

**CATALYTIC ASYMMETRIC C-H ACTIVATION OF ALKANES AND
TETRAHYDROFURAN**

Huw M. L. Davies,* Tore Hansen and Melvyn Rowen Churchill

Department of Chemistry, State University of New York at Buffalo,

Buffalo, New York 14260-3000

Supporting Information

Complete experimental data, X-ray data for **11** and **20** and NMR data for **3k**, **4b-k**, **8**, **9**,
10h, **10k**, **11**, **13**, **14**, **17a**, **17b**, **18a**, **18b**, **19a**, **19b**, **20**, **21a** and **21b**.

Experimental

General: ^1H NMR spectra were run at 300, 400 or 500 MHz and ^{13}C NMR at 75 or 125 MHz with the sample solvent being CDCl_3 unless otherwise noted. Mass spectral determinations were carried out at 70 eV. THF, diethyl ether and hexanes were dried over and distilled from sodium metal with benzophenone as indicator. Methylene chloride and acetonitrile were dried over and distilled from calcium hydride. Cyclopentane and cycloheptane were dried over molecular sieves (4A), pentane was dried over sodium and anhydrous cyclohexane was used as received. Commercially available reagents were used as received unless noted. Column chromatography was carried out on silica gel 60 (230-400) mesh. Enantiomeric excess was determined by either ^1H -NMR using chiral shift reagents, HPLC using chiral analytical columns or GC using chiral analytical columns. Reactions were carried out under an atmosphere of argon. Sub 0 °C temperatures were maintained by the use of dry ice/acetone or an immersion cooler. Degassing was carried out by bubbling Ar gas through the solution for 10–15 minutes prior to the reaction.

General procedure for synthesis of aryldiazoacetates: Methyl arylacetate (1 eq, 5-100 mmol) and *p*-ABSA¹ (1.2 eq) were dissolved in CH_3CN and cooled to 0 °C under an Ar atmosphere. DBU (1.2 eq) was added in one portion to the stirred mixture, the ice bath was removed and the mixture was stirred for 2-4 h under Ar. The reaction was quenched with saturated NH_4Cl and the water layer was extracted with diethyl ether (3x). The combined organic layers were dried (MgSO_4) and the solvent was removed under reduced pressure. The residue was triturated with 50% diethyl ether/petroleum ether, the

solid was filtered off and the solvent was removed under reduced pressure. The residue was purified by flash chromatography on silica gel (2% diethyl ether/petroleum diethyl ether).

Methyl phenyldiazoacetate (3a).² 70% yield.

Methyl 4-bromophenyldiazoacetate (3b). (52% yield) ¹H NMR (300 MHz) δ 7.50 (d, 2H, *J* = 9 Hz), 7.37 (d, 2H, *J* = 9 Hz), 3.88 (s, 3H); ¹³C NMR (125 MHz, CDCl₃) δ 165.1, 131.9, 125.2, 124.6, 119.2, 52.0 (C=N₂ signal missing); IR (neat) 3096, 2951, 2093, 1697, 1435, 1277, 1246 cm⁻¹; Anal. Calcd for C₉H₇BrN₂O₂: C, 42.38; H, 2.77. Found: C, 42.46; H, 2.77.

Methyl 4-chlorophenyldiazoacetate (3c). 70% yield; ¹H NMR (400 MHz, CDCl₃) δ 7.41 (d, 2H, *J* = 6.6 Hz), 7.34 (d, 2H, *J* = 6.6 Hz), 3.85 (s, 3H); ¹³C NMR (75 MHz, CDCl₃) δ 165.3, 131.5, 129.0, 125.0, 124.1, 52.0 (C=N₂ signal missing); IR (neat) 3101, 2955, 2094, 1700, 1500, 1436, 1249, 1281, 818 cm⁻¹; Anal. Calcd for C₉H₇N₂O₂Cl: C, 51.32; H, 3.35. Found: C, 51.23; H, 3.37.

Methyl 4-methoxyphenyldiazoacetate (3d). 40% yield; ¹H-NMR (300 MHz, CDCl₃) δ 7.38 (d, 2H, *J* = 9.2 Hz), 6.95 (d, 2H, *J* = 9.2 Hz), 3.85 (s, 3H), 3.81 (s, 3H); ¹³C-NMR (75 MHz, CDCl₃) δ 166.1, 158.0, 125.9, 116.8, 114.5, 55.3, 51.8 (C=N₂ signal missing); IR (neat) 3001, 2955, 2084, 1708, 1514, 1260, 1159, 1030, 829 cm⁻¹; Anal. Calcd for C₁₀H₁₀N₂O₃: C, 58.25; H, 4.89. Found: C, 58.26; H, 4.89.

Methyl 2-chlorophenyldiazoacetate (3e). 70% yield; ¹H-NMR (300 MHz) δ 7.57 (m, 1H), 7.45 (m, 1H), 7.32 (m, 2H) 3.87 (s, 3H); ¹³C-NMR (125 MHz, CDCl₃) δ 165.9, 133.7, 132.2, 130.0, 129.6, 127.0, 123.8, 52.2 (C=N₂ signal missing); IR (neat) 2958,

2103, 1712, 1441, 1290, 1242, 1164, 1031, 754 cm^{-1} ; Anal. Calcd for $\text{C}_9\text{H}_7\text{ClN}_2\text{O}_2$: C, 51.32; H, 3.35. Found: C, 51.60; H, 3.38.

Methyl 3-chlorophenyldiazoacetate (3f). 52% yield; ^1H -NMR (300 MHz) δ 7.71 (m, 1H), 7.56 (m, 1H), 7.32 (m, 2H), 7.17 (m, 1H), 3.90 (s, 3H); ^{13}C -NMR (125 MHz, CDCl_3) δ 164.9, 134.9, 130.0, 127.6, 125.7, 123.6, 121.5, 52.1 ($\text{C}=\text{N}_2$ signal missing); IR (neat) 2953, 2097, 1709, 1597, 1482, 1248, 1160 cm^{-1} ; Anal. Calcd for $\text{C}_9\text{H}_7\text{ClN}_2\text{O}_2$: C, 51.32; H, 3.35. Found: C, 51.60; H, 3.36.

Methyl 4-(trifluoromethyl)phenyldiazoacetate (3g). 57% yield; ^1H -NMR (300 MHz) δ 7.61 (s, 4H), 3.88 (s, 3H); ^{13}C -NMR (75 MHz, CDCl_3) δ 164.8, 130.0, 125.8, 125.8, 123.4, 52.1 ($\text{C}=\text{N}_2$ and CF_3 signals missing); IR (neat) 2964, 2109, 1687, 1443, 1337, 1246, 1114, 1074 cm^{-1} ; Anal. Calcd for $\text{C}_{10}\text{H}_7\text{F}_3\text{N}_2\text{O}_2$: C, 49.19; H, 2.89. Found: C, 49.46; H, 2.95.

Methyl 4-methylphenyldiazoacetate (3h). 66% yield; ^1H -NMR (300 MHz) δ 7.34 (d, 2H, $J = 8.4$ Hz), 7.18 (d, 1H, $J = 8.4$ Hz), 3.84 (s, 3H), 2.32 (s, 3H); ^{13}C -NMR (125 MHz, CDCl_3) δ 165.8, 135.7, 129.7, 124.0, 122.0, 51.9, 20.9 ($\text{C}=\text{N}_2$ signal missing); IR (neat) 3030, 2953, 2085, 1709, 1519, 1436, 1346, 1250, 1158, 1052 cm^{-1} ; Anal. Calcd for $\text{C}_{10}\text{H}_{10}\text{N}_2\text{O}_2$: C, 63.15; H, 5.30. Found: C, 62.90; H, 5.38.

Methyl 2-bromophenylacetate (3i). 67% yield; ^1H -NMR (400 MHz, CDCl_3) δ 7.62 (m, 1H), 7.51 (m, 1H), 7.37 (m, 1H), 7.23 (m, 1H), 3.91 (s, 3H); ^{13}C -NMR (75 MHz, CDCl_3) δ 165.4, 133.3, 132.9, 130.1, 127.7, 125.7, 124.4, 52.2 ($\text{C}=\text{N}_2$ signal missing); IR (neat) 2958, 2103, 1706, 1477, 1435, 1248, 1158, 1068, 760 cm^{-1} ; Anal. Calcd for $\text{C}_9\text{H}_7\text{BrN}_2\text{O}_2$: C, 42.38; H, 2.77. Found: C, 42.66; H, 2.85.

Methyl 3-Bromophenyldiazoacetate (3j). 55% yield; $^1\text{H-NMR}$ (300 MHz) δ 7.71 (m, 1H), 7.41 (m, 1H), 7.31 (m, 1H), 7.26 (m, 1H), 3.90 (s, 3H); $^{13}\text{C-NMR}$ (125 MHz, CDCl_3) δ 164.9, 130.2, 128.7, 127.9, 126.4, 123.1, 122.0, 52.1 ($\text{C}=\text{N}_2$ signal missing); IR (neat) 2952, 2095, 1709, 1593, 1480, 1248, 1156 cm^{-1} ; Anal. Calcd for $\text{C}_9\text{H}_7\text{BrN}_2\text{O}_2$: C, 42.38; H, 2.77. Found: C, 42.51; H, 2.80.

Methyl 2-naphthyldiazoacetate (3k). 84% yield; $^1\text{H-NMR}$ (400 MHz, CDCl_3) δ 8.01 (d, 1H, $J = 1.5$ Hz), 7.82 (m, 3H), 7.49 (m, 3H), 3.91 (s, 3H); $^{13}\text{C-NMR}$ (75 MHz, CDCl_3) δ 165.7, 133.6, 131.5, 128.7, 127.6, 126.6, 125.7, 122.6, 122.5, 121.8, 52.0 ($\text{C}=\text{N}_2$ signal missing); IR (neat) 3051, 3003, 2958, 2108, 1700, 1253 816 cm^{-1} ; HRMS calcd. for $\text{C}_{13}\text{H}_{10}\text{N}_2\text{O}_2$: 226.0747; Found: 226.0742.

Methylethyl phenyldiazoacetate (6). 47% yield; $^1\text{H-NMR}$ (300 MHz) δ 7.49 (m, 2H), 7.38 (m, 2H), 7.17 (m, 1H), 5.21 (h, 1H, $J = 6.2$ Hz), 1.27 (d, 6H, $J = 6.2$ Hz); $^{13}\text{C-NMR}$ (125 MHz, CDCl_3) δ 164.7, 128.8, 125.7, 125.6, 123.9, 68.6, 22.0 ($\text{C}=\text{N}_2$ signal missing); IR (neat) 2981, 2087, 1702, 1598, 1503, 1482, 1254, 1171, 1107, 1012, 759 cm^{-1} ; Anal. Calcd for $\text{C}_{11}\text{H}_{12}\text{N}_2\text{O}_2$: C, 64.69; H, 5.92. Found: C, 64.42; H, 5.83.

