Introduction

During the last decade the general point of view towards allenes changed from chemical curiosities to powerful intermediates in the target oriented synthesis\(^1\). Especially α-oxiranylsilanes came into the focus because they can not only be cycled under anisio-to-center chirality transfer into 2,3-dihydrofuranes\(^2\), a motif that can be found in an abundance of natural products, but also converted under Mitsunobu-conditions into α-amine- and α-diolamines and their derivatives\(^3\).

An elegant access to the required α-oxiranylsilanes relies upon the Sn-2\(^{\prime}\) opening reaction of propargylic epoxides with organometallic compounds, and in particular with organocuprates.

Although even functionalized Grignard-reagents which are transmetalated into the desired Gilman-caprates can be used in the construction of complex α-oxiranylsilanes\(^4\) the corresponding CuI-mediated or catalyzed delivery of hydride had remained undereveloped. Based on a work of Stryker\(^5\) we have established an unprecedented, mild and efficient copper-catalyzed diastereoselective Sn-2\(^{\prime}\)-reduction of propargyl oxiranes which provides, via hydrosilylation, a highly selective route to α-oxiranylsilanes bearing various functional groups (ethers, esters, alcohols, etc.).

Results

Since the early works of Stryker copper-hydride chemistry usually used for 1,2- and 1,4-reductions\(^6\) has evolved and besides tributyl phosphines N-Heterocyclic carbens (NHC)\(^7\) are frequently used for stabilizing the α-si prepared CuI-species. These catalytic systems show usually a much higher reactivity than the so-called Stryker’s reagent itself.

During optimization studies (Scheme 1) towards application in the Sn-2\(^{\prime}\)-substitution, best results were obtained by using the most frequently used combination of NaO\(_{Bu}\) and CuCl\(_{2}\) generating in situ CuH\(_{Bu}\) which is converted into the reactive CuI-species. As stabilizing ligands, the NHC precursors, the so-called Blues system L\(_2\) developed by Glorius and co-workers\(^8\) and imidazolium salt SiMes\(_2\) L\(_2\) which are both easily available in multi-gram scale\(^9\) yielded the α-oxiranylsilanes in good yields under excellent center-to-axis chirality transfer while other precursors showed lower diastereoselectivities or yield.

In all cases PMHS was used for generating the active copper-catalyst. If other silanes like TMDS or (EtO)\(_3\)SiH are used, no complete conversion or lower selectivities are detected. Encouraged by this we synthesized next a variety of functionalized propargylic oxiranes by epoxy acrylidy addition to several ketones leading to a variety of oxiranes bearing different functionalities like enynes, ethers or acetoacetates (Table 2)\(^10\).

We were delighted to observe a tremendous functional group tolerance towards enynes (entries 4, 5), ether (entry 4), chloride (entries 1, 2), propargyl alcohol (entries 3), CF\(_3\) groups (entries 6). Furthermore, the presence of primary alkyl- (entries 1, 2, 3) or tertiary hydroxy groups (entries 3-7) also allows a complete and diastereoselective Sn-2\(^{\prime}\)-reduction of the propargyl oxirane without noticeable hydrolysis of the silane or the copper hydride species.

Table 1. copper-catalyzed Sn-2\(^{\prime}\)-reduction

<table>
<thead>
<tr>
<th>Entry</th>
<th>Oxirane</th>
<th>L</th>
<th>T (°C)</th>
<th>Yield (%)</th>
<th>dS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>L2</td>
<td>15</td>
<td>0 – 20</td>
<td>81</td>
<td>&gt;95 : 5</td>
</tr>
<tr>
<td>2</td>
<td>L1</td>
<td>0.5</td>
<td>0</td>
<td>86</td>
<td>&gt;95 : 5</td>
</tr>
<tr>
<td>3</td>
<td>L1</td>
<td>1</td>
<td>0</td>
<td>77</td>
<td>&gt;95 : 5</td>
</tr>
<tr>
<td>4</td>
<td>L1</td>
<td>1</td>
<td>0</td>
<td>77</td>
<td>&gt;95 : 5</td>
</tr>
<tr>
<td>5</td>
<td>L2</td>
<td>1</td>
<td>0</td>
<td>84</td>
<td>86 : 14</td>
</tr>
<tr>
<td>6</td>
<td>L1</td>
<td>1</td>
<td>0</td>
<td>69</td>
<td>&gt;95 : 5</td>
</tr>
<tr>
<td>7</td>
<td>L1</td>
<td>1</td>
<td>0</td>
<td>70</td>
<td>&gt;95 : 5</td>
</tr>
</tbody>
</table>

Reaction conditions: CuCl (3 mol%), NaO\(_{Bu}\) (9 mol%), 3 % Ligand, 3 % Cu-Source, t-BuOH, RT, 30 h.

Indirect proof for the diminished 1,2-selectivities following the hydrometalation-protonmetalation pathway was found by adding tert-BuOH to the reaction mixture (Scheme 2).

While the enyne reaction conditions furnished the desired allene 2 in good yields and moderate selectivities, addition of the alcohol not only increased the selectivity but also lead to a byproduct, the α-alkoxyallenes 3 obviously the result of a hydrocupration\(^11\).

References

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