Organic LETTERS

Letter

pubs.acs.org/OrgLett

Enantioselective Oxidative Ring-Opening Reaction of Aziridines with α-Nitroesters Using Cinchona Alkaloid Amide/Nickel(II) Catalysts

Noriyuki Shiomi,[†,‡] Keisuke Yamamoto,[†] Kazuma Nagasaki,[†] Tsubasa Hatanaka,[§] Yasuhiro Funahashi,[§] and Shuichi Nakamura*[,†,‡]

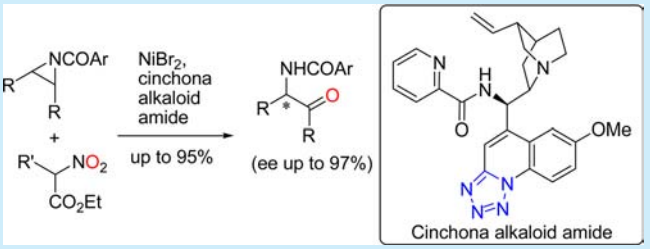
[†]Department of Life Science and Applied Chemistry, Graduate School of Engineering, Nagoya Institute of Technology, Gokiso, Showa-ku, Nagoya 466-8555, Japan

[‡]Frontier Research Institute for Material Science, Nagoya Institute of Technology, Gokiso, Showa-ku, Nagoya 466-8555, Japan

[§]Department of Chemistry, Graduate School of Science, Osaka University 1-1 Machikaneyama, Toyonaka, Osaka 560-0043, Japan

Supporting Information

ABSTRACT: The enantioselective oxidative ring-opening reaction of aziridines with α-nitroacetates has been developed. Good yields and enantioselectivity were observed for the reaction of various aziridines using a novel cinchona alkaloid amide/$NiBr_2$ catalyst. Both enantiomers of products could be obtained by using pseudoenantiomeric chiral catalysts. This process offers an efficient route for the synthesis of α-aminoketones.



An optically active α-aminocarbonyl structure is an essential structural motif in many biologically active molecules and pharmaceuticals,[1] such as cathinone,[2] pyrovalerone,[3] ketamine,[4] ifenprodil,[5] and keto-ACE,[6] as well as in useful chiral ligand backbones (Figure 1).[7]

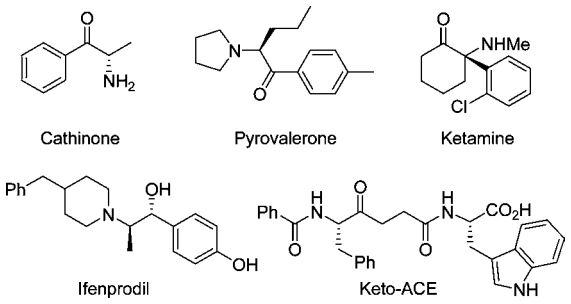
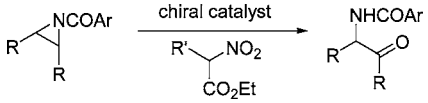


Figure 1. Biologically active compounds for chiral α-aminocarbonyl compounds.

The synthetic importance of these compounds has prompted considerable interest in developing asymmetric syntheses for α-aminocarbonyl compounds. Therefore, excellent methodologies have been developed in asymmetric syntheses of α-aminocarbonyl compounds, such as hydrogenation of α-ketoketimines,[8] cross coupling of aldehydes with imines,[9] amination of enols,[10] and other methods.[11] On the other hand, one of the most efficient methods for the synthesis of optically active α-aminocarbonyl compounds could be the oxidative desymmetrization of aziridines. Although there are many reports for the desymmetrization of aziridine using various nucleophiles and chiral catalysts to synthesize optically active amines,[12] there are no reports on the enantioselective oxidative ring-opening reaction of aziridines.[13] We recently reported the first catalytic desymmetrization of aziridines with phosphites using our original chiral catalysts derived from cinchona alkaloid.[14,15] Herein, we report the first catalytic enantioselective oxidative ring-opening reaction of aziridines with α-nitroesters as a nucleophilic oxidant using our original chiral catalysts (Scheme 1).