Dimethylethyl phenyldiazoacetate (7). 34% yield; $^1\text{H-NMR}$ (300 MHz) δ 7.46 (m, 2H), 7.37 (m, 2H), 7.17 (m, 1H), 1.55 (s, 9H); $^{13}\text{C-NMR}$ (125 MHz, CDCl_3) δ 164.6, 128.8, 126.1, 125.5, 123.9, 28.3 ($\text{C}=\text{N}_2$ signal missing); IR (neat) 2977, 2082, 1700, 1492, 1249, 1147 cm^{-1} ; LRMS m/z ($\text{M}+1$) 319.

General procedure for the decomposition of 3 in the presence of cycloalkanes. A degassed solution of methyl phenyldiazoacetate (1 mmol) in anhydrous cycloalkane (10 mL) was added dropwise over 90 min to a stirring, degassed solution of $\text{Rh}_2(\text{S-DOSP})_4^{15}$ (0.01 mmol) in anhydrous cycloalkane (5 mL) at 10 $^\circ\text{C}$. The solution was stirred at 10 $^\circ\text{C}$

for another 15 min after the addition was over and then warmed to ambient temperature. The solvent was removed under reduced pressure and the residue purified by flash chromatography on silica gel (2% diethyl ether/petroleum ether).

Methyl (*R*)- α -cyclohexylphenylacetate (4a).³ 80% yield, 95% ee (Chiralcel-OD, 1.0 mL/min, 0.6% *i*-propanol/hexane, t_R = 8.6 and 10.4 min, UV 254 nm), $[\alpha]_D^{23}$ = -36.6° (*c* 1.8, CHCl₃). CD λ (nm) and θ (deg mol⁻¹ cm²): $[\theta]_{210}$ -11000, $[\theta]_{220}$ -10000, $[\theta]_{230}$ -5000 $[\theta]_{240}$ -1000. The reaction at 81 °C gave **4a** in 83% yield and 81% ee.

Methyl (*R*)- α -cyclohexyl-4-bromophenylacetate (4b). 64% yield, 95% ee (Whelk-O, 0.5 mL/min., 5.0% *i*-propanol/hexane, t_R = 12.6 and 15.1 min, UV 254 nm); $[\alpha]_D^{25}$ = -20.2° (*c* = 2.55, CHCl₃); ¹H-NMR (500 MHz, CDCl₃) δ 7.43 (d, 2H, *J* = 8.4 Hz), 7.20 (d, 2H, *J* = 8.4 Hz), 3.64 (s, 3H), 3.18 (d, 1H, *J* = 10.6 Hz), 1.95 (m, 1H), 1.74 (m, 2H), 1.61 (m, 2H), 1.31 (m, 2H), 1.16 (m, 3H), 0.72 (m, 1H); ¹³C-NMR (75 MHz, CDCl₃) δ 174.0, 136.9, 131.6, 130.3, 121.1, 58.1, 51.8, 41.1, 31.8, 30.3, 26.2, 25.9, 25.8; IR (neat) 2927, 2851, 1739, 1488, 1160, 1012 cm⁻¹; GC/MS *m/z* (relative intensity) 310 (1), 228 (100); HRMS calcd for C₁₅H₁₉BrO₂: 310.0568. Found: 310.0580.

Methyl (*R*)- α -cyclohexyl-4-chlorophenylacetate (4c).³ 77% yield, 94% ee (¹H-NMR using Eu tris[3-(heptafluoropropylhydroxymethylene)-(+)-camphorate, $[\alpha]_D^{25}$ = -25.8° (*c* 2.35, CHCl₃). The reaction at 81 °C gave **4c** in 91% yield and 86% ee.

Methyl (*R*)- α -cyclohexyl-4-methoxyphenylacetate (4d).³ 3 mole % of Rh₂(*S*-DOSP)₄; 23% yield; 88% ee (Chiralcel-OD, 1.0 mL/min., 1.0% *i*-propanol/hexane, t_R = 6.6 and 7.6 min, UV 254 nm. The reaction at 81 °C with 1 mole % of Rh₂(*S*-DOSP)₄ gave **4d** in 85% yield and 69% ee.

Methyl (*R*)- α -cyclohexyl-2-chlorophenylacetate (4e). 81% yield, 90% ee (Whelk-O, 1.0 mL/min., 5.0% *i*-propanol/hexane, t_R = 7.1 and 8.6 min, UV 254 nm); $[\alpha]_D^{25} = -38.4^\circ$ ($c = 3.47$, CHCl_3); ^1H NMR (500 MHz, CDCl_3) δ 7.59 (dd, 1H, $J = 7.9, 1.5$ Hz), 7.38 (d, 1H, $J = 7.9$ Hz), 7.27 (t, 1H, $J = 7.3$ Hz), 7.18 (dt, 1H, $J = 7.3, 1.5$ Hz), 4.05 (d, 1H, $J = 10.7$ Hz), 3.67 (s, 3H), 2.04 (m, 1H), 1.86 (m, 1H), 1.77 (m, 1H), 1.65 (m, 2H), 1.32 (m, 2H), 1.15 (m, 3H), 0.93 (m, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 173.8, 135.7, 134.7, 129.4, 129.0, 128.0, 127.0, 52.9, 51.8, 41.7, 31.8, 29.6, 26.2, 26.0, 25.97; IR (neat) 2928, 2852, 1737, 1163 cm^{-1} ; GC/MS m/z (relative intensity) 266 (1), 184 (100); LRMS m/z ($M+1$) 267; HRMS calcd for $\text{C}_{15}\text{H}_{19}\text{ClO}_2$ 266.1073. Found 266.1087.

Methyl (*R*)- α -cyclohexyl-3-chlorophenylacetate (4f). 47% yield; $[\alpha]_D^{25} = -31.2^\circ$ ($c = 0.53$, CHCl_3); ^1H NMR (500 MHz, CDCl_3) δ 7.32 (s, 1H), 7.21 (m, 3H), 3.64 (s, 3H), 3.18 (d, 1H, $J = 10.6$ Hz), 1.96 (m, 1H), 1.74 (m, 2H), 1.61 (m, 2H), 1.28 (m, 2H), 1.14 (m, 2H), 1.04 (m, 1H), 0.71 (m, 1H); ^{13}C NMR (CDCl_3) δ 173.8, 139.9, 134.3, 129.6, 128.6, 127.4, 126.8, 58.4, 51.8, 41.1, 31.8, 30.4, 26.2, 25.9, 25.8; IR (neat) 2930, 2853, 1738, 1159; GC/MS m/z (relative intensity) 266 (2), 184 (100); HRMS calcd for $\text{C}_{15}\text{H}_{19}\text{Cl}_2$: 266.1073. Found: 266.1088. A small sample of **4f** was taken out and reduced to the alcohol with LiAlH_4 in diethyl ether. The reaction was quenched with water, and the water layer was extracted with diethyl ether. The combined organic layers were dried (MgSO_4) and the solvent was removed under reduced pressure. The residue was purified by flash chromatography on silica gel (10% diethyl ether/petroleum ether) and subjected to HPLC analysis: 90% ee, (Chiralcel-OD, 1.0 mL/min., 1.0% *i*-propanol/hexane, t_R = 25.0 and 29.1 min, UV 254 nm), ^1H -NMR (500 MHz, CDCl_3) δ 7.26 (m, 3H), 7.06 (d,

1H, $J = 7.2$ Hz), 3.93 (m, 1H), 3.73 (m, 1H), 2.54 (m, 1H), 1.85 (m, 1H), 1.73 (m, 1H), 1.57 (m, 3H), 1.39 (m, 1H), 1.20 (m, 1H), 1.10 (m, 2H), 1.00 (m, 1H), 0.78 (m, 1H).

Methyl (R)- α -cyclohexyl-4-(trifluoromethyl)phenylacetate (4g). 78% yield; 94% ee (Whelk-O, 0.7 mL/min, 1.0% *i*-propanol /hexane, $t_R = 8.7$ and 10.7 min, UV 254 nm). The reaction at 81 °C gave **4g** in 67% yield and 85% ee; $^1\text{H-NMR}$ (300 MHz, CDCl_3) δ 7.56 (d, 2H, $J = 8.1$), 7.45 (d, 2H, $J = 8.1$ Hz), 3.65 (s, 3H), 3.30 (d, 1H, $J = 10.5$ Hz), 2.01 (m, 1H), 1.81-1.55 (m, 4H), 1.33-1.03 (m, 5H), 0.78 (m, 1H); IR (neat) 2934, 2856, 1333, 1165, 1128, 1074; GC/MS m/z (relative intensity) 300 (0.1), 218 (100); HRMS calcd for $\text{C}_{16}\text{H}_{19}\text{F}_3\text{O}_2$: 300.1337. Found: 300.1351.

Methyl (R)- α -cyclohexyl-4-methylphenylacetate (4h). 63% yield, 93% ee (Chiralcel-OD, 0.7 mL/min., 0.4% *i*-propanol/hexane, $t_R = 8.6$ and 10.0 min, UV 254 nm), $[\alpha]_D^{23} = -36.2$ ($c = 1.42$, CHCl_3). The reaction at 81 °C gave **4h** in 90% yield and 77% ee; $^1\text{H-NMR}$ (500 MHz, CDCl_3) δ 7.23 (d, 2H, $J = 7.9$ Hz), 7.13 (d, 2H, $J = 7.9$ Hz), 3.65 (s, 3H), 3.21 (d, 1H, $J = 10.4$ Hz), 2.34 (s, 3H), 2.01 (m, 1H), 1.76 (m, 2H), 1.63 (m, 2H), 1.32 (m, 2H), 1.16 (m, 2H), 1.06 (m, 1H), 0.76 (m, 1H); $^{13}\text{C-NMR}$ (75 MHz, CDCl_3) δ 174.6, 136.8, 134.8, 129.1, 128.4, 58.3, 51.6, 40.9, 32.0, 30.4, 26.3, 25.9, 21.0; IR (neat) 2926, 2852, 1737, 1513, 1157 cm^{-1} ; GC/MS m/z (relative intensity) 246 (9), 164 (100); HRMS calcd for $\text{C}_{16}\text{H}_{22}\text{O}_2$: 246.1619. Found: 246.1627.

Methyl (R)- α -cyclohexyl-2-bromophenylacetate (4i). 72% yield, 90% ee (Whelk-O, 1.0 mL/min., 5.0% *i*-propanol/hexane, $t_R = 7.3$ and 9.3 min, UV 254 nm), $[\alpha]_D^{25} = -28.5$ ($c = 2.66$, CHCl_3); $^1\text{H-NMR}$ (500 MHz, CDCl_3) δ 7.58 (m, 2H), 7.30, (m, 1H), 7.12 (m, 1H), 4.05 (d, 1H, $J = 10.7$ Hz), 3.68 (s, 3H), 2.04 (m, 1H), 1.86 (m, 1H), 1.77 (m, 1H), 1.65 (m, 2H), 1.32 (m, 2H), 1.15 (m, 3H), 0.93 (m, 1H); $^{13}\text{C-NMR}$ (75 MHz, CDCl_3) δ

173.8, 137.5, 132.8, 129.1, 128.4, 127.7, 125.7, 55.7, 51.8, 42.0, 31.8, 29.6, 26.2, 26.1, 26.0; IR (neat) 2927, 2851, 1737, 1161 cm^{-1} ; GC/MS m/z (relative intensity) 310 (0.1), 228 (100); HRMS calcd for $\text{C}_{15}\text{H}_{19}\text{BrO}_2$: 310.0568. Found: 310.0569.

