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1. General Information

All reactions were carried out under N₂ unless otherwise noted. All compounds and solvents were purified according to standard methods unless otherwise noted.

¹H NMR spectra were recorded on a VARIAN Mercury 300 MHz or VARIAN Mercury 400 MHz spectrometer in chloroform-d. All signals are reported in ppm with the internal TMS signal at 0.0 ppm or chloroform signal at 7.26 ppm as a standard. The data are reported as (s = singlet, d = doublet, t = triplet, q = quadruplet, m = multiplet or unresolved, coupling constant(s) in Hz, integration). ¹³C NMR spectra were recorded on a VARIAN Mercury 75 MHz or 100 MHz spectrometer in chloroform-d. All signals are reported in ppm with the internal chloroform signal at 77.0 ppm as a standard. IR spectra were recorded on a Perkin–Elmer 983, Digital FT–IR spectrometer or Bruker–Tensor 27; frequencies are given in reciprocal centimeters (cm⁻¹) and only selected absorbance is reported; Mass spectra were determined on an Agilent 5973N MSD (EI) and Shimadzu LCMS-2010EV (ESI) mass spectrometer or Agilent G6100 LC/MSD (ESI) single Quand mass spectrometer. High resolution mass spectra were recorded on Waters Micromass GCT Premier (EI) and Bruker Daltonics, Inc. APEXIII 7.0TESLA FTMS (ESI) mass spectrometers.
2. Synthesis of Substrates

1b as an example:

\[ \text{Salicylaldehyde (2.44 g, 20 mmol), methyl 4-bromocrotonate (4.65 g, 26 mmol), K}_2\text{CO}_3 (3.59 g, 26 mmol), and acetone (60 mL) was stirred for 15 min, and then warmed to reflux. After the completion of the reaction (monitored by TLC), the resulting mixture was cooled to room temperature, filtered rapidly through a funnel with a thin layer of silica gel and eluted with DCM. The filtrate was concentrated and the residue was purified by chromatography on silica gel (PE/EA = 5/1) to afford the desired product 9 (3.6 g, 82% yield) as a pale yellow solid.}^{1}\]

\[ \text{A solution of the aldehyde 9 (3 g, 13.6 mmol) in MeOH (30 mL) was cooled to 0 °C, and then NaBH}_4 (0.126 g, 4.54 mmol) was added in one portion. After the completion of the reaction (monitored by TLC, in half an hour), saturated NH}_4\text{Cl solution was added and the solution was extracted with EtOAc and dried with anhydrous Na}_2\text{SO}_4. The solution was filtered and concentrated. The crude product 10 was pure enough for the next step without the need of further purification.} \]

\[ \text{The crude product 10 (3 g, 13.6 mmol) was then dissolved in dry Et}_2\text{O and cooled to 0 °C, and to this solution PBr}_3 (0.52 mL, 5.44 mmol) was added dropwise. After completion of the reaction (monitored by TLC, in half an hour), saturated aq.} \]
NaHCO$_3$ was added and the solution was extracted with Et$_2$O and dried with anhydrous Na$_2$SO$_4$. The solution was filtered and concentrated. The residue was purified by column chromatography on silica gel (PE/EA = 10/1) to give substrate 1b (70 % yield) as a white solid. $^1$H NMR (300 MHz, CDCl$_3$, TMS): δ 7.37-7.28 (m, 2H), 7.13 (dt, $J = 15.6$ and 4.0 Hz, 1H), 6.99-6.94 (m, 1H), 6.83 (d, $J = 8.1$ Hz, 1H), 6.31 (dt, $J = 15.6$ and 2.1 Hz, 1H), 4.81-4.79 (m, 2H), 4.60 (s, 2H), 3.78 (s, 3H). $^{13}$C NMR (100 MHz, CDCl$_3$): δ 166.4, 155.7, 142.2, 131.0, 130.1, 126.3, 121.5, 121.3, 111.8, 66.4, 51.7, 28.7.

1a, white solid; $^1$H NMR (400 MHz, CDCl$_3$, TMS): δ 7.33 (d, $J = 2.4$ Hz, 1H), 7.23 (dd, $J = 8.8$ and 2.4 Hz, 1H), 7.10 (dt, $J = 15.6$ and 4.0 Hz, 1H), 6.75 (d, $J = 8.8$ Hz, 1H), 6.26 (dt, $J = 15.6$ and 2.2 Hz, 1H), 4.78-4.76 (m, 2H), 4.51 (s, 2H), 3.77 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 166.3, 154.3, 141.7, 130.7, 129.7, 128.1, 126.1, 121.8, 113.1, 66.9, 51.7, 27.4; IR ν/ cm$^{-1}$ 2951 (w), 1718 (m), 1490 (m), 1256 (m), 1019 (m), 808 (m); MS (EI, m/z, rel. intensity) 318 (10.2, M$^+$), 140 (100.0), 112 (58.1), 77 (44.6); Anal. Calcd for C$_{12}$H$_{12}$ClBrO$_3$: C, 45.10; H, 3.78. Found: C, 45.08; H, 3.75.

1c, white solid; $^1$H NMR (300 MHz, CDCl$_3$, TMS): δ 7.16-7.06 (m, 3H), 6.72 (d, $J = 8.4$ Hz, 1H), 6.28 (d, $J = 15.6$ Hz, 1H), 4.77-4.76 (m, 2H), 4.56 (s, 2H), 3.77 (s, 3H), 2.28 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 166.5, 153.6, 142.5, 131.5, 130.6, 130.5, 126.0, 121.3, 111.8, 66.6, 51.6, 28.9, 20.2; IR ν/ cm$^{-1}$ 2951 (w), 1722 (m), 1502 (m), 1258 (m), 1020 (m), 735 (m); MS (EI, m/z, rel. intensity) 298 (12.5, M$^+$), 219 (22.1), 91 (100.0); Anal. Calcd for C$_{13}$H$_{15}$BrO$_3$: C, 52.19; H, 5.05. Found: C, 52.11; H, 4.99.
**1d**, white solid; $^1$H NMR (400 MHz, CDCl$_3$, TMS): $\delta$ 7.11 (dt, $J$ = 15.6 and 4.0 Hz, 1H), 6.91 (d, $J$ = 3.2 Hz, 1H), 6.82-6.75 (m, 2H), 6.28 (dt, $J$ = 15.6 and 2.0 Hz, 1H), 4.74-4.73 (m, 2H), 4.55 (s, 2H), 3.78 (s, 3H), 3.77 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 166.5, 153.8, 149.9, 142.7, 127.4, 121.4, 116.4, 114.9, 113.3, 67.3, 55.7, 51.7, 28.6; IR $\nu$/ cm$^{-1}$ 12950 (w), 1715 (m), 1505 (m), 1207 (m), 1041 (m), 739 (m); MS (EI, m/z, rel. intensity) 314 (88.1, M$^+$), 236 (26.2), 162 (100.0); Anal. Calcd for C$_{13}$H$_{15}$BrO$_4$: C, 49.54; H, 4.80. Found: C, 49.75; H, 4.81.

**1e**, white solid; $^1$H NMR (400 MHz, CDCl$_3$, TMS): $\delta$ 7.27-7.25 (m, 1H), 7.11 (dt, $J$ = 15.6 and 3.8 Hz, 1H), 6.48 (dd, $J$ = 8.0 and 2.0 Hz, 1H), 6.38 (d, $J$ = 2.0 Hz, 1H), 6.30 (dt, $J$ = 15.6 and 1.8 Hz, 1H), 4.76(3)-4.75(5) (m, 2H), 4.59 (s, 2H), 3.79 (s, 3H), 3.77 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 166.5, 161.5, 156.9, 144.2, 131.8, 121.6, 118.9, 105.2, 99.8, 66.6, 55.4, 51.7, 29.5; IR $\nu$/ cm$^{-1}$ 2951 (w), 1722 (m), 1508 (m), 1167(m), 1020 (m), 737 (m); HRMS (positive ESI) calcd for C$_{13}$H$_{15}$O$_3$H$^+$ ([M-Br+H]$^+$): 236.1043; Found: 236.0997.

**1f**, colorless oil; $^1$H NMR (400 MHz, CDCl$_3$, TMS): $\delta$ 7.15-6.99 (m, 4H), 6.29 (dt, $J$ = 15.6 and 2.0 Hz, 1H), 4.89-4.87 (m, 2H), 4.53 (s, 2H), 3.78 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 166.5, 155.0 (d, $J_{C-F} = 245.7$ Hz), 144.2 (d, $J_{C-F} = 10.8$ Hz), 142.6 (d, $J_{C-F} = 1.3$ Hz), 132.6 (d, $J_{C-F} = 2.6$ Hz), 126.0 (d, $J_{C-F} = 3.1$ Hz), 124.1 (d, $J_{C-F} = 7.7$ Hz), 121.6, 117.5 (d, $J_{C-F} = 19.4$ Hz), 71.7 (d, $J_{C-F} = 7.0$ Hz), 61.7, 27.2 (d, $J_{C-F} = 3.0$ Hz); IR $\nu$/ cm$^{-1}$ 2951 (w), 1726 (m), 1478 (m), 1275 (m), 1016 (m), 789 (m); MS (EI,
m/z, rel. intensity) 302 (2.9, M⁺), 124 (100.0), 99 (34.4); HRMS (EI) calcd for C₁₂H₁₂BrFO₃ (M⁺): 301.9954; Found: 301.9957.

