Supporting Information

K$_2$S$_2$O$_8$ Mediated Conjugation of $\beta$-Ketosulfones with TEMPO

Chieh-Kai Chan and Meng-Yang Chang*

*email: mychang@kmu.edu.tw

Department of Medicinal and Applied Chemistry, Kaohsiung Medical University, Kaohsiung 807, Taiwan

(1) $^1$H & $^{13}$C NMR spectroscopic data (pages S-2~S-8)
(2) Additional scanned photocopies (pages S-9~S-28)
Experimental section

General. All other reagents and solvents were obtained from commercial sources and used without further purification. Reactions were routinely carried out under an atmosphere of dry nitrogen with magnetic stirring. Products in organic solvents were dried with anhydrous magnesium sulfate before concentration in vacuo. Melting points were determined with a SMP3 melting apparatus. $^1$H and $^{13}$C NMR spectra were recorded on a Varian INOVA-400 spectrometer operating at 400 and at 100 MHz, respectively. Chemical shifts (δ) are reported in parts per million (ppm) and the coupling constants (J) are given in Hertz. High resolution mass spectra (HRMS) were measured with a mass spectrometer Finnigan/Thermo Quest MAT 95XL.

A representative synthetic procedure of skeleton 4 is as follows: K$_2$S$_2$O$_8$ (2a, 300 mg, 1.1 mmol) was added to a solution of β-ketosulfoxones 1 (1.0 mmol) and TEMPO 3a and 3b (1.2 mmol) in MeCN (5 mL) at rt. The reaction mixture was stirred at rt for 12 h and the solvent was concentrated. The residue was diluted with water (10 mL) and the mixture was extracted with EtOAc (3 x 20 mL). The combined organic layers were washed with brine, dried, filtered and evaporated to afford crude product. Purification on silica gel (hexanes/EtOAc = 10/1~6/1) afforded skeleton 4.

![Structural formula of 2-Methanesulfonyl-1-phenyl-2-(2,2,6,6-tetramethylpiperidin-1-yloxy)ethanone](image)

2-Methanesulfonyl-1-phenyl-2-(2,2,6,6-tetramethylpiperidin-1-yloxy)ethanone (4a). Compound 4a is a known compound and the analytical data are consistent with those in the literature (Wang, Z.-L.; An, X.-L.; Ge, L.-S.; Jin, J.-H.; Luo, X.; Deng, W.-P. *Tetrahedron* 2014, 70, 3788). Yield = 80% (282 mg); Colorless gum; HRMS (ESI, M$^+$+1) calcd for C$_{18}$H$_{28}$NO$_4$S 354.1739, found 354.1743; $^1$H NMR (400 MHz, CDCl$_3$): δ 8.03 (d, J = 7.2 Hz, 2H), 7.66 (t, J = 7.6 Hz, 1H), 7.54 (t, J = 7.6 Hz, 2H), 6.22 (s, 1H), 3.11 (s, 3H), 1.57 (br s, 6H), 1.43 (br s, 2H), 1.31 (br s, 4H), 1.18 (br s, 3H), 0.86 (br s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 194.15, 136.34, 133.71 (2x), 128.65 (2x), 128.43 (2x), 94.78, 61.70, 60.26, 40.25, 37.16, 33.52, 32.57, 19.81, 16.25.

![Structural formula of 2-Benzensulfonyl-1-phenyl-2-(2,2,6,6-tetramethylpiperidin-1-yloxy)ethanone](image)

