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DOUBLE ASYMMETRIC INDUCTION IN INTRAMOLECULAR C-H INSERTION REACTIONS OF α-DIAZO β-KETO ESTERS

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ABSTRACT: A new double asymmetric induction in C-C bond formation has been achieved by the use of dirhodium(II) tetrakis[*N*-phthaloyl-(*R*) or (*S*)-phenylalaninate] as a homochiral catalyst in intramolecular C-H insertion of α-diazo β-keto esters of homochiral alcohols. The matched combination of the (+)-neomenthyl esters and the catalyst derived from (*R*)-phenylalanine produces, after a removal of the ester group, optically active 3-substituted cyclopentanones of up to 80% ee.

With the advent of dirhodium(II) carboxylate catalysts, intramolecular C-H insertion reaction of α-diazocarbonyl compounds, featured by C-C bond formation at an unactivated carbon atom, has offered a potentially powerful means for the construction of both five-membered ring carbocycles and heterocycles.[2] Consequently, much attention has recently been paid to the realization of the enantioselective version of this reaction catalyzed by chiral dirhodium(II) complexes.[3,4] We have recently reported that dirhodium(II) tetrakis[*N*-phthaloyl-(*S*)-phenylalaninate], Rh_2(*S*-PTPA)$_4$, catalyzes intramolecular C-H insertion

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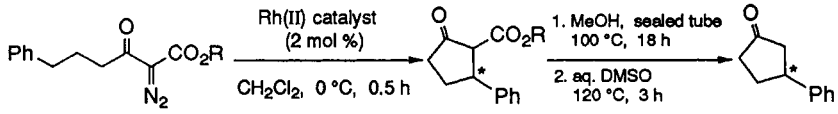
reactions of α-diazo β-keto 2,4-dimethyl-3-pentyl esters to afford, after a removal of the ester group, optically active 3-substituted cyclopentanones in up to 76% ee, wherein the enantioselectivity was found to be substantially influenced by both the alkoxy group of the ester moiety and the substituent adjacent to the target C-H bond as well as the structure of the carboxylate ligand.[5]

In order to further enhance the enantioselectivity, our efforts have been centered on a double asymmetric induction[6] with the judicious selection of a homochiral alcohol in the ester moiety.[7] Herein we wish to report that cyclization of (+)-neomenthyl α-diazo β-keto carboxylates catalyzed by Rh_2(*R*-PTPA)$_4$ produces, after a removal of the ester group, optically active 3-substituted cyclopentanones of up to 80% ee.

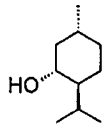
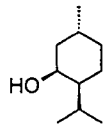
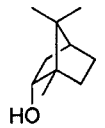
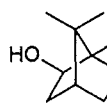
Chiral α-diazo β-keto esters **1a-d** possessing a phenyl group adjacent to the target C-H bond were prepared from the corresponding methyl ester by transesterification with the chiral auxiliary alcohols and subsequent diazo transfer. In order to recognize matched and mismatched pairs in intramolecular C-H insertion reactions of **1a-d**, a set of experiments were carried out using Rh_2(*S*-PTPA)$_4$ and Rh_2(*R*-PTPA)$_4$ as chiral catalysts and $Rh_2(OAc)_4$ as an achiral catalyst, wherein diastereomeric mixtures of the cyclic β-keto esters **2a-d** were obtained in high yields in all cases. The sense and degree of the diastereotopic selection at the insertion site were determined by transesterification of **2a-d** with methanol and subsequent demethoxycarbonylation to the known 3-phenylcyclopentanone (**3**).[5] The results are presented in **Table 1**, which offers several characteristic features of the reaction.

