Supporting Information

Nickel-Catalyzed Asymmetric α-Arylation of Ketone Enolates

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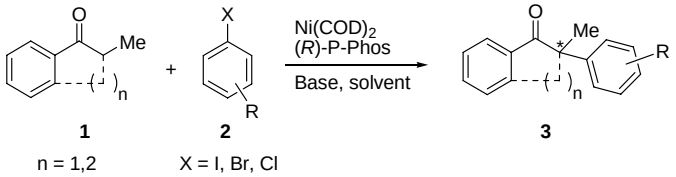
1. General considerations.

Unless otherwise noted, all reagents were purchased from commercial suppliers. All solid reagents were used without purification and all liquid reagents were dried over 4Å molecular sieves prior to use. All air-sensitive reactions were performed in Rotaflo® (England) resealable screw cap Schlenk flask (approx. 10 mL volume) or Teflon-lined screw cap vials (approx. 2 mL volume) in the presence of Teflon-coated magnetic stirrer bar (3 mm × 10 mm). Toluene and tetrahydrofuran (THF) were distilled from sodium and sodium benzophenone ketyl under nitrogen, respectively.[1] Tetralone and indanone were dried over 4Å molecular sieves prior to use. Shiny-orange $Ni(COD)_2$ crystalline solid was purchased from Aldrich Chemicals. Thin layer chromatography was performed on Merck precoated silica gel 60 F_{254} plates. Silica gel (Merck, 230-400 mesh) was used for flash column chromatography. ^{1}H NMR spectra were recorded on a Varian (500 MHz) spectrometer. Spectra were referenced internally to the residual proton resonance in $CDCl_3$ (δ 7.26 ppm), or with tetramethylsilane (TMS, δ 0.00 ppm) as the internal standard. Commercially available $CDCl_3$ was stored under anhydrous K_2CO_3 granules with 4Å molecular sieves in desiccators. Chemical shifts (δ) were reported as part per million (ppm) in δ scale downfield from TMS. ^{13}C NMR spectra were recorded on a Varian 500 spectrometer and referenced to $CDCl_3$ (δ 77.0 ppm). Coupling constants (*J*) were reported in Hertz (Hz). High-resolution mass spectra (HRMS) were obtained on a Brüker APEX 47e FT-ICR mass spectrometer (ESIMS). HPLC analyses were performed on a Waters™ 600 instrument using Chiralcel® OB-H, OJ and OT(+) (0.46 cm diameter × 25 cm length) columns. Racemic products (for chiral HPLC analysis calibration) were obtained from the same α-arylation of ketone enolate representative procedure except racemic ligand was used. The HPLC retention times of the racemic products matched those of the enantiomerically enriched products. GC-MS analysis was conducted on a HP G1800C GCD system using a HP5MS column (30 m × 0.25 mm).

2. General procedures for catalytic asymmetric α-arylation of ketone enolates

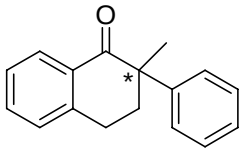


1 **2** **3**

n = 1,2 X = I, Br, Cl

General procedures for asymmetric α-arylation of ketone enolates: An oven dried Schlenk tube was charged with $Ni(COD)_2$ (2.8 mg, 2.0 mol%), (*R*)-P-Phos (7.7 mg, 2.4 mol%) and NaO*t*-Bu (96 mg, 1.0 mmol). The tube was evacuated and backfilled with nitrogen, and freshly distilled toluene (1.0 mL) was added. After stirring the mixture at room temperature for 1 min, ArX (1.5 mmol) was added, followed by stirring for another 1 min at room temperature. To the mixture **1** (76 μL, 0.5 mmol) and toluene (1.0 mL) were added, and the reaction mixture was heated to 100 °C with magnetic stirring until **1** was consumed based on GC or TLC monitoring. After cooling to RT, the reaction mixture was quenched with sat. NH_4Cl (~5 mL) and diluted with ether (~5 mL). The layers were separated and the aq. portion was extracted with ether (2 × ~10 mL). The combined organic extracts were washed with brine (~5 mL), dried over $MgSO_4$, filtered, and concentrated in *vacuo*. The crude product was purified by flash column chromatography on silica gel.

