Supporting Information for

Catalyst-free construction of *spiro* [benzoquinolizidine-chromanones] via a tandem condensation/1,5-hydride transfer/cyclization process

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1. General Information

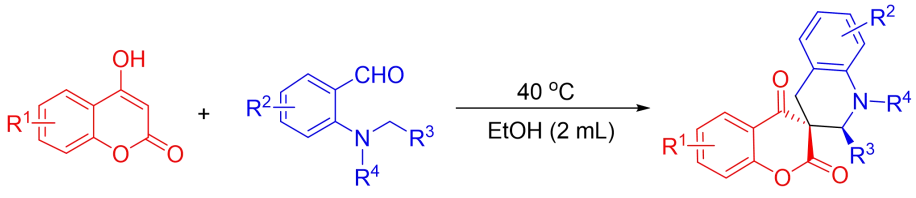
All reagents and Chemicals (AR grade) were purchased from commercial suppliers and used without further purification unless otherwise noticed. 4-hydroxycoumarins[1] and *o*-dialkylaminobenzaldehydes[2] were prepared according to literature. ^{1}H-NMR and ^{13}C-NMR (400 MHz and 101 MHz, respectively) spectra were recorded on a Bruker 400 MHz NMR spectrometer in $CDCl_3$. ^{1}H-NMR chemical shifts were reported in parts per million (d) relative to tetramethylsilane (TMS) with the solvent resonance employed as the internal standard. Data were reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, m = multiplet), coupling constants (Hz), and integration. ^{13}C-NMR chemical shifts were reported in ppm (d) from tetramethylsilane (TMS) with the solvent resonance as the internal standard. HRMS data were obtained on a LTQ Orbitrap XL mass instrument (ESI).

References:

1. Huang ZY , Matsubara O , Jia SC , Tokunaga E, Shibata N. *Org Lett.* 2017;19:934.
2. Haibach M, Deb I, De C, Seidel D. *J Am Chem Soc.* 2011;133:2100.

2 General Procedure for the Synthesis of Products

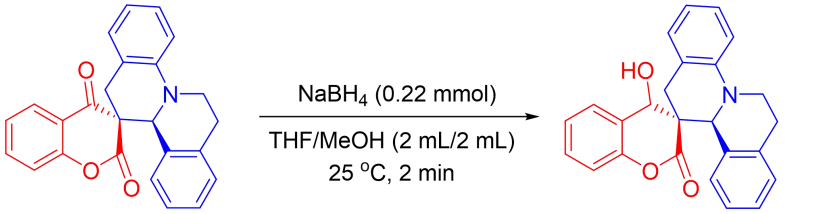
2.1 General procedure for Compounds 3:



1 (0.21 mmol) **2** (0.20 mmol) **3**

In a reaction tube, 4-hydroxycoumarin **1** (0.21 mmol) and *o*-substituted amino benzaldehyde **2** (0.20 mmol) were added into anhydrous EtOH (2 mL) at 40 °C. After the reaction was completed (monitored by TLC), product **3aa-3ka**, **3ab-3ad**, **3ag** were obtained by filtration, product **3ae** and **3af** were obtained by silica gel column chromatography (ethyl acetate/petroleum ether = 1/20 as eluent).

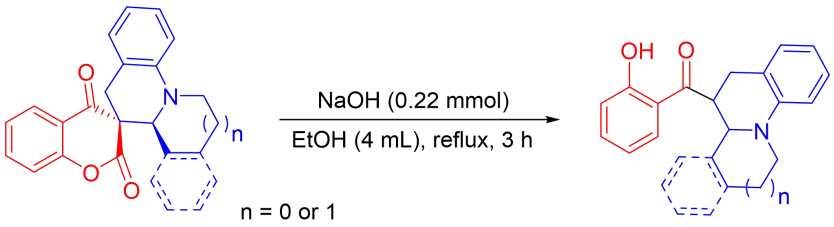
2.2 The procedure for Compounds 4aa:



3aa (0.2 mmol) **4aa** (0.194 mmol, 97% yield, >20:1 dr)

In a tube, the *spiro*[chromane-isoquinolino [2,1-a]quinoline]-2,4-dione **3aa** (0.2 mmol) was added in THF/MeOH (2 mL/2 mL) at room temperature. Then, $NaBH_4$ (0.22 mmol) was added and the reaction solution was stirred for 2 min. The solvent was removed under reduced pressure, and the residue was purified by column chromatography (dichloromethane/ methanol = 1/8 to 1/4 as eluent) to afford product **4aa** in 97% (74 mg) yield.

2.3 The procedure for Compounds 5aa and 5ae:

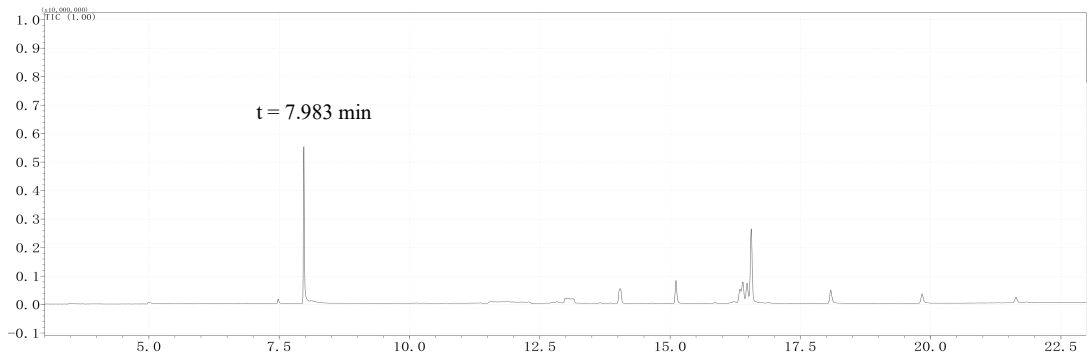


3aa/3ae (0.2 mmol) **5aa/5ae**

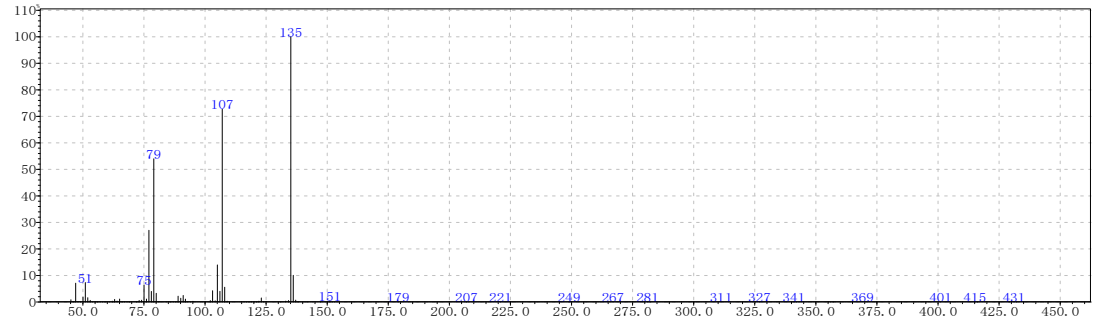
To a solution of **3aa** or **3ae** (0.2 mmol) in EtOH (4 mL) was added NaOH (0.22 mmol) at room temperature, and then the reaction mixture was refluxed 3 h. The solvents were removed under reduced pressure, the desired products **5aa** and **5ae** were obtained after silica gel column chromatography (ethyl acetate/petroleum ether = 1/8 as eluent) in 81% and 78% yields respectively.

3. The chart of Gas chromatography-mass spectrometry

a)



b)



c)

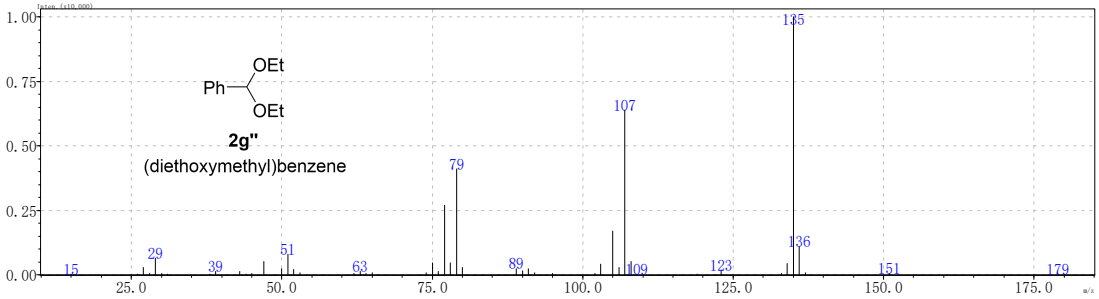
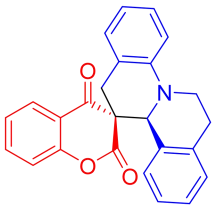


Figure S1. The chart of Gas chromatography-mass spectrometry (GC-MS) for the reaction of **1a** and **2g**. a) the chart of Gas chromatography; b) the chart of mass spectrometry for the component at 7.983 min; c) the standard mass chart of (diethoxymethyl)benzene **2g"**.

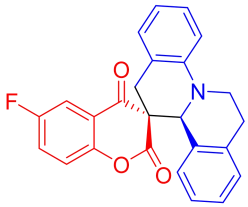
4. Characterization Data



3aa

(3S,11b'S)-7',11b'-dihydro-6'*H*,13'*H*-spiro[chromane-3,12'-isoquinolino[2,1-a]quinoline]-2,4-dione (3aa)

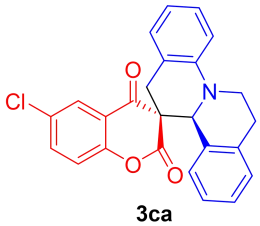
Yield: 87%, yellow solid, mp: 202-204 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.72 (d, *J* = 7.0 Hz, 1H), 7.35 – 7.28 (m, 1H), 7.26 (d, *J* = 6.0 Hz, 1H), 7.19 (t, *J* = 7.6 Hz, 1H), 7.06 (t, *J* = 7.5 Hz, 1H), 7.02 – 6.72 (m, 6H), 6.66 (d, *J* = 8.2 Hz, 1H), 4.69 (s, 1H), 4.08 (d, *J* = 17.1 Hz, 1H), 3.85 (dd, *J* = 10.6, 4.1 Hz, 1H), 3.42 – 3.31 (m, 1H), 3.18 (d, *J* = 17.1 Hz, 1H), 2.84 (s, 1H), 2.59 (d, *J* = 15.3 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 191.3, 167.9, 154.1, 145.4, 136.1, 130.0, 128.8, 128.1, 127.7, 126.46, 126.0, 125.9, 124.3, 121.7, 120.0, 118.6, 116.5, 113.2, 68.6, 62.3, 44.3, 32.9, 29.3; HRMS (ESI) for $C_{25}H_{20}NO_3$ $[M+H]^+$ calcd 382.1438, found 382.1433.



3ba

(3S,11b'S)-6-fluoro-7',11b'-dihydro-6'*H*,13'*H*-spiro[chromane-3,12'-isoquinolino[2,1-a]quinoline]-2,4-dione (3ba)

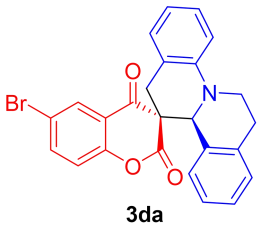
Yield: 79%, yellow solid, mp: 186-188 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.39 (dd, *J* = 7.7, 3.1 Hz, 1H), 7.29 (s, 1H), 7.23 (d, *J* = 6 Hz, 1H), 7.09 – 6.83 (m, 7H), 6.69 (dd, *J* = 9.0, 4.1 Hz, 1H), 4.70 (s, 1H), 4.10 (d, *J* = 17.2 Hz, 1H), 3.88 (dd, *J* = 10.6, 4.2 Hz, 1H), 3.45 – 3.33 (m, 1H), 3.19 (d, *J* = 17.2 Hz, 1H), 2.95 – 2.78 (m, 1H), 2.65 (d, *J* = 15.4 Hz, 1H) ; ^{13}C NMR (101 MHz, $CDCl_3$) δ 190.6 (d, *J* = 2.0 Hz), 167.4, 158.8 (d, *J* = 247.5 Hz), 150.2, 145.3, 136.1, 129.81, 128.8, 128.3, 128.1, 127.8, 126.5, 126.0, 123.3 (d, *J* = 24.2 Hz), 121.5, 120.8 (d, *J* = 7.1 Hz), 118.8, 118.5 (d, *J* = 8.1 Hz), 113.3, 111.3 (d, *J* = 24.2 Hz), 69.1, 62.2, 44.3, 32.8, 29.3; HRMS (ESI) for $C_{25}H_{19}FNO_3$ $[M+H]^+$ calcd 400.1343, found 400.1336.



3ca

(3S,11b'S)-6-chloro-7',11b'-dihydro-6'*H*,13'*H*-spiro[chromane-3,12'-isoquinolino[2,1-a]quinoline]-2,4-dione (3ca)

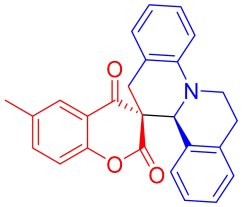
Yield: 81%, yellow solid, mp: 179-181 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 (d, *J* = 2.5 Hz, 1H), 7.28 – 7.23 (m, 2H), 7.18 (t, *J* = 7.7 Hz, 1H), 7.04 – 6.77 (m, 6H), 6.61 (d, *J* = 8.8 Hz, 1H), 4.66 (s, 1H), 4.05 (d, *J* = 17.2 Hz, 1H), 3.84 (dd, *J* = 10.3, 4.6 Hz, 1H), 3.42 – 3.30 (m, 1H), 3.15 (d, *J* = 17.2 Hz, 1H), 2.90 – 2.74 (m, 1H), 2.62 (d, *J* = 15.5 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 190.3, 167.2, 152.5, 145.3, 136.2, 135.7, 129.9, 129.8, 128.8, 128.4, 128.2, 127.8, 126.6, 126.0, 125.3, 121.4, 120.9, 118.8, 118.2, 113.3, 69.2, 62.5, 44.3, 32.7, 29.3; HRMS (ESI) for $C_{25}H_{19}ClNO_3$ $[M+H]^+$ calcd 416.1048, found 416.1044.



3da

(3S,11b'S)-6-bromo-7',11b'-dihydro-6'*H*,13'*H*-spiro[chromane-3,12'-isoquinolino[2,1-a]quinoline]-2,4-dione (3da)

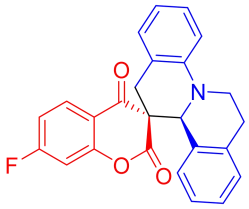
Yield: 83%, yellow solid, mp: 192-194 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.83 (d, *J* = 2.4 Hz, 1H), 7.41 (dd, *J* = 8.7, 2.4 Hz, 1H), 7.27 (d, *J* = 3.3 Hz, 1H), 7.21 (t, *J* = 7.6 Hz, 1H), 7.04 – 6.80 (m, 6H), 6.58 (d, *J* = 8.7 Hz, 1H), 4.69 (s, 1H), 4.08 (d, *J* = 17.2 Hz, 1H), 3.87 (dd, *J* = 10.3, 4.5 Hz, 1H), 3.51 – 3.32 (m, 1H), 3.17 (d, *J* = 17.2 Hz, 1H), 2.95 – 2.74 (m, 1H), 2.65 (d, *J* = 15.4 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 190.2, 167.2, 153.0, 145.2, 138.6, 136.1, 129.7, 128.8, 128.4, 128.2, 127.8, 126.6, 126.0, 121.4, 121.2, 118.8, 118.5, 117.1, 113.3, 69.2, 62.5, 44.3, 32.7, 29.3; HRMS (ESI) for $C_{25}H_{19}BrNO_3$ $[M+H]^+$ calcd 460.0543, found 460.0539.



3ea

(3S,11b'S)-6-methyl-7',11b'-dihydro-6'*H*,13'*H*-spiro[chromane-3,12'-isoquinolino[2,1-a]quinoline]-2,4-dione (3ea)

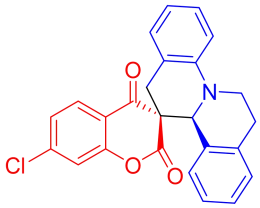
Yield: 61%, yellow solid, mp: 172-174 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.50 (s, 1H), 7.23 (s, 1H), 7.18 (t, *J* = 7.6 Hz, 1H), 7.12 (dd, *J* = 8.3, 1.7 Hz, 1H), 7.05 – 6.73 (m, 6H), 6.56 (d, *J* = 8.4 Hz, 1H), 4.68 (s, 1H), 4.05 (d, *J* = 17.1 Hz, 1H), 3.84 (dd, *J* = 9.9, 4.5 Hz, 1H), 3.37 (t, *J* = 10.1 Hz, 1H), 3.15 (d, *J* = 17.1 Hz, 1H), 2.86 (s, 1H), 2.59 (d, *J* = 15.2 Hz, 1H), 2.28 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 191.5, 145.5, 137.0, 136.2, 134.1, 130.1, 128.8, 128.1, 128.0, 127.6, 126.5, 125.8, 125.6, 121.7, 119.6, 118.5, 116.3, 113.1, 68.4, 62.2, 44.3, 33.0, 29.3, 20.6; HRMS (ESI) for $C_{26}H_{22}NO_3$ $[M+H]^+$ calcd 396.1594, found 396.1590.



3fa

(3S,11b'S)-7-fluoro-7',11b'-dihydro-6'*H*,13'*H*-spiro[chromane-3,12'-isoquinolino[2,1-a]quinoline]-2,4-dione (3fa)

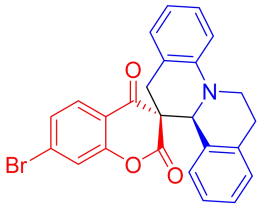
Yield: 76%, yellow solid, mp: 191-192 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.73 (dd, *J* = 8.6, 6.3 Hz, 1H), 7.24 (d, *J* = 3.9 Hz, 1H), 7.18 (t, *J* = 7.7 Hz, 1H), 7.07 – 6.67 (m, 7H), 6.34 (dd, *J* = 8.9, 2.3 Hz, 1H), 4.65 (s, 1H), 4.05 (d, *J* = 17.2 Hz, 1H), 3.83 (dd, *J* = 10.5, 4.2 Hz, 1H), 3.48 – 3.28 (m, 1H), 3.14 (d, *J* = 17.2 Hz, 1H), 2.82 (s, 1H), 2.60 (d, *J* = 15.4 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 189.8, 167.3, 166.9 (d, *J* = 259.6 Hz), 155.6 (d, *J* = 13.1 Hz), 145.3, 136.2, 129.8, 128.8, 128.6 (d, *J* = 12.1 Hz), 128.3, 128.2, 127.8, 126.5, 125.9, 121.5, 118.7, 117.0 (d, *J* = 3.0 Hz), 113.3, 112.4 (d, *J* = 23.2 Hz), 103.9 (d, *J* = 26.2 Hz), 68.8, 62.2, 44.3, 32.7, 29.3; HRMS (ESI) for $C_{25}H_{19}FNO_3$ $[M+H]^+$ calcd 400.1343, found 400.1336.