It is worthy of note that the double asymmetric C-H insertion reactions of **1a-d** using Rh_2(*S*-PTPA)$_4$ or Rh_2(*R*-PTPA)$_4$ provide (*R*)-**3** and (*S*)-**3**, respectively, which means that the preferred absolute configuration at the insertion site is

Table 1. Double Asymmetric C-H Insertion Reactions of Chiral α-Diazo β-Keto Esters **1** Catalyzed by Rh_2(*R* or *S*-PTPA)$_4$



1 **2** **3**

entry	substrate	ROH	Rh(II) catalyst	β-keto ester % yield	3-phenylcyclopentanone % yield	% ee[a]	confign
1	**1a**		$Rh_2(OAc)_4$	84	80	29	*R*
2	**1a**		Rh_2(*S*-PTPA)$_4$	83	86	27	*R*
3	**1a**		Rh_2(*R*-PTPA)$_4$	84	80	67	*S*
4	**1b**		$Rh_2(OAc)_4$	74	85	23	*S*
5	**1b**		Rh_2(*S*-PTPA)$_4$	82	88	53	*R*
6	**1b**		Rh_2(*R*-PTPA)$_4$	83	90	80	*S*
7	**1c**		$Rh_2(OAc)_4$	75	87	15	*R*
8	**1c**		Rh_2(*S*-PTPA)$_4$	77	85	60	*R*
9	**1c**		Rh_2(*R*-PTPA)$_4$	76	87	54	*S*
10	**1d**		$Rh_2(OAc)_4$	80	85	32	*R*
11	**1d**		Rh_2(*S*-PTPA)$_4$	87	81	41	*R*
12	**1d**		Rh_2(*R*-PTPA)$_4$	88	82	46	*S*

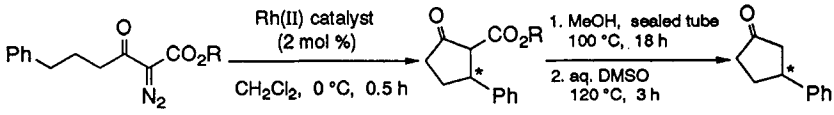
[a] Based on $[\alpha]_D^{22}$ -93.6° (*c* 1.15, $CHCl_3$) for (*S*)-**3**; see ref 5.

dependent on the chirality of the catalyst rather than that of the chiral auxiliary alcohols.[8] Except for the reaction of the (-)-menthyl ester **1a** using Rh_2(*S*-PTPA)$_4$, the higher values than 46% ee obtained with the corresponding achiral methyl ester[3c] were attained in the double asymmetric induction. Based on the combined result that $Rh_2(OAc)_4$-catalyzed cyclization of the (-)-menthyl ester **1a**

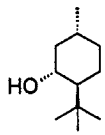
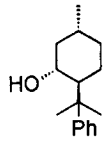
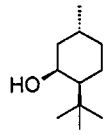
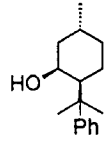
led to the formation of (*R*)-**3** in 29% ee and that the catalysis of the methyl ester using Rh_2(*S*-PTPA)$_4$ provided (*R*)-**3** in 46% ee, the combinations of **1a** + Rh_2(*S*-PTPA)$_4$ and **1a** + Rh_2(*R*-PTPA)$_4$ should constitute matched and mismatched pairs, respectively. However, the experiments showed that the reaction of **1a** using Rh_2(*R*-PTPA)$_4$ but not Rh_2(*S*-PTPA)$_4$ constituted the matched pair to afford (*S*)-**3** in 67% ee, while the combination of **1a** + Rh_2(*S*-PTPA)$_4$ resulted in the formation of (*R*)-**3** with only 27% ee. A similar trend prevails with the (-)-isobornyl ester **1d**, although the difference in double diastereoselectivity between both pairs is not so dramatic as that observed with **1a**. While the double asymmetric reactions with the (+)-neomenthyl ester **1b** and the (-)-bornyl ester **1c** constituted the expected matched and mismatched pairs, the combination of the (+)-neomenthyl ester **1b** and Rh_2(*R*-PTPA)$_4$ to exhibit 80% ee proved to be the best choice. Here again, it shoud be emphasized that the level of double stereodifferentiation with **1c** is not so significant as that observed with **1b**.