Methyl (*R*)- α -cyclohexyl-3-bromophenylacetate (4j). 62% yield, $[\alpha]_{\text{D}}^{23} = -28.2^\circ$ ($c = 0.305$, CHCl_3); $^1\text{H-NMR}$ (500 MHz, CDCl_3) δ 7.48 (s, 1H), 7.38 (m, 1H), 7.25 (m, 1H), 7.17 (m, 1H), 3.65 (s, 3H), 3.18 (d, 1H, $J = 10.6$ Hz), 1.96 (m, 1H), 1.74 (m, 2H), 1.61 (m, 2H), 1.28 (m, 2H), 1.14 (m, 2H), 1.04 (m, 1H), 0.71 (m, 1H); $^{13}\text{C-NMR}$ δ 173.8, 140.2, 131.5, 130.4, 130.0, 127.3, 122.5, 58.4, 51.8, 41.1, 31.8, 30.4, 26.2, 25.9, 25.8; IR (neat) 2928, 2851, 1736, 1159 cm^{-1} ; GC/MS m/z (relative intensity) 310 (3), 228 (100); HRMS calcd for $\text{C}_{15}\text{H}_{19}\text{BrO}_2$: 310.0568. Found: 310.0579. A small sample of **4j** was taken out and reduced to the alcohol with LiAlH_4 in diethyl ether. The reaction was quenched with water, and the water layer extracted with diethyl ether. The combined organic layers were dried (MgSO_4) and the solvent removed under reduced pressure. The residue was purified by flash chromatography on silica gel (10% diethyl ether/petroleum ether) and subjected to HPLC analysis: 90% ee (Whelk-O, 1.0 mL/min., 1.0% *i*-propanol/hexane, $t_{\text{R}} = 17.3$ and 19.8 min, UV 254 nm); $^1\text{H-NMR}$ (500 MHz, CDCl_3) δ 7.26 (m, 3H), 7.06 (d, 1H, $J = 7.2$ Hz), 3.93 (m, 1H), 3.73 (m, 1H), 2.54 (m, 1H), 1.85 (m, 1H), 1.73 (m, 1H), 1.57 (m, 3H), 1.39 (m, 1H), 1.20 (m, 1H), 1.10 (m, 2H), 1.00 (m, 1H), 0.78 (m, 1H).

Methyl (*R*)- α -cyclopentylphenylacetate (5a).³ 72% yield, 96% ee (Chiralcel-OD, 1.0 mL/min, 0.6% *i*-propanol/hexane, $t_{\text{R}} = 9.2$ and 10.8 min, UV 254 nm); $[\alpha]_{\text{D}}^{25} = -53.4^\circ$ ($c = 2.65$, CHCl_3). CD $\lambda(\text{nm})$ and $\theta(\text{deg mol}^{-1} \text{cm}^2)$: $[\theta]_{210} -13000$, $[\theta]_{220} -18000$, $[\theta]_{230} -9000$, $[\theta]_{240} -1000$. The reaction at 50 $^\circ\text{C}$ gave **5a** in 84% yield and 87% ee.

Methyl (*R*)- α -cyclopentyl-4-chlorophenylacetate (5c**).**³ 70% yield, 95% ee (Whelk-O, 2% IPA/hexane, 1 mL/min, t_R = 8.1 and 10.5 min. The reaction at 50 °C gave **5c** in 78% yield and 89% ee; $[\alpha]^{23}_D$ = -49.2° (c 0.650, CHCl_3).

***i*-Propyl (*R*)- α -cyclohexylphenylacetate (**8**).** Reaction run at 24 °C, 39% yield, 86% ee (Chiralcel-OD, 0.7 mL/min., 5.0% *i*-propanol/hexane, t_R = 7.1 and 7.8 min, UV 254 nm), $[\alpha]^{23}_D$ = -6.0 (c = 1.15, CHCl_3); $^1\text{H-NMR}$ (500 MHz, CDCl_3) δ 7.28 (m, 5H), 4.96 (h, 1H, J = 6.2 Hz), 3.64 (s, 3H), 3.16 (d, 1H, J = 10.6 Hz), 2.34 (s, 3H), 1.99 (m, 1H), 1.72 (m, 2H), 1.61 (m, 2H), 1.28 (m, 2H), 1.16 (m, 3H), 1.22 (d, 3H, J = 6.2 Hz), 1.13 (d, 3H, J = 6.2 Hz), 0.72 (m, 1H); $^{13}\text{C-NMR}$ (75 MHz, CDCl_3) δ 173.4, 138.1, 128.6, 128.3, 127.0, 67.7, 59.1, 41.1, 31.8, 30.5, 26.3, 26.0, 25.9, 21.8, 21.6; IR (neat) 2928, 2852, 1729, 1165, 1109 cm^{-1} ; GC/MS m/z (relative intensity) 246 (5), 164 (100); LRMS (FAB) ($M+1$) 261; HRMS calcd for $\text{C}_{11}\text{H}_{14}\text{O}_2$ ($M - \text{C}_6\text{H}_{10}$) 178.0994 .Found 178.1002.

***t*-Butyl (*R*)- α -cyclohexylphenylacetate (**9**).** Reaction run at 24 °C, 45% yield; $[\alpha]^{23}_D$ = 2.9 (c = 1.15, CHCl_3); $^1\text{H-NMR}$ (500 MHz, CDCl_3) δ 7.30 (m, 5H), 3.09 (d, 1H, J = 10.3 Hz), 1.93 (m, 1H), 1.87 (m, 1H), 1.73 (m, 1H), 1.57 (m, 2H), 1.39 (s, 9H), 1.28 (m, 2H), 1.12 (m, 2H), 0.86 (m, 1H), 0.72 (m, 1H); $^{13}\text{C-NMR}$ (125 MHz, CDCl_3) δ 173.2, 138.5, 128.5, 128.2, 126.8, 80.4, 59.9, 41.0, 31.8, 30.4, 28.0, 26.3, 26.0, 26.0; IR (neat) 2928, 2852, 1725, 1165, 1147 cm^{-1} ; GC/MS m/z (relative intensity) 260 (1), 178 (63), 136 (100); LRMS (FAB) ($M+1$) - (C_4H_8) 219. A small sample of **9** was taken out and reduced to the alcohol with LiAlH_4 in diethyl ether. The reaction was quenched with water and the water layer was extracted with diethyl ether. The combined ether layers were dried (MgSO_4) and the solvent removed under reduced pressure. The residue was purified by flash chromatography (5% diethyl ether/petroleum ether) and then was

subjected to chiral HPLC analysis: 20% ee (Chiralcel-OD, 1.0 mL/min., 1.0% *i*-propanol/hexane, t_R = 23.2 and 25.0 min, UV 254 nm); $^1\text{H-NMR}$ (500 MHz, CDCl_3) 7.26 (m, 5H), 3.93 (dd, 1H, J = 11.0, 5.0 Hz), 3.86 (dd, 1H, J = 11.0, 9.0 Hz), 2.56 (m, 1H) 1.88 (m, 1H), 1.74 (m, 1H), 1.59 (m, 3H), 1.39 (m, 1H), 1.23 (m, 1H), 1.10 (m, 3H), 0.81 (m, 1H).

Methyl (*R*)- α -cyclohexylphenylacetic acid. To a stirring solution of **3a** (176 mg, 0.76 mmol) and TMSCl (216 mg, 2.0 mmol) in CH_3CN was added NaI (300 mg, 2.0 mmol), and the mixture heated to reflux for 36 h and then cooled to ambient temperature. Diethyl ether was added (50 mL) and the resulting solution washed with water (25 mL), aqueous sodium thiosulphate solution (25 mL) and aqueous sodium bicarbonate solution (2x 25 mL). The combined bicarbonate layers were acidified (10% HCl) and a white solid precipitated out of solution. The solid was filtered off and dried in vacuo to give methyl (*R*)- α -cyclohexylphenylacetic acid as a white solid, $[\alpha]^{24}_D = -26.5^\circ$ (c 0.2, CHCl_3) (lit. $[\alpha]^{25}_D = -38.8^\circ$, c = 20 CDCl_3).⁴

General procedure for kinetic isotope studies. A solution of methyl aryldiazoacetate (0.49 mmol) in cyclohexane (1.0 mL, 9.2 mmol) and cyclohexane d_{12} (1.0 mL, 9.2 mmol) was added dropwise to a stirring, refluxing solution of $\text{Rh}_2(\text{S-DOSP})_4$ (10 mg, 0.005 mmol) in cyclohexane (1.0 mL, 9.2 mmol) and cyclohexane d_{12} (1.0 mL, 9.2 mmol). The resulting solution was stirred at reflux for another 10 min and then cooled to ambient temperature. The solvent was removed under reduced pressure and the residue was purified by flash chromatography (2% diethyl ether/petroleum ether) K_H/K_D were determined by $^1\text{H NMR}$ and GC/MS.

General procedure for the reaction of 3 with tetrahydrofuran. A degassed solution of **3** (1.04 mmol) in hexanes (10 mL) was added dropwise over 60 min to a degassed, stirred

solution of $\text{Rh}_2(\text{S-DOSP})_4$ (20 mg, 0.01 mmol) and THF (144 mg, 2.0 mmol) in hexanes (5 mL) at $-50\text{ }^\circ\text{C}$. The resulting solution was stirred for 10 h at $-50\text{ }^\circ\text{C}$ and then warmed slowly to ambient temperature. The solvent was removed *in vacuo*, and the residue was purified by flash chromatography on silica gel (20% diethyl ether/petroleum ether).

Methyl ($\alpha\text{S},2\text{R}$)-phenyl(tetrahydrofuran-2-yl)acetate (10a).³ 67% yield; 4/1 diastereomeric ratio, 97% ee, (2R , αS) (GC, β -TA (20m x .25mm), $110\text{ }^\circ\text{C}$, t_{R} = 38.6 and 40.3 min), $[\alpha]_{\text{D}}^{25} = -74.0^\circ$ (c 0.2, CHCl_3).

Methyl ($\alpha\text{S},2\text{R}$)-(4-chlorophenyl)-(tetrahydrofuran-2-yl)acetate (10c).³ 60% yield, 4/1 diastereomeric ratio, 97% ee, (2R , αS) (GC, β -TA (20m x .25mm), $135\text{ }^\circ\text{C}$, t_{R} = 36.5 and 37.6 min).

Methyl ($\alpha\text{S},2\text{R}$)-(4-methoxyphenyl)-(tetrahydrofuran-2-yl)acetate (10d).³ 56% yield, 3.4/1 diastereomeric ratio, 96% ee, (2R , αS) (GC, β -TA (20m x .25mm), $120\text{ }^\circ\text{C}$, t_{R} = 115 and 120 min).

