

Supplementary material ("Ruthenium- and Enzyme-Catalyzed Dynamic Kinetic Resolution of Secondary Alcohols" B. Anders Persson, Anna L. E. Larsson, Mikael Le Ray, Jan-E. Bäckvall*)

General. ^1H and ^{13}C NMR spectra were recorded on a Varian Unity-400 (400 MHz ^1H , 100 MHz ^{13}C) spectrometer in deuteriochloroform (CDCl_3), with either tetramethylsilane (TMS) (0.00 ppm ^1H , 0.00 ppm ^{13}C) or chloroform (7.26 ppm ^1H , 77.0 ppm ^{13}C) as an internal reference unless otherwise stated. Data are reported in the following order: chemical shifts in ppm (δ); multiplicities are indicated (br (broadened), s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet)); coupling constants, J , are reported in Hz and integration is provided. Analytical thin-layer chromatography was performed on Merck silica gel plates with F-254 indicator. Visualization was accomplished by UV light, phosphomolybdic acid or *p*-anisaldehyde solution. Flash column chromatography was performed by the use of 230-400 mesh silica gel (Woelm). Analytical high pressure liquid chromatography (HPLC) was performed on a Waters Liquid Chromatograph. Columns: Daicel, Chiralcel[®] OD-H. Solvents for HPLC use were spectrometric grade. Flow parameters were isocratic at the stated conditions: method (hexane/ $^i\text{PrOH}$, 95/5, 0.5 mL/min).

Derivatization of 14, 22 and 26 with 2-Chlorobenzoic Acid for Determination of ee. The following procedure is representative. To a magnetically stirred solution of 1-(1-naphthyl)-ethanol **14** (0.174 g, 1.0 mmol), DCC (0.227 g, 1.1 mmol) and DMAP (2.5 mg, 0.02 mmol) in CH_2Cl_2 (5 mL) was added 2-chlorobenzoic acid (0.172 g, 1.1 mmol) and the reaction was stirred at room temperature until judged complete by TLC. The mixture was filtered through a short plug of celite (Et_2O) and the organic phase was washed with 1.2 M HCl, 2M NaOH and subsequently dried over Na_2SO_4 . After evaporation of the solvents the residue was chromatographed (pentane/ Et_2O 9 : 1) to give the ester in quantitative yield.

Indanyl Acetate (7). Following the general procedure indanol (**6**) was converted to **7** in a mixture with 4-chlorophenyl acetate after chromatography (pentane/ Et_2O 98 : 2). Calculated yield from the mixture: 77%. The mixture was hydrolyzed following the general procedure and the ee was determined by HPLC analysis (hexane/ $^i\text{PrOH}$ 95 : 5; retention times 16.9, 18.7 min); ee >99%.

1,2,3,4-Tetrahydro-1-naphthyl Acetate (9). Following the general procedure 1,2,3,4-tetrahydro-1-naphthol (**8**) was converted to **9** in a mixture with 4-chlorophenyl acetate after

chromatography (pentane/Et₂O 98 : 2). Selective hydrolysis of 4-chlorophenyl acetate following the general procedure gave **9** in 65% overall yield after chromatography (pentane/Et₂O 9 : 1). The mixture was hydrolyzed following the general procedure and the ee was determined by HPLC analysis (hexane/¹PrOH 95 : 5; retention times 20.5, 22.1 min); ee >99%.

1-(4-Bromophenyl)ethyl Acetate (11). Following the general procedure 1-(4-bromophenyl)-ethanol (**10**) was converted to **11** in a mixture with 4-chlorophenyl acetate after chromatography (pentane/Et₂O 98 : 2). Calculated yield from the mixture: 78%. ¹H NMR δ : 7.47 (d, *J* = 8.4 Hz, 2H), 7.21 (d, *J* = 8.4 Hz, 2H), 5.82 (q, *J* = 6.6 Hz, 1H), 2.07 (s, 3H), 1.51 (d, *J* = 6.6 Hz, 3H). ¹³C NMR δ : 170.2, 140.7, 131.6, 127.8, 121.7, 71.6, 22.1, 21.3. The mixture was hydrolyzed following the general procedure and the ee was determined by HPLC analysis (hexane/¹PrOH 95 : 5; retention times 16.1, 17.3 min); ee >99%.

1-(4-Methoxyphenyl)ethyl Acetate (13). Following the general procedure 1-(4-methoxyphenyl)-ethanol (**12**) was converted to **13** in a mixture with 4-chlorophenyl acetate after chromatography (pentane/Et₂O 98 : 2). Calculated yield from the mixture: 60%. The mixture was hydrolyzed following the general procedure and the ee was determined by HPLC analysis (hexane/¹PrOH 95 : 5; retention times 20.4, 21.7 min); ee 91%.

1-(1-Naphthyl)ethyl Acetate (15). Following the general procedure 1-(1-naphthyl)-ethanol (**14**) was converted to **15** in 69% yield after chromatography (pentane/Et₂O 98 : 2). Hydrolysis and derivatization for ee determination with 2-chlorobenzoic acid following the general procedures gave **2-chlorobenzoic acid 1-naphthylethyl ester** ¹H NMR δ : 8.19 (1H, d, *J* = 8.3 Hz, ArH), 7.91-7.81 (3H, m, ArH), 7.73 (1H, dm, *J* = 7.2 Hz, ArH), 7.60-7.38 (5H, m, ArH), 7.30 (1H, m, ArH), 6.94 (1H, q, *J* = 6.6 Hz, CHO), 1.87 (3H, d, *J* = 6.6 Hz, CH₃). ¹³C NMR δ : 165.0, 137.0, 133.8, 133.7, 132.5, 131.4, 131.1, 130.4, 130.2, 128.9, 128.6, 126.6, 126.4, 125.7, 125.4, 123.5, 123.1, 77.2, 71.0, 21.8. The ee was determined by HPLC analysis (hexane/¹PrOH 95 : 5; retention times 13.2, 14.2 min); ee 99%.

