Bidentate ligand promoted palladium-catalyzed C–H olefination of aromatic compounds

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CHAPTER 5

S,O-BIDENTATE LIGAND PROMOTED PALLADIUM-CATALYZED C–H OLEFINATION OF ANILINE DERIVATIVES

Part of this chapter has been published in:
5.1 Introduction
Aromatic amines are ubiquitous structural motifs in organic functional materials, fluorescent dyes, pharmaceuticals and natural products (Figure 5.1).\(^1\) As a consequence, the direct and selective functionalization of aromatic amines is of great interest in organic chemistry.

Historically, Friedel–Crafts reactions of aniline derivatives are problematic since the nitrogen of the aniline can bind to the Lewis acid, forming a non-reactive coordination complex.\(^2\) Cross couplings are effective reactions for the functionalization of aromatic amines. However, these protocols suffer from the disadvantage of requiring pre-functionalized starting materials.\(^3\) In the context of C–H functionalization,\(^4\) the vast majority of C–H functionalization reactions of aniline derivatives relies on the use of directing groups attached to the nitrogen atom, which results in the ortho-functionalized products.\(^5\) One of the first examples of selective Pd-catalyzed C–H olefination of aniline derivatives was described by van Leeuwen and co-workers (Scheme 5.1).\(^5b\) They performed the ortho C–H olefination of anilines at room temperature using the amide moiety as directing group. Under the optimal conditions, only a few anilines bearing electron donating groups provided the desired products in fair yields.

Although ortho-functionalization reactions of aniline derivatives have been widely described, selective C–H functionalization reactions at remote positions are rare.\(^6\) To achieve meta C–H
functionalization of anilines, the use of templates and directing groups has been reported.\textsuperscript{6b-h} For example, Yu et al. demonstrated that nitrile end-on template in combination with monoprotected amino acid ligand provided the \textit{meta}-olefinated anilines in moderate to good yields (Scheme 5.2, a).\textsuperscript{6b} Miura et al. employed a carboxylic acid as traceless directing group, providing the \textit{meta}-substituted aniline after decarboxylation (Scheme 5.2, b).\textsuperscript{6f}

\textbf{Scheme 5.2} \textit{meta}-C–H Olefination of aniline derivatives.

In the particular case of metal-catalyzed \textit{para}-selective C–H functionalization of anilines, the reported transformations are limited to unsubstituted anilines or to anilines bearing electron donating or halogen substituents.\textsuperscript{7} A few exceptions to this trend have been reported (Scheme 5.3).\textsuperscript{8} For instance, anilides with an ester group or halogen atom attached to the arene have been \textit{para}-difluoromethylated using a Ru(II)-catalyst (Scheme 5.3, a).\textsuperscript{8a} Also, a highly \textit{para}-selective copper(II)-catalyzed arylation of electron-rich and poor anilines was described by Gaunt and co-workers (Scheme 5.3, b).\textsuperscript{8b}

\textbf{Scheme 5.3} \textit{para}-Selective a) C–H difluoromethylation and b) C–H arylation of aniline derivatives.
In the context of Pd-catalyzed \( \text{para} \) \( \text{C–H} \) olefination of anilines, only two examples have been reported (Schemes 5.4).\(^7a\),\(^7b\) In the first example, Ishii \textit{et al.} described the aerobic \( \text{C–H} \) olefination using Pd/HPMoV as catalyst and 2,4,6-trimethylbenzoic acid as an additive (Scheme 5.4, a).\(^7a\) Under the optimal reaction conditions using an excess of tertiary aniline (7.5 equiv), the \( \text{para} \)-olefinated products were obtained in good yields and selectivities. In the second example, Karimi and co-workers reported the Pd-catalyzed \( \text{para} \)-olefination of unsubstituted \( N,N \)-dialkylanilines using Cu as an oxidant and a mixture of DCE/AcOH as a solvent (Scheme 5.4, b).\(^7b\) Although these examples addressed highly \( \text{para} \)-selective \( \text{C–H} \) olefination of aromatic amines, these catalytic systems were limited to unsubstituted tertiary anilines. Therefore, a general strategy for \( \text{para} \)-selective \( \text{C–H} \) olefination of aromatic amines has not been reported.

![Scheme 5.4 Pd-Catalyzed \( \text{para} \)-selective \( \text{C–H} \) olefination of aniline derivatives.](image)

As described in Chapter 3, we have discovered that S,O-bidentate ligands are capable of promoting Pd-catalyzed \( \text{C–H} \) olefination reactions of non-directed arenes. In these reactions, the site selectivity was mainly dictated by the substrate and controlled by electronic factors, with preferential functionalization at the most electronic rich position of the arene. We found out that besides accelerating the reaction, the presence of the S,O-ligand influences the site selectivity of the process. With this in mind, we anticipated that using our Pd/S,O-ligand catalyst, both the reactivity and the site selectivity of the \( \text{C–H} \) olefination of aniline derivatives could be enhanced.

Herein, we describe a highly \( \text{para} \)-selective \( \text{C–H} \) olefination of a broad range of aniline derivatives by a Pd/S,O-ligand-based catalyst. The S,O-ligand is responsible for the dramatic improvements in substrate scope and the high \( \text{para} \)-selectivity observed. The methodology is operationally simple, scalable and can be performed under aerobic conditions.

### 5.2 Results and discussion

#### Optimization of the reaction conditions for the \( \text{C–H} \) olefination of \( N,N \)-dimethylaniline

We first applied our standard conditions for the \( \text{C–H} \) olefination of non-directed arenes reported in Chapter 3 [5 mol% of Pd(OAc)$_2$, 5 mol% of 3-methyl-2-(phenylthio)butanoic acid (L), 10 equiv of arene and 1 equiv of PhCO$_3$t-Bu in AcOH at 100°C for 6 h] on the model
substrates, \textit{N,N}-dimethylaniline (1a) and ethyl acrylate (2a). Unfortunately, no olefinated product was observed under these conditions (Table 5.1, entry 1). We supposed that the lack of reactivity under the conditions reported in Chapter 3 is due to the partially protonation of the aniline in AcOH. Therefore, we screened the reaction in different solvents including protic and aprotic polar solvents as well as halogenated solvents. No reaction was observed when acidic protic solvents (entries 2 and 3) with low pK\textsubscript{a} values such as TFE (pK\textsubscript{a} 12.5) or HFIP (pK\textsubscript{a} 9.3) were used. When using bulky alcohols, \textit{t}-AmylOH or \textit{t}-BuOH (entries 4 and 5), high yields but poor selectivities were obtained, while MeOH or EtOH (entries 6 and 7) provided the product in low yields and selectivities. Other non-protic solvents were tested (entries 8–14), delivering the olefinated products in good yields with moderate to good site selectivities. Furthermore, the reactions using DCE and CH\textsubscript{2}Cl\textsubscript{2} furnished the desired product in 80% and 62% yield, respectively, with excellent site selectivities (entries 15 and 16). As can be seen in Table 5.1, the higher yields were obtained when using EtOAc or DCE as a solvent, the latter being the one that provided slightly higher site selectivity (entries 14 and 15).

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|}
\hline
Entry & Solvent & NMR yield (\textit{o}:\textit{m}:\textit{p}) \\
\hline
1 & AcOH & NR \\
2 & HFIP & NR \\
3 & TFE & NR \\
4 & \textit{t}-AmylOH & 70\% (1:0:4) \\
5 & \textit{t}-BuOH & 65\% (1:0:6.2) \\
6 & MeOH & 26\% (1:0:5.5) \\
7 & EtOH & 27\% (1:0:12.5) \\
8 & MeCN & 56\% (1:0:13) \\
9 & THF & 70\% (1:0:6.8) \\
10 & 1,4-dioxane & 69\% (1:0:5.9) \\
11 & DME & 69\% (1:0:6.7) \\
12 & DMF & 71\% (1:0:13.2) \\
13 & DMA & 69\% (1:0:10.5) \\
14 & EtOAc & 82\% (1:0:9.3) \\
15 & DCE & 80\% (1:0:10.4) \\
16 & CH\textsubscript{2}Cl\textsubscript{2} & 62\% (1:0:19) \\
\hline
\end{tabular}
\caption{Screening of solvents.}
\end{table}

Yield and selectivity were determined by \textsuperscript{1}H NMR analysis of the crude mixture using CH\textsubscript{2}Br\textsubscript{2} as an internal standard. NR = no reaction.

Next, we tried to minimize the amount of \textit{N,N}-dimethylaniline from 10 to 2 equiv in order to have an applicable methodology for late-stage functionalization of complex molecules. To maintain the reaction yield, we increased the amount of Pd catalyst from 5 to 10 mol\% and left
the reaction for longer time (overnight). We applied these conditions at different temperatures ranging from room temperature to 120 °C as shown in Table 5.2. To our delight, we found out that the reaction at 40 °C furnished the desired product 3a in excellent yield and site selectivity (entry 2).

Table 5.2 Screening of temperatures.

<table>
<thead>
<tr>
<th>Entry</th>
<th>Temperature (°C)</th>
<th>NMR yield (o:m:p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RT</td>
<td>31% (only p-isomer)</td>
</tr>
<tr>
<td>2</td>
<td>40</td>
<td>89% (1:0:&gt;19)</td>
</tr>
<tr>
<td>3</td>
<td>60</td>
<td>77% (1:0:&gt;19)</td>
</tr>
<tr>
<td>4</td>
<td>80</td>
<td>71% (1:0:&gt;19)</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>59% (1:0:19)</td>
</tr>
<tr>
<td>6</td>
<td>120</td>
<td>39% (1:0:18.5)</td>
</tr>
</tbody>
</table>

Yield and selectivity were determined by $^1$H NMR analysis of the crude mixture using CH$_2$Br$_2$ as an internal standard.

The reaction stoichiometries of N,N-dimethylaniline and ethyl acrylate were then investigated (Table 5.3). The yields were slightly dropped when we minimized the amount of aniline to 1 equiv while still keeping perfect site selectivity (entries 1–3). Using 1 equiv of N,N-dimethylaniline slightly higher yields were obtained when increasing the amount of olefin (entries 4 and 5). To balance between reactivity and the amount of aniline and olefin used, the conditions outlined in entry 4 were chosen for further optimization. Next, we stopped the reaction after 6 h and in this case, 3a was obtained in moderate yield (54%, entry 6). The effect of different concentrations was also studied. The yield decreased when the reaction was diluted to 0.1 M (entry 7) and no improvement was observed when the concentration was increased to 0.8 M (entry 8).
Table 5.3 Screening the reaction stoichiometries, times and concentrations.

<table>
<thead>
<tr>
<th>Entry</th>
<th>Amount of aniline (equiv)</th>
<th>Amount of olefin (equiv)</th>
<th>Time (h)</th>
<th>Conc. (M)</th>
<th>NMR yield (α:m:p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>1</td>
<td>16</td>
<td>0.2</td>
<td>89% (1:0:&gt;19)</td>
</tr>
<tr>
<td>2</td>
<td>1.5</td>
<td>1</td>
<td>16</td>
<td>0.2</td>
<td>92% (1:0:&gt;19)</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>1</td>
<td>16</td>
<td>0.2</td>
<td>76% (1:0:&gt;19)</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>1.5</td>
<td>16</td>
<td>0.2</td>
<td>81% (1:0:&gt;19)</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>2</td>
<td>16</td>
<td>0.2</td>
<td>80% (1:0:&gt;19)</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>1.5</td>
<td>6</td>
<td>0.2</td>
<td>54% (1:0:&gt;19)</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>1.5</td>
<td>16</td>
<td>0.1</td>
<td>68% (1:0:&gt;19)</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>1.5</td>
<td>16</td>
<td>0.8</td>
<td>83% (1:0:&gt;19)</td>
</tr>
</tbody>
</table>

Yield and selectivity were determined by 1H NMR analysis of the crude mixture using CH2Br2 as an internal standard.

We explored the reaction with different palladium sources (Table 5.4). When using Pd(OPiv)2, excellent site selectivity and slightly lower yield than the reaction with Pd(OAc)2 was observed (entries 1 and 2). Pd(TFA)2 provided the desired product in low yield albeit with good site selectivity (entry 3). No reaction was observed when palladium chloride complexes were employed (entries 4–7). The reaction using palladium (0) complexes gave the products in moderate yields with excellent site selectivities (entries 8 and 9). We further investigated the amount of catalyst in the reaction from 10 to 2.5 mol% (entries 1 and 10–12). We observed that by reducing the amount of catalyst the yield decreased, with a similar turnover number in all reactions. Also, we studied the effect of different amounts of ligand L varying from 5–20 mol% using 10 mol% of Pd(OAc)2 (entries 1 and 13–15). The conditions using 1:1 ratio of Pd:ligand gave the best result while no reaction was observed when a 1:2 ratio of Pd:ligand was used (entries 1 and 15). These results suggest that the active catalyst comprises of a 1:1 ratio of Pd:ligand and a palladium catalyst bound to two S,O-ligands is inactive. A detailed study of different catalyst is described in Chapter 6.
Table 5.4 Screening of Pd sources, catalyst loading and ratio of Pd/L.

<table>
<thead>
<tr>
<th>Entry</th>
<th>Pd source</th>
<th>Amount of Pd (mol%)</th>
<th>Amount of L (mol%)</th>
<th>Pd:L ratio</th>
<th>NMR yield (o:m:p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pd(OAc)$_2$</td>
<td>10</td>
<td>10</td>
<td>1:1</td>
<td>81% (1:0:&gt;19)</td>
</tr>
<tr>
<td>2</td>
<td>Pd(OAc)$_2$</td>
<td>10</td>
<td>10</td>
<td>1:1</td>
<td>70% (1:0:&gt;19)</td>
</tr>
<tr>
<td>3</td>
<td>Pd(TFA)$_2$</td>
<td>10</td>
<td>10</td>
<td>1:1</td>
<td>17% (1:0:16)</td>
</tr>
<tr>
<td>4</td>
<td>PdCl$_2$</td>
<td>10</td>
<td>10</td>
<td>1:1</td>
<td>NR</td>
</tr>
<tr>
<td>5</td>
<td>Pd(ACN)$_2$Cl$_2$</td>
<td>10</td>
<td>10</td>
<td>1:1</td>
<td>NR</td>
</tr>
<tr>
<td>6</td>
<td>Pd(PPh$_3$)$_2$Cl$_2$</td>
<td>10</td>
<td>10</td>
<td>1:1</td>
<td>NR</td>
</tr>
<tr>
<td>7</td>
<td>(Pd(allyl)Cl)$_2$</td>
<td>10</td>
<td>10</td>
<td>1:1</td>
<td>NR</td>
</tr>
<tr>
<td>8</td>
<td>Pd(dba)$_2$</td>
<td>10</td>
<td>10</td>
<td>1:1</td>
<td>52% (1:0:&gt;19)</td>
</tr>
<tr>
<td>9</td>
<td>Pd(PPh$_3$)$_4$</td>
<td>10</td>
<td>10</td>
<td>1:1</td>
<td>50% (1:0:15.7)</td>
</tr>
<tr>
<td>10</td>
<td>Pd(OAc)$_2$</td>
<td>7.5</td>
<td>7.5</td>
<td>1:1</td>
<td>73% (1:0:&gt;19)</td>
</tr>
<tr>
<td>11</td>
<td>Pd(OAc)$_2$</td>
<td>5</td>
<td>5</td>
<td>1:1</td>
<td>49% (1:0:&gt;19)</td>
</tr>
<tr>
<td>12</td>
<td>Pd(OAc)$_2$</td>
<td>2.5</td>
<td>2.5</td>
<td>1:1</td>
<td>21% (1:0:&gt;19)</td>
</tr>
<tr>
<td>13</td>
<td>Pd(OAc)$_2$</td>
<td>10</td>
<td>5</td>
<td>1:0.5</td>
<td>68% (1.5:1:&gt;19)</td>
</tr>
<tr>
<td>14</td>
<td>Pd(OAc)$_2$</td>
<td>10</td>
<td>15</td>
<td>1:1.5</td>
<td>38% (1:0:&gt;19)</td>
</tr>
<tr>
<td>15</td>
<td>Pd(OAc)$_2$</td>
<td>10</td>
<td>20</td>
<td>1:2</td>
<td>NR</td>
</tr>
</tbody>
</table>

Yield and selectivity were determined by $^1$H NMR analysis of the crude mixture using CH$_2$Br$_2$ as an internal standard. NR = no reaction.

Finally, the reactions with different oxidants including t-BuOOH, H$_2$O$_2$, BQ, oxone, sodium and potassium persulfate, PhI(OAc)$_2$, copper and silver salts were tested (Table 5.5, entries 2–11), but no improvement was observed when compared with the conditions using PhCO$_3$t-Bu (entry 1). When the amount of PhCO$_3$t-Bu was increased from 1 to 2 equiv, the yields slightly dropped (entries 1, 12 and 13). In addition, we explored the possibility of replacing PhCO$_3$t-Bu by oxygen. The reaction using a balloon of oxygen showed the formation of the olefinated product 3a in 15% yield with good site selectivity (entry 14). To our delight, the reaction using 2 bar of oxygen provided the desired product in 57% yield with excellent para-selectivity (entry 15). We postulate that increasing the pressure of oxygen, we increase the solubility of oxygen in DCE. These results show the potential of this methodology to be implemented in the chemical industry. However, we decided to proceed further with PhCO$_3$t-Bu for technical reasons.
With the optimal conditions in hand, we compared the reactions with and without ligand (Scheme 5.5). The reaction of \(N,N\)-dimethylaniline (1a) and ethyl acrylate (2a) without ligand gave only 18\% yield of the desired product 3a with a mixture of 3 isomers while the reaction in the presence of ligand L provided 3a with excellent site selectivity and yield, isolating the para-isomer in 71\% yield. To test the applicability of the present catalytic system, a half-gram-scale reaction was conducted to afford the olefinated product 3a in 64\% isolated yield, comparable with the original value.

To prove that the higher yield observed in the presence of the S,O-ligand corresponds to an acceleration of the reaction, we studied the kinetics of the reaction with and without S,O-ligand L (Scheme 5.5). The curves clearly indicated that ligand L increased the reaction rate dramatically when compared with the reaction without ligand.
S,O-Ligand promoted Pd-catalyzed C–H olefination of aniline derivatives

With the optimal conditions in hand, we investigated the substrate scope of this transformation. We first explored the olefination reaction of several tertiary aniline derivatives (Table 5.6). N,N-Diethyl-, N,N-dibenzylaniline and 1-phenylpyrrolidine (1b–1d) were olefinated in excellent yields (73–85%) and excellent selectivities towards their para positions when ligand L was used. Good yields and slightly deteriorated selectivities were observed using 4-phenylmorpholine (1e) and N-methyldiphenylamine (1f). Julolidine reacted to form only the para-olefinated product 3g in 60% isolated yield. Having proved the compatibility of this method with a variety of tertiary aniline derivatives, different meta-substituted N,N-dimethylanilines were tested. The reaction of m-methyl N,N-dimethylaniline (1h) provided the olefinated product 3h in 70% yield and good para-selectivity (>10:1). Good yield (75%) and moderate para-selectivity were observed in the reaction of the m-methoxy N,N-dimethylaniline (1i). In contrast, the reaction of the m-phenoxy N,N-dimethylaniline (1j) exhibited a perfect para-selectivity, obtaining product 3j in 66% isolated yield. Low yield was obtained using m-phenyl N,N-dimethylaniline (1k), probably due to steric effects. The corresponding para-olefinated products of meta-halogenerated substituents such as F (1l) and Cl (1m) were obtained in 65% and 54% isolated yields, respectively. Low conversion was observed when m-bromo N,N-dimethylaniline (1n) was used as starting material. In this case, we did not observe the Heck product. Thus, the low reactivity observed for the bromo substituted aniline can be attributed to steric effects, similarly to the reaction using the m-phenyl N,N-dimethylaniline (1k). Moreover, disubstituted N,N-dimethylanilines were tested. The reaction tolerated two fluorine atoms at the meta position of the aniline, providing the para-olefinated product 3o in 42% isolated yield. The yield was slightly dropped when 3-chloro-5-fluoro-N,N-dimethylaniline (1p) was used, following the same trend as the reactions of monohalogenated anilines (1l and 1m). The reaction of anilines bearing electron deficient substituents such as CO₂Me (1q) required harsher reaction conditions (1.5 equiv of aniline with 60 °C) to give product 3q in good yield (61%). We found out that other anilines with strong electron withdrawing groups including CF₃, NO₂ and CN provided the products 3r–3t in low yields. With the exception of these anilines bearing strong electron withdrawing groups, we observed much higher yields and selectivities towards the para-olefinated products in the presence of ligand L in comparison to those without ligand.

Interestingly, and in accordance with the high para-selectivity observed in these transformations, only 3% of the ortho-olefinated product was detected when using p-methyl N,N-dimethylaniline (1u). To extend the substrate scope of the reaction, we tested the

![Scheme 5.5 C–H Olefination with and without L.](image-url)
reaction of o-methyl N,N-dimethylaniline (1v) under the standard reaction conditions, but only trace amounts of an olefinated product was detected by $^1$H NMR spectroscopy. The lack of reactivity of ortho-substituted N,N-dialkylanilines in electrophilic aromatic substitution has been previously observed. It has been postulated that the ortho-substituent clashes with the N-methyl group of the N,N-dimethylaniline forcing the lone pair of the nitrogen atom to twist out of the conjugated system and therefore deactivating the aniline derivative towards electrophilic aromatic substitution. This hypothesis is demonstrated by performing DFT calculations (*vide infra*).

**Table 5.6 Substrate scope of N,N-dialkylanilines.**

<table>
<thead>
<tr>
<th>R^1R^2N</th>
<th>1</th>
<th>+</th>
<th>CO2Et</th>
<th>(1 equiv)</th>
<th>+</th>
<th>CO2Et</th>
<th>(1.5 equiv)</th>
<th>R^1R^2N</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Et_N</td>
<td>3b, 85% (p:o &gt;19:1) [79%]</td>
<td>Bn_N</td>
<td>3c, 79% [70%]</td>
<td>3d, 73% [67%]</td>
<td>16% (mixture of 3 isomers)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28% (p:o = 8.3:1)</td>
<td>31% (p:o = 2.4:1)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ph_N</td>
<td>3e, 63% (p:o = 2.9:1) [48]%</td>
<td>3f, 72% (p:others = 3.2:1)</td>
<td>3g, 68% [80]%</td>
<td>11%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24% (o:m:p = 1:1.3:5.7)</td>
<td>0%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Me_N</td>
<td>3h, 70% (p:others = 10.7:1) [61]%</td>
<td>3i, 75% (p:o = 2.8:1)</td>
<td>3j, 66% [66]%</td>
<td>31%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11% (p:others = 2.7:1)</td>
<td>11%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Me_N</td>
<td>3k, 36% (p:others = 4.1:1)</td>
<td>3l, 74% [65]%</td>
<td>3m, 54% [54]%</td>
<td>9%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0%</td>
<td>24%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Me_N</td>
<td>3n, 8% [54]</td>
<td>3o, 52% [42]%</td>
<td>3p, 33% [54]</td>
<td>9%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9%</td>
<td>13%</td>
<td>5%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Notes:* 7e, 9
Table 5.6 Substrate scope of N,N-dialkylanilines (continued).

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Yield</th>
<th>Selectivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>3q, 61% (p:others = 11:2:1) [51%]^{a,d}</td>
<td>17% (p:others = 1.8:1)</td>
<td></td>
</tr>
<tr>
<td>3r, Traces</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3s, 16%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3t, 25%</td>
<td>26%</td>
<td></td>
</tr>
<tr>
<td>3u, 3%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>3v, 4% (1 isomer)</td>
<td>0%</td>
<td></td>
</tr>
</tbody>
</table>

Yield and selectivity were determined by \(^1\)H NMR analysis of the crude mixture using CH\(_2\)Br\(_2\) as an internal standard. Isolated yield of p-isomer is given in square bracket. \(^a\)The reaction was performed at 60 °C. \(^b\)2 M of DCE was used. \(^c\)0.8 M of DCE was used. \(^d\)1.5 equiv of aniline derivative and 1 equiv of olefin were used.

