Acyl Palladium Species in Synthesis: Single Step Synthesis of α,β-Unsaturated Ketones from Acid Chlorides

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Supplementary data

Starting materials and solvents were obtained from commercial suppliers and used without further purification unless otherwise stated. All reactions were performed in oven dried apparatus under an atmosphere of nitrogen at room temperature unless otherwise stated. Dry solvents used were obtained by filtration through drying agents and water used was previously distilled. TLC was carried out on glass plates coated with 0.2 mm silica gel 60 and visualised under ultraviolet light (254 nm) and by potassium permanganate staining and developed by heat gun. Flash chromatography was carried out using Merck silica gel (0.035 – 0.070 mm) according to the method of Still.[1] All yields reported are of purified, isolated material. ^{1}H and ^{13}C NMR spectra were obtained using a JEOL delta/GX400 spectrometer operating at 400 MHz and 100 MHz respectively or a JEOL delta/GX270 spectrometer operating at 270 MHz and 80 MHz respectively. The spectra were obtained at 298K and samples run as a dilute solution of $CDCl_3$ unless otherwise stated. All NMR spectra were referenced to tetramethylsilane (TMS δH 0, δC 0). All coupling constants are reported in hertz (Hz), and multiplicities are labelled s (singlet), d (doublet), t (triplet), q (quartet), m (multiplet) or combinations thereof. IR spectra were obtained using a Perkin Elmer FTIR spectrometer as neat liquids or as solids. High resolution mass spectra were obtained on a VG Analytical Autospec instrument. Elemental analyses were carried out in the microanalytical laboratories of the University of Bristol.

General procedure for the synthesis of enones. Unless otherwise stated the reactions were performed using the following conditions. Under an inert atmosphere (N_2), at 50 °C and shielded from light, Schwartz reagent (1.12 mmol) was added in one portion to a stirring solution of the acetylene (1.1 mmol) in anhydrous toluene (5 ml). The reaction was stirred for 1 h, after which time the white precipitate had dissolved, with colour changes ranging from yellow to black frequently observed. The reaction was cooled to room temperature and the acyl chloride (1.0 mmol) and $Pd(PPh_3)_2Cl_2$ (5 mol%) added. The reaction was stirred for a further 3 h, after which time a precipitate was frequently, though not always, observed. Completion of reaction was checked by monitoring the disappearance of acyl chloride by ^{1}H-NMR or TLC. The mixture was then purified by column chromatography (loaded directly in toluene and eluted with a 1 - 10% ethyl acetate / 40-60 °C petroleum ether solution).

_E_-1-(4-Nitrophenyl)-3-phenylprop-2-en-1-one 3.[2]

98:2 petrol-EtOAc used as solvent for chromatography (9:1 petrol-EtOAc, R_F 0.31) which gave the product (198 mg, 0.78 mmol, 78.3%) as a bright yellow solid, m.p. 145 – 146 °C (EtOH; lit[2] 149 – 150 °C). δH (400 MHz; $CDCl_3$) 8.37-8.32 (2H, m, 2 × *p*-NO_2ArC*H*), 8.16-8.12 (2H, m, 2 × *p*-NO_2ArC*H*), 7.85 (1H, d, *J* = 15.6 Hz, =C*H*), 7.68-7.64 (2H, m), 7.50-7.43 (4H, m); δC (100 MHz; $CDCl_3$) 189.0 (*C*O), 150.1, 146.8, 143.1, 134.4, 131.3, 129.5, 129.2, 128.8, 123.9, 121.4; νmax (neat)/cm^{-1} 3052 (CH), 1693 (C=O), 1661 (C=C), 1515 (NO_2); HRMS CI calcd. $[MH]^+$ 254.0817, found 254.0815; anal. calcd. for $C_{15}H_{11}NO_3$: C 71.14, H 4.38, N 5.53; found: C 70.87, H 4.35, N 5.77.

