# Sereoselective Construction of All-Carbon Quaternary Center by Means of Chiral Phosphoric Acid: Highly Enantioselective Friedel-Crafts Reaction of Indoles with β,β-Disubstituted Nitroalkenes

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***Supporting Information***

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**General experimental procedures**

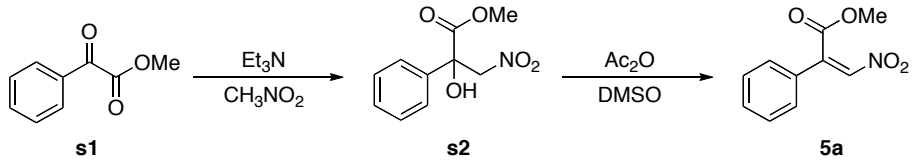
All reactions utilizing air- and moisture-sensitive reagents were performed in dried glassware under an atmosphere of dry nitrogen. Ethereal solvents (THF, $Et_2O$) were distilled from benzophenone ketyl. Dichloromethane and 1,2-dichloroethane were distilled over $CaH_2$. Benzene and toluene were distilled over $CaH_2$, and stored over 4A molecular sieves. *N*,*N*-Dimethylformamide (DMF) was distilled over $CaH_2$, and stored over 4A molecular sieves.

For thin-layer chromatography (TLC) analysis, Merck pre-coated plates (silica gel 60 $F_{254}$, Art 5715, 0.25 mm) were used. Column chromatography and preparative TLC (PTLC) were performed on PSQ 60B, Fuji Silysia Chemical Ltd. and Wakogel B-5F, Wako Pure Chemical Industries, respectively.

Melting point (mp) determinations were performed by using a AS ONE ATM-01 instrument and are uncorrected. $^{1}H$ NMR, $^{13}C$ NMR, $^{19}F$ NMR, and $^{31}P$ NMR were measured on a varian-400 MR (Varian Ltd., 400 MHz) spectrometer. Chemical shifts are expressed in parts per million (ppm) downfield from internal standard (tetramethylsilane for $^{1}H$, $CFCl_3$ for $^{19}F$, and $H_3PO_4$ for $^{31}P$ NMR, 0.00 ppm), and coupling constants are reported as hertz (Hz). Splitting patterns are indicated as follows: br, broad; s, singlet; d, doublet; t, triplet; q, quartet; sep, septet; m, multiplet. Infrared (IR) spectra were recorded on a FTIR-8600PC instrument (Shimadzu Co.). Elemental analysis (EA) was carried out on Flash2000 instrument (Amco Inc.).

## 1. Preparation of starting materials.

**Scheme 1.** General synthetic route to nitrstyrene.[1] Preparation of **5a** is shown as a representative example.




**s1** **s2** **5a**

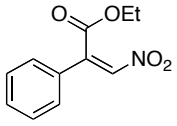
To a solution of commercially available **s1** (1.71 g, 10.5 mmol) in $CH_3NO_2$ (41.6 mL) was added $Et_3N$ (0.290 mL, 2.08 mmol). After the reaction mixture was stirred for 48 h at room temperature, the solvent was removed in vacuo. The residue was purified by column chromatography (silica gel, hexane/EtOAc = 6/1) to give alcohol **s2** (2.35 g) as a brown oil.

To a solution of **s2** in DMSO (25.2 mL) was added $Ac_2O$ (2.95 mL, 31.3 mmol) at room temperature. After being stirred for 48 h at room temperature, the reaction was atopped by addition of $H_2O$. The crude mixture was extracted with $CH_2Cl_2$ (x3) and the combined organic extracts were successively washed with saturated aqueous $NaHCO_3$, brine, dried ($Na_2SO_4$) and concentrated in vacuo. The residue was purified by column chromatography (silica gel, hexane/EtOAc = 20/1) to afford nitrostyrene **5a** (1.58 g, 68% from **s1**) as yellow oil.

$^1$H NMR (400 MHz, $CDCl_3$) δ 4.00 (s, 3H), 7.36 (s, 1H), 7.44–7.56 (m, 5H).

$^{13}$C NMR (100 MHz, $CDCl_3$) δ 53.4, 127.5, 129.3, 129.5, 132.2, 134.6, 143.1, 165.2.

The $^1$H and $^{13}$C NMR spectra were in complete agreement with those in the literature.[1]

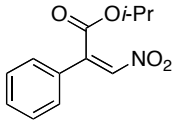



(*Z*)-Ethyl 3-nitro-2-phenylacrylate (**5b**).

$^1$H NMR (400 MHz, $CDCl_3$) δ 1.40 (t, 3H, *J* = 7.2 Hz), 4.48 (q, 2H, *J* = 6.8 Hz), 7.35 (brs, 1H), 7.42–7.56 (m, 5H).

$^{13}$C NMR (100 MHz, $CDCl_3$) δ 13.8, 62.8, 127.5, 128.4, 129,5, 132.1, 134.4, 143.3, 164.7.

The $^1$H and $^{13}$C NMR spectra were in complete agreement with those in the literature.[1]



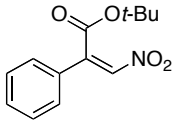

(*Z*)-Isopropyl 3-nitro-2-phenylacrylate (**5c**).

Yellow solid.

$^1$H NMR (400 MHz, $CDCl_3$) δ 1.38 (d, 6H, *J* = 6.4 Hz), 5.37 (sept, 1H, *J* = 6.4 Hz), 7.33 (s, 1H), 7.40–7.58 (m, 5H).

$^{13}$C NMR (100 MHz, $CDCl_3$) δ 21.5, 70.9, 127.4, 129.5, 129.6, 132.0, 134.2, 143.4, 164.2.

The $^1$H and $^{13}$C NMR spectra were in complete agreement with those in the literature.[1]



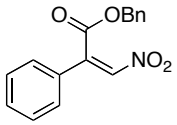

(*Z*)-*tert*-butyl 3-nitro-2-phenylacrylate (**5d**).

Yellow solid.

$^1$H NMR (400 MHz, $CDCl_3$) d 1.62 (s, 9H), 7.30 (s, 1H), 7.44–7.55 (m, 5H).

$^{13}$C NMR (100 MHz, $CDCl_3$) δ 27.9, 84.8, 127.4, 129.5, 130.0, 131.9, 133.6, 143.6, 163.5.

The $^1$H and $^{13}$C NMR spectra were in complete agreement with those in the literature.[1]




(*Z*)-Benzyl 3-nitro-2-phenylacrylate (**5e**).

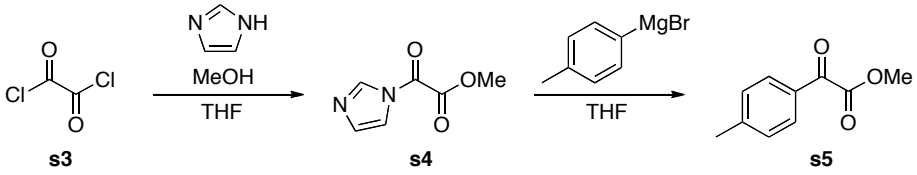
Yellow oil.

$^1$H NMR (400 MHz, $CDCl_3$) δ 5.42 (s, 2H), 7.23 (brs, 1H), 7.30–7.52 (m, 10H).

$^{13}$C NMR (100 MHz, $CDCl_3$) δ 68.5, 127.4, 128.6, 128.7, 128.8, 129.2, 129.4, 132.1, 134.3, 134.5, 142.9, 164.6.

The $^1$H and $^{13}$C NMR spectra were in complete agreement with those in the literature.[1]

**Scheme 2.** General synthetic route to substituted β-methoxycarbonyl nitrostyrenes. Preparation of **s5** is shown as a representative example.[2]




**s3** **s4** **s5**

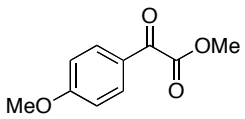
To a solution of oxalyl chloride (**s3**) (0. 68 mL, 3.94 mmol) in THF (13.4 mL) was added MeOH (0.32 mL, 3.94 mmol) at 0 °C. After stirring for 1 h 0 °C, a solution of imidazole (1.61 g, 11.8 mmol) was added to the reaction mixture at 0 °C for 20 min. After being stirred at 0 °C for 1 h, the reaction mixture was filtered through Celite® pad and concentrated in vacuo to give crude ester **s4**. This material was used to next reaction without further purification.

To a solution of **s4** in THF (31.5 mL) was added freshly prepared tolyl magnesium bromide (0.945 M in $Et_2O$, 10.0 mL, 9.45 mmol) at –78 °C. After being stirred for 0.5 h, the reaction temperature was wormed up to room temperature. The reaction was stopped by adding saturated aqueous $NH_4Cl$ at 0 °C. The crude mixture was extracted with EtOAc (x4) and the combined organic extracts were washed with brine, dried ($Na_2SO_4$), and concentrated in vacuo. The residue was purified by column chromatography (silica gel, hexane/EtOAc = 40/1) to give **s5** (824 mg, 59% from **s3**) as a colorless oil.

$^1$H NMR (400 MHz, $CDCl_3$) δ 2.42 (s, 3H), 3.96 (s, 3H), 7.29 (d, 2H, $J$ = 8.4 Hz), 7.89 (d, 2H, $J$ = 8.4 Hz).

$^{13}$C NMR (100 MHz, $CDCl_3$) δ 21.7, 52.5, 129.5, 129.8, 130.0, 146.2, 164.1, 185.6.

The $^1$H and $^{13}$C NMR spectra were in complete agreement with those in the literature.[3]




Methyl 2-(4-methoxyphenyl)-2-oxoacetate (**s6**).

Pale yellow solid.

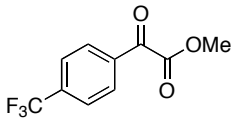
Yield: 60%.

$^1$H NMR (400 MHz, $CDCl_3$) δ 3.87 (s, 3H), 3.95 (s, 3H), 6.96 (d, 2H, $J$ = 8.4 Hz), 7.99

(d, 2H, $J$ = 8.4 Hz).

$^{13}$C NMR (100 MHz, $CDCl_3$) δ 52.4, 55.4, 114.1, 125.2, 132.4, 164.2, 164.9, 184.3.

The $^{1}$H and $^{13}$C NMR spectra were in complete agreement with those in the literature.[3]




Methyl 2-oxo-2-(4-(trifluoromethyl)phenyl)acetate (**s7**).

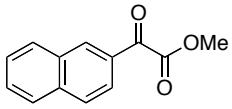
Pale yellow oil.

Yield: 54%.

$^{1}$H NMR (400 MHz, $CDCl_3$) δ 3.99 (s, 3H), 7.75–7.82 (m, 2H), 8.14–8.20 (m, 2H).

$^{13}$C NMR (100 MHz, $CDCl_3$) δ 52.8, 123.2 (q, $J$ = 270.9 Hz), 125.8 (q, $J$ = 3.8 Hz), 130.4, 135.1, 135.7 (q, $J$ = 33.0 Hz), 162.9, 184.5.

The $^{1}$H and $^{13}$C NMR spectra were in complete agreement with those in the literature.[3]




Methyl 2-(naphthalen-2-yl)-2-oxoacetate (**s8**).

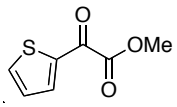
Yellow oil.

Yield: 42%.

$^{1}$H NMR (400 MHz, $CDCl_3$) δ 4.02 (s, 3H), 7.51 (ddd, 1H, $J$ = 1.2, 8.0, 8.0 Hz), 7.63 (ddd, 1H, $J$ = 1.2, 8.0, 8.0 Hz), 7.86 (d, 1H, $J$ = 8.0 Hz), 7.89 (d, 1H, $J$ = 8.8 Hz), 7.95 (d, 1H, $J$ = 8.0 Hz), 8.03 (dd, 1H, $J$ = 1.2, 8.8 Hz), 8.54 (s, 1H).