3. Characterization data of the products of α-arylation of ketone enolates

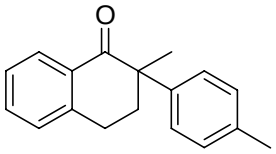


2-Methyl-2-phenyl-1-tetralone 3a[2] (Table 2, entry 1).

Purified by column chromatography (2 cm diameter × ~15 cm height) on silica gel using hexane/ethyl acetate (10:1) as eluent to obtain the title compound as colorless oil. 85% yield; 92% ee; R_f = 0.7 (hexane/ethyl acetate = 10 :1); ^{1}H NMR ($CDCl_3$, 500 MHz): δ 8.16 (d, *J* = 8.0 Hz, 1H), 7.41 (t, *J* = 7.5 Hz, 1H), 7.38-7.17 (m, 6H), 7.11 (d, *J* = 7.0 Hz, 1H), 2.85-2.80 (m, 2H), 2.59 (dt, *J* = 6.5 Hz, *J* = 17.0 Hz , 1H), 2.34-2.21 (m, 1H), 1.53 (s, 3H); ^{13}C NMR (125 MHz): δ 201.3, 143.5, 142.0, 133.1, 132.7, 128.6, 128.5, 127.9, 126.6, 126.6, 126.5, 126.3, 50.5, 36.2, 27.0, 26.1.

Chiral HPLC conditions

Column:	Chiralcel OB-H
Solvent:	Hex:IPA = 99:1
Flow rate:	0.5 mL/ min
UV lamp:	254 nm
Retention time:	20.3(main), 25.3 min



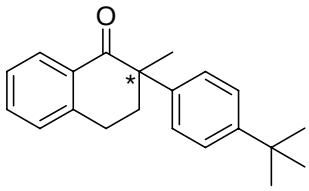
2-Methyl-2-(4-methylphenyl)-1-tetralone 3b (Table 2, entry 2).

Purified by column chromatography (2 cm diameter × ~25 cm height) on silica gel using hexane/ethyl acetate (10:1) as eluent to obtain the title compound as white solid. 78% yield; 93% *ee*. $[\alpha]^{25}_D$ = +182° (*c* = 0.28, $CHCl_3$); R_f = 0.7 (hexane/ethyl acetate = 10 :1); ^{1}H NMR ($CDCl_3$, 500 MHz): δ 8.14 (d, *J* = 8.0 Hz, 1H), 7.41 (t, *J* = 8.0 Hz, 1H), 7.29 (t, *J* = 8.0 Hz, 1H), 7.11-7.06 (m, 5H), 2.85-2.78 (m, 2H), 2.59 (dt, *J* = 14.0 Hz, *J* = 4.0 Hz, 1H), 2.27 (s, 3H), 1.50 (s, 3H);

^{13}C NMR (125 MHz): δ 201.8, 143.9, 136.7, 133.3, 132.9, 129.5, 128.9, 128.2, 126.8, 126.6, 126.5, 126.3, 50.4, 36.3, 27.4, 26.3, 21.1. IR (neat, cm^{-1}) 1679. HRMS cald. for $C_{18}H_{18}O$: 250.1358, found 250.1369.

Chiral HPLC conditions

Column:	Chiralcel OB-H
Solvent:	100%Hexane
Flow rate:	0.5 mL/ min
UV lamp:	254 nm
Retention time:	45.1(main), 58.6 min

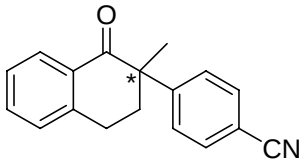


2-Methyl-2-(4-*tert*-butylphenyl)-1-tetralone 3c[3] (Table 2, entry 3).

Purified by column chromatography (2 cm diameter × ~25 cm height) on silica gel using hexane/ethyl acetate (10:1) as eluent to obtain the title compound as white solid. 92% yield; 95% ee. R_f = 0.7 (hexane/ethyl acetate = 10 :1); ^{1}H NMR ($CDCl_3$, 500 MHz): δ 8.16 (d, J = 6.5 Hz, 1H), 7.41 (dt, J = 1.5 Hz, 7.5 Hz, 1H), 7.33-7.24 (m, 4H), 7.14-7.10 (m, 2H), 2.92-2.78 (m, 2H), 2.64-2.58 (m, 1H), 2.31-2.19 (m, 1H), 1.51 (s, 3H), 1.26 (s, 9H); ^{13}C NMR (125 MHz): δ 201.3, 149.2, 143.7, 138.8, 133.0, 132.7, 128.6, 127.9, 126.5, 125.9, 125.4, 50.0, 36.2, 34.3, 31.2, 27.1, 26.1.

