Supporting Information

Enantioselective CO_2 Fixation Via a Heck-Coupling/Carboxylation Cascade Catalyzed by Nickel

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General Information

^{1}H-NMR spectra were recorded on Varian 400 (400 MHz) spectrometers. Chemical shifts are reported in ppm from TMS with the solvent resonance as the internal standard (deuterochloroform: 7.24 ppm). Data are reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, dd= doublet doublet, t = triplet, td = triple doublet, dt = double triplet, q = quartet, sext = sextet, sept = septet, p = pseudo, b = broad, m = multiplet), coupling constants (Hz). ^{13}C-NMR spectra were recorded on a Varian 400 (100 MHz) spectrometers with complete proton decoupling. Chemical shifts are reported in ppm from TMS with the solvent as the internal standard (deuterochloroform: 77.0 ppm). GC-MS spectra were taken by EI ionization at 70 eV on a Hewlett-Packard 5971 with GC injection. They are reported as: *m/z* (rel. intense). LC-electrospray ionization mass spectra were obtained with Agilent Technologies MSD1100 single-quadrupole mass spectrometer. HRMS-ESI were obtained with column Luna Omega 3um Polar C18 (size 100*3 mm) and Xevo G2-XS QTof. The enantiomeric excess (*ee*) were determined by chiral HPLC, on an Agilent Technologies Series 1200 instrument using chiral columns. The enantiomeric compositions were checked against the corresponding racemic products. Chromatographic purification was done with 240-400 mesh silica gel. Other anhydrous solvents were supplied by Sigma Aldrich in Sureseal® bottles and used without any further purification. Commercially available chemicals were purchased from Sigma Aldrich, Fluorochem, Alfa Aeser and TCI and used without any further purification. Melting points were determined with Bibby Stuart Scientific Melting Point Apparatus SMP 3 and are not corrected. Agilent Technologies LC/MSD Trap 1100 series (nebulizer: 15.0 PSI, dry Gas: 5.0 L/min, dry temperature: 325 °C, capillary voltage positive scan: 4000 mA, capillary voltage negative scan: 3500 mA). The X-ray intensity data for [(**L11**)$_2$Ni(H$_2$O)Cl]Cl and (*R*)-**3a** were measured on a Bruker Apex III CCD diffractometer. Cell dimensions and the orientation matrix were initially determined from a least-squares refinement on reflections measured in four sets of 20 exposures, collected in three different ω regions, and eventually refined against all data. A full sphere of reciprocal space was scanned by 0.5° ω steps. The software SMART[3] was used for collecting frames of data, indexing reflections and determination of lattice parameters. The collected frames were then processed for integration by the SAINT program,[1] and an empirical absorption correction was applied using SADABS.[2] The structures were solved by direct methods (SIR 2014)[3] and subsequent Fourier syntheses and refined by full-matrix least-squares on F^2 (SHELXTL)[4] using anisotropic thermal parameters for all non-hydrogen atoms. The aromatic, methyl, methylenic and methine hydrogen atoms were placed in calculated positions, refined with isotropic thermal parameters *U(H)* = 1.2 *Ueq*(C) and

[1] *SMART & SAINT Software Reference Manuals*, version 5.051 (Windows NT Version), Bruker Analytical X-ray Instruments Inc.: Madison, Wi, **1998.**

[2] Sheldrick, G. M.; *SADABS-2008/1 - Bruker AXS Area Detector Scaling and Absorption Correction*, Bruker AXS: Madison, Wisconsin, USA, **2008**.

[3] Burla, M.C.; Caliandro, R.; Carrozzini, B.; Cascarano, G.L.; Cuocci, C.; Giacovazzo, C.; Mallamo, M.; Mazzone, A.; Polidori, G.; "Crystal structure determination and refinement via SIR2014" *J. Appl. Cryst.* **2015**, *48*, 306-309.

[4] Sheldrick, G. M. *Acta Cryst C71*, **2015**, 3-8.

allowed to ride on their carrier carbons. Known compounds were prepared following the know procedure: **1a, 1d, 1e, 1f, 1k** (ref. 5)[5], Br-**1a** (ref. 6)[6], **1s** (ref. 7)[7], **1o** (ref. 8)[8], **1q** (ref. 9)[9], **1n, 1r** (ref. 10)[10], **1p** (ref. 11)[11].

[5] Yang, G.; Wenfang, X.; Huoji, C.; Wanqing, W.; Jianwen, P.; Yinglan, G.; Huanfeng, J. Pd-catalyzed highly regio- and stereoselective formation of C–C double bonds: an efficient method for the synthesis of benzofuran-, dihydrobenzofuran-, and indoline-containing alkenes**.** *J. Org. Chem.* **2015,** *80*, 7456-7467.

[6] Wang, W.; Zhou, R.; Jiang, Z.-J.; Wang, X.; Fu, H.-Y.; Zheng, X.-L.; Chen, H.; Li, R.-X. Palladium-catalyzed domino Mizoroki–Heck/intermolecular C(sp^3)-H activation sequence: an approach to the formation of C(sp^3)–C(sp^3) bonds. *Eur. J. Org. Chem.* **2015**, 2579-2584.

[7] Iain, D. G. W.; Stefanie, R.; F. Dean, T. Asymmetric synthesis of medium-sized rings by intramolecular Au(I)-catalyzed cyclopropanation. *J.Am.Chem.Soc.* **2009**, *131*, 2056-2057.

[8] Samantha, A. G.; Suhelen, V-C.; Ryan, A. S. Iron-nickel dual-catalysis: a new engine for olefin functionalization and the Formation of quaternary centers. *J. Am. Chem. Soc.* **2018**, *140*, 11317-11324

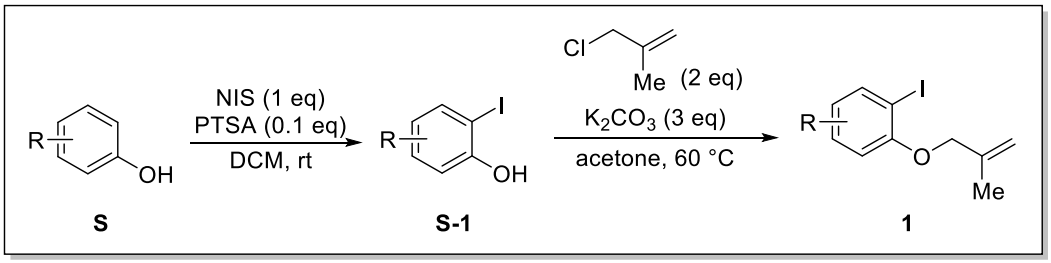
[9] Daniel, S.; Francesco, M.; Israel, F.; Miguel, A. S. Intramolecular Pd(0)-catalyzed reactions of (2-iodoanilino)-aldehydes: a joint experimental-computational Study**.** *J. Org.Chem.* **2012**, *77*, 10272-10284.

[10] Zhi-Xiong, T.; Jin-Bao, Q.; Guang-Li, X.; Xiaobo, P.; Liangliang, Q.; Wei-Yuan, M.; Zhen-Zhen, Z.; Jicheng, D.; Yun-Fei, D.; Peifeng, S.; Xue-Yuan. L.; Xing-Zhong, S. *J. Am. Chem. Soc.* **2019,** *141*, 7637-7643.

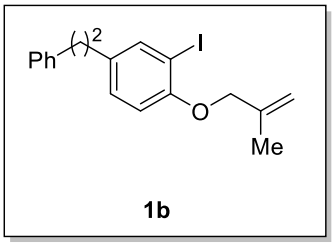
[11] Ramesh, K.; Basuli, S.; Satyanarayana, G. Microwave-assisted domino palladium catalysis in water: a diverse synthesis of 3,3′-disubstituted heterocyclic compounds. *Eur.J.Org.Chem.* **2018**, 2171-2177.

Synthesis of the new acyclic precursors 1

General procedure A



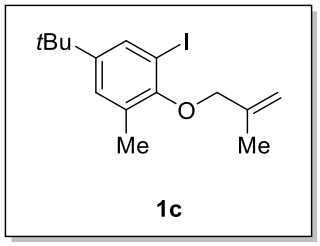
Procedure:[12,6] A solution of phenol (5.0 mmol) in DCM (15 mL) was treated with *N*-iodosuccinimide (1.12 g, 5.0 mmol) and *p*-toluenesulfonic acid monohydrate (95.1 mg, 10 mol%) at room temperature for 6 h. The reaction was quenched with water (15 mL), extracted with DCM (3 x 15 mL), and the reunited organic phases were washed with $Na_2S_2O_3$ (10 mL), dried over anhydrous Na_2SO_4, and concentrated under reduced pressure, to obtain the *o*-iodophenol quantitatively. The iodinated phenol was then dissolved in acetone (30 mL), and K_2CO_3 (2.07 g, 15.0 mmol) was added. After 10 min methallyl chloride (0.97 mL, 10 mmol) was added, and the solution was stirred at reflux for 5 h. At complete consumption of the starting material (TLC) the solvent was remooved, and the crude was dissolved in ethyl acetate (20 mL) and extracted with water (20 mL), washed with brine (15 mL), dryed over anhydrous Na_2SO_4, and concentrated under reduced pressure. The residue was purified by flash chromatography on silica gel to give the desired product.



Compound: 2-iodo-1-((2-methylallyl)oxy)-4-phenethylbenzene (**1b**), colorless oil.

Procedure: From 4-phenethylphenol. Yield = 95% (1.79 g), Rf = 0.7 (silica gel, *n*Hex). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 7.64 (t, *J* = 2.3 Hz, 1H), 7.30 (ddd, *J* = 8.1, 6.6, 2.1 Hz, 2H), 7.26 – 7.14 (m, 3H), 7.06 (dt, *J* = 8.4, 2.1 Hz, 1H), 6.71 (dd, *J* = 8.3, 1.7 Hz, 1H), 5.22 (s, 1H), 5.04 (s, 1H), 4.47 (s, 2H), 2.92 – 2.86 (m, 2H), 2.84 (m, 2H), 1.89 (s, 3H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 155.48, 141.43, 140.37, 139.28, 136.12, 129.30, 128.49 (2C), 128.40 (2C), 126.03, 112.86, 112.10, 86.51, 72.64, 38.00, 36.56, 19.55. **GC-MS (m/z):** 378.05, 287 (100), 378 (27). **Elemental analysis:** $C_{18}H_{19}IO$: 378.05; C, 57.16; H, 5.06; found: C, 57.00, H, 4.96.

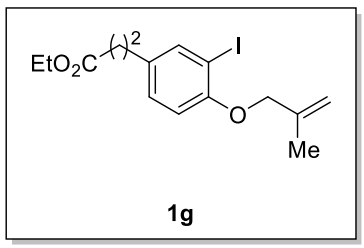
[12] Pierre-Yves, M.; Marcus, F. B.; Jyun-Hung, C.; Timothy, A. G.; Donald, S. K.; Mark, D. L.; Sha, L.; Dale, A. M.; Christopher, M. M.; Anne, R-M.; Katheen, M. O.; Deepa, R.; Anthony, W. T.; John, S. T.; Nathan, Y.; Robert, J. A. Design and synthesis of novel RXR-selective modulators with improved pharmacological profile. *Bioorg. & Med. Chem. Lett.* **2003**, *13*, 4071-4075.



1c

Compound: 5-(*tert*-butyl)-1-iodo-3-methyl-2-((2-methylallyl)oxy)benzene (**1c**), colorless oil.

Procedure: From 4-(*tert*-butyl)-2-methylphenol. Yield = 91% (1.56 g), Rf = 0.8 (silica gel, *n*Hex). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 7.58 (s, 1H), 7.13 (s, 1H), 5.19 (s, 1H), 5.00 (s, 1H), 4.24 (s, 2H), 2.31 (t, *J* = 2.3 Hz, 3H), 1.92 (s, 3H), 1.27 (t, *J* = 2.4 Hz, 9H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 153.77, 148.16, 140.50, 133.36, 130.72, 127.99, 112.20, 91.30, 75.22, 33.41, 30.62 (3C), 19.17, 16.65. **GC-MS (m/z):** 344.06, 162 (100), 334 (16), 329 (14). **Elemental analysis:** $C_{15}H_{21}IO$: 344.06; C, 52.34; H, 6.15; found: C, 52.21, H, 6.01.

