Supporting Information

Bis(trialkylsilyl) peroxides as alkylating agents in the copper-catalyzed selective mono-N-alkylation of primary amides

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General Information

$^1$H NMR spectra were measured on JEOL JNM-ECA500 (500 MHz) spectrometer. Data were reported as follows: chemical shifts in ppm from tetramethylsilane as an internal standard in CDCl$_3$, integration, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad), coupling constants (Hz), and assignment. $^{13}$C NMR spectra were measured on JEOL JNM-ECA500 (125 MHz) spectrometer with complete proton decoupling. Chemical shifts were reported in ppm from the residual solvent as an internal standard. $^{29}$Si NMR spectra were measured on JEOL JNM-ECA500 (100 MHz) spectrometer. Infrared (IR) spectra were recorded on a Thermo Scientific Nicolet iS5 spectrometer. High-resolution mass spectra (HRMS) were performed on Thermo Exactive plus. The products were purified by flash column chromatography (silica gel 60, Merck, 230-400 mesh) or preparative thin layer chromatography silica gel (PLC 60 F254, 0.5 mm). Commercially available reagents were purchased from Wako, Sigma-Aldrich, TCI and Alfa-asher chemicals and used as received. Benzene was used after the distillation from CaH$_2$. 

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Optimization of Reaction Conditions of N-Ethylation of Benzamide 2a with 1a.

Table S1. The effect of the amount of peroxide\[^{[a]}\]

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<th>3a (%)[^{[b]}]</th>
<th>2a (%)[^{[b]}]</th>
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<td>4 [^{[c]}]</td>
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\[^{[a]}\] Reaction conditions: benzamide 2a (0.1 mmol, 1.0 eq.), 1a (X eq.), CuI (10 mol%), L1 (10 mol%), benzene (0.25 mL, 0.4 M), 100 °C, 24 h. \[^{[b]}\] Yield was determined by 1H NMR spectroscopy using DMF as an internal standard. \[^{[c]}\] 1a (0.2 mmol, 2.0 eq.) was added to the reaction mixture after stirring for 1h.

Table S2. The effect of the amount of catalyst and ligand\[^{[a]}\]

<table>
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\[^{[a]}\] Reaction conditions: benzamide 2a (0.1 mmol, 1.0 eq.), 1a (X eq.), CuI (X mol%), L1 (X mol%), benzene (0.25 mL, 0.4 M), 100 °C, 24 h. \[^{[b]}\] Yield was determined by 1H NMR spectroscopy using DMF as an internal standard.
Table S3. The effect of ligand\textsuperscript{[a]}

![Reaction conditions: bezamide 2a (0.1 mmol, 1.0 eq.), 1a (0.2 mmol, 2.0 eq.), CuI (10 mol%), ligand (10 mol%), benzene (0.25 mL, 0.4 M), 100 °C, 24 h. Yield was determined by \textsuperscript{1}H NMR spectroscopy using DMF as an internal standard.]

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\textsuperscript{[a]} Reaction conditions: bezamide 2a (0.1 mmol, 1.0 eq.), 1a (0.2 mmol, 2.0 eq.), CuI (10 mol%), ligand (10 mol%), benzene (0.25 mL, 0.4 M), 100 °C, 24 h. \textsuperscript{[b]} Yield was determined by \textsuperscript{1}H NMR spectroscopy using DMF as an internal standard.
General Procedure for the Synthesis of Bis(trialkylsilyl) Peroxide (1)

To a solution of 1,4-diazabicyclo[2.2.2]octane (1.12 g, 10.0 mmol, 1.0 eq.) and H$_2$O$_2$-urea complex (941 mg, 10.0 mmol, 1.0 eq.) in dry dichloromethane (20 mL) was added a trialkylsilyl chloride (1.0 eq.) slowly at 0 °C under argon atmosphere. After 3 h of stirring at room temperature, to the reaction mixture was added pentane (20 mL), and the white precipitate was removed by filtration. Solvent was evaporated and the residue was purified by flash column chromatography on silica gel (eluting with pentane) to afford a corresponding product.

