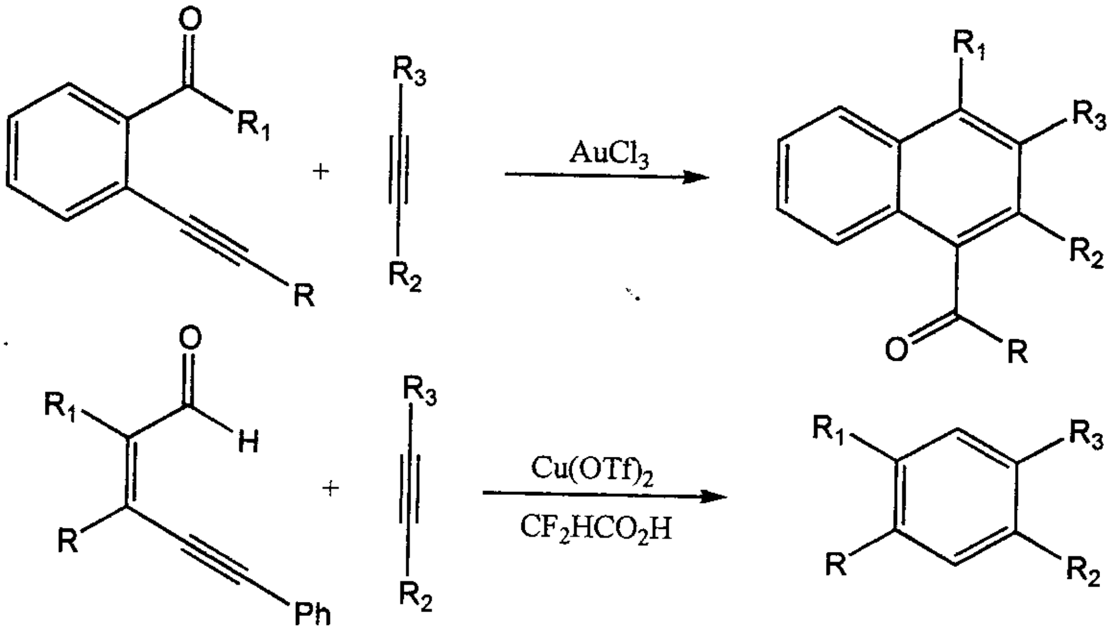
Current Literature
08/30/03
Yasunori Aoyama

Lewis Acid-Catalyzed Benzannulation via Unprecedented [4+2] Cycloaddition of *o*-Alkynyl(oxo)benzenes and Enynals with Alkynes

Asao, N.; Nogami, T.; Lee, S.; Yamamoto, Y.
J. Am. Chem. Soc. **2003**, *124*, ASAP

$AuCl_3$-Catalyzed Benzannulation: Synthesis of Naphthyl Ketone Derivatives from *o*-Alkynylbenzaldehydes with Alkynes

Asao, N.; Takahashi, K.; Lee, S.; Kasahara, T.; Yamamoto, Y.
J. Am. Chem. Soc. **2002**, *124*, 12650-12651



Contents

Introduction (Transition Metal-Catalyzed Benzannulation)

(1) Zr-Catalyzed [2+2+2] Trimerization

(2) Ti-Catalyzed [2+2+2] Trimerization

(3) Pd-Catalyzed Benzannulation

(4) W-Catalyzed Benzannulation

(5) Rh-Catalyzed Benzannulation

(6) Ir-Catalyzed Benzannulation

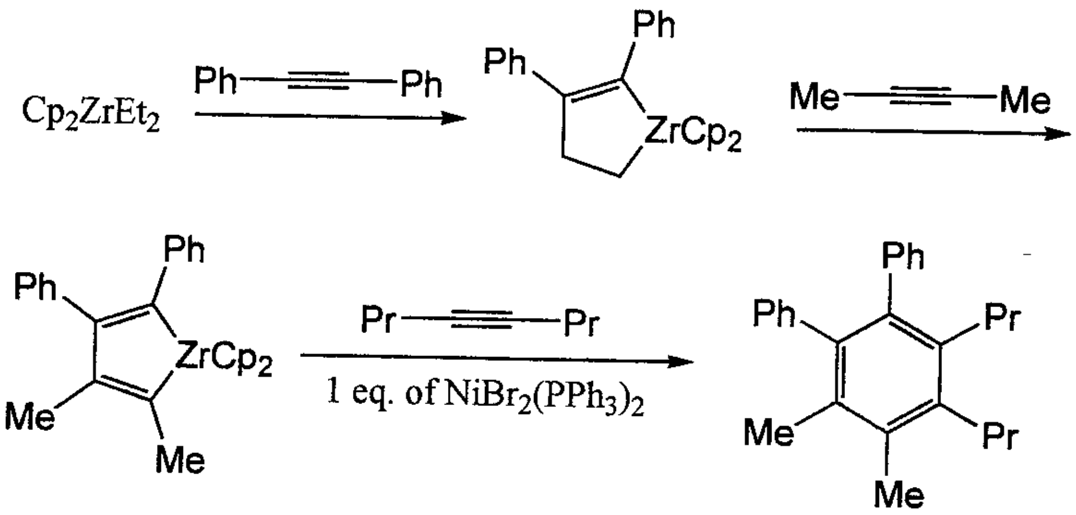
Today's topic (Lewis Acid-Catalyzed Benzannulation)

