

## Highly Regioselective Hydrothiocarboxylation of Acetylenes with Carbon Monoxide and Thiols Catalyzed by Pt(PPh<sub>3</sub>)<sub>4</sub>

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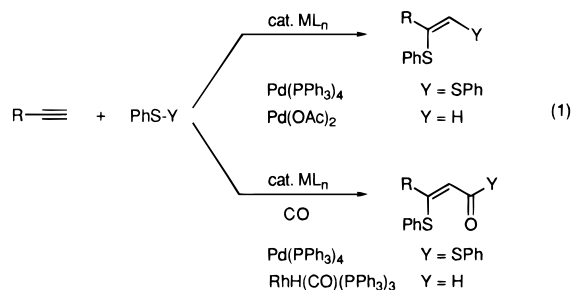
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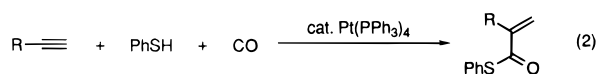
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For the last two decades, the utility of transition metal catalysts for effecting a wide range of synthetic transformations using heteroatom compounds such as organic silicon, tin, and boron compounds has been established.<sup>1</sup> Nonetheless, use of transition metal catalysts for synthetic reactions of organic sulfur compounds has remained largely unexplored,<sup>2</sup> partly because of the widespread prejudice that sulfur compounds often bind strongly to the catalysts, thus poisoning them and making the catalytic reactions ineffective. On the contrary, we have recently developed a series of transition-metal-catalyzed addition and carbonylative addition reactions of organic disulfides and thiols to acetylenes (eq 1).<sup>3</sup> These novel reactions clearly demonstrate

the efficacy of the transition metal catalysts in synthetic reactions of organic sulfur compounds.



In transition-metal-catalyzed addition and related reactions, controlling regiochemistry, as well as stereochemistry, is always of great importance. As previously reported,<sup>3c</sup> the RhH(CO)-(PPh<sub>3</sub>)<sub>3</sub>-catalyzed thioformylation reaction of acetylenes with PhSH and CO (Y = H in eq 1) exhibits the excellent regioselectivity where carbon monoxide and phenylthio group are introduced selectively into the terminal and internal positions of acetylenes, respectively. Herein, we report an interesting finding that *switching the catalyst simply from RhH(CO)(PPh<sub>3</sub>)<sub>3</sub> to Pt(PPh<sub>3</sub>)<sub>4</sub> leads to a sharp reversal of regioselectivity of CO introduction* (eq 2).



Since thiols are known to add oxidatively to platinum(0) complex forming platinum hydride complex bearing a sulfide ligand,<sup>4</sup> we investigated in detail the reactions between thiols, acetylenes, and carbon monoxide in the presence of platinum(0) catalysts. Surprisingly dramatic changeover of the regioselectivity of CO introduction was observed, and a novel “hydrothiocarboxylation” of acetylenes (that a hydride and a thiocarboxyl group are introduced into the terminal and internal positions of acetylenes, respectively) was found to take place successfully (entry 1 in Table 1).<sup>5</sup> The hydrothiocarboxylation product (**3a**), which has an α,β-unsaturated carbonyl unit, is subject to conjugate addition of PhSH, giving **4a** concomitantly. However, the use of excess acetylene afforded **3a** predominantly (entry 3). On the other hand, the reaction using excess thiol gave rise to **4a** exclusively (entry 4). Cobalt complexes such as Co<sub>2</sub>(CO)<sub>8</sub> and CoCl(PPh<sub>3</sub>)<sub>3</sub> also exhibited the catalytic activity toward the “hydrothiocarboxylation”, but the reaction was accompanied by the formation of unidentified byproducts (entries 5 and 6). As mentioned in our previous paper, palladium catalysts bearing phosphine ligands, such as Pd(PPh<sub>3</sub>)<sub>4</sub> and PdCl<sub>2</sub>(PPh<sub>3</sub>)<sub>2</sub>, resulted in the formation of a complex mixture, which, however, included a regioisomeric mixture of the hydrothiocarboxylation products (1- and 2-(phenylthiocarbonyl)-1-octene was obtained in 10 and 15% yields, respectively).<sup>3c</sup>