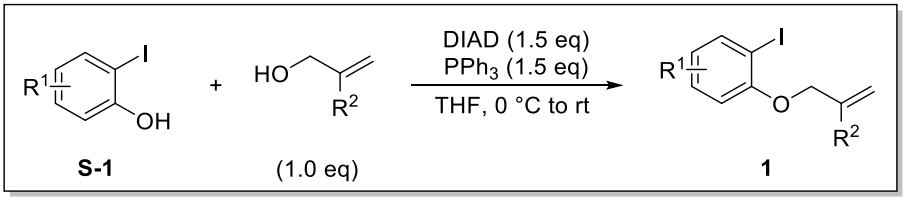


1g

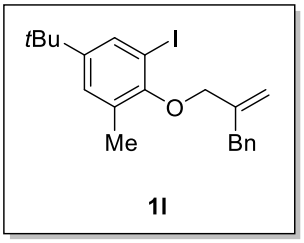
Compound: ethyl 3-(3-iodo-4-((2-methylallyl)oxy)phenyl)propanoate (**1g**), colorless oil

Procedure: From ethyl 3-(4-hydroxyphenyl)propanoate. Yield = 93% (1.74 g), Rf = 0.5 (silica gel, *n*Hex). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 7.60 (d, *J* = 2.2 Hz, 1H), 7.11 – 7.04 (m, 1H), 6.68 (d, *J* = 8.4 Hz, 1H), 5.15 (s, 1H), 4.98 (s, 1H), 4.42 (s, 2H), 4.10 (qd, *J* = 7.1, 0.9 Hz, 2H), 2.82 (t, *J* = 7.7 Hz, 2H), 2.54 (dd, *J* = 8.2, 7.2 Hz, 2H), 1.83 (s, 3H), 1.21 (t, *J* = 7.1 Hz, 3H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 172.61, 155.67, 140.25, 139.14, 134.85, 129.18, 112.83, 112.13, 86.49, 72.58, 60.43, 35.96, 29.55, 19.45, 14.22. **GC-MS (m/z):** 374.04, 159 (100), 374 (65), 287 (61). **Elemental analysis:** $C_{15}H_{19}IO_3$: 374.04; C, 48.14; H, 5.12; found: C, 48.00, H, 5.11.

General procedure B

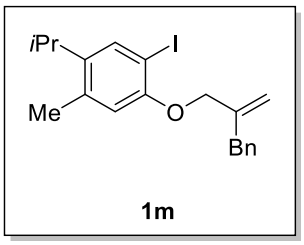


Procedure:[13] To a solution of allylic alcohol (5.0 mmol) and phenol (5.0 mmol) in THF (15 mL), under nitrogen atmosphere, was added PPh_3 (1.96 g, 7.5 mmol) at 0 °C, followed after 20 min by slow addition of DIAD (1.51 g, 7.5 mmol). The reaction mixture was allowed to warm to room temperature, and stirred for 12 h. The reaction was quenched with water (20 mL) and extracted with AcOEt (3 x 15 mL), and the organic layers were washed with brine, dried over anhydrous Na_2SO_4, and concentrated under reduced pressure. The residue was purified by flash chromatography on silica gel to give the desired product.



Compound: 2-((2-benzylallyl)oxy)-5-(*tert*-butyl)-1-iodo-3-methylbenzene (**1l**), colorless oil.

Procedure: From 4-(*tert*-butyl)-2-iodo-6-methylphenol and 2-benzylprop-2-en-1-ol. Yield = 74%, (1.55 g), Rf = 0.7 (silica gel, *n*Hex). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 7.56 (d, *J* = 2.4 Hz, 1H), 7.33 – 7.22 (m, 4H), 7.24 – 7.16 (m, 1H), 7.10 (dd, *J* = 2.4, 0.8 Hz, 1H), 5.38 (s, 1H), 5.02 (s, 1H), 4.23 (s, 2H), 3.58 (s, 2H), 2.23 (s, 3H), 1.25 (s, 9H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 154.48, 148.90, 144.34, 138.93, 134.04, 131.42, 129.10 (2C), 128.69, 128.35 (2C), 126.24, 114.21, 92.02, 74.29, 40.18, 34.12, 31.31 (3C), 17.34. **GC-MS (m/z):** calcd for $C_{21}H_{25}IO$ 420.10, 275 (100), 420 (11). **Elemental analysis:** $C_{21}H_{25}IO_3$: 420.10; C, 60.01; H, 6.00; found: C, 59.75, H, 5.88.

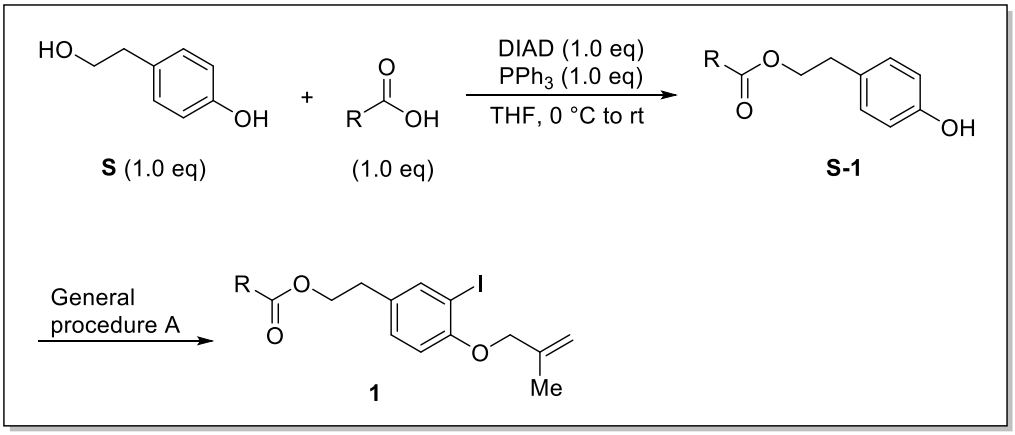


Compound: 1-((2-benzylallyl)oxy)-2-iodo-4-isopropyl-5-methylbenzene (**1m**), colorless oil.

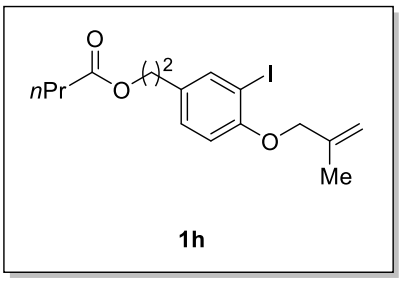
[13] Zheng, H.; Zhu, Y.; Shi, Y. Palladium(0)-catalyzed Heck reaction/C-H activation/amination sequence with diaziridinone: a facile approach to indolines. *Angew. Chem. Int. Ed.* **2014**, 53: 11280-11284.

Procedure: From 2-iodo-4-isopropyl-5-methylphenol and 2-benzylprop-2-en-1-ol. Yield = 79% (1.60 g), Rf = 0.7 (silica gel, *n*Hex). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 7.55 (s, 1H), 7.31 – 7.22 (m, 4H), 7.23 – 7.18 (m, 1H), 6.44 (s, 1H), 5.29 (dd, *J* = 1.5, 0.7 Hz, 1H), 5.05 (d, *J* = 1.3 Hz, 1H), 4.39 (s, 2H), 3.53 (s, 2H), 2.98 (sept, *J* = 6.9 Hz, 1H), 2.21 (s, 3H), 1.17 (dd, *J* = 6.9, 0.6 Hz, 6H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 154.67, 143.75, 141.45, 138.79, 136.41, 135.66, 129.05 (2C), 128.41 (2C), 126.30, 114.27, 114.03, 83.25, 70.75, 39.95, 28.61, 23.26 (2C), 19.38. **GC-MS (m/z):** calcd for $C_{20}H_{23}IO$ 406.08, 315 (100), 406 (38). **Elemental analysis:** $C_{20}H_{23}IO_3$: 406.08; C, 59.12; H, 5.71; found: C, 58.95, H, 5.55.

General procedure C



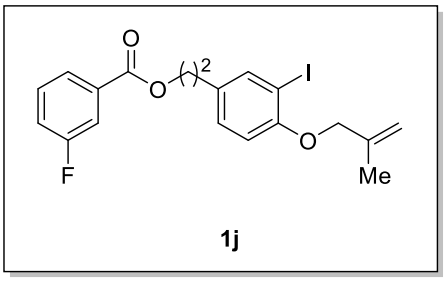
Procedure:[14] To a solution of tyrosol (0.69 g, 5.0 mmol) and the desired carboxylic acid (5.0 mmol) in THF (12 mL) at 0°C were added PPh_3 (1.31 g, 5.0 mmol) and diisopropyl azodicarboxylate (1.01 g, 5.0 mmol). The reaction mixture was allowed to rise at room temperature, and stirred for 24 h. At complete consumption of the starting material (TLC) the solvent was remooved under reduced pressure, and the residue was dissolved in ethyl acetate (30 mL) and washed with saturated acqueous solution of $NaHCO_3$ (3 x 30 mL) and brine (3 x 30 mL). The organic layer was then dried over Na_2SO_4 and concentrated under reduced pressure. The crude so obtained was directly engaged in the General procedure A, giving the desired compound.



Compound: 3-Iodo-4-((2-methylallyl)oxy)phenethyl butyrate (**1h**), colorless oil.

[14] Belnaser, A.B.; Ahmed, I.F.; Tina, M.; Khalid A.E. Olive secoiridoids and semisynthetic bioisostere analogues for the control of metastatic breast cancer. *Bioorg. & Med. Chem.* **2013**, *21*, 2117-2127.

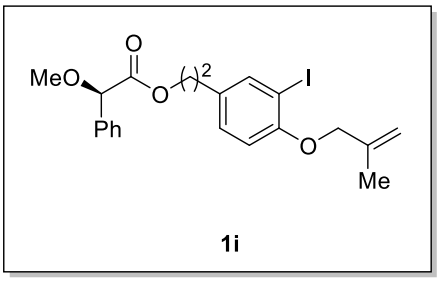
Procedure: From 4-(2-hydroxyethyl)phenol and butyric acid. Yield = 76% (1.47 g) Rf = 0.4 (silica gel, *n*Hex). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 7.61 (d, *J* = 2.1 Hz, 1H), 7.08 (dd, *J* = 8.3, 2.1 Hz, 1H), 6.69 (d, *J* = 8.4 Hz, 1H), 5.15 (s, 1H), 4.97 (s, 1H), 4.41 (s, 2H), 4.20 (t, *J* = 6.9 Hz, 2H), 2.80 (t, *J* = 6.9 Hz, 2H), 2.24 (t, *J* = 7.4 Hz, 2H), 1.83 (s, 3H), 1.60 (sext, *J* = 7.4 Hz, 2H), 0.89 (t, *J* = 7.4 Hz, 3H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 173.43, 155.90, 140.19, 139.74, 132.16, 129.69, 112.86, 112.12, 86.47, 72.56, 64.49, 36.15, 33.73, 19.46, 18.41, 13.66. **GC-MS (m/z):** calcd for $C_{16}H_{21}IO_3$ 388.05, 300 (100), 245 (43). **Elemental analysis:** $C_{16}H_{21}IO_3$: 388.05; C, 49.50; H, 5.45; found: C, 49.21, H, 5.21.



1j

Compound: 3-Iodo-4-((2-methylallyl)oxy)phenethyl 3-fluorobenzoate (**1j**), colorless oil.

