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ELECTRONIC SUPPLEMENTARY INFORMATION

Highly Enantioselective Cu-catalysed Allylic Substitutions with Grignard Reagents

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**General Procedures:** $^1$H NMR spectra were recorded at 300 or 400 MHz with CDCl$_3$ as solvent. $^{13}$C NMR spectra were obtained at 75.4 or 100.59 MHz in CDCl$_3$, (Varian VXR300 or AMX400 spectrometers). Carbon types were determined from APT $^{13}$C NMR experiments. Chemical shifts were determined relative to the residual solvent peaks (CHCl$_3$, $\delta$ = 7.26 ppm for hydrogen atoms, $\delta$ = 77.0 for carbon atoms). The following abbreviations are used to indicate signal multiplicity: s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet; br, broad. Progress and conversion of the reaction was determined by GC-MS (GC, HP6890: MS HP5973) with an HP1 or HP5 columns (Agilent Technologies, Palo Alto, CA). Enantio- and regioselectivities were determined by capillary GC analysis (HP 6890, ChiralDEX-G-TA column (30 m x 0.25 mm), CP-Chiralsil-Dex-CB (25 m x 0.25 mm)) using flame ionization detector (in comparison with racemic products). Optical rotations were measured in CHCl$_3$ on a Schmidt + Haensch polarimeter (Polartronic MH8) with a 10 cm cell ($c$ given in g/100 mL). Absolute configuration of the products was determined by comparison with compounds previously published. Thin-layer chromatography (TLC) was performed on commercial Kieselgel 60F$_{254}$ silica gel plates, and components were visualized with KMnO$_4$ reagent. Flash chromatography was performed on silica gel. Drying of solutions was performed with Na$_2$SO$_4$. Concentrations were conducted with a rotary evaporator.

Ligands 1a-1b were generously donated by Solvias. Ligand Taniaphos (2) was prepared according to literature procedures. CuCl, CuI, and CuBr SMe$_2$ were purchased from Aldrich or Acros, and used without further purification. CuTC refers to copper thiophene-2-carboxylate. Hoveyda-Grubbs 2nd generation catalyst, (E)-cinnamyl bromide (3a) and (E)-cinnamyl chloride (3b) were purchased from Aldrich. The substrates 3b, 3d-3f, 3g, and 3h were prepared according to literature procedures. Grignard reagents were purchased from Aldrich (EtMgBr, MeMgBr) or prepared from the corresponding alkyl bromides and magnesium turnings in Et$_2$O following standard procedures. Grignard reagents were titrated using $^3$BuOH and catalytic amounts of 1,10-phenanthroline. $^3$BuOMe was purchased as anhydrous grade, stored over 4Å MS and used without further purification. Et$_2$O was distilled from Na/benzophenone. CH$_2$Cl$_2$ was distilled from CaH$_2$. All reactions were conducted under argon atmosphere using standard Schlenk techniques.

Racemic products 4 and regioisomers 5 were obtained by reaction of the bromides 3 with the corresponding Grignard reagent (5.0 equiv) at -25 °C in CH$_2$Cl$_2$ in the presence of CuCN (100 mol %). In some cases, the racemic products were also obtained by using racemic-2 ligand, following the general procedure described in the next page.

Spectroscopic and analytical data of products 4b, 4e-h were obtained from their mixtures with 5. The products 4a-4l, and 6 have been previously described (see appropriate references in the following pages).

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General Procedure for the Enantioselective Cu-catalysed Allylic Alkylation with Grignard Reagents

In a Schlenk tube equipped with septum and stirring bar, CuBr SMe₂ (15.0 µmol, 3.08 mg) and ligand 2 (18 µmol, 12.4 mg) were dissolved in CH₂Cl₂ (3.0 mL) and stirred under argon at room temperature for 10 min. The mixture was cooled to –75 ºC and the corresponding Grignard reagent (solution in Et₂O, 1.73 mmol) was added dropwise. Allylic bromide 3 (1.50 mmol) was then added dropwise as a solution in CH₂Cl₂ at that temperature over 15 min via a syringe pump. Once the addition was complete the resulting mixture was further stirred at –75 ºC for 4-12h. The reaction was quenched by addition of MeOH (0.5 mL) and the mixture was allowed to reach rt. Then, aqueous NH₄Cl solution (1M, 2 mL) was added to the mixture. The organic phase was separated, and the resulting aqueous layer is extracted with Et₂O (0.5 mL, 3x). The combined organic phases were dried and concentrated to a yellow oil which was flash chromatographed (2 : 98 Et₂O/pentane) to yield the corresponding allylic substrates as a mixture of SN₂' (4) and SN₂ (5) regioisomers.