_E_-1-phenyl-3-phenylprop-2-en-1-one 6.[3]

Benzoyl chloride was distilled prior to reaction. 98:2 petrol-EtOAc used as solvent for chromatography (9:1 petrol-EtOAc, R_F 0.26) which gave the product (165 mg, 0.79 mmol, 79.3%) as a yellow solid, m.p. 54 – 55 °C (EtOH; lit[3] 56 – 57 °C). δH (270 MHz; $CDCl_3$) 8.06-8.01 (2H, m), 7.81 (1H, d, *J* = 15.5 Hz), 7.67-7.61 (2H, m), 7.60-7.46 (4H, m), 7.45-7.39 (3H, m); δC (100 MHz; $CDCl_3$) 190.6 (*C*O), 144.9, 138.3, 135.0, 132.9, 130.6, 129.1, 128.7, 128.6, 128.5, 122.2; νmax (neat)/cm^{-1} 3059 (CH), 3026 (CH), 1660 (C=O), 1599 (C=C).

_E_-1-(4-Bromophenyl)-3-phenylprop-2-en-1-one 7.[4,5]

98:2 petrol-EtOAc used as solvent for chromatography (9:1 petrol-EtOAc, R_F 0.33) which gave the product (217 mg, 0.75 mmol, 75.4%) as an off white solid, m.p. 101 – 102 °C (EtOH; lit[5] 101 – 104 °C). δH (400 MHz; $CDCl_3$) 7.86 (2H, d, *J* = 8.3Hz), 7.81 (1H, d, *J* = 15.6Hz, =C*H*), 7.66-7.62 (4H, m), 7.47 (1H, d, *J* = 15.6Hz, =C*H*), 7.44-7.41 (3H, m); δC (100 MHz; $CDCl_3$) 189.3 (*C*O), 145.4, 137.0, 134.8, 132.0, 130.8, 130.1, 129.1, 128.6, 128.0, 121.5; νmax (neat)/cm^{-1} 3057 (CH), 1656 (C=O), 1600 (C=C).

_E_-1-(4-Methoxyphenyl)-3-phenylprop-2-en-1-one 8.[6,7]

98:2 petrol-EtOAc used as solvent for chromatography (9:1 petrol-EtOAc, R_F 0.17) which gave the product (173 mg, 0.73 mmol, 72.5%; 9:1 E:Z) as a pale yellow solid, m.p. 107 – 108 °C (EtOH; lit[7] 107 °C). δH (400 MHz; $CDCl_3$) 8.05 (2H, d, *J* = 8.8Hz), 7.81 (1H, d, *J* = 15.3Hz, =CH), 7.67-7.63 (2H, m), 7.56 (1H, d, *J* = 15.1Hz, =C*H*), 7.44-7.40 (3H, m), 6.99 (2H, d, *J* = 8.8Hz), 3.90 (3H, s, OCH_3); δC (100 MHz; $CDCl_3$) 188.5 (*C*O), 163.3, 143.7, 134.9, 130.9, 130.7, 130.2, 128.8, 128.2, 121.7, 113.7, 55.3 (OCH_3); νmax (neat)/cm^{-1} 3055 (aromatic CH), 2935 (alkenyl CH), 2842 (methyl CH), 1652 (C=O), 1596 (C=C).

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***E*-1-Cyclohexyl-3-phenylprop-2-en-1-one 9.**[8,9]

98:2 petrol-EtOAc used as solvent for chromatography (9:1 petrol-EtOAc, R_F 0.42) which gave the product (194 mg, 0.91 mmol, 90.5%) as a yellow solid, m.p. 56 – 56.5 °C (EtOH; lit[9] 56 °C). δH (400 MHz; $CDCl_3$) 7.59 (1H, d, *J* = 15.6Hz, =C*H*), 7.57-7.55 (2H, m), 7.41-7.37 (3H, m), 6.82 (1H, d, *J* = 15.6Hz, =C*H*), 2.70-2.62 (1H, m, $(CH_2)_2$C*H*), 1.94-1.80 (4H, m), 1.74-1.68 (1H, m), 1.49-1.19 (5H, m); δC (100 MHz; $CDCl_3$) 202.7 (*C*O), 142.0, 134.6, 130.1, 128.7, 128.1, 124.5, 49.2, 28.5, 25.8, 25.6; νmax (neat)/cm^{-1} 3061 (aromatic CH), 2929 (alkenyl CH), 2850 (cyclohexyl CH), 1682 (CO), 1607 (C=C).