Procedure: From 4-(2-hydroxyethyl)phenol and 3-fluorobenzoic acid. Yield = 71%, (1.56 g), Rf = 0.4 (silica gel, *n*Hex). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 7.77 (d, *J* = 7.8 Hz, 1H), 7.69 (d, *J* = 2.2 Hz, 1H), 7.66 (ddd, *J* = 9.3, 2.7, 1.6 Hz, 1H), 7.38 (td, *J* = 8.0, 5.5 Hz, 1H), 7.22 (td, *J* = 8.4, 2.8 Hz, 1H), 7.15 (dd, *J* = 8.4, 2.2 Hz, 1H), 6.71 (d, *J* = 8.4 Hz, 1H), 5.16 (s, 1H), 4.98 (s, 1H), 4.49 – 4.40 (m, 4H), 2.94 (t, *J* = 6.9 Hz, 2H), 1.83 (s, 3H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 165.20 (d, *J*C-F = 3.0 Hz), 162.49 (d, *J*C-F = 247.2 Hz), 156.02, 140.17, 139.85, 132.33 (d, *J*C-F = 7.3 Hz), 131.93, 130.05 (d, *J*C-F = 7.8 Hz), 129.75, 125.29 (d, *J*C-F = 3.1 Hz), 120.01 (d, *J*C-F = 21.3 Hz), 116.41 (d, *J*C-F = 23.2 Hz), 112.89, 112.19, 86.57, 72.56, 65.62, 33.75, 19.46. **^{19}F-NMR** (376 MHz, $CDCl_3$): δ -112.14 (td, *J* = 8.8, 5.5 Hz). **GC-MS (m/z):** calcd for $C_{19}H_{18}FIO_3$ 440.03, 300 (100), 123 (43), 158 (36). **Elemental analysis:** $C_{19}H_{18}FIO_3$: 440.03; C, 51.84; H, 4.12; found: C, 51.65, H, 4.01.



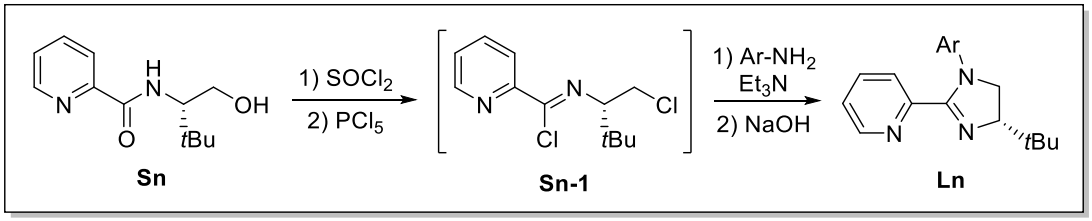
1i

Compound: 3-Iodo-4-((2-methylallyl)oxy)phenethyl (*R*)-2-methoxy-2-phenylacetate (**1i**), colorless oil.

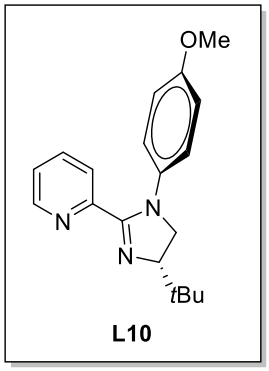
Procedure: From 4-(2-hydroxyethyl)phenol and (*S*)-2-methoxy-2-phenylacetic acid. Yield = 68% (1.58 g), Rf = 0.3 (silica gel, *n*Hex). **$[\alpha]_D^{20}$** = -10.5 (*c* = 1.0, $CHCl_3$). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 7.54 (d, *J* = 2.1 Hz, 1H), 7.40 – 7.29 (m, 5H), 6.92 (dd, *J* = 8.4, 2.2 Hz, 1H), 6.61 (d, *J* = 8.4 Hz, 1H), 5.17 (s, 1H), 5.00 (s, 1H), 4.71 (s,

1H), 4.42 (s, 2H), 4.26 (td, *J* = 6.8, 1.1 Hz, 2H), 3.36 (s, 3H), 2.75 (td, *J* = 6.8, 3.1 Hz, 2H), 1.85 (s, 3H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 170.54, 155.90, 140.21, 139.68, 136.12, 131.73, 129.67, 128.69, 128.64 (2C), 127.15 (2C), 112.90, 112.09, 86.45, 82.52, 72.57, 65.35, 57.36, 33.50, 19.47. **GC-MS (m/z):** calcd for $C_{21}H_{23}IO_4$ 466.06, 300 (100), 466 (14). **Elemental analysis:** $C_{21}H_{23}IO_3$: 466.06; C, 54.09; H, 4.97; found: C, 53.85, H, 4.68.

Synthesis of 2-pyridyl imidazoline ligands L10-11



General procedure:[15] To a solution of *N*-(pyridinoyl)-amino alcohol (1.11 g, 5.0 mmol) in chloroform (1.0 M solution), thionyl chloride (0.4 mL, 5.5 mmol) was added dropwise at room temperature, and the resulting mixture was stirred at reflux for 2 h. After completion of the reaction (TLC), phosphorus pentachloride (1.14 mg, 5.5 mmol) was added at room temperature, and the resulting suspension was refluxed until the reaction completion, determined by ^{1}H-NMR spectroscopy. The solvent was evaporated, and the $POCl_3$ was removed under high vacuum. The resulting residue was re-dissolved in chloroform (1.0 M) and the solution cooled at 0 °C when a solution of the desired aniline (6.0 mmol) and triethylamine (15 mmol) in chloroform was added dropwise. The mixture was stirred at 0 °C for 30 min and then refluxed for 12 h. After removal of the volatiles, aqueous NaOH (20% w/v, 10 mL) was added to the residue. The mixture was extracted with dichloromethane, and the combined organic layers were washed with brine, dried over Na_2SO_4, filtered and concentrated. The residue was purified by column chromatography on silica gel.

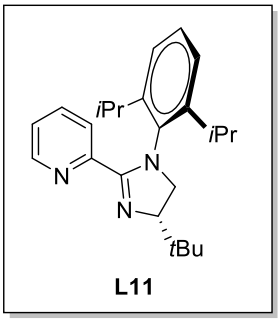


Compound: (*S*)-2-(4-(tert-butyl)-1-(4-methoxyphenyl)-4,5-dihydro-1H-imidazol-2-yl)pyridine (**L10**), sticky yellow oil.

Procedure: From (*S*)-N-(1-hydroxy-3,3-dimethylbutan-2-yl)picolinamide and *p*-anisidine. Yield = 27% (417.4 mg), Rf = 0.3 (*n*Hex:AcOEt = 2:1). **[α]$_D^{20}$** = +11.4 (*c* = 1.0, $CHCl_3$). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 8.46 (d, *J* = 2.6 Hz, 1H), 7.72 – 7.59 (m, 2H), 7.20 (dd, *J* = 4.8, 2.4 Hz, 1H), 6.75 – 6.62 (m, 4H), 4.02 (q, *J* = 11.4, 9.0 Hz, 2H), 3.69 (s, 3H), 3.66 – 3.60 (m, 1H), 0.98 (s, 9H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 159.48, 154.31, 149.13, 147.56, 135.05, 134.71, 122.56, 122.54 (2C), 122.44, 112.32 (2C), 72.73, 54.13, 53.70, 32.54, 24.35 (3C).

[15] Bo Su, T. L.; John F. H. Iridium-catalyzed, β-selective C(sp3)–H silylation of aliphatic amines to form silapyrrolidines and 1,2-amino alcohols. *J. Am. Chem. Soc.* **2018**, *140*, 18032-18038.

LC-MS (m/z): calcd for $C_{19}H_{23}N_3O$ 309.18, 310.2 $[M+H]^+$, 332.2 $[M+Na]^+$, 619.4 $[2M+H]^+$. **Elemental analysis:** $C_{19}H_{23}N_3O$: 309.18; C, 73.76; H, 7.49; found: C, 73.51, H, 7.21.

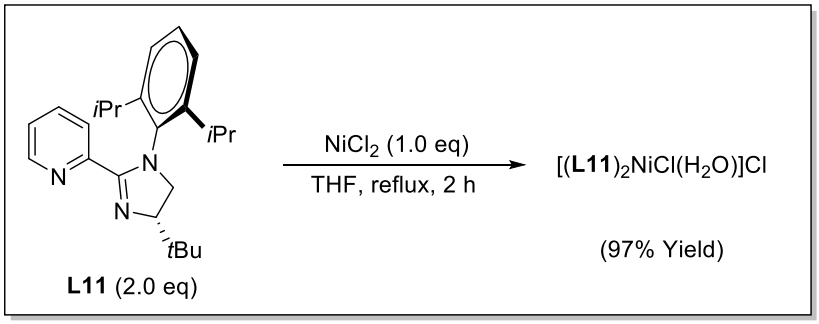


L11

Compound: (*S*)-2-(4-(tert-butyl)-1-(2,6-diisopropylphenyl)-4,5-dihydro-1H-imidazol-2-yl)pyridine (**L11**), sticky yellow oil.

Procedure: From (*S*)-N-(1-hydroxy-3,3-dimethylbutan-2-yl)picolinamide and 2,6-diisopropylaniline. Yield = 33%, (599.4 mg), Rf = 0.4 (*n*-Hex : AcOEt = 2 : 1). **$[\alpha]_D^{20}$** = -65.8 (c = 1.0, $CHCl_3$). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 8.26 (d, *J* = 4.8 Hz, 1H), 7.66 (d, *J* = 7.8 Hz, 1H), 7.50 (td, *J* = 7.7, 1.6 Hz, 1H), 7.18 (t, *J* = 7.7 Hz, 1H), 7.09 – 7.02 (m, 2H), 7.00 (d, *J* = 7.6 Hz, 1H), 4.13 (t, *J* = 11.1 Hz, 1H), 3.73 – 3.64 (m, 1H), 3.55 (t, *J* = 10.2 Hz, 1H), 3.33 (sept, *J* = 6.5 Hz, 1H), 3.11 (sept, *J* = 6.7 Hz, 1H), 1.20 (dd, *J* = 13.2, 6.9 Hz, 6H), 1.04 (s, 9H), 0.96 (d, *J* = 6.8 Hz, 3H), 0.78 (d, *J* = 6.8 Hz, 3H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 162.58, 149.86, 148.50, 147.59, 146.90, 136.88, 135.58, 127.62, 123.80 (2C), 123.75, 123.72, 74.51, 56.34, 34.21, 28.06, 27.94, 26.29 (3C), 25.37, 24.99, 23.61, 23.24. **LC-MS (m/z):** calcd for $C_{24}H_{33}N_3$ 363.27, 364.2 $[M+H]^+$, 386.4 $[M+Na]^+$, 749.4 $[2M+H]^+$. **Elemental analysis:** $C_{24}H_{33}N_3$: 363.27; C, 79.29; H, 9.15; found: C, 79.15, H, 9.00.

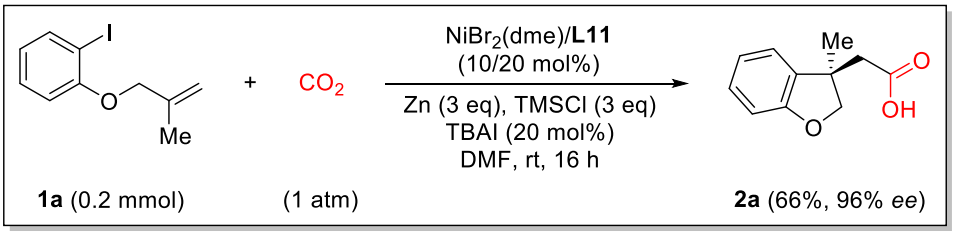
Synthesis of the nickel complex $[(L11)_2Ni(H_2O)Cl]Cl$



Procedure: A solution of flame and dried $NiCl_2$ (129.6 mg, 1.0 mmol), ligand **L11** (727.1 mg, 2.0 mmol) in anhydrous THF (1.5 mL) was refluxed for 2 h (complete consumption of the ligand, monitored by TLC). Then the mixture was slowly cooled, and the solvent was cannulated out. The pale-green solid was washed three times with Et_2O, and dried under vacuum, yielding the desired nickel complex as a fine light-green powder air-stable (848.5 mg, 97% yield). **NMR (*d*^{6}-DMSO)** spectra appeared extremely broad. **Melting point** = 190 -193 °C. **HRMS-ESI:** $[M+H^+]$ calcd for $C_{46}H_{63}Cl_2N_6Ni^+$ 829.46692, found 829.46702.

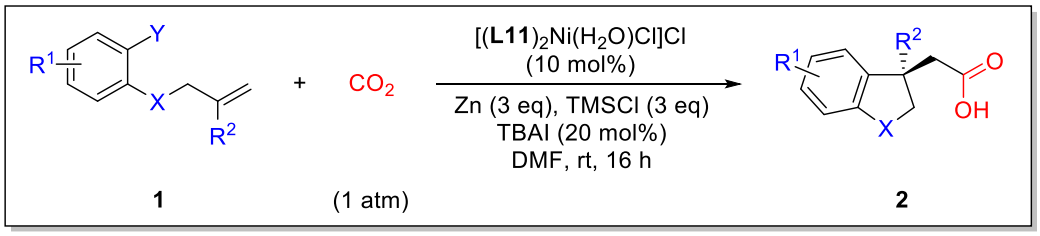
General procedure for the enantioselective Heck-carboxylation reaction

a) *In-situ* formation of the nickel complex (the case for compound **1a** is presented).



