Supporting Information

for

Palladium-Catalyzed Decarbonylative Alkylation of Acyl Fluorides

Liyan Fu,† Qiang Chen,‡ Zhenhua Wang,† and Yasushi Nishihara†,‡*

†Graduate School of Natural Science and Technology, Okayama University, 3-1-1 Tsushimanaka, Kita-ku, Okayama 700-8530, Japan
‡Research Institute for Interdisciplinary Science, Okayama University, 3-1-1 Tsushimanaka, Kita-ku, Okayama 700-8530, Japan

Phone: +81-86-251-7855
Fax: +81-86-251-7855
Email: ynishiha@okayama-u.ac.jp

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1. General

Instrumentation

Unless otherwise noted, all the reactions were carried out under an Ar atmosphere using standard Schlenk techniques. Solvents were employed as eluents for all other routine operation, and dehydrated solvents were purchased from commercial suppliers and employed without any further purification. Glassware was dried in an oven (130 °C) and heated under reduced pressure before use. For thin layer chromatography (TLC) analyses throughout this work, Merck precoated TLC plates (silica gel 60 GF254, 0.25 mm) were used. Silica gel column chromatography was carried out using Silica gel 60 N (spherical, neutral, 40–100 μm) from Kanto Chemicals Co., Ltd. NMR spectra (1H, 13C{1H}, and 19F{1H}) were recorded on Varian INOVA-600 (600 MHz) or Mercury-400 (400 MHz) spectrometers. Chemical shifts (δ) are in parts per million relative to CDCl3 at 7.26 ppm for 1H and at 77.16 ppm for 13C{1H}, respectively. The 19F{1H} NMR spectra were measured by using CCl3F (δ = 0.00 ppm) as an external standard. The GC yields were determined by GC analysis of the crude mixture, using n-dodecane as an internal standard. GC analyses were performed on a Shimadzu GC-14A equipped with a flame ionization detector using Shimadzu Capillary Column (CBP1-M25-025) and Shimadzu C-R6A-Chromatopac integrator. Infrared spectra were recorded on a Shimadzu IR Prestige-21 spectrophotometer. Elemental analyses were carried out with a Perkin-Elmer 2400 CHN elemental analyzer at Okayama University.

Chemicals

Unless otherwise noted, materials obtained from commercial suppliers were used without further purification. Bis(2,4-pentanedionato)palladium(II), 1,2-bis(diphenylphosphino)ethane, benzoyl fluoride (1a) (purity > 98%), and allylbenzene (purity > 98%) were purchased from Tokyo Chemical Industry Co., Ltd.. 9-Borabicyclo[3.3.1]nonane dimer was purchased from Sigma-Aldrich Co. Potassium fluoride (purity > 95%) was obtained from Nacalai Tesque. Dimethyl sulfoxide (super dehydrated) was purchased from Kanto Chemical Co. Acyl fluorides 1b-1t were prepared according to the literatures1 and showed the identical spectra reported.
2. **Optimization of Reaction Conditions**

Table S1. Screening of Catalysts and Ligands<sup>a</sup>

<table>
<thead>
<tr>
<th>entry</th>
<th>cat.</th>
<th>ligand</th>
<th>yield (%)&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ni(cod)₂</td>
<td>DCYPE</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>Pd(OAc)₂</td>
<td>DCYPE</td>
<td>38</td>
</tr>
<tr>
<td>3</td>
<td>Pd(dba)₂</td>
<td>DCYPE</td>
<td>42</td>
</tr>
<tr>
<td>4</td>
<td>Pd(acac)₂</td>
<td>DCYPE</td>
<td>44</td>
</tr>
<tr>
<td>5</td>
<td>Pd(tfa)₂</td>
<td>DCYPE</td>
<td>39</td>
</tr>
<tr>
<td>6&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Pd₃(dba)₃</td>
<td>DCYPE</td>
<td>33</td>
</tr>
<tr>
<td>7</td>
<td>PdCl₂</td>
<td>DCYPE</td>
<td>28</td>
</tr>
<tr>
<td>8</td>
<td>Pd(acac)₂</td>
<td>DPPM</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>Pd(acac)₂</td>
<td>DPPE</td>
<td>44</td>
</tr>
<tr>
<td>10</td>
<td>Pd(acac)₂</td>
<td>DPPP</td>
<td>17</td>
</tr>
<tr>
<td>11</td>
<td>Pd(acac)₂</td>
<td>DPPF</td>
<td>10</td>
</tr>
<tr>
<td>12</td>
<td>Pd(acac)₂</td>
<td>XantPhos</td>
<td>19</td>
</tr>
<tr>
<td>13</td>
<td>Pd(acac)₂</td>
<td>rac-BINAP</td>
<td>20</td>
</tr>
<tr>
<td>14</td>
<td>Pd(acac)₂</td>
<td>PPh₃&lt;sup&gt;d&lt;/sup&gt;</td>
<td>10</td>
</tr>
</tbody>
</table>

<sup>a</sup>Reactions were carried out with 1a (0.2 mmol, 1.0 equiv), 2a (0.3 mL, 1.0 M in mesitylene, 0.3 mmol, 1.5 equiv) and cat. (0.02 mmol, 10 mol %), [P] (0.04 mmol, 20 mol %), KF (0.3 mmol, 1.5 equiv) in mesitylene (0.7 mL) at 160 °C for 20 h. <sup>b</sup>GC yields, using n-dodecane as the internal standard. <sup>c</sup>5 mol %. <sup>d</sup>40 mol %.
Table S2. Screening of Base\textsuperscript{a}

\begin{align*}
\begin{array}{cccc}
\text{entry} & \text{base} & \text{yield (\%)}^b & 3a & 4 \\
\hline
1 & NaF & 32 & 3 \\
2 & KF & 44 & 4 \\
3 & CsF & 29 & 2 \\
4 & Cs₂CO₃ & 8 & 0 \\
5 & K₂CO₃ & 7 & 0 \\
6 & K₃PO₄ & 42 & 8 \\
7 & KOAc & 37 & 12 \\
8 & KO'Bu & 0 & 0 \\
\end{array}
\end{align*}

