Improved Ester Interchange Catalysts

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Supplemental Material

General synthetic methods All substrate and reagent esters except adamantane carboxylate methyl ester (synthesized from methanol and commercially available 1-adamantanecarbonyl chloride) were purchased from Aldrich. L-Valine methyl ester was freed from the hydrochloride salt with saturated $NaHCO_3$. All esters were dried over calcium hydride and freshly distilled, or sublimed prior to use. Sodium *tert*-butoxide and KO^tBu were sublimed, then stored and handled under inert atmosphere. Each sublimed batch was used for a period of 3-4 weeks then discarded as longer periods led to catalysts with diminished activity.

Catalyst mixture 1. The two salt components, sodium *tert*-butoxide and sodium para-*tert*-butyl phenoxide were weighed out in a 1:3 molar ratio and dissolved in THF to make the catalyst solution. Alternatively, catalyst could be made in a large batch by dissolving a 1:3 mixture of the salts in THF and removing the solvent *in vacuo*, and stored under inert atmosphere for multiple uses. Catalyst **1** can also be prepared *in situ* from a 4:3 mixture of sodium *tert*-butoxide and *para*-*tert*-butyl phenol, in THF solution.

1-Adamantanecarboxylic acid methyl ester. White crystalline solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.62 (s, 3H), 1.99 (br s, 3H), 1.860 (br s, 6H), 1.68, (m, 6H). ^{13}C NMR (400 MHz, $CDCl_3$) δ 178.2, 51.5, 40.6, 38.8, 36.45, 27.9.

Typical protocol for the synthesis of benzyl esters. To a stirring mixture of substrate ester and benzyl acetate under a dry Argon atmosphere was added a THF solution of **1**. Following catalyst addition the reaction vessel was evacuated to remove the product methyl acetate, and the progress was followed by GC. The benzyl ester product was purified by crystallization or column chromatography (10% ethyl acetate/ hexanes).

Benzyl benzoate. Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.12 (d, J = 8 Hz, 2H), 7.56 (t, J = 8 Hz, 1H), 7.49-7.33 (br m, 7H), 5.39 (s, 2H). ^{13}C NMR (400 MHz, $CDCl_3$) δ 166.3, 136.0, 132.9, 130.0, 129.6, 128.5, 128.3, 128.1, 128.1, 66.6.

Benzyl *p*-nitrobenzoate. Yellow crystalline solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.8-8.2 (m, 4H), 7.46-7.35 (br m, 5H), 5.39 (s, 2H). ^{13}C NMR (400 MHz, $CDCl_3$) δ 164.48, 150.5, 135.5, 135.2, 130.8, 128.7, 128.6, 128.4, 123.5, 67.6.

Benzyl phenoxyacetate. Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37-7.34 (m, 5H), 7.29 (t, J = 8 Hz, 2H), 7.00 (t, J = 8 Hz, 1H), 6.92 (d, J = 8 Hz, 2H), 5.24 (s, 2H), 4.66 (s, 2H). ^{13}C NMR (400 MHz, $CDCl_3$) δ 168.7, 157.6, 135.1, 129.5, 128.5, 128.4, 128.3, 121.6, 114.5, 66.8, 65.2.

Benzyl *trans*-cinnamate. Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.75 (d, J = 16 Hz, 1H), 7.53-7.50 (m, 2H), 7.45-7.34 (br m, 8H), 6.50 (d, J = 16 Hz, 1H), 5.27 (s, 2H). ^{13}C NMR (400 MHz, $CDCl_3$) δ 166.7, 145.1, 136.0, 134.2, 130.3, 128.8, 128.5, 128.19, 128.22, 128.0, 117.8, 66.3.

Benzyl hydrocinnamate. Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.38-7.19 (br m, 10H), 5.13 (s, 2H), 2.99 (t, *J* = 7.6 Hz, 2H), 2.70, (t, *J* = 7.6 Hz, 2H). ^{13}C NMR (400 MHz, $CDCl_3$) δ 172.6, 140.3, 135.9, 128.5, 128.4, 128.3, 128.2, 128.1, 126.2, 66.2, 35.8, 30.9.

Benzyl caprylate. Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.4-7.24 (m, 5H), 5.09 (s, 2H), 2.33 (t, *J* = 8 Hz, 2H), 1.66-1.57 (m, 2H), 1.33-1.25 (br m, 8H), 0.85 (t, *J* = 7.2 Hz, 3H). ^{13}C NMR (400 MHz, $CDCl_3$) δ 173.6, 136.1, 128.5, 128.2, 128.1, 66.0, 34.3, 31.6, 29.0, 28.9, 24.9, 22.5, 14.0.

Benzyl methoxyacetate. Synthesized using the protocol for *tert*-butyl esters below. Product was inseparable from *p*-^{t}Bu phenol. When sodium *para*-methoxyphenoxide was used as an catalyst additive instead, conversions were similar to those using **1** and the product was isolable with the chromatographic conditions described above. Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.36-7.34 (m, 5H), 5.19 (s, 2H), 4.06 (s, 2H), 3.44 (s, 3H). ^{13}C NMR (400 MHz, $CDCl_3$) δ 170.1, 35.3, 128.6, 128.5, 128.4, 69.8, 66.5, 59.3.