Note: GC analysis was carried out on a sample obtained after aqueous extraction with Et₂O, which has been passed through a short plug of silica gel to remove transition metal residues.

(+)-1-((S)-but-3-en-2-yl)benzene (4a): ⁹ Reaction time: 4h. Purification by column chromatography (2 : 98 Et₂O/pentane) afforded a 97 : 3 mixture of 4a and 5a as a colorless oil. [91% yield, 4a: 98% ee, [α]₀ = +5.4 (c 1.2, CHCl₃), lit. ⁹a (81% ee) [α]₀ = + 4.8 (neat), lit. ⁹b for (R)-4a (60% ee) [α]₀ = −2.2 (c 0.7, CHCl₃)]. 4a: ¹H-NMR δ 7.28-7.14 (m, 5H), 6.02-5.93 (m, 1H), 5.04-4.98 (m, 2H), 3.47-3.40 (m, 1H), 1.33 (d, J = 7.0 Hz, 3H); ¹³C-NMR δ 145.5 (C), 143.2 (CH), 128.3 (CH), 127.2 (CH), 126.0 (CH), 113.0 (CH₂), 43.1 (CH), 20.7 (CH₃). Enantioselectivity determined by chiral GC analysis, CP-Chiralsil-Dex-CB (25 m x 0.25 mm), initial temp. 75 ºC, retention times (min): 15.6 (minor) and 15.8 (major); Retention time 5a: 23.7 min.

(+)-1-((S)-pent-1-en-3-yl)benzene (4b): ¹⁰ Reaction time: 4h. Purification by column chromatography (2 : 98 Et₂O/pentane) afforded a 81 : 19 mixture of 4b and 5b as a colorless oil.

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(R)-3-methylhept-1-ene (4c):\(^{11}\) Reaction carried out using 5.0 mol% CuBr·SMe\(_2\) and 6.0 mol% 2. Reaction time: 12 h. Purification by column chromatography (2 : 98 Et\(_2\)O/pentane) afforded a 100 : 0 mixture of 4c and 5c as a colorless oil. [99\% conversion,\(^{12}\) 92\% ee]. 4c: \(^1\)H-NMR \(\delta\) 5.67-5.58 (m, 1H), 4.83 (dd, \(J = 10.4\) and 7.3 Hz, 2H), 2.05-2.01 (m, 1H), 1.28-1.19 (m, 6H), 0.91 (d, \(J = 6.7\) Hz, 3H), 0.82 (t, \(J = 7.0\) Hz, 3H); \(^{13}\)C-NMR \(\delta\) 144.9 (CH), 112.1 (CH\(_2\)), 37.7 (CH), 36.3 (CH\(_2\)), 29.4 (CH\(_2\)), 22.8 (CH\(_2\)), 20.1 (CH\(_3\)), 14.0 (CH\(_3\)). Enantioselectivity determined by chiral GC analysis, CP-Chiralsil-Dex-CB (25 m x 0.25 mm), initial temp. 55°C for 20 min, retention times (min): 5.4 (minor) and 5.5 (major).

