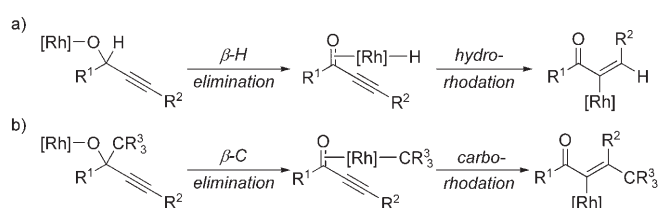


Carborhodation

Rhodium-Catalyzed Rearrangement of Aryl Bis(alkynyl) Carbinols to 3-Alkynyl-1-indanones**

Ryo Shintani,* Keishi Takatsu, Taisuke Katoh, Takahiro Nishimura, and Tamio Hayashi*

A transition-metal-catalyzed isomerization or rearrangement can provide an efficient way to convert readily accessible organic compounds into those with more structural complexity under mild conditions.^[1] For example, rhodium-catalyzed isomerization of secondary propargyl alcohols to the corresponding α,β -unsaturated ketones was described,^[2] and a reaction pathway involving β -hydrogen elimination of an alkoxorhodium species with subsequent hydorrhodation of an alkyne was proposed (Scheme 1a).^[2b] This reaction sequence



Scheme 1. a) Proposed reaction pathway for the rhodium-catalyzed isomerization of secondary propargyl alcohols; b) possible reaction pathway for the potential rhodium-catalyzed rearrangement of tertiary propargyl alcohols.

was applied to the synthesis of 1-indanones by employing α -aryl propargyl alcohols.^[3] In contrast, an analogous process with tertiary propargyl alcohols involving β -carbon elimination^[4] and successive carborhodation has yet to be reported (Scheme 1b).^[5] Within this context we describe the development of a rhodium-catalyzed rearrangement of readily available aryl bis(alkynyl) carbinols to 3-alkynyl-1-indanones under mild conditions.

Initially, we prepared phenyl bis((*tert*-butyldimethylsilyl)ethynyl) carbinol (**1a**) as a model substrate [Eq. (1)] and treated it with $[\{\text{Rh}(\text{OH})(\text{cod})\}_2]$ (8 mol % Rh) at 50 °C (Table 1, entry 1). Under these conditions indanone **2a** was obtained in only 5 % yield. The use of PPh_3 as a ligand gave a

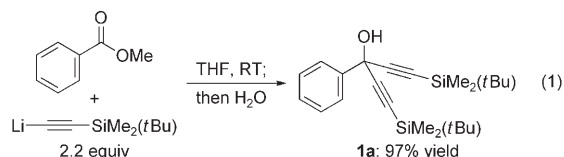


Table 1: Rhodium-catalyzed rearrangement of **1** to indanones **2**.

Entry	Substrate	Ligand	Product	Yield [%] ^[a]
1	1a (R = H, Si = SiMe ₂ (<i>t</i> Bu))	none	2a	(5)
2 ^[b]	1a	PPh ₃	2a	(19)
3	1a	dppb	2a	(9)
4	1a	dppp	2a	(45)
5	1a	binap	2a	73
6 ^[c]	1a	binap	2a	79
7	1b (R = H, Si = SiEt ₃)	binap	2b	63
8	1c (R = H, Si = Si(<i>n</i> Pr) ₃)	binap	2c	66
9	1d (R = 2-Me, Si = SiMe ₂ (<i>t</i> Bu))	binap	2d	85
10	1e (R = 4-Me, Si = SiMe ₂ (<i>t</i> Bu))	binap	2e	71
11	1f (R = 4-OMe, Si = SiMe ₂ (<i>t</i> Bu))	binap	2f	87
12	1g (R = 4-F, Si = SiMe ₂ (<i>t</i> Bu))	binap	2g	85
13	1h (R = 4-Cl, Si = SiMe ₂ (<i>t</i> Bu))	binap	2h	84

[a] Yield of isolated product. Numbers in parentheses were determined by using ¹H NMR spectroscopy with an internal standard (MeNO₂).

[b] 16 mol % of ligand was used. [c] The reaction was conducted on a 5.0 mmol scale.

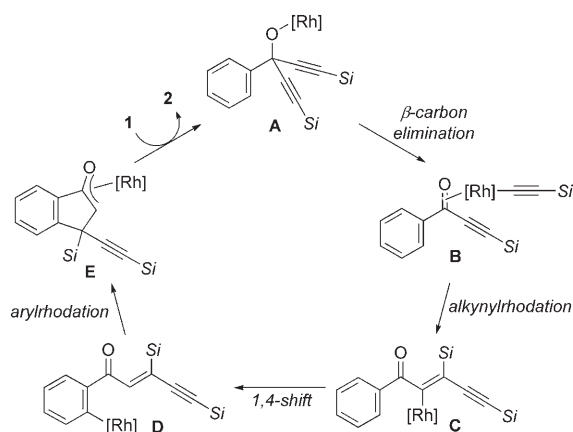
somewhat better yield (19 %) of **2a** (Table 1, entry 2), and use of dppb as the ligand resulted in a low yield of 9 % (Table 1, entry 3). In both cases the major component after the reaction was unreacted **1a**. In contrast, the yield of **2a** was improved by using other bisphosphine ligands such as dppp and binap, giving a 45 % yield (Table 1, entry 4) and a 73 % yield (Table 1, entry 5), respectively. The present reaction of **1a** can be easily scaled up to 5 mmol, and leads to 79 % yield of **2a** (Table 1, entry 6). Under the reaction conditions using binap as the ligand, substrates derived from triethylsilyl- and tri-*n*-propylsilylacetylenes (**1b** and **1c**) also underwent the rearrangement to give indanones **2b** and **2c**, respectively (63–66 % yield; Table 1, entries 7 and 8). In addition, various substituents on the aromatic ring of the substrate were tolerated, giving the corresponding indanones in high yield (71–87 % yield; Table 1, entries 9–13).^[6]