$^{13}$C NMR (100 MHz, $CDCl_3$) δ 52.8, 123.8, 127.1, 127.8, 128.9, 129.5, 129.6, 129.9, 132.2, 133.5, 136.3, 164.1, 185.9.

The $^{1}$H and $^{13}$C NMR spectra were in complete agreement with those in the literature.[3]




Methyl 2-oxo-2-(thiophen-2-yl)acetate (**s9**).

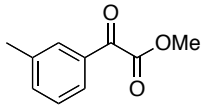
Pale yellow oil.

Yield: 50%.

$^1$H NMR (400 MHz, $CDCl_3$) δ 3.96 (s, 3H), 7.13–7.22 (m, 1H), 7.79–7.85 (m, 1H), 8.10–8.16 (m, 1H).

$^{13}$C NMR (100 MHz, $CDCl_3$) δ 52.9, 128.5, 137.2, 137.5, 138.9, 161.7, 175.7

The $^1$H and $^{13}$C NMR spectra were in complete agreement with those in the literature.[3]




Methyl 2-oxo-2-*m*-tolylacetate (**s10**).

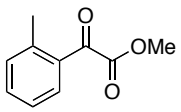
Colorless oil.

Yield: 51%.

$^1$H NMR (400 MHz, $CDCl_3$) δ 2.40 (s, 3H), 3.96 (s, 3H), 7.38 (dd, 1H, $J$ = 8.0. 8.0 Hz), 7.45 (d, 1H, $J$ = 8.0 Hz), 7.75–7.83 (m, 2H).

$^{13}$C NMR (100 MHz, $CDCl_3$) δ 21.0, 52.5, 127.1, 128.6, 130.1, 132.2, 135.7, 138.7, 164.1, 186.2.

The $^1$H and $^{13}$C NMR spectra were in complete agreement with those in the literature.[3]




Methyl 2-oxo-2-*o*-tolylacetate (**s11**).

Pale yellow oil.

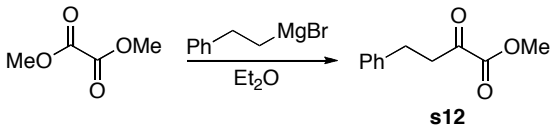
Yield: 65%.

$^1$H NMR (400 MHz, $CDCl_3$) δ 2.59 (s, 3H), 3.96 (s, 3H), 7.25–7.36 (m, 2H), 7.44–7.52 (m, 1H), 7.63–7.70 (m, 1H).

$^{13}$C NMR (100 MHz, $CDCl_3$) δ 21.3, 52.6, 125.9, 131.0, 132.2, 132.3, 133.6, 141.1, 164.8, 188.4.

The $^1$H and $^{13}$C NMR spectra were in complete agreement with those in the literature.[3]

**Scheme 3.** Preparation of **s12**.



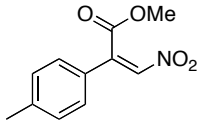

**s12**

To a solution of dimethyl oxalate (1.05 g, 8.89 mmol) in $Et_2O$ (16.9 mL) was added freshly prepared phenethyl magnesium bromide (1.50 M in $Et_2O$, 6.5 mL, 9.78 mmol) at –78 °C. After stirring for 1 h at –78 °C, the reaction temperature was warmed-up to room temperature at once. After being stirred at room temperature for 0.5 h, the reaction was stopped by adding aqueous 1 M HCl at 0 °C. The crude mixture was extracted with EtOAc (x3) and the combined organic extracts were washed with brine, dried ($Na_2SO_4$), and concentrated in vacuo. The residue was purified by column chromatography (silica gel, hexane/EtOAc = 6/1) to give **s12** (1.07 g, 63%) as a colorless oil.

$^1$H NMR (400 MHz, $CDCl_3$) δ 2.92 (t, 2H, $J$ = 7.6 Hz), 3.15 (t, 2H, $J$ = 7.6 Hz), 3.80 (s, 3H), 7.15–7.38 (m, 5H).

$^{13}$C NMR (100 MHz, $CDCl_3$) δ 28.6, 40.7, 52.6, 126.1, 128.1, 128.3, 139.8, 161.0, 192.9.

The $^1$H and $^{13}$C NMR spectra were in complete agreement with those in the literature.[4]




(*Z*)-Methyl 3-nitro-2-*p*-tolylacrylate (**5f**).

Yellow solid.

Yield: 68% (from **s5**).

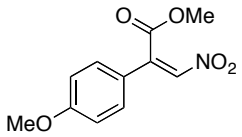
Mp. 58–61 °C.

IR (neat) 3109, 3033, 2954, 2923, 2849, 1742, 1622, 1605, 1567, 1520, 1436, 1415, 1350, 1281, 1255, 1218, 1179, 1130, 1029, 1018, 968, 918, 845, 817 $cm^{-1}$.

$^1$H NMR (400 MHz, $CDCl_3$) δ 2.41 (s, 3H), 3.99 (s, 3H), 7.27 (d, 2H, $J$ = 8.0 Hz), 7.36 (s, 1H), 7.38 (d, 2H, $J$ = 8.0 Hz).

$^{13}$C NMR (100 MHz, $CDCl_3$) δ 21.5, 53.3, 126.3, 127.4, 130.2, 133.7, 143.2, 143.2, 165.4.

Anal. Calcd for $C_{11}H_{11}NO_4$: C, 59.73; H, 5.01; N, 6.33. Found: C, 60.01; H, 4.99; N, 6.23.




(*Z*)-Methyl 2-(4-methoxyphenyl)-3-nitroacrylate (**5g**).

Yellow solid.

Mp. 79–81 °C.

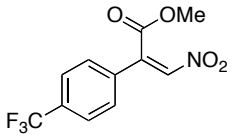
Yield: 78% (from **s6**).

IR (KBr) 3108, 2954, 2843, 1739, 1598, 1515, 1424, 1334, 1298, 1252, 1218, 1176, 1021, 968, 921, 826, 800 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CDCl_3$) δ 3.78 (s, 3H), 4.00 (s, 3H), 6.96 (d, 2H, $J$ = 8.8 Hz), 7.35 (s, 1H), 7.43 (d, 2H, $J$ = 8.8 Hz).

$^{13}C$ NMR (100 MHz, $CDCl_3$) δ 53.4, 55.6, 115.1, 121.3, 129.5, 132.5, 143.0, 163.0, 165.7.

Anal. Calcd for $C_{14}H_{11}NO_5$: C, 55.70; H, 4.67; N, 5.90. Found: C, 55.52; H, 4.46; N, 5.64.




(*Z*)-Methyl 3-nitro-2-(4-(trifluoromethyl)phenyl)acrylate (**5h**).

Pale yellow crystal.

Mp. 77–79 °C.

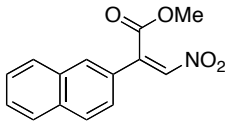
Yield: 86% (from **s7**).

IR (neat) 3455, 3108, 2957, 2850, 1928, 1737, 1629, 1577, 1523, 1440, 1414, 1356, 1324, 1255, 1222, 1166, 1120, 1070, 1029, 1013, 986, 922, 862, 842, 784 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CDCl_3$) δ 4.00 (s, 3H), 7.36 (s, 1H), 7.64 (d, 2H, $J$ = 8.4 Hz), 7.74 (d, 2H, $J$ = 8.4 Hz).

$^{13}C$ NMR (100 MHz, $CDCl_3$) δ 53.7, 123.3 (q, $J$ = 270.8 Hz), 126.5 (q, $J$ = 3.7 Hz), 127.9, 132.9, 133.6 (q, $J$ = 32.7 Hz), 136.2, 141.4, 164.6.

Anal. Calcd for $C_{11}H_8F_3NO_4$: C, 48.01; H, 2.93; N, 5.09. Found: C, 48.11; H, 2.76; N, 4.90.




(*Z*)-Methyl 2-(naphthalen-2-yl)-3-nitroacrylate (**5i**).

Yellow crystal.

Mp. 120–122 °C.

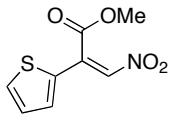
Yield: 89% (from **s8**).

IR (neat) 2920, 2850, 1738, 1613, 1521, 1435, 1346, 1322, 1230, 1174, 1129, 962, 816, 752 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CDCl_3$) δ 4.00 (s, 3H), 7.49–7.59 (m, 4H), 7.85–7.95 (m, 3Hz), 7.98 (d, 1H, $J$ = 1.2 Hz).

$^{13}C$ NMR (100 MHz, $CDCl_3$) δ 53.5, 122.7, 126.5, 127.4, 127.8, 128.6, 129.0, 129.3, 129.6, 132.9, 134.6, 134.7, 143.2, 165.4.

Anal. Calcd for $C_{14}H_{11}NO_4$: C, 65.37; H, 4.31; N, 5.44. Found: C, 65.36; H, 4.09; N, 5.52.




(*E*)-Methyl 3-nitro-2-(thiophen-2-yl)acrylate (**5j**).

Yellow solid.

Mp. 77–79 °C.

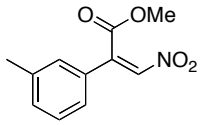
Yield: 70% (from **s9**).

IR (neat) 3096, 2954, 1741, 1606, 1517, 1436, 1418, 1361, 1326, 1254, 1221, 1177, 1061, 1006, 967, 891, 822, 720 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CDCl_3$) δ 4.02 (s, 3H), 7.15 (dd, 1H, $J$ = 4.0, 5.2 Hz), 7.35 (dd, 1H, $J$ = 1.2, 4.0 Hz), 7.38 (s, 1H), 7.59 (dd, 1H, $J$ = 1.2, 5.2 Hz),

$^{13}C$ NMR (100 MHz, $CDCl_3$) δ 53.7, 129.1, 131.7, 132.4, 133.2, 137.5, 164.5.

Anal. Calcd for $C_8H_7NO_4S$: C, 45.07; H, 3.31; N, 6.57. Found: C, 45.29; H, 3.20; N, 6.69.



(*Z*)-Methyl 3-nitro-2-*m*-tolylacrylate (**5k**).

Pale yellow solid

Mp. 49–51 °C.

Yield: 71% (from **s10**).

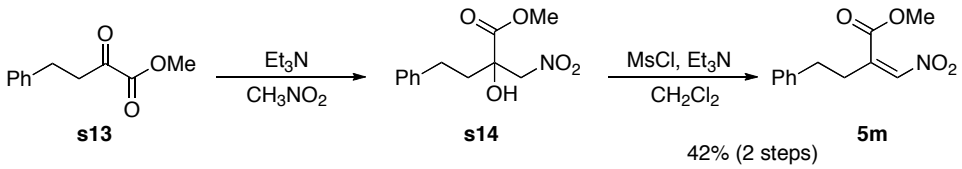
IR (neat) 3108, 2954, 1741, 1624, 1601, 1582, 1521, 1436, 1350, 1332, 1265, 1224, 1170, 1039, 967, 949, 837, 791 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CDCl_3$) δ 2.39 (s, 3H), 3.99 (s, 3H), 7.27–7.32 (m, 2H), 7.33–7.36 (m, 3H).

$^{13}C$ NMR (100 MHz, $CDCl_3$) δ 21.3, 53.4, 124.6, 128.0, 129.2, 129.4, 133.0, 134.4, 139.5, 143.3, 165.3.

Anal. Calcd for $C_{11}H_{11}NO_4$: C, 59.73; H, 5.01; N, 6.33. Found: C, 60.00; H, 5.14; N, 6.19.

