Effective Asymmetric Epoxidation of Styrenes by Chiral Dioxirane

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mp. 162.0-163.5 °C; IR (film) 1774 cm^{-1} ; ^1H NMR (300 MHz, CDCl_3) δ 7.39 (m, 2H), 7.18 (m, 2H), 4.87 (d, J = 5.1 Hz, 1H), 4.73 (d, J = 10.8 Hz, 1H), 4.66-4.60 (m, 2H), 4.26 (dd, J = 13.5, 0.6 Hz, 1H), 3.74 (d, J = 10.8 Hz, 1H), 2.33 (s, 3H), 1.49 (s, 3H), 1.43 (s, 3H); ^{13}C NMR (75 MHz, CDCl_3) δ 195.1, 151.3, 134.9, 134.6, 129.9, 118.9, 111.2, 99.2, 77.6, 75.7, 61.1, 50.0, 27.4, 26.3, 21.1. HRMS calcd for $\text{C}_{17}\text{H}_{19}\text{NO}_6$ (M^+) 333.1212, found 333.1210.

Ketone 4b

mp 135–136 °C; $[\alpha]_D^{20}$ = -40.6 (c , 0.32, CHCl_3); IR (film) 1774 cm^{-1} ; ^1H NMR (300 MHz, CDCl_3) δ 7.42 (d, J = 8.4 Hz, 2H), 7.21 (d, J = 8.4 Hz, 2H), 4.87 (d, J = 5.1 Hz, 1H), 4.74 (d, J = 10.2 Hz, 1H), 4.66-4.59 (m, 2H), 4.26 (d, J = 13.5 Hz, 1H), 3.75 (d, J = 10.2 Hz, 1H), 2.63 (q, J = 7.5 Hz, 2H), 1.48 (s, 3H), 1.43 (s, 3H), 1.22 (t, J = 7.5 Hz, 3H); ^{13}C NMR (75 MHz, CDCl_3) δ

195.1, 151.4, 141.3, 134.7, 128.7, 119.0, 111.2, 99.3, 77.7, 75.7, 61.2, 50.1, 28.5, 27.4, 26.3, 15.9. HRMS calcd for C₁₈H₂₂NO₆ (M⁺+1) 348.1447, found 348.1441.

Ketone 4c

mp 135-136 °C; $[\alpha]_D^{20} = -28.4$ (*c*, 0.66, CHCl₃); IR (film) 1776 cm⁻¹; ¹H NMR (300 MHz, CDCl₃) δ 7.41 (d, *J* = 8.4 Hz, 2H), 7.19 (d, *J* = 8.4 Hz, 2H), 4.86 (d, *J* = 5.4 Hz, 1H), 4.73 (d, *J* = 10.2 Hz, 1H), 4.66-4.58 (m, 2H), 4.25 (d, *J* = 14.4 Hz, 1H), 3.74 (d, *J* = 10.2 Hz, 1H), 2.56 (t, *J* = 7.5 Hz, 2H), 1.68-1.54 (m, 2H), 1.48 (s, 3H), 1.42 (s, 3H), 0.92 (t, *J* = 7.5 Hz, 3H); ¹³C NMR (75 MHz, CDCl₃) δ 195.1, 151.3, 139.7, 134.7, 129.3, 118.9, 111.2, 99.2, 77.7, 75.7, 61.1, 50.0, 37.5, 27.4, 26.2, 24.8, 14.0. Anal. Calcd for C₁₉H₂₃NO₆: C, 63.15; H, 6.41; N, 3.88. Found: C, 62.88; H, 6.41; N, 3.61.

Ketone 4d

mp 180–182 °C; $[\alpha]_D^{20} = -33.1$ (*c*, 0.51, CHCl₃); IR (film) 1775 cm⁻¹; ¹H NMR (300 MHz, CDCl₃) δ 7.43 (d, *J* = 8.4 Hz, 2H), 7.24 (d, *J* = 8.4 Hz, 2H), 4.87 (d, *J* = 5.1 Hz, 1H), 4.75 (d, *J* = 10.5 Hz, 1H), 4.67-4.60 (m, 2H), 4.26 (d, *J* = 14.4 Hz, 1H), 3.75 (d, *J* = 10.5 Hz, 1H), 2.96-2.84

(m, 1H), 1.48 (s, 3H), 1.43 (s, 3H), 1.23 (d, $J = 6.9$ Hz, 6H); ^{13}C NMR (100 MHz, CDCl_3) δ 195.3, 151.4, 146.0, 134.8, 127.3, 119.1, 111.2, 99.2, 77.6, 75.6, 61.1, 50.0, 33.7, 27.3, 26.1, 24.1. Anal. Calcd for $\text{C}_{19}\text{H}_{23}\text{NO}_6$: C, 63.15; H, 6.41; N, 3.88. Found: C, 63.24; H, 6.39; N, 3.76.

