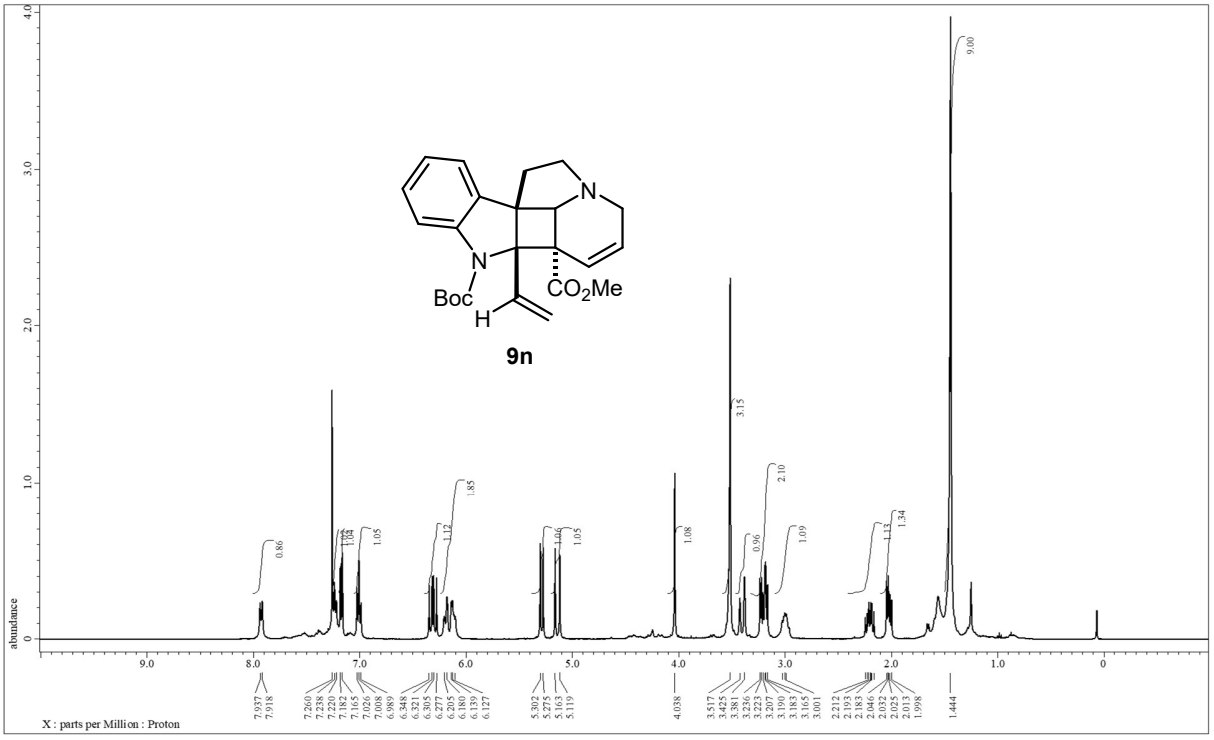


Figure S114. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) **9n**.

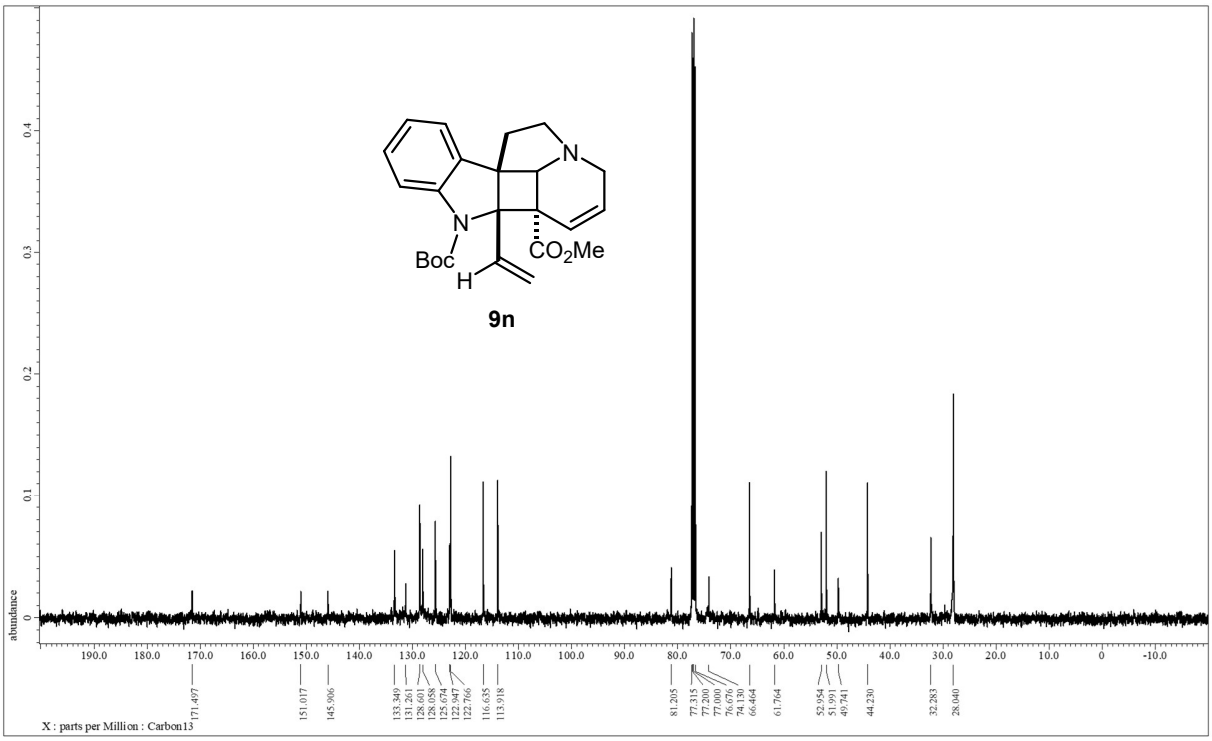


Figure S115. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **9n**.

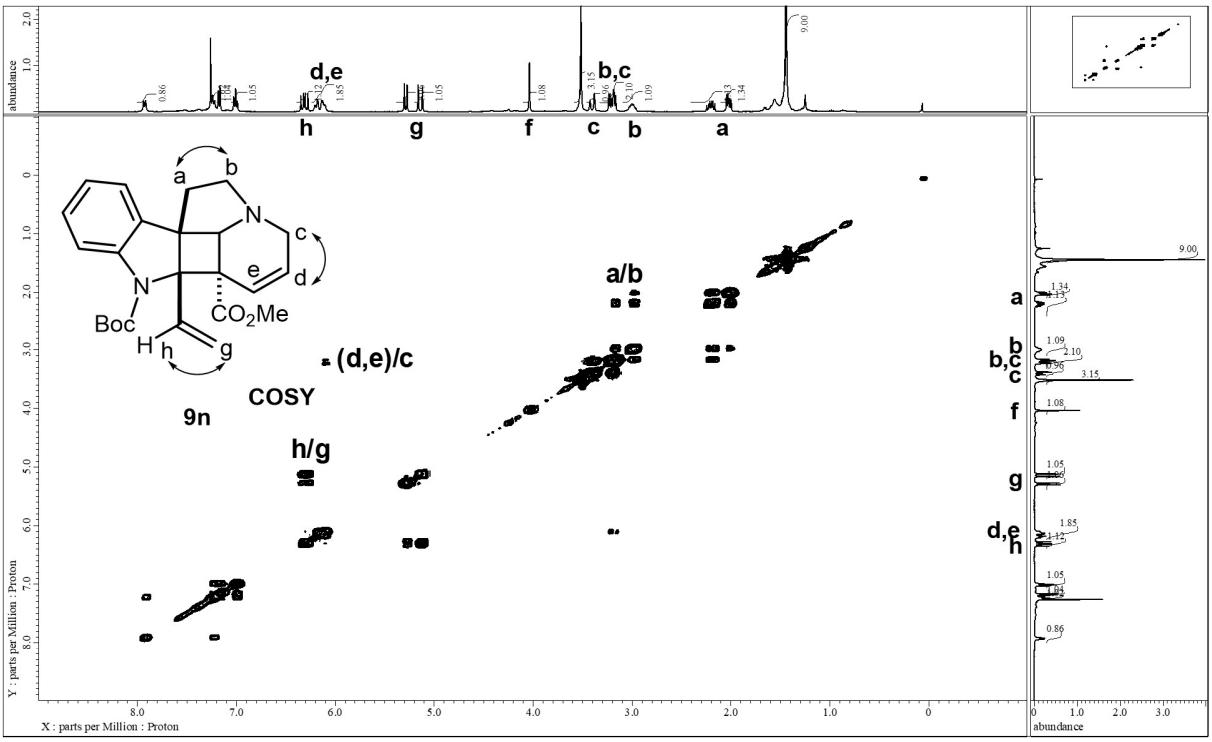


Figure S116. $^{1}H–^{1}H$ COSY spectrum (400 MHz, $CDCl_3$) of **9n**.