\textsuperscript{a}Reactions were carried out with 1\textsubscript{a} (0.2 mmol, 1.0 equiv), 2\textsubscript{a} (0.3 mL, 1.0 M in mesitylene, 0.3 mmol, 1.5 equiv) and Pd(acac)\textsubscript{2} (0.02 mmol, 10 mol %), DPPE (0.04 mmol, 20 mol %), base (0.3 mmol, 1.5 equiv) in mesitylene (0.7 mL) at 160 °C for 20 h. \textsuperscript{b}GC yields, using \textit{n}-dodecane as the internal standard.
Table S3. Screening of Amounts of Ligand and Base$^a$

![Chemical Reaction Diagram](image)

<table>
<thead>
<tr>
<th>entry</th>
<th>x</th>
<th>y</th>
<th>yield (%)$^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>3aa</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>1.5</td>
<td>40</td>
</tr>
<tr>
<td>2</td>
<td>15</td>
<td>1.5</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>20</td>
<td>1.5</td>
<td>44</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>1.0</td>
<td>48</td>
</tr>
<tr>
<td>5</td>
<td>15</td>
<td>2.0</td>
<td>50</td>
</tr>
<tr>
<td>6</td>
<td>15</td>
<td>3.0</td>
<td>52</td>
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</table>

$^a$Reactions were carried out with 1a (0.2 mmol, 1.0 equiv), 2a (0.3 mL, 1.0 M in mesitylene, 0.3 mmol, 1.5 equiv) and Pd(acac)$_2$ (0.02 mmol, 10 mol %), DPPE (x mol %), KF (y equiv) in mesitylene (0.7 mL) at 160 °C for 20 h. $^b$GC yields, using n-dodecane as the internal standard.
Table S4. Screening of Temperature<sup>a</sup>

<table>
<thead>
<tr>
<th>entry</th>
<th>T (°C)</th>
<th>yield (%)&lt;sup&gt;b&lt;/sup&gt;</th>
<th>3aa</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>130</td>
<td>47</td>
<td>0</td>
<td></td>
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<tr>
<td>2</td>
<td>140</td>
<td>59</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>150</td>
<td>52</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>160</td>
<td>52</td>
<td>5</td>
<td></td>
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</tbody>
</table>

<sup>a</sup>Reactions were carried out with 1a (0.2 mmol, 1.0 equiv), 2a (0.3 mL, 1.0 M in mesitylene, 0.3 mmol, 1.5 equiv) and Pd(acac)<sub>2</sub> (0.02 mmol, 10 mol %), DPPE (0.03 mmol, 15 mol %), KF (0.6 mmol, 3.0 equiv) in mesitylene (0.7 mL) for 20 h.  

<sup>b</sup>GC yields, using n-dodecane as the internal standard.
Table S5. Screening of Solvent<sup>a</sup>

<table>
<thead>
<tr>
<th>entry</th>
<th>toluene (mL)</th>
<th>DMSO</th>
<th>yield (%)&lt;sup&gt;b&lt;/sup&gt;</th>
<th>3aa</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.7</td>
<td>-</td>
<td>62</td>
<td>2</td>
<td></td>
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<tr>
<td>2&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.7</td>
<td>-</td>
<td>59</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1.7</td>
<td>-</td>
<td>71</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>2.7</td>
<td>-</td>
<td>66</td>
<td>3</td>
<td></td>
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<tr>
<td>5</td>
<td>1.7</td>
<td>2 equiv</td>
<td>85</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1.6</td>
<td>0.1 mL</td>
<td>87</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>1.5</td>
<td>0.2 mL</td>
<td>90</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>8&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.5</td>
<td>0.2 mL</td>
<td>90</td>
<td>0</td>
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<tr>
<td>9</td>
<td>1.2</td>
<td>0.5 mL</td>
<td>67</td>
<td>0</td>
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<sup>a</sup>Reactions were carried out with 1a (0.2 mmol, 1.0 equiv), 2a (0.3 mL, 1.0 M in toluene, 0.3 mmol, 1.5 equiv) and Pd(acac)<sub>2</sub> (0.02 mmol, 10 mol %), DPPE (0.03 mmol, 15 mol %), KF (0.6 mmol, 3.0 equiv) in solvent at 140 °C for 20 h.  
<sup>b</sup>GC yields, using n-dodecane as the internal standard.  
<sup>c</sup>Mesitylene instead of toluene.  
<sup>d</sup>KF (0.4 mmol, 1.5 equiv).
Table S6. Optimization of Reaction Time

<table>
<thead>
<tr>
<th>entry</th>
<th>time</th>
<th>yield (%)</th>
<th>3aa</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10 min</td>
<td>36</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>30 min</td>
<td>78</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1 h</td>
<td>90 (80)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>20 h</td>
<td>90</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

*a* Reactions were carried out with 1a (0.2 mmol, 1.0 equiv), 2a (0.3 mL, 1.0 M in toluene, 0.3 mmol, 1.5 equiv) and Pd(acac)$_2$ (0.02 mmol, 10 mol %), DPPE (0.03 mmol, 15 mol %), KF (0.3 mmol, 1.5 equiv) in toluene (1.5 mL), DMSO (0.2 mL) at 140 °C. *b* GC yields, using n-dodecane as the internal standard. An isolated yield is given in parentheses.
Table S7. Control Experiments

![Diagram](image)

<table>
<thead>
<tr>
<th>entry</th>
<th>conditions</th>
<th>yield (%)&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>3aa</td>
</tr>
<tr>
<td>1</td>
<td>without Pd(acac)&lt;sub&gt;2&lt;/sub&gt;</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>without DPPE</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>without KF</td>
<td>38</td>
</tr>
<tr>
<td>4</td>
<td>room temperature</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>PhCOCl instead of PhCOF</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>1.2 equiv 2a instead of 2a</td>
<td>85</td>
</tr>
<tr>
<td>7</td>
<td>PhBF&lt;sub&gt;3&lt;/sub&gt;K instead of 2a</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>PhBO instead of 2a</td>
<td>0</td>
</tr>
</tbody>
</table>

<sup>a</sup>Reactions were carried out with 1a (0.2 mmol, 1.0 equiv), 2a (0.3 mL, 1.0 M in toluene, 0.3 mmol, 1.5 equiv) and Pd(acac)<sub>2</sub> (0.02 mmol, 10 mol %), DPPE (0.03 mmol, 15 mol %), KF (0.3 mmol, 1.5 equiv) in toluene (1.5 mL), DMSO (0.2 mL) at 140 °C for 20 h. <sup>b</sup>GC yields, using n-dodecane as the internal standard.
3. Experimental Procedures and Spectroscopic Data for the Products