Table 2 lists the representative results of the Pt(PPh<sub>3</sub>)<sub>4</sub>-catalyzed hydrothiocarboxylation using several thiols and terminal acetylenes.<sup>6</sup> The procedure for this hydrothiocarboxy-

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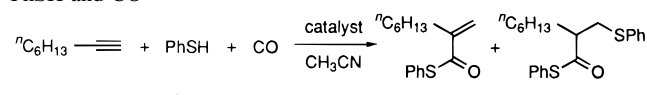
(6) The general procedure for the hydrothiocarboxylation of acetylenes with thiols and carbon monoxide is as follows: In a 50 mL stainless steel autoclave with a magnetic stirring bar under argon atmosphere were placed Pt(PPh<sub>3</sub>)<sub>4</sub> (3 mol%), acetonitrile (5 mL), acetylene (5 mmol), and cyclohexanethiol (5 mmol). Carbon monoxide was purged three times and then changed at 30 atm. The reaction was conducted with magnetic stirring for 2 h upon heating at 120 °C. After the carbon monoxide was purged, the resulting mixture was filtered through Celite and concentrated in vacuo. Purification of the product was carried out by MPLC (silica gel, 25–40 μm, length 310 mm, i.d. 25 mm, eluent hexane:Et<sub>2</sub>O = 4:1).

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**Table 1.** Regioselective Hydrothiocarboxylation of 1-Octyne with PhSH and CO<sup>a</sup>


entry	catalyst	molar ratio of 1a/2a	temp °C	time h	yield, % <sup>b</sup>	3a	4a
1	Pt(PPh <sub>3</sub> ) <sub>4</sub>	1.5	120	15	60	14	—
2	Pt(PPh <sub>3</sub> ) <sub>4</sub>	3.5	120	15	71	6	—
3	Pt(PPh <sub>3</sub> ) <sub>4</sub>	5.5	120	1	83	—	—
4	Pt(PPh <sub>3</sub> ) <sub>4</sub>	0.5 <sup>c</sup>	120	15	—	—	77
5	Co <sub>2</sub> (CO) <sub>8</sub>	1.0	100	15	39	—	—
6	CoCl(PPh <sub>3</sub> ) <sub>3</sub>	1.0	100	15	23	—	—

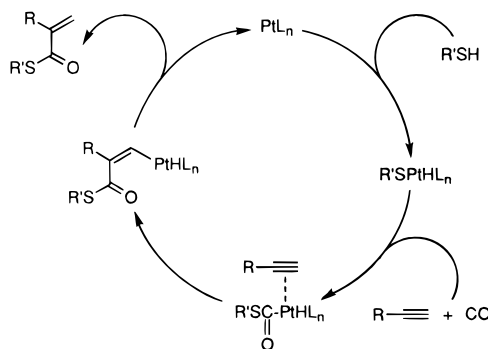
<sup>a</sup>Reaction conditions: PhSH (5 mmol), catalyst (3 mol%), CO (30 atm), CH<sub>3</sub>CN (5 mL). <sup>b</sup>Based on benzenethiol employed. <sup>c</sup>1-Octyne (5 mmol), PhSH (10 mmol).

**Table 2.** Pt(0)-Catalyzed Hydrothiocarboxylation of Acetylenes<sup>a</sup>

entry	acetylene	thiol	molar ratio of 1/2	product	yield, % <sup>b</sup>
1	<sup>n</sup> C <sub>6</sub> H <sub>13</sub> -C≡CH (1a)	<i>p</i> -X-C <sub>6</sub> H <sub>4</sub> SH (2b, X = MeO)	7.5	<sup>n</sup> C <sub>6</sub> H <sub>13</sub> -C(=O)-CH=CH-C <sub>6</sub> H <sub>4</sub> X (3a')	86
2	1a	2c (X = F)	7.5	3a''	61
3	1b	PhSH (2a)	7.5	3b	70
4	1c	7.5	3c	75	
5	1d	7.5	3d	63	
6	1a	<sup>n</sup> C <sub>8</sub> H <sub>17</sub> SH (2b)	7.5	3e	87
7	1a	cyclohexanethiol (2c)	7.5	3f	94
8	1a	0.5 <sup>c</sup>	3f	99	
9	1a	1.0	3f	99	
10	1b	1.0	3g	87	
11	1c	1.0	3h	82	
12	1e	1.0	3i	62	