***E*-4,4-Dimethyl-1-phenylpent-1-en-3-one 10.**

The second stage of the reaction was allowed to stir at room temperature for 24 hr. 98:2 petrol-EtOAc used as solvent for chromatography (9:1 petrol-EtOAc, R_F 0.42) which gave the product (169 mg, 0.90 mmol, 89.9%) as a yellow oil. δH (400 MHz; $CDCl_3$) 7.68 (1H, d, *J* = 15.6 Hz, β-*H*), 7.59-7.55 (2H, m), 7.41-7.35 (3H, m), 7.13 (1H, d, *J* = 15.6 Hz, α-*H*), 1.24 (9H, s, 3 × C*H*$_3$); δC (100 MHz; $CDCl_3$) 204.0 (*C*O), 142.9, 135.2, 130.2, 128.9 (2 × Ar*C*), 128.3 (2 × Ar*C*), 120.9, 43.3 (*C*Me$_3$), 26.4 (3 × *C*H$_3$); νmax (neat)/cm^{-1} 2962, 2874, 1689 (CO), 1665, 1611 (C=C).

***E*-1-Phenylhex-1-en-3-one 11.**

98:2 petrol-EtOAc used as solvent for chromatography (9:1 petrol-EtOAc, R_F 0.16) which gave the product (184 mg, 0.91 mmol, 90.5%) as a pale yellow liquid. δH (400 MHz; $CDCl_3$) 7.55 (1H, d, *J* = 16.1 Hz), 7.57-7.54 (2H, m), 7.41-7.38 (3H, m), 6.75 (1H, d, *J* = 16.1 Hz), 2.65 (2H, t, *J* = 7.3 Hz, C*H*$_2$CH$_2$CH$_3$), 1.72 (2H, sextet, *J* = 7.3Hz, CH$_2$C*H*$_2$CH$_3$), 0.98 (3H, t, *J* = 7.3 Hz, CH$_2$CH$_2$C*H*$_3$); δC (100 MHz; $CDCl_3$) 200.4 (*C*O), 142.2, 134.6, 130.3, 128.9, 128.2, 126.3, 42.8, 17.8, 13.8; νmax (neat)/cm^{-1} 2962, 2874, 1689 (CO), 1665, 1611 (C=C).

***E*-4-Phenylbut-3-en-2-one 12.**

98:2 petrol-EtOAc used as solvent for chromatography (9:1 petrol-EtOAc, R_F 0.16) which gave the product (67 mg, 0.67 mmol, 66.9%) as a yellow oil. δH (400 MHz; $CDCl_3$) 7.49-7.46 (2H, m), 7.45 (1H, d, *J* = 16.1 Hz, β-*H*), 7.34-7.32 (3H, m), 6.75 (1H, d, *J* = 16.1 Hz, α-*H*), 2.32 (3H, s, C*H*$_3$); δC (100 MHz; $CDCl_3$) 198.0 (*C*O), 143.3, 134.6, 130.5, 129.0 (2 × Ar*C*), 128.3 (2 × Ar*C*), 127.3, 27.5 (*C*H$_3$); νmax (neat)/cm^{-1} 2924, 2251, 1668 (CO), 1609 (C=C).

