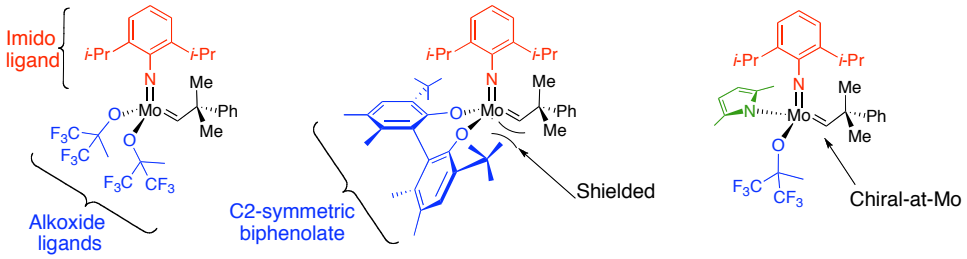
Monoalkoxidepyrrolide Catalysts for Olefin Metathesis

Patrick S. Hanley Literature Seminar October 13, 2009

Catalytic olefin metathesis has emerged as a powerful transformation in synthetic organic chemistry over the past two decades.[1] Complexes containing molybdenum, tungsten, and ruthenium promote a variety of metathesis reactions including ring-closing metathesis (RCM), ring-opening metathesis (ROM), cross-metathesis (CM), and ring-opening polymerization (ROMP). Control of stereoselectivity is a major challenge in developing new, effective olefin metathesis catalysts for both enantioselective and *cis* (*Z*) selective processes.[2] Recently, the laboratories of Schrock and Hoveyda reported a new set of chiral catalysts based on the monoalkoxide pyrrolide ligand set that contain a stereogenic center at the metal, commonly referred to as chiral-at-metal catalysts. These complexes offer unprecedented activity and selectivity for several stereoselective metathesis transformations, including the asymmetric desymmetrization of achiral trienes, *endo*-selective enyne metathesis, and *Z*-selective ring-opening/cross-metathesis.

Conventional high oxidation state catalysts for olefin metathesis are based on Mo-complex **I** (Figure 1). These Mo-alkylidenes feature two alkoxide ligands and an imido ligand that do not dissociate during the course of the catalytic cycle.[3] Generally, the alkoxide ligands are replaced with an enantiomerically enriched chelating biphenolate (complex **II**) or naphtholate ligand to generate a chiral complex. These C_2-symmetric ligands shield one face of the Mo-C double bond, and the resulting complexes serve as efficient catalysts for the enantioselective desymmetrization of achiral trienes.[4]

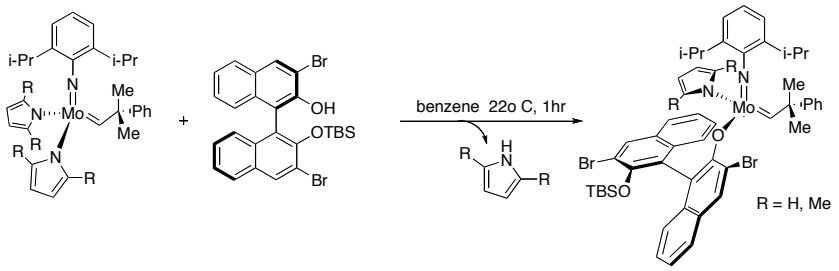


I **II** **III**

Figure 1

In 2007 a series of chiral monoalkoxide monopyrrolide (MAP) Mo-alkylidene complexes, which contain only monodentate ligands, was reported.[5] These catalysts display greater activity than complex **I** and the bisphenolate-ligated complexes (such as **II**). A set of DFT calculations are consistent with a lower barrier for olefin coordination to Mo-alkylidenes containing donor and acceptor ligands, as opposed to two acceptor or two donor ligands.[6] By synthesizing a complex with a covalently bonded pyrrolide (donor) ligand and alkoxide (acceptor) ligand (Complex **III**), a more reactive species is generated. The treatment of the bispyrrolide Mo complex **IV** with an enantiomerically pure, monoprotected 3,3′-dibromobinaphthol occurs to >98% conversion and forms complex **V** (R=H) with 19:1 diastereoselectivity (Scheme 1).[7,8] Complex **V** catalyzes the enantioselective desymmetrization

of achiral trienes to form cyclized products containing an all carbon stereocenter with up to 96% ee, requiring only 1 mol % catalyst. MAP catalysts demonstrate greater substrate compatibility with basic amines and promote the cyclization of trienes containing secondary and trialkylamines. These substrates proceed with low conversion with other available Mo- and Ru-catalysts.[7]



IV **V**

Figure 2

The highly reactive monoalkoxide monopyrrolide Mo-alkylidenes are the first high oxidation state complexes that efficiently catalyze enyne ring-closing metathesis reactions. Nearly all previously reported enyne metathesis catalysts are complexes of ruthenium that, in most instances, provide *exo* products (Figure 3). In contrast, the MAP Mo-alkylidenes are the first complexes that allow for selective formation of *endo* products.[5,9] Additionally, the diastereomerically enriched MAP complex **V** promotes the first enantioselective enyne RCM reactions.

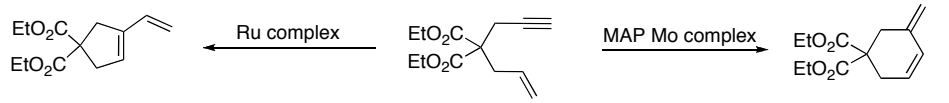


Figure 3

A major limitation of current metathesis catalysts is the inability to form *Z*-alkenes selectively. Schrock and Hoveyda recently reported a Mo-alkylidene complex that catalyzes ring-opening/cross-metathesis reactions that generate *Z*-olefins with high selectively.[10,11] The selectivity is proposed to arise from the large, freely rotating aryl oxide ligand in the metallacyclobutane intermediate, which directs the R-groups of the metallacyclobutane toward the smaller adamantylimido ligand and favors the formation of the *Z*-alkene (Figure 4).

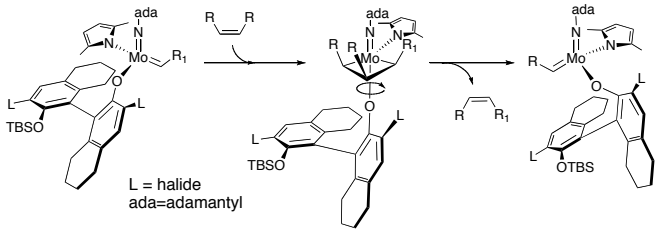


Figure 4

Complexes with stereogenic metal centers containing only monodentate ligands represents a new approach to the design of olefin metathesis catalysts. Chiral-at-metal monoalkoxide monopyrrolide Mo-alkylidene complexes offer increased reactivity and unique selectivity when compared to traditional metathesis catalysts. Not only are they effective catalysts for enantioselective metathesis reactions, but they also offer

uncommon alkene stereoselectivity in enyne RCM and *Z*-selective ring-opening/cross metathesis reactions. The true scope of MAP Mo-alkylidene reactivity is yet to be discovered, and one should expect new developments in the near future.

References

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