(1) Au-Catalyzed Benzannulation

(2) Cu-Catalyzed Benzannulation

New type of acetylen trimerization-1

Benzannulation through Zirconacycles

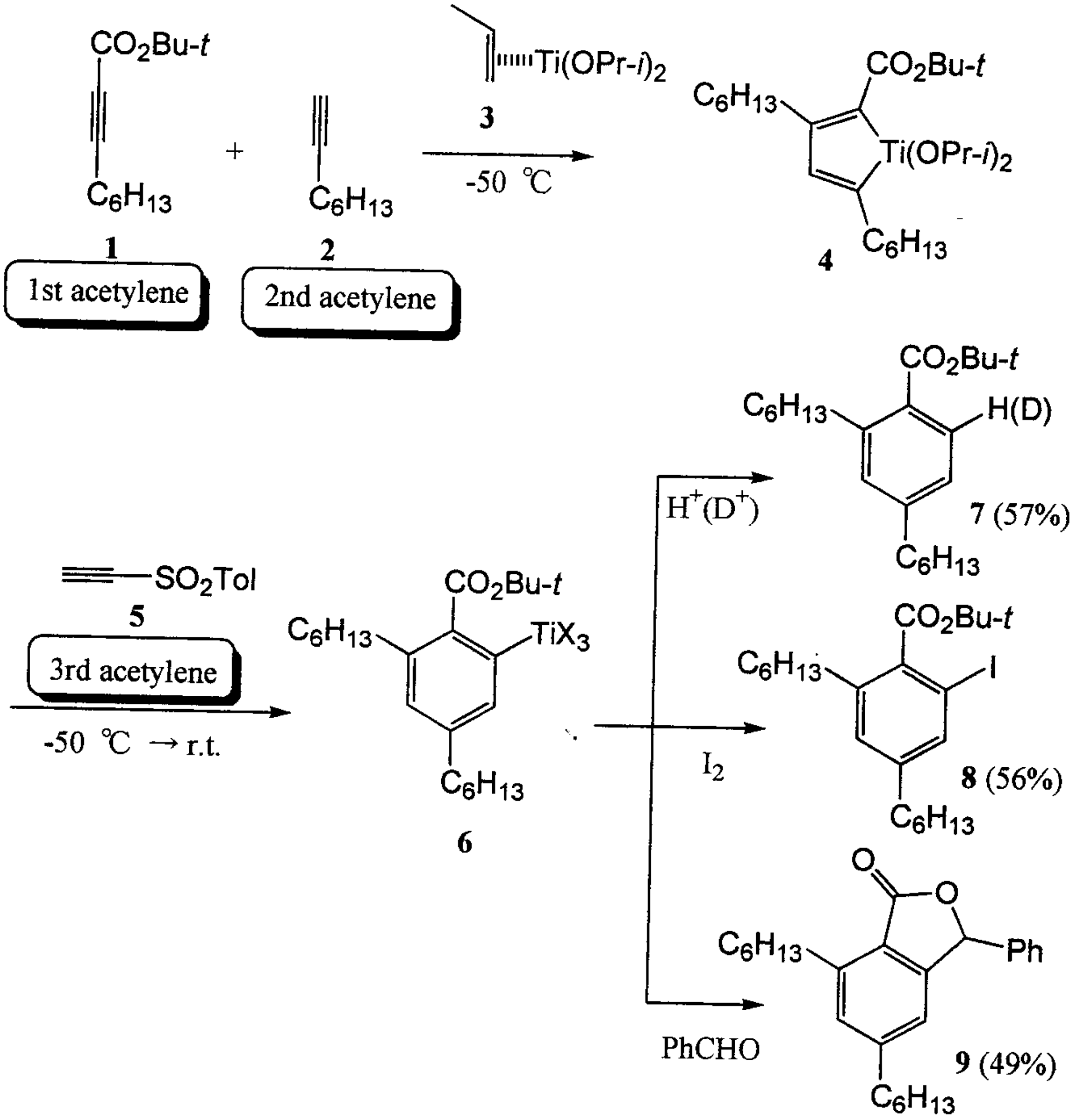


80% yield

Takahashi, T etc. *J. Am. Chem. Soc.* **1999**, *121*, 11093-11100

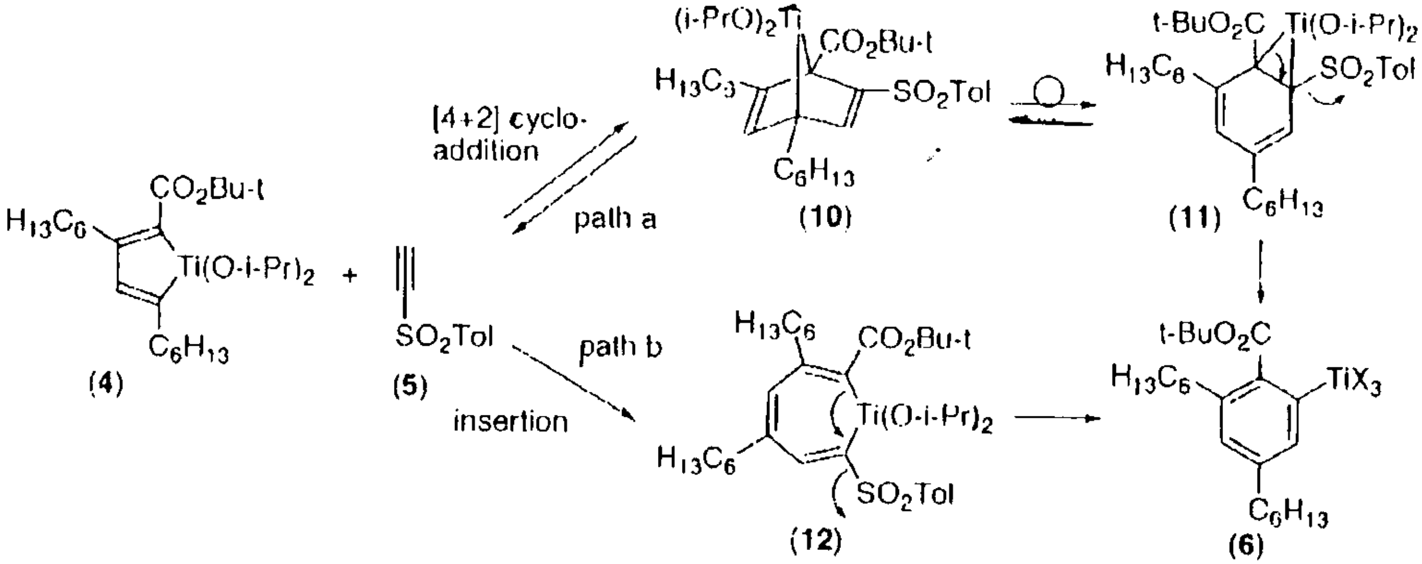
New type of acetylen trimerization-2

Benzannulation via Titanacycles



Sato, F. etc. *J. Am. Chem. Soc.* **2001**, *123*, 7925-7926

Reaction Mechanism

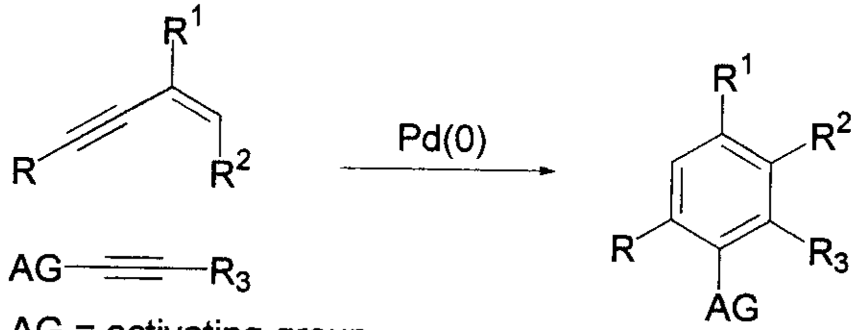


Transition metal-catalyzed benzannulation (1)

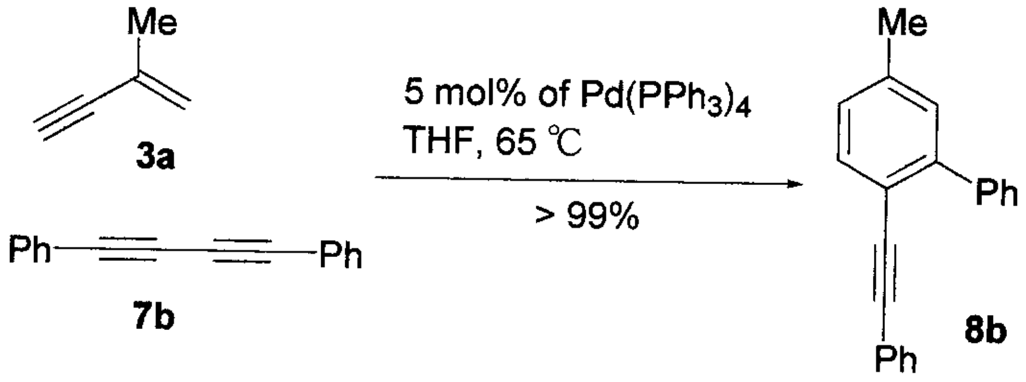
Palladium-Catalyzed [4+2] Cross-Benzannulation reaction of Conjugated Enynes with Diynes

