Palladium-Catalyzed Ring-Opening Thiocarbonylation of Vinylcyclopropanes with Thiols and Carbon Monoxide

Chang-Feng Li, Wen-Jing Xiao, and Howard Alper

*J. Org. Chem.*, 2009, 74 (2), 888-890 • DOI: 10.1021/jo801725j • Publication Date (Web): 02 December 2008

Downloaded from http://pubs.acs.org on March 2, 2009

More About This Article

Additional resources and features associated with this article are available within the HTML version:

- Supporting Information
- Links to the 1 articles that cite this article, as of the time of this article download
- Access to high resolution figures
- Links to articles and content related to this article
- Copyright permission to reproduce figures and/or text from this article

View the Full Text HTML
Palladium-Catalyzed Ring-Opening Thio carbonylation of Vinylcyclopropanes with Thiols and Carbon Monoxide

Chang-Feng Li,†,‡ Wen-Jing Xiao,*,‡ and Howard Alper*,†

Centre for Catalysis Research and Innovation, Department of Chemistry, University of Ottawa, 10 Marie Curie, Ottawa, Ontario K1N 6N5, Canada, and The Key Laboratory of Pesticide & Chemical Biology, Ministry of Education, College of Chemistry, Central China Normal University, 152 Luoyu Road, Wuhan, Hubei 430079, China

howard.alper@uottawa.ca; wxiao@mail.ccnu.edu.cn

Received August 10, 2008

Palladium-catalyzed ring-opening thio carbonylation of vinylcyclopropanes (VCPs) with thiols and carbon monoxide affords the corresponding unsaturated thiocarbonylates in moderate to excellent yields. This reaction provides a general method for the ring-opening thio carbonylation of VCPs. It further demonstrates the utility of transition metal catalysts for the synthesis of organosulfur compounds.

Transition-metal-catalyzed carbonylation is widely recognized as one of the most important carbonyl-forming reactions in organic synthesis.1 Formation of a thiocarbonyl unit and employing organosulfur compounds, especially thiols and thiophenols, as a direct substrate represents a challenging subject in transition-metal-catalyzed reactions. We and others have investigated some interesting transformations employing organosulfur compounds as substrates.2 Those results and others such as thiolation,3 thiolysis,4 thio phosphorylation,5 thi oesterification,6 thio propargylation,7 and carbothiolation8 of unsaturated compounds developed in the past few years have corrected the widely accepted concept that “sulfur compounds are poisons to transition metal catalysts.”9 The chemistry of vinylcyclopropanes (VCPs) has attracted interest in synthetic chemistry.10 Containing an olefinic moiety and a cyclopropane ring, these species demonstrate high reactivity. The ring opening of VCPs can be catalyzed by complexes of transition metal catalysts such as those containing palladium, rhodium, zirconium, chromium, nickel, and gold.11 However, there are no reports of the ring-opening thio carbonylation of VCPs. We previously demonstrated that palladium complexes can catalyze thio carbonylation reactions of unsaturated species for the synthesis of unsaturated thio esters.12 We now report a novel palladium-catalyzed ring-opening thio carbonylation reaction of VCPs with thiols and carbon monoxide to give a new class of unsaturated thio esters.

The palladium-catalyzed reaction of 1,1-dimethoxycarbonyl 2-vinylcyclopropane (1a) with thiophenol (2a) and carbon monoxide was chosen as a model reaction to determine the


TABLE 1. Ring-Opening Thiocarbonylation of 1,1-Dimethoxy carbonyl 2-Vinylcyclopropane (1a) with Thiophenol (2a) under Various Conditions

<table>
<thead>
<tr>
<th></th>
<th>Pd(OAc)2/dppb</th>
<th>CH2Cl2</th>
<th>48</th>
<th>22</th>
<th>53</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pd(OAc)2/dppp</td>
<td>CH2Cl2</td>
<td>72</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>Pd(OAc)2/Cy3P</td>
<td>CH2Cl2</td>
<td>48</td>
<td>25</td>
<td>77</td>
</tr>
<tr>
<td>3</td>
<td>Pd(OAc)2/Bu3P</td>
<td>CH2Cl2</td>
<td>48</td>
<td>31</td>
<td>31</td>
</tr>
<tr>
<td>4</td>
<td>Pd(OAc)2/PPh3</td>
<td>CH2Cl2</td>
<td>48</td>
<td>77</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>Pd(OAc)2/PPh3</td>
<td>CH3CN</td>
<td>72</td>
<td>70</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>Pd(PPh3)4/PPh3</td>
<td>CH2Cl2</td>
<td>48</td>
<td>46</td>
<td>9</td>
</tr>
<tr>
<td>7</td>
<td>RhCl(PPh3)3/PPh3</td>
<td>CH2Cl2</td>
<td>48</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>8</td>
<td>RhCl(PPh3)3/PPh3</td>
<td>CH2Cl2</td>
<td>48</td>
<td>0</td>
<td>trace</td>
</tr>
<tr>
<td>9</td>
<td>Pd(OAc)2</td>
<td>CH2Cl2</td>
<td>48</td>
<td>0</td>
<td>trace</td>
</tr>
<tr>
<td>10</td>
<td>Pd(OAc)2/PPh3</td>
<td>THF</td>
<td>48</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td>11</td>
<td>Pd(OAc)2/PPh3</td>
<td>toluene</td>
<td>48</td>
<td>56</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>Pd(OAc)2/PPh3</td>
<td>CH3CN</td>
<td>48</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>13</td>
<td>Pd(OAc)2/PPh3</td>
<td>Et3O</td>
<td>48</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>14</td>
<td>Pd(OAc)2/PPh3</td>
<td>CH2Cl2</td>
<td>48</td>
<td>41</td>
<td>15</td>
</tr>
</tbody>
</table>