**Bis(triethylsilyl) peroxide (1a)** \[^1\]

![Bis(triethylsilyl) peroxide (1a)](image)

Colorless oil.

$^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 0.98 (18H, t, $J = 7.9$ Hz, CH$_3$), 0.68 (12H, q, $J = 7.9$ Hz, SiCH$_2$); $^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 6.92, 4.01; $^{29}$Si NMR (100 MHz, CDCl$_3$) $\delta$ 28.62.

**Bis(trimethylsilyl) peroxide (1b)** \[^2\]

![Bis(trimethylsilyl) peroxide (1b)](image)

Colorless oil.

$^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 0.19 (18H, s, SiCH$_3$); $^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ –1.16; $^{29}$Si NMR (100 MHz, CDCl$_3$) $\delta$ 27.86.

**Bis(tributylsilyl) peroxide (1c)**

![Bis(tributylsilyl) peroxide (1c)](image)

Colorless oil.

$^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 1.35-1.32 (24H, m), 0.89 (18H, t, $J = 6.8$ Hz, CH$_3$), 0.69-0.65 (12H, m, SiCH$_2$); $^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 26.7, 25.6, 13.9, 12.8; $^{29}$Si NMR (100 MHz, CDCl$_3$) $\delta$ 26.51; HRMS calculated for C$_{24}$H$_{54}$O$_2$NaSi$_2$: $m/z$ 453.3555 ([M + Na]$^+$), found: $m/z$ 453.3545 ([M + Na]$^+$); IR (neat) 2956, 2922, 1465, 1195, 1081, 884, 782 cm$^{-1}$.

**Bis(dimethylisopropylsilyl) peroxide (1d)**

![Bis(dimethylisopropylsilyl) peroxide (1d)](image)

Colorless oil.

$^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 0.98-0.97 (14H, m), 0.12 (12H, s, SiCH$_3$); $^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 17.2, 13.9, –4.82; $^{29}$Si NMR (100 MHz, CDCl$_3$) $\delta$ 28.84; HRMS calculated for C$_{10}$H$_{26}$O$_2$NaSi$_2$: $m/z$ 257.1364 ([M + Na]$^+$), found: $m/z$ 257.1360 ([M + Na]$^+$); IR (neat) 2944, 2867, 1463, 1249, 1000, 813, 778 cm$^{-1}$. 

S4
Bis(dicyclohexylmethylsilyl) peroxide (1e)

Colorless oil.

$^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 1.73-1.66 (10H, m, CH$_2$), 1.23-1.12 (10H, m, CH$_2$), 0.85-0.80 (2H, m, CH$_2$), 0.12 (12H, m, SiCH$_3$); $^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 28.1, 28.0, 27.1, 27.0, 25.9, –1.41, –4.46; $^{29}$Si NMR (100 MHz, CDCl$_3$) $\delta$ 26.88; HRMS calculated for C$_{16}$H$_{34}$O$_2$NaSi$_2$: m/z 337.1990 ([M + Na]$^+$), found: m/z 337.1983 ([M + Na]$^+$); IR (neat) 2918, 2848, 1446, 1247, 818, 778 cm$^{-1}$.

Bis(tert-butyldimethylsilyl) peroxide (1f)

Colorless oil.

$^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 0.93 (18H, s, CH$_3$), 0.14 (12H, s, SiCH$_3$); $^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 26.4, 18.5, –5.59; $^{29}$Si NMR (100 MHz, CDCl$_3$) $\delta$ 29.30; HRMS calculated for C$_{12}$H$_{30}$O$_2$NaSi$_2$: m/z 285.1677 ([M + Na]$^+$), found: m/z 285.1674 ([M + Na]$^+$); IR (neat) 2955, 2878, 1458, 1238, 1005, 782, 725 cm$^{-1}$.

