Organocatalytic Asymmetric Michael Addition of 5*H*-Oxazol-4-Ones to Nitroolefins

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Supporting Information

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1. General Information

General Procedures and Methods

Experiments involving moisture and/or air sensitive components were performed under a positive pressure of nitrogen in oven-dried glassware equipped with a rubber septum inlet. Dried solvents and liquid reagents were transferred by oven-dried syringes or hypodermic syringe cooled to ambient temperature in a desiccator. Reactions mixtures were stirred in 4 mL sample vial with Teflon-coated magnetic stirring bars unless otherwise stated. Moisture in non-volatile reagents/compounds was removed in high *vacuo* by means of an oil pump and subsequent purging with nitrogen. Solvents were removed in vacuo under ~30 mmHg and heated with a water bath at 30–35 °C using rotary evaporator with aspirator. The condenser was cooled with running ethanol at 0 °C.

All experiments were monitored by analytical thin layer chromatography (TLC). TLC was performed on pre-coated plates, 60 F_{254}. After elution, plate was visualized under UV illumination at 254 nm for UV active material. Further visualization was achieved by staining $KMnO_4$, ceric molybdate, or anisaldehyde solution. For those using the aqueous stains, the TLC plates were heated on a hot plate.

Columns for flash chromatography (FC) contained silica gel 200–300 mesh. Columns were packed as slurry of silica gel in petroleum ether and equilibrated solution using the appropriate solvent system. The elution was assisted by applying pressure of about 2 atm with an air pump.

Instrumentations

Proton nuclear magnetic resonance (^{1}H NMR) and carbon NMR (^{13}C NMR) spectra were recorded in $CDCl_3$ otherwise stated. ^{1}H (400 MHz) and ^{13}C (100 MHz) were performed on a Bruker AVANCE-III (400MHz) spectrometer. Chemical shifts are reported in parts per million (ppm), using the residual solvent signal as an internal standard: $CDCl_3$ (^{1}H NMR: δ 7.26, singlet; ^{13}C NMR: δ 77.0, triplet). Multiplicities were given as: *s* (singlet), *d* (doublet), *t* (triplet), *q* (quartet), *quintet*, *m* (multiplets), *dd* (doublet of doublets), *dt* (doublet of triplets), and *br* (broad). Coupling constants (*J*) were recorded in Hertz (Hz). The number of proton

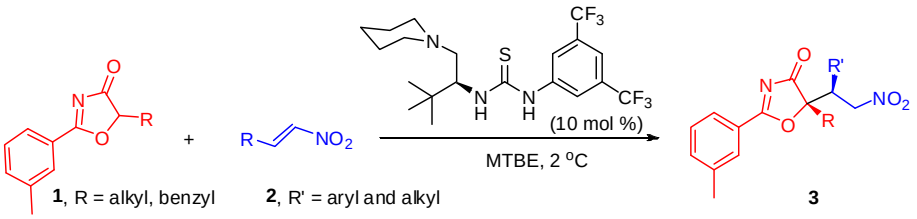
atoms (*n*) for a given resonance was indicated by *n*H. The number of carbon atoms (*n*) for a given resonance was indicated by *n*C. HRMS were reported in units of mass of charge ratio (m/z). Mass samples were dissolved in CH_3CN (HPLC Grade) unless otherwise stated. Optical rotations were recorded on a polarimeter with a sodium lamp of wavelength 589 nm and reported as follows; $[\alpha]_{\lambda}^{T^{\circ}C}$ (c = g/100 mL, solvent). Melting points were determined on a X-6 microscopic melting point apparatus.

Enantiomeric excesses were determined by chiral High Performance Liquid Chromatography (HPLC) analysis on Agilent HPLC 1260 series, including 1260 quaternary pump with degasser, 1260 thermostatted column compartment, 1260 series variable wavelength detector with manual injection valve. HPLC samples were dissolved in HPLC grade isopropanol (IPA) unless otherwise stated.

Materials

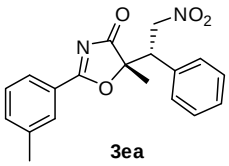
All commercial reagents were purchased from Sigma-Aldrich, J&K, Alfa-Aesar, TCI and Aladdin of the highest purity grade. They were used without further purification unless specified. All solvents used, mainly petroleum ether (PE) and ethyl acetate (EtOAc), were distilled. Anhydrous CH_2Cl_2 and MeCN were freshly distilled from CaH_2 and stored under N_2 atmosphere. THF, Et_2O, CPME, MTBE and toluene were freshly distilled from sodium/benzophenone before use. Anhydrous methanol was distilled from Mg All compounds synthesized were stored in a −20 °C freezer and light-sensitive compounds were protected with aluminium foil.

2. General Procedure for The Asymmetric Addition of 5*H*-Oxazol-4-ones 1 to Nitroolefins 2 Catalyzed by IV



5*H*-Oxazol-4-ones **1** (0.1 mmol, 1.0 equiv.) and **IV** (0.01 mmol, 0.1 equiv.) were dissolved in MTBE (1.0 mL). The reaction mixture was stirred at 2 °C for 30 minutes, nitroolefin **2** (,0.11 mmol, 1.1 equiv.) was added in one portion to the above mixture. The reaction mixture was stirred at 2 °C for 40 h and monitored by TLC. Upon complete consumption of 5*H*-oxazol-4-ones, the reaction mixture was concentrated under reduced pressure, The crude material was analyzed by ^{1}H NMR in order to determine diastereoselectivity. When the dr value is determined more than 19:1 by ^{1}H NMR, it is described in paper as >19:1 dr due to the accuracy of the measurement. The recovered crude material was subsequently purified by flash column chromatography on silica gel with PE/EtOAc mixture (20:1–5:1 ratio, the crude material was completely dissolved in CH_2Cl_2/PE before loaded on silica gel). After removing the solvent in *vacuo*, the major diasteromer of **3** could be obtained.

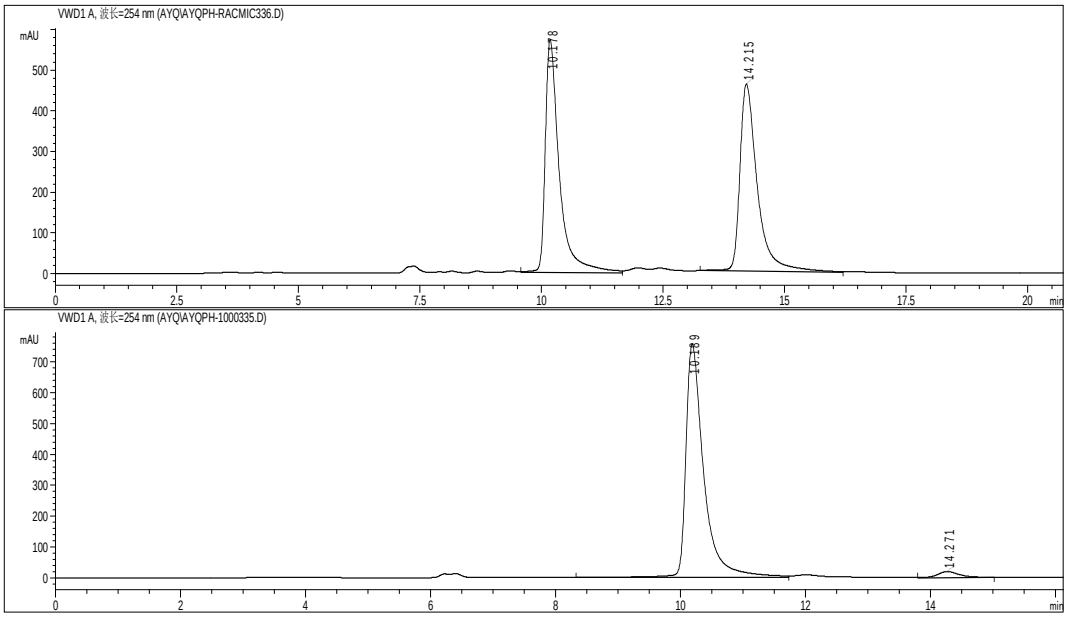
3. Characterization of Adducts

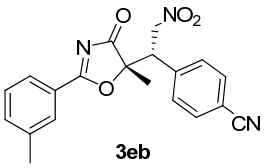


3ea

3ea, White solid; Mp 139.1–139.9 °C; 94% ee; dr >19:1; 93% yield (major diastereomer); $[\alpha]_D^{26}$ –96.5 (*c* 1.70, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 7.97–7.94 (m, 2H), 7.54–7.52 (m, 1H), 7.45–7.44 (m, 1H), 7.35–7.29 (m, 5H), 4.85 (dd, *J* = 13.2, 10.9 Hz, 1H), 4.68 (dd, *J* = 13.2, 4.5 Hz, 1H), 4.09 (dd, *J* = 10.9, 4.5 Hz, 1H), 2.44 (s, 3H), 1.51 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.3, 185.7, 139.1, 136.7, 133.1, 130.7, 129.0, 128.9, 128.8, 127.2, 124.7, 87.5, 74.8, 49.4, 21.6, 21.2; HRMS (ESI) m/z 339.1339 ($M+H^+$), calc. for $C_{19}H_{19}N_2O_4$ 339.1345.

The ee was determined by HPLC analysis. CHIRALPAK IB (4.6 mm i.d. x 250 mm); Hexane/2-propanol = 80/20; flow rate 1.0 ml/min; 25 °C; 254 nm; retention time: 10.2 min (major) and 14.3 min (minor).

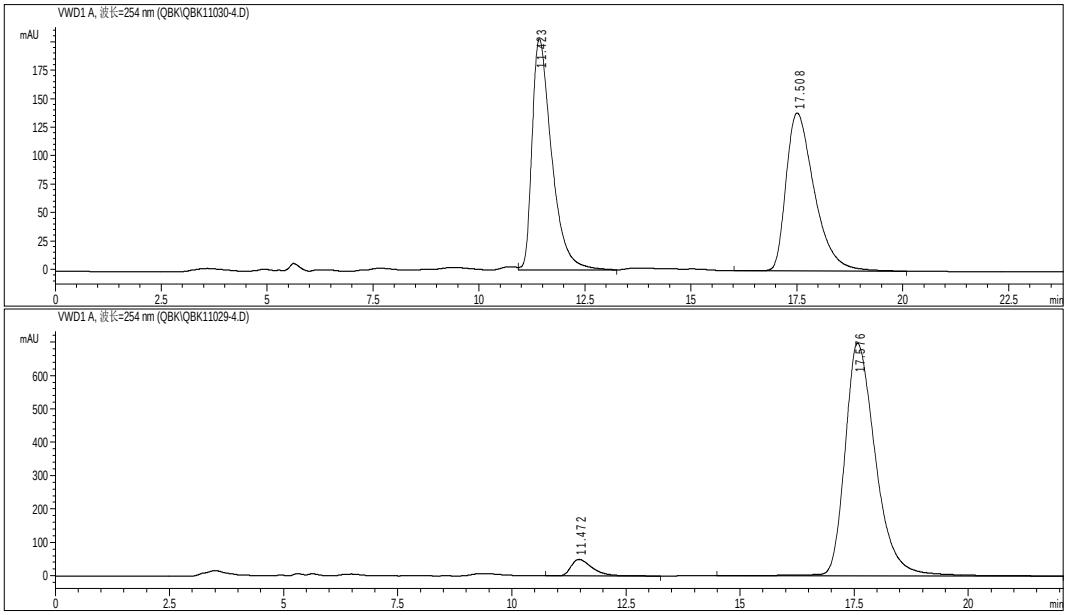




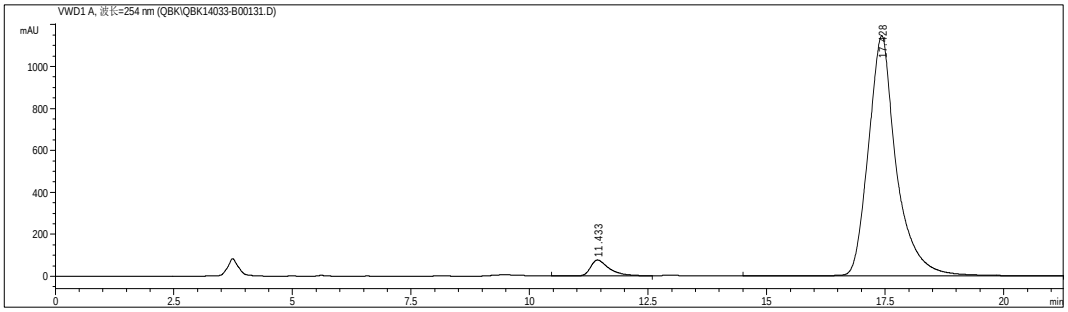
3eb

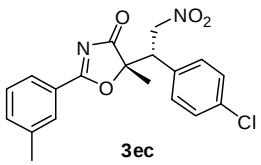
3eb, White solid; Mp 74–75 °C; 91% ee; dr >19:1; 91% yield (major diastereomer); $[\alpha]_D^{26}$ –74.2 (*c* 1.70, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 7.93–7.90 (m, 2H), 7.64 (d, *J* = 8.4 Hz, 2H), 7.55 (br d, *J* = 7.6 Hz, 1H), 7.45 (dd, *J* = 14.6, 7.9 Hz, 3H), 4.91 (dd, *J* = 13.6, 11.1 Hz, 1H), 4.75 (dd, *J* = 13.6, 4.4 Hz, 1H), 4.18 (dd, *J* = 11.1, 4.4 Hz, 1H), 2.45 (s, 3H), 1.55 (s, 3H). ^{13}C NMR (101 MHz, $CDCl_3$) δ 191.6, 185.8, 139.3, 138.6, 137.1, 132.7, 130.7, 129.7, 129.1, 127.2, 124.4, 118.0, 113.0, 86.7, 74.1, 49.2, 21.6, 21.2; HRMS (ESI) m/z 364.1297 ($M+H^+$), calc. for $C_{20}H_{18}N_3O_4$ 364.1297.

The ee was determined by HPLC analysis. CHIRALPAK IA (4.6 mm i.d. x 250 mm); Hexane/2-propanol = 75/25; flow rate 1.0 ml/min; 25 ^{o}C; 254 nm; retention time: 11.5 min (minor) and 17.6 min (major).



The **3eb** was obtained with 78% yield in 92% ee and >99:1 dr when the reaction was stopped after 18 hours.

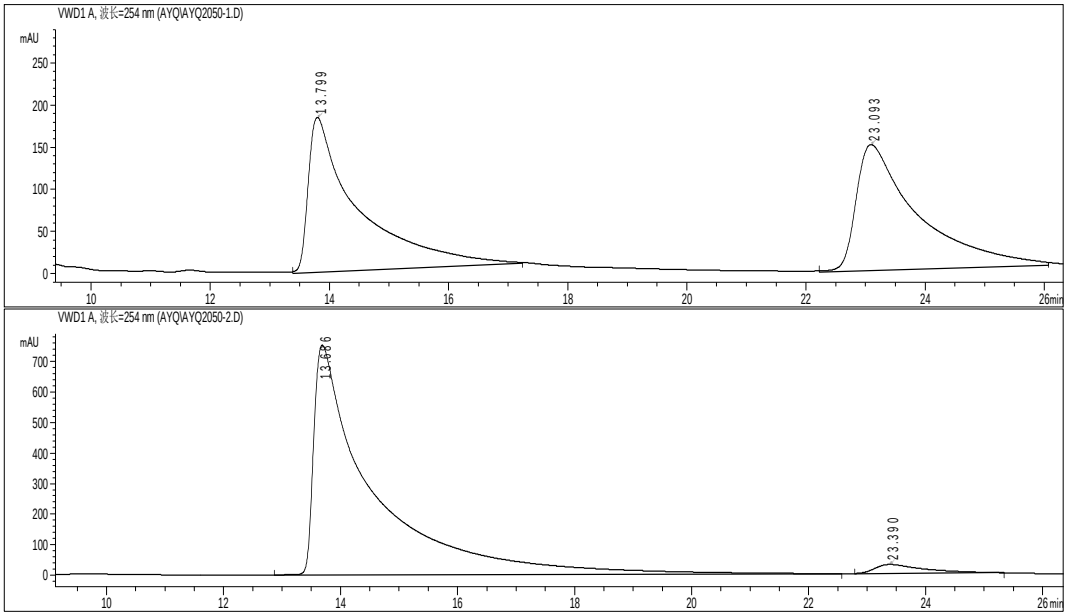


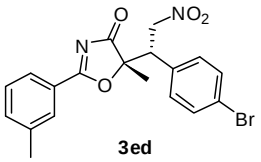


3ec

3ec, White solid; Mp 55–56 ^{o}C; 94% ee; dr >19:1; 89% yield (major diastereomer); $[\alpha]_D^{26}$ –84.2 (*c* 2.83, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.96–7.93 (m, 2H), 7.55–7.53 (m, 1H), 7.44 (t, *J* = 7.6 Hz, 1H), 7.33–7.27 (m, 4H), 4.82 (dd, *J* = 13.3, 11.1 Hz, 1H), 4.67 (dd, *J* = 13.3, 4.5 Hz, 1H), 4.08 (dd, *J* = 11.1, 4.5 Hz, 1H), 2.45 (s, 3H), 1.51 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.0, 185.7, 139.2, 136.8, 134.9, 131.7, 130.7, 130.2, 129.2, 129.0, 127.2, 125.0, 87.1, 74.6, 48.8, 21.6, 21.2; HRMS (ESI) m/z 373.0947 ($M+H^+$), calc. for $C_{19}H_{18}ClN_2O_4$ 373.0955.

The ee was determined by HPLC analysis. CHIRALPAK IB (4.6 mm i.d. x 250 mm); Hexane/2-propanol = 85/15; flow rate 1.0 ml/min; 25 ^{o}C; 254 nm; retention time: 13.7 min (major) and 23.4 min (minor).

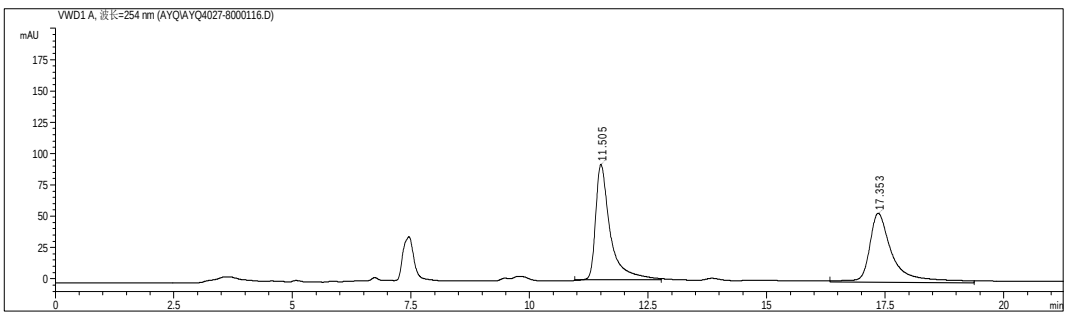


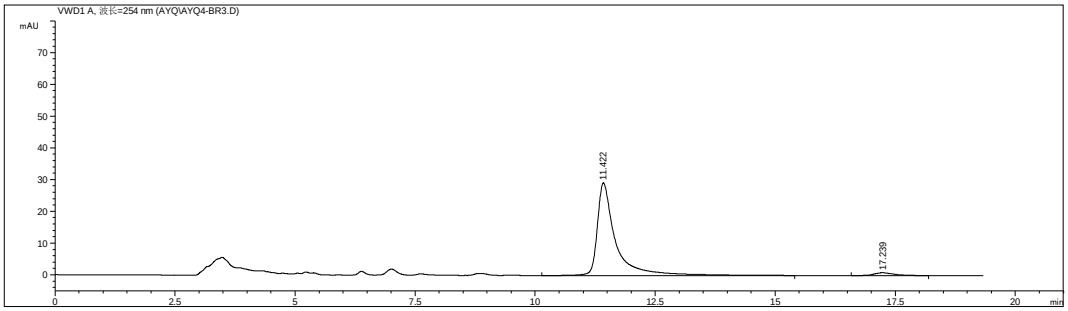


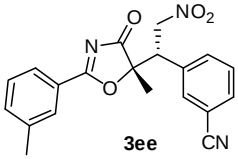
3ed

3ed, white solid; Mp 54–55 ^{o}C; 94% ee; dr >19:1; 85% yield (major diastereomer); $[\alpha]_D^{26}$ –81.7 (*c* 2.80, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.96–7.93 (m, 2H), 7.55–7.51 (m, 1H), 7.45 (dd, *J* = 16.5, 8.1 Hz, 3H), 7.21 (d, *J* = 8.4 Hz, 2H), 4.81 (dd, *J* = 13.3, 11.0 Hz, 1H), 4.67 (dd, *J* = 13.3, 4.4 Hz, 1H), 4.06 (dd, *J* = 11.0, 4.4 Hz, 1H), 2.45 (s, 3H), 1.51 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.9, 185.8, 139.2, 136.8, 132.3, 132.2, 130.7, 130.5, 129.1, 127.2, 124.7, 123.1, 87.1, 74.6, 48.9, 21.6, 21.2; HRMS (ESI) m/z 417.0443 ($M+H^+$), calc. for $C_{19}H_{17}BrN_2O_4$ 417.0450.

The ee was determined by HPLC analysis. CHIRALPAK IB (4.6 mm i.d. x 250 mm); Hexane/2-propanol = 75/25; flow rate 1.0 ml/min; 25 ^{o}C; 254 nm; retention time: 11.4 min (major) and 17.2 min (minor).

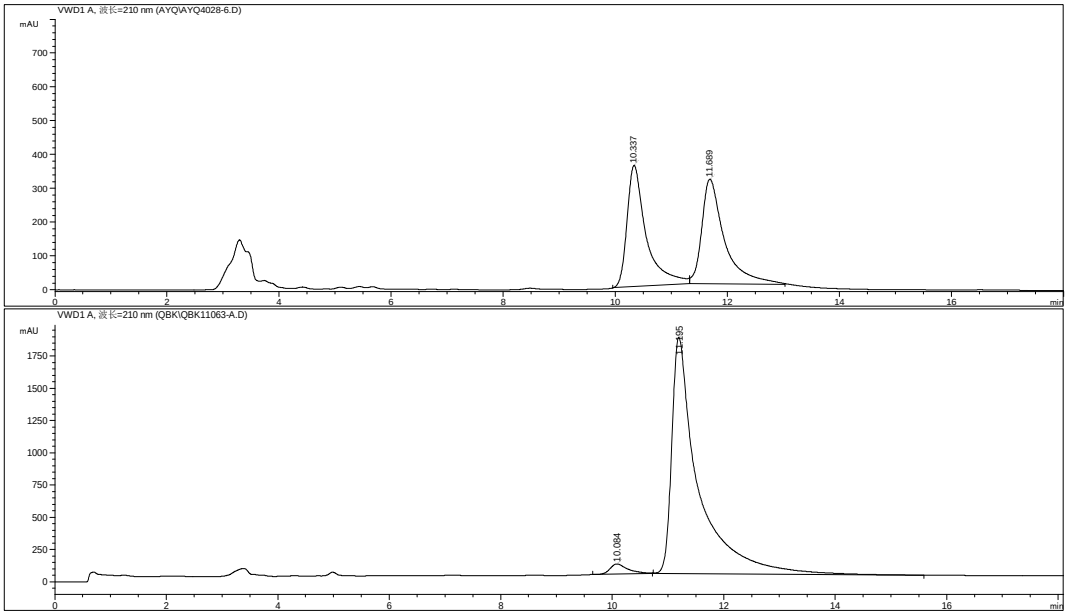


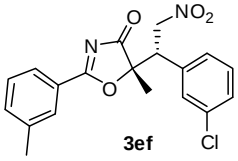




3ee, white solid; Mp 61–62 °C; 95% ee; dr >19:1; 79% yield (major diastereomer); $[\alpha]_D^{26}$ –78.9 (*c* 2.40, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95–7.92 (m, 2H), 7.66 (m, 1H), 7.63–7.52 (m, 3H), 7.46 (dt, *J* = 11.2, 7.7 Hz, 2H), 4.89 (dd, *J* = 13.6, 11.2 Hz, 1H), 4.73 (dd, *J* = 13.6, 4.4 Hz, 1H), 4.15 (dd, *J* = 11.1, 4.4 Hz, 1H), 2.45 (s, 3H), 1.54 (s, 3H); ^{113}C NMR (100 MHz, $CDCl_3$) δ 191.5, 185.8, 139.4, 137.1, 135.0, 132.7, 132.6, 130.0, 129.2, 127.3, 124.4, 118.0, 113.3, 86.7, 74.1, 49.0, 21.6, 21.2; HRMS (ESI) m/z 364.1293 ($M+H^+$), calc. for $C_{20}H_{17}N_3O_4$ 364.1297.

The ee was determined by HPLC analysis. CHIRALPAK IB (4.6 mm i.d. x 250 mm); Hexane/2-propanol = 75/25; flow rate 1.0 ml/min; 25 °C; 210 nm; retention time: 10.1 min (minor) and 11.2 min (major).

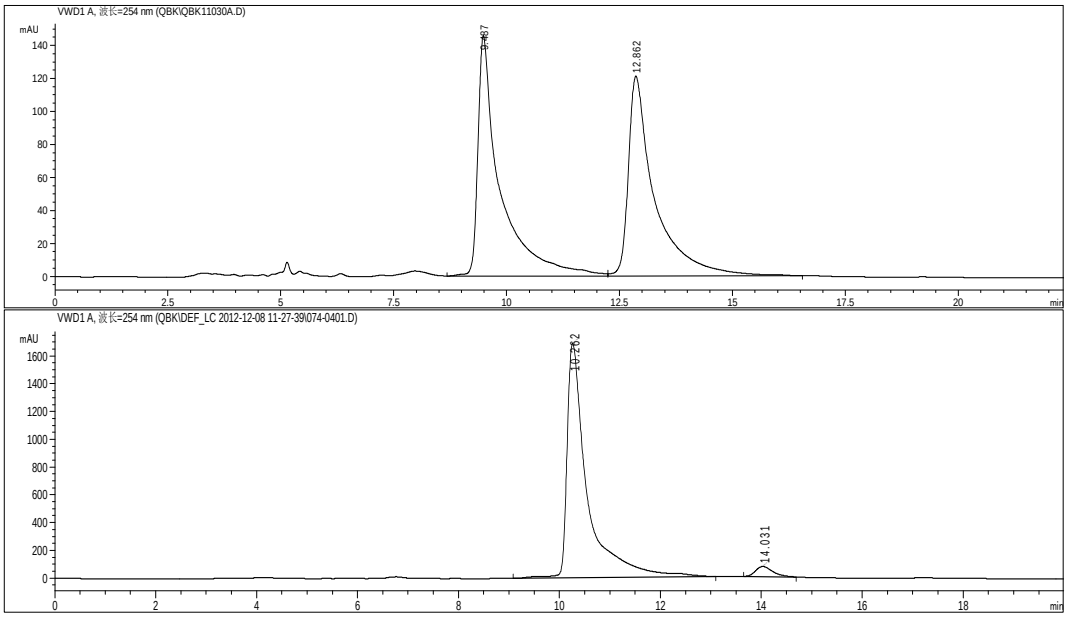


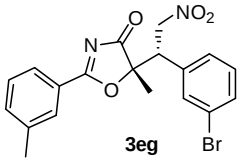


3ef, white solid; Mp 55–56 °C; 93% ee; dr >19:1; 87% yield (major diastereomer); $[\alpha]_D^{26}$ –84.2 (*c* 2.70, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97–7.95 (m, 2H), 7.55 (d, *J* = 7.6 Hz, 1H), 7.45 (t, *J* = 7.6 Hz, 1H), 7.34–7.28 (m, 3H), 7.25–7.21 (m, 1H), 4.82 (dd, *J* = 13.4, 11.0 Hz, 1H), 4.67 (dd, *J* = 13.4,

4.4 Hz, 1H), 4.07 (dd, *J* = 11.0, 4.4 Hz, 1H), 2.45 (s, 3H), 1.52 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.9, 185.8, 139.2, 136.9, 135.2, 134.8, 130.7, 130.3, 129.3 129.2 129.1, 127.3, 126.8, 124.6, 87.0, 74.4, 49.0, 21.6, 21.2; HRMS (ESI) m/z 373.0944 ($M+H^+$), calc. for $C_{19}H_{18}N_2O_4Cl$ 373.0955.

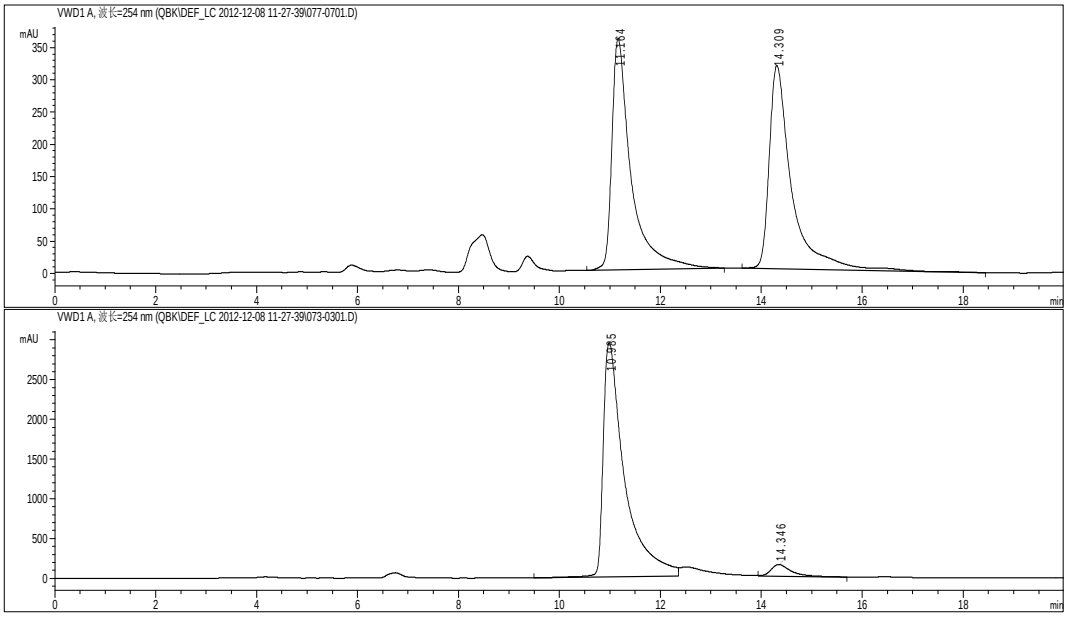
The ee was determined by HPLC analysis. CHIRALPAK IB (4.6 mm i.d. x 250 mm); Hexane/2-propanol = 75/25; flow rate 1.0 ml/min; 25 °C; 254 nm; retention time: 10.3 min (major) and 14.0 min (minor).

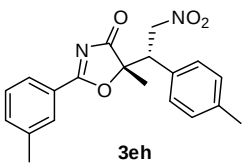




3eg, white solid; Mp 108–109 °C; 91% ee; dr >19:1; 91% yield (major diastereomer); $[\alpha]_D^{26}$ –152.3 (*c* 0.22, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97–7.94 (m, *J* = 9.3 Hz, 2H), 7.55 (d, *J* = 7.6 Hz, 1H), 7.50 (t, *J* = 1.6 Hz, 1H), 7.44 (ddd, *J* = 6.6, 4.5, 4.0 Hz, 2H), 7.28 (m, 1H), 7.22 (t, *J* = 7.8 Hz, 1H), 4.82 (dd, *J* = 13.4, 11.0 Hz, 1H), 4.67 (dd, *J* = 13.5, 4.4 Hz, 1H), 4.06 (dd, *J* = 11.0, 4.4 Hz, 1H), 2.45 (s, 3H), 1.52 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 191.8, 185.7, 139.2, 136.8, 135.5, 132.3, 132.0, 130.6, 130.5, 129.1, 127.3, 127.1, 124.6, 122.9, 87.0, 74.4, 49.0, 21.6, 21.2; HRMS (ESI) m/z 417.0443 ($M+H^+$), calc. for $C_{19}H_{18}N_2O_4Br$ 417.0450.

The ee was determined by HPLC analysis. CHIRALPAK IB (4.6 mm i.d. x 250 mm); Hexane/2-propanol = 75/25; flow rate 1.0 ml/min; 25 °C; 254 nm; retention time: 11.0 min (major) and 14.3 min (minor).

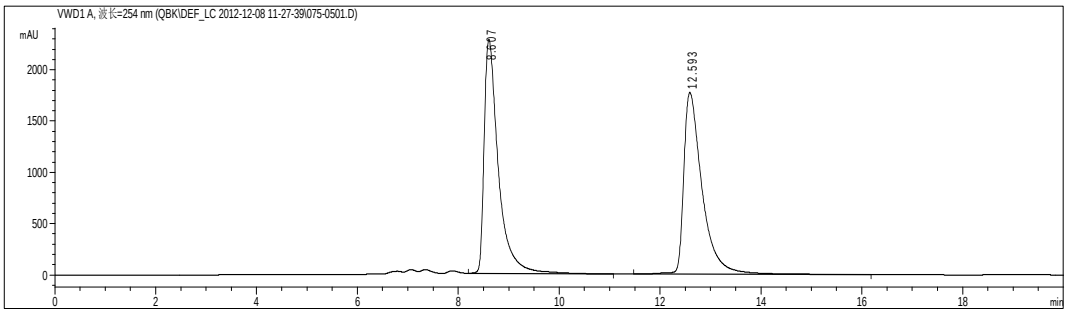


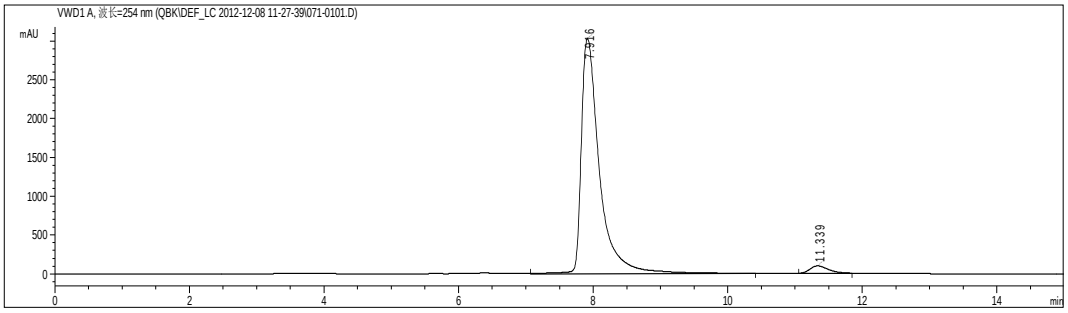


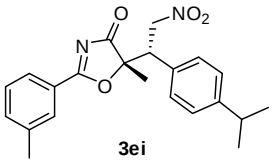
3eh

3eh, white form; 94% ee; dr >19:1; 87% yield (major diastereomer); $[\alpha]_D^{26}$ –103.5 (*c* 2.20, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.98–7.96 (m, Hz, 2H), 7.54 (d, *J* = 7.6 Hz, 1H), 7.44 (t, *J* = 7.6 Hz, 1H), 7.22 (d, *J* = 8.1 Hz, 2H), 7.14 (d, J = 7.9 Hz, 2H), 4.81 (dd, *J* = 13.0, 11.0 Hz, 1H), 4.64 (dd, *J* = 13.0, 4.5 Hz, 1H), 4.04 (dd, *J* = 11.0, 4.5 Hz, 1H), 2.45 (s, 3H), 2.30 (s, 3H), 1.49 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.4, 185.7, 139.2, 138.7, 136.7, 130.7, 130.0, 129.7, 129.0, 128.7, 127.2, 124.9, 87.6, 74.9, 49.0, 21.6, 21.2, 21.1; HRMS (ESI) m/z 353.1497 ($M+H^+$), calc. for $C_{20}H_{21}N_2O_4$ 353.1501.

The ee was determined by HPLC analysis. CHIRALPAK IB (4.6 mm i.d. x 250 mm); Hexane/2-propanol = 75/25; flow rate 1.0 ml/min; 25 ^oC; 254 nm; retention time: 7.9 min (major) and 11.3 min (minor).



