

Highly Enantioselective Cyclopropanation of Styrenes with Diazoacetates Catalyzed by Optically Active β -Ketoiminato Cobalt(II) Complexes

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(Received September 27, 1999; CL-990828)

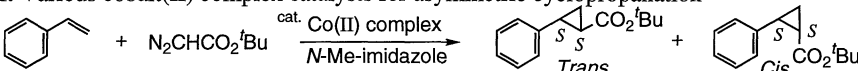
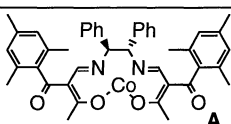
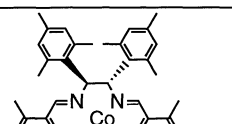
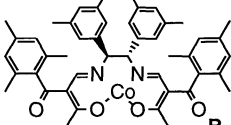
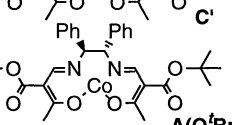
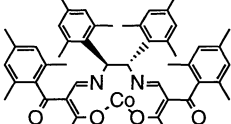
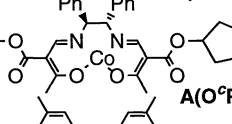
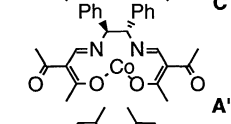
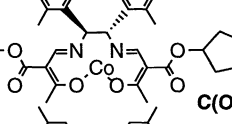
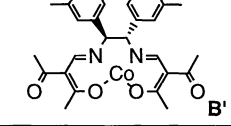
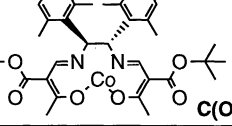
The highly enantioselective cyclopropanation of styrenes with diazoacetates was achieved using reasonably designed β -ketoiminato cobalt(II) complex catalysts. In the presence of optically active cobalt(II) complexes derived from optically active 1,2-(2,4,6-trimethylphenyl)-1,2-ethylenediamine, the cyclopropanation of styrene with methyl, ethyl, and *tert*-butyl diazoacetates proceeded to afford the corresponding cyclopropanecarboxylates with 94-96% ee.

Optically active β -ketoiminato ligands derived from various 1,3-dicarbonyl compounds and 1,2-diaryl-1,2-ethylenediamines are complexed with many varieties of metals to afford optically active β -ketoiminato complexes. It had already been reported that the optically active β -ketoiminato manganese(III) complexes catalyzed the enantioselective aerobic oxidation, and the prototype of these manganese(III) complexes was defined by X-ray structure analysis.¹ Based on their structural information, efficient ligands were rationally designed to achieve high enantioselectivity during aerobic oxidation² and the cobalt(II) complex catalyst was developed for

the enantioselective borohydride reduction.³ In a previous paper,⁴ we reported that the optically active β -ketoiminato cobalt(II) complex **A** also catalyzed the enantioselective cyclopropanation of *tert*-butyl diazoacetate with styrene and that the presence of *N*-methylimidazole remarkably accelerated the reaction and improved both the optical and chemical yields of the product. In order to complete the enantioselectivities and diastereoselectivities (*trans/cis*) of the present cyclopropanation catalyzed by the cobalt(II) complex, a rational design of the optically active β -ketoiminato ligands of the cobalt(II) complexes should be required. In this communication, we report that the highly enantioselective cyclopropanations of various diazoacetates with styrene derivatives were achieved by using the cobalt(II) complex catalysts derived from optically active 1,2-(2,4,6-trimethylphenyl)-1,2-ethylenediamine and that the corresponding cyclopropanecarboxylates were obtained with 94-96% ee.

The optically active β -ketoiminato cobalt(II) complexes **A**,⁵ **B**, and **C** were prepared from the optically active 1,2-diphenyl-1,2-ethylenediamine, 1,2-(3,5-dimethylphenyl)-1,2-

Table 1. Various cobalt(II) complex catalysts for asymmetric cyclopropanation

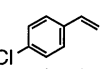
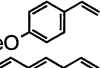
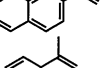
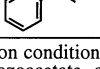
							
Entry ^a	Catalyst	Trans : Cis ^b	Optical yield / %ee ^c (Yield / %) ^d	Entry ^a	Catalyst	Trans : Cis ^b	Optical yield / %ee ^c (Yield / %) ^d
1 ^e		76:24	84 (94)	6		83:17	96 (80)
2		75:25	85 (quant.)	7		83:17	63 (94)
3		68:32	90 (89)	8		81:19	66 (quant.)
4		76:24	70 (quant.)	9		90:10	96 (97)
5		78:22	61 (quant.)	10		91:9	96 (99)

