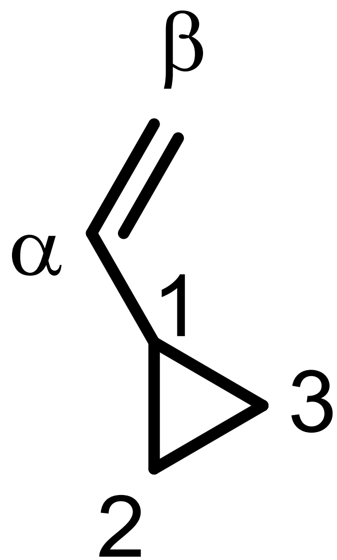
Transition metal catalyzed cycloaddition of VCP
vinylcyclopropane



Zhe Dong

2013-08-10

Outline

1. **Rhodium catalyzed cycloaddition:**

   1.1 general synthesis of different type of VCP

   1.2 VCP as 5 carbon component in the reaction

   1.3 VCP as 3 carbon component in the reaction

   1.4 Application in the total synthesis

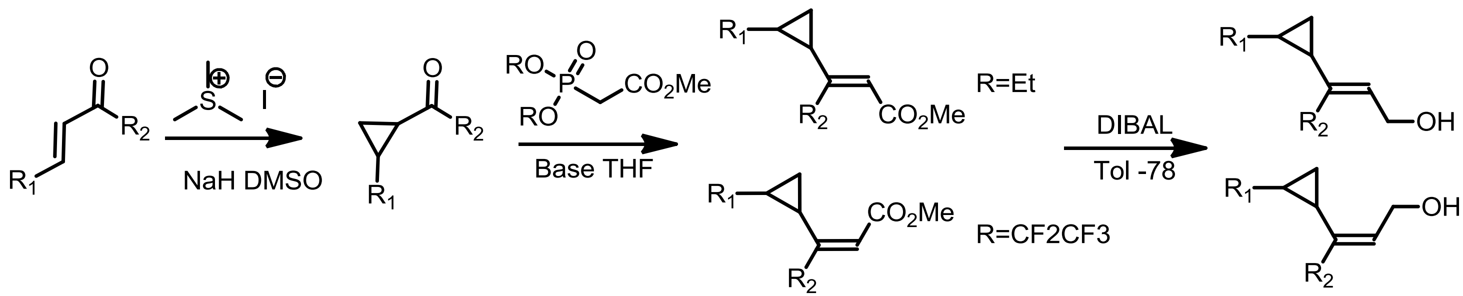
2. **Ruthenium and Iron catalyzed cycloaddition:**

   2.1 Ruthenium catalyzed 5+2

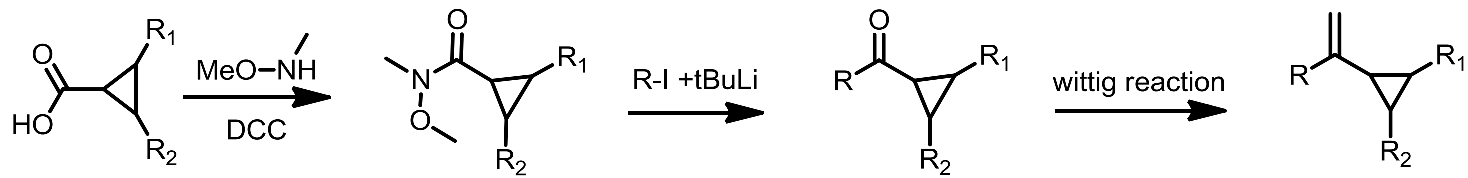
   2.2 Iron catalyzed 5+1 and 5+2

Background

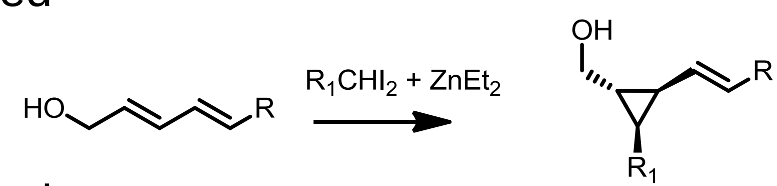
β-subtituted



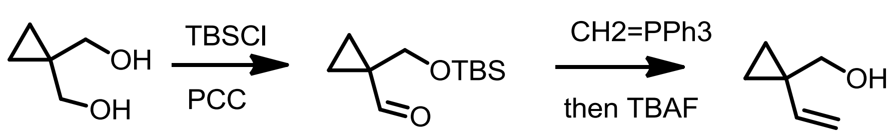
α-subtituted



2-subtituted

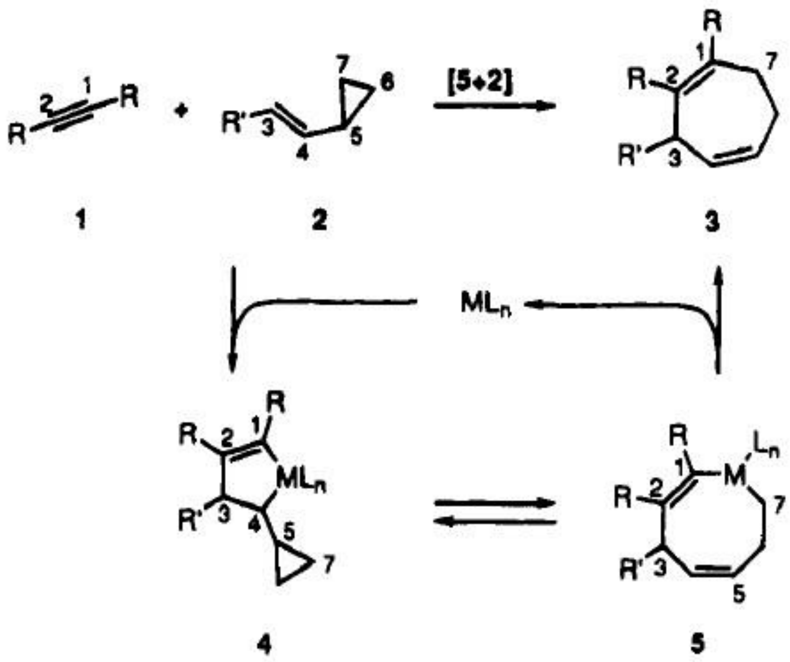


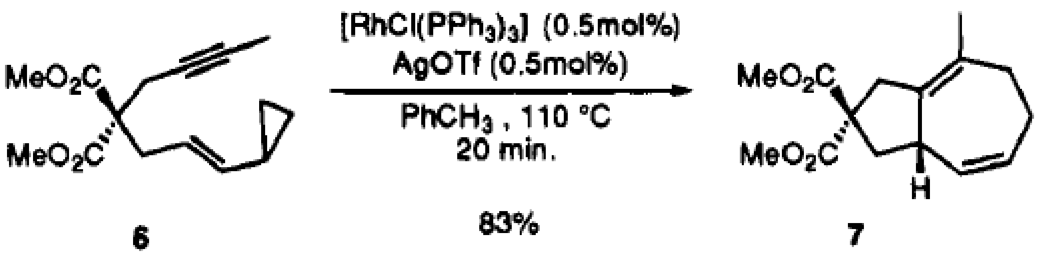
1-subtituted



Discovery of vinyl cyclopropane in the cycloaddition

Homo-Diels-Alder reaction:

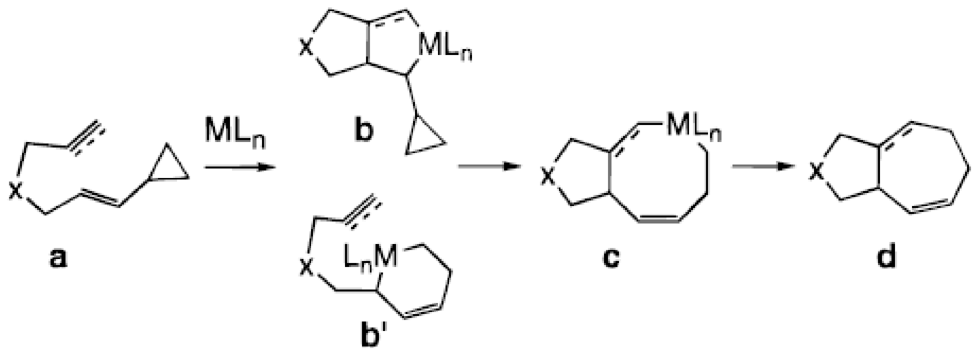


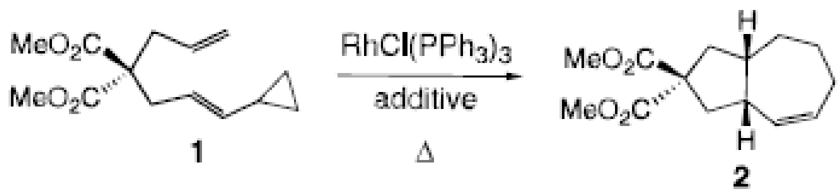


Wender; Takahashi, Witulski, *J. Am. Chem. Soc.* **1995**,*117*, 4720.

vinyl cyclopropane in 5+2

Alkene instead of Alkyne as 2C:





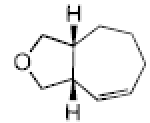
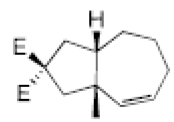
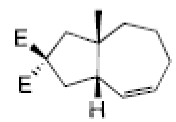
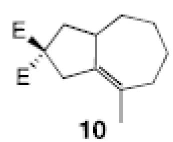
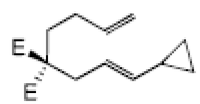
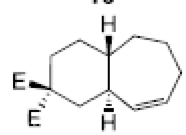
entry	mol % RhCl(PPh$_3$)$_3$	additive[b]	concn[c] (M)	time (h)	yield[d] (%)
1	0.1	AgOTf	1.0	15	90
2[e]	0.1	AgOTf	1.0	17	86
3	0.1	AgOTf	0.4	17	88
4	1	AgOTf	0.05	5	93
5	5	AgOTf	0.01	2	91
6	10	none	0.005	2.5	91

[a] Reactions were run at 110 °C in PhMe. [b] mol % AgOTf = mol % RhCl(PPh$_3$)$_3$. [c] Concentration of **1**. [d] Isolated yield of **2**. [e] Reaction run on 1 g scale.

Wender; *J. Am. Chem. Soc.* **1998,** *120,* 1940-1941

vinyl cyclopropane in 5+2

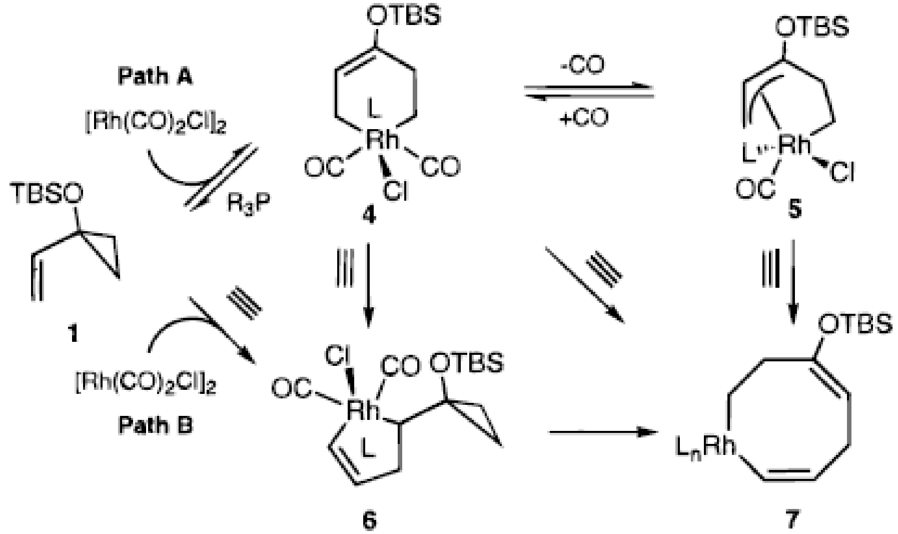
Alkene instead of Alkyne as 2C:

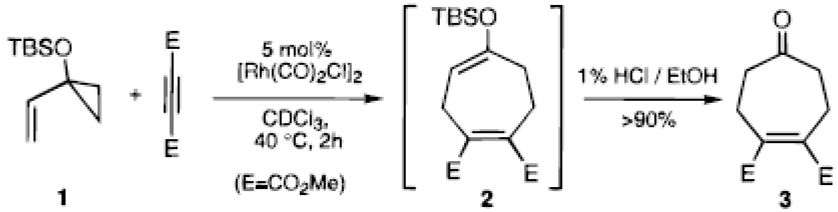
	Vinylcyclopropane-Alkene[a]	Cycloadduct(s)	Reaction Conditions, Time, Isolated Yield
1.	**1**	**2**	A[b], 17 h 86-93% (see Table 1)
2.	 **3**	 **4**	B[c], 10 h 70% (94% by GC)
3.	 **5**	 **6**	C[d], 1 h 92%
4.	 **7**	 **8**	C[d], 1 h 94%
5.	 **9**	 **10**	D[e], 15 h 78%
6.	 **11**	 **12**	E[f], 5 d 77%

Wender; *J. Am. Chem. Soc.* **1998,** *120,* 1940-1941

vinyl cyclopropane in 5+2

Intermolecular try:

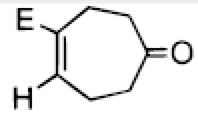
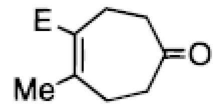
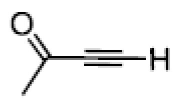
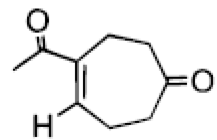
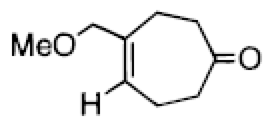
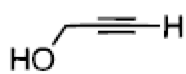
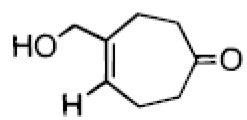
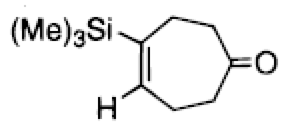




Wender; *J. Am. Chem. Soc.* **1998,** *120,* 10976-10977

vinyl cyclopropane in 5+2

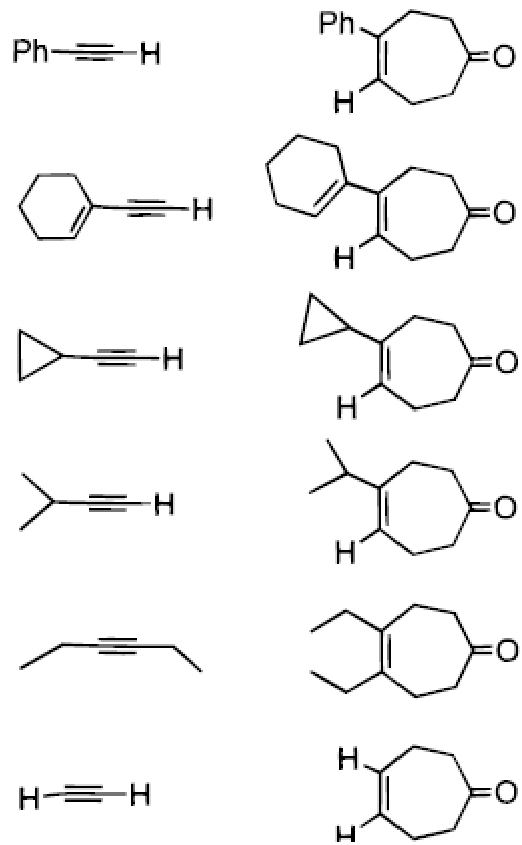
Intermolecular try:

1			2h / 40 °C	93%
2			1.5h / 40 °C	92%
3			2.5h / 40 °C	88%
4			1.5h / 40 °C	88%
5			1.5h / 40 °C	74%
6			2h / 40 °C	77%

Wender; *J. Am. Chem. Soc.* **1998,** *120,* 10976-10977

vinyl cyclopropane in 5+2

Intermolecular try:

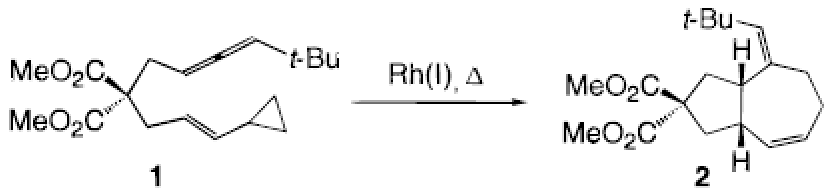


7	3h / 30 °C	81%
8	3h / 40 °C	75%
9	2h / 40 °C	88%
10	2.5h / 40 °C	84%
11	7h / 40 °C	65%
12	6h / 40 °C	79%

Wender; *J. Am. Chem. Soc.* **1998,** *120,* 10976-10977

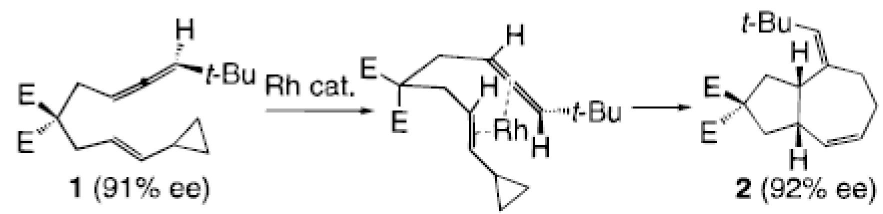
vinyl cyclopropane in 5+2

Allene as 2C :



entry	catalyst	mol % Rh	solv	concn[a]	yield[b]
1	$RhCl(PPh_3)_3$	1	$PhCH_3$	0.1 M	96%
2	$RhCl(PPh_3)_3$	0.2	$PhCH_3$	1.0 M	90%
3	$[Rh(CO)_2Cl]_2$	1	DCE[c]	0.1 M	89%

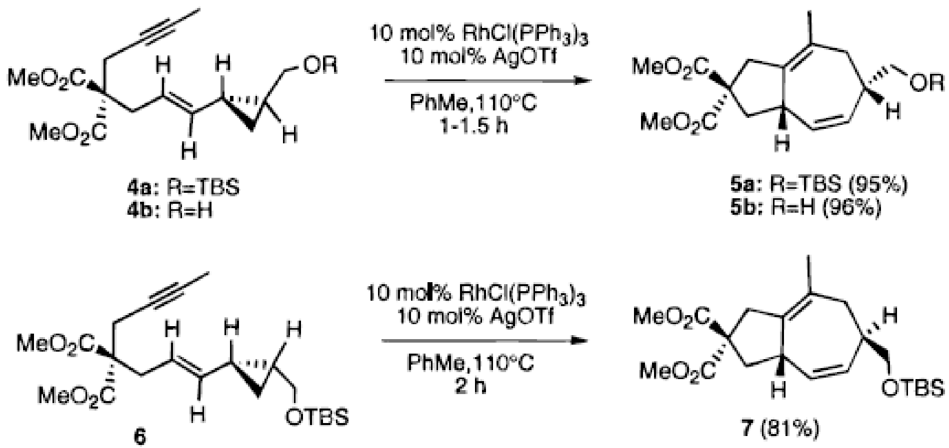
[a] Concentration of **1**. [b] Isolated yield of **2**. [c] DCE = $ClCH_2CH_2Cl$.



