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Rhodium-Catalyzed Asymmetric Phenylation of N-
Phosphinoylarylimines with Triphenylborane.a

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Triphenylborane asymmetrically transfers its phenyl group to N-
diphenylphosphinoylarylimines to give diarylmethylamines with
high ee in high yield without imine hydrolysis under the catalysis
of a chiral amidomonophosphane–rhodium(I) complex.

The success in the chiral amidomonophosphane–rhodium-
catalyzed asymmetric arylation of N-diphenylphosphinoyl
(Dpp) imines with aryloboroxines 1,2 relied on the use of
molecular sieves 4A (MS 4A) as a dehydrating agent to
realize almost water-free conditions, giving the corresponding
diarylmethylamines with extremely high enantioselectivity in
satisfactory high yields. 3,4 For example, the arylation of
benzaldehyde N-Dpp-imine 2a with 4-methylphenyl- and 4-
methoxyphenylboroxines 3b and 3c in a 5:1 mixture of
dioxane and propanol in the presence of the 1-Rh(I) catalyst
and MS 4A at 80 °C for 12 h gave the corresponding arylated
amines (S)-4b and (S)-4c with 98% ee each in 96% and 92%
products, respectively (Table 1, entries 1 and 2).4 Continuing
scope and limitation studies, however, revealed that the reaction
of less reactive 4-methyl- and 4-methoxybenzaldehyde
N-Dpp-imines 2b and 2c with phenylboroxine 3a gave the products (R)-4b and (R)-4c with lower 84% and 83% ee in
decreased 79% and 10% yields, respectively, probably due to
competitive hydrolysis of the imines (entries 3 and 4). Then,
our problem solving research was focused on the survey of
arylation conditions that give shorter reaction time to avoid
the hydrolysis.

Table 1 Scope and Limitation of Asymmetric Arylation of N-Dpp-
arylimines

<table>
<thead>
<tr>
<th>entry</th>
<th>Ar1</th>
<th>temp (°C)</th>
<th>yield ee (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2a</td>
<td>80-12</td>
<td>(S)-4b 96</td>
</tr>
<tr>
<td>2</td>
<td>2a</td>
<td>80-12</td>
<td>(S)-4c 92</td>
</tr>
<tr>
<td>3</td>
<td>2b</td>
<td>80-12</td>
<td>(R)-4b 79</td>
</tr>
<tr>
<td>4</td>
<td>2c</td>
<td>80-12</td>
<td>(R)-4c 10</td>
</tr>
<tr>
<td>5</td>
<td>2e</td>
<td>80-12</td>
<td>(R)-4c 45</td>
</tr>
<tr>
<td>6</td>
<td>2f</td>
<td>80-20</td>
<td>(R)-4b 0</td>
</tr>
</tbody>
</table>

Notes: The reaction was conducted with 1.67 equiv of (Ar3)BO; in the presence of 6.6 mol % of 1, and 6.0 mol % of the Rh(I) except entry 6.5 The ee was determined by chiral stationary phase HPLC analysis.6 See ref 4 for the microwave irradiation.7 Racemic phenyl(4-tolyl)methanol, aldehyde adduct, was obtained in 76% yield.

Microwave irradiation of a mixture of 2c and phenylboroxine 3a
at 220 °C for 10 min was apparently beneficial but not
satisfactory to give (R)-4c with 68% ee in improved 45% yield
(entry 5). A cyclic triolborate 3d failed to give an imine adduct (R)-4b but gave the corresponding racemic aldehyde adduct, phenyl(4-tolyl)methyl, in 76% yield (entry 6).

Finally, we found triphenylborane as a reactive phenylation
agent to give phenylated amines (R)-4b and (R)-4c with 93% ee each in 92% and 91% yields, respectively, without imine
hydrolysis. Herein, we report a catalytic asymmetric phenylation
of N-Dpp-arylimines 2 with triphenylborane. In contrast to the
widely used boronic reagents, triarylboranes have not been
utilized as an aryl source in asymmetric catalysis,7 although
of a mixture of triphenylborane and diethylzinc has been employed for in situ generation of diphenylzinc.7

When a mixture of 4-tolualdehyde N-Dpp-imine 2b and triphenylborane (1.67 equiv) was heated in propan-1-ol at
100 °C for 12 h in the presence of a catalytic amount of 1 (6.6 mol %) and acetylacetonatobis(ethylenediborane)(I) (6.0 mol %), the phenylated product (R)-4b with 81% ee was obtained in 63% yield (Table 2, entry 1). The reaction was then performed in the presence of KF because promotion of a
transmetallation process of organoboron reagents by fluoride
was described.8 The reactions with anhydrous KF and KF on
alumina resulted in less satisfactory 39% and 44% yields, and
60% and 81% enantioselectivity, respectively (entries 2 and 3). When the reaction was performed in the presence of KF on Celite, the reaction more smoothly proceeded to give (R)-4b with 89% ee in increased 72% yield (entry 4). A mixture of dioxane and
propanol4 was not suitable solvent for the reaction with
triphenylborane, and only a trace amount of the product was
produced (entry 5). Finally, tert-butanol was found to be the
choice to complete the reaction in only 1 h at 100 °C, giving (R)-
4b with 93% ee in 92% yield (entry 6).