Scheme 1. Catalytic Desymmetrization of Aziridines with α-Nitroesters Using Chiral Catalysts Derived from Cinchona Alkaloids



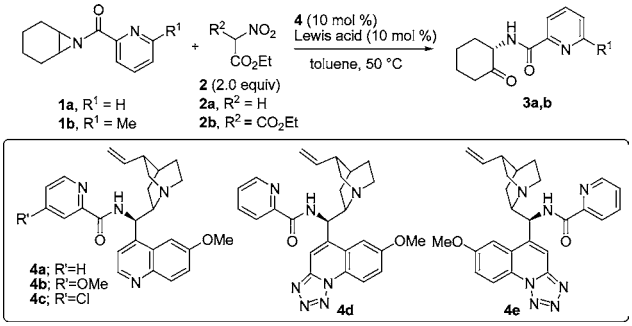
The enantioselective reaction of aziridine **1a** with ethyl α-nitroacetate **2a** (2.0 equiv) was carried out in the presence of 10 mol % of picolinamide catalysts **4** derived from quinidine or quinine (Table 1).

The reaction of **1a** with **2a** using only *N*-picolinoyl-9-amino-9-deoxy-*epi*-quinidine **4a** as organocatalyst did not give any products (Table 1, entry 1). The combined catalyst between **4a** and metal species, especially $Ni(OTf)_2$, gave product **3a** in moderate yield but with low enantioselectivity (Table 1, entries 2−4). Optimization experiments by employing nickel salt were examined to improve the yield and stereoselectivity of the reaction, and as a result, $NiBr_2$ was found to be the most suitable Lewis acid (Table 1, entry 5). Next, we investigated the effect of

Received: November 8, 2016
Published: December 15, 2016

DOI: 10.1021/acs.orglett.6b03346
Org. Lett. 2017, 19, 74−77

Table 1. Enantioselective Oxidative Ring-Opening Reaction of Aziridines 1 with α-Nitroesters 2 Using Various Metal Species and Picolinamide 4[a]



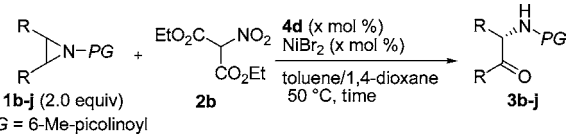
entry	Lewis acid	R^1	2	4	time (h)	yield (%)	ee[b] (%)
1		H	**2a**	**4a**	24	0	
2	$Zn(OTf)_2$	H	**2a**	**4a**	24	17	0
3	$Cu(OTf)_2$	H	**2a**	**4a**	24	29	12
4	$Ni(OTf)_2$	H	**2a**	**4a**	8	53	17
5	$NiBr_2$	H	**2a**	**4a**	24	58	60
6	$NiBr_2$	H	**2b**	**4a**	2	79	63
7	$NiBr_2$	Me	**2b**	**4a**	4	83	81
8	$NiBr_2$	Me	**2b**	**4b**	4	84	87
9	$NiBr_2$	Me	**2b**	**4c**	4	88	70
10	$NiBr_2$	Me	**2b**	**4d**	4	82	90
11[c]	$NiBr_2$	Me	**2b**	**4d**	4	85	92
12[c,d]	$NiBr_2$	Me	**2b**	**4d**	4	95	97
13[c,d]	$NiBr_2$	Me	**2b**	**4e**	4	93	85[e]