3.1 General Procedure for Pd-catalyzed Decarbonylative Alkylation of Acyl Fluorides 1 with Alkylboranes

An oven-dried Schlenk tube (25 mL) containing a magnetic stirring bar was charged with Pd(acac)$_2$ (6.1 mg, 0.02 mmol, 10 mol %), DPPE (12.0 mg, 0.03 mmol, 15 mol %), KF (17.4 mg, 0.3 mmol, 1.5 equiv), toluene (1.5 mL), and DMSO (0.2 mL) under argon and the reaction mixture was stirred for 30 sec at room temperature. After the solution of alkyl 9-BBN 2 (0.3 mL/1.0 M, 1.5 equiv), derived from the reaction of 9-BBN-dimer (1.0 equiv) and the alkene (2.0 equiv) in dry toluene at 80 °C (oil bath temp) for 3 h, was added to the Schlenk tube, and sequentially acyl fluoride 1 (0.2 mmol, 1.0 equiv) was added. The reaction mixture was heated at 140 °C with stirring for 1 h. After the mixture was cooled to room temperature, quenched with saturated NH$_4$Cl, and extracted with Et$_2$O. The combined organic extracts were dried over anhydrous MgSO$_4$, and filtered and evaporated under vacuum to obtain the crude product which was purified by column chromatography (EtOAc/hexane) on silica gel to afford the desired products 3.

3.2 Spectroscopic Data for the Products.

1,3-Diphenylpropane (3aa)$^2$

Colorless oil. $R_f = 0.44$ (hexane). Isolated yield is 80% (31.3 mg). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 1.96-2.04 (m, 2H), 2.69 (t, $J = 7.8$ Hz, 4H), 7.20-7.23 (m, 6H), 7.30-7.34 (m, 4H); $^{13}$C {$^1$H} NMR (101 MHz, CDCl$_3$): $\delta$ 33.1, 35.6, 125.9, 128.4, 128.6, 142.4.
1-Methyl-2-(3-phenylpropyl)benzene (3ba)

Colorless oil. $R_f = 0.40$ (hexane). Isolated yield is 93% (39.1 mg). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 1.88-1.96 (m, 2H), 2.28 (s, 3H), 2.65 (t, $J = 7.8$ Hz, 2H), 2.71 (t, $J = 7.8$ Hz, 2H), 7.10-7.14 (m, 4H), 7.18-7.22 (m, 3H), 7.28-7.32 (m, 2H); $^{13}$C($^1$H) NMR (101 MHz, CDCl$_3$): $\delta$ 19.4, 31.9, 33.0, 36.0, 125.9, 126.0, 126.0, 128.4, 128.5, 128.9, 130.3, 136.0, 140.6, 142.4.

1-Methyl-3-(3-phenylpropyl)benzene (3ca)

Colorless oil. $R_f = 0.36$ (hexane). Isolated yield is 67% (28.2 mg). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 1.96-2.03 (m, 2H), 2.37 (s, 3H), 2.64-2.72 (m, 4H), 7.02-7.05 (m, 3H), 7.20-7.24 (m, 4H), 7.31-7.34 (m, 2H); $^{13}$C($^1$H) NMR (101 MHz, CDCl$_3$): $\delta$ 21.6, 33.1, 35.5, 35.7, 125.6, 125.8, 126.3, 128.4, 128.6, 129.4, 137.9, 142.4, 142.5.

1-Methyl-4-(3-phenylpropyl)benzene (3da)

Colorless oil. $R_f = 0.42$ (hexane). Isolated yield is 59% (24.7 mg). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 1.91-1.99 (m, 2H), 2.33 (s, 3H), 2.61-2.68 (m, 4H), 7.07-7.12 (m, 4H), 7.17-7.21 (m, 3H), 7.27-7.31 (m, 2H); $^{13}$C($^1$H) NMR (151 MHz, CDCl$_3$): $\delta$ 21.2, 33.2, 35.1, 35.6, 125.8, 128.4, 128.5, 128.6, 129.1, 135.3, 139.3, 142.5.
1,3,5-Trimethyl-2-(3-phenylpropyl)benzene (3ea)

Colorless oil. $R_f = 0.32$ (hexane). Isolated yield is 87% (41.3 mg). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 1.75-1.83 (m, 2H), 2.24 (s, 6H), 2.25 (s, 3H), 2.59-2.63 (m, 2H), 2.76 (t, $J$ = 7.6 Hz, 2H), 6.83 (s, 2H), 7.19-7.24 (m, 3H), 7.29-7.33 (m, 2H); $^{13}$C{$^1$H} NMR (101 MHz, CDCl$_3$): $\delta$ 19.8, 20.9, 29.1, 30.8, 36.5, 125.9, 128.4, 128.5, 129.0, 135.0, 136.0, 136.3, 142.4.

1-(tert-Butyl)-4-(3-phenylpropyl)benzene (3fa)

Colorless oil. $R_f = 0.50$ (hexane). Isolated yield is 61% (30.6 mg). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 1.32 (s, 9H), 1.93-2.01 (m, 2H), 2.62-2.69 (m, 4H), 7.13 (d, $J$ = 8.0 Hz, 2H), 7.17-7.21 (m, 3H), 7.27-7.33 (m, 4H); $^{13}$C{$^1$H} NMR (101 MHz, CDCl$_3$): $\delta$ 31.6, 33.0, 34.5, 35.0, 35.7, 125.3, 125.8, 128.2, 128.4, 128.6, 139.3, 142.5, 148.6.

