Stereoselective α-Hydrazination of α,β-Unsaturated Carboxylates Catalyzed by Manganese(III) Complex with Dialkylazodicarboxylate and Phenylsilane

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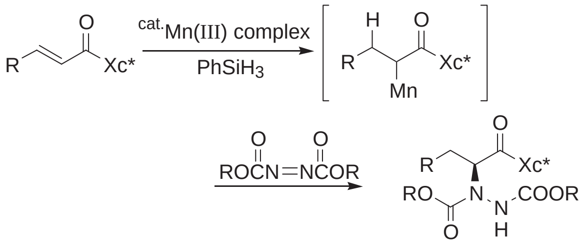
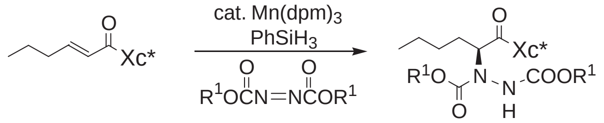
In the presence of a catalytic amount of bis(dipivaloylmethanato)manganese(III) complex, the α,β-unsaturated carboxylates with camphorsultam as a chiral auxiliary reacted with phenylsilane and dialkyl azodicarboxylates to afford the corresponding α-hydrazinated carboxylates with high stereoselectivities.

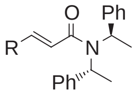
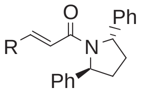
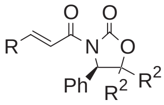
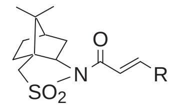
Various oxidation processes for the introduction of oxygen functionalities on carbon–carbon double bonds[1] have been successfully provided including their enantioselective versions,[2] whereas there has been few reports on the corresponding amination reactions for practical use. It was reported from this laboratory that in the presence of a catalytic amount of the bis(diketonato)cobalt(II) or bis(diketonato)manganese(II) complex, reducing agents reacted with carbon–carbon double bonds to generate carbanion equivalents, which accepted various electrophiles. Molecular oxygen was then trapped by the carbanion equivalents generated from unfunctionalized olefins or α,β-unsaturated carboxylates to afford the hydrated product[3] or silylperoxide[4] with a secondary alcohol or silane[5] catalyzed by the diketonatocobalt(II) or manganese(III) complexes. Nitric oxide[6] and butyl nitrite[7] were also reactive as electrophiles to afford the α-nitrosocarboxylates and/or α-hydroxyiminocarboxylates from α,β-unsaturated carboxylates and nitrosoalkanes[8] from simple alkenes. It was reported that dialkyl azodicarboxylates[9] reacted as electrophiles with the carbanion equivalents generated from olefinic compounds and phenylsilane in the presence of bis(diketonato)cobalt(II)[10] and tris(diketonato)manganese(III)[11] complexes, though the stereoselection[12] in these reactions remained to be developed. Recently, stereoselections of the aerobic hydration reaction were examined and it was determined that the α,β-unsaturated carboxamide containing a C_2-symmetrical chiral auxiliary afforded the corresponding α-hydroxycarboxamide in high stereoselectivity.[13] In this communication, we report that the highly stereoselective α-hydrazination of α,β-unsaturated carboxylates with a chiral auxiliary occurred in the presence of the tris(diketonato)manganese(III) complex catalyst and phenylsilane.



Scheme 1. Stereoselective α-hydrazination of α,β-unsaturated carboxylates.

Table 1. Various chiral auxiliaries for the stereoselective hydrazination of the *trans*-2-hexenoates[a]



Entry	Substrate	R^1 (Azodicarboxylate)	Yield / %[b]	dr[c]
1		*t*-Bu	Complex mixture	
2			78	89 : 11
3		R^2 = H	75	68 : 32
4		R^2 = Ph	51	65 : 35
5		Et	Complex mixture	
6		*i*-Pr	47	90 : 10
7		*t*-Bu	81	96 : 4

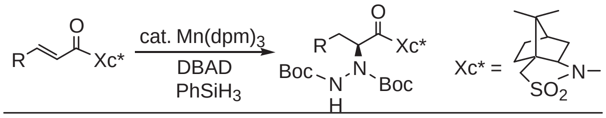
[a]Reaction conditions: 5 mol % of tris(dipivaloylmethanato)manganese(III) complex ($Mn(dpm)_3$), 0.1 mmol of α,β-unsaturated carboxylate, 0.2 mmol of dialkylazodicarboxylate and 0.2 mmol of phenylsilane in 2-propanol at 0 °C under N_2 atmosphere for 1–1.5 h. [b]Isolated yield. [c]Diastereomer ratio was determined by HPLC analysis.