With the matched and mismatched pairs being identified with **1a** and **1b**, we were intrigued by the viability of further enhancement of the selectivity by the modification at C-8 of (-)-menthol and (+)-neomenthol. Thus, cyclizations of **1e-h** featured by the substitution of methyl or phenyl groups for a hydrogen at C-8 were examined. As illustrated in **Table 2**, a set of reactions with **1e,f** in (-)-menthol series showed an apparent anomaly to the expected multiplicativity as with the case of **1a**, although the difference in double diastereoselectivity in either case was much smaller than that observed with **1a**. As anticipated, cyclizations of **1g,h** in (+)-neomenthol series were found to exhibit a similar trend to the case of **1b**. The catalysis of **1e,g** with a methyl substituent exhibited much higher selectivities than that of **1f,h** with a phenyl substituent in the matched combination (entries 3 and 8 vs. 6 and 12), however, higher values than 80% ee obtained with **1b** could not be attained.

Table 2. Double Asymmetric C-H Insertion Reactions of Chiral α-Diazo β-Keto Esters **1** Catalyzed by Rh_2(*R* or *S*-PTPA)$_4$



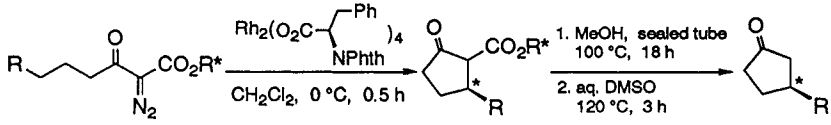
1 **2** **3**

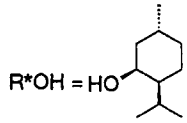
entry	substrate	ROH	Rh(II) catalyst	β-keto ester % yield	3-phenylcyclopentanone % yield	% ee[a]	confign
1	**1e**		$Rh_2(OAc)_4$	82	85	23	*R*
2	**1e**		Rh_2(*S*-PTPA)$_4$	78	83	63	*R*
3	**1e**		Rh_2(*R*-PTPA)$_4$	80	84	74	*S*
4	**1f**		$Rh_2(OAc)_4$	74	84	35	*R*
5	**1f**		Rh_2(*S*-PTPA)$_4$	70	82	44	*R*
6	**1f**		Rh_2(*R*-PTPA)$_4$	70	83	59	*S*
7	**1g**		$Rh_2(OAc)_4$	77	86	15	*R*
8	**1g**		Rh_2(*S*-PTPA)$_4$	70	85	75	*R*
9	**1g**		Rh_2(*R*-PTPA)$_4$	76	88	58	*S*
10	**1h**		$Rh_2(OAc)_4$	70	85	4	*S*
11	**1h**		Rh_2(*S*-PTPA)$_4$	72	89	51	*R*
12	**1h**		Rh_2(*R*-PTPA)$_4$	68	88	62	*S*

[a] Based on $[\alpha]_D^{22}$ -93.6° (*c* 1.15, $CHCl_3$) for (*S*)-**3**; see ref 5.

Since the combination of **1b** and Rh_2(*R*-PTPA)$_4$ proved to be the matched pair of choice, we then examined Rh_2(*R*-PTPA)$_4$-catalyzed cyclizations of (+)-neomenthyl α-diazo β-keto carboxylates **4-6** possessing other substituents than a phenyl group at the insertion site. The results are summarized in **Table 3**. As was the case with **1b**, the catalysis of **4-6** involving diastereotopic differentiation of aliphatic or allylic methylene C-H bonds exhibited much higher selectivities than

Table 3. Double Asymmetric C-H Insertion Reactions of α-Diazo β-Keto (+)-Neomenthyl Esters Catalyzed by Rh_2(*R*-PTPA)$_4$





entry	substrate R	β-keto ester	% yield	3-substituted cyclopentanone	% yield	% ee[a,b]	confign
1	**4** Me	**7**	84	**10**	80	34 (24)	*S*
2	**5** C_5H_{11}	**8**	83	**11**	86	36 (29)	*S*
3	**6** CH_2=CH	**9**	84	**12**	80	53 (38)	*S*
4	**1b** Ph	**2b**	74	**3**	85	80 (46)	*S*

[a] Determined by analysis of ^{13}C NMR spectra of the diastereomeric ketals prepared from the corresponding ketones and (2*R*,3*R*)-2,3-butanediol. [b] The values in parentheses were obtained with the corresponding methyl esters; see ref 3c.