Chiral HPLC conditions

Column:	Chiralcel OJ
Solvent:	100%Hexane
Flow rate:	0.5 mL/ min
UV lamp:	254 nm
Retention time:	43.6(main), 52.8 min

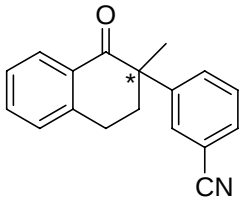


2-Methyl-2-(4-cyanophenyl)-1-tetralone 3d[3] (Table 2, entry 4).

Purified by column chromatography (2 cm diameter × ~15 cm height) on silica gel using hexane/ethyl acetate (5:1) as eluent to obtain the title compound as yellow solid. 94% yield; 98% ee. R_f = 0.3 (hexane/ethyl acetate = 10 :1); ^{1}H NMR ($CDCl_3$, 500 MHz): δ 8.15 (d, J = 8.0 Hz, 1H), 7.58 (t, J = 8.0 Hz, 2H), 7.46 (t, J = 7.0 Hz, 1H), 7.35-7.30 (m, 3H), 7.14 (d, J = 7.0 Hz, 1H), 2.92-2.71 (m, 2H), 2.60 (dt, J = 4.0 Hz, 14.0 Hz, 1H), 2.33-2.4 (m,1H), 1.54 (s, 3H) ^{13}C NMR (125 MHz): δ 200.3, 148.2, 143.4, 133.8, 132.7, 132.1, 128.7, 128.0, 127.4, 127.0, 118.6, 110.7, 50.7, 36.0, 26.2, 25.8.

Chiral HPLC conditions

Column:	Chiralcel OB-H
Solvent:	Hex:IPA = 80:20
Flow rate:	1.0 mL/ min
UV lamp:	254 nm
Retention time:	15.2(main), 21.5 min

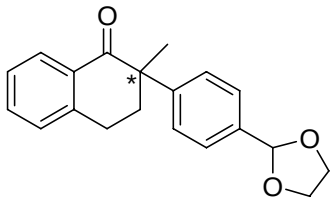


2-Methyl-2-(3-cyanophenyl)-1-tetralone 3e (Table 2, entry 5).

Purified by column chromatography (2 cm diameter × ~15 cm height) on silica gel using hexane/ethyl acetate (5:1) as eluent to obtain the title compound as yellow solid. 79% yield; 95% ee. $[\alpha]^{25}_D$ = +179° (c = 0.25, $CHCl_3$); R_f = 0.3 (hexane/ethyl acetate = 10 :1); ^{1}H NMR ($CDCl_3$, 500 MHz): δ 8.14 (dd, J = 1.5 Hz, J = 8.0 Hz, 1H), 7.54-7.32 (m, 6H), 7.14 (d, J = 8.0 Hz, 1H), 2.92-2.77 (m, 2H), 2.62 (m, 1H), 2.32-2.26 (m, 1H), 1.53 (s, 3H); ^{13}C NMR (125 MHz): δ 200.4, 144.5, 143.4, 133.9, 132.7, 131.5, 130.8, 130.4, 129.7, 129.1, 128.5, 127.2, 113.2, 50.8, 36.3, 26.6, 26.1. IR (neat, cm^{-1}) 2235, 1685. HRMS cald. for $C_{18}H_{15}NO$: 261.1154, found 261.1159.

Chiral HPLC conditions

Column:	Chiralcel OB-H
Solvent:	Hex:IPA = 80:20
Flow rate:	1.0 mL/ min
UV lamp:	254 nm
Retention time:	12.7(main), 21.0 min

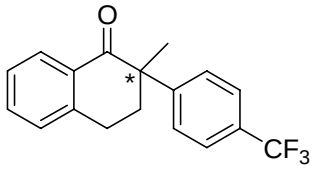


2-Methyl-2-[4-(2-dioxolane)phenyl]-1-tetralone 3f (Table 2, entry 6).