(R)-3-ethylhept-1-ene (4d):\(^{14}\) Reaction carried out using 5.0 mol% CuBr·SMe\(_2\) and 6.0 mol% 2. Reaction time: 12 h. Purification by column chromatography (2 : 98 Et\(_2\)O/pentane) afforded a 100 : 0 mixture of 4d and 5d as a colorless oil. [99\% conversion,\(^{12}\) 93\% ee]. 4d: \(^1\)H-NMR \(\delta\) 5.51-5.42 (m, 1H), 4.92-4.86 (m, 2H), 1.80-1.77 (m, 1H), 1.37-1.15 (m, 8H), 0.85-0.78 (m, 6H); \(^{13}\)C-NMR \(\delta\) 143.4 (CH), 113.9 (CH\(_2\)), 45.8 (CH), 34.4 (CH\(_2\)), 29.4 (CH\(_2\)), 27.7 (CH\(_2\)), 22.8 (CH\(_2\)), 14.1 (CH\(_3\)), 11.6 (CH\(_3\)); LRMS (EI) \(m/z\) 126 (M\(^+\), 3), 97 (18), 84 (72), 69 (81), 55 (100). Enantioselectivity determined by chiral GC analysis, CP-Chiralsil-Dex-CB (25 m x 0.25 mm), initial temp. 55°C for 20 min, retention times (min): 9.8 (minor) and 9.9 (major).

(−)-1-((S)-pent-1-en-3-yl)naphthalene (4e):\(^{10a,16}\) Reaction time: 4h. Purification by column chromatography (2 : 98 Et\(_2\)O/pentane) afforded a 87 : 13 mixture of 4e and 5e as a colorless oil. [86\% yield, 90\% ee, [\(\alpha\)]\(_D\) = -26 (c 1.0, CHCl\(_3\))]. 4e: \(^1\)H-NMR \(\delta\) 8.12 (d, \(J = 8.1\) Hz, 1H), 7.84 (d, \(J = 7.9\) Hz, 1H), 7.70 (d, \(J = 7.9\) Hz, 1H), 7.51-7.36 (m, 4H), 6.11-6.02 (m, 1H), 5.11-5.07 (m, 2H), 4.01 (q, \(J = 7.1\) Hz, 1H), 1.95-1.88 (m, 2H), 0.95 (t, \(J = 7.4\) Hz, 3H); \(^{13}\)C-NMR \(\delta\) 142.8 (CH), 141.5 (C), 135.3 (C), 132.9 (C), 130.0 (CH), 127.7 (CH), 126.7 (CH), 126.6 (CH), 126.4 (CH), 125.0 (CH), 124.5 (CH), 115.7 (CH\(_2\)), 47.1 (CH), 29.1 (CH\(_2\)), 13.5 (CH\(_3\)); LRMS (EI) \(m/z\) 196 (M\(^+\), 26),


\(^{12}\) Conversion based on GC. The high volatility of the products 4c and 4d did not allow to completely remove the solvents after the chromatography, impeding the calculation of an accurate isolated yield.

\(^{13}\) With 1.0 mol% CuBr·SMe\(_2\) and 1.12 mol% 2 the product 4c was obtained with 99\% conversion, a regioselectivity of 100 : 0, but a slightly lower enantioselectivity (84\% vs. 92\%ee).


\(^{15}\) With 1.0 %CuBr·SMe\(_2\) and 1.1 % 2, 4d was obtained with 99\% conversion, 97 : 3 regioselectivity and 88\% ee.

1-Chloro-4-((S)-pent-1-en-3-yl)benzene (4f): Reaction time: 4h. Purification by column chromatography (2 : 98 Et₂O/pentane) afforded a 82 : 18 mixture of 4f and 5f as a colorless oil. [80% yield, 96% ee] 4f: 1H-NMR δ 7.25 (d, J = 8.4 Hz, 2H), 7.09 (d, J = 8.4 Hz, 2H), 5.88 (m, 1H), 5.00 (m, 2H), 3.10 (dt, J = 7.7 and 7.3 Hz, 1H), 1.69 (m, 2H), 0.83 (t, J = 7.3 Hz, 3H). Enantioselectivity determined by chiral GC analysis, CP-Chiralsil-Dex-CB (25 m x 0.25 mm), initial temp. 80 °C for 60 min, then 5 °C/min to 140 °C (final temp), retention times (min): 30.0 (minor) and 30.3 (major); retention time 5f: 56.0 min.