***E*-1-(4-Nitrophenyl)hept-2-en-1-one 13.**

98:2 petrol-EtOAc used as solvent for chromatography (9:1 petrol-EtOAc, R_F 0.29) which gave the product (207 mg, 0.89 mmol, 89%) as a yellow oil. δH (400 MHz; $CDCl_3$) 8.33-8.23 (2H, m, 2 × *p*-NO$_2$Ar*H*), 8.07-7.94 (2H, m, 2 × *p*-NO$_2$Ar*H*), 7.10 (1H, dt, *J* = 15.2, 6.9 Hz, β-*H*), 6.82 (1H, dt, *J* = 15.2, 1.3 Hz, α-*H*), 2.3 (2H, dq, *J* = 6.9, 1.3 Hz, C*H*$_2$CH$_2$CH$_2$CH$_3$), 1.58-1.30 (4H, m, CH$_2$C*H*$_2$C*H*$_2$CH$_3$), 0.9 (3H, t, *J* = 7.9 Hz, C*H*$_3$); δC (100 MHz; $CDCl_3$) 189.3 (*C*O), 152.4, 152.3, 150.1, 143.0 (2 × *p*-NO$_2$Ar*C*), 129.4, 125.7 (2 × *p*-NO$_2$Ar*C*), 123.7, 32.7, 32.6 (*C*H$_2$CH$_2$CH$_2$CH$_3$), 30.2 (CH$_2$*C*H$_2$CH$_2$CH$_3$), 22.3 (CH$_2$CH$_2$*C*H$_2$CH$_3$), 13.7 (*C*H$_3$); νmax (neat)/cm^{-1} 2958 (CH), 2930 (CH), 2861 (CH), 1672 (C=O), 1619, 1601 (C=C), 1521 (NO_2); HRMS CI calcd. $[MH]^+$ 234.1130, found 234.1129.

***E*-3-Cyclohexyl-1-(4-nitrophenyl)prop-2-en-1-one 14.**[10]

98:2 petrol-EtOAc used as solvent for chromatography (9:1 petrol-EtOAc, R_F 0.41) which gave the product (183 mg, 0.71 mmol, 71%) obtained as a yellow solid, m.p. 66 – 68 °C (EtOH). δH (400 MHz; $CDCl_3$) 8.33-8.27 (2H, m, 2 × *p*-NO$_2$Ar*H*), 8.05-7.99 (2H, m, 2 × *p*-NO$_2$Ar*H*), 7.04 (1H, dd, *J* = 15.5, 7.3 Hz, β-*H*), 6.77 (1H, dd, *J* = 15.5, 1.3 Hz, α-*H*), 2.3-2.2 (1H, m, CH=CHC*H*), 1.89-1.64 (5H, m, 5 × cyclohexyl-*H*), 1.43-1.11 (5H, m, 5 × cyclohexyl-*H*); δC (100 MHz; $CDCl_3$) 189.8 (*C*O), 157.2, 150.0, 143.1, 129.5 (2 × *p*-NO$_2$Ar*C*), 123.8 (2 × *p*-NO$_2$Ar*C*), 123.1, 41.2, 31.8, 25.9, 25.7; νmax (neat)/cm^{-1} 2927 (CH), 2851 (CH), 1661 (C=O), 1600 (C=C), 1523 (NO_2); HRMS EI calcd. $[M]^+$ 259.1208, found 259.1206; anal. calcd. for $C_{15}H_{17}NO_3$: C 69.48, H 6.61, N 5.40; found: C 69.51, H 6.73, N 5.66.

***E*-4,4-Dimethyl-1-(4-nitrophenyl)pent-2-en-1-one 15.**

$Pd(PPh_3)_2Cl_2$ (15 mol%) used. 98:2 petrol-EtOAc used as solvent for chromatography (9:1 petrol-EtOAc, R_F 0.35) which gave the product (148 mg, 0.63 mmol, 63%) as a yellow solid, m.p. 78 °C (EtOH). δH (270 MHz; $CDCl_3$) 8.34-8.28 (2H, m, 2 × *p*-NO$_2$Ar*H*), 8.05-8.00 (2H, m, 2 × *p*-NO$_2$Ar*H*), 7.09 (1H, d, *J* = 15.6 Hz, β-*H*), 6.72 (1H, d, *J* = 15.6 Hz, α-*H*), 1.16 (9H, s, ^{t}Bu); δC (100 MHz; $CDCl_3$) 189.9 (*C*O), 161.8, 150.1, 143.2, 129.4 (2 × *p*-NO$_2$Ar*C*), 123.7 (2 × *p*-NO$_2$Ar*C*), 120.8, 34.4 (*C*Me$_3$) 28.6 (3 × *C*H$_3$); νmax (neat)/cm^{-1} 2965 (CH), 2870 (CH), 1666 (C=O), 1599 (C=C) 1519 (NO_2); HRMS CI calcd. $[MH]^+$ 234.1130, found 234.1123; anal. calcd. for $C_{13}H_{15}NO_3$: C 66.94, H 6.48, N 6.00; found: C 67.29, H 6.49, N 6.14.