Ketone 4e

mp 164-166 °C; $[\alpha]_D^{20} = -32.9$ (c , 0.28, CHCl_3); IR (film) 1776 cm^{-1} ; ^1H NMR (300 MHz, CDCl_3) δ 7.45-7.39 (m, 2H), 7.22-7.14 (m, 2H), 4.87 (d, $J = 5.4$ Hz, 1H), 4.74 (d, $J = 10.5$ Hz, 1H), 4.66-4.60 (m, 2H), 4.26 (d, $J = 13.8$ Hz, 1H), 3.75 (d, $J = 10.5$ Hz, 1H), 2.59 (t, $J = 7.5$ Hz, 2H), 1.63-1.57 (m, 2H), 1.48 (s, 3H), 1.43 (s, 3H), 1.41-1.26 (m, 2H), 0.91 (t, $J = 7.5$ Hz, 3H); ^{13}C NMR (75 MHz, CDCl_3) δ 195.3, 151.5, 140.1, 134.8, 129.4, 119.0, 111.3, 99.3, 77.7, 75.7, 61.1, 50.0, 35.1, 33.8, 27.3, 26.2, 22.4, 14.1. Anal. Calcd for $\text{C}_{20}\text{H}_{25}\text{NO}_6$: C, 63.99; H, 6.71; N, 3.73. Found: C, 64.00; H, 6.77; N, 3.76.

Ketone 4f

mp 172-174 °C; $[\alpha]_D^{20} = -36.0$ (c , 0.28, CHCl_3); IR (film) 1775 cm^{-1} ; ^1H NMR (400 MHz, CDCl_3) δ 7.47-7.36 (m, 4H), 4.87 (d, $J = 5.2$ Hz, 1H), 4.75 (d, $J = 10.4$ Hz, 1H), 4.67-4.60 (m,

2H), 4.27 (d, $J = 14.0$ Hz, 1H), 3.75 (d, $J = 10.4$ Hz, 1H), 1.49 (s, 3H), 1.43 (s, 3H), 1.31 (s, 9H); ^{13}C NMR (100 MHz, CDCl_3) δ 195.3, 151.5, 148.3, 134.6, 126.3, 118.8, 111.3, 99.3, 77.7, 75.7, 61.1, 50.0, 34.6, 31.5, 27.3, 26.2. HRMS calcd for $\text{C}_{20}\text{H}_{26}\text{NO}_6$ ($\text{M}^+ + 1$) 376.1760, found 376.1764.

Ketone 4g

mp 93-94 °C; $[\alpha]_D^{20} = -26.9$ (c , 0.36, CHCl_3); IR (film) 1776 cm^{-1} ; ^1H NMR (300 MHz, CDCl_3) δ 7.42 (d, $J = 7.8$ Hz, 2H), 7.20 (d, $J = 7.8$ Hz, 2H), 4.87 (d, $J = 5.4$ Hz, 1H), 4.75 (d, $J = 10.8$ Hz, 1H), 4.67-4.60 (m, 2H), 4.26 (d, $J = 14.4$ Hz, 1H), 3.75 (d, $J = 10.8$ Hz, 1H), 2.59 (t, $J = 7.2$ Hz, 2H), 1.66-1.52 (m, 2H), 1.49 (s, 3H), 1.44 (s, 3H), 1.36-1.24 (m, 4H), 0.89 (t, $J = 6.9$ Hz, 3H); ^{13}C NMR (75 MHz, CDCl_3) δ 195.2, 151.3, 139.9, 134.7, 129.2, 118.8, 111.1, 99.2, 77.6, 75.6, 61.0, 49.9, 35.3, 31.4, 31.2, 27.2, 26.1, 22.6, 14.1. Anal. Calcd for $\text{C}_{21}\text{H}_{27}\text{NO}_6$: C, 64.77; H, 6.99; N, 3.60. Found: C, 64.90; H, 6.99; N, 3.49.

Ketone 4h

mp 71-72 °C; $[\alpha]_D^{20} = -30.5$ (*c*, 0.44, CHCl₃); IR (film) 1777 cm⁻¹; ¹H NMR (300 MHz, CDCl₃) δ 7.41 (d, *J* = 8.4 Hz, 2H), 7.19 (d, *J* = 8.4 Hz, 2H), 4.87 (d, *J* = 5.1 Hz, 1H), 4.74 (d, *J* = 10.5 Hz, 1H), 4.67-4.60 (m, 2H), 4.26 (d, *J* = 13.8 Hz, 1H), 3.75 (d, *J* = 10.5 Hz, 1H), 2.58 (t, *J* = 7.5 Hz, 2H), 1.66-1.52 (m, 2H), 1.49 (s, 3H), 1.43 (s, 3H), 1.36-1.22 (m, 8H), 0.88 (t, *J* = 7.2 Hz, 3H); ¹³C NMR (75 MHz, CDCl₃) δ 195.3, 151.3, 139.9, 134.7, 129.2, 118.8, 111.1, 99.2, 77.6, 75.6, 61.0, 49.9, 35.3, 31.8, 31.5, 29.2, 27.2, 26.0, 22.7, 14.2. Anal. Calcd for C₂₃H₃₁NO₆: C, 66.17; H, 7.48; N, 3.35. Found: C, 66.10; H, 7.55; N, 3.18.