[a]Reaction conditions: aziridine **1** (0.1 mmol), **2** (0.2 mmol), metal species (10 mol %), and **4** (10 mol %) in toluene (0.1 M) were used. [b]The ee was determined by HPLC analysis using a chiral column. [c]Aziridines **1** (0.2 mmol) and **2** (0.1 mmol) were used. [d]Toluene/1,4-dioxane (0.1 M, v/v = 9/1) was used. [e]The opposite enantiomer was obtained.

the substituent on the nucleophile and protecting group of aziridine **1**. We found that the reaction using α-nitromalonate **2b**, which has a highly acidic proton compared with α-nitroacetate **2a**, improved the reactivity of the reaction, and the enantioselectivity increased slightly (Table 1, entry 6). The reaction of aziridine **1b** having a 6-methylpicolinoyl group afforded product **3b** with good enantioselectivity (Table 1, entry 7). Furthermore, we examined various ligands to improve the enantioselectivity of the product. The reaction using **4b** having an electron-donating group at the 4-position on the picolinamide group slightly improved enantioselectivity (Table 1, entry 8), but the electron-withdrawing group diminished enantioselectivity, probably due to the coordination ability of picolinamide group to Lewis acid catalysts (Table 1, entry 9). On the other hand, we expected that undesired coordination of the quinoline group to the Lewis acid would interfere in the highly enantioselective reaction pathway, so we introduced a tetrazolo[1,5-*a*]quinoline group to chiral catalysts. The reaction using **4d** having a tetrazole group afforded α-aminoketone **3b** with higher enantioselectivity than that using catalysts **4a**–**c** (90% ee, Table 1, entry 10). After optimization of the reaction conditions such as the ratio of the reagent and solvent, the enantioselectivity improved to 97% ee (Table 1, entries 11 and 12). An opposite enantiomer of **3b** could be obtained by the reaction using **4e** derived from 9-amino-9-deoxy-*epi*-quinine in high yield with good enantioselectivity (93%, 85% ee) (Table 1, entry 13).

Next, we examined the reaction of **2b** with various aziridines **1b**–**j** in the presence of **4d** and $NiBr_2$ (Table 2).

Table 2. Enantioselective Oxidative Ring-Opening Reaction of Aziridines 1b–j with α-Nitromalonate 2b[a]



entry	aziridine, **1**	x	time (h)	yield (%)	ee[b] (%)
1	**1b**	10	4	95	97
2	**1c**	10	12	78	83
3	**1d**	10	12	81	70
4	**1e**	10	12	71	84
5	**1f**	20	72	54	96
6	**1g**	10	12	94	90
7	**1h**	20	12	76	92
8	**1i**	20	12	81	88
9	**1j**	10	72	89	81

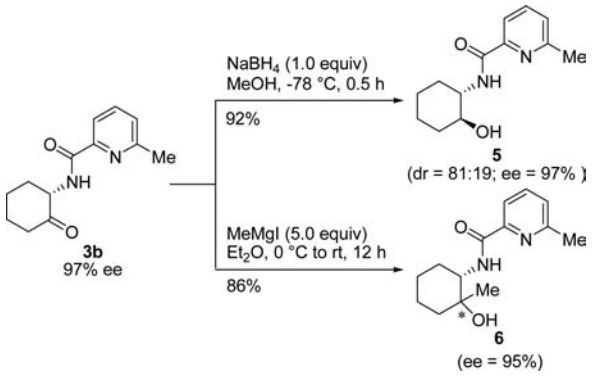
[a]Reaction conditions: aziridine **1** (0.2 mmol), **2** (0.1 mmol), $NiBr_2$ (10 mol %), and **4d** (10 mol %) in toluene:1,4-dioxane (0.1 M, v/v = 9/1) were used. [b]Ee was determined by HPLC analysis using a chiral column.