To avoid this steric interaction that forces the lone pair of nitrogen to twist out of conjugation, we decided to use mono-protected ortho-substituted anilines. In this regard, we found that the N-benzyl protecting group is suitable for the para-olefination of ortho-substituted anilines using our Pd/S,O-ligand catalyst (Table 5.7). For these substrates, higher temperature (80 °C) and 1.5 equiv of aniline were required to form the olefinated products in high yields. Both reactions, with and without ligand, were again performed to evaluate the effect of the S,O-ligand in the reaction. The reactions with ligand of o-Me, -OMe, -F, -Cl, -Br, -CF\(_3\), -CO\(_2\)Me, and -COMe substituted N-benzylaniline derivatives exhibited perfect para-selectivities, providing the olefinated products 3w–3ad in moderate to good yields (31–70%). Using N-benzyl o-NO\(_2\) (1ae) and -CN (1af) anilines, no significant improvement of yields was observed in the presence of the ligand, similar to the reactivity observed with tertiary anilines. After proving the efficiency of the new catalytic system in anilines bearing both electron donating and withdrawing groups, we evaluated a variety of di- and trisubstituted N-benzylaniline derivatives. Disubstituted anilines with an ortho methylester group and different substituents at the meta-position, i.e. F, OMe and Me, underwent C–H olefination to provide the para-olefinated products 3ag–3ai in good yields (57–75%). N-Benzyl-m-methyl-o-(trifluoromethyl)aniline (1aj) and o-chloro-m-methoxyaniline (1ak) were also compatible with this catalytic system, providing the para-olefinated products in 53% and 52% isolated yields, respectively. The reaction yields dropped with anilines bearing two electron donating groups as in the case of N-benzyl-o-methyl-m-methoxyaniline (1al) and N-benzyl-5,6,7,8-tetrahydroanaphthalen-1-amine (1am). High yields of the olefinated products 3an and 3ao were obtained when 2,5-dichloro- and 2,3-dichloroaniline derivatives were used. Unexpectedly, the reaction of N-benzyl-1-naphthalenamine (1ap) provided the para-product 3ap in only 28% yield. Finally, the reaction of the trisubstituted o-methylester m,m'-difluoroaniline derivative furnished the para-olefinated product 3aq in 60% isolated yield. In all cases, except for anilines bearing a strong electron withdrawing group, the reactions with ligand showed perfect para-selectivities and an improvement of the reaction yields compared with the reactions without ligand. In some of these reactions, a small amount of byproduct 3', coming from the C–H activation at the ortho position of the benzyl ring, was formed.
Interestingly, these byproducts were detected as major components when reactions were performed without ligand.

### Table 5.7 Substrate scope of N-benzylanilines.

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Yield (%)</th>
<th>Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>3w+3w', 51%[45%]+5%</td>
<td>0%+11%</td>
<td>(1.5 equiv)</td>
</tr>
<tr>
<td>3x+3x', 53%[42%]+3%</td>
<td>0%+7%</td>
<td>(1 equiv)</td>
</tr>
<tr>
<td>3y+3y', 32%+4%</td>
<td>0%+12%</td>
<td>L, No ligand</td>
</tr>
<tr>
<td>3z+3z', 55%[46%]+7%</td>
<td>6%+24%</td>
<td></td>
</tr>
<tr>
<td>3aa+3aa', 31%+5%</td>
<td>4%+9%</td>
<td></td>
</tr>
<tr>
<td>3ab+3ab', 62%[53%]+12%</td>
<td>18%+39%</td>
<td></td>
</tr>
<tr>
<td>3ac+3ac', 70%[62%]+3%</td>
<td>27%+24%</td>
<td></td>
</tr>
<tr>
<td>3ad+3ad', 47%[39%]+12%</td>
<td>traces+24%</td>
<td></td>
</tr>
<tr>
<td>3ae+3ae', 46%+12%</td>
<td>37%+14%</td>
<td></td>
</tr>
<tr>
<td>3af+3af', 29%+0%</td>
<td>25%+10%</td>
<td></td>
</tr>
<tr>
<td>3ag+3ag', 75%[73%]</td>
<td>13%</td>
<td></td>
</tr>
<tr>
<td>3ah+3ah', 59%[58%]</td>
<td>9%</td>
<td></td>
</tr>
<tr>
<td>3ai+3ai', 57%[52%]+traces</td>
<td>traces+28%</td>
<td></td>
</tr>
<tr>
<td>3aj+3aj', 64%[53%]+7%</td>
<td>0%+38%</td>
<td></td>
</tr>
<tr>
<td>3ak+3ak', 52%[52%]+traces</td>
<td>traces+14%</td>
<td></td>
</tr>
<tr>
<td>3al+3al', 32%+0%</td>
<td>0%+9%</td>
<td></td>
</tr>
<tr>
<td>3am+3am', 18%+4%</td>
<td>0%+8%</td>
<td></td>
</tr>
<tr>
<td>3an+3an', 66%[66%]+5%</td>
<td>20%+18%</td>
<td></td>
</tr>
</tbody>
</table>
Table 5.7 Substrate scope of \(N\)-benzylanilines (continued).

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Yield and selectivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>3ao+3ao*, 63%[57%]+2% 9%+19%</td>
<td></td>
</tr>
<tr>
<td>3ap+3ap*, 28%+0%c 0%+4%</td>
<td></td>
</tr>
<tr>
<td>3aq+3aq*, 62%[60%]+6% 8%+18%</td>
<td></td>
</tr>
</tbody>
</table>

Yield and selectivity were determined by \(^{1}\)H NMR analysis of the crude mixture using CH\(_2\)Br\(_2\) as an internal standard. Isolated yield of \(p\)-isomer is given in square bracket. \(^a\)2 equiv of aniline derivative was used. \(^b\)0.1 M of DCE was used. \(^c\)1 equiv of aniline derivative and 1.5 equiv of olefin were used. \(^d\)Yield was determined by \(^{1}\)H NMR analysis of the crude mixture using hexafluorobenzene as an internal standard.

Finally, we studied the compatibility of the current catalytic system with primary anilines (Table 5.8). For these substrates, a higher temperature (80 °C) and 1.5–2 equiv of anilines with at least two substituents at \(ortho\) positions respect to the nitrogen atom were required to form the olefinated products in high yields. In the presence of ligand, the reaction conditions worked well with 2,6-dimethylester aniline, providing the desired product 3ar in 68% yield. However, we observed that the efficiency of the reaction is highly dependent on the substituents attached to the aromatic ring. When both substituents were electron withdrawing, with the exception of 2,6-dimethylester aniline 1ar, or electron donating, low yields were obtained (3as–3av). We assume that anilines bearing two electron withdrawing substituents are not reactive enough due to the poor electron density of the aromatic ring. In the case of 2,6-dimethylester aniline 1ar, we believe that hydrogen bonding is playing a crucial role for the high reactivity observed. On the other hand, the lack of reactivity of anilines bearing two electron donating substituents can be rationalized in terms of substrate inhibition due to the high nucleophilicity of the nitrogen atom. To our delight, the olefinated products were obtained in high yields with perfect \(para\)-selectivities with \(ortho\)-disubstituted anilines bearing one ester group at the \(ortho\)-position. Different substituents at the other \(ortho\)-position such as Me, OMe, and Cl were compatible with the reaction, providing the olefinated products 3aw–3ay in high yields (72–80%).

The reaction of trisubstituted aniline 1az bearing two fluorine atoms and a methylester furnished the olefinated aniline 3az in 70% isolated yield. We performed the reaction of \(ortho\)-disubstituted anilines bearing one CF\(_3\) group and a Me or OMe (1ba or 1bb) substituent at the other \(ortho\) position. The reaction with the aniline 1ba, bearing CF\(_3\) and Me groups, provided the product in only 25% yield. However, this improved to a 48% yield when using a more electron rich aniline such as 1bb, in which the weakly \(\sigma\)-electron donating Me group is replaced by the strong \(\pi\)-donating OMe group. A similar trend was observed with \(ortho\)-disubstituted anilines bearing one NO\(_2\) and a Me or OMe group (1bc or 1bd). The results obtained with these substrates (1ba–1bd) confirm that the reactivity is highly dependent on the electronic density of the aniline. The best substrates, with the exception of anilines bearing an ester group, are the ones that have a medium electronic density. For comparison, we performed the reactions under the same conditions without ligand. In most cases, lower yields of the desired products 3 together with a higher amount of the oxidative amination byproducts 3” were observed.
We then explored the scope of olefins as depicted in Table 5.9. The reactions of 1 equiv of \(N,N\)-diethylaniline with 1.5 equiv of methyl, cyclohexyl and phenyl acrylates using the ligand provided the products \(4a-4c\) in high yields (85–96%) and selectivities. \(\alpha\)-Methylene-\(\gamma\)-butyrolactone afforded compound \(4d\) in excellent yield as a mixture of \(4dA\) and \(4dE\) in 1.4 to 1 ratio. Likewise, other activated olefins, i.e. vinyl amide, methyl vinyl ketone, vinyl phosphonate and vinyl sulfonate, were also employed to provide products \(4e-4h\) in good
yields. The reaction using acrylonitrile provided the olefinated product 4i in 46% yield as a mixture of E/Z isomers (3.2:1). The reaction using methyl 2-butenoate as alkene gave compound 4j in 32% yield. As expected, when using a more steric hindered alkene, such as ethyl cinnamate, the desired product 4k was obtained in lower yield (17%). We also tested our catalytic system with allyl acetate; however, a low yield was obtained.

In general, in all these reactions (Tables 5.6–5.9), the presence of the S,O-ligand is crucial to achieve good yield and high para-selectivity.

Table 5.9 Substrate scope of alkenes.

Table 5.9 Substrate scope of alkenes.

<table>
<thead>
<tr>
<th>Substrate</th>
<th>Yield/Selectivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Et₂N·CO₂Me</td>
<td>4a, 86% [79%] 32% (p:o = 15:1)</td>
</tr>
<tr>
<td>Et₂N·CO₂Ph</td>
<td>4c, 96% [95%] 34%</td>
</tr>
<tr>
<td>Et₂N·CONMe₂</td>
<td>4e, 86% [77%] &lt;5%</td>
</tr>
<tr>
<td>Et₂N·COMe</td>
<td>4f, 71% [68%] 24%</td>
</tr>
<tr>
<td>Et₂N·P(OMe)₂</td>
<td>4g, 79% [76%] &lt;40%</td>
</tr>
<tr>
<td>Et₂N·SO₂Ph</td>
<td>4h, 55% [55%] 8%</td>
</tr>
<tr>
<td>Et₂N·CO₂Et</td>
<td>4k, 17% (E:Z = 2.4:1) 7% (E:Z = 2.5:1)</td>
</tr>
<tr>
<td>Et₂N·OAc</td>
<td>4i, 10% 7%</td>
</tr>
</tbody>
</table>

Yield and selectivity were determined by ¹H NMR analysis of the crude mixture using CH₂Br₂ as an internal standard. Isolated yield of p-isomer was given in square bracket.
Explanation of the difference in reactivity of tertiary and secondary anilines respect to the ortho-substituent

As shown in Table 5.6, the reaction of o-methyl N,N-dimethylaniline (1v) under optimal conditions provided only traces amount of olefinated product. In contrast, N-benzyl ortho-substituted anilines were efficiently para-olefinated using our Pd/S,O-ligand based catalyst (Table 5.7). As previously mentioned, we postulated that the ortho-substituent clashes with the N-methyl group of the N,N-dimethylaniline forcing the nitrogen to twist out of the plane with the aromatic ring, reducing the conjugation of the nitrogen lone pair and therefore deactivating the aniline derivative toward electrophilic aromatic substitution. To corroborate this, we calculated the torsion angle and the Voronoi deformation density (VDD) charges of 1v and 1w (Figure 5.2) at dispersion-corrected density functional theory (DFT) level. In the case of o-methyl N-benzyl aniline (1w), the H of the NHBN almost remains in the plane (δ = 18°), and points towards the o-methyl group. In contrast, one of the Me groups of the NMe2 of 1v is twisted out of the plane (δ = 69°) to avoid the interaction with the methyl group at the ortho position. As a consequence, the C atoms at the ortho and para positions of 1w (-85 and -88 me., respectively) are more negatively charged than the equivalent ones in 1v (-77 and -74 me., respectively). Therefore, the lack of reactivity observed in o-substituted N,N-dialkylanilines is a direct consequence of the lower nucleophilicity of these anilines compared with unsubstituted N,N-dialkylanilines or with o-substituted N-benzyl anilines.

Figure 5.2 Dihedral angle and VDD charges (in me.) for compounds 1v and 1w.

5.3 Conclusions

In conclusion, we have developed the first general para-selective C–H olefination of aniline derivatives by Pd/S,O-ligand catalyst. The reaction proceeds under mild reaction conditions with a broad range of anilines including mono-, di- and trisubstituted anilines bearing electron donating and withdrawing groups. We have demonstrated that the new catalyst is compatible with tertiary, secondary and primary anilines. We have observed that the electronic properties of the aniline play a pivotal role in the reactivity of this transformation. We have also shown that it is possible to use oxygen as a sole oxidant and this methodology is operationally simple and scalable. The S,O-ligand is responsible for the dramatic improvements in substrate scope and the high para-selectivity observed in this transformation.
5.4 Acknowledgements
Nick Westerveld is kindly acknowledged for his contribution to this chapter. Dr. Jordi Poater and Prof. F. Matthias Bickelhaupt are acknowledged for the DFT calculations. Ed Zuidinga and Dorette Tromp are thanked for the high resolution mass measurements.

5.5 Experimental section

General information
Chromatography: Silicycle Silica Flash P60 size 40–63 µm (230–400 mesh), TLC: Merck silica gel 60 (0.25mm). Visualization of the TLC was performed by UV, phosphomolybdic acid or KMnO₄ staining. Mass spectra were recorded on AccuTOF GC v 4g, JMS-T100GCV and AccuTOF LC, JMS-T100LP mass spectrometers. ¹H, ¹³C, ¹⁹F and ³¹P NMR were recorded on Bruker 400 and Bruker DRX 300 using CDCl₃ as a solvent. Chemical shift values are reported in ppm with the solvent resonance as an internal standard (CDCl₃: δ 7.26 for ¹H, δ 77.16 for ¹³C). Data are reported as follows: chemical shifts, multiplicity (s = singlet, bs = broad singlet, d = doublet, dd = doublet of doublets, t = triplet, td = triplet of doublets, q = quartet, m = multiplet), coupling constants (Hz) and integration. Infrared spectra were recorded on a Bruker IFS 28 FT-spectrophotometer and wavelengths are reported in cm⁻¹. Melting points were measured in a POLYTHERM A Heiztisch Mikroskop. GC analysis was performed on a Shimadzu GC-2010 Plus Gas Chromatograph using SH-Rxi-5HT (30 m, 0.25 mm, D 0.25 µm) column. All reagents and solvents were used as received. Pd(OAc)₂ was purchased from Strem. Some aniline derivatives and all olefins were purchased from commercial suppliers. 3-Methyl-2-(phenylthio)butanoic acid (L) was prepared according to the procedure described in Chapter 3.

5.5.1 Synthesis of protected aniline derivatives

General procedure for the synthesis of N,N-dimethylaniline derivatives
N,N-Dimethylaniline derivatives were prepared following the procedure described in the literature.¹⁰ To a solution of the corresponding aniline (1 equiv) in AcOH (0.2 M) under nitrogen atmosphere at room temperature, paraformaldehyde (10 equiv) followed by NaBH₃CN (5 equiv) were added. The reaction was stirred overnight. The resulting crude was poured into ice-cold 40% NaOH solution (50–100 mL) and stirred for 30 min. The aqueous layer was extracted with CH₂Cl₂ 3 times. The combined organic layers were dried over anh. MgSO₄, filtered and concentrated under reduced pressure. The crude residue was purified as specified in each case to obtain the desired product.

N,N,3-Trimethylaniline (1h)

\[
\text{Me}_2\text{NN} \quad \text{Me} \quad \text{Me} \\
\text{1h}
\]

N,N,3-Trimethylaniline (1h) was prepared following the general procedure using 3-methylaniline (1.00 mL, 9.33 mmol, 1 equiv), paraformaldehyde (2.80 g, 93.30 mmol, 10 equiv), NaBH₃CN (3.02 g, 46.65 mmol, 5 equiv) in AcOH (50 mL, 0.2 M). The resulting crude was poured into ice-cold 40% NaOH solution (100 mL). The crude residue was purified by column chromatography using CH₂Cl₂ as an eluent providing the titled compound as a clear liquid (0.89 g, 71% yield). ¹H NMR spectra data of the isolated material matched with the spectra data reported in the
S,O-Ligand promoted C–H olefination of aniline derivatives

literature for this compound.\textsuperscript{11} \textsuperscript{1}H NMR (400 MHz) δ = 7.19 (t, J = 7.5 Hz, 1H), 6.64 – 6.60 (m, 3H), 2.93 (s, 6H), 2.40 (s, 3H).

3-Methoxy-\(N,N\)-dimethylaniline (1i)

\[ \text{Me}_2\text{N} \quad \text{OMe} \]

3-Methoxy-\(N,N\)-dimethylaniline (1i) was prepared following the general procedure using 3-methoxyaniline (1.05 mL, 9.33 mmol, 1 equiv), paraformaldehyde (2.80 g, 93.30 mmol, 10 equiv), NaBH\(_3\)CN (3.02 g, 46.65 mmol, 5 equiv) in AcOH (50 mL, 0.2 M). The resulting crude was poured into ice-cold 40% NaOH solution (100 mL). The crude residue was purified by column chromatography using CH\(_2\)Cl\(_2\) as an eluent providing the titled compound as a yellow liquid (0.47 g, 33% yield). \textsuperscript{1}H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound.\textsuperscript{12} \textsuperscript{1}H NMR (400 MHz) δ = 7.16 (t, \(J = 7.9\) Hz, 1H), 6.38 (d, \(J = 8.4\) Hz, 1H), 6.32 – 6.30 (m, 2H), 3.80 (s, 3H), 2.94 (s, 6H).

3-Phenoxy-\(N,N\)-dimethylaniline (1j)

\[ \text{Me}_2\text{N} \quad \text{OPh} \]

3-Phenoxy-\(N,N\)-dimethylaniline (1j) was prepared following the general procedure using 3-phenoxyaniline (0.93 g, 5.00 mmol, 1 equiv), paraformaldehyde (1.50 g, 50.00 mmol, 10 equiv), NaBH\(_3\)CN (1.57 g, 25.00 mmol, 5 equiv) in AcOH (25 mL, 0.2 M). The resulting crude was poured into ice-cold 40% NaOH solution (50 mL). The crude residue was purified by column chromatography using Et\(_2\)O:petroleum ether (1:9 v/v) as an eluent providing the titled compound as a white solid (0.91 g, 86% yield). \textsuperscript{1}H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound.\textsuperscript{13} \textsuperscript{1}H NMR (400 MHz) δ = 7.33 (t, \(J = 7.9\) Hz, 2H), 7.18 (t, \(J = 8.2\) Hz, 1H), 7.10 – 7.03 (m, 3H), 6.50 (dd, \(J = 8.3, 2.1\) Hz, 1H), 6.44 (s, 1H), 6.35 (d, \(J = 8.0\) Hz, 1H), 2.94 (s, 6H).

3-Phenyl-\(N,N\)-dimethylaniline (1k)

\[ \text{Me}_2\text{N} \quad \text{Ph} \]

3-Phenyl-\(N,N\)-dimethylaniline (1k) was prepared following the general procedure using 3-phenylaniline (0.42 g, 2.50 mmol, 1 equiv), paraformaldehyde (0.75 g, 25.00 mmol, 10 equiv), NaBH\(_3\)CN (0.79 g, 12.50 mmol, 5 equiv) in AcOH (12.5 mL, 0.2 M). The resulting crude was poured into ice-cold 40% NaOH solution (50 mL). The crude residue was purified by column chromatography using Et\(_2\)O:petroleum ether (1:19 v/v) as an eluent providing the titled compound as a clear oil (0.33 g, 67% yield). \textsuperscript{1}H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound.\textsuperscript{14} \textsuperscript{1}H NMR (300 MHz) δ = 7.65 – 7.55 (m, 2H), 7.47 – 7.39 (m, 2H), 7.37 – 7.28 (m, 2H), 6.99 – 6.92 (m, 2H), 6.76 (d, \(J = 8.7\) Hz, 1H), 3.01 (s, 6H).

3-Fluoro-\(N,N\)-dimethylaniline (1l)

\[ \text{Me}_2\text{N} \quad \text{F} \]

3-Fluoro-\(N,N\)-dimethylaniline (1l) was prepared following the general procedure using 3-fluoroaniline (0.91 mL, 9.33 mmol, 1 equiv), paraformaldehyde (2.80 g, 93.30 mmol, 10 equiv), NaBH\(_3\)CN (3.02 g, 46.65 mmol, 5 equiv) in AcOH (50 mL, 0.2 M). The resulting crude was poured into ice-cold 40% NaOH solution (100 mL). The crude residue was purified by column
chromatography using CH$_2$Cl$_2$ as an eluent providing the titled compound as a pale yellow liquid (0.72 g, 55% yield). $^1$H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound.$^{15}$ $^1$H NMR (400 MHz) $\delta$ = 7.19 – 7.13 (m, 1H), 6.48 – 6.46 (m, 1H), 6.42 – 6.40 (m, 1H), 6.39 – 6.38 (m, 1H), 2.95 (s, 6H).

3-Chloro-$N,N$-dimethylaniline (1m)

3-Chloro-$N,N$-dimethylaniline (1m) was prepared following the general procedure using 3-chloroaniline (0.99 mL, 9.33 mmol, 1 equiv), paraformaldehyde (2.80 g, 93.30 mmol, 10 equiv), NaBH$_3$CN (3.02 g, 46.65 mmol, 5 equiv) in AcOH (50 mL, 0.2 M). The resulting crude was poured into ice-cold 40% NaOH solution (100 mL). The crude residue was purified by column chromatography using CH$_2$Cl$_2$ as an eluent providing the titled compound as a pale yellow liquid (0.79 g, 54% yield). $^1$H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound.$^{11}$ $^1$H NMR (300 MHz) $\delta$ = 7.13 (t, $J$ = 8.4 Hz, 1H), 6.68 – 6.66 (m, 2H), 6.59 (dd, $J$ = 8.4, 1.8 Hz, 1H), 2.95 (s, 6H).

3-Bromo-$N,N$-dimethylaniline (1n)

3-Bromo-$N,N$-dimethylaniline (1n) was prepared following the general procedure using 3-bromoaniline (1.02 mL, 9.33 mmol, 1 equiv), paraformaldehyde (2.8 g, 93.3 mmol, 10 equiv), NaBH$_3$CN (3.02 g, 46.65 mmol, 5 equiv) in AcOH (50 mL, 0.2 M). The resulting crude was poured into ice-cold 40% NaOH solution (100 mL). The crude residue was purified by column chromatography using CH$_2$Cl$_2$ as an eluent providing the titled compound as a clear liquid (1.46 g, 78% yield). $^1$H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound.$^{16}$ $^1$H NMR (400 MHz) $\delta$ = 7.07 (t, $J$ = 8.0 Hz, 1H), 6.83 (s, 1H), 6.82 (d, $J$ = 8.6 Hz, 1H), 6.63 (d, $J$ = 8.5 Hz, 1H), 2.94 (s, 6H).

3,5-Difluoro-$N,N$-dimethylaniline (1o)

3,5-Difluoro-$N,N$-dimethylaniline (1o) was prepared following the general procedure using 3,5-difluoroaniline (0.65 g, 5.00 mmol, 1 equiv), paraformaldehyde (1.50 g, 50.00 mmol, 10 equiv), NaBH$_3$CN (1.57 g, 25.00 mmol, 5 equiv) in AcOH (25 mL, 0.2 M). The resulting crude was poured into ice-cold 40% NaOH solution (50 mL). The crude residue was purified by column chromatography using Et$_2$O:petroleum ether (1:9 v/v) as an eluent providing the titled compound as a clear liquid (0.38 g, 48% yield). $^1$H NMR (300 MHz) $\delta$ = 6.17 – 6.10 (m, 3H), 2.94 (s, 6H); $^{13}$C NMR (75 MHz) $\delta$ = 164.3 (dd, $J$ = 242.4, 16.4 Hz), 152.5 (dd, $J$ = 13.2, 13.2 Hz), 95.0 (d, $J$ = 29.1 Hz), 91.3 (dd, $J$ = 26.3, 26.3 Hz), 40.4; $^{19}$F NMR (282 MHz) $\delta$ = -110.57 (t, $J$ = 9.3 Hz); IR $\nu$ = 2905, 1632, 1577, 1109, 987, 809 cm$^{-1}$; HRMS (El) calcd for C$_8$H$_9$F$_2$N [M]$^+$: 157.0703; found: 157.0710.
3-Chloro-5-fluoro-N,N-dimethylaniline (1p)

3-Chloro-5-fluoro-N,N-dimethylaniline (1p) was prepared following the general procedure using 3-chloro-5-fluoroaniline (0.50 mL, 5.00 mmol, 1 equiv), paraformaldehyde (1.50 g, 50.00 mmol, 10 equiv), NaBH₃CN (1.57 g, 25.00 mmol, 5 equiv) in AcOH (25 mL, 0.2 M). The resulting crude was poured into ice-cold 40% NaOH solution (50 mL). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:9 v/v) as an eluent providing the titled compound as a pale yellow liquid (0.56 g, 64% yield).