that of the corresponding methyl esters, but the selectivities were found to be comparable to those obtained with the corresponding 2,4-dimethyl-3-pentyl esters.[5] While the consistent sense of double diastereoselection was observed with Rh_2(*R*-PTPA)$_4$ regardless of the R substituents, it is of interest to note that the substituent effects on double diastereoselectivities as well as on enantioselectivities[5] were more pronounced with the phenyl and vinyl groups (entries 1 and 2 vs. 3 and 4).[9]

In conclusion, we have demonstrated that the chirality of the dirhodium(II) catalyst rather than that of the substrate dictates the stereochemical course of double asymmetric C-H insertion reactions of chiral α-diazo β-keto esters, wherein the combination of the (+)-neomenthyl ester **1b** and Rh_2(*R*-PTPA)$_4$ provides 3(*S*)-phenylcyclopentanone of 80% ee, the highest achievement so far reported with carbocyclic system.

Experimental Section

General. Melting points were determined on a Yanagimoto micro melting apparatus and are not corrected. Infrared (IR) spectra were recorded on a JASCO A-302 diffraction grating infrared spectrometer. NMR spectra were recorded in $CDCl_3$ with a JEOL JNM-GX 400 spectrometer, ^1H at 400 MHz and ^{13}C at 100.6 MHz, with tetramethylsilane (δ 0.0, ^1H) or chloroform-d_1 (δ 77.0, ^{13}C) as an internal standard. Optical rotations were recorded on a JASCO DIP-370 polarimeter. Mass spectra (MS) were determined on a JEOL JMS-D 300 mass spectrometer, operating with an ionization energy of 70 eV. Column chromatography was done with Fuji Davison silica gel BW-820MH (70~200 mesh).

(-)-8-Phenylmenthol was purchased from Aldrich Chemical Co. (1*S*,2*S*,5*R*)-5-Methyl-2-(1-methyl-1-phenylethyl)-cyclohexan-1-ol,[10] (1*R*,2*S*,5*R*)-2-dimethylethyl-5-methyl-cyclohexan-1-ol,[11] and (1*S*,2*S*,5*R*)-2-dimethylethyl-5-methyl-cyclohexan-1-ol[11] were prepared from (+)-pulegone according to literature procedures. (-)-Isoborneol was prepared from (+)-camphor by literature method.[12] Methanesulfonyl azide was prepared according to the procedure of Danheiser.[13]

Representative Procedure for Transesterifications of β-Keto Methyl Esters with Chiral Auxiliary Alcohols. Preparation of (+)-Neomenthyl 3-Oxo-6-phenylhexanoate. A solution of methyl 3-oxo-6-phenylhexanoate (3.0 g, 13.2 mmol) and (+)-neomenthol (2.1 g, 13.2 mmol) in dry toluene (20 mL) was heated at reflux, during which time the solvent was slowly distilled off. After the reaction proceeded to completion (6 h), the remaining solvent was evaporated *in vacuo* and the residue was purified by column chromatography (silica gel 50 g, 15:1 hexane/EtOAc) to give the title compound (4.04 g, 89%) as a colorless oil: $[\alpha]_D^{22}$ +19.2° (*c* 2.21, THF); IR (film) 1735, 1716, 1641, 1454, 1240 cm^{-1}; ^1H NMR δ 7.31-7.11 (m, 5H), 5.23 (m, 1H), 3.39 (*s*, 2H), 2.63 (t, J = 7.5 Hz, 2H), 2.54 (t, J = 7.5 Hz, 2H), 1.96 (m, 1H), 1.92 (quint, J = 7.5 Hz, 2H), 1.79-1.68 (m, 2H), 1.53 (m, 1H), 1.38 (m, 1H), 1.25 (m, 1H), 1.04 (m, 1H), 1.0-0.88 (m, 2H), 0.90, 0.89, and 0.88 (3 x d, J = 6.5 Hz, 3 x 3H); MS *m/z* 344 (M^+), 240, 188, 138, 104; HRMS calcd for $C_{22}H_{32}O_3$ (M^+) 344.2353, found 344.2355.

