Pergamon

Tetrahedron Letters 40 (1999) 7811–7814

TETRAHEDRON
LETTERS

Rhodium-catalyzed carbonylation of alkynes in the presence of alcohols: selective synthesis of 3-alkoxycarbonylindanones

Eiji Yoneda, Takayuki Kaneko, Shi-Wei Zhang, Kiyotaka Onitsuka and Shigetoshi Takahashi *
The Institute of Scientific and Industrial Research, Osaka University, Mihogaoka, Ibaraki, Osaka 567-0047, Japan

Received 2 July 1999; revised 18 August 1999; accepted 20 August 1999

Abstract

Rhodium-catalyzed cyclic carbonylation of alkynes **1** in the presence of alcohols gives selectively 3-alkoxycarbonylindanones **2** which are derived from **1**, one molecule of alcohol and two molecules of carbon monoxide. © 1999 Elsevier Science Ltd. All rights reserved.

Recently, much attention has been paid to the synthesis of indanone derivatives which exhibit significant biological activities. The indanone skeleton is constructed by following strategies: e.g. cyclization of either arylpropionic acid or acylophenone,[1] protonation of *trans*-chalcone,[2] cyclization of alkynes with Fe–aryl complex,[3] cobalt-catalyzed cyclocarbonylation of alkynes under water–gas shift conditions,[4] rhodium-catalyzed desilylative cyclocarbonylation of 1-aryl-2-(trimethylsilyl)acetylenes,[5] and so on. Thus, although many synthetic methods have been developed, the synthesis of indanone derivatives having an ester group at the 3 position is scarcely reported. Indanone derivatives such as alkoxycarbonylindanones **2** may be useful as a precursor of 1-indancarboxylic acid which has an ability of anti-inflammation. Only two papers on the synthesis have appeared in the literature: (1) Friedel–Crafts reaction of succinic anhydride containing aryl groups;[6] and (2) palladium-catalyzed carbonylative cyclization of 1-iodo-2-alkenylbenezenes.[7] These two reactions, however, are not satisfactory to low selectivity or complex starting materials. Thus, an efficient and general route to indancarboxylic acid is still of current interest in synthetic organic chemistry.

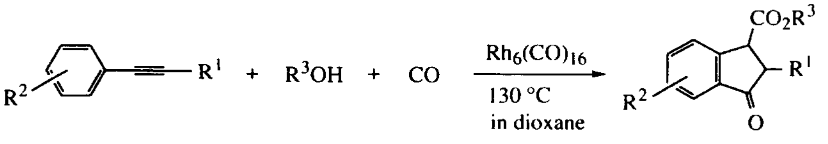
Previously, we developed the carbonylation of alkynes under water–gas shift reaction conditions (CO+water) selectively to give furan-2(5*H*)-ones in the presence of a rhodium catalyst.[8] This time, when the carbonylation of diphenylacetylene was performed in the presence of alcohols instead of water, we found that 3-alkoxycarbonylindanones **2** were formed in a good yield up to 93% (Scheme 1).

A representative reaction is as follows. In a stainless steel autoclave, $Rh_6(CO)_{16}$ (0.005 mmol), diphenylacetylene **1a** (R^1=Ph, R^2=H, 5.0 mmol), methanol (R^3=Me, 10.0 mmol) and 1,4-dioxane (30 ml) were placed, and the mixture was reacted at 130°C for 14 h under 100 atm of carbon monoxide.

---

* Corresponding author.

PII: S0040-4039(99)01625-1



1

2

a: R^1 = Ph, R^2 = H

b: R^1 = CH_2Ph, R^2 = H

c: R^1 = *p*-$MeOC_6H_4$, R^2 = *p*-MeO

Scheme 1.

After usual work-up, isolation by column chromatography on silica using benzene gave 2-phenyl-3-methoxycarbonyl-1-indanone **2a** in high yield (88% HPLC yield, and 76% isolated yield). Compound **2a** was identified by ^1H and ^{13}C NMR, IR, and mass spectra.[9] The mass spectrum of **2a** showed an *m/z* of 266 (M^+) corresponding to the sum of mass number 178 (starting substrate **1a**) and 88 (2CO+MeOH). In the IR spectrum, characteristic absorptions appeared at 1717 and 1734 cm^{-1} due to the carbonyl groups of lactone and ester, respectively. The ^1H NMR spectrum was consistent with 2-phenyl-3-methoxycarbonyl-1-indanone (**2a**: R^1=Ph, R^2=H, R^3=Me). The molecular structure of **2a** was finally confirmed by an X-ray crystallographic analysis.