Ketone 4i

mp 110-111 °C; $[\alpha]_D^{20} = -40.6$ (*c*, 0.32, CHCl₃); IR (film) 3436, 1774 cm⁻¹; ketone: ¹H NMR (300 MHz, CDCl₃) δ 7.44-7.38 (m, 2H), 7.24-7.12 (m, 2H), 4.87 (d, *J* = 5.1 Hz, 1H), 4.74 (d, *J* = 10.5 Hz, 1H), 4.68-4.60 (m, 2H), 4.26 (d, *J* = 13.8 Hz, 1H), 3.75 (d, *J* = 10.5 Hz, 1H), 2.62-2.54 (m, 2H), 1.63-1.52 (m, 2H), 1.49 (s, 3H), 1.43 (s, 3H), 1.34-1.20 (m, 14H), 0.87 (t, *J* = 6.9 Hz, 3H); hydrate: ¹³C NMR (100 MHz, CDCl₃) δ 153.3, 139.0, 135.1, 128.8, 118.8, 110.0, 101.9, 91.2, 76.0, 73.3, 63.3, 53.6, 35.2, 31.8, 31.4, 29.6, 29.5, 29.3, 29.2, 26.1, 24.6, 22.6, 14.0. Anal. Calcd for C₂₆H₃₇NO₆: C, 67.95; H, 8.11; N, 3.05. Found: C, 68.12; H, 7.94; N, 3.04.

Ketone 4j

mp 48-50 °C; $[\alpha]_D^{20} = -47.2$ (*c*, 0.13, CHCl₃); IR (film) 3406, 1762 cm⁻¹; ¹H NMR (300 MHz, CDCl₃) δ 7.46-7.38 (m, 2H), 7.31-7.13 (m, 7H), 4.86 (d, *J* = 5.6 Hz, 1H), 4.72 (d, *J* = 10.4 Hz, 1H), 4.65-4.58 (m, 2H), 4.25 (d, *J* = 12.8 Hz, 1H), 3.96 (s, 2H), 3.73 (d, *J* = 10.4 Hz, 1H), 1.48 (s, 3H), 1.42 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) 195.3, 151.4, 140.9, 138.2, 135.3, 129.9, 129.0, 128.7, 126.4, 119.0, 111.2, 99.3, 77.6, 75.6, 61.1, 49.9, 41.4, 27.3, 26.1. HRMS calcd for C₂₃H₂₄NO₆ (*M*⁺+1) 410.1604, found 410.1603.

Ketone 4k

mp 76-78 °C; $[\alpha]_D^{20} = -77.9$ (*c*, 0.20, CHCl₃); IR (film) 1776 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 7.65-7.55 (m, 6H), 7.46-7.42 (m, 2H), 7.37-7.33 (m, 1H), 4.89 (d, *J* = 5.6 Hz, 1H), 4.80 (d, *J* = 10.4 Hz, 1H), 4.68-4.61 (m, 2H), 4.28 (d, *J* = 12.8 Hz, 1H), 3.81 (d, *J* = 10.4 Hz, 1H), 1.50 (s, 3H), 1.44 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 195.2, 151.3, 140.2, 138.0, 136.4, 129.0, 128.0, 127.6, 127.1, 119.1, 111.3, 99.3, 77.7, 75.7, 61.2, 49.9, 27.3, 26.2; HRMS calcd for C₂₂H₂₂NO₆ (*M*⁺+1) 396.1447, found 396.1440.

Ketone 4l

mp 52-56 °C; $[\alpha]_D^{20} = -39.2$ (*c*, 0.28, CHCl₃); IR (film) 1764 cm⁻¹; ¹H NMR (300 MHz, CDCl₃) δ 7.43-7.26 (m, 7H), 7.01-6.92 (m, 2H), 5.05 (s, 2H), 4.86 (d, *J* = 4.8 Hz, 1H), 4.71 (d, *J* = 10.8 Hz, 1H), 4.66-4.58 (m, 2H), 4.26 (d, *J* = 14.4 Hz, 1H), 3.72 (d, *J* = 10.8 Hz, 1H), 1.48 (s, 3H), 1.43 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) 195.3, 156.3, 151.6, 136.9, 130.4, 128.8, 128.3, 127.6, 121.0, 115.7, 111.2, 99.3, 77.7, 75.7, 70.5, 61.1, 50.3, 27.3, 26.2; HRMS calcd for C₂₃H₂₃NO₇ (M⁺) 425.1475, found 425.1469.

Ketone 4m

mp 136–138 °C; $[\alpha]_D^{20} = -5.9$ (*c*, 1.75, CHCl₃); IR (film) 3385, 1752 cm⁻¹; hydrate: ¹H NMR (400 MHz, CDCl₃) δ 7.46-7.40 (m, 2H), 7.35-7.26 (m, 2H), 7.12-7.04 (m, 1H), 7.00-6.94 (m, 4H), 4.59 (d, *J* = 10.0 Hz, 1H), 4.46 (d, *J* = 7.2 Hz, 1H), 4.42 (m, 1H), 4.33 (d, *J* = 12.8, 2.4 Hz, 1H), 3.95 (d, *J* = 12.8 Hz, 1H), 3.80 (d, *J* = 10.0 Hz, 1H), 2.32 (brs, H), 1.56 (s, 3H), 1.38 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 157.4, 154.1, 153.5, 132.9, 129.9, 123.5, 120.9, 119.6,

118.8, 110.4, 102.0, 91.2, 76.2, 73.4, 63.4, 53.8, 26.4, 24.8. HRMS calcd for $C_{22}H_{21}NO_7$ (M^+) 411.1318, found 411.1326.