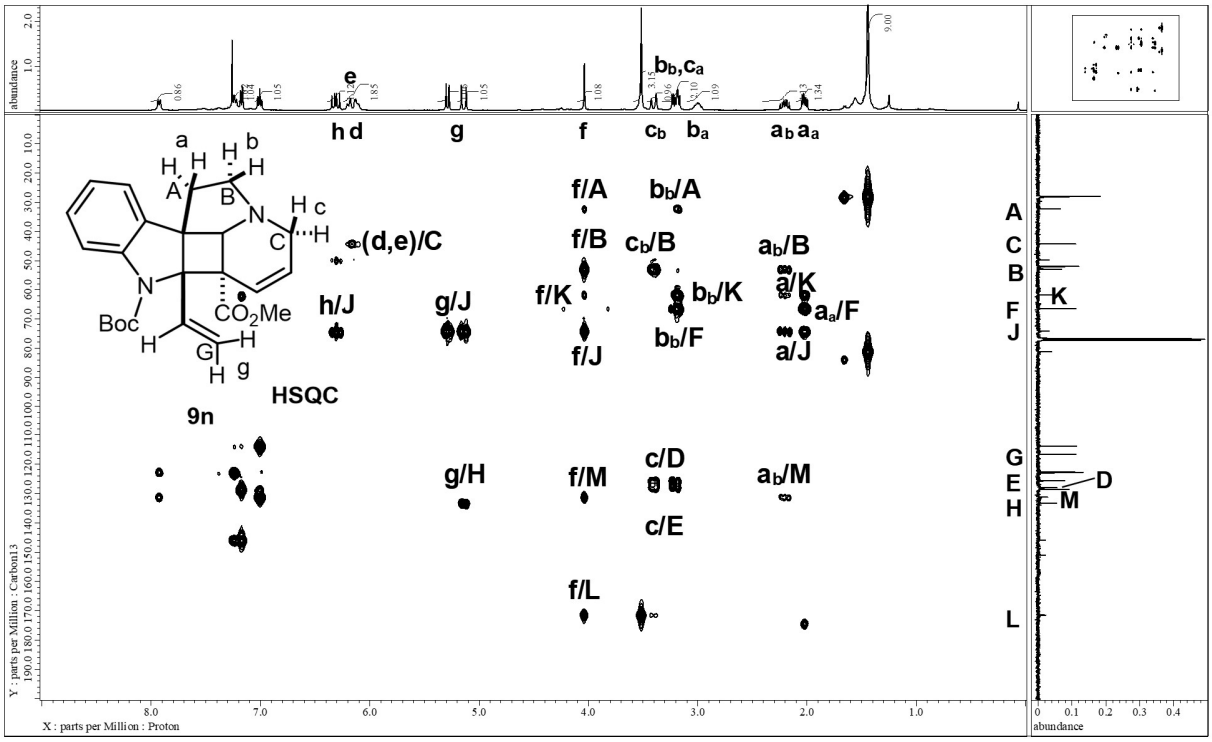


Figure S117. $^{1}H–^{13}C\{^{1}H\}$ HMBC NMR spectrum (100 MHz, $CDCl_3$) of **9n**.

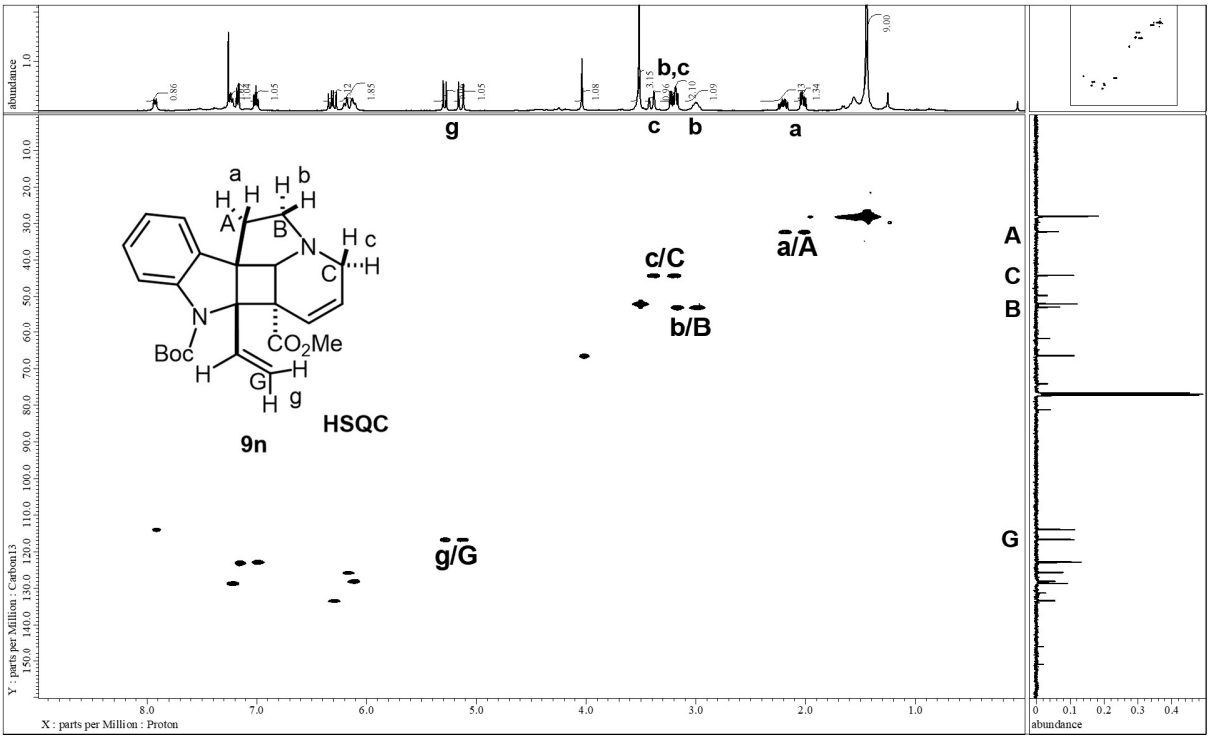


Figure S118. $^{1}H–^{13}C\{^{1}H\}$ HSQC NMR spectrum (100 MHz, $CDCl_3$) of **9n**.

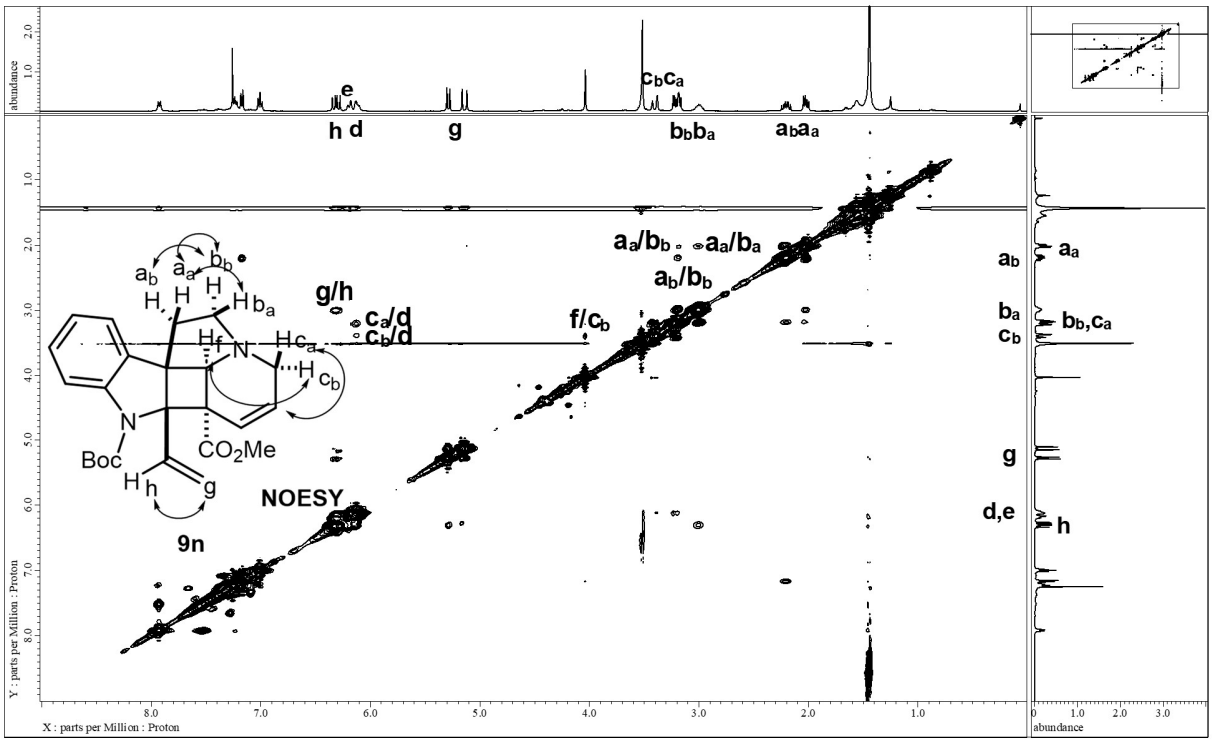


Figure S119. $^{1}H–^{1}H$ NOESY spectrum (400 MHz, $CDCl_3$) of **9n**.