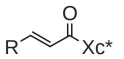
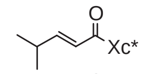
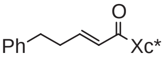
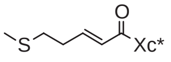
It was reported that cobalt(II), manganese(II), manganese(III), or iron(III) complexes efficiently catalyzed the oxidation with molecular oxygen or the amination with alkyl nitrite or nitric oxide in the presence of silanes. The preliminary screening of various metal complexes[14] revealed that tris(dipivaloylmethanato)manganese(III) complex ($Mn(dpm)_3$) was the most effective catalyst for the present hydrazination with a dialkyl azodicarboxylate and phenylsilane. Then, in the presence of 5 mol % of $Mn(dpm)_3$, *trans*-2-hexenoates with various chiral auxiliaries were treated with phenylsilane and several azodicarboxylates (Table 1).[15] The C_2-symmetrical dibenzylamines, effective for the diastereoselective hydration previously reported, were employed as a chiral auxiliary. Although the reaction of the carboxamide with (*R*,*R′*)-bis(1-phenylethyl)amine resulted in complex mixtures (Entry 1), the carboxamide with (2*S*,5*S*)-2,5-diphenylpyrrolidine was treated with phenylsilane and bis(*tert*-butyl)azodicarboxylate to afford the corresponding α-hydrazinecarboxylate in 78% yield with 89:11 diastereoselectivity (Entry 2). The amides are generally resistant to hydrolysis, whereas the optically active oxazolidinones are one of the most reliable chiral auxiliaries for various diastereoselective transformations and can be removed under the milder conditions after the desired stereoselective reactions.[16] For the present hydrazination, the (*S*)-4-phenyl- and (*S*)-4,5,5-triphenyl-2-oxazolidinones,[17] were used to obtain the corresponding α-hydrazinecarboxylates in good yields but with low diastereoselectivities (Entries 3 and 4). The camphorsultam derivatives[18] were smoothly converted to the corresponding α-hydrazinecarboxamides. Though diethyl azodicarboxylate did not afford the corresponding α-hydrazinated product, the diisopropyl azodicarboxylate produced the corresponding α-hydrazinecarboxamide in 47% yield with a 90:10 diastereoselectivity. The chemical yield and the diastereoselectivity were improved to 81% and 96:4 when di-*tert*-butylazodicarboxylate (DBAD) was used as the electrophile.[19,20]

Various alkenoates containing camphorsultam as a chiral auxiliary were successfully applied to the stereoselective α-hydrazination reaction with di-*tert*-butyl azodicarboxylate and phenylsilane in the presence of $Mn(dpm)_3$ (Table 2). Acrylate and crotonate with camphorsultam were subjected to the reaction to obtain the corresponding α-hydrazinecarboxamides in 56 and 84% yields and with 91:9 and 98:2 diastereoselectivities, respectively (Entries 1 and 2). The α,β-unsaturated carboxyamides with a longer straight-chain, such as 2-hexenoate and 2-decenoate, were smoothly converted to the corresponding α-hydrazinecarboxamides in high yields with 96:4 diastereoselectivities (Entries 3 and 4). The γ-branched alkenoate, 4-methyl-2-pentenoate, was hydrazinated to the corresponding 2-hydrazinecarboxylate with a 99:1 selectivity (Entry 5). During the reaction of 5-phenyl-2-pentenoate and 5-methylthio-2-pentenoate, the benzylic carbon and the sulfur atom were unreactive and the corresponding α-hydrazinecarboxamides were smoothly obtained in high yields with high stereoselectivities (Entries 6 and 7).

It is noted that in the presence of a catalytic amount of the tris(dipivaloylmethanato)manganese(III) complex, the α,β-unsaturated carboxylate containing camphorsultam as the chiral auxiliary smoothly reacted with di-*tert*-butyl azodicarboxylate and phenylsilane to afford the corresponding α-hydrazinecarboxylate in high yield with a high stereoselectivity. Further investigation into the corresponding enantioselective catalytic version is currently underway.

Table 2. Various α,β-unsaturated carboxylates for stereoselective α-hydrazination[a]

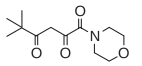


Entry	Substrate		Time / h	Yield / %[b]	dr[c]
1		R = H	1	56	91 : 9
2		R = CH_3	1	84	98 : 2
3		R = C_3H_7	1.5	81	96 : 4
4		R = C_7H_{15}	1.5	80	96 : 4
5			1.5	78	99 : 1
6			1.5	68	97 : 3
7			1	72	96 : 4

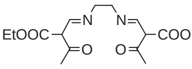
[a]Reaction conditions: 5 mol % of tris(dipivaloylmethanato)-manganese(III) complex ($Mn(dpm)_3$), 0.1 mmol of α,β-unsaturated carboxylate, 0.2 mmol of DBAD and 0.2 mmol of phenylsilane in 2-propanol at 0 °C under N_2 atmosphere. [b]Isolated yield. [c]Diastereomer ratio was determined by HPLC analysis.