***E*-3-(Trimethylsilyl)-1-(4-nitrophenyl)prop-2-en-1-one 16.**

98:2 petrol-EtOAc used as solvent for chromatography (9:1 petrol-EtOAc, R_F 0.47) which gave the product (107 mg, 0.43 mmol, 43%) as a yellow solid, m.p. 80 °C (EtOH). δH (270 MHz; $CDCl_3$) 8.36-8.31 (2H, m, 2 × *p*-NO$_2$Ar*H*), 8.08-8.03 (2H, m, 2 × *p*-NO$_2$Ar*H*), 7.34 (1H, d, *J* = 18.1 Hz, β-*H*), 7.18 (1H, d, *J* = 18.1 Hz, α-*H*), 0.21 (9H, s, SiMe$_3$); δC (100 MHz; $CDCl_3$) 189.2 (*C*O), 152.5, 150.2, 142.5, 137.6, 129.7 (2 × *p*-NO$_2$Ar*C*), 123.8 (2 × *p*-NO$_2$Ar*C*), 1.8 (3 × *C*H$_3$); νmax (neat)/cm^{-1} 3122 (CH), 2955 (CH), 1660 (C=O), 1602 (C=C), 1523 (NO_2); HRMS CI calcd. $[MH]^+$ 250.0899, found 250.0892; anal. calcd. for $C_{12}H_{15}NO_3Si$: C 57.80, H 6.06, N 5.62; found: C 57.69, H 6.27, N 5.68.

***E*-1-(4-Nitrophenyl)-4-phenylbut-2-en-1-one 17.**

98:2 petrol-EtOAc used as solvent for chromatography (9:1 petrol-EtOAc, R_F 0.25) which gave the product (211 mg, 0.88 mmol, 88%) as a yellow solid, m.p. 98 – 100 °C (EtOH). δH (400 MHz; $CDCl_3$) 8.36-8.24 (2H, m, 2 × *p*-NO$_2$Ar*H*), 8.05-7.96 (2H, m, 2 × *p*-NO$_2$Ar*H*), 7.39-7.17 (6H, m, 5 × Ar*H* + β-*H*), 6.80 (1H, dt, *J* = 15.5, 1.7 Hz, α-*H*), 3.66 (2H, dd, *J* = 6.6, 1.7 Hz, C*H*$_2$); δC (100 MHz; $CDCl_3$) 189.3 (*C*O), 150.1 (1 × Ar*C*), 142.7 (quaternary Ar*C*), 137.3 (quaternary Ar*C*), 129.5 (2 × *p*-NO$_2$Ar*C*), 128.9 (4 × Ar*C*), 127.0 (alkene-*C*H), 126.4 (alkene-*C*H), 123.8 (2 × *p*-NO$_2$Ar*C*), 39.2 (*C*H$_2$); νmax (neat)/cm^{-1} 3027 (CH), 2909 (CH), 1667 (C=O), 1619 (C=C), 1515 (NO_2); HRMS EI calcd. $[M]^+$ 267.0895, found 267.0893; anal. calcd. for $C_{16}H_{13}NO_3$: C 71.90, H 4.90, N 5.24; found: C 72.18, H 4.96, N 5.27.

E-4-(Benzyloxy)-1-(4-nitrophenyl)but-2-en-1-one 18.

90:10 petrol-EtOAc used as solvent for chromatography (9:1 petrol-EtOAc, R_F 0.14) which gave the product (194 mg, 0.65 mmol, 65%) as a yellow oil. δH (400 MHz; $CDCl_3$) 8.33-8.29 (2H, m, 2 × *p*-NO_2Ar*H*), 8.09-8.05 (2H, m, 2 × *p*-NO_2Ar*H*), 7.41-7.30 (5H, m, 5 × Ar*H*), 7.21 (1H, dt, *J* = 15.3, 1.5 Hz, β-*H*), 7.13 (1H, dt, *J* = 15.3, 3.4 Hz, α-*H*), 4.64 (2H, s, benzyl CH_2), 4.31 (2H, dd, *J* = 3.4, 1.9 Hz, C=C-CH_2); δC (100 MHz; $CDCl_3$) 188.9 (*C*O), 150.2, 146.9, 142.5, 137.7, 129.6, 128.7, 128.1, 127.8, 127.0, 124.2, 123.9, 73.2, 69.1; νmax (neat)/cm^{-1} 3031 (CH), 2860 (CH), 1674 (C=O), 1626, 1602 (C=C), 1523 (NO_2); HRMS CI calcd. $[MH]^+$ 298.1079, found 298.1079.