3ga

(3S,11b'S)-7-chloro-7',11b'-dihydro-6'*H*,13'*H*-spiro[chromane-3,12'-isoquinolino[2,1-a]quinoline]-2,4-dione (3ga)

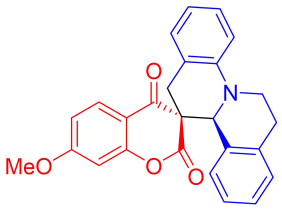
Yield: 75%, yellow solid, mp: 202-204 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.65 (d, *J* = 8.4 Hz, 1H), 7.25 (d, *J* = 3.2 Hz, 1H), 7.19 (t, *J* = 7.7 Hz, 1H), 7.04 – 6.98 (m, 2H), 6.96 – 6.76 (m, 5H), 6.66 (d, *J* = 1.8 Hz, 1H), 4.67 (s, 1H), 4.06 (d, *J* = 17.2 Hz, 1H), 3.84 (dd, *J* = 10.6, 4.2 Hz, 1H), 3.37 (td, *J* = 12.2, 3.1 Hz, 1H), 3.16 (d, *J* = 17.2 Hz, 1H), 2.81 (t, *J* = 11.3 Hz, 1H), 2.61 (d, *J* = 15.5 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 190.2, 167.2, 154.4, 145.3, 141.9, 136.1, 129.8, 128.8, 128.3, 128.1,127.8, 127.1, 126.5, 126.0, 124.9, 121.5, 118.8, 118.5, 116.8, 113.3, 69.0, 62.5, 44.2, 32.6, 29.3; HRMS (ESI) for $C_{25}H_{19}ClNO_3$ $[M+H]^+$ calcd 416.1048, found 416.1043.



3ha

(3S,11b'S)-7-bromo-7',11b'-dihydro-6'*H*,13'*H*-spiro[chromane-3,12'-isoquinolino[2,1-a]quinoline]-2,4-dione (3ha)

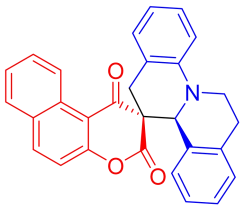
Yield: 73%, yellow solid, mp: 208-210 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.60 (d, *J* = 8.0 Hz, 1H), 7.27 (d, *J* = 6.0 Hz, 1H), 7.22 (m, 2H), 7.05 (m, 1H), 6.94-6.85 (m, 6H), 4.70 (s, 1H), 4.09 (d, *J* = 16.0 Hz, 1H), 3.88 (m, 1H), 3.40 (t, *J* = 12.0 Hz, 1H), 3.19 (d, *J* = 16.0 Hz, 1H), 2.84 (t, *J* = 12.0 Hz, 1H), 2.64 (d, *J* = 16.0 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 190.4, 167.1, 154.2, 145.3, 136.1, 130.3, 129.7, 128.8, 128.3, 128.1, 127.8, 127.1, 126.5, 126.0, 121.5, 119.8, 118.9, 118.8, 113.3, 69.1, 62.6, 44.2, 32.6, 29.3; HRMS (ESI) for $C_{25}H_{19}BrNO_3$ $[M+H]^+$ calcd 40.0543, found 460.0540.



3ia

(3S,11b'S)-7-methoxy-7',11b'-dihydro-6'*H*,13'*H*-spiro[chromane-3, 12'-isoquinolino[2,1-a]quinoline]-2,4-dione (3ia)

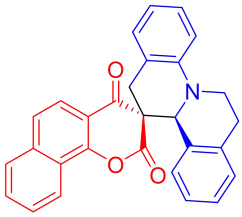
Yield: 85%, yellow solid, mp: 188-190 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.70 (d, *J* = 6.6 Hz, 1H), 7.28 (s, 1H), 7.21 (t, *J* = 7.5 Hz, 1H), 7.10 – 6.75 6.94 (m, 6H), 6.64 (dd, *J* = 8.8, 2.2 Hz, 1H), 6.12 (d, *J* = 2.0 Hz, 1H), 4.69 (s, 1H), 4.08 (d, *J* = 17.1 Hz, 1H), 3.88 (d, *J* = 3.5 Hz, 1H), 3.76 (s, 3H), 3.40 (s, 1H), 3.17 (d, *J* = 17.1 Hz, 1H), 3.03 – 2.50 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 189.7, 166.0, 145.5, 136.3, 130.2, 128.8, 127.9, 127.7, 126.4, 125.8, 121.7, 118.5, 113.8, 113.1, 112.1, 100.2, 68.1, 61.5, 55.9, 44.4, 32.9, 29.3; HRMS (ESI) for $C_{26}H_{22}NO_4$ $[M+H]^+$ calcd 412.1543, found 412.1541.



3ja

(2S,11b'S)-7',11b'-dihydro-1H,3H,6'*H*,13'*H*-spiro[benzo[f]chromene-2, 12'-isoquinolino[2,1-a]quinoline]-1,3-dione (3ja)

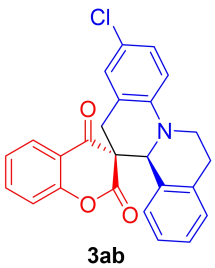
Yield: 81%, yellow solid, mp: 222-224 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 9.30 (s, 1H), 7.80 – 7.63 (m, 3H), 7.51 (t, *J* = 7.4 Hz, 1H), 7.33 (t, *J* = 9.0 Hz, 1H), 7.26 – 6.22 (m, 8H), 4.74 (s, 1H), 4.16 (d, *J* = 17.0 Hz, 1H), 3.84 (d, *J* = 5.2 Hz, 1H), 3.47 – 3.13 (m, 2H), 2.39 (s, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 191.9, 168.0, 145.5, 137.3, 136.4, 130.4, 130.3, 130.2, 130.0, 128.8, 128.5, 128.0, 127.8, 127.4, 126.4, 126.1, 125.8, 125.2, 122.1, 118.7, 116.3, 112.9, 68.4, 62.9, 43.9, 33.0, 29.1; HRMS (ESI) for $C_{29}H_{22}NO_3$ $[M+H]^+$ calcd 432.1594, found 432.1585.



3ka

(3S,11b'S)-7',11b'-dihydro-2H,4H,6'*H*,13'*H*-spiro[benzo[h]chromene-3, 12'-isoquinolino[2,1-a]quinoline]-2,4-dione (3ka)

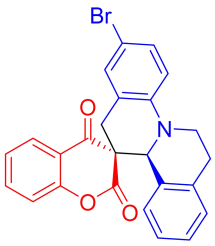
Yield: 77%, yellow solid, mp: 219-221 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.13 (d, *J* = 8.4 Hz, 1H), 7.73 (t, *J* = 8.9 Hz, 2H), 7.61 (t, *J* = 7.5 Hz, 1H), 7.50 (t, *J* = 8.5 Hz, 2H), 7.32 (d, *J* = 7.5 Hz, 1H), 7.24 (t, *J* = 7.6 Hz, 1H), 7.07 – 6.83 (m, 3H), 6.72 (d, *J* = 7.1 Hz, 1H), 6.64 (d, *J* = 6.9 Hz, 1H), 6.56 (t, *J* = 7.4 Hz, 1H), 4.79 (s, 1H), 4.17 (d, *J* = 17.1 Hz, 1H), 3.94 – 3.88 (m, 1H), 3.53 – 3.33 (m, 1H), 3.28 (d, *J* = 17.1 Hz, 1H), 2.99 (s, 1H), 2.60 (d, *J* = 15.2 Hz, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 191.2, 157.6, 152.4, 145.5, 137.4, 136.1, 130.1, 129.9, 128.8, 127.8, 127.6, 127.5, 126.8, 126.5, 125.8, 124.0), 122.9, 122.4, 121.7, 120.5, 118.6, 115.2, 113.2, 68.8, 62.3, 44.4, 32.9, 29.2; HRMS (ESI) for $C_{29}H_{22}NO_3$ $[M+H]^+$ calcd 432.1594, found 432.1588.



3ab

(3S,11b'S)-2'-chloro-7',11b'-dihydro-6'*H*,13'*H*-spiro[chromane-3,12'-isoquinolino[2,1-a]quinoline]-2,4-dione (3ab)

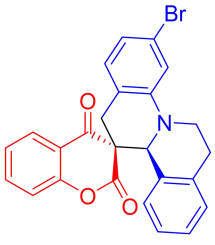
Yield: 91%, yellow solid, mp: 204-206 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.71 (t, *J* = 10.2 Hz, 1H), 7.35 – 7.28 (m, 1H), 7.20 (d, *J* = 2.3 Hz, 1H), 7.12 (dd, *J* = 8.7, 2.4 Hz, 1H), 7.06 (t, *J* = 7.2 Hz, 1H), 7.03 – 6.52 (m, 6H), 4.61 (s, 1H), 4.01 (d, *J* = 17.3 Hz, 1H), 3.77 (d, *J* = 5.2 Hz, 1H), 3.34 (t, *J* = 11.2 Hz, 1H), 3.11 (d, *J* = 17.3 Hz, 1H), 2.58 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 191.1, 167.6, 153.7, 144.1, 136.3, 135.9, 129.5, 128.4, 128.3, 127.7, 126.4, 126.0, 124.4, 123.3, 119.9, 116.5, 114.4, 68.3, 61.7, 44.5, 32.6, 29.20; HRMS (ESI) for $C_{25}H_{19}ClNO_3$ $[M+H]^+$ calcd 416.1048, found 416.1046.



3ac

(3S,11b'S)-2'-bromo-7',11b'-dihydro-6'*H*,13'*H*-spiro[chromane-3,12'-isoquinolino[2,1-a]quinoline]-2,4-dione (3ac)

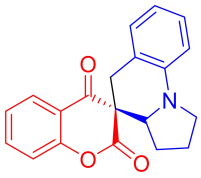
Yield: 70%, yellow solid, mp: 208-210 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.71 (d, *J* = 7.5 Hz, 1H), 7.41 – 7.26 (m, 3H), 7.15 – 6.59 (m, 7H), 4.63 (s, 1H), 4.04 (d, *J* = 17.3 Hz, 1H), 3.78 (dd, *J* = 9.9, 4.4 Hz, 1H), 3.35 (t, *J* = 10.1 Hz, 1H), 3.12 (d, *J* = 17.3 Hz, 1H), 2.66 (m, 2H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 191.1, 167.6, 144.5, 136.3, 135.9, 131.3, 129.5, 129.3, 128.3, 128.1, 127.7, 126.0, 124.5, 123.8, 119.9, 116.6, 114.8, 110.7, 68.3, 61.6, 44.4, 32.6, 29.2; HRMS (ESI) for $C_{25}H_{19}BrNO_3$ $[M+H]^+$ calcd 460.0543, found 460.0539.



3ad

(3S,11b'S)-3'-bromo-7',11b'-dihydro-6'*H*,13'*H*-spiro[chromane-3,12'-isoquinolino[2,1-a]quinoline]-2,4-dione (3ad)

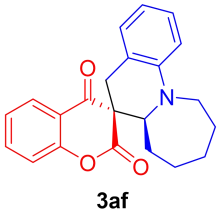
Yield: 77%, yellow solid, mp: 241-243 °C; ^{1}H NMR (400 MHz, DMSO) δ 7.62 (d, *J* = 7.5 Hz, 1H), 7.42 (t, *J* = 7.7 Hz, 1H), 7.14 (dd, *J* = 13.6, 7.3 Hz, 2H), 7.04–6.65 (m, 7H), 4.59 (s, 1H), 3.74 (m, 2H), 3.33–3.16 (m, 3H), 2.60 (s, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 191.0, 146.6, 136.3, 135.9, 130.0, 129.5, 128.2, 127.6, 126.0, 124.5, 121.4, 120.6, 120.1, 119.9, 116.6, 116.1, 67.8, 61.9, 43.9, 32.6, 29.2; HRMS (ESI) for $C_{25}H_{19}BrNO_3$ $[M+H]^+$ calcd 460.0543, found 460.0539.



3ae

(3S,3a'R)-1',2',3',3a'-tetrahydro-5'*H*-spiro[chromane-3,4'-pyrrolo[1,2-a]quinoline]-2,4-dione (3ae)

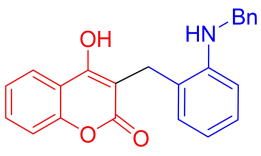
Yield: 91%, yellow solid; ^{1}H NMR (400 MHz, DMSO) δ 8.00 (dd, *J* = 8.0, 1.6 Hz, 1H), 7.69 (dd, *J* = 8.4, 2.0 Hz, 0.4H), 7.68-7.62 (m, 1.4H), 7.32 (td, *J* = 8.0, 0.8 Hz, 1H), 7.29(m, 0.4H), 7.24(m, 1H), 7.21-7.15(m, 1.8H), 7.07(d, *J* = 7.6 Hz, 1H) , 6.97(d, *J* = 7.2 Hz, 0.4H), 6.71-6.61(m, 2.8H), 4.08 (m, 0.4H), 3.88 (m, 1H), 3.62-3.54 (m, 2.8H), 3.40-3.33(m, 1.4H), 3.17-3.05(m, 1.4H), 2.18(m, 0.4H), 2.07-1.88(m, 3.8H), 1.64(m, 1.4H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 192.7, 189.5, 170.2, 164.9, 155.2, 154.2, 143.7, 143.2, 137.3, 136.6, 128.4, 128.2, 127.8, 127.6, 127.2, 127.1, 125.2, 125.0, 119.3, 118.4, 117.7, 117.3, 117.2, 116.3, 116.2, 111.3, 111.2, 63.9, 55.2, 54.4, 48.1, 47.5, 37.9, 36.3, 28.1, 27.8, 23.6, 23.4; HRMS (ESI) for $C_{20}H_{18}NO_3$ $[M+H]^+$ calcd 320.1281, found 320.1278.



3af

(6S,6aS)-6a,7,8,9,10,11-hexahydro-5*H*-spiro[azepino[1,2-a]quinoline-6,3'-chromane]-2',4'-dione (3af)

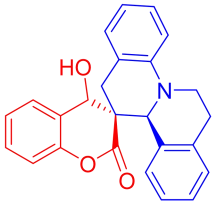
Yield: 87%, yellow solid; ^{1}H NMR (400 MHz, DMSO) δ 7.91-7.85 (m, 1.8H), 7.71-7.64 (m, 1.8H), 7.30-7.26 (m, 1.8H), 7.25-7.18 (m, 3.6H), 7.10 (t, *J* = 7.6 Hz, 1.8H), 6.80-6.73 (m, 1.8H), 6.70-6.65 (m, 1.8H), 3.90 (m, 1H), 3.80-3.63 (m, 3.6H), 3.51-3.39 (m, 1.8H), 3.12-3.05 (m, 1.8H) , 2.97 (m, 0.8H), 2.01 (m, 1.8H), 1.67-1.26 (m, 12.6H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 191.1, 191.0, 167.8, 167.6, 154.8, 154.3, 136.9, 136.4, 129.0, 128.8, 127.4, 127.2, 127.0, 126.8, 124.9, 119.1, 117.8, 117.4, 117.2, 112.6, 111.5, 65.6, 64.3, 60.1, 59.4, 50.7, 50.4, 30.2, 29.6, 28.8, 28.0, 27.7, 26.4, 26.1, 25.7, 25.6, 25.2; HRMS (ESI) for $C_{22}H_{22}NO_3$ $[M+H]^+$ calcd 348.1594, found 348.1598.



3ag

3-(2-(benzylamino)benzyl)-4-hydroxy-2H-chromen-2-one (3ag)

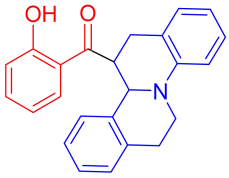
Yield: 80%, white solid, mp: 204-206 °C; ^{1}H NMR (400 MHz, DMSO) δ 7.97 (d, *J* = 8.0, 1H), 7.67–7.56 (t, *J* = 8.0, 1H), 7.44–7.31 (m, 6H), 7.23 (m, 1H), 6.92 (m, 2H), 6.58 (m, 2H), 4.42 (s, 2H), 3.77 (s, 2H); ^{13}C NMR (101 MHz, DMSO) δ 163.8, 162.6, 152.6, 145.0, 134.0, 132.3, 128.8, 128.2, 127.9, 127.3, 127.2, 125.5, 124.3, 123.8, 118.2, 117.1, 116.7, 112.6, 48.1, 25.7; HRMS (ESI) for $C_{23}H_{20}NO_3$ $[M+H]^+$ calcd 358.1438, found 358.1432.



4aa

4-hydroxy-7',11b'-dihydro-6'H,13'H-spiro[chromane-3,12'-isoquinolino[2,1-a]quinolin]-2-one (4aa)

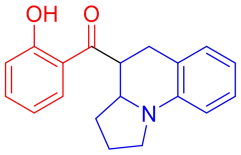
Yield: 97%, white solid, mp >250 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.76-7.68 (m, 2H), 7.38 (td, *J* = 8.4, 1.6 Hz, 1H), 7.28-7.10 (m, 9H), 4.40-4.24 (m, 2H), 3.94 (s, 2H), 3.65-3.35 (m, 3H), 3.10-2.90 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 164.2, 162.8, 152.5, 147.1, 135.5, 132.9, 132.7, 132.2, 131.3, 129.1, 128.1, 127.3, 127.1, 126.5, 123.6, 123.4, 120.4, 117.0, 116.2, 103.7, 51.9, 27.8, 25.6; HRMS (ESI) for $C_{25}H_{22}NO_3$ $[M+H]^+$ calcd 384.1594, found 384.1596.



5aa

(2-hydroxyphenyl)(7,11b,12,13-tetrahydro-6H-isoquinolino[2,1-a]quinolin-12-yl)methanone (5aa)

Yield: 85%, light yellow solid, mp: 186-187 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 12.40 (s, 1H), 7.65 (d, *J* = 8.0 Hz, 1H), 7.46 (t, *J* = 7.6 Hz, 1H), 7.17 (t, *J* = 7.6 Hz, 1H), 7.13-6.95 (m, 5H), 6.91-6.80 (m, 3H), 6.73 (t, *J* = 7.6 Hz, 1H), 5.04 (d, *J* = 8.0 Hz, 1H), 4.09 (m, 1H), 3.93-3.85 (m, 1H), 3.56-3.47 (m, 1H), 3.25-3.08 (m, 2H), 3.01-2.97 (m, 1H), 2.91-2.87 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 206.9, 163.3, 145.6, 137.2, 136.7, 135.9, 129.6, 128.6, 128.1, 127.6, 126.9, 126.4, 125.7, 123.7, 119.2, 118.9, 117.7, 112.9, 58.6, 46.1, 45.9, 31.7, 27.9; HRMS (ESI) for $C_{24}H_{22}NO_2$ $[M+H]^+$ calcd 356.1645, found 356.1635.

