**Introduction**

Metal-free organocatalysis employing N-heterocyclic carbenes (NHCs) has attracted great interest because of its use in the construction of intricate molecular architectures from simple starting materials under mild reaction conditions.\(^1\) The catalytic pathway of NHCs mimics that of thiamine-dependent enzymatic processes and passes through discrete reactive species, such as acyl anions and enolate or homoenolate equivalents.\(^2\) This enables the selective generation of a set of versatile electrophilic (acyl azoliums) and nucleophilic (enolates, homoenolates) intermediates and makes NHCs efficient catalysts in such various reactions as acylation, cycloaddition, β-borylation, and elimination.

**N-Mesityl substituted imidazolium (cat. A) and triazolium (cat. B and C) salts were introduced by Bode and co-workers as stable NHC precursors.**\(^3\) The imidazolium derivative favors the homoenolate pathway, whereas the triazolium precursor promotes almost all NHC-catalyzed transformations, except for benzoin and Stetter reactions. Chiral pre-catalysts like C and its enantiomer are also commercially available.\(^4\)

It should be noted that the N-substituent is of crucial importance; for example, an N-phenyl substituents might not provide any product, while the Bode (N-mesityl) or Rovis (N-pentafluorophenyl)\(^5\) catalysts are highly catalytically active.

![Figure 1](image_url)

**Abstracts**

(A) Bode catalysts were first found to be efficient for the esterification of aldehydes via the activated carboxylates generated from \(\alpha,\beta\)-epoxyaldehydes, enals, and cyclopropanes. You et al. used a similar methodology for the ring expansion of formylcyclopropanes to afford 3,4-dihydro-\(\alpha\)-pyrones.\(^6\) Although in situ generated acyl azoliums did not react directly with amines, amidation was possible using a co-catalyst with additives such as imidazole, triazole, hydroxamic acid, HOBT, HOAt, or pentafluorophenol.\(^7\) This approach was successfully in the catalytic kinetic resolution of cyclic amines using the chiral hydroxamic acid 1 or 2 as co-catalyst.\(^7\) Recent development includes the use of a polymer-supported histidine-bound NHC precursor in which the histidine moiety acts as co-catalyst.\(^3\)
B) Ester enolate equivalents generated from α-halo- and α,β-unsaturated aldehydes underwent enantioselective oxa- and aza-Diels–Alder reactions. Strikingly, bench-stable bisulfite adducts of urated aldehydes underwent enantioselective oxa- and aza-Diels–Alder reactions.1a Strikingly, bench-stable bisulfite adducts of urated aldehydes underwent enantioselective oxa- and aza-Diels–Alder reactions.11c NHC-catalyzed aza-Claisen rearrangement of enals with vinylogous enals. Mechanistical insights into this transformation led to the transformation furnished a functionalized bicyclic scaffold possessing three contiguous stereogenic centers with a good diastereo- selectivity.

(D) In course of their work on kojic acids, Bode and co-workers discovered a new enantioselective azolium-catalyzed annulation of α-halo enal products by the reaction of enals with chalcones. In 2013, Chi et al. developed a selective β-formation of homoenolate and acyl azolium pathways. 12 In the latter case, the pre-catalyst C ensured the first annulation of α- and β-substituted enals with a high enantio- and diastereoselectivity.

(E) The NHC-promoted addition of enals to imine electrophiles represents a particular reactivity. Ketimines derived from saccharine were found to be excellent electrophiles in annihilation reactions proceeding via homoenolate and acyl azolium pathways. In the latter case, the pre-catalyst C ensured the first annulation of α- and β′-substituted enals with a high enantio- and diastereoselectivity.

(F) Recently, Alexakis and co-workers reported the stereoselective annihilation between α-cyano-1,4-diketones and ynamides. Starting from achiral material and in the presence of achiral pre-catalyst B, this transformation furnished a functionalized bicyclic scaffold possessing three contiguous stereogenic centers with a good diastereo- selectivity.

References