General Procedure for Mono-N-Alkylation of Amide (2) with Disilyl Peroxide (1)

To a solution of amide 2 (0.2 mmol, 1.0 eq.), CuI (3.8 mg, 10 mol%) and 1,10-phenanthroline (3.6 mg, 10 mol%) in benzene (0.5 mL) was added disilyl peroxide 1 (0.4 mmol, 2.0 eq.) under argon atmosphere. The reaction mixture was stirred at 100 °C for 1 h. After cooling to room temperature, the reaction mixture was quenched with H$_2$O, extracted with Et$_2$O for three times. The combined organic layer was washed with brine, dried over Na$_2$SO$_4$ and concentrated. The residue was purified by flash column chromatography on silica gel (eluting with ethyl acetate/hexane = 2/3) to afford a corresponding product.

$N$-Ethylbenzamide (3a) $^{[3]}$

White solid, 18.6 mg, 62% yield.

$^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 7.77-7.75 (2H, ), 7.49-7.47 (1H, m, ArH), 7.44-7.40 (2H, m, ArH), 6.14 (1H, br, NH), 3.53-3.47 (2H, m, NCH$_2$), 1.25 (3H, t, J = 7.4 Hz, CH$_3$); $^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 167.6, 134.9, 131.5, 128.7, 127.0, 35.1, 15.0.
**N-Methylbenzamide (3b) [4]**

Me$_3$SiO-OSiMe$_3$ (1b) (4.0 eq.) was used for the reaction.

White solid, 10.0 mg, 37% yield.

$^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 7.76-7.75 (2H, m, ArH), 7.51-7.48 (1H, m, ArH), 7.44-7.41 (2H, m, ArH), 6.13 (1H, br, NH)$_3$, 3.02 (3H, d, NCH$_3$, $J = 4.8$ Hz); $^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 168.5, 134.8, 131.5, 128.7, 127.0, 27.0.

**N-Butylbenzamide (3c) [5]**

$n$Bu$_3$SiO-OSi$n$Bu$_3$ (1c) (4.0 eq.) was used for the reaction.

White solid, 20.2 mg, 57% yield.

$^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 7.76-7.75 (2H, m, ArH), 7.51-7.47 (1H, m, ArH), 7.44-7.41 (2H, m, ArH), 6.08 (1H, br, NH)$_3$, 3.49-3.45 (2H, m, NCH$_2$), 1.62-1.58 (2H, m, CH$_2$), 1.45-1.40 (2H, m, CH$_2$), 0.97 (3H, t, $J = 7.4$ Hz, CH$_3$); $^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 167.7, 134.8, 131.0, 128.2, 127.0, 39.8, 31.6, 20.1, 13.7.

**N-Isopropylbenzamide (3d) [6]**

White solid, 20.6 mg, 63% yield.

$^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 7.76-7.74 (2H, m, ArH), 7.50-7.47 (1H, m, ArH), 7.44-7.41 (2H, m, ArH), 5.89 (1H, br, NH)$_3$, 4.33-4.26 (1H, m, NCH$_3$), 1.27 (6H, d, $J = 6.5$ Hz, CH$_3$); $^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 166.8, 135.2, 131.4, 128.7, 126.9, 42.0, 23.0.

**N-Cyclohexylbenzamide (3e) [7]**

White solid, 24.8 mg, 61% yield.

$^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 7.76-7.74 (2H, m, ArH), 7.49-7.47 (1H, m, ArH), 7.44-7.42 (2H, m, ArH), 5.94 (1H, br, NH)$_3$, 4.02-3.96 (1H, m, NCH$_2$), 2.06-2.02 (2H, m, CH$_2$), 1.77-1.74 (2H, m, CH$_2$), 1.68-1.64 (1H, m, CH$_2$), 1.48-1.40 (2H, m, CH$_2$), 1.28-1.20 (3H, m, CH$_2$); $^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 166.8, 135.3, 131.4, 128.7, 127.0, 48.8, 33.4, 25.7, 25.1.