Representative Procedure for Diazo Transfer Reactions. Preparation of (+)-Neomenthyl 2-Diazo-3-oxo-6-phenylhexanoate (1b). Methanesulfonyl azide (1.23 g, 10.2 mmol) was added to a stirred mixture

of the β-keto ester (3.2 g, 9.29 mmol) obtained above and triethylamine (1.6 g, 15.6 mmol) in dry CH_3CN (7 mL) at 0 °C. After 6 h of stirring at room temperature, the whole mixture was concentrated *in vacuo* and the residue was dissolved in EtOAc (40 mL). The resulting solution was washed successively with 10% aqueous NaOH (15 mL), H_2O (2 x 10 mL) and brine (10 mL), and then dried over anhydrous Na_2SO_4. Filtration and evaporation *in vacuo* furnished the crude product (3.32 g), which was purified by column chromatography (silica gel 60 g, 20:1 hexane/EtOAc) to give **1b** (3.18 g, 92%) as a yellow oil: $[\alpha]_D^{22}$ +14.5° (*c* 2.22, $CHCl_3$); IR (film) 2131, 1712, 1657, 1454, 1296 cm^{-1}; ^1H NMR δ 7.29 (d, J = 8.0 Hz, 2H), 7.18 (m, 3H), 5.36 (m, 1H), 2.88 (t, J = 7.5 Hz, 2H), 2.68 (t, J = 7.5 Hz, 2H), 2.00 (m, 1H), 1.99 (quint, J = 7.5 Hz, 2H), 1.80-1.75 (m, 2H), 1.54 (m, 1H), 1.39 (m, 1H), 1.20 (m, 1H), 1.08 (m, 1H), 1.05 (m, 1H), 0.92 (m, 1H), 0.91, 0.90, and 0.88 (3 x d, J = 6.6 Hz, 3 x 3H); MS *m/z* 370 (M^+), 238, 204, 186; HRMS calcd for $C_{22}H_{30}N_2O_3$ (M^+) 370.2258, found 370.2258.

Representative Procedure for Double Asymmetric Intramolecular C-H Insertion Reactions. Preparation of (+)-Neomenthyl 2-Oxo-5-phenylcyclopentanecarboxylate (2b) (Table 1, entry 6). Bis(ethyl acetate) adduct[5] of Rh_2(*S*-PTPA)$_4$ (38 mg, 0.024 mmol) was added in one portion to a stirred solution of **1b** (450 mg, 1.21 mmol) in CH_2Cl_2 (10 mL) at 0°C under an argon atmosphere. The mixture was stirred for 0.5 h at this temperature and the solvent was removed *in vacuo*. The greenish residue was purified by column chromatography (silica gel 20 g, 20:1 hexane/EtOAc) to provide **2b** (341 mg, 82%) as an inseparable mixture of diastereomers: mp 93-102 °C (soften at 61 °C); $[\alpha]_D^{22}$ +21.2° (*c* 3.00, THF); IR (nujol) 1751, 1718, 1379 cm^{-1}; ^1H NMR δ 10.86 (s, 1H for enol form of the minor isomer), 10.82 (s, 1H for enol form of the major isomer), 7.30 (d, J = 8.0 Hz, 2H), 7.18 (m, 3H), 5.20 (m, 1H), 3.76 (dt, J = 11.8, 5.9 Hz, 1H), 3.33 (d, J = 12.0 Hz, 1H for keto form of the major isomer), 3.32 (d, J = 11.6 Hz, 1H for keto form of the minor isomer), 2.61 (m, 1H), 2.53-2.40 (m, 2H), 2.08-1.88 (m, 2H), 1.81-1.59 (m, 3H), 1.54 (m, 1H), 1.23 (m, 1H),1.10 (m, 1H), 0.99 (m, 1H), 0.95-0.81 (m, 2H), 0.81, 0.76, and 0.69 (3 x d, J = 6.6 Hz, 3 x 3H); MS *m/z* 342 (M^+), 204, 186; HRMS calcd for $C_{22}H_{30}O_3$ (M^+) 342.2196, found 342.2195. A sample for combustion analysis was obtained by recrystallization from 80% aqueous MeOH as colorless needles: mp 96-102 °C; Anal. Calcd for $C_{22}H_{30}O_3$: C, 77.15; H, 8.83. Found: C, 77.02; H, 8.83. The percentage of the major isomer was not enriched by recrystallization.