Ketone 4n

mp 56-59 °C; $[\alpha]_D^{20} = -47.6$ (*c*, 0.15, $CHCl_3$); IR (film) 3419, 1760 cm^{-1} ; 1H NMR (300 MHz, $CDCl_3$) δ 7.48-7.40 (m, 2H), 7.16-7.08 (m, 2H), 7.02-6.85 (m, 4H), 4.87 (d, *J* = 5.6 Hz, 1H), 4.74 (d, *J* = 10.4 Hz, 1H), 4.66-4.59 (m, 2H), 4.27 (d, *J* = 13.2 Hz, 1H), 3.74 (d, *J* = 10.4 Hz, 1H), 2.33 (s, 3H), 1.48 (s, 3H), 1.43 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) 195.3, 155.2, 154.7, 151.6, 133.3, 132.1, 130.5, 120.8, 119.2, 119.1, 111.2, 99.3, 77.6, 75.6, 61.1, 50.2, 27.3, 26.1, 20.9. HRMS calcd for $C_{23}H_{23}NO_7$ (M^+) 425.1475, found 425.1465.

Ketone 4o

mp 116-118 °C; $[\alpha]_D^{20} = -24.3$ (*c*, 0.61, $CHCl_3$); IR (film) 1778, 1760 cm^{-1} ; 1H NMR (400 MHz, $CDCl_3$) δ 7.36-7.25 (m, 3H), 6.99 (d, *J* = 6.8 Hz, 1H), 4.87 (d, *J* = 4.8 Hz, 1H), 4.74 (d, *J* = 10.4 Hz, 1H), 4.67-4.59 (m, 2H), 4.26 (d, *J* = 13.6 Hz, 1H), 3.75 (d, *J* = 10.4 Hz, 1H), 2.37 (s, 3H), 1.48 (s, 3H), 1.43 (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 195.2, 151.2, 139.4, 137.1,

129.2, 125.9, 119.5, 115.9, 111.1, 99.2, 77.6, 75.6, 61.0, 49.9, 27.2, 26.1, 21.7; Anal. Calcd for $C_{17}H_{19}NO_6$: C, 61.25; H, 5.75; N, 4.20. Found: C, 61.02; H, 5.61; N, 4.10.

Ketone 4p

mp 135-136 °C; $[\alpha]_D^{20} = -25.1$ (*c*, 0.48, $CHCl_3$); IR (film) 1777 cm^{-1} ; 1H NMR (300 MHz, $CDCl_3$) δ 7.38-7.24 (m, 3H), 7.03 (m, 1H), 4.87 (d, *J* = 5.4 Hz, 1H), 4.77 (d, *J* = 10.5 Hz, 1H), 4.67-4.60 (m, 2H), 4.27 (d, *J* = 14.4 Hz, 1H), 3.77 (d, *J* = 10.5 Hz, 1H), 2.67 (q, *J* = 7.8 Hz, 2H), 1.49 (s, 3H), 1.44 (s, 3H), 1.24 (t, *J* = 7.8 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) 195.3, 151.4, 145.8, 137.2, 129.3, 124.8, 118.5, 116.3, 111.2, 99.2, 77.7, 75.7, 61.1, 50.0, 29.2, 27.3, 26.2, 15.7. Anal. Calcd for $C_{18}H_{21}NO_6$: C, 62.24; H, 6.09; N, 4.03. Found: C, 62.50; H, 6.13; N, 3.86.

Ketone 4q

mp 125-126 °C; $[\alpha]_D^{20} = -26.5$ (*c*, 0.22, $CHCl_3$); IR (film) 1775 cm^{-1} ; 1H NMR (300 MHz, $CDCl_3$) δ 7.39 (s, 1H), 7.33-7.30 (m, 2H), 7.08-7.03 (m, 2H), 4.87 (d, *J* = 5.1 Hz, 1H), 4.77 (d, *J* = 10.5 Hz, 1H), 4.67-4.60 (m, 2H), 4.27 (d, *J* = 14.1 Hz, 1H), 3.77 (d, *J* = 10.5 Hz, 1H), 3.00-2.84 (m, 1H), 1.49 (s, 3H), 1.43 (s, 3H), 1.25 (d, *J* = 6.9 Hz, 6H); ^{13}C NMR (100 MHz, $CDCl_3$) δ

195.3, 151.3, 150.4, 137.1, 129.3, 123.2, 117.1, 116.4, 111.2, 99.2, 77.6, 75.6, 61.0, 50.0, 34.4, 27.2, 26.1, 24.1, 24.0. Anal. Calcd for C₁₉H₂₃NO₆: C, 63.15; H, 6.41; N, 3.88. Found: C, 63.31; H, 6.48; N, 3.76.

Ketone 4r

mp 58-60 °C; $[\alpha]_D^{20} = -46.0$ (*c*, 0.15, CHCl₃); IR (film) 3411, 1759 cm⁻¹; ketone: ¹H NMR (400 MHz, CDCl₃) δ 7.38-7.16 (m, 8H), 7.01 (d, *J* = 7.6 Hz, 1H), 4.86 (d, *J* = 5.6 Hz, 1H), 4.71 (d, *J* = 10.4 Hz, 1H), 4.65-4.58 (m, 2H), 4.24 (d, *J* = 13.6 Hz, 1H), 3.99 (s, 2H), 3.72 (d, *J* = 10.4 Hz, 1H), 1.48 (s, 3H), 1.42 (s, 3H); hydrate: ¹³C NMR (100 MHz, CDCl₃) 153.1, 142.4, 140.7, 137.8, 129.3, 129.0, 128.7, 126.4, 125.3, 119.3, 116.6, 110.3, 101.6, 91.0, 76.2, 73.3, 63.0, 53.2, 42.1, 27.3, 24.8; HRMS calcd for C₂₃H₂₄NO₆ (*M*⁺+1) 410.1604, found 410.1616.