The reaction of aziridines **1c**–**e** having a five- or six-membered ring also afforded products **3c**–**e** with good enantioselectivities (Table 2, entries 2–4). Although the reaction of aziridine **1f** bearing a seven-membered ring afforded product **3f** in moderate yield (54%) due to the low reactivity of aziridine, the product was obtained with high enantioselectivity (96% ee) (Table 2, entry 5). The reaction with acyclic aziridines **1g**–**j** showed that these were also good electrophiles in the oxidative ring-opening reaction, giving products **3g**–**j** in 76–94% yield with 81–92% ee (Table 2, entries 6–9). These results are the first example of the enantioselective oxidative ring-opening reaction of aziridines.

The obtained product **3b** could be transformed to *trans*-1,2-amino alcohol **5** by the reduction of the carbonyl group using $NaBH_4$ (92%, dr = 81:19, ee = 97%) (Scheme 2). The absolute stereochemistry of product **3b** was assigned as *S* in comparison with the value of the specific rotation of **5** prepared from commercially available (1*S*,2*S*)-*trans*-2-aminocyclohexanol (see the Supporting Information). Furthermore, we succeeded in the

DOI: 10.1021/acs.orglett.6b03346
Org. Lett. 2017, 19, 74–77

Scheme 2. Transformation of 3b to Chiral 1,2-Amino Alcohols 5 and 6



preparation of 1,2-amino alcohol **6** having a tetrasubstituted chiral carbon center by using MeMgI as a nucleophile. The reaction afforded product **6** as a single diastereomer in good yield with 95% ee.

The proposed catalytic cycle for the ring-opening reaction of aziridine **1b** with α-nitromalonate **2b** using ligand **4d** is shown in Figure 2. The coordination of nickel bromide to picolinamide

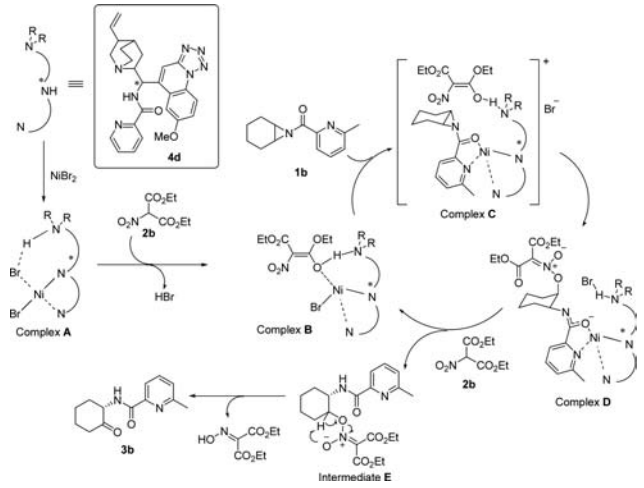


Figure 2. Assumed reaction cycle for the enantioselective desymmetrization of aziridines with α-nitromalonates.

ligand **4d** gives complex **A**, which reacts with nitromalonate **2b** to form complex **B**. Then the coordination of pyridine nitrogen and carbonyl oxygen in aziridine **1b** to complex **B** gives complex **C**, and the reaction between activated α-nitromalonate **2b** with aziridine **1b** proceeds in the coordination sphere of nickel(II) to give a ring-opening product (complex **D**), which subsequently undergoes deprotonation and decomplexation to give intermediate **E** and regenerated complex **B**. Finally, the oxy-Cope-type elimination of intermediate **E** leads to product **3b** and oxime compound.[16,17] In order to clarify the assumed reaction mechanism, we conducted spectroscopic analyses. The ESI-MS analysis of the mixture of **1b**, $NiBr_2$, and **4d** in a 1:1:1 ratio in toluene/1,4-dioxane (0.1 M, v/v = 9/1) showed complex **C** (cation mode, calcd for $C_{39}H_{42}N_9NiO_3$ as complex **C**−**2b**-Br^- 742.2, found 742.2; see the Supporting Information). This signals support for our proposed reaction mechanism.

In order to clarify the structure of the chiral catalyst, we studied the X-ray crystallographic analysis of **4d** (Figure 3).

