Electronic Supplementary Material (ESI) for ChemComm.

Supporting Information

Copper-catalyzed decarboxylative propargylation/hydroamination reactions: access to C3 *β*-ketoester-functionalized indoles

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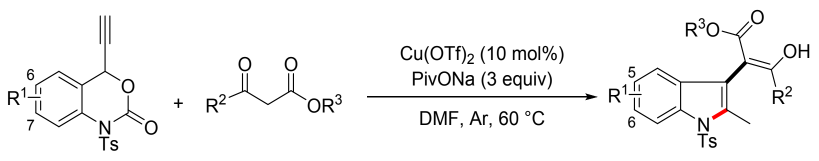
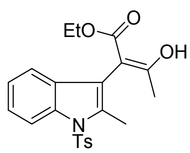
I. General Information

All ethynyl benzoxazinanones were prepared according to the known literatures, and the corresponding spectrum data matches that reported in the literatures.[1] All chemicals including *β*–ketoesters were commercially available from J&K, Energy, Damao *etc,* and used without further purification. All reactions were performed under Ar atmosphere. TFE (2,2,2-Trifluoroethanol), anhydrous DMF and anhydrous DMSO were purchased directly. Tetrahydrofuran and Toluene were distilled from sodium. DCM, DCE and ACN were distilled from CaH. Silica gels 60 (0.040-0.063 mm) from Tsingdao silica gel were used. For analytical TLC, Huanghai silica gel plates (0.25 mm, HSGF-254) were visualized with UV light and/or $KMnO_4$ (aq.). ^{1}H and ^{13}C NMR spectra of related chemicals were recorded on Brucker 300, 400 or 500 UltraShield™ spectrometers by assigning in ppm, relative to TMS [^{1}H δ = 0.00, ^{13}C δ = 0.00] or $CHCl_3$ [^{1}H δ = 7.26, ^{13}C δ = 77.36] resonance. ^{1}H NMR spectral data were assigned: chemical shift (δ/ppm), multiplicity (br = broad, m = multiplet, q = quartet, t = triplet, d = doublet, s = singlet), coupling constant (*J*/Hz) and integration. And ^{13}C NMR spectral data were assigned according to the chemical shift. IR spectral data were recorded in terms of frequency of absorption (cm^{-1}) on a Shimadzu IRPrestige-21. High-resolution mass spectrometry (HRMS) was performed on Bruker Apex IV RTMS. X-ray diffraction was conducted on Rigaku Saturn70 CCD diffractometer at a temperature of 100 ±1 K, employing graphite monochromated Cu-Kα radiation. Crystallographic data were provided by Oxford diffraction single-crystal X-ray diffractometer (Gemini S Ultra).

II. Copper-Catalyzed Sequential Decarboxylative Propargylation/Cycloisomerization

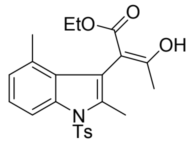


General procedure: To a 10 mL oven-dried flask, was added *β*–ketoester **2** (0.12 mmol, 1.2 equiv), PivONa (37.2 mg, 0.3 mmol, 3.0 equiv), $Cu(OTf)_2$ (3.6 mg, 0.01 mmol, 0.1 equiv) and ethynyl benzoxazinanones **1** (0.1 mmol, 1 equiv). DMF was then added under Ar atmosphere. After being stirred for 22 h at 60 °C, the solution was cooled to room temperature and quenched with water. The aqueous phase was extracted with EtOAc (3 mL × 3). And the combined organic layer was then washed with water (3 mL × 3) and dried over anhydrous Na_2SO_4. Afterward, silica gel was added before solvent was removed. The evaporated residue was further purified by flash chromatography (silica gel, hexanes/EtOAc = 40:1~10:1) to furnish compound **3**.



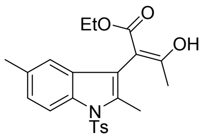
3aa

Ethyl (*Z*)-3-hydroxy-2-(2-methyl-1-tosyl-1H-indol-3-yl)but-2-enoate (3aa): Following above procedure, compound **3aa** was obtained in 77% yield (31.8 mg, pale yellow oil). ^{1}H NMR (500 MHz, $CDCl_3$) δ 13.31 (d, *J* = 0.5 Hz, 1H), 8.19 (d, *J* = 8.3 Hz, 1H), 7.60 (d, *J* = 8.4 Hz, 2H), 7.30–7.24 (m, 1H), 7.21 (td, *J* = 7.4, 0.9 Hz, 1H), 7.18 (m, 3H), 4.16–3.98 (m, 2H), 2.42 (s, 3H), 2.33 (s, 3H), 1.68 (d, 3H), 1.02 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 176.3, 172.4, 144.6, 136.5, 136.4, 135.6, 130.7, 129.7, 126.2, 124.0, 123.5, 119.0, 115.9, 114.7, 93.4, 60.5, 21.5, 19.5, 14.0, 13.6. HRMS (ESI) calculated for $C_{22}H_{24}NO_5S$ (M + H)$^+$: 414.1375, found: 414.1367.



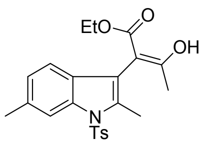
3ba

Ethyl (*Z*)-2-(2,4-dimethyl-1-tosyl-1H-indol-3-yl)-3-hydroxybut-2-enoate (3ba): Following above procedure, compound **3ba** was obtained in 82% yield (35.2 mg, colorless oil). ^{1}H NMR (400 MHz, $CDCl_3$) δ 13.13 (d, *J* = 0.5 Hz, 1H), 8.06 (d, *J* = 8.4 Hz, 1H), 7.58 (d, *J* = 8.4 Hz, 2H), 7.17 (d, *J* = 8.3 Hz, 2H), 7.13 (d, *J* = 8.3 Hz, 1H), 6.95 (d, *J* = 7.3 Hz, 1H), 4.16-4.04 (m, 2H), 2.40 (s, 3H), 2.33 (s, 3H), 2.31 (s, 3H), 1.66 (d, *J* = 0.6 Hz, 3H), 1.04 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.0, 172.4, 144.4, 136.6, 136.3, 135.3, 130.1, 129.6, 128.7, 126.1, 125.4, 123.7, 116.0, 112.5, 95.9, 60.5, 21.4, 19.4, 18.8, 14.0, 13.1. HRMS (ESI) calculated for $C_{23}H_{26}NO_5S$ $(M + H)^+$: 428.1532, found: 428.1528.



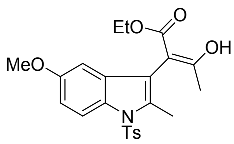
3ca

Ethyl (*Z*)-2-(2,5-dimethyl-1-tosyl-1H-indol-3-yl)-3-hydroxybut-2-enoate (3ca): Following above procedure, compound **3ca** was obtained in 85% yield (36.3 mg, pale yellow solid). ^{1}H NMR (400 MHz, $CDCl_3$) δ 13.31 (d, *J* = 0.5 Hz, 1H), 8.05 (d, *J* = 8.5 Hz, 1H), 7.59 (d, *J* = 8.4 Hz, 2H), 7.17 (d, *J* = 8.1 Hz, 2H), 7.08 (dd, *J* = 8.5, 1.4 Hz, 1H), 6.96 (s, 1H), 4.17–3.97 (m, 2H), 2.39 (s, 3H), 2.39 (s, 3H), 2.33 (s, 3H), 1.68 (s, 3H), 1.03 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 176.2, 172.4, 144.4, 136.3, 135.6, 134.5, 133.1, 130.8, 129.6, 126.1, 125.3, 118.9, 115.7, 114.3, 93.4, 60.4, 21.4, 21.2, 19.5, 14.0, 13.5. HRMS (ESI) calculated for $C_{23}H_{26}NO_5S$ $(M + H)^+$: 428.1532, found: 428.1528.



3da

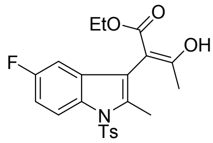
Ethyl (*Z*)-2-(2,6-dimethyl-1-tosyl-1H-indol-3-yl)-3-hydroxybut-2-enoate (3da): Following above procedure, compound **3da** was obtained in 67% yield (28.5 mg, pale yellow solid, mp. 66.1–69.9 °C). ^{1}H NMR (500 MHz, $CDCl_3$) δ 13.29 (s, 1H), 8.01 (s, 1H), 7.59 (d, *J* = 8.4 Hz, 2H), 7.18 (d, *J* = 8.1 Hz, 2H), 7.10 – 7.01 (m, 2H), 4.15–3.99 (m, 2H), 2.48 (s, 3H), 2.38 (s, 3H), 2.34 (s, 3H), 1.68 (s, 3H), 1.02 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 176.2, 172.5, 144.5, 136.9, 136.7, 134.8, 134.0, 129.7, 128.4, 126.2, 124.9, 118.6, 115.8, 115.0, 93.5, 60.5, 21.9, 21.5, 19.5, 14.0, 13.5. HRMS (ESI) calculated for $C_{23}H_{26}NO_5S$ $(M + H)^+$: 428.1532, found: 428.1526.



3ea

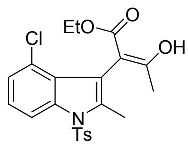
Ethyl (*Z*)-3-hydroxy-2-(5-methoxy-2-methyl-1-tosyl-1H-indol-3-yl)but-2-enoate (3ea): Following above procedure, compound **3ea** was obtained in 60% yield (26.7 mg, pale yellow solid, mp. 138.5–144.2 °C). ^{1}H NMR (400 MHz, $CDCl_3$) δ 13.31 (d, *J* = 0.6 Hz, 1H), 8.07 (d, *J* = 9.0 Hz, 1H), 7.57 (d, *J* = 8.4 Hz, 2H), 7.16 (d, *J* = 8.0 Hz, 2H), 6.87 (dd, *J* = 9.0, 2.6 Hz, 1H), 6.60 (d, *J* = 2.6 Hz, 1H), 4.20-3.90 (m, 2H), 3.79 (s, 3H), 2.39 (s, 3H), 2.33 (s, 3H), 1.68 (d, *J* = 0.5 Hz, 3H), 1.03 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 176.3, 172.3, 156.6, 144.4, 136.3, 136.2, 131.8, 130.8, 129.6, 126.1, 116.0, 115.6, 112.4, 101.6, 93.3, 60.5, 55.5, 21.4, 19.4, 14.0, 13.6. HRMS (ESI) calculated for $C_{23}H_{26}NO_6S$ $(M + H)^+$: 444.1481, found:

444.1474.



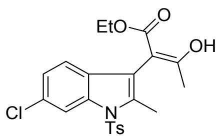
3fa

Ethyl (*Z*)-2-(5-fluoro-2-methyl-1-tosyl-1H-indol-3-yl)-3-hydroxybut-2-enoate (3fa): Following above procedure, compound **3fa** was obtained in 68% yield (29.3 mg, colorless oil). ^{1}H NMR (400 MHz, CDCl$_3$) δ 13.30 (d, *J* = 0.5 Hz, 1H), 8.13 (dd, *J* = 9.1, 4.4 Hz, 1H), 7.57 (d, *J* = 8.4 Hz, 2H), 7.19 (d, *J* = 8.1 Hz, 2H), 6.99 (td, *J* = 9.0, 2.6 Hz, 1H), 6.83 (dd, *J* = 8.6, 2.6 Hz, 1H), 4.17–3.99 (m, 2H), 2.41 (s, 3H), 2.35 (s, 3H), 1.69–1.65 (m, 3H), 1.03 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, CDCl$_3$) δ 176.4, 172.1, 160.0 (d, *J* = 239 Hz), 144.7, 137.4, 136.0, 132.5, 131.9 (d, *J* = 10 Hz), 129.7, 126.1, 115.8 (d, *J* = 4 Hz), 115.7 (d, *J* = 9 Hz), 111.6 (d, *J* = 25 Hz), 104.6 (d, *J* = 24 Hz), 92.9, 60.5, 21.4, 19.4, 13.9, 13.6. HRMS (ESI) calculated for $C_{22}H_{23}FNO_5S$ (M + H)$^+$: 432.1281, found: 432.1276.



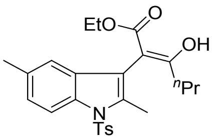
3ga

Ethyl (*Z*)-2-(4-chloro-2-methyl-1-tosyl-1H-indol-3-yl)-3-hydroxybut-2-enoate (3ga): Following above procedure, compound **3ga** was obtained in 64% yield (28.6 mg, pale yellow oil). ^{1}H NMR (400 MHz, CDCl$_3$) δ 13.18 (s, 1H), 8.17–8.11 (m, 1H), 7.59 (d, *J* = 8.4 Hz, 2H), 7.20 (d, *J* = 8.1 Hz, 2H), 7.18–7.14 (m, 2H), 4.09 (qd, *J* = 7.1, 2.8 Hz, 2H), 2.42 (s, 3H), 2.35 (s, 3H), 1.67 (s, 3H), 1.03 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, CDCl$_3$) δ 174.9, 172.3, 144.9, 137.6, 136.7, 135.9, 129.8, 127.2, 126.1, 125.7, 124.7, 124.3, 115.2, 113.2, 94.8, 60.4, 21.5, 19.4, 14.0, 13.2. HRMS (ESI) calculated for $C_{22}H_{23}ClNO_5S$ (M + H)$^+$: 448.0985, found: 448.0979.



3ha

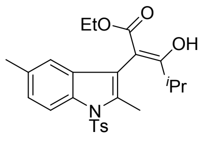
Ethyl (*Z*)-2-(6-chloro-2-methyl-1-tosyl-1H-indol-3-yl)-3-hydroxybut-2-enoate (3ha): Following above procedure, compound **3ha** was obtained in 68% yield (30.3 mg, pale yellow solid, mp. 111.0–113.8 °C). ^{1}H NMR (400 MHz, CDCl$_3$) δ 13.29 (s, 1H), 8.23 (d, *J* = 1.7 Hz, 1H), 7.61 (d, *J* = 8.4 Hz, 2H), 7.24–7.20 (m, 2H), 7.19 (d, *J* = 1.8 Hz, 1H), 7.09 (d, *J* = 8.3 Hz, 1H), 4.15–3.99 (m, 2H), 2.39 (s, 3H), 2.36 (s, 3H), 1.67 (s, 3H), 1.02 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, CDCl$_3$) δ 176.3, 172.2, 144.9, 136.6, 136.1, 136.1, 129.9, 129.8, 129.0, 126.2, 124.0, 119.7, 115.4, 114.8, 92.9, 60.5, 21.5, 19.4, 13.9, 13.5. HRMS (ESI) calculated for $C_{22}H_{23}ClNO_5S$ (M + H)$^+$: 448.0985, found: 448.0980.



3cb

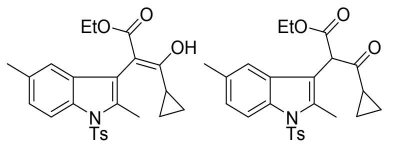
Ethyl (*Z*)-2-(2,5-dimethyl-1-tosyl-1H-indol-3-yl)-3-hydroxyhex-2-enoate (3cb): Following above procedure, compound **3cb** was obtained in 87% yield (39.7 mg, pale yellow oil). ^{1}H NMR (400 MHz, CDCl$_3$) δ 13.37 (s, 1H), 8.06 (d, *J* = 8.5 Hz, 1H), 7.58 (d, *J* = 8.4 Hz, 2H), 7.16 (d, *J* = 8.1 Hz, 2H), 7.09 (dd, *J* = 8.5, 1.4 Hz, 1H), 6.96 (s, 1H), 4.22–3.94 (m, 2H), 2.39 (s, 6H), 2.32 (s, 3H), 1.88 (dd, *J* = 8.2, 6.5 Hz, 2H), 1.45–1.35 (m, 2H), 1.02 (t, *J* = 7.1 Hz, 3H), 0.66 (t, *J* = 7.4 Hz, 3H). ^{13}C

NMR (100 MHz, $CDCl_3$) δ 179.3, 172.5, 144.4, 136.3, 135.7, 134.6, 133.1, 131.1, 129.6, 126.1, 125.3, 118.8, 115.7, 114.4, 93.0, 60.4, 34.7, 21.4, 21.2, 19.6, 14.0, 13.6, 13.5. HRMS (ESI) calculated for $C_{25}H_{30}NO_5S$ $(M + H)^+$: 456.1845, found: 456.1843.



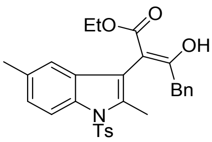
3cc

Ethyl (*Z*)-2-(2,5-dimethyl-1-tosyl-1H-indol-3-yl)-3-hydroxy-4-methylpent-2-enoate (3cc): Following above procedure, compound **3cc** was obtained in 85% yield (38.6 mg, pale yellow crystal, mp. 144.1–148.2 °C). ^1H NMR (400 MHz, $CDCl_3$) δ 13.39 (d, *J* = 1.4 Hz, 1H), 8.05 (d, *J* = 8.5 Hz, 1H), 7.56 (d, *J* = 8.4 Hz, 2H), 7.16 (d, *J* = 8.1 Hz, 2H), 7.08 (dd, *J* = 8.5, 1.4 Hz, 1H), 6.97 (s, 1H). 4.17–3.94 (m, 2H), 2.39 (s, 3H), 2.39 (s, 3H), 2.33 (s, 3H), 2.17–2.09 (m, 1H), 1.01 (t, *J* = 7.1 Hz, 3H), 0.95 (d, *J* = 6.8 Hz, 3H), 0.92 (d, *J* = 6.9 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 183.5, 172.7, 144.3, 136.3, 135.7, 134.7, 133.2, 131.4, 129.5, 126.0, 125.3, 118.6, 115.7, 114.4, 91.1, 60.4, 31.3, 21.4, 21.2, 19.5, 19.2, 14.0, 13.5. HRMS (ESI) calculated for $C_{25}H_{30}NO_5S$ $(M + H)^+$: 456.1845, found: 456.1840.



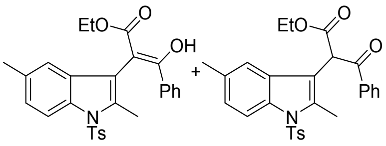
3cd

Ethyl (*Z*)-3-cyclopropyl-2-(2,5-dimethyl-1-tosyl-1H-indol-3-yl)-3-hydroxyacrylate (3cd): Following above procedure, compound **3cd** was obtained in 89% yield (40.4 mg, white solid, mp. 135.3–136.5 °C). Major: ^1H NMR (500 MHz, $CDCl_3$) δ 13.52 (d, *J* = 1.5 Hz, 1H), 8.06 (d, *J* = 8.5 Hz, 1H), 7.59 (d, *J* = 8.4 Hz, 2H), 7.15 (d, *J* = 8.1 Hz, 2H), 7.10–7.07 (m, 1H), 7.06 (d, *J* = 0.5 Hz, 1H), 4.15–3.99 (m, 2H), 2.44 (s, 3H), 2.40 (s, 3H), 2.32 (s, 3H), 1.16–1.05 (m, 3H), 1.03 (t, *J* = 7.1 Hz, 3H), 0.68–0.54 (m, 2H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 179.3, 172.4, 144.3, 136.5, 136.1, 134.7, 133.0, 131.4, 129.5, 126.2, 125.2, 119.4, 115.7, 114.4, 91.8, 60.3, 21.4, 21.2, 14.0, 13.7, 13.2, 8.4, 8.1. Minor: ^1H NMR (500 MHz, $CDCl_3$) δ 8.08 (d, *J* = 8.8 Hz, 1H), 7.63 (d, *J* = 8.4 Hz, 2H), 7.23 (s, 1H), 7.18 (d, *J* = 8.1 Hz, 2H), 7.12–7.07 (m, 1H), 4.95 (s, 1H), 4.18 (q, *J* = 7.1 Hz, 2H), 2.58 (s, 3H), 2.41 (s, 3H), 2.33 (s, 3H), 1.72–1.66 (m, 1H), 1.22 (t, *J* = 7.1 Hz, 3H), 1.00–0.95 (m, 1H), 0.92–0.76 (m, 3H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 203.6, 168.1, 144.7, 136.3, 134.6, 133.2, 129.8, 129.4, 126.3, 125.7, 118.9, 114.3, 112.4, 61.5, 56.7, 21.4, 21.3, 19.6, 14.0, 13.4, 11.9, 11.9. HRMS (ESI) calculated for $C_{25}H_{28}NO_5S$ $(M + H)^+$: 454.1688, found 454.1695.



3ce

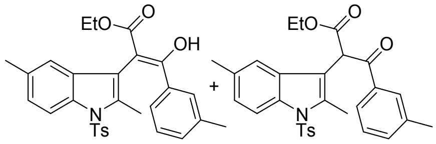
Ethyl (*Z*)-2-(2,5-dimethyl-1-tosyl-1H-indol-3-yl)-3-hydroxy-4-phenylbut-2-enoate (3ce): Following above procedure, compound **3ce** was obtained in 73% yield (36.7 mg, pale yellow solid, mp. 110.3–113.9 °C). ^1H NMR (400 MHz, $CDCl_3$) δ 13.35 (s, 1H), 8.10 (d, *J* = 8.5 Hz, 1H), 7.60 (d, *J* = 8.3 Hz, 2H), 7.13–7.09 (m, 6H), 6.95 (s, 1H), 6.81 (d, *J* = 6.3 Hz, 2H), 4.20–3.15 (m, 2H), 3.20 (s, 2H), 2.39 (s, 3H), 2.27 (s, 3H), 2.27 (s, 3H), 1.02 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 176.9, 172.5, 144.5, 136.3, 136.2, 135.8, 134.6, 133.2, 130.9, 129.6, 128.8, 128.1, 126.6, 126.1, 125.4, 118.9, 115.3, 114.4, 93.9, 60.6, 39.1, 21.4, 21.2, 13.9, 13.5. HRMS (ESI) calculated for $C_{29}H_{29}NO_5SNa$ $(M + Na)^+$: 526.1664, found: 526.1660.



major minor

3cf

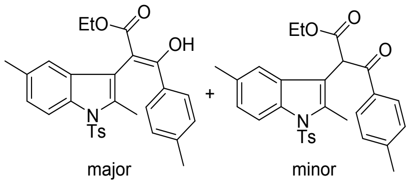
Ethyl (*Z*)-2-(2,5-dimethyl-1-tosyl-1H-indol-3-yl)-3-hydroxy-3-phenylacrylate (3cf): Following above procedure, compound **3cf** was obtained in 70% yield (34.5 mg, pale yellow oil). Major: ^{1}H NMR (400 MHz, $CDCl_3$) δ 13.79 (s, 1H), 8.02 (d, *J* = 8.5 Hz, 1H), 7.49 (d, *J* = 8.3 Hz, 2H), 7.16 –7.00 (m, 6H), 7.02 (s, 1H), 6.91 (t, *J* = 7.8 Hz, 2H), 4.27–4.06 (m, 2H), 2.38 (s, 3H), 2.37 (s, 3H), 2.15 (s, 3H), 1.09 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.4, 173.3, 144.3, 136.7, 135.2, 134.7, 134.3, 132.9, 131.3, 129.8, 129.8, 127.8, 127.7, 126.3, 125.3, 119.4, 115.63, 114.1, 93.7, 61.0, 21.6, 21.3, 14.1, 13.3. Ketone isomer: ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02 (d, *J* = 8.5 Hz, 1H), 7.77–7.72 (m, 2H), 7.53–7.42 (m, 3H), 7.33 (s, 1H), 7.29 (d, *J* = 8.0 Hz, 2H), 7.16–7.00 (m, 3H), 5.60 (s, 1H), 4.27–4.06 (m, 2H), 2.56 (s, 3H), 2.42 (s, 3H), 2.31 (s, 3H), 1.23 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (75 MHz, $CDCl_3$) δ 193.9, 168.4, 144.6, 136.2, 136.0, 135.4, 134.7, 133.5, 133.4, 129.8, 129.2, 128.6, 128.4, 126.1, 125.9, 118.8, 114.4, 112.9, 61.8, 52.5, 42.0, 21.5, 14.1, 13.4. HRMS (ESI) calculated for $C_{28}H_{27}NO_5SNa$ (M + Na)$^+$: 512.1508, found: 512.1504.



major minor

3cg

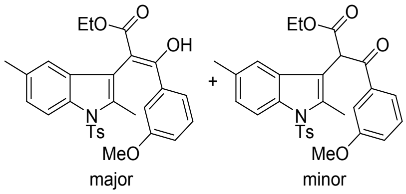
Ethyl (*Z*)-2-(2,5-dimethyl-1-tosyl-1H-indol-3-yl)-3-hydroxy-3-(m-tolyl)acrylate (3cg): Following above procedure, compound **3cg** was obtained in 82% yield (41.1 mg, pale yellow oil). Major: ^{1}H NMR (400 MHz, $CDCl_3$) δ 13.78 (s, 1H), δ 7.99 (d, *J* = 8.4 Hz, 1H), 7.50 (d, *J* = 8.4 Hz, 2H), 7.18 (s, 1H), 7.14 (d, *J* = 8.1 Hz, 2H), 7.08 (d, *J* = 8.5 Hz, 1H), 7.07 – 7.02 (m, 1H), 7.01 (d, *J* = 0.6 Hz, 1H), 6.95 (d, *J* = 7.5 Hz, 1H), 6.76 (d, *J* = 7.8 Hz, 1H), 4.27 – 4.08 (m, 2H), 2.36 (s, 3H), 2.36 (s, 3H), 2.18 (s, 3H), 2.11 (s, 3H), 1.08 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.5, 173.3, 144.1, 137.3, 136.6, 135.1, 134.6, 134.2, 132.8, 131.3, 130.5, 129.6, 128.2, 127.3, 126.2, 125.1, 124.9, 119.3, 115.6, 113.9, 93.5, 60.8, 21.4, 21.2, 21.1, 14.0, 13.2. Minor: ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02 (d, *J*=6.0, 1H), 7.63 (s, 1H), 7.54 – 7.45 (m, 3H), 7.34 (s, 1H), 7.28 (d, *J* = 7.6 Hz, 1H), 7.10–7.25 (m, 1H), 6.69 (d, *J* = 7.6 Hz, 2H), 6.67 (d, *J* = 7.7 Hz, 1H), 5.60 (s, 1H), 4.27 – 4.08 (m, 2H), 2.57 (s, 3H), 2.42 (s, 3H), 2.31 (s, 3H), 2.27 (s, 3H), 1.23 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.8, 168.3, 144.4, 138.3, 136.1, 135.9, 135.3, 134.6, 134.1, 133.2, 129.7, 129.1, 128.9, 128.3, 126.0, 125.7, 125.4, 118.9, 114.3, 112.8, 61.6, 52.3, 21.4, 21.3, 21.2, 14.0, 13.2. HRMS (ESI) calculated for $C_{29}H_{30}NO_5S$ (M + H)$^+$: 504.1845, found: 504.1838.



major minor

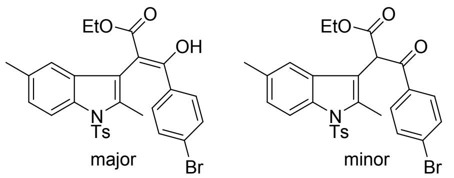
3ch

Ethyl (*Z*)-2-(2,5-dimethyl-1-tosyl-1H-indol-3-yl)-3-hydroxy-3-(p-tolyl)acrylate (3ch): Following above procedure, compound **3ch** was obtained in 90% yield (45.1 mg, white oil). Major: ^{1}H NMR (400 MHz, $CDCl_3$) δ 13.83 (s, 1H), 8.03 (d, *J* = 8.5 Hz, 1H), 7.52 (d, *J* = 8.4 Hz, 2H), 7.16 (d, *J* = 8.1 Hz, 2H), 7.11–7.03 (m, 3H), 7.02 (s, 1H), 6.72 (d, *J* = 8.0 Hz, 2H), 4.19 – 4.07 (m, 2H), 2.38 (s, 3H), 2.37 (s, 3H), 2.22 (s, 3H), 2.16 (s, 3H), 1.07 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.4, 173.2, 144.1, 139.9, 136.7, 135.0, 134.3, 132.8, 131.7, 129.6, 129.2, 128.3, 127.8, 126.2, 125.2, 119.4, 115.74, 113.95, 93.0, 60.8, 21.5, 21.3, 21.2, 14.0, 13.2. Minor: ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.01 (d, *J* = 8.5 Hz, 1H), 7.66 (d, *J* = 8.3 Hz, 2H), 7.48 (d, *J* = 8.4 Hz, 2H), 7.33 (s, 1H), 7.11-7.04 (m, 5H), 5.58 (s, 1H), 4.25–4.19 (m, 2H), 2.56 (s, 3H), 2.42 (s, 3H), 2.35 (s, 3H), 2.32 (s, 3H), 1.23 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.4, 168.4, 144.4, 144.2, 136.2, 135.8, 134.6, 133.3, 132.8, 131.3, 129.7, 129.1, 128.4, 126.0, 125.7, 118.8, 114.3, 113.0, 61.6, 52.3, 21.6, 21.5, 14.0, 13.2. HRMS (ESI) calculated for $C_{29}H_{30}NO_5S$ $(M + H)^+$: 504.1845, found: 504.1843.