**Scheme 4.** Preparation of **5m**.[1]




To a solution of **s13** in $CH_3NO_2$ (22.3 mL) was added $Et_3N$ (0.160 mL, 1.14 mmol) at room temperature. After the reaction mixture was stirred for 48 h at room temperature, the solvent was removed in vacuo to give crude **s14**. This material was used to next reaction without further purification.

To a solution of **s15** in $CH_2Cl_2$ (25.1 mL) were successively added MsCl (1.16 mL, 15.0 mmol) and $Et_3N$ (2.11 mL, 15.1 mmol) at –20 °C. After being stirred for 4 h at –20 °C, the reaction mixture was poured into crash ice. The crude mixture was extracted with $CH_2Cl_2$ (x3) and the combined organic extracts were washed with brine, dried ($Na_2SO_4$) and concentrated in vacuo. The residue was purified by column chromatography (silica gel, hexane/EtOAc = 20/1) to afford nitrostyrene **5m** (494 mg, 42% from dimethyl oxalate) as a yellow oil.

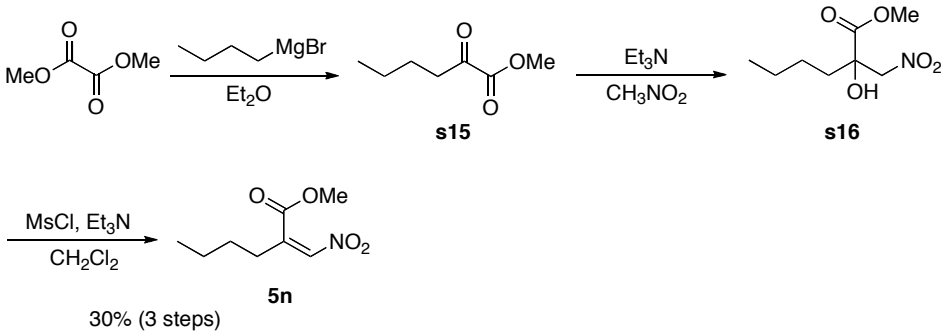
IR (neat) 3111, 3087, 3064, 3030, 2954, 2866, 2849, 1732, 1637, 1533, 1496, 1454, 1438, 1355, 1337, 1253, 1176, 1095, 910, 734 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CDCl_3$) δ 2.79–2.90 (m, 2H), 3.00–3.11 (m, 2H), 3.83 (s, 3H), 7.18–7.38 (m, 5H), 7.68 (s, 1H).

$^{13}C$ NMR (100 MHz, $CDCl_3$) δ 29.5, 34.5, 53.2, 126.4, 128.5, 128.5, 139.6, 140.0, 144.0, 165.3.

Anal. Calcd for $C_{12}H_{13}NO_4$: C, 61.27; H, 5.57; N, 5.95. Found: C, 61.24; H, 5.78; N, 5.81.

**Scheme 5.** Preparation of **5n**.[1]




To a solution of dimethyl oxalate (1.02 g, 8.64 mmol) in $Et_2O$ (17.3 mL) was added freshly prepared phenethyl magnesium bromide (1.46 M in $Et_2O$, 6.5 mL, 9.50 mmol) at –78 °C. After stirring for 1 h at –78 °C, the reaction temperature was warmed-up to room temperature at once. After being stirred at room temperature for 0.5 h, the reaction was stopped by adding aqueous 1 M HCl at 0 °C. The crude mixture was extracted with EtOAc (x3) and the combined organic extracts were washed with brine, dried ($Na_2SO_4$), and concentrated in vacuo to give crude **s15**. This material was used to next reaction without further purification.

To a solution of commercially **s15** in $CH_3NO_2$ (30.0 mL) was added $Et_3N$ (0.240 mL, 1.72 mmol) at room temperature. After the reaction mixture was stirred for 48 h at room temperature, the solvent was removed in vacuo to give crude **s15**. This material was used to next reaction without further purification.

To a solution of **s16** in $CH_2Cl_2$ (40.0 mL) were successively added MsCl (2.01 mL, 26.0 mmol) and $Et_3N$ (3.63 mL, 26.0 mmol) at –20 °C. After being stirred for 7 h at –20 °C, the reaction mixture was poured into crash ice. The crude mixture was extracted with $CH_2Cl_2$ (x3) and the combined organic extracts were successively washed with 10%

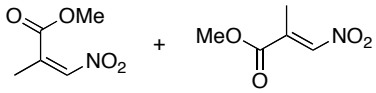
NaOH aq., $H_2O$, brine, dried ($Na_2SO_4$) and concentrated in vacuo. The residue was purified by column chromatography (silica gel, hexane/EtOAc = 20/1) to afford nitrostyrene **5n** (480 mg, 30% from dimethyl oxalate) as a yellow oil.

IR (neat) 3105, 2959, 2935, 2874, 1741, 1650, 1531, 1437, 1355, 1228, 1142, 1094, 968, 931, 846, 789, 736 $cm^{-1}$.

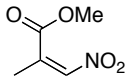
$^1H$ NMR (400 MHz, $CDCl_3$) δ 0.94 (t, 3H, *J* = 7.2 Hz), 1.32–1.45 (m, 2H), 1.45–1.58 (m, 2H), 2.35–2.49 (m, 2H), 3.89 (s, 3H), 6.86 (s, 1H).

$^{13}C$ NMR (100 MHz, $CDCl_3$) δ 29.5, 34.5, 53.2, 126.4, 128.5, 128.5, 139.6, 140.0, 144.0, 165.3.

Anal. Calcd for $C_8H_{13}NO_4$: C, 51.33; H, 7.00; N, 7.48. Found: C, 51.48; H, 6.92; N, 7.42.




(*Z*)-Methyl 2-methyl-3-nitroacrylate (*Z*-**5o**) and (*E*)-Methyl 2-methyl-3-nitroacrylate (*E*-**5o**) were synthesized according to procedure of the preparation of **5m**.



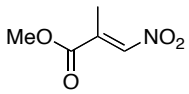

Pale yellow oil.

Yield: 53% (from commercially available methyl acetoacetate).

$^1H$ NMR (400 MHz, $CDCl_3$) δ 2.12 (d, 3H, *J* = 2.0 Hz), 3.87 (s, 3H), 6.94 (q, 1H, *J* = 2.0 Hz).

$^{13}C$ NMR (100 MHz, $CDCl_3$) δ 17.5, 53.1, 135.9, 140.6, 166.6.

The $^1H$ and $^{13}C$ NMR spectra were in complete agreement with those in the literature.[5]




Pale yellow oil.

Yield: 7% (from commercially available methyl acetoacetate

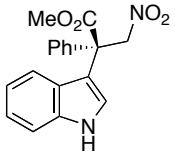
$^1H$ NMR (400 MHz, $CDCl_3$) δ 2.33 (d, 3H, *J* = 2.0 Hz), 3.88 (d, 3H, *J* = 2.0 Hz), 7.73 (q, 1H, *J* = 2.0 Hz).

$^{13}$C NMR (100 MHz, $CDCl_3$) δ 13.7, 53.3, 136.4, 144.1, 165.7.

The $^{1}$H and $^{13}$C NMR spectra were in complete agreement with those in the literature.[5]

**3. Asymmetric Friedel-Crafts reaction of indoles with nitroalkenes by means of chiral phosphoric acid.**

To a solution of β-methoxycarbonyl-β,β-disubstituted nitroalkenes **5** (0.30–0.40 mmol) and powered MS5A (25.0 mg, activated) in $CH_2Cl_2$ (0.20 mL) and cyclohexane (0.80 mL) were successively added chiral phosphoric acid **1h** (0.010 mmol, 5 mol%) and indole **2** (0.20 mmol) at room temperature. After completion of the reaction, the reaction mixture was concentrated in vacuo. The residue was purified by preparative TLC to give Friedel-Crafts adduct **6**.




(*R*)-methyl 2-(1*H*-indol-3-yl)-3-nitro-2-phenylpropanoate (**6a**).

Pale red solid.

Yield: 91%, 92% ee.

HPLC [DAICEL CHIRALPAK® AD-H, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 10/1, 1.0 mL/min, 228 nm, retention time (min) = 31.2 (95.4%), 44.8 (4.6 %)].

$[\alpha]_D^{23}$ –103.0 (c 1.0, $CHCl_3$).

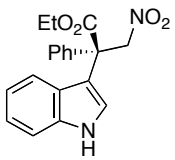
Mp 181–183 °C.

IR (neat) 3412, 3058, 2952, 2922, 1735, 1556, 1469, 1459, 1447, 1418, 1376, 1338, 1269, 1216, 1136, 1103, 1063, 1005, 967, 853, 792 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CDCl_3$) δ 3.77 (s, 3H), 5.43 (d, 1H, *J* = 13.2 Hz), 5.38 (d, 1H, *J* = 13.2 Hz), 6.53 (d, 1H, *J* = 8.0 Hz), 6.87 (ddd, 1H, *J* = 0.8, 8.0, 8.0 Hz), 7.11 (ddd, 1H, *J* = 1.2, 8.0, 8.0 Hz), 7.27–7.38 (m, 6 H), 7.46 (d, 1H, *J* = 2.8 Hz), 8.28 (brs, 1H).

$^{13}C$ NMR (100 MHz, $CDCl_3$) δ 53.0, 54.6, 80.6, 111.4, 112.1, 119.8, 120.4, 122.2, 125.1, 125.2, 127.8, 128.1, 128.6, 136.2, 137.7, 171.5.

Anal. Calcd for $C_{18}H_{16}N_2O_4$: C, 66.66; H, 4.97; N, 8.64. Found: C, 66.88; H, 4.95; N, 8.46.




(*R*)-Ethyl 2-(1*H*-indol-3-yl)-3-nitro-2-phenylpropanoate (**6b**).

Pale red solid.

Yield: 95%, 92% ee.

HPLC [DAICEL CHIRALPAK® AD-H, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 10/1, 1.0 mL/min, 228 nm, retention time (min) = 24.71 (95.8%), 40.0 (4.2%)].

$[\alpha]_D^{23}$ –44.8 (c 1.00, $CHCl_3$).

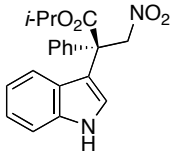
Mp. 126–128 °C.

IR (neat) 3411, 3058, 2981, 2925, 2854, 1726, 1619, 1556, 1496, 1459, 1447, 1419, 1375, 1337, 1270, 1215, 1100, 1062, 1015, 861, 746 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CDCl_3$) δ 1.19 (t, 3H, *J* = 7.2 Hz), 4.18–4.32 (m, 2H), 5.43 (d, 1H, *J* = 13.6, Hz), 5.62 (d, 1H, *J* = 13.6 Hz), 6.77 (d, *J* = 8.4 Hz), 6.85 (ddd, 1H, *J* = 0.8, 8.0, 8.0 Hz), 7.09 (ddd, 1H, *J* = 0.8, 8.0, 8.0 Hz), 7.21–7.38 (m, 6H), 7.41 (d, 1H, *J* = 2.8 Hz), 8.32 (brs, 1H).

$^{13}C$ NMR (100 MHz, $CDCl_3$) δ 13.8, 54.7, 62.1, 80.6, 111.4, 112.1, 119.7, 120.5, 122.1, 125.1, 127.8, 128.0, 128.5, 136.2, 137.8, 170.9.

Anal. Calcd for $C_{19}H_{18}N_2O_4$: C, 67.44; H, 5.36; N, 8.28. Found: C, 67.59; H, 5.61; N, 8.45.




(*R*)-Isopropyl 2-(1*H*-indol-3-yl)-3-nitro-2-phenylpropanoate (**6c**).

