Phosphomolybdic Acid Supported on Silica Gel as an Efficient and Reusable Catalyst for Cyanosilylation of Aldehydes

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Phosphomolybdic acid supported on silica gel (PMA-SiO₂) is an efficient catalyst for the activation of TMSCN for the facile cyanosilylation of various aldehydes. Cyano transfer from TMSCN to aldehyde proceeds smoothly at rt in presence of 0.8 mol % of PMA-SiO₂ leading to a range of cyanosilylether in excellent yield (mostly over 93%) within short reaction time (30 min). The catalyst can be recovered and reused several times without loss of activity.

Key Words : PMA-SiO₂, Heterogeneous catalysis, Cyanosilylation, Aldehydes

Introduction

Cyanosilylation of carbonyl compound is an efficient procedure for synthesis of silylated cyanohydrins. Cyano hydrins represents one of the most valuable synthon that can be elaborated into a variety of useful synthetic building blocks, such as α-hydroxy acids, α-hydroxy aldehyde, 1,2-diols, α-amino alcohol. Because of their importance in organic synthesis and life science, a large body of work has been devoted to the development of synthesis of cyanohydrin. One of the most common methods to prepare cyanohydrin involves the cyanosilylation of carbonyl compound using TMSCN (trimethylsilyl cyanide). Transfer of cyano group from TMSCN to carbonyl compound can be catalyzed by plethora of reagents, including Lewis acids, Lewis base, metal alkoxide, bifunctional catalyst and inorganic salts. Our group has developed numerous chiral and achiral catalytic systems for the cyanosilylation of carbonyl compound. Phosphomolybdic acid belongs to the class of heteropolyacids (HPA). HPA are several times stronger than H₂SO₄, TsOH, BF₃·Et₂O and ZnCl₂. This makes it possible to carry out reaction in low concentration and lower temperature. Synthetically a variety of method has been developed and commercialized using HPA as catalys. For example oxidation of alcohol, Fries rearrangement of phenyl acetate, regioselective ring opening of aziridines, chemoselective deprotection of isopropylidene acetals and hydrolysis of tert-butyldimethylsilyl ether have been reported with HPA.

Results and Discussion

In continuation of our efforts to explore the synthetic utility of phosphomolybdic acid, we report herein cyanosilylation of aldehydes with TMSCN using 0.8 mol% of phosphomolybdic acid supported on silica gel. Anisaldehyde (1 mmol) reacts with TMSCN (1.2 mmol) at rt in presence of 0.8 mol % of PMA-SiO₂ to give 97% yield within 10 min. Accordingly we further examine the structurally diverse aldehydes like aliphatic, aromatic and heterocyclic aldehydes. Aromatic aldehydes with electron-donating groups such as anisaldehyde, p-toluyldehyde and 2-hydroxy-4-methoxy benzaldehyde produce 97, 91 and 94% yield, respectively (entries 1, 2 and 3). Naphthaldehyde gave the corresponding silylether in excellent yield (entry 6). The effect of substituent on aromatic ring plays very important role in cyanosilylation. Even unsubstituted benzaldehyde gives no...
Butyraldehyde and hexanal give 95 and 90% of yield in 8 aldehyde requires longer reaction time (23 min) with less and 16 min, respectively (entries 11 and 12). But isobutyraliphatic aldehydes were silylated in good to high yield. yield within 15 min (entry 7). Aliphatic and branched 82% yield in 28 min (entry 10). Cinnamaldehyde gives 97% branched citral is smoothly converted to cyanosilylether in produces 64% yield within 35 min (entry 5). Unsaturated drawing chlorine substituent only 2-chlorobenzaldehyde even after overnight reaction. Among all the electron-with- hyde are also unable to yield corresponding cyanosilylether product. Trifluoro-