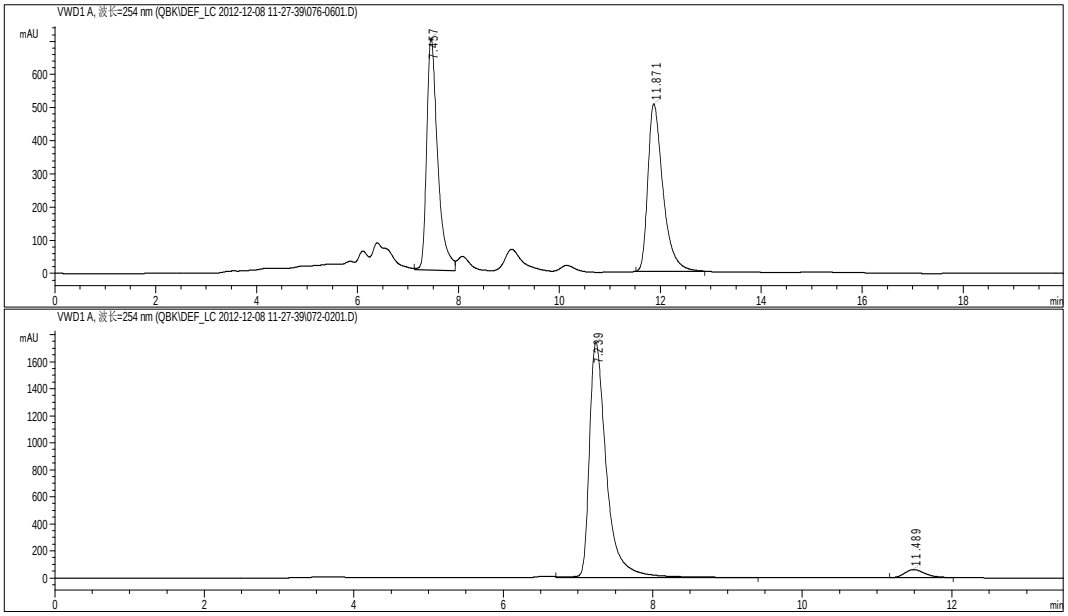


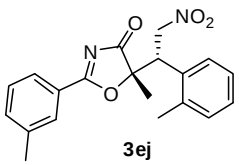


3ei

3ei, white solid; Mp 35–36 °C; 92% ee; dr >19:1; 99% yield; $[\alpha]_D^{26}$ –122.9 (*c* 0.80, $CHCl_3$); 1H NMR (400 MHz, $CDCl_3$) δ 7.97–7.94 (m, 2H), 7.53 (d, *J* = 7.6 Hz, 1H), 7.44 (t, *J* = 7.6 Hz, 1H), 7.24 (d, *J* = 8.3 Hz, 2H), 7.18 (d, *J* = 8.2 Hz, 2H), 4.81 (dd, *J* = 13.1, 11.0 Hz, 1H), 4.64 (dd, *J* = 13.1, 4.5 Hz, 1H), 4.06 (dd, *J* = 10.9, 4.5 Hz, 1H), 2.84 (dq, *J* = 13.9, 6.9 Hz, 1H), 2.45 (s, 3H), 1.50 (s, 3H), 1.17 (dd, *J* = 6.9, 2.9 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.4, 185.8, 149.5, 139.1, 136.6, 130.7, 130.3, 129.0, 128.8, 127.2, 127.0, 124.9, 87.7, 74.8, 49.1, 33.7, 23.7, 21.6, 21.2. HRMS (ESI) m/z 381.1804 ($M+H^+$), calc. for $C_{22}H_{25}N_2O_4$ 381.1814.

The ee was determined by HPLC analysis. CHIRALPAK IB (4.6 mm i.d. x 250 mm); Hexane/2-propanol = 75/25; flow rate 1.0 ml/min; 25 °C; 254 nm; retention time: 7.2 min (major) and 11.5 min (minor).



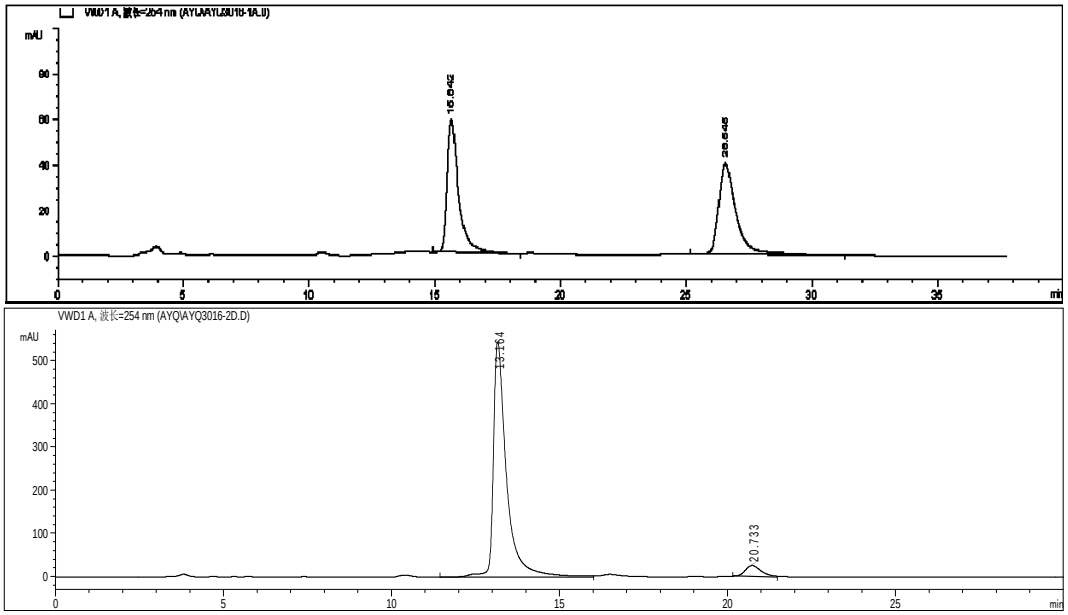


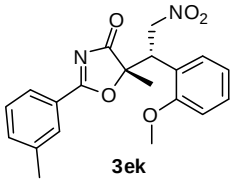
3ej

3ej, white solid; Mp 128–129 °C; 90% ee; dr >19:1; 99% yield; $[\alpha]_D^{26}$ –114.9 (*c* 1.68, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 7.98–7.96 (m, Hz, 2H), 7.54 (d, *J* = 7.6 Hz, 1H), 7.44 (t, *J* = 7.6 Hz, 1H), 7.22 (d, *J* =

8.1 Hz, 2H), 7.14 (d, *J* = 7.9 Hz, 2H), 4.81 (dd, *J* = 13.0, 11.0 Hz, 1H), 4.64 (dd, *J* = 13.0, 4.5 Hz, 1H), 4.04 (dd, *J* = 11.0, 4.5 Hz, 1H), 2.45 (s, 3H), 2.30 (s, 3H), 1.49 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.4, 185.7, 139.2, 138.7, 136.7, 130.7, 130.0, 129.7, 129.0, 128.7, 127.2, 124.9, 87.6, 74.9, 49.0, 21.6, 21.2, 21.1; HRMS (ESI) m/z 353.1504 ($M+H^+$), calc. for $C_{20}H_{21}N_2O_4$ 353.1501.

The ee was determined by HPLC analysis. CHIRALPAK IB (4.6 mm i.d. x 250 mm); Hexane/2-propanol = 90/10; flow rate 1.0 ml/min; 25 °C; 254 nm; retention time: 13.2 min (major) and 20.7 min (minor).

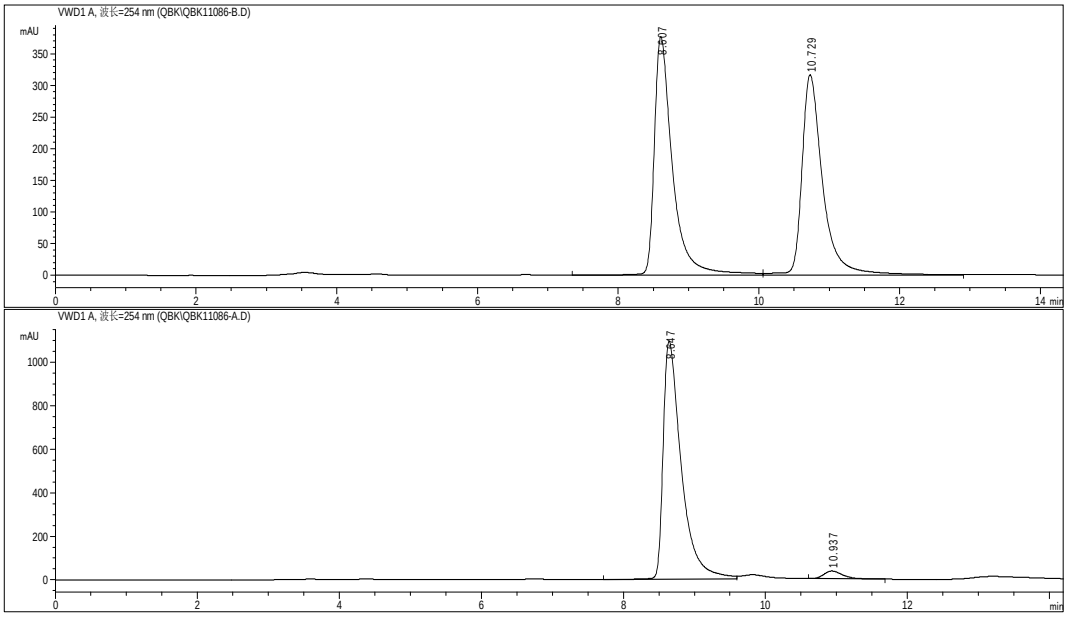


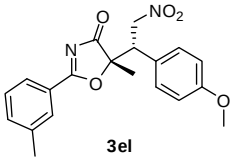


3ek

3ek, white solid; Mp 133–135 °C; 94% ee; dr >19:1; 99% yield; $[\alpha]_D^{26}$ –100.0 (*c* 2.50, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.95 (m, 2H), 7.52–7.40 (m, 2H), 7.27–7.23 (m, 2H), 6.91 (dd, *J* = 37.4, 7.3 Hz, 2H), 4.76 (d, *J* = 49.4 Hz, 3H), 3.85 (s, 3H), 2.43 (s, 3H), 1.52 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.4, 185.4, 157.9, 139.0, 136.4, 130.6, 129.9, 128.9, 127.1, 125.1, 121.7, 120.9, 111.2, 74.4, 55.6, 21.2; HRMS (ESI) m/z 369.1443 ($M+H^+$), calc. for $C_{20}H_{21}N_2O_5$ 369.1450.

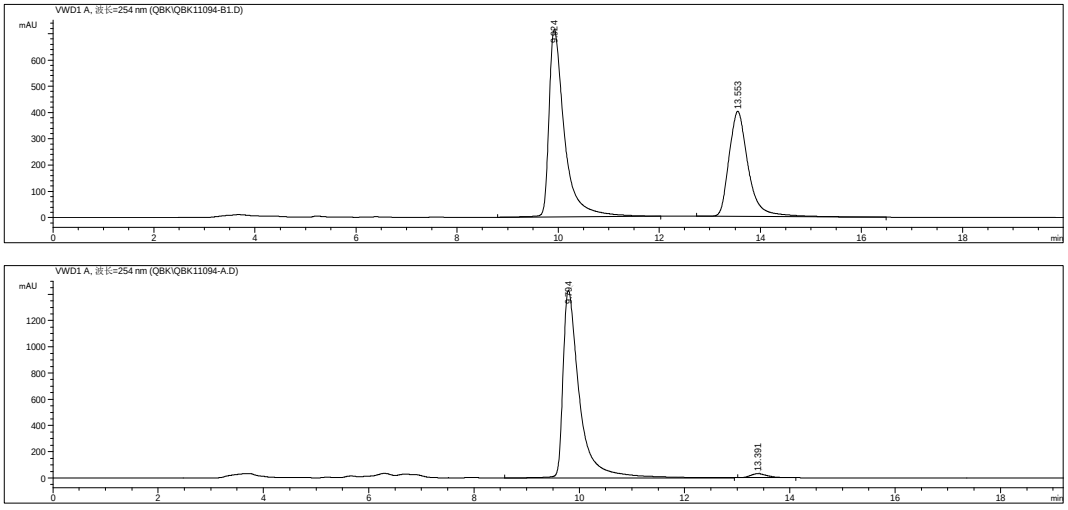
The ee was determined by HPLC analysis. CHIRALPAK IB (4.6 mm i.d. x 250 mm); Hexane/2-propanol = 75/25; flow rate 1.0 ml/min; 25 °C; 254 nm; retention time: 8.6 min (major) and 10.9 min (minor).

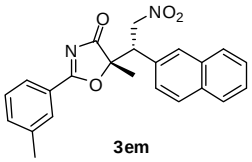




3el, white solid; Mp 32–33 ^{o}C; 96% ee; dr >19:1; 96% yield (major diastereomer); $[\alpha]_D^{26}$ –87.7 (*c* 2.97, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.97–7.94 (m, 2H), 7.53–7.52 (m, 1H), 7.43 (t, *J* = 7.6 Hz, 1H), 7.25–7.22 (m, 2H), 6.85 (d, *J* = 8.7 Hz, 2H), 4.81 (dd, *J* = 12.9, 11.1 Hz, 1H), 4.65 (dd, *J* = 13.0, 4.5 Hz, 1H), 4.03 (dd, *J* = 11.0, 4.5 Hz, 1H), 3.75 (s, 3H), 2.44 (s, 3H), 1.50 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.4, 185.7, 159.7, 139.1, 136.6, 130.7, 130.0, 129.0, 127.2, 124.9, 124.9, 114.3, 87.7, 75.0, 55.2, 48.8, 21.6, 21.2; HRMS (ESI) m/z 369.1444 ($M+H^+$), calc. for $C_{20}H_{21}N_2O_5$ 369.1450.

The ee was determined by HPLC analysis. CHIRALPAK IB (4.6 mm i.d. x 250 mm); Hexane/2-propanol = 75/25; flow rate 1.0 ml/min; 25 ^{o}C; 254 nm; retention time: 9.7 min (major) and 13.4 min (minor).

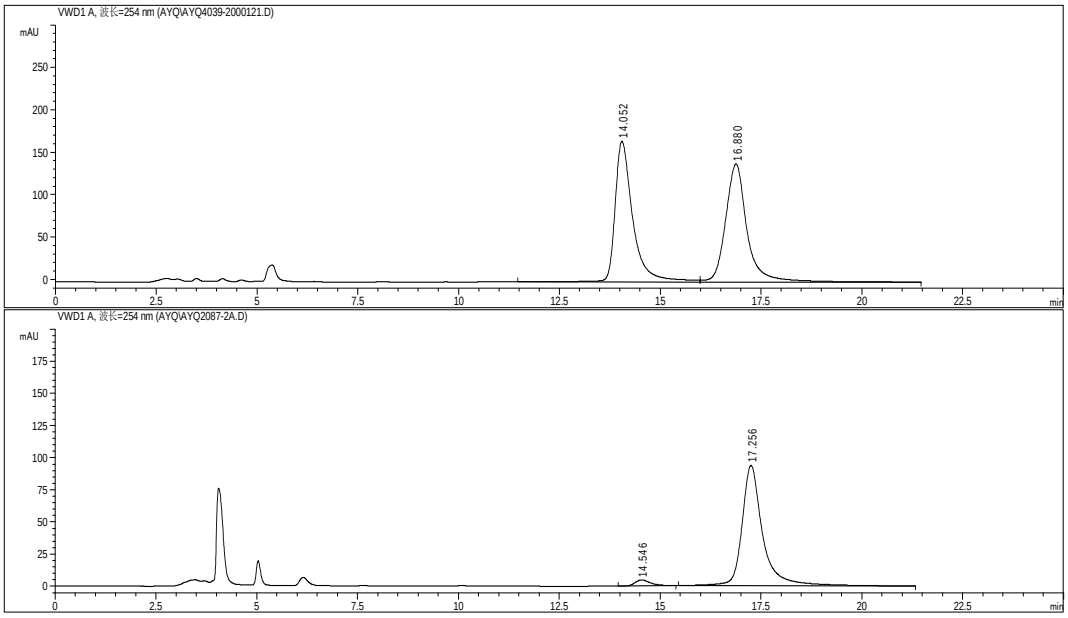


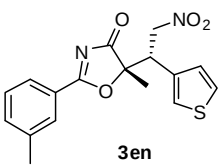


3em

3em, white solid; Mp 127–128 °C; 93% ee; dr > 19:1; 95% yield (major diastereomer); $[\alpha]_D^{26}$ –101.2 (*c* 3.35, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 8.00–7.98 (m, 2H), 7.87–7.80 (m, 4H), 7.51–7.42 (m, 5H), 4.95 (dd, *J* = 13.1, 11.0 Hz, 1H), 4.73 (dd, *J* = 13.2, 4.3 Hz, 1H), 4.27 (dd, *J* = 11.0, 4.4 Hz, 1H), 2.44 (s, 3H), 1.53 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.3, 185.8, 139.2, 136.7, 133.2, 133.1, 130.7, 130.7, 129.0, 129.0 , 128.9, 128.0, 127.6, 127.2, 126.7, 126.6, 125.6, 124.8, 87.6, 75.0, 49.6, 21.8, 21.2; HRMS (ESI) m/z 389.1490 ($M+H^+$), calc. for $C_{23}H_{21}N_2O_4$ 389.1501.

The ee was determined by HPLC analysis. CHIRALPAK IB (4.6 mm i.d. x 250 mm); Hexane/2-propanol = 75/25; flow rate 1.0 ml/min; 25 °C; 254 nm; retention time: 14.5 min (major) and 17.3 min (minor).



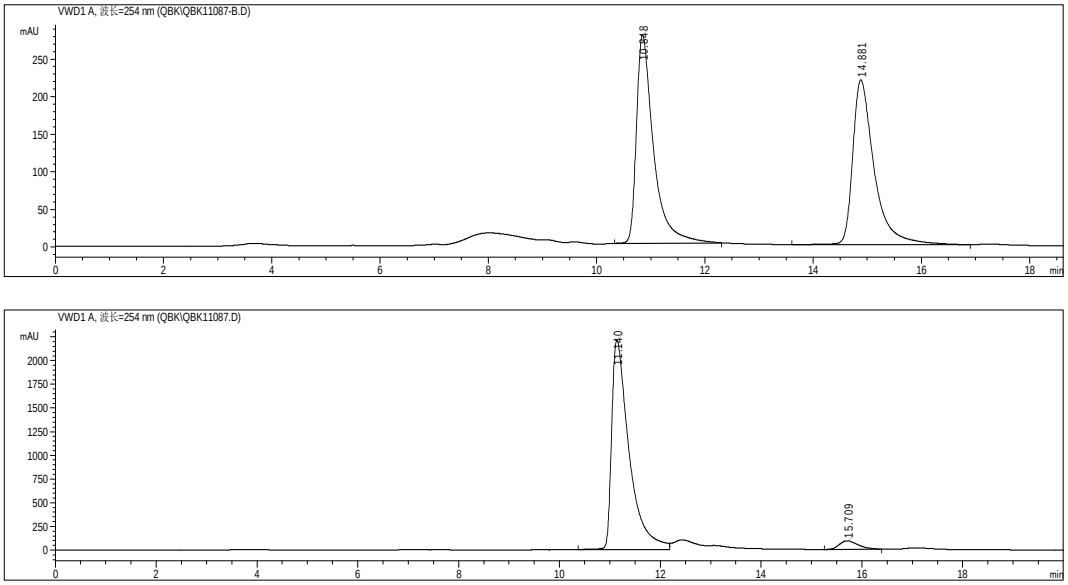


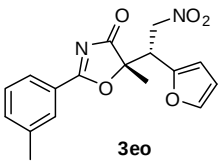
3en

3en, white solid; Mp 122–123 °C; 92% ee; dr = 16:1; 84% yield (major diastereomer); $[\alpha]_D^{26}$ –76.5 (*c* 3.00, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 7.98–7.94 (m, 2H), 7.55–7.53 (m, 1H), 7.44 (t, *J* = 7.6 Hz, 1H), 7.30 (dd, *J* = 5.0, 2.9 Hz, 1H), 7.27–7.26 (m, 1H), 7.08-7.06 (m, 1H), 4.78 (dd, *J* = 13.0, 10.8 Hz, 1H), 4.67 (dd, *J* = 13.0, 4.6 Hz, 1H), 4.27 (dd, *J* = 10.8, 4.5 Hz, 1H), 2.45 (s, 3H), 1.55 (s, 3H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 192.1, 185.7, 139.2, 136.7, 133.4, 130.6, 129.0, 127.2, 126.9, 125.0, 124.9, 87.3, 75.0, 44.9, 21.3, 21.2; HRMS (ESI) m/z 345.0905

($M+H^+$), calc. for $C_{17}H_{17}N_2O_4S$ 345.0909.

The ee was determined by HPLC analysis. CHIRALPAK IB (4.6 mm i.d. x 250 mm); Hexane/2-propanol = 75/25; flow rate 1.0 ml/min; 25 ^oC; 254 nm; retention time: 11.1 min (major) and 15.7 min (minor).

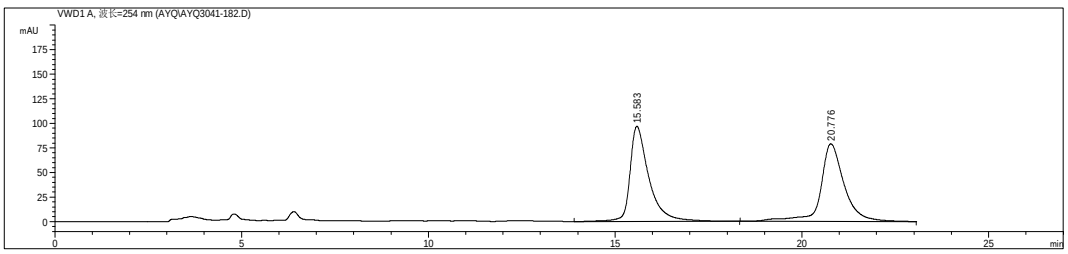


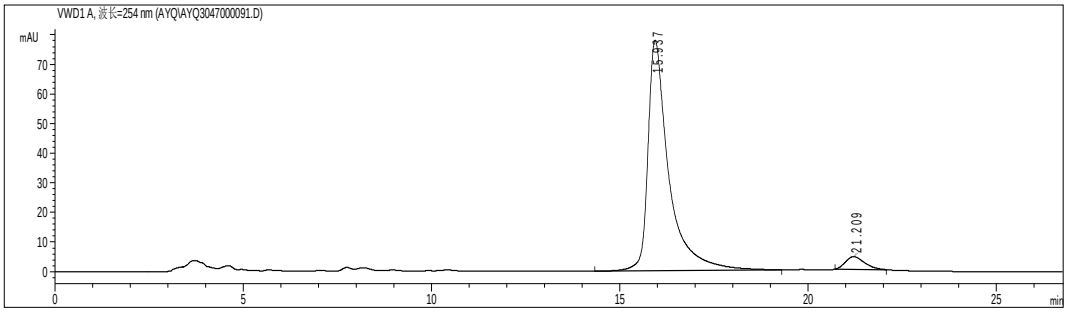


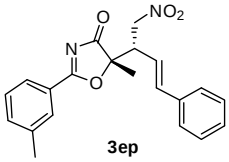
3eo

3eo, white solid; Mp 111–112 ^oC; 90% ee; dr = 10:1; 84% yield (major diastereomer); $[\alpha]_D^{26}$ –75.9 (*c* 1.43, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 7.99–7.97 (m, 2H), 7.53 (br d, *J* = 7.6 Hz, 1H), 7.44 (t, *J* = 7.6 Hz, 1H), 7.37 (d, *J* = 1.1 Hz, 1H), 6.39–6.25 (m, 2H), 4.88 (dd, *J* = 13.4, 10.5 Hz, 1H), 4.65 (dd, *J* = 13.4, 4.4 Hz, 1H), 4.25 (dd, *J* = 10.5, 4.4 Hz, 1H), 2.45 (s, 3H), 1.58 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.6, 185.8, 146.8, 143.4, 139.1, 136.7, 130.7, 129.0, 127.4, 124.9, 110.6, 110.5, 86.2, 73.0, 43.3, 21.2, 21.1; HRMS (ESI) m/z 329.1135 ($M+H^+$), calc. for $C_{17}H_{17}N_2O_5$ 329.1137.

The ee was determined by HPLC analysis. CHIRALPAK IB (4.6 mm i.d. x 250 mm); Hexane/2-propanol = 90/10; flow rate 1.0 ml/min; 25 ^oC; 254 nm; retention time: 15.9 min (major) and 21.2 min (minor).



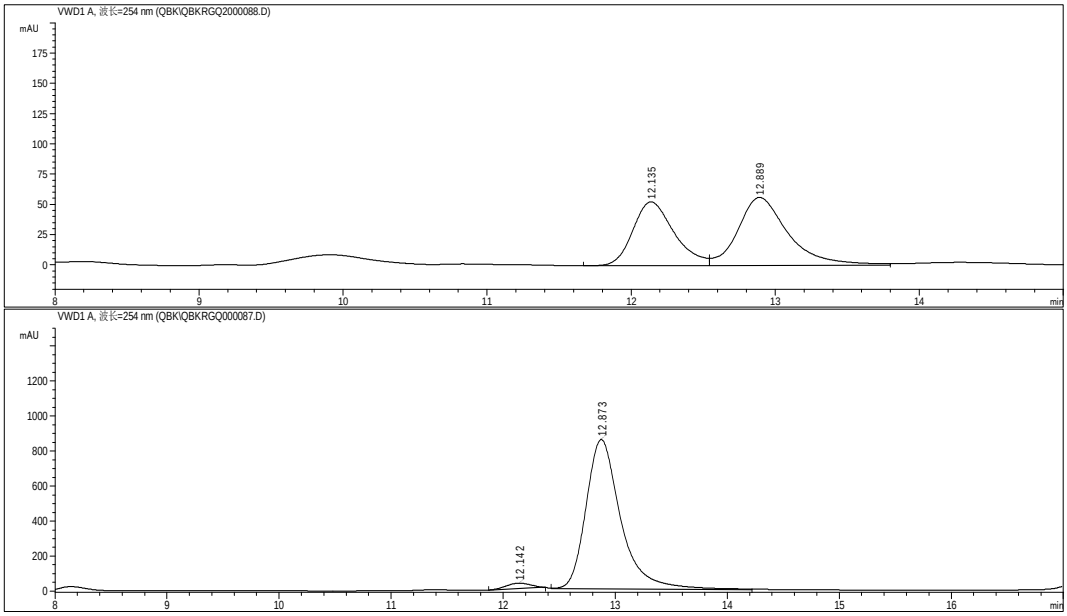


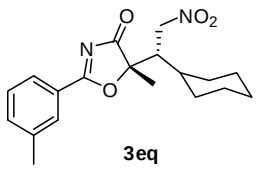


3ep

3ep, yellow solid; Mp 117–118 °C; 95% ee; dr >19:1; 89% yield (major diastereomer); $[\alpha]_D^{26}$ –77.9 (*c* 2.45, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 8.02–8.00 (m, 2H), 7.53 (br d, *J* = 7.7 Hz, 1H), 7.45–7.42 (m, 1H), 7.34–7.25 (m, 5H), 6.66 (d, *J* = 15.7 Hz, 1H), 6.02 (dd, *J* = 15.7, 9.7 Hz, 1H), 4.52 (qd, *J* = 12.2, 7.5 Hz, 2H), 3.63 (td, *J* = 9.9, 4.7 Hz, 1H), 2.44 (s, 3H), 1.65 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.9, 185.9, 139.1, 138.3, 136.7, 135.5, 130.7, 129.0, 128.6, 128.5, 127.4, 126.7, 124.9, 120.0, 86.8, 74.9, 47.8, 21.2; HRMS (ESI) m/z 365.1496 ($M+H^+$), calc. for $C_{21}H_{20}N_2O_4$ 365.1501.

The ee was determined by HPLC analysis. CHIRALPAK IB (4.6 mm i.d. x 250 mm); Hexane/2-propanol = 80/20; flow rate 1.0 ml/min; 25 °C; 254 nm; retention time: 12.1 min (major) and 12.9 min (minor).



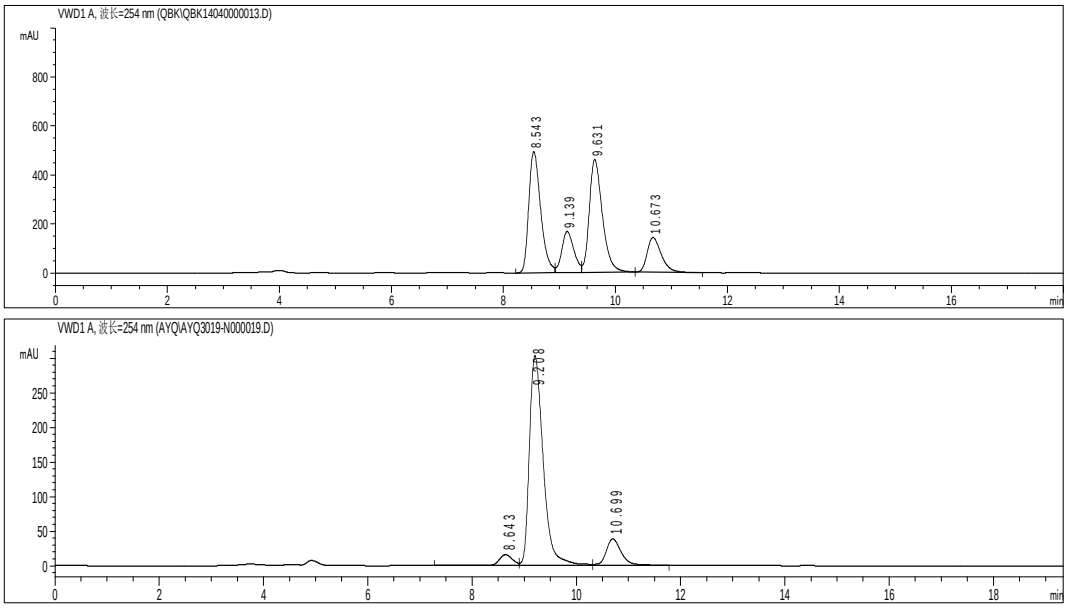


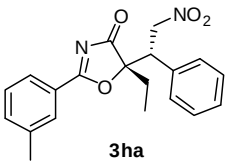
3eq

3eq, as a slightly sticky white solid; 78% ee; dr >19:1; 42% yield (major diastereomer); $[\alpha]_D^{26}$ –67.4 (*c* 0.35, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 8.01–7.96 (m, 2H), 7.54 (d, *J* = 7.5 Hz, 1H), 7.45 (t,

J = 7.7 Hz, 1H), 4.64 (dd, *J* = 14.2, 6.5 Hz, 1H), 4.48 (dd, *J* = 14.2, 5.1 Hz, 1H), 2.45 (s, 3H), 1.88 (t, *J* = 11.8 Hz, 1H), 1.62 (m, 4H), 1.35–0.81 (m, 10H); ^{13}C NMR (101 MHz, $CDCl_3$) δ 192.9, 185.4, 139.2, 136.5, 130.8, 129.0, 127.3, 125.1, 87.1, 72.1, 48.1, 36.20, 32.2, 28.2, 26.6, 26.3, 25.8, 21.2; HRMS (ESI) m/z 345.1808 ($M+H^+$), calc. for $C_{19}H_{25}N_2O_4$ 345.1814.

The ee was determined by HPLC analysis. CHIRALPAK IB (4.6 mm i.d. x 250 mm); Hexane/2-propanol = 90/10; flow rate 1.0 ml/min; 25 °C; 254 nm; retention time: 8.6 min (minor), 9.2 min (major) and 10.7 min (minor).

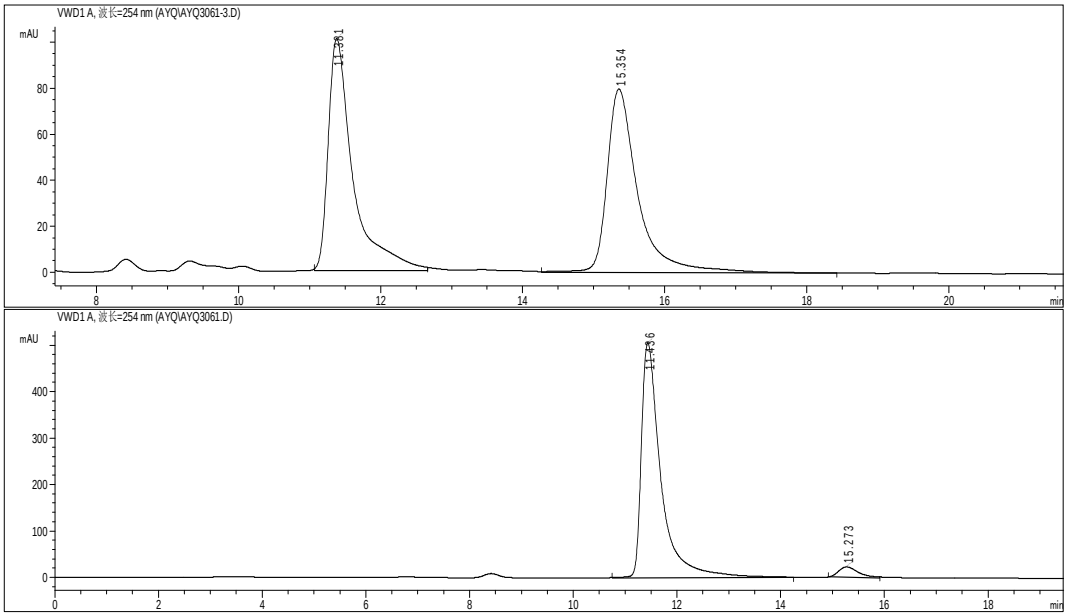


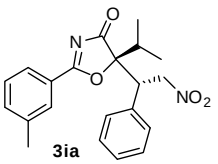


3ha

3ha, white solid; Mp 113–114 °C; 91% ee; dr >19:1; 94% yield; $[\alpha]_D^{26}$ –76.8 (*c* 1.93, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.98–7.95 (m, 2H), 7.55-7.53 (br d, *J* = 7.7 Hz, 1H), 7.44 (t, *J* = 7.6 Hz, 1H), 7.30 (dt, *J* = 8.2, 3.9 Hz, 5H), 4.85 (dd, *J* = 13.1, 11.2 Hz, 1H), 4.68 (dd, *J* = 13.1, 4.3 Hz, 1H), 4.11 (dd, *J* = 11.1, 4.3 Hz, 1H), 2.45 (s, 3H), 1.96 (dq, *J* = 14.7, 7.4 Hz, 1H), 1.82 (dq, *J* = 14.6, 7.3 Hz, 1H), 0.80 (t, *J* = 7.4 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.0, 186.3, 139.2, 136.7, 133.3, 130.7, 129.0, 128.9, 128.9, 128.8, 127.2, 124.6, 91.1, 74.9, 48.9, 28.3, 21.2, 6.9; HRMS (ESI) m/z 375.1317 ($M+Na^+$), calc. for $C_{20}H_{20}N_2O_4Na$ 375.1321.

The ee was determined by HPLC analysis. CHIRALPAK IB (4.6 mm i.d. x 250 mm); Hexane/2-propanol = 90/10; flow rate 1.0 ml/min; 25 °C; 254 nm; retention time: 11.4 min (major) and 15.3 min (minor).