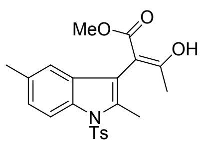
3ci

Ethyl (*Z*)-2-(2,5-dimethyl-1-tosyl-1H-indol-3-yl)-3-hydroxy-3-(3-methoxyphenyl)acrylate (3ci): Following above procedure, compound **3ci** was obtained in 71% yield (36.8 mg, pare yellow oil). Major: ^{1}H NMR (400 MHz, $CDCl_3$) δ 13.76 (s, 1H), 7.98 (d, *J* = 8.4 Hz, 1H), 7.46 (d, *J* = 8.4 Hz, 2H), 7.12 (d, *J* = 8.1 Hz, 2H), 7.07 (s, 1H), 7.06 – 7.03 (m, 1H), 6.87 (t, *J* = 7.8 Hz, 1H), 6.79 (dt, *J* = 7.7, 1.2 Hz, 1H), 6.72 – 6.65 (m, 2H), 4.20 – 4.09 (m, 2H), 3.16 (s, 3H), 2.37 (s, 3H), 2.36 (s, 3H), 2.19 (s, 3H), 1.08 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.3, 173.2, 158.5, 144.2, 136.4, 135.8, 135.3, 134.1, 133.0, 131.6, 129.6, 128.6, 126.0, 125.1, 120.1, 119.1, 117.1, 115.7, 114.0, 111.8, 93.6, 60.9, 54.4, 21.4, 21.2, 14.0, 13.1. Minor: ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.03 (d, *J* = 8.5 Hz, 1H), 7.46 (d, *J* = 8.4 Hz, 2H), 7.35 (s, 1H), 7.32 (d, *J* = 7.9 Hz, 1H), 7.27-7.25 (m, 1H), 7.20 – 7.14 (m, 1H), 7.14 – 7.03 (m, 3H), 7.03 – 6.99 (m, 1H), 5.59 (s, 1H), 4.26 – 4.20 (m, 2H), 3.60 (s, 3H), 2.56 (s, 3H), 2.42 (s, 3H), 2.30 (s, 3H), 1.24 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 193.5, 168.2, 159.5, 144.5, 136.5, 136.2, 136.0, 134.6, 133.3, 129.7, 129.4, 129.1, 126.0, 125.7, 120.8, 120.4, 118.6, 114.4, 112.9, 112.2, 61.7, 55.1, 52.4, 21.4, 21.3, 14.0, 13.3. HRMS (ESI) calculated for $C_{29}H_{30}NO_6S$ $(M + H)^+$: 520.1794, found: 520.1781.



3cj

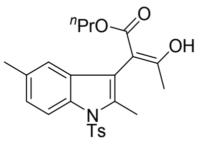
Ethyl (*Z*)-3-(4-bromophenyl)-2-(2,5-dimethyl-1-tosyl-1H-indol-3-yl)-3-hydroxyacrylate (3cj): Following above procedure, compound **3cj** was obtained in 46% yield (32.6 mg, pale yellow solid, mp. 149.2–155.8 °C). Major: ^{1}H NMR (400 MHz, $CDCl_3$) δ 13.78 (s, 1H), 8.07 (d, *J* = 8.5 Hz, 1H), 7.51 (d, *J* = 8.4 Hz, 2H), 7.21 (d, *J* = 8.1 Hz, 2H), 7.09 (d, *J* = 8.4 Hz, 1H), 7.03 (s, 1H), 7.02–6.94 (m, 4H), 4.28–4.07 (m, 2H), 2.43 (s, 3H), 2.39 (s, 3H), 2.14 (s, 3H), 1.10 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 173.2, 171.6, 144.6, 136.5, 134.9, 134.2, 133.5, 133.0, 131.1, 130.8, 129.7, 129.4, 126.2, 125.4, 124.2, 119.2, 115.2, 114.1, 94.0, 61.1, 21.7, 21.2, 14.0, 13.1. Minor: ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.03 (d, *J* = 8.6 Hz, 1H), 7.56 (d, *J* = 8.7 Hz, 2H), 7.44 (d, *J* = 8.4 Hz, 2H), 7.38 (d, *J* = 8.7 Hz, 2H), 7.28 (s, 1H), 7.13–7.06 (m, 3H), 5.50 (s, 1H), 4.27–4.07 (m, 2H), 2.53 (s, 3H), 2.43 (s, 3H), 2.35 (s, 3H), 1.27–1.21 (t, *J* = 7.1, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.9, 167.9, 144.7, 135.9, 134.6, 133.9, 133.5, 131.8, 129.7, 129.7, 128.9, 128.8, 128.5, 125.9, 125.8, 118.4, 114.5, 112.7, 61.8, 52.5, 29.6, 21.5, 21.3, 13.2. HRMS (ESI) calculated for $C_{28}H_{27}BrNO_5S$ $(M + H)^+$: 568.0793, found: 568.0791.



3ck

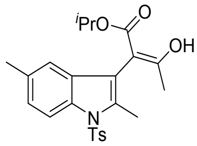
Methyl (*Z*)-2-(2,5-dimethyl-1-tosyl-1H-indol-3-yl)-3-hydroxybut-2-enoate (3ck): Following above procedure, compound

3ck was obtained in 77% yield (31.9 mg, white solid, mp. 177.4–178.5 °C). ^{1}H NMR (400 MHz, $CDCl_3$) δ 13.22 (s, 1H), 8.05 (d, *J* = 8.5 Hz, 1H), 7.60 (d, *J* = 8.4 Hz, 2H), 7.18 (d, *J* = 8.1 Hz, 2H), 7.09 (dd, *J* = 8.5, 1.2 Hz, 1H), 6.96 (s, 1H), 3.60 (s, 3H), 2.40 (s, 3H), 2.39 (s, 3H), 2.34 (s, 3H), 1.68 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 176.3, 172.8, 144.5, 136.3, 135.7, 134.5, 133.2, 130.8, 129.6, 126.1, 125.4, 118.8, 115.6, 114.4, 93.2, 51.7, 21.4, 21.2, 19.4, 13.5. HRMS (ESI) calculated for $C_{22}H_{24}NO_5S$ $(M + H)^+$: 414.1375, found: 414.1376.



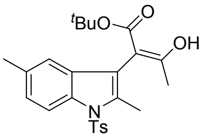
3cl

Propyl (*Z*)-2-(2,5-dimethyl-1-tosyl-1H-indol-3-yl)-3-hydroxybut-2-enoate (3cl): Following above procedure, compound **3cl** was obtained in 79% yield (35.1 mg, pale yellow oil). ^{1}H NMR (400 MHz, $CDCl_3$) δ 13.29 (s, 1H), 8.05 (d, *J* = 8.5 Hz, 1H), 7.62 – 7.56 (m, 2H), 7.16 (d, *J* = 8.1 Hz, 2H), 7.08 (dd, *J* = 8.5, 1.4 Hz, 1H), 6.96 (s, 1H), 4.06 – 3.88 (m, 2H), 2.40 (s, 3H), 2.38 (s, 3H), 2.33 (s, 3H), 1.68 (s, 3H), 1.43 – 1.32 (m, 2H), 0.63 (t, *J* = 7.4 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 176.1, 172.5, 144.4, 136.3, 135.4, 134.5, 133.0, 130.8, 129.6, 126.1, 125.3, 119.0, 115.7, 114.3, 93.4, 66.0, 21.7, 21.4, 21.2, 19.4, 13.5, 10.0. HRMS (ESI) calculated for $C_{24}H_{27}NO_5SNa$ $(M + Na)^+$: 464.1508, found: 464.1502.



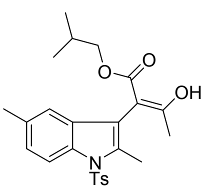
3cm

Isopropyl (*Z*)-2-(2,5-dimethyl-1-tosyl-1H-indol-3-yl)-3-hydroxybut-2-enoate (3cm): Following above procedure, compound **3cm** was obtained in 77% yield (34.1 mg, pale yellow solid, mp. 117.2–119.9 °C). ^{1}H NMR (400 MHz, $CDCl_3$) δ 13.39 (s, 1H), 8.05 (d, *J* = 8.5 Hz, 1H), 7.58 (d, *J* = 8.4 Hz, 2H), 7.16 (d, *J* = 8.1 Hz, 2H), 7.08 (dd, *J* = 8.5, 1.4 Hz, 1H), 6.95 (s, 1H), 5.05–4.95 (m, 1H), 2.39 (s, 6H), 2.33 (s, 3H), 1.68 (s, 3H), 1.02 (d, *J* = 6.3 Hz, 3H), 0.99 (d, *J* = 6.2 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.9, 172.0, 144.35, 136.4, 135.4, 134.5, 133.0, 130.8, 129.6, 126.1, 125.2, 119.0, 115.8, 114.3, 93.7, 67.9, 21.6, 21.4, 21.4, 21.2, 19.5, 13.5. HRMS (ESI) calculated for $C_{24}H_{28}NO_5S$ $(M + H)^+$: 442.1688, found: 442.1687.



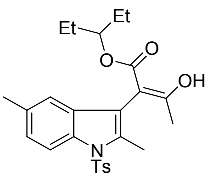
3cn

tert-Butyl (*Z*)-2-(2,5-dimethyl-1-tosyl-1H-indol-3-yl)-3-hydroxybut-2-enoate (3cn): Following above procedure, compound **3cn** was obtained in 69% yield (31.4 mg, pale yellow crystal, mp. 146.0–149.0 °C). ^{1}H NMR (500 MHz, $CDCl_3$) δ 13.47 (s, 1H), 8.05 (d, *J* = 8.5 Hz, 1H), 7.59 (d, *J* = 8.4 Hz, 2H), 7.15 (d, *J* = 8.1 Hz, 2H), 7.09–7.05 (m, 1H), 6.97 (s, 1H), 2.39 (s, 3H), 2.39 (s, 3H), 2.32 (s, 3H), 1.67 (s, 3H), 1.24 (s, 9H). ^{13}C NMR (125 MHz, $CDCl_3$) δ 175.5, 172.3, 144.4, 136.6, 135.1, 134.6, 132.9, 130.9, 129.7, 126.2, 125.2, 119.1, 116.3, 114.3, 94.6, 81.3, 27.9, 21.4, 21.3, 19.6, 13.6. HRMS (ESI) calculated for $C_{25}H_{29}NO_5SNa$ $(M + Na)^+$: Exact Mass: 478.1664, found: 478.1650.



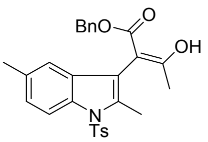
3co

***iso*butyl (*Z*)-2-(2,5-dimethyl-1-tosyl-1H-indol-3-yl)-3-hydroxybut-2-enoate (3co)**: Following above procedure, compound **3co** was obtained in 80% yield (36.4 mg, pale yellow solid, mp. 76.0–80.9 °C). ^{1}H NMR (400 MHz, $CDCl_3$) δ 13.26 (d, *J* = 0.6 Hz, 1H), 8.06 (d, *J* = 8.5 Hz, 1H), 7.60 (d, *J* = 8.4 Hz, 2H), 7.16 (d, *J* = 8.0 Hz, 2H), 7.08 (dd, *J* = 8.5, 1.4 Hz, 1H), 6.96 (s, 1H), 3.79 (ddd, *J* = 26.8, 10.6, 6.5 Hz, 2H), 2.41 (s, 3H), 2.38 (s, 3H), 2.33 (s, 3H), 1.69 (d, *J* = 0.5 Hz, 3H), 1.66–1.54 (m, 1H), 0.60 (d, *J* = 6.7 Hz, 3H), 0.57 (d, *J* = 6.7 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 176.0, 172.5, 144.4, 136.3, 135.3, 134.5, 133.0, 130.8, 129.6, 126.1, 125.3, 119.0, 115.7, 114.2, 93.3, 70.5, 27.4, 21.4, 21.1, 19.4, 18.7, 18.6, 13.4. HRMS (ESI) calculated for $C_{25}H_{30}NO_5S$ $(M + H)^+$: 456.1845, found: 456.1842.



3cp

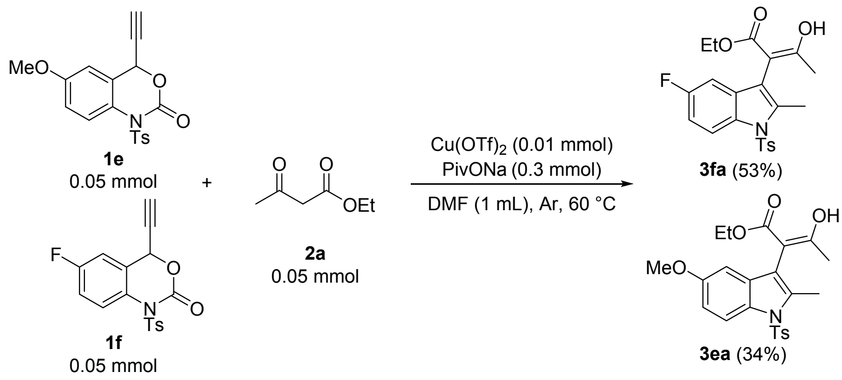
Pentan-3-yl (*Z*)-2-(2,5-dimethyl-1-tosyl-1H-indol-3-yl)-3-hydroxybut-2-enoate (3cp): Following above procedure, compound **3cp** was obtained in 76% yield (35.7 mg, pale yellow solid, mp. 103.2–104.8 °C). ^{1}H NMR (400 MHz, $CDCl_3$) δ 13.36 (d, *J* = 0.5 Hz, 1H), 8.06 (d, *J* = 8.5 Hz, 1H), 7.58 (d, *J* = 8.4 Hz, 2H), 7.16 (d, *J* = 8.1 Hz, 2H), 7.08 (dd, *J* = 8.5, 1.4 Hz, 1H), 6.97 (s, 1H), 4.80–4.65 (m, 1H), 2.40 (s, 3H), 2.38 (s, 3H), 2.33 (s, 3H), 1.67 (s, 3H), 1.40–1.17 (m, 4H), 0.65 (t, *J* = 7.4 Hz, 3H), 0.57 (t, *J* = 7.4 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 175.8, 172.3, 144.3, 136.4, 135.3, 134.5, 133.0, 131.0, 129.6, 126.0, 125.3, 118.9, 116.1, 114.2, 93.5, 76.8, 26.1, 26.0, 21.4, 21.1, 19.3, 13.4, 9.2, 9.0. HRMS (ESI) calculated for $C_{26}H_{31}NO_5SNa$ $(M + Na)^+$: 492.1821, found: 492.1816.



3cq

Benzyl (*Z*)-2-(2,5-dimethyl-1-tosyl-1H-indol-3-yl)-3-hydroxybut-2-enoate (3cq): Following above procedure, compound **3cq** was obtained in 72% yield (35.3 mg, pare yellow oil). ^{1}H NMR (400 MHz, $CDCl_3$) δ 13.19 (s, 1H), 8.03 (d, *J* = 8.5 Hz, 1H), 7.52 (d, *J* = 8.4 Hz, 2H), 7.27 – 7.19 (m, 3H), 7.11 – 7.02 (m, 5H), 6.94 (s, 1H), 5.08 (q, *J* = 12.6 Hz, 2H), 2.38 (s, 3H), 2.37 (s, 3H), 2.28 (s, 3H), 1.70 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 176.6, 172.2, 144.3, 136.3, 135.8, 135.6, 134.6, 133.1, 130.8, 129.6, 128.3, 127.9, 127.5, 126.0, 125.3, 119.1, 115.5, 114.3, 93.3, 65.9, 21.4, 21.2, 19.4, 13.5. HRMS (ESI) calculated for $C_{28}H_{28}NO_5S$ $(M + H)^+$: 490.1688, found: 490.1686.

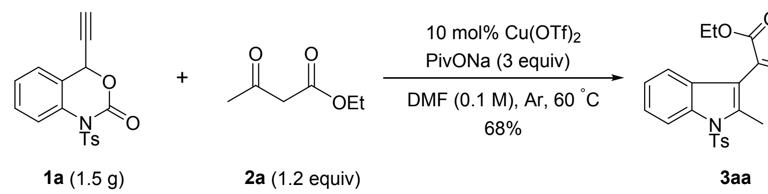
III. Crossover Reaction



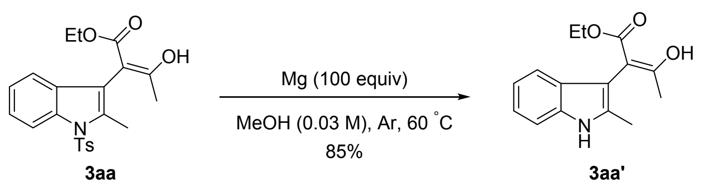
General procedures for crossover reaction: To a 10 mL oven-dried flask, was added *β*–ketoester **2a** (0.05 mmol, 1 equiv), PivONa (37.2 mg, 0.3 mmol, 6 equiv), $Cu(OTf)_2$ (3.6 mg, 0.01 mmol, 0.2 equiv) and ethynyl benzoxazinanones **1f** (17.3 mg, 0.05 mmol, 1 equiv) and **1e** (17.9 mg, 0.05 mmol, 1 equiv). DMF was then added under Ar atmosphere. After being stirred for 22 h at 60 °C, the solution was cooled to room temperature and quenched with water. The aqueous phase was extracted with EtOAc (3 mL × 3). And the combined organic layer was then washed with water (3 mL × 3) and dried over anhydrous Na_2SO_4. Afterward, solvent was removed and the evaporated residue was used directly to afford the corresponding ^1H NMR yield (1,3,5-trimethoxybenzene as an internal standard).

IV. Synthetic Transformations

a) A gram-scale experiment



b) Deprotection of the tosyl (Ts) group of **3aa**



A gram-scale reaction: To a 100 mL oven-dried flask, was added ethynyl benzoxazinanones **1a** (1.5 g, 4.58 mmol, 1 equiv), PivONa (1.7 g, 13.74 mmol, 3.0 equiv) and $Cu(OTf)_2$ (165.5 mg, 0.46 mmol, 0.1 equiv). Then DMF followed by *β*–ketoester **2a** (716.4 mg, 5.50 mmol, 1.2 equiv) were added under Ar atmosphere. After being stirred for 22 h at 60 °C, the solution was cooled to room temperature and quenched with water. The aqueous phase was extracted with EtOAc (30 mL × 3). And the combined organic layer was then washed with water (30 mL × 3) and dried over anhydrous Na_2SO_4. Afterward, silica gel was added before solvent was removed. The evaporated residue was further purified by flash chromatography (silica gel, hexanes/EtOAc = 40:1~10:1) to furnish compound **3aa** in 68% yield (1.29 g).

Deprotection of the tosyl (Ts) group of 3aa: According to the known procedure[1a], to a flame-dried 25 mL flask was charged **3aa** (62mg, 0.15mmol, 1 equiv) and Mg (360 mg, 15 mmol, 100 equiv). Then anhydrous MeOH (5 mL) was added under Ar atmosphere. After being stirred for 1 h at 60 °C, the solution was cooled to room temperature and quenched with saturated solution of NH_4Cl. The aqueous phase was extracted with EtOAc (15 mL × 5). And the combined organic layer was then dried over anhydrous Na_2SO_4. Afterward, silica gel was added before solvent was removed. The evaporated residue was further purified by flash chromatography (silica gel, hexanes/EtOAc = 20:1~5:1) to furnish compound **3aa'** in a total yield of 85% (33.1 mg, major:minor = 1.4:1, pale yellow oil). ^1H NMR (400 MHz, $CDCl_3$) δ 13.41 (s, 1H), 8.06 (s, 1H), 7.96 (s, 1H), 7.54–7.50 (m, 1H), 7.27 (dd, *J* = 13.6, 5.0 Hz, 3H), 7.19–7.03 (m, 4H), 4.88 (s, 1H), 4.23 (q, *J* = 7.2 Hz, 2H), 4.19–4.10 (m, 2H), 2.39 (s, 3H), 2.26 (s, 3H), 2.14 (s, 3H), 1.84 (s, 3H), 1.27 (t, *J* = 7.1 Hz, 3H), 1.14 (t, *J* = 7.1 Hz, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 202.62, 175.76, 173.49, 169.34, 135.24, 135.19, 134.03, 133.48, 129.10, 127.66, 121.60, 121.00, 120.05, 119.48, 118.77, 118.57, 110.49, 110.28, 106.90, 103.49, 94.75, 61.38, 60.38, 57.11, 28.33, 19.75, 14.28, 14.14, 12.23, 12.14. HRMS (ESI) calculated for $C_{15}H_{18}NO_3$ $(M + H)^+$: 260.1287, found: 260.1280.

V. ^{1}H and ^{13}C NMR Spectra

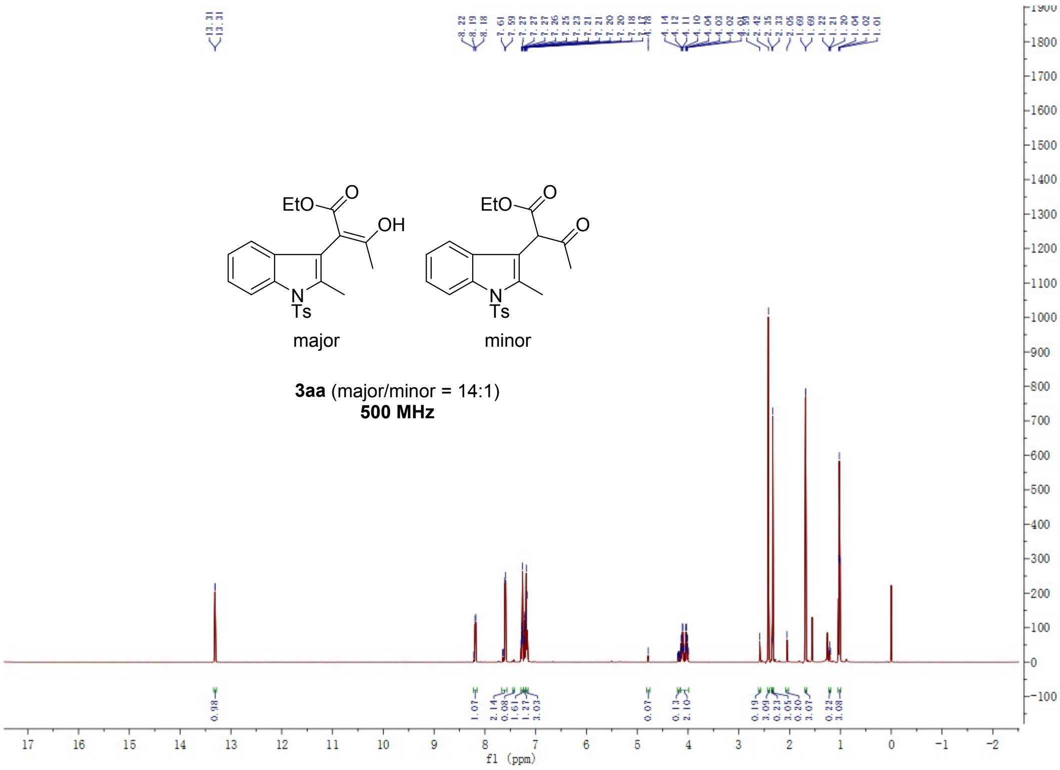


Fig. S1. ^{1}H NMR Spectrum of 3aa (500 MHz, $CDCl_3$).