1g, white solid; ¹H NMR (400 MHz, CDCl₃, TMS): δ 7.47 (d, J = 2.4 Hz, 1H), 7.37 (dd, J = 8.8 and 2.4 Hz, 1H), 7.09 (dt, J = 15.6 and 3.8 Hz, 1H), 6.71 (d, J = 8.4 Hz, 1H), 6.28-6.24 (m, 1H), 4.78-4.76 (m, 2H), 6.71 (d, J = 8.4 Hz, 1H), 6.28-6.24 (m, 1H), 4.78-4.76 (m, 2H), 4.50 (s, 2H), 3.77 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 166.3, 154.8, 141.6, 133.5, 132.7, 128.5, 121.8, 113.5, 113.2, 66.8, 51.7, 27.3; IR ν/ cm⁻¹ 2950 (w), 1719 (m), 1490 (m), 1258 (m), 1021 (m), 739 (m); MS (EI, m/z, rel. intensity) 362 (11.1, M⁺), 99 (100.0), 77 (84.2); Anal. Calcd for C₁₂H₁₂BrFO₃: C, 39.59; H, 3.32. Found: C, 39.66; H, 3.62.

1h, white solid; ¹H NMR (300 MHz, CDCl₃, TMS): δ 8.04 (d, J = 9.0 Hz, 1H), 7.85-7.80 (m, 2H), 7.64-7.59 (m, 1H), 7.44-7.39 (m, 1H), 7.21-7.13 (m, 2H), 6.30 (dt, J = 15.9 and 2.1 Hz, 1H), 5.11 (s, 2H), 4.94-4.92 (m, 2H), 3.77 (s, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 166.4, 153.4, 142.4, 132.1, 131.0, 129.3, 128.5, 127.4, 124.2, 122.6, 121.7, 118.8, 113.7, 67.5, 51.7, 24.7; IR ν/ cm⁻¹ 2951 (w), 1720 (m), 1434 (m), 1225 (m), 1019 (m), 804 (m); MS (EI, m/z, rel. intensity) 256 (81.8, [M-Br]⁺), 182 (67.2), 128 (42.1), 99 (100.0); Anal. Calcd for C₁₆H₁₅BrO₃: C, 57.33; H, 4.51. Found: C, 57.23; H, 4.50.

1i, white solid; ¹H NMR (400 MHz, CDCl₃, TMS): δ 8.02-7.99 (m, 1H), 7.85-7.83 (m, 1H), 7.65 (d, J = 8.0 Hz, 1H), 7.54-7.50 (m, 2H), 7.46 (d, J = 8.4 Hz, 1H), 7.26-7.20 (m, 1H), 6.50 (dt, J = 16.0 and 2.0 Hz, 1H), 4.85-4.84 (m, 2H), 4.74 (s,
2H), 3.82 (s, 3H); $^{13}$C NMR (75 MHz, CDCl$_3$): δ 166.6, 152.6, 142.9, 135.0, 128.2, 127.8, 127.7, 127.0, 126.6(7), 126.6(6), 125.2, 122.0, 121.2, 72.6, 51.8, 28.2; IR ν/cm$^{-1}$ 2949 (w), 1719 (m), 1434 (m), 1215 (m), 815 (m), 750 (m); MS (EI, m/z, rel. intensity) 334 (98.2, M$^+$), 181 (94.8), 128 (100.0); Anal. Calcd for C$_{16}$H$_{15}$BrO$_3$: C, 57.33; H, 4.51. Found: C, 57.37; H, 4.69.

![Chemical Structure](image)

**$^{1j}$**, white solid; $^1$H NMR (400 MHz, CDCl$_3$, TMS): δ 7.35-7.32 (m, 1H), 7.25-7.21 (m, 1H), 7.05 (dd, J = 15.6 and 4.4 Hz, 1H), 6.94-6.90 (m, 1H), 6.77 (d, J = 8.4 Hz, 1H), 6.11 (dd, J = 15.6 and 1.6 Hz, 1H), 5.06-5.00 (m, 1H), 4.58 (s, 2H), 3.74 (s, 3H), 1.54 (d, J = 7.8 Hz, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 166.6, 155.2, 147.7, 131.0, 130.0, 126.7, 121.1, 120.8, 113.0, 72.7, 51.7, 29.0, 20.6; IR ν/cm$^{-1}$ 2984 (w), 1723(m), 1491 (m), 1245(m), 752 (m); MS (EI, m/z, rel. intensity) 298 (1.3, M$^+$), 219 (2.5), 107 (100.0); HRMS (EI) calcd for C$_{15}$H$_{15}$BrO$_3$ (M$^+$): 298.0205; Found: 298.0211.

![Chemical Structure](image)

**$^{1k}$**, white solid; $^1$H NMR (400 MHz, CDCl$_3$, TMS): δ 7.35 (d, J = 7.6 and 1.6 Hz, 1H), 7.30-7.26 (m, 1H), 6.98-6.93 (m, 2H), 6.83 (d, J = 8.4 Hz, 1H), 4.80 (dd, J = 5.6 and 0.8 Hz, 2H), 4.58 (s, 2H), 4.23 (q, J = 7.2 Hz, 2H), 1.94 (d, J = 1.2 Hz, 3H), 1.32 (t, J = 7.2 Hz, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 167.2, 156.1, 136.2, 131.1, 130.1(1), 130.1(0), 126.5, 121.2, 111.9, 65.3, 60.9, 28.8, 14.2, 13.1; IR ν/cm$^{-1}$ 2979 (w), 1710 (m), 1492 (m), 1246 (m), 1019 (m), 751 (m); MS (EI, m/z, rel. intensity) 312 (1.3, M$^+$), 233 (7.5), 107 (100.0); Anal. Calcd for C$_{16}$H$_{17}$BrO$_3$: C, 53.69; H, 5.47. Found: C, 53.64; H, 5.75.
1l, white solid; $^1$H NMR (400 MHz, CDCl$_3$, TMS): $\delta$ 7.47 (d, $J = 2.4$ Hz, 1H), 7.37 (dd, $J = 8.8$ and 2.4 Hz, 1H), 7.08 (dt, $J = 16.0$ and 4.0 Hz, 1H), 6.71 (d, $J = 8.4$ Hz, 1H), 6.23 (dt, $J = 16.0$ and 1.6 Hz, 1H), 4.77-4.75 (m, 2H), 4.51 (s, 2H), 4.23 (q, $J = 7.2$ Hz, 2H), 1.31 (t, $J = 7.2$ Hz, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 165.9, 154.8, 141.3, 133.6, 132.7, 128.5, 122.3, 113.6, 113.2, 66.9, 60.7, 27.3, 14.2; IR v/ cm$^{-1}$ 2962 (w), 1707 (m), 1490 (m), 1259 (m), 1019 (m), 800 (m); MS (EI, m/z, rel. intensity) 376 (14.3, M$^+$), 184 (100.0), 77 (74.3); HRMS (EI) calcd for C$_{13}$H$_{14}$Br$_2$O$_3$ (M$^+$): 375.9310; Found: 375.9309.

1m, white solid; $^1$H NMR (400 MHz, CDCl$_3$, TMS): $\delta$ 7.37-7.34 (m, 1H), 7.30-7.26 (m, 1H), 7.04-6.94 (m, 2H), 6.83 (d, $J = 8.4$ Hz, 1H), 6.17 (dt, $J = 15.6$ and 2.0 Hz, 1H), 4.77-4.76 (m, 2H), 4.60 (s, 2H), 1.50 (s, 9H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 165.3, 155.8, 140.7, 130.9, 130.1, 126.3, 123.7, 121.2, 111.9, 80.6, 66.7, 28.7, 28.0; IR v/ cm$^{-1}$ 2965 (m), 1711 (w), 1258 (m), 1020 (m), 800 (m), 750 (m); MS (EI, m/z, rel. intensity) 326 (5.11, M$^+$), 191 (100.0), 145 (58.2), 107 (77.8); HRMS (EI) calcd for C$_{15}$H$_{19}$BrO$_3$ (M$^+$): 326.0518; Found: 326.0512.

1n, white solid; $^1$H NMR (400 MHz, CDCl$_3$, TMS): $\delta$ 7.36-7.33 (m, 1H), 7.31-7.26 (m, 1H), 7.13 (dt, $J = 15.2$ and 3.6 Hz, 1H), 6.96-6.92 (m, 2H), 6.85 (d, $J = 8.0$ Hz, 1H), 4.83-4.82 (m, 2H), 4.62 (s, 2H), 3.69 (s, 3H), 3.27 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 166.2, 155.9, 140.2, 130.9, 130.2, 126.2, 121.1, 119.4, 111.8, 66.7, 62.0, 32.3, 29.0; IR v/ cm$^{-1}$ 3052 (w), 2936 (w), 1738 (m), 1381 (m), 1009 (m), 735
(m); MS (ESI, positive mode, m/z) 313.9 ([M+H]+). HRMS (positive ESI) calcd for C_{13}H_{16}BrNO_3H^+ ([M+H]^+): 314.0386; Found: 314.0385.