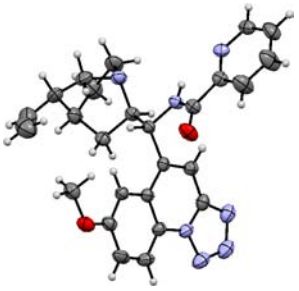


Figure 3. X-ray crystal structure of **4d**.

In this structure, two nitrogens for pyridine and quinuclidine directed to the proton on picolinoyl amide. The distances between the amide proton and the two nitrogens are 2.32 and 2.63 Å, respectively. Considering the structure of **4d**, the reaction mechanism of aziridines with α-nitromalonates using a chiral catalyst derived from **4d** and Ni(II) is shown in Figure 4.

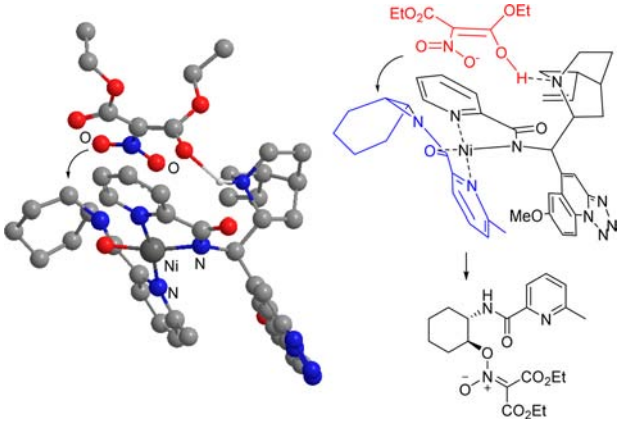


Figure 4. Proposed transition state of the reaction of aziridine **1b** with α-nitromalonate **2b** using **4d**-Ni(II). H atoms have been omitted for clarity.

Three nitrogens from ligand **4d** and aziridine **1b** and one oxygen from **1b** coordinate to nickel(II) in a distorted square planar manner, and activated α-nitromalonate **2b** attacks aziridine. In general, the α-nitroester generally acts as a C-nucleophile;[18] however, in this reaction, the α-nitroester reacted with aziridine by including oxygen in the nitro group.[19] This result supports the assumption that the reaction proceeds in the coordination sphere of nickel(II). Because of the distance between nucleophilic oxygen in **2b** and electrophilic aziridine, the (*S*)-isomer was formed. Further studies are required to fully elucidate the mechanistic detail of the reaction.

In conclusion, we developed the enantioselective oxidative ring-opening reaction of aziridines with α-nitroesters using novel cinchona alkaloid catalysts having a tetrazole group and a 2-picolynoyl group. The reaction was screened for a broad range of aziridines, and this process offers an efficient route for the synthesis of α-aminocarbonyl compounds in an optically active form. The obtained product can be converted to optically active 1,2-amino alcohols. This process provides stereodivergent access to optically active α-aminocarbonyl compounds. Further studies are in progress to determine the potential of these catalytic systems to other processes.

DOI: 10.1021/acs.orglett.6b03346
Org. Lett. 2017, 19, 74−77

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available free of charge on the ACS Publications website at DOI: 10.1021/acs.orglett.6b03346.

X-ray data for compound **4d** (CIF)
^{1}H and ^{13}C NMR spectra and experimental procedures for all new compounds (PDF)

■ AUTHOR INFORMATION

Corresponding Author

*E-mail: snakamur@nitech.ac.jp.

ORCID

Shuichi Nakamura: 0000-0001-5633-8367

Notes

The authors declare no competing financial interest.

■ ACKNOWLEDGMENTS

This work was partially supported by Grants-in-Aid for Scientific Research on Innovative Areas "Advanced Molecular Transformations by Organocatalysts" from MEXT (26105727) and the Uehara Memorial Foundation.