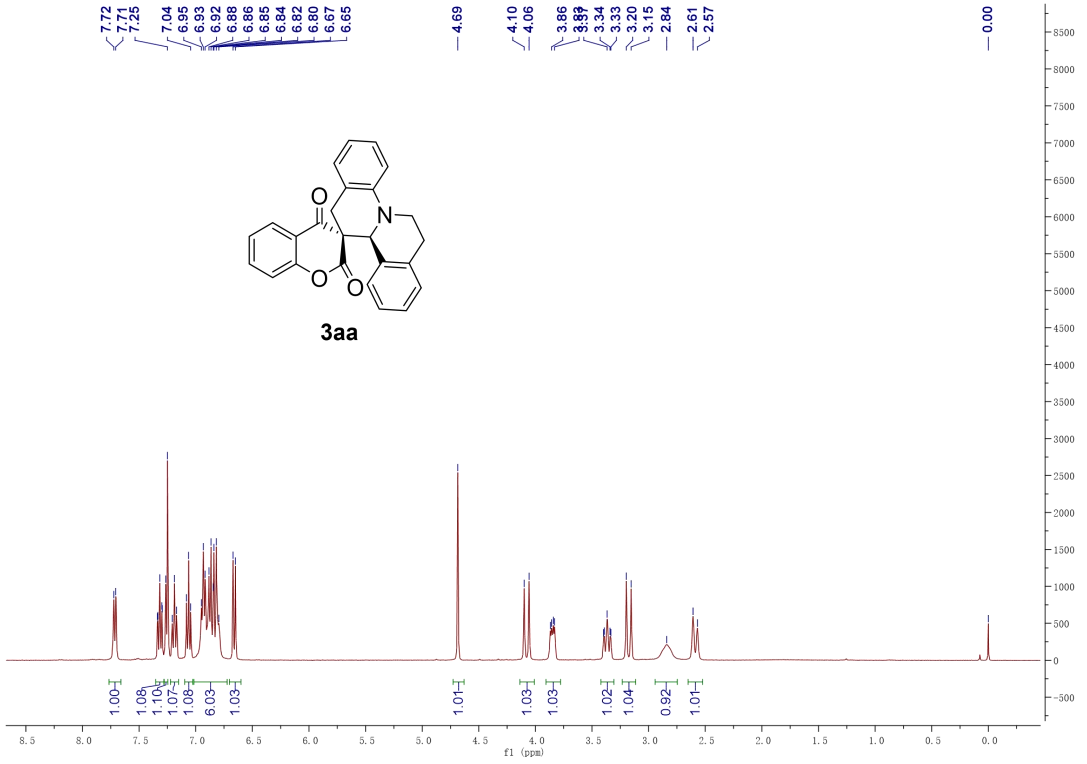


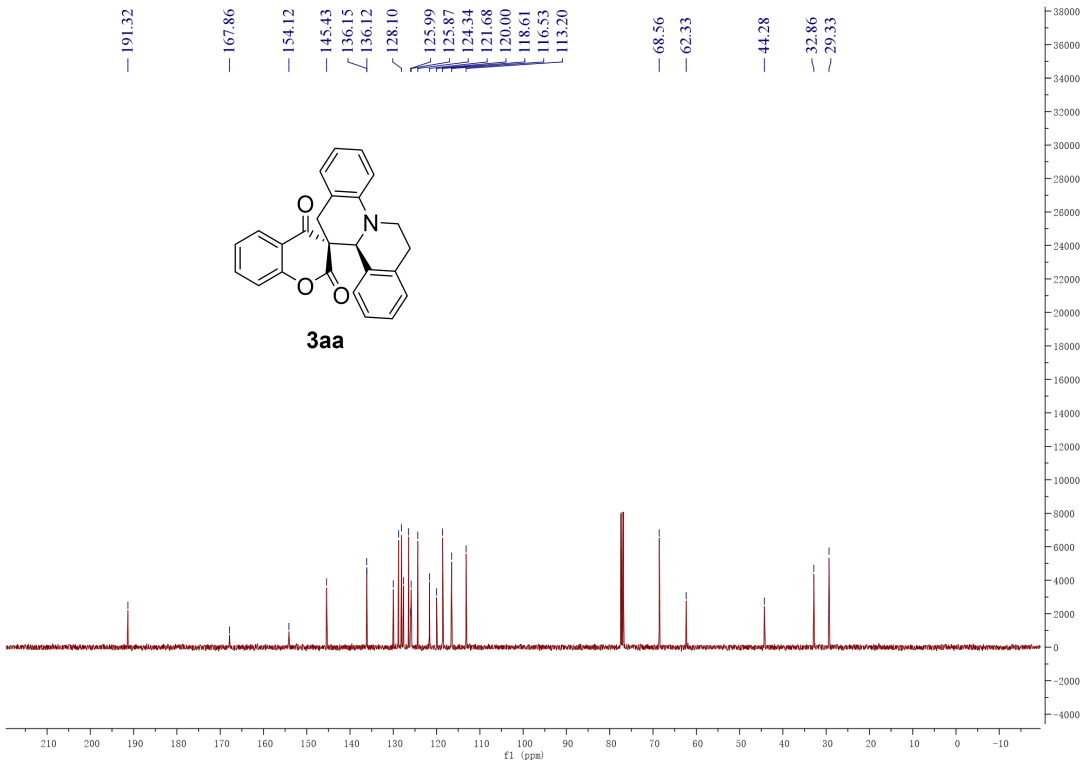
5ae

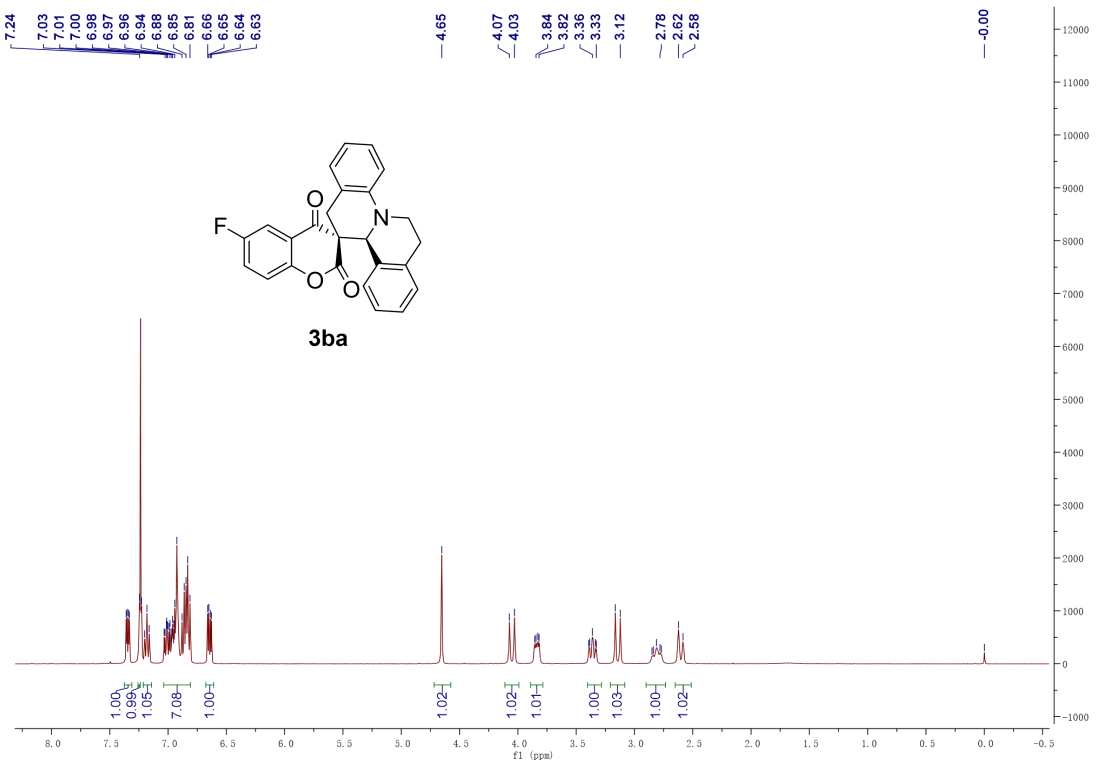
(1,2,3,3a,4,5-hexahydropyrrolo[1,2-a]quinolin-4-yl)(2-hydroxyphenyl)methanone (5ae)

Yield: 90%, light yellow solid, mp: 158-160 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 12.52 (s, 1H), 7.79 (dd, *J* = 8.4, 1.2 Hz, 1H), 7.49 (td, *J* = 8.4, 1.2 Hz, 1H), 7.14 (t, *J* = 7.6 Hz, 1H), 7.05-7.00 (m, 2H), 6.89 (t, *J* = 8.0 Hz, 1H), 6.60 (t, *J* = 7.2 Hz, 1H), 6.50 (d, *J* = 8.0 Hz, 1H), 3.78-3.70 (m, 1H), 3.45 (td, *J* = 8.8, 1.6 Hz, 1H), 3.37 (td, *J* = 8.0, 4.0 Hz, 1H), 3.30-3.22 (m, 1H), 3.12-3.05 (m, 1H), 2.99-2.93 (m, 1H), 2.14-1.91 (m, 3H), 1.47-1.36 (m, 1H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 209.0, 163.1, 143.8, 136.8, 130.1, 128.6, 127.9, 120.1, 119.4, 119.1, 118.9, 115.2, 110.4, 60.0, 47.1, 43.9, 33.8, 31.6, 24.0; HRMS (ESI) for $C_{19}H_{20}NO_2$ $[M+H]^+$ calcd 294.1489, found 294.1481.

5. Copies of NMR spectra



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3.82
3.36
3.33
3.12
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2.62
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O
N
O
O
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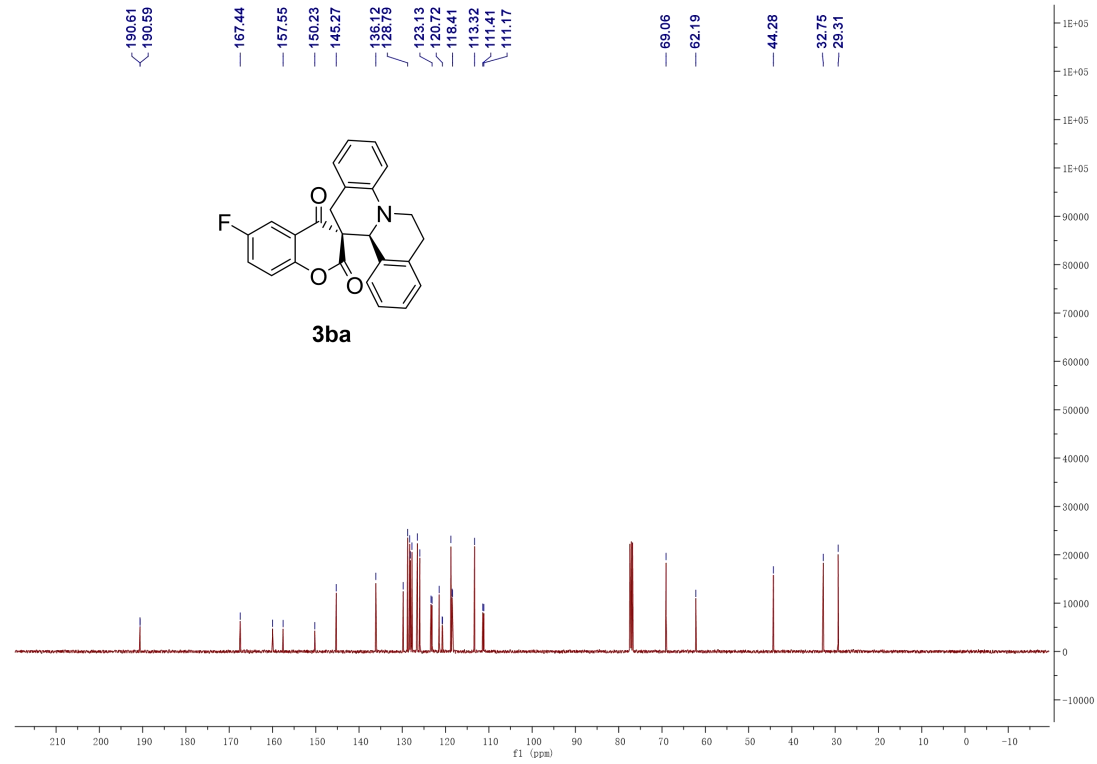
1.01
1.00
1.03
1.00
1.02
f1 (ppm)

3ba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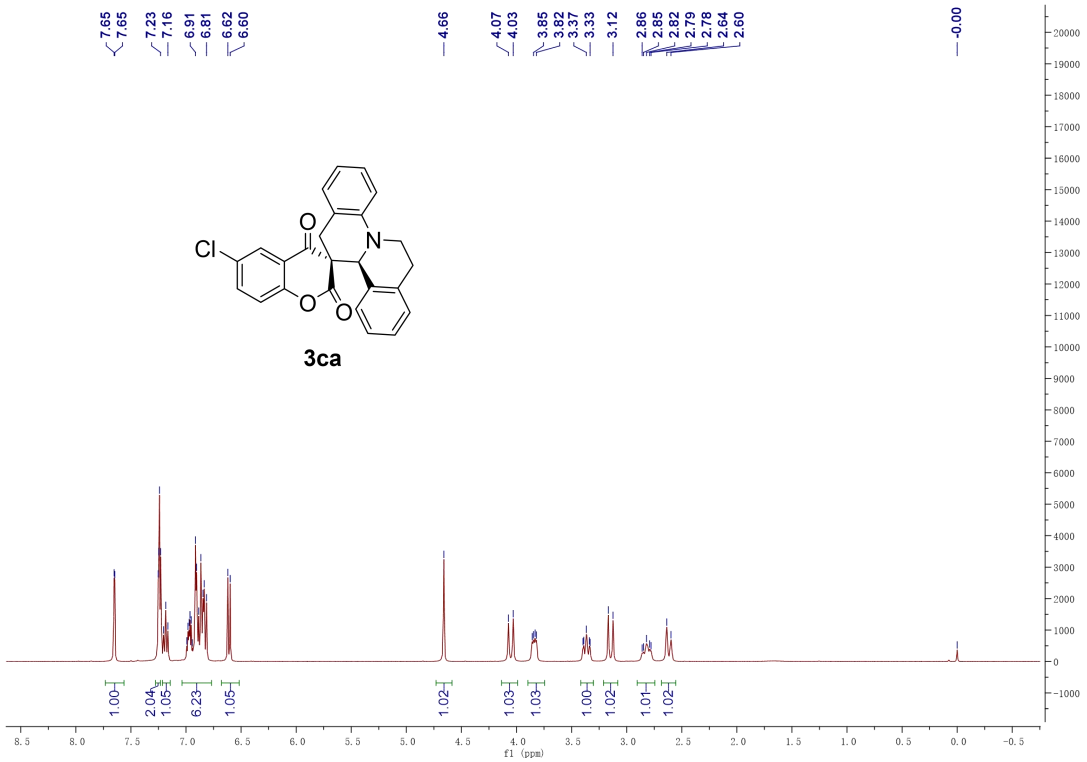
32.75
29.31
F
O
N
O
O
f1 (ppm)

3ba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N
O
O
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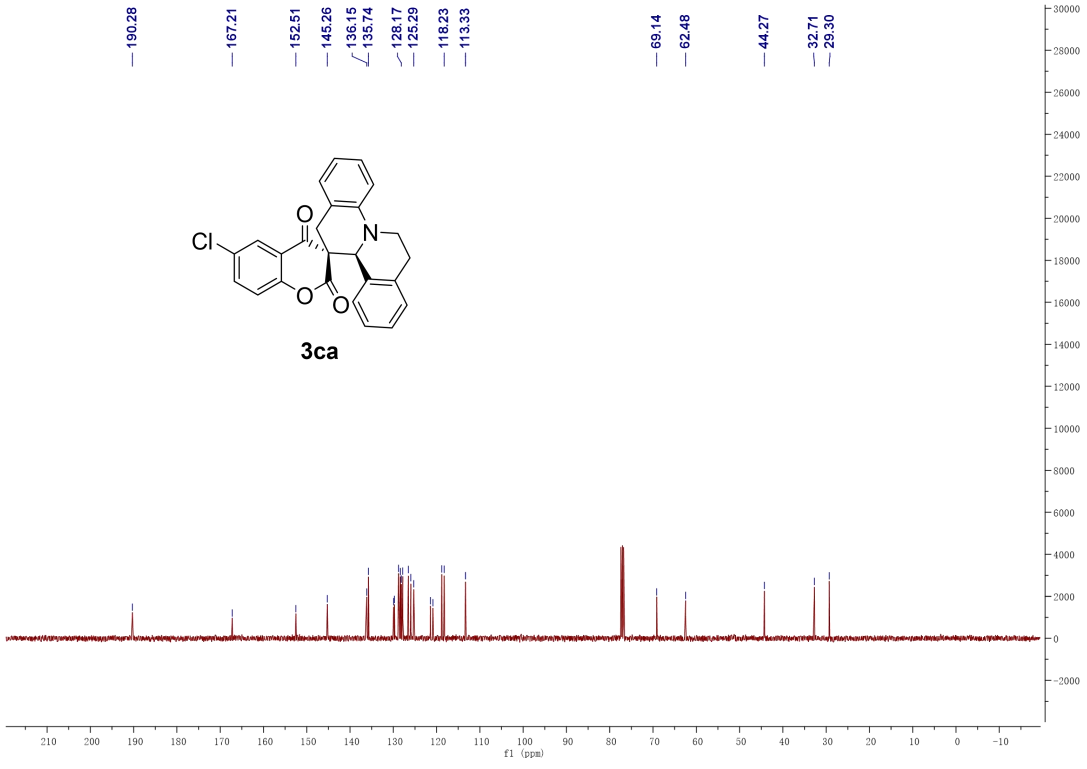
1.02
1.01
1.02
f1 (ppm)