4-(3-Phenylpropyl)-1,1'-biphenyl (3ga)

Colorless oil. $R_f = 0.30$ (hexane). Isolated yield is 88% (47.9 mg). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 1.98-2.05 (m, 2H), 2.68-2.73 (m, 4H), 7.19-7.23 (m, 3H), 7.29-7.36 (m, 5H), 7.44 (t, $J$ = 7.6 Hz, 2H), 7.53 (d, $J$ = 7.6 Hz, 2H), 7.59-7.61 (m, 2H); $^{13}$C{$^1$H} NMR (101 MHz, CDCl$_3$): $\delta$ 33.1, 35.2, 35.6, 125.9, 127.1 (2C), 127.2, 128.5, 128.6, 128.9, 129.0, 138.8, 141.2, 141.6, 142.4.
1-Methoxy-4-(3-phenylpropyl)benzene (3ha)

\[
\text{3ha}
\]

Colorless oil. \(R_f = 0.39\) (EtOAc:hexane = 1:20). Isolated yield is 57% (26.0 mg). \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta\) 1.91-1.98 (m, 2H), 2.60-2.68 (m, 4H), 3.81 (s, 3H), 6.85 (d, \(J = 8.8\) Hz, 2H), 7.12 (d, \(J = 8.8\) Hz, 2H), 7.18-7.22 (m, 3H), 7.28-7.32 (m, 2H); \(^{13}\)C\{\(^1\)H\} NMR (101 MHz, CDCl\(_3\)): \(\delta\) 33.4, 34.6, 35.5, 55.4, 113.8, 125.8, 128.4, 128.6, 129.4, 134.5, 142.5, 157.8.

5-(3-Phenylpropyl)benzo[\(d\)[1,3]]dioxole (3ia)

\[
\text{3ia}
\]

Colorless oil. \(R_f = 0.44\) (EtOAc:hexane = 1:20). Isolated yield is 56% (26.8 mg). \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta\) 1.88-1.96 (m, 2H), 2.58 (t, \(J = 7.6\) Hz, 2H), 2.64 (t, \(J = 7.6\) Hz, 2H), 5.93 (s, 2H), 6.62-6.75 (m, 3H), 7.18-7.21 (m, 3H), 7.27-7.30 (m, 2H); \(^{13}\)C\{\(^1\)H\} NMR (101 MHz, CDCl\(_3\)): \(\delta\) 33.4, 35.3, 35.4, 100.9, 108.2, 109.0, 121.3, 125.9, 128.4, 128.6, 136.3, 142.4, 145.6, 147.6.

1-Fluoro-4-(3-phenylpropyl)benzene (3ja)

\[
\text{3ja}
\]

Colorless oil. \(R_f = 0.39\) (hexane). Isolated yield is 68% (29.0 mg). \(^1\)H NMR (400 MHz, CDCl\(_3\)): \(\delta\) 1.92-1.99 (m, 2H), 2.62-2.68 (m, 4H), 6.96-7.00 (m, 2H), 7.13-7.16 (m, 2H), 7.19-7.23 (m, 3H), 7.29-7.33 (m, 2H); \(^{13}\)C\{\(^1\)H\} NMR (101 MHz, CDCl\(_3\)): \(\delta\) 33.2, 34.7, 35.5, 115.1 (d, \(\beta_{C-F} = 21\) Hz), 125.9, 128.5, 128.6, 129.8 (d, \(\beta_{C-F} = 8\) Hz), 138.0, 142.2, 161.3 (d, \(\beta_{C-F} = 244\) Hz); \(^{19}\)F\{\(^1\)H\} NMR (376 MHz, CDCl\(_3\), rt): \(\delta\) -117.9.
1-(3-Phenylpropyl)-2-(trifluoromethyl)benzene (3ka)

![Structure of 3ka](image)

Colorless oil. \( R_f = 0.48 \) (hexane). Isolated yield is 74% (38.9 mg). \(^1\)H NMR (600 MHz, CDCl\(_3\)):\( \delta 1.94-1.99 \) (m, 2H), 2.73 (t, \( J = 8.1 \) Hz, 2H), 2.83 (t, \( J = 8.1 \) Hz, 2H), 7.19-7.22 (m, 3H), 7.27-7.32 (m, 4H), 7.46 (t, \( J = 7.8 \) Hz, 1H), 7.62 (d, \( J = 7.8 \) Hz, 1H); \(^{13}\)C\(^{\{1\}}\)H NMR (151 MHz, CDCl\(_3\)):\( \delta 32.5, 33.5, 36.1, 124.8 \) (q, \( J_{C-F} = 274 \) Hz), 125.97, 125.99, 126.0 (q, \( J_{C-F} = 6 \) Hz), 128.49, 128.52, 128.53 (q, \( J_{C-F} = 29 \) Hz), 131.0, 131.8, 141.3, 142.1; \(^{19}\)F\(^{\{1\}}\)H NMR (282 MHz, CDCl\(_3\), rt): \( \delta -59.7 \).

1-(\textit{tert}-Butyl)-4-(3-phenylpropyl)benzene (3la)

![Structure of 3la](image)

Colorless oil. \( R_f = 0.40 \) (hexane). Isolated yield is 61% (32.2 mg). \(^1\)H NMR (400 MHz, CDCl\(_3\)):\( \delta 1.94-2.02 \) (m, 2H), 2.64-2.73 (m, 4H), 7.18-7.22 (m, 3H), 7.28-7.32 (m, 4H), 7.54 (d, \( J = 8.0 \) Hz, 2H); \(^{13}\)C\(^{\{1\}}\)H NMR (151 MHz, CDCl\(_3\)):\( \delta 32.8, 35.3, 35.5, 124.5 \) (q, \( J_{C-F} = 271 \) Hz), 125.4 (q, \( J_{C-F} = 4 \) Hz), 126.0, 128.3 (q, \( J_{C-F} = 32 \) Hz), 128.5, 128.6, 128.9, 142.0, 146.5; \(^{19}\)F\(^{\{1\}}\)H NMR (376 MHz, CDCl\(_3\), rt): \( \delta -62.3 \).

4-(3-Phenylpropyl)benzonitrile (3ma)

![Structure of 3ma](image)

Colorless oil. \( R_f = 0.28 \) (EtOAc:hexane = 1:20). Isolated yield is 68% (30.2 mg). \(^1\)H NMR (600 MHz, CDCl\(_3\)):\( \delta 1.94-1.99 \) (m, 2H), 2.65 (t, \( J = 7.8 \) Hz, 2H), 2.70 (t, \( J = 7.8 \) Hz, 2H), 7.17-7.22 (m, 3H), 7.27-7.31 (m,
4-Phenyl-(3-phenylpropyl)phenylmethanone (3na)

Colorless oil. 