^aReaction conditions: 5 mol% of catalyst, 5.0 mmol of styrene, 1.0 mmol of *tert*-butyl diazoacetate and 10 mol% (2.0 equiv. vs. Co(II) complex) of additive in THF at 25-40 °C under N₂ atmosphere for 2-10 h. ^bDetermined by GC. ^cOptical yields of *trans*-products were determined by HPLC analysis after reduction of the isolated products into the corresponding alcohols (*Trans*: Daicel Chiralcel OD-H and/or OB-H, hexane / 2-propanol). Absolute configuration of the *trans* isomer: (+)-(1*S*,2*S*) corresponding to (*S*)-complex. ^dIsolated yield based on *tert*-butyl diazoacetate. ^eReported in ref. 4.

ethylenediamine, and 1,2-(2,4,6-trimethylphenyl)-1,2-ethylenediamine, respectively.⁶ They were first examined in the cyclopropanation of styrene with *tert*-butyl diazoacetate (Entries 1-3 in Table 1). The cobalt(II) complexes **A** and **B** catalyzed the reaction to afford the resulting cyclopropanecarboxylates with 84-85% ee and 75-76% *trans*-selectivity, whereas complex **C** improved the optical yield of the product to 90% ee but decreased the *trans*-selectivity (68:32). The cobalt(II) complexes **A'**, **B'**, and **C'** with a smaller side chain³(acetyl in **A'** series vs. mesityl in **A** series) were then subjected to the cyclopropanation (Entries 4-6). When the complex catalyst **A'** or **B'** was used, the optical yield of the product was lower than that using complex catalyst **A** or **B**. On the contrary, in the reaction catalyzed by complex **C'**,⁷ the optical yield of the product was remarkably improved to 96% ee and the *trans*-selectivity was also enhanced to 83%. These observations suggested that the sterically required diamine would be effective for improving the enantioselection and that the side chain of the complexes could contribute to the *trans*-selection in the present cyclopropanation. Various cobalt(II) complexes with ester moieties on the side chains were then synthesized and tested. When complexes **A(OⁱBu)** and **A(OⁱPent)**² with *tert*-butyl and cyclopentyl esters were used as catalysts, the *trans*-selectivities of the product were enhanced compared to that by complex catalyst **A** (Entries 7 and 8). Finally, the cobalt(II) complexes having ester side chains and an optically active 1,2-(2,4,6-trimethylphenyl)-1,2-ethylenediamine unit, **C(OⁱPent)** and **C(OⁱBu)**, were designed and synthesized.⁸ In the presence of these complexes, the cyclopropanation was smoothly completed and the products were obtained in 96% ee with 90% *trans*-selectivity (**C(OⁱPent)**, Entry 9) and in 96% ee with 91% *trans*-selectivity (**C(OⁱBu)**, Entry 10), respectively.

The cobalt(II) complex catalysts, **C(OⁱPent)** and **C(OⁱBu)**,

Table 2. Various olefins and diazoacetates (N₂CHCO₂R) in asymmetric cyclopropanation

Entry ^a	Olefin	R	Catalyst	T: C ^b	Optical yield/ ^c %ee ^d (Yield / %)
1		-CH ₃	C(OⁱBu)	85:15	94 ^e (83)
2		-C ₂ H ₅	C(OⁱBu)	84:16	95 ^e (87)
3		- ⁱ C ₄ H ₉	C(OⁱBu)	91: 9	96 ^e (99)
4			C(OⁱPent)	86:14	94 ^e (94)
5		- ⁱ C ₄ H ₉	C(OⁱPent)	90:10	96 ^f (93)
6			C(OⁱPent)	82:18	92 ^f (85)
7			C(OⁱPent)	87:13	96 ^f (95)
8			C(OⁱPent)	47:53	99 ^f (47)

^aReaction conditions: 5 mol% of catalyst, 5.0 mmol of olefin, 1.0 mmol of diazoacetate and 10 mol%(2.0 equiv. vs. Co(II) complex) of *N*-methylimidazole in THF at 40-50 °C under N₂ atmosphere for 9-27 h. ^b*Trans* : *Cis* ratio was determined by GC. ^cOptical yields of *trans*-products were determined by HPLC analysis after reduction of the isolated products into the corresponding alcohols (*Trans*: Daicel Chiralcel OD-H and/or OB-H, hexane / 2-propanol). ^dIsolated yield based on diazoacetate. ^eAbsolute configuration of the *trans* isomer was (+)-(1*S*,2*S*) corresponding to (*S*)-complex. ^fAbsolute configurations of the *trans* isomers were not determined.