**4-Chloro-N-ethylbenzamide (4a) [8]**

Pale yellow solid, 23.2 mg, 63% yield.

$^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 7.71-7.69 (2H, m, ArH), 7.41-7.39 (2H, m, ArH), 6.03 (1H, br, NH)$_3$, 3.52-3.47 (2H, m, NCH$_2$), 1.26 (3H, t, $J = 7.4$ Hz, CH$_3$); $^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 166.5, 137.7, 133.3, 128.9, 128.4, 35.2, 15.0.
4-Bromo-N-ethylbenzamide (4b) [9]

Pale yellow solid, 27.4 mg, 60% yield.

\[
\begin{align*}
\text{H NMR } (500 \text{ MHz, CDCl}_3) & \delta 7.64-7.62 (2\text{H, m, ArH}), 7.58-7.56 (2\text{H, m, ArH}), 6.02 (1\text{H, br, NH}), 3.52-3.47 (2\text{H, m, NCH}_2), 1.26 (3\text{H, t, } J = 7.4 \text{ Hz, CH}_3); \\
\text{C NMR } (125 \text{ MHz, CDCl}_3) & \delta 166.6, 133.8, 131.9, 128.6, 126.1, 35.2, 15.0.
\end{align*}
\]

4-Acetoxy-N-ethylbenzamide (4c)

Et₃Si-O-SiEt₃ (1a) (4.0 eq.) was used for the reaction.

White solid, 19.9 mg, 48% yield.

\[
\begin{align*}
\text{H NMR } (500 \text{ MHz, CDCl}_3) & \delta 7.78 (2\text{H, d, } J = 8.8 \text{ Hz, ArH}), 7.16 (2\text{H, d, } J = 8.8 \text{ Hz, ArH}), 6.00 (1\text{H, br, NH}), 3.53-3.47 (2\text{H, m, NCH}_2), 2.32 (3\text{H, t, } J = 7.4 \text{ Hz, CH}_3); \\
\text{C NMR } (125 \text{ MHz, CDCl}_3) & \delta 169.2, 166.7, 153.1, 132.6, 128.4, 121.9, 35.1, 21.3, 15.0; \\
\text{HRMS calculated for } C_{11}H_{13}O_3NNa: m/z & 230.0788 ([M + Na]^+), \text{ found: } m/z 230.0787 ([M + Na]^+); \\
\text{IR (neat)} & 3305, 2921, 1749, 1634, 1540, 1255, 1198 \text{ cm}^{-1}.
\end{align*}
\]

N-Ethyl-4-methoxybenzamide (4d) [8]

White solid, 20.1 mg, 56% yield.

\[
\begin{align*}
\text{H NMR } (500 \text{ MHz, CDCl}_3) & \delta 7.74-7.72 (2\text{H, m, ArH}), 6.93-6.91 (2\text{H, m, ArH}), 5.98 (1\text{H, t, } J = 7.4 \text{ Hz, CH}_3); \\
\text{C NMR } (125 \text{ MHz, CDCl}_3) & \delta 167.1, 162.2, 128.4, 121.9, 35.1, 21.3, 15.0.
\end{align*}
\]

N-Ethyl-4-methylbenzamide (4e) [8]

White solid, 19.6 mg, 60% yield.

\[
\begin{align*}
\text{H NMR } (500 \text{ MHz, CDCl}_3) & \delta 7.66 (2\text{H, d, } J = 8.2 \text{ Hz, ArH}), 7.23 (2\text{H, d, } J = 8.2 \text{ Hz, ArH}), 6.03 (1\text{H, br, NH}), 3.52-3.46 (2\text{H, m, NCH}_2), 2.39 (3\text{H, s, ArCH}_3), 1.25 (3\text{H, t, } J = 7.1 \text{ Hz, CH}_3); \\
\text{C NMR } (125 \text{ MHz, CDCl}_3) & \delta 167.5, 141.8, 132.1, 129.3, 127.0, 35.0, 21.6, 15.1.
\end{align*}
\]