$R_f = 0.25$ (EtOAc:hexane = 1:20). Isolated yield is 70% (42.3 mg).

$^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 1.99-2.06 (m, 2H), 2.70 (t, $J = 7.8$ Hz, 2H), 2.75 (t, $J = 7.8$ Hz, 2H), 7.20-7.23 (m, 3H), 7.30-7.33 (m, 4H), 7.47-7.51 (m, 2H), 7.57-7.61 (m, 1H), 7.75-7.80 (m, 2H), 7.81-7.83 (m, 2H); $^{13}$C $\{^1\text{H}\}$ NMR (101 MHz, CDCl$_3$): $\delta$ 32.7, 35.5, 35.6, 126.0, 128.3, 128.49 (2C), 128.54, 130.1, 130.5, 132.3, 135.3, 138.0, 142.0, 147.6, 196.6. FT-IR (cm$^{-1}$): 785 (s), 849 (s), 972 (s), 1001 (s), 1177 (s), 1279 (s), 1301 (s), 1323, 1353, 1380, 1420, 1476, 1966. Anal. Calcd for C$_{22}$H$_{20}$O: C, 87.96; H, 6.71%. Found: C, 87.72; H, 6.81%.

1-(3-Phenylpropyl)naphthalene (3oa)$^{11}$

Colorless oil. $R_f = 0.27$ (hexane). Isolated yield is 78% (38.5 mg).

$^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 2.07-2.15 (m, 2H), 2.77 (t, $J = 7.8$ Hz, 2H), 3.12 (t, $J = 7.8$ Hz, 2H), 7.19-7.24 (m, 3H), 7.29-7.34 (m, 3H), 7.38-7.42 (m, 1H), 7.45-7.51 (m, 2H), 7.72 (d, $J = 8.4$ Hz, 1H), 7.84-7.87 (m, 1H), 7.95-7.98 (m, 1H); $^{13}$C $\{^1\text{H}\}$ NMR (101 MHz, CDCl$_3$): $\delta$ 32.4, 32.7, 36.0, 123.9, 125.5, 125.7, 125.8, 125.9, 126.1, 126.7, 128.5, 128.6, 128.9, 132.0, 134.0, 138.5, 142.3.

2-(3-Phenylpropyl)naphthalene (3pa)$^{2}$
Colorless oil. $R_f = 0.27$ (hexane). Isolated yield is 81% (39.7 mg). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 2.03-2.10 (m, 2H), 2.70 (t, $J = 7.6$ Hz, 2H), 2.83 (t, $J = 7.6$ Hz, 2H), 7.20-7.23 (m, 3H), 7.28-7.36 (m, 3H), 7.41-7.79 (m, 2H), 7.63 (s, 1H), 7.77-7.83 (m, 3H); $^{13}$C{$^1$H} NMR (101 MHz, CDCl$_3$): $\delta$ 33.0, 35.6, 35.7, 125.2, 125.9, 126.0, 126.6, 127.51, 127.54, 127.7, 128.0, 128.5, 128.6, 132.1, 133.7, 139.9, 142.4.

2-(3-Phenylpropyl)benzofuran (3qa)$^{12}$

Pale yellow oil. $R_f = 0.54$ (EtOAc:hexane = 1:20). Isolated yield is 54% (25.5 mg). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 2.06-2.13 (m, 2H), 2.73 (t, $J = 7.8$ Hz, 2H), 2.81 (t, $J = 7.8$ Hz, 2H), 6.41 (s, 1H), 7.17-7.24 (m, 5H), 7.29-7.33 (m, 2H), 7.41-7.43 (m, 1H), 7.48-7.50 (m, 1H); $^{13}$C{$^1$H} NMR (101 MHz, CDCl$_3$): $\delta$ 28.0, 29.4, 35.3, 102.3, 110.9, 120.3, 122.5, 123.3, 126.1, 128.5, 128.7, 129.1, 141.9, 154.8, 159.3.

2-(3-Phenylpropyl)benzothiophene (3ra)$^{13}$

Pale yellow solid. $R_f = 0.54$ (EtOAc:hexane = 1:20). Isolated yield is 64% (32.3 mg). $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 2.06-2.13 (m, 2H), 2.73 (t, $J = 7.6$ Hz, 2H), 2.94 (t, $J = 7.6$ Hz, 2H), 7.02 (s, 1H), 7.19-7.25 (m, 4H), 7.27-7.33 (m, 3H), 7.66-7.68 (m, 1H), 7.76-7.78 (m, 1H); $^{13}$C{$^1$H} NMR (101 MHz, CDCl$_3$): $\delta$ 30.4, 32.8, 35.3, 120.9, 122.3, 122.8, 123.6, 124.2, 126.0, 128.5, 128.6, 139.5, 140.3, 141.9, 146.3.

4-Methyl-(3-phenylpropyl) benzoate (3sa)$^{14}$
Colorless oil.  $R_f = 0.28$ (EtOAc:hexane = 1:20).  Isolated yield is 78% (39.6 mg).  $^1$H NMR (600 MHz, CDCl$_3$): $\delta$ 1.95-2.00 (m, 2H), 2.65 (t, $J = 7.8$ Hz, 2H), 2.70 (t, $J = 7.8$ Hz, 2H), 3.91 (s, 3H), 7.17-7.21 (m, 3H), 7.25-7.28 (m, 2H), 7.29-7.31 (m, 2H), 7.95-7.97 (m, 2H); $^{13}$C{$^1$H} NMR (151 MHz, CDCl$_3$): $\delta$ 32.8, 35.5, 35.6, 52.1, 126.0, 127.9, 128.5, 128.6, 129.8, 142.0, 148.0, 167.3.

4-Phenyl-(3-phenylpropyl)benzoate (3ta)

Colorless oil.  $R_f = 0.29$ (EtOAc:hexane = 1:20).  Isolated yield is 65% (41.0 mg).  $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 1.98-2.05 (m, 2H), 2.68 (t, $J = 7.6$ Hz, 2H), 2.75 (t, $J = 7.6$ Hz, 2H), 7.19-7.23 (m, 5H), 7.27-7.34 (m, 5H), 7.42-7.46 (m, 2H), 8.12-8.15 (m, 2H); $^{13}$C{$^1$H} NMR (101 MHz, CDCl$_3$): $\delta$ 32.7, 35.5, 35.6, 121.9, 125.9, 126.0, 127.3, 128.5, 128.6, 128.8, 129.6, 130.4, 142.0, 148.8, 151.1, 165.3.  FT-IR (cm$^{-1}$): 700 (s), 745 (s), 1018 (s), 1070 (s), 1177 (s), 1198 (s), 1267 (s), 1493 (s), 1736 (s).  Anal. Calcd for C$_{22}$H$_{20}$O$_2$: C, 83.51; H, 6.37%.  Found: C, 83.51; H, 6.40%.