Ketone 4s

mp 136-138 °C; $[\alpha]_D^{20} = -40.8$ (*c*, 5.4, CHCl₃); IR (film) 1778 cm⁻¹; ¹H NMR (300 MHz, CDCl₃) δ 7.38-7.22 (m, 5H), 7.14-7.09 (m, 1H), 7.04-6.98 (m, 2H), 6.81-6.76 (m, 1H), 4.85 (d, *J* = 5.4 Hz, 1H), 4.70 (d, *J* = 10.5 Hz, 1H), 4.65-4.56 (m, 2H), 4.25 (d, *J* = 12.6 Hz, 1H), 3.73 (d,

$J = 10.5$ Hz, 1H), 1.47 (s, 3H), 1.42 (s, 3H); ^{13}C NMR (75 MHz, CDCl_3) δ 195.0, 158.1, 156.6, 151.0, 138.5, 130.3, 129.9, 123.8, 119.1, 114.9, 113.1, 111.2, 109.4, 99.2, 77.7, 75.6, 61.2, 49.9, 27.3, 26.2. HRMS calcd for $\text{C}_{22}\text{H}_{21}\text{NO}_7(\text{M}^+)$ 411.1318, found 411.1305.

Ketone 4t

mp 191–193 °C; $[\alpha]_{\text{D}}^{20} = -37.4$ (c , 0.50, CHCl_3); IR (film) 1773, 1756 cm^{-1} ; ^1H NMR (300 MHz, CDCl_3) δ 7.30–7.12 (m, 3H), 4.87 (d, $J = 5.1$ Hz, 1H), 4.74 (d, $J = 10.5$ Hz, 1H), 4.67–4.60 (m, 2H), 4.26 (d, $J = 13.5$ Hz, 1H), 3.73 (d, $J = 10.5$ Hz, 1H), 2.27 (s, 3H), 2.24 (s, 3H), 1.48 (s, 3H), 1.43 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 195.3, 151.4, 137.7, 134.8, 133.6, 130.3, 120.3, 116.5, 111.1, 99.2, 77.6, 75.6, 61.0, 50.0, 27.2, 26.1, 20.1, 19.3. Anal. Calcd for $\text{C}_{18}\text{H}_{21}\text{NO}_6$: C, 62.24; H, 6.09; N, 4.03. Found: C, 62.30; H, 5.85; N, 3.99.

Ketone 4u

mp 108–110 °C; $[\alpha]_{\text{D}}^{20} = -21.2$ (c , 0.34, CHCl_3); IR (film) 1772 cm^{-1} ; ^1H NMR (400 MHz, CDCl_3) δ 7.35 (d, $J = 2.2$ Hz, 1H), 6.86 (d, $J = 8.8$ Hz, 1H), 6.79 (dd, $J = 8.8, 2.2$ Hz, 1H), 4.88 (d, $J = 5.2$ Hz, 1H), 4.74 (d, $J = 10.4$ Hz, 1H), 4.66–4.60 (m, 2H), 4.27 (d, $J = 13.2$ Hz, 1H), 3.91

(s, 3H), 3.88 (s, 3H), 3.74 (d, $J = 10.4$ Hz, 1H), 1.48 (s, 3H), 1.43 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 195.3, 151.4, 149.4, 146.6, 130.6, 111.3, 111.1, 111.0, 104.0, 99.1, 77.6, 75.6, 61.0, 56.2, 56.1, 50.3, 27.2, 26.1; HRMS calcd for $\text{C}_{18}\text{H}_{21}\text{NO}_8(\text{M}^+)$ 379.1267, found 379.1268.

Ketone 4v

mp 146-148 °C; $[\alpha]_{\text{D}}^{20} = -44.4$ (c , 0.135, CHCl_3); IR (film) 3404, 1774 cm^{-1} ; ketone: ^1H NMR (300 MHz, CDCl_3) δ 7.70 (d, $J = 2.4$ Hz, 1H), 7.37 (dd, $J = 8.4, 2.4$ Hz, 1H), 7.21 (d, $J = 8.4$ Hz, 1H), 4.85 (d, $J = 5.4$ Hz, 1H), 4.69 (d, $J = 10.2$ Hz, 1H), 4.66-4.55 (m, 2H), 4.25 (d, $J = 12.6$ Hz, 1H), 3.71 (d, $J = 10.2$ Hz, 1H), 2.35 (s, 3H), 1.46 (s, 3H), 1.41 (s, 3H); hydrate: ^{13}C NMR (100 MHz, CDCl_3) δ 152.9, 136.4, 133.7, 130.7, 124.9, 122.1, 117.4, 110.1, 101.9, 91.1, 76.0, 73.3, 63.4, 53.3, 26.2, 24.7, 22.1. HRMS calcd for $\text{C}_{17}\text{H}_{18}\text{BrNO}_6(\text{M}^+\text{H})$ 412.0396, found 412.0395.

