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Dialkylzinc additions with a chiral osmaimidazolidine ligand from asymmetric diamination of olefins

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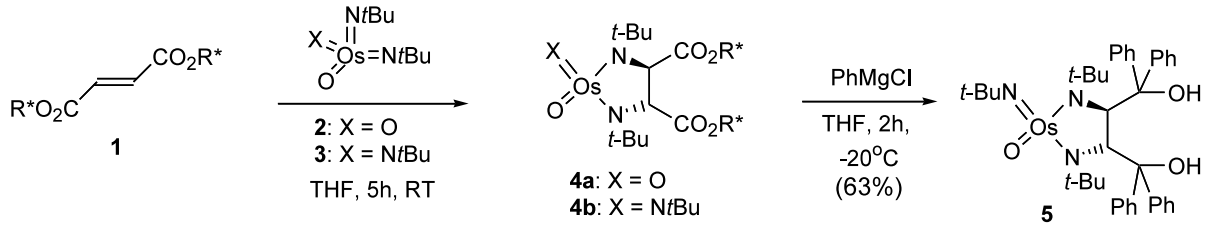
Abstract—A new chiral ligand was prepared in a convenient two-step procedure starting from an asymmetric diamination reaction. Subsequent treatment of the resulting osmaimidazolidine with a phenyl Grignard reagent and titanium tetra(*iso*-propoxide) furnished a complex that catalyses asymmetric dialkylzinc additions to aromatic aldehydes. © 2003 Elsevier Science Ltd. All rights reserved.

We have recently described a first stereoselective diamination of olefins.[1] This one-step process employs known achiral imidoosmium(VIII) reagents[2–4] and acrylic esters bearing chiral non-racemic (–)-8-phenyl menthol. The products are obtained as diastereomerically enriched osma(VI)imidazolidine complexes that are stable under a variety of conditions. A second asymmetric reaction of this type has employed commercially available bis(menthyl) fumarate **1** as substrate and both the bis- and the trisimido complexes **2** and **3** underwent diamination reactions with high diastereomeric excesses to yield the symmetrically substituted osmaimidazolidines **4a** and **4b** with 76 and 90% de, respectively (Scheme 1).[1,5]

Within the attempts to remove the chiral auxiliary and thus generate enantiopure osmaimidazolidines it was anticipated that reduction of the ester moieties with suitable carbon nucleophiles should furnish tertiary alcohols. While addition of phenyl lithium to a solution of **4a** led to a complex mixture of products, use of the related phenyl magnesiumchloride gave a clean reaction. Unfortunately, due to the loss of the electron-withdrawing ester group that is believed to act as a stabilising element within the osmaimidazolidines, the resulting complex did not display high stability and underwent loss of the osmium moiety. However, the corresponding complex **4b** bearing an additional imido ligand at osmium led to the product **5** which was sufficiently stable for isolation and complete characterisation.[5] The difference in stability of the two products is noteworthy, but can be rationalised from the difference in electron density at the osmium metal. While in the case of the labile dioxo derivative there is no other stabilising moment than the lone pairs of the two nitrogens of the metallaimidazolidine ring, the corresponding reaction starting from **4b** generates an osmaimidazolidine with an additional imido moiety at the central Os atom. Apparently this additional electronic factor enhances the stability of **5**. This result is in good agreement with a report by Schrock on related osmaimidazolidines containing arylimido ligands[6] and is reminiscent to related discussions on nitrogen donor stability in osmium complexes for olefin functionalization.[7]



Scheme 1. Asymmetric diamination and subsequent Grignard addition [R*OH = (–)-menthol].

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Interestingly, the structure of **5** with the nitrogen chelated osmium atom displays a certain similarity to Seebach's TADDOL compounds (Fig. 1) that represent successful ligands for transition metal mediated and catalysed transformations.[8]

In view of the successful chelating ability of TADDOL for a variety of transition metals, a metal complex from **5** and titanium tetra(*iso*-propoxide) was considered a promising target. Catalytic amounts of related complexes on the TADDOL basis are known to promote several asymmetric reactions, among which is catalytic addition of dialkylzinc to aldehydes (Scheme 2, Eq. (1)).[9,10] Thus, when **5** was treated in situ with titanium tetra(*iso*-propoxide), formation of the bimetallic complex **6** could be anticipated which was then employed in the prototypical diethylzinc addition to benzaldehyde.[10] As already described by Seebach for his Ti-TADDOLate catalysts, use of a catalytic amount of **6** alone had no decisive effect since the respective reaction proceeded at very low rate and the crude reaction mixture contained various products. However, the reaction proceeded efficiently in the presence of an equimolar amount of the achiral titanium reagent, and 2-phenyl propanol of 87% ee was isolated from a diethylzinc addition to benzaldehyde when 20 mol% of **5** had been added previously (Table 1, entry 1).[11]

Other aldehydes can be submitted to alkylation under identical reaction conditions (Table 1). For diethylzinc additions, 4-nitro benzaldehyde gave the best result (91% ee) while the electron-rich 4-methoxy benzaldehyde was rather problematic. Dimethylzinc worked equally well as alkylating reagent and the respective secondary alcohols were isolated with enantiomeric