![Chemical Structure](image)

1o, pale yellow solid; ^1^H NMR (300 MHz, CDCl_3, TMS): δ 8.03-8.01 (m, 2H), 7.61-7.46 (m, 4H), 7.38-7.19 (m, 3H), 7.00-6.95 (m, 1H), 6.88 (d, J = 8.7 Hz, 1H), 4.91-4.90 (m, 2H), 4.66 (s, 2H); ^13^C NMR (100 MHz, CDCl_3): δ 189.7, 155.8, 141.7, 137.4, 133.0, 130.9, 130.3, 128.6(4), 128.6(0), 126.2, 125.2, 121.2, 111.8, 66.8, 29.2; IR ν/ cm⁻¹ 2960 (m), 1674 (m), 1414 (m), 1102 (m), 752 (s); MS (EI, m/z, rel. intensity) 252 (5.3, [M-Br]^+), 145 (53.8), 132 (100.0), 77 (48.8); Anal. Calcd for C_{13}H_{15}BrO_2: C, 61.65; H, 4.56. Found: C, 61.87; H, 4.56.

![Chemical Structure](image)

1p, pale yellow solid; ^1^H NMR (300 MHz, CDCl_3, TMS): δ 8.03-8.01 (m, 2H), 7.60-7.46 (m, 4H), 7.26-7.18 (m, 2H), 7.09 (d, J = 8.7 Hz, 1H), 6.77 (d, J = 8.1 Hz, 1H), 4.88-4.87 (m, 2H), 4.63 (s, 2H), 2.29 (s, 3H); ^13^C NMR (100 MHz, CDCl_3): δ 189.8, 153.8, 142.0, 137.4, 133.0, 131.6, 137.7(0), 136.6(7), 128.7, 128.6, 126.0, 125.2, 111.9, 67.0, 29.4, 20.3; IR ν/ cm⁻¹ 2912 (m), 1672 (m), 1414 (m), 1179 (m), 672 (m); HRMS (positive ESI) calcd for C_{18}H_{17}BrO_2H^+ ([M+H]^+): 345.0485; Found: 345.0472.

![Chemical Structure](image)

1q, pale yellow solid; ^1^H NMR (400 MHz, CDCl_3, TMS): δ 7.86 (d, J = 3.6 Hz, 1H), 7.68 (d, J = 3.6 Hz, 1H), 7.45-7.36 (m, 2H), 7.33-7.22 (m, 2H), 7.17-7.15 (m, 1H), 6.99-6.95 (m, 1H), 6.87 (d, J = 8.0 Hz, 1H), 4.91-4.89 (m, 2H), 4.67 (s, 2H); ^13^C NMR (100 MHz, CDCl_3): δ 181.6, 155.8, 145.0, 141.0, 134.4, 132.6, 131.0, 130.8, 128.9, 127.6, 111.9, 67.0, 29.4, 20.3; IR ν/ cm⁻¹ 2912 (m), 1672 (m), 1414 (m), 1179 (m), 672 (m); HRMS (positive ESI) calcd for C_{18}H_{17}BrO_2S^+ ([M+H]^+): 374.0485; Found: 374.0472.
130.4, 128.3, 126.1, 124.9, 121.3, 111.7, 66.6, 26.3; IR ν/ cm⁻¹ 3085 (m), 2972 (m), 1622 (m), 1413 (m), 1252 (m), 813.5 (m), 775 (m); HRMS (positive ESI) calcld for C_{15}H_{13}BrO_{2}SH⁺ ([M+H]⁺): 336.9892; Found: 336.9884.

1r, white solid; ¹H NMR (300 MHz, CDCl₃, TMS): δ 7.37-7.28 (m, 2H), 7.02-6.97 (m, 1H), 6.91 (dt, J = 16.2 and 3.5 Hz, 1H), 6.81 (d, J = 8.4 Hz, 1H), 5.97 (dt, J = 16.2 and 2.4 Hz, 1H), 4.78 (dd, J = 4.8 and 2.4 Hz, 2H), 4.56 (s, 2H); ¹³C NMR (75 MHz, CDCl₃): δ 155.3, 148.2, 131.1, 130.3, 126.3, 121.8, 116.9, 111.7, 100.8, 66.1, 28.7; IR ν/ cm⁻¹ 2963 (m), 2222 (w), 1432 (m), 1258 (m), 795 (s); MS (EI, m/z, rel. intensity) 251 (6.7, M⁺), 172 (97.7), 91 (26.3), 78 (100.0); Anal. Calcd for C₁₁H₁₀BrNO: C, 52.41; H, 4.00; N, 5.56. Found: C, 52.89; H, 3.93; N, 5.40.

1s, white solid; ¹H NMR (400 MHz, CDCl₃, TMS): δ 7.47 (d, J = 2.4 Hz, 1H), 7.40 (dd, J = 8.8 and 2.8 Hz, 1H), 6.88 (dt, J = 16.4 and 2.8 Hz, 1H), 6.69 (d, J = 8.8 Hz, 1H), 5.92 (dt, J = 16.4 and 2.4 Hz, 1H), 4.75-4.74 (m, 2H), 4.74 (s, 2H); ¹³C NMR (100 MHz, CDCl₃): δ 154.4, 147.6, 133.7, 132.9, 128.5, 116.7, 113.8, 113.5, 101.1,
66.4, 27.2; IR ν/cm$^{-1}$ 2963 (m), 2225 (m), 1491 (m), 1257 (m), 1077 (m), 804 (m); MS (EI, m/z, rel. intensity) 329 (16.3, M$^+$), 171 (65.4), 77 (100.0); HRMS (EI) calcd for C$_{11}$H$_9$Br$_2$NO (M$^+$): 328.9051; Found: 328.9054.

1t, white solid; $^1$H NMR (400 MHz, CDCl$_3$, TMS): δ 7.37 (d, J = 8.8 Hz, 1H), 7.31-7.26 (m, 1H), 7.11 (dt, J = 15.6 and 4.0 Hz, 1H), 6.99-6.95 (m, 1H), 6.83 (d, J = 8.4 Hz, 1H), 6.26 (dt, J = 15.6 and 2.0 Hz, 1H), 4.76-4.75 (m, 2H), 4.68 (s, 2H), 3.76 (s, 3H).

$^{13}$C NMR (100 MHz, CDCl$_3$): δ 166.4, 155.6, 142.3, 130.7, 130.0, 126.0, 121.4, 121.3, 111.7, 66.4, 51.6, 41.5; IR ν/cm$^{-1}$ 2963 (m), 1260 (m), 1089 (m), 1018 (m), 798 (m); MS (EI, m/z, rel. intensity) 240 (15.3, M$^+$), 106 (100.0), 78 (71.1); HRMS (EI) calcd for C$_{13}$H$_{15}$O$_3$Cl (M$^+$): 240.0553; Found: 240.0556.

1u, white solid; $^1$H NMR (400 MHz, CDCl$_3$, TMS): δ 7.42 (dd, J = 7.6 and 2.0 Hz, 1H), 7.39-7.35 (m, 1H), 7.10 (dt, J = 16.0 and 4.4 Hz, 1H), 7.05-7.01 (m, 1H), 6.87 (d, J = 8.0 Hz, 1H), 6.22 (dt, J = 16.0 and 2.0 Hz, 1H), 5.35 (s, 2H), 4.79-4.77 (m, 2H), 3.77 (s, 3H), 2.98 (s, 3H).

$^{13}$C NMR (100 MHz, CDCl$_3$): δ 166.3, 156.1, 142.0, 131.2, 131.1, 122.0, 121.9, 121.4, 111.6, 67.2, 66.6, 51.8, 38.0; IR ν/cm$^{-1}$ 2953 (m), 1718 (m), 1170 (m), 1018 (m), 752 (m); MS (EI, m/z, rel. intensity) 300(1.1, M$^+$), 96 (90.4), 79 (100.0); HRMS (positive ESI) calcd for C$_{13}$H$_{16}$O$_6$SNH$_4$$^+$ ([M+NH$_4$]$^+$): 318.1011; Found: 318.1022.

4a, white solid; $^1$H NMR (400 MHz, CDCl$_3$, TMS): δ 7.57 (dd, J = 7.6 and 1.2 Hz, 1H), 7.52-7.50 (m, 2H), 7.35-7.29 (m, 3H), 7.18-7.14 (m, 1H), 6.92 (dt, J = 15.6 and
6.8 Hz, 1H), 6.57 (d, J = 8.0 Hz, 1H), 5.81 (dt, J = 15.6 and 1.2 Hz, 1H), 4.96-4.93 (m, 1H), 4.54-4.42 (m, 2H), 4.17-4.11 (m, 1H), 3.68 (s, 3H), 2.45 (s, 3H); \[^{13}C\) NMR (100 MHz, CDCl\(_3\)): δ 165.8, 144.2, 141.7, 139.3, 137.2, 134.6, 132.2, 129.7, 129.3, 129.0, 128.4, 128.0, 124.4, 52.6, 51.6, 29.1, 21.6; IR ν cm\(^{-1}\) 2956 (w), 1722 (m), 1436 (m), 1284, 1244, 52.6, 51.6, 29.1, 21.6; MS (EI, m/z, rel. intensity) 437 (2.0, M\(^+\)), 358 (11.3), 91 (100.0); Anal. Calcd for C\(_{19}\)H\(_{20}\)BrN\(_4\)S: C, 52.06; H, 4.60; N, 3.2. Found: C, 51.96; H, 4.87; N, 2.86.