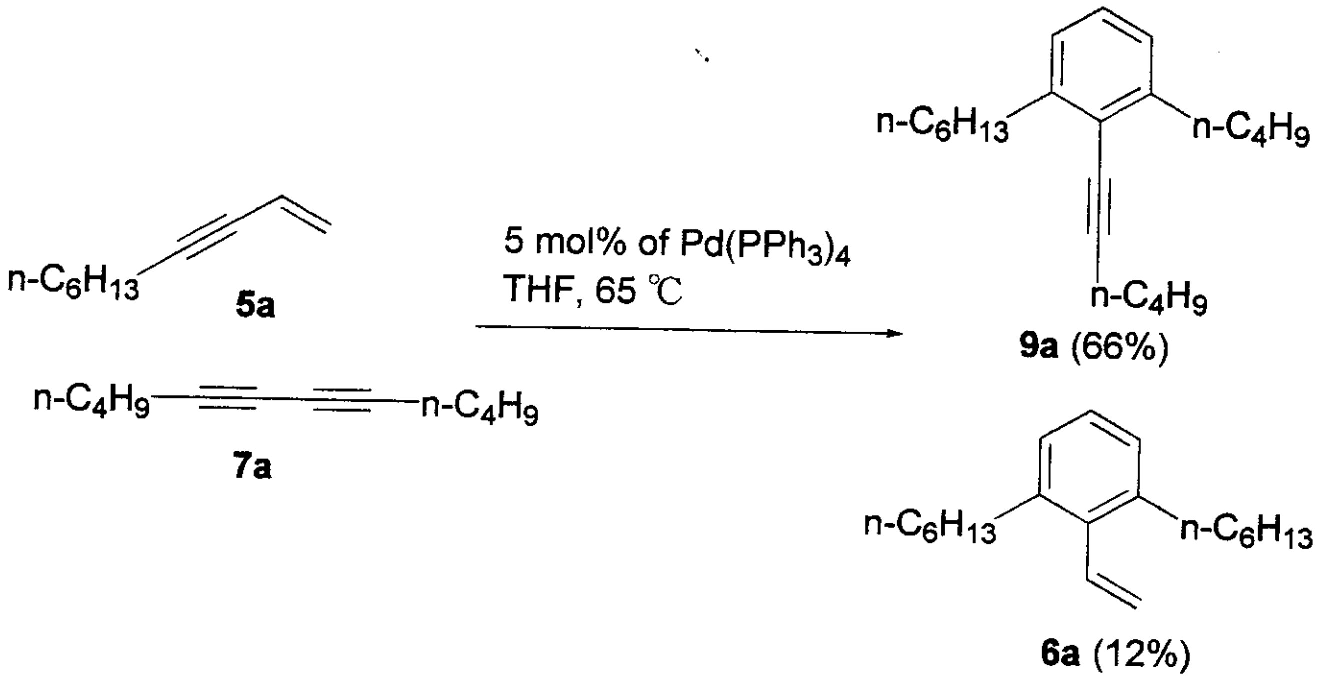
Pd

Yamamoto, Y. etc. *J. Am. Chem. Soc.* **1999**, *121*, 6391-6402



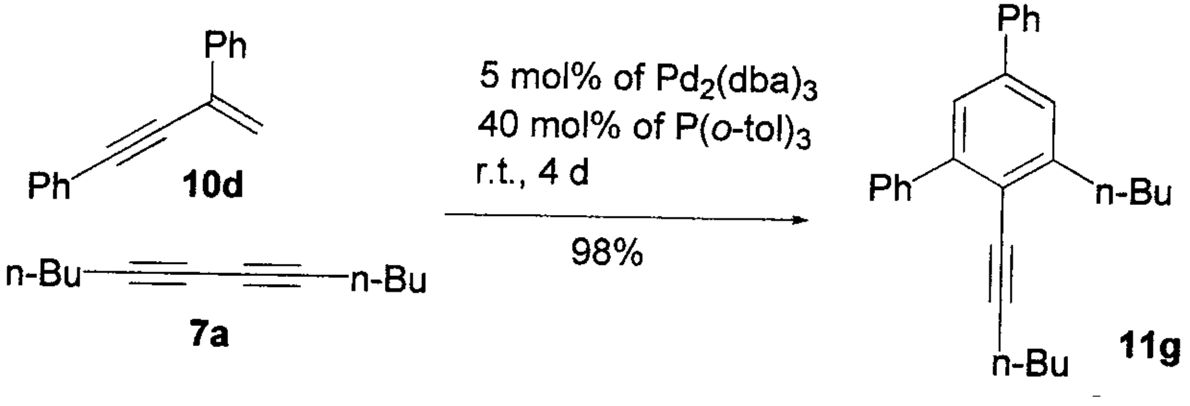
AG = activating group





Pd

Transition metal-catalyzed benzannulation (1)