1-(2-Naphthyl)ethyl Acetate (17). Following the general procedure 1-(2-naphthyl)-ethanol (**16**) was converted to **17** in 79% yield after chromatography (pentane/Et₂O 98 : 2). The

acetate was hydrolyzed following the general procedure and the ee was determined by HPLC analysis (hexane/ⁱPrOH 95 : 5; retention times 29.3, 31.0 min); ee >99%.

1-Phenyl-1-propyl Acetate (19). Following the general procedure 1-phenyl-1-propanol (18) was converted to **19** in a mixture with 4-chlorophenyl acetate after chromatography (pentane/Et₂O 98 : 2). Calculated yield from the mixture: 80%. The mixture was hydrolyzed following the general procedure and the ee was determined by HPLC analysis (hexane/ⁱPrOH 95 : 5; retention times 14.7, 16.2 min); ee 98%.

1-Phenoxy-2-propyl Acetate (21). Following the general procedure 1-phenoxy-2-propanol (20) was converted to **21** in 88% yield after chromatography (pentane/Et₂O 95 : 5). The acetate was hydrolyzed following the general procedure and the ee was determined by HPLC analysis (hexane/ⁱPrOH 93 : 7; retention times 17.9, 36.8 min); ee >99%.

1-Cyclohexylethyl Acetate (23). Following the general procedure with the exception that half the amount of solvent was used, 1-cyclohexyl-ethanol (22) was converted to **23** in a mixture with 4-chlorophenyl acetate after chromatography (pentane/Et₂O 98 : 2). Calculated yield from the mixture: 79%. ¹H NMR δ : 4.73 (quint, *J* = 6.3 Hz, 1H), 2.04 (s, 3H), 1.79-1.63 (m, 6H), 1.44 (m, 1H), 1.30-1.10 (m, 2H), 1.17 (d, *J* = 6.3 Hz, 3H), 1.00 (m, 2H). ¹³C NMR δ : 74.6, 42.5, 28.49, 28.47, 26.4, 26.02, 25.97, 21.3, 17.1. Hydrolysis and derivatization with 2-chlorobenzoic acid following the general procedures gave **2-chlorobenzoic acid 1-cyclohexylethyl ester** ¹H NMR δ : 7.79 (1H, dd, *J* = 7.8, 1.7 Hz, ArH), 7.46-7.37 (2H, m, ArH), 7.31 (1H, ddd, *J* = 7.5, 7.5, 1.6 Hz, ArH), 5.03 (1H, quint, *J* = 6.3 Hz, CHO), 1.88-1.54 (6H, m) 1.31 (3H, d, *J* = 6.3 Hz, CH₃), 1.30-1.02 (8H, m). ¹³C NMR δ : 165.5, 133.4, 132.1, 131.1, 130.9, 126.5, 76.3, 42.6, 28.6, 28.5, 26.4, 26.1, 26.0, 17.0. The ee was determined by HPLC analysis (hexane/ⁱPrOH 98 : 2; retention times 31.7, 33.5 min); ee >99%.

2-Octyl Acetate (25). Following the general procedure, with the exception that half the amount of solvent was used, 2-octanol (24) was converted to **25** in 80% yield after chromatography (pentane/Et₂O 97 : 3). The acetate was hydrolyzed following the general procedure and the ee was determined by GC analysis; ee >97%. (Complete base-line separation was not obtained).

2,5-Diacetoxyhexane (27). Following the general procedure 2,5-hexanediol (**26**) was converted to **27** (*R,R/meso* 86 : 14) in 63% yield after chromatography (pentane/Et₂O 95 : 5). ¹H NMR (mixture of *R,R/meso*) δ : 4.89 (m, 2H), 2.03 (s, 6H), 1.68-1.41 (m, 4H), 1.21 (d, *J* = 6.2 Hz, 6H). ¹³C NMR (mixture of *R,R/meso*) δ : 70.7 (70.5), 31.8 (31.7), 21.4, 19.9. Hydrolysis and derivatization with 2-chlorobenzoic acid following the general procedures gave **hexane-2,5-diyl bis(2-chlorobenzoate)** ¹H NMR δ : 7.77 (2H, dm, *J* = 7.8 Hz, ArH), 7.46-7.37 (4H, m, ArH), 7.30 (2H, ddd, *J* = 7.8, 7.1, 1.6 Hz, ArH), 5.23 (2H, m, CHO), 1.96-1.70 (4H, m, CH₂), 1.39 (6H, d, *J* = 6.3 Hz, CH₃) ¹³C NMR δ : 165.5, 133.4, 132.3, 131.1, 131.0, 130.9, 126.5, 77.2, 72.3, 72.1, 31.9, 31.7, 19.9. The ee was determined by HPLC analysis (hexane/¹PrOH 96 : 4); *R,R/meso* 86 : 14; ee >99%.

1-Chloro-3-phenoxy-2-propyl Acetate (29). Following the general procedure with the exception that half the amount of solvent and enzyme was used and double the amount of ruthenium catalyst **2**, 1-Chloro-3-phenoxy-2-propanol (**28**) was converted to **29** in 67% yield after chromatography (pentane/Et₂O 98 : 2). The ee was determined on the acetate by HPLC analysis (hexane/¹PrOH 90 : 10; retention times 15.4, 16.7 min); ee 79%.