Asymmetric Michael Addition Mediated by Novel Cinchona Alkaloid-derived Bifunctional Catalysts Containing Sulfonamides

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SUPPORTING INFORMATION

A. General Information

^1H and ^{13}C NMR spectra were recorded on a Bruker ACF300 or DPX300 (300 MHz) 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. 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. Flash chromatography separation was performed on Merck 60 (0.040 - 0.063 mm) mesh silica gel.

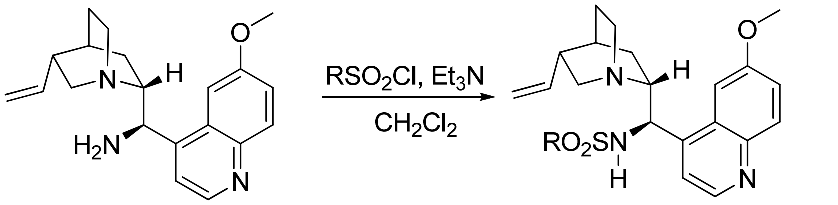
The enantiomeric excesses of products were determined by chiral-phase HPLC analysis, using a Daicel Chiralcel OD-H column (250 x 4.6 mm), or Chiralpak AD-H column, or IA column (250 x 4.6 mm).

Chemicals and solvents were purchased from commercial suppliers and used as received. **QD-1**,[1] **QD-2**[2] and **QD-3**[3] were prepared according to the literature procedure, but using quinidine as the starting material. All the α-substituted cyclic β-ketoesters[4] and nitroolefins[5] were prepared according to the literature procedures.

The absolute configuration of **3b** was assigned by comparing its specific rotation and HPLC data with those of the known compound reported in the literature[6,7] (page S6), and configurations of other Michael adducts were assigned by analogy.[7]

B. Preparation of cinchona alkaloid-derived catalysts

General procedure for the preparation of catalysts



QD-4: R = 4-CH_3Ph-
QD-5: R = 3,5-CF_3Ph-
QD-6: R = 4-FPh-
QD-7: R = 2-OH-3,5-ClPh-

9-Amino-9-deoxyepiquinidine was prepared from quinidine following the literature procedure.[1]

Preparation of **QD-4**

To a solution of 9-amino-9-deoxyepiquinidine (1.0 g, 3.09 mmol) in anhydrous dichloromethane (15 mL) at 0 ^{o}C was added triethylamine (1.3 mL, 9.27 mmol) under nitrogen atmosphere, followed by TsCl (0.62 g, 3.25 mmol). The reaction mixture was then stirred overnight at room temperature, and the solvent was removed *in vacuo*. The residue was purified by column chromatography to afford **QD-4** as a light yellow powder (1.2 g, 81%).

QD-4: a light yellow powder; $[\alpha]^{25}_{D}$ = + 58.7 (c 0.95, $CHCl_3$); ^{1}H NMR (500 MHz, CD_3OD) δ 8.47 (d, *J* = 4.4 Hz, 1H), 7.83 (d, *J* = 8.8 Hz, 1H), 7.47 (d, *J* = 4.4 Hz, 1H), 7.36 (m, 3H), 7.23 (s, 1H), 6.99 (d, *J* = 7.5 Hz, 2H), 5.77 (m, 1H), 5.02 (d, *J* = 10.7 Hz, 1H), 4.84 (m, 2H), 3.94 (s, 3H), 2.96 (m, 3H), 2.84 (m, 1H), 2.54 (m, 1H), 2.29 (s, 3H), 2.25 (br, 1H), 1.09 (m, 3H), 0.95 (m, 1H), 0.85 (m, 1H); ^{13}C NMR (125 MHz, CD_3OD) δ

158.3, 146.7, 145.5, 143.4, 143.3, 140.6, 136.5, 130.0, 128.8, 128.6, 127.1, 122.3, 120.3, 113.6, 100.4, 60.6, 54.9, 51.9, 48.5, 45.9, 38.2, 27.3, 25.8, 24.2, 19.9; HRMS (ESI) *m/z* calcd for $C_{27}H_{31}N_3O_3S$ $[M+H]^+$ 478.2164, found: 478.2141.

QD-5: a white powder (86% yield); $[\alpha]^{25}_D$ = + 89.2 (c 0.61, $CHCl_3$); ^1H NMR (500 MHz, CD_3OD) δ 8.39 (d, *J* = 5.1 Hz, 1H), 7.64-7.78 (m, 4H), 7.36 (d, *J* = 5.1 Hz, 1H), 7.30 (m, 2H), 5.83 (m, 1H), 5.12-5.17 (m, 3H), 3.93 (s, 3H), 3.88 (m, 1H), 3.35 (m, 1H), 3.05–3.10 (m, 3H), 2.45 (m, 1H), 1.66 (br, 3H), 1.03 (m, 1H); ^{13}C NMR (125 MHz, CD_3OD) δ 160.6, 148.0, 147.0, 146.0, 144.7, 140.7, 132.6, 132.4, 131.4, 129.4, 127.9, 125.6, 124.9, 123.9, 122.8, 121.2, 115.9, 101.6, 62.1, 56.2, 53.9, 49.9, 47.1, 38.9, 28.4, 26.2, 25.4; HRMS (IT-TOF) *m/z* calcd for $C_{28}H_{27}N_3O_3SF_6$ $[M+H]^+$ 600.1756, found: 600.1407.

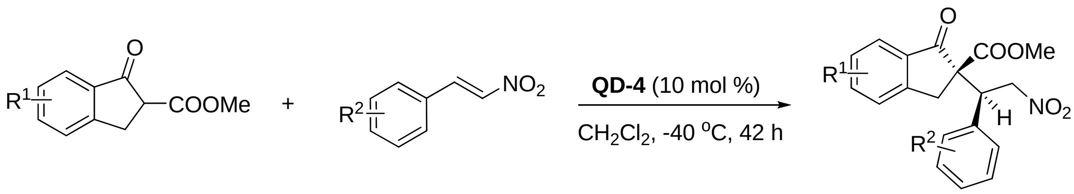
QD-6: a white powder (89% yield); $[\alpha]^{25}_D$ = + 92.3 (c 0.69, $CHCl_3$); ^1H NMR (500 MHz, CD_3OD) δ 8.47 (s, 1H), 7.85 (d, *J* = 8.8 Hz, 1H), 7.31–7.47 (m, 5H), 6.85–6.88 (m, 2H), 5.82 (m, 1H), 4.97-5.08 (m, 3H), 3.97 (s, 3H), 2.67–3.04 (m, 5H), 2.27 (br, 1H), 1.56 (br, 3H), 1.04 (m, 1H), 0.83 (m, 1H); ^{13}C NMR (125 MHz, CD_3OD) δ 167.0, 165.0, 159.8, 148.1, 146.6, 144.7, 141.9, 137.8, 131.5, 131.1, 131.0, 130.0, 123.8, 121.6, 116.5, 116.4, 116.3, 116.2, 115.1, 101.8, 79.5, 61.7, 56.3, 53.3, 49.9, 47.5, 39.6, 28.6, 27.2, 25.7; HRMS (IT-TOF) *m/z* calcd for $C_{26}H_{28}N_3O_3SF$ $[M+H]^+$ 482.1914, found: 482.1612.

QD-7: a slightly yellow powder (76% yield); $[\alpha]^{25}_D$ = + 55.0 (c 0.32, $CHCl_3$); ^1H NMR (300 MHz, d_6-DMSO) δ 8.77 (d, *J* = 4.7 Hz, 1H), 7.99 (d, *J* = 9.1 Hz, 1H), 7.57–7.63 (m, 2H), 7.48 (d, *J* = 9.1 Hz, 1H), 7.38 (s, 1H), 7.27 (d, *J* = 2.6 Hz, 1H), 5.88 (m, 1H), 5.47 (d,

J = 10.8 Hz, 1H), 5.11–5.17 (m, 2H), 4.14 (m, 1H), 3.99 (s, 3H), 3.42 (m, 4H), 2.71 (br, 1H), 1.74–1.99 (m, 3H), 1.48 (br, 1H), 0.79 (m, 1H); ^{13}C NMR (75 MHz, d_6-DMSO) δ 158.7, 148.5, 145.2, 141.5, 139.3, 133.7, 132.4, 128.7, 128.2, 128.1, 126.5, 122.8, 121.4, 117.0, 112.0, 102.8, 80.2, 60.7, 56.6, 49.8, 49.3, 46.2, 37.1, 27.4, 24.8, 23.8; HRMS (IT-TOF) *m/z* calcd for $C_{26}H_{27}N_3O_4Cl_2$ $[M+H]^+$ 548.1178, found: 548.0946.

C. Representative Procedure

General procedure for Micheal Addition of β-keto esters to aryl nitroolefins

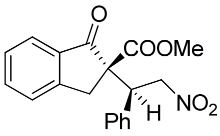


4a-4n

To a solution of aryl nitroolefin (0.055 mmol) and catalyst **QD-4** (0.005 mmol) in dichloromethane (0.15 mL) was added α-substituted cyclic β-ketoesters (0.05 mmol) at -40 °C. The reaction mixture was kept stirring at that temperature for the time specified. The mixture was then filtered through a short pad of silica gel, and the filtrate was concentrated *in vacuo*. Purification of the residue by flash chromatography afforded the desired Michael adduct.

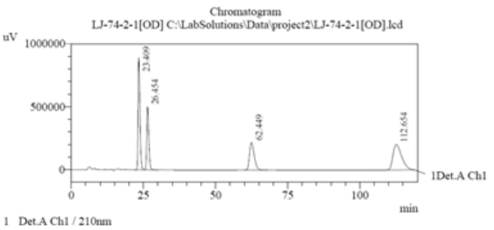
D. Analytical Data and HPLC Chromatogram of Michael Adducts

Methyl 2,3-dihydro-2-(2-nitro-1-phenylethyl)-1-oxo-1H-indene-2-carboxylate **3a**



3a

A yellow oil; diastereomeric ratio: 5.1 to 1, and the diastereomers could not be separated; the characterization data were in agreement with the literature value;[7] the ee value of the major isomer was 92%, t_R (major) = 23.4 min, 112.7 min, t_R (minor) = 26.5 min, 62.4 min (Chiralcel OD-H, λ = 210 nm, 20% *i*PrOH/hexanes, flow rate = 0.5 mL/min).

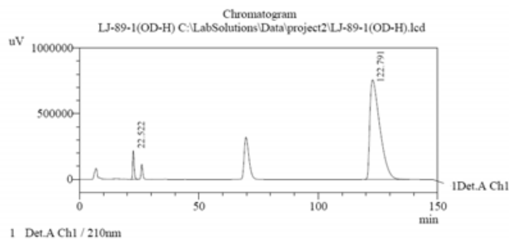


PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	23.409	40457274	891029	30.551	49.169
2	26.454	24547470	500752	18.537	27.632
3	62.449	25014780	218615	18.890	12.064
4	112.654	42404855	201795	32.022	11.135
Total		132424379	1812191	100.000	100.000

Racemic **3a**



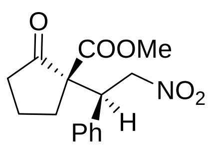
PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	22.522	9527880	218980	4.136	22.412
2	122.791	220820508	758101	95.864	77.588
Total		230348387	977081	100.000	100.000

Enantiomeric enriched **3a**

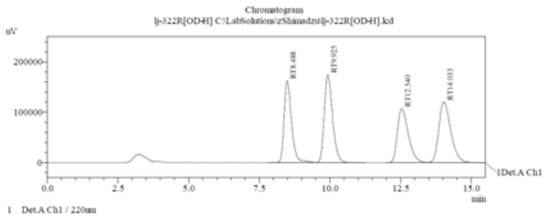
Methyl 1-(2-nitro-1-phenylethyl)-2-oxocyclopentanecarboxylate **3b**



3b

A colorless oil; the diastereomeric ratio was greater than 50 to 1, and the major diastereomer was obtained in pure form; $[\alpha]^{25}_D$ = -33.6 (c 0.79, $CHCl_3$), (lit[6]: $[\alpha]^{25}_D$ = +36.5 (c, 0.84, $CHCl_3$)). ^1H NMR (500 MHz, $CDCl_3$) δ 7.20-7.34 (m, 5H), 5.18 (dd, *J* =

13.8 Hz, 3.8 Hz, 1H), 5.03 (dd, J = 13.8 Hz, 10.7 Hz, 1H), 4.09 (dd, J = 10.8 Hz, 3.8 Hz, 1H), 3.78 (s, 3H), 2.32-2.42 (m, 2H), 1.85-2.07 (m, 4H). The ^{1}H NMR data were in agreement with the literature values;[6] The ee value of the major isomer was 90% (catalyzed by **QD-4**) and 91% (catalyzed by **QD-6**), t_R (major) = 9.9 min, 14.0 min (Chiralcel OD-H, λ = 220 nm, 20% *i*PrOH/hexanes, flow rate = 1.0 mL/min). For the minor diastereomers, t_R (minor) = 8.5 min, 12.5 min. (literature[6]: t_R (major) = 11.0 min, 17.0 min, t_R (minor) = 9.3 min, 13.0 min (Chiralcel OD-H, λ = 220 nm, 20% *i*PrOH/hexanes, flow rate = 1.0 mL/min)).

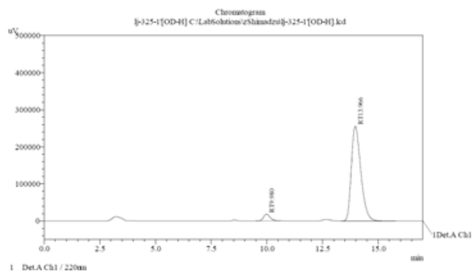


PeakTable

SPD-20A Ch1 220nm

Peak#	Name	Ret. Time	Area	Height	Area %	Units
1	RT8.488	8.488	2972327	162365	22.917	ppm
2	RT9.925	9.925	3555722	173872	27.415	ppm
3	RT12.540	12.540	2881967	107121	22.220	ppm
4	RT14.033	14.033	3560184	120430	27.449	ppm
Total			12970200	563789	100.000	

Racemic **3b**



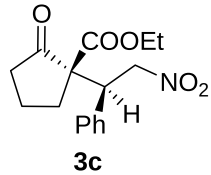
PeakTable

SPD-20A Ch1 220nm

Peak#	Name	Ret. Time	Area	Height	Area %	Units
1	RT9.980	9.980	374436	18268	4.719	ppm
2	RT13.966	13.966	7559544	255557	95.281	ppm
Total			7933980	273825	100.000	

Enantiomeric enriched **3b**,
(catalyzed by **QD-4**)

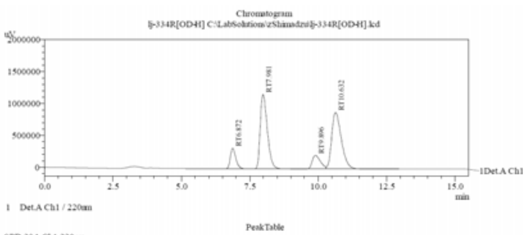
Ethyl 1-(2-nitro-1-phenylethyl)-2-oxocyclopentanecarboxylate **3c**



3c

A colorless oil; diastereomeric ratio was greater than 50 to 1, and the major diastereomer was obtained in pure form; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.25 – 7.30 (m, 5H), 5.17 (dd, J = 13.25, 3.8 Hz, 1H), 5.01 (dd, J = 13.25, 3.8 Hz, 1H), 4.21 (m, 2H), 4.07 (dd, J =

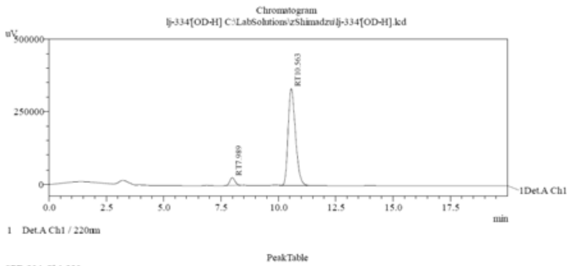
11.35, 3.8 Hz, 1H), 2.36 (m, 2H), 2.01 (m, 2H), 1.85 (m, 1H), 1.27 (t, J = 7.6, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 212.3, 169.3, 135.4, 129.3, 128.8, 128.3, 76.5, 62.5, 62.2, 46.2, 37.9, 31.3, 19.3, 14.0; HRMS (ESI) *m/z* calcd for $C_{16}H_{19}NO_5$ $[M+Na]^+$ 328.1161, found 328.1056; the ee value of the major isomer was 90%, t_R (major) = 8.0 min, 10.6 min, t_R (minor) = 6.9 min, 9.9 min (Chiralcel OD-H, λ = 220 nm, 20% *i*PrOH/hexanes, flow rate = 1.0 mL/min).



SPD-20A Ch1 220nm

Peak#	Name	Ret. Time	Area	Height	Area %	Units
1	RT6.872	6.872	4516861	321198	8.723	ppm
2	RT7.981	7.981	21116883	1169195	40.783	ppm
3	RT9.896	9.896	4430633	212135	8.557	ppm
4	RT10.632	10.632	21714822	885787	41.937	ppm
Total			51779200	2588316	100.000	

Racemic **3c**

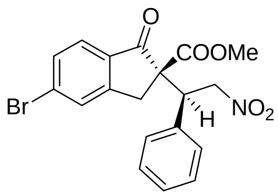


SPD-20A Ch1 220nm

Peak#	Name	Ret. Time	Area	Height	Area %	Units
1	RT7.989	7.989	403801	26633	5.137	ppm
2	RT10.563	10.563	7456151	332760	94.863	ppm
Total			7859953	359393	100.000	

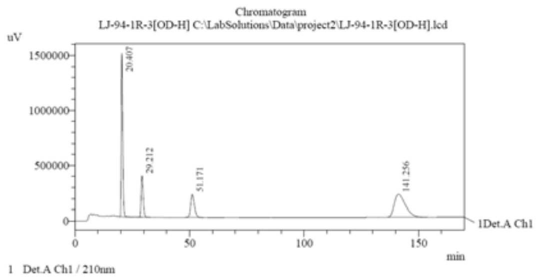
Enantiomeric enriched **3c**,
(catalyzed by **QD-6**)

Methyl 4-bromo-2,3-dihydro-2-(2-nitro-1-phenylethyl)-1-oxo-1H-indene-2-carboxylate **4a**



4a

A light yellow oil; diastereomeric ratio: 4.1 to 1, and the diastereomers could not be separated; ^{1}H NMR (500 MHz, $CDCl_3$) the major isomer: δ 7.65 – 7.43 (m, 3H), 7.28 - 7.15 (m, 5H), 5.42 – 5.16 (m, 2H), 4.26 (dd, J = 10.7 Hz, 3.8 Hz, 1H), 3.78 (s, 3H), 3.65 (d, J = 17.7 Hz, 1H), 3.22 (d, J = 17.7 Hz, 1H); the minor isomer: δ 7.65 – 7.43 (m, 3H), 7.28 -7.15 (m, 5H), 5.25 – 5.09 (m, 2H), 4.48 (dd, J = 10.7 Hz, 3.8 Hz, 1H), 3.73 (s, 3H), 3.47 (d, J = 17.7 Hz, 1H), 3.17 (d, J = 17.7 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 200.91, 198.61, 169.38, 153.90, 153.73, 135.34, 134.99, 134.52, 132.83, 131.78, 131.46, 131.31, 129.42, 128.96, 128.92, 128.80, 128.50, 128.45, 126.26, 125.82, 125.52, 76.63, 62.92, 61.70, 53.35, 52.87, 47.43, 46.92, 36.22, 34.65; HRMS (ESI) *m/z* calcd for $C_{19}H_{16}BrNO_5$ $[M+Na]^+$ 440.0110, found 440.0103; the ee value of the major isomer was 92%, t_R (major) = 20.4 min and 141.3 min, t_R (minor) = 29.2 min, 51.2 min (Chiralcel OD-H, λ = 210 nm, 30% *i*PrOH/hexanes, flow rate = 0.5 mL/min).

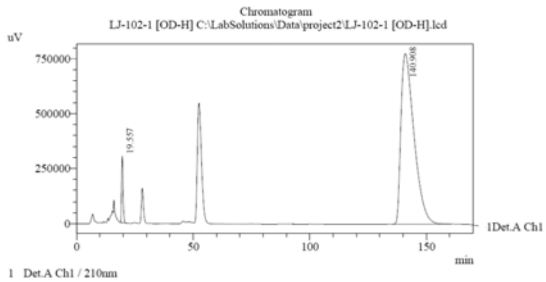


PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	20.407	66000877	1480801	36.708	65.545
2	29.212	22815013	371070	12.689	16.425
3	51.171	23014117	203010	12.800	8.986
4	141.256	67970105	204323	37.803	9.044
Total		179800112	2259204	100.000	100.000

Racemic **4a**



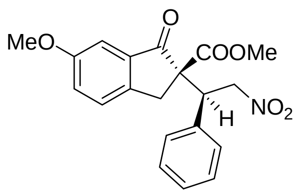
PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	19.557	13292972	301354	4.220	27.981
2	140.908	301681940	775647	95.780	72.019
Total		314974912	1077001	100.000	100.000

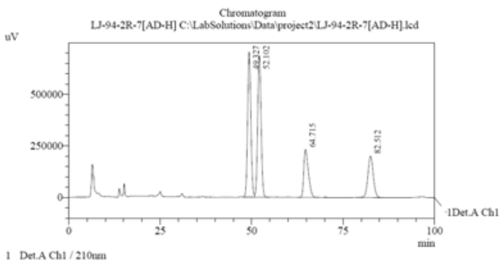
Enantiomeric enriched **4a**

Methyl 2,3-dihydro-6-methoxy-2-(2-nitro-1-phenylethyl)-1-oxo-1H-indene-2-carboxylate **4b**



4b

A colorless oil; diastereomeric ratio: 3.3 to 1, and the diastereomers could not be separated; ^{1}H NMR (500 MHz, $CDCl_3$): the major isomer, δ 7.29 – 7.10 (m, 8H), 5.46 – 5.42 (m, 1H), 5.22 – 5.17 (m, 1H), 4.27 – 4.24 (m, 1H), 3.82 (s, 3H), 3.76 (s, 3H), 3.58 (d, *J* = 17.0 Hz, 1H), 3.16 (d, *J* = 17.7 Hz, 1H); the minor isomer, δ 7.63 – 7.47 (m, 3H), 7.30 -7.10 (m, 5H), 5.31 – 5.06 (m, 2H), 4.51 – 4.48 (m, 1H), 3.86 (s, 3H), 3.73 (s, 3H), 3.42 (d, *J* = 17.0 Hz, 1H), 3.10 (d, *J* = 17.7 Hz, 1H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 201.97, 199.82, 171.29, 169.96, 159.82, 145.44, 145.35, 139.06, 137.38, 135.80, 135.24, 134.82, 132.14, 129.41, 129.14, 129.06, 129.00, 128.84, 128.65, 128.33, 126.80, 125.48, 125.30, 106.03, 105.37, 76.92, 63.59, 62.51, 55.63, 53.21, 47.61, 47.12, 35.95, 34.50; (75 MHz, $CDCl_3$) HRMS (ESI) *m/z* calcd for $C_{20}H_{19}NO_6$ $[M+Na]^+$ 392.1110, found 392.1101; the ee value of the major isomer was 90%, t_R (major) = 49.3 min and 52.1 min, t_R (minor) = 64.7 min, 82.5 min (Chiralcel AD-H, λ = 210 nm, 5% *i*PrOH/hexanes, flow rate = 0.5 mL/min).