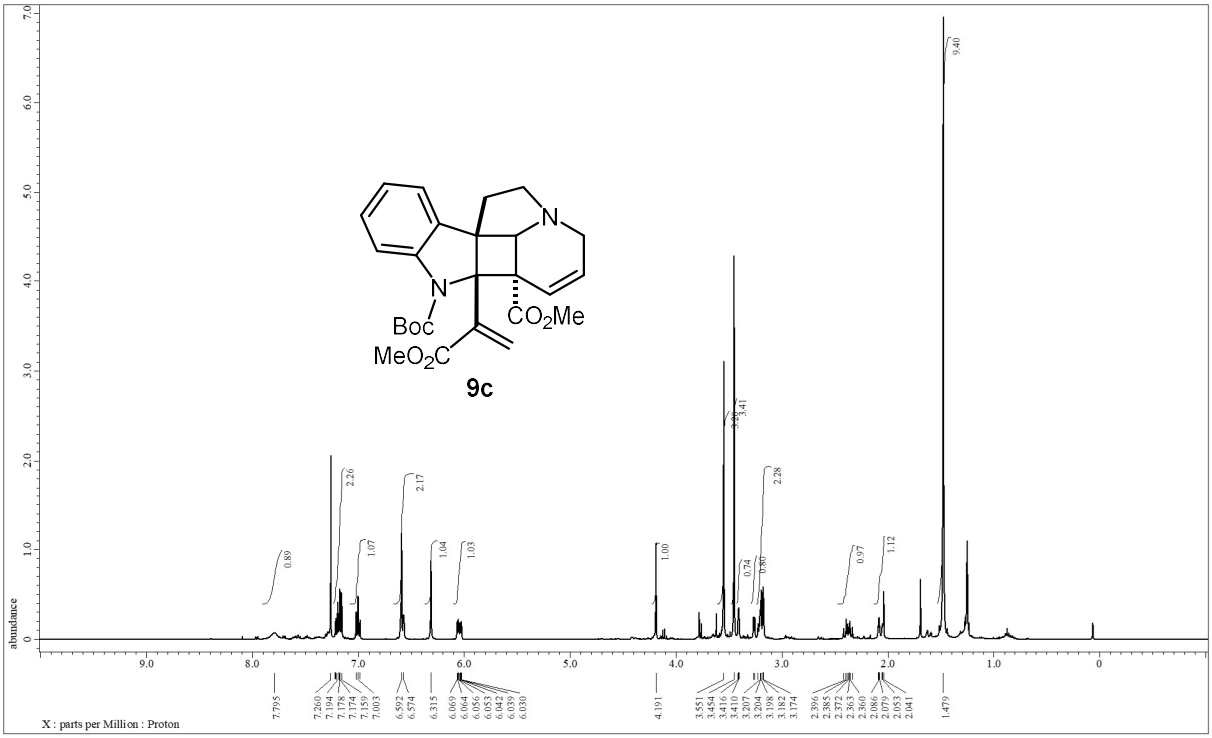


Figure S120. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **9c**.

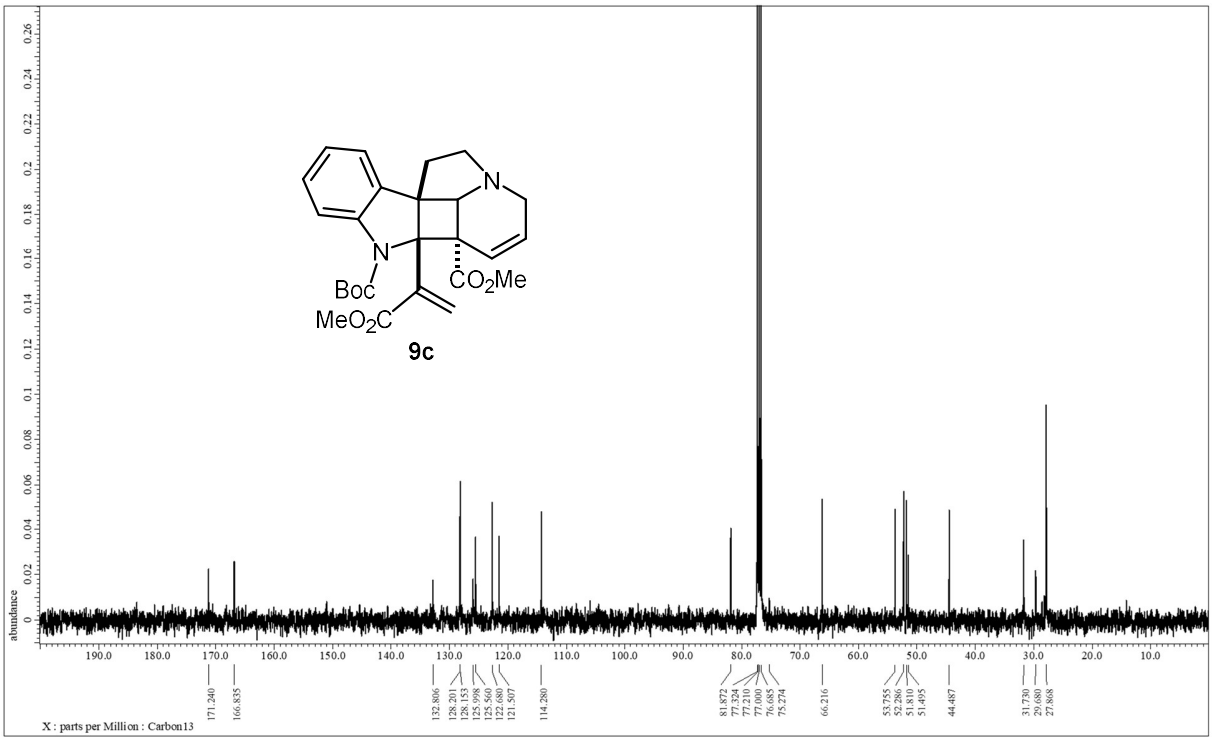


Figure S121. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **9c**.

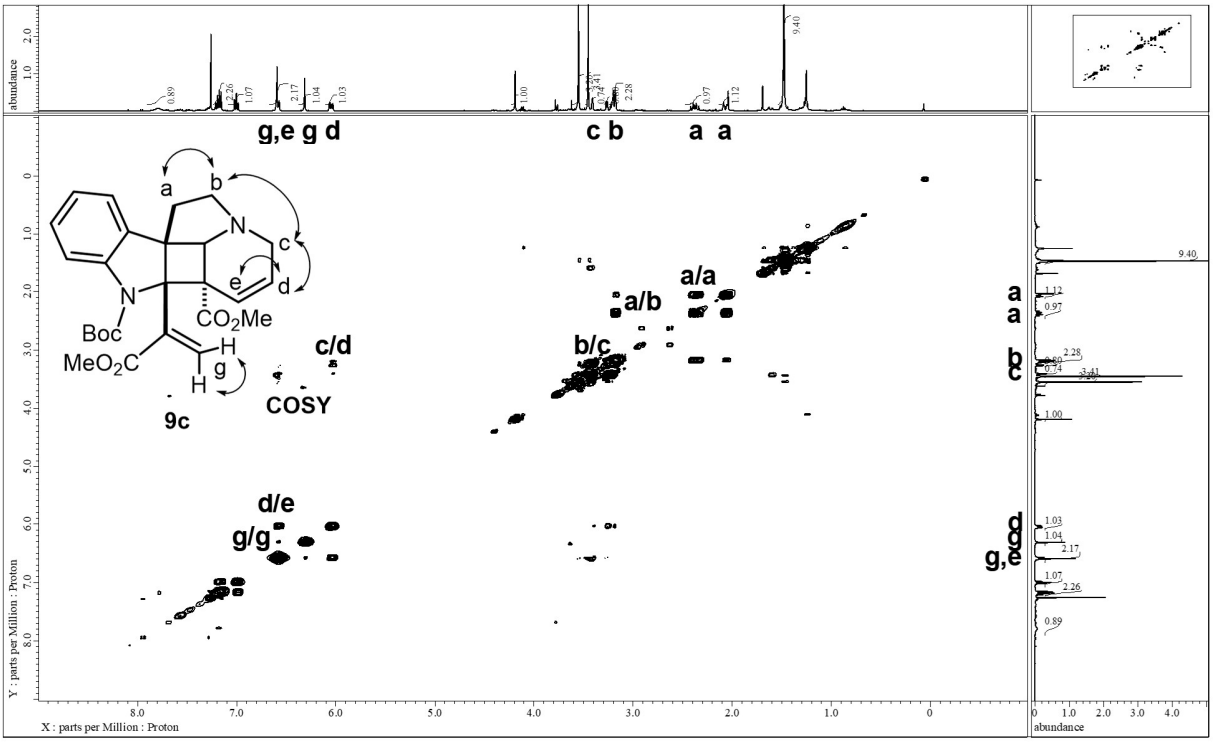


Figure S122. ^{1}H–^{1}H COSY spectrum (400 MHz, $CDCl_3$) of **9c**.