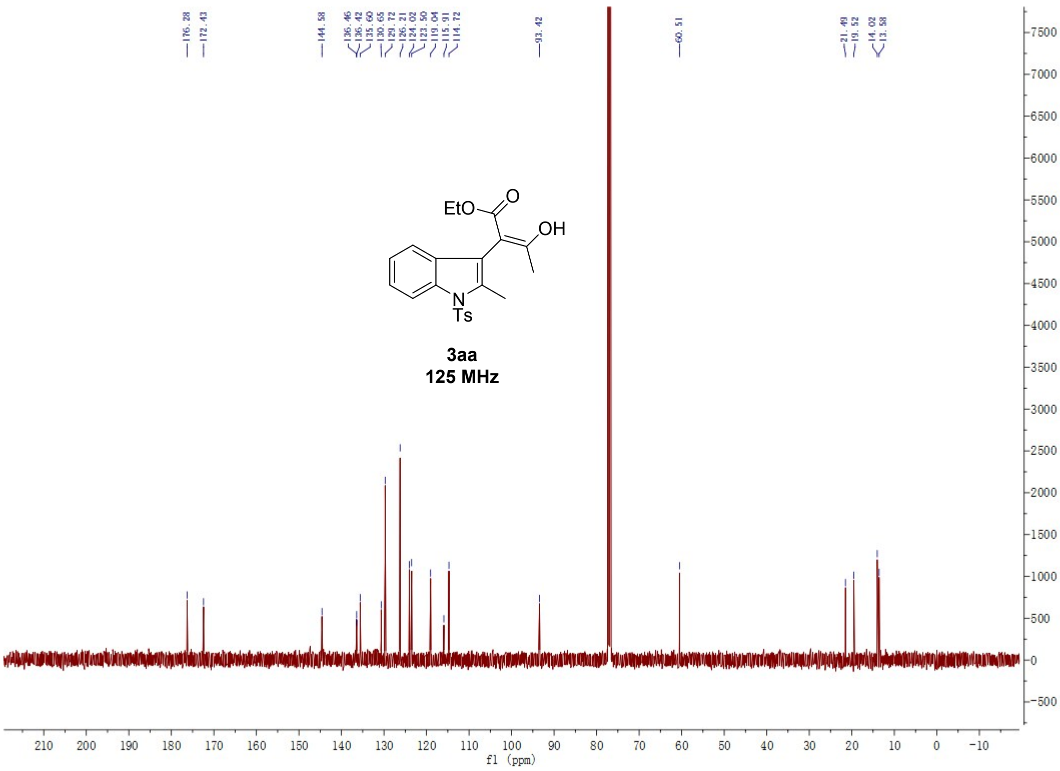


Fig. S2. ^{13}C NMR Spectrum of 3aa (125 MHz, $CDCl_3$).

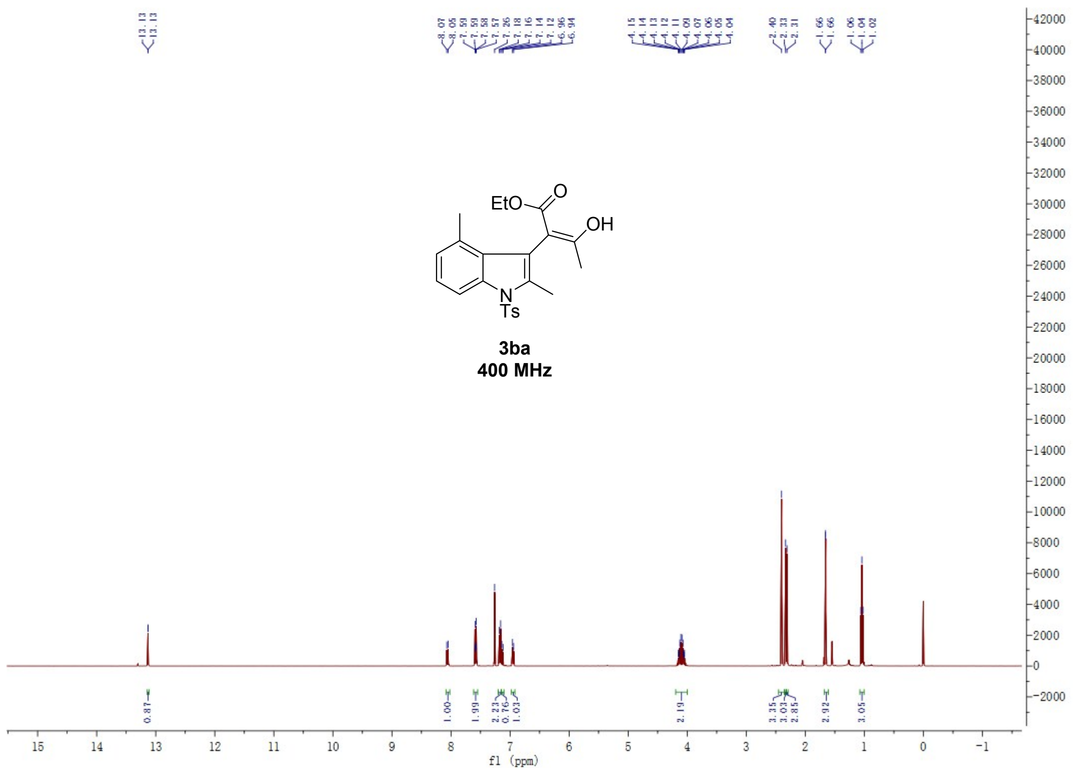


Fig. S3. ^{1}H NMR Spectrum of 3ba (400 MHz, $CDCl_3$).

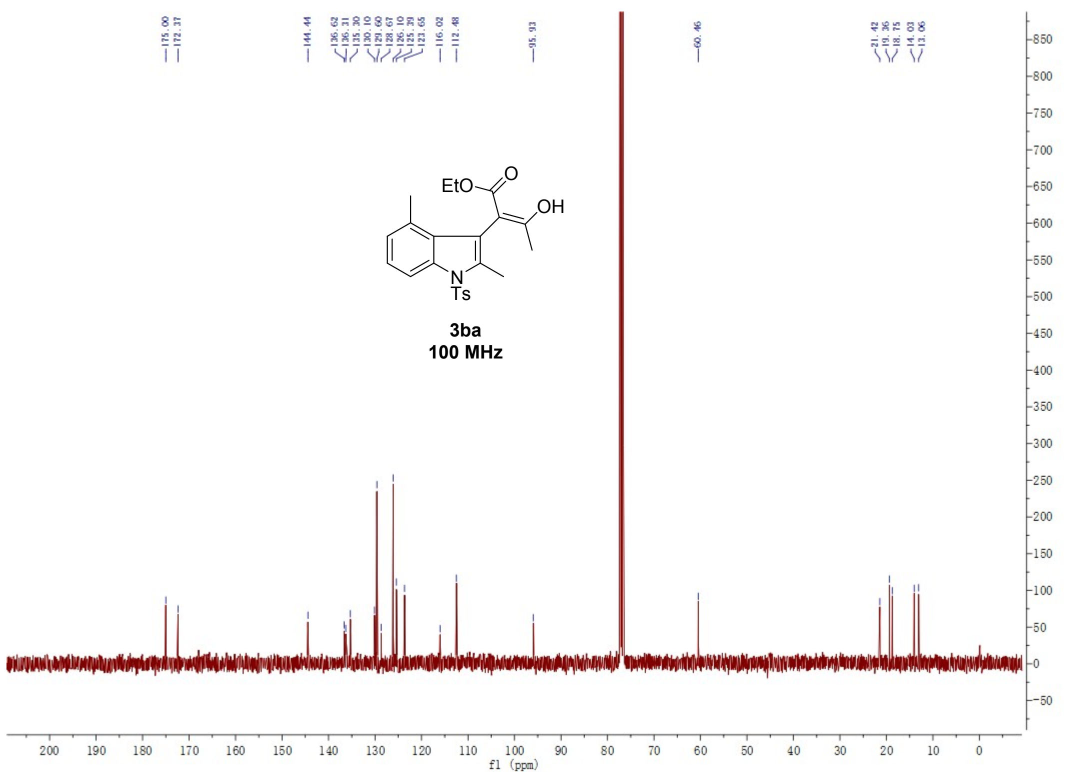


Fig. S4. ^{13}C NMR Spectrum of 3ba (100 MHz, $CDCl_3$).

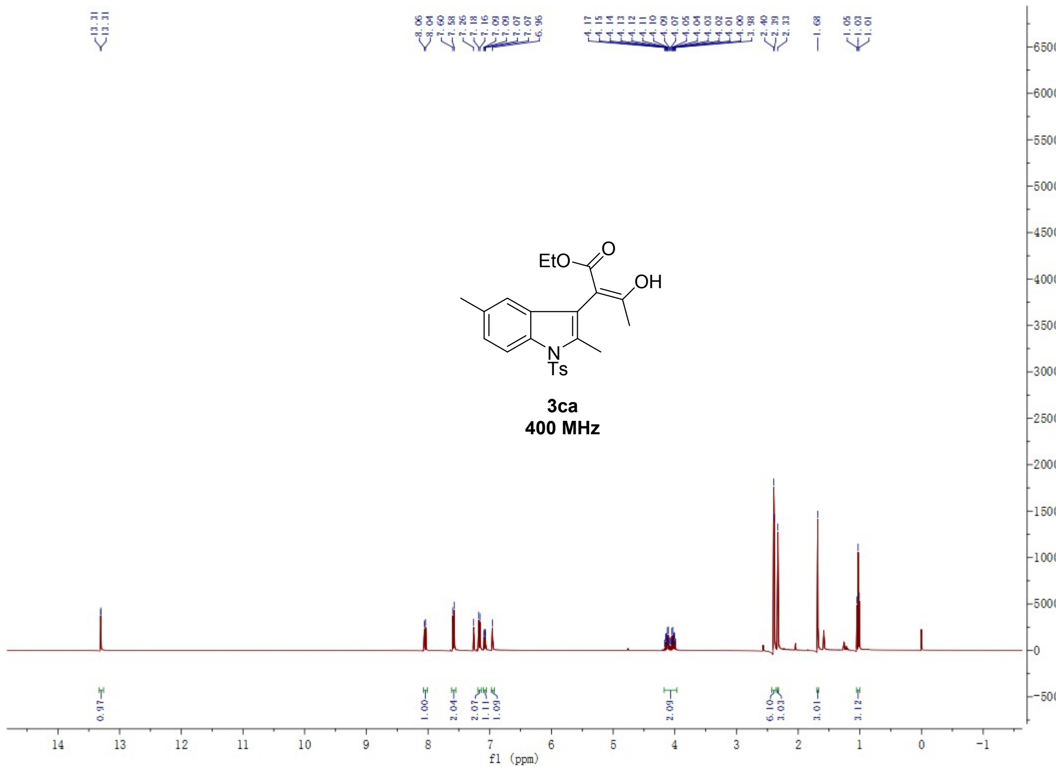


Fig. S5. ^{1}H NMR Spectrum of 3ca (400 MHz, $CDCl_3$).

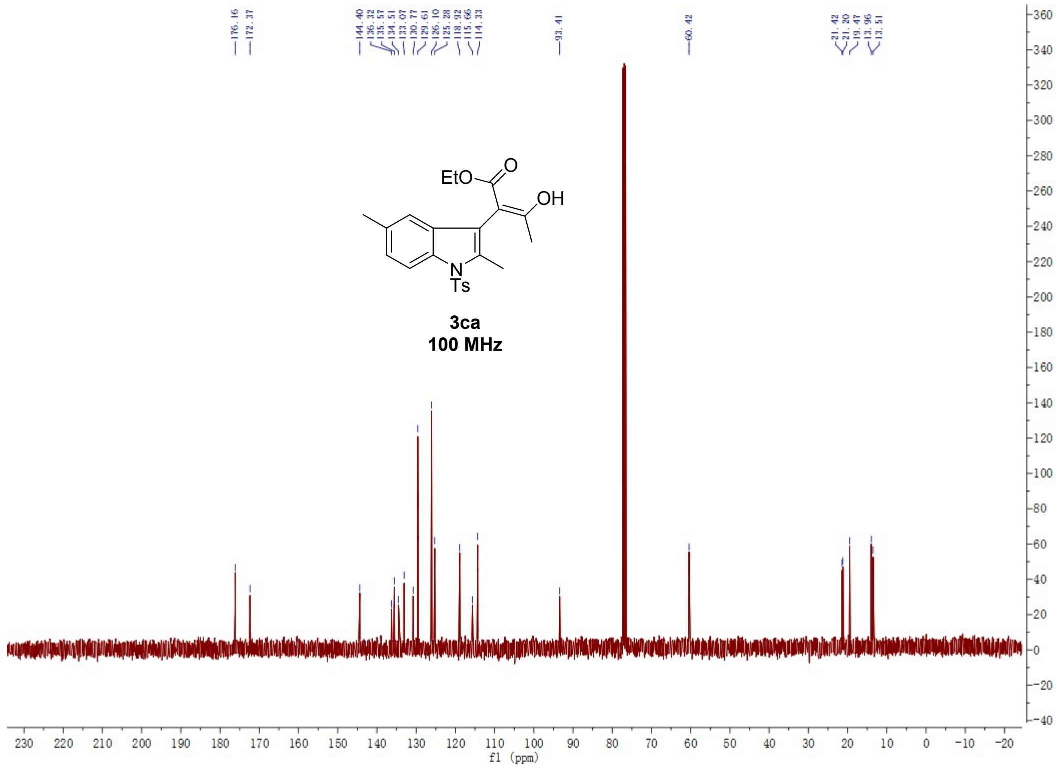


Fig. S6. ^{13}C NMR Spectrum of 3ca (100 MHz, $CDCl_3$).

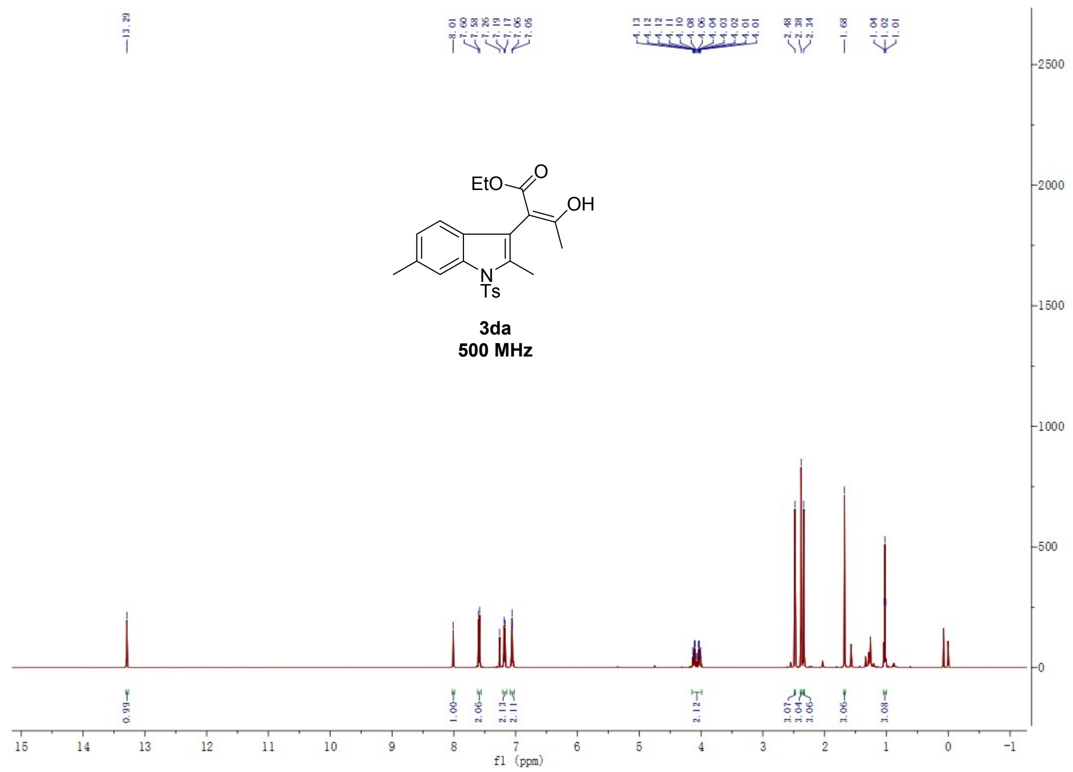


Fig. S7. ^{1}H NMR Spectrum of 3da (500 MHz, $CDCl_3$).

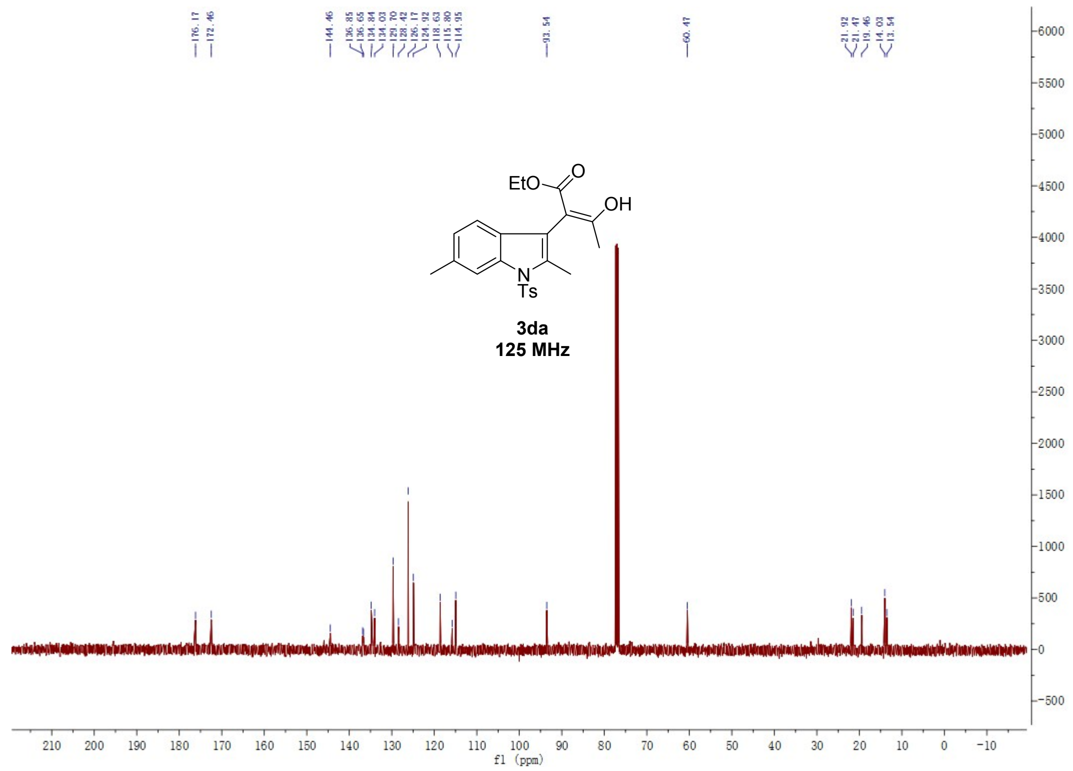


Fig. S8. ^{13}C NMR Spectrum of 3da (125 MHz, $CDCl_3$).

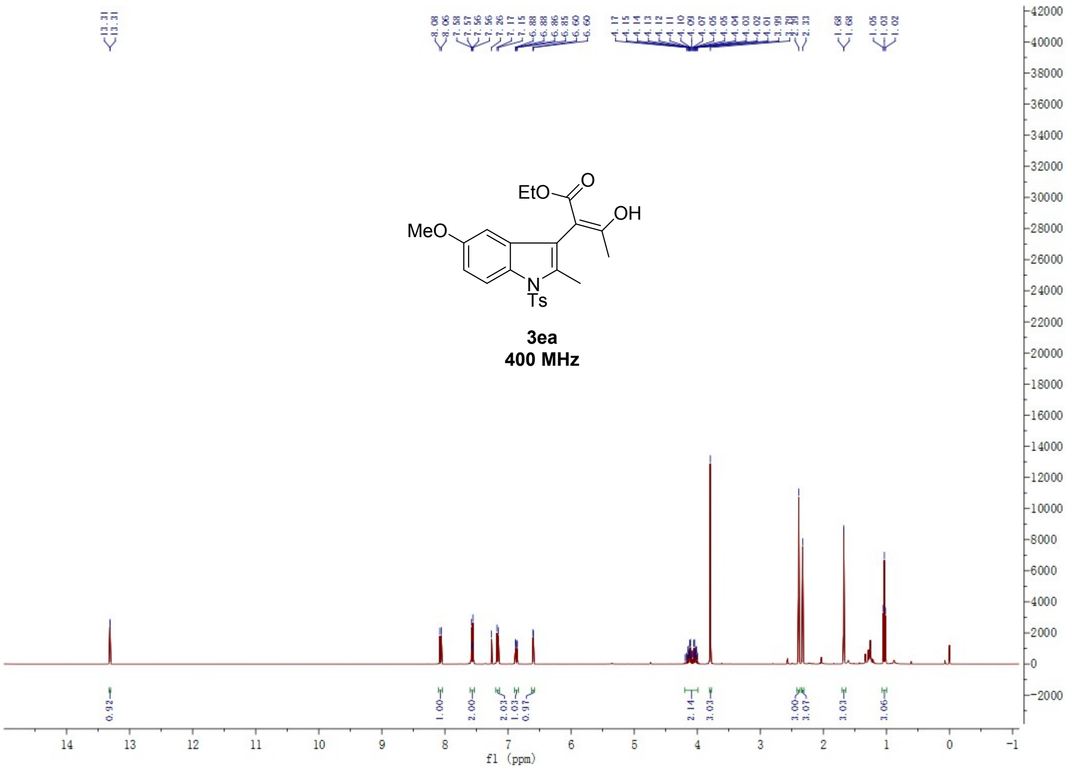


Fig. S9. ^{1}H NMR Spectrum of 3ea (400 MHz, CDCl$_3$).

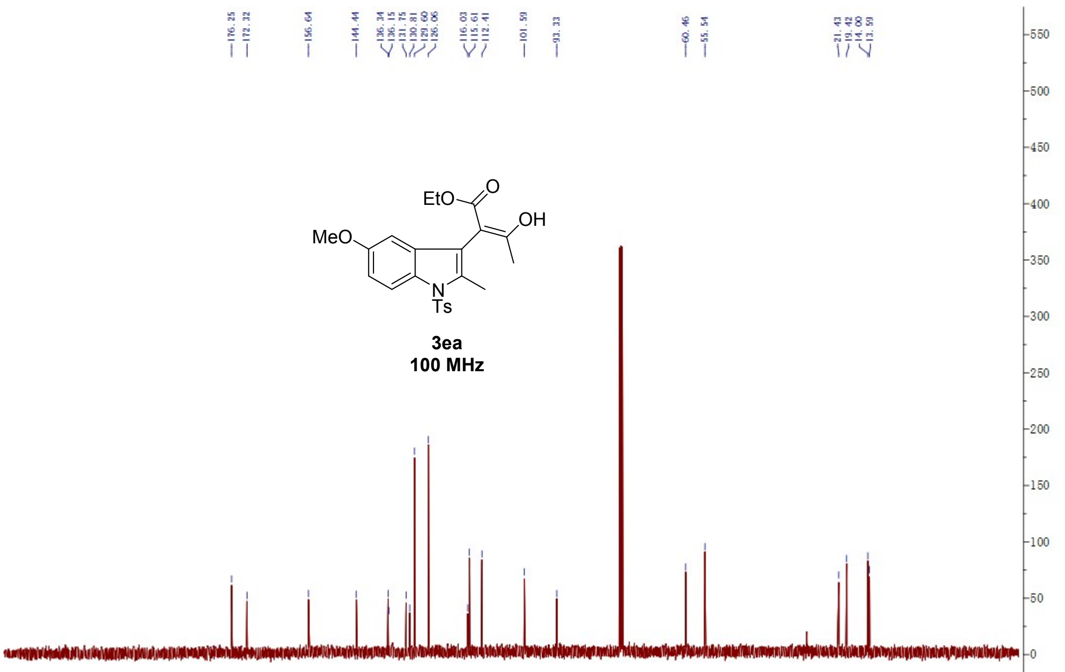


Fig. S10. ^{13}C Spectrum of 3ea (100 MHz, CDCl$_3$).

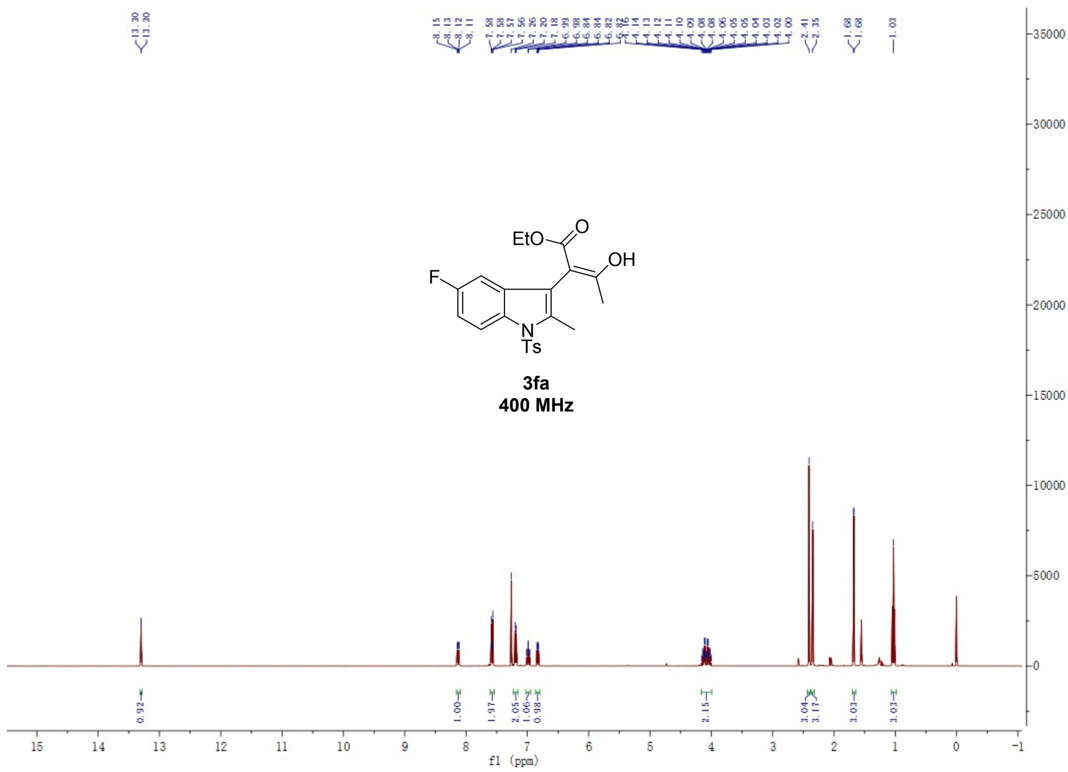


Fig. S11. ^{1}H NMR Spectrum of 3fa (400 MHz, $CDCl_3$).