Ketone 4w

mp 161-162 °C; $[\alpha]_{\text{D}}^{20} = -17.8$ (c , 0.47, CHCl_3); IR (film) 1774 cm^{-1} ; ^1H NMR (300 MHz, CDCl_3) δ 7.92 (d, $J = 2.4$ Hz, 1H), 7.46 (dd, $J = 8.4, 2.4$ Hz, 1H), 7.23 (d, $J = 8.4$ Hz, 1H), 4.86 (d, $J = 5.7$ Hz, 1H), 4.71 (d, $J = 10.2$ Hz, 1H), 4.66-4.58 (m, 2H), 4.27 (d, $J = 13.8$ Hz, 1H), 3.72

(d, $J = 10.2$ Hz, 1H), 2.41 (s, 3H), 1.48 (s, 3H), 1.43 (s, 3H); ^{13}C NMR (75 MHz, CDCl_3) δ 195.1, 151.1, 138.3, 135.7, 129.8, 128.7, 118.6, 111.2, 101.1, 99.3, 77.5, 75.6, 61.1, 49.8, 27.5, 27.2, 26.1. Anal. Calcd for $\text{C}_{17}\text{H}_{18}\text{INO}_6$: C, 44.46; H, 3.95; N, 3.05. Found: C, 44.26; H, 4.15; N, 2.76.

Ketone 4x

mp 154-155 °C; $[\alpha]_D^{20} = -23.5$ (c , 0.77, CHCl_3); IR (film) 1776 cm^{-1} ; ^1H NMR (400 MHz, CDCl_3) δ 7.15 (s, 2H), 6.84 (s, 1H), 4.88 (d, $J = 5.2$ Hz, 1H), 4.76 (d, $J = 10.8$ Hz, 1H), 4.67-4.63 (m, 2H), 4.27 (d, $J = 13.2$ Hz, 1H), 3.75 (d, $J = 10.8$ Hz, 1H), 2.34 (s, 6H), 1.50 (s, 3H), 1.45 (s, 3H); ^{13}C NMR (100 MHz, CDCl_3) δ 195.3, 139.3, 137.1, 127.0, 116.9, 111.3, 99.2, 77.7, 75.7, 61.1, 50.1, 27.3, 26.2, 21.7. HRMS calcd for $\text{C}_{18}\text{H}_{21}\text{NO}_6$ (M^+) 347.1369, found 347.1370.

Ketone 4y

mp 58-66 °C; $[\alpha]_D^{20} = -44.8$ (*c*, 0.25, CHCl₃); IR (film) 3450, 1759 cm⁻¹; hydrate: ¹H NMR (400 MHz, CDCl₃) δ 6.75 (s, 2H), 4.62 (d, *J* = 10.0 Hz, 1H), 4.47 (d, *J* = 6.8 Hz, 1H), 4.42 (m, 1H), 4.32 (dd, *J* = 12.8, 2.4 Hz, 1H), 3.94 (d, *J* = 12.8 Hz, 1H), 3.82-3.78 (m, 10 H), 1.56 (s, 3H), 1.39 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 153.3, 153.2, 135.0, 133.5, 110.1, 101.7, 97.1, 91.1, 76.0, 73.2, 63.3, 60.8, 56.1, 53.8, 26.2, 24.6. HRMS calcd for C₁₉H₂₃NO₉ (M⁺) 409.1373, found 409.1369.

Ketone 4z

mp 78-80 °C; $[\alpha]_D^{20} = -45.7$ (*c*, 0.07, CHCl₃); IR (film) 3450, 1774 cm⁻¹; ¹H NMR (300 MHz, CDCl₃) δ 7.43-7.38 (m, 1H), 7.23-7.16 (m, 2H), 4.87 (d, *J* = 5.4 Hz, 1H), 4.74 (d, *J* = 10.5 Hz, 1H), 4.67-4.60 (m, 2H), 4.26 (d, *J* = 13.8 Hz, 1H), 3.74 (d, *J* = 10.5 Hz, 1H), 2.94-2.82 (m, 4H), 2.13-2.02 (m, 2H), 1.48 (s, 3H), 1.43 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 153.4, 145.6, 141.1, 135.7, 124.8, 117.4, 115.9, 110.4, 101.7, 91.1, 76.2, 73.4, 63.0, 53.8, 33.2, 32.5, 26.5, 25.8, 24.9. Anal. Calcd for C₁₉H₂₁NO₆: C, 63.50; H, 5.89; N, 3.90. Found: C, 63.39; H, 5.76; N, 3.79.

Ketone 4aa

mp 138-140 °C; $[\alpha]_D^{20} = -34.8$ (*c*, 0.46, EtOH); IR (film) 3374, 1748 cm^{-1} ; hydrate: ^1H NMR (300 MHz, CDCl_3) δ 7.22 (s, 1H), 6.76 (m, 2H), 5.96 (s, 2H), 4.48 (d, $J = 9.9$ Hz, 1H), 4.43 (m, 2H), 4.35-4.28 (m, 1H), 4.01 (d, $J = 13.2$ Hz, 1H), 3.81 (brs, 1H), 3.78 (d, $J = 9.9$ Hz, 1H), 3.56 (brs, 1H), 1.59 (s, 3H), 1.41 (s, 3H); ^{13}C NMR (100 MHz, $\text{CO}(\text{CD}_3)_2$) δ 153.4, 149.0, 145.0, 134.0, 112.1, 110.5, 108.8, 102.4, 101.7, 92.4, 77.4, 74.5, 64.8, 55.1, 26.7, 25.0. HRMS calcd for $\text{C}_{17}\text{H}_{17}\text{NO}_8$ (M^+) 363.0954, found 363.0951.