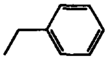
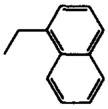
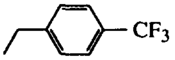
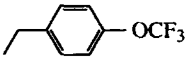
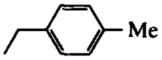
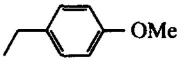
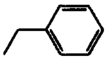
In the absence of MeOH, the carbonylation reaction of **1a** did not occur and starting substrate **1a** was quantitatively recovered. Addition of 0.4 equiv. of MeOH based on the substrate resulted in 52% conversion of **1a** and a lower product yield (32%) of **2a**. When 1.0 equiv. of MeOH was added, the reaction proceeded smoothly and completely. Although rhodium complexes such as $[Rh(CO)_2Cl]_2$ and $RhCl_3$ showed almost the same catalytic activity as $Rh_6(CO)_{16}$, no activities were recognized for metal carbonyls such as $Ru_3(CO)_{12}$, $Fe_2(CO)_{10}$ and $Co_2(CO)_8$ under the same reaction conditions.

In order to know the scope of the present reaction, the carbonylation of alkynes **1** bearing several kinds of substituents R^1 and R^2 were carried out in alcohols R^3OH. The results are summarized in Table 1, and these suggest that the present reaction is applicable to some alkynes and alcohols. Most of the reactions in Table 1 proceeded smoothly to give **2** in good yields. Primary alcohols gave a higher yield of indanone derivatives than secondary alcohols, indicating that the reaction may depend on the acidity of alcohols, and lower acidity might decrease the yield of **2**. On the other hand, *t*-butyl alcohol did not give indanone derivatives, but an unidentified complex mixture (Run 5, Table 1). The reactions of diphenylacetylene with benzyl alcohol derivatives gave the corresponding indanone derivatives in good yields (Runs 6–11, Table 1). In particular, the reaction of *p*-trifluoromethoxybenzyl alcohol having higher acidity than benzyl alcohol gave **2i** in the best yield (93%), while *p*-methoxybenzyl alcohol gave **2k** in 65% yield even after longer reaction time, also suggesting that the acidity of alcohols affects the carbonylation reaction. Under the same reaction conditions alkylphenylacetylenes such as 1-phenyl-1-propyne and 1-phenyl-1-hexyne did not give the corresponding indanone derivatives but a complex mixture of products.

Diols such as ethylene glycol and *p*-xylylene glycol similarly reacted with **1a** to give compounds **3** and **4**, respectively, in moderate yields, in which two hydroxyl groups participated in the carbonylation (Scheme 2).

The alkoxycarbonylation of alkenes is well known[10] and some mechanistic studies have been reported.[11] For the present carbonylation of alkynes, two reaction paths, path A and path B, could be considered (Scheme 3). In path A, as we previously proposed for the cobalt-catalyzed carbonylation,[4] the cyclic carbonylation of alkyne **1** gives indenone **5**, followed by hydroesterification of the double bond in **5** resulting in the formation of **2**. We then prepared indenone **5** in a separate experiment and tried

Table 1
Carbonylation of **1** with alcohol

Run	Acetylene	R^3	Product	Yield(%)[a]
1	**1a**	Me	**2a**	88(76)
2	**1a**	Et	**2b**	75(68)
3	**1a**	n-Octyl	**2c**	72(61)
4	**1a**	i-Pr	**2d**	66(51)
5	**1a**	t-Bu	**2e**	complex mixture
6	**1a**		**2f**	91(85)
7	**1a**		**2g**	85(77)
8	**1a**		**2h**	90(80)
9	**1a**		**2i**	93(82)
10	**1a**		**2j**	82(73)
11	**1a**		**2k**	65(52)[b]
12	**1b**	Me	**2l**	51(38)
13	**1c**	Me	**2m**	85(71)
14	**1c**		**2n**	88(81)

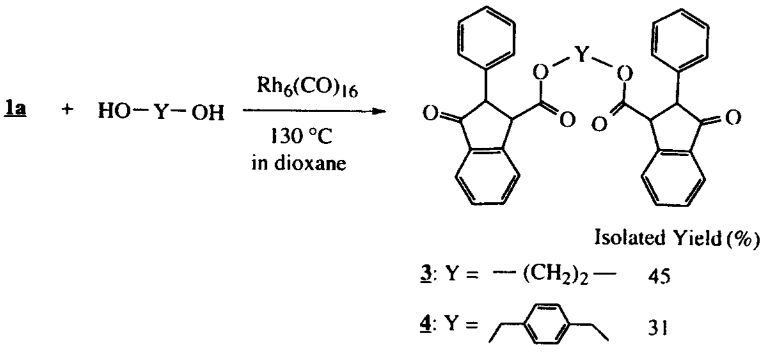
Reaction conditions: acetylene, 5.0 mmol; alcohol, 10.0 mmol; $Rh_6(CO)_{16}$, 0.1 mol%; dioxane, 30 ml; CO pressure, 100 atm; reaction temperature, 130 °C; reaction time, 15 h.

a) Yields are based on diphenylacetylen and determined by HPLC; parenthese indicate isolated yields. b) Reaction time, 45 h.

