Electronic Supplementary Material (ESI) for Chemical Communications

Asymmetric Synthesis of 3-Spirocyclopropyl-2-oxindoles via Intramolecular Trapping of Chiral Aza-ortho-xylylene

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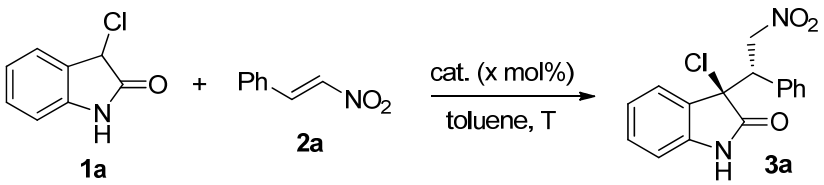
A. General Information

All the starting materials were obtained from commercial sources and used without further purification unless otherwise stated. ^{1}H and ^{13}C NMR spectra were recorded on a Bruker ACF300 or AMX500 (500 MHz) spectrometer. Chemical shifts were reported in parts per million (ppm), and the residual solvent peak was used as an internal reference: proton (chloroform δ 7.26), carbon (chloroform δ 77.0). Multiplicity was indicated as follows: s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet), dd (doublet of doublet), br s (broad singlet). Coupling constants were reported in Hertz (Hz). Low resolution mass spectra were obtained on a Finnigan/MAT LCQ spectrometer in ESI mode, and a Finnigan/MAT 95XL- T mass spectrometer in FAB mode. All high resolution mass spectra were obtained on a Finnigan/MAT 95XL- T spectrometer. For thin layer chromatography (TLC), Merck pre-coated TLC plates (Merck 60 F254) were used, and compounds were visualized with a UV light at 254 nm. Further visualization was achieved by staining with iodine, or ceric ammonium molybdate followed by heating on a hot plate. Flash chromatographic separations were performed on Merck 60 (0.040- 0.063 mm) mesh silica gel. The enantiomeric excesses of products were determined by chiral-phase HPLC analysis.

3-Chlorooxindole starting material was prepared following the literature procedure.[1]

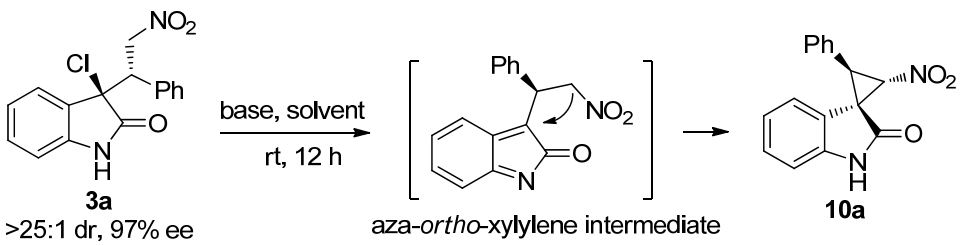
B. Representative Procedure

Asymmetric Synthesis of the aza-*ortho*-Xylylene Precusor: Conjugate Addition of 3-Cl-oxindole 1a to Nitroolefin 2a



To a mixture of **1a** (16.7mg, 0.1 mmol) and **2a** (17.9 mg, 0.12 mmol) in toluene (1.0 mL) at the temperature specified (Table 1) was added the catalyst (x mol % as indicated in Table 1), and the resulting mixture was stirred at that temperature for the time specified. At the end of the reaction, the reaction mixture was directly purified by flash column chromatography (ethyl acetate/hexane = 1:3) to afford the desired adduct **3a**. The enantiomeric excessess of **3a** were determined by chiral HPLC analysis.

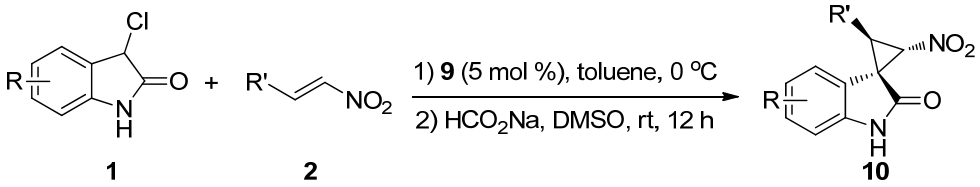
Intramolecular Cyclization of aza-*ortho*-Xylylene intermediate: Synthesis of Spirooxindole 10a



To a stirred solution of **3a** (97% ee, dr >25:1, 15.8 mg, 0.05 mmol) in the solvent specified (0.5 mL) in a sample vial was added base (0.15 mmol), and the resulting mixture was stirred at room temperature for 12 h. The mixture was diluted with ethyl acetate (5 mL) and washed with brine (5 mL x 3). The combined organic phases were dried over anhydrous Na_2SO_4, filtered and concentrated, and the residue was purified by column chromatography (hexane/ethyl acetate = 2:1) to afford the

3-spirocyclopropyl-2-oxindole **10a** as a white solid. The enantiomeric excessess of **10a** were determined by chiral HPLC analysis.

Asymmetric Synthesis of Spiro Cyclopropyl Oxindoles 10

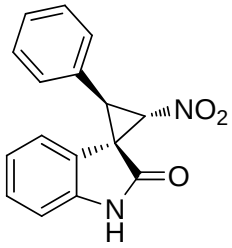


1 **2** **10**

3-Cl-Oxindole **1** (0.1 mmol) was added to a solution of nitroolefin **2** (0.12 mmol) and catalyst **9** (4.7 mg, 0.005 mmol) in toluene (1.0 mL) in a sample vial at 0 °C, and the resulting mixture was sealed and stirred at 0 °C for the time specified in Table 2. At the end of the reaction, the reaction solution was directly purified by flash column chromatography (hexane/ethyl acetate = 5:2 or dichloromethane) to afford crude **3**, which was dissolved directly in DMSO (1.0 mL) in a sample vial, and HCO_2Na (20.4 mg, 0.15 mmol) was added, and the resulting mixture was stirred at room temperature for 12 h. The solution was diluted with ethyl acetate (5 mL) and washed with brine (5 mL x 3). The combined organic phases were dried over anhydrous Na_2SO_4, filtered and concentrated, and the residue was purified by column chromatography (hexane/ethyl acetate = 2:1) to afford the 3-spirocyclopropyl-2-oxindole **10**. The enantiomeric excessess of **10** were determined by chiral HPLC analysis.

C. Analytical data and HPLC Chromatogram of the Products

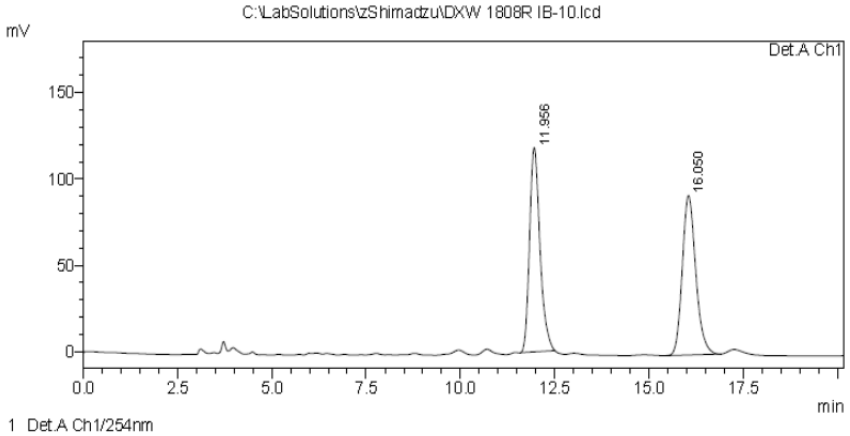
(1*R*,2*S*,3*R*)-2-Nitro-3-phenylspiro[cyclopropane-1,3'-indolin]-2'-one **10a**



10a

A white solid; ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.35 (d, *J* = 6.3 Hz, 1H), 5.46 (d, *J* = 6.3 Hz, 1H), 6.87 (d, *J* = 7.6 Hz, 1H), 7.10 (t, *J* = 7.9 Hz, 1H), 7.29-7.34 (m, 6H), 7.38 (d, *J* = 7.6 Hz, 1H), 8.34 (br s, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 40.4, 41.8, 72.0, 110.3, 122.5, 122.9, 123.4, 128.4, 128.5, 128.8, 129.0, 129.8, 141.4, 171.4; The *ee* value was 97%, t_R (minor) = 11.82 min, t_R (major) = 15.83 min (Chiralcel IA, λ = 254 nm, 10% *i*PrOH/hexanes, flow rate = 1.0 mL/min); HRMS (ESI) m/z calcd for $C_{16}H_{11}N_2O_3$ $[M-H]^-$ = 279.0775, found = 279.0762.

<Chromatogram>



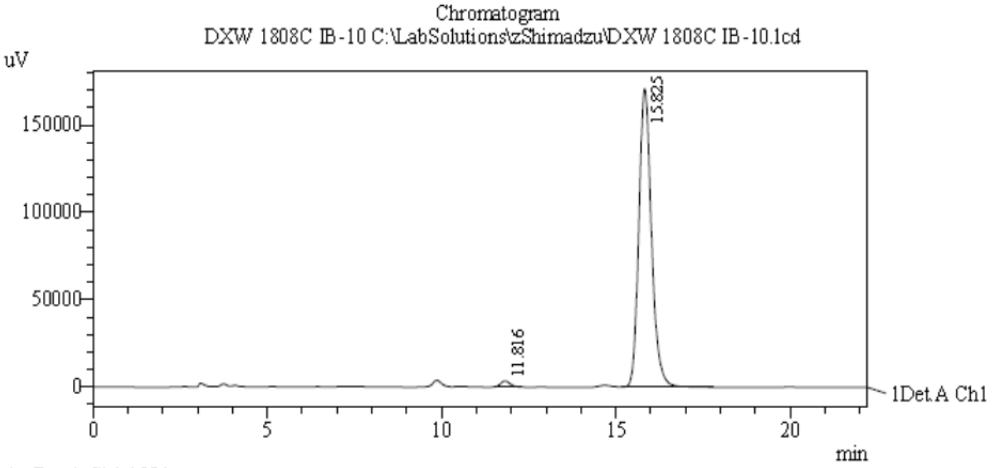
1 Det.A Ch1/254nm

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.956	2282035	118460	49.828	56.191
2	16.050	2297825	92355	50.172	43.809
Total		4579860	210815	100.000	100.000

(racemic **10a**)



1 Det.A Ch1 / 254nm

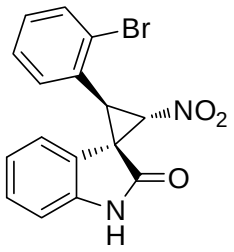
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.816	64485	3471	1.475	1.991
2	15.825	4306909	170837	98.525	98.009
Total		4371394	174308	100.000	100.000

(enantiomerically enriched **10a**)

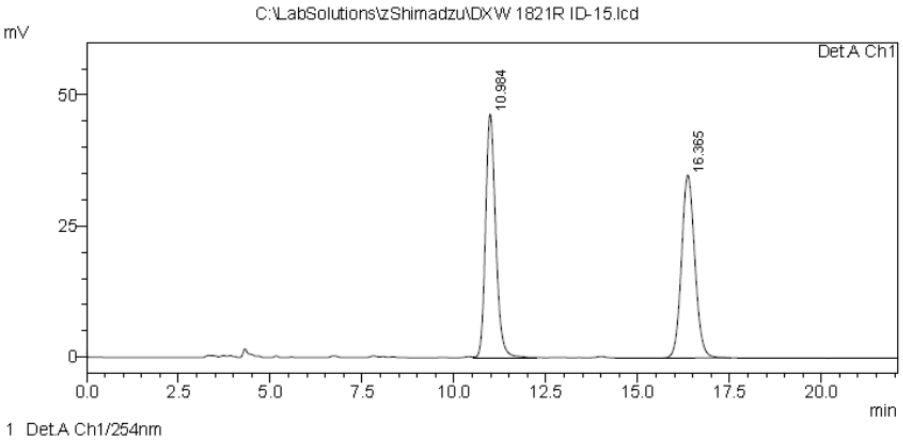
(1*R*,2*S*,3*S*)-2-(2-Bromophenyl)-3-nitrospiro[cyclopropane-1,3'-indolin]-2'-one **10b**



10b

A light yellow solid; ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.23 (d, *J* = 6.3 Hz, 1H), 5.36 (d, *J* = 6.3 Hz, 1H), 6.76 (d, *J* = 7.6 Hz, 1H), 7.08 (t, *J* = 7.6 Hz, 1H), 7.17 (t, *J* = 7.6 Hz, 1H), 7.23-7.37 (m, 4H), 7.50 (d, *J* = 7.6 Hz, 1H), 8.68 (br s, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 40.5, 42.0, 72.1, 110.4, 122.6, 122.9, 123.0, 125.1, 127.3, 128.4, 129.0, 129.8, 130.3, 132.7, 141.6, 171.7; The *ee* value was 95%, t_R (minor) = 10.98 min, t_R (major) = 16.26 min (Chiralcel ID, λ = 254 nm, 15% *i*PrOH/hexanes, flow rate = 1.0 mL/min); HRMS (ESI) m/z calcd for $C_{16}H_{10}N_2O_3{}^{79}Br$ $[M-H]^-$ = 356.9880, found = 356.9869.

<Chromatogram>



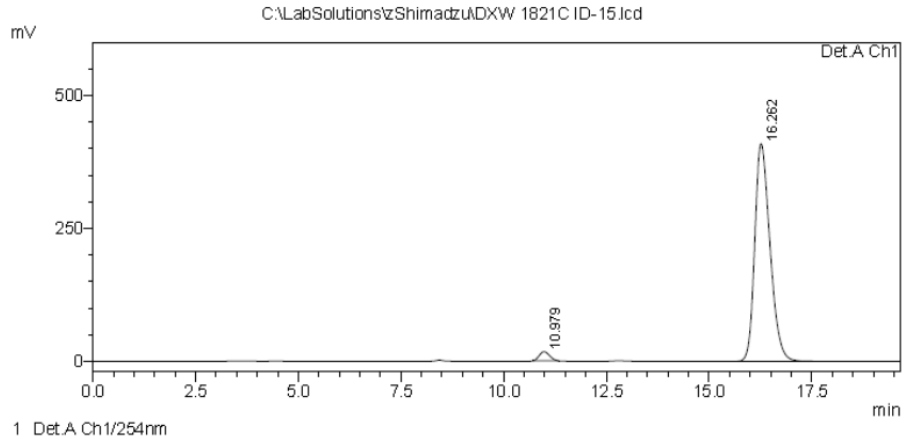
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.984	891067	46440	50.285	57.092
2	16.365	880950	34903	49.715	42.908
Total		1772017	81343	100.000	100.000

(racemic **10b**)

<Chromatogram>



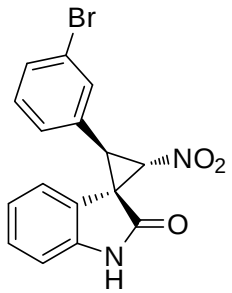
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.979	296900	17157	2.723	4.022
2	16.262	10605035	409449	97.277	95.978
Total		10901935	426607	100.000	100.000

(enantiomerically enriched **10b**)

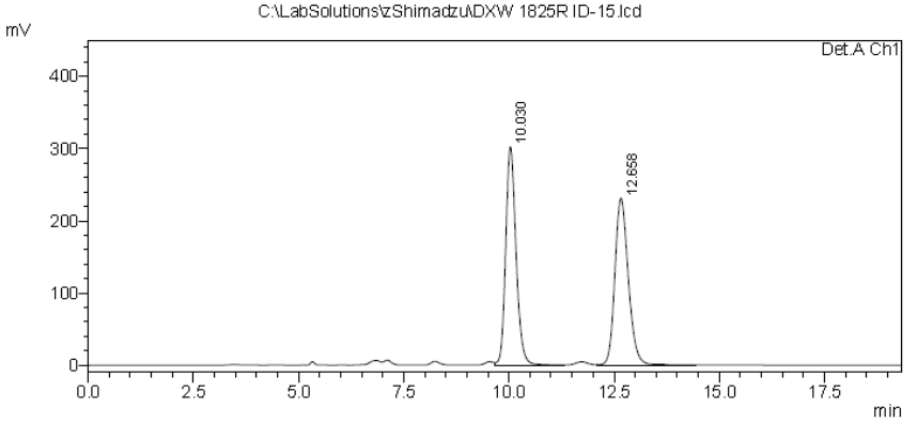
(1*R*,2*R*,3*S*)-2-(3-Bromophenyl)-3-nitrospiro[cyclopropane-1,3'-indolin]-2'-one **10c**



10c

A light yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.30 (d, *J* = 6.3 Hz, 1H), 5.43 (d, *J* = 6.3 Hz, 1H), 6.89 (d, *J* = 7.6 Hz, 1H), 7.10 (t, *J* = 7.6 Hz, 1H), 7.19-7.25 (m, 2H), 7.30-7.36 (m, 2H), 7.44 (t, *J* = 10.4 Hz, 2H), 8.66 (br s, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 39.3, 41.7, 71.6, 110.6, 122.4, 122.5, 122.9, 123.0, 127.5, 129.3, 130.0, 131.5, 131.9, 132.1, 141.5, 171.4; The *ee* value was 92%, t_R (minor) = 10.05 min, t_R (major) = 12.62 min (Chiralcel ID, λ = 254 nm, 15% *i*PrOH/hexanes, flow rate = 1.0 mL/min); HRMS (ESI) m/z calcd for $C_{16}H_{10}N_2O_3{}^{79}Br$ $[M-H]^-$ = 356.9880, found = 356.9869.

<Chromatogram>



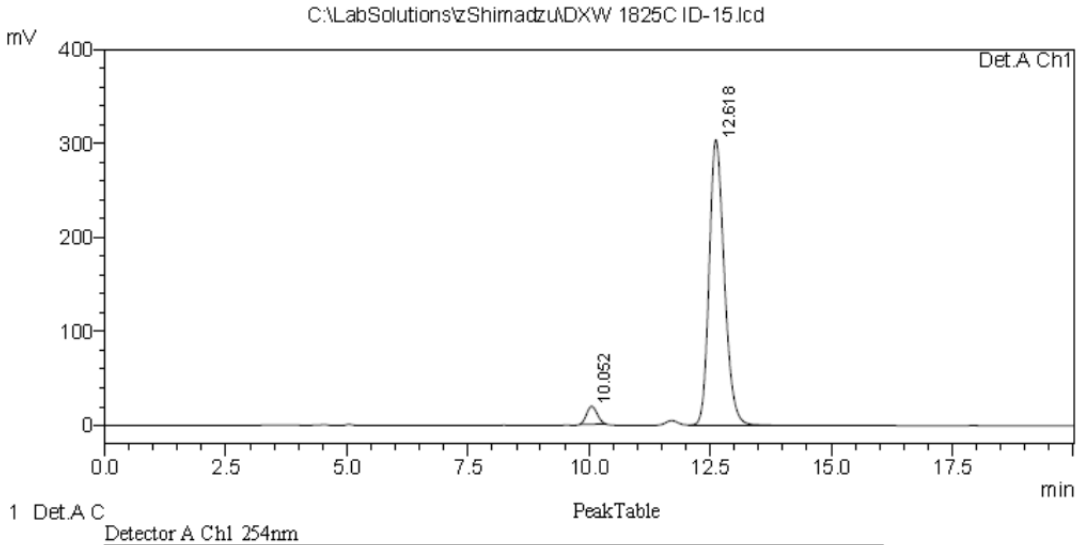
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.030	5163440	302301	50.095	56.692
2	12.658	5143758	230932	49.905	43.308
Total		10307197	533233	100.000	100.000

(racemic **10c**)

<Chromatogram>



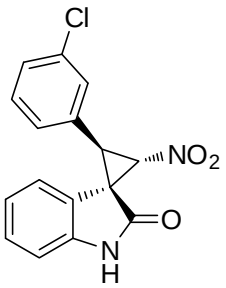
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.052	285030	18922	4.124	5.864
2	12.618	6626983	303735	95.876	94.136
Total		6912013	322658	100.000	100.000

(enantiomerically enriched **10c**)

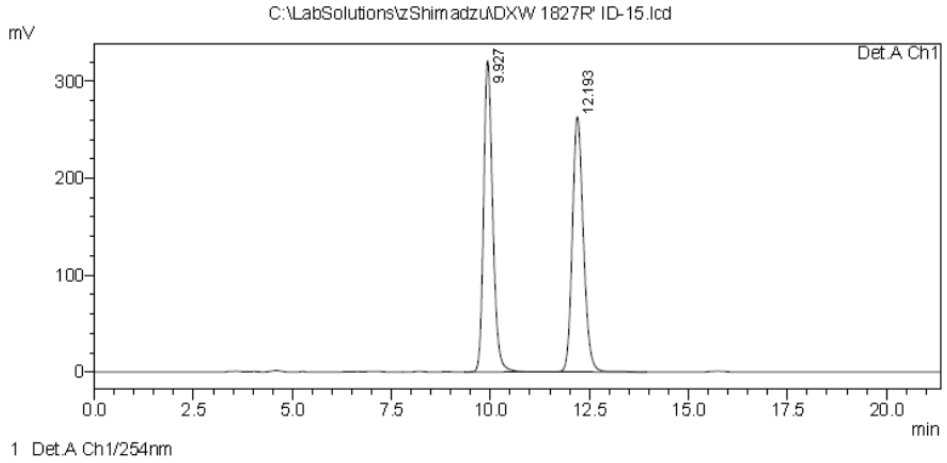
(1*R*,2*R*,3*S*)-2-(3-Chlorophenyl)-3-nitrospiro[cyclopropane-1,3'-indolin]-2'-one **10d**



10d

A white solid; ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.30 (d, *J* = 6.3 Hz, 1H), 5.43 (d, *J* = 6.3 Hz, 1H), 6.87 (d, *J* = 8.2 Hz, 1H), 7.10 (t, *J* = 7.9 Hz, 1H), 7.19-7.20 (m, 1H), 7.25-7.36 (m, 5H), 8.60 (br s, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 39.4, 41.7, 71.6, 110.5, 122.5, 122.9, 123.0, 127.1, 128.6, 129.1, 129.2, 129.7, 131.8, 134.4, 141.5, 171.4; The *ee* value was 91%, t_R (minor) = 10.10 min, t_R (major) = 12.34 min (Chiralcel ID, λ = 254 nm, 15% *i*PrOH/hexanes, flow rate = 1.0 mL/min); HRMS (ESI) m/z calcd for $C_{16}H_{10}N_2O_3Cl$ $[M-H]^-$ = 313.0385, found = 313.0374.

<Chromatogram>



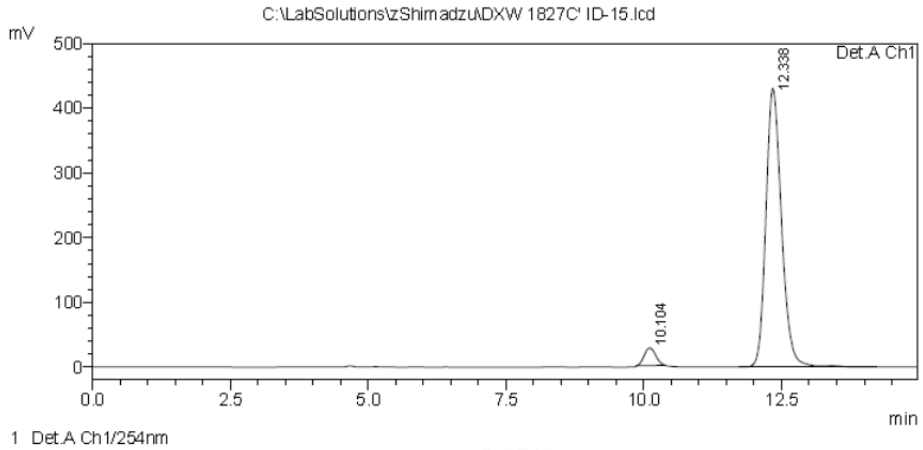
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	9.927	5138313	320894	50.127	54.955
2	12.193	5112252	263028	49.873	45.045
Total		10250565	583921	100.000	100.000

(racemic **10d**)

<Chromatogram>



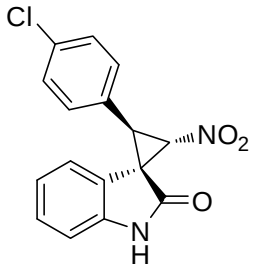
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.104	395552	27382	4.443	5.981
2	12.338	8508169	430440	95.557	94.019
Total		8903721	457822	100.000	100.000

(enantiomerically enriched **10d**)

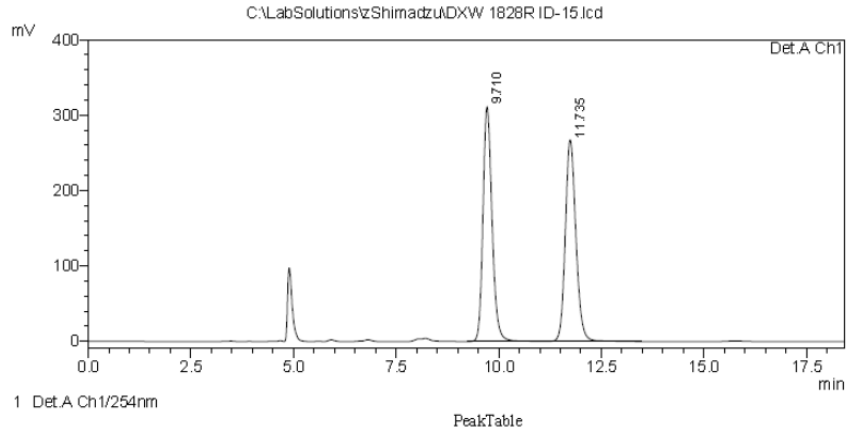
(1*R*,2*R*,3*S*)-2-(4-Chlorophenyl)-3-nitrospiro[cyclopropane-1,3'-indolin]-2'-one **10e**



10e

A white solid; ^{1}H NMR (500 MHz, $CDCl_3$ & d6-Acetone v/v=1:1) δ 4.34 (d, *J* = 6.3 Hz, 1H), 5.49 (d, *J* = 6.3 Hz, 1H), 6.99-7.03(m, 2H), 7.23-7.29 (m, 4H), 7.37 (d, *J* = 8.8 Hz, 2H), 9.79 (br s, 1H); ^{13}C NMR (125 MHz, $CDCl_3$ & d6-Acetone v/v=1:1) δ 37.9, 40.6, 71.0, 109.4, 121.0, 121.2, 122.5, 127.4, 128.0, 128.5, 129.8, 132.6, 141.8, 169.7; The *ee* value was 92%, t_R (minor) = 9.62 min, t_R (major) = 11.57 min (Chiralcel ID, λ = 254 nm, 15% *i*PrOH/hexanes, flow rate = 1.0 mL/min); HRMS (ESI) m/z calcd for $C_{16}H_{10}N_2O_3Cl$ $[M-H]^-$ = 313.0385, found = 313.0374.