3ca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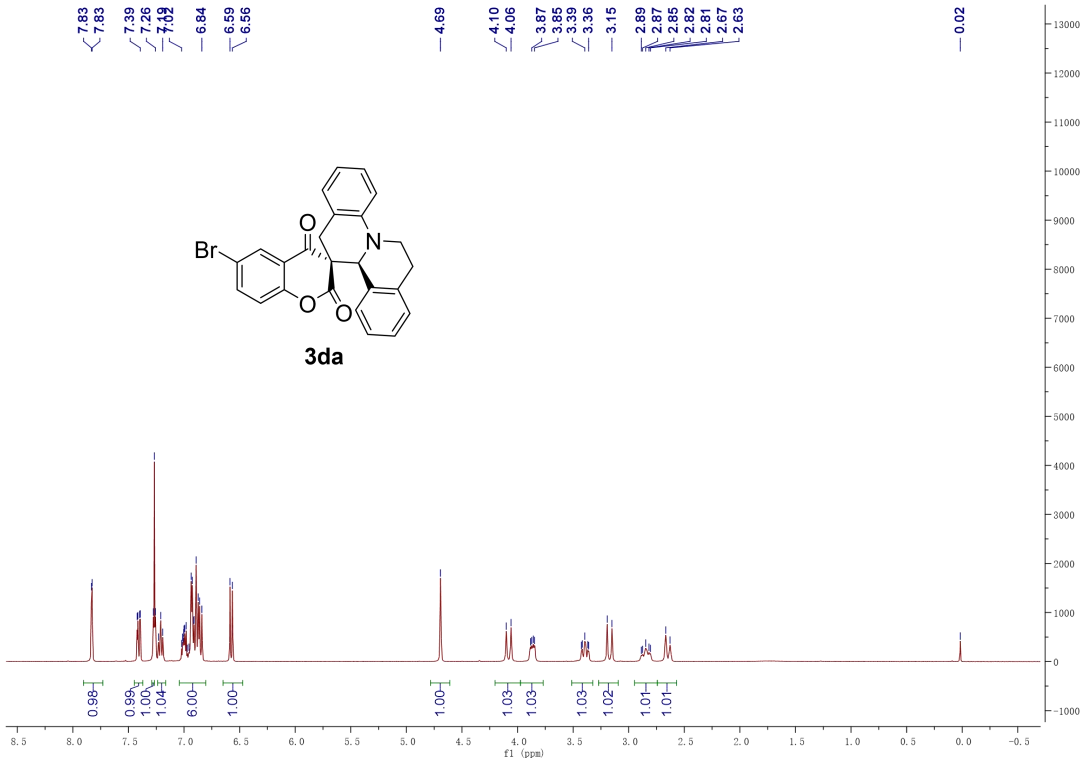
O
f1 (ppm)

3ca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N
O
O
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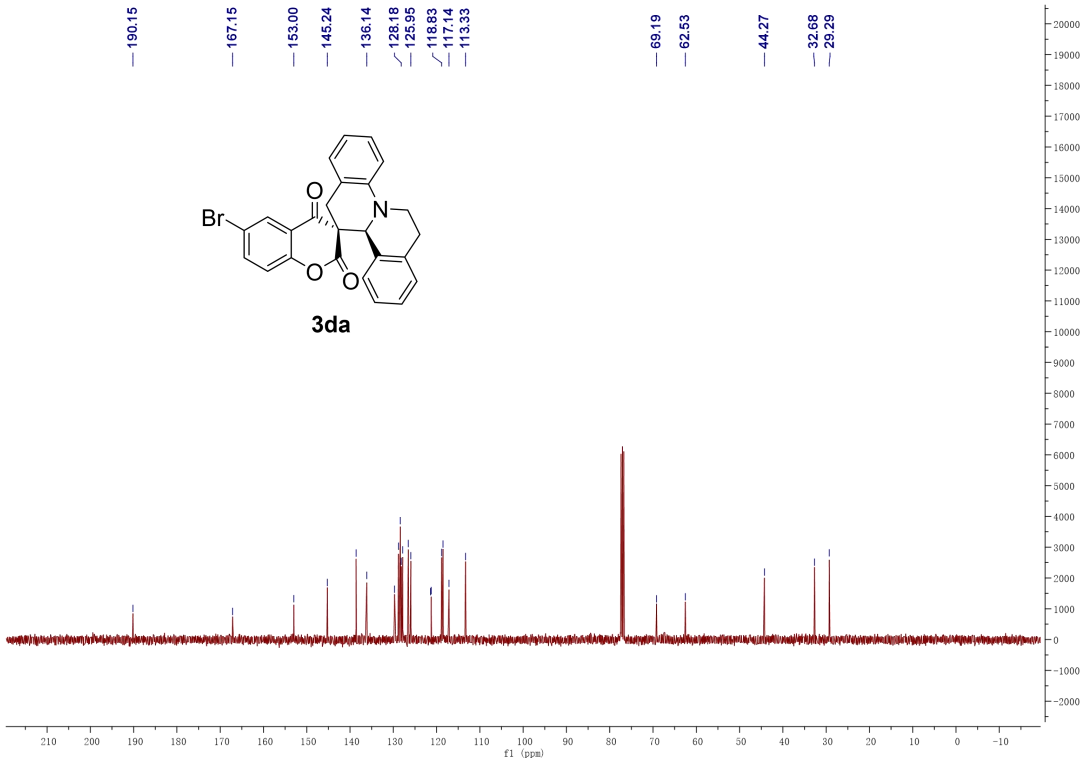
f1 (ppm)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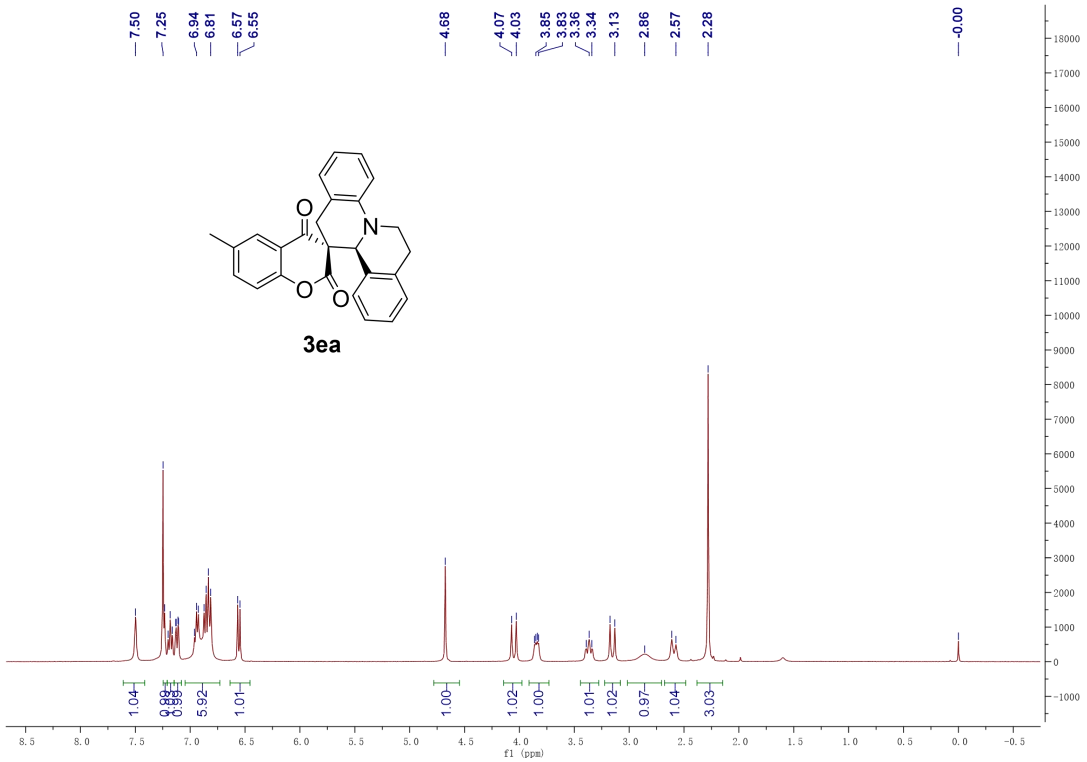
3da
f1 (ppm)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3.13
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2.57
2.28
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0.89
0.89
0.99
5.92
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1.02
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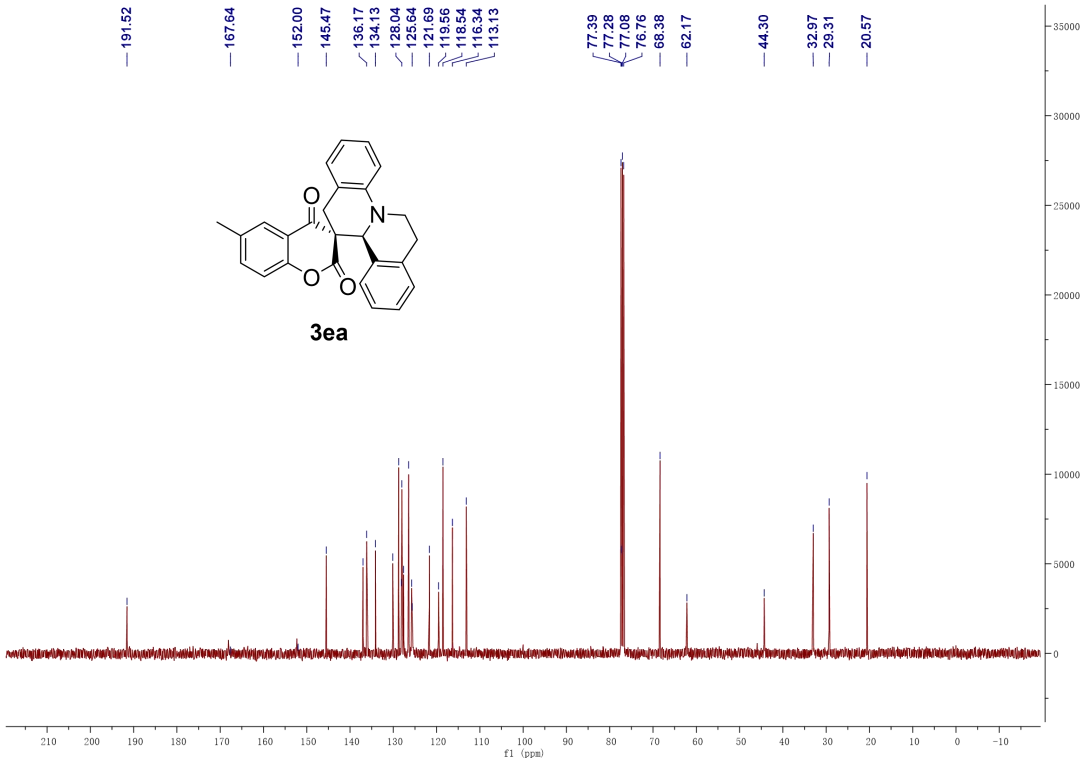
1.01
1.02
0.97
1.04
3.03
f1 (ppm)

3ea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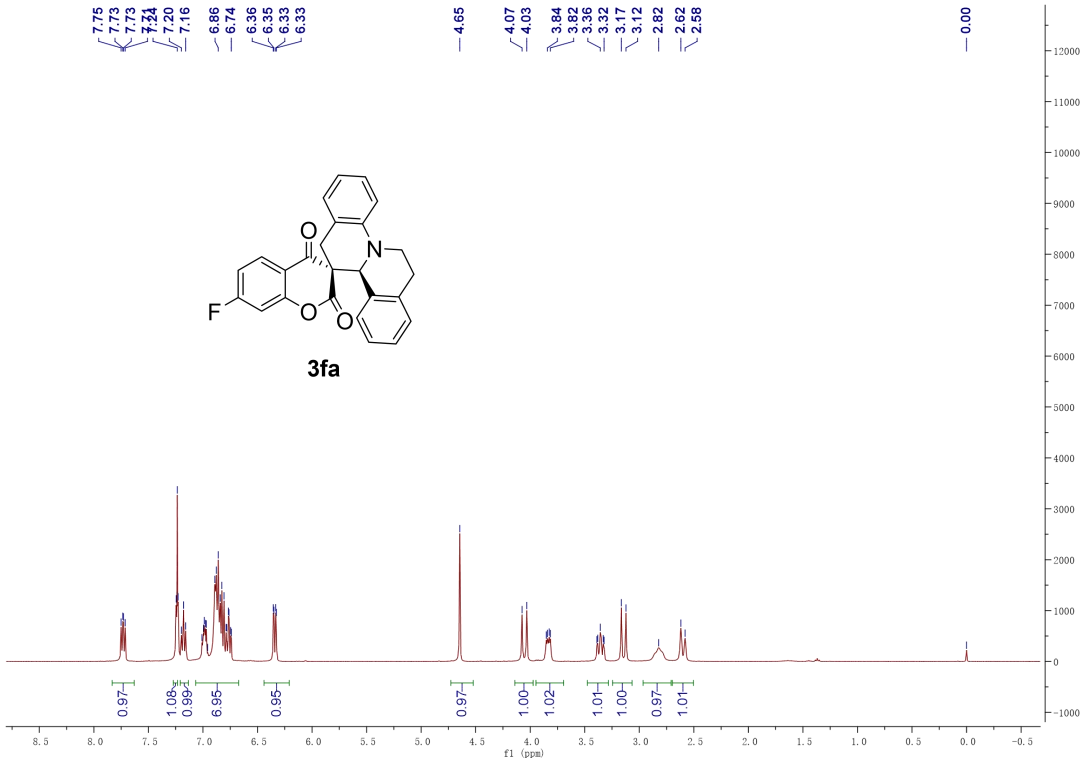
32.97
29.31
20.57
f1 (ppm)