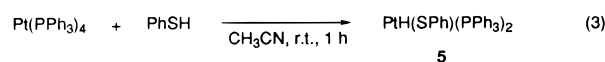
<sup>a</sup>Reaction conditions: PhSH (5 mmol), CO (30 atm), Pt(PPh<sub>3</sub>)<sub>4</sub> (3 mol%), CH<sub>3</sub>CN (5 mL), 120 °C, 1–7 h. <sup>b</sup>Based on the thiols employed. <sup>c</sup>1-Octyne (5 mmol), cyclohexanethiol (10 mmol).

lation can be employed with a variety of aromatic and aliphatic thiols, giving the corresponding  $\alpha,\beta$ -unsaturated thioesters regioselectively in good to excellent yields (entries 1–12). In particular, the hydrothiocarboxylation with aliphatic thiols proceeded smoothly without using excess amounts of acetylenes (entries 8–12). For aromatic thiols, the higher acidity of aromatic thiols (compared with aliphatic ones) probably causes

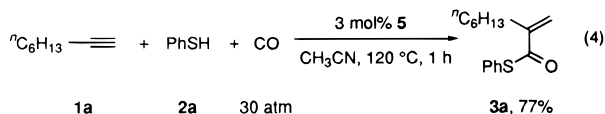
**Scheme 1.** A Possible Pathway for Hydrothiocarboxylation

the competitive conjugate addition of thiols to  $\alpha,\beta$ -unsaturated thioesters.

To explore the reaction pathway of this hydrothiocarboxylation, stoichiometric reaction of the platinum(0) complex with benzenethiol was examined. The equimolar reaction of Pt(PPh<sub>3</sub>)<sub>4</sub> with PhSH at 20 °C in acetonitrile under argon atmosphere afforded a yellow solid, the measurement of melting point and <sup>1</sup>H NMR of which indicates unambiguously that the formed complex is identified with *trans*-PtH(SPh)(PPh<sub>3</sub>)<sub>2</sub> (5) reported in the literature<sup>4</sup> (eq 3). The catalytic reaction of 1-octyne with benzenethiol and CO in the presence of 3 mol% of complex 5 afforded the hydrothiocarboxylation product 3a in good yield (eq 4). Although elucidation of the precise



<sup>1</sup>H NMR (CDCl<sub>3</sub>)  $\delta$  -10.01 (Pt-H)  
 $J_{\text{Pt-H}} = 961 \text{ Hz}$ ;  $J_{\text{P-H}} = 14.0 \text{ Hz}$



mechanism requires further detailed investigation, a possible reaction pathway for this hydrothiocarboxylation may include CO insertion to the Pt–S bond of complex 5, followed by regioselective acylplatinumation of acetylene and reductive elimination of the product, as shown in Scheme 1.<sup>7</sup>

In summary, we have developed a highly selective hydrothiocarboxylation of acetylenes with thiols and CO. From the same starting materials (acetylene, thiol, and CO), therefore, two types of reactions, *i.e.*, “hydrothiocarboxylation” and “thioformylation”, can be selected only by changing the catalysts, *i.e.*, Pt(PPh<sub>3</sub>)<sub>4</sub> and RhH(CO)(PPh<sub>3</sub>)<sub>3</sub>, respectively. We are currently examining application of this methodology to a variety of different classes of substrates.

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**Supporting Information Available:** Experimental details and spectral and analytical data (5 pages). See any current masthead page for ordering and Internet access instructions.

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