2-Benzensulfonyl-1-phenyl-2-(2,2,6,6-tetramethylpiperidin-1-yloxy)ethanone (4b). Yield = 83% (344 mg); Colorless gum; HRMS (ESI, M$^+$+1) calcd for C$_{23}$H$_{30}$NO$_4$S 416.1896, found 416.1903; $^1$H NMR (400 MHz, CDCl$_3$): δ 8.08 (d, J = 7.6 Hz, 2H), 7.93 (d, J = 8.0 Hz, 2H), 7.73-7.53 (m, 6H), 6.42 (s, 1H), 1.64 (br s, 3H), 1.56 (br s, 3H), 1.38 (br s, 6H), 1.01 (br s, 4H), 0.77 (br s, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 192.25, 135.83, 135.61, 133.19, 132.86, 128.97 (2x), 128.14 (2x), 127.70 (2x), 127.46 (2x), 97.85, 60.98, 59.67, 39.80 (2x), 32.85, 32.07, 19.53, 19.24, 15.65.
1-Phenyl-2-(2,2,6,6-tetramethylpiperidin-1-yloxy)-2-(toluene-4-sulfonyl)ethanone (4c). Yield = 83% (356 mg); Colorless solid; mp = 113-114 °C (recrystallized from hexanes and EtOAc); HRMS (ESI, M+1) calcd for C_{24}H_{32}NO_{5}S 430.2052, found 430.2055; ^1H NMR (400 MHz, CDCl_3): δ 8.17 (d, J = 6.8 Hz, 2H), 7.88 (d, J = 7.6 Hz, 2H), 7.77-7.73 (m, 1H), 7.66-7.63 (m, 2H), 7.47 (d, J = 8.0 Hz, 2H), 6.50 (s, 1H), 2.59 (s, 3H), 1.75 (br s, 3H), 1.67 (br s, 3H), 1.48 (br s, 6H), 1.12 (br s, 4H), 0.87 (br s, 2H); ^13C NMR (100 MHz, CDCl_3): δ 190.58, 142.42, 133.88, 131.08 (2x), 130.96, 127.23 (4x), 126.40 (2x), 125.94 (2x), 95.90, 59.19, 57.80, 38.12, 31.11, 30.30, 19.06, 17.75, 17.47, 13.92.

2-(2,2,6,6-Tetramethylpiperidin-1-yloxy)-2-(toluene-4-sulfonyl)-1-p-tolylethanone (4d). Yield = 85% (377 mg); Colorless solid; mp = 104-105 °C (recrystallized from hexanes and EtOAc); HRMS (ESI, M+1) calcd for C_{25}H_{34}NO_{4}S 444.2209, found 444.2213; ^1H NMR (400 MHz, CDCl_3): δ 8.09 (d, J = 7.6 Hz, 2H), 7.89 (d, J = 7.6 Hz, 2H), 7.49-7.45 (m, 4H), 6.49 (s, 1H), 2.61 (s, 3H), 2.60 (s, 3H), 1.75 (br s, 3H), 1.67 (br s, 3H), 1.48 (br s, 6H), 1.12 (br s, 4H), 0.87 (br s, 2H); ^13C NMR (100 MHz, CDCl_3): δ 189.80, 142.42, 133.88, 131.08 (2x), 130.96, 127.23 (4x), 126.38, 126.20 (4x), 125.94 (2x), 95.67, 58.94, 57.66, 37.89, 30.87, 30.15, 18.91, 17.58, 17.30, 13.77.