\begin{center}
\includegraphics[width=0.3\textwidth]{4b}
\end{center}

\textbf{4b}, white solid; \[^1\)H NMR (300 MHz, CDCl\(_3\), TMS): δ 7.43-7.37 (m, 2H), 7.30-7.22 (m, 2H), 7.00-6.90 (m, 1H), 5.79 (d, J = 15.9 Hz, 1H), 4.71 (s, 2H), 3.74-3.66 (m, 5H); \[^{13}C\) NMR (100 MHz, CDCl\(_3\)): δ 166.2, 142.6, 139.0, 134.4, 132.3, 130.8, 129.2, 127.9, 123.1, 51.6, 35.8, 31.9; IR ν cm\(^{-1}\) 2951 (w), 1721 (m), 1436 (m), 1199 (m), 738 (m); MS (EI, m/z, rel. intensity) 300 (13.6, M\(^+\)), 221 (11.0), 121 (100.0); Anal. Calcd for C\(_{12}\)H\(_{13}\)BrO\(_2\): C, 47.85; H, 4.35. Found: C, 48.07; H, 4.48

\begin{center}
\includegraphics[width=0.3\textwidth]{4c}
\end{center}

\textbf{4c}, pale yellow solid; \[^1\)H NMR (400 MHz, CDCl\(_3\), TMS): δ 7.35-7.33 (m, 1H), 7.29-7.26 (m, 1H), 7.22-7.18 (m, 2H), 7.05 (dt, J = 15.6 and 6.8 Hz, 1H), 5.92-5.88 (m, 1H), 4.53 (s, 2H), 3.74 (s, 3H), 2.92-2.88 (m, 2H), 2.62-2.56 (m, 2H); \[^{13}C\) NMR (100 MHz, CDCl\(_3\)): δ 166.8, 147.9, 139.6, 135.3, 130.6, 129.5, 129.1, 126.8, 121.6, 51.4, 32.9, 31.4, 30.5; IR ν cm\(^{-1}\) 2963 (w), 1719 (m), 1435 (m), 1261 (m), 1018 (m), 798 (m); MS (EI, m/z, rel. intensity) 202 (25.1, [M-Br]\(^+\)), 143 (100.0), 104 (95.3); HRMS (EI) calcd for C\(_{13}\)H\(_{15}\)BrO\(_2\) (M\(^+\)): 282.0255; Found: 282.0254.

\begin{center}
\includegraphics[width=0.3\textwidth]{4d}
\end{center}

S12
4d, white solid; $^1$H NMR (400 MHz, CDCl$_3$, TMS): $\delta$ 7.36-7.34 (m, 1H), 7.31-7.22 (m, 2H), 7.19-7.12 (m, 2H), 5.76 (dt, $J = 15.6$ and 1.8 Hz, 1H), 4.47 (s, 2H), 3.72 (s, 3H), 3.68 (dd, $J = 6.4$ and 2.0 Hz, 2H). $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 166.6, 146.6, 136.6, 135.7, 130.6, 130.4, 129.3, 127.5, 122.2, 51.4, 34.9, 31.3.
3. Reaction Optimization

3.1 Base effect:

A mixture of substrate 1a (0.3 mmol), PPh₃ (0.36 mmol), base (0.9 mmol), H₂O (0.75 mmol), and i-PrOAc (4 mL) was stirred under a nitrogen atmosphere at 80 °C until 1a completely consumed (monitored by TLC). After the reaction was completed, the resulting mixture was filtered rapidly through a funnel with a thin layer of silica gel and eluted with EA. The filtrate was concentrated and the residue was purified by chromatography on silica gel (PE/EA=25/1) to afford the desired product.

<table>
<thead>
<tr>
<th>Entry</th>
<th>Time (h)</th>
<th>Base</th>
<th>Yield [%] 2a/3a</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>28</td>
<td>Na₂CO₃</td>
<td>20/20</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>K₂CO₃</td>
<td>65/16</td>
</tr>
<tr>
<td>3</td>
<td>28</td>
<td>Cs₂CO₃</td>
<td>75/trace</td>
</tr>
<tr>
<td>4</td>
<td>18</td>
<td>t-BuONa</td>
<td>13/7</td>
</tr>
<tr>
<td>5</td>
<td>24</td>
<td>t-BuOK</td>
<td>trace</td>
</tr>
<tr>
<td>6</td>
<td>24</td>
<td>NaOH</td>
<td>54/14</td>
</tr>
<tr>
<td>7</td>
<td>18</td>
<td>KOH</td>
<td>50/20</td>
</tr>
<tr>
<td>8</td>
<td>24</td>
<td>DMAP</td>
<td>trace</td>
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<tr>
<td>9</td>
<td>24</td>
<td>DBU</td>
<td>trace</td>
</tr>
<tr>
<td>10</td>
<td>24</td>
<td>K₃PO₄·3H₂O</td>
<td>51/40</td>
</tr>
<tr>
<td>11</td>
<td>22</td>
<td>K₂HPO₄</td>
<td>60/10</td>
</tr>
</tbody>
</table>

3.2 Solvent and temperature effect:

A mixture of substrate 1a (0.3 mmol), PPh₃ (0.36 mmol), Cs₂CO₃ (0.9 mmol),
H₂O (0.75 mmol), and solvent (4 mL) was stirred under a nitrogen atmosphere at 80 °C until 1a completely consumed monitored by TLC. After the reaction was completed, the resulting mixture was filtered rapidly through a funnel with a thin layer of silica gel and eluted with EA. The filtrate was concentrated and the residue was purified by chromatography on silica gel (PE/EA=25/1) to afford the desired product.

<table>
<thead>
<tr>
<th>Entry</th>
<th>Time (h)</th>
<th>Slovent</th>
<th>Yield[a] (%) 2a/3a</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21</td>
<td>DCE</td>
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<tr>
<td>2</td>
<td>24</td>
<td>CH₃Ph</td>
<td>74/7</td>
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<tr>
<td>3</td>
<td>24</td>
<td>CH₃CN</td>
<td>39/trace</td>
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<tr>
<td>4</td>
<td>21</td>
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<td>trace</td>
</tr>
<tr>
<td>5</td>
<td>24</td>
<td>1,4-dioxane</td>
<td>46/51</td>
</tr>
<tr>
<td>6</td>
<td>45</td>
<td>THF[b]</td>
<td>68/trace</td>
</tr>
<tr>
<td>7</td>
<td>28</td>
<td>i-PrOAc</td>
<td>75/trace</td>
</tr>
<tr>
<td>8</td>
<td>24</td>
<td>EtOAc (80 °C)</td>
<td>84/trace</td>
</tr>
<tr>
<td>9</td>
<td>41</td>
<td>EtOAc (40 °C)</td>
<td>38/32</td>
</tr>
<tr>
<td>10</td>
<td>40</td>
<td>EtOAc (60 °C)</td>
<td>67/4</td>
</tr>
<tr>
<td>11</td>
<td>24</td>
<td>n-BuOAc</td>
<td>71/trace</td>
</tr>
<tr>
<td>12</td>
<td>24</td>
<td>i-BuOAc</td>
<td>66/trace</td>
</tr>
<tr>
<td>13</td>
<td>48</td>
<td>1,4-dioxane</td>
<td>43/50</td>
</tr>
<tr>
<td>14[c]</td>
<td>24</td>
<td>EtOAc (80 °C)</td>
<td>78/trace</td>
</tr>
</tbody>
</table>

[a] Isolated yield. [b] 65 °C. [c] Using AR-grade EtOAc, with 1b, no water was added.

3.3 Results with the Corresponding Chloride and Mesylate under Standard Conditions (Quaternerazation at 80 °C).

1t

80 °C, TBAI (15 mol%), 3d+25 h, 75% yield

1u

80 °C, 24 + 25 h, 86% yield
4. General Procedure for the Phosphine-Mediated Coupling Reactions

A mixture of substrate 1 (0.3 mmol), PPh$_3$ (0.45 mmol), and EA (4 mL) was stirred under a nitrogen atmosphere at 60 °C until 1 was completely consumed (monitored by TLC). Cs$_2$CO$_3$ (0.9 mmol), H$_2$O (0.75 mmol), and EA (2 mL) were added and then warmed to 80 °C for another 25 h. After the reaction was completed, the resulting mixture was filtered rapidly through a funnel with a thin layer of silica gel and eluted with EA. The filtrate was concentrated and the residue was purified by chromatography on silica gel to afford the desired product.

2a, white solid, 87% yield; $^1$H NMR (400 MHz, CDCl$_3$, TMS): δ 7.04 (dd, $J = 8.8$ and 2.8 Hz, 1H), 7.00 (d, $J = 2.8$ Hz, 1H), 6.73 (d, $J = 8.8$ Hz, 1H), 4.22-4.19 (m, 1H), 3.91-3.86 (m, 1H), 3.71 (s, 3H), 2.97-2.90 (m, 1H), 2.57-2.49 (m, 2H), 2.46-2.32 (m, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 172.2, 152.8, 129.4, 127.4, 125.1, 122.2, 117.8, 69.5, 51.8, 35.8, 30.7, 28.6; IR ν cm$^{-1}$ 2961 (w), 1734 (m), 1484 (m), 1260 (m), 1024 (m), 811 (m); MS (EI, m/z, rel. intensity) 240 (24.0, M$^+$), 99 (100.0), 77 (14.4); HRMS (EI) calcd for C$_{12}$H$_{13}$ClO$_3$ (M$^+$): 240.0553; Found: 240.0550.