N-Ethyl-2-methylbenzamide (4f) [9]

White solid, 19.9 mg, 61% yield.

\[
\begin{align*}
\text{H NMR } (500 \text{ MHz, CDCl}_3) & \delta 7.35-7.34 (1\text{H, m, ArH}), 7.31-7.28 (1\text{H, m, ArH}), 7.22-7.18 (2\text{H, m, ArH}), 5.70 (1\text{H, br, NH}), 3.51-3.46 (2\text{H, m, NCH}_2), 2.45 (3\text{H, s, ArCH}_3), 1.25 (3\text{H, t, } J = 7.4 \text{ Hz, CH}_3); \\
\text{C NMR } (125 \text{ MHz, CDCl}_3) & \delta 170.2, 136.9, 136.1, 131.1, 129.9, 126.7, 125.8, 34.8, 19.8, 15.1.
\end{align*}
\]
**N-Ethyl-2,3,4,5,6-pentafluorobenzamide (4g)**

White solid, 30.1 mg, 63% yield.

\[ \text{F} \quad \text{F} \quad \text{F} \quad \text{N} \quad \text{O} \quad \text{H} \]

\[ \delta 5.88 (1H, \text{br, NH}), 3.55-3.49 (2H, \text{m, NC}_2H_2), 1.27 (3H, \text{t, J = 7.4 Hz, CH}_3) \]

\[ \text{C} \quad \text{F} \quad \text{F} \]

\[ \delta 157.3, 145.3(\text{m}), 143.3-143.2 (\text{m}), 141.3 (\text{m}), 138.9-138.7 (\text{m}), 136.9-136.7 (\text{m}), 35.5, 14.7; \text{HRMS calculated for C}_9H_6OaN_F_5Na: m/z 262.0262 ([M + Na]^+), \text{found: m/z 262.0263 ([M + Na]^+); IR (neat) 1655, 1502, 1326, 1265, 991, 735 cm}^{-1}. \]

**N-Ethyl-2-furancarboxamide (4h)**

Pale yellow oil, 14.8 mg, 53% yield.

\[ \text{O} \quad \text{N} \quad \text{H} \]

\[ \delta 7.42-7.41 (1H, \text{m, Ar H}), 7.10-7.09 (1H, \text{m, Ar H}), 6.50-6.48 (1H, \text{m, Ar H}), 6.32 (1H, \text{br, NH}), 3.50-3.44 (2H, \text{m, NC}_2H_2), 1.24 (3H, \text{t, J = 7.4 Hz, CH}_3) \]

\[ \text{C} \quad \text{H} \quad \text{O} \]

\[ \delta 158.4, 148.3, 143.7, 113.8, 112.1, 34.1, 15.0. \]

**(E)-N-Ethyl-3-phenyl-2-propenamide (4i)**

White solid, 14.0 mg, 40% yield.

\[ \text{H} \quad \text{N} \quad \text{O} \]

\[ \delta 7.62 (1H, \text{d, J = 15.6 Hz, CH}), 7.51-7.49 (2H, \text{m, Ar H}), 7.37-7.34 (3H, \text{m, Ar H}), 6.37 (1H, \text{d, J = 15.6 Hz, CH}), 5.29 (1H, \text{br, NH}), 3.47-3.41 (2H, \text{m, NCH}_2), 1.22 (3H, \text{t, J = 7.4 Hz, CH}_3) \]

\[ \text{C} \quad \text{H} \quad \text{O} \]

\[ \delta 166.0, 140.9, 135.1, 129.7, 128.9, 127.9, 121.1, 34.7, 15.0; \text{HRMS calculated for C}_{11}H_{13}ONa: m/z 198.0889 ([M + Na]^+), \text{found: m/z 198.0893 ([M + Na]^+); IR (neat) 3273, 1655, 1616, 1549, 1336, 1225, 977 cm}^{-1}. \]