1H NMR (300 MHz) δ = 6.46 – 6.37 (m, 2H), 6.25 (dt, J = 12.4, 2.2 Hz, 1H), 2.94 (s, 6H); 13C NMR (75 MHz) δ = 163.9 (d, J = 244.0 Hz), 152.2 (d, J = 12.1 Hz), 135.4 (d, J = 14.0 Hz), 108.0 (d, J = 2.4 Hz), 103.5 (d, J = 25.8 Hz), 97.5 (d, J = 26.0 Hz), 40.3; 19F NMR (282 MHz) δ = -111.44 (dd, J = 11.7, 8.8 Hz); IR ν = 2892, 2812, 1605, 1560, 1497, 1439, 1144, 1015, 910, 812 cm⁻¹; HRMS (ESI) calcd for C₈H₁₀ClFN [M+H]⁺: 174.0486; found: 174.0485.

3-Methoxycarbonyl-N,N-dimethylaniline (1q)

3-Methoxycarbonyl-N,N-dimethylaniline (1q) was prepared following the general procedure using methyl 3-aminobenzoate (0.76 g, 5.00 mmol, 1 equiv), paraformaldehyde (1.50 g, 50.00 mmol, 10 equiv), NaBH₃CN (1.57 g, 25.00 mmol, 5 equiv) in AcOH (25 mL, 0.2 M). The resulting crude was poured into ice-cold 40% NaOH solution (50 mL). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:4 v/v) as an eluent providing the titled compound as a pale yellow liquid (0.59 g, 66% yield).

1H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound.¹⁷ 1H NMR (300 MHz) δ = 7.40 – 7.37 (m, 2H), 7.31 – 7.26 (m, 1H), 6.91 (dd, J = 8.1, 1.5 Hz, 1H), 3.90 (s, 3H), 2.99 (s, 6H).

3-(Trifluoromethyl)-N,N-dimethylaniline (1r)

3-(Trifluoromethyl)-N,N-dimethylaniline (1r) was prepared following the general procedure using 3-(trifluoromethyl)aniline (1.17 mL, 9.33 mmol, 1 equiv), paraformaldehyde (2.8 g, 93.3 mmol, 10 equiv), NaBH₃CN (3.02 g, 46.65 mmol, 5 equiv) in AcOH (50 mL, 0.2 M). The resulting crude was poured into ice cold 40% NaOH solution (100 mL). The crude residue was purified by column chromatography using CH₂Cl₂ as an eluent providing the titled compound as a colorless liquid (0.81 g, 46% yield). ¹H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound.¹⁸ ¹H NMR (400 MHz) δ = 7.33 – 7.29 (m, 1H), 6.95 – 6.85 (m, 3H), 3.00 (s, 3H).

3-Cyano-N,N-dimethylaniline (1t)

3-Cyano-N,N-dimethylaniline (1t) was prepared following the general procedure using 3-cyanoaniline (0.59 g, 5.00 mmol, 1 equiv), paraformaldehyde (1.50 g, 50.00 mmol, 10 equiv), NaBH₃CN (1.57 g, 25.00 mmol, 5 equiv) in AcOH (25 mL, 0.2 M). The resulting crude was poured into ice-cold 40% NaOH solution (50 mL). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:4 v/v) as an eluent providing the titled compound as a colorless liquid (0.67 g, 68% yield).
compound as a pale yellow oil (0.48 g, 66% yield). $^1$H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound. $^{19}$ $^1$H NMR (400 MHz) $\delta = 7.31 – 7.22$ (m, 1H), 6.95 (d, $J = 7.5$ Hz, 1H), 6.91 – 6.85 (m, 2H), 2.98 (s, 6H).

$N,N,4$-Trimethylaniline (1u)

$N,N,4$-Trimethylaniline (1u) was prepared following the general procedure using 4-methylaniline (1.00 g, 9.33 mmol, 1 equiv), paraformaldehyde (2.80 g, 93.30 mmol, 10 equiv), NaBH$_3$CN (3.02 g, 46.65 mmol, 5 equiv) in AcOH (50 mL, 0.2 M). The resulting crude was poured into ice-cold 40% NaOH solution (100 mL). The crude residue was purified by column chromatography using CH$_2$Cl$_2$ as an eluent providing the titled compound as a yellow oil (0.74 g, 59% yield). $^1$H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound. $^{11}$ $^1$H NMR (400 MHz) $\delta = 7.08$ (d, $J = 8.3$ Hz, 2H), 6.71 (d, $J = 8.3$ Hz, 2H), 2.90 (s, 6H), 2.30 (s, 3H).

$N,N,2$-Trimethylaniline (1v)

$N,N,2$-Trimethylaniline (1v) was prepared following the general procedure using 2-methylaniline (1.00 g, 9.33 mmol, 1 equiv), paraformaldehyde (2.80 g, 93.30 mmol, 10 equiv), NaBH$_3$CN (3.02 g, 46.65 mmol, 5 equiv) in AcOH (50 mL, 0.2 M). The resulting crude was poured into ice-cold 40% NaOH solution (100 mL). The crude residue was purified by column chromatography using CH$_2$Cl$_2$ as an eluent providing the titled compound as a pale yellow liquid (0.70 g, 56% yield). $^1$H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound. $^{12}$ $^1$H NMR (400 MHz) $\delta = 7.16$ (t, $J = 6.6$ Hz, 2H), 7.05 (d, $J = 8.3$ Hz, 1H), 6.96 (t, $J = 7.3$ Hz, 1H), 2.71 (s, 6H), 2.34 (s, 3H).

**General procedure for the synthesis of N-benzylaniline derivatives**

$N$-Benzylaniline derivatives were prepared following the procedure described in the literature. $^{8b}$ To a solution of the corresponding aniline (1 equiv) in AcOH (0.5 M), benzaldehyde (1.3 equiv) was added and stirred at room temperature for 30 min. The reaction was cooled down to 0 °C and NaBH$_4$ (1.04 equiv) was added to the reaction and stirred for 5 min. The reaction was quenched with H$_2$O. The aqueous layer was extracted with CH$_2$Cl$_2$ 3 times. The combined organic layers were dried over anh. MgSO$_4$, filtered and concentrated under reduced pressure. The crude residue was purified by column chromatography to obtain the desired product.

$N$-Benzyl-2-methylaniline (1w)

$N$-Benzyl-2-methylaniline (1w) was prepared following the general procedure using 2-methylaniline (0.54 mL, 5.00 mmol, 1 equiv), benzaldehyde (0.66 mL, 6.50 mmol, 1.3 equiv), NaBH$_4$ (0.20 g, 5.20 mmol, 1.04 equiv) in AcOH (10 mL, 0.5 M). The crude residue was purified by column chromatography using Et$_2$O:petroleum ether (1:9 v/v) as an eluent providing the titled compound as a white solid (0.82 g, 83% yield). $^1$H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound. $^{20}$ $^1$H NMR (400 MHz) $\delta = 7.41 – 7.35$ (m,
S,O-Ligand promoted C–H olefination of aniline derivatives

N-Benzyl-2-methoxyaniline (1x)

N-Benzyl-2-methoxyaniline (1x) was prepared following the general procedure using 2-methoxyaniline (0.57 mL, 5.00 mmol, 1 equiv), benzaldehyde (0.66 mL, 6.50 mmol, 1.3 equiv), NaBH₄ (0.20 g, 5.20 mmol, 1.04 equiv) in AcOH (10 mL, 0.5 M). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:9 v/v) as an eluent providing the titled compound as a pale yellow oil (0.76 g, 71% yield). ¹H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound.¹¹ ¹H NMR (300 MHz) δ = 7.41 – 7.26 (m, 5H), 6.87 – 6.79 (m, 2H), 6.71 – 6.65 (m, 1H), 6.62 – 6.59 (m, 1H), 4.64 (bs, 1H), 4.36 (s, 2H), 3.86 (s, 3H).

N-Benzyl-2-fluoroaniline (1y)

N-Benzyl-2-fluoroaniline (1y) was prepared following the general procedure using 2-fluoroaniline (0.49 mL, 5.00 mmol, 1 equiv), benzaldehyde (0.66 mL, 6.50 mmol, 1.3 equiv), NaBH₄ (0.20 g, 5.20 mmol, 1.04 equiv) in AcOH (10 mL, 0.5 M). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:9 v/v) as an eluent providing the titled compound as a pale yellow oil (0.94 g, 94% yield). ¹H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound.¹² ¹H NMR (400 MHz) δ = 7.41 – 7.33 (m, 4H), 7.32 – 7.25 (m, 1H), 7.02 – 6.91 (m, 2H), 6.73 – 6.59 (m, 2H), 4.38 (bs, 2H), 4.33 (s, 1H).

N-Benzyl-2-chloroaniline (1z)

N-Benzyl-2-chloroaniline (1z) was prepared following the general procedure using 2-chloroaniline (0.53 mL, 5.00 mmol, 1 equiv), benzaldehyde (0.66 mL, 6.50 mmol, 1.3 equiv), NaBH₄ (0.20 g, 5.20 mmol, 1.04 equiv) in AcOH (10 mL, 0.5 M). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:9 v/v) as an eluent providing the titled compound as a white solid (1.06 g, 97% yield). ¹H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound.¹³ ¹H NMR (400 MHz) δ = 7.39 – 7.34 (m, 4H), 7.31 – 7.27 (m, 2H), 7.09 (td, J = 7.7, 1.5 Hz, 1H), 6.66 – 6.62 (m, 2H), 4.76 (bs, 1H), 4.41 (s, 2H).

N-Benzyl-2-bromoaniline (1aa)

N-Benzyl-2-bromoaniline (1aa) was prepared following the general procedure using 2-bromoaniline (0.86 g, 5.00 mmol, 1 equiv), benzaldehyde (0.66 mL, 6.50 mmol, 1.3 equiv), NaBH₄ (0.20 g, 5.20 mmol, 1.04 equiv) in AcOH (10 mL, 0.5 M). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:9 v/v) as an eluent providing the titled compound as a pale yellow liquid (1.27 g, 97% yield). ¹H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound.¹⁴ ¹H NMR (400 MHz) δ = 7.44 (d, J =
7.8 Hz, 1H), 7.39 – 7.24 (m, 5H), 7.17 – 7.09 (m, 1H), 6.65 – 6.53 (m, 2H), 4.80 (bs, 1H), 4.41 (s, 2H).

**N-Benzyl-2-(trifluoromethyl)aniline (1ab)**

N-Benzyl-2-(trifluoromethyl)aniline (1ab) was prepared following the general procedure using 2-(trifluoromethyl)aniline (0.63 mL, 5.00 mmol, 1 equiv), benzaldehyde (0.66 mL, 6.50 mmol, 1.3 equiv), NaBH₄ (0.20 g, 5.20 mmol, 1.04 equiv) in AcOH (10 mL, 0.5 M). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:9 v/v) as an eluent providing the titled compound as a pale yellow liquid (1.01 g, 80% yield). ¹H NMR (400 MHz) δ = 7.48 (d, J = 7.8 Hz, 1H), 7.38 – 7.31 (m, 6H), 6.76 – 6.70 (m, 2H), 4.83 (bs, 1H), 4.44 (s, 2H); ¹³C NMR (101 MHz) δ = 145.5, 138.5, 133.2, 128.9, 127.6, 127.2, 126.7 (q, J = 5.6 Hz), 124.0, 116.3, 113.6 (q, J = 29.2 Hz), 112.3, 47.8; ¹⁹F NMR (282 MHz) δ = -62.41; IR ν = 3470, 1613, 1586, 1519, 1496, 1330, 1288, 1123, 1031, 819, 747, 728 cm⁻¹; HRMS (EI) calcd for C₁₄H₁₁F₃N [M-H]⁺: 250.0844; found: 250.0830.

**N-Benzyl-2-cyanoaniline (1af)**

N-Benzyl-2-cyanoaniline (1af) was prepared following the general procedure using 2-cyanoaniline (0.59 g, 5.00 mmol, 1 equiv), benzaldehyde (0.66 mL, 6.50 mmol, 1.3 equiv), NaBH₄ (0.20 g, 5.20 mmol, 1.04 equiv) in AcOH (10 mL, 0.5 M). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:4 v/v) as an eluent providing the titled compound as a pale yellow solid (0.29 g, 28% yield). ¹H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound.²⁵ ¹H NMR (400 MHz) δ = 7.46 – 7.27 (m, 7H), 6.69 (t, J = 7.5 Hz, 1H), 6.63 (d, J = 8.5 Hz, 1H), 5.02 (bs, 1H), 4.44 (s, 2H).

**N-Benzyl-5-fluoro-2-(methoxycarbonyl)aniline (1ag)**

N-Benzyl-5-fluoro-2-(methoxycarbonyl)aniline (1ag) was prepared following the general procedure using methyl 2-amino-4-fluorobenzoate (0.85 g, 5.00 mmol, 1 equiv), benzaldehyde (0.66 mL, 6.50 mmol, 1.3 equiv), NaBH₄ (0.20 g, 5.20 mmol, 1.04 equiv) in AcOH (10 mL, 0.5 M). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:9 v/v) as an eluent providing the titled compound as a clear oil (1.03 g, 79% yield). ¹H NMR (300 MHz) δ = 8.35 (bs, 1H), 7.93 (dd, J = 9.6, 6.8 Hz, 1H), 7.36 – 7.26 (m, 5H), 6.33 – 6.28 (m, 2H), 4.41 (d, J = 5.6 Hz, 2H), 3.86 (s, 3H); ¹³C NMR (75 MHz) δ = 168.5, 167.3 (d, J = 251.3 Hz), 153.2 (d, J = 12.5 Hz), 138.2, 134.3 (d, J = 11.7 Hz), 128.9, 127.5, 127.2, 107.0 (d, J = 1.6 Hz), 102.8 (d, J = 22.8 Hz), 98.1 (d, J = 25.8 Hz), 51.7, 47.2; ¹⁹F NMR (282 MHz) δ = -103.22 (dd, J = 17.3, 7.8 Hz); IR ν = 3352, 1682, 1616, 1583, 1519, 1434, 1251, 1219, 1180, 1129, 1099, 826, 761, 693 cm⁻¹; HRMS (FD) calcd for C₁₅H₁₄FNO₂ [M⁺]: 259.1009; found: 259.1015.
**N-Benzyl-5-methoxy-2-(methoxycarbonyl)aniline (1ah)**

*N*-Benzyl-5-methoxy-2-(methoxycarbonyl)aniline (1ah) was prepared following the general procedure using methyl 2-amino-4-methoxybenzoate (0.91 g, 5.00 mmol, 1 equiv), benzaldehyde (0.66 mL, 6.50 mmol, 1.3 equiv), NaBH₄ (0.20 g, 5.20 mmol, 1.04 equiv) in AcOH (10 mL, 0.5 M). The crude residue was purified by column chromatography using Et₂O:petroleum ether (3:17 v/v) as an eluent providing the titled compound as a pale yellow oil (0.94 g, 69% yield). ¹H NMR (300 MHz) δ = 8.30 (bs, 1H), 7.88 (d, J = 8.9 Hz, 1H), 7.40 – 7.19 (m, 5H), 6.19 (dd, J = 8.9, 2.3 Hz, 1H), 6.10 (d, J = 2.3 Hz, 1H), 4.44 (d, J = 5.3 Hz, 2H), 3.85 (s, 3H), 3.74 (s, 3H); ¹³C NMR (75 MHz) δ = 168.9, 164.8, 152.9, 138.8, 133.6, 128.8, 127.3, 127.3, 104.0, 102.2, 95.8, 55.2, 51.4, 47.2; IR ν = 3357, 2948, 2838, 1673, 1611, 1574, 1516, 1250, 1137, 1100, 695 cm⁻¹; HRMS (FD) calcd for C₁₆H₁₇NO₃ [M⁺]: 271.1208; found: 271.1203.

**N-Benzyl-5-methyl-2-(methoxycarbonyl)aniline (1ai)**

*N*-Benzyl-5-methyl-2-(methoxycarbonyl)aniline (1ai) was prepared following the general procedure using methyl 2-amino-4-methylbenzoate (0.83 g, 5.00 mmol, 1 equiv), benzaldehyde (0.66 mL, 6.50 mmol, 1.3 equiv), NaBH₄ (0.20 g, 5.20 mmol, 1.04 equiv) in AcOH (10 mL, 0.5 M). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:9 v/v) as an eluent providing the titled compound as a white solid (0.98 g, 77% yield). ¹H NMR (300 MHz) δ = 8.19 (bs, 1H), 7.87 (d, J = 8.2 Hz, 1H), 7.43 – 7.29 (m, 5H), 6.52 (s, 1H), 6.48 (d, J = 8.2 Hz, 1H), 4.48 (d, J = 5.5 Hz, 2H), 3.88 (s, 3H), 2.30 (s, 3H); ¹³C NMR (75 MHz) δ = 169.2, 151.1, 145.5, 139.0, 131.7, 128.8, 127.2, 127.2, 116.4, 111.9, 107.8, 51.5, 47.1, 22.3; IR ν = 3383, 2947, 1673, 1573, 1436, 1230, 1188, 1145, 768, 692 cm⁻¹; HRMS (FD) calcd for C₁₆H₁₇NO₂ [M⁺]: 255.1259; found: 255.1269; mp 62 – 64 °C.

**N-Benzyl-5-methyl-2-(trifluoromethyl)aniline (1aj)**

*N*-benzyl-5-methyl-2-(trifluoromethyl)aniline (1aj) was prepared following the general procedure using 5-methyl-2-(trifluoromethyl)aniline (0.88 g, 5.00 mmol, 1 equiv), benzaldehyde (0.66 mL, 6.50 mmol, 1.3 equiv), NaBH₄ (0.20 g, 5.20 mmol, 1.04 equiv) in AcOH (10 mL, 0.5 M). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:9 v/v) as an eluent providing the titled compound as a clear oil (1.15 g, 87% yield). ¹H NMR (300 MHz) δ = 7.37 – 7.27 (m, 6H), 6.56 – 6.52 (m, 2H), 4.71 (bs, 1H), 4.41 (bs, 1H), 4.41 (s, 2H), 2.28 (s, 3H); ¹³C NMR (75 MHz) δ = 145.5 (q, J = 1.5 Hz), 143.7 (q, J = 1.5 Hz), 138.7, 128.9, 127.6, 127.3, 126.7 (q, J = 5.4 Hz), 125.6 (q, J = 271.7 Hz), 117.3, 112.8, 111.2 (q, J = 29.5 Hz), 47.8, 22.0; ¹⁹F NMR (282 MHz) δ = -61.83; IR ν = 3468, 2923, 1582, 1321, 1287, 1089, 1031, 800 cm⁻¹; HRMS (ESI) calcd for C₁₅H₁₅F₃N [M+H]⁺: 266.1511; found: 266.1151.

**N-Benzyl-2-chloro-5-methoxyaniline (1ak)**

*N*-benzyl-2-chloro-5-methoxyaniline (1ak) was prepared following the general procedure using 2-chloro-5-methoxyaniline (0.79 g, 5.00 mmol, 1 equiv), benzaldehyde (0.66 mL, 6.50 mmol, 1.3 equiv), NaBH₄ (0.20 g, 5.20 mmol, 1.04 equiv) in AcOH (10 mL, 0.5 M). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:9 v/v) as an eluent providing the titled compound as a white solid (0.87 g, 77% yield). ¹H NMR (300 MHz) δ = 7.30 – 7.24 (m, 6H), 6.42 – 6.38 (m, 2H), 4.41 (bs, 1H), 4.39 (bs, 1H), 4.31 (s, 2H), 2.28 (s, 3H); ¹³C NMR (75 MHz) δ = 143.7 (q, J = 1.5 Hz), 143.7 (q, J = 1.5 Hz), 138.7, 128.9, 127.6, 127.3, 126.7 (q, J = 5.4 Hz), 125.6 (q, J = 271.7 Hz), 117.3, 112.8, 111.2 (q, J = 29.5 Hz), 47.8, 22.0; ¹⁹F NMR (282 MHz) δ = -61.83; IR ν = 3468, 2923, 1582, 1321, 1287, 1089, 1031, 800 cm⁻¹; HRMS (ESI) calcd for C₁₅H₁₅F₃N [M+H]⁺: 266.1511; found: 266.1151.
5.20 mmol, 1.04 equiv) in AcOH (10 mL, 0.5 M). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:9 v/v) as an eluent providing the titled compound as a white solid (1.10 g, 89% yield). ¹H NMR (300 MHz) δ = 7.38 – 7.26 (m, 5H), 7.19 – 7.15 (m, 1H), 6.22 – 6.20 (m, 2H), 4.73 (bs, 1H), 4.38 (s, 2H), 3.72 (s, 3H); ¹³C NMR (75 MHz) δ = 159.7, 144.8, 138.7, 129.4, 128.9, 127.5, 127.5, 111.4, 102.2, 98.5, 55.4, 48.0; IR ν = 3413, 2835, 1599, 1513, 1318, 1208, 1168, 824, 724 cm⁻¹; HRMS (ESI) calcd for C₁₄H₁₅ClNO [M+H]⁺: 248.0842; found: 248.0844; mp 78 – 80 °C.

**N-Benzyl-5-methoxy-2-methylaniline (1al)**

N-Benzyl-5-methoxy-2-methylaniline (1al) was prepared following the general procedure using 5-methoxy-2-methylaniline (0.69 g, 5.00 mmol, 1 equiv), benzaldehyde (0.66 mL, 6.50 mmol, 1.3 equiv), NaBH₄ (0.20 g, 5.20 mmol, 1.04 equiv) in AcOH (10 mL, 0.5 M). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:9 v/v) as an eluent providing the titled compound as a pale yellow solid (0.29 g, 25% yield). ¹H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound.²⁶ ¹H NMR (300 MHz) δ = 7.44 – 7.27 (m, 5H), 6.98 (d, J = 8.9 Hz, 1H), 6.28 – 6.18 (m, 2H), 4.36 (s, 2H), 3.88 (bs, 1H), 3.75 (s, 3H), 2.11 (s, 3H).

**N-Benzyl-5,6,7,8-tetrahydronaphthalen-1-amine (1am)**

N-Benzyl-5,6,7,8-tetrahydronaphthalen-1-amine (1am) was prepared following the general procedure using 5,6,7,8-tetrahydronaphthalen-1-amine (0.74 g, 5.00 mmol, 1 equiv), benzaldehyde (0.66 mL, 6.50 mmol, 1.3 equiv), NaBH₄ (0.20 g, 5.20 mmol, 1.04 equiv) in AcOH (10 mL, 0.5 M). The crude residue was purified by column chromatography using CH₂Cl₂:petroleum ether (2:3 v/v) as an eluent providing the titled compound as a clear oil (0.82 g, 69% yield). ¹H NMR (300 MHz) δ = 7.47 – 7.26 (m, 5H), 7.02 (t, J = 7.8 Hz, 1H), 6.54 (d, J = 7.6 Hz, 1H), 6.47 (d, J = 8.0 Hz, 1H), 4.37 (s, 2H), 3.87 (bs, 1H), 2.76 (t, J = 6.0 Hz, 2H), 2.44 (t, J = 6.3 Hz, 2H), 1.95 – 1.83 (m, 2H), 1.82 – 1.71 (m, 2H); ¹³C NMR (75 MHz) δ = 145.8, 139.7, 137.7, 128.7, 127.6, 127.3, 126.2, 121.2, 118.6, 107.4, 48.5, 30.2, 24.0, 23.2, 22.8; IR ν = 3436, 2923, 1587, 1466, 1282, 761, 733, 695 cm⁻¹; HRMS (ESI) calcd for C₁₇H₂₀N [M+H]⁺: 238.1596; found: 238.1583.