2b, colorless oil, 96% yield; $^1$H NMR (300 MHz, CDCl$_3$, TMS): δ 7.15-7.02 (m, 2H), 6.87-6.79 (m, 2H), 4.25-4.20 (m, 1H), 3.92-3.86 (m, 1H), 3.71 (s, 3H), 3.02-2.93 (m, 1H), 2.63-2.33 (m, 4H); $^{13}$C NMR (75 MHz, CDCl$_3$): δ 172.4, 154.1, 129.9, 127.3,
120.6, 120.5, 116.5, 69.4, 51.7, 35.9, 30.8, 28.9; IR ν/ cm\(^{-1}\) 2952 (w), 1733 (m), 1490 (m), 1244 (m), 1021 (m), 753 (m); MS (EI, m/z, rel. intensity) 206 (20.7, M\(^+\)), 131 (100.0), 99 (52.3); HRMS (EI) calcd for C\(_{12}\)H\(_{14}\)O\(_3\) (M\(^+\)): 206.0943; Found: 206.0942.

2c, white solid, 93% yield; \(^1\)H NMR (300 MHz, CDCl\(_3\), TMS): δ 6.90 (d, J = 8.1 Hz, 1H), 6.84 (s, 1H), 6.71 (d, J = 8.1 Hz, 1H), 4.20-4.17 (m, 1H), 3.90-3.84 (m, 1H), 3.71 (s, 3H), 2.97-2.88 (m, 1H), 2.58-2.32 (m, 4H), 2.25 (s, 3H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): δ 172.4, 151.9, 130.2, 129.6, 128.0, 120.2, 116.2, 69.4, 51.7, 35.7, 30.8, 29.1, 20.4; IR ν/ cm\(^{-1}\) 2953 (m), 1735 (m), 1500 (m), 1220 (m), 814 (m); MS (EI, m/z, rel. intensity) 220 (29.8, M\(^+\)), 145 (66.9), 99 (100.0); HRMS (EI) calcd for C\(_{13}\)H\(_{16}\)O\(_3\) (M\(^+\)): 220.1099; Found: 220.1098.

2d, white solid, 92% yield; \(^1\)H NMR (300 MHz, CDCl\(_3\), TMS): δ 6.76-6.66 (m, 2H), 6.57 (d, J = 2.7 Hz, 1H), 4.19-4.15 (m, 1H), 3.88-3.82 (m, 1H), 3.74 (s, 3H), 3.71 (s, 3H), 3.00-2.91 (m, 1H), 2.57-2.32 (m, 4H); \(^{13}\)C NMR (100 MHz, CDCl\(_3\)): δ 172.4, 153.4, 148.1, 121.1, 117.0, 114.3, 113.4, 69.3, 55.6, 51.6, 35.9, 31.0, 29.0; IR ν/ cm\(^{-1}\) 2923 (m), 1738 (m), 1502 (m), 1220 (m), 815 (m); MS (EI, m/z, rel. intensity) 236 (65.6, M\(^+\)), 162 (51.9), 99 (100.0); HRMS (EI) calcd for C\(_{13}\)H\(_{16}\)O\(_4\) (M\(^+\)): 236.1049; Found: 236.1048.

2e, colorless oil, 72% yield; \(^1\)H NMR (400 MHz, CDCl\(_3\), TMS): δ 6.91 (d, J = 8.4 Hz, 1H), 6.45 (dd, J = 8.4 and 2.4 Hz, 1H), 6.37 (d, J = 2.4 Hz, 1H), 4.21-4.18 (m, 1H), 3.89-3.84 (m, 1H), 3.74 (s, 3H), 3.70 (s, 3H), 2.91-2.86 (m, 1H), 2.56-2.32 (m,
$^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 172.4, 159.0, 154.8, 130.3, 112.6, 107.4, 101.3, 69.5, 55.2, 51.7, 35.9, 30.1, 29.1; IR ν/ cm$^{-1}$ 2937 (m), 1736 (m), 1620 (m), 1156 (m), 736 (m); MS (El, m/z, rel. intensity) 236 (44.3, M$^+$), 163 (100.0), 99 (56.4); HRMS (El) calcd for C$_{13}$H$_{16}$O$_4$ (M$^+$): 236.1049; Found: 236.1052.

2f, colorless oil, 92% yield; $^1$H NMR (400 MHz, CDCl$_3$, TMS): $\delta$ 6.93-6.88 (m, 1H), 6.82-6.74 (m, 2H), 4.32-4.28 (m, 1H), 3.99-3.89 (m, 1H), 3.71 (s, 3H), 3.03-2.96 (m, 1H), 2.63-2.54 (m, 2H), 2.49-2.33 (m, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 172.2, 151.4 (d, $J_{CF} = 243.8$ Hz), 142.4 (d, $J_{CF} = 10.9$ Hz), 124.8 (d, $J_{CF} = 3.1$ Hz), 123.2, 119.9 (d, $J_{CF} = 7.3$ Hz), 113.8 (d, $J_{CF} = 17.9$ Hz), 69.7, 51.7, 35.8, 30.4 (d, $J_{CF} = 2.3$ Hz), 28.7; IR ν/ cm$^{-1}$ 2955 (w), 1737 (m), 1487 (m), 1260 (m), 1029 (m), 795 (m); MS (El, m/z, rel. intensity) 224 (37.1, M$^+$), 150 (100.0), 99 (73.1); HRMS (El) calcd for C$_{12}$H$_{13}$FO$_3$ (M$^+$): 224.0849; Found: 224.0851.

2g, white solid, 83% yield; $^1$H NMR (400 MHz, CDCl$_3$, TMS): $\delta$ 7.19-7.15 (m, 2H), 6.69 (d, $J = 8.8$ Hz, 1H), 4.22-4.19 (m, 1H), 3.91-3.86 (m, 1H), 3.71 (s, 3H), 2.98-2.91 (m, 1H), 2.57-2.32 (m, 4H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 172.2, 153.3, 132.3, 130.2, 122.8, 118.3, 112.4, 69.5, 51.7, 35.8, 30.6, 28.6; IR ν/ cm$^{-1}$ 2953 (w), 1730 (s), 1483 (m), 1256 (m), 1025(m), 811 (m); MS (El, m/z, rel. intensity) 284 (19.7, M$^+$), 99 (100.0), 77 (17.5); HRMS (El) calcd for C$_{12}$H$_{13}$BrO$_3$ (M$^+$): 284.0048; Found: 284.0052.

2h, colorless oil, 63% yield; $^1$H NMR (400 MHz, CDCl$_3$, TMS): $\delta$ 7.78-7.75 (m, 2H), 7.62 (d, $J = 9.2$ Hz, 1H), 7.50-7.46 (m, 1H), 7.37-7.33 (m, 1H), 7.05 (d, $J = 8.8$ Hz,
1H), 4.31-4.27 (m, 1H), 3.99-3.94 (m, 1H), 3.72 (s, 3H), 3.29-3.23 (m, 1H), 2.81-2.68 (m, 2H), 2.56-2.44 (m, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 172.5, 151.9, 133.1, 129.0, 128.4, 127.8, 126.4, 123.4, 121.7, 118.7, 112.4, 69.2, 51.8, 36.3, 28.9, 27.5; IR ν/ cm$^{-1}$: 3061 (w), 2952 (w), 1733 (m), 1230 (m), 810 (m), 745 (m); MS (EI, m/z, rel. intensity) 256 (69.6, M$^+$), 182 (100.0), 99 (59.1); HRMS (EI) calcd for C$_{16}$H$_{16}$O$_3$ (M$^+$): 256.1099; Found: 256.1095.

![image of structure 2i]

2i, white solid, 97% yield; $^1$H NMR (300 MHz, CDCl$_3$, TMS): δ 8.16-8.13 (m, 1H), 7.76-7.73 (m, 1H), 7.47-7.41 (m, 2H), 7.35 (d, J = 7.8 Hz, 1H), 7.12 (d, J = 8.1 Hz, 1H), 4.43-4.40 (m, 1H), 4.10-4.04 (m, 1H), 3.72 (s, 3H), 3.13-3.04 (m, 1H), 2.70-2.62 (m, 2H), 2.55-2.39 (m, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 172.5, 149.1, 133.2, 127.8, 127.3, 125.6, 125.2, 124.9, 121.4, 119.8, 114.2, 69.6, 51.6, 36.0, 30.9, 29.0; IR ν/ cm$^{-1}$: 3053 (w), 2930 (w), 1736 (m), 1262 (m), 1104 (m), 802 (m), 738 (m); MS (EI, m/z, rel. intensity) 256 (44.8, M$^+$), 181 (42.4), 99 (100.0); HRMS (EI) calcd for C$_{16}$H$_{16}$O$_3$ (M$^+$): 256.1099; Found: 256.1095.