Table 2 Survey of Reaction Conditions

<table>
<thead>
<tr>
<th>entry</th>
<th>Solvent</th>
<th>KF source</th>
<th>time (h)</th>
<th>yield (%)</th>
<th>ee (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PrOH</td>
<td>-</td>
<td>12</td>
<td>63</td>
<td>81</td>
</tr>
<tr>
<td>2</td>
<td>PrOH</td>
<td>KF</td>
<td>6</td>
<td>39</td>
<td>60</td>
</tr>
<tr>
<td>3</td>
<td>PrOH</td>
<td>KF/Al(O)</td>
<td>6</td>
<td>44</td>
<td>81</td>
</tr>
<tr>
<td>4</td>
<td>PrOH</td>
<td>KF/Celite</td>
<td>6</td>
<td>72</td>
<td>89</td>
</tr>
<tr>
<td>5</td>
<td>dioxane/PrOH (1:1)</td>
<td>KF/Celite</td>
<td>6</td>
<td>&lt;5</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>t-BuOH</td>
<td>KF/Celite</td>
<td>1</td>
<td>92</td>
<td>93</td>
</tr>
</tbody>
</table>

* The reaction was conducted with 1.67 equiv of Ph3B in the presence of 2.0 equiv of the indicated KF source, 6.6 mol % of 1, and 6.0 mol % of Rh(acac)2(C6H5)3.8 The ee was determined by chiral stationary phase HPLC analysis.
This asymmetric phenylation with triphenylborane was applicable to other N-Dpp-arylimines 2 (Table 3). Phenylation of 3-tolylinine 2d gave the corresponding 4d with high 90% ee in high 92% yield (entry 2). Electron-deficient 4-chlorobenzaldimine 2f bearing a chlorine atom was converted to 4f with 92% ee in 91% yield (entry 4). Although the reaction of sterically demanding ortho-substituted arylimines 2e and 2g was slower, the reaction proceeded in highly enantiomeric manner to give 4e and 4g with 90% ee and 93% ee in 86% and 84% yield, respectively (entries 3 and 5). It is noteworthy that the reaction of 4-methoxybenzaldimine 2c, a versatile starting point for this study (Table 1, entry 4), also successfully proceeded for 12 h to give 4c with 93% ee in 91% yield (entry 6). Polyaromatic 2-naphthalaldimine 2h and heteroaromatic 2-furancarboaldimine 2i were also good substrates to give 4h and 4i with 90% and 91% ee in 94% and 86% yield, respectively (entries 7 and 8).

Table 3 Catalytic Asymmetric Phenylation of N-Dpp-arylimines 2 with Triphenylborane

<table>
<thead>
<tr>
<th>entry</th>
<th>Ar</th>
<th>time (h)</th>
<th>yield (%)</th>
<th>ee (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3-MeC₆H₄</td>
<td>1</td>
<td>92</td>
<td>93</td>
</tr>
<tr>
<td>2</td>
<td>3-MeC₆H₄</td>
<td>1</td>
<td>92</td>
<td>96</td>
</tr>
<tr>
<td>3</td>
<td>2-PrC₆H₄</td>
<td>10</td>
<td>86</td>
<td>90</td>
</tr>
<tr>
<td>4</td>
<td>4-ClC₆H₄</td>
<td>1</td>
<td>91</td>
<td>92</td>
</tr>
<tr>
<td>5</td>
<td>2-ClC₆H₄</td>
<td>10</td>
<td>84</td>
<td>93</td>
</tr>
<tr>
<td>6</td>
<td>4-ClC₆H₄</td>
<td>12</td>
<td>91</td>
<td>93</td>
</tr>
<tr>
<td>7</td>
<td>2-naphthyl</td>
<td>1</td>
<td>94</td>
<td>90</td>
</tr>
<tr>
<td>8</td>
<td>2-furyl</td>
<td>1</td>
<td>86</td>
<td>91</td>
</tr>
</tbody>
</table>

* The reaction was conducted with 1.67 equiv of Ph₃B in the presence of 2.0 equiv of KF/Celite, 6.6 mol % of I, and 6.0 mol % of the Rh(I).
* The ee was determined by chiral stationary phase HPLC analysis.
* Entry 6 of Table 2 is presented for comparison.

In conclusion, we have developed a widely applicable chiral amidomonophosphine–rhodium-catalyzed enantioselective phenylation of aryl-N-Dpp- imines with triphenylborane. The results clearly indicate the utility of triarylborane in avoiding in situ water generation. Because a Dpp group is cleaved under milder acidic conditions than a Boc group, this reaction provides a versatile methodology to access a variety type of optically active diarylmethanines.

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Notes and references

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† Electronic Supplementary Information (ESI) available: experimental details, analytical, and spectral characterization data of the products. See DOI: 10.1039/b000000x/
‡ General procedure of the catalytic asymmetric phenylation: Under argon atmosphere, a round-bottom flask was charged with Rh(acac)(C₆H₆) (3.1 mg, 0.012 mmol), I (6.5 mg, 0.013 mmol), 2 (0.200 mmol), triphenylborane (0.334 mmol), and 50% KF on celite (40 mg). To the flask was added t-BuOH (0.5 mL), and the mixture was stirred at 100 °C. After the indicated reaction time, the mixture was diluted with AcOEt, washed with brine, dried over Na₂SO₄, and then concentrated. The resulting residue was purified through silica gel column chromatography.