Supporting Information for

Flavin Catalyzed Oxidations of Sulfides and Amines with Molecular Oxygen

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General. NMR spectra were obtained on a JEOL JNM-GSX-270 NMR spectrometer (^1H , 270 MHz; ^{13}C , 68 MHz) and a Varian Unity-Inova 500 NMR spectrometer (^1H , 500 MHz; ^{13}C , 126 MHz); chemical shifts (δ) were expressed in parts per million relative to tetramethylsilane (^1H) or CDCl_3 (^{13}C). Splitting patterns are designated as s, singlet; d, doublet; t, triplet; m, multiplet. Mass spectra were obtained on a JEOL JMS-DX303HF mass spectrometer and a JEOL The MStation JMS-700 mass spectrometer. IR spectra were recorded on a Hitachi 215 spectrometer. Optical rotations were measured by a JASCO DIP-4 polarimeter.

Materials. $\text{NH}_2\text{NH}_2 \cdot \text{H}_2\text{O}$ (Nacalai Tesque) and 2,2,2-trifluoroethanol (Nacalai Tesque) were commercially available and used without further purification. $\text{FIEt}^+\cdot\text{ClO}_4^-$ (**3**)¹ and (1*R*, *R*_S)-2-hydroxy-1-[(*p*-toluenesulfinyl)methyl]-1,2,3,4-tetrahydroisoquinoline² were prepared according to the literature procedure.

General Procedure for Oxidation of Sulfides. Dibutyl Sulfoxide.³ To a solution of $\text{FIEt}^+\cdot\text{ClO}_4^-$ (**3**) (4.0 mg, 0.010 mmol) and dibutyl sulfide (146 mg, 1.00 mmol) in 2,2,2-trifluoroethanol (1.0 mL) was added $\text{NH}_2\text{NH}_2 \cdot \text{H}_2\text{O}$ (50.1 mg, 1.00 mmol). The flask was filled with molecular oxygen using an O_2 balloon. The reaction mixture was stirred vigorously in a water-bath at 35 °C for 2 h. Saturated aqueous Na_2SO_3 was added to quench the reaction, and the reaction mixture was extracted with CH_2Cl_2 . The combined extracts were dried (MgSO_4) and evaporated. The crude product was purified by Kugelrohr distillation (130 °C, 30 mmHg) to afford dibutyl sulfoxide as a colorless oil (155 mg, 96 %): ^1H NMR (CDCl_3 , 270 MHz) δ 0.90 (t, $J=7.3$ Hz, 6H, CH_3), 1.35-1.50 (m, 4H, $-\text{CH}_2-$), 1.64-1.75 (m, 4H, $-\text{CH}_2-$), 2.55-2.77 (m, 4H, $-\text{CH}_2-$); ^{13}C NMR (68 MHz, CDCl_3) δ 13.6, 22.0, 24.6, 51.8; MS (CI) m/z 163 ($\text{M} + \text{H}^+$).

1,3-Dithiane Oxide.⁴ ^1H NMR (CDCl_3 , 500 MHz) δ 2.20-2.26 (m, 1H, $-\text{CHH}-$), 2.49-2.70 (m, 4H, $-\text{CH}_2-$), 3.32-3.36 (m, 1H, $-\text{CHH}-$), 3.66 (d, $J=12.6$ Hz, 1H, $-\text{SCHHS}-$), 4.01-4.04 (d, $J=12.8$ Hz, 1H,

-SCHHS-); ^{13}C NMR (126 MHz, CDCl_3) δ 27.1, 28.2, 50.3, 52.8; MS (CI) m/z 137 ($\text{M} + \text{H}^+$).