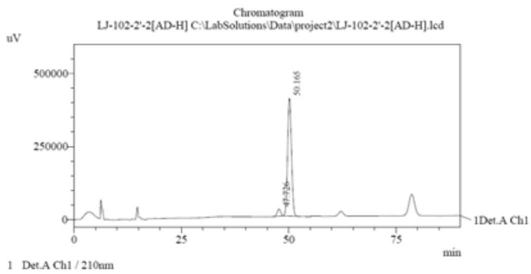


PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	49.327	44085095	703921	34.083	38.596
2	52.102	44367567	686394	34.302	37.635
3	64.715	20254432	232247	15.659	12.734
4	82.512	20638618	201245	15.956	11.034
Total		129345712	1823807	100.000	100.000

Racemic **4b**



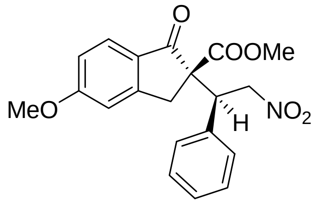
PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	47.726	1382549	24481	5.177	5.724
2	50.165	25321260	403221	94.823	94.276
Total		26703809	427702	100.000	100.000

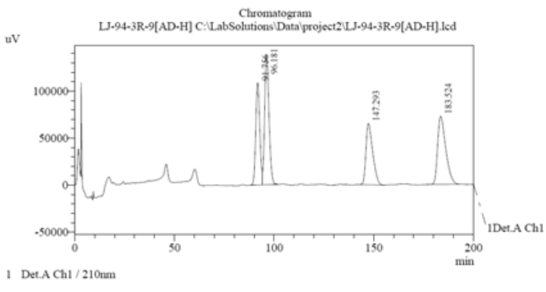
Enantiomeric enriched **4**

Methyl 2,3-dihydro-5-methoxy-2-(2-nitro-1-phenylethyl)-1-oxo-1H-indene-2-carboxylate **4c**



4c

A colorless oil; diastereomeric ratio: 3.3 to 1, and the diastereomers could not be separated; ^{1}H NMR (500 MHz, $CDCl_3$): the major isomer, δ 7.64 (d, J = 8.9 Hz, 1H), 7.28 – 7.18 (m, 5H), 6.91 – 6.62 (m, 2H), 5.50 – 5.47 (m, 1H), 5.24 – 5.20 (m, 1H), 4.23 – 4.20 (m, 1H), 3.89 (s, 3H), 3.77 (s, 3H), 3.60 (d, J = 17.7 Hz, 1H), 3.16 (d, J = 17.5 Hz, 1H); the minor isomer, δ 7.72 (d, J = 9.5 Hz, 1H), 7.28 – 7.15 (m, 5H), 6.91 -6.62 (m, 2H), 5.20 – 5.07 (m, 2H), 4.51 – 4.49 (m, 1H), 3.84 (s, 3H), 3.72 (s, 3H), 3.42 (d, J = 17.5 Hz, 1H), 3.11 (d, J = 17.5 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 197.71, 170.07, 166.19, 155.54, 135.95, 129.39, 129.01, 128.80, 128.61, 128.24, 126.97, 126.55, 126.24, 116.19, 109.18, 109.07, 77.19, 63.00, 55.72, 53.15, 47.43, 47.23, 36.35, 35.18; HRMS (ESI) *m/z* calcd for $C_{20}H_{19}NO_6$ $[M+Na]^+$ 392.1110, found 392.1115; the ee value of the major isomer was 95%, t_R (major) = 91.8 min and 147.3 min, t_R (minor) = 96.2 min, 183.5 min (Chiralcel AD-H, λ = 210 nm, 1.5% *i*PrOH/hexanes, flow rate = 1.0 mL/min).

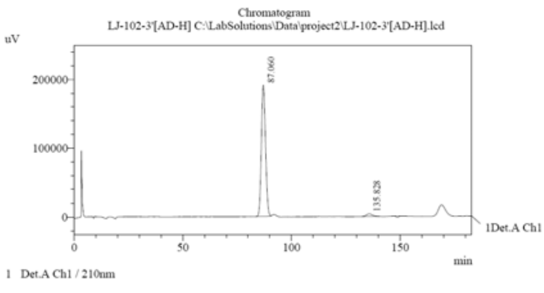


PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	91.756	15260747	108511	21.205	28.267
2	96.181	20965039	137721	29.131	35.877
3	147.293	15329009	65139	21.299	16.969
4	183.524	20414284	72501	28.365	18.887
Total		71969079	383872	100.000	100.000

Racemic **4c**



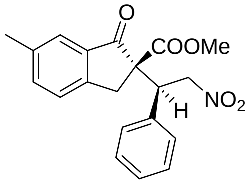
PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	87.060	25288926	190559	97.266	98.087
2	135.828	710781	3716	2.734	1.913
Total		25999707	194275	100.000	100.000

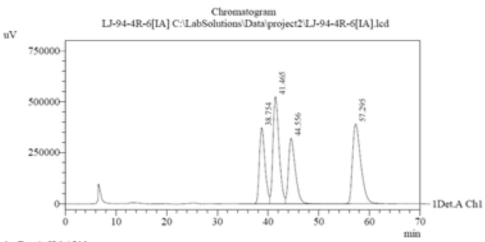
Enantiomeric enriched **4c**

Methyl 2,3-dihydro-6-methyl-2-(2-nitro-1-phenylethyl)-1-oxo-1H-indene-2-carboxylate **4d**



4d

A colorless oil; diastereomeric ratio: 5.9 to 1, and the diastereomers could not be separated; ^{1}H NMR (500 MHz, $CDCl_3$): the major isomer, δ 7.50 – 7.14 (m, 8H), 5.49 – 5.44 (m, 1H), 5.27 – 5.18 (m, 1H), 4.26 – 4.21 (m, 1H), 3.77 (s, 3H), 3.62 (d, *J* = 17.4 Hz, 1H), 3.19 (d, *J* = 17.4 Hz, 1H), 2.40 (s, 3H); the minor isomer, δ 7.58 – 7.14 (m, 8H), 5.23 – 5.06 (m, 2H), 4.54 – 4.26 (m, 1H), 3.73 (s, 3H), 3.45 (d, *J* = 10.5 Hz, 1H), 3.13 (d, *J* = 10.5 Hz, 1H), 2.42 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 199.82, 171.24, 169.92, 149.80, 149.74, 138.08, 138.03, 137.12, 137.00, 135.80, 134.82, 134.11, 129.00, 128.94, 128.75, 128.57, 128.20, 125.68, 124.99, 124.25, 76.87, 63.07, 62.01, 53.09, 47.46, 47.06, 36.14, 34.82, 20.93; HRMS (ESI) *m/z* calcd for $C_{20}H_{19}NO_5$ $[M+Na]^+$ 376.1161, found 376.1170; the ee value of the major isomer was 93%, t_R (major) = 38.8 min and 44.6 min, t_R (minor) = 41.5 min, 57.3 min (Chiralcel IA, λ = 210 nm, 2% *i*PrOH/hexanes, flow rate = 0.5 mL/min).

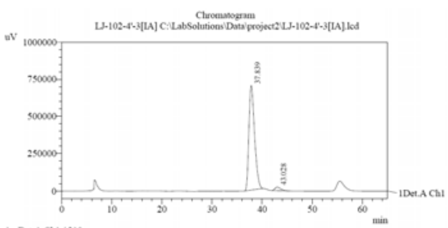


PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	38.754	28637481	372241	19.522	23.156
2	41.465	44060333	524926	30.035	32.654
3	44.556	29994997	319746	20.447	19.890
4	57.295	44001970	390628	29.996	24.300
Total		146694781	1607540	100.000	100.000

Racemic **4d**



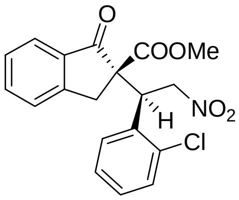
PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	37.839	54891225	699969	96.590	96.721
2	43.028	1937598	23733	3.410	3.279
Total		56828824	723701	100.000	100.000

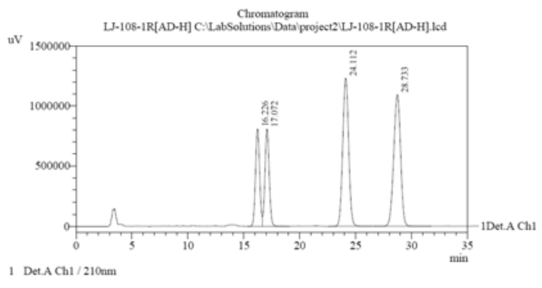
Enantiomeric enriched **4d**

Methyl 2-(1-(2-chlorophenyl)-2-nitroethyl)-2,3-dihydro-1-oxo-1H-indene-2-carboxylate **4e**



4e

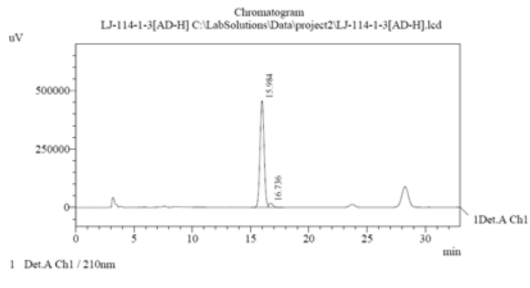
A colorless oil; diastereomeric ratio: 2.4 to 1, and the diastereomers could not be separated; ^{1}H NMR (300 MHz, $CDCl_3$): the major isomer, δ 7.82 – 7.18 (m, 8H), 5.76 – 5.70 (m, 1H), 5.42 – 5.34 (m, 1H), 4.62 – 4.57 (m, 1H), 3.72 (s, 3H), 3.53 (d, *J* = 17.4 Hz, 1H), 3.14 (d, *J* = 17.4 Hz, 1H); the minor isomer, δ 7.77 – 6.90 (m, 8H), 5.35 – 5.22 (m, 3H), 3.73 (s, 3H), 3.45 (d, *J* = 17.8 Hz, 1H), 3.13 (d, *J* = 17.8 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 200.07, 171.49, 169.93, 152.53, 152.45, 136.13, 135.73, 135.38, 133.50, 132.82, 130.21, 130.10, 129.45, 129.31, 128.89, 128.32, 128.20, 127.94, 127.77, 127.06, 126.24, 125.98, 125.46, 124.30, 76.65, 62.81, 61.17, 53.25, 53.05, 41.89, 36.62, 36.48; HRMS (ESI) *m/z* calcd for $C_{19}H_{16}NO_5Cl$ $[M+Na]^+$ 396.0615, found 396.0622; the ee value of the major isomer was 93%, t_R (major) = 16.2 min and 17.1 min, t_R (minor) = 24.1 min, 28.7 min (Chiralcel AD-H, λ = 210 nm, 5% *i*PrOH/hexanes, flow rate = 1.0 mL/min).



PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	16.226	20827200	808159	15.523	20.516
2	17.072	21324318	806870	15.894	20.483
3	24.112	45448266	1231295	33.874	31.257
4	28.733	46567427	1092930	34.709	27.745
Total		134167210	3939255	100.000	100.000



PeakTable

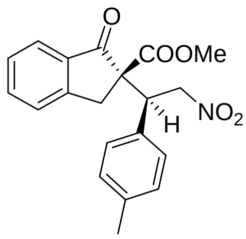
Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.984	11263071	457029	96.435	96.313
2	16.736	416416	17497	3.565	3.687
Total		11679488	474526	100.000	100.000

Racemic **4e**

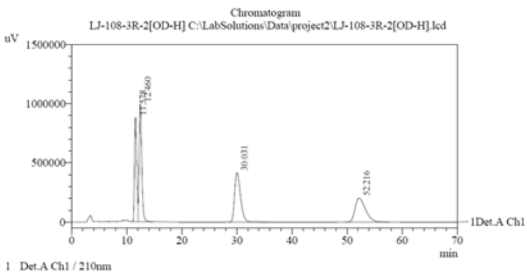
Enantiomeric enriched **4e**

Methyl 2,3-dihydro-2-(2-nitro-1-*p*-tolylethyl)-1-oxo-1H-indene-2-carboxylate **4f**



4f

A colorless oil; diastereomeric ratio: 7.1 to 1, and the diastereomers could not be separated; ^{1}H NMR (300 MHz, $CDCl_3$): the major isomer, δ 7.70 – 7.01 (m, 8H), 5.44 – 5.38 (m, 1H), 5.21 – 5.13 (m, 1H), 4.18 – 4.13 (m, 1H), 3.73 (s, 3H), 3.63 (d, J = 17.8 Hz, 1H), 3.20 (d, J = 17.8 Hz, 1H), 2.24 (s, 3H); the minor isomer, δ 7.78 – 6.92 (m, 8H), 5.20 – 5.00 (m, 2H), 4.47 – 4.42 (m, 1H), 3.69 (s, 3H), 3.48 (d, J = 17.7 Hz, 1H), 3.16 (d, J = 17.7 Hz, 1H), 2.19 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 199.83, 171.15, 169.80, 152.43, 152.36, 138.00, 135.75, 135.60, 133.98, 132.61, 131.57, 129.47, 129.30, 128.83, 128.75, 127.95, 127.90, 126.03, 125.16, 124.38, 77.19, 62.85, 61.82, 53.11, 47.16, 46.76, 36.45, 35.21, 20.89; HRMS (ESI) *m/z* calcd for $C_{20}H_{19}NO_5$ $[M+Na]^+$ 376.1161, found 376.1165; the ee value of the major isomer was 93%, t_R (major) = 11.6 min and 52.2 min, t_R (minor) = 12.5 min, 30.0 min (Chiralcel OD-H, λ = 210 nm, 15% *i*PrOH/hexanes, flow rate = 1.0 mL/min).

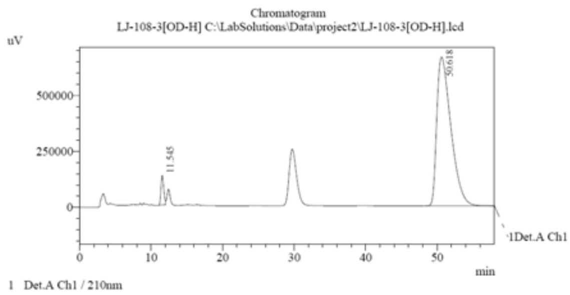


PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.578	24731494	882324	21.605	35.332
2	12.460	31994011	995581	27.950	39.867
3	30.031	31149221	417077	27.212	16.702
4	52.216	26594076	202244	23.233	8.099
Total		114468802	2497225	100.000	100.000

Racemic **4f**



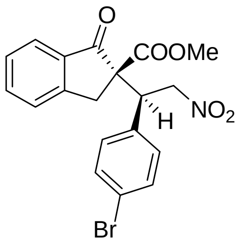
PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	11.545	3527489	131894	3.723	16.551
2	50.618	91233445	665016	96.277	83.449
Total		94760934	796910	100.000	100.000

Enantiomeric enriched **4f**

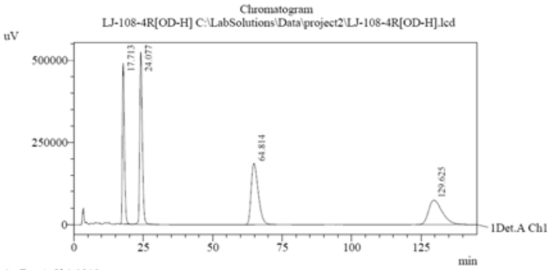
Methyl 2-(1-(4-bromophenyl)-2-nitroethyl)-2,3-dihydro-1-oxo-1H-indene-2-carboxylate **4g**



4g

A light yellow oil; diastereomeric ratio: 3.5 to 1, and the diastereomers could not be separated; ^{1}H NMR (300 MHz, $CDCl_3$): the major isomer, δ 7.70 – 7.14 (m, 8H), 5.42 – 5.36 (m, 1H), 5.18 – 5.10 (m, 1H), 4.22 – 4.17 (m, 1H), 3.72 (s, 3H), 3.63 (d, *J* = 17.4 Hz, 1H), 3.15 (d, *J* = 17.4 Hz, 1H); the minor isomer, δ 7.80 – 7.01 (m, 8H), 5.19 – 5.01 (m, 2H), 4.47 – 4.43 (m, 1H), 3.69 (s, 3H), 3.49 (d, *J* = 17.1 Hz, 1H), 3.11 (d, *J* = 17.1 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 199.56, 170.92, 169.72, 152.15, 152.07, 135.98, 135.92, 134.70, 133.86, 132.68, 131.95, 131.81, 130.73, 130.58, 130.30, 128.18, 126.11, 126.05, 125.26, 124.47, 122.49, 76.80, 62.46, 61.43, 53.25, 46.90, 46.41, 36.48, 35.11; HRMS (ESI) *m/z* calcd for $C_{19}H_{16}NO_5Br$ $[M+Na]^+$ 440.0110, found 440.0095; the ee value of the major isomer was 93%, t_R (major) = 17.7 min and 129.6 min, t_R (minor) =

24.1 min, 64.8 min (Chiralcel OD-H, λ = 210 nm, 15% *i*PrOH/hexanes, flow rate = 1.0 mL/min).



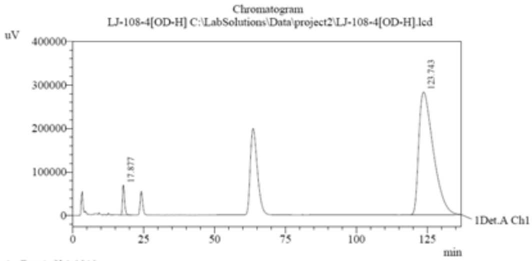
1 Det.A Ch1 / 210nm

PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	17.713	24686800	489495	21.255	38.494
2	24.077	33759695	524315	29.066	41.232
3	64.814	32671883	185351	28.130	14.576
4	129.625	25029497	72455	21.550	5.698
Total		116147874	1271615	100.000	100.000

Racemic **4g**



1 Det.A Ch1 / 210nm

PeakTable

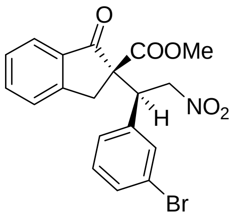
Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	17.877	3573538	69107	3.433	19.687
2	123.743	100530859	281922	96.567	80.313
Total		104104397	351029	100.000	100.000

-

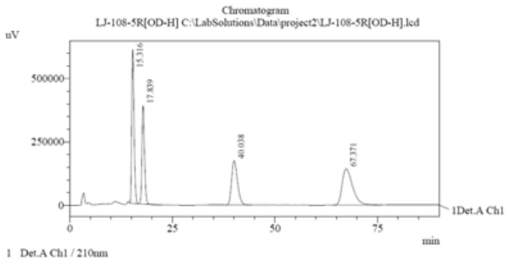
Enantiomeric enriched **4g**

<u>Methyl 2-(1-(3-bromophenyl)-2-nitroethyl)-2,3-dihydro-1-oxo-1H-indene-2-carboxylate **4h**</u>



4h

A light yellow oil; diastereomeric ratio: 4.4 to 1, and the diastereomers could not be separated; ^{1}H NMR (300 MHz, $CDCl_3$): the major isomer, δ 7.71 – 7.00 (m, 8H), 5.47 – 5.41 (m, 1H), 5.21 – 5.12 (m, 1H), 4.16 – 4.11 (m, 1H), 3.73 (s, 3H), 3.63 (d, *J* = 17.8 Hz, 1H), 3.14 (d, *J* = 17.8 Hz, 1H); the minor isomer, δ 7.79 – 6.98 (m, 8H), 5.10 – 5.01 (m, 2H), 4.47 – 4.42 (m, 1H), 3.70 (s, 3H), 3.50 (d, *J* = 17.1 Hz, 1H), 3.11 (d, *J* = 17.1 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 201.63, 199.65, 170.87, 169.75, 152.20, 152.14, 138.23, 136.05, 135.95, 133.85, 132.26, 132.01, 131.54, 130.35, 130.14, 128.22, 127.88, 127.39, 126.13, 125.31, 124.52, 122.86, 122.64, 76.53, 62.47, 61.57, 53.31, 46.98, 46.66, 36.48, 35.39; HRMS (ESI) *m/z* calcd for $C_{19}H_{16}NO_5Br$ $[M+Na]^+$ 440.0110, found 440.0092; the ee value of the major isomer was 95%, t_R (major) = 15.3 min and 67.4 min, t_R (minor) = 17.8 min, 40.0 min (Chiralcel OD-H, λ = 210 nm, 15% *i*PrOH/hexanes, flow rate = 1.0 mL/min).