<Chromatogram>



1 Det.A Ch1/254nm

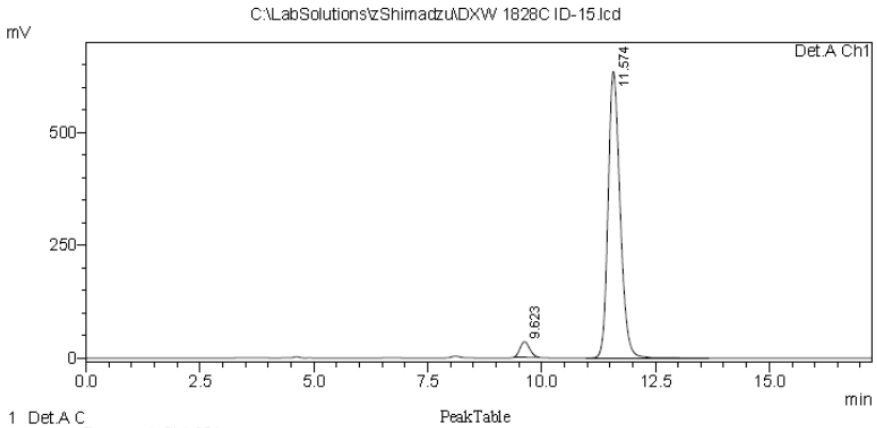
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	9.710	4809294	311581	49.998	53.789
2	11.735	4809592	267688	50.002	46.211
Total		9618886	579269	100.000	100.000

(racemic **10e**)

<Chromatogram>



1 Det.A C

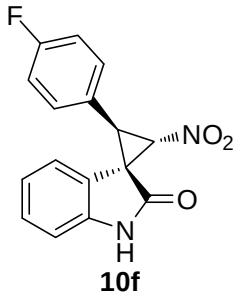
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	9.623	505867	34521	4.166	5.158
2	11.574	11637315	634722	95.834	94.842
Total		12143182	669243	100.000	100.000

(enantiomerically enriched **10e**)

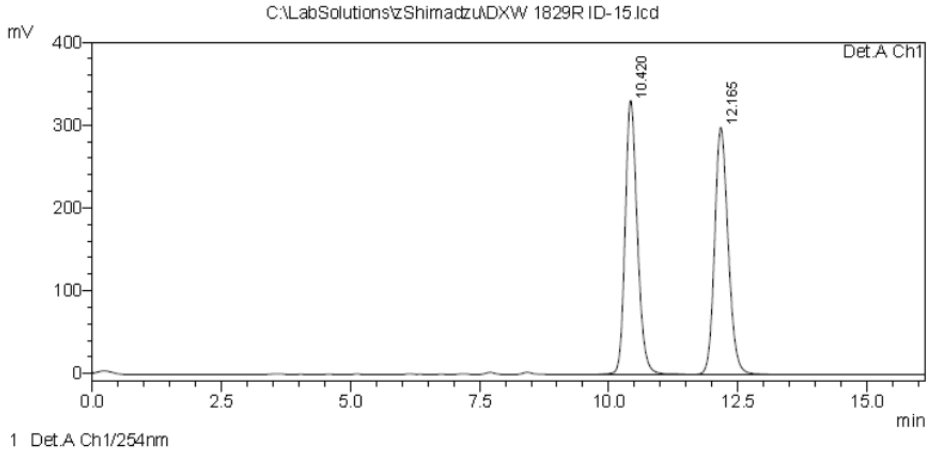
(1*R*,2*R*,3*S*)- 2-(4-Fluorophenyl)-3-nitrospiro[cyclopropane-1,3'-indolin]-2'-one **10f**



10f

A white solid; ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.31 (d, *J* = 7.0 Hz, 1H), 5.46 (d, *J* = 6.3 Hz, 1H), 6.86 (d, *J* = 7.6 Hz, 1H), 7.00-7.04 (m, 2H), 7.09-7.12 (m, 1H), 7.27-7.33 (m, 3H), 7.36 (d, *J* = 7.6 Hz, 1H), 8.55 (br s, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 39.5, 41.8, 72.0, 110.5, 115.6 (d, *J* = 21.9 Hz), 122.5, 123.0, 123.2, 125.6 (d, *J* = 2.7 Hz), 129.2, 130.6 (d, *J* = 8.2 Hz), 141.4, 162.6 (d, *J* = 246.9 Hz), 171.5; The *ee* value was 92%, t_R (minor) = 10.44 min, t_R (major) = 12.14 min (Chiralcel ID, λ = 254 nm, 15% *i*PrOH/hexanes, flow rate = 1.0 mL/min); HRMS (ESI) m/z calcd for $C_{16}H_{10}N_2O_3F$ $[M-H]^-$ = 297.0681, found = 297.0679.

<Chromatogram>



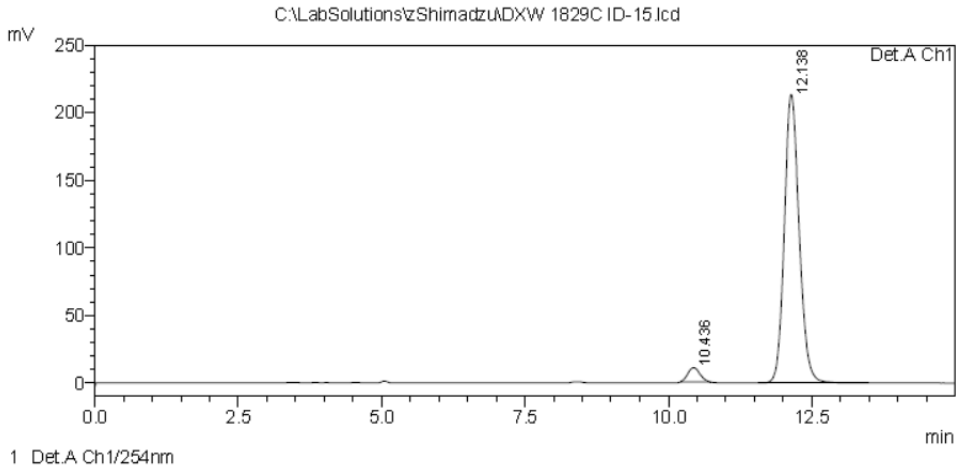
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.420	5471397	331214	50.025	52.601
2	12.165	5465880	298456	49.975	47.399
Total		10937277	629670	100.000	100.000

(racemic **10f**)

<Chromatogram>



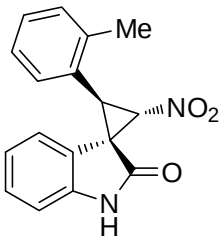
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.436	152102	10489	3.794	4.682
2	12.138	3856877	213544	96.206	95.318
Total		4008979	224033	100.000	100.000

(enantiomerically enriched **10f**)

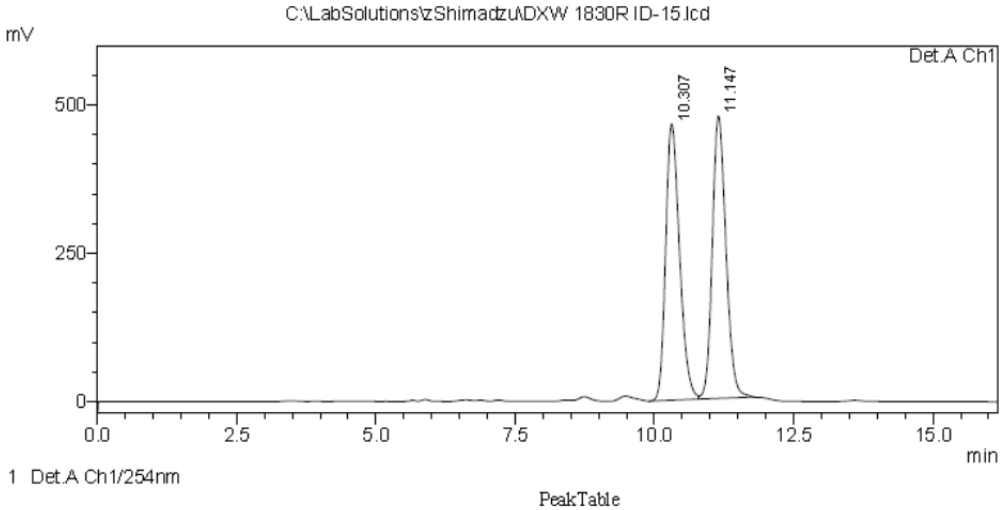
(1*R*,2*S*,3*R*)-2-Nitro-3-(o-tolyl)spiro[cyclopropane-1,3'-indolin]-2'-one **10g**



10g

A yellow solid; ^{1}H NMR (500 MHz, $CDCl_3$) δ 2.03 (s, 3H), 4.21 (d, *J* = 6.3 Hz, 1H), 5.43 (d, *J* = 6.9 Hz, 1H), 6.84 (d, *J* = 7.6 Hz, 1H), 7.09-7.15 (m, 2H), 7.21-7.32 (m, 4H), 7.40 (d, *J* = 7.6 Hz, 1H), 8.46 (br s, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 19.4, 39.5, 41.6, 72.1, 110.5, 122.4, 123.0, 123.1, 125.9, 128.4, 128.5, 128.6, 129.0, 130.3, 137.5, 141.4, 171.6; The *ee* value was 99%, t_R (minor) = 10.37 min, t_R (major) = 11.12 min (Chiralcel ID, λ = 254 nm, 15% *i*PrOH/hexanes, flow rate = 1.0 mL/min); HRMS (ESI) m/z calcd for $C_{17}H_{13}N_2O_3$ $[M-H]^-$ = 293.0932, found = 293.0929.

<Chromatogram>



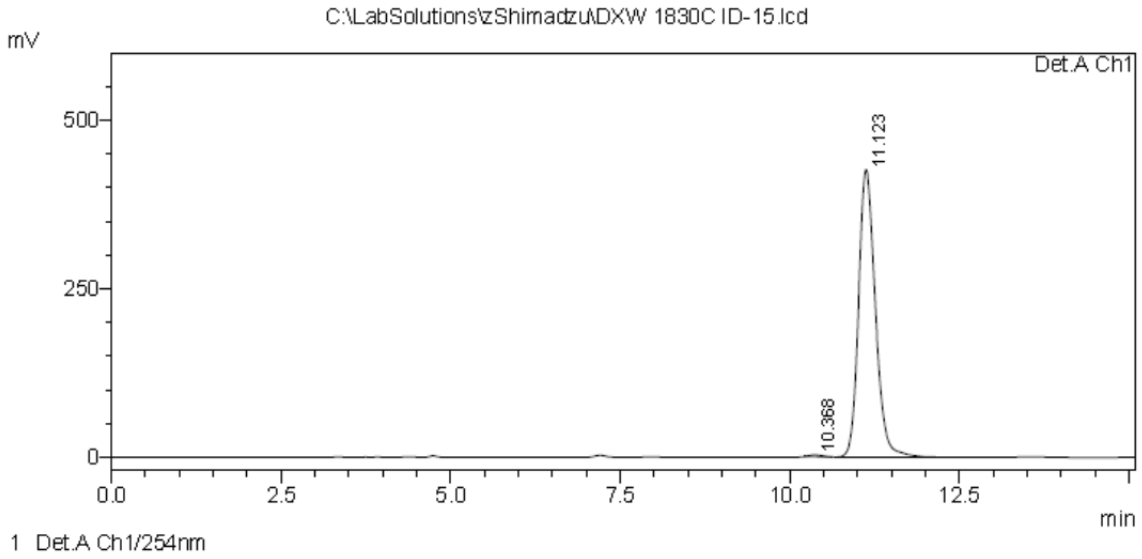
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.307	8088393	465739	49.963	49.444
2	11.147	8100454	476211	50.037	50.556
Total		16188847	941950	100.000	100.000

(racemic **10g**)

<Chromatogram>



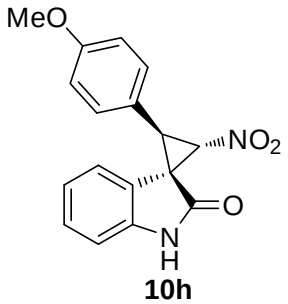
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	10.368	33114	2565	0.448	0.598
2	11.123	7357419	426634	99.552	99.402
Total		7390533	429199	100.000	100.000

(enantiomerically enriched **10g**)

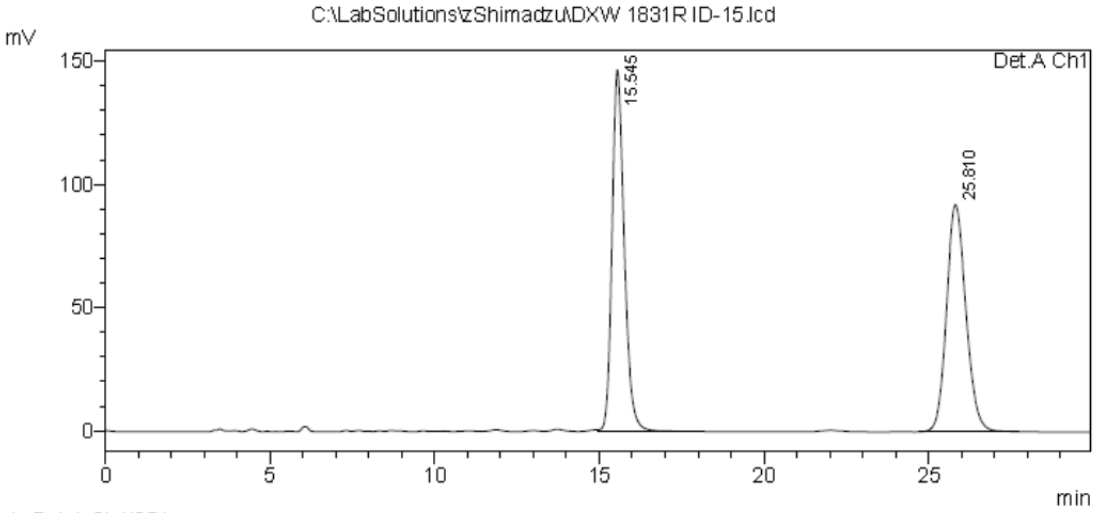
(1*R*,2*R*,3*S*)-2-(4-Methoxyphenyl)-3-nitrospiro[cyclopropane-1,3'-indolin]-2'-one **10h**



10h

A yellow oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 3.77 (s, 3H), 4.29 (d, *J* = 6.3 Hz, 1H), 5.44 (d, *J* = 6.3 Hz, 1H), 6.85-6.88 (m, 3H), 7.09 (t, *J* = 7.6 Hz, 1H), 7.22 (d, *J* = 8.8 Hz, 2H), 7.29 (t, *J* = 7.9 Hz, 1H), 7.36 (d, *J* = 7.6 Hz, 1H), 8.33 (br s, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 40.2, 41.9, 55.2, 72.2, 110.3, 114.0, 121.6, 122.4, 122.8, 123.5, 128.9, 130.0, 141.3, 159.5, 171.5; The *ee* value was 94%, t_R (minor) = 15.73 min, t_R (major) = 26.15 min (Chiralcel ID, λ = 254 nm, 15% *i*PrOH/hexanes, flow rate = 1.0 mL/min); HRMS (ESI) m/z calcd for $C_{17}H_{13}N_2O_4$ $[M-H]^-$ = 309.0881, found = 309.0872.

<Chromatogram>



1 Det.A Ch1/254nm

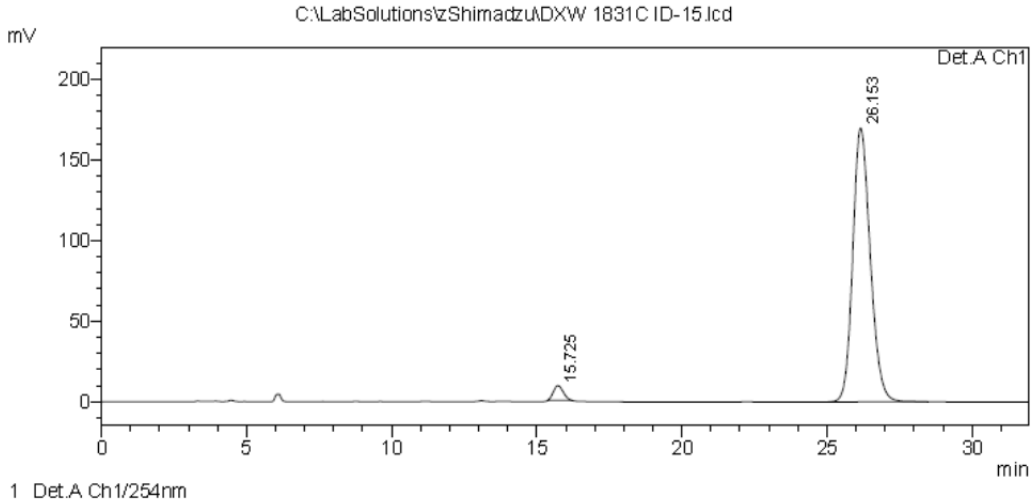
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.545	3793595	146768	50.121	61.436
2	25.810	3775282	92127	49.879	38.564
Total		7568876	238896	100.000	100.000

(racemic **10h**)

<Chromatogram>



1 Det.A Ch1/254nm

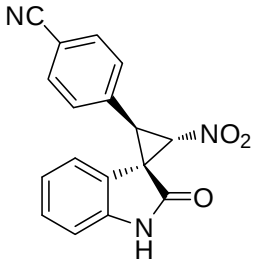
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.725	212860	9100	2.899	5.084
2	26.153	7128503	169905	97.101	94.916
Total		7341364	179006	100.000	100.000

(enantiomerically enriched **10h**)

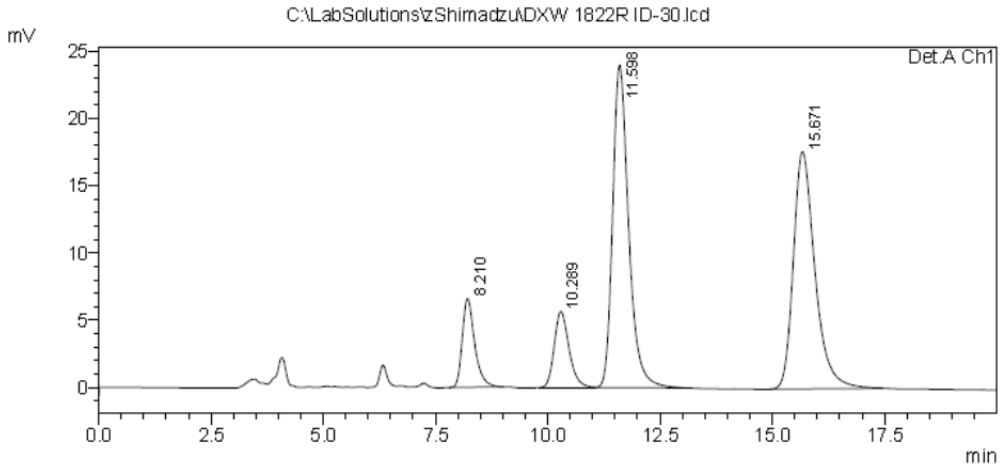
4-((1*R*,2*S*,3*R*)-2-Nitro-2'-oxospiro[cyclopropane-1,3'-indolin]-3-yl)benzonitrile **10i**



10i

A white solid; ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.35 (d, *J* = 7.0 Hz, 1H), 5.45 (d, *J* = 6.3 Hz, 1H), 6.92 (d, *J* = 7.6 Hz, 1H), 7.12 (t, *J* = 7.6 Hz, 1H), 7.33-7.37 (dd, *J* = 7.6 Hz & 14.5 Hz, 2H), 7.44 (d, *J* = 8.2 Hz, 2H), 7.63 (d, *J* = 8.2 Hz, 2H), 8.37 (br s, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 39.2, 41.7, 71.3, 110.6, 112.3, 118.3, 122.5, 122.6, 123.2, 129.6, 129.8, 132.2, 135.2, 141.4, 171.0; The *ee* value was 86%, t_R (minor) = 11.58 min, t_R (major) = 15.35 min (Chiralcel ID, λ = 254 nm, 30% *i*PrOH/hexanes, flow rate = 1.0 mL/min); HRMS (ESI) m/z calcd for $C_{17}H_{10}N_3O_3$ $[M-H]^-$ = 304.0728, found = 304.0717.

<Chromatogram>



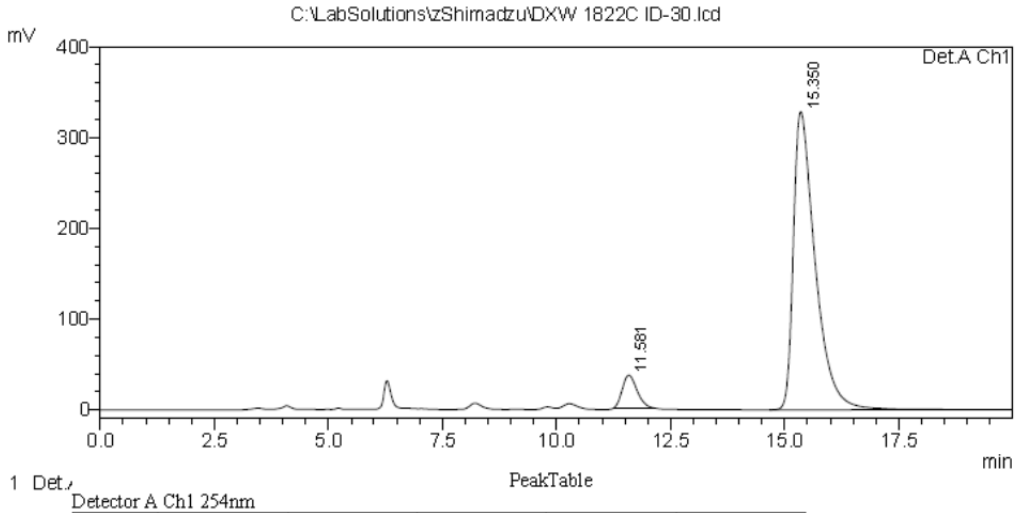
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	8.210	127204	6604	8.811	12.247
2	10.289	130518	5669	9.041	10.511
3	11.598	595092	24016	41.221	44.532
4	15.671	590865	17641	40.928	32.711
Total		1443680	53929	100.000	100.000

(racemic **10i**)

<Chromatogram>

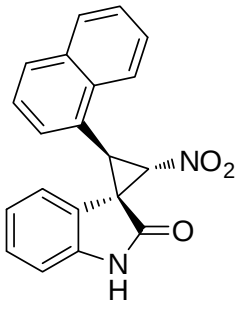


Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.581	814706	36390	6.924	9.976
2	15.350	10951418	328383	93.076	90.024
Total		11766124	364773	100.000	100.000

(enantiomerically enriched **10i**)

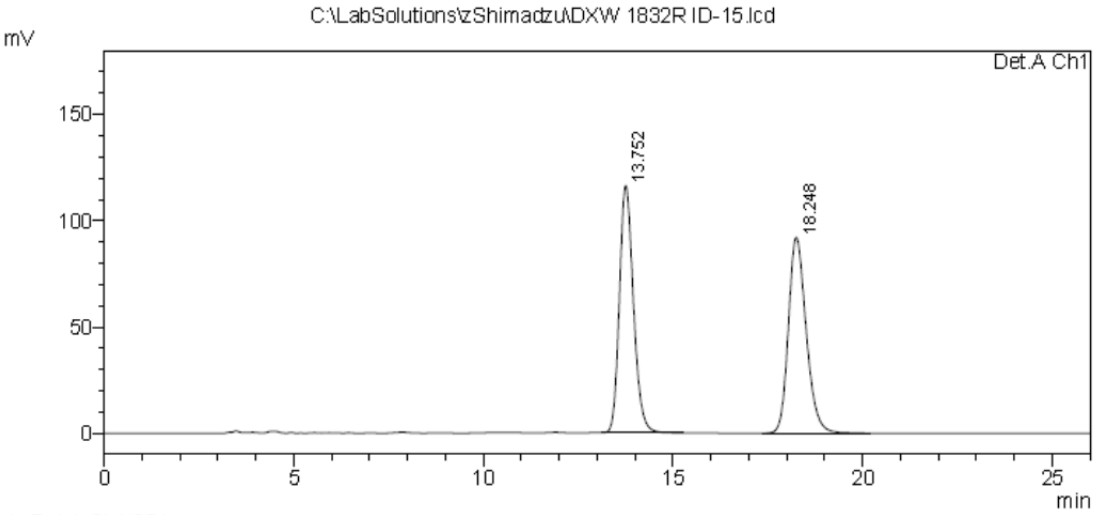
(1*R*,2*R*,3*S*)-2-(Naphthalen-1-yl)-3-nitrospiro[cyclopropane-1,3'-indolin]-2'-one **10j**



10j

A white solid; ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.60 (d, *J* = 7.0 Hz, 1H), 5.56 (d, *J* = 7.0 Hz, 1H), 6.77 (d, *J* = 7.6 Hz, 1H), 7.17 (t, *J* = 7.9 Hz, 1H), 7.30-7.54 (m, 7H), 7.81 (dd, *J* = 6.0 Hz & 7.2 Hz, 2H), 8.16 (br s, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 38.7, 41.7, 71.8, 110.5, 122.5, 122.6, 122.9, 123.1, 125.1, 126.0, 126.3, 126.8, 126.9, 129.0, 129.1, 129.2, 132.2, 133.6, 141.6, 171.1; The *ee* value was 99%, t_R (minor) = 13.78 min, t_R (major) = 18.15 min (Chiralcel ID, λ = 254 nm, 15% *i*PrOH/hexanes, flow rate = 1.0 mL/min); HRMS (ESI) m/z calcd for $C_{20}H_{13}N_2O_3$ $[M-H]^-$ = 329.0932, found = 329.0925.

<Chromatogram>



1 Det.A Ch1/254nm

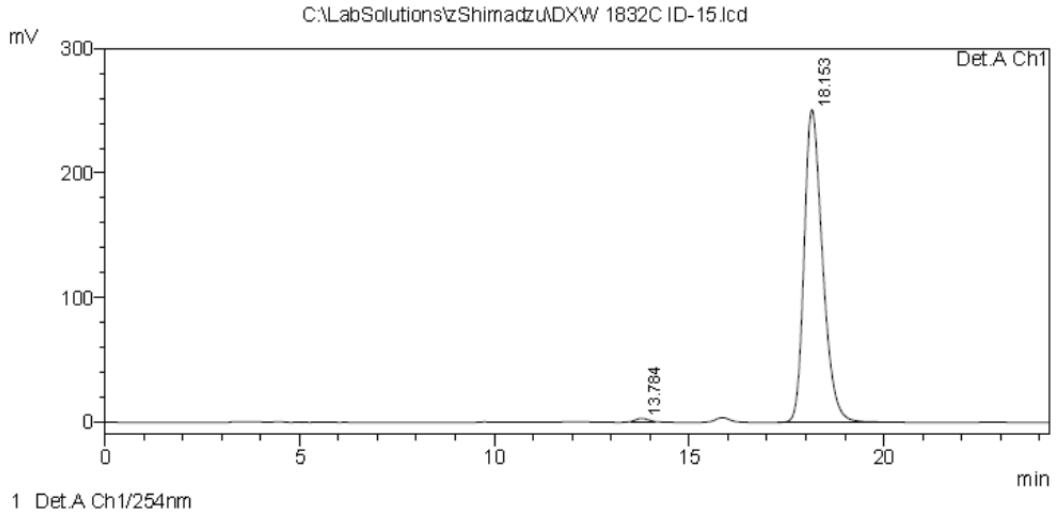
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	13.752	2996999	116357	49.856	55.811
2	18.248	3014322	92128	50.144	44.189
Total		6011321	208485	100.000	100.000

(racemic **10j**)

<Chromatogram>



1 Det.A Ch1/254nm

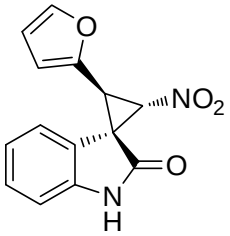
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	13.784	51538	2495	0.620	0.984
2	18.153	8262664	250960	99.380	99.016
Total		8314202	253454	100.000	100.000

(enantiomerically enriched **10j**)

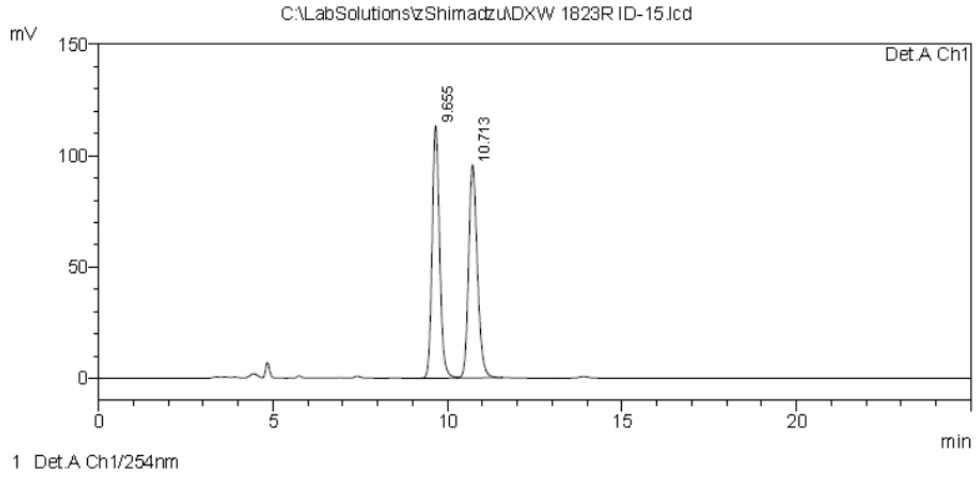
(1*R*,2*R*,3*S*)-2-(Furan-2-yl)-3-nitrospiro[cyclopropane-1,3'-indolin]-2'-one **10k**



10k

A light yellow solid; ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.21 (d, *J* = 6.3 Hz, 1H), 5.44 (d, *J* = 6.3 Hz, 1H), 6.38-6.39 (m, 1H), 6.43 (d, *J* = 8.2 Hz, 1H), 6.94 (d, *J* = 8.2 Hz, 1H), 7.08 (t, *J* = 7.6 Hz, 1H), 7.29-7.32 (m, 2H), 7.37 (s, 1H), 8.44 (br s, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 32.9, 40.9, 70.9, 110.1, 110.4, 110.9, 122.4, 122.6, 123.0, 129.2, 141.4, 142.9, 143.8, 171.0; The *ee* value was 95%, t_R (minor) = 10.73 min, t_R (major) = 9.64 min (Chiralcel ID, λ = 254 nm, 15% *i*PrOH/hexanes, flow rate = 1.0 mL/min); HRMS (ESI) m/z calcd for $C_{14}H_9N_2O_4$ $[M-H]^-$ =269.0568, found = 269.0563.