Table 1

<table>
<thead>
<tr>
<th>Entry</th>
<th>Substrate</th>
<th>Product</th>
<th>Time (min)</th>
<th>Yield (%)</th>
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<tbody>
<tr>
<td>1</td>
<td>4-Me-C6H5CHO</td>
<td>3a</td>
<td>10</td>
<td>97</td>
</tr>
<tr>
<td>2</td>
<td>4-Me-C6H5CHO</td>
<td>3b</td>
<td>12</td>
<td>91</td>
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<tr>
<td>3</td>
<td>4-Me-2-OHC6H3CHO</td>
<td>3c</td>
<td>10</td>
<td>94</td>
</tr>
<tr>
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<td>3-Oph-C6H5CHO</td>
<td>3d</td>
<td>18</td>
<td>88</td>
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<tr>
<td>5</td>
<td>2-Cl-C6H5CHO</td>
<td>3e</td>
<td>35</td>
<td>64</td>
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<tr>
<td>6</td>
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<td>8</td>
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<tr>
<td>7</td>
<td>C6H5CH=CHCHO</td>
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<td>15</td>
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<tr>
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<td>C6H11CHO</td>
<td>3h</td>
<td>5</td>
<td>98</td>
</tr>
<tr>
<td>9</td>
<td>(Me)2-C6H5CHO</td>
<td>3i</td>
<td>23</td>
<td>77</td>
</tr>
<tr>
<td>10</td>
<td>(Me)2CHCHCH2CH(Me)-CH3CHO</td>
<td>3j</td>
<td>28</td>
<td>82</td>
</tr>
<tr>
<td>11</td>
<td>Me(CH2)2CHO</td>
<td>3k</td>
<td>8</td>
<td>95</td>
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<tr>
<td>12</td>
<td>Me(CH3)2CHO</td>
<td>3l</td>
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<td>90</td>
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<tr>
<td>15</td>
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<td>3o</td>
<td>3</td>
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<tr>
<td>16</td>
<td>C4H4OCHO</td>
<td>3p</td>
<td>12</td>
<td>NR</td>
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Table 2

<table>
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<tr>
<th>No</th>
<th>Number of cycles</th>
<th>Time (min)</th>
<th>Yield (%)</th>
</tr>
</thead>
<tbody>
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<td>95</td>
</tr>
<tr>
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<td>24</td>
<td>94</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>45</td>
<td>94</td>
</tr>
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</table>

We have described a simple, convenient and efficient protocol for the cyanosilylation of aldehydes using a phosphomolybdic acid supported on silica gel as reusable cata-

Conclusion

Experimental

1H NMR (200 MHz) spectra were recorded with Varian Gemini 2000 spectrometer. Chemical shifts are reported in CDCL3 with tetramethylsilane as an internal standard. 13C NMR data were collected on a Varian Gemini 400 spectrometer (100 MHz). Some compounds are also identified by HRMS (EI+) by Jeol DMX.

Spectroscopic data for selected compounds.

1H NMR (200 MHz) spectra were recorded with Varian Gemini 2000 spectrometer. Chemical shifts are reported in CDCl3 with tetramethylsilane as an internal standard. 13C NMR data were collected on a Varian Gemini 400 spectrometer (100 MHz). Some compounds are also identified by HRMS (EI+) by Jeol DMX.

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(d, 1H), 9.24 (s, 1H). $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta = -0.199$, 55.33, 58.87, 104.90, 1.63, 119.49, 128.85, 153.084, 160.11.

(E)-4-Phenyl-2-(trimethylsiloxy)but-3-enenitrile (entry 7): $^1$H NMR (200 MHz, CDCl$_3$) $\delta = 0.25$ (s, 9H), 5.10-5.12 (d, 1H), 6.19-6.2 (d, 1H), 6.79-6.8 (d, 1H) 7.35-7.39 (m, 5H).

$^{13}$C NMR (100 MHz, CDCl$_3$): $\delta = -0.02$, 62.34, 118.48, 127.07, 128.45, 128.84, 128.89, 134.08, 135.16. HRMS (EI): m/z [M+H]$^+$ calcd. for C$_{15}$H$_{17}$NOSi : 231.1075; found: 231.1075.

1H NMR (200 MHz, CDCl$_3$): $\delta = 0.21$ (s, 9H), 1.60-2.12 (m, 7H), 4.23-4.27 (m, 1H), 5.70 (s, 2H). $^{13}$C NMR (100 MHz, CDCl$_3$): $\delta = 23.93, 24.49, 26.80, 39.20, 55.33, 58.87, 104.90, 1.63, 119.49, 128.85, 153.084, 160.11.

2-(Cyclohex-3-enyl)-2-(trimethylsiloxy)acetonitrle (entry 13): $^1$H NMR (200 MHz, CDCl$_3$): $\delta = 23.93, 24.49, 26.80, 39.20, 55.33, 58.87, 104.90, 1.63, 119.49, 128.85, 153.084, 160.11.

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