1-(4-Fluorophenyl)-2-(2,2,6,6-tetramethylpiperidin-1-yloxy)-2-(toluene-4-sulfonyl)ethanone (4e). Yield = 80% (358 mg); Colorless solid; mp = 115-116 °C (recrystallized from hexanes and EtOAc); HRMS (ESI, M+1) calcd for C_{24}H_{31}FNO_{4}S 448.1958, found 448.1965; ^1H NMR (400 MHz, CDCl_3): δ 8.42 (br s, 2H), 8.14 (br s, 2H), 7.90 (br s, 2H), 7.76 (br s, 2H), 6.67 (s, 1H), 2.89 (s, 3H), 1.99 (br s, 3H), 1.95 (br s, 3H), 1.75 (br s, 6H), 1.39 (br s, 4H), 1.14 (br s, 2H); ^13C NMR (100 MHz, CDCl_3): δ 184.65, 137.80, 132.93, 127.23, 126.26, 123.22, 123.22, 122.41, 121.92 (3x), 121.81 (2x), 92.25, 54.53, 53.15, 38.37, 26.38, 25.63, 22.11, 14.62, 13.05, 12.81, 9.24.
1-(4-Methoxyphenyl)-2-(2,2,6,6-tetramethylpiperidin-1-ylxy)-2-(toluene-4-sulfonyl)ethanone (4f). Yield = 56% (257 mg); Colorless solid; mp = 91-92 °C (recrystallized from hexanes and EtOAc); HRMS (ESI, M^+1) calcld for C_{35}H_{34}NO_{10}S 460.2158, found 460.2163; ^1H NMR (400 MHz, CDCl₃): δ 8.04 (d, J = 8.4 Hz, 2H), 7.74 (d, J = 8.0 Hz, 2H), 7.33 (d, J = 8.0 Hz, 2H), 6.99 (d, J = 8.8 Hz, 2H), 6.31 (s, 1H), 3.90 (s, 3H), 2.46 (s, 3H), 1.61 (br s, 3H), 1.55 (br s, 3H), 1.39 (br s, 6H), 0.99 (br s, 4H), 0.76 (br s, 2H); ^13C NMR (100 MHz, CDCl₃): δ 190.59, 163.39, 144.36, 133.28, 131.01, 129.22, 128.38 (4x), 113.19 (4x), 96.07, 61.19, 59.94, 54.84, 40.12, 33.03, 32.39, 21.01, 19.80, 19.58, 15.98.

![Structure of 1-(4-Methoxyphenyl)-2-(2,2,6,6-tetramethylpiperidin-1-ylxy)-2-(toluene-4-sulfonyl)ethanone (4f)]

1-(4-Nitrophenyl)-2-(2,2,6,6-tetramethylpiperidin-1-ylxy)-2-(toluene-4-sulfonyl)ethanone (4g). Yield = 80% (379 mg); Colorless solid; mp = 93-94 °C (recrystallized from hexanes and EtOAc); HRMS (ESI, M^+1) calcld for C_{36}H_{34}N₂O₆S 475.1903, found 475.1914; ^1H NMR (400 MHz, CDCl₃): δ 8.36 (d, J = 8.8 Hz, 2H), 8.23 (d, J = 8.8 Hz, 2H), 7.72 (d, J = 8.4 Hz, 2H), 7.36 (d, J = 8.0 Hz, 2H), 6.25 (s, 1H), 2.47 (s, 3H), 1.53 (br s, 6H), 1.31 (br s, 8H), 0.94 (br s, 2H), 0.69 (br s, 2H); ^13C NMR (100 MHz, CDCl₃): δ 192.46, 150.44, 145.71, 140.62, 136.40, 130.34 (2x), 129.81 (2x), 124.02 (4x), 100.36, 62.16, 61.02, 40.77, 34.00, 33.04, 29.60, 21.72, 20.50, 20.25, 16.58.

![Structure of 1-(4-Nitrophenyl)-2-(2,2,6,6-tetramethylpiperidin-1-ylxy)-2-(toluene-4-sulfonyl)ethanone (4g)]

1-Naphthalen-2-yl-2-(2,2,6,6-tetramethylpiperidin-1-ylxy)-2-(toluene-4-sulfonyl)ethanone (4h). Yield = 85% (383 mg); Colorless solid; mp = 86-87 °C (recrystallized from hexanes and EtOAc); HRMS (ESI, M^+1) calcld for C_{39}H_{34}NO_{10}S 480.2209, found 480.2214; ^1H NMR (400 MHz, CDCl₃): δ 8.61 (s, 1H), 8.04 (d, J = 8.4 Hz, 2H), 7.94-7.90 (m, 2H), 7.76 (d, J = 8.0 Hz, 2H), 7.68-7.59 (m, 2H), 7.33 (d, J = 7.6 Hz, 2H), 6.49 (br s, 1H), 2.46 (s, 3H), 1.70 (br s, 1H), 1.72-1.62 (m, 4H), 1.55 (br s, 5H), 1.37 (br s, 4H), 1.28 (br s, 4H); ^13C NMR (100 MHz, CDCl₃): δ 192.85, 144.95, 135.49, 132.00, 131.50, 129.79, 129.75, 128.86 (2x), 128.74, 128.44, 128.29, 127.43, 126.57, 125.55, 123.92, 56.48, 40.65, 40.48, 34.58, 33.54, 32.91, 29.33, 27.11, 21.44, 20.28, 19.99, 16.40.