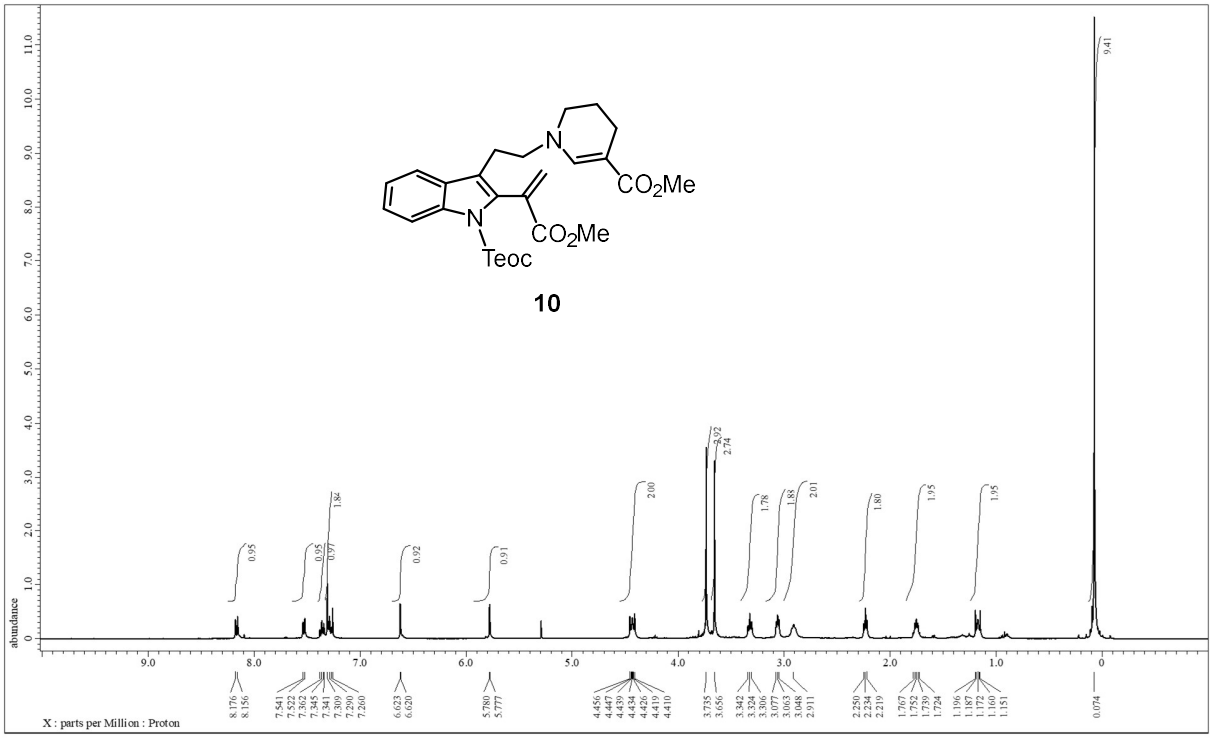


Figure S123. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **10**.

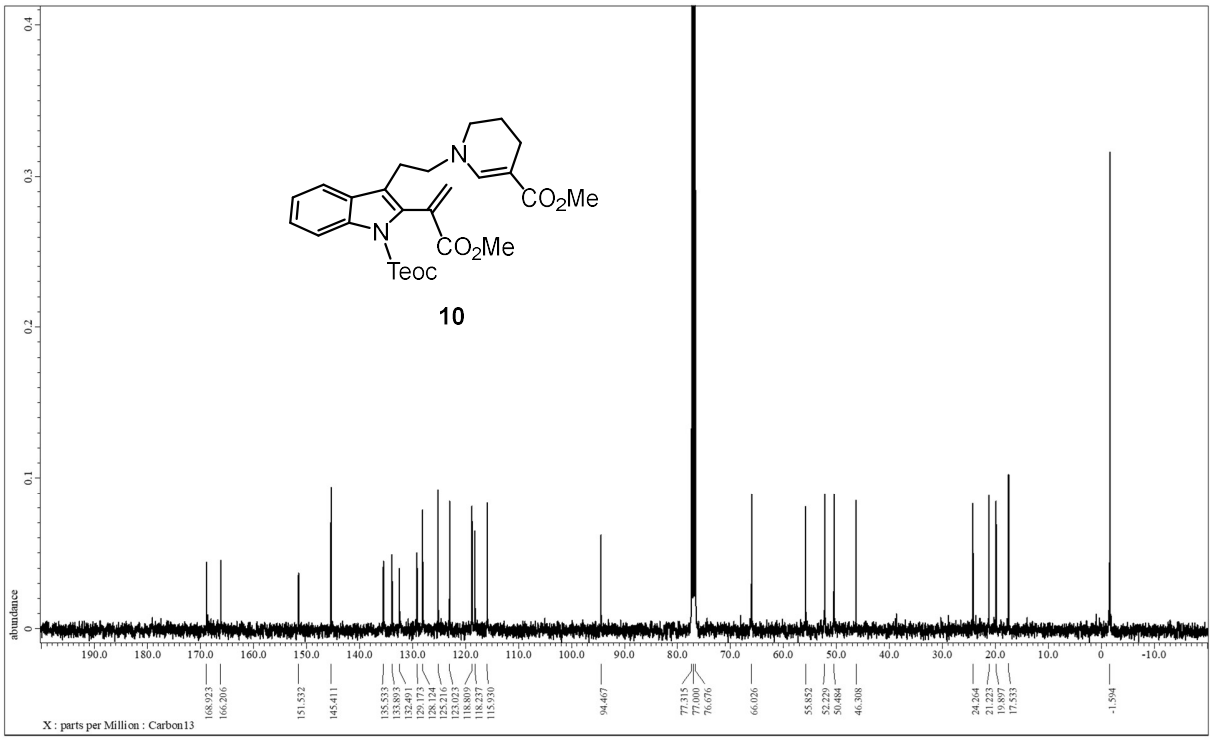


Figure S124. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **10**.