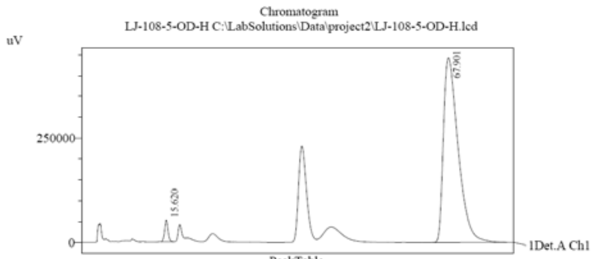


PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.316	24024104	606611	28.640	46.212
2	17.839	17001105	388550	20.268	29.600
3	40.038	17462193	174666	20.818	13.306
4	67.371	25394330	142856	30.274	10.883
Total		83881732	1312682	100.000	100.000

Racemic **4h**



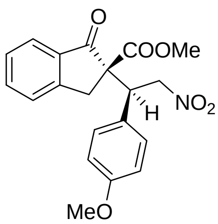
PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.620	2275356	52860	2.640	10.671
2	67.901	83901045	442489	97.360	89.329
Total		86176400	495349	100.000	100.000

Enantiomeric enriched **4h**

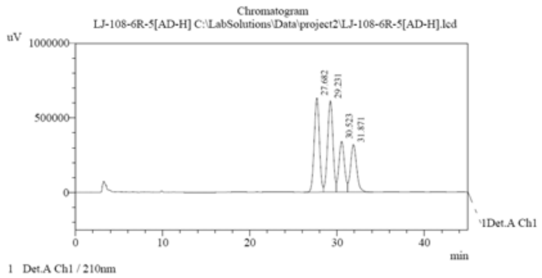
<u>Methyl 2,3-dihydro-2-(1-(4-methoxyphenyl)-2-nitroethyl)-1-oxo-1H-indene-2-carboxylate **4i**</u>



4i

A colorless oil; diastereomeric ratio: 4.6 to 1, and the diastereomers could not be separated; ^{1}H NMR (300 MHz, $CDCl_3$): the major isomer, δ 7.69 – 7.15 (m, 6H), 6.75 (d, *J* = 8.7 Hz, 2H), 5.39 – 5.34 (m, 1H), 5.18 – 5.10 (m, 1H), 4.20 – 4.15 (m, 1H), 3.74 (s, 3H), 3.72 (s, 3H), 3.63 (d, *J* = 17.7 Hz, 1H), 3.20 (d, *J* = 17.8 Hz, 1H); the minor isomer, δ 7.77 – 7.04 (m, 6H), 6.65 (d, *J* = 8.7 Hz, 2H), 5.20 – 4.99 (m, 2H), 4.44 – 4.39 (m, 1H), 3.69 (s, 3H), 3.68 (s, 3H), 3.47 (d, *J* = 17.4 Hz, 1H), 3.16 (d, *J* = 17.4 Hz, 1H); ^{13}C NMR

(75 MHz, $CDCl_3$) δ 202.10, 199.86, 171.21, 169.85, 159.28, 152.40, 152.33, 136.12, 135.75, 135.65, 134.02, 130.12, 130.03, 127.98, 127.91, 127.42, 126.43, 126.05, 126.02, 125.14, 124.36, 114.13, 113.97, 77.14, 62.95, 61.83, 55.08, 55.03, 53.11, 46.85, 46.37, 36.54, 35.07; HRMS (ESI) *m/z* calcd for $C_{20}H_{19}NO_6$ $[M+Na]^+$ 392.1110, found 392.1099; the ee value of the major isomer was 96%, t_R (major) = 30.5 min and 31.9 min, t_R (minor) = 27.7 min, 29.2 min (Chiralcel AD-H, λ = 210 nm, 6% *i*PrOH/hexanes, flow rate = 1.0 mL/min).

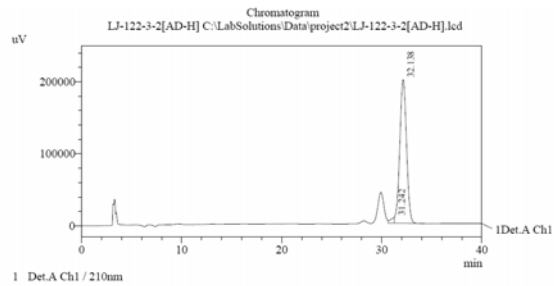


PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	27.682	26127453	632162	31.539	33.210
2	29.231	26206805	612259	31.635	32.165
3	30.523	15017254	340020	18.128	17.863
4	31.871	15489484	319078	18.698	16.763
Total		82840996	1903519	100.000	100.000

Racemic **4i**



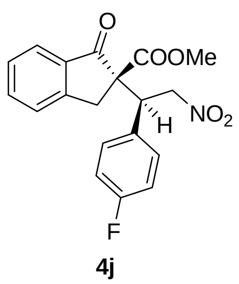
PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	31.242	198544	8095	2.076	3.901
2	32.138	9364856	199384	97.924	96.099
Total		9563400	207479	100.000	100.000

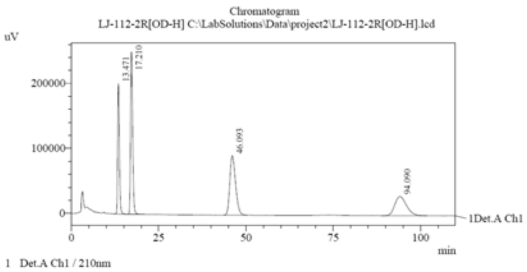
Enantiomeric enriched **4i**

Methyl 2-(1-(4-fluorophenyl)-2-nitroethyl)-2,3-dihydro-1-oxo-1H-indene-2-carboxylate **4j**



4j

A light yellow oil; diastereomeric ratio: 3.5 to 1, and the diastereomers could not be separated; ^1H NMR (300 MHz, $CDCl_3$): the major isomer, δ 7.68 – 6.88 (m, 8H), 5.41 – 5.35 (m, 1H), 5.18 – 5.09 (m, 1H), 4.27 – 4.22 (m, 1H), 3.73 (s, 3H), 3.63 (d, *J* = 17.8 Hz, 1H), 3.17 (d, *J* = 17.8 Hz, 1H); the minor isomer, δ 7.78 – 6.80 (m, 8H), 5.21 – 5.02 (m, 2H), 4.49 – 4.44 (m, 1H), 3.70 (s, 3H), 3.49 (d, *J* = 17.4 Hz, 1H), 3.11 (d, *J* = 17.4 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$) δ 201.92, 199.76, 171.09, 169.84, 164.05, 160.76, 152.28, 135.96, 135.90, 135.45, 133.97, 131.34, 131.29, 130.85, 130.74, 130.62, 128.17, 126.07, 125.23, 124.47, 115.92, 115.79, 115.54, 115.51, 76.74, 62.68, 61.59, 53.27, 46.80, 46.25, 36.59, 35.01; HRMS (ESI) *m/z* calcd for $C_{19}H_{16}NO_5F$ $[M+Na]^+$ 380.0910, found 380.0909; the ee value of the major isomer was 94%, t_R (major) = 13.5min, 94.1 min, t_R (minor) = 17.2 min, 46.1 min (Chiralcel OD-H, λ = 210 nm, 15% *i*PrOH/hexanes, flow rate = 1.0 mL/min).

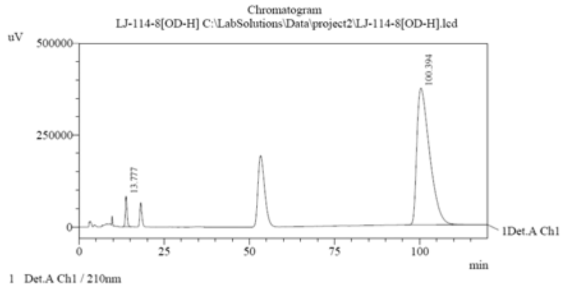


PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	13.471	6941524	200813	19.935	35.110
2	17.210	10472908	250003	30.076	43.710
3	46.093	10508713	91537	30.179	16.004
4	94.090	6898408	29604	19.811	5.176
Total		34821554	571957	100.000	100.000

Racemic **4j**



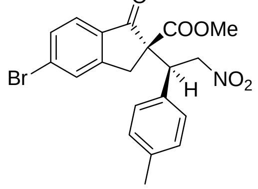
PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	13.777	2952658	82405	2.959	18.146
2	100.394	96846828	371714	97.041	81.854
Total		99799487	454119	100.000	100.000

Enantiomeric enriched **4j**

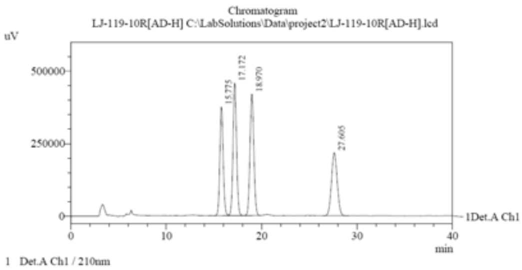
Methyl 5-bromo-2,3-dihydro-2-(2-nitro-1-p-tolylethyl)-1-oxo-1H-indene-2-carboxylate **4k**



4k

A light yellow oil; diastereomeric ratio: 3.3 to 1, and the diastereomers could not be separated; ^{1}H NMR (300 MHz, $CDCl_3$): the major isomer, δ 7.56 – 6.96 (m, 7H), 5.38 –

5.32 (m, 1H), 5.17 – 5.09 (m, 1H), 4.22 – 4.17 (m, 1H), 3.74 (s, 3H), 3.61 (d, J = 17.8 Hz, 1H), 3.19 (d, J = 17.8 Hz, 1H), 2.25 (s, 3H); the minor isomer, δ 7.63 – 6.93 (m, 7H), 5.22 – 5.01 (m, 2H), 4.26 – 4.38 (m, 1H), 3.70 (s, 3H), 3.42 (d, J = 17.8 Hz, 1H), 3.14 (d, J = 17.8 Hz, 1H), 2.21 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$)) δ 201.52, 198.63, 170.92, 169.38, 153.96, 153.82, 138.23, 135.02, 132.86, 132.22, 131.74, 131.53, 131.42, 131.24, 130.13, 129.62, 129.51, 129.44, 128.82, 128.76, 127.79, 126.28, 125.82, 125.51, 77.11, 63.03, 61.79, 53.33, 47.13, 46.62, 36.22, 34.65, 20.96; HRMS (ESI) *m/z* calcd for $C_{20}H_{18}NO_5Br$ $[M+Na]^+$ 454.0266, found 454.0271; the ee value of the major isomer was 90%, t_R (major) = 15.8 min, 27.6 min, t_R (minor) = 17.2 min, 19.0 min (Chiralcel AD-H, λ = 210 nm, 10% *i*PrOH/hexanes, flow rate = 1.0 mL/min).

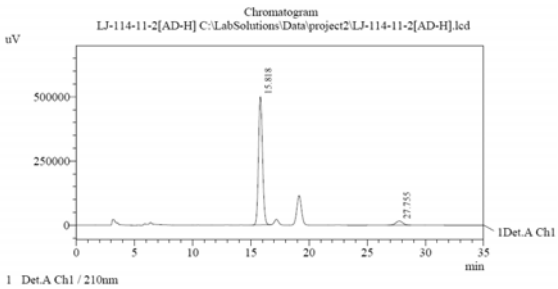


PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.775	9261521	375189	22.055	25.545
2	17.172	11860037	457331	28.242	31.138
3	18.970	11788330	418674	28.072	28.506
4	27.605	9083857	217524	21.631	14.810
Total		41993746	1468718	100.000	100.000

Racemic **4k**



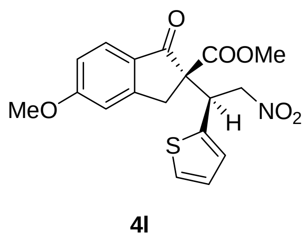
PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	15.818	12097025	500236	94.913	96.936
2	27.755	648345	15814	5.087	3.064
Total		12745370	516050	100.000	100.000

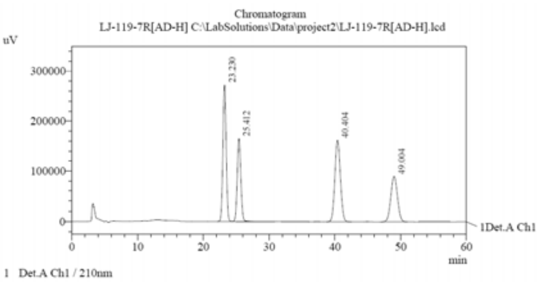
Enantiomeric enriched **4k**

<u>Methyl 2,3-dihydro-5-methoxy-2-(2-nitro-1-(thiophen-2-yl)ethyl)-1-oxo-1H-indene-2-carboxylate **4l**</u>



4l

A yellow oil; diastereomeric ratio: 3.1 to 1, and the diastereomers could not be separated; ^{1}H NMR (300 MHz, $CDCl_3$): the major isomer, δ 7.67 (d, *J* = 8.5 Hz, 1H), 7.18 – 7.17 (m, 1H), 6.97 – 6.85 (m, 4H), 5.44 – 5.40 (m, 1H), 5.15 – 5.10 (m, 1H), 4.597 – 4.56 (m, 1H), 3.91 (s, 3H), 3.78 (s, 3H), 3.65 (d, *J* = 17.7 Hz, 1H), 3.26 (d, *J* = 17.7 Hz, 1H); the minor isomer, δ 7.73 (d, *J* = 8.5 Hz, 1H), 7.15 – 7.13 (m, 1H), 6.96 – 6.80 (m, 4H), 5.06 – 5.01 (m, 1H), 4.94 – 4.90 (m, 2H), 3.88 (s, 3H), 3.73 (s, 3H), 3.57 (d, *J* = 17.7 Hz, 1H), 3.24 (d, *J* = 17.7 Hz, 1H); ^{13}C NMR (75 MHz, $CDCl_3$)) δ 198.63, 197.42, 170.52, 169.90, 166.26, 166.17, 155.67, 155.59, 138.09, 137.28, 128.94, 128.53, 127.85, 127.07, 127.00, 126.72, 126.62, 126.44, 125.87, 125.60, 116.32, 116.27, 109.26, 77.88, 63.03, 62.78, 55.70, 53.20, 53.17, 43.24, 42.74, 35.99, 35.74; HRMS (ESI) *m/z* calcd for $C_{18}H_{17}NO_6S$ $[M+Na]^+$ 398.0674, found 398.0682; the ee value of the major isomer was 90%, t_R (major) = 23.2 min, 40.4 min, t_R (minor) = 25.4 min, 49.0 min (Chiralcel AD-H, λ = 210 nm, 10% *i*PrOH/hexanes, flow rate = 1.0 mL/min).

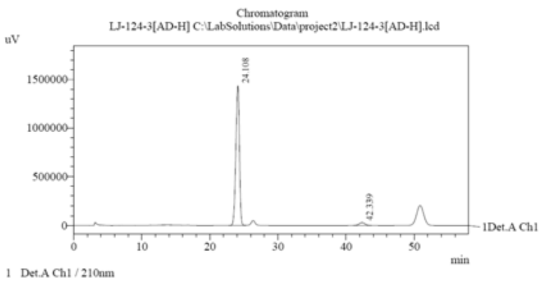


PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	23.230	9351211	272728	29.816	39.511
2	25.412	6280525	165249	20.025	23.940
3	40.404	9450692	162347	30.133	23.520
4	49.004	6280433	89939	20.025	13.030
Total		3			100.000

Racemic **4l**



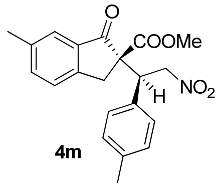
PeakTable

Detector A Ch1 210nm

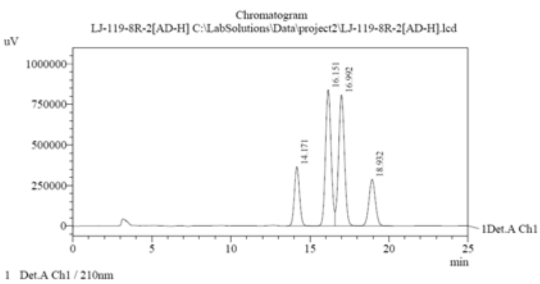
Peak#	Ret. Time	Area	Height	Area %	Height %
1	24.108	52522534	1436256	96.785	97.998
2	42.339	1744876	29343	3.215	2.002
Total					

Enantiomeric enriched **4l**

Methyl 2,3-dihydro-6-methyl-2-(2-nitro-1-p-tolylethyl)-1-oxo-1H-indene-2-carboxylate **4m**



A colorless oil; diastereomeric ratio: 8.8 to 1, and the diastereomers could not be separated; ^{1}H NMR (500 MHz, $CDCl_3$): the major isomer, δ 7.51 (s, 1H), 7.44 – 7.04 (m, 6H), 5.44 – 5.41 (m, 1H), 5.22 – 5.17 (m, 1H), 4.19 – 4.16 (m, 1H), 3.75 (s, 3H), 3.59 (d, *J* = 17.7 Hz, 1H), 3.18 (d, *J* = 17.7 Hz, 1H), 2.39 (s, 3H), 2.27 (s, 3H); the minor isomer, δ 7.59 (s, 1H), 7.38 – 6.96 (m, 6H), 5.20 – 5.02 (m, 2H), 4.48 – 4.45 (m, 1H), 3.71 (s, 3H), 3.44 (d, *J* = 17.7 Hz, 1H), 3.14 (d, *J* = 17.7 Hz, 1H), 2.41 (s, 3H), 2.22 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$)) δ 199.91, 169.97, 149.91, 138.09, 137.99, 137.15, 137.02, 136.29, 134.16, 132.76, 129.51, 129.36, 128.90, 128.80, 126.17, 125.76, 125.05, 124.30, 77.04, 63.22, 53.40, 53.14, 47.18, 46.81, 36.11, 34.91, 21.00, 20.96; HRMS (ESI) *m/z* calcd for $C_{21}H_{21}NO_5$ $[M+Na]^+$ 390.1317, found 390.1312; the ee value of the major isomer was 91%, t_R (major) = 16.2 min, 17.0 min, t_R (minor) = 14.2 min, 18.9 min (Chiralcel AD-H, λ = 210 nm, 6% *i*PrOH/hexanes, flow rate = 1.0 mL/min).

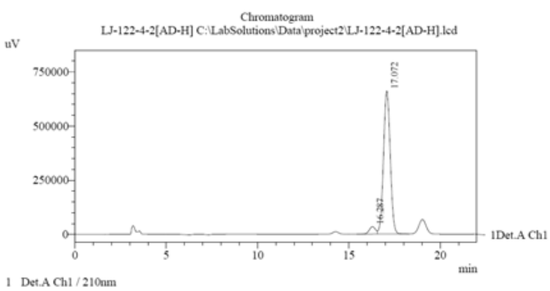


PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	14.171	8179543	364993	14.061	15.872
2	16.151	20834099	839747	35.816	36.517
3	16.992	20976346	808080	36.060	35.140
4	18.932	8180170	286782	14.062	12.471
Total		58170157	2299602	100.000	100.000

Racemic **4m**



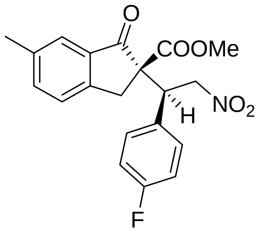
PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	16.287	810569	34231	4.581	4.929
2	17.072	16884988	660262	95.419	95.071
Total		17695557	694494	100.000	100.000

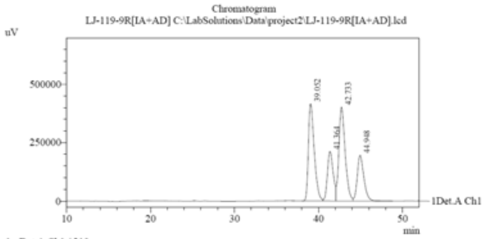
Enantiomeric enriched **4m**

Methyl 2-(1-(4-fluorophenyl)-2-nitroethyl)-2,3-dihydro-6-methyl-1-oxo-1H-indene-2-carboxylate **4n**



4n

A colorless oil; diastereomeric ratio: 4.1 to 1, and the diastereomers could not be separated; ^{1}H NMR (500 MHz, $CDCl_3$): the major isomer, δ 7.49 (s, 1H), 7.43 (d, *J* = 8.5 Hz, 1H), 7.31 – 7.25 (m, 3H), 6.96 – 6.92 (m, 2H), 5.41 – 5.37 (m, 1H), 5.18 – 5.13 (m, 1H), 4.28 – 4.25 (m, 1H), 3.75 (s, 3H), 3.60 (d, *J* = 17.7 Hz, 1H), 3.15 (d, *J* = 17.7 Hz, 1H), 2.39 (s, 3H); the minor isomer, δ 7.58 (s, 1H), 7.38 (d, *J* = 8.5 Hz, 1H), 7.17 – 7.14 (m, 3H), 6.88 – 6.85 (m, 2H), 5.22 – 5.05 (m, 2H), 4.50 – 4.47 (m, 1H), 3.72 (s, 3H), 3.45 (d, *J* = 17.7 Hz, 1H), 3.09 (d, *J* = 17.7 Hz, 1H), 2.41 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3$)) δ 201.97, 199.78, 171.23, 169.97, 164.02, 160.74, 149.72, 149.64, 138.29, 137.30, 137.25, 136.25, 134.14, 131.41, 131.36, 130.86, 130.75, 130.63, 125.74, 125.05, 124.31, 115.91, 115.79, 115.62, 115.51, 77.11, 62.99, 61.87, 53.23, 46.79, 46.23, 36.24, 34.62, 20.99; HRMS (ESI) *m/z* calcd for $C_{20}H_{18}NO_5F$ $[M+Na]^+$ 394.1067, found 394.1059; the ee value of the major isomer was 94%, t_R (major) = 41.4 min, 44.9 min, t_R (minor) = 39.1 min, 42.7 min (Chiralcel IA + AD-H, λ = 210 nm, 5% *i*PrOH/hexanes, flow rate = 1.0 mL/min).