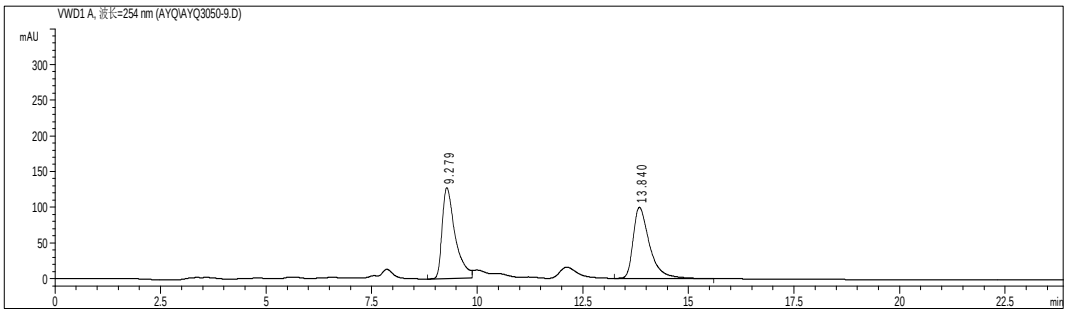


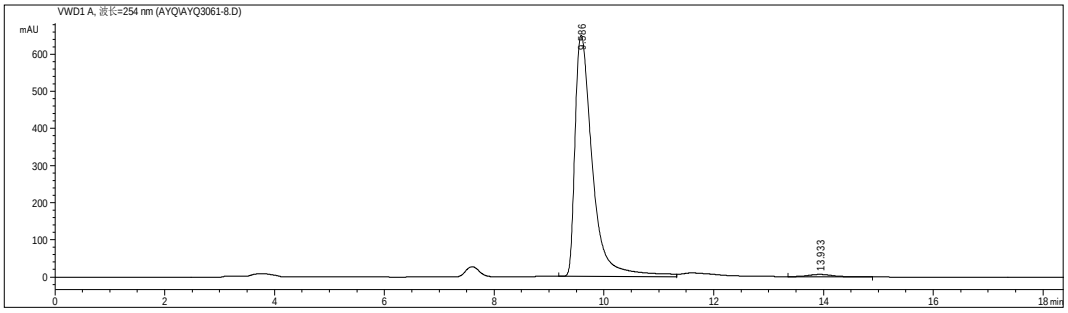


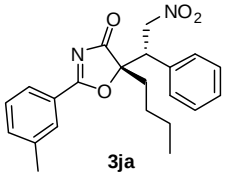
3ia

3ia, white solid; Mp 134–135 ^{o}C; 98% ee; dr >19:1; 70% yield; $[\alpha]_D^{26}$ –54.1 (*c* 0.50, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.90–7.89 (m, 2H), 7.52–7.50 (m, 1H), 7.41 (t, *J* = 7.8 Hz, 1H), 7.34–7.32 (m, 2H), 7.29–7.27 (m, 1H), 7.25–7.20 (m, 2H), 5.01 (dd, *J* = 13.1, 11.6 Hz, 1H), 4.70 (dd, *J* = 13.1, 3.9 Hz, 1H), 4.29 (dd, *J* = 11.5, 3.9 Hz, 1H), 2.43 (s, 3H), 2.28–2.15 (m, 1H), 1.09 (d, *J* = 6.8 Hz, 3H), 1.00 (d, *J* = 6.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.9, 186.2, 139.1, 136.5, 133.0, 130.6, 128.9, 128.8, 128.8, 127.0, 124.7, 92. 8, 74.8, 46.7, 32.1, 21.2, 16.1, 15.8; HRMS (ESI) m/z 367.1656 ($M+H^+$), calc. for $C_{21}H_{23}N_2O_4$ 367.1658.

The ee was determined by HPLC analysis. CHIRALPAK IB (4.6 mm i.d. x 250 mm); Hexane/2-propanol = 90/10; flow rate 1.0 ml/min; 25 ^{o}C; 254 nm; retention time: 9.6 min (major) and 13.9 min (minor).



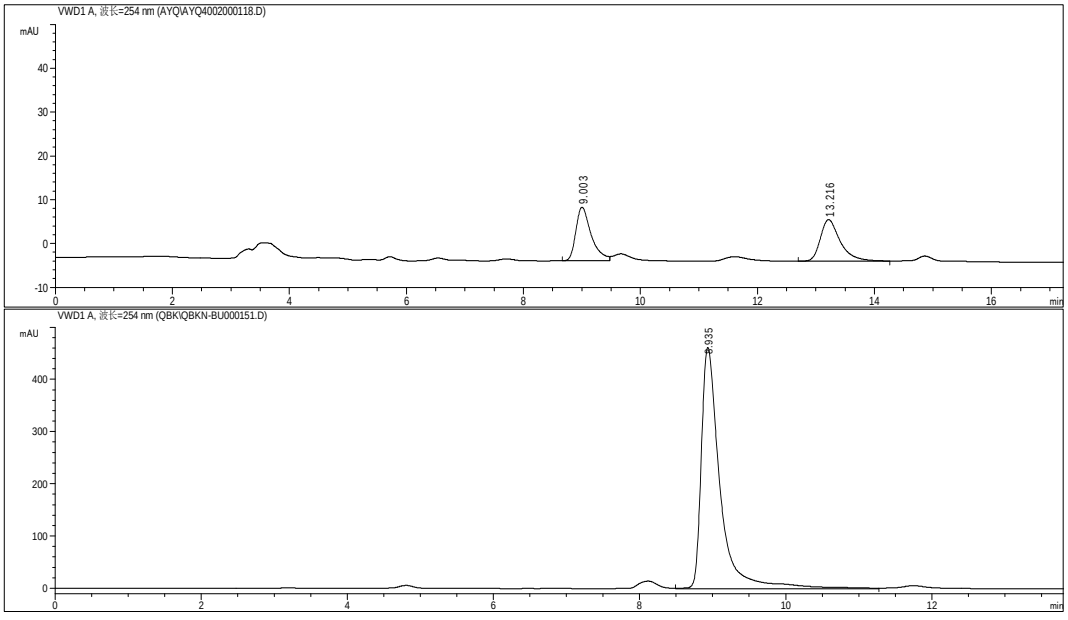


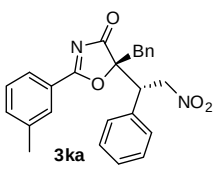


3ja

3ja, white solid; Mp 148.9–149.2 °C; 99% ee; dr >19:1; 99% yield; $[\alpha]_D^{26}$ –77.3 (*c* 0.90, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 7.97–7.94 (m, 2H), 7.54-7.53 (m, 1H), 7.44 (t, *J* = 7.7 Hz, 1H), 7.32–7.28 (m, 5H), 4.87 (dd, *J* = 13.1, 11.1 Hz, 1H), 4.69 (dd, *J* = 13.1, 4.3 Hz, 1H), 4.10 (dd, *J* = 7.6, 3.4 Hz, 1H), 2.45 (s, 3H), 1.95–1.86 (m, 1H), 1.83–1.72 (m, 1H), 1.24–1.11 (m, 4H), 0.78 (t, *J* = 7.1 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 192.1, 186.2, 139.2, 136.7, 133.2, 130.7, 129.0, 128.9, 128.8, 127.2, 124.7, 90.7, 74.9, 49.1, 34.7, 24.6, 22.3, 21.2, 13.7; HRMS (EI) m/z 381.1806 ($M+H^+$), calc. for $C_{22}H_{25}N_2O_4$ 381.1814.

The ee was determined by HPLC analysis. CHIRALPAK IB (4.6 mm i.d. x 250 mm); Hexane/2-propanol = 90/10; flow rate 1.0 ml/min; 25 °C; 254 nm; retention time: 8.9 min (major) and 13.0 min (minor).



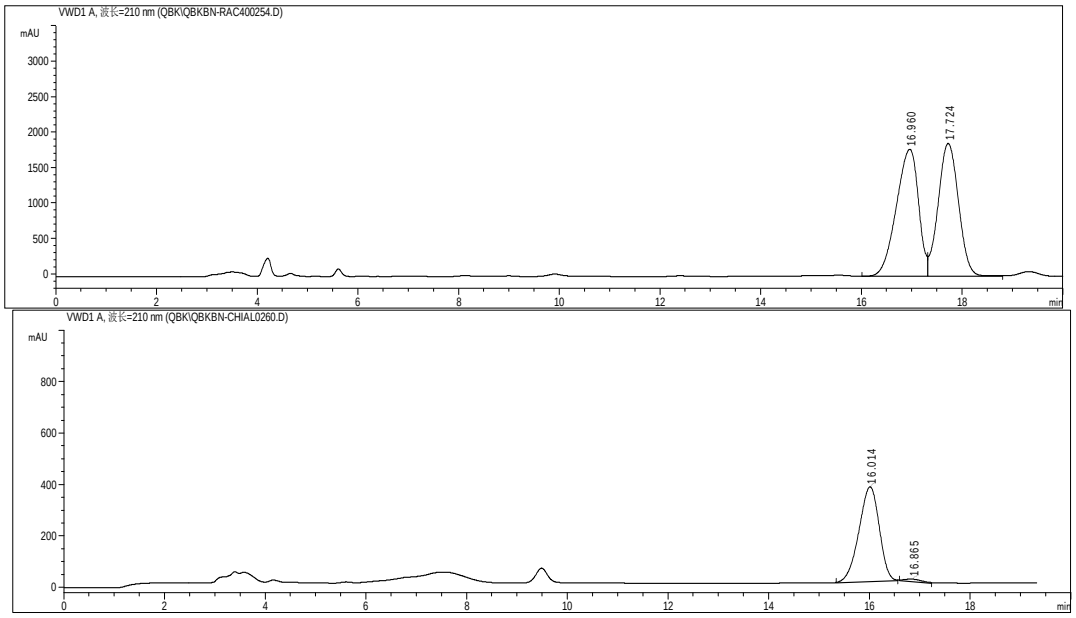


3ka

3ka, white solid; Mp 135–136 °C; 95% ee; dr >19:1; 85% yield; $[\alpha]_D^{26}$ –70.0 (*c* 0.10, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 7.81–7.79 (m, 2H), 7.49–7.47 (m, 1H), 7.41–7.32 (m, 6H), 7.11–7.06 (m, 5H), 4.88 (dd, *J* =

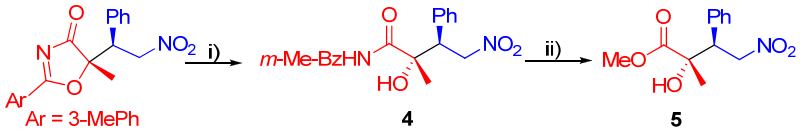
13.0, 11.3 Hz, 1H), 4.72 (dd, *J* = 13.1, 4.2 Hz, 1H), 4.22 (dd, *J* = 11.3, 4.2 Hz, 1H), 3.18 (d, *J* = 14.0 Hz, 1H), 3.02 (d, *J* = 14.0 Hz, 1H), 2.40 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.4, 185.9, 139.0, 136.5, 133.3, 131.9, 130.5, 129.9, 129.1, 128.9, 128.9, 128.4, 127.7, 126.8, 124.6, 90.5, 75.0, 49.0, 41.1, 21.2; HRMS (ESI) m/z 415.1662 ($M+H^+$), calc. for $C_{25}H_{23}N_2O_4$ 415.1658.

The ee was determined by HPLC analysis. CHIRALCEL ADH (4.6 mm i.d. x 250 mm); Hexane/2-propanol = 85/15; flow rate 1.0 ml/min; 25 ^{o}C; 210 nm; retention time: 16.0 min (major) and 16.9 min (minor).



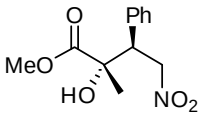
4. Synthesis and Characterization of 5 and 6

a）Synthesis and Characterization of 5



i) 0.5 mL NaOH aqueous solution (1.0 N, 5.0 equiv.) was added dropwise to a stirred solution of **3ea** (33.8 mg, 0.10 mmol, 1.0 equiv.) in THF (3mL) at –15 °C. After stirring at the same temperature for 6 hours, 1.5 mL HCl aqueous solution (2.0 *N*) was added to the reaction mixture. Then the mixture was extracted three times with EtOAc, and the combined organic phase was washed with brine, dried (Na_2SO_4) and concentrated under reduced pressure. The residue was purified by silica gel chromatography (PE/EtOAc = 2/1), affording product **4** (26.0 mg, 73% yield) as a white solid.

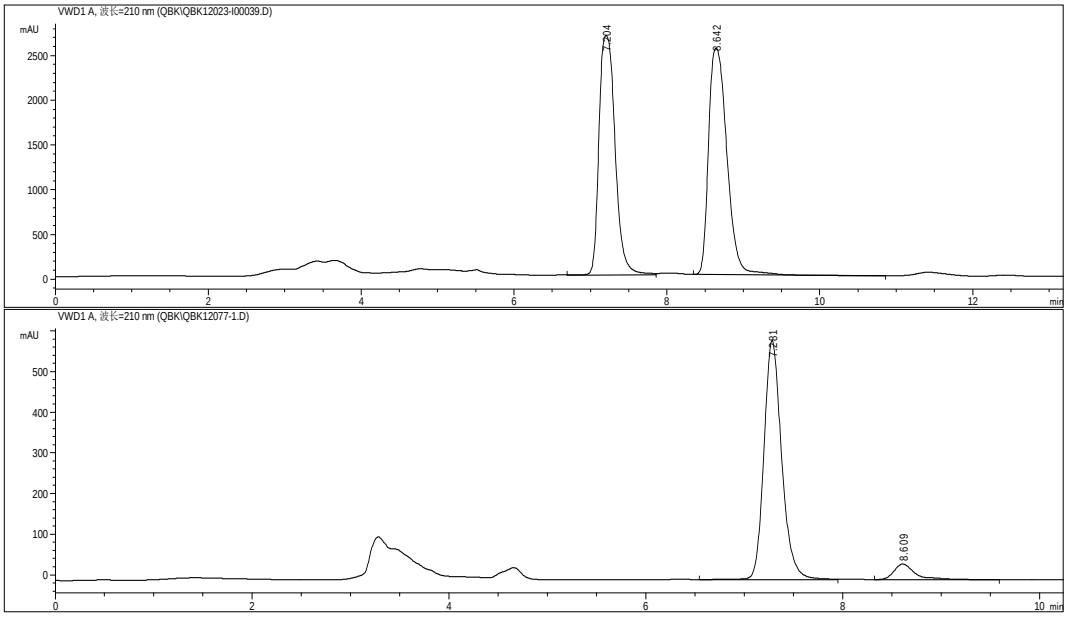
ii) To a solution of **4** (17.8 mg, 0.05 mmol) in MeOH (0.5 mL) was added $Er(OTf)_3$ (30.7 mg, 0.05 mmol). The resulting mixture was stirred for 24 hours at 60 °C. The solvent was removed under reduced pressure, and the residue was purified by flash chromatography on silica gel (PE/EtOAc = 5/1) to afford compound **5** (9.0 mg) as a white solid in 71% yield and 94% ee.



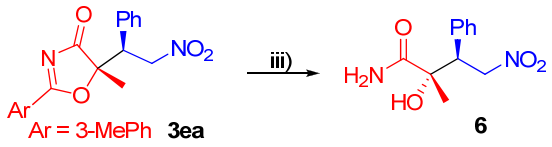
5

White solid, Mp 148.2–148.7 °C; 94% ee; 52% yield (two steps); $[\alpha]_D^{26}$ +150.0 (*c* 0.20, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 7.34 (m, 5H), 4.85 (dd, *J* = 13.1, 9.9 Hz, 1H), 4.60 (dd, *J* = 13.2, 4.7 Hz, 1H), 3.90 (d, *J* = 4.8 Hz, 1H), 3.87 (s, 3H), 3.34 (s, 1H), 1.20 (s, 3H); ^{13}C NMR (100 MHz, DMSO) δ 175.0, 135.8, 129.5, 128.1, 127.7, 76.8, 75.3, 52.3, 50.7, 24.0; HRMS (EI) m/z 254.1031 ($M+H^+$), calc. for $C_{12}H_{16}NO_5$ 254.1028.

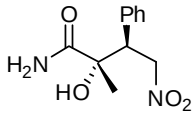
The *ee* was determined by HPLC analysis. CHIRALPAK IC (4.6 mm i.d. x 250 mm); Hexane/2-propanol = 80/20; flow rate 1.0 ml/min; 25 °C; 210 nm; retention time: 7.3 min (major), 8.6 min (minor).



b）Synthesis and Characterization of 6



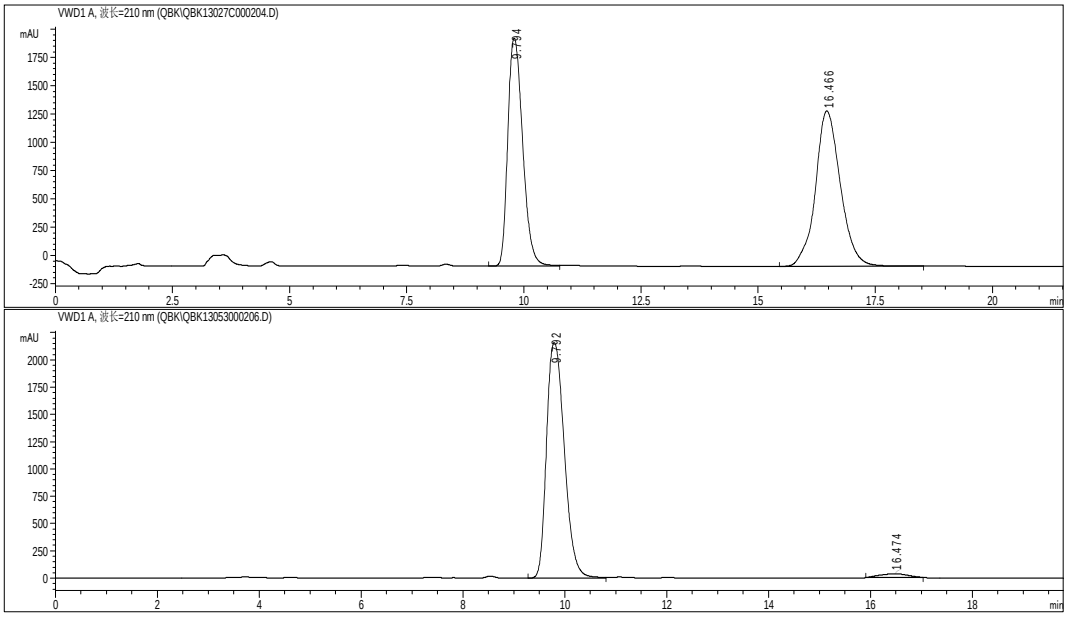
To a solution of **3ea** (33.8 mg, 0.1 mmol) in EtOH (0.5 mL) was added 0.5 mL NaOH aqueous solution (2.0 N, 10 equiv.). The resulting mixture was stirred for 1 hours at 60 ^{o}C , then the reaction mixtures were directly loaded onto silica gel column, followed by gradient elution with PE/EtOAc (20/1–2/1 ratio) and EtOAc/MeOH (100/1–10/1 ratio). Removing the solvent in *vacuo*, afforded products **6** (20.5 mg) as a white solid in 86% yield and 94% ee.



6

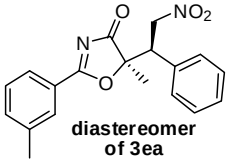
White solid, Mp 183.5–184.5 ^{o}C; 94% ee; 86% yield; $[\alpha]_D^{26}$ +18.9 (*c* 0.35, MeOH); ^{1}H NMR (400 MHz, MeOD) δ 7.18 (m, 2H), 7.11 (m, 3H), 4.77 (t, *J* = 12.3 Hz, 1H), 4.47 (dd, *J* = 12.9, 3.0 Hz, 1H), 3.67 (dd, *J* = 11.6, 2.8 Hz, 1H), 0.92 (s, 3H); ^{13}C NMR (100 MHz, MeOD) δ 181.1, 137.3, 130.8, 129.3, 128.9, 78.1, 77.3, 52.2, 25.5; HRMS(EI) m/z 239.1040 ($M+H^+$), calc. for $C_{11}H_{15}N_2O_4$ 239.1032.

The *ee* was determined by HPLC analysis. CHIRALPAK IC (4.6 mm i.d. x 250 mm); Hexane/2-propanol = 80/20; flow rate 1.0 ml/min; 25 ^{o}C; 210 nm; retention time: 9.8 min (major), 16.5 min (minor).


VWD1 A, 波长=210 nm (QBK\QBK13027C000204.D)
mAU
9.794
16.466
min
VWD1 A, 波长=210 nm (QBK\QBK13053000206.D)
mAU
9.792
16.474
min

5. Determination of the Absolute Configuration

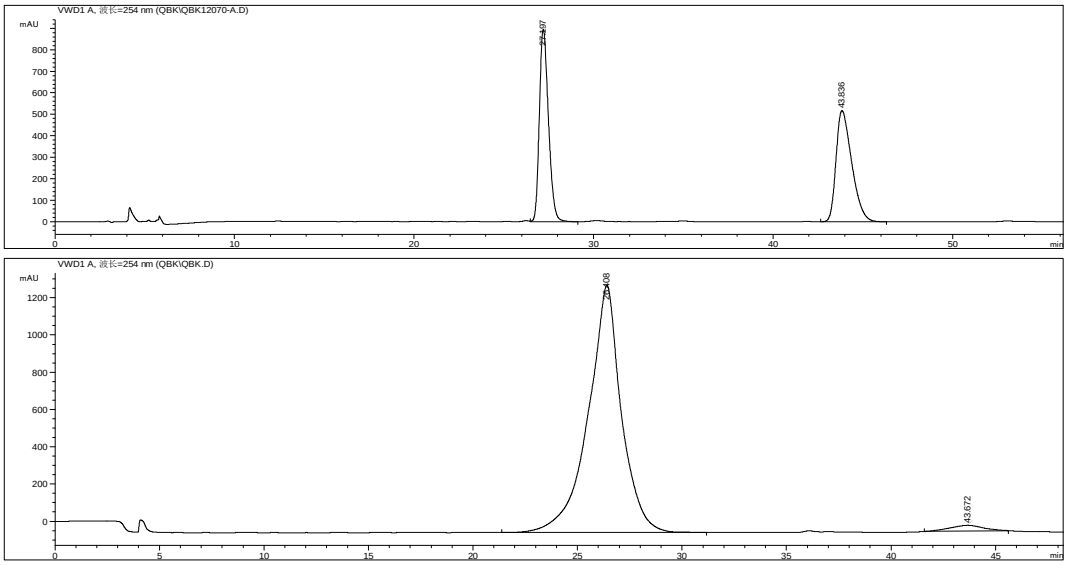
a. From ^{1}H NMR of **3ea**, chemical shifts and coupling constants of all peaks are same as literature[1] reported, indicating that the obtained major diastereomer of **3ea** has the same relative configuration. We also isolated another diastereomer and checked with ^{1}H NMR as well as ^{13}C NMR, and the results were different which confirmed our proposed relative configuration.



^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.93–7.90 (m, 2H), 7.53–7.51 (m, 1H), 7.42 (t, *J* = 7.7, 1H), 7.24–7.17 (m, 5H), 5.11 (dd, *J* = 13.4, 5.2, 1H), 5.00 (dd, *J* = 13.4, 10.2, 1H), 4.13 (dd, *J* = 10.2, 5.3, 1H), 2.43 (s, 3H), 1.65 (s, 3H). ^{13}C NMR (100 MHz, $CDCl_3$) δ 191.4, 185.3, 139.1, 136.54, 132.6, 130.6, 129.0, 128.9, 128.8, 128.6, 127.2, 125.0, 87.0, 74.6, 48.4, 21.2, 20.2.

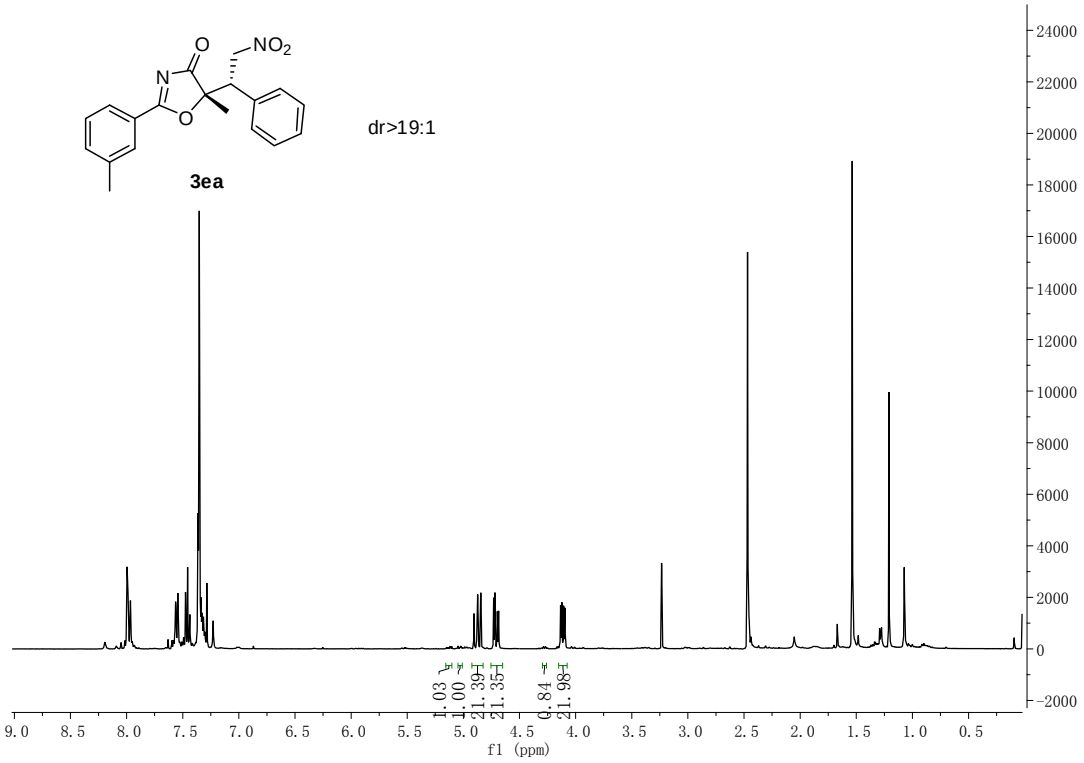
b. Under the same HPLC conditions, we found that **3ea** has opposite absolute configuration comparing with literature from the retention times.

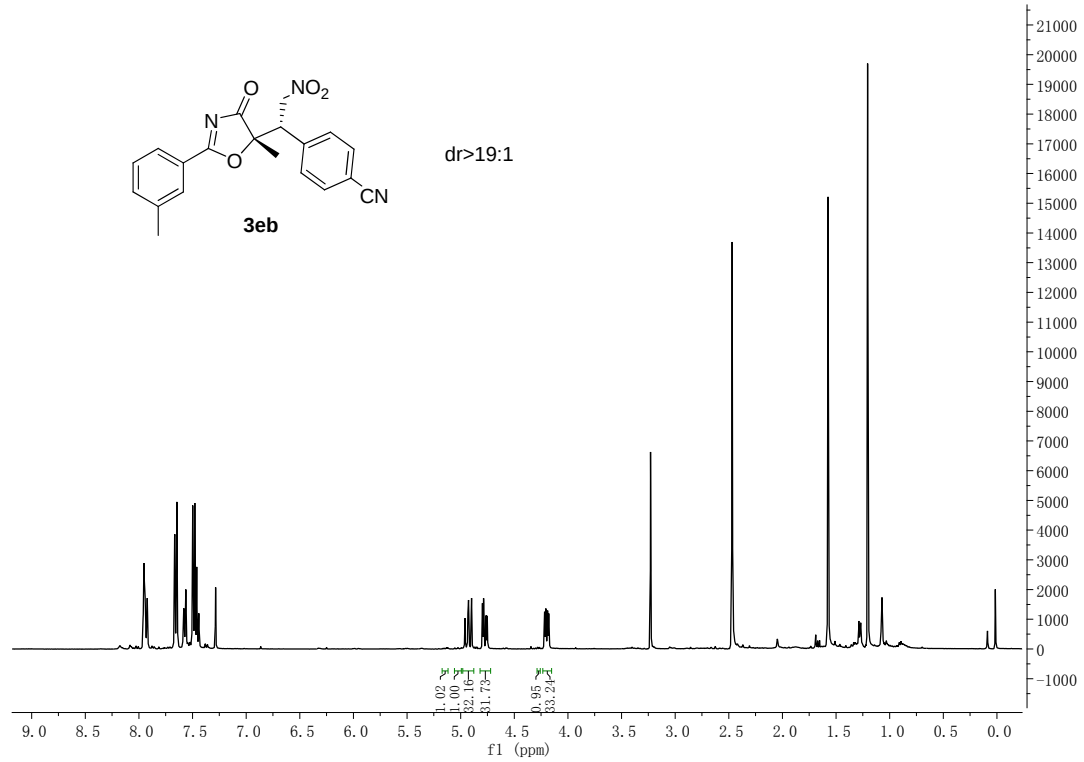
The ee was determined by HPLC analysis. CHIRALPAK IC (4.6 mm i.d. x 250 mm); Hexane/Ethyl acetate = 88/12; flow rate 0.8 ml/min; 25 °C; 254 nm; retention time: 26.4 min (major) and 43.7 min (minor).

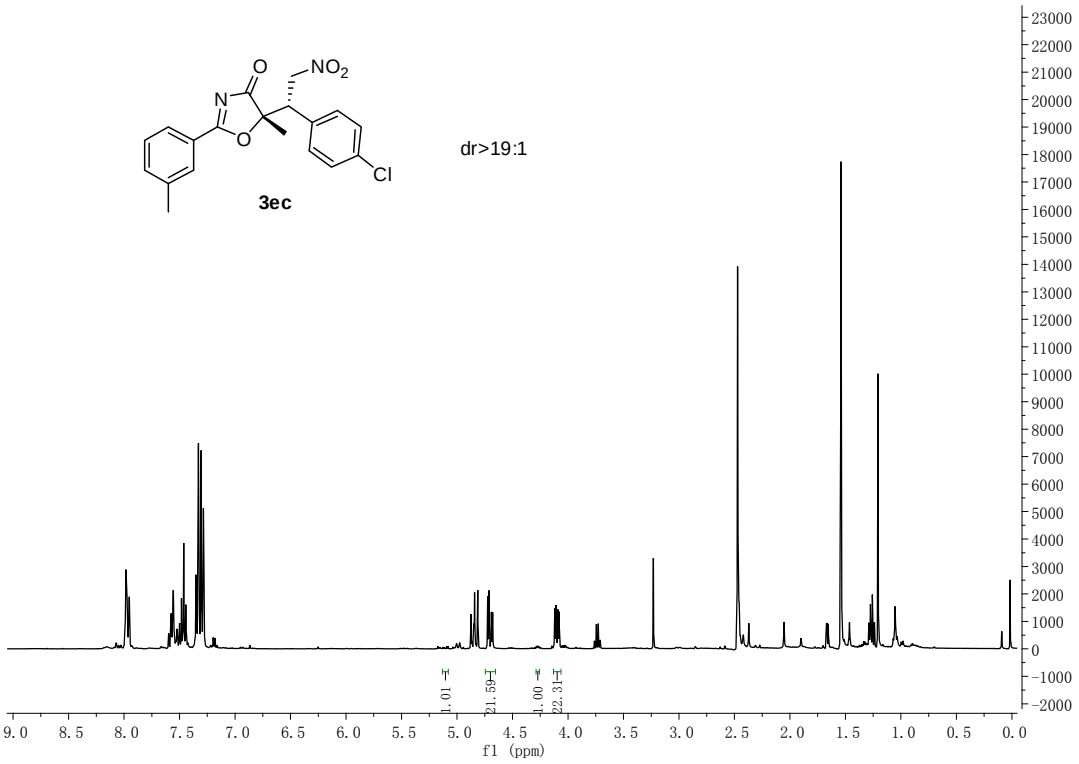


[1] B. M. Trost, K. Hirano, *Angew. Chem. Int. Ed.* 2012, **51**, 6480.