References and Notes

1 "Comprehensive Organic Synthesis," ed. by B. M. Trost and I. Fleming, Pergamon Press, Oxford (1991), Vol. 7, Chap. 3.
2 a) I. Ojima, in "Catalytic Asymmetric Synthesis," 2nd ed., Wiley-VHC, New York (2000), Chap. 6, p 229. b) "Comprehensive Asymmetric Catalysis," ed. by E. N. Jacobsen, A. Pfaltz, and H. Yamamoto, Springer, Berlin (1999). c) R. Noyori, in "Asymmetric Catalysis in Organic Synthesis," John Wiley & Sons, New York (1994). d) H. C. Kolb, M. S. VanNieuwenhze, and K. B. Sharpless, *Chem. Rev.*, **94**, 2483 (1994). e) T. Katsuki, *Coord. Chem. Rev.*, **140**, 189 (1995).
3 a) K. Kato, T. Yamada, T. Takai, S. Inoki, and S. Isayama, *Bull. Chem. Soc. Jpn.*, **63**, 179 (1990). b) S. Isayama and T. Mukaiyama, *Chem. Lett.*, **1989**, 1071. c) S. Inoki, K. Kako, S. Isayama, and T. Mukaiyama, *Chem. Lett.*, **1990**, 1869.
4 S. Isayama and T. Mukaiyama, *Chem. Lett.*, **1989**, 573.
5 S. Isayama, *Bull. Chem. Soc. Jpn.*, **63**, 1305 (1990).
6 K. Kato and T. Mukaiyama, *Chem. Lett.*, **1990**, 1395.
7 a) K. Kato and T. Mukaiyama, *Chem. Lett.*, **1990**, 1917. b) K. Kato and T. Mukaiyama, *Bull. Chem. Soc. Jpn.*, **64**, 2948 (1991).
8 K. Kato and T. Mukaiyama, *Chem. Lett.*, **1992**, 1137.
9 a) R. Huisgen and F. Jakob, *Justus Liebigs Ann. Chem.*, **1954**, 590. b) O. Diels and H. Behncke, *Chem. Ber.*, **57**, 653 (1924).
10 J. Waser and E. M. Carreira, *J. Am. Chem. Soc.*, **126**, 5676 (2004).
11 J. Waser and E. M. Carreira, *Angew. Chem., Int. Ed.*, **43**, 4099 (2004).
12 T. Mukaiyama, K. Yorozu, K. Kato, and T. Yamada, *Chem. Lett.*, **1992**, 181.
13 M. Sato, Y. Gunji, T. Ikeno, and T. Yamada, *Chem. Lett.*, **33**, 1304 (2004).
14 The catalytic activities of the metal complexes were examined by adopting the reaction of the 2-hexenoic acid derivative with (*S*)-4,5,5-triphenyl-2-oxazolidinone as the chiral auxiliary. The reduced products from azodicarboxylate and/or a trace amount of α-hydrazinecarboxylate were detected in the reaction catalyzed by $Co(acac)_2$, $Co(tfa)_2$, $Co(modp)_2$, Co(eobe), $Mn(acac)_2$, $Mn(tfa)_2$, $Mn(hfa)_2$. K. Kato, T. Yamada, T. Takai, S. Inoki, and S. Isayama, *Bull. Chem. Soc. Jpn.*, **63**, 179 (1990); K. Kato and T. Mukaiyama, *Chem. Lett.*, **1990**, 1395.



Hmodp



H_2eobe

15 Typical procedure: To a solution of $Mn(dpm)_3$ (3.0 mg, 0.005 mmol) in 2-propanol (0.5 mL) was added the α,β-unsaturated carboxamide (Table 1, Entry 7) (31.1 mg, 0.1 mmol) in CH_2Cl_2 (0.3 mL) at 0 °C under a N_2 atmosphere, and then di-*tert*-butyl azodicarboxylate (46.0 mg, 0.2 mmol) in 2-propanol (0.5 mL) and $PhSiH_3$ (24.4 µL, 0.2 mmol) were added to the solution. After stirring for 1.5 h at 0 °C, the reaction was quenched with saturated aqueous $Na_2S_2O_3$. The organic materials were extracted with ethyl acetate, washed with brine, and dried over Na_2SO_4. The crude product was purified by flash chromatography on silica gel to obtain the corresponding α-hydrazinecarboxylate (43.8 mg, 81% yield, 96% stereoselectivity). The diastereomer ratio was determined by an HPLC analysis.
16 D. J. Ager, I. Prakash, and D. R. Schaad, *Chem. Rev.*, **96**, 835 (1996).
17 S. D. Bull, S. G. Davis, S. Jones, and H. J. Sanganee, *J. Chem. Soc., Perkin Trans. 1*, **1999**, 387.
18 W. Oppolzer, C. Chapuis, and G. Bernardinelli, *Helv. Chim. Acta*, **67**, 1397 (1984).
19 For the reactions of the dimethyl, diethyl-, and dibenzyl azodicarboxylates, complex mixtures were obtained and the reduced products from the azodicarboxylates were detected.
20 Because of their steric demands of electrophiles, camphorsultam was employed as effective chiral auxiliary for azodicarboxylate in α-hydrazination while 2,5-diarylpyrrolidine for molecular oxygen in α-hydroxylation.[13]

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