

SYNLETT Spotlight 59

NHC Ruthenium Complexes as Second Generation Grubbs Catalysts

Compiled by Javier Guerra



This feature focuses on a reagent chosen by a postgraduate, highlighting the uses and preparation of the reagent in current research

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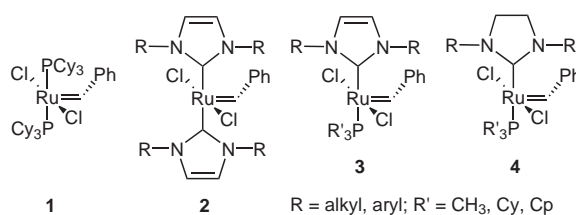
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Introduction

Developments in two seemingly unconnected fields have given rise to a new family of powerful catalysts with many applications in olefin metathesis. On the one hand, the progress made over the past decade in the synthesis of *N*-heterocyclic carbenes (NHCs) and their complexes, as well as the catalytic applications of these systems, has been impressive.^{1,2} On the other hand, the achievements in the evolution of homogeneous catalysts for olefin metathesis have turned this reaction into a common C–C coupling process³ with various possibilities including ring-opening metathesis polymerization (ROMP), ring-closing metathesis (RCM), acyclic diene metathesis polymerization (ADMET), ring-opening metathesis (ROM), and cross-metathesis (CM or XMET).

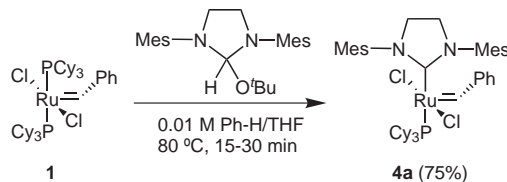
Herrmann et al.⁴ were the first to synthesize a modified Grubbs catalyst that included *N*-heterocyclic carbene ligands. The bis(NHC)-substituted derivatives **2** showed a minor improvement in terms of catalytic activity compared to conventional Grubbs catalyst **1**. Soon after, papers concurrently published by Nolans,⁵ Grubbs,⁶ and Herrmanns⁷ groups described the synthesis of mono(NHC)-substituted complexes such as those of type **3** and **4**. This new family of compounds has been called the second generation Grubbs catalysts.

The strong σ donor character of NHC ligands facilitates the dissociation of the phosphine in compounds **3** and **4** due to the *trans* effect, although the key step for olefin metathesis consists of the coordination of the olefin to the unsaturated ruthenium complex.⁸ These new compounds (**3** and **4**), which are reasonably air- and water-stable, are more active than **2** or **1** and can also tolerate the presence of different functional groups (with the ex-



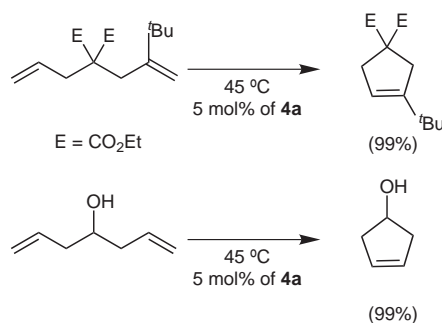
ception of basic ones like nitriles and amines).^{3a} The enhanced activity of these compounds means that the reactions can be carried out under mild conditions. Three years after its synthesis,^{6b} complex **4a** [R = Mes (mesityl), R' = Cy] has become commercially available⁹ owing to its wide-ranging applications.

Compound **4a** was synthesized from **1** and the saturated 1,3-dimethyl-2,3,4,5-tetrahydro-1*H*-imidazol-2-ylidene, which was protected as the alkoxide to generate the free carbene ligands *in situ*.

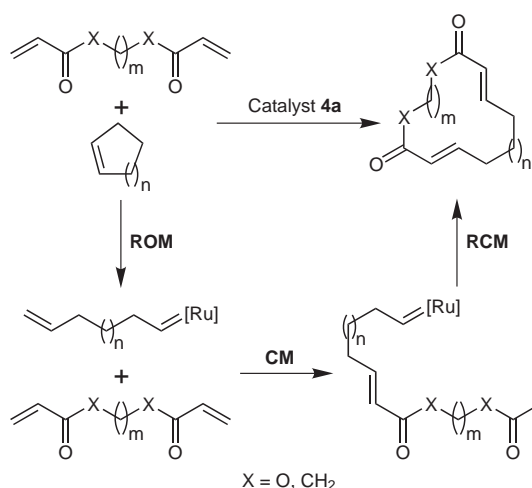


Abstracts

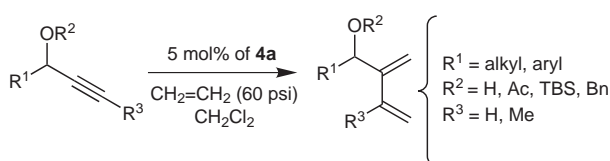
Complex **4a** is able to catalyse RCM to give di-, tri- or tetra-substituted cycloolefins while complex **1** failed in the case of tri- and tetrasubstituted ones. The stability and tolerance towards different functional groups of the second generation Grubbs' catalyst has also been demonstrated.^{6b}



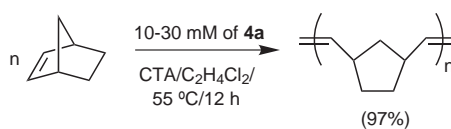
The syntheses of several macrocycles by ring expansion have recently been published.¹⁰ Bis-(vinylketones) and bis-acrylate systems react with a set of cycloalkenes, giving rise to a variety of structures in an atom-economical process employing only one catalyst. Factors like concentration or stoichiometry are crucial in order to control the product distribution.



En-yne CM between ethylene and alkynes substituted with a heteroatom in the propargylic or homopropargylic position failed when **1** was employed – except in the case where the heteroatom was protected. Nevertheless, even when a protection protocol is employed alcohols, ethers or silyl ethers do not react or react very poorly.¹¹ Chelation at the Ru centre is thought to be responsible for decelerating or shutting down catalysis. Complex **4a** is successful in this reaction without resorting to a protection/deprotection sequence and gives the desired products with good/excellent yields.^{12,13}



Catalyst **4a** also performs well in ROMP reactions, thus showing its ability to build polymeric structures while tolerating the presence of a huge variety of polar functional groups. Different low-strain cyclic olefins, like cyclooctene or norbornene [using 1,4-bis(acetoxy)-*cis*-2-butene as a chain transfer agent (CTA)], have also been studied.^{14,15}



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