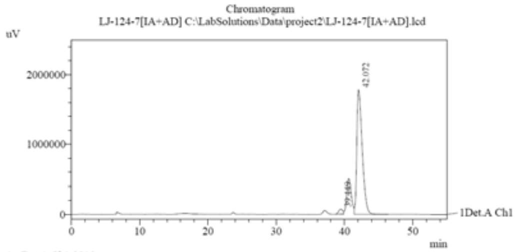
1 Det.A Ch1 / 210nm

PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	39.052	20135864	415524	32.726	34.028
2	41.364	9959515	210541	16.187	17.242
3	42.733	20810248	401350	33.822	32.867
4	44.948	10623270	193704	17.265	15.863
Total		61528897	1221118	100.000	100.000

Racemic **4n**



1 Det.A Ch1 / 210nm

PeakTable

Detector A Ch1 210nm

Peak#	Ret. Time	Area	Height	Area %	Height %
1	39.449	2970778	71839	2.923	3.875
2	42.072	98648122	1782124	97.077	96.125
Total		101618900	1853963	100.000	100.000

Enantiomeric enriched **4n**

References

[1] B. Vakulya, S. Varga, A. Csámpai, T. Soós, *Org. Lett.* **2005**, *7*, 1967.

[2] H. Li, Y. Wang, L. Tang, L. Deng, *J. Am. Chem. Soc.* **2004**, *126*, 9906.

[3] L. Deng, X. Liu, Y. Chen, S. Tian, *PCT Int. Appl.*, 2004110609, 2004.

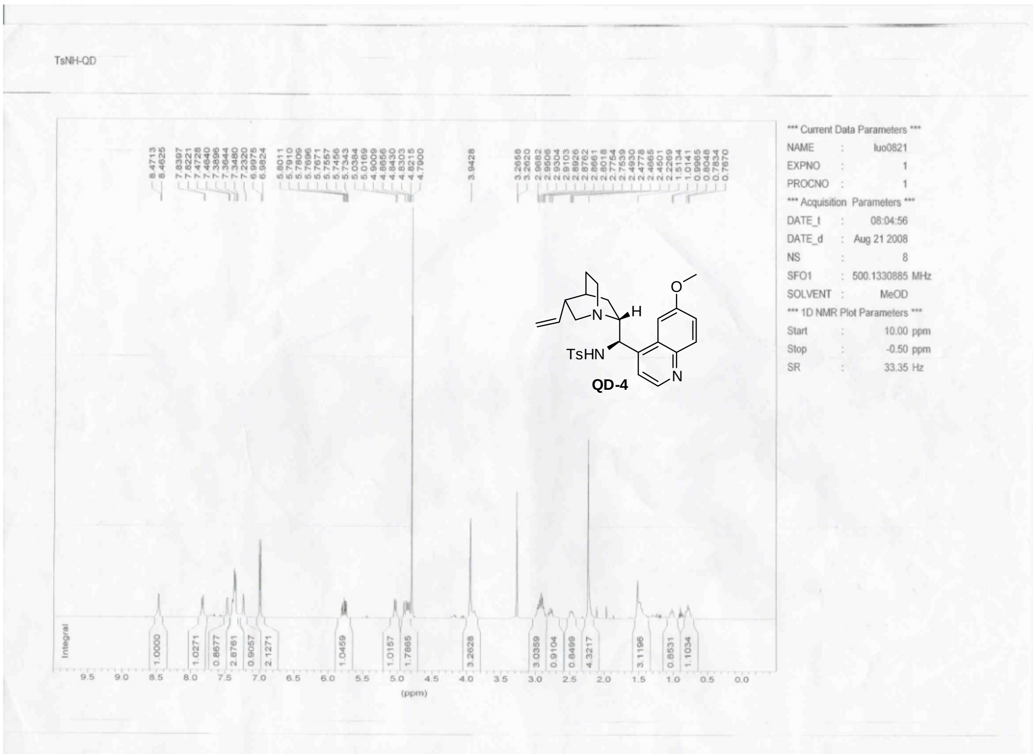
[4] S. Kobayashi, T. Gustafsson, Y. Shimizu, H. Kiyohara, R. Matsubara, *Org. Lett.* **2006**, *8*, 4923.

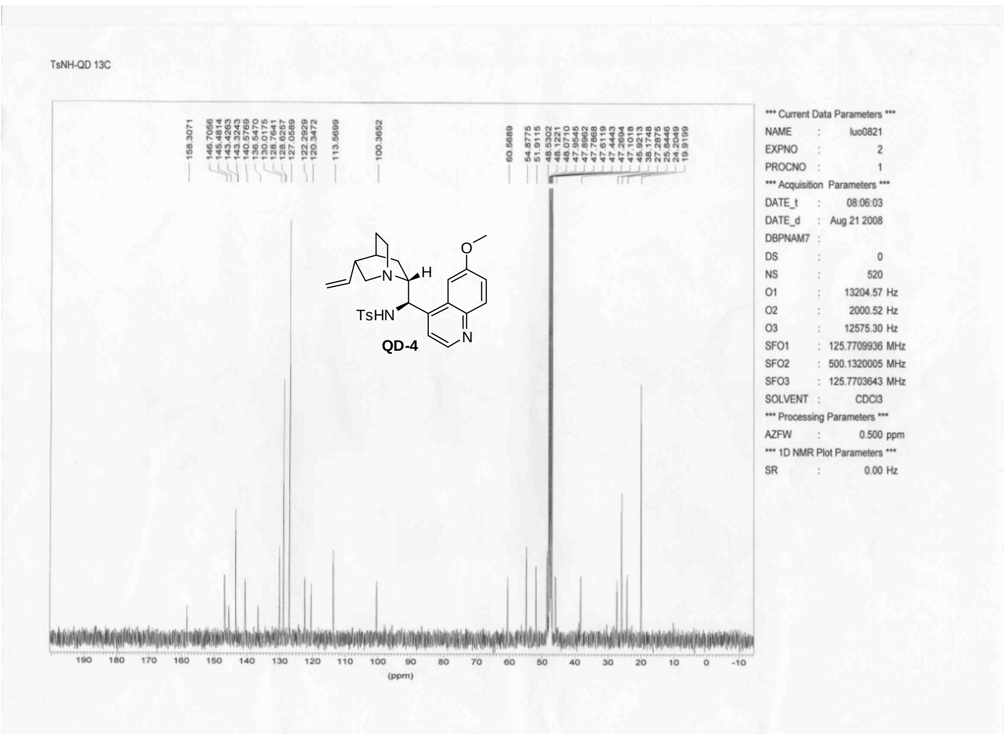
[5] B. M. Trost, C. Müller, *J. Am. Chem. Soc.* **2008**, *130*, 2438.

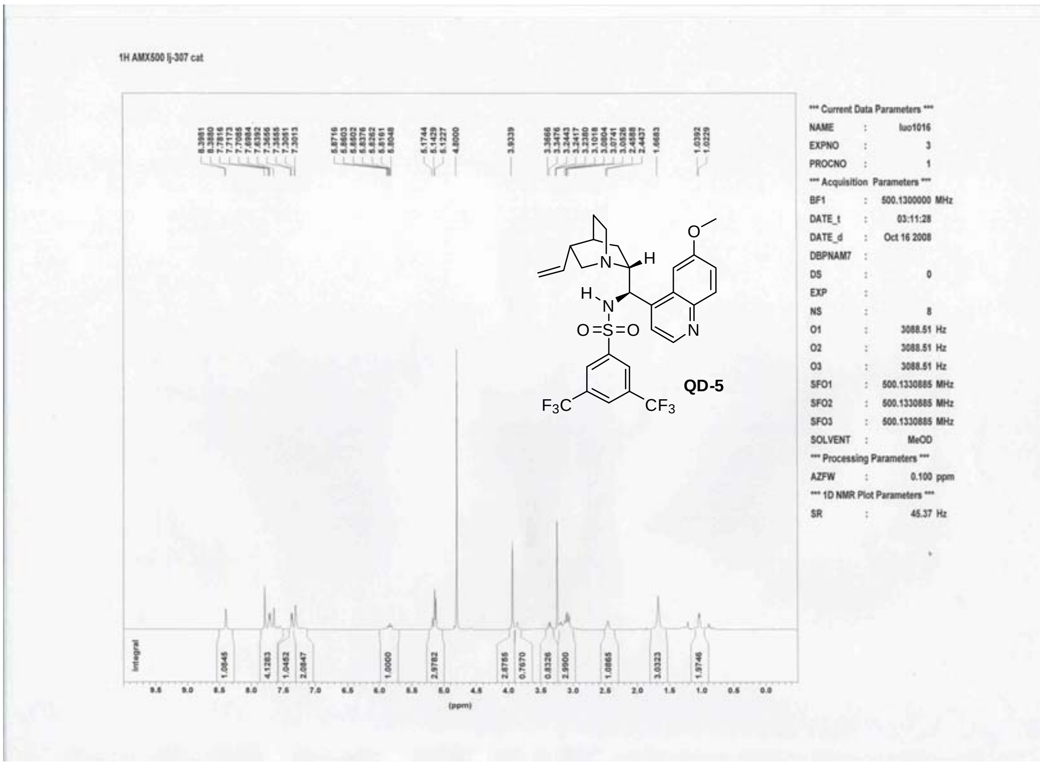
[6] H. Li, Y. Wang, L. Tang, F. Wu, X. Liu, C. Guo, B. M. Foxman, L. Deng, *Angew. Chem. Int. Ed.* **2005**, *44*, 105.

[7] T. Okino, Y. Hoashi, T. Furukawa, X. Xu, Y. Takemoto, *J. Am. Chem. Soc.* **2005**, *127*, 119.

E. NMR Spectra of Products



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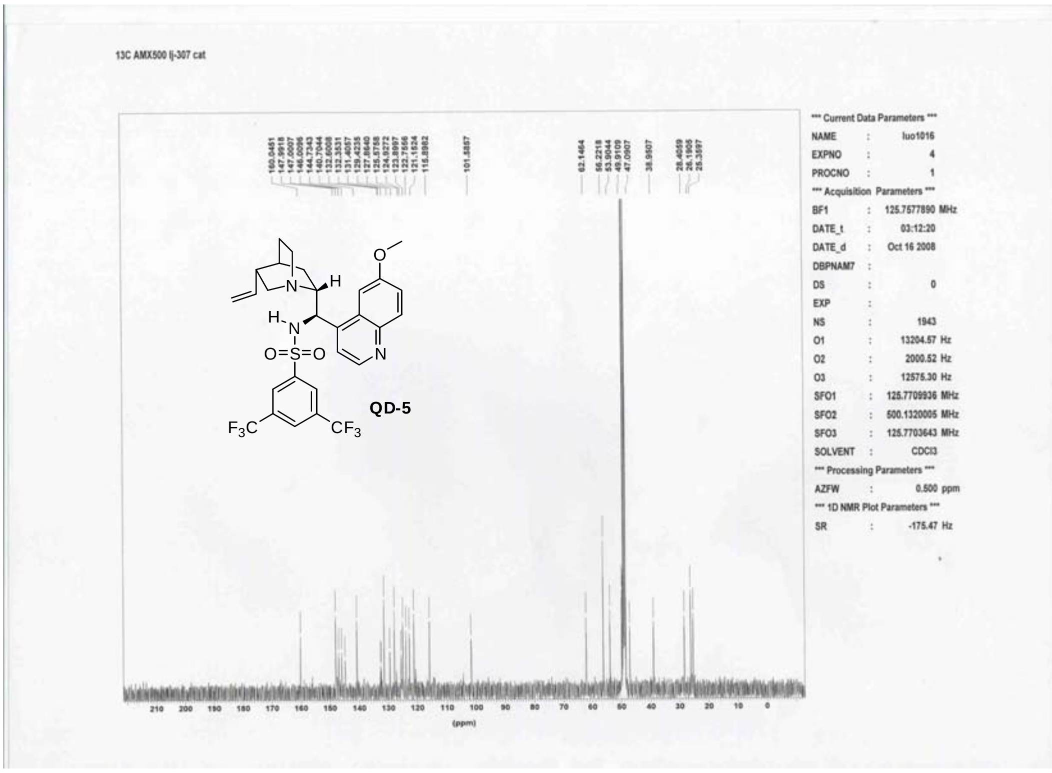
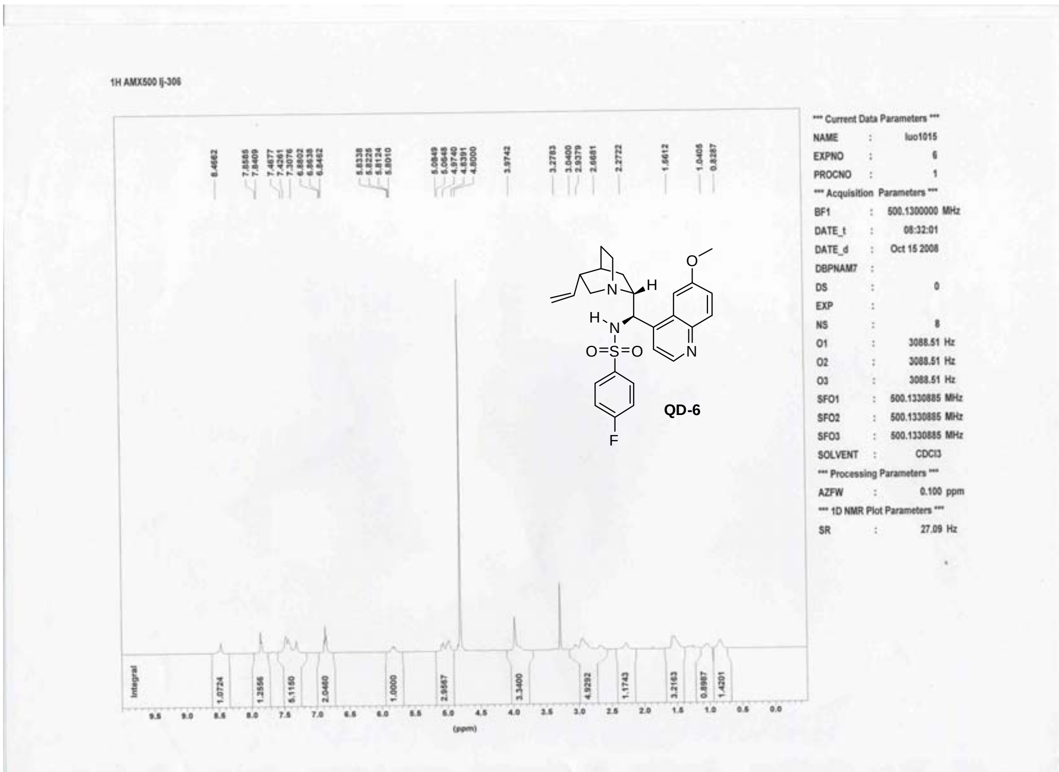
QD-5
(ppm)
SOLVENT : MeOD


13C AMX500 lj-307 cat
QD-5
(ppm)
SOLVENT : CDCl3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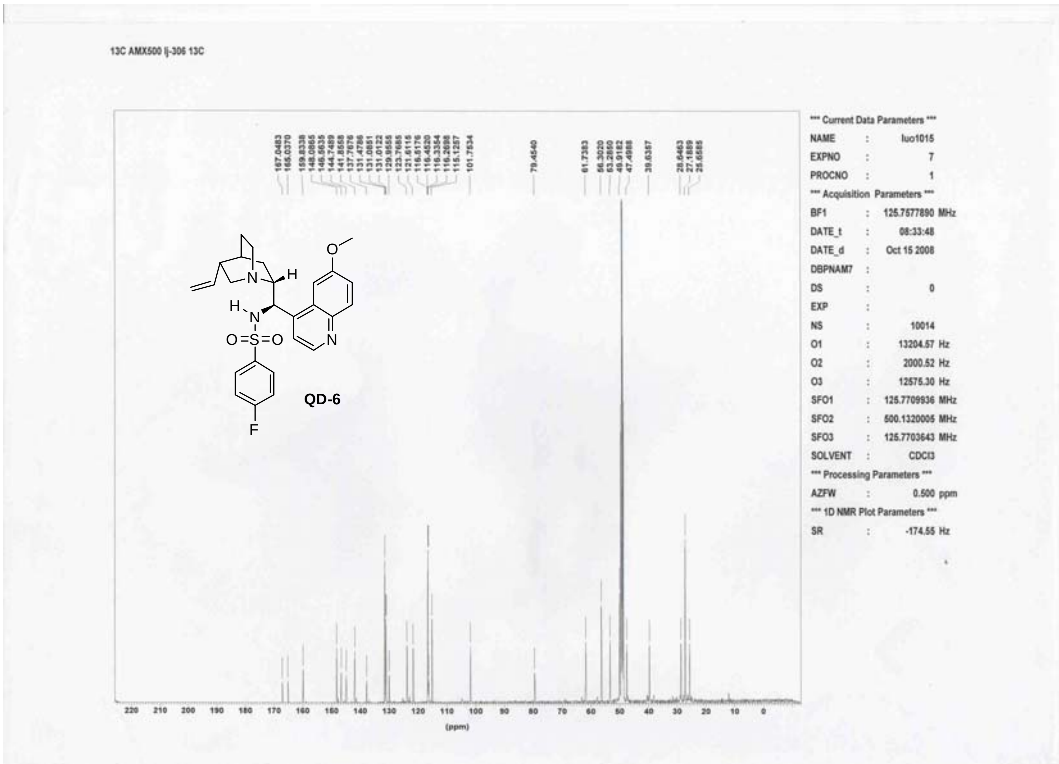
NAME : luo1015
EXPNO : 6
PROCNO : 1
*** Acquisition Parameters ***
BF1 : 500.1300000 MHz
DATE_t : 08:32:01
DATE_d : Oct 15 2008
DBPNAM7 :
DS : 0
EXP :
NS : 8
O1 : 3088.51 Hz
O2 : 3088.51 Hz
O3 : 3088.51 Hz
SFO1 : 500.1330885 MHz
SFO2 : 500.1330885 MHz
SFO3 : 500.1330885 MHz
SOLVENT : CDCl3
*** Processing Parameters ***
AZFW : 0.100 ppm
*** 1D NMR Plot Parameters ***
SR : 27.09 Hz
QD-6
Integral
(ppm)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*** Current Data Parameters ***
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EXPNO : 7
PROCNO : 1
*** Acquisition Parameters ***
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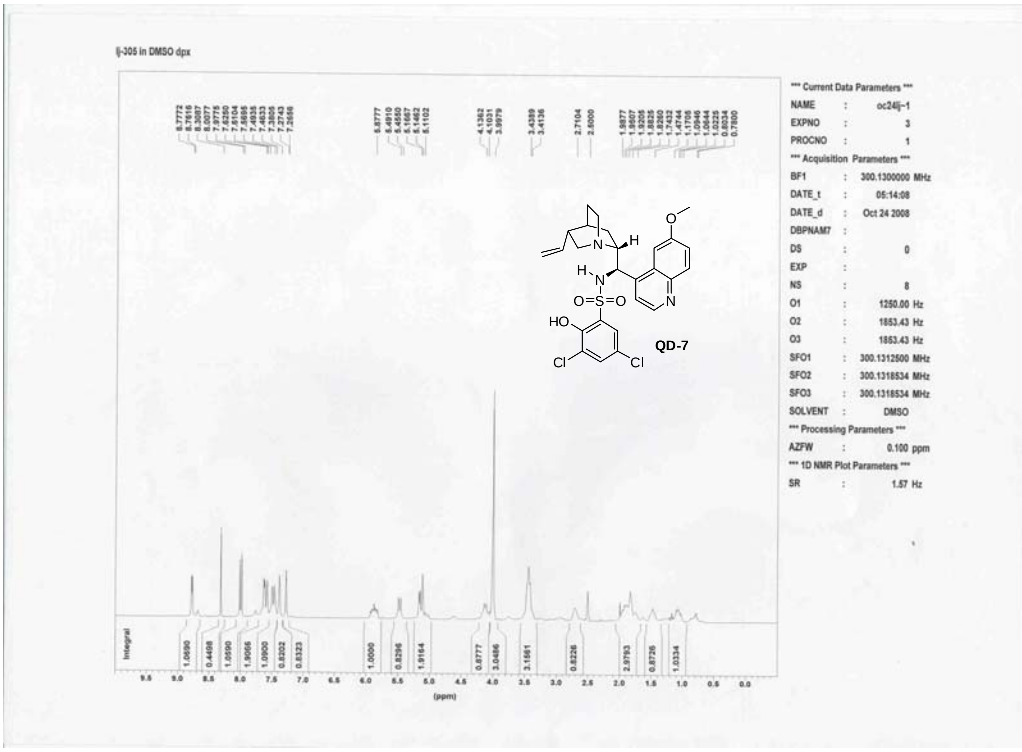
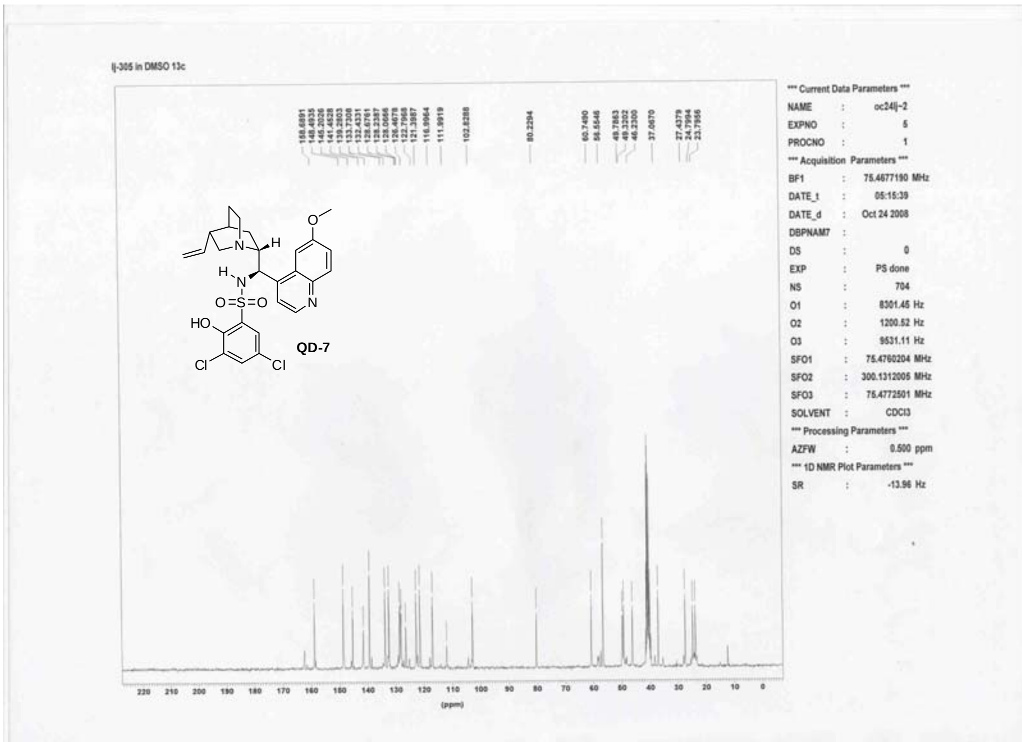
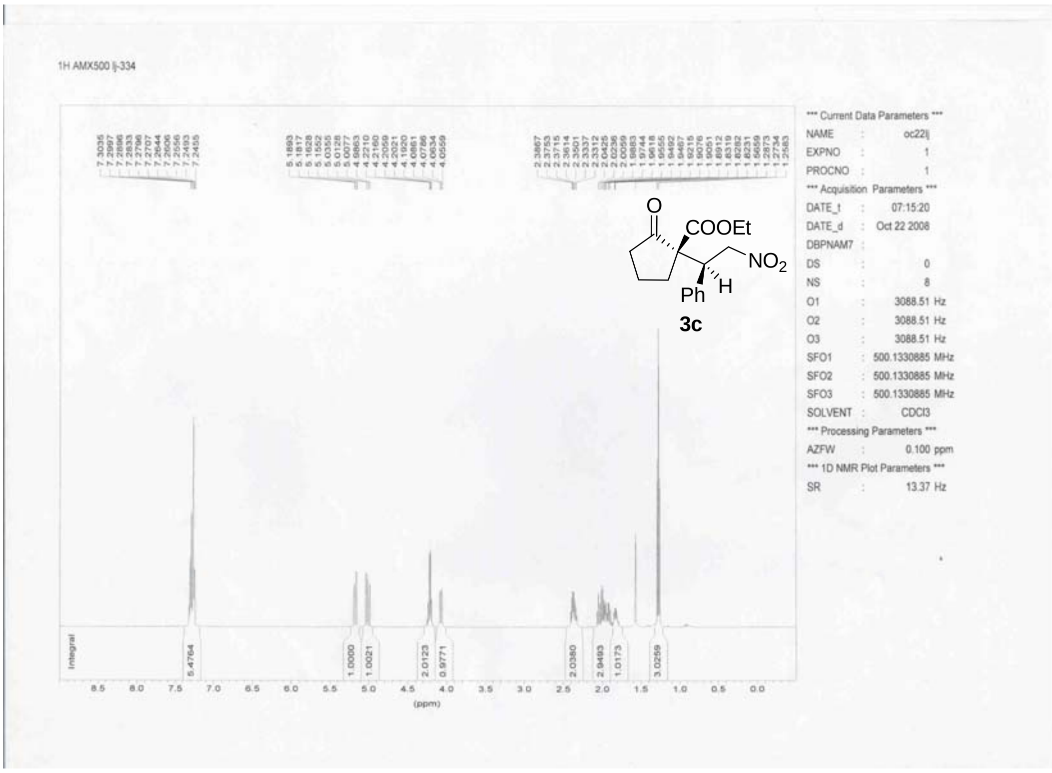
DATE_t : 08:33:48
DATE_d : Oct 15 2008
DBPNAM7 :
DS : 0
EXP :
NS : 10014
O1 : 13204.57 Hz
O2 : 2000.52 Hz
O3 : 12575.30 Hz
SFO1 : 125.7709936 MHz
SFO2 : 500.1320005 MHz
SFO3 : 125.7703643 MHz
SOLVENT : CDCl3
*** Processing Parameters ***
AZFW : 0.500 ppm
*** 1D NMR Plot Parameters ***
SR : -174.55 Hz
QD-6
(ppm)