**N-Ethyl-3-phenylpropanamide (4j)**

\[ \text{Et}_3\text{SiO-OSiEt}_3 (1a) (2.0 eq.) was added to the reaction mixture after 1 h of stirring at 100 °C, and then the reaction mixture was stirred at 100 °C for another 1 h.} \]

\[ \text{Et}_3\text{SiO-OSiEt}_3 \]

\[ \delta 7.30-7.27 (2H, \text{m, Ar H}), 7.21-7.19 (3H, \text{m, Ar H}), 5.29 (1H, \text{br, NH}), 3.27-3.24 (2H, \text{m, NCH}_2), 2.96 (2H, \text{t, J = 7.4 Hz, CH}_2), 2.45 (2H, \text{t, J = 7.9 Hz, CH}_2), 1.06 (3H, \text{t, J = 7.4 Hz, CH}_3) \]

\[ \text{C} \quad \text{H} \quad \text{O} \]

\[ \delta 156.4, 141.1, 128.6, 128.5, 126.3, 38.7, 34.4, 31.9, 14.9. \]

**Benzyl N-ethylcarbamate (4k)**

\[ \text{H} \quad \text{N} \quad \text{O} \]

\[ \delta 7.39-7.29 (5H, \text{m, Ar H}), 5.10 (2H, \text{s, OCH}_2), 4.68 (1H, \text{br, NH}), 3.27-3.22 (2H, \text{m, NCH}_2), 1.15 (3H, \text{t, J = 7.4 Hz, CH}_3) \]

\[ \text{C} \quad \text{H} \quad \text{O} \]

\[ \delta 156.4, 136.7, 128.5-128.0(3 \text{ peaks overlap), 66.5, 35.9, 15.2.} \]
1-Ethyl-3-phenylurea (4l) \[^{[12]}\]

\[
\text{H NMR (500 MHz, CDCl}_3\text{)} \delta 7.34-7.31 (2H, m, ArH), 7.28-7.27 (2H, m, ArH), 7.12-7.10 (1H, m, ArH), 6.17 (1H, br, NH), 4.63 (1H, br, NH), 3.33-3.28 (2H, m, NCH\textsubscript{2}), 1.16 (3H, t, J = 7.1 Hz, CH\textsubscript{3}); \]
\[
\text{C NMR (125 MHz, CDCl}_3\text{)} \delta 156.5, 139.1, 129.2, 123.4, 120.7, 35.2, 15.5.
\]

2-Ethylaminopyrimidine (4n) \[^{[13]}\]

\[
\text{H NMR (500 MHz, CDCl}_3\text{)} \delta 8.21 (2H, d, J = 4.8 Hz, ArH), 6.44 (1H, t, J = 4.8 Hz, ArH), 5.72 (1H, br, NH), 3.42-3.36 (2H, m, NCH\textsubscript{2}), 1.19 (3H, t, J = 7.1 Hz, CH\textsubscript{3}); \]
\[
\text{C NMR (125 MHz, CDCl}_3\text{)} \delta 162.4, 158.0, 110.2, 36.2, 14.9.
\]

Reference

$^1$H NMR spectrum of 1a (CDCl$_3$, 500 MHz)

$^{13}$C NMR spectrum of 1a (CDCl$_3$, 125 MHz)
$^{29}$Si NMR spectrum of 1a (CDCl$_3$, 100 MHz)

$^1$H NMR spectrum of 1b (CDCl$_3$, 500 MHz)
$^{13}$C NMR spectrum of 1b (CDCl$_3$, 125 MHz)

$^{29}$Si NMR spectrum of 1b (CDCl$_3$, 100 MHz)
$^1$H NMR spectrum of 1c (CDCl$_3$, 500 MHz)

$^{13}$C NMR spectrum of 1c (CDCl$_3$, 125 MHz)
$^{29}$Si NMR spectrum of 1c (CDCl$_3$, 100 MHz)