<Chromatogram>



1 Det.A Ch1/254nm

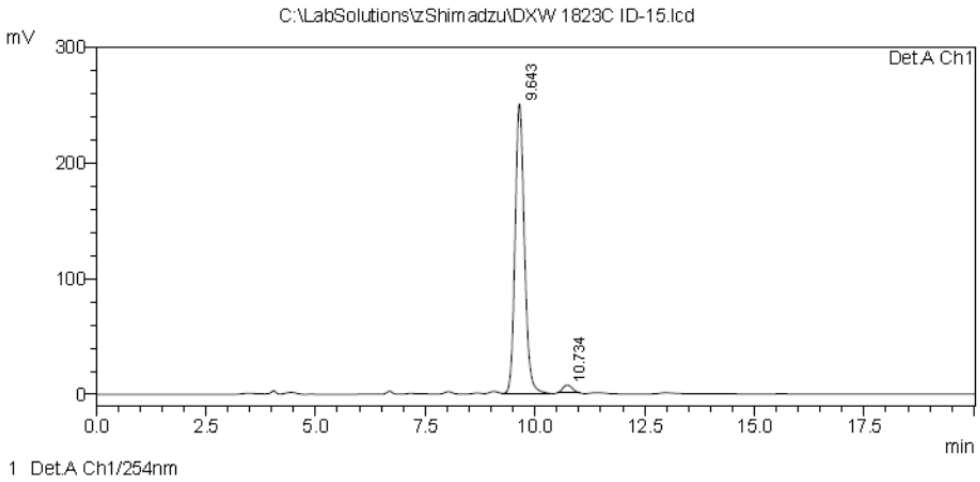
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	9.655	1686283	113369	50.189	54.239
2	10.713	1673581	95649	49.811	45.761
Total		3359864	209018	100.000	100.000

(racemic **10k**)

<Chromatogram>



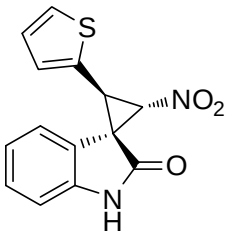
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	9.643	3693831	250146	97.364	97.379
2	10.734	99996	6732	2.636	2.621
Total		3793827	256878	100.000	100.000

(enantiomerically enriched **10k**)

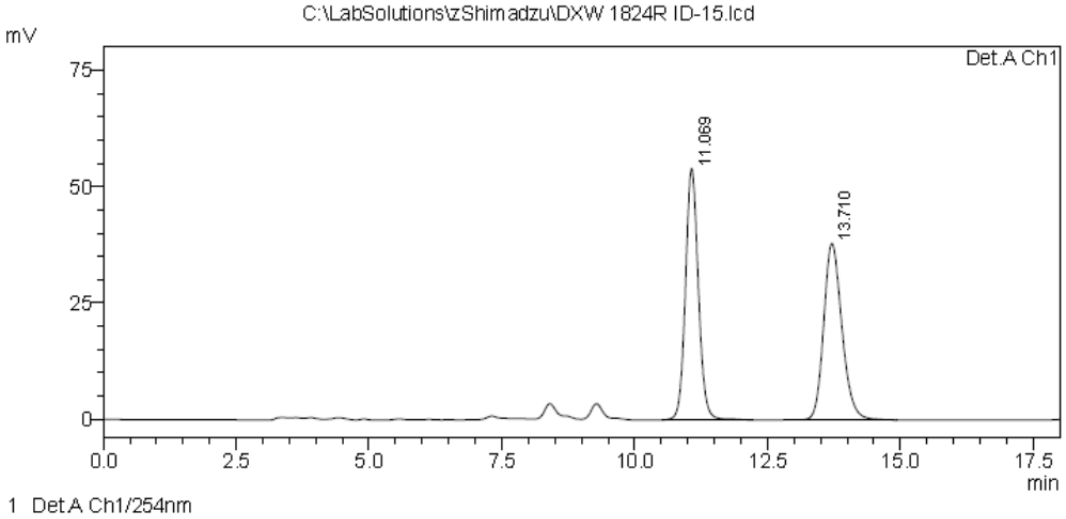
(1*R*,2*S*,3*R*)-2-Nitro-3-(thiophen-2-yl)spiro[cyclopropane-1,3'-indolin]-2'-one **10l**



10l

A yellow solid; ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.37 (d, *J* = 6.3 Hz, 1H), 5.45 (d, *J* = 6.3 Hz, 1H), 6.92 (d, *J* = 8.2 Hz, 1H), 6.99 (dd, *J* = 3.2 Hz & 5.1 Hz, 1H), 7.08-7.12 (m, 2H), 7.26 (d, *J* = 4.5 Hz, 1H), 7.30-7.35 (m, 2H), 8.34 (br s, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 35.5, 42.1, 72.7, 110.4, 122.5, 122.8, 123.0, 126.1, 127.0, 128.1, 129.2, 131.7, 141.4, 170.8; The *ee* value was 95%, t_R (minor) = 13.67 min, t_R (major) = 11.01 min (Chiralcel ID, λ = 254 nm, 15% *i*PrOH/hexanes, flow rate = 1.0 mL/min); HRMS (ESI) m/z calcd for $C_{14}H_9N_2O_3S$ $[M-H]^-$ =285.0339, found = 285.0327.

<Chromatogram>



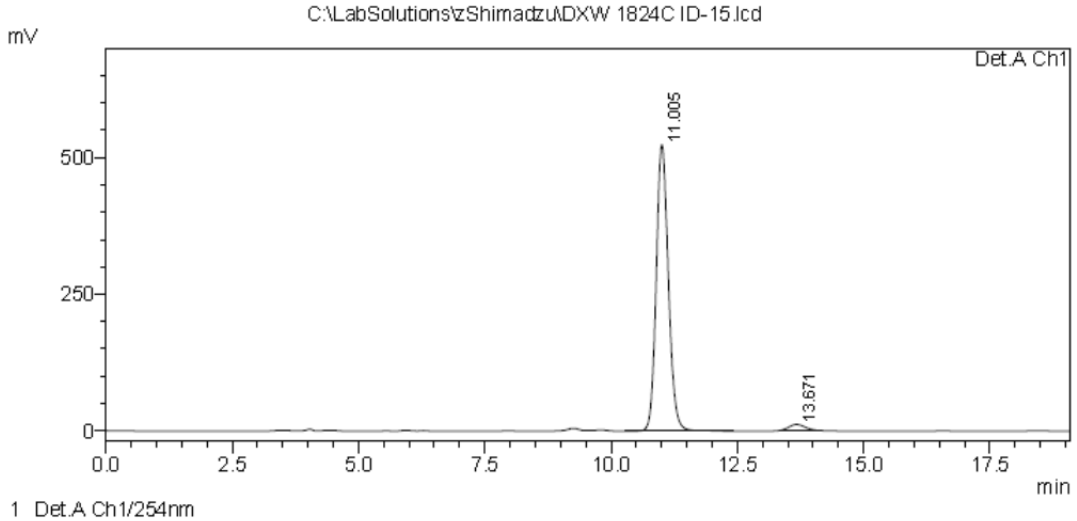
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.069	913876	54029	50.243	58.780
2	13.710	905049	37888	49.757	41.220
Total		1818926	91917	100.000	100.000

(racemic **10l**)

<Chromatogram>



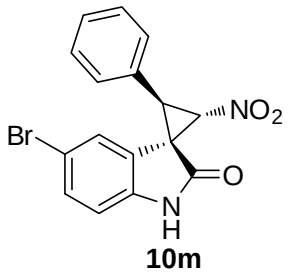
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.005	8774491	524037	97.749	98.101
2	13.671	202048	10143	2.251	1.899
Total		8976540	534179	100.000	100.000

(enantiomerically enriched **10l**)

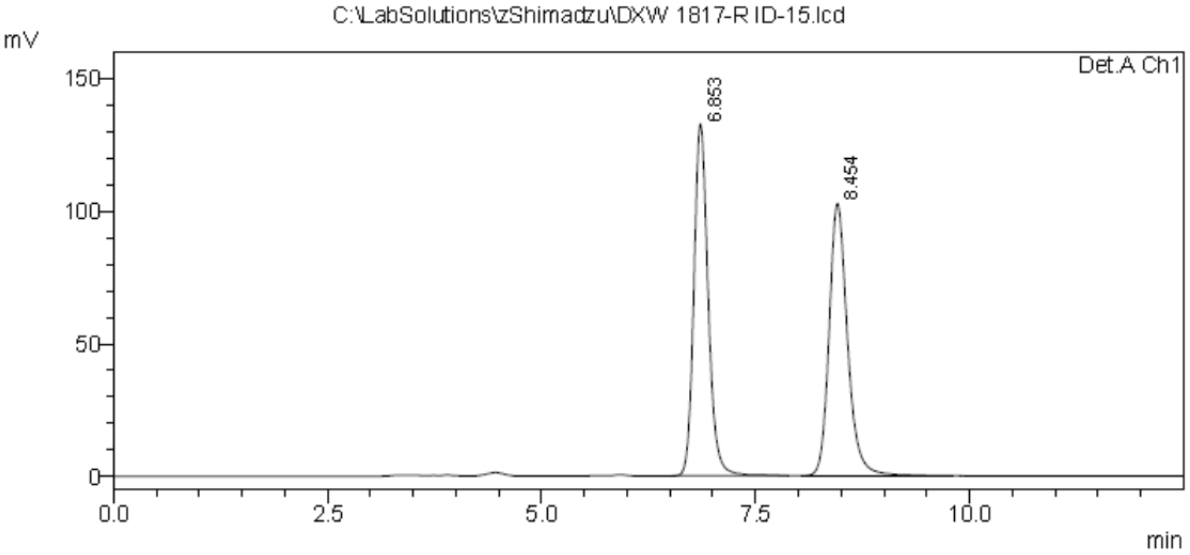
(1*R*,2*S*,3*R*)-5'-Bromo-2-nitro-3-phenylspiro[cyclopropane-1,3'-indolin]-2'-one **10m**



10m

A white solid; ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.33 (d, *J* = 7.0 Hz, 1H), 5.46 (d, *J* = 7.0 Hz, 1H), 6.70 (d, *J* = 8.2 Hz, 1H), 7.27-7.34 (m, 5H), 7.41-7.43 (m, 1H), 7.51 (s, 1H), 8.83 (br s, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 40.8, 41.6, 71.9, 111.9, 115.6, 125.3, 125.8, 128.5, 128.6, 128.8, 129.3, 131.9, 140.4, 171.2; The *ee* value was 97%, t_R (minor) = 6.86 min, t_R (major) = 8.44 min (Chiralcel ID, λ = 254 nm, 15% *i*PrOH/hexanes, flow rate = 1.0 mL/min); HRMS (ESI) m/z calcd for $C_{16}H_{10}N_2O_3{}^{79}Br$ $[M-H]^-$ = 356.9880, found = 356.9869.

<Chromatogram>



1 Det.A Ch1/254nm

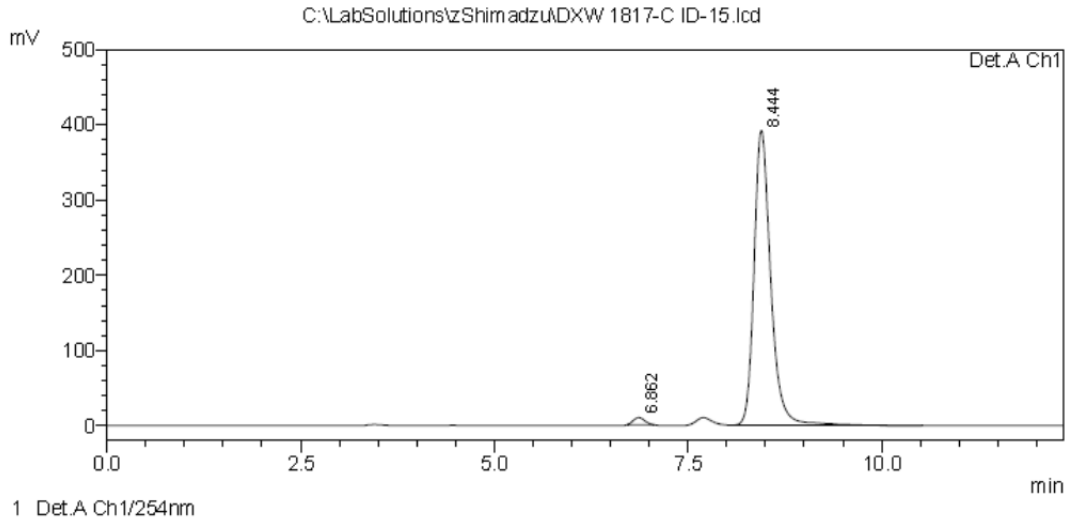
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	6.853	1545788	132909	50.201	56.411
2	8.454	1533404	102697	49.799	43.589
Total		3079192	235606	100.000	100.000

(racemic **10m**)

<Chromatogram>



1 Det.A Ch1/254nm

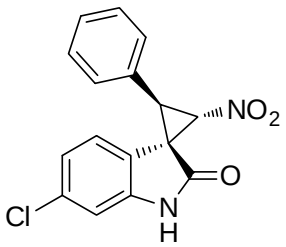
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	6.862	93812	9375	1.567	2.337
2	8.444	5894536	391831	98.433	97.663
Total		5988349	401207	100.000	100.000

(enantiomerically enriched **10m**)

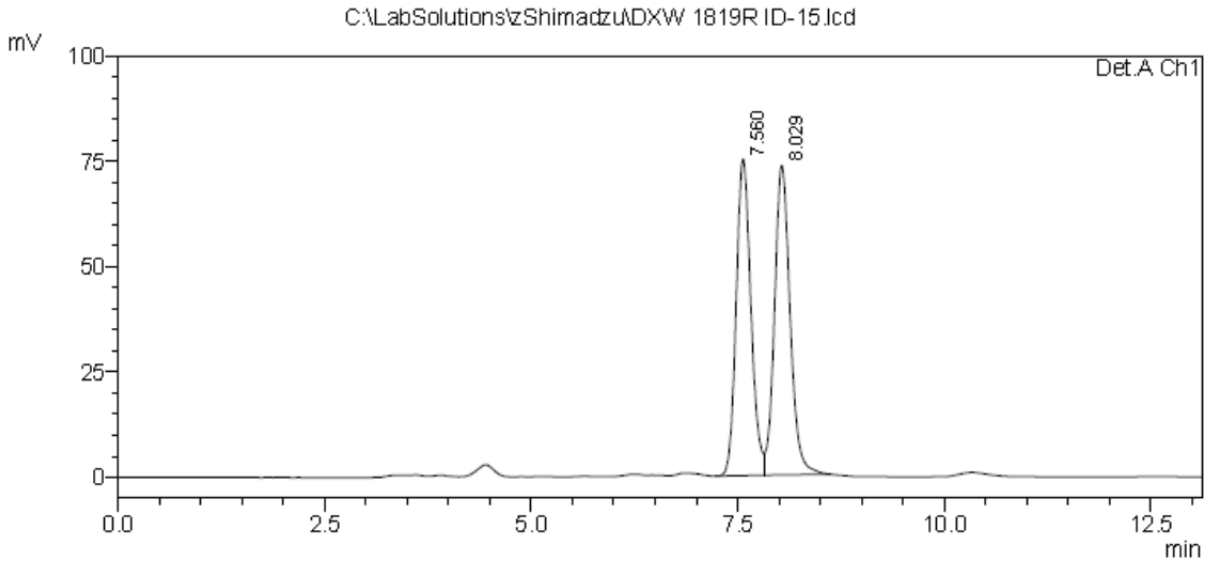
(1*R*,2*S*,3*R*)-6'-Chloro-2-nitro-3-phenylspiro[cyclopropane-1,3'-indolin]-2'-one **10n**



10n

A white solid; ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.33 (d, *J* = 6.3 Hz, 1H), 5.45 (d, *J* = 7.0 Hz, 1H), 6.83 (d, *J* = 7.6 Hz, 1H), 7.08 (dd, *J* = 1.9 Hz & 8.2 Hz, 1H), 7.27-7.37 (m, 6H), 8.69-8.83 (br, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 40.5, 41.5, 71.9, 111.2, 121.7, 123.0, 123.6, 128.6, 128.7, 128.8, 129.4, 135.0, 142.5, 171.6; The *ee* value was 98%, t_R (minor) = 7.58 min, t_R (major) = 8.02 min (Chiralcel ID, λ = 254 nm, 15% *i*PrOH/hexanes, flow rate = 1.0 mL/min); HRMS (ESI) m/z calcd for $C_{16}H_{10}N_2O_3Cl$ $[M-H]^-$ = 313.0385, found = 313.0374.

<Chromatogram>



1 Det.A Ch1/254nm

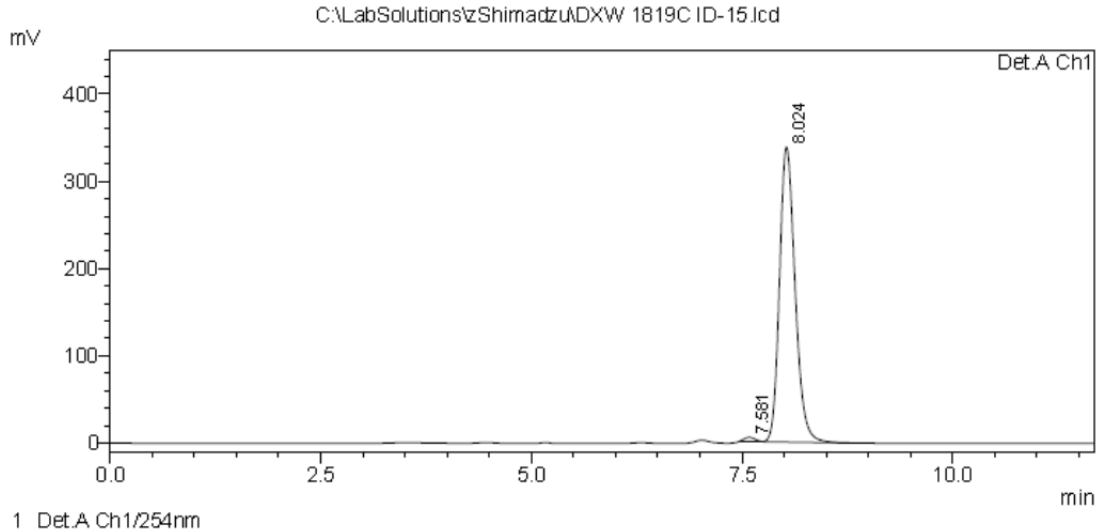
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	7.560	931147	75165	49.237	50.580
2	8.029	960024	73440	50.763	49.420
Total		1891171	148605	100.000	100.000

(racemic **10n**)

<Chromatogram>



1 Det.A Ch1/254nm

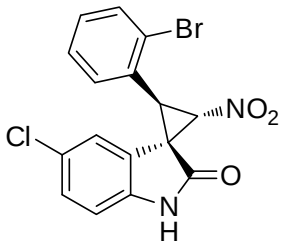
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	7.581	43462	4730	0.994	1.381
2	8.024	4330789	337845	99.006	98.619
Total		4374251	342575	100.000	100.000

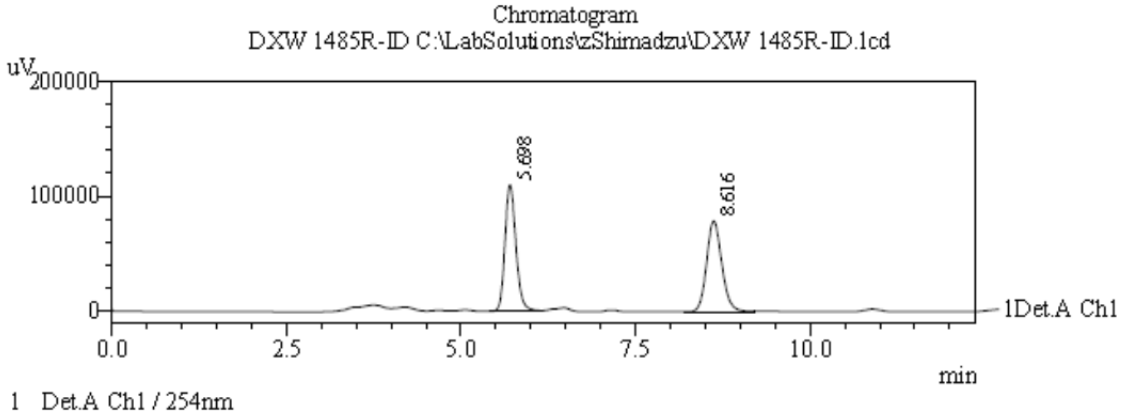
(enantiomerically enriched **10n**)

(1*R*,2*S*,3*S*)-2-(2-Bromophenyl)-5'-chloro-3-nitrospiro[cyclopropane-1,3'-indolin]-2'-one **10o**



10o

A white solid; ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.23 (d, *J* = 5.3 Hz, 1H), 5.38 (d, *J* = 6.3 Hz, 1H), 6.77 (d, *J* = 8.9 Hz, 1H), 7.20-7.24 (m, 1H), 7.29 (dd, *J* = 2.2 Hz & 8.5 Hz, 1H), 7.34-7.41 (m, 3H), 7.53 (d, *J* = 7.6 Hz, 1H), 8.37 (br s, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 41.0, 41.8, 72.0, 111.2, 123.3, 124.7, 125.1, 127.5, 128.5, 129.1, 129.9, 130.1, 130.6, 132.8, 140.1, 171.0; The *ee* value was 99%, t_R (minor) = 5.65 min, t_R (major) = 8.47 min (Chiralcel ID, λ = 254 nm, 20% *i*PrOH/hexanes, flow rate = 1.0 mL/min); HRMS (ESI) m/z calcd for $C_{16}H_9Cl^{79}BrN_2O_3$ $[M-H]^-$ = 390.9647, found = 390.9639, calcd for $C_{16}H_9Cl^{81}BrN_2O_3$ $[M-H]^-$ = 392.9627, found = 392.9613.



1 Det.A Ch1 / 254nm

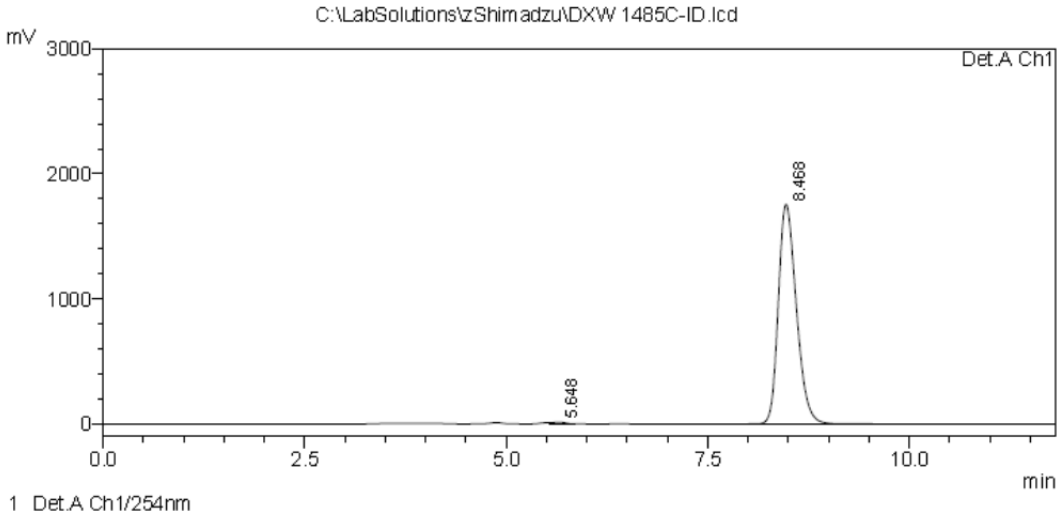
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	5.698	1206167	110141	50.136	58.262
2	8.616	1199611	78902	49.864	41.738
Total		2405778	189043	100.000	100.000

(racemic **10o**)

<Chromatogram>



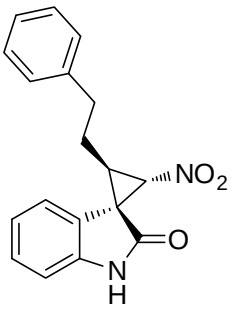
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	5.648	149055	14234	0.540	0.804
2	8.468	27473240	1756128	99.460	99.196
Total		27622294	1770361	100.000	100.000

(enantiomerically enriched **10o**)

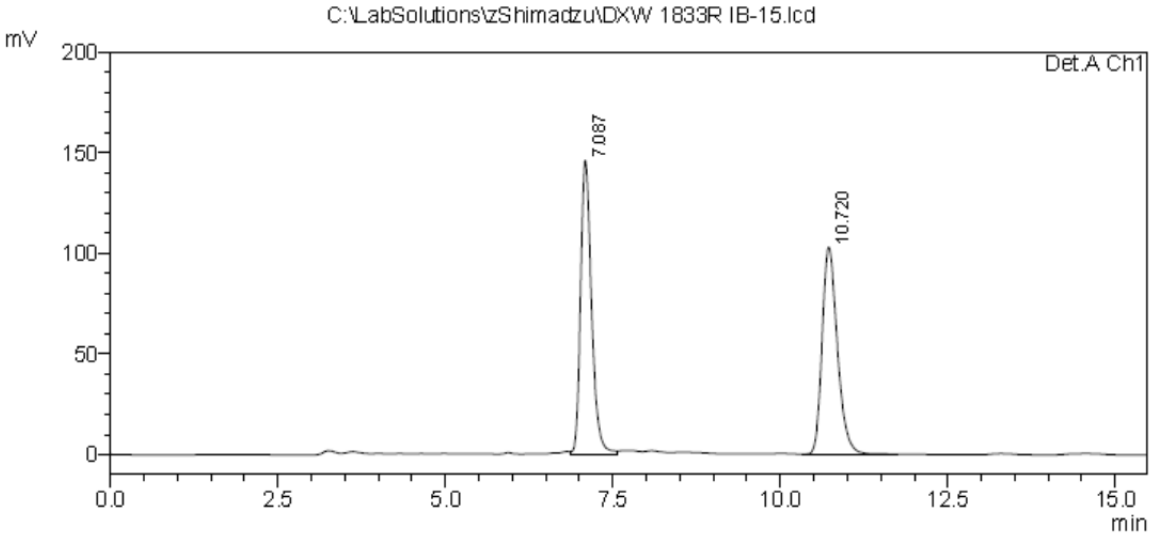
(1*R*,2*S*,3*R*)-2-Nitro-3-phenethylspiro[cyclopropane-1,3'-indolin]-2'-one**10p**



10p

A colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 2.25-2.40 (m, 2H), 2.68-2.77 (m, 2H), 2.96-3.00 (m, 1H), 4.78 (d, *J* = 6.3 Hz, 1H), 6.89 (d, *J* = 7.6 Hz, 1H), 7.03-7.06 (m, 3H), 7.13-7.16 (m, 3H), 7.19 (d, *J* = 7.6 Hz, 1H), 7.25-7.28 (m, 2H), 8.15 (br s, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 24.6, 34.8, 36.2, 39.9, 73.1, 110.0, 122.4, 122.8, 123.7, 126.2, 128.4, 128.6, 128.7, 139.8, 141.0, 172.7; The *ee* value was 95%, t_R (minor) = 10.74 min, t_R (major) = 7.08 min (Chiralcel IB, λ = 254 nm, 15% *i*PrOH/hexanes, flow rate = 1.0 mL/min); HRMS (ESI) m/z calcd for $C_{18}H_{15}N_2O_3$ $[M-H]^-$ = 307.1088, found = 307.1081.