Purified by column chromatography (2 cm diameter × ~15 cm height) on silica gel using hexane/ethyl acetate (10:1) as eluent to obtain the title compound as slightly yellow solid. 90% yield; 96% ee. $[\alpha]^{25}_{D}$ = +194° (*c* = 0.36, $CHCl_3$); R_f = 0.6 (hexane/ethyl acetate = 10:1); ^{1}H NMR ($CDCl_3$, 500 MHz): δ 8.13 (d, *J* = 7.5 Hz, 1H), 7.42-7.22 (m, 7H), 7.09 (d, *J* = 7.5 Hz, 1H), 4.12-3.97 (m, 4H), 2.89-2.77 (m, 2H), 2.64-2.60 (m, 1H), 2.30-2.24 (m, 1H), 1.51 (s, 3H); ^{13}C NMR (125 MHz): δ 207.6, 145.8, 133.4, 128.9, 128.2, 126.9, 126.7, 118.3, 103.7, 65.6, 36.2, 27.3, 26.3. IR (neat, cm^{-1}) 1680. HRMS cald. for $C_{20}H_{20}O_3$: 308.1412, found 308.1408.

Chiral HPLC conditions

Column:	Chiralcel OB-H
Solvent:	Hex:IPA = 80:20
Flow rate:	1.0 mL/ min
UV lamp:	254 nm
Retention time:	23.0(main), 31.6 min

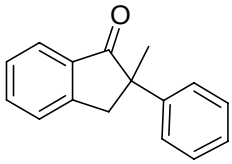


2-Methyl-2-(4-trifloromethylphenyl)-1-tetralone 3e (Table 2, entry 7).

Purified by column chromatography (2 cm diameter × ~15 cm height) on silica gel using hexane/ethyl acetate (10:1) as eluent to obtain the title compound as white solid. 66% yield; 70% ee. $[\alpha]^{25}_{D}$ = +147° (*c* = 0.20, $CHCl_3$); R_f = 0.7 (hexane/ethyl acetate = 10 :1); ^{1}H NMR ($CDCl_3$, 500 MHz): δ 8.15 (dd, *J* = 1.5 Hz, *J* = 7.5 Hz, 1H), 7.53 (d, *J* = 8.0 Hz, 1H), 7.44 (td, *J* = 7.0 Hz, *J* = 1.5 Hz,1H), 7.33 (m, 3H), 7.14 (d, *J* = 7.5 Hz, 1H), 2.90-2.76 (m, 2H), 2.62 (dt, *J* = 14.0 Hz, *J* = 4.0 Hz, 1H), 2.33-2.26 (m, 1H), 1.55 (s, 3H); ^{13}CNMR (125MHz): δ 203.8, 146.8, 143.5, 133.7, 129.0, 128.3, 127.0, 125.8, 50.7, 36.3, 26.8, 26.2. IR (neat, cm^{-1}) 1679. HRMS cald. for $C_{18}H_{15}F_3O$: 304.1075, found 304.1073.

Chiral HPLC conditions

Column:	Chiralcel OJ
Solvent:	Hex:IPA = 98:2
Flow rate:	0.5 mL/ min
UV lamp:	254 nm
Retention time:	11.1(main), 15.2 min



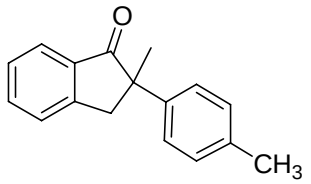
2-Methyl-2-henyl-1-indanone 5a (Table 3, entry 1).

Purified by column chromatography (2 cm diameter × ~15 cm height) on silica gel using hexane/ethyl acetate (10:1) as eluent to obtain the title compound as colorless oil. 78% yield; 88% *ee.* $[\alpha]^{25}_{D}$ = +29° (*c* = 0.88, $CHCl_3$); R_f = 0.6 (hexane/ethyl acetate = 10 :1); ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.84 (d, *J* = 8.0 Hz, 1H), 7.68 (m, 1H), 7.52-7.18 (m, 7H), 2.96-2.80 (m, 2H), 2.62 (dt, *J* = 14.0 Hz, *J* = 4.0 Hz, 1H), 2.33-2.26 (m, 1H), 1.55 (s, 3H); ^{13}C NMR (125MHz):

δ 207.8, 152.3, 143.5, 137.7, 135.3, 129.5, 128.1, 126.9, 126.3, 125.4, 53.9, 45.4, 24.8. IR (neat, cm^{-1}) 1708, 1607. HRMS cald. for $C_{16}H_{14}O$: 222.1045, found 222.1037.

