Programmed synthesis of triarylnitroimidazoles via sequential cross-coupling reactions

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Table S1: Optimization of reaction conditions:

![Reaction Scheme](image)

<table>
<thead>
<tr>
<th>entry</th>
<th>catalyst</th>
<th>AgF</th>
<th>temp (°C)</th>
<th>solvent</th>
<th>yieldb (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pd(OAc)$_2$</td>
<td>1</td>
<td>120</td>
<td>DMF</td>
<td>33</td>
</tr>
<tr>
<td>2</td>
<td>Pd(OAc)$_2$</td>
<td>2</td>
<td>120</td>
<td>DMF</td>
<td>46</td>
</tr>
<tr>
<td>3c</td>
<td>Pd(OAc)$_2$</td>
<td>2</td>
<td>120</td>
<td>DMF</td>
<td>37</td>
</tr>
</tbody>
</table>

*aReaction Conditions: 3a (0.179 mmol), 4 (0.215 mmol), Pd(OAc)$_2$ (5 mol%), Cu(OAc)$_2$·H$_2$O (0.358 mmol), AgF in 1.5 mL solvent, 16 h, air. *bIsolated yields of 5a. *cWhen reaction was carried out for 40 h.

Table S2: Optimization of reaction conditions:

![Reaction Scheme](image)

<table>
<thead>
<tr>
<th>entry</th>
<th>catalyst</th>
<th>base</th>
<th>temp (°C)</th>
<th>solvent</th>
<th>yieldb (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>NiCl$_2$(PPh$_3$)$_2$</td>
<td>K$_3$PO$_4$</td>
<td>120</td>
<td>dioxane</td>
<td>43</td>
</tr>
<tr>
<td>2c</td>
<td>NiCl$_2$(PPh$_3$)$_2$</td>
<td>K$_3$PO$_4$</td>
<td>120</td>
<td>dioxane</td>
<td>47</td>
</tr>
<tr>
<td>3d</td>
<td>NiCl$_2$(PPh$_3$)$_2$</td>
<td>K$_3$PO$_4$</td>
<td>120</td>
<td>dioxane</td>
<td>31</td>
</tr>
</tbody>
</table>

*aReaction conditions: 5a (0.131 mmol), 2 (0.157 mmol), catalyst (2 mol%), K$_3$PO$_4$ (0.393 mmol) in 1mL dioxane at 120 °C for 18 h, air. *bIsolated yields of 6a. *cWhen 4 mol% of catalyst was used. *dWhen reaction was carried out for 30 h.
2-Chloro-4-nitro-1-phenyl-1\textit{H}-imidazole (3a):

![NMR spectrum of 2-Chloro-4-nitro-1-phenyl-1\textit{H}-imidazole (3a)]

N
N
O
C
Cl

3a

O
N
N
Cl

3a
2-Chloro-1-(4-methoxyphenyl)-4-nitro-1H-imidazole (3b):

\[
\begin{align*}
\text{f1 (ppm)} & : 3.06, 2.03, 1.99, 0.92, 3.895, 7.040, 7.063, 7.308, 7.331, 7.868 \\
\text{f2 (ppm)} & : 55.74, 115.10, 121.65, 127.12, 127.26, 161.01
\end{align*}
\]
2-Chloro-4-nitro-1-(4-(trifluoromethoxy)phenyl)-1H-imidazole (3c):

![Diagram of 2-Chloro-4-nitro-1-(4-(trifluoromethoxy)phenyl)-1H-imidazole (3c)](image-url)
1-(4-(2-Chloro-4-nitro-1H-imidazol-1-yl)phenyl)ethan-1-one (3d):
2-Chloro-1-(4-fluorophenyl)-4-nitro-1H-imidazole (3e):
2-Chloro-1-(4-chlorophenyl)-4-nitro-1H-imidazole (3f):

\[
\begin{align*}
\text{\begin{center}
\begin{tabular}{c}
\text{f1 (ppm)}
\end{tabular}
\end{center}}
\end{align*}
\]

\[
\begin{align*}
\text{\begin{center}
\begin{tabular}{c}
\text{O} & \text{N} & \text{N} & \text{Cl} & \text{Cl}
\end{tabular}
\end{center}}
\end{align*}
\]