Methyl ($\alpha\text{S},2\text{R}$)-(4-methylphenyl)-(tetrahydrofuran-2-yl)acetate (10h). 74% yield, 4/1 diastereomeric ratio; major diastereomer **10h**: 98% ee 2R , αS (GC, β -TA (20m x .25mm), $110\text{ }^\circ\text{C}$, t_{R} = 76.3 and 81.0 min); $[\alpha]_{\text{D}}^{25} = -70.0^\circ$ (c 1.7, CHCl_3 , 2R , αS), ^1H -NMR (300 MHz, CDCl_3) (2R , αS) δ 7.27 (d, 2H, J = 8.0 Hz), 7.14 (d, 2H, J = 8.0 Hz), 4.42 (q, 1H, J = 7.0 Hz), 3.80 (m, 1H), 3.70 (m, 1H), 3.68 (s, 3H), 3.59 (d, 1H, J = 8.4 Hz), 2.32 (s, 3H), 2.11 (m, 1H), 1.87 (m, 2H), 1.65 (m, 1H); ^{13}C -NMR (75 MHz, CDCl_3) δ 172.6 (C), 137.0 (C), 133.5 (C), 129.2 (CH), 128.3 (CH), 79.9 (CH), 68.1 (CH_2), 56.3 (CH), 51.8 (CH_3), 30.0 (CH_2), 25.5 (CH_2), 21.0 (CH_3); IR (neat) 2951, 2872, 1738, 1514, 1435, 1165, 1072, 817, 750 cm^{-1} ; GC/MS m/z (relative intensity) 234 (0.5), 164 (57), 71 (100); HRMS calcd $\text{C}_{14}\text{H}_{18}\text{O}_3$ 234.1263, found 234.1255. minor diastereomer: ^1H -NMR

(300 MHz, CDCl_3) (2*S*, α *S*) δ 7.23 (d, 2H, J = 8.0 Hz), 7.15 (d, 2H, J = 8.0 Hz), 4.50 (m, 1H), 3.86 (m, 1H), 3.84 (m, 1H), 3.68 (s, 3H), 3.49 (d, 1H, J = 9.9 Hz), 2.32 (s, 3H), 1.86 (m, 1H), 1.77 – 1.66 (m, 2H), 1.41 (m, 1H); ^{13}C -NMR (75 MHz, CDCl_3) δ 173.5, 129.4, 128.9, 128.6, 128.2, 79.8, 68.4, 57.0, 51.8, 29.4, 25.4, 21.0.

Methyl (α *S*,2*R*)-(2-naphthyl)-(tetrahydrofuran-2-yl)acetate (10k). 62% yield, 1.6/1 diastomeric ratio. major diastereomer **10k**: 95% ee 2*R*, α *S* (Chiralcel-OD, 1.0 mL/min, 2.0% *i*-propanol/hexane, t_R = 11.8 and 13.2 min, UV 254 nm); $[\alpha]_D^{25}$ = -87.0° (*c* 1.71, CHCl_3 , 2*R*, α *S*), ^1H -NMR (300 MHz, CDCl_3) (2*R*, α *S*) δ 7.80 (m, 4H), 7.52 (dd, 1H, J = 8.5, 1.5 Hz), 7.43 (m, 2H), 4.56 (q, 1H, J = 7.3 Hz), 3.79 (m, 2H), 3.70 (q, 1H, J = 7.0 Hz), 3.66 (s, 3H), 2.14 (m, 1H), 1.87 (m, 2H), 1.69 (m, 1H); ^{13}C -NMR (75 MHz, CDCl_3) δ 172.5 (C), 134.0 (C), 133.3 (C), 132.7 (C), 128.1 (CH), 127.8 (CH), 127.7 (CH), 127.5 (CH), 126.4 (CH), 126.0 (CH), 125.8 (CH), 79.9 (CH), 68.3 (CH₂), 56.7 (CH), 52.0 (CH₃), 30.0 (CH₂), 25.5 (CH₂); IR (neat) 3060, 2951, 2872, 1738, 1605, 1508, 1163, 1072, 817, 756 cm^{-1} . minor diastereomer: ^1H -NMR (300 MHz, CDCl_3) (2*S*, α *S*) δ 7.80 (m, 4H), 7.46 (m, 3H), 4.63 (m, 1H), 3.93 (m, 1H), 3.85 (m, 1H), 3.70 (s, 3H), 3.68 (d, 1H, J = 3.3 Hz), 1.83 (m 2H), 1.69 (m, 1H) 1.47 (m, 1H); ^{13}C -NMR (75 MHz, CDCl_3) δ 173.0, 133.3, 132.8, 128.5, 127.8, 127.6, 127.4, 126.3, 126.1, 126.0, 80.6, 68.5, 57.6, 52.1, 29.5, 25.4; GC/MS m/z (relative intensity) 270 (3), 200 (47), 71 (100); HRMS calcd for $\text{C}_{17}\text{H}_{18}\text{O}_3$: 270.1246. Found 270.1255.

(2*R*)-2-[(1*R*)-2-(4-iodophenylcarbonyloxy)-1-(2-naphthyl)ethyl]oxolane (11). To a stirring solution of methyl (α *S*,2*R*)-(2-naphthyl)-(tetrahydrofuran-2-yl)acetate (130 mg, 0.48 mmol) in diethyl ether (10 mL) was added lithium aluminum hydride (18 mg, 0.48 mmol) and the resulting solution stirred for 30 min at 24 °C. The reaction was quenched

with water and then 10% HCl. The water layer was extracted with diethyl ether and the combined organic layers were dried (MgSO_4). The solvent was removed under reduced pressure and the residue purified by flash chromatography on silica gel (10% Et_2O /petroleum ether) to give 111 mg of the alcohol. To a stirring solution of the alcohol (111 mg, 0.45 mmol) and triethylamine (63 mg, 0.63 mmol) in CH_2Cl_2 (5 mL), was added 4-iodobenzoyl chloride (167 mg, 0.62 mmol) and the reaction stirred overnight at ambient temperature. The reaction was quenched with water and the organic layer was washed with brine then dried (MgSO_4). The solvent was removed under reduced pressure and the residue was purified by flash chromatography on silica gel (40% diethyl ether/petroleum ether) to give 183 mg (80%) of **11** as a white, crystalline solid, mp = 163–165 °C; ^1H -NMR (500 MHz, CDCl_3) δ 7.91 (m, 1H), 7.84 (m, 3H), 7.75 (d, 2H, J = 8.2 Hz), 7.64 (d, 2H, J = 8.2 Hz), 7.54 (m, 1H), 7.47 (m, 2H), 4.80 (dd, 1H, J = 11.0, 6.7 Hz), 4.72 (dd, 1H, J = 11.0, 7.6 Hz), 4.39 (m, 1H), 3.76 (m, 2H), 3.35 (m, 1H), 2.05 (m, 1H), 1.82 (m, 1H), 1.65 (m, 2H); ^{13}C -NMR (125 MHz, CDCl_3) δ 165.9, 138.3, 137.6, 136.3, 133.3, 132.6, 132.3, 130.9, 128.0, 127.9, 127.7, 127.6, 127.0, 125.9, 125.6, 79.2, 68.3, 66.7, 49.7, 29.6, 25.8; LRMS (FAB) ($M+1$) 473; HRMS calcd for $\text{C}_{23}\text{H}_{21}\text{O}_3\text{I}$: 472.0535. Found 472.0525.

Methyl (*R*)-2-phenyl-3,3-dimethylbutanoate (13). A refluxing solution **3a** (57 mg, 0.32 mmol) in isobutane (10 mL) was added dropwise to a stirring, refluxing solution of $\text{Rh}_2(\text{S-DOSP})_4$ (9 mg, 0.005 mmol) in isobutane (10 mL). The cold trap was removed and the solvent was evaporated. The residue was purified by flash chromatography on silica gel (2% diethyl ether/petroleum ether) to give 13 mg (20%) of **13** as a colorless oil, 74% ee (Chiralcel-OD, 0.7 mL/min, 0.4% *i*-propanol/hexane, t_R = 7.8 and 13.0 min, UV

254 nm); $[\alpha]_D^{26} = -35.6$ ($c = 0.27$, CHCl_3); $^1\text{H-NMR}$ (300 MHz, CDCl_3) δ 7.39 (m, 2H), 7.28 (m, 3H), 3.64 (s, 3H), 3.43 (s, 1H), 0.99 (s, 9H); $^{13}\text{C-NMR}$ (125 MHz, CDCl_3) δ 173.6, 136.2, 129.9, 127.8, 127.1, 61.4, 51.4, 34.5, 27.8; IR (neat) 2955, 1737, 1367, 1205, 1148, 703 cm^{-1} ; CD $\lambda(\text{nm})$ and θ ($\text{deg mol}^{-1} \text{cm}^2$): $[\theta]_{210} - 5000$, $[\theta]_{220} - 11000$, $[\theta]_{230} - 5000$, $[\theta]_{240} - 1000$. GC/MS m/z (relative intensity) 206 (0.1), 150 (100); LRMS (FAB) m/z ($M+1$) 207. HRMS calcd for $\text{C}_9\text{H}_{10}\text{O}_2$ ($M-\text{C}_4\text{H}_8$): 150.0680. Found 150.0665.

Methyl (*R*)-2-phenyl-3,3,4-trimethylpentanoate (14). A degassed solution of **3a** (93 mg, 0.53 mmol) in 2,3-dimethylbutane (5 mL) was added dropwise to a degassed, stirring solution of $\text{Rh}_2(\text{S-DOSP})_4$ (50 mg, 0.026 mmol) in 2,3-dimethylbutane (5 mL) at reflux. The resulting solution was stirred for another 10 min and then cooled to ambient temperature. The solvent was removed *in vacuo*, to give a mixture of **14**, (*E/Z*)-**15**⁵ and methyl benzoylformate azine (**16**)⁶ (ratio of **15** : **16** = 75 : 25). The crude material was purified by flash chromatography on silica gel (2% diethyl ether/petroleum ether) to give 33 mg (27%) of **14** as a colorless oil, 66% ee (Chiralcel-OD, 0.7 mL/min, 0.4% *i*-propanol/hexane, $t_R = 7.4$ and 9.5 min, UV 254 nm); $[\alpha]_D^{26} = -36.4^\circ$ ($c = 1.4$, CHCl_3); $^1\text{H-NMR}$ (400 MHz, CDCl_3) δ 7.38 (m, 2H), 7.26 (m, 3H), 3.75 (s, 1H), 3.61 (s, 3H), 1.55 (m, 1H), 0.97 (s, 3H), 0.90 (d, 3H, $J = 7.0$ Hz), 0.86 (d, 3H), 0.78 (s, 3H); $^{13}\text{C-NMR}$ (75 MHz, CDCl_3) δ 173.7, 136.2, 130.4, 127.8, 127.0, 57.7, 51.3, 39.6, 34.1, 20.6, 20.5, 17.8, 17.2; IR (neat) 2970, 1737, 1156, 704 cm^{-1} ; CD $\lambda(\text{nm})$ and θ ($\text{deg mol}^{-1} \text{cm}^2$): $[\theta]_{210} - 3000$, $[\theta]_{220} - 11000$, $[\theta]_{230} - 6000$, $[\theta]_{240} - 1000$. GC/MS m/z (relative intensity) 150 (100); LRMS (FAB) ($M+1$) 235; HRMS calcd for $\text{C}_9\text{H}_{10}\text{O}_2$ ($M-\text{C}_6\text{H}_{12}$) 150.0680. Found: 150.0678.