<Chromatogram>



1 Det.A Ch1/254nm

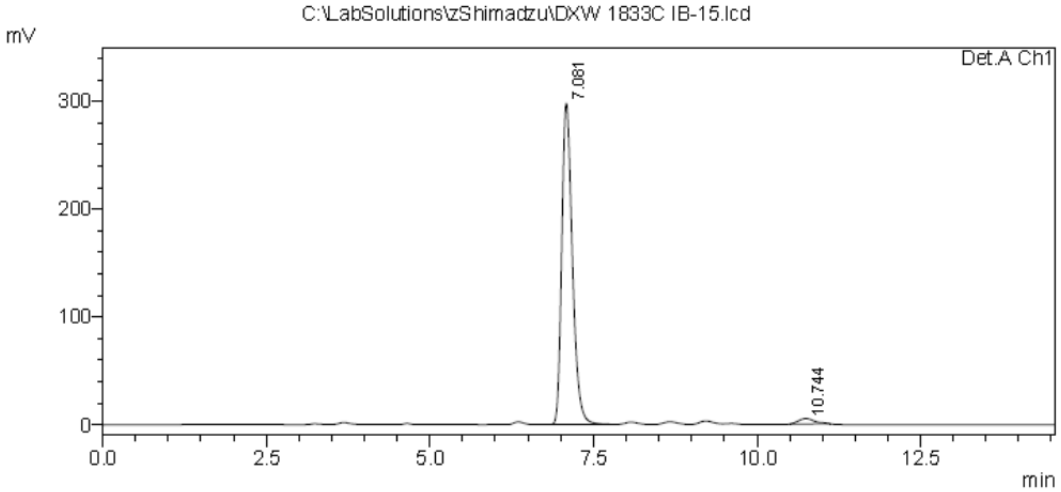
PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	7.087	1661121	146088	50.463	58.677
2	10.720	1630618	102881	49.537	41.323
Total		3291739	248970	100.000	100.000

(racemic **10p**)

<Chromatogram>



1 Det.A Ch1/254nm

PeakTable

Detector A Ch1 254nm

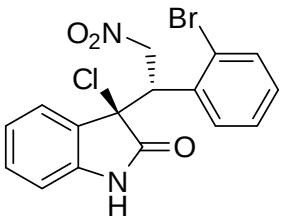
Peak#	Ret. Time	Area	Height	Area %	Height %
1	7.081	3386565	298030	97.588	98.357
2	10.744	83690	4980	2.412	1.643
Total		3470255	303010	100.000	100.000

(enantiomerically enriched **10p**)

D. X-Ray Crystallographic Analysis and Determination of the Absolute Configurations of the Products

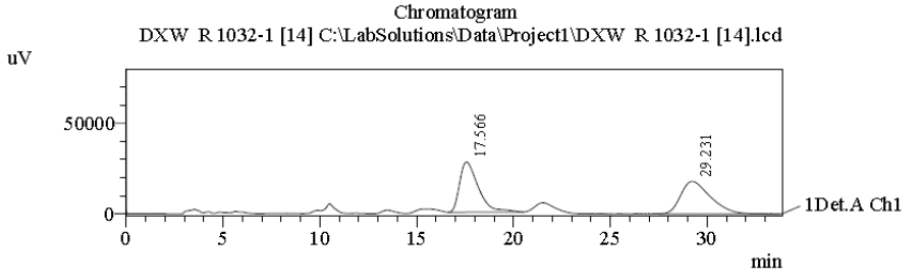
X-Ray Crystallographic Analysis of **3b**

(*R*)-3-((*S*)-1-(2-Bromophenyl)-2-nitroethyl)-3-chloroindolin-2-one **3b**



3b

A white solid; ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.88 (dd, *J* = 3.2 Hz & 10.7 Hz, 1H), 5.15 (dd, *J* = 5.7 Hz & 14.5 Hz, 1H), 5.87 (dd, *J* = 3.8 Hz & 13.9 Hz, 1H), 6.06 (d, *J* = 7.6 Hz, 1H), 6.83 (t, *J* = 7.6 Hz, 1H), 6.92 (d, *J* = 8.2 Hz, 1H), 7.22-7.30 (m, 2H), 7.40 (t, *J* = 7.6 Hz, 1H), 7.50 (d, *J* = 8.2 Hz, 1H), 7.66 (d, *J* = 7.6 Hz, 1H), 8.64 (br s, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 46.3, 65.8, 74.7, 110.6, 123.3, 126.1, 127.4, 127.7, 128.4, 128.7, 130.4, 130.9, 133.2, 133.3, 139.4, 174.6; The *ee* value was 96%, t_R (minor) = 18.54 min, t_R (major) = 30.18 min (Chiralcel OD-H, λ = 220 nm, 14% *i*PrOH/hexanes, flow rate = 1.0 mL/min); HRMS (ESI) m/z calcd for $C_{16}H_{11}{}^{79}BrClN_2O_3$ $[M-H]^-$ = 392.9647, found = 392.9639; HRMS (ESI) m/z calcd for $C_{16}H_{11}{}^{81}BrClN_2O_3$ $[M-H]^-$ = 394.9627, found = 394.9613.



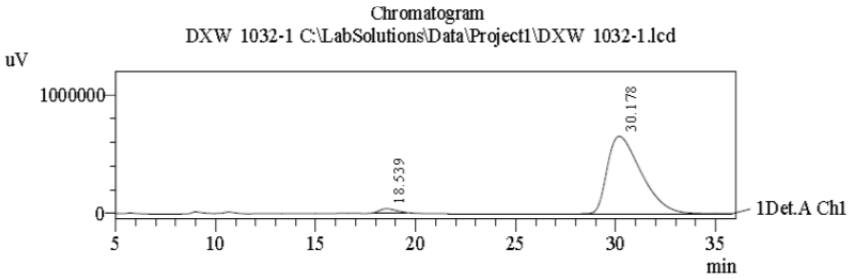
1 Det.A Ch1 / 254nm

PeakTable

Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	17.566	1860852	27740	49.319	60.756
2	29.231	1912253	17918	50.681	39.244
Total		3773105	45658	100.000	100.000

(racemic **3b**)



1 Det.A Ch1 / 220nm

PeakTable

Detector A Ch1 220nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	18.539	1713699	32578	2.173	4.741
2	30.178	77157441	654636	97.827	95.259
Total		78871141	687214	100.000	100.000

(enantiomerically enriched **3b**)

The absolute configuration of the product **3b** was assigned based on the X-ray crystallographic analysis of a single crystal of **3b** (Figure 1). The configurations of other Michael addition products were assigned by analogy.

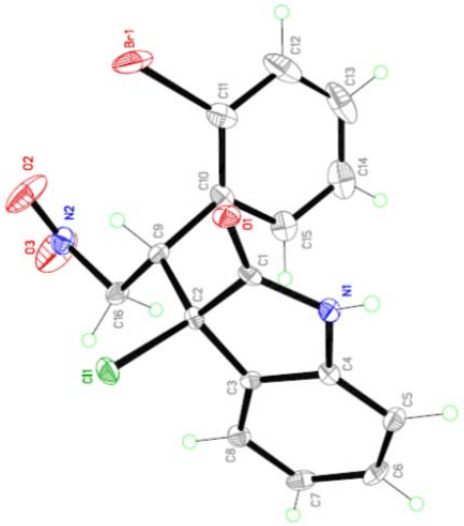


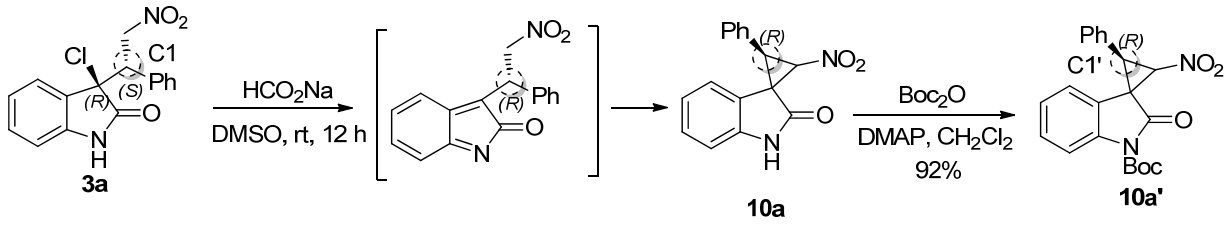
Figure 1. X-ray structure of **3b**

Table 1. Crystal data and structure refinement for C321.

Identification code	c321	
Empirical formula	C16 H12 Br Cl N2 O3	
Formula weight	395.64	
Temperature	100(2) K	
Wavelength	0.71073 Å	
Crystal system	Orthorhombic	
Space group	P2(1)2(1)2(1)	
Unit cell dimensions	a = 8.3011(7) Å	α= 90°.
	b = 14.7678(12) Å	β= 90°.
	c = 25.328(2) Å	γ = 90°.

Volume	3104.9(4) Å^3
Z	8
Density (calculated)	1.693 Mg/m^3
Absorption coefficient	2.836 mm^{-1}
F(000)	1584
Crystal size	0.52 x 0.51 x 0.28 mm^3
Theta range for data collection	1.60 to 27.50°.
Index ranges	-10<=h<=10, -19<=k<=16, -31<=l<=32
Reflections collected	22091
Independent reflections	7096 [R(int) = 0.0409]
Completeness to theta = 27.50°	99.9 %
Absorption correction	Semi-empirical from equivalents
Max. and min. transmission	0.5040 and 0.3202
Refinement method	Full-matrix least-squares on F^2
Data / restraints / parameters	7096 / 0 / 423
Goodness-of-fit on F^2	0.976
Final R indices [I>2sigma(I)]	R1 = 0.0303, wR2 = 0.0607
R indices (all data)	R1 = 0.0356, wR2 = 0.0619
Absolute structure parameter	0.002(5)
Largest diff. peak and hole	0.724 and -0.493 e.Å^{-3}

Absolute Configuration Assignment of Spirooxindole Product **10a**

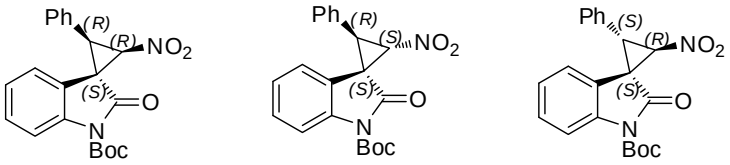


(**Scheme 1**)

To determine the absolute configuration of **10a**, **10a** was transformed to compound **10a'** which was reported in literature.[2, 3] To a stirred solution of **10a** (0.05 mmol, 14.0 mg) in CH_2Cl_2 (1.0 mL) in a sample vial at room temperature were added Boc_2O (13.1 mg, 1.2 equiv.) and DMAP (1.2 mg, 20 mol %), and the resulting mixture was stirred at room temperature for 15 min. The solution was concentrated, and the residue was purified by column chromatography (hexane/ethyl acetate = 7:1) to afford the 3-spirocyclopropyl-2-oxindole **10a'** as a colorless oil (17.5 mg, 92% yield).

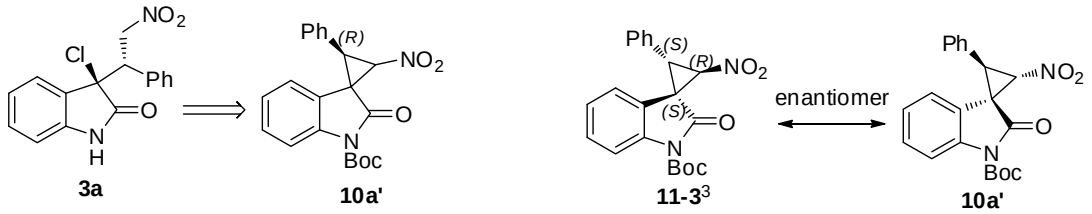
A colorless oil; ^{1}H NMR (500 MHz, $CDCl_3$) δ 1.59 (s, 9H), 4.33 (d, *J* = 6.9 Hz, 1H), 5.49 (d, *J* = 6.9 Hz, 1H), 7.21-7.24 (m, 1H), 7.30-7.42 (m, 7H), 7.93 (d, *J* = 8.2 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 28.0, 41.3, 41.9, 72.8, 85.1, 115.3, 121.6,

122.0, 124.8, 128.5, 128.6, 128.9, 129.1, 129.3, 140.5, 148.5, 167.8; MS (ESI) m/z calcd for $C_{21}H_{20}N_2O_5Na$ $[M+Na]^+$ = 403.1, found = 403.1.



11-1[2] **11-2**[2] **11-3**[3]

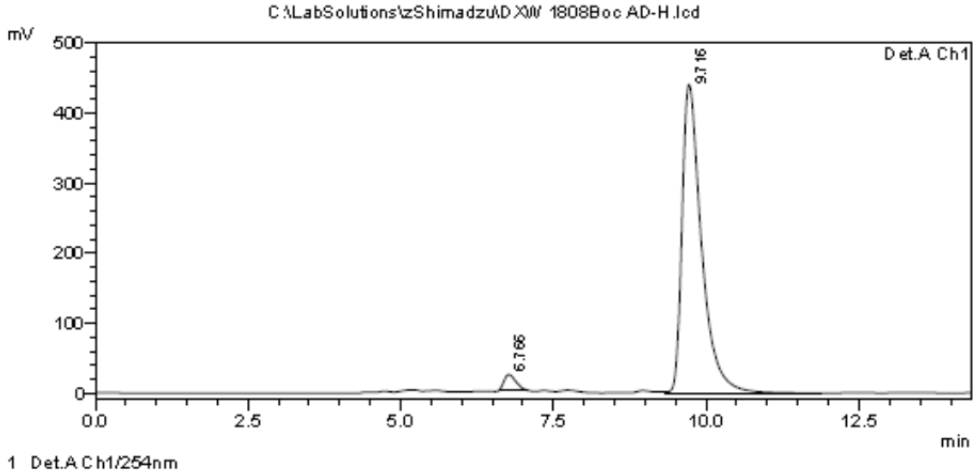
^{1}H NMR spectrum of **10a'** was identical to that of **11-3**, but different from those of **11-1** and **11-2**, proving that **10a'** was **11-3** or its enantiomer. As shown in the Scheme 1, the chiral center at C1 of **3a** did not change during the cyclopropanation step, thus the chiral center at C1' of **10a'** should remain as *R*, **10a'** was assigned as the enantiomer of **11-3**.



3a **10a'** **11-3**[3] **10a'**

HPLC analysis also supported that **10a'** is the enantiomer of **11-3**. Following the reported HPLC conditions (ref 3. Daicel Chiralpak AD-H column, 90/10 hexane/*i*-PrOH, flow rate 0.750 mL/min, λ = 254 nm: t_{major} = 6.88 min, t_{minor} = 11.22 min) , the opposite peaks were observed.

<Chromatogram>



1 Det.A Ch1/254nm

Peak Table

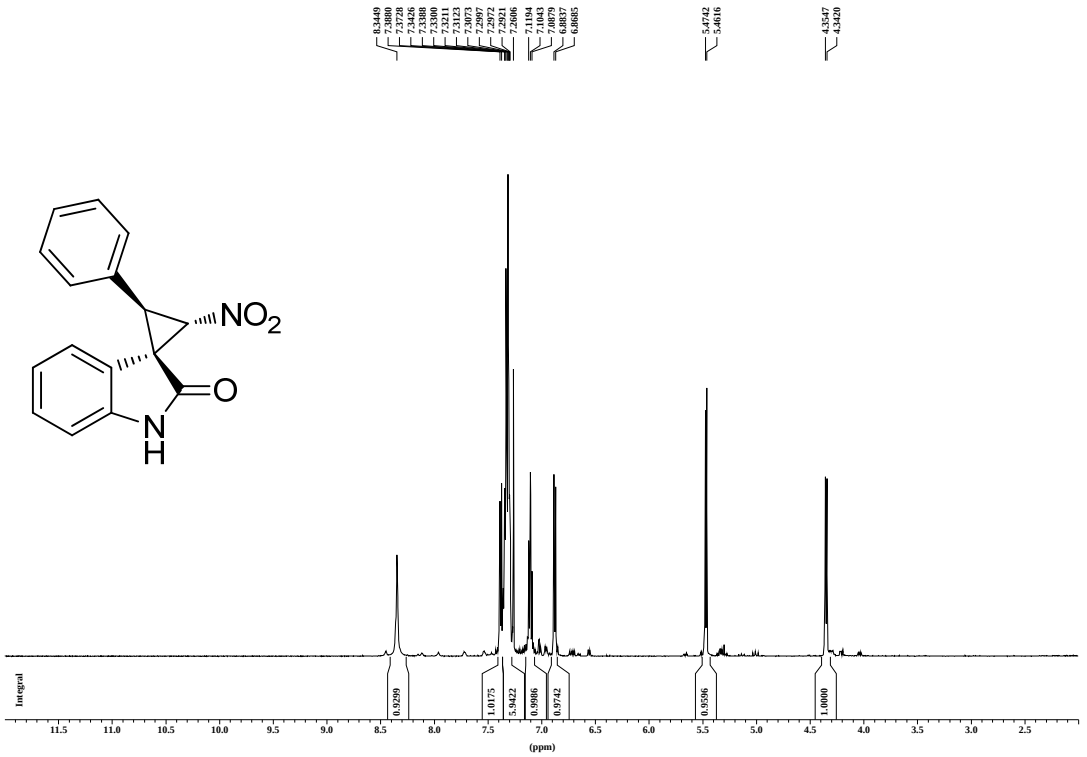
Detector A Ch1 254nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	6.766	292443	22194	2.892	4.788
2	9.716	9818386	441336	97.108	95.212
Total		10110829	463530	100.000	100.000

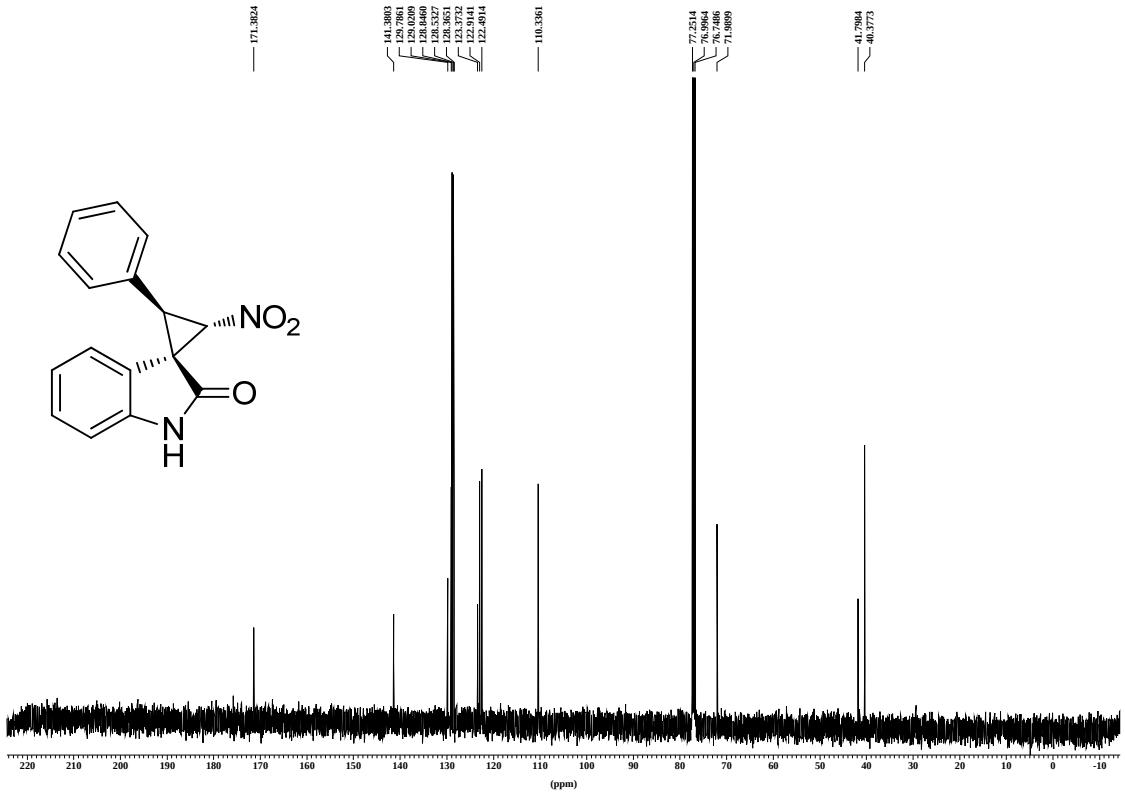
(enantiomerically enriched **10a'**)