were successfully used for the enantioselective cyclopropanation of various diazoacetates and styrene derivatives. In the presence of 5 mol% of cobalt(II) complex **C(OⁱBu)**, methyl, ethyl, cyclohexyl, and *tert*-butyl diazoacetates (Entries 1-4 in Table 2) were reacted with styrene to afford the corresponding cyclopropanecarboxylates in high yield with high diastereoselectivity (82-91%) and very high enantioselectivity (92-96% ee). It was reported that the high enantiomeric and diastereomeric excesses of the products were generally achieved by using diazoacetates with bulky alkyl groups, such as menthyl,⁹ dicyclohexylmethyl,¹⁰ or 2,6-di-*tert*-butyl-4-methylphenyl¹¹ groups, and only a few complex catalysts that realize highly enantioselective cyclopropanation of methyl or ethyl diazoacetate were found in literature.¹² In the present cyclopropanation catalyzed by the optically active β-ketoiminato cobalt(II) complexes, the steric size of the alkyl groups in the diazoacetates had little influence on the enantioselection and even the methyl diazoacetate with styrene gave a product with 94% ee. Various styrene derivatives, *p*-chlorostyrene, *p*-methoxystyrene, and 2-vinylnaphthalene, were also converted to the corresponding cyclopropanecarboxylates in high yields with 92-96% ee (Entries 5-7) and α-methylstyrene was also transformed into the corresponding cyclopropane in 47% yield with 99% ee (for *trans* product, Entry 8).

In conclusion, reasonably designed cobalt(II) complexes prepared from 1,2-(2,4,6-trimethylphenyl)-1,2-ethylenediamine and β-ketocarboxylates produced high enantioselective and *trans*-selective cyclopropanations of various diazoacetates and styrene derivatives. Further investigations into the reaction mechanism and stereoselectivities are now in progress.

References and Notes

- 1 T. Nagata, K. Imagawa, and T. Yamada, *Inorg. Chim. Acta*, **220**, 1259 (1994).
- 2 T. Nagata, K. Imagawa, T. Yamada, and T. Mukaiyama, *Bull. Chem. Soc. Jpn.*, **68**, 1455 (1995).
- 3 T. Nagata, K. Yoroze, T. Yamada, and T. Mukaiyama, *Angew. Chem., Int. Ed. Engl.*, **34**, 2145 (1995).
- 4 T. Yamada, T. Ikeno, H. Sekino, and M. Sato, *Chem. Lett.*, **1999**, 719. References are cited therein.
- 5 T. Yamada, T. Nagata, T. Ikeno, Y. Ohtsuka, A. Sagara, and T. Mukaiyama, *Inorg. Chim. Acta*, in print.
- 6 These cobalt(II) complexes proved to be efficient catalysts for the enantioselective borohydride reduction of aryl ketones, *N*-phosphinyl imines, and α,β-unsaturated carboxamides; (ketones) T. Nagata, K. D. Sugi, T. Yamada, and T. Mukaiyama, *Synlett*, **1996**, 1076; (imines) K. D. Sugi, T. Nagata, T. Yamada, and T. Mukaiyama, *Chem. Lett.*, **1997**, 493; (α,β-unsaturated carboxamides) T. Yamada, Y. Ohtsuka, and T. Ikeno, *Chem. Lett.*, **1998**, 1129.
- 7 The structure of cobalt(II) complex **C'** was determined by X-ray analysis. Unpublished result.
- 8 Novel optically active ligands for **C(OⁱPent)** and **C(OⁱBu)** were prepared according to reference 2, and complexation with cobalt(II) were according to reference 5.
- 9 T. Aratani, Y. Yoneyoshi, and T. Nagase, *Tetrahedron Lett.*, **1977**, 2599; H. Fritsch, U. Leutenegger, and A. Pfaltz, *Helv. Chim. Acta*, **71**, 1553 (1988).
- 10 R. E. Lowenthal and S. Masamune, *Tetrahedron Lett.*, **32**, 7373 (1991).
- 11 M. P. Doyle, V. Bagheri, T. J. Wandless, N. K. Harn, D. A. Brinker, C. T. Eagle, and K.-L. Loh, *J. Am. Chem. Soc.*, **112**, 1906 (1990); M. M.-C. Lo and G. C. Fu, *J. Am. Chem. Soc.*, **120**, 10270 (1998). References are cited therein.
- 12 M. P. Doyle, M. A. McKervy, and T. Ye, "Modern Catalytic Method for Organic Synthesis with Diazo Compounds," John Wiley & Sons, New York (1998).