Methyl (*R*)-2-phenyl-3,3-dimethylpentanoate (17a). A degassed solution of **3a** (62 mg, 0.35 mmol) in 2-methylbutane (10 mL) was added dropwise over 1 h to a degassed solution of $\text{Rh}_2(\text{S-DOSP})_4$ (10 mg, 0.005 mmol) in 2-methyl-butane (10 mL) at 24 °C. The resulting solution was stirred for another 10 min and then the solvent was removed under reduced pressure. The residue was purified by flash chromatography on silica (2% diethyl ether/petroleum ether) to give 46 mg (60%) of **17a** as a viscous oil, 68% ee (Chiralcel-OD, 0.7 mL/min, 0.4% *i*-propanol/hexane, t_R = 7.9 and 11.6 min, UV 254 nm); $[\alpha]_D^{25} = -33.5^\circ$ ($c = 0.4$, CHCl_3); $^1\text{H-NMR}$ (400 MHz, CDCl_3) δ 7.40 (m, 2H), 7.29 (m, 3H), 3.63 (s, 3H), 3.52 (s, 1H), 1.38 (m, 1H), 1.26 (m., 1H), 0.99 (s, 3H), 0.89 (s, 3H), 0.86 (t, 3H, $J = 7.3$ Hz); $^{13}\text{C-NMR}$ (75 MHz, CDCl_3) δ 173.6 (C), 136.0 (C), 130.1 (CH), 127.8 (CH), 127.1 (CH), 59.9 (CH), 51.3 (CH_3), 37.1 (C), 32.8 (CH_2), 23.9 (CH_3), 23.6 (CH_3), 8.2 (CH_3); IR (neat) 2969, 1743, 1204, 1152 702 cm^{-1} ; CD $\lambda(\text{nm})$ and θ (deg $\text{mol}^{-1} \text{cm}^2$): $[\theta]_{210} - 5000$, $[\theta]_{220} - 12000$, $[\theta]_{230} - 6000$ $[\theta]_{240} - 1000$. GC/MS m/z (relative intensity) 150 (100); LRMS (FAB) m/z (M+1) 221; HRMS calcd for $\text{C}_{19}\text{H}_{24}\text{O}_2$: Found:.

Methyl (*R*)-2-(4-bromophenyl)-3,3-dimethylpentanoate (17b). A degassed solution of methyl 4-bromophenyldiazoacetate (130 mg, 0.51 mmol) in 2-methylbutane (5.0 mL) and cyclohexane (1.0 mL) was added dropwise to a degassed solution of $\text{Rh}_2(\text{S-DOSP})_4$ (10 mg, 0.005 mmol) in 2-methylbutane (5.0 mL) and cyclohexane (1.0 mL) at 24 °C. The resulting solution was stirred for another 10 min and then the solvent was removed *in vacuo*. The residue was purified by flash chromatography on silica gel (1% diethyl ether/petroleum ether) to give 21 mg (14%) of **17b** and 58 mg (36%) of **4b**. **17b**: $^1\text{H-NMR}$ (400 MHz, CDCl_3) δ 7.41 (d, 2H, $J = 8.4$ Hz), 7.27 (d, 2H, $J = 8.4$ Hz), 3.62 (s, 3H), 3.47 (s, 1H), 1.30 (m, 1H), 1.20 (m, 1H), 0.96 (s, 3H), 0.85 (s, 3H), 0.83 (m, 3H);

^{13}C -NMR (75 MHz, CDCl_3) δ 173.3 (C), 135.0 (C), 131.8 (CH), 130.9 (CH), 121.3 (C), 59.5 (CH), 51.4 (CH_3), 42.9 (CH_2), 37.1 (C), 24.4 (CH_3), 24.1 (CH_3), 14.7 (CH_3); IR (neat) 2960, 2872, 1737, 1490, 1145, 1012 cm^{-1} ; GC/MS m/z (relative intensity) 228 (100), 230 (96); HRMS calcd for $\text{C}_9\text{H}_9\text{BrO}_2$ (M- C_5H_{10}) 227.9786. Found: 227.9807.

Methyl (2R, 3S)-2-phenyl-3,5-dimethylhexanoate (18a) and methyl (R)-2-phenyl-3,3-dimethylhexanoate (19a). A solution of **3a** (191 mg, 1.12 mmol) in degassed 2-methylpentane (10 mL) was added dropwise over 2 h to a stirring, refluxing solution of $\text{Rh}_2(\text{S-DOSP})_4$ (20 mg, 0.01 mmol) in degassed 2-methylpentane (5 mL). The resulting solution was stirred for another 10 min at reflux and then cooled to ambient temperature. The solvent was removed under reduced pressure and the residue was purified by flash chromatography on silica (1% diethyl ether/petroleum ether) to give 106 mg of **18a** in fraction 13-16, 15 mg of **18a** and **19a** as a mixture in fraction 17-18 and 77 mg of **19a** in fraction 19-25 (75% total yield). Ratio of **18a** : **19a** = 1.38 (by ^1H -NMR) and **19a** was a 4:1 mixture of diastereomers (by ^1H -NMR and GC/MS). **18a**: 25% ee (Chiralcel-OD, 0.7 mL/min, 0.4% *i*-propanol/hexane, t_R = 7.0 and 10.8 min, UV 254 nm); $[\alpha]_D^{25}$ = -11.1° (c = 0.99, CHCl_3); ^1H -NMR (500 MHz, CDCl_3) δ 7.43 (m, 2H), 7.33 (m, 3H), 3.66 (s, 3H), 3.56 (s, 1H), 1.35 (m, 3H), 1.21 (m, 1H), 1.05 (s, 3H), 0.94 (s, 3H), 0.91 (t, 3H, J = 7.1 Hz); ^{13}C -NMR 173.6, 136.0, 130.1, 127.7, 127.0, 60.2, 51.3, 43.0, 37.1, 24.6, 24.2, 17.0, 14.8; IR (neat) 2957, 2871, 1740, 1459, 1366, 1148, 743, 705 cm^{-1} ; CD λ (nm) and θ (deg $\text{mol}^{-1} \text{cm}^2$): $[\theta]_{210}$ -1000, $[\theta]_{220}$ -2500, $[\theta]_{230}$ -1500 $[\theta]_{240}$ 0. LRMS m/z (M+1) 235. HRMS calcd for $\text{C}_9\text{H}_{10}\text{O}_2$ (M- C_6H_{12}) 150.0681. Found: 150.0691. **19a**: 86% ee (Chiralcel -OD, 0.7 mL/min, 0.4% *i*-propanol/hexane, t_R = 8.4 and 9.9 min, UV 254 nm); $[\alpha]_D^{26}$ = -51.0° (c = 0.2, CHCl_3); ^1H -NMR (500 MHz, CDCl_3) δ 7.34 (m, 3H), 7.28 (m,

2H), 3.67 (s, 3H), 3.25 (d, 1H, $J = 10.7$ Hz), 2.28 (m, 1H), 1.61 (m, 1H), 1.00 (d, 3H, $J = 6.4$ Hz), 0.93 (m, 1H), 0.87 (m, 1H), 0.79 (d, 3H, $J = 6.7$ Hz), 0.75 (d, 3H, $J = 6.7$ Hz); ^{13}C -NMR (125 MHz, CDCl_3) δ 174.5, 138.1, 128.6, 128.4, 127.2, 59.4, 51.7, 43.0, 34.2, 25.0, 24.0, 20.9, 18.0; IR (neat) 2955, 2930, 2870, 1737, 1155, 702 cm^{-1} ; CD $\lambda(\text{nm})$ and $\theta(\text{deg mol}^{-1} \text{cm}^2)$: $[\theta]_{210} - 6000$, $[\theta]_{220} - 7000$, $[\theta]_{230} - 3000$, $[\theta]_{240} + 1000$. GC/MS major isomer: m/z (relative intensity) 234 (0.4), 150 (100), 118 (40), 91 (30); minor isomer: m/z (relative intensity) 234 (0.4), 150 (100), 118 (37), 91 (24); HRMS calcd for $\text{C}_{15}\text{H}_{22}\text{O}_2$ 234.1619. Found: 234.1640.

Methyl (2R, 3S)-2-(4-bromophenyl)-3,5 dimethylhexanoate (18b) and methyl (R)-2-(4-bromophenyl)-3,3-dimethylhexanoate (19b). A solution of **3b** (255 mg, 1.0 mmol) in degassed 2-methylpentane (10 mL) was added dropwise over 2 h to a stirring, refluxing solution of $\text{Rh}_2(\text{S-DOSP})_4$ (20 mg, 0.01 mmol) in degassed 2-methylpentane (5 mL). The resulting solution was stirred at reflux for another 10 min and then cooled to ambient temperature. The solvent was removed under reduced pressure and the residue purified by flash chromatography (1% diethyl ether/petroleum ether) to give 112 mg of **18b** in fraction 8-11, 16 mg of **18b** and **19b** as a mixture in fraction 12-13 and 30 mg of **19b** in fraction 14-19 (50% total yield). The ratio of **18b** : **19b** = 3.33 (by ^1H -NMR) and **18b** was a 4:1 mixture of diastereomers (by ^1H -NMR and GC/MS). **18b**: $[\alpha]_{\text{D}}^{25} = -4.2^\circ$ ($c = 2.8$, CHCl_3); ^1H -NMR (500 MHz, CDCl_3) δ 7.42 (d, 2H $J = 8.7$ Hz), 7.27 (d, 2H, $J = 8.7$ Hz), 3.64 (s, 3H), 3.47 (s, 1H), 1.30 (m, 3H), 1.15 (m, 1H), 0.97 (s, 3H), 0.88 (s, 3H), 0.83 (t, 3H, $J = 7.0$ Hz); ^{13}C -NMR (300 MHz, CDCl_3) δ 173.2 (C), 135.0 (C), 131.8 (CH), 130.9 (CH), 121.3 (C), 59.5 (CH), 51.4 (CH_3), 42.9 (CH_2), 37.0 (C), 24.4 (CH_3), 24.1 (CH_3), 17.0 (CH_2), 14.8 (CH_3); IR (neat) 2960, 2872, 1740, 1496, 1150, 1013 cm^{-1} ;

CD λ (nm) and θ (deg mol⁻¹ cm²): $[\theta]_{210} - 1000$, $[\theta]_{220} - 2000$, $[\theta]_{230} - 1000$ $[\theta]_{240} 0$. LRMS (FAB) (M+1) 313; HRMS calcd for C₉H₉BrO₂ (M - C₆H₁₂) 227.9786. Found 227.9793.