Chiral HPLC conditions

Column:	Chiralcel OB-H
Solvent:	Hex:IPA = 97 : 3
Flow rate:	0.5 mL/ min
UV lamp:	254 nm
Retention time:	25.1(main), 28.7 min

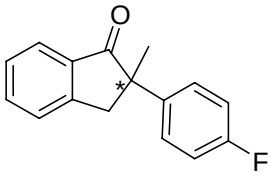


2-Methyl-2-(4-methylhenyl)-1-indanone 5b (Table 3, entry 2).

Purified by column chromatography (2 cm diameter × ~15 cm height) on silica gel using hexane/ethyl acetate (10:1) as eluent to obtain the title compound as white solid. 69% yield; 87% *ee*. $[\alpha]^{25}_{D}$ = +17° (*c* = 1.0, $CHCl_3$), R_f = 0.6 (hexane/ethyl acetate = 10 :1); ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.81 (d, *J* = 8.0 Hz, 1H), 7.63 (td, *J* = 8.0 Hz, *J* = 1.5 Hz, 1H), 7.19 (d, *J* = 8.0 Hz, 2H), 7.10 (d, *J* = 8.0 Hz, 2H), 3.58 (d, *J* = 18.0 Hz, 1H), 3.29 (d, *J* = 18.0 Hz, 1H), 1.64 (s, 3H); ^{13}CNMR (125MHz): δ 202.9, 152.3, 143.5, 135.3, 129.5, 127.9, 126.6, 126.2, 125.1, 53.6, 45.0, 24.7, 21.2. IR (neat, cm^{-1}) 1710, 1607. HRMS cald. for $C_{17}H_{16}O$: 236.1201, found 236.1202.

Chiral HPLC conditions

Column:	Chiralcel OB-H
Solvent:	Hex:IPA = 99 : 1
Flow rate:	0.5 mL/ min
UV lamp:	254 nm
Retention time:	52.3(main), 59.4 min



2-Methyl-2-(4-fluorophenyl)-1-indanone 5c (Table 2, entry 6).

Purified by column chromatography (2 cm diameter × ~15 cm height) on silica gel using hexane/ethyl acetate (10:1) as eluent to obtain the title compound as white solid. 66% yield; 70% *ee*. $[\alpha]^{25}_{D}$ = +59° (*c* = 0.60, $CHCl_3$), R_f = 0.6 (hexane/ethyl acetate = 10 :1); ^{1}H NMR ($CDCl_3$, 500 MHz): δ 7.82 (d, *J* = 7.5 Hz, 1H), 7.65 (t, *J* = 7.5 Hz, 1H), 7.49 (d, *J* = 7.5 Hz, 1H), 7.43 (t, *J* = 7.5 Hz, 1H), 7.29-7.27 (m, 2H), 6.99-6.96 (t, *J* = 8.0 Hz, 2H), 3.55 (d, *J* = 17.0 Hz, 1H), 3.31 (d, *J* =17.0Hz, 1H), 1.64 (s, 3H); ^{13}CNMR,125MHz): δ 207.8, 152.3, 143.5, 137.7, 135.3, 128.6, 128.1, 126.9, 126.3, 125.4, 53.9, 45.4, 24.8. IR (neat, cm^{-1}) 1710, 1609. HRMS cald. for $C_{16}H_{13}FO$: 240.0950, found 240.0946.

Chiral HPLC conditions

Column:	Chiralcel OB-H
Solvent:	Hex:IPA = 95 : 5
Flow rate:	0.5 mL/ min
UV lamp:	254 nm
Retention time:	17.2(main), 23.4 min

5. References

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(2) A. O.-L. Moring, J. Delaunay and J. Simonet, *Tetrahedron* 1985, **41**, 4483.

(3) J. Åhman, J. P. Wolfe, M. V. Troutman, M. Palucki and S. L. Buchwald, *J. Am. Chem. Soc.* 1998**, 120***,* 1918.