E. NMR Spectra of the Catalysts and Products

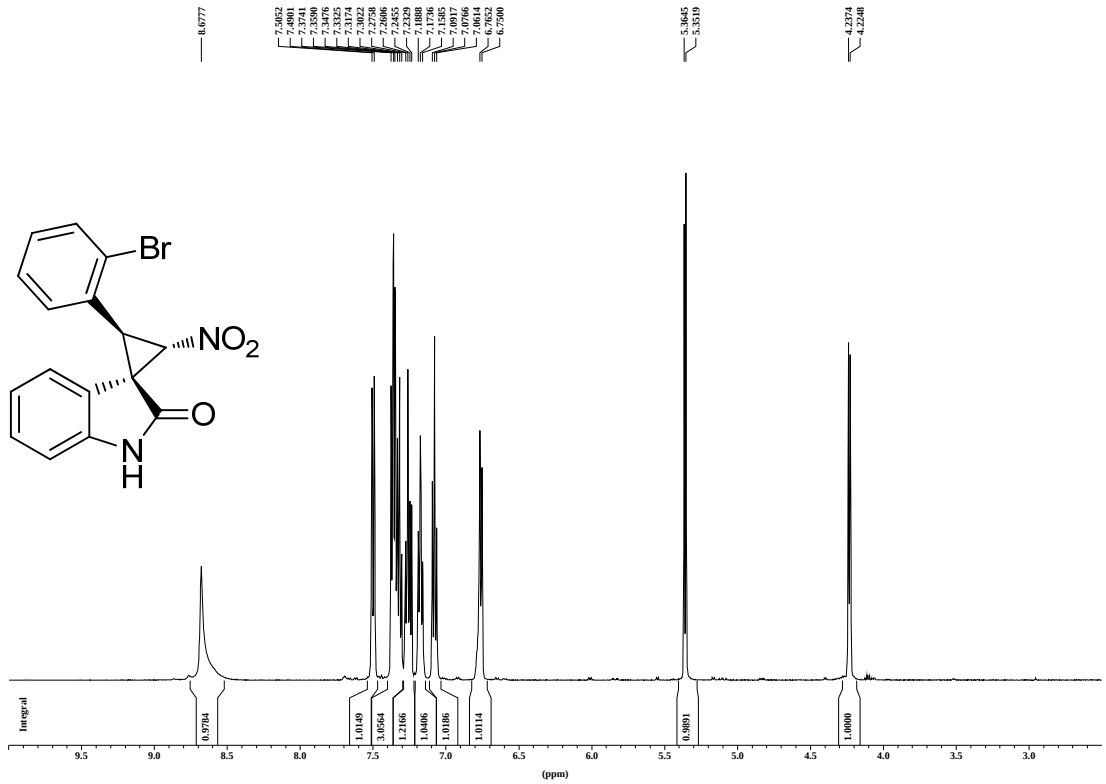
1H AMX500 dxw0501-3 1808H



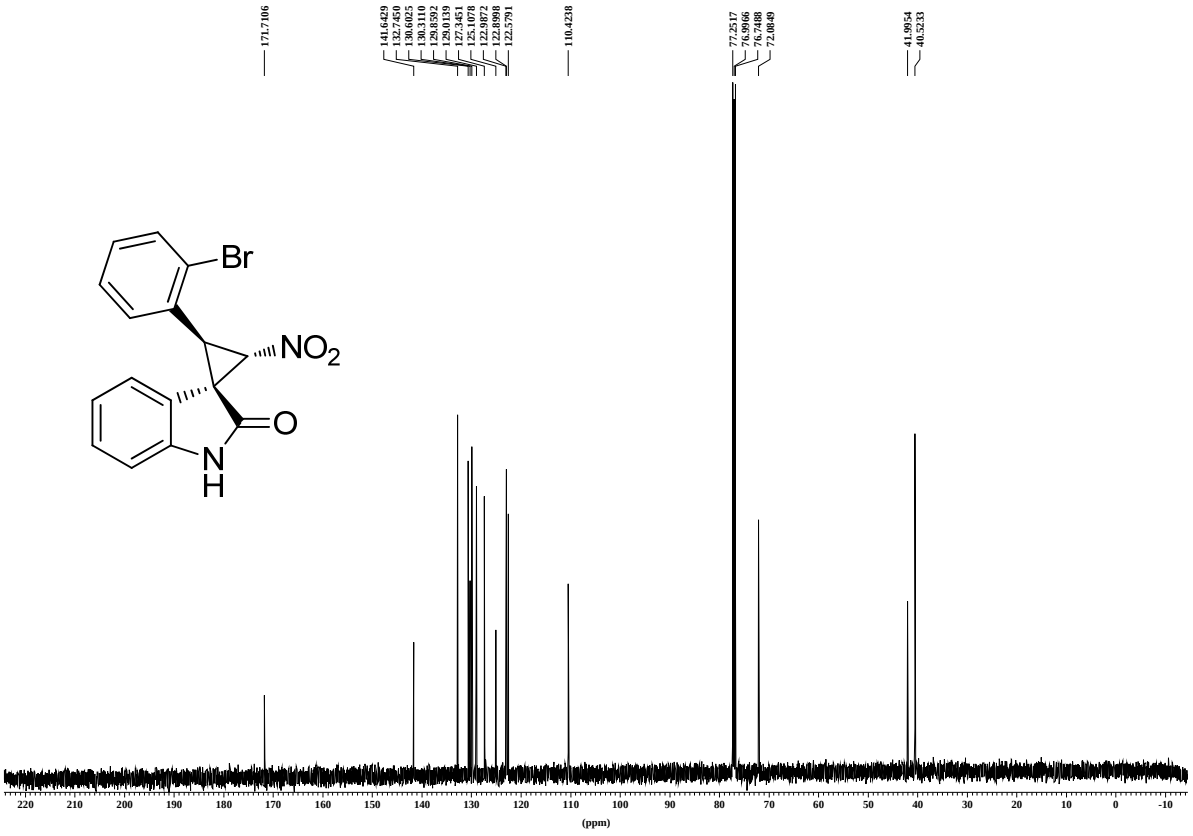
13C AMX500 dxw0501-4 1808C



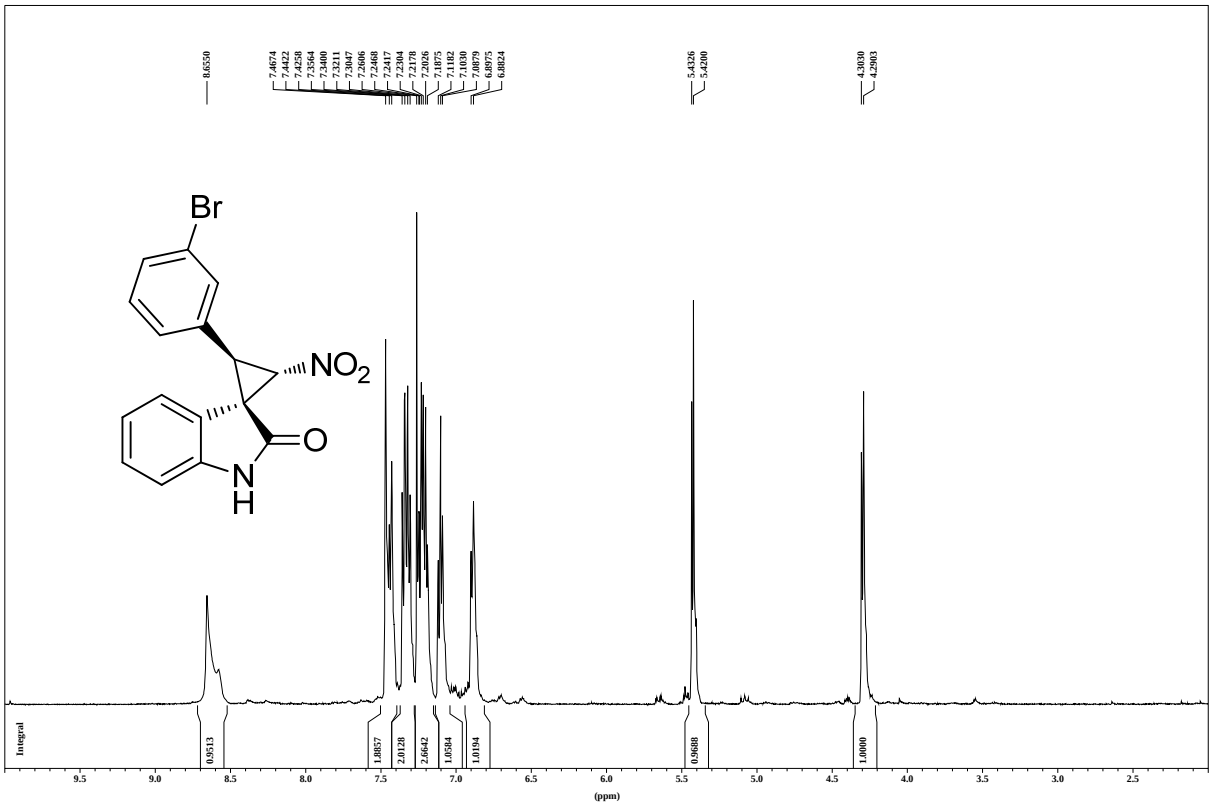
1H AMX500 dxw0328-5 1821H



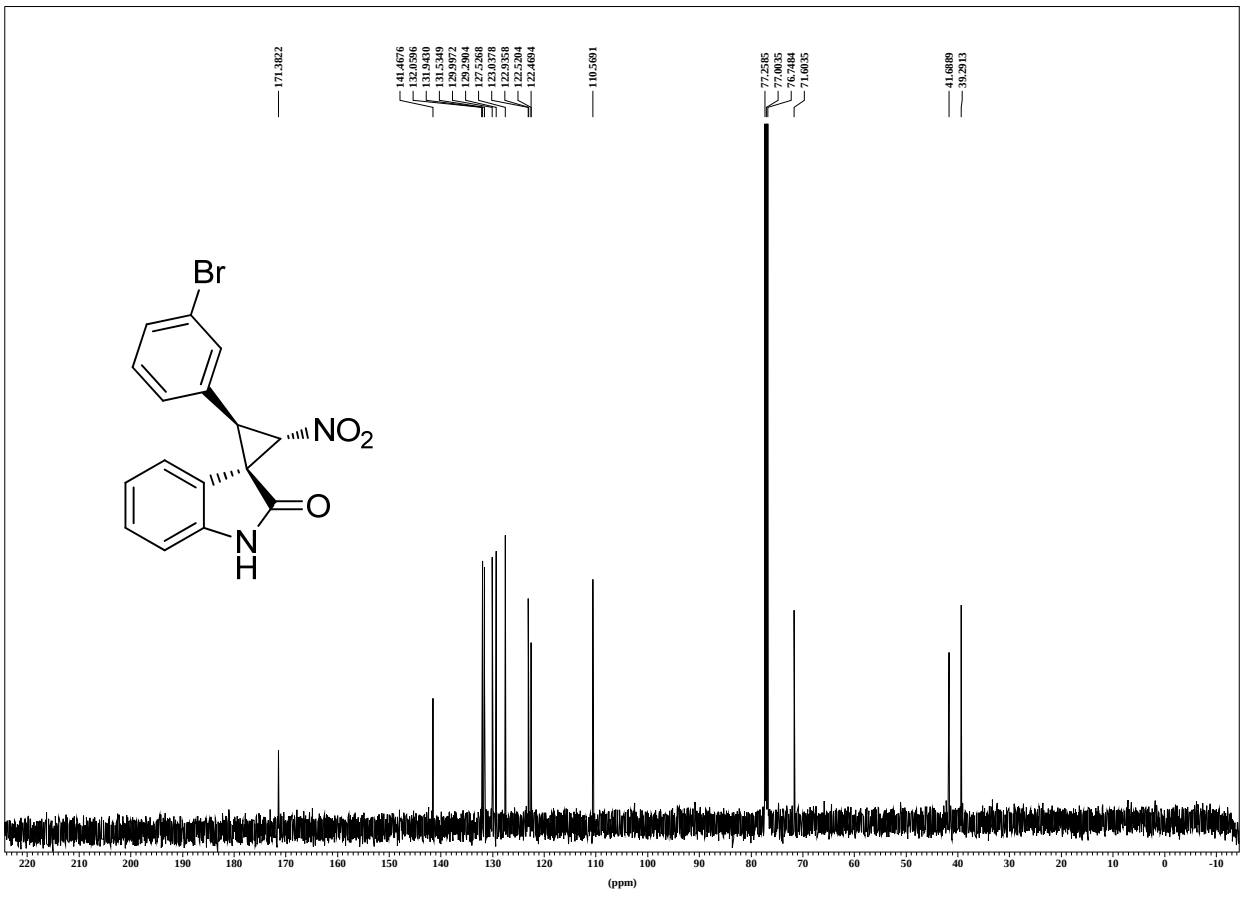
13C AMX500 dxw0328-6 1821C



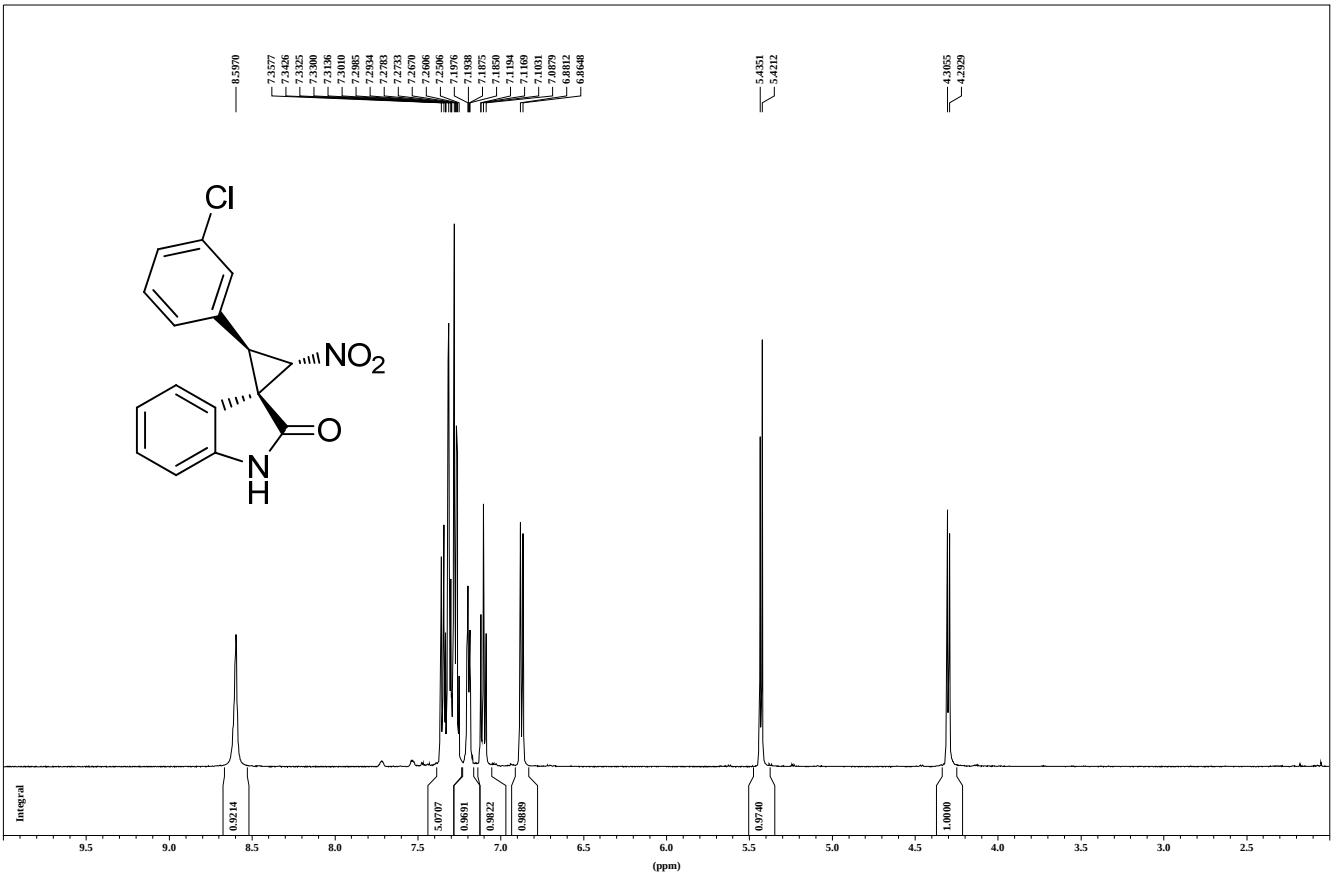
1H AMX500 dxw0403-1 1825H



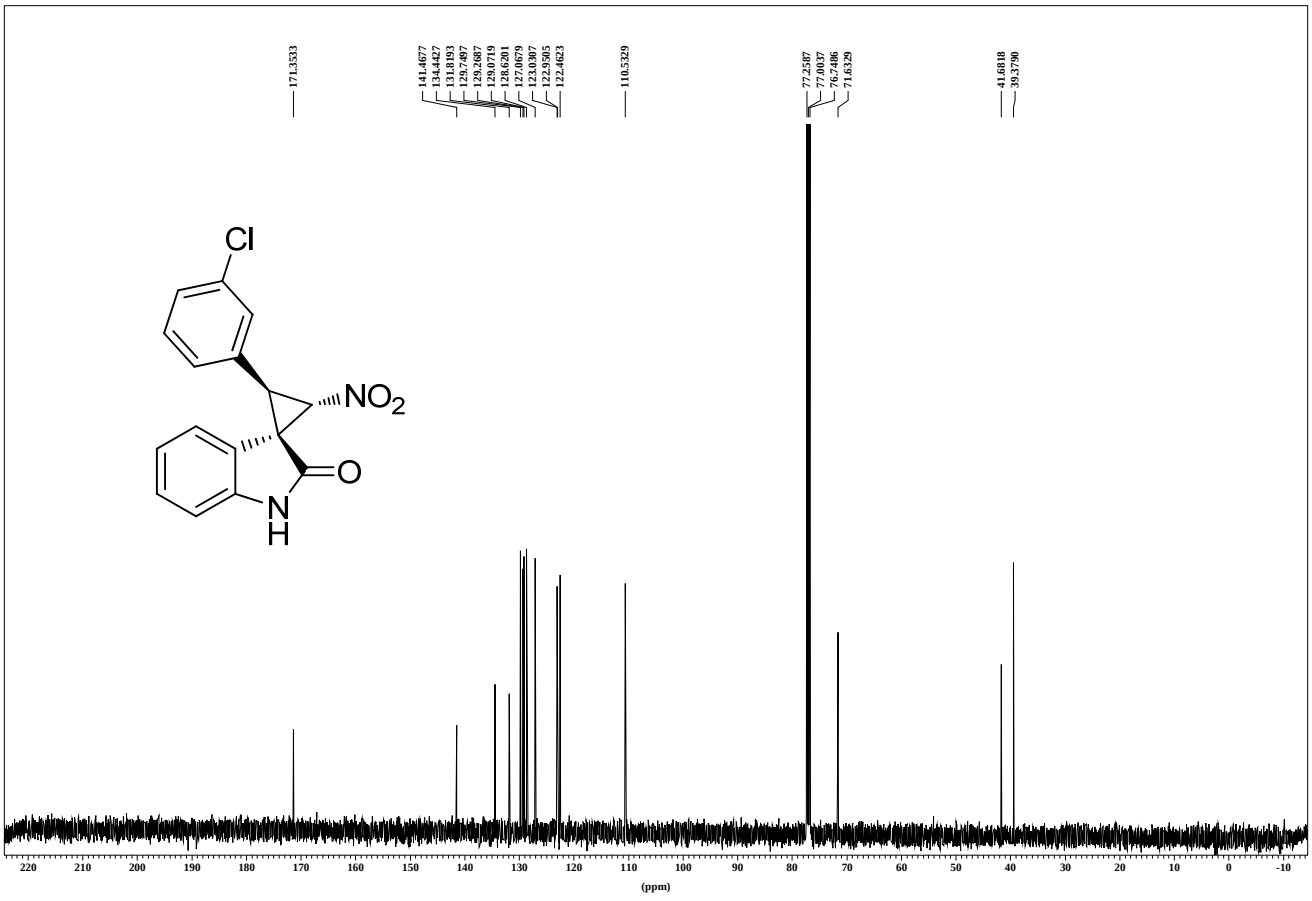
13C AMX500 dxw0403-2 1825C



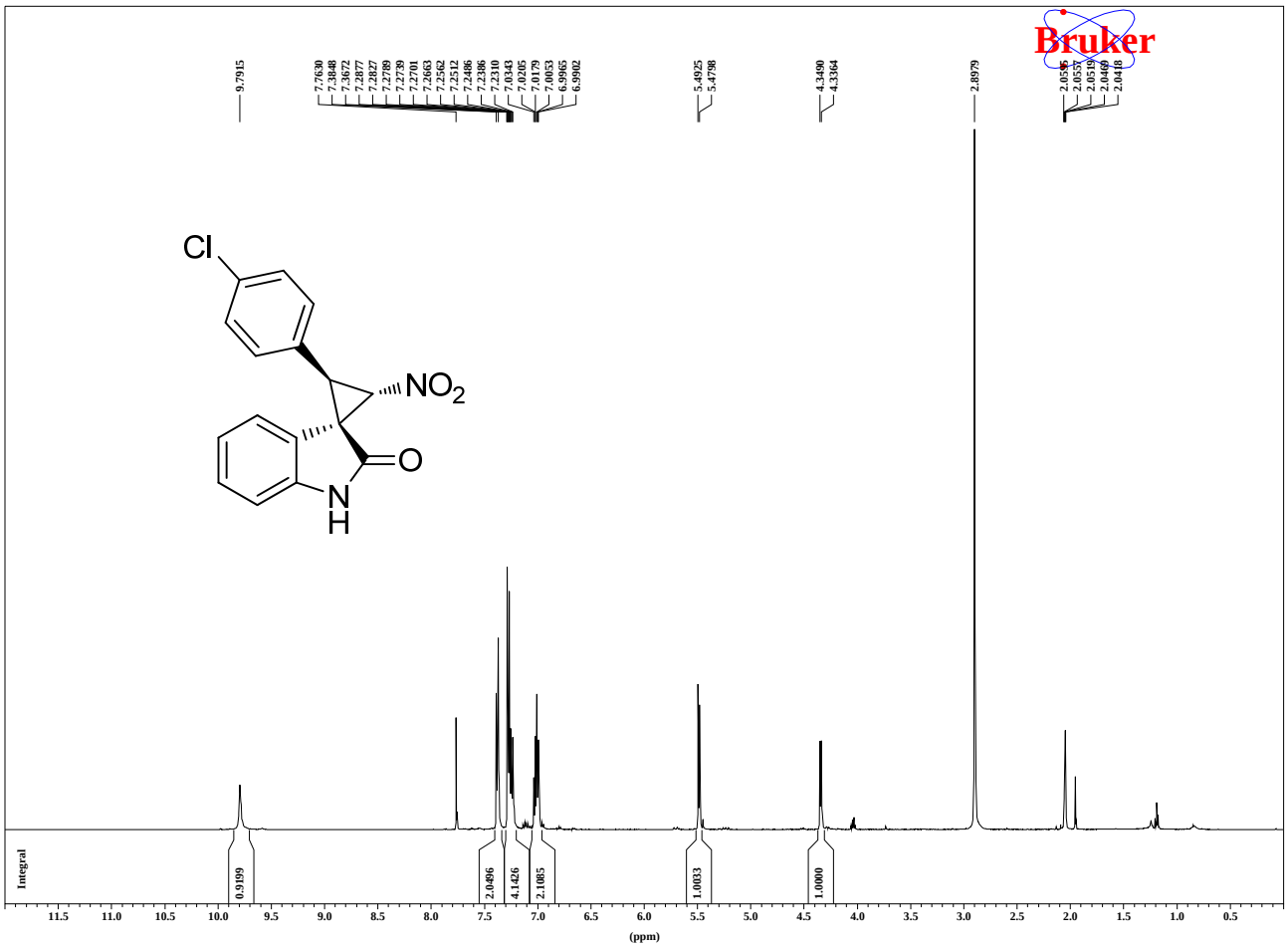
1H AMX500 dxw0403-3 1827H



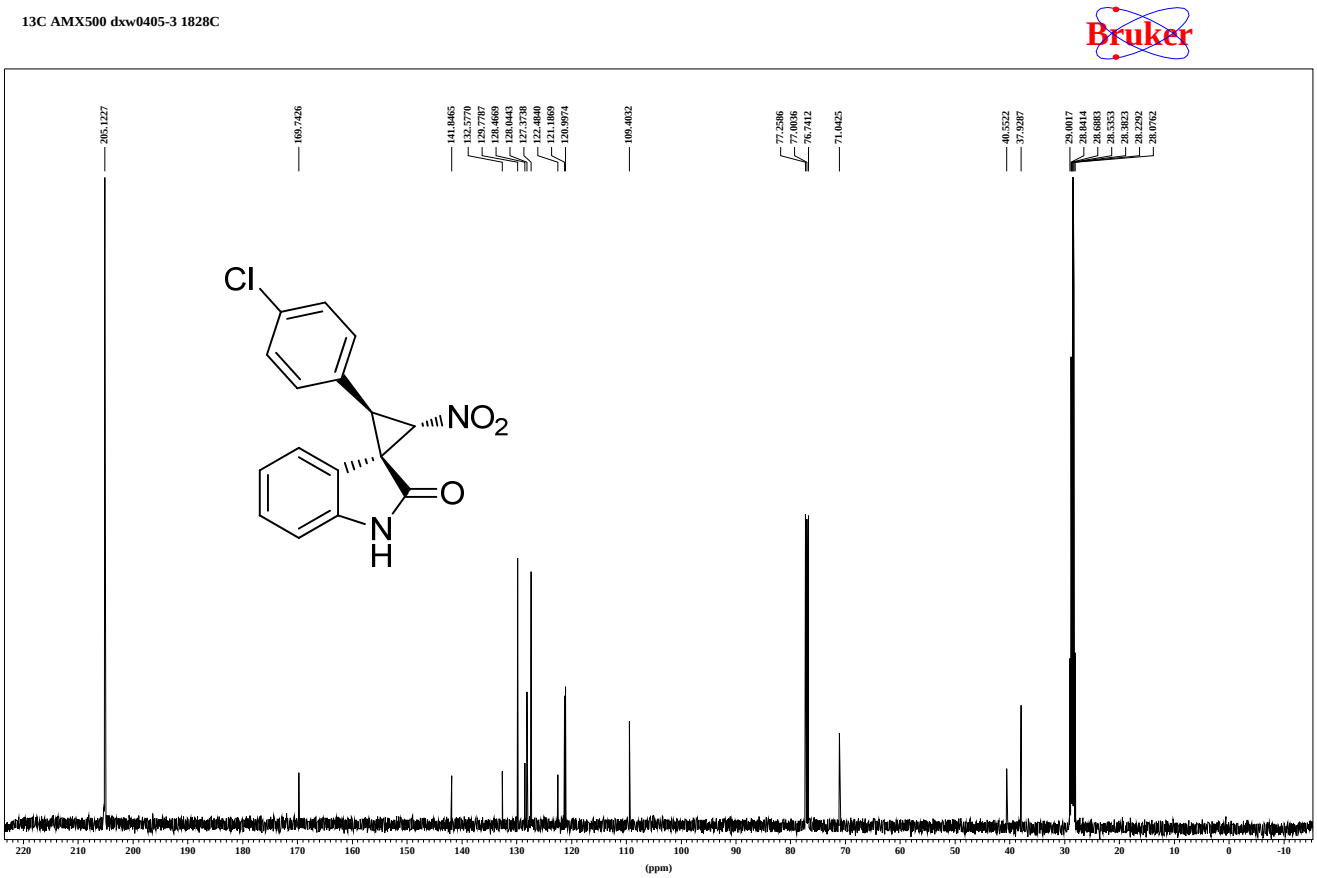
13C AMX500 dxw0403-4 1827C



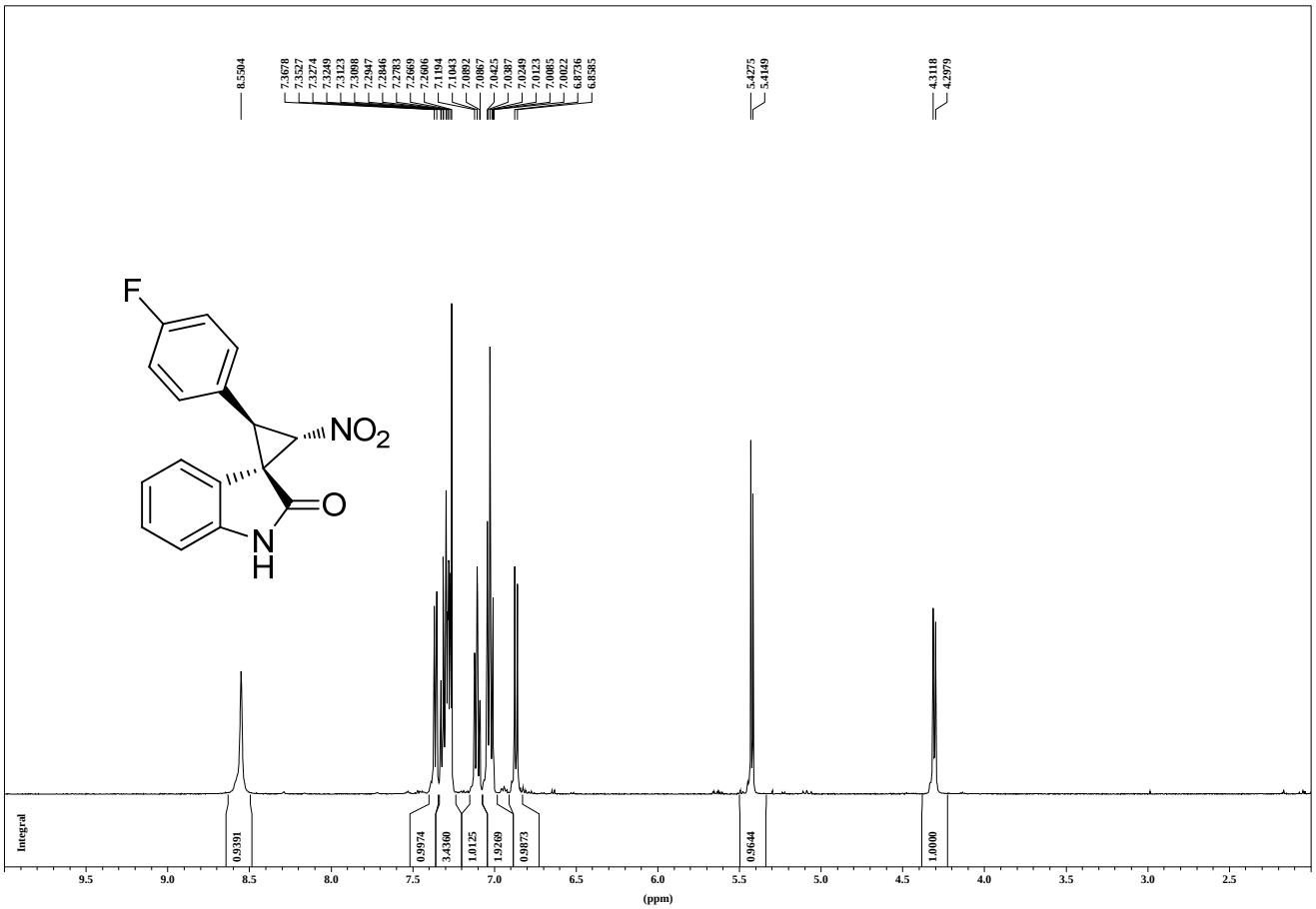
1H AMX500 dxw0405-2 1828H (4-Cl)