**N-Benzyl-2,5-dichloroaniline (1an)**

N-Benzyl-2,5-dichloroaniline (1an) was prepared following the general procedure using 2,5-dichloroaniline (0.81 g, 5.00 mmol, 1 equiv), benzaldehyde (0.66 mL, 6.50 mmol, 1.3 equiv), NaBH₄ (0.20 g, 5.20 mmol, 1.04 equiv) inAcOH (10 mL, 0.5 M). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:9 v/v) as an eluent providing the titled compound as a clear oil (1.02 g, 81% yield). ¹H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound.²⁷ ¹H NMR (300 MHz) δ = 7.41 – 7.29 (m, 5H), 7.19 – 7.16 (m, 1H), 6.63 – 6.59 (m, 2H), 4.75 (bs, 1H), 4.37 (s, 2H).
N-Benzyl-2,3-dichloroaniline (1ao)

N-Benzyl-2,3-dichloroaniline (1ao) was prepared following the general procedure using 2,3-dichloroaniline (0.81 g, 5.00 mmol, 1 equiv), benzaldehyde (0.66 mL, 6.50 mmol, 1.3 equiv), NaBH₄ (0.20 g, 5.20 mmol, 1.04 equiv) in AcOH (10 mL, 0.5 M). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:9 v/v) as an eluent providing the titled compound as a clear oil (1.08 g, 86% yield).

1H NMR (300 MHz) δ = 7.46 – 7.34 (m, 5H), 7.05 (t, J = 8.1 Hz, 1H), 6.86 (dd, J = 8.1, 1.2 Hz, 1H), 6.57 (d, J = 8.1 Hz, 1H), 4.97 (bs, 1H), 4.44 (s, 2H); 13C NMR (75 MHz) δ = 145.3, 138.3, 132.9, 128.9, 127.8, 127.6, 127.3, 118.2, 117.2, 109.5, 48.0; IR ν = 3423, 3029, 2854, 1585, 1494, 1449, 1038, 759, 695 cm⁻¹; HRMS (FD) calcd for C₁₃H₁₁Cl₂N [M]+: 251.0269; found: 251.0333.

N-Benzyl(naphthalen-1-amine (1ap)

N-Benzyl naphthalen-1-amine (1ap) was prepared following the general procedure using naphthalen-1-amine (0.72 g, 5.00 mmol, 1 equiv), benzaldehyde (0.66 mL, 6.50 mmol, 1.3 equiv), NaBH₄ (0.20 g, 5.20 mmol, 1.04 equiv) in AcOH (10 mL, 0.5 M). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:9 v/v) as an eluent providing the titled compound as a yellow solid (0.65 g, 56% yield).

1H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound.

1H NMR (300 MHz) δ = 7.85 (d, J = 7.9 Hz, 2H), 7.57 – 7.28 (m, 9H), 6.68 (d, J = 7.3 Hz, 1H), 4.74 (bs, 1H), 4.53 (s, 2H).

N-Benzyl-3,5-difluoro-2-(methoxycarbonyl)aniline (1aq)

N-Benzyl-3,5-difluoro-2-(methoxycarbonyl)aniline (1aq) was prepared following the general procedure using methyl 2-amino-4,6-difluorobenzoate (0.94 g, 5.00 mmol, 1 equiv), benzaldehyde (0.66 mL, 6.50 mmol, 1.3 equiv), NaBH₄ (0.20 g, 5.20 mmol, 1.04 equiv) in AcOH (10 mL, 0.5 M). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:9 v/v) as an eluent providing the titled compound as a clear oil (0.98 g, 71% yield). 1H NMR (300 MHz) δ = 8.42 (bs, 1H), 7.40 – 7.27 (m, 5H), 6.14 – 6.05 (m, 2H), 4.38 (d, J = 3.1 Hz, 2H), 3.89 (s, 3H); 13C NMR (75 MHz) δ = 167.8 (d, J = 4.2 Hz), 167.5 (dd, J = 88.8, 16.9 Hz), 164.2 (dd, J = 96.6, 17.0 Hz), 153.3 (dd, J = 14.5, 6.8 Hz), 137.7, 129.0, 127.6, 127.2, 97.4 (dd, J = 13.4, 2.8 Hz), 94.1 (dd, J = 25.7, 3.2 Hz), 92.3 (dd, J = 28.8, 26.8 Hz), 52.0, 47.6; 19F NMR (282 MHz) δ = -99.85 (t, J = 13.2 Hz), -101.69 (dd, J = 23.4, 11.7 Hz); IR ν = 3341, 2952, 1677, 1586, 1438, 1348, 1242, 1117, 815, 695 cm⁻¹; HRMS (FD) calcd for C₁₃H₁₁F₂NO₂ [M]+: 277.0914; found: 277.0903.

Procedure for the synthesis of N-Benzyl-2-(methoxycarbonyl)aniline (1ac)

N-Benzyl-2-(methoxycarbonyl)aniline (1ac) was prepared following the procedure described in the literature. 2-Methylester)aniline (1.29 mL, 10.00 mmol, 1 equiv), benzyl bromide (1.43 mL, 12.00 mmol, 1.2 equiv), K₂CO₃ (3.46 g, 25.00 mmol, 2.5 equiv) in acetone (30 mL, 0.33 M) were refluxed overnight. The solution was filtered and concentrated under reduced pressure. The crude
residue was purified by column chromatography using Et₂O:petroleum ether (1:9 v/v) as an eluent providing the titled compound as a pale yellow solid (1.54 g, 64% yield). ¹H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound.³⁹ ¹H NMR (400 MHz) δ = 8.17 (bs, 1H), 7.93 (dd, J = 8.0, 1.6 Hz, 1H), 7.37 – 7.25 (m, 6H), 6.64 (d, J = 8.5 Hz, 1H), 6.62 – 6.58 (m, 1H), 4.46 (d, J = 2.8 Hz, 2H), 3.87 (s, 3H).

**Procedure for the synthesis of N-benzyl-2-acetyl aniline (1ad)**

N-benzyl-2-acetyl aniline (1ad) was prepared following the procedure described in the literature.³⁰ To a solution of K₂CO₃ (0.69 g, 5.00 mmol, 1 equiv) in MeCN (5 mL, 1 M), 2-(acetyl)aniline (0.61 mL, 5.00 mmol, 1 equiv) and benzyl bromide (0.60 mL, 5.00 mmol, 1 equiv) were added. The reaction was heated at 60 °C for 5 h. K₂CO₃ was filtered out and the solvent was concentrated under reduced pressure. The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:9 v/v) as an eluent providing the titled compound as a yellow solid (0.75 g, 67% yield). ¹H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound.³⁰ ¹H NMR (300 MHz) δ = 9.33 (bs, 1H), 7.78 (dd, J = 8.0, 1.4 Hz, 1H), 7.35 – 7.26 (m, 6H), 6.67 – 6.58 (m, 2H), 4.47 (d, J = 5.6 Hz, 2H), 2.61 (s, 3H).

**Procedure for the synthesis of N-benzyl-2-nitroaniline (1ae)**

N-Benzyl-2-nitroaniline (1ae) was prepared following the procedure described in the literature.³¹ 2-Nitroaniline (1.38 g, 10.00 mmol, 1 equiv) and benzyl bromide (1.43 mL, 12.00 mmol, 1.2 equiv) in water (20 mL) were heated at 100 °C for 2.5 h. The reaction was cooled down to room temperature and then NaHCO₃ (850 mg) was added to the solution. The aqueous layer was extracted with EtOAc 2 times. The combined organic layers were washed with water, dried over anh. MgSO₄, filtered and concentrated under reduced pressure. The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:9 v/v) as an eluent providing the titled compound as an orange solid (1.59 g, 70% yield). ¹H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound.³¹ ¹H NMR (400 MHz) δ = 8.43 (bs, 1H), 8.20 (dd, J = 8.6, 1.5 Hz, 1H), 7.45 – 7.27 (m, 6H), 6.82 (d, J = 8.7 Hz, 1H), 6.67 (ddd, J = 8.3, 7.0, 1.1 Hz, 1H), 4.56 (d, J = 5.5 Hz, 2H).

5.5.2 Pd-Catalyzed C–H olefination of aniline derivatives with activated alkenes

**Pd-Catalyzed C–H olefination of N,N-dimethylaniline**

A stock solution of ligand L (0.0846 M in CH₂Cl₂) (150 µL, 12.5 µmol, 5 mol%) was added into a pressure tube and dried with nitrogen steam until dryness followed by Pd(OAc)₂ (2.8 mg, 12.5 µmol, 5 mol%), t-butyl peroxylbenzoate (47 µL, 0.25 mmol, 1 equiv), ethyl acrylate (27 µL, 0.25 mmol, 1 equiv), N,N-dimethylaniline (0.31 mL, 2.5 mmol, 10 equiv) and the corresponding solvent (1.25 mL, 0.2 M). The pressure tube was sealed with a screw cap and the reaction was placed in a 100 °C pre-heated oil bath and stirred for 6 h. The resulting mixture was diluted with EtOAc, filtered through a plug of Celite and concentrated under
reduced pressure. The $^1$H NMR yield was determined by adding CH$_2$Br$_2$ (17.5 µL, 0.25 mmol, 1 equiv) as an internal standard.

*Screening of temperatures*

A stock solution of ligand L (0.0846 M in CH$_2$Cl$_2$) (300 µL, 25 µmol, 10 mol%) was added into a pressure tube and dried with nitrogen steam until dryness followed by Pd(OAc)$_2$ (5.6 mg, 25 µmol, 10 mol%), t-butyl peroxybenzoate (47 µL, 0.25 mmol, 1 equiv), ethyl acrylate (27 µL, 0.25 mmol, 1 equiv), N,N-dimethylaniline (63 µL, 0.5 mmol, 2 equiv) and DCE (1.25 mL, 0.2 M). The pressure tube was sealed with a screw cap and the reaction was placed in a pre-heated oil bath at the indicated temperature and stirred for 16 h. The resulting mixture was diluted with EtOAc, filtered through a plug of Celite and concentrated under reduced pressure. The $^1$H NMR yield was determined by adding CH$_2$Br$_2$ (17.5 µL, 0.25 mmol, 1 equiv) as an internal standard.

*Optimization of stoichiometries of N,N-dimethylaniline and ethyl acrylate*

A stock solution of ligand L (0.0846 M in CH$_2$Cl$_2$) (300 µL, 25 µmol, 10 mol%) was added into a pressure tube and dried with nitrogen steam until dryness followed by Pd(OAc)$_2$ (5.6 mg, 25 µmol, 10 mol%), t-butyl peroxybenzoate (47 µL, 0.25 mmol, 1 equiv), ethyl acrylate (1–2 equiv), N,N-dimethylaniline (1–2 equiv) and DCE (1.25 mL, 0.2 M). The pressure tube was sealed with a screw cap and the reaction was placed in a 40 °C pre-heated oil bath and stirred for 16 h. The resulting mixture was diluted with EtOAc, filtered through a plug of Celite and concentrated under reduced pressure. The $^1$H NMR yield was determined by adding CH$_2$Br$_2$ (17.5 µL, 0.25 mmol, 1 equiv) as an internal standard.

<table>
<thead>
<tr>
<th>Entry</th>
<th>Amount of N,N-dimethylaniline</th>
<th>Amount of ethyl acrylate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2 equiv, 0.5 mmol, 63 µL</td>
<td>1 equiv, 0.25 mmol, 27 µL</td>
</tr>
<tr>
<td>2</td>
<td>1.5 equiv, 0.375 mmol, 48 µL</td>
<td>1 equiv, 0.25 mmol, 27 µL</td>
</tr>
<tr>
<td>3</td>
<td>1 equiv, 0.25 mmol, 32 µL</td>
<td>1 equiv, 0.25 mmol, 27 µL</td>
</tr>
<tr>
<td>4</td>
<td>1 equiv, 0.25 mmol, 32 µL</td>
<td>1.5 equiv, 0.375 mmol, 40 µL</td>
</tr>
<tr>
<td>5</td>
<td>1 equiv, 0.25 mmol, 32 µL</td>
<td>2 equiv, 0.5 mmol, 53 µL</td>
</tr>
</tbody>
</table>

*Optimization of the reaction time*

A stock solution of ligand L (0.0846 M in CH$_2$Cl$_2$) (300 µL, 25 µmol, 10 mol%) was added into a pressure tube and dried with nitrogen steam until dryness followed by Pd(OAc)$_2$ (5.6 mg, 25 µmol, 10 mol%), t-butyl peroxybenzoate (47 µL, 0.25 mmol, 1 equiv), ethyl acrylate (40 µL, 0.375 mmol, 1.5 equiv), N,N-dimethylaniline (32 µL, 0.25 mmol, 1 equiv) and DCE (1.25 mL, 0.2 M). The pressure tube was sealed with a screw cap and the reaction was placed in a 40 °C pre-heated oil bath over the time period indicated for each reaction. The resulting mixture was diluted with EtOAc, filtered through a plug of Celite and concentrated under reduced pressure. The $^1$H NMR yield was determined by adding CH$_2$Br$_2$ (17.5 µL, 0.25 mmol, 1 equiv) as an internal standard.
Effect of the concentration
A stock solution of ligand L (0.0846 M in CH$_2$Cl$_2$) (300 µL, 25 µmol, 10 mol%) was added into a pressure tube and dried with nitrogen steam until dryness followed by Pd(OAc)$_2$ (5.6 mg, 25 µmol, 10 mol%), t-butyl peroxybenzoate (47 µL, 0.25 mmol, 1 equiv), ethyl acrylate (40 µL, 0.375 mmol, 1.5 equiv), N,N-dimethylaniline (32 µL, 0.25 mmol, 1 equiv) and the corresponding concentration of DCE (0.1–0.8 M). The pressure tube was sealed with a screw cap and the reaction was placed in a 40 °C pre-heated oil bath and stirred for 16 h. The resulting mixture was diluted with EtOAc, filtered through a plug of Celite and concentrated under reduced pressure. The $^1$H NMR yield was determined by adding CH$_2$Br$_2$ (17.5 µL, 0.25 mmol, 1 equiv) as an internal standard.

<table>
<thead>
<tr>
<th>Entry</th>
<th>Concentration (M)</th>
<th>Amount of solvent (mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.2</td>
<td>1.25</td>
</tr>
<tr>
<td>2</td>
<td>0.1</td>
<td>2.5</td>
</tr>
<tr>
<td>3</td>
<td>0.8</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Screening of Pd sources
A stock solution of ligand L (0.0846 M in CH$_2$Cl$_2$) (300 µL, 25 µmol, 10 mol%) was added into a pressure tube and dried with nitrogen steam until dryness followed by the corresponding Pd source (25 µmol, 10 mol%), t-butyl peroxybenzoate (47 µL, 0.25 mmol, 1 equiv), ethyl acrylate (40 µL, 0.375 mmol, 1.5 equiv), N,N-dimethylaniline (32 µL, 0.25 mmol, 1 equiv) and DCE (1.25 mL, 0.2 M). The pressure tube was sealed with a screw cap and the reaction was placed in a 40 °C pre-heated oil bath and stirred for 16 h. The resulting mixture was diluted with EtOAc, filtered through a plug of Celite and concentrated under reduced pressure. The $^1$H NMR yield was determined by adding CH$_2$Br$_2$ (17.5 µL, 0.25 mmol, 1 equiv) as an internal standard.

<table>
<thead>
<tr>
<th>Entry</th>
<th>Pd source</th>
<th>Amount of Pd source (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pd(OAc)$_2$</td>
<td>5.6</td>
</tr>
<tr>
<td>2</td>
<td>Pd(OPiv)$_2$</td>
<td>7.7</td>
</tr>
<tr>
<td>3</td>
<td>Pd(TFA)$_2$</td>
<td>8.3</td>
</tr>
<tr>
<td>4</td>
<td>PdCl$_2$</td>
<td>4.4</td>
</tr>
<tr>
<td>5</td>
<td>Pd(ACN)$_2$Cl$_2$</td>
<td>6.5</td>
</tr>
<tr>
<td>6</td>
<td>Pd(PPh$_3$)$_2$Cl$_2$</td>
<td>17.5</td>
</tr>
<tr>
<td>7</td>
<td>(Pd(allyl)Cl)$_2$</td>
<td>9.1</td>
</tr>
<tr>
<td>8</td>
<td>Pd(dba)$_2$</td>
<td>14.4</td>
</tr>
<tr>
<td>9</td>
<td>Pd(PPh$_3$)$_4$</td>
<td>28.9</td>
</tr>
</tbody>
</table>

Optimization of the catalyst loading
A stock solution of ligand L (0.0846 M in CH$_2$Cl$_2$) (2.5–10 mol%) was added into a pressure tube and dried with nitrogen steam until dryness followed by the corresponding amount of Pd(OAc)$_2$ (2.5–10 mol%), t-butyl peroxybenzoate (47 µL, 0.25 mmol, 1 equiv), ethyl acrylate...
S,O-Ligand promoted C–H olefination of aniline derivatives

(40 µL, 0.375 mmol, 1.5 equiv), N,N-dimethylaniline (32 µL, 0.25 mmol, 1 equiv) and DCE (1.25 mL, 0.2 M). The pressure tube was sealed with a screw cap and the reaction was placed in a 40 °C pre-heated oil bath and stirred for 16 h. The resulting mixture was diluted with EtOAc, filtered through a plug of Celite and concentrated under reduced pressure. The ¹H NMR yield was determined by adding CH₂Br₂ (17.5 µL, 0.25 mmol, 1 equiv) as an internal standard.

Table 5.13 Optimization of the catalyst loading.

<table>
<thead>
<tr>
<th>Entry</th>
<th>Amount of catalyst</th>
<th>Pd(OAc)₂ (mg)</th>
<th>Stock solution of ligand (µL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10 mol%, 25 µmol</td>
<td>5.6</td>
<td>300</td>
</tr>
<tr>
<td>2</td>
<td>7.5 mol%, 18.75 µmol</td>
<td>4.2</td>
<td>220</td>
</tr>
<tr>
<td>3</td>
<td>5 mol%, 12.5 µmol</td>
<td>2.8</td>
<td>150</td>
</tr>
<tr>
<td>4</td>
<td>2.5 mol%, 6.25 µmol</td>
<td>1.4</td>
<td>75</td>
</tr>
</tbody>
</table>

Optimization of the ratio Pd:ligand

A stock solution of ligand L (0.0846 M in CH₂Cl₂) (5–20 mol%) was added into a pressure tube and dried with nitrogen steam until dryness followed by Pd(OAc)₂ (5.6 mg, 25 µmol, 10 mol%), t-butyldiperoxide (47 µL, 0.25 mmol, 1 equiv), ethyl acrylate (40 µL, 0.375 mmol, 1.5 equiv), N,N-dimethylaniline (32 µL, 0.25 mmol, 1 equiv) and DCE (1.25 mL, 0.2 M). The pressure tube was sealed with a screw cap and the reaction was placed in a 40 °C pre-heated oil bath and stirred for 16 h. The resulting mixture was diluted with EtOAc, filtered through a plug of Celite and concentrated under reduced pressure. The ¹H NMR yield was determined by adding CH₂Br₂ (17.5 µL, 0.25 mmol, 1 equiv) as an internal standard.

Table 5.14 Optimization of the ratio of Pd:ligand.

<table>
<thead>
<tr>
<th>Entry</th>
<th>Pd:L ratio</th>
<th>Ligand (mol%)</th>
<th>Stock solution of ligand (µL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1:0.5</td>
<td>5</td>
<td>150</td>
</tr>
<tr>
<td>2</td>
<td>1:1</td>
<td>10</td>
<td>300</td>
</tr>
<tr>
<td>3</td>
<td>1:1.5</td>
<td>15</td>
<td>450</td>
</tr>
<tr>
<td>4</td>
<td>1:2</td>
<td>20</td>
<td>600</td>
</tr>
</tbody>
</table>

Screening of oxidants

A stock solution of ligand L (0.0846 M in CH₂Cl₂) (300 µL, 25 µmol, 10 mol%) was added into a pressure tube and dried with nitrogen steam until dryness followed by Pd(OAc)₂ (5.6 mg, 25 µmol, 10 mol%), the corresponding oxidant (1 equiv), ethyl acrylate (40 µL, 0.375 mmol, 1.5 equiv), N,N-dimethylaniline (32 µL, 0.25 mmol, 1 equiv) and DCE (1.25 mL, 0.2 M). The pressure tube was sealed with a screw cap and the reaction was placed in a 40 °C pre-heated oil bath and stirred for 16 h. The resulting mixture was diluted with EtOAc, filtered through a plug of Celite and concentrated under reduced pressure. The ¹H NMR yield was determined by adding CH₂Br₂ (17.5 µL, 0.25 mmol, 1 equiv) as an internal standard.
Table 5.15 Screening of oxidants.

<table>
<thead>
<tr>
<th>Entry</th>
<th>Oxidant</th>
<th>Amount of oxidant</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PhCO₃-t-Bu</td>
<td>47 µL</td>
</tr>
<tr>
<td>2</td>
<td>t-BuOOH (80% in di-t-butylperoxide)</td>
<td>31 µL</td>
</tr>
<tr>
<td>3</td>
<td>H₂O₂ (35% in H₂O)</td>
<td>22 µL</td>
</tr>
<tr>
<td>4</td>
<td>BQ</td>
<td>27 mg</td>
</tr>
<tr>
<td>5</td>
<td>Oxone</td>
<td>76.8 mg</td>
</tr>
<tr>
<td>6</td>
<td>Na₂S₂O₈</td>
<td>59.5 mg</td>
</tr>
<tr>
<td>7</td>
<td>K₂S₂O₈</td>
<td>67.6 mg</td>
</tr>
<tr>
<td>8</td>
<td>PhI(OAc)₂</td>
<td>80.5 mg</td>
</tr>
<tr>
<td>9</td>
<td>Cu(OAc)₂</td>
<td>45.4 mg</td>
</tr>
<tr>
<td>10</td>
<td>AgOAc</td>
<td>41.7 mg</td>
</tr>
<tr>
<td>11</td>
<td>Ag₂CO₃</td>
<td>68.9 mg</td>
</tr>
<tr>
<td>12</td>
<td>O₂</td>
<td>1 bar</td>
</tr>
<tr>
<td>13</td>
<td>O₂</td>
<td>2 bar</td>
</tr>
</tbody>
</table>

Optimization of the amount of oxidant
A stock solution of ligand L (0.0846 M in CH₂Cl₂) (300 µL, 25 µmol, 10 mol%) was added into a pressure tube and dried with nitrogen steam until dryness followed by Pd(OAc)₂ (5.6 mg, 25 µmol, 10 mol%), t-butyl peroxybenzoate (1–2 equiv), ethyl acrylate (40 µL, 0.375 mmol, 1.5 equiv), N,N-dimethylaniline (32 µL, 0.25 mmol, 1 equiv) and DCE (1.25 mL, 0.2 M). The pressure tube was sealed with a screw cap and the reaction was placed in a 40 °C pre-heated oil bath and stirred for 16 h. The resulting mixture was diluted with EtOAc, filtered through a plug of Celite and concentrated under reduced pressure. The ¹H NMR yield was determined by adding CH₂Br₂ (17.5 µL, 0.25 mmol, 1 equiv) as an internal standard.

Table 5.16 Optimization of the amount of oxidant.