6. Crude ^{1}H NMR spectra to determine dr



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NO2
N
O
Cl
3ec
dr>19:1
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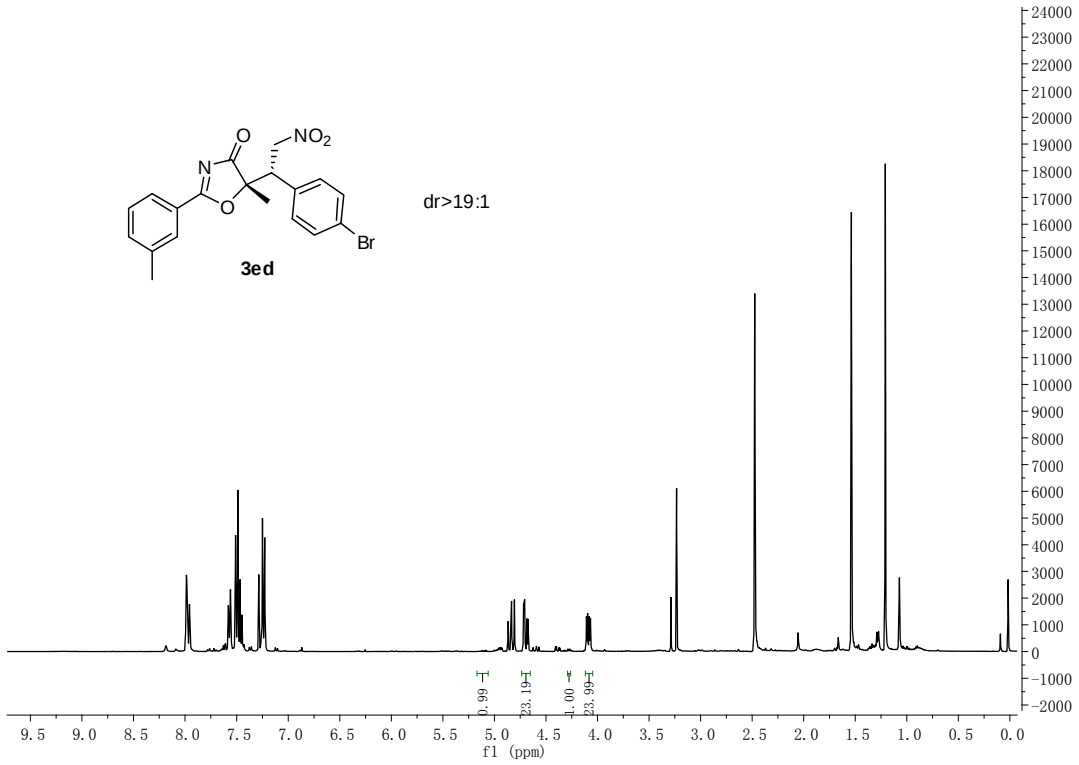
21.59
1.00
22.31
f1 (ppm)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N
O
Br
3ed
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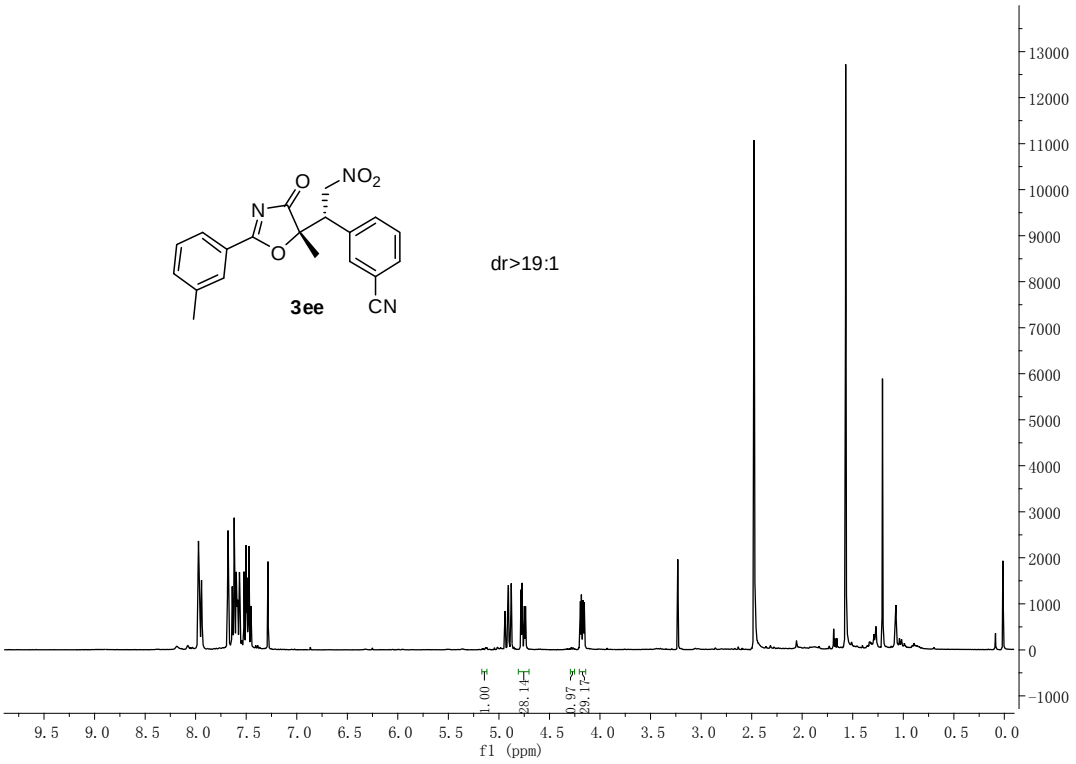
23.19
1.00
23.99
f1 (ppm)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O
3ee
CN
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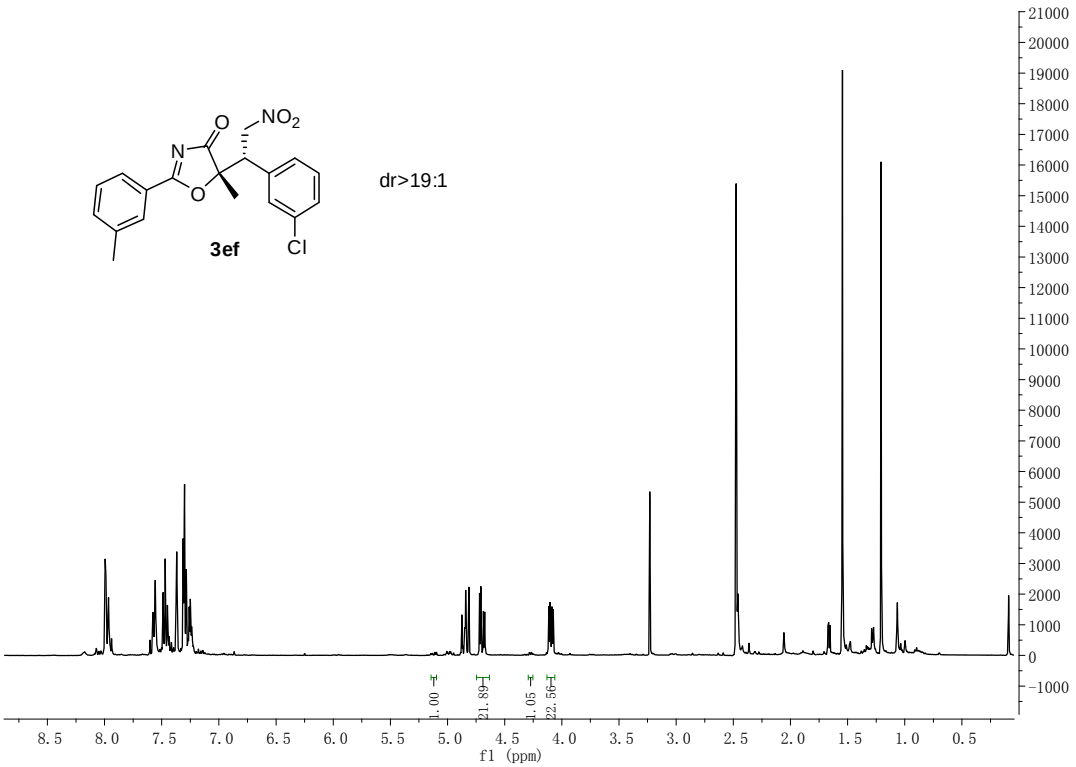
f1 (ppm)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O
3ef
Cl
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1.05
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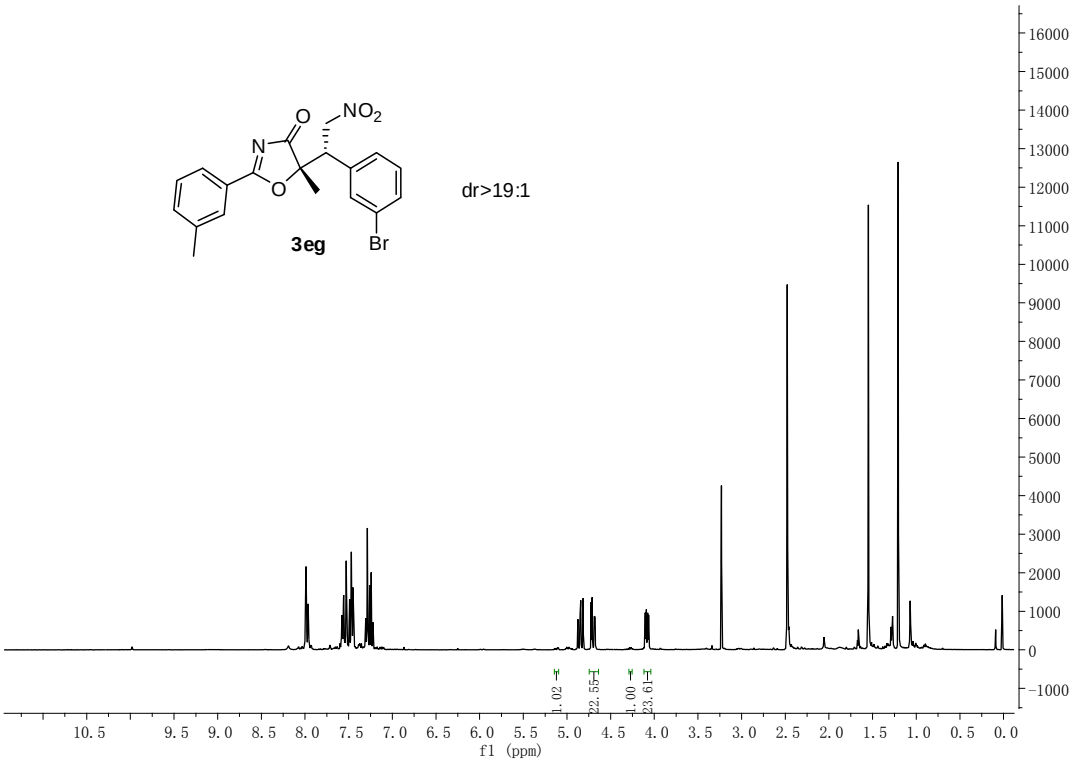
f1 (ppm)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N
O
Br
3eg
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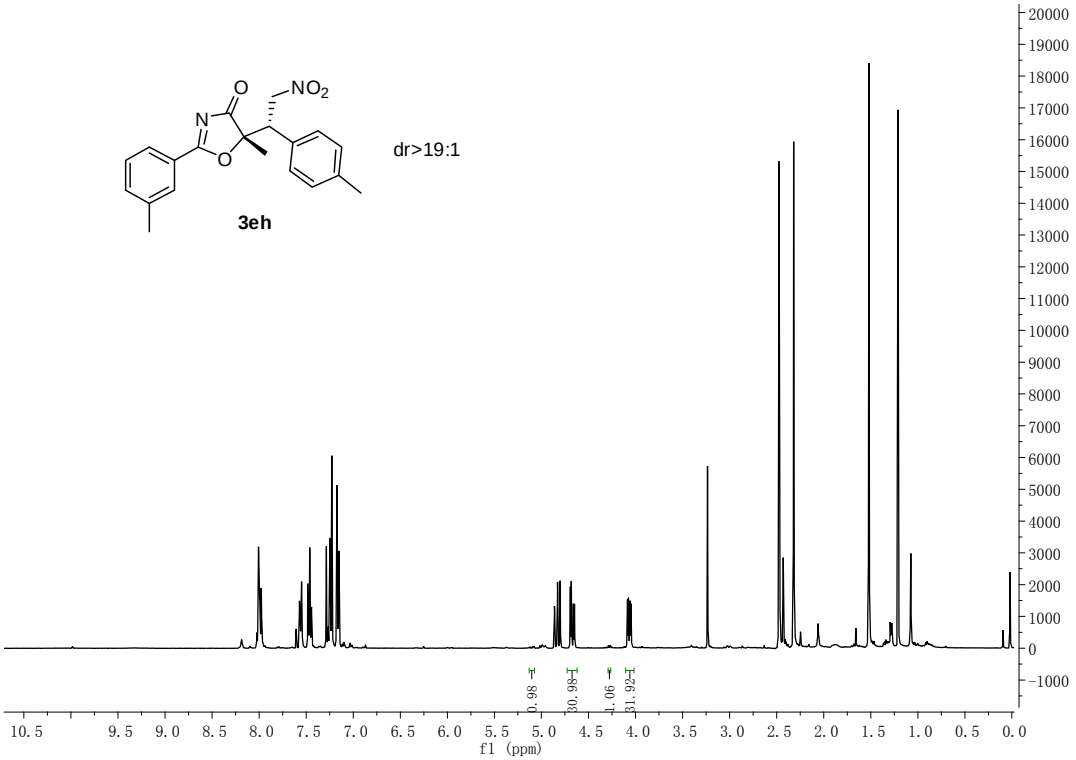
22.55
1.00
23.61
f1 (ppm)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NO2
N
O
3eh
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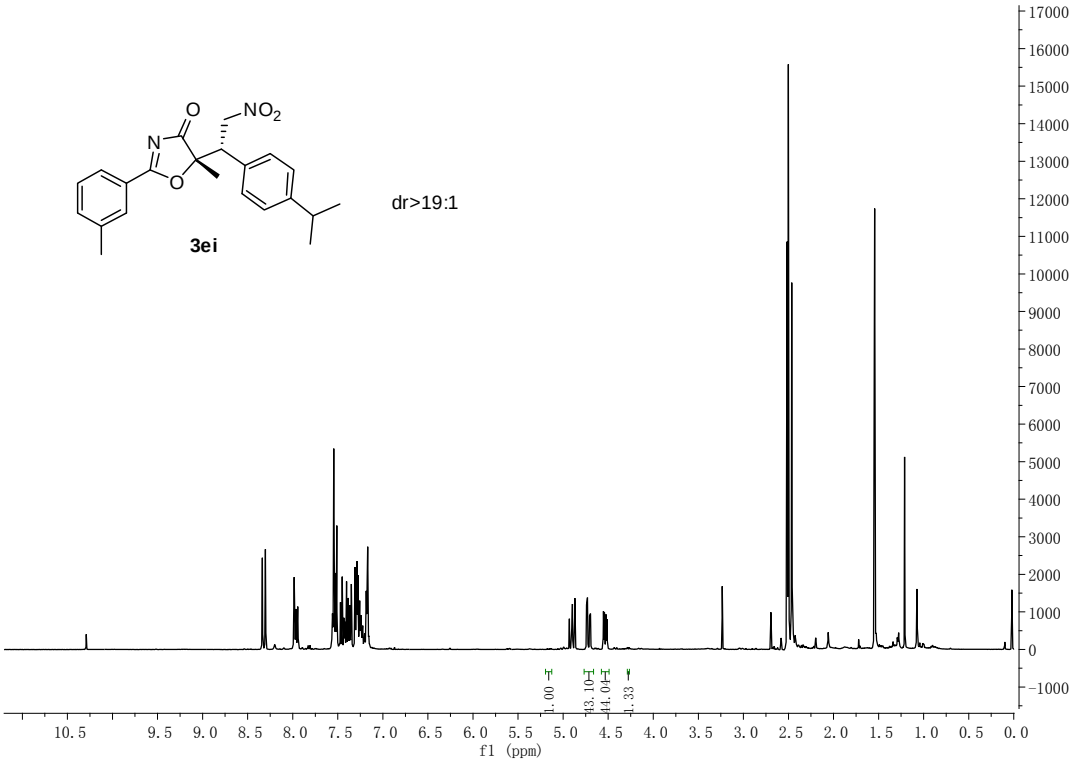
1.06
31.92
f1 (ppm)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N
O
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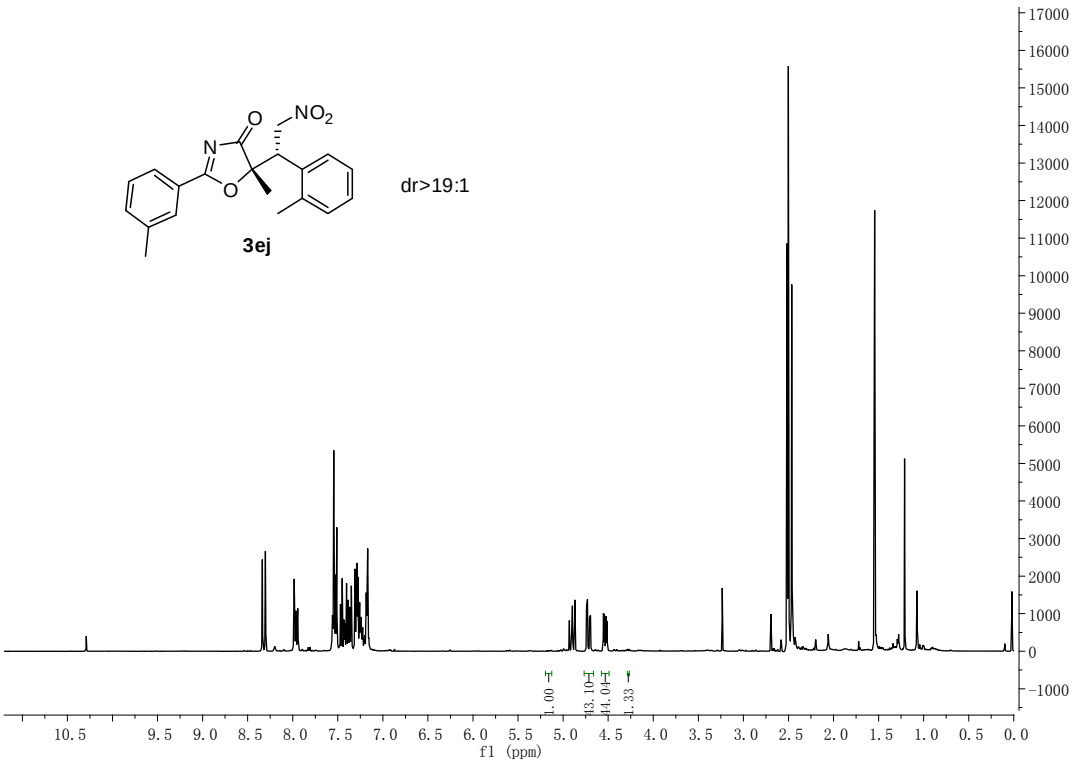
13.10
44.04
1.33
f1 (ppm)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NO2
N
O
3ej
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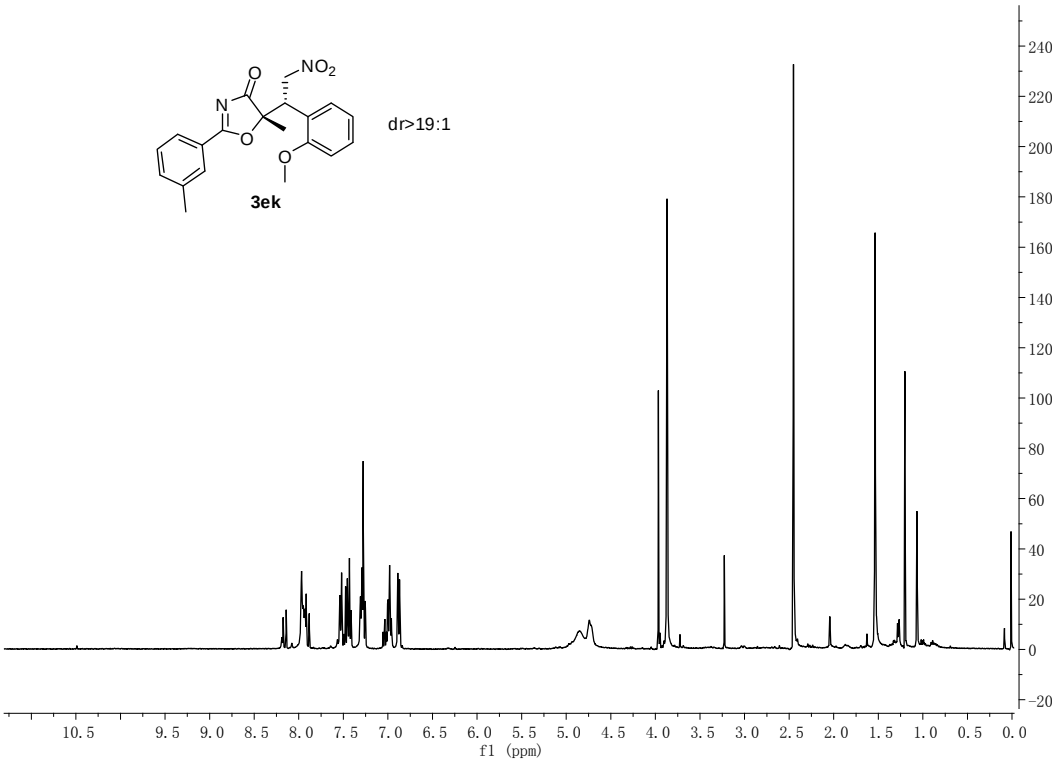
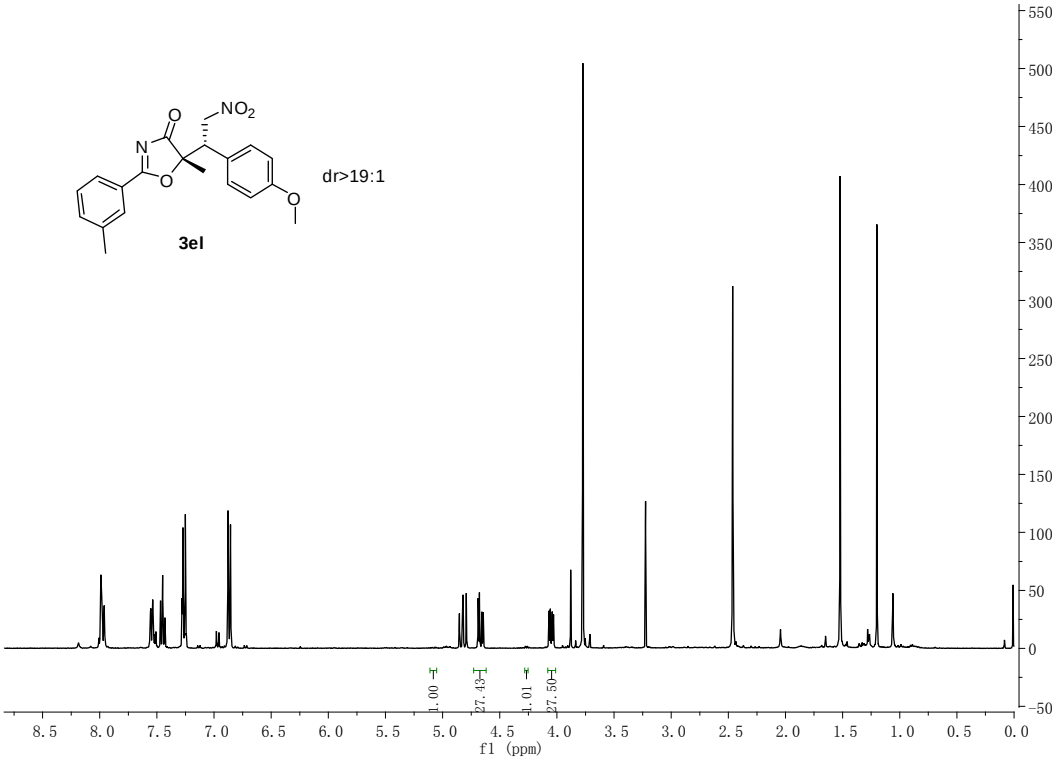
13.10
44.04
1.33
f1 (ppm)


NO2
O
N
O
O
dr>19:1
3ek
f1 (ppm)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O
O
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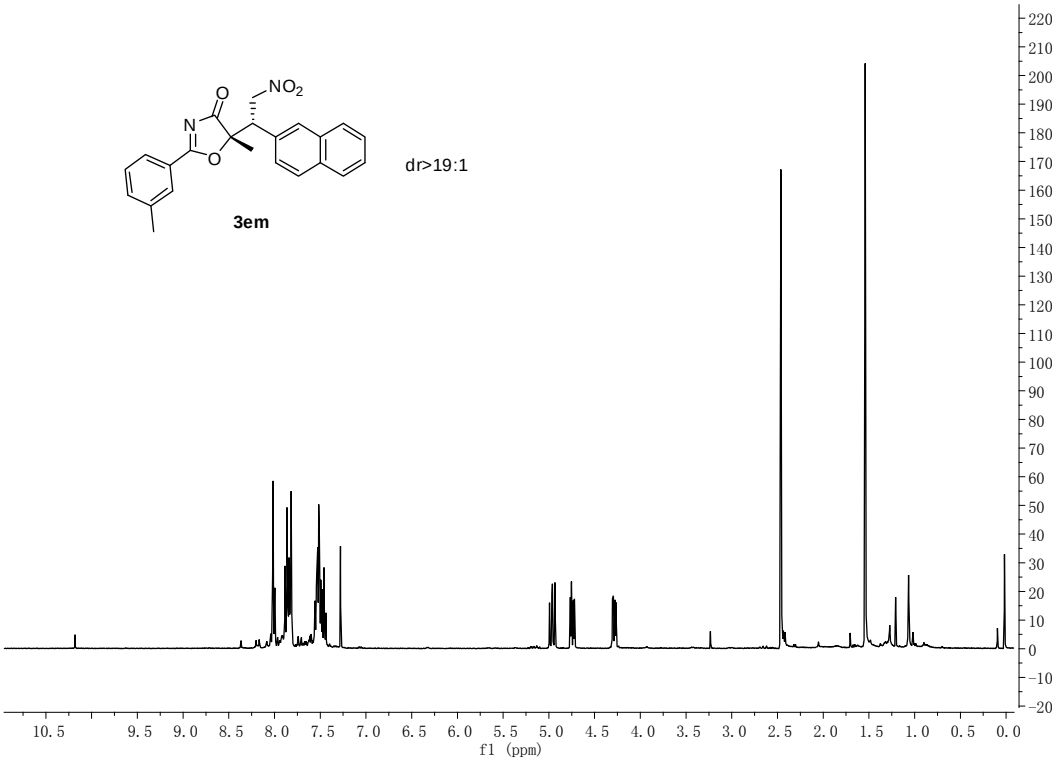
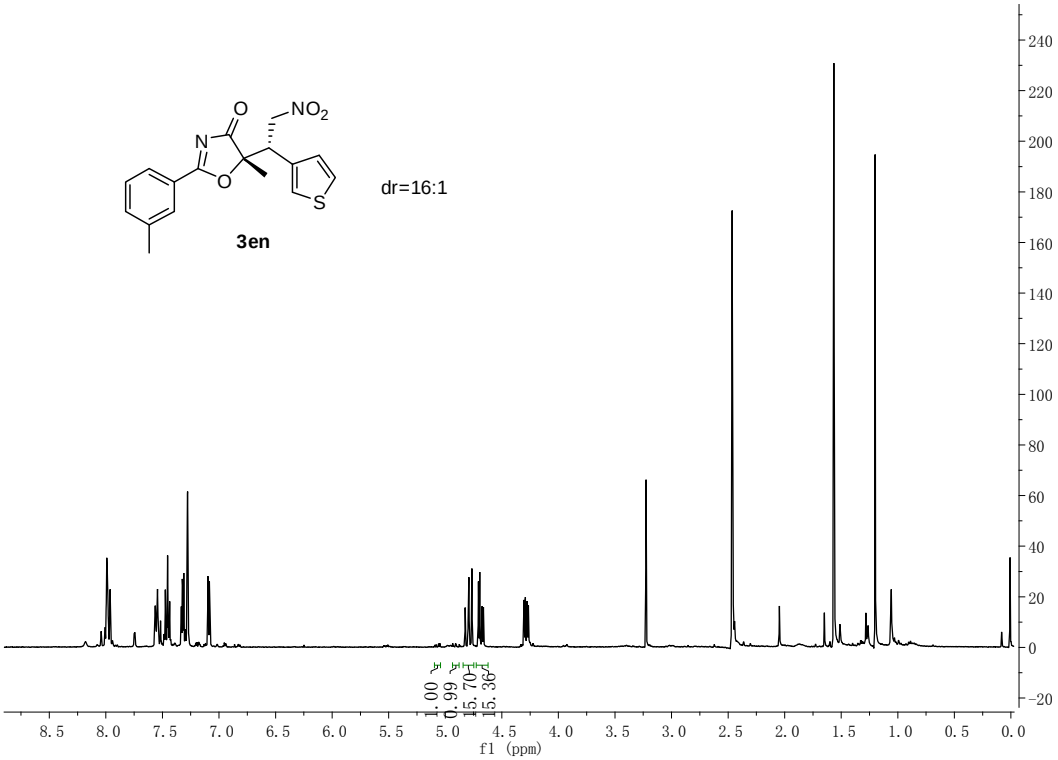
27.43
1.01
27.50
f1 (ppm)


NO2
O
N
O
3em
dr>19:1
f1 (ppm)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O
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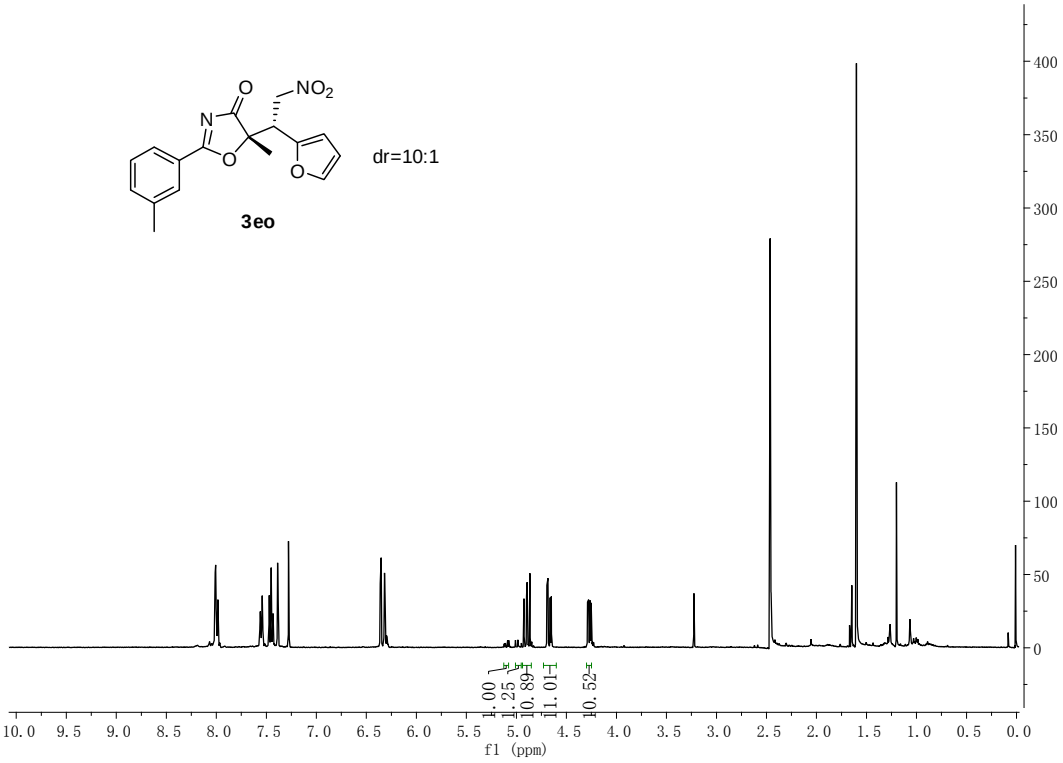
15.70
15.36
f1 (ppm)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N
O
O
3eo
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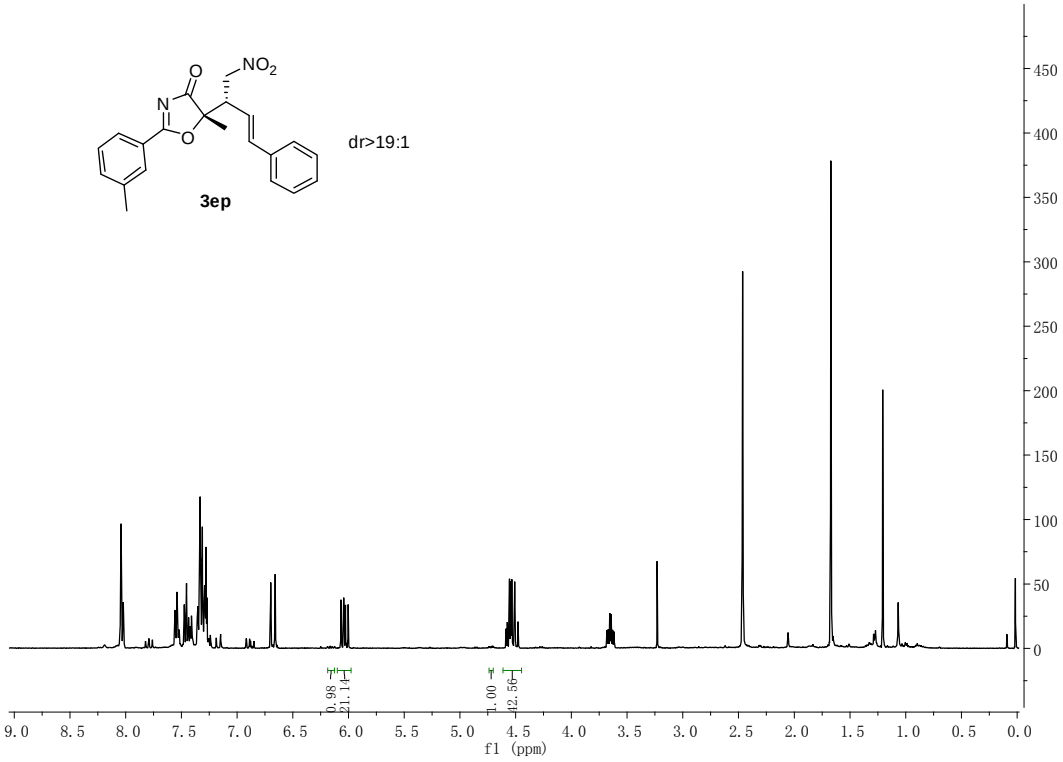
1.00
1.25
10.89
11.01
10.52
f1 (ppm)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NO2
N
O
3ep
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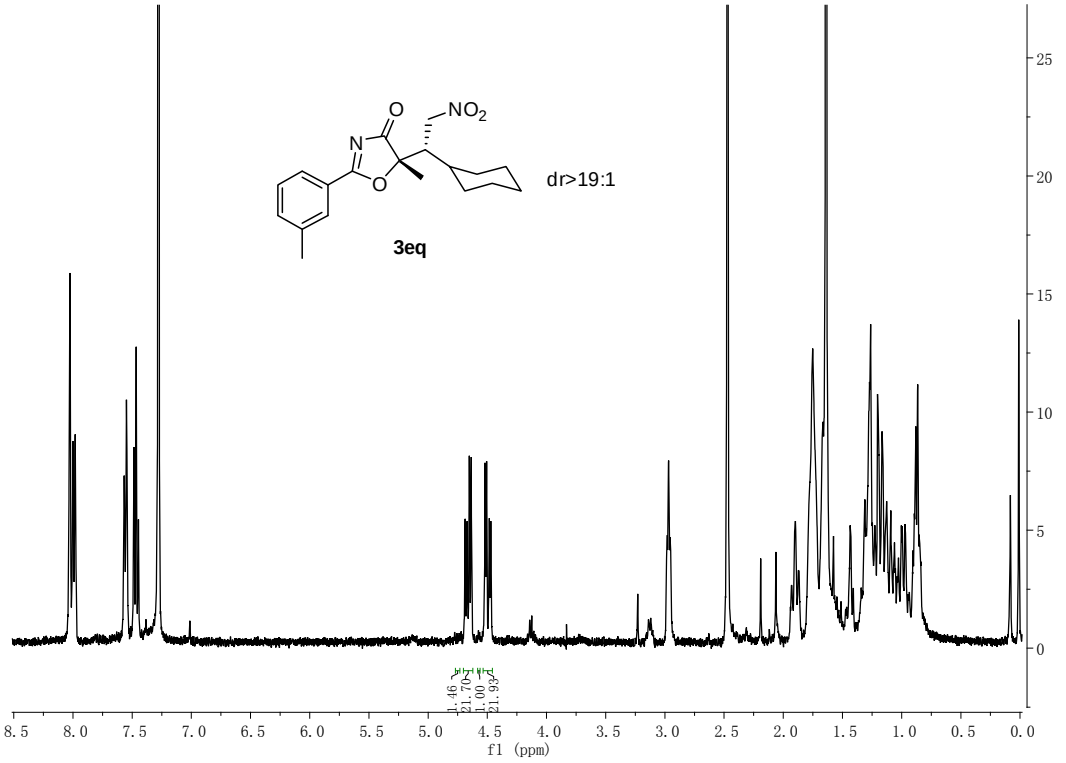
21.14
1.00
42.56
f1 (ppm)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N
O
NO2
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1.46
21.70
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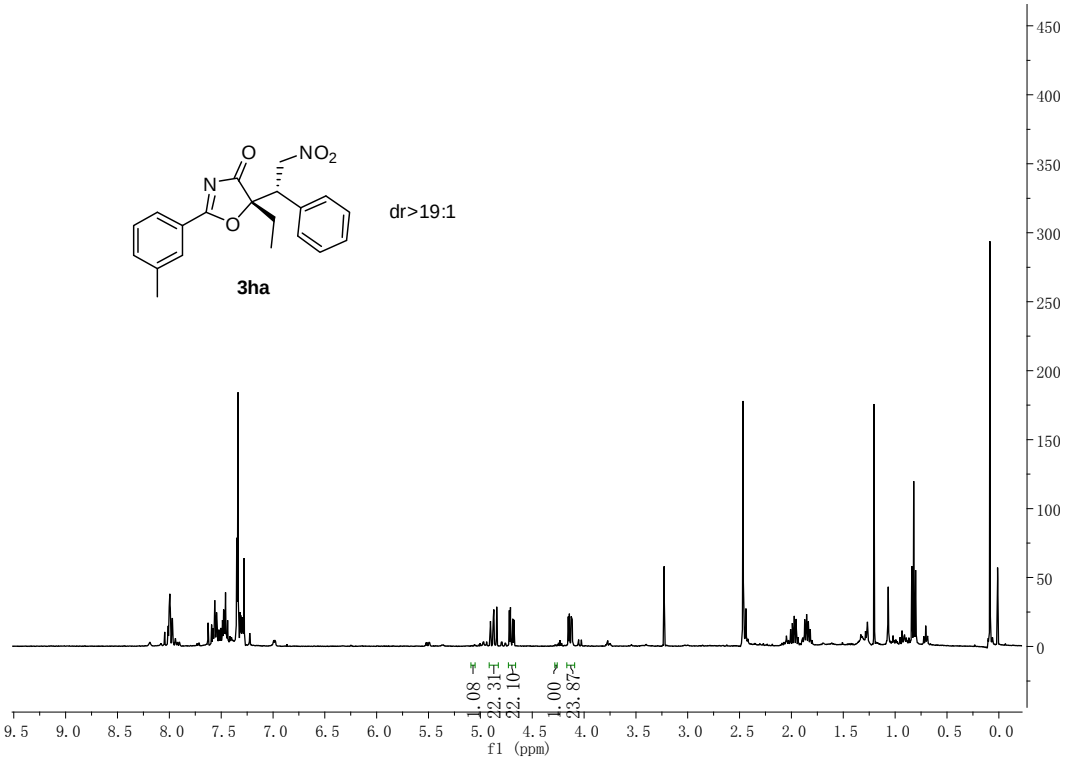
21.93
f1 (ppm)