(+)-1-((S)-hept-1-en-3-yl)benzene (4g): Reaction time: 4h. Purification by column chromatography (2 : 98 Et₂O/pentane) afforded a 91 : 9 mixture of 4g and 5g as a colorless oil. [92% yield, 94% ee, [α]D = +47 (c 0.5, CHCl₃), lit.10a (88% ee) [α]D = + 44 (c 0.1, CHCl₃)]. 4g: 1H-NMR δ 7.21 (m, 5H), 5.95 (m, 1H), 5.02 (m, 2H), 3.32 (q, J = 7.5 Hz, 1H), 1.70 (q, J = 7.4 Hz, 2H), 1.39-1.02 (m, 4H), 0.87 (t, J = 7.0 Hz, 3H); 13C-NMR δ 144.7, 142.5, 128.4, 127.6, 126.0, 113.8, 49.9, 35.1, 29.7, 22.6, 14.0. Enantioselectivity determined by chiral GC analysis, CP-Chiralsil-Dex-CB (25 m x 0.25 mm), initial temp. 80 °C for 60 min, then 10 °C/min to 140 °C (final temp), retention times (min): 53.7 (minor) and 54.2 (major); retention time 5g: 70.4 min.

(+)-1-((S)-hepta-1,6-dien-3-yl)benzene (4h): Reaction time: 4h. Purification by column chromatography (2 : 98 Et₂O/pentane) afforded a 91 : 9 mixture of 4h and 5h as a colorless oil. [93% yield, 95% ee, [α]D = +36 (c 1.5, CHCl₃), lit.10b (92% ee) [α]D = + 33 (c 1.0, CHCl₃)]. 4h: 1H-NMR δ 7.30-7.16 (m, 5H), 5.95 (m, 1H), 5.79 (m, 1H), 5.03-4.92 (m, 4H), 3.26 (q, J = 7.5 Hz, 1H), 2.10-1.94 (m, 2H), 1.81-1.75 (m, 2H); 13C-NMR δ 144.1 (C), 142.1 (CH), 138.4 (CH), 128.4 (CH), 127.6 (CH), 126.1 (CH), 114.6 (CH₂), 114.1 (CH₂), 49.1 (CH), 34.4 (CH₂), 31.5 (CH₂); LRMS (EI) m/z 172 (M⁺, 13), 159 (6), 130 (33), 117 (100), 115 (41), 91 (48); HRMS Calcd. for C₁₃H₁₆ 172.12520, found 172.12554. Enantioselectivity determined by chiral GC analysis, CP-Chiralsil-Dex-CB (25 m x 0.25 mm), initial temp. 90 °C for 45 min, then 5 °C/min to 140 °C (final temp), retention times (min): 30.0 (minor) and 30.3 (major); retention time 5h: 56.0 min.

(−)-1-((S)-but-3-en-2-yl)naphthalene (4i): Reaction time: 4h. Purification by column chromatography (2 : 98 Et₂O/pentane) afforded a 100 : 0 mixture of 4i and 5i as a colorless oil. [87% yield, 96% ee, [α]D = - 29.8 (c 1.1, CHCl₃); lit.16 [α]D = - 29 (c 1.0, CHCl₃); lit.18a [α]D = - 37 (neat); lit.9b for (R)-4i (90% ee) +16.3 (c 0.4, CHCl₃)]. 4i: 1H-NMR δ 8.15 (d, J = 8.3 Hz, 1H), 7.87 (d, J = 7.8 Hz, 1H), 7.74 (d, J = 8.0 Hz, 1H), 7.54-7.41 (m, 4H), 6.23-6.15 (m, 1H), 5.17-5.13

(-)-1-((S)-but-3-en-2-yl)-4-chlorobenzene (4j): \(^{19}\) Reaction time: 4h. Purification by column chromatography (2 : 98 Et\(_2\)O/pentane) afforded a 99 : 1 mixture of 4j and 5j as a colorless oil. [95% yield, 97% ee, \(\alpha\)D = +12 (c 1.6, CHCl\(_3\))]. 

4j: \(^1\)H-NMR \(\delta\) 7.29 (d, J = 8.5 Hz, 2H), 7.07 (d, J = 8.5 Hz, 2H), 6.00-5.90 (m, 1H), 5.06-4.97 (m, 2H), 3.44-3.36 (m, 1H), 1.32 (d, J = 7.0 Hz, 3H); LRMS (EI) \(m/z\) 166 (M\(^+\), 47), 165 (9), 151 (10), 139 (10), 131 (68), 91 (100); HRMS Calcd. for C\(_{10}\)H\(_{11}\)Cl 166.05492, found 166.05570. Enantioselectivity determined by chiral GC analysis, CP-Chiralsil-Dex-CB (25 m x 0.25 mm), initial temp. 105 °C for 70 min, then 1°C/min to 140 °C (final temp), retention times (min): 71.7 (minor) and 72.1 (major); retention time 5k: 93.8 min.