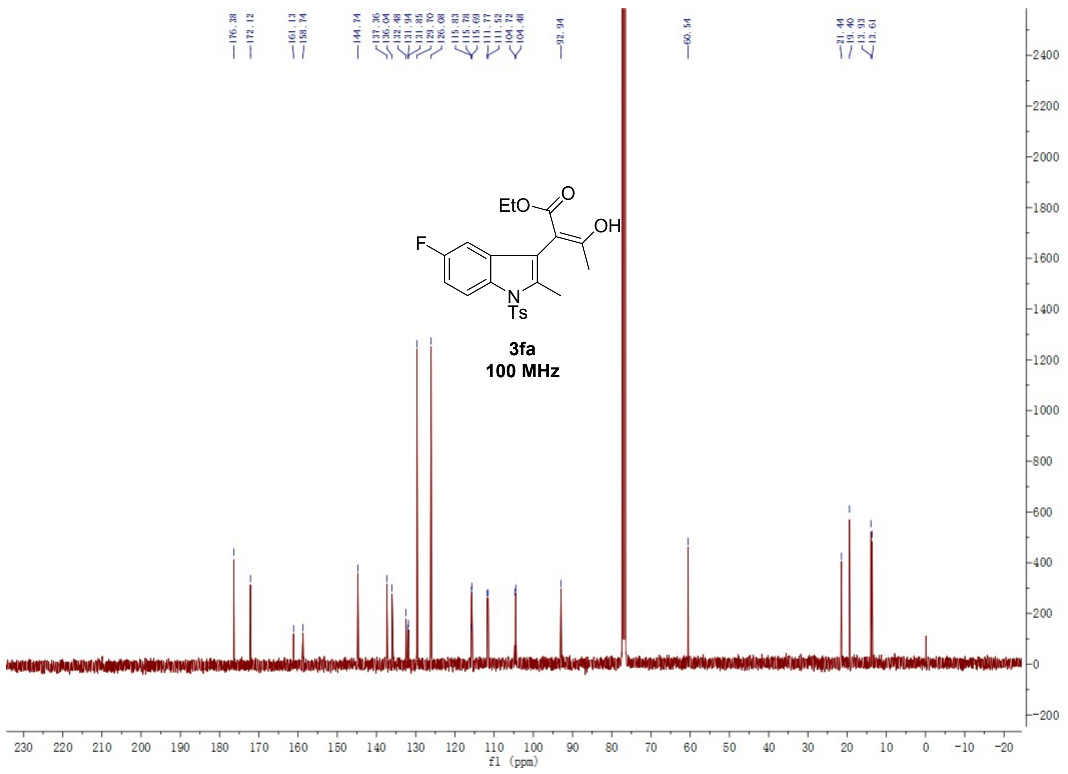


Fig. S12. ^{13}C NMR Spectrum of 3fa (100 MHz, $CDCl_3$).

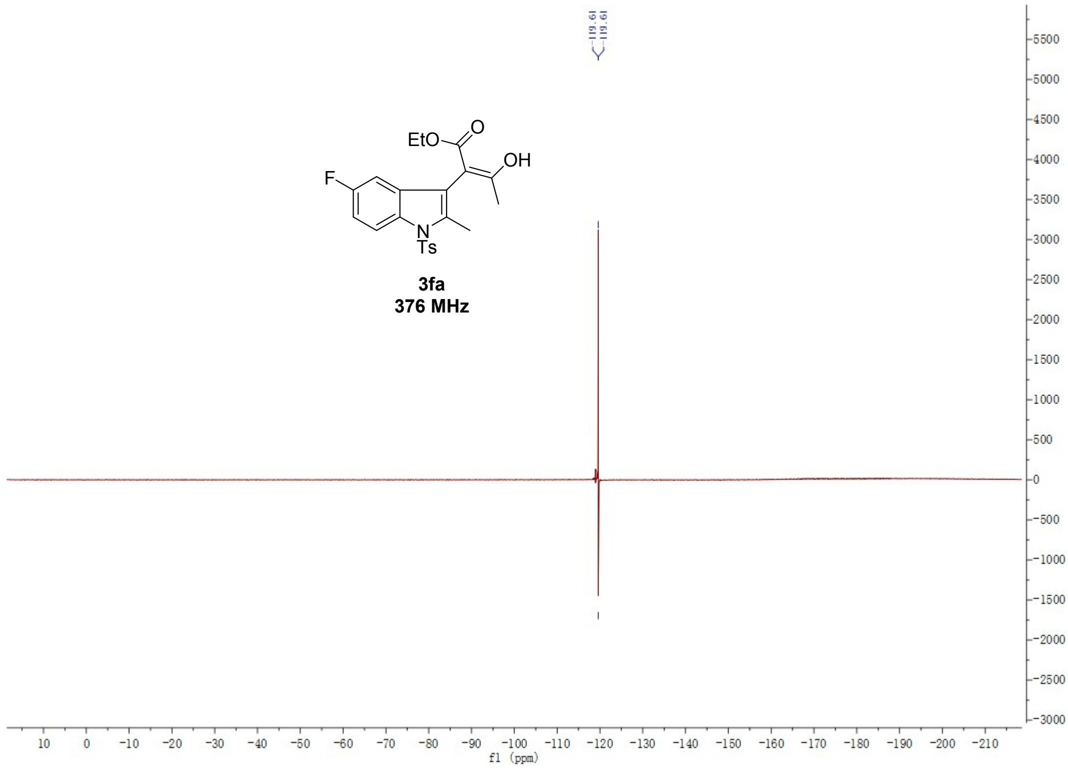


Fig. S13. [19]F NMR Spectrum of 3fa (376 MHz, $CDCl_3$).

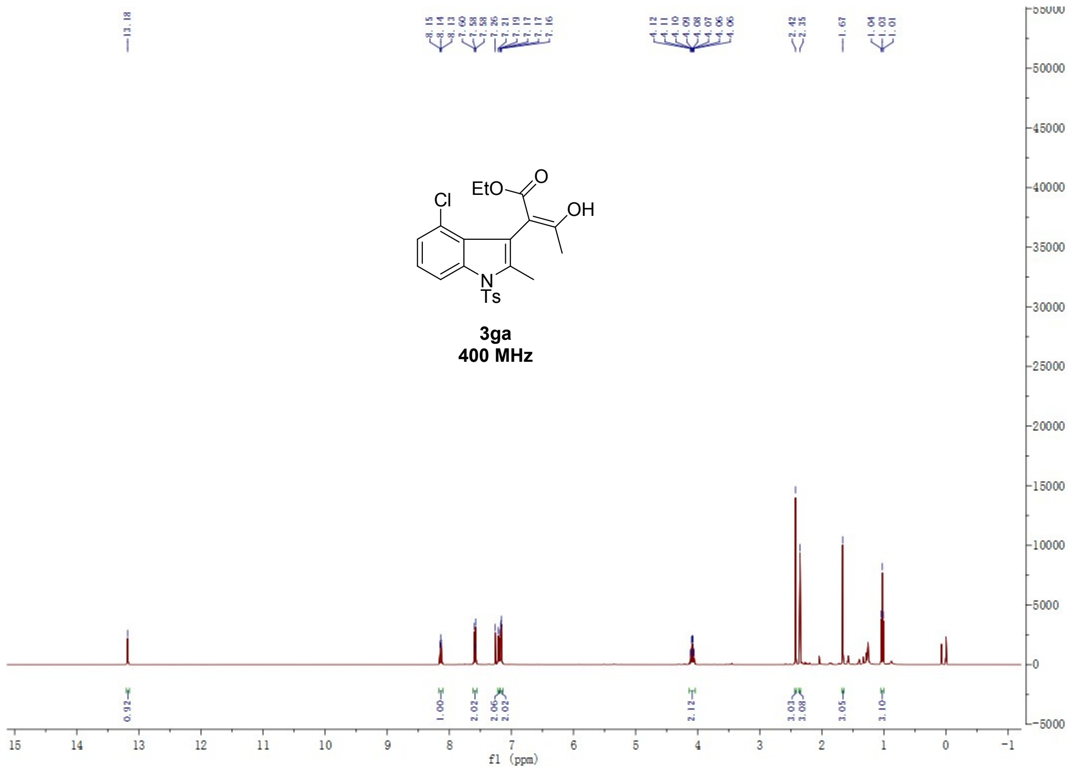


Fig. S14. [1]H NMR Spectrum of 3ga (400 MHz, $CDCl_3$).

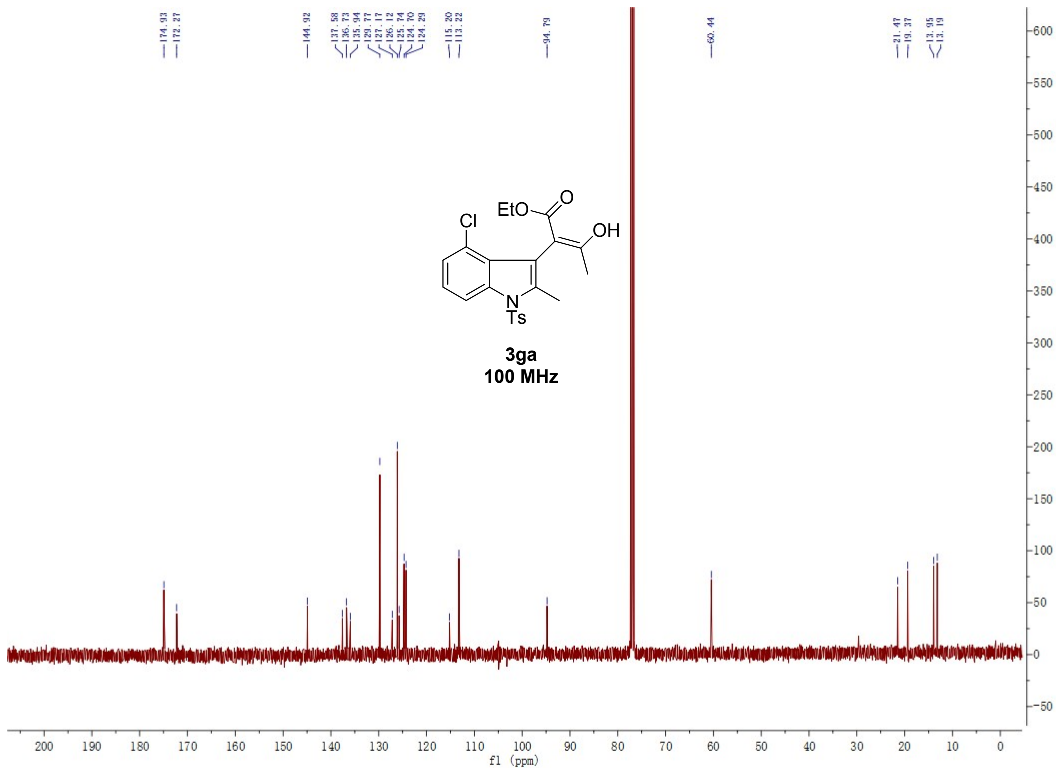


Fig. S15. ^{13}C NMR Spectrum of 3ga (100 MHz, $CDCl_3$).

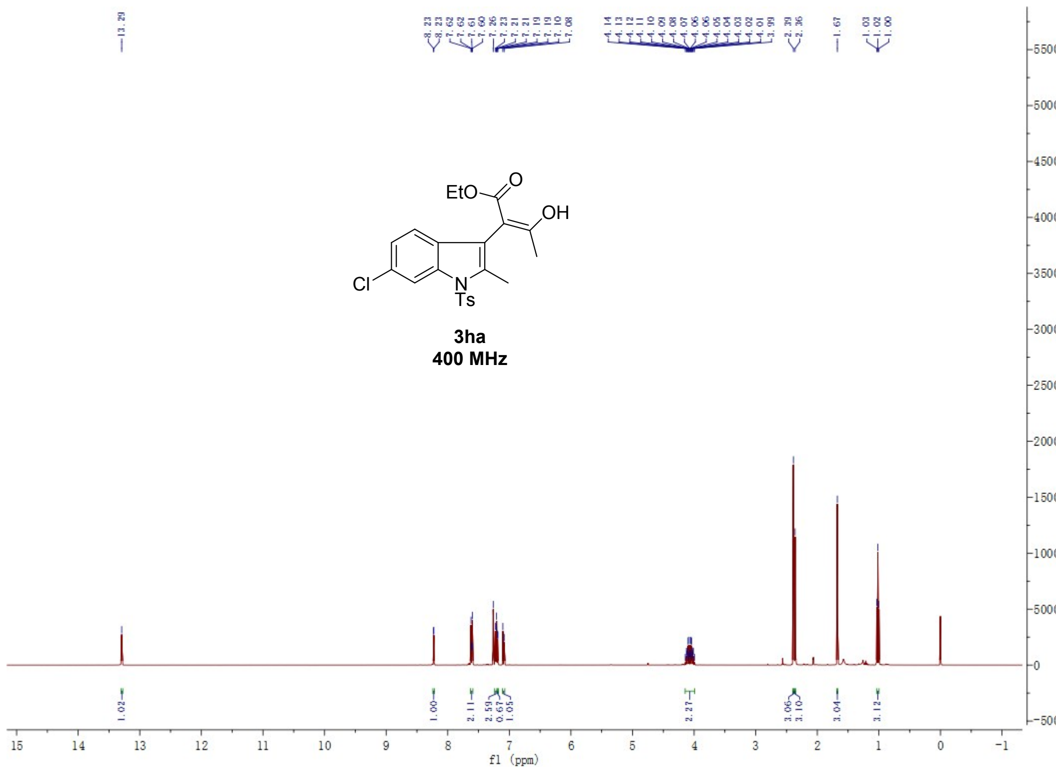


Fig. S16. ^{1}H NMR Spectrum of 3ha (400 MHz, $CDCl_3$).

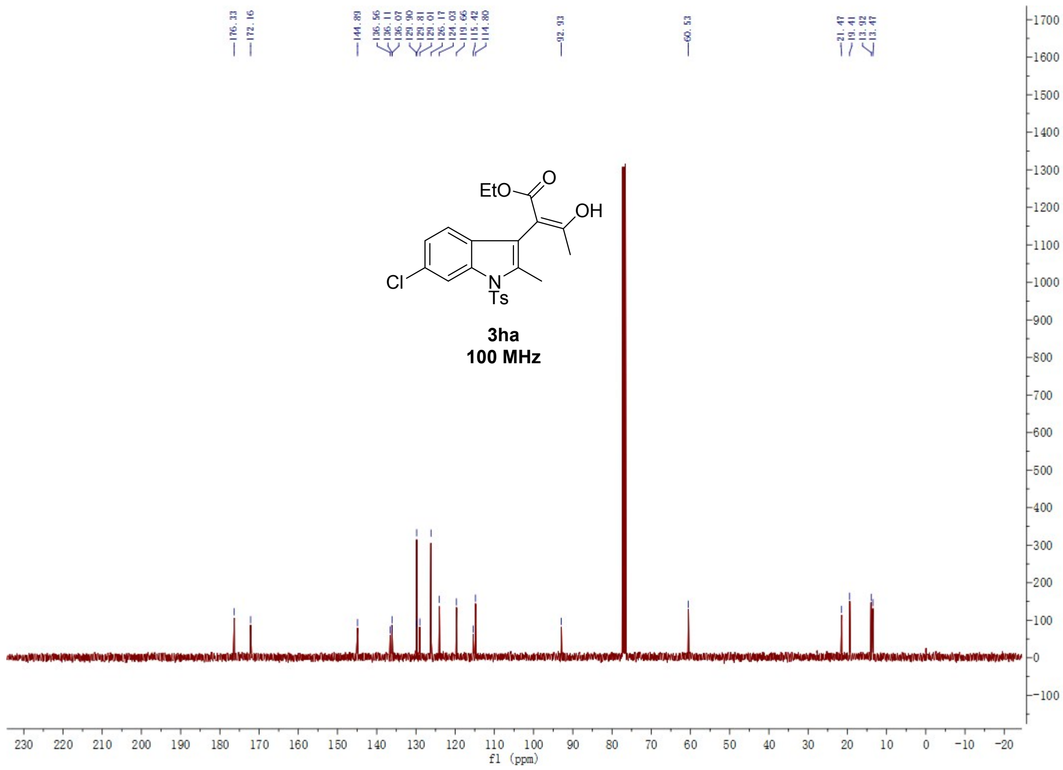


Fig. S17. ^{13}C NMR Spectrum of 3ha (100 MHz, CDCl$_3$).

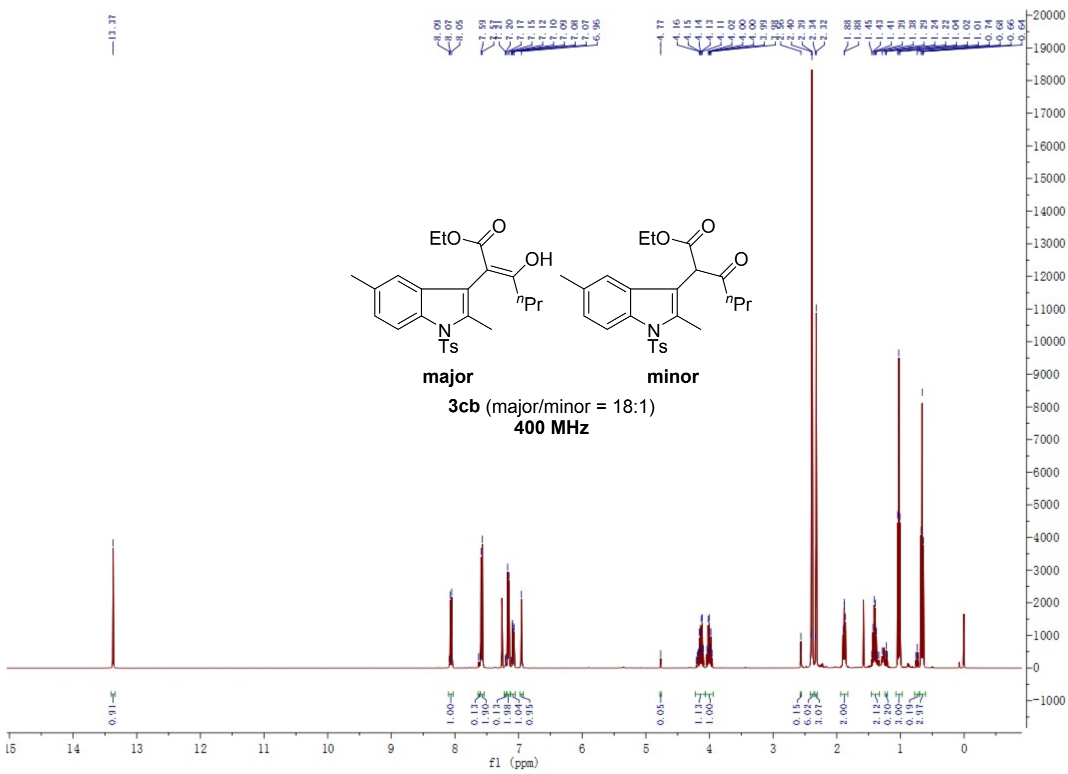


Fig. S18. ^{1}H NMR Spectrum of 3cb (400 MHz, $CDCl_3$).

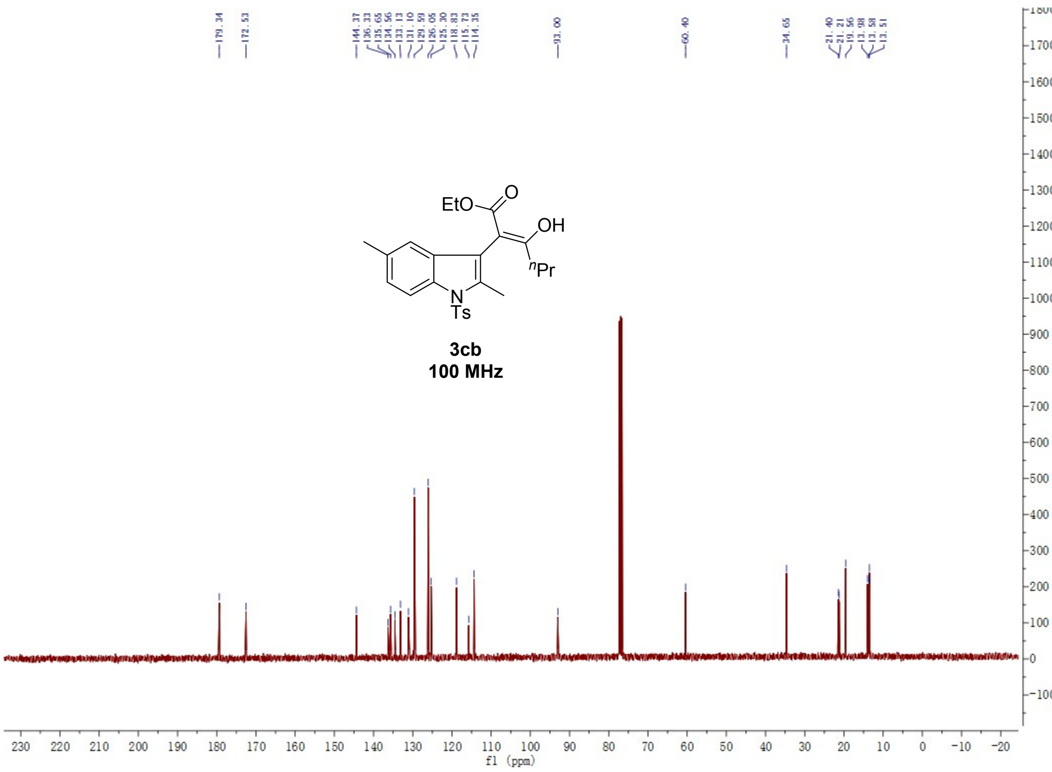


Fig. S19. ^{13}C NMR Spectrum of 3cb (100 MHz, $CDCl_3$).

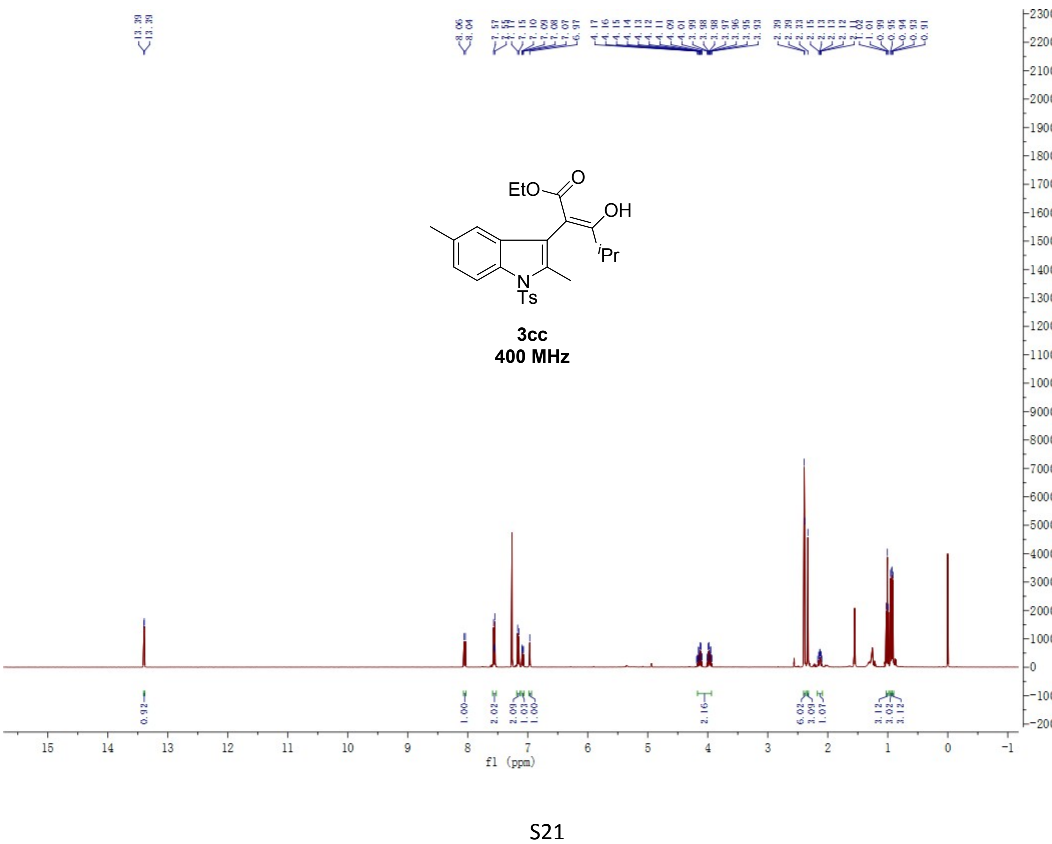


Fig. S20. ^{1}H NMR Spectrum of 3cc (400 MHz, $CDCl_3$).