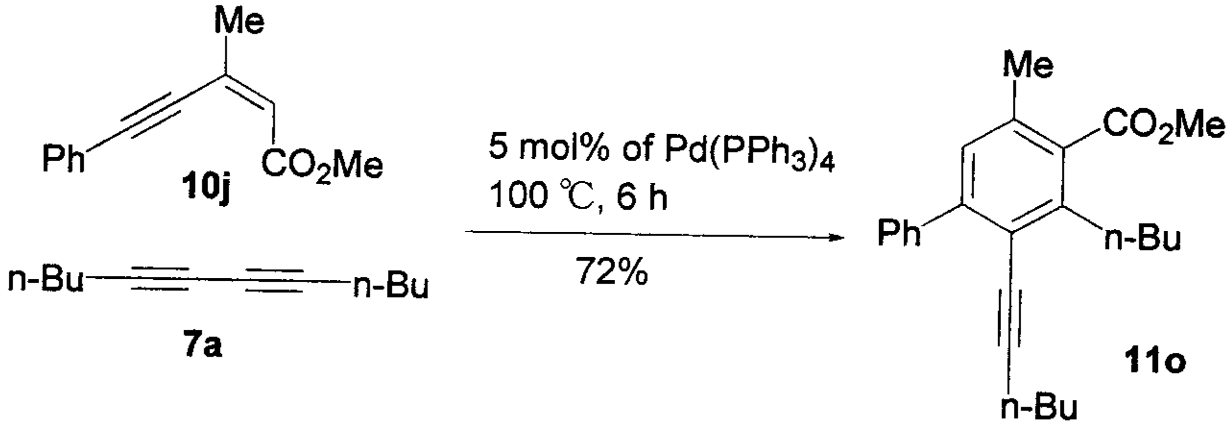
10d

7a

5 mol% of $Pd_2(dba)_3$
40 mol% of $P(o\text{-tol})_3$
r.t., 4 d

98%

11g



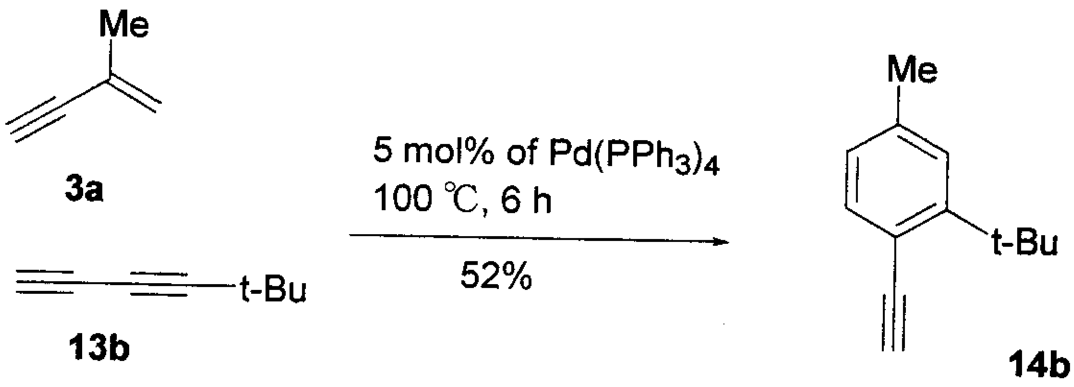
10j

7a

5 mol% of $Pd(PPh_3)_4$
100 ℃, 6 h

72%

11o



3a

13b

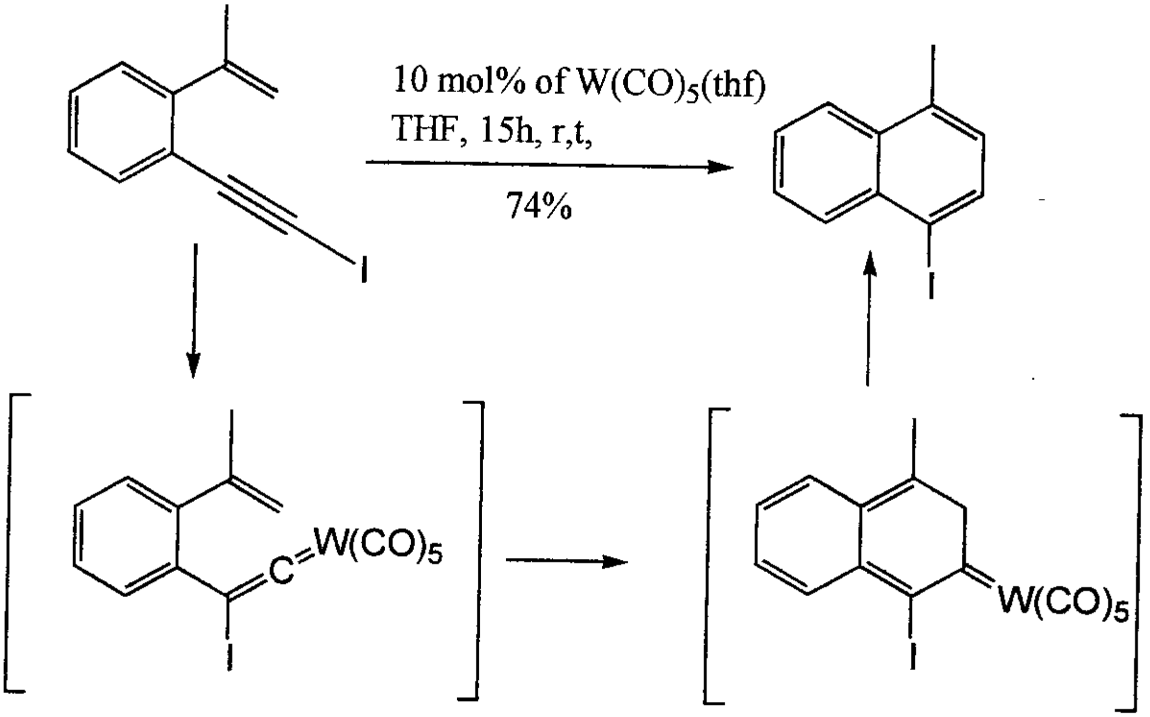
5 mol% of $Pd(PPh_3)_4$
100 ℃, 6 h

52%

14b

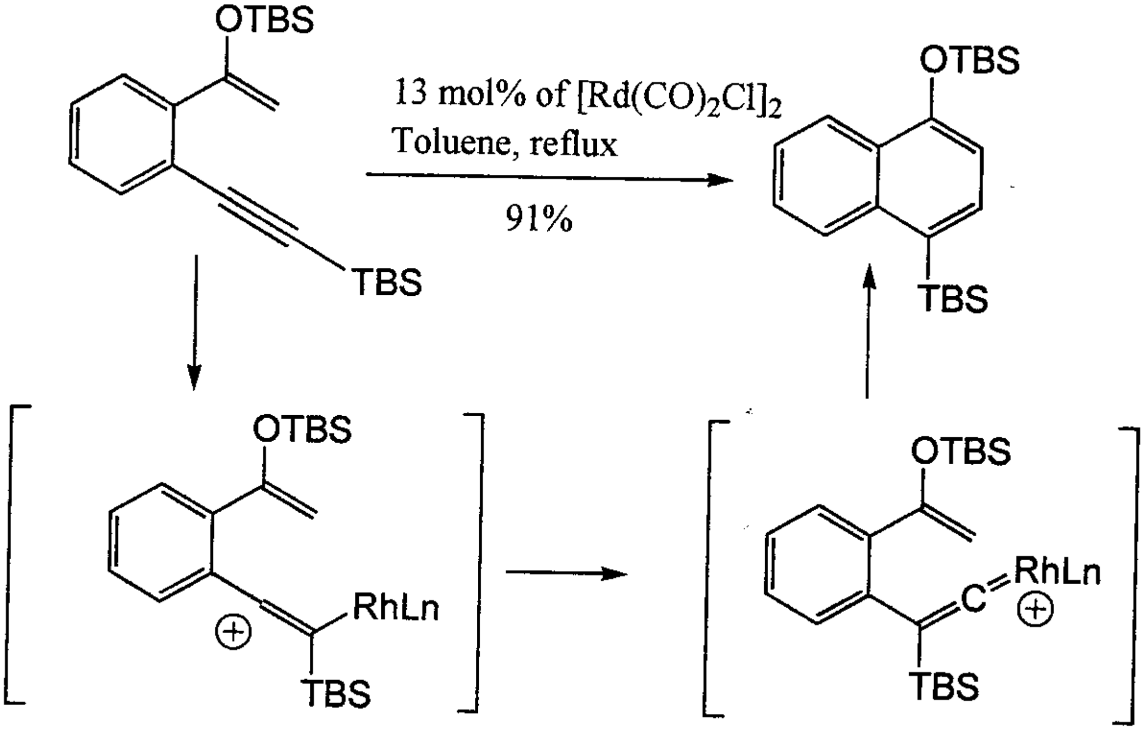
Transition metal-catalyzed benzannulation (2)