![Structure of 1-Naphthalen-2-yl-2-(2,2,6,6-tetramethylpiperidin-1-ylxy)-2-(toluene-4-sulfonyl)ethanone (4h)]

2-(4-Fluorobenzenesulfonyl)-1-phenyl-2-(2,2,6,6-tetramethylpiperidin-1-ylxy)ethanone (4i). Yield = 81% (351 mg); Colorless solid; mp = 98-99 °C (recrystallized from hexanes and EtOAc); HRMS (ESI, M^+1) calcld for C_{39}H_{29}FNO_{10}S 434.1801, found 434.1810; ^1H NMR (400 MHz, CDCl₃): δ 8.04-7.99 (m, 2H),
7.90-7.85 (m, 2H), 7.66-7.60 (m, 1H), 7.55-7.48 (m, 2H), 7.24-7.18 (m, 2H), 6.37 (s, 1H), 1.60-1.21 (m, 14H), 0.95 (br s, 2H), 0.70 (br s, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 193.50, 166.28 (d, $J = 254.7$ Hz), 134.91, 133.98 (2x), 133.05 (d, $J = 9.9$ Hz, 2x), 129.87, 129.15 (2x), 115.82 (d, $J = 22.7$ Hz, 2x), 98.36, 62.11, 60.72, 40.88, 40.79, 39.24, 33.88, 33.10, 20.55, 20.30, 16.68.

2-(4-Methoxybenzenesulfonyl)-1-phenyl-2-(2,2,6,6-tetramethylpiperidin-1-yloxy)ethanone (4j). Yield = 52% (231 mg); Colorless solid; mp = 94-95 °C (recrystallized from hexanes and EtOAc); HRMS (ESI, M$^+$+1) calcd for C$_{24}$H$_{22}$NO$_5$S 446.0201, found 446.0210; $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 8.02-8.00 (m, 2H), 7.78-7.74 (m, 2H), 7.52-7.48 (m, 2H), 7.00-6.96 (m, 2H), 6.33 (br s, 1H), 3.88 (s, 3H), 1.66-1.60 (m, 3H), 1.54 (br s, 4H), 1.32 (br s, 4H), 1.29-1.24 (m, 3H), 0.96 (br s, 2H), 0.71 (br s, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 193.66, 164.23, 136.83, 133.76 (2x), 132.38 (2x), 129.20, 128.68 (2x), 128.09, 113.74 (2x), 98.90, 76.89, 62.04, 60.69, 55.59, 40.86, 33.93, 33.11, 20.59, 20.25, 16.72.

2-(4-Hydroxy-2,2,6,6-tetramethylpiperidin-1-yloxy)-1-phenyl-2-(toluene-4-sulfonyl)ethanone (4k). Yield = 81% (360 mg); Colorless gum; HRMS (ESI, M$^+$+1) calcd for C$_{24}$H$_{32}$NO$_5$S 446.0101, found 446.0109; $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 8.11-8.10 (m, 2H), 7.81-7.80 (m, 2H), 7.72-7.71 (m, 1H), 7.62-7.61 (m, 2H), 7.43-7.41 (m, 2H), 6.43 (s, 1H), 4.12 (br s, 1H), 2.56 (s, 3H), 1.96 (br s, 1H), 1.72 (br s, 5H), 1.47 (br s, 4H), 1.37-1.35 (m, 1H), 1.12 (br s, 3H), 0.85 (br s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta$ 191.31, 143.50, 134.64, 132.10, 131.58, 128.14 (2x), 127.34 (2x), 127.27 (2x), 126.89 (2x), 96.22, 60.46, 60.33, 59.22, 47.54, 47.17, 32.01, 31.25, 19.94, 19.60, 19.31.