E-4-(4-Nitrophenyl)-4-oxobut-2-enyl acetate 19.

90:10 petrol-EtOAc used as solvent for chromatography (9:1 petrol-EtOAc, R_F 0.39) which gave the product (68 mg, 0.27 mmol, 27%) as an orange solid, m.p. 96 – 98 °C (EtOH). δH (270 MHz; $CDCl_3$) 8.37-8.30 (2H, m, 2 × *p*-NO_2Ar*H*), 8.11-8.05 (2H, m, 2 × *p*-NO_2Ar*H*), 7.09-7.06 (2H, m, 2 × alkene C*H*), 4.89 (2H, d, *J* = 2.6 Hz, CH_2), 2.18 (3H, s, CH_3); δC (100 MHz; $CDCl_3$) 188.6 (Ar*C*O), 170.4 (*C*O), 143.5, 142.2, 129.6 (2 × *p*-NO_2Ar*C*), 125.3, 124.0 (2 × *p*-NO_2Ar*C*), 63.0, 20.8; νmax (neat)/cm^{-1} 3112 (CH), 3075 (CH), 3049 (CH), 2932 (CH), 1737 (ester C=O), 1671 (enone C=O), 1626, 1601 (C=C), 1518 (NO_2); anal. calcd. for $C_{12}H_{11}NO_3$: C 57.83, H 4.45, N 5.62; found: C 58.08, H 4.45, N 5.28.

E-2-Ethyl-1-(4-nitrophenyl)pent-2-en-1-one 22.

98:2 petrol-EtOAc used as solvent for chromatography (9:1 petrol-EtOAc, R_F 0.38) which gave the product (144 mg, 0.73 mmol, 73%) as a yellow solid, m.p. 32 – 34 °C (EtOH). δH (400 MHz; $CDCl_3$) 8.28-8.25 (2H, m, 2 × *p*-NO_2Ar*H*), 7.75-7.71 (2H, m, 2 × *p*-NO_2Ar*H*), 6.18 (1H, t, *J* = 7.3 Hz, β-*H*), 2.49 (2H, q, *J* = 7.3Hz, αCCH_2), 2.33 (2H, quintet, *J* = 7.3Hz, βCCH_2), 1.06 (6H, q, *J* = 7.3Hz, 2 × CH_3); δC (100 MHz; $CDCl_3$) 196.9 (*C*O), 149.8, 145.0, 142.2, 129.9 (2 × *p*-NO_2Ar*C*), 123.4 (2 × *p*-NO_2Ar*C*), 22.4 (*C*H_2), 19.7 (*C*H_2), 13.7 (*C*H_3), 13.4 (*C*H_3); νmax (neat)/cm^{-1} 3102 (CH), 3074 (CH), 2968 (CH), 2936 (CH), 2875 (CH), 1649 (C=O), 1625, 1600 (C=C), 1529, 1516 (NO_2); HRMS CI calcd. $[MH]^+$ 234.1130, found 234.1131; anal. calcd. for $C_{13}H_{15}NO_3$: C 66.94, H 6.48, N 6.00; found: C 67.04, H 6.14, N 6.15.

E-2-Methyl-1-(4-nitrophenyl)hex-2-en-1-one 23.