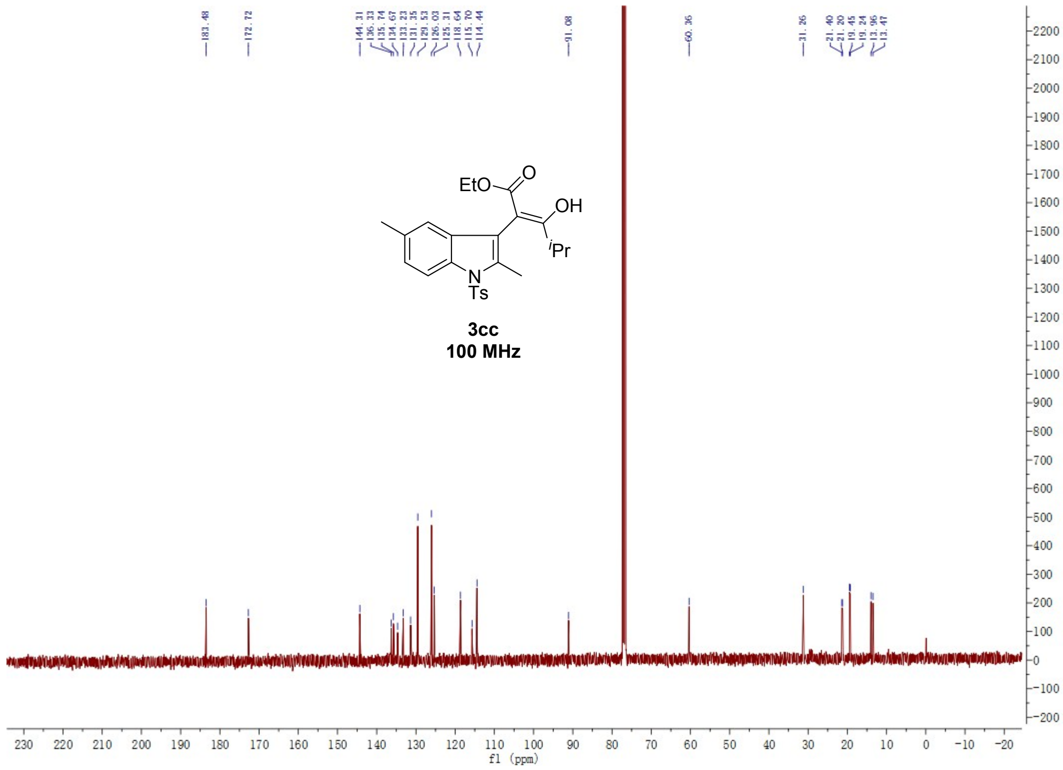


Fig. S21. ^{13}C NMR Spectrum of 3cc (100 MHz, $CDCl_3$).

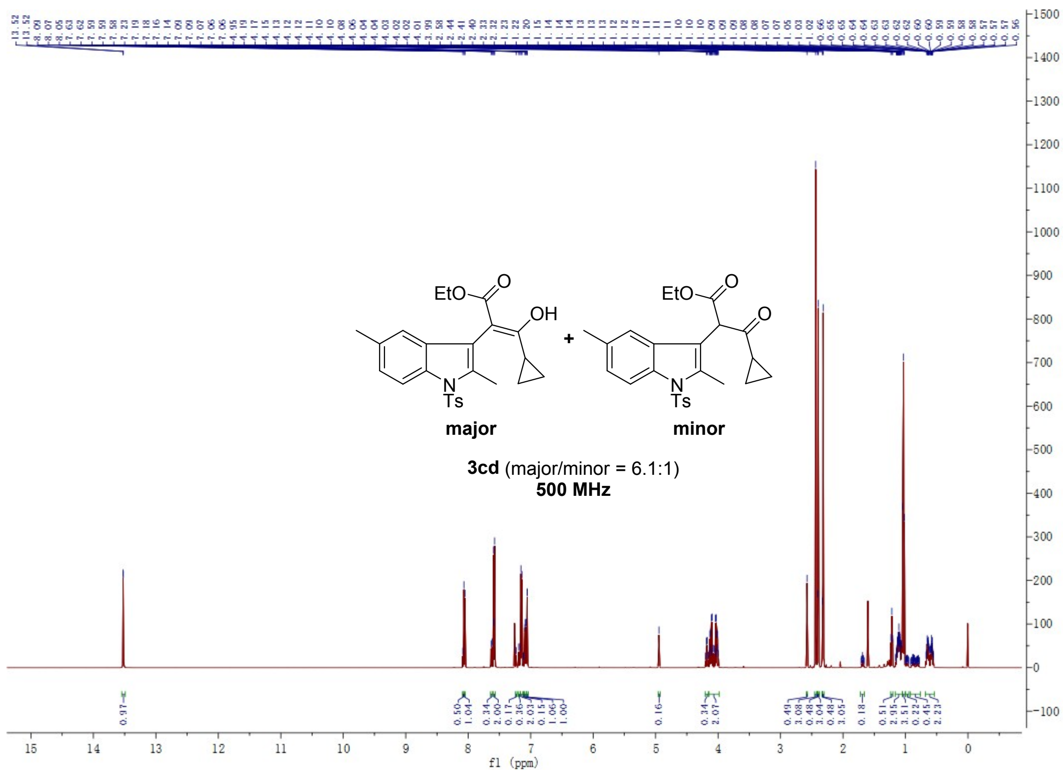


Fig. S22. ^{1}H NMR Spectrum of 3cd (500 MHz, CDCl$_3$).

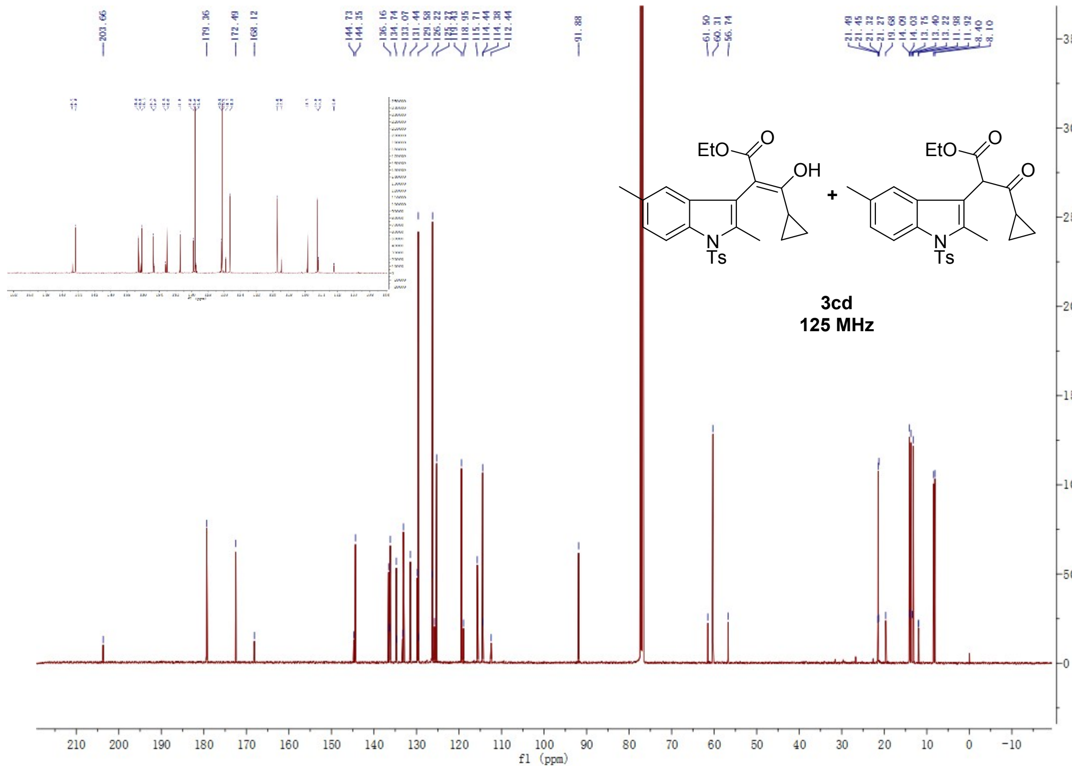


Fig. S23. ^{13}C NMR Spectrum of 3cd (125 MHz, CDCl$_3$).

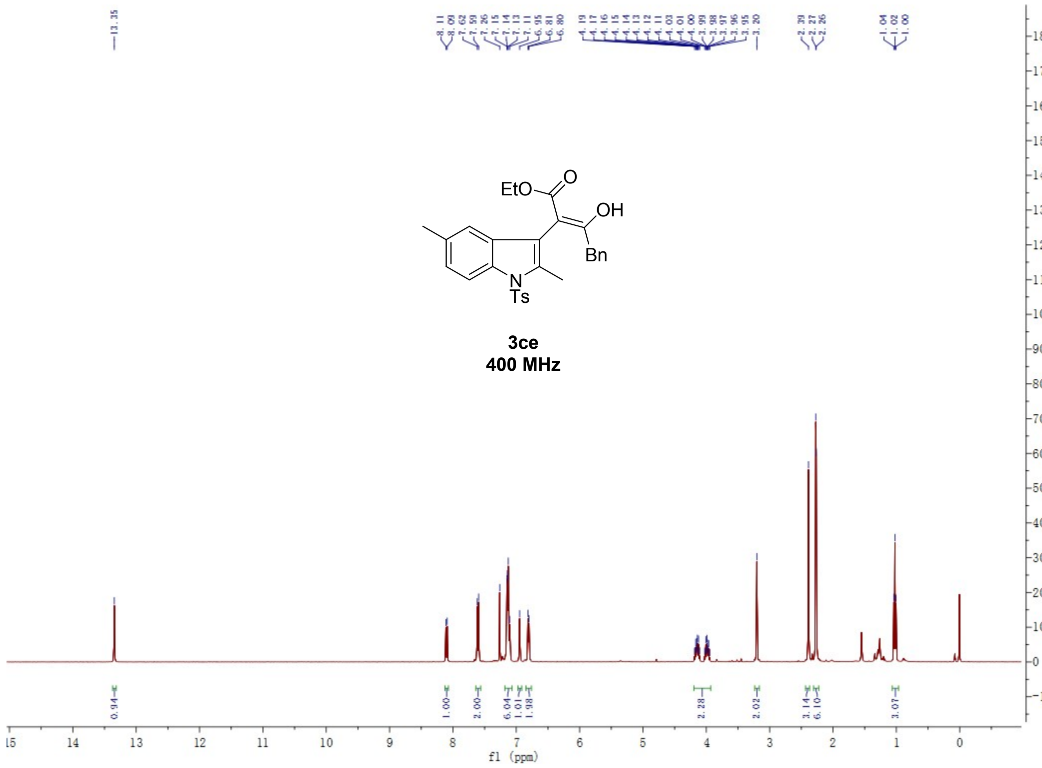


Fig. S24. ^{1}H NMR Spectrum of 3ce (400 MHz, CDCl$_3$).

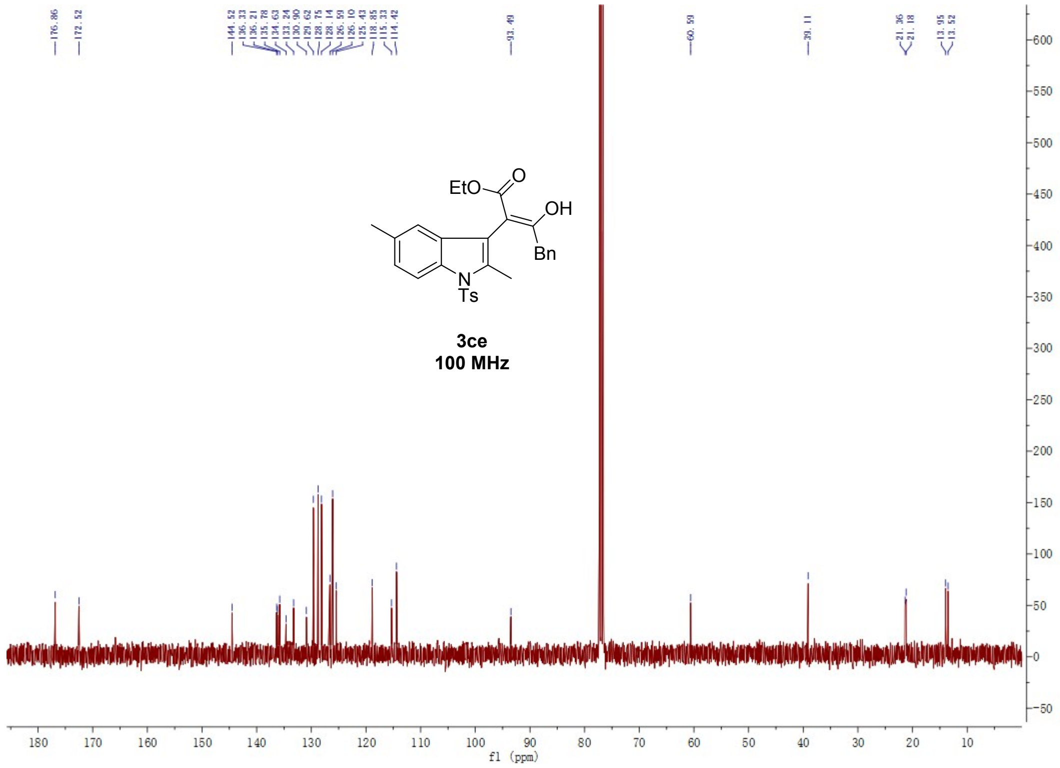


Fig. S25. ^{13}C NMR Spectrum of 3ce (100 MHz, CDCl$_3$).

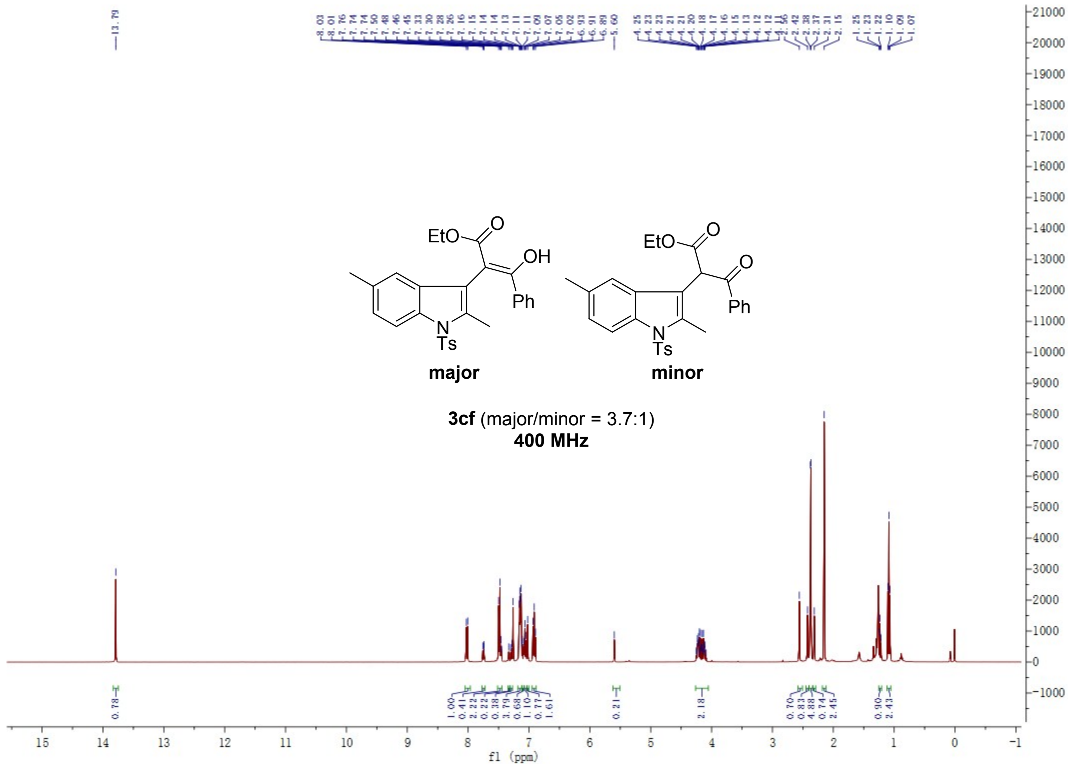


Fig. S26. ¹H NMR Spectrum of 3cf (400 MHz, CDCl$_3$).

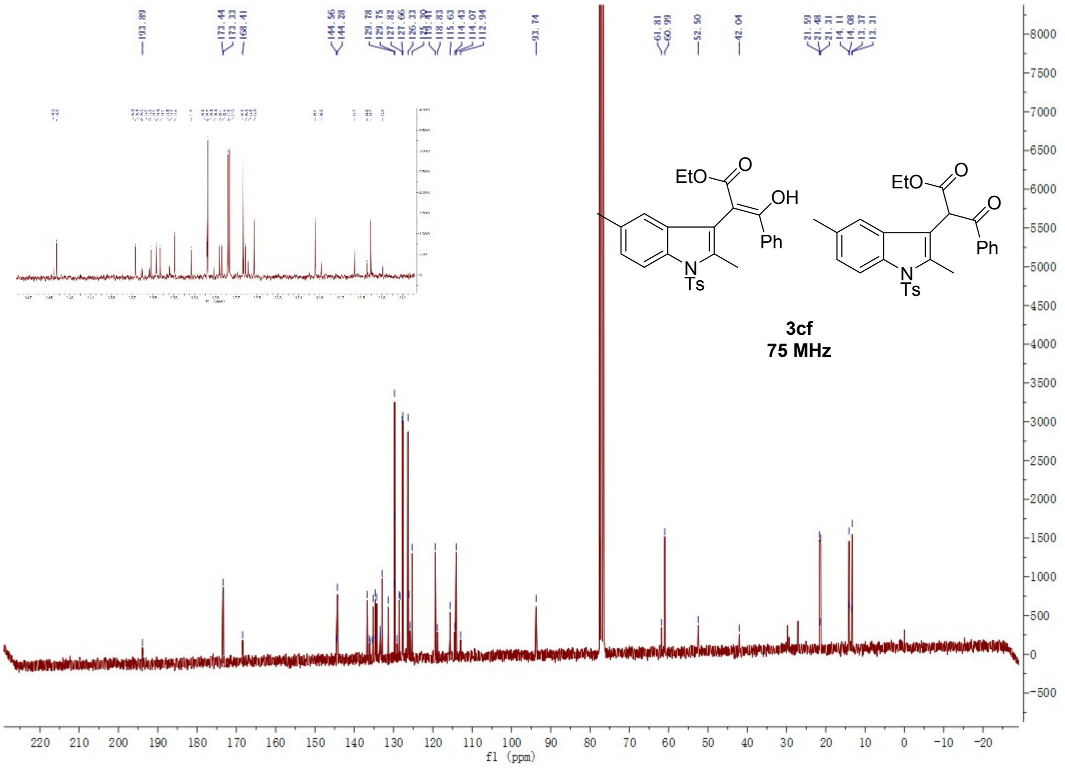


Fig. S27. ¹³C NMR Spectrum of 3cf (75 MHz, CDCl$_3$).

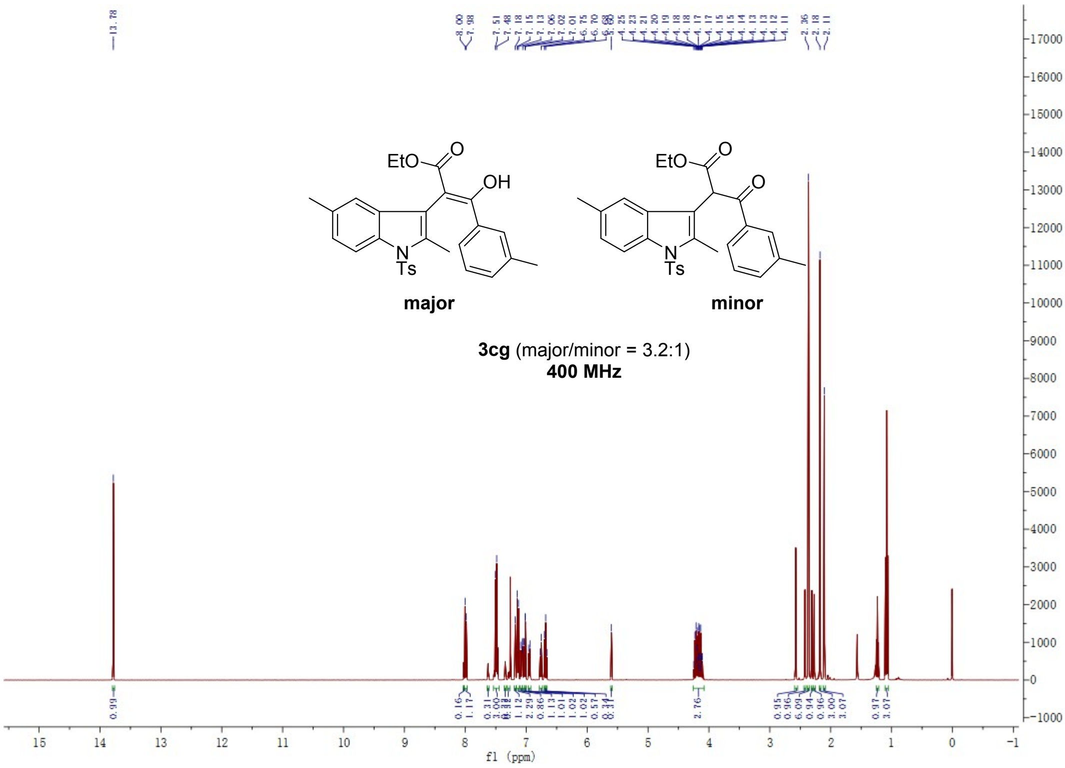


Fig. S28. [1]H NMR Spectrum of 3cg (400 MHz, $CDCl_3$).

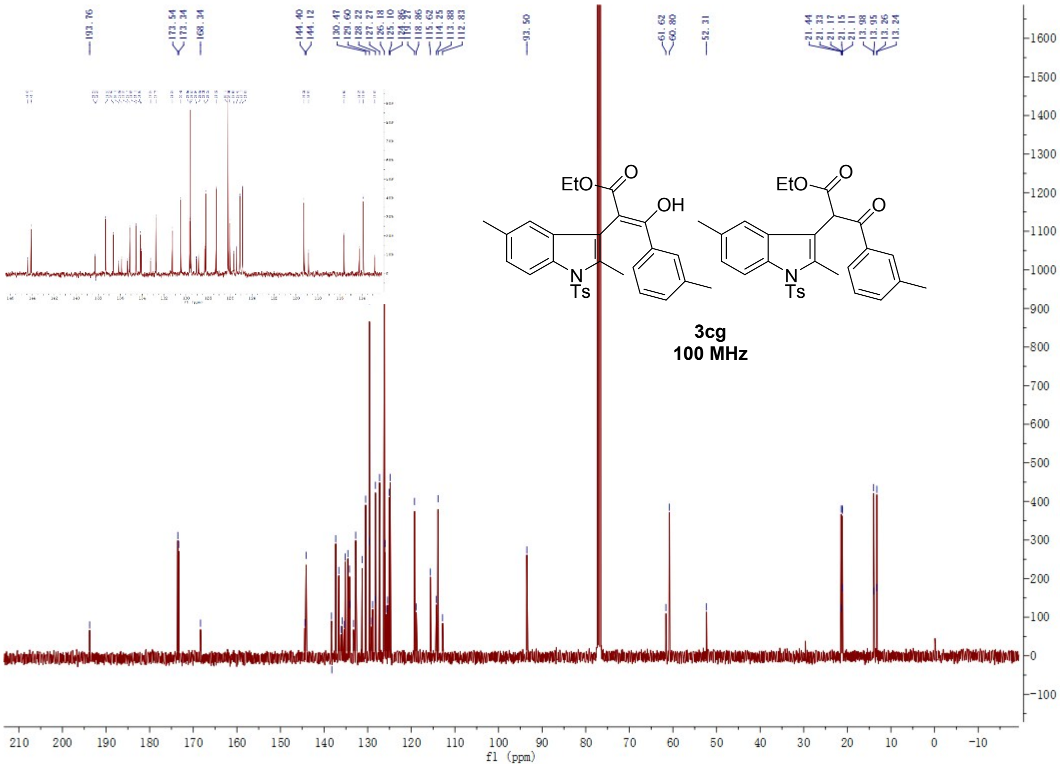


Fig. S29. [13]C NMR Spectrum of 3cg (100 MHz, $CDCl_3$).