3ea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4.03
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F
O
O
O
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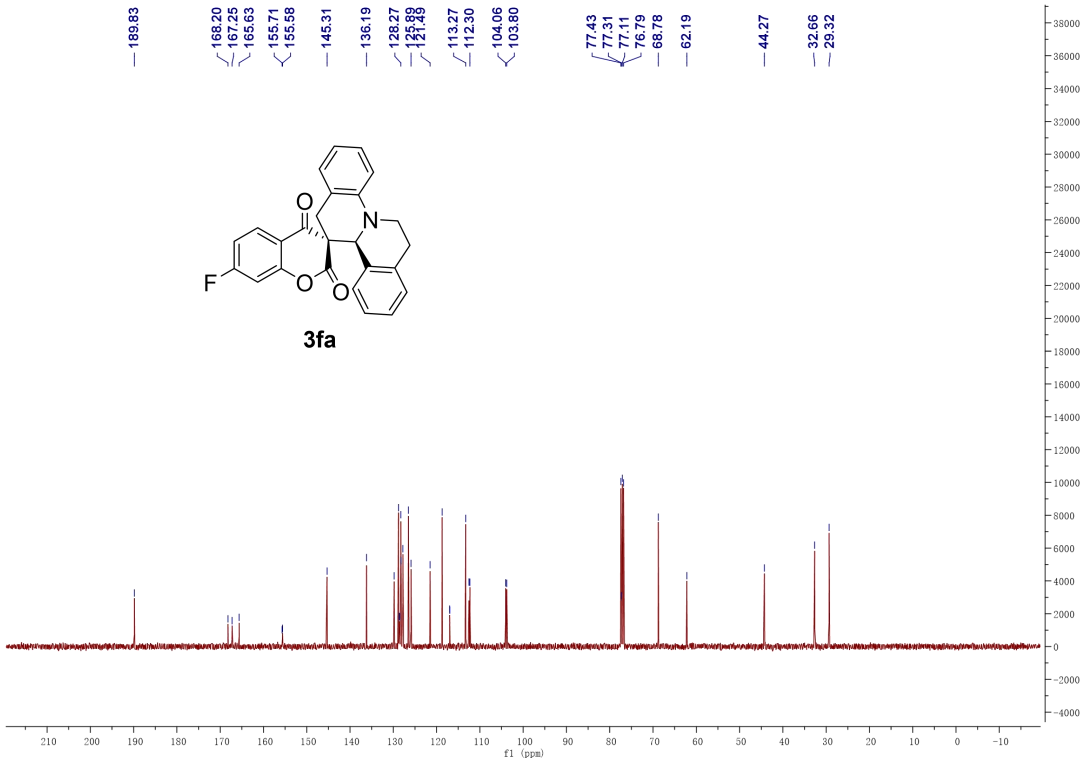
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77.43
77.31
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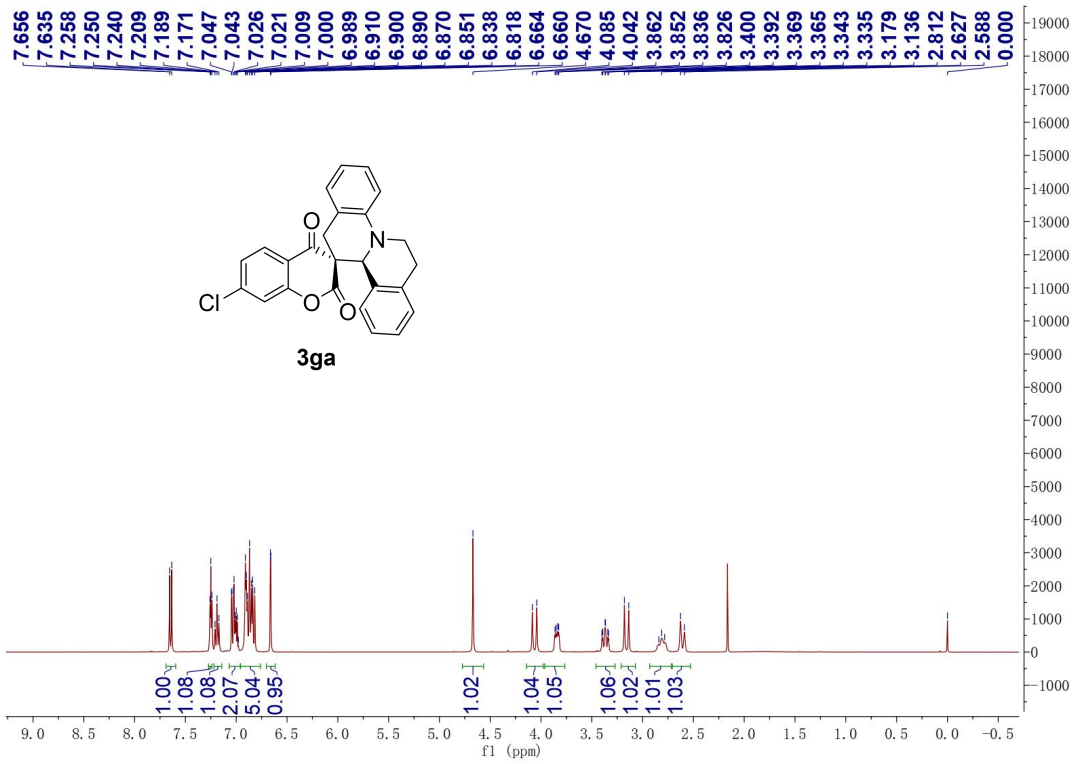
f1 (ppm)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6.870
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6.838
6.818
6.664
6.660
4.670
4.085
4.042
3.862
3.852
3.836
3.826
3.400
3.392
3.369
3.365
3.343
3.335
3.179
3.136
2.812
2.627
2.588
0.000
O
N
Cl
O
O
3ga
1.00
1.08
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1.04
1.05
1.06
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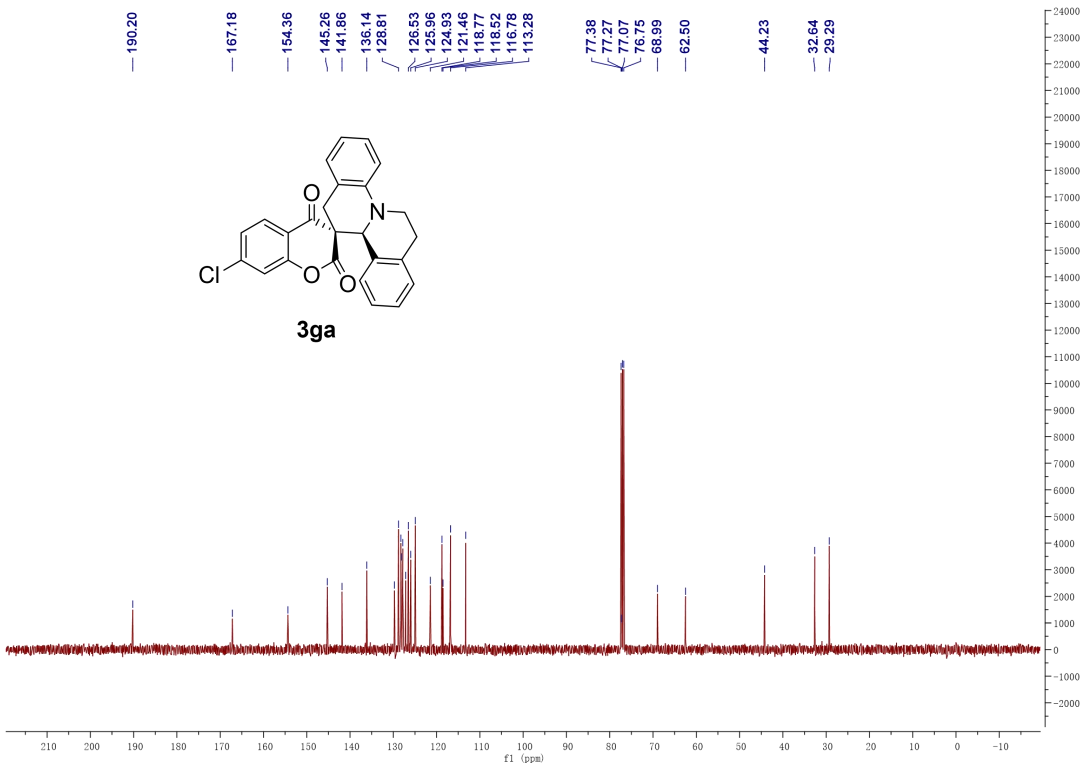
1.03
f1 (ppm)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113.28
77.38
77.27
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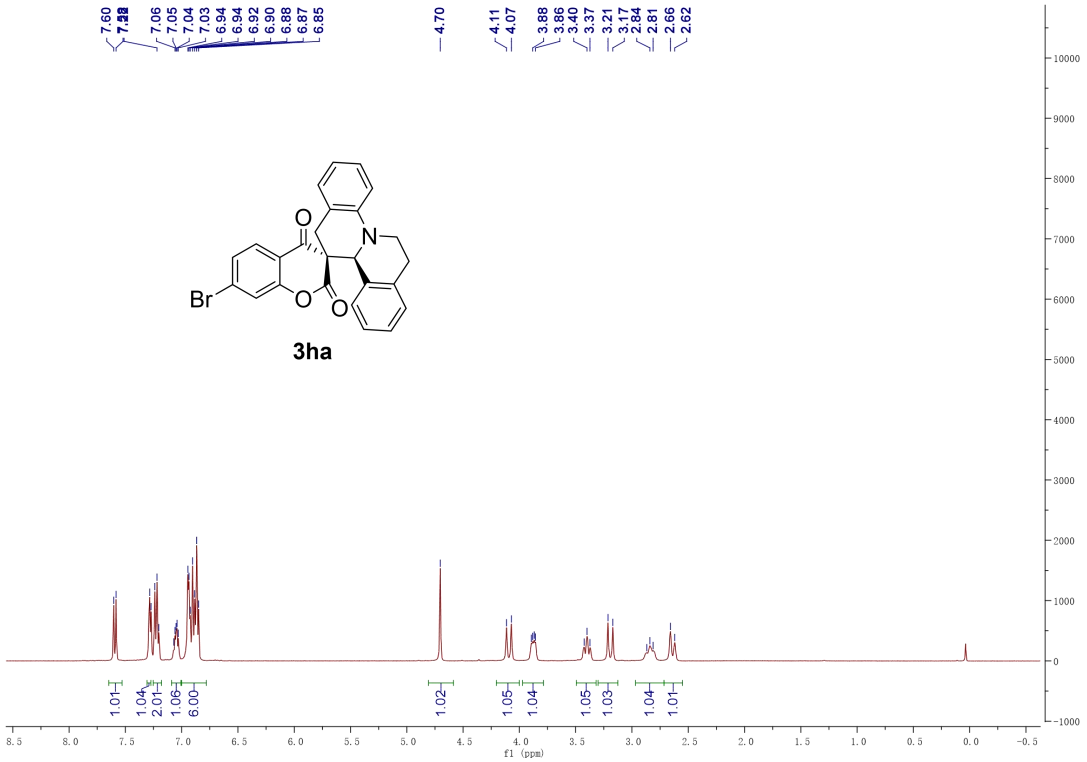
N
Cl
O
O
3ga
f1 (ppm)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4.07
3.88
3.86
3.40
3.37
3.21
3.17
2.84
2.81
2.66
2.62
O
N
Br
O
O
1.01
1.04
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1.02
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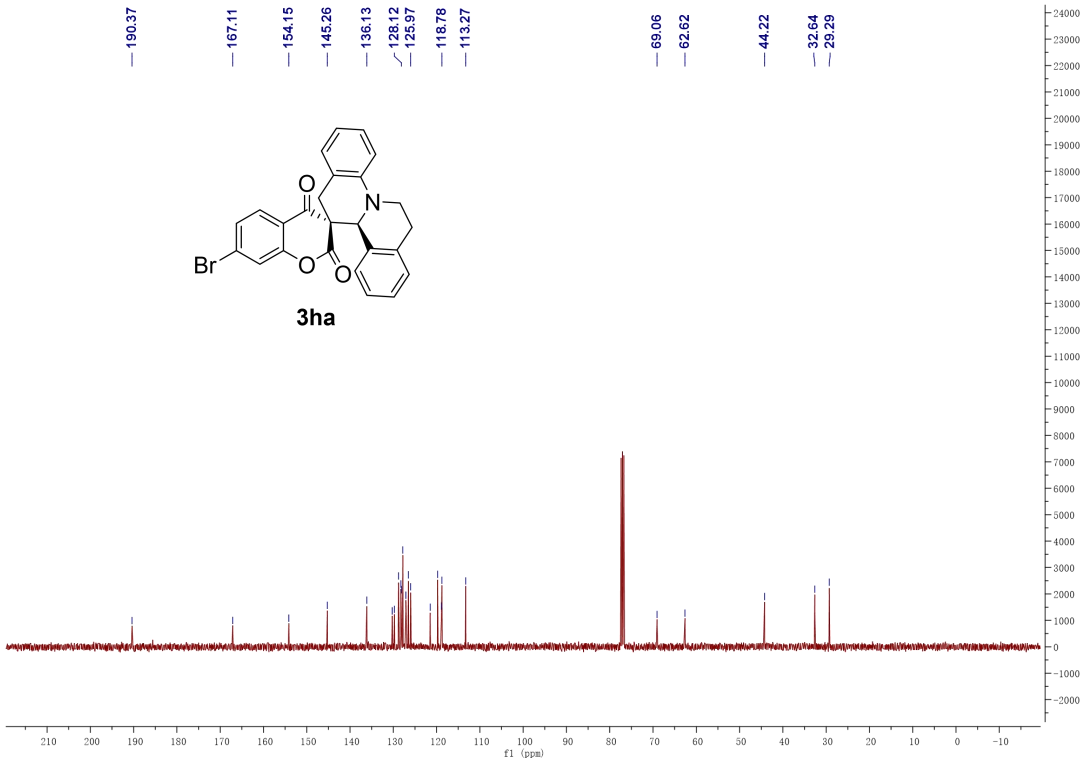
1.04
1.05
1.03
1.04
1.01
f1 (ppm)

3ha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62.62
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32.64
29.29
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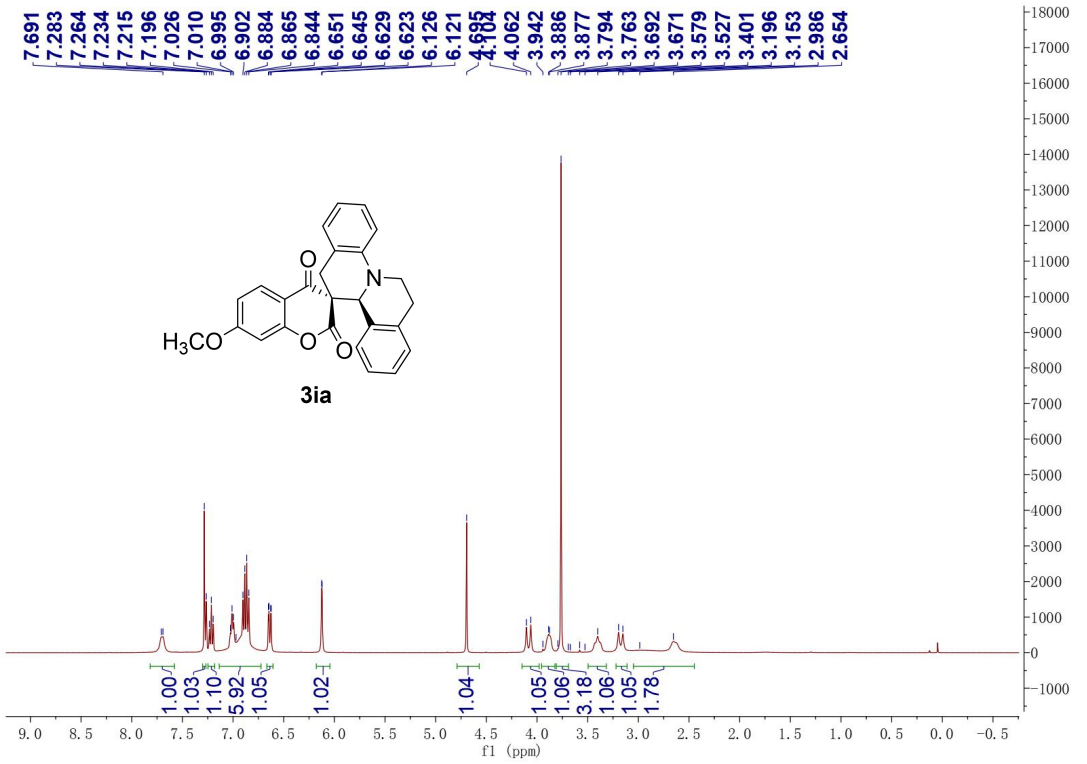
N
Br
O
O
f1 (ppm)