■ REFERENCES

(1) (a) Kalix, P. *Psychopharmacology* **1981**, *74*, 269. (b) Besse, P.; Veschambre, H.; Dickman, M.; Chênevert, R. *J. Org. Chem.* **1994**, *59*, 8288.

(2) Brenneisen, R.; Fisch, H. U.; Koelbing, U.; Geisshüsler, S.; Kalix, P. Br. *J. Clin. Pharmacol.* **1990**, *30*, 825.

(3) Meltzer, P. C.; Butler, D.; Deschamps, J. R.; Madras, B. K. *J. Med. Chem.* **2006**, *49*, 1420.

(4) (a) Arendt-Nielsen, L.; Nielsen, J.; Petersen-Felix, S.; Schnider, T. W.; Zbinden, A. M. *Br. J. Anaesth.* **1996**, *77*, 625. (b) Rossetti, R. B.; Cortopassi, S. R G.; Intelizano, T.; Machado, T. S. D. L.; Cruz, R. S. F. D. *Vet. Anaesth. Analg.* **2008**, *35*, 30. (c) Singh, N. S.; Bernier, M.; Camandola, S.; Khadeer, M. A.; Moaddel, R.; Mattson, M. P.; Wainer, I. W. *Br. J. Pharmacol.* **2015**, *172*, 4546.

(5) (a) Chenard, B. L.; Shalaby, I. A.; Koe, B. K.; Ronau, R. T.; Butler, T. W.; Prochniak, M. A.; Schmidt, A. W.; Fox, C. B. *J. Med. Chem.* **1991**, *34*, 3085. (b) Bouteiller, C.; Becerril-Ortega, J.; Marchand, P.; Nicole, O.; Barré, L.; Buisson, A.; Perrio, C. *Org. Biomol. Chem.* **2010**, *8*, 1111.

(6) Nchinda, A. T.; Chibale, K.; Redelinghuys, P.; Sturrock, E. D. *Bioorg. Med. Chem. Lett.* **2006**, *16*, 4612.

(7) (a) Vedejs, E.; Garcia-Rivas, J. A. *J. Org. Chem.* **1994**, *59*, 6517. (b) O'Brien, P.; Warren, S. *Synlett* **1996**, *1996*, 579.

(8) Wen, W.; Zeng, Y.; Peng, L.-Y.; Fu, L.-N.; Guo, Q.-X. *Org. Lett.* **2015**, *17*, 3922.

(9) (a) Mennen, S. M.; Gipson, J. D.; Kim, Y. R.; Miller, S. J. *J. Am. Chem. Soc.* **2005**, *127*, 1654. (b) Sun, L.-H.; Liang, Z.-Q.; Jia, W.-Q.; Ye, S. *Angew. Chem., Int. Ed.* **2013**, *52*, 5803.

(10) For reviews, see: (a) Vilaivan, T.; Bhanthumnavin, W. *Molecules* **2010**, *15*, 917. (b) Smith, A. M. R.; Hii, K. K. *Chem. Rev.* **2011**, *111*, 1637. (c) Zhou, F.; Liao, F.-M.; Yu, J.-S.; Zhou, J. *Synthesis* **2014**, *46*, 2983. See also recent reports: (d) Cecere, G.; König, C. M.; Alleva, J. L.; MacMillan, D. W. C. *J. Am. Chem. Soc.* **2013**, *135*, 11521. (e) Huang, X.; Webster, R. D.; Harms, K.; Meggers, E. *J. Am. Chem. Soc.* **2016**, *138*, 12636.