![image of structure 2j]

2j, on 0.2 mmol scale, colorless oil, 96% yield; $^1$H NMR (400 MHz, CDCl$_3$, TMS): δ 7.11-7.02 (m, 2H), 6.87-6.77 (m, 2H), 4.30 (dq, J = 6.4 and 2.0 Hz, 0.43H), 4.07-4.01 (m, 0.57H), 3.71 (s, 1.71H), 3.68 (s, 1.29H), 3.04-2.90 (m, 1H), 3.65-2.17 (m, 4H), 1.37 (d, J = 6.4 Hz, 1.71H), 1.31 (d, J = 6.4 Hz, 1.29H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 173.4, 172.6, 154.0, 153.7, 130.1, 129.6, 127.4, 127.3, 120.6, 120.4, 120.2, 119.9, 116.6(0), 116.5(8), 74.8, 73.4, 51.7, 36.9, 34.3, 32.4(7), 32.4(6), 30.3, 29.3, 19.1, 17.1; IR ν/ cm$^{-1}$: 2919 (m), 1734 (m), 1488 (m), 1244 (m), 1119 (m), 752 (m); MS (EI, m/z, rel. intensity) 222 (40.4, M$^+$), 146 (57.8), 131 (100.0); HRMS (EI) calcd for C$_{13}$H$_{10}$O$_3$ (M$^+$): 220.1099; Found: 220.1133.
2k, with PMe₃, colorless oil, 79% yield. ¹H NMR (400 MHz, CDCl₃, TMS): δ 7.11-7.01 (m, 2H), 6.86-6.79 (m, 2H), 4.29-4.14 (m, 3H), 3.94-3.89 (m, 0.6H), 3.84-3.79 (m, 0.4H), 2.87-2.82 (m, 1H), 2.65-2.57 (m, 1H), 2.52-2.41 (m, 1H), 2.37-2.25 (m, 1H), 1.30-1.24 (m, 6H); ¹³C NMR (100 MHz, CDCl₃): δ 175.2, 154.4, 130.0, 129.8, 127.4, 127.3, 121.1, 121.0, 120.5, 120.4, 116.5, 116.4, 68.8, 68.0, 60.6, 60.5, 40.9(4), 40.9(2), 35.1, 34.9, 29.3, 28.5, 14.8, 14.4, 14.2; IR ν/ cm⁻¹ 2926 (m), 1729 (m), 1490 (m), 1016 (m), 752 (m); MS (EI, m/z, rel. intensity) 234 (39.8, M⁺), 132 (77.6), 102 (100.0); HRMS (EI) calcd for C₁₄H₁₈O₃ (M⁺): 234.1256; Found: 234.1254.

3k, white solid, 87% yield. ¹H NMR (300 MHz, CDCl₃, TMS): δ 7.18-7.13 (m, 2H), 6.97-6.86 (m, 2H), 6.80-6.77 (m, 1H), 4.72 (d, J = 4.8 Hz, 2H), 4.23 (q, J = 7.2 Hz, 2H), 2.25 (s, 3H), 1.93 (s, 3H), 1.32 (t, J = 7.2 Hz, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 167.3, 156.4, 136.9, 130.8, 129.6, 127.0, 126.7, 120.7, 110.9, 64.9, 60.8, 16.2, 14.2, 13.0; IR ν/ cm⁻¹ 2964 (m), 2902 (w), 1712 (m), 1261 (m), 1019 (m), 800 (m); MS (EI, m/z, rel. intensity) 234 (4.0, M⁺), 189 (6.0), 108 (100.0), 91 (5.9); HRMS (EI) calcd for C₁₄H₁₈O₃ (M⁺): 234.1256; Found: 234.1254

2l, white solid, 79% yield; ¹H NMR (400 MHz, CDCl₃, TMS): δ 7.19-7.15 (m, 2H), 6.69 (d, J = 8.8 Hz, 1H), 4.23-4.14 (m, 3H), 3.90-3.85 (m, 1H), 2.97-2.90 (m, 1H), 2.57-2.49 (m, 2H), 2.44-2.30 (m, 2H), 1.27 (t, J = 7.2 Hz, 3H); ¹³C NMR (100 MHz, CDCl₃): δ 171.7, 153.3, 132.3, 130.2, 122.8, 118.3, 112.4, 69.5, 60.6, 36.0, 30.6, 28.6, 14.2; IR ν/ cm⁻¹ 2963 (m), 1730 (m), 1481 (m), 1157 (m), 1018 (m), 810 (m);
MS (EI, m/z, rel. intensity) 298 (42.7, M⁺), 210 (87.8), 113 (100.0); HRMS (EI) calcd for C₁₃H₁₅BrO₃ (M⁺): 298.0205; Found: 298.0203.

2m, white solid, 90% yield; ¹H NMR (400 MHz, CDCl₃, TMS): δ 7.11-7.01 (m, 2H), 6.86-6.79 (m, 2H), 4.23-4.20 (m, 1H), 3.87-3.82 (m, 1H), 2.96-2.91 (m, 1H), 2.57-2.48 (m, 2H), 2.35-2.23 (m, 2H), 1.46 (s, 9H); ¹³C NMR (100 MHz, CDCl₃): δ 171.2, 154.2, 129.9, 127.3, 120.9, 120.4, 116.4, 80.7, 69.6, 37.7, 30.9, 29.2, 28.1; IR ν/ cm⁻¹ 2974 (m), 1725 (m), 1490 (m), 1146 (m), 1018 (m), 752 (m); MS (EI, m/z, rel. intensity) 248 (16.8, M⁺), 192 (92.7), 132 (100.0); HRMS (EI) calcd for C₁₅H₂₀O₃ (M⁺): 248.1412; Found: 248.1409.

2n, on 0.2 mmol scale, white solid, 83% yield. ¹H NMR (300 MHz, CDCl₃, TMS): δ 7.11-7.02 (m, 2H), 6.87-6.79 (m, 2H), 4.24-4.21 (m, 1H), 3.97-3.91 (m, 1H), 3.63 (s, 3H), 3.20 (s, 3H), 3.05-2.98 (m, 1H), 2.68-2.42 (m, 4H); ¹³C NMR (100 MHz, CDCl₃): δ 172.6, 154.3, 130.0, 127.2, 121.0, 120.4, 116.5, 69.8, 61.2, 33.5, 32.1, 31.0, 28.4; IR ν/ cm⁻¹ 2931 (m), 1738 (m), 1655 (m), 1450 (m), 1298 (m), 753 (m); MS (EI, m/z, rel. intensity) 235 (26.4, M⁺), 128 (76.6), 103 (100.0); HRMS (EI) calcd for C₁₃H₁₅NO₃ (M⁺): 235.1208; Found: 235.1204.

2o

A mixture of substrate 1o (0.3 mmol), PPh₃ (0.45 mmol), and EA (4 mL) was stirred under a nitrogen atmosphere at 60 °C until 1o was completely consumed (29 h, monitored by TLC), and then cooled to 40 °C. Cs₂CO₃ (0.9 mmol), H₂O (6.0 mmol), and EA (2 mL) were added and stirred for another 30 h at 40 °C. After the reaction was completed, the resulting mixture was filtered rapidly through a funnel with a thin
layer of silica gel and eluted with EA. The filtrate was concentrated and the residue was purified by chromatography on silica gel to afford the product 2o in 82% yield as a white solid. ¹H NMR (300 MHz, CDCl₃, TMS): δ 7.97-7.94 (m, 2H), 7.59-7.54 (m, 1H), 7.48-7.43 (m, 2H), 7.13-7.08 (m, 1H), 7.04-7.01 (m, 1H), 6.88-6.81 (m, 2H), 4.28-4.24 (m, 1H), 4.03-3.97 (m, 1H), 3.17-2.96 (m, 3H), 2.85-2.78 (m, 1H), 2.62-2.55 (m, 1H); ¹³C NMR (75 MHz, CDCl₃): δ 198.4, 154.2, 136.8, 133.2, 130.1, 128.6, 128.0, 127.3, 120.8, 120.5, 116.5, 69.7, 40.0, 30.9, 28.0; IR ν cm⁻¹ 2963 (m), 1682 (s), 1260 (m), 1017 (m), 799 (m); MS (EI, m/z, rel. intensity) 252 (5.4, M⁺), 145 (59.8), 132 (100.0); HRMS (EI) calcd for C₁₇H₁₆O₂ (M⁺): 252.1150; Found: 252.1148.

According to the procedure as 2o, 2p, white solid; ¹H NMR (400 MHz, CDCl₃, TMS): δ 7.96-7.94 (m, 2H), 7.58-7.54 (m, 1H), 7.47-7.43 (m, 2H), 7.92-7.89 (m, 1H), 6.83 (s, 1H), 6.72 (d, J = 8.4 Hz, 1H), 4.24-4.20 (m, 1H), 4.00-3.96 (m, 1H), 3.16-2.97 (m, 3H), 2.82-2.77 (m, 1H), 2.57-2.52 (m, 1H), 2.24 (s, 1H); ¹³C NMR (100 MHz, CDCl₃): δ 191.4, 154.2, 144.2, 133.9, 132.1, 130.4, 129.6, 130.4, 126.5, 128.0, 127.9, 120.4, 116.2, 69.6, 39.9, 30.9, 28.0, 20.4; IR ν cm⁻¹ 2923 (m), 1683 (m), 1450 (m), 1218 (m), 1027 (m), 813 (m), 689 (m); HRMS (positive ESI) calcd for C₁₈H₁₈O₂H⁺ ([M+H]⁺): 267.1380; Found: 267.1376.