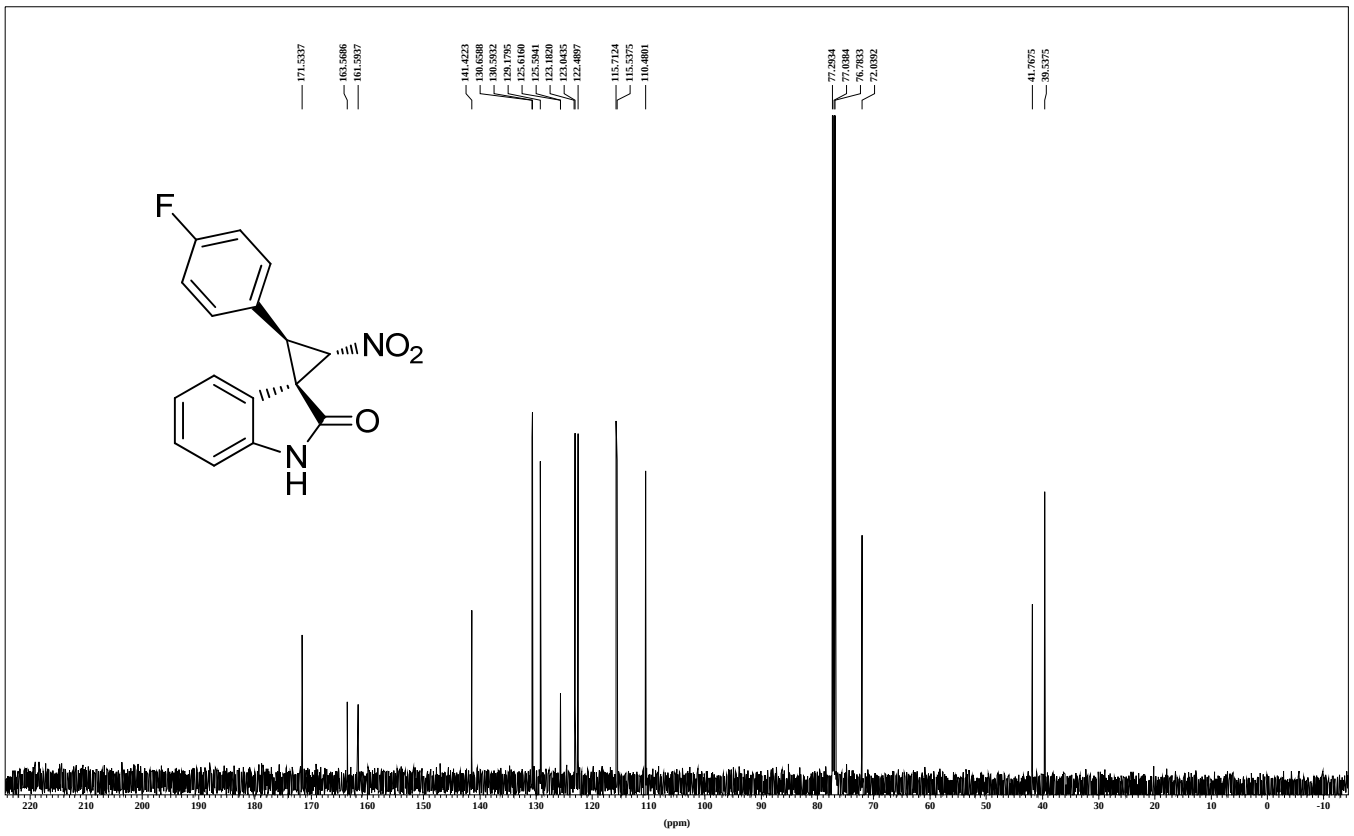
13C AMX500 dxw0405-3 1828C



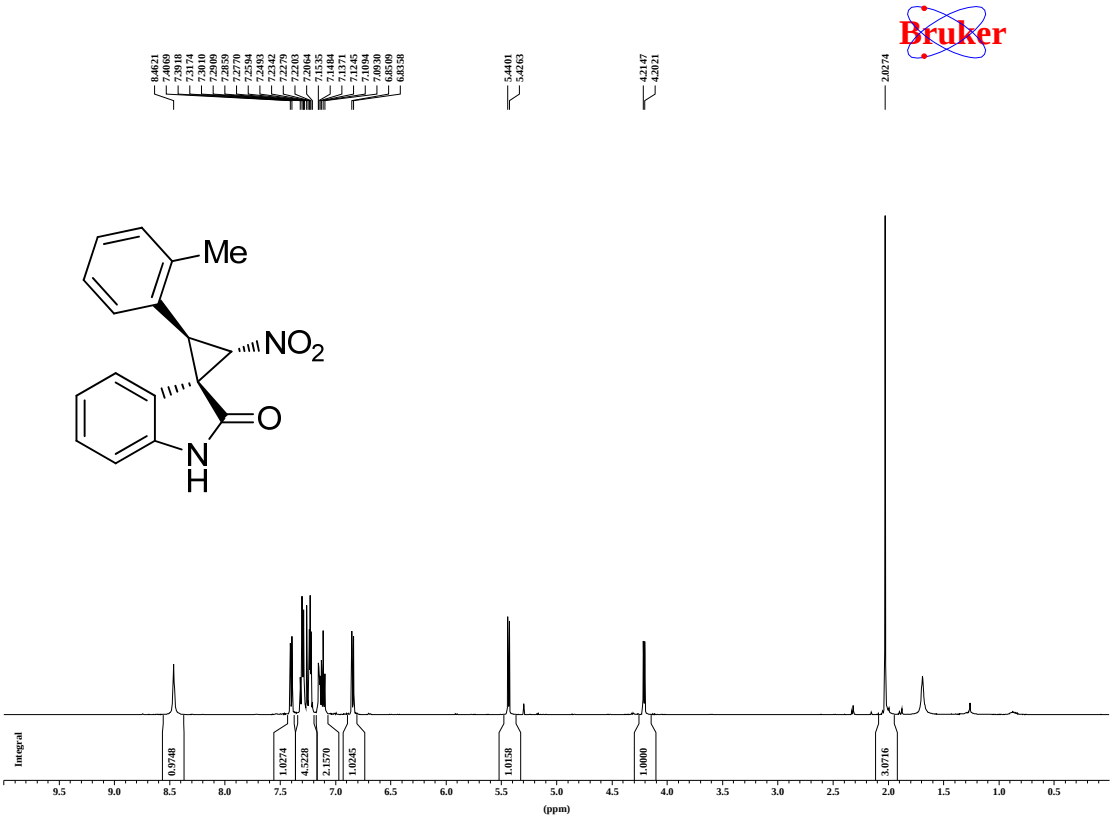
1H AMX500 dxw0403-7 1829H



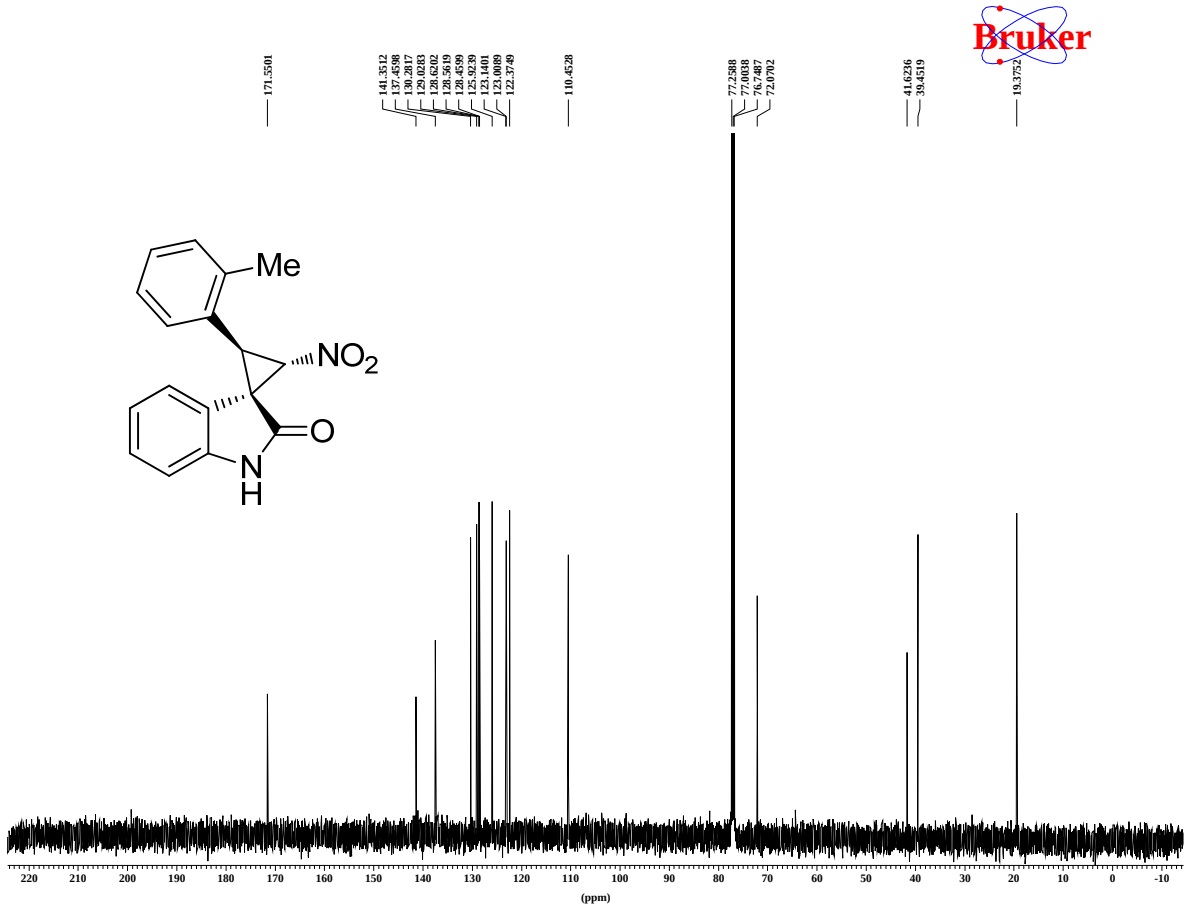
13C AMX500 dxw0403-8 1829C



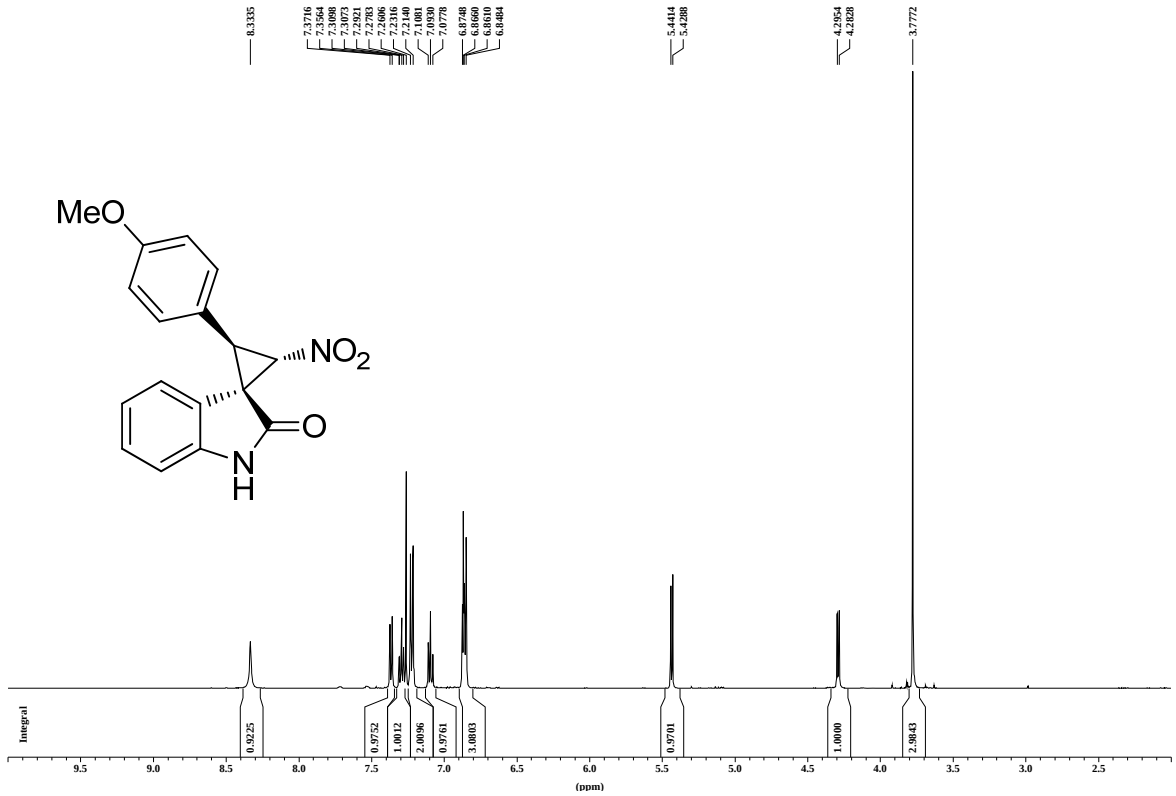
1H AMX500 dxw0404-1 1830H (2-Me)



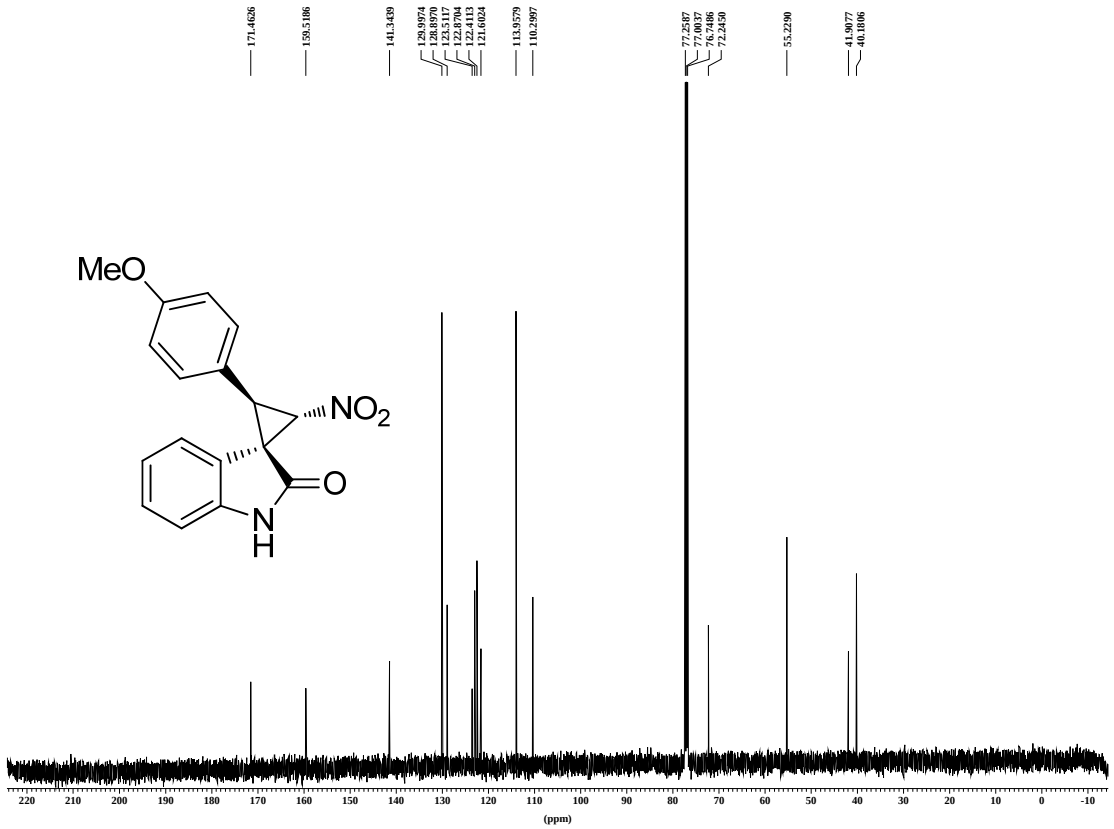
13C AMX500 dxw0404-2 1830C (2-Me)



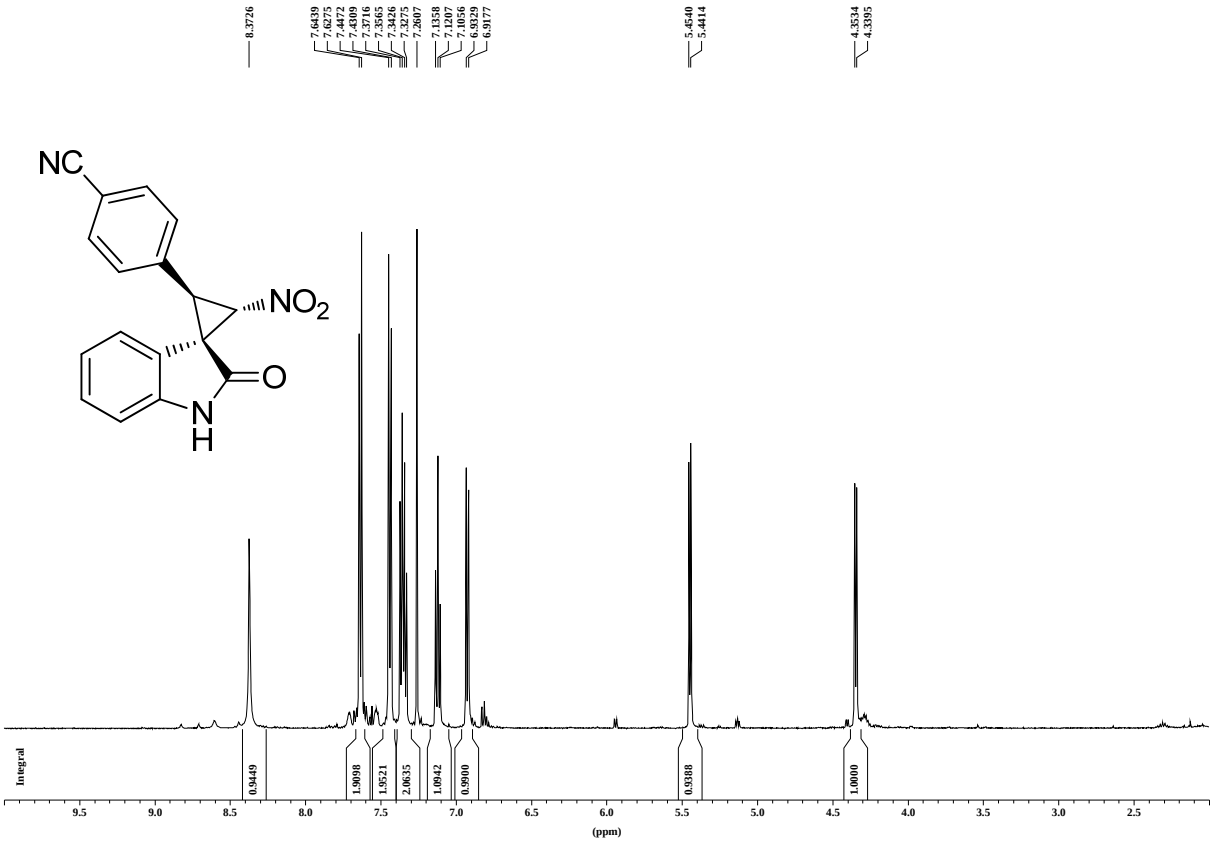
1H AMX500 dxw0404-3 1831H (4-OMe)



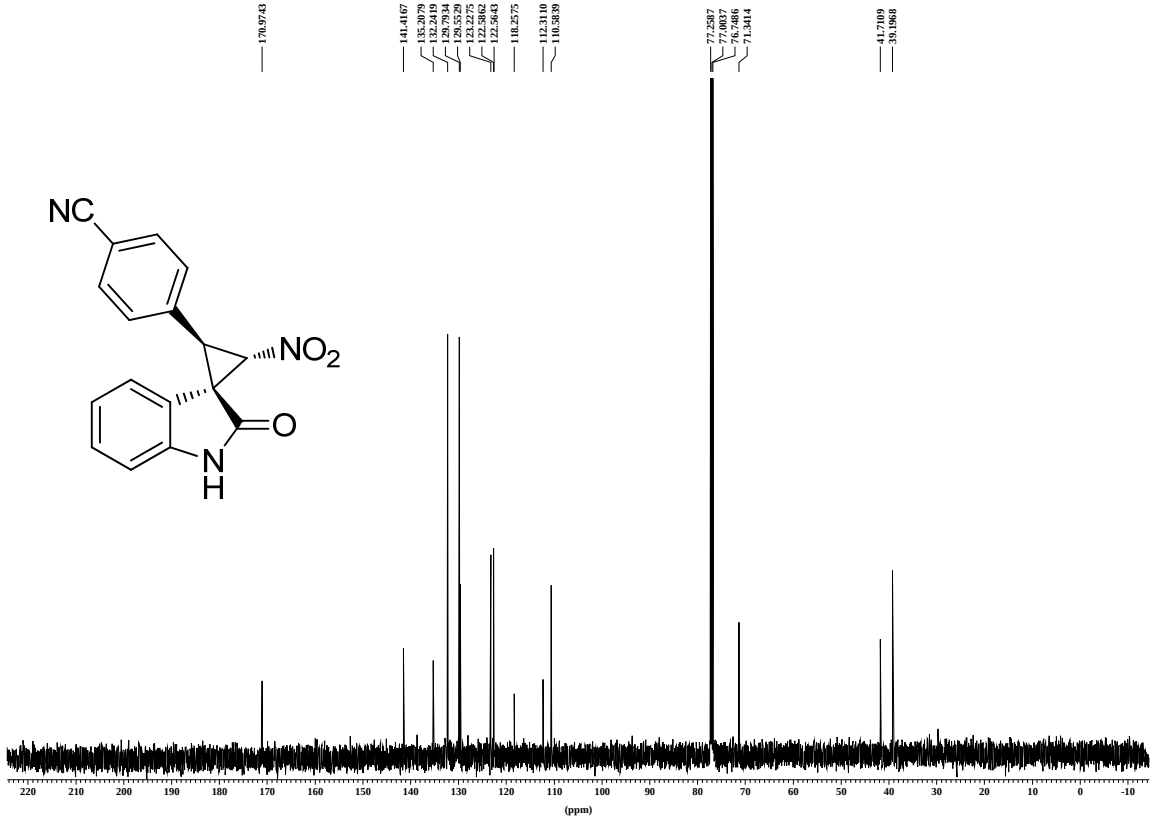
13C AMX500 dxw0404-4 1831C (4-OMe)



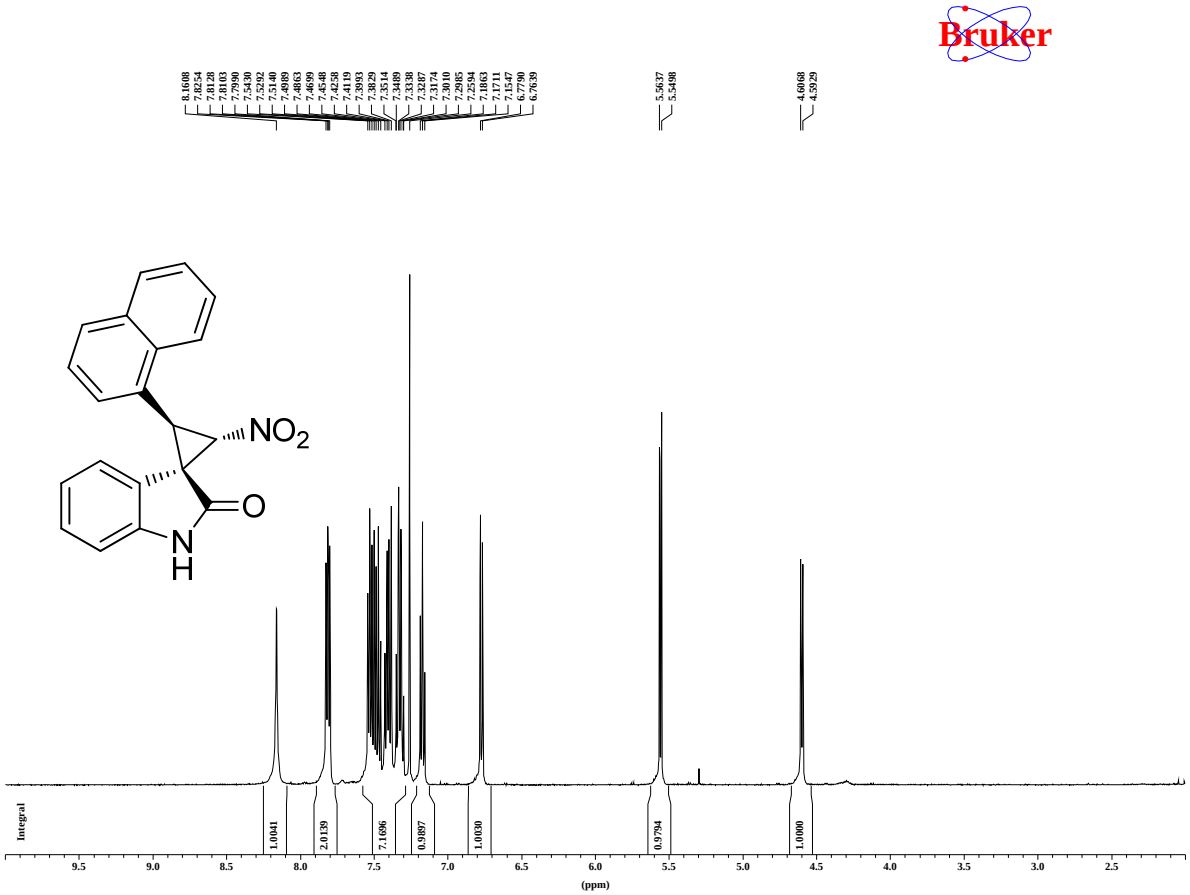
1H AMX500 dxw0401-1 1822H



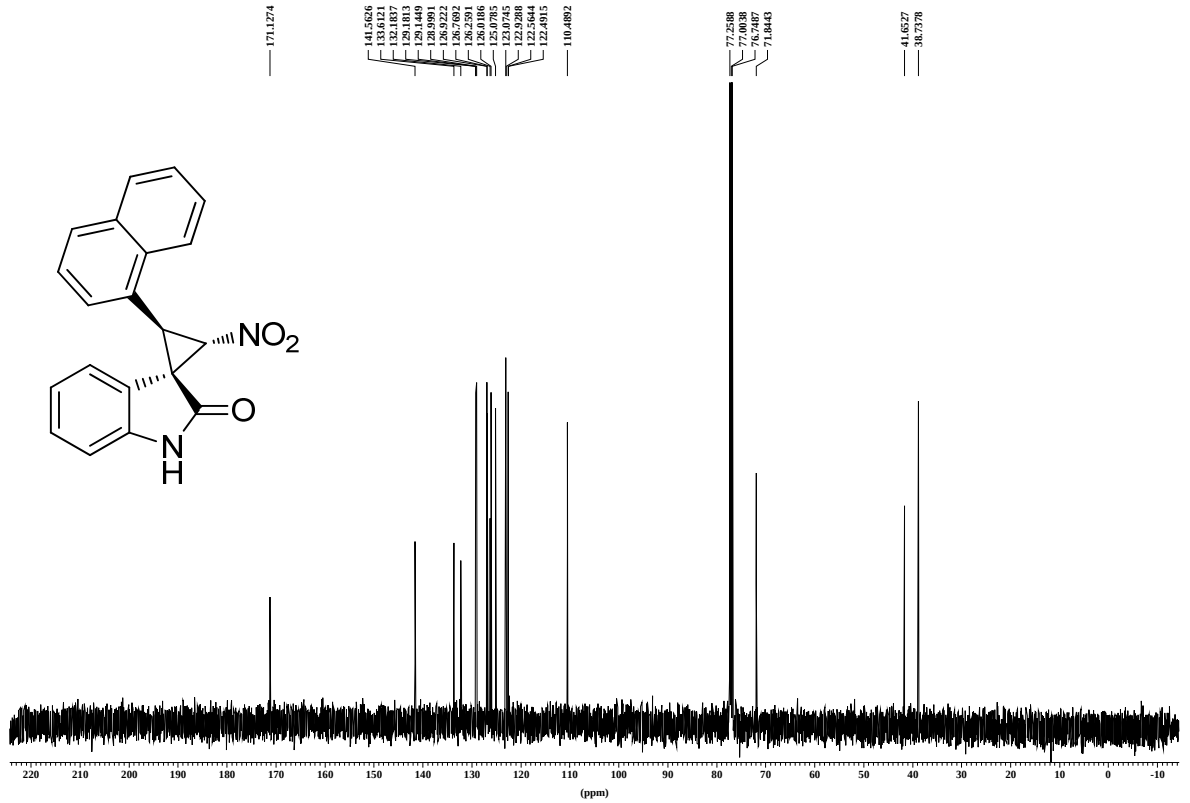
13C AMX500 dxw0401-2 1822C



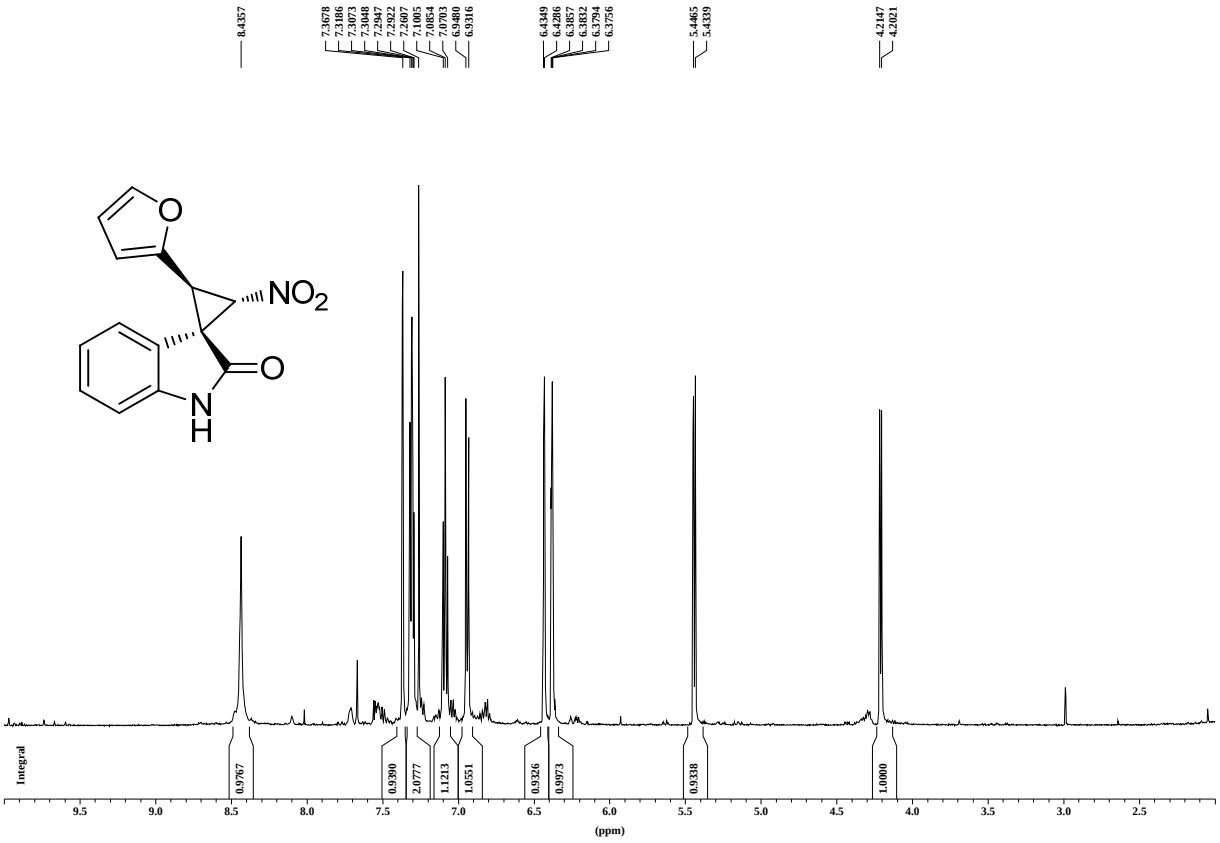
1H AMX500 dxw0404-5 1832H (1-naph)