O
N
O
NO2
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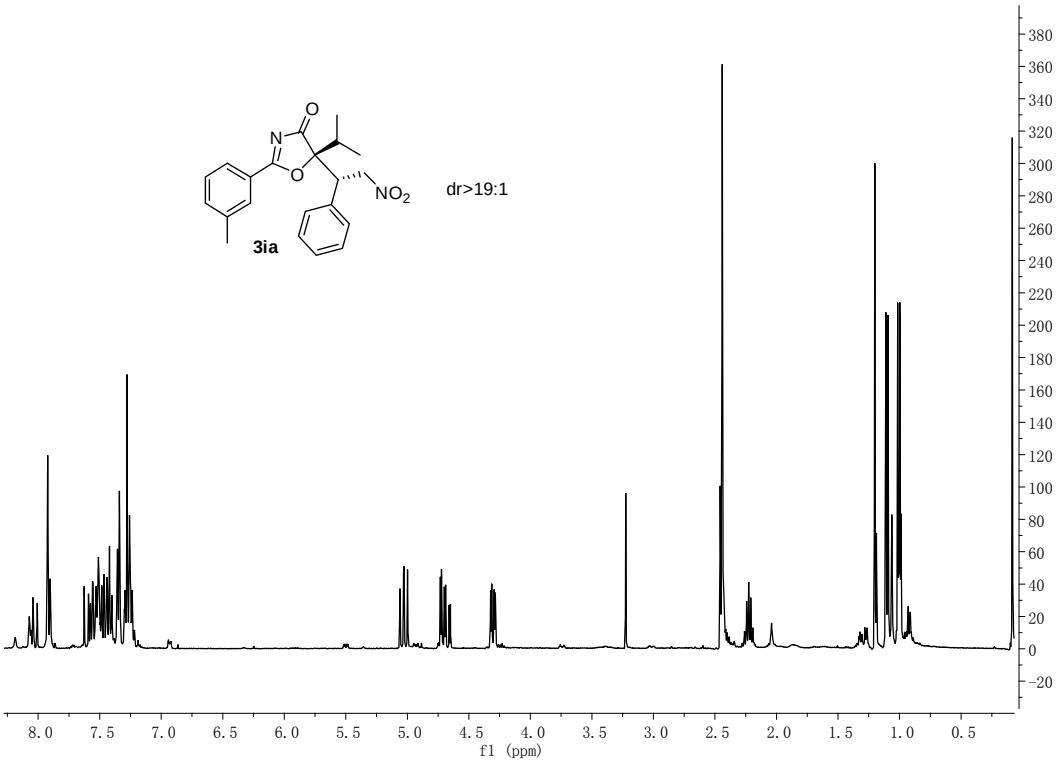
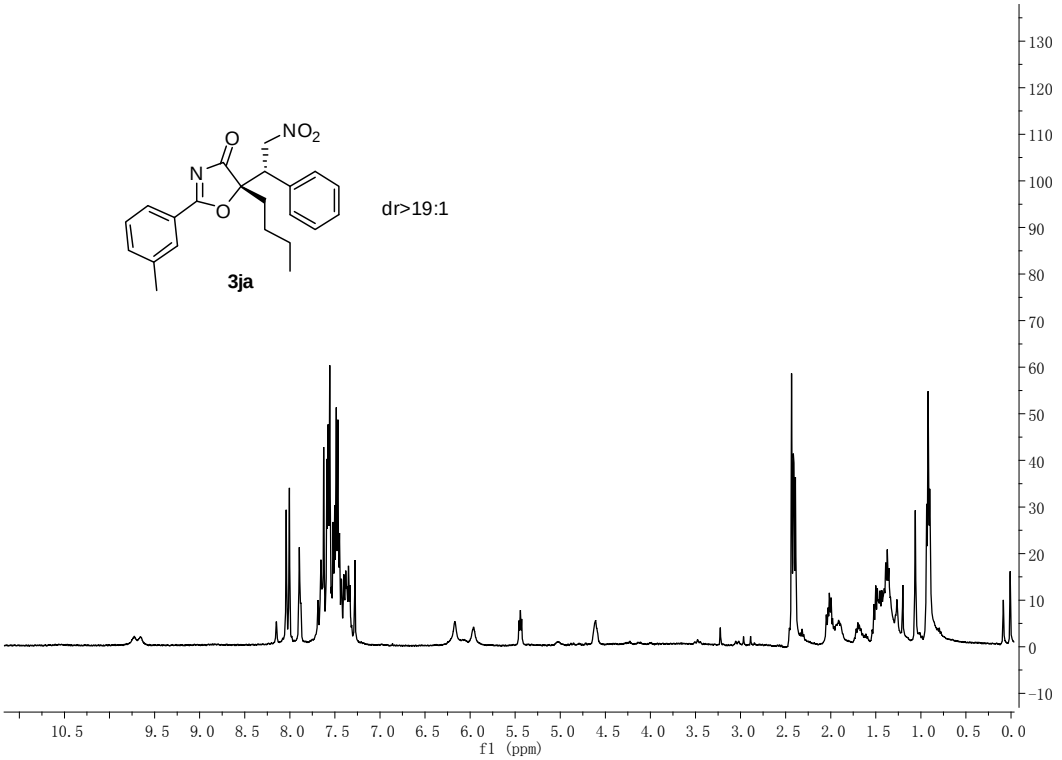
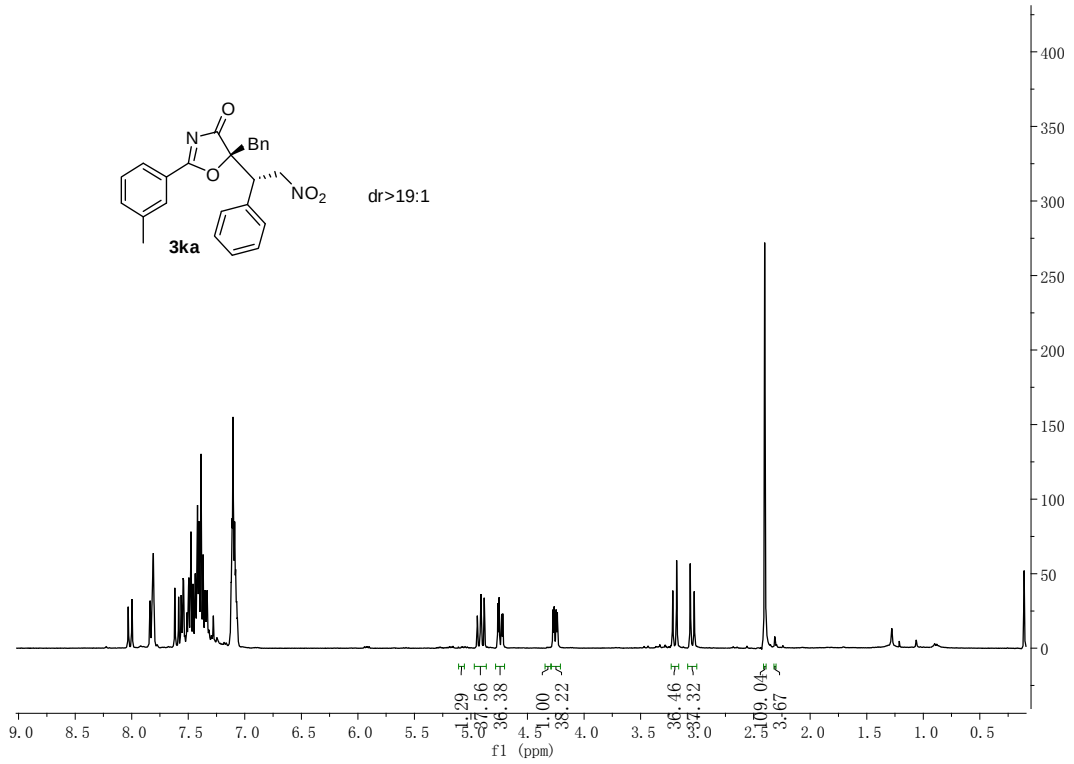
1.08
22.31
22.10
1.00
23.87
f1 (ppm)


O
N
O
NO2
dr>19:1
3ia
f1 (ppm)


NO2
O
N
O
dr>19:1
3ja
f1 (ppm)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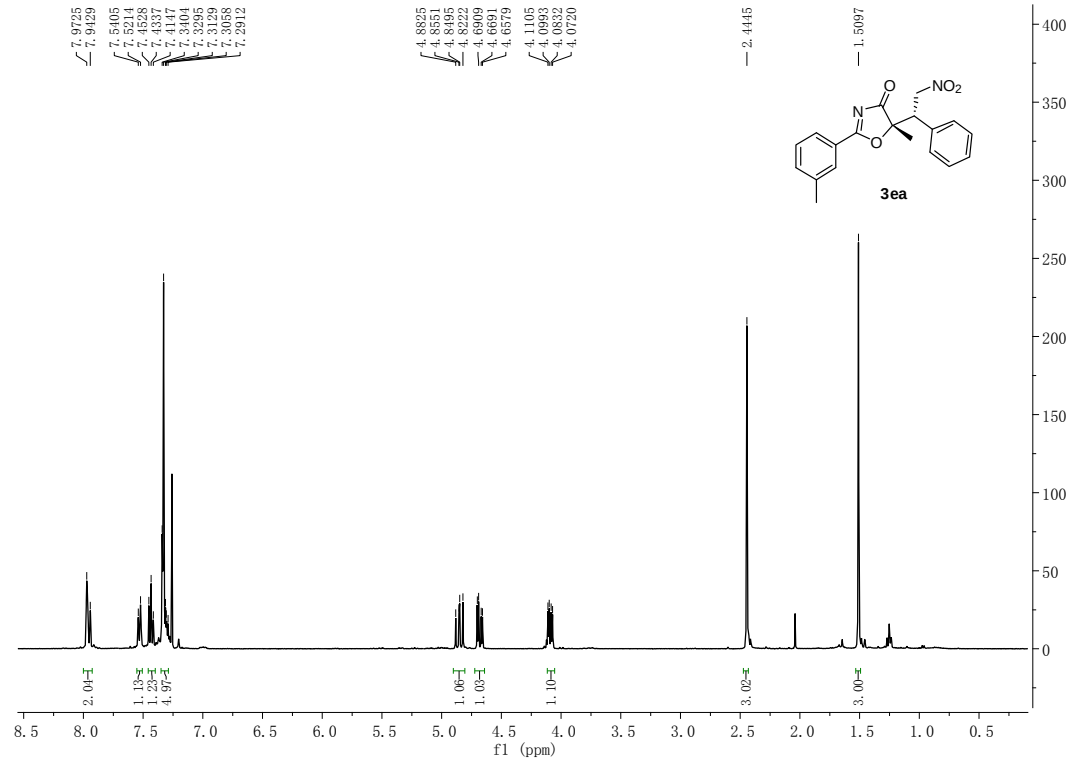
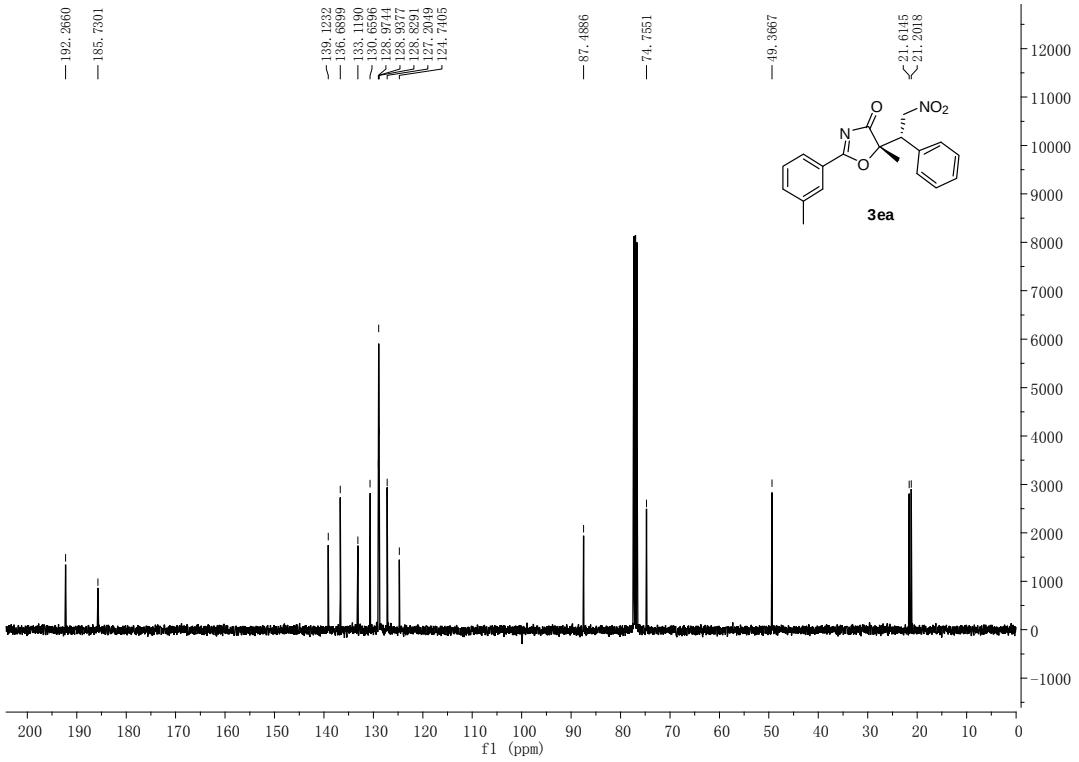
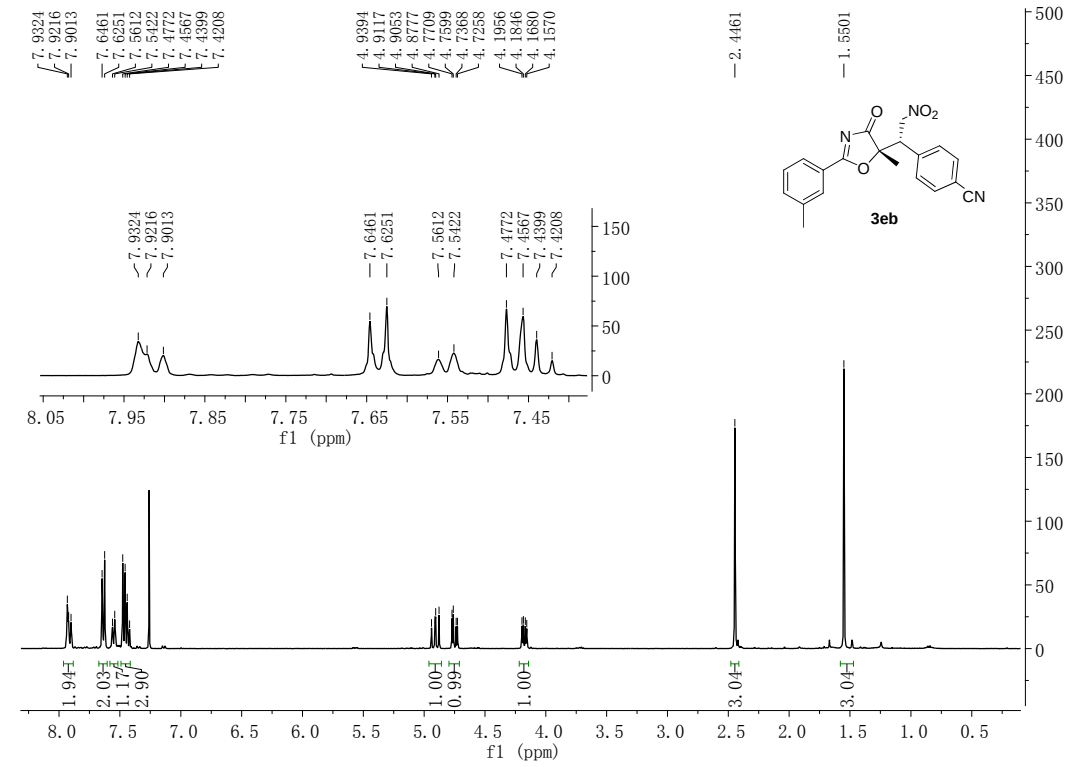
N
O
Bn
NO2
3ka
dr>19:1
1.29
7.56
6.38
1.00
8.22
6.46
4.32
09.04
3.67
f1 (ppm)

7. Copies of NMR Spectra



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7.5422
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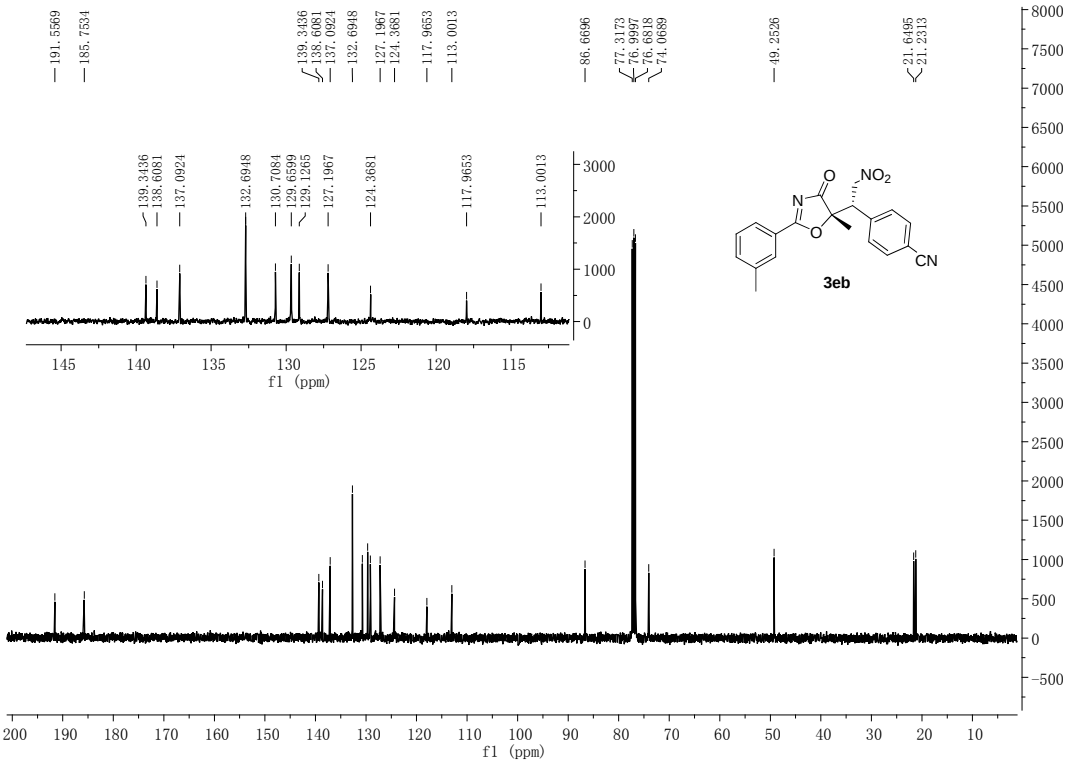
7.4567
7.4399
7.4208
4.9394
4.9117
4.9053
4.8777
4.7709
4.7599
4.7368
4.7258
4.1956
4.1846
4.1680
4.1570
2.4461
1.5501
O
NO2
N
O
CN
3eb
f1 (ppm)
1.94
2.03
1.17
2.90
1.00
0.99
1.00
3.04
3.04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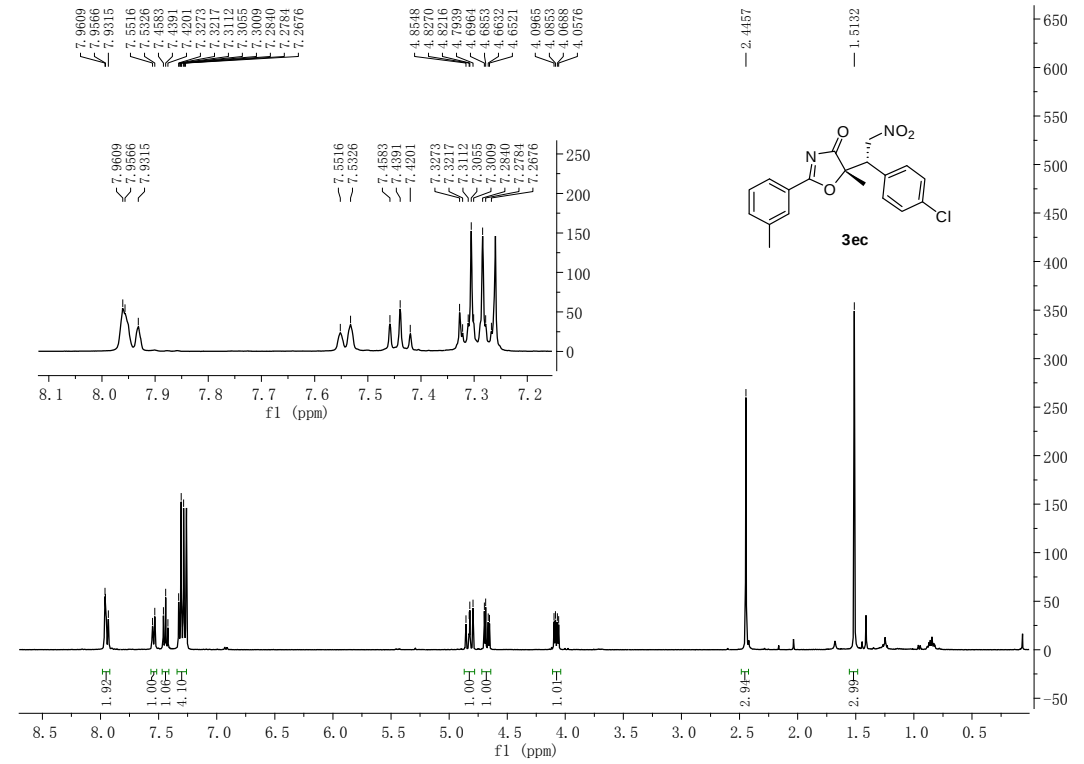
185.7534
139.3436
138.6081
137.0924
132.6948
127.1967
124.3681
117.9653
113.0013
86.6696
77.3173
76.9997
76.6818
74.0689
49.2526
21.6495
21.2313
130.7084
129.6599
129.1265
O
NO2
N
O
CN
3eb
f1 (ppm)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7.9315
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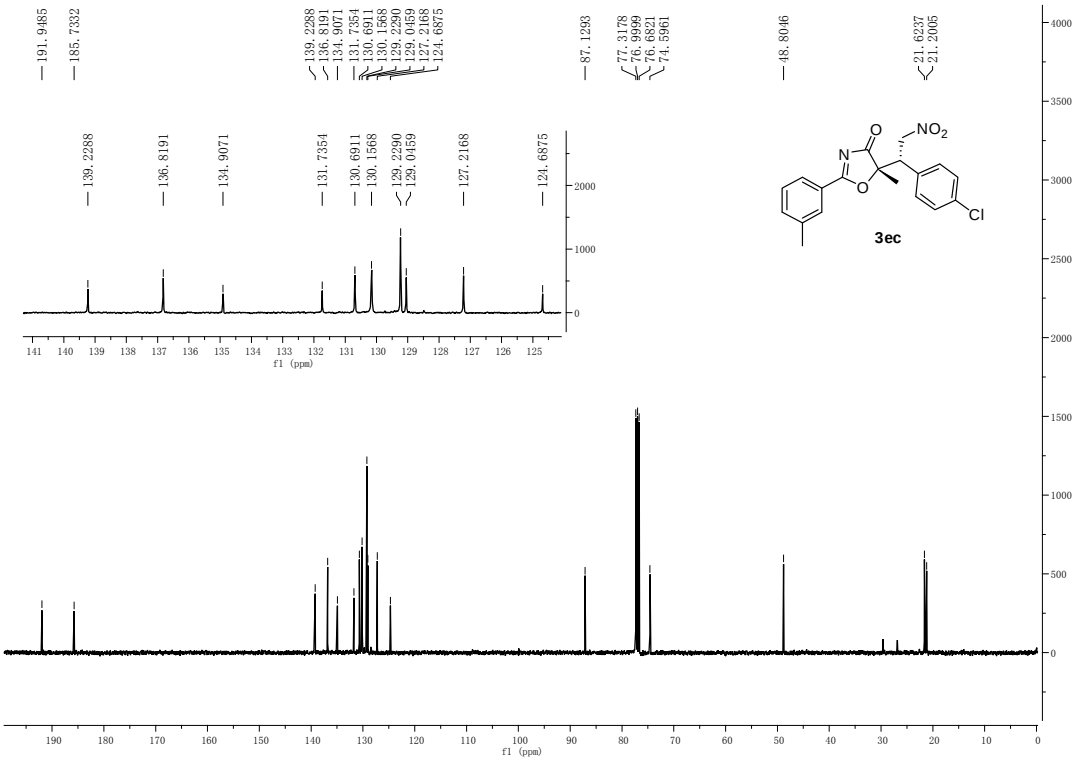
7.5326
7.4583
7.4391
7.4201
7.3273
7.3217
7.3112
7.3055
7.3009
7.2840
7.2784
7.2676
4.8548
4.8270
4.8216
4.7939
4.6964
4.6853
4.6632
4.6521
4.0965
4.0853
4.0688
4.0576
2.4457
1.5132
3ec
f1 (ppm)
1.92
1.00
1.06
4.10
1.00
1.00
1.01
2.94
2.99