Procedure: A flame-dried, nitrogen filled Schlenk tube equipped with a stirring bar was charged with Nickel catalyst (10 mol%, 6.2 mg), zinc (0.6 mmol, 39.2 mg) and TBAI (20 mol%, 14.8 mg). The nitrogen atmosphere was evacuated, and the tube was backfilled with CO_2 (1 bar). This operation was repeated three times. Then DMF (3 mL, 0.07 M) and ligand **L11** (20 mol %, 14.5 mg) were added under flow of CO_2, and the reaction mixture was stirred for 15 min. Under flow of CO_2, substrate **1** (0.2 mmol) was added, and CO_2 was bubbled in the solution. Then TMSCl (0.6 mmol, 76 µL) was added by syringe, and the reaction mixture was stirred (1000 rpm) for 16 h at rt. The reaction was quenched with HCl (10 mL, 1.0 M), and extracted with ethyl acetate (3 x 10 mL). The combined organic layers were washed with HCl twice (2 mL, 1.0 M), dried over anhydrous Na_2SO_4, and concentrated under reduced pressure. The residue was purified by flash chromatography on silica gel [*n*-Hex:AcOEt] to afford the desired product **2a** (25.3 mg, 66% yield). A small amount of the product (ca. 1 mg) was then dissolved in MeOH and $TMSCHN_2$ (25 µL) was added. The solvent was removed, and the so obtained methyl ester was injected in chiral HPLC (96% *ee*).

b) Use of preformed nickel complex.



Procedure: A flame dried, nitrogen filled Schlenk tube equipped with a stirring bar was charged with Nickel catalyst (10 mol%, 17.5 mg), zinc (0.6 mmol, 39.2 mg) and TBAI (20 mol%, 14.8 mg). The nitrogen atmosphere was evacuated, and the tube was backfilled with CO_2 (1 bar). This operation was repeated three times. Then DMF (3 mL, 0.07 M) was added under flow of CO_2, and the reaction mixture was stirred for 15 min. Under flow of CO_2, substrate **1** (0.2 mmol) was added, and CO_2 was bubbled in the solution. Then, TMSCl (0.6 mmol, 76 µL) was added by syringe, and the reaction mixture was stirred (1000 rpm) for 16 h at rt. The reaction was quenched with HCl (10 mL, 1.0 M), and extracted with ethyl acetate (3 x 10 mL). The combined organic layers were washed with HCl twice (2 mL, 1.0 M), dried over anhydrous Na_2SO_4, and concentrated under reduced pressure. The residue was purified by flash chromatography on silica gel to afford the desired product **2**. A

small amount of the product (ca 1 mg) was then dissolved in MeOH and $TMSCHN_2$ (25 µL) was added. The solvent was removed, and the so obtained methyl ester was injected in chiral HPLC.

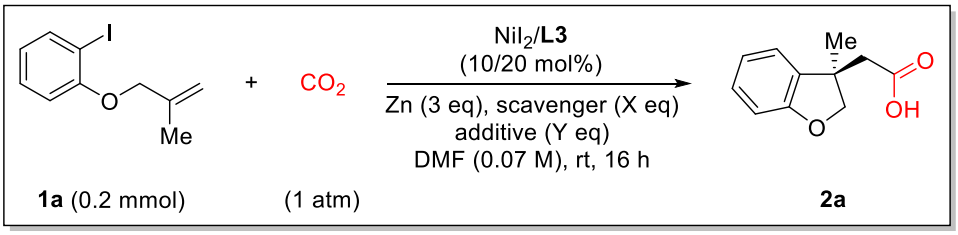
Optimization reaction conditions

Table S1. Reducing agent

Entry	Reducing agent	Yield (%)[a]	*ee* (%)[b]
1	Mn powder (> 99%)	< 5[d,e]	n.d.
2	$ZnMe_2$	NR[d]	n.d.
3	$ZnEt_2$	NR[d]	n.d.
4	Zn (20 mesh, 99.8%)	< 5[e]	n.d.
5	Zn dust (< 10 µm, > 98%)	28	93
6	Zn dust activated	< 5[e]	n.d.
7	Zn dust (4 eq)	24	92

[a] Determined after flash chromatography. [b] Determined via chiral HPLC (CHIRALPAK IC, 30 °C, *n*hex/*i*PrOH 97:3, 0.5 mL/min, 280.16 nm). [c] Inverted stereoinduction was observed. [d] Substantial decomposition of the starting material was recorded. [e] By-products were isolated as major outcomes. nr: no reaction. nd: not determined. DME: dimethoxyethane.

Table S2. Additives

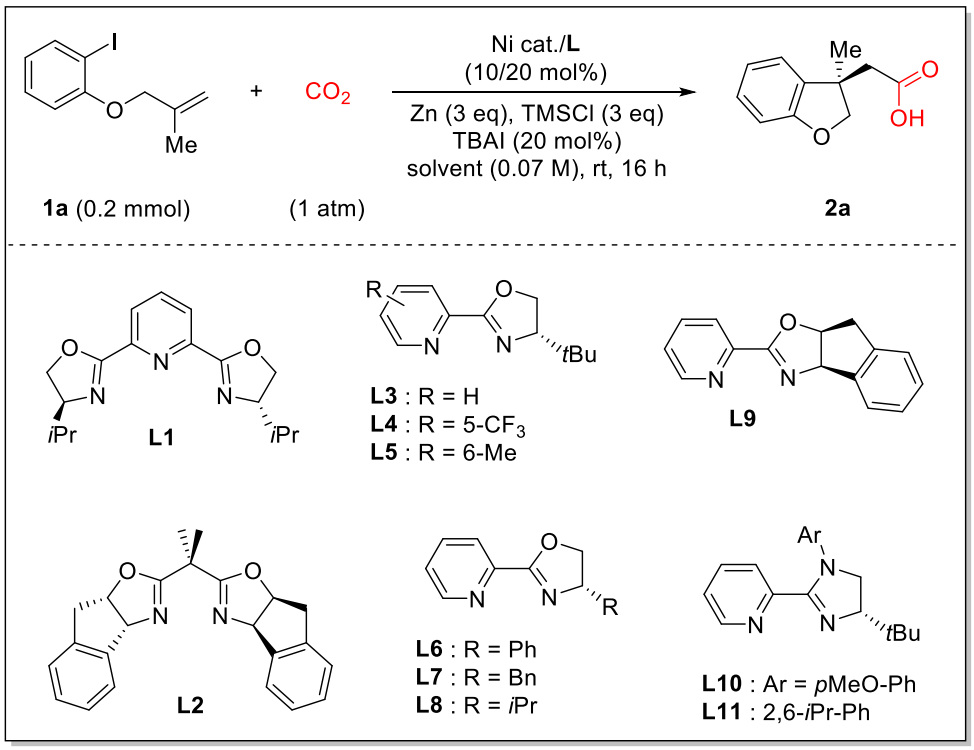


Entry	Additive	Scavenger	Yield (%)[a]	*ee* (%)[b]

1	/	TMSCl (3 eq)	35	93
2	LiI (1 eq)	TMSCl (3 eq)	< 5[d,e]	n.d.
3	ZnI_2 (20 mol%)	TMSCl (3 eq)	17[d]	91
4	TBAI (1 eq)	TMSCl (3 eq)	39	92
5	TBAI (20 mol%)	TMSCl (3 eq)	52	93
6	TBAB (20 mol %)	TMSCl (3 eq)	< 5[d]	n.d.
7	$MgBr_2$ (1 eq)	TMSCl (3 eq)	NR[d]	n.d.
8	TBAI (20 mol%)	/	NR	n.d.
9	TBAI (20 mol%)	TMSBr (3 eq)	41	89
10	TBAI (20 mol%)	TMSCl (1 eq)	15[e]	90

[a] Determined after flash chromatography. [b] Determined via chiral HPLC (CHIRALPAK IC, 30 °C, *n*Hex/*i*PrOH 97:3, 0.5 mL/min, 280.16 nm). [c] Inverted stereoinduction was observed. [d] Substantial decomposition of the starting material was recorded. [e] By-products were isolated as major outcomes. nr: no reaction. nd: not determined. DME: dimethoxyethane.

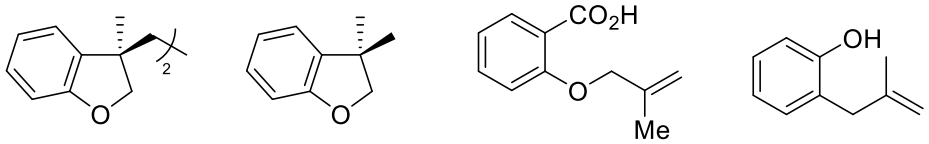
Table S3. Optimization catalytic system



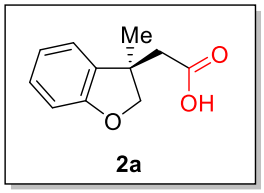
Entry	Catalyst	Ligand	solvent	T (°C)	Yield (%)[a]	*ee* (%)[b]
1	NiI_2	**L3**	THF	rt	NR	n.d.
2	NiI_2	**L3**	THF/DMF (1:1)	rt	NR[e]	n.d.
3	NiI_2	**L3**	MeCN	rt	NR	n.d.
4	NiI_2	**L3**	dioxane	rt	NR	n.d.
5	NiI_2	**L3**	DMF	rt	52	93
6	NiI_2	**L3**	DMA	rt	23	86
7	NiI_2	**L1**	DMF	rt	< 5[d]	n.d.
8	NiI_2	**L2**	DMF	rt	13[d]	-21[c]
9	NiI_2	**L4**	DMF	rt	< 5[d]	n.d.
10	NiI_2	**L5**	DMF	rt	8[d]	-7[c]
11	NiI_2	**L6**	DMF	rt	18[e]	41
12	NiI_2	**L7**	DMF	rt	< 5[d]	n.d.
13	NiI_2	**L8**	DMF	rt	30	71
14	NiI_2	**L9**	DMF	rt	11[d]	-72[c]
15	NiI_2	**L10**	DMF	rt	36	90
16	NiI_2	**L11**	DMF	rt	58	96
17	$NiBr_2$•DME	**L11**	DMF	rt	66	96
18	$NiCl_2$•glyme	**L11**	DMF	rt	60	93
19	$NiBr_2$•DME	**L11**	DMF	0	31[e]	98
20	$NiBr_2$•DME	**L11**	DMF	60	14[d]	95

[a] Determined after flash chromatography. [b] Determined via chiral HPLC (CHIRALPAK IC, 30 °C, *n*Hex/*i*PrOH 97:3, 0.5 mL/min, 280.16 nm). [c] Inverted stereoinduction was observed. [d] Substantial decomposition of the starting material was recorded. [e] By-products were isolated as major outcomes. nr: no reaction. nd: not determined. DME: dimethoxyethane.

Identified by-products

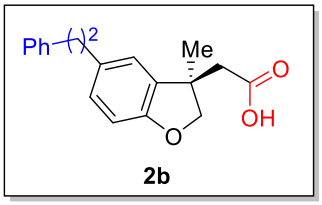


I **II** **III** **IV**



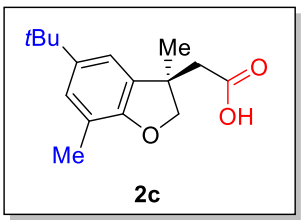
2a

Compound: (*R*)-2-(3-methyl-2,3-dihydrobenzofuran-3-yl)acetic acid (**2a**). From **1a** (54.8 mg, 0.2 mmol). Purified by flash chromatography on silica gel [*n*Hex:AcOEt = 7:3], 23.4 mg, 61% yield, 96% *ee*, white solid. **Melting point:** 88 - 90 °C. **$[\alpha]_D^{20}$** = +46.2 (*c* = 0.5, $CHCl_3$). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 7.19 – 7.06 (m, 2H), 6.88 (td, *J* = 7.4, 1.0 Hz, 1H), 6.80 (d, *J* = 8.0 Hz, 1H), 4.61 (dd, *J* = 9.2, 1.3 Hz, 1H), 4.31 (dd, *J* = 9.2, 1.3 Hz, 1H), 2.80 – 2.65 (m, 2H), 1.45 (s, 3H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 177.18, 159.25, 134.22, 128.93, 122.90, 120.97, 110.21, 82.43, 44.24, 43.85, 25.22. **GC-MS (m/z):** calcd for $C_{20}H_{22}O_3$ 206.09 (M-OMe) 133 (100), 206 (36). **Elemental analysis:** $C_{11}H_{12}O_3$: 192.04; C, 68.74, H, 6.29; found: C, 68.65, H, 6.21.