3ha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6.121
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3.877
3.794
3.763
3.692
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3.579
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3.401
3.196
3.153
2.986
2.654
O
N
H3CO
O
O
3ia
1.00
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1.05
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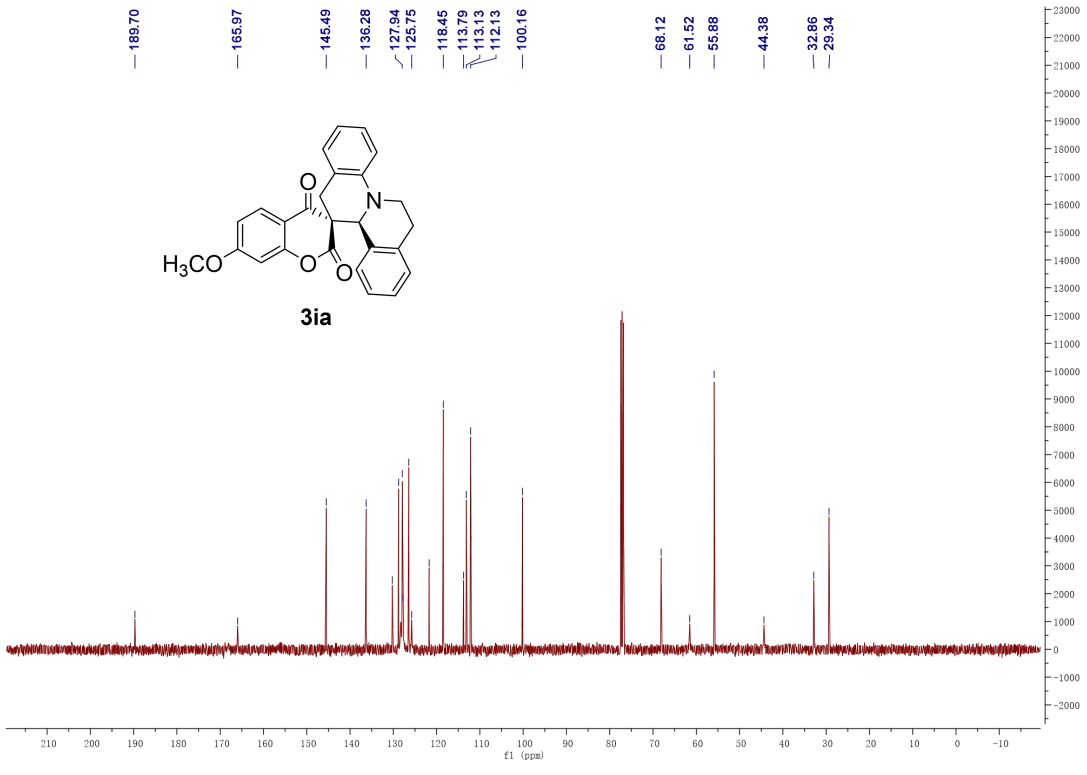
f1 (ppm)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112.13
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55.88
44.38
32.86
29.34
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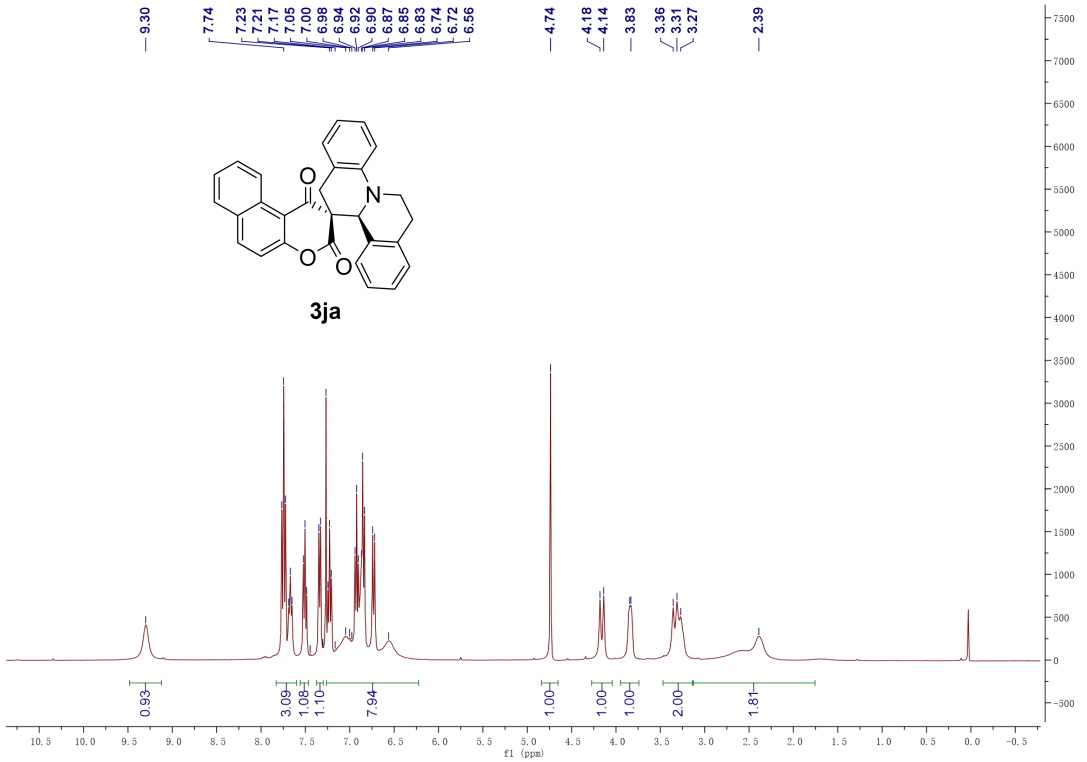
N
H3CO
O
O
3ia
f1 (ppm)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7.05
7.00
6.98
6.94
6.92
6.90
6.87
6.85
6.83
6.74
6.72
6.56
4.74
4.18
4.14
3.83
3.36
3.31
3.27
2.39
O
N
O
O
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1.00
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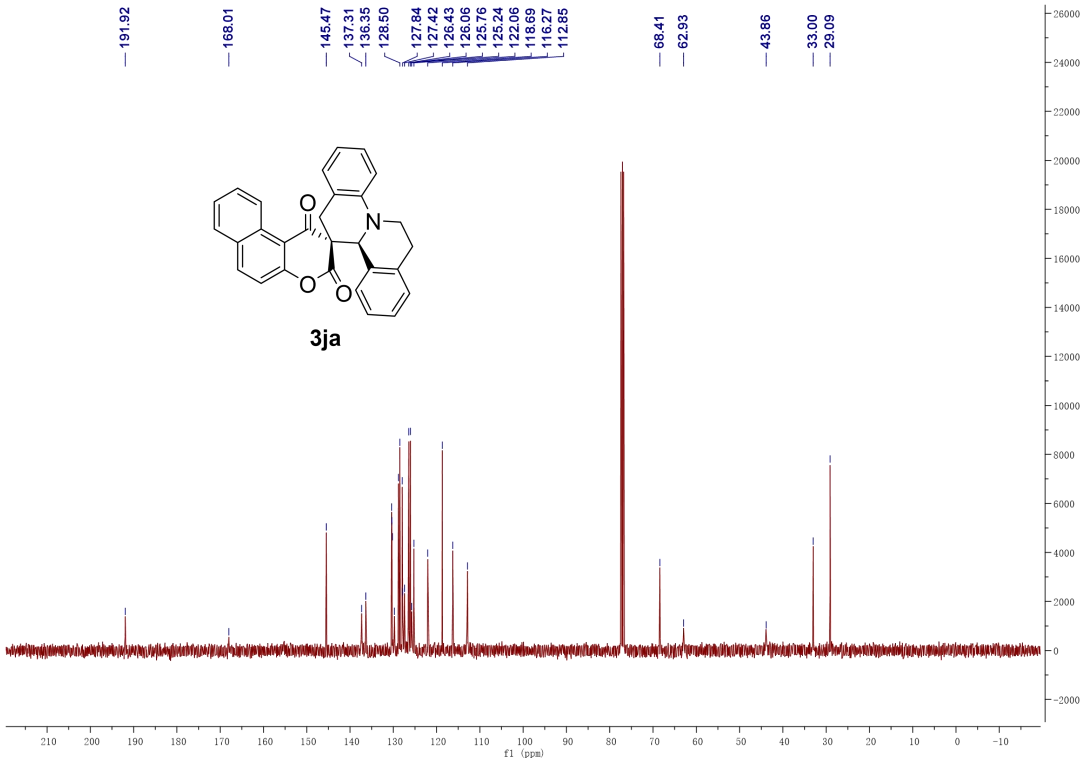
f1 (ppm)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127.42
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126.06
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122.06
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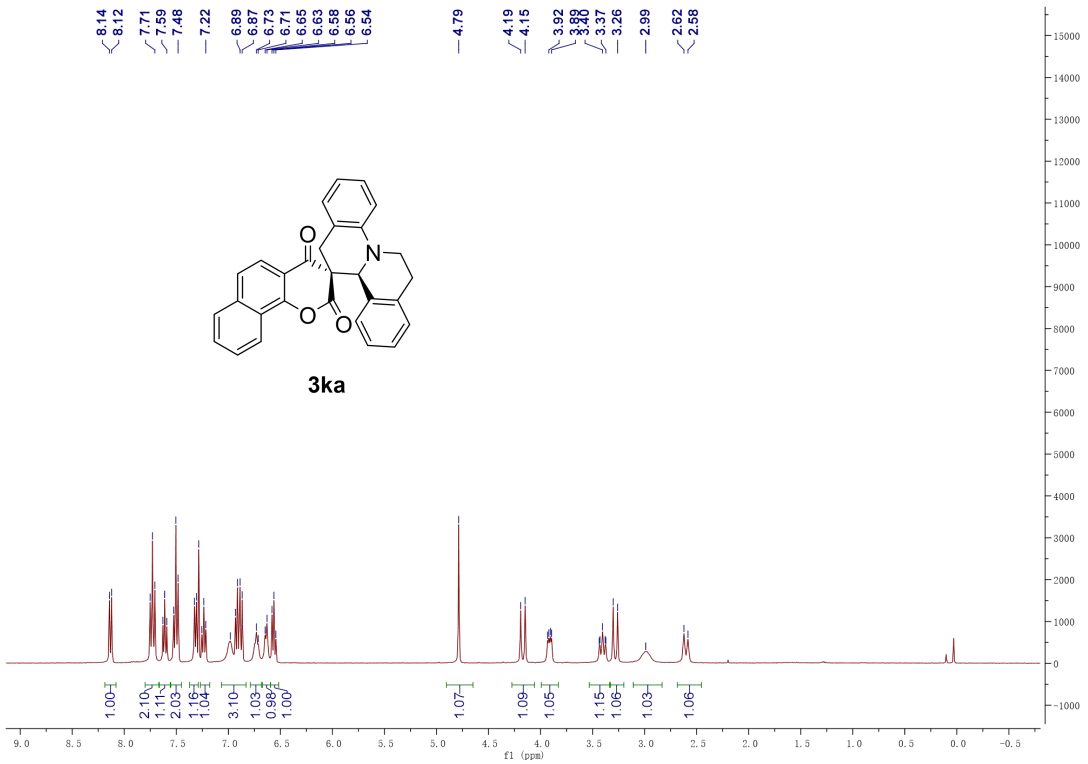
68.41
62.93
43.86
33.00
29.09
O
N
O
O
3ja
f1 (ppm)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6.87
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6.63
6.58
6.56
6.54
4.79
4.19
4.15
3.92
3.88
3.40
3.37
3.26
2.99
2.62
2.58
O
N
O
O
3ka
1.00
2.10
1.11
2.03
1.16
1.04
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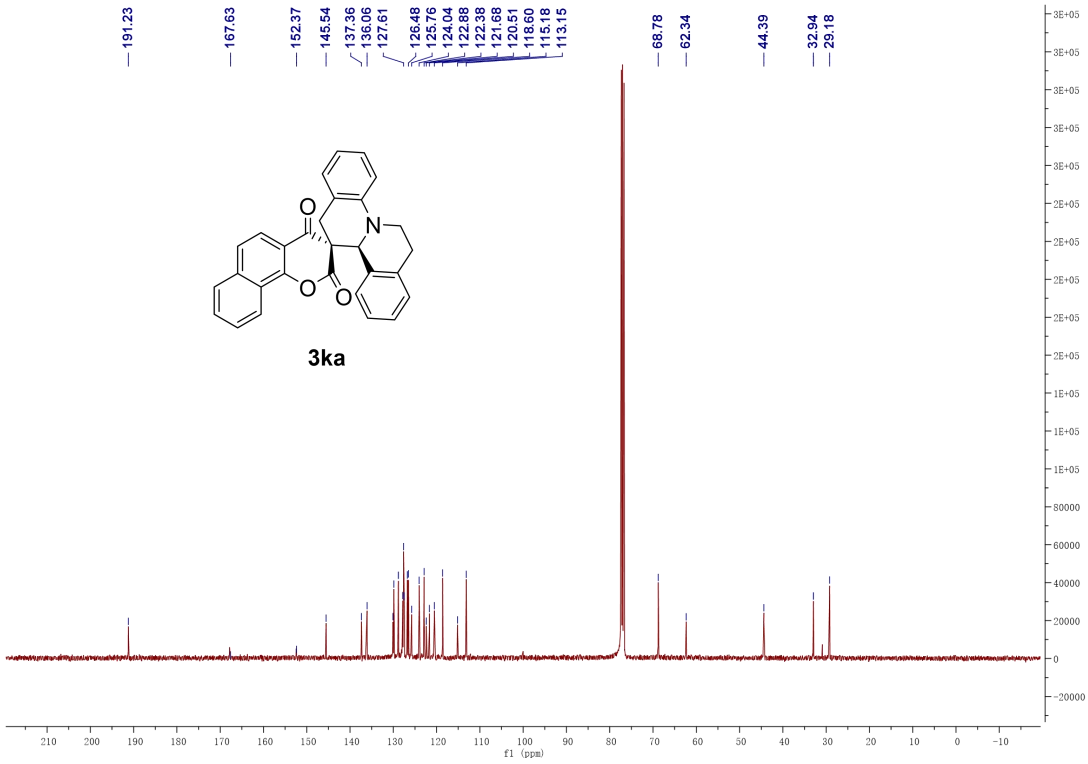
1.09
1.05
1.15
1.06
1.03
1.06
f1 (ppm)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120.51
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62.34
44.39
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O
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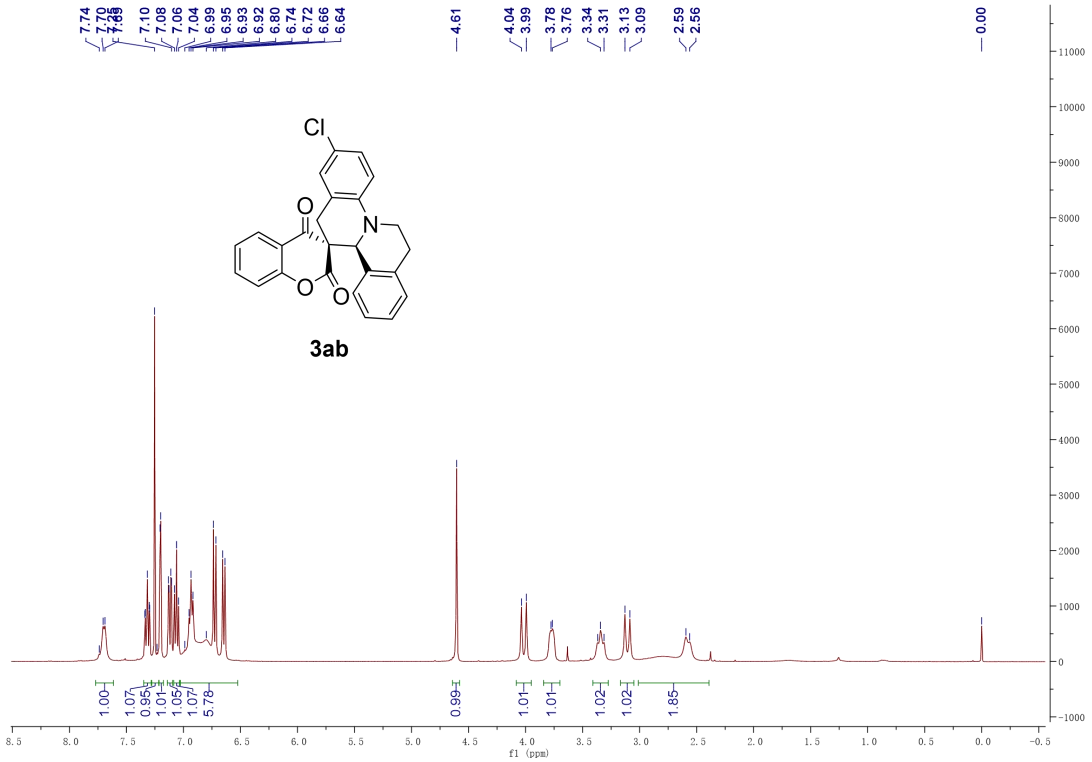
O
O
3ka
f1 (ppm)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7.06
7.04
6.99
6.95
6.93
6.92
6.80
6.74
6.72
6.66
6.64
4.61
4.04
3.99
3.78
3.76
3.34
3.31
3.13
3.09
2.59
2.56
0.00
Cl
O
N
O
O
3ab
1.00
1.07
0.95
1.01
1.05
1.07
5.78
0.99
1.01
1.01
1.02
1.02
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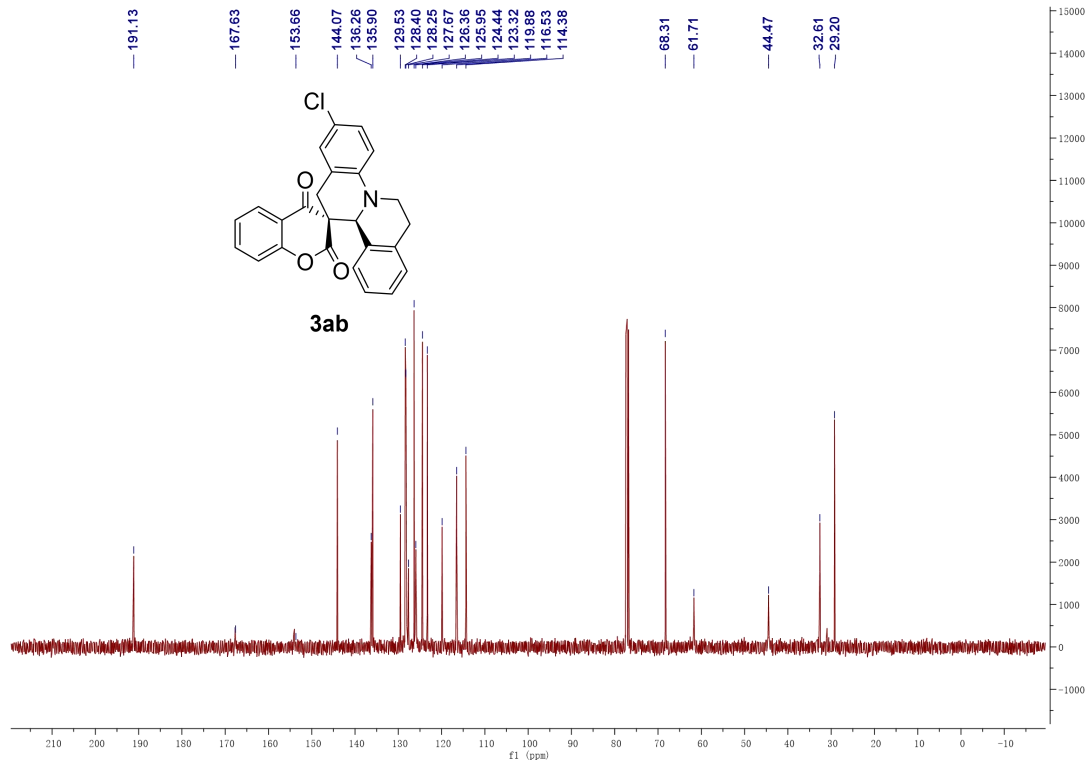
f1 (ppm)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128.40
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123.32
119.88
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61.71
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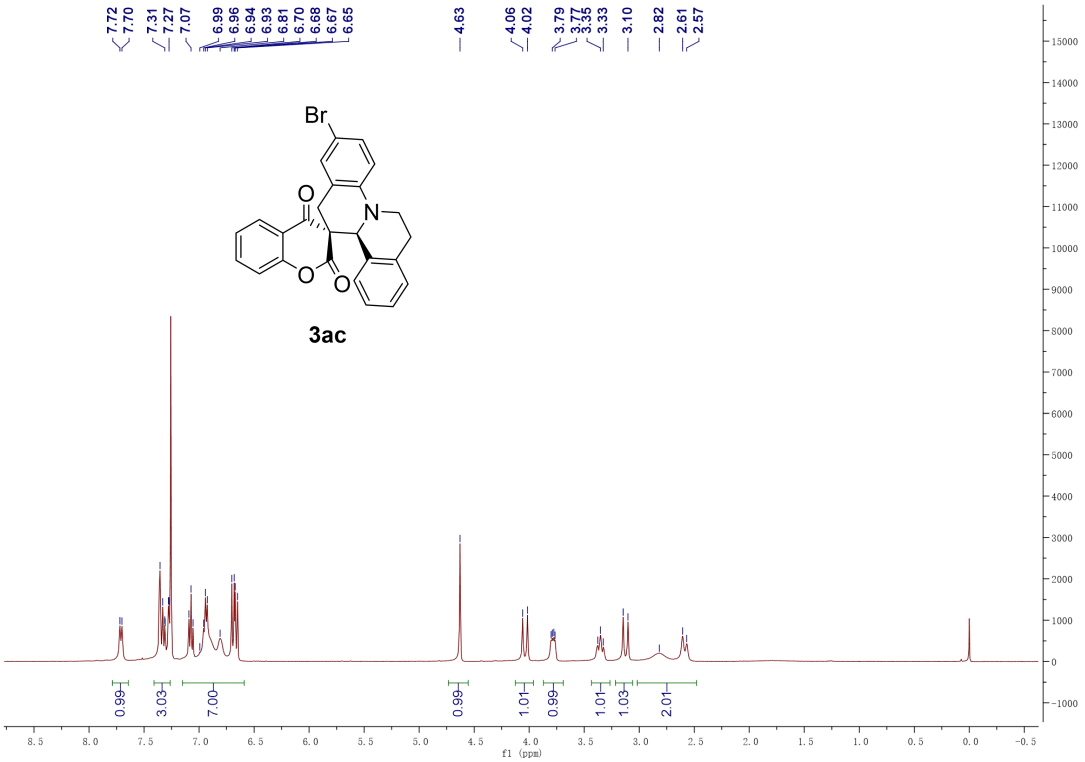
32.61
29.20
Cl
O
N
O
O
3ab
f1 (ppm)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6.99
6.96
6.94
6.93
6.81
6.70
6.68
6.67
6.65
4.63
4.06
4.02
3.79
3.77
3.35
3.33
3.10
2.82
2.61
2.57
Br
O
N
O
O
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7.00
0.99
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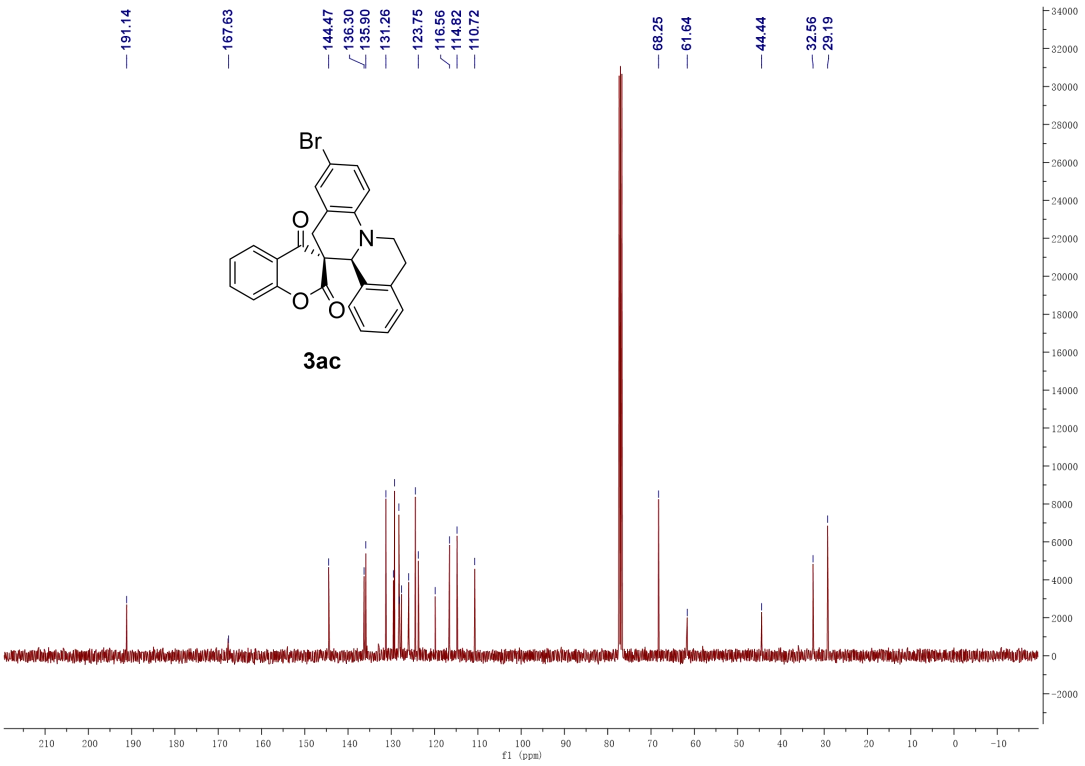
0.99
1.01
1.03
2.01
f1 (ppm)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136.30
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131.26
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116.56
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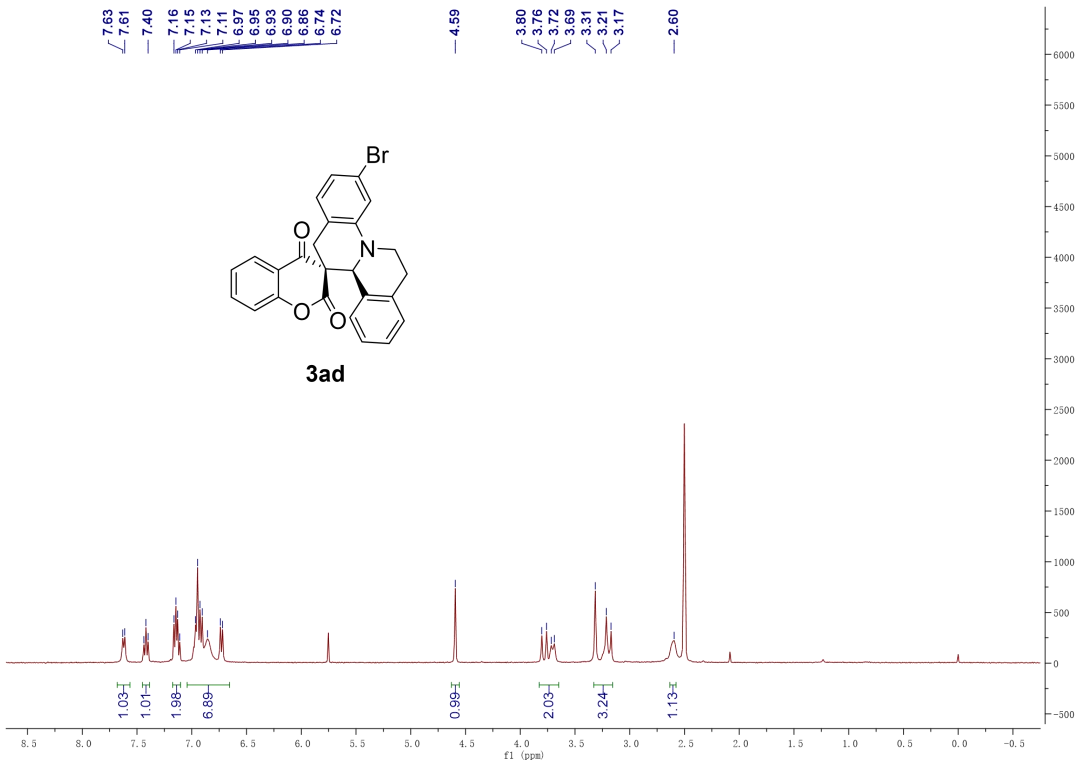
61.64
44.44
32.56
29.19
Br
O
N
O
O
3ac
f1 (ppm)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6.93
6.90
6.86
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3.76
3.72
3.69
3.31
3.21
3.17
2.60
Br
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1.01
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2.03
3.24
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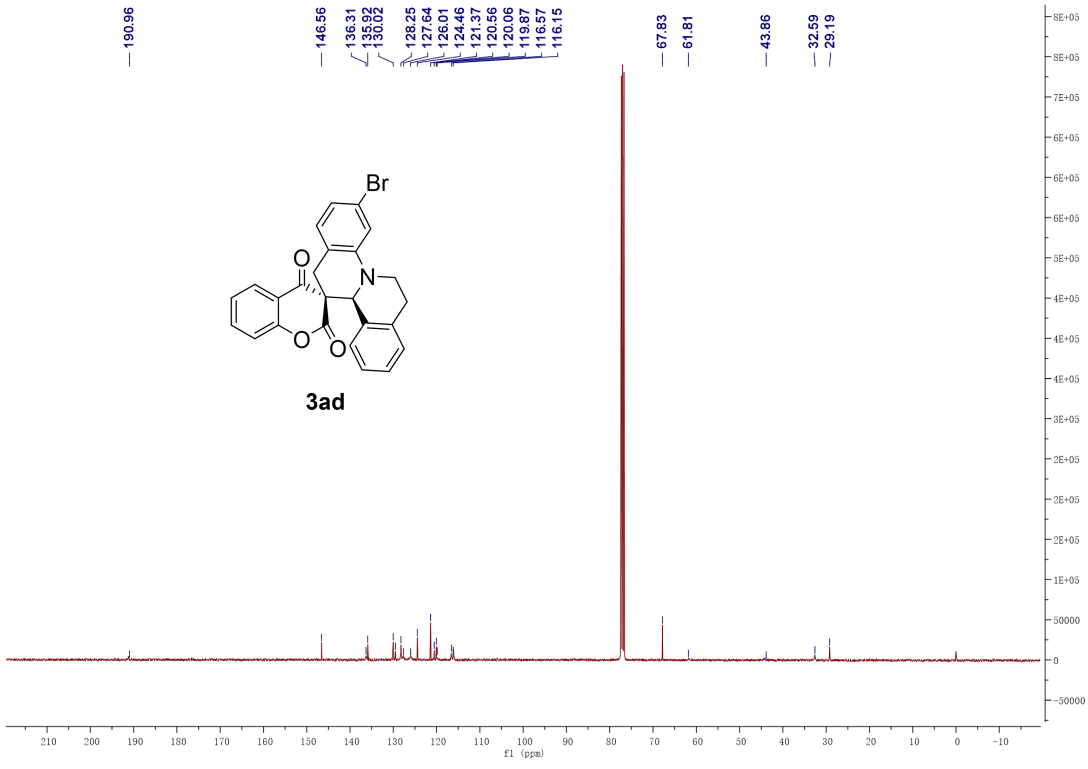
f1 (ppm)