Ⓦ Iwasawa, N. etc. *J. Am. Chem. Soc.* **2002**, *124*, 518-519



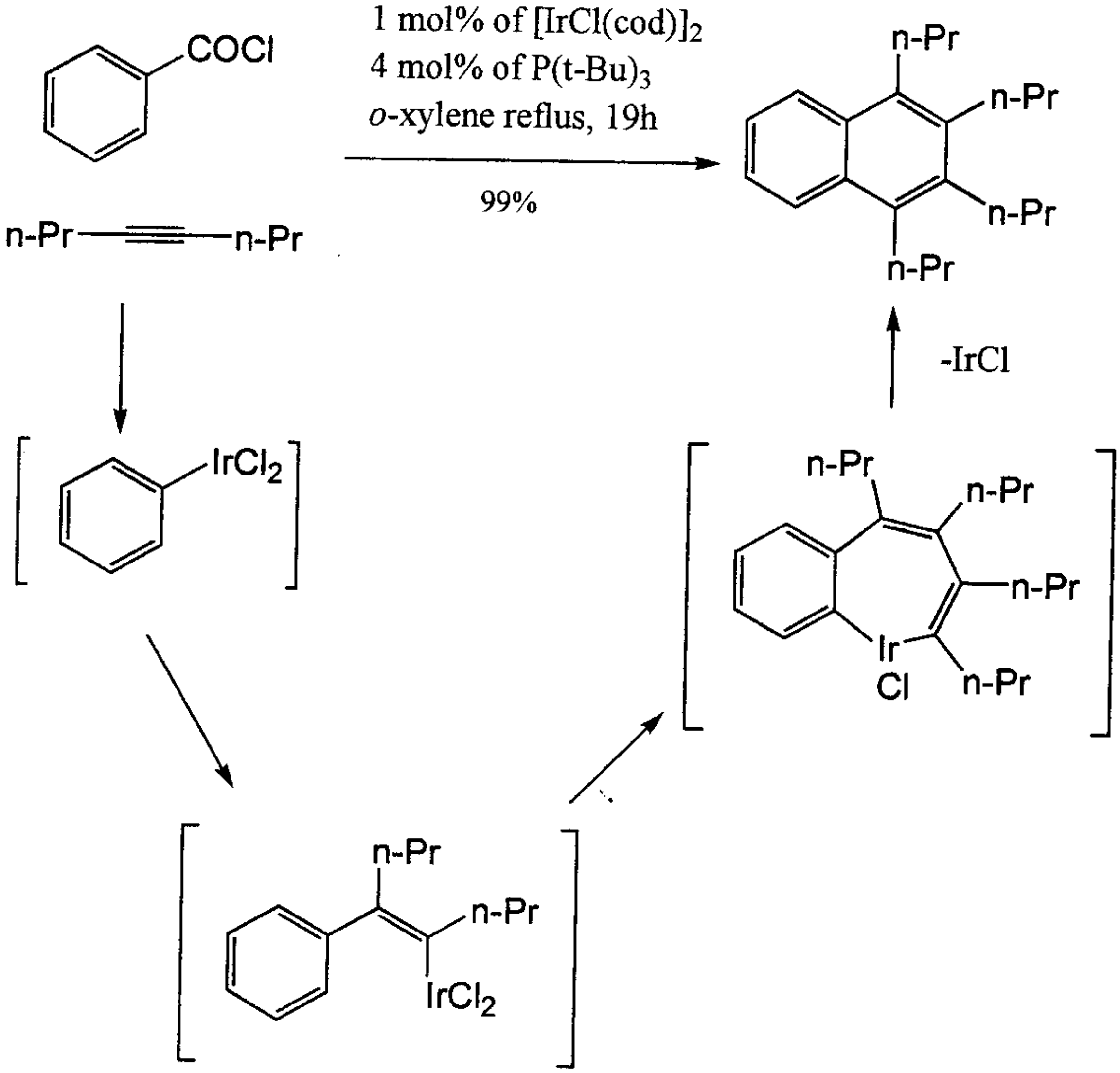
Transition metal-catalyzed benzannulation (3)

Rh Dankwardt, J. W. *Tetrahedron Lett.* **2001**, *42*, 5809-5812



Transition metal-catalyzed benzannulation (4)

Ir Miura, M. etc. *J. Am. Chem. Soc.* **2002**, *124*, 12680-12681



1 mol% of $[IrCl(cod)]_2$
4 mol% of $P(t\text{-}Bu)_3$
o-xylene reflus, 19h
99%

$AuCl_3$-Catalyzed Benzannulation: Synthesis of Naphthyl Ketone Derivatives from *o*-Alkynylbenzaldehydes with Alkynes

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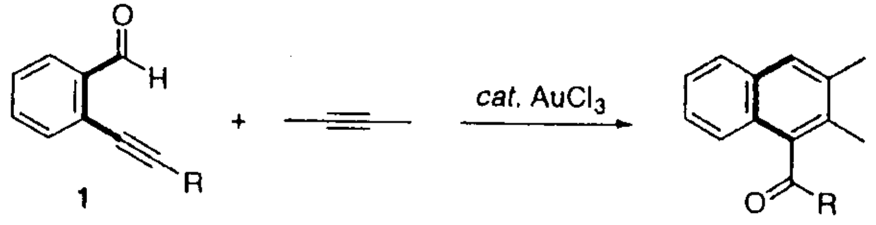
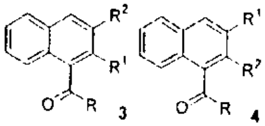
Department of Chemistry, Graduate School of Science, Tohoku University, Sendai 980-8578, Japan

Received August 13, 2002



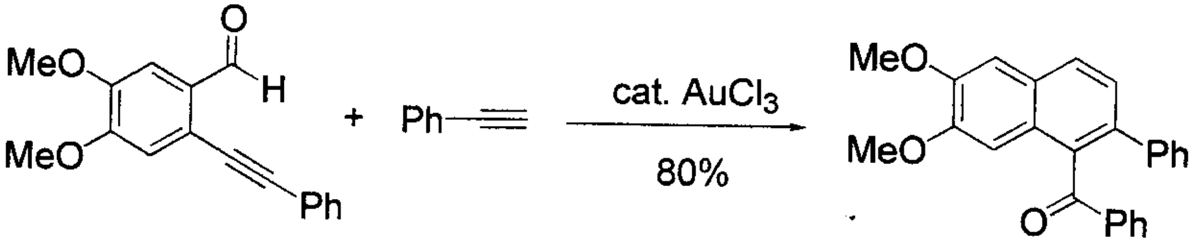
(1)

Table 1. The AuX_3-Catalyzed Reaction of *o*-Alkynylbenzaldehydes **1** with Alkynes **2**[a]