According to the procedure as 2o, 2q, white solid; ¹H NMR (400 MHz, CDCl₃, TMS): δ 7.68-7.64 (m, 2H), 7.13-7.09 (m, 2H), 7.03-7.01 (m, 1H), 6.87-6.81 (m, 2H), 4.26-4.23 (m, 1H), 4.02-3.97 (m, 1H), 3.08-2.91 (m, 3H), 2.84-2.76 (m, 1H), 2.62-2.56 (m, 1H); ¹³C NMR (100 MHz, CDCl₃): δ 191.4, 154.2, 144.2, 133.9, 132.1, 130.0, 128.1, 127.3, 120.7, 120.5, 116.5, 69.5, 40.6, 30.8, 28.4; IR ν cm⁻¹ 2923 (m), 1683 (m), 1450 (m), 1218 (m), 1027 (m), 813 (m), 689 (m); HRMS (positive ESI) calcd for C₁₈H₁₈O₂H⁺ ([M+H]⁺): 267.1380; Found: 267.1376.
According to the general procedure, 2r, white solid, 93% yield; $^1$H NMR (300 MHz, CDCl$_3$, TMS): δ 7.15-7.05 (m, 2H), 6.92-6.81 (m, 2H), 4.25-4.21 (m, 1H), 4.06-4.01 (m, 1H), 3.11-3.05 (m, 1H), 2.72-2.66 (m, 1H), 2.54-2.43 (m, 3H); $^{13}$C NMR (75 MHz, CDCl$_3$): δ 153.6, 130.0, 127.8, 121.0, 119.1, 118.1, 116.7, 68.1, 29.9, 29.4, 19.4; IR ν/cm$^{-1}$: 2923 (w), 2244 (m), 1490 (m), 1245 (m), 762 (m), 737 (m); MS (EI, m/z, rel. intensity) 173 (63.3, M$^+$), 131 (100.0), 105 (55.3); HRMS (EI) calcd for C$_{11}$H$_{11}$NO (M$^+$): 173.0841; Found: 173.0839.

According to the general procedure, 2s, white solid, 86% yield; $^1$H NMR (300 MHz, CDCl$_3$, TMS): δ 7.22-7.18 (m, 2H), 6.71 (d, $J$ = 8.7 Hz, 1H), 4.23-4.20 (m, 1H), 4.06-4.00 (m, 1H), 3.07-3.02 (m, 1H), 2.70-2.63 (m, 1H), 2.53-2.42 (m, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 152.8, 132.4, 130.7, 121.3, 118.5, 117.7, 113.0, 68.1, 29.7, 29.0, 19.3; IR ν/cm$^{-1}$: 2963 (m), 2241 (w), 1479 (m), 1231 (m), 1027 (m), 822 (m); MS (EI, m/z, rel. intensity) 251 (100.0, M$^+$), 132 (49.2), 77 (41.5); HRMS (EI) calcd for C$_{11}$H$_{10}$BrNO (M$^+$): 250.9946; Found: 250.9949.

A mixture of substrate 4a (0.3 mmol), PPh$_3$ (0.45 mmol), and EA (4 mL) was stirred under a nitrogen atmosphere at 80 °C until 4a was completely consumed (monitored by TLC, 2 d). Cs$_2$CO$_3$ (0.9 mmol), H$_2$O (0.75 mmol), and EA (2 mL) were then added and stirred for another 25 h. After the reaction was completed, the resulting mixture was filtered rapidly through a funnel with a thin layer of silica gel.
and eluted with EA. The filtrate was concentrated and the residue was purified by chromatography on silica gel to afford the product 5a as a white solid in 88% yield.

$^1$H NMR (300 MHz, CDCl$_3$, TMS): $\delta$ 7.80 (d, $J = 8.1$ Hz, 1H), 7.54-7.51 (m, 2H), 7.22-7.16 (m, 3H), 7.09-6.98 (m, 2H), 4.28-4.22 (m, 1H), 3.70 (s, 3H), 3.23-3.15 (m, 1H), 2.67-2.60 (m, 1H), 2.38 (s, 3H), 2.28-2.10 (m, 4H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 171.7, 143.5, 136.4, 136.2, 129.5, 129.1, 128.8, 127.0, 126.5, 124.8, 123.9, 51.6, 50.6, 37.8, 32.9, 28.8, 21.4; IR v/ cm$^{-1}$: 3056 (w), 2939 (w), 1736 (m), 1350 (m), 1164 (m), 736 (m), 664 (m); MS (EI, m/z, rel. intensity) 359 (5.5, M$^+$), 144 (90.9), 130 (100.0); HRMS (EI) calcd for C$_{19}$H$_{21}$NO$_4$S (M$^+$): 359.1191; Found: 359.1195.

A mixture of substrate 4b (0.3 mmol), PPh$_3$ (0.45 mmol), and EA (4 mL) was stirred under a nitrogen atmosphere at 60 °C until 4b was completely consumed (10h, monitored by TLC). Cs$_2$CO$_3$ (0.9 mmol), H$_2$O (0.75 mmol), and EA (2 mL) were added and then warmed to 80 °C for another 11 h. After the reaction was completed, the resulting mixture was filtered rapidly through a funnel with a thin layer of silica gel and eluted with EA. The filtrate was concentrated and the residue was purified by chromatography on silica gel to afford the desired product 5b as a pale yellow oil in 71% yield; $^1$H NMR (400 MHz, CDCl$_3$, TMS): $\delta$ 7.10-7.04 (m, 2H), 7.01-6.95 (m, 2H), 3.70 (s, 3H), 3.10-3.07 (m, 1H), 2.94-2.83 (m, 2H), 2.67-2.59 (m, 2H), 2.54-2.40 (m, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 172.5, 132.2, 132.0, 130.4, 126.5, 126.2, 124.1, 51.6, 38.7, 35.3, 31.8, 29.6; IR v/ cm$^{-1}$: 2924 (w), 1737 (m), 1438 (m), 1206 (m), 1006 (m), 739 (s); MS (EI, m/z, rel. intensity) 222 (79.1, M$^+$), 123 (72.4), 99 (100.0); HRMS (EI) calcd for C$_{12}$H$_{14}$O$_2$S (M$^+$): 222.0715; Found: 222.0717.

According to the general procedure, 5c, white solid, 89% yield; $^1$H NMR (400 MHz, CDCl$_3$, TMS): $\delta$ 7.11-7.04 (m, 4H), 3.70 (s, 3H), 2.92-2.82 (m, 3H), 2.53-2.47 (m,
1H), 2.39-2.38 (m, 2H), 2.31-2.25 (m, 1H), 1.99-1.94 (m, 1H), 1.53-1.43 (m, 1H);

$^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 173.2, 136.2, 135.7, 129.1, 128.8, 125.7, 125.6, 51.5, 40.8, 35.6, 31.4, 29.1, 28.7; IR v/ cm$^{-1}$: 2916 (w), 1734 (m), 1435 (m), 1152 (m), 1014 (m), 800 (m), 743 (m); MS (EI, m/z, rel. intensity) 204 (9.6, M$^+$), 130 (100.0);

HRMS (EI) calcd for C$_{13}$H$_{16}$O$_2$ (M$^+$): 204.1150; Found: 204.1147.

According to the general procedure, 5d, white solid, 95% yield; $^1$H NMR (400 MHz, CDCl$_3$, TMS): $\delta$ 7.23-7.16 (m, 2H), 7.15-7.11 (m, 2H), 3.69 (s, 3H), 3.13 (dd, $J =$ 15.2 and 7.6 Hz, 2H), 2.92-2.84 (m, 1H), 2.64 (dd, $J =$ 15.6 and 7.2 Hz, 2H), 2.49 (d, $J =$ 7.2 Hz, 2H). $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 173.3, 142.6, 126.2, 124.4, 51.5, 39.7, 38.9, 36.0.
5. Synthesis of Glycoprotein IIb-IIIa Antagonist 8.

A flame-dried resealable Schlenk tube was charged with 2l (149.6 mg, 0.5 mmol), 6 (109.6 mg, 0.75 mmol), Pd$_2$(dba)$_3$ (45.8 mg, 0.05 mmol), Xantphos (86.8 mg, 0.15 mmol), and Cs$_2$CO$_3$ (439.8 mg, 1.35 mmol). The Schlenk tube was evacuated and backfilled with N$_2$ three times, and then the 1,4-dioxane (5 mL) was added. The mixture was stirred at 100 °C until the starting aryl halide 2l had been completely consumed monitored by TLC for 27 h. The resulting mixture was then cooled to room temperature, and filtered rapidly through a funnel with a thin layer of silica gel and eluted with EA. The filtrate was concentrated and the residue was purified by chromatography on silica gel to afford the product 11 (129.9 mg, 71% yield) as pale yellow solid. $^1$H NMR (400 MHz, CDCl$_3$, TMS): δ 7.95 (d, $J$ = 8.0 Hz, 2H), 7.88 (s, 1H), 7.76 (d, $J$ = 8.4 Hz, 2H), 7.42 (s, 1H), 7.20 (dd, $J$ = 7.8 and 2.4 Hz, 1H), 6.80 (dd, $J$ = 8.4 and 2.4 Hz, 1H), 4.24-4.14 (m, 3H), 3.92-3.87 (m, 1H), 3.00-2.93 (m, 1H), 2.57-2.52 (m, 2H), 2.45-2.32 (m, 2H), 1.28 (t, $J$ = 7.2 Hz, 3H).