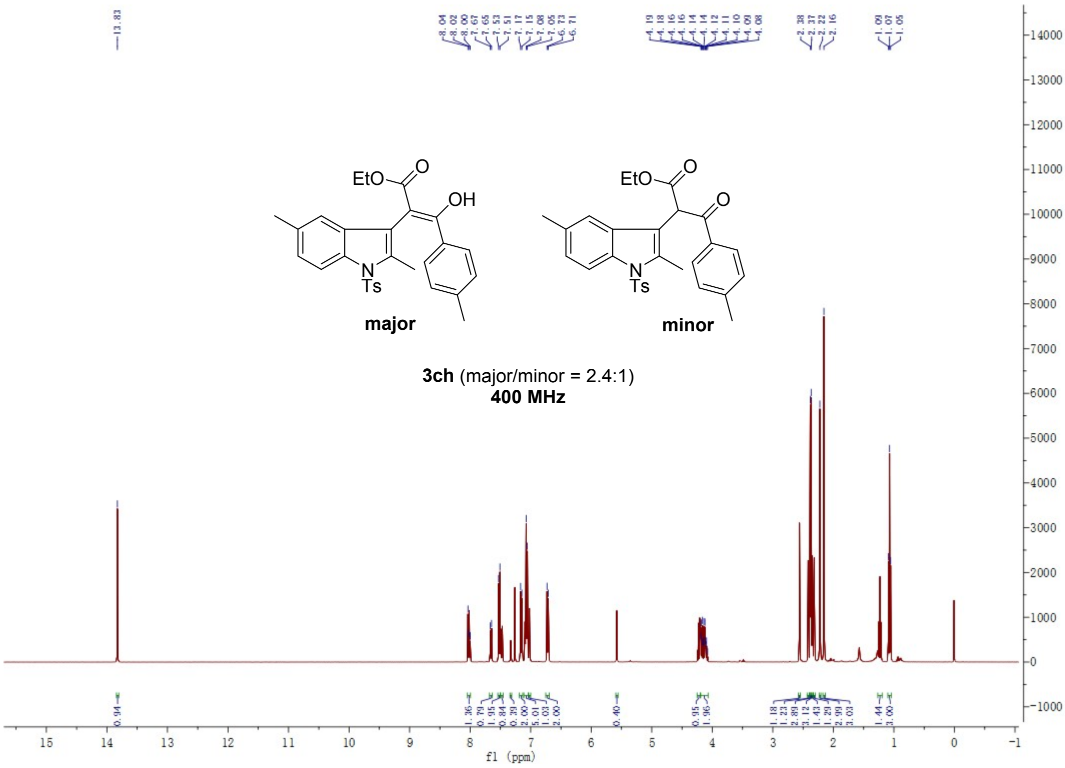


Fig. S30. ^{1}**H NMR Spectrum of 3ch (400 MHz, CDCl$_3$).**

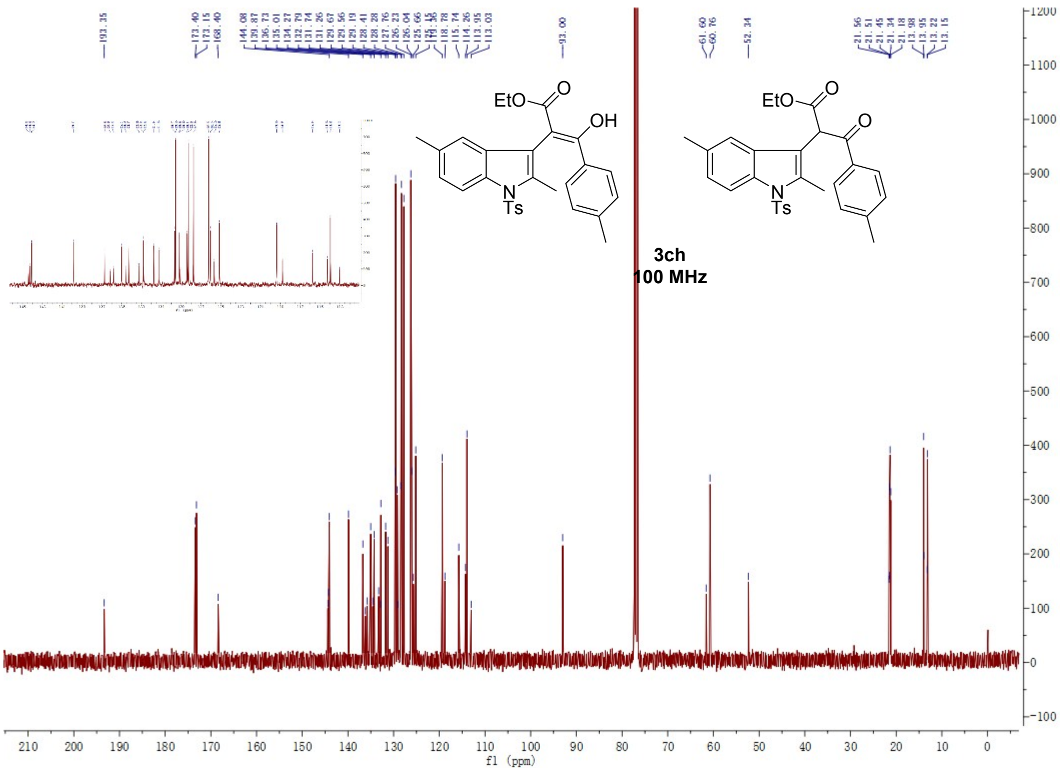


Fig. S31. ^{13}**C NMR Spectrum of 3ch (100 MHz, CDCl$_3$).**

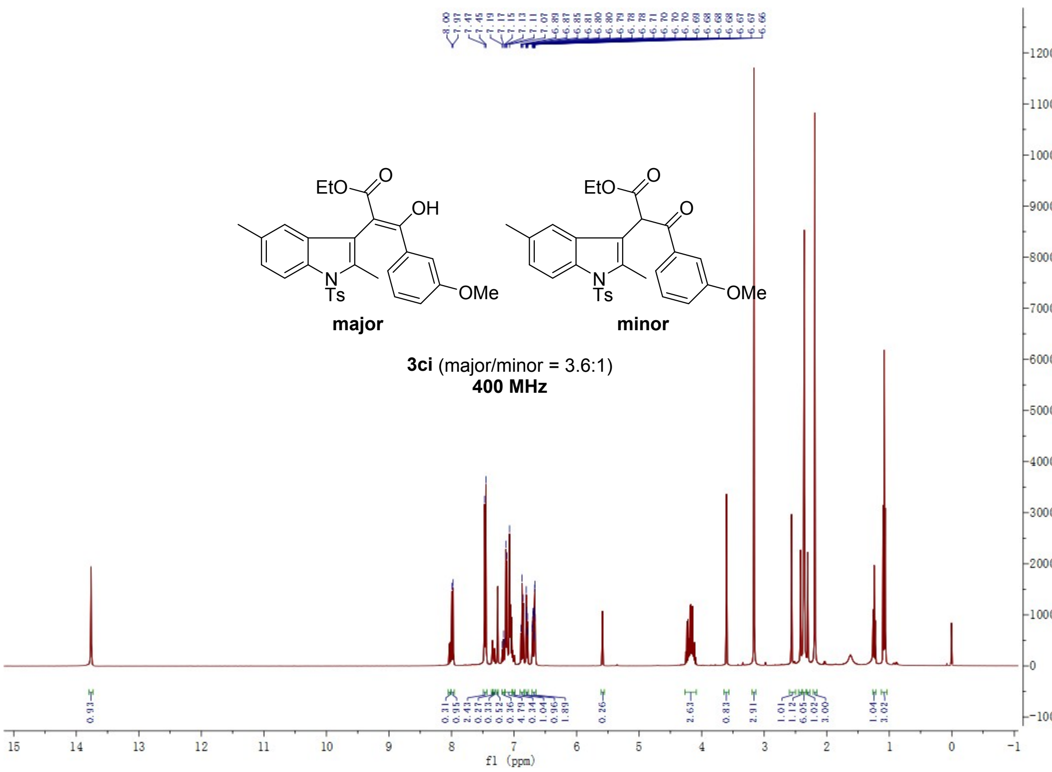


Fig. S32. ^{1}H NMR Spectrum of 3ci (400 MHz, $CDCl_3$).

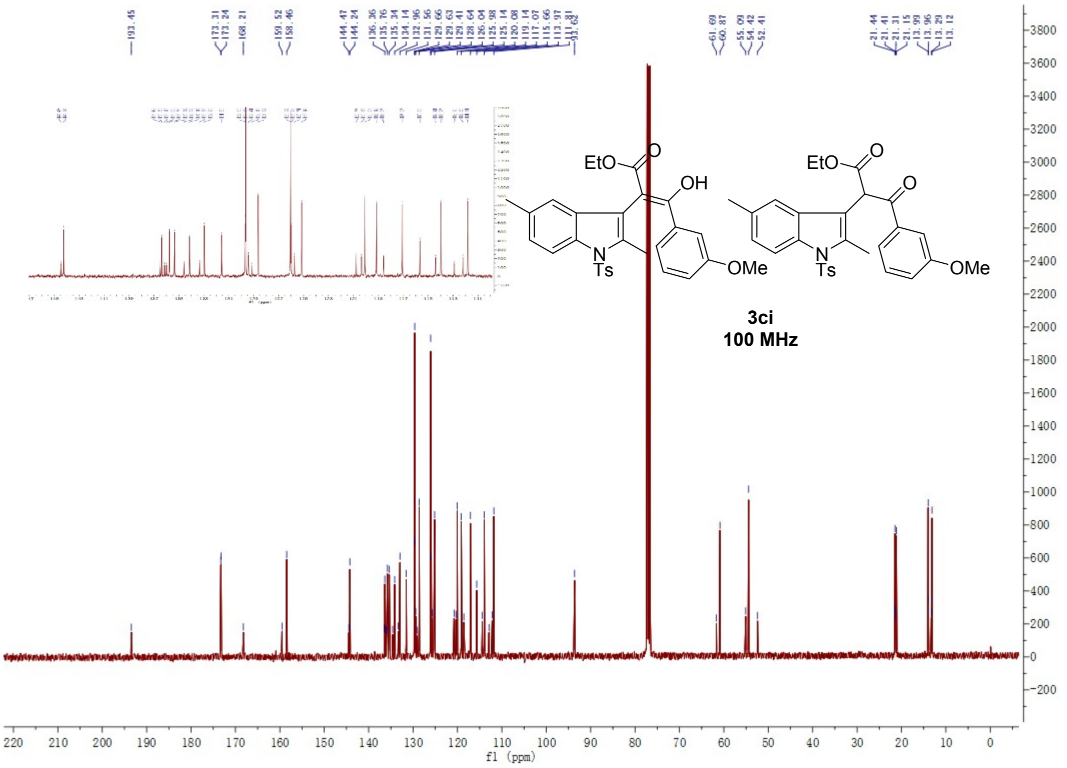


Fig. S33. ^{13}C NMR Spectrum of 3ci (100 MHz, $CDCl_3$).

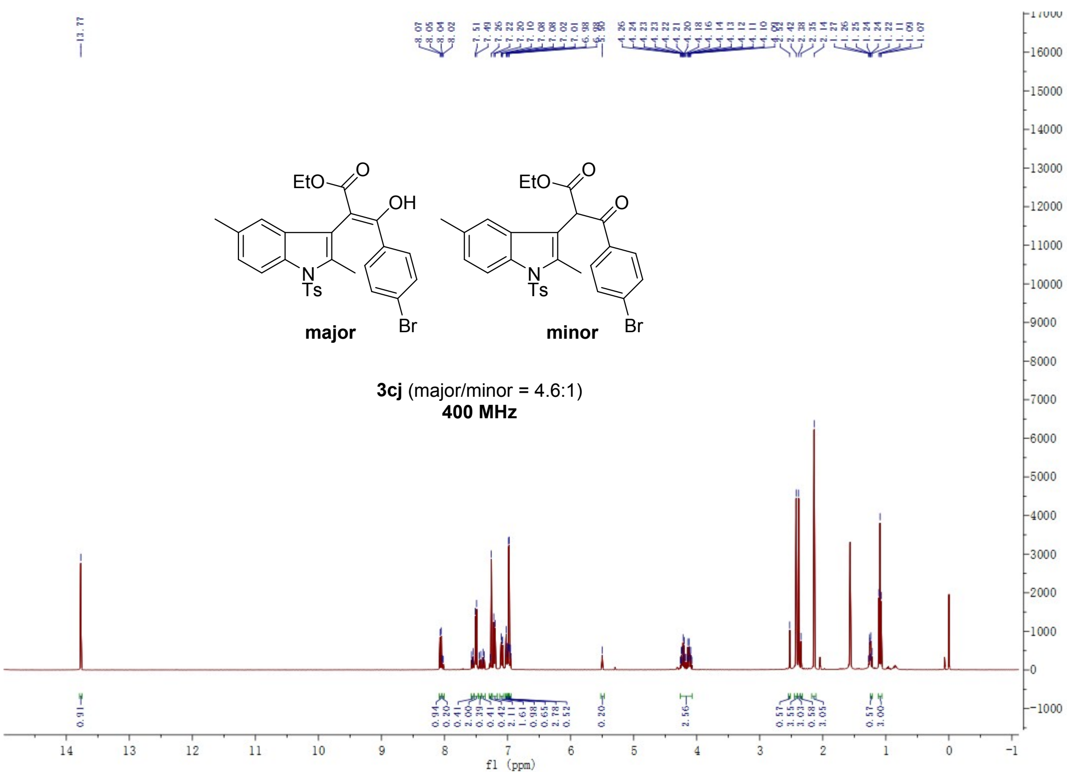


Fig. S34. ^{1}H NMR Spectrum of 3cj (400 MHz, CDCl$_3$).

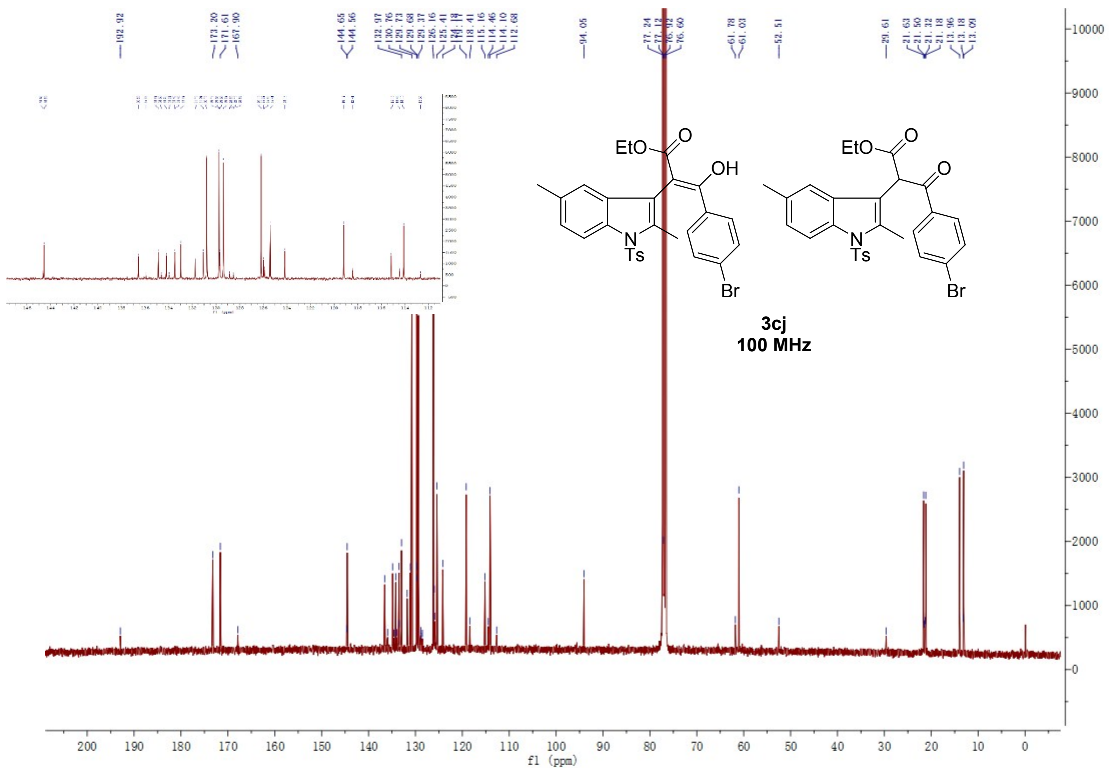


Fig. S35. ^{13}C NMR Spectrum of 3cj (100 MHz, CDCl$_3$).

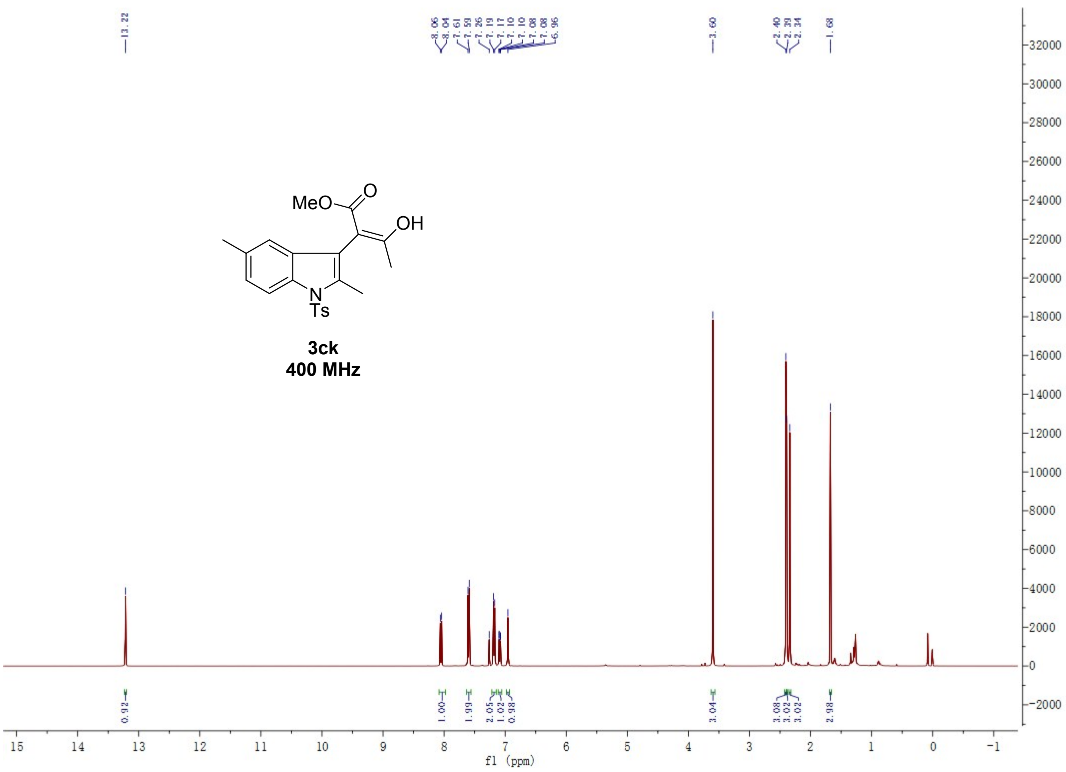


Fig. S36. ^{1}H NMR Spectrum of 3ck (400 MHz, CDCl$_3$).

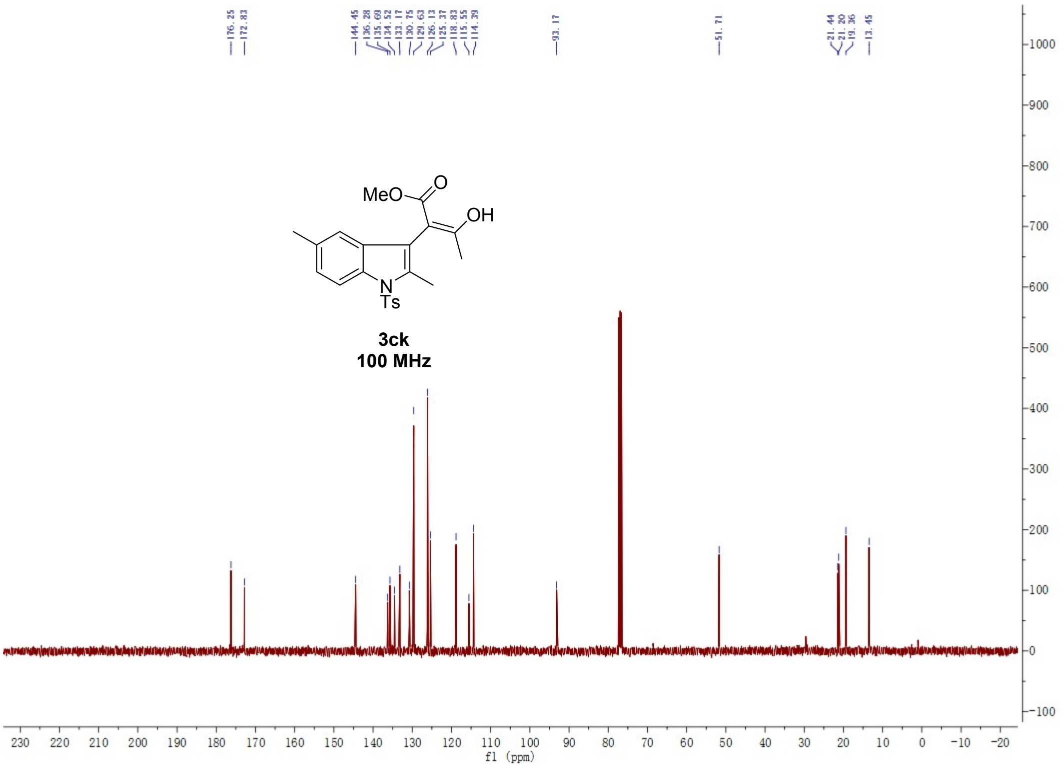


Fig. S37. ^{13}C NMR Spectrum of 3ck (100 MHz, CDCl$_3$).

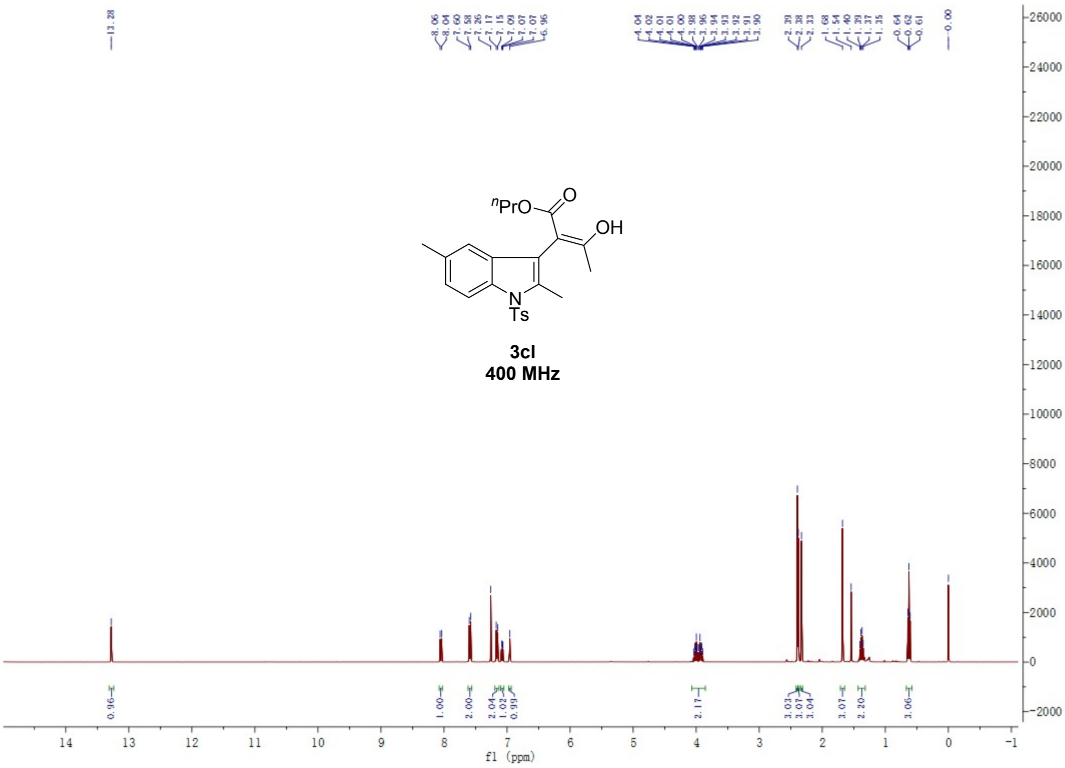


Fig. S38. ^{1}H NMR Spectrum of 3cl (400 MHz, $CDCl_3$).

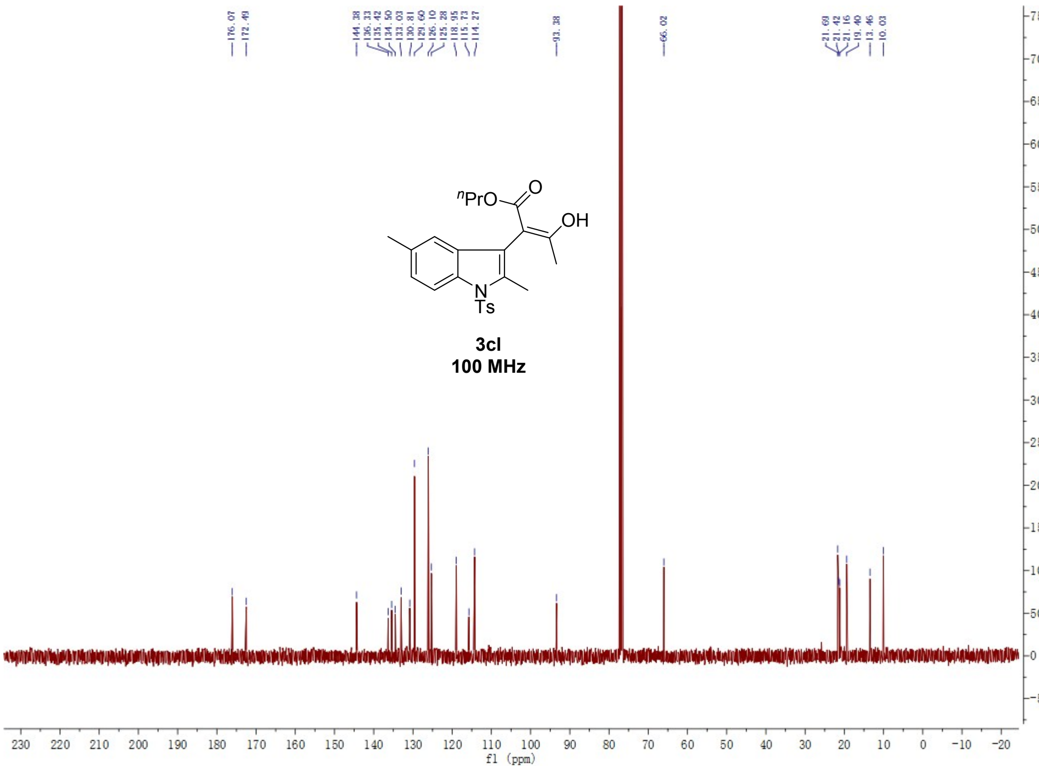


Fig. S39. ^{13}C NMR Spectrum of 3cl (100 MHz, $CDCl_3$).