Standard reaction conditions plus second stage of reaction heated with stirring for 20 hr. 98:2 petrol-EtOAc used as solvent for chromatography (9:1 petrol-EtOAc, R_F 0.43) which gave the product (207 mg, 0.88 mmol, 88%) as a yellow oil. δH (400 MHz; $CDCl_3$) 8.27-8.22 (2H, m, 2 × *p*-NO_2Ar*H*), 7.74-7.69 (2H, m, 2 × *p*-NO_2Ar*H*), 6.28 (1H, tq, *J* = 7.3, 1.3Hz, β-*H*), 2.28 (2H, qd, *J* = 7.32 and 1.3Hz, C$H_2$$CH_2CH_3$), 1.96 (3H, d, *J* = 1.2Hz, α-CH_3), 1.46 (2H, sextet, *J* = 7.32Hz, CH_2C$H_2$$CH_3$), 0.92 (3H, t, *J* = 7.3Hz, CH_2CH_2CH_3); δC (100 MHz; $CDCl_3$) 196.8 (*C*O), 149.2, 144.6, 136.7, 129.7 (2 × *p*-NO_2Ar*C*), 123.2 (2 × *p*-NO_2Ar*C*), 31.2 (*C*H_2), 21.7 (*C*H_2), 13.8 (*C*H_3), 11.9 (*C*H_3); νmax (neat)/cm^{-1} 3107 (CH), 2960 (CH), 2930 (CH), 2872 (CH), 1651 (C=O), 1601 (C=C), 1521 (NO_2); HRMS EI calcd. $[M]^+$ 233.1052, found 233.1047; anal. calcd. for $C_{13}H_{15}NO_3$: C 66.94, H 6.48, N 6.00; found: C 66.79, H 6.77, N 5.68.

E-2-Methyl-1-(4-nitrophenyl)-3-phenylprop-2-en-1-one 24.

98:2 petrol-EtOAc used as solvent for chromatography (9:1 petrol-EtOAc, R_F 0.43) which gave the product (47.1 mg, 0.16 mmol, 16%) as a brown oil. δH (270 MHz; $CDCl_3$) 8.35-8.28 (2H, m, 2 × *p*-NO_2Ar*H*), 7.88-7.82 (2H, m, 2 × *p*-NO_2Ar*H*), 7.49-7.36 (5H, m, Ar*H*), 7.16-7.14 (1H, m, β-*H*), 2.29 (3H, d, *J* = 1.3 Hz); δC (100 MHz; $CDCl_3$) 197.5 (*C*O), 149.4, 144.6, 144.5, 136.6, 135.2, 130.1, 130.0, 129.4, 128.7, 123.6, 14.1 (*C*H_3); νmax (neat)/cm^{-1} 3056, 2925, 1647 (CO), 1600 (C=C), 1520 (NO_2); CI calcd. $[MH]^+$ 268.0974, found 268.0964.

(3*S*,4*R*)-5-Benzyloxy-3,4-dihydroxy-pentan-2-one 25.[12]

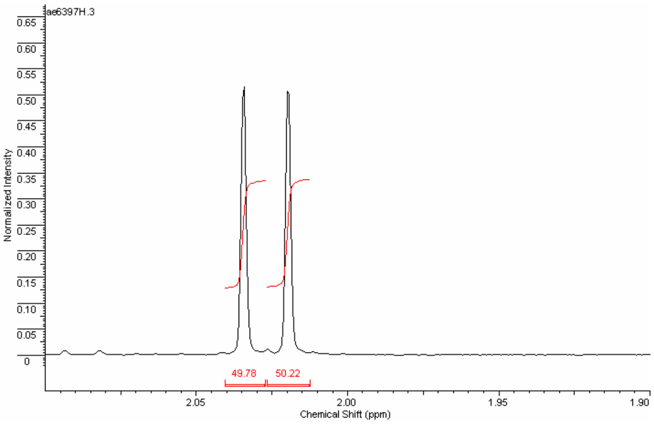
The procedure of Cox *et al* was modified.[11] $(DHQD)_2$PHAL (1.35 g) was dissolved in stirring anh. DCM (20 mL) under an inert atmosphere (N_2) at room temperature. To this was added dropwise a solution of OsO_4 (211 mg) in anh. Et_2O (10 mL) at room temperature. The reaction mixture was cooled to -19 °C and to it was added dropwise a solution of enone **27** (156.8 mg) in anh. DCM (15 mL), washing with anh. DCM (10 mL). The reaction mixture was warmed to room temperature over 3 hr, at which point TLC confirmed no starting material present. The solvent was removed *in vacuo* to give a black oil which was then re-dissolved in MeOH (40 ml). The solution was acidified (37% $HCl_{(aq)}$, 38 drops) until pH 2. Stirred for 20 hr. The solvent was reduced *in vacuo* and the resulting oil purified by flash chromatography. 60:40 petrol-EtOAc used as solvent for chromatography (9:1 petrol-EtOAc, R_F 0.19) which gave the product (110 mg, 0.49 mmol, 59%, 93% e.e.) as a yellow oil. δH (400 MHz; $CDCl_3$) 7.41-7.30 (5H, m, Ar*H*), 4.59 (2H, s, CH_2Ph), 4.26 (1H, dd, *J* = 4.4 and 2.0Hz, α-*H*), 4.22-4.18 (1H, m, β-*H*), 3.69 (1H, d, *J* = 4.4Hz, α-O*H*), 3.65 (1H, d, J = 5.9Hz, γ-CH_2), 2.29 (3H, s, CH_3), 2.27 (1H, d, β-O*H*); δC (100 MHz; $CDCl_3$) 208.1 (*C*O), 137.7, 128.4, 127.9, 127.8, 77.2, 73.6, 71.1, 70.4, 25.6 (*C*H_3); HRMS CI calcd. $[MH]^+$ 225.1127, found 225.1124.