Methyl *p*-Tolyl Sulfoxide.⁵ ^1H NMR (CDCl_3 , 270 MHz) δ 2.42 (s, 3H, ArCH_3), 2.73 (s, 3H, SCH_3), 7.33 (dd, $J=0.7$ and 8.6 Hz, 2H, ArH), 7.54 (ddd, $J=1.8$, 1.8, and 8.3 Hz, 2H, ArH); ^{13}C NMR (68 MHz, CDCl_3) δ 21.3, 44.0, 123.5, 130.0, 141.5, 142.6; MS (CI) m/z 155 ($\text{M} + \text{H}^+$).

General Procedure for Oxidation of Secondary Amines and Hydroxylamines.

3,4-Dihydroisoquinoline *N*-Oxide.⁶ To a solution of $\text{FIEt}^+\text{ClO}_4^-$ (**3**) (10.0 mg, 0.0250 mmol) and $\text{NH}_2\text{NH}_2 \cdot \text{H}_2\text{O}$ (27.6 mg, 0.55 mmol) in 2,2,2-trifluoroethanol (0.5 mL) was added 1,2,3,4-tetrahydroisoquinoline (66.6 mg, 0.500 mmol). The flask was filled with molecular oxygen using an O_2 balloon. The reaction mixture was stirred vigorously in a water-bath at 60 $^\circ\text{C}$ for 3 h. Saturated aqueous Na_2SO_3 was added to quench the reaction, and the reaction mixture was extracted with CH_2Cl_2 . The combined extracts were dried (Na_2SO_4) and evaporated. The crude product was purified by column chromatography on silica gel to give 3,4-dihydroisoquinoline *N*-oxide as a white solid (63.1 mg, 85%); ^1H NMR (CDCl_3 , 500 MHz) δ 3.20 (t, $J=7.78$ Hz, 2H, ArCH_2 -), 4.12 (dt, $J=0.92$ and 7.3 Hz, 2H, $-\text{CH}_2\text{N}-$), 7.12-7.15 (m, 1H, ArH), 7.22-7.23 (m, 1H, ArH), 7.28-7.30 (m, 2H, ArH), 7.77 (s, 1H, $-\text{CH}=\text{N}-$); ^{13}C NMR (126 MHz, CDCl_3) δ 27.7, 57.9, 125.4, 127.2, 127.6, 128.3, 129.4, 130.0, 134.1; MS (CI) m/z 148 ($\text{M} + \text{H}^+$).

***N*-Benzylidenbenzylamine *N*-Oxide.**⁶ mp 82.7-83.2 $^\circ\text{C}$; ^1H NMR (CDCl_3 , 500 MHz) δ 5.06 (s, 2H, $-\text{CH}_2-$), 7.39-7.49 (m, 9H, ArH and $-\text{CH}=\text{N}-$), 8.20-8.22 (m, 2H, ArH ortho to $-\text{CH}=\text{N}(\text{O})-$); ^{13}C NMR (126 MHz, CDCl_3) δ 71.2, 128.4, 128.6, 128.92, 128.93, 129.2, 130.3, 130.4, 133.1, 134.2; MS (CI) m/z 212 ($\text{M} + \text{H}^+$).

(*R_S*)-1-(*p*-Toluenesulfinyl)methyl-3,4-dihydroisoquinoline *N*-Oxide. mp 89.5-91.0 $^\circ\text{C}$; $[\alpha]_{\text{D}}^{25} +64.2^\circ$ (c 1.23, CHCl_3); IR (KBr) 1210 (s, N-O), 1045 (s, S=O) cm^{-1} ; ^1H NMR (CDCl_3 , 270 MHz) δ 2.41 (s, 3H, PhCH_3), 3.04-3.20 (m, 2H, $-\text{CH}_2-$), 4.08-4.13 (m, 1H, $-\text{CHH}-$), 4.19-4.26 (m, 1H, $-\text{CHH}-$), 4.29 (d, $J=12.6$ Hz, 1H, $-\text{CHHS}-$), 4.46 (dd, $J=1.1$ and 12.4 Hz, 1H, $-\text{CHHS}-$), 7.19 (d, $J=6.9$ Hz, 1H, ArH), 7.25-7.32 (m, 4H, ArH), 7.45-7.47 (m, 1H, ArH), 7.69 (d, $J=8.2$ Hz, 1H); ^{13}C NMR (126 MHz, CDCl_3) δ 21.4, 27.8, 57.5, 58.5, 109.1, 123.9, 125.1, 127.2, 127.8, 129.1, 129.8, 130.7, 138.0, 140.9, 141.7; HRMS (FAB) calcd for $\text{C}_{17}\text{H}_{18}\text{O}_2\text{NS}$ ($\text{M} + \text{H}^+$) 300.1058, found 300.1030.