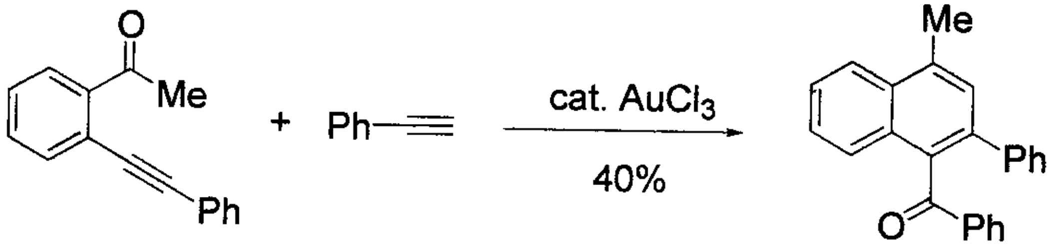
entry	1	R	2	$R^1-\equiv-R^2$ R^1	 R^2	catalyst	time	 ratio[b]	yield (%)[c]
1[d]	**1a**	Ph	**2a**	C_3H_7	H	$AuCl_3$	1 d	**3a**:**4a** = 95:5	57
2	**1a**	Ph	**2a**	C_3H_7	H	$AuCl_3$	1.5 h	**3a**:**4a** = 92:8	91
3[e]	**1a**	Ph	**2a**	C_3H_7	H	$AuCl_3$	3 h	**3a**:**4a** = 89:11	72
4	**1a**	Ph	**2a**	C_3H_7	H	$AuBr_3$	1.5 h	**3a**:**4a** = 93:7	100
5[f]	**1a**	Ph	**2b**	Ph	H	$AuCl_3$	2.5 h	**3b**:**4b** = 99:<1	96
6[f]	**1a**	Ph	**2b**	Ph	H	$AuBr_3$	0.7 h	**3b**:**4b** = 99:<1	100
7	**1a**	Ph	**2c**	Me_3Si	H	$AuCl_3$	6 h	**3c**:**4c** = 16:84	82
8	**1a**	Ph	**2d**	CO_2Et	H	$AuCl_3$	3 h	**3d**:**4d** = 18:82	72
9	**1a**	Ph	**2e**	$COCH_3$	H	$AuCl_3$	3.5 h	**3e**:**4e** = <1:99	75
10	**1a**	Ph	**2f**	C_3H_7	C_3H_7	$AuCl_3$	2.5 h	**3f**(=**4f**)	52
11	**1a**	Ph	**2f**	C_3H_7	C_3H_7	$AuBr_3$	2.5 h	**3f**(=**4f**)	70
12	**1a**	Ph	**2g**	Ph	Me_3Si	$AuCl_3$	2 h	**3g**:**4g** = 99:<1	92
13	**1a**	Ph	**2h**	Ph	Me	$AuCl_3$	3 h	**3h**:**4h** = 99:<1	89
14	**1b**	C_6H_{13}	**2b**	Ph	H	$AuCl_3$	1.5 h	**3i**:**4i** = 92:8	91

[a] The reaction was performed using *o*-alkynylbenzaldehydes **1** (1 equiv) and alkynes **2** (3 equiv) in the presence of AuX_3 (3 mol %) in $(ClCH_2)_2$ at 80 °C unless otherwise noted. [b] Determined by ^1H NMR. [c] Combined isolated yield. [d] The reaction was carried out at 30 °C in CH_2Cl_2. [e] The reaction was carried out in the presence of 1 mol % of $AuCl_3$. [f] The reaction was carried out using 1.2 equiv of **2b**.

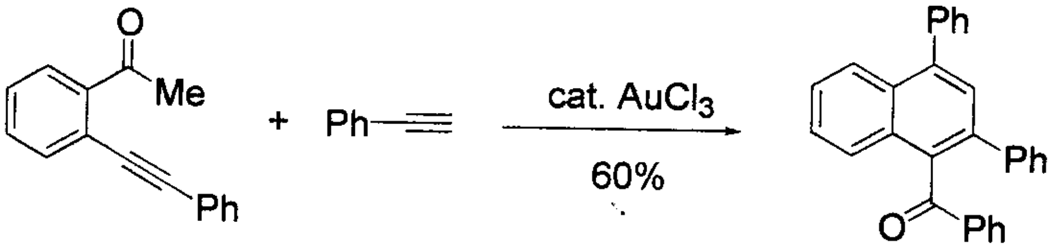
$AuCl_3$-Catalyzed Benzannulation: *another exaples*