E-5-(Benzyloxy)pent-3-en-2-one 27.[12]

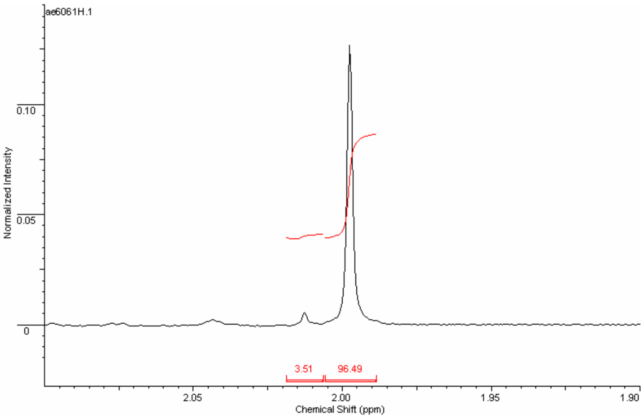
The reaction was scaled up from standard conditions by 5 times. 90:10 petrol-EtOAc used as solvent for chromatography (9:1 petrol-EtOAc, R_F 0.14) which gave the product (655 mg, 3.45 mmol, 72%) as a yellow oil. δH (400 MHz; $CDCl_3$) 7.43-7.30 (5H, m, Ar*H*), 6.82 (1H, dt, *J* = 16.7 and 4.3Hz, β-*H*), 6.37 (1H, dt, *J* = 16.7 and 2.0Hz, α-*H*), 4.58 (2H, s, CH_2Ph), 4.22 (2H, dd, *J* = 4.3 and 2.0Hz, βCCH_2), 2.28 (3H, s, CH_3); δC (100 MHz; $CDCl_3$) 198.0 (*C*O), 148.9, 137.8, 130.5, 128.6, 127.9, 127.7, 73.1 (*C*H_2), 68.9 (*C*H_2), 27.3 (*C*H_3); νmax (neat)/cm^{-1} 3031 (CH), 2920 (CH), 2854 (CH), 1674 (C=O), 1633 (C=C).

Measurement of Enantiomeric Purity of (3*S*,4*R*)-5-Benzyloxy-3,4-dihydroxy-pentan-2-one 25.

The enantiomeric excess of the diol **25** was determined by ^{1}H NMR at 500 MHz in the presence of the chiral additive (1*R*)-1-(9-anthryl)-2,2,2-trifluoroethanol. Diol **25** (3 mg) and the chiral additive (120 mg) were dissolved in $CDCl_3$ (0.85 ml) and examined by ^{1}H NMR.



^{1}H NMR of the methyl region of racemic **25** in the presence of (1*R*)-1-(9-anthryl)-2,2,2-trifluoroethanol.



^{1}H NMR of the methyl region of enantio-enriched **25** in the presence of (1*R*)-1-(9-anthryl)-2,2,2-trifluoroethanol. *N.b.* absolute δ values of **25** vary with the concentration of (1*R*)-1-(9-anthryl)-2,2,2-trifluoroethanol.

Notes and references

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