A proposed catalytic cycle of this process is illustrated in Scheme 2. Alkoxorhodium species **A**, which is initially

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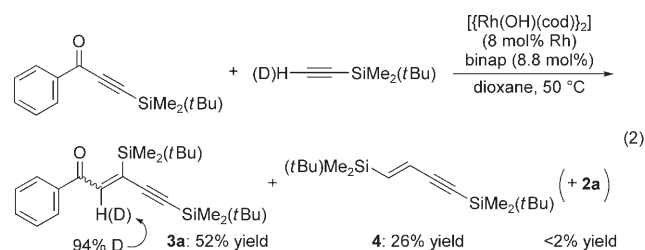
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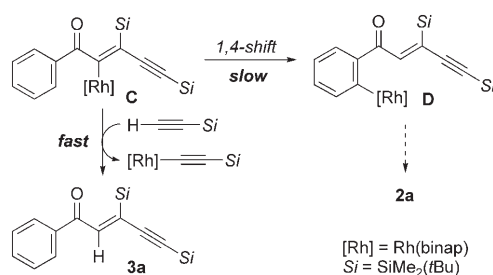
Scheme 2. Proposed catalytic cycle of the rhodium-catalyzed rearrangement of **1** to **2**. [Rh] = Rh(binap), Si = Si(alkyl)₃.

generated from the hydroxorrhodium catalyst and substrate **1a**, undergoes β -alkynyl elimination to give intermediate **B**.^[7] Alkynylrhodation of **B** to the conjugated alkyne generates alkenylrhodium species **C** with subsequent 1,4-rhodium migration to form arylrhodium intermediate **D**.^[3,8] This intermediate undergoes intramolecular 1,4-addition (arylrhodation) to give oxa- π -allylrhodium **E** with subsequent protolysis by alcohol **1** to produce indanone **2** and regenerate alkoxyrhodium **A**.

It is worth comparing the present rearrangement with an intermolecular reaction between an aryl alkynyl ketone and a terminal alkyne,^[9] which in principle can also provide the same 3-alkynyl-1-indanone as the product.^[8d,e] In reality, however, a reaction of 3-(*tert*-butyldimethylsilyl)-1-phenyl-2-propyn-1-one with (*tert*-butyldimethylsilyl)acetylene in the presence of a Rh/binap catalyst gave almost no indanone **2a** and the major products were uncyclized conjugated ynenone **3a** (52 % yield) and alkyne dimer **4** (26 % yield) [Eq. (2)].^[10]



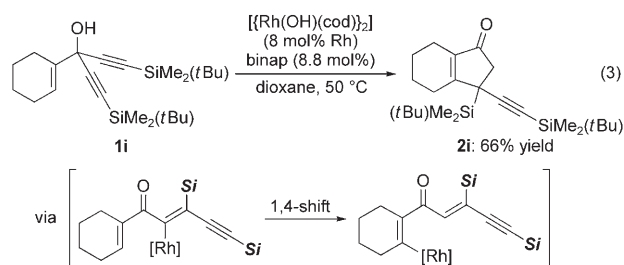
The use of deuterated (*tert*-butyldimethylsilyl)acetylene in this reaction revealed that the deuterium was mostly incorporated at the alkenyl carbon atom adjacent to the carbonyl group of product **3a**. This result indicates that the ligand exchange between alkenylrhodium intermediate **C** and a terminal alkyne occurs faster than the 1,4-rhodium migration from **C** to **D**, suppressing the subsequent formation of indanone **2a** (Scheme 3, see also Scheme 2). Because a free terminal alkyne does not exist in the rearrangement of aryl bis(alkynyl) carbinols, our newly developed catalysis has a



Scheme 3. Proposed reaction pathway for the formation of **3a**.

significant advantage for the efficient synthesis of 3-alkynyl-1-indanones.

The same mode of rearrangement is also observed with substrate **1i** which has 1-cyclohexenyl group at the bis(propargylic) position, giving cyclopentenone derivative **2i** in 66 % yield [Eq. (3)]. This outcome represents a rare example



that involves 1,4-rhodium migration from an alkenyl carbon atom to another alkenyl carbon atom.

In summary, we have developed a rhodium-catalyzed rearrangement of aryl bis(alkynyl) carbinols to 3-alkynyl-1-indanones through a pathway involving a β -carbon elimination/carborhodation sequence under mild conditions. Considering the ease of the synthesis of carbinol substrates from an aromatic ester and a terminal alkyne in a single step, the present catalysis provides an efficient way of preparing 3-alkynyl-1-indanones.

Experimental Section

General procedure for Table 1: A solution of $[\text{Rh}(\text{OH})(\text{cod})]_2$ (3.6 mg, 16 μmol Rh) and ligand (18 μmol) in 1,4-dioxane (3.0 mL) was stirred for 20 min at room temperature. Compound **1** (0.20 mmol) was added with additional 1,4-dioxane (2.0 mL) and the mixture was stirred for 48 h at 50 °C. The reaction was quenched with water and extracted with Et_2O . The organic layer was dried over MgSO_4 , filtered, and concentrated under vacuum. The residue was purified by silica gel preparative TLC with EtOAc /hexanes to afford product **2**.

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