3ad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130.02
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126.01
124.46
121.37
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120.06
119.87
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61.81
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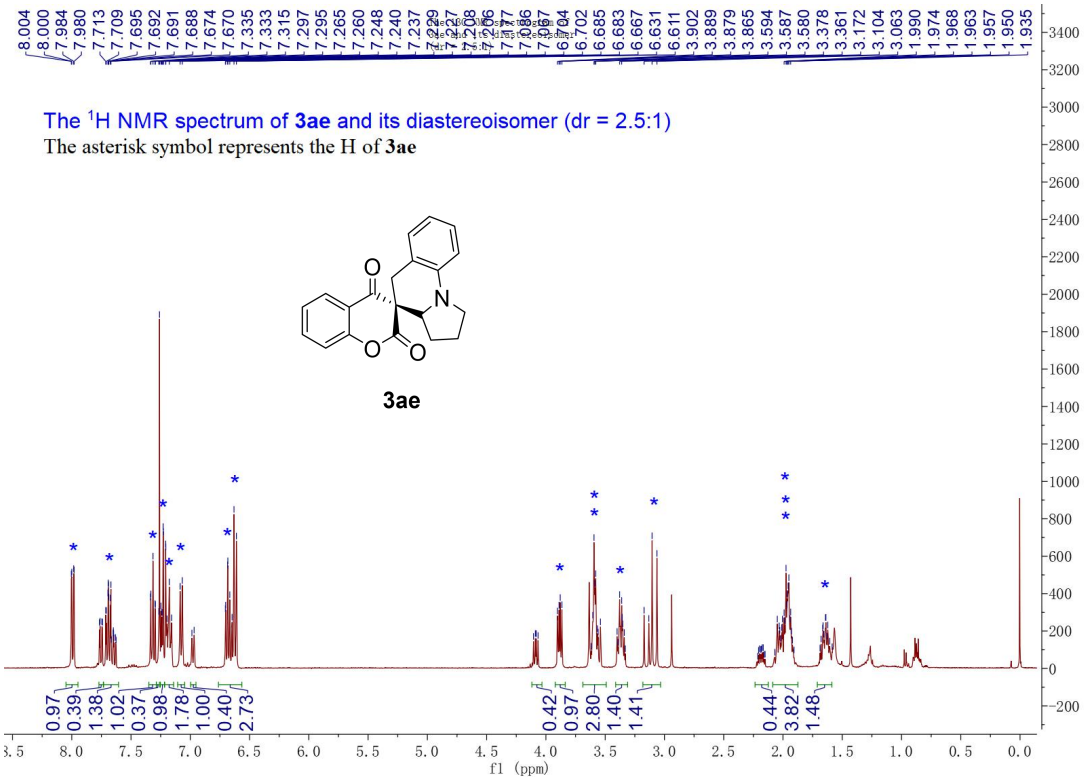
32.59
29.19
Br
O
N
O
O
f1 (ppm)

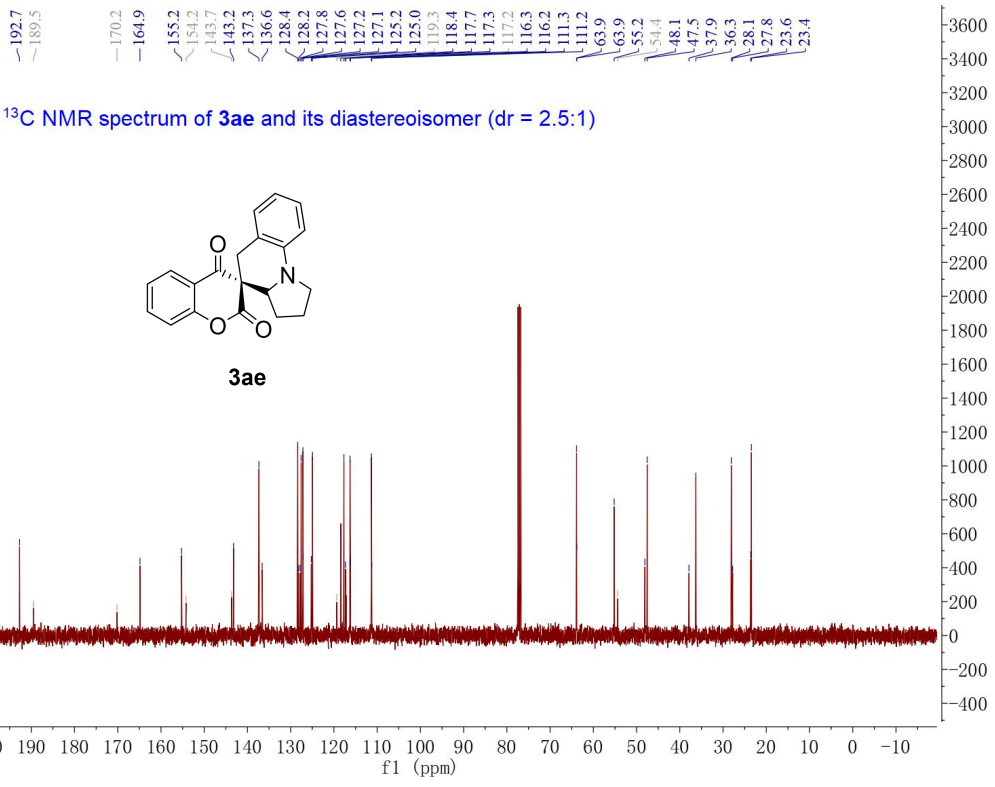
3ad



The ^{1}H NMR spectrum of **3ae** and its diastereoisomer (dr = 2.5:1)

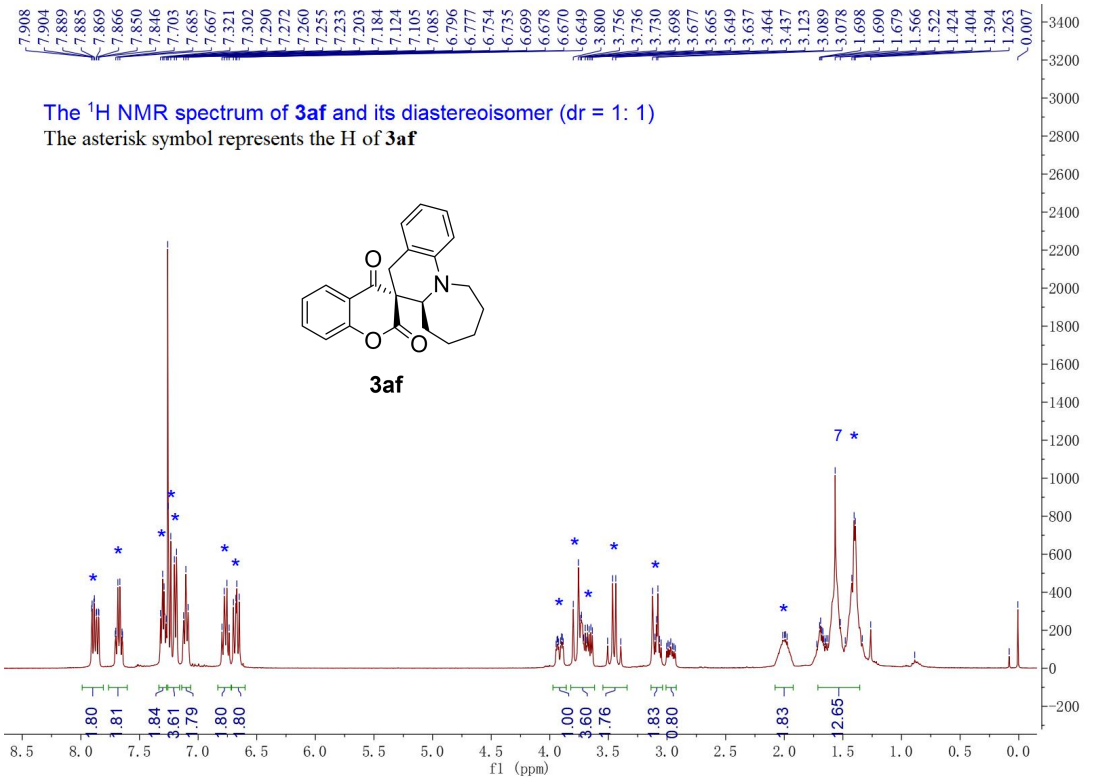
The asterisk symbol represents the H of **3ae**

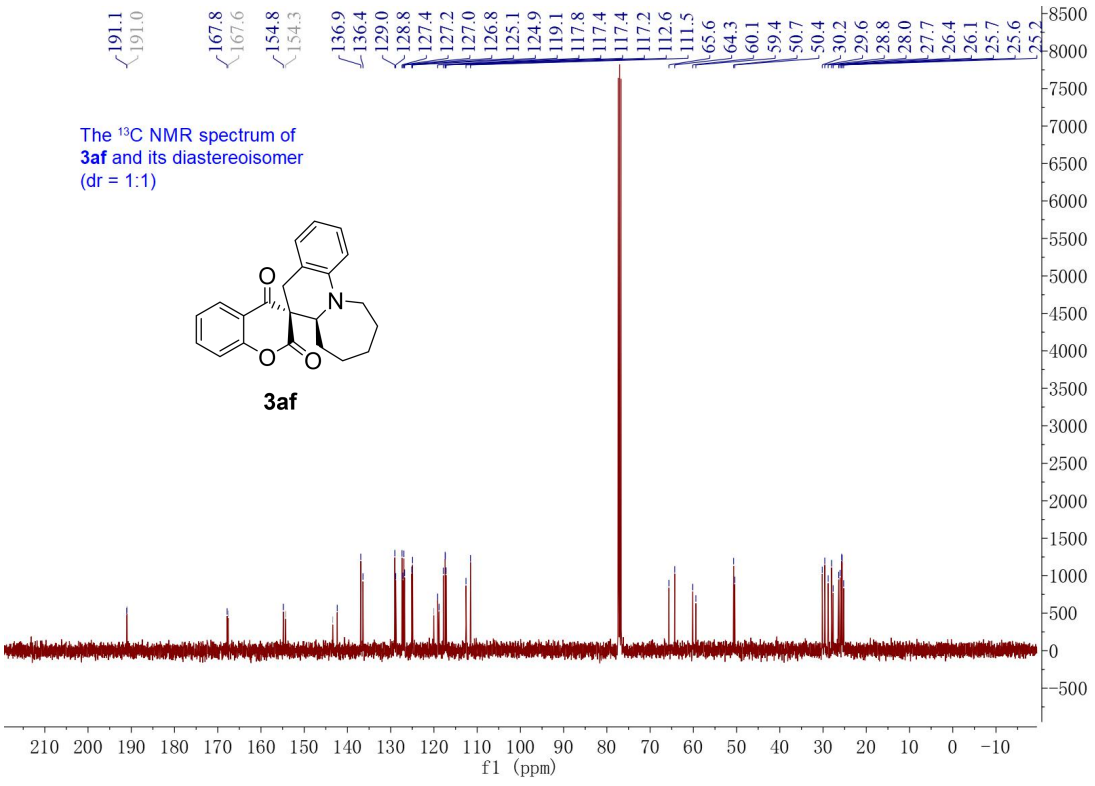
3ae

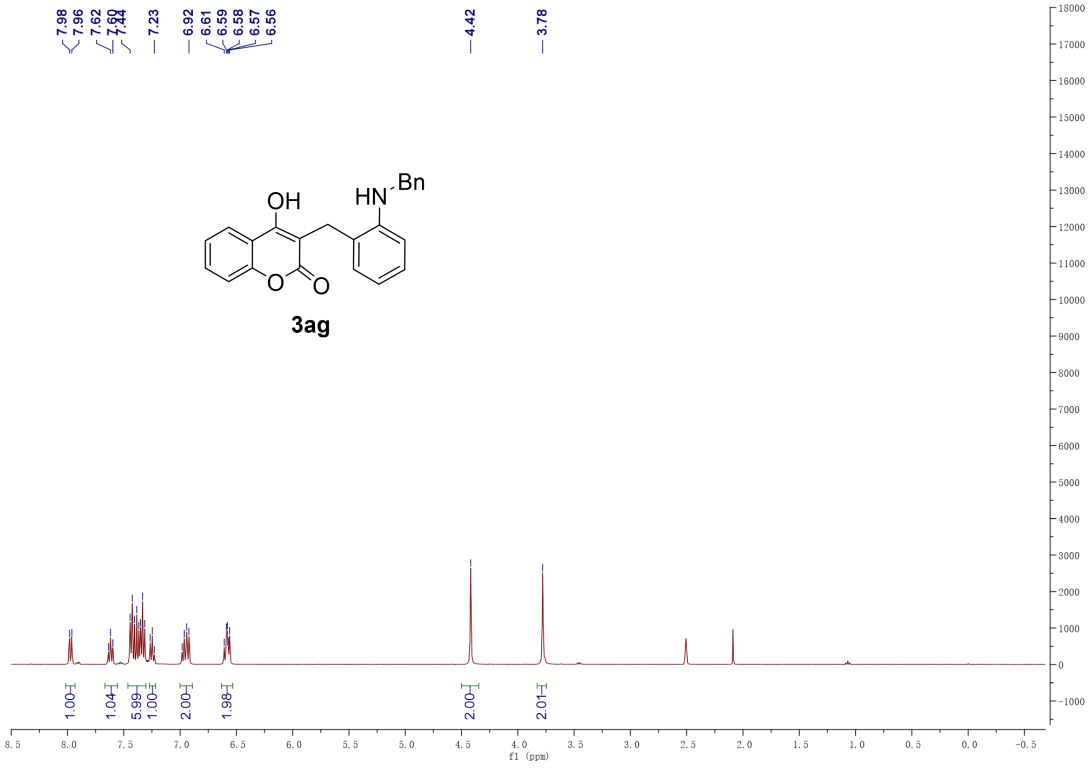


The ^{13}C NMR spectrum of **3ae** and its diastereoisomer (dr = 2.5:1)

3ae


The ^{1}H NMR spectrum of **3af** and its diastereoisomer (dr = 1: 1)
The asterisk symbol represents the H of **3af**
3af
f1 (ppm)