191.9485
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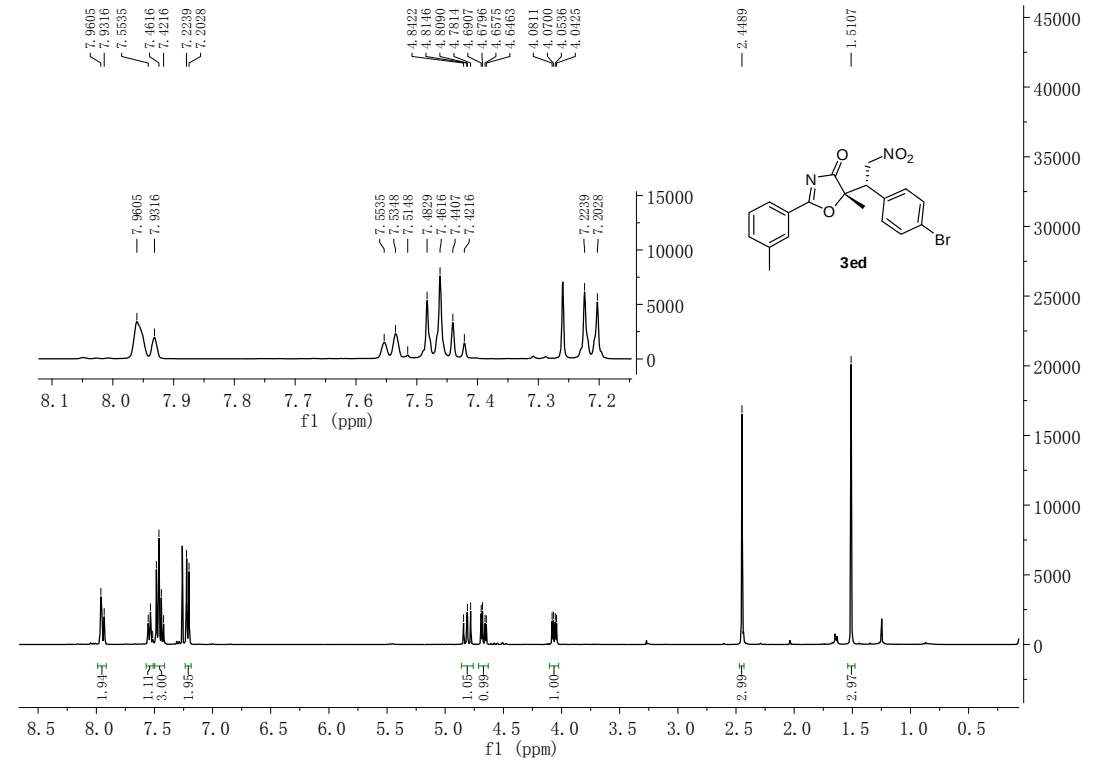
139.2288
136.8191
134.9071
131.7354
130.6911
130.1568
129.2290
129.0459
127.2168
124.6875
87.1293
77.3178
76.9999
76.6821
74.5961
48.8046
21.6237
21.2065
3ec
f1 (ppm)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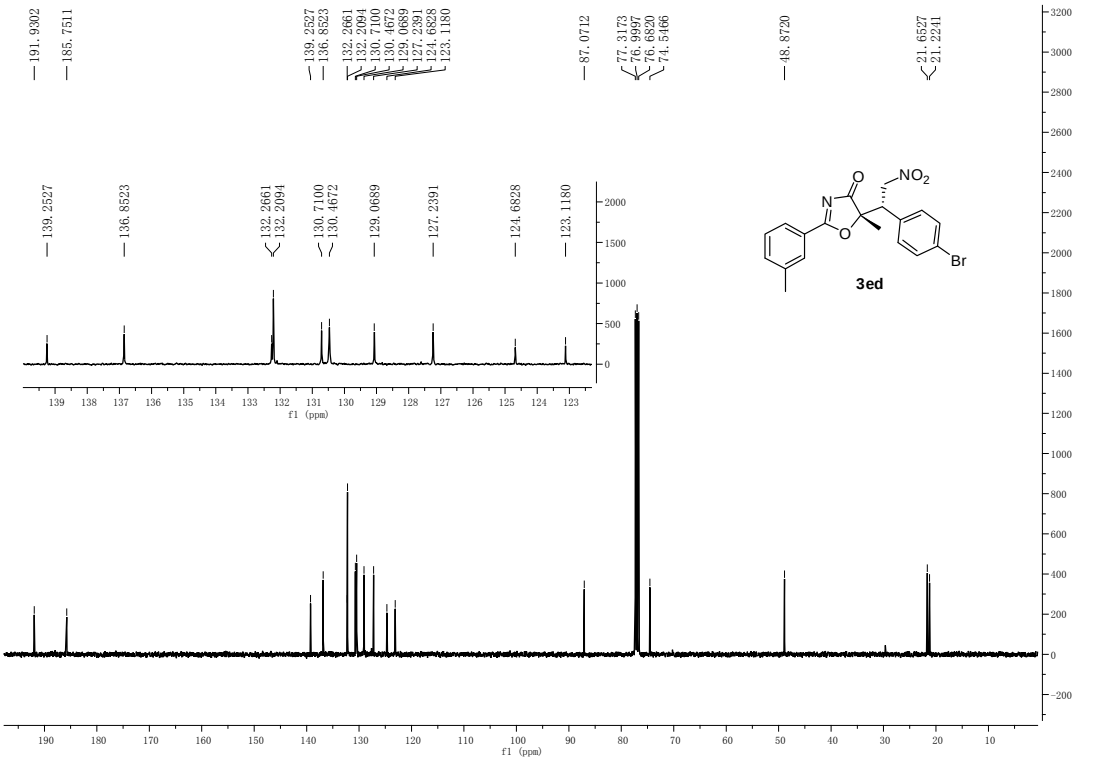
7.9316
7.5535
7.4616
7.4216
7.2239
7.2028
4.8422
4.8146
4.8090
4.7814
4.6907
4.6796
4.6575
4.6463
4.0811
4.0700
4.0536
4.0425
2.4489
1.5107
3ed
f1 (ppm)
1.94
1.11
3.00
1.95
1.05
0.99
1.00
2.99
2.97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139.2527
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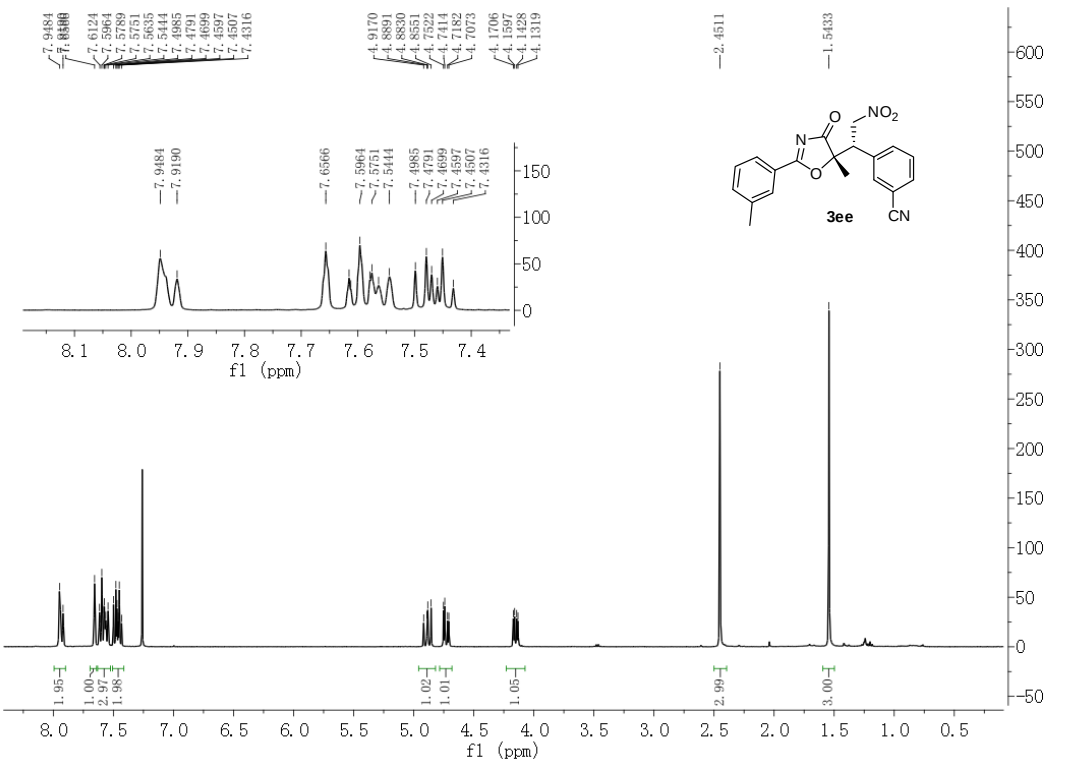
130.7100
130.4672
129.0689
127.2391
124.6828
123.1180
87.0712
77.3173
76.9997
76.6820
74.5466
48.8720
21.6527
21.2241
3ed
f1 (ppm)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7.6566
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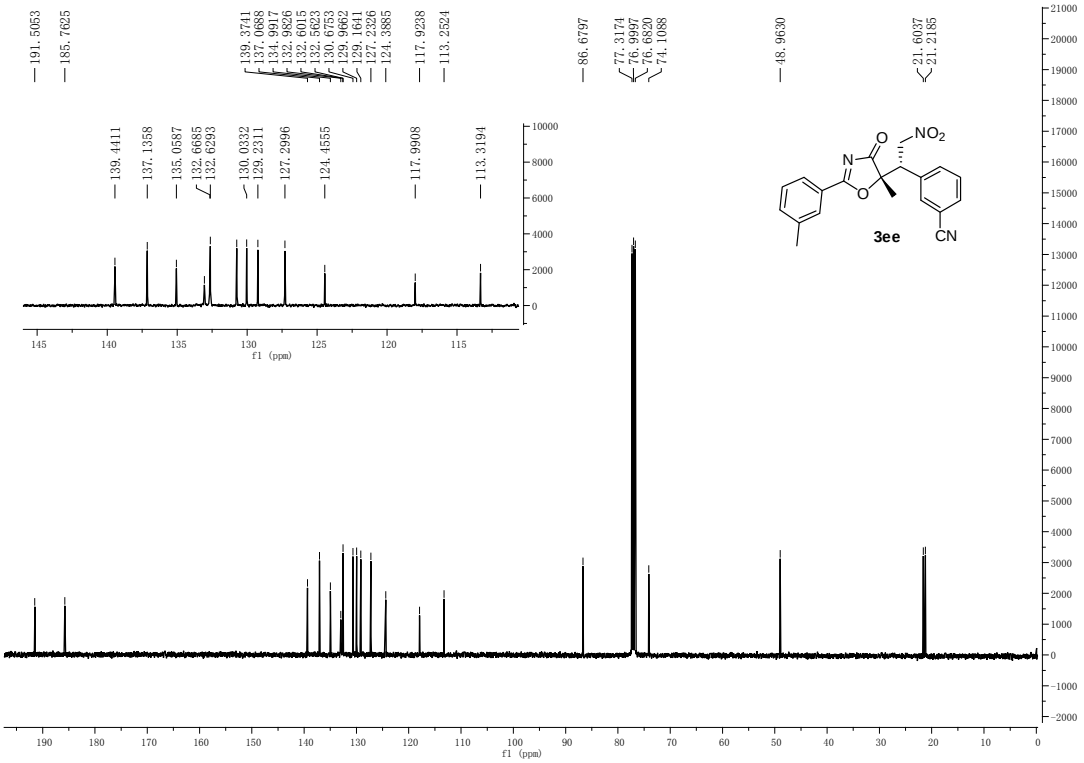
7.5964
7.5789
7.5751
7.5635
7.5444
7.4985
7.4791
7.4699
7.4597
7.4507
7.4316
4.9170
4.8891
4.8830
4.8551
4.7522
4.7414
4.7182
4.7073
4.1706
4.1597
4.1428
4.1319
2.4511
1.5433
NO2
O
N
O
3ee
CN
f1 (ppm)
1.95
1.00
2.97
1.98
1.02
1.01
1.05
2.99
3.00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139.3741
137.0688
134.9917
132.9826
132.6015
132.5623
130.6753
129.9662
129.1641
127.2326
124.3885
117.9238
113.2524
86.6797
77.3174
76.9997
76.6820
74.1088
48.9630
21.6037
21.2185
139.4411
137.1358
135.0587
132.6685
132.6293
130.0332
129.2311
127.2996
124.4555
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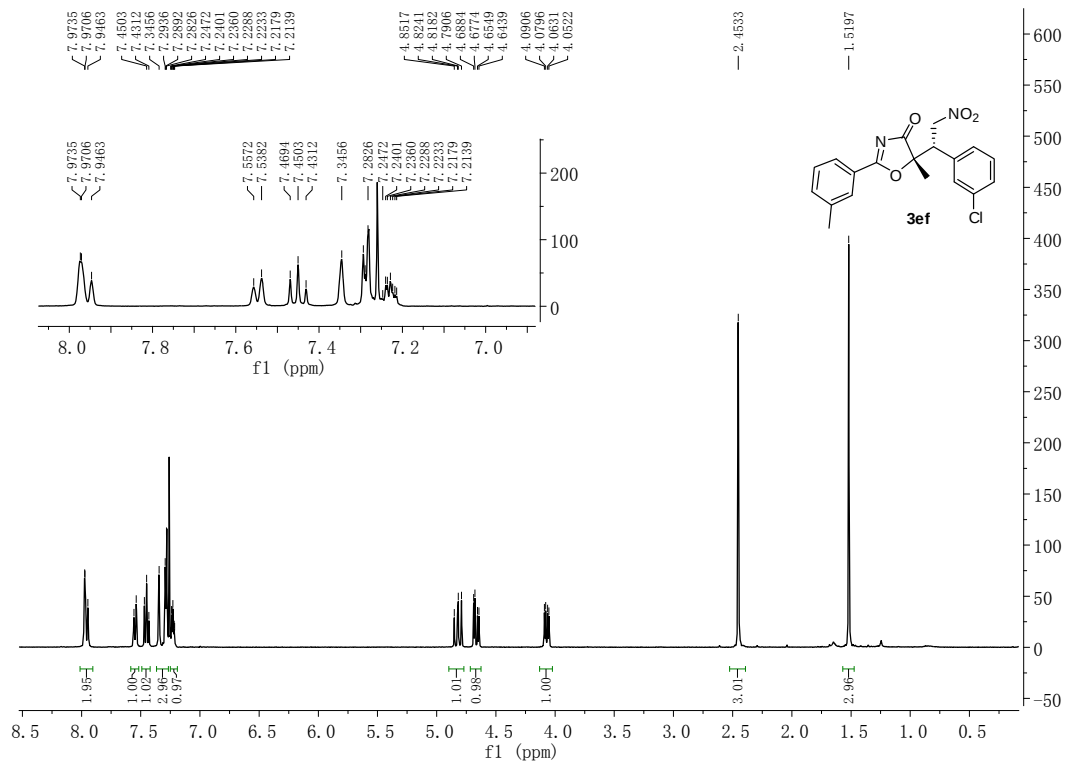
NO2
O
N
O
3ee
CN
f1 (ppm)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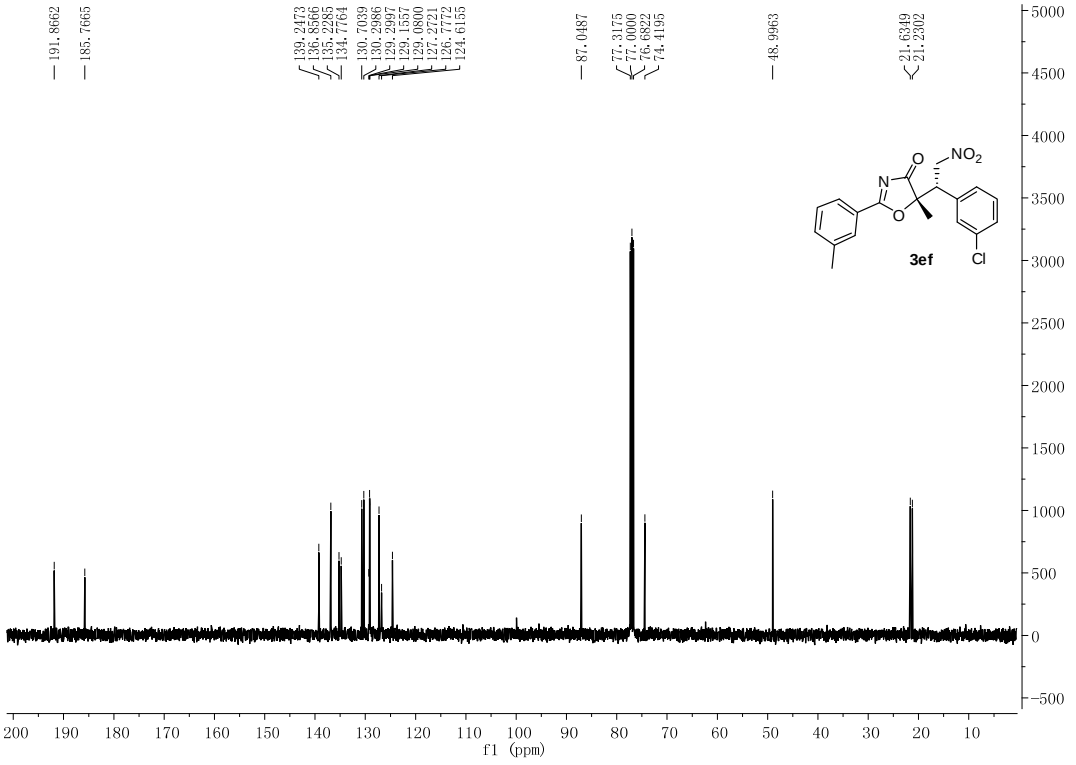
7.4312
7.3456
7.2936
7.2892
7.2826
7.2472
7.2401
7.2360
7.2288
7.2233
7.2179
7.2139
4.8517
4.8241
4.8182
4.7906
4.6884
4.6774
4.6549
4.6439
4.0906
4.0796
4.0631
4.0622
2.4533
1.5197
7.5572
7.5382
7.4694
7.4503
7.4312
7.3456
7.2826
f1 (ppm)
1.95
1.00
1.02
2.96
0.97
1.01
0.98
1.00
3.01
2.96
3ef
Cl
NO2
f1 (ppm)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129.0800
127.2721
126.7772
124.6155
87.0487
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76.6822
74.4195
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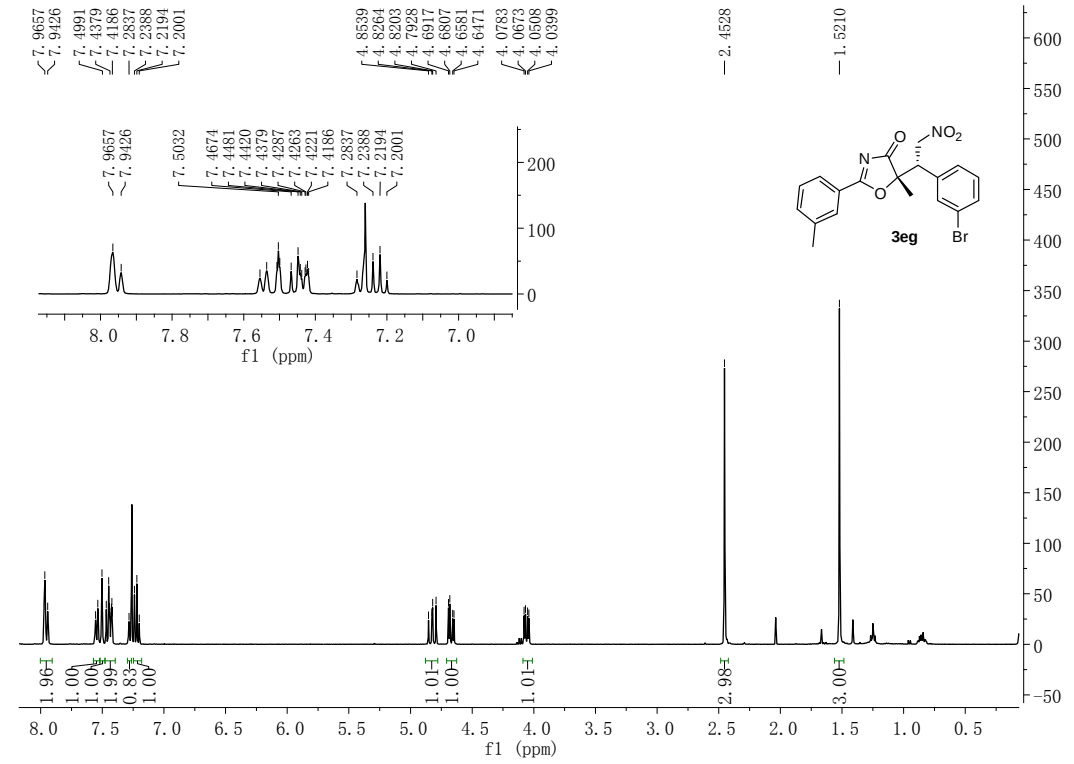
21.2302
3ef
Cl
NO2
f1 (ppm)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7.4186
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7.2001
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4.8264
4.8203
4.7928
4.6917
4.6807
4.6581
4.6471
4.0783
4.0673
4.0508
4.0399
2.4528
1.5210
7.5032
7.4674
7.4481
7.4420
7.4379
7.4287
7.4263
7.4221
7.4186
7.2837
7.2388
7.2194
7.2001
NO2
O
N
O
3eg
Br
f1 (ppm)
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1.00
1.99
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1.00
1.01
1.00
1.01
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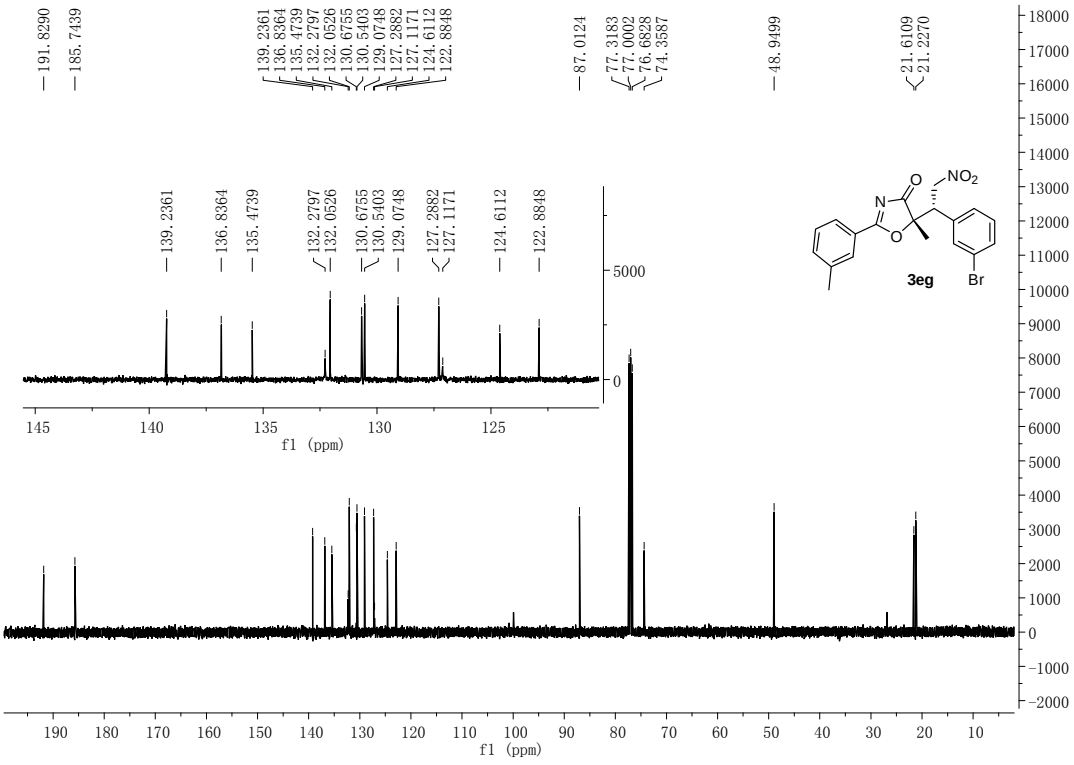
3.00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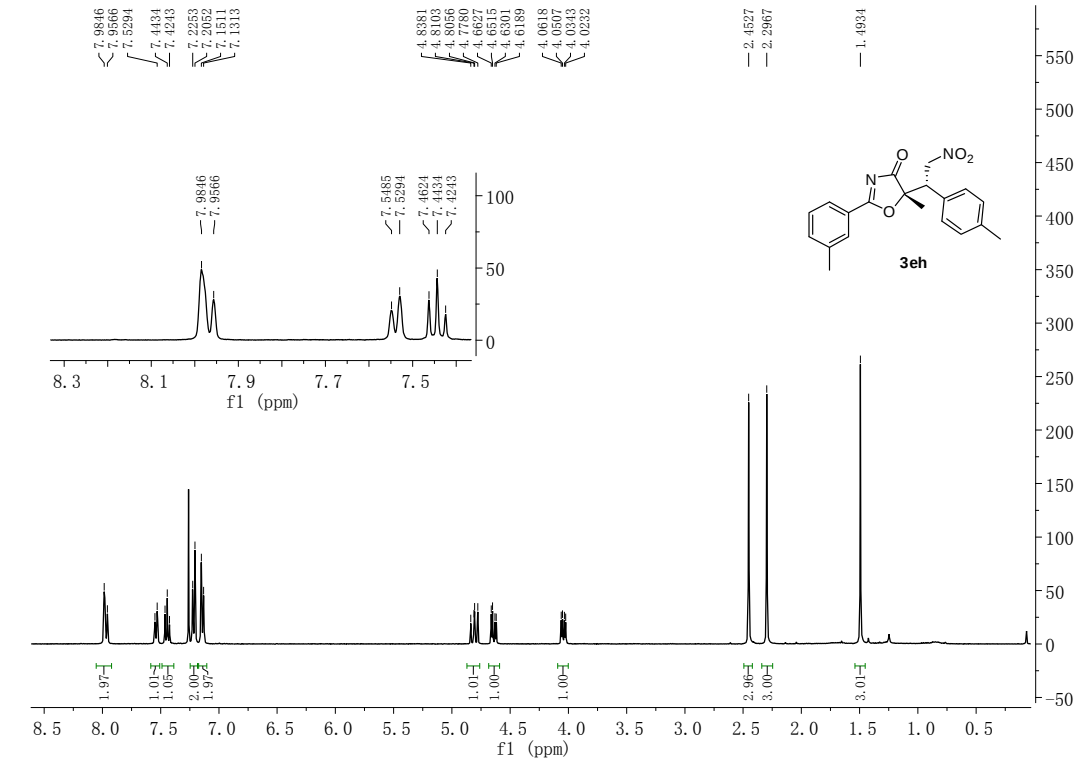
139.2361
136.8364
135.4739
132.2797
132.0526
130.6755
130.5403
129.0748
127.2882
127.1171
124.6112
122.8848
87.0124
77.3183
77.0002
76.6828
74.3587
48.9499
21.6109
21.2270
NO2
O
N
O
3eg
Br
f1 (ppm)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7.5294
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7.4243
7.2253
7.2052
7.1511
7.1313
4.8381
4.8103
4.8056
4.7780
4.6627
4.6515
4.6301
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4.0507
4.0343
4.0232
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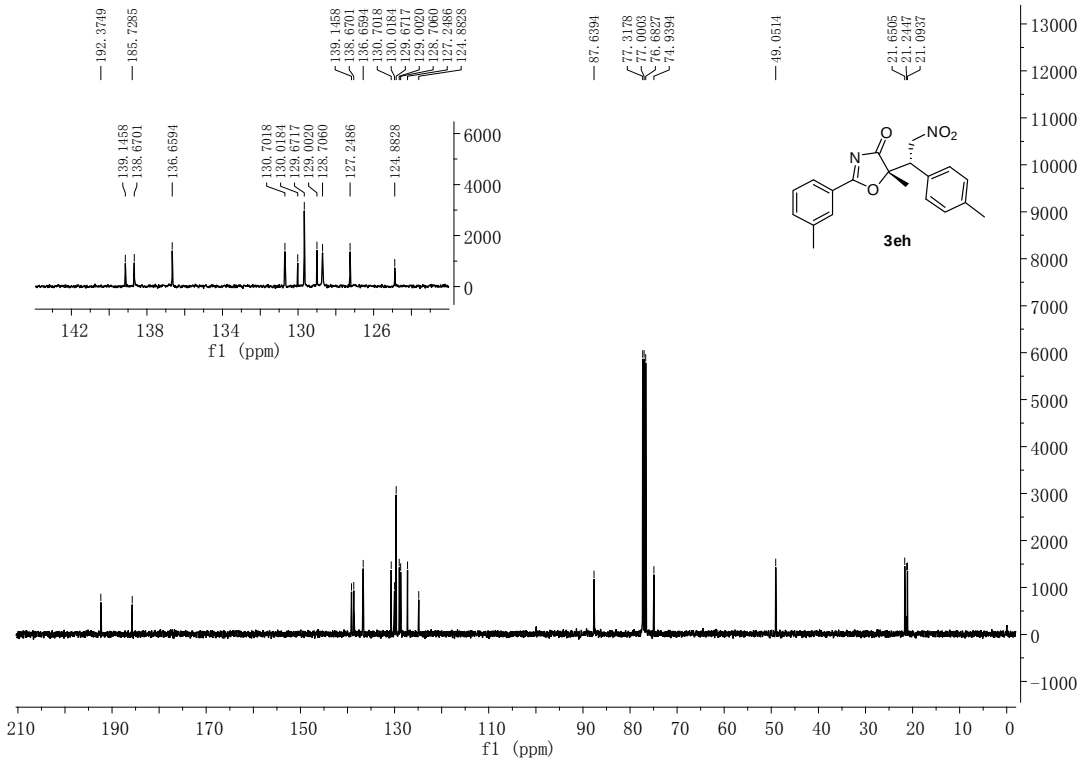
NO2
3eh
f1 (ppm)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130.0184
129.6717
129.0020
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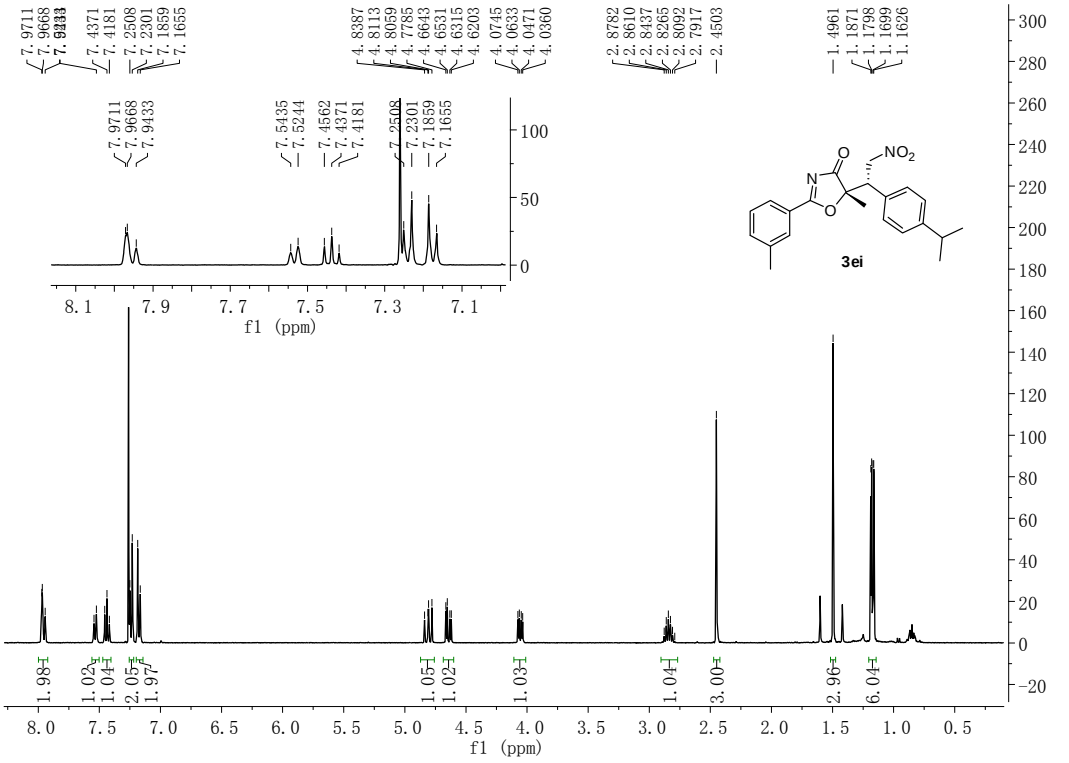
127.2486
124.8828
87.6394
77.3178
77.0003
76.6827
74.9394
49.0514
21.6505
21.2447
21.0937
NO2
3eh
f1 (ppm)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7.2301
7.1859
7.1655
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4.8113
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4.7785
4.6643
4.6531
4.6315
4.6203
4.0745
4.0633
4.0471
4.0360
2.8782
2.8610
2.8437
2.8265
2.8092
2.7917
2.4503
1.4961
1.1871
1.1798
1.1699
1.1626
NO2
3ei
f1 (ppm)
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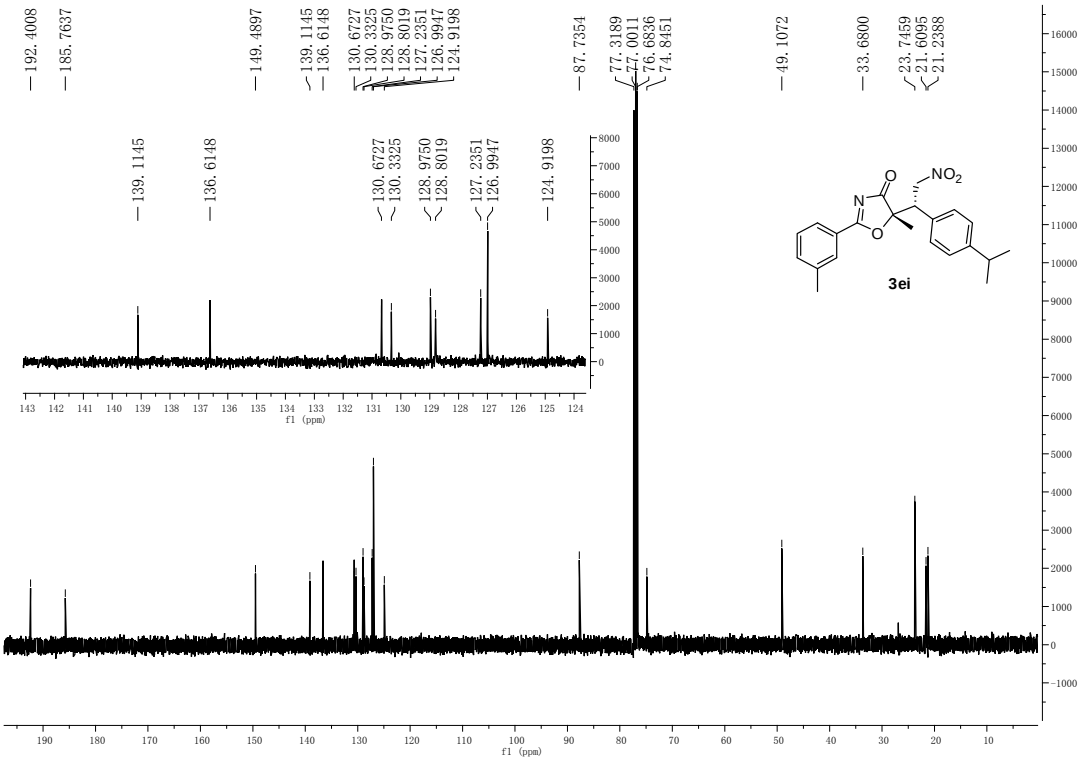
6.04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124.9198
87.7354
77.3189
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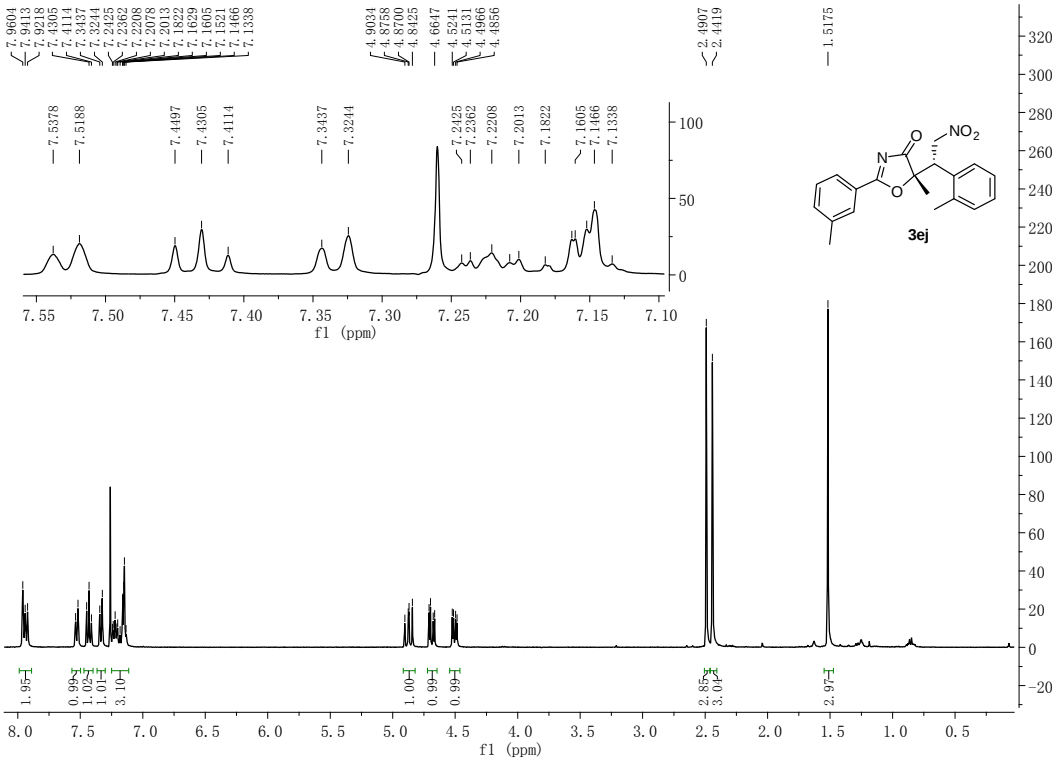
74.8451
49.1072
33.6800
23.7459
21.6095
21.2388
NO2
3ei
f1 (ppm)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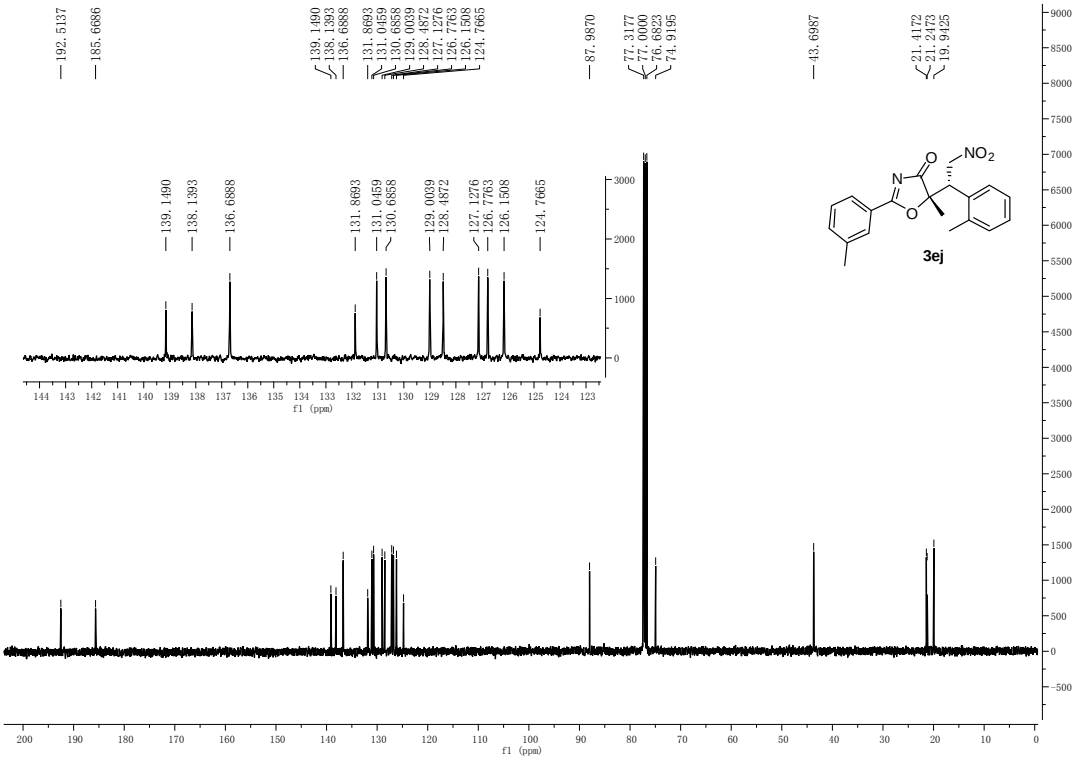
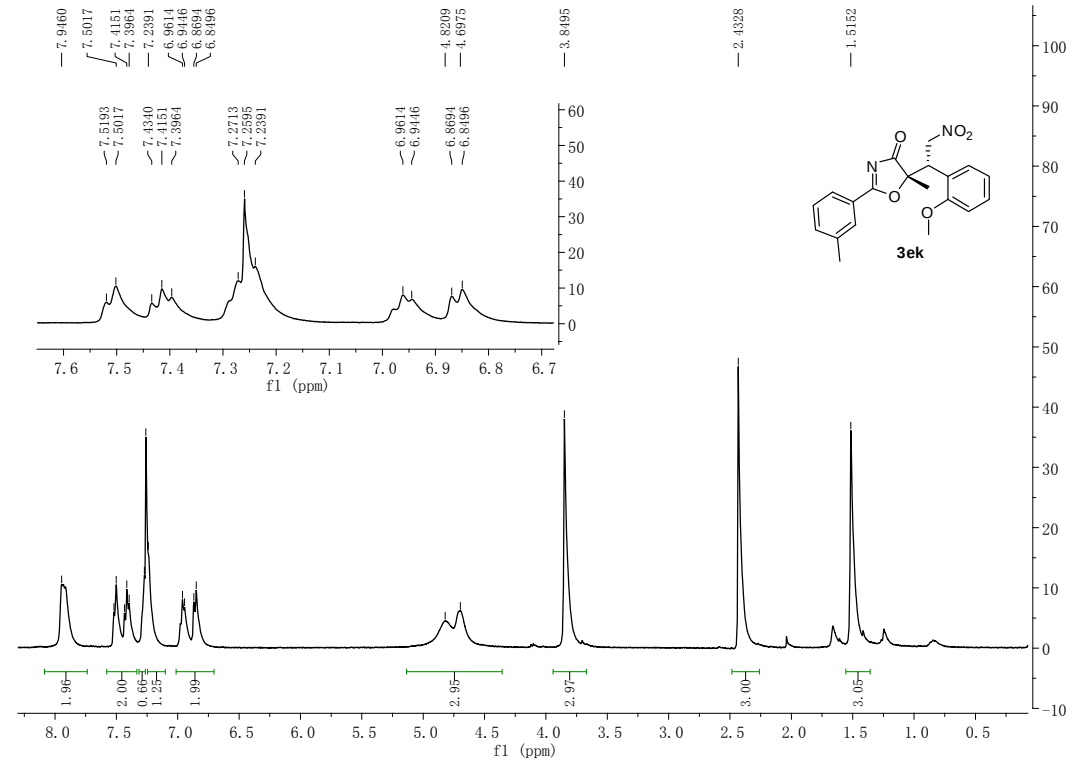
f1 (ppm)