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EXPNO : 1
PROCNO : 1
*** Acquisition Parameters ***
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DATE_d : Oct 22 2008
DBPNAM7 :
DS : 0
NS : 8
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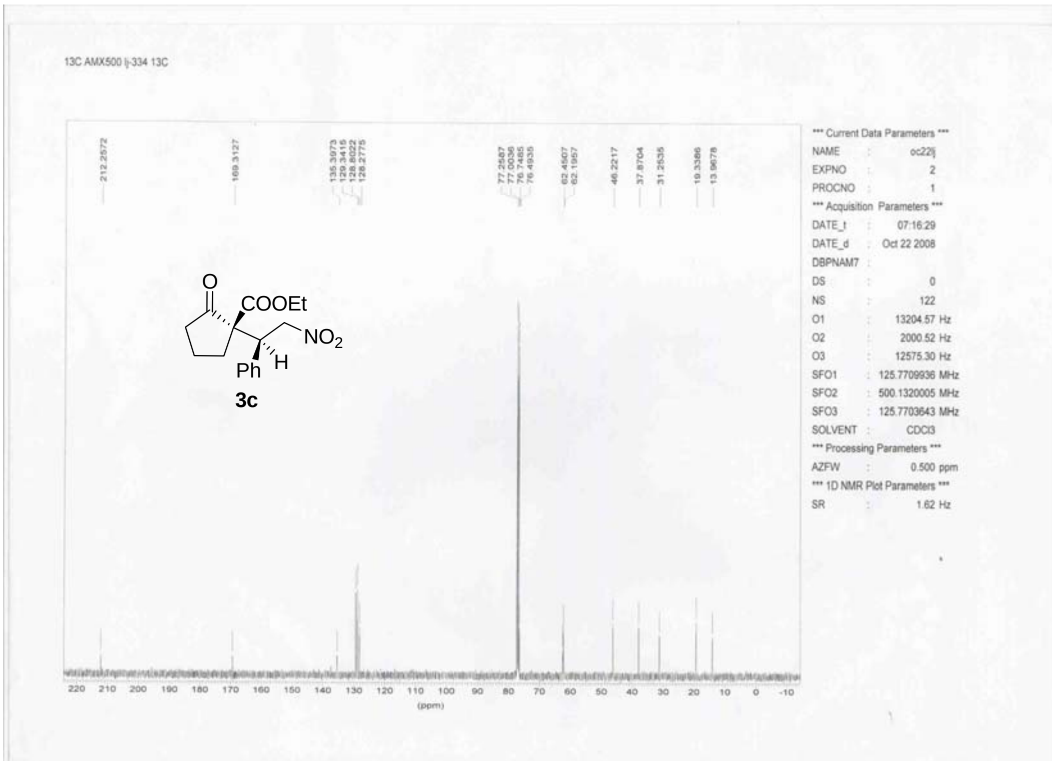
O2 : 3088.51 Hz
O3 : 3088.51 Hz
SFO1 : 500.1330885 MHz
SFO2 : 500.1330885 MHz
SFO3 : 500.1330885 MHz
SOLVENT : CDCl3
*** Processing Parameters ***
AZFW : 0.100 ppm
*** 1D NMR Plot Parameters ***
SR : 13.37 Hz
COOEt
NO2
Ph
H
3c
Integral
5.4764
1.0000
1.0021
2.0123
0.9771
2.0380
2.9493
1.0173
3.0259
(ppm)


13C AMX500 lj-334 13C
212.2572
169.3127
135.3973
129.3415
128.8022
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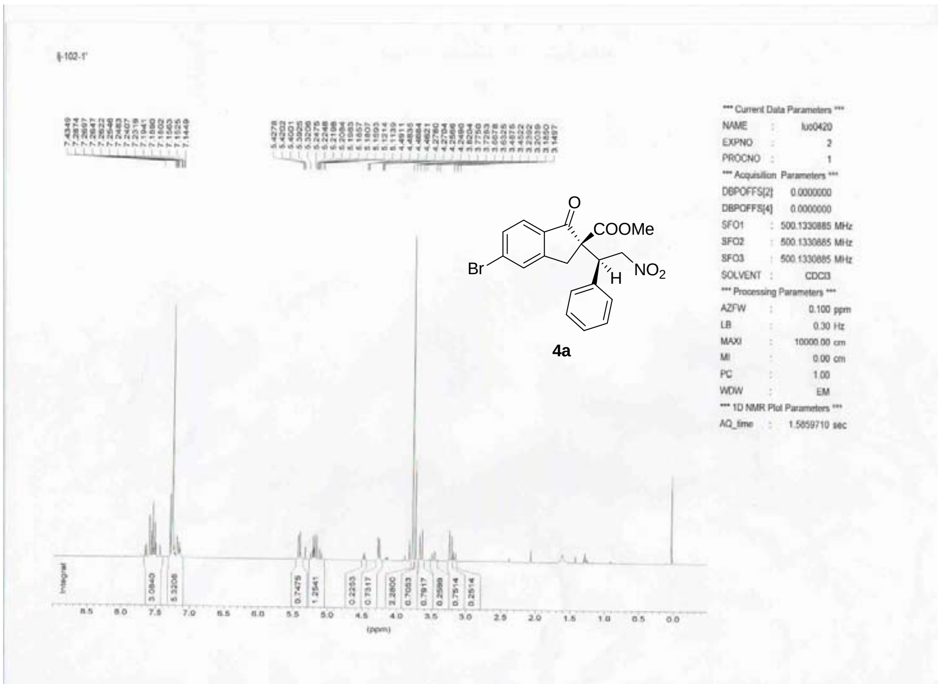
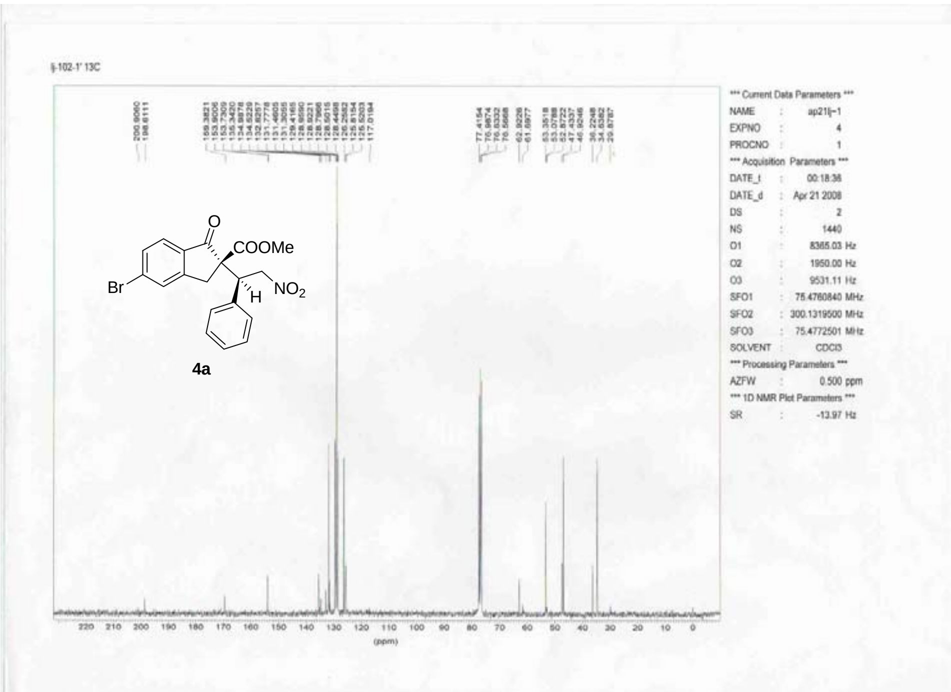
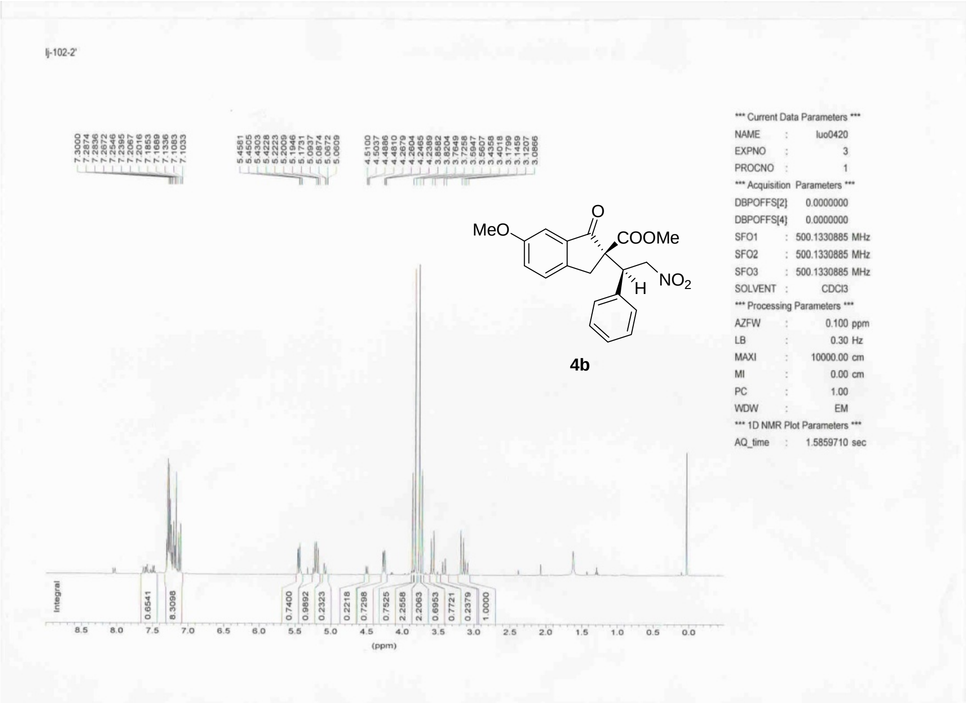
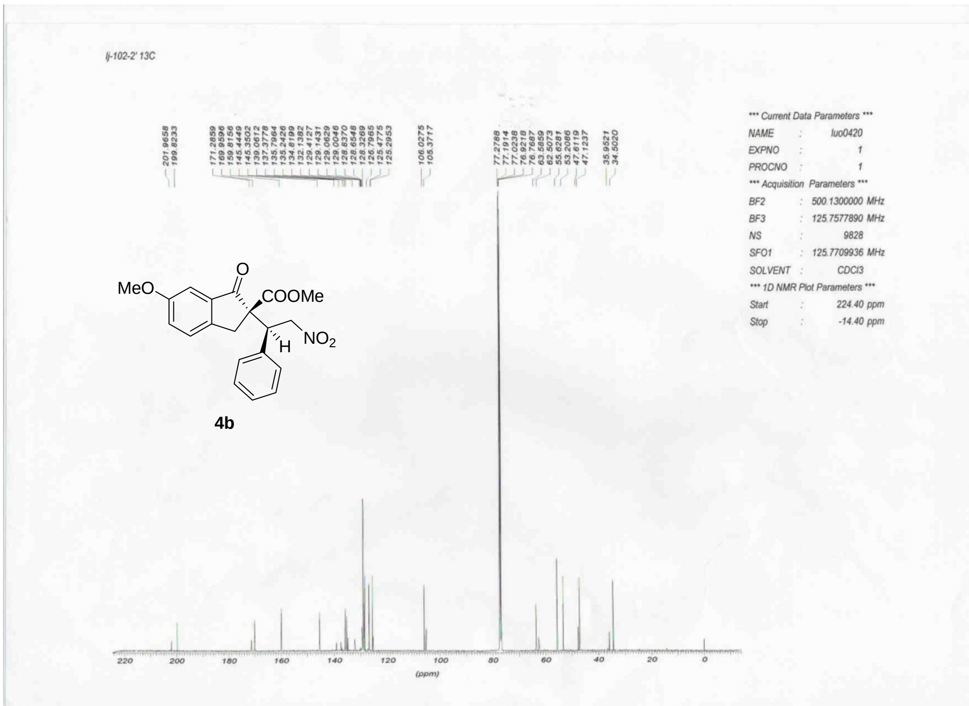
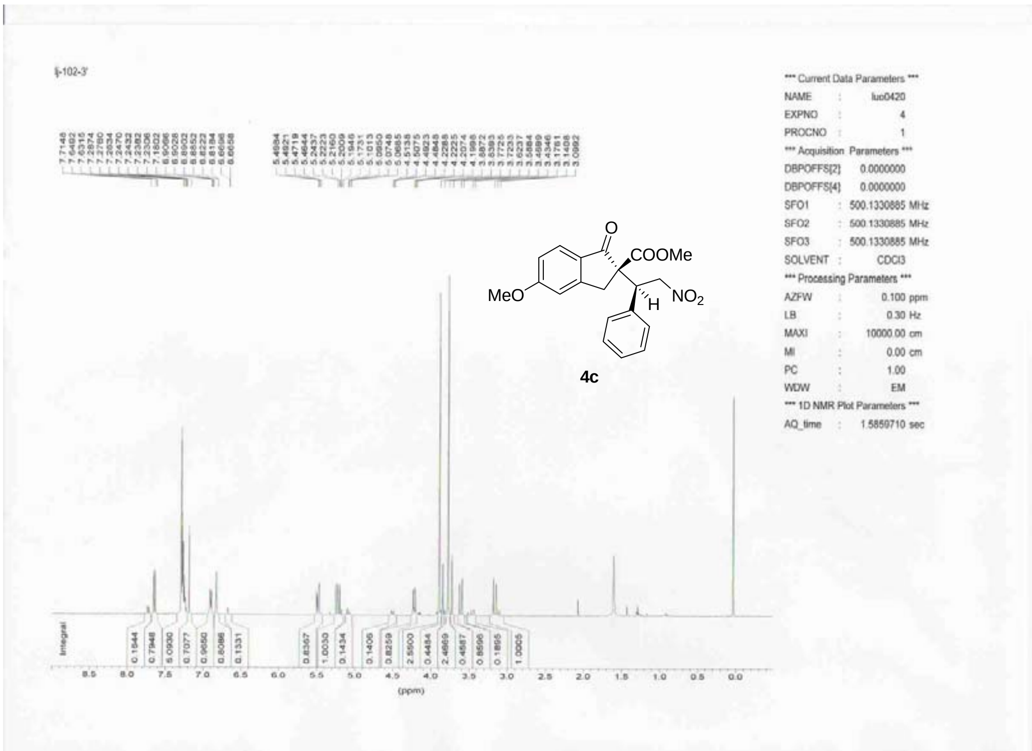
77.2587
77.0036
76.7485
76.4935
62.4507
62.1957
46.2217
37.8704
31.2535
19.3386
13.9678
*** Current Data Parameters ***
NAME : oc22lj
EXPNO : 2
PROCNO : 1
*** Acquisition Parameters ***
DATE_t : 07:16:29
DATE_d : Oct 22 2008
DBPNAM7 :
DS : 0
NS : 122
O1 : 13204.57 Hz
O2 : 2000.52 Hz
O3 : 12575.30 Hz
SFO1 : 125.7709936 MHz
SFO2 : 500.1320005 MHz
SFO3 : 125.7703643 MHz
SOLVENT : CDCl3
*** Processing Parameters ***
AZFW : 0.500 ppm
*** 1D NMR Plot Parameters ***
SR : 1.62 Hz
COOEt
NO2
Ph
H
3c
(ppm)