1-(4-Fluorophenyl)-2-(4-hydroxy-2,2,6,6-tetramethylpiperidin-1-yloxy)-2-(toluene-4-sulfonyl)ethanone (4l). Yield = 88% (407 mg); Colorless solid; mp = 105-106 °C (recrystallized from hexanes and EtOAc); HRMS (ESI, M$^+$+1) calcd for C$_{24}$H$_{31}$FNO$_5$S 464.1907, found 464.1912; $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 8.06 (dd, $J = 5.6$, 8.4 Hz, 2H), 7.69 (d, $J = 8.4$ Hz, 2H), 7.33 (d, $J = 8.0$ Hz, 2H), 7.18 (t, $J = 8.4$ Hz, 2H), 6.24 (br s, 1H), 3.93 (br s, 1H), 2.46 (s, 3H), 1.86-1.83 (m, 1H), 1.70-1.67 (m, 1H), 1.60 (br s, 3H), 1.36 (br s, 4H), 1.29 (br s, 3H).
1.26-1.25 (m, 2H), 1.01 (br s, 3H), 0.74 (br s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 191.36, 167.22, 164.66, 145.31, 131.88, 131.79, 129.68 (2x), 129.03 (4x), 128.87, 115.89, 115.65, 62.02, 60.88, 48.82, 48.48, 33.59, 32.89, 21.50, 21.22, 20.97.

2-(4-Hydroxy-2,2,6,6-tetramethylpiperidin-1-yloxy)-1-(4-methoxyphenyl)-2-(toluene-4-sulfonyl)ethanone (4m). Yield = 50% (238 mg); Colorless solid; mp = 86-87 °C (recrystallized from hexanes and EtOAc); HRMS (ESI, M$^+$+1) calcd for C$_{25}$H$_{34}$NO$_6$S 476.2107, found 476.2116; $^1$H NMR (400 MHz, CDCl$_3$): δ 7.98 (d, $J$ = 8.8 Hz, 2H), 7.67 (d, $J$ = 8.4 Hz, 2H), 7.29 (d, $J$ = 8.0 Hz, 2H), 6.96 (d, $J$ = 8.8 Hz, 2H), 7.81 (s, 1H), 3.87 (s, 3H), 3.09 (br s, 1H), 2.43 (s, 3H), 1.83-1.79 (m, 1H), 1.69-1.54 (m, 4H), 1.50-1.48 (m, 2H), 1.43-1.31 (m, 6H), 1.00 (br s, 2H), 0.73 (br s, 2H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 191.15, 164.25, 145.28, 132.78, 131.72, 129.96, 129.15 (2x), 128.93, 125.75, 113.99 (2x), 62.29, 61.13, 57.95, 55.53 (2x), 49.01, 48.65, 43.62, 33.71, 33.13, 30.23, 25.42, 21.71.

$^{1}$Biphenyl-4-yl-2-(4-hydroxy-2,2,6,6-tetramethylpiperidin-1-yloxy)-2-(toluene-4-sulfonyl)ethanone (4n). Yield = 80% (417 mg); Colorless gum; HRMS (ESI, M$^+$+1) calcd for C$_{30}$H$_{36}$NO$_5$S 522.2314, found 522.2322; $^1$H NMR (400 MHz, CDCl$_3$): δ 8.09 (d, $J$ = 8.4 Hz, 2H), 7.73 (d, $J$ = 8.4 Hz, 4H), 7.66-7.63 (m, 2H), 7.51-7.40 (m, 3H), 7.33 (d, $J$ = 8.0 Hz, 2H), 6.37 (br s, 1H), 3.96-3.90 (m, 1H), 2.45 (s, 3H), 1.88-1.85 (m, 2H), 1.72-1.56 (m, 4H), 1.56-1.50 (m, 1H), 1.39 (br s, 4H), 1.04 (br s, 3H), 0.79 (br s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 192.63, 146.58, 145.42, 139.49, 130.02, 129.76, 129.18 (4x), 128.93 (4x), 128.41, 127.32, 127.24 (4x), 62.42, 62.26, 61.22, 49.07, 48.70, 33.86, 33.06, 21.72, 21.46, 21.20.