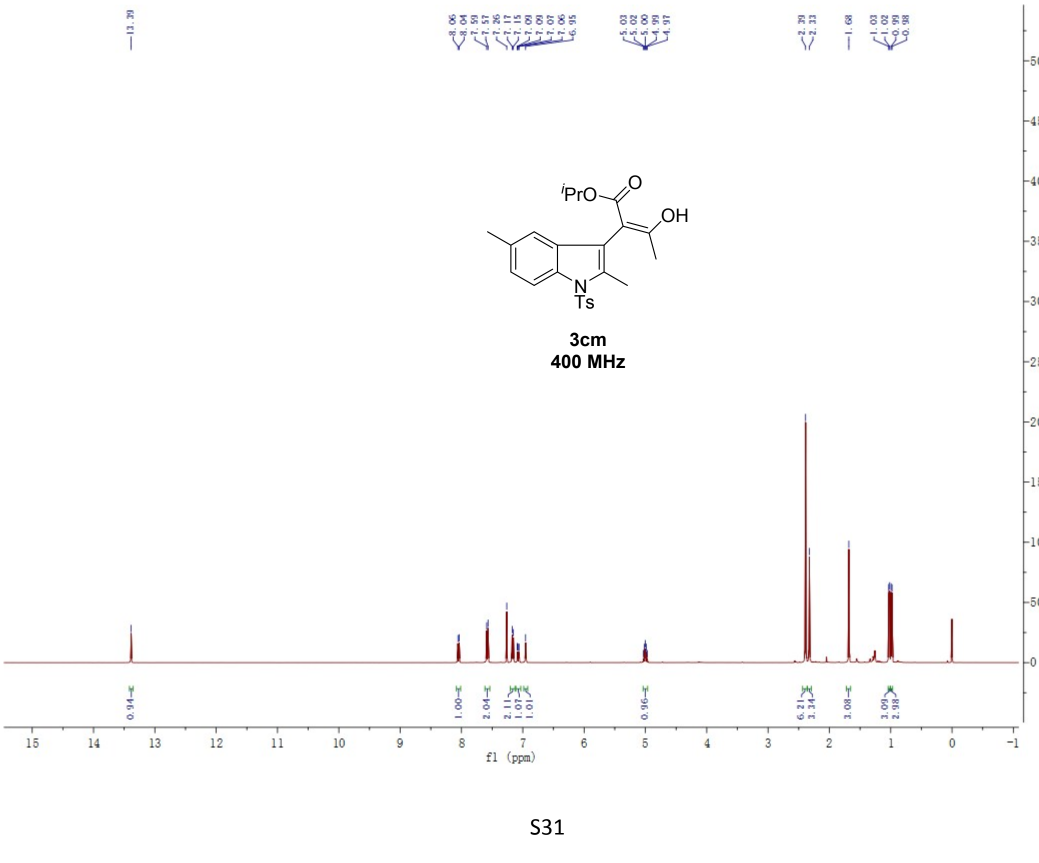


Fig. S40. ^{1}H NMR Spectrum of 3cm (400 MHz, CDCl$_3$).

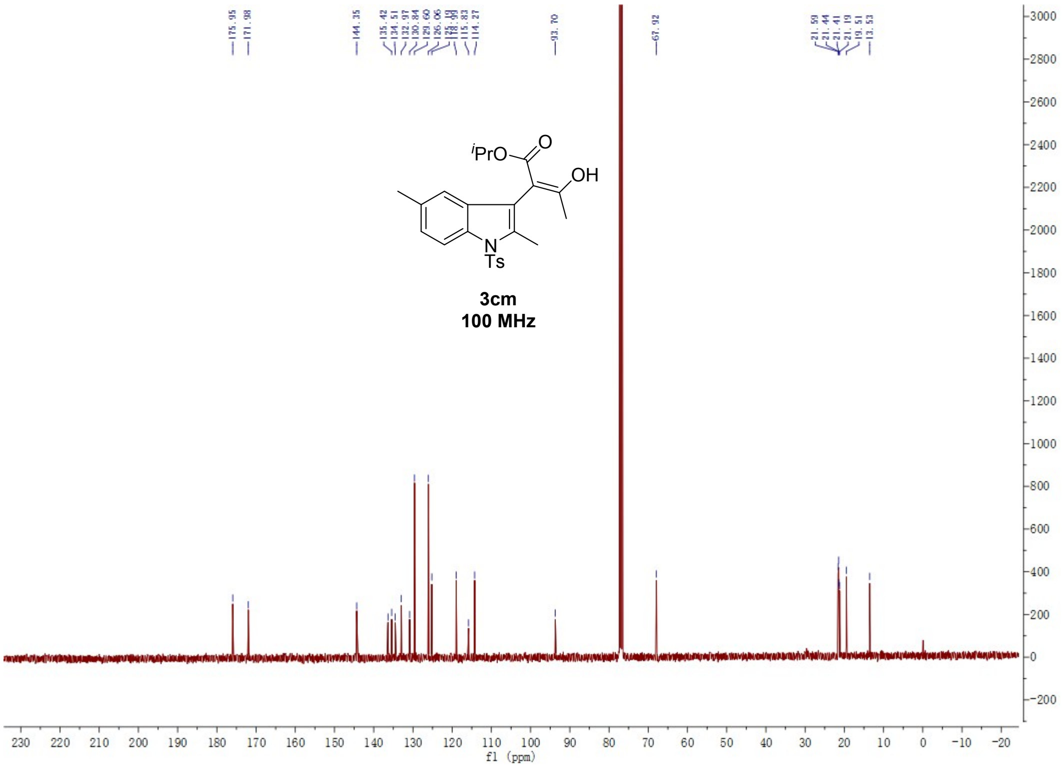


Fig. S41. ^{13}C NMR Spectrum of 3cm (100 MHz, CDCl$_3$).

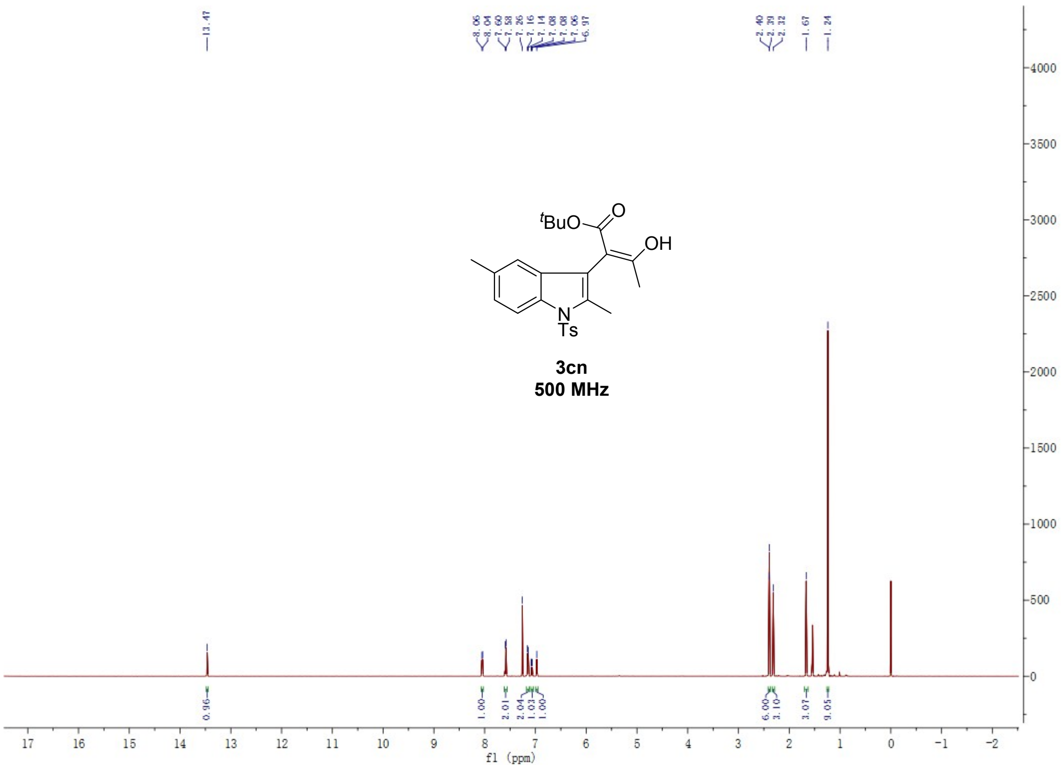


Fig. S42. ^{1}H NMR Spectrum of 3cn (500 MHz, $CDCl_3$).

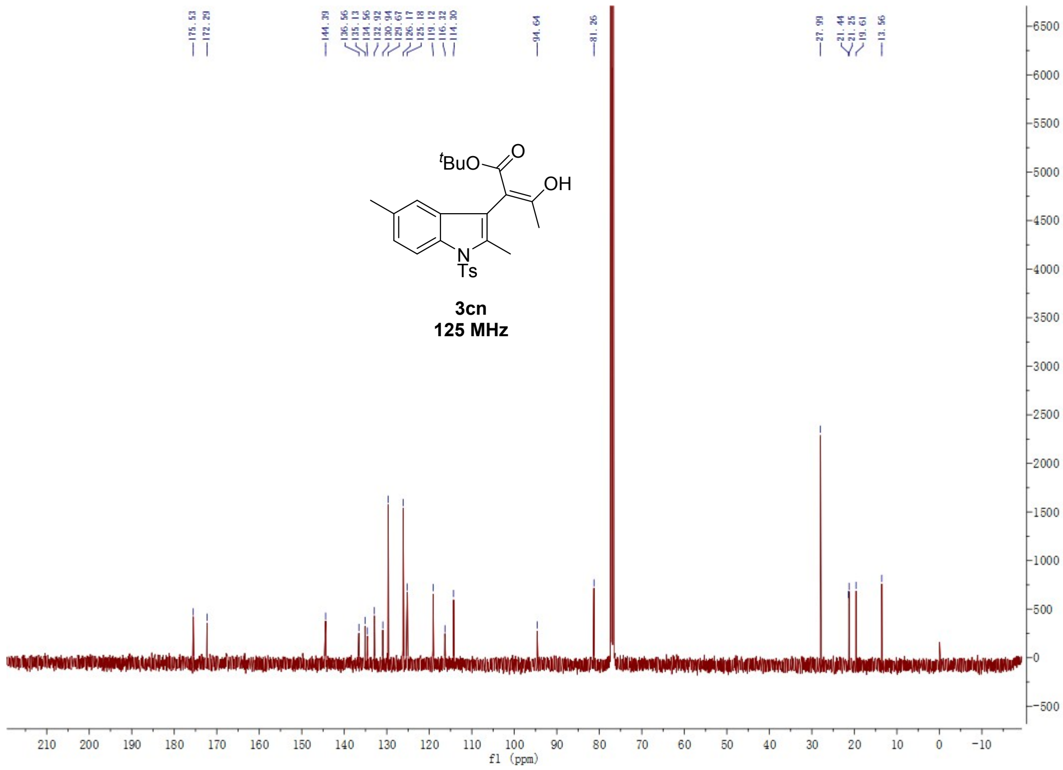


Fig. S43. ^{13}C NMR Spectrum of 3cn (125 MHz, $CDCl_3$).

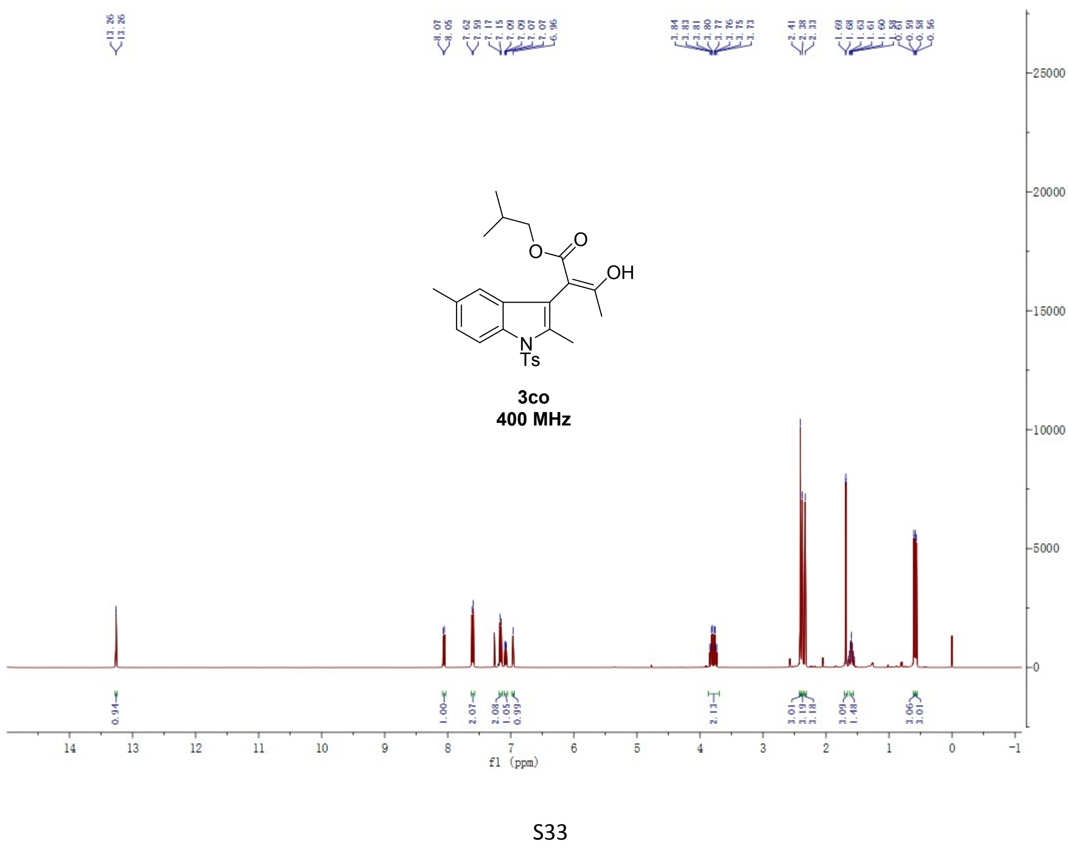


Fig. S44. ^{1}H NMR Spectrum of 3co (400 MHz, $CDCl_3$).

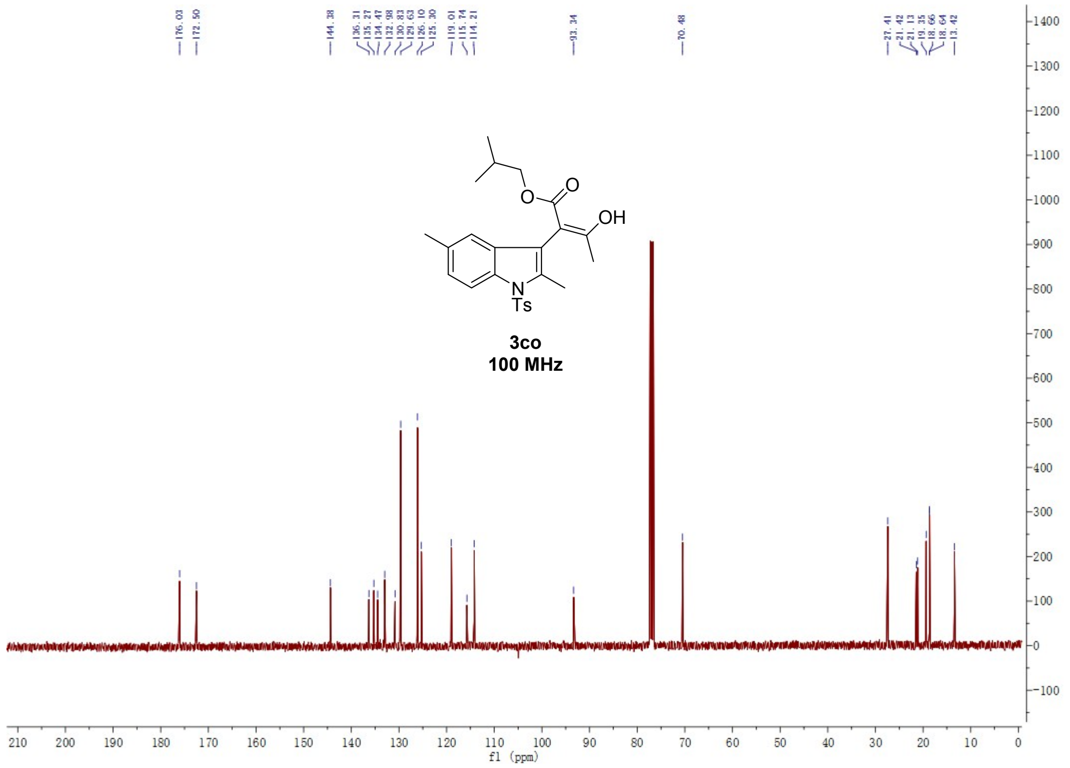


Fig. S45. ^{13}C NMR Spectrum of 3co (100 MHz, $CDCl_3$).

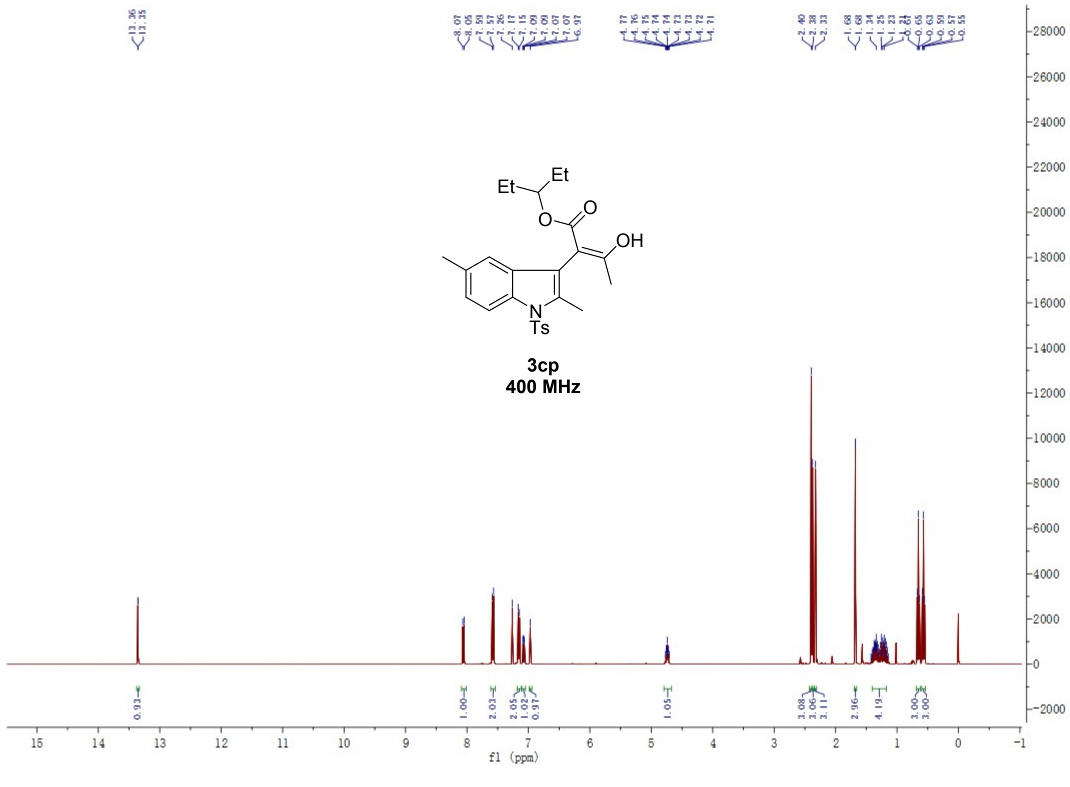


Fig. S46. [1]H NMR Spectrum of 3cp (400 MHz, CDCl$_3$).

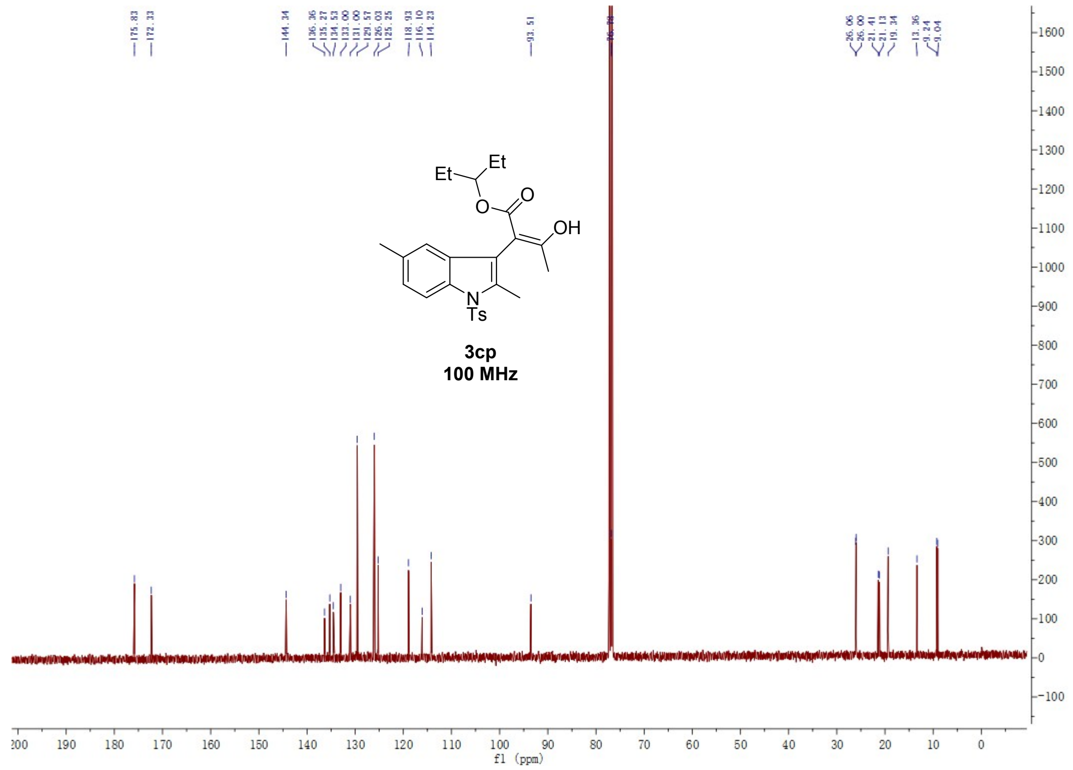


Fig. S47. [13]C NMR Spectrum of 3cp (100 MHz, CDCl$_3$).

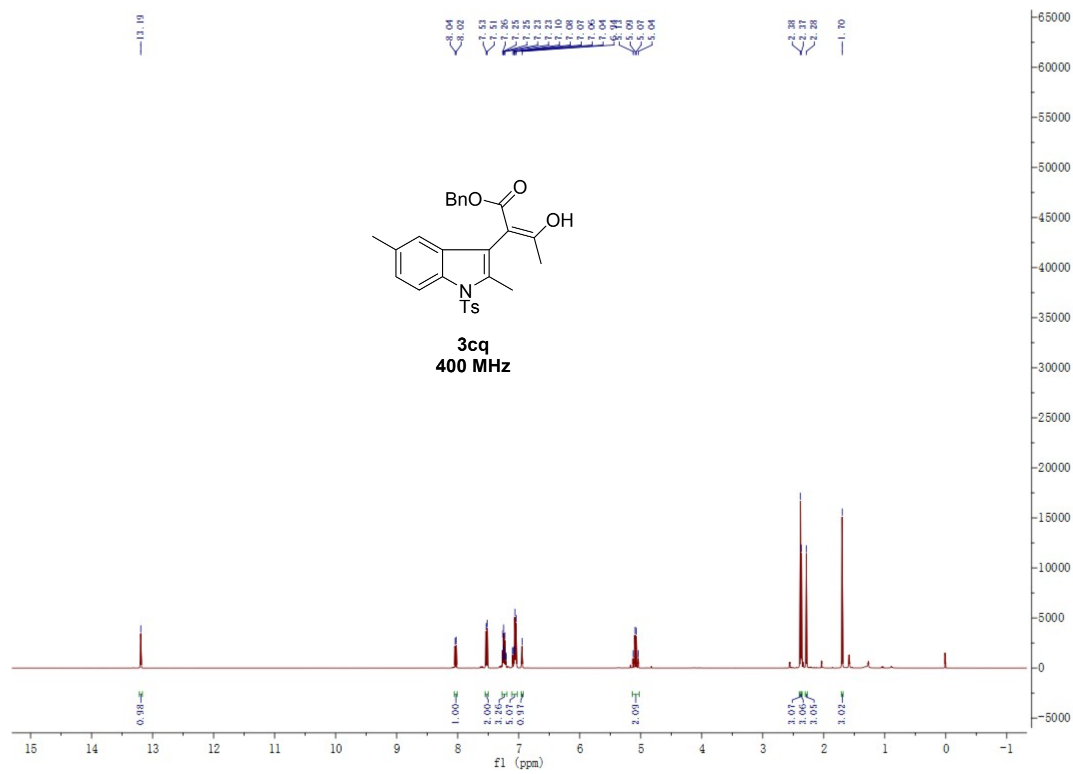


Fig. S48. [1]H NMR Spectrum of 3cq (400 MHz, CDCl$_3$).