A small sample of **18b** was taken out and reduced to the alcohol with LiAlH₄. The reaction was quenched with water and the water layer extracted with diethyl ether. The combined organic layer was dried (MgSO₄) and the solvent was removed under reduced pressure. The residue was purified by flash chromatography on silica gel (10% diethyl ether/petroleum ether) and subjected to HPLC analysis: 30% ee (Whelk-O, 1.0 mL/min, 6% *i*-propanol/hexane, t_R = 10.5 and 19.8 min, UV 254 nm); IR (neat) 3366, 2956, 1489, 1013, 830, 706. **19b**: $[\alpha]_D^{25} = -31.7^\circ$ ($c = 0.43$, CHCl₃); ¹H-NMR (300 MHz, CDCl₃) δ 7.42 (d, 2H, $J = 8.4$ Hz), 7.19 (d, 2H, $J = 8.4$ Hz), 3.64 (s, 3H), 3.17 (d, 1H, $J = 10.4$ Hz), 2.20 (m, 1H), 1.55 (m, 1H), 0.96 (d, 3H, $J = 6.4$ Hz), 0.85 (m, 2H), 0.77 (d, 3H, $J = 6.7$ Hz), 0.71 (d, 3H, $J = 6.7$ Hz); ¹³C-NMR (75 MHz, CDCl₃) δ 174.0, 137.1, 131.6, 130.4, 121.2, 58.7, 51.8, 43.0, 34.4, 25.0, 24.0, 20.9, 17.9; IR (neat) 2960, 2872, 1740, 1493, 1150, 1013 cm⁻¹; CD λ (nm) and θ (deg mol⁻¹ cm²): $[\theta]_{210} - 10000$, $[\theta]_{220} - 10000$, $[\theta]_{230} - 3000$ $[\theta]_{240} + 2000$. GC/MS major isomer: m/z (relative intensity) 314 (3), 312 (3), 230 (96), 228 (100), 198 (23), 196 (23), 171 (19), 169 (20); minor isomer: m/z (relative intensity) 314 (35), 312 (35), 230 (94), 228 (100), 198 (20), 196 (20), 171 (16), 169 (16); LRMS (FAB) (M+1) 313; HRMS calcd for C₁₅H₂₁BrO₂ 312.0724. Found 312.0699. A small sample was taken out and reduced to the alcohol with LiAlH₄. The reaction was quenched with water and the water layer extracted with diethyl ether. The combined organic layer were dried (MgSO₄) and the solvent removed under reduced pressure. The residue was purified by flash chromatography on silica gel (10% diethyl ether/petroleum

ether) and subjected to HPLC analysis to give 85% ee (Whelk-O, 1.0 mL/min, 6% *i*-propanol/hexane, t_R = 6.6 and 7.9 min, UV 254 nm); IR (neat) 3392, 2955, 1468, 1055.

(2*R*, 3*S*)-2-(4-bromophenyl)-3,5 dimethylhexanoic acid pyrrolidine amide (20). To a stirring solution of the major diastereomer of **19b** (82 mg, 0.26 mmol) and TMSCl (113 mg, 1.0 mmol) in CH₃CN (10 mL) was added NaI (150 mg, 1.0 mmol) and the mixture heated to reflux for 48 h. To the cooled solution was added ether (50 mL) and the resulting solution was extracted with water (50 mL), sodium thiosulphate solution (20 mL) and brine (20 mL). The ether layer was dried (MgSO₄) and the solvent was removed under reduced pressure. The residue was purified to give 50 mg (67%) of (2*R*, 3*R*)-2-(4-bromophenyl)-3,5 dimethylhexanoic acid. To a solution of (2*R*, 3*R*)-2-(4-bromophenyl)-3,5 dimethylhexanoic acid (32 mg, 0.11 mmol), pyrrolidine (9 mg, 0.12 mmol) and DMAP (1mg) in CH₂Cl₂ (5 mL) was added DCC (25 mg, 0.12 mmol) and the resulting solution was stirred at ambient temperature for 4h. The solvent was removed under reduced pressure and the residue purified by flash chromatography on silica gel (1:1 ether/petroleum ether) to give 13 mg (33%) of **20** as a white solid, mp = 135-136 °C; ¹H-NMR (500 MHz, CDCl₃) δ 7.42 (d, 2H, *J* = 8.2 Hz), 7.25 (d, 2H, *J* = 8.2 Hz), 3.54 (m, 2H), 3.38 (m, 2H), 3.22 (d, 1H, *J* = 10.0 Hz), 2.32 (m, 1H), 1.96 (m, 1H), 1.83 (m, 4H), 1.58 (m, 1H), 0.98 (d, 3H, *J* = 6.4 Hz), 0.82 (m, 1H), 0.77 (d, 3H, *J* = 6.4 Hz), 0.71 (d, 3H, *J* = 6.4 Hz); ¹³C-NMR (125 MHz, CDCl₃) δ 171.3, 137.9, 131.5, 130.5, 120.7, 57.5, 46.6, 45.8, 43.2, 34.7, 26.0, 25.0, 24.2, 20.9, 18.4; IR 2954, 2870, 1639, 1425; GC/MS *m/z* (relative intensity) 297 (97), 295 (100), 254 (14), 256 (14), 171 (40), 169 (40); HRMS calcd for C₁₈H₂₆BrNO (M-CH₃) 336.0963. Found 336.0968.

Methyl (*R*)-2-adamantanyphenylacetate (21a). A solution of **3a** (80 mg, 0.45 mmol) in 2,2-dimethylbutane (5 mL) was added dropwise over 60 min to a stirring, degassed solution of $\text{Rh}_2(\text{S-DOSP})_4$ (10 mg, 0.005 mmol) and adamantane (153 mg, 0.89 mmol) in 2,2-dimethylbutane (5 mL) at 24 °C. The resulting solution was stirred for another 10 min and then the solvent was removed under reduced pressure. Excess adamantane was removed by sublimation under high vacuum. The residue was purified by flash chromatography on silica gel (4% diethyl ether/petroleum ether) to give 86 mg (62%) of **21a** as a viscous oil, 90% ee (Chiralcel-OD, 0.7 mL/min, 0.4% *i*-propanol/hexane, t_R = 7.9 and 12.1 min, UV 254 nm); $[\alpha]_D^{25} = -22.9$ ($c = 0.75$, CHCl_3); $^1\text{H-NMR}$ (300 MHz, CDCl_3) δ 7.38 (m, 2H), 7.28 (m, 3H), 3.64 (s, 3H), 3.28 (s, 1H), 1.95 (s, 3H), 1.73 – 1.50 (m, 12H); $^{13}\text{C-NMR}$ (75 MHz, CDCl_3) δ 174.2, 134.8, 130.2, 127.7, 127.1, 63.0, 51.2, 39.8, 36.7, 36.2, 28.5; IR (neat) 2908, 2849, 1732, 1456, 1199, 1150, 702 cm^{-1} ; CD $\lambda(\text{nm})$ and $\theta(\text{deg mol}^{-1} \text{cm}^2)$: $[\theta]_{210} -5000$, $[\theta]_{220} -9000$, $[\theta]_{230} -3000$, $[\theta]_{240} -1000$. GC/MS m/z (relative intensity) 284 (4), 135 (100); HRMS calcd for $\text{C}_{19}\text{H}_{24}\text{O}_2$: 284.1776. Found: 284.1761.

Methyl (*R*)-2-adamantanyl-4-bromophenylacetate (21b). A degassed solution of **3b** (1.325 g, 5.19 mmol) in 2,2-dimethylbutane (40 mL) was added dropwise over 2 h to a degassed solution of $\text{Rh}_2(\text{S-DOSP})_4$ (51 mg, 0.027 mmol) and adamantane (1.373 g, 10.08 mmol) in 2,2-dimethylbutane (20 mL) at 24 °C. The resulting solution was stirred for another 10 min and then the solvent was removed under reduced pressure. Excess adamantane was removed by sublimation under high vacuum. The residue was purified by flash chromatography on silica gel (4% diethyl ether/petroleum ether) to give 1.317 g (70%) of **21b** as a white solid. $[\alpha]_D^{24} = -17.1$ ($c = 1.1$, CHCl_3); $^1\text{H-NMR}$ (300 MHz,

CDCl₃) δ 7.42 (d, 2H, J = 8.4 Hz), 7.25 (d, 2H, J = 8.4 Hz), 3.64 (s, 3H), 3.24 (s, 1H), 1.95 (s, 3H), 1.73 – 1.50 (m, 12H); ¹³C-NMR (75 MHz, CDCl₃) δ 174.8 (C), 133.8 (C), 131.8 (CH), 130.7 (CH), 121.2 (C), 62.2 (CH), 51.3 (CH₃), 39.7 (CH₂), 36.6 (CH₂), 36.2 (C), 28.4 (CH); IR (neat) 2906, 1735, 1491, 1201, 1153, 1014 cm⁻¹; CD λ (nm) and θ (deg mol⁻¹ cm²): [θ]₂₁₀ – 7000, [θ]₂₂₀ – 18000, [θ]₂₃₀ – 11000 [θ]₂₄₀ – 1000. GC/MS m/z (relative intensity) 364 (5), 135 (100); LRMS (FAB) m/z (M+1) 363, HRMS calcd for C₁₉H₂₃BrO₂: 362.0881. Found: 362.0869. A small sample of **21b** was taken out and reduced to the alcohol with LiAlH₄. The reaction was quenched with water and the water layer extracted with diethyl ether. The combined organic layer were dried (MgSO₄) and the solvent removed under reduced pressure. The residue was purified by flash chromatography on silica gel (10% diethyl ether/petroleum ether) and subjected to HPLC analysis: 96% ee (Whelk-O, 1.0 mL/min, 6% *i*-propanol/hexane, t_R = 9.6 and 12.8 min, UV 254 nm), ¹H-NMR δ 7.32 (m, 3H), 7.20 (m, 2H), 4.02 (m, 2H), 2.53 (m, 1H), 1.92 (s, 3H), 1.62 – 0.97 (m, 12H); IR (neat) 3300, 2900, 2849, 1451, 1051, 703 cm⁻¹; GC/MS m/z (relative intensity) 135 (60), 104 (100).