Paul Wender. Frank Glorius; *J. Am. Chem. Soc.* **1999,** *121,* 5348-5349

vinyl cyclopropane in 5+2

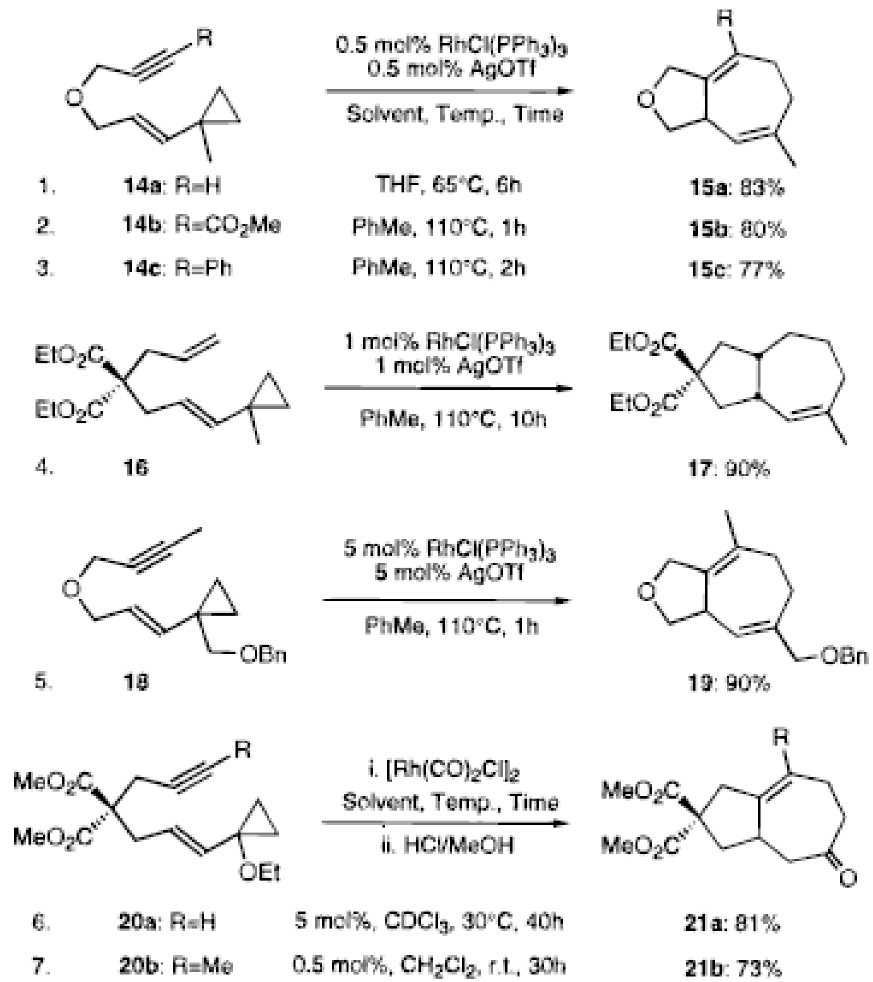
Regio- and Stereoselectivity:



Paul Wender.; *J. Am. Chem. Soc.* **1999,** *121,* 10442-10443

vinyl cyclopropane in 5+2

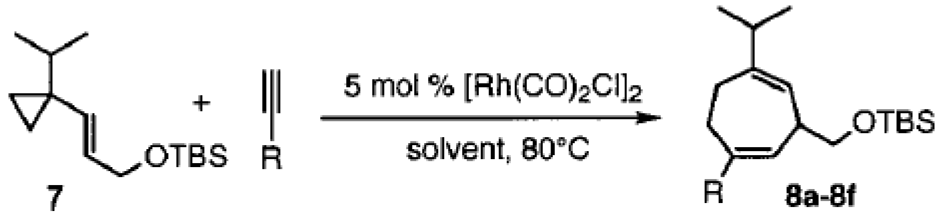
Regio- and Stereoselectivity:



Paul Wender.; *J. Am. Chem. Soc.* **1999,** *121,* 10442-10443

vinyl cyclopropane in 5+2

Simple vcp as 5C:



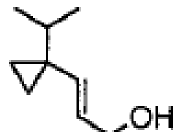
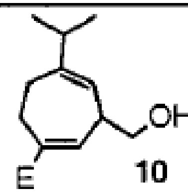
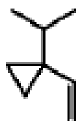
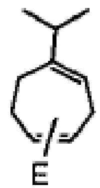
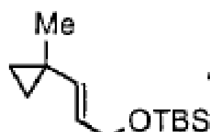
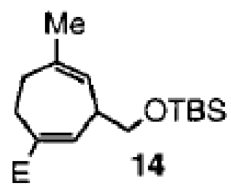
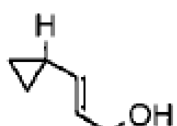
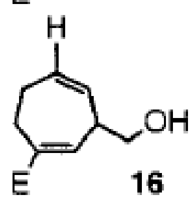
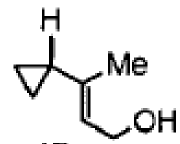
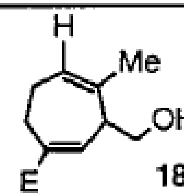
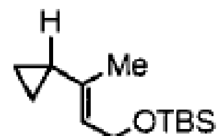
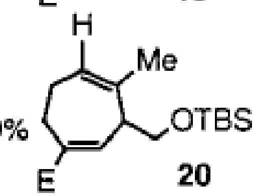
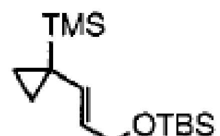
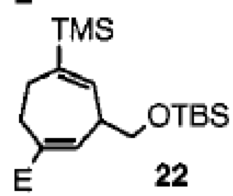
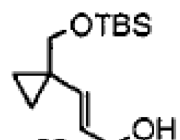
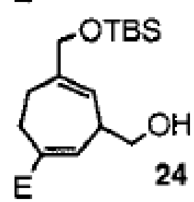
entry	R	solvent[a]	time	conv, %	yield, %	product
1	CO_2Me	A	2 h	100	93	**8a**
2	CO_2Me	B	1 h	100	**95**	**8a**
3	CO_2Me	C	30 min	100	85	**8a**
4	Ph	A	4 h	100	**92**	**8b**
5	Ph	B	2 h	100	81	**8b**
6	CH_2OMe	A	22 h	56	49	**8c**
7	CH_2OMe	B	5 h	>95	**90**	**8c**
8	CH_2OH	A	6 h	80	73	**8d**
9	CH_2OH	B	5 h	>95	**90**	**8d**
10	C_3H_7	A	48 h	90	79	**8e**
11	C_3H_7	B	23 h	91	**81**	**8e**
12	TMS	A	72 h		77	**8f**
13	TMS	B	23 h	>95	**90**	**8f**

[a] Solvents: A = DCE, B = 5% TFE in DCE, C = TFE.

Paul Wender.; *J. Am. Chem. Soc.* **2001,** *123,* 179-180

vinyl cyclopropane in 5+2

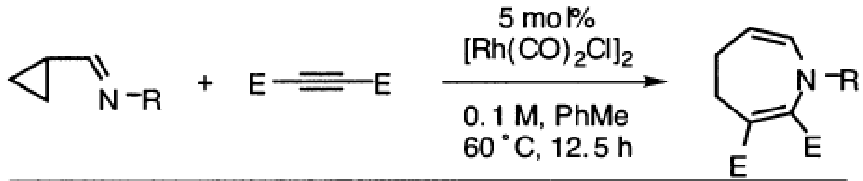
Simple vcp as 5C:

Entry	VCP	Cond.[a]/ Yield	Product
1	 9	A 2h/ 82%	 10
2	 11	A 1.5h/ 76%	 12
3	 13	A 8h/ 81%	 14
4	 15	A 30h/ 23% B 2h/ dec.	 16
5	 17	A 72h/ 38% B 6h/ dec.	 18
6	 19	A 72h/ 64% B 45 min/ 69%	 20
7	 21	A 3h/ 53%	 22
8	 23	A 2h/ 82%	 24

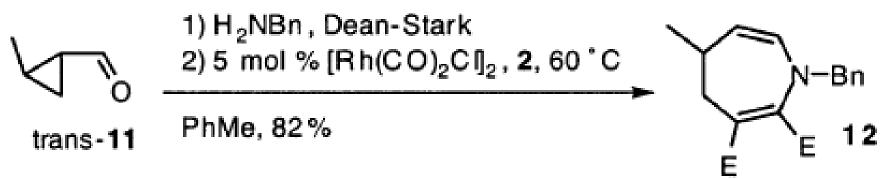
Paul Wender.; *J. Am. Chem. Soc.* **2001,** *123,* 179-180

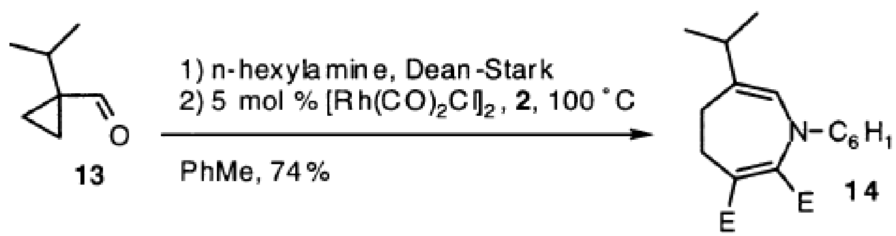
vinyl cyclopropane in 5+2

Aza vcp as 5C:



entry	R =	Product	yield[a]
1	Cy	**3**	85% (83%)
2	*n*-hexyl	**5**	95% (91%)
3		**6**	(83%)
4		**7**	(79%)
5		**8**	68% (61%)

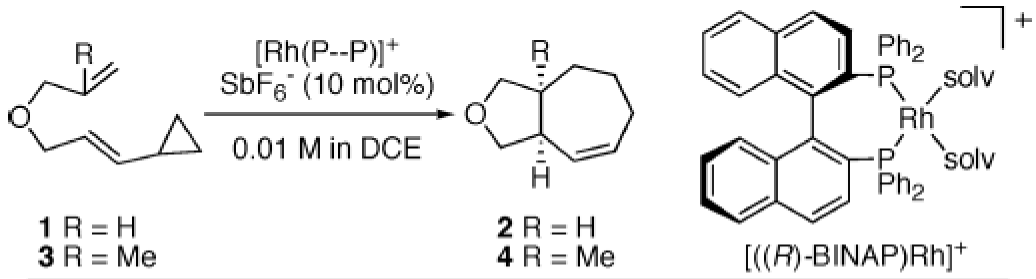


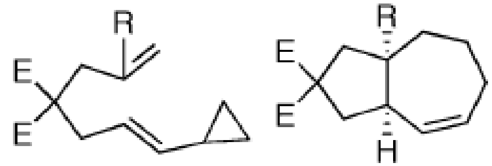


Paul Wender.; *J. Am. Chem. Soc.* **2002,** *124, 1*5154-15155

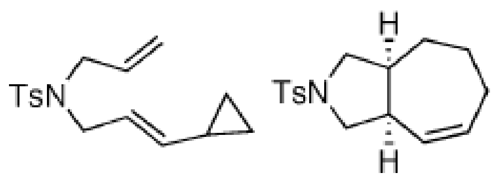
vinyl cyclopropane in 5+2

VCP as 5C:
Asymmetric reaction

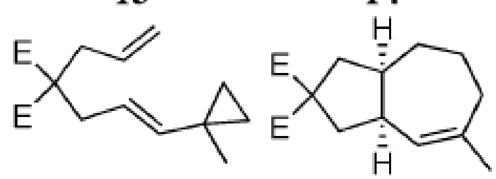




1	**7** R = Me	**8** R = Me	70 °C, 2 d, 0.05 M	72%, >95%[a]
2	**9** R = CH_2OBn	**10** R = CH_2OBn	70 °C, 2 d, 0.01 M	80%, >99%[b]
3	**11** R = H	**12** R = H	50 °C, 1.5 d, 0.03 M	73%, 52%[c]



4	**13**	**14**	40-60 °C, 8 d, 0.01 M	90%, 96%[c]

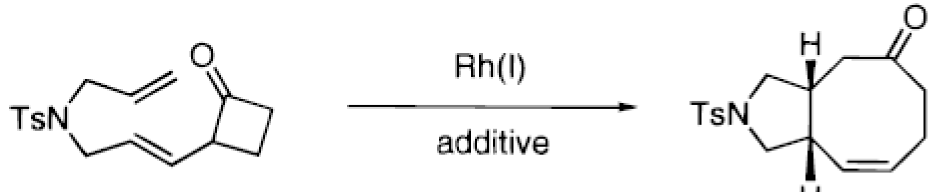


5	**15**	**16**	70 °C, 6 d, 0.01 M	92%, 95%[c]

Paul Wender.; *J. Am. Chem. Soc.* **2002,** *124, 1*5154-15155

vinyl cyclopropane in 5+2+1

Original idea of 5+2+1:



1 2

[a] Ts = *p*-$CH_3C_6H_4SO_2$.

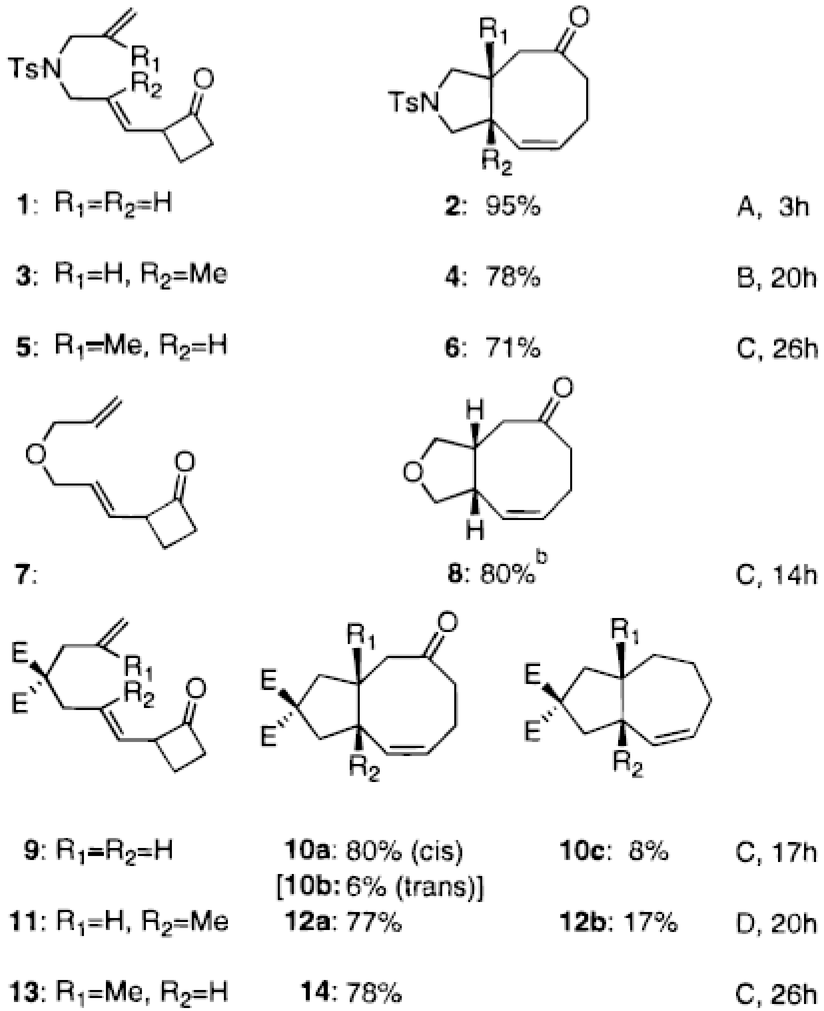
Table 1. Cycloaddition of 2-Vinylcyclobutanone **1**[a]

entry	mol % $[Rh(CO)_2Cl]_2$ [b]	concn (M)[c]	time (h)	yield (%)[d]
1	5	0.01	3	92
2	2.5	0.05	6.5	82
3	2.5	0.1	9	48
4	2.5	<0.1[e]	9	81
5	5	0.5	4	39
	mol % $RhCl(PPh_3)_3$ [f]			
6	10	0.014	3	95
7	5	0.05	7.5	86

Paul Wender.; *J. Am. Chem. Soc.* **2000,** *122,* 7815-7816

vinyl cyclopropane in 5+2+1

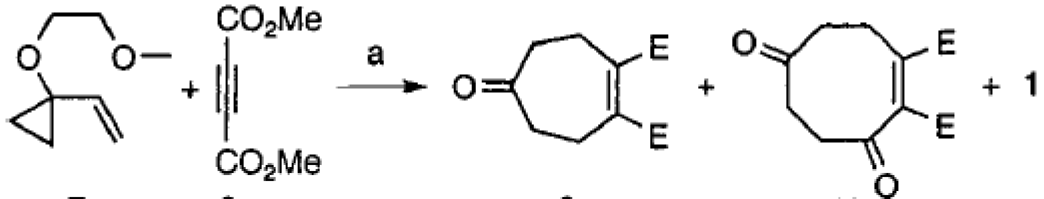
Original idea of 5+2+1:



Paul Wender.; *J. Am. Chem. Soc.* **2000,** *122,* 7815-7816

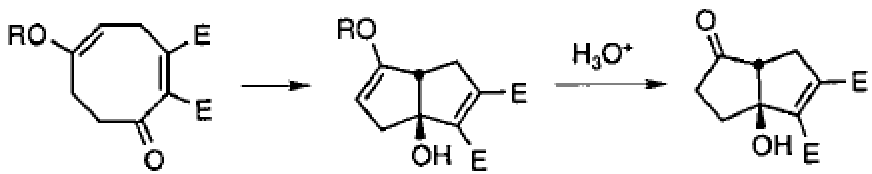
vinyl cyclopropane in 5+2+1

VCP in 5+2+1:



7 **8** **9** **10**

[a] Key: (a) CO (1 atm), $[Rh(CO)_2Cl]_2$ (5 mol %), 1,2-dichloroethane (0.1M, 7), 60 °C; H_3O^+.

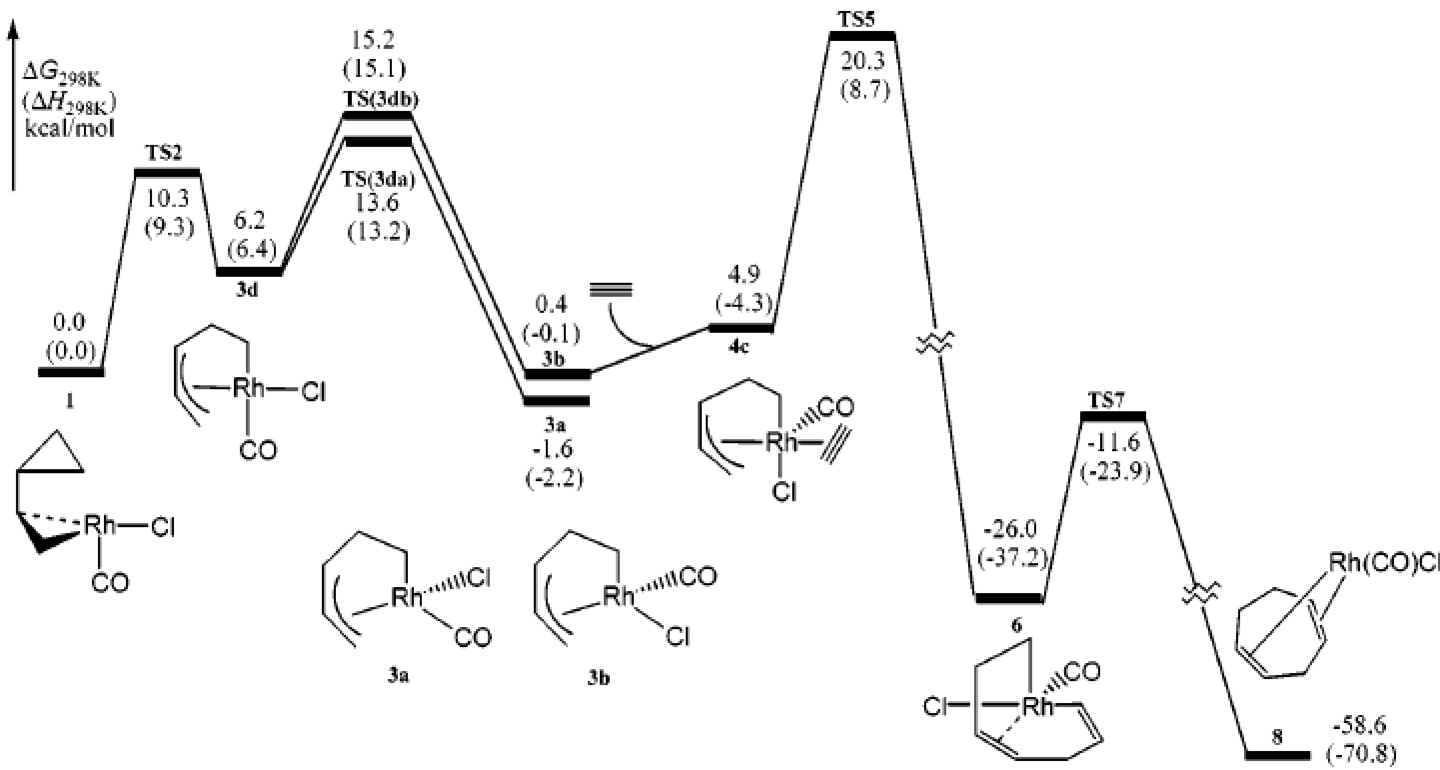


12, R= $CH_2CH_2OCH_3$ **13** **11**

Paul Wender.; *J. Am. Chem. Soc.* **2002,** *124, 2876*-2877

vinyl cyclopropane in 5+2

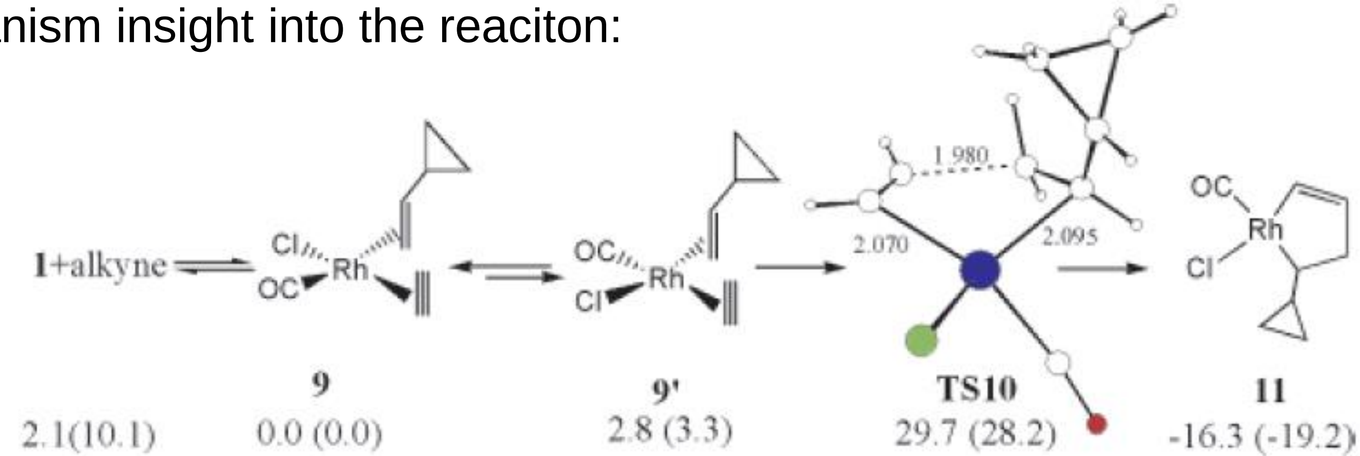
Mechanism insight into the reaciton:

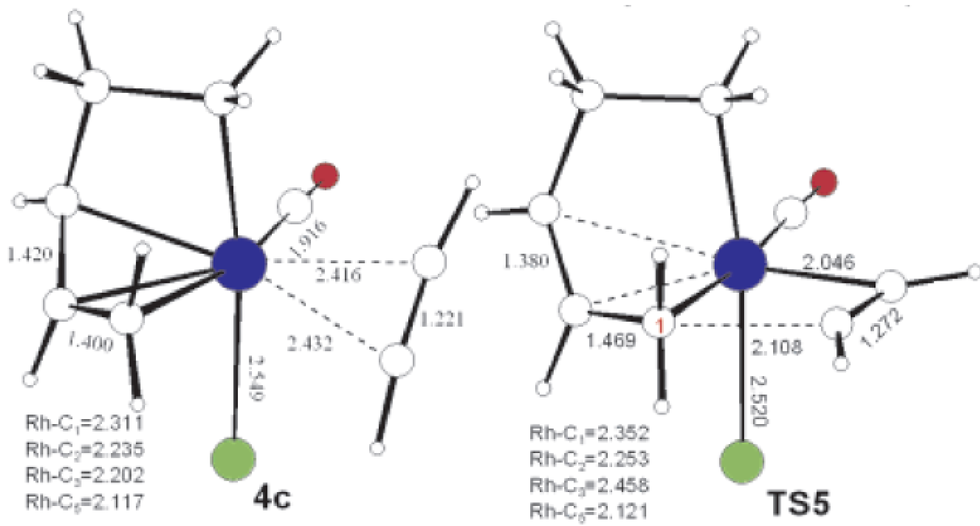


Z-X. Yu. K. Houk .; *J. Am. Chem. Soc.* **2002,** *126, 9154*-9155

vinyl cyclopropane in 5+2

Mechanism insight into the reaciton:

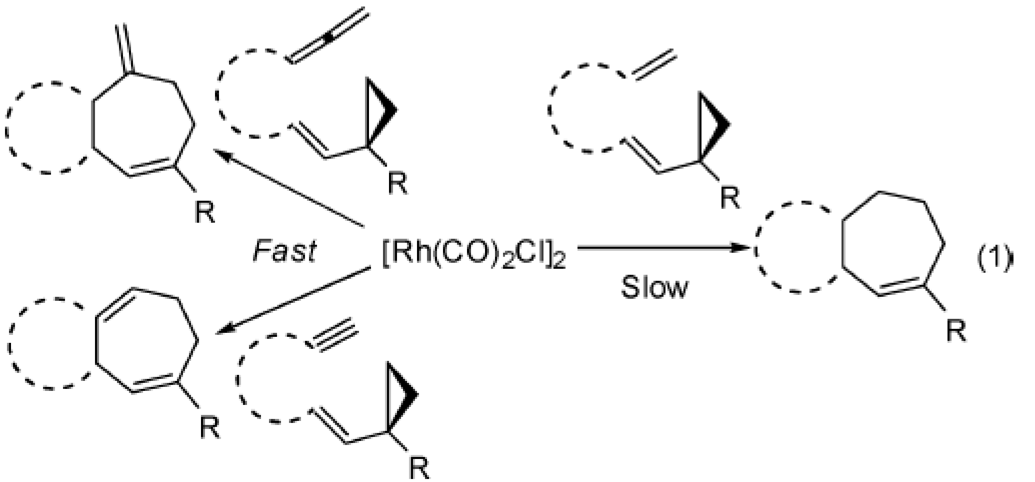




Z-X. Yu. K. Houk .; *J. Am. Chem. Soc.* **2002,** *126, 9154*-9155

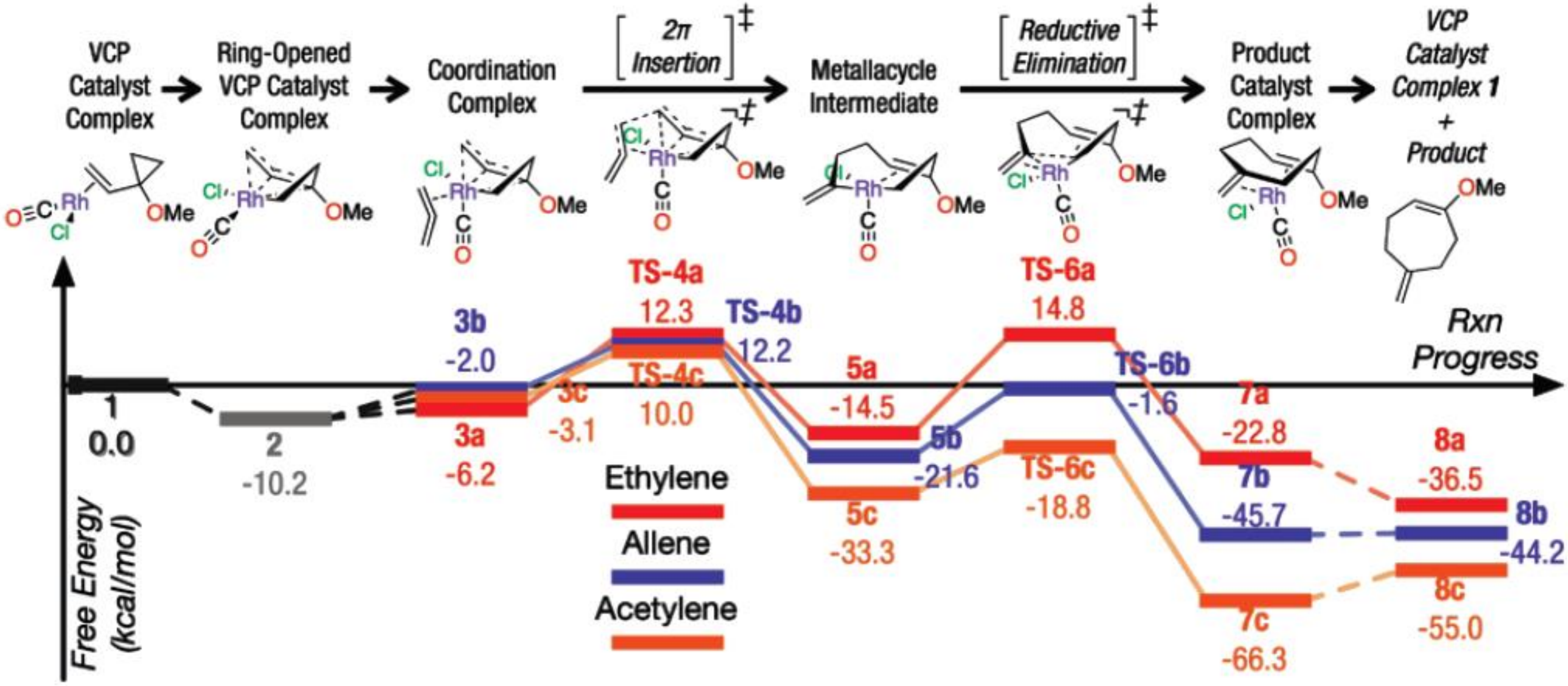
vinyl cyclopropane in 5+2

Mechanism insight into the reaciton:



vinyl cyclopropane in 5+2

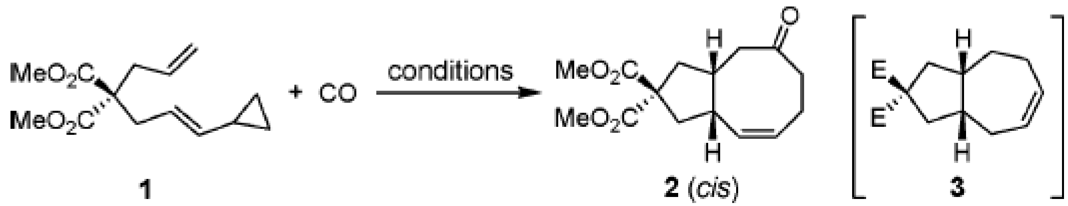
Mechanism insight into the reaciton:



Z-X. Yu. K. Houk .; *J. Am. Chem. Soc.* **2008,** *130, 2378*-2379

vinyl cyclopropane in 5+2+1

DFT inspired reaction:

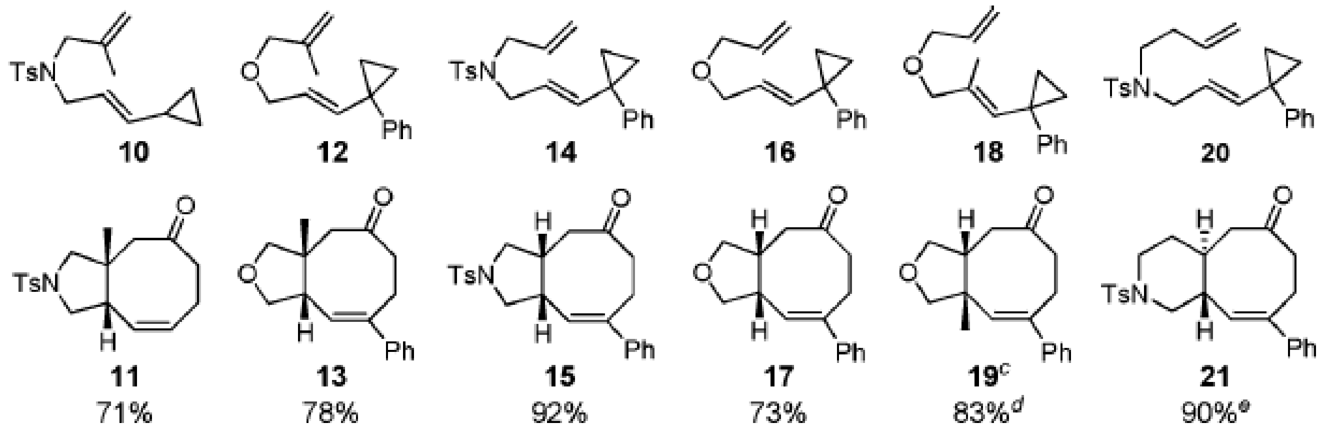


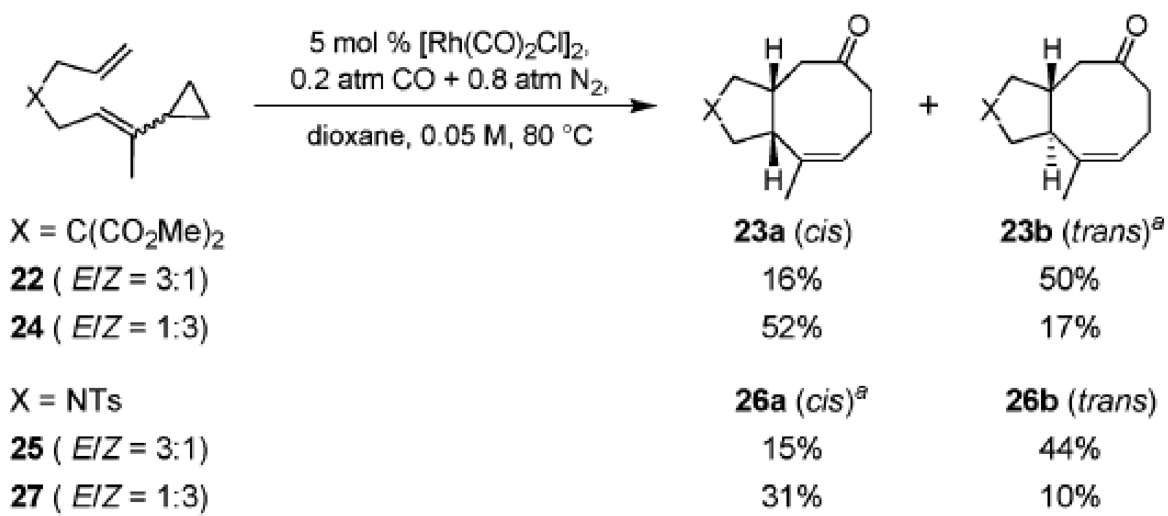
entry	CO [atm]	catalyst [mol %]	T [°C]	solvent	concn [M]	t [h]	yield [%]
1	0	10% $[Rh(CO)_2Cl]_2$	110	toluene	0.05	24	10[a]
2	1	5% $[Rh(CO)_2Cl]_2$	80	dioxane	0.05	5	44[b]
3	4	5% $[Rh(CO)_2Cl]_2$	80	dioxane	0.05	24	8
4	0.2[c]	5% $[Rh(CO)_2Cl]_2$	80	dioxane	0.05	5	70[d]
5	0.2	5% $[Rh(CO)_2Cl]_2$	60	dioxane	0.05	48	17
6	0.2	5% $[Rh(CO)_2Cl]_2$	90	dioxane	0.05	5	70
7	0.2	5% $[Rh(CO)_2Cl]_2$	100	dioxane	0.05	5	61
8	0.2	5% $[Rh(CO)_2Cl]_2$	80	DCE	0.05	5	62[e]
9	0.2	5% $[Rh(CO)_2Cl]_2$	80	toluene	0.05	12	14
10	0.2	5% $[Rh(CO)_2Cl]_2$	80	dioxane	0.01	5	68
11	0.2	5% $[Rh(CO)_2Cl]_2$	80	dioxane	0.20	5	34
12	0.2	10% $[Rh(CO)_2Cl]_2$	80	dioxane	0.05	5	72
13	1	10% $RhCl(PPh_3)_3$	80	dioxane	0.05	17	N.R.
14	1	10% $RhCl(PPh_3)_3$ + 10% AgOTf	80	dioxane	0.05	18	23[f]
15	1	5% $[Rh(CO)_2Cl]_2$ + 10% AgOTf	80	dioxane	0.05	13	7

Z-X. Yu.; *J. Am. Chem. Soc.* **2007,** *129,* 10060-10061

vinyl cyclopropane in 5+2+1

DFT inspired reaction:

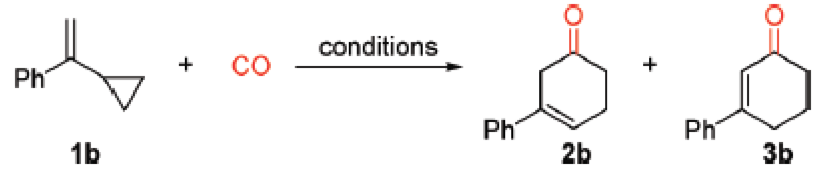




Z-X. Yu.; *J. Am. Chem. Soc.* **2007,** *129,* 10060-10061

vinyl cyclopropane in 5+1

Simple reaction

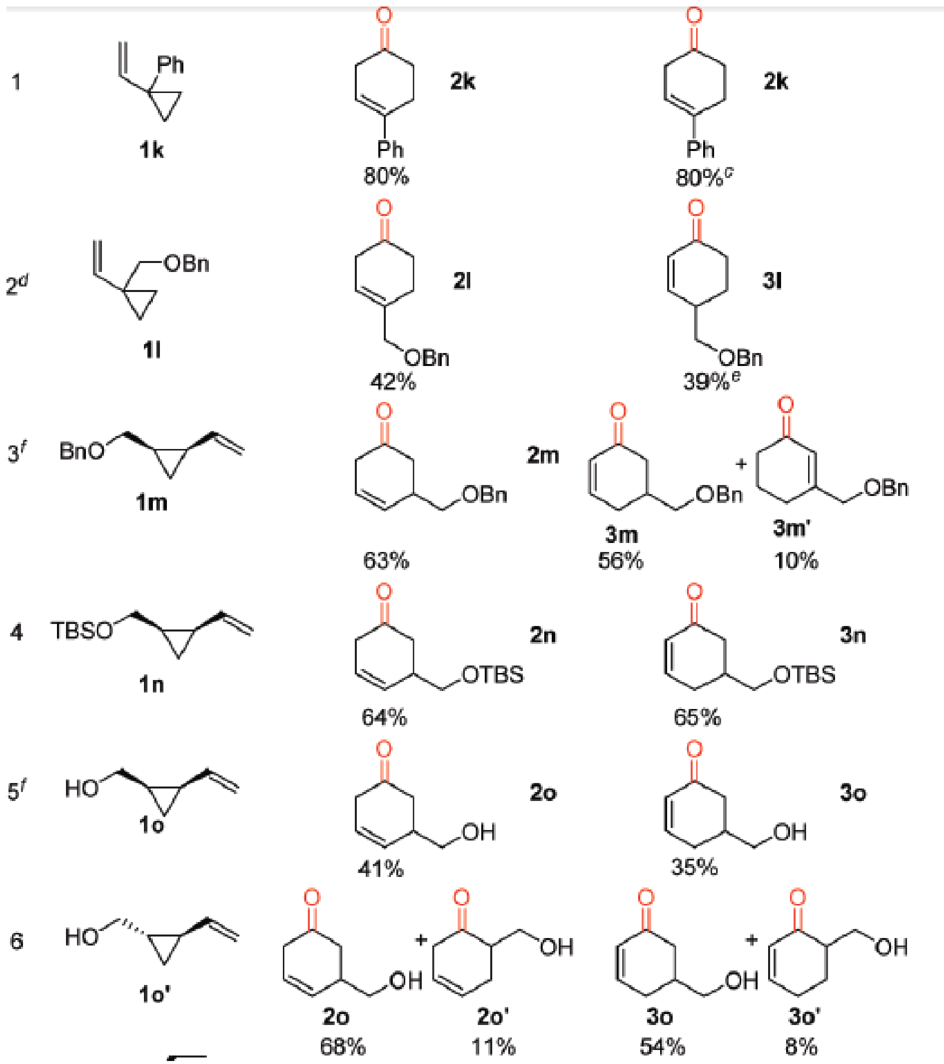


entry	catalyst[b]	solvent[c]	t (°C)	CO (atm)	additive	yields (**2b**, **3b**)[d] (%)
1	[Rh(dppp)]SbF_6	DCE	85	0.2	4 Å MS	41, 34
2	$[Rh(CO)_2Cl]_2$	DCE	85	0.2	4 Å MS	NR[e]
3	$[Rh(CO)_2]SbF_6$	DCE	85	0.2	4 Å MS	dec[f]
4	[Rh(dppm)]SbF_6	DCE	85	0.2	4 Å MS	NR[e]
5	[Rh(dppe)]SbF_6	DCE	85	0.2	4 Å MS	20, 15
6	[Rh(dppb)]SbF_6	DCE	85	0.2	4 Å MS	19, 24
7	[Rh(dppp)]SbF_6	DCE	85	0.2	no	0, 44
8	[Rh(dppp)]SbF_6	DCE	95	0.2	4 Å MS	dec[f]
9	[Rh(dppp)]SbF_6	DCE	75	0.2	4 Å MS	NR[e]
10	[Rh(dppp)]SbF_6	DCE	85	1	4 Å MS	dec[f]
11	[Rh(dppp)]SbF_6	DCE	85	0.1	4 Å MS	27, 39
12	[Rh(dppp)]OTf	DCE	85	0.2	4 Å MS	66, 12
13	[Rh(dppp)]OTf	DME	85	0.2	4 Å MS	16, 0
14	[Rh(dppp)]OTf	dioxane	85	0.2	4 Å MS	dec[f]
15[g]	[Rh(dppp)]SbF_6	DCE	85	0.2	4 Å MS	0, 73

Z-X. Yu. *Org. Lett*. **2012**,*14*, 692-695

vinyl cyclopropane in 5+1

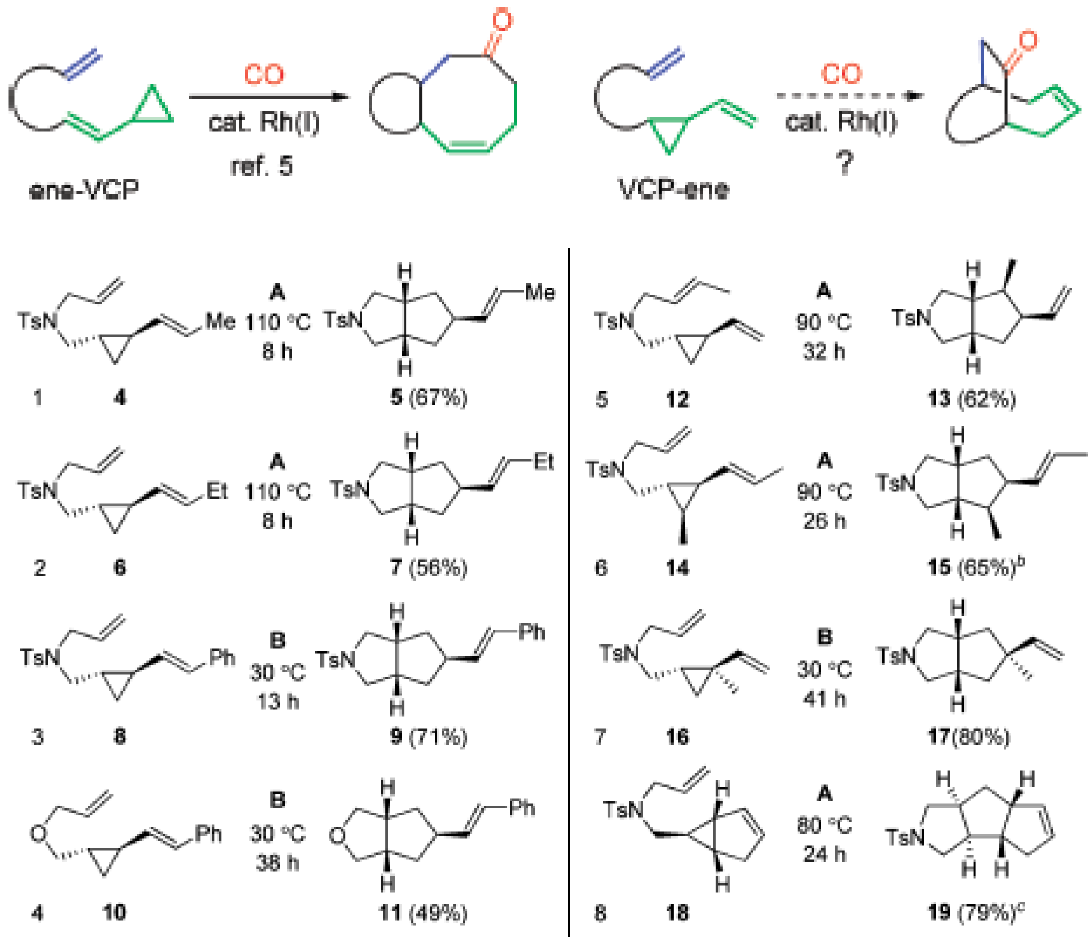
DFT inspired reaction:



Z-X. Yu. *Org. Lett*. **2012**,*14*, 692-695

vinyl cyclopropane in 3+2

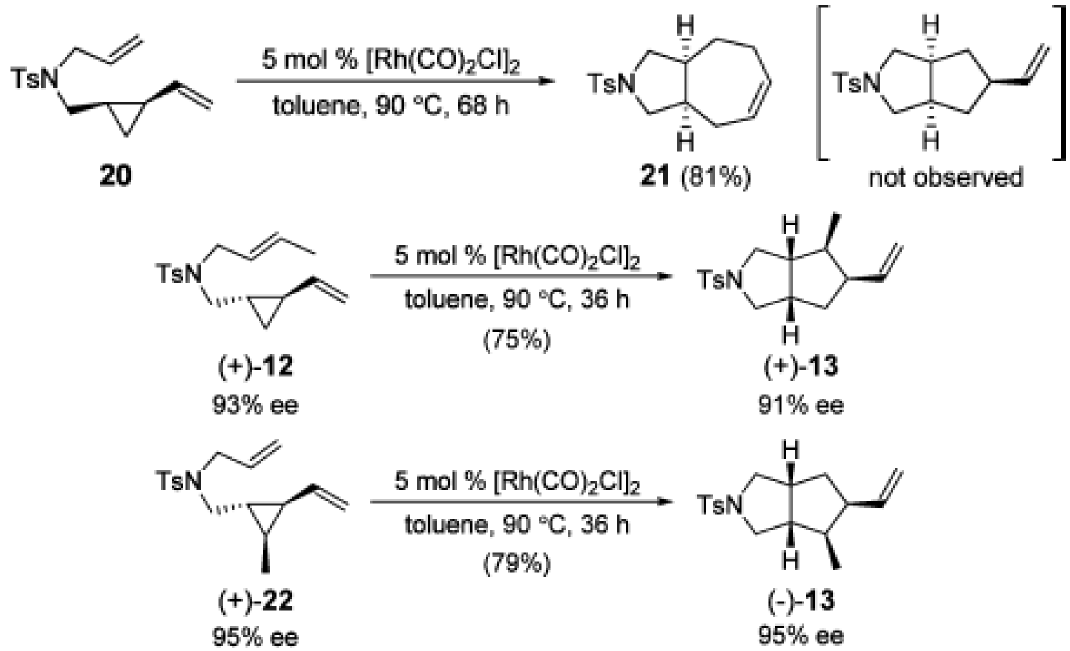
VCP as 3C:



L. Jiao. Z-X. Yu.; *J. Am. Chem. Soc.* **2008**, *130*, 7178-7179.

vinyl cyclopropane in 3+2

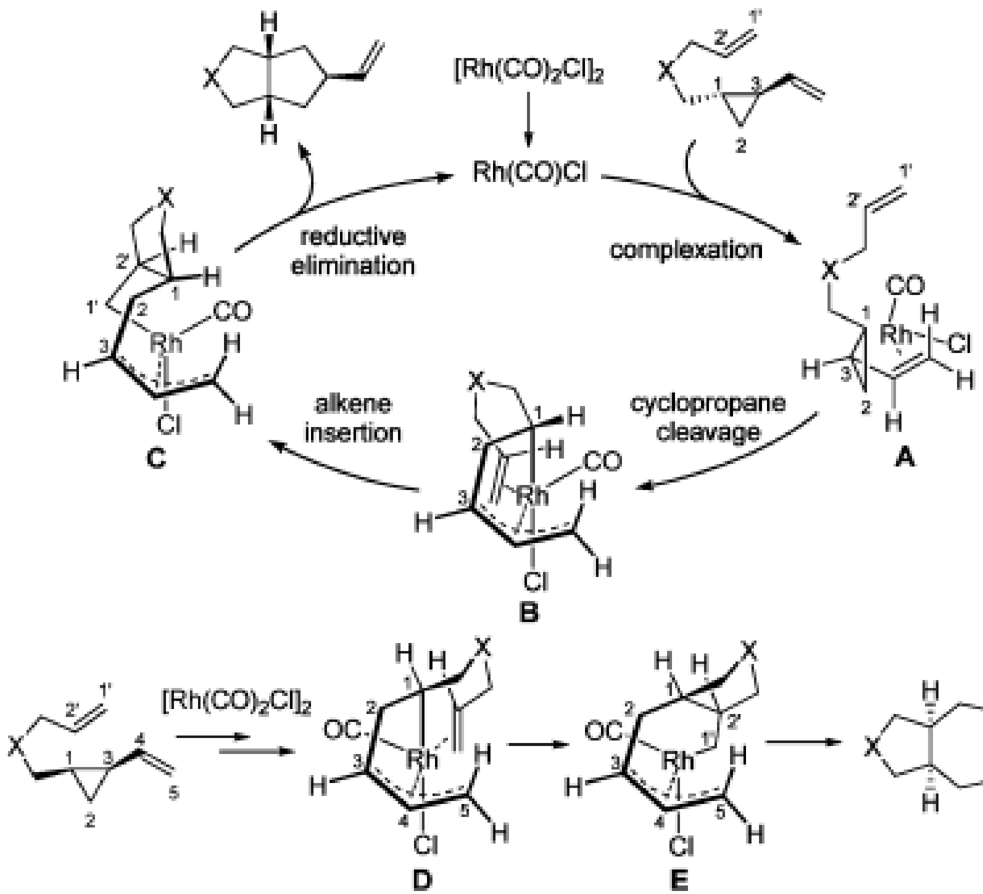
VCP as 3C:



L. Jiao. Z-X. Yu.; *J. Am. Chem. Soc.* **2008**, *130*, 7178-7179.

vinyl cyclopropane in 3+2

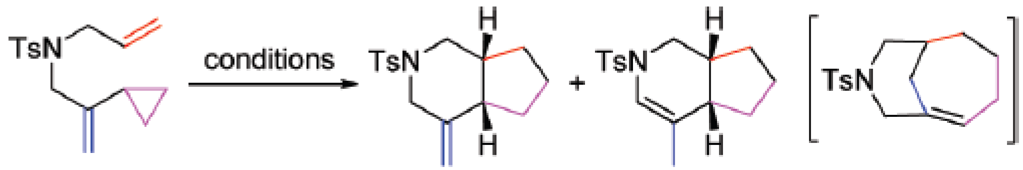
VCP as 3C:



L. Jiao. Z-X. Yu.; *J. Am. Chem. Soc.* **2008**, *130*, 7178-7179.

vinyl cyclopropane in 3+2

VCP as 3C:

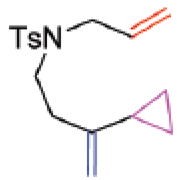
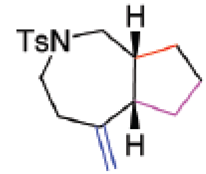
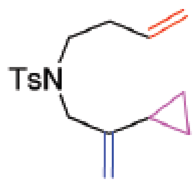
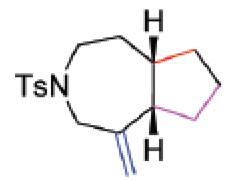
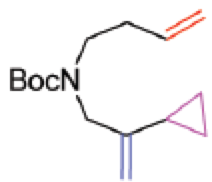
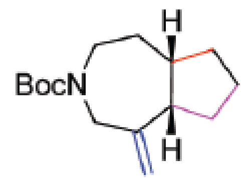
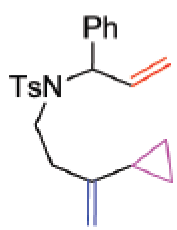
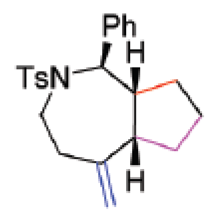


entry	catalyst	t (h)	additive	yield (**2a**, **2a'**)[b]
1	$[Rh(CO)_2Cl]_2$	24		<5%, <5%
2	$[Rh(CO)_2]SbF_6$[c]	24		<5%, <5%
3	$[Rh(dppm)]SbF_6$[d]	24		61%, 10%
4	$[Rh(dppe)]SbF_6$[d]	24		46%, 5%
5	$[Rh(dppp)]SbF_6$[d]	24		12%, <5%
6	$[Rh(dppb)]SbF_6$[d]	24		<5%, <5%[e]
7	$[Rh(BINAP)]SbF_6$[d]	24		<5%, <5%[e]
8	$[Rh(dppf)]SbF_6$[d]	24		–[f]
9	$[Rh(dppCy)]SbF_6$[d]	24		–[f]
10	$[Rh(dppm)]SbF_6$[d]	6	4 Å MS	94%, 0%

Z-X. Yu.; *Org. Lett.*, **2010**, *12*, 1332–1335.

vinyl cyclopropane in 3+2

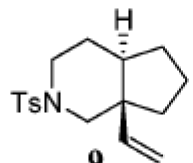
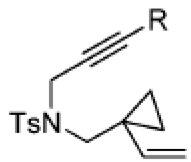
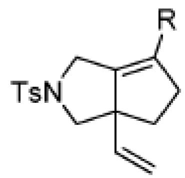
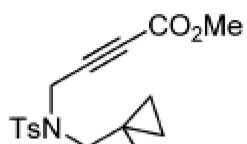
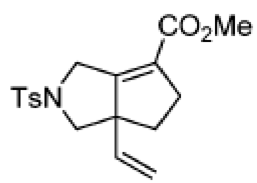
VCP as 3C:

Entry	Substrate	Time	Yield	Product
1	 **3a**	10 h	91%	 **4a**
2	 **3b**	36 h	71% (79%)[b]	 **4b**
3	 **3c**	36 h	82%	 **4c**
4	 **3d**	60 h	56% (90%)[b] dr > 19:1[c]	 **4d**

Z-X. Yu.; *Org. Lett.*, **2010**, *12*, 1332–1335.

vinyl cyclopropane in 3+2

VCP as 3C:

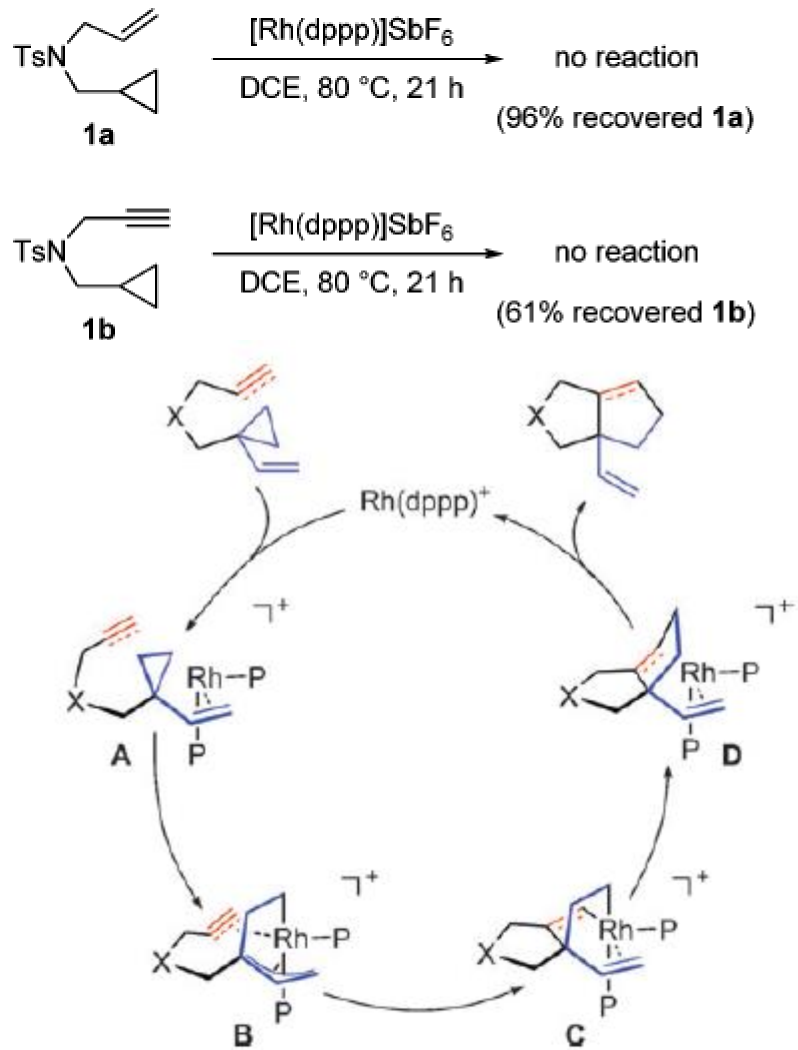
4	 **8**	 **9**	80 °C, 12 h	98%
				
5	**10** R = H	**11**	80 °C, 5 h	82%
6	**12** R = Me	**13**	80 °C, 23 h	78%
7	**14** R = *i*-Pr	**15**	80 °C, 48 h	35%[d]
8	 **16**	 **17**	80 °C, 13 h	66%

L. Jiao. Z-X. Yu.; *Chem. Commun.*, **2010**, *46*, 1059 - 1061

.

vinyl cyclopropane in 3+2

VCP as 3C:

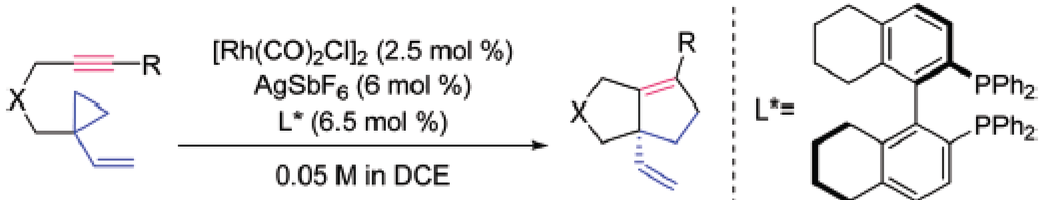


L. Jiao. Z-X. Yu.; *Chem. Commun.*, **2010**, *46*, 1059 - 1061

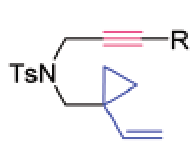
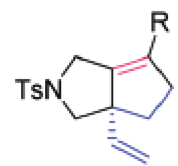
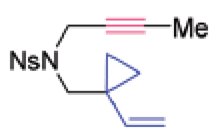
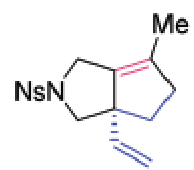
.

vinyl cyclopropane in 3+2

VCP as 3C:



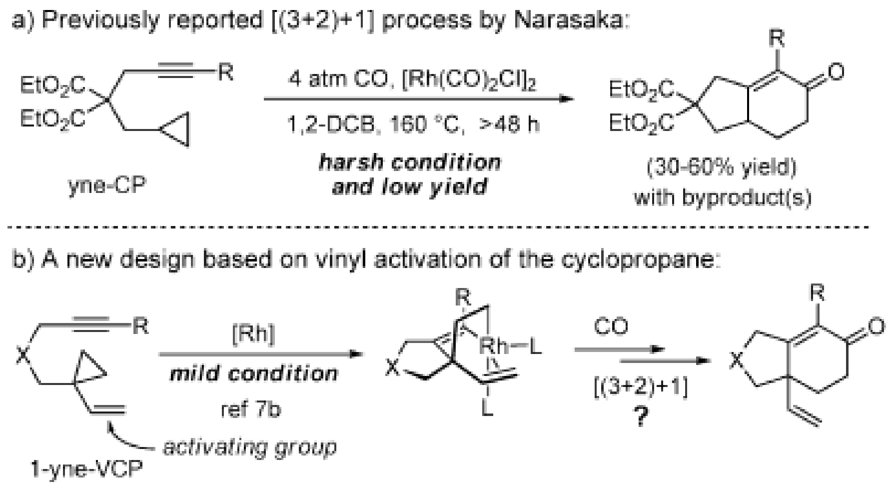
1 **2** (*R*)-ligand **B**

entry	substrate	cycloadduct	temperature [°C]	*t* [h]	yield [%][b]	*ee* [%][c]
						
1	**1a** R = Me	**2a**	70	1	90	97
2	**1b** R = H	**2b**	50	3	90	87
3	**1c** R = Et	**2c**	70	2.5	90	93
4	**1d** R = $(CH_2)_3Cl$	**2d**	60	10	74	94
5	**1e** R = $(CH_2)_3$OTBS	**2e**	70	4	63	95
6	**1f** R = COMe	**2f**	70	1	70	98
7	**1g** R = CO_2Me	**2g**	70	1	62	99
8	**1h** R = Ph	**2h**	60	7	69	48
9[d]	**1i** R = TMS	**2i**	70	120	60 (brsm)	61
10	 **1j**	 **2j**	70	1	87	96

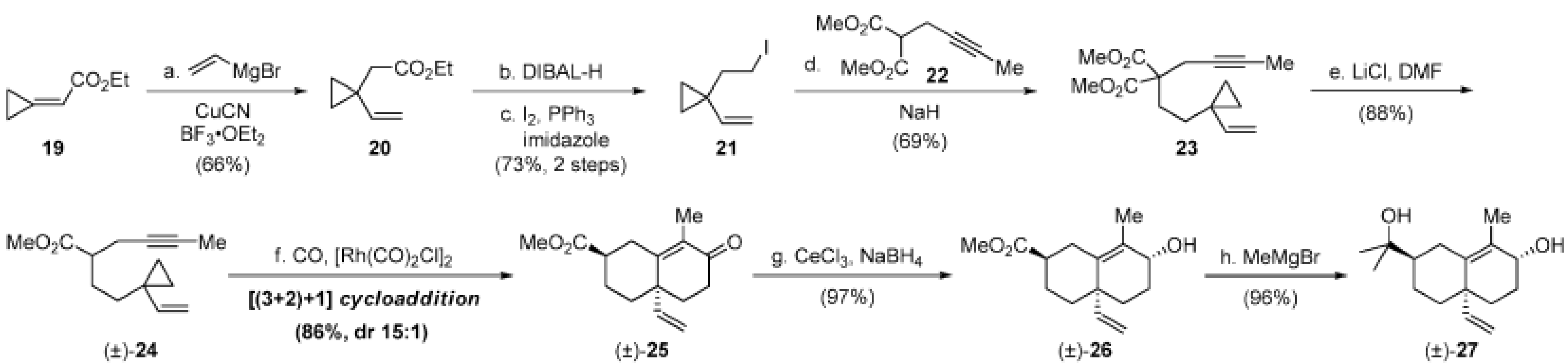
Z-X. Yu.; *J. Am. Chem. Soc.*, **2012**, *134* , 398–405..

vinyl cyclopropane in 3+2+1

VCP as 3C:



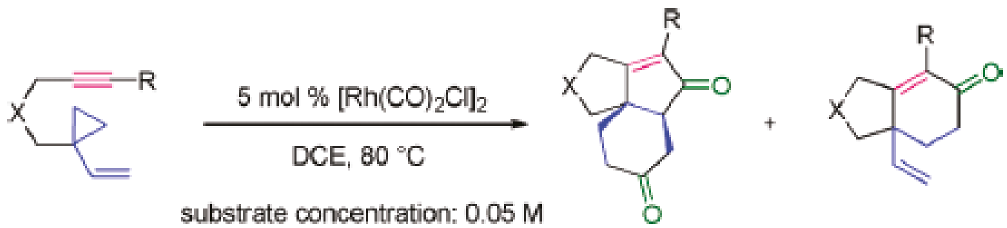
^{a} 1,2-DCB = 1,2-dichlorobenzene.



Z-X. Yu.; *Org. Lett.*, **2010**, *12* ,2528–253

vinyl cyclopropane in 5+1/2+2+1

VCP as 3C:



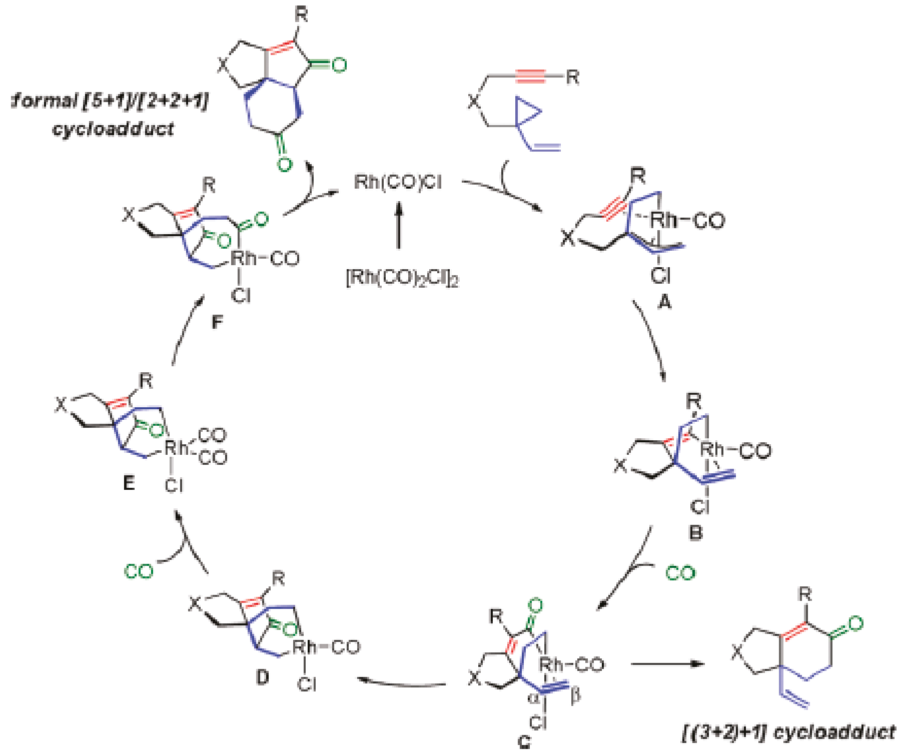
1 2 3

entry		substrate	CO pressure (atm)	t (h)	yield (%)[a] 2	yield (%)[a] 3
		X = TsN				
1	**1b**	R = Et	0.5	2.5	58	4
2	**1c**	R = ^{i}Pr	1	4	72	9
3	**1d**	R = ^{t}Bu	1	3.5	71	26
4	**1e**	R = $(CH_2)_3Cl$	0.5	3.5	60	29
5	**1f**	R = Cy	1	2	61	14
6	**1g**	R = TMS	0.2	5	39	6
		X = $C(CO_2Me)_2$				

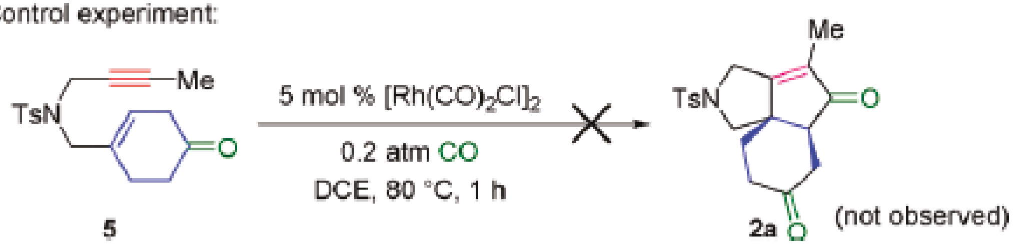
Z-X. Yu.; *J. Am. Chem. Soc.*, **2011**, *133*, 1690–1693

vinyl cyclopropane in 5+1/2+2+1

VCP as 3C:



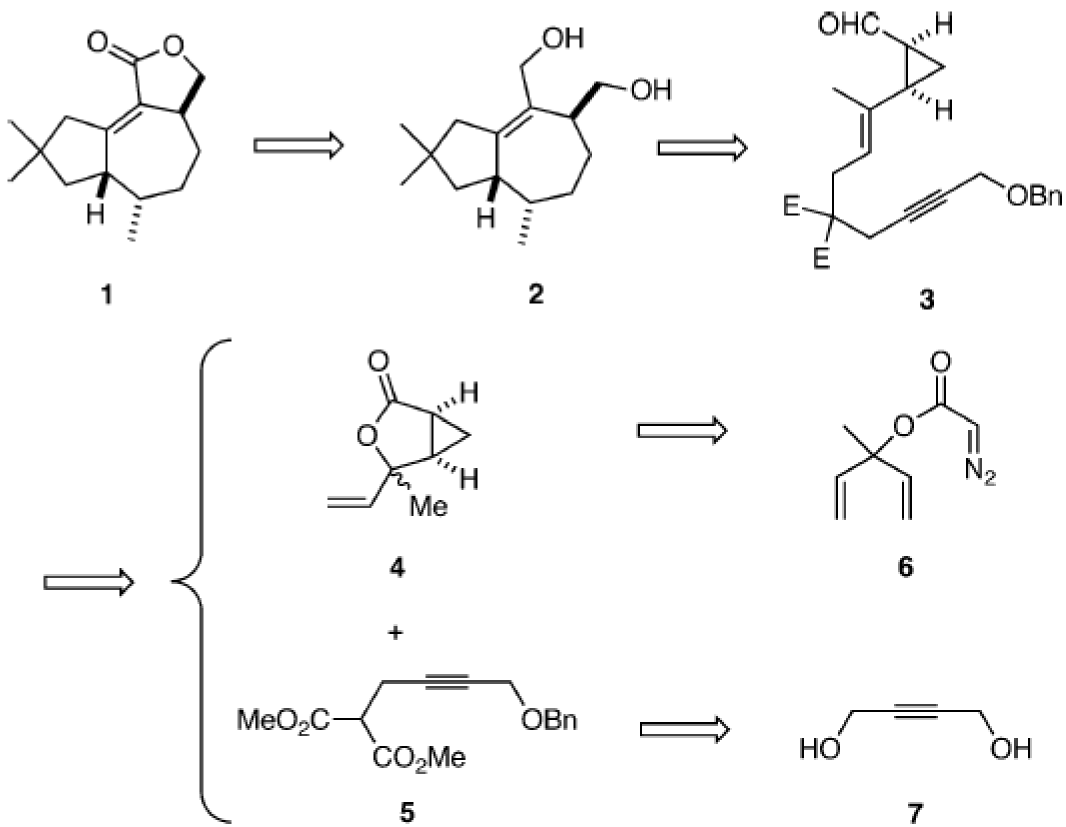
b) Control experiment:



Z-X. Yu.; *J. Am. Chem. Soc.*, **2011**, *133*, 1690–1693

vinyl cyclopropane in 5+2

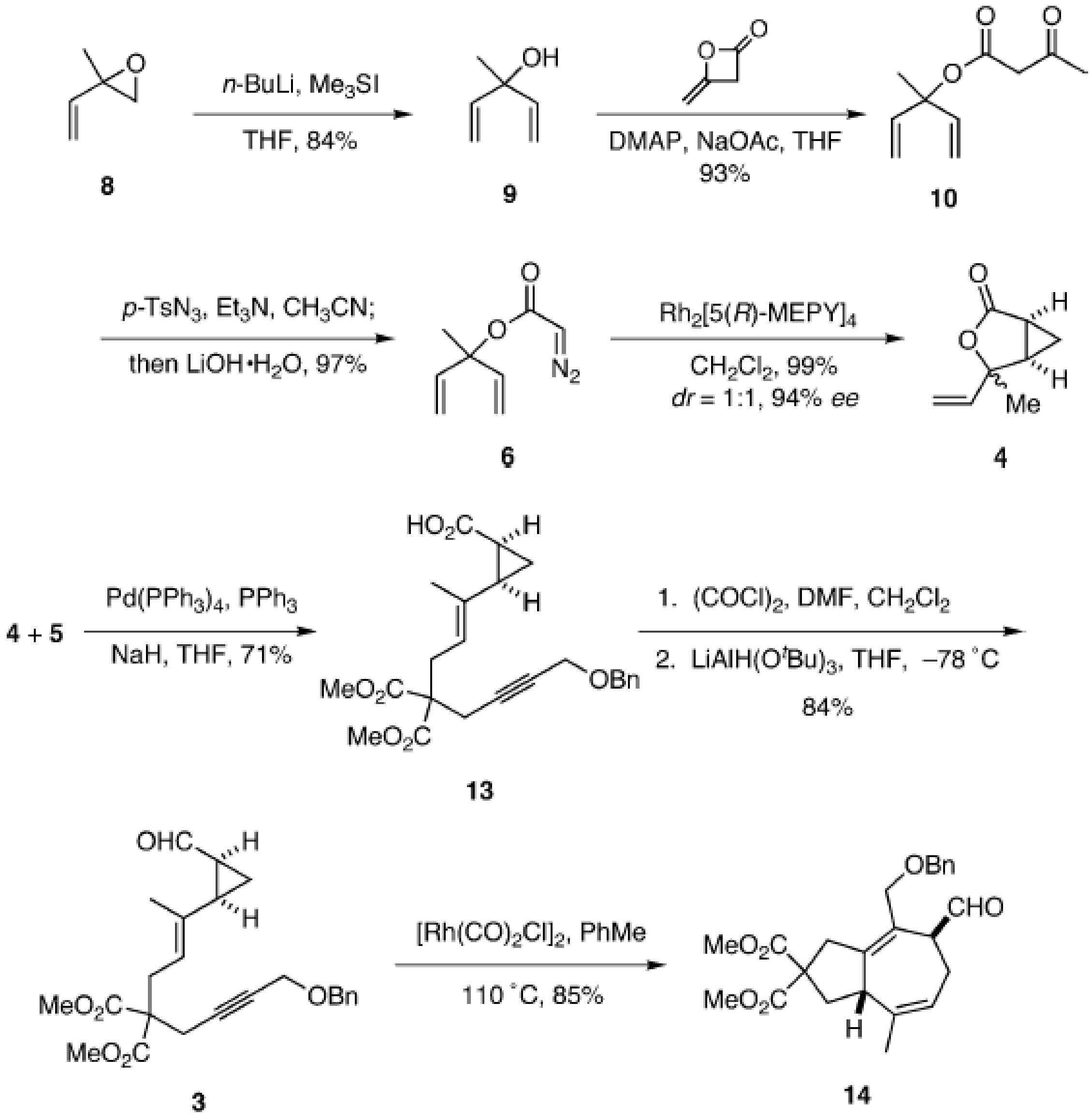
Total synthesis application:



Stephen F. Martin.; *Org. Lett*., **2005**, *7*, 4535–4537

vinyl cyclopropane in 5+2

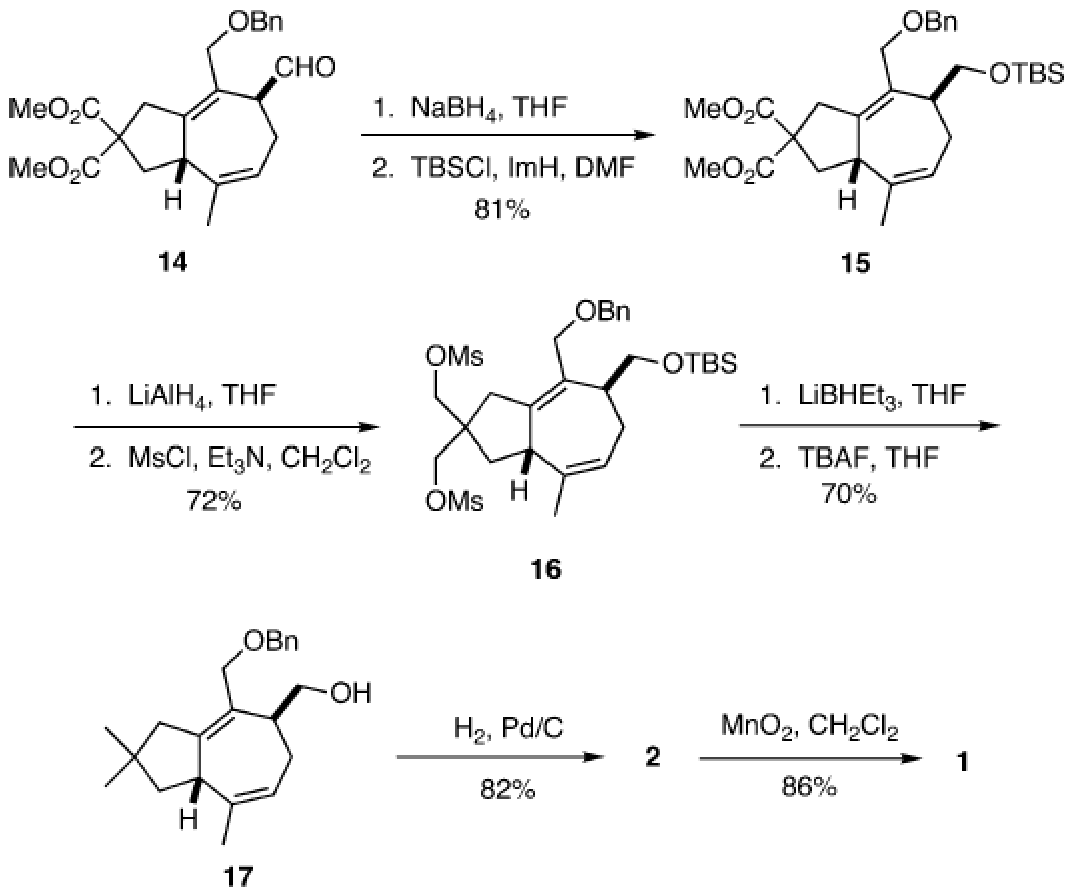
Total synthesis application:



Stephen F. Martin.; *Org. Lett.*, **2005**, *7*, 4535–4537

vinyl cyclopropane in 5+2

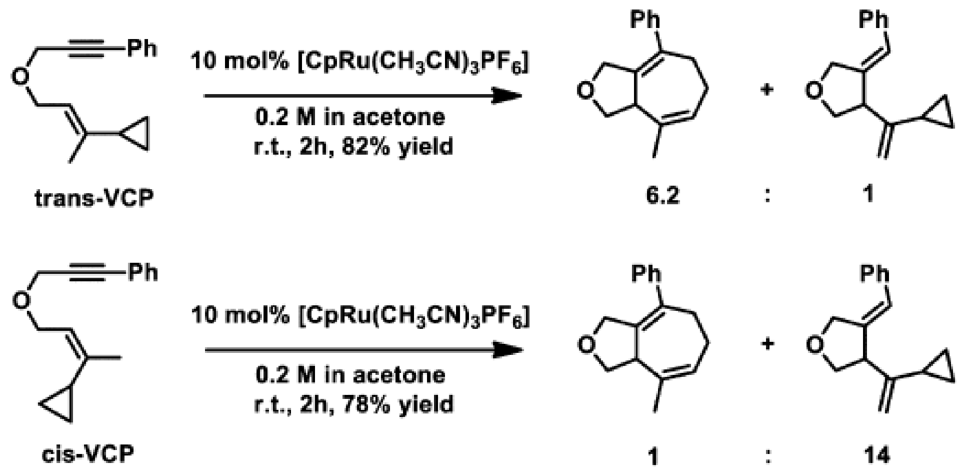
Total synthesis application:

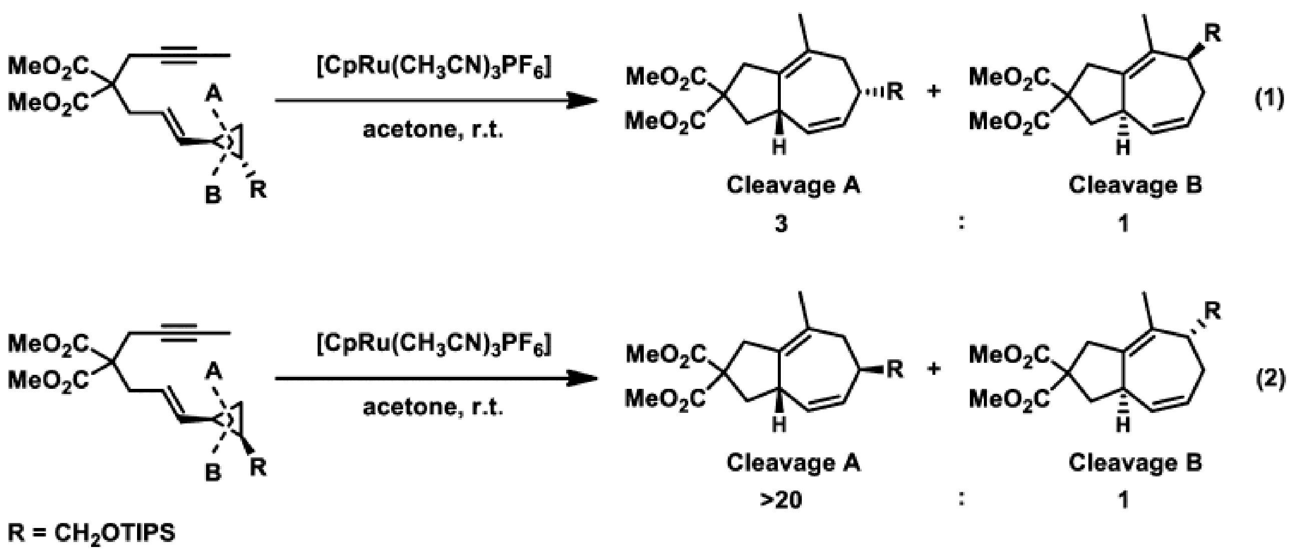


Stephen F. Martin.; *Org. Lett*., **2005**, *7*, 4535–4537

vinyl cyclopropane in 5+2

Ru catalyzed 5+2:

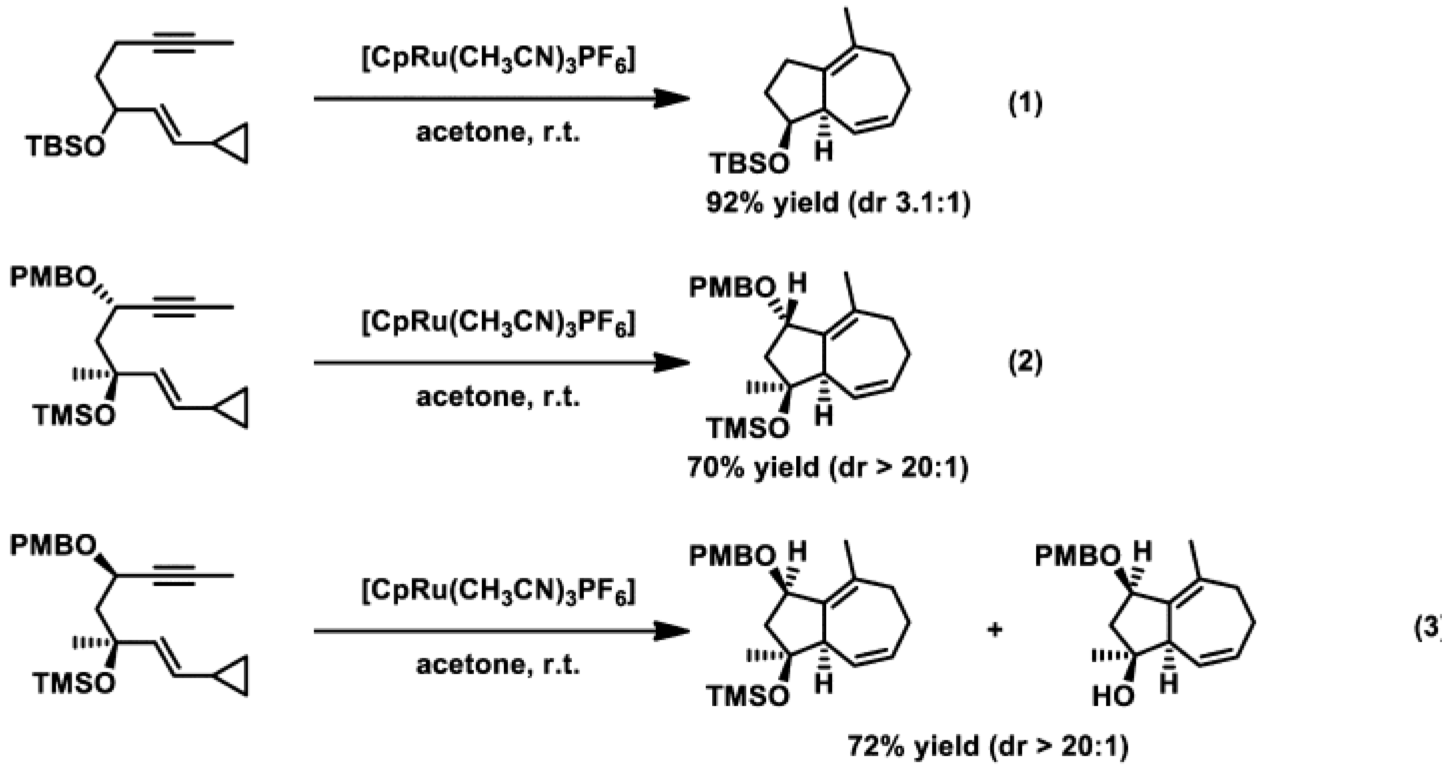




Trost.; *J. Am. Chem. Soc*., **2000**, *122*, 2379-2380

vinyl cyclopropane in 5+2

Ru catalyzed 5+2:

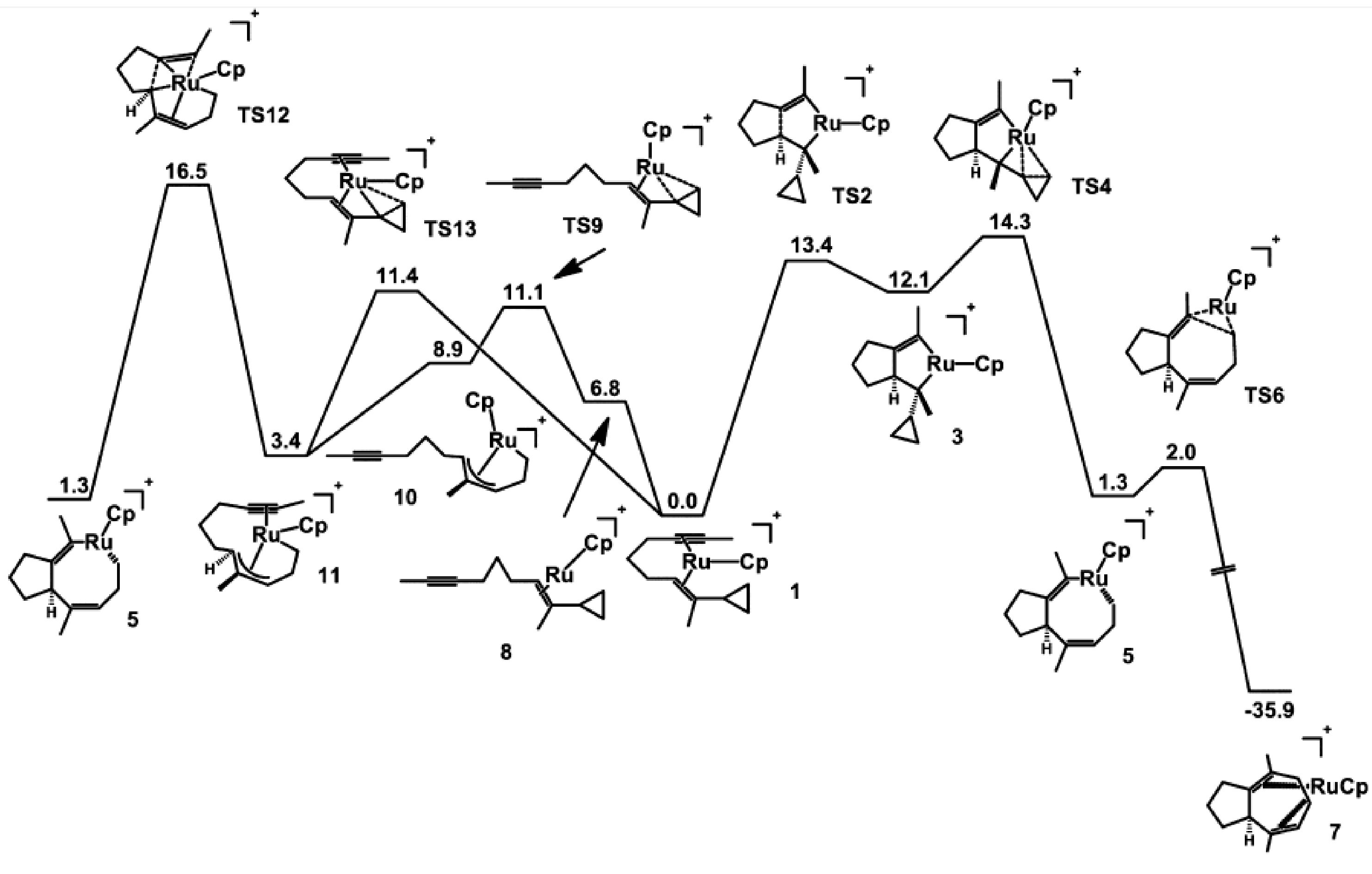


Trost.; *J. Am. Chem. Soc.*, **2000**, *122*, 2379-2380

Trost.; *Chem.Eur. J*. **2005,** *11*, 2577.

vinyl cyclopropane in 5+2

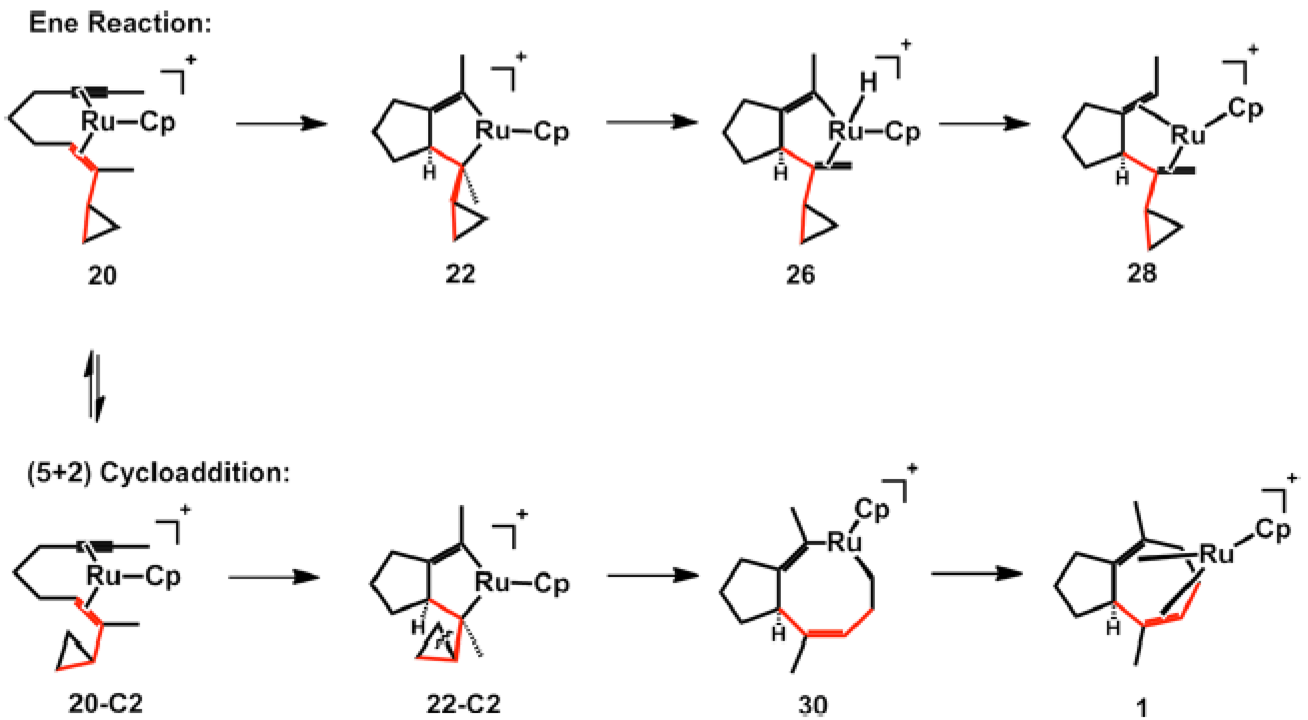
Ru catalyzed 5+2:



Trost. Houk ; *J. Am. Chem. Soc.*, **2013**, *135*, 6588-6600

vinyl cyclopropane in 5+2

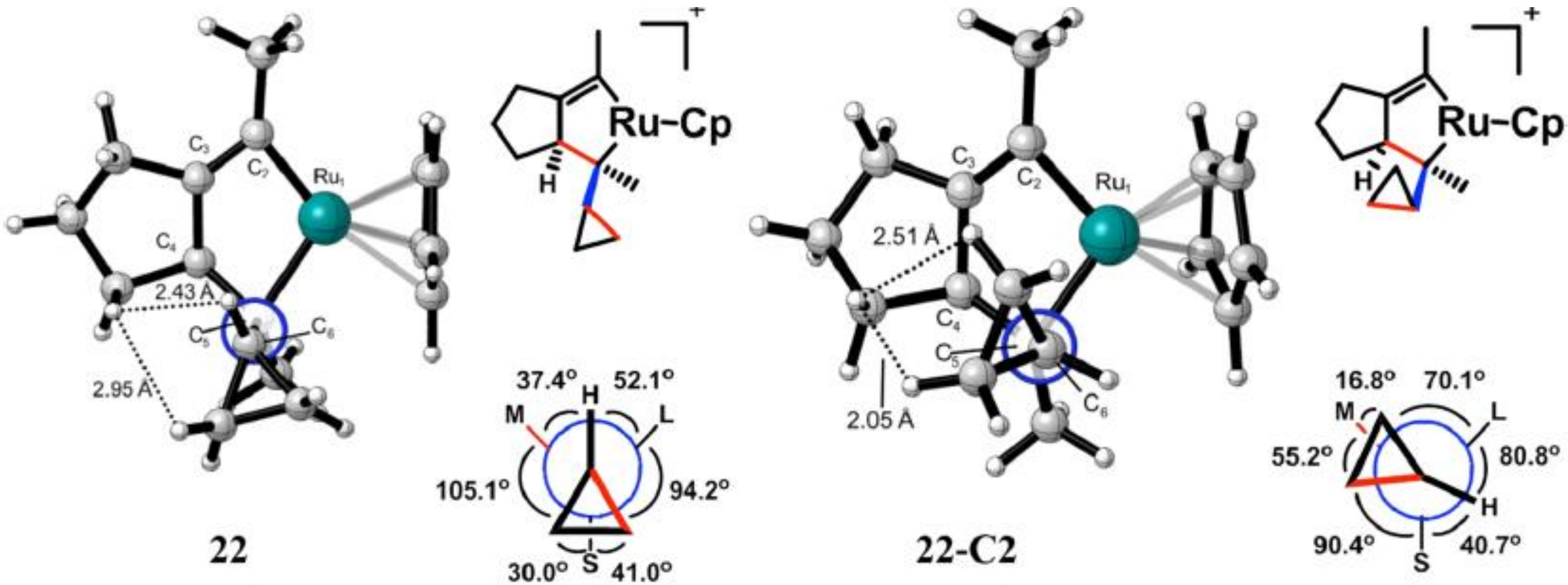
Ru catalyzed 5+2:



Trost. Houk ; *J. Am. Chem. Soc*., **2013**, *135*, 6588-6600

vinyl cyclopropane in 5+2

Ru catalyzed 5+2:



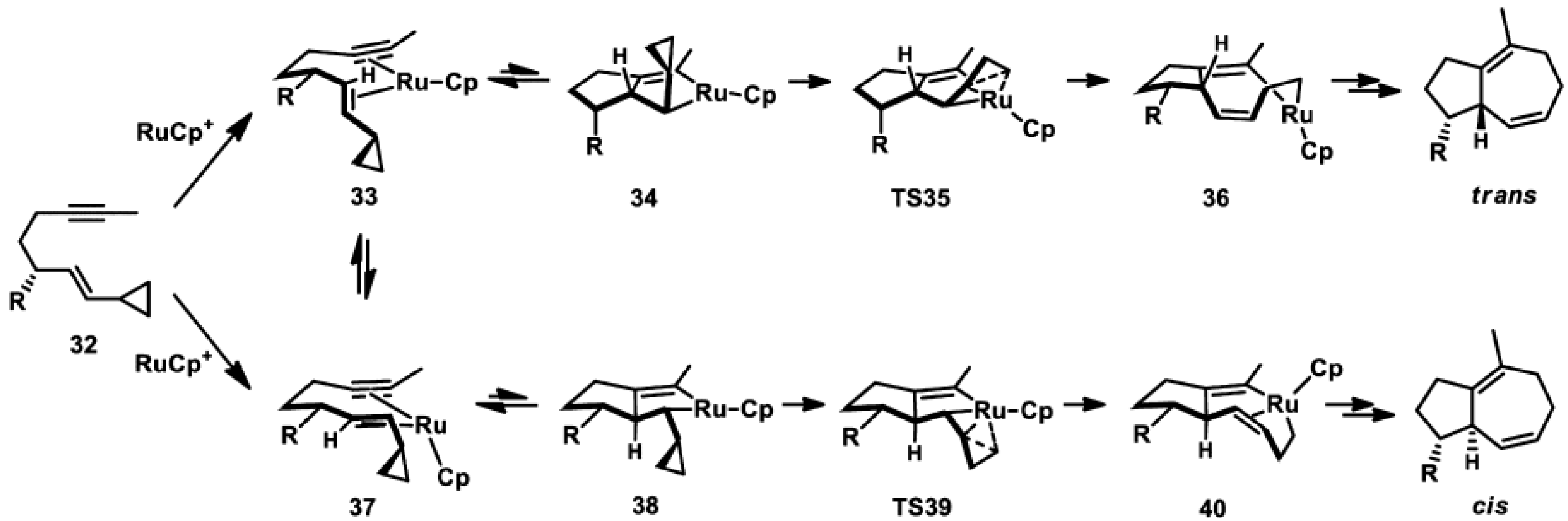
22 **0.0 kcal/mol**

22-C2 **7.4 kcal/mol**

Trost. Houk ; *J. Am. Chem. Soc.*, **2013**, *135*, 6588-6600

vinyl cyclopropane in 5+2

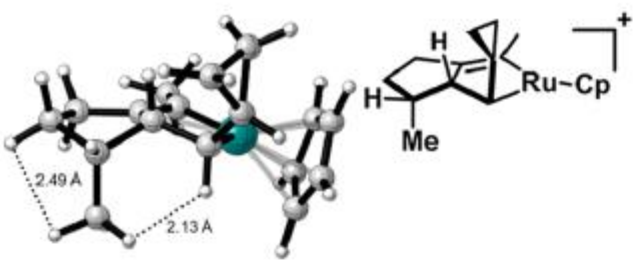
Ru catalyzed 5+2:



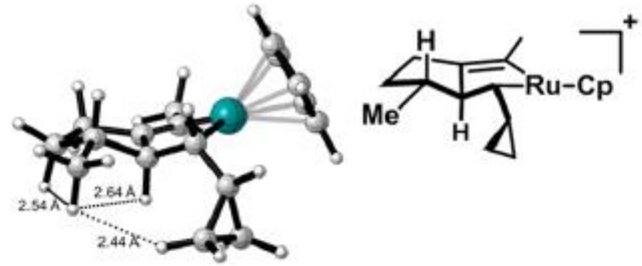
Trost. Houk ; *J. Am. Chem. Soc.*, **2013**, *135*, 6588-6600

vinyl cyclopropane in 5+2

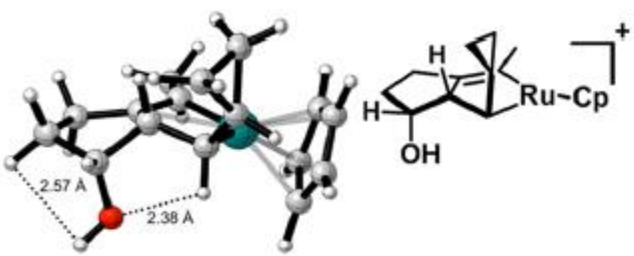
Ru catalyzed 5+2:



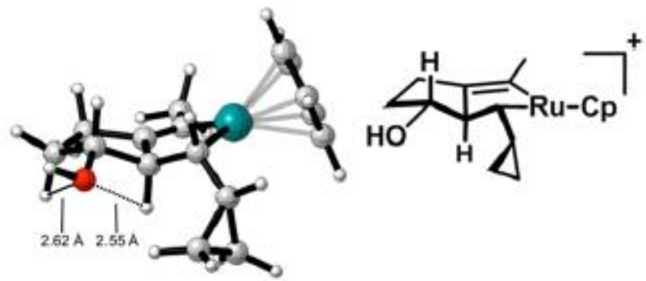
34-1
+1.6 kcal/mol



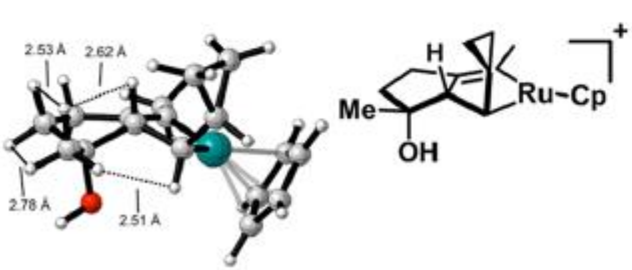
38-1
0.0 kcal/mol



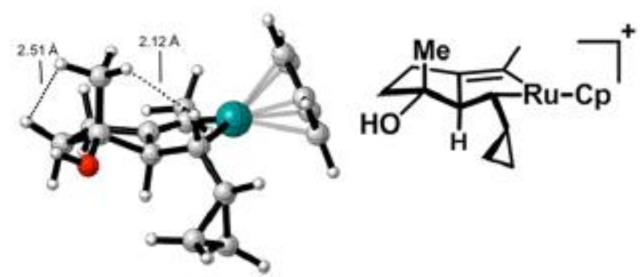
34-2
-0.6 kcal/mol



38-2
0.0 kcal/mol



34-3
-2.4 kcal/mol

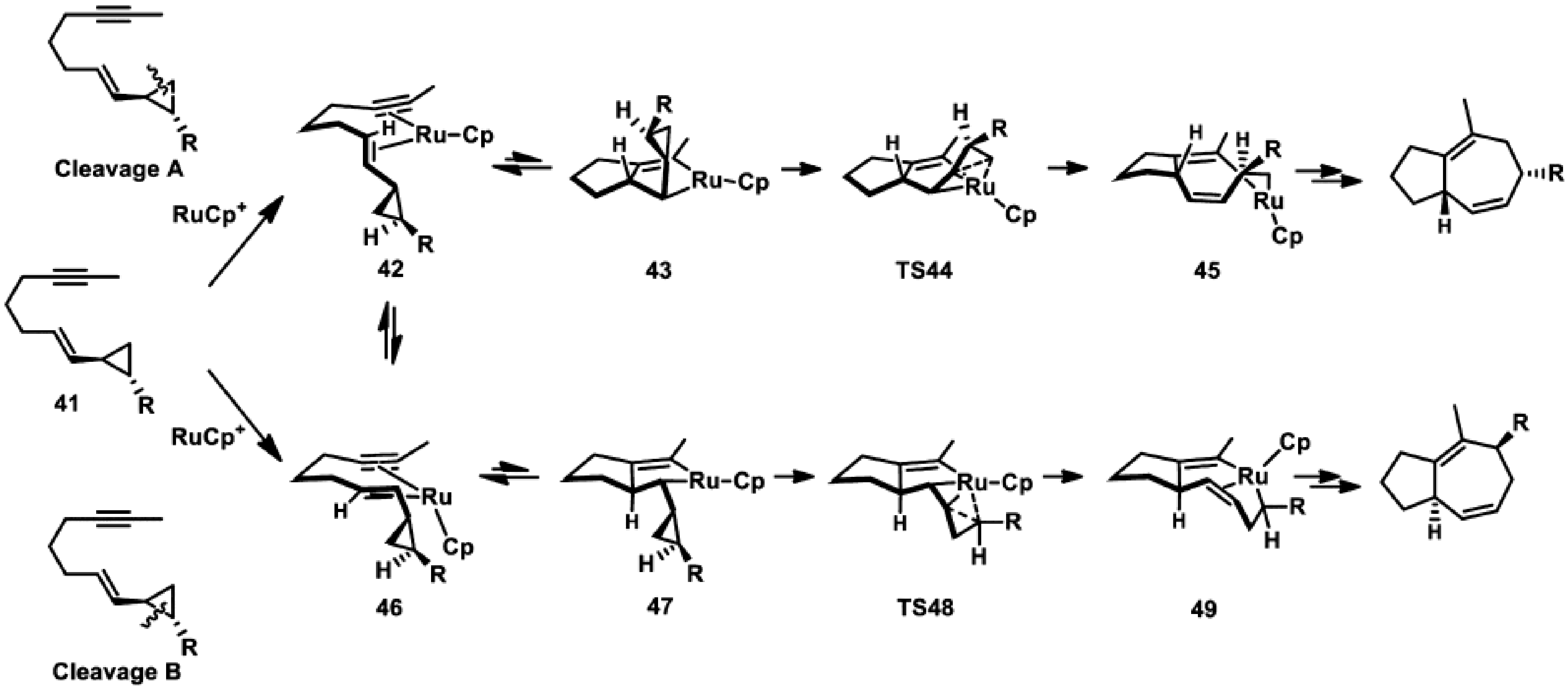


38-3
0.0 kcal/mol

Trost. Houk ; *J. Am. Chem. Soc.*, **2013**, *135*, 6588-6600

vinyl cyclopropane in 5+2

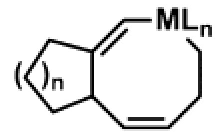
Ru catalyzed 5+2:

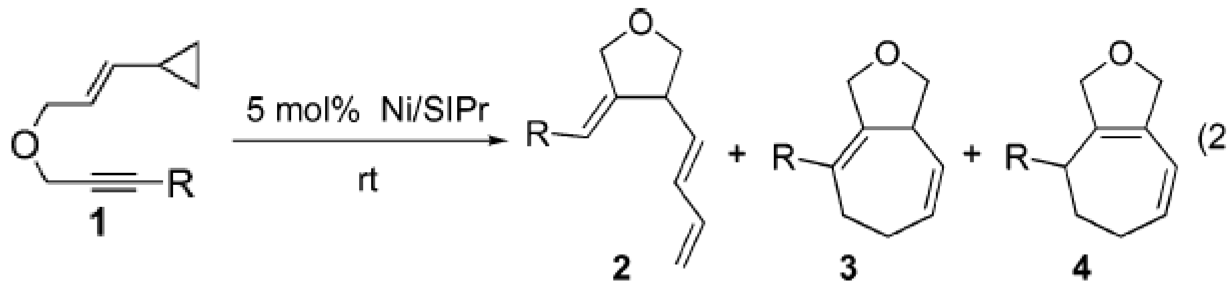


Trost. Houk ; *J. Am. Chem. Soc.*, **2013**, *135*, 6588-6600

vinyl cyclopropane in 5+2

Ni catalyzed 5+2:



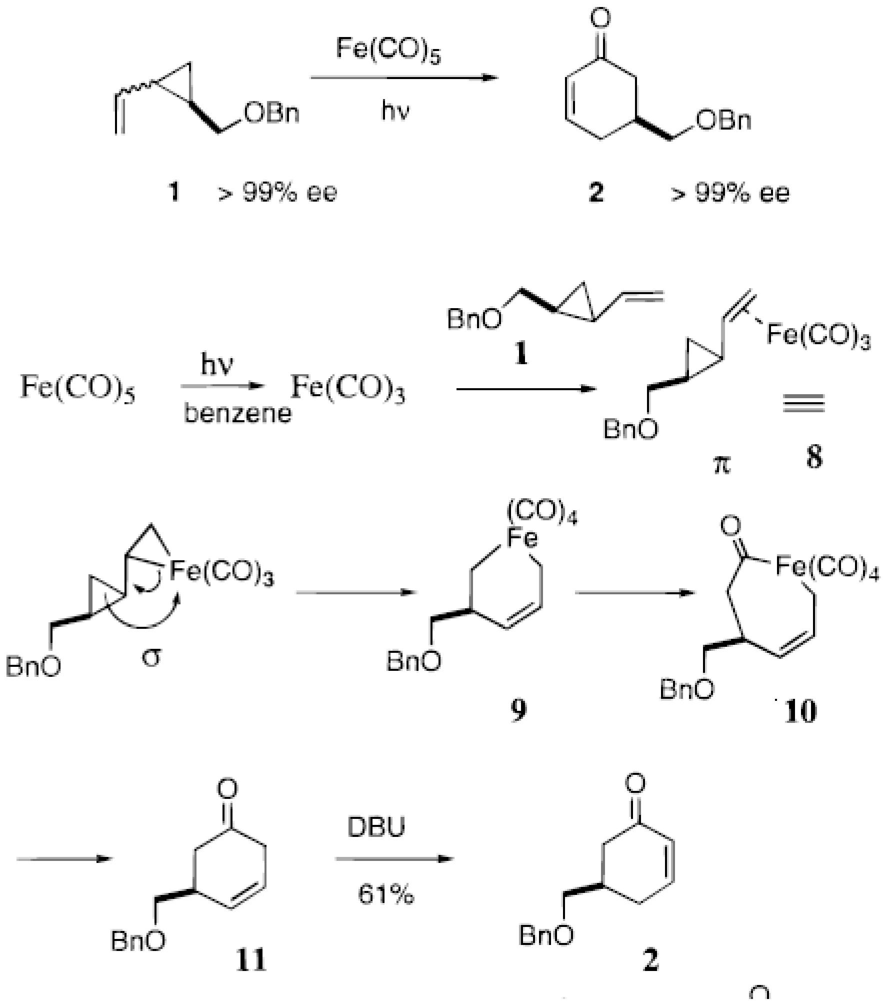


entry	substrate	2:3:4[b]	% yield[c]
1	R = Me (**1a**)	1:0:0	54% (**2a**)
2	R = Et (**1b**)	3:2:0	34% (**2b**)
			27% (**3b**)
3	R = *i*-Pr (**1c**)	1:2:0	28% (**2c**)
			38% (**3c**)
4	R = *t*-Bu (**1d**)	0:0:1	82% (**4d**)
5	R = TMS (**1e**)	0:0:1	88% (**4e**)

Janis Louie .; *J. Am. Chem. Soc*., **2005**, *127*, 5798-99

vinyl cyclopropane in 5+2

Fe mediated 5+1:



Taber; *J. Am. Chem. Soc.*, **2000**, *122*, 6807-08

vinyl cyclopropane in 5+2

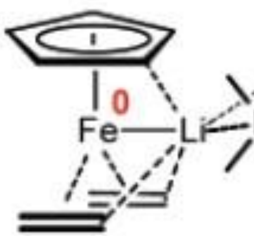
Fe catalyzed 5+2:

Fe^0: [Ar] $3d^6\ 4s^2$

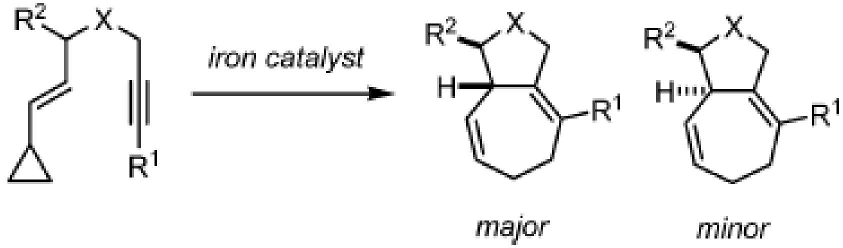
Ru^0: [Kr] $3d^6\ 4s^2$

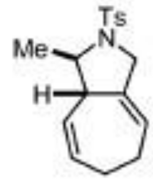
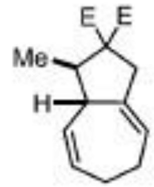
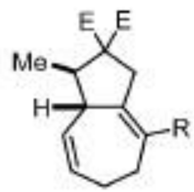
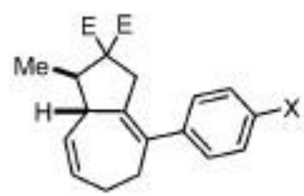
Rh^I: [Kr] $3d^8\ 4s^0$

Ir^I: [Xe] $3d^8\ 4s^0$



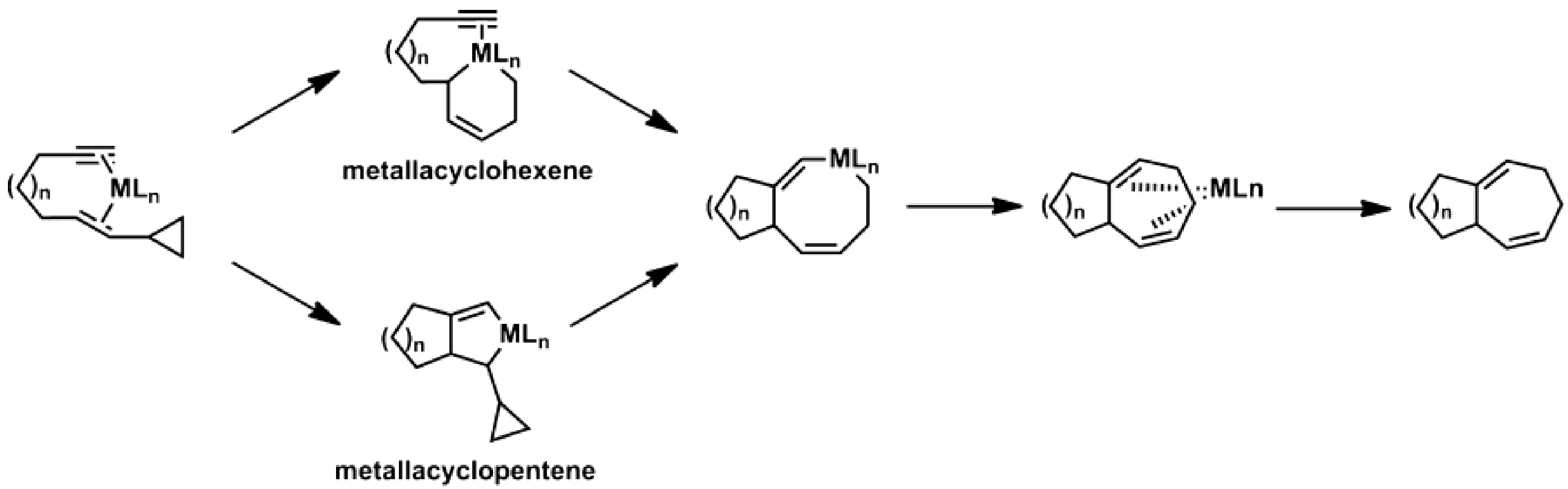
1



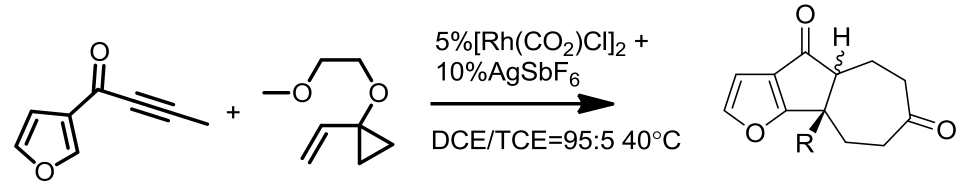
9 10		A B	56%[d] 70%	5.5:1 5.7:1
11		A	91%[e]	6.7:1
12 13 14		A A A	92% (R = Me)[d] 76% (R = COOEt)[d] 99% (R = $SiMe_3$)	9.4:1 2.3:1 15:1
15 16 17		A A A	98% (X = H) 98% (X = OMe) 97% (X = F)	6.2:1 7.3:1 6.6:1

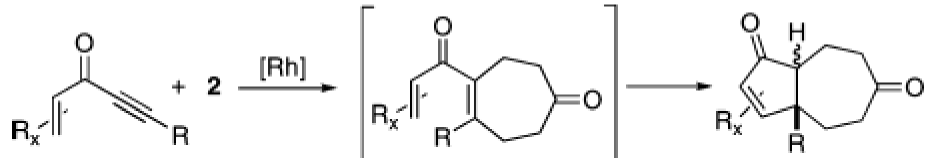
A. Fürstner *J. Am. Chem. Soc.* **2008**, *130*,1992-2004

Summary

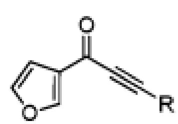


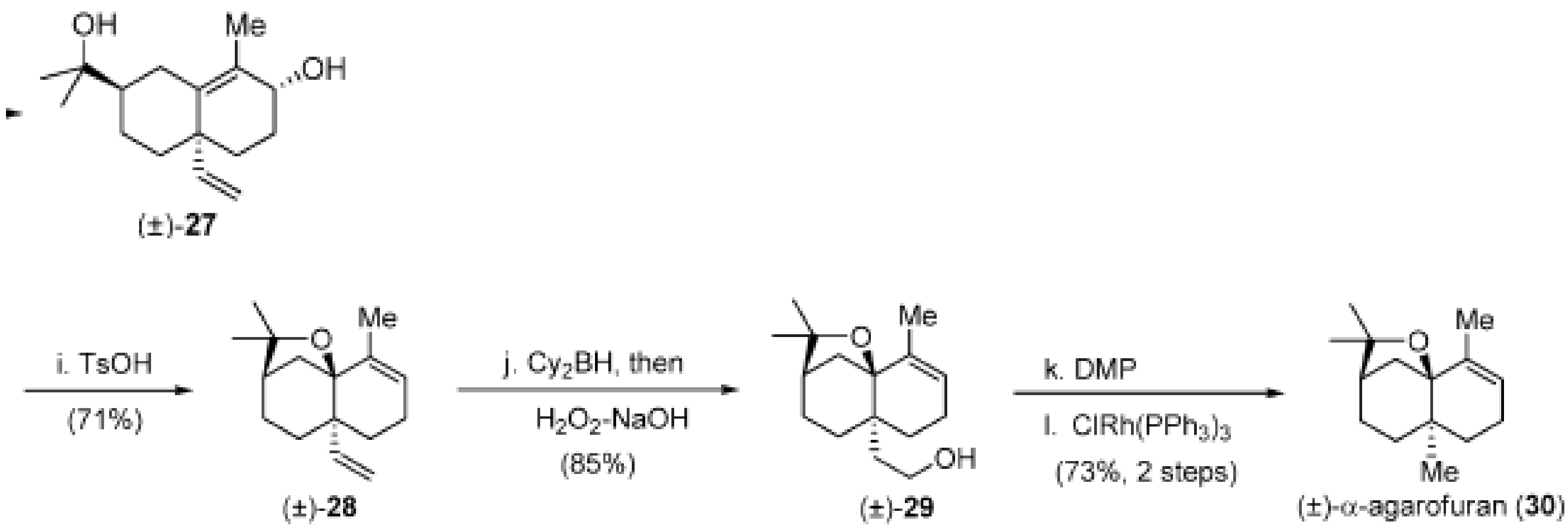
Thanks for your attention



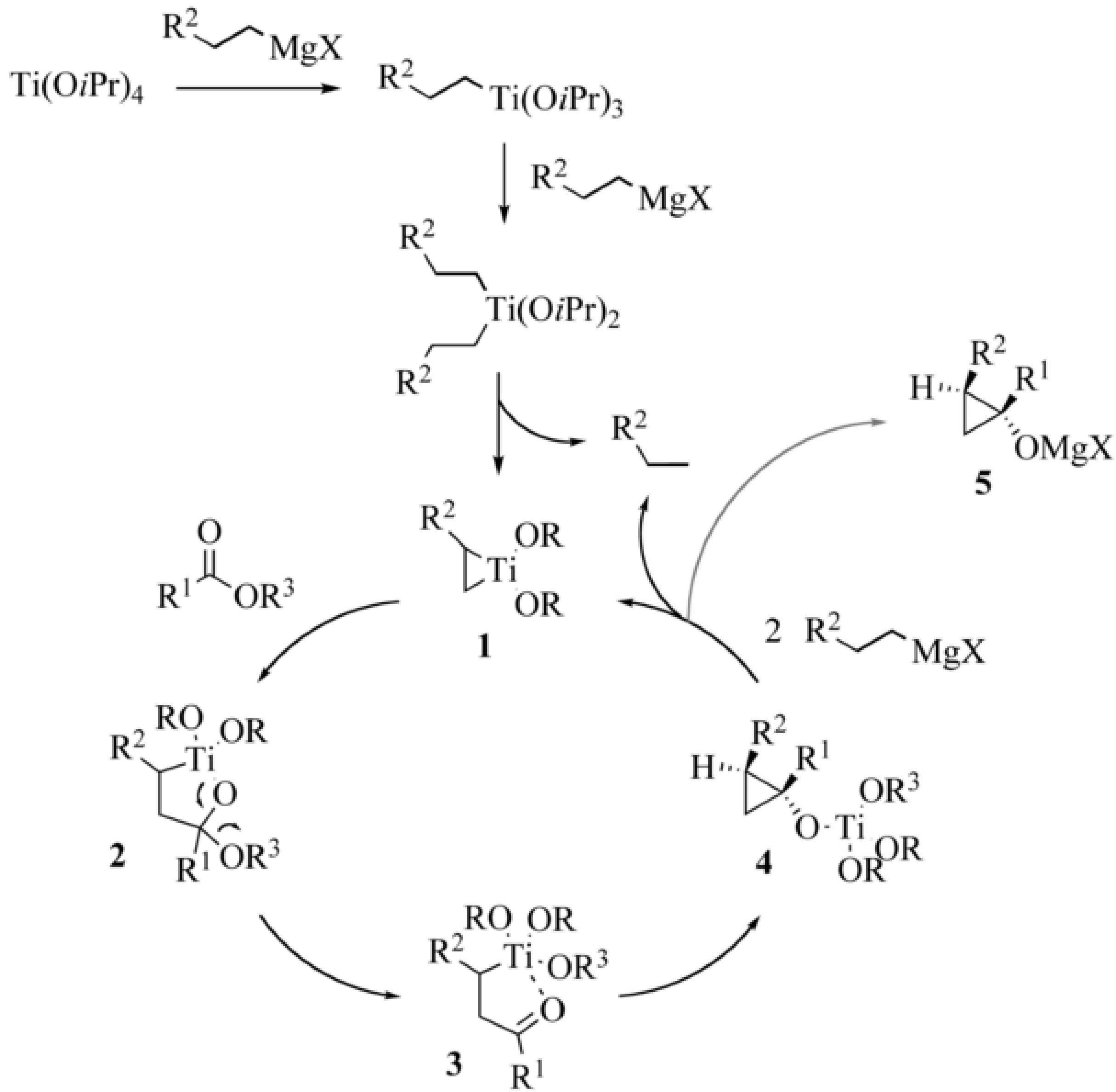


entry	ynone	conditions[a]	*t* (h)[b]	product(s)	yield (ratio)[c]
1	**1a**	A	15, 1	**4**[d]	82% (dr 2.0:1)
2		B	0.25, 2		71% (dr 2.0:1)
3	**1b**	A	20, 1.5	**5**	76% (dr >20:1)
4		B	0.25, 2		78% (dr >20:1)
5	**1c**	A	20, 1	**6**	82% (dr 3.6:1)
6		B	0.25, 2		89% (dr 3.8:1)
7	**1d**	A	4, 22	**7**	68% (dr 19:1)
8		B[e]	0.25, 20		54% (dr >20:1)
9	**1h**	A[f]	13, 3	**11**	77% (dr >20:1)
10		C	16		56% (dr >20:1)
11		D	24		95% (dr >20:1)

4		**1d**	Me
5		**1e**	H



(±)-27
i. TsOH
(71%)
(±)-28
j. Cy2BH, then
H2O2-NaOH
(85%)
(±)-29
k. DMP
l. ClRh(PPh3)3
(73%, 2 steps)
(±)-α-agarofuran (30)



Ti(OiPr)4
R2 MgX
R2 Ti(OiPr)3
R2 MgX
Ti(OiPr)2
R2
R2
R2
R2
H
R1
OMgX
5
R2
OR
Ti
OR
1
O
R1
OR3
2 R2 MgX
RO
OR
R2
Ti
O
2
R1
OR3
H
R2
R1
OR3
O-Ti
OR
OR
4
RO
OR
R2
Ti
OR3
O
3
R1