\[
\begin{align*}
\text{\begin{center}
\begin{tabular}{c}
\text{f1 (ppm)}
\end{tabular}
\end{center}}
\end{align*}
\]

\[
\begin{align*}
\text{\begin{center}
\begin{tabular}{c}
\text{O} & \text{N} & \text{N} & \text{Cl} & \text{Cl}
\end{tabular}
\end{center}}
\end{align*}
\]

\[
\begin{align*}
\text{\begin{center}
\begin{tabular}{c}
\text{f1 (ppm)}
\end{tabular}
\end{center}}
\end{align*}
\]
2-Chloro-1-(3-methoxyphenyl)-4-nitro-1H-imidazole (3g):
2-Chloro-4-nitro-1-(3-nitrophenyl)-1\textit{H}-imidazole (3h):
2-Chloro-4-nitro-1-(o-tolyl)-1H-imidazole (3i):
1-(2-Bromophenyl)-2-chloro-4-nitro-1\textit{H}-imidazole (3j):

![Chemical structure of 3j](image)

![NMR spectra of 3j](image)
2-Chloro-1-(3,5-dimethoxyphenyl)-4-nitro-1H-imidazole (3k):
2-Chloro-1-(3,5-dibromophenyl)-4-nitro-1H-imidazole (3l):
1-(Benzo[d][1,3]dioxol-5-yl)-2-chloro-4-nitro-1H-imidazole (3m)
2-Chloro-4-nitro-1-(thiophen-3-yl)-1H-imidazole (3n):

\[
\begin{align*}
N & \quad N \\
\| & \quad Cl \\
\| & \quad S \\
\end{align*}
\]

\[
\begin{align*}
\text{O}_2N & \quad \text{N} \\
\| & \quad \text{Cl} \\
\| & \quad \text{S} \\
\end{align*}
\]

\[
\begin{align*}
of(\text{ppm}) & \quad \begin{array}{c}
1.05 \\
2.03 \\
1.00 \\
7.205 \\
7.214 \\
7.222 \\
7.545 \\
7.553 \\
7.929 \\
\end{array} \\
121.39 \\
121.65 \\
123.88 \\
127.71 \\
132.05 \\
132.63 \\
\end{align*}
\]

\[
\begin{align*}
of(\text{ppm}) & \quad \begin{array}{c}
10.0 \\
9.5 \\
9.0 \\
8.5 \\
8.0 \\
7.5 \\
7.0 \\
6.5 \\
6.0 \\
5.5 \\
5.0 \\
4.5 \\
4.0 \\
3.5 \\
3.0 \\
2.5 \\
2.0 \\
1.5 \\
1.0 \\
0.5 \\
0.0 \\
-0.5 \\
\end{array} \\
150 \\
140 \\
130 \\
120 \\
110 \\
100 \\
90 \\
80 \\
70 \\
60 \\
50 \\
40 \\
30 \\
20 \\
10 \\
0 \\
\end{align*}
\]
2-Chloro-1-(naphthalen-2-yl)-4-nitro-1H-imidazole (3o):
1-Ethyl-1H-indole (4f):

- Chemical structure of 1-Ethyl-1H-indole (4f).
- NMR data for various chemical shifts (f1 ppm) and their corresponding chemical shifts (N, Et).

Chemical Shifts:
- N: 15.45, 40.96
- Et: 101.07, 109.28, 119.24, 121.01, 121.36, 126.98, 128.72, 135.77
1-Methyl-1\textit{H}-pyrrole-2-carbaldehyde (4g):
2-Chloro-4-nitro-1-phenyl-5-(thiophen-2-yl)-1H-imidazole (5a):
5-(Benzob[thiophen-2-yl]-2-chloro-4-nitro-1-phenyl-1H-imidazole (5b):

[Chemical structure image]

