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Catalytic Asymmetric Diamination of Conjugated Dienes and Triene

Haifeng Du, Weicheng Yuan, Baoguo Zhao, and Yian Shi*

Department of Chemistry, Colorado State University, Fort Collins, Colorado 80523

Received June 26, 2007; E-mail: yian@lamar.colostate.edu

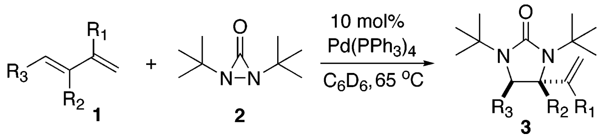
Vicinal diamines are very important functional moieties contained in various biologically active compounds and are also effective chiral control elements in asymmetric synthesis.[1] Metal-mediated and catalyzed diamination of olefins provides an effective approach to the synthesis of vicinal diamines, and various diamination systems have been developed.[1−6] Chiral auxiliary-based[7] and chiral Lewis acid-catalyzed[8] asymmetric diamination of α,*β*-unsaturated esters and related oxazolidinones using bisimidoosmium as reagent have also been reported. Generally speaking, asymmetric diamination of olefins with a catalytic amount of metal has yet to be developed. Recently, we reported a Pd(0)-catalyzed regio- and stereoselective diamination of conjugated dienes and trienes using di-*tert*-butyldiaziridinone (**2**)[9] as nitrogen source (Scheme 1).[10,11] Herein we wish to report a catalytic asymmetric process for this diamination.

Asymmetric diamination was initially examined using 1,3-hexadiene as substrate with catalysts generated from $Pd_2(dba)_3$ and various commercially available or easily prepared chiral ligands in C_6D_6 for 1.5 h (Scheme 2). Some of the results are summarized in Chart 1. Phosphine and phosphite ligands **L1**−**L3** gave 4−26% ee.[12] Studies with BINOL-based chiral phosphorus amidite ligands **L4**−**L6**[13] showed that the steric bulkiness of the nitrogen substituent has a large impact on both reactivity and enantioselectivity for the diamination. In search for more effective ligands, it was found that quantitative conversion and 92% ee were obtained with tetramethylpiperidine-derived ligand **L7**.[14] Promising results were also obtained with commercially available ligands **L8** and **L9**,[15] which provide additional opportunities for further improvement.

Encouraged by the results obtained with ligand **L7**, asymmetric diaminations of various conjugated dienes were subsequently investigated. As shown in Table 1, a variety of conjugated dienes can be diaminated in good yields and high enantioselectivities (87−95% ee). Like racemic diaminations with $Pd(PPh_3)_4$,[10,11] the reaction occurred highly regioselectively at the internal double bond and highly diastereoselectively, as well. When a mixture of *E* and *Z* dienes were used (Table 1, entries 2, 4−6, and 12), only *E* isomers were diaminated. When a conjugated triene was used, the diamination occurred cleanly at the middle double bond in high enantioselectivity (Table 1, entry 14).[16,17]

The resulting cyclic ureas[18] provide access to various optically active diamine compounds. For example, free diamine **8** can be obtained in high yield and ee from **6** by deprotection with CF_3CO_2H[19] and HCl[20] (Scheme 3).[11] Olefins present in diamination products also provide good opportunities for further elaboration. For example, compound **6** can be readily converted into optically active 2,3-diamino acid **11**[20] by oxidation of the olefin[21] and deprotection (Scheme 3).[22] The selective monodeprotection of **9** was also achieved cleanly to give **12** with CF_3CO_2H at rt,[10] providing opportunities to introduce different groups on the nitrogens if desired.[23]

Scheme 1



Scheme 2

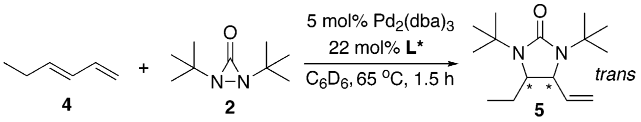
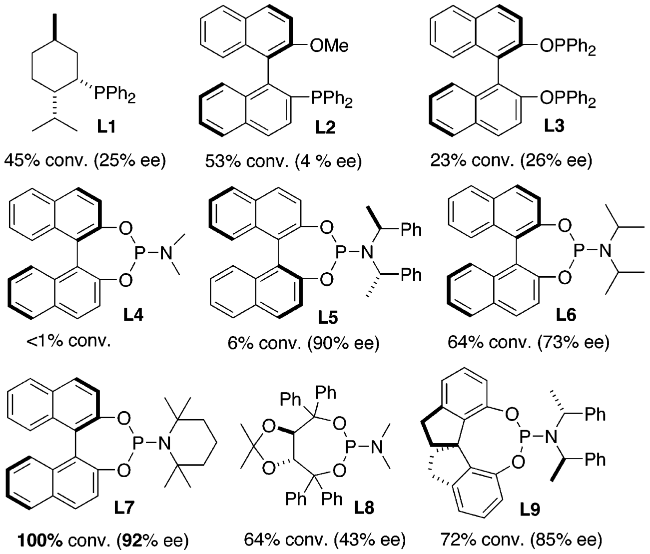
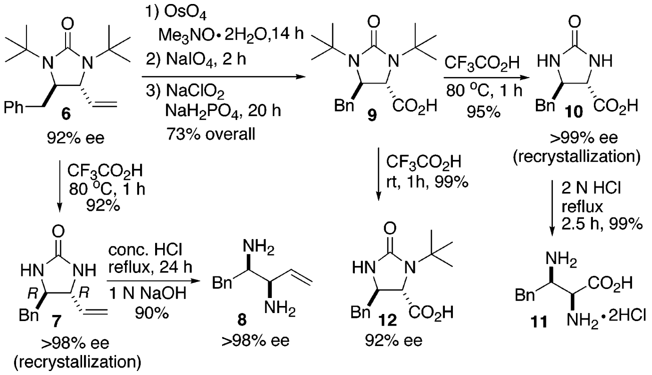