A representative synthetic procedure of skeleton 6 is as follows: K$_2$S$_2$O$_8$ (2a, 300 mg, 1.1 mmol) was added to a solution of 5a-c (1.0 mmol) and TEMPO 3a (1.2 mmol) in MeCN (5 mL) at rt. The reaction mixture was stirred at rt for 12 h and the solvent was concentrated. The residue was diluted with water (10 mL) and the mixture was extracted with EtOAc (3 x 20 mL). The combined organic layers were washed with brine, dried, filtered and evaporated to afford crude product. Purification on silica gel (hexanes/EtOAc = 10/1-6/1) afforded skeleton 6.
1-Phenyl-2-(2,2,6,6-tetramethylpiperidin-1-yloxy)butane-1,3-dione (6a). Compound 6a is a known compound and the analytical data are consistent with those in the literature (Feng, P.; Song, S.; Zhang, L.-H.; Jiao, N. Synlett 2014, 25, 2717; Schroll, P.; Konig, B. Eur. J. Org. Chem. 2015, 309). Yield = 47% (149 mg); Colorless solid; mp = 66-68 °C (recrystallized from hexanes and EtOAc); HRMS (ESI, M+1) calcd for C_{19}H_{28}NO_{3} 318.2069, found 318.2078; $^1$H NMR (400 MHz, CDCl$_3$): δ 8.10-8.06 (m, 2H), 7.59-7.55 (m, 1H), 7.48-7.44 (m, 2H), 5.60 (s, 1H), 2.24 (s, 3H), 1.62-1.31 (m, 6H), 1.33-1.22 (m, 3H), 1.07 (s, 3H), 1.05 (s, 3H), 0.83 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 203.32, 195.38, 134.84, 133.78, 129.82 (2x), 128.55 (2x), 100.12, 60.2, 59.99, 40.12, 39.08, 33.01, 32.4, 26.70, 20.25, 20.14, 16.94.

1,3-Diphenyl-2-(2,2,6,6-tetramethylpiperidin-1-yloxy)propane-1,3-dione (6b). Compound 6b is a known compound and the analytical data are consistent with those in the literature (Feng, P.; Song, S.; Zhang, L.-H.; Jiao, N. Synlett 2014, 25, 2717; Schroll, P.; Konig, B. Eur. J. Org. Chem. 2015, 309). Yield = 53% (201 mg); Colorless solid; mp = 87-89 °C (recrystallized from hexanes and EtOAc); HRMS (ESI, M+1) calcd for C$_{24}$H$_{30}$NO$_3$ 380.2226, found 380.2237; $^1$H NMR (400 MHz, CDCl$_3$): δ 8.21-8.18 (m, 4H), 7.56-7.52 (m, 2H), 7.47-7.44 (m, 4H), 6.29 (s, 1H), 1.54-1.26 (m, 6H), 1.13 (br s, 6H), 0.95 (br s, 6H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 195.02 (2x), 134.73 (2x), 133.66 (2x), 130.17 (4x), 128.40 (4x), 99.12, 60.17 (2x), 40.08 (2x), 32.94, 20.24 (2x), 16.97 (2x).

3-Oxo-3-phenyl-2-(2,2,6,6-tetramethylpiperidin-1-yloxy)-propionic acid ethyl ester (6c). Compound 6c is a known compound and the analytical data are consistent with those in the literature (Wang, Z.-L.; An, X.-L.; Ge, L.-S.; Jin, J.-H.; Luo, X.; Deng, W.-P. Tetrahedron 2014, 70, 3788). Yield = 31% (108 mg); Colorless oil; HRMS (ESI, M+1) calcd for C$_{20}$H$_{30}$NO$_3$ 348.2175, found 348.2183; $^1$H NMR (400 MHz, CDCl$_3$): δ 8.15-8.13 (m, 2H), 7.59-7.55 (m, 1H), 7.48-7.44 (m, 2H), 5.41 (s, 1H), 4.20-4.14 (m, 2H), 1.48-1.18 (m, 9H), 1.25 (s, 3H), 1.16 (t, $J$ = 7.2 Hz, 3H), 0.99 (s, 3H), 0.83 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 193.67, 168.29, 134.53, 133.58, 129.81 (2x), 128.46 (2x), 92.88, 61.63, 40.19, 40.03, 33.14, 32.47, 29.67, 27.77, 20.23, 16.97 (2x), 13.95.