Ketone 4bb

mp 140-142 °C; $[\alpha]_D^{20} = -33.3$ (*c*, 0.38, EtOH); IR (film) 3400, 1749 cm^{-1} ; hydrate: ^1H NMR (300 MHz, CDCl_3) δ 7.06 (d, $J = 2.4$ Hz, 1H), 6.97 (dd, $J = 8.7, 2.4$ Hz, 1H), 6.83 (d, $J = 8.7$ Hz, 1H), 4.47 (d, $J = 10.2$ Hz, 1H), 4.42 (s, 2H), 4.32 (dd, $J = 13.2, 1.8$ Hz, 1H), 4.26-4.20 (m, 4H), 4.01 (d, $J = 13.2$ Hz, 1H), 3.77 (d, $J = 10.2$ Hz, 1H), 3.72 (brs, 1H), 3.46 (brs, 1H), 1.59 (s, 3H), 1.41 (s, 3H); ^{13}C NMR (100 MHz, $\text{CO}(\text{CD}_3)_2$) δ 153.3, 144.7, 141.2, 133.2, 118.0, 112.2, 110.4, 108.6, 102.4, 92.4, 77.4, 74.5, 65.4, 65.1, 64.7, 54.8, 26.7, 25.0. Anal. Calcd for $\text{C}_{18}\text{H}_{19}\text{NO}_8$: C, 57.29; H, 5.08; N, 3.71. Found: C, 57.15; H, 5.15; N, 3.53.

Ketone 4cc

mp 195-197 °C; $[\alpha]_D^{20} = -82.6$ (*c*, 0.12, CHCl₃); IR (film) 3400, 1757 cm⁻¹; hydrate: ¹H NMR (300 MHz, CDCl₃) δ 7.75-7.64 (m, 3H), 7.48-7.24 (m, 4H), 4.63 (d, *J* = 10.2 Hz, 1H), 4.46 (m, 2H), 4.35 (dd, *J* = 12.9, 2.1 Hz, 1H), 4.05 (brs, 1H), 4.02 (d, *J* = 12.9 Hz, 1H), 3.88 (d, *J* = 10.2 Hz, 1H), 3.88 (brs, 1H), 3.81 (s, 2H), 1.61 (s, 3H), 1.42 (s, 3H); ¹³C NMR (100 MHz, CDCl₃) δ 153.3, 144.5, 143.3, 141.1, 138.6, 136.2, 127.0, 126.7, 125.2, 120.3, 119.9, 117.8, 116.2, 110.5, 101.9, 91.3, 76.2, 73.4, 63.2, 53.7, 37.2, 26.5, 24.9. HRMS calcd for C₂₃H₂₂NO₆ (M⁺+1) 408.1447, found 408.1439.

The chromatograms for the determination of enantiomeric excess of the epoxides.

(R)-Styrene oxide (Table 2, Entry 1)

GC Cond.: Column: Chiraldex BDM (Cat. No. 77023), Adv. Separation Technologies, Inc.
Oven: 80° C; Carrier: Helium, head pressure 25 psi: Detection: FID 250° C

2-Fluorostyrene oxide (Table 2, Entry 2)

Peak No	Peak Name	Result ()	Ret. Time (min)
1		92.8418	12.139
2		7.1583	12.819
Totals		100.0001	

GC Cond.: Column: Chiraldex BDM (Cat. No. 77023), Adv. Separation Technologies, Inc.
Oven: 80° C; Carrier: Helium, head pressure 25 psi: Detection: FID 250° C

Peak No	Peak Name	Result ()	Ret. Time (min)
1		50.3680	9.824
2		49.6320	10.394
Totals		100.0000	

Peak No	Peak Name	Result ()	Ret. Time (min)
1		89.8063	9.786
2		10.1937	10.359
Totals		100.0000	

(R)-4-Chlorostyrene oxide (Table 2, Entry 3)

Peak No	Peak Name	Result ()	Ret. Time (min)
1		49.4743	18.849
2		50.5257	19.868
Totals		100.0000

Peak No	Peak Name	Result ()	Ret. Time (min)
1		92.8989	18.791
2		7.1011	19.853
Totals		100.0000	

(R)-4-Bromostyrene oxide (Table 2, Entry 4)

Peak No	Peak Name	Result ()	Ret. Time (min)
1		49.4556	22.192
2		50.5444	23.179
Totals		100.0000

Peak No	Peak Name	Result ()	Ret. Time (min)
1		93.4894	22.286
2		6.5106	23.301
Totals		100.0000	

(R)-4-Cyanoostyrene oxide (Table 2, Entry 5)

GC Cond.: Column: Chiraldex BDM (Cat. No. 77023), Adv. Separation Technologies, Inc.
Oven: 115° C; Carrier: Helium, head pressure 25 psi: Detection: FID 250° C

Peak No	Peak Name	Result ()	Ret. Time (min)
1		49.7992	32.951
2		50.2008	34.572
Totals		100.0000