General Procedure for Oxidation of Tertiary Amines. *N*-Methylmorpholine *N*-Oxide.⁷ To a solution of $\text{FIEt}^+\text{ClO}_4^-$ (**3**) (4.0 mg, 0.010 mmol) and *N*-methylmorpholine (101 mg, 1.00 mmol) in 2,2,2-trifluoroethanol (1.0 mL) was added $\text{NH}_2\text{NH}_2 \cdot \text{H}_2\text{O}$ (50.1 mg, 1.00 mmol). The flask was filled with

molecular oxygen using an O₂ balloon. The reaction mixture was stirred vigorously in a water-bath at 60 °C for 2 h. Saturated aqueous Na₂SO₃ was added to quench the reaction, and the reaction mixture was extracted with CH₂Cl₂. The combined extracts were dried (Na₂SO₄) and evaporated. The crude product was purified by column chromatography on alumina to give *N*-methylmorpholine *N*-oxide as a white solid (114 mg, 97%); mp 74.4-75.3 °C; ¹H NMR (CDCl₃, 500 MHz) δ 3.15 (d, J=11.9 Hz, 2H), 3.26 (s, 3H, CH₃), 3.33-3.39 (m, 2H), 3.79 (d, J=12.6 Hz, 2H), 4.39-4.44 (m, 2H); ¹³C NMR (126 MHz, CDCl₃) δ 60.9, 61.6, 65.7; MS (CI) m/z 118 (M + H⁺).

***N,N*-Dimethylaniline *N*-Oxide.**⁸ ¹H NMR (CDCl₃, 500 MHz) δ 3.60 (s, 6H, CH₃), 7.40-7.43 (m, 1H, ArH), 7.46-7.50 (m, 2H, ArH), 7.97-7.99 (m, 2H, ArH); ¹³C NMR (126 MHz, CDCl₃) δ 63.2, 119.8, 128.9, 129.1, 154.1; MS (CI) m/z 138 (M + H⁺).

Competitive Reaction of Substituted Thioanisoles (X-C₆H₄SCH₃, X= *p*-MeO, *p*-Me, H, *p*-CN, *p*-NO₂) for the FIEt⁺·ClO₄⁻ (1) Catalyzed Aerobic Oxidation. To a solution of FIEt⁺·ClO₄⁻ (3) (4.0 mg, 0.010 mmol), thioanisole (62.1 mg, 0.500 mmol), and substituted thioanisole (0.50 mmol) in 2,2,2-trifluoroethanol (1.0 mL) was added NH₂NH₂·H₂O (50.1 mg, 1.00 mmol). The flask was filled with molecular oxygen using an O₂ balloon, and the mixture was stirred vigorously in a water-bath at 35 °C for 15 min. Saturated aqueous Na₂SO₃ was added to quench the reaction, and the reaction mixture was extracted with ether. The combined extracts were dried (MgSO₄) and evaporated. The product ratio were determined by the integration of the methyl protons of X-C₆H₄S(O)CH₃. The singlet signals of methyl protons of X-C₆H₄SOCH₃ are observed at 2.71 ppm (*p*-MeO), 2.71 ppm (*p*-Me), 2.73 ppm (H), 2.75 ppm (*p*-CN), and 2.78 ppm (*p*-NO₂).

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