<table>
<thead>
<tr>
<th>Entry</th>
<th>Amount of oxidant</th>
<th>Volume (µL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 equiv, 0.25 mmol</td>
<td>47</td>
</tr>
<tr>
<td>2</td>
<td>1.5 equiv, 0.375 mmol</td>
<td>71</td>
</tr>
<tr>
<td>3</td>
<td>2 equiv, 0.5 mmol</td>
<td>95</td>
</tr>
</tbody>
</table>

Kinetic profile of the Pd-catalyzed C–H olefination of N,N-dimethylaniline with and without ligand L
Pd(OAc)₂ (11.2 mg, 50 µmol, 10 mol%), a stock solution of ligand L (0.0846 M in DCE) (600 µL, 50 µmol, 10 mol%), t-butyl peroxybenzoate (94 µL, 0.5 mmol, 1 equiv), ethyl acrylate (82 µL, 0.75 mmol, 1.5 equiv), N,N-dimethylaniline (1a) (63 µL, 0.5 mmol, 1 equiv) and DCE (1.9 mL, 0.2 M) were added into a pressure tube. n-Decane (97 µL, 0.5 mmol, 1 equiv) was added in a reaction tube as an internal standard for quantitative GC analysis. The pressure tube was sealed with a crimp cap with septa and the reaction was placed in a 40 °C pre-heated oil bath. The reaction was followed during time by sampling 0.1 mL. The reaction mixture was diluted with EtOAc (1 mL). The organic layer was filtered through a plug of Celite and analyzed by GC.
A parallel reaction without ligand was also performed to compare the kinetic profile. Pd(OAc)$_2$ (11.2 mg, 50 µmol, 10 mol%), t-butyl peroxybenzoate (94 µL, 0.5 mmol, 1 equiv), ethyl acrylate (82 µL, 0.75 mmol, 1.5 equiv), N,N-dimethylaniline (1a) (63 µL, 0.5 mmol, 1 equiv) and DCE (2.5 mL, 0.2 M) were added into a pressure tube. n-Decane (97 µL, 0.5 mmol, 1 equiv) was added in a reaction tube as an internal standard for quantitative GC analysis. The pressure tube was sealed with a crimp cap with septa and the reaction was placed in a 40 °C pre-heated oil bath. The reaction was followed during time by sampling 0.1 mL. The reaction mixture was diluted with EtOAc (1 mL). The organic layer was filtered through a plug of Celite and analyzed by GC.

### Table 5.17 Kinetic profile of Pd-catalyzed C–H olefination of N,N-dimethylaniline.

<table>
<thead>
<tr>
<th>Entry</th>
<th>Reaction time (h)</th>
<th>GC yield of p- and o-olefinated products (L)</th>
<th>GC yield of p- and o-olefinated products (no ligand)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5</td>
<td>4%</td>
<td>1%</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>10%</td>
<td>2%</td>
</tr>
<tr>
<td>3</td>
<td>1.5</td>
<td>15%</td>
<td>3%</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>20%</td>
<td>3%</td>
</tr>
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<td>5</td>
<td>2.5</td>
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<td>6%</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>27%</td>
<td>7%</td>
</tr>
<tr>
<td>7</td>
<td>4</td>
<td>35%</td>
<td>9%</td>
</tr>
<tr>
<td>8</td>
<td>5</td>
<td>43%</td>
<td>10%</td>
</tr>
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**Note:** The reactions with and without L were performed at the same time to compare the kinetic profiles.

**Pd-Catalyzed C–H olefination of aniline derivatives**

**General procedure A**

Pd(OAc)$_2$ (5.6 mg, 25.0 µmol, 10 mol%), a stock solution of ligand L (0.0846 M in DCE) (300 µL, 25.0 µmol, 10 mol%), t-butyl peroxybenzoate (47 µL, 0.25 mmol, 1 equiv), ethyl acrylate (1–1.5 equiv), the corresponding aniline derivative (1–2 equiv) and DCE (concentration as indicated for each reaction) were added into a pressure tube. The pressure tube was sealed with a screw cap and the reaction was placed in a pre-heated oil bath at the indicated temperature and stirred for 16 h. The resulting mixture was diluted with EtOAc, filtered through a plug of Celite and concentrated under reduced pressure. The $^1$H NMR yield was determined by adding CH$_2$Br$_2$ (17.5 µL, 0.25 mmol, 1 equiv) as an internal standard. The crude residue was purified by column chromatography to obtain the desired product.
General procedure B
A stock solution of ligand L (0.0846 M in CH₂Cl₂) (300 µL, 25.0 µmol, 10 mol%) was added into a pressure tube and dried with nitrogen steam until dryness followed by Pd(OAc)₂ (5.6 mg, 25.0 µmol, 10 mol%), t-butyl peroxybenzoate (47 µL, 0.25 mmol, 1 equiv), ethyl acrylate (40 µL, 0.375 mmol, 1.5 equiv), the corresponding aniline derivative (0.25 mmol, 1 equiv) and DCE (concentration as indicated for each reaction). The pressure tube was sealed with a screw cap and the reaction was placed in a 40 °C pre-heated oil bath and stirred for 16 h. The resulting mixture was diluted with EtOAc, filtered through a plug of Celite and concentrated under reduced pressure. The ¹H NMR yield was determined by adding CH₂Br₂ (17.5 µL, 0.25 mmol, 1 equiv) as an internal standard. The crude residue was purified by column chromatography to obtain the desired product.

Ethyl (E)-3-(4-(dimethylamino)phenyl)acrylate (3a)

\[
\text{Me}_2\text{N} \quad \text{CO}_2\text{Et} \\
\text{3a}
\]

General procedure A was followed using N,N-dimethylaniline (1a) (32 µL, 0.25 mmol, 1 equiv) and ethyl acrylate (40 µL, 0.375 mmol, 1.5 equiv) in DCE (0.95 mL, 0.2 M) at 40 °C, providing the olefinated products in 81% ¹H NMR yield (p:o >19:1). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:4 v/v) as an eluent providing the titled compound as a yellow solid (38.7 mg, 71% yield). ¹H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound.³² ¹H NMR (400 MHz) δ = 7.62 (d, J = 15.8 Hz, 1H), 7.42 (d, J = 8.6 Hz, 2H), 6.66 (d, J = 8.6 Hz, 2H), 6.22 (d, J = 15.8 Hz, 1H), 4.24 (q, J = 7.1 Hz, 2H), 3.01 (s, 6H), 1.32 (t, J = 7.1 Hz, 3H).

A parallel reaction without ligand was also performed providing the olefinated products in 18% ¹H NMR yield (o:m:p = 1:1:16).

Preparative scale synthesis
General procedure A was followed using ligand L (86.8 mg, 0.413 mmol, 10 mol%), Pd(OAc)₂ (92.7 mg, 0.413 mmol, 10 mol%), t-butyl peroxybenzoate (0.77 mL, 4.13 mmol, 1 equiv), ethyl acrylate (0.66 mL, 6.20 mmol, 1.5 equiv), N,N-diethylaniline (1a) (0.52 mL, 4.13 mmol, 1 equiv) and DCE (8.25 mL, 0.5 M) at 40 °C, providing the compounds in 67% NMR yield (p:o >19:1). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:4 v/v) as an eluent providing the titled compound as a yellow solid (0.58 g, 64% yield).

Ethyl (E)-3-(4-(diethylamino)phenyl)acrylate (3b)

\[
\text{Et}_2\text{N} \quad \text{CO}_2\text{Et} \\
\text{3b}
\]

General procedure A was followed using N,N-diethylaniline (1b) (40 µL, 0.25 mmol, 1 equiv) and ethyl acrylate (40 µL, 0.375 mmol, 1.5 equiv) in DCE (0.95 mL, 0.2 M) at 40 °C, providing the olefinated products 85% ¹H NMR yield (p:o >19:1). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:4 v/v) as an eluent providing the titled compound as a yellow oil (49.0 mg, 79% yield). ¹H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this
S,O-Ligand promoted C–H olefination of aniline derivatives

$^1$H NMR (400 MHz) $\delta = 7.61$ (d, $J = 15.8$ Hz, 1H), 7.39 (d, $J = 8.5$ Hz, 2H), 6.62 (d, $J = 8.5$ Hz, 2H), 6.19 (d, $J = 15.8$ Hz, 1H), 4.24 (q, $J = 7.1$ Hz, 2H), 3.38 (q, $J = 7.1$ Hz, 4H), 1.32 (t, $J = 7.1$ Hz, 3H), 1.18 (t, $J = 7.1$ Hz, 6H).

A parallel reaction without ligand was also performed providing the olefinated products in 28% $^1$H NMR yield ($p:o = 8.3:1$).

**Ethyl (E)-3-(4-(dibenzylamino)phenyl)acrylate (3c)**

General procedure A was followed using N,N-dibenzylaniline (1c) (68.3 mg, 0.25 mmol, 1 equiv) and ethyl acrylate (40 µL, 0.375 mmol, 1.5 equiv) in DCE (0.95 mL, 0.2 M) at 60 °C, providing 3c in 79% $^1$H NMR yield. The crude residue was purified by column chromatography using Et$_2$O:petroleum ether (1:4 v/v) as an eluent providing the titled compound as a yellow solid (65.0 mg, 70% yield).

$^1$H NMR (400 MHz) $\delta = 7.64$ (d, $J = 15.8$ Hz, 1H), 7.40 – 7.36 (m, 6H), 7.33 – 7.31 (m, 2H), 7.29 – 7.25 (m, 4H), 6.75 (d, $J = 8.4$ Hz, 2H), 6.23 (d, $J = 15.8$ Hz, 1H), 4.73 (s, 4H), 4.27 (q, $J = 7.1$ Hz, 2H), 1.36 (t, $J = 7.1$ Hz, 3H); $^{13}$C NMR (101 MHz) $\delta = 167.9$, 150.8, 144.9, 137.8, 130.0, 128.9, 127.3, 126.6, 123.1, 113.1, 112.3, 60.2, 54.2, 14.5; IR $\nu = 1700, 1596, 1521, 1157$ cm$^{-1}$; HRMS (FD) calcd for C$_{25}$H$_{25}$NO$_2$ [M$^+$]: 371.1885; found: 371.1885; mp 97 – 100 °C.

A parallel reaction without ligand was also performed providing the olefinated products in 31% $^1$H NMR yield ($p:o = 2.4:1$).

**Ethyl (E)-3-(4-(pyrrolidinyl)phenyl)acrylate (3d)**

General procedure A was followed using 1-phenylpyrrolidine (1d) (36 µL, 0.25 mmol, 1 equiv) and ethyl acrylate (40 µL, 0.375 mmol, 1.5 equiv) in DCE (0.95 mL, 0.2 M) at 40 °C, providing 3d in 73% $^1$H NMR yield. The crude residue was purified by column chromatography using Et$_2$O:petroleum ether (1:4 v/v) as an eluent providing the titled compound as a pale yellow solid (40.8 mg, 67% yield). $^1$H NMR (400 MHz) $\delta = 7.62$ (d, $J = 15.8$ Hz, 1H), 7.40 (d, $J = 8.7$ Hz, 2H), 6.52 (d, $J = 8.7$ Hz, 2H), 6.20 (d, $J = 15.8$ Hz, 1H), 4.24 (q, $J = 7.1$ Hz, 2H), 3.34 – 3.31 (m, 4H), 2.03 – 2.00 (m, 4H), 1.32 (t, $J = 7.1$ Hz, 3H); $^{13}$C NMR (101 MHz) $\delta = 168.1$, 149.4, 145.5, 130.0, 121.7, 111.9, 111.7, 60.1, 47.7, 25.6, 14.6; IR $\nu = 2965$, 2849, 1694, 1600, 1524, 1153, 1035, 812 cm$^{-1}$; HRMS (EI) calcd for C$_{15}$H$_{15}$NO$_2$ [M$^+$]: 245.1416; found: 245.1421; mp 121 – 126 °C.

A parallel reaction without ligand was also performing the olefinated products in 16% $^1$H NMR yield (mixture of 3 isomers).

**Ethyl (E)-3-(4-morpholinophenyl)acrylate (3e)**

General procedure A was followed using 4-phenylmorpholine (1e) (40.8 mg, 0.25 mmol, 1 equiv) and ethyl acrylate (40 µL, 0.375 mmol, 1.5 equiv) in DCE (0.95 mL, 0.2 M) at 60 °C, providing the olefinated products in 63% $^1$H NMR yield ($p:o = 2.9:1$). The crude
residue was purified by column chromatography using Et₂O:petroleum ether (1:1 v/v) as an eluent providing the titled compound as a yellow solid (31.4 mg, 48% yield). \(^1\)H NMR spectra of the isolated material matched with the spectra data reported in the literature for this compound.\(^7\) \(^1\)H NMR (300 MHz) \(\delta = 7.62\) (d, \(J = 15.9\) Hz, 1H), 7.44 (d, \(J = 8.6\) Hz, 2H), 6.86 (d, \(J = 8.6\) Hz, 2H), 6.28 (d, \(J = 15.9\) Hz, 1H), 4.24 (q, \(J = 7.1\) Hz, 2H), 3.87 – 3.83 (m, 4H), 3.25 – 3.21 (m, 4H), 1.32 (t, \(J = 7.1\) Hz, 3H).

A parallel reaction without ligand was also performed providing the olefinated products in 24% \(^1\)H NMR yield (\(\alpha:\text{m}:\text{p} = 1:1.3:5.7\)).

**Ethyl (E)-3-(4-(methyl(phenyl)amino)phenyl)acrylate (3f)**

\[
\begin{align*}
\text{N} \quad \text{Ph}^- \\
\text{Ph} \quad \text{Me} \quad \text{EtCO}_2 \quad \text{Me} \\
\end{align*}
\]

General procedure A was followed using \(N\)-methyl diphenylamine (1f) (44 µL, 0.25 mmol, 1 equiv) and ethyl acrylate (40 µL, 0.375 mmol, 1.5 equiv) in DCE (0.95 mL, 0.2 M) at 40 °C, providing the olefinated products in 72% \(^1\)H NMR yield (\(p:others = 3.2:1\)). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:4 v/v) as an eluent providing the titled compound as a yellow oil (35.2 mg, 50% yield). \(^1\)H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound.\(^3\) \(^1\)H NMR (300 MHz) \(\delta = 7.62\) (d, \(J = 15.9\) Hz, 1H), 7.40 – 7.35 (m, 4H), 7.20 – 7.14 (m, 3H), 6.82 (d, \(J = 8.8\) Hz, 2H), 6.25 (d, \(J = 15.9\) Hz, 1H), 4.25 (q, \(J = 7.1\) Hz, 2H), 3.35 (s, 3H), 1.33 (t, \(J = 7.1\) Hz, 3H).

A parallel reaction without ligand was also performed. This reaction gave no product.

**9-[2-(Ethoxycarbonyl)vinyl]julolidine (3g)**

\[
\begin{align*}
\text{N} \quad \text{Me} \quad \text{Me} \quad \text{EtCO}_2 \quad \text{Et} \\
\end{align*}
\]

General procedure B was followed using julolidine (1g) (43.3 mg, 0.25 mmol, 1 equiv) in DCE (0.13 mL, 2 M) at 40 °C, providing 3g in 68% \(^1\)H NMR yield. The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:4 v/v) as an eluent providing the titled compound as a yellow oil (40.4 mg, 60% yield). \(^1\)H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound.\(^3\) \(^1\)H NMR (400 MHz) \(\delta = 7.52\) (d, \(J = 15.8\) Hz, 1H), 6.98 (s, 2H), 6.14 (d, \(J = 15.8\) Hz, 1H), 4.22 (q, \(J = 7.1\) Hz, 2H), 3.21 (t, \(J = 5.6\) Hz, 4H), 2.73 (t, \(J = 6.3\) Hz, 4H), 1.98 – 1.92 (m, 4H), 1.31 (t, \(J = 7.1\) Hz, 3H).

A parallel reaction without ligand was also performed providing 3g in 11% \(^1\)H NMR yield.

**Ethyl (E)-3-(4-(dimethylamino)-2-methylphenyl)acrylate (3h)**

\[
\begin{align*}
\text{Me}_2\text{N} \quad \text{Me} \quad \text{Me} \quad \text{EtCO}_2 \quad \text{Me} \\
\end{align*}
\]

General procedure A was followed using \(N,N,3\)-trimethylaniline (1h) (33.8 mg, 0.25 mmol, 1 equiv) and ethyl acrylate (40 µL, 0.375 mmol, 1.5 equiv) in DCE (0.8 M) at 40 °C, providing the olefinated products in 70% \(^1\)H NMR yield (\(p:others = 10.7:1\)). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:9 v/v) as an eluent providing the titled compound as a yellow oil (35.7 mg, 61% yield). \(^1\)H NMR (400 MHz)
S,O-Ligand promoted C–H olefination of aniline derivatives

δ = 7.93 (d, J = 15.7 Hz, 1H), 7.51 (d, J = 8.8 Hz, 1H), 6.55 (d, J = 8.8 Hz, 1H), 6.48 (s, 1H), 6.20 (d, J = 15.7 Hz, 1H), 4.24 (q, J = 7.1 Hz, 2H), 3.00 (s, 6H), 2.42 (s, 3H), 1.33 (t, J = 7.1 Hz, 3H); 13C NMR (101 MHz) δ = 168.2, 151.7, 142.5, 139.6, 128.0, 121.3, 113.5, 113.4, 110.2, 60.2, 40.2, 20.6, 14.6; IR ν = 2977, 2901, 1697, 1587, 1146, 1096 cm\(^{-1}\); HRMS (FD) calcd for C\(_{14}\)H\(_{19}\)NO\(_2\) [M]+: 233.1416; found: 233.1427.

A parallel reaction without ligand was also performed providing the olefinated products in 11% \(^1\)H NMR yield (p:others = 2.7:1).

**Ethyl (E)-3-(4-(dimethylamino)-2-methoxyphenyl)acrylate (3i)**

General procedure A was followed using 3-methoxy-\(N,N\)-dimethylaniline (1i) (37.8 mg, 0.25 mmol, 1 equiv) and ethyl acrylate (40 µL, 0.375 mmol, 1.5 equiv) in DCE (0.8 M) at 40 °C, providing the olefinated products in 75% \(^1\)H NMR yield (p:o = 2.8:1). The crude residue was purified by column chromatography using Et\(_2\)O:petroleum ether (3:7 v/v) as an eluent providing the titled compound as a yellow oil (30.8 mg, 49% yield). \(^1\)H NMR (400 MHz) δ = 7.90 (d, J = 16.0 Hz, 1H), 7.37 (d, J = 8.7 Hz, 1H), 6.34 (d, J = 16.0 Hz, 1H), 6.29 (dd, J = 8.7, 2.4 Hz, 1H), 6.13 (d, J = 2.4 Hz, 1H), 4.23 (q, J = 7.2 Hz, 2H), 3.88 (s, 3H), 3.03 (s, 6H), 1.32 (t, J = 7.2 Hz, 3H); 13C NMR (101 MHz) δ = 168.6, 160.2, 153.3, 140.7, 130.6, 113.2, 112.1, 104.8, 94.7, 60.0, 55.3, 40.4, 14.6; IR ν = 2977, 2934, 1693, 1591, 1518, 1361, 1240, 1165, 1136, 1029, 980, 808, 790 cm\(^{-1}\); HRMS (ESI) calcd for C\(_{14}\)H\(_{20}\)NO\(_3\) [M+H]+: 250.1443; found: 250.1456.

A parallel reaction without ligand was also performed providing 3i in 11% \(^1\)H NMR yield.

**Ethyl (E)-3-(4-(dimethylamino)-2-phenoxyphenyl)acrylate (3j)**

General procedure A was followed using 3-phenoxy-\(N,N\)-dimethylaniline (1j) (53.3 mg, 0.25 mmol, 1 equiv) and ethyl acrylate (40 µL, 0.375 mmol, 1.5 equiv) in DCE (0.8 M) at 40 °C, providing 3j in 66% \(^1\)H NMR yield. The crude residue was purified by column chromatography using Et\(_2\)O:petroleum ether (1:4 v/v) as an eluent providing the titled compound as a yellow oil (51.7 mg, 66% yield). \(^1\)H NMR (400 MHz) δ = 7.90 (d, J = 16.0 Hz, 1H), 7.51 (d, J = 8.8 Hz, 1H), 7.32 (t, J = 7.9 Hz, 2H), 7.08 (t, J = 7.4 Hz, 1H), 7.00 (d, J = 8.0 Hz, 2H), 6.48 (dd, J = 8.8, 2.3 Hz, 1H), 6.33 (d, J = 16.0 Hz, 1H), 6.14 (d, J = 2.3 Hz, 1H), 4.20 (q, J = 7.1 Hz, 2H), 2.92 (s, 6H), 1.29 (t, J = 7.1 Hz, 3H); 13C NMR (101 MHz) δ = 168.1, 157.5, 157.3, 153.0, 139.6, 129.8, 123.2, 118.6, 114.4, 114.1, 108.1, 102.4, 100.1, 60.1, 40.2, 14.5; IR ν = 2977, 1698, 1596, 1219, 1147, 1093 cm\(^{-1}\); HRMS (FD) calcd for C\(_{19}\)H\(_{21}\)NO\(_3\) [M]+: 311.1521; found: 311.1525.

A parallel reaction without ligand was also performed providing 3j in 31% \(^1\)H NMR yield.
Ethyl (E)-3-(5-(dimethylamino)-[1,1'-biphenyl]-2-yl)acrylate (3k)

General procedure A was followed using 3-phenyl-\(N,N\)-dimethylaniline (1k) (49.3 mg, 0.25 mmol, 1 equiv) and ethyl acrylate (40 \(\mu\)L, 0.375 mmol, 1.5 equiv) in DCE (0.95 mL, 0.2 M) at 40 °C, providing the olefinated products in 36% \(^1\)H NMR yield (\(\rho:\) others = 4.1:1). Characteristic \(^1\)H NMR signal for 3k: 6.24 (d, \(J = 15.8\) Hz, 1H).

A parallel reaction without ligand was also performed. The reaction gave no product.

Ethyl (E)-3-(4-(dimethylamino)-2-fluorophenyl)acrylate (3l)

General procedure A was followed using 3-fluoro-\(N,N\)-dimethylaniline (1l) (34.8 mg, 0.25 mmol, 1 equiv) and ethyl acrylate (40 \(\mu\)L, 0.375 mmol, 1.5 equiv) in DCE (0.8 M) at 40 °C, providing 3l in 74% \(^1\)H NMR yield. The crude residue was purified by column chromatography using \(\text{Et}_2\text{O}:\text{petroleum ether}\) (1:4 v/v) as an eluent providing the titled compound as a pale yellow solid (38.3 mg, 65% yield). \(^1\)H NMR (400 MHz) \(\delta = 7.73\) (d, \(J = 16.0\) Hz, 1H), 7.36 (t, \(J = 8.7\) Hz, 1H), 6.63 (dd, \(J = 8.8, 2.5\) Hz, 1H), 6.32 (dd, \(J = 14.5, 1.8\) Hz, 1H), 6.30 (d, \(J = 16.0\) Hz, 1H), 4.23 (q, \(J = 7.1\) Hz, 2H), 2.99 (s, 6H), 1.32 (t, \(J = 7.1\) Hz, 3H); \(^{13}\)C NMR (101 MHz) \(\delta = 167.9, 163.1\) (d, \(J = 251.1\) Hz), 153.1 (d, \(J = 11.8\) Hz), 138.1 (d, \(J = 2.2\) Hz), 130.1 (d, \(J = 5.5\) Hz), 114.8 (d, \(J = 6.5\) Hz), 110.1 (d, \(J = 12.5\) Hz), 108.0 (d, \(J = 1.8\) Hz), 98.6 (d, \(J = 26.7\) Hz), 60.3, 40.2, 14.5; \(^{19}\)F NMR (282 MHz) \(\delta = -113.08\) (dd, \(J = 14.5, 8.4\) Hz); IR \(\nu = 2978, 1696, 1608, 1524\), 1169, 1152, 813, 811 cm\(^{-1}\); HRMS (ESI) calcd for \(\text{C}_{13}\text{H}_{17}\text{FNO}_2\) [M+H]\(^+\): 238.1243; found: 238.1254; mp 38 – 42 °C.

A parallel reaction without ligand was also performed providing 3l in 24% \(^1\)H NMR yield.

Ethyl (E)-3-(2-chloro-4-(dimethylamino)phenyl)acrylate (3m)

General procedure A was followed using 3-chloro-\(N,N\)-dimethylaniline (1m) (38.9 mg, 0.25 mmol, 1 equiv) and ethyl acrylate (40 \(\mu\)L, 0.375 mmol, 1.5 equiv) in DCE (0.8 M) at 40 °C, providing 3m in 54% \(^1\)H NMR yield. The crude residue was purified by column chromatography using \(\text{Et}_2\text{O}:\text{petroleum ether}\) (1:4 v/v) as an eluent providing the titled compound as a yellow oil (34.3 mg, 54% yield). \(^1\)H NMR (400 MHz) \(\delta = 8.04\) (d, \(J = 15.9\) Hz, 1H), 7.51 (d, \(J = 8.9\) Hz, 1H), 6.65 (d, \(J = 2.6\) Hz, 1H), 6.56 (dd, \(J = 8.9, 2.6\) Hz, 1H), 6.24 (d, \(J = 15.9\) Hz, 1H), 4.25 (q, \(J = 7.1\) Hz, 2H), 3.00 (s, 6H), 1.33 (t, \(J = 7.1\) Hz, 3H); \(^{13}\)C NMR (101 MHz) \(\delta = 167.6, 152.1, 140.8, 136.8, 128.4, 119.7, 115.0, 112.2, 110.9, 60.4, 40.2, 14.5\); IR \(\nu = 2979, 2902, 1700, 1510, 1500, 1162, 1150, 1034, 800, 801\) cm\(^{-1}\); HRMS (ESI) calcd for \(\text{C}_{13}\text{H}_{17}\text{ClNO}_2\) [M+H]\(^+\): 254.0948; found: 254.0939.