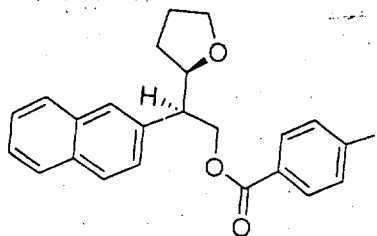
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STRUCTURE DETERMINATION SUMMARYCrystal Data

Empirical Formula	$C_{23} H_{21} I O_3$
Color; Habit	colorless rectangular plate
Crystal Size (mm)	0.51 x 0.22 x 0.15
Crystal System	Orthorhombic
Space Group	$P2_12_12_1$ (No. 19)
Unit Cell Dimensions	$a = 5.665(1) \text{ \AA}$ $b = 8.631(2) \text{ \AA}$ $c = 40.605(9) \text{ \AA}$
Volume	$1985.4(7) \text{ \AA}^3$
Z	4
Formula weight	472.3
Density(calc.)	1.580 Mg/m^3
Absorption Coefficient	1.613 mm^{-1}
F(000)	944



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Data Collection

Diffractometer Used	Siemens R3m/V
Radiation	Mo K α (λ = 0.71073 Å)
Temperature (K)	297
Monochromator	Highly oriented graphite crystal
2 θ Range	5.0 to 42.0°
Scan Type	ω
Scan Speed	Constant; 1.50°/min. in ω
Scan Range (ω)	0.50°
Background Measurement	Stationary crystal and stationary counter at beginning and end of scan, each for 25.0% of total scan time
Standard Reflections	3 measured every 197 reflections
Index Ranges	$0 \leq h \leq 5$, $0 \leq k \leq 8$, $-40 \leq l \leq 40$
Reflections Collected	2624
Independent Reflections	2148 (R_{int} = 0.91%)
Observed Reflections	2148 ($F > 0.3\sigma(F)$)
Absorption Correction	Semi-empirical
Min./Max. Transmission	0.5875 / 0.6807

Solution and Refinement

System Used	Siemens SHELXTL PLUS Release 4.11(VMS)
Solution	Patterson synthesis
Refinement Method	Full-Matrix Least-Squares
Quantity Minimized	$\sum w(F_o - F_c)^2$
Absolute Structure	$\eta = 1.09(6)$ (Chirality secure)
Extinction Correction	$\chi = 0.00010(6)$, where $F^* = F [1 + 0.002\chi F^2 / \sin(2\theta)]^{-1/4}$
Hydrogen Atoms	Riding model, $U(H) = U(C) + 0.01$
Weighting Scheme	$w^{-1} = \sigma^2(F) + 0.0002F^2$
Number of Parameters refined	246
Final R indices (obs. data)	$R = 3.25\%$, $wR = 3.12\%$
R Indices (all data)	$R = 3.25\%$, $wR = 3.12\%$
Goodness-of-Fit	1.28
Largest and Mean Δ/σ	0.001, 0.000
Data-to-Parameter Ratio	8.7:1
Largest Difference Peak	$0.59 \text{ e}\text{\AA}^{-3}$
Largest Difference Hole	$-0.48 \text{ e}\text{\AA}^{-3}$

Table 1. Atomic coordinates ($\times 10^4$) and equivalent isotropic displacement coefficients ($\text{\AA}^2 \times 10^3$)

	x	y	z	U(eq)
I(1)	3863(1)	5515(1)	4489(1)	60(1)
C(1)	4120(11)	637(7)	7083(1)	42(2)
C(2)	2635(10)	212(7)	6838(1)	40(2)
C(3)	581(9)	-622(8)	6915(1)	47(2)
C(4)	95(10)	-1041(7)	7232(1)	47(2)
C(5)	1149(13)	-1005(7)	7826(1)	56(2)
C(6)	2677(12)	-566(9)	8065(1)	57(2)
C(7)	4717(12)	244(8)	7984(2)	62(3)
C(8)	5208(10)	645(8)	7673(1)	49(2)
C(9)	3652(11)	233(6)	7417(1)	42(2)
C(10)	1618(9)	-616(7)	7492(1)	40(2)
C(11)	3126(9)	728(7)	6485(1)	42(2)
C(12)	1270(13)	1883(7)	6376(1)	51(2)
O(13)	1957(7)	2484(5)	6058(1)	51(2)
C(14)	359(12)	3336(7)	5897(2)	45(3)
O(15)	-1549(9)	3653(5)	6011(1)	67(2)
C(21)	1242(12)	3846(6)	5570(1)	43(2)
C(22)	3376(11)	3353(7)	5447(1)	50(2)
C(23)	4104(12)	3827(7)	5138(1)	48(2)
C(24)	2670(11)	4817(7)	4961(1)	46(2)
C(25)	586(11)	5344(7)	5082(1)	54(2)
C(26)	-147(11)	4845(7)	5391(1)	48(2)
O(31)	1170(8)	-1340(4)	6184(1)	45(1)
C(32)	3413(9)	-568(7)	6230(1)	45(2)
C(33)	5154(10)	-1837(7)	6312(1)	50(2)
C(34)	4134(13)	-3221(7)	6133(1)	62(3)
C(35)	1526(13)	-2985(7)	6184(2)	63(3)

* Equivalent isotropic U defined as one third of the trace of the orthogonalized U_{ij} tensor

Table 2. Bond lengths (Å)

I(1)-C(24)	2.119 (6)	C(1)-C(2)	1.352 (8)
C(1)-C(9)	1.424 (7)	C(2)-C(3)	1.403 (8)
C(2)-C(11)	1.530 (7)	C(3)-C(4)	1.368 (7)
C(4)-C(10)	1.411 (7)	C(5)-C(6)	1.353 (9)
C(5)-C(10)	1.421 (7)	C(6)-C(7)	1.390 (9)
C(7)-C(8)	1.338 (8)	C(8)-C(9)	1.410 (8)
C(9)-C(10)	1.400 (8)	C(11)-C(12)	1.514 (9)
C(11)-C(32)	1.532 (8)	C(12)-O(13)	1.447 (6)
O(13)-C(14)	1.336 (8)	C(14)-O(15)	1.206 (8)
C(14)-C(21)	1.487 (8)	C(21)-C(22)	1.376 (9)
C(21)-C(26)	1.376 (8)	C(22)-C(23)	1.384 (8)
C(23)-C(24)	1.380 (8)	C(24)-C(25)	1.357 (9)
C(25)-C(26)	1.388 (8)	O(31)-C(32)	1.447 (7)
O(31)-C(35)	1.434 (7)	C(32)-C(33)	1.511 (8)
C(33)-C(34)	1.514 (9)	C(34)-C(35)	1.505 (10)

Table 3. Bond angles ($^{\circ}$)

C(2)-C(1)-C(9)	121.1(5)	C(1)-C(2)-C(3)	119.6(5)
C(1)-C(2)-C(11)	119.8(5)	C(3)-C(2)-C(11)	120.5(5)
C(2)-C(3)-C(4)	120.7(5)	C(3)-C(4)-C(10)	120.9(5)
C(6)-C(5)-C(10)	119.8(6)	C(5)-C(6)-C(7)	120.3(5)
C(6)-C(7)-C(8)	121.6(6)	C(7)-C(8)-C(9)	120.2(6)
C(1)-C(9)-C(8)	121.7(5)	C(1)-C(9)-C(10)	119.3(5)
C(8)-C(9)-C(10)	119.0(5)	C(4)-C(10)-C(5)	122.5(5)
C(4)-C(10)-C(9)	118.4(5)	C(5)-C(10)-C(9)	119.1(5)
C(2)-C(11)-C(12)	109.8(4)	C(2)-C(11)-C(32)	116.1(5)
C(12)-C(11)-C(32)	111.0(4)	C(11)-C(12)-O(13)	108.0(5)
C(12)-O(13)-C(14)	116.8(5)	O(13)-C(14)-O(15)	123.1(5)
O(13)-C(14)-C(21)	111.8(5)	O(15)-C(14)-C(21)	125.1(6)
C(14)-C(21)-C(22)	121.9(5)	C(14)-C(21)-C(26)	117.8(6)
C(22)-C(21)-C(26)	120.3(5)	C(21)-C(22)-C(23)	120.0(5)
C(22)-C(23)-C(24)	118.6(6)	I(1)-C(24)-C(23)	117.2(4)
I(1)-C(24)-C(25)	120.6(4)	C(23)-C(24)-C(25)	122.1(5)
C(24)-C(25)-C(26)	118.9(6)	C(21)-C(26)-C(25)	120.1(6)
C(32)-O(31)-C(35)	109.3(5)	C(11)-C(32)-O(31)	109.3(4)
C(11)-C(32)-C(33)	116.7(4)	O(31)-C(32)-C(33)	105.6(5)
C(32)-C(33)-C(34)	102.5(5)	C(33)-C(34)-C(35)	101.6(5)
O(31)-C(35)-C(34)	105.8(5)		

Table 4. Anisotropic displacement coefficients ($\text{\AA}^2 \times 10^3$)

	U_{11}	U_{22}	U_{33}	U_{12}	U_{13}	U_{23}
I(1)	79(1)	57(1)	42(1)	-3(1)	3(1)	7(1)
C(1)	42(3)	42(3)	41(3)	-12(5)	8(3)	0(3)
C(2)	44(3)	40(4)	35(3)	-2(3)	0(3)	-3(3)
C(3)	39(4)	54(4)	47(4)	-11(4)	-1(3)	0(3)
C(4)	38(3)	65(4)	38(4)	-11(3)	7(3)	7(3)
C(5)	52(4)	68(4)	47(4)	3(4)	17(4)	7(3)
C(6)	67(4)	83(5)	23(3)	4(5)	3(3)	-1(4)
C(7)	66(5)	67(5)	53(4)	2(4)	-10(3)	-15(4)
C(8)	55(4)	58(4)	33(3)	-6(4)	0(3)	-8(3)
C(9)	43(3)	46(3)	36(3)	7(4)	-8(3)	-3(3)
C(10)	34(4)	52(3)	33(3)	9(4)	4(3)	-1(3)
C(11)	37(3)	53(4)	35(3)	-7(3)	4(2)	4(3)
C(12)	64(4)	54(4)	34(3)	2(4)	18(4)	4(3)
O(13)	57(3)	55(2)	40(2)	5(2)	7(2)	10(2)
C(14)	48(5)	41(4)	47(4)	0(3)	2(3)	-5(3)
O(15)	68(4)	79(3)	56(3)	19(3)	14(3)	13(2)
C(21)	46(3)	40(3)	42(3)	-6(3)	-1(4)	-7(3)
C(22)	49(4)	47(3)	55(4)	9(3)	-6(3)	7(3)
C(23)	43(4)	60(4)	42(3)	-3(4)	11(3)	0(3)
C(24)	56(4)	42(4)	38(3)	-10(3)	-9(3)	5(3)
C(25)	61(5)	48(4)	55(4)	13(4)	-7(3)	11(4)
C(26)	55(4)	55(4)	35(3)	16(3)	3(3)	1(3)
O(31)	44(2)	47(2)	45(2)	0(3)	-12(2)	-2(2)
C(32)	46(4)	52(3)	36(3)	3(4)	9(3)	1(3)
C(33)	48(4)	65(4)	36(3)	11(3)	2(3)	5(3)
C(34)	76(6)	55(4)	55(4)	17(4)	5(4)	-3(3)
C(35)	64(5)	59(4)	66(4)	2(4)	-15(4)	-2(3)

The anisotropic displacement exponent takes the form:

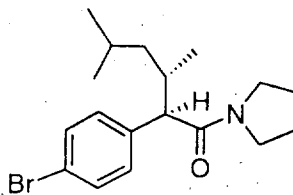
$$-2\pi^2(h^2a^{*2}U_{11} + \dots + 2hka^*b^*U_{12})$$

Table 5. H-Atom coordinates ($\times 10^4$) and isotropic displacement coefficients ($\text{\AA}^2 \times 10^3$)

	x	y	z	U
H(1A)	5511	1222	7031	51
H(3A)	-493	-904	6742	57
H(4A)	-1300	-1632	7280	57
H(5A)	-248	-1578	7882	66
H(6A)	2351	-816	8291	68
H(7A)	5800	521	8156	72
H(8A)	6621	1215	7625	59
H(11A)	4597	1281	6489	52
H(12A)	1154	2712	6533	61
H(12B)	-240	1383	6361	61
H(22A)	4359	2678	5576	51
H(23A)	5578	3477	5048	58
H(25A)	-364	6050	4956	65
H(26A)	-1623	5200	5479	58
H(32A)	3871	-110	6024	55
H(33A)	5226	-2016	6545	59
H(33B)	6705	-1591	6233	59
H(34A)	4662	-4177	6228	72
H(34C)	4534	-3205	5903	72
H(35C)	641	-3464	6010	73
H(35A)	1038	-3423	6391	73