Anhydrous HCl was bubbled into an ice-cooled suspension of 11 (36.4 mg, 0.1 mmol) in EtOH (2 mL) for 1.5 h. The mixture was stirred for 4 h at room temperature and concentrated in vacuo. The resulting solid was triturated with Et$_2$O, dried under reduced pressure and dissolved in EtOH (2 mL), to this solution morpholine (0.6 mmol) was added, and the mixture was stirred for 20 h at room temperature,
concentrated in vacuo, The resulting solid was triturated with Et$_2$O, dried under reduced pressure and treated with ethanolic HCl to afford product 8 (42.3 mg, 87% yield) as a pale yellow solid. $^1$H NMR (400 MHz, DMSO-$_d_6$, TMS): $\delta$ 10.38 (s, 1H), 9.75-9.72 (m, 2H), 8.18 (d, $J$ = 8.4 Hz, 2H), 7.77 (d, $J$ = 8.0 Hz, 2H), 7.53 (s, 1H), 7.48 (d, $J$ = 8.4 Hz, 1H), 6.76 (d, $J$ = 8.4 Hz, 1H), 4.18 (d, $J$ = 10.0 Hz, 1H), 4.11 (q, $J$ = 7.2 Hz, 2H), 3.87-3.79 (m, 5H), 3.70-3.62 (m, 2H), 3.41-3.29 (m, 2H), 2.91-2.84 (m, 1H), 2.56-2.33 (m, 4H), 1.21 (t, $J$ = 7.2 Hz, 3H).
6. References


7. NMR Spectra

\[ \text{\(^1H\) NMR (300 M Hz in CDCl}_3\) } \]

![NMR Spectra Image]
$\text{Br}$

$\text{O}$

$\text{CO}_2\text{Me}$

$1b$

$^1\text{H NMR (300 M Hz in CDCl}_3)$
$\text{Br}$

$\text{CO}_2\text{Me}$

$1b$

$^{13}$C NMR (100 M Hz in CDCl$_3$)
$^1$H NMR (400 M Hz in CDCl$_3$)
$^{13}$C NMR (100 M Hz in CDCl$_3$)

![Carbon-13 NMR spectrum of compound 1a]
$^1$H NMR (300 MHz in CDCl$_3$)
$^13$C NMR (100 M Hz in CDCl$_3$)
$\text{MeO}$

MeO

Br

CO$_2$Me

$^{1}$H NMR (400 MHz in CDCl$_3$)
$^{13}$C NMR (100 M Hz in CDCl$_3$)
$^1$H NMR (400 M Hz in CDCl$_3$)
$^{13}$C NMR (100 M Hz in CDCl$_3$)
$^1$H NMR (400 M Hz in CDCl$_3$)
$^{13}$C NMR (100 M Hz in CDCl$_3$)
$^{1}H$ NMR (400 M Hz in CDCl$_3$)
$^{13}$C NMR (100 M Hz in CDCl$_3$)
**1H NMR (300 M Hz in CDCl₃)**

![Chemical Structure](image)

Electronic Supplementary Material (ESI) for Chemical Communications
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13C NMR (100 M Hz in CDCl₃)
$^1$H NMR (400 M Hz in CDCl$_3$)
$^{13}$C NMR (75 M Hz in CDCl$_3$)
$^1$H NMR (400 M Hz in CDCl$_3$)
$^{13}$C NMR (100 M Hz in CDCl$_3$)
1H NMR (400 MHz in CDCl$_3$)
$\text{Br}$
\begin{align*}
\text{CH}_3
\end{align*}
$\text{CO}_2\text{Et}$

$^{13}$C NMR (100 M Hz in CDCl$_3$)
$^1$H NMR (400 M Hz in CDCl$_3$)
Br\[\text{O}\]Br
\[\text{CO}_2\text{Et}\]

$^{13}$C NMR (100 M Hz in CDCl$_3$)
$^{1}H$ NMR (400 M Hz in CDCl$_3$)
$^{13}$C NMR (100 M Hz in CDCl$_3$)
$\text{H NMR (400 M Hz in CDCl}_3\text{)}$
$\text{Br}$
$\text{O}$
$\text{O}$

$\text{1n}$

$^{13}$C NMR (100 M Hz in CDCl$_3$)
$\text{Br}$

$\text{O}$

$\text{COPh}$

$\text{10}$

$^1\text{H NMR (300 M Hz in CDCl$_3$)}$
$^{13}$C NMR (100 M Hz in CDCl$_3$)
$^1$H NMR (300 M Hz in CDCl$_3$)
$^{13}$C NMR (100 M Hz in CDCl$_3$)
\[ ^1H \text{NMR (400 M Hz in CDCl}_3) \]
$^{13}$C NMR (100 M Hz in CDCl$_3$)
$\text{H NMR (300 MHz in CDCl}_3)$
$^{13}$C NMR (75 M Hz in CDCl$_3$)
$^{1}$H NMR (300 M Hz in CDCl$_3$)
$^{13}$C NMR (100 M Hz in CDCl$_3$)
Br\[O\backslash\text{CN}

$^{1}$H NMR (400 M Hz in CDCl$_3$)
$^{13}$C NMR (100 M Hz in CDCl$_3$)
$^1$H NMR (400 M Hz in CDCl$_3$)
$^{13}$C NMR (100 M Hz in CDCl$_3$)
$^{1}$H NMR (400 M Hz in CDCl$_3$)
$^{13}$C NMR (100 M Hz in CDCl$_3$)
\[^1\text{H} \text{NMR (400 M Hz in CDCl}_3\text{)}\]
$^{13}$C NMR (100 M Hz in CDCl$_3$)
\[ \text{H NMR (300 M Hz in CDCl}_3 \text{)} \]

![NMR Spectrogram](image)
$^{13}$C NMR (100 M Hz in CDCl$_3$)
$^1$H NMR (400 M Hz in CDCl$_3$)

![NMR Spectrum](image-url)
$^{13}$C NMR (100 M Hz in CDCl$_3$)
**Figure: H NMR (400 MHz in CDCl$_3$)**

The figure shows an NMR spectrum of a compound with a bromine and a methoxycarbonyl group. The spectrum is labeled as 4d and includes chemical shifts for various protons in the molecule.
$^{13}$C NMR (100 MHz in CDCl$_3$)
$^1$H NMR (400 MHz in CDCl$_3$)
$^{13}$C NMR (100 M Hz in CDCl$_3$)
**1H NMR (300 M Hz in CDCl₃)**
$^{13}$C NMR (75 M Hz in CDCl$_3$)
$^{1} \text{H NMR (300 M Hz in CDCl}_3$)
$^13$C NMR (100 MHz in CDCl$_3$)
$^1$H NMR (300 M Hz in CDCl$_3$)
$^{13}$C NMR (100 MHz in CDCl$_3$)
1H NMR (400 M Hz in CDCl₃)
$^{13}$C NMR (100 MHz in CDCl$_3$)
$^1$H NMR (400 MHz in CDCl$_3$)
$^{13}$C NMR (100 MHz in CDCl$_3$)
$^1$H NMR (400 M Hz in CDCl$_3$)
$^{13}$C NMR (100 M Hz in CDCl$_3$)
$^1$H NMR (400 M Hz in CDCl$_3$)
$^{13}$C NMR (100 MHz in CDCl$_3$)
$^1$H NMR (300 M Hz in CDCl$_3$)
$^{13}$C NMR (100 M Hz in CDCl$_3$)
$^1$H NMR (400 M Hz in CDCl$_3$)
$^{13}$C NMR (100 MHz in CDCl$_3$)
$^1$H NMR (400 M Hz in CDCl$_3$)
$^{13}$C NMR (100 M Hz in CDCl$_3$)
$^1$H NMR (300 MHz in CDCl$_3$)
$^{13}$C NMR (100 M Hz in CDCl$_3$)
Br

H

O

CO_2Et

2I

^1^H NMR (400 M Hz in CDCl_3)
$^{13}$C NMR (100 M Hz in CDCl$_3$)
$^{1}H$ NMR (400 M Hz in CDCl$_3$)
$^{13}$C NMR (100 M Hz in CDCl$_3$)
$^1$H NMR (300 M Hz in CDCl$_3$)
$^{13}$C NMR (100 M Hz in CDCl$_3$)
$^1$H NMR (300 M Hz in CDCl$_3$)
$^{13}$C NMR (75 M Hz in CDCl$_3$)
H$_3$C

\[
\text{H NMR (400 M Hz in CDCl$_3$)}
\]
$^{13}$C NMR (100 M Hz in CDCl$_3$)
\( ^1H \) NMR (400 M Hz in CDCl\(_3\))
$^{13}$C NMR (100 M Hz in CDCl$_3$)
\[ \text{H NMR (300 M Hz in CDCl}_3) \]
$\text{O}$

$\text{CN}$

$2r$

$^{13}\text{C} \text{NMR (75 M Hz in } \text{CDCl}_3)$
Br

2s

CN

$^1$H NMR (400 MHz in CDCl$_3$)
$^{13}$C NMR (100 M Hz in CDCl$_3$)
$^1$H NMR (300 M Hz in CDCl$_3$)
$\text{Ts}$

5a

$\text{CO}_2\text{Me}$

$^{13}$C NMR (100 MHz in CDCl$_3$)
$^1$H NMR (400 MHz in CDCl$_3$)
$^{13}$C NMR (100 M Hz in CDCl$_3$)
$^1$H NMR (400 M Hz in CDCl$_3$)
$^{13}$C NMR (100 MHz in CDCl$_3$)
$^1$H NMR (400 M Hz in CDCl$_3$)
$^{13}$C NMR (100 M Hz in CDCl$_3$)
$^{1}H$ NMR (400 M Hz in CDCl$_3$)
$^1$H NMR (400 M Hz in DMSO-$d_6$)