Pale red solid.

Yield: 77%, 86% ee.

HPLC [DAICEL CHIRALPAK® ID, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 10/1, 1.0 mL/min, 254 nm, retention time (min) = 8.9 (93.2%), 11.3 (6.8%)].

$[\alpha]_D^{23}$ –86.1 (c 1.0, $CHCl_3$).

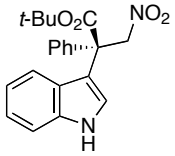
Mp. 136–137 °C.

IR (neat) 3411, 2983, 1723, 1556, 1490, 1459, 1419, 1375, 1338, 1272, 1218, 1100, 1021, 920, 828, 745 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CDCl_3$) δ 1.12 (d, 3H, *J* = 6.4 Hz), 1.23 (d, 3H, *J* = 6.0 Hz), 5.12 (t, 1H, *J* = 6.4 Hz ), 5.42 (d, 1H, *J* = 13.2 Hz), 5.64 (d, 1H, = 13.2 Hz) 6.78 (d, 1H, *J* = 8.0 Hz), 6.86 (ddd, 1H, *J* = 0.8, 8.0, 8.0 Hz), 7.12 (ddd, 1H, *J* = 1.2, 7.2, 7.2 Hz), 7.20–7.38 (m, 6H), 7.35–7.37 (m, 2H), 7.48 (d, 1H, *J* = 2.8 Hz), 8.28 (brs, 1H).

$^{13}$C NMR (100 MHz, $CDCl_3$) δ 21.3, 21.4, 54.8, 69.8, 80.5, 111.4, 112.2, 119.7, 120.6, 122.1, 125.2, 125.3, 127.8, 127.9, 128.5, 136.2, 137.9, 170.3.

Anal. Calcd for $C_{20}H_{20}N_2O_4$: C, 68.17; H, 5.72; N, 7.95. Found: C, 68.40; H, 5.46; N, 7.69.




(*R*)-*tert*-Butyl 2-(1*H*-indol-3-yl)-3-nitro-2-phenylpropanoate (**6d**).

Pale red solid.

Yield: 81%, 91% ee.

HPLC [DAICEL CHIRALPAK® AD-H, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 10/1, 1.0 mL/min, 254 nm, retention time (min) = 15.12 (95.7%), 22.65 (4.9%)].

$[\alpha]_D^{25}$ –60.9 (c 1.0, $CHCl_3$).

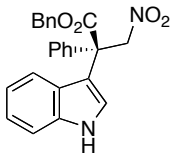
Mp. 182–184 °C.

IR (neat) 3412, 3059, 2979, 2930, 1720, 1619, 1556, 1490, 1458, 1419, 1393, 1370, 1337, 1276, 1241, 1153, 1104, 1062, 1016, 989, 846, 800, 746 $cm^{-1}$.

$^1$H NMR (400 MHz, $CDCl_3$) δ 1.40 (s, 9H), 5.38 (d, 1H, *J* = 13.6 Hz), 5.58 (d, 1H, *J* = 13.2 Hz), 6.76 (d, 1H, *J* = 8.0 Hz), 6.85 (ddd, 1H, *J* = 0.8, 7.2, 7.2 Hz), 7.09 (ddd, 1H, *J* = 0.8, 7.2, 7.2Hz), 7.25–7.38 (m, 6H), 7.43 (d, 1H, *J* = 2.8 Hz), 8.28 (brs, 1H).

$^{13}$C NMR (100 MHz, $CDCl_3$) δ 27.6, 55.3, 80.7, 82.7, 111.4, 112.4, 119.5, 120.6, 122.0, 125.2, 125.3, 127.7, 127.8, 128.4, 136.2, 138.2, 169.7.

Anal. Calcd for $C_{21}H_{22}N_2O_4$: C, 68.84; H, 6.05; N, 7.65. Found: C, 68.86; H, 6.30; N, 7.75.




(*R*)-Benzyl 2-(1*H*-indol-3-yl)-3-nitro-2-phenylpropanoate (**6e**).

Red solid.

Yield: 67%, 97% ee.

HPLC [DAICEL CHIRALPAK® ID, f 0.46 x 25 cm, hexane/*i*-PrOH = 10/1, 1.0 mL/min, 228 nm, retention time (min) = 8.9 (98.6%), 10.2 (1.4%)].

$[\alpha]_D^{24}$ –91.2 (c 1.0, $CHCl_3$).

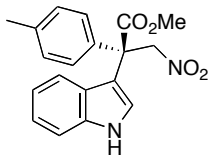
Mp. 183–184 °C.

IR (neat) 3458, 2922, 1738, 1556, 1496, 1458, 1419, 1376, 1336, 1211, 1099, 1022, 909, 747 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CDCl_3$) δ 5.20 (s, 2H), 5.43(d, 1H, *J* =13.6 Hz), 5.65 (d, 1H, *J* =13.6 Hz), 6.73 (d, 1H, *J* = 8.0 Hz), 6.84 (ddd, 1H, *J* =1.2, 7.2, 7.2 Hz), 7.05–7.18 (m, 3H), 7.22–7.38 (m, 9H), 7.44 (d, 1H, *J* = 2.8 Hz), 8.20 (brs, 1H).

$^{13}C$ NMR (100 MHz, $CDCl_3$) δ 54.8, 67.7, 80.5, 111.4, 111.9, 119.8, 120.4, 122.1, 125.1, 125.4, 127.8, 128.0, 128.1, 128.2, 128.4, 128.6, 135.2, 136.2, 137.6, 170.7.

Anal. Calcd for $C_{24}H_{20}N_2O_4$: C, 71.99; H, 5.03; N, 7.00. Found: C, 71.77; H, 5.12; N, 7.23.




(*R*)-Methyl 2-(6-chloro-1*H*-indol-3-yl)-3-nitro-2-phenylpropanoate (**6f**).

Pale red oil.

Yield: 87%, 89% ee.

HPLC [DAICEL CHIRALPAK® ID, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 10/1, 1.0 mL/min, 254 nm, retention time (min) = 12.9 (94.5%), 14.7 (5.5%)].

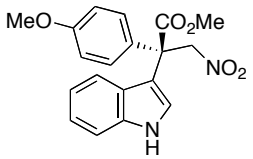
$[\alpha]_D^{23}$ –169.7 (c 1.100, $CHCl_3$).

IR (neat) 3412, 3028, 2952, 2921, 1733, 1618, 1556, 1511, 1459, 1435, 1419, 1376, 1337, 1272, 1213, 1136, 1102, 1069, 1041, 1017, 1003, 967, 857, 821, 747 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CDCl_3$) δ 2.30 (s, 3H), 3.76 (s, 3H), 5.41 (d, 1H, *J* = 14.0 Hz), 5.61 (d, 1H, *J* = 14.0 Hz), 6.78 (d, 1H, *J* = 8.0 Hz), 6.87 (ddd, 1H, *J* = 0.8, 8.0. 8.0 Hz), 7.06–7.12 (m, 3H), 7.18-7.24 (m, 2H), 7.29 (d, 1H, *J* = 8.0 Hz), 7.41 (d, 1H, *J* = 2.8 Hz), 8.29 (brs, 1H).

$^{13}C$ NMR (100 MHz, $CDCl_3$) δ 21.0, 52.9, 54.3, 80.7, 111.4, 112.1, 119.7, 120.4, 122.1, 125.1, 125.2, 127.6, 129.3, 134.6, 136.2, 137.8, 171.7.

Anal. Calcd for $C_{19}H_{18}N_2O_4$: C, 67.44; H, 5.36; N, 8.28. Found: C, 67.68; H, 5.64; N, 8.21.




(*R*)-Methyl 2-(6-chloro-1*H*-indol-3-yl)-3-nitro-2-phenylpropanoate (**6g**).

Red solid.

Yield: 81%, 89% ee.

HPLC [DAICEL CHIRALPAK® AD-H, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 10/1, 1.0 mL/min, 254 nm, retention time (min) = 18.1 (94.7%), 19.7 (5.3%)].

$[\alpha]_D^{16}$ –16.7 (c 1.110, $CHCl_3$).

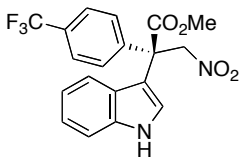
Mp. 196–198 °C.

IR (neat) 3650, 3410, 3004, 2953, 2839, 2253, 1732, 1609, 581, 1556, 1510, 1459, 1437, 1419, 1376, 1337, 1298, 1254, 1215, 1183, 1136, 1102, 1068, 1029, 967, 909, 856, 832, 799, 768, 736 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CDCl_3$) δ 3.76 (s, 6H), 5.42 (d, 1H, *J* = 13.6 Hz), 5.58 (d, 1H, *J* = 13.6 Hz), 6.80 (dd, 3H, *J* = 2.4, 6.8 Hz), 6.88 (ddd, 1H, *J* = 7.2, 8.0, 15.2 Hz), 7.11 (ddd, 1H, *J* = 1.2, 7.2, 15.2 Hz), 7.22–7.27 (m, 4H), 7.29 (d, 1H, *J* = 8.4 Hz), 7.40 (d, 1H, *J* = 2.8 Hz), 8.31 (brs, 1H).

$^{13}C$ NMR (100 MHz, $CDCl_3$) δ 53.0, 54.0, 55.2, 80.7, 111.4, 112.2, 113.9, 119.8, 120.5, 122.2, 125.2, 129.0, 129.6, 136.2, 159.1, 171.7.

Anal. Calcd for $C_{19}H_{18}N_2O_5$: C, 64.40; H, 5.12; N, 7.91. Found: C, 64.54; H, 5.08; N, 7.99.




(*R*)-Methyl 2-(6-chloro-1*H*-indol-3-yl)-3-nitro-2-phenylpropanoate (**6h**).

Red oil.

Yield: 72%, 93% ee.

HPLC [DAICEL CHIRALPAK® AD-H, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 10/1, 1.0 mL/min, 254 nm, retention time (min) = 24.2 (96.7%), 32.0 (3.3%)].

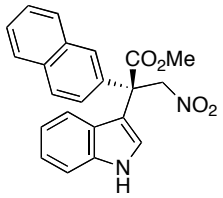
$[\alpha]_D^{17}$ –28.3 (c 1.10, $CHCl_3$).

IR (neat) 3410, 1738, 1620, 1557, 1459, 1415, 1376, 1328, 1219, 1169, 1123, 1072, 1016, 842, 748 $cm^{-1}$.

$^1$H NMR (400 MHz, $CDCl_3$) δ 3.78 (s, 3H), 5.51 (d, 1H, *J* = 13.6 Hz), 5.54 (d, 1H, *J* = 13.6 Hz), 6.91 (ddd, 1H, *J* = 0.8, 8.0, 8.0 Hz), 7.14 (ddd, 1H, *J* = 0.8, 6.8, 6.8 Hz), 7.33 (d, 1H, *J* = 8.4 Hz), 7.44 (d, 1H, *J* = 2.8 Hz), 7.49 (d, 2H, *J* = 8.8 Hz), 7.55 (d, 2H, *J* = 8.8 Hz), 8.36 (brs, 1H).

$^{13}$C NMR (100 MHz, $CDCl_3$) δ 53.2, 54.6, 80.4, 111.6, 120.2, 120.2, 122.5, 123.8 (q, *J* = 270.9 Hz), 124.7, 124.7, 125.5 (q, *J* = 3.7 Hz), 128.6, 130.3 (q, *J* = 4.6 Hz), 136.3, 141.7, 170.8.

Anal. Calcd for $C_{19}H_{15}F_3N_2O_4$: C, 58.17; H, 3.85; N, 7.14. Found: C, 58.21; H, 3.65; N, 7.12.