1c **2b** **3f**

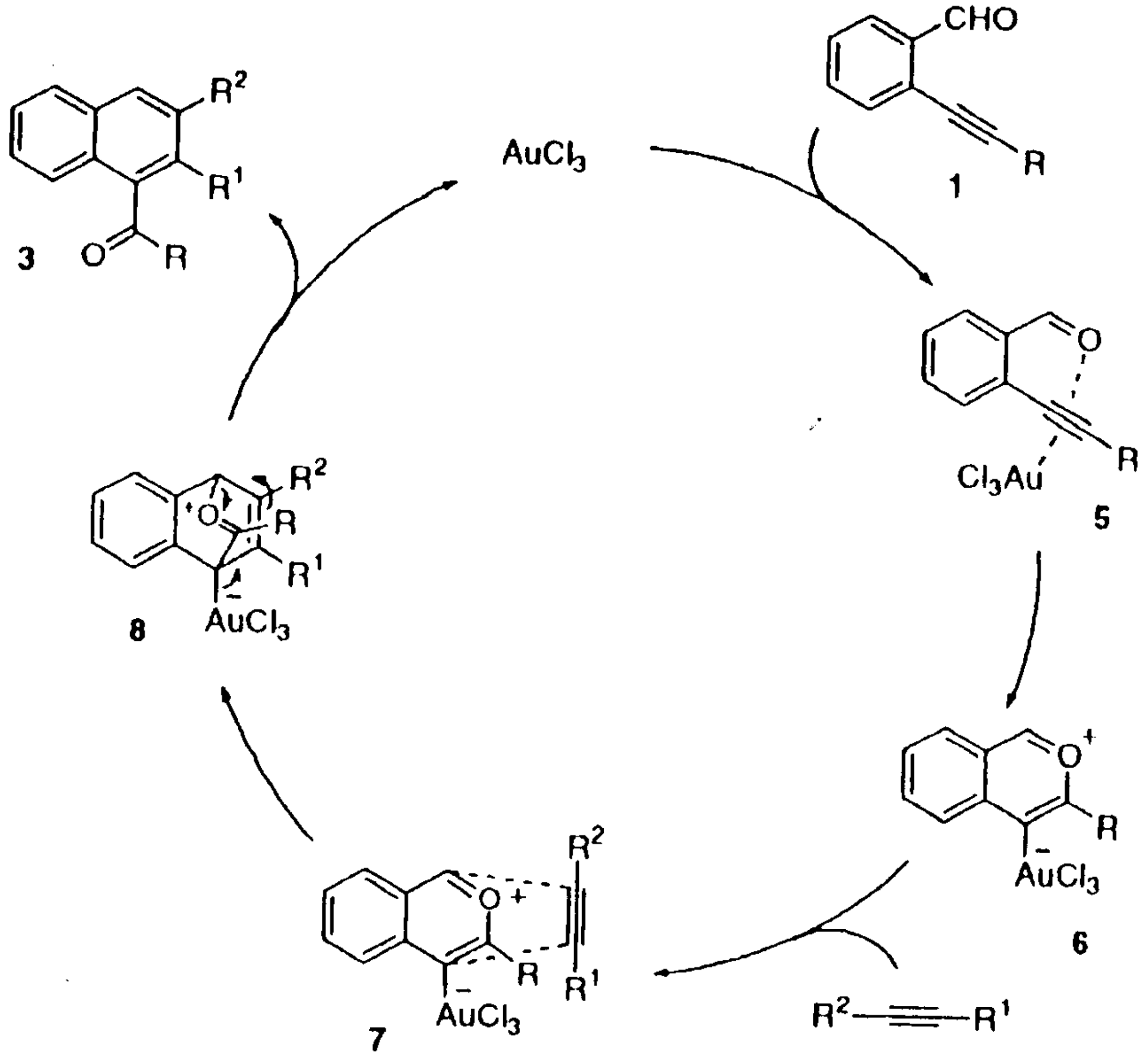


10a **2b** **11a**



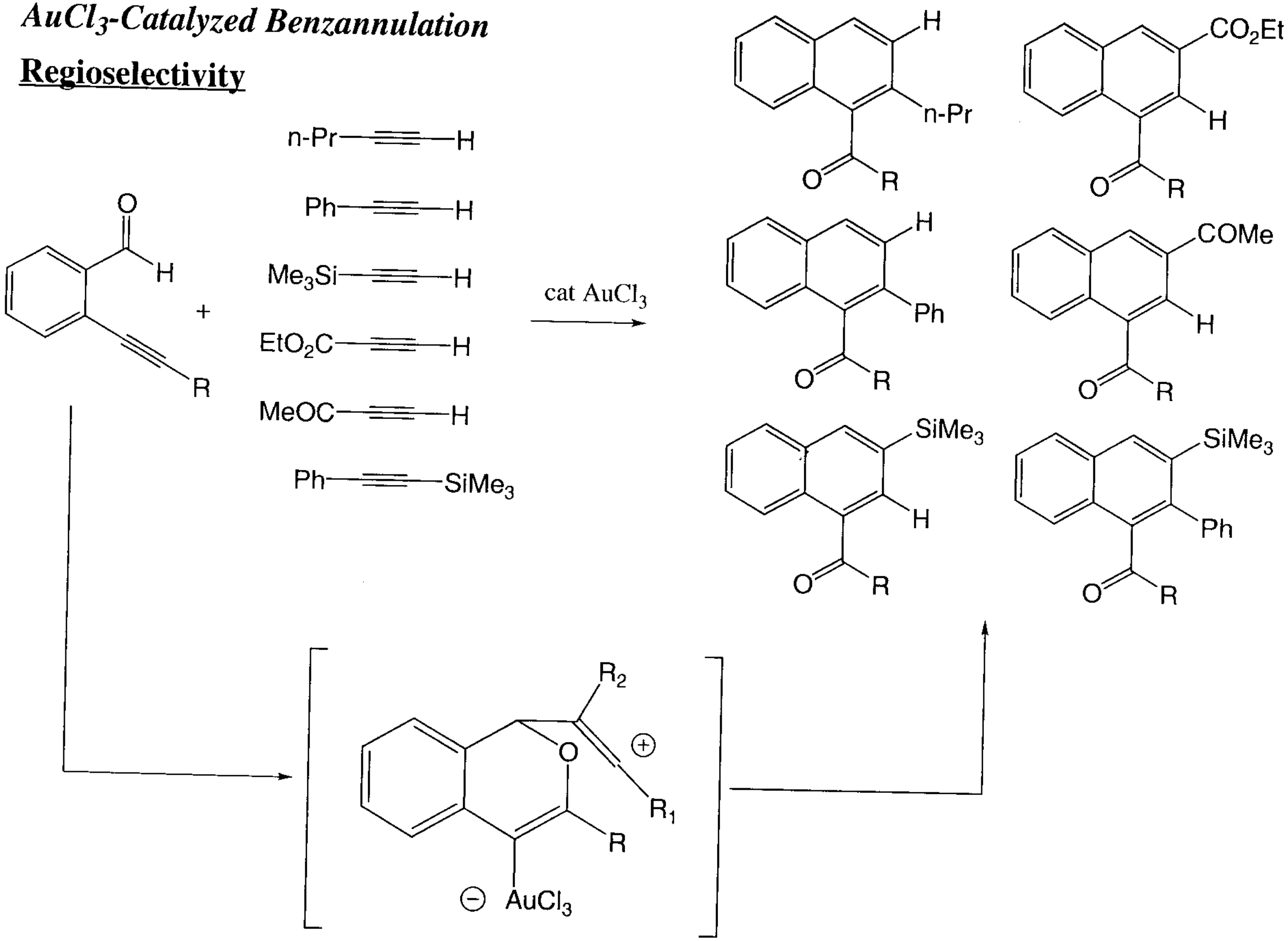
10b **2b** **11b**

Reaction Mechanism

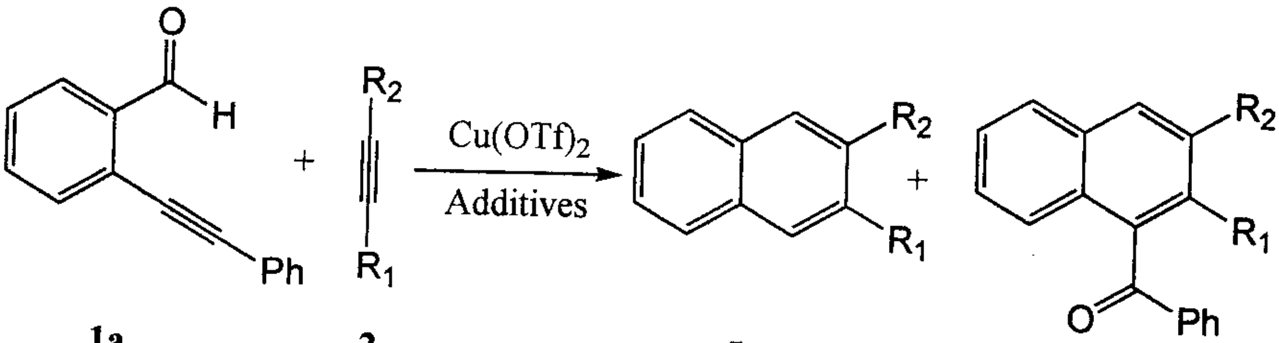


$AuCl_3$-Catalyzed Benzannulation

Regioselectivity



Cu(OTf)$_2$-Catalyzed Benzannulation



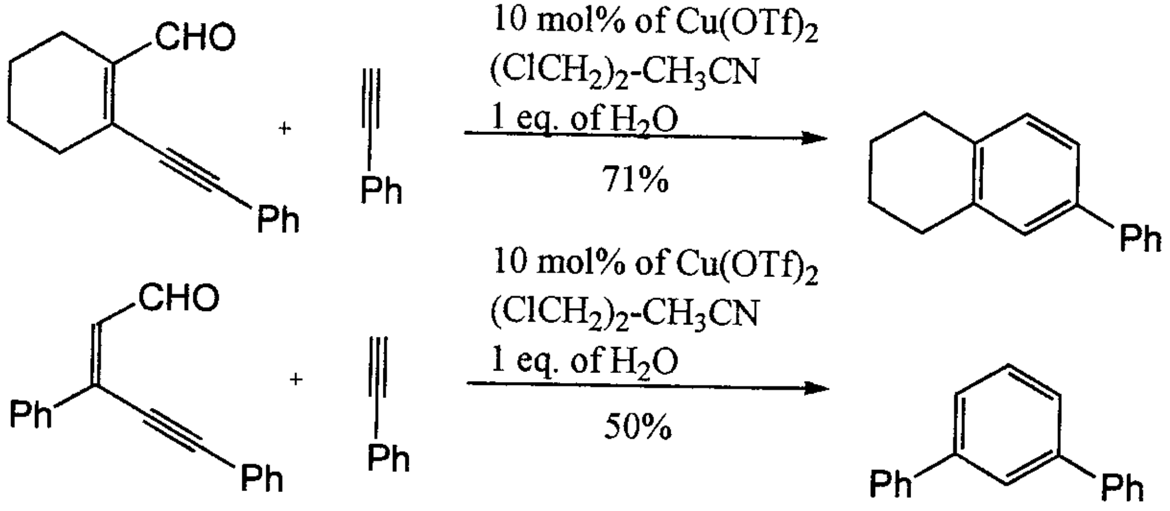
1a **2** **5** **3**

Table 2. The Cu(OTf)$_2$-Catalyzed Reaction of *o*-(Phenylethynyl)benzaldehyde **1a** with Alkynes **2**[a]