2b

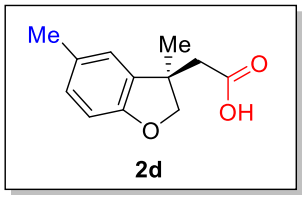
Compound: (*R*)-2-(3-methyl-5-phenethyl-2,3-dihydrobenzofuran-3-yl)acetic acid (**2b**). From **1b** (75.6 mg, 0.2 mmol). Purified by flash chromatography on silica gel [*n*Hex:AcOEt = 7:3], 36.1 mg, 61% yield, 96% *ee*, white solid. **Melting point:** 87 - 89 °C. **$[\alpha]_D^{20}$** = + 24.2° (*c* = 1.0, $CHCl_3$). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 7.26 (t, *J* = 7.9 Hz, 2H), 7.16 (m, 3H), 6.96 (dd, *J* = 8.1, 1.8 Hz, 1H), 6.82 (d, *J* = 1.9 Hz, 1H), 6.72 (d, *J* = 8.1 Hz, 1H), 4.60 (d, *J* = 9.2 Hz, 1H), 4.30 (d, *J* = 9.2 Hz, 1H), 2.86 (s, 4H), 2.68 (s, 2H), 1.42 (s, 3H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 177.07, 157.27, 141.70, 134.18, 133.95, 128.63, 128.53 (2C), 128.27 (2C), 125.86, 122.72, 109.58, 82.33, 43.95, 43.63, 38.44, 37.50, 24.86. **GC-MS (m/z):** calcd for $C_{20}H_{22}O_3$ 310.16 (M-OMe) 219 (100), 310 (9). **Elemental analysis:** $C_{19}H_{20}O_3$: 296.14; C, 77.00, H, 6.80; found: C, 76.90, H, 6.61.



2c

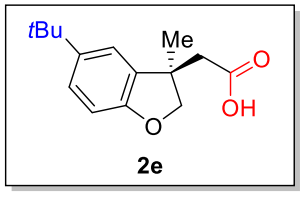
Compound: (*R*)-2-(5-(tert-butyl)-3,7-dimethyl-2,3-dihydrobenzofuran-3-yl)acetic acid (**2c**). From **1c** (68.8 mg, 0.2 mmol). Purified by flash chromatography on silica gel [*n*Hex:AcOEt = 8:2], 35.6 mg, 68% yield, 95% *ee*, colorless oil. **$[\alpha]_D^{20}$** = +24.7° (*c* = 1.0, $CHCl_3$). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 7.00 (s, 1H), 6.95 (s, 1H), 4.59 (d, *J* = 9.1 Hz, 1H), 4.30 (d, *J* = 9.1 Hz, 1H), 2.80 – 2.63 (m, 2H), 2.21 (s, 3H), 1.45 (s, 3H), 1.28 (s, 9H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 177.30, 155.11, 143.85, 132.89, 126.93, 119.06, 116.72, 82.26, 44.13, 44.07, 34.31,

31.73 (3C), 24.62, 15.31. **GC-MS (m/z):** calcd for $C_{17}H_{24}O_3$ 276.17 (M-OMe) 261 (100), 276 (18). **Elemental analysis:** $C_{16}H_{22}O_3$: 262.16; C, 73.25, H, 8.45; found: C, 73.15, H, 8.33.



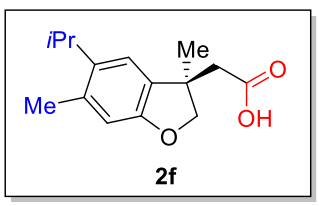
2d

Compound: (*R*)-2-(3,5-dimethyl-2,3-dihydrobenzofuran-3-yl)acetic acid (**2d**). From **1d** (57.6 mg, 0.2 mmol). Purified by flash chromatography on silica gel [*n*Hex:AcOEt = 7:3], 26.4 mg, 64% yield, 99% *ee*, white solid. **Melting point:** 98 - 100 °C. **$[\alpha]_D^{20}$** = +33.4° (*c* = 1.0, $CHCl_3$). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 7.01 – 6.84 (m, 2H), 6.68 (d, *J* = 8.1 Hz, 1H), 4.58 (d, *J* = 9.2 Hz, 1H), 4.29 (d, *J* = 9.2 Hz, 1H), 2.80 – 2.61 (m, 2H), 2.27 (s, 3H), 1.43 (s, 3H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 176.45, 157.14, 134.27, 130.28, 129.30, 123.40, 109.74, 82.52, 44.08, 43.90, 25.12, 21.08. **GC-MS (m/z):** calcd for $C_{13}H_{16}O_3$ 220.11 (M-OMe) 147 (100), 119 (41), 220 (20). **Elemental analysis:** $C_{12}H_{14}O_3$: 206.09; C, 69.89, H, 6.84; found: C, 69.75, H, 6.61.



2e

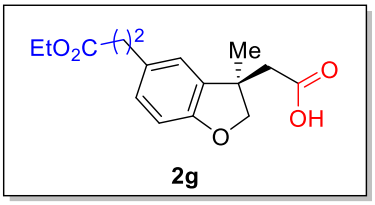
Compound: (*R*)-2-(5-(tert-butyl)-3-methyl-2,3-dihydrobenzofuran-3-yl)acetic acid (**2e**). From **1e** (66.0 mg, 0.2 mmol). Purified by flash chromatography on silica gel [*n*Hex:AcOEt = 7:3], 33.7 mg, 68% yield, 97% *ee*, white solid. **Melting point:** 99-101 °C. **$[\alpha]_D^{20}$** = +34.6° (*c* = 1.0, $CHCl_3$). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 7.19 (dd, *J* = 8.4, 2.1 Hz, 1H), 7.16 – 7.10 (m, 1H), 6.74 (dd, *J* = 8.4, 0.5 Hz, 1H), 4.61 (d, *J* = 9.2 Hz, 1H), 4.32 (d, *J* = 9.2 Hz, 1H), 2.84 – 2.61 (m, 2H), 1.48 (s, 3H), 1.30 (s, 9H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 177.15, 156.75, 143.86, 133.54, 125.51, 119.43, 109.11, 82.48, 44.05, 43.79, 34.40, 31.69, 24.68. **GC-MS (m/z):** calcd for $C_{16}H_{22}O_3$ 262.16 (M-OMe) 247 (100), 262 (41). **Elemental analysis:** $C_{15}H_{20}O_3$: 248.14; C, 72.55, H, 8.12; found: C, 72.34, H, 8.01.



2f

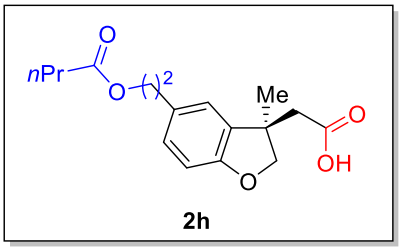
Compound: (*R*)-2-(5-isopropyl-3,6-dimethyl-2,3-dihydrobenzofuran-3-yl)acetic acid (**2f**). From **1f** (66.0 mg, 0.2 mmol). Purified by flash chromatography on silica gel [*n*Hex:AcOEt = 7:3], 31.3 mg, 63% yield, 95% *ee*,

colorless oil. **[α]$_D^{20}$** = +23.4° (*c* = 1.0, $CHCl_3$). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 6.96 (s, 1H), 6.59 (s, 1H), 4.56 (d, *J* = 9.1 Hz, 1H), 4.27 (d, *J* = 9.1 Hz, 1H), 3.06 (sept, *J* = 6.8 Hz, 1H), 2.78 – 2.62 (m, 2H), 2.27 (s, 3H), 1.44 (s, 3H), 1.18 (dd, *J* = 6.9, 3.4 Hz, 6H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 176.39, 156.76, 139.34, 135.64, 131.66, 118.67, 111.32, 82.43, 44.00, 43.73, 28.88, 24.74, 23.50 (2C), 19.63. **GC-MS (m/z):** calcd for $C_{16}H_{22}O_3$ 262.16 (M-OMe) 189 (100), 147 (92), 262 (86). **Elemental analysis:** $C_{15}H_{20}O_3$: 248.14; C, 72.55, H, 8.12; found: C, 72.41, H, 8.05.



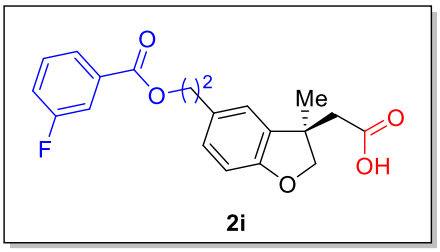
2g

Compound: (*R*)-2-(5-(3-ethoxy-3-oxopropyl)-3-methyl-2,3-dihydrobenzofuran-3-yl)acetic acid (**2g**). From **1g** (74.8 mg, 0.2 mmol). Purified by flash chromatography on silica gel [*n*Hex:AcOEt = 2:1], 40.3 mg, 69% yield, 98% *ee*, colorless oil. **[α]$_D^{20}$** = +21.7° (*c* = 1.0, $CHCl_3$). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 6.96 (dd, *J* = 8.1, 1.9 Hz, 1H), 6.93 (d, *J* = 1.8 Hz, 1H), 6.70 (d, *J* = 8.1 Hz, 1H), 4.58 (d, *J* = 9.2 Hz, 1H), 4.29 (d, *J* = 9.2 Hz, 1H), 4.10 (q, *J* = 7.1 Hz, 2H), 2.87 (t, *J* = 7.8 Hz, 2H), 2.76 – 2.63 (m, 2H), 2.56 (t, *J* = 7.8 Hz, 2H), 1.43 (s, 3H), 1.21 (td, *J* = 7.1, 0.8 Hz, 3H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 176.67, 173.27, 157.78, 134.47, 133.24, 128.77, 122.78, 109.96, 82.63, 60.65, 44.11, 43.88, 36.68, 30.77, 25.10, 14.44. **GC-MS (m/z):** calcd for $C_{17}H_{22}O_5$ 306.15 (M-OMe) 145 (100), 233 (51), 306 (30). **Elemental analysis:** $C_{16}H_{20}O_5$: 292.13; C, 65.74, H, 6.90; found: C, 65.58, H, 6.74.



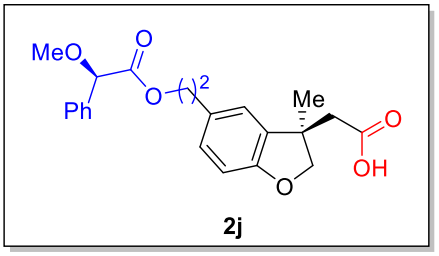
2h

Compound: (*R*)-2-(5-(2-(butyryloxy)ethyl)-3-methyl-2,3-dihydrobenzofuran-3-yl)acetic acid (**2h**). From **1h** (77.6 mg, 0.2 mmol). Purified by flash chromatography on silica gel [*n*Hex:AcOEt = 2:1], 34.9 mg, 57% yield, 98% *ee*, colorless oil. **[α]$_D^{20}$** = +16.6 (*c* = 1.0, $CHCl_3$). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 7.01 – 6.92 (m, 2H), 6.72 (d, *J* = 8.1 Hz, 1H), 4.60 (d, *J* = 9.2 Hz, 1H), 4.30 (d, *J* = 9.2 Hz, 1H), 4.22 (t, *J* = 7.1 Hz, 2H), 2.86 (t, *J* = 7.1 Hz, 2H), 2.76 – 2.62 (m, 2H), 2.25 (t, *J* = 7.4 Hz, 2H), 1.61 (sext, *J* = 7.4 Hz, 2H), 1.44 (s, 3H), 0.91 (t, *J* = 7.4 Hz, 3H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 176.56, 173.72, 157.80, 134.30, 130.15, 129.18, 123.12, 109.76, 82.40, 65.03, 43.90, 43.63, 36.21, 34.64, 24.89, 18.40, 13.62. **LC-MS (m/z):** calcd for $C_{17}H_{22}O_5$ 306.15, 305.0 $[M-H]^-$, 235.2 [M-71-H]. **Elemental analysis:** $C_{17}H_{22}O_5$: 306.15; C, 66.65, H, 7.24; found: C, 65.50, H, 7.10.