STRUCTURE DETERMINATION SUMMARYCrystal Data

Empirical Formula	C ₁₈ H ₂₆ Br N O
Color; Habit	colorless parallelepiped (cut)
Crystal Size (mm)	0.50 x 0.34 x 0.58
Crystal System	Orthorhombic
Space Group	P2 ₁ 2 ₁ 2 ₁ (No. 19)
Unit Cell Dimensions	$\underline{a}$ = 9.5740(10) Å $\underline{b}$ = 11.565(2) Å $\underline{c}$ = 16.600(2) Å
Volume	1837.9(5) Å ³
Z	4
Formula weight	352.3
Density(calc.)	1.273 Mg/m ³
Absorption Coefficient	2.213 mm ⁻¹
F(000)	736



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Data Collection

Diffractometer Used	Siemens R3m/V
Radiation	Mo K α (λ = 0.71073 Å)
Temperature (K)	297
Monochromator	Highly oriented graphite crystal
2 θ Range	5.0 to 45.0°
Scan Type	2 θ - θ
Scan Speed	Constant; 3.00°/min. in ω
Scan Range (ω)	0.70° plus K α -separation
Background Measurement	Stationary crystal and stationary counter at beginning and end of scan, each for 25.0% of total scan time
Standard Reflections	3 measured every 197 reflections
Index Ranges	$0 \leq h \leq 10$, $-12 \leq k \leq 12$, $-17 \leq l \leq 17$
Reflections Collected	5158
Independent Reflections	2409 (R_{int} = 1.20%)
Observed Reflections	1953 ($F > 4.0\sigma(F)$)
Absorption Correction	Semi-empirical
Min./Max. Transmission	0.2637 / 0.3033

Solution and Refinement

System Used	Siemens SHELXTL PLUS Release 4.11(VMS)
Solution	Patterson synthesis
Refinement Method	Full-Matrix Least-Squares
Quantity Minimized	$\sum w(F_o - F_c)^2$
Absolute Structure	$\eta = 1.01(2)$
Extinction Correction	$\chi = 0.0001(2)$, where $F^* = F [1 + 0.002\chi F^2 / \sin(2\theta)]^{-1/4}$
Hydrogen Atoms	Riding model, isotropic U's refined
Weighting Scheme	$w^{-1} = \sigma^2(F) + 0.0004F^2$
Number of Parameters refined	192
Final R indices (obs. data)	R = 3.28 %, wR = 3.17 %
R Indices (all data)	R = 4.66 %, wR = 3.45 %
Goodness-of-Fit	0.99
Largest and Mean Δ/σ	0.001, 0.000
Data-to-Parameter Ratio	10.2:1
Largest Difference Peak	0.37 eÅ ⁻³
Largest Difference Hole	-0.30 eÅ ⁻³

Table 1. Atomic coordinates ($\times 10^4$) and equivalent isotropic displacement coefficients ($\text{\AA}^2 \times 10^3$)

	x	y	z	U(eq)
Br(1)	3451(1)	6400(1)	3008(1)	61(1)
N(1)	9818(4)	3981(3)	1640(2)	47(1)
O(1)	9269(3)	2573(3)	2502(2)	46(1)
C(1)	10160(8)	5572(5)	5941(3)	123(4)
C(2)	10274(6)	4528(4)	5370(3)	71(2)
C(3)	9875(5)	4877(4)	4527(2)	49(2)
C(4)	9970(4)	3972(3)	3868(2)	38(1)
C(5)	9487(4)	4476(3)	3060(3)	36(1)
C(6)	9535(4)	3599(4)	2377(2)	36(1)
C(11)	8006(3)	4953(3)	3088(2)	30(1)
C(12)	6870(4)	4244(4)	3217(3)	42(2)
C(13)	5536(5)	4649(4)	3214(3)	44(2)
C(14)	5299(4)	5801(4)	3066(3)	42(2)
C(15)	6408(4)	6555(3)	2955(2)	44(1)
C(16)	7746(4)	6118(3)	2962(3)	39(1)
C(21)	9405(8)	3568(7)	5694(3)	121(3)
C(41)	11462(5)	3475(4)	3785(3)	59(2)
C(91)	10106(7)	5171(4)	1386(3)	76(2)
C(92)	10243(8)	5104(6)	492(3)	106(3)
C(93)	9919(11)	3958(7)	258(3)	193(6)
C(94)	9728(6)	3203(4)	937(3)	69(2)

* Equivalent isotropic U defined as one third of the trace of the orthogonalized U_{ij} tensor

Table 2. Bond lengths (Å)

Br(1)-C(14)	1.903 (4)	N(1)-C(6)	1.328 (5)
N(1)-C(91)	1.466 (6)	N(1)-C(94)	1.475 (6)
O(1)-C(6)	1.231 (6)	C(1)-C(2)	1.540 (8)
C(2)-C(3)	1.506 (6)	C(2)-C(21)	1.488 (9)
C(3)-C(4)	1.517 (6)	C(4)-C(5)	1.535 (6)
C(4)-C(41)	1.546 (6)	C(5)-C(6)	1.522 (6)
C(5)-C(11)	1.522 (5)	C(11)-C(12)	1.379 (5)
C(11)-C(16)	1.386 (5)	C(12)-C(13)	1.360 (6)
C(13)-C(14)	1.374 (6)	C(14)-C(15)	1.386 (6)
C(15)-C(16)	1.377 (6)	C(91)-C(92)	1.493 (7)
C(92)-C(93)	1.415 (10)	C(93)-C(94)	1.437 (8)

Table 3. Bond angles ($^{\circ}$)

C(6)-N(1)-C(91)	128.0(4)	C(6)-N(1)-C(94)	120.9(4)
C(91)-N(1)-C(94)	110.9(3)	C(1)-C(2)-C(3)	110.1(4)
C(1)-C(2)-C(21)	108.9(5)	C(3)-C(2)-C(21)	113.2(5)
C(2)-C(3)-C(4)	118.0(4)	C(3)-C(4)-C(5)	110.5(3)
C(3)-C(4)-C(41)	112.1(4)	C(5)-C(4)-C(41)	110.0(3)
C(4)-C(5)-C(6)	112.9(3)	C(4)-C(5)-C(11)	113.0(3)
C(6)-C(5)-C(11)	107.0(3)	N(1)-C(6)-O(1)	121.2(4)
N(1)-C(6)-C(5)	118.0(4)	O(1)-C(6)-C(5)	120.7(4)
C(5)-C(11)-C(12)	121.6(3)	C(5)-C(11)-C(16)	121.0(3)
C(12)-C(11)-C(16)	117.4(3)	C(11)-C(12)-C(13)	122.3(4)
C(12)-C(13)-C(14)	119.3(4)	Br(1)-C(14)-C(13)	121.0(3)
Br(1)-C(14)-C(15)	118.5(3)	C(13)-C(14)-C(15)	120.5(4)
C(14)-C(15)-C(16)	118.7(4)	C(11)-C(16)-C(15)	121.7(3)
N(1)-C(91)-C(92)	104.7(4)	C(91)-C(92)-C(93)	107.5(5)
C(92)-C(93)-C(94)	112.5(5)	N(1)-C(94)-C(93)	104.0(4)

Table 4. Anisotropic displacement coefficients ($\text{\AA}^2 \times 10^3$)

	U_{11}	U_{22}	U_{33}	U_{12}	U_{13}	U_{23}
Br(1)	42(1)	68(1)	74(1)	17(1)	-1(1)	3(1)
N(1)	65(3)	41(2)	34(2)	2(2)	4(2)	-4(2)
O(1)	51(2)	33(2)	56(2)	-1(1)	2(2)	-1(2)
C(1)	230(9)	84(5)	54(4)	2(5)	-26(6)	-13(3)
C(2)	94(5)	65(4)	52(3)	-2(3)	-9(3)	-5(3)
C(3)	61(3)	48(3)	36(3)	6(3)	-5(3)	-1(2)
C(4)	40(2)	40(3)	36(2)	4(2)	-1(2)	3(2)
C(5)	29(2)	34(2)	46(3)	-2(2)	6(3)	4(2)
C(6)	30(2)	40(3)	37(2)	8(2)	-1(2)	2(2)
C(11)	30(2)	33(2)	29(2)	-1(2)	2(2)	0(2)
C(12)	41(3)	31(2)	53(3)	9(2)	-3(2)	3(2)
C(13)	38(3)	44(3)	50(3)	-2(2)	1(2)	0(2)
C(14)	37(3)	48(3)	41(3)	14(2)	-3(3)	1(2)
C(15)	51(3)	36(2)	44(2)	6(3)	-2(3)	2(3)
C(16)	42(2)	32(3)	44(2)	-2(2)	-3(2)	3(2)
C(21)	198(8)	112(5)	53(3)	-59(6)	16(4)	6(4)
C(41)	49(3)	69(3)	58(3)	17(3)	-9(3)	-4(3)
C(91)	122(5)	56(3)	51(3)	-20(4)	12(3)	9(3)
C(92)	175(8)	84(5)	59(4)	-21(5)	9(4)	7(4)
C(93)	441(18)	88(6)	50(4)	-29(9)	32(8)	0(4)
C(94)	93(4)	63(3)	50(3)	6(3)	6(3)	-11(3)

The anisotropic displacement exponent takes the form:

$$-2\pi^2(h^2a^{*2}U_{11} + \dots + 2hka^*b^*U_{12})$$

Table 5. H-Atom coordinates ($\times 10^4$) and isotropic displacement coefficients ($\text{\AA}^2 \times 10^3$)

	x	y	z	U
H(1A)	10720	6197	5739	102
H(1B)	9202	5815	5973	396
H(1C)	10483	5357	6468	118
H(2A)	11228	4272	5357	141
H(3A)	8929	5151	4549	88
H(3B)	10452	5517	4369	35
H(4A)	9357	3346	4006	70
H(5A)	10105	5100	2924	20
H(12A)	7031	3436	3313	56
H(13A)	4762	4140	3310	62
H(15A)	6238	7367	2887	53
H(16A)	8520	6627	2865	47
H(21A)	9454	2899	5352	117
H(21B)	9736	3371	6222	113
H(21C)	8455	3828	5727	234
H(41A)	11757	3149	4289	104
H(41B)	11482	2888	3376	97
H(41C)	12081	4093	3638	93
H(91A)	10946	5452	1634	79
H(91B)	9347	5673	1529	137
H(92A)	11192	5267	343	262
H(92B)	9647	5661	235	191
H(93A)	9060	3985	-39	354
H(93B)	10630	3656	-91	226
H(94A)	8839	2820	925	137
H(94B)	10457	2633	954	110