Determination of Absolute Configuration and Diastereomeric Excess. Chemical Correlation of (+)-2b with 3(*S*)-phenylcyclopentanone ((*S*)-3) (Table 1, entry 6). In a 20-mL Pyrex tube (12-mm outside diameter) capped with a rubber septum was placed a solution of (+)-**2b** (300 mg, 0.87 mmol) in MeOH (8 mL). The reaction vessel was sealed under a positive pressure of argon and then immersed in a pre-heated oil bath (100 °C). The mixture was stirred at this temperature for 18 h and allowed to cool to room temperature. The solvent was removed by rotary evaporation and the residue was purified by column chromatography (silica gel 18 g, 5:1 hexane/EtOAc) to provide the corresponding methyl ester (180 mg, 95%) as a white solid: mp 66-68 °C; $[\alpha]_D^{23}$ -4.36° (*c* 3.11, THF); IR (nujol) 1750, 1710, 1370, 1350, 1280, 1120, 1110, 760, 740, 700 cm^{-1}; ^1H NMR δ 7.5-7.1 (m, 5H), 3.82 (dt, J = 12.0, 5.6 Hz, 1H), 3.72 (s, 3H), 3.37 (d, J = 12.0 Hz, 1H), 2.60 (m, 1H), 2.54-2.40 (m, 2H), 2.02 (m, 1H); MS *m/z* 219 (M^++1), 218 (M^+).

A solution of the methyl ester (176 mg, 0.8 mmol) in 90% aqueous DMSO (3.2 mL) was heated at 120 °C for 3 h. The mixture was cooled to room temperature and partitioned between ether (15 mL) and H_2O (10 mL). The organic layer was washed with brine (10 mL) and dried over anhydrous Na_2SO_4. The solvent was removed by rotary evaporation and the residue was purified by column chromatography (silica gel 10 g, 3:1 hexane/ether) to afford (*S*)-**3** (122 mg, 95%) as a colorless oil: $[\alpha]_D^{23}$ -74.6° (*c* 0.92, $CHCl_3$); IR (film) 1730, 1600, 1490, 1400, 1130, 700 cm^{-1}; ^1H NMR δ 7.5-7.2 (m, 5H), 3.44 (tt, J = 11.2, 7.2 Hz, 1H), 2.69 (dd, J = 18.4, 7.2 Hz, 1H), 2.61-2.40 (m, 2H), 2.33 (ddd, J = 18.4, 11.2, 1.4 Hz, 1H,), 2.29 (m, 1H), 2.01 (ddt, J = 12.4, 11.2, 8.4 Hz, 1H); MS *m/z* 160 (M^+). The optical purity was determined to be 80% by comparison of the rotation value with that of the authentic sample previously reported,[5] which was further confirmed by analysis of ^{13}C NMR spectrum of the diastereomeric ketals prepared from the ketone and (2*R*,3*R*)-2,3-butanediol [δ value at C-3: 43.48 (minor isomer) and 43.03 (major isomer)].