A parallel reaction without ligand was also performed providing 3m in 9% \(^1\)H NMR yield.
S,O-Ligand promoted C–H olefination of aniline derivatives

**Ethyl (E)-3-(2-bromo-4-(dimethylamino)phenyl)acrylate (3n)**

General procedure A was followed using 3-bromo-N,N-dimethylaniline (1n) (50.0 mg, 0.25 mmol, 1 equiv) and ethyl acrylate (40 µL, 0.375 mmol, 1.5 equiv) in DCE (0.8 M) at 40 °C, providing 3n in 8% $^1$H NMR yield. Characteristic $^1$H NMR signal for 3n: 6.21 (d, $J = 15.8$ Hz, 1H).

A parallel reaction without ligand was also performed providing 3n in 9% $^1$H NMR yield.

**Ethyl (E)-3-(4-(dimethylamino)-2,6-difluorophenyl)acrylate (3o)**

General procedure A was followed using 3,5-difluoro-N,N-dimethylaniline (1o) (39.3 mg, 0.25 mmol, 1 equiv) and ethyl acrylate (40 µL, 0.375 mmol, 1.5 equiv) in DCE (0.8 M) at 40 °C, providing 3o in 52% $^1$H NMR yield. The crude residue was purified by column chromatography using Et$_2$O:petroleum ether (1:4 v/v) as an eluent providing the titled compound as a pale yellow solid (26.9 mg, 42% yield). $^1$H NMR (300 MHz) δ = 7.71 (d, $J = 16.3$ Hz, 1H), 6.48 (d, $J = 16.3$ Hz, 1H), 6.20 – 6.11 (m, 2H), 4.24 (q, $J = 7.1$ Hz, 2H), 2.98 (s, 6H), 1.32 (t, $J = 7.1$ Hz, 3H); $^{13}$C NMR (75 MHz) δ = 168.1, 163.3 (dd, $J = 250.8$, 11.1 Hz), 152.2 (dd, $J = 14.6$, 14.6 Hz), 132.0 (dd, $J = 2.0$, 2.0 Hz), 118.1 (dd, $J = 8.3$, 8.3 Hz), 100.4 (dd, $J = 16.0$, 16.0 Hz), 95.0 (d, $J = 29.2$ Hz), 60.3, 40.1, 14.5; $^{19}$F NMR (282 MHz) δ = -110.10 (d, $J = 12.7$ Hz); IR ν = 2919, 1697, 1637, 1609, 1525, 1303, 1205, 1160, 982, 810 cm$^{-1}$; HRMS (ESI) calcd for C$_{13}$H$_{16}$F$_2$NO$_2$ [M+H]$^+$: 256.1149; found: 256.1150; mp 63 – 65 °C.

A parallel reaction without ligand was also performed providing 3o in 13% $^1$H NMR yield.

**Ethyl (E)-3-(2-chloro-4-(dimethylamino)-6-fluorophenyl)acrylate (3p)**

General procedure A was followed using 3-chloro-5-fluoro-N,N-dimethylaniline (1p) (43.4 mg, 0.25 mmol, 1 equiv) and ethyl acrylate (40 µL, 0.375 mmol, 1.5 equiv) in DCE (0.8 M) at 40 °C, providing 3p in 33% $^1$H NMR yield. Characteristic $^1$H NMR signal for 3p: 6.55 (d, $J = 16.2$ Hz, 1H).

A parallel reaction without ligand was also performed providing 3p in 5% $^1$H NMR yield.

**Methyl (E)-5-(dimethylamino)-2-[2-(ethoxycarbonyl)vinyl]benzoate (3q)**

General procedure A was followed using 3-methoxycarbonyl-N,N-dimethylaniline (1q) (44.8 mg, 0.375 mmol, 1.5 equiv) and ethyl acrylate (27 µL, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 60 °C, providing the olefinated products in 61% $^1$H NMR yield (p:others = 11.2:1). The crude residue was purified by column chromatography using Et$_2$O:petroleum ether (2:3 v/v) as an eluent providing the titled compound as a yellow oil (35.4 mg, 51% yield). $^1$H NMR (300 MHz) δ = 8.31 (d, $J = 15.8$ Hz, 1H), 7.56 (d, $J = 8.9$ Hz, 1H), 7.13 (d, $J = 2.8$ Hz, 1H), 6.79 (dd, $J = 8.9$, 2.8 Hz, 1H), 6.21 (d, $J = 15.8$ Hz, 1H), 4.24 (q, $J = 7.1$ Hz, 2H), 2.98 (s, 6H), 1.32 (t, $J = 7.1$ Hz, 3H); $^{13}$C NMR (75 MHz) δ = 168.1, 163.3 (dd, $J = 250.8$, 11.1 Hz), 152.2 (dd, $J = 14.6$, 14.6 Hz), 132.0 (dd, $J = 2.0$, 2.0 Hz), 118.1 (dd, $J = 8.3$, 8.3 Hz), 100.4 (dd, $J = 16.0$, 16.0 Hz), 95.0 (d, $J = 29.2$ Hz), 60.3, 40.1, 14.5; $^{19}$F NMR (282 MHz) δ = -110.10 (d, $J = 12.7$ Hz); IR ν = 2919, 1697, 1637, 1609, 1525, 1303, 1205, 1160, 982, 810 cm$^{-1}$; HRMS (ESI) calcd for C$_{13}$H$_{16}$F$_2$NO$_2$ [M+H]$^+$: 256.1149; found: 256.1150; mp 63 – 65 °C.
A parallel reaction without ligand was also performed providing the olefinated products in 17% \(^1\)H NMR yield (\(\rho:others = 1.8:1\)).

**Ethyl (E)-3-(4-(dimethylamino)-2-(trifluoromethyl)phenyl)acrylate (3r)**

General procedure A was followed using 3-(trifluoromethyl)-\(N,N\)-dimethylaniline (\(1r\)) (47.3 mg, 0.25 mmol, 1 equiv) and ethyl acrylate (40 \(\mu\)L, 0.375 mmol, 1.5 equiv) in DCE (0.8 M) at 40 °C, providing 3r in traces amount. Characteristic \(^1\)H NMR signal for 3r: 6.30 (d, \(J = 15.7\) Hz, 1H).

A parallel reaction without ligand was also performed providing 3r in traces amount.

**Ethyl (E)-3-(4-(dimethylamino)-2-nitrophenyl)acrylate (3s)**

General procedure A was followed using 3-nitro-\(N,N\)-dimethylaniline (\(1s\)) (41.5 mg, 0.25 mmol, 1 equiv) and ethyl acrylate (40 \(\mu\)L, 0.375 mmol, 1.5 equiv) in DCE (0.8 M) at 40 °C, providing 3s in 16% \(^1\)H NMR yield. Characteristic \(^1\)H NMR signal for 3s: 6.27 (d, \(J = 15.7\) Hz, 1H).

A parallel reaction without ligand was also performed providing 3s in traces amount.

**Ethyl (E)-3-(2-cyano-4-(dimethylamino)phenyl)acrylate (3t)**

General procedure A was followed using 3-cyano-\(N,N\)-dimethylaniline (\(1t\)) (36.5 mg, 0.25 mmol, 1 equiv) and ethyl acrylate (40 \(\mu\)L, 0.375 mmol, 1.5 equiv) in DCE (0.8 M) at 40 °C, providing 3t in 25% \(^1\)H NMR yield. Characteristic \(^1\)H NMR signal for 3t: 6.27 (d, \(J = 15.8\) Hz, 1H).

A parallel reaction without ligand was also performed providing 3t in 26% \(^1\)H NMR yield.

**Ethyl (E)-3-(2-(dimethylamino)-5-methylphenyl)acrylate (3u)**

General procedure A was followed using \(N,N,4\)-trimethylaniline (\(1u\)) (33.8 mg, 0.25 mmol, 1 equiv) and ethyl acrylate (40 \(\mu\)L, 0.375 mmol, 1.5 equiv) in DCE (0.95 mL, 0.2 M) at 40 °C, providing 3u in 3% \(^1\)H NMR yield. \(^1\)H NMR spectra data of the crude mixture matched with the spectra data reported in the literature for this compound. \(^5\) Characteristic \(^1\)H NMR signal for 3u: 6.42 (d, \(J = 16.0\) Hz, 1H).

A parallel reaction without ligand was also performed. The reaction gave no product.
Ethyl (E)-3-((dimethylamino) methylphenyl)acrylate (3v)

General procedure A was followed using N,N,2-trimethylaniline (1v) (33.8 mg, 0.25 mmol, 1 equiv) and ethyl acrylate (40 µL, 0.375 mmol, 1.5 equiv) in DCE (0.95 mL, 0.2 M) at 40 °C, providing the compound in 4% ¹H NMR yield (1 isomer). Characteristic ¹H NMR signal for 3v: 6.34 (d, J = 16.1 Hz, 1H).

A parallel reaction without ligand was also performed. The reaction gave no product.

Ethyl (E)-3-(4-(benzylamino)-3-methoxyphenyl)acrylate (3w)

General procedure A was followed using N-benzyl-2-methylaniline (1w) (98.6 mg, 0.50 mmol, 2 equiv) and ethyl acrylate (27 µL, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing 3w in 51% ¹H NMR yield (5% ¹H NMR yield of byproduct 3w'). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:4 v/v) as an eluent providing the titled compound as a yellow oil (33.0 mg, 45% yield).

1H NMR (300 MHz) δ = 7.60 (d, J = 15.9 Hz, 1H), 7.38 – 7.26 (m, 8H), 6.57 (d, J = 8.9 Hz, 1H), 6.23 (d, J = 15.9 Hz, 1H), 4.43 (s, 2H), 4.24 (q, J = 7.1 Hz, 2H), 2.18 (s, 3H); ¹³C NMR (75 MHz) δ = 168.0, 148.2, 145.4, 138.8, 130.1, 128.9, 128.5, 127.6, 127.5, 123.5, 122.0, 113.1, 109.8, 60.2, 48.1, 17.6, 14.5; IR ν = 3413, 2977, 1692, 1597, 1516, 1256, 1154, 1132, 1029, 869 cm⁻¹; HRMS (FD) calcd for C_{19}H_{21}NO_2 [M]⁺: 295.1572; found: 295.1570.

A parallel reaction without ligand was also performed. The reaction gave no product (11% ¹H NMR yield of byproduct 3w').

Ethyl (E)-3-(4-(benzylamino)-3-methoxyphenyl)acrylate (3x)

General procedure A was followed using N-benzyl-2-methoxyaniline (1x) (106.6 mg, 0.50 mmol, 2 equiv) and ethyl acrylate (27 µL, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing 3x in 53% ¹H NMR yield (3% ¹H NMR yield of byproduct 3x'). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:4 v/v) as an eluent providing the titled compound as a yellow oil (32.8 mg, 42% yield).

1H NMR (300 MHz) δ = 7.62 (d, J = 15.9 Hz, 1H), 7.37 – 7.29 (m, 5H), 7.02 (dd, J = 8.1, 1.5 Hz, 1H), 6.97 (d, J = 1.5 Hz, 1H), 6.52 (d, J = 1.5 Hz, 1H), 6.22 (d, J = 15.8 Hz, 1H), 5.00 (bs, 1H); 4.40 (s, 2H), 4.25 (q, J = 7.1 Hz, 2H), 3.88 (s, 3H), 1.34 (t, J = 7.1 Hz, 3H); ¹³C NMR (101 MHz) δ = 167.9, 146.7, 145.6, 140.6, 138.9, 128.8, 127.5, 127.5, 124.2, 123.1, 112.9, 109.2, 107.6, 60.2, 55.6, 47.6, 14.6; IR ν = 3423, 2977, 2936, 1694, 1593, 1521, 1220, 1155, 1135, 1029, 843, 803, 730, 696 cm⁻¹; HRMS (FD) calcd for C_{19}H_{21}NO_3 [M]⁺: 311.1521; found: 311.1520.

A parallel reaction without ligand was also performed. The reaction gave no product (7% ¹H NMR yield of byproduct 3x').
Ethyl (E)-3-(4-(benzylamino)-3-fluorophenyl)acrylate (3y)

General procedure A was followed using N-benzyl-2-fluoroaniline (1y) (75.5 mg, 0.375 mmol, 1.5 equiv) and ethyl acrylate (27 µL, 0.25 mmol, 1 equiv) in DCE (2.20 mL, 0.1 M) at 80 °C, providing 3y in 32% 1H NMR yield (4% 1H NMR yield of byproduct 3y'). Characteristic 1H NMR signal for 3y: 6.26 (d, J = 15.8 Hz, 1H).

A parallel reaction without ligand was also performed. The reaction gave no product (12% 1H NMR yield of byproduct 3y').

Ethyl (E)-3-(4-(benzylamino)-3-chlorophenyl)acrylate (3z)

General procedure A was followed using N-benzyl-2-chloroaniline (1z) (81.6 mg, 0.375 mmol, 1.5 equiv) and ethyl acrylate (27 µL, 0.25 mmol, 1 equiv) in DCE (2.20 mL, 0.1 M) at 80 °C, providing 3z in 55% 1H NMR yield (7% 1H NMR yield of byproduct 3z'). The crude residue was purified by column chromatography using Et2O:petroleum ether (1:4 v/v) as an eluent providing the titled compound as a yellow oil (36.7 mg, 46% yield). 1H NMR (300 MHz) δ = 7.53 (d, J = 15.9 Hz, 1H), 7.48 (d, J = 1.9 Hz, 1H), 7.40 – 7.24 (m, 6H), 6.60 (d, J = 8.5 Hz, 1H), 6.21 (d, J = 15.9 Hz, 1H), 5.07 (t, J = 5.3 Hz, 1H), 4.44 (d, J = 5.6 Hz, 2H), 4.24 (q, J = 7.1 Hz, 2H), 1.32 (t, J = 7.1 Hz, 3H); 13C NMR (75 MHz) δ = 167.5, 145.4, 143.8, 138.1, 129.0, 128.9, 128.6, 127.7, 127.3, 124.2, 119.4, 114.5, 111.2, 60.4, 47.7, 14.5; IR ν = 3413, 2979, 2928, 1698, 1698, 1594, 1521, 1150, 1037, 806, 732, 695 cm⁻¹; HRMS (FD) calcd for C18H18ClNO2 [M]+: 315.1026; found: 315.1022.

A parallel reaction without ligand was also performed providing 3z in 6% 1H NMR yield (24% 1H NMR yield of byproduct 3z').

Ethyl (E)-3-(2-[[2-chlorophenyl]amino)methyl]phenyl)acrylate (3z')

The titled compound was obtained as a yellow oil. 1H NMR (400 MHz) δ = 8.01 (d, J = 15.8 Hz, 1H), 7.62 (dd, J = 7.4, 1.5 Hz, 1H), 7.42 – 7.26 (m, 4H), 7.11 (td, J = 7.7, 1.4 Hz, 1H), 6.66 (td, J = 7.7, 1.4 Hz, 1H), 6.61 (dd, J = 8.2, 1.2 Hz, 1H), 6.40 (d, J = 15.8 Hz, 1H), 4.63 (d, J = 5.0 Hz, 1H), 4.51 (d, J = 5.4 Hz, 2H), 4.26 (q, J = 7.1 Hz, 2H), 1.31 (t, J = 7.1 Hz, 3H); 13C NMR (101 MHz) δ = 166.8, 143.7, 141.1, 137.5, 133.5, 130.4, 129.3, 128.7, 128.1, 128.0, 127.2, 120.9, 119.4, 111.7, 111.7, 60.8, 45.8, 14.4; IR ν = 3412, 2979, 1707, 1596, 1504, 1311, 1173, 1032, 739 cm⁻¹; HRMS (FD) calcd for C18H18ClNO2 [M]+: 315.1026; found: 315.1044.

Ethyl (E)-3-(4-(benzylamino)-3-bromophenyl)acrylate (3aa)

General procedure A was followed using N-benzyl-2-bromoaniline (1aa) (98.3 mg, 0.375 mmol, 1.5 equiv) and ethyl acrylate (27 µL, 0.25 mmol, 1 equiv) in DCE (2.20 mL, 0.1 M) at 80 °C, providing 3aa in 31% 1H NMR yield (5% 1H NMR yield of byproduct 3aa'). Characteristic 1H NMR signal for 3aa: 6.24 (d, J = 15.9 Hz, 1H).
A parallel reaction without ligand was also performed providing 3aa in 4% $^1$H NMR yield (9% $^1$H NMR yield of byproduct 3aa').

**Ethyl (E)-3-(4-(benzylamino)-3-(trifluoromethyl)phenyl)acrylate (3ab)**

General procedure A was followed using N-benzyl-2-(trifluoromethyl)aniline (1ab) (94.2 mg, 0.375 mmol, 1.5 equiv) and ethyl acrylate (27 µL, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing 3ab in 62% $^1$H NMR yield (12% $^1$H NMR yield of byproduct 3ab'). The crude residue was purified by column chromatography using Et$_2$O:petroleum ether (1:4 v/v) as an eluent providing the titled compound as a pale yellow solid (46.4 mg, 53% yield).

$^1$H NMR (400 MHz) δ = 7.63 (s, 1H), 7.58 (d, $^J = 15.9$ Hz, 1H), 7.48 (d, $^J = 8.7$ Hz, 1H), 7.39 – 7.29 (m, 5H), 6.68 (d, $^J = 8.7$ Hz, 1H), 6.25 (d, $^J = 15.9$ Hz, 1H), 5.09 (bs, 1H), 4.47 (d, $^J = 5.4$ Hz, 2H), 4.24 (q, $^J = 7.1$ Hz, 2H), 1.32 (t, $^J = 7.1$ Hz, 3H); $^{13}$C NMR (101 MHz) δ = 167.4, 146.7, 143.6, 137.7, 132.9, 129.1, 127.8, 127.2 (q, $^J = 5.5$ Hz), 127.1, 124.8 (q, J = 272.4 Hz), 122.8, 115.0, 113.8 (q, J = 29.3 Hz), 112.5, 60.5, 47.7, 14.5; $^{19}$F NMR (282 MHz) δ = -59.12; IR ν = 3421, 1693, 1615, 1571, 1530, 1172, 1103 cm$^{-1}$; HRMS (FD) calcd for C$_{19}$H$_{18}$F$_3$NO$_2$ [M]$^+$: 349.1290; found: 349.1288; mp 96 – 98 °C.

A parallel reaction without ligand was also performed providing 3ab in 18% $^1$H NMR yield (39% $^1$H NMR yield of byproduct 3ab').

**Ethyl (E)-3-[2-[[2-(trifluoromethyl)phenylamino]methyl]phenyl]acrylate (3ab')**

The titled compound was obtained as a pale yellow solid. $^1$H NMR (400 MHz) δ = 7.99 (d, J = 15.8 Hz, 1H), 7.62 – 7.0 (m, 1H), 7.46 (d, J = 7.5 Hz, 1H), 7.41 – 7.31 (m, 4H), 6.75 (t, J = 7.6 Hz, 1H), 6.67 (d, J = 8.3 Hz, 1H), 6.40 (d, J = 15.8 Hz, 1H), 4.66 (bs, 1H), 4.53 (s, 2H), 4.25 (q, J = 7.1 Hz, 2H), 1.30 (t, J = 7.1 Hz, 3H); $^{13}$C NMR (101 MHz) δ = 167.4, 146.7, 143.6, 137.7, 132.9, 129.1, 127.8, 127.2 (q, J = 5.5 Hz), 127.1, 124.8 (q, J = 272.4 Hz), 122.8, 115.0, 113.8 (q, J = 29.3 Hz), 112.5, 60.5, 47.7, 14.5; $^{19}$F NMR (282 MHz) δ = -62.38; IR ν = 3473, 2925, 1707, 1470, 1314, 1164, 1092, 1031, 741 cm$^{-1}$; HRMS (FD) calcd for C$_{19}$H$_{18}$F$_3$NO$_2$ [M]$^+$: 349.1290; found: 349.1314; mp 53 – 56 °C.

**Methyl (E)-2-(benzylamino)-5-[2-(ethoxycarbonyl)vinyl]benzoate (3ac)**

General procedure A was followed using N-benzyl-2-(methoxycarbonyl)aniline (1ac) (90.5 mg, 0.375 mmol, 1.5 equiv) and ethyl acrylate (27 µL, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing 3ac in 70% $^1$H NMR yield (3% $^1$H NMR yield of byproduct 3ac'). The crude residue was purified by column chromatography using Et$_2$O:petroleum ether (3:7 v/v) as an eluent providing the titled compound as a yellow oil (52.8 mg, 62% yield). $^1$H NMR (300 MHz) δ = 8.51 (t, J = 5.4 Hz, 1H), 8.12 (d, J = 2.1 Hz, 1H), 7.58 (d, J = 15.9 Hz, 1H), 7.48 (dd, J = 8.9, 2.1 Hz, 1H), 7.35 – 7.27 (m, 5H), 6.64 (d, J = 8.9 Hz, 1H), 6.23 (d, J = 15.9 Hz, 1H), 4.48 (d, J = 5.7 Hz, 2H), 4.24 (q, J = 7.1 Hz, 2H), 3.88 (s, 3H), 1.32 (t, J = 7.1 Hz, 3H); $^{13}$C NMR (101 MHz) δ = 168.7, 167.6, 152.2, 144.3, 138.2, 133.8.
A parallel reaction without ligand was also performed providing 3ac in 27% \(^1\)H NMR yield (24% \(^1\)H NMR yield of byproduct 3ac').

Ethyl (E)-3-[3-acetyl-4-(benzylamino)phenyl]acrylate (3ad)

General procedure A was followed using \(N\)-benzyl-2-acetylaniline (1ad) (84.5 mg, 0.375 mmol, 1.5 equiv) and ethyl acrylate (27 µL, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing 3ad in 47% \(^1\)H NMR yield (12% \(^1\)H NMR yield of byproduct 3ad').

A parallel reaction without ligand was also performed providing 3ad in traces amount (24% \(^1\)H NMR yield of byproduct 3ad').

Ethyl (E)-3-(4-(benzylamino)-3-nitrophenyl)acrylate (3ae)

General procedure A was followed using \(N\)-benzyl-2-nitroaniline (1ae) (57.1 mg, 0.25 mmol, 1 equiv) and ethyl acrylate (40 µL, 0.375 mmol, 1.5 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing 3ae in 46% \(^1\)H NMR yield (12% \(^1\)H NMR yield of byproduct 3ae').

A parallel reaction without ligand was also performed providing 3ae in 37% \(^1\)H NMR yield (14% \(^1\)H NMR yield of byproduct 3ae').

Ethyl (E)-3-(4-(benzylamino)-3-cyanophenyl)acrylate (3af)

General procedure A was followed using \(N\)-benzyl-2-cyanoaniline (1af) (52.1 mg, 0.25 mmol, 1 equiv) and ethyl acrylate (40 µL, 0.375 mmol, 1.5 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing 3af in 29% \(^1\)H NMR yield. Characteristic \(^1\)H NMR signal for 3af: 6.22 (d, \(J = 15.9\) Hz, 1H).