(*R*)-Methyl 2-(6-chloro-1*H*-indol-3-yl)-3-nitro-2-phenylpropanoate (**6i**).

Red oil.

Yield: 88%, 90% ee.

HPLC [DAICEL CHIRALPAK® ID, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 10/1, 1.0 mL/min, 254 nm, retention time (min) = 13.8 (94.9%), 16.6 (5.1%)].

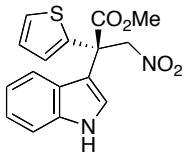
$[\alpha]_D^{23}$ – 18.8 (c 1.11, $CHCl_3$).

IR (neat) 3413, 3057, 2952, 2923, 2851, 1734, 1598, 1556, 1507, 1458, 1435, 1418, 1375, 1337, 1273, 1215, 1170, 1103, 1044, 1014, 965, 908, 863, 819, 739 $cm^{-1}$.

$^1$H NMR (400 MHz, $CDCl_3$) δ 3.77 (s, 3H), 5.54 (d, 1H, *J* = 13.6 Hz), 5.78 (d, 1H, *J* = 13.6 Hz), 6.72–6.81 (m, 2H), 7.07 (dtd, 1H, *J* = 1.6, 2.8 Hz), 7.30 (d, 1H, *J* = 8.0 Hz), 7.39 (dd, 1H, *J* = 2.0, 8.4 Hz), 7.45–7.53 (m, 3H), 7.72 (d, 1H, *J* = 8.8 Hz), 7.76–7.82 (m, 2H), 7.78 (d, 1H, *J* = 1.6 Hz), 8.33 (brs, 1H).

$^{13}$C NMR (100 MHz, $CDCl_3$) δ 53.1, 54.7, 80.6, 111.4, 111.9, 119.9, 120.2, 122.1, 125.1, 125.4, 125.7, 126.4, 126.4, 126.6, 127.5, 128.4, 128.5, 132.7, 132.9, 135.2, 136.2, 171.5.

Anal. Calcd for $C_{22}H_{18}N_2O_4$: C, 70.58; H, 4.85; N, 7.48. Found: C, 70.90; H, 4.55; N, 7.38.




(*S*)-Methyl 2-(1*H*-indol-3-yl)-3-nitro-2-(thiophen-2-yl)propanoate (**6j**).

Pale red amorphous.

Yield: 75%, 89% ee.

HPLC [DAICEL CHIRALPAK® OD-H, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 7/3, 1.0 mL/min, 254 nm, retention time (min) = 8.4 (94.5%), 12.0 (5.6%)].

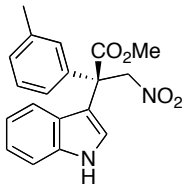
$[\alpha]_D^{23}$ –1.280 (c 1.220, $CHCl_3$).

IR (neat) 3412, 3023, 2952, 1737, 1556, 1492, 1459, 1419, 1375, 1338, 1278, 1216, 1136, 1102, 1052, 1001, 964, 849, 750, 708 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CDCl_3$) d 3.81 (s, 3H), 5.42 (d, 1H, *J* = 14.4 Hz), 5.58 (d, 1H, *J* = 14.4 Hz), 6.92–7.06 (m, 3H), 7.12–7.34 (m, 5H), 8.29 (brs, 1H).

$^{13}C$ NMR (100 MHz, $CDCl_3$) δ 52.1, 53.2, 80.9, 111.6, 112.7, 120.1, 120.2, 12 2.5, 123.7, 124.9, 126 .3, 126.5, 127.2, 136.3, 141.0, 170.8.

Anal. Calcd for $C_{16}H_{14}N_2O_4S$: C, 58.17; H, 4.27; N, 8.48. Found: C, 58.40; H, 4.10; N, 8.77.




(*R*)-Methyl 2-(6-chloro-1*H*-indol-3-yl)-3-nitro-2-phenylpropanoate (**6k**).

Pale red oil.

Yield: 70%, 91% ee.

HPLC [DAICEL CHIRALPAK® ID, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 10/1, 1.0 mL/min, 254 nm, retention time (min) = 10.1 (95.4%), 12.0 (4.6%)].

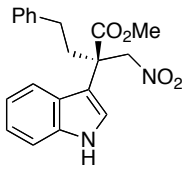
$[\alpha]_D^{21}$ –53.6 (c 1.10, $CHCl_3$).

IR (neat) 3421, 3055, 2952, 1733, 1605, 1556, 1489, 1459, 1419, 1376, 1338, 1272, 1213, 1102, 1014, 967, 794, 766, 743, 704 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CDCl_3$) δ 2.28 (s, 3H), 3.78 (s, 3H), 5.41 (d, 1H, *J* = 13.6 Hz), 5.67 (d, 1H, *J* = 13.6 Hz), 6.76 (d, 1H, *J* = 8.4 Hz), 6.87 (dd, 1H, *J* = 8.0, 8.0 Hz), 7.07–7.21 (m, 5H), 7.48 (d, 1H, *J* = 2.8 Hz), 8.28 (brs, 1H).

$^{13}$C NMR (100 MHz, $CDCl_3$) δ 21.6, 53.0, 54.5, 80.6, 111.4, 112.1, 119.8, 120.3, 122.1, 124.7, 125.2, 125.4, 128.2, 128.5, 128.9, 136.2, 137.7, 138.3, 171.6.

Anal. Calcd for $C_{19}H_{18}N_2O_4$: C, 67.44; H, 5.36; N, 8.28. Found: C, 67.59; H, 5.51; N, 8.25.




(*R*)-Methyl 2-(1*H*-indol-3-yl)-2-(nitromethyl)hexanoate (**6m**).

Colorless solid.

Yield: 52%, 87% ee.

HPLC [DAICEL CHIRALPAK® ID, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 10/1, 1.0 mL/min, 254 nm, retention time (min) = 10.0 (93.4%), 11.1 (6.6%)].

$[\alpha]_D^{26}$ 20.7 (c 9.70, $CHCl_3$).

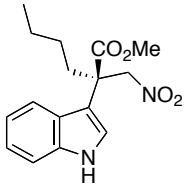
Mp. 107–110 °C.

IR (neat) 3415, 3060, 3028, 2952, 1728, 1552, 1496, 1460, 1377, 1339, 1217, 1109, 909, 744, 701 $cm^{-1}$.

$^1$H NMR (400 MHz, $CDCl_3$) δ 2.40–2.61 (m, 2H), 2.63–2.80 (m, 2H), 3.76 (s, 3H), 5.20 (d, 1H, *J* = 12.4 Hz), 5.29 (d, 1H, *J* = 12.4 Hz), 7.07 (d, 1H, *J* = 2.8 Hz), 7.10–7.34 (m, 7H), 7.38 (d, 1H, *J* = 8.0 Hz), 7.60 (d, 1H, *J* = 8.0 Hz), 8.20 (brs, 1H).

$^{13}$C NMR (100 MHz, $CDCl_3$) δ 30.8, 35.1, 50.0, 52.9, 78.4, 111.8, 112.4, 119.0, 120.4, 122.5, 122.7, 124.6, 126.2, 128.4, 128.5, 136.5, 140.9, 173.0.

Anal. Calcd for $C_{20}H_{20}N_2O_4$: C, 68.17; H, 5.72; N, 7.95. Found: C, 68.36; H, 6.02; N, 7.84.




(*R*)-Methyl 2-(1*H*-indol-3-yl)-2-(nitromethyl)-4-phenylbutanoate (**6n**).

Colorless Solid.

Yield: 43%, 85% ee.

HPLC [DAICEL CHIRALPAK® ID, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 20/1, 1.0 mL/min, 254 nm, retention time (min) = 11.9 (92.3%), 13.3 (7.7%)].

$[\alpha]_D^{22}$ 82.86 (c 1.310, $CHCl_3$).

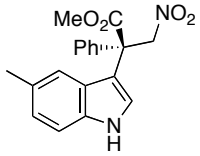
Mp. 116–119 °C.

IR (neat) 3413, 2957, 2932, 2871, 1727, 1553, 1460, 1433, 1378, 1339, 1241, 1215, 1144, 1119, 1016, 909 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CDCl_3$) δ 2.40–2.61 (m, 2H), 2.63–2.80 (m, 2H), 3.76 (s, 3H), 5.20 (d, 1H, *J* = 12.4 Hz), 5.29 (d, 1H, *J* = 12.4 Hz), 7.04 (d, 1H, *J* = 2.8 Hz), 7.12 (ddd, 1H, *J* = 0.8, 8.0, 8.0 Hz), 7.21 (dd, 1H, *J* = 8.0. 8.0 Hz), 7.35 (d, 1H, *J* = 8.0 Hz), 7.56 (d, 1H, *J* = 8.0 Hz), 8.18 (brs, 1H).

$^{13}C$ NMR (100 MHz, $CDCl_3$) δ 13.8, 22.8, 26.3, 32.6, 49.9, 52.8, 78.2, 111.7, 112.9, 119.0, 120.2, 122.4, 122.5, 124.7, 136.5, 173.3.

Anal. Calcd for $C_{16}H_{20}N_2O_4$: C, 63.14; H, 6.62; N, 9.20. Found: C, 63.37; H, 6.84; N, 9.38.




(*R*)-Methyl 2-(6-chloro-1*H*-indol-3-yl)-3-nitro-2-phenylpropanoate (**6o**).

Red solid.

Yield: 87%, 93% ee.

HPLC [DAICEL CHIRALPAK® AD-H, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 10/1, 1.0 mL/min, 228 nm, retention time (min) = 22.8 (96.6%), 27.7 (3.4%)].

$[\alpha]_D^{23}$ –97.8 (c 1.00, $CHCl_3$).

Mp. 153–155 °C.

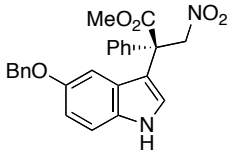
IR (neat) 3408, 3029, 2952, 2919, 1734, 1556, 1484, 1447, 1436, 1418, 1376, 1339, 1273, 1217, 1141, 1096, 1061, 1046, 1026, 968, 910, 865, 799 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CDCl_3$) δ 2.21 (s, 3H), 3.77 (s, 3H), 5.45 (d, 1H, *J* =13.6 Hz), 5.61 (d, 1H, *J* =13.6 Hz), 6.53 (s, 1H), 6.93 (dd, 1H, *J* =1.2, 8.4 Hz), 7.20 (d, 1H, *J* =8.4 Hz), 7.26–7.38 (m, 5H), 7.40 (d, 1H, *J* =2.8 Hz), 8.17 (brs, 1H).

$^{13}C$ NMR (100 MHz, $CDCl_3$) δ 21.5, 53.0, 54.6, 80.6, 111.1, 111.5, 119.9, 123.8, 125.3, 125.3, 127.8, 128.0, 128.6, 129.0, 134.6, 137.7, 171.6.

Anal. Calcd for $C_{19}H_{18}N_2O_4$: C, 67.44; H, 5.36; N, 8.28. Found: C, 67.72; H, 5.38; N,

8.19.




(*R*)-Methyl 2-(5-(benzyloxy)-1*H*-indol-3-yl)-3-nitro-2-phenylpropanoate (**6p**).

Palw red oil.

Yield: 80%, 90% ee.

HPLC [DAICEL CHIRALPAK® ID, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 5/1, 1.0 mL/min, 254 nm, retention time (min) = 9.9 (94.9%), 11.1 (5.1%)].

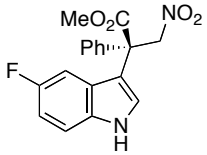
$[\alpha]_D^{23}$ –75.67 (c 1.230, $CHCl_3$).