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References and Notes

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2. For reviews, see: (a) Doyle, M. P. *Chem. Rev.* **1986**, *86*, 919; *Acc. Chem. Res.* **1986**, *19*, 348. (b) Adams, J.; Spero, D. M. *Tetrahedron* **1991**, *47*, 1765. (c) Padwa, A.; Krumpe, K. E. *Tetrahedron* **1992**, *48*, 5385.
3. (a)Kennedy, M.; McKervey, M. A.; Maguire, A. R.; Roos, G. H. P. *J. Chem. Soc., Chem. Commun.* **1990**, 361. (b) Brunner, H.; Wutz, K.; Doyle, M. P. *Monatsh. Chem.* **1990**, *121*, 755. (c) Hashimoto, S.; Watanabe, N.; Ikegami, S. *Tetrahedron Lett.* **1990**, *31*, 5173.
4. (a) Doyle, M. P.; van Oeveren, A.; Westrum, L. J.; Protopopova, M. N.; Clayton, T. W. Jr. *J. Am. Chem. Soc.* **1991**, *113*, 8982. (b) McKervey, M. A.; Ye, T. *J. Chem. Soc., Chem. Commun.* **1992**, 823. (c) Doyle, M. P.; Protopopova, M. N.; Winchester, W. R.; Daniel, K. L. *Tetrahedron Lett.* **1992**, *33*, 7819.
5. Hashimoto, S.; Watanabe, N.; Sato, T.; Shiro, M.: Ikegami, S. *Tetrahedron Lett.* **1993**, *34*, 5109.
6. Masamune, S.; Choy, W.; Petersen, J. S.; Sita, L. R. *Angew. Chem. Int. Ed. Engl.* **1985**, *24*, 1.
7. For a diastereoselective intramolecular C-H insertion of chiral α-diazo β-keto esters, see: (a) Taber, D. F.; Raman, K. *J. Am. Chem. Soc.* **1983**, *105*, 5935. (b) Taber, D. F.; Raman, K.; Gaul, M. D. *J. Org. Chem.* **1987**, *52*, 28.
8. There have been recorded many examples of chiral Cu(I)- and Rh(II)-catalyzed cyclopropanation of olefins with chiral diazoacetates in which the chirality of the catalyst is the dominating factor for the stereochemical course of this process. Compared to the use of the chiral Cu(I) catalysts, the catalyses with chiral Rh(II) complexes frequently exhibit significant levels of double stereodifferentiation. (a) For double asymmetric cyclopropanation with chiral Cu(I) catalysts, see: (i) Aratani, T. *Pure Appl. Chem.* **1985**, *57*, 1839. (ii) Fritschi, H.; Leutenegger, U.; Pfaltz, A. *Helv. Chim. Acta.* **1988**, *71*, 1553. (iii) Lowenthal, R. E.; Abiko, A.; Masamune, S. *Tetrahedron Lett.* **1990**, *31*, 6005. (iv) Dauben, W. G.; Hendricks, R. T.; Luzzio, M. J.; Ng, H. P. *Tetrahedron Lett.* **1990**, *31*, 6969. (b) For double asymmetric

cyclopropanation with chiral Rh(II) catalysts, see: (i) Doyle, M. P.; Brandes, B. D.; Kazala, A. P.; Pieters, R. J.; Jarstfer, M. B.; Watkins, L. M.; Eagle, C. T. *Tetrahedron Lett.* **1990**, *31*, 6613. (ii) Protopopova, M. N.; Doyle, M. P.; Müller, P.; Ene, D. *J. Am. Chem. Soc.* **1992**, *114*, 2755. (iii) Doyle, M. P.; Protopopova, M. N.; Brandes, B. D.; Davies, H. M. L.: Huby, N. J. S.; Whitesell, J. K. *Synlett* **1993**, 151. (iv) Davies, H. M. L.; Huby, N. J. S.; Cantrell, W. R. Jr.: Olive, J. L. *J. Am. Chem. Soc.* **1993**, *115*, 9468.

9. For the substituent effects at the insertion site on enantioselectivities in intramolecular C-H insertion reactions, see: Hashimoto, S.; Watanabe, N.; Ikegami, S. *Synlett* **1994**, in press.
10. Quinkert, G.; Schmalz, H.-G.; Dzierzynski, E. M.; Dürner, G.; Bats, J. W. *Angew. Chem. Int. Ed. Engl.* **1986**, *25*, 992.
11. Djerassi, C.; Hart, P. A.; Warawa, E. J. *J. Am. Chem. Soc.* **1964**, *86*, 78.
12. Darby, N.; Lamb, N.; Money, T. *Can. J. Chem.* **1979**, *57*, 742.
13. Danheiser, R. L.; Miller, R. F.; Brisbois, R. G.; Park, S. Z. *J. Org. Chem.* **1990**, *55*, 1959.

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