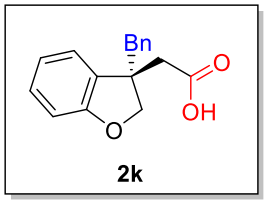
2i

Compound: (*R*)-2-(5-(2-((3-fluorobenzoyl)oxy)ethyl)-3-methyl-2,3-dihydrobenzofuran-3-yl)acetic acid (**2j**). From **1j** (88.0 mg, 0.2 mmol). Purified by flash chromatography on silica gel [*n*Hex:AcOEt = 2:1], 44.4 mg, 62% yield, 98% *ee*, colorless oil. **[α]$_D^{20}$** = +14.2° (*c* = 1.0, $CHCl_3$). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 7.79 (dt, *J* = 7.7, 1.2 Hz, 1H), 7.67 (ddd, *J* = 9.3, 2.7, 1.5 Hz, 1H), 7.39 (td, *J* = 8.0, 5.5 Hz, 1H), 7.28 – 7.19 (m, 1H), 7.07 – 6.97 (m, 2H), 6.74 (d, *J* = 8.1 Hz, 1H), 4.60 (d, *J* = 9.2 Hz, 1H), 4.47 (t, *J* = 7.0 Hz, 2H), 4.31 (d, *J* = 9.2 Hz, 1H), 2.99 (t, *J* = 7.0 Hz, 2H), 2.76 – 2.62 (m, 2H), 1.43 (s, 3H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 176.17, 165.33 (d, *J*C-F = 3.0 Hz), 162.51 (d, *J*C-F = 247.1 Hz), 157.92, 134.43, 132.43 (d, *J*C-F = 7.5 Hz), 130.02, 129.98 (d, *J*C-F = 7.8 Hz), 129.18, 125.25 (d, *J*C-F = 3.1 Hz), 123.30, 120.01 (d, *J*C-F = 21.3 Hz), 116.42 (d, *J*C-F = 22.9 Hz), 109.89, 82.43, 66.10, 43.84, 43.63, 34.69, 24.89. **^{19}F-NMR** (376 MHz, $CDCl_3$): δ -112.37 (td, *J* = 8.8, 5.5 Hz). **GC-MS (m/z):** calcd for $C_{20}H_{19}FO_5$ 358.12, 357.2 $[M-H]^-$, 235.2 [M-123-H]. **Elemental analysis:** $C_{20}H_{19}FO_5$: 358.12; C, 67.03; H, 5.34; F, 5.30; found: C, 66.81, H, 5.21.



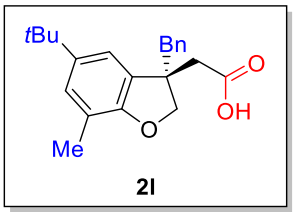
2j

Compound: 2-((*R*)-5-(2-((*R*)-2-methoxy-2-phenylacetoxy)ethyl)-3-methyl-2,3-dihydrobenzofuran-3-yl)acetic acid (**2i**). From **1i** (93.2 mg, 0.2 mmol). Purified by flash chromatography on silica gel [*n*Hex:AcOEt = 2:1], 43.7 mg, 60% yield, 25:1 *dr*, 97% *ee*, colorless oil. **[α]$_D^{20}$** = +5.4° (*c* = 1.0, $CHCl_3$). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 7.41 – 7.29 (m, 5H), 6.87 (d, *J* = 1.9 Hz, 1H), 6.82 (dd, *J* = 8.2, 1.9 Hz, 1H), 6.64 (d, *J* = 8.1 Hz, 1H), 4.73 (d, *J* = 2.5 Hz, 1H), 4.58 (d, *J* = 9.2 Hz, 1H), 4.32 – 4.24 (m, 3H), 3.36 (d, *J* = 1.0 Hz, 3H), 2.80 (t, *J* = 7.2 Hz, 2H), 2.72 – 2.59 (m, 2H), 1.40 (s, 3H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 175.91, 170.61, 157.83, 136.10, 134.38, 129.72, 129.17, 128.72, 128.62 (2C), 127.21 (2C), 123.02, 109.71, 82.57, 82.48, 65.89, 57.26, 43.90, 43.62, 34.44, 24.86. **LC-MS (m/z):** calcd for $C_{22}H_{24}O_6$ 384.16, 383.2 $[M-H]^-$, 235.0 $[M-149-H]^-$. **Elemental analysis:** $C_{22}H_{24}O_6$: 384.16; C, 68.74; H, 6.29; found: C, 68.55, H, 6.15.



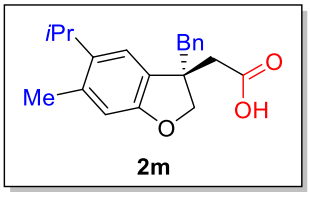
2k

Compound: (*R*)-2-(3-benzyl-2,3-dihydrobenzofuran-3-yl)acetic acid (**2k**). From **1k** (70.0 mg, 0.2 mmol). Purified by flash chromatography on silica gel [*n*Hex : AcOEt = 7 : 3], 26.3 mg, 49% yield, 98% *ee*, white solid. **Melting point:** 137 - 139 °C. **[α]$_D^{20}$** = +44.3° (*c* = 1.0, $CHCl_3$). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 7.24 – 7.18 (m, 3H), 7.14 (td, *J* = 7.7, 1.4 Hz, 1H), 6.92 – 6.86 (m, 2H), 6.81 (td, *J* = 7.4, 1.0 Hz, 1H), 6.79 – 6.71 (m, 2H), 4.66 (d, *J* = 9.4 Hz, 1H), 4.46 (d, *J* = 9.3 Hz, 1H), 3.13 – 3.01 (m, 2H), 2.93 (d, *J* = 16.4 Hz, 1H), 2.71 (d, *J* = 16.4 Hz, 1H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 176.90, 159.50, 136.41, 131.40, 130.54 (2C), 128.92, 127.97 (2C), 126.74, 124.26, 120.11, 109.88, 81.01, 47.94, 43.67, 41.11. **GC-MS (m/z):** calcd for $C_{18}H_{18}O_3$ 282.13 (M-OMe) 131 (100), 191 (41), 282 (7). **Elemental analysis:** $C_{17}H_{16}O_3$: 268.11; C, 76.10; H, 6.01; found: C, 75.95, H, 5.80.



2l

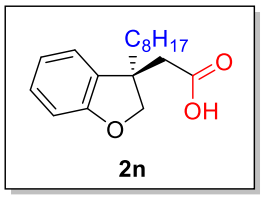
Compound: (*R*)-2-(3-benzyl-5-(tert-butyl)-7-methyl-2,3-dihydrobenzofuran-3-yl)acetic acid (**2l**). From **1l** (84.0 mg, 0.2 mmol). Purified by flash chromatography on silica gel [*n*Hex:AcOEt = 7:3], 45.3 mg, 67% yield, 95% *ee*, colorless oil. **[α]$_D^{20}$** = +26.1° (*c* = 1.0, $CHCl_3$). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 7.21 (dd, *J* = 4.9, 1.8 Hz, 3H), 7.01 – 6.96 (m, 1H), 6.92 – 6.85 (m, 2H), 6.39 (d, *J* = 2.1 Hz, 1H), 4.66 (d, *J* = 9.3 Hz, 1H), 4.45 (d, *J* = 9.3 Hz, 1H), 3.14 (d, *J* = 13.3 Hz, 1H), 3.01 (d, *J* = 13.2 Hz, 1H), 2.92 (d, *J* = 16.5 Hz, 1H), 2.66 (d, *J* = 16.4 Hz, 1H), 2.20 (s, 3H), 1.19 (s, 9H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 177.24, 155.43, 142.81, 136.67, 130.77 (2C), 130.16, 127.87 (2C), 126.96, 126.58, 119.03, 118.84, 81.87, 48.30, 43.15, 40.44, 34.16, 31.59 (3C), 15.33. **GC-MS (m/z):** calcd for $C_{23}H_{28}O_3$ 352.20 (M-OMe) 205 (100), 261 (21), 352 (10). **Elemental analysis:** $C_{22}H_{26}O_3$: 338.19; C, 78.07; H, 7.74, found: C, 77.91, H, 7.59.



2m

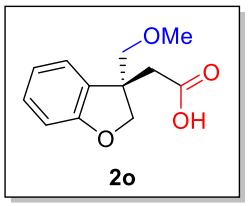
Compound: (*R*)-2-(3-benzyl-5-isopropyl-6-methyl-2,3-dihydrobenzofuran-3-yl)acetic acid (**2m**). From **1m** (81.2 mg, 0.2 mmol). Purified by flash chromatography on silica gel [*n*Hex:AcOEt = 7:3], 36.3 mg, 56% yield,

98% *ee*, white solid. **Melting point:** 111 - 113 °C. **[α]$_D^{20}$** = +20.7° (*c* = 1.0, $CHCl_3$). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 7.25 – 7.19 (m, 3H), 6.90 (dd, *J* = 6.5, 2.9 Hz, 2H), 6.58 (s, 1H), 6.43 (s, 1H), 4.64 (d, *J* = 9.3 Hz, 1H), 4.44 (d, *J* = 9.3 Hz, 1H), 3.14 (d, *J* = 13.3 Hz, 1H), 3.07 – 2.96 (m, 2H), 2.93 (d, *J* = 16.5 Hz, 1H), 2.66 (d, *J* = 16.5 Hz, 1H), 2.28 (s, 3H), 1.08 (dd, *J* = 10.3, 6.8 Hz, 6H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 177.47, 157.07, 138.46, 136.67, 135.74, 130.74 (2C), 128.88, 127.94 (2C), 126.60, 120.84, 111.20, 81.95, 47.99, 43.24, 40.65, 28.69, 23.40, 23.38, 19.68. **GC-MS (m/z):** calcd for $C_{22}H_{26}O_3$ 338.19 (M-OMe) 189 (100), 338 (12). **Elemental analysis:** $C_{21}H_{24}O_3$: 324.17; C, 77.75; H, 7.46; found: C, 77.60; H, 7.31.



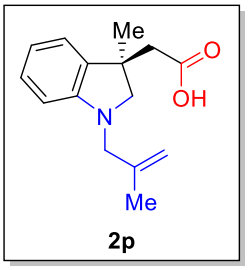
2n

Compound: (*R*)-2-(3-octyl-2,3-dihydrobenzofuran-3-yl)acetic acid (**2n**), From **1n** (74.4 mg, 0.2 mmol). Purified by flash chromatography on silica gel [*n*Hex:AcOEt = 7:3], 29.6 mg, 51% yield, 80% *ee*, colorless oil. **[α]$_D^{20}$** = +68.4° (*c* = 1.0, $CHCl_3$). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 7.13 (ddd, *J* = 8.0, 7.4, 1.4 Hz, 1H), 7.07 (dd, *J* = 7.4, 1.4 Hz, 1H), 6.86 (td, *J* = 7.4, 1.0 Hz, 1H), 6.78 (d, *J* = 8.0 Hz, 1H), 4.53 (d, *J* = 9.4 Hz, 1H), 4.46 (d, *J* = 9.4 Hz, 1H), 2.83 (d, *J* = 15.7 Hz, 1H), 2.71 (d, *J* = 15.6 Hz, 1H), 1.80 (td, *J* = 12.9, 4.3 Hz, 1H), 1.65 (td, *J* = 13.2, 12.5, 4.3 Hz, 1H), 1.29 (m, 1H), 1.25 – 1.17 (m, 10H), 1.03 (m, 1H), 0.84 (t, *J* = 6.9 Hz, 3H). **^{13}C-NMR** (100 MHz, $CDCl_3$): 175.48, 159.62, 132.05, 128.65, 123.28, 120.42, 109.75, 80.75, 47.16, 42.66, 38.30, 31.77, 29.91, 29.34, 29.18, 24.12, 22.58, 14.05. **GC-MS (m/z):** calcd for $C_{19}H_{28}O_3$ 304.20 (M-OMe) 131 (100), 191 (36), 231 (17), 304 (7). **Elemental analysis:** $C_{18}H_{26}O_3$: 290.19; C, 74.45; H, 9.02; found: C, 74.35, H, 8.85.