(11) Selected examples for the asymmetric synthesis of α-aminocarbonyl compounds: (a) Ooi, T.; Takahashi, M.; Doda, K.; Maruoka, K. *J. Am. Chem. Soc.* **2002**, *124*, 7640. (b) Kuwano, R.; Ishida, N.; Murakami, M. *Chem. Commun.* **2005**, 3951. (c) Garrett, M. R.; Tarr, J. C.; Johnson, J. S. *J. Am. Chem. Soc.* **2007**, *129*, 12944. (d) Sun, T.; Hou, G.; Ma, M.; Zhang, X. *Adv. Synth. Catal.* **2011**, *353*, 253. (e) Frongia, A.; Secci, F.; Capitta, F.; Piras, P. P.; Sanna, M. L. *Chem. Commun.* **2013**, *49*, 8812. (f) Xu, B.; Zhu, S.-F.; Zuo, X.-D.; Zhang, Z.-C.; Zhou, Q.-L. *Angew. Chem., Int. Ed.* **2014**, *53*, 3913. (g) Zhang, X.; Staples, R. J.; Rheingold, A. L.; Wulff, W. D. *J. Am. Chem. Soc.* **2014**, *136*, 13971.

(12) For reviews of enantioselective desymmetrization of aziridines, see: (a) Pineschi, M. *Eur. J. Org. Chem.* **2006**, *2006*, 4979. (b) Hu, X. E. *Tetrahedron* **2004**, *60*, 2701. (c) Schneider, C. *Angew. Chem., Int. Ed.* **2009**, *48*, 2082. (d) Wang, P.-A. *Beilstein J. Org. Chem.* **2013**, *9*, 1677.

(13) For racemic oxidative ring-opening reactions of aziridines using DMSO, see: (a) Heine, H. W.; Newton, T. *Tetrahedron Lett.* **1967**, *8*, 1859. (b) Fujita, S.; Hiyama, T.; Nozaki, H. *Tetrahedron* **1970**, *26*, 4347. Using pyridine *N*-oxide, see: (c) Luo, Z.-B.; Wu, J.-Y.; Hou, X.-L.; Dai, L.-X. *Org. Biomol. Chem.* **2007**, *5*, 3428. Using IBX reagent, see: (d) Surendra, K.; Krishnaveni, S. N.; Reddy, M. A.; Nageswar, Y. V. D.; Rao, K. R. *J. Org. Chem.* **2003**, *68*, 9119. Using NBS, see: (e) Reddy, M. S.; Narender, M.; Rao, K. R. *Tetrahedron Lett.* **2005**, *46*, 1299. (f) Surendra, K.; Krishnaveni, N. S.; Rao, K. R. *Tetrahedron Lett.* **2005**, *46*, 4111.

(14) Hayashi, M.; Shiomi, N.; Funahashi, Y.; Nakamura, S. *J. Am. Chem. Soc.* **2012**, *134*, 19366.

(15) For related our researches on desymmetrization of aziridines, see: (a) Nakamura, S.; Hayashi, M.; Kamada, Y.; Sasaki, R.; Hiramatsu, Y.; Shibata, N.; Toru, T. *Tetrahedron Lett.* **2010**, *51*, 3820. (b) Nakamura, S.; Ohara, M.; Koyari, M.; Hayashi, M.; Hyodo, K.; Nabisaheb, N. R.; Funahashi, Y. *Org. Lett.* **2014**, *16*, 4452. For related research on novel catalysts derived from cinchona alkaloids, see: (c) Hayashi, M.; Iwanaga, M.; Shiomi, N.; Nakane, D.; Masuda, H.; Nakamura, S. *Angew. Chem., Int. Ed.* **2014**, *53*, 8411. (d) Hayashi, M.; Sano, M.; Funahashi, Y.; Nakamura, S. *Angew. Chem., Int. Ed.* **2013**, *52*, 5557. (e) Hara, N.; Nakamura, S.; Sano, M.; Tamura, R.; Funahashi, Y.; Shibata, N. *Chem. - Eur. J.* **2012**, *18*, 9276. (f) Nakamura, S.; Takahashi, S.; Nakane, D.; Masuda, H. *Org. Lett.* **2015**, *17*, 106. (g) Nakamura, S.; Sano, M.; Toda, A.; Nakane, D.; Masuda, H. *Chem. - Eur. J.* **2015**, *21*, 3929. (h) Nakamura, S.; Takahashi, S. *Org. Lett.* **2015**, *17*, 2590. (i) Nakamura, S.; Yamaji, R.; Hayashi, M. *Chem. - Eur. J.* **2015**, *21*, 9615.