$^1$H NMR spectrum of 1d (CDCl$_3$, 500 MHz)
$^{13}$C NMR spectrum of 1d (CDCl$_3$, 125 MHz)

$^{29}$Si NMR spectrum of 1d (CDCl$_3$, 100 MHz)
$^1$H NMR spectrum of 1e (CDCl$_3$, 500 MHz)

$^{13}$C NMR spectrum of 1e (CDCl$_3$, 125 MHz)
$^{29}$Si NMR spectrum of 1e (CDCl$_3$, 100 MHz)

$^1$H NMR spectrum of 1f (CDCl$_3$, 500 MHz)
$^{13}$C NMR spectrum of 1f (CDCl$_3$, 125 MHz)

$^{29}$Si NMR spectrum of 1f (CDCl$_3$, 100 MHz)
$^1$H NMR spectrum of 3a (CDCl$_3$, 500 MHz)

$^{13}$C NMR spectrum of 3a (CDCl$_3$, 125 MHz)
$^1$H NMR spectrum of 3b (CDCl$_3$, 500 MHz)

$^{13}$C NMR spectrum of 3b (CDCl$_3$, 125 MHz)
$^1$H NMR spectrum of 3c (CDCl$_3$, 500 MHz)

$^{13}$C NMR spectrum of 3c (CDCl$_3$, 125 MHz)
$^1$H NMR spectrum of 3d (CDCl$_3$, 500 MHz)

$^{13}$C NMR spectrum of 3d (CDCl$_3$, 125 MHz)
$^1$H NMR spectrum of 3e (CDCl$_3$, 125 MHz)

$^{13}$C NMR spectrum of 3e (CDCl$_3$, 125 MHz)
$^1$H NMR spectrum of 4a (CDCl$_3$, 500 MHz)

$^{13}$C NMR spectrum of 4b (CDCl$_3$, 125 MHz)
$^1$H NMR spectrum of 4b (CDCl$_3$, 500 MHz)

$^{13}$C NMR spectrum of 4b (CDCl$_3$, 125 MHz)
$^1$H NMR spectrum of 4c (CDCl$_3$, 500 MHz)

$^{13}$C NMR spectrum of 4c (CDCl$_3$, 125 MHz)
$^1$H NMR spectrum of 4d (CDCl$_3$, 500 MHz)

$^{13}$C NMR spectrum of 4d (CDCl$_3$, 500 MHz)
$^1$H NMR spectrum of 4e (CDCl$_3$, 500 MHz)

$^{13}$C NMR spectrum of 4e (CDCl$_3$, 125 MHz)
$^1$H NMR spectrum of 4f (CDCl$_3$, 500 MHz)

$^{13}$C NMR spectrum of 4f (CDCl$_3$, 500 MHz)
$^1$H NMR spectrum of 4g (CDCl$_3$, 500 MHz)

$^{13}$C NMR spectrum of 4g (CDCl$_3$, 125 MHz)
$^1$H NMR spectrum of 4h (CDCl$_3$, 500 MHz)

$^{13}$C NMR spectrum of 4h (CDCl$_3$, 125 MHz)
$^1$H NMR spectrum of 4i (CDCl$_3$, 500 MHz)

$^{13}$C NMR spectrum of 4i (CDCl$_3$, 125 MHz)
$^1$H NMR spectrum of 4j (CDCl$_3$, 500 MHz)

$^{13}$C NMR spectrum of 4j (CDCl$_3$, 125 MHz)
$^1$H NMR spectrum of 4k (CDCl$_3$, 500 MHz)

$^{13}$C NMR spectrum of 4k (CDCl$_3$, 125 MHz)
$^1$H NMR spectrum of 4l (CDCl$_3$, 500 MHz)

$^{13}$C NMR spectrum of 4l (CDCl$_3$, 125 MHz)
$^1$H NMR spectrum of 4n (CDCl$_3$, 500 MHz)

$^{13}$C NMR spectrum of 4n (CDCl$_3$, 125 MHz)