A representative synthetic procedure of skeleton 7 is as follows: 1,2-Diaminobenzene (120 mg, 1.1 mmol)
were added to a solution of 4c-d or 4f (1.0 mmol) in dioxane (5 mL) at rt. The reaction mixture was stirred at reflux for 10 h, cooled to rt, and the solvent was concentrated. The residue was diluted with water (10 mL) and the mixture was extracted with CH$_2$Cl$_2$ (3 x 20 mL). The combined organic layers were washed with brine, dried, filtered and evaporated to afford crude product. Purification on silica gel (hexanes/EtOAc = 10/1~3/1) afforded skeleton 7.

2-Phenylquinoxaline (7a). Compound 7a is a known compound and the analytical data are consistent with those in the literature (Song, J.; Li, X.; Chen, Y.; Zhao, M.; Dou, Y.; Chen, B. Synlett 2012, 23, 2416). Yield = 69% (142 mg); Colorless solid; mp = 75-76 °C (recrystallized from hexanes and EtOAc); HRMS (ESI, M$^+$+1) calc for C$_{14}$H$_{11}$N$_2$ 207.0922, found 207.0916; $^1$H NMR (400 MHz, CDCl$_3$): δ 9.31 (s, 1H), 8.19-8.10 (m, 4H), 7.78-7.70 (m, 2H), 7.57-7.48 (m, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 151.70, 143.21, 142.18, 141.42, 136.63, 130.19, 130.09, 129.51, 129.45, 129.05 (2x), 128.99, 127.45 (2x).

2-p-Tolylquinoxaline (7b). Compound 7b is a known compound and the analytical data are consistent with those in the literature (Song, J.; Li, X.; Chen, Y.; Zhao, M.; Dou, Y.; Chen, B. Synlett 2012, 23, 2416). Yield = 62% (136 mg); Colorless solid; mp = 92-93 °C (recrystallized from hexanes and EtOAc); HRMS (ESI, M$^+$+1) calc for C$_{15}$H$_{13}$N$_2$ 221.1079, found 221.1083; $^1$H NMR (400 MHz, CDCl$_3$): δ 9.29 (s, 1H), 8.14-8.07 (m, 4H), 7.78-7.70 (m, 2H), 7.35 (d, $J = 0.8, 8.4$ Hz, 2H), 2.43 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 151.70, 143.17, 142.22, 141.30, 140.42, 133.85, 130.12, 129.80 (2x), 129.44, 129.21, 128.98, 127.34 (2x), 21.35.

2-(4-Methoxyphenyl)quinoxaline (7c). Compound 7c is a known compound and the analytical data are consistent with those in the literature (Song, J.; Li, X.; Chen, Y.; Zhao, M.; Dou, Y.; Chen, B. Synlett 2012, 23, 2416). Yield = 71% (168 mg); Colorless solid; mp = 95-96 °C (recrystallized from hexanes and EtOAc); HRMS (ESI, M$^+$+1) calc for C$_{15}$H$_{13}$N$_2$O 237.1028, found 237.1030; $^1$H NMR (400 MHz, CDCl$_3$): δ 9.27 (s, 1H), 8.15 (d, $J = 9.2$ Hz, 2H), 8.12-8.07 (m, 2H), 7.76-7.67 (m, 2H), 7.06 (d, $J = 9.2$ Hz, 2H), 3.88 (s, 3H); $^{13}$C NMR (100 MHz, CDCl$_3$): δ 161.41, 151.34, 142.93, 142.21, 141.05, 130.15, 129.29, 129.14, 129.02, 128.94, 128.92 (2x), 114.52 (2x), 55.36.
Compound 4a
Compound 4g
Compound 4c
Compound 4d
Compound 4e
Compound 4f
Compound 4h
Compound 4i
Compound 4j
Compound 4k
Compound 41
Compound 4m
Compound 4n
Compound 6a
Compound 6c
Compound 7c