1,2-Diphenylethane (3ab)$^{15}$

White solid.  $R_f = 0.44$ (hexane).  Isolated yield is 80% (29.2 mg).  $^1$H NMR (400 MHz, CDCl$_3$): $\delta$ 2.93 (s, 4H), 7.19-7.22 (m, 6H), 7.27-7.31 (m, 4H); $^{13}$C{$^1$H} NMR (101 MHz, CDCl$_3$): $\delta$ 38.1, 126.1, 128.5, 128.6, 141.9.
1,4-Diphenylbutane (3ac)\textsuperscript{15}

![3ac]

Colorless oil.  \( R_f = 0.44 \) (hexane).  Isolated yield is 81\% (34.2 mg).  \(^1\)H NMR (400 MHz, CDCl\(_3\)): \( \delta \) 1.68-1.71 (m, 4H), 2.64-2.68 (m, 4H), 7.18-7.22 (m, 6H), 7.27-7.32 (m, 4H); \(^1\)C\{\(^1\)H\} NMR (101 MHz, CDCl\(_3\)): \( \delta \) 31.3, 36.0, 125.8, 128.4, 128.6, 142.7.

1-Octylbenzene (3ad)\textsuperscript{16}

![3ad]

Colorless oil.  \( R_f = 0.73 \) (hexane).  Isolated yield is 54\% (20.7 mg).  \(^1\)H NMR (400 MHz, CDCl\(_3\)): \( \delta \) 0.86-0.90 (m, 3H), 1.27-1.31 (m, 10H), 1.57-1.65 (m, 2H), 2.60 (t, \( J = 7.8 \) Hz, 2H), 7.16-7.19 (m, 3H), 7.28-7.30 (m, 2H); \(^1\)C\{\(^1\)H\} NMR (101 MHz, CDCl\(_3\)): \( \delta \) 14.3, 22.8, 29.4, 29.5, 29.6, 31.7, 32.1, 36.2, 125.7, 128.4, 128.5, 143.1.

1-Dodecylbenzene (3ae)\textsuperscript{17}

![3ae]

Colorless oil.  \( R_f = 0.73 \) (hexane).  Isolated yield is 62\% (30.4 mg).  \(^1\)H NMR (400 MHz, CDCl\(_3\)): \( \delta \) 0.87-0.91 (m, 3H), 1.26-1.31 (m, 18H), 1.58-1.65 (m, 2H), 2.60 (t, \( J = 7.8 \) Hz, 2H), 7.16-7.19 (m, 3H), 7.28-7.30 (m, 2H); \(^1\)C\{\(^1\)H\} NMR (151 MHz, CDCl\(_3\)): \( \delta \) 14.3, 22.9, 29.51, 29.52, 29.7, 29.76, 29.8, 29.83, 29.84, 31.7, 32.1, 36.1, 125.7, 128.3, 128.5, 143.1.

2-Cyclohexylethylbenzene (3af)\textsuperscript{17}
Colorless oil. $R_f = 0.73$ (hexane). Isolated yield is 79% (29.7 mg). $^1$H NMR (400 MHz, CDCl$_3$): $\delta 0.90$-0.98 (m, 2H), 1.15-1.27 (m, 4H), 1.49-1.54 (m, 2H), 1.65-1.80 (m, 5H), 2.63 (t, $J = 8.2$ Hz, 2H), 7.16-7.20 (m, 3H), 7.27-7.31 (m, 2H); $^{13}$C ($^1$H) NMR (101 MHz, CDCl$_3$): $\delta 26.5$, 26.9, 33.4, 33.5, 37.5, 39.6, 125.6, 128.4, 128.5, 143.4.

1-Methoxy-4-(3-phenylpropyl)benzene (3ha)

Colorless oil. $R_f = 0.39$ (EtOAc:hexane = 1:20). Isolated yield is 82% (37.3 mg). The NMR data is shown in the reaction of 1h with 2a.

5-(3-Phenylpropyl)benzo[d][1,3]dioxole (3ia)

Colorless oil. $R_f = 0.44$ (EtOAc:hexane = 1:20). Isolated yield is 91% (43.7 mg). The NMR data is shown in the reaction of 1i with 2a.
Colorless oil.  \( R_f = 0.47 \) (hexane).  Isolated yield is 72% (41.0 mg).  \(^1\)H NMR (600 MHz, CDCl\(_3\)): \( \delta \) 1.90-1.95 (m, 2H), 2.68 (t, \( J = 7.5 \) Hz, 2H), 2.74 (t, \( J = 7.5 \) Hz, 2H), 7.18-7.21 (m, 3H), 7.28-7.31 (m, 2H); \(^{13}\)C\(^{1}\)H NMR (151 MHz, CDCl\(_3\)): \( \delta \) 22.2, 30.8, 35.5, 115.1-115.3 (m), 126.2, 128.4, 128.6, 137.5 (dm, \( J_{\text{C-F}} = 252 \) Hz), 139.6 (dm, \( J_{\text{C-F}} = 252 \) Hz), 141.3, 145.1 (dm, \( J_{\text{C-F}} = 245 \) Hz); \(^{19}\)F\(^{1}\)H NMR (376 MHz, CDCl\(_3\), rt): \( \delta \) –162.9 (td, \( J = 21.6, 7.1 \) Hz, 2F), –158.0 (t, \( J = 20.8 \) Hz, 1F), –144.2 (dd, \( J = 22.2, 8.4 \) Hz, 2F).