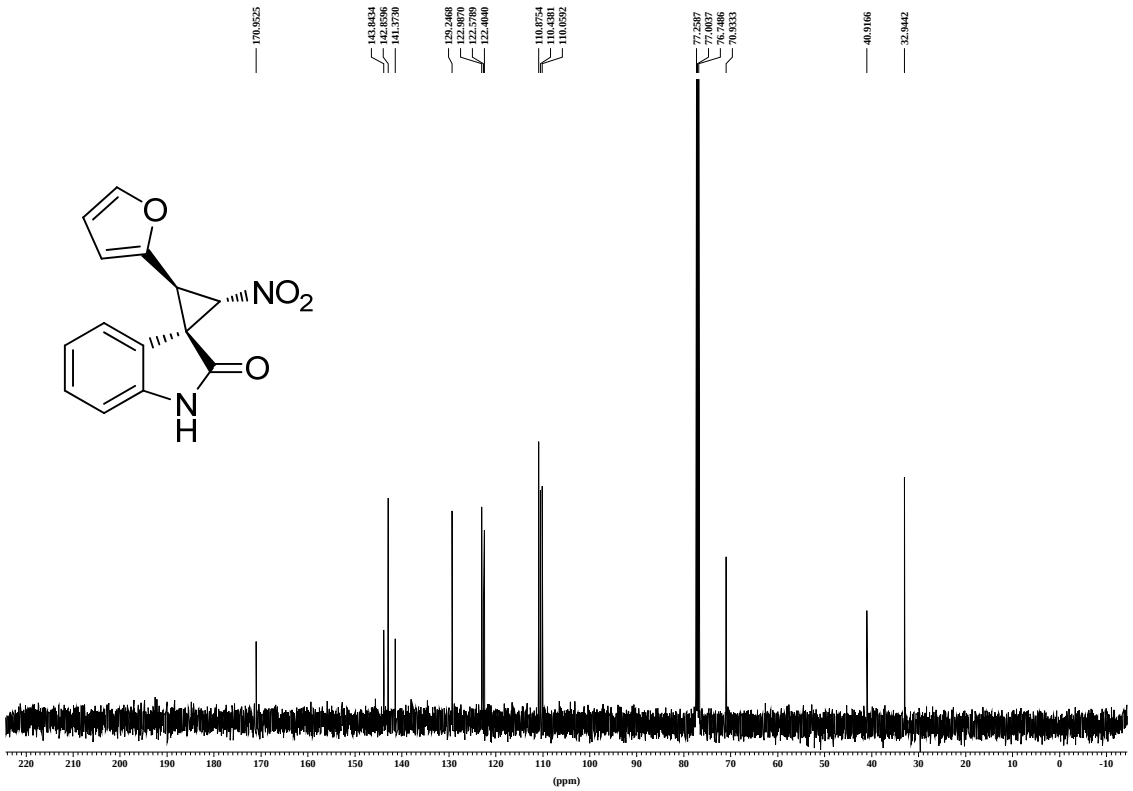
13C AMX500 dxw0404-6 1832C (1-naph)