IR (neat) 3417, 3031, 2952, 1735, 1624, 1556, 1483, 1454, 1435, 1376, 1293, 1217, 1106, 1025, 923, 847, 804, 755 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CDCl_3$) δ 3.71 (s, 3H), 4.72 (s, 2H), 5.34 (d, 1H, *J* = 13.6 Hz), 5.54 (d, 1H, 13.6 Hz), 6.21 (d, 1H, *J* = 2.0 Hz), 6.82 (dd, 1H, *J* = 2.0, 8.8 Hz), 7.15 (d, 1H, *J* = 8.8 Hz), 7.20–7.36 (m, 11H), 8.22 (brs, 1H).

$^{13}C$ NMR (100 MHz, $CDCl_3$) δ 53.0, 54.5, 70.5, 80.5, 104.0, 111.8, 112.1, 113.1, 125.5, 125.7, 127.5, 127.7, 127.8, 128.0, 128.4, 128.6, 131.5, 137.3, 137.5, 152.8, 171.5.

Anal. Calcd for $C_{24}H_{22}N_2O_5$: C, 69.76; H, 5.15; N, 6.51. Found: C, 69.48; H, 4.93; N, 6.22.




(*R*)-Methyl 2-(5-fluoro-1*H*-indol-3-yl)-3-nitro-2-phenylpropanoate (**6q**).

Pale yellow amorphous.

Yield: 72%, 94% ee.

HPLC [DAICEL CHIRALPAK® AD-H, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 10/1, 1.0 mL/min, 254 nm, retention time (min) = 28.9 (97.0%), 32.8 (3.0%)].

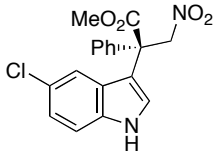
$[\alpha]_D^{22}$ –105.1 (c 1.0, $CHCl_3$).

IR (neat) 3423, 3032, 2954, 2360, 1735, 1631, 1580, 1557, 1486, 1458, 1436, 1420, 1376, 1345, 1317, 1290, 1218, 1175, 1107, 1090, 1060, 1026, 1005, 967, 931, 910, 856, 803, 760, 730 $cm^{-1}$.

$^1$H NMR (400 MHz, $CDCl_3$) δ 3.78 (s, 3 H), 5.36 (d, 1H, *J* =13.6 Hz), 5.65 (d, 1H, *J* = 13.6 Hz), 6.36 (dd, 1H, *J* = 2.4, 10.4 Hz), 6.84 (ddd, 1H, *J* = 2.8, 9.2, 9.2 Hz), 7.20 (q, 1H, *J* = 4.4, 8.8 Hz), 7.25 (s, 3H), 7.31 (s, 5H), 7.59 (d, 1H, *J* = 2.8 Hz), 8.35 (brs, 1H).

$^{13}$C NMR (100 MHz, $CDCl_3$) δ 53.1, 54.5, 80.5, 105.3 (d, *J* = 24.6 Hz), 110.7 (d, *J* = 26.0 Hz), 112.1 (d, *J* = 9.7 Hz), 125.5 (d, *J* = 10.4 Hz), 127.0, 127.6, 128.3, 128.8, 137.2, 157.4 (d, *J* = 234.4 Hz), 171.4.

Anal. Calcd for $C_{18}H_{15}FN_2O_4$: C, 63.15; H, 4.42; N, 8.18. Found: C, 62.85; H, 4.57; N, 8.36.




(*R*)-Methyl 2-(5-chloro-1*H*-indol-3-yl)-3-nitro-2-phenylpropanoate (**6r**).

Pale red solid.

Yield: 72%, 94% ee.

HPLC [DAICEL CHIRALPAK® AD-H, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 10/1, 1.0 mL/min, 254 nm, retention time (min) = 27.3 (97.0%), 30.1 (3.0%)].

$[\alpha]_D^{23}$ –105.3 (c 1.110, $CHCl_3$).

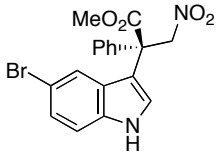
Mp. 175–178 °C.

IR (neat) 3651, 3420, 3132, 3026, 2982, 2953, 2923, 2739, 1956, 1732, 1598, 1557, 1497, 1464, 1449, 1436, 1418, 1375, 1336, 1296, 1217, 1140, 1110, 1068, 1045, 1027, 1006, 967, 917, 895, 864, 802, 793, 756, 727 $cm^{-1}$.

$^1$H NMR (400 MHz, $CDCl_3$) δ 3.78 (s, 3H), 5.35 (d, 1H, *J* = 13.6 Hz), 5.67 (d, 1H, *J* = 13.6 Hz), 6.66 (d, 1H, *J* = 2.0 Hz), 7.04 (dd, 1H, *J* = 2.0, 8.8 Hz), 7.21 (d, 1H, *J* = 8.8 Hz), 7.28–7.38 (m, 5H), 7.50 (d, 1H, *J* =2.8 Hz), 8.40 (brs, 1H).

$^{13}$C NMR (100 MHz, $CDCl_3$) δ 53.1, 54.5, 80.5, 111.8, 112.5, 119.7, 122.6, 125.5, 126.2, 126.8, 127.5, 128.4, 128.9, 134.6, 137.2, 171.4.

Anal. Calcd for $C_{18}H_{15}ClN_2O_4$: C, 60.26; H, 4.21; N, 7.81. Found: C, 60.14; H, 3.94; N, 8.07.




(*R*)-Methyl 2-(5-bromo-1*H*-indol-3-yl)-3-nitro-2-phenylpropanoate (**6s**).

Pale red solid.

Yield: 75%, 91% ee.

HPLC [DAICEL CHIRALPAK® AD-H, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 10/1, 1.0 mL/min, 210 nm, retention time (min) = 31.6 (95.6%), 36.0 (4.4%)].

$[\alpha]_D^{22}$ –130.8 (c 1.110, $CHCl_3$).

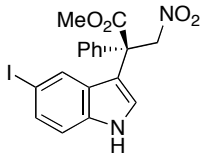
Mp. 193–195 °C.

IR (neat) 3420, 3026, 2952, 1733, 1556, 1497, 1459, 1449, 1436, 1415, 1376, 1335, 1296, 1217, 1141, 1107, 1054, 1026, 1005, 967, 885, 864, 800 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CDCl_3$) d 3.78 (s, 3H), 5.35 (d, 1H, *J* = 13.6 Hz), 5.69 (d, 1H, *J* = 13.6 Hz), 6.81 (s, 1H), 7.20 (s, 2H), 7.28–7.36 (m, 5H), 7.52 (d, 1H, *J* = 2.4 Hz), 8.35 (brs, 1H).

$^{13}C$ NMR (100 MHz, $CDCl_3$) d 53.1, 54.5, 80.5, 111.8, 112.9, 113.2, 122.8, 125.2, 126.7, 126.9, 127.5, 128.4, 128.9, 134.8, 137.2, 171.3.

Anal. Calcd for $C_{18}H_{15}BrN_2O_4$: C, 53.62; H, 3.75; N, 6.95. Found: C, 53.71; H, 3.47; N, 6.80.




(*R*)-Methyl 2-(5-iodo-1*H*-indol-3-yl)-3-nitro-2-phenylpropanoate (**6t**).

Pale red amorphous.

Yield: 57%, 91% ee.

HPLC [DAICEL CHIRALPAK® AD–H, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 10/1, 1.0 mL/min, 254 nm, retention time (min) = 31.3 (95.5%), 38.9 (4.5%)].

$[\alpha]_D^{22}$ –53.5 (c 0.830, $CHCl_3$).

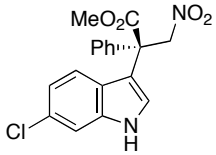
IR (neat) 3418, 3060, 3025, 2952, 2922, 2850, 1733, 1597, 1556, 1497, 1449, 1436, 1413, 1376, 1331, 1294, 1217, 1144, 1106, 1065, 1049, 1026, 1004, 966, 879, 799 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CDCl_3$) d 3.79 (s, 3H), 5.34 (dd, 1H, *J* = 14.0 Hz), 5.68 (dd, 1H, *J* = 14.0 Hz), 7.00 (s, 1H), 7.08 (d, 1H, *J* = 8.8 Hz), 7.16–7.40 (m, 6H), 7.44 (s, 1H), 8.36

(brs, 1H).

$^{13}$C NMR (100 MHz, $CDCl_3$) d 53.1, 54.5, 80.6, 83.5, 111.4, 113.4, 126.3, 127.5, 127.6, 128.4, 128.8, 129.0, 130.5, 135.3, 137.2, 171.4.

Anal. Calcd for $C_{18}H_{15}IN_2O_4$: C, 48.02; H, 3.36; N, 6.22. Found: C, 48.24; H, 3.39; N, 6.33.




(*R*)-Methyl 2-(6-chloro-1*H*-indol-3-yl)-3-nitro-2-phenylpropanoate (**6u**).

Pale red solid.

Yield: 61%, 89% ee.

HPLC [DAICEL CHIRALPAK® ID, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 10/1, 1.0 mL/min, 254 nm, retention time (min) = 9.2 (94.3%), 11.0 (5.7%)].

$[\alpha]_D^{23}$ –13.5 (c 1.00, $CHCl_3$).

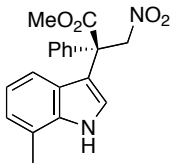
Mp. 194–196 °C.

IR (neat) 3422, 3062, 2953, 1732, 1618, 1556, 1497, 1450, 1436, 1395, 1376, 1335, 1272, 1217, 1144, 1104, 1065, 1026, 1004, 966, 908, 850, 806, 786 $cm^{-1}$.

$^1$H NMR (400 MHz, $CDCl_3$) δ 3.79 (s, 3 H), 5.37 (d, 1H, *J* = 13.6 Hz), 5.65 (d, 1H, *J* = 13.6 Hz), 6.62 (d, 1H, *J* = 8.8 Hz), 6.83 (dd, 1H, *J* = 1.6, 8.4 Hz), 7.28–7.35 (m, 6H), 7.49 (d, 1H, *J* = 2.4 Hz), 8.29 (brs, 1H).

$^{13}$C NMR (100 MHz, $CDCl_3$) δ 53.1, 54.5, 80.6, 111.4, 112.4, 120.6, 121.3, 123.8, 125.9, 127.6, 128.2, 128.3, 128.8, 136.6, 137.5, 171.3.

Anal. Calcd for $C_{18}H_{15}ClN_2O_4$: C, 60.26; H, 4.21; N, 7.81. Found: C, 60.44; H, 4.33; N, 7.70.




(*R*)-Methyl 2-(6-chloro-1*H*-indol-3-yl)-3-nitro-2-phenylpropanoate (**6v**).

Pale red solid.

Yield: 88%, 88% ee.

HPLC [DAICEL CHIRALPAK® ID, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 10/1, 1.0 mL/min, 254 nm, retention time (min) = 11.5 (94.0%), 13.1 (6.0%)].

$[\alpha]_D^{22}$ –154.6 (c 1.100, $CHCl_3$).

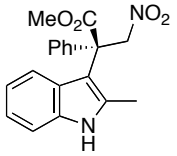
Mp. 178–180 °C.

IR (neat) 3412, 3056, 2952, 2920, 2857,1617, 1591, 1556, 1495, 1736, 1447, 1435, 1376, 1345, 1329, 1274, 1216, 1175, 1145, 1109, 1068, 1044, 1030, 968, 909, 861, 848, 782 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CDCl_3$) δ 2.41 (s, 3H), 3.77 (s, 3H), 5.45 (d, 1H, *J* = 13.6 Hz), 5.64 (d, 1H, *J* = 13.6 Hz), 6.60 (d, 1H, *J* = 8.0 Hz), 6.78 (dd, 1H, *J* = 7.2, 8.0 Hz), 6.91 (d, 1H, *J* = 7.2 Hz), 7.25–7.38 (m, 5H), 7.45 (d, 1H, *J* = 2.4 Hz), 8.25 (brs, 1H).