(+)-Methyl 4-((S)-but-3-en-2-yl)benzoate (4k): \(^{20}\) Reaction time: 4h. Purification by column chromatography (2 : 98 Et\(_2\)O/pentane) afforded a 98 : 2 mixture of 4k and 5k as a colorless oil. [94% yield, 97% ee, \(\alpha\)D = +12 (c 0.9, CHCl\(_3\))]. 

4k: \(^1\)H-NMR \(\delta\) 7.91 (d, J = 8.30 Hz, 2H), 7.22 (d, J = 8.30 Hz, 2H), 5.97-5.90 (m, 1H), 5.03-4.98 (m, 2H), 3.84 (s, 3H), 3.49-3.44 (m, 1H), 1.32 (d, J = 7.0 Hz, 3H); \(^{13}\)C-NMR \(\delta\) 167.0 (C), 150.9 (C), 142.2 (CH), 129.7 (CH), 128.0 (C), 127.2 (CH), 113.8 (CH\(_2\)), 51.9 (CH\(_3\)), 43.1 (CH), 20.5 (CH\(_3\)); LRMS (EI) \(m/z\) 190 (M\(^+\), 44), 159 (33), 131 (100), 115 (25), 91 (22), 59 (8); HRMS Calcd. for C\(_{12}\)H\(_{14}\)O\(_2\) 190.09937, found 190.09969. Enantioselectivity determined by chiral GC analysis, CP-Chiralsil-Dex-CB (25 m x 0.25 mm), initial temp. 105 °C for 70 min, then 1°C/min to 140 °C (final temp), retention times (min): 71.7 (minor) and 72.1 (major); retention time 5k: 93.8 min.

(−)-((S)-2-methylbut-3-enyloxy)methylbenzene (4l): \(^{21}\) Reaction time: 12 h. Purification by column chromatography (2 : 98 Et\(_2\)O/pentane) afforded a 100 : 0 mixture of 4l and 5l as a colorless oil. [93% yield, 92% ee, \(\alpha\)D = −6 (c 1.1, CHCl\(_3\)); lit. \(^{21a}\) [\(\alpha\)D] = −3 (c 1.0, CHCl\(_3\))]. 

4l: \(^1\)H-NMR \(\delta\) 7.32 (d, J = 4.5 Hz, 4H), 7.29-7.21 (m, 1H), 5.83-5.74 (m, 1H), 5.07-4.99 (m, 2H), 4.50 (s, 2H), 3.36 (dd, J = 9.1 and 6.5 Hz, 1H), 3.28 (dd, J = 9.1 and 6.8 Hz, 1H), 2.52-2.44 (m, 1H), 1.03 (d, J = 6.8 Hz, 3H); \(^{13}\)C-NMR \(\delta\) 141.3 (CH), 138.6 (C), 128.3 (CH), 127.5 (CH), 127.4 (CH), 114.0 (CH\(_2\)), 75.0 (CH\(_2\)), 72.9 (CH\(_2\)), 37.8 (CH), 16.6 (CH\(_3\)); LRMS (EI) \(m/z\) 176 (M\(^+\), 12), 175 (5), 92 (11), 91 (100), 65 (7); HRMS Calcd. for C\(_{12}\)H\(_{16}\)O 176.12011, found 176.12262. Enantioselectivity


determined by chiral HPLC analysis, Chiralcel OD-H (99.75% heptane/iPrOH), 40°C, retention times (min): 10.9 (minor) and 11.2 (major).