6-Phenylmethylhexanoate (3ah)

\[ \begin{align*} \text{3ah} & \quad \ce{O} \\ & \quad \text{O} \\ & \quad \text{O} \\ & \quad \text{O} \\ & \quad \text{O} \end{align*} \]

Colorless oil.  \( R_f = 0.28 \) (EtOAc:hexane = 1:20).  Isolated yield is 76% (31.2 mg).  \(^1\)H NMR (600 MHz, CDCl\(_3\)): \( \delta \) 1.34-1.39 (m, 2H), 1.61-1.69 (m, 4H), 2.31 (t, \( J = 7.8 \) Hz, 2H), 2.61 (t, \( J = 7.8 \) Hz, 2H), 3.66 (s, 3H), 7.16-7.19 (m, 3H), 7.26-7.29 (m, 2H); \(^{13}\)C\(^{1}\)H NMR (151 MHz, CDCl\(_3\)): \( \delta \) 25.0, 28.9, 31.2, 34.2, 35.9, 51.6, 125.8, 128.4, 128.5, 142.6, 174.4.

6-Phenylhexyloxy-\((\text{tert}-\text{butyl})\text{dimethylsilane}\) (3ai)

\[ \begin{align*} \text{3ai} & \quad \text{OTBS} \end{align*} \]

Colorless oil.  \( R_f = 0.32 \) (EtOAc:hexane = 1:20).  Isolated yield is 85% (49.7 mg).  \(^1\)H NMR (400 MHz, CDCl\(_3\)): \( \delta \) 0.04 (s, 6H), 0.89 (s, 9H), 1.33-1.36 (m, 4H), 1.48-1.64 (m, 4H), 2.60 (t, \( J = 7.8 \) Hz, 2H), 3.59 (t, \( J = 6.6 \) Hz, 2H), 7.15-7.19 (m, 3H), 7.27-7.28 (m, 2H); \(^{13}\)C\(^{1}\)H NMR (101 MHz, CDCl\(_3\)): \( \delta \) –5.1, 18.5, 25.8, 26.1, 29.3, 31.7, 32.9, 36.1, 63.4, 125.7, 128.4, 128.5, 143.0.
Limitation of Substrates

6-(3-phenylpropyl)quinoline

From Probenecid

9% 0%
3.3 Gram-Scale Experiment.

An oven-dried two-necked flask (200 mL) containing a magnetic stirring bar was charged with Pd(acac)$_2$ (122.9 mg, 0.4 mmol, 5 mol %), DPPE (239.1 mg, 0.6 mmol, 7.5 mol %), KF (697.2 mg, 12 mmol, 1.5 equiv), toluene (24 mL), and DMSO (4 mL) under argon and the reaction mixture was stirred for 30 sec at room temperature. After the solution of alkyl 9-BBN 2a (12 mL/1.0 M, 1.5 equiv), derived from the reaction of 9-BBN-dimer (1.0 equiv) and allylbenzene (2.0 equiv) in dry toluene at 80 °C for 3 h, was added into the Schlenk tube, benzoyl fluoride (1a) (992.9 mg, 8 mmol, 1.0 equiv) was added. The mixture was heated at 140 °C with stirring for 1 h. After the mixture was cooled to room temperature, the mixture was quenched with saturated NH$_4$Cl and the aqueous solution was extracted with Et$_2$O. The combined organic extracts were dried over anhydrous MgSO$_4$, and filtered and evaporated under vacuum to give the crude product which was purified by column chromatography (hexane) on silica gel to afford the desired product 3aa (925 mg, 4.71 mmol) in 59% yield.

3.4 Alkylation of 3ta: Formation of 5.

The reaction was conducted according to the reported procedure.$^{14}$ An oven-dried Schlenk tube (25 mL) containing a magnetic stirring bar was charged with Pd(OAc)$_2$ (4.6 mg, 0.02 mmol, 10 mol %), DCYPE (16.8 mg, 0.04 mmol, 20 mol %), KF (17.4 mg, 0.3 mmol, 1.5 equiv), and toluene (0.6 mL) under argon and the reaction mixture was stirred for 30 sec at room temperature. After the solution of alkyl 9-BBN 2a (0.3 mL/1.0
M, 1.5 equiv), derived from the reaction of 9-BBN-dimer (1.0 equiv) and allylbenzene (2.0 equiv) in dry toluene at 80 °C for 3 h, was added into the Schlenk tube, and sequentially 3a (63.3 mg, 0.2 mmol, 1.0 equiv) was added. The mixture was heated at 160 °C with stirring for 40 h. After the mixture was cooled to room temperature, quenched with saturated NH4Cl, and extracted with Et2O. The combined organic extracts were dried over anhydrous MgSO4, and filtered and evaporated under vacuum to afford the crude product which was purified by column chromatography on silica gel to afford 5 (44.5 mg) in 71% yield. Colorless oil. Rf = 0.25 (hexane). 1H NMR (400 MHz, CDCl3): δ 1.91-1.99 (m, 4H), 2.61-2.67 (m, 8H), 7.11 (s, 4H), 7.16-7.20 (m, 6H), 7.28 (t, J = 7.4 Hz, 4H); 13C{1H} NMR (101 MHz, CDCl3): δ 33.2, 35.2, 35.6, 125.8, 128.4, 128.5, 128.6, 139.7, 142.5.