$^{13}C$ NMR (100 MHz, $CDCl_3$) δ 16.5, 53.0, 54.7, 80.6, 112.6, 118.1, 120.0, 120.6, 122.7, 124.7, 125.0, 127.8, 128.0, 128.6, 135.8, 137.8, 171.5.

Anal. Calcd for $C_{19}H_{18}N_2O_4$: C, 67.44; H, 5.36; N, 8.28. Found: C, 67.67; H, 5.53; N, 8.50.




(*R*)-Methyl 2-(6-chloro-1*H*-indol-3-yl)-3-nitro-2-phenylpropanoate (**6w**).

Yellow solid.

Yield: 41%, 26% ee.

HPLC [DAICEL CHIRALPAK® AD-H, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 15/1, 1.0 mL/min, 228 nm, retention time (min) = 42.8 (37.1%), 45.5 (62.9%)].

$[\alpha]_D^{21}$ –0.61 (c 0.83, $CHCl_3$).

Mp. 214–216 °C.

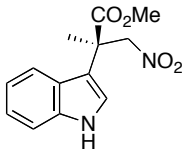
IR (neat) 3397, 2952, 1729, 1556, 1490, 1460, 1447, 1434, 1376, 1221, 1099, 1075, 1030, 745 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CDCl_3$) δ 2.17 (s, 3H), 3.76 (s, 3H), 5.57 (d, 1H, *J* = 12.8 Hz), 5.68 (d, 1H, *J* = 12.8 Hz), 6.73 (d, 1H, *J* = 8.0 Hz), 6.87 (ddd, 1H, *J* = 0.8, 8.0, 8.0 Hz), 7.06 (ddd, 1H, *J* = 0.8, 8.0, 8.0 Hz), 7.20–7.34 (m, 4H), 7.42–7.48 (m, 2H), 7.98 (brs, 1H).

$^{13}C$ NMR (100 MHz, $CDCl_3$) δ 14.4, 52.9, 55.3, 79.8, 108.5, 110.5., 119.6, 119.7, 121.3, 127.0, 127.9, 128.2, 128.4, 134.5, 134.9, 138.5, 171.7.

Anal. Calcd for $C_{19}H_{18}N_2O_4$: C, 67.44; H, 5.36; N, 8.28. Found: C, 67.54; H, 5.20; N,

8.13.




(*R*)-Methyl 2-(1*H*-indol-3-yl)-2-methyl-3-nitropropanoate (**6x**).

Pale red solid.

Yield: 75%, 84% ee.

HPLC [DAICEL CHIRALPAK® AD-H, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 10/1, 0.5 mL/min, 254 nm, retention time (min) = 19.9 (92.1%), 21.0 (7.9%)].

$[\alpha]_D^{21}$ 77.8 (c 0.980, $CHCl_3$).

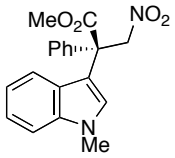
Mp. 114–116 °C.

IR (neat) 3414, 2952, 1728, 1553, 1460, 1419, 1374, 1338, 1286, 1222, 1113, 1016, 985, 849, 746 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CDCl_3$) δ 1.89 (s, 3H), 3.73 (s, 3H), 4.81 (d, 1H, *J* = 12.8 Hz), 5.35 (d, 1H, *J* = 12.8 Hz), 7.01 (d, 1H, *J* = 2.8 Hz), 7.05–7.26 (m, 2H), 7.32–7.37 (m, 1H), 7.68 (ddd, 1H, *J* = 1.2, 8.0, 8.0 Hz), 8.30 (brs, 1H).

$^{13}C$ NMR (100 MHz, $CDCl_3$) δ 20.9, 45.9, 52.8, 80.8, 111.8, 113.5, 119.6, 120.2, 122.0, 122.6, 124.6, 136.76, 173.4.

Anal. Calcd for $C_{13}H_{14}N_2O_4$: C, 59.54; H, 5.38; N, 10.68. Found: C, 59.69; H, 5.50; N, 10.85.




(*R*)-Methyl 2-(6-chloro-1*H*-indol-3-yl)-3-nitro-2-phenylpropanoate (**13**).

Yelloe solid.

Yield: 20%, 8% ee.

HPLC [DAICEL CHIRALPAK® ID, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 20/1, 1.0 mL/min, 254 nm, retention time (min) = 15.8 (54.3%), 16.9 (45.7%)].

$[\alpha]_D^{23}$ –13.0 (c 1.20, $CHCl_3$).

Mp. 158–160 °C.

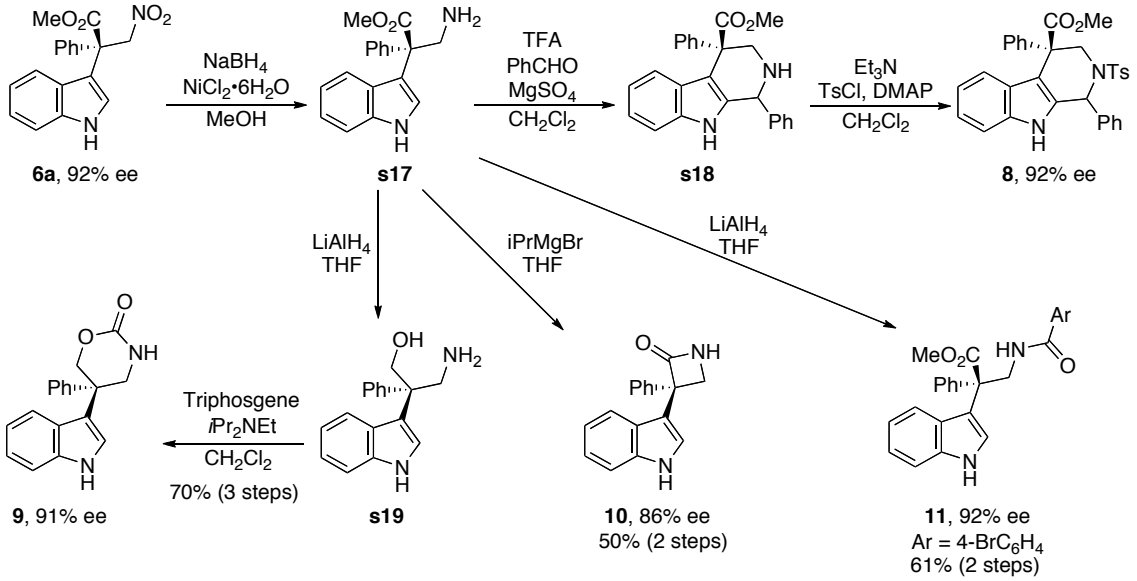
IR (neat) 2952, 1741, 1556, 1484, 1435, 1377, 1332, 1213, 1088, 1018, 744 $cm^{-1}$.

$^{1}$H NMR (400 MHz, $CDCl_3$) δ 3.78 (s, 3H), 3.79 (s, 3H), 5.43 (d, 1H, *J* = 13.6 Hz), 5.64 (d, 1H, *J* = 13.6 Hz), 6.73 (d, 1H, *J* = 8.0 Hz), 6.86 (ddd, 1H, *J* = 0.8, 8.0, 8.0 Hz), 7.14 (ddd, 1H, *J* = 0.8, 8.0, 8.0 Hz), 7.23–7.38 (m, 7H).

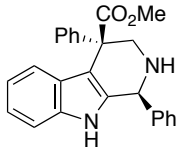
$^{13}$C NMR (100 MHz, $CDCl_3$) δ 33.0, 53.0, 54.6, 80.6, 109.5, 110.4, 119.4, 120.4, 121.7, 125.7, 127.8, 128.0, 128.6, 129.9, 137.1, 137.9, 171.6.

Anal. Calcd for $C_{19}H_{18}N_2O_4$: C, 67.44; H, 5.36; N, 8.28. Found: C, 67.24; H, 5.26; N, 8.34.

## 4. Further Transformations.




**Scheme 6.** Further transformations from Friedel-Crafts adduct **6a**.



***Synthesis of (1S,4R)-methyl 1,4-diphenyl-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indole-4-carboxylate (s18):***

To a solution of **6a** (30.6 mg, 0.0943 mmol) in MeOH (1.0 mL) were successively added $NiCl_2$•$6H_2O$ (22.4 mg, 0.0943 mmol) and $NaBH_4$ (17.8 mg, 0.472 mmol) at 0 °C. After stirring for 1 h at room temperature, the reaction was stopped by adding aqueous saturated $NaHCO_3$ at 0 °C. The crude mixture was extracted with $CH_2Cl_2$ (x3) and the combined organic extracts were washed with brine, dried ($Na_2SO_4$), and concentrated in vacuo to give crude **s17** (30.0 mg). This material was used to next reaction without further purification.

To a solution of **s17** in $CH_2Cl_2$ (1.0 mL) were successively added $MgSO_4$ (69.0 mg) and benzaldehyde (12.0 μL, 0.118 mmol) at room temperature. After stirring for 1 h at room temperature, trifluoroacetic acid (14.0 μL, 0.189 mmol) was added to the reaction mixture. After stirring for 48 h at room temperature, the reaction was stopped by adding aqueous saturated $NaHCO_3$ at 0 °C. The crude mixture was extracted with $CH_2Cl_2$ (x3) and the combined organic extracts were washed with brine, dried ($Na_2SO_4$), and concentrated in vacuo. The residue was purified by column chromatography

(silica gel, hexane/EtOAc = 1/1) to afford cyclized adduct **s18** (35.0 mg, 97%) as a red solid.

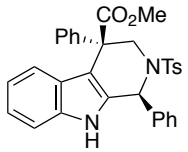
Mp. 280–282 °C.

IR (KBr) 3404, 3321, 3142, 3058, 3029, 2928, 2855, 1713, 1601, 1491, 1455, 1433, 1336, 1306, 1255, 1227, 1164, 1100, 1062, 1031, 1015, 997, 977, 954, 882, 869, 740, 700 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CDCl_3$) δ 2.51 (brs, 1H), 2.91 (d, 1H, *J* = 13.6 Hz), 3.74 (s, 3H), 3.96 (d, 1H, *J* = 13.6 Hz), 5.21 (s, 1H), 6.96 (dd, 1H, *J* = 7.6, 7.6 Hz), 7.06–7.45 (m, 13H), 7.68 (brs, 1H).

$^{13}C$ NMR (100 MHz, $CDCl_3$) δ 52.2, 53.6, 57.0, 58.2, 110.2, 110.8, 119.6, 121.8, 122.2, 126.5, 126.9, 127.1, 128.3, 128.4, 128.6, 129.1, 135.8, 138.4, 140.5, 141.0, 175.7.

Anal. Calcd for $C_{25}H_{22}N_2O_2$: C, 78.51; H, 5.80; N, 7.32. Found: C, 78.54; H, 5.82; N, 7.27.




***Synthesis of (4R)-Methyl 1,4-diphenyl-2-tosyl-2,3,4,9-tetrahydro-1H-pyrido[3,4-b]indole-4-carboxylate (8):***

To a solution of **s18** (34.5 mg, 0.0902 mmol) in $CH_2Cl_2$ (1.0 mL) were successively added $Et_3N$ (80.0 μL, 0.541 mmol) and *p*-toluenesulfonyl chloride (85.9 mg, 0.451 mmol) at room temperature. After the reaction mixture was refluxing for 6 h, the reaction was stopped by adding aqueous saturated $NaHCO_3$ at 0 °C. The crude mixture was extracted with EtOAc (x4) and the combined organic extracts were washed with brine, dried ($Na_2SO_4$), and concentrated in vacuo. The residue was purified by column chromatography (silica gel, hexane/EtOAc = 3/1) to afford Ts-amide **8** (38.9 mg, 80%) as a pale yellow oil.