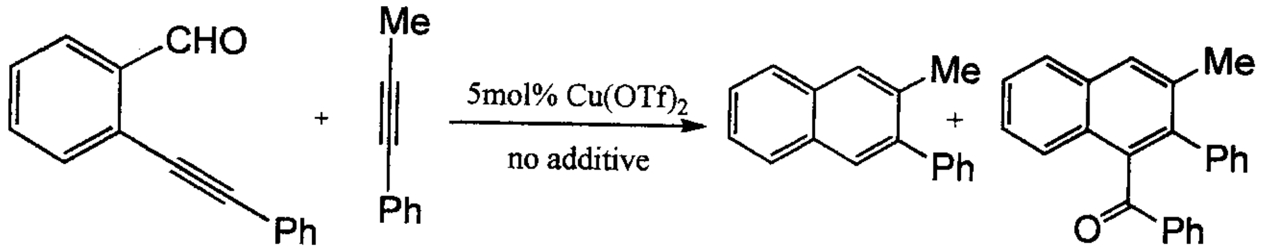
entry	2	R^1	R^2	additive	conditions	yield (%)[b]			
						5		3	
1	**2h**	Ph	Me	none	80 °C, 0.5 h	**5a**	56	**3h**	22
2	**2h**	Ph	Me	H_2O	80 °C, 19 h	**5a**	52	**3h**	12
3	**2h**	Ph	Me	MeOH	80 °C, 1 h	**5a**	44	**3h**	13
4	**2h**	Ph	Me	HCO_2H	80 °C, 0.5 h	**5a**	79	**3h**	8
5	**2h**	Ph	Me	CH_3CO_2H	80 °C, 0.5 h	**5a**	67	**3h**	17
6	**2h**	Ph	Me	CF_2HCO_2H	80 °C, 0.5 h	**5a**	82	**3h**	trace
7	**2h**	Ph	Me	CF_3CO_2H	80 °C, 0.5 h	**5a**	78	**3h**	trace
8[c]	**2h**	Ph	Me	CF_2HCO_2H	80 °C, 15 h	**5a**	6	**3h**	0
9	**2h**	Ph	Me	CF_2HCO_2H	100 °C, 0.25 h	**5a**	86	**3h**	0
10	**2b**	Ph	H	CF_2HCO_2H	100 °C, 0.25 h	**5b**	90	**3b**	0
11	**2i**	C_4H_9	H	CF_3CO_2H	100 °C, 0.25 h	**5c**	72	**3j**	8
12	**2j**	Ph	Ph	CF_2HCO_2H	100 °C, 0.25 h	**5d**	85	**3k**	0
13	**2f**	C_3H_7	C_3H_7	CF_2HCO_2H	100 °C, 0.25 h	**5e**	74	**3f**	0
14	**2k**	Ph	Br	CF_2HCO_2H	100 °C, 0.25 h	**5f**	73	**3l**	0
15	**2l**	Ph	PhS	CF_2HCO_2H	100 °C, 0.25 h	**5g**	60	**3m**	0
16	**2d**	CO_2Et	H	CF_3CO_2H	100 °C, 0.25 h	**5h**	60	**3d**	0[d]

[a] The reaction was carried out using **1a** (1 equiv) and **2** (1.2 equiv) in the presence of Cu(OTf)$_2$ (5 mol %) and additives (1 equiv) in $(ClCH_2)_2$ unless otherwise noted. [b] Isolated yield. [c] The reaction was performed in the presence of 10 mol % of TfOH instead of Cu(OTf)$_2$. [d] **4d** was obtained in 14% yield.

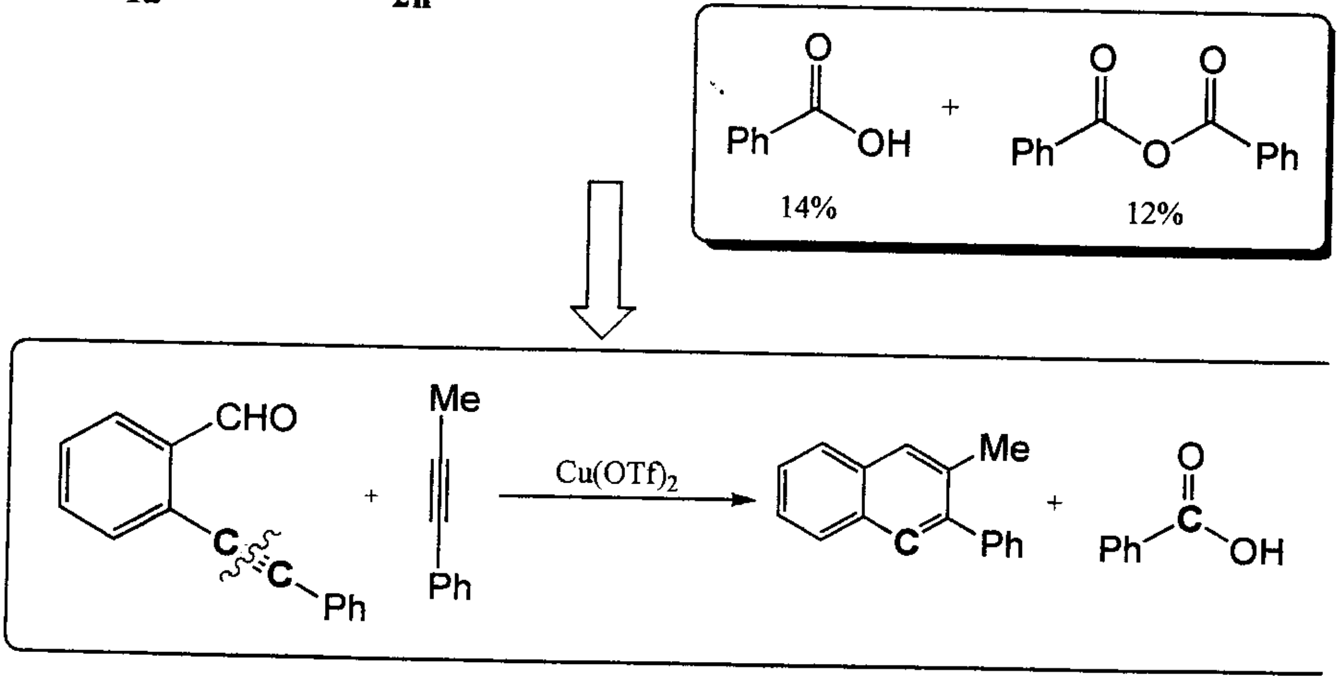
Cu(OTf)$_2$-Catalyzed Benzannulation: another examples



Entry 1



1a **2h** **5a** (56%) **3h** (22%)



Reaction Mechanism