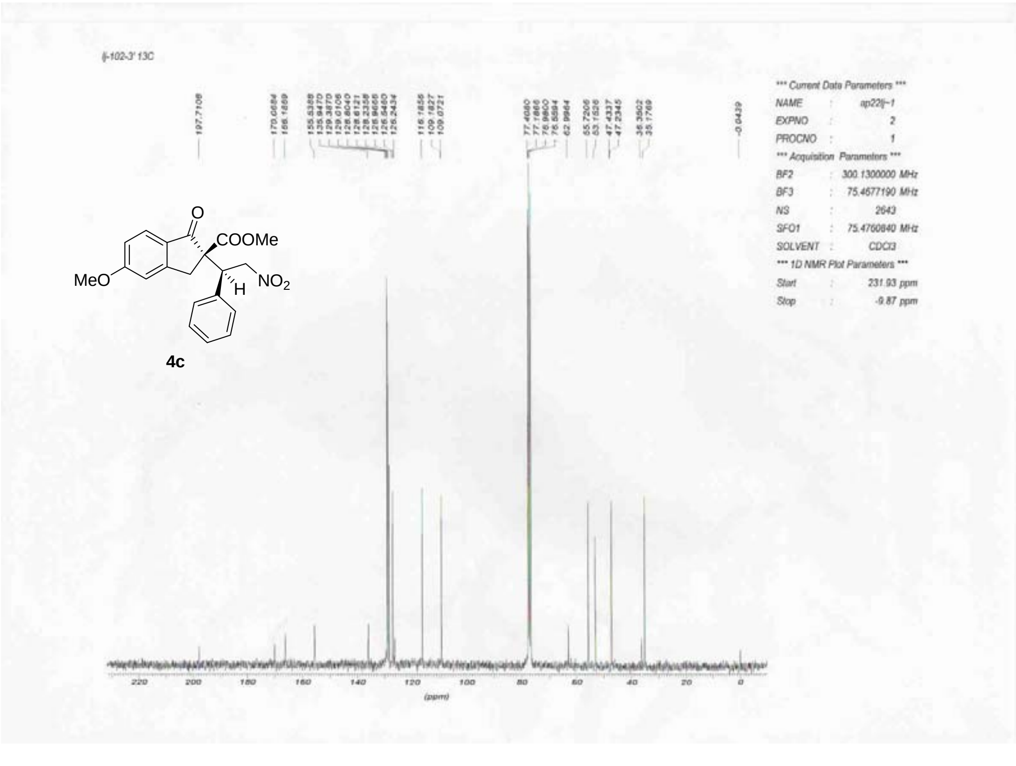


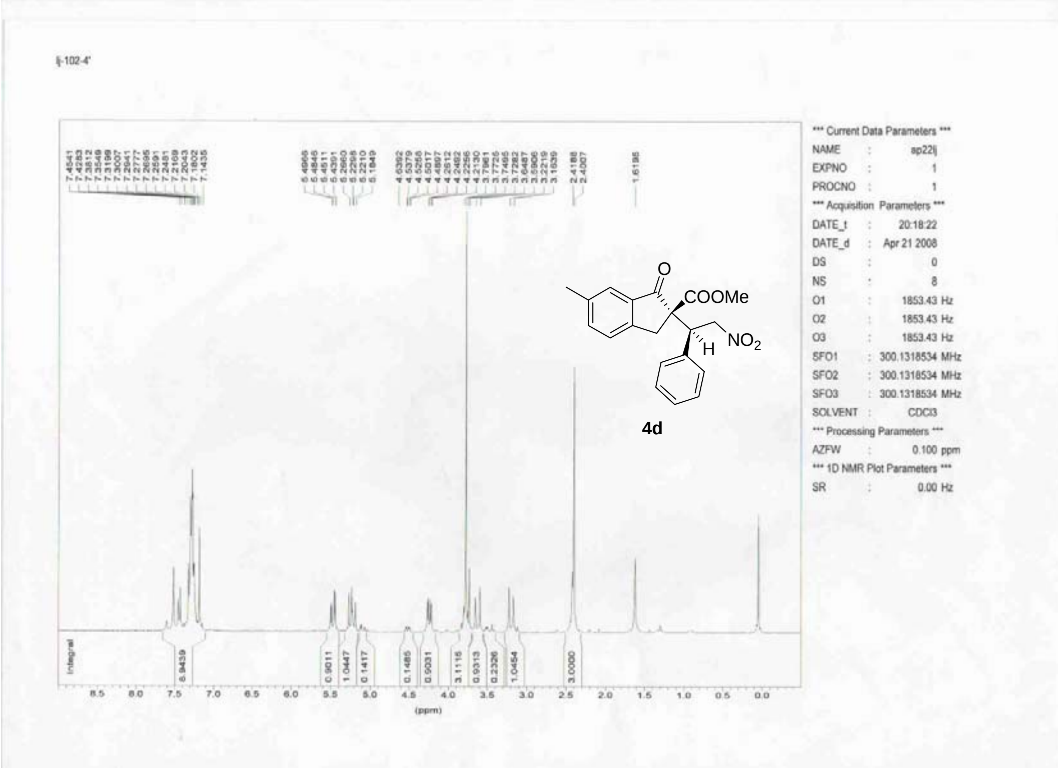


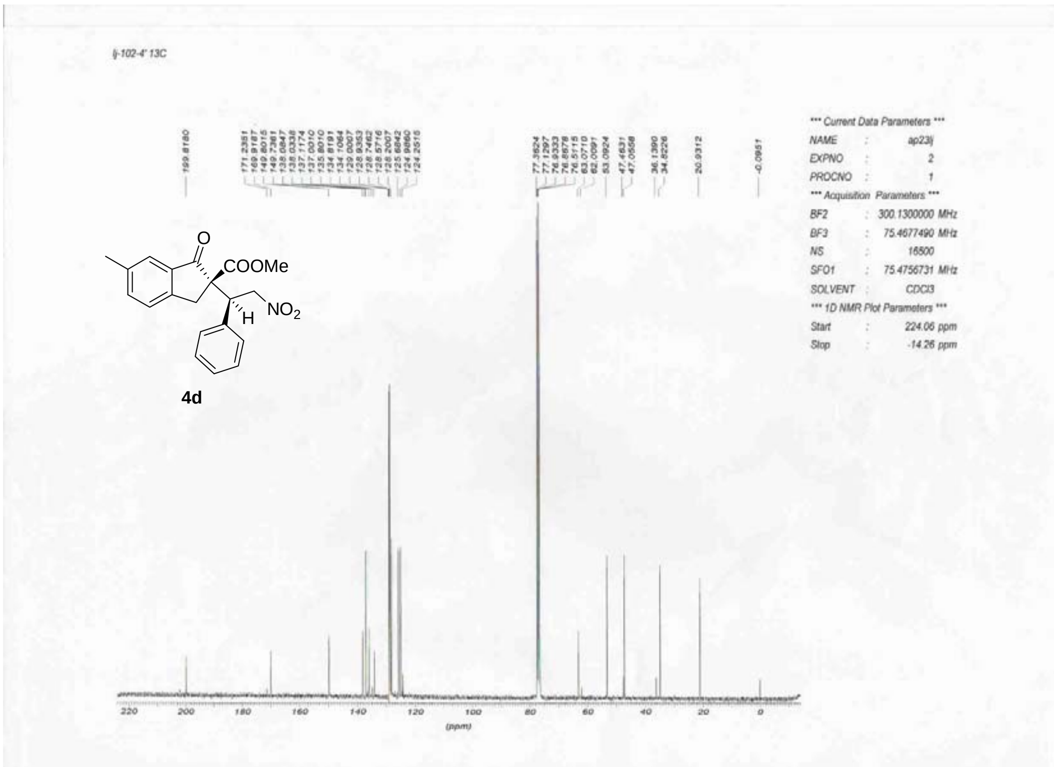


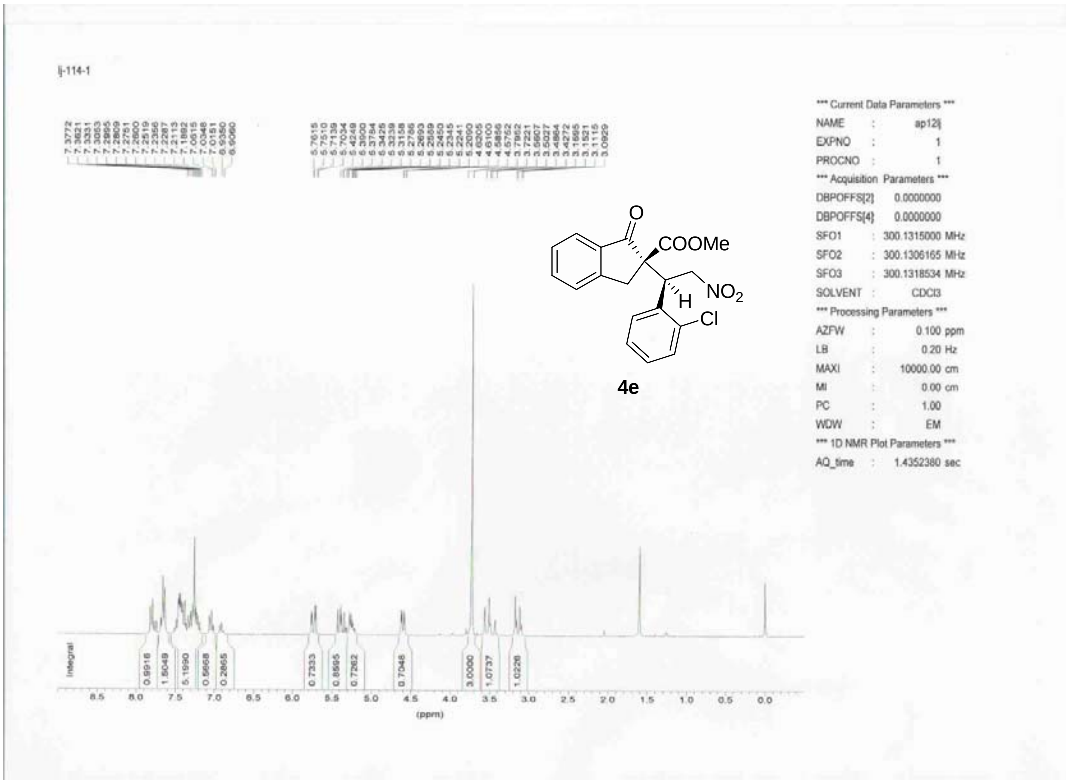


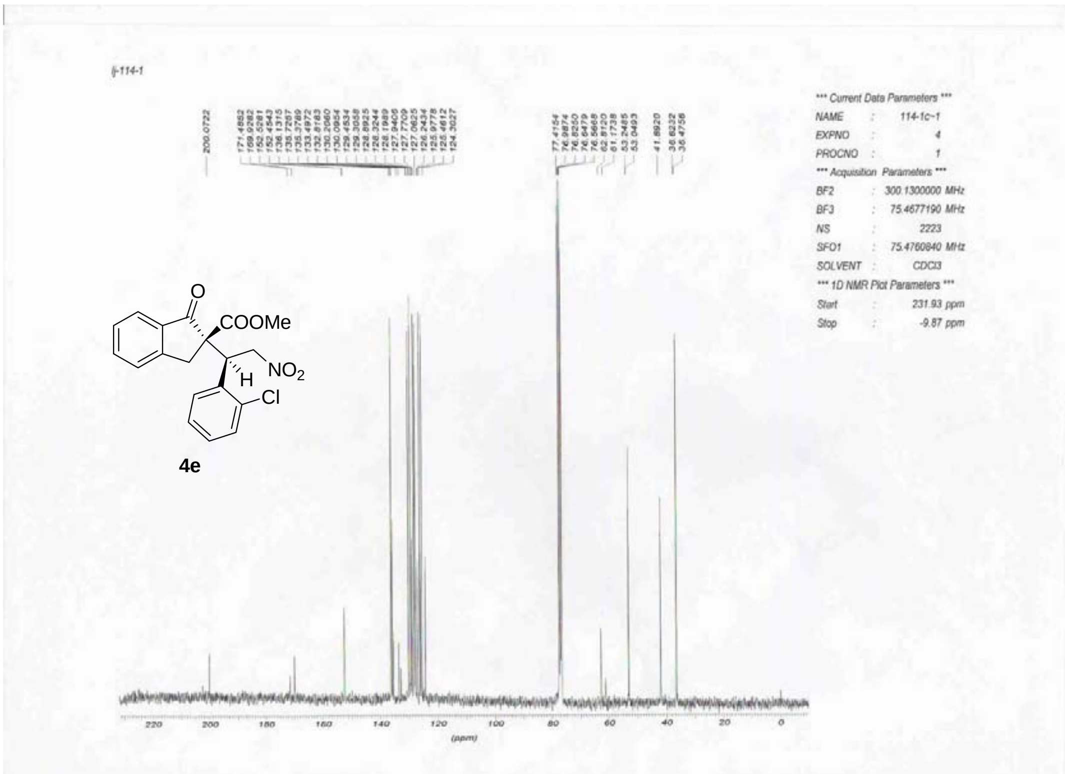


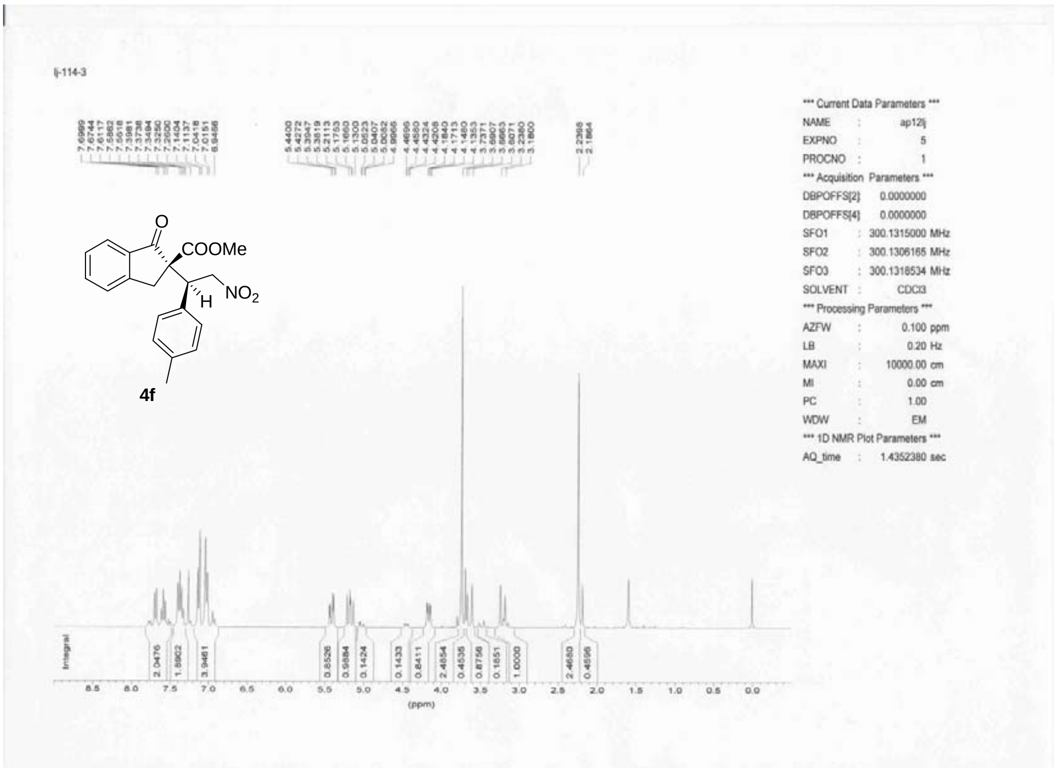


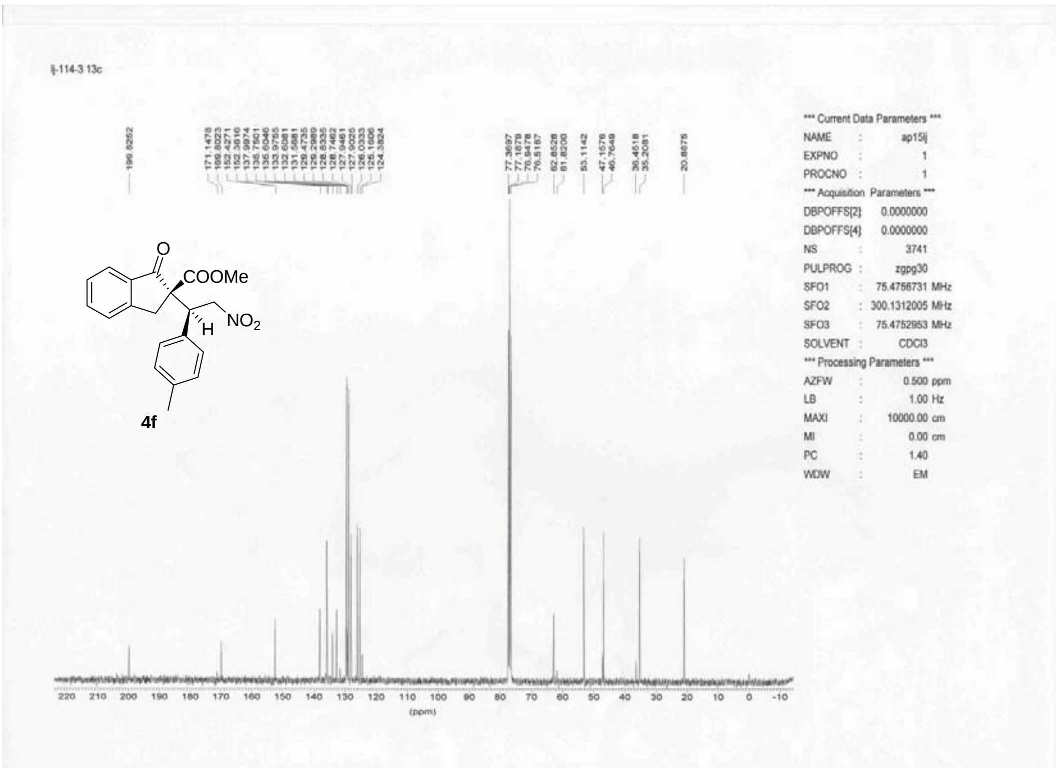

lj-102-4'
4d
*** Current Data Parameters ***
NAME : ap22lj
EXPNO : 1
PROCNO : 1
*** Acquisition Parameters ***
DATE_t : 20:18:22
DATE_d : Apr 21 2008
DS : 0
NS : 8
O1 : 1853.43 Hz
O2 : 1853.43 Hz
O3 : 1853.43 Hz
SFO1 : 300.1318534 MHz
SFO2 : 300.1318534 MHz
SFO3 : 300.1318534 MHz
SOLVENT : CDCl3
*** Processing Parameters ***
AZFW : 0.100 ppm
*** 1D NMR Plot Parameters ***
SR : 0.00 Hz
(ppm)

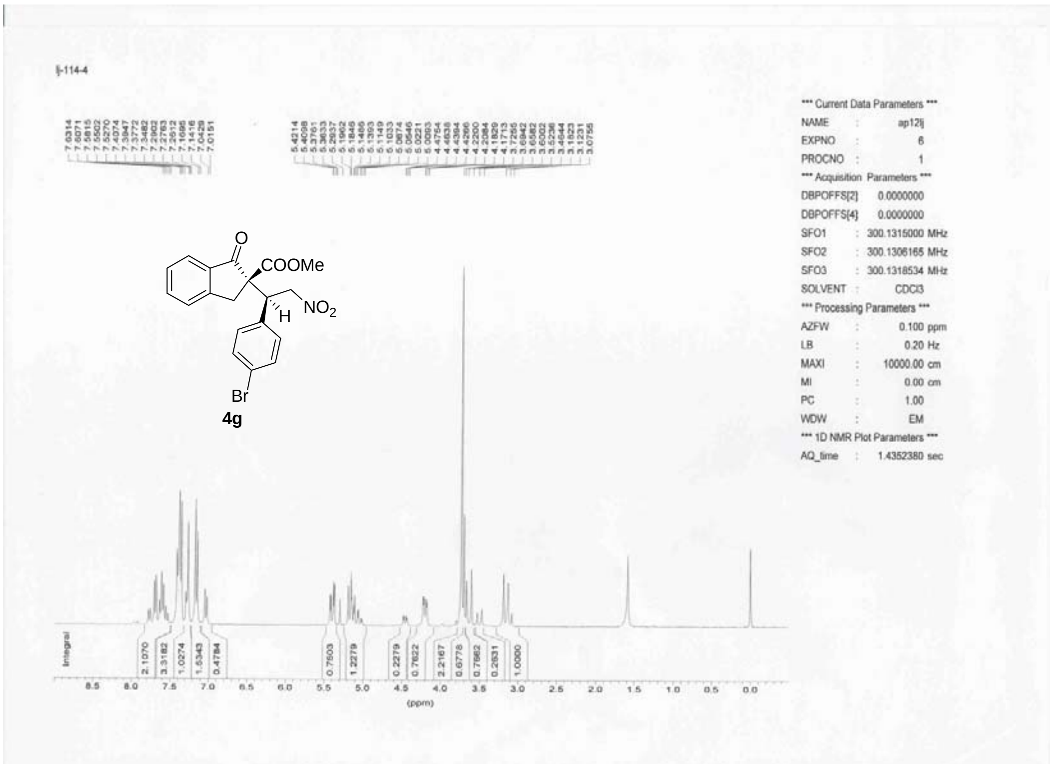

lj-102-4' 13C
4d
*** Current Data Parameters ***
NAME : ap23lj
EXPNO : 2
PROCNO : 1
*** Acquisition Parameters ***
BF2 : 300.1300000 MHz
BF3 : 75.4677490 MHz
NS : 16500
SFO1 : 75.4756731 MHz
SOLVENT : CDCl3
*** 1D NMR Plot Parameters ***
Start : 224.06 ppm
Stop : -14.26 ppm
(ppm)