HPLC [DAICEL CHIRALPAK® OD-H, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 5/1, 0.5mL/min, 254 nm, retention time (min) = 21.6 (4.1%), 27.7 (95.9%)].

$[\alpha]_D^{22}$ 27.830 (c 1.220, $CHCl_3$), 92% ee.

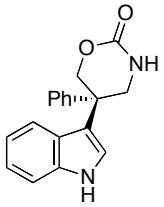
IR (neat) 3368, 3060, 2961, 2926, 2870, 1725, 1599, 1494, 1457, 1382, 1335, 1306,

1254, 1233, 1186, 1157, 1116, 1092, 1071, 1016, 982, 950, 874, 831, 812, 739, 700 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CDCl_3$) δ 2.28 (s, 3H), 3.42 (s, 3H), 4.00 (d, 1H, *J* = 13.6 Hz), 4.56 (d, 1H, *J* = 13.6 Hz), 6.05 (s, 1H), 6.89 (d, 2H, *J* = 8.0 Hz), 6.98–7.06 (m, 3H), 7.11–7.31 (m, 13H), 7.83 (brs, 1H).

$^{13}C$ NMR (100 MHz, $CDCl_3$) δ 21.4, 51.9, 52.6, 53.5, 56.9, 109.4, 111.1, 120.1, 121.1, 122.4, 125.9, 127.1, 128.0, 128.1, 128.5, 128.6, 129.1, 129.3, 134.1, 136.4, 136.9, 137.8, 139.7, 142.6, 173.5.

Anal. Calcd for $C_{32}H_{28}N_2O_4S$: C, 71.62; H, 5.26; N, 4.94. Found: C, 71.67; H, 5.29; N, 4.91.




***Synthesis of (R)-5-(1H-Indol-3-yl)-5-phenyl-1,3-oxazinan-2-one (9):***

To a solution of **6a** (21.0 mg, 0.0647 mmol) in MeOH (1.0 mL) were successively added $NiCl_2$•$6H_2O$ (15.3 mg, 0.0647 mmol) and $NaBH_4$ (12.2 mg, 0.324 mmol) at 0 °C. After stirring for 1 h at room temperature, the reaction was stopped by adding aqueous saturated $NaHCO_3$ at 0 °C. The crude mixture was extracted with $CH_2Cl_2$ (x3) and the combined organic extracts were washed with brine, dried ($Na_2SO_4$), and concentrated in vacuo to give crude **s17** (21.4 mg). This material was used to next reaction without further purification.

To a solution of **s17** in THF (1.0 mL) was added $LiAlH_4$ (3.7 mg, 0.0971 mmol) at 0 °C (portionwise). After being stirred for 0.5 h at 0 °C, the reaction was stopped by adding $Na_2SO_4$•$10H_2O$. After being stirred for another 0.5 h at room temperature, the crude material was filtered through Celite® pad and the resulting filtrate was concentrated in vacuo to give crude **s19** (19.8 mg). The crude material was used for the next reaction without further purification.

To a solution of **s19** in $CH_2Cl_2$ (1.0 mL) were successively added *i*-$Pr_2NEt$ (56.0 μL, 0.324 mmol) and triphosgene (9.6 mg, 0.0324 mmol) at 0 °C. After the reaction mixture was stirred for 4 h at 0 °C, the reaction was stopped by adding aqueous saturated $NaHCO_3$ at 0 °C. The crude mixture was extracted with EtOAc (x4) and the

combined organic extracts were washed with brine, dried ($Na_2SO_4$), and concentrated in vacuo. The residue was purified by preparative TLC (silica gel, $CH_2Cl_2$/MeOH = 20/1) to afford carbamate **9** (13.3 mg, 70% from **6a**) as a white solid.

HPLC [DAICEL CHIRALPAK® ID, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 10/1, 1.0 mL/min, 254 nm, retention time (min) = 30.9 (4.6%), 38.2 (95.4%)].

$[\alpha]_D^{25}$ – 16.7 (c 1.20, $CHCl_3$), 91% ee.

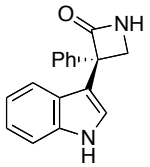
Mp. 217–220 °C.

IR (KBr) 3406, 3289, 3059, 2921, 1699, 1488, 1458, 1436, 1338, 1287, 1244, 1145, 1107, 1046, 1016, 833, 758, 743, 700 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CD_3OD$) δ 3.98 (d, 1H, *J* = 12.0 Hz), 4.07 (d, 1H, *J* = 12.0 Hz), 4.80–4.94 (m, 2H), 6.78 (dd, 1H, *J* = 8.0, 8.0 Hz), 6.96 (d, 1H, *J* = 8.0 Hz), 7.02 (dd, 1H, *J* = 8.0, 8.0 Hz), 7.20–7.45 (m, 7H).

$^{13}C$ NMR (100 MHz, $CD_3OD$) δ 29.5, 41.2, 75.0, 112.6, 116.2, 119.8, 120.7, 122.6, 123.8, 126.6, 128.2, 128.3, 129.6, 138.7, 142.8, 156.5.

Anal. Calcd for $C_{18}H_{16}N_2O_2$: C, 73.95; H, 5.52; N, 9.58. Found: C, 74.20; H, 5.79; N, 9.39.




***Synthesis of (R)-3-(1H-Indol-3-yl)-3-phenylazetidin-2-one (10):***

To a solution of **6a** (23.0 mg, 0.0709 mmol) in MeOH (1.0 mL) were successively added $NiCl_2$•$6H_2O$ (16.9 mg, 0.0709 mmol) and $NaBH_4$ (13.4 mg, 0.354 mmol) at 0 °C. After stirring for 1 h at room temperature, the reaction was stopped by adding aqueous saturated $NaHCO_3$ at 0 °C. The crude mixture was extracted with $CH_2Cl_2$ (x3) and the combined organic extracts were washed with brine, dried ($Na_2SO_4$), and concentrated in vacuo to give crude **s17** (23.0 mg). This material was used to next reaction without further purification.

To a solution of **s17** in THF (1.0 mL) was added freshly prepared isopropyl magnesium bromide (0.709 M in $Et_2O$, 1.0 mL, 0.709 mmol) at 0 °C. After stirring for 1 h at room temperature, the reaction was stopped by adding aqueous saturated $NaHCO_3$ at 0 °C.

The crude mixture was extracted with EtOAc (x3) and the combined organic extracts were washed with brine, dried ($Na_2SO_4$), and concentrated in vacuo. The residue was purified by preparative TLC (silica gel, $CH_2Cl_2$/MeOH = 20/1) to afford β-lactam **10** (9.3 mg, 50% from **6a**) as a colorless amorphous.

HPLC [DAICEL CHIRALPAK® ID, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 10/1, 1.0 mL/min, 254 nm, retention time (min) = 17.1 (6.9%), 18.4 (93.1%)].

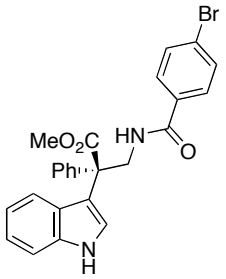
$[\alpha]_D^{25}$ –65.4 (c 1.10, $CHCl_3$), 86% ee.

IR (neat) 3297, 3059, 2971, 2917, 2849, 1745, 1494, 1458, 1446, 1417, 1335, 1245, 1194, 1099, 1011, 908, 743, 699 $cm^{-1}$.

$^1H$ NMR (400 MHz, $CDCl_3$) δ 4.00 (d, 1H, *J* = 5.2 Hz), 4.03 (d, 1H, *J* = 5.2 Hz), 6.01 (brs, 1H), 7.07 (ddd, 1H, *J* = 0.8, 8.0, 8.0 Hz), 7.14–7.40 (m, 6H), 7.46–7.55 (m, 3H), 8.18 (brs, 1H).

$^{13}C$ NMR (100 MHz, $CDCl_3$) δ 29.7, 50.7, 111.5, 114.9, 119.5, 119.9, 122.4, 122.9, 126.0, 127.0, 127.3, 128.5, 136.6, 139.4, 170.9.

Anal. Calcd for $C_{17}H_{14}N_2O$: C, 77.84; H, 5.38; N, 10.68. Found: C, 77.91; H, 5.44; N, 10.84.




***Synthesis of (R)-Methyl 3-(4-bromobenzamido)-2-(1H-indol-3-yl)-2-phenylpropanoate (11):***

To a solution of **6a** (18.3 mg, 0.0547 mmol) in MeOH (1.0 mL) were successively added $NiCl_2$•$6H_2O$ (13.4 mg, 0.0547 mmol) and $NaBH_4$ (10.7 mg, 0.274 mmol) at 0 °C. After stirring for 1 h at room temperature, the reaction was stopped by adding aqueous saturated $NaHCO_3$ at 0 °C. The crude mixture was extracted with $CH_2Cl_2$ (x3) and the combined organic extracts were washed with brine, dried ($Na_2SO_4$), and concentrated in vacuo to give crude **s17** (18.7 mg). This material was used to next reaction without further purification.

To a solution of **s17** in $CH_2Cl_2$ (1.0 mL) were successively added pyridine (10.0 μL, 0.109 mmol) and 4-bromobenzoyl chloride (18.6 mg, 0.0821 mmol) at 0 °C. After the reaction mixture was stirred for 4.5 h at room temperature, the reaction was stopped by adding aqueous saturated $NaHCO_3$ at 0 °C. The crude mixture was extracted with EtOAc (x3) and the combined organic extracts were washed with brine, dried ($Na_2SO_4$), and concentrated in vacuo. The residue was purified by column chromatography (silica gel, hexane/EtOAc = 2/1) to afford benzamide **11** (18.7 mg, 70% from **6a**) as a colorless solid.

HPLC [DAICEL CHIRALPAK® OD-H, ϕ 0.46 x 25 cm, hexane/*i*-PrOH = 7/3, 1.0 mL/min, 254 nm, retention time (min) = 6.2 (96.1%), 7.0 (3.9%)].
$[\alpha]_D^{23}$ –0.5667 (c 1.110, $CHCl_3$), 92% ee.
Mp. 227–230 °C.
IR (KBr) 3435, 3283, 3007, 2951, 1716, 1655, 1590, 1522, 1479, 1459, 1434, 1337, 1236, 1111, 1071, 1011, 969, 843, 751 $cm^{-1}$.
$^1H$ NMR (400 MHz, $CDCl_3$) δ 3.73 (s, 3H), 4.29 (dd, 1H, *J* = 4.4, 13.6 Hz), 4.59 (dd, 1H, *J* = 7.6, 13.6 Hz), 6.69 (brs, 1H), 6.95 (dd, 1H, *J* = 8.0, 8.0 Hz), 7.09–7.20 (m, 2H), 7.21–7.50 (m, 11H), 8.46 (brs, 1H).
$^{13}C$ NMR (100 MHz, $CDCl_3$) δ 46.3, 52.6, 56.3, 111.4, 114.7, 119.6, 121.7, 122.2, 123.9, 126.0, 127.6, 128.0, 128.3, 128.4, 131.7, 133.4, 136.7, 139.4, 166.2, 175.0.
Anal. Calcd for $C_{25}H_{21}BrN_2O_3$: C, 62.90; H, 4.43; N, 5.87. Found: C, 63.12; H, 4.45; N, 6.03.

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