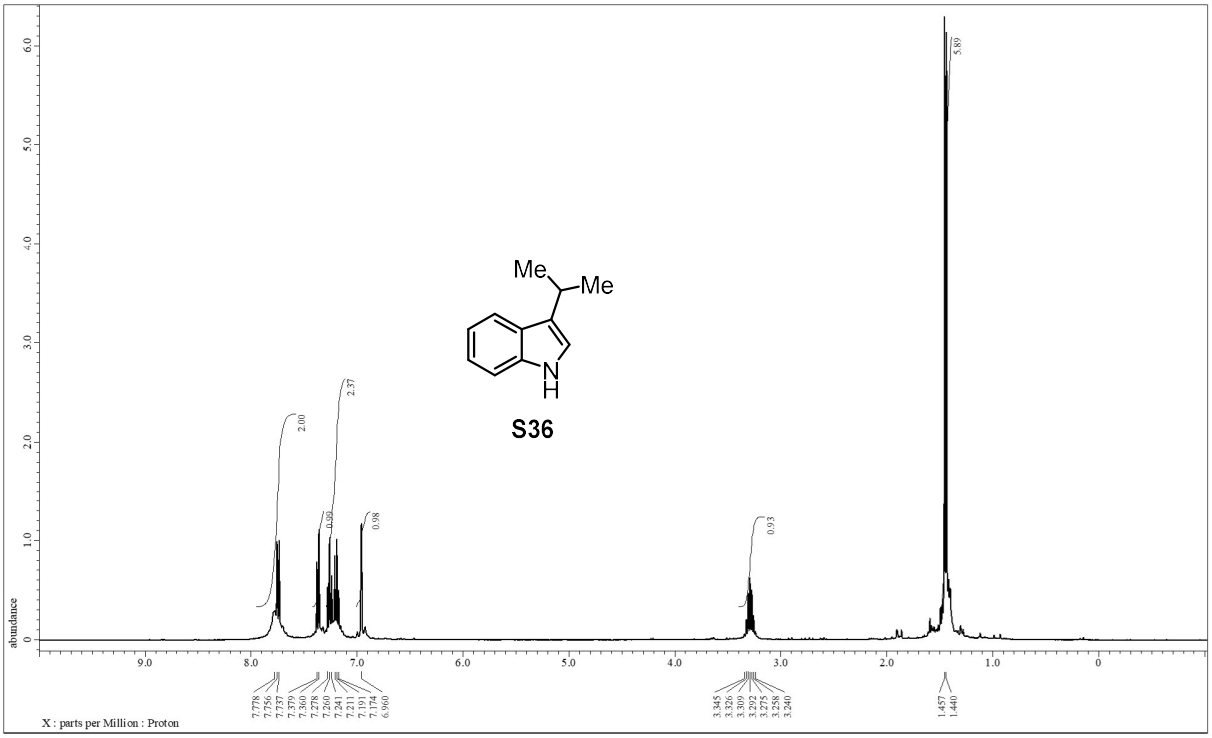


Figure S125. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **S36**.

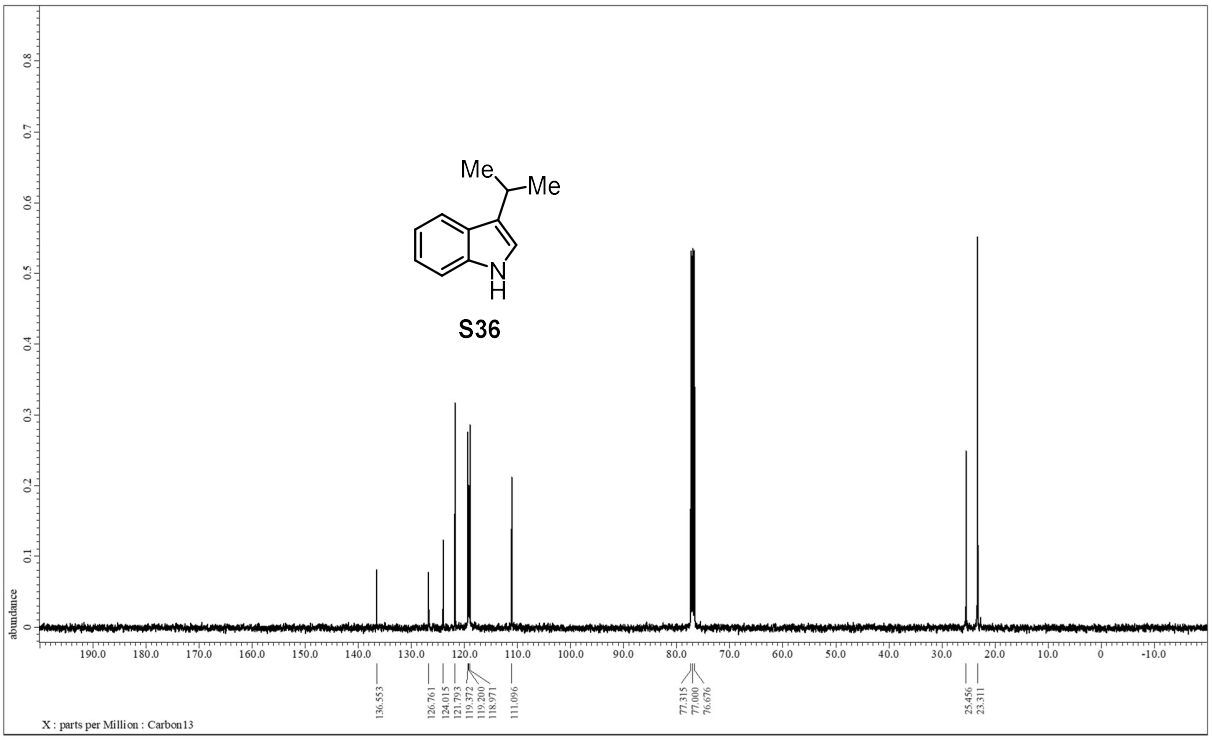


Figure S126. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **S36**.

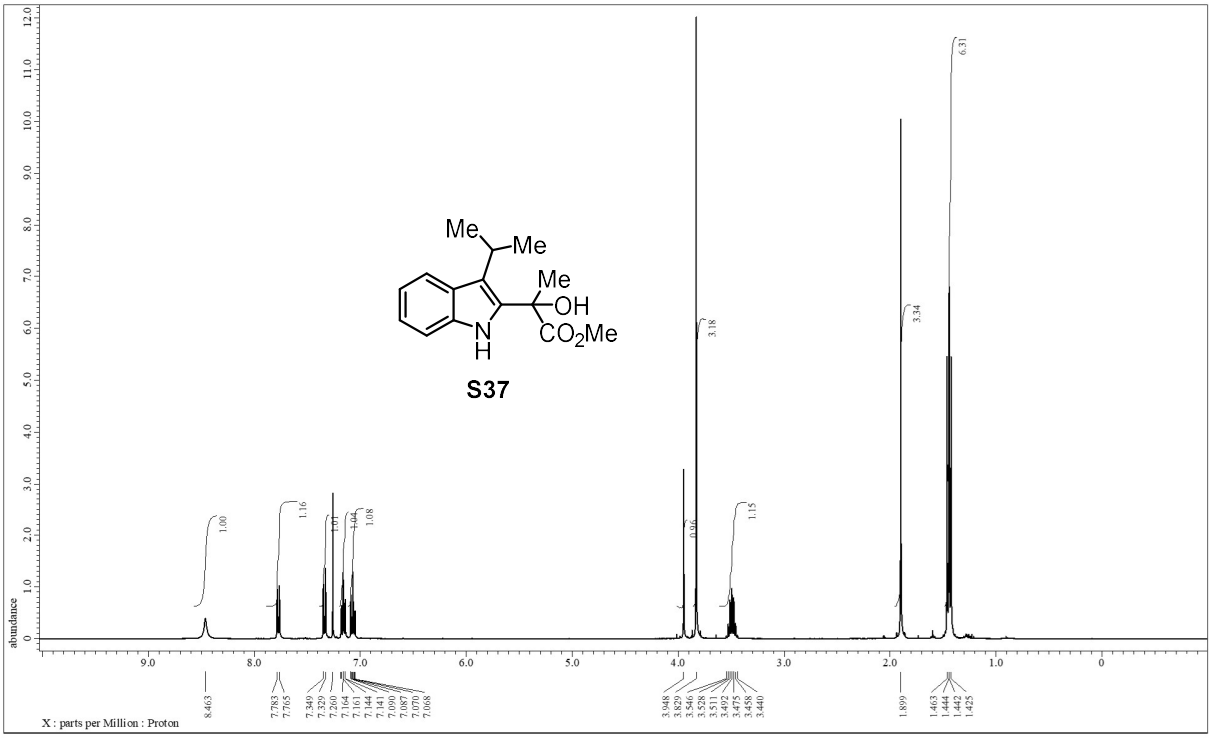


Figure S127. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **S37**.