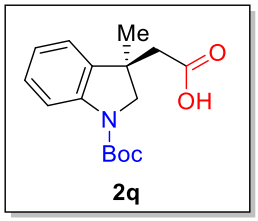
2o

Compound: (*R*)-2-(3-(methoxymethyl)-2,3-dihydrobenzofuran-3-yl)acetic acid (**2o**). From **1o** (60.8 mg, 0.2 mmol). Purified by flash chromatography on silica gel [*n*Hex:AcOEt = 7:3], 20.9 mg, 47% yield, 94% *ee*, colorless oil. **[α]$_D^{20}$** = +21.4° (*c* = 1.0, $CHCl_3$). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 7.22 – 7.11 (m, 2H), 6.85 (td, *J* = 7.5, 1.0 Hz, 1H), 6.79 (dt, *J* = 8.0, 0.7 Hz, 1H), 4.53 (d, *J* = 9.6 Hz, 1H), 4.47 (d, *J* = 9.6 Hz, 1H), 3.55 (m, 2H), 3.32 (s, 3H), 2.96 (d, *J* = 15.9 Hz, 1H), 2.74 (d, *J* = 15.8 Hz, 1H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 176.77, 159.65, 130.28, 129.17, 124.14, 120.54, 109.89, 78.69, 76.80, 59.32, 48.19, 39.55. **GC-MS (m/z):** calcd for $C_{13}H_{16}O_4$ 236.10 (M-OMe) 131 (100), 191 (31), 236 (10). **Elemental analysis:** $C_{12}H_{14}O_4$: 222.09; C, 64.85; H, 6.35; found: C, 64.75, H, 6.22.



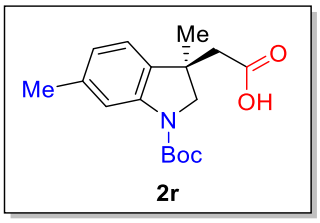
2p

Compound: (*R*)-2-(3-methyl-1-(2-methylallyl)indolin-3-yl)acetic acid (**2p**). From **1p** (65.4 mg, 0.2 mmol). Purified by flash chromatography on silica gel [*n*Hex:AcOEt = 2:1], 23.1 mg, 47% yield, 11% *ee*, orange oil. **[α]$_D^{20}$** = +8.4° (*c* = 1.0, $CHCl_3$). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 7.07 (td, *J* = 7.6, 1.3 Hz, 1H), 7.01 (dd, *J* = 7.3, 1.3 Hz, 1H), 6.67 (td, *J* = 7.4, 1.0 Hz, 1H), 6.48 (d, *J* = 7.9 Hz, 1H), 4.95 (s, 1H), 4.88 (s, 1H), 3.65 – 3.50 (m, 2H), 3.46 (d, *J* = 9.3 Hz, 1H), 3.13 (d, *J* = 9.3 Hz, 1H), 2.66 (s, 2H), 1.76 (s, 3H), 1.42 (s, 3H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 177.29, 151.07, 141.99, 136.17, 128.10, 122.13, 117.53, 112.18, 107.06, 65.23, 55.14, 43.85, 41.99, 24.62, 20.30. **GC-MS (m/z):** calcd for $C_{15}H_{19}NO_2$ 259.16 (M-OMe) 186 (100), 130 (59), 144 (56), 259 (44). **Elemental analysis:** $C_{15}H_{19}NO_2$: 245.14; C, 66.65, H, 7.24; found: C, 66.25, H, 7.04.



2q

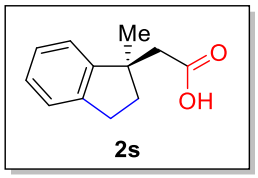
Compound: (*R*)-2-(1-(tert-butoxycarbonyl)-3-methylindolin-3-yl)acetic acid (**2q**). From **1q** (74.6 mg, 0.2 mmol). Purified by flash chromatography on silica gel [*n*Hex:AcOEt = 2:1], 18.0 mg, 31% yield, 63% *ee*, orange oil (as a 83:17 inseparable mixture with the benzoic acid by-product). **[α]$_D^{20}$** = +5.0° (*c* = 1.0, $CHCl_3$). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ [7.83 (m), 7.55 – 7.42 (m), 1H], 7.18 (t, *J* = 7.7 Hz, 1H), 7.10 (dd, *J* = 7.6, 1.3 Hz, 1H), 6.95 (td, *J* = 7.5, 1.1 Hz, 1H), 4.11 (d, *J* = 11.7 Hz, 1H), 3.82 – 3.73 (m, 1H), 2.74 – 2.60 (m, 2H), 1.56 (s, 9H), 1.43 (s, 3H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 175.36, 152.54, 141.55, 135.42, 128.24, 122.42, 114.86, 110.95, 77.18, 59.88, 44.40, 28.44 (3C), 26.34, 20.29. **GC-MS (m/z):** calcd for $C_{17}H_{23}NO_4$ 305.16 (M-OMe) 290 (100), 190 (41), 305 (6). **Elemental analysis:** $C_{16}H_{21}NO_4$: 291.15; C, 65.96; H, 7.27; found: C, 65.80, H, 7.12.



2r

Compound: (*R*)-2-(1-(tert-butoxycarbonyl)-3,6-dimethylindolin-3-yl)acetic acid (**2r**). From **1r** (77.4 mg, 0.2 mmol). Purified by flash chromatography on silica gel [*n*Hex:AcOEt = 2:1], 27.5 mg, 45% yield, 69% *ee*, orange

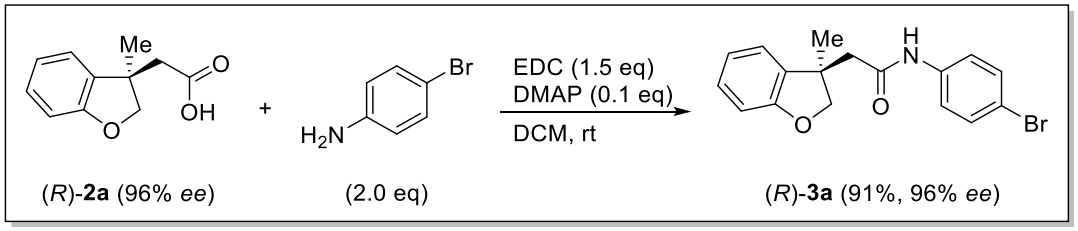
oil (as a 76:24 inseparable mixture with the benzoic acid by-product). **$[\alpha]_D^{20}$** = +11.3° (*c* = 1.0, $CHCl_3$). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 7.69 (m), 7.28 (m), 1H], 6.97 (d, *J* = 7.6 Hz, 1H), 6.76 (d, *J* = 7.6 Hz, 1H), 4.09 (d, *J* = 11.6 Hz, 1H), 3.75 (d, *J* = 11.2 Hz, 1H), 2.70 – 2.56 (m, 2H), 2.31 (s, 3H), 1.55 (s, 9H), 1.40 (s, 3H). **^{13}C-NMR (**100 MHz, $CDCl_3$): δ 176.15, 152.59, 141.93, 131.71, 129.32, 127.48, 123.13, 112.02, 80.53, 60.22, 44.72, 28.42 (3C), 28.10, 26.39, 20.39. **GC-MS (m/z):** calcd for $C_{18}H_{25}NO_4$ 319.18 (M-OMe) 304 (100), 319 (20). **Elemental analysis:** $C_{17}H_{23}NO_4$: 305.16; C, 66.86; H, 7.59; found: C, 66.75, H, 7.44.



2s

Compound: (*R*)-2-(1-methyl-2,3-dihydro-1H-inden-1-yl)acetic acid (**2s**). From **1s** (54.4 mg, 0.2 mmol). Purified by flash chromatography on silica gel [*n*Hex:AcOEt = 8:2], 15.6 mg, 41% yield, 98% *ee*, colorless oil. **$[\alpha]_D^{20}$** = +20.9° (*c* = 1.0, $CHCl_3$). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 7.23 – 7.11 (m, 4H), 2.92 (t, *J* = 7.2 Hz, 2H), 2.64 (d, *J* = 14.2 Hz, 1H), 2.54 (d, *J* = 14.2 Hz, 1H), 2.36 – 2.25 (m, 1H), 1.98 (dt, *J* = 12.8, 7.4 Hz, 1H), 1.39 (s, 3H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 177.67, 149.95, 142.72, 126.88, 126.45, 124.70, 122.36, 46.02, 44.86, 38.68, 29.97, 26.17. **GC-MS (m/z):** calcd for $C_{13}H_{16}O_2$ 204.12 (M-OMe) 131 (100), 115 (43), 204 (8). **Elemental analysis:** $C_{12}H_{14}O_2$: 190.10; C, 75.76; H, 7.42; found: C, 75.66, H, 7.31.

Synthesis of the amide derivative

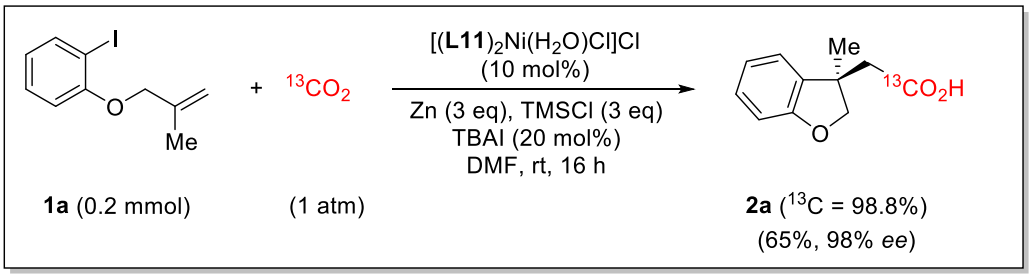


Compound: (*R*)-N-(4-bromophenyl)-2-(3-methyl-2,3-dihydrobenzofuran-3-yl)acetamide (**3a**).

Procedure: To a solution of acid (*R*)-**2a** (96.1 mg, 0.5 mmol, *ee* = 96%), 4-bromoaniline (172.0 mg, 1.0 mmol) and DMAP (6.0 mg, 10 mol%) in CH_2Cl_2 (2.5 mL) was added EDC (148.2 mg, 1.5 mmol) and the reaction mixture was stirred at room temperature for 6 h. Then CH_2Cl_2 (2.5 mL) was added, and the solution was washed with 1 M HCl (3 x 3 mL), water (3 x 3 mL) and brine (3 mL) and dried with Na_2SO_4 and concentrated. The residue was purified by flash chromatography on silica gel [*n*Hex:AcOEt = 8:2], to obtain the amide (*R*)-**3a**. Yield = 91%, (157.5 mg), 96% *ee*, pale yellow solid.

Melting point: 127 - 129 °C. **$[\alpha]_D^{20}$** = -10.4° (*c* = 1.0, $CHCl_3$). **^{1}H-NMR** (400 MHz, $CDCl_3$): δ 7.35 (d, *J* = 8.7 Hz, 2H), 7.24 – 7.01 (m, 5H), 6.90 (t, *J* = 7.4 Hz, 1H), 6.80 (d, *J* = 8.0 Hz, 1H), 4.65 (d, *J* = 9.1 Hz, 1H), 4.30 (d, *J* = 9.1 Hz, 1H), 2.70 – 2.56 (m, 2H), 1.49 (s, 3H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 168.67, 159.37, 136.45, 133.83, 131.88 (2C), 128.95, 122.61, 121.60 (2C), 120.80, 117.09, 110.28, 82.24, 47.93, 44.48, 25.11. **LC-MS (m/z):** calcd for $C_{17}H_{16}BrNO_2$ 345.04, 346.2 $[M+H]^+$, 713.2 $[2M+Na]^+$. **Elemental analysis:** $C_{17}H_{16}BrNO_2$: 345.04; C, 58.98; H, 4.66; found: C, 58.74, H, 4.41.