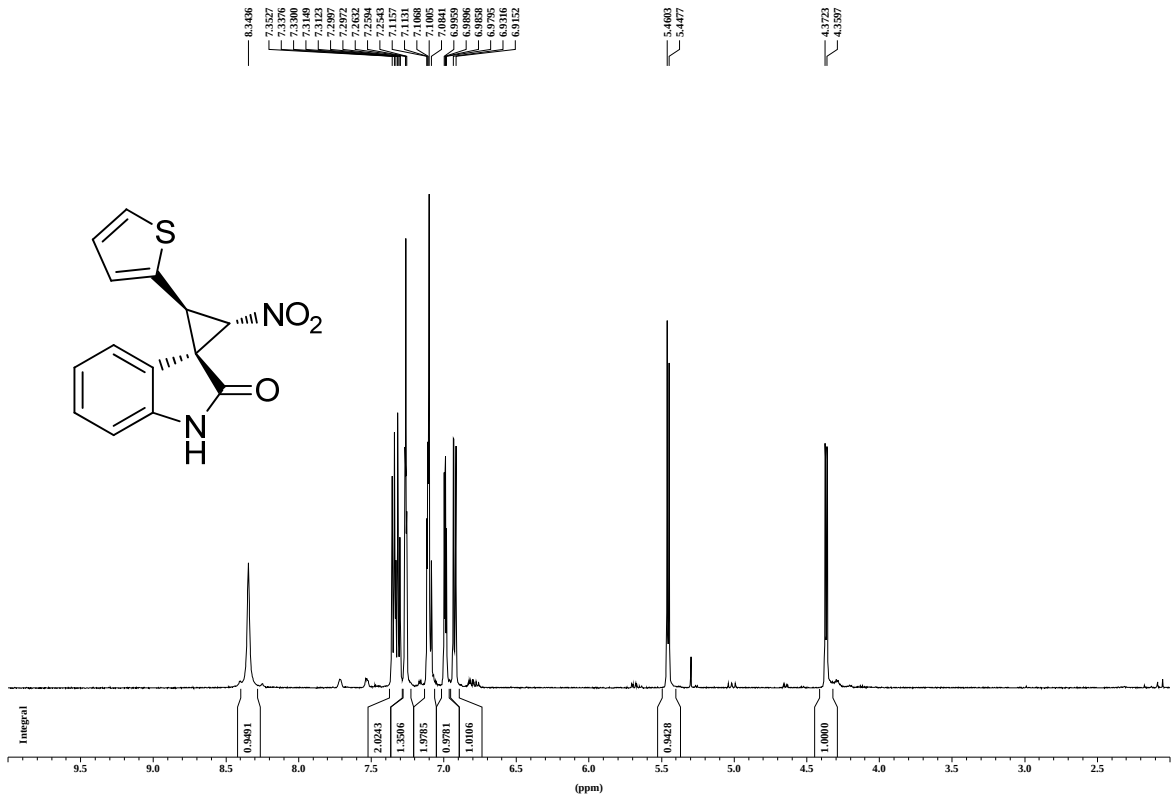
1H AMX500 dxw0401-3 1823H



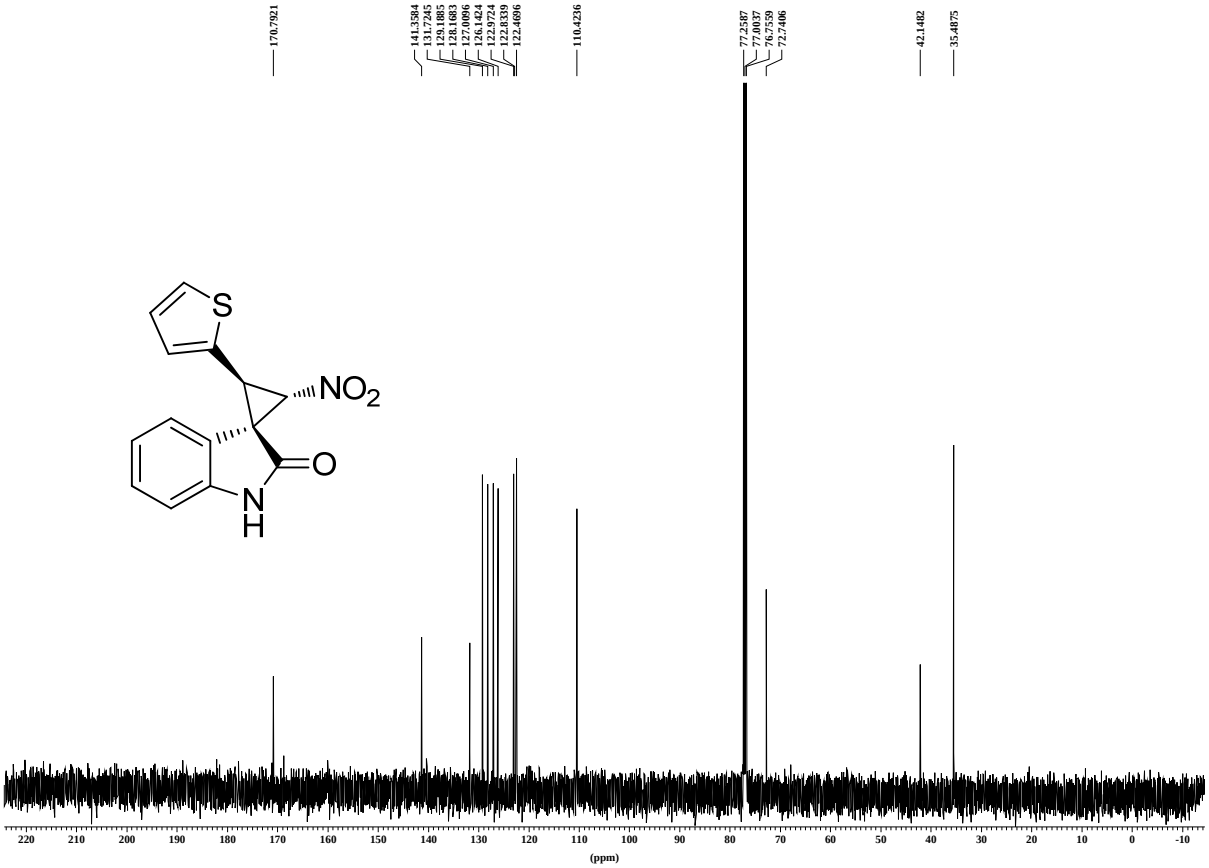
13C AMX500 dxw0401-4 1823C



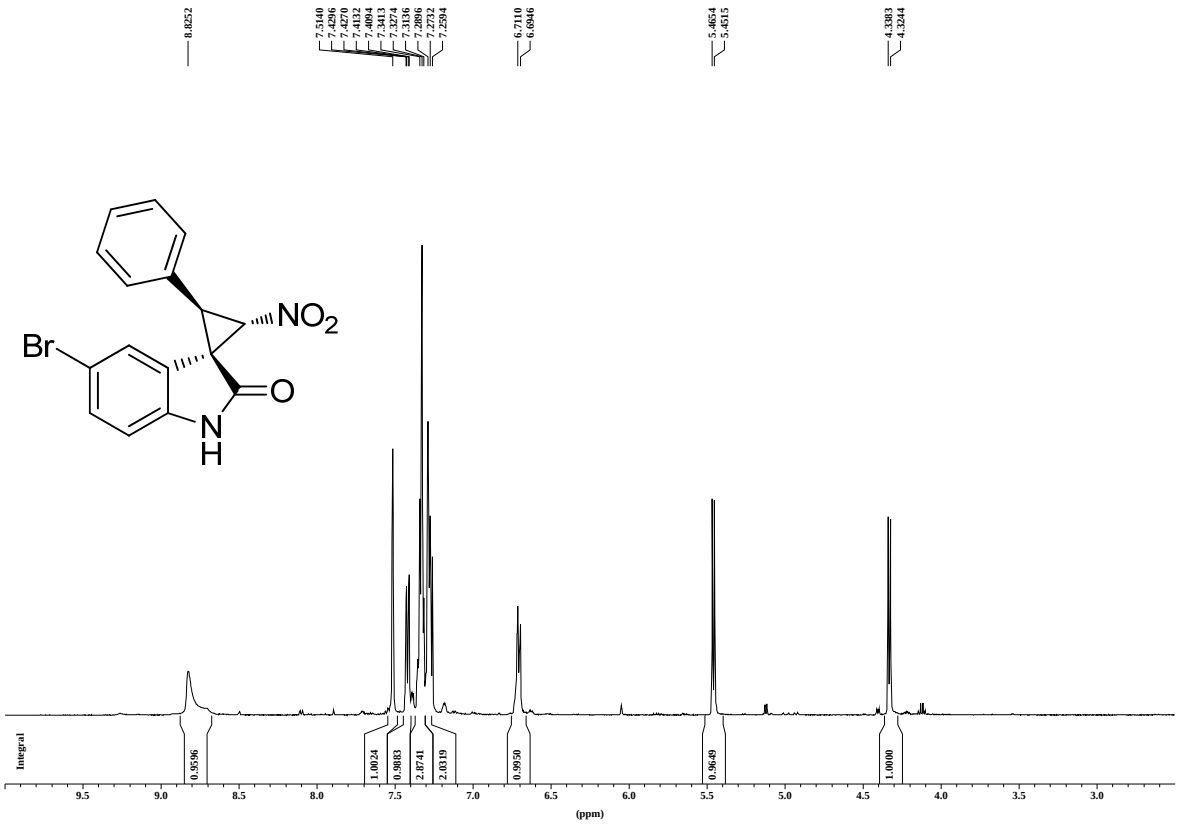
1H AMX500 dxw0401-5 1824H



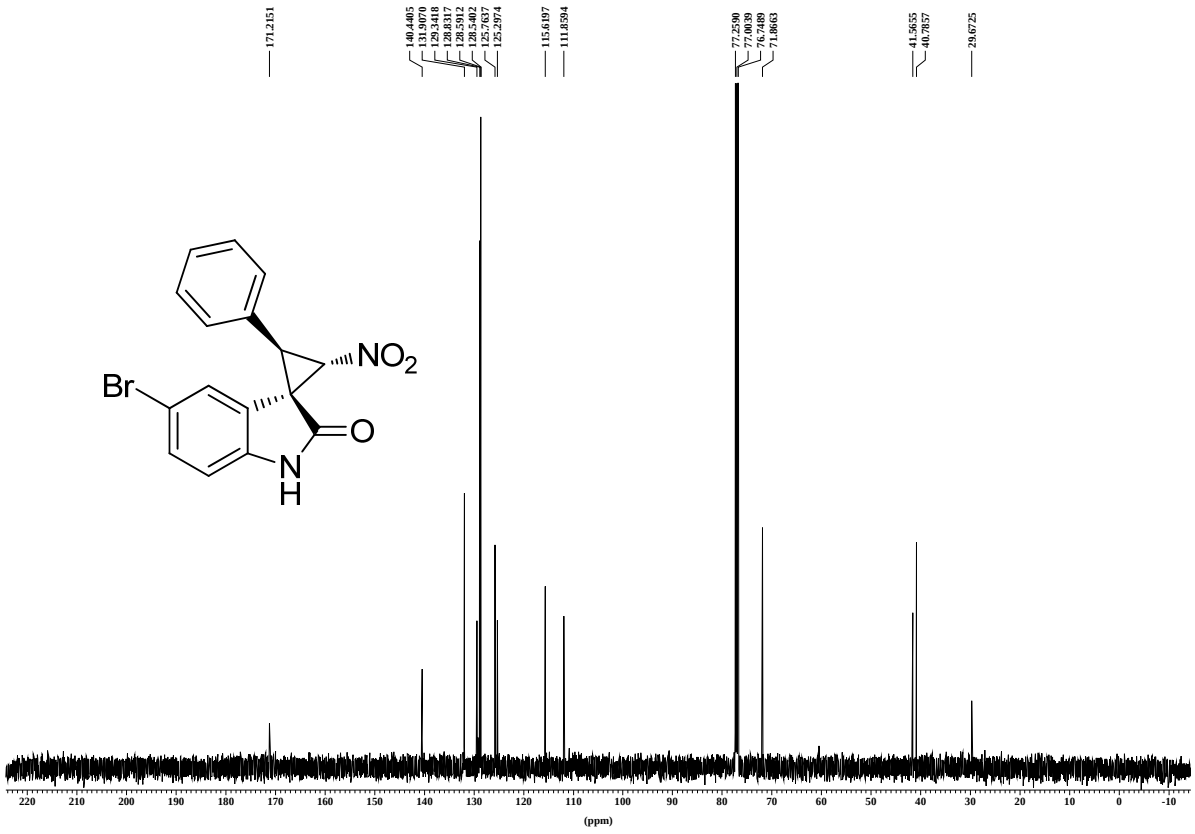
13C AMX500 dxw0401-6 1824C



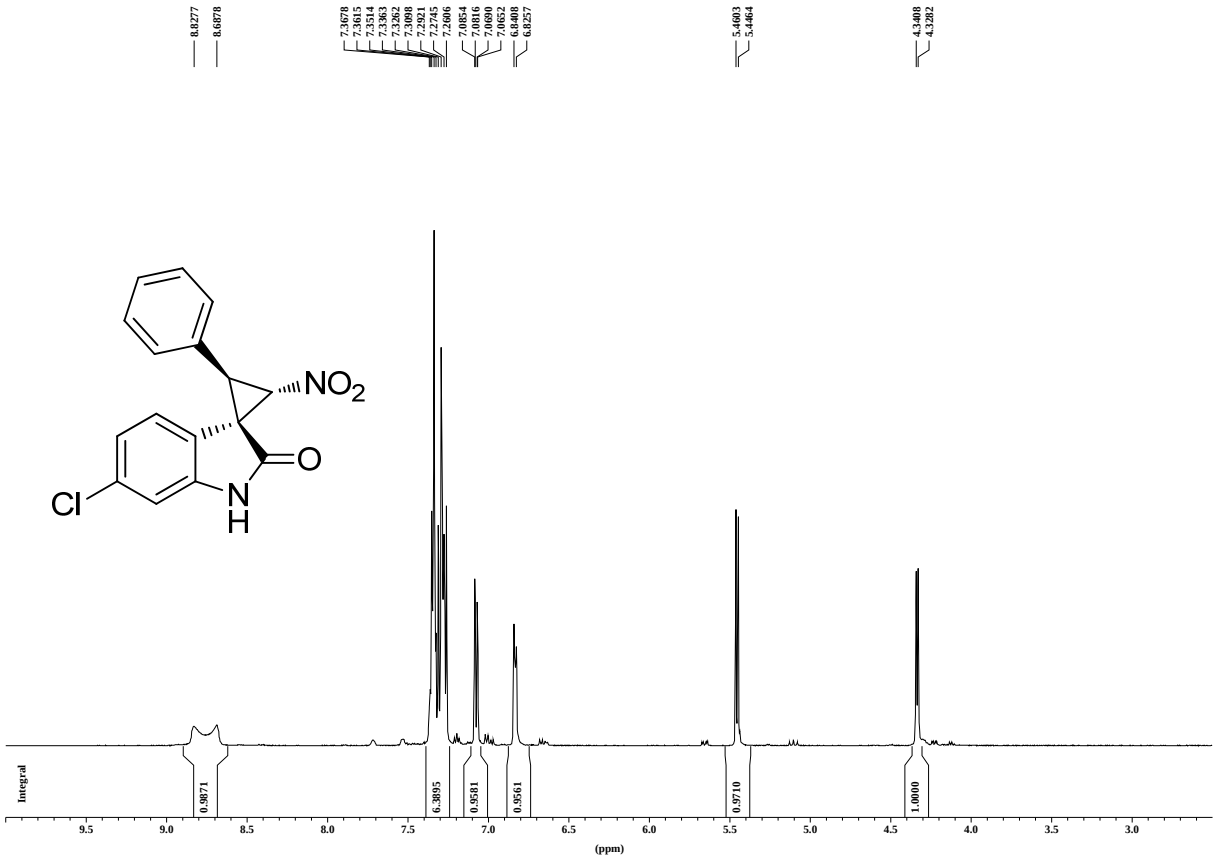
1H AMX500 dxw0328-1 1817H



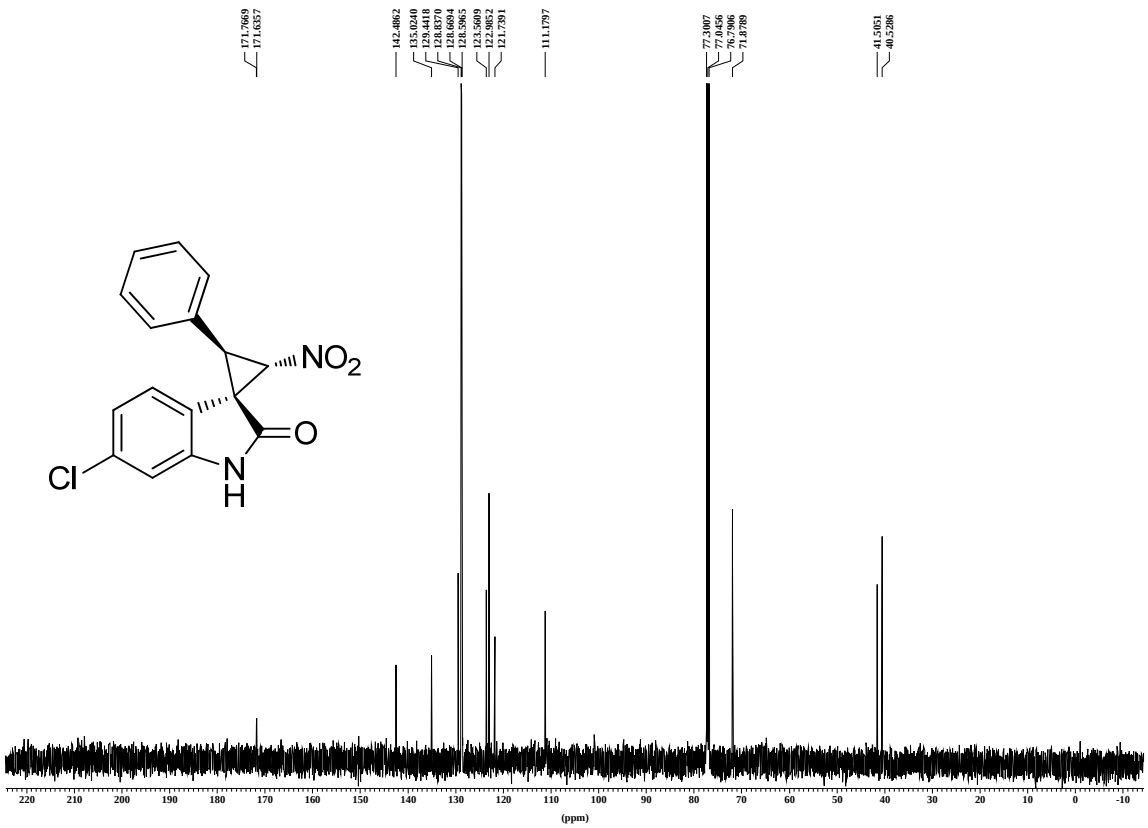
13C AMX500 dxw0328-2 1817C



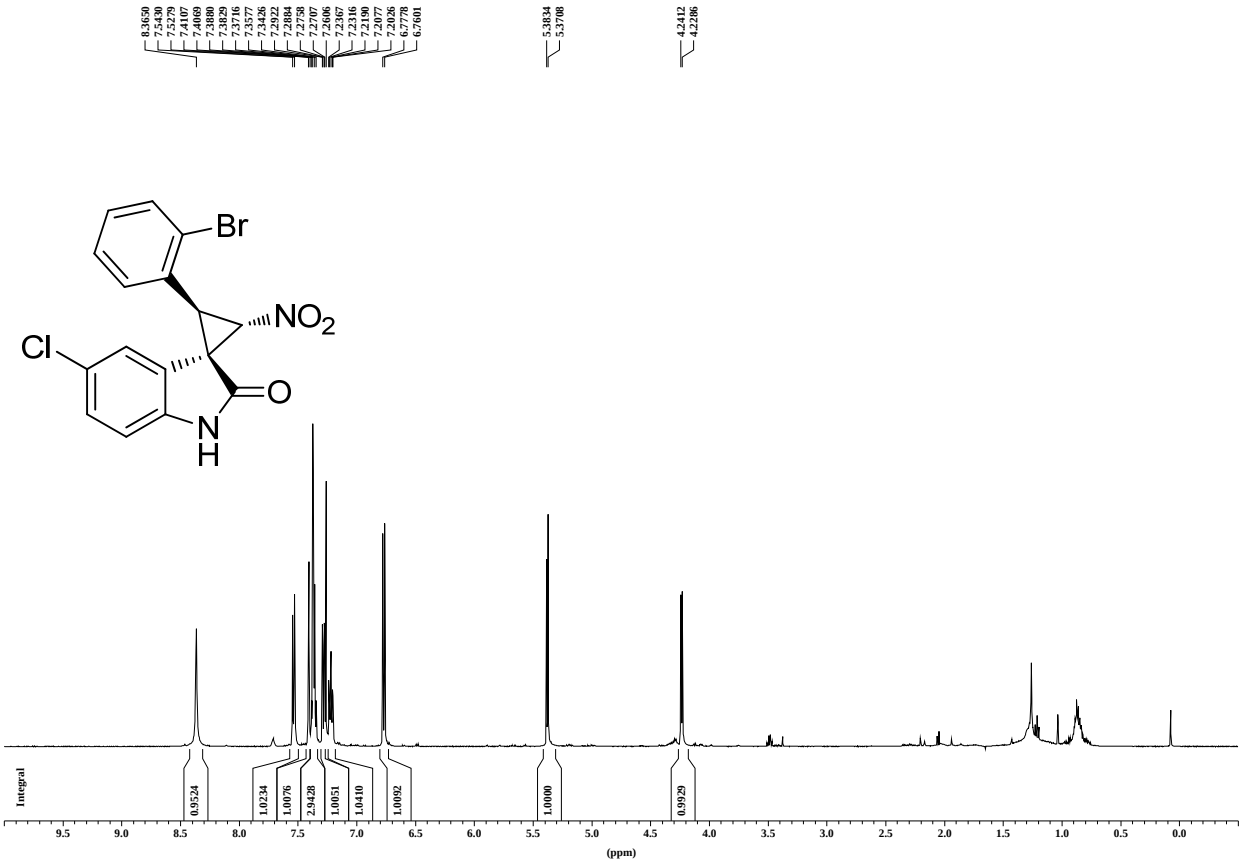
1H AMX500 dxw0328-7 1819H



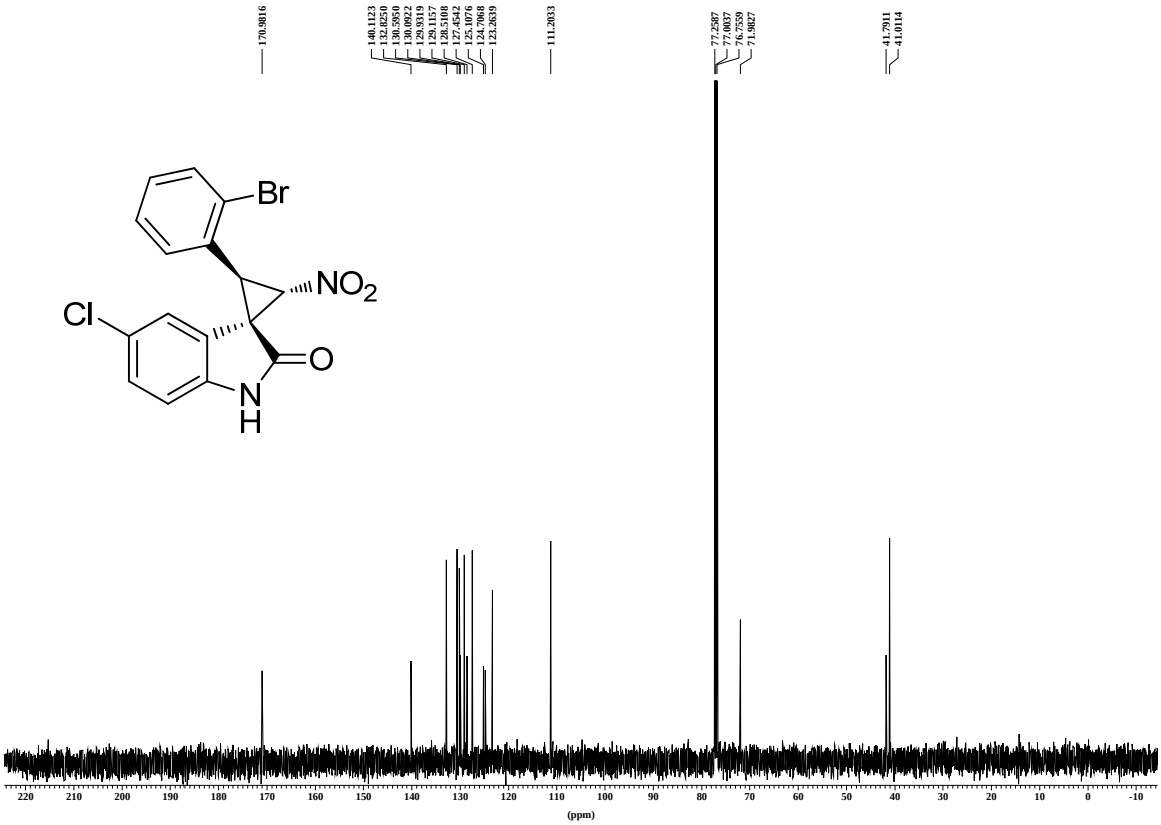
13C AMX500 dxw0328-4 1819C



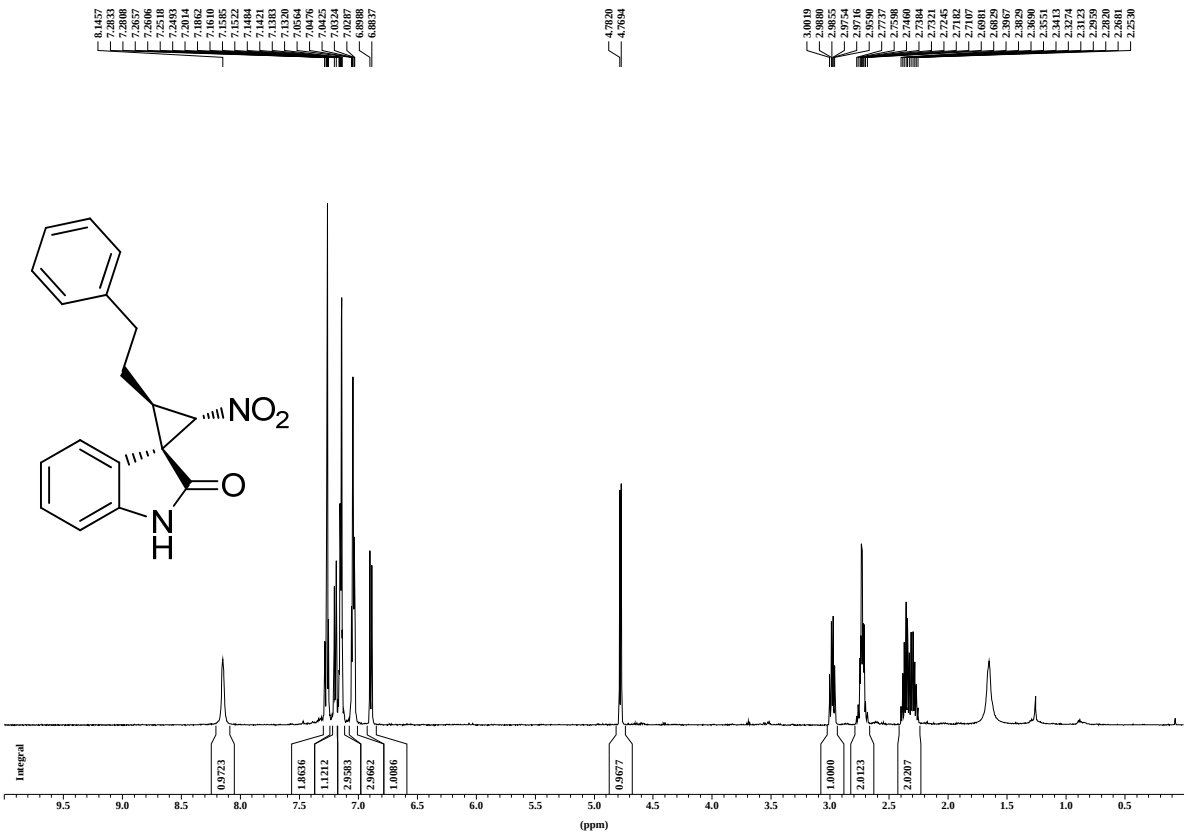
1H AMX500 dxw0619-2 1485c



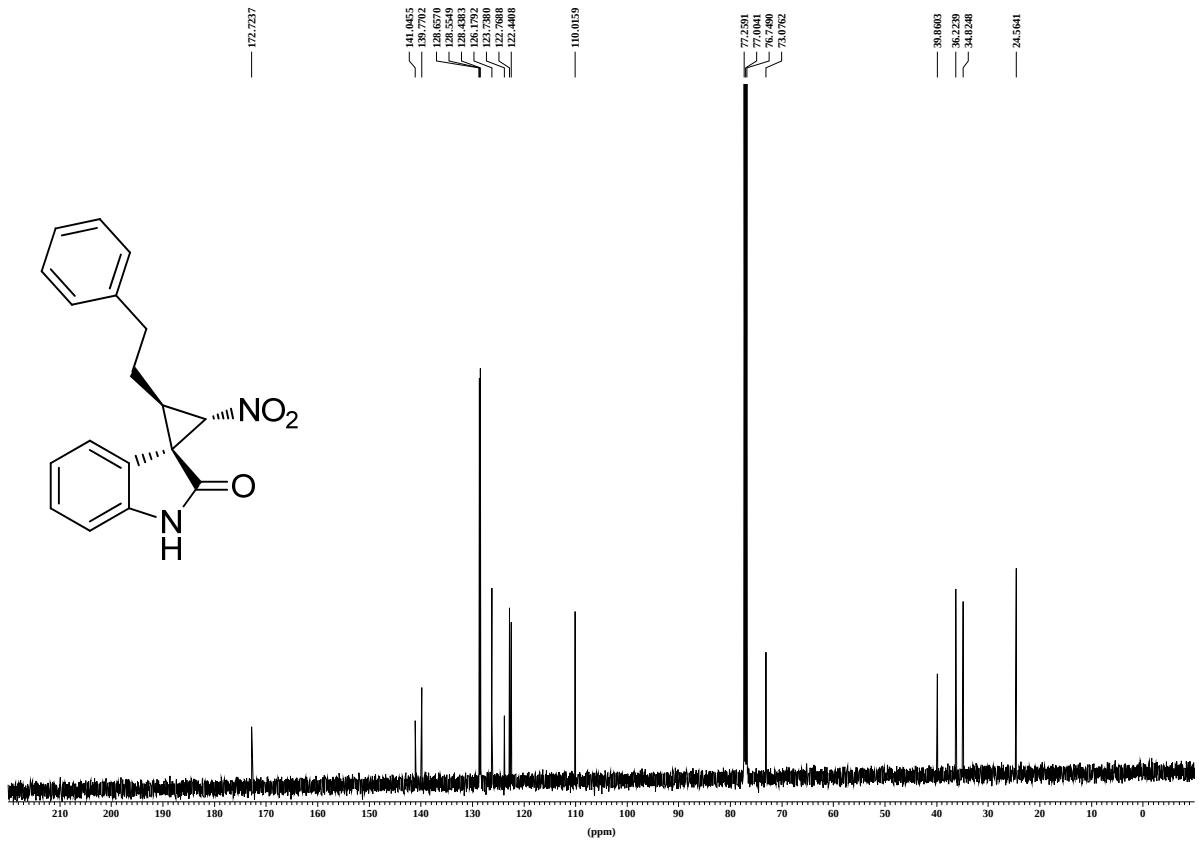
13C AMX500 dxw0619-3 1485c



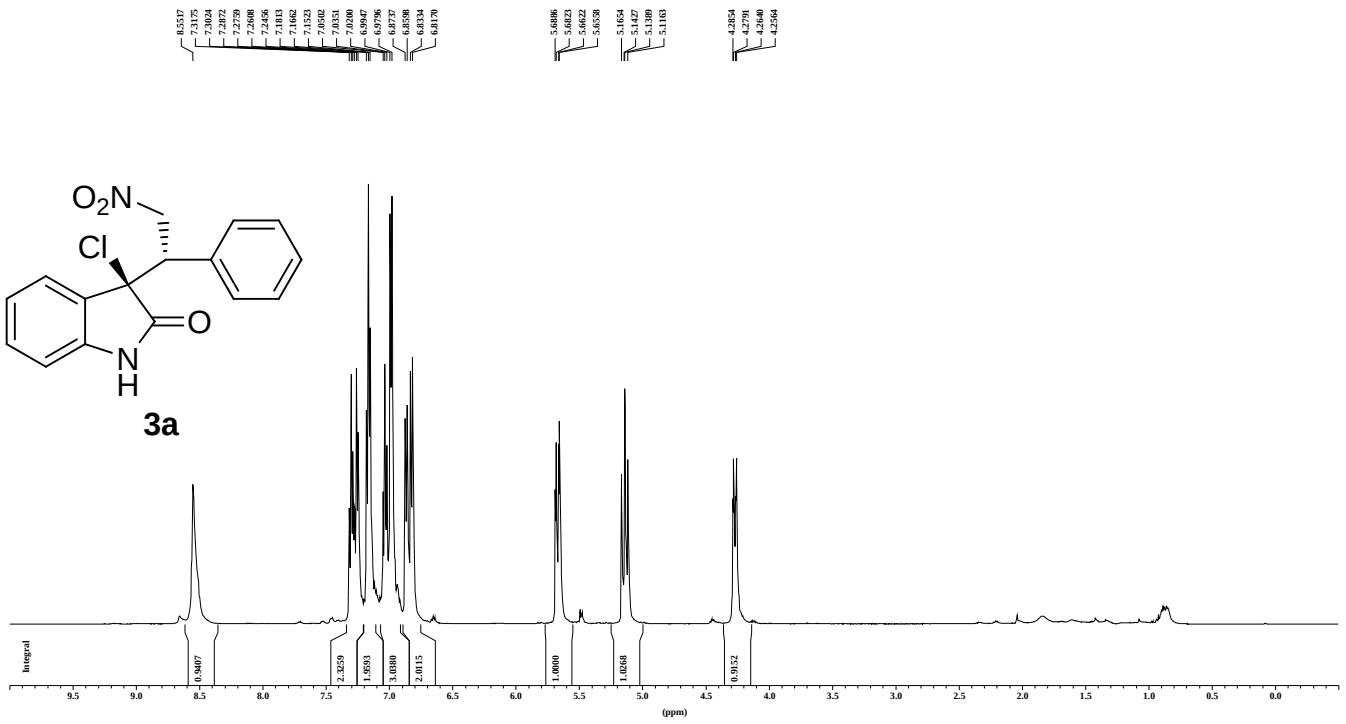
1H AMX500 dxw0408-1 1833H



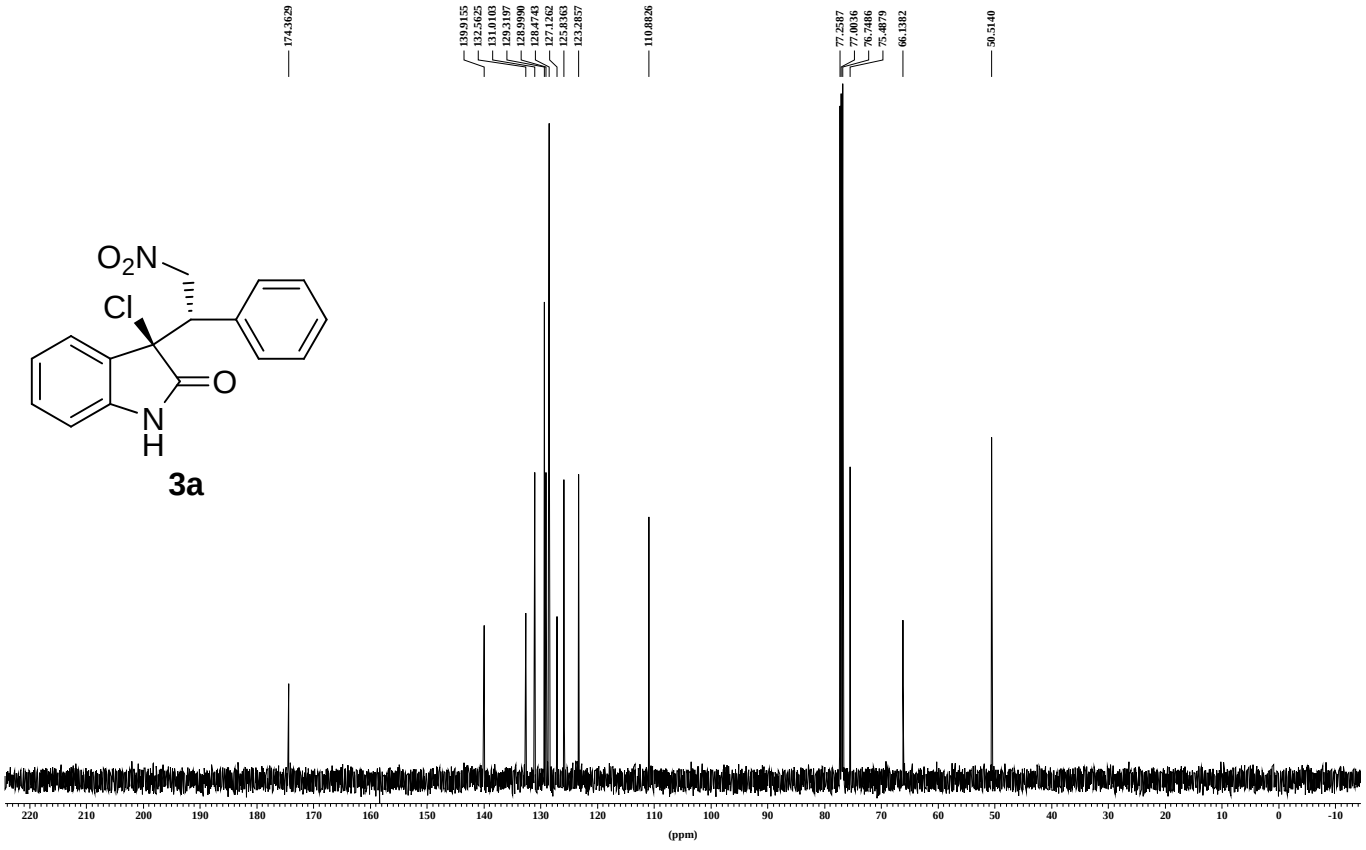
13C AMX500 dxw0408-2 1833C



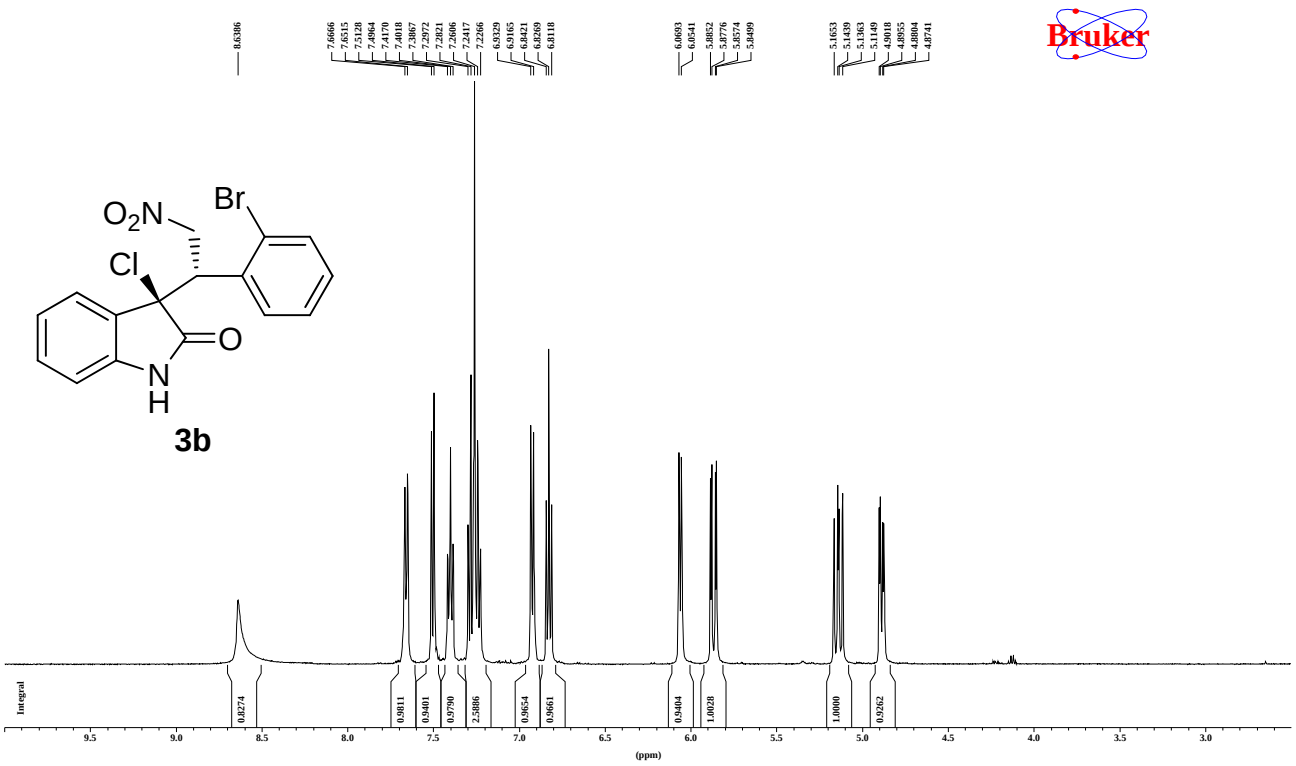
1H AMX500 dxw0424-3 1028Ph H



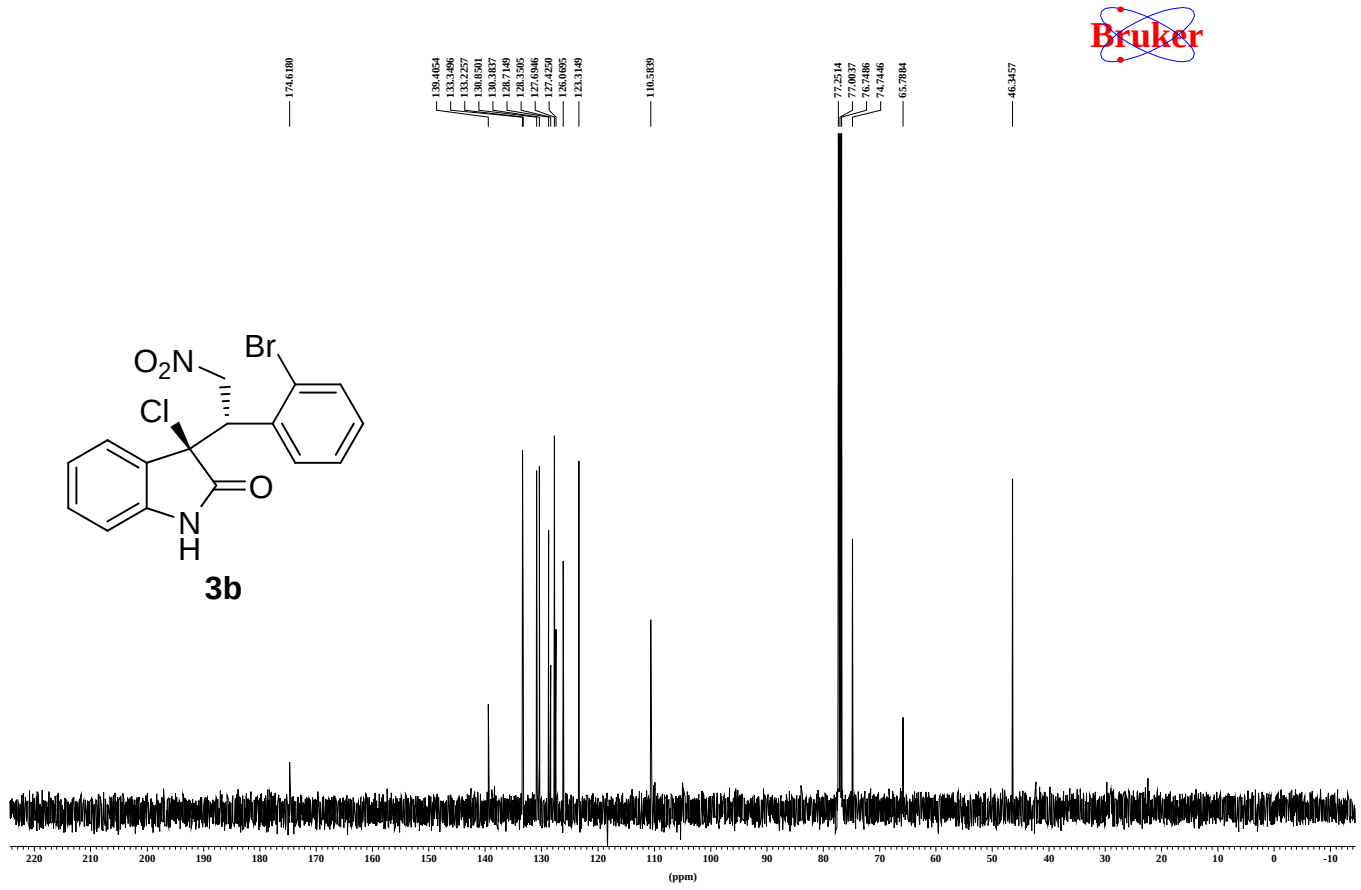
13C AMX500 dxw0424-2 1028 Ph

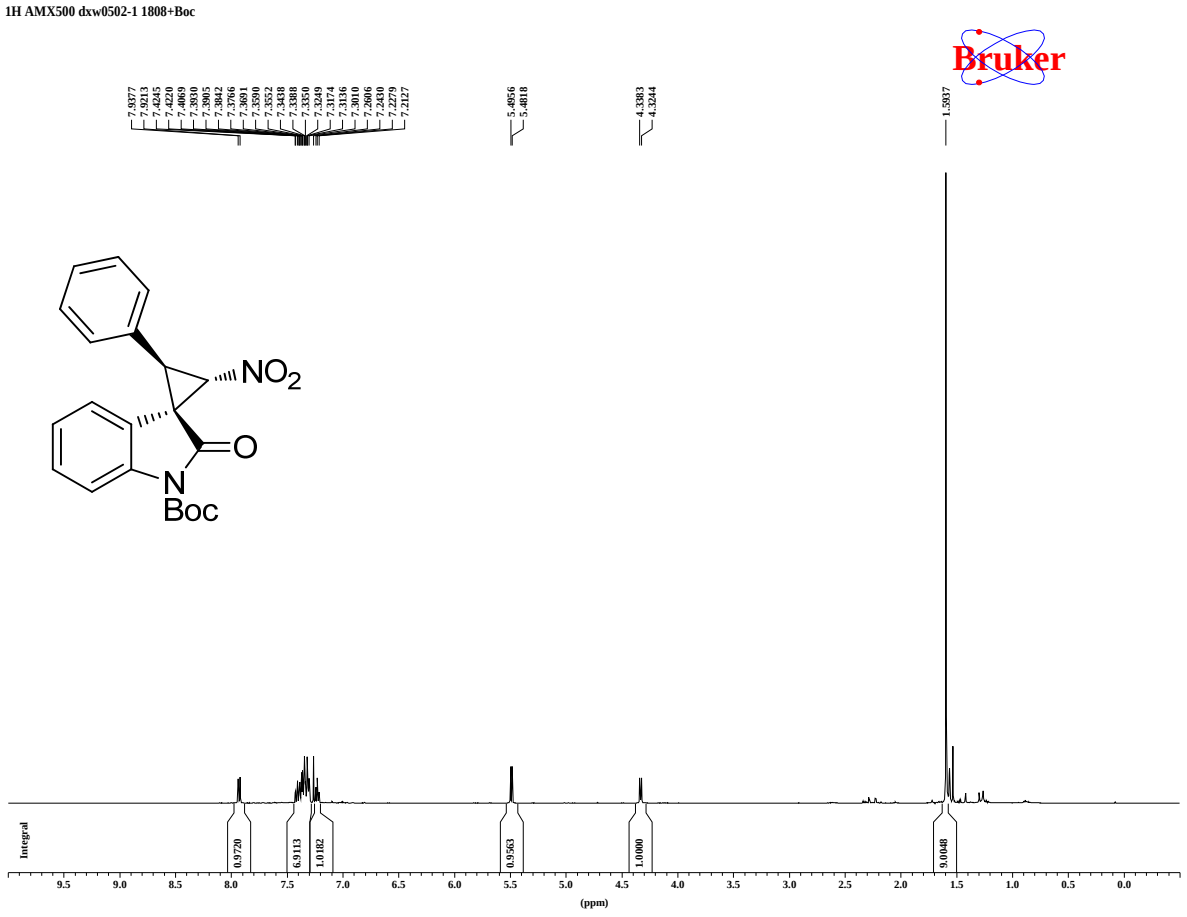


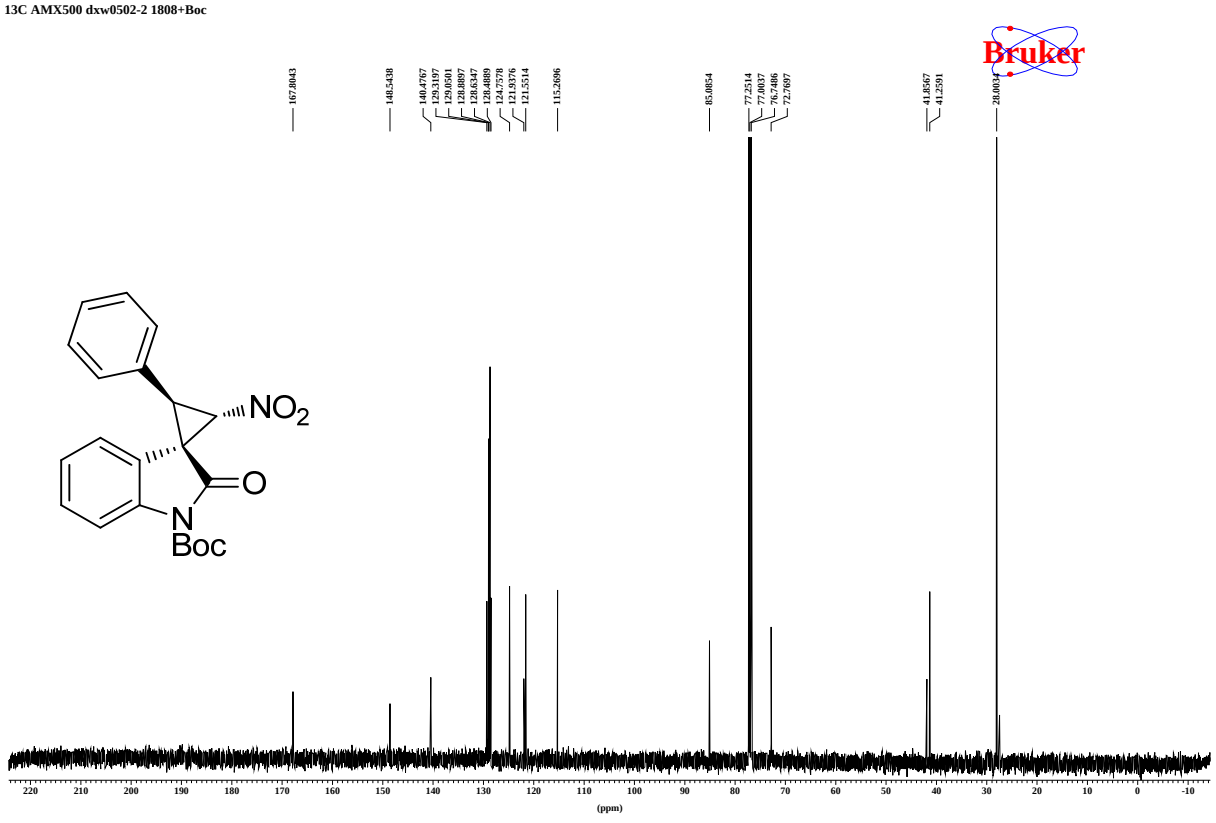
1H AMX500 dxw0427-3 1032-1 2-Br



13C AMX500 dxw0427-4 1032-1 2-Br




1H AMX500 dxw0502-1 1808+Boc
Bruker
7.9377
7.9213
7.4245
7.4220
7.4069
7.3930
7.3905
7.3842
7.3766
7.3691
7.3590
7.3552
7.3438
7.3388
7.3350
7.3249
7.3174
7.3116
7.3010
7.2606
7.2430
7.2279
7.2127
5.4056
5.4018
4.3383
4.3244
1.5937
NO2
O
N
Boc
Integral
0.9720
6.9113
1.0182
0.9563
1.0000
9.0048
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
(ppm)


13C AMX500 dxw0502-2 1808+Boc
Bruker
167.8043
148.5438
140.4767
129.3197
129.0501
128.8897
128.6347
124.7578
121.9376
121.5514
115.2696
85.0854
77.2514
77.0037
76.7486
72.7697
41.8567
41.2591
28.0034
NO2
O
N
Boc
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
(ppm)

References

[1] (a) Demerseman, P.; Guillaumel, J.; Royer, J.-M. C. R. *Tetrahedron Lett.* **1978**, *23*, 2011. (b) Guillaumel, J.; Demerseman, P.; Royer, J.-M. C. R. *Tetrahedron* **1980**, *36*, 2459. (c) Guillaumel, J.; Demerseman, P.; Royer, J.-M. C. R. *J. Heterocyclic Chem.* **1980**, *17*, 1531. (d) Noole, A.; Järving, I.; Werner, F.; Lopp, M.; Malkov, A.; Kanger, T. *Org. Lett.* **2012**, *14*, 4922.

[2] Dou, X.; Lu, Y. *Chem. Eur. J.* **2012**, *18*, 8315.

[3] Pesciaioli, F; Righi, P.; Mazzanti, A.; Bartoli, G.; Bencivenni, G. *Chem. Eur. J.* **2011**, *17*, 2842.