(+)-1-(((S)-2-ethylbut-3-enyloxy)methyl)benzene (4m): Reaction time: 12 h. Purification by column chromatography (2 : 98 Et₂O/pentane) afforded a 98 : 2 mixture of 4m and 5m as a colorless oil. [97% yield, 94% ee, [α]D = + 19 (c 1.1, CHCl₃)]. 4m: ¹H-NMR δ 7.30-7.21 (m, 5H), 5.66-5.57 (m, 1H), 5.06-5.01 (m, 2H), 4.47 (s, 2H), 3.35 (d, J = 6.5 Hz, 2H), 2.22 (m, 1H), 1.56-1.47 (m, 1H), 1.27-1.20 (m, 1H), 0.83 (t, J = 7.5 Hz, 3H); ¹³C-NMR δ 140.0 (CH), 138.6 (C), 128.3 (CH), 127.5 (CH), 127.4 (CH), 115.6 (CH₂), 73.6 (CH₂), 73.0 (CH₂), 45.7 (CH), 24.0 (CH₂), 11.4 (CH₃); LRMS (EI) m/z 190 (M⁺, 11), 189 (11), 123 (21), 105 (100), 91 (79), 77 (30); HRMS Calcd. for C₁₃H₁₈O 190.13576, found 190.13505. Enantioselectivity determined by chiral HPLC analysis, Chiralcel OD-H (99.75% heptane/iPrOH), 40°C, retention times (min): 9.9 (minor) and 10.9 (major).

(−)-(S,E)-methyl 4-phenylpent-2-enoate (6): Following the general procedure, in a Schlenk tube equipped with septum and stirring bar, CuBr SMe₂ (15.0 µmol, 3.08 mg) and ligand 2 (18.0 µmol, 12.4 mg) were dissolved in CH₂Cl₂ (3.0 mL) and stirred under argon at room temperature for 10 min. The mixture was cooled to −75 °C and MeMgBr (3.0 M solution in Et₂O, 1.73 mmol, 0.575 ml) was added dropwise. Cinnamyl bromide 3a (296 mg, 1.50 mmol) was then added dropwise over 15 min via a syringe pump at that temperature. Once the addition was complete the resulting mixture was further stirred at −75 °C for 4 h. The reaction was quenched by addition of MeOH (0.5 mL) and the mixture was allowed to reach rt. Then, aqueous NH₄Cl solution (1M, 2 mL) was added to the mixture. The organic phase was separated, and the resulting aqueous layer is extracted with Et₂O (0.5 mL, 3x). The combined organic phases were dried and concentrated to a yellow oil which was dissolved in CH₂Cl₂ (3 mL) in a dried Schlenk tube. Methyl acrylate (645 mg, 7.5 mmol) and Hoveyda-Grubbs 2nd generation catalyst (18 mg, 0.03 mmol) were sequentially added producing a light green solution which was stirred for 36 h at rt. The mixture was then concentrated in vacuo to a dark brown oil. Purification of this residue by silica gel chromatography (2 : 98 to 5/ 95 Et₂O/pentane) affords 6 as a colorless oil [66% yield, [α]D = −20 (c 0.3, CHCl₃)]; ¹H-NMR δ 7.29-7.25 (m, 2H), 7.21-7.14 (m, 3H), 7.07 (dd, J = 15.7 and 6.7 Hz, 1H), 5.77 (dd, J = 15.7 and 1.5 Hz, 1H), 3.67 (s, 3H), 3.61-3.54 (m, 1H), 1.38 (d, J = 7.1 Hz, 3H); ¹³C-NMR δ 167.1, 152.9, 143.2, 128.6, 127.3, 126.7, 119.6, 51.4, 42.0, 20.1; LRMS (EI) m/z 190 (M⁺, 40), 159 (18), 131 (100), 91 (22), 51 (13); HRMS Calcd. for C₁₂H₁₄O₂ 190.09937, found 190.09953.