The ^{13}C NMR spectrum of **3af** and its diastereoisomer (dr = 1:1)
3af
f1 (ppm)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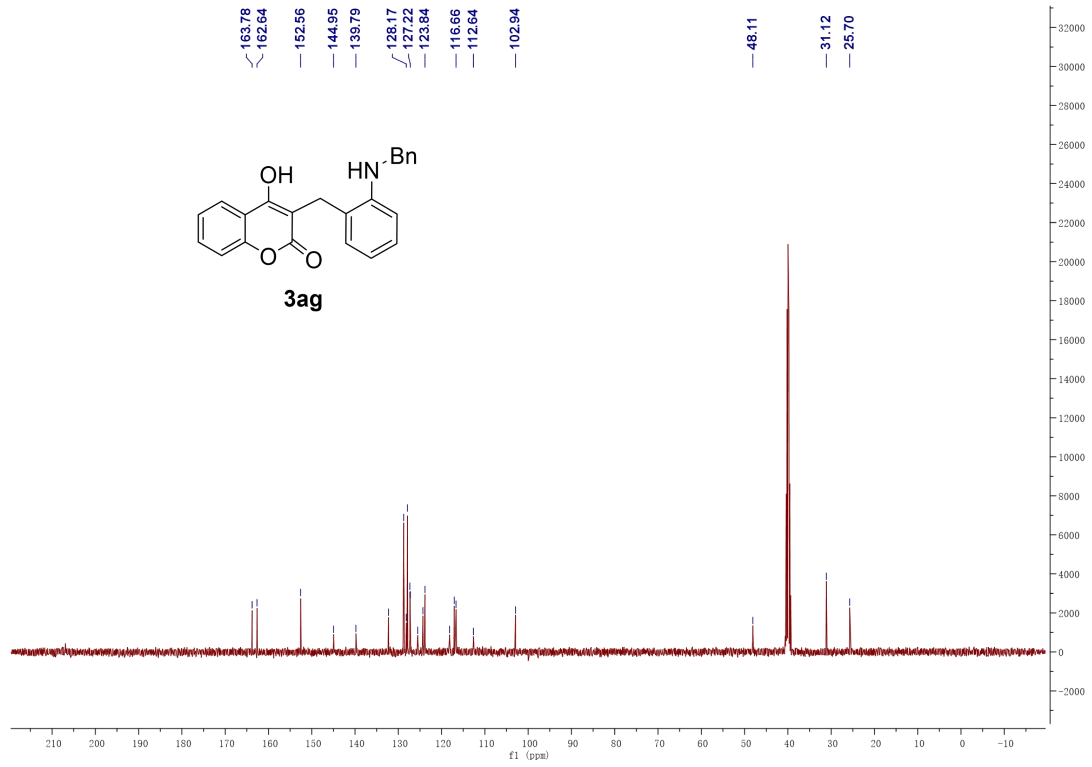
7.60
7.44
7.23
6.92
6.61
6.59
6.58
6.57
6.56
4.42
3.78
OH
HN
Bn
O
O
3ag
1.00
1.04
5.99
1.00
2.00
1.98
2.00
2.01
f1 (ppm)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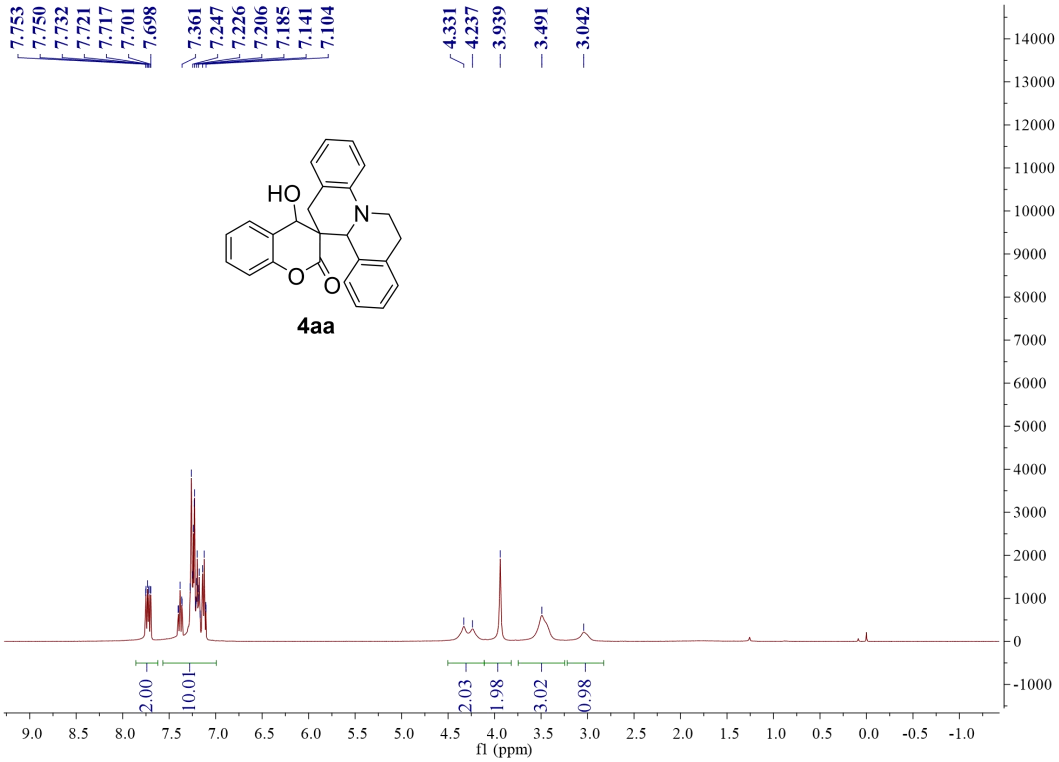
162.64
152.56
144.95
139.79
128.17
127.22
123.84
116.66
112.64
102.94
48.11
31.12
25.70
OH
HN
Bn
O
O
3ag
f1 (ppm)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7.732
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7.717
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7.361
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7.226
7.206
7.185
7.141
7.104
4.331
4.237
3.939
3.491
3.042
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N
O
O
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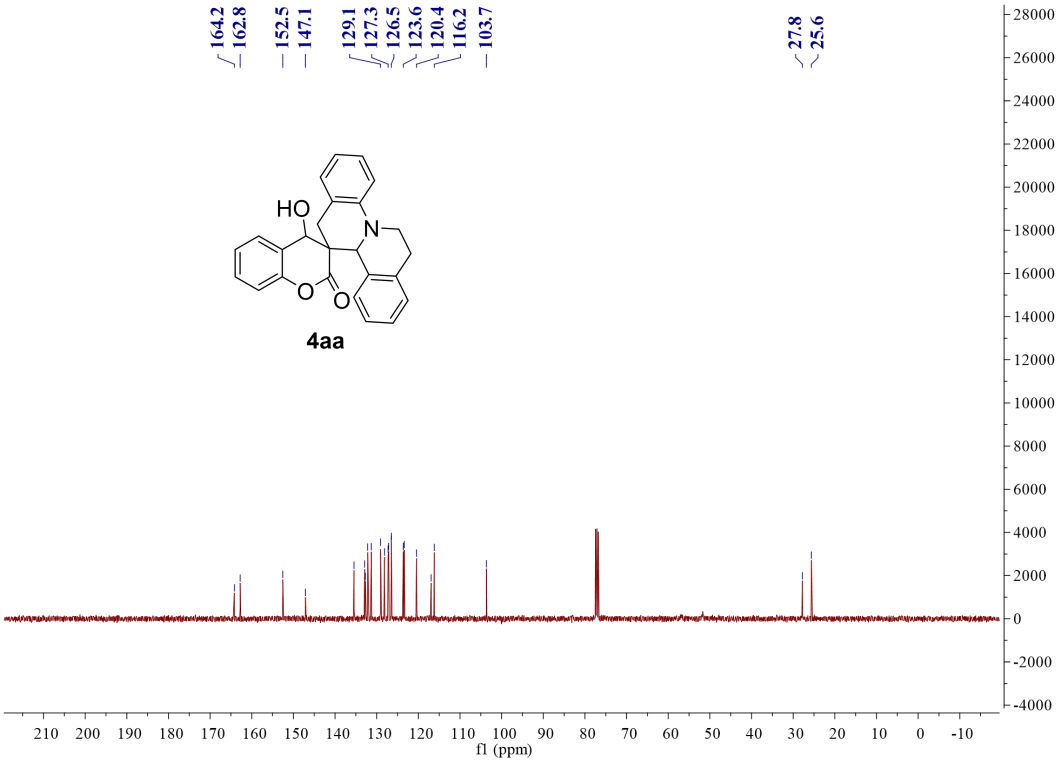
2.00
10.01
2.03
1.98
3.02
0.98
f1 (ppm)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129.1
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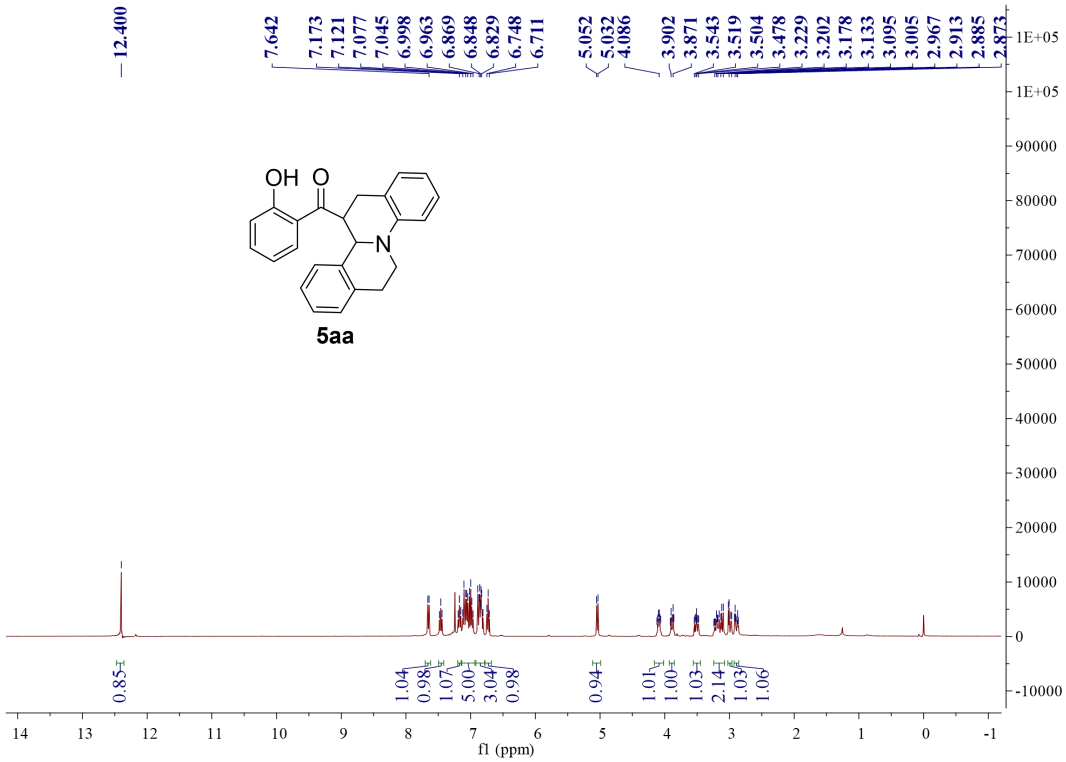
126.5
123.6
120.4
116.2
103.7
27.8
25.6
HO
N
O
O
4aa
f1 (ppm)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6.963
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6.848
6.829
6.748
6.711
5.052
5.032
4.086
3.902
3.871
3.543
3.519
3.504
3.478
3.229
3.202
3.178
3.133
3.095
3.005
2.967
2.913
2.885
2.873
OH O
N
5aa
0.85
1.04
0.98
1.07
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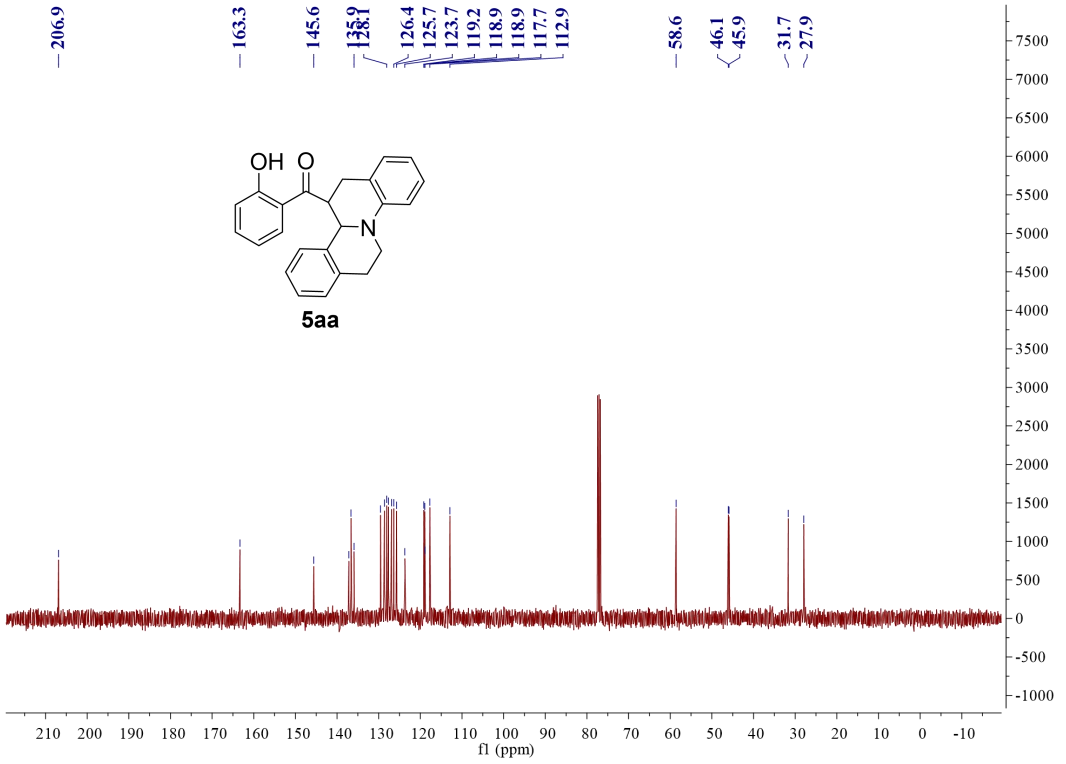
0.98
0.94
1.01
1.00
1.03
2.14
1.03
1.06
f1 (ppm)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125.7
123.7
119.2
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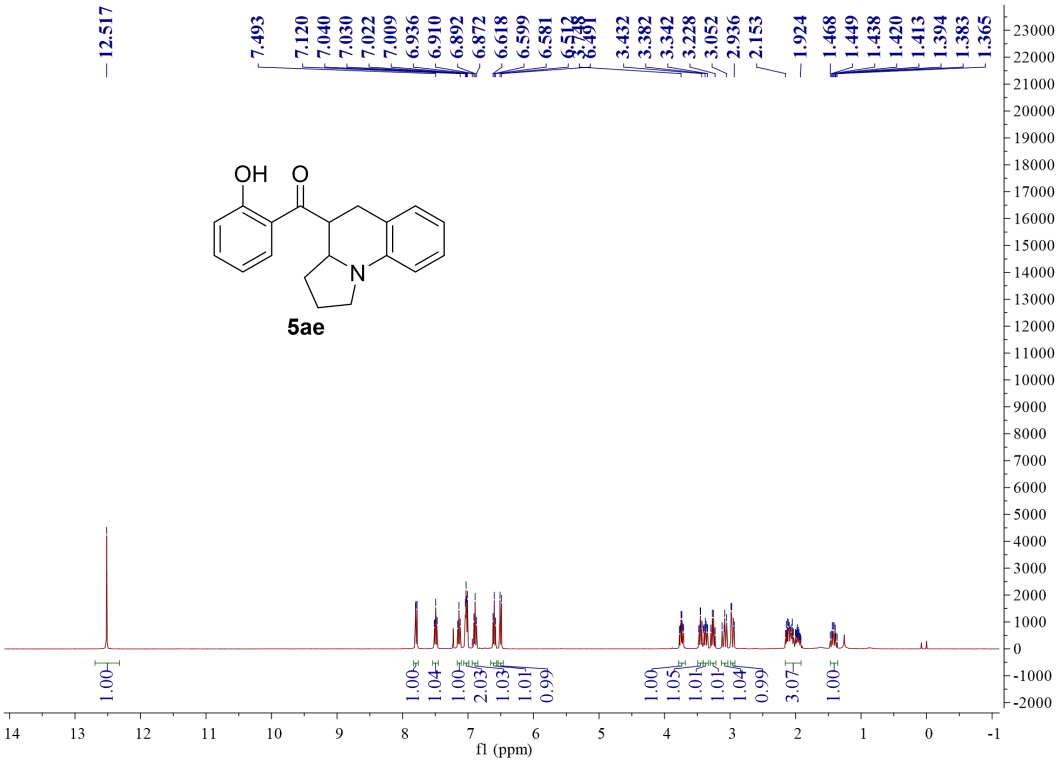
112.9
58.6
46.1
45.9
31.7
27.9
OH O
N
5aa
f1 (ppm)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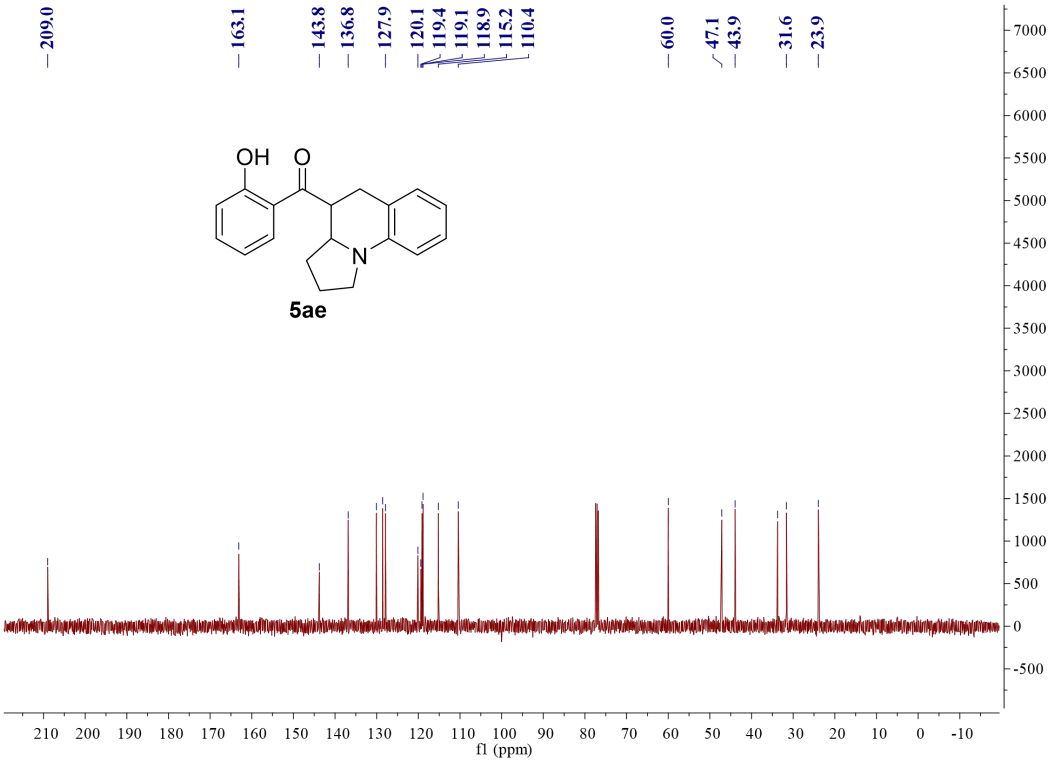
6.599
6.581
3.432
3.382
3.342
3.228
3.052
2.936
2.153
1.924
1.468
1.449
1.438
1.420
1.413
1.394
1.383
1.365
OH
O
N
5ae
1.00
1.04
1.00
2.03
1.03
1.01
0.99
1.00
1.05
1.01
1.01
1.04
0.99
3.07
1.00
f1 (ppm)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127.9
120.1
119.4
119.1
118.9
115.2
110.4
60.0
47.1
43.9
31.6
23.9
OH
O
N
5ae
f1 (ppm)