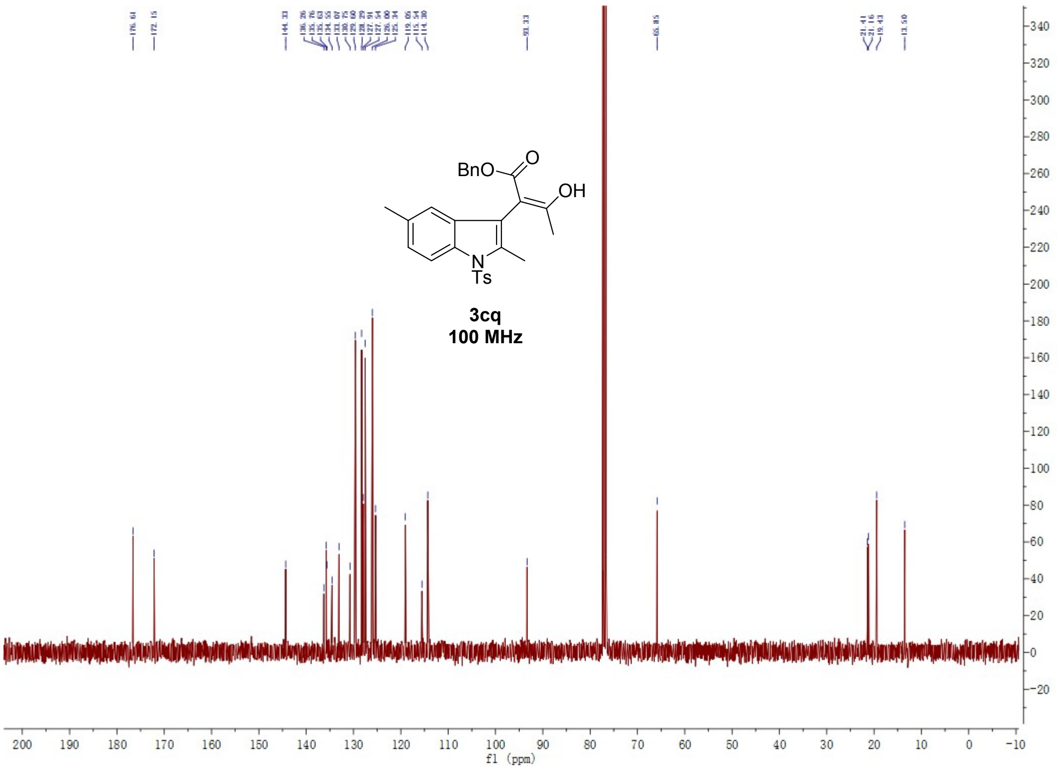


Fig. S49. [13]C NMR Spectrum of 3cq (100 MHz, CDCl$_3$).

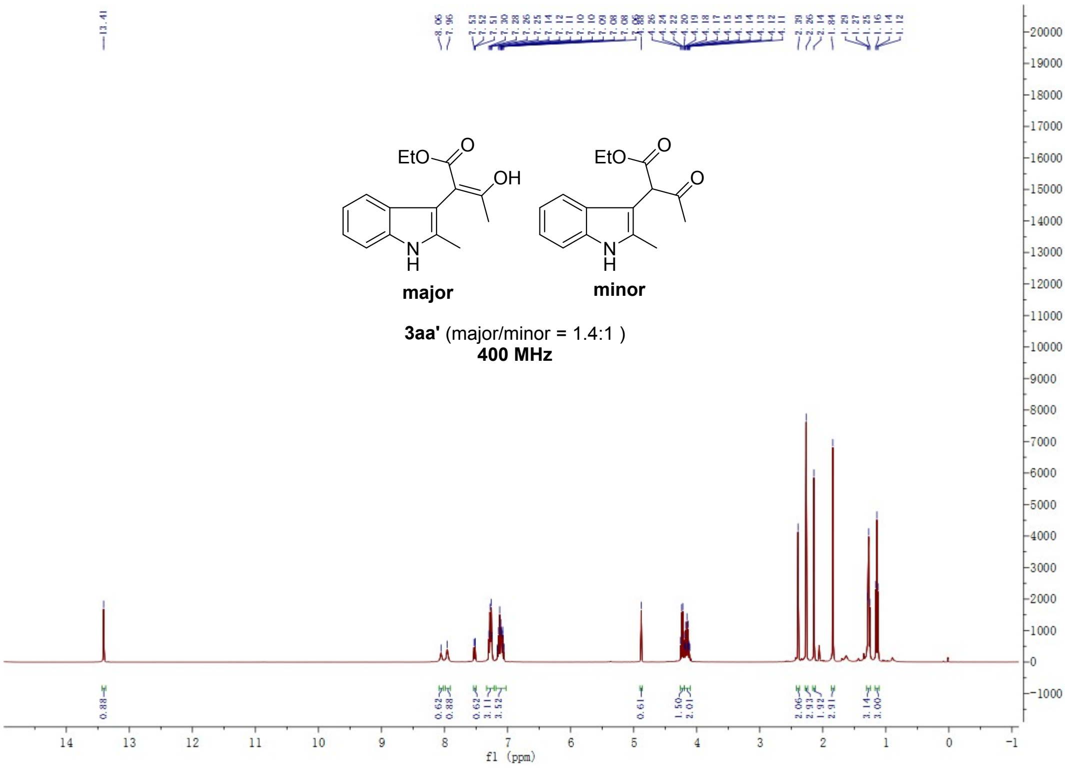


Fig. S50. ^{1}H NMR Spectrum of 3aa' (400 MHz, $CDCl_3$).

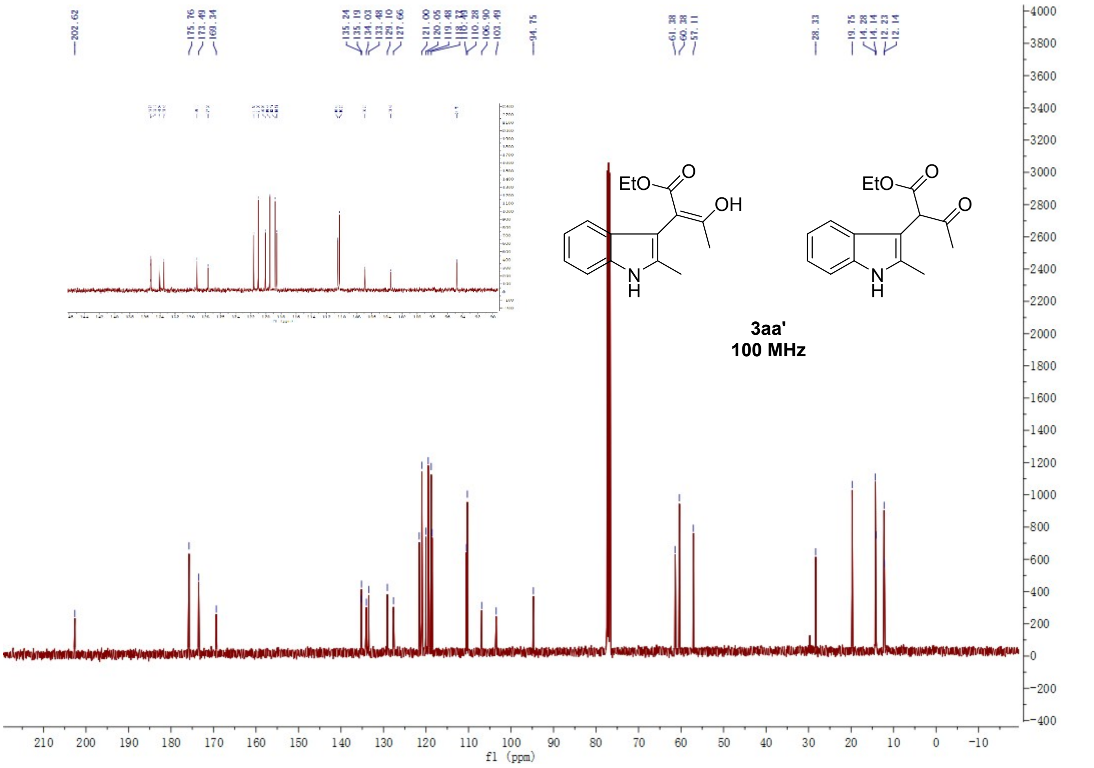
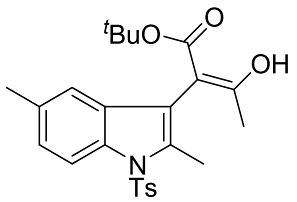


Fig. S51. ^{13}C NMR Spectrum of 3aa' (100 MHz, $CDCl_3$).

VI. Crystal Structure of 3cn



3cn
CCDC (1837721)

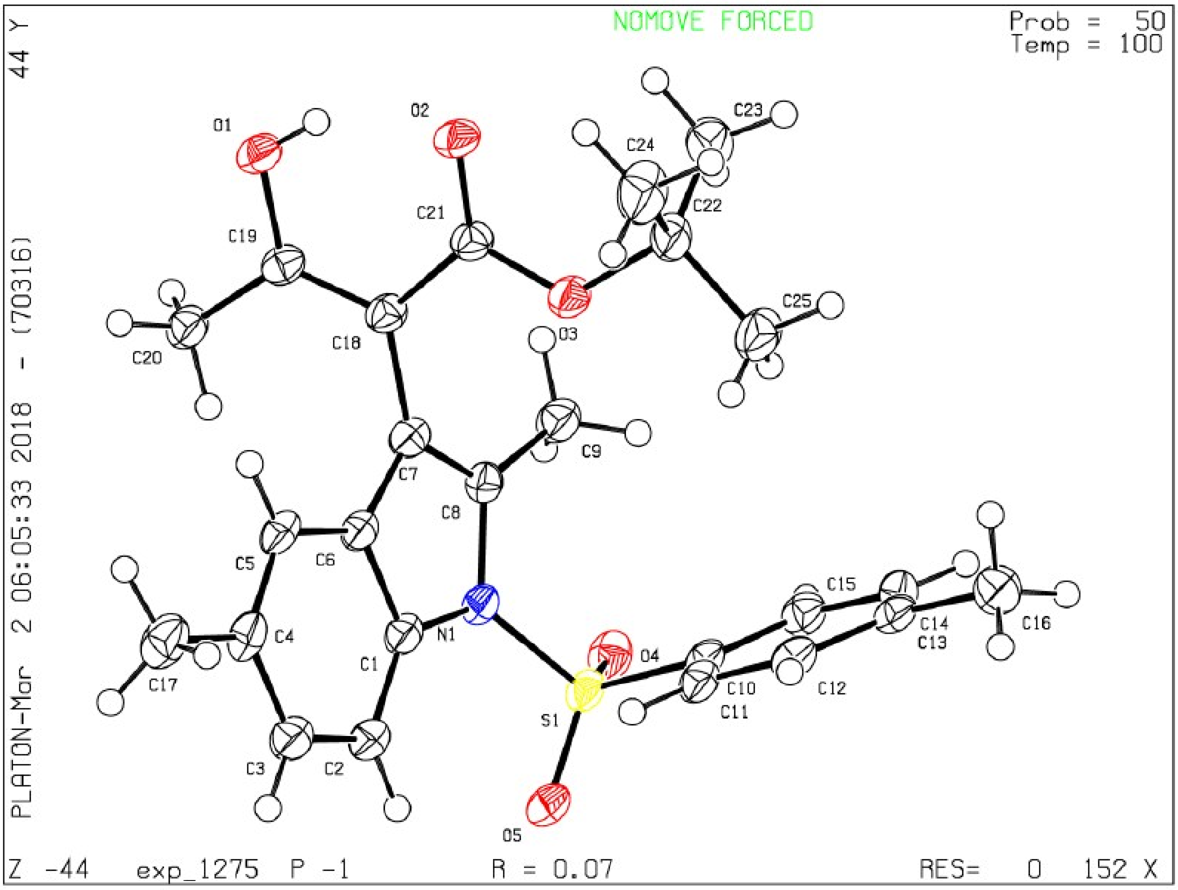


Table 1. Crystal data and structure refinement for 3cn.

Identification code	**3cn**
Empirical formula	$C_{25}H_{29}NO_5S$
Formula weight	455.55
Temperature/K	100.00(10)

Crystal system	triclinic
Space group	P-1
a/Å	9.0009(6)
b/Å	9.4814(5)
c/Å	14.6222(10)
α/°	92.269(5)
β/°	102.450(6)
γ/°	100.774(5)
Volume/Å^3	1192.88(13)
Z	2
ρ_{calc}g/cm^3	1.268
μ/mm^{-1}	1.497
F(000)	484.0
Crystal size/mm^3	0.13 × 0.12 × 0.11
Radiation	CuKα (λ = 1.54184)
2Θ range for data collection/°	6.212 to 147.566
Index ranges	-10 ≤ h ≤ 7, -11 ≤ k ≤ 11, -16 ≤ l ≤ 18
Reflections collected	7966
Independent reflections	4642 [R_{int} = 0.0421, R_{sigma} = 0.0573]
Data/restraints/parameters	4642/0/297
Goodness-of-fit on F^2	1.096
Final R indexes [I>=2σ (I)]	R_1 = 0.0655, wR_2 = 0.1737
Final R indexes [all data]	R_1 = 0.0758, wR_2 = 0.1830
Largest diff. peak/hole / e Å^{-3}	0.80/-0.56

Table 2. Fractional Atomic Coordinates (×10^4) and Equivalent Isotropic Displacement Parameters (Å^2×10^3) for 3cn. U_{eq} is defined as 1/3 of of the trace of the orthogonalised U_{IJ} tensor.

Atom	*x*	*y*	*z*	U(eq)
S(1)	3884.7(7)	4888.9(7)	7123.9(5)	24.4(2)
O(4)	3682(2)	5570(2)	7960.7(15)	30.4(5)
O(1)	5899(2)	-1509(2)	9504.5(14)	28.1(4)
O(5)	2789(2)	4875(2)	6264.5(15)	31.4(5)
O(2)	8367(2)	103(2)	9313.8(15)	29.8(5)
O(3)	8149(2)	1988(2)	8433.9(15)	29.2(4)
N(1)	3900(3)	3167(2)	7310.9(16)	23.7(5)
C(1)	3529(3)	2026(3)	6584.8(19)	23.4(5)
C(5)	4021(3)	-387(3)	6405.2(19)	25.4(6)
C(6)	4204(3)	900(3)	6963.3(19)	22.1(5)
C(7)	4995(3)	1356(3)	7920.8(19)	22.8(5)

C(8)	4838(3)	2728(3)	8117.2(19)	23.7(5)
C(12)	7719(3)	5649(3)	6093(2)	27.5(6)
C(11)	6245(3)	5071(3)	6220(2)	27.2(6)
C(10)	5761(3)	5615(3)	6973.2(19)	24.6(5)
C(2)	2661(3)	1896(3)	5673(2)	29.8(6)
C(19)	5127(3)	-689(3)	8933.7(19)	23.8(5)
C(21)	7559(3)	809(3)	8806.2(19)	24.2(5)
C(13)	8694(3)	6778(3)	6706(2)	27.1(6)
C(4)	3200(4)	-527(3)	5487(2)	29.2(6)
C(15)	6706(3)	6717(3)	7603(2)	27.2(6)
C(18)	5872(3)	479(3)	8568.7(18)	23.1(5)
C(3)	2519(4)	613(3)	5136(2)	32.1(6)
C(20)	3418(3)	-1170(3)	8755(2)	26.9(6)
C(14)	8170(3)	7298(3)	7453(2)	28.9(6)
C(9)	5489(4)	3666(3)	9006(2)	29.6(6)
C(16)	10274(4)	7399(4)	6551(2)	35.5(7)
C(17)	3024(4)	-1875(3)	4859(2)	37.6(7)
C(22)	9844(3)	2576(3)	8637(2)	33.2(7)
C(23)	10437(4)	2985(4)	9684(3)	43.9(8)
C(24)	10665(4)	1495(4)	8269(3)	45.7(9)
C(25)	9910(4)	3903(4)	8087(3)	44.7(9)

Table 3. Anisotropic Displacement Parameters (Å^2×10^3) for 3cn. The Anisotropic displacement factor exponent takes the form: $-2\pi^2[h^2a^{*2}U_{11}+2hka^*b^*U_{12}+…]$.

Atom	U_{11}	U_{22}	U_{33}	U_{23}	U_{13}	U_{12}
S(1)	25.6(3)	16.1(3)	33.2(4)	5.1(2)	7.2(3)	7.4(2)
O(4)	30.8(11)	21.8(10)	41.6(12)	2.6(8)	12.0(9)	8.1(8)
O(1)	29.8(10)	24.4(10)	31.7(10)	9.3(8)	5.6(8)	9.2(8)
O(5)	34.1(11)	19.2(9)	40.7(12)	8.9(8)	4.1(9)	8.8(8)
O(2)	25.8(10)	27.8(10)	37.4(11)	11.6(8)	4.0(8)	10.9(8)
O(3)	21.5(10)	27.5(10)	39.9(11)	12.0(8)	7.0(8)	6.6(8)
N(1)	24.6(11)	17.6(11)	28.8(12)	5.5(9)	5.2(9)	4.0(8)
C(1)	23.5(13)	18.9(12)	29.4(14)	5.8(10)	8.1(10)	5(1)
C(5)	29.4(14)	17.7(12)	33.1(14)	7.8(10)	12.3(11)	7.6(10)
C(6)	20.3(12)	19.6(12)	29.0(13)	6.6(10)	8.7(10)	5.5(9)
C(7)	21.6(12)	22.8(13)	27.3(13)	6.5(10)	9.4(10)	7.2(10)
C(8)	21.4(12)	22.1(13)	27.3(13)	5.4(10)	5.8(10)	2.1(10)
C(12)	33.6(15)	22.7(13)	29.6(14)	6.4(11)	9.6(11)	10.1(11)

C(11)	33.4(15)	17.5(12)	30.0(14)	4.7(10)	5.6(11)	4.8(11)
C(10)	29.1(14)	16.6(12)	29.2(13)	6.7(10)	6.4(11)	6.6(10)
C(2)	33.1(15)	20.6(13)	32.6(15)	6.4(11)	0.8(12)	4.8(11)
C(19)	27.8(14)	20.3(12)	25.8(13)	2.5(10)	6.9(10)	9.5(10)
C(21)	22.7(13)	24.3(13)	27.2(13)	5.6(10)	6.3(10)	7.8(10)
C(13)	28.4(14)	21.0(13)	32.9(14)	10.3(11)	4.9(11)	8.1(11)
C(4)	37.6(15)	18.3(13)	31.9(14)	3.0(11)	11.7(12)	1.7(11)
C(15)	31.5(14)	21.6(13)	29.9(14)	3.4(10)	6.9(11)	8.5(11)
C(18)	23.3(13)	21.9(13)	26.4(13)	4.9(10)	7(1)	7.8(10)
C(3)	40.1(16)	24.1(14)	28.1(14)	3.9(11)	1.3(12)	3.6(12)
C(20)	29.0(14)	21.5(13)	31.2(14)	5.4(10)	7.4(11)	6(1)
C(14)	28.6(14)	21.4(13)	33.7(15)	2.8(11)	2.9(11)	2.1(11)
C(9)	35.6(15)	23.0(13)	30.0(14)	4.2(11)	6.1(12)	6.4(11)
C(16)	28.6(15)	36.0(17)	42.9(17)	7.8(13)	8.7(13)	7.1(12)
C(17)	52.6(19)	23.7(14)	36.9(16)	1.6(12)	12.2(14)	6.0(13)
C(22)	17.6(13)	28.6(15)	54.3(19)	12.1(13)	8.1(12)	4.8(11)
C(23)	34.1(17)	30.2(17)	61(2)	6.2(15)	-2.2(15)	5.2(13)
C(24)	29.1(16)	40.3(19)	75(3)	12.4(17)	24.5(16)	8.9(14)
C(25)	25.9(15)	38.5(18)	72(2)	24.9(17)	12.7(15)	5.1(13)

Table 4. Bond Lengths for 3cn.

Atom	Atom	Length/Å	Atom	Atom	Length/Å
S(1)	O(4)	1.423(2)	C(8)	C(9)	1.486(4)
S(1)	O(5)	1.418(2)	C(12)	C(11)	1.392(4)
S(1)	N(1)	1.668(2)	C(12)	C(13)	1.398(4)
S(1)	C(10)	1.764(3)	C(11)	C(10)	1.384(4)
O(1)	C(19)	1.337(3)	C(10)	C(15)	1.384(4)
O(2)	C(21)	1.232(3)	C(2)	C(3)	1.391(4)
O(3)	C(21)	1.333(3)	C(19)	C(18)	1.373(4)
O(3)	C(22)	1.484(3)	C(19)	C(20)	1.482(4)
N(1)	C(1)	1.425(3)	C(21)	C(18)	1.453(4)
N(1)	C(8)	1.420(3)	C(13)	C(14)	1.388(4)
C(1)	C(6)	1.400(4)	C(13)	C(16)	1.502(4)
C(1)	C(2)	1.381(4)	C(4)	C(3)	1.401(4)
C(5)	C(6)	1.404(4)	C(4)	C(17)	1.507(4)
C(5)	C(4)	1.375(4)	C(15)	C(14)	1.397(4)
C(6)	C(7)	1.436(4)	C(22)	C(23)	1.518(5)

C(7)	C(8)	1.360(4)		C(22)	C(24)	1.516(5)
C(7)	C(18)	1.483(4)		C(22)	C(25)	1.519(4)

Table 5. Bond Angles for 3cn.

Atom	Atom	Atom	Angle/°	Atom	Atom	Atom	Angle/°
O(4)	S(1)	N(1)	107.17(12)	C(15)	C(10)	S(1)	119.5(2)
O(4)	S(1)	C(10)	108.47(13)	C(1)	C(2)	C(3)	117.2(3)
O(5)	S(1)	O(4)	119.82(13)	O(1)	C(19)	C(18)	122.3(2)
O(5)	S(1)	N(1)	106.11(12)	O(1)	C(19)	C(20)	113.0(2)
O(5)	S(1)	C(10)	109.17(13)	C(18)	C(19)	C(20)	124.7(2)
N(1)	S(1)	C(10)	105.11(12)	O(2)	C(21)	O(3)	123.2(2)
C(21)	O(3)	C(22)	121.7(2)	O(2)	C(21)	C(18)	124.1(3)
C(1)	N(1)	S(1)	124.26(18)	O(3)	C(21)	C(18)	112.7(2)
C(8)	N(1)	S(1)	123.29(18)	C(12)	C(13)	C(16)	120.0(3)
C(8)	N(1)	C(1)	108.1(2)	C(14)	C(13)	C(12)	118.6(3)
C(6)	C(1)	N(1)	106.9(2)	C(14)	C(13)	C(16)	121.4(3)
C(2)	C(1)	N(1)	131.6(2)	C(5)	C(4)	C(3)	118.8(3)
C(2)	C(1)	C(6)	121.5(3)	C(5)	C(4)	C(17)	121.2(3)
C(4)	C(5)	C(6)	119.8(2)	C(3)	C(4)	C(17)	120.0(3)
C(1)	C(6)	C(5)	119.8(3)	C(10)	C(15)	C(14)	118.3(3)
C(1)	C(6)	C(7)	108.0(2)	C(19)	C(18)	C(7)	121.4(2)
C(5)	C(6)	C(7)	132.2(2)	C(19)	C(18)	C(21)	118.2(2)
C(6)	C(7)	C(18)	125.0(2)	C(21)	C(18)	C(7)	120.3(2)
C(8)	C(7)	C(6)	108.6(2)	C(2)	C(3)	C(4)	122.8(3)
C(8)	C(7)	C(18)	126.3(2)	C(13)	C(14)	C(15)	121.6(3)
N(1)	C(8)	C(9)	123.2(2)	O(3)	C(22)	C(23)	109.3(3)
C(7)	C(8)	N(1)	108.4(2)	O(3)	C(22)	C(24)	109.9(2)
C(7)	C(8)	C(9)	128.4(3)	O(3)	C(22)	C(25)	101.6(2)
C(11)	C(12)	C(13)	120.8(3)	C(23)	C(22)	C(25)	111.2(3)
C(10)	C(11)	C(12)	119.1(3)	C(24)	C(22)	C(23)	112.8(3)
C(11)	C(10)	S(1)	118.9(2)	C(24)	C(22)	C(25)	111.5(3)
C(11)	C(10)	C(15)	121.7(3)				

Table 6. Hydrogen Atom Coordinates (Å×10^4) and Isotropic Displacement Parameters (Å^2×10^3) for 3cn.

Atom	*x*	*y*	*z*	U(eq)
H(1)	6833.37	-1171.74	9609.94	42

H(5)	4454.96	-1143.3	6656.3	30
H(12)	8057.97	5280.79	5593.05	33
H(11)	5595.33	4329.03	5804.8	33
H(2)	2189.42	2635.28	5427.71	36
H(15)	6373.96	7061.09	8112.95	33
H(3)	1948.92	507.99	4517.44	38
H(20A)	3127.81	-2142.49	8472.69	40
H(20B)	2924.33	-552.14	8337.37	40
H(20C)	3094.96	-1127.13	9337.64	40
H(14)	8808.53	8051.9	7863.58	35
H(9A)	6232.06	4474.35	8899.84	44
H(9B)	5989.09	3125.88	9477.88	44
H(9C)	4665.66	4003.17	9213.62	44
H(16A)	11003.93	6839.49	6841.15	53
H(16B)	10596.06	8376.33	6822.8	53
H(16C)	10231.27	7378.7	5888.35	53
H(17A)	3724.91	-1704.37	4446.37	56
H(17B)	1976.33	-2136.23	4493.54	56
H(17C)	3260.09	-2643.92	5237.47	56
H(23A)	9777.63	3546.32	9900.22	66
H(23B)	11477.05	3539.44	9802.9	66
H(23C)	10432	2126.7	10011.86	66
H(24A)	10582.3	661.93	8620.93	69
H(24B)	11740.61	1924.87	8334.45	69
H(24C)	10192.75	1214.06	7617.45	69
H(25A)	9501.65	3616.97	7429.87	67
H(25B)	10968.4	4407.47	8184.02	67
H(25C)	9302.98	4525.02	8299.11	67

Crystal structure determination of 3cn

Crystal Data for $C_{25}H_{29}NO_5S$ (M =455.55 g/mol): triclinic, space group P-1 (no. 2), a = 9.0009(6) Å, b = 9.4814(5) Å, c = 14.6222(10) Å, α = 92.269(5)°, β = 102.450(6)°, γ = 100.774(5)°, V = 1192.88(13) Å^3, Z = 2, T = 100.00(10) K, μ(CuKα) = 1.497 mm^{-1},$Dcalc$ = 1.268 g/cm^3, 7966 reflections measured (6.212° ≤ 2Θ ≤ 147.566°), 4642 unique (R_{int} = 0.0421, R_{sigma} = 0.0573) which were used in all calculations. The final R_1 was 0.0655 (I > 2σ(I)) and wR_2 was 0.1830 (all data).

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