(16) For oxy-Cope-type elimination, see: (a) Semmelhack, M. F.; Schmid, C. R.; Cortés, D. A. *Tetrahedron Lett.* **1986**, *27*, 1119. (b) Chalmers, B. A.; Morris, J. C.; Fairfull-Smith, K. E.; Grainger, R. S.; Bottle, S. E. *Chem. Commun.* **2013**, *49*, 10382. (c) Murakami, K.; Sasano, Y.; Tomizawa, M.; Shibuya, M.; Kwon, E.; Iwabuchi, Y. *J. Am. Chem. Soc.* **2014**, *136*, 17591.

(17) The oxime compound was obtained in 95% yield (Table 1, entry 6).

(18) For selected examples for the enantioselective reaction using α-nitroesters, see: (a) Singh, A.; Yoder, R. A.; Shen, B.; Johnston, J. N. *J. Am. Chem. Soc.* **2007**, *129*, 3466. (b) Chen, Z.; Morimoto, H.; Matsunaga, S.; Shibasaki, M. *J. Am. Chem. Soc.* **2008**, *130*, 2170. (c) Uraguchi, D.; Koshimoto, K.; Ooi, T. *J. Am. Chem. Soc.* **2008**, *130*, 10878. (d) Han, B.; Liu, Q.-P.; Li, R.; Tian, X.; Xiong, X.-F.; Deng, J.-G.; Chen, Y.-C. *Chem. - Eur. J.* **2008**, *14*, 8094. (e) Liu, C.; Lu, Y. *Org. Lett.* **2010**, *12*, 2278.

(19) For intramolecular nucleophilic reaction of oxygen in a nitro group, see: (a) Rosini, G.; Galarini, R.; Marotta, E.; Righi, P. *J. Org. Chem.* **1990**, *55*, 781. (b) Rosini, G.; Marotta, E.; Righi, P.; Seerden, J.-P. *J. Org. Chem.* **1991**, *56*, 6258. (c) Righi, P.; Marotta, E.; Landuzzi, A.; Rosini, G. *J. Am. Chem. Soc.* **1996**, *118*, 9446. (d) Marotta, E.; Micheloni, L. M.; Scardovi, N.; Righi, P. *Org. Lett.* **2001**, *3*, 727. (e) Righi, P.; Scardovi, N.; Marotta, E.; ten Holte, P.; Zwanenburg, B. *Org. Lett.* **2002**, *4*, 497. (f) Guo, Z.-W.; Xie, J.-W.; Chen, C.; Zhu, W.-D. *Org. Biomol. Chem.* **2012**, *10*, 8471. For intermolecular nucleophilic *O*-alkylation in a nitro group, see: (g) Bachman, G. B.; Hokama, T. *J. Am. Chem. Soc.* **1959**, *81*, 4223. (h) Kornblum, N. *Angew. Chem., Int. Ed. Engl.* **1975**, *14*, 734. (i) Kim, K. E.; Adolph, H. G. *Synthesis* **1987**, 1029. (j) Kang, F.-A.; Yin, C.-L.; She, S.-W. *J. Org. Chem.* **1996**, *61*, 5523. For synthesis of carbonyl compounds via *O*-alkylation in a nitro group, see: (k) Weisler, L.; Helmkamp, R. W. *J. Am. Chem. Soc.* **1945**, *67*, 1167. (l) Kornblum, N.; Fifolt, M. J. *J. Org. Chem.* **1980**, *45*, 360.

DOI: 10.1021/acs.orglett.6b03346
Org. Lett. 2017, 19, 74−77