A parallel reaction without ligand was also performed providing 3af in 25% \(^1\)H NMR yield (10% \(^1\)H NMR yield of byproduct 3af').
Methyl (E)-2-(benzlamino)-5-[2-(ethoxycarbonyl)vinyl]-4-fluorobenzoate (3ag)

General procedure A was followed using N-benzyl-5-fluoro-2-(methoxycarbonyl)aniline (1ag) (97.2 mg, 0.375 mmol, 1.5 equiv) and ethyl acrylate (27 µL, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing 3ag in 75% ¹H NMR yield [hexafluorobenzene (29 µL, 0.25 mmol, 1 equiv) was added as an internal standard]. The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:4 v/v) as an eluent providing the titled compound as a yellow oil (65.3 mg, 73% yield). ¹H NMR (300 MHz) δ = 8.58 (bs, 1H), 8.17 (d, J = 8.5 Hz, 1H), 7.65 (d, J = 16.0 Hz, 1H), 7.37 – 7.26 (m, 5H), 6.36 (d, J = 16.0 Hz, 1H), 6.31 (d, J = 13.5 Hz, 1H), 4.42 (d, J = 5.6 Hz, 2H), 4.24 (q, J = 7.1 Hz, 2H), 3.87 (s, 3H), 1.32 (t, J = 7.1 Hz, 3H); ¹³C NMR (75 MHz) δ = 168.1, 167.5, 165.7 (d, J = 259.2 Hz), 153.7 (d, J = 13.4 Hz), 137.5, 137.4 (d, J = 1.5 Hz), 134.4 (d, J = 6.8 Hz), 129.0, 127.7, 127.1, 116.5 (d, J = 6.6 Hz), 110.5 (d, J = 13.6 Hz), 107.5 (d, J = 1.5 Hz), 98.4 (d, J = 26.6 Hz), 60.4, 52.0, 47.2, 14.5; ¹⁹F NMR (282 MHz) δ = -104.84 – -104.92 (m); IR ν = 3338, 1683, 1619, 1529, 1219, 1169, 721 cm⁻¹; HRMS (FD) calcd for C₂₀H₂₀FNO₄ [M⁺]: 357.1376; found: 357.1382.

A parallel reaction without ligand was also performed providing 3ag in 13% ¹H NMR yield.

Note: By ¹H NMR analysis of crude mixture we could not determine whether or not byproduct 3ag’ is formed.

Methyl (E)-2-(benzlamino)-5-[2-(ethoxycarbonyl)vinyl]-4-methoxybenzoate (3ah)

General procedure A was followed using N-benzyl-5-methoxy-2-(methoxycarbonyl)aniline (1ah) (101.7 mg, 0.375 mmol, 1.5 equiv) and ethyl acrylate (27 µL, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing 3ah in 59% ¹H NMR yield. The crude residue was purified by column chromatography using Et₂O:petroleum ether (2:3 v/v) as an eluent providing the titled compound as a pale yellow solid (53.3 mg, 58% yield). ¹H NMR (300 MHz) δ = 8.63 (t, J = 5.0 Hz, 1H), 8.15 (s, 1H), 7.82 (d, J = 16.0 Hz, 1H), 7.37 – 7.28 (m, 5H), 6.40 (d, J = 16.0 Hz, 1H), 6.01 (s, 1H), 4.49 (d, J = 5.4 Hz, 2H), 4.25 (q, J = 7.1 Hz, 2H), 3.86 (s, 3H), 3.75 (s, 3H), 1.33 (t, J = 7.1 Hz, 3H); ¹³C NMR (75 MHz) δ = 168.5, 168.2, 163.4, 153.8, 140.0, 138.1, 134.2, 128.9, 127.6, 127.2, 114.6, 112.0, 103.8, 93.2, 60.1, 55.4, 51.6, 47.3, 14.5; IR ν = 3357, 2981, 1709, 1671, 1601, 1291, 1219, 1169, 721 cm⁻¹; HRMS (FD) calcd for C₂₁H₂₂NO₅ [M⁺]: 369.1576; found: 369.1596; mp 103 – 105 °C.

A parallel reaction without ligand was also performed providing 3ah in 9% ¹H NMR yield.

Note: By ¹H NMR analysis of crude mixture we could not determine whether or not byproduct 3ah’ is formed.
Methyl (E)-2-(benzylamino)-5-[2-(ethoxycarbonyl)vinyl]-4-methylbenzoate (3ai)

General procedure A was followed using N-benzyl-5-methyl-2-(methoxycarbonyl)aniline (1ai) (95.7 mg, 0.375 mmol, 1.5 equiv) and ethyl acrylate (27 µL, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing 3ai in 57% 1H NMR yield (traces amount of byproduct 3ai'). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:4 v/v) as an eluent providing the titled compound as a pale yellow solid (46.2 mg, 52% yield). 1H NMR (300 MHz) δ = 8.36 (t, J = 5.3 Hz, 1H), 8.25 (s, 1H), 7.83 (d, J = 15.8 Hz, 1H), 7.38 – 7.27 (m, 5H), 6.47 (s, 1H), 6.27 (d, J = 15.8 Hz, 1H), 4.47 (d, J = 5.5 Hz, 2H), 4.25 (q, J = 7.1 Hz, 2H), 3.87 (s, 3H), 2.36 (s, 3H), 1.33 (t, J = 7.1 Hz, 3H); 13C NMR (75 MHz) δ = 168.7, 167.8, 151.7, 145.1, 141.7, 138.3, 130.7, 128.9, 127.5, 120.8, 114.8, 113.0, 108.9, 60.3, 51.7, 47.0, 20.8, 14.5; IR ν = 3335, 2952, 1679, 1598, 1564, 1438, 1228, 1164, 978, 699 cm⁻¹; HRMS (FD) calcd for C₂₁H₂₃NO₄ [M]+: 353.1627; found: 353.1610; mp 87 – 89 °C.

A parallel reaction without ligand was also performed providing 3ai in traces amount (28% 1H NMR yield of byproduct 3ai').

Ethyl (E)-3-(4-benzylamino)-2-methyl-5-(trifluoromethyl)phenyl)acrylate (3aj)

General procedure A was followed using N-benzyl-5-methyl-2-(trifluoromethyl)aniline (1aj) (99.5 mg, 0.375 mmol, 1.5 equiv) and ethyl acrylate (27 µL, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing 3aj in 64% 1H NMR yield (7% 1H NMR yield of byproduct 3aj'). The crude residue was purified by column chromatography using Et₂O:petroleum ether (1:4 v/v) as an eluent providing the titled compound as a white solid (48.3 mg, 53% yield). 1H NMR (300 MHz) δ = 7.85 (d, J = 15.8 Hz, 1H), 7.72 (s, 1H), 7.40 – 7.28 (m, 5H), 6.52 (s, 1H), 6.25 (d, J = 15.8 Hz, 1H), 4.97 (bs, 1H), 4.44 (d, J = 5.2 Hz, 2H), 4.26 (q, J = 7.1 Hz, 2H), 2.37 (s, 3H), 1.33 (t, J = 7.1 Hz, 3H); 13C NMR (75 MHz) δ = 167.5, 146.2 (q, J = 1.5 Hz), 146.3 (q, J = 0.8 Hz), 141.2, 137.9, 129.0, 127.8, 127.2, 125.5 (q, J = 5.5 Hz), 125.0 (q, J = 272.2 Hz), 121.8, 115.9, 113.8, 112.1 (q, J = 29.9 Hz), 60.5, 47.7, 20.4, 14.5; 19F NMR (282 MHz) δ = -62.06; IR ν = 3442, 2976, 1697, 1603, 1565, 1517, 1438, 1228, 1164, 978, 699 cm⁻¹; HRMS (FD) calcd for C₂₀H₂₀F₃NO₂ [M]+: 363.1446; found: 363.1435; mp 95 – 97 °C.

A parallel reaction without ligand was also performed. The reaction gave no product (38% 1H NMR yield of byproduct 3aj').

Ethyl (E)-3-(4-benzylamino)-5-chloro-2-methoxyphenyl)acrylate (3ak)

General procedure A was followed using N-benzyl-2-chloro-5-methoxyaniline (1ak) (92.9 mg, 0.375 mmol, 1.5 equiv) and ethyl acrylate (27 µL, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing 3ak in 52% 1H NMR yield (traces amount of byproduct 3ak'). The crude residue was purified by column chromatography using Et₂O:petroleum ether (3:7 v/v) as an eluent providing the titled compound as a yellow solid (45.1 mg, 52% yield). 1H
NMR (300 MHz) \( \delta = 7.82 \ (d, J = 16.0 \text{ Hz}, 1H), 7.41 - 7.26 \ (m, 6H), 6.30 \ (d, J = 16.0 \text{ Hz}, 1H), 6.10 \ (s, 1H), 5.07 \ (t, J = 5.0 \text{ Hz}, 1H), 4.44 \ (d, J = 5.5 \text{ Hz}, 2H), 4.23 \ (q, J = 7.1 \text{ Hz}, 2H), 3.72 \ (s, 3H); 13C NMR (75 MHz) \delta = 168.1, 158.9, 146.3, 139.3, 138.0, 129.2, 129.0, 127.8, 127.4, 114.6, 113.2, 111.1, 94.7, 60.2, 55.6, 47.9, 14.5; IR \nu = 3390, 2900, 1700, 1591, 1522, 1301, 1163, 804, 697 \text{ cm}^{-1}; \text{HRMS (FD) calcd for } C_{19}H_{20}ClNO_3 [M]^+ : 345.1132; \text{found: } 345.1125; \text{mp } 117 - 119 ^\circ \text{C.}

A parallel reaction without ligand was also performed providing the compound in traces amount (14% \(^1H\) NMR yield of byproduct 3ak').

**Ethyl (E)-3-(4-(benzylamino)-2-methoxy-5-methylphenyl)acrylate (3a)**

General procedure A was followed using N-benzyl-5-methoxy-2-methylaniline (1al) (85.2 mg, 0.375 mmol, 1.5 equiv) and ethyl acrylate (27 \( \mu \)L, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 \( ^\circ \text{C} \), providing 3al in 32% \(^1H\) NMR yield. Characteristic \(^1H\) NMR signal for 3al: 6.39 (d, \( J = 16.0 \text{ Hz}, 1H \)).

A parallel reaction without ligand was also performed. The reaction gave no product (9% \(^1H\) NMR yield of byproduct 3al').

**Ethyl (E)-3-(4-(benzylamino)-5,6,7,8-tetrahydronaphthalen-1-yl)acrylate (3am)**

General procedure A was followed using N-benzyl-5,6,7,8-tetrahydronaphthalen-1-amine (1am) (59.3 mg, 0.25 mmol, 1 equiv) and ethyl acrylate (40 \( \mu \)L, 0.375 mmol, 1.5 equiv) in DCE (0.95 mL, 0.2 M) at 80 \( ^\circ \text{C} \), providing 3am in 18% \(^1H\) NMR yield (4% \(^1H\) NMR yield of byproduct 3am'). Characteristic \(^1H\) NMR signal for 3am: 6.23 (d, \( J = 15.6 \text{ Hz}, 1H \)).

A parallel reaction without ligand was also performed. The reaction gave no product (8% \(^1H\) NMR yield of byproduct 3am').

**Ethyl (E)-3-(4-(benzylamino)-2,5-dichlorophenyl)acrylate (3an)**

General procedure A was followed using N-benzyl 2,5-dichloroaniline (1an) (94.6 mg, 0.375 mmol, 1.5 equiv) and ethyl acrylate (27 \( \mu \)L, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 \( ^\circ \text{C} \), providing 3an in 66% \(^1H\) NMR yield (5% \(^1H\) NMR yield of byproduct 3an'). The crude residue was purified by column chromatography using Et\(_2\)O:petroleum ether (1:4 v/v) as an eluent providing the titled compound as a pale yellow solid (57.6 mg, 66% yield). \(^1H\) NMR (300 MHz) \( \delta = 7.94 \ (d, J = 15.9 \text{ Hz}, 1H), 7.57 \ (s, 1H), 7.41 - 7.30 \ (m, 5H), 6.64 \ (s, 1H), 6.24 \ (d, J = 15.9 \text{ Hz}, 1H), 5.03 \ (t, J = 5.5 \text{ Hz}, 1H), 4.40 \ (d, J = 5.5 \text{ Hz}, 2H), 4.25 \ (q, J = 7.1 \text{ Hz}, 2H), 1.33 \ (t, J = 7.1 \text{ Hz}, 3H); 13C NMR (75 MHz) \delta = 167.1, 145.7, 139.6, 137.4, 135.2, 129.1, 128.0, 127.7, 127.4, 121.5, 118.2, 116.8, 111.6, 60.5, 47.7, 14.5; IR \nu = 3386, 2980, 1692, 1590, 1510, 1257, 1043, 972, 822, 693 \text{ cm}^{-1}; \text{HRMS (FD) calcd for } C_{18}H_{17}Cl_2NO_2 [M]^+ : 349.0636; \text{found: } 349.0654; \text{mp 91 - 93 }^\circ \text{C.}
A parallel reaction without ligand was also performed providing 3an in 20% \(^1\)H NMR yield (18% \(^1\)H NMR yield of byproduct 3an').

**Ethyl (E)-3-(4-(benzylamino)-2,3-dichlorophenyl)acrylate (3ao)**

General procedure A was followed using N-benzyl 2,3-dichloroaniline (1ao) (94.6 mg, 0.375 mmol, 1.5 equiv) and ethyl acrylate (27 µL, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing 3ao in 63% \(^1\)H NMR yield (2% \(^1\)H NMR yield of byproduct 3ao'). The crude residue was purified by column chromatography using Et\(_2\)O:petroleum ether (1:4 v/v) as an eluent providing the titled compound as a pale yellow solid (49.6 mg, 57% yield).

\(^1\)H NMR (300 MHz) δ = 8.04 (d, \(J = 15.9\) Hz, 1H), 7.41 (d, \(J = 8.8\) Hz, 1H), 7.38 – 7.28 (m, 5H), 6.55 (d, \(J = 8.8\) Hz, 1H), 6.23 (d, \(J = 15.9\) Hz, 1H), 5.20 (bs, 1H), 4.46 (s, 2H), 4.25 (q, \(J = 7.1\) Hz, 2H), 1.33 (t, \(J = 7.1\) Hz, 3H);

\(^13\)C NMR (75 MHz) δ = 167.2, 146.3, 140.9, 137.7, 134.2, 129.0, 127.8, 127.2, 126.4, 122.4, 117.9, 116.9, 109.4, 60.6, 47.8, 14.5; IR ν = 3430, 2977, 1699, 1590, 1515, 1264, 1220, 1028, 975, 804, 739, 695 cm\(^{-1}\); HRMS (FD) calcd for C\(_{18}\)H\(_{17}\)Cl\(_2\)NO\(_2\) [M]\(^+\): 349.0636; found: 349.0637; mp 87 – 89 °C.

A parallel reaction without ligand was also performed providing 3ao in 9% \(^1\)H NMR yield (19% \(^1\)H NMR yield of byproduct 3ao').

**Ethyl (E)-3-(4-(benzylamino)naphthalen-1-yl)acrylate (3ap)**

General procedure A was followed using N-benzylnaphthalen-1-amine (1ap) (58.3 mg, 0.25 mmol, 1 equiv) and ethyl acrylate (40 µL, 0.375 mmol, 1.5 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing 3ap in 28% \(^1\)H NMR yield. Characteristic \(^1\)H NMR signal for 3ap: 6.45 (d, \(J = 15.6\) Hz, 1H).

A parallel reaction without ligand was also performed. The reaction gave no product (4% \(^1\)H NMR yield of byproduct 3ap').

**Methyl (E)-6-(benzylamino)-3-[2-(ethoxycarbonyl)vinyl]-2,4-difluorobenzoate (3aq)**

General procedure A was followed using N-benzyl-3,5-difluoro-2-(methoxycarbonyl)aniline (1aq) (104.0 mg, 0.375 mmol, 1.5 equiv) and ethyl acrylate (27 µL, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing 3aq in 62% \(^1\)H NMR yield (6% \(^1\)H NMR yield of byproduct 3aq'). The crude residue was purified by column chromatography using Et\(_2\)O:petroleum ether (1:4 v/v) as an eluent providing the titled compounds as a pale yellow solid (56.0 mg, 60% yield). \(^1\)H NMR (300 MHz) δ = 8.58 (bs, 1H), 7.67 (d, \(J = 16.3\) Hz, 1H), 7.39 – 7.28 (m, 5H), 6.49 (d, \(J = 16.3\) Hz, 1H), 6.17 (d, \(J = 13.7\) Hz, 1H), 4.40 (d, \(J = 5.4\) Hz, 2H), 4.24 (q, \(J = 7.1\) Hz, 2H), 3.90 (s, 3H), 1.31 (t, \(J = 7.1\) Hz, 3H);

\(^13\)C NMR (75 MHz) δ = 167.7, 167.5 (d, \(J = 3.9\) Hz), 166.5 (dd, \(J = 89.8, 8.6\) Hz), 163.0 (dd, \(J = 97.0, 11.4\) Hz), 152.9 (dd, \(J = 15.8, 8.0\) Hz), 137.1, 131.1 (d, \(J = 3.9\) Hz), 129.1, 127.9, 127.2, 119.6 (dd, \(J = 8.9, 8.9\) Hz), 101.2 (dd, \(J = 16.9, 16.9\) Hz), 98.0 (dd, \(J = 13.1, 3.3\) Hz),
94.5 (dd, \( J = 27.0, 2.7 \) Hz), 60.5, 52.3, 47.4, 14.4; \(^{19}\)F NMR (282 MHz) \( \delta = -99.62 \) (d, \( J = 12.5 \) Hz), -101.76 (t, \( J = 12.9 \) Hz); IR \( \nu = 3327, 2953, 1681, 1616, 1569, 1436, 1163, 1120, 1029, 698 \) cm\(^{-1}\); HRMS (FD) calcd for \( \text{C}_{20}\text{H}_{19}\text{F}_{2}\text{NO}_{4} \) [M]+: 375.1282; found: 375.1267; mp 75 – 77 °C.

A parallel reaction without ligand was also performed providing \( 3\text{aq} \) in 8% \(^{1}\)H NMR yield (18% \(^{1}\)H NMR yield of byproduct \( 3\text{aq}' \)).

**Dimethyl (E)-2-amino-5-(3-ethoxy-3-oxoprop-1-en-1-yl)isophthalate (3ar)**

General procedure A was followed using dimethyl 2-aminoisophthalate (1ar) (78.5 mg, 0.375 mmol, 1.5 equiv) and ethyl acrylate (27 \( \mu \)L, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing \( 3\text{ar} \) in 68% \(^{1}\)H NMR yield. The crude residue was purified by column chromatography using \( \text{Et}_2\text{O} : \text{petroleum ether} \) (3:7 v/v) as an eluent providing the titled compound as a pale yellow solid (48.9 mg, 64% yield). \(^{1}\)H NMR (400 MHz) \( \delta = 8.38 \) (bs, 2H), 8.24 (s, 2H), 7.53 (d, \( J = 15.9 \) Hz, 1H), 6.27 (d, \( J = 15.9 \) Hz, 1H), 4.24 (q, \( J = 7.1 \) Hz, 2H), 3.88 (s, 6H), 1.32 (t, \( J = 7.1 \) Hz, 3H); \(^{13}\)C NMR (101 MHz) \( \delta = 167.7, 167.3, 154.0, 143.5, 137.0, 120.3, 115.0, 112.1, 60.4, 52.1, 14.5; \) IR \( \nu = 3438, 3320, 1707, 1697, 1613, 1563, 1233, 973, 801 \) cm\(^{-1}\); HRMS (ESI) calcd for \( \text{C}_{15}\text{H}_{18}\text{NO}_{6} \) [M+H]+: 308.1134; found: 308.1128; mp 144 – 146 °C.

A parallel reaction without ligand was also performed providing \( 3\text{ar} \) in 20% \(^{1}\)H NMR yield.

**Ethyl (E)-3-(4-amino-3,5-bis(trifluoromethyl)phenyl)acrylate (3as)**

General procedure A was followed using 2,6-bis(trifluoromethyl)aniline (1as) (85.9 mg, 0.375 mmol, 1.5 equiv) and ethyl acrylate (27 \( \mu \)L, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing \( 3\text{as} \) in 26% \(^{1}\)H NMR yield. Characteristic \(^{1}\)H NMR signal for \( 3\text{as} \): 6.35 (d, \( J = 16.0 \) Hz, 1H).

A parallel reaction without ligand was also performed providing \( 3\text{as} \) in 4% \(^{1}\)H NMR yield.

**Ethyl (E)-3-(4-amino-3,5-dichlorophenyl)acrylate (3at)**

General procedure A was followed using 2,6-dichloroaniline (1at) (60.8 mg, 0.375 mmol, 1.5 equiv) and ethyl acrylate (27 \( \mu \)L, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing \( 3\text{at} \) in 14% \(^{1}\)H NMR yield. Characteristic \(^{1}\)H NMR signal for \( 3\text{at} \): 6.25 (d, \( J = 16.0 \) Hz, 1H).

A parallel reaction without ligand was also performed providing \( 3\text{at} \) in 11% \(^{1}\)H NMR yield.
Ethyl (E)-3-(4-amino-3,5-dimethylphenyl)acrylate (3au)

General procedure A was followed using 2,6-dimethylaniline (1au) (45.4 mg, 0.375 mmol, 1.5 equiv) and ethyl acrylate (27 µL, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing 3au in 18% 1H NMR yield (19% 1H NMR yield of byproduct 3au’’). Characteristic 1H NMR signal for 3au: 6.30 (d, J = 15.8 Hz, 1H).

A parallel reaction without ligand was also performed. The reaction gave no product (11% 1H NMR yield of byproduct 3au’’).

Ethyl (E)-3-(4-amino-3,5-dimethoxyphenyl)acrylate (3av)

General procedure A was followed using 2,6-dimethoxyaniline (1av) (57.4 mg, 0.375 mmol, 1.5 equiv) and ethyl acrylate (27 µL, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing 3av in 6% 1H NMR yield (26% 1H NMR yield of byproduct 3av’’). Characteristic 1H NMR signal for 3av: 6.19 (d, J = 15.6 Hz, 1H).

A parallel reaction without ligand was also performed providing 3av in 4% 1H NMR yield (35% 1H NMR yield of byproduct 3av’’).

Methyl (E)-2-amino-5-(3-ethoxy-3-oxoprop-1-en-1-yl)-3-methylbenzoate (3aw)

General procedure A was followed using methyl 2-amino-3-methylbenzoate (1aw) (82.6 mg, 0.5 mmol, 2 equiv) and ethyl acrylate (27 µL, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing 3aw in 72% 1H NMR yield (3% 1H NMR yield of byproduct 3aw’’). The crude residue was purified by column chromatography using Et2O:petroleum ether (3:7 v/v) as an eluent providing the titled compound as a pale yellow solid (45.5 mg, 69% yield). 1H NMR (400 MHz) δ = 7.95 (s, 1H), 7.56 (d, J = 15.9 Hz, 1H), 7.39 (s, 1H), 6.24 (d, J = 15.9 Hz, 1H), 6.16 (bs, 2H), 4.23 (q, J = 7.1 Hz, 2H), 3.87 (s, 3H), 2.17 (s, 3H), 1.32 (t, J = 7.1 Hz, 3H); 13C NMR (101 MHz) δ = 168.6, 167.6, 150.8, 144.5, 133.5, 130.9, 123.5, 122.1, 114.1, 110.0, 60.3, 51.9, 17.6, 14.5; IR v = 3468, 3356, 1687, 1607, 1567, 1436, 1248, 1208, 1150, 794 cm⁻¹; HRMS (ESI) calcd for C₁₄H₁₈NO₄ [M+H]⁺: 264.1236; found: 264.1231; mp 65 – 68 °C.

A parallel reaction without ligand was also performed providing 3aw in 3% 1H NMR yield (11% 1H NMR yield of byproduct 3aw’’).

Methyl (E)-2-amino-5-(3-ethoxy-3-oxoprop-1-en-1-yl)-3-methoxybenzoate (3ax)

General procedure A was followed using methyl 2-amino-3-methoxybenzoate (1ax) (90.6 mg, 0.5 mmol, 2 equiv) and ethyl acrylate (27 µL, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing 3ax in 73% 1H NMR yield (3% 1H NMR yield of byproduct 3ax’’). The crude residue was purified by column chromatography using Et₂O:petroleum ether (3:7 v/v) as an eluent providing the titled
compound as a pale yellow solid (46.6 mg, 67% yield). $^1$H NMR (400 MHz) $\delta = 7.64$ (s, 1H), 7.58 (d, $J = 15.8$ Hz, 1H), 6.99 (s, 1H), 6.37 (bs, 2H), 6.21 (d, $J = 15.8$ Hz, 1H), 4.24 (q, $J = 7.1$ Hz, 2H), 3.89 (s, 3H), 3.87 (s, 3H), 1.32 (t, $J = 7.1$ Hz, 3H); $^{13}$C NMR (101 MHz) $\delta = 168.1, 167.3, 147.0, 144.7, 125.4, 121.1, 113.6, 109.6, 109.1, 60.1, 55.6, 51.6, 14.3; IR v = 3489, 3373, 2985, 1682, 1613, 1552, 1430, 1255, 1048, 791, 597 cm$^{-1}$; HRMS (ESI) calcd for C$_{14}$H$_{18}$NO$_5$ [M+H]$^+$: 280.1185; found: 280.1189; mp 92–95 °C.