3ej
f1 (ppm)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7.4151
7.3964
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2.4328
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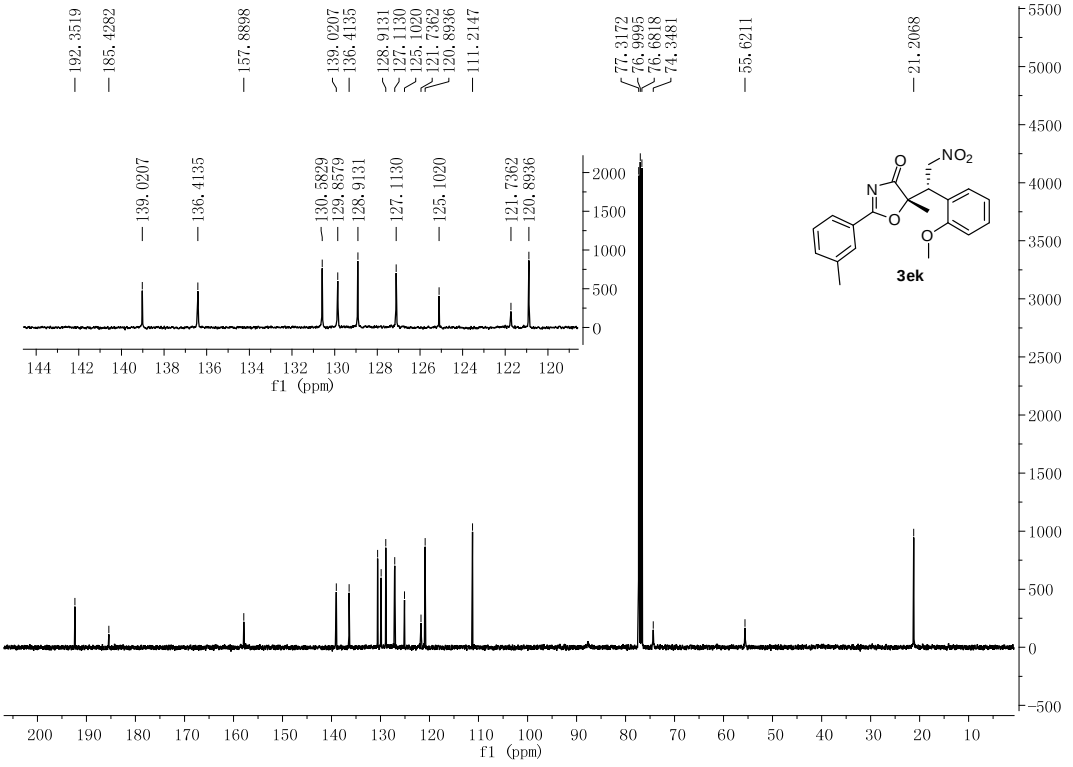
f1 (ppm)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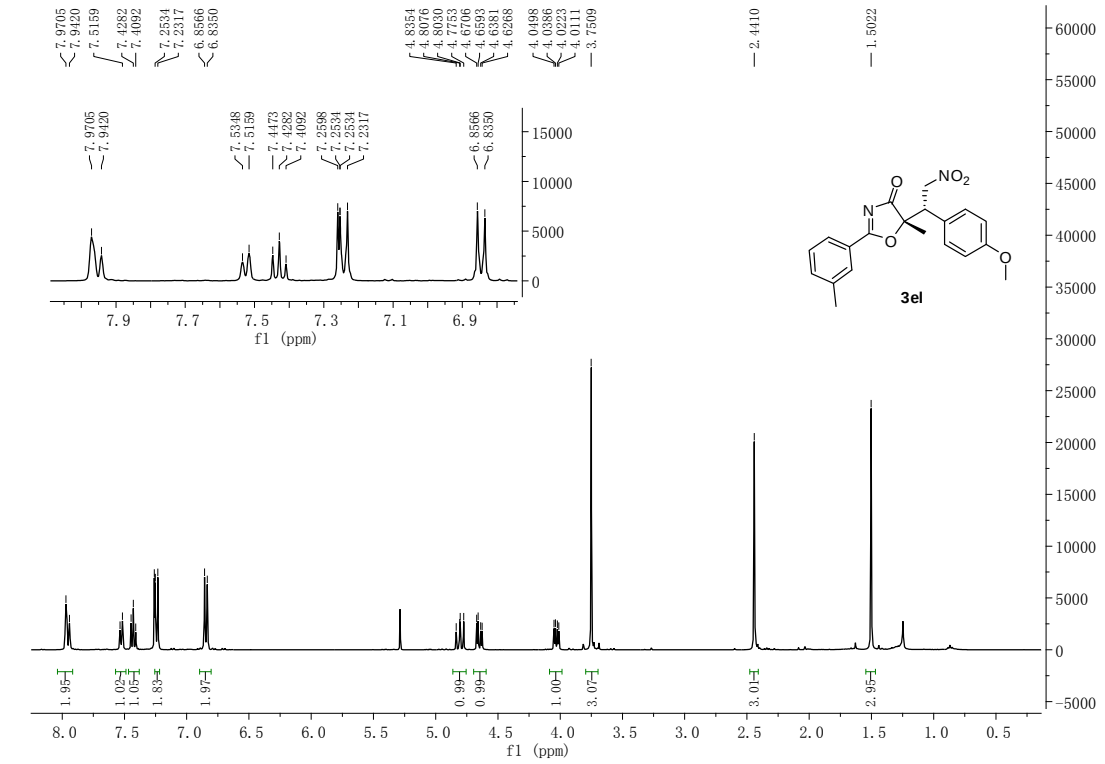
55.6211
21.2068
3ek
f1 (ppm)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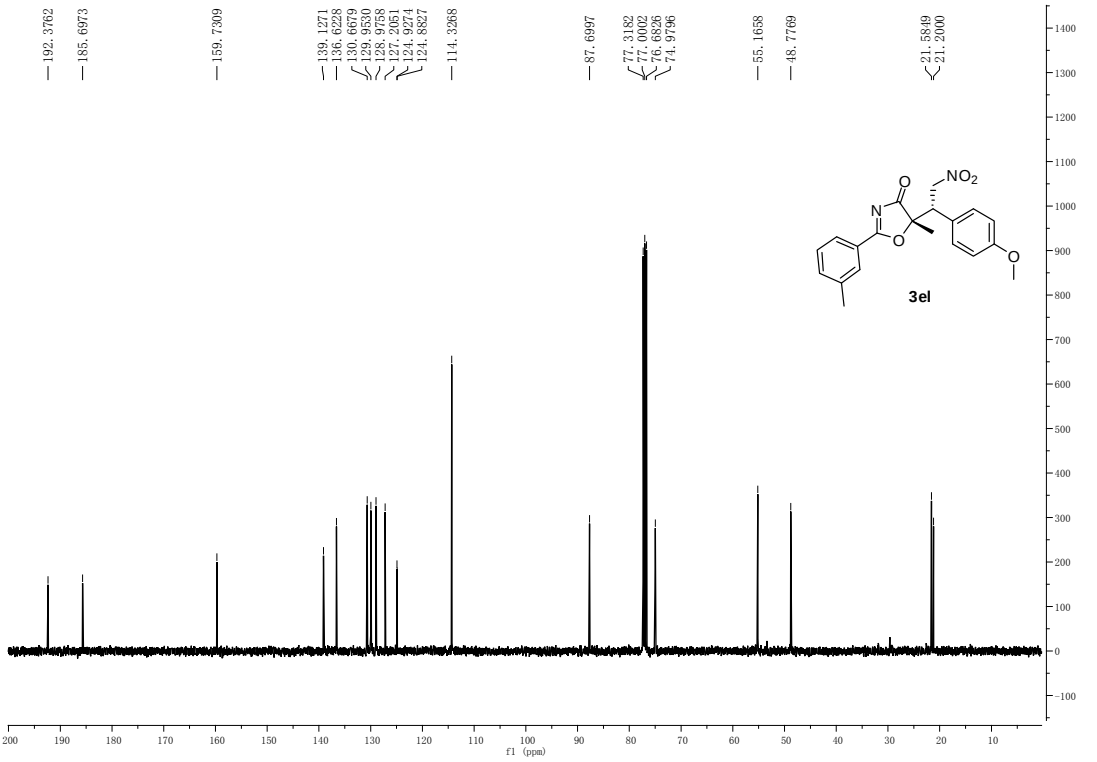
7.5159
7.4282
7.4092
7.2534
7.2317
6.8566
6.8350
4.8354
4.8076
4.8030
4.7753
4.6706
4.6593
4.6381
4.6268
4.0498
4.0386
4.0223
4.0111
3.7509
2.4410
1.5022
1.95
1.02
1.05
1.83
1.97
0.99
0.99
1.00
3.07
3.01
2.95
f1 (ppm)
NO2
O
N
O
O
3el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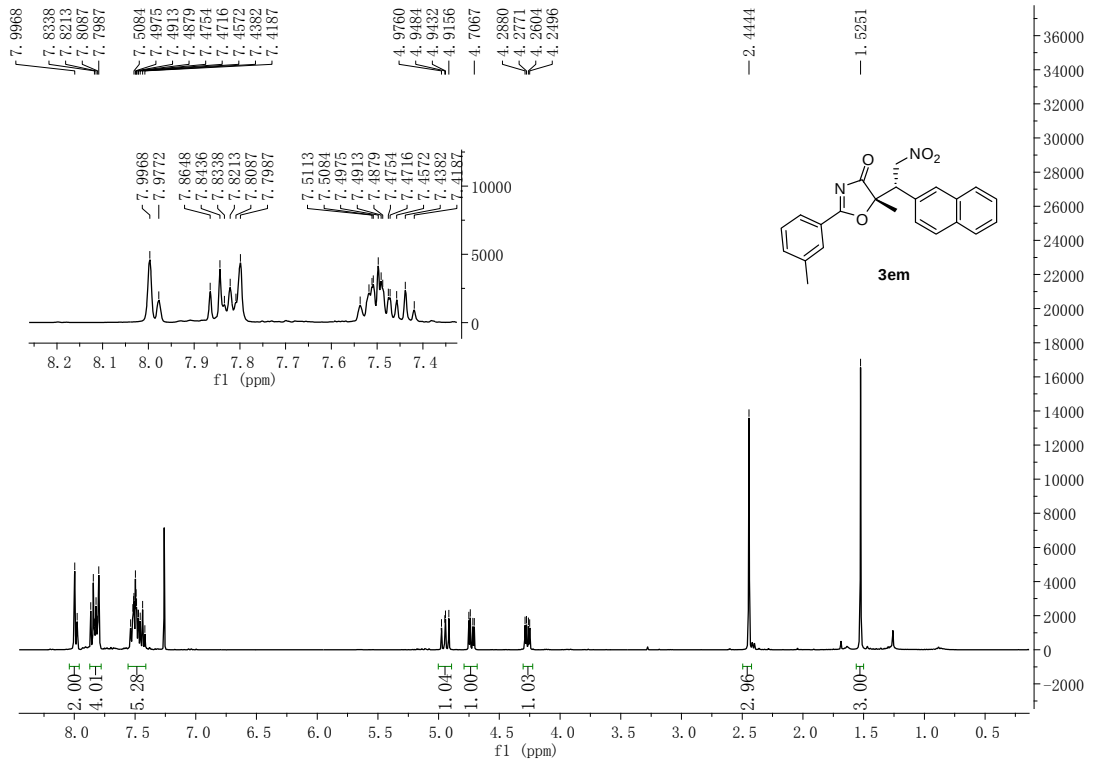
124.8827
114.3368
87.6997
77.3182
77.0002
76.6826
74.9796
55.1658
48.7769
21.5849
21.2000
f1 (ppm)
NO2
O
N
O
O
3el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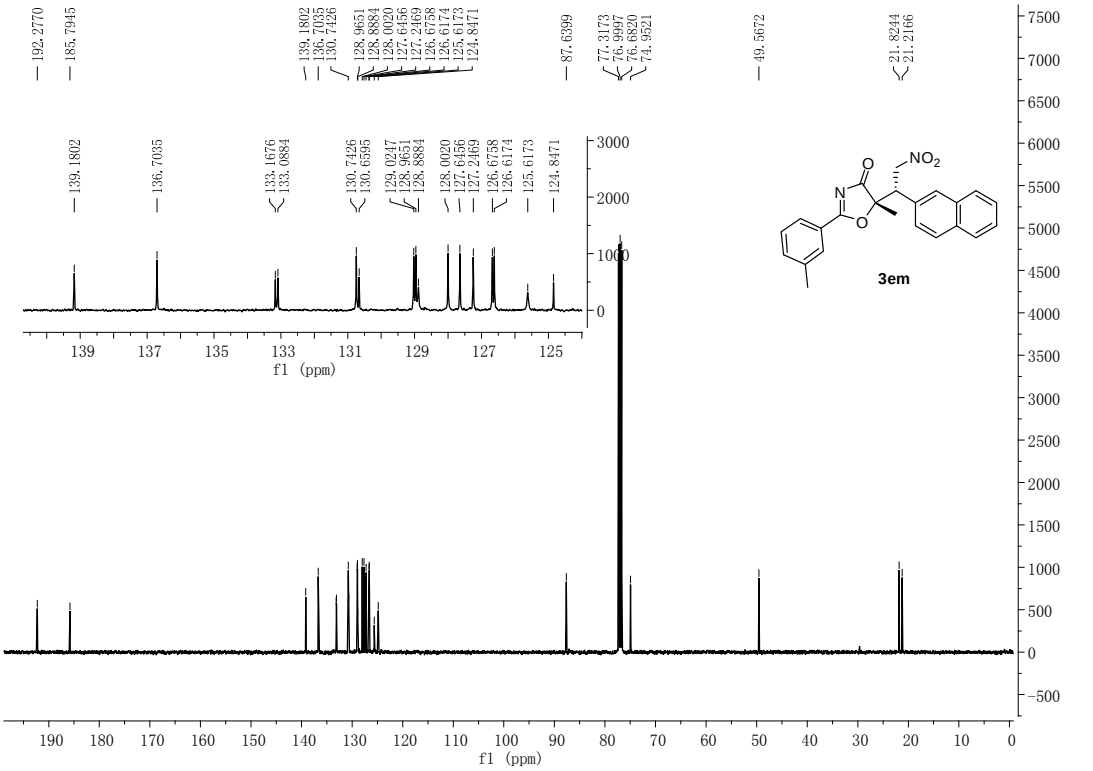
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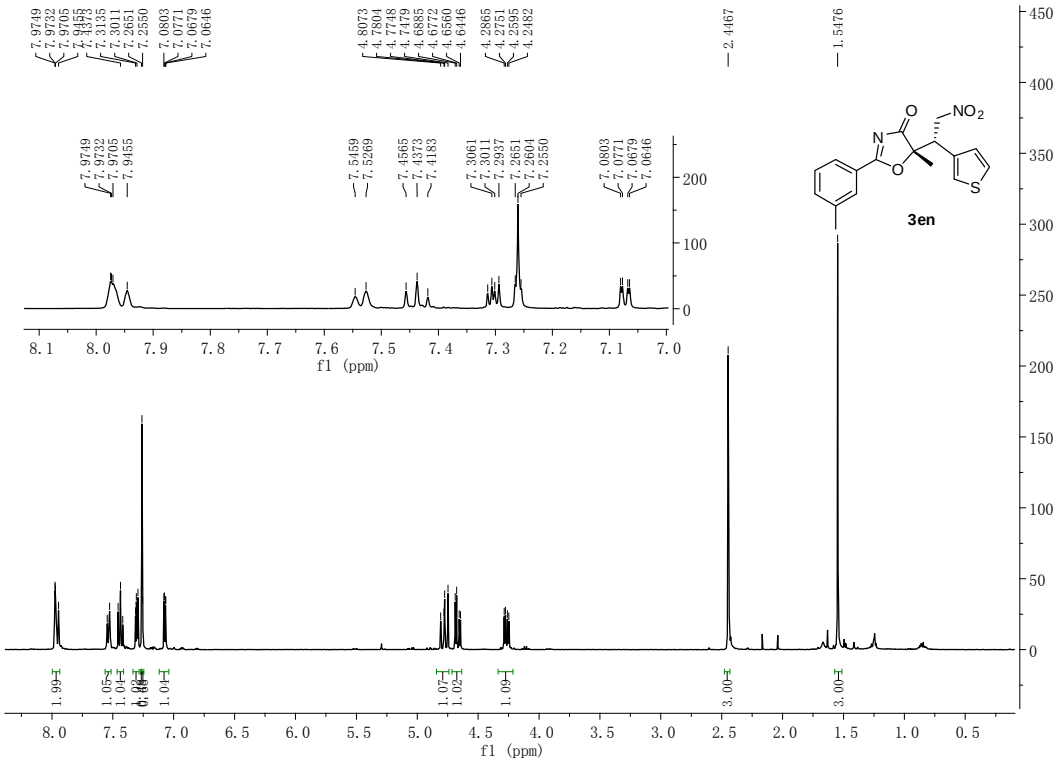
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7.3011
7.2937
7.2651
7.2604
7.2550
7.0803
7.0771
7.0679
7.0646
4.8073
4.7804
4.7748
4.7479
4.6885
4.6772
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4.2865
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4.2595
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2.4467
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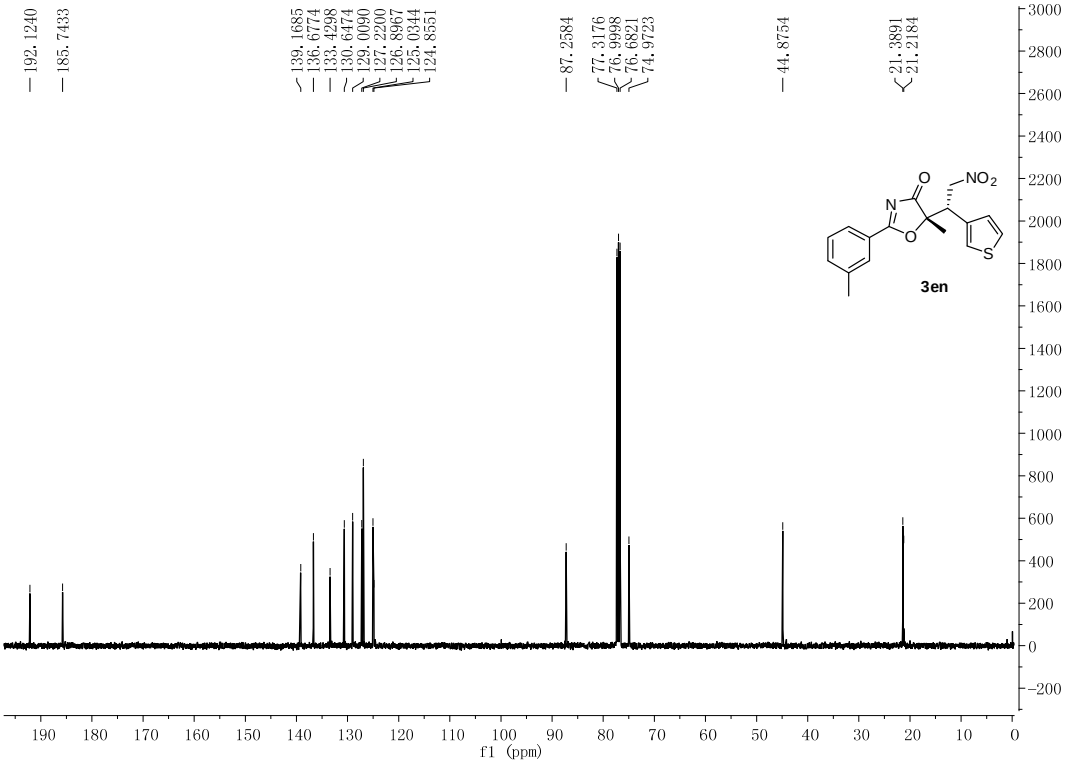
3en
f1 (ppm)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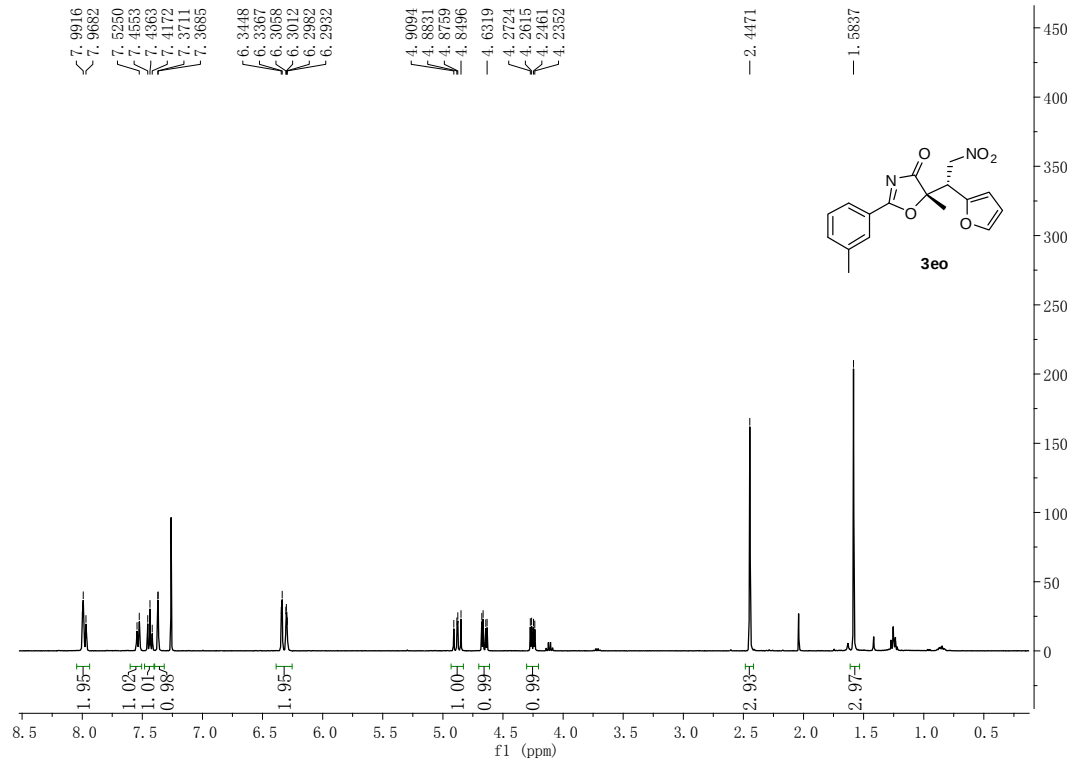
3en
f1 (ppm)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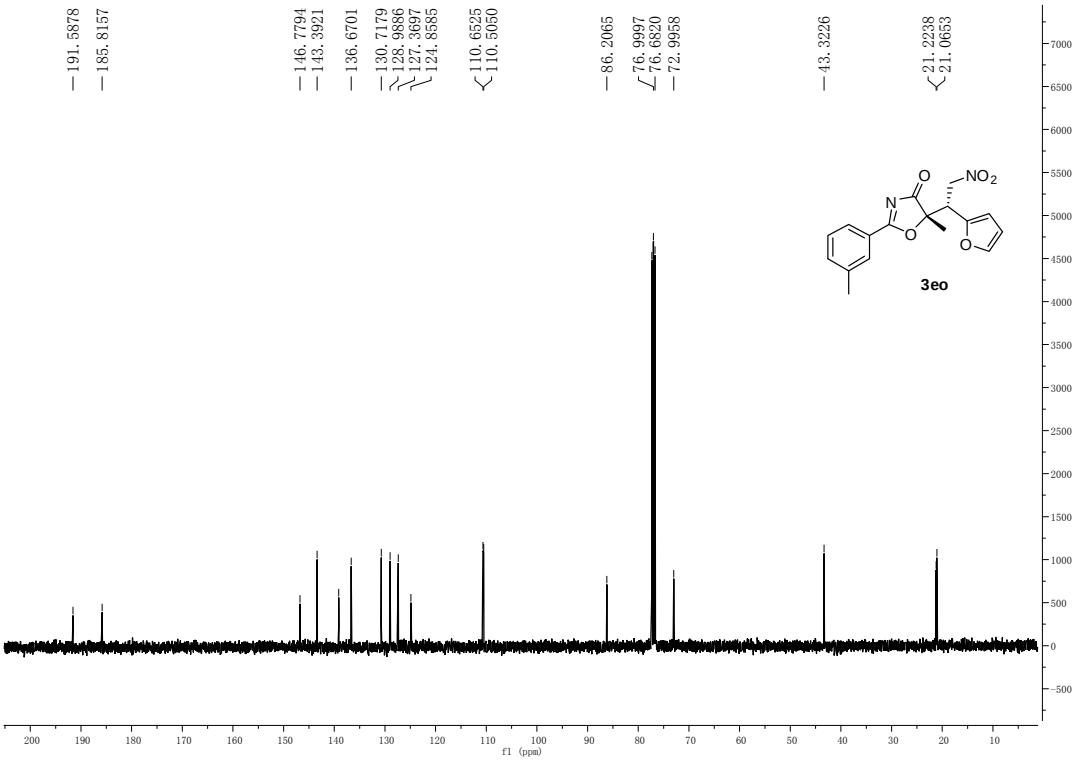
7.4553
7.4363
7.4172
7.3711
7.3685
6.3448
6.3367
6.3058
6.3012
6.2982
6.2932
4.9094
4.8831
4.8759
4.8496
4.6319
4.2724
4.2615
4.2461
4.2352
2.4471
1.5837
1.95
1.02
1.01
0.98
1.95
1.00
0.99
0.99
2.93
2.97
f1 (ppm)
3eo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185.8157
146.7794
143.3921
136.6701
130.7179
128.9886
127.3697
124.8585
110.6525
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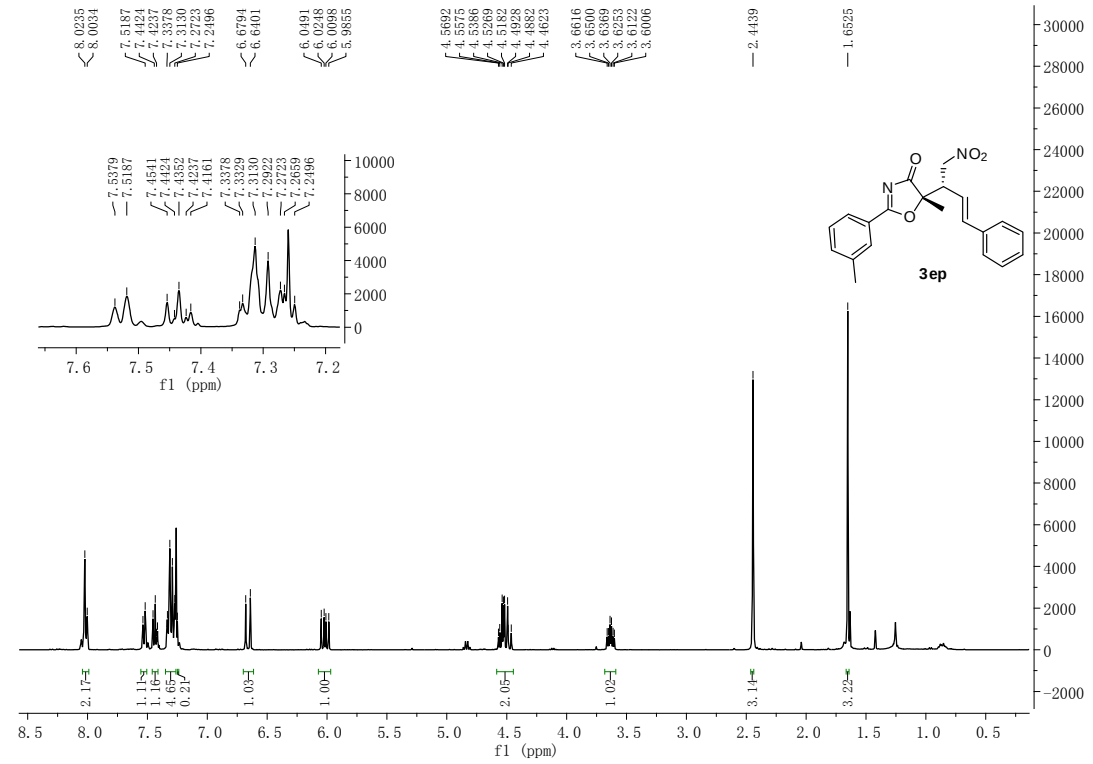
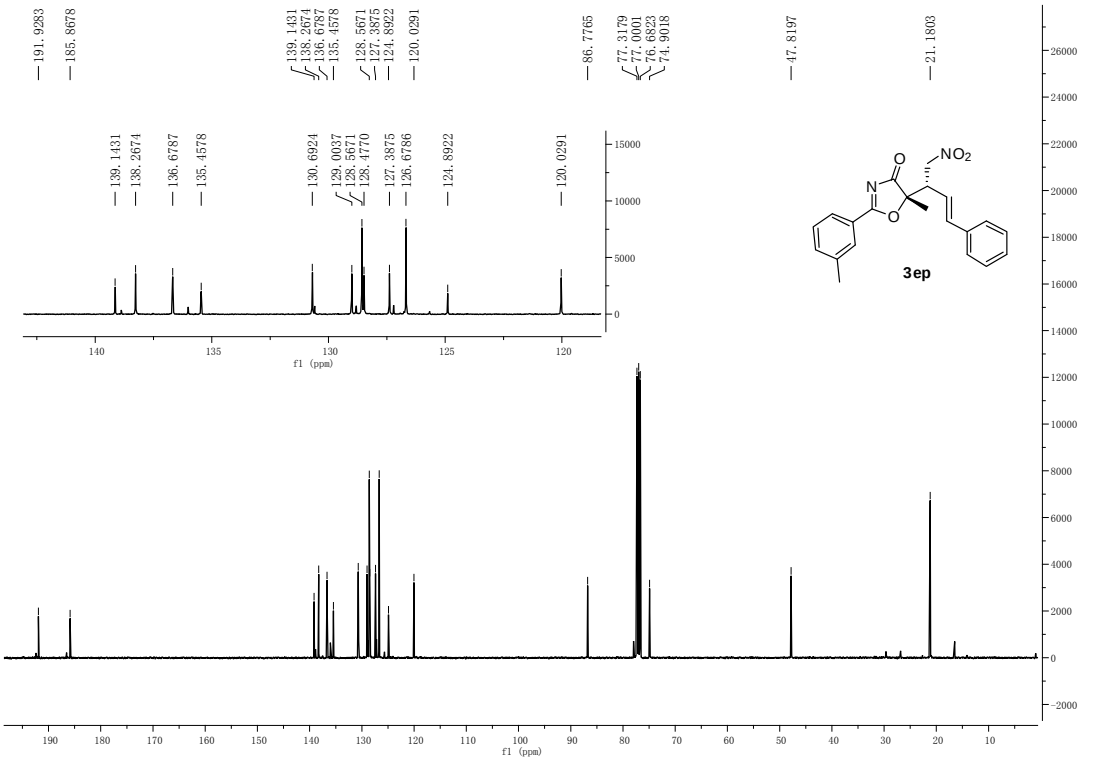
86.2065
76.9997
76.6820
72.9958
43.3226
21.2238
21.0653
f1 (ppm)
3eo


8.0235
8.0034
7.5187
7.4424
7.4237
7.3378
7.3130
7.2723
7.2496
6.6794
6.6401
6.0491
6.0248
6.0098
5.9855
4.5692
4.5575
4.5386
4.5269
4.5182
4.4928
4.4882
4.4623
3.6616
3.6500
3.6369
3.6253
3.6122
3.6006
2.4439
1.6525
7.5379
7.5187
7.4541
7.4424
7.4352
7.4237
7.4161
7.3378
7.3329
7.3130
7.2922
7.2723
7.2659
7.2496
f1 (ppm)
NO2
O
N
O
3ep
2.17
1.11
1.16
4.65
0.21
1.03
1.00
2.05
1.02
3.14
3.22
f1 (ppm)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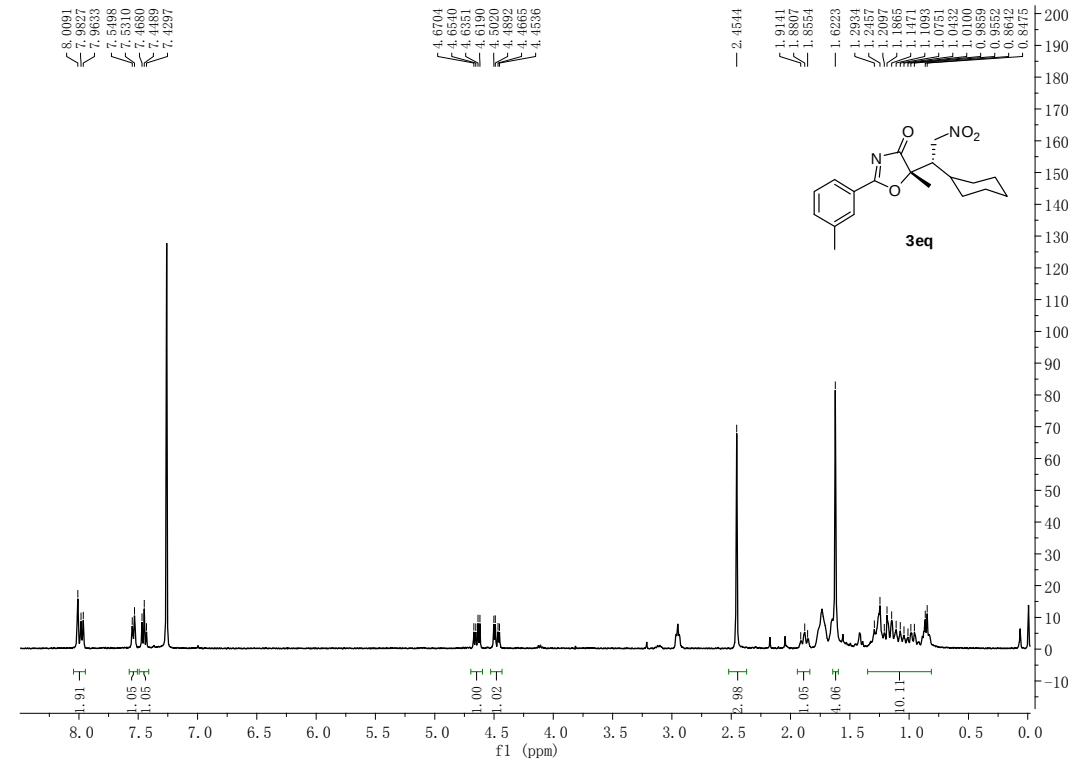
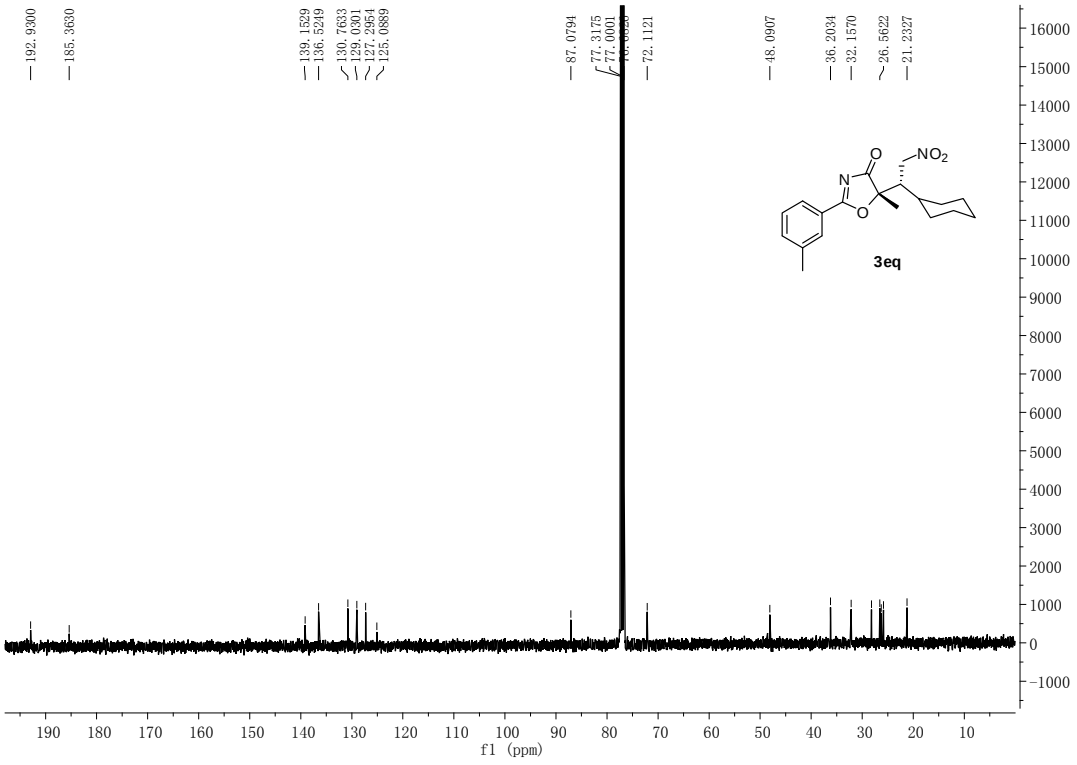
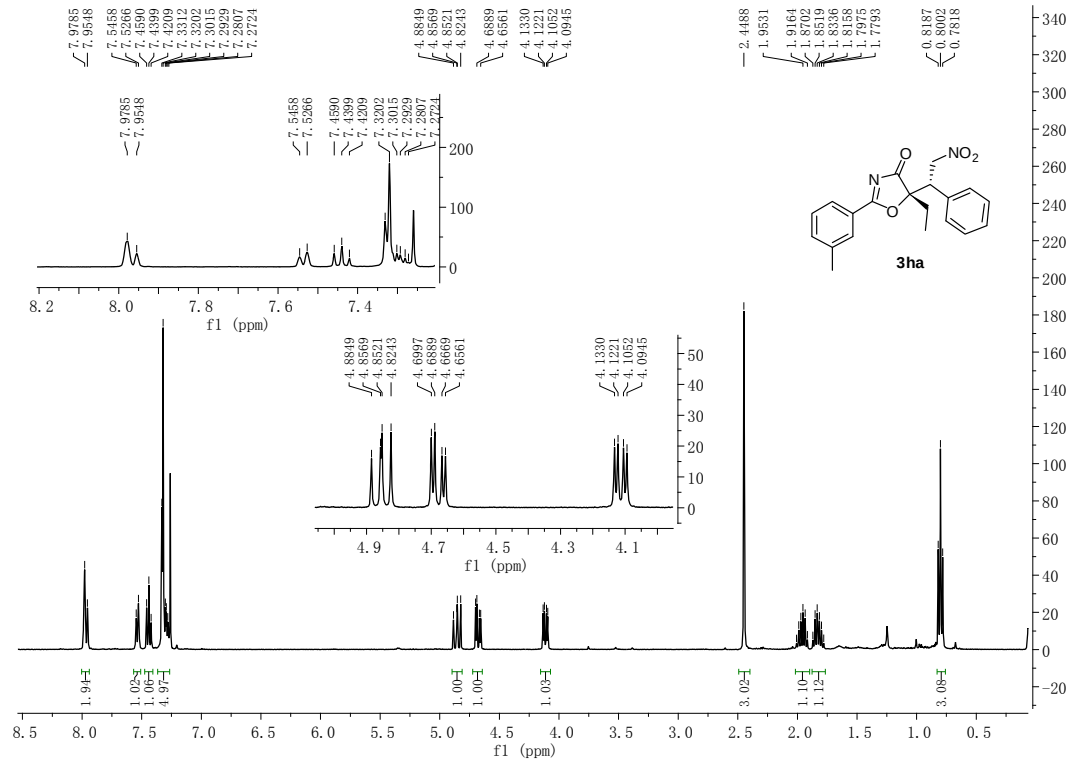
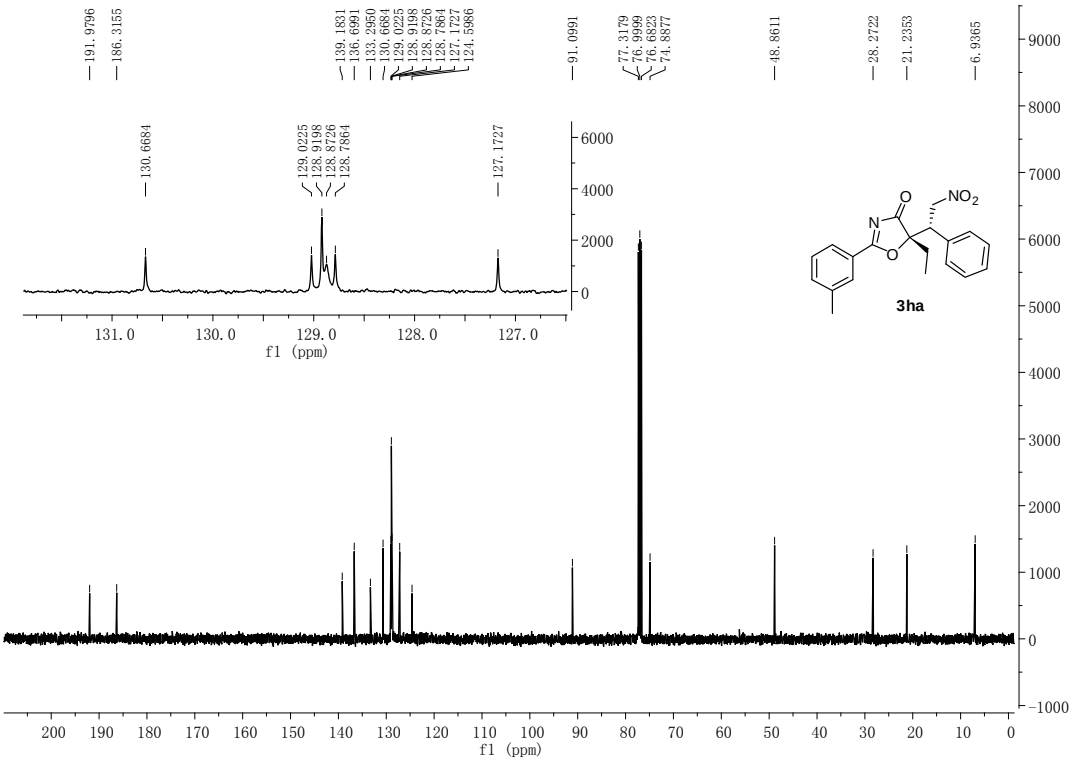
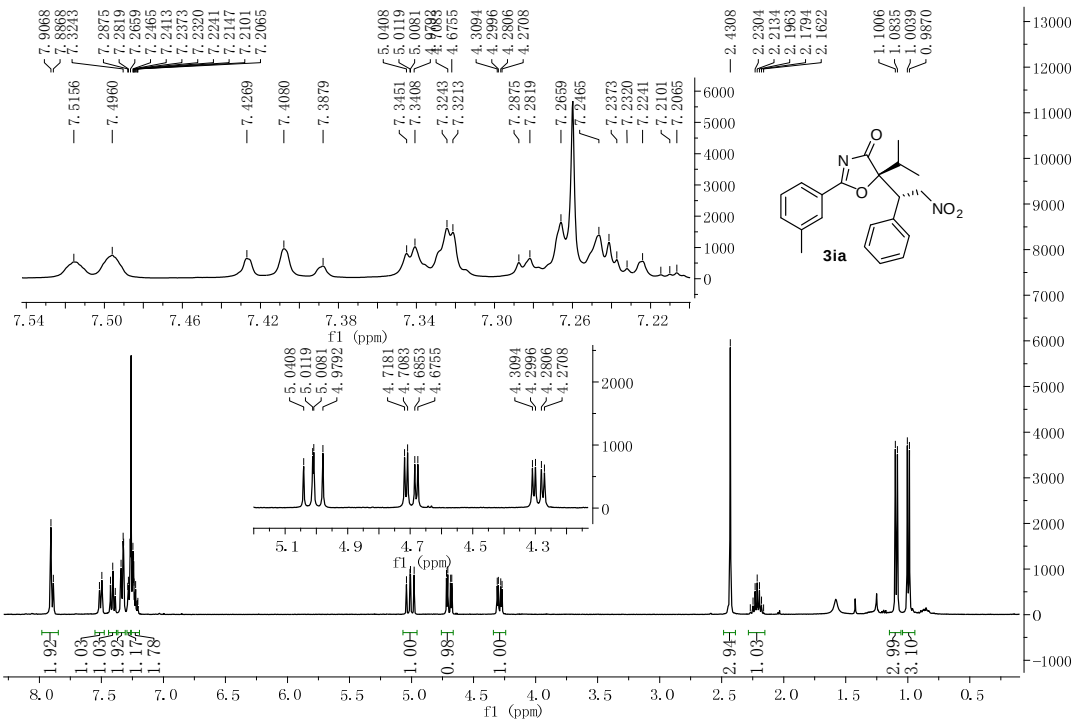
185.8678
139.1431
138.2674
136.6787
135.4578
128.5671
127.3875
124.8922
120.0291
86.7765
77.3179
77.0001
76.6823
74.9018
47.8197
21.1803
139.1431
138.2674
136.6787
135.4578
130.6924
129.0037
128.5671
128.4770
127.3875
126.6786
124.8922
120.0291
f1 (ppm)
NO2
O
N
O
3ep
f1 (ppm)