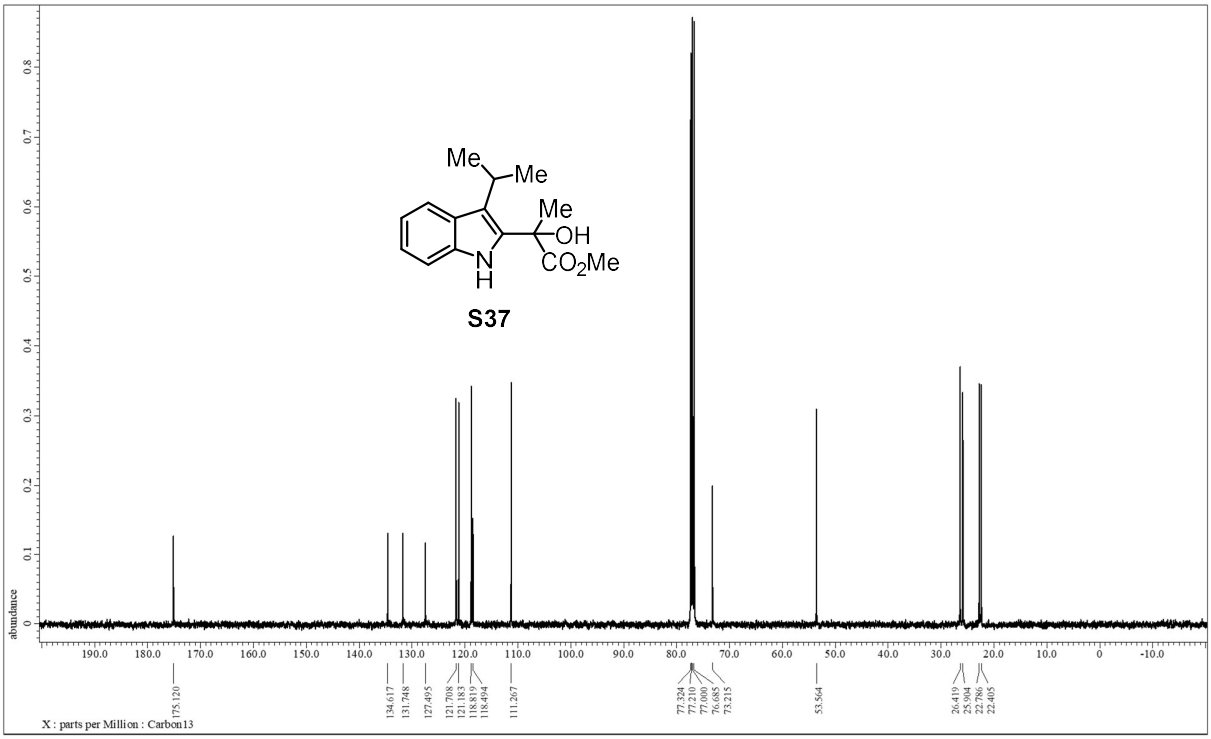


Figure S128. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **S37**.

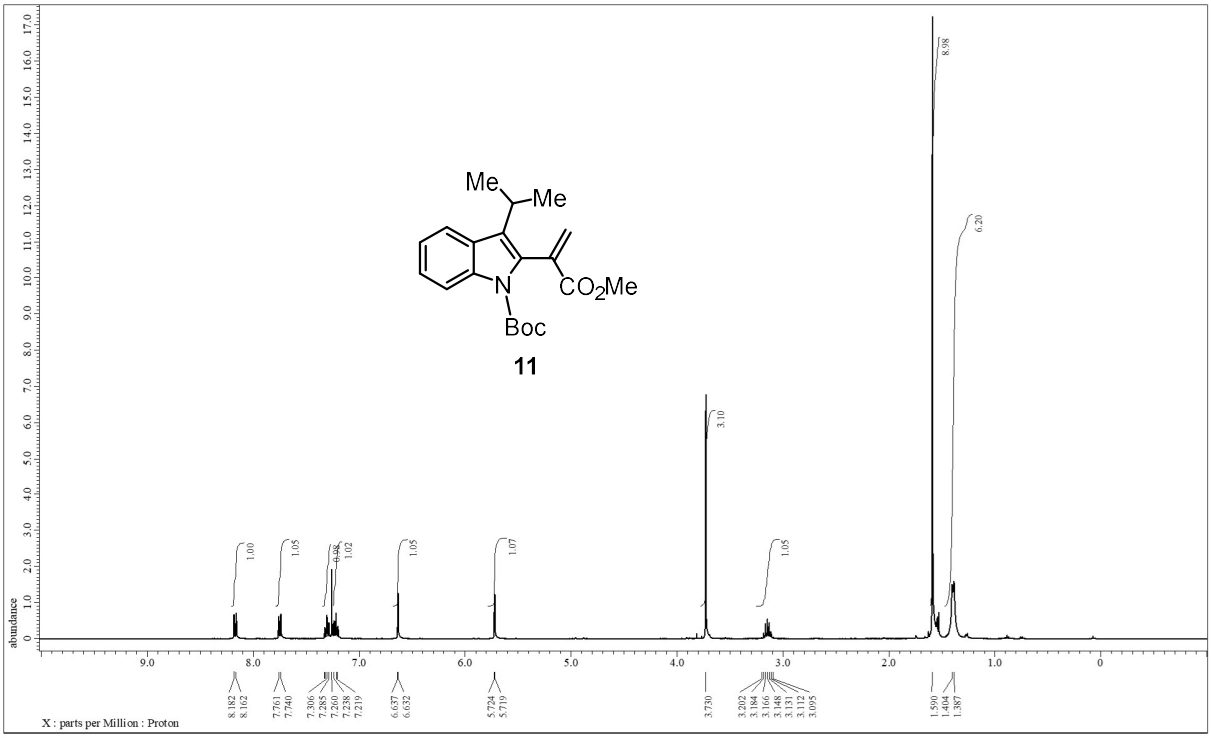


Figure S129. ^{1}H NMR spectrum (400 MHz, $CDCl_3$) of **11**.

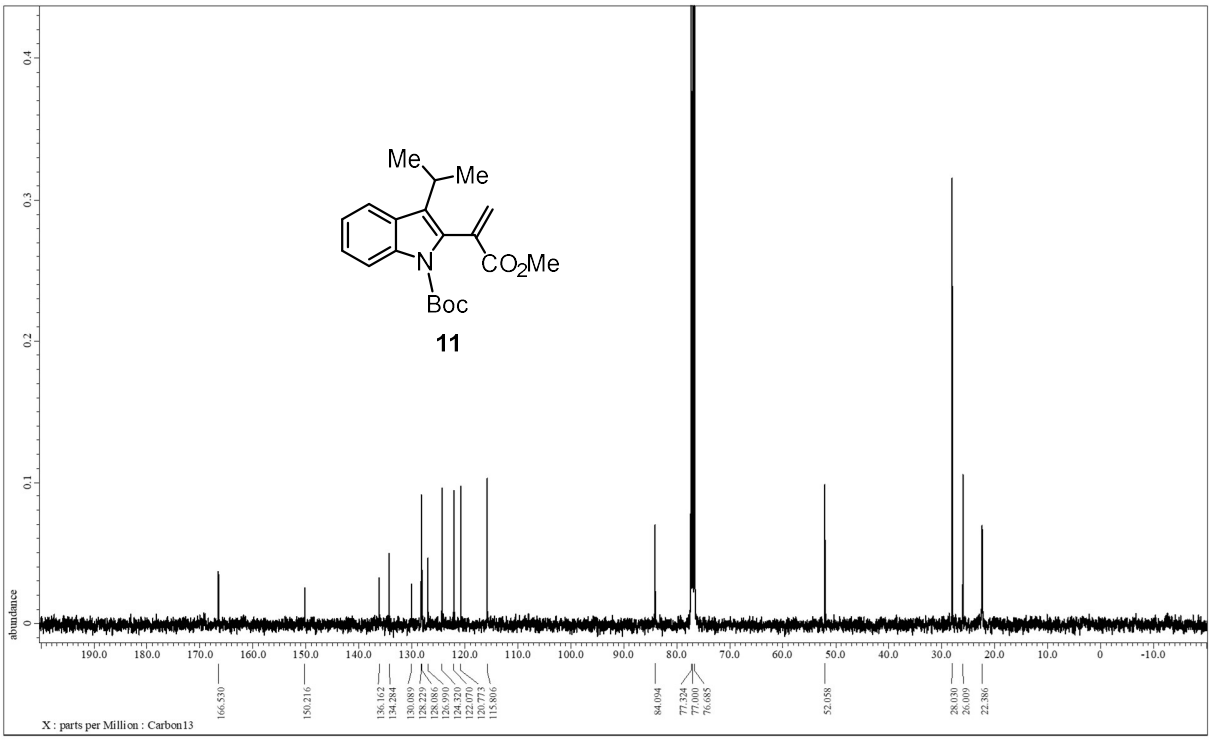


Figure S130. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **11**.