Chart 1. Asymmetric Diamination of Diene **4** with Selected Ligands



Scheme 3



In summary, a catalytic asymmetric diamination for a variety of conjugated dienes and triene has been effectively achieved using di-*tert*-butyldiaziridinone as nitrogen source with a catalyst generated from $Pd_2(dba)_3$ and tetramethylpiperidine-derived phosphorus amidite ligand **L7**, giving diamination products in good yields with

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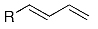
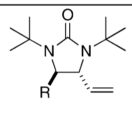
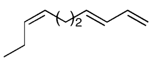
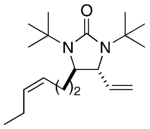
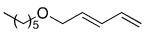
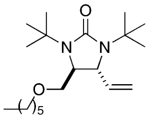
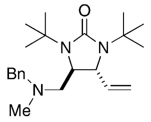
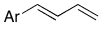
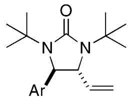
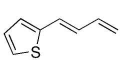
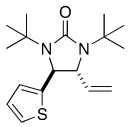
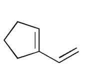
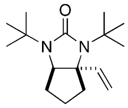
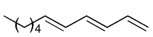
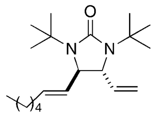
Table 1. Catalytic Asymmetric Diamination of Dienes and Triene[a]

Entry	Substrate	Product[d]	Yield[e] (%)	ee (%)
				
1	R = Me		91	91^{f,10}
2^{b}	R = Et		91	92^{g,10}
3	R = C_5H_{11}		90	92^{g,10}
4^{b}	R = CH_2Ph		94	92^{h}
5^{b,c}	R = CH_2CH_2Ph		95	92^{h}
6^{b}	R = c-C_6H_{11}		72	95^{f}
7			90	93^{g}
8			86	92^{g,10}
9			70	92^{g}
				
10^{c}	Ar = Ph		62	93^{i,10}
11^{c}	Ar = p-MeOPh		82	92^{h,10}
12^{b}			72	93^{f}
13			83	87^{g}
14^{c}			60	92^{g}

[a] All reactions were carried out with diene or triene (0.40 mmol), diaziridinone **2** (0.50 mmol), $Pd_2(dba)_3$ (0.02 mmol), and **L7** (0.088 mmol) in benzene-d_6 (0.2 mL) in an NMR tube at 65 °C under argon for 1.5 h unless otherwise stated. [b] A mixture of *E* and *Z* isomers was used. For entry 2, diene (0.88 mmol, $E/Z = 1/1.2$, *E* isomer: 0.40 mmol); for entry 4, diene (1.0 mmol, $E/Z = 1/1.5$, *E* isomer: 0.40 mmol); for entry 5, diene (0.73 mmol, $E/Z = 1.2/1$, *E* isomer: 0.40 mmol); for entry 6, diene (0.64 mmol, $E/Z = 1.67/1$, *E* isomer: 0.40 mmol); for entry 12, diene (0.64 mmol, $E/Z = 1.67/1$, *E* isomer: 0.40 mmol). [c] The reaction time was 2 h. [d] For entry 4, the absolute configuration (*R*,*R*) was determined by comparing the optical rotation with the reported one after removal of *t*-butyl groups (ref 21). For the rest, the absolute configurations are not determined, and the stereochemistry indicated represents the relative stereochemistry. [e] Isolated yield based on diene or triene. [f] The ee was determined by chiral GC (Chiraldex B-DM column) after removal of *t*-butyl group. [g] The ee was determined by chiral GC (Chiraldex B-DM column). [h] The ee was determined by chiral HPLC (Chiralpak AD-H column). [i] The ee was determined by chiral HPLC (Chiralpak AD column) after removal of *t*-butyl groups.

high regio-, diastereo-, and enantioselectivities. The resulting diamination products are potentially valuable intermediates for the synthesis of various optically active compounds such as diamine, 2,3-diamino acid. Further development of a more effective asymmetric catalytic process using different nitrogen sources, metal catalysts, and chiral ligands as well as expansion of the substrate scope and synthetic application is currently underway.

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Supporting Information Available: Experimental procedures, characterizations, and data for determination of enantiomeric excess of diamination products and their derivatives along with the ^{1}H and ^{13}C NMR spectra of compounds. This material is available free of charge via the Internet at http://pubs.acs.org.

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(23) The ee of **8** was determined after being converted into diamide; the ee's of **10** and **12** were determined after being converted into methyl esters.

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