Enantioselective Catalytic Conjugate Addition of EtMgBr to (S)-6.²³

(+)-(3S,4S)-methyl 3-ethyl-4-phenylpentanoate (7): In a Schlenk tube CuBr SMe2 (8.0 µmol, 1.62 mg) and ligand (R,S)-1b (9.4 µmol, 5.60 mg) were dissolved in CH2Cl2 (1.5 mL) and stirred under argon at room temperature for 10 min. The mixture was cooled to -75 °C and EtMgBr (3.0 M in Et2O, 0.78 mmol) was added dropwise. After stirring for 5 min at that temperature a solution of 6 (30 mg, 0.16 mmol) in CH2Cl2 (0.25 mL) was added dropwise over 10 min. After stirring at –75 °C for 22 h, MeOH (0.25 mL) and NH4Cl (1M, 2 mL) were sequentially added, and the mixture was warmed to rt. After extraction with Et2O (0.5 mL, 3x), the combined organic phases were dried and concentrated to a yellow oil which was flash chromatographed (2 : 99 Et2O/pentane) to yield 7 as a colourless oil [81% yield, 98% de, [α]D = +25 (c 0.2, CHCl3)]; 1H-NMR δ 7.26-7.12 (m, 5H), 3.57 (s, 3H), 2.82-2.73 (m, 1H), 2.30-2.15 (m, 2H), 2.08-1.97 (m, 1H), 1.38-1.27 (m, 1H), 1.17 (d, J = 7.1 Hz, 3H), 1.14-1.06 (m, 1H), 0.81 (t, J = 7.4 Hz, 3H); 13C-NMR δ 174.1 (C), 145.6 (C), 128.2 (CH), 127.7 (CH), 126.0 (CH), 51.4 (CH3), 42.8 (CH), 41.4 (CH), 35.3 (CH2), 24.4 (CH2), 17.1 (CH3), 11.1 (CH3); LRMS (EI) m/z 220 (M+, 20), 189 (11), 146 (43), 105 (100) 57 (21); HRMS Calcd. for C14H20O2 220.14632, found 220.14572. Diastereoselectivity determined by Chiraldex G-TA column (30 m x 0.25 mm), 100 ºC, retention times (min): 59.6 (minor: 3R,4S and 3S,4R) and 62.4 (major, 3S,4S). Alternatively, the diastereoselectivity could also be determined by 1H-NMR, by integration of the 3.5 ppm signals corresponding to the methyl ester group.

Note: The conjugate addition of EtMgBr to (S)-6, following the procedure described above, but using racemic-1b instead of (R,S)-1b led to a 84 : 16 mixture of 7 and 8, as deduced by GC [Chiraldex G-TA column (30 m x 0.25 mm), 100 ºC, retention times (min): 59.6 (minor: 3R,4S), 62.4 (minor: 3S,4S) and 63.3 (minor: 3R, 4R). Alternatively, the de could also be determined by 1H-NMR, by integration of the 3.57 and 3.53 ppm signals corresponding to the methyl ester groups of 7 and 8.

(+)-(3R,4S)-methyl 3-ethyl-4-phenylpentanoate (8): Same procedure as above but using (S,R)-1b instead of (R,S)-1b. [84% yield, 92% de, [α]D = +6 (c 0.6, CHCl3)]; 1H-NMR δ 7.24-7.20 (m, 2H), 7.14-7.11 (m, 3H), 7.01 (s, 1H), 2.71-2.67 (m, 1H), 2.16-2.01 (m, 2H), 1.44-1.29 (m, 2H), 1.19 (d, J = 7.2 Hz, 3H), 0.83 (t, J = 7.4 Hz, 3H); 13C-NMR δ 174.0 (C), 145.6 (C), 128.2 (CH), 127.8 (CH), 126.1 (CH), 51.3 (CH3), 42.5 (CH), 41.8 (CH), 36.3 (CH2), 23.1 (CH2), 18.2 (CH3), 10.4 (CH3); LRMS (EI) m/z 220 (M+, 18), 189 (12), 146 (58), 105 (100); HRMS Calcd. for C14H20O2 220.14632, found 220.14572. Diastereoselectivity determined by Chiraldex G-TA column (30 m x 0.25 mm), 100 ºC, retention times (min): 59.6 (major: 3R,4S), 62.4 (minor: 3S,4S) and 63.3 (minor: 3R, 4R). Alternatively, the de could also be determined by 1H-NMR, by integration of the 3.57 and 3.53 ppm signals corresponding to the methyl ester groups of 7 and 8.
Influence of the copper source and Grignard halide in the enantioselective allylic alkylation of cinnamyl halides catalyzed by Taniaphos 2.

![Reaction Scheme]

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