Peak No	Peak Name	Result ()	Ret. Time (min)
1		95.1693	33.018
2		4.8307	35.004
Totals		100.0000	

(R)-4-Nitrostyrene oxide (Table 2, Entry 6)

GC Cond.: Column: Chiraldex BDM (Cat. No. 77023), Adv. Separation Technologies, Inc.
Oven: 125° C; Carrier: Helium, head pressure 30 psi: Detection: FID 250° C

Peak No	Peak Name	Result ()	Ret. Time (min)
1		49.6084	33.397
2		50.3916	34.909
Totals		100.0000

Peak No	Peak Name	Result ()	Ret. Time (min)
1		95.0826	33.224
2		4.9174	34.899
Totals		100.0000	

4-Trifluoromethylstyrene oxide (Table 2, Entry 7)

Peak No	Peak Name	Result ()	Ret. Time (min)
1		50.3194	19.104
2		49.6806	20.927
Totals		100.0000	

Chiral Epoxide

Peak No	Peak Name	Result ()	Ret. Time (min)
1		95.8819	18.983
2		4.1181	20.897
Totals		100.0000	

3-Benzyloxystyrene oxide (Table 2, Entry 8)

HPLC Cond.: Column: Chiralcel AD (Column No. AD00CE-BE096), Chiral Technologies, Inc.
Eluent: Hexane/IPA (95/5); Flow Rate: (1.0 mL/min); Detection: UV 270

Racemate

Peak No	Peak Name	Result ()	Ret. Time (min)
1		49.9238	8.596
2		50.0763	9.671
Totals		00.0001	

Chiral Epoxide

Peak No	Peak Name	Result ()	Ret. Time (min)
1		93.2806	8.113
2		6.7194	9.001
Totals		00.0000	

3-Methylstyrene oxide (Table 2, Entry 9)

GC Cond.: Column: Chiraldex BDM (Cat. No. 77023), Adv. Separation Technologies, Inc.
Oven: 60° C; Carrier: Helium, head pressure 20 psi; Detection: FID 250° C

Peak No	Peak Name	Result ()	Ret. Time (min)
1		50.1996	76.842
2		49.8004	80.891
Totals		100.0000

Peak No	Peak Name	Result ()	Ret. Time (min)
1		95.0948	75.116
2		4.9052	80.199
Totals		100.0000	

3-Chlorostyrene oxide (Table 2, Entry 10)

HPLC Cond.: Column: Chiralcel OD (Column No. OD00CE-DL010), Chiral Technologies, Inc.
Eluent: Hexane/IPA (99/1); Flow Rate: (1.0 mL/min) Detection: UV 220

Peak No	Peak Name	Ret Time (min)	Result ()
1		13.979	50.0626
2		15.858	49.9374
Totals			100.0000

Peak No	Peak Name	Ret Time (min)	Result ()
1		14.283	92.9896
2		16.456	7.0104
Totals			100.0000

3-Nitrostyrene oxide (Table 2, Entry 11)

HPLC Cond.: Column: Chiralcel OD (Column No. OD00CE-DL010), Chiral Technologies, Inc.

Eluent: Hexane/IPA (95/5); **Flow Rate:** (1.0 mL/min) **Detection:** UV 254

Racemate

Peak No	Peak Name	Ret Time (min)	Result ()
1		9.969	50.6367
2		11.011	49.3633
Totals			100.0000

Chiral Epoxide

Peak No	Peak Name	Ret Time (min)	Result ()
1		11.182	6.2420
2		12.449	93.7580
Totals			100.0000

2-Naphthalene oxide (Table 2, Entry 12)

HPLC Cond.: Column: Chiralcel OJ (Column No. OJ00CE-DE008), Chiral Technologies, Inc.

Eluent: Hexane/IPA (100/0); **Flow Rate:** (1.0 mL/min) **Detection:** UV 210

Racemate

Peak No	Peak Name	Ret Time (min)	Result ()
1		69.844	49.6956
2		96.201	50.3044
Totals			100.0000

Chiral Epoxide

Peak No	Peak Name	Ret Time (min)	Result ()
1		72.253	93.6696
2		109.171	6.3304
Totals			100.0000

3,4-Dichlorostyrene oxide (Table 2, Entry 13)

GC Cond.: Column: Chiraldex BDM (Cat. No. 77023), Adv. Separation Technologies, Inc.
Oven: 80° C; Carrier: Helium, head pressure 25 psi; Detection: FID 250° C

Peak No	Peak Name	Result ()	Ret. Time (min)
1		50.1752	66.447
2		49.8248	74.494
Totals		100.0000

Peak No	Peak Name	Result ()	Ret. Time (min)
1		94.7711	69.946
2		5.2289	81.523
Totals		100.0000	

3,5-Dimethylstyrene oxide (Table 2, Entry 14)

GC Cond.: Column: Chiraldex BDM (Cat. No. 77023), Adv. Separation Technologies, Inc.
Oven: 70° C; Carrier: Helium, head pressure 20 psi; Detection: FID 250° C

Peak No	Peak Name	Result ()	Ret. Time (min)
1		49.7436	88.214
2		50.2564	91.389
Totals		100.0000

Peak No	Peak Name	Result ()	Ret. Time (min)
1		5.1846	88.952
2		94.8154	91.556
Totals		100.0000