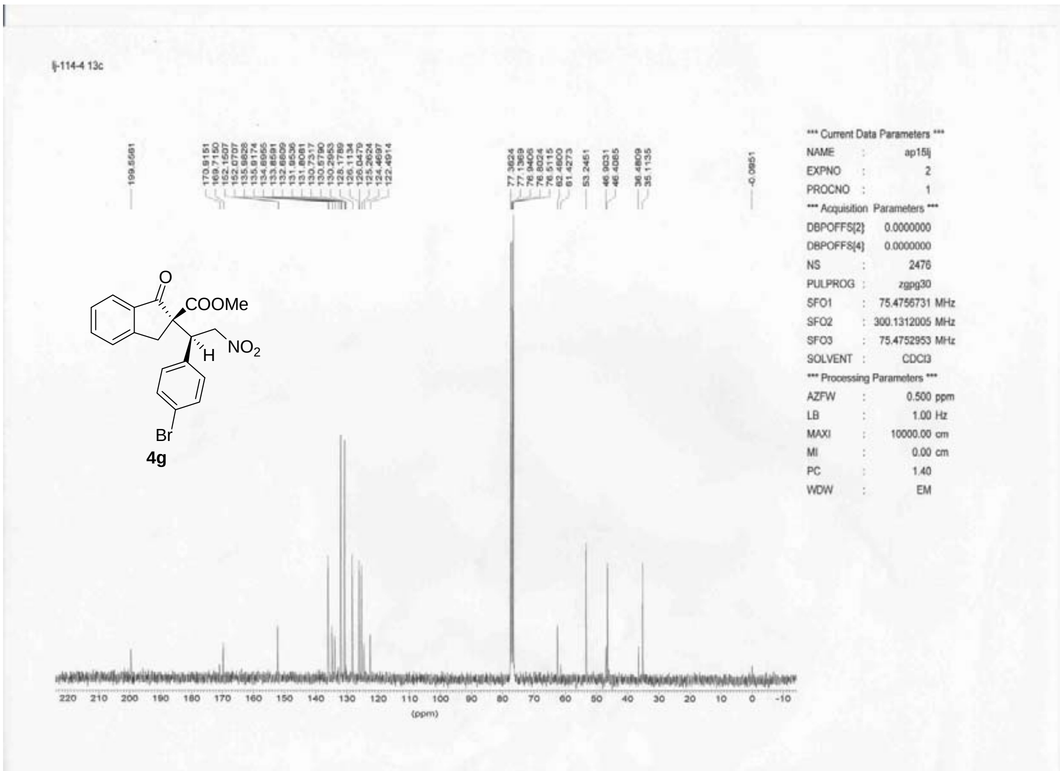


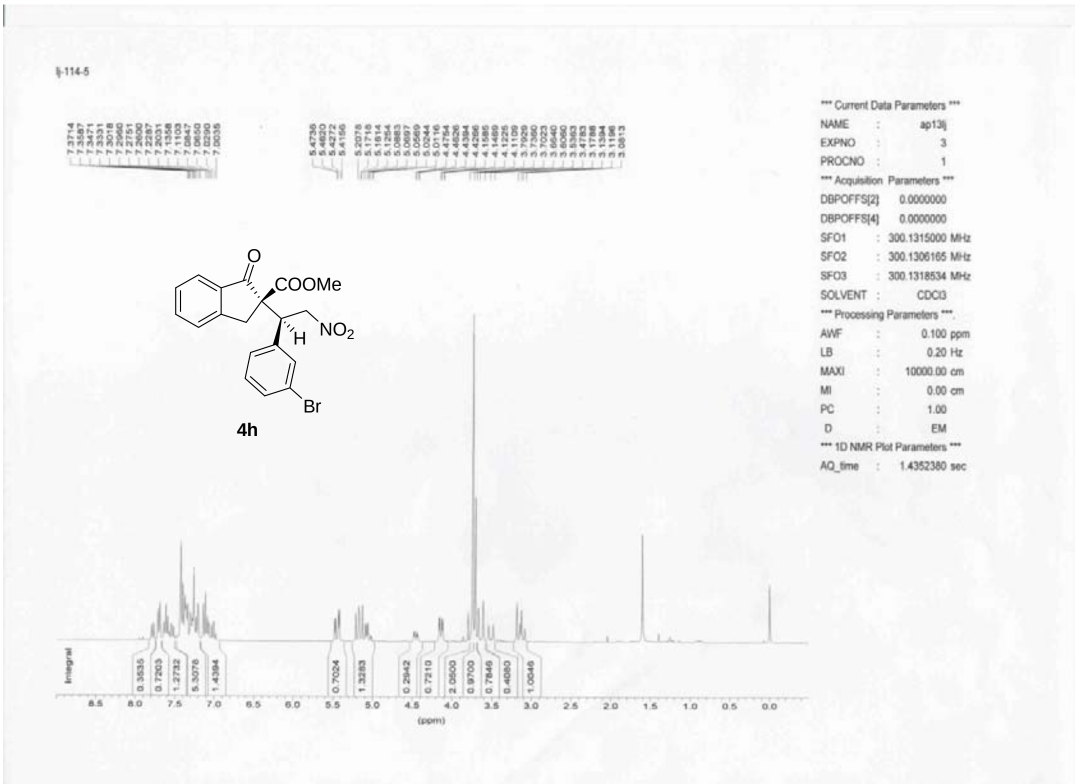


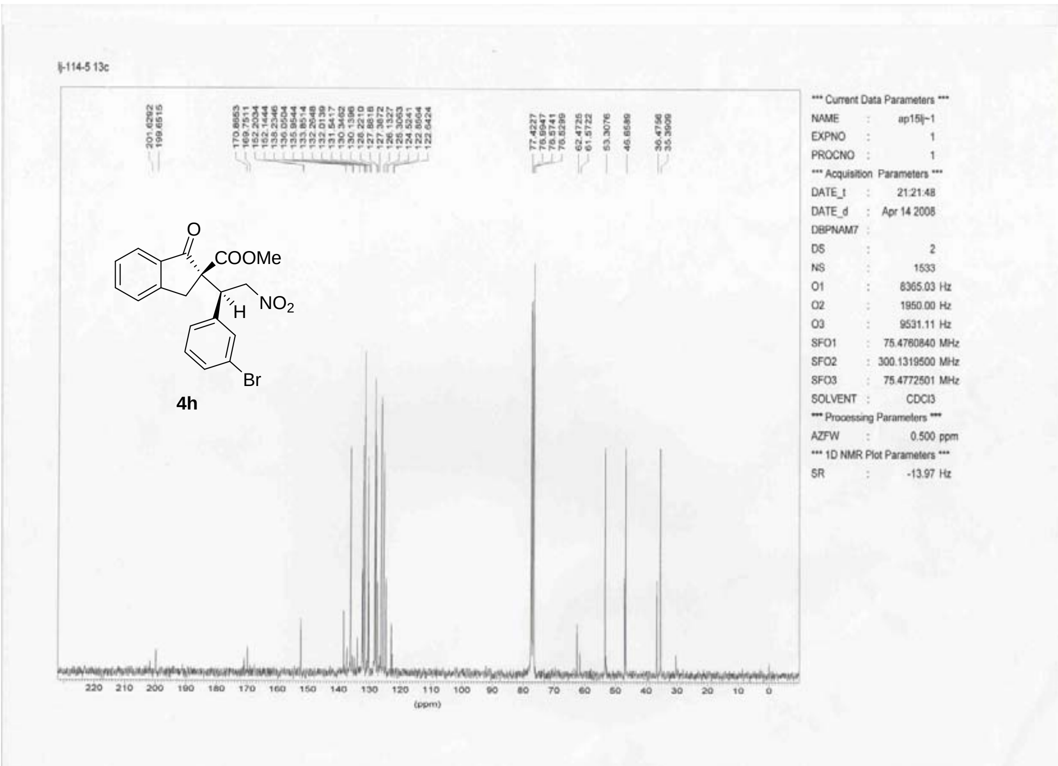

lj-114-3
4f
*** Current Data Parameters ***
NAME : ap12lj
EXPNO : 5
PROCNO : 1
*** Acquisition Parameters ***
SFO1 : 300.1315000 MHz
SFO2 : 300.1306165 MHz
SFO3 : 300.1318534 MHz
SOLVENT : CDCl3
*** Processing Parameters ***
AZFW : 0.100 ppm
LB : 0.20 Hz
MAXI : 10000.00 cm
MI : 0.00 cm
PC : 1.00
WDW : EM
*** 1D NMR Plot Parameters ***
AQ_time : 1.4352380 sec
(ppm)

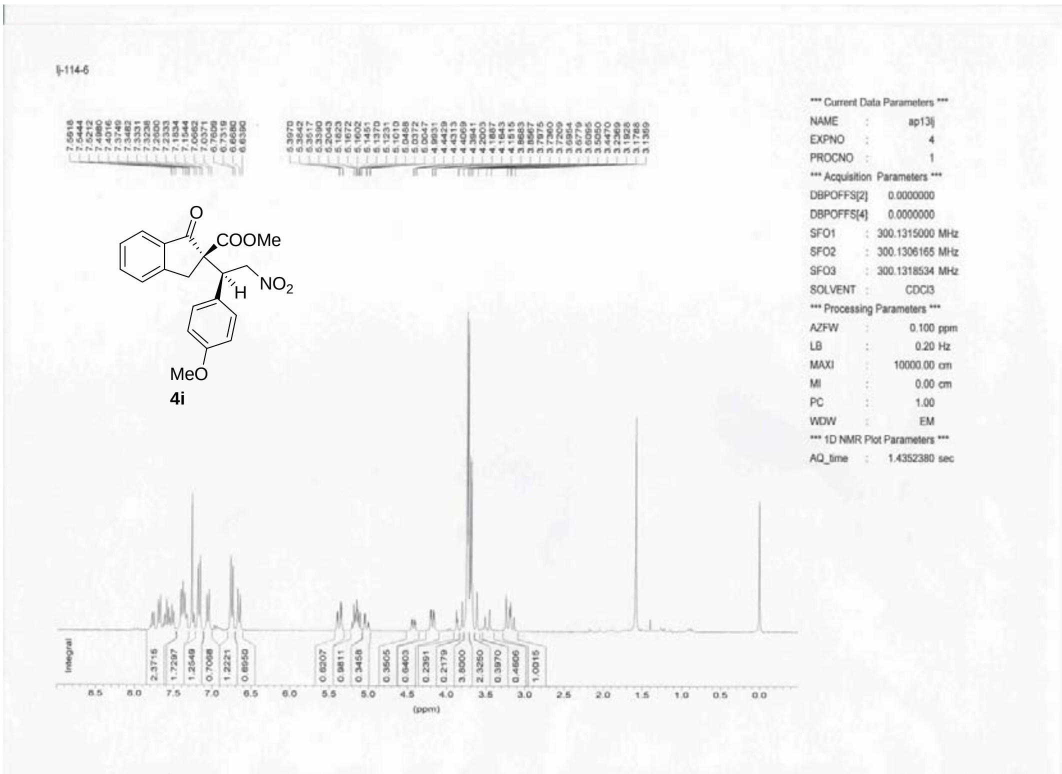

lj-114-3 13c
4f
*** Current Data Parameters ***
NAME : ap15lj
EXPNO : 1
PROCNO : 1
*** Acquisition Parameters ***
NS : 3741
PULPROG : zgpg30
SFO1 : 75.4756731 MHz
SFO2 : 300.1312005 MHz
SFO3 : 75.4752953 MHz
SOLVENT : CDCl3
*** Processing Parameters ***
AZFW : 0.500 ppm
LB : 1.00 Hz
MAXI : 10000.00 cm
MI : 0.00 cm
PC : 1.40
WDW : EM
(ppm)