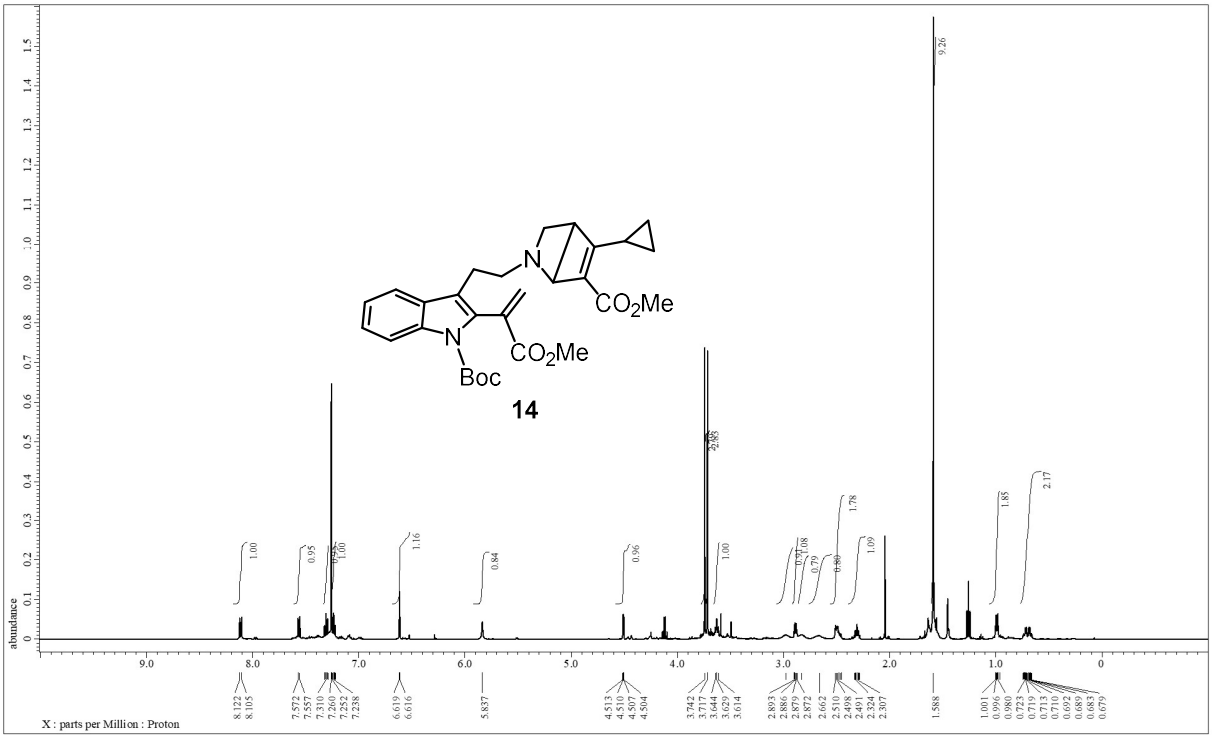


Figure S131. ^{1}H NMR spectrum (500 MHz, $CDCl_3$) of **14**.

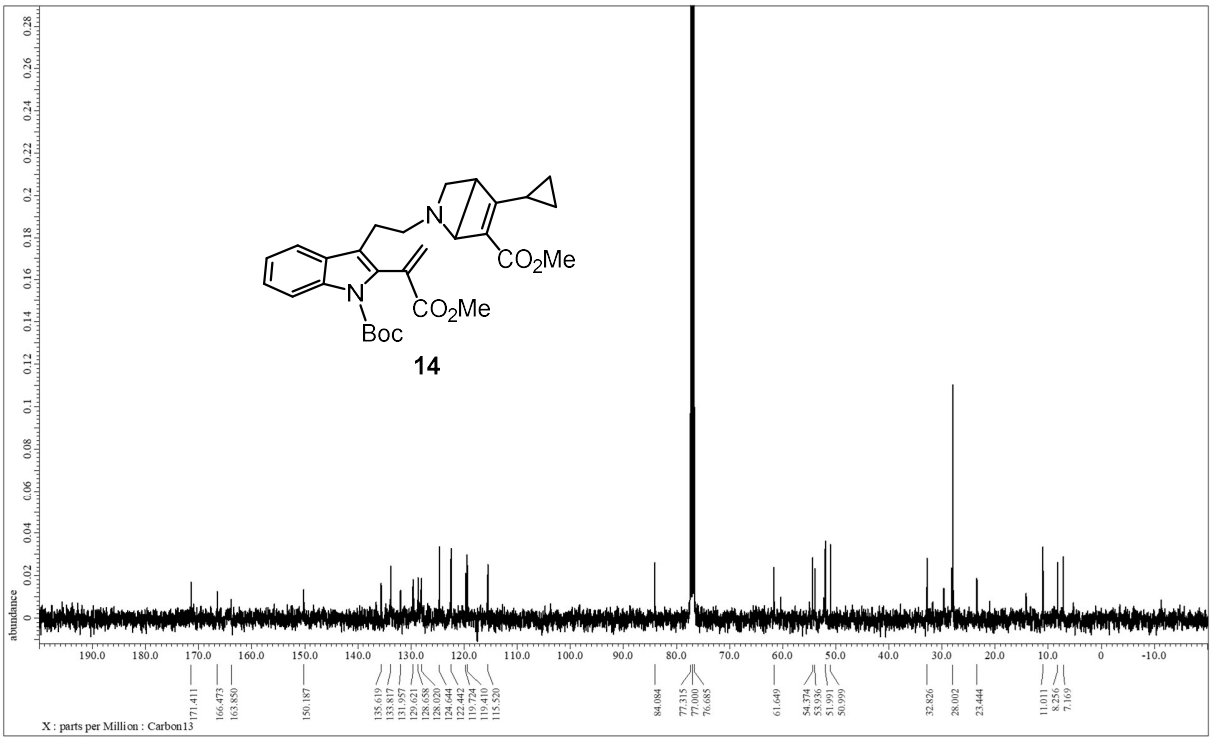


Figure S132. $^{13}C\{^{1}H\}$ NMR spectrum (100 MHz, $CDCl_3$) of **14**.

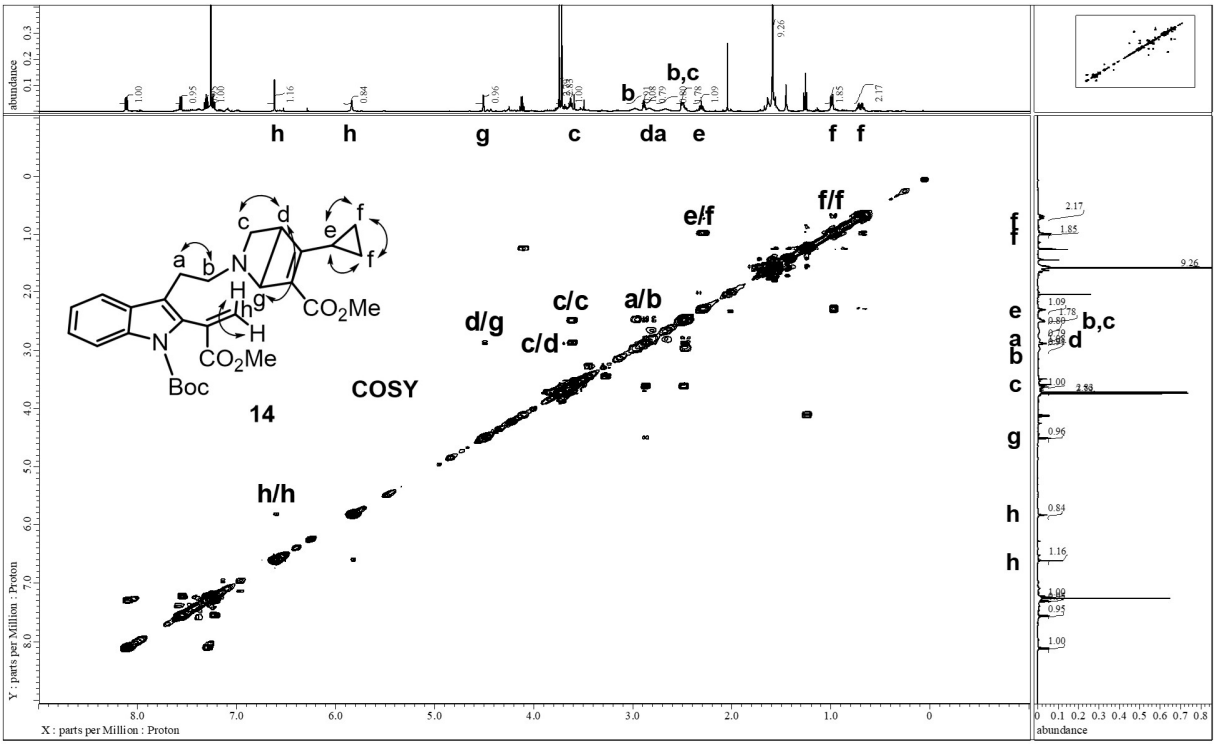


Figure S133. $^{1}H–^{1}H$ COSY spectrum (400 MHz, $CDCl_3$) of **14**.