* Reaction conditions: 1,1-dimethoxy carbonyl 2-vinyl cyclopropane (1a. 2 mmol), thiophenol (2a. 1 mmol), catalyst (0.05 mmol), PPh3 (22.5 mol %, if used), 400 psi of CO, solvent (5 mL).  4a Isolated yield. 4b 1 equiv of Pd(OAc)2/ PPh3 was used. The thiocarbonylation reactions of a series of diastereomeric mixtures of VCPs (1b–h) with thiols (2a–h) were performed by using 5 mol % of Pd(OAc)2 and 22.5 mol % of PPh3 in CH2Cl2 (5 mL per 1 mmol of thiol) at 400 or 600 psi of carbon monoxide for 48–120 h at 100 °C, and the results are summarized in Table 2. In most cases, the thiocarbonylation was accompanied with the isomerization process to the conjugated thioester in some extent (Table 2, entries 2–5 and 7–13). The thiophenols were found to work more effectively than alkyl thiols. For examples, 1a reacted with thiophenol (2a), viability of the process and the optimum reaction conditions (Table 1). A series of reactions between 1a and 2a were carried out under various conditions. It was shown that Pd(OAc)2 with PPh3 was the best catalyst system among those examined, and the reaction proceeded efficiently in dichloromethane (Table 1, entry 5). Using Pd(OAc)2 without any ligand gave only a trace amount of the nucleophilic addition product (Table 1, entry 9). This product arises by using 1 equiv of 1a, while the thiocarbonylated product was also formed in lower yield (Table 1, entries 5 vs 14). In accord with our observation,12b,e,f,i the sulfide 4a can be suppressed by employing excess VCPs (e.g., 2 equiv relative to thiol(s)). Pd(PPh3)3 with PPh3 is also a good catalytic system for this reaction (Table 1, entry 6). However, other catalyst systems, such as Pd(dba)·CHCl3 and RhCl(PPh3)3 with PPh3, were ineffective in this reaction (Table 1, entries 1 and 8). The nature of the solvent strongly affected the yield of β,γ-unsaturated thioester 3a in this reaction. With the Pd(OAc)2/P Ph3 catalyst system, the reaction works well at 100 °C in CH2Cl2 and was completed in 48 h to form the pure β,γ-unsaturated thioester.

The thiocarbonylation reactions of a series of diastereomeric mixtures of VCPs (1a–h) with thiols (2a–h) were performed by using 5 mol % of Pd(OAc)2 and 22.5 mol % of PPh3 in CH2Cl2 (5 mL per 1 mmol of thiol) at 400 or 600 psi of CO, solvent (5 mL). Isolated yield. 4a 1 equiv of Pd(OAc)2/ PPh3 was used. The thiocarbonylation reactions of a series of diastereomeric mixtures of VCPs (1a–h) with thiols (2a–h) were performed by using 5 mol % of Pd(OAc)2 and 22.5 mol % of PPh3 in CH2Cl2 (5 mL per 1 mmol of thiol) at 400 or 600 psi of carbon monoxide for 48–120 h at 100 °C, and the results are summarized in Table 2. In most cases, the thiocarbonylation was accompanied with the isomerization process to the conjugated thioester in some extent (Table 2, entries 2–5 and 7–13). The thiophenols were found to work more effectively than alkyl thiols. For examples, 1a reacted with thiophenol (2a), p-bromobenzenethiol (2b), and p-chlorobenzenethiol (2c), affording the ring-opening carbonylated products in good to excellent yields (Table 2, entries 1–3), while the corresponding reaction with alkane thiol gave the carbonylated products in moderate yields (Table 2, entries 6 and 7). Reactions involving alkylthiols took longer to complete than those with arylthiols. The reactivity of the reaction was rather sensitive to both the acidity (electronic factor) and the bulkiness (steric factors) of the thiol. For example, 2d (p-methylbenzenethiol), an arylthiol with an electron-donating p-methyl group, and 2b (p-bromobenzenethiol), an arylthiol with an electron-withdrawing group, show different behavior in this reaction. Using 2d as the substrate gives a mixture of 3d and 3′d (3d/3′d = 8:1, 77% yield) and 4d (9% yield) (Table 2, entry 4), whereas 2b gives only the carbonylative product in 88% yield (3b/3′b = 11:1)
SCHEME 1. Proposed Reaction Pathway