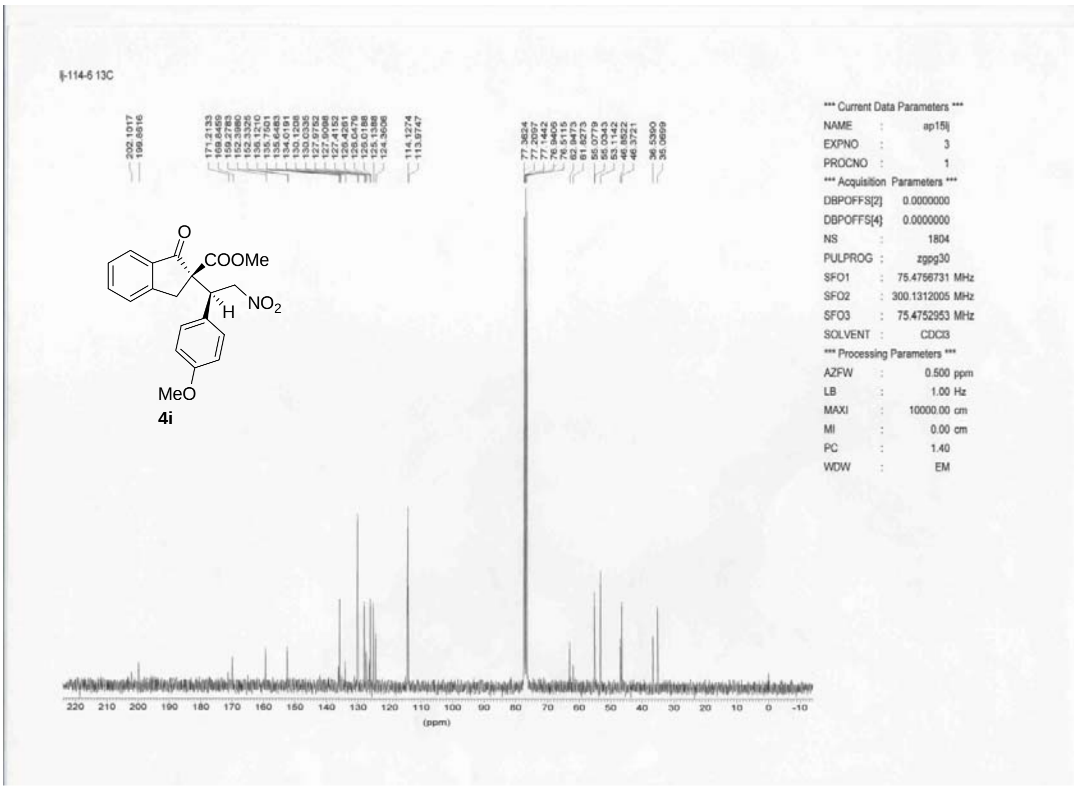


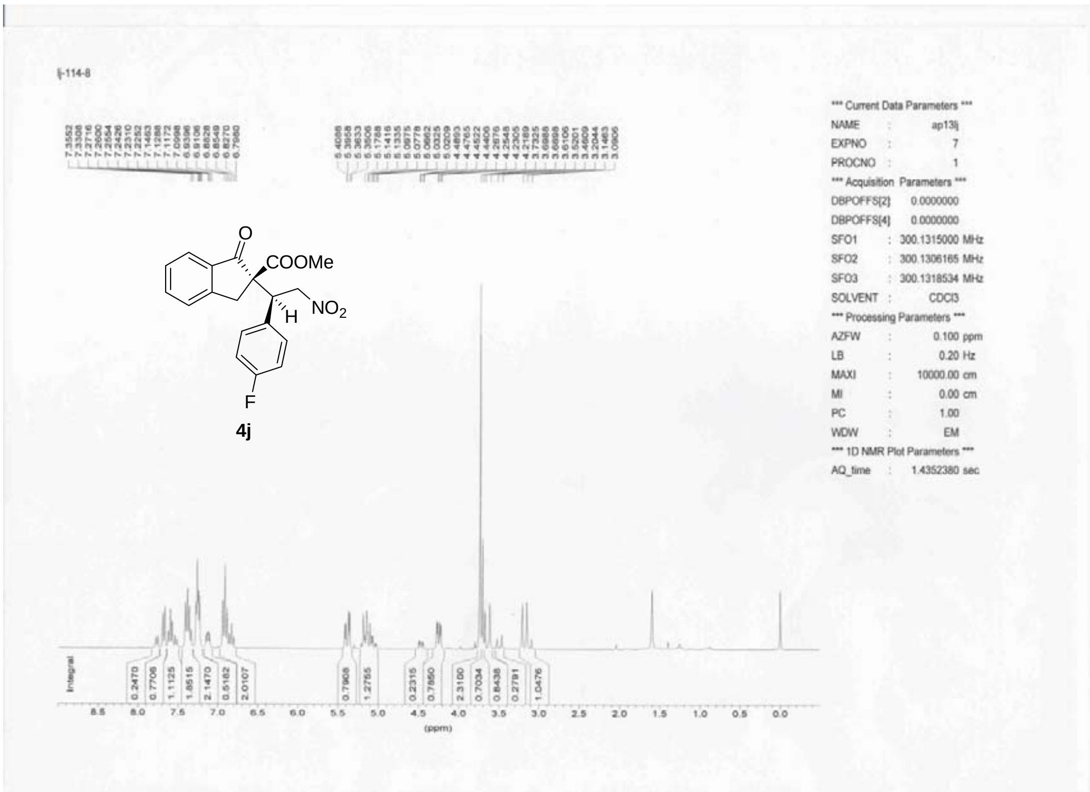


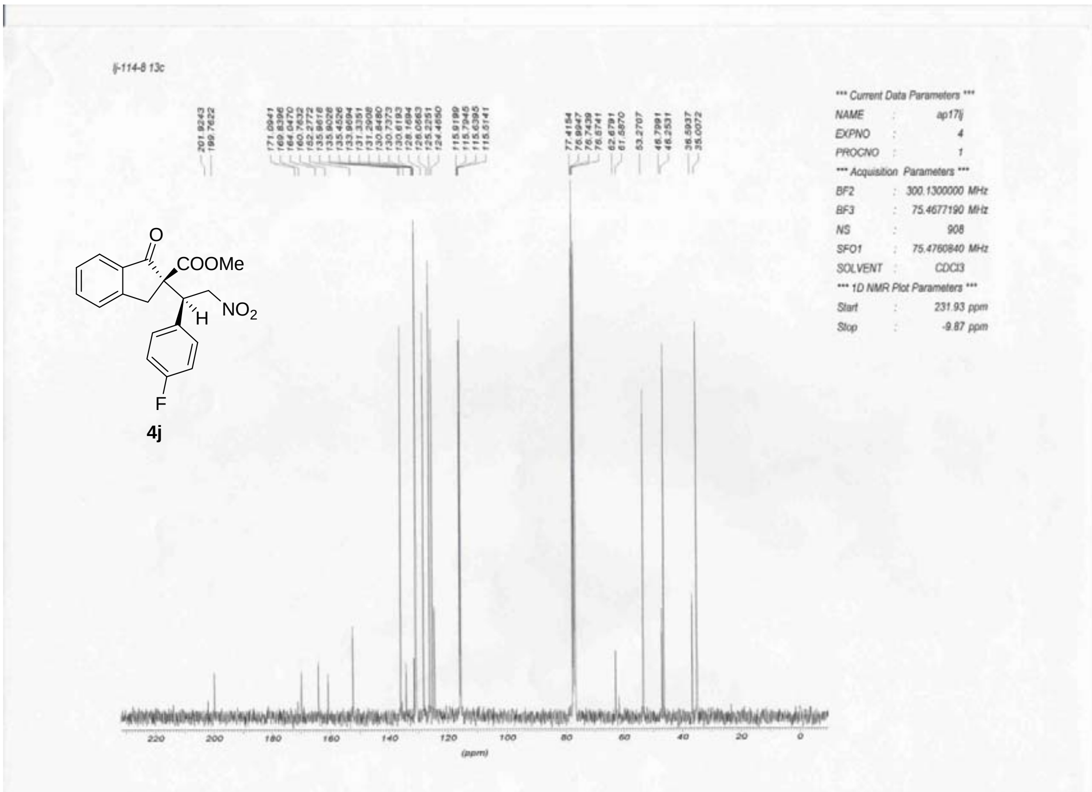


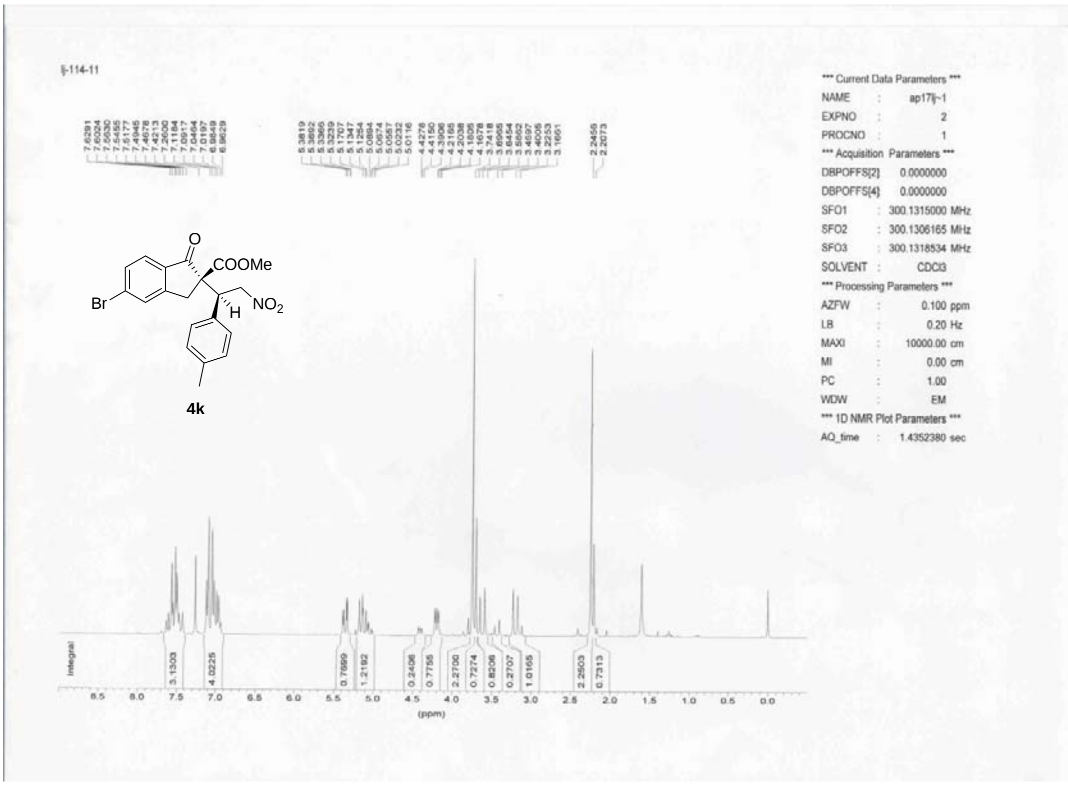


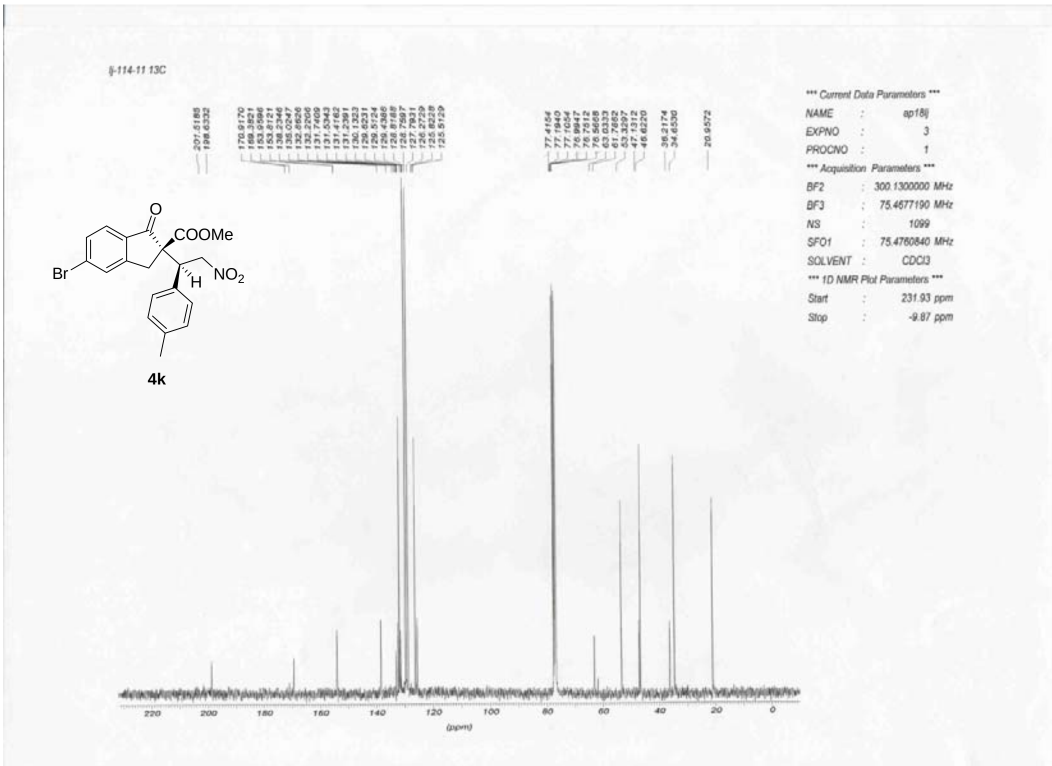


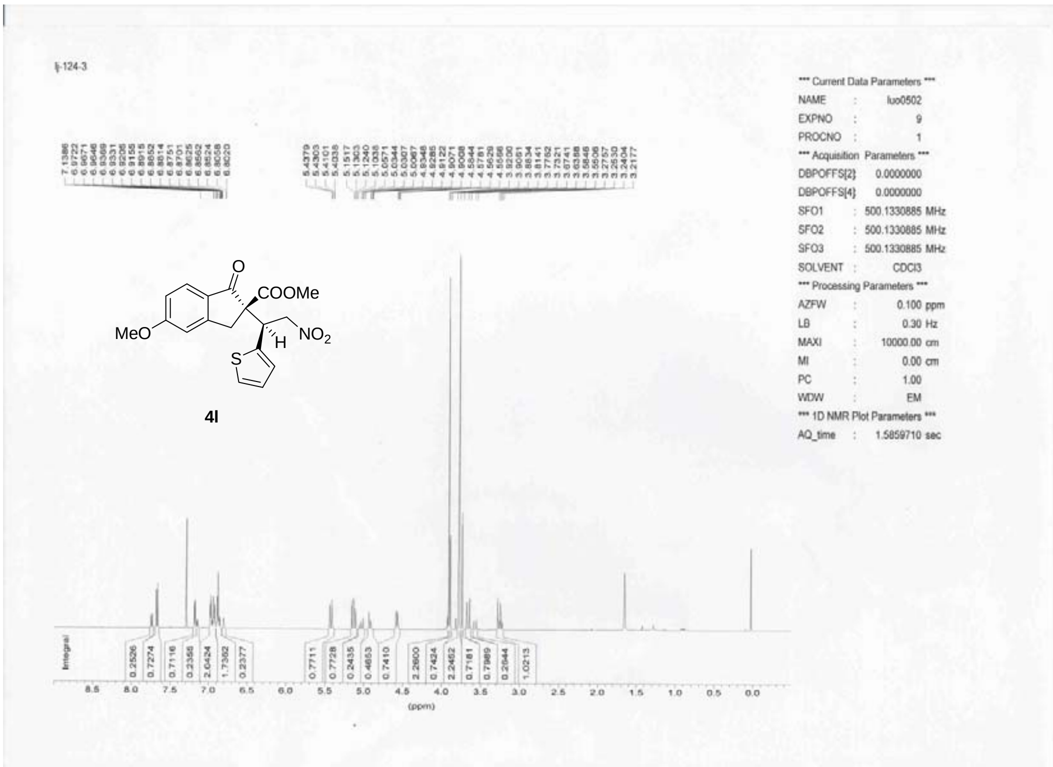


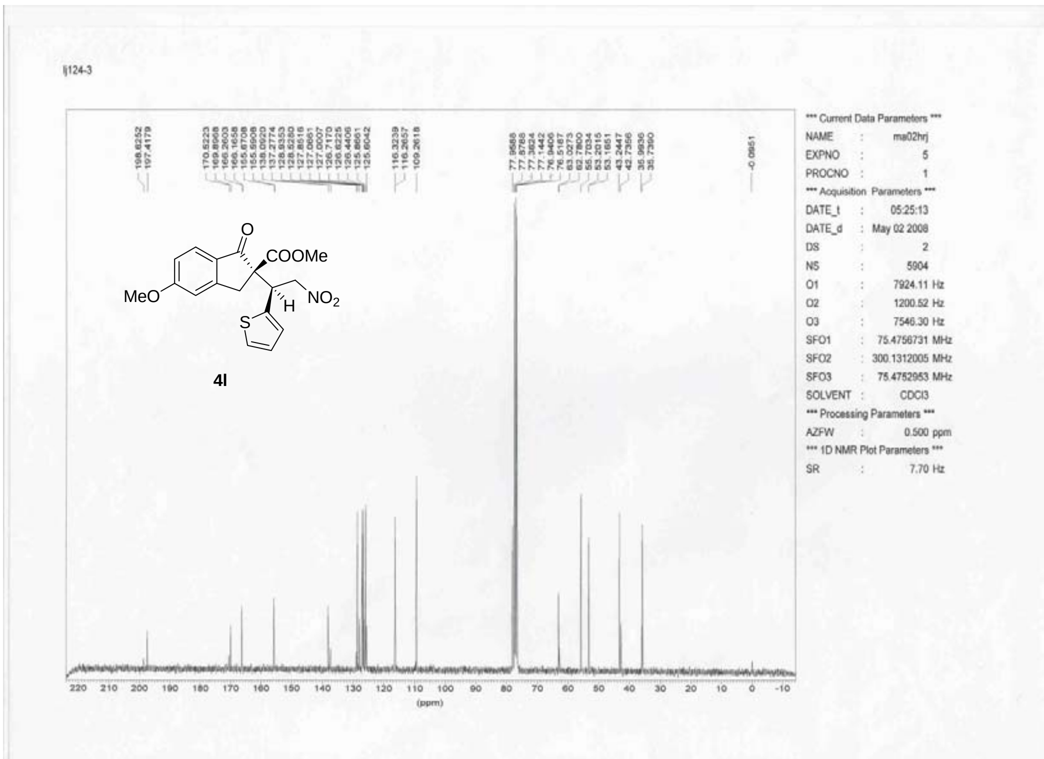


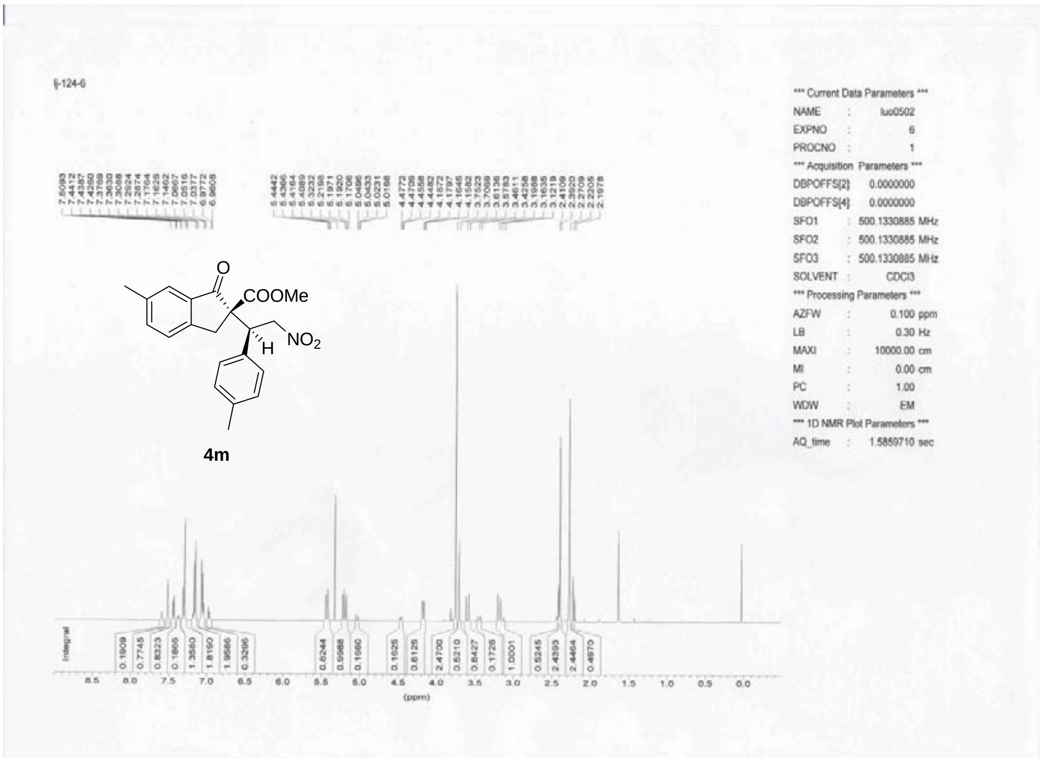


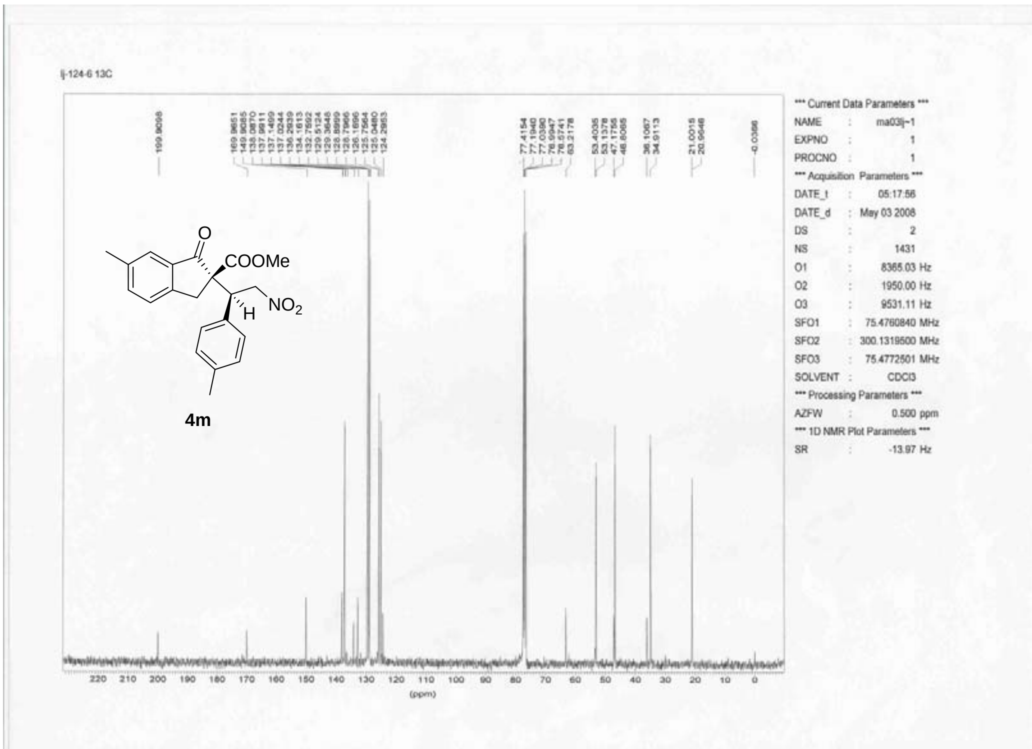

lj-114-11
*** Current Data Parameters ***
NAME : ap17lj~1
EXPNO : 2
PROCNO : 1
*** Acquisition Parameters ***
DBPOFFS[2] 0.0000000
DBPOFFS[4] 0.0000000
SFO1 : 300.1315000 MHz
SFO2 : 300.1306165 MHz
SFO3 : 300.1318534 MHz
SOLVENT : CDCl3
*** Processing Parameters ***
AZFW : 0.100 ppm
LB : 0.20 Hz
MAXI : 10000.00 cm
MI : 0.00 cm
PC : 1.00
WDW : EM
*** 1D NMR Plot Parameters ***
AQ_time : 1.4352380 sec
COOMe
Br
H
NO2
4k
(ppm)

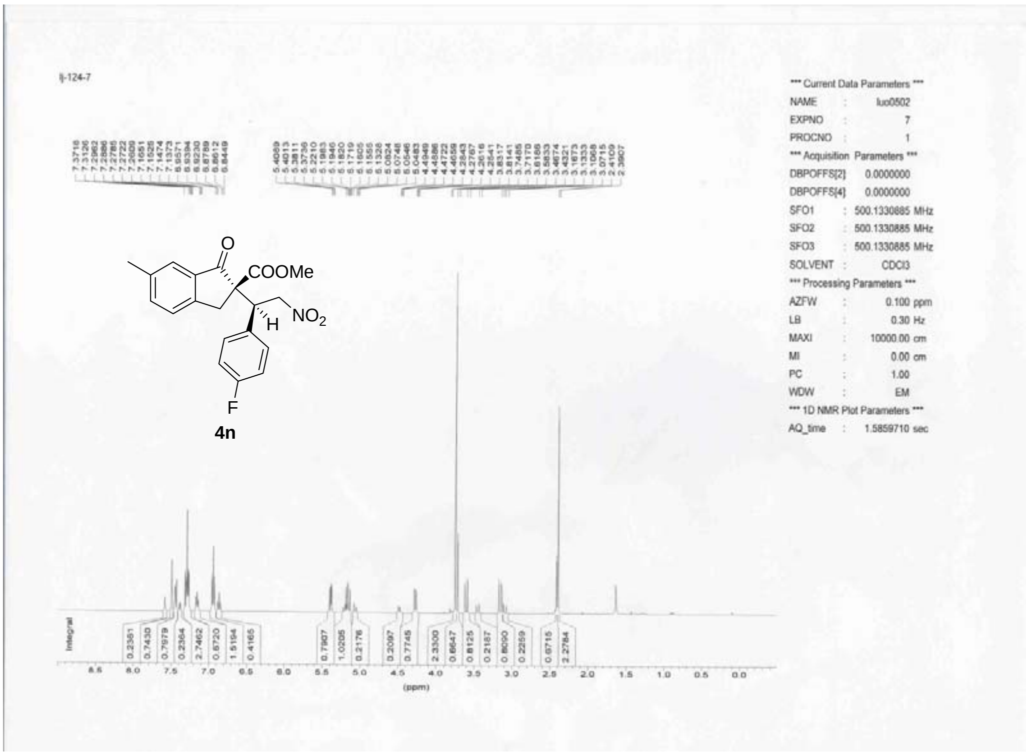

lj-114-11 13C
*** Current Data Parameters ***
NAME : ap18lj
EXPNO : 3
PROCNO : 1
*** Acquisition Parameters ***
BF2 : 300.1300000 MHz
BF3 : 75.4677190 MHz
NS : 1099
SFO1 : 75.4760840 MHz
SOLVENT : CDCl3
*** 1D NMR Plot Parameters ***
Start : 231.93 ppm
Stop : -9.87 ppm
COOMe
Br
H
NO2
4k
(ppm)

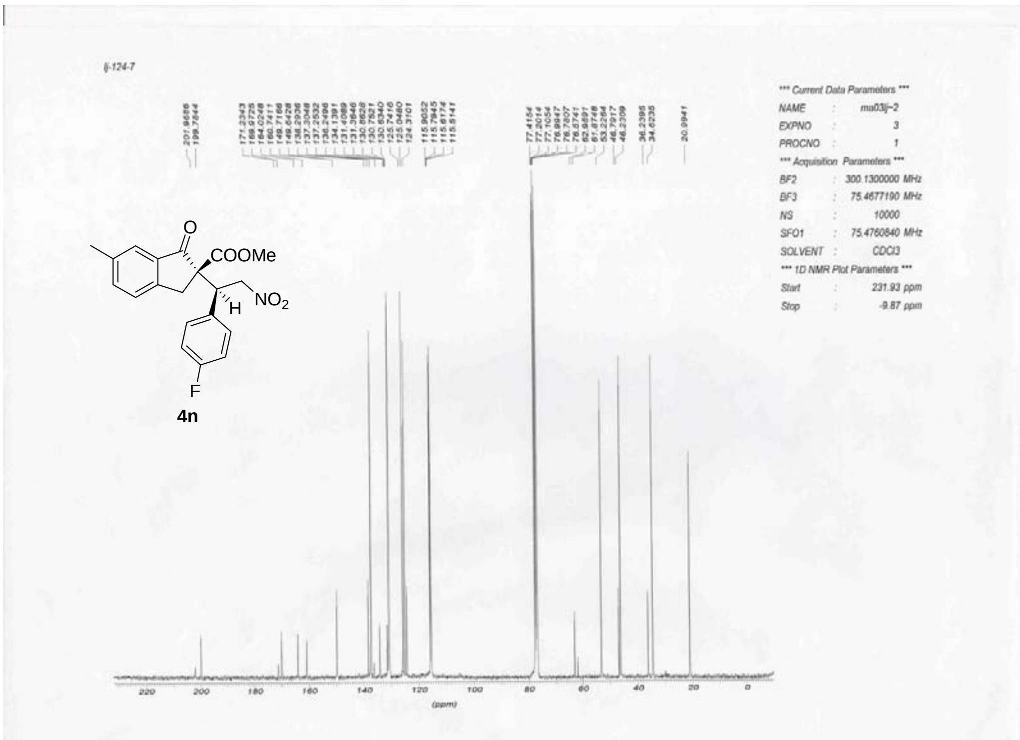

lj-124-3
*** Current Data Parameters ***
NAME : luo0502
EXPNO : 9
PROCNO : 1
*** Acquisition Parameters ***
DBPOFFS[2] 0.0000000
DBPOFFS[4] 0.0000000
SFO1 : 500.1330885 MHz
SFO2 : 500.1330885 MHz
SFO3 : 500.1330885 MHz
SOLVENT : CDCl3
*** Processing Parameters ***
AZFW : 0.100 ppm
LB : 0.30 Hz
MAXI : 10000.00 cm
MI : 0.00 cm
PC : 1.00
WDW : EM
*** 1D NMR Plot Parameters ***
AQ_time : 1.5859710 sec
COOMe
MeO
NO2
H
S
4l
Integral
(ppm)


lj124-3
*** Current Data Parameters ***
NAME : ma02hrj
EXPNO : 5
PROCNO : 1
*** Acquisition Parameters ***
DATE_t : 05:25:13
DATE_d : May 02 2008
DS : 2
NS : 5904
O1 : 7924.11 Hz
O2 : 1200.52 Hz
O3 : 7546.30 Hz
SFO1 : 75.4756731 MHz
SFO2 : 300.1312005 MHz
SFO3 : 75.4752953 MHz
SOLVENT : CDCl3
*** Processing Parameters ***
AZFW : 0.500 ppm
*** 1D NMR Plot Parameters ***
SR : 7.70 Hz
COOMe
MeO
NO2
H
S
4l
(ppm)


lj-124-6
*** Current Data Parameters ***
NAME : luo0502
EXPNO : 6
PROCNO : 1
*** Acquisition Parameters ***
DBPOFFS[2] 0.0000000
DBPOFFS[4] 0.0000000
SFO1 : 500.1330885 MHz
SFO2 : 500.1330885 MHz
SFO3 : 500.1330885 MHz
SOLVENT : CDCl3
*** Processing Parameters ***
AZFW : 0.100 ppm
LB : 0.30 Hz
MAXI : 10000.00 cm
MI : 0.00 cm
PC : 1.00
WDW : EM
*** 1D NMR Plot Parameters ***
AQ_time : 1.5859710 sec
O
COOMe
H
NO2
4m
Integral
(ppm)


lj-124-6 13C
*** Current Data Parameters ***
NAME : ma03lj-1
EXPNO : 1
PROCNO : 1
*** Acquisition Parameters ***
DATE_t : 05:17:56
DATE_d : May 03 2008
DS : 2
NS : 1431
O1 : 8365.03 Hz
O2 : 1950.00 Hz
O3 : 9531.11 Hz
SFO1 : 75.4760840 MHz
SFO2 : 300.1319500 MHz
SFO3 : 75.4772501 MHz
SOLVENT : CDCl3
*** Processing Parameters ***
AZFW : 0.500 ppm
*** 1D NMR Plot Parameters ***
SR : -13.97 Hz
O
COOMe
H
NO2
4m
(ppm)


lj-124-7
COOMe
NO_2
H
F
4n
*** Current Data Parameters ***
NAME : luo0502
EXPNO : 7
PROCNO : 1
*** Acquisition Parameters ***
DBPOFFS[2] 0.0000000
DBPOFFS[4] 0.0000000
SFO1 : 500.1330885 MHz
SFO2 : 500.1330885 MHz
SFO3 : 500.1330885 MHz
SOLVENT : CDCl3
*** Processing Parameters ***
AZFW : 0.100 ppm
LB : 0.30 Hz
MAXI : 10000.00 cm
MI : 0.00 cm
PC : 1.00
WDW : EM
*** 1D NMR Plot Parameters ***
AQ_time : 1.5859710 sec
Integral
(ppm)


lj-124-7
COOMe
NO_2
H
F
4n
*** Current Data Parameters ***
NAME : ma03lj-2
EXPNO : 3
PROCNO : 1
*** Acquisition Parameters ***
BF2 : 300.1300000 MHz
BF3 : 75.4677190 MHz
NS : 10000
SFO1 : 75.4760840 MHz
SOLVENT : CDCl3
*** 1D NMR Plot Parameters ***
Start : 231.93 ppm
Stop : -9.87 ppm
(ppm)