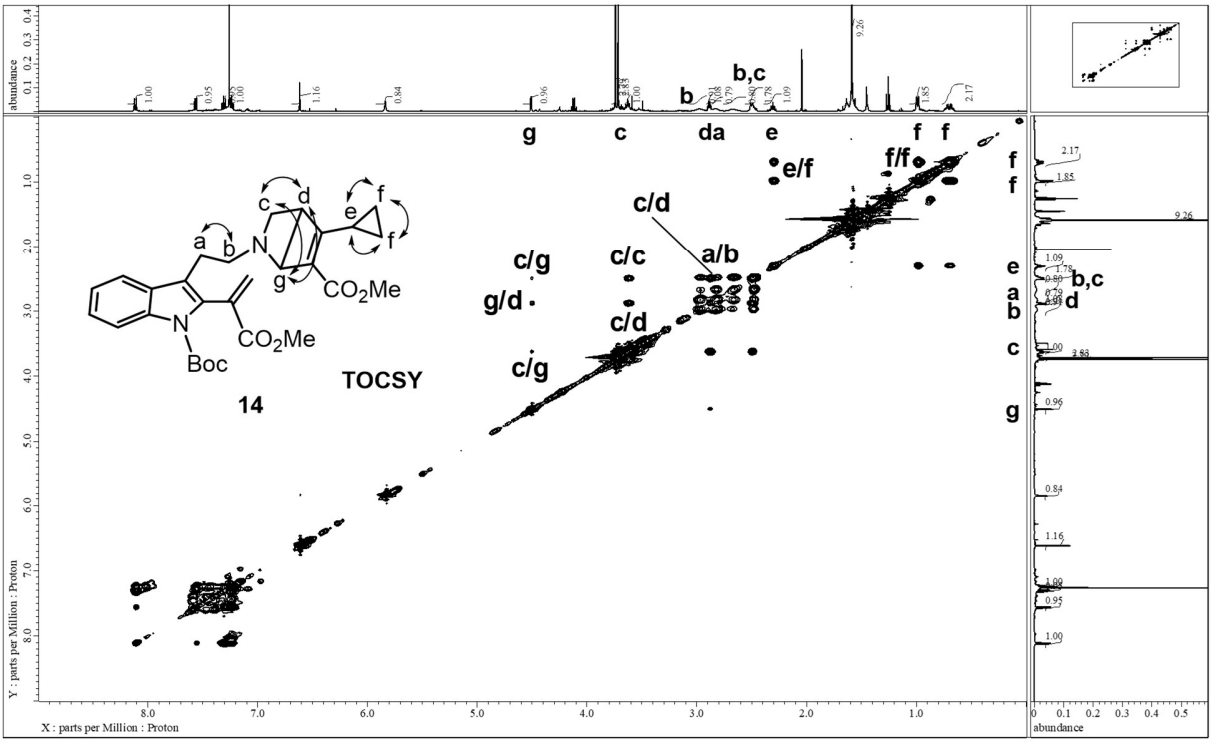


Figure S134. $^{1}H–^{1}H$ TOCSY NMR spectrum (400 MHz, $CDCl_3$) of **14**.

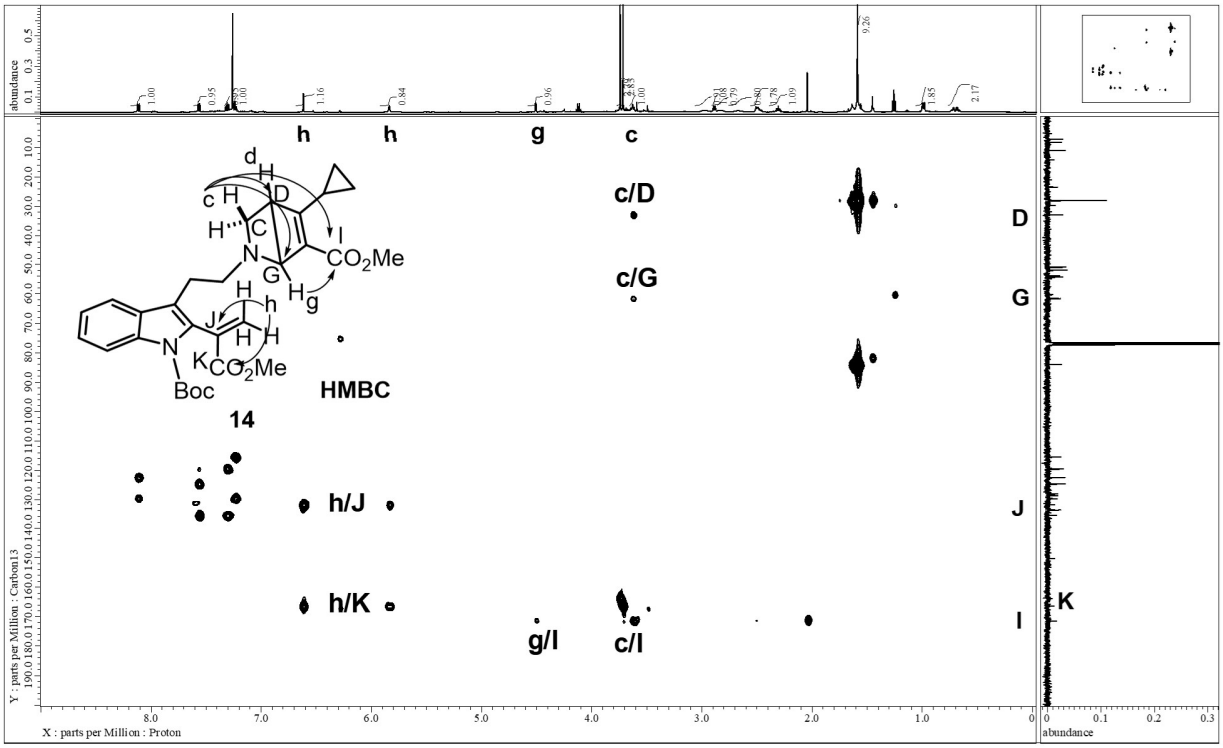


Figure S135. $^{1}H–^{13}C\{^{1}H\}$ HMBC NMR spectrum (100 MHz, $CDCl_3$) of **14**.

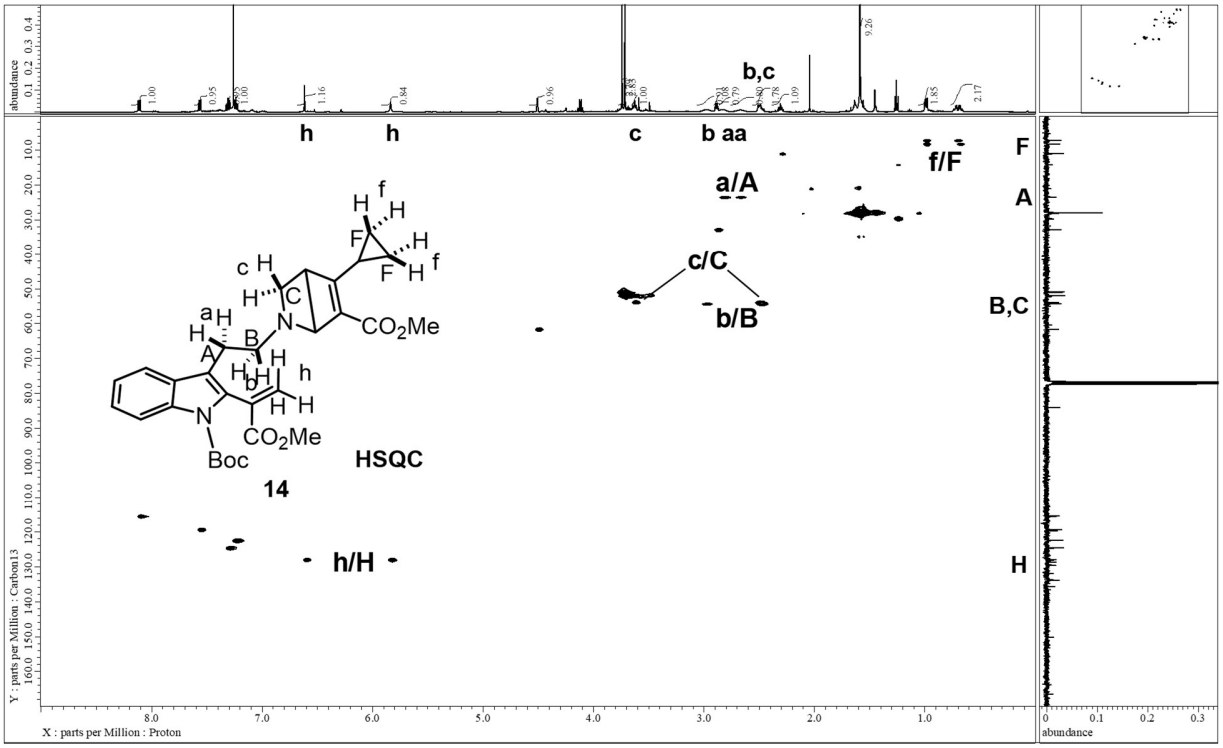


Figure S136. $^{1}H–^{13}C\{^{1}H\}$ HSQC spectrum (100 MHz, $CDCl_3$) of **14**.