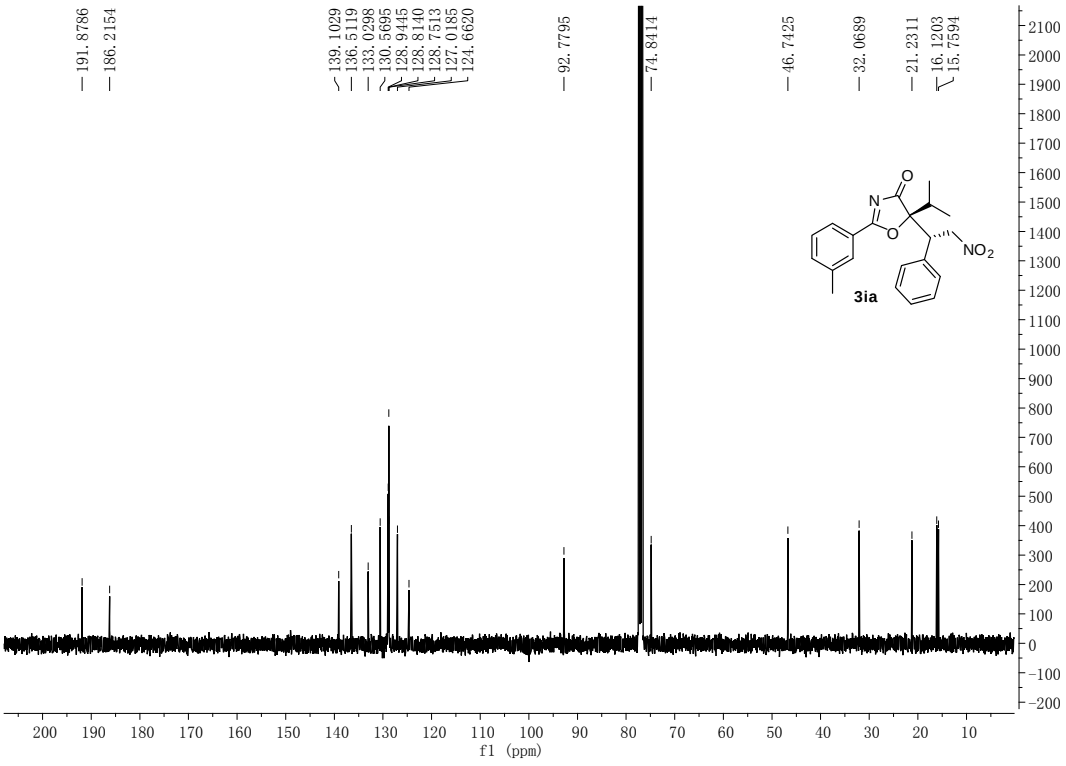

8.0091
7.9827
7.9633
7.5498
7.5310
7.4680
7.4489
7.4297
4.6704
4.6540
4.6351
4.6190
4.5020
4.4892
4.4665
4.4536
2.4544
1.9141
1.8807
1.8554
1.6223
1.2934
1.2457
1.2097
1.1865
1.1471
1.1093
1.0751
1.0432
1.0100
0.9859
0.9552
0.8642
0.8475
1.91
1.05
1.05
1.00
1.02
2.98
1.05
4.06
10.11
f1 (ppm)
3eq

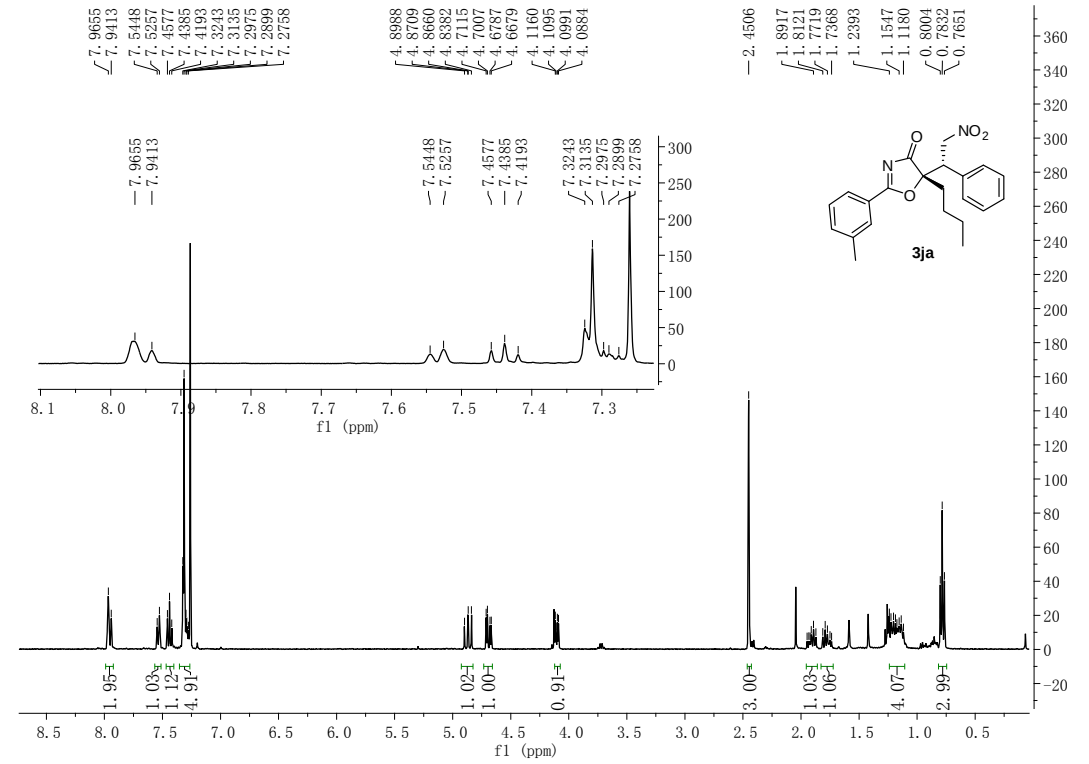

192.9300
185.3630
139.1529
136.5249
130.7633
129.0301
127.2954
125.0889
87.0794
77.3175
77.0001
72.1121
48.0907
36.2034
32.1570
26.5622
21.2327
f1 (ppm)
3eq

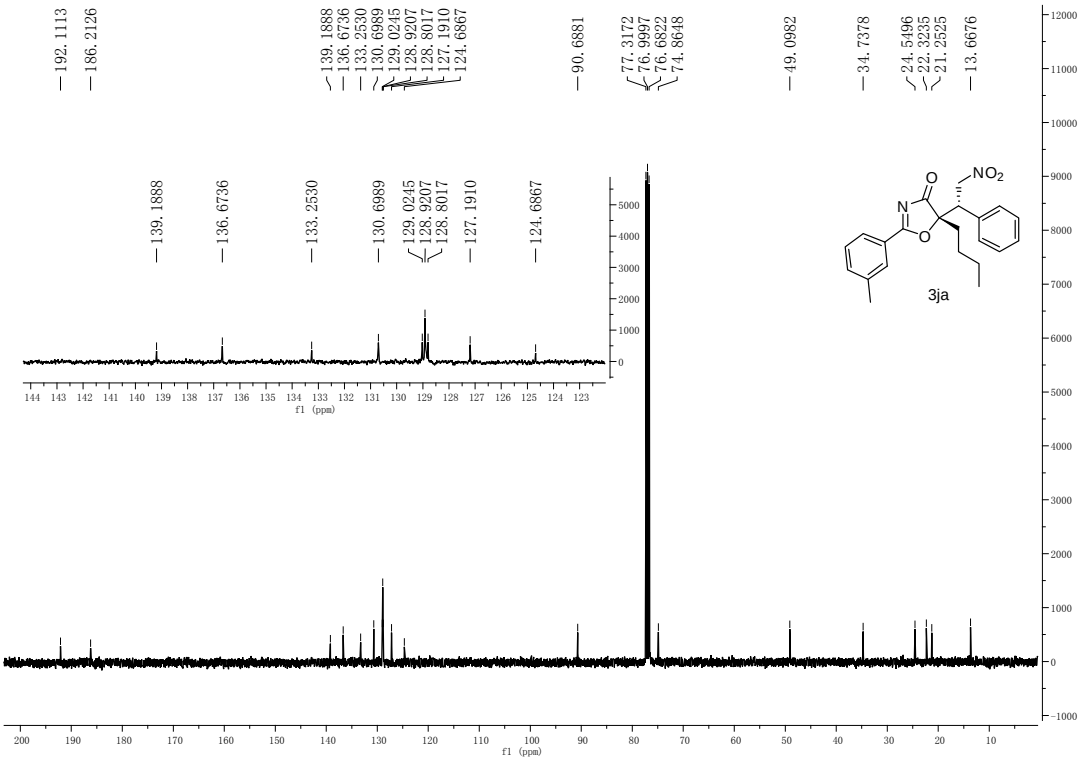

3ha
f1 (ppm)

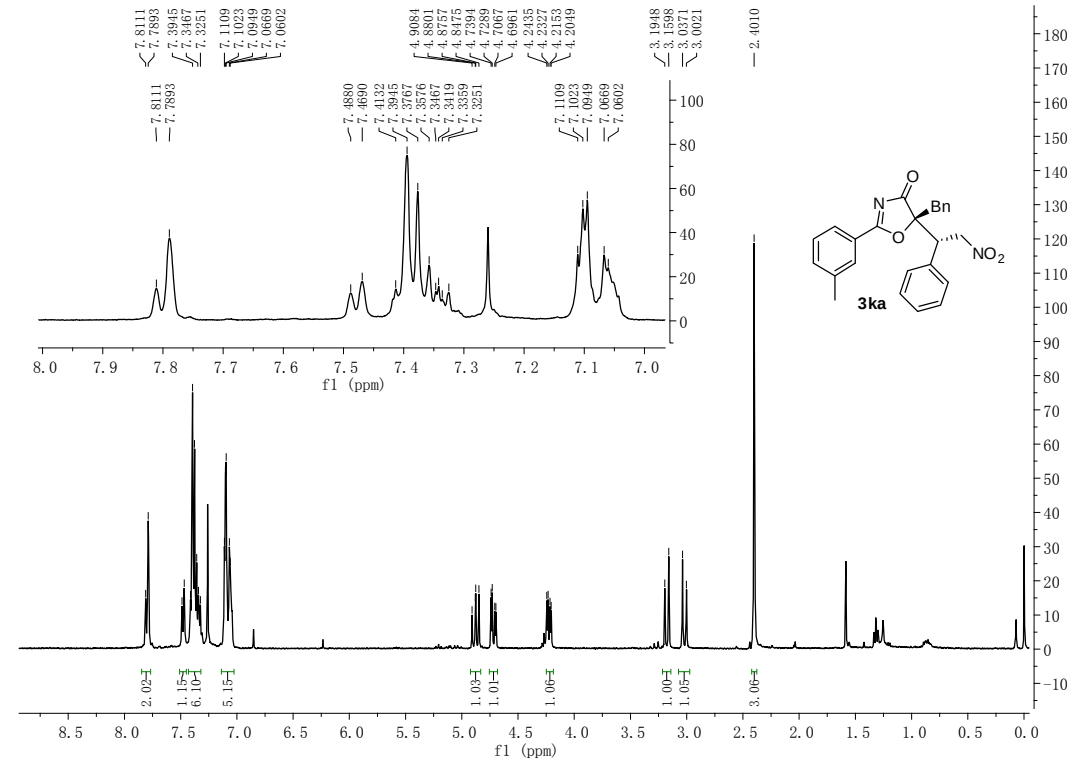

3ha
f1 (ppm)

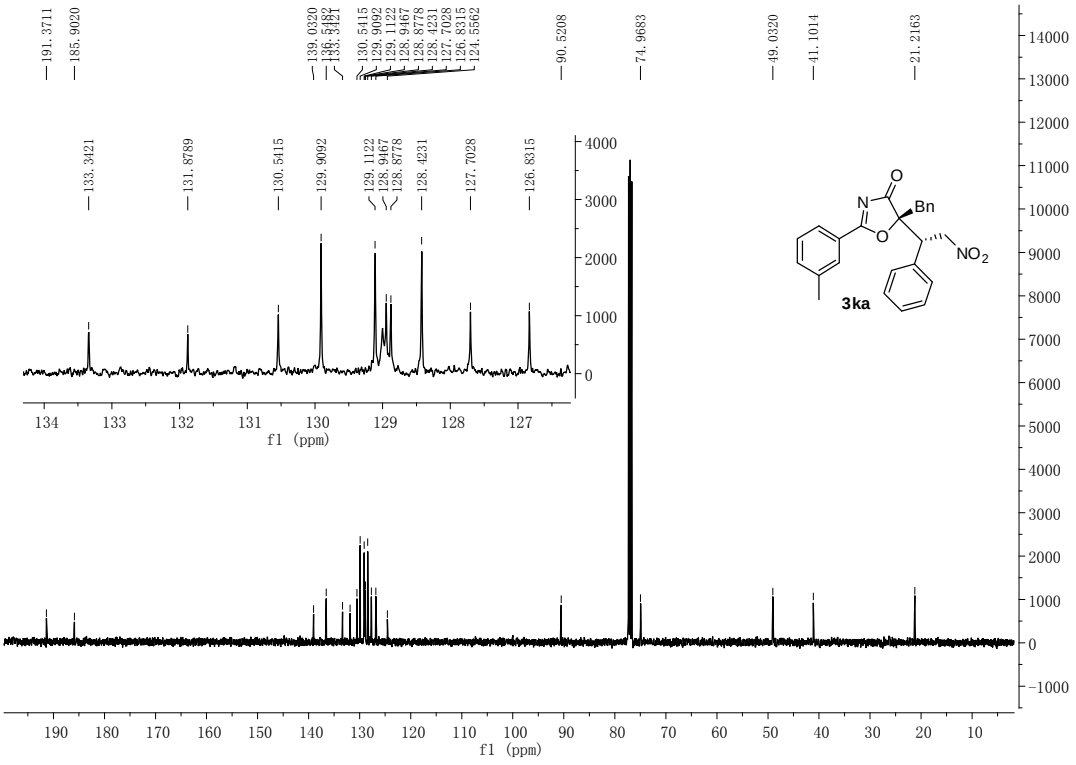

3ia
f1 (ppm)

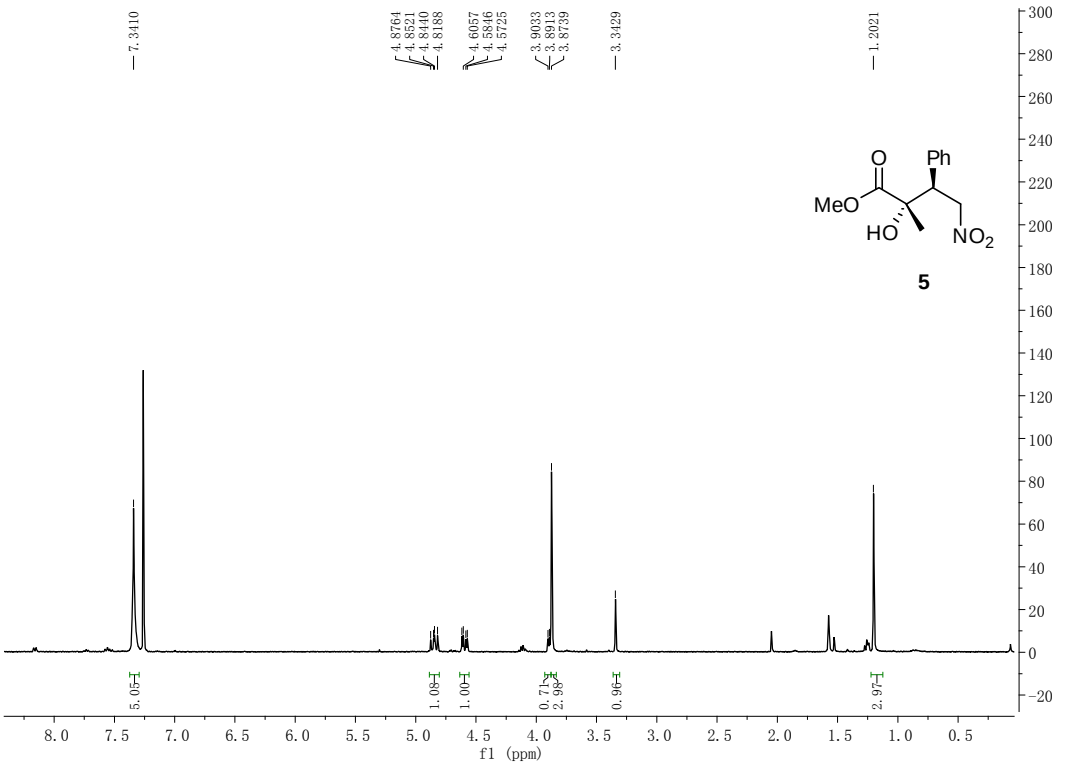

3ia
f1 (ppm)

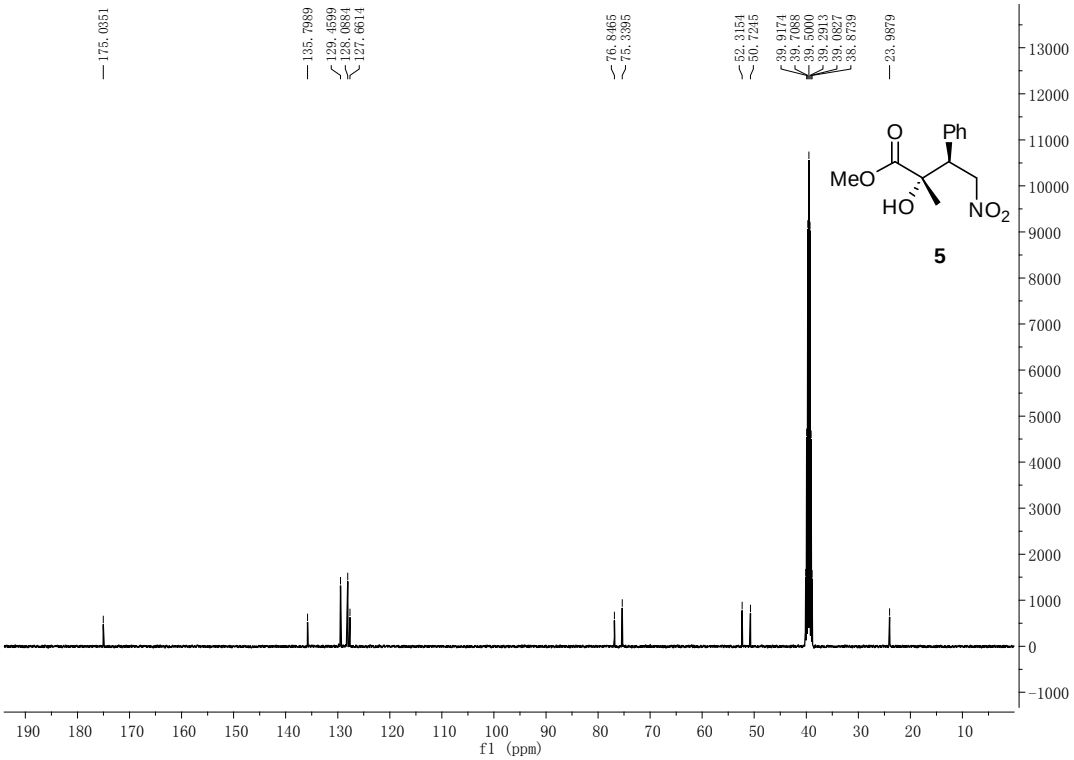

7.9655
7.9413
7.5448
7.5257
7.4577
7.4385
7.4193
7.3243
7.3135
7.2975
7.2899
7.2758
4.8988
4.8709
4.8660
4.8382
4.7115
4.7007
4.6787
4.6679
4.1160
4.1095
4.0991
4.0884
2.4506
1.8917
1.8121
1.7719
1.7368
1.2393
1.1547
1.1180
0.8004
0.7832
0.7651
NO2
O
N
O
3ja
f1 (ppm)
1.95
1.03
1.12
4.91
1.02
1.00
0.91
3.00
1.03
1.06
4.07
2.99

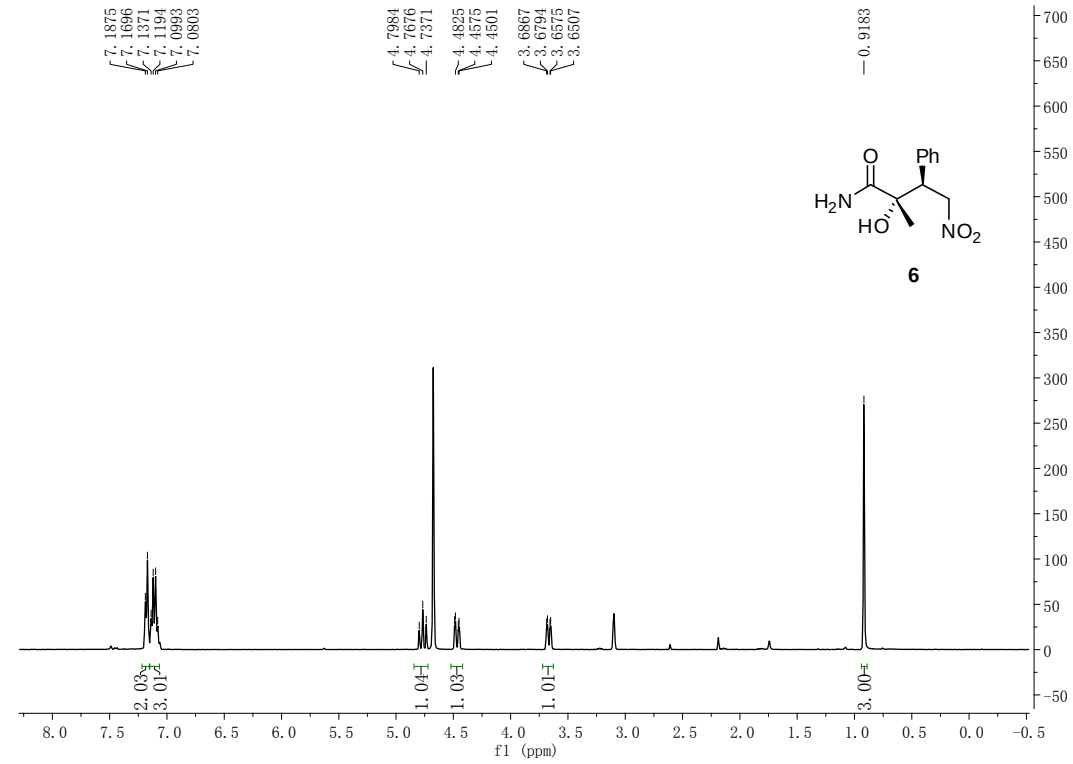

192.1113
186.2126
139.1888
136.6736
133.2530
130.6989
129.0245
128.9207
128.8017
127.1910
124.6867
90.6881
77.3172
76.9997
76.6822
74.8648
49.0982
34.7378
24.5496
22.3235
21.2525
13.6676
NO2
O
N
O
3ja
f1 (ppm)

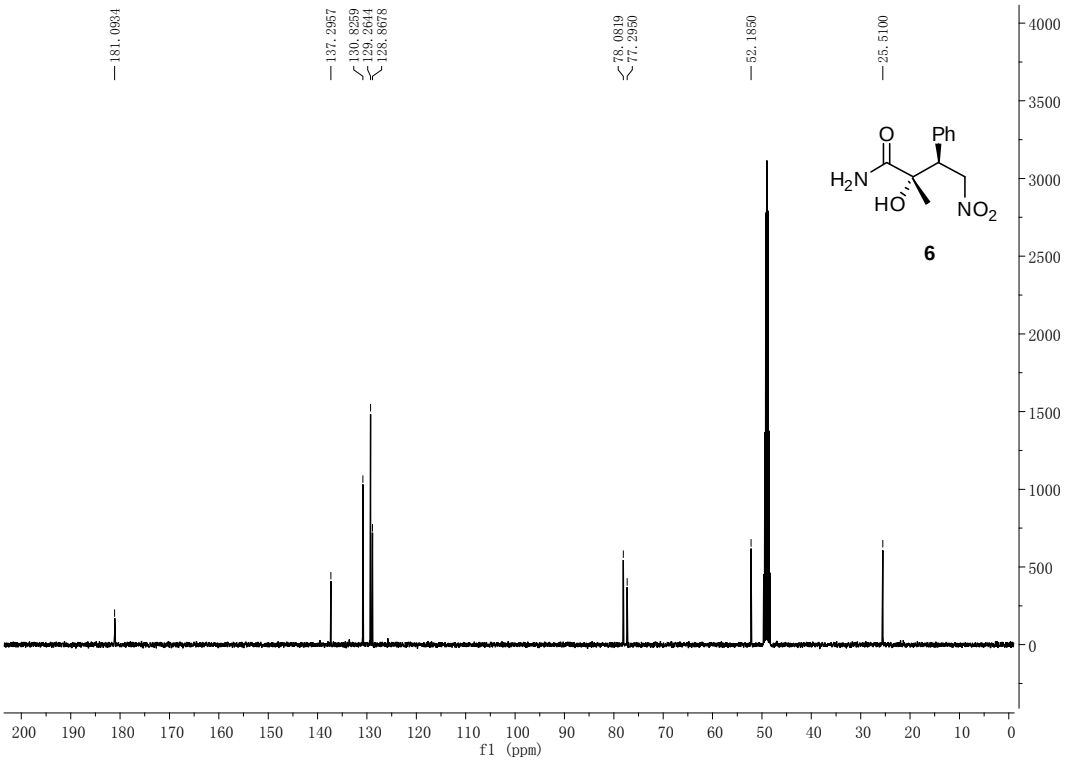

7.8111
7.7893
7.3945
7.3467
7.3251
7.1109
7.1023
7.0949
7.0669
7.0602
4.9084
4.8801
4.8757
4.8475
4.7394
4.7289
4.7067
4.6961
4.2435
4.2327
4.2153
4.2049
3.1948
3.1598
3.0371
3.0021
2.4010
7.4880
7.4690
7.4132
7.3945
7.3767
7.3576
7.3467
7.3419
7.3359
7.3251
f1 (ppm)
2.02
1.15
6.10
5.15
1.03
1.01
1.06
1.00
1.05
3.06
Bn
NO2
3ka

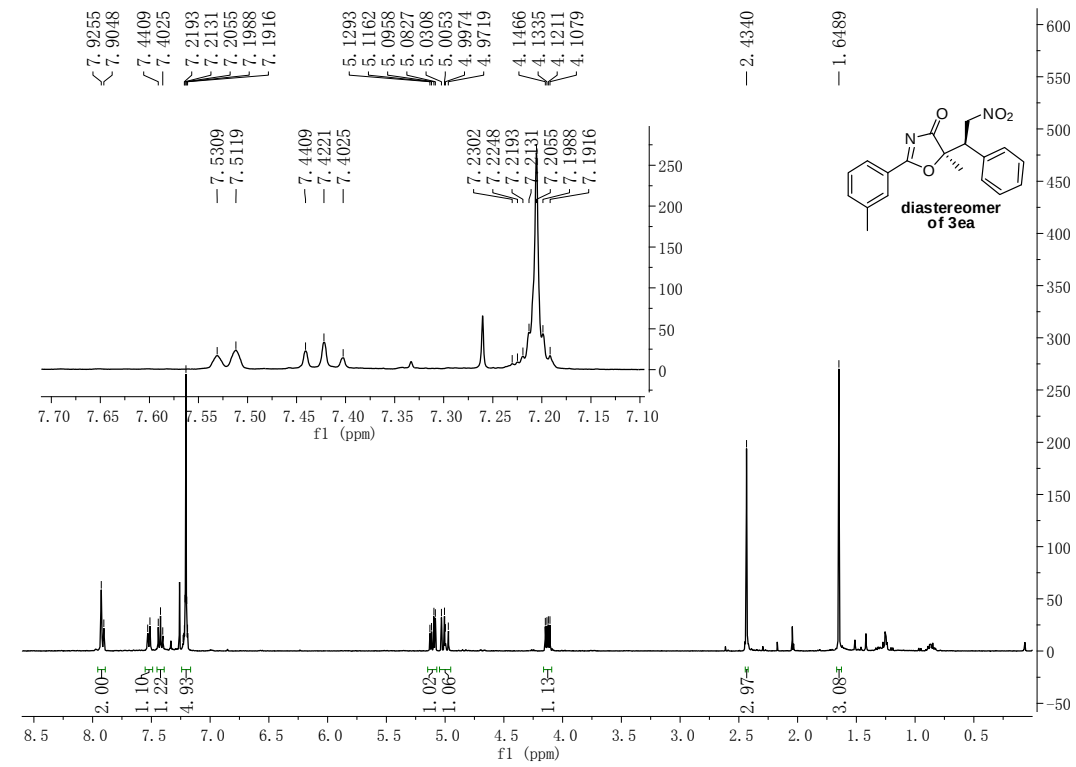

191.3711
185.9020
139.0320
138.5182
138.3141
130.5415
129.9092
129.1122
128.9467
128.8778
128.4231
127.7028
126.8315
124.5562
90.5208
74.9683
49.0320
41.1014
21.2163
133.3421
131.8789
130.5415
129.9092
129.1122
128.9467
128.8778
128.4231
127.7028
126.8315
f1 (ppm)
Bn
NO2
3ka

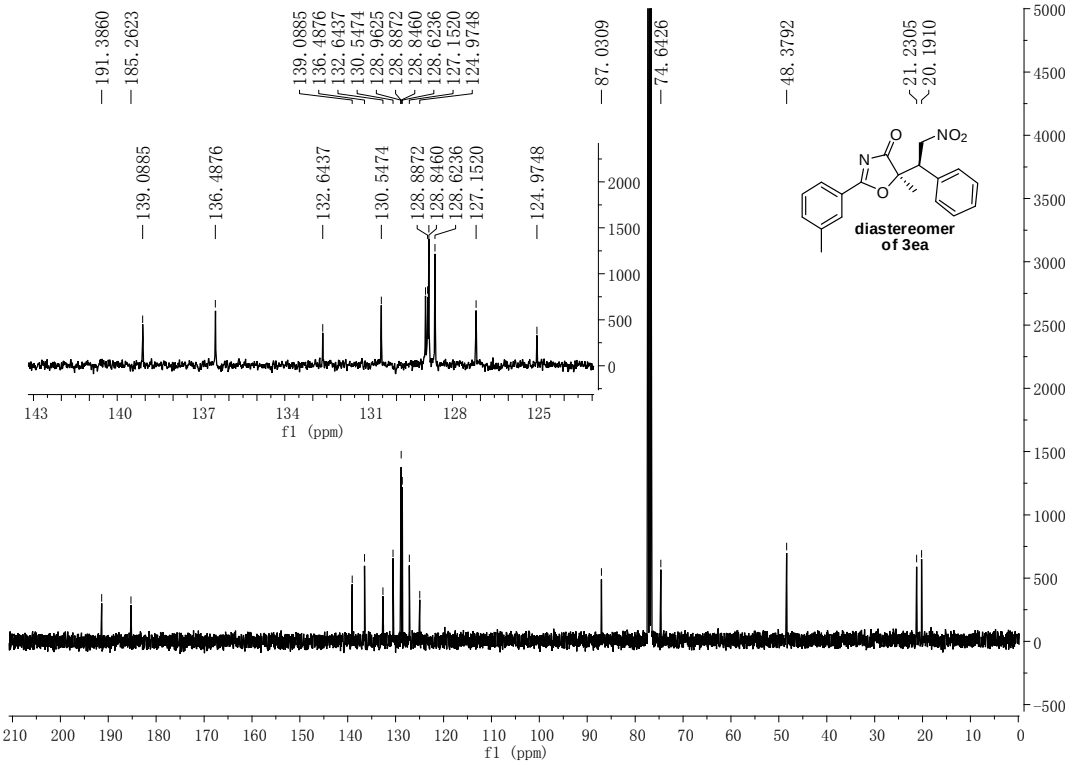

7.3410
4.8764
4.8521
4.8440
4.8188
4.6057
4.5846
4.5725
3.9033
3.8913
3.8739
3.3429
1.2021
O
Ph
MeO
HO
NO2
5
5.05
1.08
1.00
0.71
2.98
0.96
2.97
f1 (ppm)


175.0351
135.7989
129.4599
128.0884
127.6614
76.8465
75.3395
52.3154
50.7245
39.9174
39.7088
39.5000
39.2913
39.0827
38.8739
23.9879
O
Ph
MeO
HO
NO2
5
f1 (ppm)


7.1875
7.1696
7.1371
7.1194
7.0993
7.0803
4.7984
4.7676
4.7371
4.4825
4.4575
4.4501
3.6867
3.6794
3.6575
3.6507
0.9183
2.03
3.01
1.04
1.03
1.01
3.00
f1 (ppm)
O
Ph
H2N
HO
NO2
6


181.0934
137.2967
130.8259
129.2644
128.8678
78.0819
77.2950
52.1850
25.5100
f1 (ppm)
O
Ph
H2N
HO
NO2
6


7.9255
7.9048
7.4409
7.4025
7.2193
7.2131
7.2055
7.1988
7.1916
5.1293
5.1162
5.0958
5.0827
5.0308
5.0053
4.9974
4.9719
4.1466
4.1335
4.1211
4.1079
2.4340
1.6489
7.5309
7.5119
7.4409
7.4221
7.4025
7.2302
7.2248
7.2193
7.2131
7.2055
7.1988
7.1916
NO2
O
N
O
diastereomer
of 3ea
2.00
1.10
1.22
4.93
1.02
1.06
1.13
2.97
3.08
f1 (ppm)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128.9625
128.8872
128.8460
128.6236
127.1520
124.9748
87.0309
74.6426
48.3792
21.2305
20.1910
NO2
O
N
O
diastereomer
of 3ea
f1 (ppm)