1-Adamantane carboxylic acid benzyl ester. White solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.37-7.27 (br m, 5H), 5.08 (s, 2H), 2.0 (br s, 3H), 1.90 (d, *J* = 2.8 Hz, 6H), 1.69 (dt, *J* = 13.6, 2.4 Hz, 6H). ^{13}C NMR (400 MHz, $CDCl_3$) δ 177.5, 137.0, 128.9, 128.3, 128.1, 66.2, 41.2, 39.2, 36.9, 28.4. Anal, calcd for $C_{18}H_{22}O_2$: C, 79.96; H, 8.20. Found: C, 80.05, H, 8.34.

Typical protocol for the synthesis of *tert*-butyl esters. To a stirring mixture of substrate ester and *tert*-butyl acetate was added a THF solution of **1**. The reaction was immediately placed under reduced static pressure (40-50 mm mercury) and with the help of a distillation head, the volatile methyl acetate collected in a liquid N_2 cooled trap. Reactions were run for about 6 h and monitored by GC. The remainder of *tert*-butyl acetate was removed *in vacuo*, and the products were isolated by flash chromatography(5% ethyl acetate/hexanes).

***tert*-Butyl benzoate.** Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.00-7.95 (m, 2H), 7.52-7.46 (m, 1H), 7.42-7.36 (m, 2H), 1.58 (s, 9H). ^{13}C NMR (400 MHz, $CDCl_3$) δ 165.8, 132.4, 132.0, 129.4, 128.1, 80.9, 28.2.

***tert*-Butyl *p*-nitrobenzoate.** Pale yellow crystalline solid. ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.24 (d, *J* = 8.8 Hz, 2H), 8.12 (d, *J* = 8.8 Hz, 2H), 1.61 (s, 9H). ^{13}C NMR (400 MHz, $CDCl_3$) δ 163.7, 150.2, 137.4, 130.5, 123.4, 82.6, 28.1.

***tert*-Butyl phenoxyacetate**. Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.28-7.23 (m, 2H), 6.98-6.93 (m, 1H), 6.89-6.85 (m, 2H), 4.48 (s, 2H), 1.47 (s, 9H). ^{13}C NMR (400 MHz, $CDCl_3$) δ 168.1, 157.9, 129.5, 121.5, 114.6, 82.3, 65.7, 28.0.

***tert*-Butyl *trans*-cinnamate.** Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.57 (d, *J* = 16 Hz, 1H), 7.51-7.46 (m, 2H), 7.38-7.32 (m, 3H), 6.35 (d, *J* = 16 Hz, 1H), 1.52 (s, 9H). ^{13}C NMR (400 MHz, $CDCl_3$) δ 174.1, 144.0, 135.1, 130.4, 129.2, 128.4, 120.6, 80.9, 28.6.

***tert*-Butyl hydrocinnamate.** Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.32-7.28 (m, 2H), 7.23-7.21 (m, 3H), 2.93 (t, *J* = 7.6 Hz, 2H), 2.56 (t, *J* = 7.6 Hz, 2H), 1.44 (s, 9H) ^{13}C NMR (400 MHz, $CDCl_3$) δ 174.2, 140.8, 128.4, 128.3, 126.1, 80.3, 37.1, 31.1, 28.1.

***tert*-Butyl caprylate.** Colorless oil. ^{1}H NMR (400 MHz, $CDCl_3$) δ 2.16 (t, *J* = 7.6 Hz, 2H), 1.53 (br t, *J* = 7.6, 2H), 1.40 (s, 9H), 1.30-1.19 (br m, 8H), 0.85 (t, *J* = 6.8 Hz, 3H).

^{13}C NMR (400 MHz, $CDCl_3$) δ 173.3, 79.2, 35.6, 34.0, 31.6, 29.1, 29.0, 28.1, 25.1, 22.56, 14.0.

***tert*-Butyl methoxyacetate.** Colorless oil.Some tert-butyl acetate lost during the evacuation portion of the synthesis, the remainder was purified by flash chromatography. ^{1}H NMR (400 MHz, $CDCl_3$) δ 3.82 (s, 2H), 3.34 (s, 2H), 1.40 (s, 9H). ^{13}C NMR (400 MHz, $CDCl_3$) δ 169.3, 81.4, 70.1, 59.0, 27.9.

L-Valine (-)menthyl ester racemization experiments. To a mixture of 1 mmol (1.31 g) L-valine methyl ester and 10 mmol (2.14 mL), (-)menthyl acetate stirring under argon was added 0.1 mL of a 0.2 M solution of **1** or 0.25 mL 0.2 M MOtBu in THF. The reaction was stirred under reduced pressure and refilled with argon prior to taking each aliquot and quenching in brine. Conversion to diastereomeric products was monitored by gas chromatography using an HP-5 column (110℃ for 2 min; ramp to 175℃ at 50℃/min. and hold for 5 min).