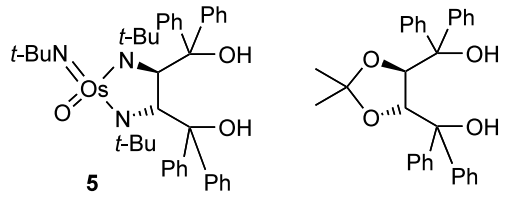
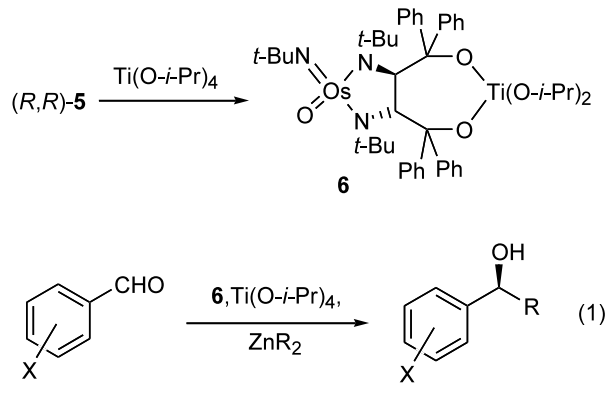


Figure 1. Structural relation of **5** and TADDOL.



Scheme 2. In situ formation of the assumed catalyst **6** for dialkylzinc addition to aldehydes.

Table 1. Dialkylzinc addition to aromatic aldehydes with a catalyst derived from complex **5** (Scheme 2)[11]

Entry	Rest	Rest R	Yield (%)[a,b]	Ee (%)[c]
1	C_6H_5	Et	87 (99)	87
2[d]	4-NO_2-C_6H_4	Et	93 (99)	91
3[d]	4-OMe-C_6H_4	Et	83 (95)	85[e]
4	C_6H_5	Me	92 (99)	91
5[d]	C_6H_5	Me	94 (99)	90
6[f]	C_6H_5	Me	91 (99)	75
7	4-MeO-C_6H_4	Me	94 (96)	88[e]
8	Naphthyl	Me	91 (97)	92[e]
9[d]	Naphthyl	Me	90 (96)	92[e]
10[d,g]	Ferrocenyl	Me	91 (98)	91

[a] Isolated yields after standard work-up and column chromatography.
[b] Yields in brackets refer to % conversion as estimated from the proton NMR of the crude reaction mixture.
[c] Determined by HPLC.
[d] A 0.5-M catalyst stock solution prepared from **5** and Ti(O-*i*-Pr)$_4$ in toluene was used.
[e] Determined by NMR analysis after conversion to the respective Mosher ester.
[f] With a sample of **6** containing 82% ee (see text).
[g] Reaction was carried out at –20°C.

excesses in the range of 88–92%. As judged by comparison with literature data, the products were *S*-configurated in all cases. This indicates an identical reaction course via *Si*-face addition and is in agreement with those transition states assumed for related catalysts derived from (*R*,*R*)-configurated TADDOL. While **6** contains two metal centres, the osmium centre does not participate in catalysis: because of its electron donating imido ligand it is formally an electronically saturated metal centre with no Lewis acidity. For the same reason, the nitrogen groups of the osmaimidazolidine backbone do not participate in the formation of alternative, catalytically active species. These observations confirm that **5** indeed behaves as a TADDOL-analogue in the present reaction, although the sterical bulk from the *tert*-butylimido ligand renders the observed enantioselectivities lower than those for reactions with TADDOL itself.[10] In view of the rather tedious purification of the osmaimidazolidine, an alternative one-pot procedure for the preparation of a stock solution of **6** was pursued. Thus, treatment of **4b** with 4.8 equiv. of the phenyl Grignard reagent followed by methanol addition, filtration through celite, evaporation of the solvents and addition of 2.6 equiv. of Ti(O-*i*-Pr)$_4$ in toluene allowed for the preparation of a 0.5-M toluene stock solution of the catalyst that was sufficiently stable when stored under argon at –24°C. The results from reactions using this catalyst solution are given in Table 1, entries 2, 3, 5, 9 and 10, and show that this procedure gives nearly identical results. However, the exact course of these reactions remains to be elucidated since the prepared stock solution of **6** may still contain additional salt complexes generated from the excess Grignard reagent and the liberated mentholate, respectively. However, even if such species are present, their catalytic reactivity should be low rendering their influence on the stereochemical reaction course rather small.

Since the initial diamination reaction in the formation of **4b** proceeds with high, albeit not with complete diastereoselectivity, it was possible to obtain diastereomeric mixtures for the preparation of enantioenriched ligands. For example, when catalyst **6** was prepared by the in situ protocol from a sample of **4b** with 82% diastereomeric excess, a dimethylzinc addition to benzaldehyde yielded a product with 75% ee. This value points to a linear relation between the ee of the catalyst and the ee of the product. Therefore, the actual catalyst can be considered monomeric in nature, a fact that is evidenced from the steric properties of **5** and **6**.[12,13]

This successful first application of osmaimidazolidine **5** to asymmetric catalysis demonstrates that diamination reactions with the bisimido reagents **2** and **3** can furnish synthetically valuable intermediates even for those cases where the *tert*-butyl substituents at nitrogen are not removed afterwards. This feature had previously been regarded as the most significant drawback in the diamination of olefins by means of *tert*-butylimido osmium reagents.[1,2] However, in the present case one might speculate that due to their steric bulk these moieties enforce a rigid configurational catalyst environment.

In summary, we have described a selective modification of stereochemically defined osmaimidazolidines that can be obtained in a one-step procedure from a chiral commercially available olefin and easily accessible osmium reagents. The application of such a modified complex **5** in asymmetric catalytic C–C bond formation has been demonstrated and represents the first example of an osmaimidazolidine ligand in asymmetric catalysis. Current work is aimed to enhance the application of this catalyst and related ones in other areas of asymmetric catalysis, especially in that of oxidative transformations.

Acknowledgements

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