[Graphical representation of the NMR spectrum]
5-(Benzofuran-2-yl)-2-chloro-4-nitro-1-phenyl-1H-imidazole (5c):
2-Chloro-5-(5-methylthiophen-2-yl)-4-nitro-1-phenyl-1H-imidazole (5d):
3-(2-Chloro-4-nitro-1-phenyl-1H-imidazol-5-yl)-1-methyl-1H-pyrrolo[2,3-b]pyridine (5e):
3-(2-Chloro-4-nitro-1-phenyl-1H-imidazol-5-yl)-1-ethyl-1H-indole (5f):
5-(2-Chloro-4-nitro-1-phenyl-1H-imidazol-5-yl)-1-methyl-1H-pyrrole-2-carbaldehyde (5g):
5-(2-Chloro-4-nitro-1-phenyl-1H-imidazol-5-yl)furan-2-carbaldehyde (5h):
5-(2-Chloro-1-(3-methoxyphenyl)-4-nitro-1H-imidazol-5-yl)furan-2-carbaldehyde (5i):
2-Chloro-1-(4-fluorophenyl)-4-nitro-5-(thiophen-2-yl)-1H-imidazole (5j):
2-Chloro-1-(4-methoxyphenyl)-5-(5-methylthiophen-2-yl)-4-nitro-1H-imidazole (5k):
2-Chloro-5-(5-methylthiophen-2-yl)-4-nitro-1-(o-tolyl)-1H-imidazole (5l):
5-(2-Chloro-1-(naphthalen-2-yl)-4-nitro-1\(H\)-imidazol-5-yl)furan-2-carbaldehyde (5m):
2-Chloro-1-(3,5-dimethoxyphenyl)-4-nitro-5-(thiophen-3-yl)-1H-imidazole (5n):
2-(4-Chlorophenyl)-4-nitro-1-phenyl-5-(thiophen-2-yl)-1H-imidazole (6a):
5-(Benzofuran-2-yl)-4-nitro-1-phenyl-2-(4-(trifluoromethyl)phenyl)-1H-imidazole (6b):
5-(2-(4-Fluorophenyl)-4-nitro-1-phenyl-1H-imidazol-5-yl)furan-2-carbaldehyde (6c):
5-(4-Nitro-1,2-diphenyl-1H-imidazol-5-yl)furan-2-carbaldehyde (6d):
2-(4-Methoxyphenyl)-5-(5-methylthiophen-2-yl)-4-nitro-1-phenyl-1H-imidazole (6e):

![Chemical Structure](image)

![NMR Spectrum](image)
5-(5-Methylthiophen-2-yl)-4-nitro-1,2-diphenyl-1H-imidazole (6f):

![Chemical structure of 5-(5-Methylthiophen-2-yl)-4-nitro-1,2-diphenyl-1H-imidazole (6f)]
5-(4-5-(4-Nitro-1-phenyl-2-(p-tolyl)-1H-imidazol-5-yl)furan-2-carbaldehyde (6g):
5-(Benzofuran-2-yl)-2-(naphthalen-2-yl)-4-nitro-1-phenyl-1H-imidazole (6h):
4-Nitro-1,2-diphenyl-1H-imidazole (7a):

[Chemical structure image]

[Graph image showing NMR spectra]

[Chemical structure image]
2-(4-Methoxyphenyl)-4-nitro-1-phenyl-1H-imidazole (7b):
2-(4-Fluorophenyl)-4-nitro-1-phenyl-1H-imidazole (7c):
4-Nitro-1-phenyl-2-(p-tolyl)-1H-imidazole (7d):

[Diagram of molecular structure]

[Graph of spectral data]

[Graph of spectral data]
4-Nitro-1-phenyl-2-(4-(trifluoromethoxy)phenyl)-1H-imidazole (7e):
2-(Naphthalen-2-yl)-4-nitro-1-phenyl-1H-imidazole (7f):
2-(Benzo[d][1,3]dioxol-5-yl)-4-nitro-1-phenyl-1H-imidazole (7g):
4-Nitro-1-phenyl-2-(thiophen-3-yl)-1H-imidazole (7h):

\[
\text{O}_2\text{N} \quad \text{N} \quad \text{N} \\
\text{S} \quad 7h
\]

\[
\text{O}_2\text{N} \quad \text{N} \quad \text{N} \\
\text{S} \quad 7h
\]
2-chloro-4-nitro-1H-imidazole 1: