Iridium Catalyzed allylic substitutions

Cory Newman

Group Meeting

February 26, 2004

Takeuchi, R. *Synlett* **2002** 1954-1965

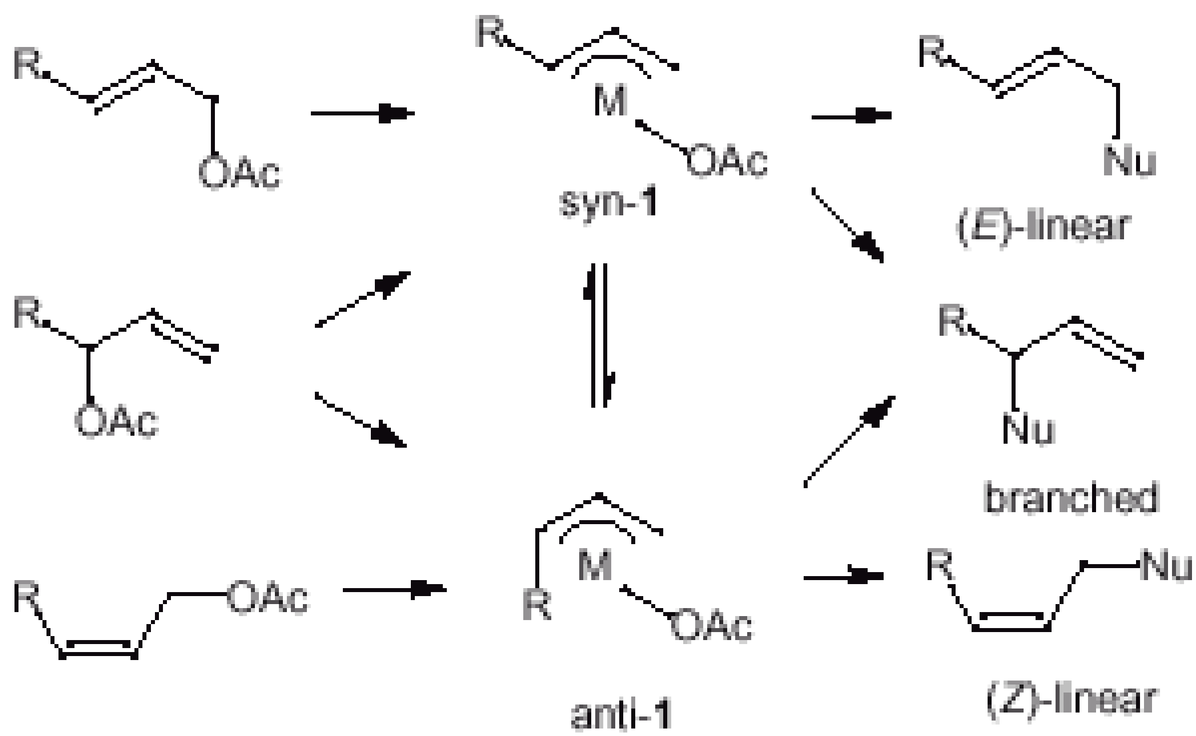
Lipowsky, G.; Helmchen, G. *Chem. Comm..* **2004** 2054-2056

Lopez, F.; Ohmura, T., Hartwit, J. F. *J. Am. Chem. Soc*. **2003** 3426-3427

Kanayama, T.; Yoshida, K.; Miyabe, H.; Takemoto, Y. *Ang. Chem. Int. Ed.* **2003** 2054-2056

Kanayama, T.; Yoshida, K.; Miyabe, H.; Kimachi, T.; Takemoto, Y. *J. Org. Chem.* **2003** 6197-6201

Possible Reaction Pathways



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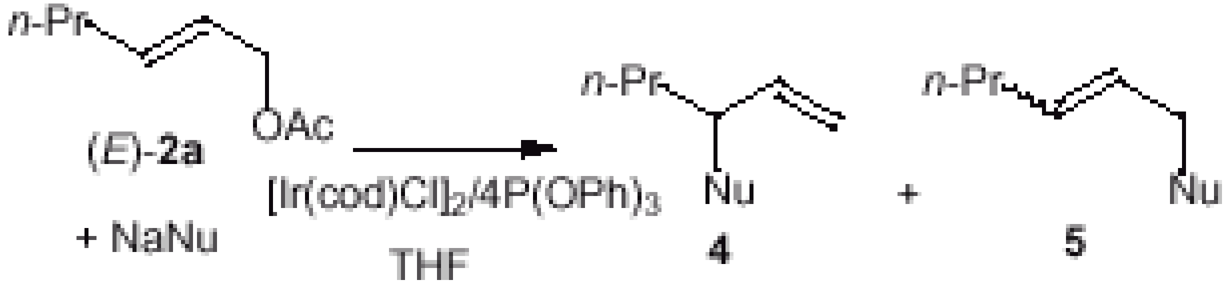
Sodium Malonate Examples



3b: Nu=$CH(CO_2Me)_2$ rt 3 h Yield 90% **4b** : **5b**=97 : 3

3c: Nu=$CHAcCO_2Et$ reflux 7 h Yield 85% **4c** : **5c**=93 : 7

3d: Nu=$CMe(CO_2Et)_2$ reflux 1 h Yield 87% **4d** : **5d**=29 : 71

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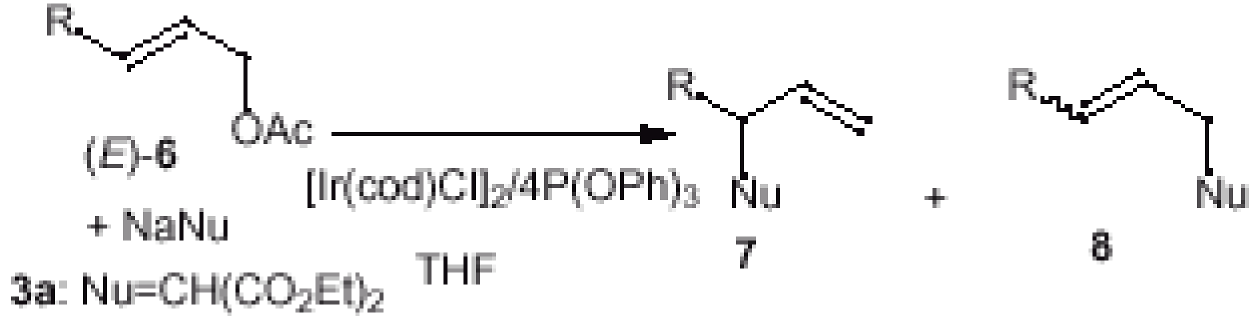
Effect of R-Group on Substitution



6a: R=Me	rt 2 h	Yield 77%	**7a** : **8a**=97 : 3
6b: R=Ph	rt 3 h	Yield 98%	**7b** : **8b**=99 : 1
6c: R=*n*-Hex	rt 5 h	Yield 99%	**7c** : **8c**=95 : 5
6d: R=*n*-Oct	rt 5 h	Yield 95%	**7d** : **8d**=95 : 5

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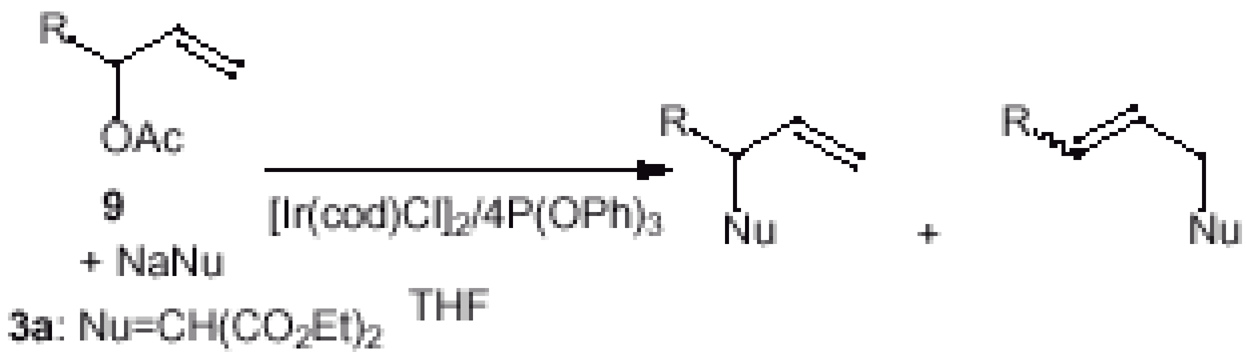
Effect of Position of L.G.



9a: R=*n*-Pr	rt 3 h	Yield 86%	**4a** : **5a**=95 : 5
9b: R=Ph	rt 3 h	Yield 91%	**7b** : **8b**=99 : 1
9d: R=*n*-Oct	rt 3 h	Yield 95%	**7d** : **8d**=95 : 5

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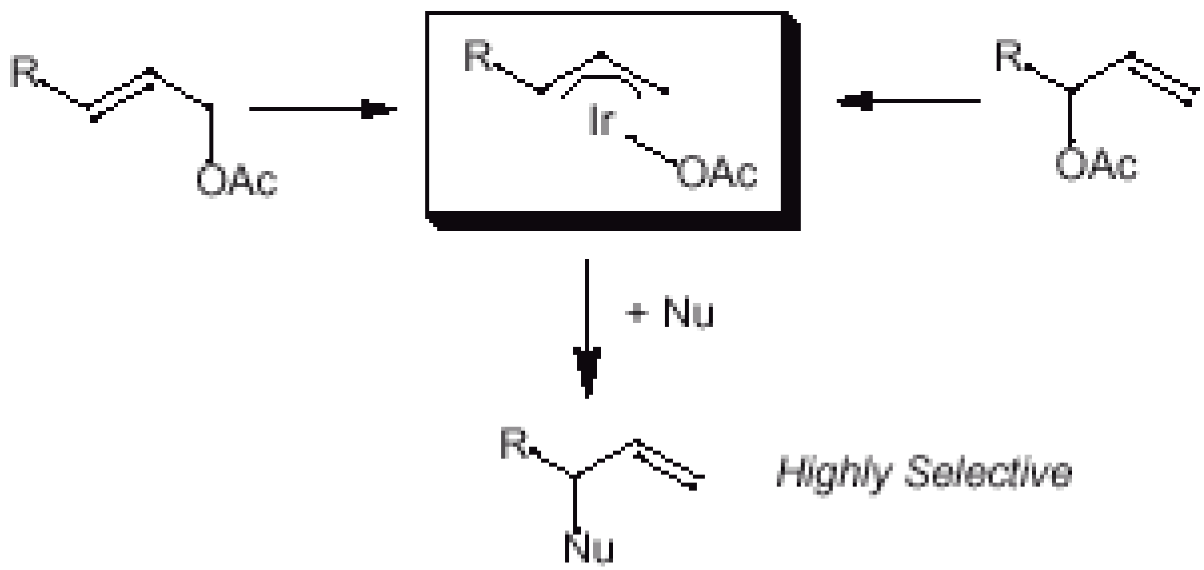
Suggestion of π-allyl Intermediate



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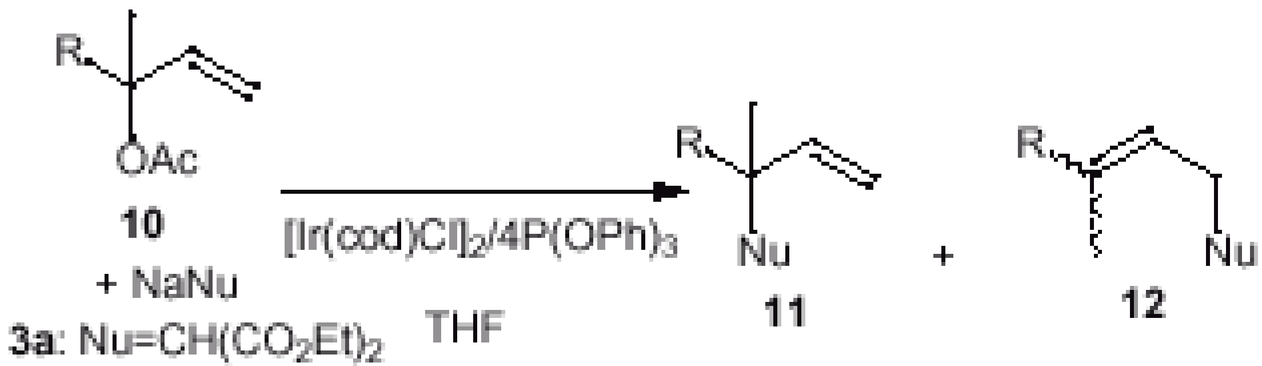
Disubsituted 3^{o} Allylic Terminus



10a: R=Me	rt 2 h	Yield 80%	**11a** : **12a**=100 : 0
10b: R=*n*-Bu	rt 16 h	Yield 80%	**11b** : **12b**=100 : 0
10c: R=$CH_2CH_2C=CMe_2$	rt 16 h	Yield 85%	**11c** : **12c**=100 : 0

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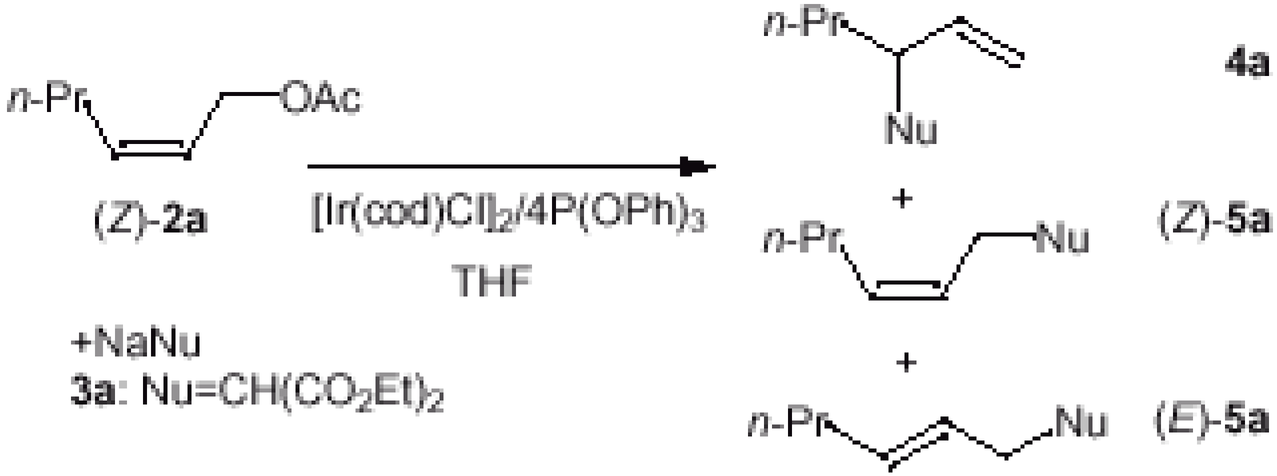
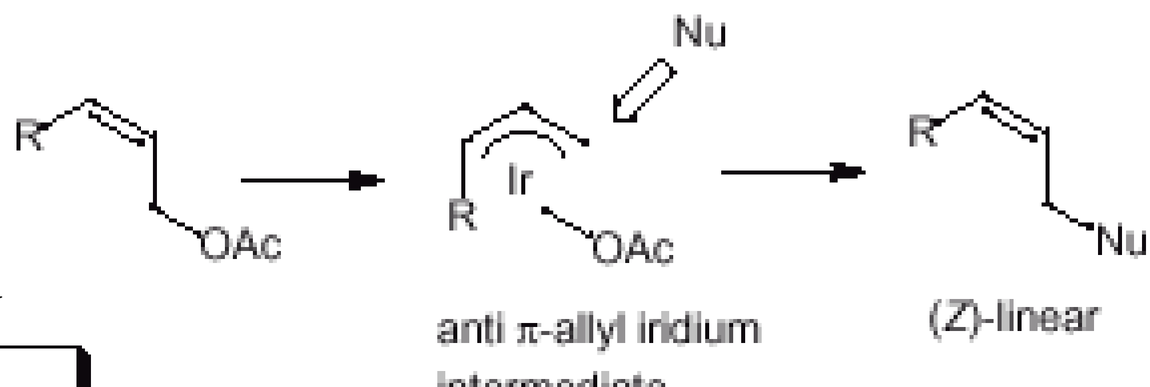
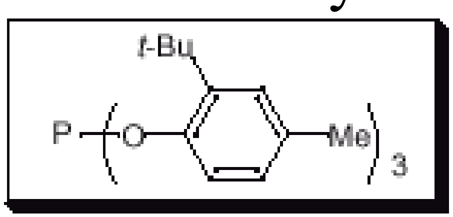
Z-Selective Allylic Alkylation



rt 2 h Yield 81% **4a** : (*Z*)-**5a** : (*E*)-**5a** = 25 : 70 : 5



Linear Only



26

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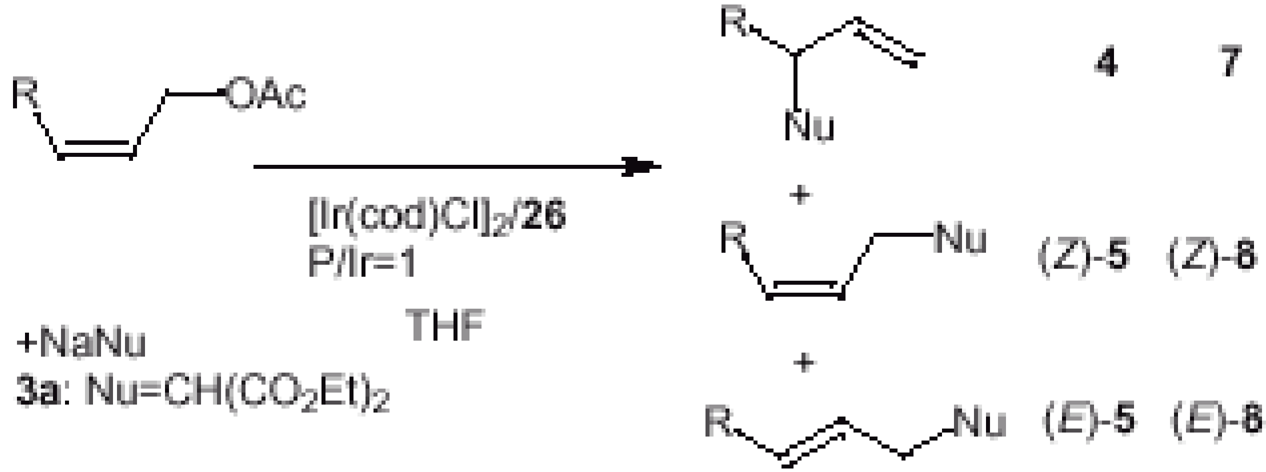
Z-Selective Allylic Alkylation



(*Z*)-**2a**: R=*n*-Pr	reflux 5 h	Yield 85%	**4a** : (*Z*)-**5a** : (*E*)-**5a** = 3 : 90 : 7
(*Z*)-**6c**: R=*n*-Hex	reflux 3 h	Yield 86%	**7c** : (*Z*)-**8c** : (*E*)-**8c** = 2 : 89 : 9
(*Z*)-**6d**: R=*n*-Oct	reflux 3 h	Yield 84%	**7d** : (*Z*)-**8d** : (*E*)-**8d** = 2 : 87 : 11

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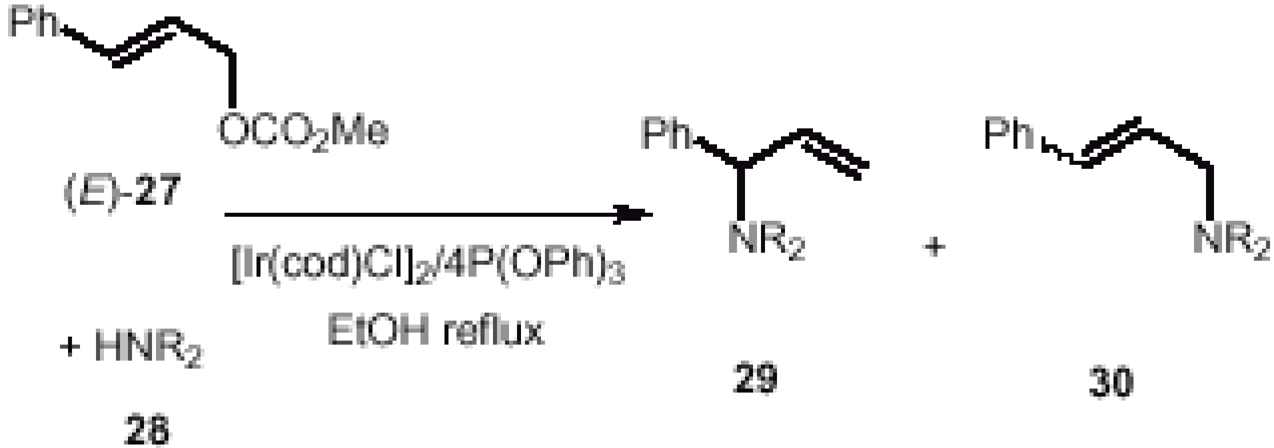
Allylic Amination



28b: pyrrolidine	Yield 95%	**29b** : **30b**=96 : 4	(E/Z=100/0)
28c: morpholine	Yield 92%	**29c** : **30c**=92 : 8	(E/Z=100/0)
28d: cyclopentylamine	Yield 93%	**29d** : **30d**=96 : 4	(E/Z=100/0)
28e: *n*-butylamine	Yield 79%	**29e** : **30e**=95 : 5	(E/Z=100/0)
28f: diethylamine	Yield 75%	**29f** : **30f**=65 : 35	(E/Z=100/0)
28g: *tert*-butylamine	Yield 92%	**29g** : **30g**=81 : 19	(E/Z=100/0)
28h: benzylamine	Yield 89%	**29h** : **30h**=96 : 4	(E/Z=100/0)

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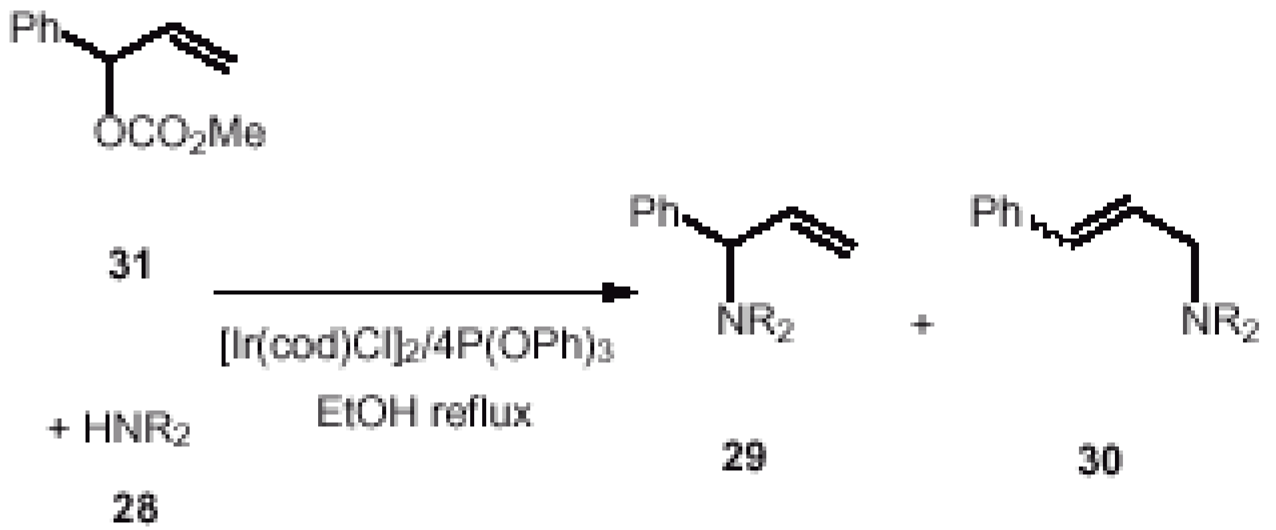
Allylic Amination



28a: piperidine Yield 85% **29a** : **30a**=98 : 2 (*E*/*Z*=100/0)

28e: *n*-butylamine Yield 89% **29e** : **30e**=99 : 1 (*E*/*Z*=100/0)

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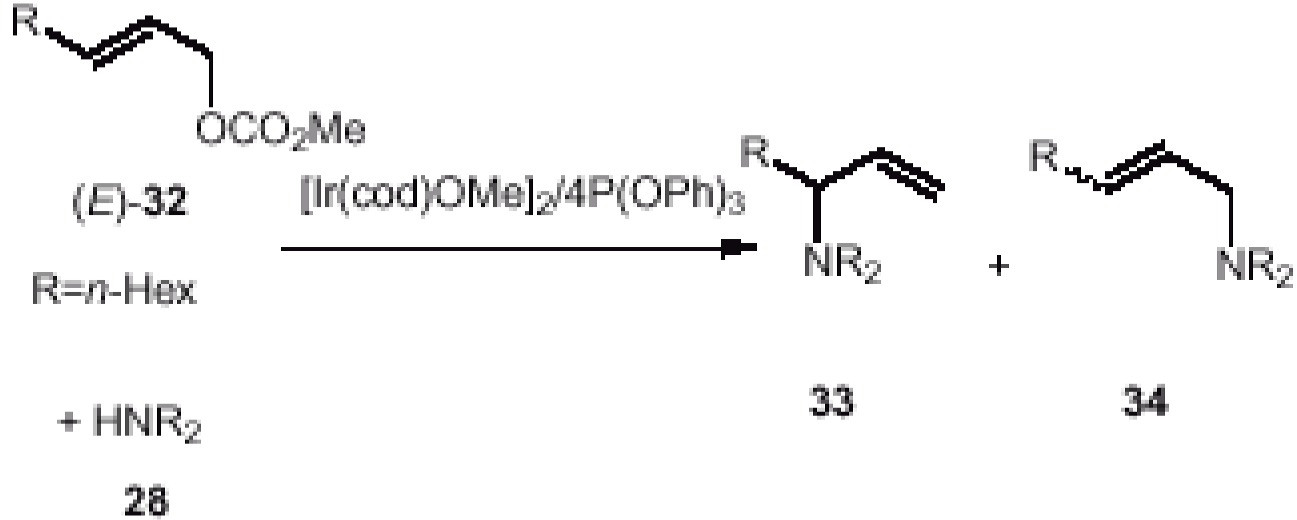
Allylic Amination



28a: piperidine	acetone reflux 3 h	Yield 87%	**33a** : **34a**=81 : 19	(*E*/*Z*=100/0)
28d: cyclopentylamine	MeCN reflux 24 h	Yield 76%	**33d** : **34d**=92 : 8	(*E*/*Z*=100/0)
28e: *n*-butylamine	MeCN reflux 24 h	Yield 70%	**33e** : **34e**=95 : 5	(*E*/*Z*=100/0)
28i: aniline	EtOH reflux 2 h	Yield 95%	**33i** : **34i**=93 : 7	(*E*/*Z*=100/0)

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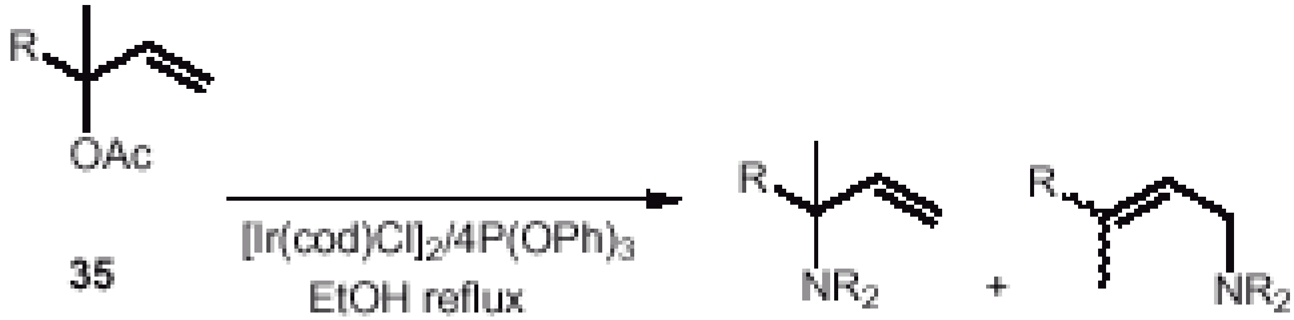
Disubstituted Allylic Amination



35 **36** **37**

35a: R=*n*-Pentyl

35b: R=$Me_2C{=}CHCH_2CH_2$

+ HNR_2

28

35a	**28a** piperidine	Yield 76%	**36aa** : **37aa**=100 : 0
35a	**28b** pyrrolidine	Yield 70%	**36ab** : **37ab**=100 : 0
35a	**28e** *n*-butylamine	Yield 59%	**36ae** : **37ae**=100 : 0
35a	**28i** aniline	Yield 77%	**36ai** : **37ai**= 100 : 0
35b	**28a** piperidine	Yield 76%	**36ba** : **37ba**=100 : 0

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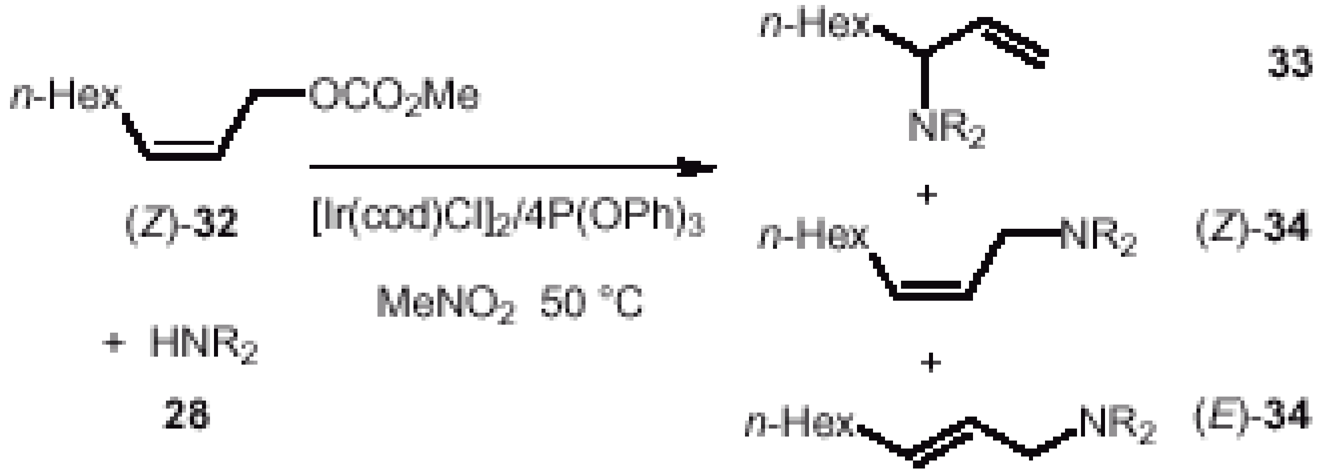
Z-Selective Allylic Amination/Different Amines



28b: pyrrolidine	Yield 80%	**33b** : (*Z*)-**34b** : (*E*)-**34b** = 6 : 94 : 0
28c: morpholine	Yield 80%	**33c** : (*Z*)-**34c** : (*E*)-**34c** = 12 : 88 : 0
28e: *n*-butylamine	Yield 56%	**33e** : (*Z*)-**34e** : (*E*)-**34e** = 21 : 79 : 0
28f: diethylamine	Yield 69%	**33f** : (*Z*)-**34f** : (*E*)-**34f** = 3 : 97 : 0

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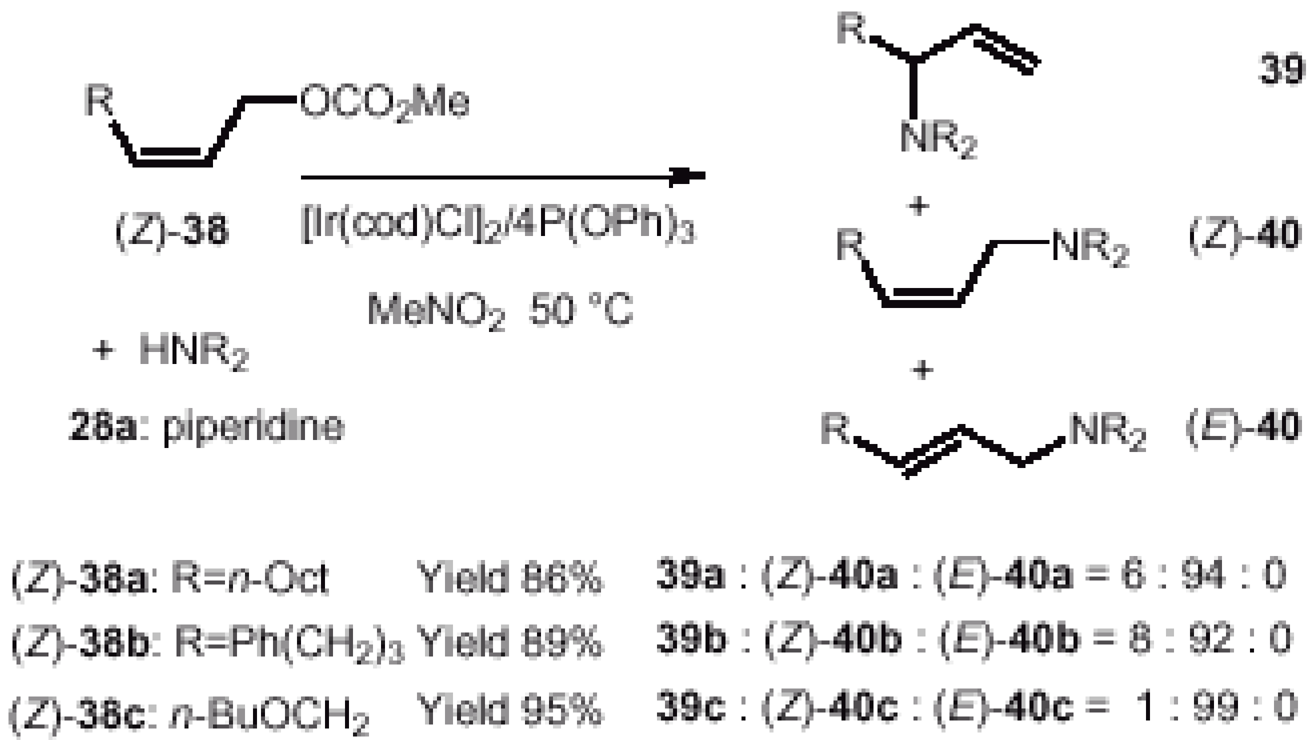
Z-Selective Allylic Amination/Different R-Group



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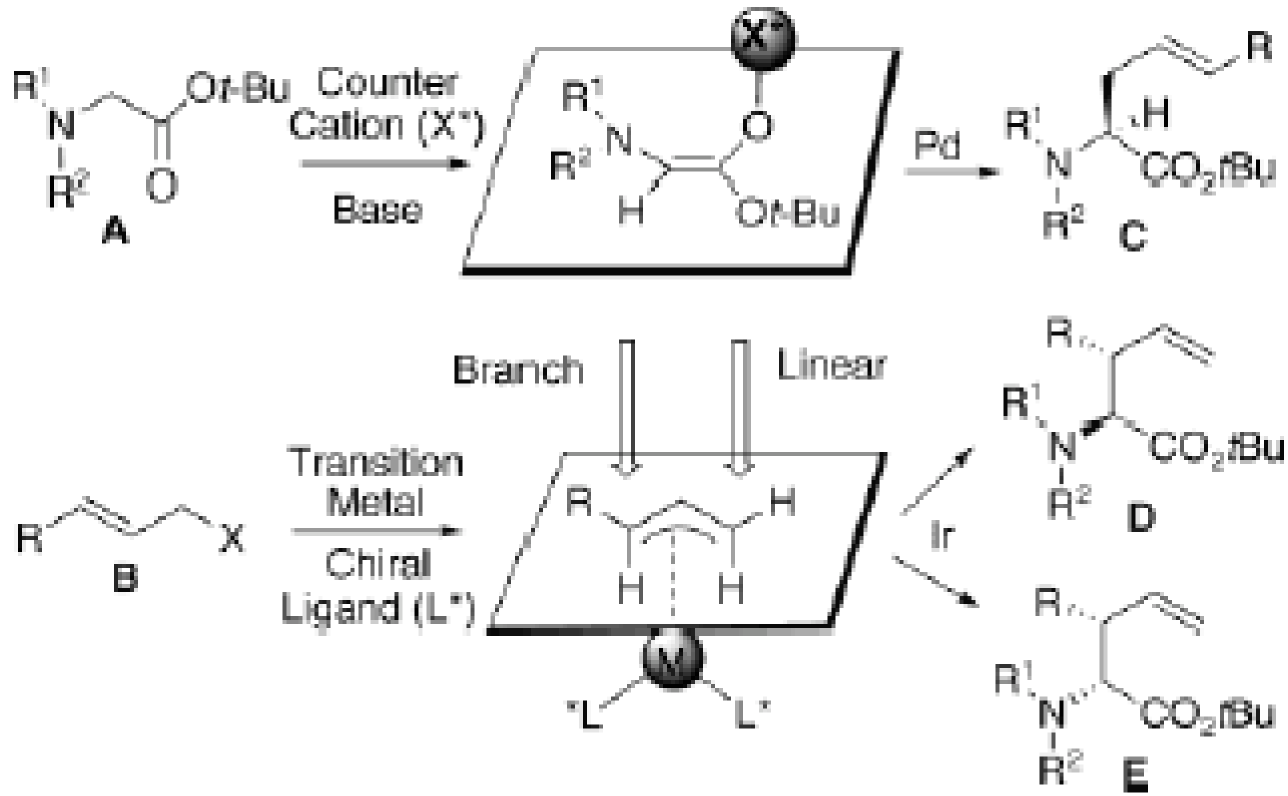
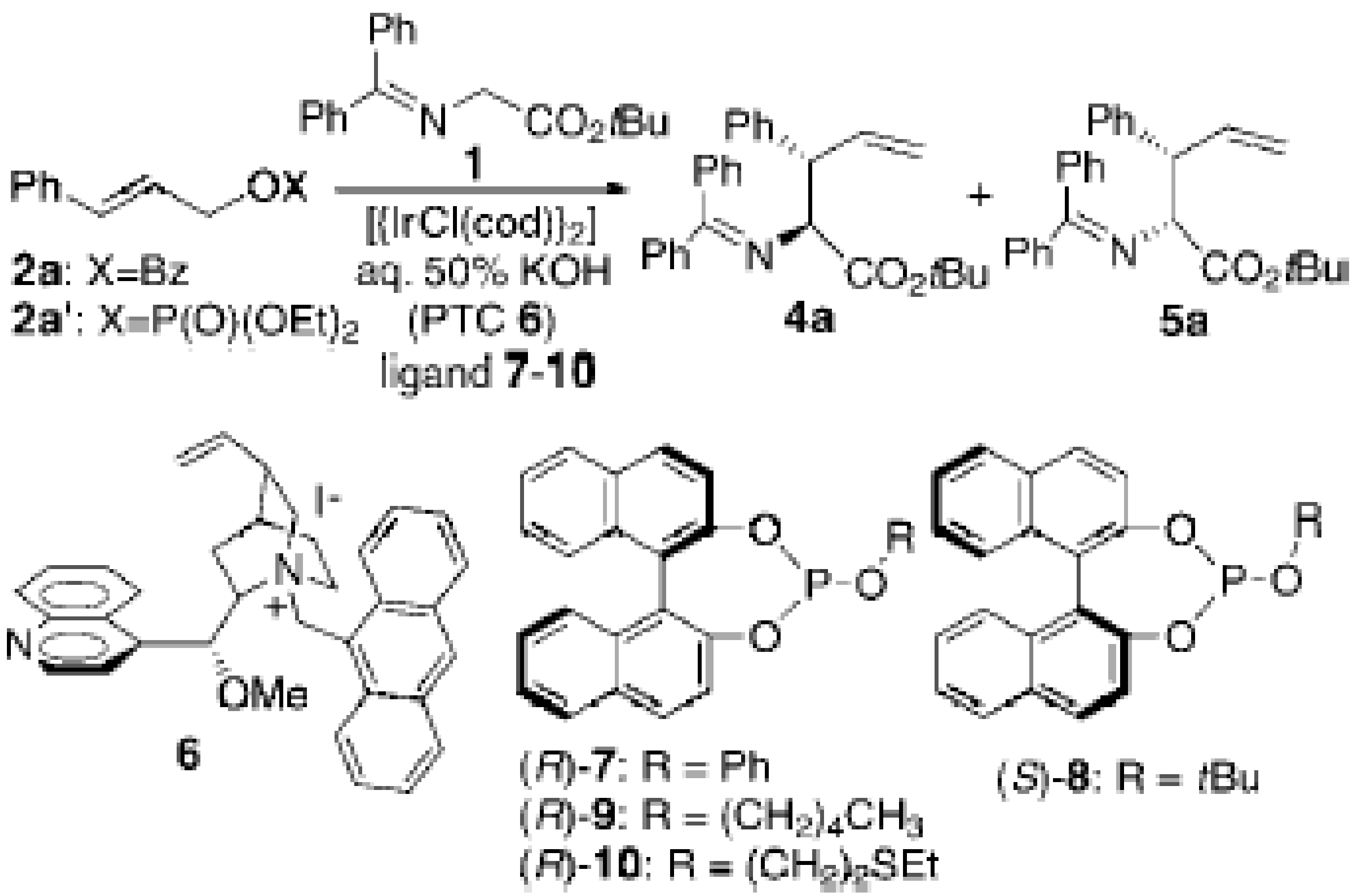
Enantio- And Diastereoselective Ir-Catalyzed Allylic Substitutions for Asymmetric Synthesis of Amino Acid Derivatives

Kanayama, T.; Yoshida, K.; Miyabe, H.; Takemoto, Y. *Ang. Chem. Int. Ed.* **2003** 2054-2056



Ir-Catalyzed Asymmetric Allylic Substitution→Reaction Studied



Scheme 2. Ir-catalyzed asymmetric allylic substitution of **1** with **2 a, a'**.

Kanayama, T.; Yoshida, K.; Miyabe, H.; Takemoto, Y. *Ang. Chem. Int. Ed.* **2003** 2054-2056

Effect of Ligand

Effect of Ligand

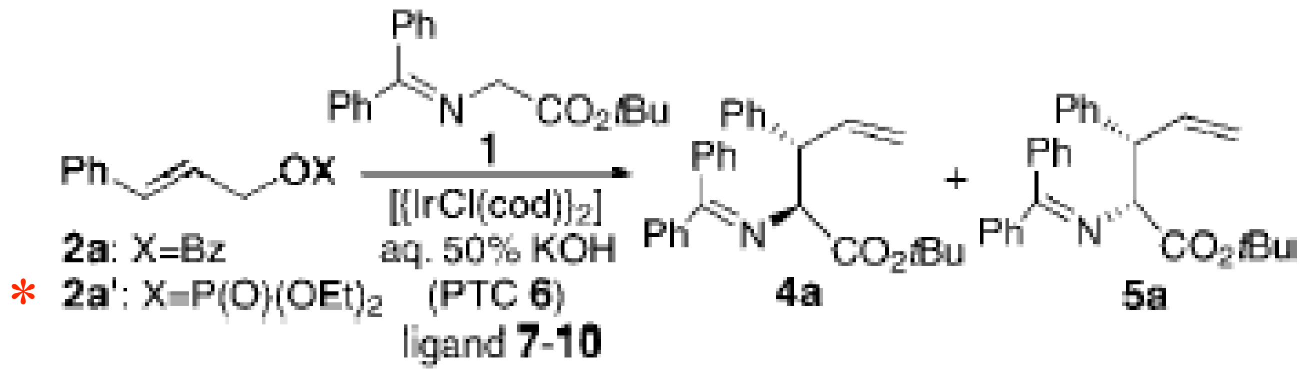


Table 1: Ir-catalyzed asymmetric allylic substitution of **1** and **2 a,a′** with chiral PTC **6** or various chiral ligands **7–10**.[a]

Entry	Substrate	Ligand (mol %)	Yield [%][b] (**4**:**5**)	*ee* of **4** [%][c]
1	**2 a**	**6** (10), $(PhO)_3P$ (40)	40 (75:25)	46
2	**2 a**	(*R*)-**7** (20)	29 (69:31)	32[d]
3	**2 a**	(*S*)-**8** (40)	7 (86:14)	68[d]
4	**2 a**	(*R*)-**9** (20)	6 (67:33)	95
5	**2 a**	(*R*)-**10** (20)	11 (73:27)	93
6[e]	**2 a′**	(*R*)-**9** (20)	0	–
* 7[e]	**2 a′**	(*R*)-**10** (20)	82 (82:18)	97

[a] All reactions were carried out in toluene. The ratio of **1**:**2**:50% KOH:[{IrCl(cod)}$_2$] was 100:100:300:10 unless otherwise noted. [b] Yields of isolated products. [c] Determined by HPLC analysis with Daicel Chiral Pack OD-H column. [d] The enantiomer of **4** was obtained. [e] The reaction was carried out at 0°C.

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Effect of Countercation

Effect of Countercation

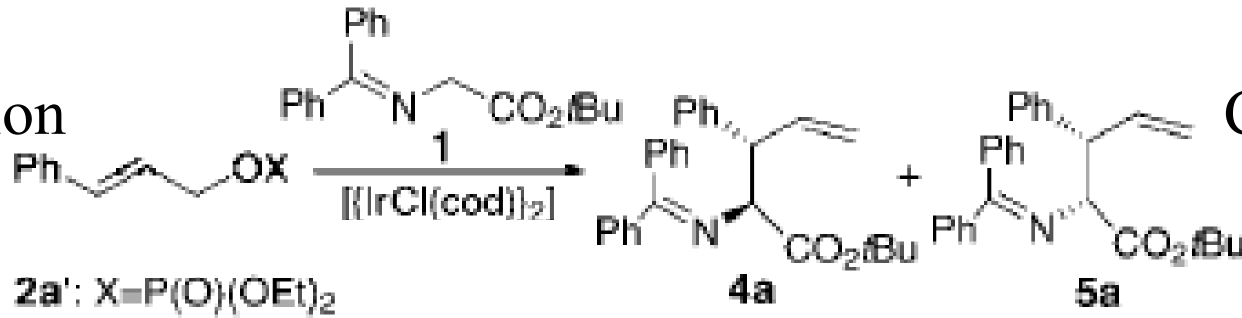

Table 2: Ir-catalyzed allylic substitution of **1** and **2a'** under various reaction conditions.[a]

Entry	Reaction conditions	Yield [%][b] branched	Yield [%][b] linear	Ratio (**4**:**5**)	*ee* [%][c] **4**	*ee* [%][c] **5**
1	$CsOH\cdot H_2O$, toluene	43	0	70:30	95	59
2	50% KOH, toluene	82	0	82:18	97	66
3	$KN(SiMe_3)_2$, THF	28	0	79:21	48	72
4	NaH, THF	29	0	62:38	91	73
5	LiBr, DBU[d], THF	20	23	30:70	44	63
6	LDA, THF	56	3	11:89	–[e]	96
7	$LiN(SiMe_3)_2$, THF	82	<1	12:88	56	92

[a] All reactions were carried out at 0°C in the presence of [{IrCl(cod)}$_2$] (10 mol%) and (*R*)-**10** (20 mol%). [b] Yields of isolated products. [c] Determined by HPLC analysis with Daicel Chiral Pack OD-H column. [d] DBU = 1,8-diazabicyclo[5.4.0]undec-7-ene. [e] The *ee* was not determined.

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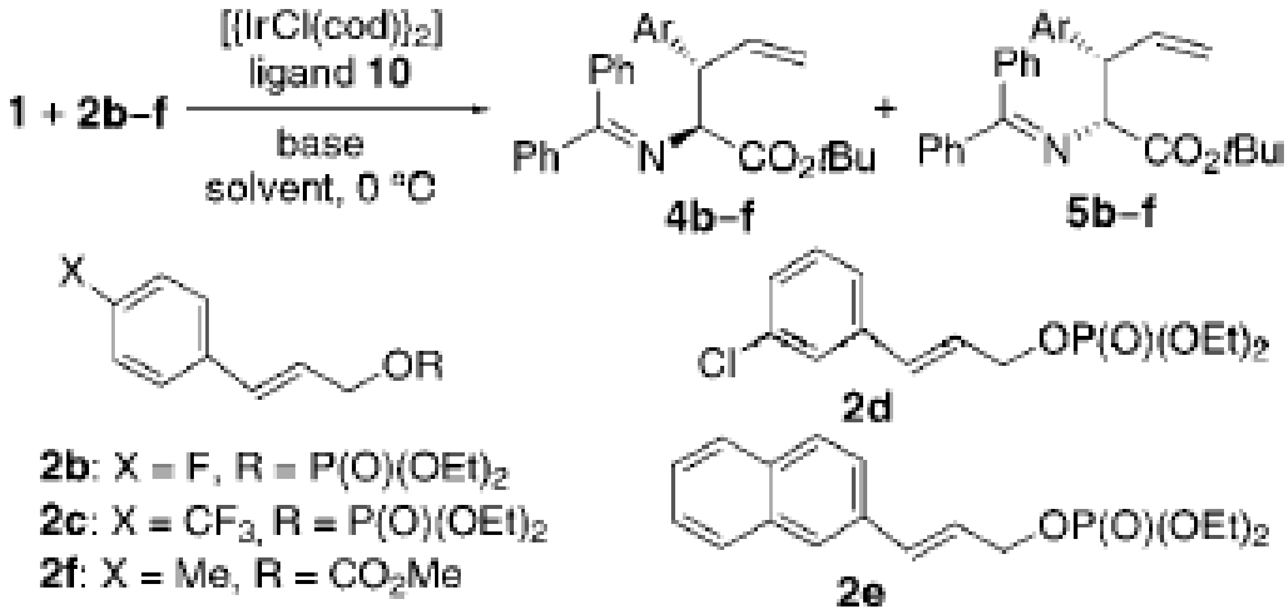
Different Substrates



A = KOH
B = $LiN(SiMe_3)_2$

Entry	Substrate 2	Method[a]	Yield [%][b] branched	Yield [%][b] linear	Ratio (4:5)	*ee* [%][c] 4	*ee* [%][c] 5
1	**2b**	A	77	0	78:22	97	63
2	**2c**	A	77	0	68:32	97	68
3	**2d**	A	79	0	76:24	97	74
4	**2e**	A	97	0	77:23	94	69
5[d]	**2f**	A	63	0	83:17	91	74
6	**2b**	B	82	0	13:87	59	85
7	**2c**	B	78	0	10:90	93	94
8	**2d**	B	81	<1	10:90	73	94
9	**2e**	B	84	<1	11:89	67	96
10	**2f**	B	88	1.1	34:66	51	70

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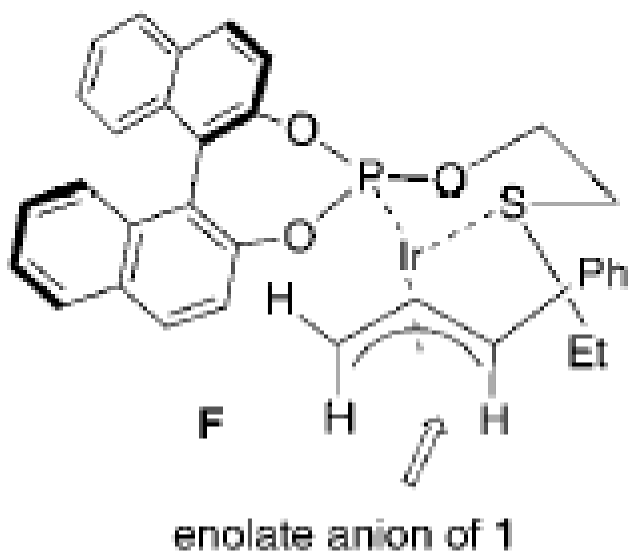
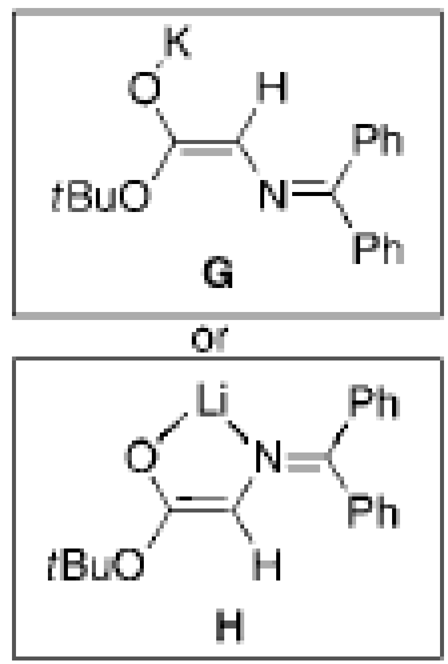
Plausible Allyl Ir^{III} Complex





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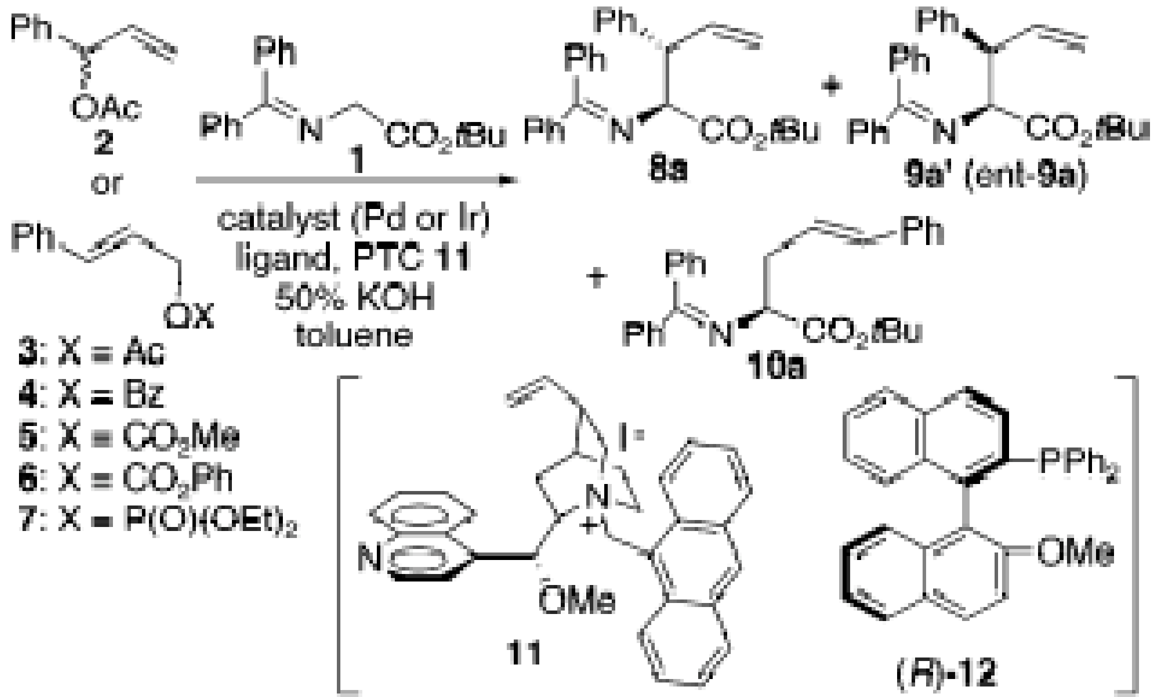
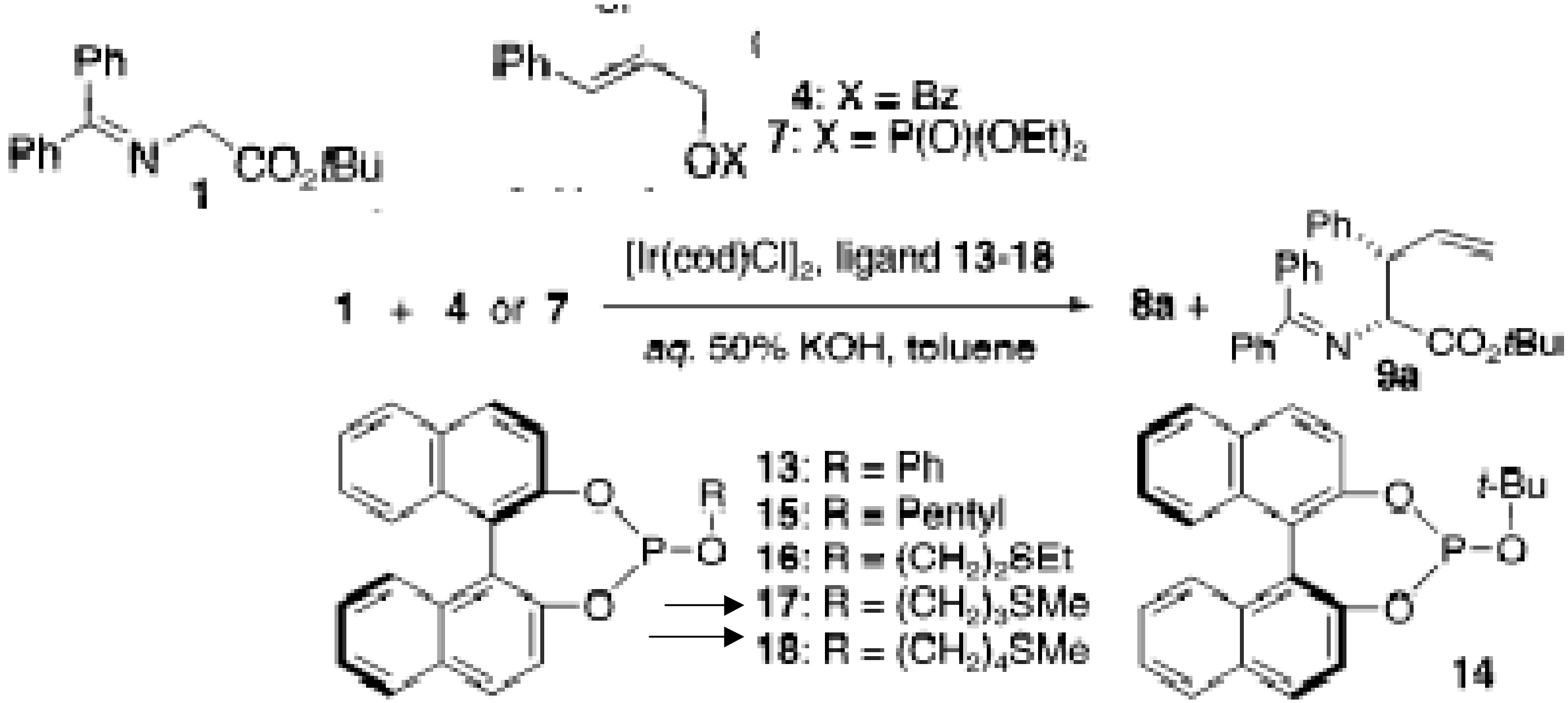
Synthesis of β-Substituted α-Amino Acids With Use of Iridium-Catalyzed Asymmetric Allylic Substitution

Kanayama, T.; Yoshida, K.; Miyabe, H.; Kimachi, T.; Takemoto, Y. *J. Org. Chem.* **2003** 6197-6201



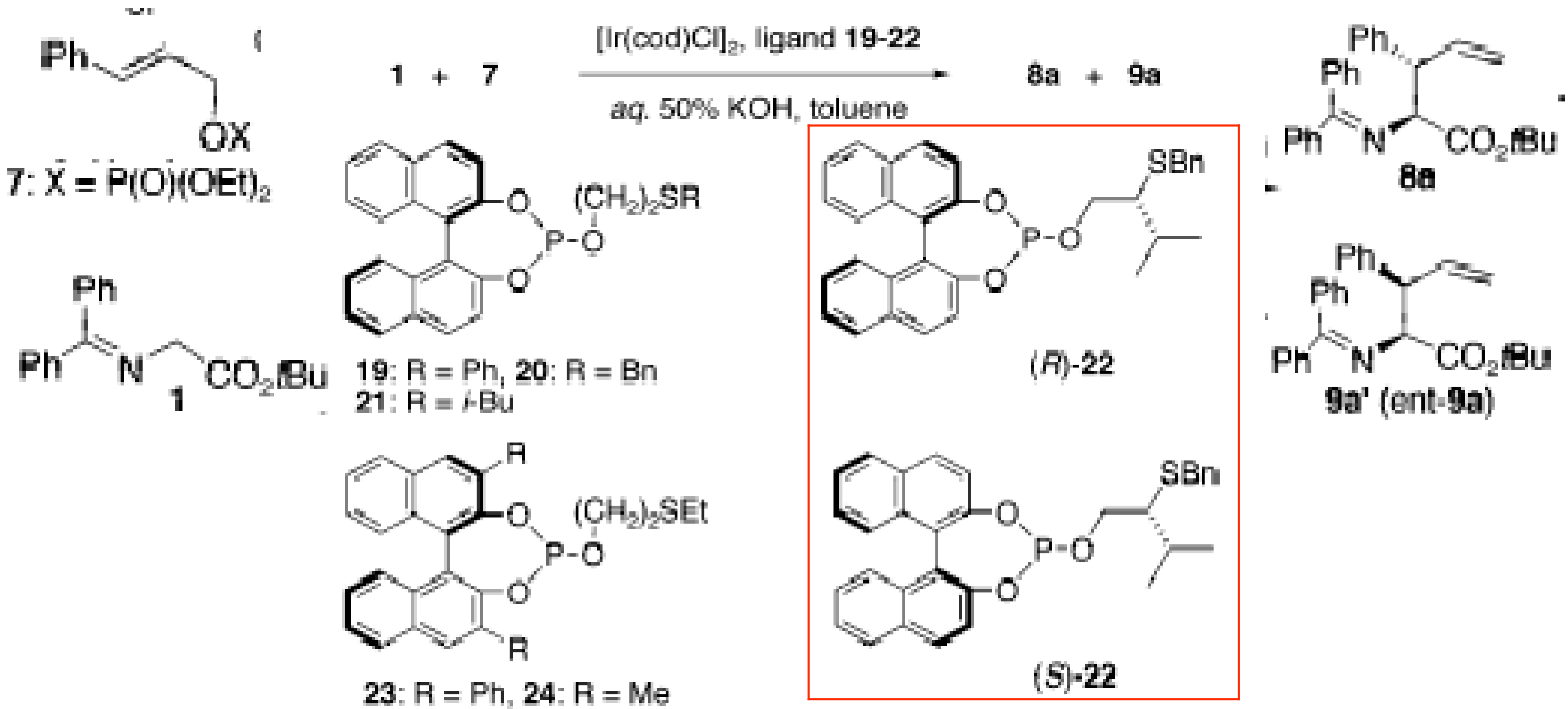
entry	substrate	conditions	yield, % 8a + 9a′	yield, % 10a	ratio 8a:9a′	ee, % 8a	ee, % 9a′
1	**2**	**A**[a]	13	71	5:95	*c*	85
2	**3**	**B**[b]	31	0	77:23	49	*c*
3	**4**	**B**[b]	40	0	75:25	46	*c*
4	**5**	**B**[b]	15	0	80:20	29	*c*
5	**6**	**B**[b]	23	0	83:17	57	*c*
6	**7**	**B**[b]	47	0	83:17	26	*c*

[a] $Pd_2(dba)_3 \cdot CHCl_3$ (3 mol %), chiral ligand **12** (9 mol %), 0 °C.
[b] $[Ir(cod)Cl]_2$ (10 mol %), $(PhO)_3P$ (40 mol %), room temperature.
[c] Not determined.



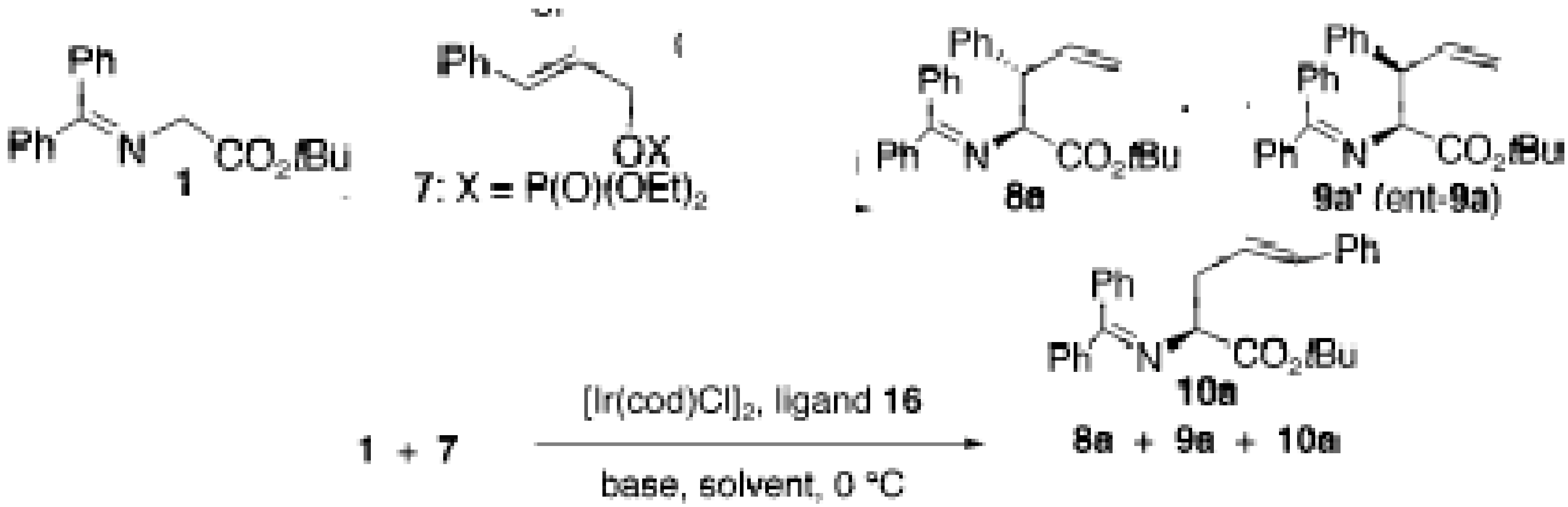
entry	substrate	ligand, conditions	yield, % **8a** + **9a**	ratio **8a**:**9a**	ee, % **8a**	ee, % **9a**
1	**4**	**13**, rt	29	69:31	*a*	23[a]
2	**4**	**14**, rt	7	86:14	68[a]	*b*
3	**4**	**15**, rt	6	67:33	95	46
4	**4**	**16**, rt	11	73:27	93	25
5	**7**	**16**, 0 °C	82	82:18	97	66
6	**7**	**15**, 0 °C	0			
→ 7	**7**	**17**, 0 °C	43	65:35	29	39
→ 8	**7**	**18**, 0 °C	4	75:25	41	53

[a] The enantiomers of **8a** and **9a** were obatined as a major product. [b] Not determined.



entry	ligand	yield, % 8a + 9a	ratio 8a:9a	ee, % 8a	ee, % 9a
1	(*R*)-**19**	17	71:29	82	52
2	(*R*)-**20**	62	71:29	97	42
3	(*R*)-**21**	67	75:25	96	*a*
4	(*R*)-**22**	37	81:19	95	*a*
5	(*S*)-**22**	52	79:21	68[b]	25[b]

[a] Not determined. [b] The enantiomers of **8a** and **9a** were obatined as a major product.



entry	reaction conditions	yield, % 8a:9a	yield, % 10a	ratio 8a:9a	ee, % 8a	ee, % 9a
1	**11**, 50%KOH, Tol.	30	0	83:17	95	87
2	PTC,[a] 50%KOH, Tol.	41	0	51:49	95	60
3	solid KOH, Tol.	71	0	70:30	97	*b*
4	$KN(SiMe_3)_2$, THF	28	0	79:21	48	72
5	$CsOH{\cdot}H_2O$, Tol.	43	0	70:30	95	59
6	NaH, THF	29	0	62:38	91	73
7	LiBr, DBU, THF	20	23	30:70	44	63
8	LDA, THF	56	3	11:89	*b*	96
9	$LiN(SiMe_3)_2$, THF	82	<1	12:88	56	92

[a] PTC: $[CH_3(CH_2)_{15}N(CH_3)_3]Br$. [b] Not determined.

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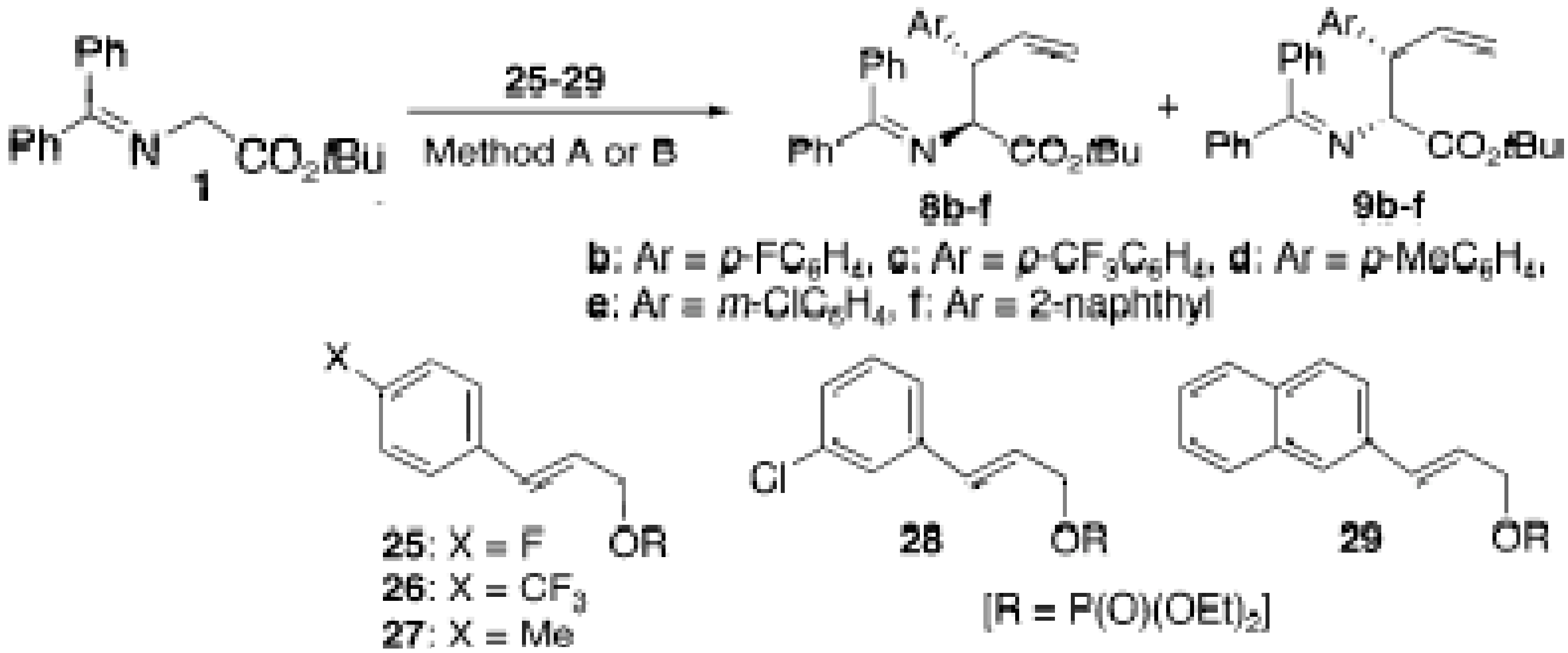
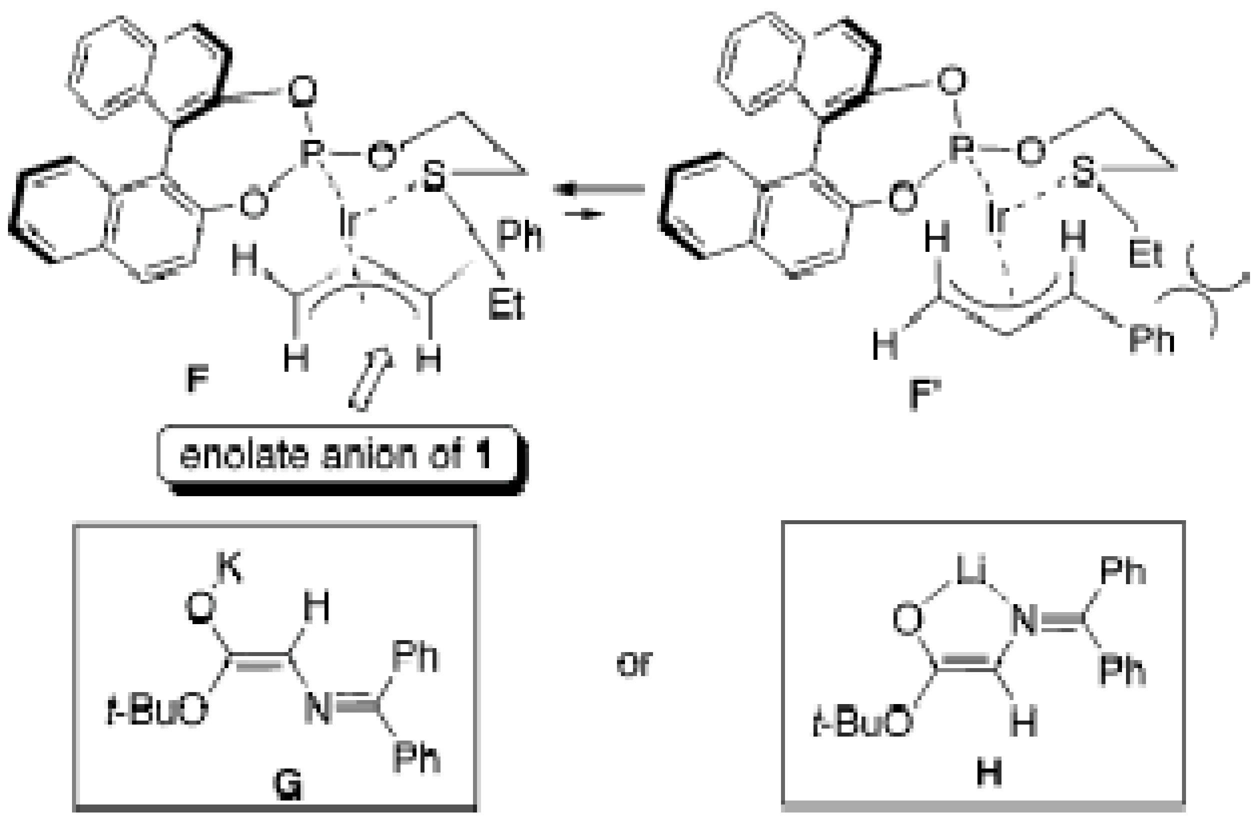


entry	substrate	method[a]	yield, % 8 + 9	ratio 8:9	ee, % 8	ee, % 9
1	**25**	A	77	78:22	97	63
2	**26**	A	78	71:29	98	61
3	**27**[b]	A	86	79:21	90	70
4	**28**	A	79	76:24	97	74
5	**29**	A	97	77:23	94	69
6	**25**	B	81	10:90	62	88
7	**26**	B	78	10:90	93	94
8	**27**[b]	B	70	13:87	46	90
9	**28**	B	81	10:90	73	94
10	**29**	B	84	11:89	67	96

[a] Method A: In toluene at 0 °C. The ratio of **1**:**25**−**29**:50% KOH:$[Ir(cod)Cl]_2$:(*R*)-**16** was 100:100:300:10:20. Method B: In THF at 0 °C. The ratio of **1**:**25**−**29**:$LiN(SiMe_3)_2$:$[Ir(cod)Cl]_2$:(*R*)-**16** was 150:100:150:10:20. [b] The crude phosphate **27** was used without purification.

Kanayama, T.; Yoshida, K.; Miyabe, H.; Kimachi, T.; Takemoto, Y. *J. Org. Chem.* **2003** 6197-6201

Proposed Explanation for Selectivity



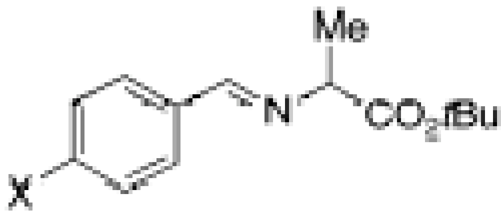
Kanayama, T.; Yoshida, K.; Miyabe, H.; Kimachi, T.; Takemoto, Y. *J. Org. Chem.* **2003** 6197-6201

Quaternary Example

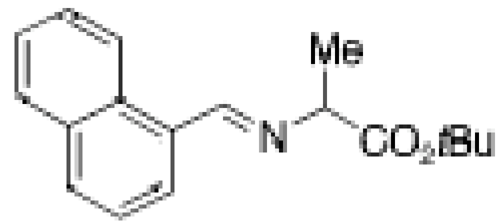
41a-b **42a-b**

a: Ar = Ph, b: Ar = 2-naphthyl

Quaternary Example



38: X = Cl
39: X = OMe



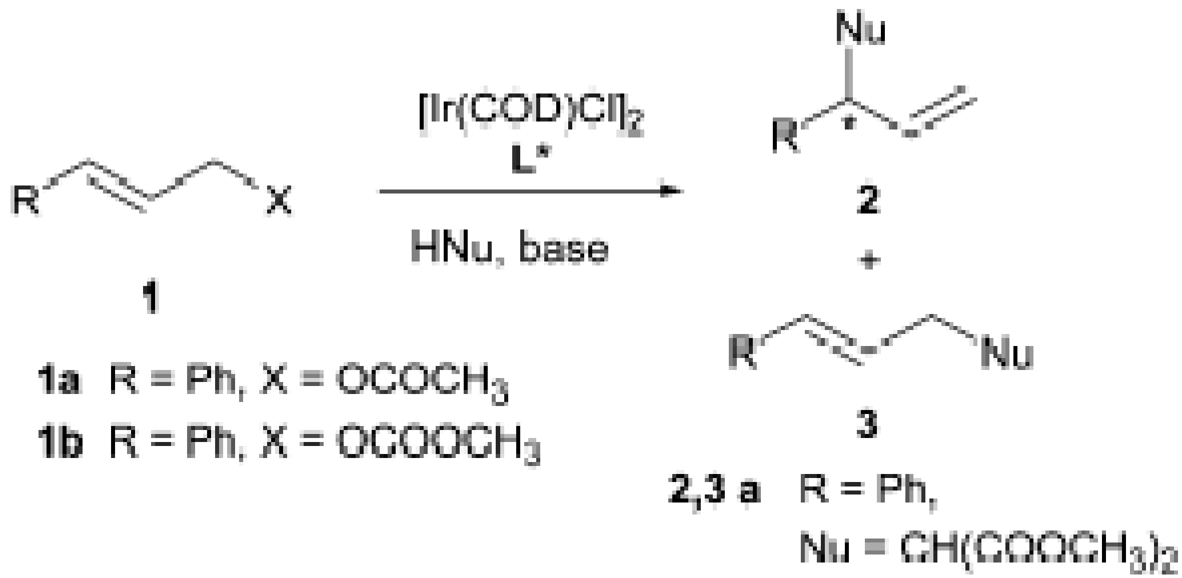
40

entry	substrate	method[a]	yield, % **41** + **42**	ratio **41**:**42**	ee, % **41**	ee, % **42**
1	**38** + **7**	A	18	50:50	92	30
2	**38** + **29**	A	22	50:50	91	35
3	**40** + **29**	A + **11**[b]	17	65:35	91	46
4	**40** + **29**	A + PTC[c]	49	55:45	93	66
5	**38** + **29**	B	59	17:83	84	82
6	**39** + **29**	B	47	19:81	82	75
7	**40** + **29**	B	64	25:75	87	83

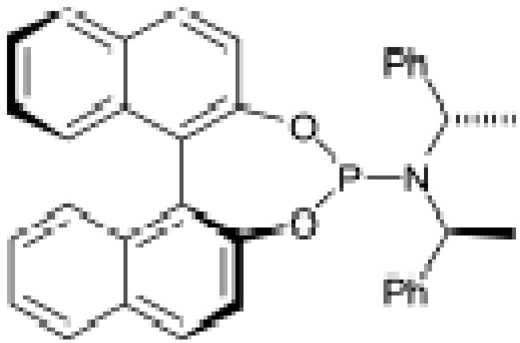
[a] Method A: In toluene at 0 °C. The ratio of **38**−**40**:**7**−**29**:50% KOH:$[Ir(cod)Cl]_2$:(*R*)-**16** was 100:100:300:10:20. Method B: In THF at 0 °C. The ratio of **38**−**40**:**29**:$LiN(SiMe_3)_2$:$[Ir(cod)Cl]_2$:(*R*)-**16** was 150:100:150:10:20. [b] **11** (10 mol %). [c] PTC: $[CH_3(CH_2)_{15}N(CH_3)_3]Br$ (10 mol %).

Regio- and Enantioselective Iridium Catalyzed Allylic Aminations and Alkylations of Dienyl Esters

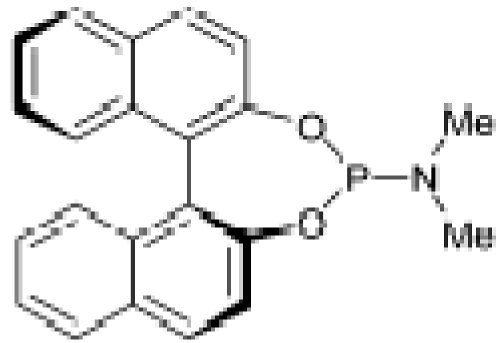
Lipowsky, G.; Helmchen, G. *Chem. Comm..* **2004** 2054-2056



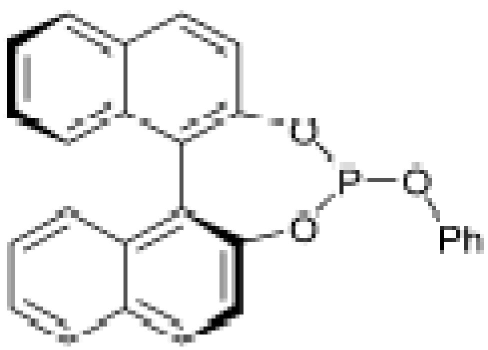
Ligands Screened



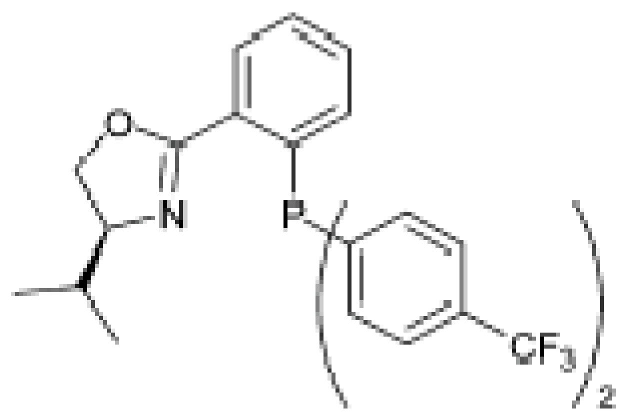
L1 (*S*,*S*,*aS*)



L2 (*aS*)

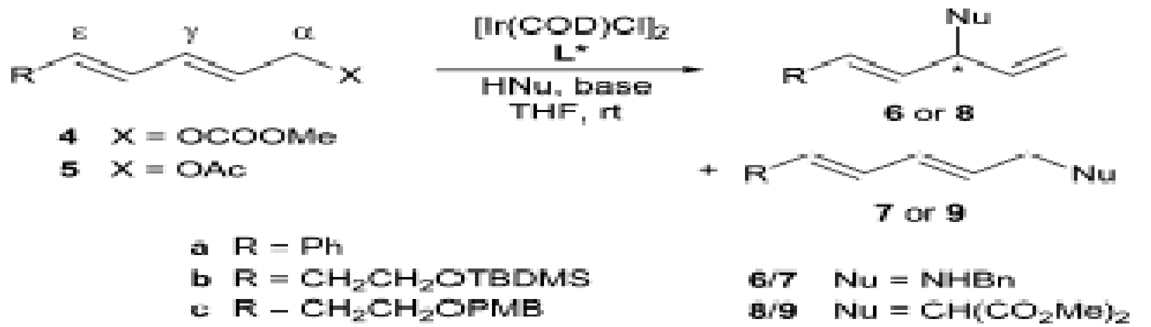


L3 (*aS*)



L4 (*R*)

Lipowsky, G.; Helmchen, G. *Chem. Comm.*. **2004** 2054-2056



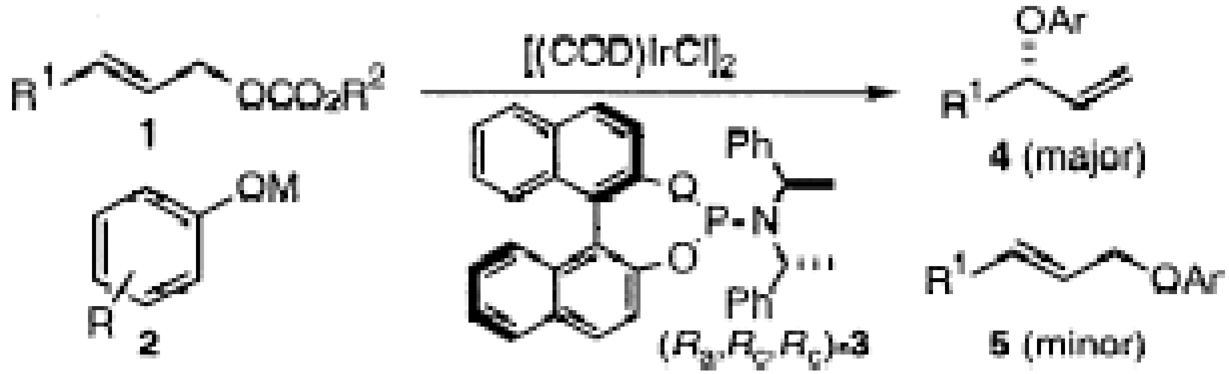
Entry	Substrate	Ligand	Nucleophile	t[a]/h	Yield (%)[b] of **6** + **7** or **8** + **9**	Ratio[c,d] **6** : **7** or **8** : **9**	ee (%)[e] (Confign.)
1	**4a**	**L1**	$BnNH_2$	24	61	99 : 1	**6a**: 97 (+)(*S*)
2	**4b**	**L1**	$BnNH_2$	48	72	94 : 6	**6b**: 97 (−)
3	**4c**	**L1**	$BnNH_2$	14	71	96 : 4	**6c**: 97 (−)
4	**4a**	**L2**	$LiCHE_2$	23	76	95 : 5	**8a**: 0
5	**5a**	**L2**[f]	$LiCHE_2$	40	40	99 : 1	**8a**: 80 (+)
6	**5a**	**L2**[f]	$NaCHE_2$	12	88	99 : 1	**8a**: 50 (+)
7	**4a**	**L1**	$LiCHE_2$	24[g]	62	99 : 1	**8a**: 76 (−)
8	**4a**	**L1**	$LiCHE_2$–LiCl[h]	43[g]	63	79 : 21	**8a**: 66 (−)
9	**4a**	**L1**	$LiCHE_2$–$ZnCl_2$[h]	43[g]	77	95 : 5	**8a**: 78 (−)
10	**4a**	**L1**	$NaCHE_2$–LiCl[h]	22[g]	87	94 : 6	**8a**: 90 (−)
11	**5a**	**L1**	$LiCHE_2$	43[g]	49	91 : 9	**8a**: 84 (−)
12	**5a**	**L1**	$NaCHE_2$–LiCl[h]	23[g]	76	92 : 8	**8a**: 89 (−)
13	**4a**	**L3**	$LiCHE_2$	17	64	94 : 6	**8a**: 58 (+)
14	**4a**	**L3**	$NaCHE_2$	72	84	95 : 5	**8a**: 10 (−)
15	**4b**	**L1**	$LiCHE_2$	24[g]	84	94 : 6	**8b**: 87 (−)

[a] Reaction time. [b] Yield of isolated product. [c] The product of ε-attack was not observed. [d] Determined by ^1H NMR of the crude products. [e] Determined by HPLC (Daicel columns, 250 × 4.6 mm, 5 µm, + guard cartridge 10 × 4 mm, 5 µm, flow: 0.5 ml min^{-1}); **6a**: (Daicel Chiralcel OD-H, eluent: *n*-hexane–*i*-PrOH 99 : 1 + 0.1% $HNEt_2$): t_R[(*R*)-**6a**] = 21 min, t_R[(*S*)-**6a**)] = 27 min; **6b**: determination after transformation to **6c**; **6c**: (Daicel Chiralpak AD-H, 20 °C, eluent: *n*-hexane–*i*-PrOH 99.5 : 0.5 + 0.1% $HNEt_2$): t_R[(−)-**6c**] = 79 min, t_R(+) = 111 min; **8a**: (Daicel Chiralcel OJ-H, eluent: *n*-hexane–*i*-PrOH 90 : 10): t_R[(−)-**8a**] = 26 min, t_R[(+)-**8a**] = 29 min; **8b**: determination after transformation to **8c**; **8c**: (Daicel Chiralcel AD-H, eluent: *n*-hexane–*i*-PrOH 98 : 2): t_R[(+)-**8b**] = 45 min, t_R[(−)-**8b**] = 53 min. [f] Ratio Ir : ligand = 1 : 2. [g] Reaction temperature: 50 °C. [h] Addition of 1 eq. of LiCl or $ZnCl_2$ to the catalyst solution.

Lipowsky, G.; Helmchen, G. *Chem. Comm.*. **2004** 2054-2056

Regio- and Enatioselective Iridium-Catalyzed Intermolecular Allylic Etherification of Achiral Allylic Carbonates with Phenoxides

Lopez, F.; Ohmura, T., Hartwit, J. F. *J. Am. Chem. Soc*. **2003** 3426-3427



Effect of Nucleophile

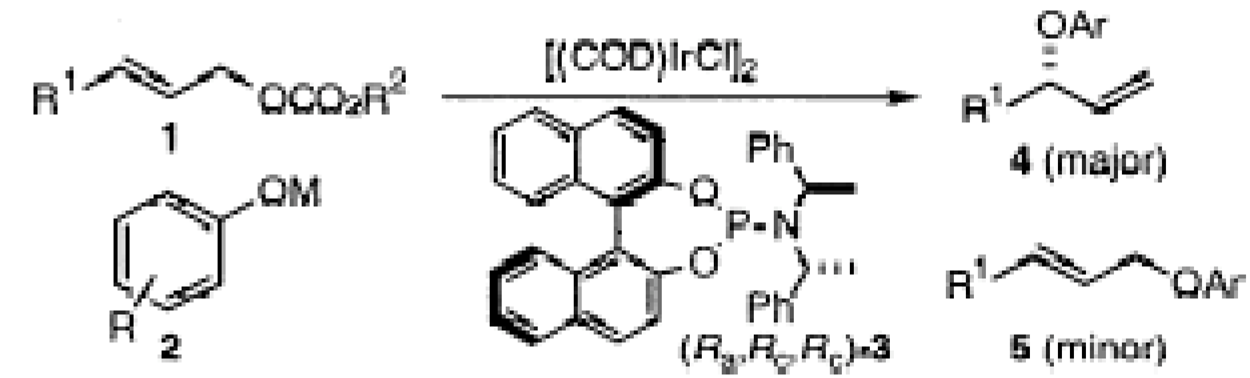
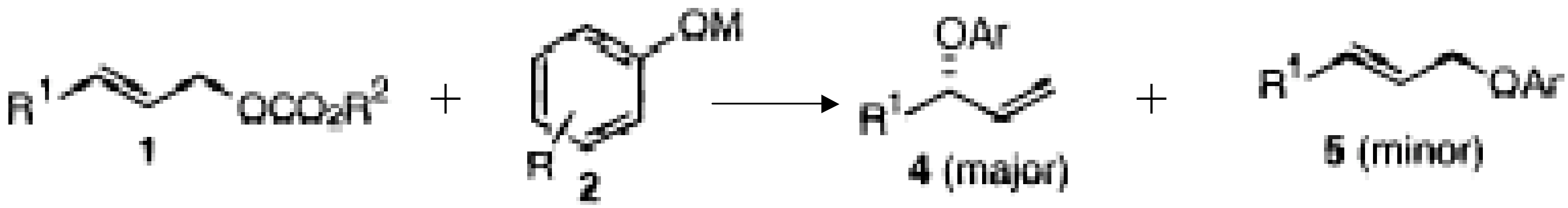


Table 1. Effect of Nucleophile on the Ir-Catalyzed Enantioselective Allylic Etherification of (*E*)-Cinnamyl Carbonates (R^1 = Ph)[a]

entry	R^2	**1**	M–OPh	temp (°C)	time (h)	**4/5**[b]	yield (%)[c]	% ee[d]
1	Me	**1a**	PhOH/Et_3N	50	15	93/7	76	84
2	Me	**1a**	PhOH/*i*-Pr_2NEt	50	45	89/11	66	78
3	Me	**1a**	PhOH/Me_2NEt	50	11	53/47	31	45
4	Me	**1a**	NaOPh **2a**[e]	23	22	97/3	40	92
5	Et	**1b**	NaOPh **2a**[e]	23	35	99/1	76	94
6	Et	**1b**	NaOPh **2a**[e]	50	17	95/5	78	92
7	Me	**1a**	LiOPh **2b**[f]	50	20	96/4	86[g]	96
8	Me	**1a**	LiOPh/CuCl[f]	50	12	96/4	73	37

Lopez, F.; Ohmura, T., Hartwit, J. F. *J. Am. Chem. Soc*. **2003** 3426-3427

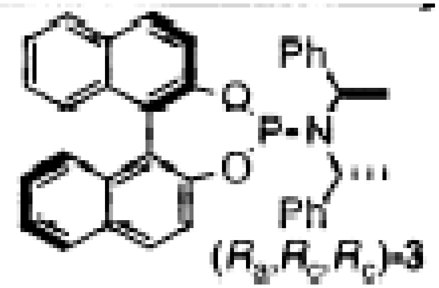


entry	R1, R2 (1)	metal–aryloxide (2)	time (h)	4/5[b]	yield (%)[c]	ee (%)
1	Ph, Me (**1a**)	2-MeC$_6$H$_4$OLi **2c**	14	96/4	87	95 (*R*)[d]
2	Ph, Me (**1a**)	4-MeC$_6$H$_4$OLi **2d**	22	98/2	91	95
3	Ph, Me (**1a**)	4-MeOC$_6$H$_4$OLi **2e**	8	98/2	88	97
4	Ph, Me (**1a**)	3-MeOC$_6$H$_4$OLi **2f**	17	95/5	84[e]	96
5	Ph, Me (**1a**)	3-PhC$_6$H$_4$OLi **2g**	13	96/4	76	95
6	Ph, Me (**1a**)	2-PhC$_6$H$_4$OLi **2h**	10	96/4	65	93
7	Ph, Me (**1a**)	3-Me$_2$NC$_6$H$_4$OLi **2i**	14	99/1	56	97
8	Ph, Me (**1a**)	3,4-(OCH$_2$O)C$_6$H$_3$OLi **2j**	18	99/1	65	94
9	Ph, Me (**1a**)	2,4-Me$_2$C$_6$H$_3$OLi **2k**	11	98/2	85[e]	95
10	Ph, Me (**1a**)	2,4,6-Me$_3$C$_6$H$_2$OLi **2l**	22	93/7	82[e]	93
11	Ph, Et (**1b**)	4-BrC$_6$H$_4$ONa **2m**[f]	8	96/4	91	90
12	Ph, Et (**1b**)	4-ClC$_6$H$_4$ONa **2n**[f]	20	93/7	86	92
13	Ph, Et (**1b**)	4-Br,3-MeC$_6$H$_3$ONa **2o**[f]	8	95/5	89	87
14	Ph, Et (**1b**)	4-CF$_3$C$_6$H$_4$ONa **2p**[f]	10	90/10	92	80 (*R*)[d]
15	2-MeOC$_6$H$_4$, Me (**1c**)	PhOLi **2b**	41	98/2	79	75
16	4-MeOC$_6$H$_4$, Me (**1d**)	PhOLi **2b**[g]	13	97/3	70	86
17	*n*-Pr, Me (**1e**)	PhOLi **2b**	14	92/8	93	92
18	*n*-Pr, Me (**1e**)	2-MeC$_6$H$_4$OLi **2c**	20	87/13	86	90
19	*n*-Pr, Me (**1e**)	4-MeOC$_6$H$_4$OLi **2e**	14	90/10	73	85

Catalyst*

[(COD)IrCl]$_2$

+



Lopez, F.; Ohmura, T., Hartwit, J. F.
J. Am. Chem. Soc. **2003** 3426-3427

CONCLUSIONS

- Ir can be used to selectively produce the highly branched products

-Diastereoselectivity can be controlled by using Li or K as counter ion

-Good method for preparing unnatural amino acids as well as quaternary amino acids