A parallel reaction without ligand was also performed providing 3ax in 15% $^1$H NMR yield (17% $^1$H NMR yield of byproduct 3ax$''$).

**Methyl (E)-2-amino-3-chloro-5-(3-ethoxy-3-oxoprop-1-en-1-yl)benzoate (3ay)**

General procedure A was followed using methyl 2-amino-3-chlorobenzoate (1ay) (92.8 mg, 0.5 mmol, 2 equiv) and ethyl acrylate (27 $\mu$L, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing 3ay in 80% $^1$H NMR yield. The crude residue was purified by column chromatography using Et$_2$O:petroleum ether (1:4 v/v) as an eluent providing the titled compound as a pale yellow solid (50.7 mg, 71% yield). $^1$H NMR (400 MHz) $\delta = 7.95$ (s, 1H), 7.58 (s, 1H), 7.49 (d, $J = 15.9$ Hz, 1H), 6.57 (bs, 2H), 6.23 (d, $J = 15.9$ Hz, 1H), 4.23 (q, $J = 7.1$ Hz, 2H), 3.88 (s, 3H), 1.31 (t, $J = 7.1$ Hz, 3H); $^{13}$C NMR (101 MHz) $\delta = 167.7, 167.2, 147.9, 143.0, 132.4, 131.0, 122.6, 120.8, 115.5, 111.5, 111.6, 120.8, 115.5, 111.5, 110.5, 122.6, 120.8, 115.5, 111.5, 111.6, 113.3, 112.4, 116.3, 789 cm$^{-1}$; HRMS (ESI) calcd for C$_{13}$H$_{15}$ClNO$_4$ [M+H]$^+$: 284.0690; found: 284.0682; mp 58–60 °C.

A parallel reaction without ligand was also performed providing 3ay in 19% $^1$H NMR yield.

**Methyl (E)-2-amino-5-(3-ethoxy-3-oxoprop-1-en-1-yl)-3,4-difluorobenzoate (3az)**

General procedure A was followed using methyl 2-amino-3,4-difluorobenzoate (1az) (93.6 mg, 0.5 mmol, 2 equiv) and ethyl acrylate (27 $\mu$L, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing 3az in 74% $^1$H NMR yield. The crude residue was purified by column chromatography using Et$_2$O:petroleum ether (3:7 v/v) as an eluent providing the titled compound as a pale yellow solid (49.9 mg, 70% yield). $^1$H NMR (300 MHz) $\delta = 7.85$ (dd, $J = 7.6, 2.0$ Hz, 1H), 7.59 (d, $J = 16.1$ Hz, 1H), 6.39 (d, $J = 16.1$ Hz, 1H), 6.19 (bs, 2H), 4.24 (q, $J = 7.1$ Hz, 2H), 3.88 (s, 3H), 1.32 (t, $J = 7.1$ Hz, 3H); $^{13}$C NMR (75 MHz) $\delta = 167.1, 167.0$ (d, $J = 2.6$ Hz), 152.1 (d, $J = 259.8, 10.7$ Hz), 142.5 (d, $J = 11.1, 4.6$ Hz), 139.3 (dd, $J = 240.5, 14.7$ Hz), 136.7 (dd, $J = 3.2, 1.2$ Hz), 127.4 (dd, $J = 4.9, 3.4$ Hz), 118.3 (d, $J = 7.1$ Hz), 111.7 (d, $J = 10.3$ Hz), 108.2 (dd, $J = 3.6, 2.4$ Hz), 60.6, 52.2, 14.4; $^{19}$F NMR (282 MHz) $\delta = -133.14$ (dd, $J = 18.2, 7.2$ Hz), -160.79 (d, $J = 18.2$ Hz); IR v = 3461, 3355, 1687, 1628, 1483, 1445, 1265, 1149, 972, 788 cm$^{-1}$; HRMS (FD) calcd for C$_{13}$H$_{13}$F$_2$NO$_4$ [M]$^+$: 285.0813; found: 285.0825; mp 107–109 °C.

A parallel reaction without ligand was also performed providing 3az in 33% $^1$H NMR yield.
Chapter 5

Ethyl (E)-3-(4-amino-3-methyl-5-(trifluoromethyl)phenyl)acrylate (3ba)

General procedure A was followed using 2-methyl-6-(trifluoromethyl)aniline (1ba) (65.7 mg, 0.375 mmol, 1.5 equiv) and ethyl acrylate (27 µL, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing 3ba in 25% ¹H NMR yield (7% ¹H NMR yield of byproduct 3ba⁺⁺). Characteristic ¹H NMR signal for 3ba: 6.31 (d, J = 15.9 Hz, 1H).

A parallel reaction without ligand was also performed providing 3ba in 7% ¹H NMR yield (5% ¹H NMR yield of byproduct 3ba⁺⁺).

Ethyl (E)-3-(4-amino-3-methoxy-5-(trifluoromethyl)phenyl)acrylate (3bb)

General procedure A was followed using 2-methoxy-6-(trifluoromethyl)aniline (1bb) (95.6 mg, 0.5 mmol, 2 equiv) and ethyl acrylate (27 µL, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing 3bb in 48% ¹H NMR yield (6% ¹H NMR yield of byproduct 3bb⁺⁺). The crude residue was purified by column chromatography using Et₂O:petroleum ether (3:7 v/v) as an eluent providing the titled compound as a pale yellow solid (32.9 mg, 45% yield).

¹H NMR (400 MHz) δ = 7.57 (d, J = 15.9 Hz, 1H), 7.22 (s, 1H), 7.05 (s, 1H), 6.26 (d, J = 15.9 Hz, 1H), 4.71 (s, 2H), 4.25 (q, J = 7.1 Hz, 2H), 3.92 (s, 3H), 1.33 (t, J = 7.1 Hz, 3H); ¹³C NMR (75 MHz) δ = 167.3, 147.5, 144.2, 137.4 (d, J = 1.6 Hz), 124.8 (d, J = 272.6 Hz), 123.2, 120.2 (q, J = 5.0 Hz), 115.2, 113.0 (q, J = 30.2 Hz), 110.4, 60.5, 56.1, 14.5; ¹⁹F NMR (282 MHz) δ = -62.67 (s); IR ν = 3483, 3360, 2928, 1693, 1620, 1503, 1271, 1046, 859, 595 cm⁻¹; HRMS (ESI) calcd for C₁₃H₁₅F₃NO₃ [M+H]⁺: 290.1004; found: 290.0998; mp 103 – 106 °C.

A parallel reaction without ligand was also performed providing 3bb in 7% ¹H NMR yield (28% ¹H NMR yield of byproduct 3bb⁺⁺).

Ethyl (E)-3-(4-amino-3-methyl-5-nitrophenyl)acrylate (3bc)

General procedure A was followed using 2-methyl-6-nitroaniline (1bc) (76.1 mg, 0.5 mmol, 2 equiv) and ethyl acrylate (27 µL, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing 3bc in 17% ¹H NMR yield. Characteristic ¹H NMR signal for 3bc: 6.30 (d, J = 15.9 Hz, 1H).

A parallel reaction without ligand was also performed providing 3bc in 8% ¹H NMR yield.

Ethyl (E)-3-(4-amino-3-methoxy-5-nitrophenyl)acrylate (3bd)

General procedure A was followed using 2-methoxy-6-nitroaniline (1bd) (84.1 mg, 0.5 mmol, 2 equiv) and ethyl acrylate (27 µL, 0.25 mmol, 1 equiv) in DCE (0.95 mL, 0.2 M) at 80 °C, providing 3bd in 33% ¹H NMR yield. Characteristic ¹H NMR signal for 3bd: 6.28 (d, J = 15.9 Hz, 1H).
A parallel reaction without ligand was also performed providing 3bd in 8% $^1$H NMR yield.

**General procedure for the Pd-catalyzed C–H olefination of N,N-diethylaniline with activated olefins**

Pd(OAc)$_2$ (5.6 mg, 25 µmol, 10 mol%), a stock solution of ligand L (0.0846 M in DCE) (300 µL, 25 µmol, 10 mol%), t-butyl peroxynbenzoate (47 µL, 0.25 mmol, 1 equiv), the corresponding olefin (0.375 mmol, 1.5 equiv), N,N-diethylaniline (1b) (40 µL, 0.25 mmol, 1 equiv) and DCE (0.95 mL, 0.2 M) were added into a pressure tube. The pressure tube was sealed with a screw cap and the reaction was placed in a 40 °C pre-heated oil bath and stirred for 16 h. The resulting mixture was diluted with EtOAc, filtered through a plug of Celite and concentrated under reduced pressure. The $^1$H NMR yield was determined by adding CH$_2$Br$_2$ (17.5 µL, 0.25 mmol, 1 equiv) as an internal standard. The crude residue was purified by column chromatography to obtain the desired product.

**Methyl (E)-3-(4-(diethylamino)phenyl)acrylate (4a)**

General procedure was followed using methyl acrylate (34 µL, 0.375 mmol, 1.5 equiv), providing 4a in 86% $^1$H NMR yield. The crude residue was purified by column chromatography using Et$_2$O:petroleum ether (1:4 v/v) as an eluent providing the titled compound as a pale yellow oil (46.1 mg, 79% yield). $^1$H NMR spectra data of the isolated material matched with the spectra data reported in the literature for this compound.$^{36}$$^1$H NMR (300 MHz) δ = 7.60 (d, $J = 15.8$ Hz, 1H), 7.37 (d, $J = 8.9$ Hz, 2H), 6.60 (d, $J = 8.9$ Hz, 2H), 6.17 (d, $J = 15.8$ Hz, 1H), 3.75 (s, 3H), 3.36 (q, $J = 7.1$ Hz, 4H), 1.16 (t, $J = 7.1$ Hz, 6H).

A parallel reaction without ligand was also performed providing the olefinated products in 32% $^1$H NMR yield ($\rho:o = 15:1$).

**Cyclohexyl (E)-3-(4-(diethylamino)phenyl)acrylate (4b)**

General procedure was followed using cyclohexyl acrylate (59 µL, 0.375 mmol, 1.5 equiv). The crude residue was purified by column chromatography using Et$_2$O:petroleum ether (1:4 v/v) as an eluent providing the titled compound as a yellow oil (64.3 mg, 85% yield). $^1$H NMR (300 MHz) δ = 7.59 (d, $J = 15.8$ Hz, 1H), 7.39 (d, $J = 8.9$ Hz, 2H), 6.62 (d, $J = 8.9$ Hz, 2H), 6.19 (d, $J = 15.8$ Hz, 1H), 4.90 – 4.82 (m, 1H), 3.38 (q, $J = 7.1$ Hz, 4H), 1.94 – 1.90 (m, 2H), 1.79 – 1.74 (m, 2H), 1.59 – 1.26 (m, 6H), 1.18 (t, $J = 7.1$ Hz, 6H); $^{13}$C NMR (75 MHz) δ = 167.6, 149.3, 145.0, 130.1, 121.6, 112.6, 111.2, 72.2, 44.5, 32.0, 25.6, 24.0, 12.7; IR ν = 2967, 2932, 2857, 1695, 1626, 1519, 1166, 1144, 811 cm$^{-1}$; HRMS (FD) calcd for C$_{19}$H$_{27}$NO$_2$ [M]$^+$: 301.2042; found: 301.2056.

A parallel reaction without ligand was also performed providing 4b in 36% isolated yield.
Phenyl (E)-3-(4-(diethylamino)phenyl)acrylate (4c)

General procedure was followed using phenyl acrylate (52 µL, 0.375 mmol, 1.5 equiv), providing 4c in 96% ¹H NMR yield. The crude residue was purified by column chromatography using Et₂O:pentane ether (1:4 v/v) as an eluent providing the titled compound as a yellow solid (69.8 mg, 95% yield).

¹H NMR (300 MHz) δ = 7.84 (d, J = 15.8 Hz, 1H), 7.50 (d, J = 8.9 Hz, 2H), 7.47 – 7.41 (m, 2H), 7.29 – 7.20 (m, 3H), 6.69 (d, J = 8.9 Hz, 2H), 6.42 (d, J = 15.8 Hz, 1H), 3.45 (q, J = 7.1 Hz, 4H), 1.24 (t, J = 7.1 Hz, 6H); ¹³C NMR (75 MHz) δ = 166.5, 151.2, 149.7, 147.3, 130.5, 129.4, 125.5, 121.9, 121.2, 111.3, 110.6, 44.6, 12.7; IR ν = 2971, 1721, 1591, 1521, 1185, 1117, 813 cm⁻¹; HRMS (FD) calcd for C₁₉H₂₁NO₂ [M⁺]: 295.1572; found: 295.1575; mp 98 – 100 °C.

A parallel reaction without ligand was also performed providing 4c in 34% ¹H NMR yield.

(E)-3-(4-(Diethylamino)benzylidene)dihydrofuran-2(3H)-one (4dA) and 3-(4-(diethylamino)benzyl)furan-2(5H)-one (4dB)

General procedure was followed using α-methylene-γ-butyrolactone (33 µL, 0.375 mmol, 1.5 equiv), providing 4d in quantitative ¹H NMR yield (4dA:4dB = 1.4:1). The crude residue was purified by column chromatography using CH₂Cl₂:petroleum ether to Et₂O:petroleum ether (7:3 to 3:2 v/v) as an eluent providing mixture of the titled compounds as a yellow oil (56.9 mg, 93% yield).

¹H NMR (300 MHz) δ = 7.47 (t, J = 2.6 Hz, 1H), 7.39 (d, J = 9.0 Hz, 2H), 7.07 (d, J = 8.3 Hz, 2H), 6.95 (t, J = 2.1 Hz, 1H), 6.68 (d, J = 9.0 Hz, 2H), 6.64 (d, J = 8.3 Hz, 2H), 4.73 (d, J = 2.1 Hz, 2H), 4.43 (t, J = 7.4 Hz, 2H), 3.48 (d, J = 2.1 Hz, 2H), 3.41 (q, J = 7.1 Hz, 4H), 3.33 (q, J = 7.1 Hz, 4H), 3.19 (td, J = 7.4, 2.6 Hz, 2H), 1.20 (t, J = 7.1 Hz, 6H), 1.15 (t, J = 7.1 Hz, 6H); ¹³C NMR (75 MHz) δ = 174.3, 173.7, 148.8, 145.2, 137.4, 135.1, 132.3, 129.8, 121.7, 116.5, 112.1, 111.3, 70.3, 65.3, 44.5, 44.4, 30.8, 27.6, 12.6; IR ν = 2969, 1737, 1592, 1518, 1351, 1267, 1170, 1039, 800 cm⁻¹; HRMS (FD) calcd for C₁₅H₁₉NO₂ [M⁺]: 245.1416; found: 245.1410.

A parallel reaction without ligand was also performed providing 4d in 26% ¹H NMR yield (4dA:4dB = 5.5:1).

(E)-3-(4-(Diethylamino)phenyl)-N,N-dimethylacrylamide (4e)

General procedure was followed using N,N-dimethylacrylamide (39 µL, 0.375 mmol, 1.5 equiv), providing 4e in 86% ¹H NMR yield. The crude residue was purified by column chromatography using EtOAc as an eluent providing the titled compound as a pale yellow solid (47.2 mg, 77% yield). ¹H NMR (300 MHz) δ = 7.60 (d, J = 15.2 Hz, 1H), 7.40 (d, J = 8.9 Hz, 2H), 6.64 (d, J = 15.2 Hz, 1H), 6.61 (d, J = 8.9 Hz, 2H), 3.37 (q, J = 7.1 Hz, 4H), 3.14 (s, 3H), 3.04 (s, 3H), 1.17 (t, J = 7.1 Hz, 6H); ¹³C NMR (75 MHz) δ = 167.7, 148.8, 143.0, 129.7, 122.4, 111.4, 111.3, 44.5, 37.5, 36.0, 12.7; IR ν = 2969, 1638, 1581, 1516, 1388, 1189, 1125,
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816 cm\(^{-1}\); HRMS (ESI) calcd for C\(_{15}\)H\(_{23}\)N\(_2\)O \([\text{M+H}]^+\): 247.1810; found: 247.1808; mp 77 – 80 °C.

A parallel reaction without ligand was also performed providing 4e in <5% \(^1\)H NMR yield.

**(E)-4-(4-(Diethylamino)phenyl)-3-buten-2-one (4f)**

General procedure was followed using methyl vinyl ketone (30 µL, 0.375 mmol, 1.5 equiv), providing 4f in 71% \(^1\)H NMR yield. The crude residue was purified by column chromatography using Et\(_2\)O:pentroleum ether (1:1 v/v) as an eluent providing the titled compound as a yellow oil (37.1 mg, 68% yield). \(^1\)H NMR (300 MHz) δ = 7.45 (d, \(J = 16.1\) Hz, 1H), 7.41 (d, \(J = 8.9\) Hz, 2H), 6.64 (d, \(J = 8.9\) Hz, 2H), 6.52 (d, \(J = 16.1\) Hz, 1H), 3.40 (q, \(J = 7.1\) Hz, 4H), 2.33 (s, 3H), 1.19 (t, \(J = 7.1\) Hz, 6H); \(^13\)C NMR (75 MHz) δ = 198.6, 149.7, 144.6, 130.5, 121.9, 121.2, 111.4, 44.6, 27.2, 12.7; IR ν = 2969, 1673, 1571, 1517, 1353, 1154, 986, 803 cm\(^{-1}\); HRMS (ESI) calcd for C\(_{14}\)H\(_{20}\)NO \([\text{M+H}]^+\): 218.1545; found: 218.1540.

A parallel reaction without ligand was also performed providing 4f in 24% \(^1\)H NMR yield.

**Dimethyl (E)-(4-(diethylamino)styryl)phosphonate (4g)**

General procedure was followed using dimethyl vinyl phosphonate (45 µL, 0.375 mmol, 1.5 equiv), providing 4g in 79% \(^1\)H NMR yield. The crude residue was purified by column chromatography using EtOAc:CH\(_2\)Cl\(_2\) (3:2 v/v) as an eluent providing the titled compound as a clear oil (53.7 mg, 76% yield). \(^1\)H NMR (300 MHz) δ = 7.48 – 7.40 (m, 1H), 7.36 (d, \(J = 8.9\) Hz, 2H), 6.61 (d, \(J = 8.9\) Hz, 2H), 5.91 – 5.79 (m, 1H), 3.74 (s, 3H), 3.71 (s, 3H), 3.37 (q, \(J = 7.1\) Hz, 4H), 1.16 (t, \(J = 7.1\) Hz, 6H); \(^13\)C NMR (75 MHz) δ = 150.4 (d, \(J = 7.2\) Hz), 149.4, 129.8, 121.7 (d, \(J = 23.8\) Hz), 111.2, 104.3 (d, \(J = 195.4\) Hz), 52.4, 52.3, 44.5, 12.6; \(^{31}\)P NMR (121 MHz) δ = 25.25; IR ν = 2970, 1592, 1519, 1181, 1018, 860, 815, 788 cm\(^{-1}\); HRMS (ESI) calcd for C\(_{14}\)H\(_{23}\)NO\(_3\)P \([\text{M+H}]^+\): 284.1416; found: 284.1416.

A parallel reaction without ligand was also performed providing 4g in <40% \(^1\)H NMR yield.

**(E)-N,N-Diethyl-4-[2-(phenylsulfonyl)vinyl]aniline (4h)**

General procedure was followed using phenyl vinyl sulfone (63.1 mg, 0.375 mmol, 1.5 equiv), providing 4h in 55% \(^1\)H NMR yield. The crude residue was purified by column chromatography using CH\(_2\)Cl\(_2\):petroleum ether to EtOAc:petroleum ether (4:1 to 3:7 v/v) as an eluent providing the titled compound as a yellow oil (43.2 mg, 55% yield). \(^1\)H NMR (300 MHz) δ = 7.94 – 7.91 (m, 2H), 7.60 – 7.47 (m, 4H), 7.33 (d, \(J = 8.9\) Hz, 2H), 6.60 (d, \(J = 8.9\) Hz, 2H), 6.54 (d, \(J = 15.2\) Hz, 1H), 3.38 (q, \(J = 7.1\) Hz, 4H), 1.17 (t, \(J = 7.1\) Hz, 6H); \(^13\)C NMR (75 MHz) δ = 150.0, 143.5, 142.2, 132.8, 130.8, 129.2, 127.3, 120.0, 119.0, 111.3, 44.6, 12.6; IR ν = 1588, 1522, 1138, 1080, 786, 586 cm\(^{-1}\); HRMS (ESI) calcd for C\(_{18}\)H\(_{22}\)NO\(_2\)S \([\text{M+H}]^+\): 316.1371; found: 316.1362.
A parallel reaction without ligand was also performed providing 4h in 8% $^1$H NMR yield.

(\(E\))-3-(4-(diethylamino)phenyl)acrylonitrile (4i\(E\)) and (\(Z\))-3-(4-(diethylamino)phenyl)acrylonitrile (4i\(Z\))

General procedure was followed using acrylonitrile (25 \(\mu\)L, 0.375 mmol, 1.5 equiv), providing 4i in 46% $^1$H NMR yield ($E:Z = 3.2:1$). Characteristic $^1$H NMR signals for 4i: 4i\(E\): 5.55 (d, \(J = 16.5\) Hz, 1H) and 4i\(Z\): 5.06 (d, \(J = 12.0\) Hz, 1H).

A parallel reaction without ligand was also performed providing 4i in 12% $^1$H NMR yield ($E:Z = 5:1$).

Methyl (\(E\))-3-(4-(diethylamino)phenyl)but-2-enoate (4j)

General procedure was followed using methyl crotonate (40 \(\mu\)L, 0.375 mmol, 1.5 equiv), providing 4j in 32% $^1$H NMR yield. Characteristic $^1$H NMR signal for 4j: 6.16 (s, 1H).

A parallel reaction without ligand was also performed providing 4j in 10% $^1$H NMR yield.

Ethyl (\(E\))-3-(4-(diethylamino)phenyl)-3-phenylacrylate (4k\(E\)) and ethyl (\(Z\))-3-(4-(diethylamino)phenyl)-3-phenylacrylate (4k\(Z\))

General procedure was followed using ethyl cinnamate (63 \(\mu\)L, 0.375 mmol, 1.5 equiv), providing 4k in 17% $^1$H NMR yield ($E:Z = 2.4:1$). Characteristic $^1$H NMR signals for 4k: 4k\(E\): 6.34 (s, 1H) and 4k\(Z\): 6.15 (s, 1H).

A parallel reaction without ligand was also performed providing 4k in 7% $^1$H NMR yield ($E:Z = 2.5:1$).

(\(E\))-3-(4-(diethylamino)phenyl)allyl acetate (4l)

General procedure was followed using allyl acetate (41 \(\mu\)L, 0.375 mmol, 1.5 equiv), providing 4l in 10% $^1$H NMR yield. Characteristic $^1$H NMR signal for 4l: $^1$H NMR \(\delta = 4.73\) (dd, \(J = 6.9, 1.2\) Hz, 1H).

A parallel reaction without ligand was also performed providing 4l in 7% $^1$H NMR yield.

5.5.3 Computational studies

All calculations were carried out with the Amsterdam Density Functional (ADF)\(^{37}\) program using dispersion-corrected density functional theory at the ZORA-BLYP-D3BJ/TZ2P level of theory.\(^{38}\) The effect of solvation in DCE was simulated by means of the Conductor like Screening Model (COSMO) of solvation as implemented in ADF.\(^{39}\) All stationary points were verified to be minima on the potential energy surface through vibrational analysis. The approach has been benchmarked against highly correlated post-Hartree-Fock methods and
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experimental data and was found to work reliably. Voronoi deformation density charges have also been computed.

Table 5.18 Cartesian coordinates of systems under analysis (in Å) optimized at ZORA-BLYP-D3BJ/TZ2P level of theory in DCE (COSMO). Total ADF electronic energies (in kcal mol$^{-1}$) in parenthesis.

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5.6 References


Chapter 5


S,O-Ligand promoted C–H olefination of aniline derivatives