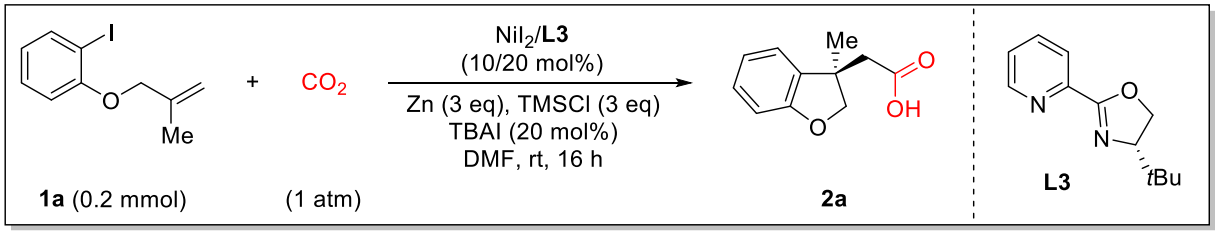
Labeling experiment with marked carbon dioxide



Procedure: A flame dried, nitrogen filled Schlenk tube equipped with a stirring bar was charged with Nickel catalyst (17.5 mol%, 9.8 mg), Zn (0.6 mmol, 39.2 mg) and TBAI (20 mol%, 14.8 mg). The nitrogen atmosphere was evacuated, and the tube was backfilled with CO_2 (1 bar). This operation was repeated three times. Then DMF (3 mL, 0.07 M) was added under flow of CO_2, and the reaction mixture was stirred for 15 min. Under flow of CO_2, substrate **1a** (54.8 mg, 0.2 mmol) was added, and CO_2 was bubbled in the solution. Then, TMSCl (0.6 mmol, 76 µL) was added by syringe, and the reaction mixture was stirred (1000 rpm) for 16 h at rt. The reaction was quenched with HCl (10 mL, 1.0 M), and extracted with ethyl acetate (3 x 10 mL). The combined organic layers were washed with HCl twice (2 mL, 1.0 M), dried over anhydrous Na_2SO_4, and concentrated under reduced pressure. The residue was purified by flash chromatography on silica gel [*n*Hex:AcOEt = 7:3] to afford the desired product **2a-*^{13}C*** (^{13}C = 98.8%), 25.0 mg, 65% yield, 98% *ee*. A small amount of the product (≈ 1 mg) was then dissolved in MeOH and $TMSCHN_2$ (25 µL) was added. The solvent was removed, and the so obtained methyl ester was injected in chiral HPLC.

^{1}H-NMR (400 MHz, $CDCl_3$): δ 7.18 – 7.08 (m, 2H), 6.88 (t, *J* = 7.4 Hz, 1H), 6.80 (d, *J* = 8.0 Hz, 1H), 4.61 (d, *J* = 9.2 Hz, 1H), 4.31 (d, *J* = 9.2 Hz, 1H), 2.73 (t, *J* = 6.3 Hz, 2H), 1.45 (s, 3H). **^{13}C-NMR** (100 MHz, $CDCl_3$): δ 176.54, 159.02, 133.98 (d, *J* = 4.2 Hz), 128.68, 122.66, 120.72, 109.97, 82.20, 43.98 (d, *J* = 57.3 Hz), 43.63, 24.98. **HRMS-ESI:** [M-H$^+$] calcd for $C_{10}{}^{13}CH_{11}O_3^-$ 192.07429, found 192.07433.

Non-linear-effect Experiments

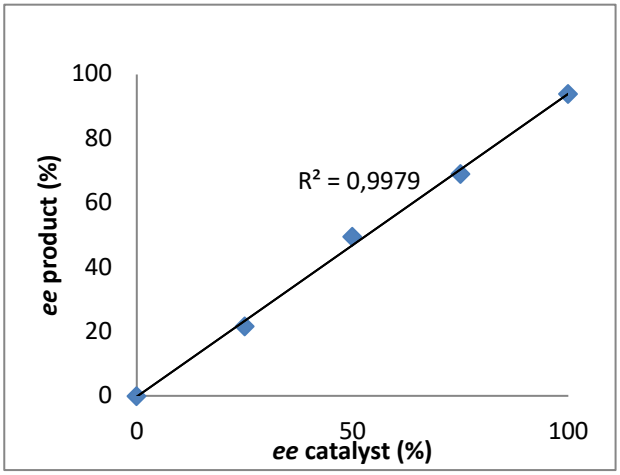


Procedure: The experiments were performed following the general procedure for the enantioselective Heck-carboxylation reaction (*In-situ* formation of the nickel complex), by using differently enantio-enriched ligand **L3** for each run.

Figure S1.

R² = 0.9979

Run	*ee* **L3** (%)	*ee* **2a** (%)
1	0	0
2	25	21.6
3	50	49.6
4	75	69.2
5	100	93



Crystallographic data for [(L11)$_2$Ni(H$_2$O)Cl]Cl and (*R*)-3a

A total solvent accessible void volume of 1046 Å^3 (18.9%) and 161 electron counts were detected in the unit cell of [(**L11**)$_2$Ni(H$_2$O)Cl]Cl by the SQUEEZE routine of PLATON.[16] This void volume is attributed to the presence of four highly disordered THF molecules in the unit cell. In the unit cell of (*R*)-**3a** two independent molecules are present. These molecules are rotational conformers generated by rotation along the C7-C8 bond to optimize the hydrogen bonding interactions of the amide group. Molecular drawings were generated using Mercury, **Figure S1** and **Figure S2**.[17] Crystal data and details of the data collection for compounds [(**L11**)$_2$Ni(H$_2$O)Cl]Cl and (*R*)**-3a** are reported in **Table S4**. Hydrogen bond interaction are reported in **Table S5** and **Table S6.** Crystallographic data have been deposited with the Cambridge Crystallographic Data Centre (CCDC) as supplementary publication number CCDC 2057596 for [(**L11**)$_2$Ni(H$_2$O)Cl]Cl and 2057597 for (*R*)-**3a**, respectively. Copies of the data can be obtained free of charge via www.ccdc.cam.ac.uk/getstructures , or by emailing data_request@ccdc.cam.ac.uk.

Table S4. Crystal data and structure refinement for compounds [(**L11**)$_2$Ni(H$_2$O)Cl]Cl and (*R*)-**3a.**

Compound	[(**L11**)$_2$Ni(H$_2$O)Cl]Cl	(*R*)-**3a**
Formula	$C_{48}H_{66}ON_6NiCl_2$	$C_{17}H_{16}O_2NBr$
Fw	872.67	346.22
T, K	296	296
λ, Å	0.71073	0.71073
Crystal symmetry	Orthorhombic	Triclinic
Space group	*P2$_1$2$_1$2$_1$*	*P1*
a, Å	14.2788(13)	9.8490(5)
b, Å	18.7966(16)	9.9955(5)
c, Å	20.5752(17)	10.0346(5)
α	90.00	113.883(2)
β	90.00	100.760(2)
γ	90.00	111.697(2)
Cell volume, Å^3	5522.2(8)	770.70(7)
Z	4	2
D_C, Mg m^{-3}	1.050	1.492
μ(Mo-K$_\alpha$), mm^{-1}	0.483	2.670
F(000)	1864	352
Crystal size/ mm	0.451 x 0.284 x 0.118	0.511 x 0.334 x 0.162
θ limits, °	1.736 – 26.531	2.417 – 26.994
Reflections collected	77870	15044
Unique obs. Reflections [$F_o > 4\sigma(F_o)$]	11340 [R(int) = 0.0527]	6528 [R(int) = 0.0522]
Goodness-of-fit-on F^2	1.027	0.982
R_1 (F)[a], wR_2 (F^2)[b] [I > 2σ(I)]	0.0414 – 0.0.0989	0.0334 – 0.826
Largest diff. peak and hole, e. Å^{-3}	0.322 - -0.295	0.335 and -0.520

a) $R_1 = \Sigma||F_o|-|F_c||/\Sigma|F_o|$. b $wR_2 = [\Sigma w(F_o^2-F_c^2)^2/\Sigma w(F_o^2)^2]^{1/2}$ where $w = 1/[\sigma^2(F_o^2) + (aP)^2 + bP]$ where $P = (F_o^2 + F_c^2)/3$.

[16] Speck, A.L.; "*PLATON* SQUEEZE: a tool for the calculation of the disordered solvent contribution to the calculated structure factors", *Acta Cryst., C71*, **2015**, 9-18.
[17] Macrae, C. F.; Sovago, I. ; Cottrell, S. J. ; Galek, P. T. A.; McCabe, P.; Pidcock, E.; Platings, M.; Shields, G. P.; Stevens, J. S.; Towler M.; Wood, P. A.; "*Mercury 4.0*: from visualization to analysis, design and prediction", *J. Appl. Cryst.*, **2020**, *53*, 226-235.

Table S5. Most relevant hydrogen bonds for [(**L11**)$_2$Ni(H$_2$O)Cl]Cl [Å and °].

D-H…A	d(D-H) [Å]	d(H…A) [Å]	d(D…A) [Å]	<(DHA) [°]
C(8)-H(8)...Cl(2)	0.98	2.94	3.722 (4)	137.4
C(1B)-H(1B)...Cl(2)	0.93	2.66	3.582 (4)	169.0
C(2)-H(2)...Cl(2)[a]	0.93	2.61	3.535 (4)	173.3
O(1)-H(1W)...Cl(2)	0.80(5)	2.23(5)	3.020 (4)	172(4)

Symmetry transformations used to generate equivalent atoms: [a] -x+2,y-1/2,-z+1/2

Table S6. Most relevant hydrogen bonds for (*R*)-**3a** [Å and °].

D-H…A	d(D-H) [Å]	d(H…A) [Å]	d(D…A) [Å]	<(DHA) [°]
C(1B)-H(1B)...O(2B)	0.93	2.42	2.903(5)	112.4
C(17B)-H(17E)...Br(1A)[a]	0.96	2.84	3.708(6)	151.4
N(1B)-H(1NB)...O(2A)	0.86(5)	2.07(5)	2.888(4)	156(5)
N(1A)-H(1NA)...O(2B)[b]	0.82(4)	2.17(4)	2.912(4)	151(4)

Symmetry transformations used to generate equivalent atoms: [a] x-1,y-1,z; [b] x,y,z-1

Figure S2. ORTEP drawing of [(**L11**)$_2$Ni(H$_2$O)Cl]Cl with atom labelling.

Thermal ellipsoids are drawn at 30% of the probability level

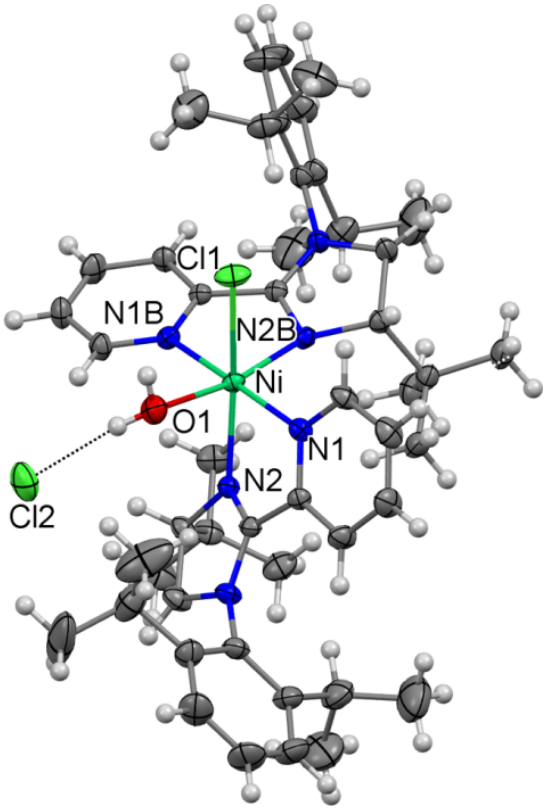


Figure S3. ORTEP drawing of the two independent molecules of (*R*)-**3a** with atom labelling.

Thermal ellipsoids are drawn at 30% of the probability level.