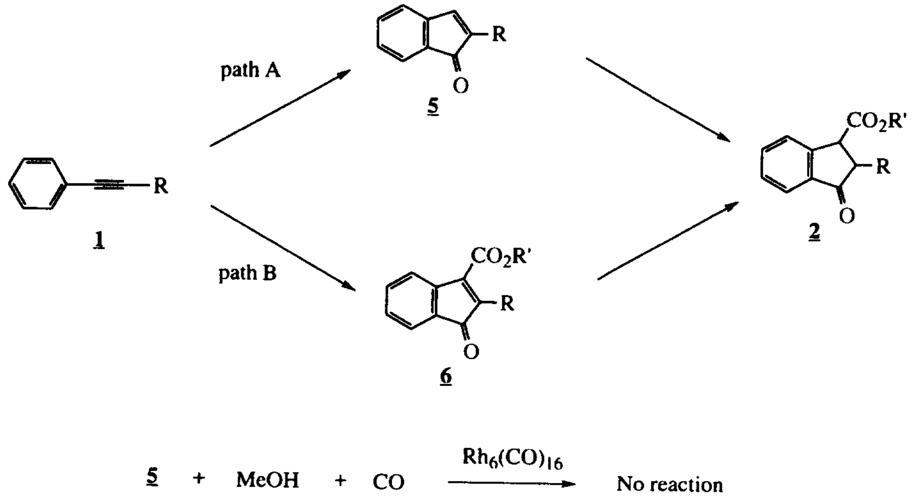
the hydrocarbonylation of **5**. As a result, no reaction occurred and **5** was recovered intact, suggesting that the present cyclic carbonylation may proceed via an intermediate such as **6**, followed by hydrogenation to produce **2** (path B). Path B may be supported by the fact that α,β-unsaturated carbonyl compounds undergo hydrogenation by the catalysis of $Rh_6(CO)_{16}$ under water–gas shift reaction conditions.[12]

References

1. Carter, R. H.; Colyer, R. M.; Hill, R. A.; Staunton, J. *J. Chem. Soc., Perkin Trans. 1* **1976**, *13*, 1438.
2. McDonald, E.; Smith, P. *J. Chem. Soc., Perkin Trans. 1* **1980**, *4*, 837.



Scheme 2.



Scheme 3.

3. Butler, I. R.; Cullen, W. R.; Lindsell, W. E.; Preston, P. N.; Rettig, S. J. *J. Chem. Soc., Chem. Commun.* **1987**, 439.
4. Joh, T.; Doyama, K.; Fujiwara, K.; Maeshima, K.; Takahashi, S. *Organometallics* **1991**, *10*, 508.
5. Takeuchi, R.; Yasue, H. *J. Org. Chem.* **1993**, *58*, 5386.
6. House, H. O.; Larson, J. K.; Muller, H. C. *J. Org. Chem.* **1968**, *33*, 961.
7. Negishi, E.; Coperet, C.; Ma, S.; Mita, T.; Sugihara, T.; Tour, J. M. *J. Am. Chem. Soc.* **1996**, *118*, 5904.
8. Joh, T.; Doyama, K.; Onitsuka, K.; Shiohara, S.; Takahashi, S. *Organometallics* **1991**, *10*, 2493.
9. Compound **2a**: needles; ^{1}H NMR (400 MHz, $CDCl_3$) 3.82 (3H, s, CH_3), 4.37 (1H, d, CH), 4.38 (1H, d, CH), 7.19 (2H, d, *J*=8.3, Ph), 7.26–7.35 (3H, m, Ph), 7.52 (1H, t, *J*=7.5, Ph), 7.68–7.75 (2H, m, Ph), 7.84 (1H, d, *J*=7.5, Ph); ^{13}C NMR (100 MHz, $CDCl_3$) 52.8, 53.2, 56.6, 124.6, 126.1, 127.5, 128.2, 129.0, 129.1, 135.3, 135.6, 138.1, 149.7, 171.8, 203.5; IR(KBr) 1734 cm^{-1} (ν C=O), 1713 cm^{-1} (ν C=O); MS(EI) *m/z*: 266 (M^+); (found: C, 76.8; H, 5.1; $C_{17}H_{14}O_3$ requires: C, 76.7; H, 5.3%).
10. Ali, B. E.; Alper, H. *Transition Metals for Organic Synthesis*; Beller, M.; Bolm, C., Eds.; Wiley: New York, 1998; Vol. 1, Chapter 2, p. 49.
11. (a) Despeyroux, B.; Alper, H. *Ann. N.Y. Acad. Sci.* **1983**, 415, 118. (b) Huf, K. T.; Alper, H. *Bull. Korean Chem. Soc.* **1994**, 15, 304. (c) Lee, C. W.; Alper, H. *J. Org. Chem.* **1995**, *60*, 250.
12. Joh, T.; Fujiwara, K.; Takahashi, S. *Bull. Chem. Soc. Jpn.* **1993**, *66*, 978.