3.5 Decarbonylative Alkylation of Acyl Fluorides under Previously Reported Catalytic Systems.

The following reaction was conducted according to the reported procedure. An oven-dried Schlenk tube (25 mL) containing a magnetic stirring bar was charged with Ni(cod)2 (5.5 mg, 0.02 mmol, 10 mol %), DCYPE (33.6 mg, 0.08 mmol, 40 mol %), CsF (15.2 mg, 0.2 mmol, 1.0 equiv), and toluene (0.6 mL) under argon and the mixture was stirred for 30 sec at room temperature. After the solution of alkyl 9-BBN 2a (0.4 mL/1.0 M, 2.0 equiv), derived from the reaction of 9-BBN-dimer (1.0 equiv) and allylbenzene (2.0 equiv) in dry toluene at 80 °C for 3 h, was added into the Schlenk tube, benzoyl fluoride (1a) (24.8 mg, 0.2 mmol, 1.0 equiv) was added. The mixture was heated at 150 °C with stirring for 65 h. After the mixture was cooled to room temperature, the mixture was quenched with saturated NH4Cl and the aqueous solution was extracted with Et2O. The combined organic extracts were dried over anhydrous MgSO4, filtered, and evaporated under vacuum to give the crude product. The GC yield was calculated using n-dodecane as an internal standard.
The following reaction was conducted according to the reported procedure.\textsuperscript{14} An oven-dried Schlenk tube (25 mL) containing a magnetic stirring bar was charged with Pd(OAc)\textsubscript{2} (2.3 mg, 0.01 mmol, 5 mol %), DCYPE (8.4 mg, 0.02 mmol, 10 mol %), KF (17.4 mg, 0.3 mmol, 1.5 equiv), toluene (0.6 mL) under argon and the reaction mixture was stirred for 30 sec at room temperature. After the solution of alkyl 9-BBN 2a (0.3 mL/1.0 M, 1.5 equiv), derived from the reaction of 9-BBN-dimer (1.0 equiv) and allylbenzene (2.0 equiv) in dry toluene at 80 °C for 3 h, was added into the Schlenk tube, benzoyl fluoride (1a) (24.8 mg, 0.2 mmol, 1.0 equiv) was added. The mixture was heated at 160 °C with stir ring for 40 h. After the mixture was cooled to room temperature, the mixture was quenched with saturated NH\textsubscript{4}Cl and the aqueous solution was extracted with Et\textsubscript{2}O. The combined organic extracts were dried over anhydrous MgSO\textsubscript{4}, filtered, and evaporated under vacuum to give the crude product. The GC yield was calculated using n-dodecane as an internal standard.
4. Copies of $^1H$, $^{13}C$($^1H$), and $^{19}F$($^1H$) NMR Charts for the Products

$^1H$ NMR (400 MHz) and $^{13}C$($^1H$) NMR (101 MHz) spectra of 3aa (rt, CDCl$_3$).
$^1$H NMR (400 MHz) and $^{13}$C $^1$H NMR (101 MHz) spectra of 3ba (rt, CDCl$_3$).
$^1$H NMR (400 MHz) and $^{13}$C ($^1$H) NMR (101 MHz) spectra of 3ca (rt, CDCl$_3$).
$^1$H NMR (400 MHz) and $^{13}$C$\{^1$H$\}$ NMR (151 MHz) spectra of 3da (rt, CDCl$_3$).
$^1$H NMR (400 MHz) and $^{13}$C{$_^1$H} NMR (101 MHz) spectra of 3ea (t, CDCl$_3$).
$^1$H NMR (400 MHz) and $^{13}$C{$^1$H} NMR (101 MHz) spectra of 3fa (rt, CDCl₃).
$^1$H NMR (400 MHz) and $^{13}$C{$^1$H} NMR (101 MHz) spectra of 3ga (rt, CDCl$_3$).
$^1$H NMR (400 MHz) and $^{13}$C($^1$H) NMR (101 MHz) spectra of 3ha (rt, CDCl$_3$)
$^1$H NMR (400 MHz) and $^{13}$C{$^1$H} NMR (101 MHz) spectrum of 3ia (rt, CDCl$_3$).
$^1$H NMR (400 MHz), $^{13}$C{$^1$H} NMR (101 MHz), and $^{19}$F{$^1$H} NMR (376 MHz) spectra of 3ja (rt, CDCl$_3$).
$^1$H NMR (600 MHz), $^{13}$C{$^1$H} NMR (151 MHz), and $^{19}$F{$^1$H} NMR (282 MHz) spectra of 3ka (rt, CDCl$_3$).
$^1$H NMR (400 MHz), $^{13}$C ($^1$H) NMR (151 MHz), and $^{19}$F ($^1$H) NMR (376 MHz) spectra of 3la (rt, CDCl$_3$).
$^1$H NMR (600 MHz) and $^{13}$C{$^1$H} NMR (151 MHz) spectra of 3ma (rt, CDCl$_3$).
$^1$H NMR (400 MHz) and $^{13}$C$\{^1$H$\}$ NMR (101 MHz) spectra of 3na (rt, CDCl$_3$).
$^1$H NMR (400 MHz) and $^{13}$C ($^1$H) NMR (101 MHz) spectra of 3oa (rt, CDCl$_3$).
$^1$H NMR (400 MHz) and $^{13}$C{$^1$H} NMR (101 MHz) spectra of 3pa (rt, CDCl$_3$).
$^1$H NMR (400 MHz) and $^{13}$C($^1$H) NMR (101 MHz) spectra of 3qa (rt, CDCl$_3$).
$^{1}$H NMR (400 MHz) and $^{13}$C ($^{1}$H) NMR (101 MHz) spectra of 3ra (rt, CDCl$_3$).
$^1$H NMR (600 MHz) and $^{13}$C{$^1$H} NMR (151 MHz) spectra of 3sa (rt, CDCl$_3$).
$^1$H NMR (400 MHz) and $^{13}$C {$^1$H} NMR (101 MHz) spectra of 3ta (rt, CDCl$_3$).
$^1$H NMR (400 MHz) and $^{13}$C $^1$H NMR (101 MHz) spectra of 3ab (rt, CDCl$_3$).
$^{1}H$ NMR (400 MHz) and $^{13}C\{^{1}H\}$ NMR (101 MHz) spectra of 3ac (rt, CDCl$_3$).
$^1$H NMR (400 MHz) and $^{13}$C $^1$H NMR (101 MHz) spectra of 3ad (rt, CDCl$_3$).
$^1$H NMR (400 MHz) and $^{13}$C{$^1$H} NMR (151 MHz) spectrum of 3ae (rt, CDCl$_3$).
$^1$H NMR (400 MHz) and $^{13}$C{$^1$H} NMR (101 MHz) spectrum of 3af (rt, CDCl$_3$).
$^1$H NMR (600 MHz), $^{13}$C($^1$H) NMR (151 MHz), and $^{19}$F($^1$H) NMR (376 MHz) spectra of 3ag (rt, CDCl$_3$).
$^1$H NMR (600 MHz) and $^{13}$C($^1$H) NMR (151 MHz) spectra of 3ah (rt, CDCl$_3$).
$^1$H NMR (400 MHz) and $^{13}$C($^1$H) NMR (101 MHz) spectra of 3ai (rt, CDCl$_3$).
$^{1}\text{H NMR (400 MHz) and }^{13}\text{C}\{^1\text{H}\} \text{ NMR (101 MHz) spectra of 5 (rt, CDCl$_3$).}$
5. References


